MINERvA is a dedicated neutrino-nucleus cross-section experiment in the NuMI Beamline

### NuMI Beamline Ingredients:
- 120 GeV Protons
- 2 interaction length graphite target
- 2 Al Horns
- Fe Decay Pipe

**Muon Monitors**

Different sources of neutrinos have to be constrained by different measurements:
- *Primary* $p ightarrow K^+ 
u$, constrained by hadron production data
- *Secondary* and *tertiary* $\pi$ in constrained by FTFP model, uncertainty evaluated by comparing different models

**Current Flux Constraints**

**Hadron Production: NA49**

NA49, a hadron production experiment at CERN, measured pion production with 158 GeV protons on a thin graphite target. These data (plot at left) cover the relevant kinematics for the NuMI Beam (plot below).

**Tertiary Production**

Different hadron cascade models predict different neutrino fluxes from tertiary pion production, as shown in the two plots below. Note the 30% variations at the focusing peak.

**Beam Focusing**

Uncertainties in beamline alignment and horn magnetic field are estimated to be small at minimum bias, but are significant (8%) at fall-off of focusing peak (see plot at right).

**Overall Rate Constraint:**

Simple final state and well understood cross-sections provide overall flux constraint. The challenge is to isolate the signal from background events. EIP provides discrimination, as shown at right. Estimated statistical precision for MINERvA LE Run: ~10% (Ref: J. Park, NuFact’12)

**New Hadron Production Measurements: NA61**

In order to improve its flux prediction, MINERvA (and other NuMI-based experiments and LBNE) are collaborating with NA61, a new hadron production experiment at CERN. Plans for taking data with 120 GeV protons on a thick NuMI target are underway.

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**Table at right shows sizes of various sources of pions that produce neutrinos, integrated over all energies.**

<table>
<thead>
<tr>
<th>Source</th>
<th>Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Hall Chase [air]</td>
<td>2.2%</td>
</tr>
<tr>
<td>Decay Pipe Walls [Fe]</td>
<td>2.6%</td>
</tr>
<tr>
<td>Target Fins (84.4%)</td>
<td>89.0%</td>
</tr>
<tr>
<td>Budal Monitor (4.6%)</td>
<td></td>
</tr>
</tbody>
</table>

**CURRENT FLUX CONSTRAINTS**

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