Energy scale studies update

Seb Jones

12/03/2018
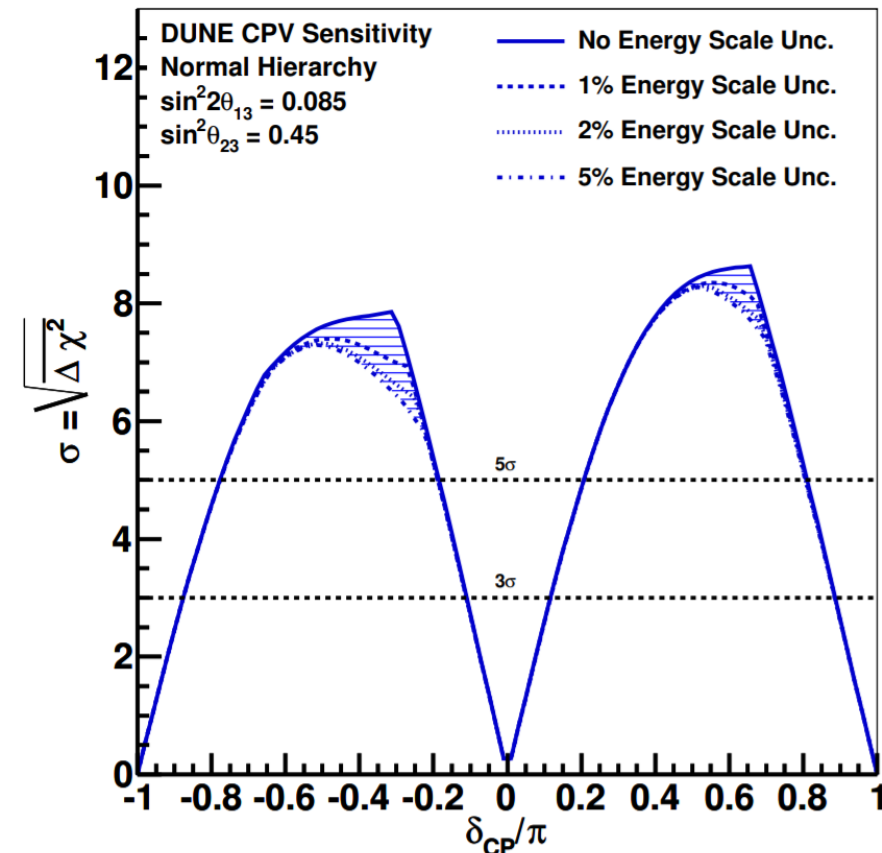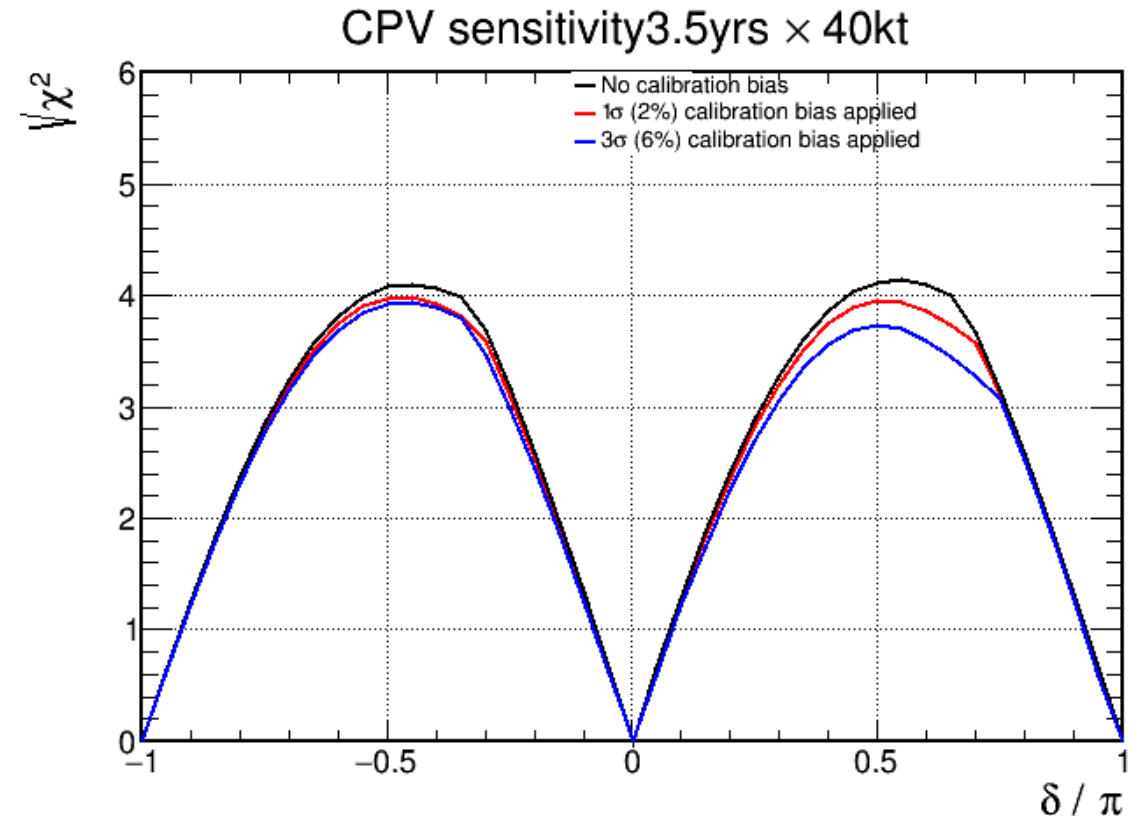
Recap

- Previously spoke about this at January collaboration meeting
- Aim was to reproduce results seen in GLoBES for energy scale systematic
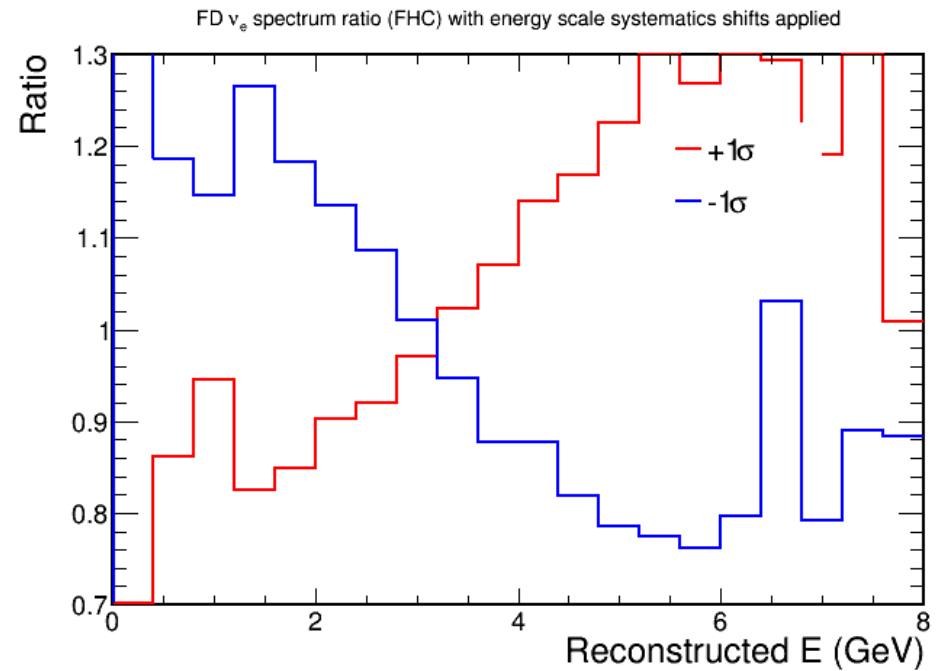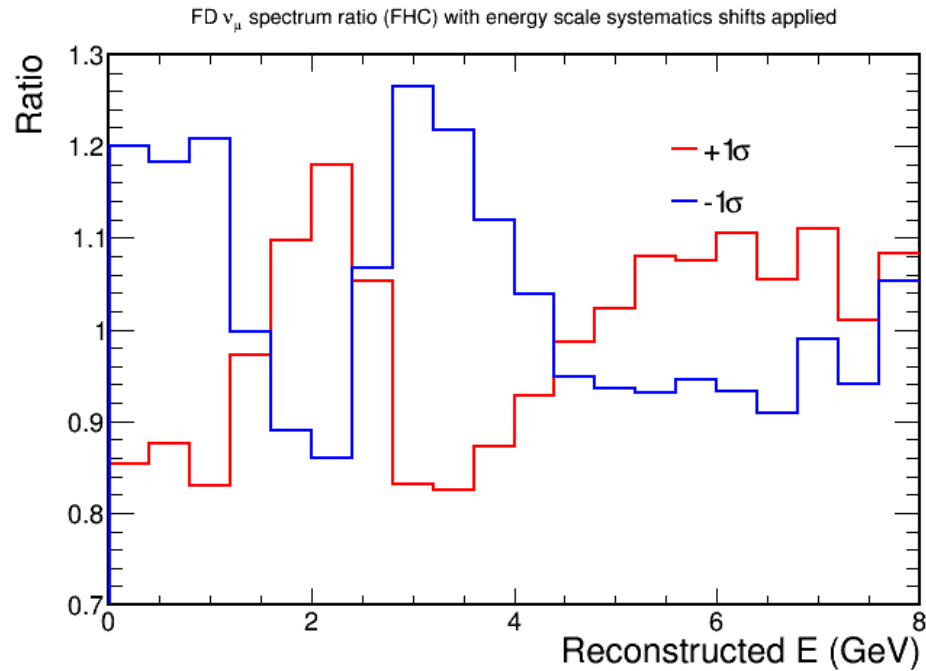 - Seemed like an unusually small effect

Recap

- Results (right), seemed to align with what was seen previously – smaller drop in sensitivity than might be expected

- However, number of areas were identified for improvement
  - Assumed perfect knowledge of the flux and cross-section
  - No near detector
  - Differing shifts for hadronic and leptonic components

CPV sensitivity3.5yrs × 40kt

No calibration bias
1σ (2%) calibration bias applied
3σ (6%) calibration bias applied

$\sqrt{\chi^2}$

δ / π

New energy scale systematics

- Created 3 new systematics in CAFAna based upon the inelasticity of the neutrino interactions
    - Define inelasticity, $Y = 1 - \dfrac{E_{lep}}{E_v}$
    - For both numu and nue events, have a 15% uncertainty on the 'hadronic' component of the neutrino energy
        - $E = E_v * (1 - Y + Y * (1 + 0.15\sigma))$
    - For numu and nue events, have a 2% uncertainty on the 'leptonic' component of the neutrino energy
        - Separate systematics for nue and numu events
        - $E = E_v * ((1 - Y) * (1 + 0.02\sigma) + Y)$

New energy scale systematics

FD ν_μ spectrum ratio (FHC) with energy scale systematics shifts applied

FD ν_e spectrum ratio (FHC) with energy scale systematics shifts applied
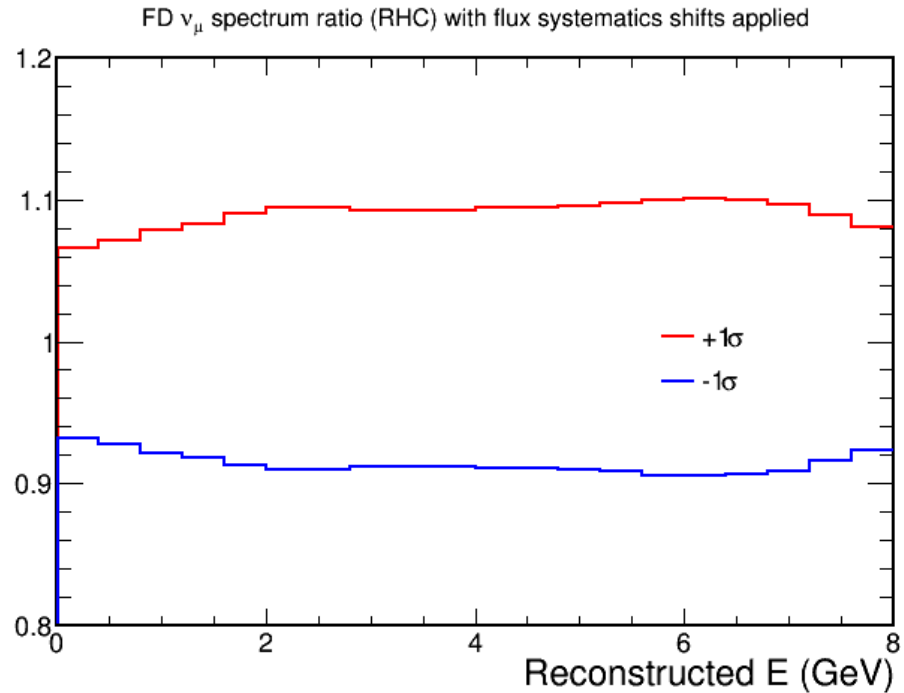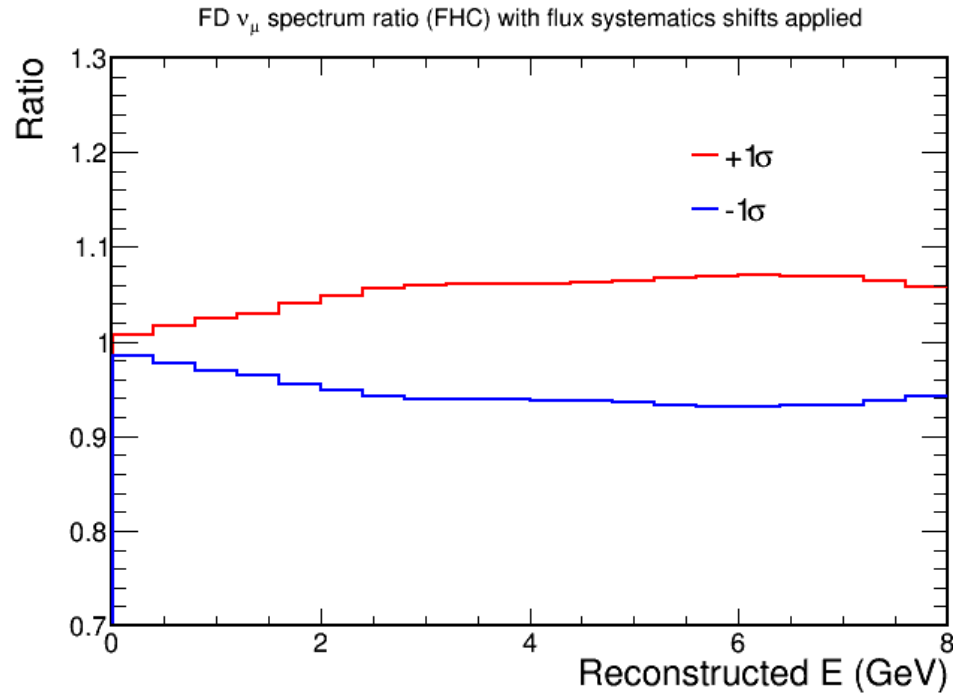
- Examples of ratios of shifted to unshifted spectra shown here – rest are shown in backup slides

New energy scale systematics

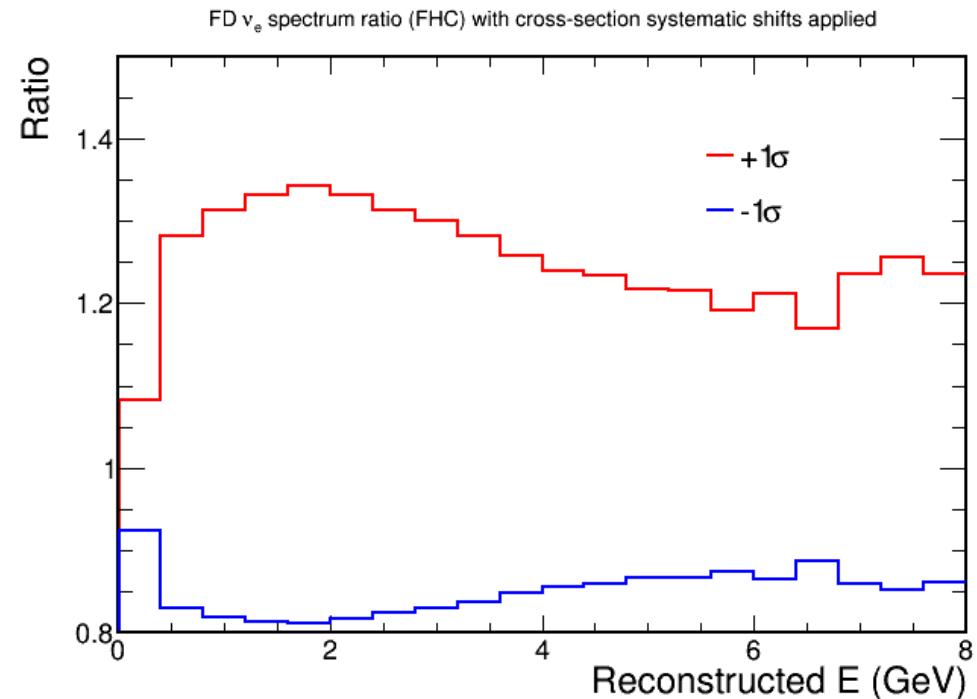CPV sensitivity with energy scale systematics (3.5yr × 40kt × 2 horn polarities)
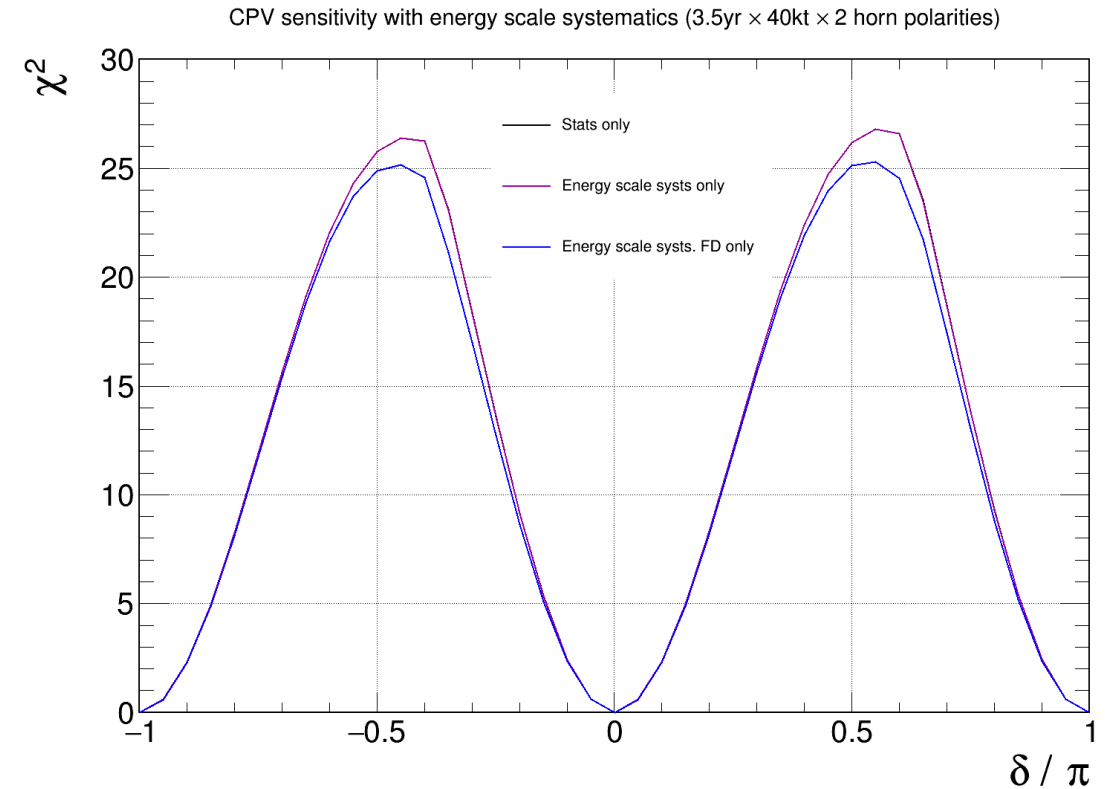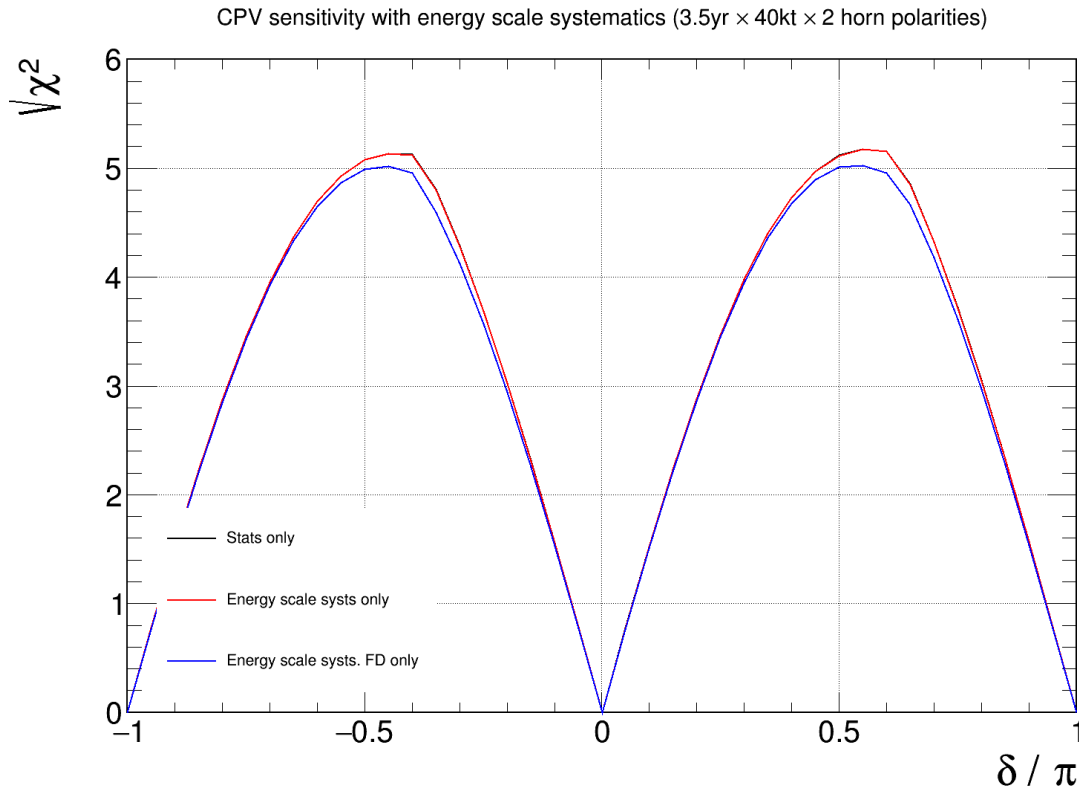
- CPV sensitivity plots with these new energy scale systematics shown here
- Adding in near detector effectively takes you back to stats only case
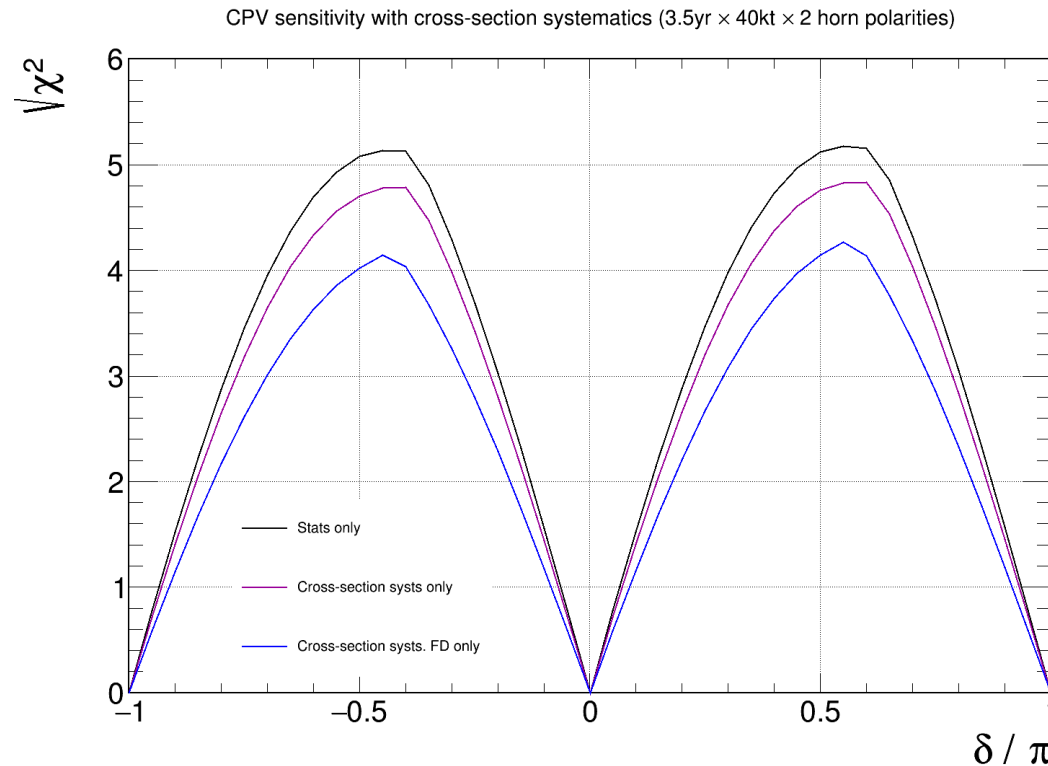
Flux systematics

- **Once again these are ratios of the shifted to unshifted spectra for the flux systematics – again, full details in backup**

Cross-section systematics

FD ν_μ spectrum ratio (FHC) with cross-section systematics shifts applied

FD ν_e spectrum ratio (FHC) with cross-section systematic shifts applied

- Once again these are ratios of the shifted to unshifted spectra for the flux systematics – again, full details in backup
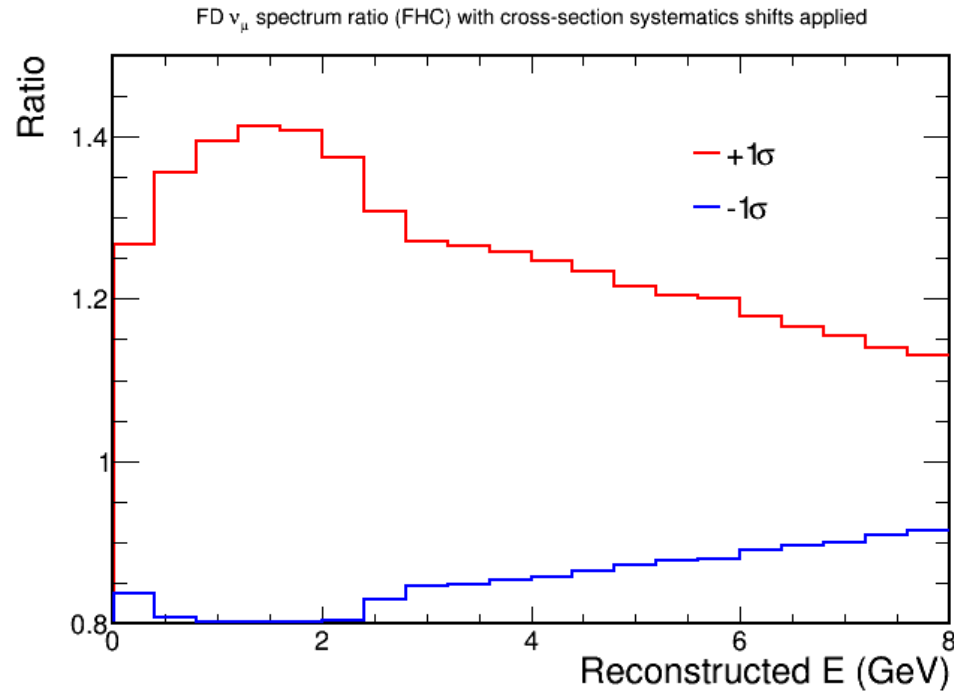
Cross-section systematics

CPV sensitivity with cross-section systematics (3.5yr × 40kt × 2 horn polarities)

- • CPV sensitivity with just cross-section systematics, in the case with and without a ND

Combined plot

CPV sensitivity with flux, cross-section and energy scale systematics (3.5yr × 40kt × 2 horn polarities)
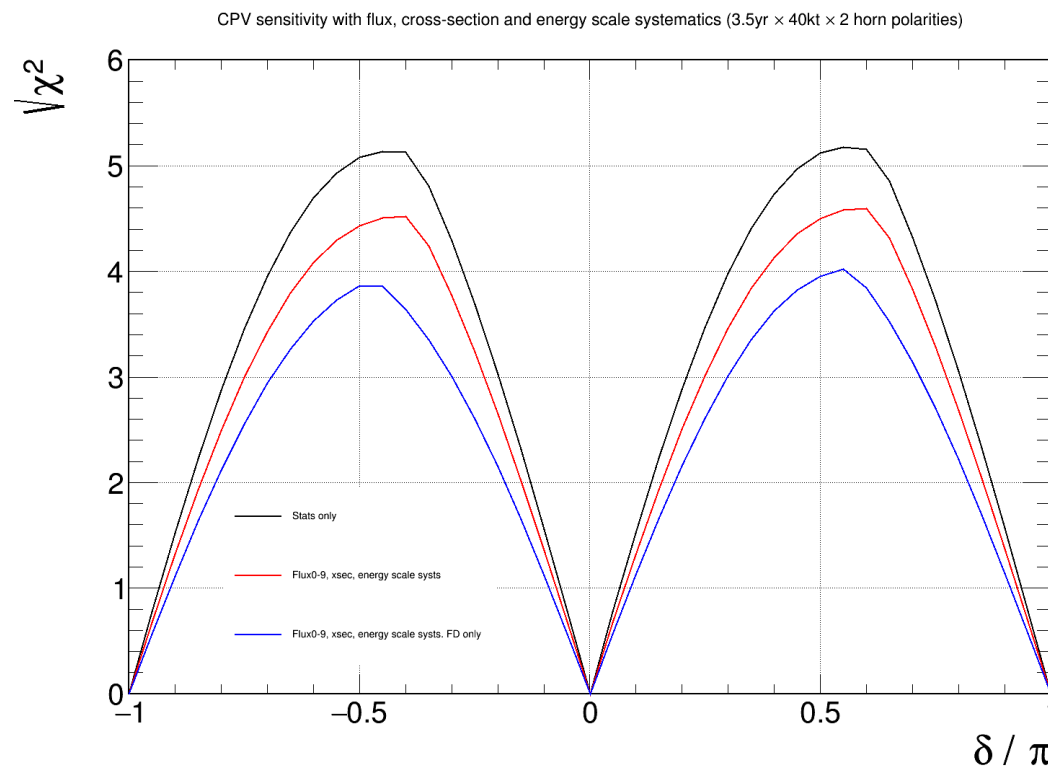
- CPV sensitivity shown here for all 3 sets of systematics in combination
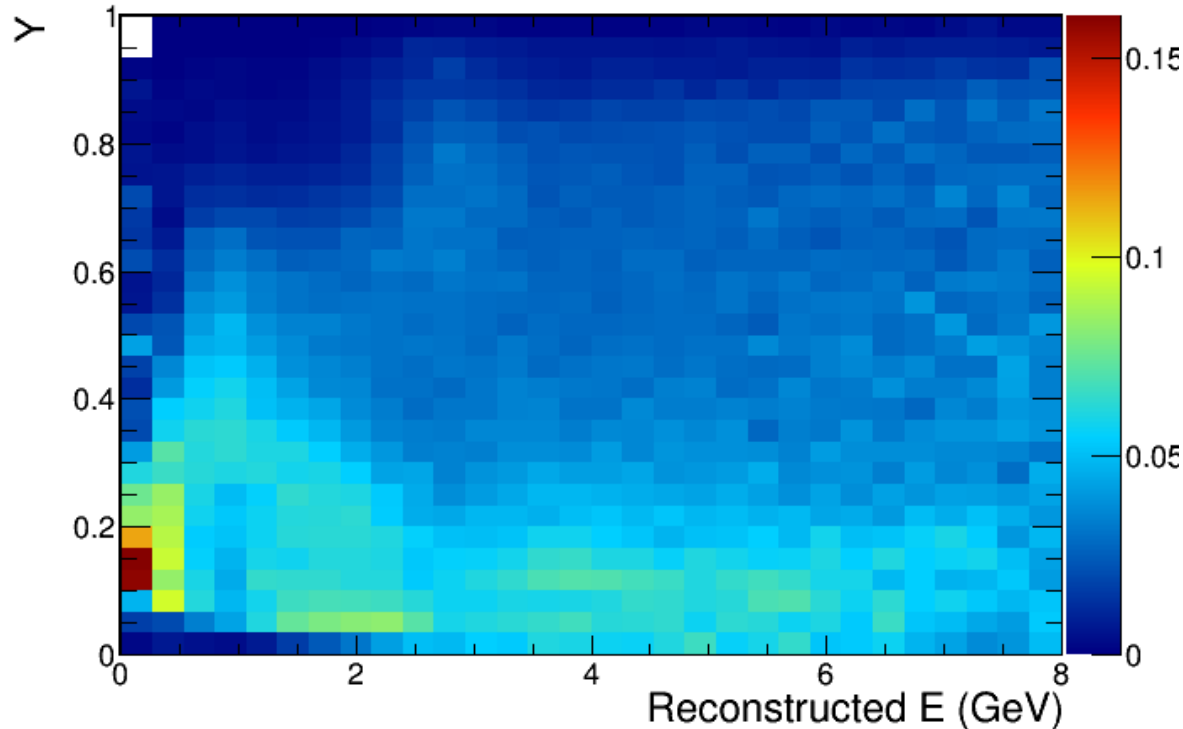- Hopefully, this is a more realistic view than the previous study
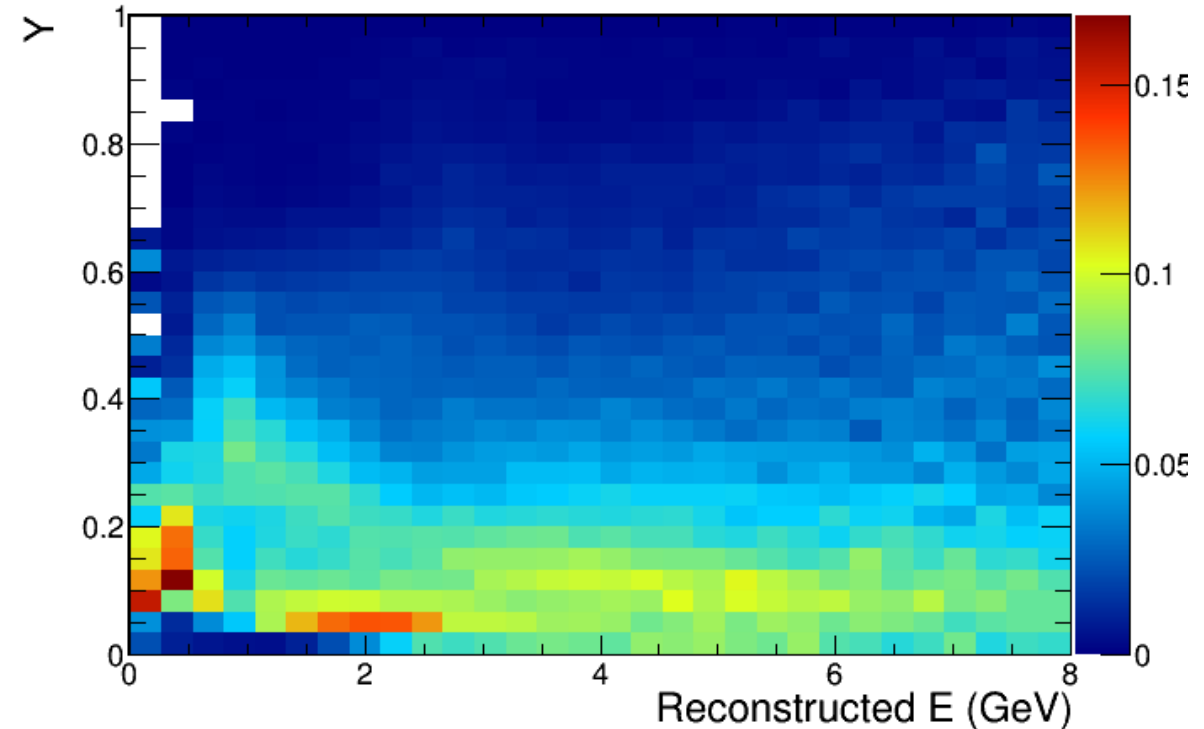
Backup

Inelasticity versus energy, numu FD

Inelasticity versus energy for FD ν_μ FHC interactions normalized by energy spectrum (3.5yr × 40kt)
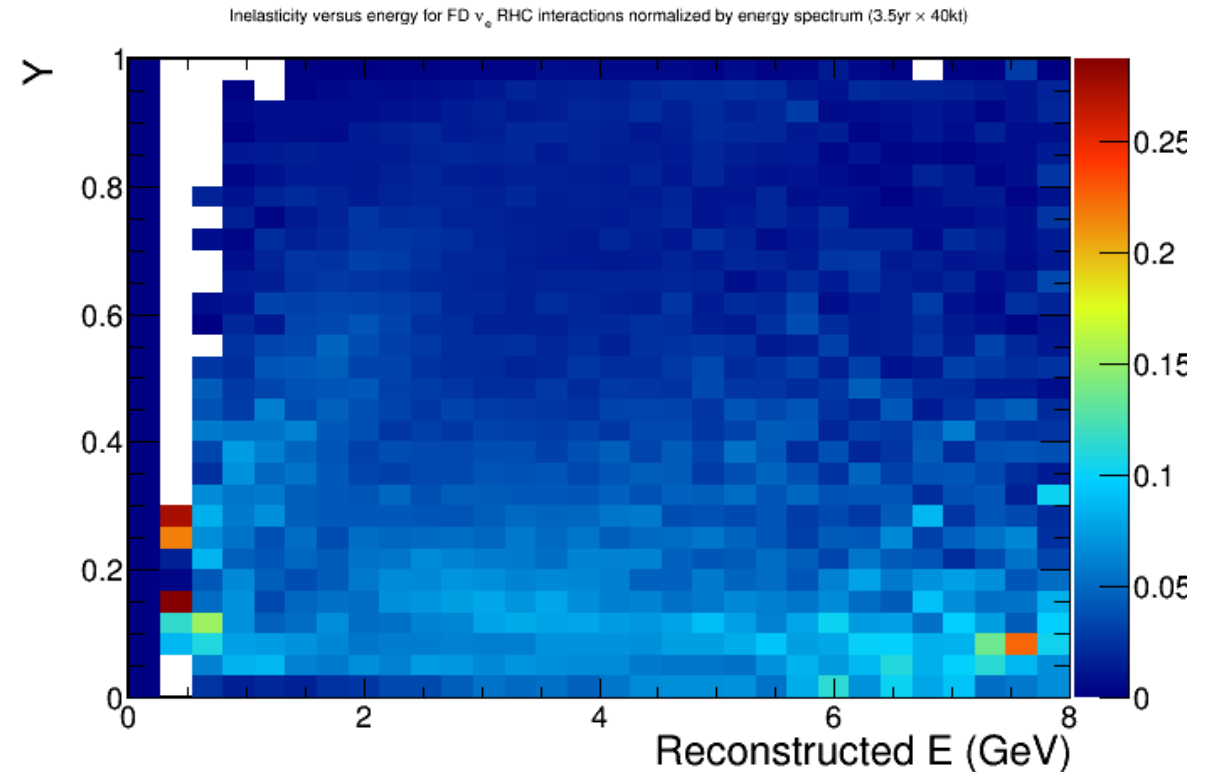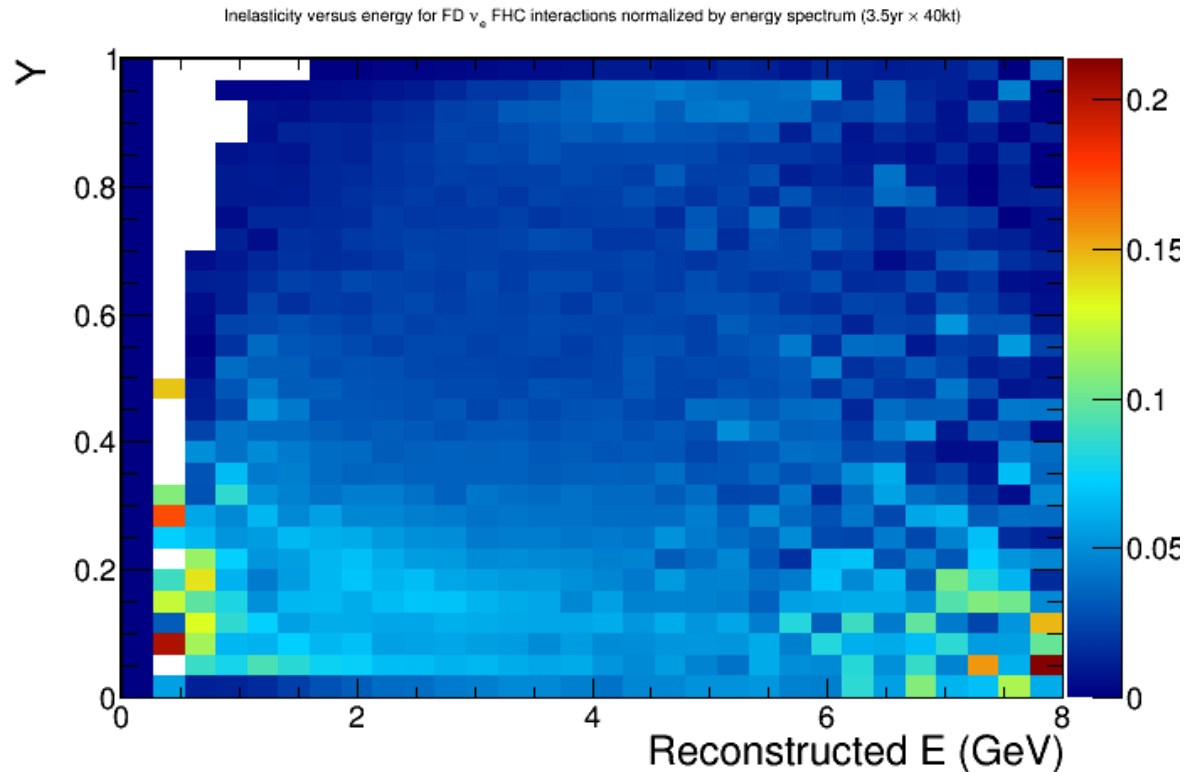
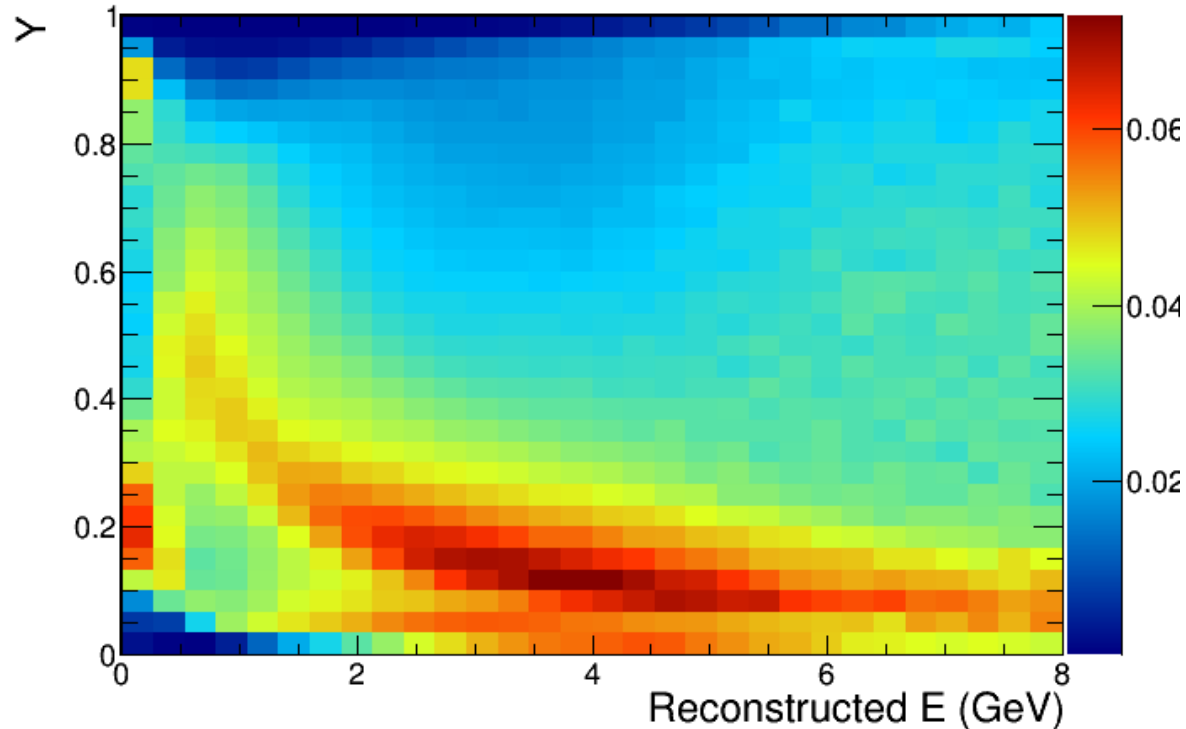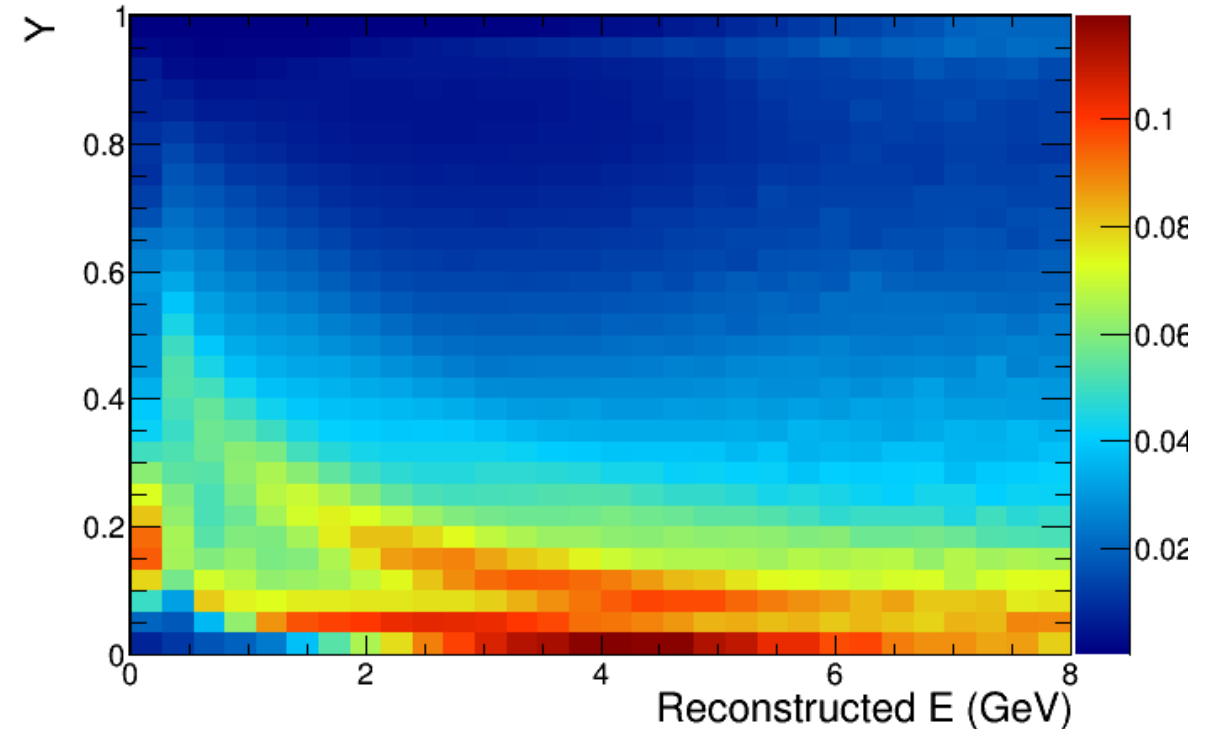Inelasticity versus energy for FD ν_μ RHC interactions normalized by energy spectrum (3.5yr × 40kt)

Inelasticity versus energy, nue FD

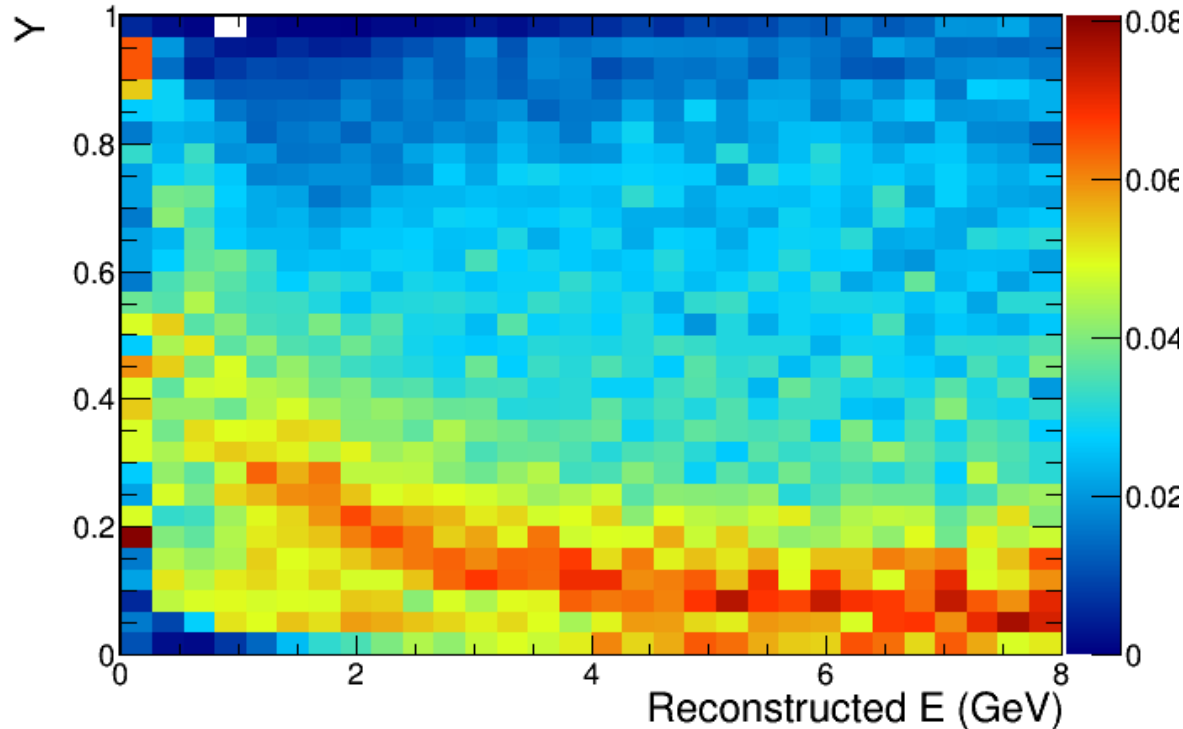Inelasticity versus energy for FD ν_e FHC interactions normalized by energy spectrum (3.5yr × 40kt)

Inelasticity versus energy for FD ν_e RHC interactions normalized by energy spectrum (3.5yr × 40kt)

Inelasticity versus energy, numu ND

Inelasticity versus energy for ND ν_μ FHC interactions normalized by energy spectrum (3.5yr × 40kt)

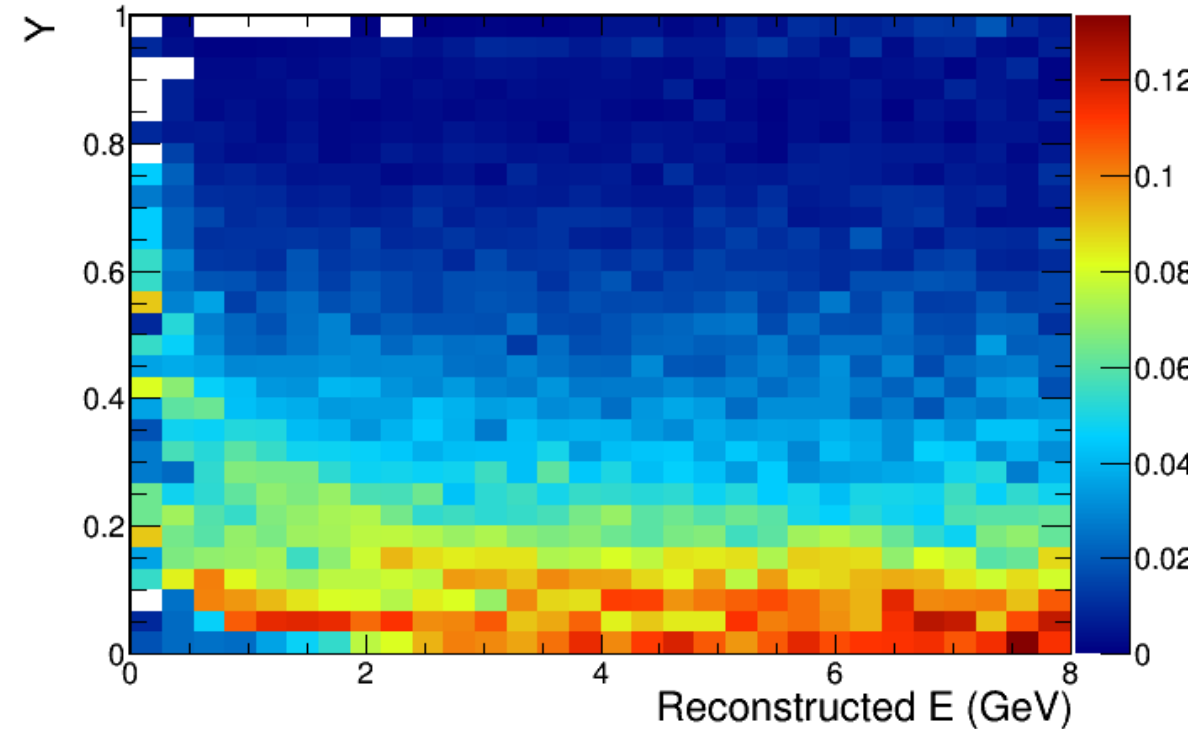Inelasticity versus energy for ND ν_μ RHC interactions normalized by energy spectrum (3.5yr × 40kt)
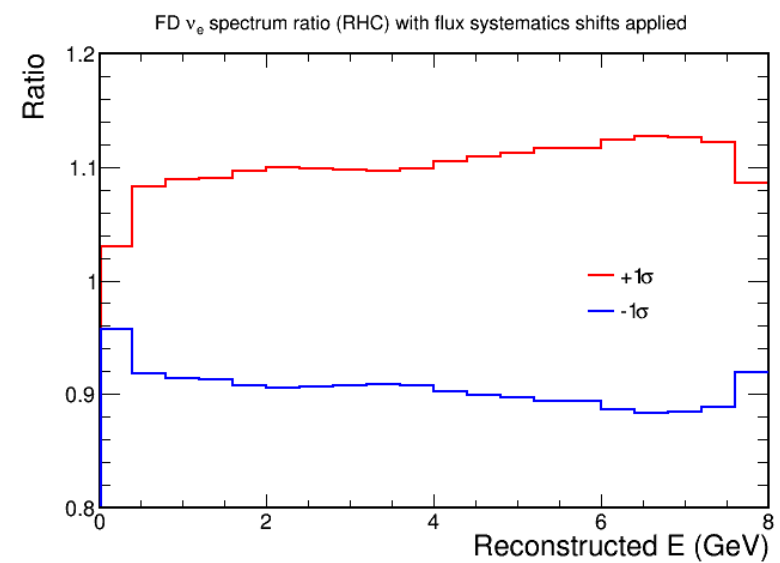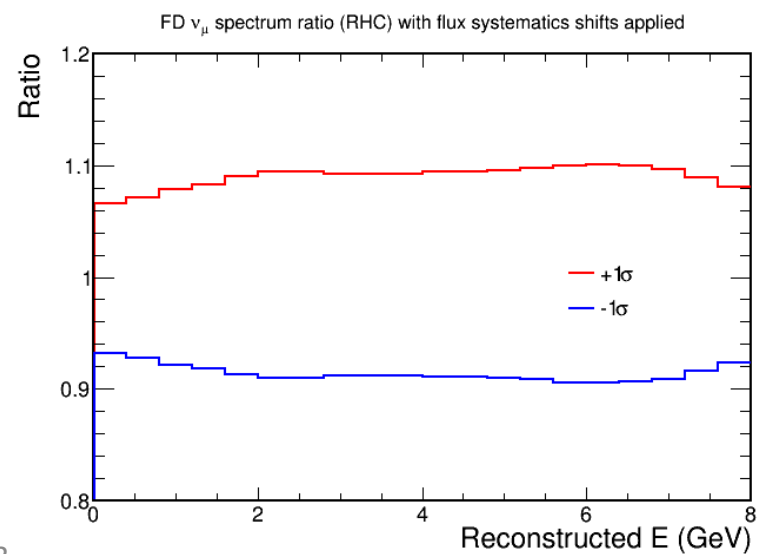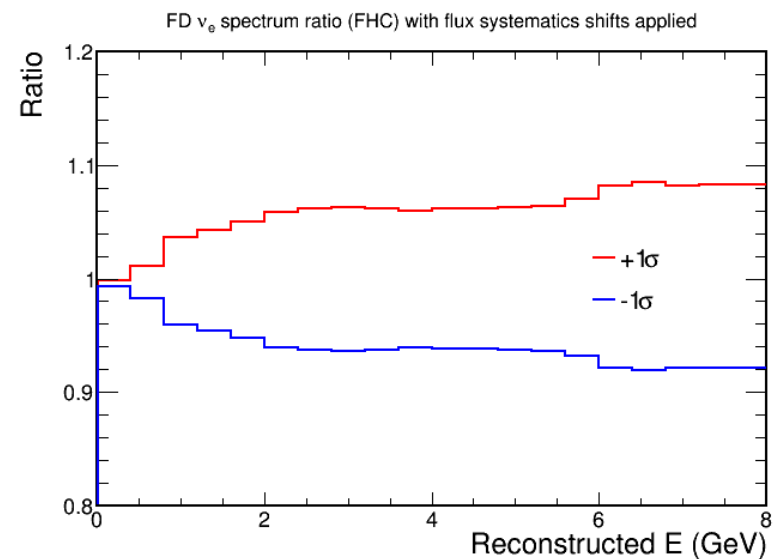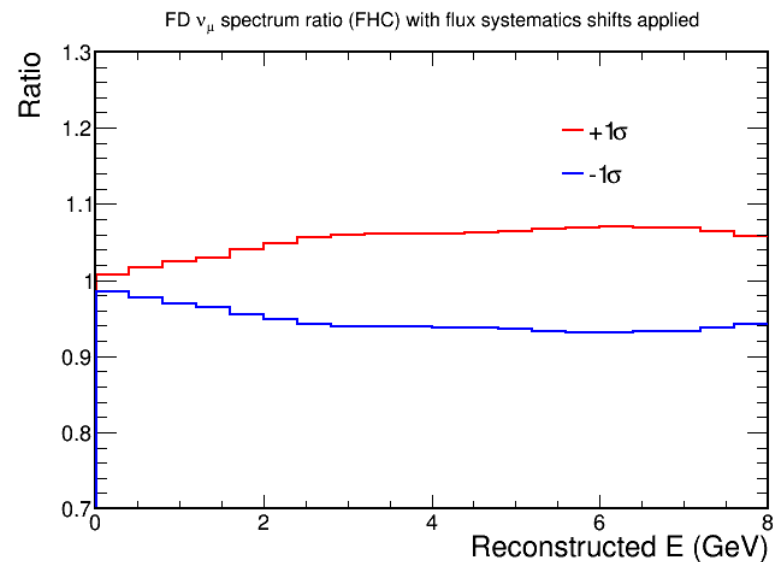
Inelasticity versus energy, nue ND

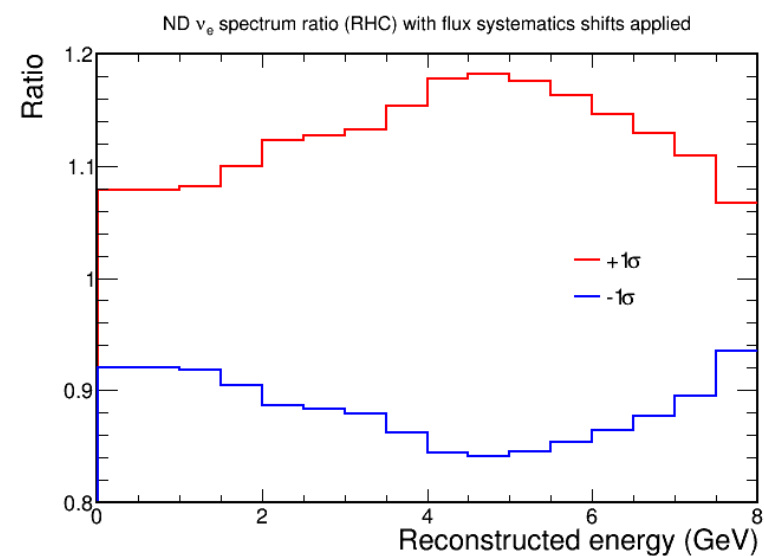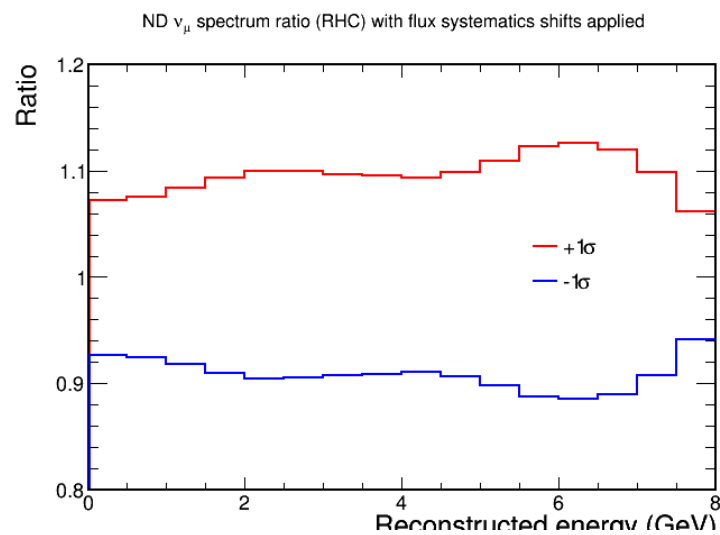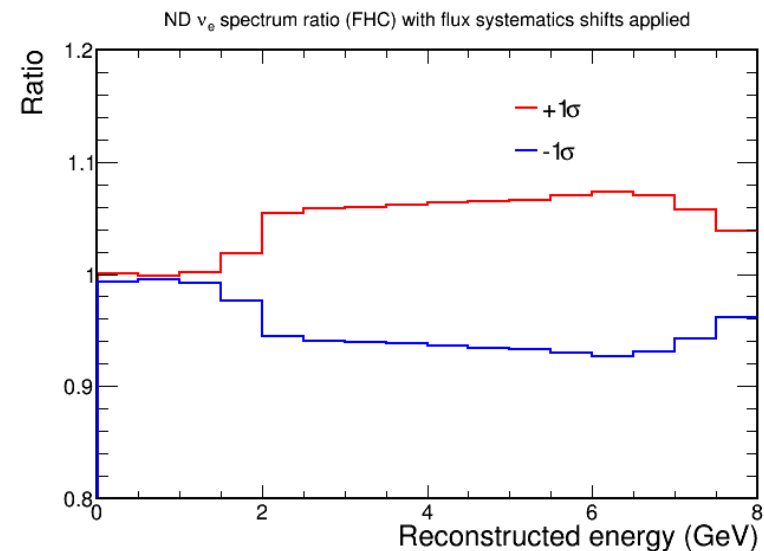Inelasticity versus energy for ND ν_e FHC interactions normalized by energy spectrum (3.5yr × 40kt)

Inelasticity versus energy for ND ν_e RHC interactions normalized by energy spectrum (3.5yr × 40kt)

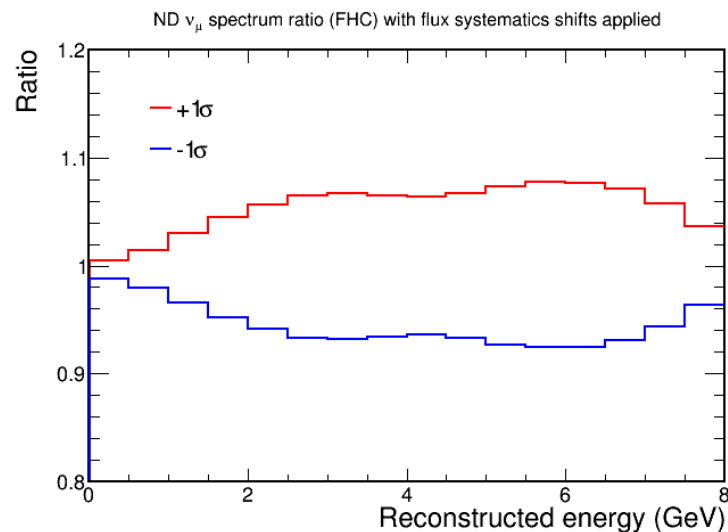# Flux systematics

FD ν_μ spectrum ratio (FHC) with flux systematics shifts applied

FD ν_e spectrum ratio (FHC) with flux systematics shifts applied

FD ν_μ spectrum ratio (RHC) with flux systematics shifts applied

FD ν_e spectrum ratio (RHC) with flux systematics shifts applied

Flux systematics

ND ν_μ spectrum ratio (FHC) with flux systematics shifts applied

ND ν_e spectrum ratio (FHC) with flux systematics shifts applied

ND ν_μ spectrum ratio (RHC) with flux systematics shifts applied

ND ν_e spectrum ratio (RHC) with flux systematics shifts applied

Cross-section systematics

Cross-section systematics

ND ν_μ spectrum ratio (FHC) with cross-section systematics shifts applied

ND ν_e spectrum ratio (FHC) with cross-section systematic shifts applied

FD ν_μ spectrum ratio (RHC) with cross-section systematics shifts applied

ND ν_e spectrum ratio (RHC) with cross-section systematic shifts applied

Energy scale systematics

FD ν_μ spectrum ratio (FHC) with energy scale systematics shifts applied

FD ν_e spectrum ratio (FHC) with energy scale systematics shifts applied

FD ν_μ spectrum ratio (RHC) with energy scale systematics shifts applied

FD ν_e spectrum ratio (RHC) with energy scale systematics shifts applied