Characterisation of a scintillating fibre-based hodoscope exposed to the CNAO low-energy proton beam

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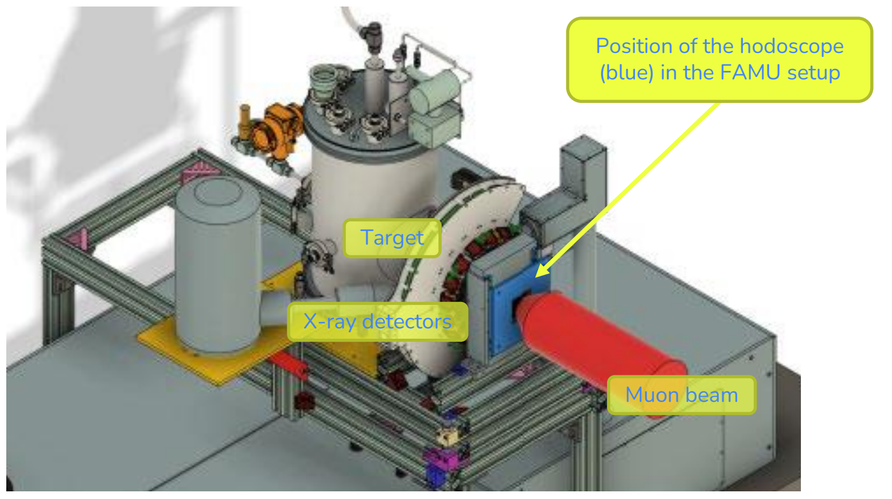
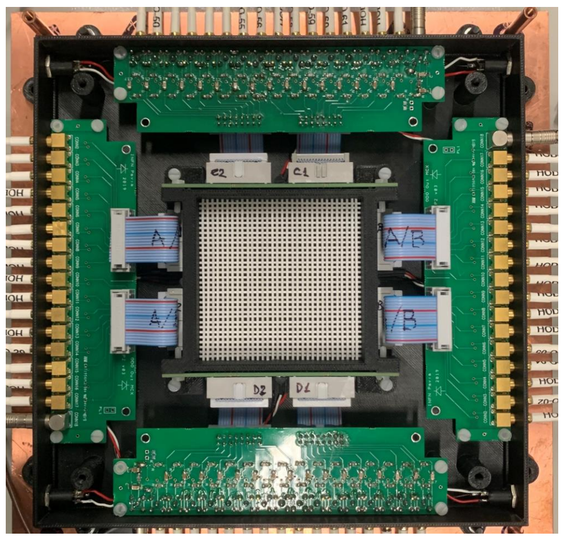
The **FAMU** (Fisica degli Atomi MUonici) experiment at RAL (UK) aims to estimate the proton Zemach radius by measuring the hyperfine splitting in muonic hydrogen (μp).

The μp atoms are obtained by injecting a 60 MeV/c negative muon beam at RAL Port 1 on a hydrogen-based gaseous target. A beam hodoscope is needed to characterise the muon beam directed against the target.





The hodoscope characterised in this work proved to be a good beam monitor even for other applications, e.g. accelerator monitoring for medical phycics (hadron therapy).

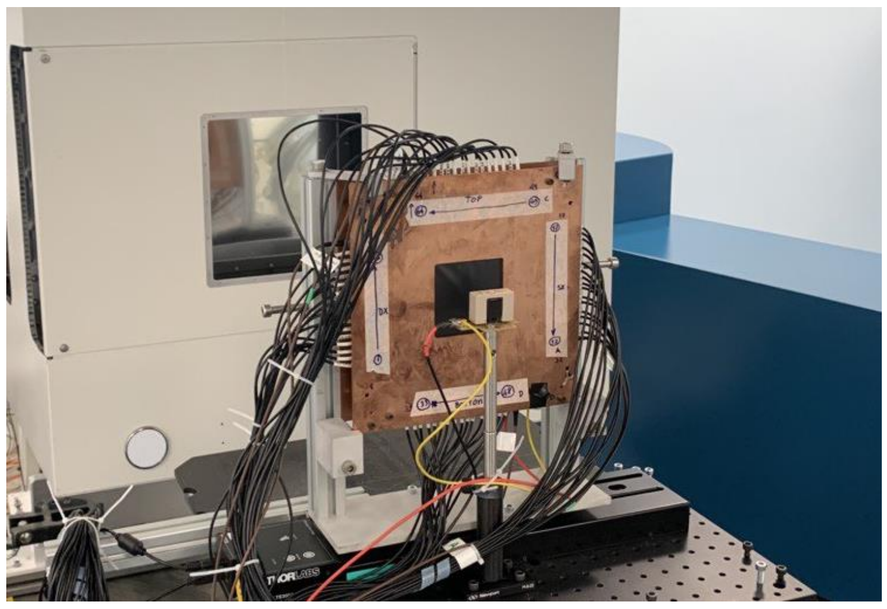
Hodoscope **characteristics**:

- 32x32 Bicron 1 mm^2 single-clad BCF12 scintillating fibres
- 6x6 cm^2 active area
- Each fibre read by a 1 mm^2 SiPM mounted in 4x16 arrays
- Bias around –70 mV, finely tuned for each 16-SiPM array

A **calibration** using single protons at 150 MeV (their energy loss curve is similar to the one of 60 MeV/c muons) is needed to enable muon counting at the high rates experienced in FAMU.

The CNAO syncrotron has been used on this purpose.

CNAO is a hadron-therapy facility located in Pavia, Italy.
It is featured with a synchrotron able to produce proton, C and O ion beams.
Maximum proton energy in the synchrotron: 250 MeV.



The **experimental setup at CNAO** (picture on the right):

- Hodoscope mounted on a translation stage remotely controlled
- Beam: 50 protons per second, adjustable kinetic energy (125-150-175) MeV
- Trigger: 1 cm^3 plastic scintillator aligned with the proton beam
- DAQ: CAEN V1742 digitisers (5 GS/s) due to the fast signals (up to 40 ns)

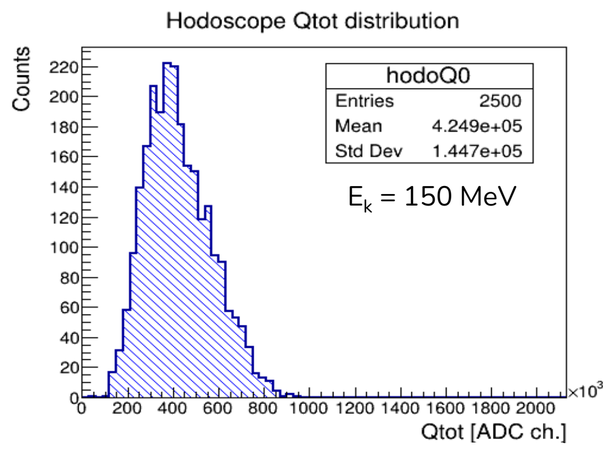
Experimental **procedure**:

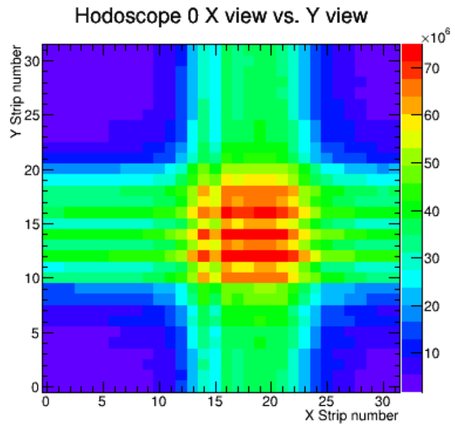
- One single proton for each trigger (50 Hz beam rate vs. 1 μs gate/trigger).
- Similar tabulated energy loss dE/dx for 150 MeV protons and 60 MeV muons (PDG).
- Distribution of deposited energy (in ADC channels) at 150 MeV → equivalent deposited charge for a proton, equal to the one for a 70 MeV/c muon, given the particular choice of proton energy.

Result:

- Estimation of the number of muons interacting in the detector during the experimental runs of FAMU is made possible (rate $3 \cdot 10^4$ muons/s → unresolved).

During normal operation, the hodoscope will also return a beam profile as the one here reported (obtained with an analogous detector on the RAL Port 1 muon beam in 2018).





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