ν-e Flux Constraint

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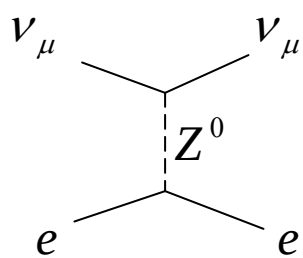
Neutrino Scattering on ~~Nucleon~~

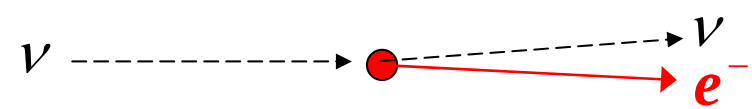
Electron

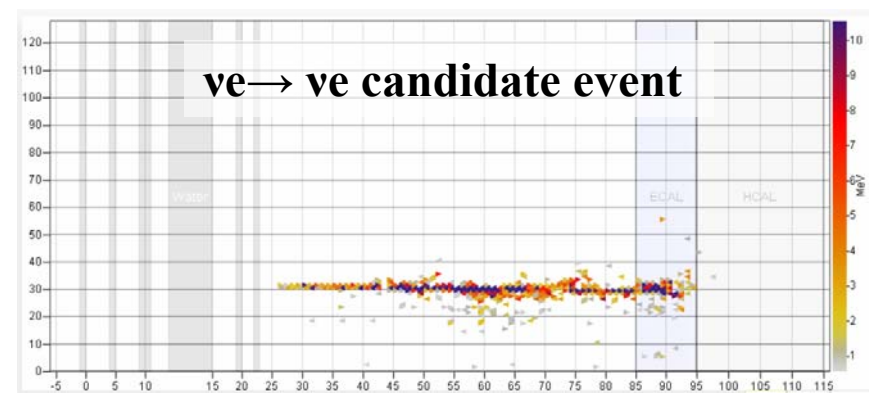
$$\nu_\mu + e^- \rightarrow \nu_\mu + e^-$$

$$\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$$



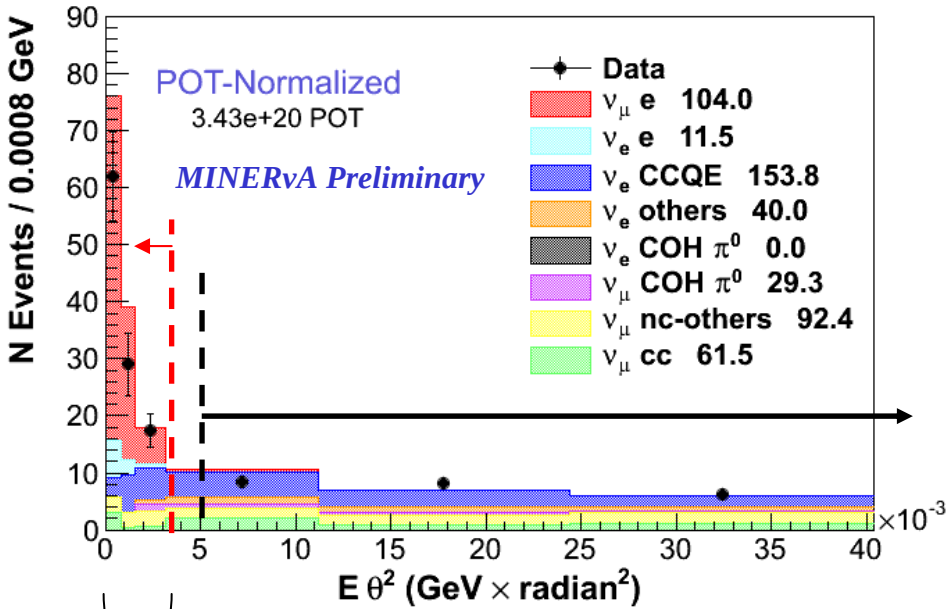
Very forward single electron final state

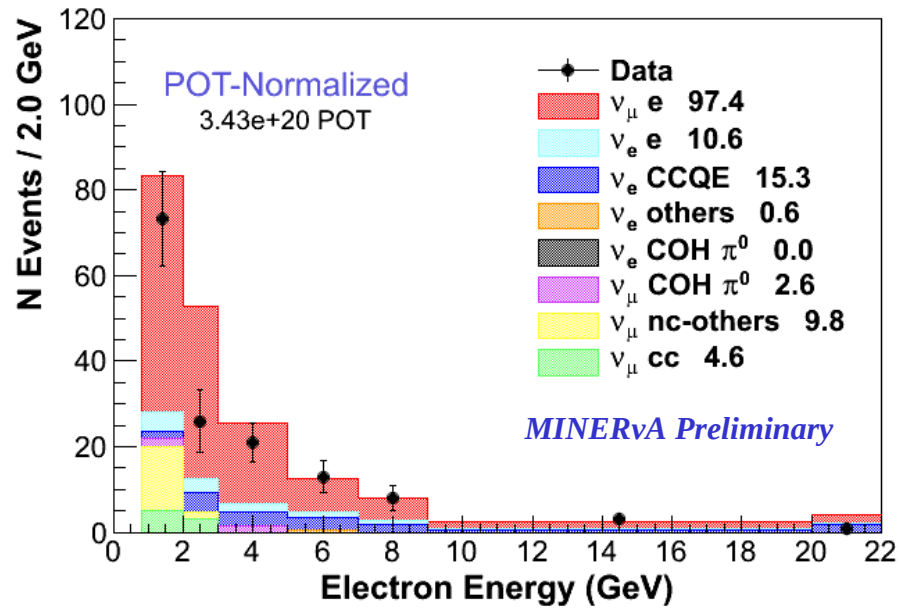




- Let's use well-known reaction to measure the flux
- Standard electroweak theory predicts it precisely
  - Point-like scattering
- Very small cross section (~1/2000 of ν-nucleon scattering)
  - Low center of mass energy due to light electron
- Very forward electron final state (Experimental signature)
- Good angular resolution is important to isolate the signal

νe Events = Single Highly Forward Electron





Signal

$E\theta^2 < 0.0032$

Sideband

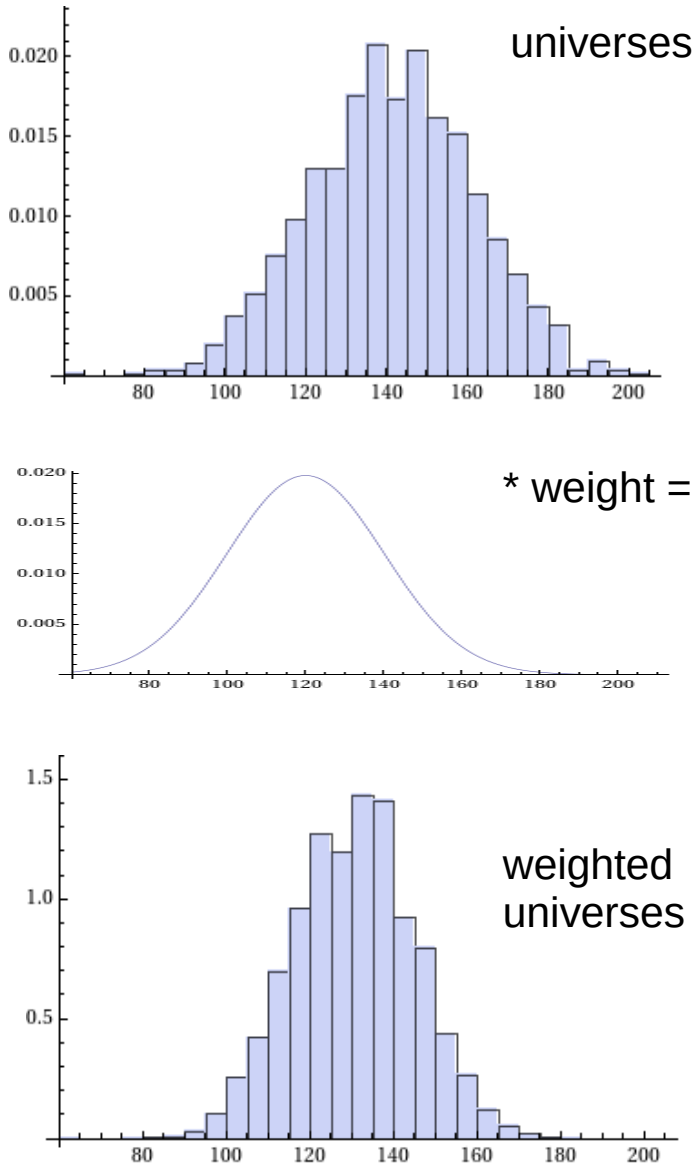
$E\theta^2 > 0.005\,\mathrm{GeV}\cdot\mathrm{rad}^2$

Signal electron spectrum

- Total νe events = Energy integrated flux normalization
- νe electron spectrum = Flux shape (but needs high statistics)

How does this work?

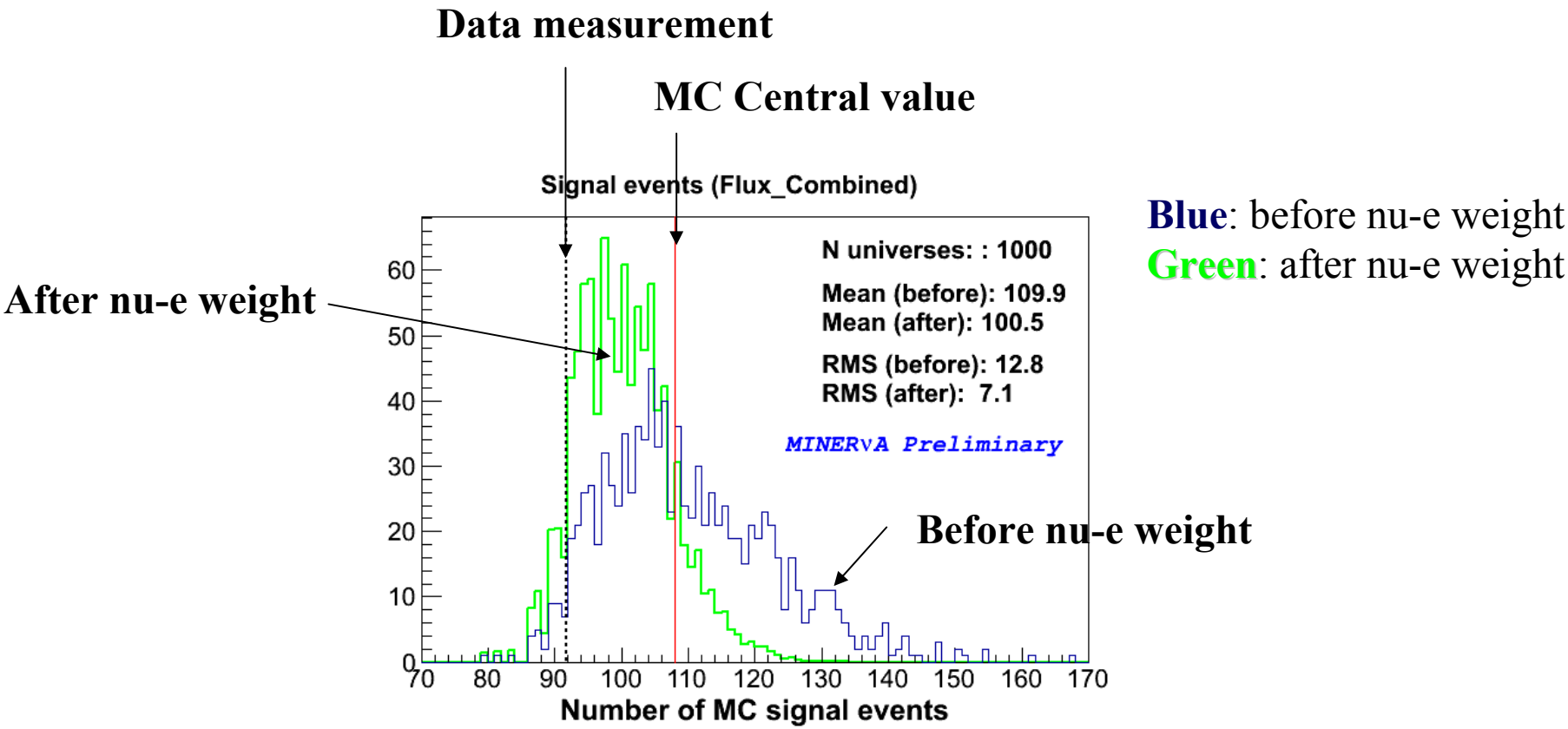
- Take a simple toy example of a single measurement with a Gaussian *a priori* probability which seeds multi-universes
  - For this toy, assumed a priori prediction was 141.2±20.1 and the measurement 120±20.2
  - Preferred value shifts and uncertainty is reduced



What is Different in this Application?

- Neutrino-electron scattering samples different parts of the flux differently
  - Higher energies appear in a greater range of electron energies
  - Lower neutrino neutrinos are not constrained as well because of 800 MeV electron energy cut
  - Electron neutrinos (ok, sub-dominant, but still) are oversampled 6x because of cross-section
- We are relying on the correlations in the multi-universes to account for this different sampling

Before and After Applying nu-e Weights



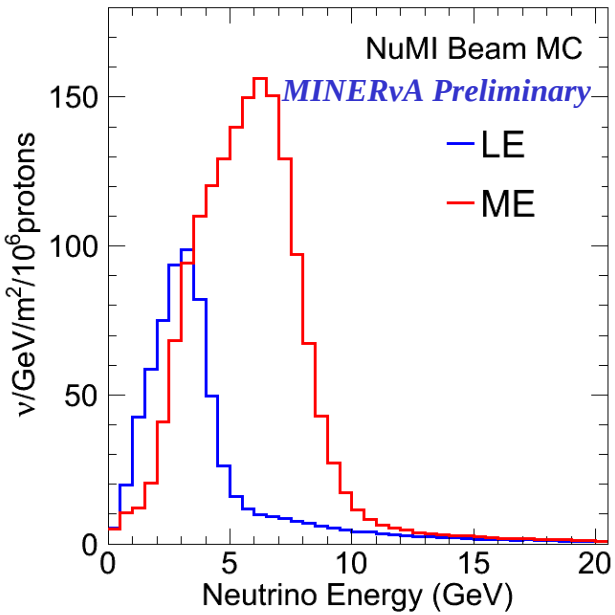
- Fractional uncertainty (Before) = 12.8/108 = 0.12
- Fractional uncertainty (After) = 7.1/108=0.07

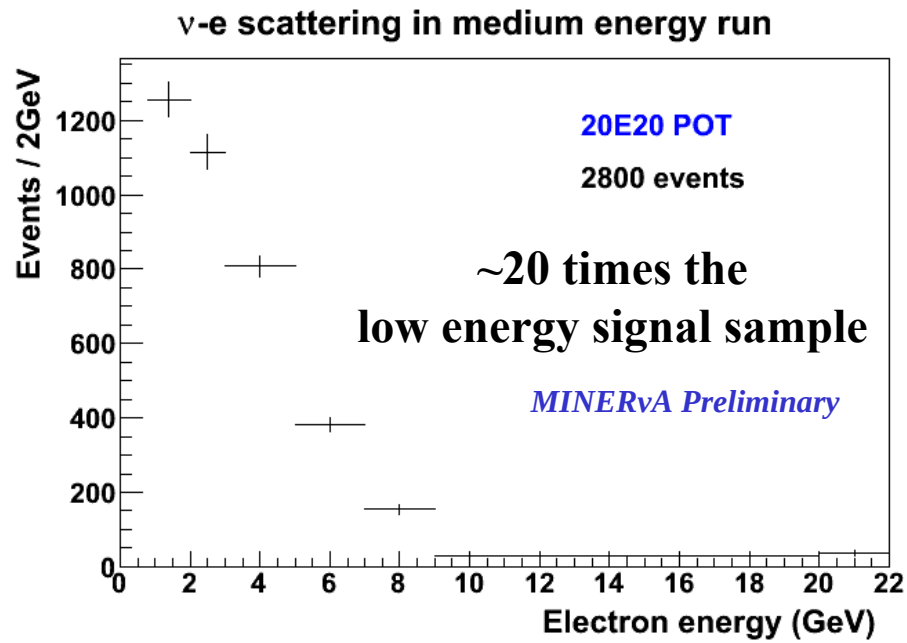
Summary

- νe constraint reduces flux uncertainty
- Using electron spectrum would give slightly better constraint but haven't done yet
- ME will get benefit from higher statistics

Backup

Future Flux Measurement at NuMI



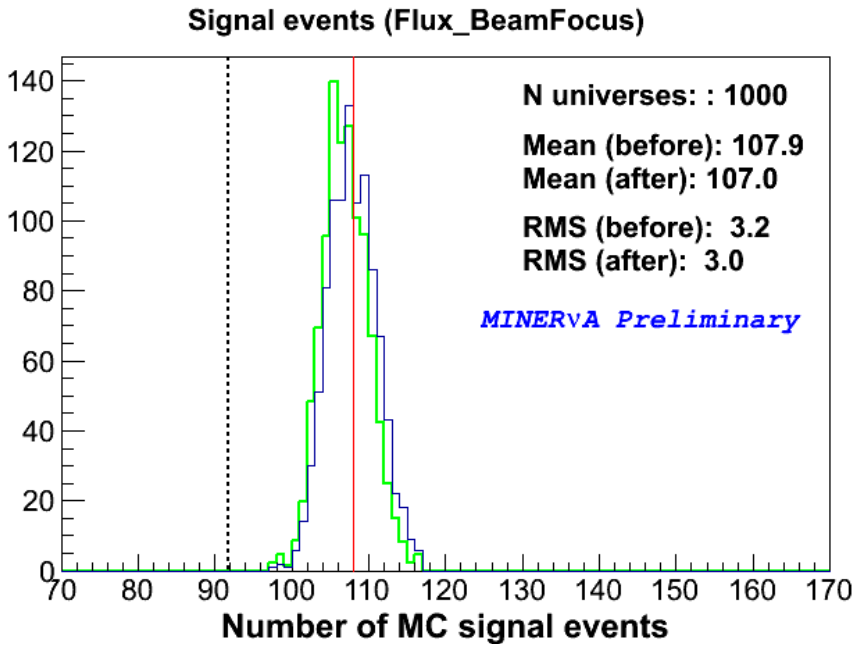
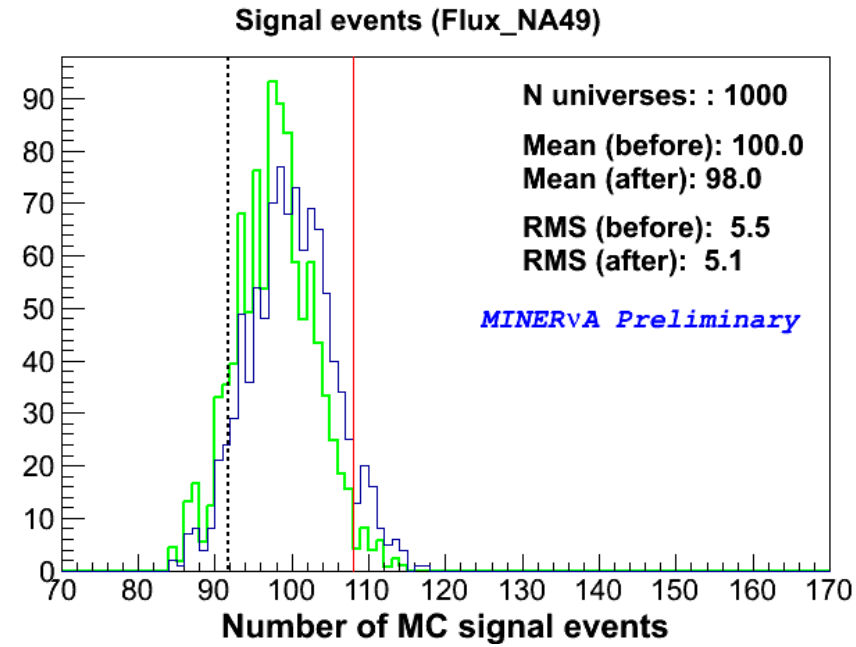
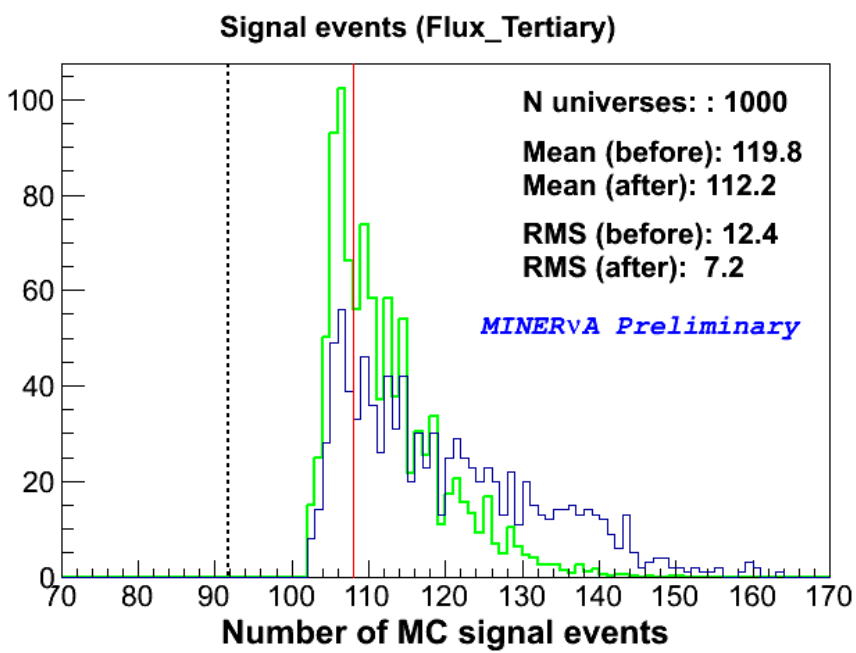
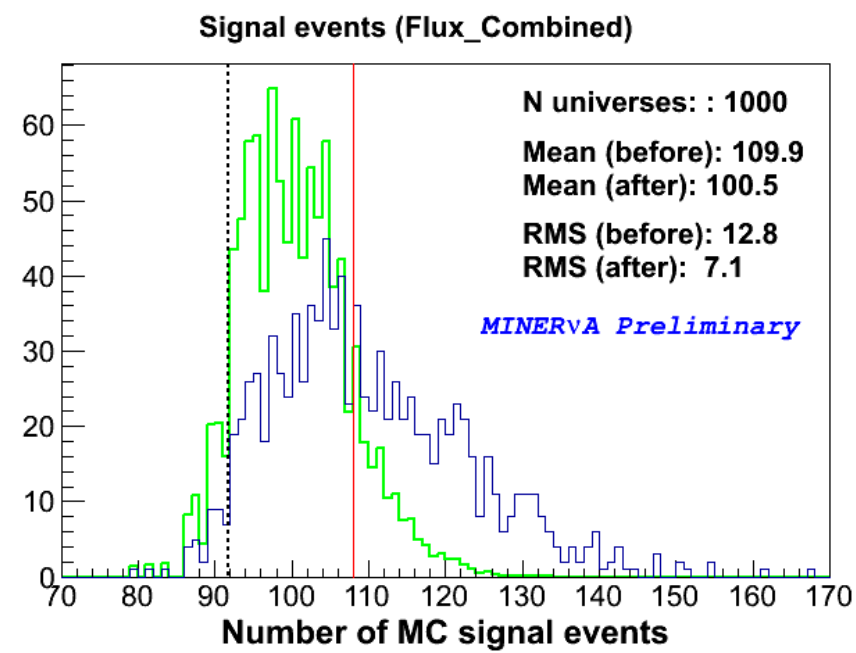


Medium Energy Flux:
Now being produced in the NuMI Beamline, as of September 2013

- Assuming similar signal/background ratio as in Low Energy Run:
  - Can expect statistical uncertainty = ~2%
  - Total systematic uncertainty on this measurement: 7%
  - Total uncertainty = ~7.3%

Weight

- μ: data events
- σ: error on data (fraction uncertainty = 13%)
- x: MC events in i-th multi-universe
- Weight = Probability = f

$$f(x,\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Individual Flux Uncertainties