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

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FAMU (Fisica degli Atomi MUonici) is an INFN-led experiment aimed at measuring the Zemach radius of the proton. It is being carried out at the RIKEN-RAL muon facility at the ISIS Neutron and Muon Source, in the UK. Right away in the early stages of the experiment, having control on the muon beam shape and flux proved to be crucial for setup preparation and data normalisation.

The experiment is featured with a set of different beam hodoscopes which can be mounted between the target and the beam snout to monitor the incident 60 MeV/c negative muon beam. All hodoscopes consist in 32×32 polystyrene scintillating fibres read by SiPMs from one side. The pitch of each fibre is either 3 mm or 1 mm and the size of the active area goes from 3.2×3.2 cm^2 to 9.6×9.6 cm^2, depending on the specific detector geometry. Given the average particle rate is $7 \cdot 10^4$ muons/s, delivered in two 70 ns spills with a repetition rate of 50 Hz, it is impossible to perform particle counting by resolving single muons, considering that each signal lasts at least 20 ns.

A possible way out is retrieving the deposited energy of a single muon in the detector and using it to estimate the muon flux during each beam spill, by measuring the total deposited energy. To do so, we use a low-rate proton beam having momentum selected to have the same energy loss (dE/dx) as the 60 MeV/c muons used in FAMU. This procedure was conceptualised, optimised and performed at the CNAO synchrotron in Pavia (Italy), one of the most advanced hadron therapy centres in Europe, using both protons and carbon ions.

The measurements have been accompanied by Monte Carlo simulation of the detectors in Geant4 to understand the processes going on, hence the resulting spectra. These simulations were crucial to select the proton energy and understand the response function of the detector when irradiated with muons and protons of different energies.

A complete study and characterisation of the detectors has been carried out at CNAO preparing for the FAMU experimental runs starting in 2023. The detectors have also been exposed to the RIKEN-RAL muon beam to compare the results to those obtained with more rudimental calibration techniques, such as using cosmic muons.