The MU-RAY project: volcanoes radiography with cosmic ray muons

F. Ambrosino

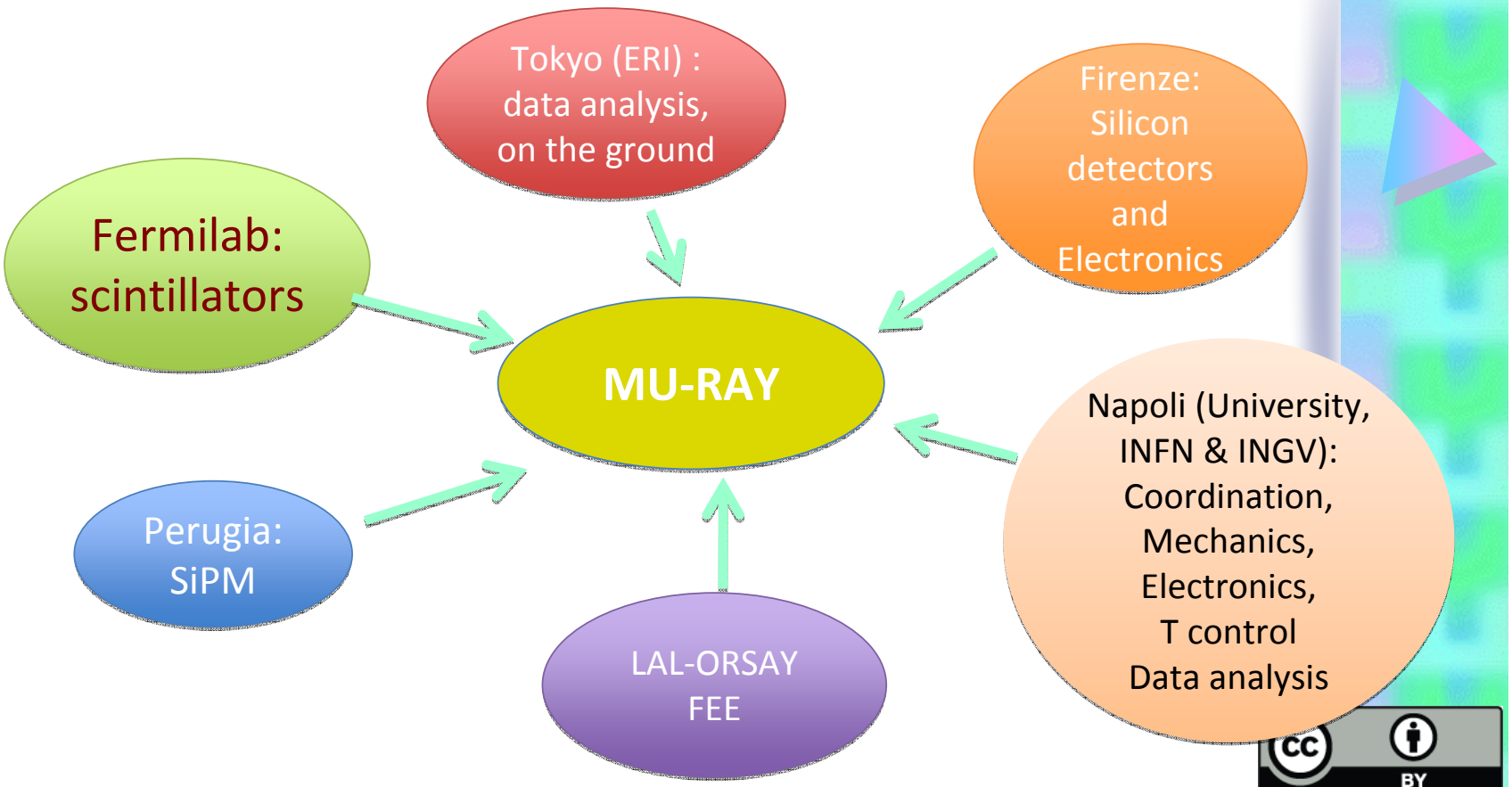
Università e Sezione INFN, Napoli

for the MU-RAY collaboration team

CC BY

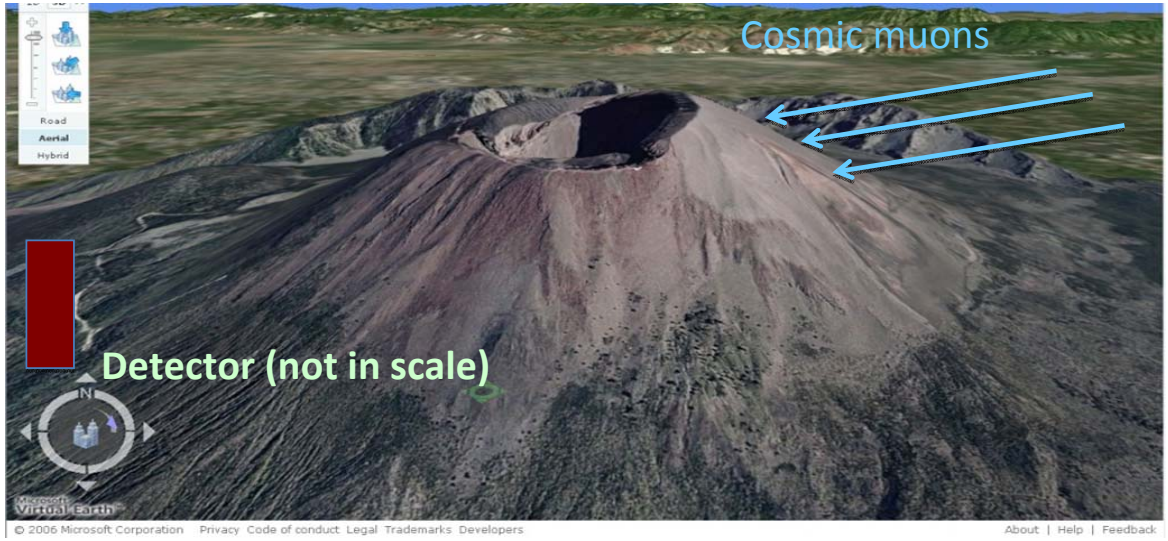
The MU-RAY project

The MU-RAY project profits from different experiences and aims at putting together the know-how of both the particle physics and geophysics communities to make a step ahead in muon radiography.



CC BY

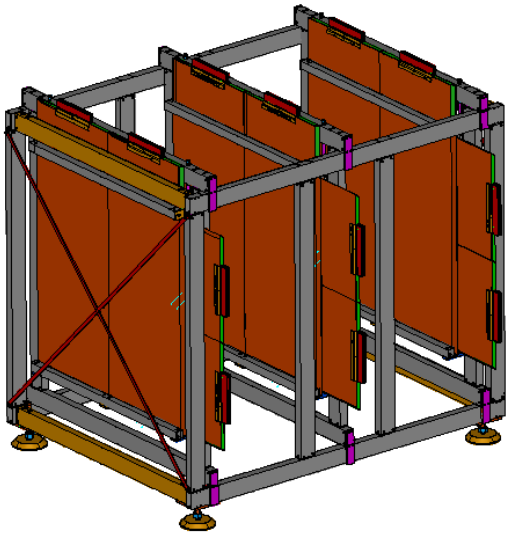
The detector guidelines



- Tracking capability: direction of muons (flux and energy depends on azimuth). Possibly high spatial resolution.
- Low energy consumption
- Resistant and modular structure: usage in volcanic area
- Low noise and large area (low muon flux)
- Redundant background suppression capability
- Low cost: larger telescope area
- Uniform response

CC BY

Our solution

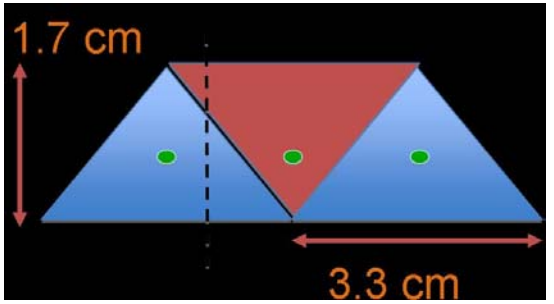


✓Three xy measuring planes telescope

- Tracking capability: direction of muons (flux and energy depends on azimuth). Possibly high spatial resolution.
- Low energy consumption
- Resistant and modular structure: usage in volcanic area
- Low noise and large area (low muon flux)
- Redundant background suppression capability
- Low cost: larger telescope area
- Uniform response

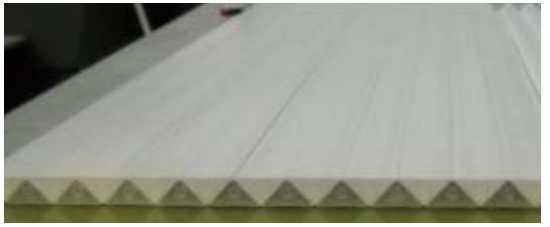
CC BY

Our solution



✓Three xy measuring planes telescope

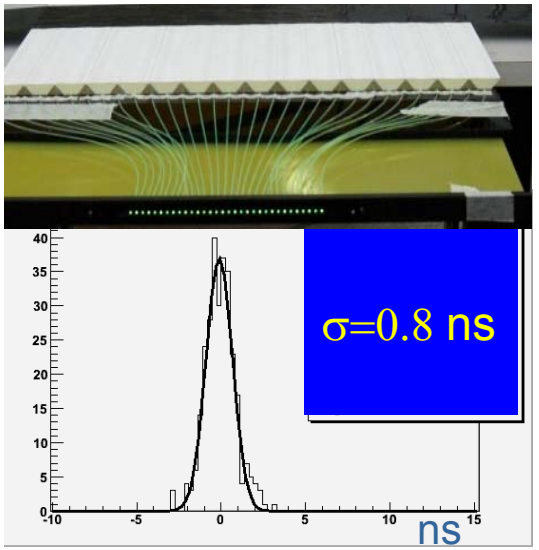
✓Co-extruded triangular scintillator bars



- Tracking capability: direction of muons (flux and energy depends on azimuth). Possibly high spatial resolution.
- Low energy consumption
- Resistant and modular structure: usage in volcanic area
- Low noise and large area (low muon flux)
- Redundant background suppression capability
- Low cost: larger telescope area
- Uniform response

CC BY

Our solution



✓Three xy measuring planes telescope

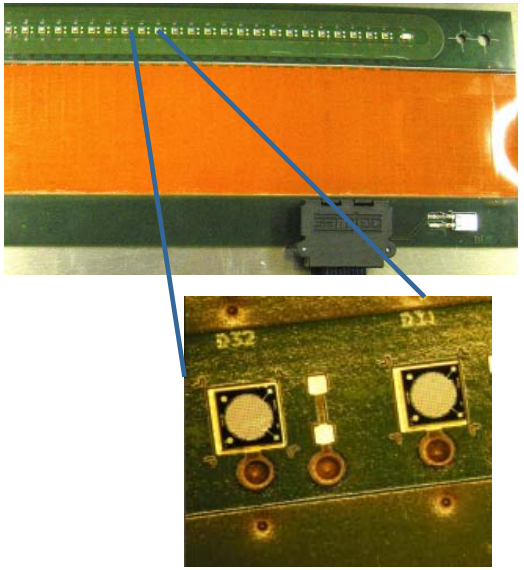
✓Co-extruded triangular scintillator bars

✓Fast WaveLength Shifting (WLS) fibers allowing time resolution < 1ns

- Tracking capability: direction of muons (flux and energy depends on azimuth). Possibly high spatial resolution.
- Low energy consumption
- Resistant and modular structure: usage in volcanic area
- Low noise and large area (low muon flux)
- Redundant background suppression capability
- Low cost: larger telescope area
- Uniform response

CC BY

Our solution



✓Three xy measuring planes telescope

✓Co-extruded triangular scintillator bars

✓Fast WaveLength Shifting (WLS) fibers allowing time resolution < 1ns

✓Silicon Photomultipliers readout

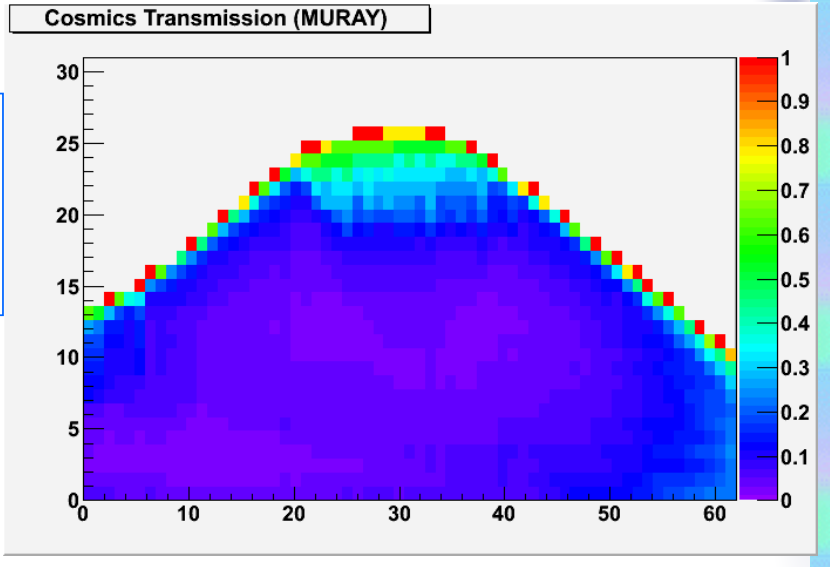
- Tracking capability: direction of muons (flux and energy depends on azimuth). Possibly high spatial resolution.
- Low energy consumption
- Resistant and modular structure: usage in volcanic area
- Low noise and large area (low muon flux)
- Redundant background suppression capability
- Low cost: larger telescope area
- Uniform response

CC BY

Expected performances

- **<10 mm spatial resolution**
  (3 mm reached w similar detector)
- **1ns time resolution -> Time of flight**
- **Tens of Watts of power consumption**

<10 mrad angular resolution
<10 m for a 1km far volcano
(no multiple scattering)

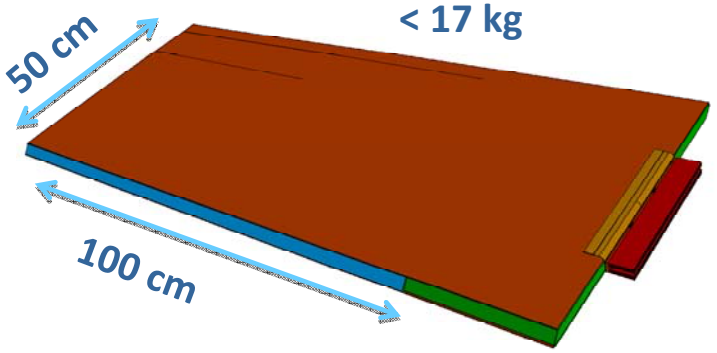


Simulation of a Vesuvius radiography with the MU-RAY detector

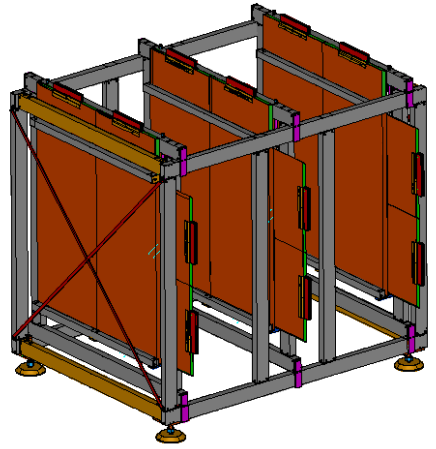
CC BY

Detector structure

- **Prototype: three X-Y stations of 1x1 m^2 area**
- **12 modules easy to transport and to assembly**
- **Resistant and easy to replace**



< 17 kg



< 280 kg

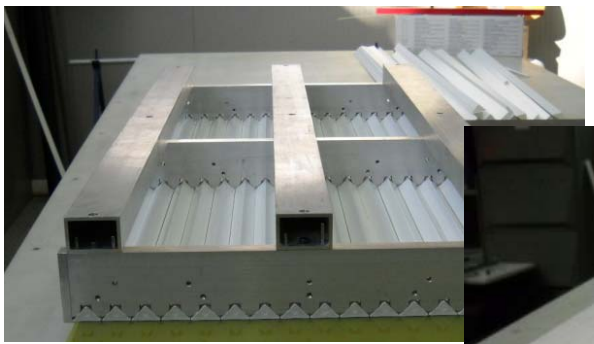
CC BY

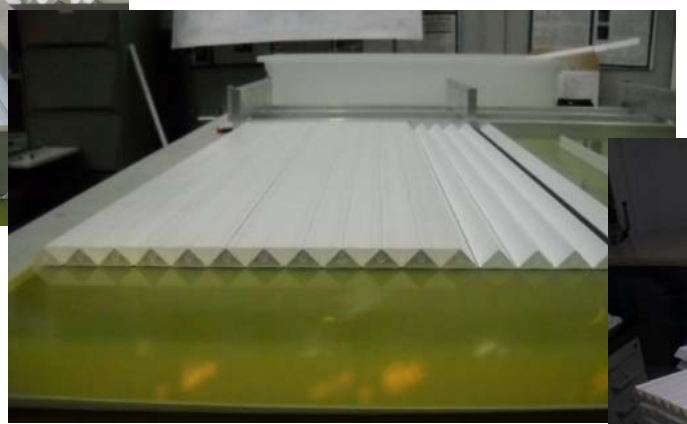
Detector construction and quality checks

Scintillator bars glueing

Connector production and quality check

Final glueing of the fibers to optimize optical coupling



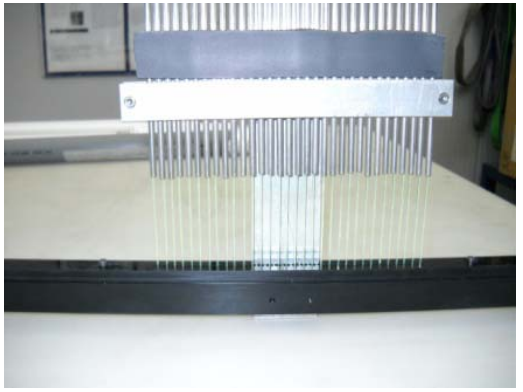


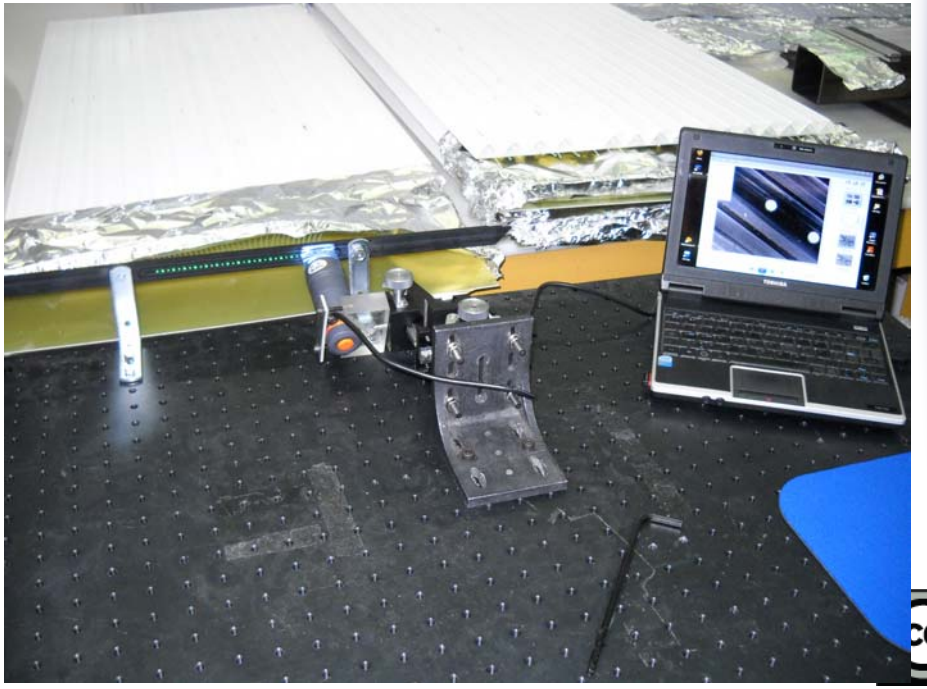
Detector construction and quality checks

Scintillator bars glueing

Connector production and quality check

Final glueing of the fibers to optimize optical coupling





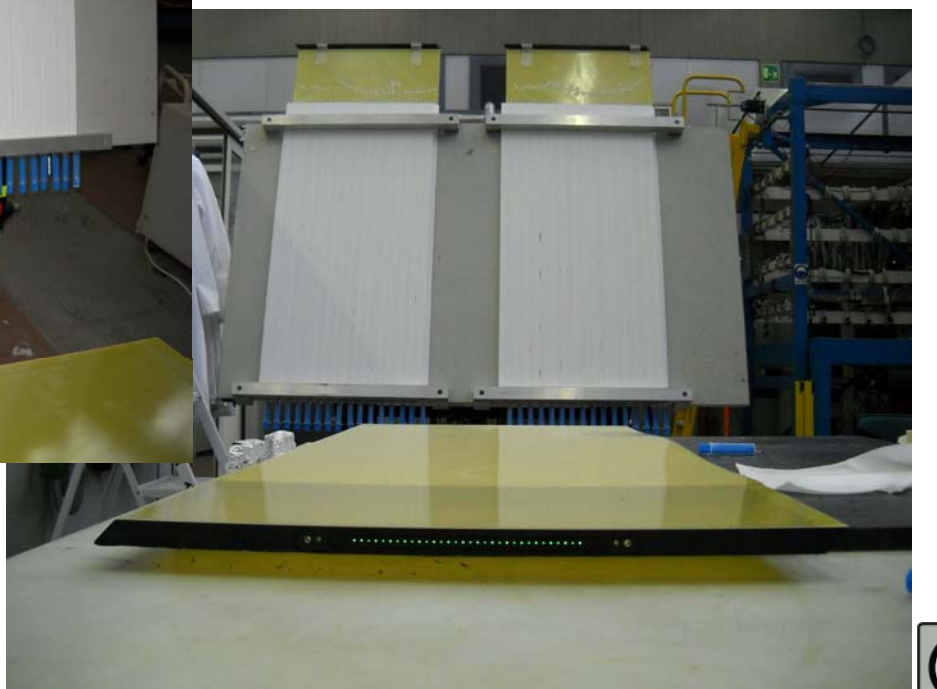
cc BY

Detector construction and quality checks

Scintillator bars glueing

Connector production and quality check

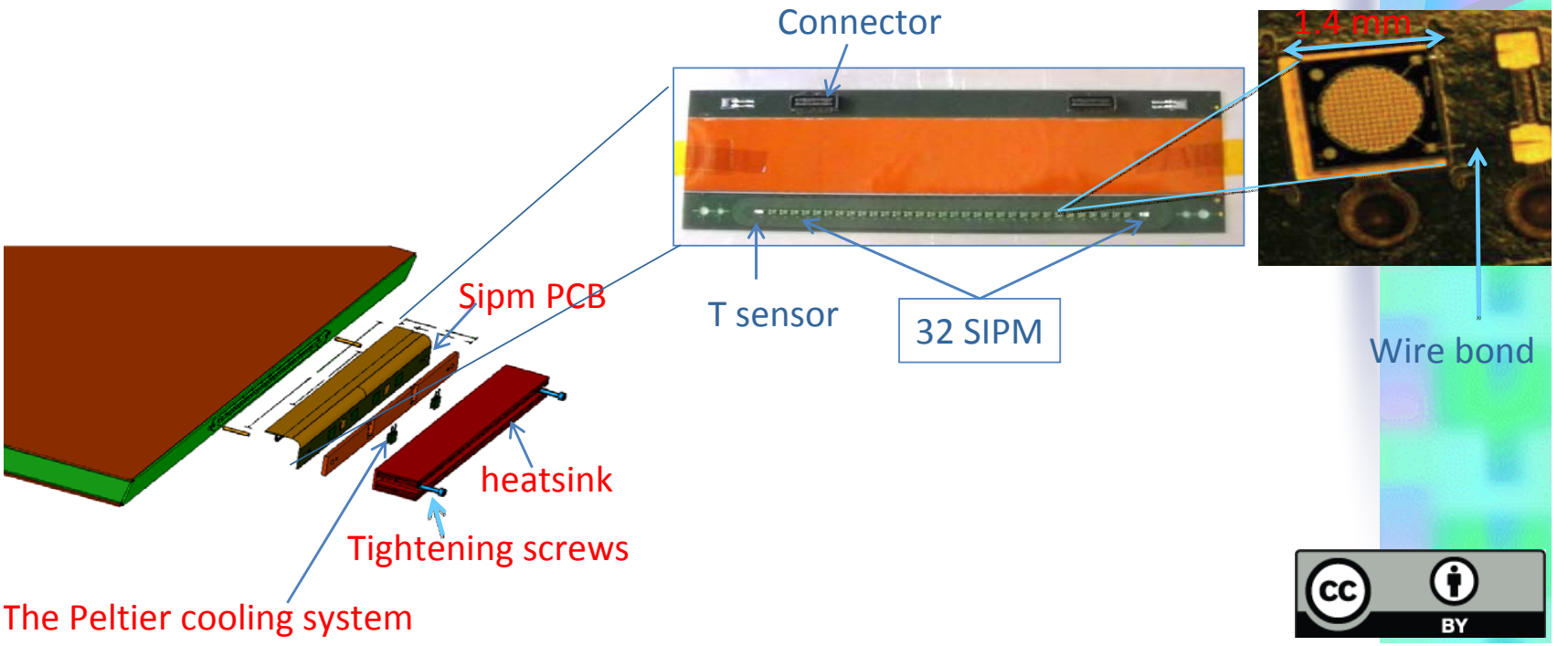
Final glueing of the fibers to optimize optical coupling



CC BY

The readout

The signals of the 32 fibers is read by means of a custom designed SiPM PCB in which each SiPM is positioned with precision below 100 μm and wire bonded.
SiPMs are kept at constant and uniform temperature by means of a custom designed electronic thermal feedback system using Peltier cells



CC BY

The Front End Electronics

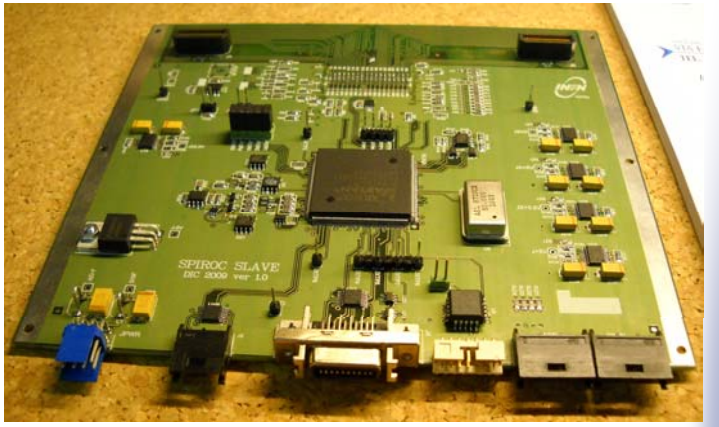
The signals from SiPM are read by an Application-Specific Integrated Circuit (ASIC) called SPIROC and developed at LAL (Orsay) appositely for SiPM readout. The SPIROC main features are:

- Up to 36 channels (SiPMs) management
- Independent fine Vbias setting for each SiPM
- Independent threshold setting fro each channel
- Variable gain for signal amplification
- Fast amplifier for time measurement
- Low power consumption (20 μW/channel)
- Multiplexed analog output
- External trigger

CC BY

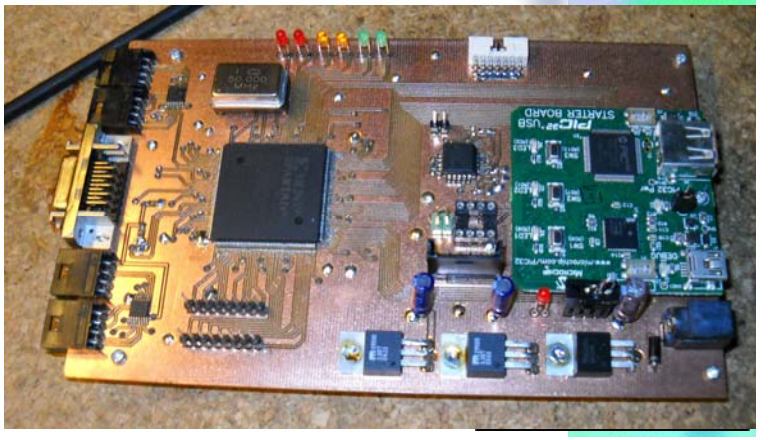
The data acquisition

The SPIROC chip is controlled by a dedicated board (slave) where digitization of charges and time is performed



The 12 slave boards are controlled by a master board that provides:

- communications with the SPIROCs
- the trigger logic
- the data readout from slaves
- data transfer to external world



Where we are now

- ✓ 1/2 of modules completely assembled. Expect completion before end of next week.
- ✓ SiPM PCBs in production (1/3 are ready)
- ✓ All slave boards ready and tested
- ✓ Master prototype board ready and under test
- ✓ T control board prototype ready and under test
- ✓ Measurement set-up for modules characterization ready
- ✓ Design of the tracker support completed

CC BY

Coming soon

- **Characterization of the module prototype**
- **Building the telescope structure**
- **Assembling the full telescope**
- **Commissioning of the telescope**
- **Starting to take data at Vesuvius**

CC BY

Future plans

- **Starting measurements on different volcanoes or other relevant sites with the 1m^2 prototype (e.g. Stromboli)**
- **Starting design and realize larger area telescopes (2x2) m^2**
- **Design a new front end board based on the new chip "SPIROC light"**
- **Implement tomography**

CC BY