Muon Monitor Signal to Predict NuMI Beam Parameters and Horn Current by Applying Machine Learning Techniques

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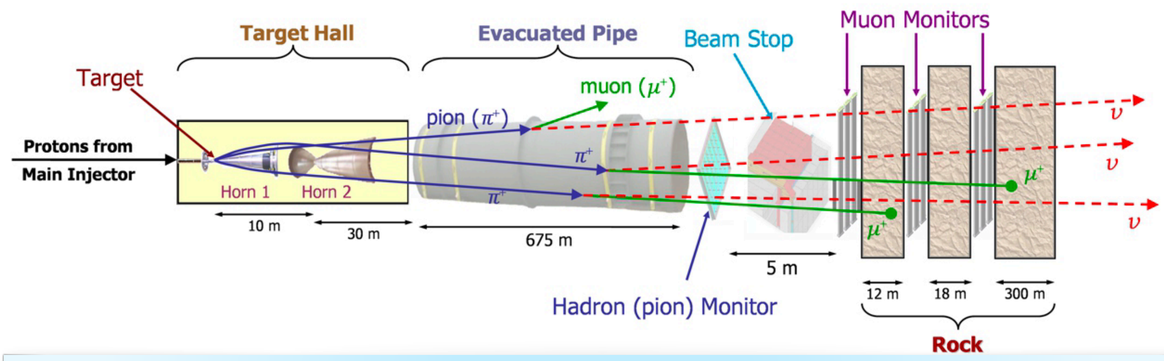
Introduction

A muon monitor which measures muon beam profile, is a key beam element to maintain the quality of muon neutrino beam. Three arrays of muon monitors located in the downstream of the hadron absorber provide the measurements of the primary beam quality. The responses of muon monitors have been used to implement Machine Learning (ML) algorithms to predict the beam parameters by spill-to-spill. In this work we demonstrate a ML application of predicting the beam position, beam intensity and horn current.

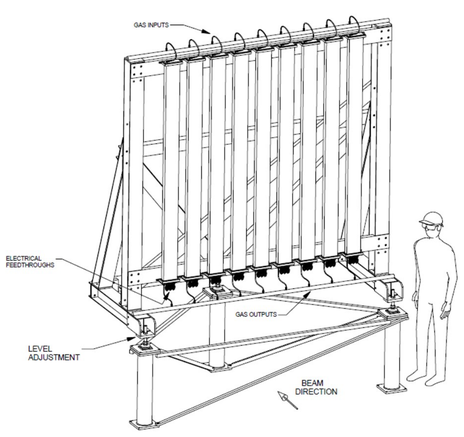
NuMI neutrino beam at Fermilab

120 GeV/c momentum protons from the Main Injector are striking with 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.

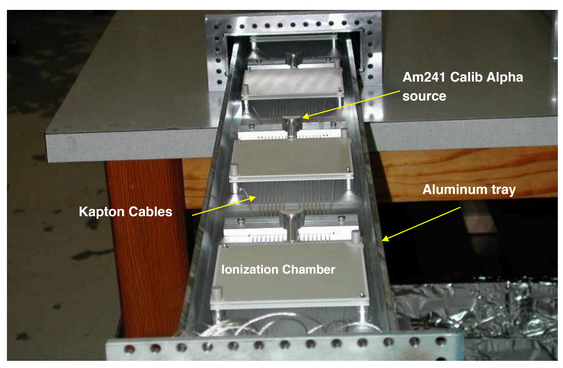


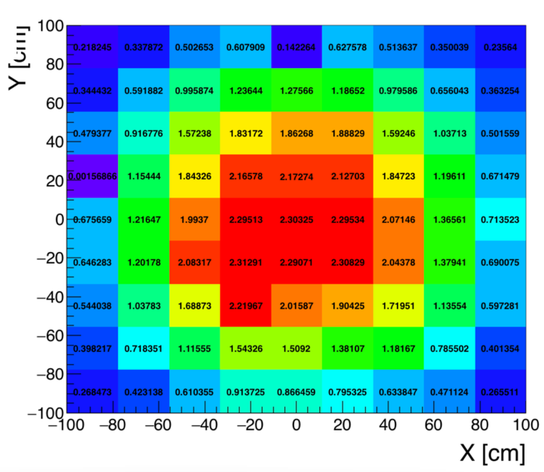
Muon Monitors

- Each muon monitor consists of 9×3 arrays of ionization chambers
- Each ionization chamber consists of two parallel plate electrodes with the separation of 3 mm gap
- The chambers are filled with He gas



Ionization chamber





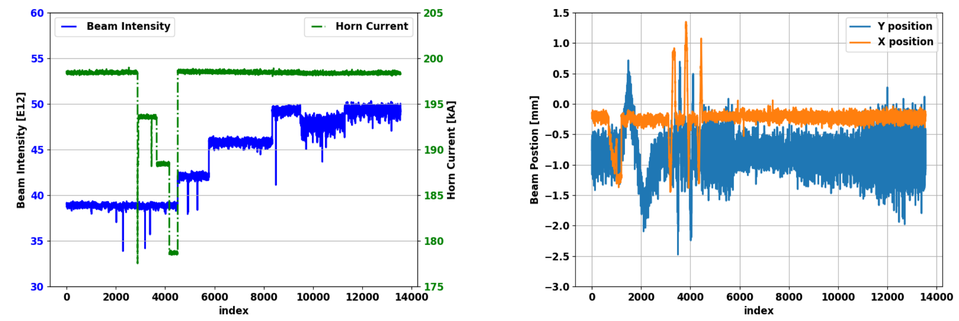
81 pixels of muon monitor signal readout

Data Preparation

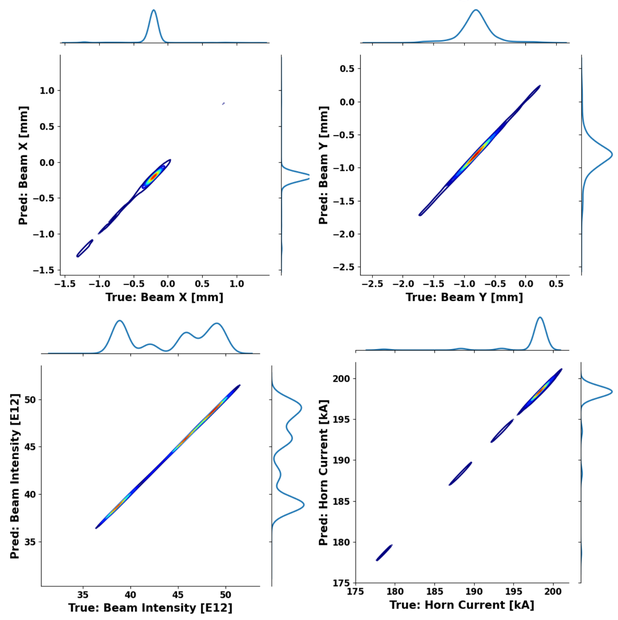
- The data samples have been collected from the spill-by-spill time series measurements of devices in the NuMI beamline for proton beam settings and horn current settings.
- Input variables: the pedestal subtracted signal measurements of 243 pixels of three muon monitors
- Output variables: horizontal and vertical proton beam positions at the target, beam intensity and horn current.
- The randomly sampled training (70%) and validation (30%) data samples were selected from the target scans and normal operations.

Machine Learning Model Building

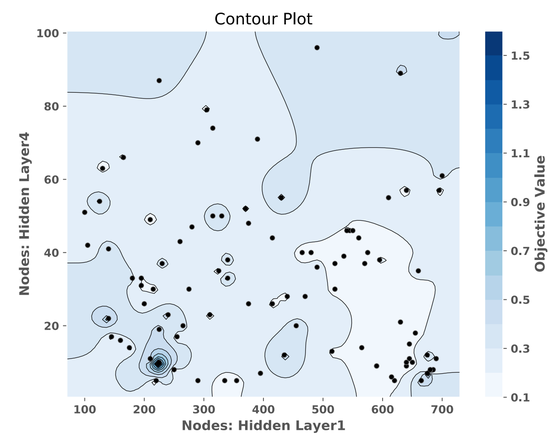
- The ML model architecture is defined as artificial neural network (ANN) with multiple hidden layers
- The model parameters are tuned based on Bayesian Optimization Algorithm



Training and validation data

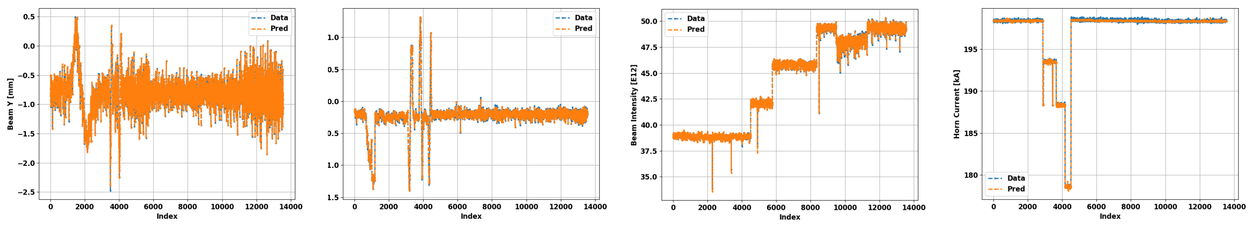


An example of searching the best model parameter space

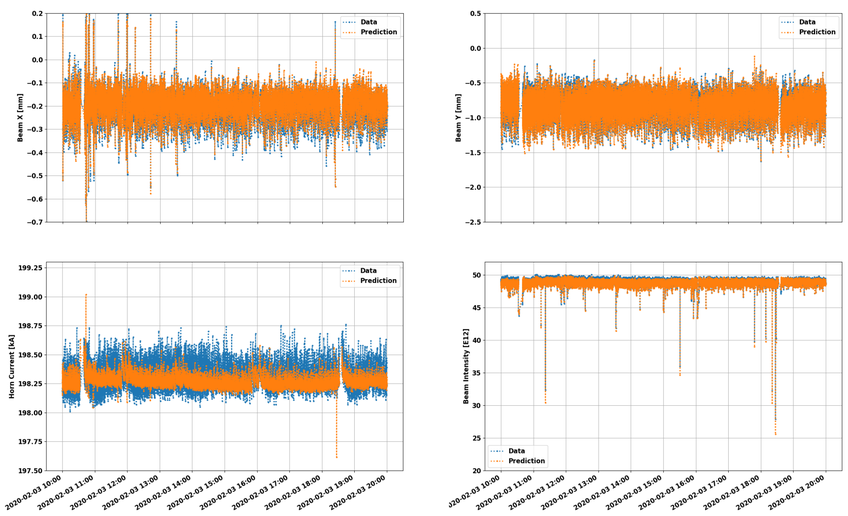


Model Testing and Validation

The model validation and performance testing have been done by using the randomly selected validation sample.



The model has been tested with randomly selected data sets for the normal beam operations



Remarks

- We demonstrate a machine learning approach to predict the beam parameters by using muon monitor signals
- ML predictions give extra measurement of the beam parameters and horn current for neutrino experiment
- Helpful to monitor the beam quality and issues
- Our results demonstrate the capability of developing useful ML applications for future beamlines such as DUNE
- This ML application will be useful to reduce the neutrino flux systematics with the help of simulation studies

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