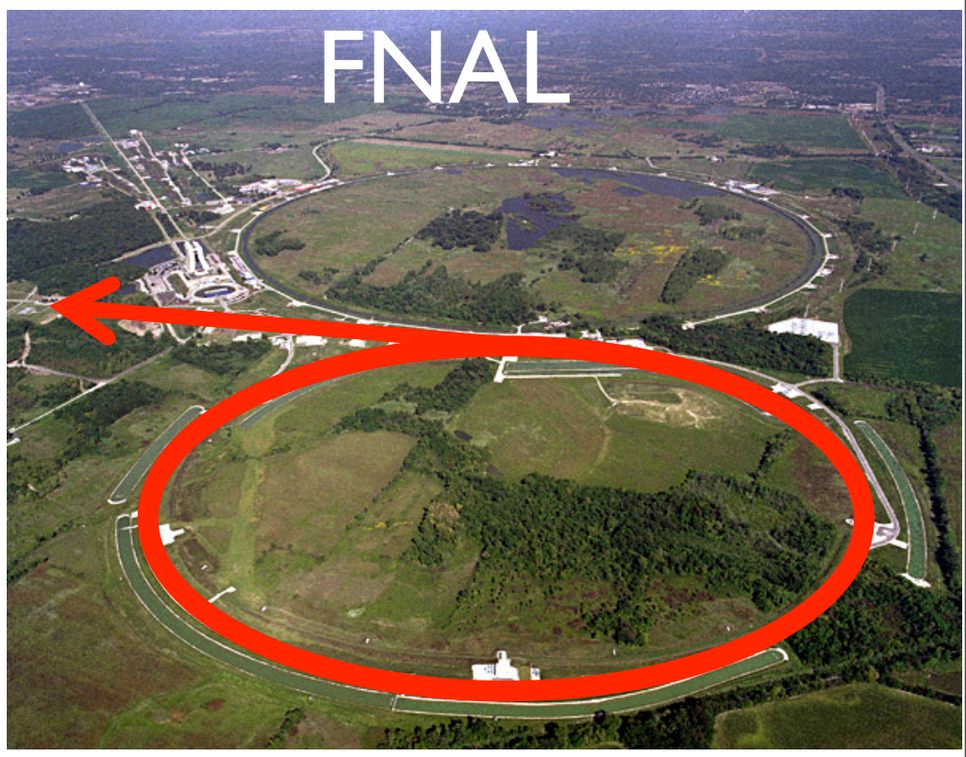
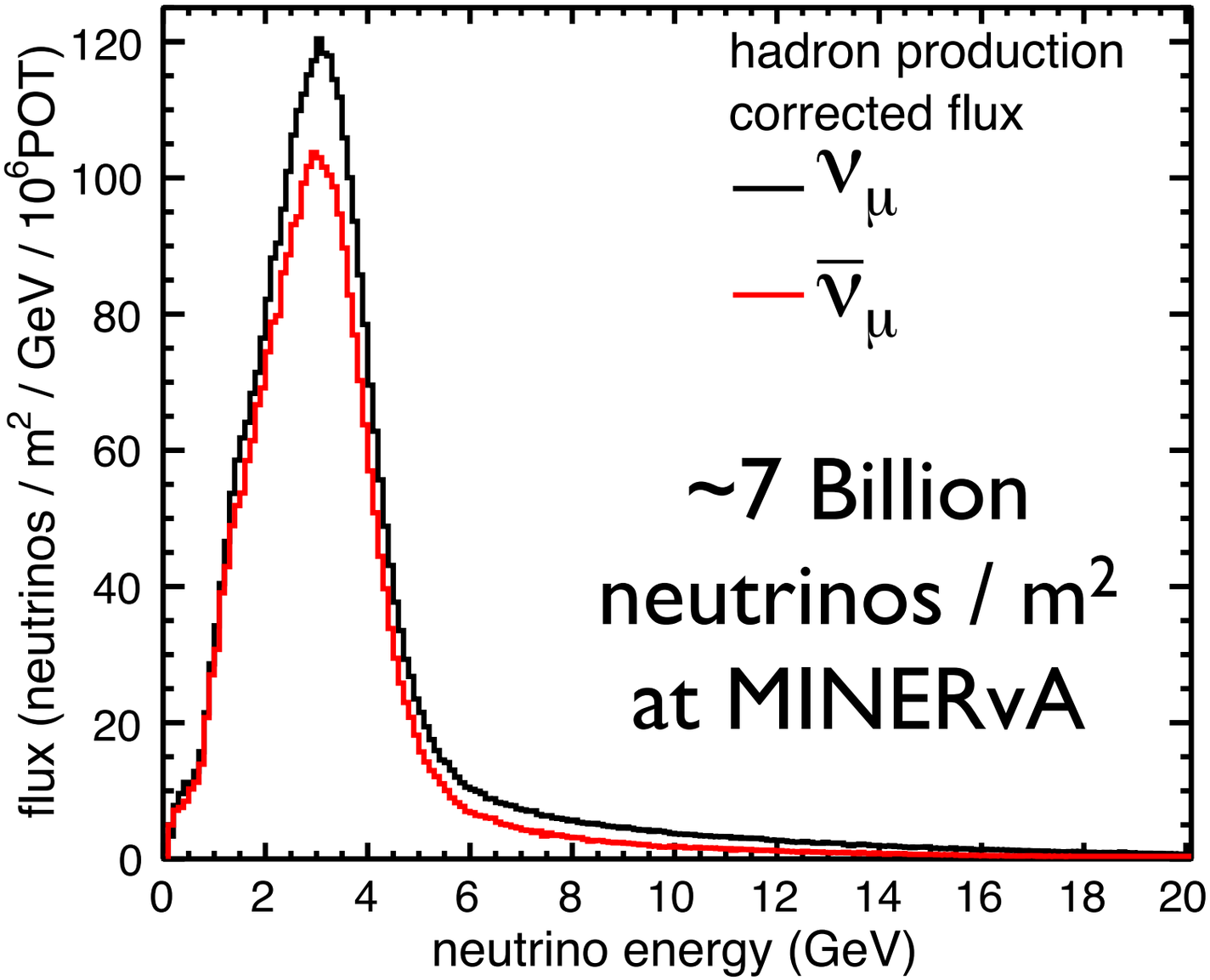
MINERvA Flux: Executive Summary

- GEANT4 FTFP with central value re-weighting using NA49 data scaled to 120 GeV.
- ~10% uncertainty on the absolutely normalized $d\sigma/dQ^2$, roughly flat across Q^2. ~1% uncertainty on the shape-only $d\sigma/dQ^2$.
- Total uncertainties are computed by varying the event-weights within parameter uncertainties and re-doing the analysis. The RMS spread of the different outputs around the central value builds the uncertainty band and correlation matrix.

Neutrino Beam





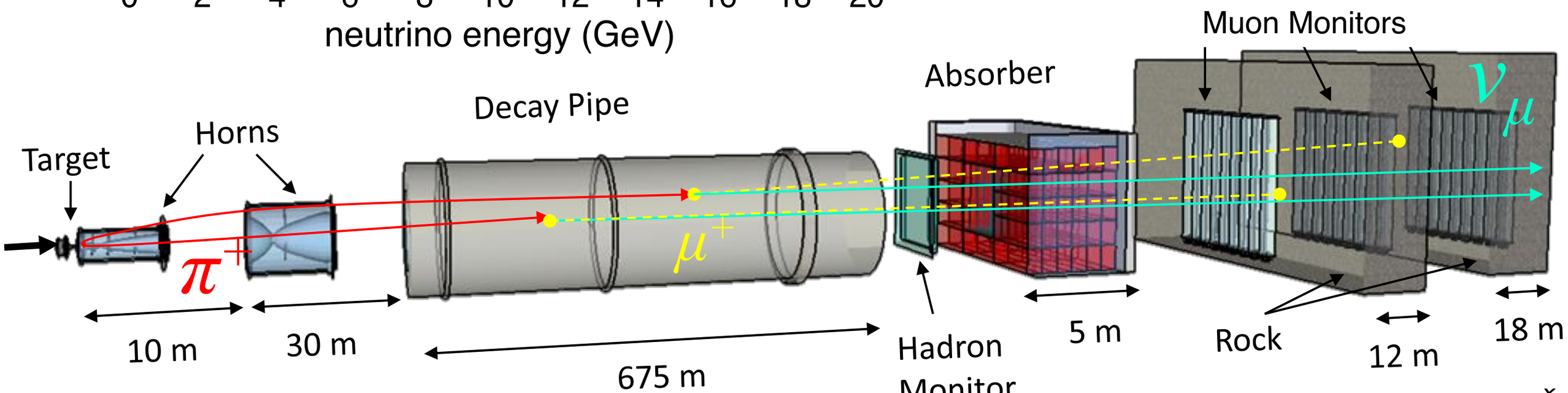


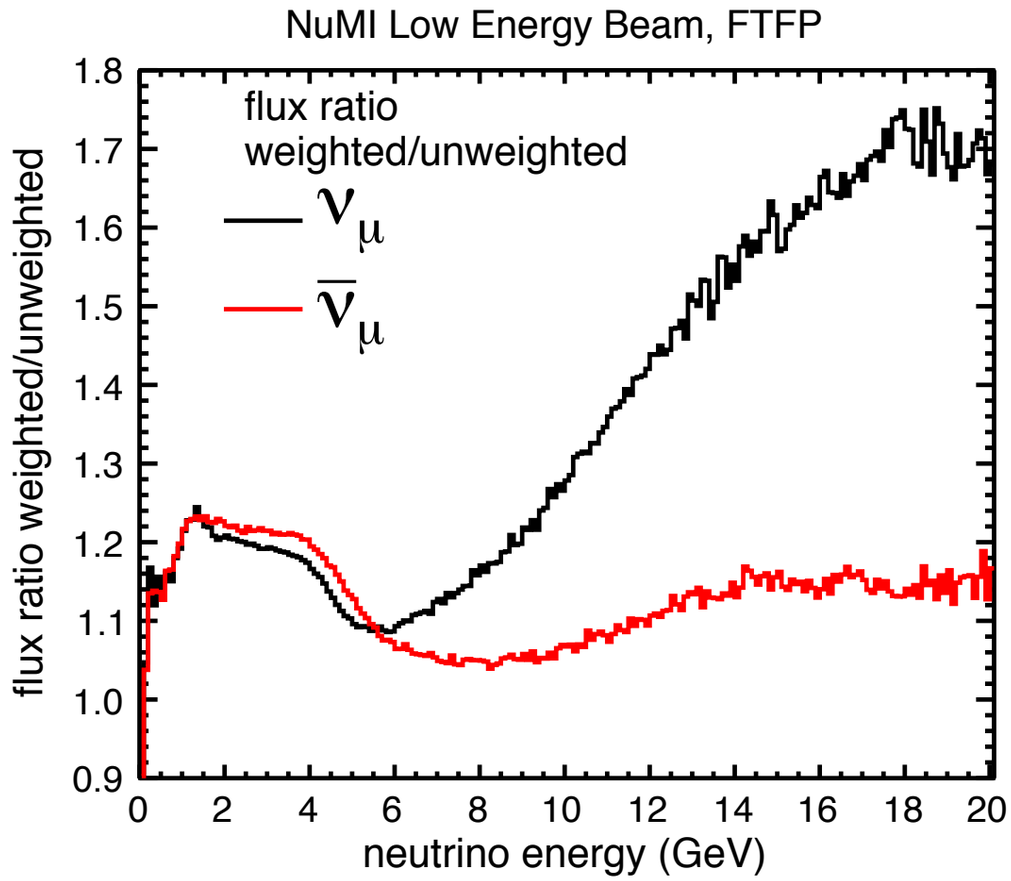
figure courtesy Ž. Pavlović

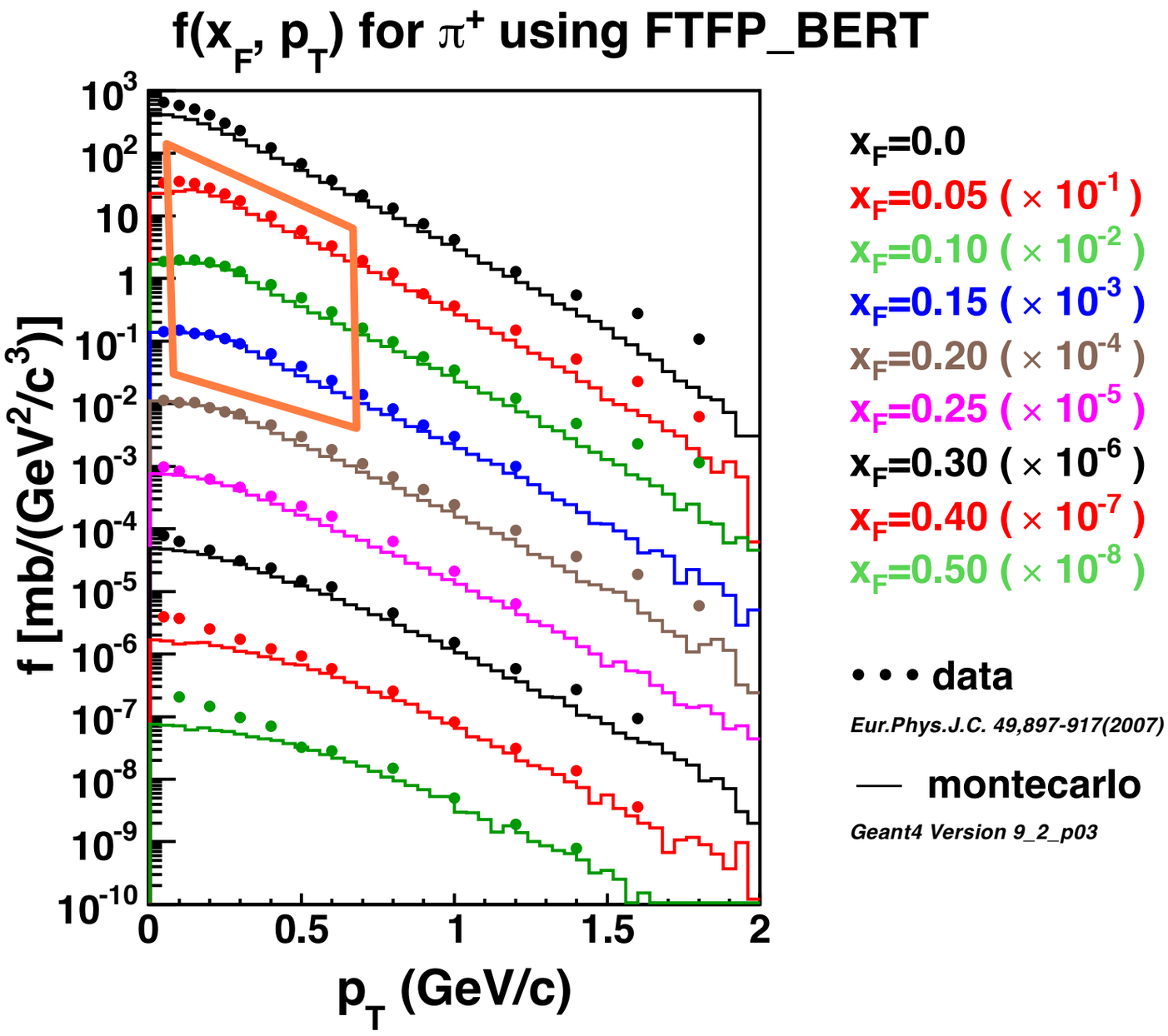
MINERvA Flux: Central Values

- The FTFP model of GEANT4 9_2_p03 is our baseline MC.
- We then re-weight proton-Carbon to charged-pion + X, charged Kaon + X, and proton/anti-proton + X over 12-120 GeV assuming that the data/MC ratio for invariant cross sections measured at 158 GeV can be used at all energies with a scaling correction.
- We use mostly data published by the NA49 collaboration for $x_F < 0.5$, and other data for $x_F > 0.5$, and we compute the scaling factor using FLUKA. We cross-check the scaling by using NA61 measurements at 31 GeV and find agreement.

Beam Flux

- Hadron production re-weighting is complicated by relatively sparse data, and the problems associated with thick targets.





Special Runs / Beam Fits

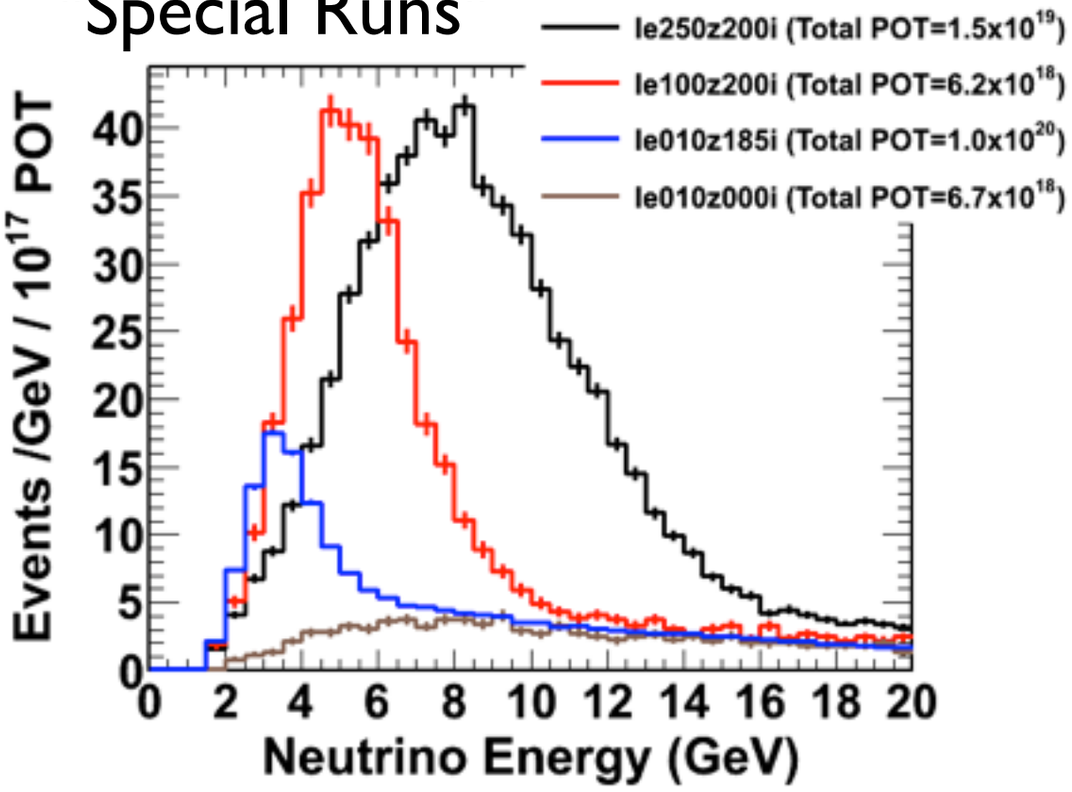
- MINERvA recorded data with different horn currents and target positions to sample different regions of pion x_F and p_T.

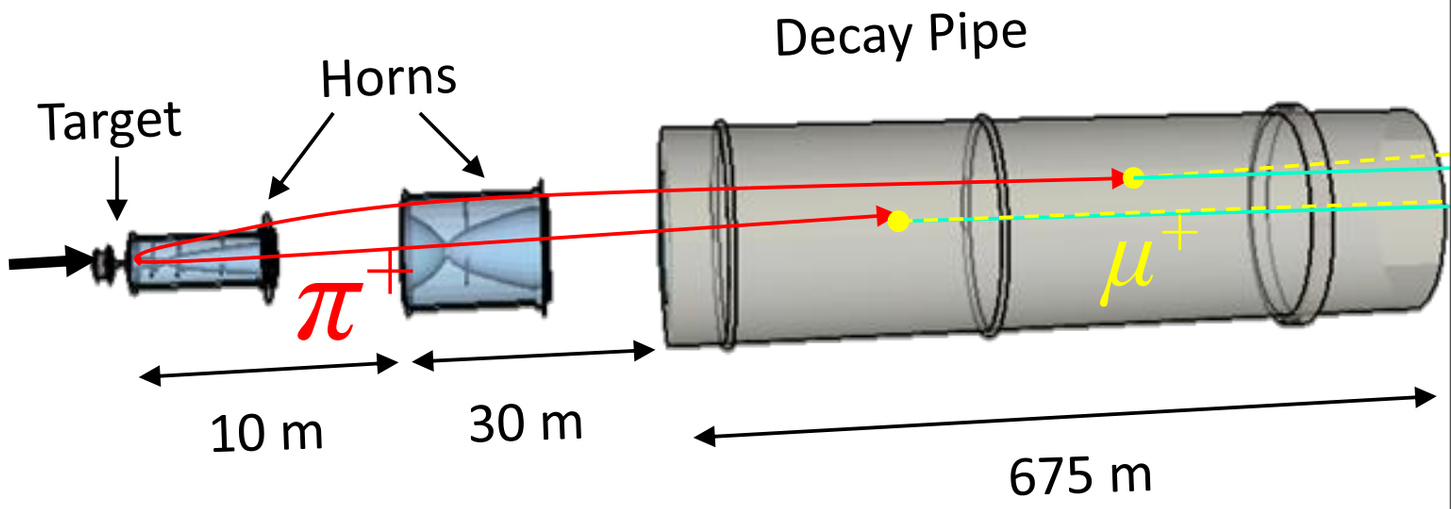
- We adjust charged pion and kaon yields as functions of x_F and p_T, with some hadron production constraints (pion/kaon ratios) enforced.

ν_μ	$\bar{\nu}_\mu$
LE010z185i	LE010z-185i
LE100z200i	LE100z-200i
LE010z000i	LE010z000i
LE250z200i	

Beam Flux

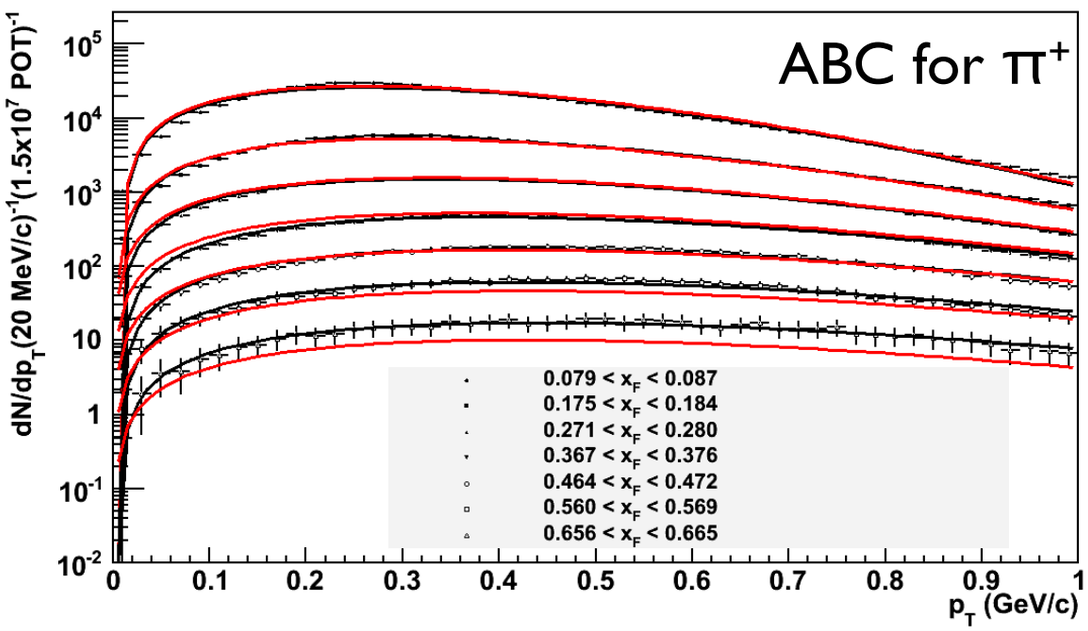
"Special Runs"



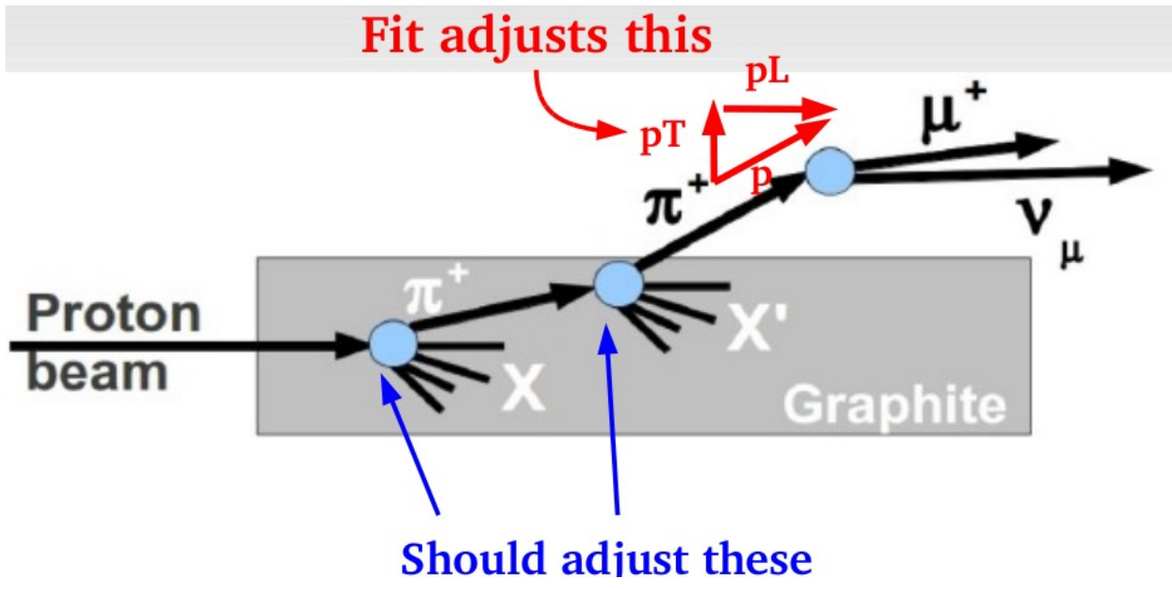


Vary target position and horn current.

$$\frac{d^2N}{dx_F\,dp\,T} = [A(x_F) + B(x_F)\,p_T + D(x_F)\,p_T^2]\,e^{-C(x_F)\,p_T^{E(x_F)}}$$



Dots: FTFP
Solid: ABC
Solid: Parameterized ABC



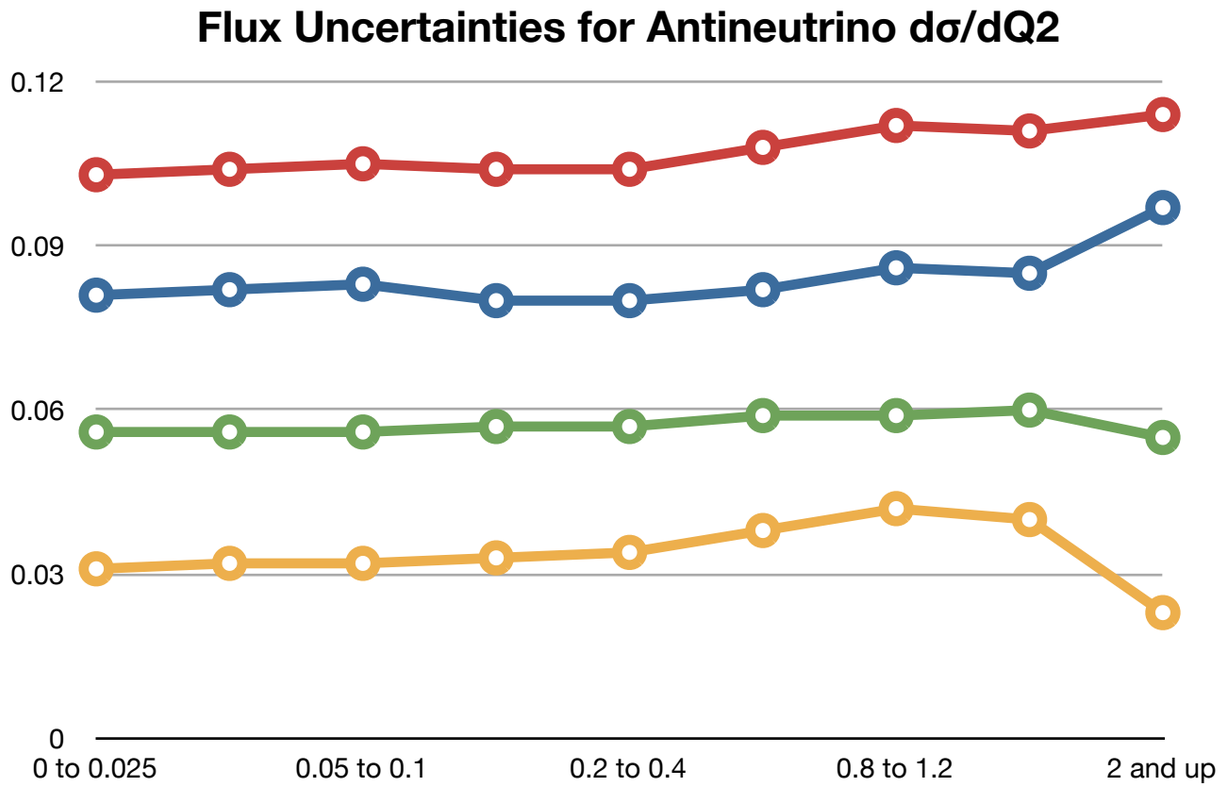
Thick targets!

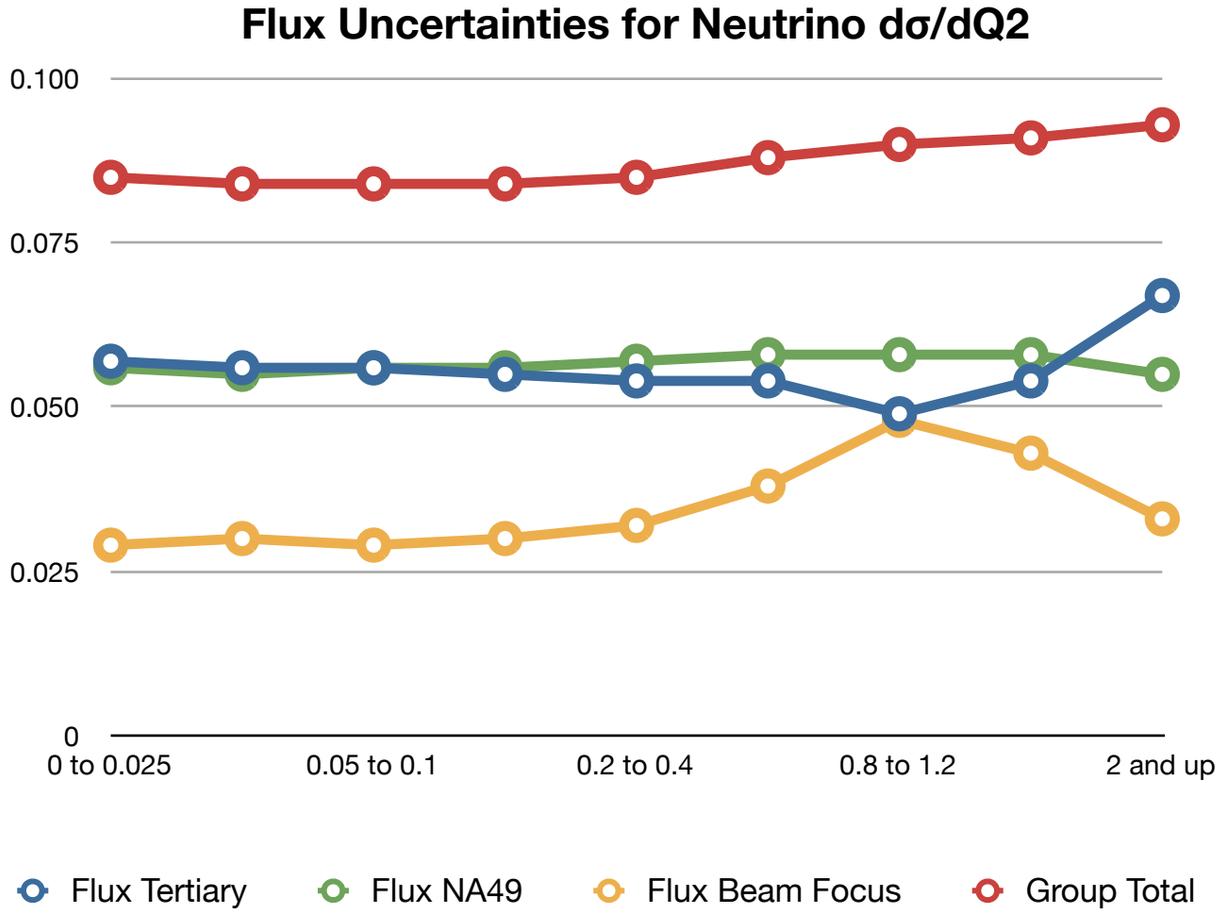
Other Refinements & Cross-Checks

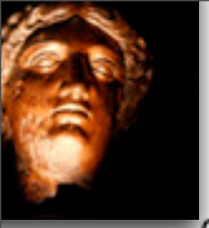
- Low-nu measurements.
  - See, for example: A. Bodek et al Eur Phys J C72 (2012) 1973, and D. Naples et al Phys Rev D 81 (2010) 072002
- Neutrino-electron scattering.
  - Precision process, but low statistics.

Uncertainties

- Three pieces:
  - NA49 - Published uncertainties on the data used for re-weighting.
  - Beam-Focusing - MINOS Thesis (Z. Pavlovic).
  - Tertiary Production - All production not re-weighted by NA49. Computed by model spread from different MC predictions.







Absolute → Shape Only