Mark Messier
Harvard University
NBI2002, CERN
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Latest News On NuMI Beam Simulation

- Basics of LE beam
- Attempt to optimize for flux
- Variable target position
- Commissioning studies
- Hadron production

NuMI Monte Carlos

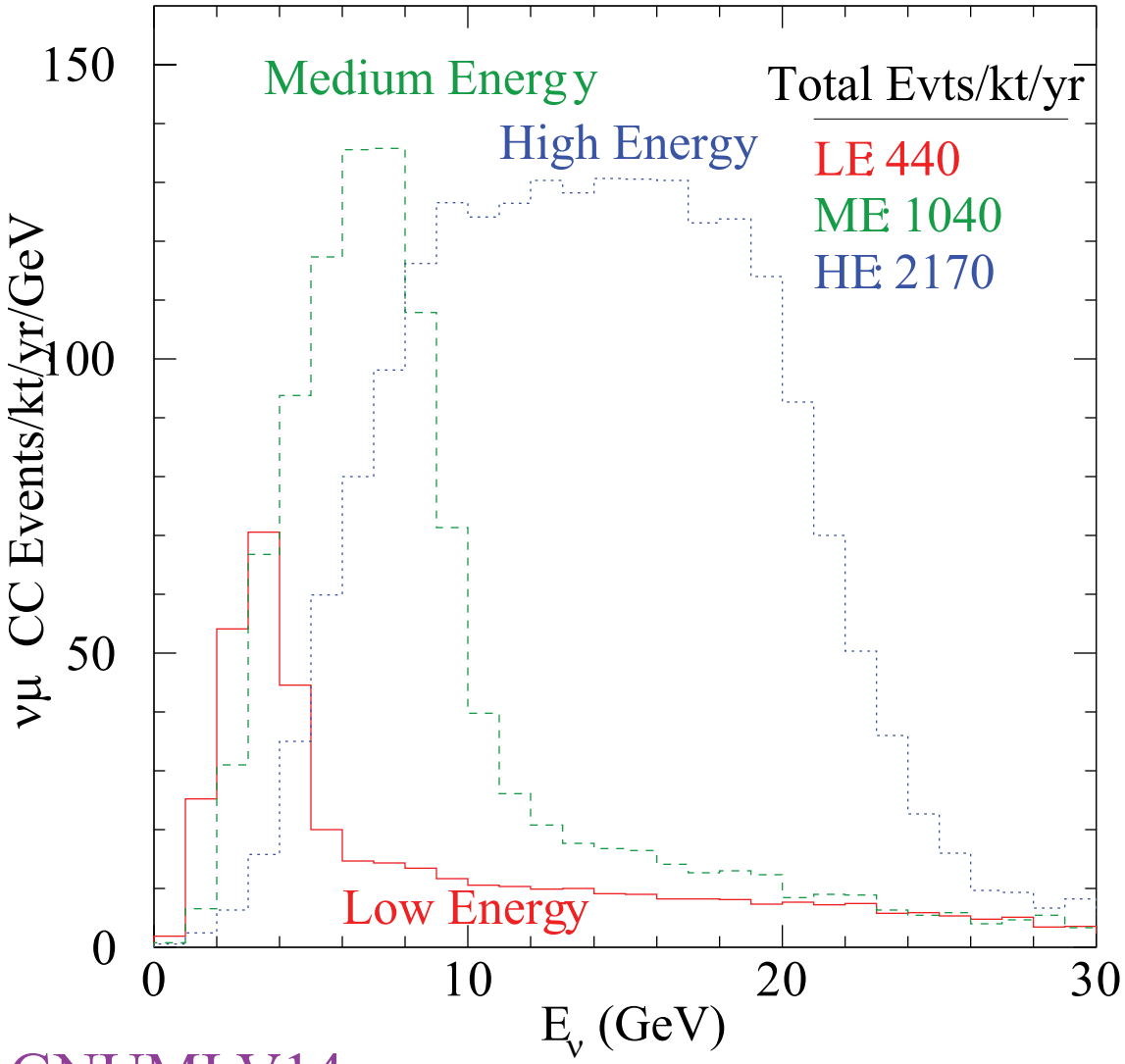
NuMI currently uses three MC's for beam

GNUMI - GEANT3/GEANT-FLUKA based
- Used for prediction of all neutrino species
- No hard coded geometry
- All information about decays stored
- Inputs from own target simulation or particle list

PBEAM - Fast parametric MC for muon neutrino fluxes
- Used for quick optimization studies and alignment
- Used to generate muon inputs for GNUMI
- Approximate treatment of multiple scattering and absorption
- Fast! 100x GNUMI

MARS - Fermilab FLUKA equivalent
- Used for radiation protection and energy deposition calculations
- Also used to simulate target cascade as input to GNUMI

Latest NuMI Spectra

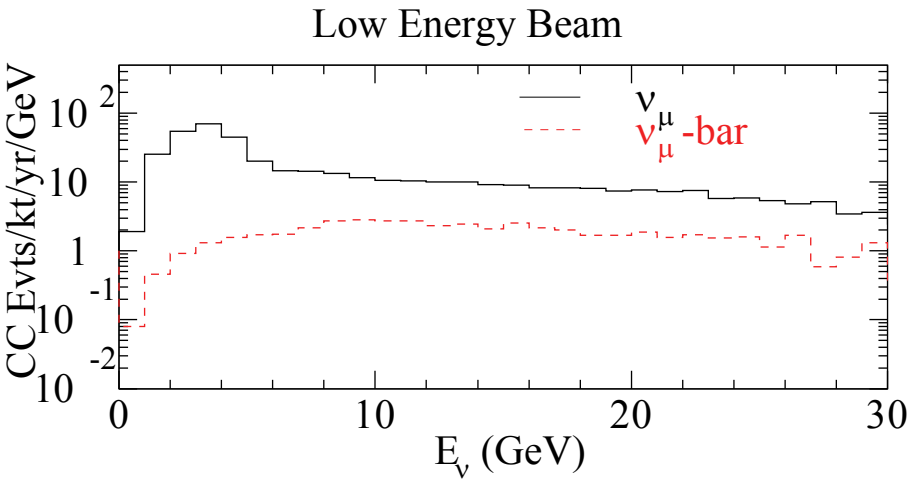


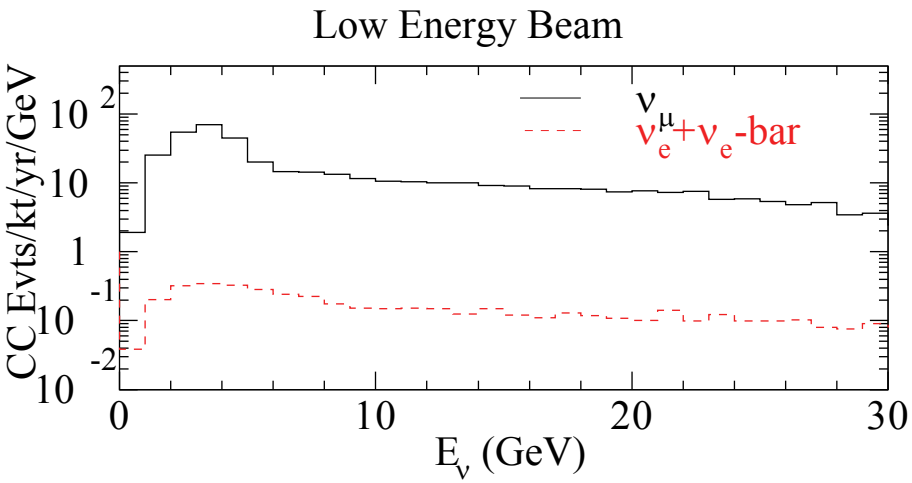
GNUMI V14

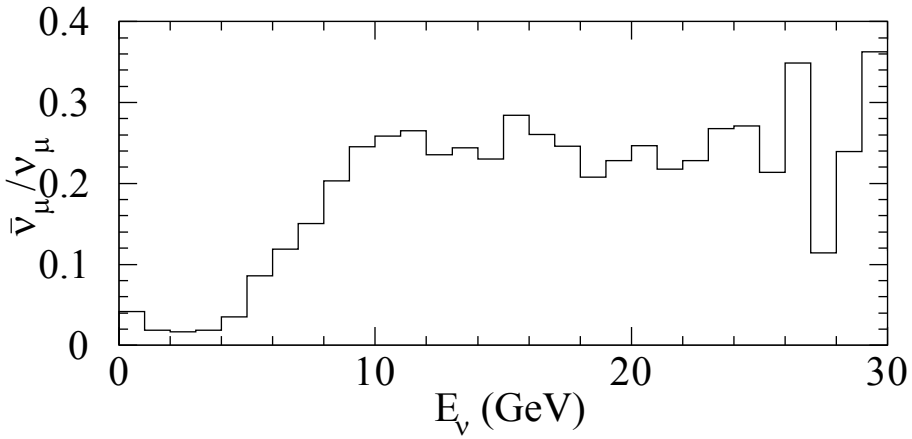
GEANT-FLUKA Target Model

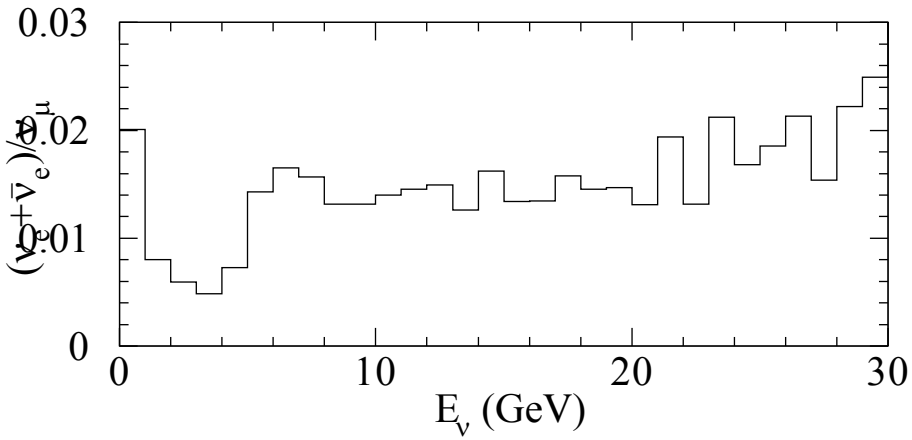
Physics results not updated. Still beam changes to put in...

Low Energy Beam Composition

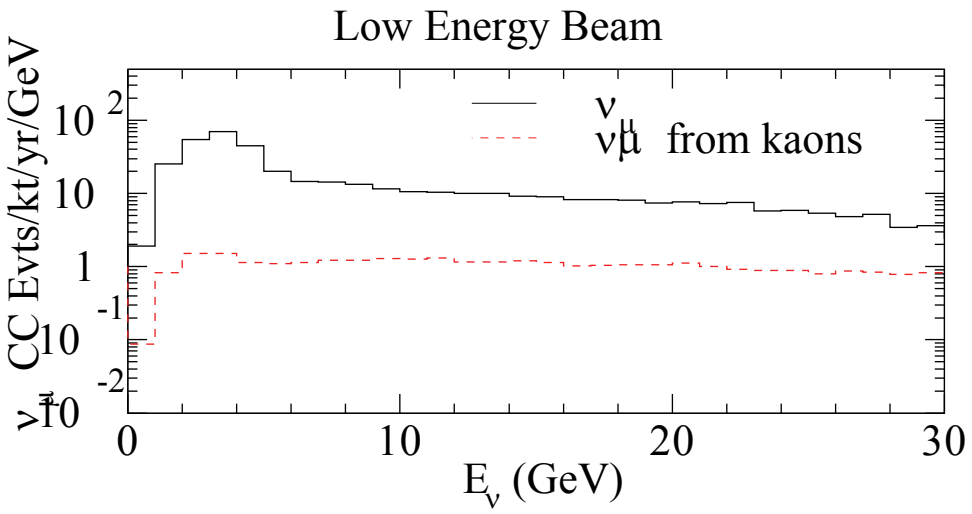


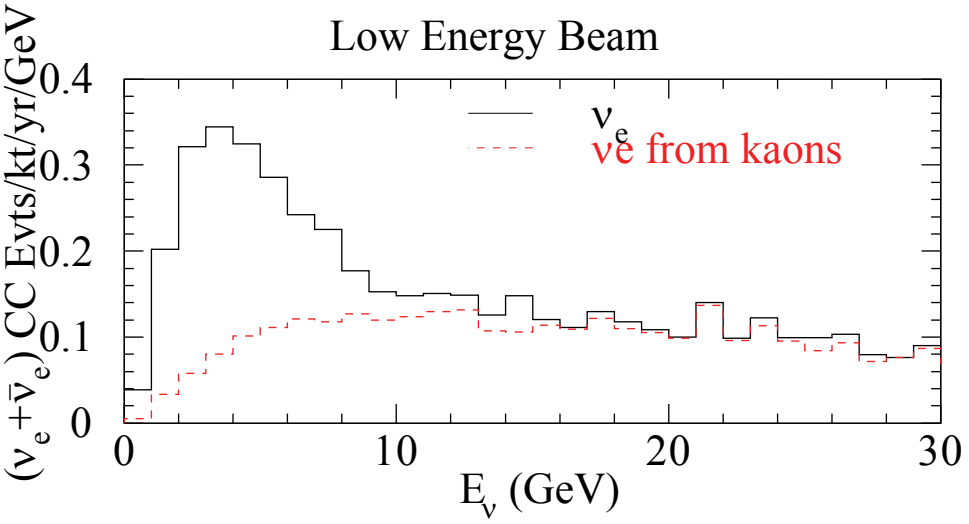


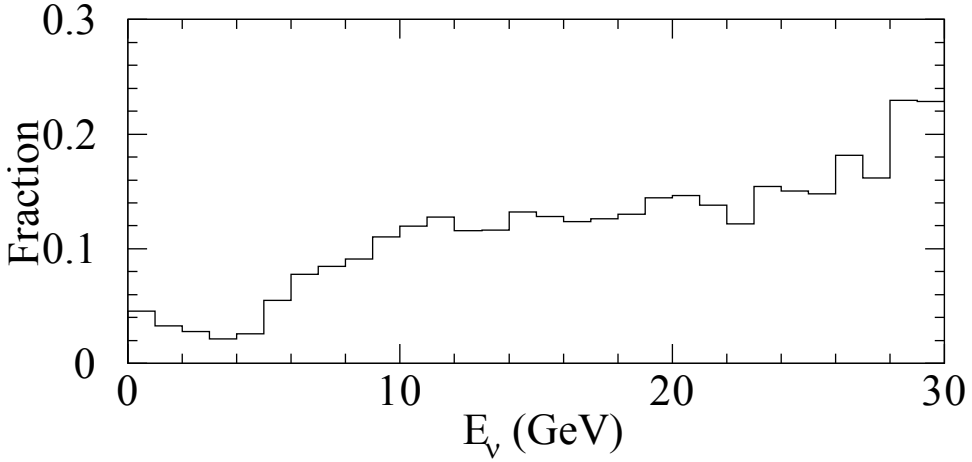


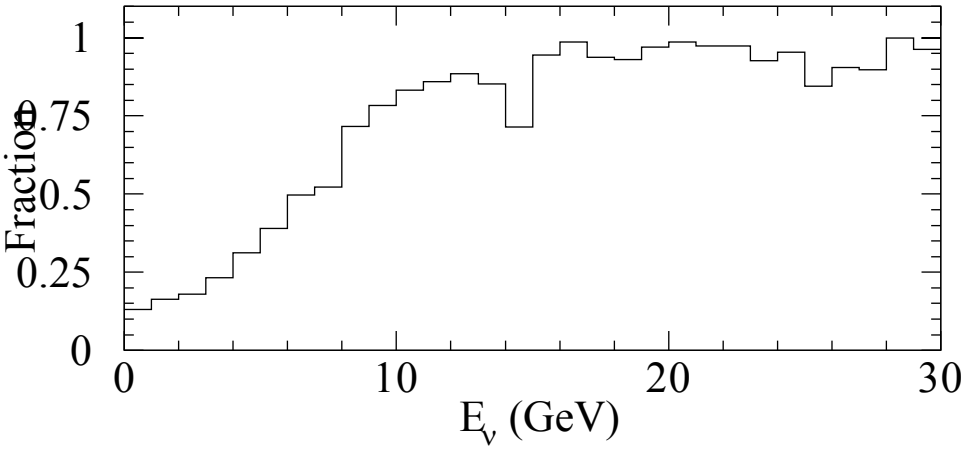


LE Beam Kaon Contribution



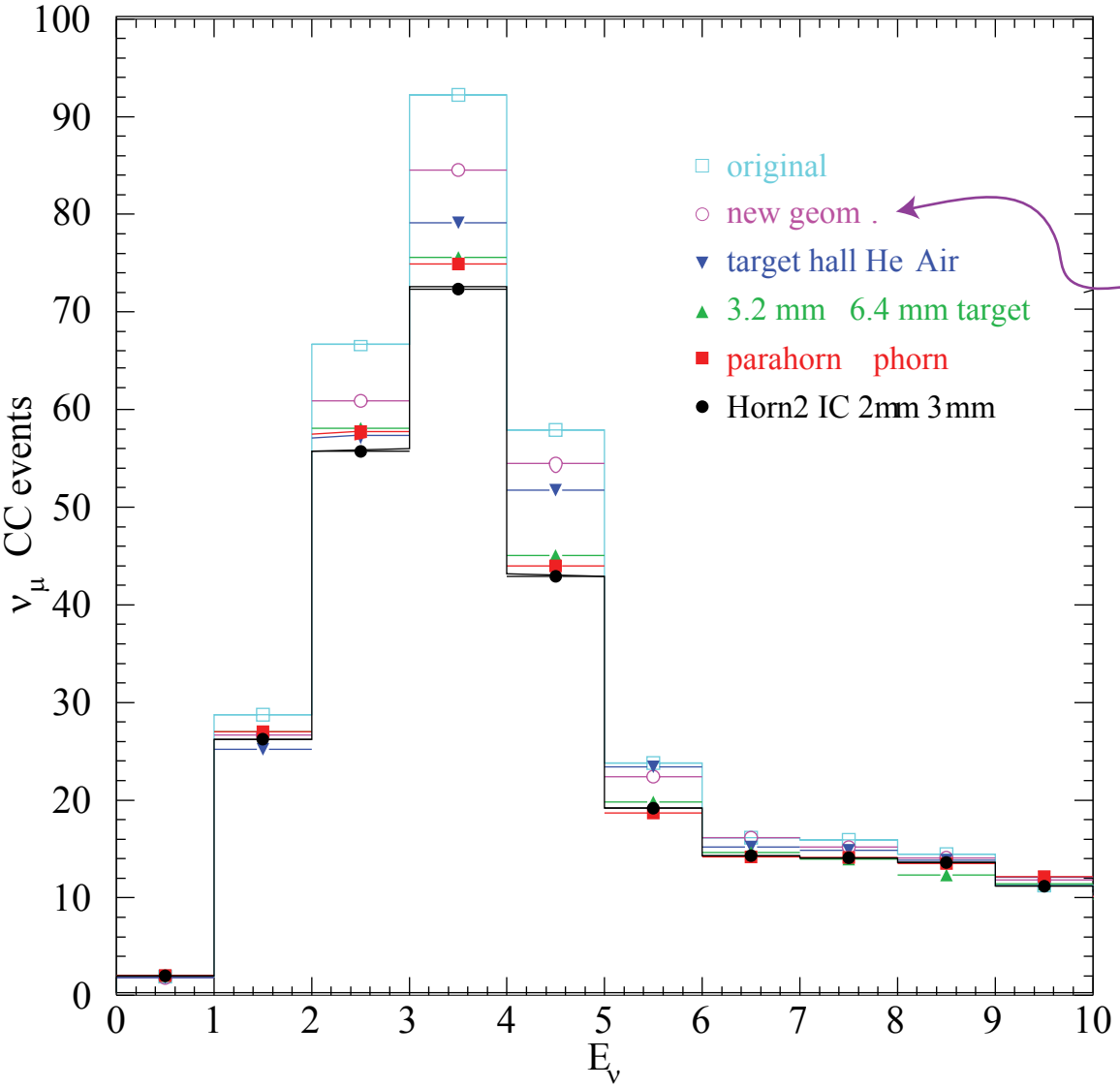






Geometry Update

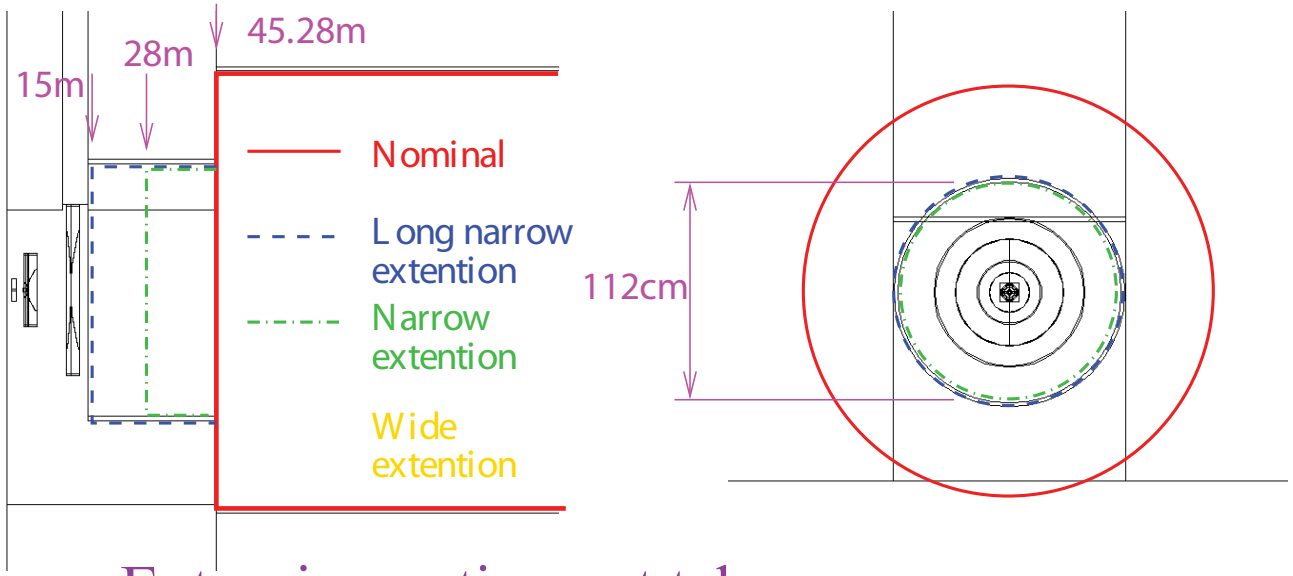
- Summer last year undertook comprehensive audit of beam line geometry to bring 'official' spectra inline with current design
- Plot shows effect of each change applied cumulatively



Chase area reduced and distance to Soudan changed (both ~1% effects) Rest is due to increased decay pipe window thickness!

Decay Pipe Extension

- ME and HE beams are not optimized for current SK and K2K oscillation parameters
- Considered giving up optimal ME and HE beams in favor of more LE flux
- ME and HE beams still possible via target shifts



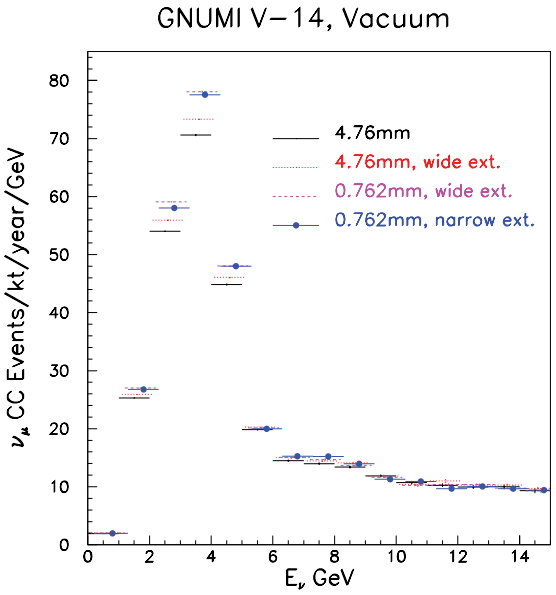
Extension option not taken

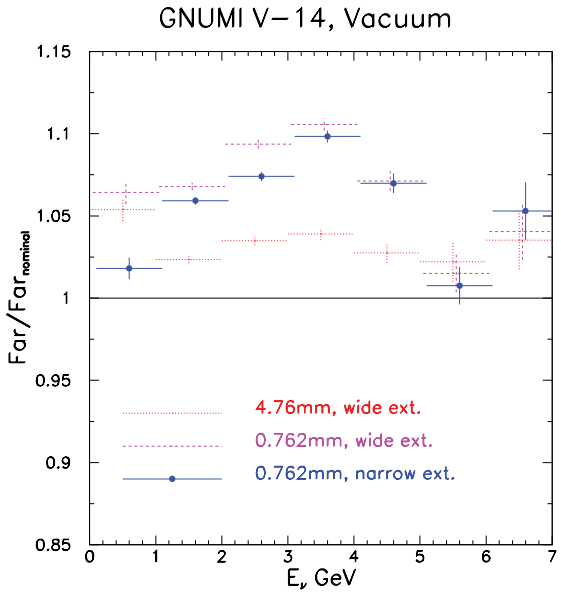
Flexibility is good (off axis beams),

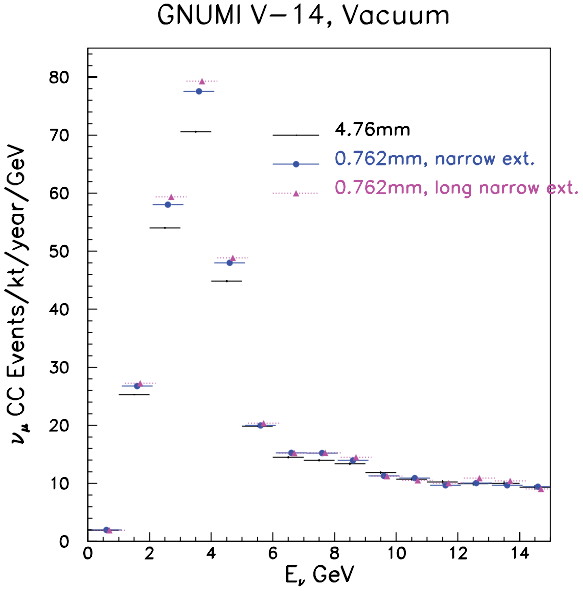
Radiation issues with extension pipe,

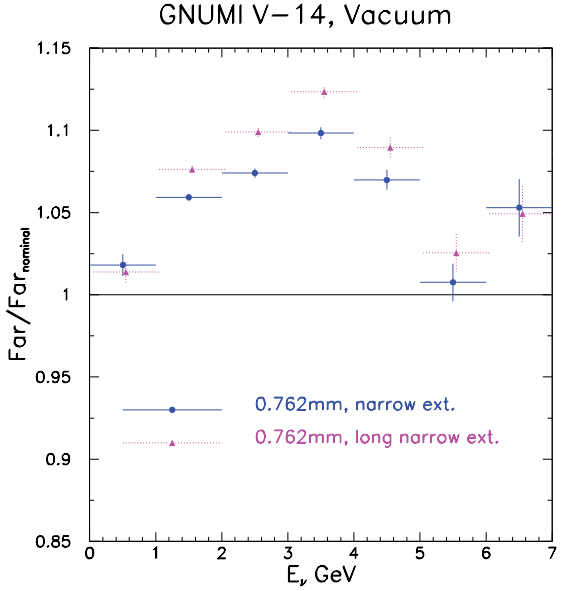
Major change to nearly complete design

Decay Pipe Extension and Window Options









10% Increase in rate possible with extended pipe and thin window

Roughly 1/2 due to extension (35% RL of air) and 1/2 due to window (also about 35% RL of iron)

Opted for thinner window w/o extension

(M. Kostin)

Semi-Beams

- Move Target but leave horn 2 in LE position
- If extension option were taken these would be only ME and He options available

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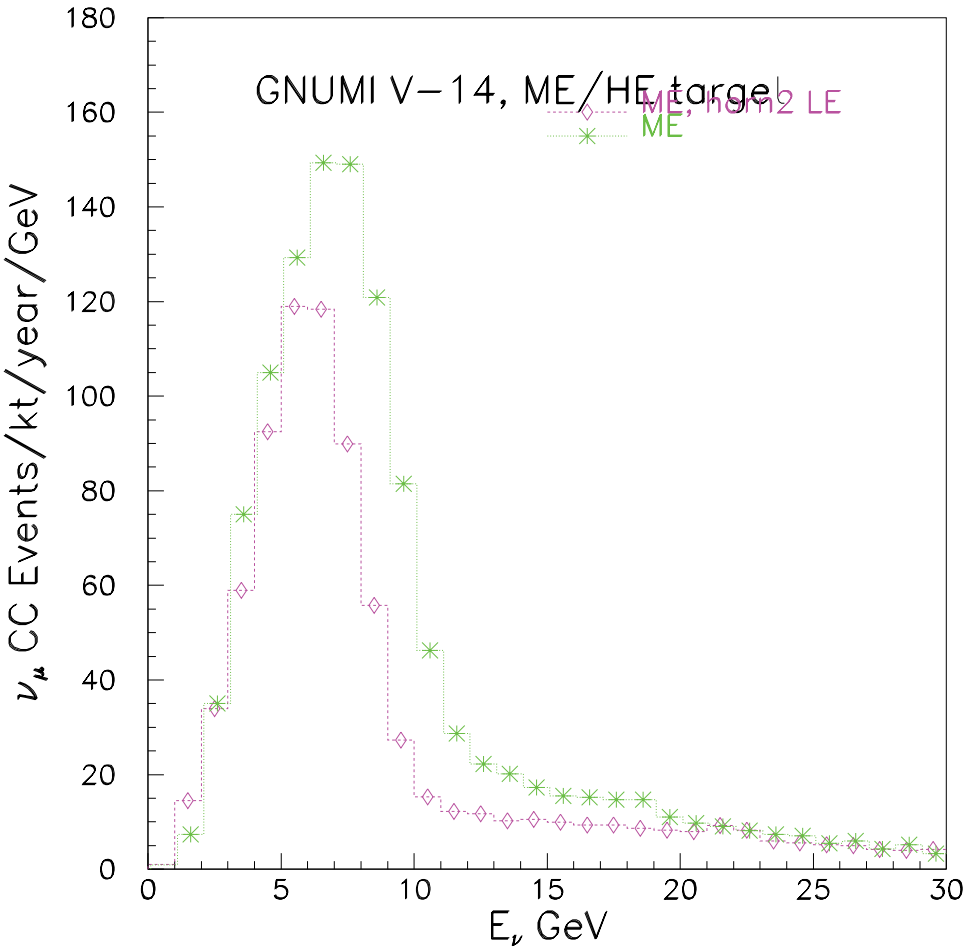
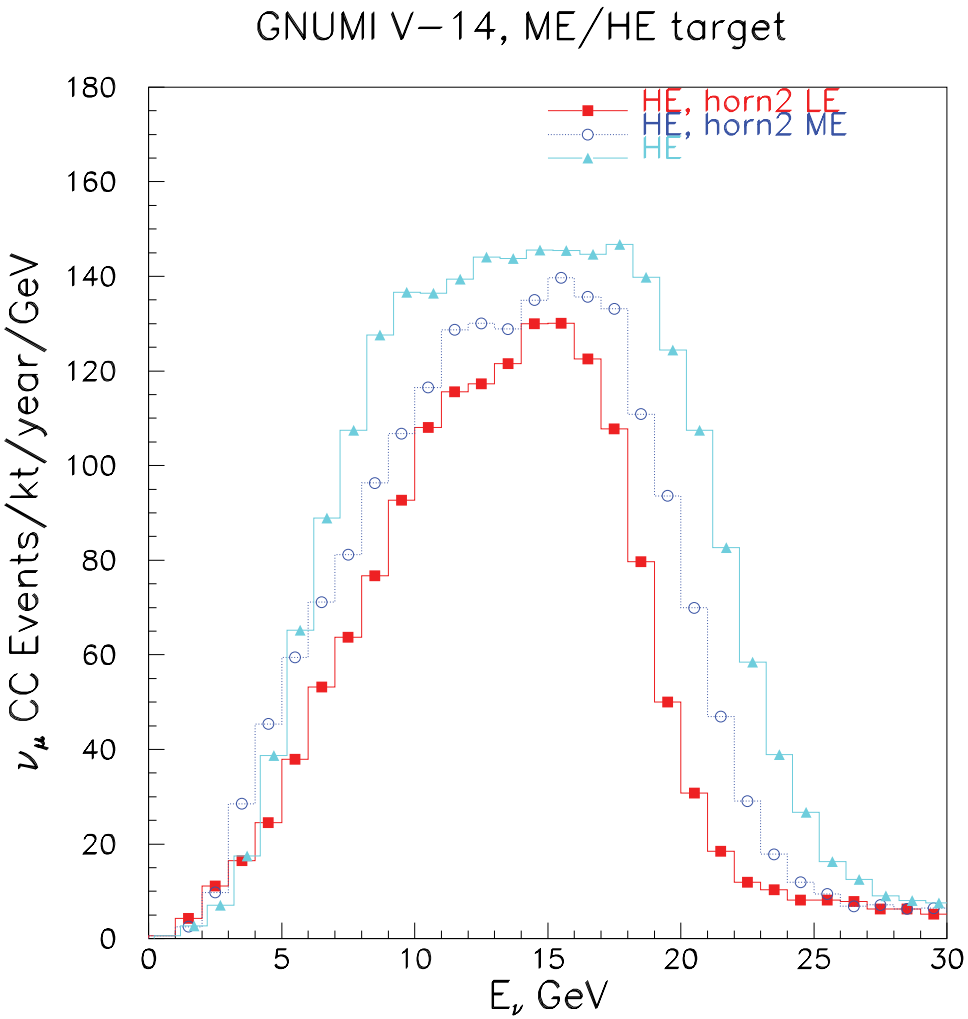
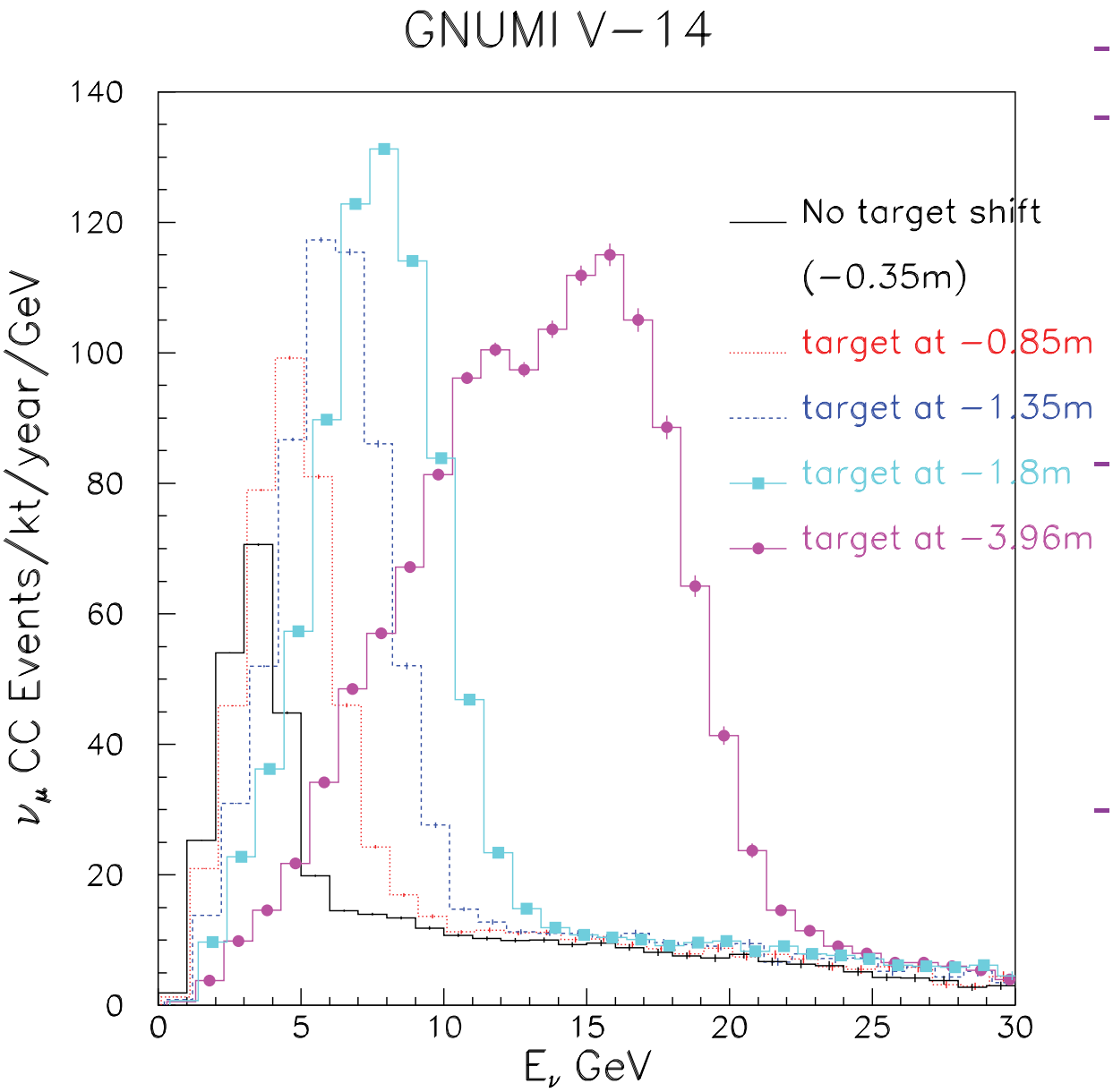




- Got us to thinking about target motions. LE target already must move 1 m to be inserted into horn. Turns out 2.5 m of motion is not much harder ..

Spectra as Function of Target Motion

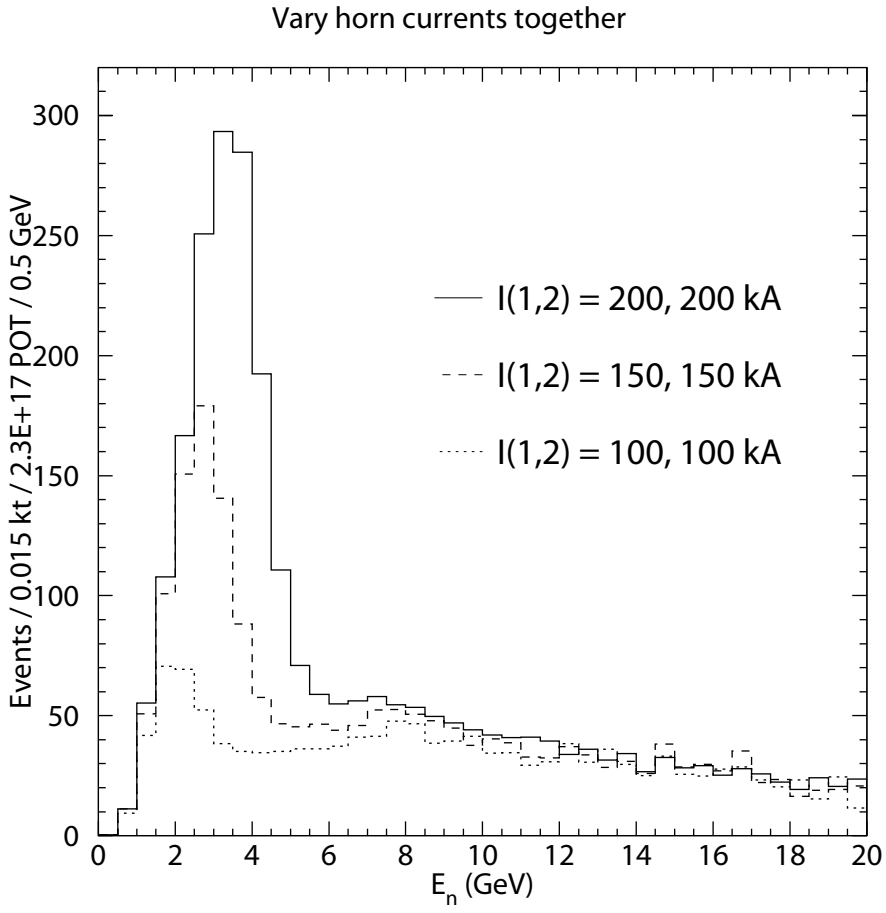


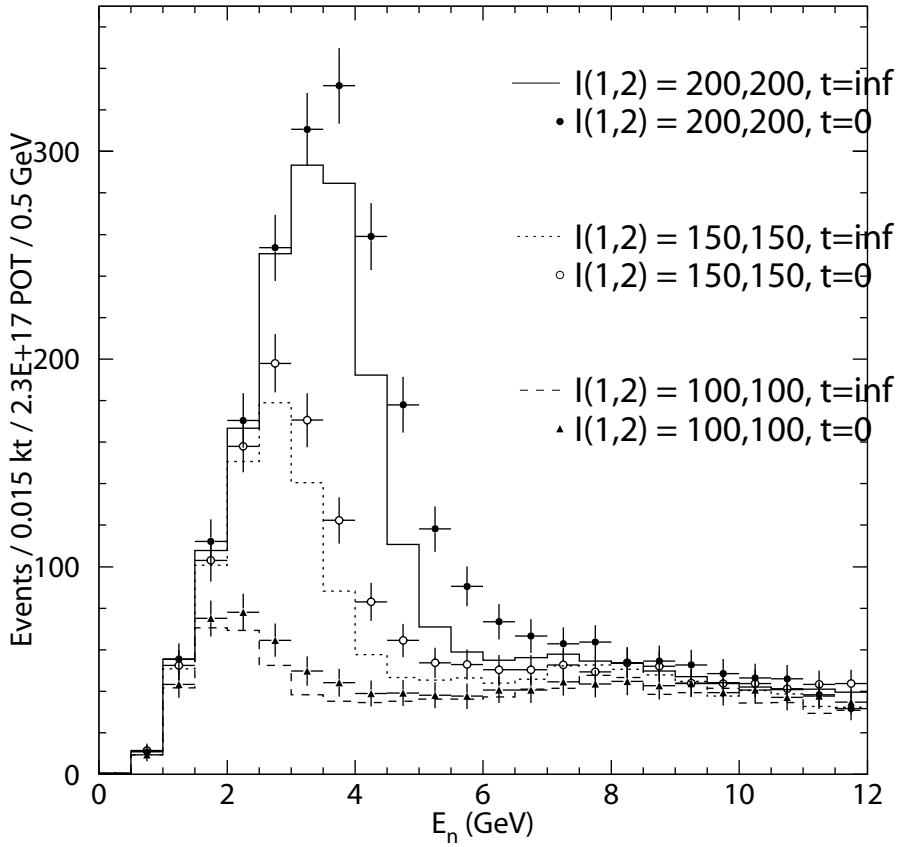
- Up to 2.5 meters possible
- Allows experiment to tune beam quickly to place 'sweet spot' of beam in potentially interesting energy bin
- Excellent monitoring tool. Muon rates in alcoves go up with energy. Possible to monitor and find error conditions in the beam line.
- More handles on beam simulation. Tune MC to data taken during commissioning at various target positions

Other Games to Play During Commissioning

Can we convince ourselves that we understand our beam during commissioning?

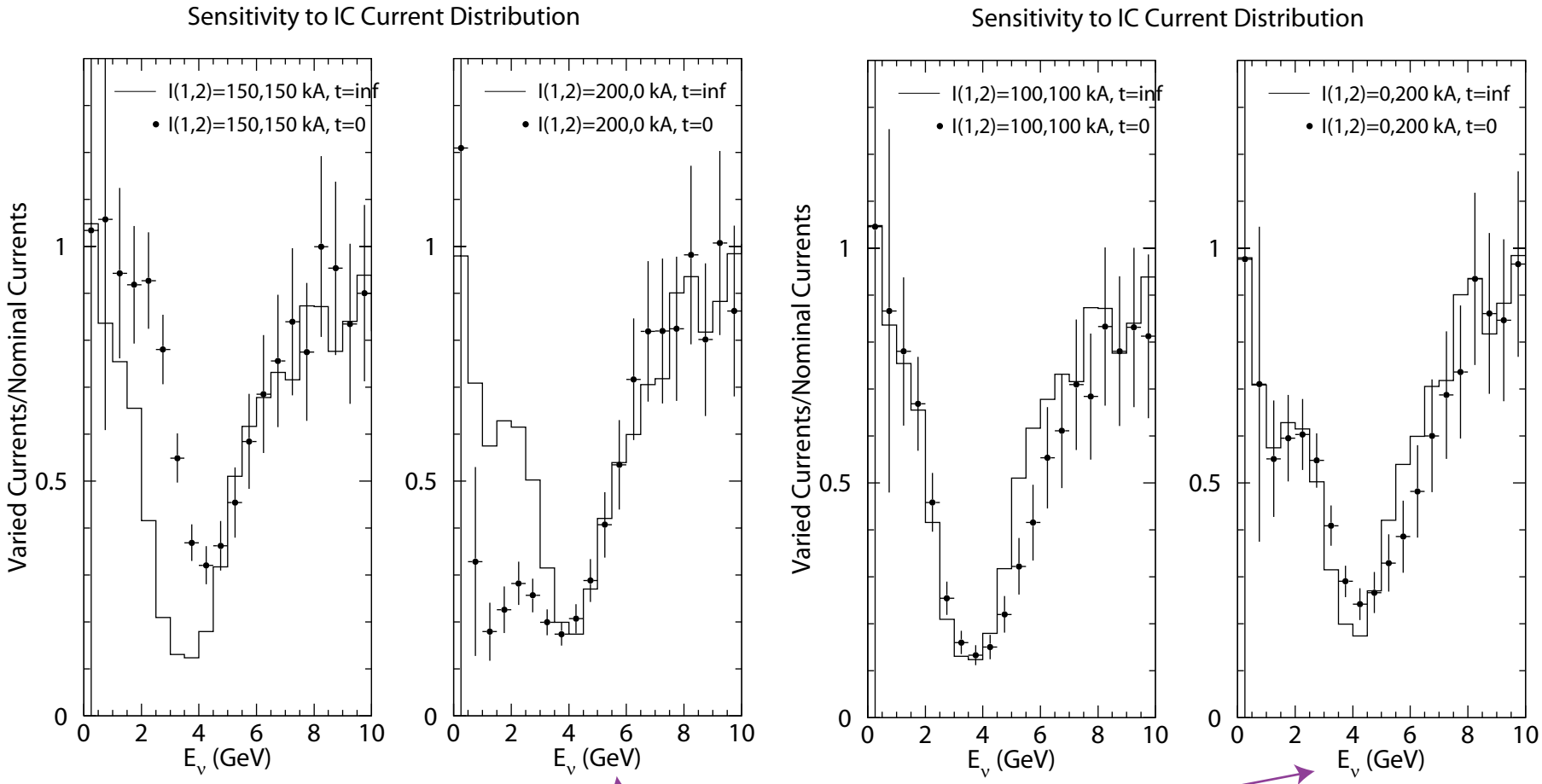
(stat. errors for ~1 day of Near Detector)





Two curves compare current distribution on horn IC at t=0 and t=inf.

Comparisons of Near Spectra at Different Horn Currents

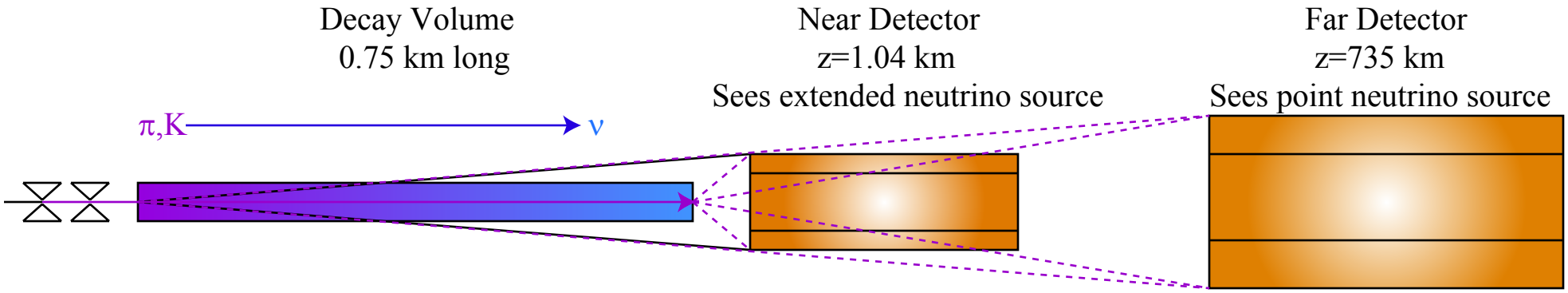


(swapping in dummy load during commisioning is too hard so these are not possible)

Near - Far Spectrum Comparison

MINOS Near and Far detectors are built to be a similar as possible
- iron and scintillator thickness and spacing are same
- average B field

Neutrino flux as two sites is different



Predict far flux by extrapolating high statistics measurement at near detector

$$N(E)^{predicted}_{FAR} = N(E)^{measured}_{NEAR} \; R(E)^{predicted}_{FAR/NEAR}$$

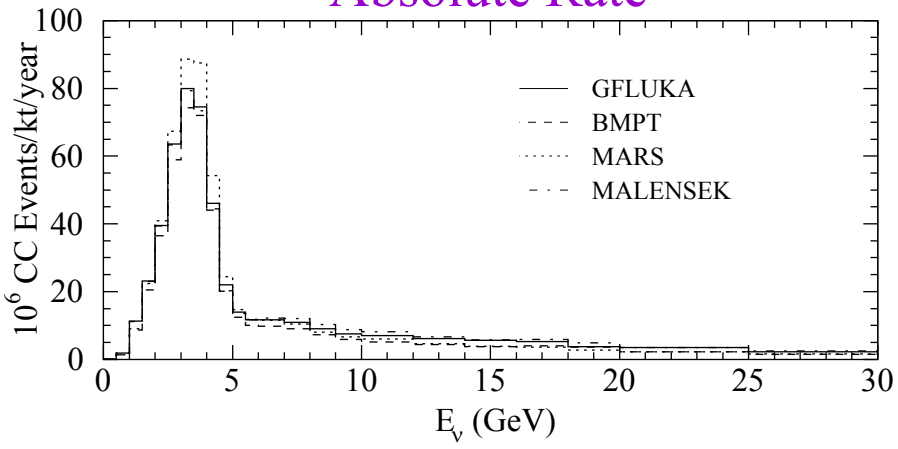
point source: $R(E)^{predicted}_{FAR/NEAR} = Z^2_{NEAR}/Z^2_{FAR} = 1.04^2/735^2 = 2x10^{-6}$

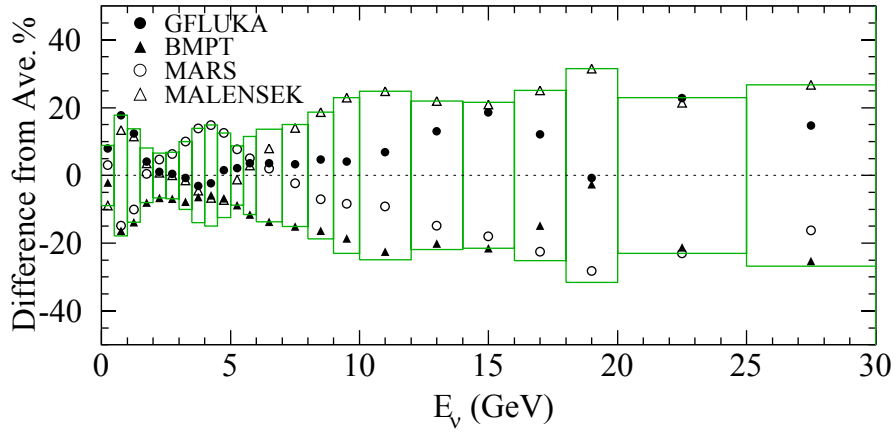
line source: $R(E)^{predicted}_{FAR/NEAR} = \dfrac{\int exp(-z/\gamma c\tau)/(1/(z-z_{far})^2)dz}{\int exp(-z/\gamma c\tau)/(1/(z-z_{near})^2)dz}$

Ultimately need simulation of beam line to account for
- production of particles in target
- horn acceptances
- beam line acceptances

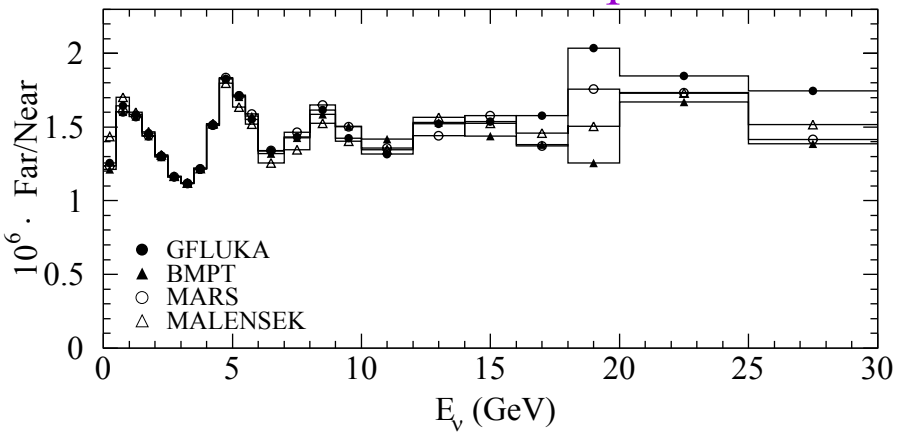
Uncertainties Due To Hadron Production

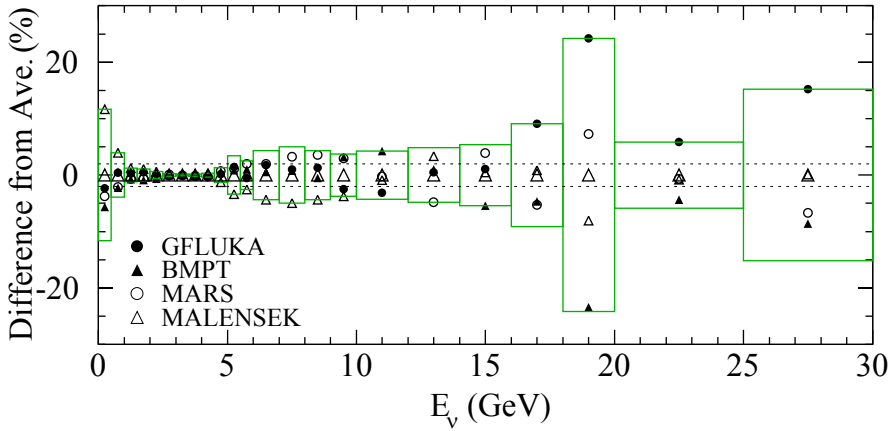
Absolute Rate





Far to Near Comparison

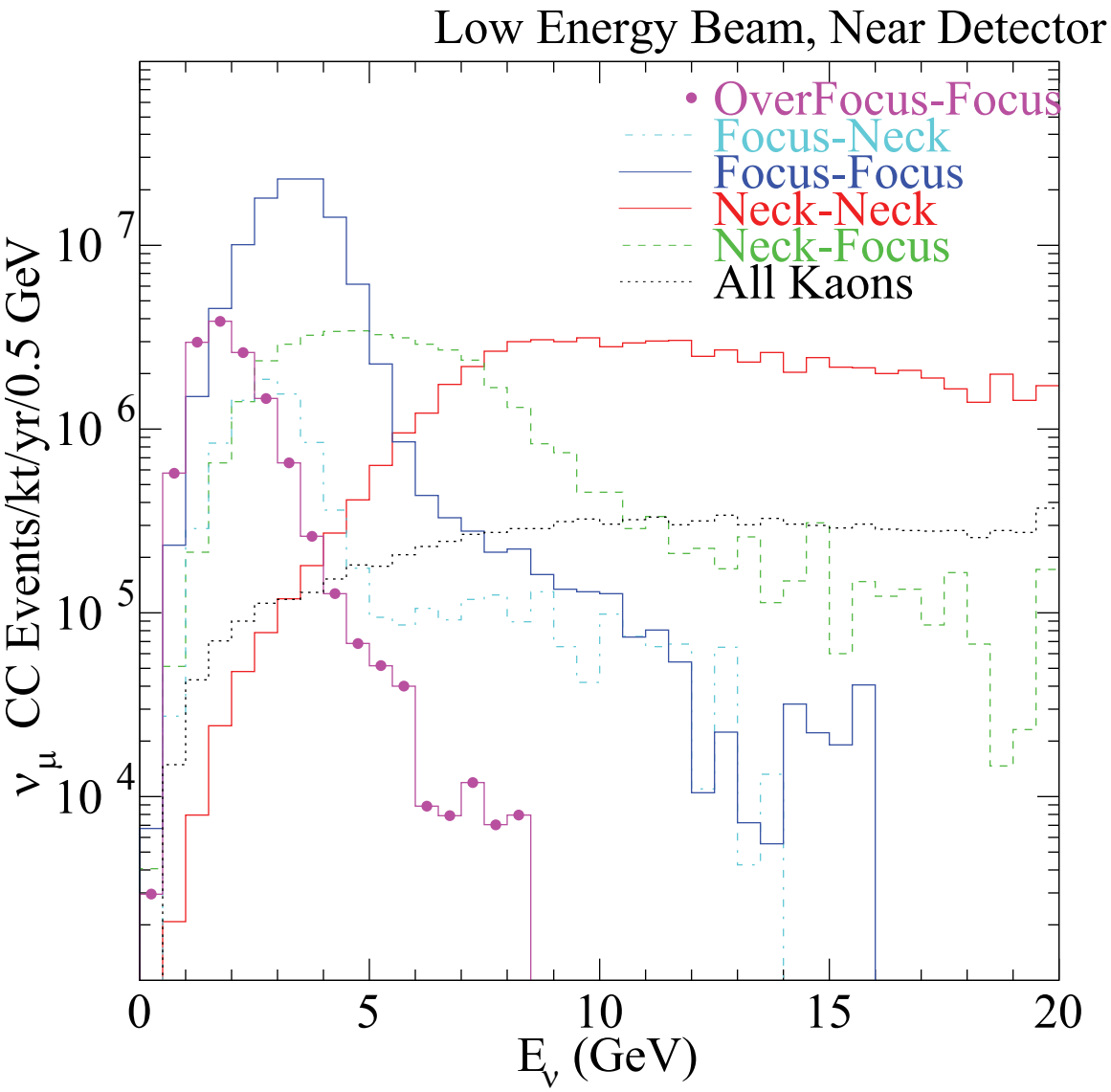


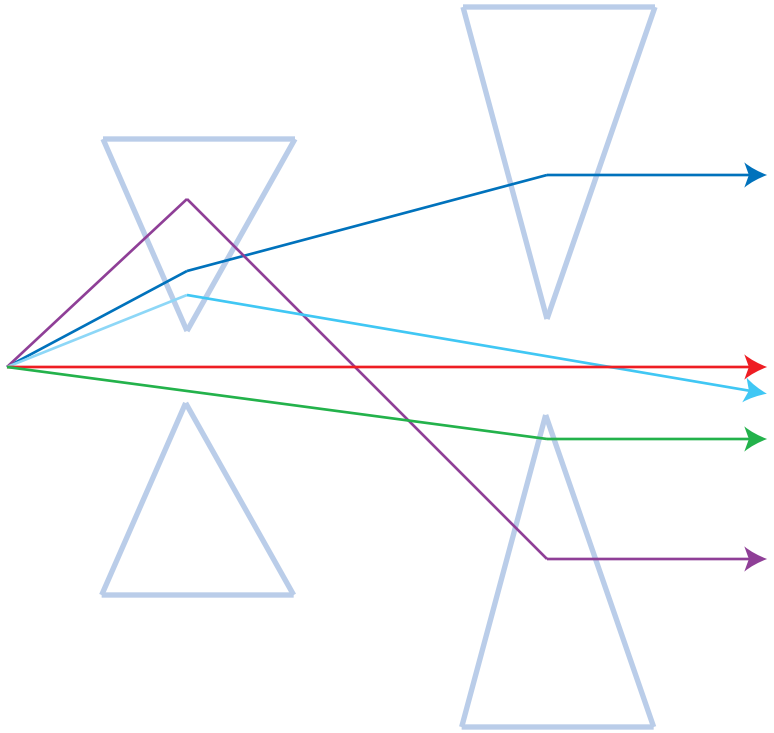


10 to 30% uncertainties in absolute rate

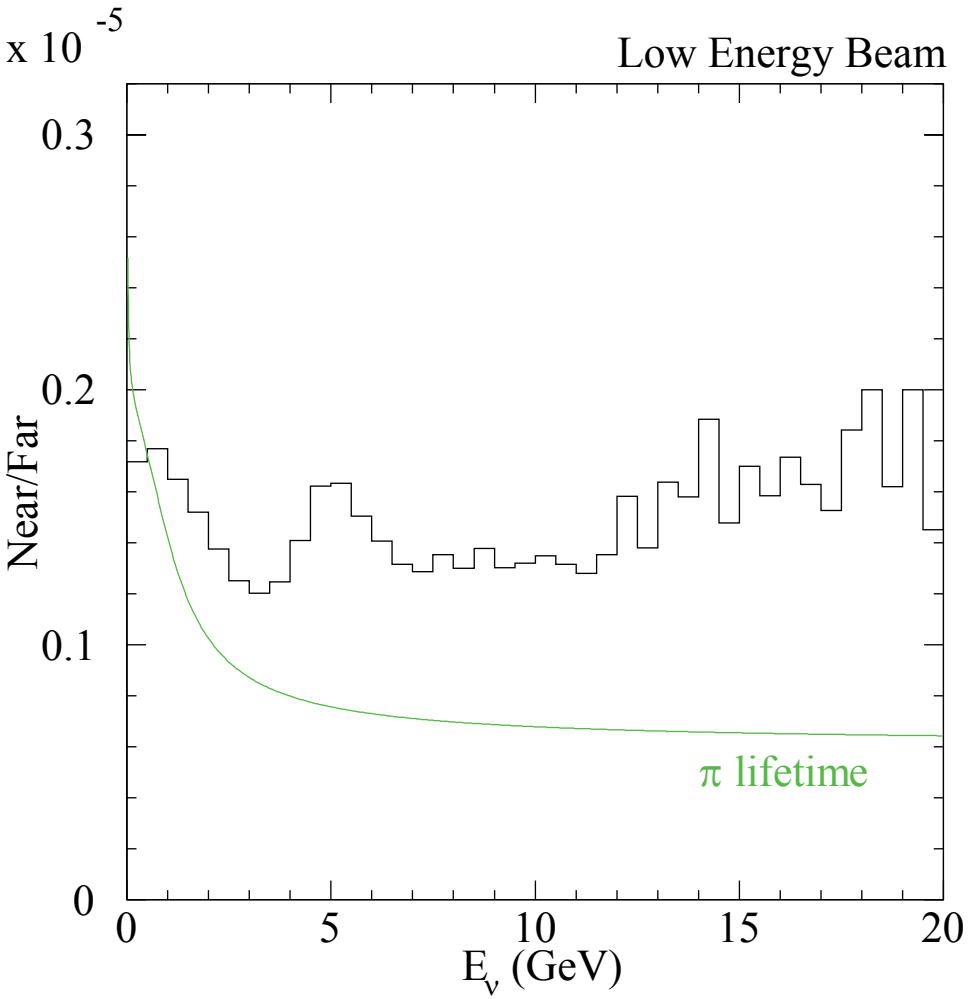
2-10% uncertainties in far to near comparison

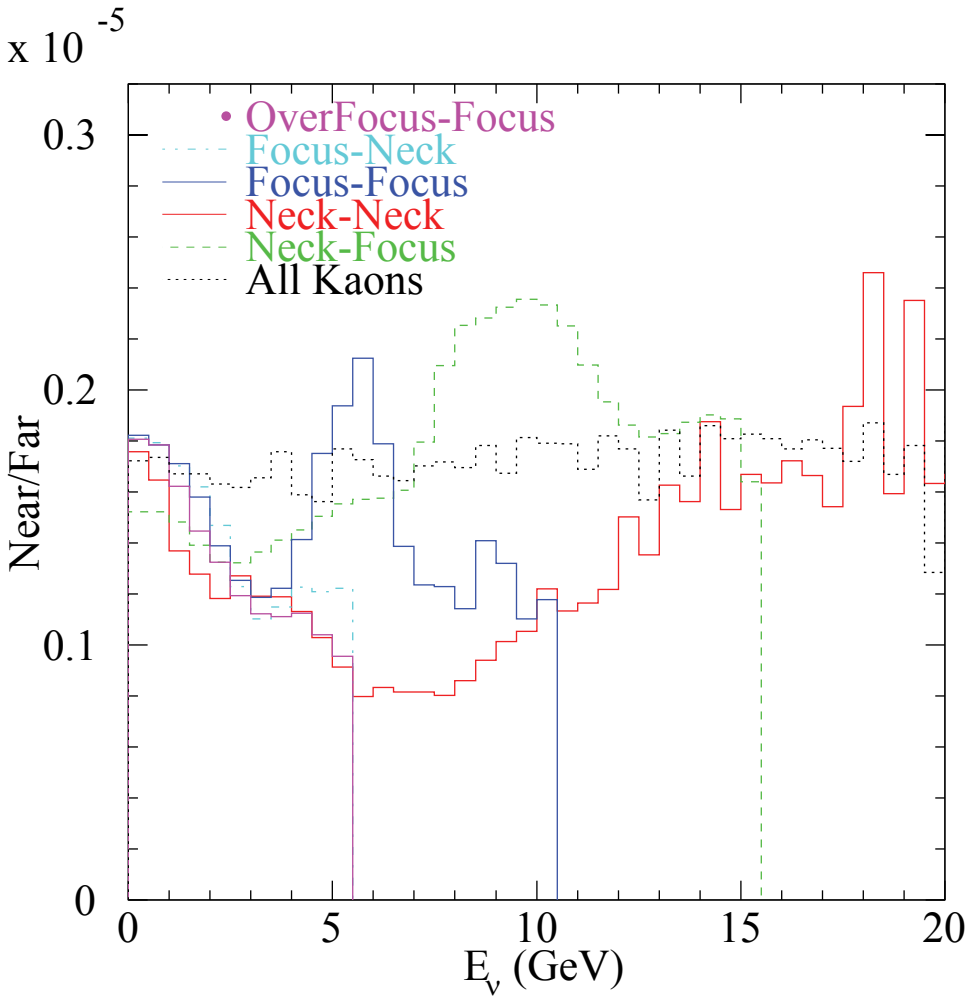
Components of LE Beam





Far/Near By Track Type



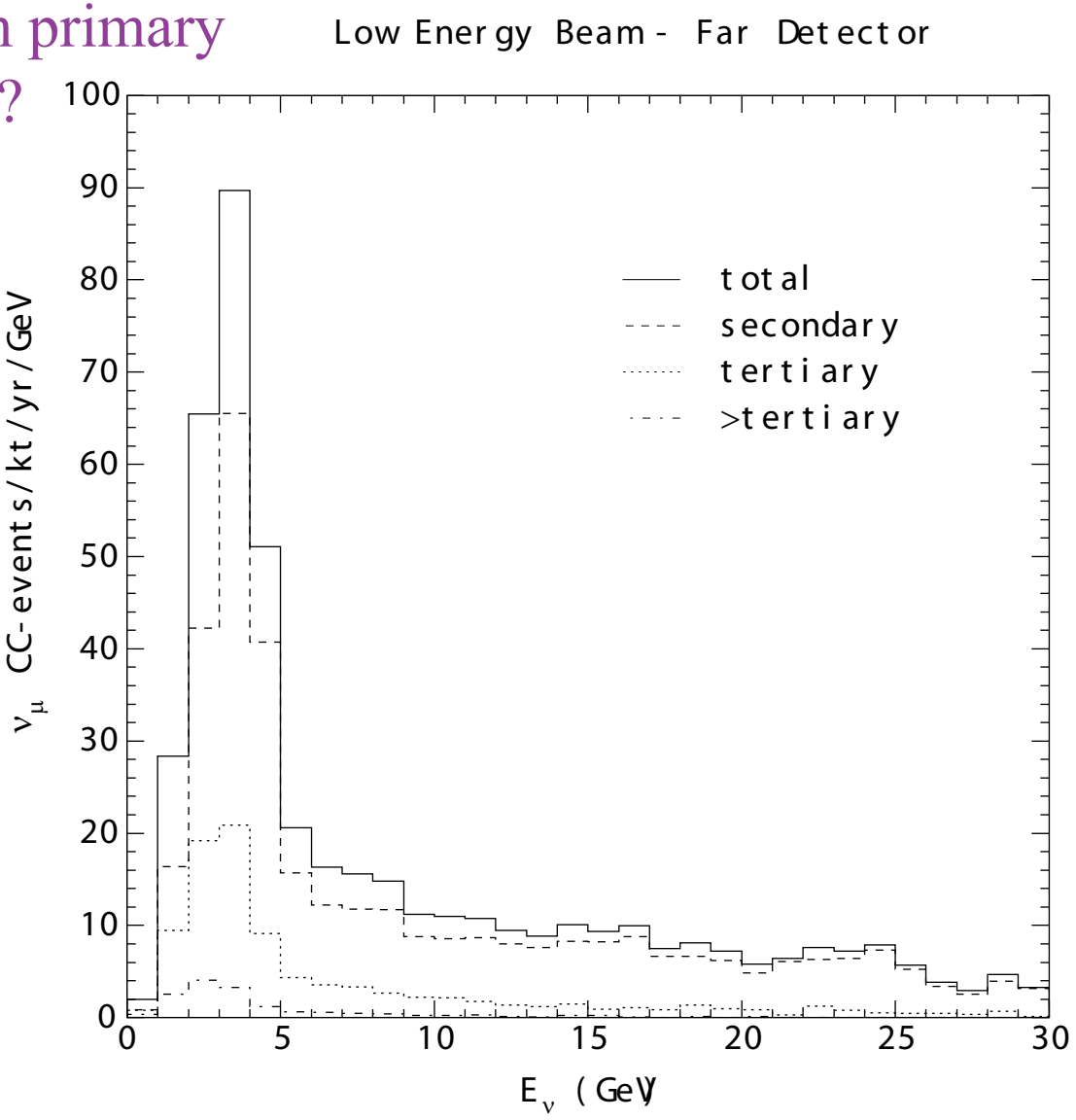


Target Model

How many neutrinos come from primary interaction in target? Secondary?

For LE beam full cascade is important

Hadron production measurements beyond primary interaction needed



Target Model

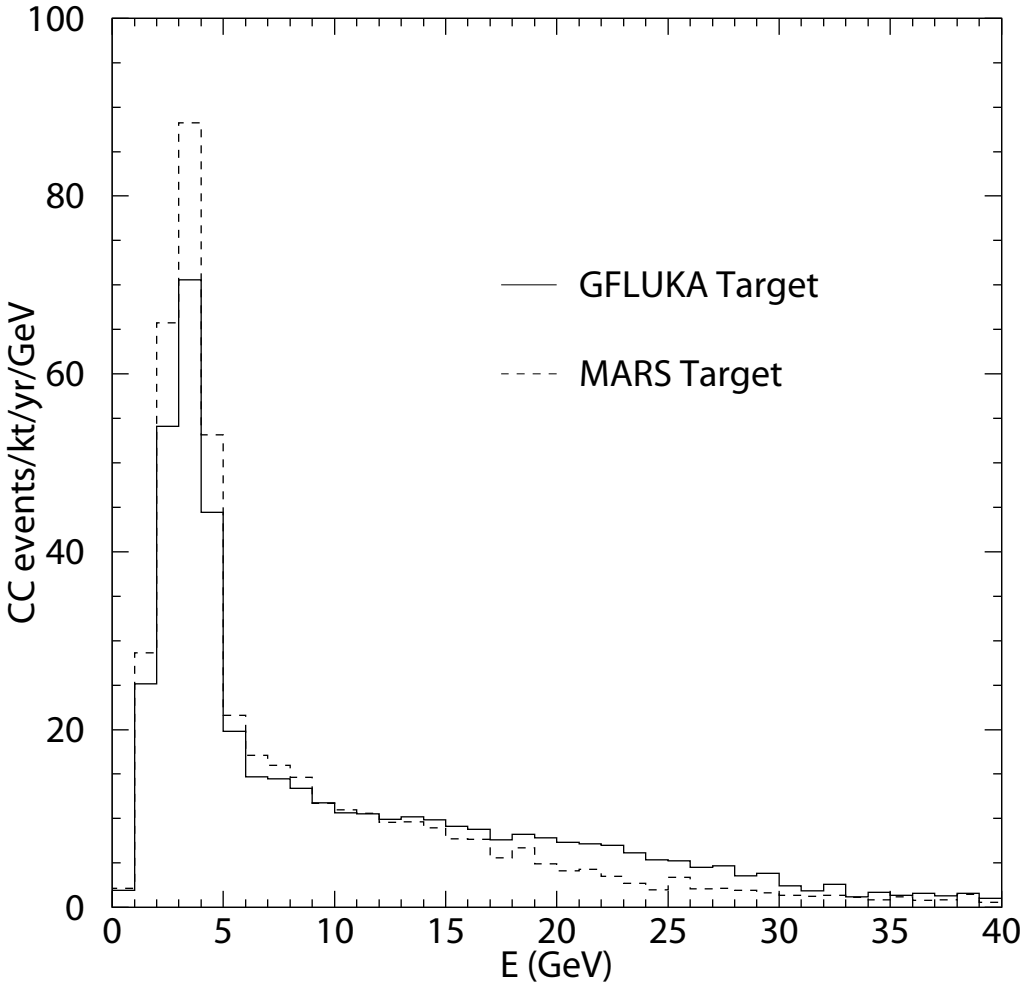
- Currently different models of target are produced using weighting functions of p and p_T. Effects of target length, phi, etc. are ignored
- Official neutrino spectra based on GEANT-FLUKA. Would like to update to better model. Candidates are:

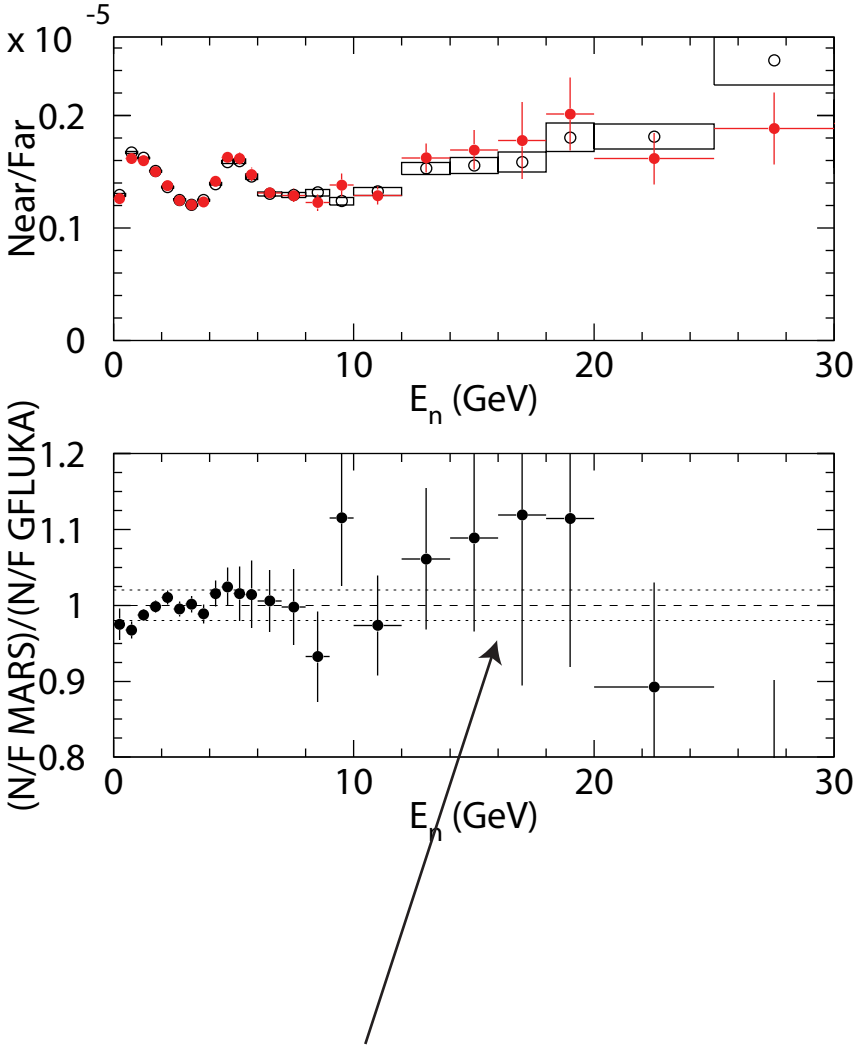
MARS	'standard' at FNAL. Access to source code is difficult
FLUKA	Widely used. Good agreement with data. Access to source code is not permitted
DMPJET3	Widely considered best model at NuMI energies. Source freely available. But interface to tracking code (GEANT3) does not exist.

Leaning towards MARS

Have detailed simulation of target using MARS and have used it to produce results with GNUMI

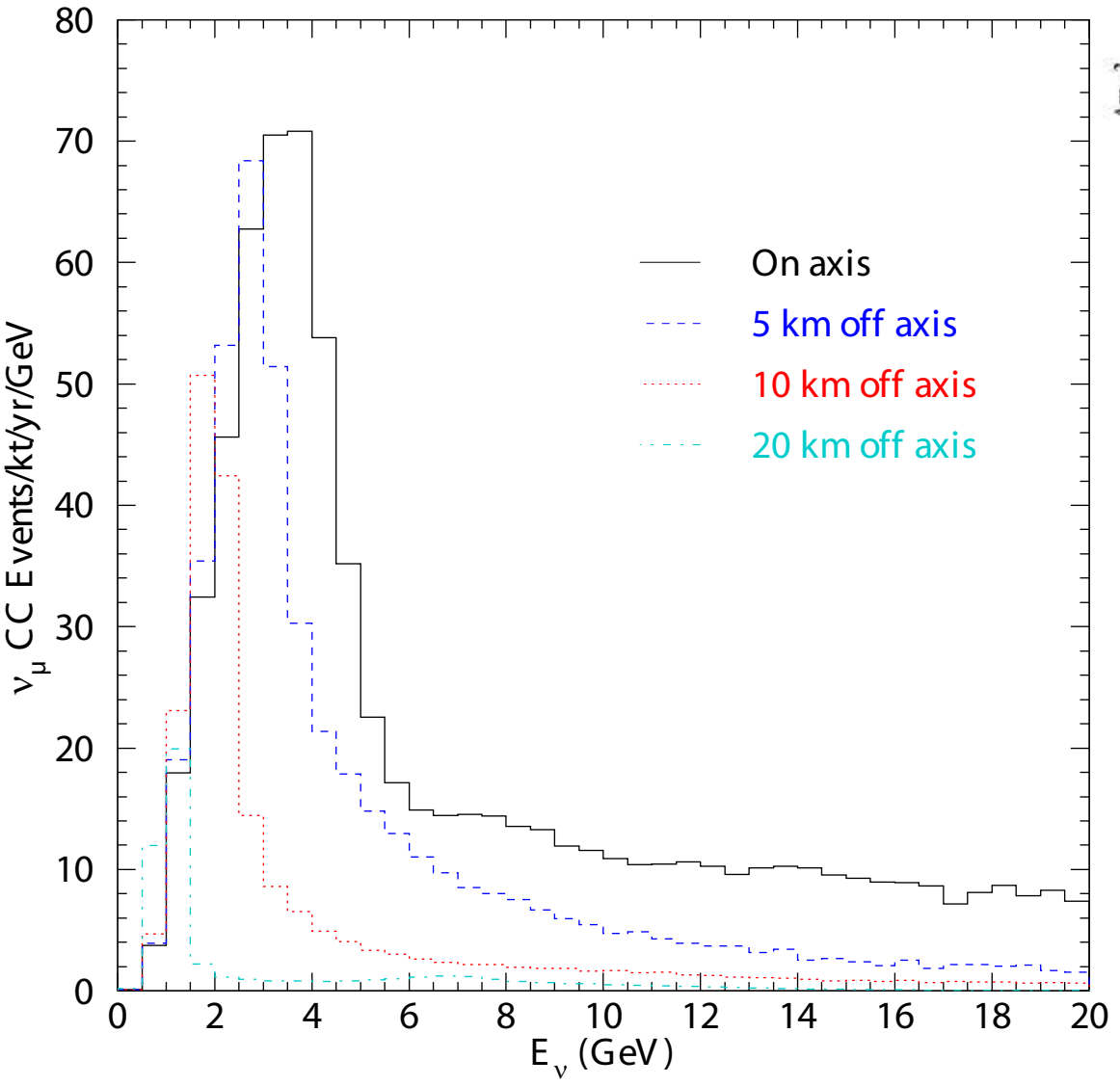
Comparison of MARS Target Model with GFLUKA

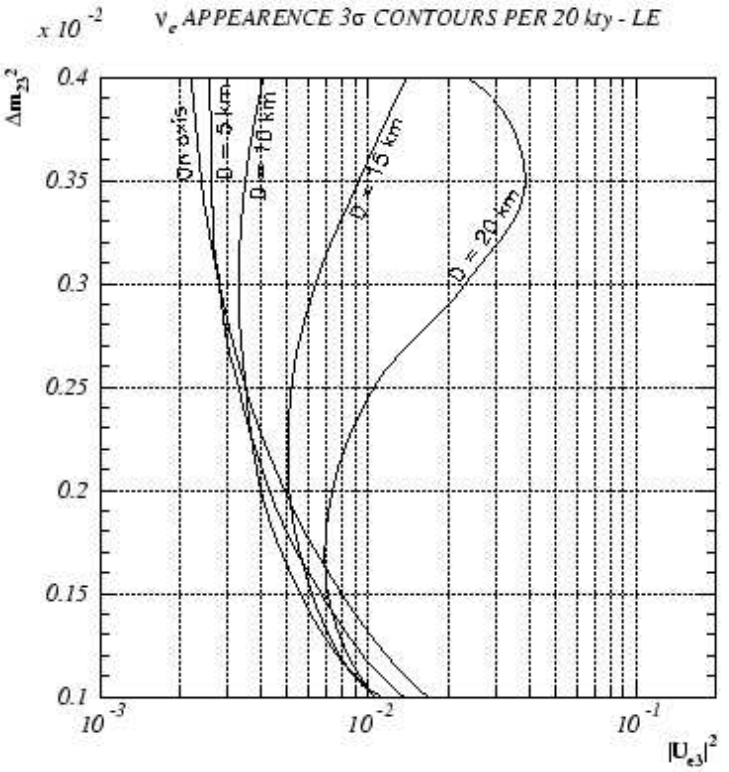




(statistics were better with reweighting!)

NuMI Off-Axis Neutrino Beams





~1% measurements should be possible

Detailed studies of detector technologies underway