Muon Monitors Quick Overview

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Current Personnel

- Alysia Marino, Eric Zimmerman, Zachary Liptak, Jeremy Lopez, several undergrads (Colorado)
- Geoff Mills (LANL)
- Chuck Lane (Drexel)
- Jan Boissevain

Conveners: Geoff Mills & Jeremy Lopez

Detectors

Three types:

1. Ionization detector array: options are likely gas, diamond & silicon
   - Purpose is to measure beam direction, muon flux (above 6 GeV)
2. Threshold gas Cherenkov detectors
   - Purpose is to measure the muon spectrum by scanning over the Cherenkov threshold and the detector orientation
3. Stopped muon counters
   - Purpose is to measure the muon rate at several specific energies, may be able to do some separation of mu/anti-mu signals

Prototypes

At NuMI Muon Alcove 2:

- 3 diamond detectors borrowed from CNGS beam
- Cherenkov detector

At Colorado:

- Stopped muon detector prototype (just completed, still need gated base for running at NuMI)
- Small Cherenkov detector (run on cosmics)
- Bare diamonds (to see if we can build detectors, run them more cheaply), silicon photodiode (none of these have been used yet)

WG Goals

1. Evaluate the requirements on the Muon Monitors system for neutrino beam monitoring and for its potential use for neutrino flux prediction. Discuss possible limitations on the measurements due to the absorber design
2. Document the status of the present design and development of the proposed muon monitors detectors, including beam test results. Generate a plan for future detector developments and beam tests.
3. Simulate the response of the Muon Monitors detectors in the LBNF beamline and quantitatively assess their performance for neutrino beam monitoring and possibly as an aid in neutrino flux prediction

CDR Physics Goals

1. Determine absolute muon flux greater than 6 GeV to 5% accuracy - try to use to constrain beam ν_e backgrounds
2. Measure the beam direction to within 0.2 mrad (beam centroid to within 5 cm) - keep uncertainty below 1% in different energy bins

Physics Goals

The numbers are with an old beamline design and the physics goals should be driven by what is most useful for the DUNE physics program, and oscillation physics in particular.

1. How dependent on the beamline design are these numbers?
2. Are these realistic goals or aspirational goals?
3. What are the bare minimum requirements that we absolutely need for the muon monitors? What work might need to be done to determine these requirements?
4. What are the goals that we would like to achieve? Do we need to redefine our goals from those in the DUNE CDR?

Detectors Questions

- How stable do detectors need to operate (currently get shot-by-shot total flux to a precision of ¡1% in diamond and Cherenkov detectors at NuMI) to achieve our goals: Need to run simulations of LBNF beam with some toy detector simulation to see what kind of gain fluctuations or noise we can handle
- How long do individual detectors need to last? (In T2K, Si detectors need to be replaced about every $4x10^20$ POT or so). Need particle fluxes downstream of the absorber to determine how long we expect detectors to last. Diamonds cannot be replaced often due to the huge expense of purchasing them.
- Are there any issues that might crop up with a high power beam (nonlinear response in gas detectors, for example)? This may depend on the expected beam structure
- What kinds of calibrations/monitoring do we need?
- What kind of readout do we need? (integrated total signal, time samples across the spill, etc)

Practical Physics Questions

- How much does the absorber design affect what can be done with muon monitors? If a sizeable fraction of muons originate in the absorber, this may make it difficult to constrain the neutrino flux at the near/far detectors. It may alsi affect the beamline direction
- What kind of uncertainties do we get with just the beam simulation and no muon monitors? (i.e. what does a 5% absolute flux measurement or a spectrum at X% uncertainty per bin buy us for flux uncertainties?)
- How do we prepare muon data for inclusion into the flux model? Should we be thinking about this now?

Work Strategy

There are several things being worked on right now:

- Detector prototypes/hardware work
- Detector simulation (standalone, at NuMI, at LBNF)

This is mostly aimed at evaluation and recommendation of detector technologies, which is maybe a somewhat long term goal.
What are the near term goals that people would like to see from the muon monitors WG?
My suggestion: Building some infrastructure for evaluating what a generic muon system can provide (i.e. build infrastructure for quantitative evaluation of how muon measurements affect beam uncertainties in the oscillation analysis).

Anything Else?

Any other discussion