Invisible Structure of the Church of San Lorenzo in Turin, Italy

Investigating the structure through construction sequence hypotheses, and deformation control

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Abstract

The church of San Lorenzo in Turin [], among one of the most significant works of Guarino Guarini, has been explored extensively regarding its geometrically complex dome and peculiar spatial experience. The so-called Guarinian devices, such as the injection of Gothic principles to that of Roman, visual illusion, and play of light, recur in this church so as to create a unique experience in a baroque space. However, what remains limitedly investigated, is the principal element that has enabled the visible complexities of the church_ the invisible structure. This thesis as a consequent, attempts to study the structural state, composition, and construction sequence of San Lorenzo as was built originally by Guarini, mentioning the 19th century reinforcements.

The research combines a thorough literature review on the personal life and career of the architect, with a digital investigation focused on the structure. Original engravings, and archival documents complemented by a three-dimensional point cloud survey, as well as multiple on-site visits, not only made the comprehension of the building easier, but also resulted in a digital model designed in order to support the constructional analysis. Subsequent to the historical framework of the study that situates San Lorenzo within Guarini's broader work, and with the ongoing scholarly research, is a deformation analysis essentially based on sectional evaluation derived from the point cloud data, manually carried out in AutoCAD, together with an algorithmic analysis in MATLAB. Finally, an investigation of a single architectural corner of the church described the elements present in the composition of the building, and how they interact, with the use of hypothesis based on construction logics and the aforementioned sources.

Replacing a rather symbolic interpretation of the church, with a more constructional and structural approach, resulted in this study which explored a new perspective on San Lorenzo through which, the geometry, construction logic, structural stability, and hidden structure came together to give more depth to the essence of the distinctiveness of this building.

Keywords: Guarino Guarini, San Lorenzo, Construction Sequence, Deformation Control, Structural Analysis, Hidden Structure, HBIM

ii Acknowledgment

This thesis would not have been possible without the guidance and support of many people to whom I owe my deepest gratitude.

Firstly, I would like to express my sincere appreciation to Professors Edoardo Piccoli, Cesare Tocci, and Giulio Ventura, whose supervision, insightful feedback, and continuous encouragement have guided this research from its earliest stages to completion.

Special thanks to the Geomatics Laboratory at Politecnico di Torino, especially to the doctoral researcher, Giacomo Patrucco, for his generous assistance with the point cloud data, and all the technical questions related to the processing of such data. I would also like to acknowledge the Archivio di Stato di Torino, for providing essential resources that were the foundation of this study, as well as the authorities and custodians of the Church of San Lorenzo in Turin, whose collaboration made the on-site comprehension of the structure possible.

I am profoundly thankful to my family for their belief in me, and to my friends, whose understanding, kindness, and emotional support have made this journey far more enjoyable and meaningful.

Finally, my heartfelt thanks go to my partner, Julien Laspalles, for his constant support, collaboration, and particularly for his contribution to the analysis of La Chiave della Cupola. His presence and encouragement have given me the confidence to complete this journey.

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Table of Content

Generative AI tools have been solely used for some editorial purposes, such as translation from Italian to English, grammar correction, and paraphrasing suggestions. The essential content, and final language of the thesis are entirely author's.

01
Introduction

Theatine Guarino Guarini (1624-1683), the architect of several exemplary Baroque churches of the Seicento, drew upon principles of his various fields of profession in his architectural practice. These include geometry, astronomy, mathematics, philosophy, and theology. His experiments of bringing together such topics, connected to his major stays in Modena, Messina, Rome, Paris, Turin, and Veneto, resulted in eclectic works towards the end of his career.

Chiesa di San Lorenzo in Turin, as one of the his most mature works, is a proper example of a Guarinian originality. Originally an ongoing project, commissioned by Emanuele Filiberto, Duca di Savoia, to honor San Lorenzo after his victory at the Battaglia di San Quintino in 1557, the project was later entrusted to Carlo di Castellamonte, with construction beginning in 1634. Guarini's project commenced in 1668, with actual construction breaking ground in 1670 over the already built foundations by Castellamonte, on the west side of the Piazza Castello, and lasted until the late 1680s (Guarini died in 1683, after the completion of the building's structure). While information about the building's maintenance over time are scarce, the important restoration and structural strengthening works carried out in the 19th century by Carlo Randoni are documented and will be also considered here. Other lesser-known interventions on the structure date from the 20th century, both before and after World War II.

This church showcases ingenious structural and geometrical solutions, resulting in intersecting ribs of the dome, Gothic influences, and a "constructive", dramatic use of lighting. The most decisive factor in creating the aforementioned peculiarities, is the so-called hidden structure. The desire for a light-looking, open interior with slender columns, apparently too thin to support the superposed dome, was achieved through the use of four large supporting arches, or arconi, concealed behind the internal walls. Thanks to this crucial system of invisible elements, the visitor is struck by the structural paradox of a light structure supporting a heavy one, among other mysteries present in the church.

To this end, the study investigates this load-bearing mystery, to understand how the given documentation, and on-site investigation of the building, can help us to unveil its possible construction sequence. How did the hidden structure and the visible interior structure interact during the original construction, and how did the 19th-century reinforcements impact on the original layout, making it harder to grasp? In trying to answer this question, an educated guess is attempted on how Guarini managed the construction of each element, and how they would impact one another in different conditions, and/or time phases.

Methodology

This research has been essentially conducted by combining different sources of information:

1. The original engravings of Guarini
2. The archival documents from the Archivio di Stato di Torino and the Fondo Passanti (Galleria d'Arte Moderna)
3. Point Cloud data
4. Direct access to the building (sketches, notes, photographs, and recordings)
5. Secondary Sources and historiography: Books, dissertations, articles, and journals

The 3-dimensional point cloud survey of the church was conducted during the Campagna di rilievo 2023/2024, authorized by Geomatics Lab at Politecnico di Torino. This was acquired with a multi-sensor approach by using terrestrial LIDAR laser scanning, drone-based digital photogrammetry, and SLAM-based methods. This process allows the integration of different levels of scans and resolution to obtain a reliable geometric modelling and digital reconstruction. Ultimately, this dataset was used as the geometric basis for all subsequent procedures in this thesis, including the and deformation assessment, and the modeling of a "Digital Twin" through an HBIM process in Revit of a selected architectural corner.
The initial data was captured through TLS using a FARO Focus 3D phase-shift scanner placed in several positions capturing 8-10 scans. Secondly, for the areas higher in the church that were out of access to the TLS, a drone was used to capture overlapping photos. Finally, a handheld mobile 3D laser scanner (StoneX X120GO SLAM) was utilized at the hidden parts of the building, since the acquisition of data from those area was difficult with a TLS. In general, the level of precision that LIDAR provides is on the scale of 1:50 to 1:100, while the SLAM-based results contain a lower nominal precision of 1:200 to 1:400. Subsequently, the results from the SLAM-based method were controlled taking the LIDAR as the "Ground Truth" using the "Cloud-Cloud Distances" tool in CloudCompare. Finally, manual segmentation, and planar slicing were applied to isolate architectural features relevant to the present analysis.

Structure of the Thesis

This thesis approaches the topics discussed above, in the following structure:

Guarino Guarini:

An initial overview of the previous academic research on the life of the architect, his career, writings, and his architectural approach, which makes clear the peculiarity and impact of Guarini. This is followed by a more specific focus on the church of San Lorenzo, going through an overview on the construction, actors, forms, spaces, and symbolic aspect of the building. Finally, a thematic review of the literature on the hidden structure of the church lays the ground work, and purpose of the current thesis which attempts to investigate this matter through a construction sequence point of view. The shortcomings, innovativeness, and future discussions on the topic are what concludes this chapter.

Deformation Analysis

A deformation analysis on the general structural condition of the building, as well as some localized assessments is what this chapter has investigated. For the sake of this structural control, a sectional, and planar analysis was carried out in an attempt to verify the precision of the construction globally. Furthermore, specific investigations were done in order to clarify any structural abnormality in the pendentive zone of the church, which is the representative of the main structural system of the building.

A Corner

The core thesis of this research is described in the last chapter, which depicts a possible construction sequence of a corner of the church. This has been carried out through two main parts, starting from a geometrical composition of the elements existing in that corner, continued by a hypothesis on the construction sequence of those elements. To this end, a 3D model is used as a description of what exists today, providing a broad idea of the construction Guarini might have undertaken, as well as documenting the subsequent restoration and alterations.

02

Guarino Guarini

"Non di rado accade trovarsi negli uomini di gran talento delle inclinazioni, che portano al singolare e straordinario. Il calcare le altrui pedate, il seguire i documenti de' maggiori, sembra una servitù disdicevole a chi crede avere abilità per inventare. Le Opere di Architettura del celebre Francesco Borromini ne sono una riprova. Altrettanto, anzi assai più ci additano quelle del nostro Guarino. Non per questo pensiamo doversi annoverare tra i pazzerelli i partitanti di esse, come con soverchia libertà ha asserito un moderno Scrittore."

(It often happens that men of great talent possess inclinations that lead them toward the singular and the extraordinary. To tread in the footsteps of others, to follow the teachings of the great masters, seems an unworthy servitude to one who believes himself capable of invention. The architectural works of the celebrated Francesco Borromini are proof of this; equally—indeed, even more so—those of our own Guarini. Yet for this reason we do not think that the followers of such works should be counted among the madmen, as a modern writer has too freely asserted.)[1]

Antonio Francesco Vezzosi [2]

Figure 1 – Engraved portrait of Guarino Guarini, engraved by Giovanni Abbiati. From Dissegni d'architettura civile et ecclesiastica (Torino: Per gl'Eredi Gianelli, 1686), accessed August 2025, https://archive.org/details/gri_33125008641249/page/

2.1. Literature Review and Bibliography

The rather insufficiently documented nature of Guarini's career seems to be a good reason for adopting a thematic, or typological analysis of his works [3]. Even one of the most comprehensive publications—the proceedings of the 1968 Turin congress [4] —only gathered numerous contributions of articles of differing quality [5]. Later publications are sometimes precious, but do not attempt a new overall synthesis. Additionally, as Meek argues, an attempt to a chronological study based on educational guess about the way his drawing and supposedly design development is also futile, due to the continuously varied, layered [6] character of Guarini's design which makes it unpredictable for the observer to guess what will be on the next level of a section [7]. To this end, our study adopts a rather thematic approach based on a juxtaposition of previous scholarly works to provide an overview of the architect's career.

Guarino Guarini, born on 17th of January 1624 in Modena, was one of the five sons to Raimondo Guarini, and Eugenia Marescotti. As far as Guarino Guarini's biography is concerned, there has been five early writings on this matter, as listed by Dr. Susan Klaiber in her website [8], which state a rather non-architectural description of the Theatine's life. These short summaries of Guarini's studies, teachings, writings, buildings, and remarks on his mastery, are preliminary, rather subjective [9] descriptions of his life, and lack detailed information on his familial status. A later relatively extensive booklet on Guarini's life is that of Sandonnini's in 1890, which appears to be more objective and reliable. This text, together with later books of Baudi di Vesme, and Augsutua Lange are known to be basics of the architect's life story. Even with the advancement of these studies, what is known on the early life of Guarini, together with the Modenese archives, is limited; what is sure is that all of the five brothers joined the Theatine Order, suggesting the religious roots of the family [10]. To this end, November 27th 1639 is recorded as Guarini's departure to San Silvestro al Quirinale in Rome at the age of fifteen, on probation in the Theatine church, until he vowed to the Roman Theatine Order, and car-

[1] Translation from Italian to English by ChatGPT, OpenAI, conversation with the author, November 5, 2025.

[2] Antonio Francesco Vezzosi, I scrittori de' Cherici Regolari detti Teatini, vol. 1 (Rome: Propaganda Fide, 1780), 432–33.

[3] Harold Alan Meek, Guarino Guarini and His Architecture (London: A. Zwemmer Ltd, 1991); Susan Klaiber, Guarino Guarini's Theatine Architecture (PhD diss., Harvard University, 1993).

[4] Atti del Congresso Internazionale di Studi Guarineschi, Torino 11–15 settembre 1968 (Turin: Accademia delle Scienze, 1970).

[5] Susan Klaiber, review of *Guarino Guarini and His Architecture*, by H. A. Meek, *AA Files*, no. 17 (Spring 1989): 107–108, https://www.jstor.org/stable/29543649

[6] Elwin Clark Robison, Guarino Guarini's Church of San Lorenzo in Turin, PhD diss., Cornell University, 1985 (Ann Arbor, MI: University Microfilms International, 1985), 28.

[7] Meek argues that this unpredictability can be seen when Portoghesi and Wittkower dated the church in Messina to completely different periods of Guarini's career. Meek, Guarino Guarini and His Architecture, 131.

[8] Susan Klaiber, "Early Biographies of Guarini," Susan Klaiber, accessed August 2025, https://susanklaiber.wordpress.com/resources/early-biographies-of-guarini/

[9] "A chi piace l'Architettura del Guarini, buon prò gli faccia, ma stia tra pazzarelli." Girolamo Tiraboschi, Biblioteca modenese, vol. 3 (Modena: Società tipografica,1783), 38.

[10] Klaiber mentions that Sandonnini claimed this, and it is true based on the records of Modena. See Susan Klaiber, Guarino Guarini's Theatine Architecture (PhD diss., Columbia University, 1993; Ann Arbor, MI: University Microfilms International, 1993), 16.

ried on his priesthood studies until 1647. What the aforementioned writings lack, is to channel the descriptive experiences of Guarini's life into a more critical analysis which underlines how integrated, and influential his fields of expertise are on one another. Hence, a highly important scholar on this matter is Susan Klaiber, who for the first time put forward the relationship between Guarini's religious involvements, and his artistic career, in her PhD thesis [11].

The Congregation of Clerics Regular (Congregatio Clericorum Ragolarium), were a Catholic Order also known as the Theatines. Gian Pietro Carafa, who later becomes the Pope Paul IV in 1555, was one of the four members of the oratory of Divine Love, who initiated this counter reformational Order on September 1524 with the intention to "reform the church in the head, and in the members" [12] . Chieti, the homeland of Carafa, translates to Latin as Theate, which titles the Order as Theatine [13]. A common error in the Theatine-Guarini literally works, is the claim that the internal priests of the order were chosen as the architect for the church missions; while this will be the case with Guarini, this claim proved to be false: his involvement with the architecture of his Order is quite the exception and not the rule [14]. Concerning the architectural matter, the Theatine churches expressed a variety of needs, such as the requirement for a well-designed aggregational space, or Choir, as one of their principles is "special emphasis on the communal recitation." [11]. This is a key factor in Guarini's designs throughout his career, present in almost all of the churches executed by him.

The Theatine seven-to-eight-year education on philosophy and theology constituted the base for Guarini's education: philosophy and theology remained the inseparable facets of his later career. From his critics on philosophical issues, as stated by Tiraboschi [15], to his flexible design process, he is considered to have been a man of broad-mindedness, thus welcoming also the change of mind on architectural conventions.

Guarini's Career

Guarini traveled extensively and lived in several cities during his lifetime: his path comprised six major cities: Modena, Rome, Messina, Paris, Turin, and Veneto. Shorter stays in Parma, Guastalla, as well as uncertain stops in Napoli, Lisbon, Spain, and Prague, conclude what is known to be the journey of the architect. This pan-European journey[16], which is known to us only to the extent to which the documents have survived, is only partly due to his architectural commissions. In fact, the multidisciplinary nature of his life becomes clear only if we put together his non-architectural motivations, studies and activities, such as teaching, with the architectural ones. The preliminary Theatine-related activities of Guarini's formative years in Rome, for instance, provides an acquaintance with building-related activities of Bernini, Fontana, and the extremely influen-

[11] Klaiber, Guarino Guarini's Theatine Architecture.

[12] "The Theatine," Teatinos, accessed September 9, 2025, Teatinos website, https://teatinos.org/en/the theatine/.

[13] See the thorough description of Klaiber on the Theatine order. Klaiber, Guarino Guarini's Theatine Architecture, 10-30.

[14] Klaiber, Guarino Guarini's Theatine Architecture, 4.

[15] Tiraboschi, Biblioteca Modenese, 38-39.

[16] Robison, 1.

[17] Moreover, Klaiber mentions François Mansart as the most influential French architect on Guarini, almost as much as Borromini. While Meek argues that Guarini is more mannerist in his design, than Borromini. And nearly as much as Borromini. Klaiber, Guarino Guarini's Theatine Architecture, 131; Meek, Guarino Guarini and His Architecture, 23.

tial Borromini[17]. The rigorous study of Klaiber, interweaving priesthood and architectural training in the life of Guarini for the first time in 1993, has clarified many of these aspects and remains a fundamental reference.

Early Formation

At the age of 23, after completing his studies, Guarini returned to his hometown, continuing his priesthood activities in the Theatine casa of San Vincenzo, which tied him to the start of his architectural activities simultaneously. After ample struggles over the construction, and structural stability of the San Vincenzo church in Modena, Guarini's impressive design proposal of the dome with the light materials of wood, and lead for the dome, was perhaps his first recorded architectural design, never realized due to unknown reasons[18]. While his activity as a designer partly escapes us, the casa dei Teatini in Modena was also restructured, if not completely rebuilt, under his design (many drawings by Guarini still remain, making the Casa modenese one of the better documented of Guarini's projects), only to be heavily modified internally during the 20th century.

Together with these, his positions recorded as the treasurer of the Archivio di Stato in 1650, lecturer of philosophy in the same year, and the preposito of the Modenese church in 1655 [19], conclude the overall activities of Guarini in Modena. For unclear reasons the duke decided to select Bernardo Castagnini "in Guarini's stead" [20], as the preposito of the Theatine, and so the architect's Modenese career ended in 1656, remaining the *persona non grata* [21] of the city, being able to only visit occasionally until his death. Finally, the Modenese asked for his return, but *troppo tardi lo riaccolse* [22].

Little is left from the documented evidence on Guarini's activ-

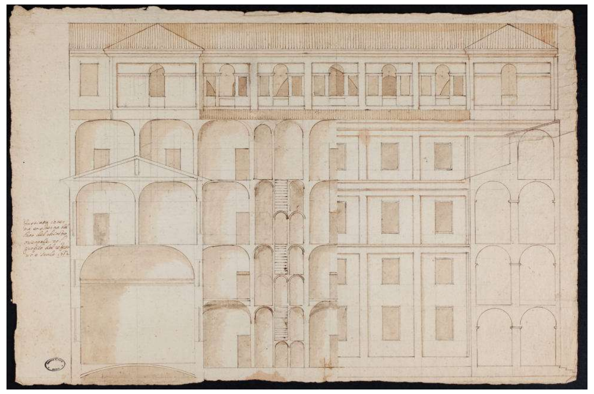


Figure 2 –SanVincenzo, Modena, Guarini facade project (1662), image by Susan Klaiber, Resources on Guarino Guarini, accessed September 2025, https://susanklaiber.wordpress.com/1035_guarini_san-vincenzo_1/

Figure 3 –Modena Theatine Convent, design attributed to Guarino Guarini. From Guarino Guarini e la magia delle forme, ed. Maria Carfì, Debora Credi, and Lorenza Iannacci, in the exhibition catalogue Oltre l'architettura: Guarino Guarini e Modena — a quattrocento anni dalla nascita (Modena, 22–23 March 2024).

ities in Messina, due to the earthquakes of 1793, and 1908, as well as the WW2 destructions. What is known is that his stay in Messina officially pinpoints the start of his major teaching career. In terms of architecture, the façade of Santissima An-

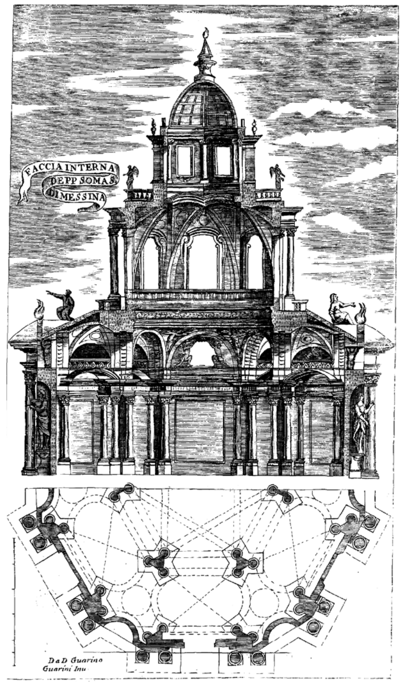
[18] Meek, Guarino Guarini and His Architecture, 10.

[19] Klaiber, Guarino Guarini's Theatine Architecture, 73-74.

[20] Klaiber, Guarino Guarini's Theatine Architecture, 74.

[21] Meek, 26.

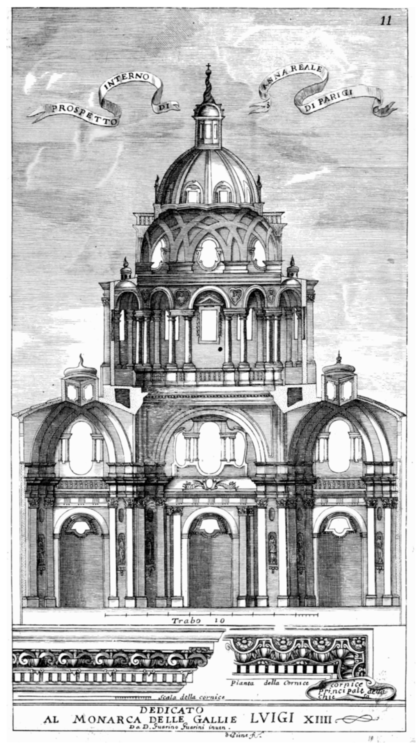
[22] "Modena, dopo averlo bandito, troppo tardi lo riaccolse per fruire adeguatamente delle inimitabili testimonianze della sua architettura." Nino Carboneri, "Guarini a Modena," in Guarino Guarini e l'internazionalità del Barocco, ed. Marcello Fagiolo and Giuseppe Bonaccorso (Rome: Officina Edizioni, 1970), 60.



nunziata [23] (Figure 4) with the adjoining theatine convent façade are the only Messinese design to have been executed (only to be destroyed by the Messina earthquake of 1908), whereas the Church of Padri Somaschi, and San Filippo [24] remain unsure in their execution. Messina also marked the start of his publishing career in 1660, with La Pieta Triofante, a theological tragicomedy.
Lastly, Guarini's connection to Veneto, specifically to Verona, was somewhat intermittent. His activity in the region included the design for the high altar of San Nicolò in Verona [25] , the unbuilt project for San Gaetano in Vicenza, and involvement with Santa Maria dell'Araceli, discovered by Portoghesi in 1957 [26], leading to its construction (supervised by local builders). Though episodic, his works in Veneto were considered by Klaiber potentially as significant as that of Turin, and Paris [27].

Paris and Abroad

Guarini's arrival to Paris in 1662 ended up in "his largest church ever, in the most cosmopolitan city of his career" .[28] The Church of Ste. Anne-la-Royale (Figure 5), though left incomplete, was the only realized project constructed outside of Italy, and attracted the attention of Bernini who, while in Paris in 1665, visited the church during construction, and reportedly commented in favor of the design [29]. The four-year Paris chapter of the architect's life is perhaps where his former Borrominian borrowings, were to some extent blended with that of Gothic.
Beyond Paris, other foreign projects attributed to Guarini or published in his treatise are documented with varying degree of certainty. Among them



[23] The Messina earthquake of 1793, and 1908, and WW2 leave us little evidence about his activities but through the Architettura Civile treatise, and some photographs, we can assume his involvement in the design of the cupola of SS.Annunziata. Robison, 10.

[24] Sandonnini suggests possible association of the architect with San Filippo, together with Robison mentioning a possible chapel, while Portoghesi puts forward a possibility of the stucco chapel being a part of the San Filippo church.

[25] Klaiber, Guarino Guarini's Theatine Architecture, 399.

[26] Susan Klaiber, "Sketching Santa Maria d'Araceli, Vicenza," Susan Klaiber: Architectural Historian, March 31, 2016, https://susanklaiber.wordpress.com/2016/03/31/sketching-santa-maria-daraceli-vicenza/

[27] Klaiber, Guarino Guarini's Theatine Architecture, 419.

[28] Klaiber, Guarino Guarini's Theatine Architecture, 155.

[29] Coffin notes Bernini's comment as, "I believe that it will turn out beautiful". David R. Coffin, "Padre Guarino Guarini in Paris," Journal of the Society of Architectural Historians 15, no. 2 (May 1956): 3–11, https://doi.org/10.2307/987807

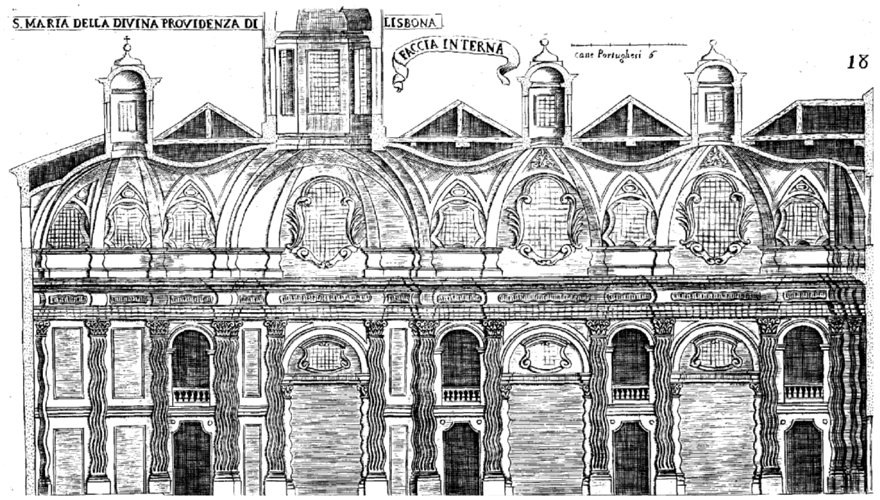
[30] Klaiber, Guarino Guarini's Theatine Architecture, 330.

[31] Klaiber, Guarino Guarini's Theatine Architecture, 305

[32] Bernardo Vittone is the actual architect of the church in the 18th century. Robison, Guarino Guarini's Church of San Lorenzo, 293.

Figure 4 –Section and plan of the Padri Somaschi Church, Messina. From Architettura Civile by Guarino Guarini (Turin: Gianfrancesco Mairesse, 1737), tav11.

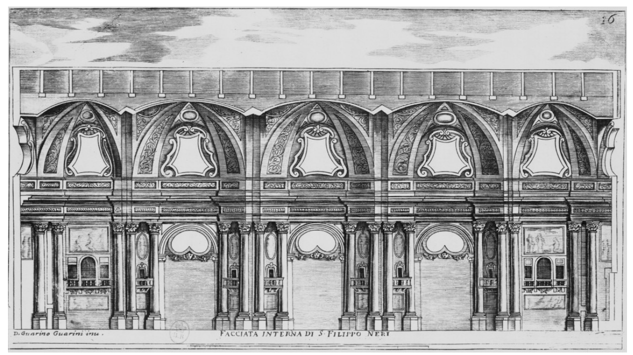
Figure 5 –Section of St.Anne Royale in Paris. From Architettura Civile by Guarino Guarini (1737).



is the church of Santa Maria della Divina Provvidenza in Lisbon (Figure 6), considered as his second-largest Theatine design [30]; if it was partially built, it did not survive the 1755 earthquake [31]. The church of San Gaetano in Nice [32], together with Santa Maria di Ettinga in Prague, belong on the other hand to the same group of unexecuted, or remotely designed projects of the architect. Assumptions on the presence of Guarini in Spain, or Bohemia continue to be unproven [33].

Turin

The most documented oeuvres of the architect, the highest number of his publications, his most mature architectures, the realization of his first civil buildings, and the most influential location so as to make Guarini the most influential baroque architect of the century, took place from 1666 to 1683 in Turin, la citta' della sua maturita', [che] puo' essere considerata la sua patria piu vera"[34]. His new designs for this city and



its surroundings, besides churches, were not limited to palaces only, but also urban infrastructures, such as the Porta di Po (Figure7), a city gate of which only some engravings remains, following its early 19th-century demolition[35].

In Turin, six churches in general involved Guarini's participation, two of which remain of significance; the church of San Lorenzo, and the chapel of Holy Shroud. The others in-

[33] Meek argues in opposed to Sandonnini's suggestion Guarini's stay in Bohemia between 1657, and 1660, that he probably never left Italy since 1666. Meek, 127

[34] Umberto Chierici, "Guarini a Torino," in Guarino Guarini e l'internazionalità del Barocco, vol 1, ed. Marcello Fagiolo and Giuseppe Bonaccorso (Rome: Officina Edizioni, 1970), 359.

[35] Klaiber, Guarino Guarini's Theatine Architecture, 143.

[36] Robison, 303.

[37] Guarini refused to modernize this church, as he was requested, and did a whole new design. Meek, 140.

Figure 6 –Section of Santa Maria della Divina Providenza in Lisbon. From Architettura Civile by Guarino Guarini (1737).

Figure 7 –Porta di Pio. From Architettura Civile by Guarino Guarini (1737).

Figure 8 –Section of S.Filippo Neri in Turin. From Architettura Civile by Guarino Guarini (1737).

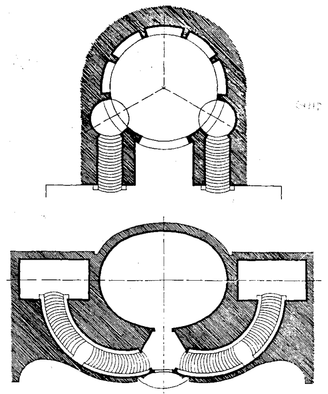


Figure 9 –Similar staircase solutions for Palazzo Carignano and Holy Shroud Chape. From Mario Passanti, Nel mondo magico di Guarino Guarini (Toso, 1963)

clude a partial involvement in the church of San Filippo Neri shown in Figure 8 (project commissioned to him in 1679[36], but ultimately realized following a different design by Baroncelli, after Guarini 's death), a reconstruction project for the Consolata, only partly realized, an unrealized design for Oropa[37], and the uncertain attribution to him of the Immacolata Concezione[38].

Further civil buildings by Guarini include Palazzo Carignano, and the refurbishment of the Carignano family castle at Racconigi that illustrated the capacity of the architect to bring in his former ecclesiastical language to a secular typology. Indeed, this was succeeded specifically with Palazzo Carignano, considered as one the most accomplished Palaces of Italian baroque with "the most spectacular late 17th century grand salon in Italy"[39].

The Torinese period until the death of the architect, shows an integration of typologies. Even though the functions differ, there are Guarinian devices common to both, namely, the resemblance of Sidone staircase solution, and that of Carignano (Figure 9). Likewise, the integration of his writing and architectural pursuit, is mainly what made Turin the nuclei of Guarini's legacy.

Writings

The architectural activity of Guarini is tightly interconnected with other activities, as well as being in accordance to his legacy of "modernizing/turning things unconventional" in anything he produced. To this end, a brief mention to his writings is relevant. La Pieta Trionfante, 1660, is the very first published text by Guarini: this tragicomedy play is considered as "una visione Moderna" [40]. This drama, dedicated to the Duke of Modena, was played by his students of mathematics in Messina [41], and in fact, was watched by Giuseppe Silos, who comments on it on his 1666 book [42]. The subsequent publications by Guarini can be broadly categorized into philosophical, mathematical/scientific, and architectural works. In terms of his philosophic position, Guarini's geocentrism advocacy in the midst of the development of heliocentrism is probably another proof of his unconventionality. Even so, Placita Philosophica published in 1665 is thought to be of importance in the realms of metaphysics, natural philosophy, ethics, and theology.

The 5 books by Guarini on the subjects of math, geometry, astronomy, optics, projection were certainly a base for the architect's architectural career. The Euclides adauctus & methodicus mathematicaque universalis, 1671, published in Turin, was

[38] Luciano Tamburini, "La Chiesa dell'Immacolata Concezione di Torino," in Guarino Guarini e l'internazionalità del Barocco, vol 1, ed. Marcello Fagiolo and Giuseppe Bonaccorso (Rome: Officina Edizioni, 1970), 389-90.

[39] Meek, 94.

[40] Maria Carfì, Debora Credi, and Lorenza Iannacci, eds., Guarino: Architettura, Natura, Universo (Turin: Museo Torino, 2022), 295.

[41] Meek, 21-26.

[42] Giuseppe Silos, Historiarum clericorum regularium, vol. 3 (Palermo: Petri de Insula, 1666), 572–73.

an explanation on the geometric constructions that will in fact be used in his practice. Starting from 1674, the remaining years of Guarini's life were marked by highly accelerated new printings, separated by one- or two-year gaps, exploring topics of construction and astronomy. Il modo di misurare le fabbriche, 1674, a rather short manual for manufacturers to measure and approximate the construction costs; Compendio della Sfera Celeste, 1675, and Leges temporum et planetarum 1678, are on celestial topics; and Trattato di Fortificazione, 1676 a second technical treatise, where Guarini admits, however, that he doesn't really have experience in the subject [43]. 5 years later in Milan, at the verge of Guarini's death, his final non-architectural text was published, the Leges temporum et planetarum: "in a word, it is a manual of gnomonics, or the art of dialling" [44].

Guarini left his architectural treatise, a text with illustrations, unpublished at his death. This led, after his passing, to a printing in 1686 of the Dissegni d'architettura civile et ecclesiastica, inventati & delinaeti dal padre D. Guarino Guarini, including only a selection of engravings,. This was the only architecture-exclusive book of Guarini published in the 17th century. With the addition of 34 technical plates, and the omission of S.

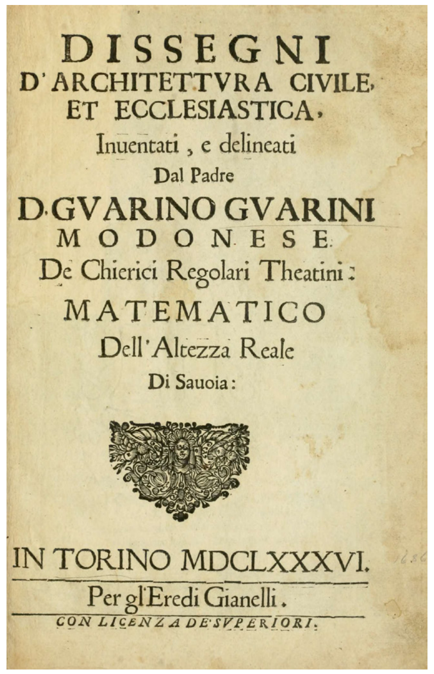


Figure 10 –Title page of Disegni d'architettura civile et ecclesiastica, by Guarino Guarini. Turin: per gli Eredi Gianelli, 1686.

Figure 11 –Title page of Architettura civile, by Padre D. Guarino Guarini, opera postuma. Turin: Appresso Gianfrancesco Mairelli all'Insegna di Santa Teresa di Gesù, 1737.

Maria Annunziata elevation [45], the final version of the treatise titled as Architettura Civile was finally published in 1737 by Vittone. It is as of today, the most complete written work of Guarini on his legacy of architecture, in addition to it being "the only significant baroque architectural treatise published in Italy" [46].

Architecture

Guarini's prophecy in architecture goes beyond stylistic evolution, or typological innovation; it is a combined evolution

[43] Meek, 146.

[44] Meek, 147-48.

[45] Meek, 150.

[46] Susan Klaiber, "Vitruvius and Guarino Guarini," in Brill's Companion to the Reception of Vitruvius, ed. Ingrid D. Rowland and Sinclair W. Bell (Leiden: Brill, 2024), 284.

[47] Klaiber, Guarino Guarini's Theatine Architecture, 129.

of form, structure, and perception. Noteworthy in his legacy is the ingenious addition of Gothic slenderness (despite Guarini's criticism of Gothic proportions)[47] to Roman principles, allowing for the expression of a rich and original spirituality and achieving a new and striking visual experience.

Form, Space, and Geometry

Most scholars esteem Guarini's centralized churches as more relevant, compared to the longitudinal ones [48].Notwithstanding this well-established categorization, repeated in the writings of several authors [49], we should not overlook the importance of Guarini's Latin cross layouts; longitudinal projects such as S. Filippo Neri, S. Maria di Lisbona (Figure 13), and S. Maria di Ettinga a Praga, as investigated by De Bernardi Ferrero [50], are proof of the mastery of the architect even in organizing longitudinal space. Guarini's tendency "to accept the usual form and then to inflect it in a curve" [51] turn out particularly useful when developing forms of "alternative centrality" [52] in the longitudinal churches (Figure 12). Typical of baroque's departure from static forms, these concave and convex geometries are among the most frequently cited by Guarini scholars. These undulations happen not only in plan, but may spread

Figure 12 – Longitudinal designs of Guarini containing alternative centrality. From Harold Alan Meek, *Guarino Guarini and His Architecture* (London: A. Zwemmer Ltd, 1991).

Figure 13 – Santa Maria della Divina Provvidenza da Lisbona, never-built project by Guarino Guarini, digital reconstruction based on original drawing scans. From DR3D Works (2020), accessed August, 2025, https://dr3dworks.wordpress.com/2020/09/12/santa-maria-della-divina-provvidenza-da-lisbona/

to the building's elevation, and its ornamentation. The "wavy" floor plan of Lisbon, its spatial fusion [53], and its undulating order of columns, as well as the swelling façade of Palazzo Carignano, are all examples of such curvatures used by Guarini on different scales of his projects.

Guarini's architecture achieves its most refined expression in the design of vaults and domes, where geometry and stereotomy converge. He approaches this specific application of geometry to architecture in Euclides adauctus, Modo di misurare le fabriche, and finally in Architettura Civile, which includes "a rigorous and systematic discussion of vaulted systems" [54].

48 Rudolf Wittkower, Art and Architecture in Italy, 1600 to 1750, Pelican History of Art (Harmondsworth, Eng.: Penguin Books, 1973), 270.

49 Mario Passanti, Nel mondo magico di Guarino Guarini (Toso, 1963); Meek, Guarino Guarini and His Architecture.

50 Daria De Bernardi Ferrero, "Chiese Longitudinali del Guarini," in Guarino Guarini e l'internazionalità del Barocco, vol 1, ed. Marcello Fagiolo and Giuseppe Bonaccorso (Rome: Officina Edizioni, 1970), 415-424.

51 Meek, 71.

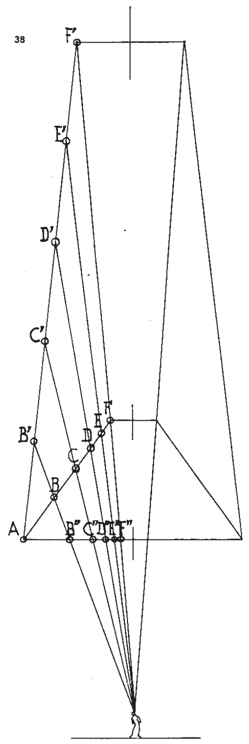
52 Meek, 123.

53 Meek, 15.

54 Roberta Spallone, "Lunette Vaults in Guarini's Work: Digital Models between Architettura Civile and Modo di Misurare le Fabriche / Volte a lunette nell'opera di Guarini: Modelli digitali fra Architettura Civile e Modo di misurare le fabriche," DISEGNO 4 (2019): 91, https://doi.org/10.26375/disegno.4.2019.10

Among his famous ribbed domes, star-shaped vaults, banded vaults (volte a fasce), and basket vaults (volte a cestello), his most peculiar vault seem to be those based on conic sections. The inspiration for such vaulting systems, even though commonly attributed to his being acquainted with French stone-vaulting techniques in Paris, has not been concretely proven: as Taraldsen simply noted, "correlation does not necessarily entail causation" [55].

The so-called process of vertical stacking, combining "autonomous zones" [56] in a building's elevation (a notable built example being San Lorenzo) is another noteworthy technique used by Guarini to develop most of his church designs, perhaps except for the church of Oropa in which these zones are more coherent, and less stacked [57]. The telescopic assemblage of levels has been attributed to Spanish references as well [58], while it can be put among the other mighty "vernacular coincidences" [59] regarding the architect's source of inspiration.



Movement and Perception

A factor always to be considered in the exam of Guarini's work is the visitor's perception and his movement within the building (Figure 14). This should be intended not only as the physical movement in the space, but also the movement of the eye, and the reaction to, and perception of, symbolic elements (such as the geometric patterns embedded in the Sidone vaulted surfaces). Guarini at times introduces visual paradoxes, such as windows in the pendentives [60]; a significant instance of such paradoxical technique is closely related to the purpose of this study, considering the hidden structure of the church that is concealed behind the San Lorenzo drum just under the dome, hollowed out with 8 windows. This type of contradiction, is interpreted by Battisti as a kind of metaphysical poetry [61], whose potential is enhanced by the skilled use of light in the architect's designs. Light is indeed and indispensable component to Guarini's design. The manner in which Guarini transforms light into a structural presence, is not only related to his characteristic typologies of kidney-shaped, trefoil, or violin-like windows, but also to the hollowing out of masonry structures and solid walls to create mysterious "camere", both light and dark spaces, such as the "camere di luce" in San Lorenzo's dome, and the "dark rooms" over the San Lorenzo side chapels.

55 Simen Dalen Taraldsen, "French Influence on Guarino Guarini's Theory of Stereotomy," Nexus Network Journal 25, suppl. 1 (2023): 367–71.

56 Meek, 45.

57 Klaiber, Guarino Guarini's Theatine Architecture, 340-341.

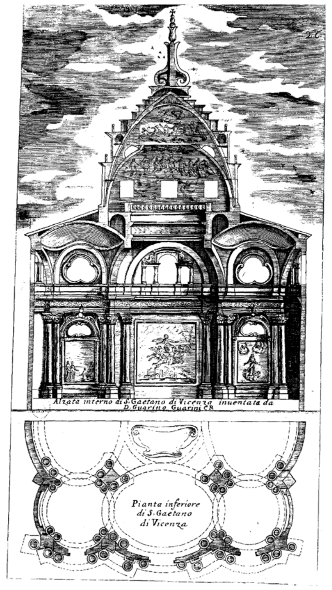
58 Klaiber, Guarino Guarini's Theatine Architecture, 314.

59 Meek, 75.

60 Meek, 71.

61 Eugenio Battisti, "Schemata nel Guarini," in Guarino Guarini e l'internazionalità del Barocco, ed. Vol 2, Marcello Fagiolo and Giuseppe Bonaccorso (Rome: Officina Edizioni, 1970), 107-77.

Figure 14 –Trinitarian concept of Holy shroud church. From Mario Passanti, Nel mondo magico di Guarino Guarini (Toso, 1963)



Construction and Structure

Guarini's attitude towards the structural systems of his buildings stands in opposition to that of Borromini, in that he tends to conceal the load-bearing elements, or distract the visitor from the reality, while Borromini's attempt was to clarify it[62]. This intention is evident in several works of him, namely in Capella della SS. Sindone where the real load of the dome is counteracted by the invisible external buttresses of the dome [63]; In S. Gaetano (Figure 15), similar to St. Anne in Paris, and Somaschi in Messina [64] the domes seem to be supported by ground floor piers, whereas the real bearing elements are arches spanning over the vaults of the side chapels. The transition between octagon and rectangles in Madonna dell'Oropa, is done with squinches that are hidden externally [65]. A more complex version of an invisible squinch exists in the church at the discussion of this study, San Lorenzo, which expresses the ultimate realization of this concealing technique, having 4 big arches placed behind the visible interior of the church supposedly springing from above the aforesaid squinches themselves hidden by the elaborate vaults over the side chapels. This matter will be explored in more detail in the following chapters.

2.2. The Church of San Lorenzo

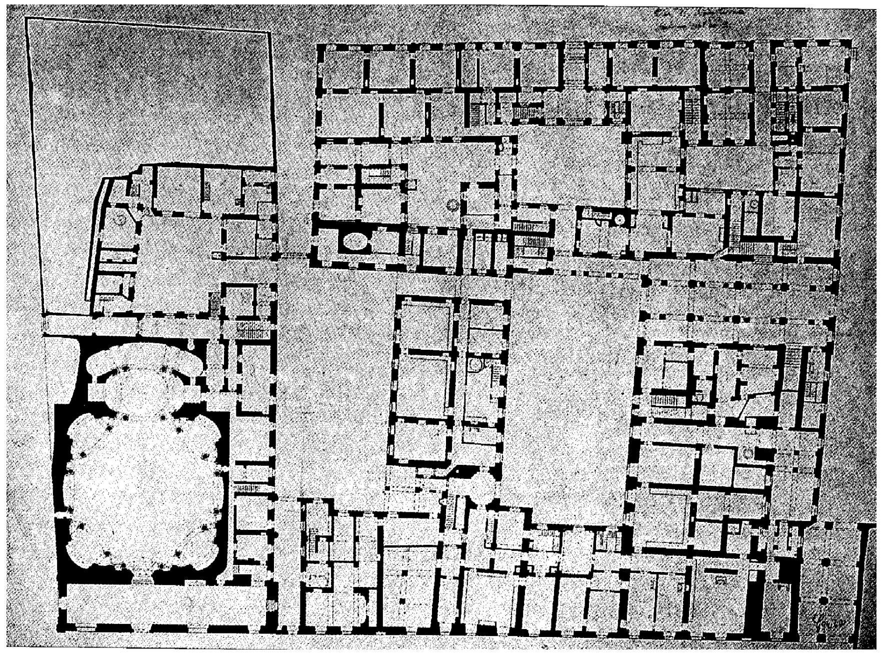


Figure 15 –Section of S.Gaetano church in Vicenza. From Architettura Civile by Guarino Guarini (1737).

Figure 16 –San Lorenzo Context plan. Scanned from Andrew Morrogh, *Guarino Guarini*, 2006.

[62] Wittkower, 271.

[63] Meek, 75.

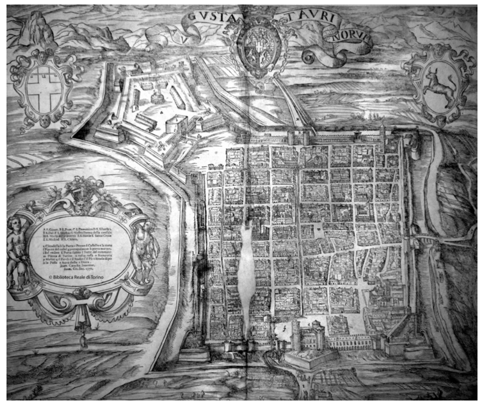
[64] Klaiber, Guarino Guarini's Theatine Architecture, 403.

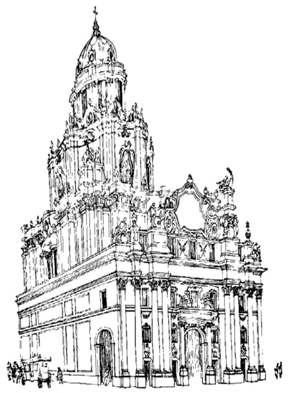
[65] Klaiber, Guarino Guarini's Theatine Architecture, 141.

As one of his most mature works, Chiesa di San Lorenzo in Turin was originally an ongoing project, commissioned by Emanuele Filiberto, Duca di Savoia, to honor San Lorenzo after his victory at the Battaglia di San Quintino in 1557. The cornerstone of the church was laid in 1634. Based on Meek, there has been a perspective sketch of this initial state in a metal cylinder placed inside the new foundation[66]. The plan used to be a Latin cross. The project was later entrusted to Carlo di Castellamonte, with construction beginning in 1634. Guarini's project commenced in 1668 with already built foundation of Castellamonte, on the west side of the Piazza Castello, and lasted until 1687. Further restoration projects have been carried out on the church in the 19th century by Carlo Randoni, as well as some Post World War II restorations. This church shows ingenious structural and geometrical solutions, that have resulted in the intersecting ribs of the dome, Gothic hints, and constructive light.

Construction and Actors

San Lorenzo an originally 12th century religious space, in spite of its poor state until the 16th century[67] became a ducal project[68], shifting its future to an exemplary baroque church. The history of the site before Guarini's arrival remains somewhat clear from Crepaldi (a socio-cultural study of the church), and Klaiber, although she finds his claims not fully supported by reliable documents. Nonetheless, what is assumed of the location of the church before its current place, from 1563 to the 1634 ducal donation, is someplace in the proximity of the northern city walls, in the Palazzo Ducale area (Figure 17). The exact site remains unclear; however, the Theatine's docu-





mentary approves a transfer, while the specific reasons for it revolve around urbanistic considerations, ducal policies, and Theatine visibility. The elements existing in this site consisted of a portico, an oratory, a temporary church, and some shops, which were mostly were removed shortly before Guarini's involvement in the project[69].

Nevertheless, most of what remained at the time of Guarini's arrival in 1666 was removed[70], except for the exist-

Figure 17 –Carta del Caracca, historical map of Turin. From Gruppo Archeologico Torinese (GAT), ArcheoGAT.

Figure 18 –San Lorenzo's facade based on Guarini's engravingg. From Ferrero

[66] Meek, 45.

[67] Robison, 66.

[68] 84% of the funds which built S. Lorenzo came from the ducal family. Klaiber, Guarino Guarini's Theatine Architecture, 246.

[69] See Klaiber for detailed analysis of the site transformation and condition. Klaiber, Guarino Guarini's Theatine Architecture, 184-245.

[70] Klaiber, Guarino Guarini's Theatine Architecture, 239.

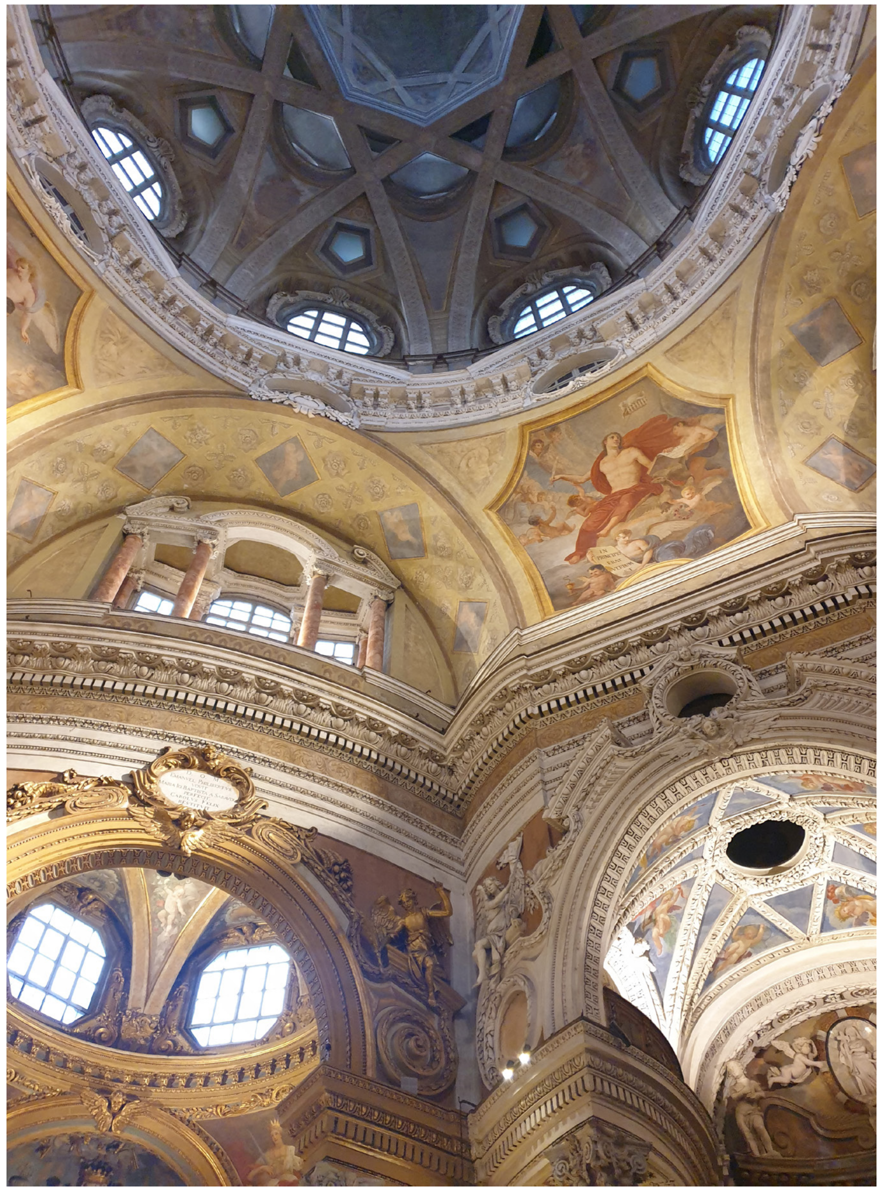


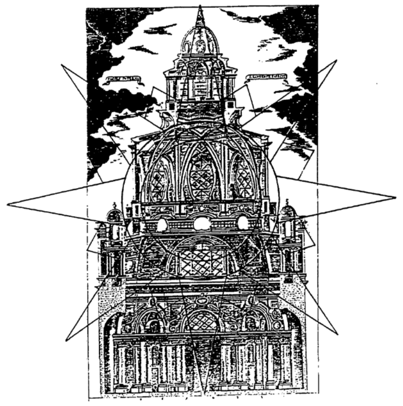
Figure 19 –Interior view of San Lorenzo. Photograph by the author, March, 2025.

Figure 20 –The "keys" to the dome located beneath the large structural arch behind the kidney-shaped window. Photograph by Edoardo Piccoli, 2025.

Figure 21 –Pendntive curved form and Serliana. Photograph by Edoardo Piccoli, 2024.

ing Castellamonte foundations, which made this project "the first time he designed a whole church from the ground up" [71]. The only notable restriction regarding San Lorenzo, is that the Vittozi elevations of the Piazza Castello had to remain consistent, which resulted in an entirely different façade, from what is illustrated in the engraving of the architect. A drawing of the original on-paper façade has been reproduced by Ferrero (Figure 18). Further constraints were clearly the portico on the eastern side, and a 5-meter-wide part on the north related to the casa, and its clausura with the former[72].

Forms and Spaces



In terms of the spatial experience, the church brings in plenty of the aforesaid Guarinian devices[73] from the convexities of the ground floor plan to concavities of the pendentive level[74], to the four stacked layers[75], to the ribbed domes, the genius capture of light, and finally the complex structural system, put out of sight, behind what is observed inside the church. The main wonder being the interlaced dome on an octagon, though present in Somaschi, Gaetano in Nice, and St. Anne in Paris, finds its finest execution in San Lorenzo due to the addition of further complexities that makes it appear deeper[76],and more delicate.

The sense of depth is largely achieved with the oval essence of the church. The ribs in turn, having an elliptical shape, emphasize on the deepening of the dome. In spite of their form, the architect's source of inspiration for such ribbed technique's remains ambiguous. As Meek explains, there are differences between Guarini's ribbed domes, and that of the Gothic, or Islamic, since he lays them out in parallel, instead of converging, and fills the gaps between them while introducing an upper space; features that oppose the former styles respectively[77]. Noteworthy, is the proportional relationship that the ellipse form of these arches has with the circles contained in the star pattern on the floor of the church[78] (Figure 22).

This geometrical

Figure 22 – Star motif projected on engraved section. From Elwin Clark Robison, *Guarino Guarini's Church of San Lorenzo in Turin.*

Figure 23 –The hidden structure of San Lorenzo from Franco Rosso, *Guarino Guarini,* 2006. Photograph by Giuseppe Dell'Aquila.

[71] Klaiber, Guarino Guarini's Theatine Architecture, 251.

[72] Klaiber, Guarino Guarini's Theatine Architecture, 250; Robison, 114.

[73] Meek, 10.

[74] Meek, 48.

[75] As Gasparini, and Volpato note, these four levels consist of the ground floor chapels until their cornice, the pendentives and the Serliana windows, the drum, and the main dome upwards. Elena Gasparini and Ramona Volpato, "Guarino Guarini e la chiave della cupola di San Lorenzo di Torino: La complessità nascosta," Galileo: Rivista di scienza e innovazione per l'ingegneria 158 (June–July 2003): 38.

[76] Robison argues that Guarini used ribs to deepen the dome. Robison, 263.

[77] Another factor mentioned by Meek is the importance of the structural performance of interlacing ribs that is to prevent buckling, by segmenting the arches and so not to reduce the general span of the arch. Meek, Guarino Guarini and His Architecture, 48, 53.

[78] Robison, 258.

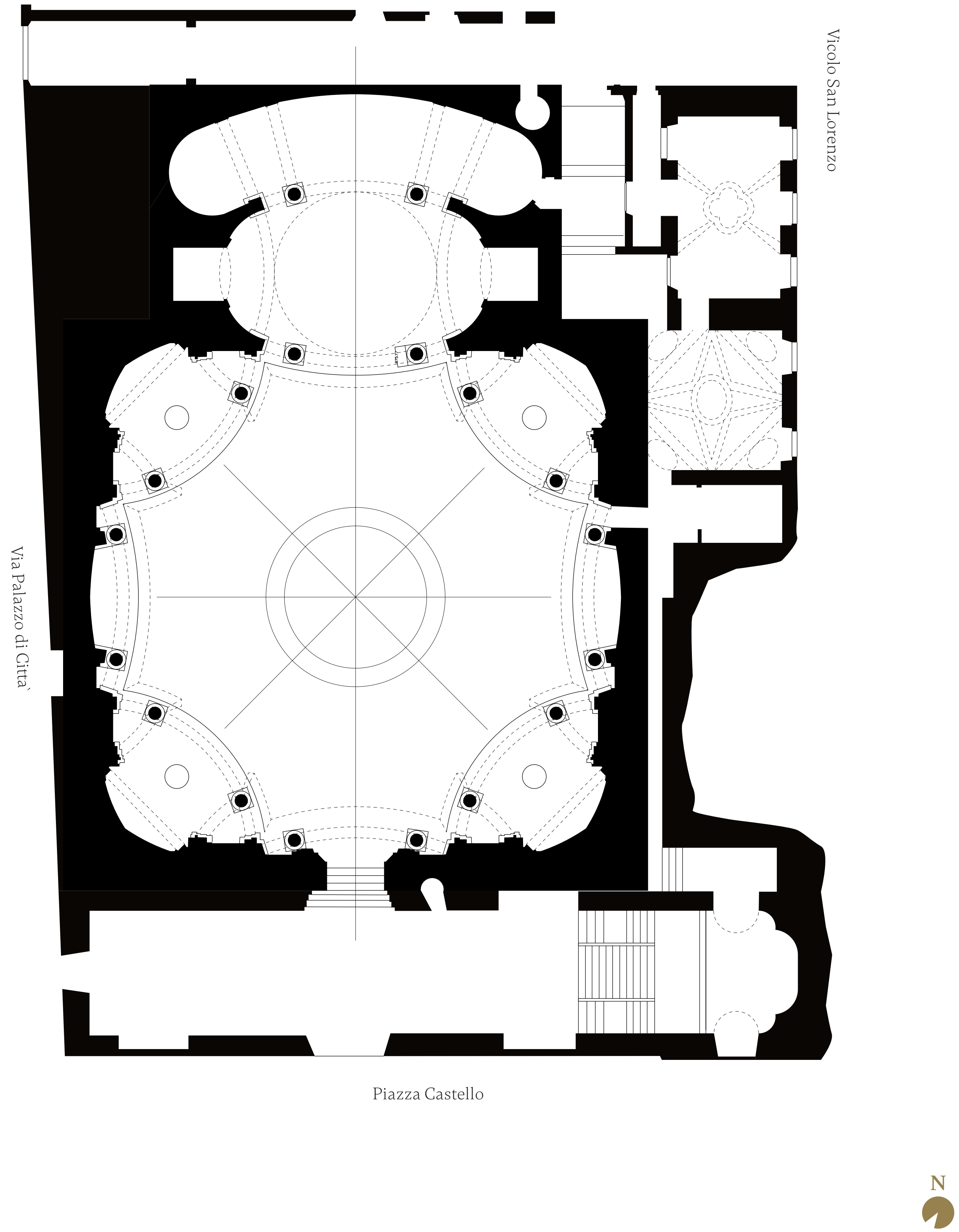
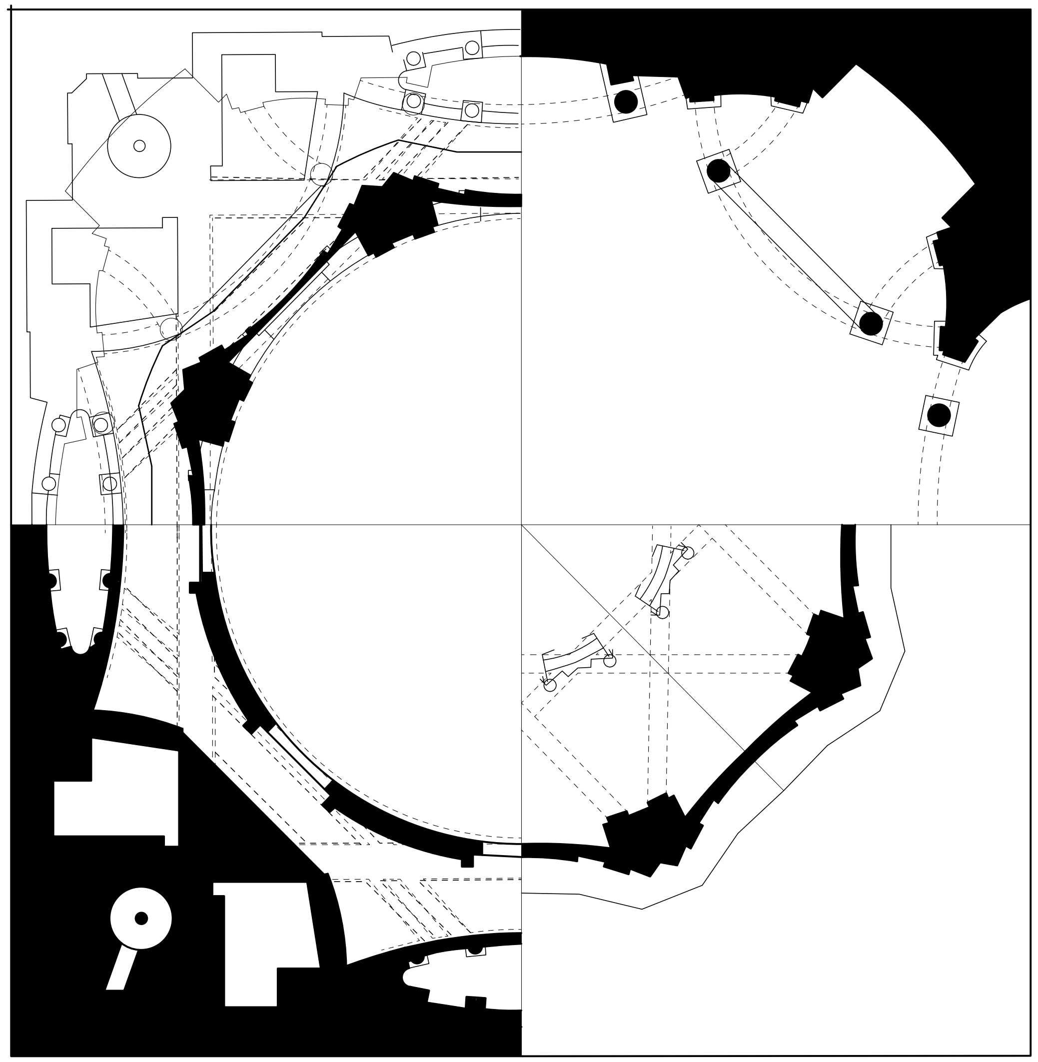
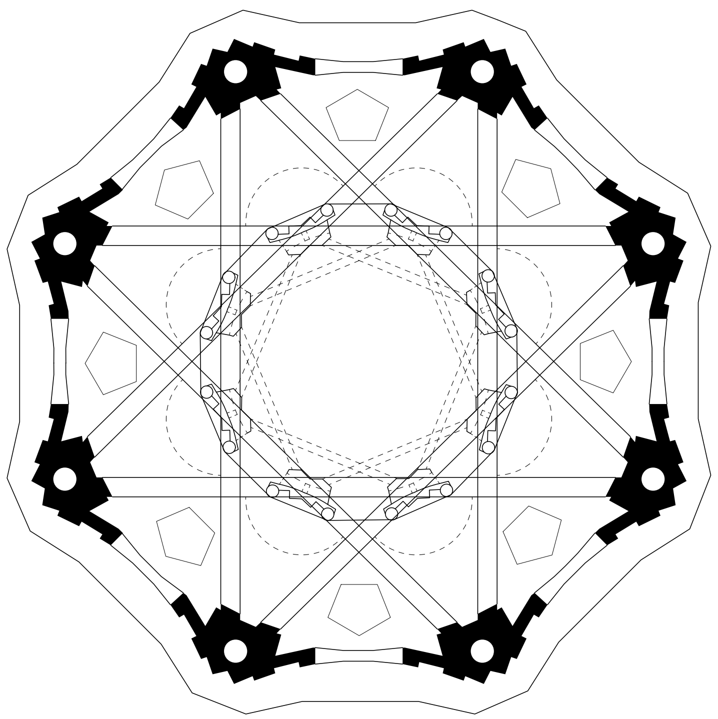


Figure 24 –San Lorenzo, simplified ground floor plan with surrounding structures, scale 1:200.





N

Figure 25 – Plans of San Lorenzo in four levels, scale 1:200. From AST, Randoni drawings.

sophistication, comes with a further contributing factor, the invisible structure, in creating the light-weight-looking dome (Figure 23). The slender marble columns of the ground floor, only to some extent bear the loads of the parts above, since the springing point of the aforementioned ribs are 4 large arches, located behind the pendentive level elements. The extent to which these arches have been explored, and further hypothesis on them are presented in the following chapters. What concerns here, is the peculiarity this structural system brings to San Lorenzo compared to similar designs of the architect.

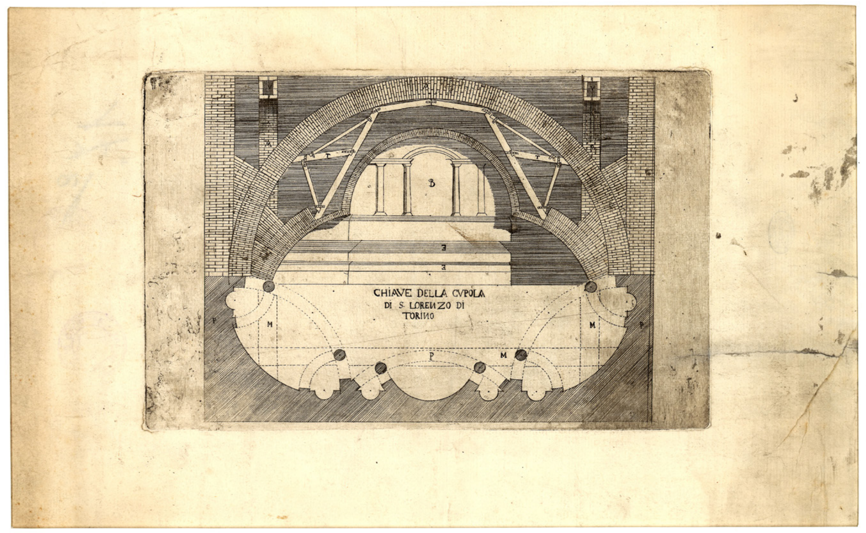


Figure 26 – *Chiave della Cupola*, engraving by Guarini. From Disegni d'architettura civile et ecclesiastica, 1686.

2.3. The Hidden Structure of San Lorenzo

As previously mentioned, scholars attempted to deepen understanding of Guarini, establishing his brilliance, finding the best chronology of his life and work, highlighting geometrical solutions in his design, and his Theatine career's influence on his architecture; however, relatively less is explored on the structure of his buildings. Brief descriptions are present in most of the aforementioned literature of this study, few articles on the structure of San Lorenzo and other churches, are what concluded the former structural investigation on the architect.

Somewhere at the back of the star-shaped vaults of the diagonal chapels, up until the end of the pendentive zone in the church of San Lorenzo, there exists a concealed structural system that actually sustains the load coming from the upper "true structure"[79] of the church. The engraving that has been attributed to Guarini, titled as "Chiave della Cupola" (Figure 26) is what initiated this matter, depicting briefly, the way the core hidden structural system of the church works, which consists of four large arches so-called *arconi*. Together with these *arconi*, the drawing showcases the serliana, a part of the pendentive,

[79] Meek, 60.

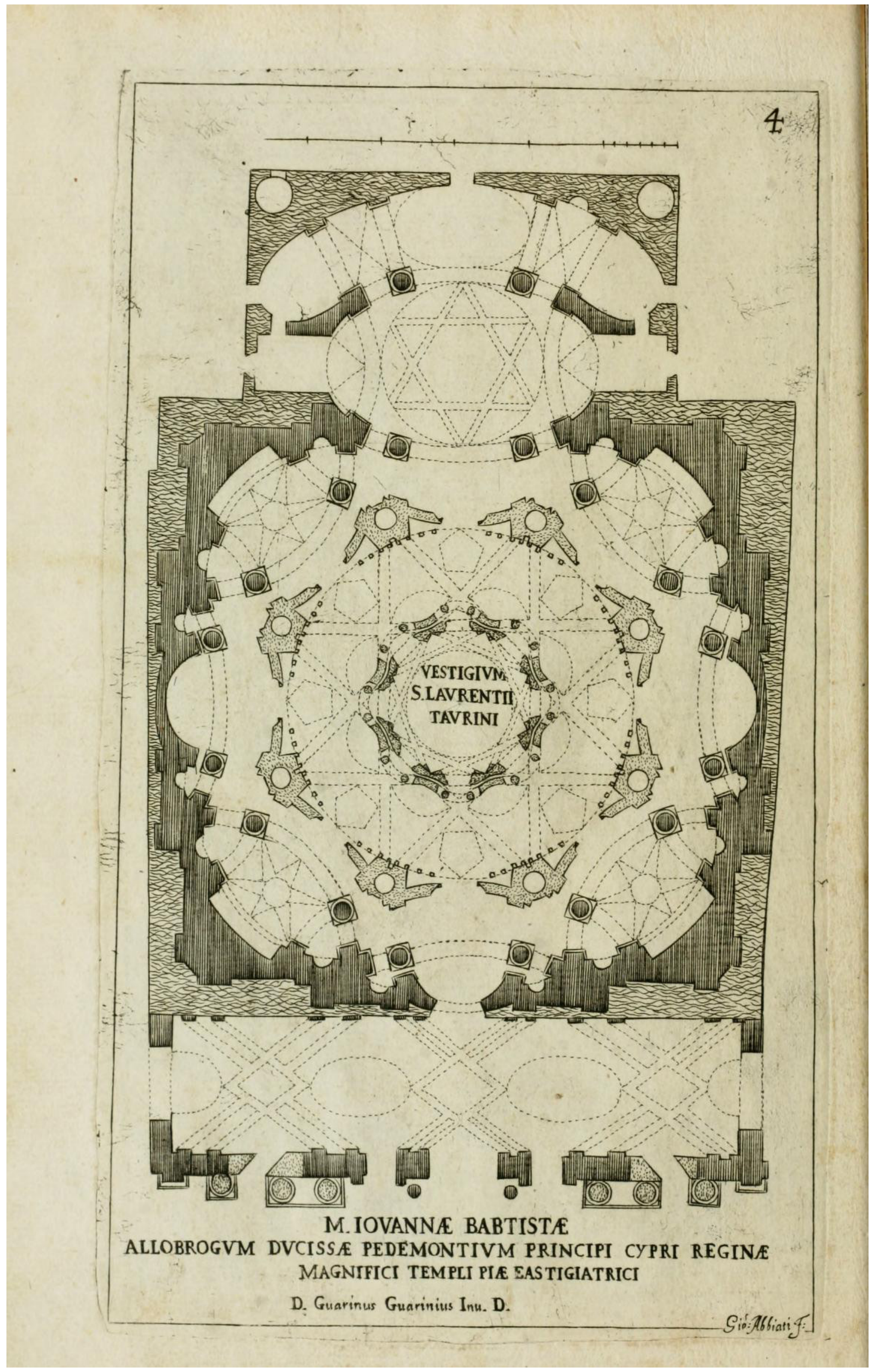


Figure 27 — Engraving plan of San Lorenzo by Guarini. From Disegni d'architettura civile et ecclesiastica, 1686.

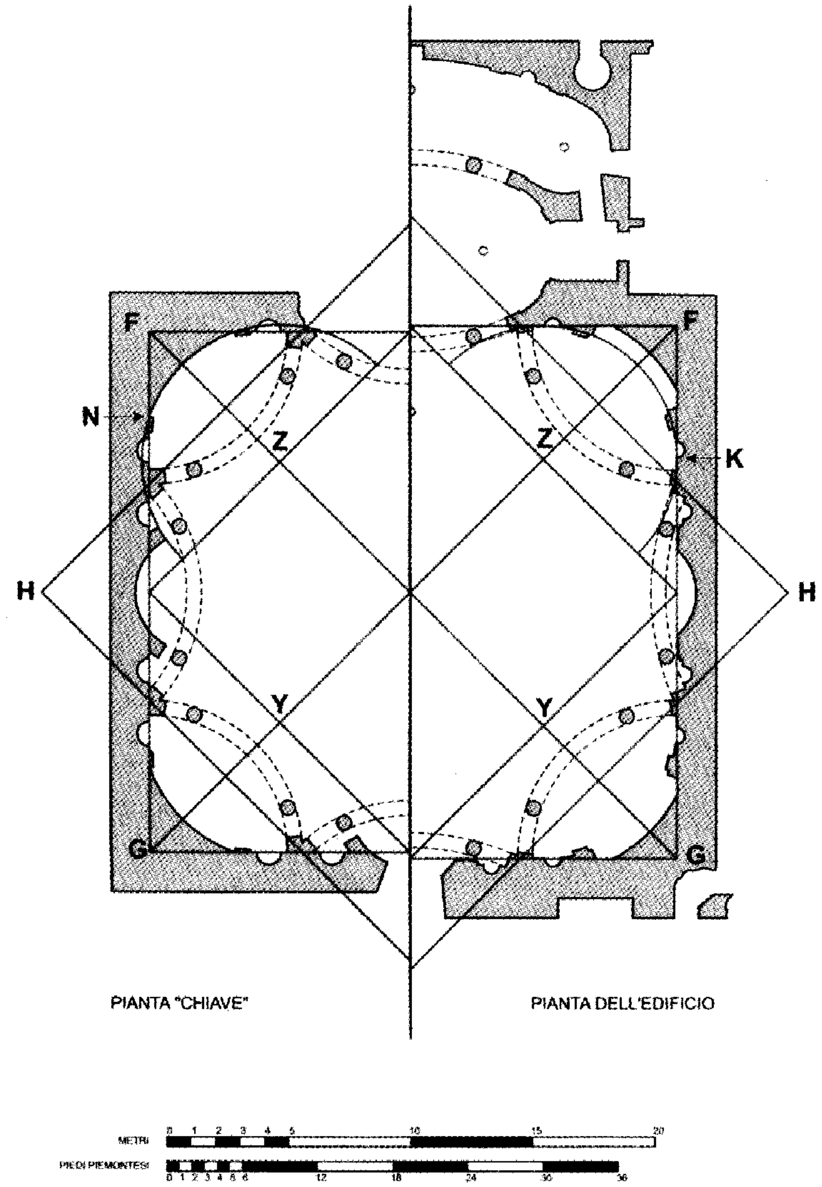


Figure 28 — Comparative plans of San Lorenzo from Guarini's engraving and the as-built church. From Andrew Morrogh, *Guarino Guarini*, 2006.

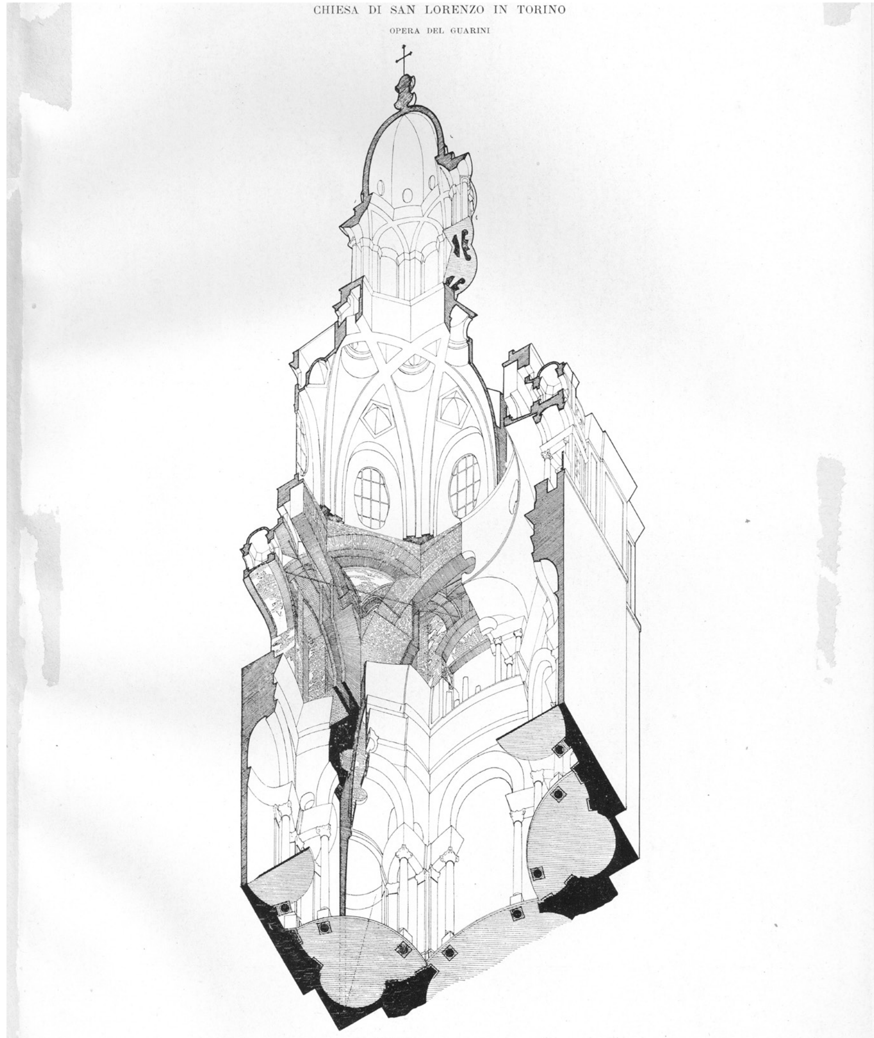


Figure 29 – Cut-out isometric view of San Lorenzo, depicting the structural system of the church. From Luigi Denina and Alessandro Proto, La Real Chiesa di San Lorenzo, 1920.

the partial ground floor plan, and the wooden framework to build the four large arches. The details on the specific reading of this engraving, being to some extent studies by few authors, remain not fully clear. There are mentions of this engraving, as the most technical of the other drawings of the church, by almost all the authors that have published at least a general descriptive text on San Lorenzo. However, few have demonstrated clarifying analysis on the ambiguity of this hidden structure.

The 1920 article of Denina and Proto [81], contained an illustration on this topic and has been cited by many, which up to now is an important drawing in spelling out how the structural system works (Figure 29).

Noteworthy, is Andrew Morrogh in La Pianta di San Lorenzo[80], that investigates a comparative study of the plan in the engraving, and the actual building by scaling the engraving based on the scale of Guarini's treaties' plan (Figure 28). Although this article does not specifically talk about the structural behavior, it does analyze the engraving's accuracy. Initially he tried to establish the geometrical constructive shapes that constitute the plan, and compare the same methodology on the actual building's plan. Finally, the conclusion made from this study is the one-meter increase, in the diameter of the dome in the construction phase compared to the treaties' plan noting that Guarini was inspired by the geometrical principles, but

[80] Andrew Morrogh, "La pianta di San Lorenzo," in Guarino Guarini, ed. Giuseppe Dardanello, Susan Klaiber, and Henry A. Millon (Torino: Allemandi, 2006), 339–47.

[81] Luigi Denina and Alessandro Proto, "La real Chiesa di San Lorenzo in Torino," *Architettura Italiana 15*, no. 5 (May 1920): 34–38, plate 20.

still open to modify or even abandon those rules based on the survey of the site.

The Chiave della Cupola drawing has been published in the studies of Robison's thesis[82], to reveal the hidden structure to the reader; whereas no information is given on the Chiave themselves. Klaiber, in her thesis, mentions that the engraving predates the treaties plan[83], yet not including any further explanation. It is assumed that the first to have discussed this matter was Giambattista Borra (1713-1786), whose treaty explains in a paragraph, how Guarini has built the wooden centering that rests on the same imposts as of the arches (Figure 30). The text seems to indicate that this centering differs from the Chiave, and is meant to be a prior temporary centering. He writes:

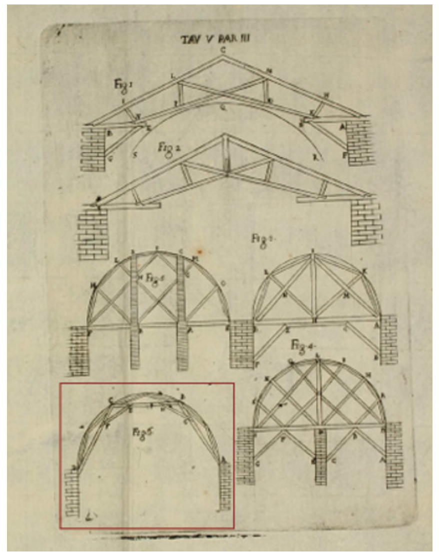


Figure 30 – Indication of the centering system attributed to San Lorenzo by Giovanni Borra. From Trattato della cognizione pratica, 1748.

> Three pieces of wood placed in the angles AB, BC, CD, circumscribed the shape of the arch to this figure, as can be seen, and to keep the said beams joined together, he tied the corners with other pieces of wood EF, GH, then placed on the first three beams AB, BC, CD other armatures in the form of a frontispiece to support the weight at the weakest points[84].

Subsequently, Elena Gasparini and Ramona Volpato's 2003 study only mentions briefly " I quattro arconi principali sono rinforzati da una struttura lignea..." assigning a load bearing function to these wooden beams[85]. Later in 2006, with the publication of the resulting book of a seminar about Guarini held in Centro Internazionale di Studi di Architettura Andrea Palladio in Vicenza, for the first-time a thorough analysis of the Chiave was published by the article of Franco Rosso[86]. In this article, after a general analysis of the plan, the Chiave are in-

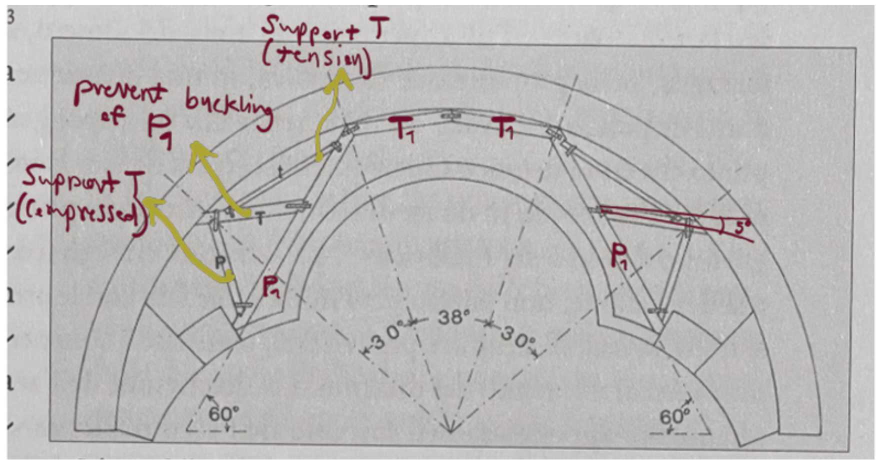


Figure 31 –Notes on the Franco Rosso redrawing of the *Chiave della Cupola,* indicating elements of the system. From author's interpretation notes.

[82] Robison, Guarino Guarini's Church of San Lorenzo.

[83] Klaiber argues that the engraving of the Chiave della Cupola comes first, compared to the section engraving from the Dissegni, since the latter shows heavier, taller, and thinner arch with the hollowed part smaller than that of the former, which is more coherent to what has been realized. Klaiber, Guarino Guarini's Theatine Architecture, 300.

[84] Giovanni Battista Borra, Trattato della cognizione pratica delle resistenze geometricamente dimostrato dall'Architetto Giambatista Borra ad uso d'ogni sorta d'edifizj (Torino: Stamperia Reale, 1748), 284.

[85] Gasparini and Volpato, "Guarino Guarini e la chiave della cupola, 41.

troduced as being initially a support for the Arconi, and their components are described (Trave=T, Puntone=P, and tirante=t), as well as their dimensions and contribution to the system (Figure 31). According to Rosso, the Chiave were to prevent the deformation of the big arches, and the static role of them are taken away due to the restoration of the 19th century.

2.4. The Construction of San Lorenzo

To recognize a general construction sequence, and logic of San Lorenzo, which will be addressed in the fourth chapter of this study, this section provides a brief outline of the previous documents on the building stages of the church, along with the uncertainties about this matter. Accordingly, a reading of th Chiave della Cupola engraving, contributes to an understanding of the architect's possible intentions towards the structure.

There exists three major works on the construction of the San Lorenzo church initially provided by Robison in his

Quarello 1995			
Year	**Month**	**Day**	**Construction/Event**
1177			Oldest document on Santa Maria del Presepe
1562 1563			Restoration of the church and dedication to san lorenzo
1634			First stone of the church layed
1668 (until 1679)			**Guarini's construction until the closing of the dome**
1678			Request for the completion of the church until the dome base
1679			Construction of altare maggiore The cross was placed on dome
1751 (until 1755)			Choir's roof repair (request from the theatine fathers)
1752			Floor completed
1756			Request for the repair of Addolorata's roof
1757	September	13	Renewal of the request for the roof
1795	July	7	Design of the façade for the chapel of Addolorata
1805			General roof repairs (Abate Mossi)
1811 (until 1813)			Façade of the oratorio dell'Addolorata
1818	June	20	Choir roof gutter replacement
1825 (until 1829)			Reinforsing-arches under the squinches (Randoni)
1828	May	7	Replacement of 8 serliana columns
1828	July	19	25000 bricks for filling the arconi
1828	November	13	Insertion of 8 reinforcing arches to the ribs of the dome due to damages of earthquake
1829	April	11	Floor refurbishment
1830			Replacement of chapels' frescos, as well as domes decorations
1832	August	14	Reconstruction of the dome's roof
1833	August	17	Re-covering the roof around the dome
1834	August		Choir roof re-covering
1846			Renovation of the Addolorata
1847	April-May		Floor renovation proposal for the chapel of Addolorata
1847	November	20	Drawings for the elevation of the chapel of Addolorata
1848	June	30	Design for the decoration of Addolorata

Table 1. San Lorenzo's construction sequence. From Quarello

1985 phd thesis[87], and later slightly revised by Susan Klaiber in 1993[88] (Table 1). Furthermore, the 1995 master degree thesis by Quarello, and Leoncini[89] gives an insight into the later interventions of the 18th and 19th century (Table 2). This study, has indeed taken into account these aforementioned hypotheses, together with some educational guess based on the previous documentary, as well as extensive on-site gatherings, and the point cloud data.

The seventies of the seventeenth century contains most

[86] Franco Rosso, "Arconi laterizi e 'chiavi' lignee nella chiesa guariniana di San Lorenzo," in Guarino Guarini, ed. Giuseppe Dardanello, Susan Klaiber, and Henry A. Millon (Turin: Allemandi, 2006), 349–56.

[87] Robison, Guarino Guarini's Church of San Lorenzo, 123--31

[88] Klaiber, Guarino Guarini's Theatine Architecture, 242-45

[89] Cristina Leoncini and Ugo Quarello, "La doppia struttura della chiesa di S. Lorenzo del Guarini, esempio di architettura nella Torino del Seicento" (n.p., 1995).

Robison + Klaiber			
Year	**Month**	**Day**	**Construction/Event**
1177			The existence of Santa Maria el Presepe documented for the first time by Crepaldi
1563			Start of the refurbishment of Santa Maria del Presepe
1564			The new Santa Maria del Presepe marble alter was dedicated
1572			Order of Saints made it their magisterial basilica
1634	June	6	Latin cross design first stone layed
1635			Duke bought a house and a courtyard to have transept of the latin cross
1670			**Since Guarini: the accnount and the construciton began and during the first months materials were assembled on the site**
1670	April-May		Demolition of houses towards Strada Nuova and three shops
1670	June		Delivery of the bricks
1670	June		Payment for the foundation
1671	July		End of the foundation (at least until this date)
1671			scarepellini started carving bases and capitals of the columns
1673	September		Column Placements (in October one of them was replaced)
1674			continued placing columns
1675			Cornice above the ground floor chapels
1675	September		Wooden covering for the high alter's small dome (which is at the level of the cornice of the chapel which means by 1675 everything was finished until below the pendentive zone)
1676	March		Resetting of one column
1676	March		Upper-level / Pendentive zone (payments for the horses and hoisting machine)
1677	July		Chiave della Cupola
1677	summer		Madama Reale wanted to see the volta della chiasa
1678	March		Main dome
1678	May		Cornice above the pendentive
1678	September		The exterior cornice above the drum
1679	May		Sacffolding probably for the upper dome
1679	July		Balusters crowning the main drum
1679	October	27	Completion of the dome
1680	May	12	Inaugural mass with Guarini
1680	July		Payments for the pavement
1680	August		Payment for the windows
1680	Mid-September		Guarini received commision for the high alter

Tab2. San Lorenzo's construction sequence from Robison with minor modifications of Klaiber

of the construction of the church with the inauguration on May 12th, 1680 with the presence of Guarini. What remains certain of the details of this decade's buildings is the completion of the ground floor zone up until the pendentive zone by 1675. The next year is followed by the most intense campaign on the pendentive level, and the dome which was concluded with the mass of 1680.

Regarding further alterations of the church, the eighteenth century restoration of Carlo Randoni is considered to be the most significant, carried out by essentially adding mass, and metal reinforcing elements. Among the addition of masonry there exists the thickening of the four big arches, and the diagonal arches and buttresses; the addition of a reinforcing arch under the squinch; and the closure of the serliana arches (Figure 32).

Uncertainties exist in the chronology in which specific elements were built, but also regarding the material, centering system, successive restorations, and even the architect's drawing. When accessing the backside structural part of the build-

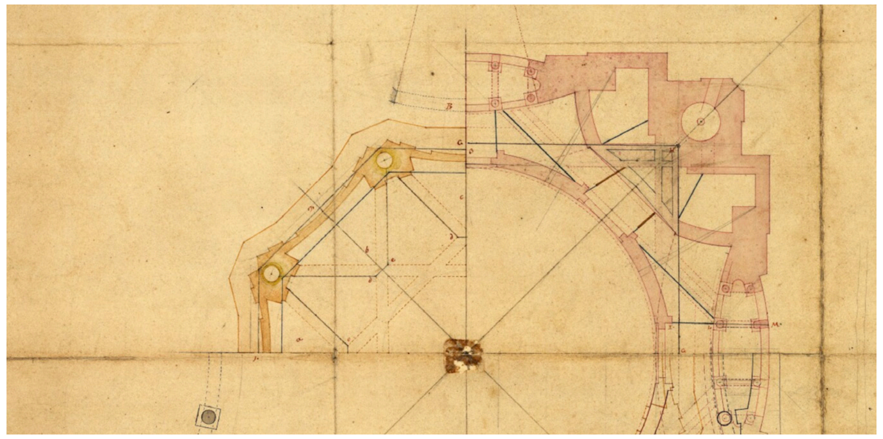


Figure 32 –Randoni's plan showing the metal elements for the reinforcement of the church.

[90] Rosso, "Arconi laterizi e 'chiavi' lignee nella chiesa guariniana di San Lorenzo," 351.

ing, it is rather difficult to distinguish between the original bricks and those that were utilized by the restorer. The temporary frameworks used to build vaults, and arches are as well inconclusive to this day. What is notable among the ambiguous topics, is the only technical drawing attributed to this church known as Chiave della Cupola. Although July 1677 as the date for the construction of the Chiave is an occasional detail on the chronology, what is uncertain is the reading of this document. Since these wooden elements referred to as the "keys" of the dome are part of the ambiguity of the structural system of San Lorenzo, an analysis on this topic helps to unveil the structural logic to some extent.

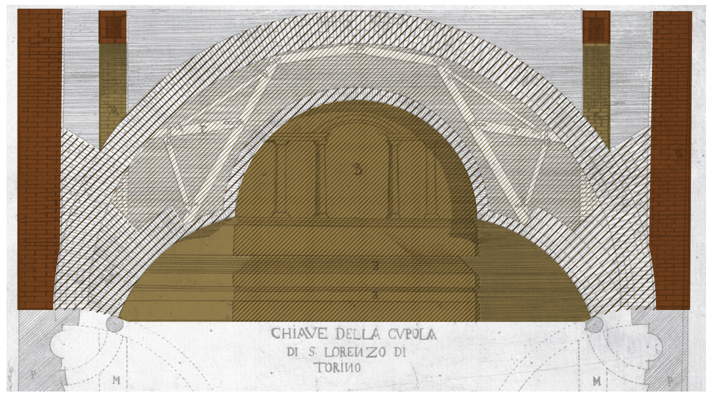
2.4.1. Chiave della Cupola

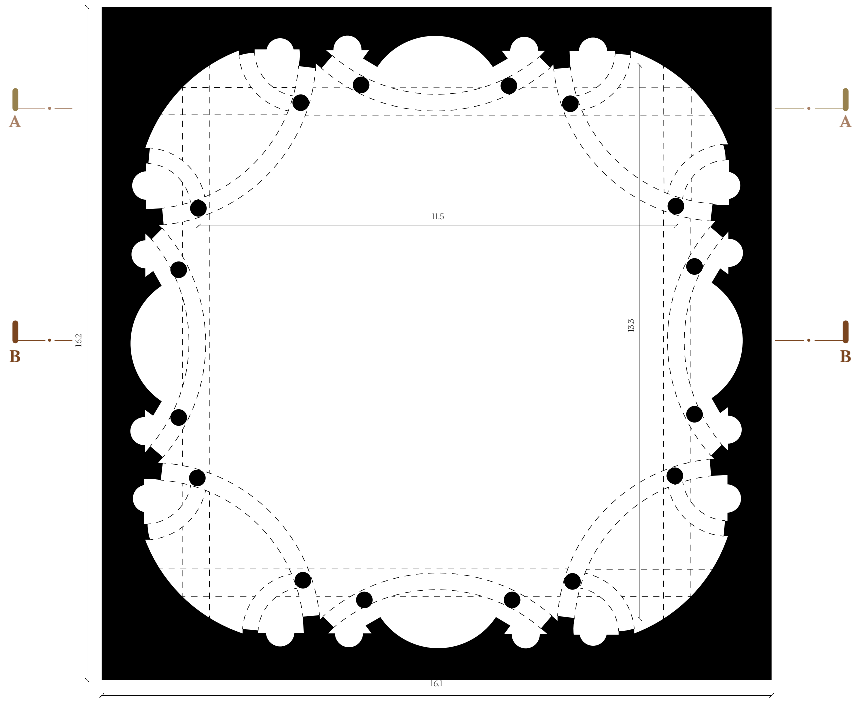
In the following section, an interpretation has been done on the engraving in order to better understand the layers of the drawing. Since different elements belonging to different planes can be seen, it was assumed that there are two section lines related to this document. One cutting in the middle of the perpendicular arches' crown and one cutting the arch orthogonal to the former (Figure33 and 34).

Afterwards, technical redrawing of the engraving, helped to visualize 3 dimensionally (Figure 35), the possible design of Guarini for this level of the church, putting together all the elements present in the drawings in 3d. The scaling of the documents was done based on the assumption of Franco Rosso:
"si assume come unità di misura lo spessore costante dell'arcone (10 millimetri), valuta bile attraverso i mattoni che lo costituiscono (perfettamente visibili nelle troncature V) 0,787 metri[1]2. La corda degli arconi trasversali (16,4 centimetri) misurerà allora 12,90 metri; la freccia (8 centimetri) 6,29 metri. La distanza poi fra gli arconi longitudinali (14 centimetri) 11 metri; e la larghezza totale della fabbrica (20,6 centimetri) 16,21 metri, più corta rispetto alla larghezza della chiesa eseguita (24,7 metri) grosso modo 8,50 metri."[90]

As a comparison tool, the 3d model was overlapped with the chiave, with the perspective cutting the model in the middle, as one of the assumed section lines used to decompose and read the drawing (Figure 37). Allegedly, from this section line and with the perspective, it is possible to see the hidden arches cut at the right spot, but also the different elements that constitute the drawing if the section line was located there. Therefore, a point to be noted is the missing chiave under the arches running perpendicular to the one in elevation.

Furthermore, the point cloud data and the as-built digital model of the church were superposed, in order to highlight possible differences with the former superposition. This allowed to see the two main differences: the tilt of the chiave in the building as-built, and the difference of size based on the as-





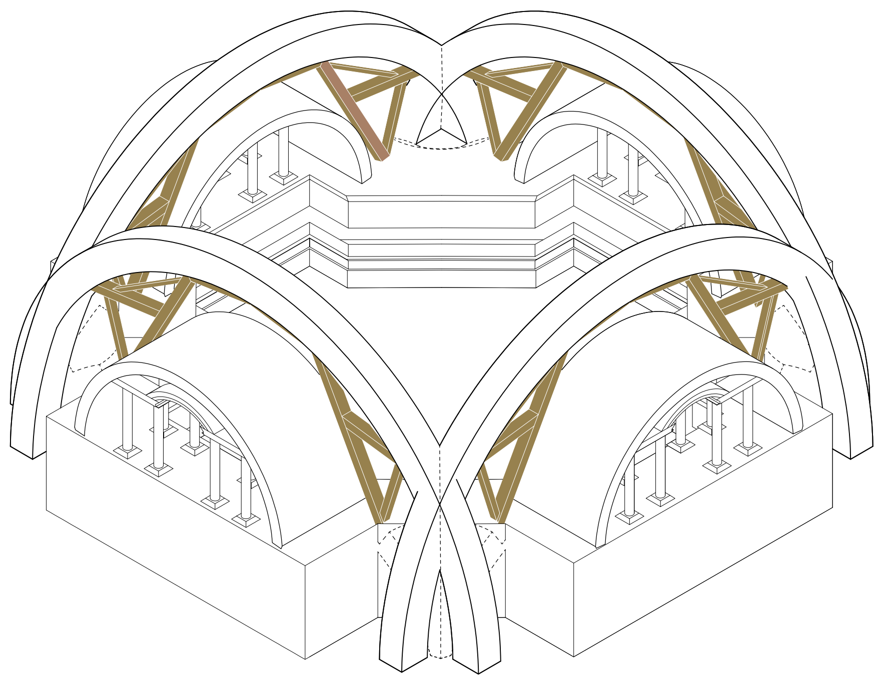


Figure 33 –Annotated section for the reading of *Chiave della Cupola* engraving.

Figure 34 –Completed plan of San Lorenzo based on the partial plan on the *Chiave della Cupola* engraving.

Figure 35 –Axonometric view of the three dimensional model of San Lorenzo based on the *Chiave della Cupola* engraving.

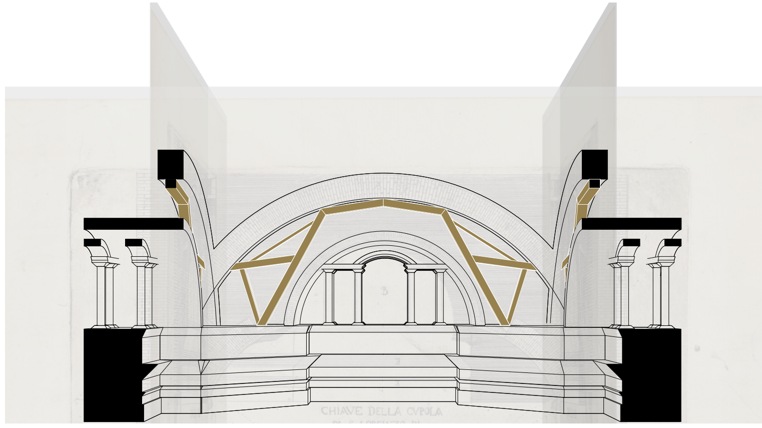
[91] Klaiber, Guarino Guarini's Theatine Architecture, 269.

sumption of Franco Rosso for the size of the building represented in the engraving.

The inclination of this timber system, has been discussed in Chapter 04 of this thesis. However, the function for which the *Chiave* were built for, also contain ambiguities that could be addressed here. Carlo Randoni for instance, considered these "keys" of the dome to be structural, while Klaiber argued that "...far too flimsy to lend any real support to the structure".[91]

Several points of presumed contact with the masonry of the arch, appear to be discontented (Figure 36), suggesting no mechanical engagement of the *Chiave* with the arch, at least in their current state. This condition might imply material loss over time, or later alterations, it nonetheless complicates the interpretation of the functionality of the *Chiave.* Consequently, the original state of these wooden beams remain uncertain, while for the purpose of this investigation it was assumed for the *Chiave della Cupola* to have been simply a centering system of the *arconi*. This assumption leaves us with an investigation on the form that the beams take which has been addressed later.

Figure 36 –The disconnected of the crown of the *arcone* and *Chiave della Cuploa*. From Franco Rosso, *Guarino Guarini*, 2006. Photography by Giuseppe Dell'Aquila.



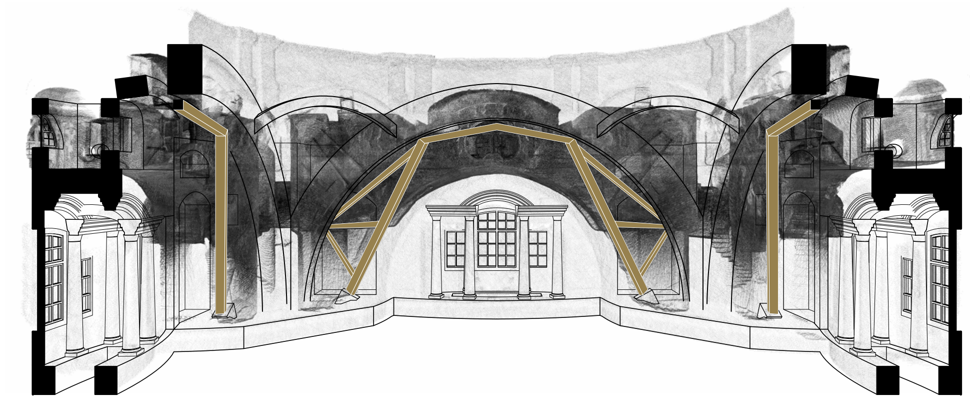


Figure 37 –Cut-out perspective views of San Lorenzo's digital model based on the engraving, and the realized project compared on the same scale.

03

Deformation Analysis

“NB. È la difformità degli archi a det[erminare] l’irregolarità delle parti. Sicché tutta la bontà di arch[itetti] e maestranze è consistita in successive messe a punto per adeguarsi a quest airregolarità senza che la si possa percepire dal basso.”

(Note. It is the lack of uniformity of the arches that determines the irregularity of the parts. Thus, the entire merit of the architects and craftsmen consisted in successive adjustments aimed at adapting to this irregularity, in such a way that it cannot be perceived from below.)[92]

Franco Rosso [93]

The geometric deformation analysis, is set to investigate the performance of the church of San Lorenzo, through several point-cloud-based analyses done at different scales. Rather than identification of a structural problem, or definitive causes of deformation, this chapter focuses on introducing a methodology for measuring geometric deviations in the existing building, using consistent reference systems.

The aforementioned method comes relevant to this church, due to its strong geometric and symmetric characteristics. The comparison between supposed ideal forms of Guarini, and the built reality, gave an opportunity to evaluate the coherence between the design intentions and the real constructed church, as well as documenting possible settlements over time.

In terms of previous assessments of the church, Carlo Randoni’s 1827-1830 restoration project is considered the most significant structural intervention on San Lorenzo, by adding masonry and metal elements to strengthen the building. This campaign initiated by the results of his inspection, in a technical report (*Relazione*) which identified cracks existing in the masonry of the building, specifically at the springing of the *arconi* (Figure 38). This was considered to be due to the exceptional load from the dome. Further, is Randoni’s structural reinforcements which were done supposedly to prevent retrofitting. He mentioned cracks existing in the arconi but in his report there is no more information concerning the specificity of such cracks.

In addition to Randonian intervention, is the Franco Rosso survey of 1999 (Figure 39) which highlights important measurements in order to perform a leveling check, done with traditional techniques, such as optical leveling instrument, while being highly accurate to this day. His analyses mainly focused on detained measurements of elements, deviation values of supposed similar elements from their ideal reference axis, as well as several comparative measurements. Noteworthy is the study of the ground level’s columns bases and the steps below them which illustrates a difference in values, assuming that the construction had taken care of the irregularities of the

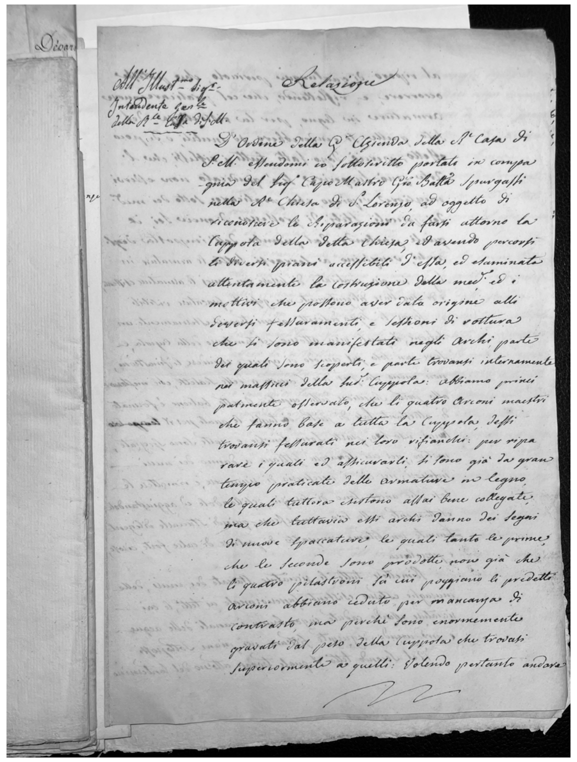
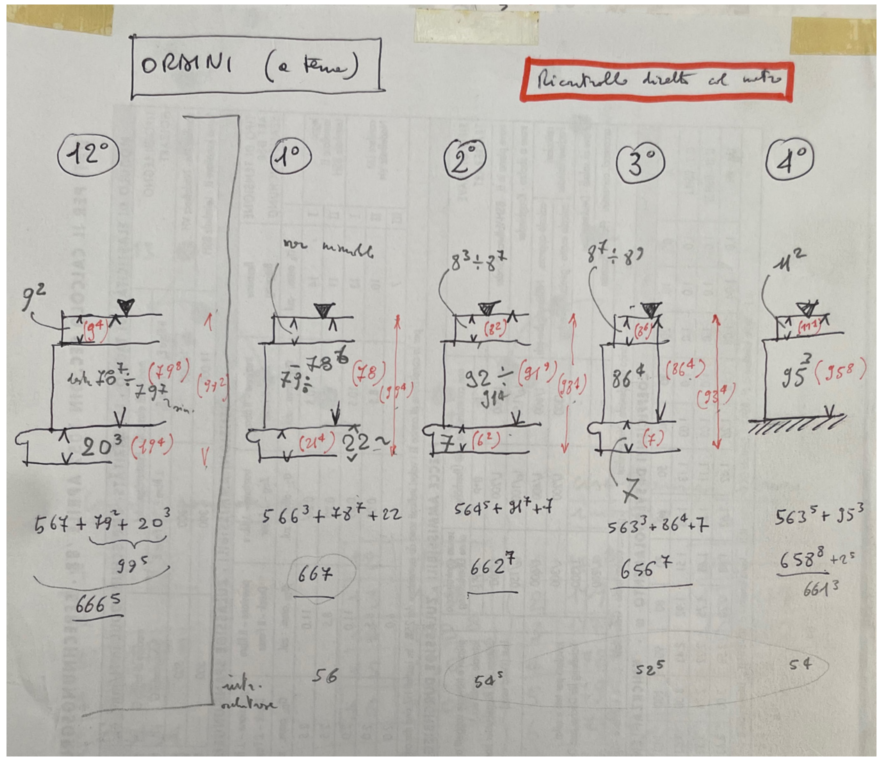


Figure 38 –Carlo Randoni, technical report on the condition of the Church of San Lorenzo, early nineteenth century. Archivio di Stato di Torino (AST), *Real Casa, San Lorenzo, lavori e contratti*, “1823 e ss., Real Casa, buste 2051–2054, San Lorenzo.”

[92] Translation from Italian to English by ChatGPT, OpenAI, conversation with the author, January 21, 2026.

[93] handwritten note from the survey papers of Franco Rosso in 1999, Archivio di Stato di Torino (ASTR), Archivio Franco Rosso, Studi e Ricerche, Studi e ricerche su Guarino Guarini, folder 65.



ground through this solution. Such logic, has been implemented to the concept of this chapter, as an attempt to geometrically read the building with qualitative, quantitative, and comparative methods.

To this end, the analyses in this study were essentially based on the three-dimensional point cloud data and were conducted gradually from a small to a larger scale extracting the desired data with the use of CloudCompare. Initially, a vertical sectional analysis was performed in which angular deviations were calculated between a reference defined at the ground level, and corresponding elements at different elevations. This was followed by shifting the vertical investigation into a horizontal capturing of fitting planes belonging to the same former levels carried out with the use of MATLAB software. Finally, a series of localized deformation controls dedicated to the hidden structure of the church was done in five steps. These include the evaluation of the relative height of the indicative points on the *oculus* under the dome's ribs as well as the large windows of the drum, the analysis of the main big arches' intrados, and finally the study on the conical vaults above the serliana through circular fitting and sectional comparison. Altogether, this investigation concludes a multi-scale geometric reading of the state of San Lorenzo, as a semi-quantitative methodology, rather than a definitive structural assessment.

The limitations regarding the methodology for the following chapter includes the process of manual point pickings which increases the errors, for which the solution was to pick several points at a specific target, to make sure the average number for the coordinates does not show a high discrepancy. Moreover, the point cloud data contain a specific scale of precision. The point cloud used to analyze the interior visible parts

Figure 39 –Franco Rosso, survey indicating measurements at the base of the columns of the Church of San Lorenzo, 1999. Archivio di Stato di Torino (ASTR), Archivio Franco Rosso, Studi e Ricerche, Studi e ricerche su Guarino Guarini, folder 65.

of the church was the LIDAR acquisition which included partially the hidden structure, while the SLAM co-registered data were used for the entire hidden structure located behind the interior walls of the building, and are accessible only through a narrow walkway. The TLS acquired data are of millimeter level of accuracy while the SLAM has a relatively lower nominal accuracy.

3.1. Global Assessment

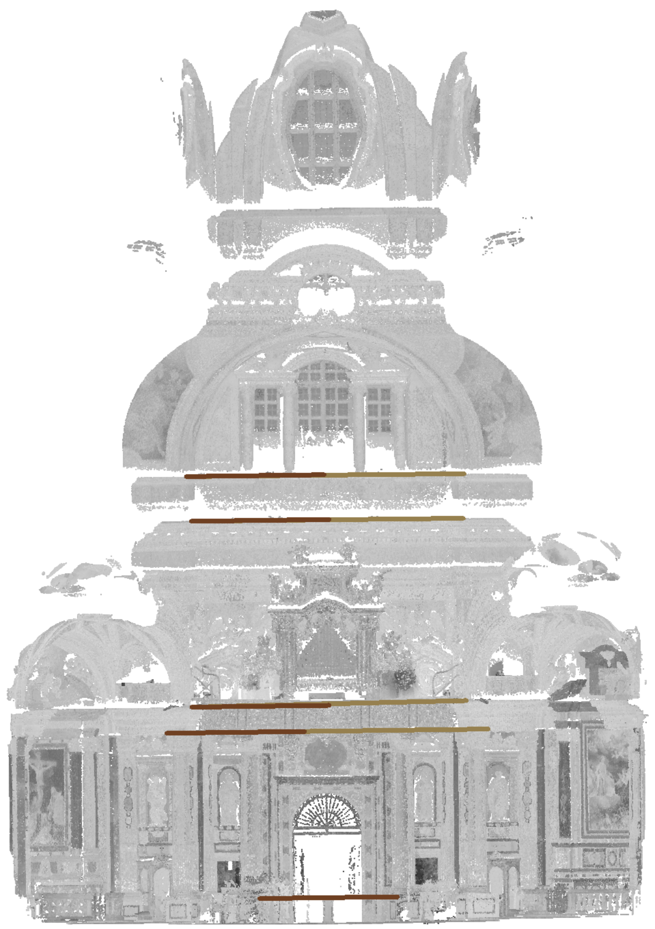
This part of the study, aims for a general deformation control on the global structure of the church to verify the care that has been taken of the church throughout its lifetime both by the architect and the restorers. The goal was to determine whether any measurable tilt could be recognized with the help of the point cloud data. What is presumed is for the chosen level to be horizontal, unless a settlement might have happened during decades. Therefore, two processes were carried out; a sectional analysis, as well as a planar fitting across the selected elevation levels in the former process, using MATLAB-based modeling, and geometric regression.

3.1.1. Sectional Analysis

In the initial sectional analysis, a total of 8 sections were taken from the LIDAR data, two transversal, two longitudinal, and four diagonal ones. The diagonal sections allowed for a more precise evaluation of the asymmetry. Moreover, these specific section lines were chosen in order to obtain a less dense point cloud view, and thereby clearly, and symmetrically, recognize the targeted critical points. These series of reference points correspond to key architectural features of each level of the building taking into consideration their recognizability from the point cloud (Figure 40).

To begin with, the edges of the base of a set of corresponding col-

Figure 40 –Indication of the five levels studied in the sectional and planar analyses



Section 1

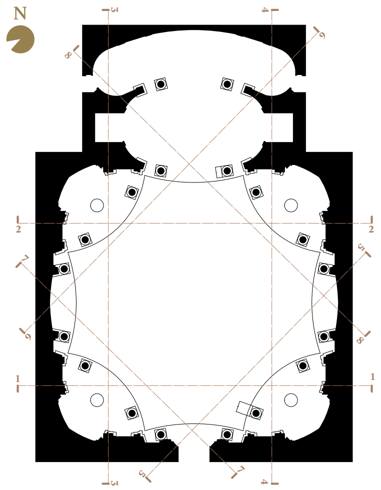
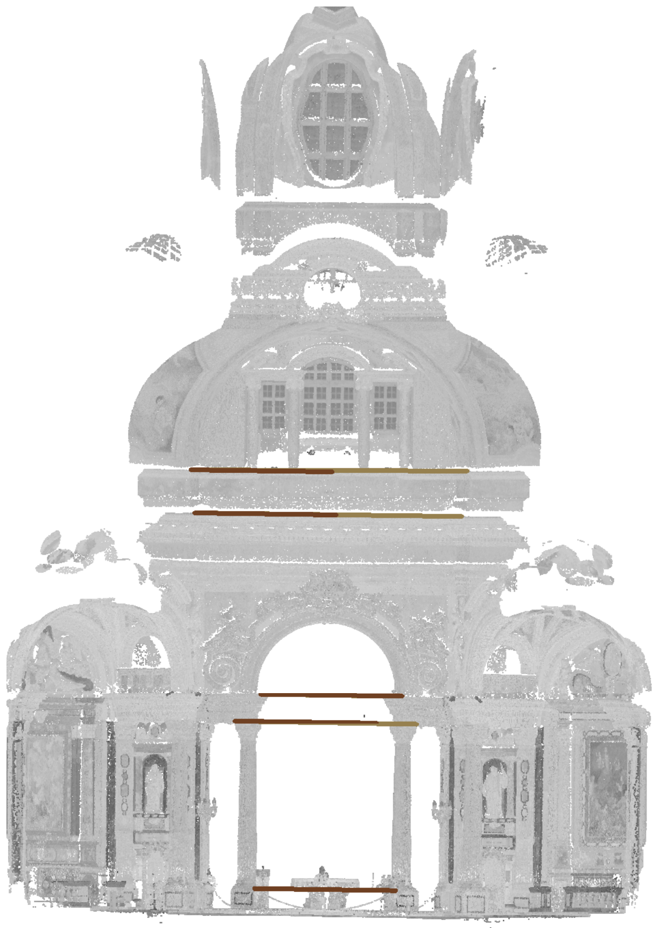
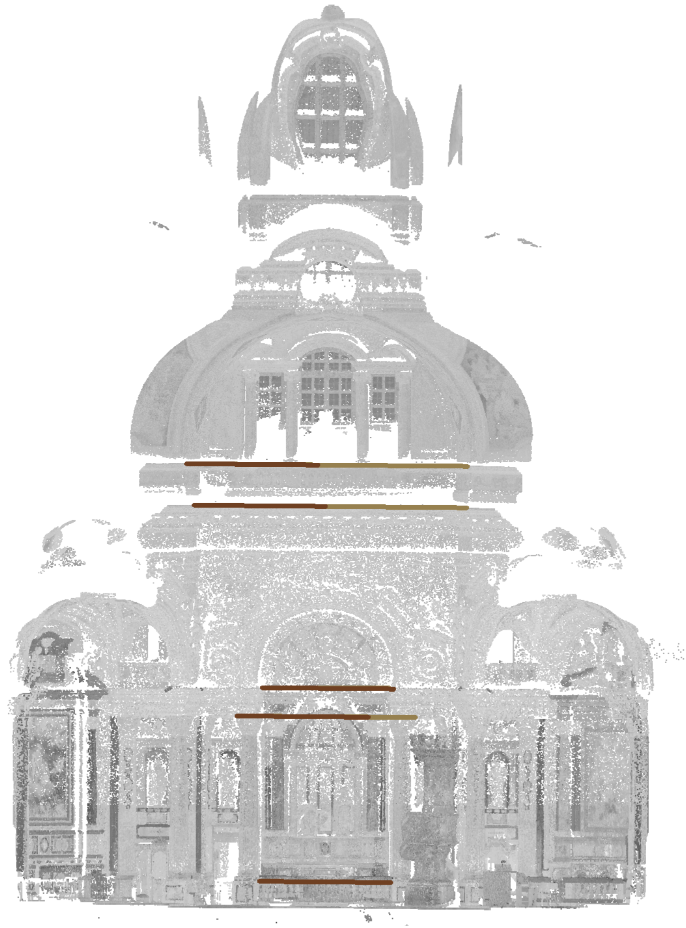


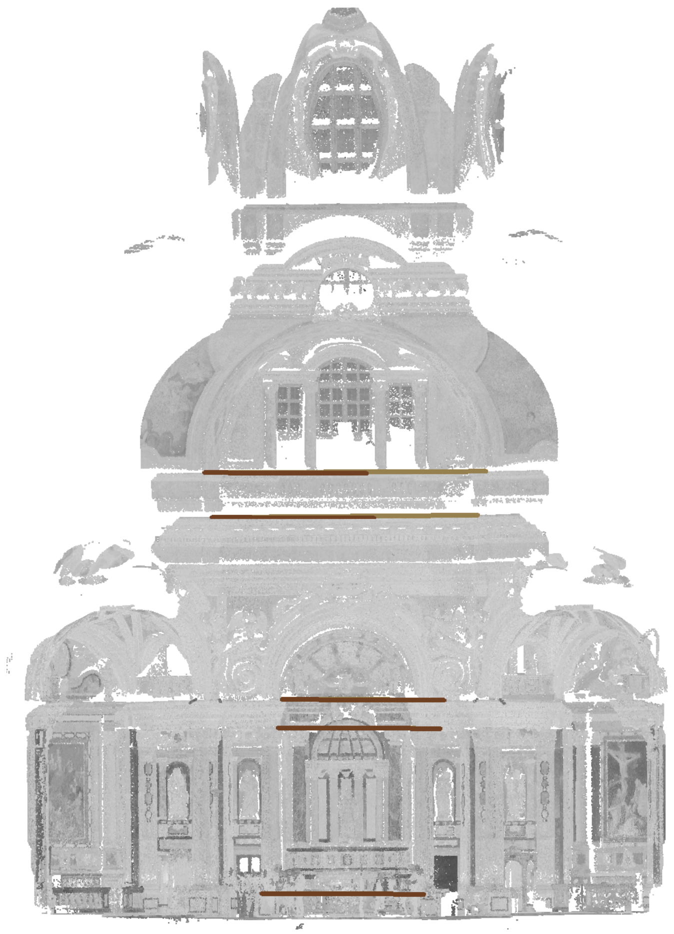
Figure 41 – Sections one to four depicting the angular measurements with respect to the reference lines.



Section 2

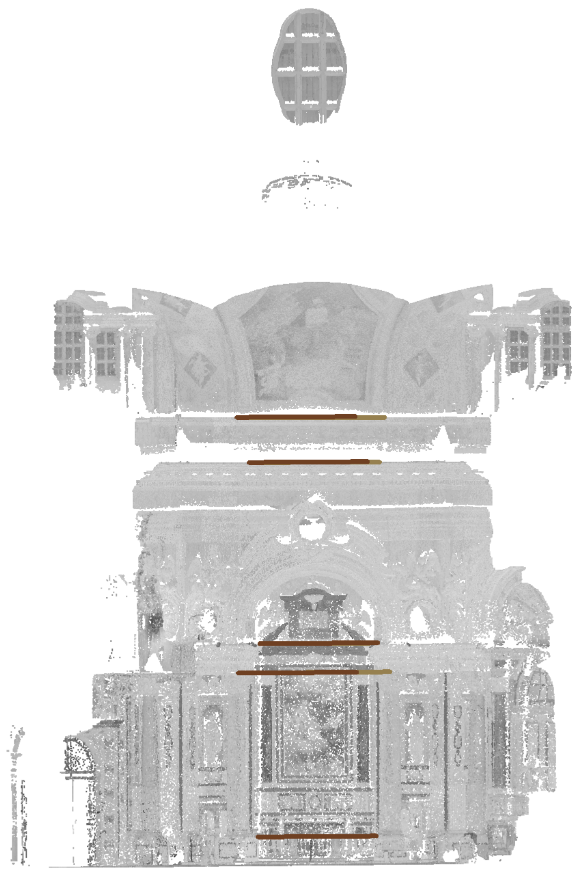


Section 3



Section 4

Section 5



Section 7

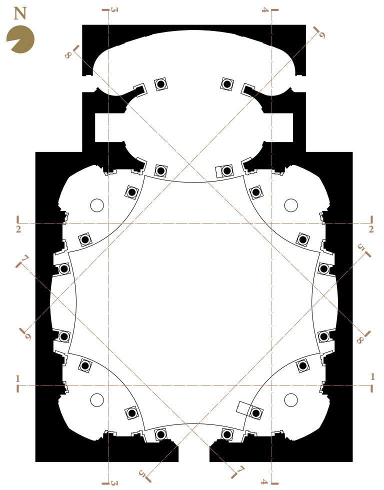


Figure 42 –Sections five to eight depicting the angular measurements with respect to the reference lines.

Section 6

Section 8

Level	Angle [°]							
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8
Capital	0.01	0.18	0.10	0.04	0.14	0.78	0.06	0.22
Entablature	0.63	0.05	0.51	0.19	0.23	0.14	0.38	0.05
Cornice	0.12	0.05	0.00	0.77	0.50	0.72	0.29	0.17
Serliana	0.17	0.56	0.03	0.55	0.09	0.72	0.48	0.32

Table 3 - top - Angles between the elevation-level lines and the ground-level lines on the eight sections.

Section 1 (b=4.9m)		
Level	Angle [°]	d [cm]
Capital	0.01	~0.09
Entablature	0.63	~5.3
Cornice	0.12	~1.03
Serliana	0.17	~1.45

Section 2 (b=4.9m)		
Level	Angle [°]	d [cm]
Capital	0.18	~1.54
Entablature	0.05	~0.43
Cornice	0.05	~0.43
Serliana	0.56	~4.79

Section 3 (b=4.6m)		
Level	Angle [°]	d [cm]
Capital	0.10	~0.8
Entablature	0.51	~4.09
Cornice	0.00	~0
Serliana	0.03	~0.24

Section 4 (b=5.6m)		
Level	Angle [°]	d [cm]
Capital	0.04	~0.39
Entablature	0.19	~1.86
Cornice	0.77	~7.53
Serliana	0.55	~5.38

Section 5 (b=4.5m)		
Level	Angle [°]	d [cm]
Capital	0.14	~1.1
Entablature	0.23	~1.81
Cornice	0.50	~3.93
Serliana	0.09	~0.71

Section 6 (b=4.6m)		
Level	Angle [°]	d [cm]
Capital	0.78	~6.26
Entablature	0.14	~1.12
Cornice	0.72	~5.78
Serliana	0.72	~5.78

Section 7 (b=4m)		
Level	Angle [°]	d [cm]
Capital	0.06	~0.42
Entablature	0.38	~2.65
Cornice	0.29	~2.02

Table 4 - bottom - The vertical displacement with respect to the angular deviation of the sectional analysis along each level

umns, the most identifiable in the targeted view, with respect to the symmetrical axis of the church were connected with a line, as the reference line later taken to measure the possible deformation. This line was assumed as an internal geometric base for the section (Figures 41 and 42).

Within each section, the key points were identified at each elevation, and connected with a line to the corresponding point on the opposite side; this resulted in four main levels at the ground floor column's capital, ground floor column's entablature, chapel's cornice, and the serliana base (Figure 40). The former reference line was brought up to these levels, and compared to each other, by measuring the angle between the two (Table 3). This procedure was repeated across the 8 sections along the width and length of the church, in order to perform a thorough analysis for a higher precision. The resulting angles represent relative inclinations and do not imply absolute verticality or undeformed conditions.

The angles measured between the ground-level reference and four elevation levels were recorded, all of which remained below 1°, with the range of values between 0.00° and a local maximum of 0.77°. This represents that the angular deviations are small in magnitude, yet sufficient to be measured and compared across sections and levels (Table 3). These numbers do not show a uniform increase within a specific height, while different sections showcase

different behavior. Certain sections display higher angular values, while some remain consistent. This variation suggests a complex behavior from which a global deformation cannot be detected, but rather a direction dependent trend.

In order to express the measurements in spatial terms, the angles were converted into vertical displacements relative to the ground-level reference. This vertical displacement (d) was calculated according to:

$$d = b \cdot \tan(\alpha)$$

where b is the width of the section under analysis to the ground level, α is the deviation angle.

The resulting values (Table 4) generally represent limited magnitudes. The smallest values occur at the capital level, where most sections exhibit negligible deviations, showing a more regular geometry at the level. Slightly larger displacements were observed at the entablature and cornice levels, particularly in Sections 4 and 6 where the numbers exceed 5 cm. These results seemed consistent with the increased structural complexity and load transfer mechanisms acting at higher elevations.

The results of the sectional analysis indicates no global inclination in the church, since the angular deviations as well as the vertical displacements do not increase consistently vertically, or across the sections. On the other hand, the higher values occur occasionally which suggests localized behavior. Such values existing in the upper levels might be due to the increased geometric and structural complexities of the building. These results lay the basis for the subsequent investigations on horizontal planes, and localized analyses.

3.1.2. Planar Analysis

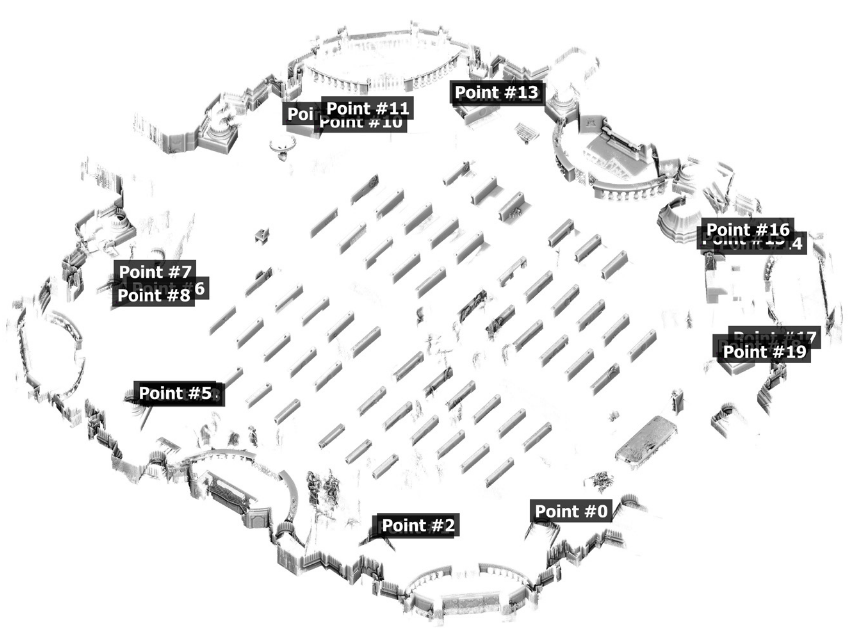
A complementary phase of the general deformation control was developed, to assess the deviation from the best horizontal planes fitting the selected elevation levels. Therefore, a broader set of points were manually chosen from the point cloud not only in a 2d section but collecting all the eligible points of that level in 3d space of the church. These points were assumed to have to be on the same plane since they belong to the edge of similar architectural elements, such as the base or capital of the ground level columns. Each point was selected multiple times to ensure redundancy and lower the manual point picking errors (Figure 43).

With the aid of MATLAB, each set of points were coded to a linear regression model (fitlm):

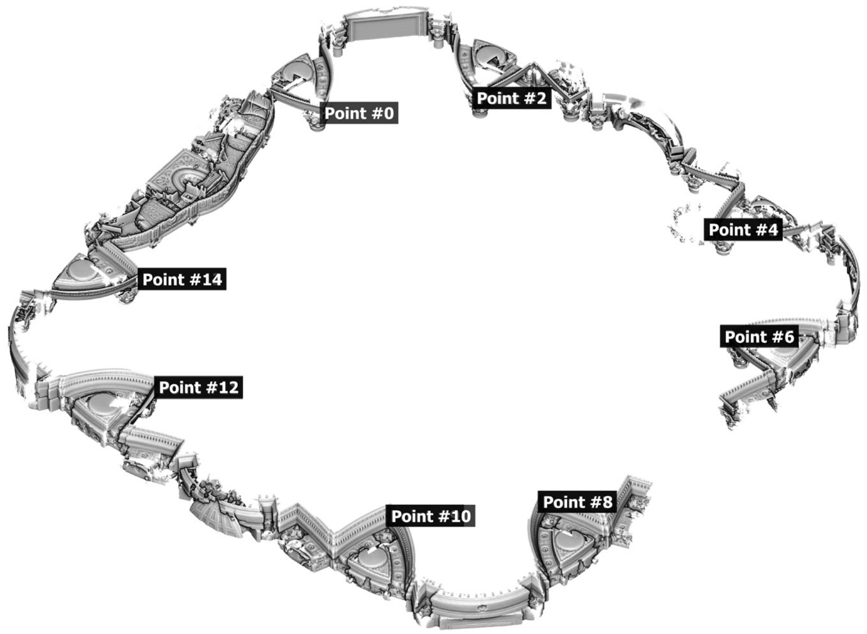
$$z = ax + by + c$$

where a and b represent the slopes on the horizontal axes, and c is a vertical offset. The inclination was evaluated with the

Base



Capital



Entablature

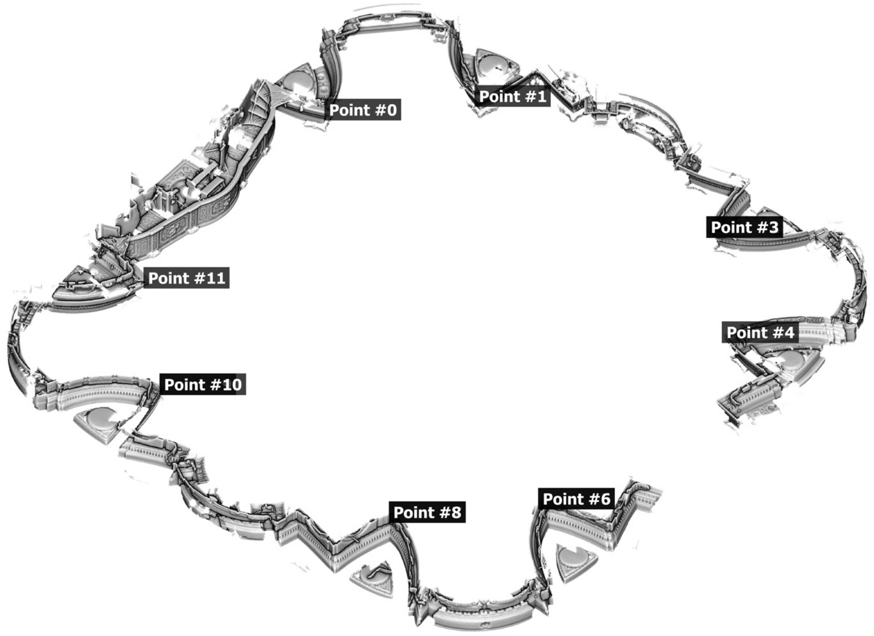
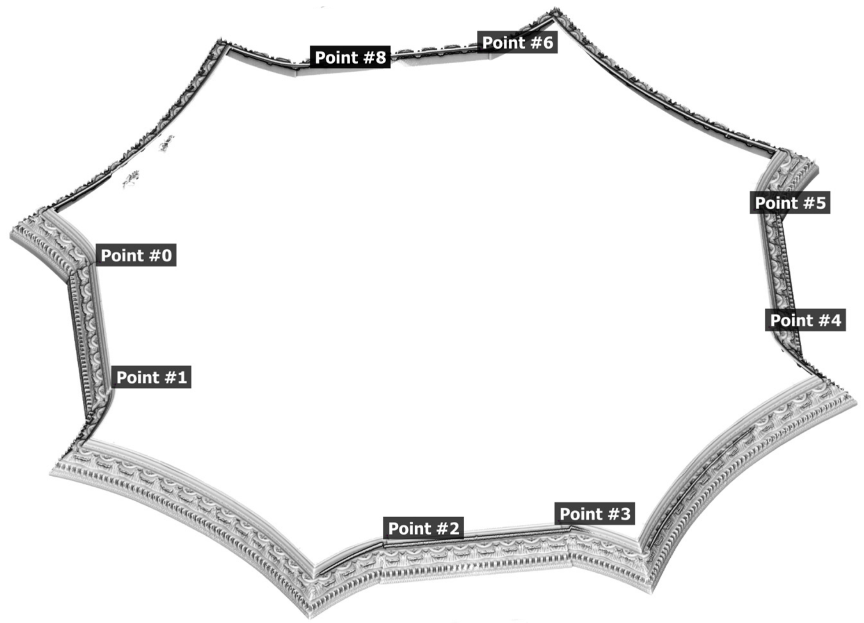
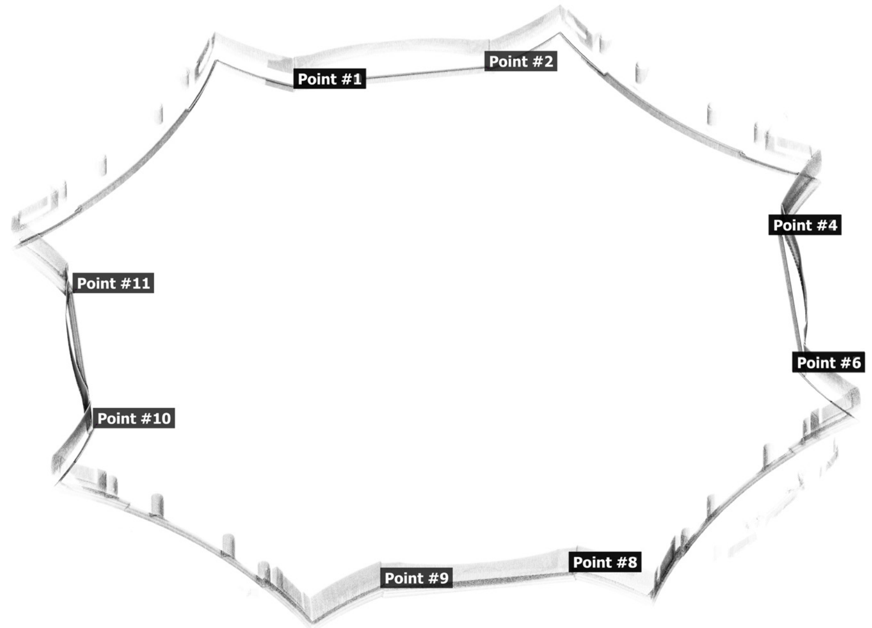


Figure 43 –Cut-out axonometric view of the point cloud levels, from CloudCompare, together with the picked points.

Cornice



Serliana



orientation of its normal vector, and the vector was visualized using an amplification factor for a qualitative comparison between the selected levels. Moreover, the color-code on the graph helped better visualize the height difference.

The results (Figure 44) of the analysis show that all the planes of the levels deviate from the ideal horizontal plane, to a limited extent, more at the capital and entablature level. These deviations remain low within the plane itself. Instead, each level behaves as a geometrically coherent surface with a mild tilt. At higher levels of cornice and serliana levels, planar inclinations are present while the internal coherence of the surface is preserved. Despite the increased complexity of the building at these levels no substantial displacement can be seen.

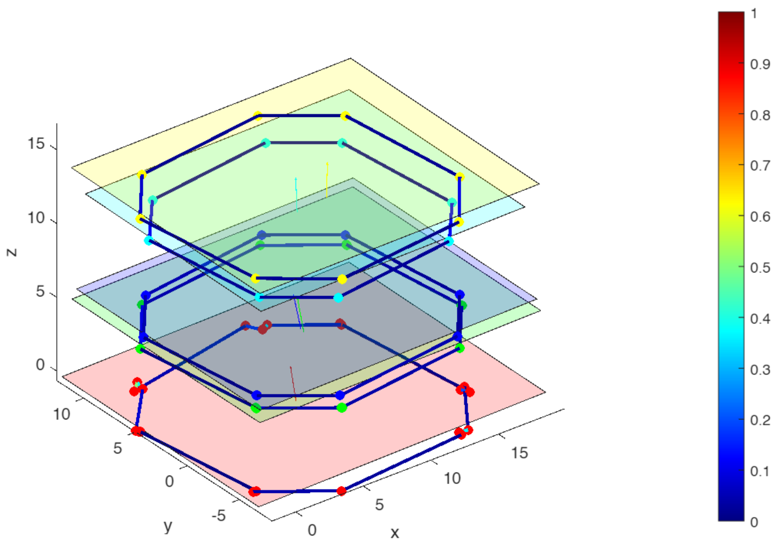


Figure 44 –MATLAB resulting graph color coded with a maximum and minimum horizontal distance to the perfect plane on a scale of 0 to 1

3.2. Localized Evaluation

While the previous sections attempted a global behavior of the church of San Lorenzo through sectional and planar analyses, this part of the study shifted its focus onto localized structural elements that are key to the church's architectural and structural concept. This includes hidden or visible elements related to the main load-bearing system of the building to different extents, such as the *oculus,* the large windows of the drum, the four main big arches, and the conical vaults above the serliana. The purpose, apart from the assessment of the relative heights of crucial levels, was to examine the current state of the geometries of these elements with respect to their supposed ideal reference shape.

3.2.1. Oculus

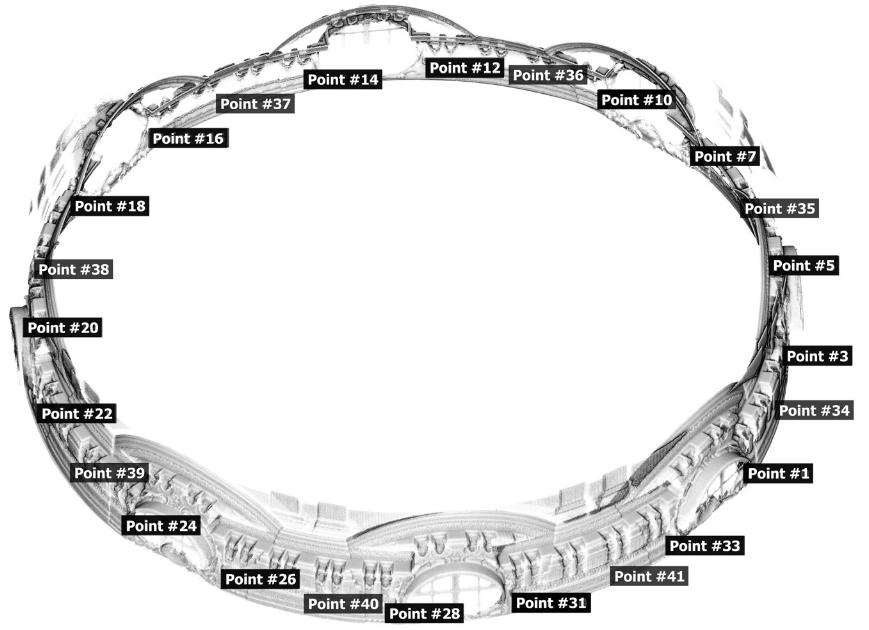
The initial part of the analysis includes a control on whether the points adjacent to the kidney-shaped windows of the oculus, ideally lay on the same horizontal plane.

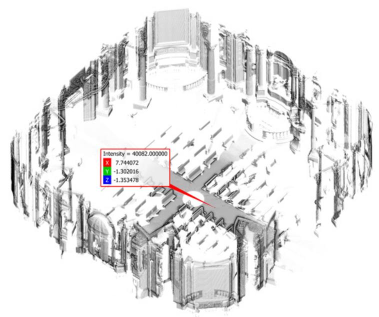
A set of 42 points at the aforementioned locations were picked from the point cloud, as well as a reference point on the ground level so as to have the relative heights of the set of points (Figure 45). The resulting heights range between:

Maximum relative height = 20.72 m
Minimum relative height = 20.98 m

Thus, as seen in Table 5, the total height deviation being 26 cm, which is considered a measurable distance to the perfect horizontal plane, however, an observation on the dataset, illustrate

Maximum height [m]	20.98
Minimum height [m]	20.72
Total height deviation [m]	0.26 **26 cm**





a continuous distribution of values in the parameter of the oculus, that gradually increase and decrease, showing a smooth variation. Due to the scale of the structure and the height at which these set of points were extracted, the magnitude of the resulting values remain moderate which might have been caused by the construction tolerances, long-term structural adjustments or settlements. Furthermore, since the procedure is based on a single reference point, the results showcase an internal geometric coherence, rather than an definitive result on the global reference system.

3.2.2. Four main arches (*arconi)*

The main structural essence of the church of San Lorenzo, so-called *arconi,* were analyzed to investigate the conformity of their intrados tracing to an ideal circle. Due to the importance of these elements, this check was carried out in terms of geometrical regularity rather than a mechanical assessment.

Each of the main arches were sectioned vertically through their plane and extracted from the point cloud, and the supposed intrados circle was drawn in AutoCAD, with the help of three points, two of which qualitatively positioned at the one third from the springing points and one point around the crown on the arch (Figure 46). These points were selected solely because they were identifiable in the point cloud data.

The resulting illustrations show the drawn circles fitting the reality well and do not show irregularities at the crown or the springing areas of the arches.

Figure 45 –Axonometric view of the point cloud horizontal cutout of the oculus level, together with the picked points. The reference point for acquiring the relative heights are shown on the left.

Table 5. Relative heights' interpretation of the extracted points from the oculus

West

East

South

North

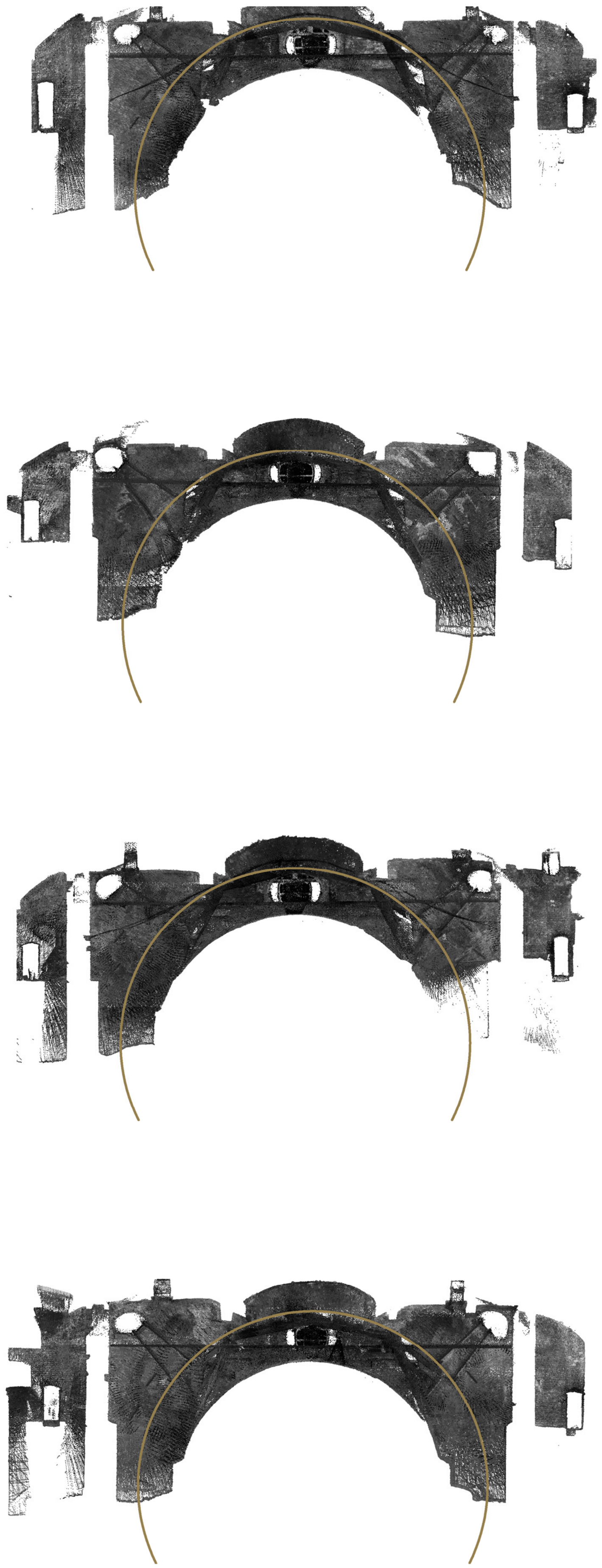


Figure 46 –Arconi cut-out sections from the point cloud, and the fitting circles traced based on three points

3.2.2. Conical Vaults and Serliana

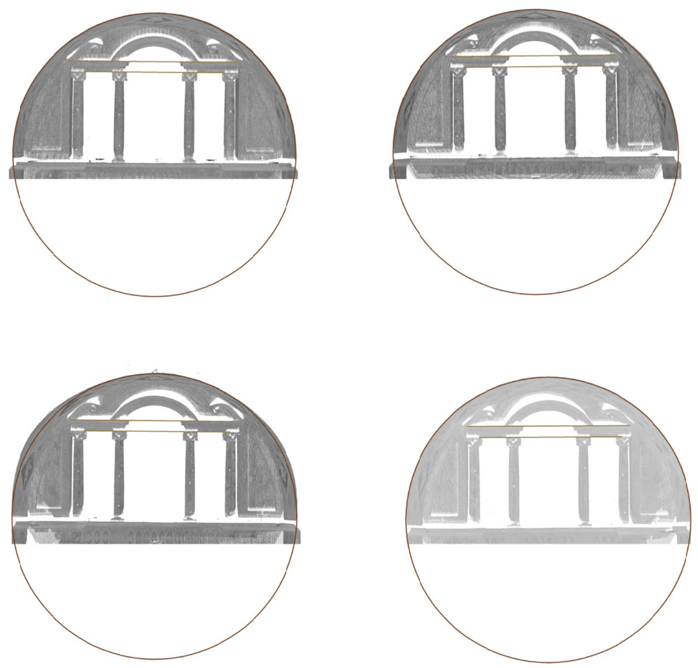
In order to check the collective group of serliana and conical vault zone, firstly horizontal lines were drawn orthogonally on the entablature of the serliana columns, in order to check if these elements incline towards a direction (Figure 47). This analysis has been carried out due to the diagonal buttresses of the arconi being located directly on top of the serliana, which could cause deformation or critical settlement of the affected elements.

Secondly, for each of the conical vaults above the serliane, three recognizable points along the intrados were used to draw a reference circle that supposedly should fit the as-built geometry (Figure 47). This method was done to verify a geometrical conformity rather than a absolute numerical fitting.

Lastly, a cross section in the middle of the conical vaults were extracted, in order to examine the profile of the vaults. The conical characteristic of these vaults inevitably reveals an inclined profile, with respect to the horizontal plane, which was intended to be compared to each other as a general control on these elements (Figure 48).

In result, the entablatures' elevations follow the orthogonal lines traced on them suggesting no noticeable deformation in the serliana. Regarding the conical vault analysis, the northern, eastern, and western front profiles show a generally acceptable correspondence to the reference circle, with the point cloud profile remaining close to the circular arc throughout the span of the vault. However, the southern profile depicts a less consistent fitting to the reference at the springing area of th vault, yet keeping the correspondence around the crown.

To this end, the cross-sectional investigation showed the following angles as the inherent inclination of the profiles:



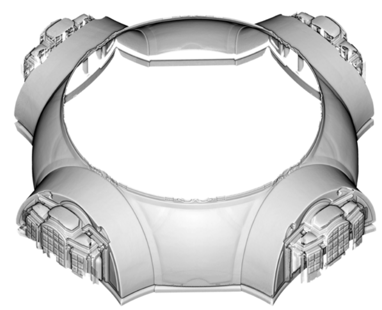


Figure 47 –Serliana and Conical Vaults cut-out from the point cloud, with circular and linear analyses

Northern vault = 11°
Southern vault = 7°
Eastern vault = 9°
Western vault = 10°

which indicate that while the northern, eastern, and western vaults share relatively close values, the southern value is noticeably lower. This is consistent with the previous results from the front profile of the vaults, in which the vault on the south side illustrated a downward deformation. Taken together, these findings suggest that this vault might geometrically differ from the others, due to construction difference or subsequent deformations.

East- West

North-South

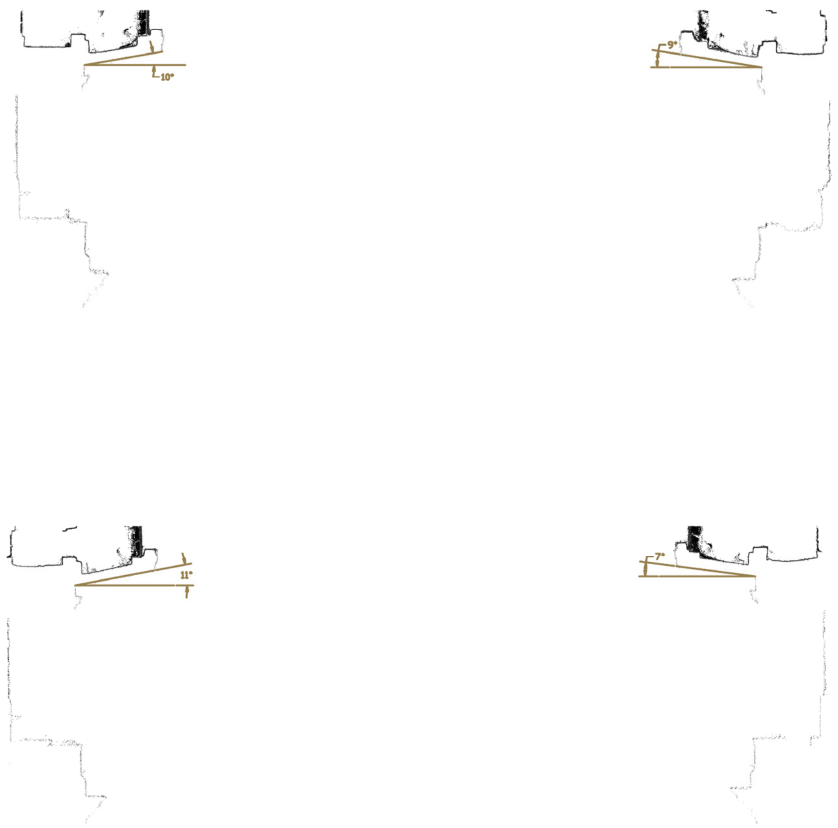


Figure 48 –Conical Vaults cross section to compare the inclinations.

3.3. Synthesis

The deformation control on the church of San Lorenzo consisted of global and localized assessments based on the point cloud data available. Analyses along sections and planes provided a macroscopic overview of the church's behavior, and the localized evaluation allowed for a more specific study on the more structural elements of the building.

The findings show measurable but moderate deviations from perfect supposed geometries, both vertically and locally. These deformations remain continuous with no sudden discontinuity or separate abnormality that would break the general structural condition of the church.

Noteworthy, is the limitations concerning every part of these analyses which addressed different aspects of the structure, and the combination of them provided with a geometrical reading of San Lorenzo.

04

A Corner

"La posizione del Guarini nella storia della tecnica costruttiva non è chiara, anzitutto perché l'architetto nel suo voluminoso trattato non ce ne parla: nella sezione dedicata alle volte si dice che sarebbe stato desiderio da parte sua scrivere anche un capi- tolo relativo alla costruzione, ma nel volume questa parte non si trova: essa mai scrit- ta. essi dunque o non fu pubblicata dal Vittone."

(Guarini's position in the history of construction technique is not clearly defined, first of all because the architect himself does not address it in his extensive treatise. In the section devoted to vaults, he states that it had been his intention to write a chapter specifically dedicated to construction; however, this part is not found in the published volume, as it was never written or was never published by Vittone.) [94]

Paolo Verzone [95]

This chapter presents a focused investigation of only a quarter of San Lorenzo, located on the north-western side of the church. Through the construction of a 3D model, a corner of the church is studied not as an isolated unit, but as a representative of Guarini's spatial and structural principles. This portion has been chosen as a specific case study of this matter, simply due to the symmetry existing in the church, allowing one segment to speak for the entire building.

The analysis consists of two main stages: a brief overview on the architectural composition of a corner of the church, and the proposed hypothesis on the construction sequence of the same segment, indeed with the help of the previous chapter's discussion on the construction timeline of the church. The proposal has been put forward, only regarding the original construction by Guarini. In other words, post-Guarini preservations, or alterations, although historically significant, have been excluded from this chapter's drawings, and are mentioned in case of interpretation on the original structure.

This process is done not only with the digital reconstructed model, but also with the support of archival documents, point cloud data, and on-site imagery. The essential methodology used to carry out the digital model, was basing the model on the point cloud data, that was exported from Cloud Compare, passed from Autodesk ReCap to Autodesk Revit, to perform an HBIM-based process that was aided with archives and images.

The proposed results do not claim to reconstruct an exact historical process of construction, but simply offer a coherent interpretation that is consistent to Guarini's construction logic, as well as in-person observations.

4.1. Architectural Composition

The architectural composition of the corner represents an overlap of the point cloud survey and the reconstructed digital model (Figure 50). This comparison is intended to provide an overall reading of the space observed by a visitors, as well as partial hints to the hidden pathways at the back of the interior walls.

The drawing also serves as a reference to identifying the element that are addressed in the subsequent drawings in this chapter, allowing the reader to better locate components.

[94] Translation from Italian to English by ChatGPT, OpenAI, conversation with the author, January 23, 2026.

[95] Paolo Verzone, "Struttura delle Cupole del Guarini," in Guarino Guarini e l'internazionalità del Barocco, vol 1, ed. Marcello Fagiolo and Giuseppe Bonaccorso (Rome: Officina Edizioni, 1970), 401.

Figure 49 –Site Plan of San Lorenzo Church. The portion of the church under study has been indicated. Scale 1:500

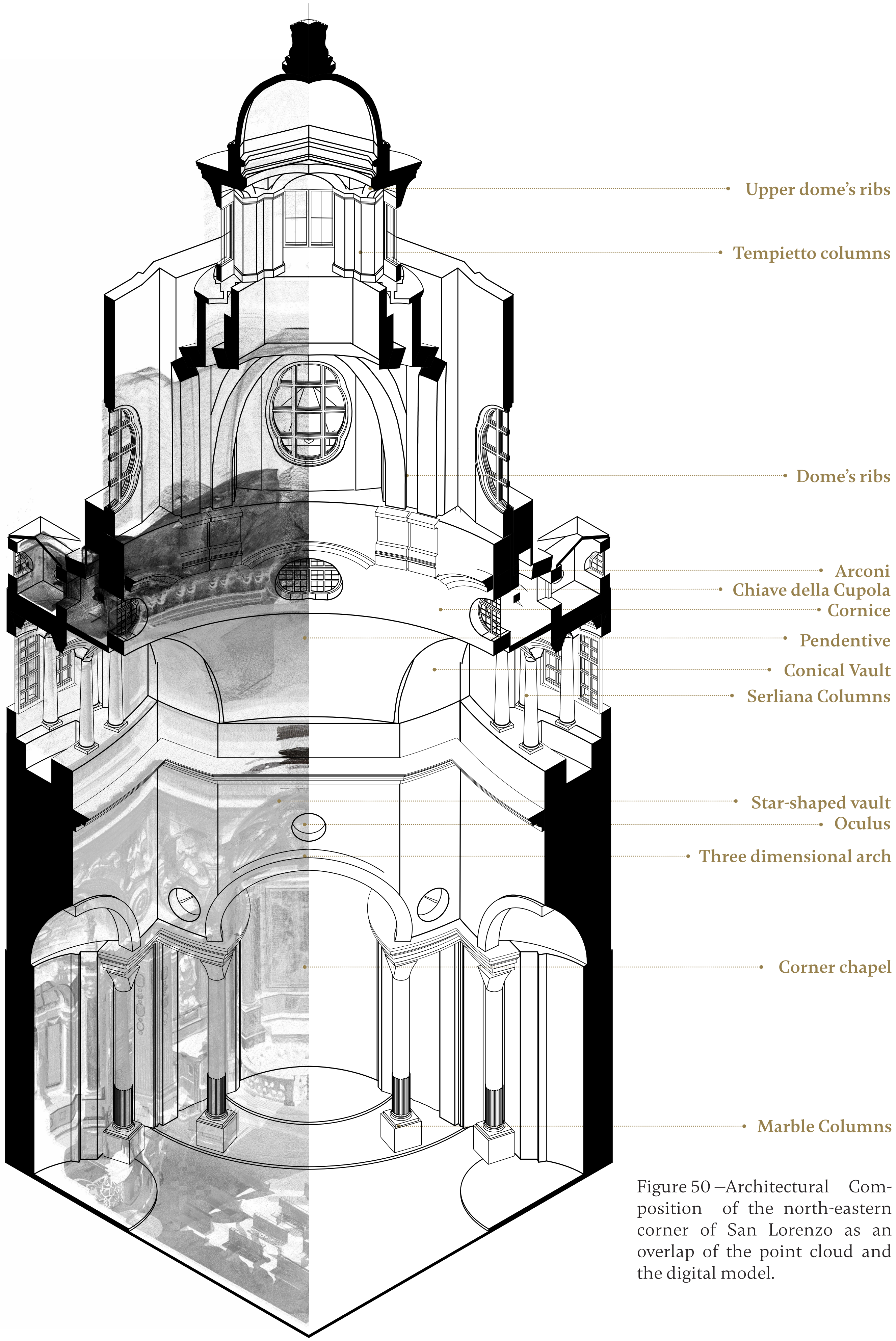


Figure 50 –Architectural Composition of the north-eastern corner of San Lorenzo as an overlap of the point cloud and the digital model.

4.2. Hypothetical Building Sequence

The hypothesis on the sequence in which the church was built has been made in this section, based on the previous scholars' suppositions, construction hints observed on-site, as well as basic building logics. Such hints as the basis of this study included:

Hint 1. Where one element rests on another, it has been assumed that the supporting elements was built prior to the other.
Hint 2. Where the masonry of two elements are clearly toothed together, it was assumed that they were built simultaneously, at least until some springing parts, if not entirely.
Hint 3. The type and relevance of the centering system was taken into account, as this has direct implications on the order of the building.

Considering the aforementioned hints, and by taking into account the construction sequences gathered by other scholars, let us divide the timeline of the church into three main levels. These levels of completion have been defined according to the purposes of this study and are not necessarily compatible with the campaigns that were in reality carried out.

A. The beginning of the construction with Guarini's arrival in 1670, until the columns of the ground floor were set in their place in 1674.
B. The construction of the squinch until the completion up until the pendentive zone in 1675.
C. The start of the main hidden structure zone in 1676 until the completion of the cornice above the pendentive in 1678.

For the purposes of this study regarding the main invisible system that carries the loads, the upper part of the church including the dome and the upper dome were neglected.

4.2.1. Phase 1 _ Preparation, Perimeter walls, and Ground Floor Columns (1670-1674)

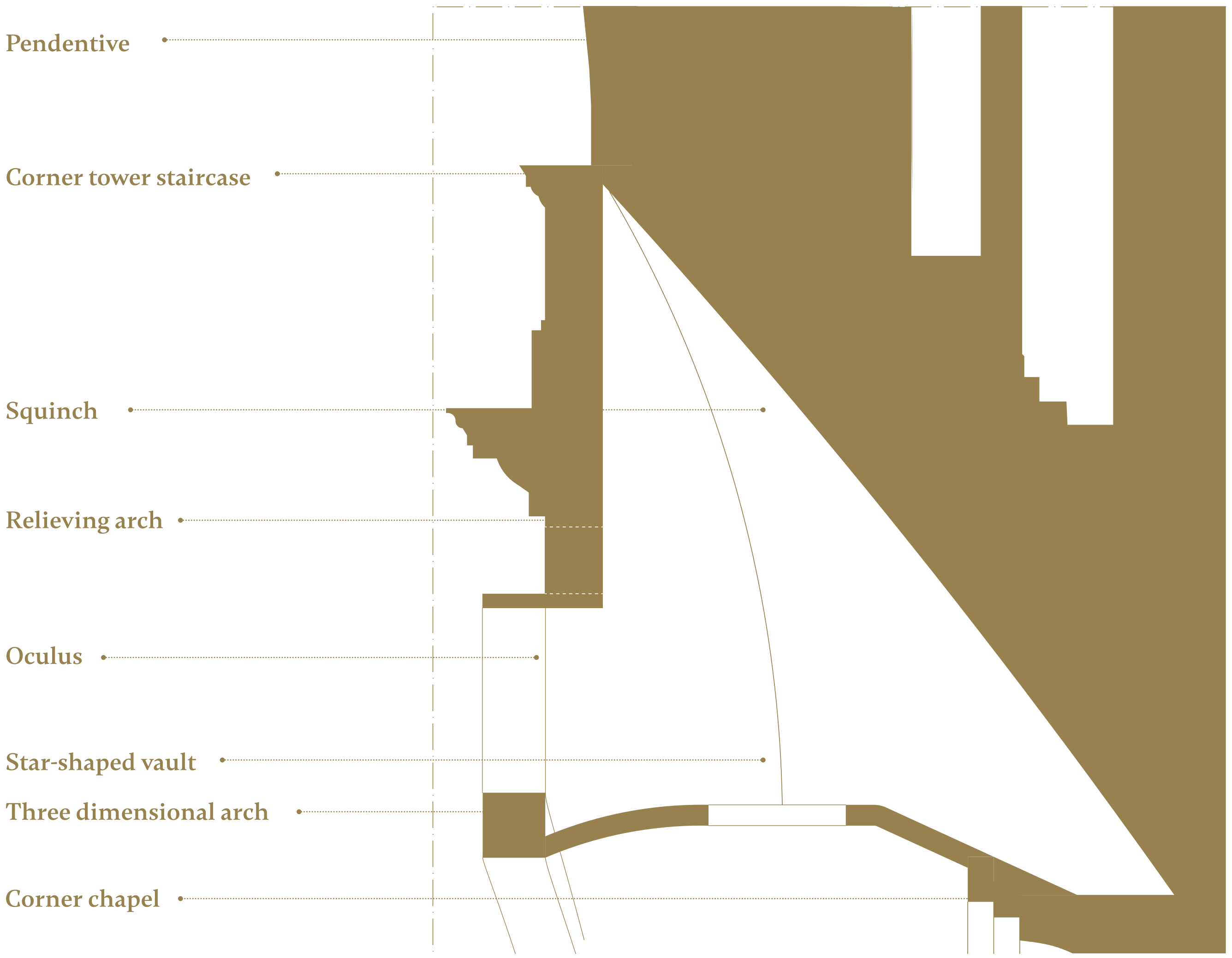
Phase 1 represents the preparatory works since the arrival of Guarini to the site, the removal of unnecessary elements, the assemblage of the materials, and the placement of the columns. Although this ground-level construction naturally comes to mind as the most principal structural stage, since it establishes the lowest and most extensive system upon which the building has been built, San Lorenzo appears different; the perimeter walls act as the base for the main system that bears the loads of the church, which is located somewhere about 9 meters higher than the ground, and continues until about 20 meters from the floor of the church. Furthermore, the columns present in this phase, are merely supporting the visible structure of the church which include the walls, entablatures, and cornices that close what is hidden behind. To this end, due to the invisible and visible nature of the church, the perimeter walls are addressed to be a hidden structure, and the columns as an apparent one, indicated as H1 and A1 for the sake of clarification.

4.2.2. Phase 2 _ The Squinch, Corner tower, and the Star-Shaped Vault (until 1675)

Phase 2 essentially includes the more unaccessible structural entity of the church_ the squinch (Figure 51). This stage consists of the construction of the squinch vault, the corner tower's base, the walls on top of the chapel arches, and the star-shaped vault (Figure 53). Moreover, there exists a relieving arch embedded to the wall in front of the squinch to reinforce the performance of the apparent structure (Figure 52).

The exact sequence in which these elements were built remain unclear, however, taking into account the third construction hint discussed earlier, since the squinch might have needed a substantial centering system which would have con-

Figure 51 – The space between the star-shaped vault and the intrados of the squinch. From Franco Rosso, *Guarino Guarini,* 2006. Photograph by Giuseppe Dell'Aquila.



strained the construction of the elements that were supposed to be at the location of the centering, it was assumed that such components were, entirely or partially, built after the removal of the centering. The dismantling of the centering system could have been subsequent to the completion of the main structural system in the pendentive zone, or somewhere earlier after the base of the corner tower was built, yet the possibility that the

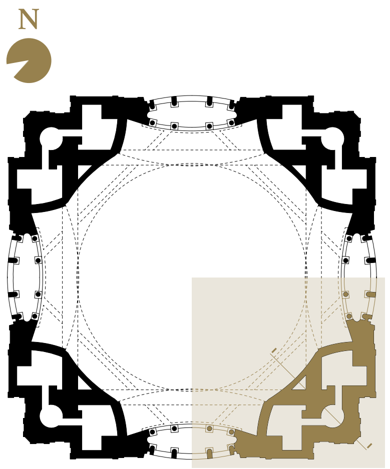


Figure 52 – Squinch area indicative diagram of elements, excluding additions by Randoni.

Figure 53 – The star-shaped vault. From Fondo Passanti

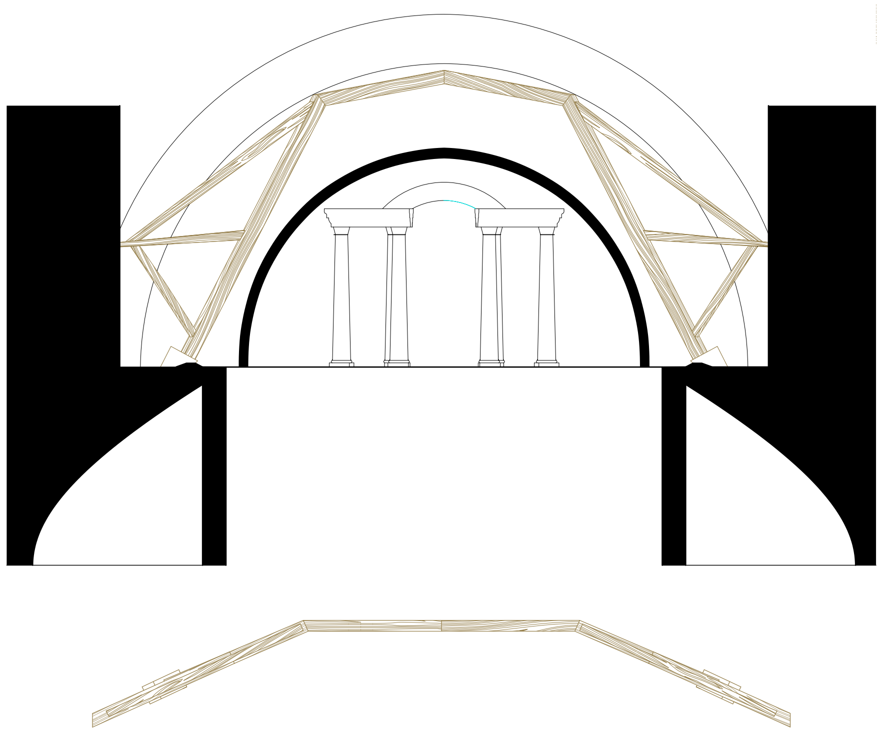
star-shaped vault was completed at least after the finalization of the squinch remains extremely high.

4.2.3. Phase 3 _ The Pendentive Zone, and the Main Invisible Structure (1676-1678)

The last phase, considered as covering the full height of the pendentives, accounts for the construction of all the components now standing behind the pathways and accessible cavities behind the interior "skin" of the church. This phase of construction took place in 1678, as the documents state that the dome was started in March of that year and that the cornice on top of the pendentives was built in the same year, suggesting that the structure bearing the dome was also completed by then.

At this stage, the church's structural logic departs from conventional masonry practices. The members that form this composite system are: the Chiave della Cupola, the four large arches (arconi), the diagonal arches located at 45 degrees to the arconi, the arches buttressing the arconi, the couple of thin walls under the arconi, the corner tower, the conical vault, and the pendentive. Indeed, the serliana are also present in this level which will be addressed separately from the complex interaction between the rest.

Although one can simply classify these items into visible and invisible elements as shown in Figures 64 and 65, as H3 and A3, their construction cannot be separated easily, due to the little evidence that may be based on the three "hints" mentioned above, deducted during the site visits.
Let us assume, then, that the springing parts of the corner tow-



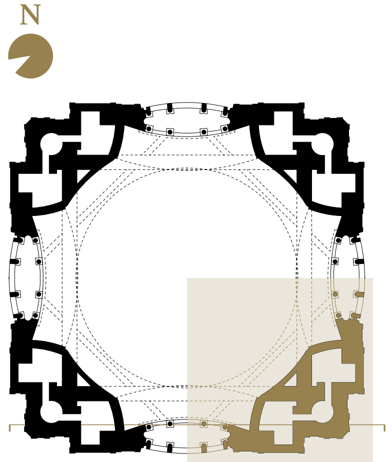


Figure 54 – Chiave della Cupola scheme, representing the general geometry of the system. Below, the plan of the chiave is shown.

er, arconi, pendentive, conical vault, and the thin walls were built first (Figure 59.a.). This assumption can be plausible since a toothing of the masonry at the intersection of the pendentive and the thin walls, as well as the pendentive and the conical vault, can be seen.

This initial step was then followed by the erection of the Chiave della Cupola's wooden elements (Figure 54) and by the construction of the main arch. The actual function of the Chiave remains a mystery, but not the time of its first construction. In other words, whether the Chiave was built to support the arches structurally or simply to serve as a temporary system, it was first built in this phase. Of course, it might have been later modified or adjusted to fit the completed structure.

The tilting of the elements of the Chiave and their true function remain a mystery. While the functionality of the Chiave, as previously discussed, is assumed to be a temporary centering for the arches (see Chapter 02), the inclination of the beams is what concerns us now. If the Chiave were to be without inclination, the beams at the base of the system would interfere with the thin walls under the arconi. Naturally, one

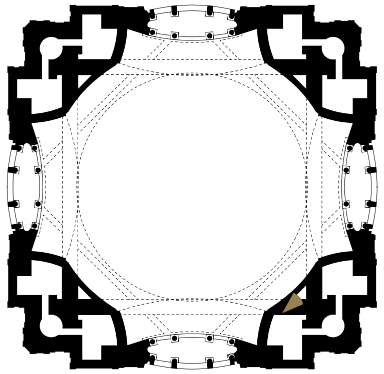


Figure 55 —The thin walls under the arconi resting on the pendentive extrados. Photography by Edoardo Piccoli, 2024.

1

2

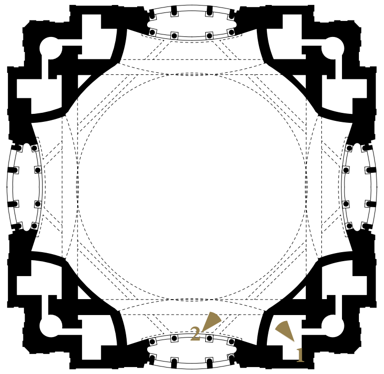


Figure 56 —Photo of the toothing between the thin walls and the conical vault. Photography by Edoardo Piccoli, 2024.

Figure 57 —The thin walls under the arconi resting on the pendentive extrados. Photography by Edoardo Piccoli, 2024.

might argue that the walls were not built by Guarini and are only later additions; however, this study has assumed that the walls were built partly by Guarini, at least until the radial brick assemblage can be seen. As a consequence, the chiave might have been moved out of the axis of the arch to prevent such overlap or embedding of elements.

Furthermore, following such hypothesis, we can assume that what remains of the chiave today is only a part of the original structure, and that it had a complementary side connected to it, standing inside the church and somehow supported from below. This claim has been explored in more detail in the thesis of Renata Rinaldi and Livia Lopomo[96] as shown in Figure 58.

[96] Renata Rinaldi and Livia Lopomo, *Le strutture nascoste della Real Chiesa di San Lorenzo a Torino. La configurazione guariniana degli arconi di sostegno e le trasformazioni successive*, Master's thesis, Politecnico di Torino, 2025/26.

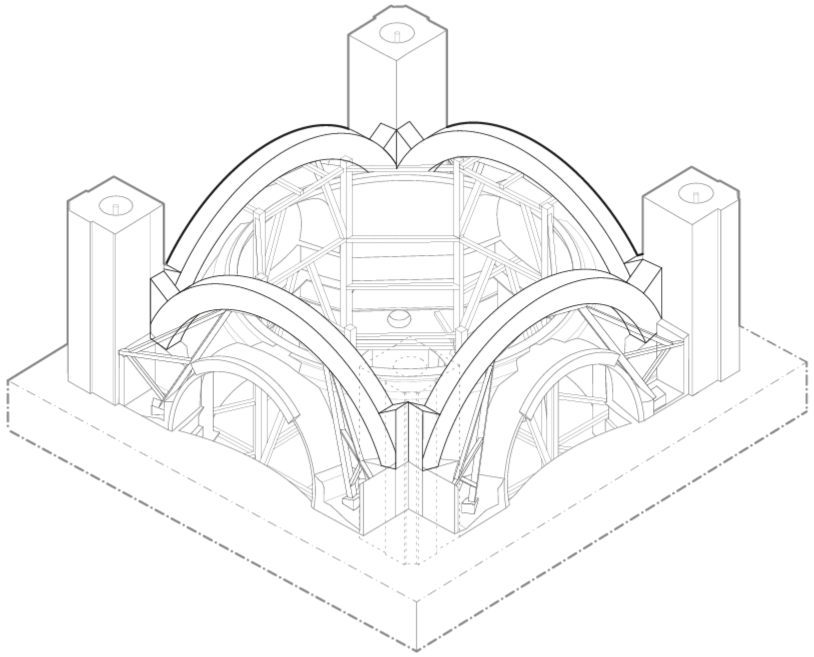


Figure 58 – Diagram of the possible temporary system to build the arconi. From Rinaldi and Lopomo, *Le strutture nascoste della Real Chiesa di San Lorenzo.*

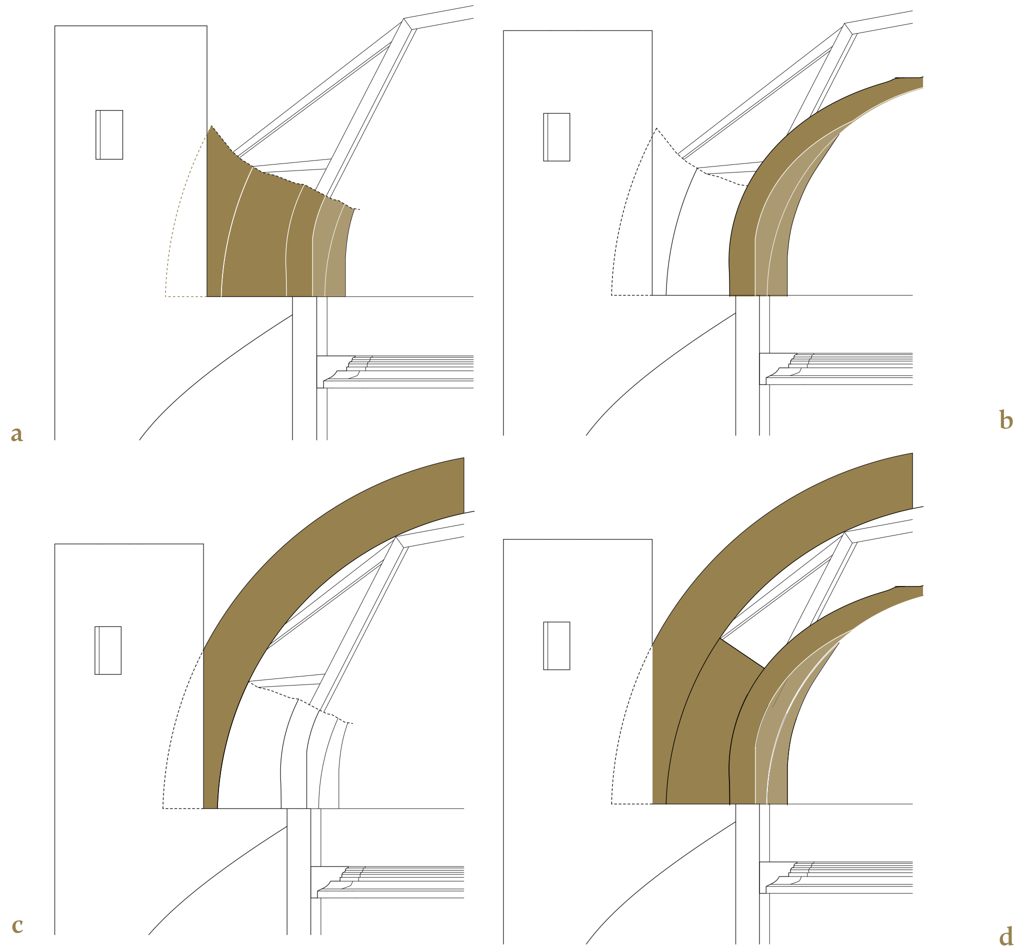
Going back to the pendentive zone, as well as the chiave, the diagrams b-d in Figure 59 depict all possible scenarios regarding the completion of the aforementioned components of this zone:
Figure 59.b. shows the condition in which the Arconi were completed first, followed by the construction of the pendentive and conical vault. Figure 59.c. on the contrary illustrates the opposite case in which the pendentive and the vault were completed prior to the arconi. The last scenario illustrated in Figure 59.d. simply presents both groups and all elements as built in parallel at the same time.

- **Serliana, Diagonal Arches, and Buttressing Arches**

Considering that traditionally the buttressing elements are built before or simultaneous to the element they are supporting, the diagonal and buttressing arches in San Lorenzo are assumed to lie within the same convention. Since the buttresses rest on the serliana columns, based on Hint 1, it can be

deducted that the latter was built first.

Consequently, Phase 3 is understood not as a linear se-



quence of isolated operations, but as a process involving overlapping sub-phases, and temporary supports.

To this end he diagrams and axonometric reconstructions presented as H1-A1, H2-A2, H3-A3, synthesize all the aforesaid hypotheses by facing the hidden-versus-apparent systems relevant to the conceptual essence of this church. A definitive solution for the construction's chronological order has not been reached, reflecting both the complexity of the architect's design and the limitations in reconstructing historical building processes.

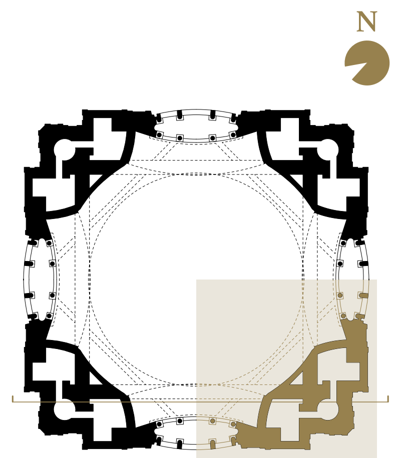
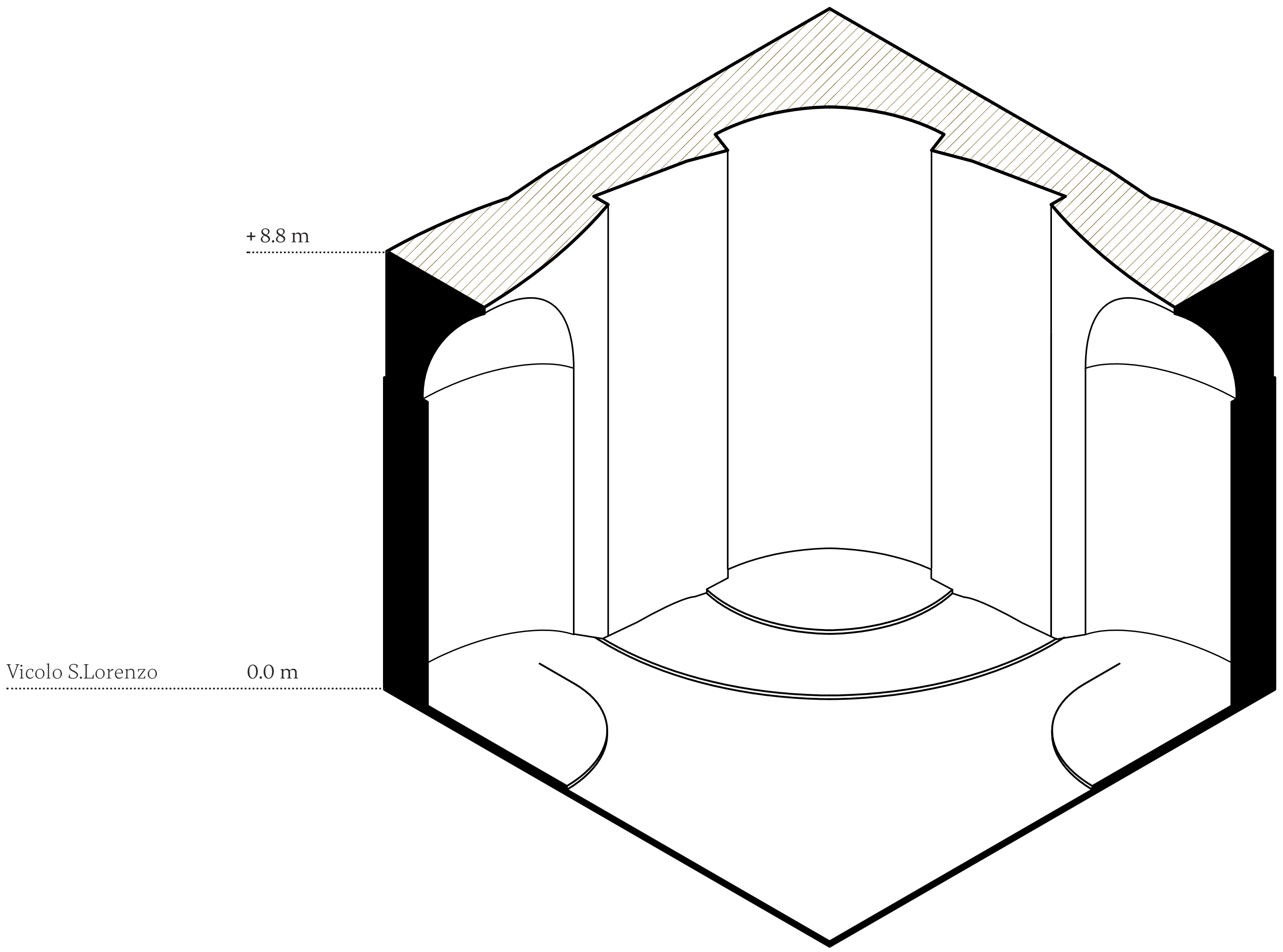


Figure 59 – Assumption schemes on the construction of the hidden structure.

H1

Hidden Structure



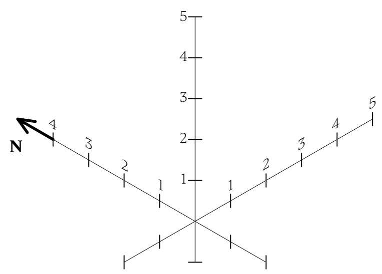
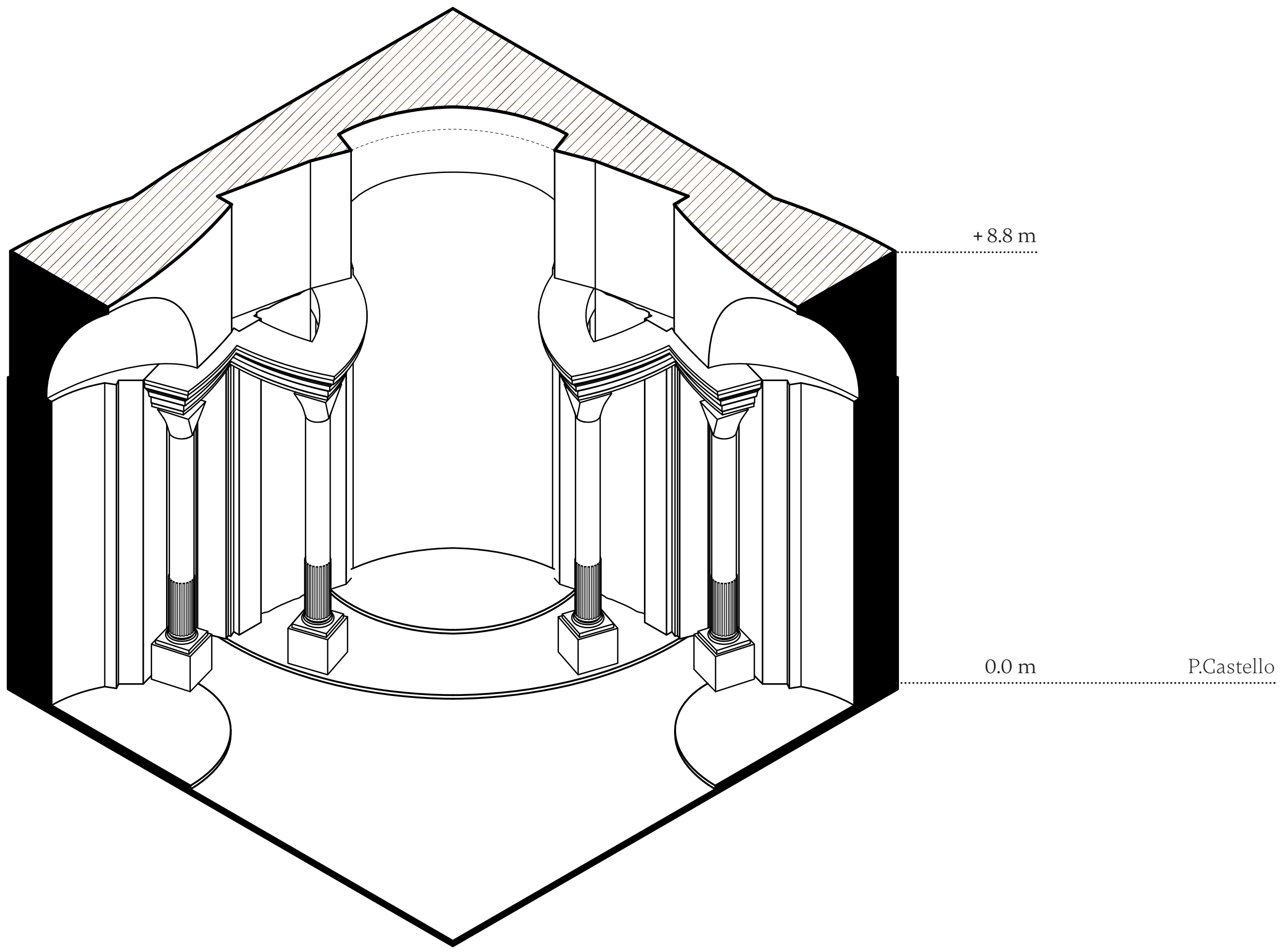


Figure 60 –Construction Phase 1, assumed as showing the hidden elements of the phase (H1)

Apparent Structure

A1



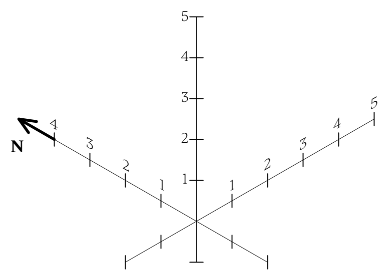
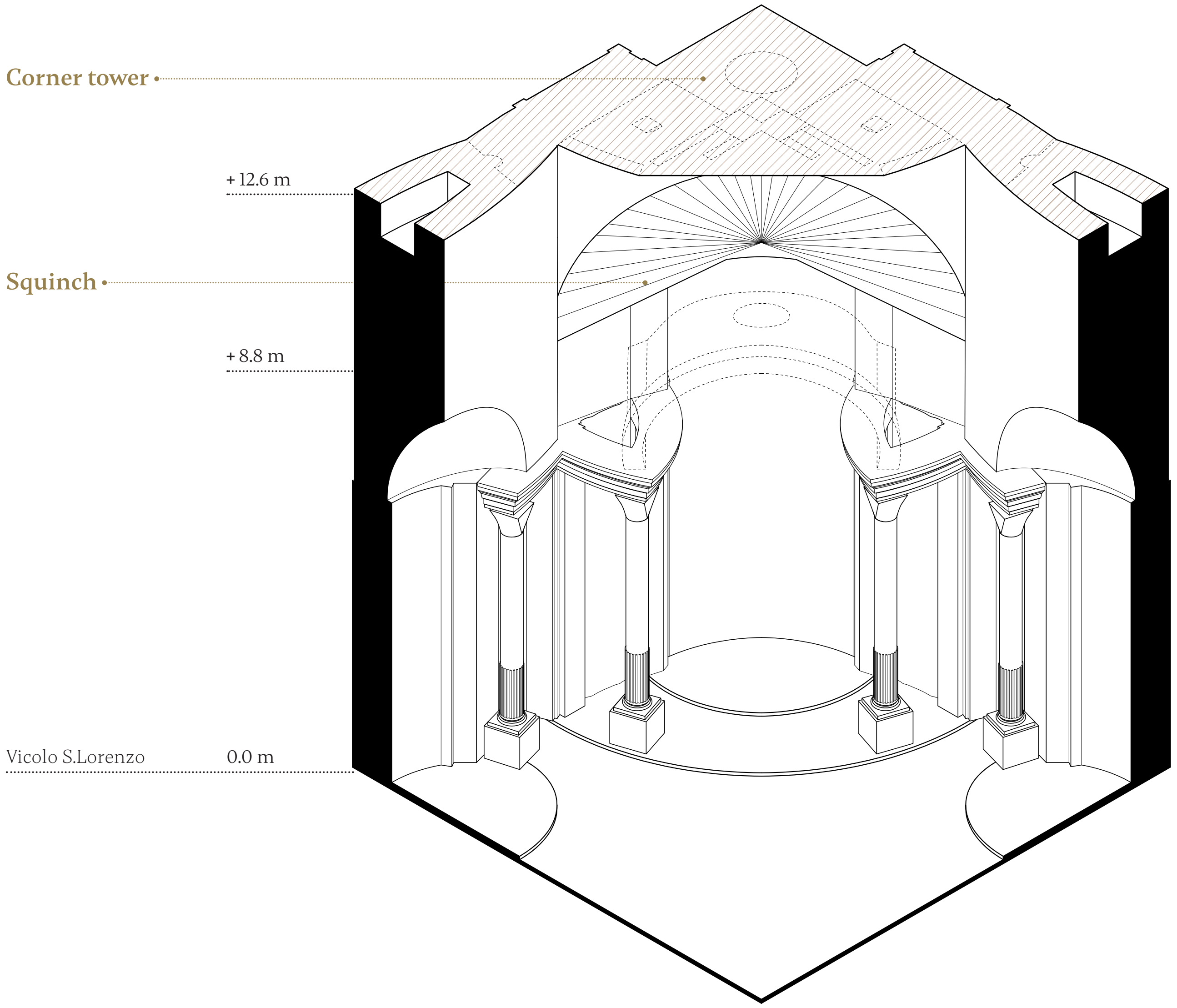


Figure 61 –Construction Phase 1, assumed as showing the apparent elements of the phase (A1)

H2

Hidden Structure



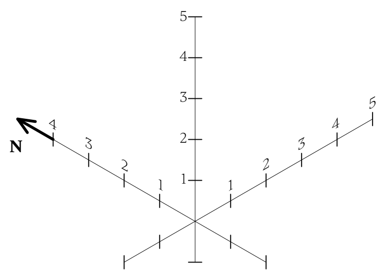
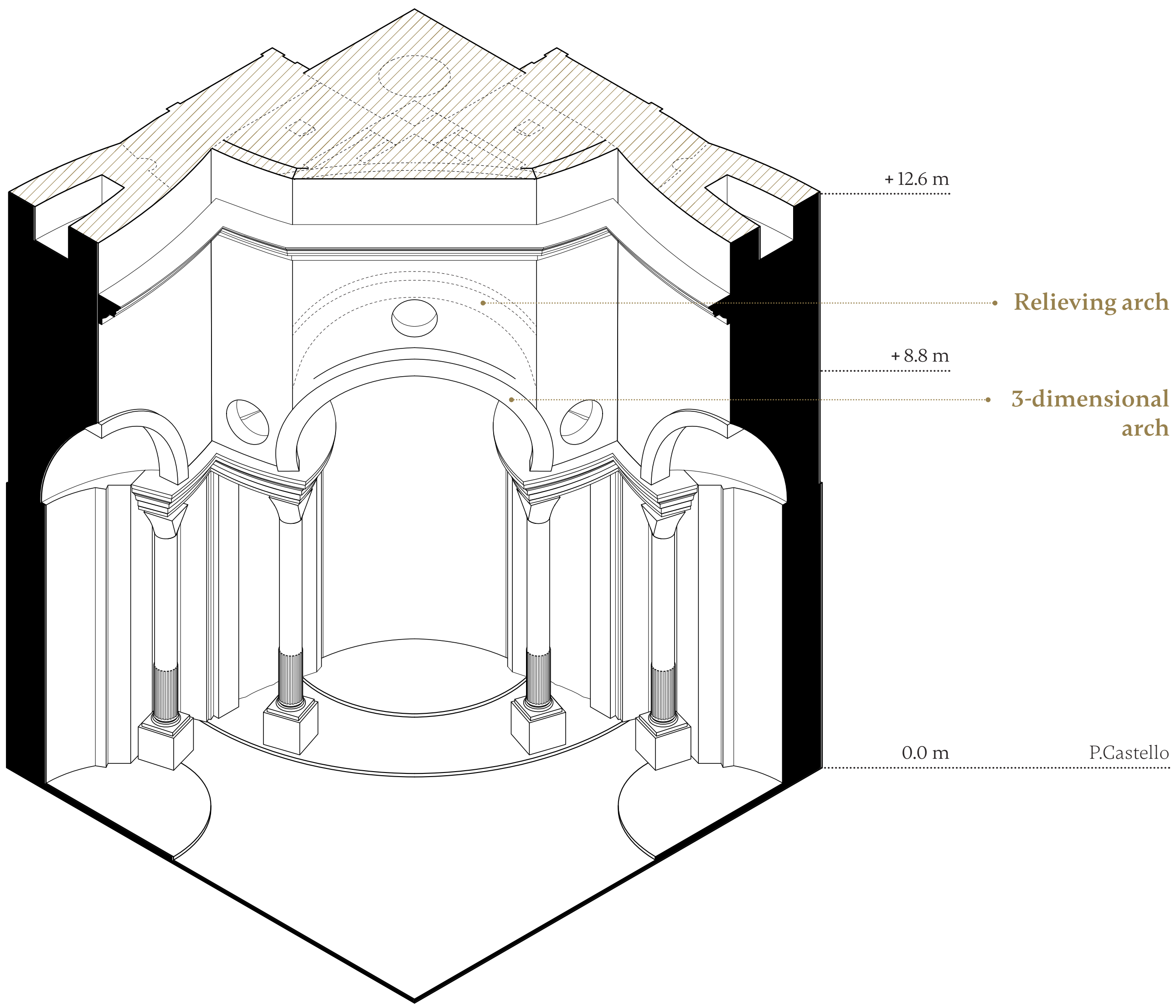


Figure 62 –Construction Phase 2, assumed as showing the hidden elements of the phase (H2)

Apparent Structure

A2



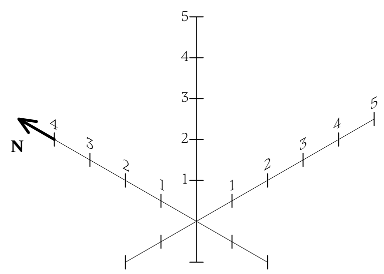


Figure 63 –Construction Phase 2, assumed as showing the apparent elements of the phase (A2)

H3

Hidden Structure

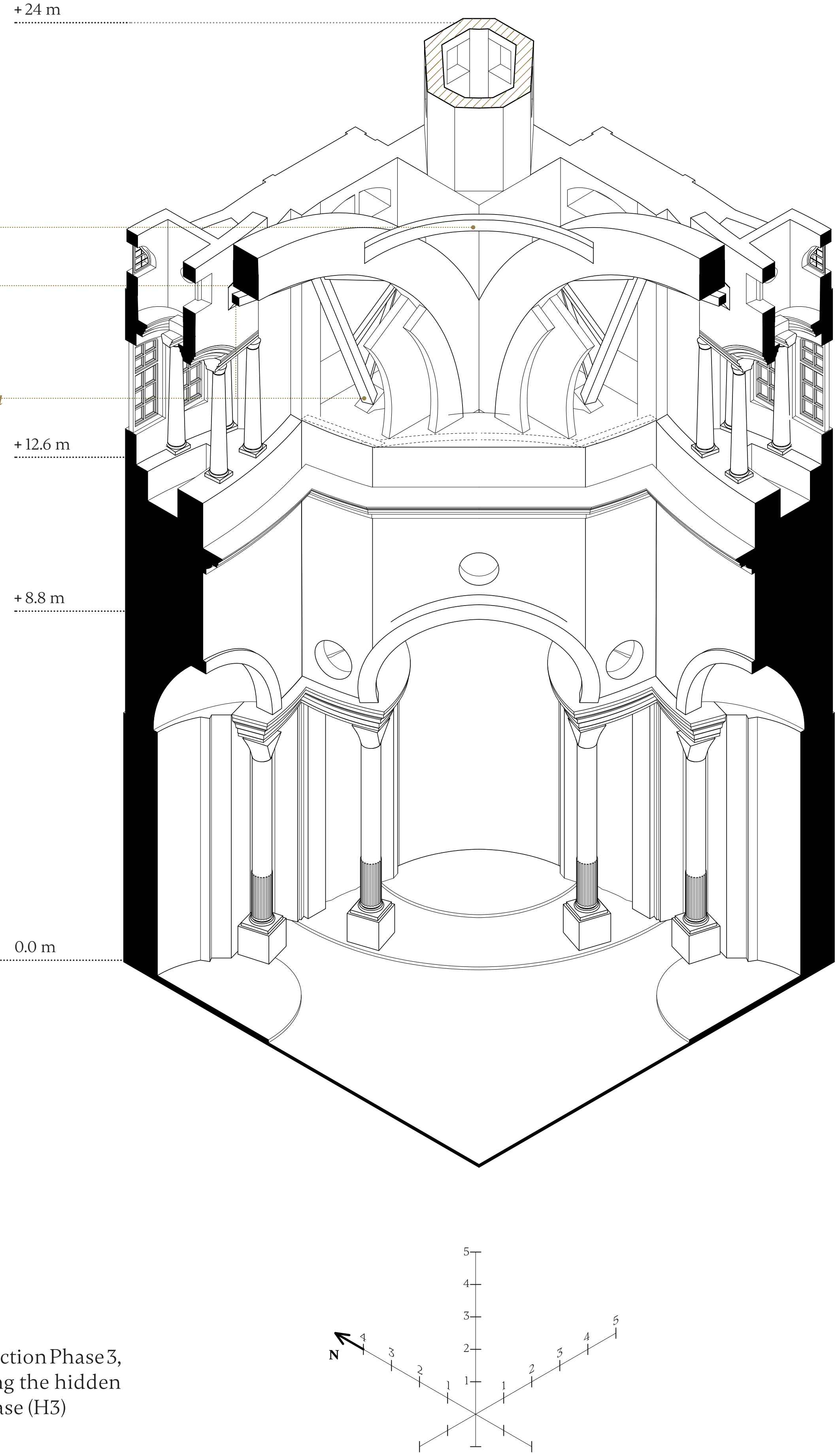


Figure 64 –Construction Phase 3, assumed as showing the hidden elements of the phase (H3)

Apparent Structure

A3

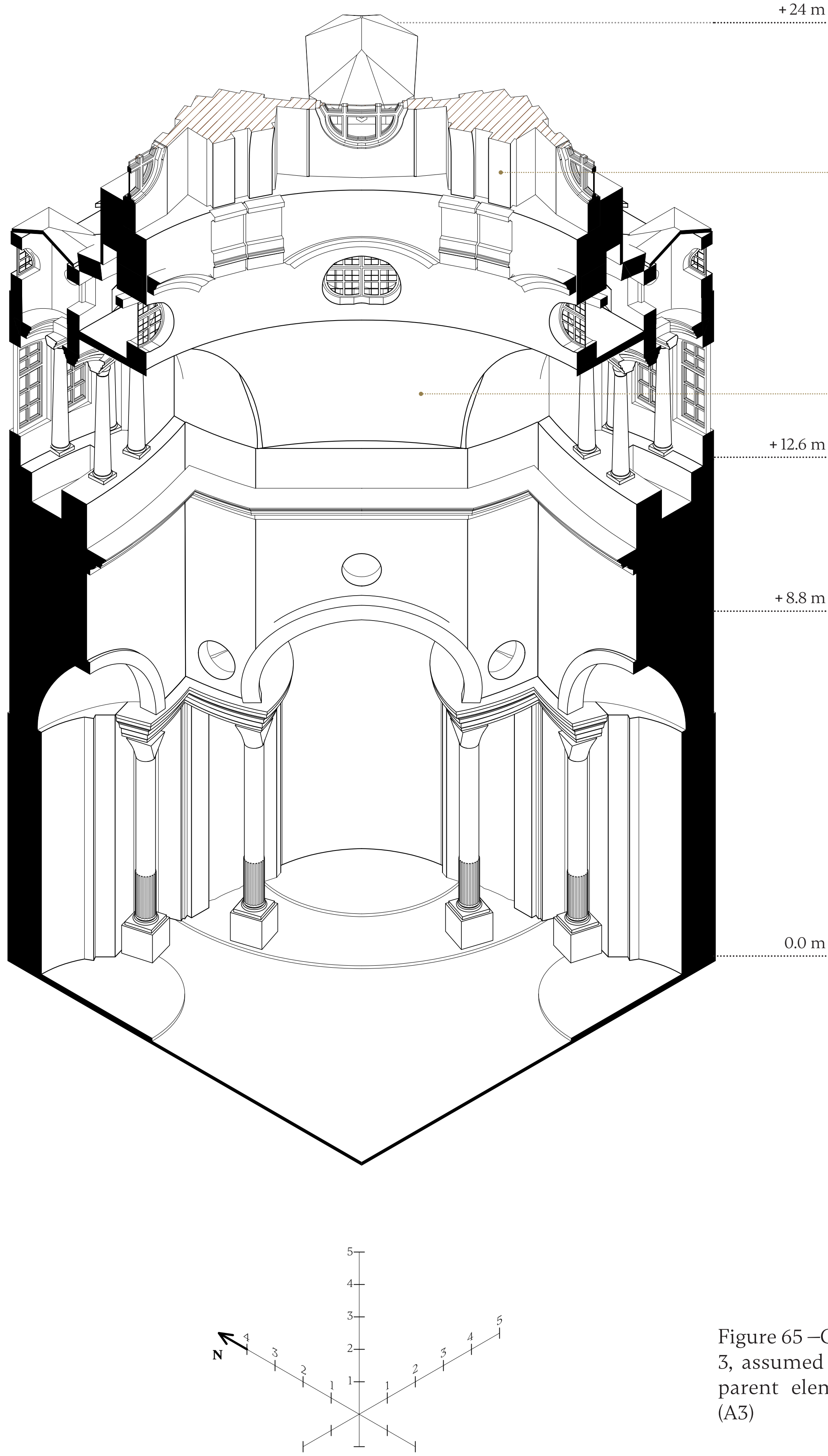


Figure 65 –Construction Phase 3, assumed as showing the apparent elements of the phase (A3)

05 Conclusion

This study set out to explore the hidden structural system of the church of San Lorenzo in Turin, constructed by Guarino Guarini, through the use of construction logics and possible building sequence, as well as deformation analysis in different scales. Rather than reaching a definitive reconstruction of the historical building, the thesis attempted to bridge the gaps between archival documents, previous scholarly research, and data acquired from the as-built situation of the church.

The initial part of the research presented a theoretical framework on Guarini's personal and professional life, his career and writings, and finally the church of San Lorenzo. This juxtaposition of sources allowed to better recognize the place that San Lorenzo takes within the works of the architect. As one of the most original and conceptually complex works of Guarini, the literature yet revealed uncertainties regarding these complexities. The questions remaining unanswered were the relationship and interaction of the hidden and visible layers of the building, the *Chiave della Cupola,* the reading of what belonged to the original construction and what to the nineteenth-century restoration led by Carlo Randoni. Hence, this chapter attempted to indicate such limitations, and propose analytical hypotheses to lay the ground for further investigations of the study.

The third chapter addressed the current geometric and structural condition of the church through deformation analyses based on the point cloud data. Sectional, planar, and localized investigations resulted in a both quantitative and qualitative report on the overall structural situation of San Lorenzo, that showed no critical pathologies, and the present irregularities are distributed unevenly. The results implied not a contradiction to the longevity of the church, but a proof on the complex construction process that Guarini carried out.

The last chapter presented the core contribution of this study to the knowledge on this church, proposing a hypothetical construction sequence for a corner of the building. This was focused exclusively on what can be reasonably attributed to Guarini's original campaign, excluding later restorations or alterations. This required the translation of historical knowledge and on-site observations into a construction logic, which was possible by taking into account a couple of construction hints, such as structural hierarchy, masonry toothing, and centering system requirements. The results of the discussions proposed by this chapter were illustrated in phased drawings, depicting the relationship between the hidden and apparent structures, not in a certain chronological order but in phases. The detailed analysis on each phase's components were explained through schematic illustrations to show how multiple elements may have been constructed in parallel or in close succession.

An important outcome of this exploration was the recognition that in San Lorenzo, while the perimeter walls and ground floor columns are indispensable supports, the true structure lies at a higher level consisting of a system of arches and transitional vaults. This distortion from the intuitive structural logic reinforces the paradoxical character of Guarini's architecture: an light and fragile interior, is being supported by a carefully built and large invisible system.

Finally, this thesis does not claim to reconstruct the exact historical sequence of the building of San Lorenzo or resolve the ambiguities about the hidden structure, but to propose a method of analyzing such topics through the use of reasonable hypotheses, based on historical documentations, digital geometric data, and on-site considerations. Further research could extend this approach to other parts of the building, include material analysis, and comparative studies, in order to further refine the understanding of this extraordinary structure of Guarino Guarini.

06

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07

List of Illustrations

08

Annex


```
clear
close
figure; hold on;

filename = 'M_P.xlsx';
T= readtable(filename);
DataArray = T{:,["elevation_class",'x','y','z']};
normal_amplification = 50;
cmap = jet(256); % init colormap
caxis = ([0 256]);
kslope = 5000;

elevation_classes = [1 2 3 4 5];
elevation_colors = ['r','g','b','c','y'];
n_elevations= length(elevation_classes);

for e=1:n_elevations
   elevation_class = elevation_classes(e);
   rows = find(DataArray(:,1) == elevation_class);
   FilteredDataArray = DataArray(rows,[2,3,4]);
   mdl=fitlm(FilteredDataArray(:,[1,2]),FilteredDataArray(:,3));
   FilteredDataLen = size(FilteredDataArray(:,1),1);

    x = [0.8*min(FilteredDataArray(:,1)); 1.2*max(FilteredDataAr-
ray(:,1)); 1.2*max(FilteredDataArray(:,1)); 0.8*min(FilteredDataAr-
ray(:,1))];
    y = [0.8*min(FilteredDataArray(:,2)); 0.8*min(FilteredDataAr-
ray(:,2)); 1.2*max(FilteredDataArray(:,2)); 1.2*max(FilteredData-
Array(:,2))];
   z = predict(mdl,[x,y]);

   patch(x,y,z,elevation_colors(elevation_class),'FaceAlpha',0.2);
  scatter3(FilteredDataArray(:,1), FilteredDataArray(:,2), Filtered-
DataArray(:,3),'filled','MarkerFaceColor',elevation_colors(eleva-
tion_class))
   maxslope=0; minslope=0;
   for i=1:FilteredDataLen
      if i < FilteredDataLen
            len = norm([(FilteredDataArray(i,1)-FilteredDataAr-
ray(i+1,1))^2, (FilteredDataArray(i,2)-FilteredDataArray(i+1,2))^2,
(FilteredDataArray(i,3)-FilteredDataArray(i+1,3))^2]);
      slope = abs(FilteredDataArray(i,3)-FilteredDataArray(i+1,3))/
len;
        maxslope=max(maxslope,round(slope*kslope)); minslope
=min(minslope,round(slope*kslope));
        k = max(1,round(min(256, slope*kslope)));
         line([FilteredDataArray(i,1),FilteredDataArray(i+1,1)], [Fil-
teredDataArray(i,2),FilteredDataArray(i+1,2)], [FilteredDataAr-
ray(i,3),FilteredDataArray(i+1,3)],'Color', cmap(k, :),'linewidth',2);
      else
            len = norm([(FilteredDataArray(i,1)-FilteredDataAr-
```

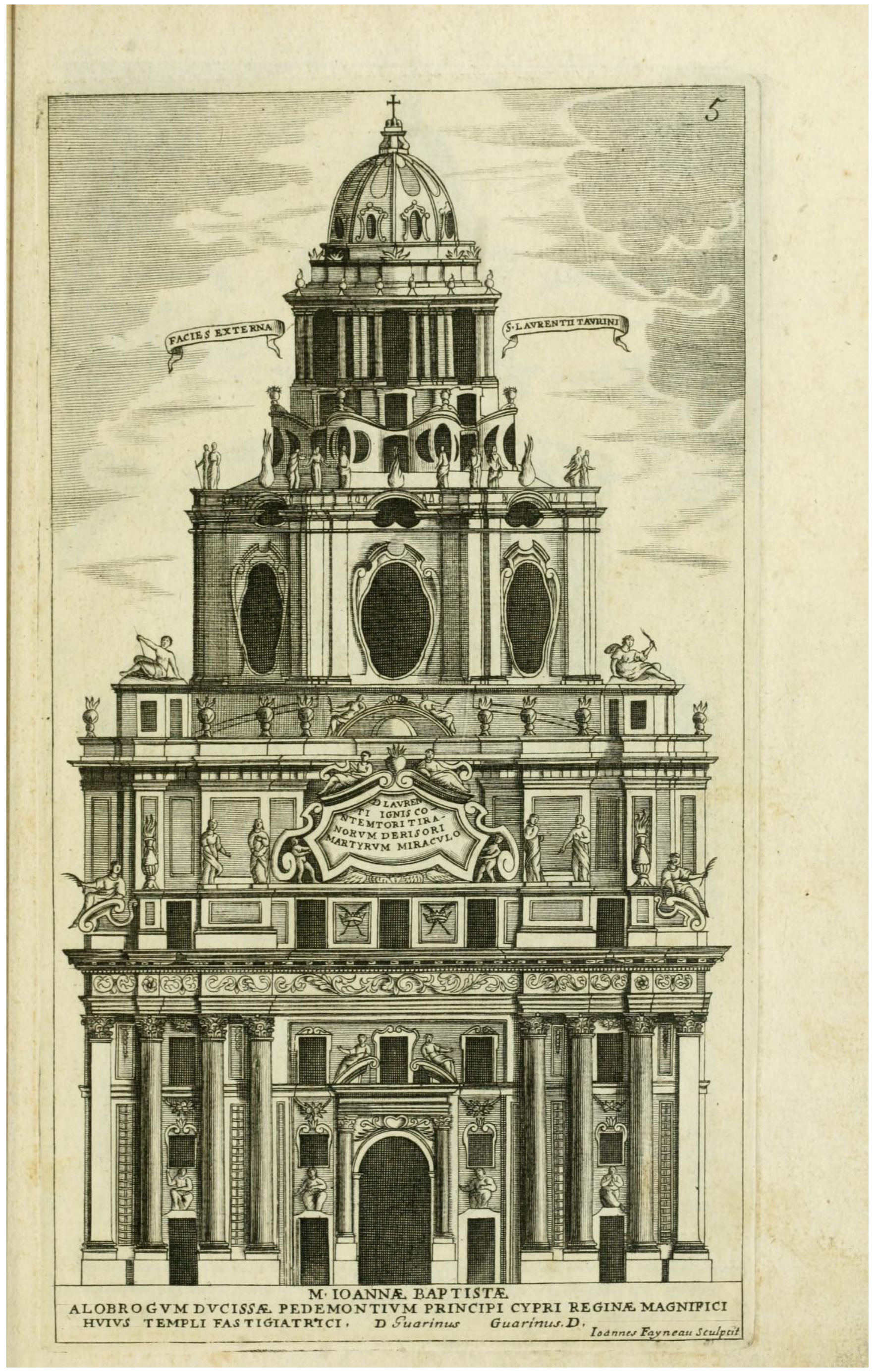
The MATLAB code used in the deformation analysis in chapter 03.

```
ray(1,1))^2, (FilteredDataArray(i,2)-FilteredDataArray(1,2))^2, (Fil-
teredDataArray(i,3)-FilteredDataArray(1,3))^2]);
        slope = abs(FilteredDataArray(i,3)-FilteredDataArray(1,3))/
len;
                                            maxslope=max(maxslope,slope);
minslope=min(minslope,slope);
         k = max(1,round(min(256, slope*kslope)));
             line([FilteredDataArray(i,1),FilteredDataArray(1,1)], [Fil-
teredDataArray(i,2),FilteredDataArray(1,2)],    [FilteredDataAr-
ray(i,3),FilteredDataArray(1,3)],'Color', cmap(k, :),'linewidth',2);
      end
   end
   X = mean(FilteredDataArray(:,1));
   Y = mean(FilteredDataArray(:,2));
   Z = mean(FilteredDataArray(:,3));
   U = -normal_amplification * mdl.Coefficients(2,1).(1);
   V = -normal_amplification * mdl.Coefficients(3,1).(1);
   W = 3;
   quiver3(X,Y,Z,U,V,W,elevation_colors(elevation_class))
end

colormap(jet)
colorbar
view(3)
axis equal
xlabel('x');
ylabel('y');
zlabel('z');


%img = imread('peppers.png');     % Load a sample image
%xImage = [-0.5 0.5; -0.5 0.5];    % The x data for the image cor-
ners
%yImage = [0 0; 0 0];          % The y data for the image corners
%zImage = [0.5 0.5; -0.5 -0.5];  % The z data for the image corners
%surf(xImage,yImage,zImage,...    % Plot the surface
%    'CData',img,...
%    'FaceColor','texturemap');
%set(gca, 'ZLim',[238 242])
```

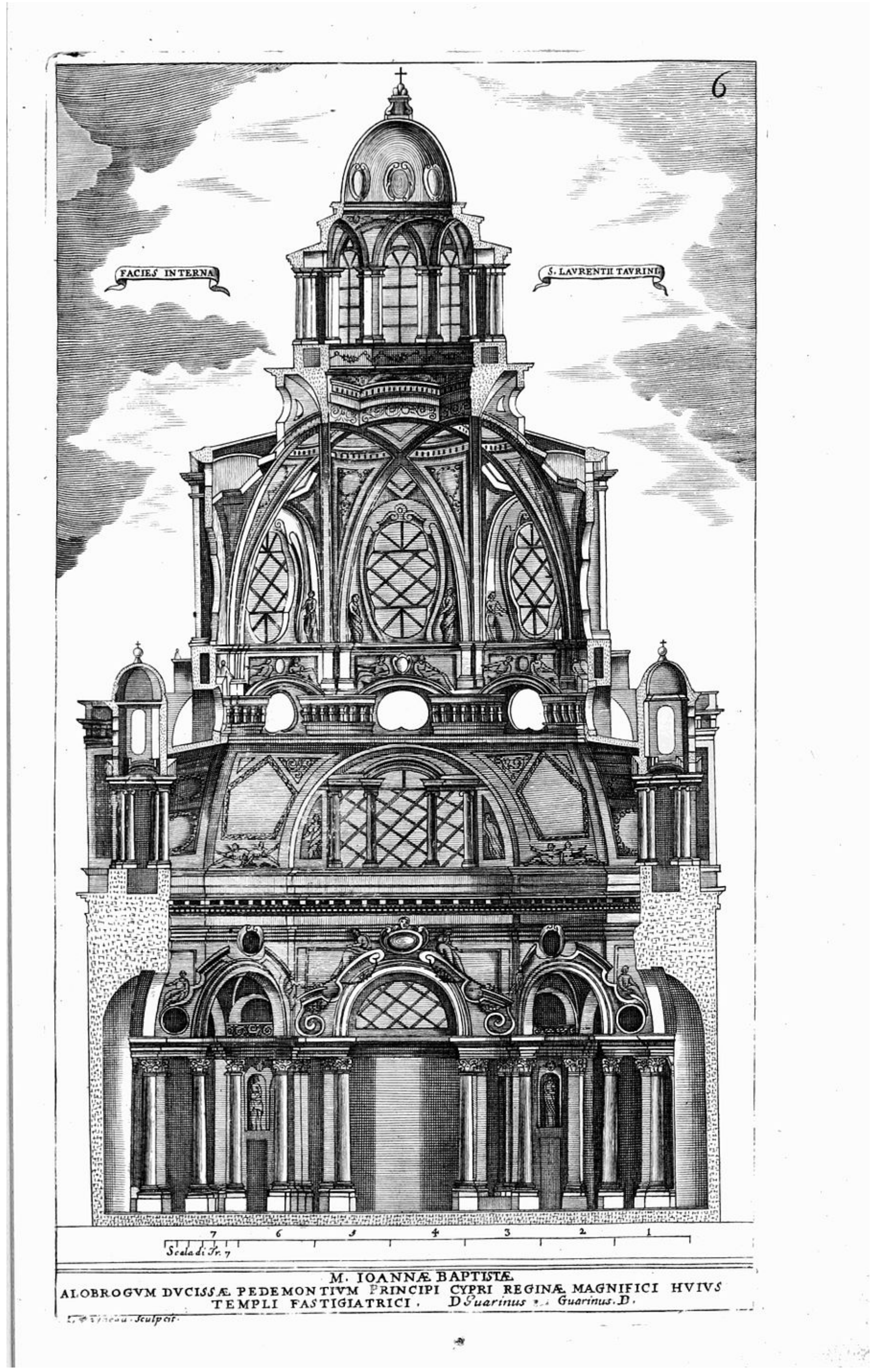

Level	elevation_class	x	y	z
	1	3.556949854	-7.957220078	-0.556389987
	1	-0.567960262	-4.819809914	-0.597859979
	1	-0.385437965	-4.860435963	-0.599167585
	1	-1.563461781	4.743684769	-0.583462059
	1	-1.606780529	4.843175888	-0.581295788
	1	-1.693161488	5.029984474	-0.583072066
	1	1.503602028	8.547163963	-0.517887533
	1	1.736158371	9.373624802	-0.50448209
	1	0.956069946	8.658060074	-0.525290012
Base	1	10.61398792	10.49387455	-0.306362063
	1	11.08968163	9.508503914	-0.298697561
	1	11.67716026	9.767055511	-0.292435765
	1	15.16735268	7.21416378	-0.339717567
	1	15.19864273	7.369944096	-0.33969757
	1	16.39248276	-3.597976208	-0.39162755
	1	16.16140175	-3.033486128	-0.388267547
	1	16.55716133	-2.856326103	-0.387467563
	1	13.6752224	-6.977566242	-0.423497558
	1	13.05089188	-6.881546021	-0.430797547
	1	12.99279404	-7.18529129	-0.432560146
	2	11.09085846	9.709404945	5.331717968
	2	15.11243248	6.570483685	5.398452282
	2	15.07722664	6.613766193	5.4095355885
	2	16.18494987	-3.085327625	5.325535297
	2	16.19928932	-3.051417589	5.327005386
	2	13.06208706	-6.954154015	5.336045742
	2	13.02577019	-6.982467651	5.3384552
Capital	2	3.458800077	-8.07283783	5.162575245
	2	3.480990171	-8.081687927	5.161875248
	2	-0.503806114	-4.963051319	5.116319656
	2	-0.482068062	-4.993316174	5.112242222
	2	-1.674399853	4.605259895	5.129940033
	2	-1.656710148	4.642062664	5.141395569
	2	1.466650009	8.53473568	5.222324371
	2	1.452857971	8.521684647	5.218408108
	3	11.04754734	9.504205704	6.1425457
	3	14.91942692	6.47115612	6.178955555
	3	16.04953957	-3.066344023	6.092514038
	3	16.0537014	-3.063376188	6.092262268
	3	12.97678185	-6.861145973	6.110752583
Entablature	3	3.492452145	-7.886536598	5.889422417
	3	3.492563963	-7.89121151	5.887929916
	3	-0.356107712	-4.886356354	5.866592407
	3	-0.361407757	-4.86939621	5.862902641
	3	-1.487800121	4.552710056	5.876480103
	3	-1.494960308	4.547049999	5.880000114
	3	1.573753834	8.348749161	5.922169685
	4	1.703670025	7.872012615	12.53347492
	4	-1.208280087	4.377102375	12.45094585
	4	-0.049562931	-4.740953922	12.36231613
	4	3.569787025	-7.608183861	12.37949562
Cornice	4	12.66153145	-6.472206116	12.47631264
	4	15.45679283	-3.105776072	12.55735207
	4	14.52285004	6.274950027	12.64570045
	4	10.97457695	9.05139637	12.63476563
	4	10.97299767	9.047885895	12.63680553
	5	10.95182419	9.713559151	14.16639996
	5	10.94482994	9.715132713	14.16714573
	5	15.00566006	6.583909988	14.17138004
	5	16.05318642	-3.051143885	14.08480549
	5	16.05916977	-3.056390047	14.08024025

Points picked in Cloud Compare to be analyzed in the MATLAB analysis of chapter 03.

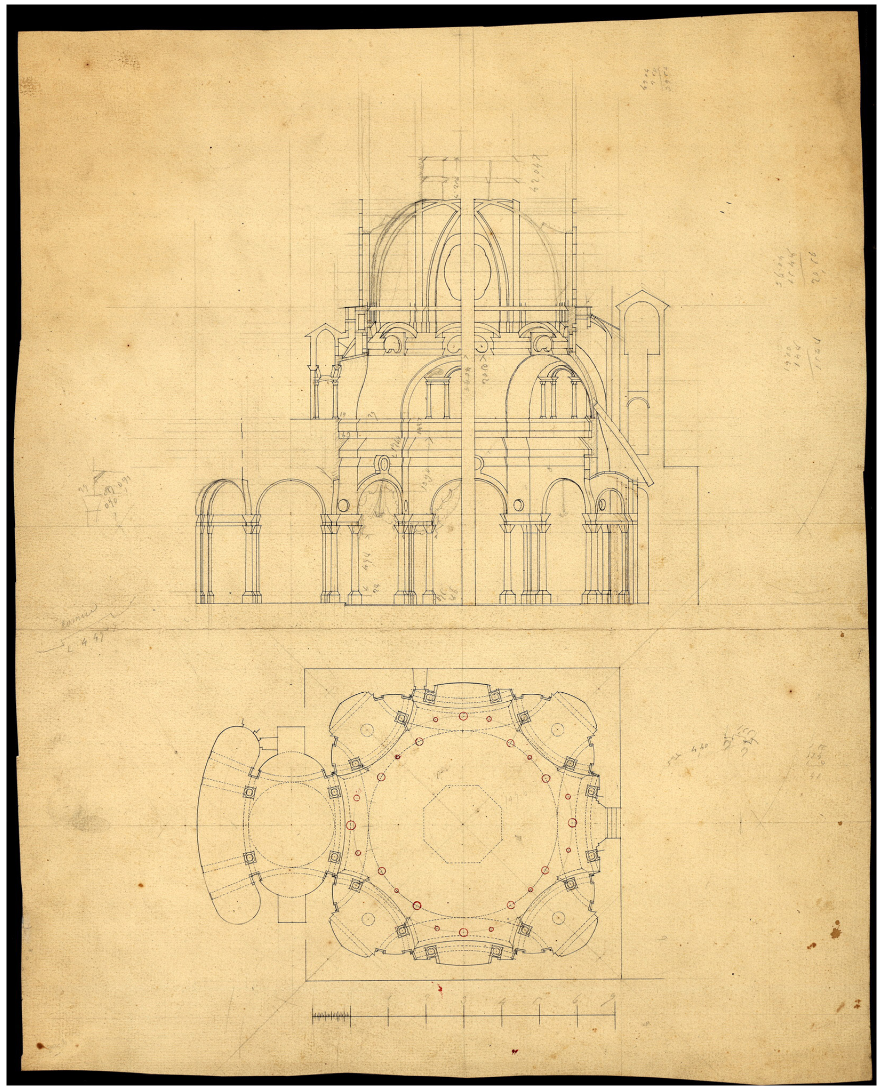
Serliana	5	12.92891026	-7.067317486	13.98405552
	5	12.91508675	-7.095334053	13.98160553
	5	3.436790228	-8.164847374	13.9360857
	5	3.421850204	-8.159087181	13.93857574
	5	-0.554080009	-5.05125761	13.95796585
	5	-1.742432117	4.567430973	14.00801659
	5	1.41936779	8.495740891	14.07793713



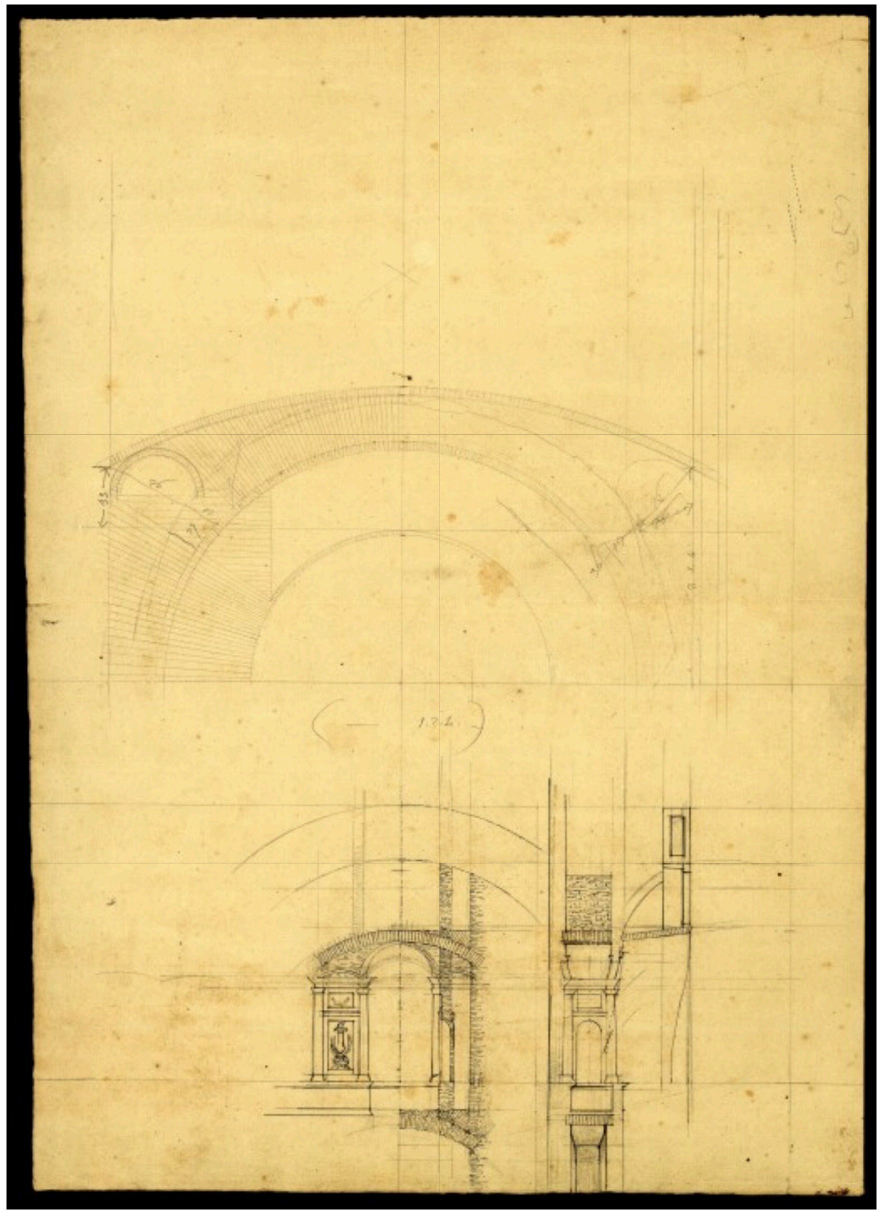
Elevation of San Lorenzo by Guarini. From Dissegni d'architettura civile et ecclesiastica (Torino: Per gl'Eredi Gianelli, 1686)



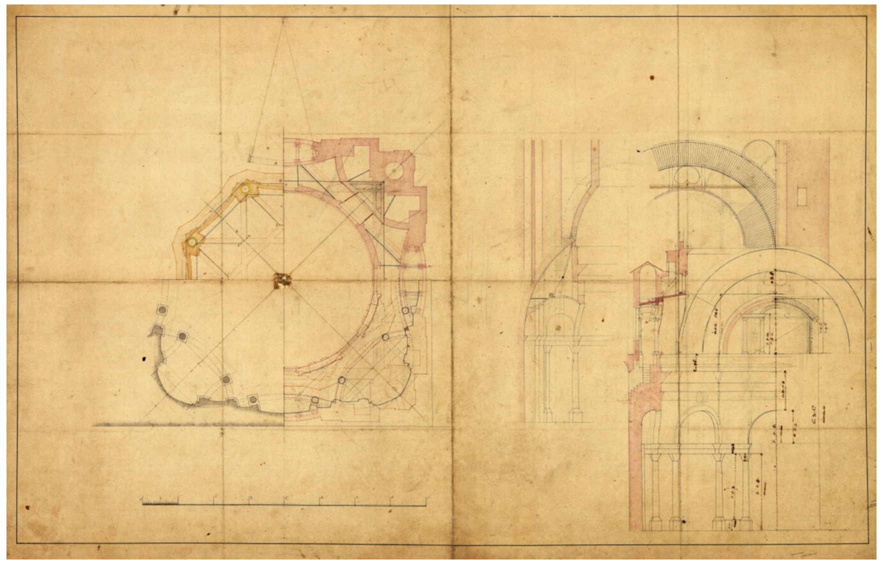
Section of San Lorenzo by Guarini. From Dissegni d'architettura civile et ecclesiastica (Torino: Per gl'Eredi Gianelli, 1686)

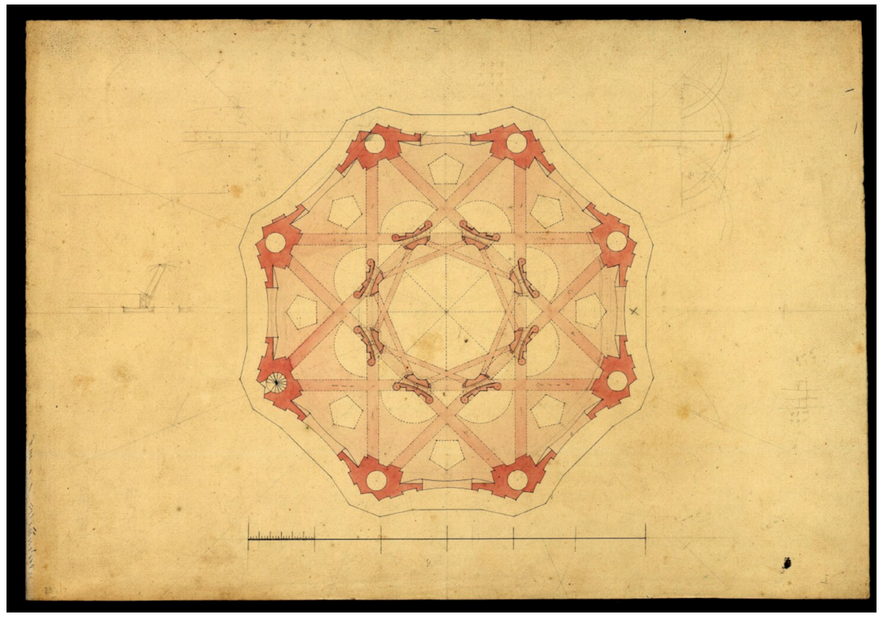


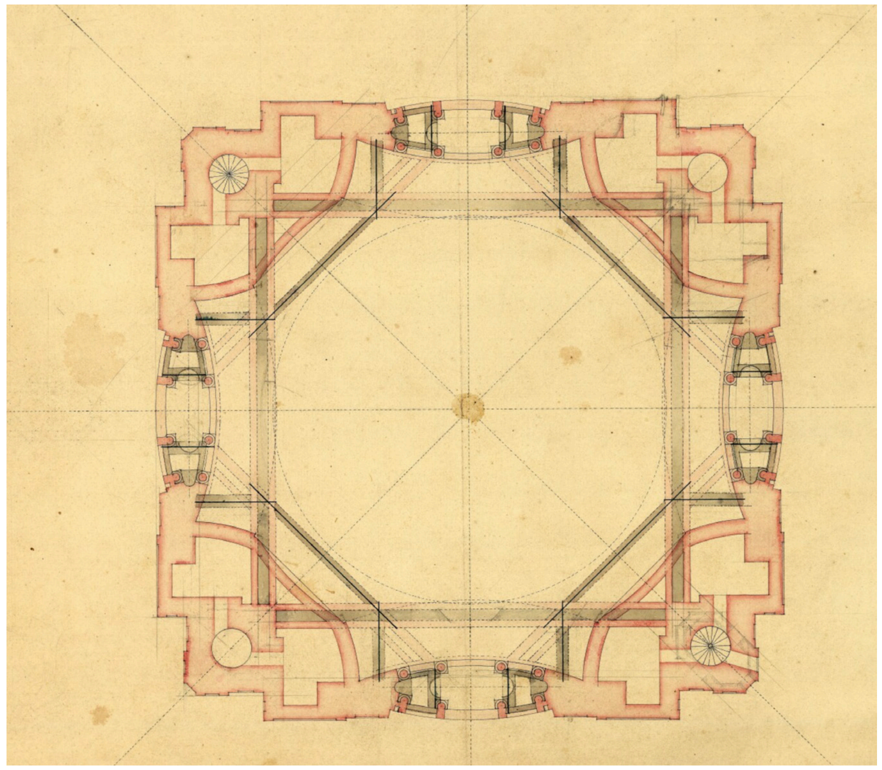
Ground level plan, longitudinal and diagonal section of San Lorenzo, undated and unsigned. Archivio di Stato di Torino, Casa di Sua Maestà (formerly Archivio Segreto di Sua Maestà), inv. no. 295/2.



Schizzo di arcate (sketch of arches) for the Church of San Lorenzo, undated and unsigned. Archivio di Stato di Torino, Casa di Sua Maestà (formerly Archivio Segreto di Sua Maestà), Tipi e disegni, inv. no. 298.

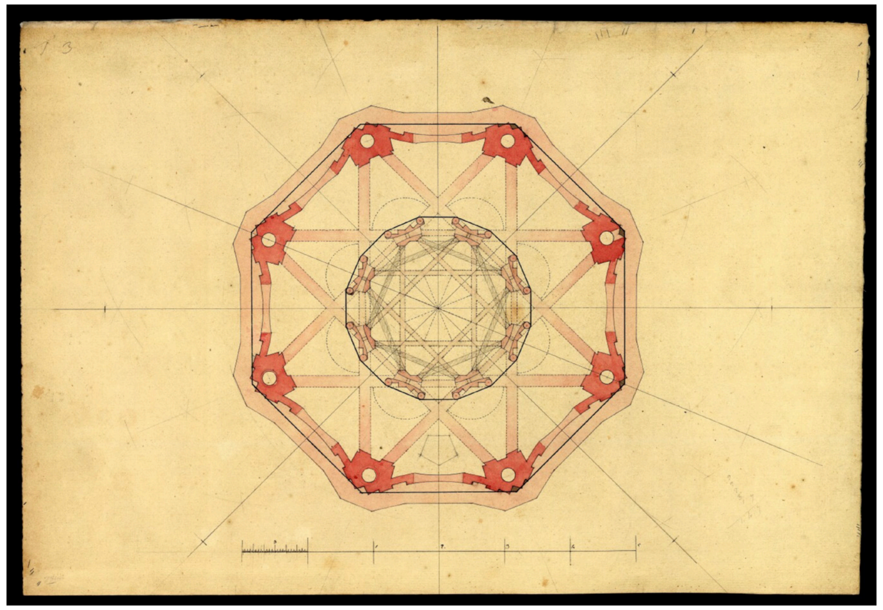






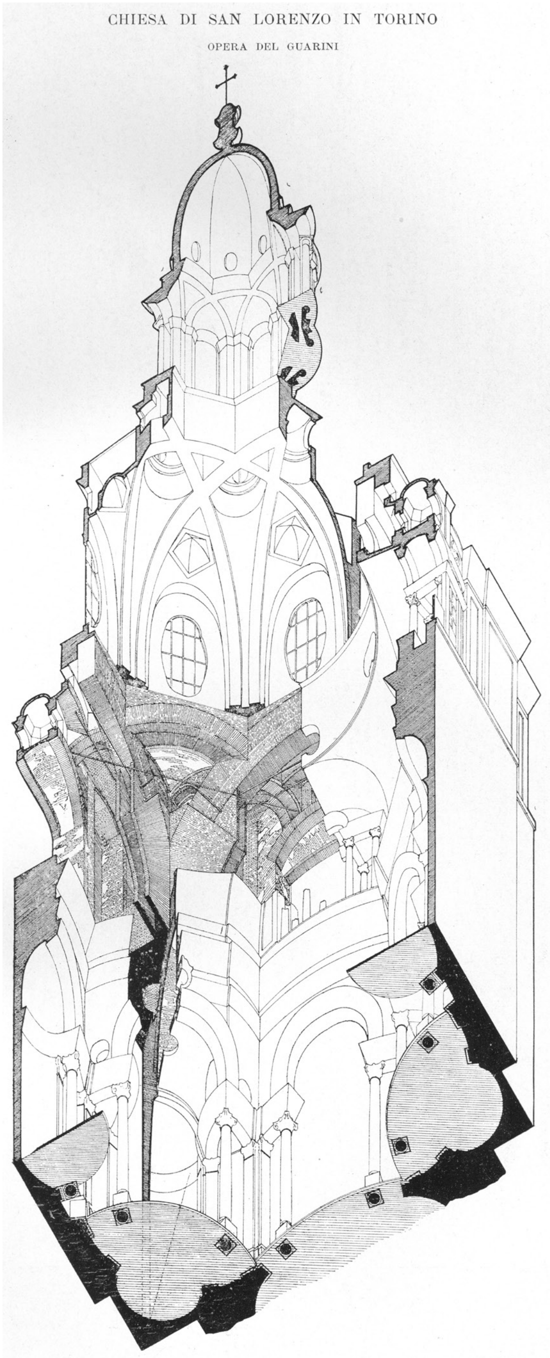
On the left, the plans of different levels, and on the right, details of the hidden structure of San Lorenzo, undated and unsigned. Archivio di Stato di Torino, Casa di Sua Maestà (formerly Archivio Segreto di Sua Maestà), inv. no. 295/1.

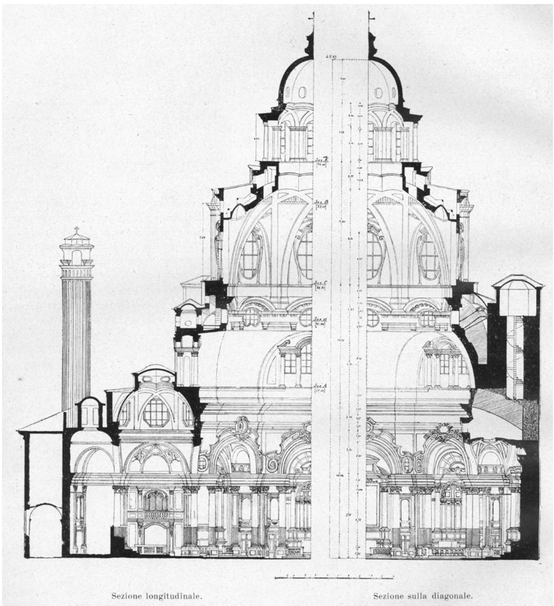
Pendentive level plan of San Lorenzo, undated and unsigned. Archivio di Stato di Torino, Casa di Sua Maestà (formerly Archivio Segreto di Sua Maestà), inv. no. 294/2.



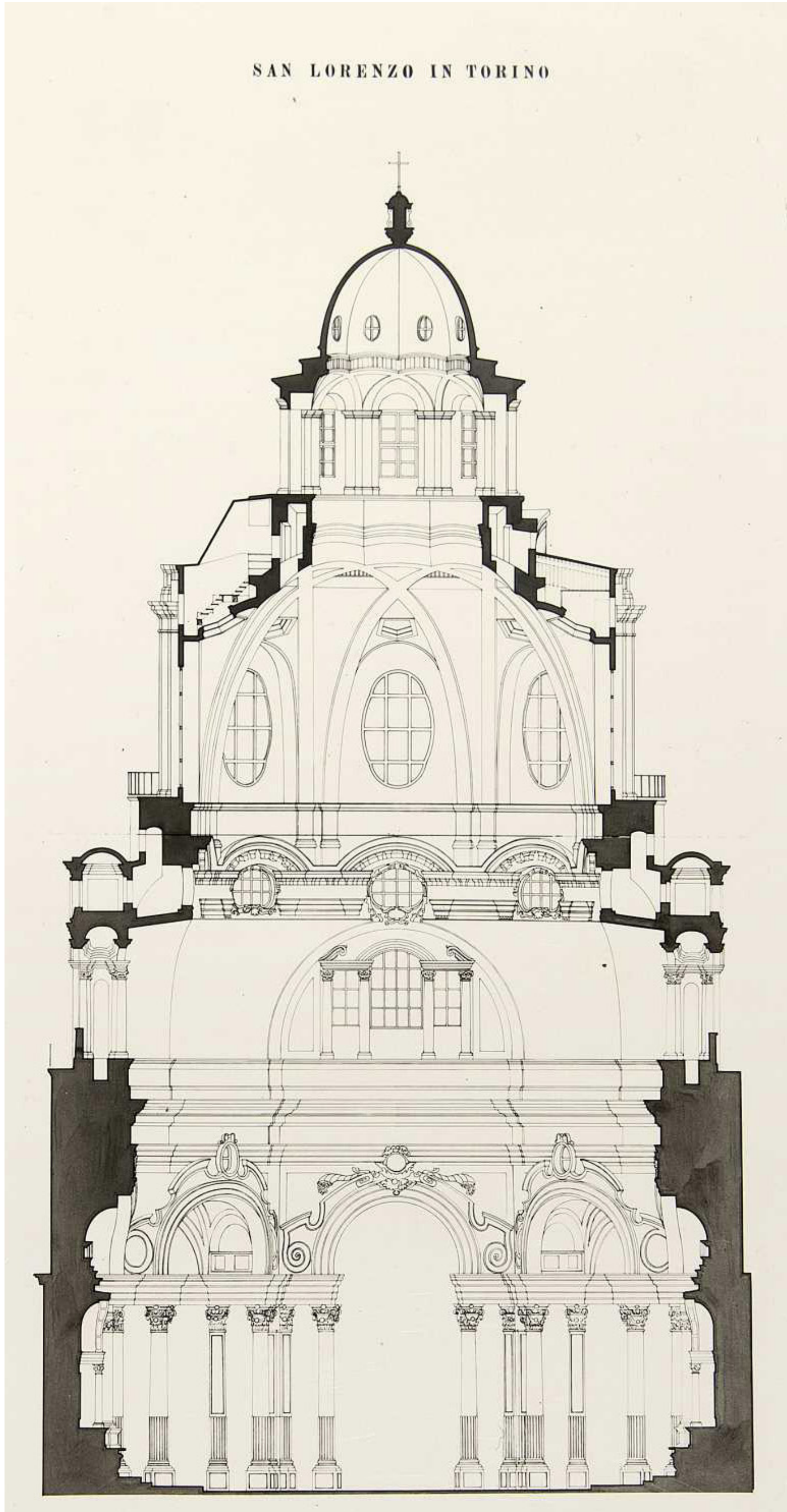
Dome's base plan of San Lorenzo, undated and unsigned. Archivio di Stato di Torino, Casa di Sua Maestà (formerly Archivio Segreto di Sua Maestà), inv. no. 294/3.

Dome's base plan of San Lorenzo together with the upper dome plan, undated and unsigned. Archivio di Stato di Torino, Casa di Sua Maestà (formerly Archivio Segreto di Sua Maestà), inv. no. 294/4.

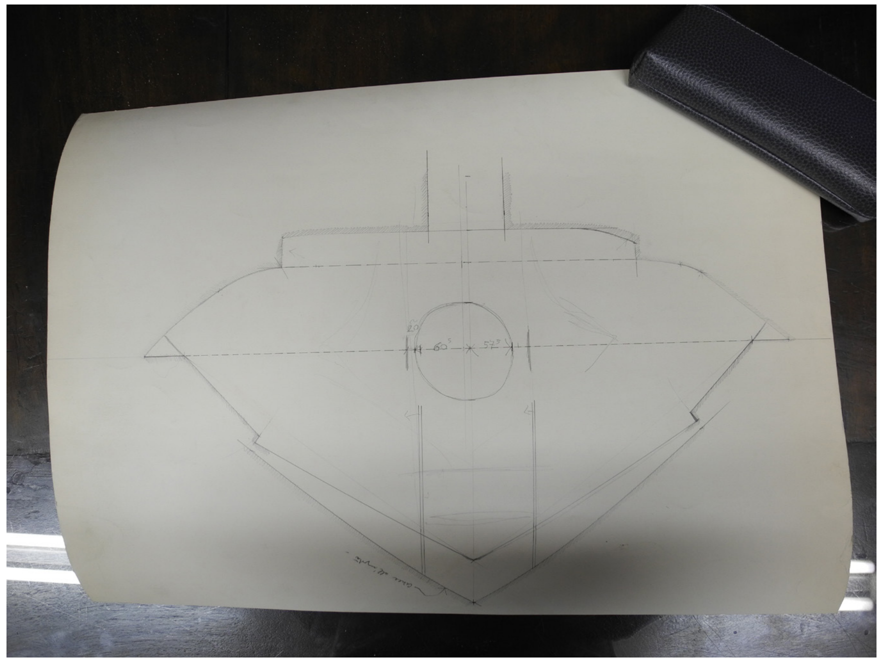


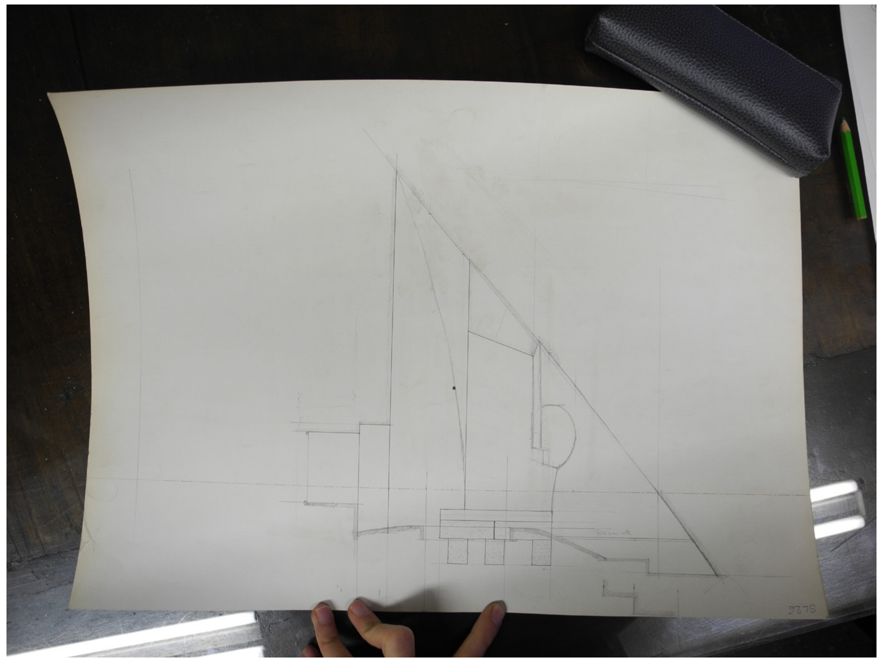


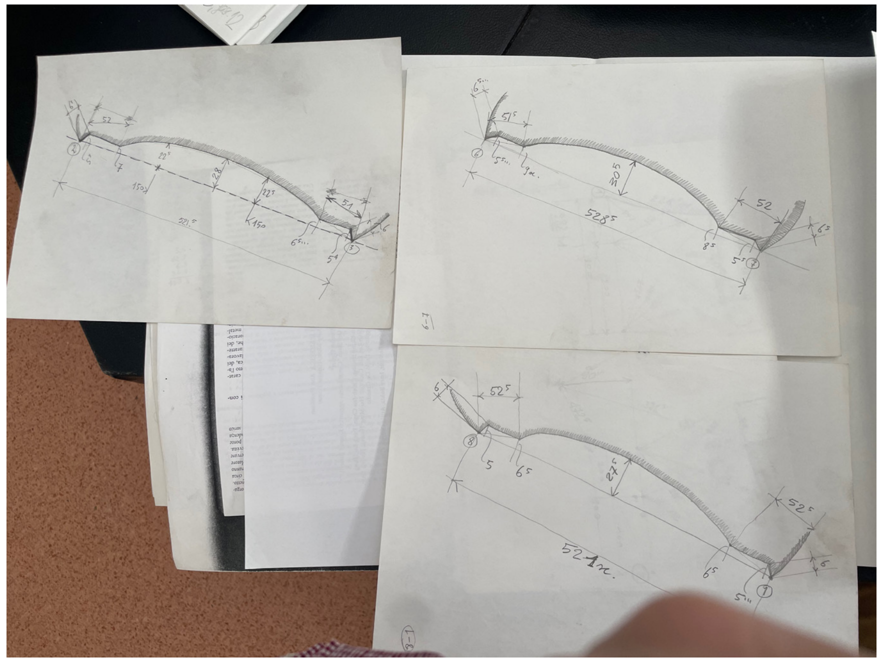
Isometric partial view of the structure of San Lorenzo. Longitudinal and diagonal section of San Lorenzo.



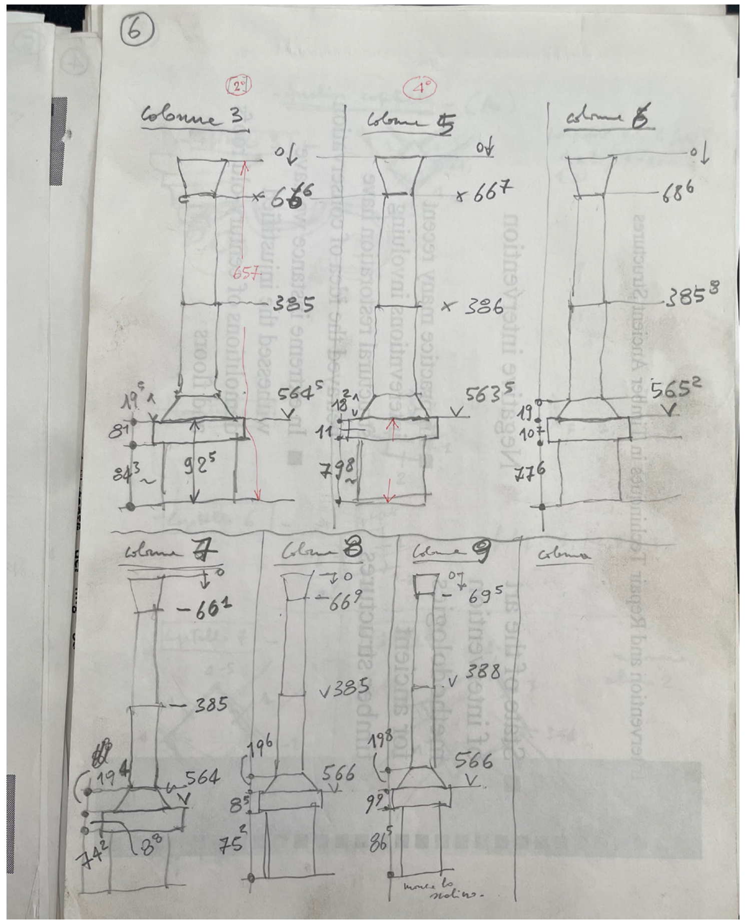
Transversal section of San Lorenzo. From Fondo Mario Passanti







Top and middle: plan and section of the squinch
Comparative plans of the springing level of the three different pendentives



The view from the middle of the kidney-shaped window comparing interior and hidden parts of the church. From Franco Rosso, *Guarino Guarini*, 2006. Photograph by Giuseppe Dell'Aquila.

Top: The space between the extrados of the star-shaped vault and the intrados of the squinch.
Bottom: The view from the hidden pathway, showing the *Chiave della Cupola.* From Franco Rosso, *Guarino Guarini,* 2006. Photograph by Giuseppe Dell'Aquila.

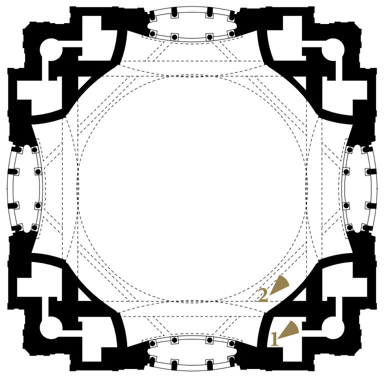
Exterior southern view of San Lorenzo.
Exterior south-eastern view of San Lorenzo. Photography by Edoardo Piccoli, 2025.

View of the church's dome.

View from the serliana on the northern side of the church.

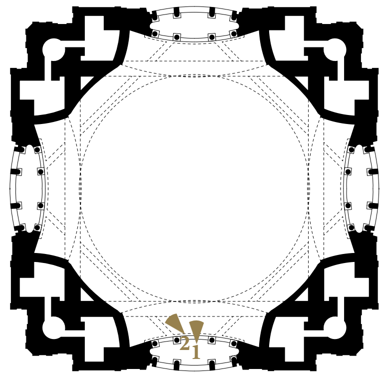
North-eastern corner chapel.

Side chapel.



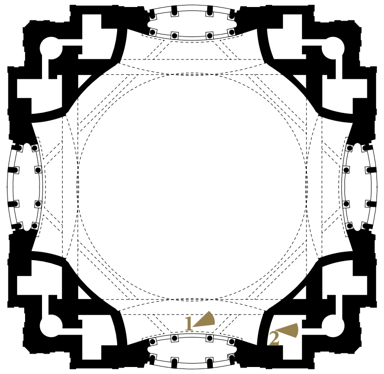
Corner tower's opening, and the springing of the arconi on the left.

Kidney-shaped window and the elements on top of the penden-tive extrados



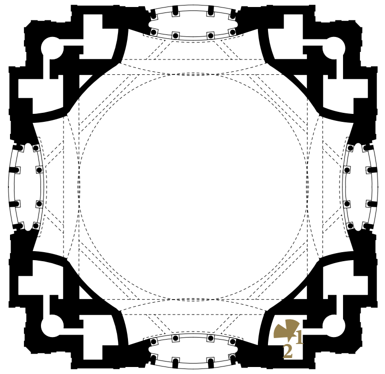
Chiave della Cupola crown.

Thin walls under the arconi, metal enforcements, and a beam of chiave della cupola.



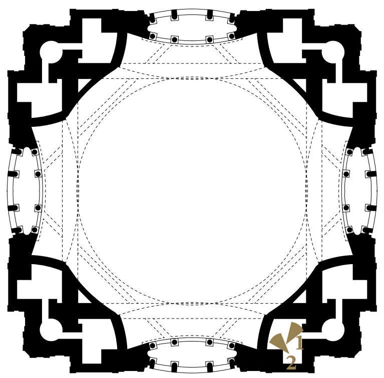
Chiave della cupola, pendentive's uppermost extrados and the conical vault extrados.

Chiave della Cupola's interaction with Randoni's additional vault to walk on



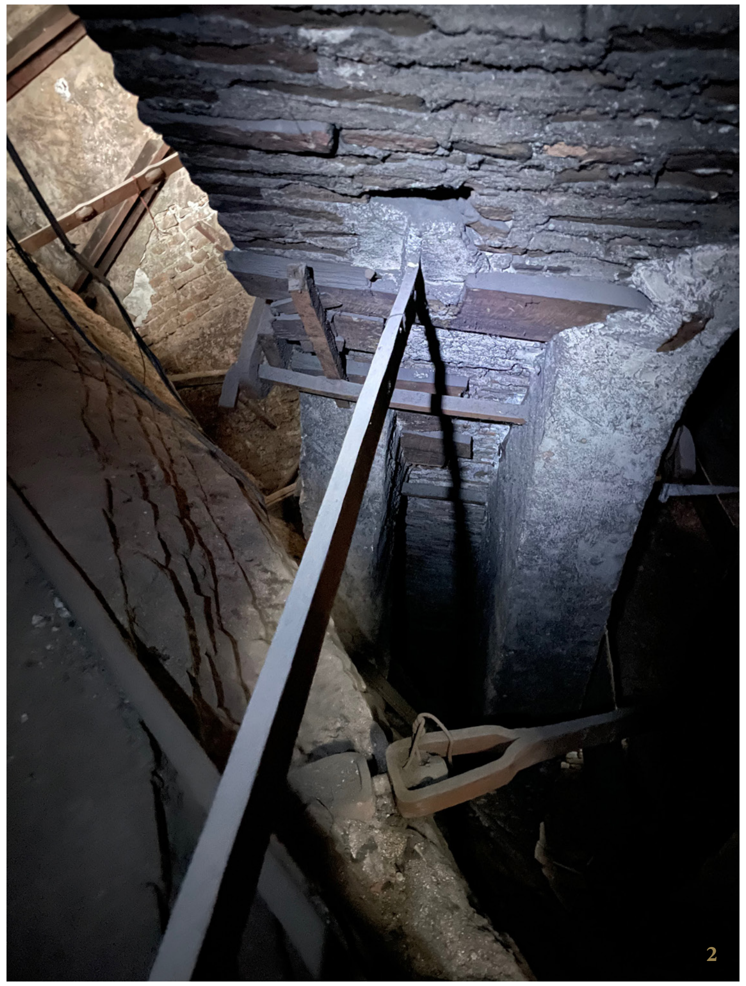
The base of Chiave della Cupola.

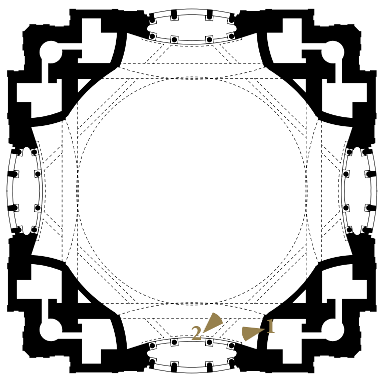
Arconi's thickness indicated by Randoni, as well as the 50 cm addition to the arch.



The intersection of the corner tower and the arcone.

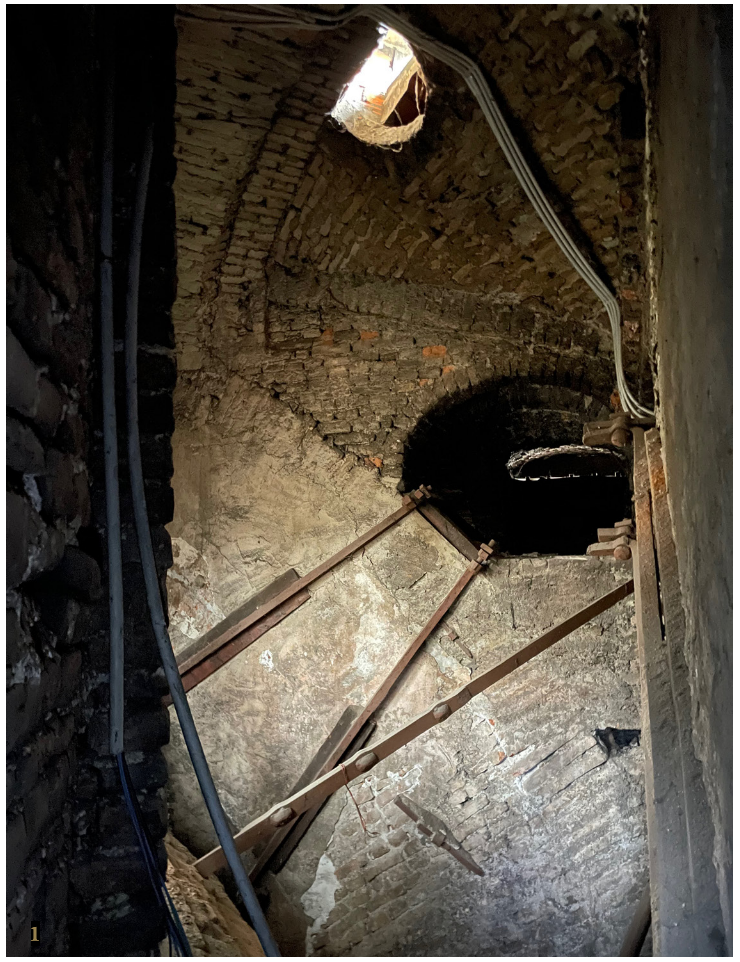
The intersection of Randoni's addition vault and the corner tower.

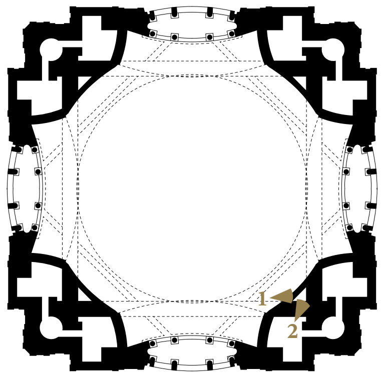




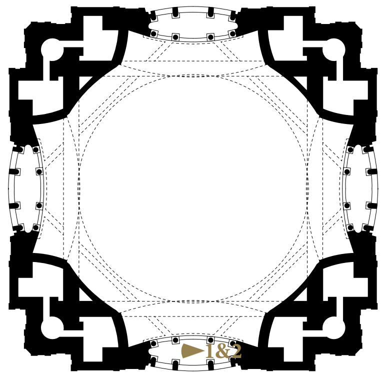
The buttress arches to the arconi.

Arconi and the double thin walls below.





The triangular space in the plan at the level of the hidden structure, seen from different points of view.



The rooms on top of the serliana entablatures closed by Randoni.