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Characterisation of a low-momentum high-rate muon beam monitor for the FAMU experiment at RIKEN-RAL

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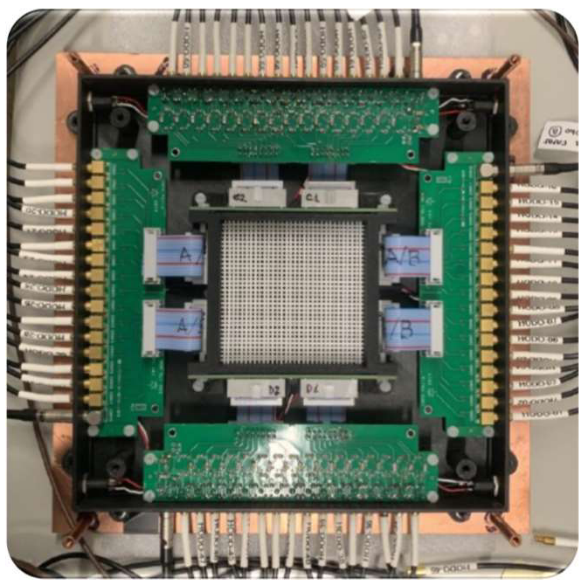


Inside of the FAMU beam hodoscope

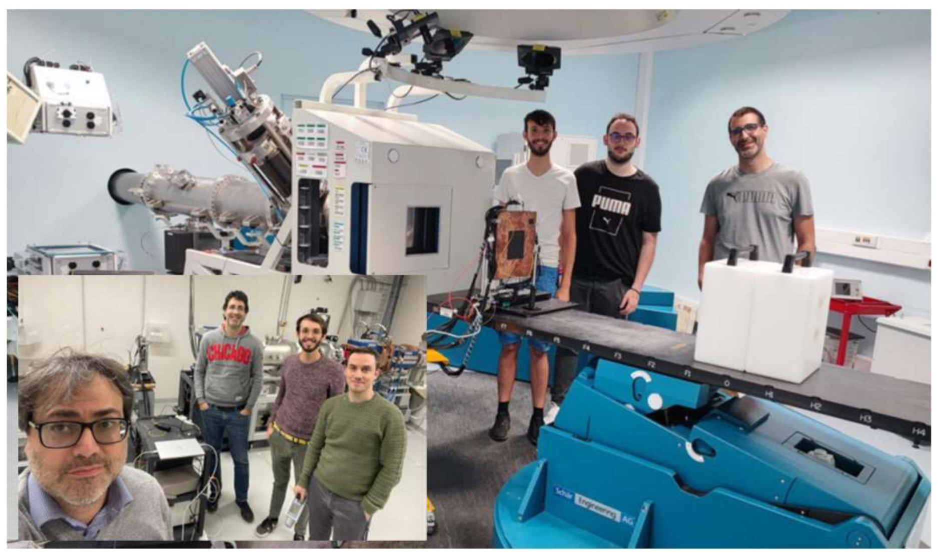
FAMU is a Nuclear Physics experiment devoted at the measurement of the proton Zemach radius in muonic hydrogen.
Hodoscopes to be used as negative muon beam monitors for FAMU:

- 32x32 1 mm-pitch polystyrene cladded BCF-12 scintillating fibres
- each fibre read out by a Hamamatsu 13xxx SiPM on one side
- thin PVC entrance window

Muon beam configuration at RIKEN-RAL for the FAMU experiment:

- $p = 60$ MeV/c, with $\Delta p/p \simeq 5\,\%$.
- average muon flux: $\phi = 3 \cdot 10^7$ muons per second
- two 100 ns spills at a rate of 50 Hz

→ it is impossible to resolve single-muon responses → single-particle response function has to be measured and used to estimate the number of muons per each spill at RAL.



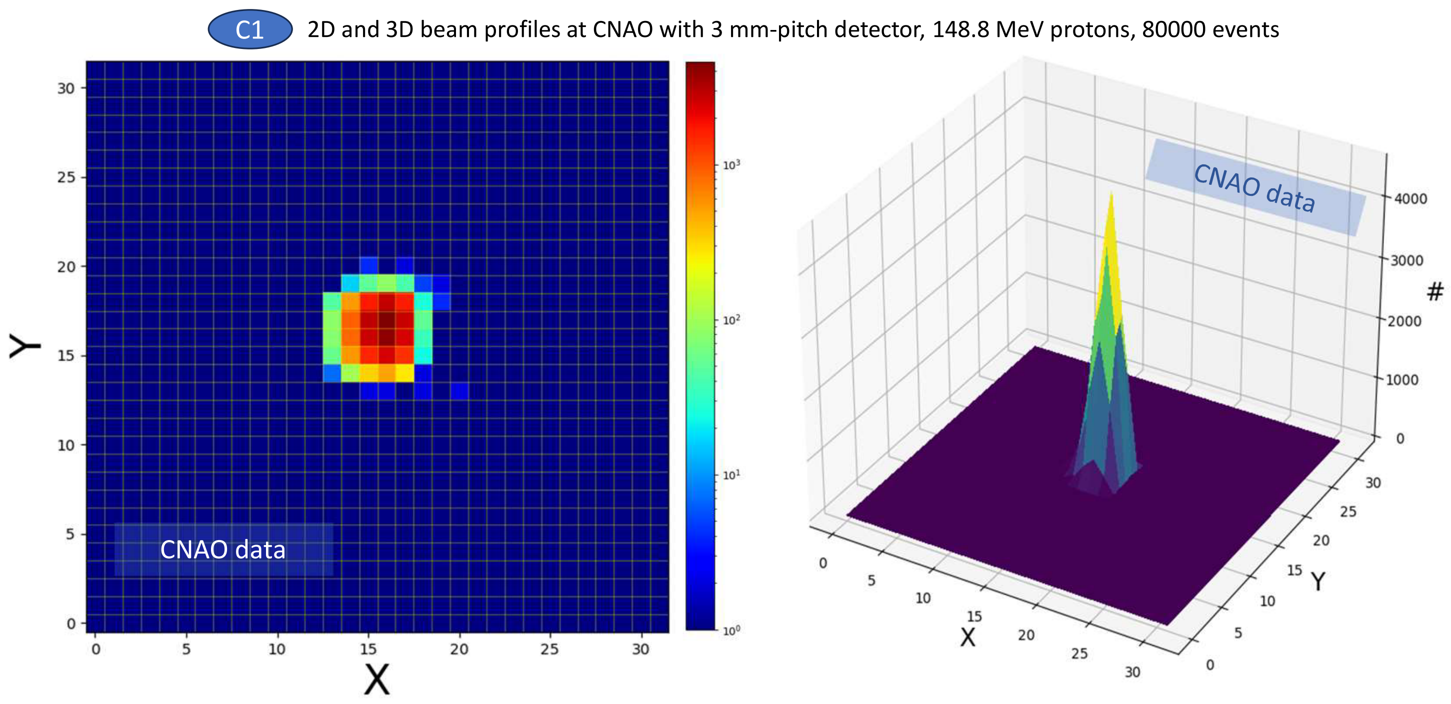
Group photos taken during CNAO beam tests

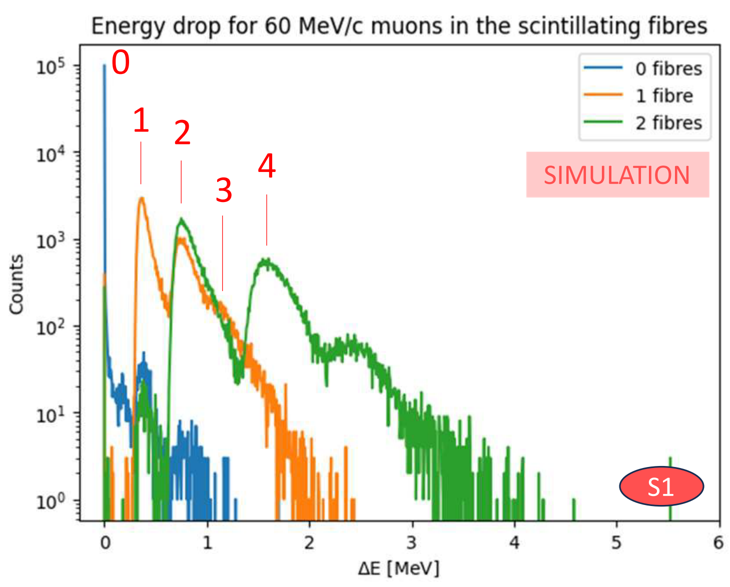
Calibration tests were carried out at the Italian National Centre for Hadrontherapy (**CNAO**) synchrotron, in Pavia, with 150 MeV protons. This energy had been selected through simulations in order to match the average energy loss of FAMU muons.

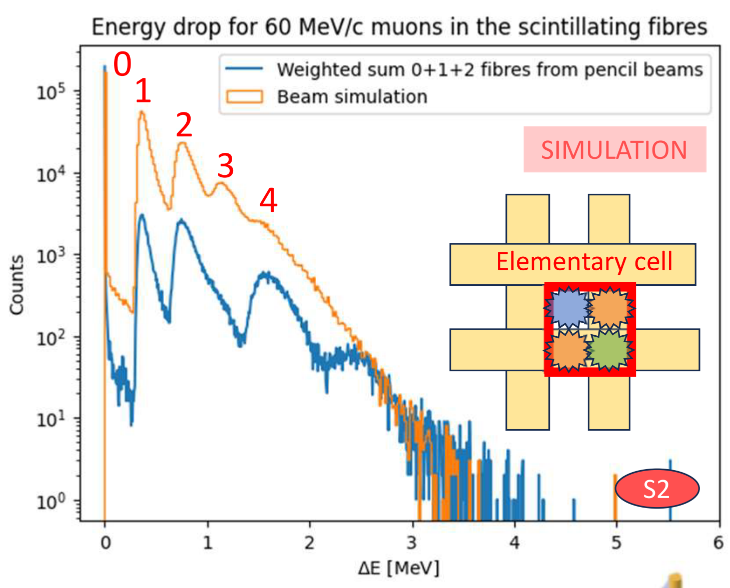
The plots on the right show the beam profile (plot **C1**) extracted from a beam run at CNAO and the related response function of the whole detector (plot **C2**), from which it is possible to extract the single particle equivalent charge $Q_p = Q_\mu$ to be used for the muon flux estimation at RAL.

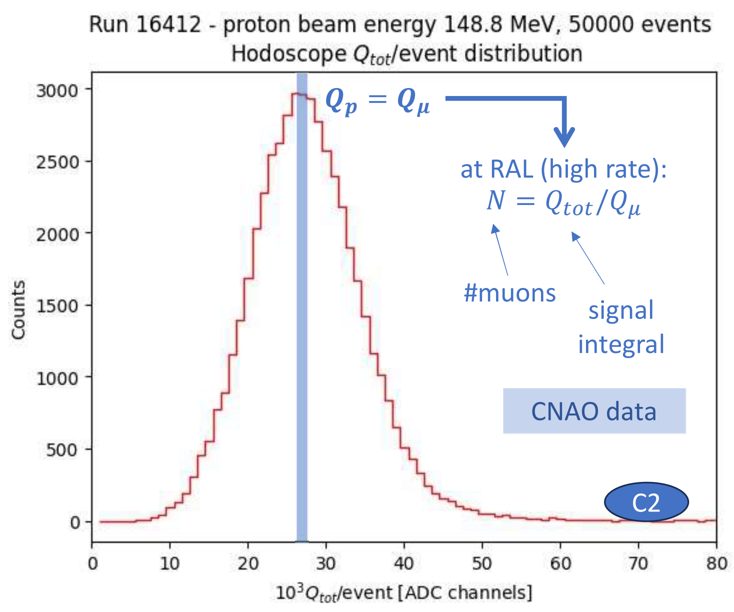
The **simulation** of the detector has been carried out using Geant4 and it plays a crucial role in the interpretation of the response function to single particles measured at CNAO. The simulation of pencil beams hitting 0,1,2 fibres (plots **S1**, **S2**) has been used to evaluate the nature of the peaks present in the simulated response functions for two types of detector (with or without inter-fibre spacing) to 60 MeV muons (plot **S3**).

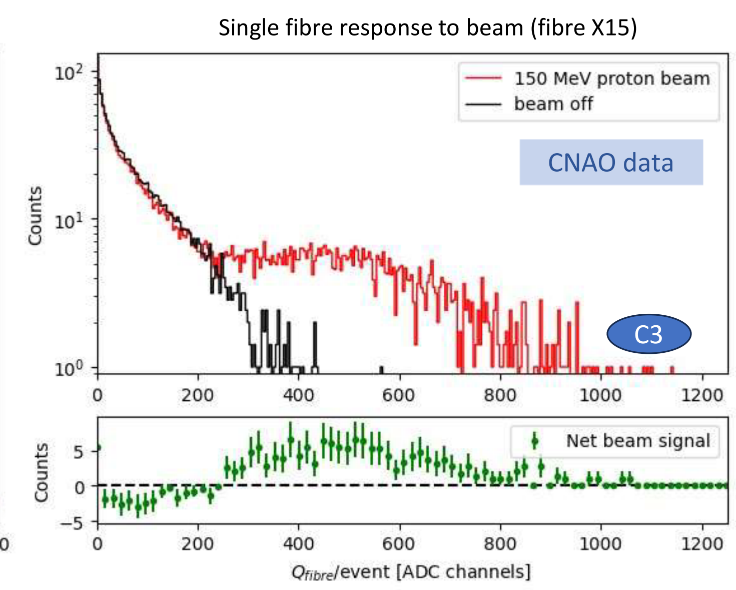
C1 2D and 3D beam profiles at CNAO with 3 mm-pitch detector, 148.8 MeV protons, 80000 events

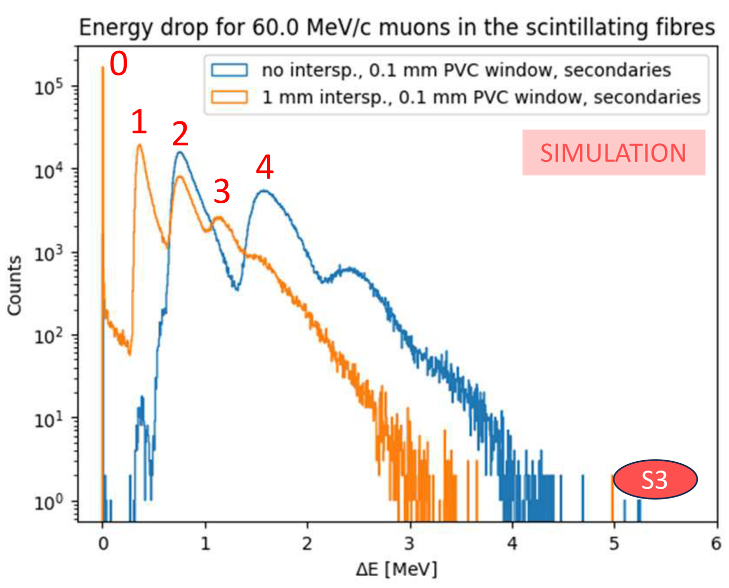


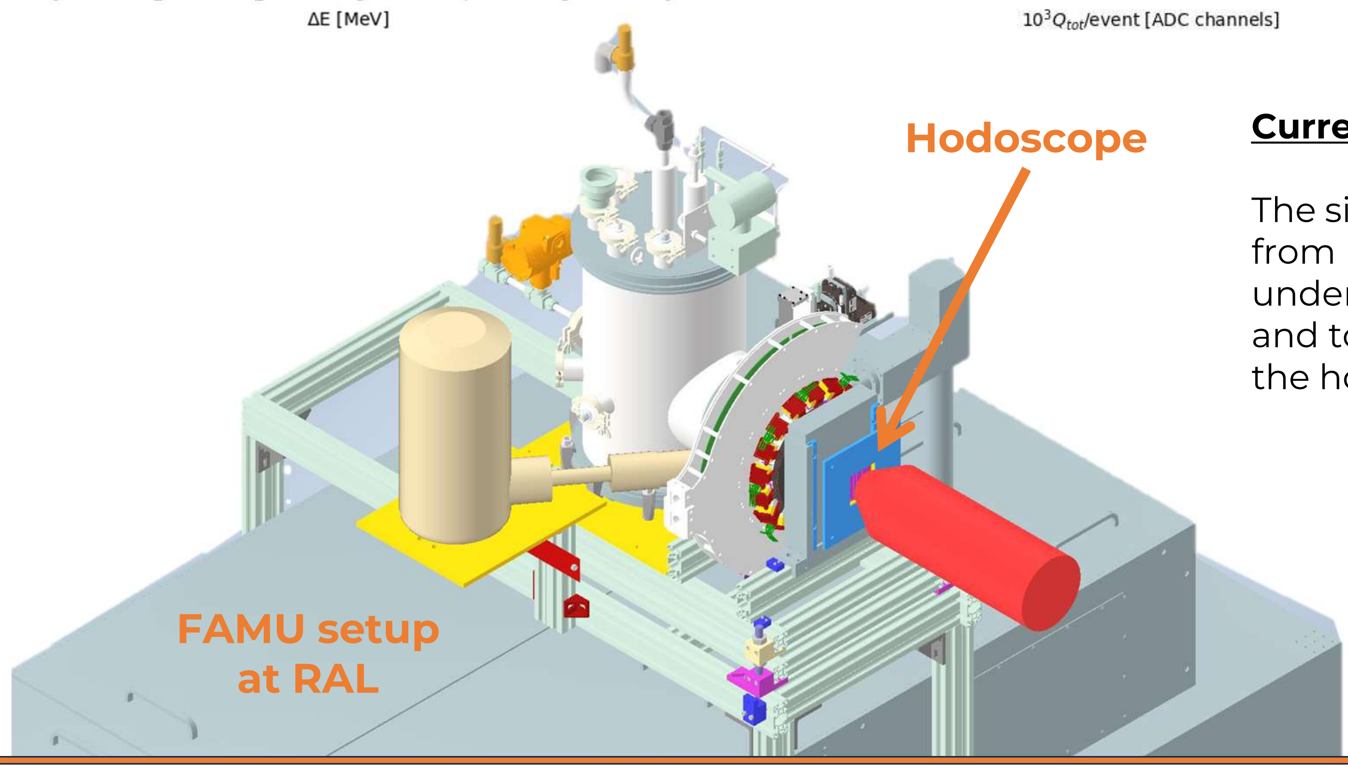












Current/future developments

The single-fibre response function is to be studied from both data (plot **C3**) and simulation to better understand how the particles interact in the detector and to characterise the beam perturbation caused by the hodoscope.

These results were obtained also thanks to the use of the CNAO experimental facility built in collaboration with INFN.

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Science and Technology Facilities Council
ISIS Neutron and Muon Source

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CNAO The National Center for Oncological Hadrontherapy