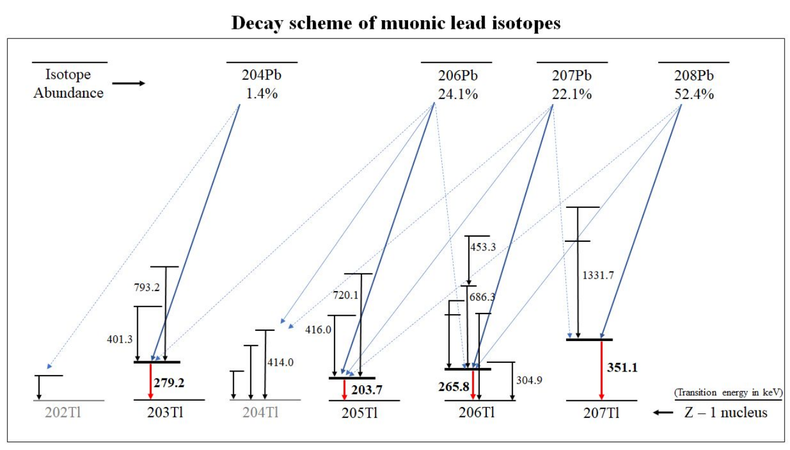
16th Pisa Meeting on Advanced Detectors - La Biodola, Isola d'Elba (Italy), 26th May - 1st June 2024

A muon beam monitor for the **CHNet-MAXI** experiment at the RIKEN-RAL laboratory

Riccardo Rossini[1,2,3], Maurizio Bonesini[4,5], Matteo Cataldo[3,4,5], Giancarlo Ceruti[4], Antonio de Bari[2], Lisa Malliolio[1], Alessandro Menegolli[1,2], Paola Monza[6,7], Piernicola Oliva[6,7], Federico Palenzona[1], Maurizio Perego[4], Marco C. Prata[2], Massimo Rossella[2], Valeria Sipala[6,7] and Massimiliano Clemenza[4]

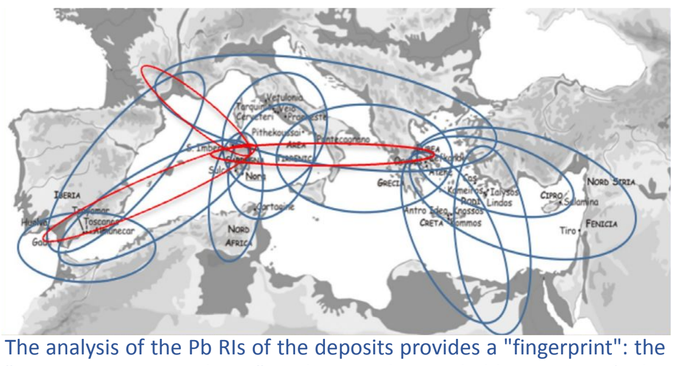


CHNet-MAXI is an experiment supported by the Cultural Heritage Network of the Italian Institute for Nuclear Physics (INFN), aiming to develop a non-invasive technique to determine the Pb isotope ratios (RI) in ancient artefacts. This can be a powerful tool to determine the provenance of such objects.

CHNet-MAXI technique is based on the Muonic Atom X-ray and prompt gamma spectroscopy for Isotopic analysis: the idea is to identify the characteristic X-rays emitted by a muonic atom formed after the exposure of the archaeological sample to a low momentum muon beam.

Different muonic Pb isotopes would emit characteristic X-rays, following well known decay schemes. The main goal of the experiment is to prove for the first time the possibility to disentangle these X-rays, by exposing several isotope-enriched targets of Pb to the high intensity muon beam provided by the ISIS accelerator complex (RAL laboratory, UK).

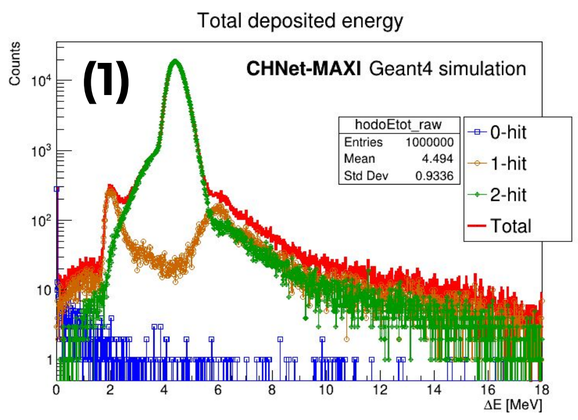
The prompt gamma radiation and the X-rays will be detected by an array of HPGe and by innovative scintillation detectors (CLLB and GAGG-HR) surrounding the samples, while a custom beam monitor will be used to precisely place the targets on the muon beam centroid.



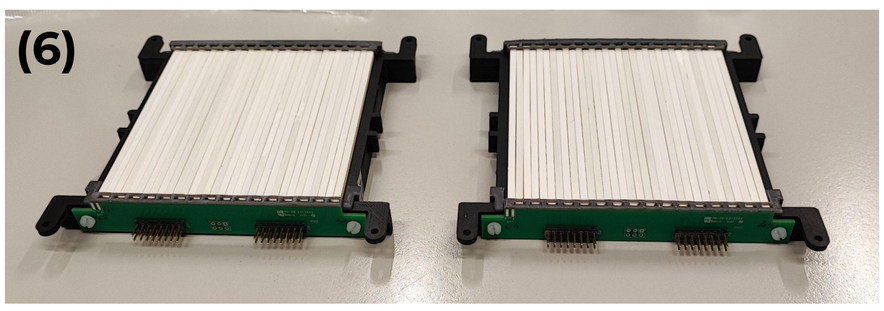
The analysis of the Pb RIs of the deposits provides a "fingerprint": the "isotopic correspondence" indicates the probable origin of the material/artefact from a specific area.

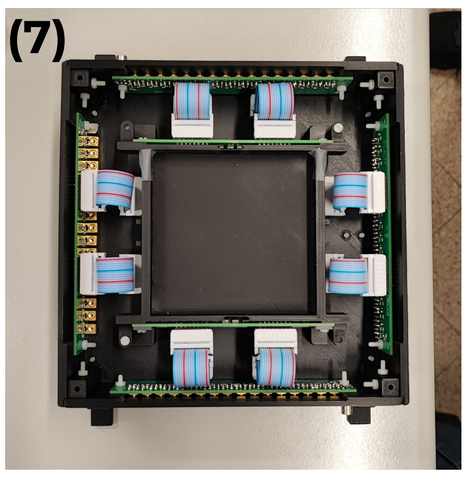
Idea. Feature CHNet-MAXI with a muon beam hodoscope to be used as a beam X/Y profiler and a beam intensity monitor, with 3 mm space resolution, an homogeneous entrance window before the sample and a portable setup based on desktop HV and digitizer modules.

Simulation. Preliminary Geant4 simulations have been carried out to characterize the detector **(1)**. The response function to single muons has been characterised separating the contributions coming from particles hitting 0, 1, 2 fibres to reconstruct the total response function.



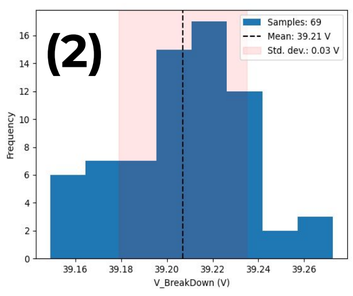
Assembly. The PCBs for the readout have been designed at INFN Pavia, while the mechanical structure has been designed and 3D printed by INFN Milano Bicocca. The detector was fully assembled and all channels were individually tested with cosmic rays and radioactive sources **(6-7)**

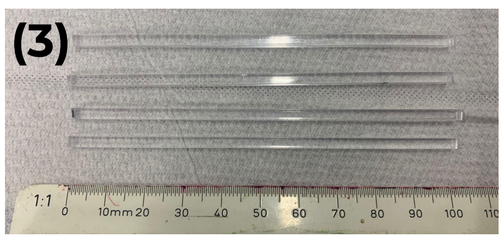


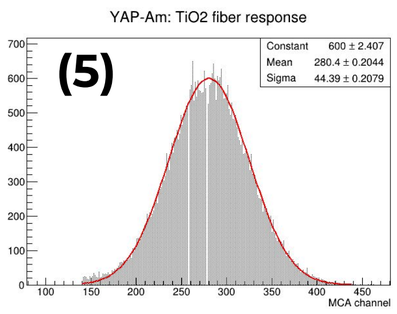


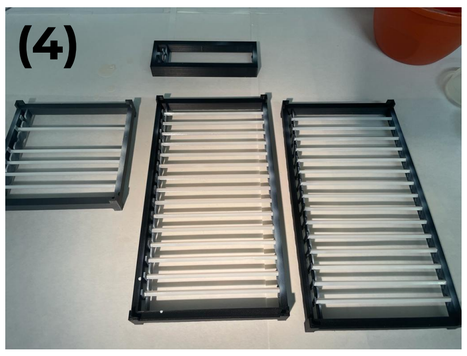
Active parts. The detector is based on 32+32 squared 3 mm scintillating fibres in X/Y mode, each read by one Hamamatsu S14160-3015PS SiPM. After the determination of the SIPM breakdown voltage **(2)**, the fibers have been cut, polished, and finally coated with TiO2 paint (**3-4**).

A YAP crystal doped with ^{241}Am was used as a monochromatic source of light from the excitation of the scintillator by the alpha particles emitted by ^{241}Am. It was coupled to the fiber read by a SiPM, demonstrating that the light was efficiently transmitted **(5)**.





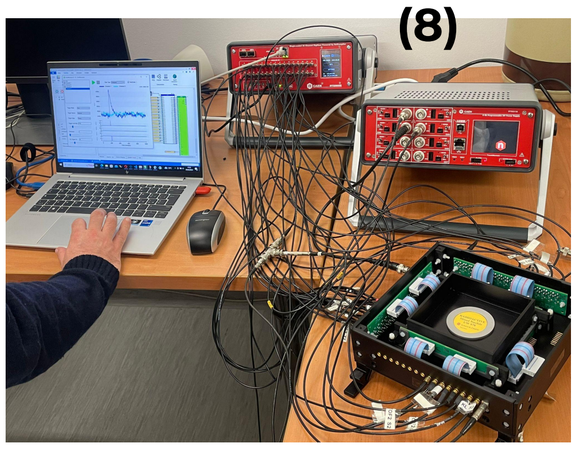


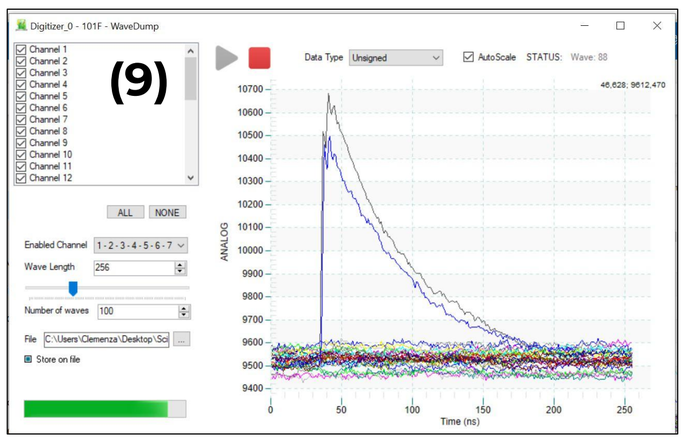


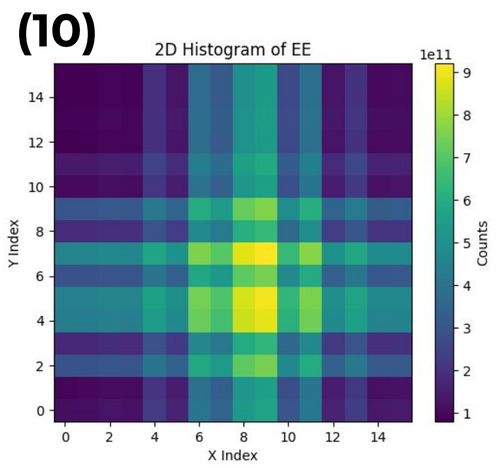
DAQ test. A first test of the detector with a 37 kBq source of ^{90}Sr/^{90}Y (beta emitter with Q-value = 2.2 MeV) **(8)** has been carried out by powering a sub-sample of fibers with a CAEN DT8031M desktop module.

The DAQ was implemented using a 32 channel CAEN DT550SE Open-FPGA desktop digitizer. It was programmed through the SciCompiler interface developed by Nuclear Instruments.

The overall system worked without issues and all the tested channels provided signals well above the background noise, allowing to highlight the shape of the beta source (**9-10**).







<u>Future developments</u>

A first test beam of the detector will be performed in summer 2024 at the CNAO synchrotron (~ 150 MeV proton beam) in Pavia (Italy).

After that, the beam monitor will be used for the first CHNet-MAXI run at the ISIS facility with the isotope-enriched Pb targets, foreseen for autumn 2024.

Contact: riccardo.rossini@pv.infn.it

1. Dept. of Physics, University of Pavia, Pavia, Italy.
2. INFN Sezione di Pavia, Pavia, Italy.
3. ISIS Neutron and Muon Source, Science and Technology Facilities Council (STFC), Didcot, United Kingdom.
4. INFN Sezione di Milano-Bicocca, Milan, Italy.
5. Dept. of Physics “G. Occhialini”, University of Milano-Bicocca, Milan, Italy.
6. Dept. of Chemical, Physical, Mathematical and Natural Sciences, University of Sassari, Sassari, Italy
7. INFN Sezione di Cagliari, Cagliari, Italy.