Need for NA61/SHINE measurements for the Fermilab neutrino programme

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USNA61
23 October, 2012

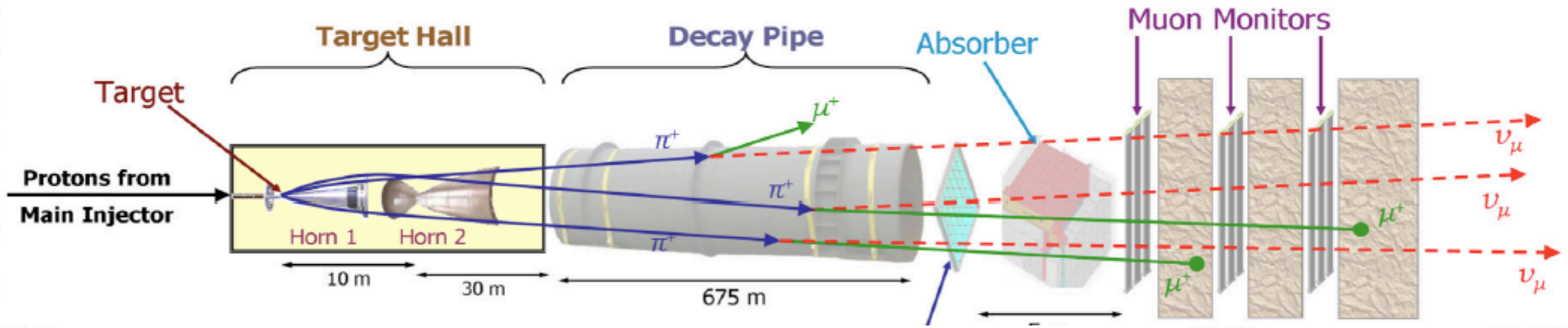
Fermilab Neutrino Program(me)

- 120 GeV primary proton beam:
  - MINOS
    - On-axis Far-Near ratio oscillation measurement, graphite target
  - Minerva
    - Cross section measurements, graphite target
  - Nova:
    - Off-axis Far-Near ratio oscillation measurement, graphite target
  - LBNE
    - On-axis oscillation measurement, graphite target
- 8 GeV booster beam
  - MicroBooNE

Different Needs

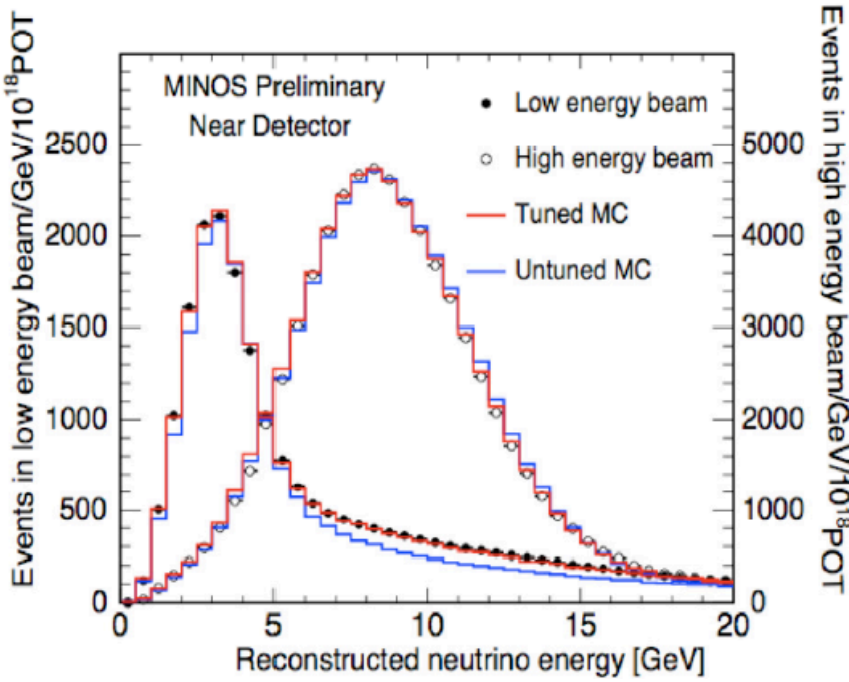
- Oscillation experiments with two detectors:
  - Near detector allows characterization of neutrino rates directly ("tuning" of the simulation)
  - Horn itself can be used as a crude charged particle spectrometer by varying target positions and currents, and looking at changes in the near-detector neutrino rates (e.g. MINOS and Nova) since neutrino rate is high
- Cross section experiments and oscillation experiments with one detector:
  - One must characterize the neutrino flux indirectly (e.g. Minerva, MicroBooNE, and LBNE)
  - This is a much more challenging task
- *While there are many techniques for controlling neutrino flux uncertainties, the consensus is that good hadron production measurements are essential*

Ex. NuMI Neutrino Beamline

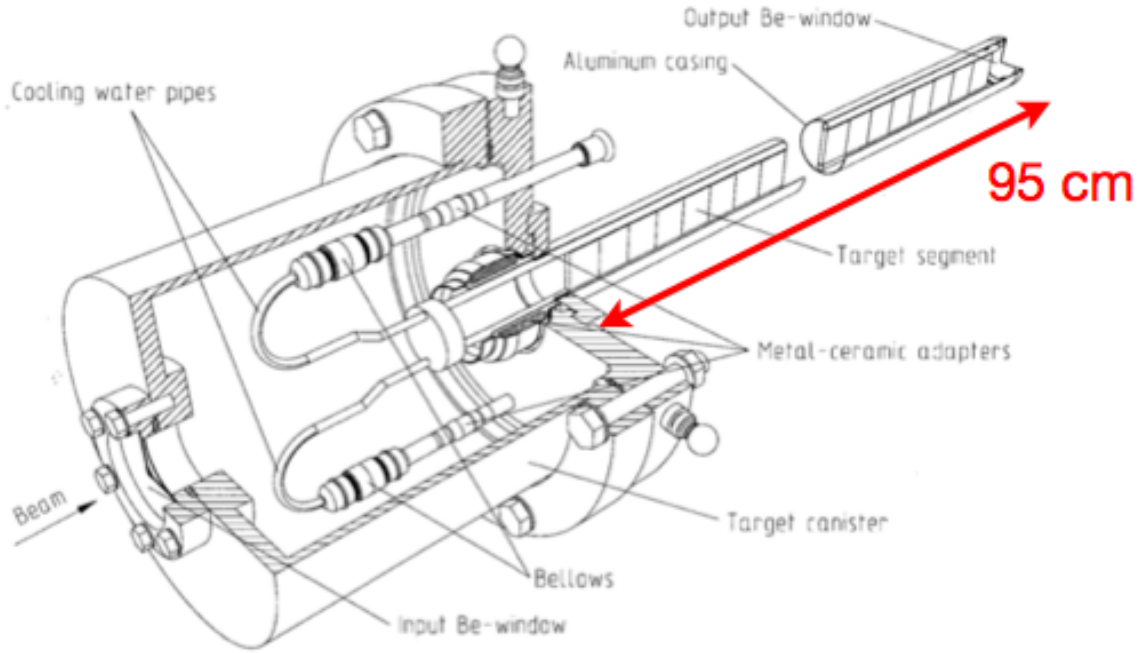


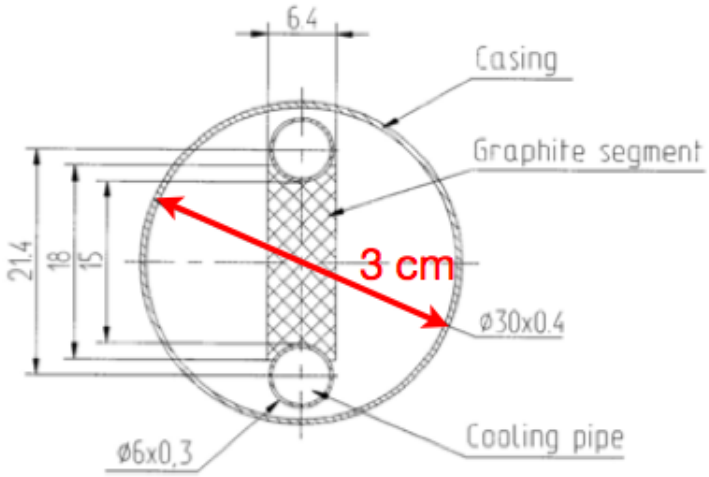
- 120 GeV Protons from Main Injector impinge on a graphite target to produce π, K
- Beam energy spectrum can be modified by varying the relative positions of target and horns
- Most data taken in the "Low Energy" configuration, which optimizes L/E for the measurement of Δm^2_{atm}
- Beam composition in the LE configuration:

91.8% ν_μ, 6.9% $\bar{\nu}_\mu$, 1.3% $\nu_e + \bar{\nu}_e$



Ex. NuMI Target





- Rectangular shape 6.4mm X 15 mm
- Metal cooling pipes
- 0.4mm thick aluminum sheath

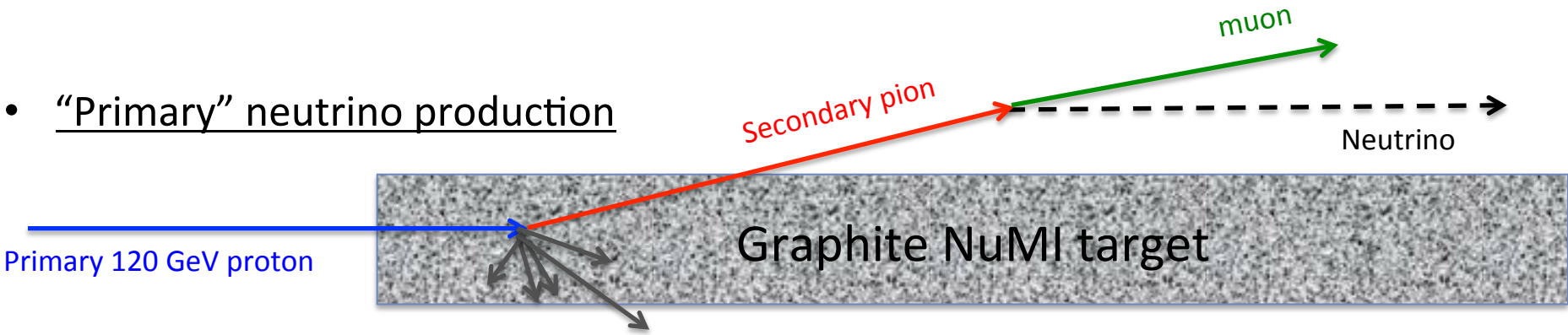
(from D. Schmitz)

Hadron Production

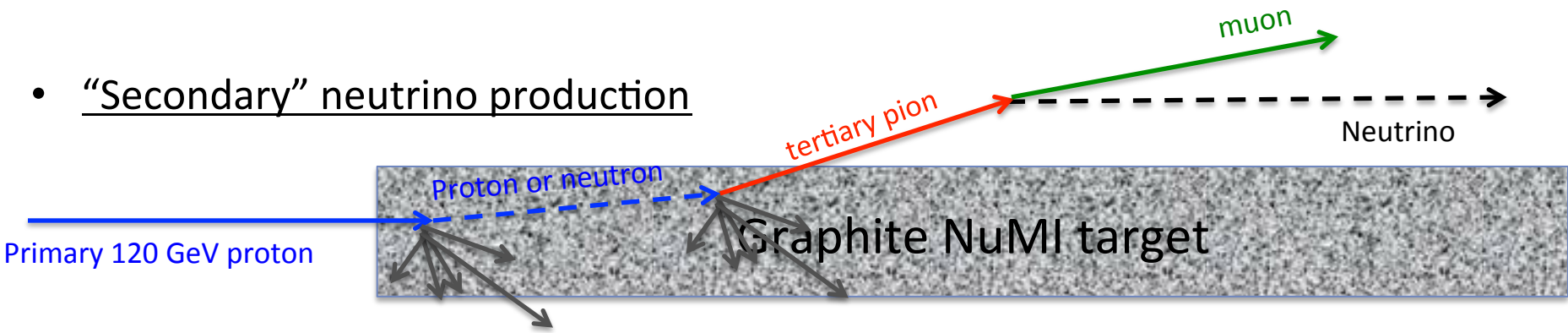
- Typically the largest source of uncertainty in neutrino flux predictions for "wide-band" (horn focused) beams
- It is not obvious why this is the case, but clearly there is no first-principle calculation for hadron production
- Currently empirical models (scaling) are used
  - They are only as good as the input data
  - Extrapolation errors are difficult to control

Neutrino Production

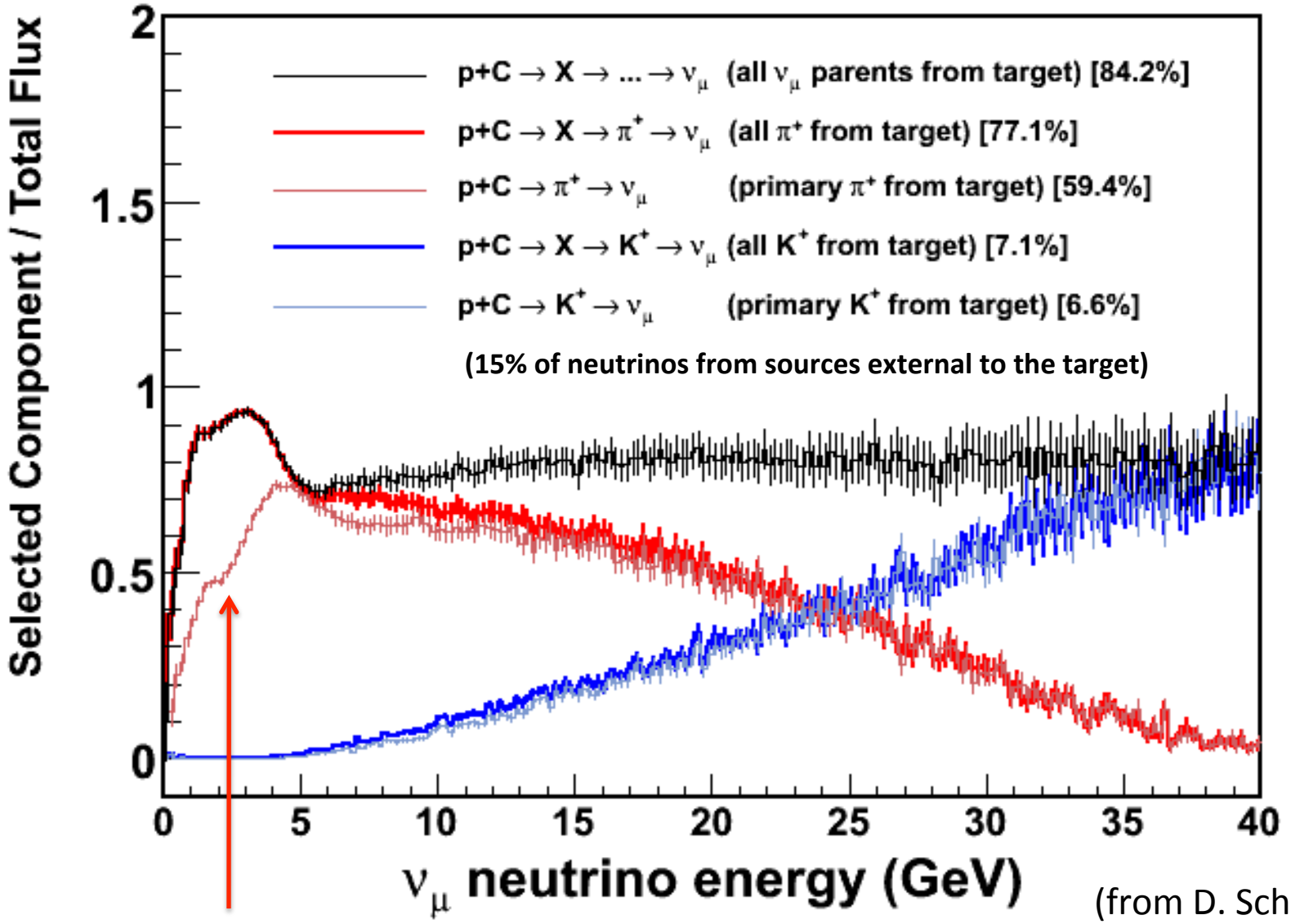
- "Primary" neutrino production



- "Secondary" neutrino production



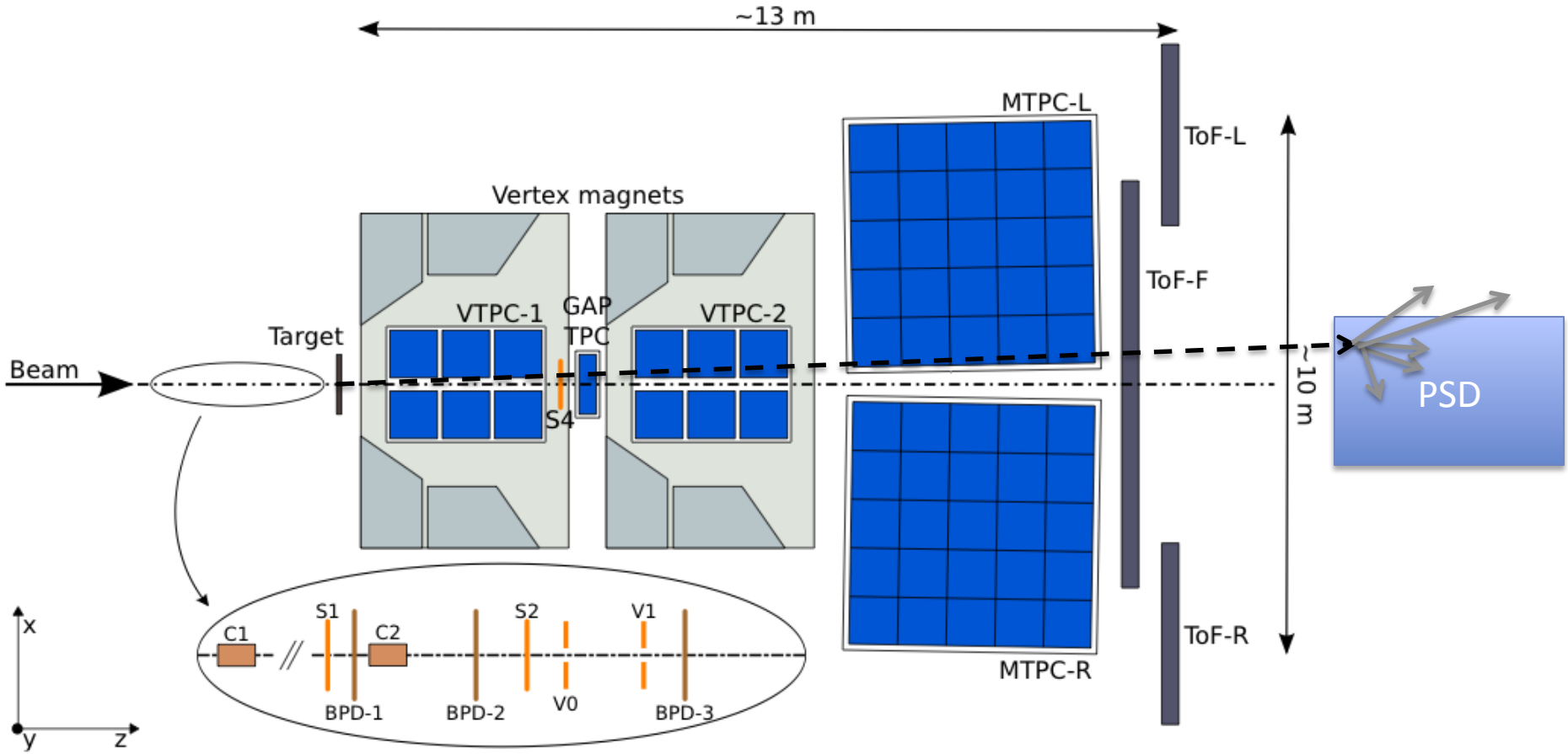
Fractional NuMI Fluxes



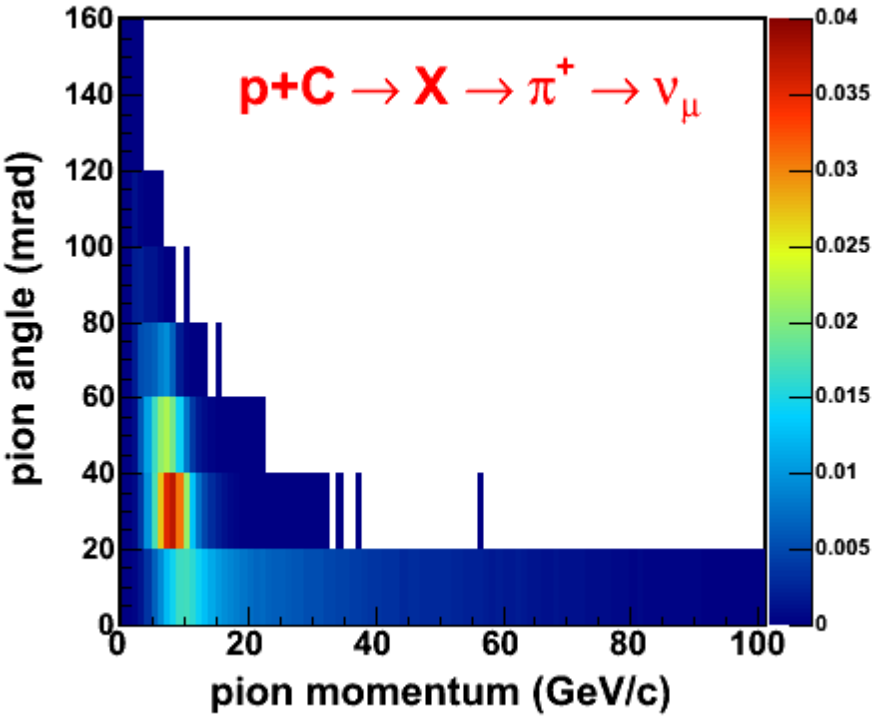
(from D. Schmitz)

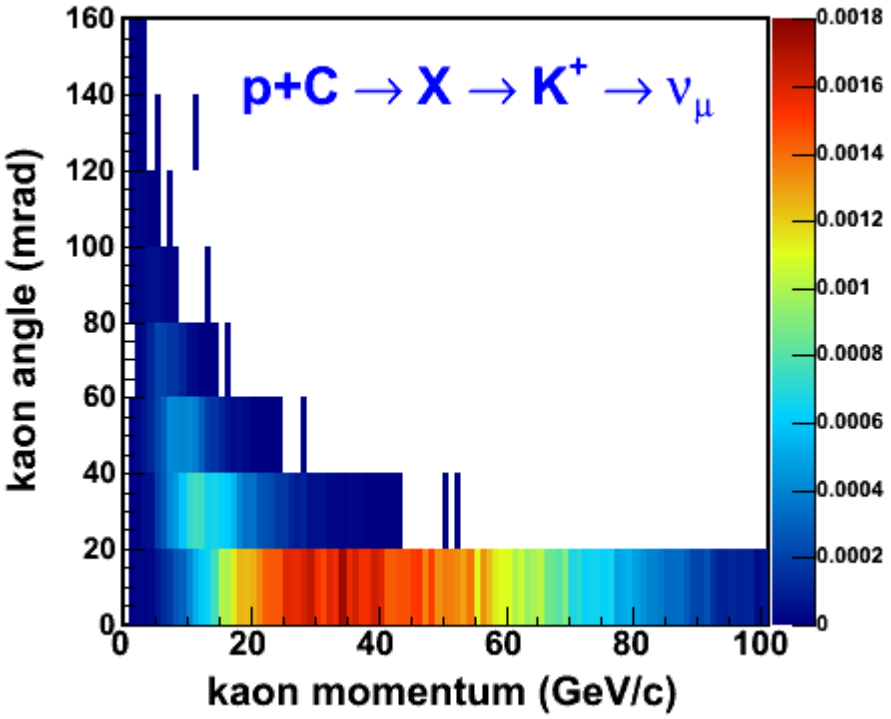
This is the piece one directly constrains with the NA49 data, though in a slightly model dependent way since it is at 158 GeV/c

NA61 Detector



NuMI Meson Parent Kinematics

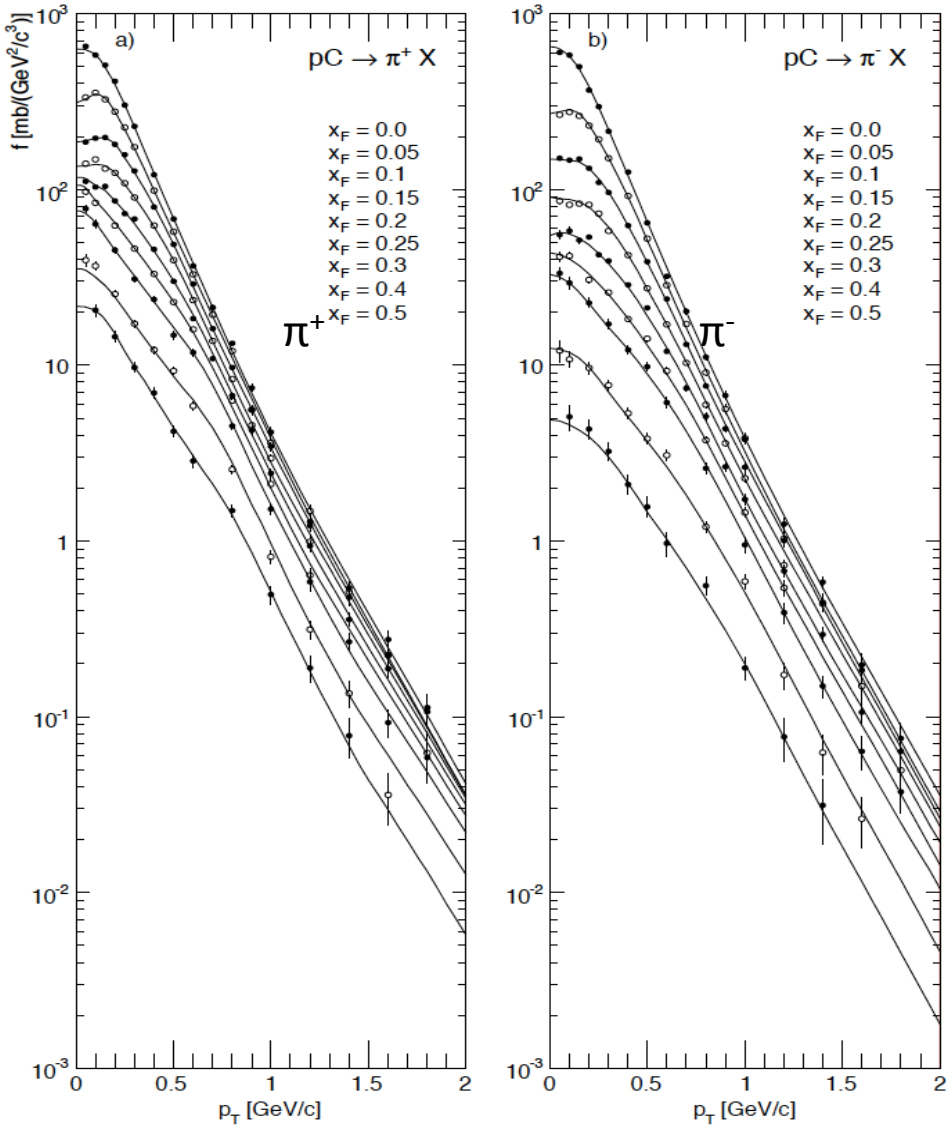




- Pions and kaons coming out of the target structure that create a ν_μ in NuMI Near Detector

(from D. Schmitz)

Existing Proton-C Data



- NA49 data at 158 GeV/c
  - Probably the best data available nearby 120 GeV but must be extrapolated to lower energy
  - Lacks very forward production

LOI Submitted to DOE

US participation in the NA61/SHINE experiment at CERN

Letter of Intent

May 2, 2012

Abstract

This is a Letter of Intent to develop a limited-scope collaboration with the NA61/SHINE experiment at CERN to exploit its unique capabilities for particle production measurements. This effort would allow the US group to collect dedicated and optimized high-precision hadron production data needed for improved neutrino beams modeling necessary for ongoing and future experiments at Fermilab. The ultimate goal of this effort is to expose thin targets and replicas of targets used at Fermilab to the NA61 hadron beam to accumulate a suitably large sample of events to provide a data set which would be essential for future neutrino beams.

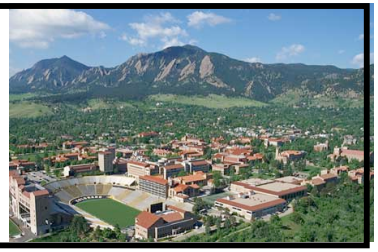
(please refer to the supporting documentation)

Pilot Run in June 2012

- Brought several senior researchers, postdocs, and students (8 total) to CERN to participate in NA61 startup and shifts
- Began integrating with calibration effort (TPC's and other systems)
- Setup of 120 GeV/c beam
- In July, approximately 3.5 million triggers of p-C (thin) at 120 GeV/c were recorded
- non-standard magnet configuration (Vtx-1 off)
- Helping with software modernization and QA

US Pilot Run Members

University of Colorado
Alysia Marino,
Scott Johnson
T2K, LBNE



University of Pittsburgh
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Los Alamos National Lab
Geoffrey Mills, Elena Guardincerri, Kevin Yarritu
MiniBooNE, LBNE

College of William and Mary
Leonidas Aliaga
Minerva

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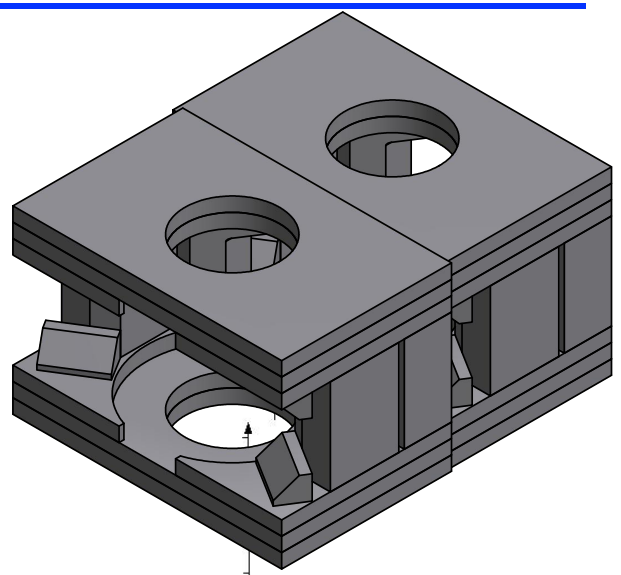
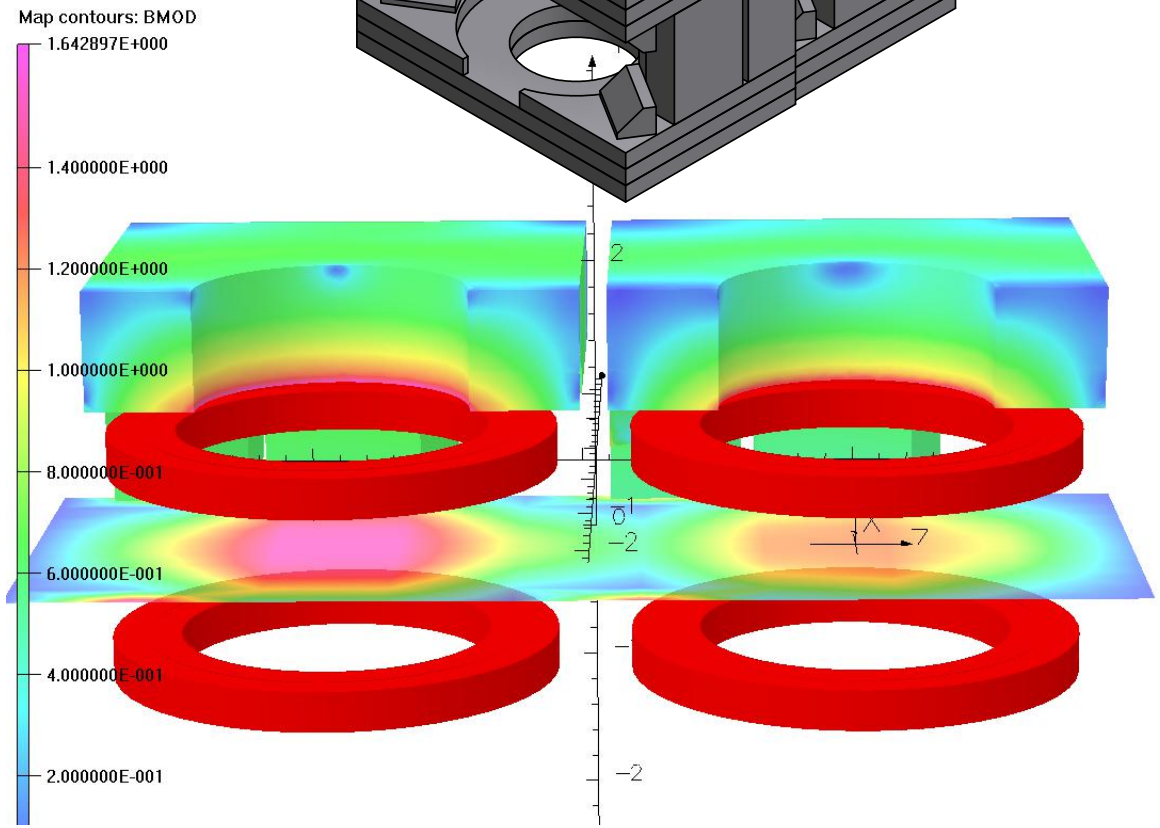
Magnetic Field Calculations

- Generated new 3D model
- New field maps with OPERA/TOSCA
- Extension of field maps into steel regions





Future Plans

- In the process of evaluating NA61 capabilities in order to plan for possible additions or upgrades
  - DAQ or new instrumentation (?)
- More data with different energies and/or target designs could occur in 2014 and 2015 but will depend on the direction the neutrino community takes
  - Beryllium targets, thick graphite targets, lower energy settings
- Review process:
  - DOE proposal in 6 months
  - Addendum to NA61 proposal Oct-Nov 2013 (SPSC)

USNA61 Collaboration

The US NA61 Collaboration

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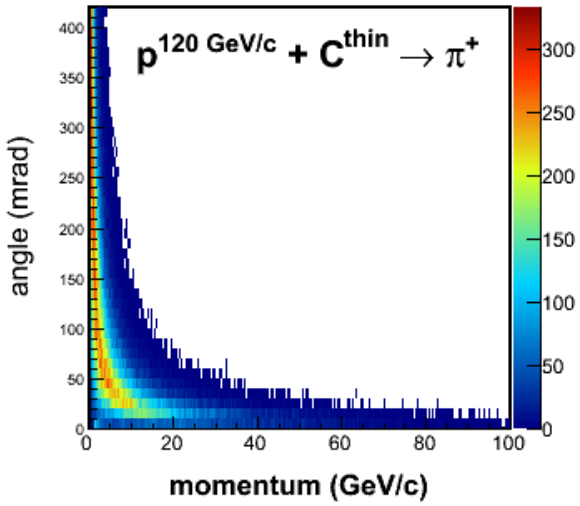
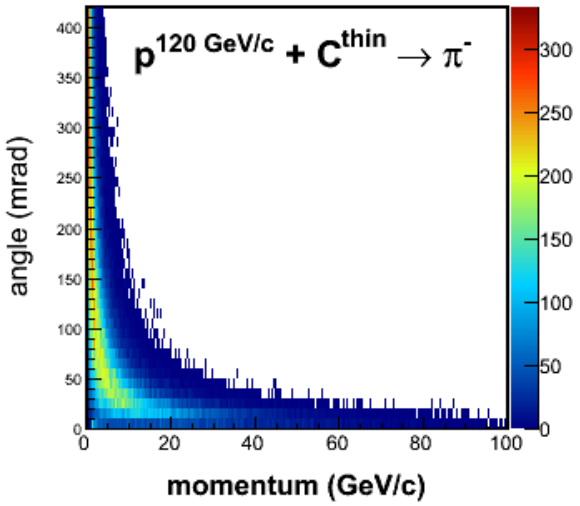
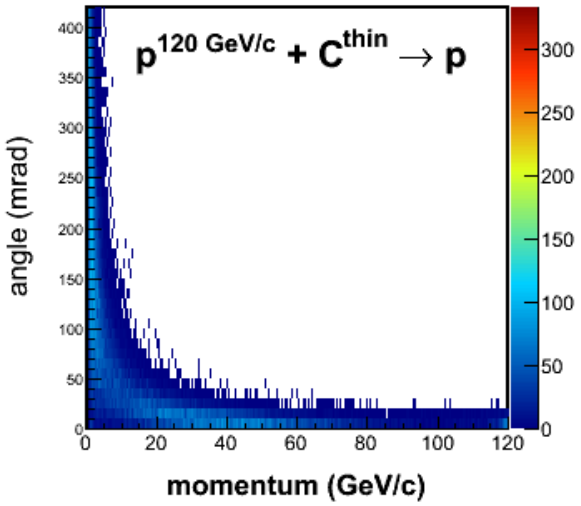
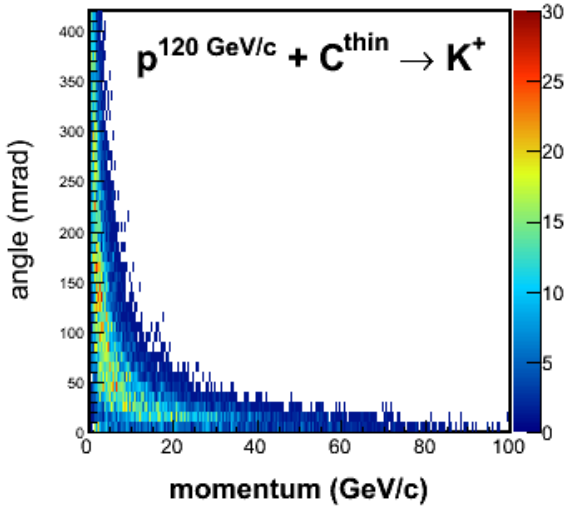
REFERENCE SLIDES

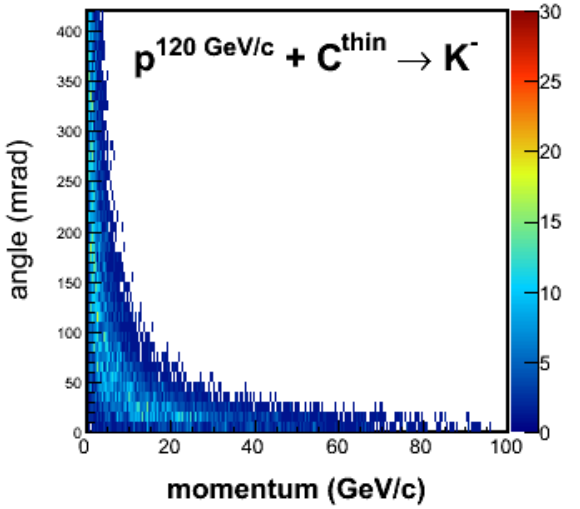
Particle Production Spectra from MC

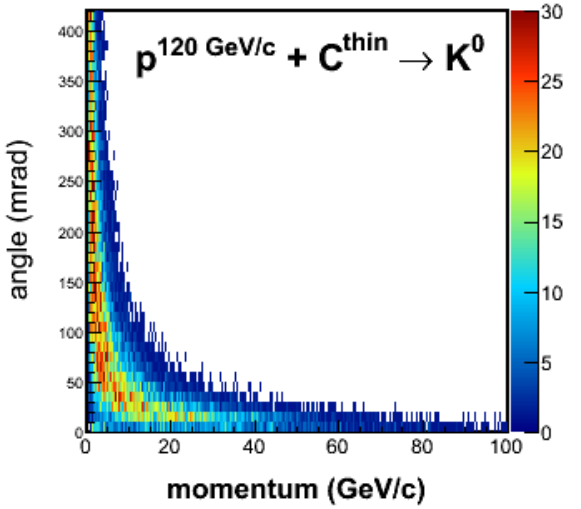








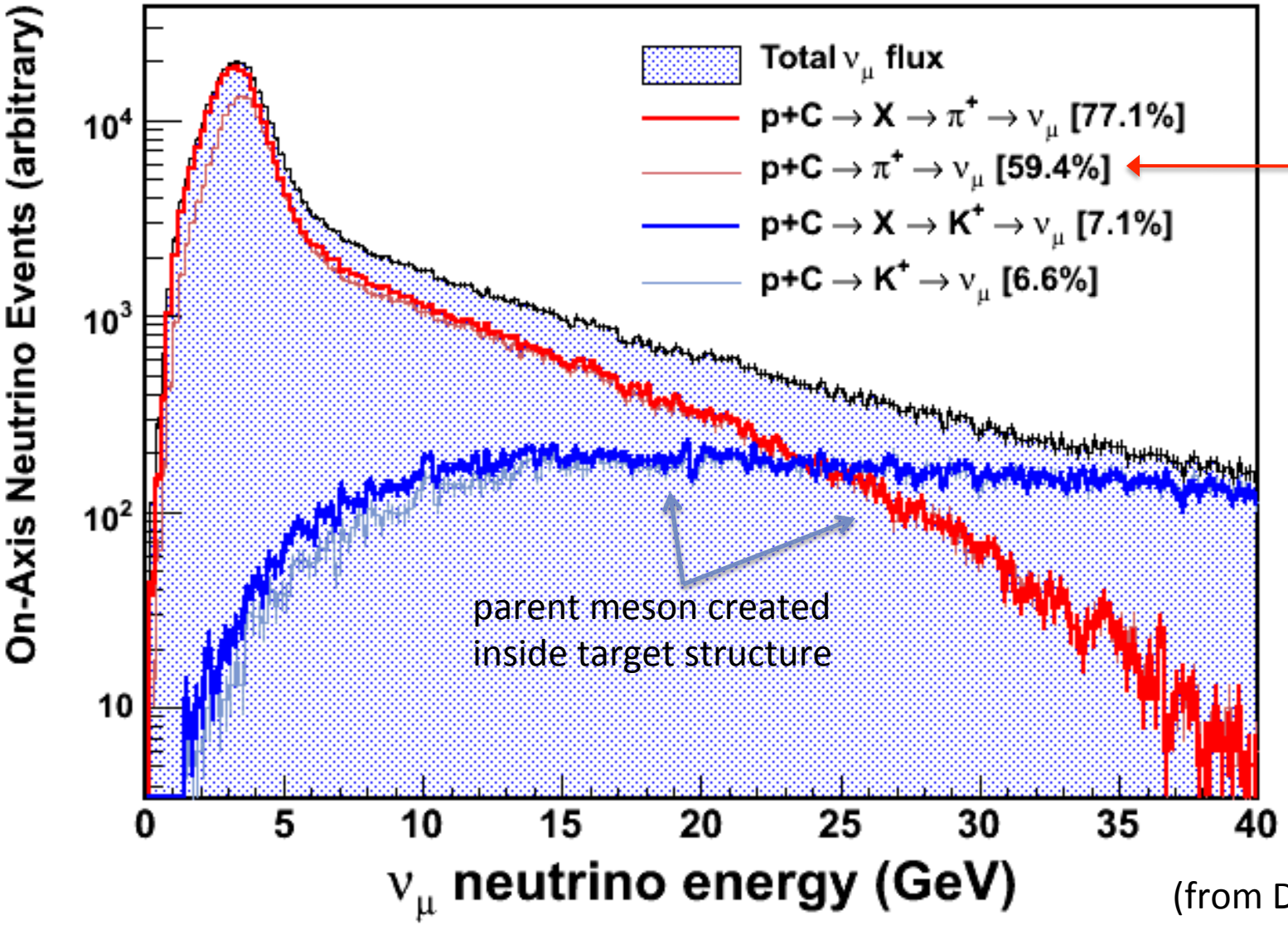




(from D. Schmitz)

*MC samples (thin/thick, pion/proton) all generated by Leo Aliaga

NuMI Flux



can be compared to 90.3% in Booster beamline

(from D. Schmitz)