Arts and science: the SCENA project

Scientific Cosmic Experiments with Narrative Arts

Interdisciplinary project combining science, art, and public engagement

1-5 JUNE BUDAPEST Muographers 2026

Germano Bonomi

UNIVERSITAS STUDIORUM BRIXIAE
UNIVERSITY OF BRESCIA

INFN Pavia

Opportunity: funding call for interaction between Arts and Science (100 k€)

The partnership

The results of the call will be communicated in July

UNIVERSITY
OF BRESCIA
Department of Mechanical
and Industrial Engineering

Bonomi Germano
Davide Pagano

ACCADEMIA
DI BELLE ARTI
SANTAGIULIA

Paolo Sacchini
Massimo Tantardini

Alice Benazzi, Marco La Rosa, Maurizio Rinaldi, Fabrizio Saiu

SantaGiulia Fine Arts Academy in Brescia

Academy

SantaGiulia Fine Arts Academy
Headquarter and laboratories
ECTS (European Credits Transfer System)

SantaGiulia Academy is an educational institute part of the new high Music and Artistic Formation (AFAM) under the instructions of the Italian Education University and Research Ministry. It has been one of the first Italian institution to have actively implemented the Italian laws in education (D.M. 03/07/2009 n. 89 and D.M. 30/03/2009 n. 123) which have radically changed the university system.

SantaGiulia Academy offers more than 260 courses, that go through all the artistic and design ambits, from the interior design, to the digital cultures, from the web design to the virtual setting. Teachers are young and dynamics, well famous professional figures able to offer to the students an inestimable heritage of knowledges and experience and to put them in contact, immediately and at a very high level, with the national and international labour market.

The first and second level diploma courses active at the Santa Giulia Academy belong to 9 Ordinary Schools (Ministerial Decree 07/03/2009 n. 89 - Ministerial Decree 09/30/2009 n. 123):

- GRAPHICS
- DECORATION: addresses ARTISTIC DECORATION and INTERIOR DESIGN
- PAINTING
- SCULPTURE
- DESIGN
- ARTISTIC DESIGN FOR THE COMPANY
- NEW TECHNOLOGIES OF ART
- TEACHING OF ART
- COMMUNICATION AND ENHANCEMENT OF ARTISTIC HERITAGE

The scientific goal:

to build a detector prototype to monitor the stability of historical buildings

The artistic goal:

To build an artistic clone to translate (real data) cosmic rays into lights and sounds

and to popularize what a cosmic ray is

The genesis

In particle and nuclear physics, muons are often used to “calibrate” the experimental apparatuses, that is, to measure the relative position of different detectors with respect one to each other

Can we do the same for civil applications?

We started to investigate the possibility to use of the cosmic ray muons to monitor the alignment of physical part of a vertical structure (tower, pillar, mechanical press, etc., etc.)

IOP Publishing — Measurement Science and Technology

Meas. Sci. Technol. **18** (2007) 3537–3546 doi:10.1088/0957-0233/18/11/03

2007

Cosmic ray detection based measurement systems: a preliminary study

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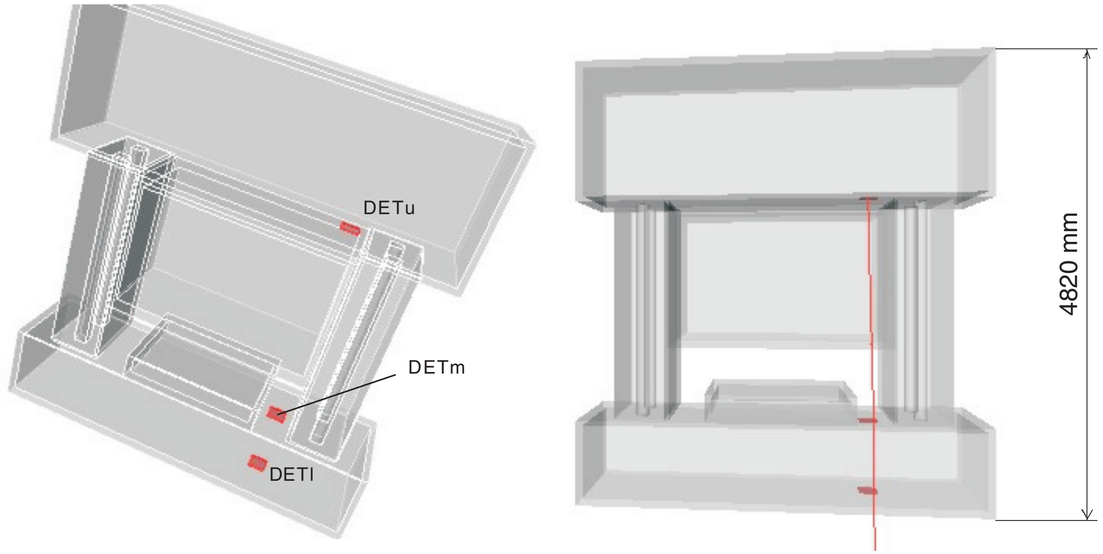


Figure 1. Pictures of the simulated configuration for the structure of the industrial press and the detectors, crossed by a cosmic ray. The upper (DETu), middle (DETm) and lower (DETl) detectors constitute the detection system, called telescope. They are mechanically connected to the parts of the structure whose relative positions have to be monitored.

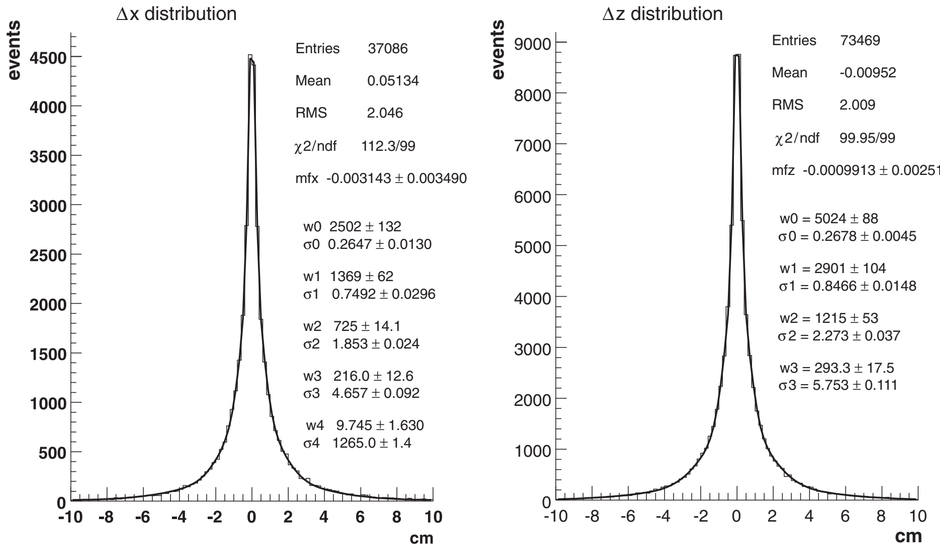


Figure 4. In these two figures the best-fit functions are superimposed on their respective Monte Carlo distributions for Δx and Δz statistical variables. Moreover the reduced χ^2 values, the best-fit function mean values (m_{f_x} and m_{f_z}) and the values of the (σ_i, w_i) parameters are reported.

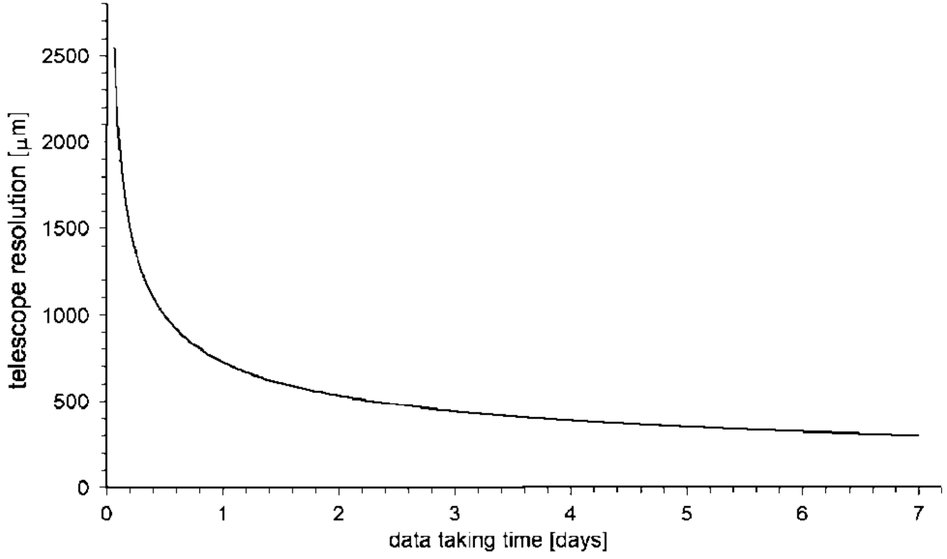


Figure 9. Resolution of the measurement system as a function of the data-taking time calculated for the considered geometry and supposing a calibration data taking of 1 week.

The idea => stability monitoring **historical buildings**

Mechanical or optical systems are usually used

- **invasiveness (meters of rods) limits the use for building with high historical and cultural value**
- **large distances or floors limit the use of optical systems**

PRO: use of a free natural source of radiation

PRO: μ are highly penetrating => walls and floors are easily traversed

PRO: no need of visibility or empty spaces

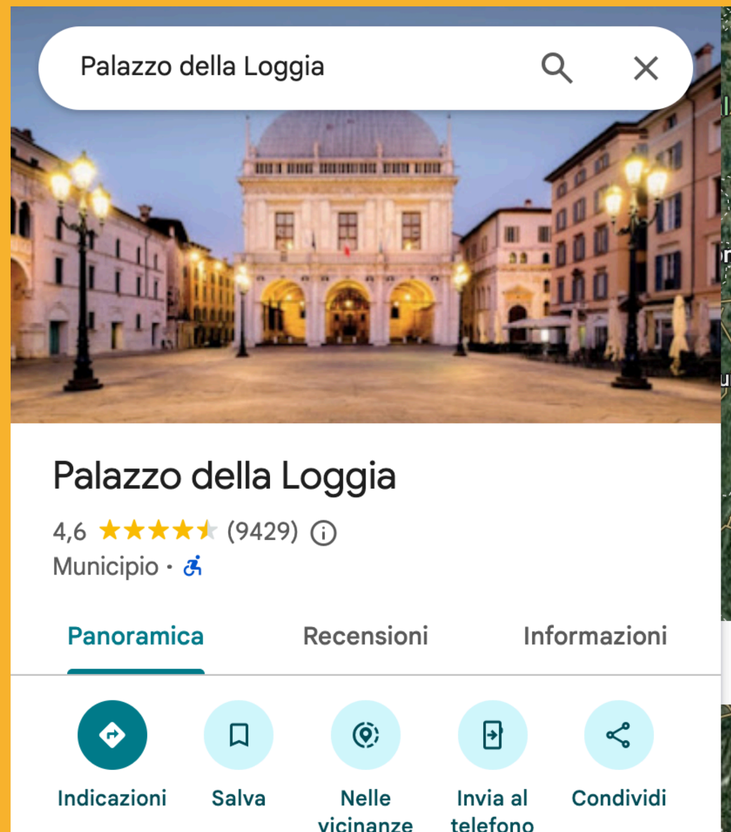
PRO: limited invasiveness

PRO: possibility to design a global monitoring system

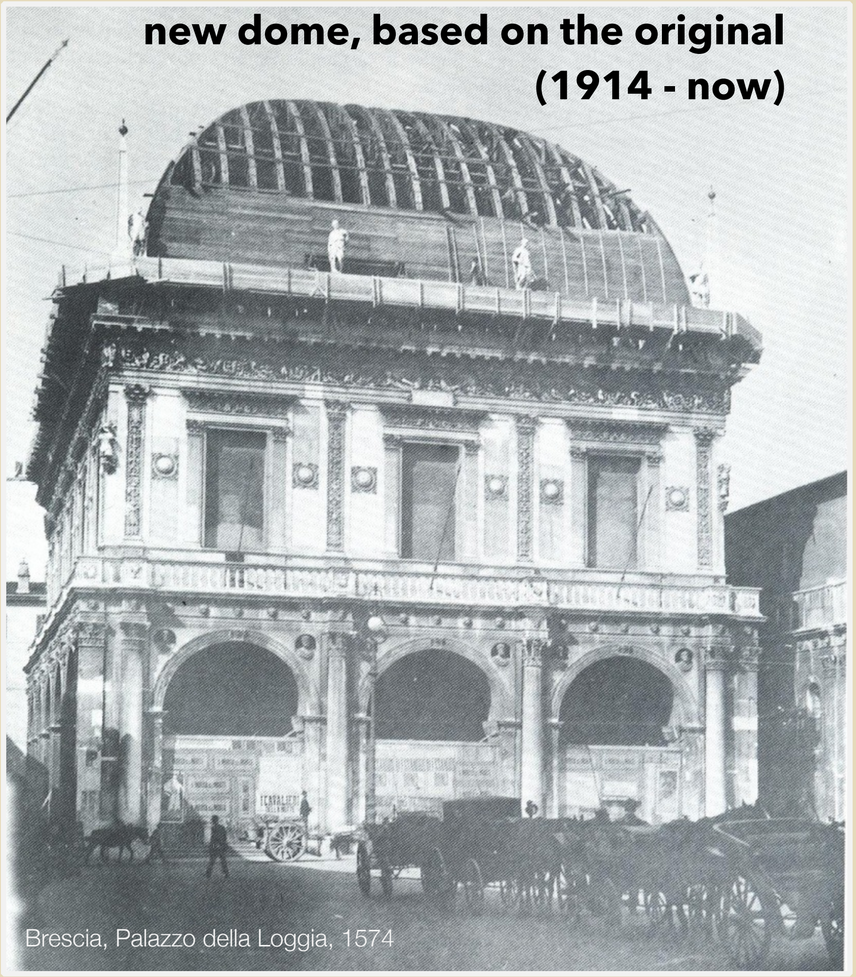
CON fixed rate of cosmic muons => (relatively) long data taking

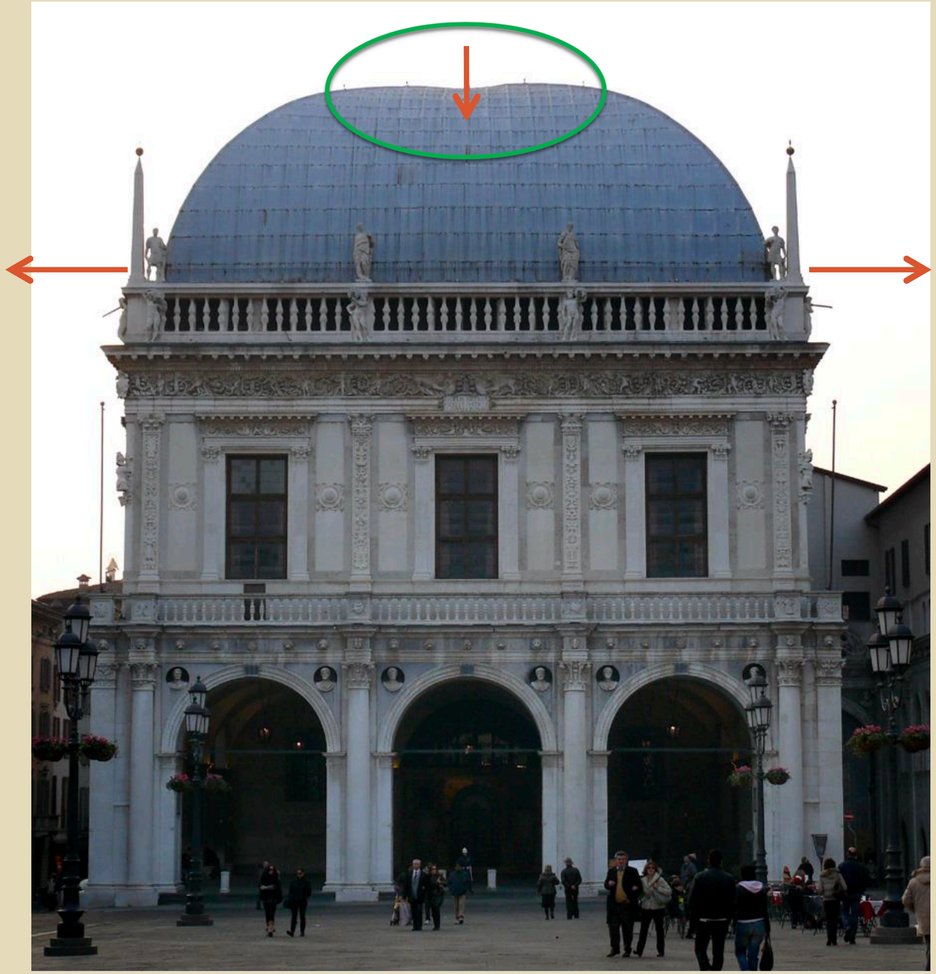
CON: need to be proved (with a prototype)

Case study: il Palazzo della Loggia in Brescia



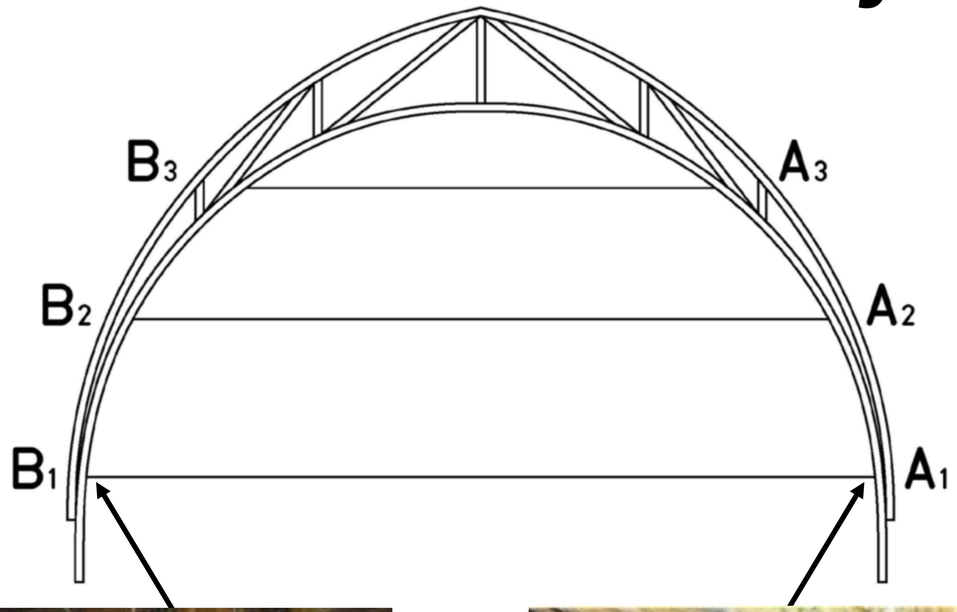
Palazzo della Loggia 1492 1574

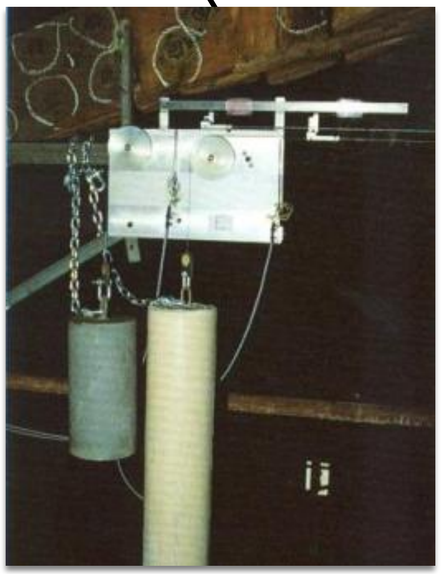


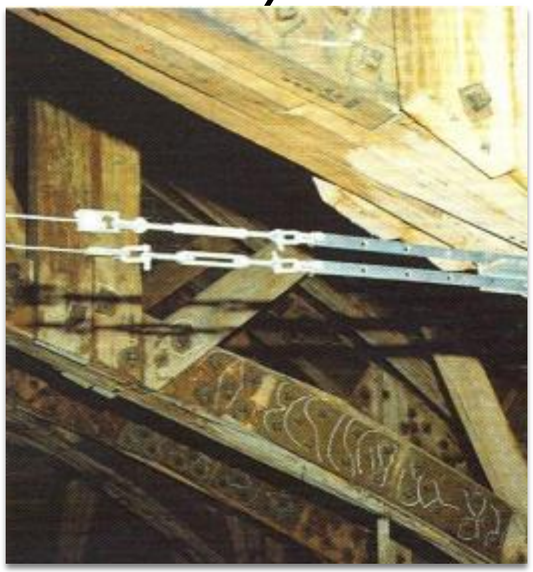


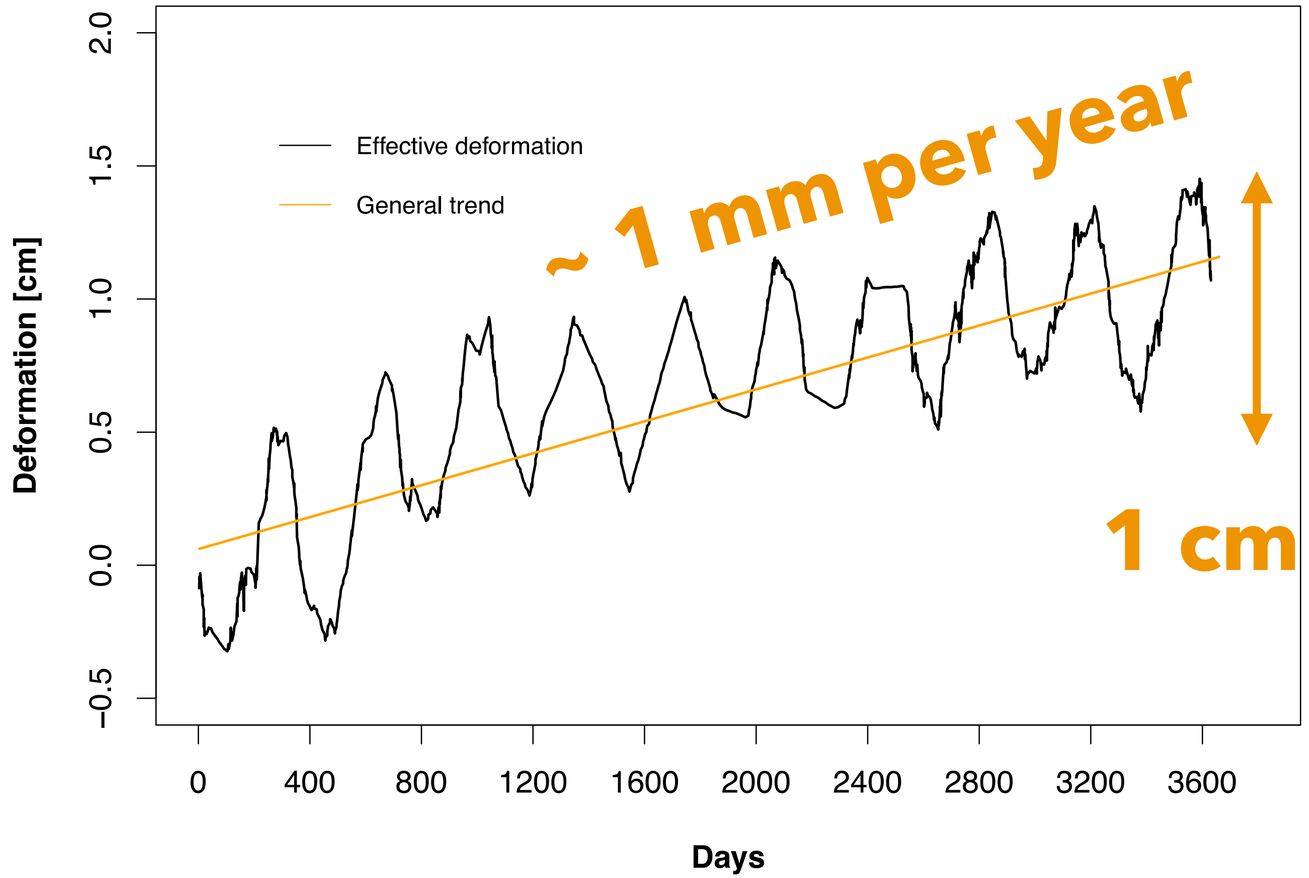
The dome immediately after its completion showed progressive deformation

10 years of “mechanical” measurements





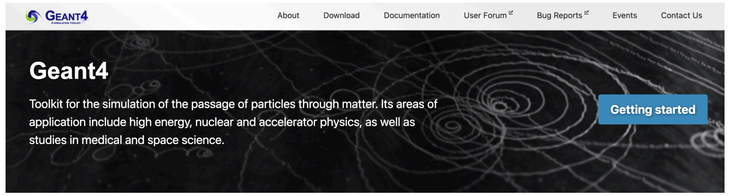


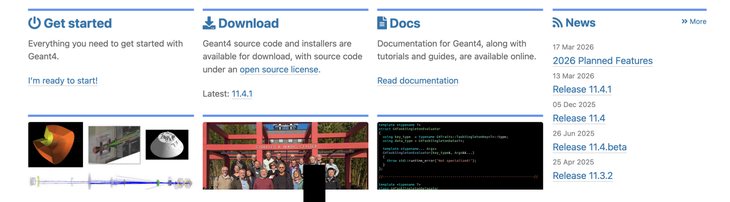


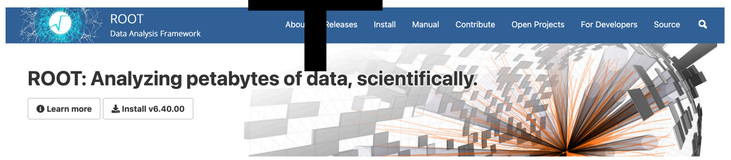
A. Bellini et al., “Il Palazzo della Loggia di Brescia - Indagini e progetti per la conservazione”, Starrylink editrice, 2007

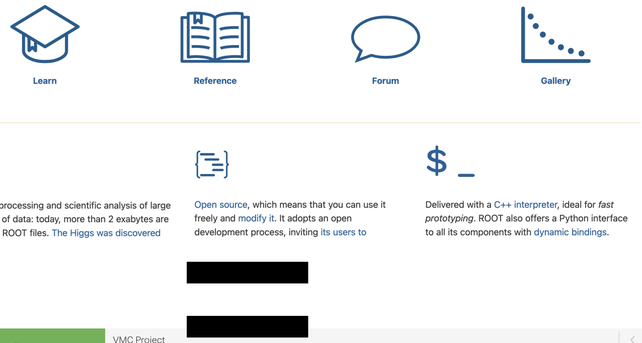
Would we have been able to do the same with muography?

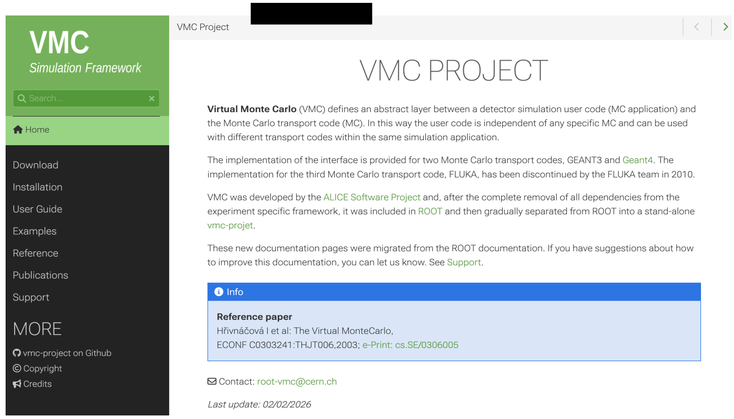
Simulation



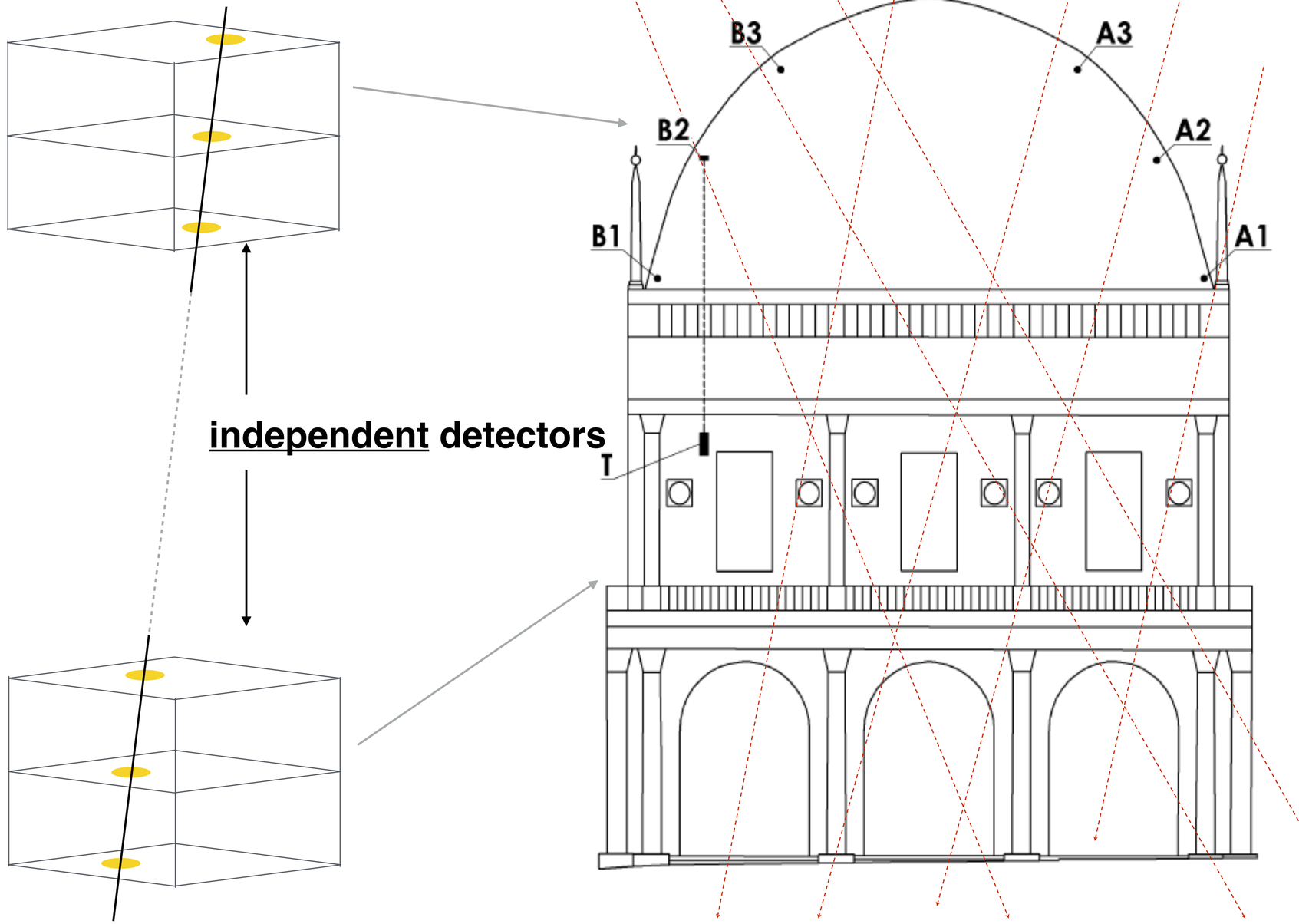








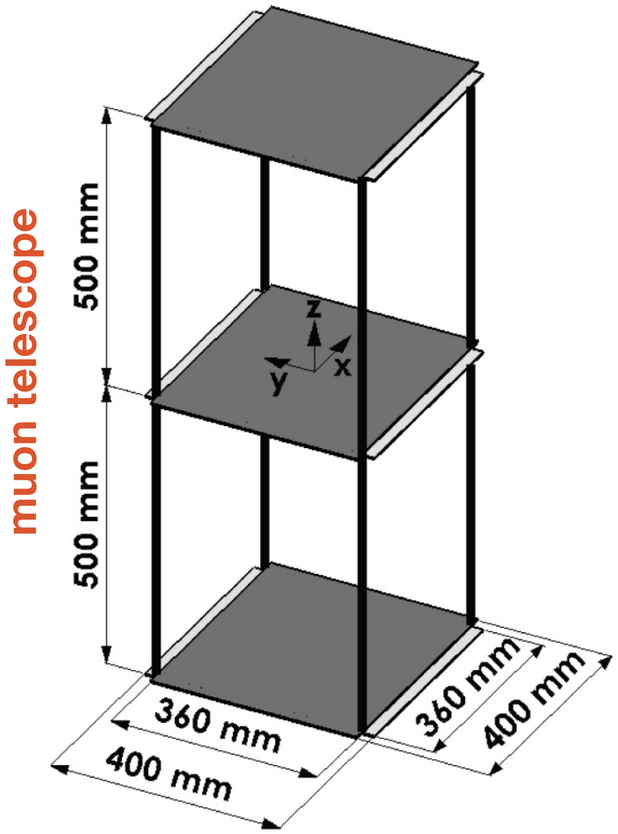
https://vmc-project.github.io/



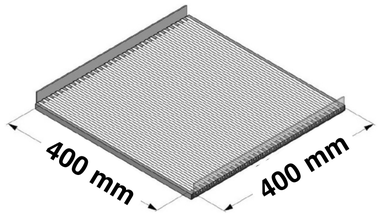
Realistic cosmic muon generator based on experimental data (will become **EcoMug**)

[Bonechi et al. (2005) Proc. 29th Int. Cosmic Ray Conf. vol 9 p 283]

Simulation



1) $\Delta z_1 = 350\ cm$
2) $\Delta z_2 = 880\ cm$
3) $\Delta z_3 = 1300\ cm$



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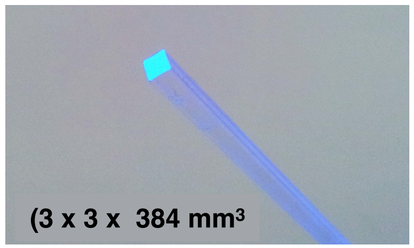
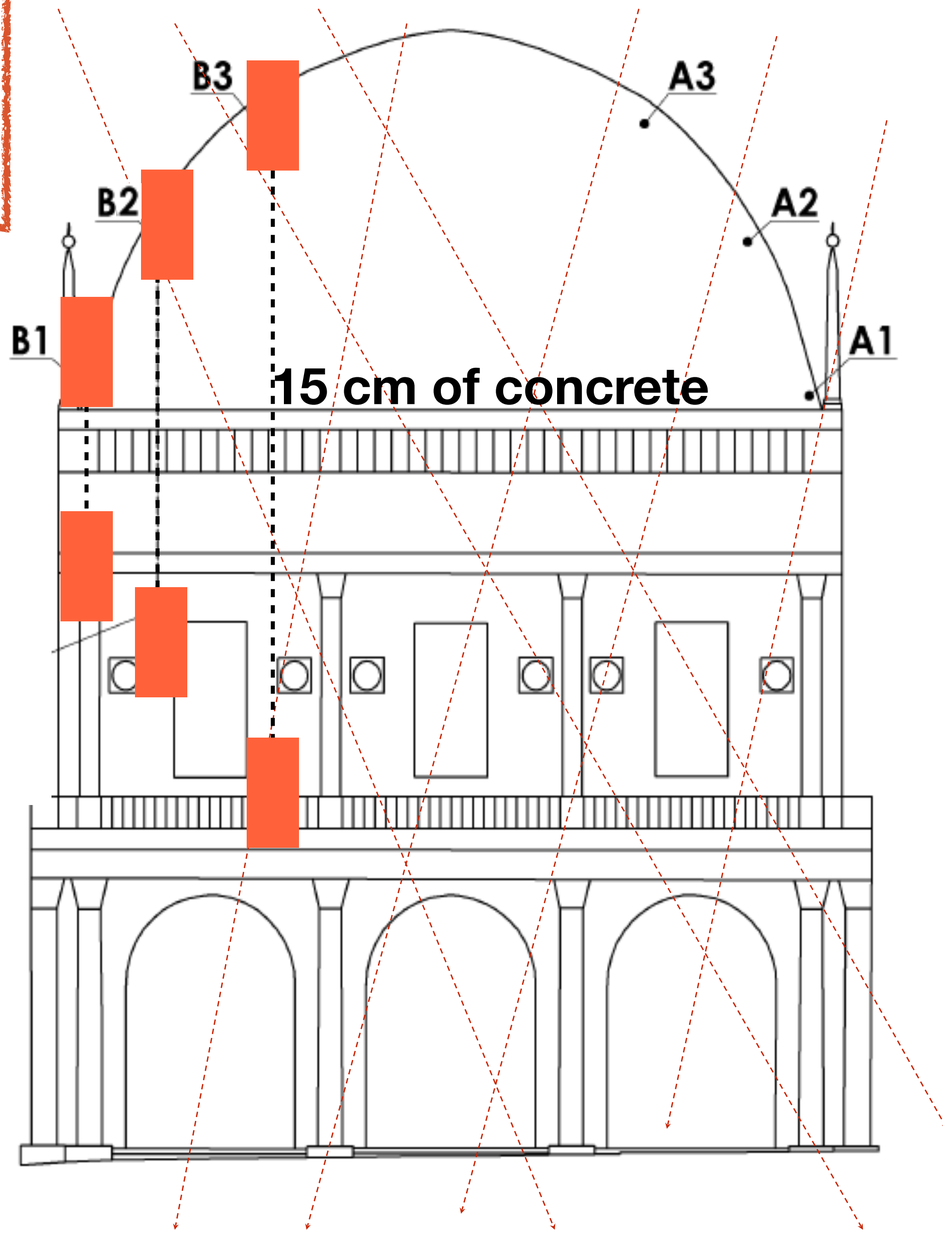




"Standard detector"

3 planes (2 ⊥ layers x plane = 6 layers)

of scintillator fibers (3 x 3 mm²)

coupled to SiPM

Realistic cosmic muon generator based on experimental data (will become **EcoMug**)

[Bonechi et al. (2005) Proc. 29th Int. Cosmic Ray Conf. vol 9 p 283]

For perfectly aligned geometry expected values:

$$E\left[x_h^{'} - x_l^{'}\right] = 0 \text{ and } E\left[\theta_h^{'} - \theta_l^{'}\right] = 0$$

For not aligned geometry expected values:

$$E\left[x_h^{'} - x_l^{'}\right] = x_d \text{ and } E\left[\theta_h^{'} - \theta_l^{'}\right] = \theta_d$$

Time zero [calibration] measurement

Estimates of $\hat{x}_d$ and $\hat{\theta}_d$ from minimization

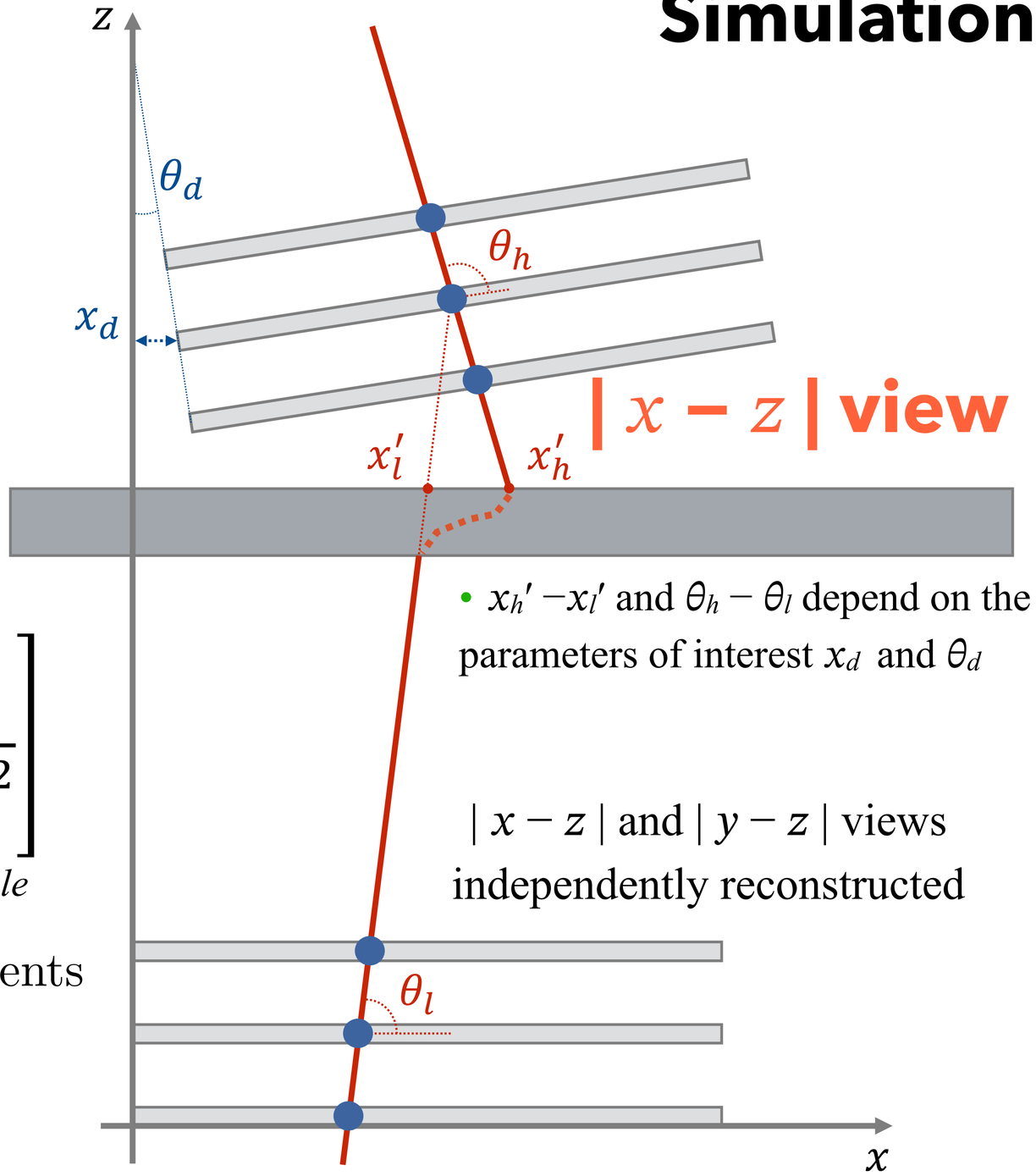
$$\chi^2 = \sum_i \left[\frac{(x'_{h,i} - x'_{l,i})^2}{(\sigma^2_{x'_h,i} + \sigma^2_{x'_l,i})^2} + \frac{(\theta_{h,i} - \theta_{l,i})^2}{(\sigma^2_{\theta_{h,i},i} + \sigma^2_{\theta_{l,i},i})^2} \right]$$

index i runs over the reconstruted muons in the data sample

Monitoring of $\hat{x}_d$ and $\hat{\theta}_d$ can reveals relative movements

detect deformation of the structure to which the detectors are anchored

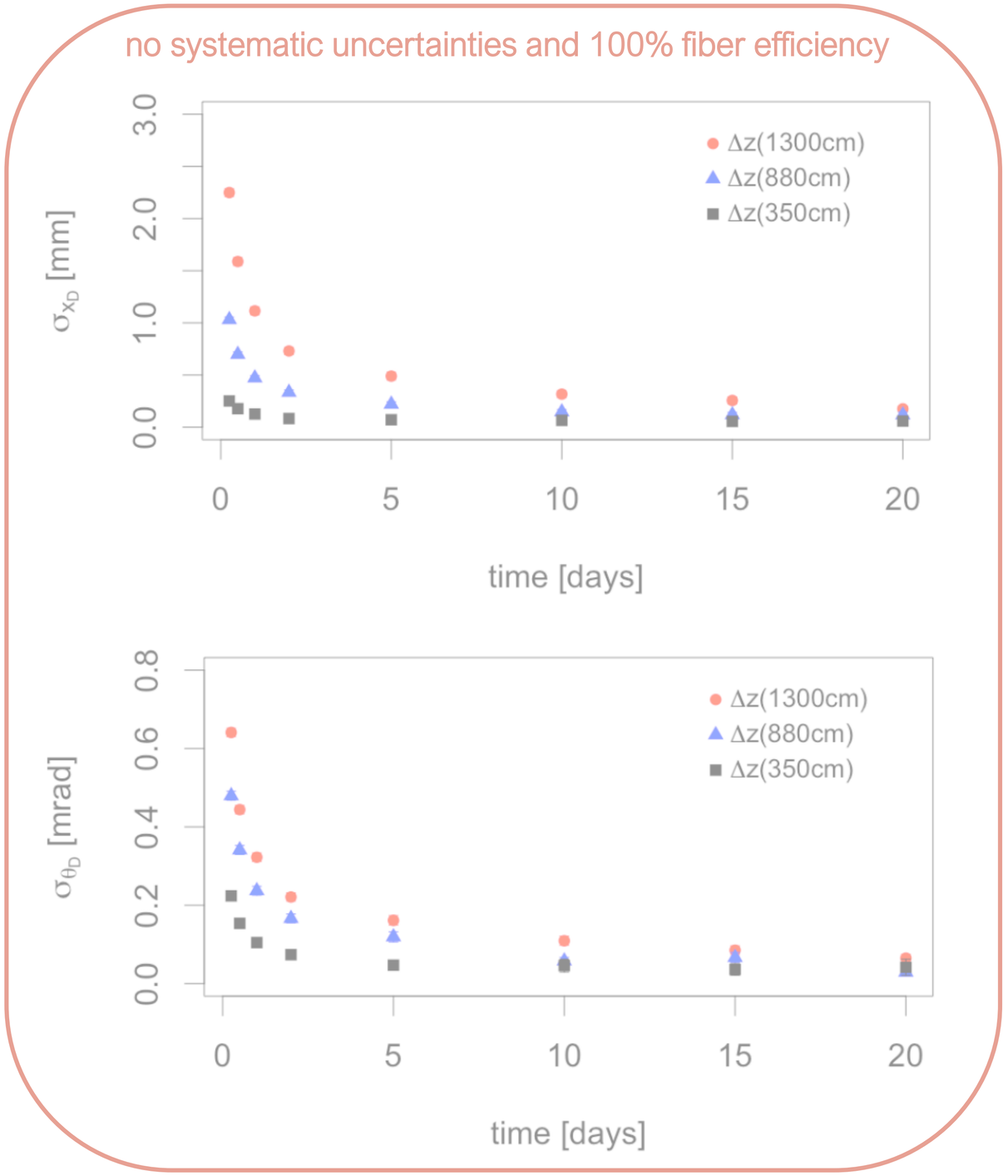
Simulation



| x − z | view

- $x_h' - x_l'$ and $\theta_h - \theta_l$ depend on the parameters of interest x_d and θ_d

| x − z | and | y − z | views independently reconstructed

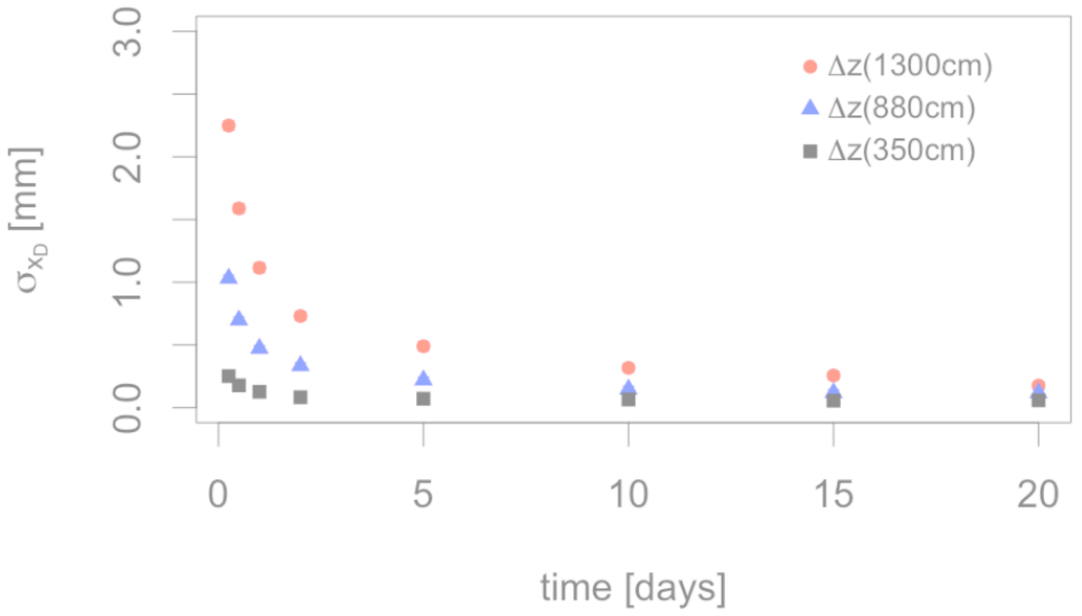


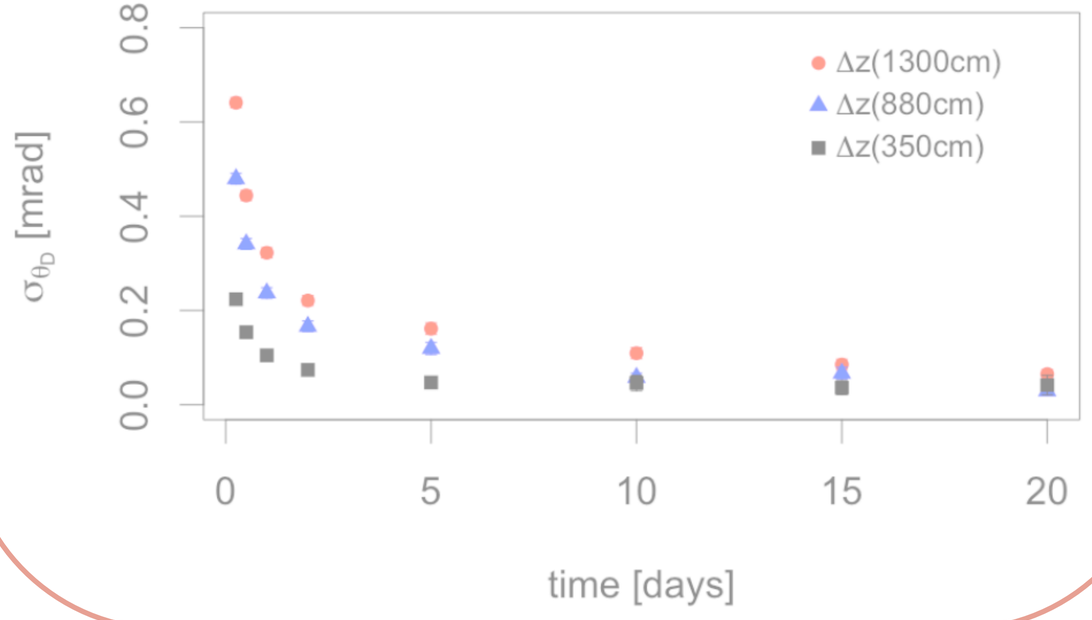
5.2. Systematic uncertainties

The results presented above presume an exact knowledge of the geometry of the measurement system. Clearly this is not realistic since any mechanical structure holding the detectors has tolerances and uncertainties. In the following, the effect of the inaccuracies in the positioning of the detector planes and of the two telescopes on the precision of the measurement system itself is studied. As a first step, we investigated which are the possible effects in measuring the position and the orientation of a plane in space. While the position can easily be assessed with a resolution of $\sim$100 µm, the horizontality of a module can be measured, with standard instrumentation such as mechanical inclinometers, with a resolution of 2 min of degree or better. When considering a rotation around the vertical axis, instruments such as magnetometers, coupled to geometrical and optical measurements, can achieve resolutions of 0.10–0.15 degrees or better.

Given such values, in a specific simulation, each of the three detection planes of the two telescopes could be positioned, with respect to the 'nominal' position and orientation, extracting a Gaussian distributed random number having as standard deviation the values reported previously. In other words, for each detection plane, six parameters such as the δx, δy, δz, $\delta\theta_x$, $\delta\theta_y$ and $\delta\theta_z$ were extracted randomly and the module was correspondently positioned inside the telescope. On top of that also the relative position and orientation of the two telescopes, relatively one with respect to the other, was also set in the same way extracting random values from Gaussian distributions with the specified standard deviations.

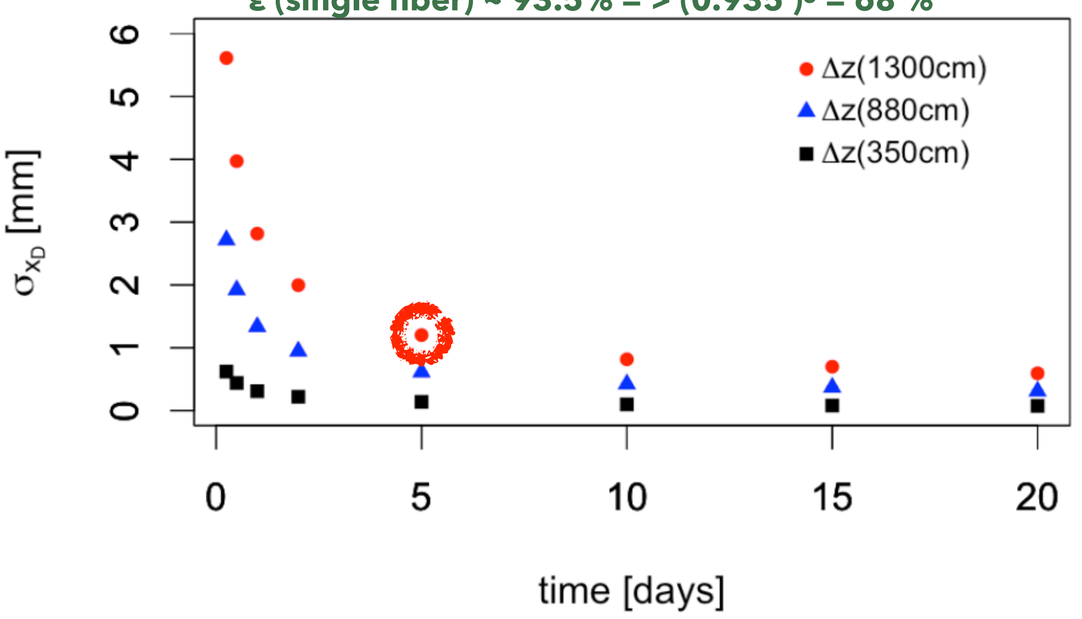
no systematic uncertainties and 100% fiber efficiency

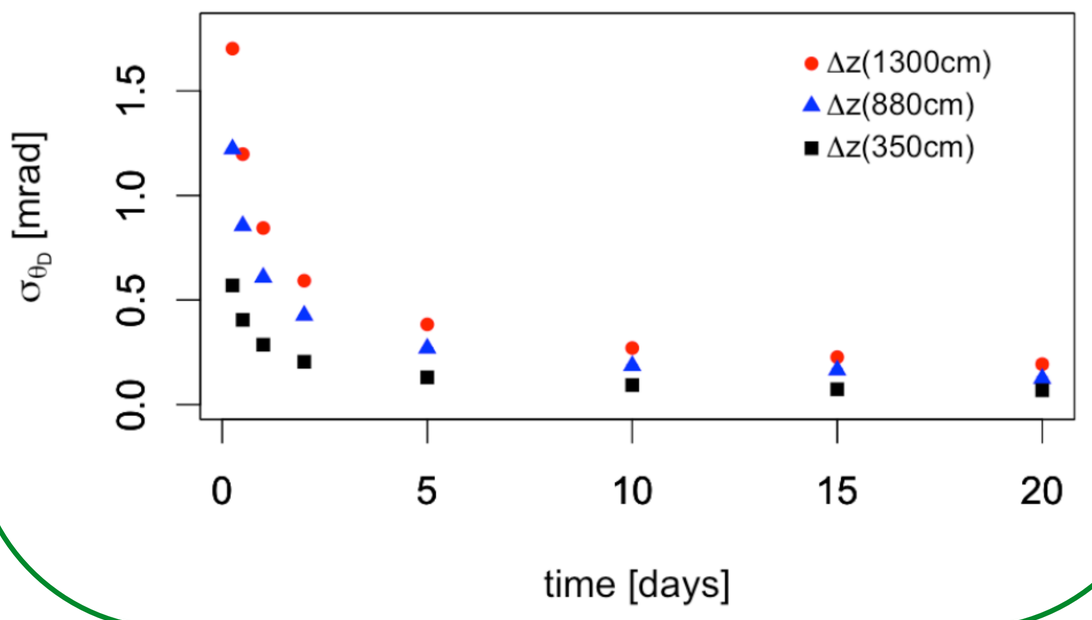




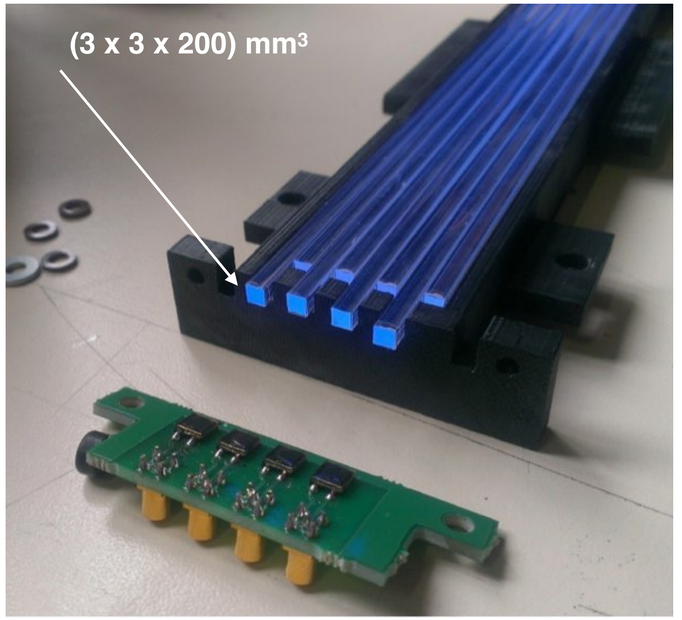
with systematic uncertainties and 68% fiber efficiency

ε (single fiber) ~ 93.5% = > (0.935)⁶ = 68 %





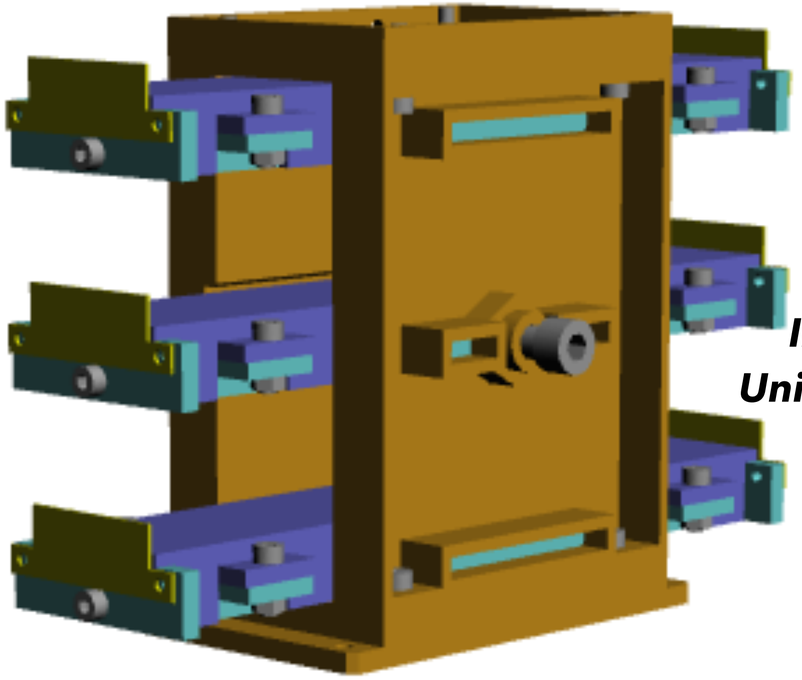
A small-scale “toy” detection system, consisting of one telescope and a single layer, was designed, created and operated



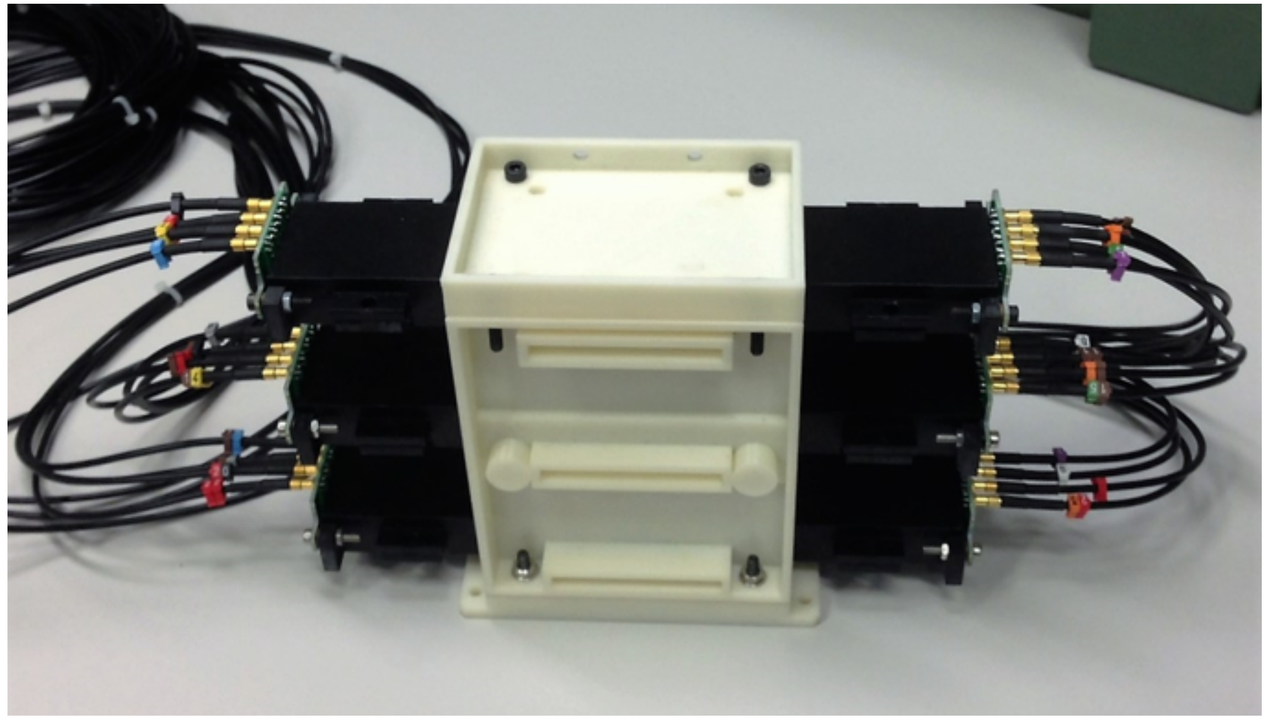
all the mechanical supports (ABS) created with a 3D printer

each layers composed by 8 scintillating fibers (BCF-10 from Saint-Gobain)

signals from SiPMs amplified with a (custom made) three stages amplification



In collaboration with University and INFN Pavia (Paolo Vitulo)



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2019

Cosmic ray tracking to monitor the stability of historical buildings: a feasibility study

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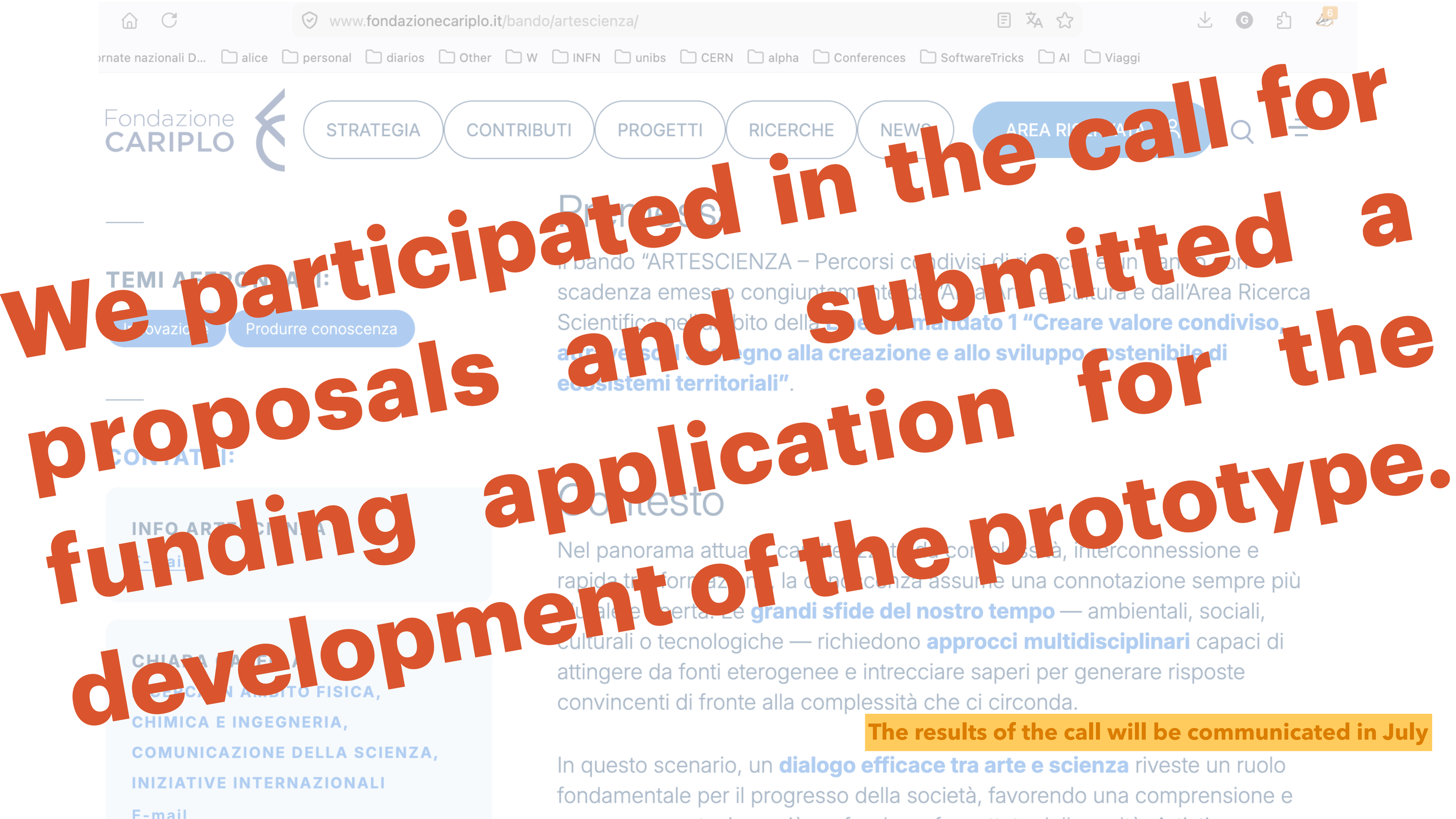
Abstract

A cosmic ray muon detection system is proposed for stability monitoring in the field of civil engineering, in particular for the static monitoring of historical buildings, where conservation constraints are severe and the time evolution of the deformation phenomena under study may be of the order of months or years. The stability monitoring of the wooden vaulted roof of the *Palazzo della Loggia*, located in the town of Brescia, Italy, has been considered as a case study. The feasibility, as well as the performance and limitations of a stability monitoring system based on cosmic ray tracking have been studied by Monte Carlo simulations. A study of possible systematic uncertainties is presented along with a realistic design for the construction of a measurement system prototype.

From a simulation to a prototype: a long path (for us)



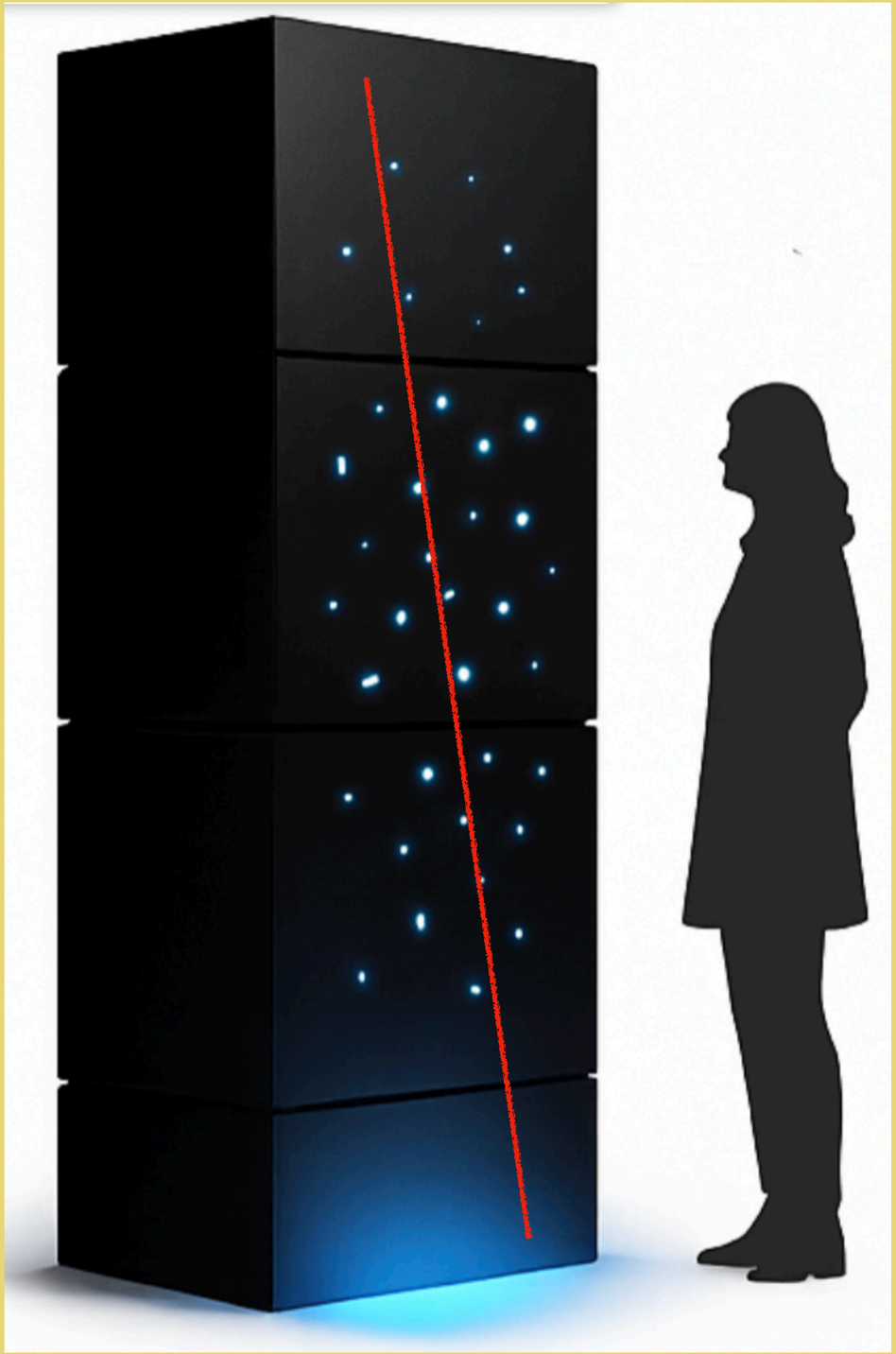
We participated in the call for proposals and submitted a funding application for the development of the prototype.

The results of the call will be communicated in July

The artistic objective of the project is to make knowledge of cosmic rays accessible to a broad audience—an extraordinarily fascinating phenomenon that nonetheless remains surprisingly little known, communicating their poetic and evocative nature to the public. **The central idea is to transform the arrival of these invisible particles into sensory experiences (visual, auditory, and narrative) capable of capturing the imagination of visitors.**

THE ARTISTIC-CLONE

The project envisions the creation of **an artistic clone of the scientific detector**. This replica, equipped with light and sound elements, will function as a sensory interface between cosmic rays and the public. In parallel there will be the preparation of an audiovisual/performative work



THANK YOU