Constraints on Hadron Production from the MINOS Near Detector

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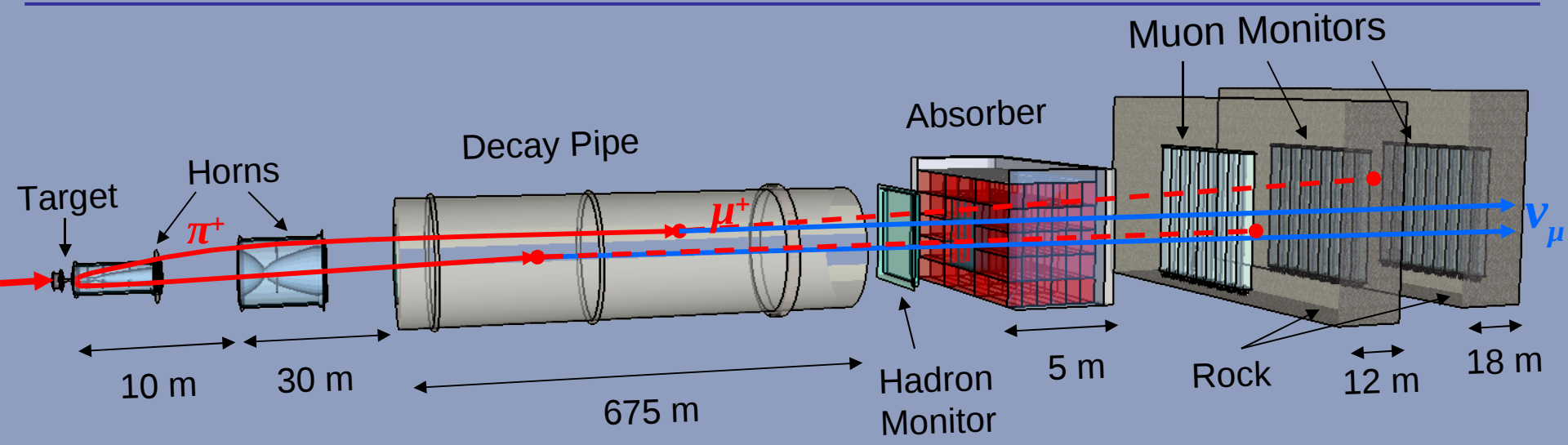
FNAL, March 2009

Outline

- NuMI beamline, calculating flux and systematic errors
- Fitting the ND data (Beam tuning)
- Few comments on NuMI offaxis flux
- Conclusion

Neutrino Beamline

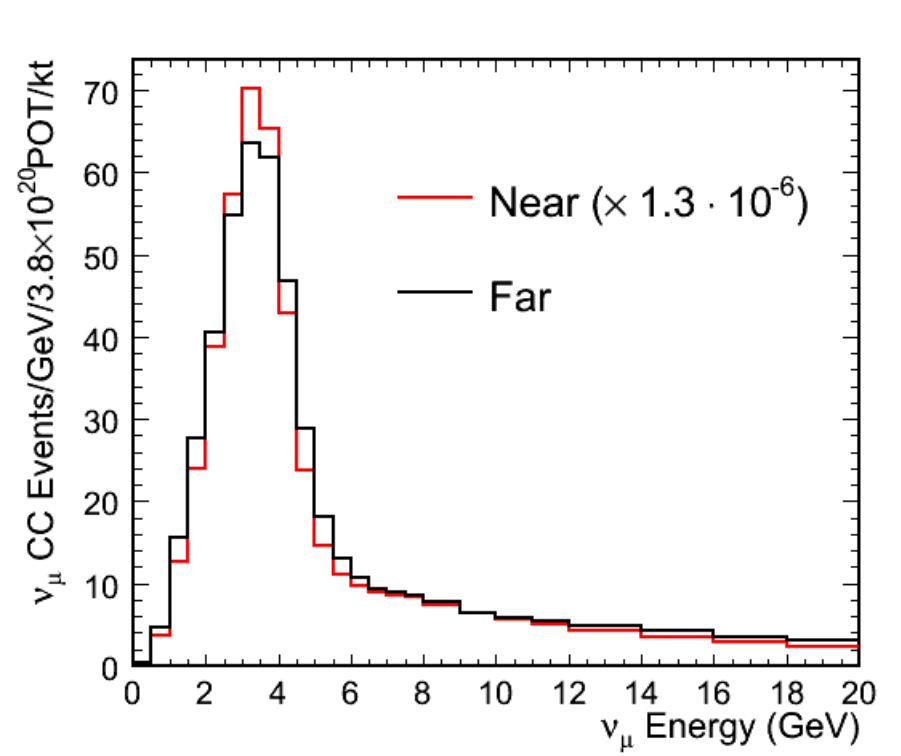


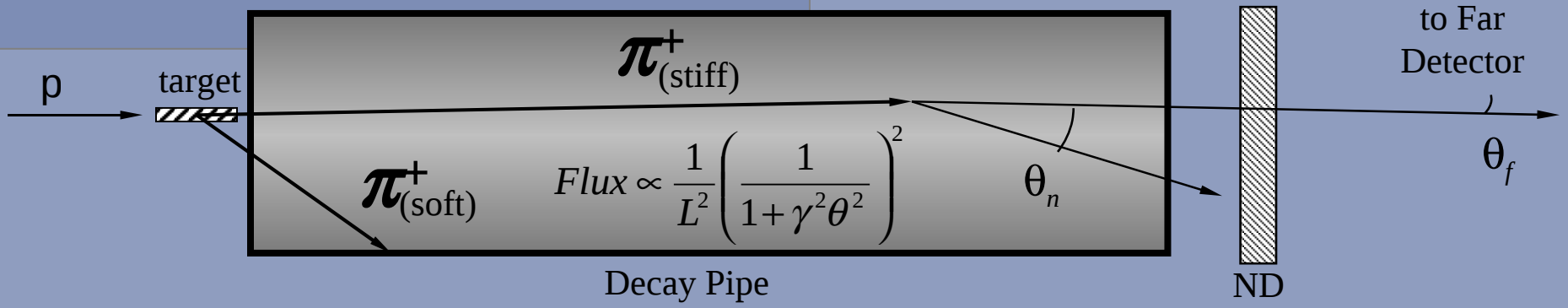
- 120 GeV protons
- 1m long graphite target
- 2 magnetic horns
- Variable beam energy
- Beam composition (LE10/185kA):
  - 92.9% υ_μ
  - 5.8% $\overline{\upsilon_\mu}$
  - 1.3% υ_e / $\overline{\upsilon}_e$

Near and Far Spectra

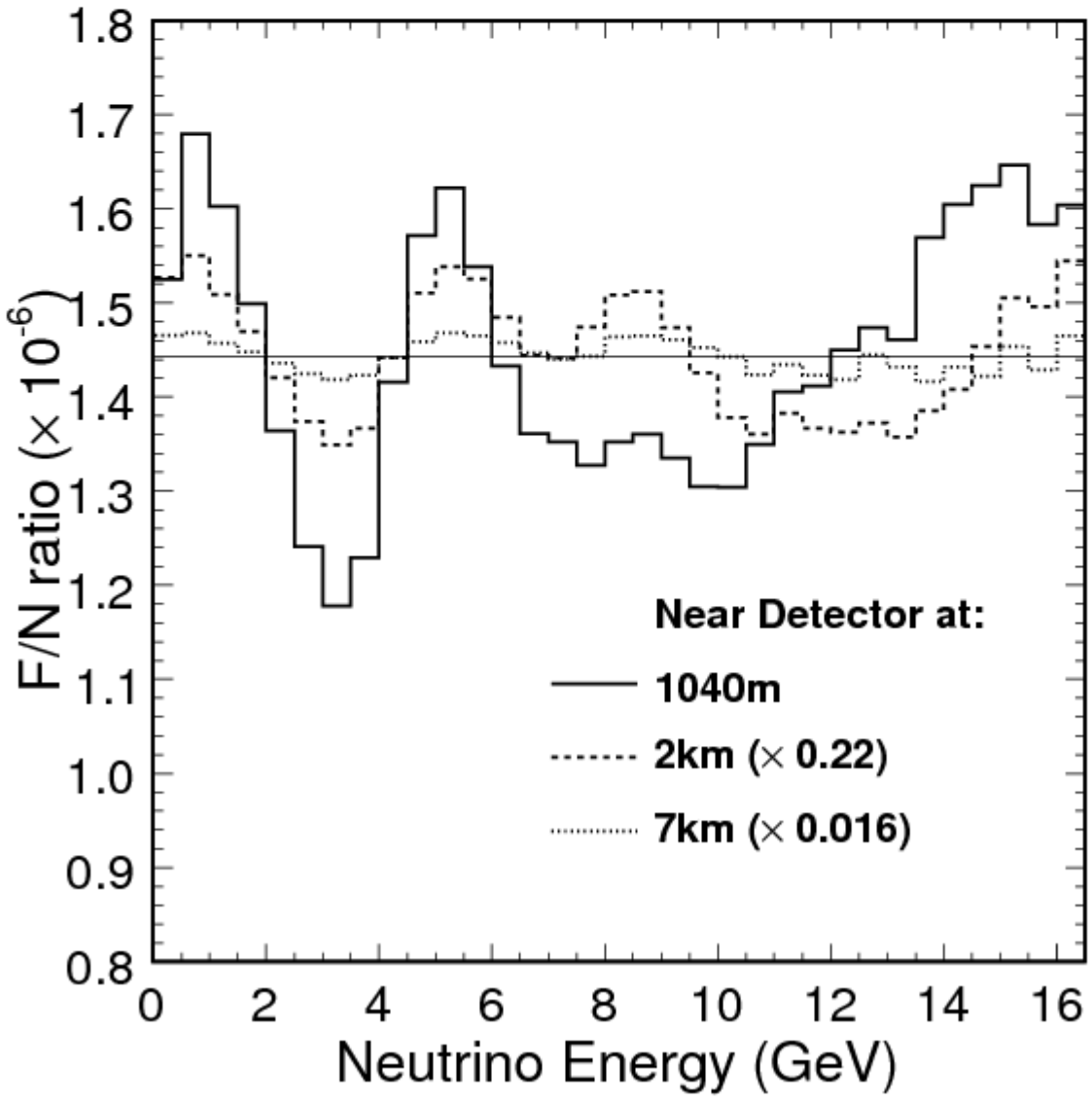
- Flux at Near and Far detector not the same
- Neutrino energy depends on angle w.r.t parent momentum

$$E_\nu = \frac{0.43E_\pi}{1+\gamma^2\theta^2}$$



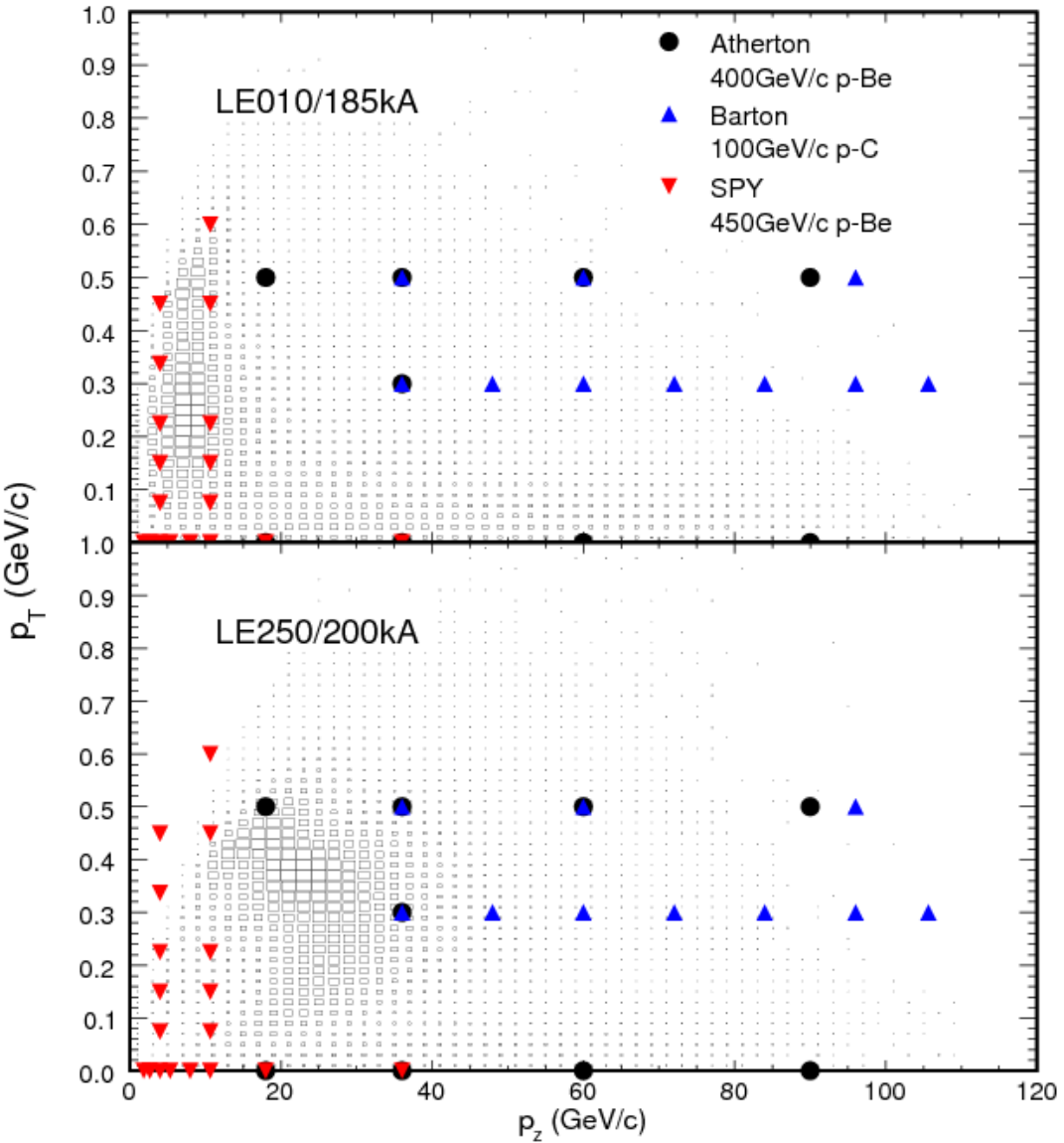


Far over near ratio



- 20-30% correction on top of R^{-2} for ND at ~1km
- Need to have detector at 7km to have corrections at 2% level

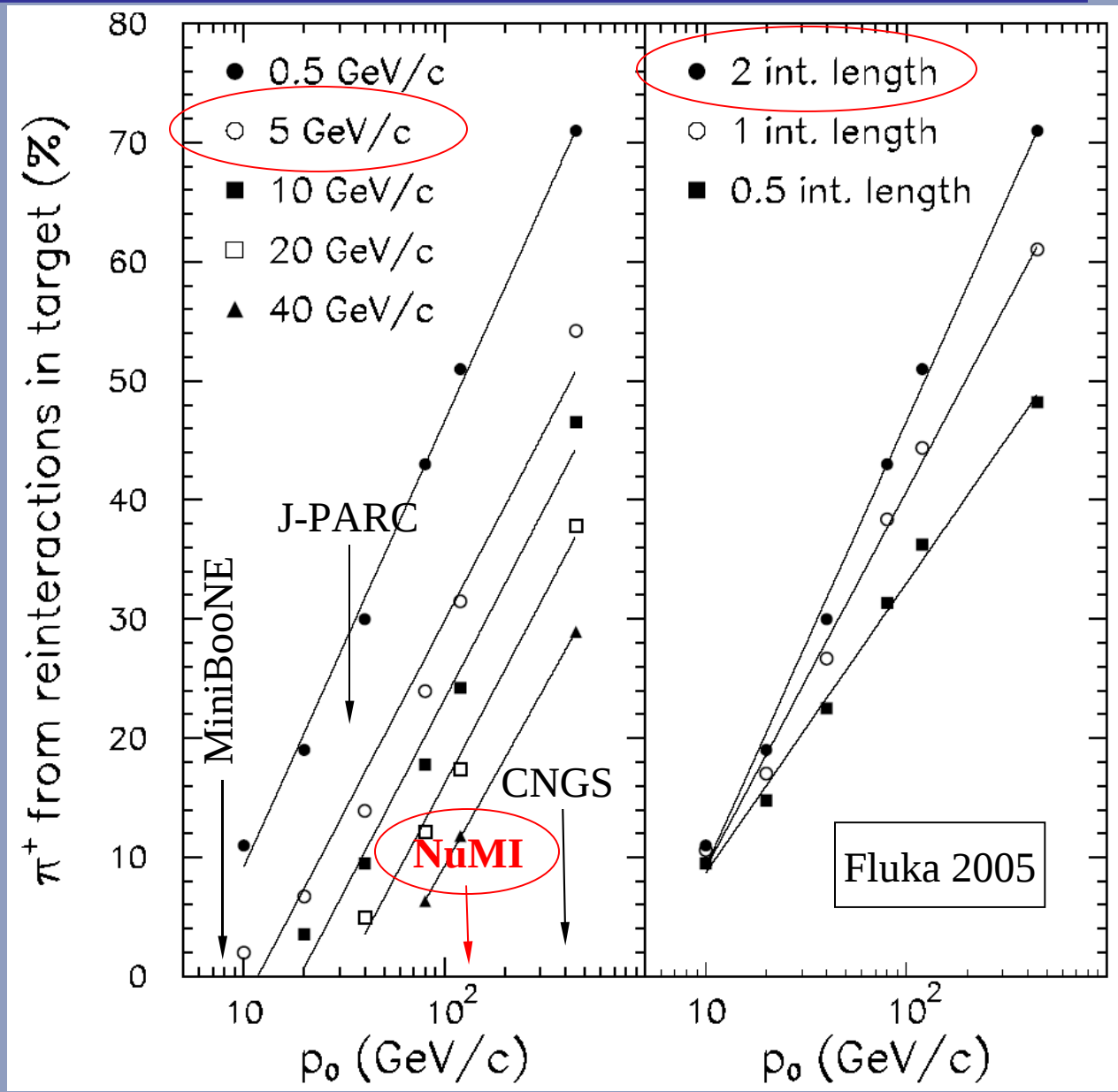
Hadron production



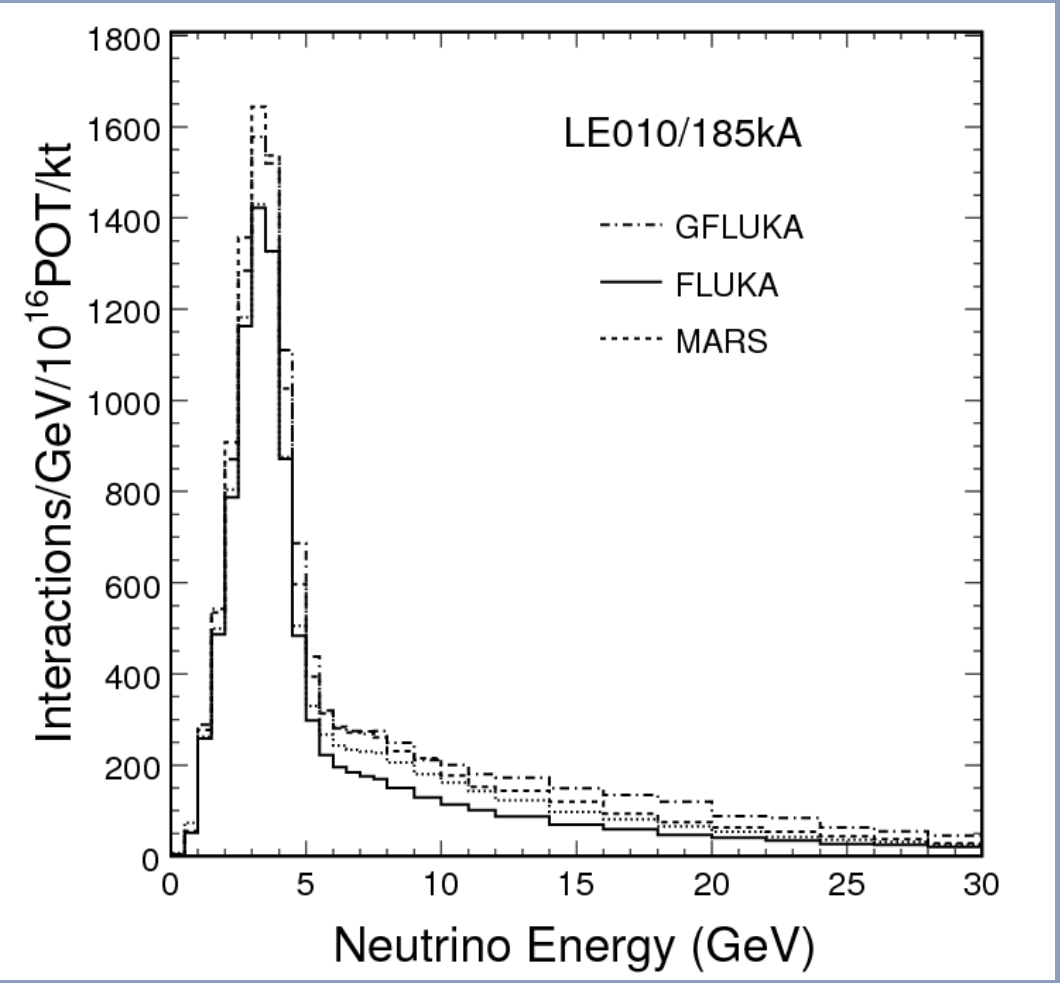
- Proton beam momentum
- Target material
- Thick target

Thick-Target Effects

- Hadron production data largely from 'thin' targets.
- Particles are created from reinteractions in NuMI target.
- Approx 30% of yield at NuMI p_0=120 GeV/*c*

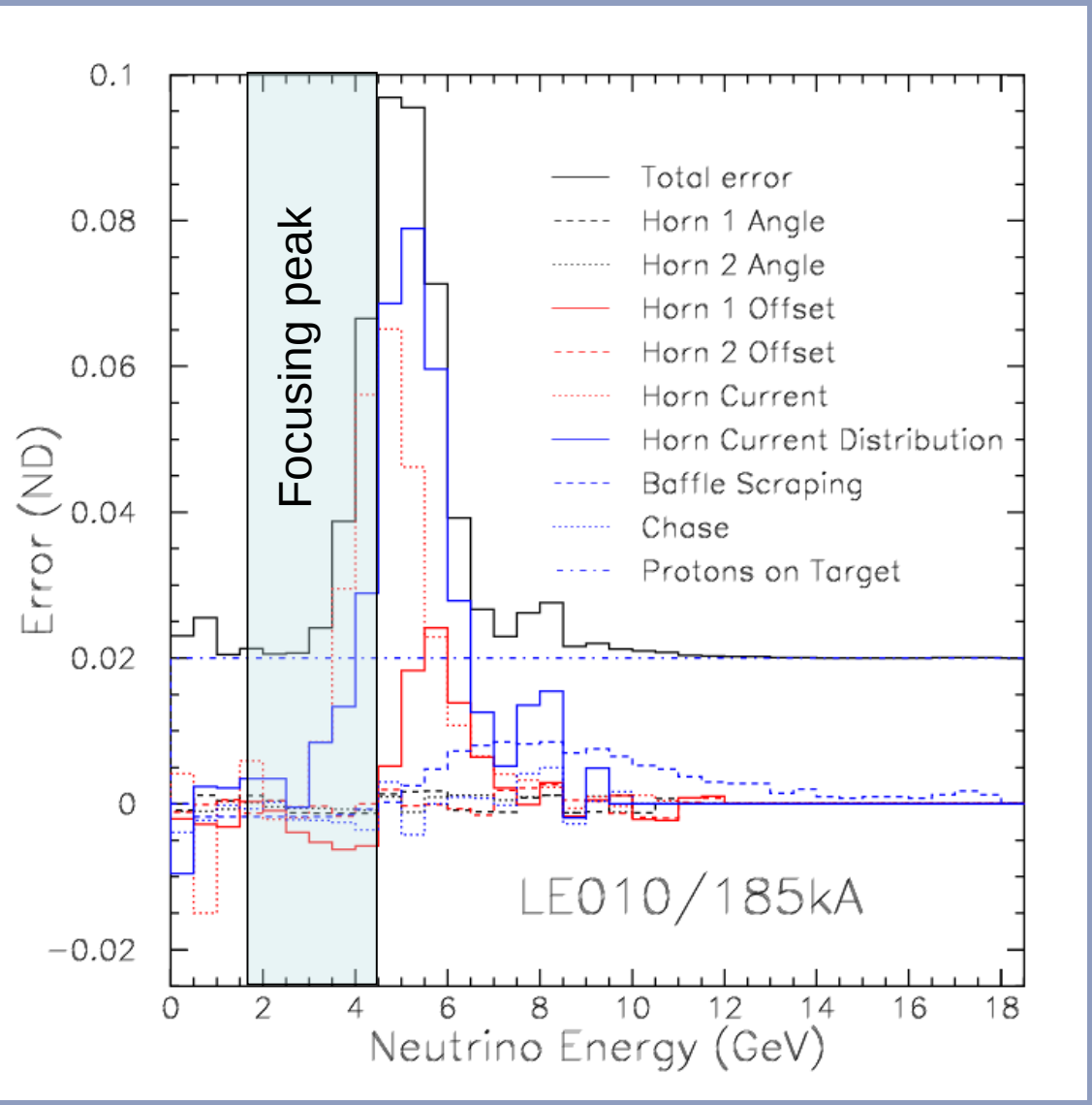


Cascade models



- Variation in calculated flux depending on the cascade model
- Indicates ~8% uncertainty in peak and ~15% in high energy tail

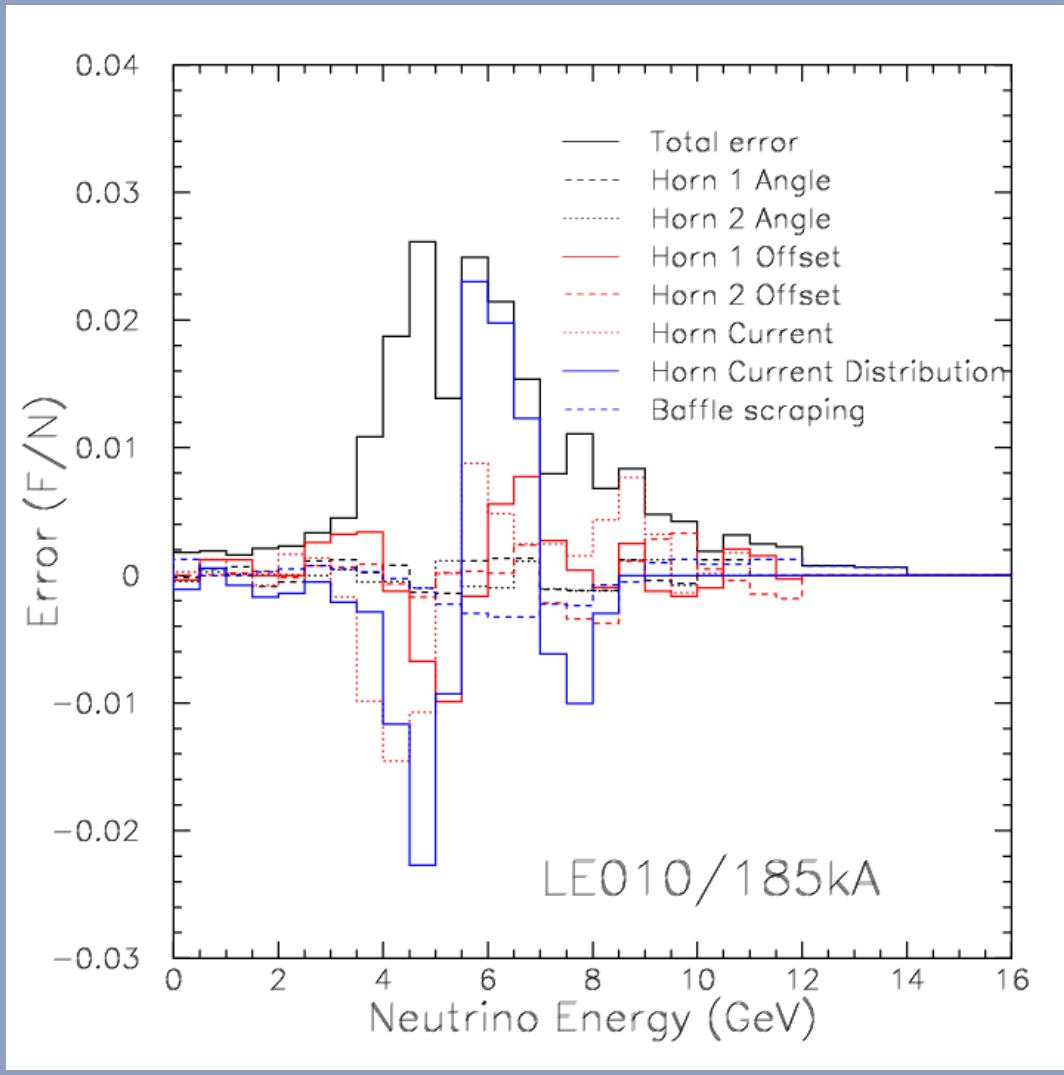
Focusing uncertainties



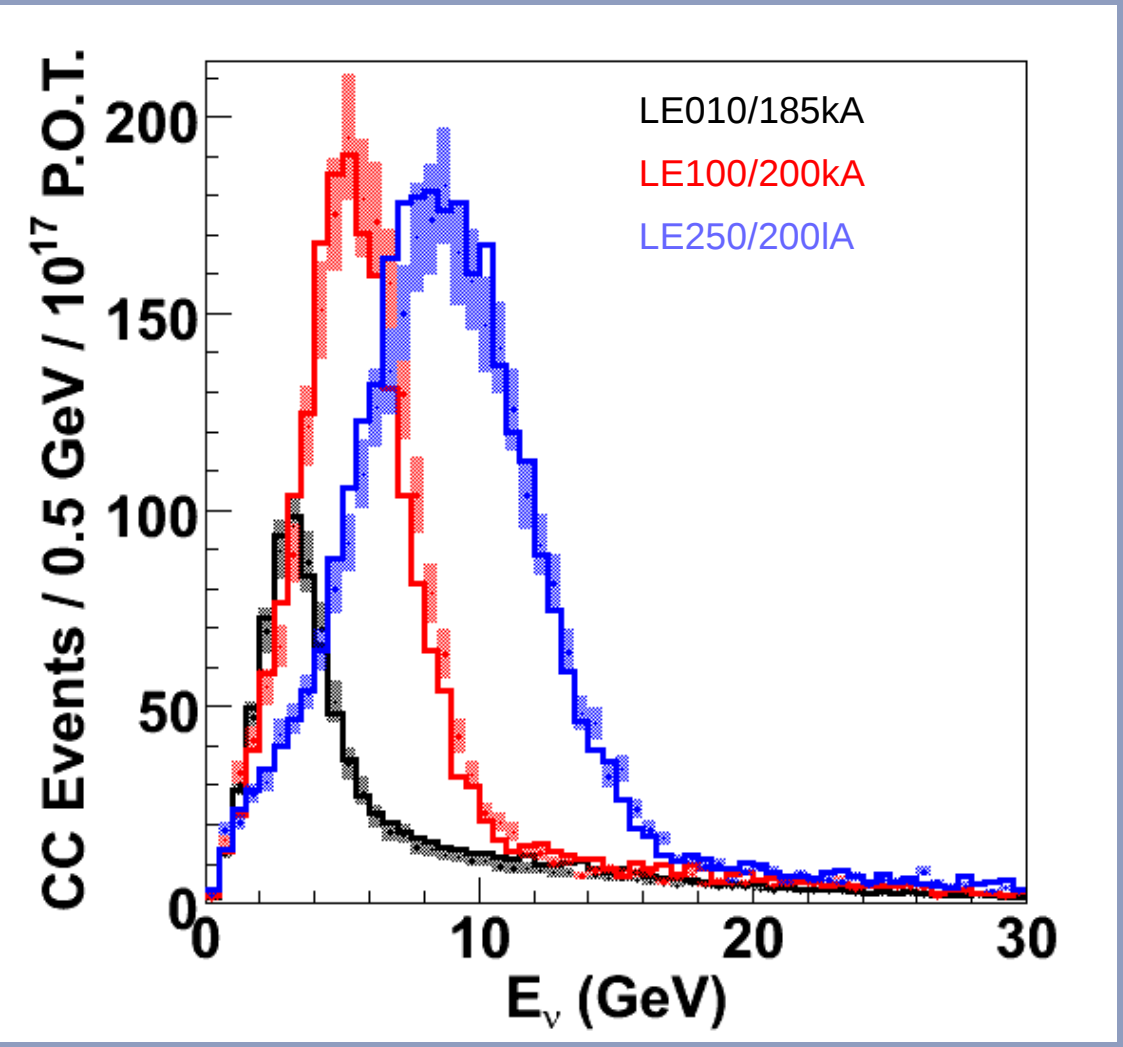
- Misalignments & miscalibrations
- Input from beamline instrumentation
- Affects falling edge of the peak

F/N focusing uncertainties

- Small effect on Far/Near ratio (2% level)

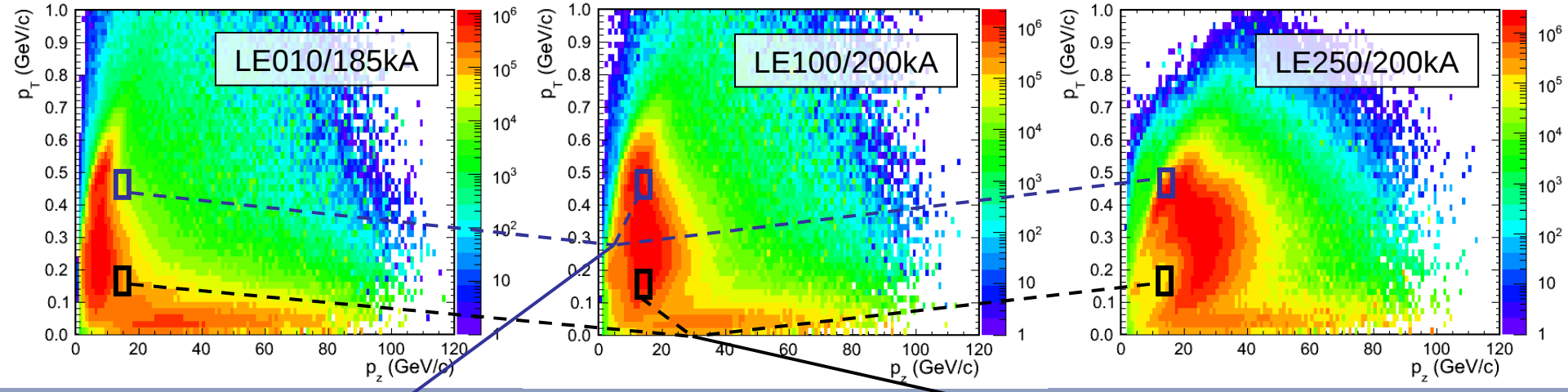


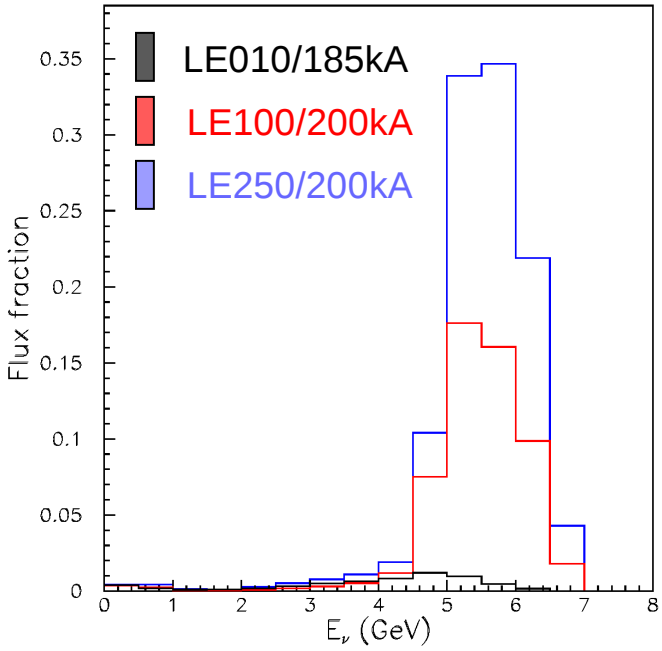
ND Data/MC



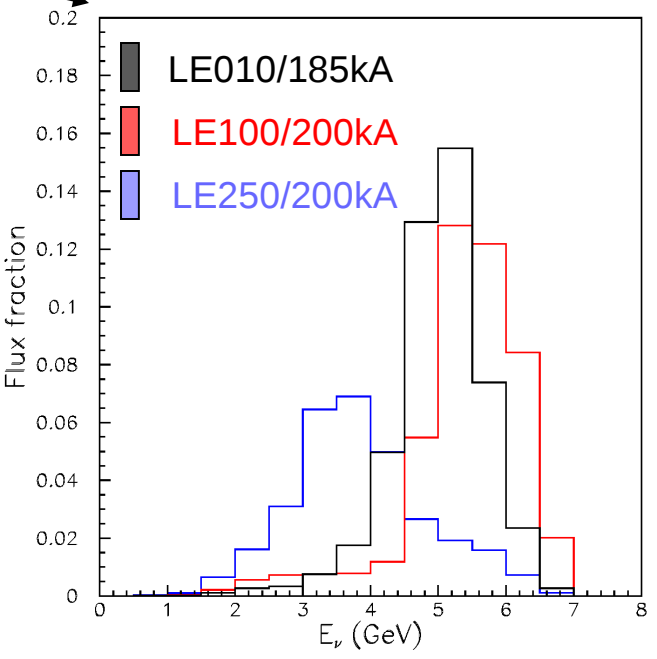
- MC/Data show some disagreement
- Adjust the yields of $\pi^{\pm}$ and $K^{\pm}$
- Fit data from all the beams simultaneously

Hadron Production



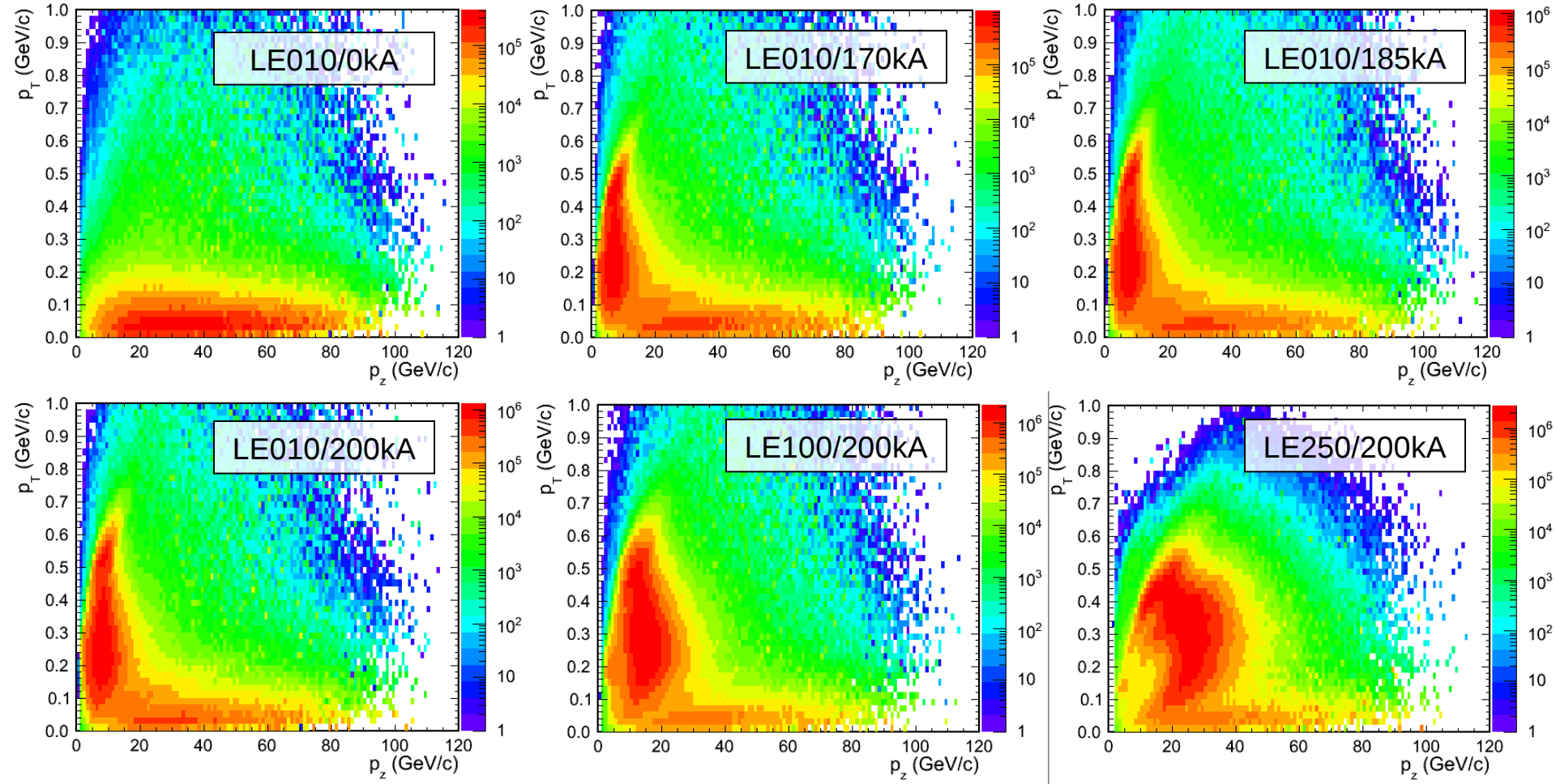


- Same p_T-x_F bin contributes differently to different beams

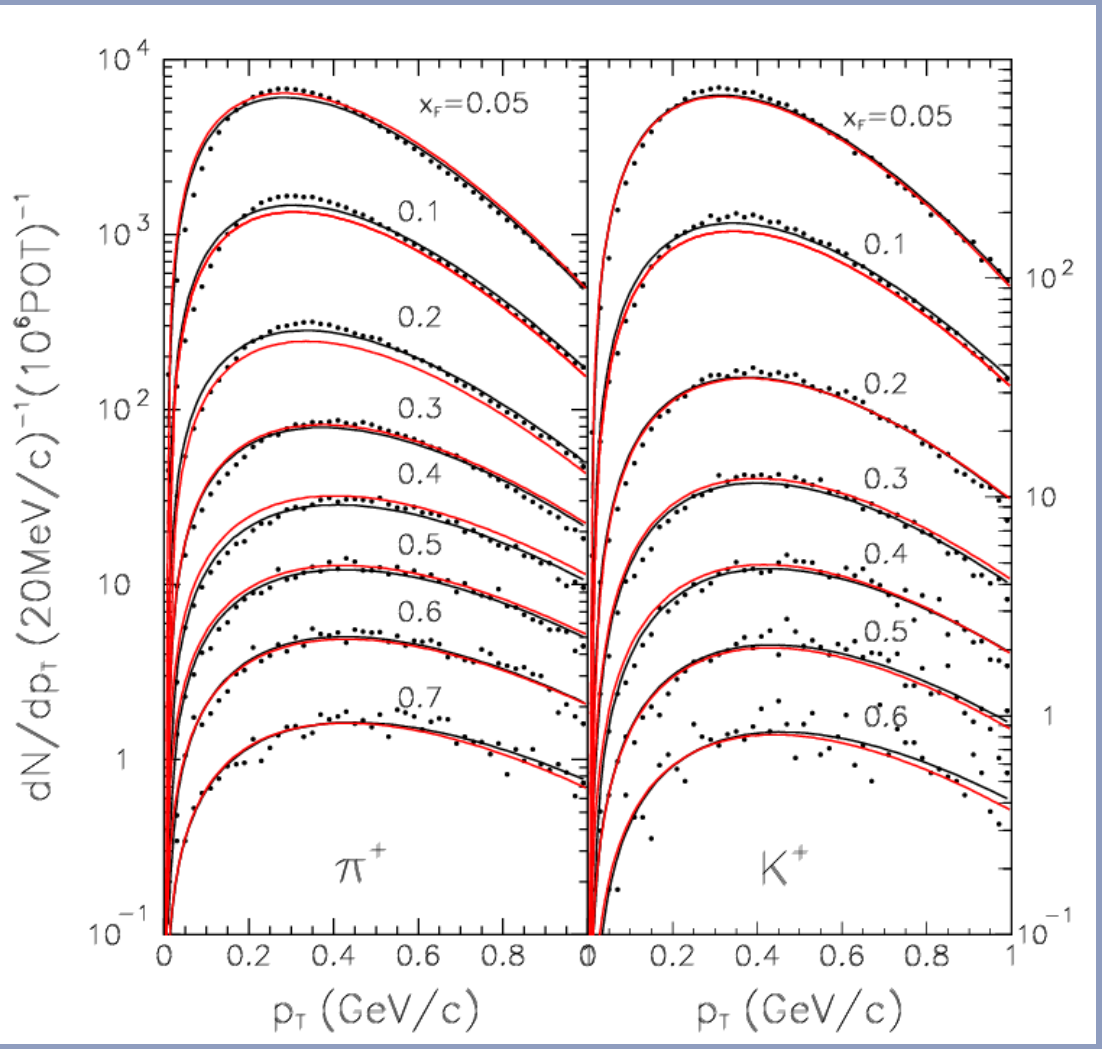


Hadron Production (cont'd)

- Different beams sample different pions
  - Not shown, but also using data from LE150/200kA



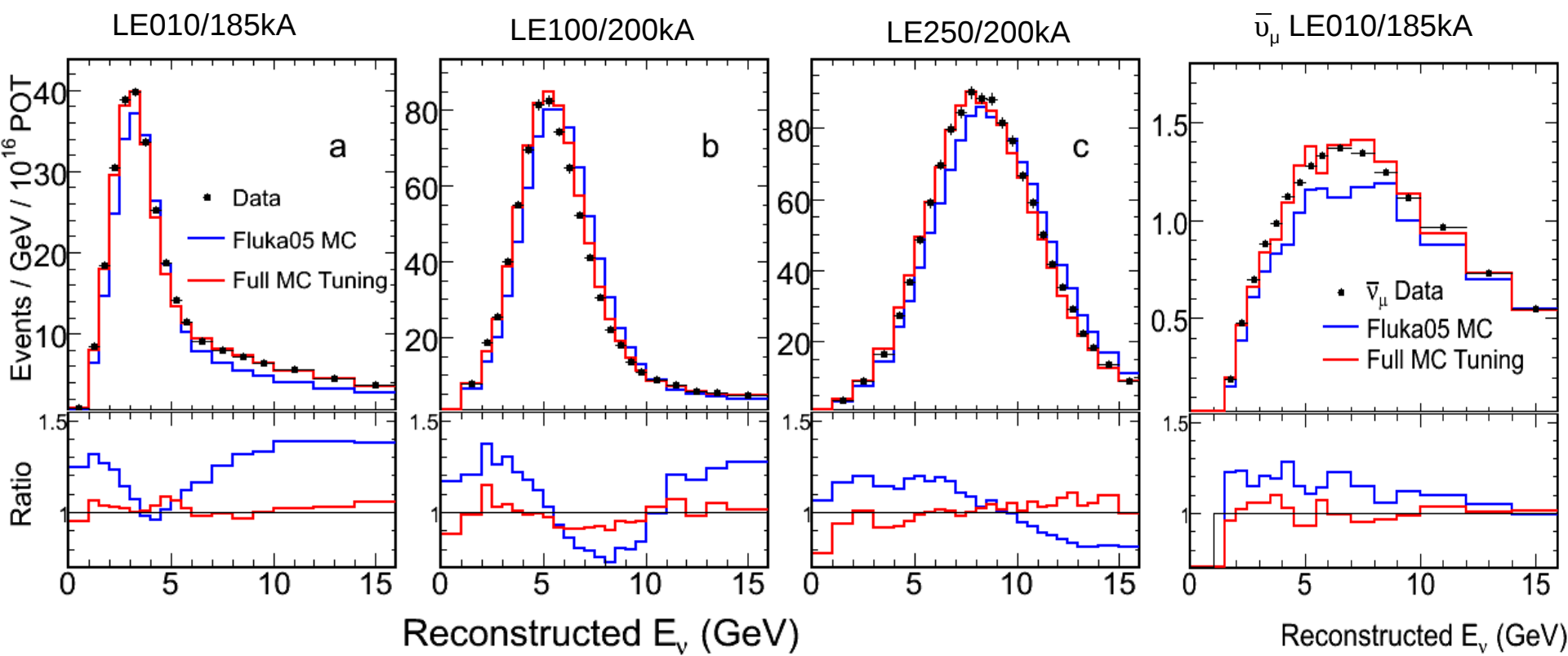
Hadron production parameterization



- Adjust yields as a function of p_T-p_z
- Parameterize fluka yields using 16 parameters

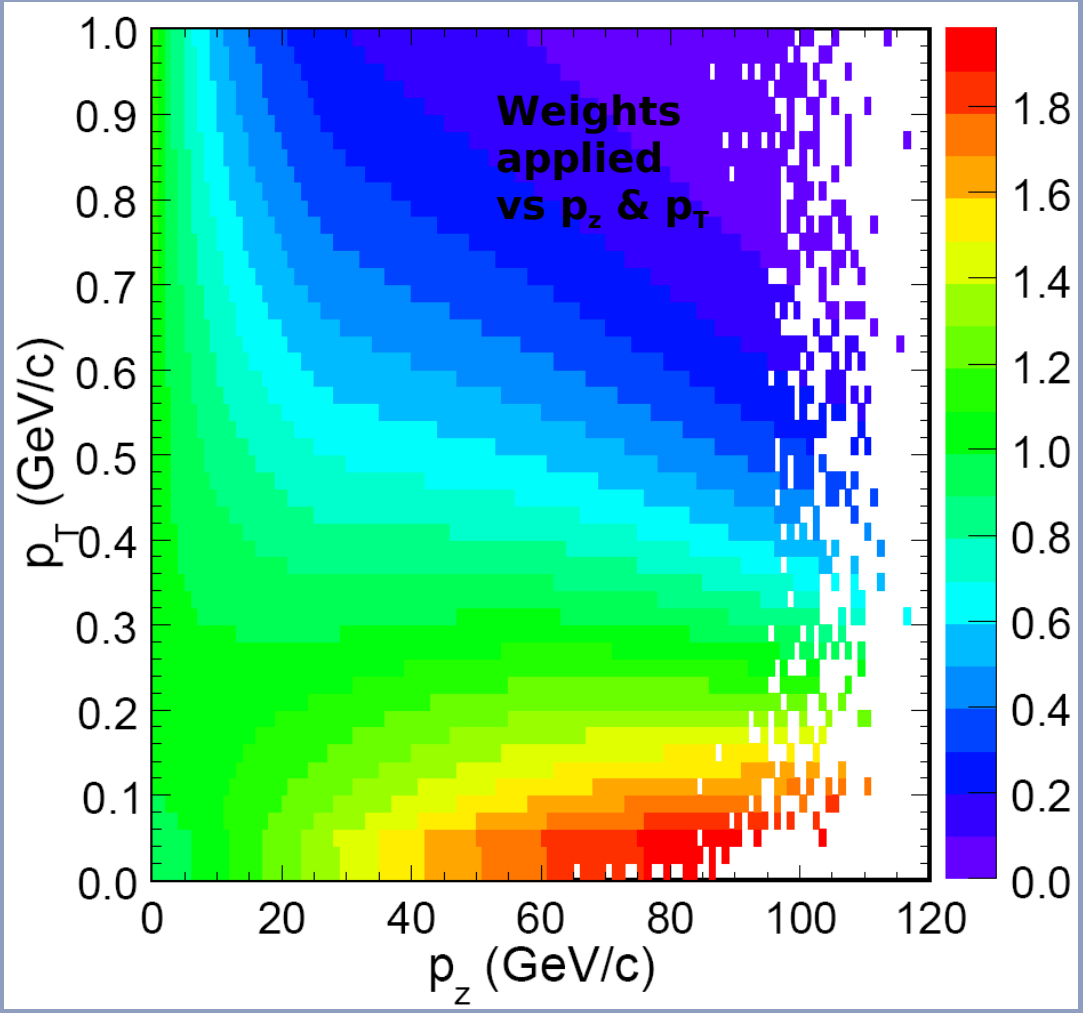
Tuning MC

- Fit ND data from all beam configurations
- Simultaneously fit ν_μ and $\bar{\nu}_\mu$ spectra
- Allow that some discrepancy due to cross sections and detector reconstruction



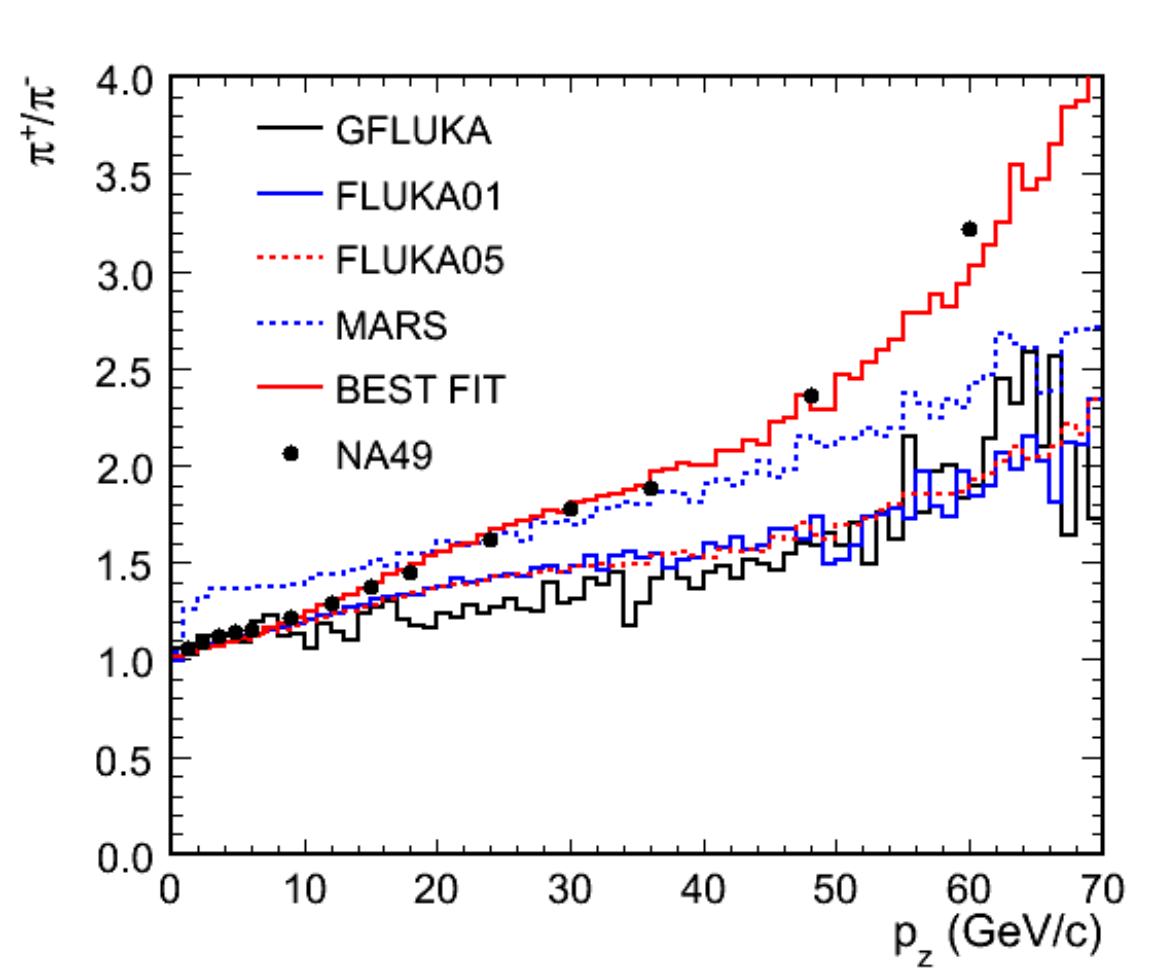
Tuning MC

- Adjust the yields of $\pi^{\pm}$ and $K^{\pm}$
- Re-weight MC based on p_T-x_F



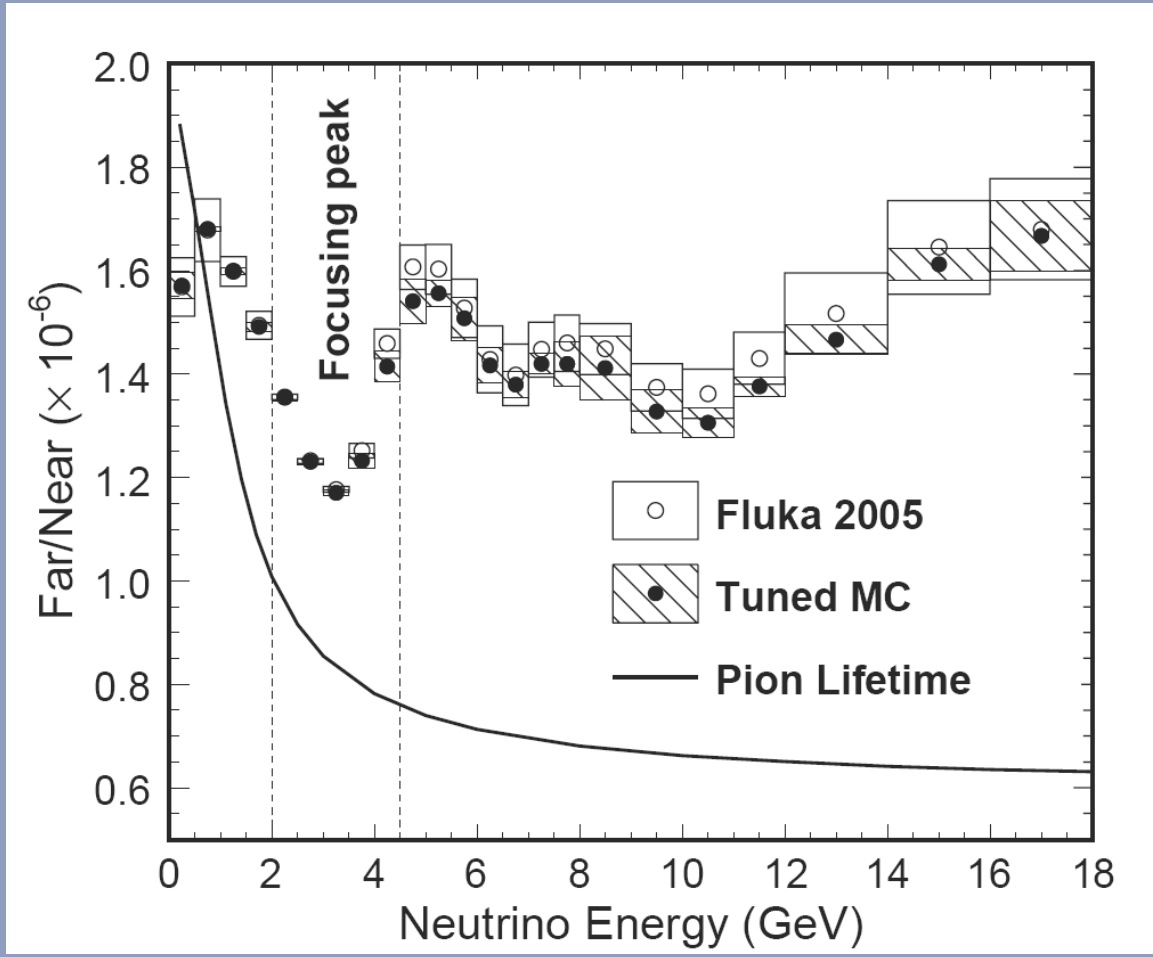
π^+/π^- ratio

- Best fit to ν_μ and $\bar{\nu}_\mu$ changes the π^+/π^- ratio
- Good agreement with NA49 data and preliminary MIPP results



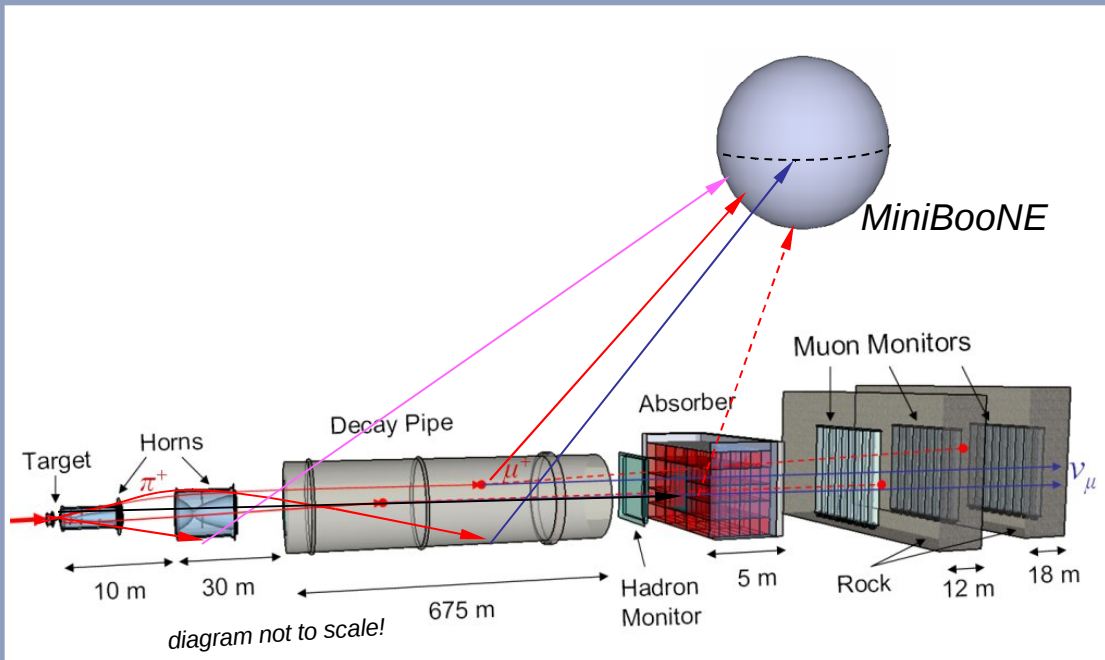
Far/Near Ratio

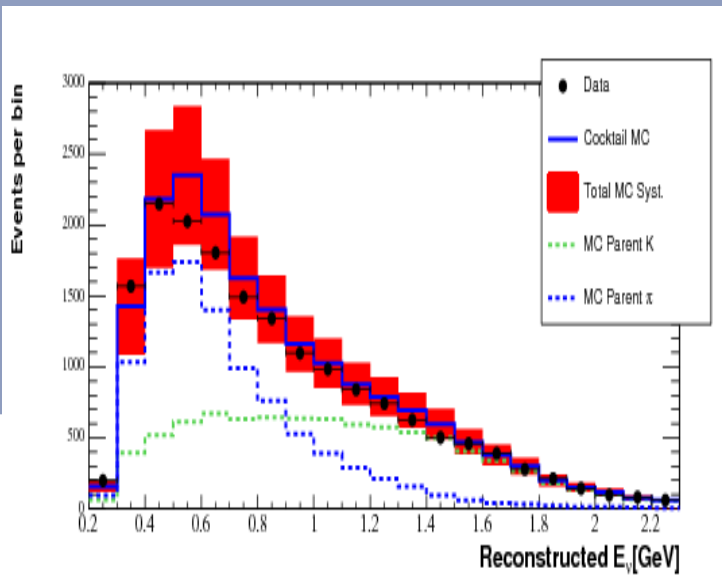
- Constrained hadron production using ND data
- Reduced errors on F/N ratio
- Systematic error due to beam uncertainty small

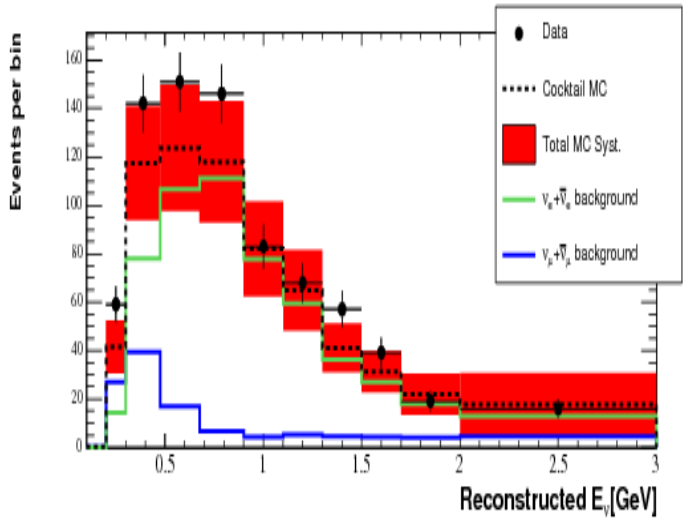


NuMI offaxis beam

- MiniBooNE detector sees offaxis neutrinos from NuMI (110mrad)
- Good agreement between data and MC



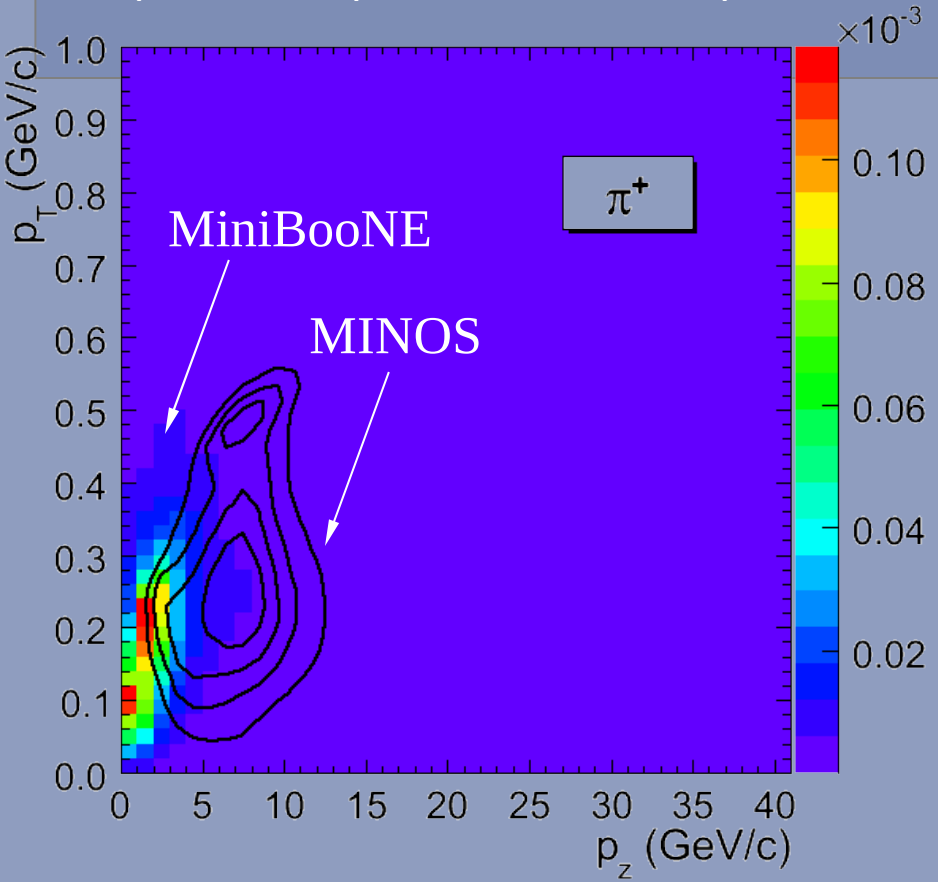


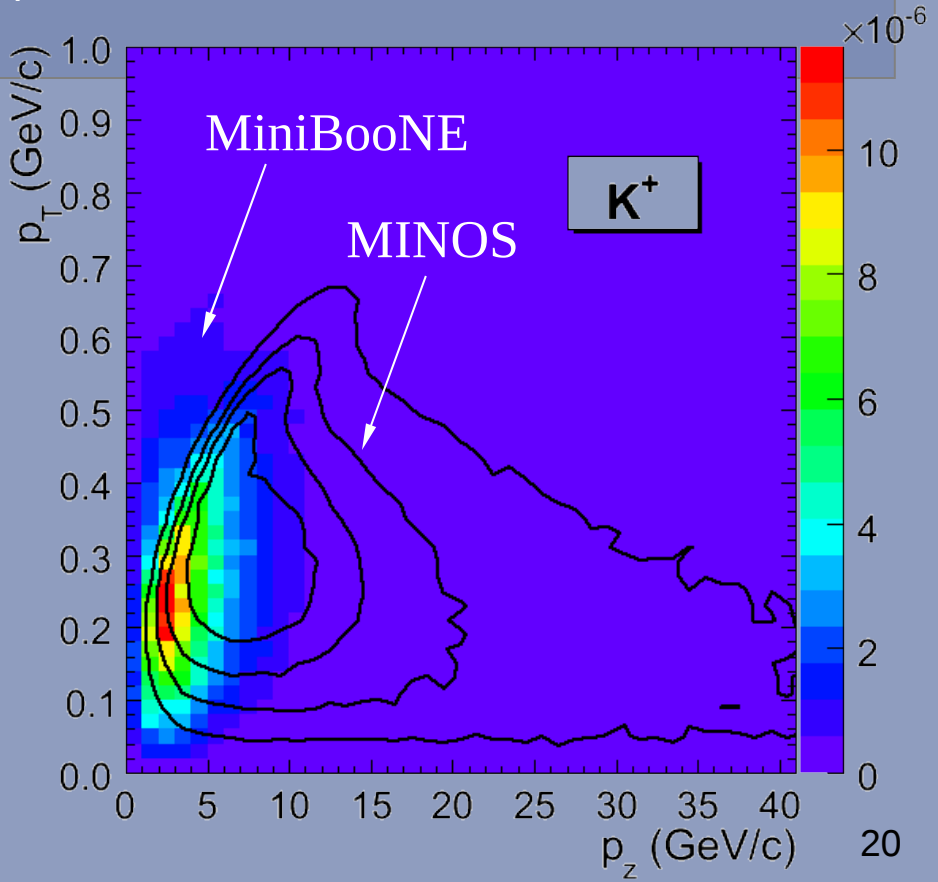


Two views of the same decays

- Decays of hadrons produce neutrinos that strike both MINOS and MiniBooNE
- Parent hadrons ‘sculpted’ by the two detectors’ acceptances.

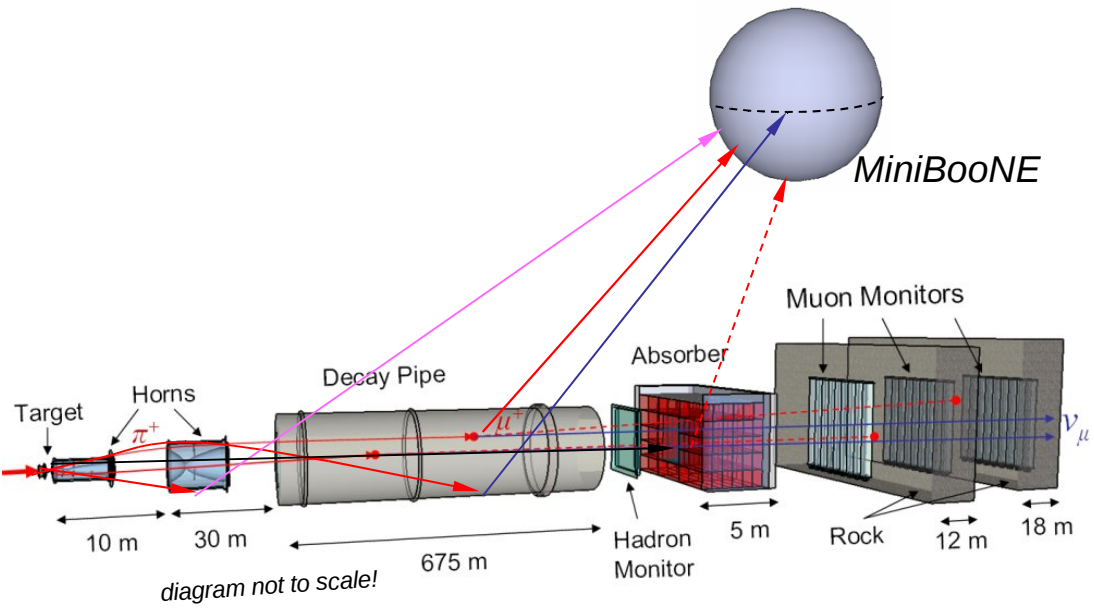
- Plotted are p_T and $p_{||}$ of hadrons which contribute neutrinos to MINOS (contours) or MiniBooNE (color scale)

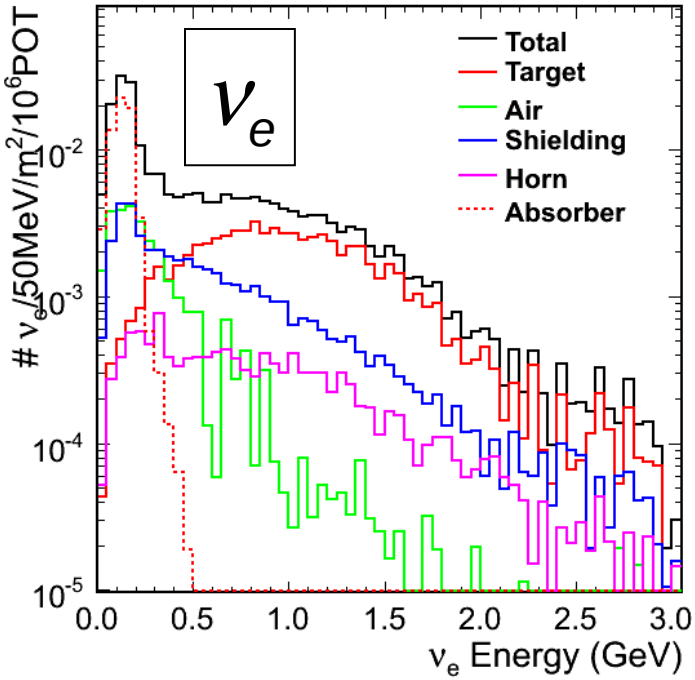


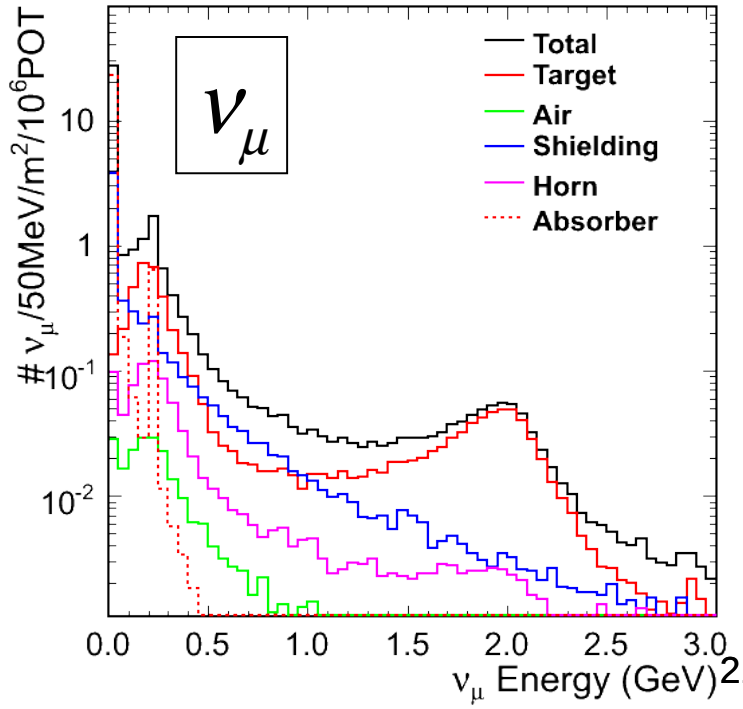


NuMI offaxis beam

- MINOS ND constrains only the target component
- Larger error on parents produced in downstream shielding and especially absorber
- Excluded neutrinos from absorber in this analysis







Conclusion

- Tune hadron production to simultaneously fit all ND data
- Technique independent of particle production experiments
- Beam systematics well constrained