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Characterizing ground motion of historical earthquakes : the case of Sant'Agata del Mugello

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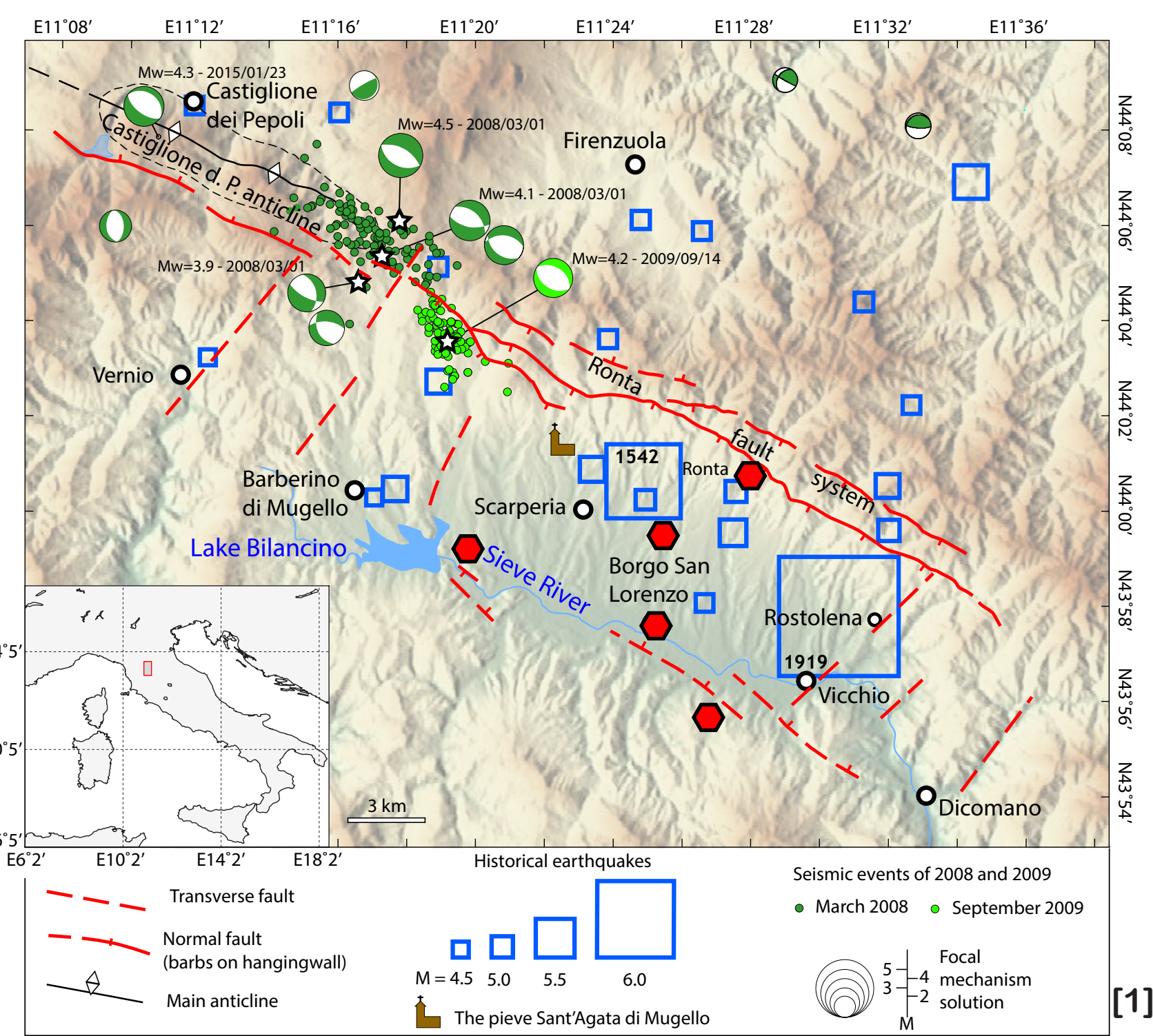
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Introduction

The quantification of historical earthquakes is a key element in seismic hazard assessment. Over the last decades approaches such as historical seismology, archaeoseismology and paleoseismology have been developed chasing alternative sources of information. Among them, historical buildings recorded in their walls disorders induced by ancient earthquakes as «stone seismometers» and might be used to infer key ground motion characteristics.

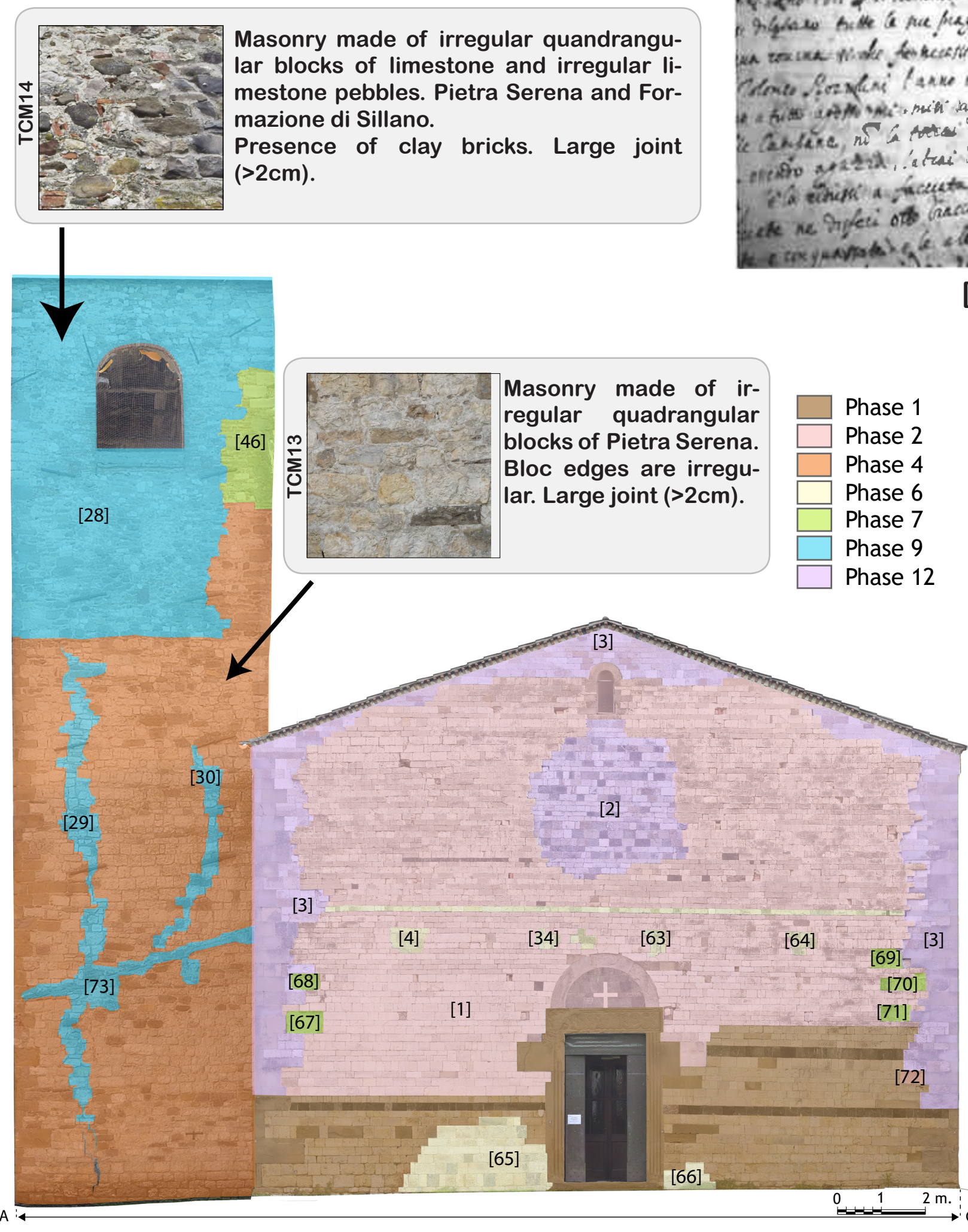
An innovative method is developed by connecting building archaeology, seismology and earthquake engineering through the case study of the medieval church of Sant'Agata del Mugello (Central Apennines, Italy) for which many historical sources described the damage induced by past earthquakes, and their post seismic repair.

The evolution of the building history is first described combining historical information and a stratigraphic analysis. A linear finite element model of the church is then updated based on its constructive history and a structural identification in its current state. A continuum model is used to identify the limit of the linear domain. This limit allows to discriminate the non-damaging round motion from the potentially damaging ones



Tracing the seismic history

- 13 building phases
- 3 major historical earthquakes
- Characterization of damage mechanisms

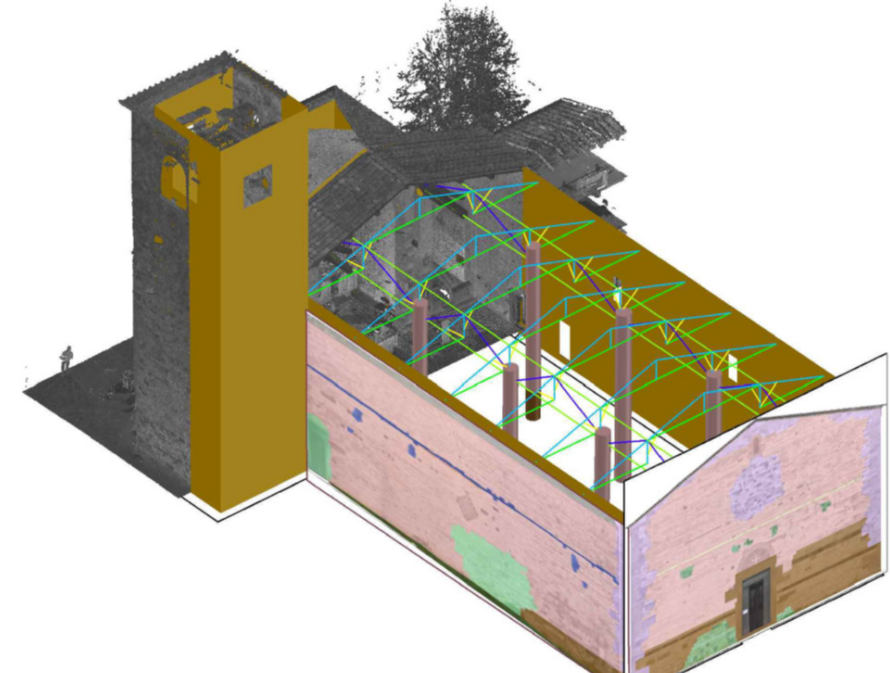


Source	Date	Origine	Seismic intensity	Phases	Type of operation	Building evolution
	2008					
	1980					
	1969		Io=4.5, h=7			
	1963-1967					
	1960		Io=7, h=7	13		
	1939		Io=7, h=7			
	1931		Io=6, h=7			
	1929		Io=6.7, h=7			
	1919		Io=10, h=7			
	1914					
	1912		Io=5, h=7			
	1905					
	1875					
	1864		Io=7, h=7	12		
	1843		Io=6.7, h=7			
	1835		Io=6, h=7			
	1833-1834					
	1819					
	1802			11		
	1762/04/15		Io=7, h=7			
	1748					
	1727		Io=6.7, h=7			
	1659			10		
	1611-1630			9		
	1611		Io=7, h=7			
	1608-1611			8		
	1597		Io=7.8, h=7			
	1553			7		
	1548					
	1546					
	1544					
	1542		Io=9, h=9			
	1536					
	1528					
	1525-1526			6		
	1512-1513					
	1500					
	1497			5		
	?			4		
	XV			3		
	XIII - XIII ^o			2		
	1175			1		
	948					
	<984 A.D.			0		

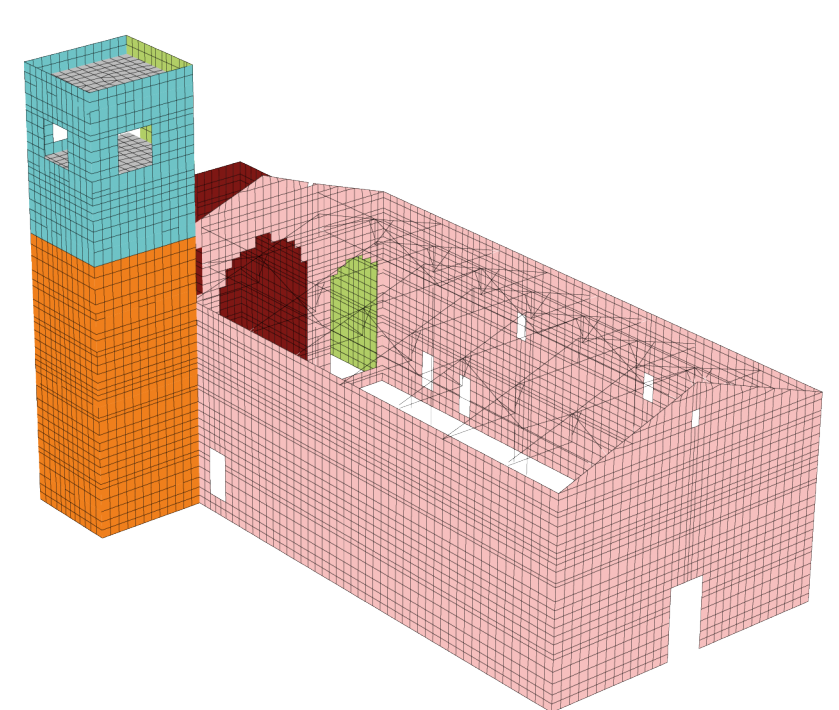
Modeling the «stone seismometer»

Meshing

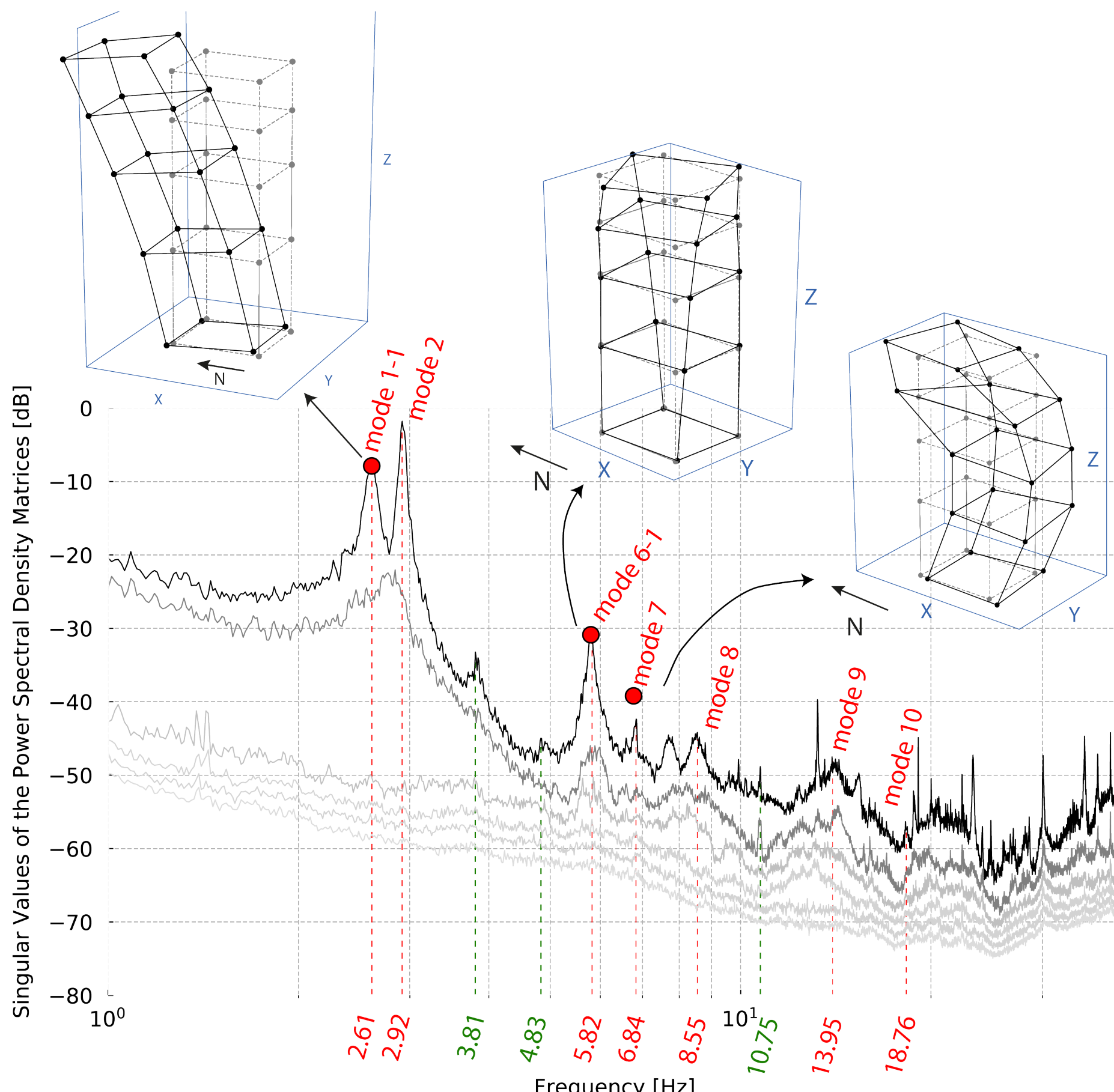
- A CAD-model is built from a point cloud and the constructive history of the church.



- A finite element model is generated (Cast3M). The building techniques are expressed in material properties.

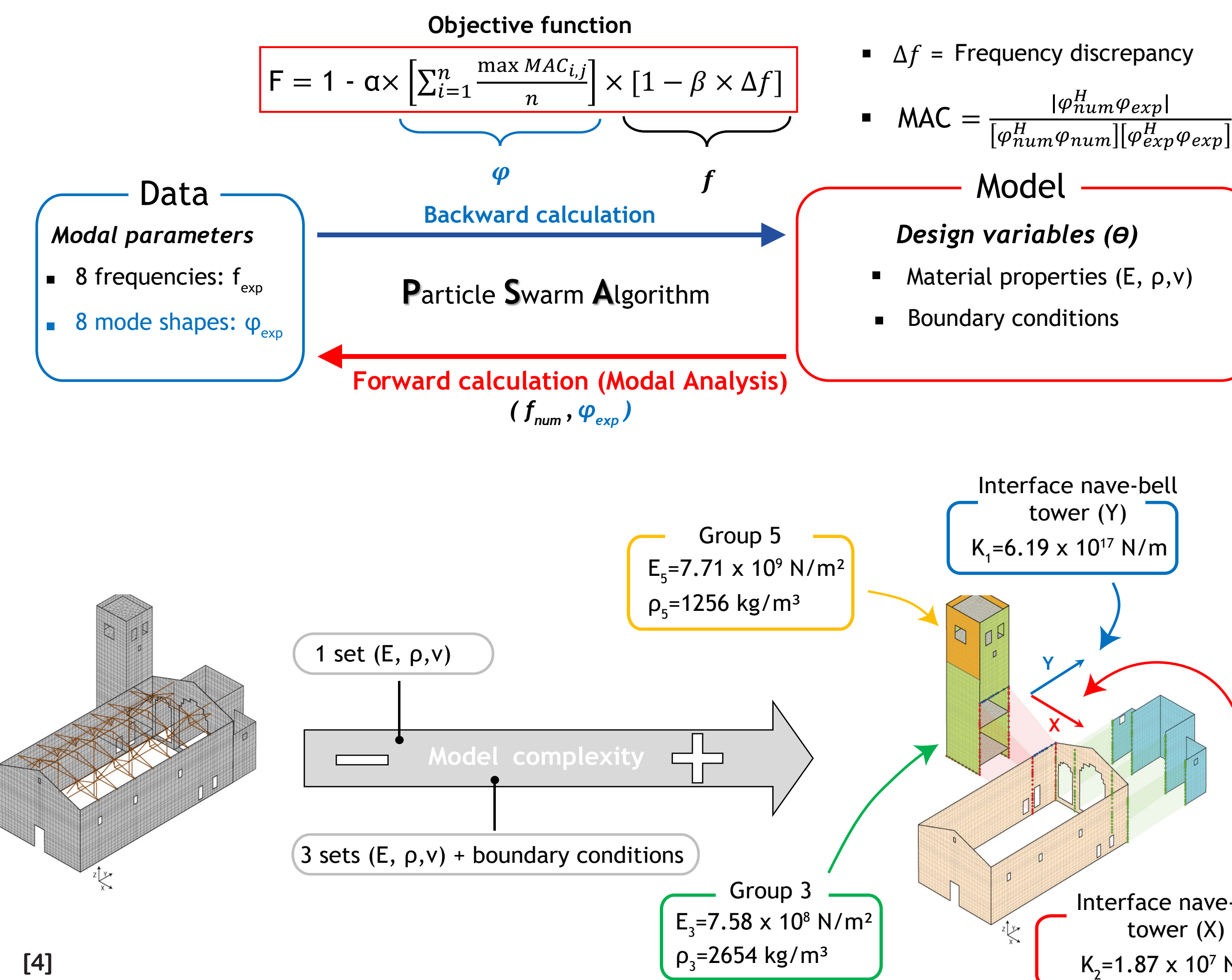


Structural identification



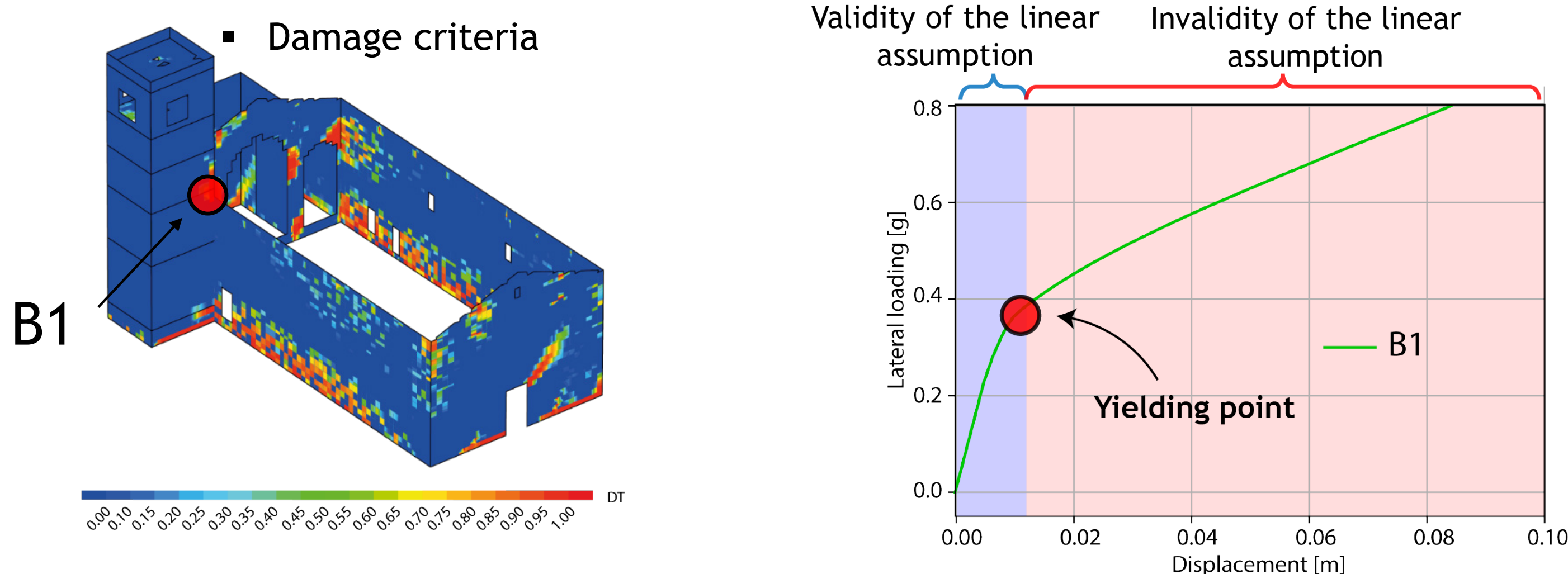
- 2 Ambient Vibration Testings surveys
- 83 measurement points
- 8 measured vibration modes (natural frequency, mode shape, damping ratio)

Model updating

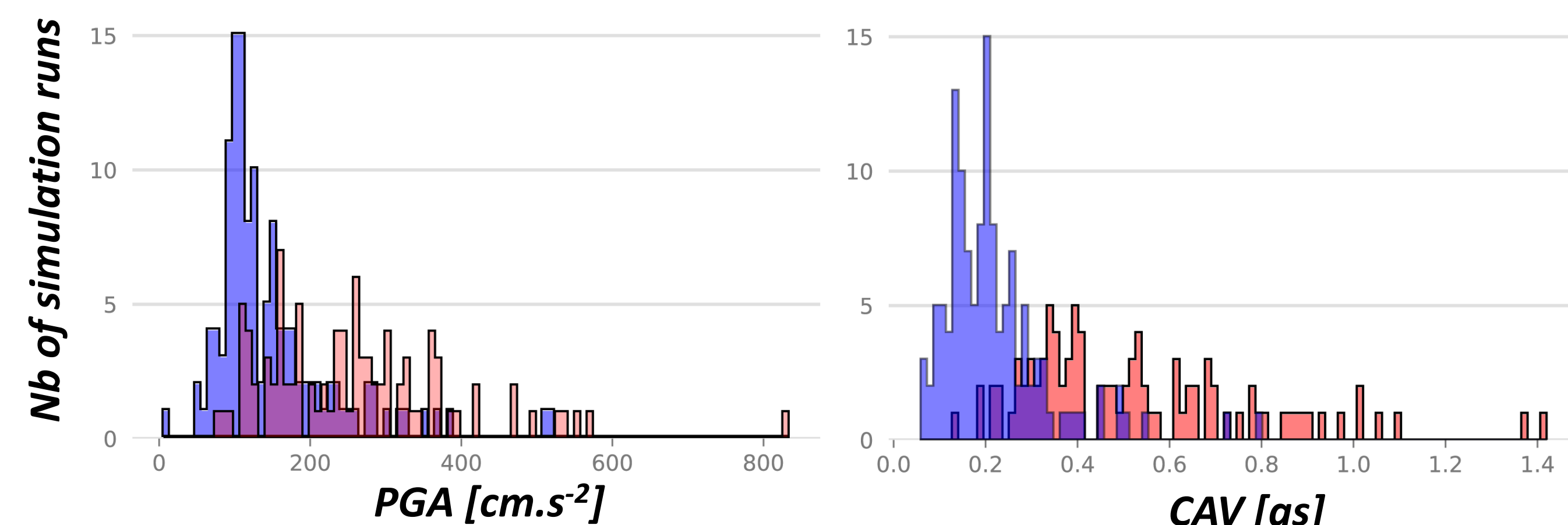


Characterizing the ground motion

- A continuum damage model [5] is used to identify the limit of linear model in displacement at strategic locations through a pushover analysis.



- 34 selected seismic events from the ITACA database
- 236 selected ground motions (Mw > 5, PGA in [0.001g, 0.86g])



Conclusion

- Historical documents allowed to quantify some damages and repairs related with past earthquakes;
- The stratigraphical analysis confirmed historical sources data bringing more quantitative information. It also allowed to identify repairs and damages which were not described in historical sources (collapse of the lateral apses, overturning of the facade);
- Stratigraphical analysis and scanner data are used to design a CAD-based model;
- 2 Ambient vibration Testings surveys (in the bell tower and in the nave) provide 8 vibration modes;
- A vibration based-model updating using measured vibration modes and exhaustive information from the constructive history of the church provides a reliable linear model of the building in its current state;
- A continuum damage model is used to evaluate the limit of the linear model of the church at strategic locations;
- 236 ground motions are selected from the ITACA database;
- Linear dynamic computations allow to discriminate ground motion keeping the church's model in its linear regime and potentially damaging signals.

Outlook

- An in-depth study of the results for other control points/IMs/pushover direction/IMs combination/...
- The use of simplified model for the previous state of the church (before 1542);
- Characterizing ground motion is sensitive to the modeling strategy. However, non linear dynamic computation can be highly time-consuming. In order to find a compromise other modeling strategies will be implemented (simplified approach, 2D, 3D models; etc);
- The work based on a single test site is not sufficient to constrain the source of the earthquakes, neither the impact of the alluvial basin properties on the ground motion. The ACROSS project proposes to extent this approach to five bell towers disseminated in and around the Mugello basin.

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Instituts

