

NuMI BEAM MUON MONITOR DATA ANALYSIS AND SIMULATION FOR IMPROVED BEAM MONITORING

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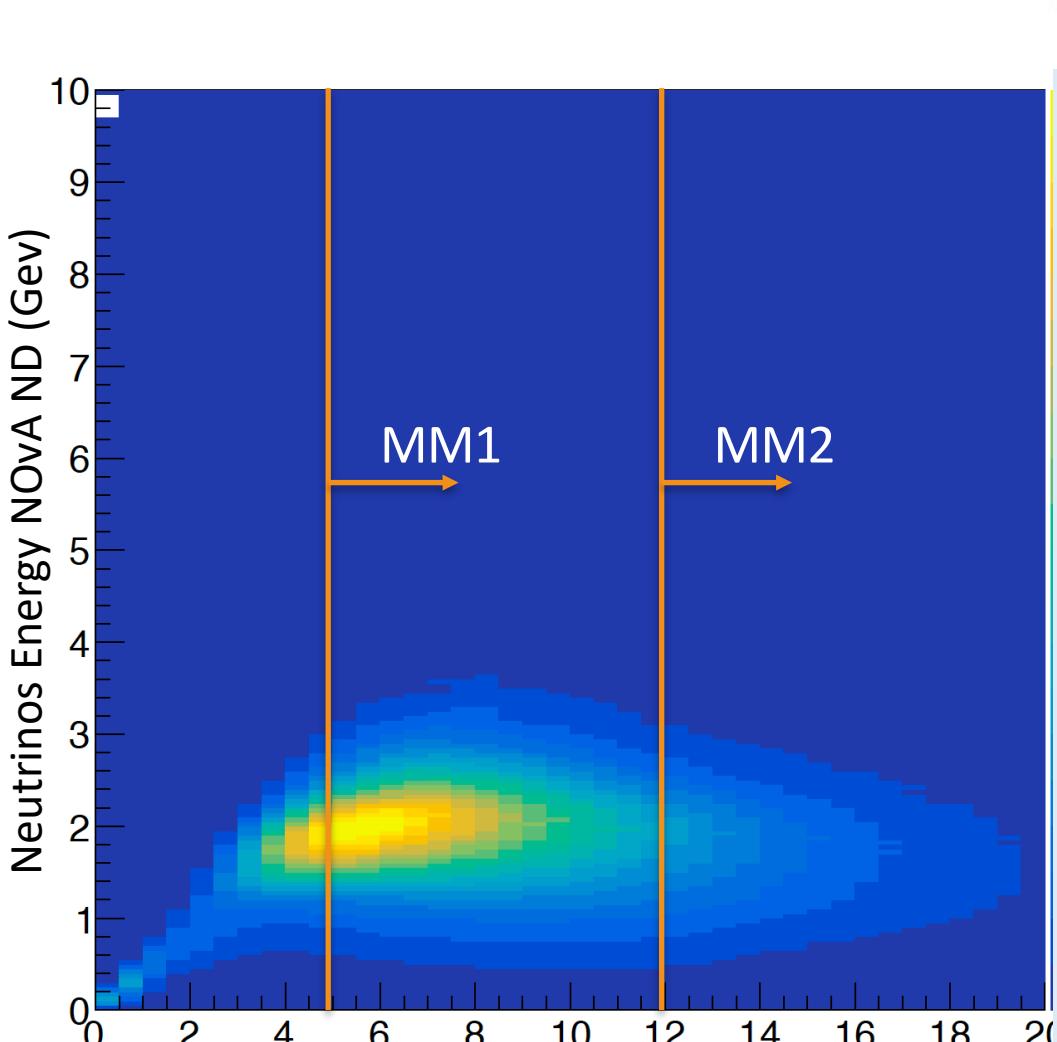
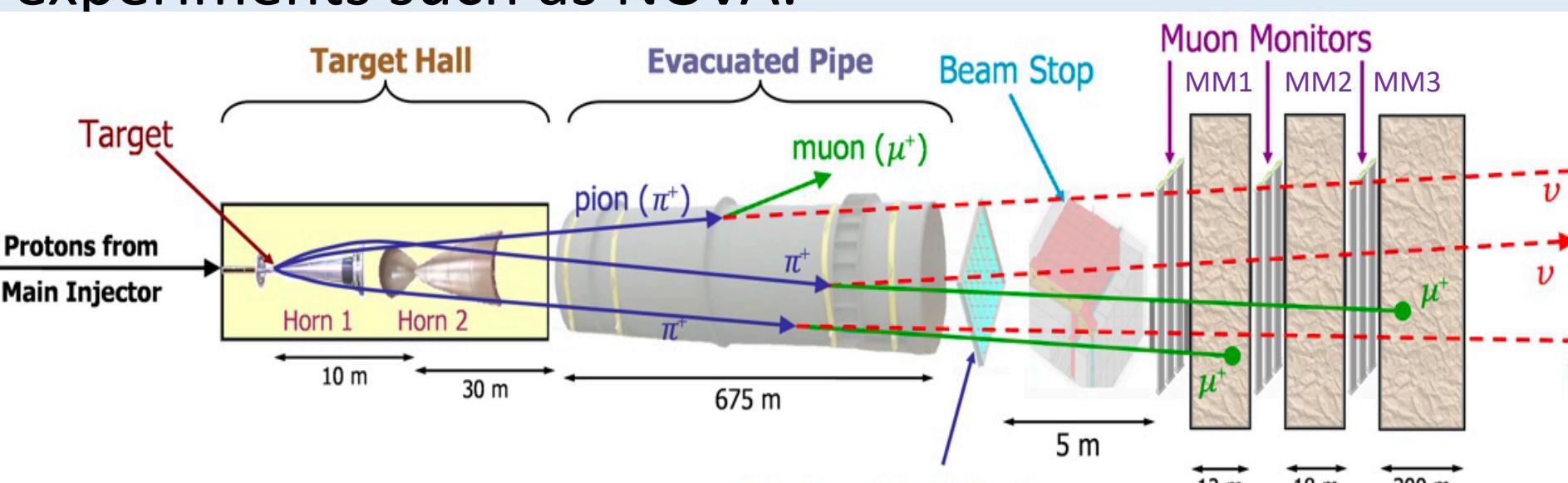
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Introduction

The NuMI muon monitors (MMs) are a very important diagnostic tool for monitoring the stability of the neutrino beam used by the NOvA experiment at Fermilab. The goal of our study is to maintain the quality of the MM signal and to establish the correlations between the neutrino and muon beam profile. This study could also inform the LBNF decision on the beam diagnostic tools. We report on the progress of beam scan data analysis (beam position, spot size, and magnetic horn current scan) and comparison with the simulation outcomes.

NuMI neutrino beam at Fermilab

120 GeV protons from the Main Injector strike a graphite target to produce mesons. Charged mesons are focused into the decay pipe. The decay of pions and kaons produces muons and muon-neutrinos. This muon-neutrino beam is delivered to neutrino experiments such as NOvA.

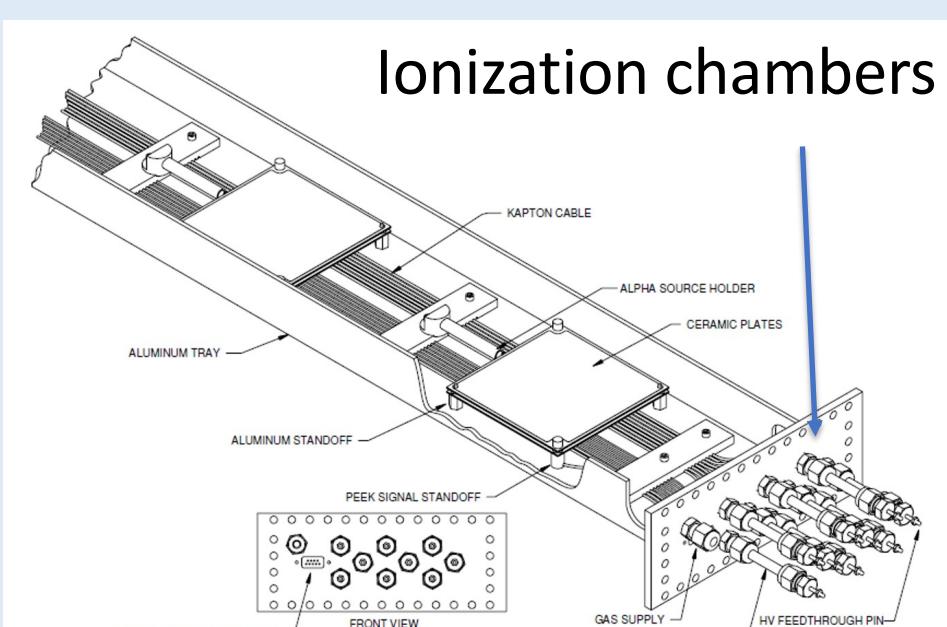
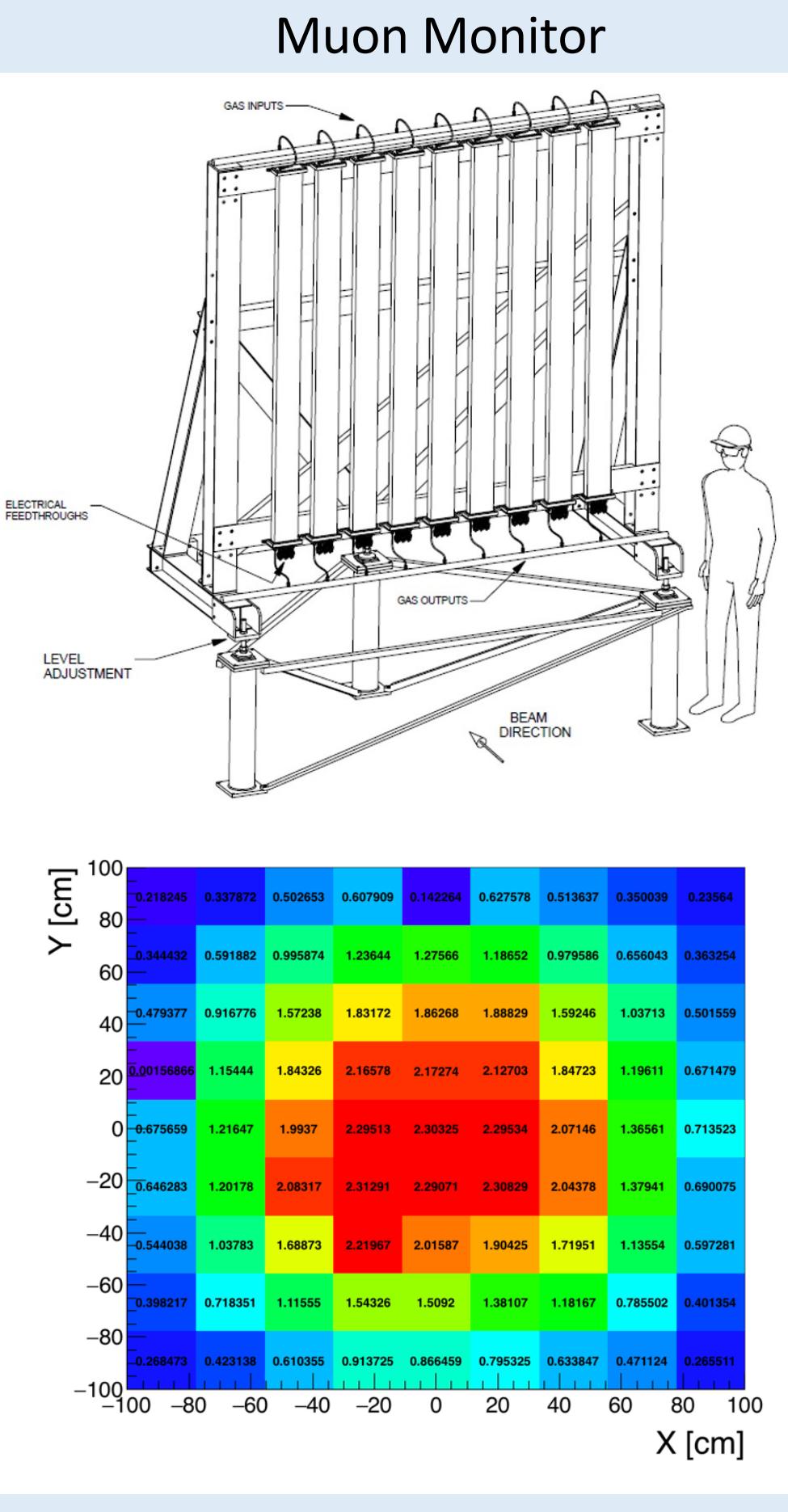


According to Monte Carlo (MC) simulation studies, MM1 has a good sensitivity to see the correlation of neutrino beam to muons.

$\pi^+ \rightarrow \mu^+ + \nu_\mu$

- Seen at nova detector
- Seen at muon monitor

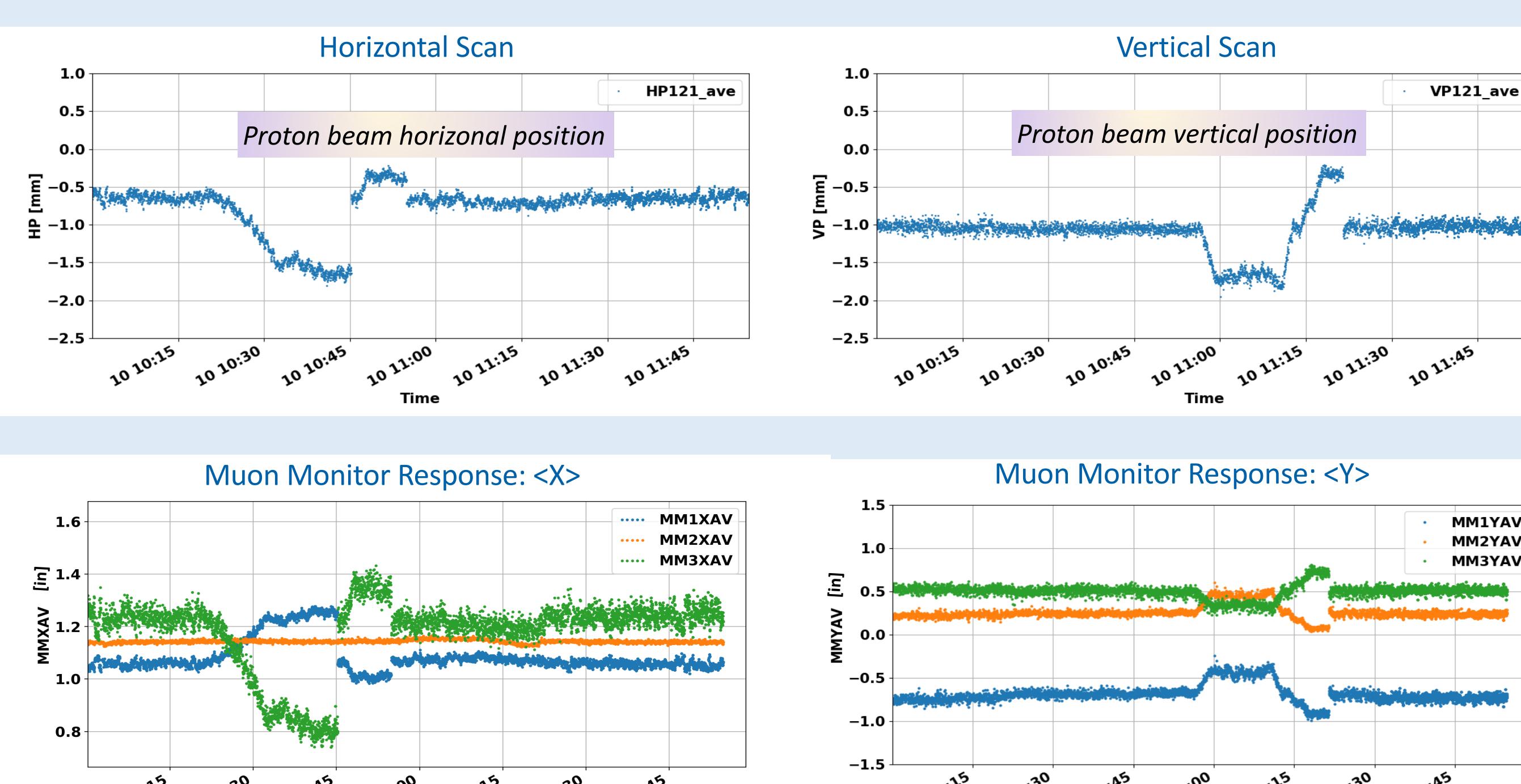
Muon Monitors



- Three muon monitors are located downstream of the hadron absorber
- Each muon monitor consists of a 9x9 array of ionization chambers
- Each ionization chamber consists of two parallel plate electrodes separated by a 3 mm gap
- The chambers are filled with He gas

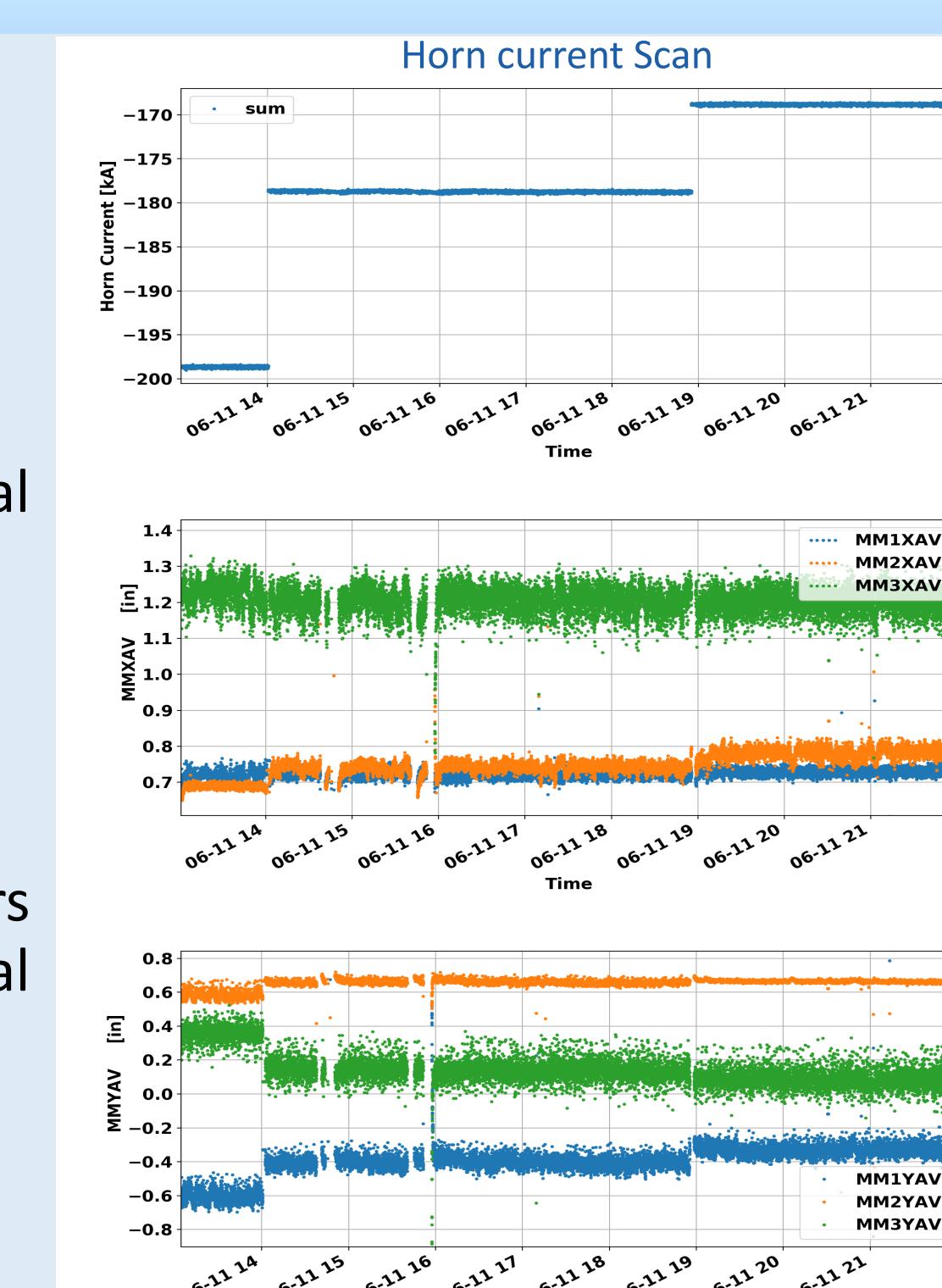
81 pixels of signal readouts on Muon Monitor 1

Target Scan Studies

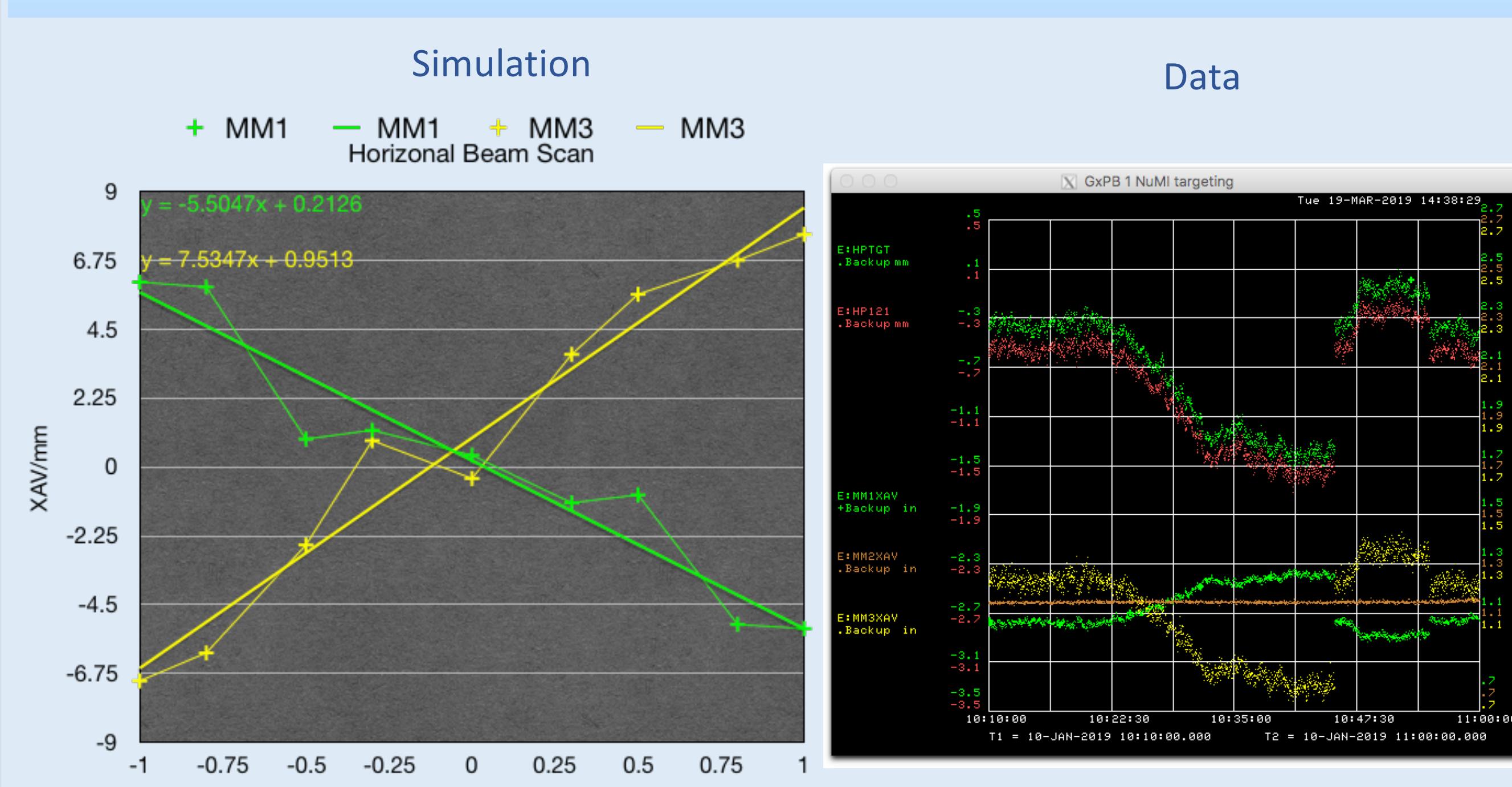


Horn Current Scan Studies

- Target scans show how each muon monitor responds to beam position variations in horizontal and vertical directions.
- Horn current scan shows muon monitors (especially the vertical position measurements) sensitive to horn current.

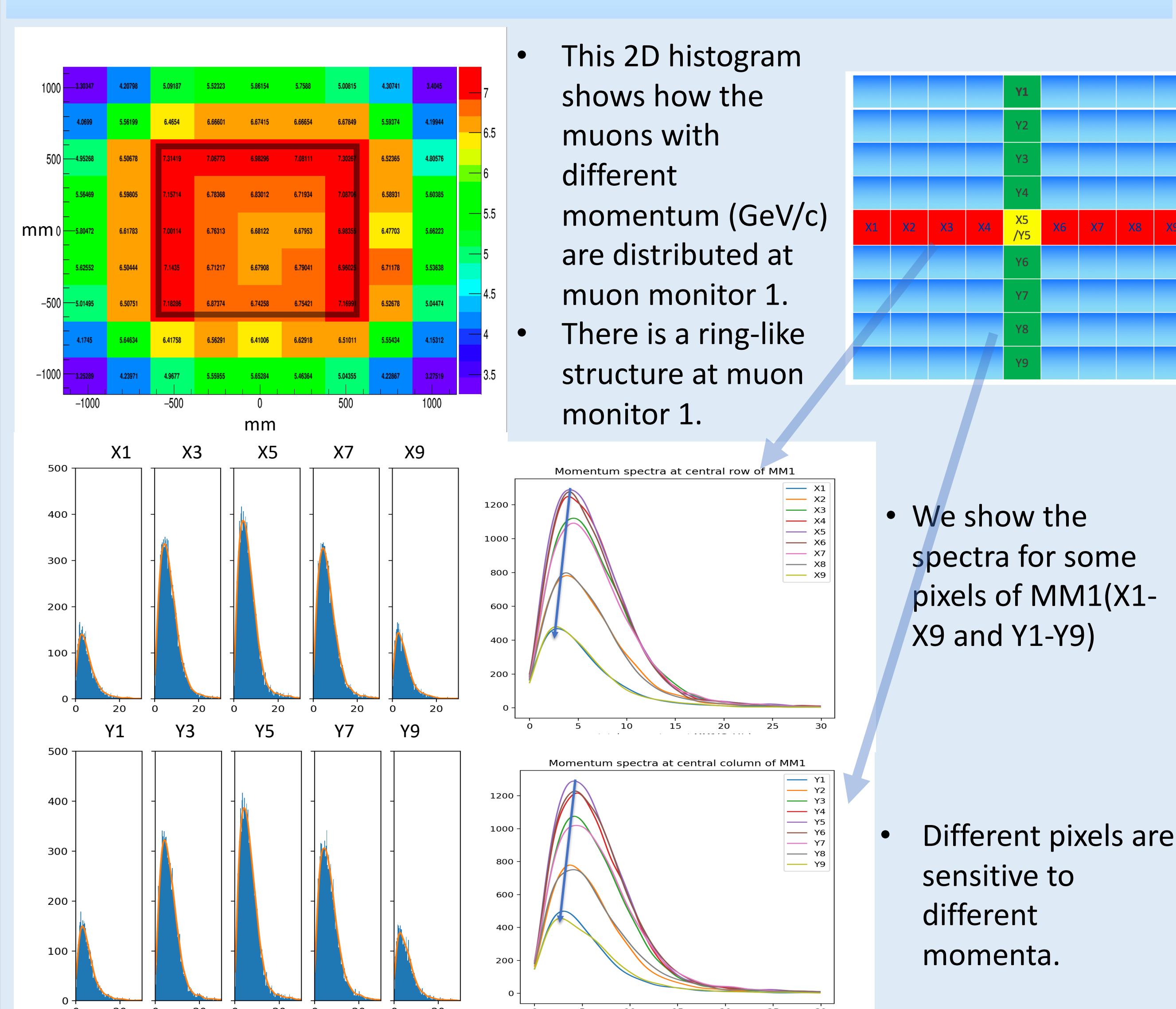


Target Scan Simulation



- Simulation results are consistent with horizontal beam scan data.

Spectra of Muons in Simulation



Machine Learning Applications to Monitor the Beam

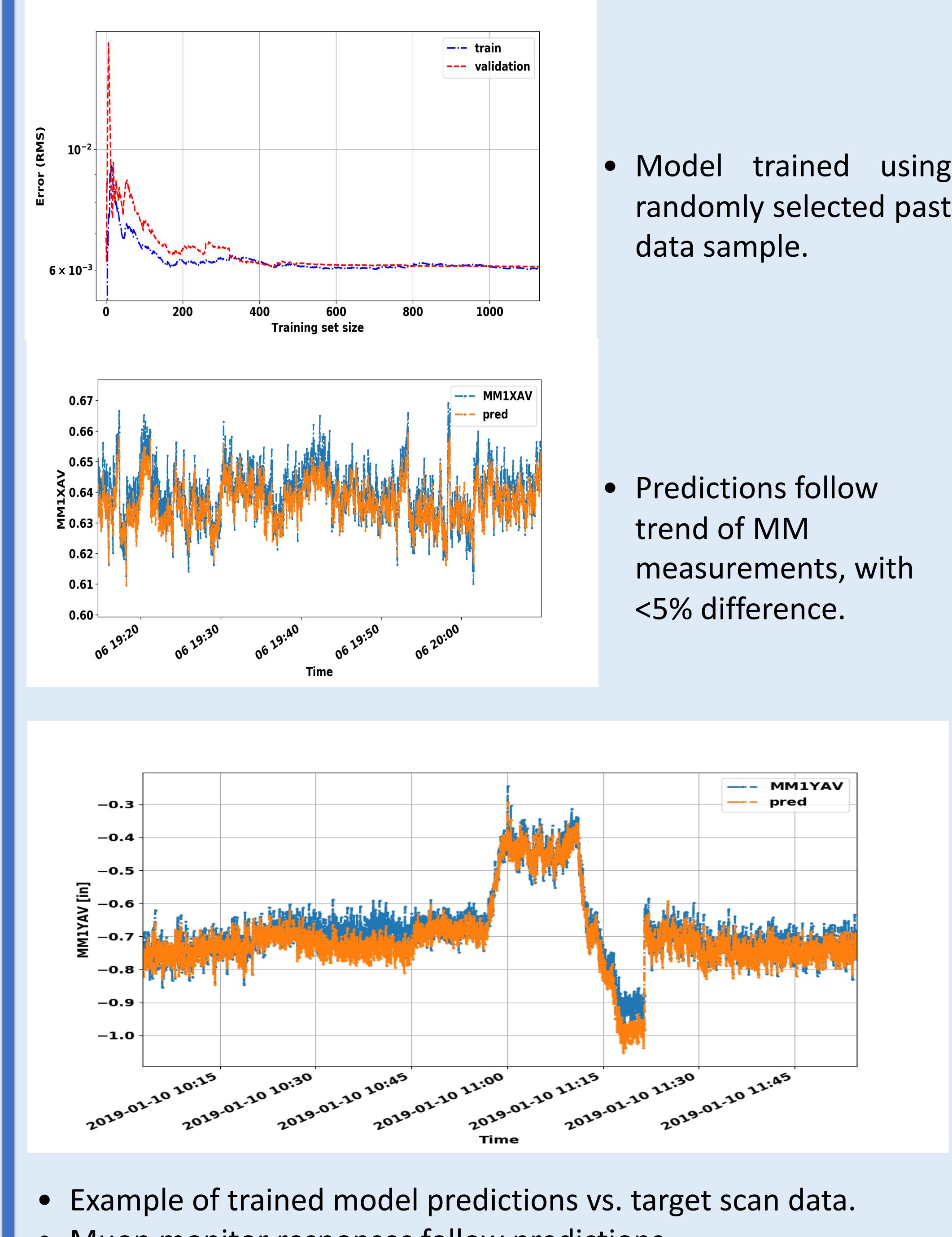
We are working on using ML algorithms to understand the neutrino beam variations with the help of the muon monitor data and simulation studies.

Example of muon beam centroid prediction with ML

The muon beam centroids in each muon monitor have been modeled vs. incident beam profile measurements and horn current data.

$\text{prediction} = f(x_b, y_b, \sigma_x, \sigma_y, p_{\text{beam}}, I_{\text{horn}})$

where x_b, y_b are the muon beam centroid coordinates, σ_x and σ_y are the beam sizes, p_{beam} is the number protons on target per spill, and I_{horn} is the horn current.



Reconstructed Spectra of Neutrinos in Simulation

- We simulate the spectra of neutrinos at NOvA Near Detector for different horn currents and beam positions on target in horizontal and vertical directions.
- Spectra insensitive to a 10 kA change in horn current(Flux and peak locations are quite stable).
- Flux depends asymmetrically on vertical position of beam.

