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Elena Guardincerri
Tracking muons to reduce nuclear threats and help preserve architectural treasures

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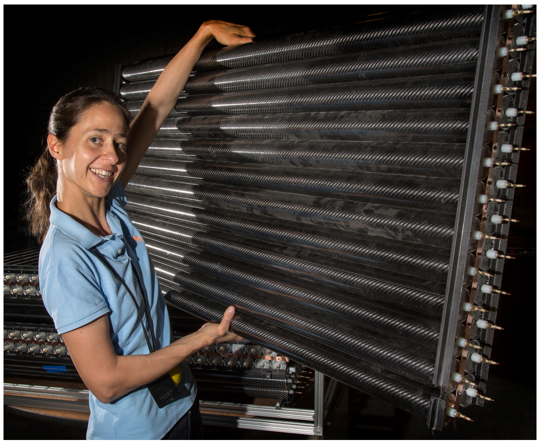

Photo by Richard Robinson
To reveal structural secrets of the Florence cathedral and help protect it against further damage, Elena Guardincerri is designing lightweight muon trackers, made of 2-inch-diameter carbon fiber drift tubes, for measurements of thick walls in the dome's narrow passageways.

When Elena Guardincerri was a physics PhD student at the University of Genova, she considered muons a nuisance. She built muon detectors to snare these secondary cosmic rays, which were interfering with her experiments to study elusive neutrinos.

Now, as a member of Subatomic Physics's (P-25) Muon Tomography team, she is developing a muon detector to assist in saving a 37,000-ton masonry cathedral dome (known as *il Duomo*) in Florence, Italy, from severe cracks and earthquake damage. Her novel method uses muons as a probe to image reinforcement elements inside thick-walled structures.

"Elena is an extremely creative physicist," said her team leader Chris Morris, who invented multiple scattering muon imaging, which exposes smuggled nuclear material even when it is concealed by shielding material.

Muons can identify dense objects and make distinctions between substances, such as water and melted nuclear fuel, and unlike x-rays, they can penetrate deep inside materials, allowing images of very thick objects. Cosmic muon radiography does all of this without damaging structures and without the need of an artificial radiation source.

Guardincerri helped write software for the muon trackers built in Japan by Toshiba that will obtain precise images of the Fukushima Daiichi nuclear power plant, a critical step before disaster cleanup can begin safely. In other high-profile work, Guardincerri is “contributing enormously to the Physics Division threat reduction effort,” Morris said. For instance, she is testing how well muons can scout for nuclear weapons effects underground.

Guardincerri credits former team member Cas Milner for proposing muon tomography for the dome—one of several ideas the Lab presented to an Italian delegation of conservation experts in 2013.

Designed by the secretive master builder Filippo Brunelleschi, the 15th-century dome of Santa Maria del Fiore Cathedral is an architectural marvel, and it is has been affected by ever-expanding cracks for centuries. Some scholars believe, based on historical documents, that iron reinforcements might be inside the dome’s thick masonry, but investigations with metal detectors failed to yield conclusive evidence either for or against this view.

To determine the dome’s strength and need for further reinforcements, the cathedral’s preservationists are looking to Los Alamos to help determine the exact location of the iron, if it exists, and compile a more detailed crack profile, which will be used in their models.

In 2015, Guardincerri visited Florence to explain to the cathedral’s conservation committee why she believes the Lab’s muon tracker technology could provide precious information regarding the inside of the dome. She presented vivid images of iron bars embedded in a replica wall built at Los Alamos. The committee approved the design of a pair of portable trackers, each weighing no more than 220 pounds, one of which will be suspended inside the cathedral near Giorgio Vasari’s Last Judgment fresco.

“This will be a great stage to show the world that this [muon imaging] works,” said Guardincerri, who grew up in a nearby town.

She recently received Laboratory Directed R&D Early Career Award funding to take Milner’s idea and work to make it real. National Geographic signed on as a partner after she and colleague Matt Durham (P-25) explained how the one-detector method that has been used for pyramids is better for a wider field of view and the Los Alamos technology is better for seeing details in smaller structures. By sandwiching a structure between two detectors and measuring the muon rays entering and exiting a structure, the Los Alamos muon tracker distinguishes dense objects with a resolution that other muon imaging methods cannot achieve.

Los Alamos scientists are currently the only ones performing multiple scattering muon imaging. For the dome application, "Our technique is more accurate and the spatial resolution is much better,” Guardincerri said.

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Elena Guardincerri's favorite experiment

What: Demonstrated that multiple scattering muon radiography is a new method to image reinforcement elements inside thick-walled structures. It uses cosmic-ray muons as probes.
Why: To determine if this imaging tool, developed at Los Alamos, could provide crucial information about the cracking dome of the Florence Cathedral and solve the mystery of its internal supports (iron bars, clamps, and chains)
When: Summer 2015
Where: Los Alamos Neutron Science Center
Who: Elena Guardincerri, Matt Durham, Chris Morris, Jeff Bacon, Tess Daughton, Shelby Fellows, Olivia Johnson, Deborah Morley, Kenie Plaud-Ramos, Daniel Poulson, Zhehui Wang (all P-25)
How: Summer students built a replica of the dome's thickest inner wall and hid three iron bars inside it. Two muon tracker modules, placed on either side of the wall, took data for 35 days.
The "a-ha moment:" After 17 days of taking data, all three iron bars were visible. Guardincerri reported the results in Florence, receiving approval from the cathedral's guild to develop thinner, portable muon tracker modules to install in the dome.