Neutrino Oscillation Prospects with a Dual-Baseline Beam from BNL to SNOLAB and DUNE

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Nishat Fiza

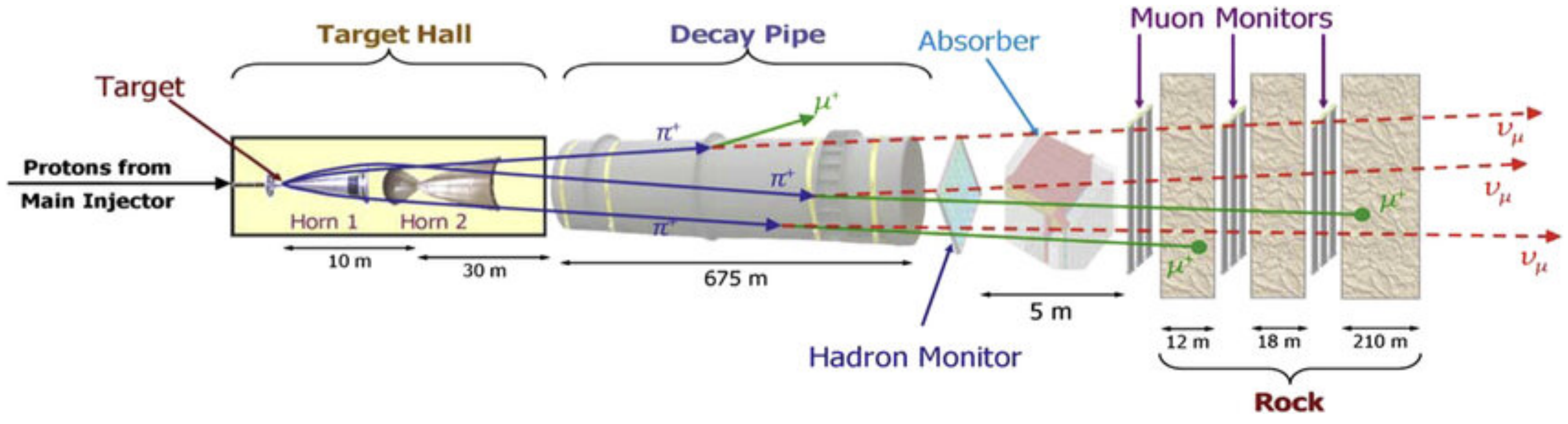
중앙대학교
CHUNG-ANG UNIVERSITY

Plan of the talk

- Introduction
- Proposal for a new neutrino beam
- Neutrino flux calculation
- Results
- Conclusion

NuMI beam (Fermilab)

Baseline 1300 km for DUNE experiment

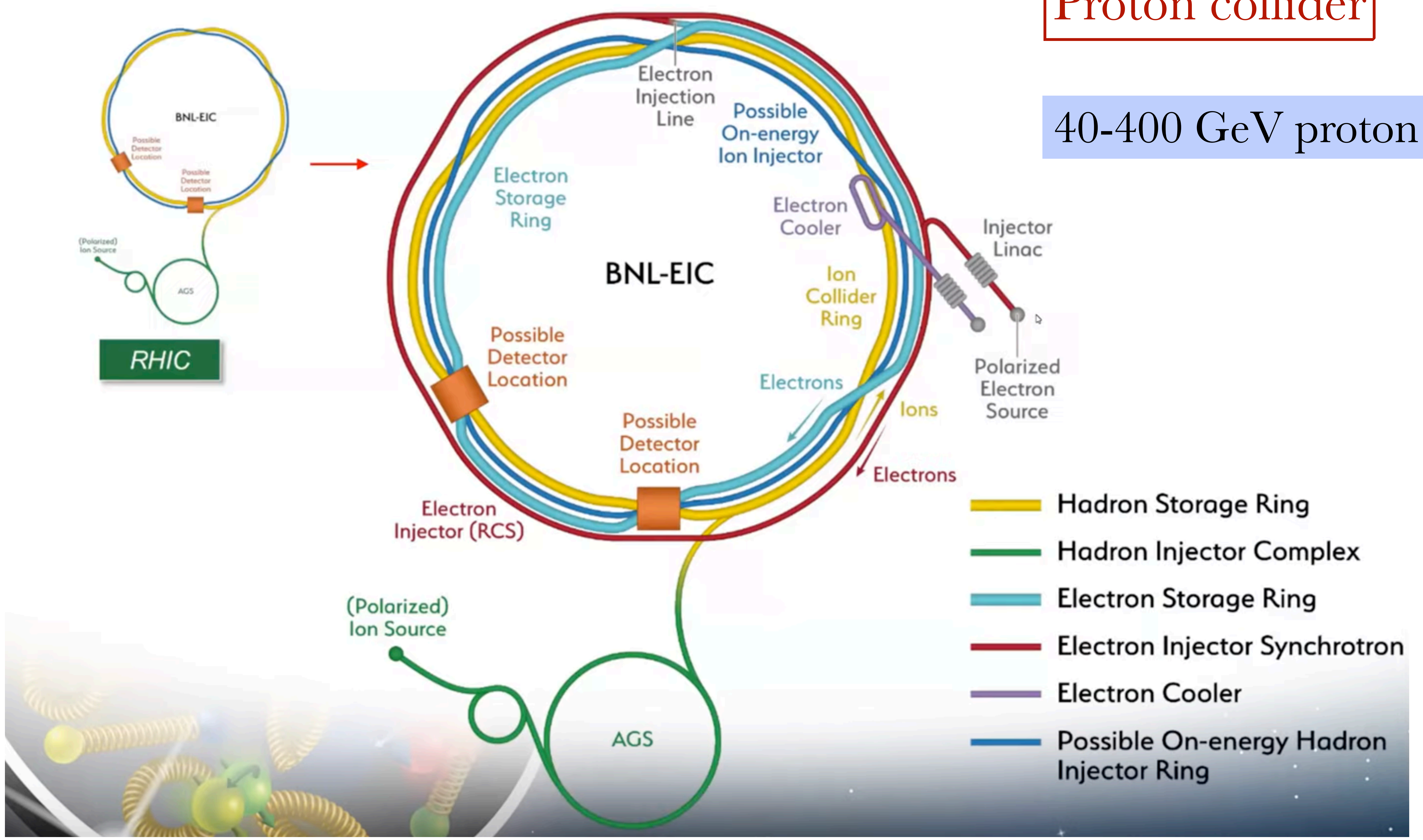


120 GeV proton

POT ~ 10^{21}/year

Electron Ion Collider (BNL)

Baseline 2900 km from EIC to DUNE Far Detector

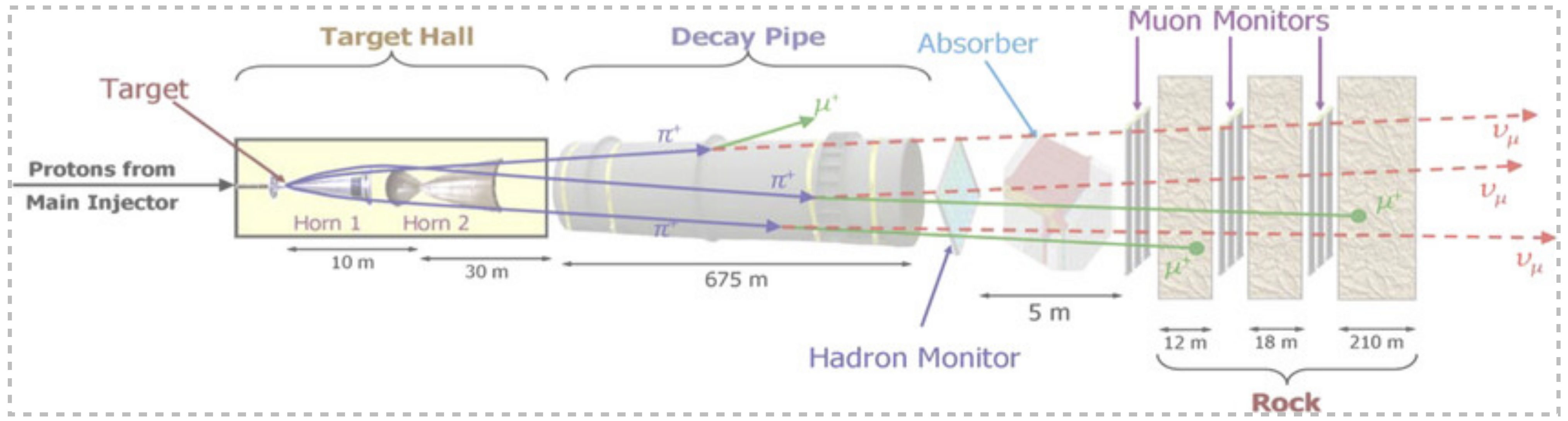


Proton collider

40-400 GeV proton

Proton luminosity ~ 10^{33} cm^{-2} s^{-1}
Which can result up to POT ~ 10^{40}/year

Proton on Graphite target (Simulated)



Capable of producing ν's with higher energy

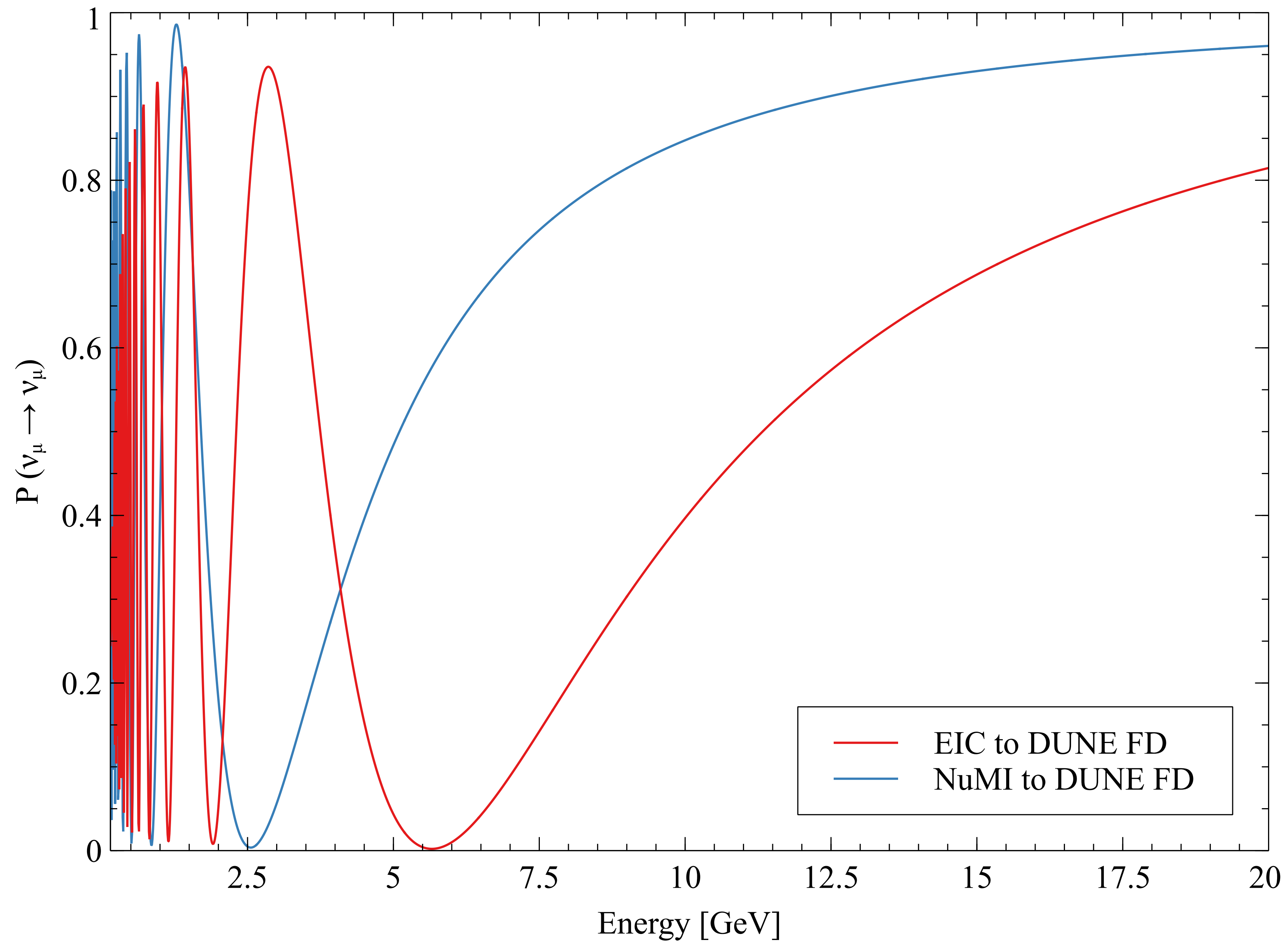
Oscillation Probability

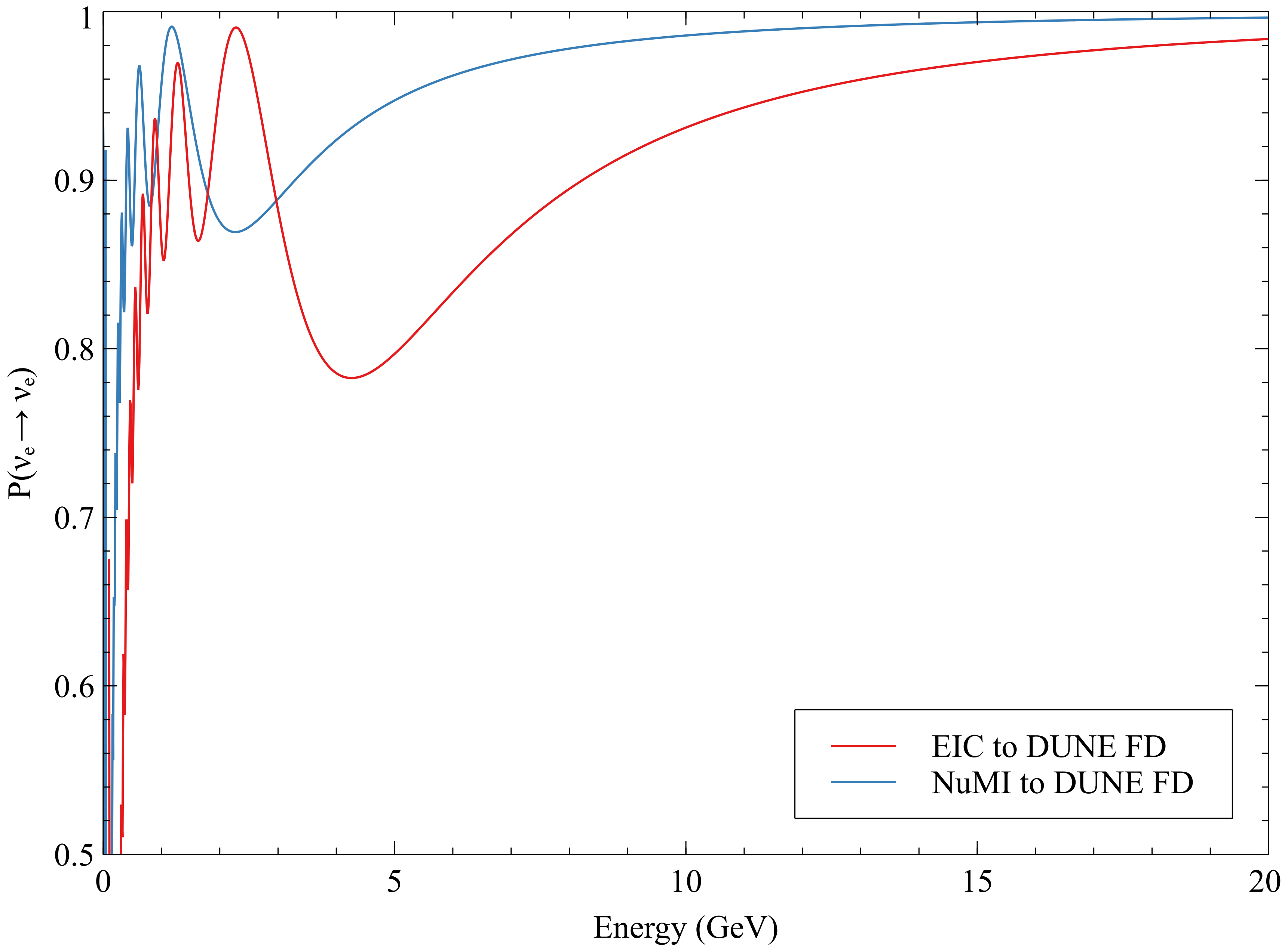
- Neutrinos from different sources will arrive at the DUNE Far Detector (FD) with different oscillation phases

- These phase differences result in oscillation maxima and minima occurring at different neutrino energies

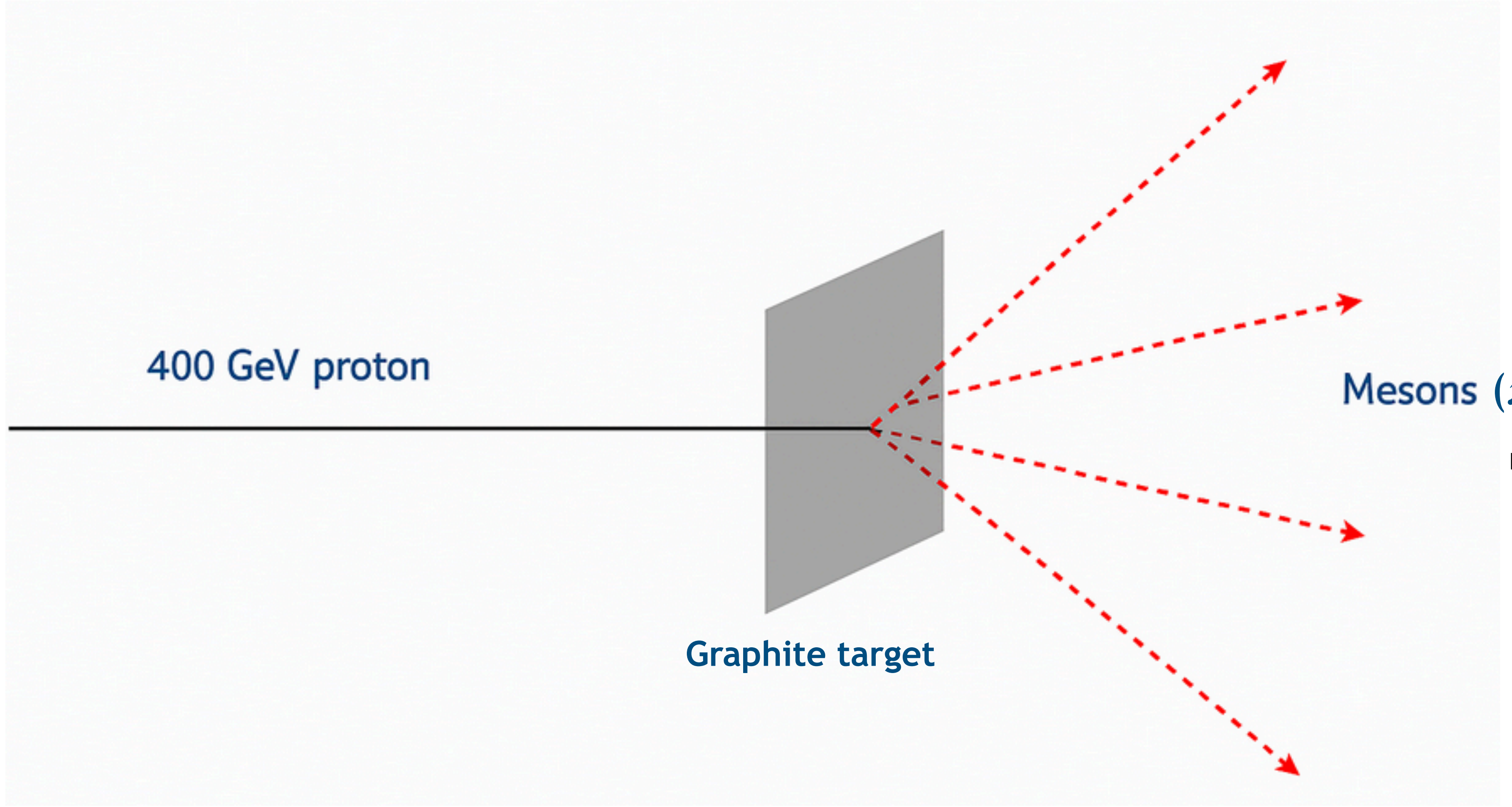
- The variation in energy-dependent features enables the study of different oscillation parameters

- This approach enhances sensitivity to the full range of neutrino oscillation phenomena

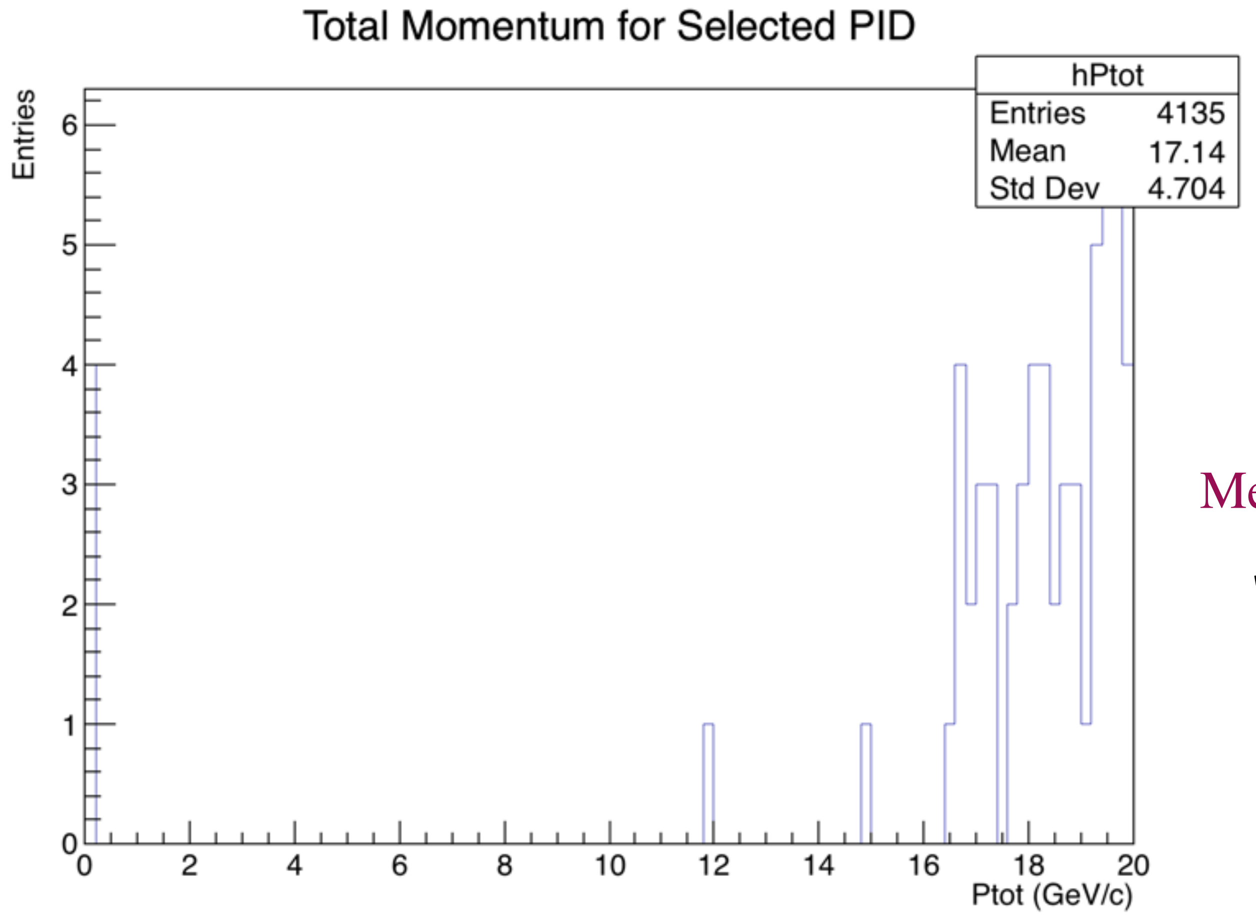




Flux calculation

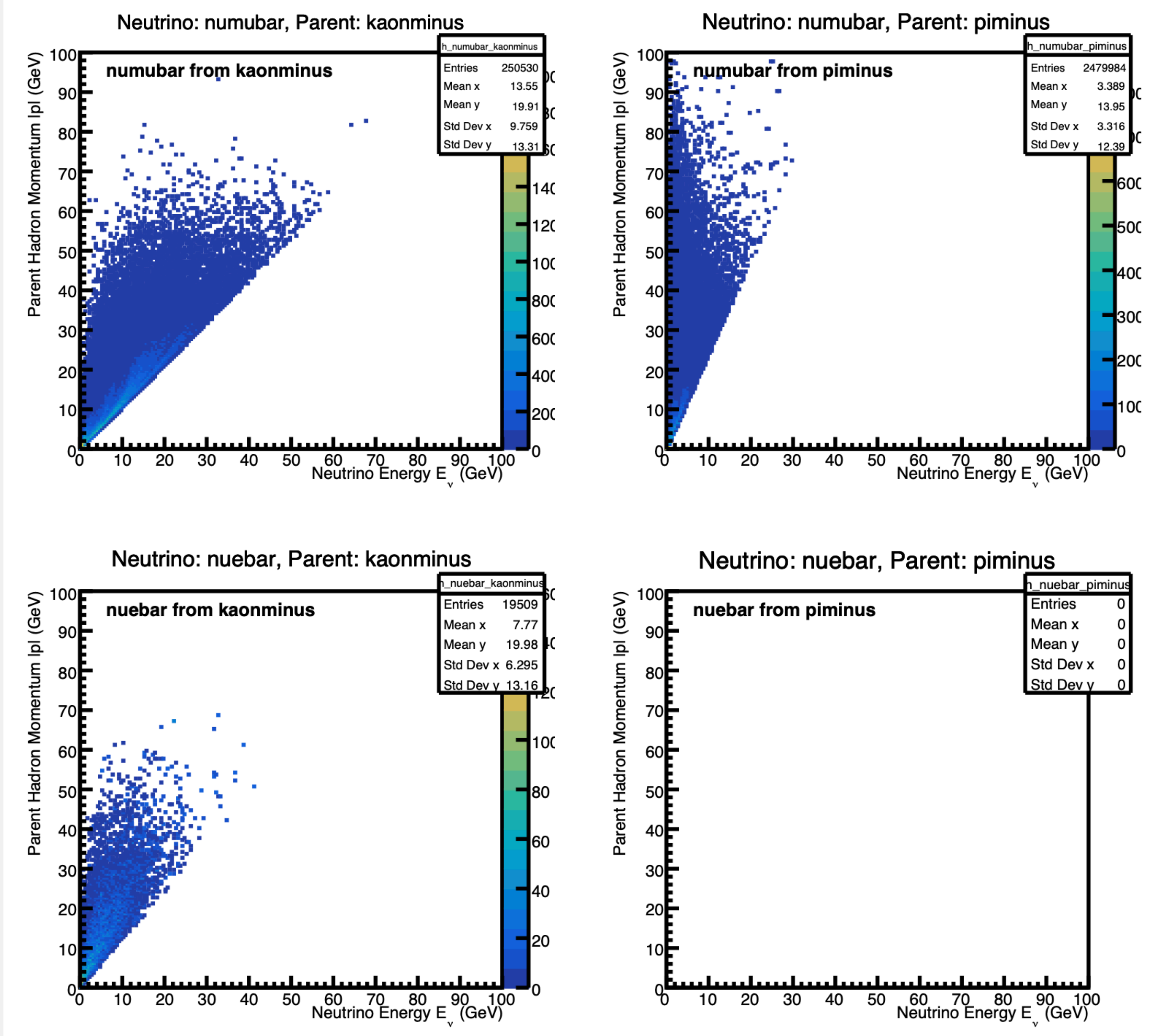


Mesons $(\pi^{\pm}, \mu^{\pm}, K^{\pm})$

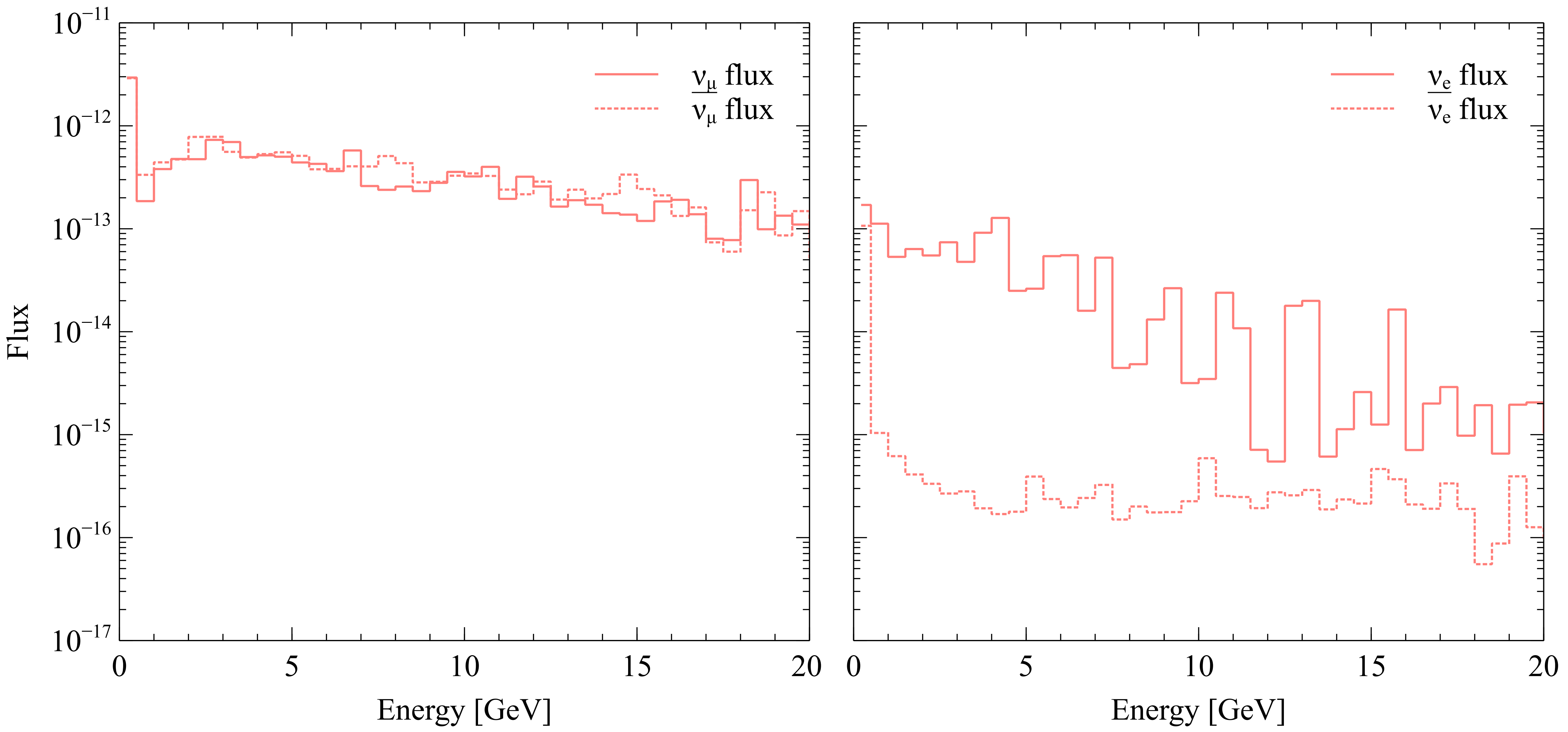


Meson momentum distribution

Correlation between meson and neutrino momenta

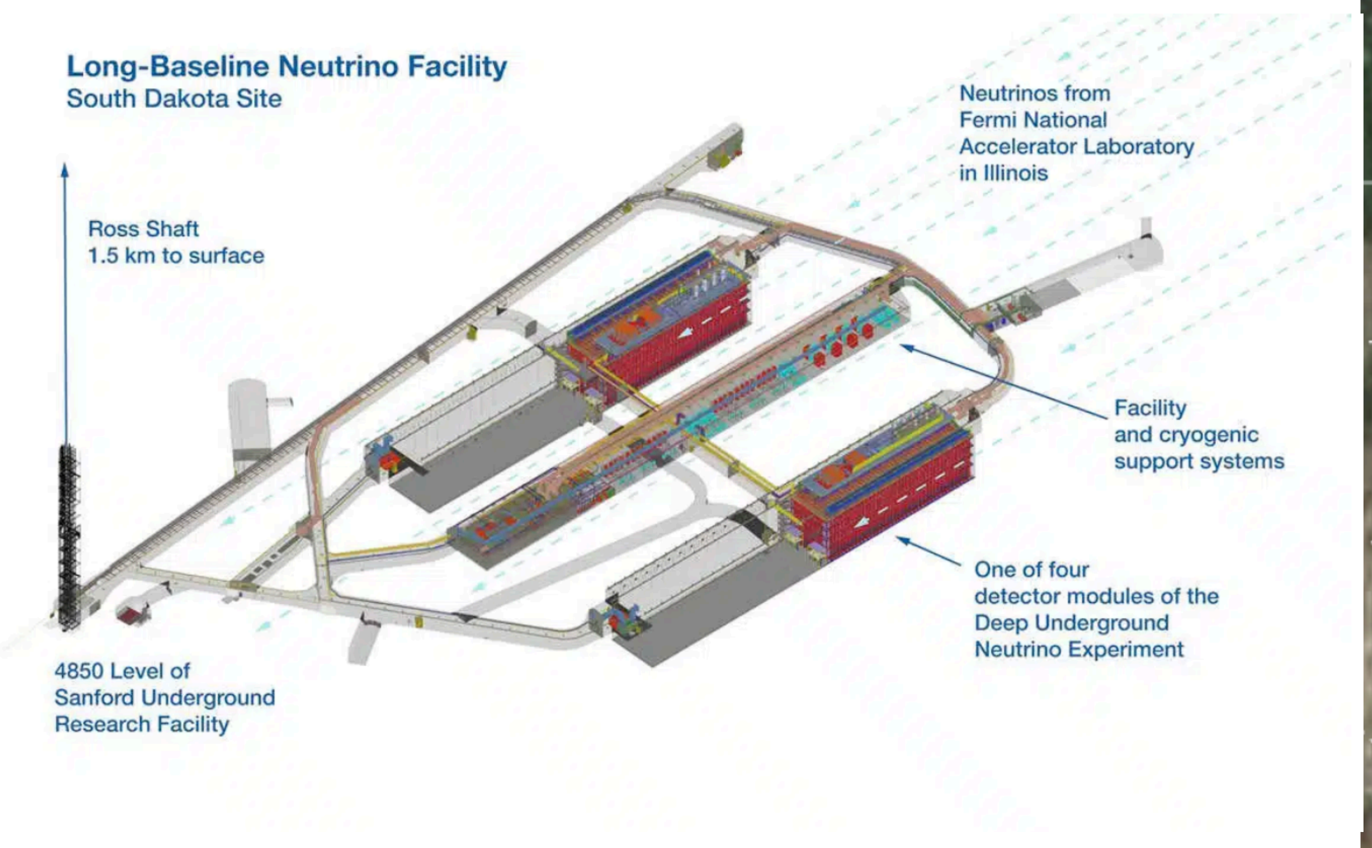


Combining these informations, using ROOT



Detectors associated

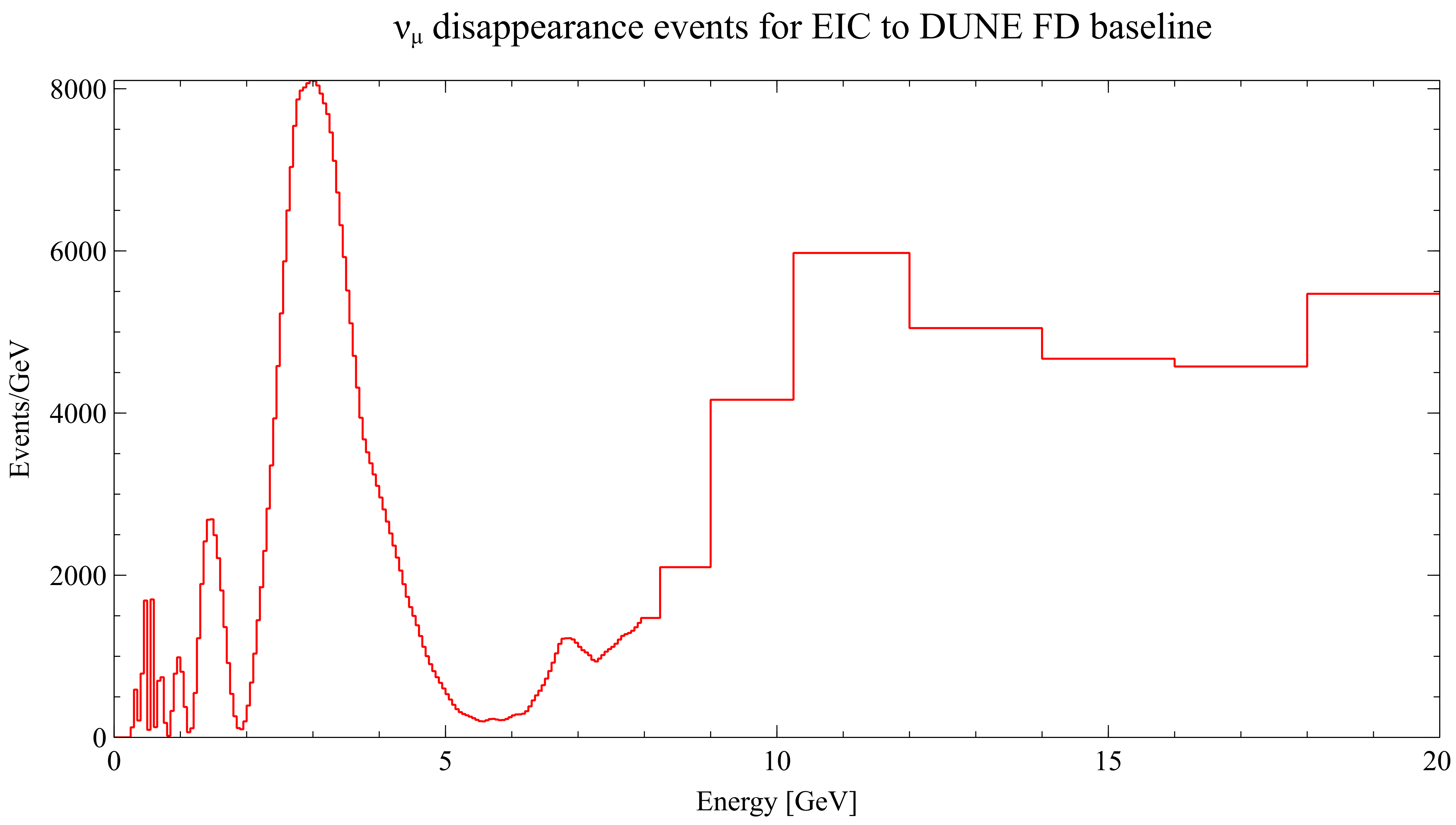
Detector 1 (baseline 900 km)



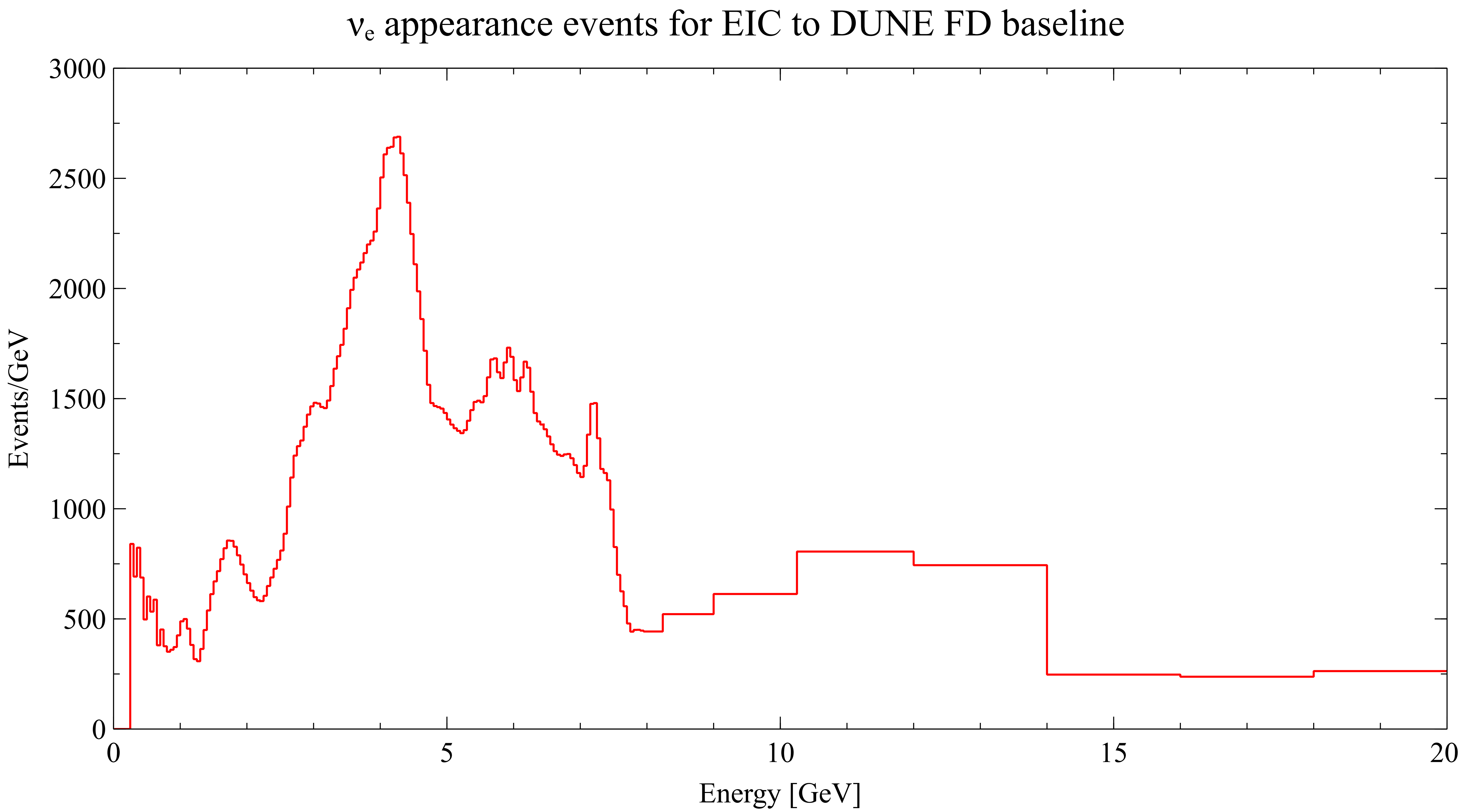
Detector 2 (baseline 2900 km)

ν_μ disappearance events at DUNE FD

- Assumed proton-on-target (POT) ~ $10^{23}\ y^{-1}$
- Events generated using **GLoBES** simulation software
- DUNE Far Detector configuration based on the **Technical Design Report (TDR)**

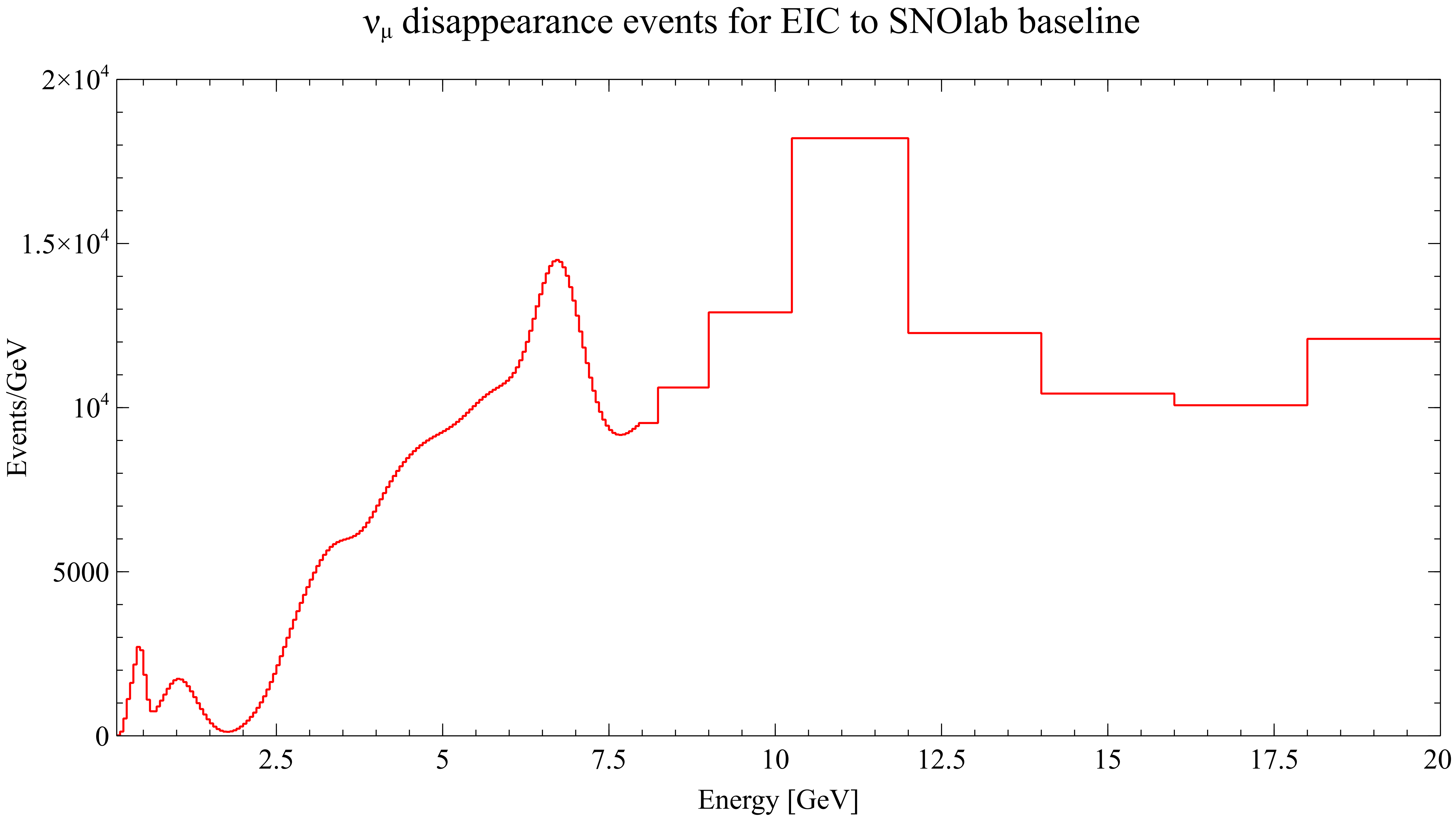


ν_e appearance events at DUNE FD

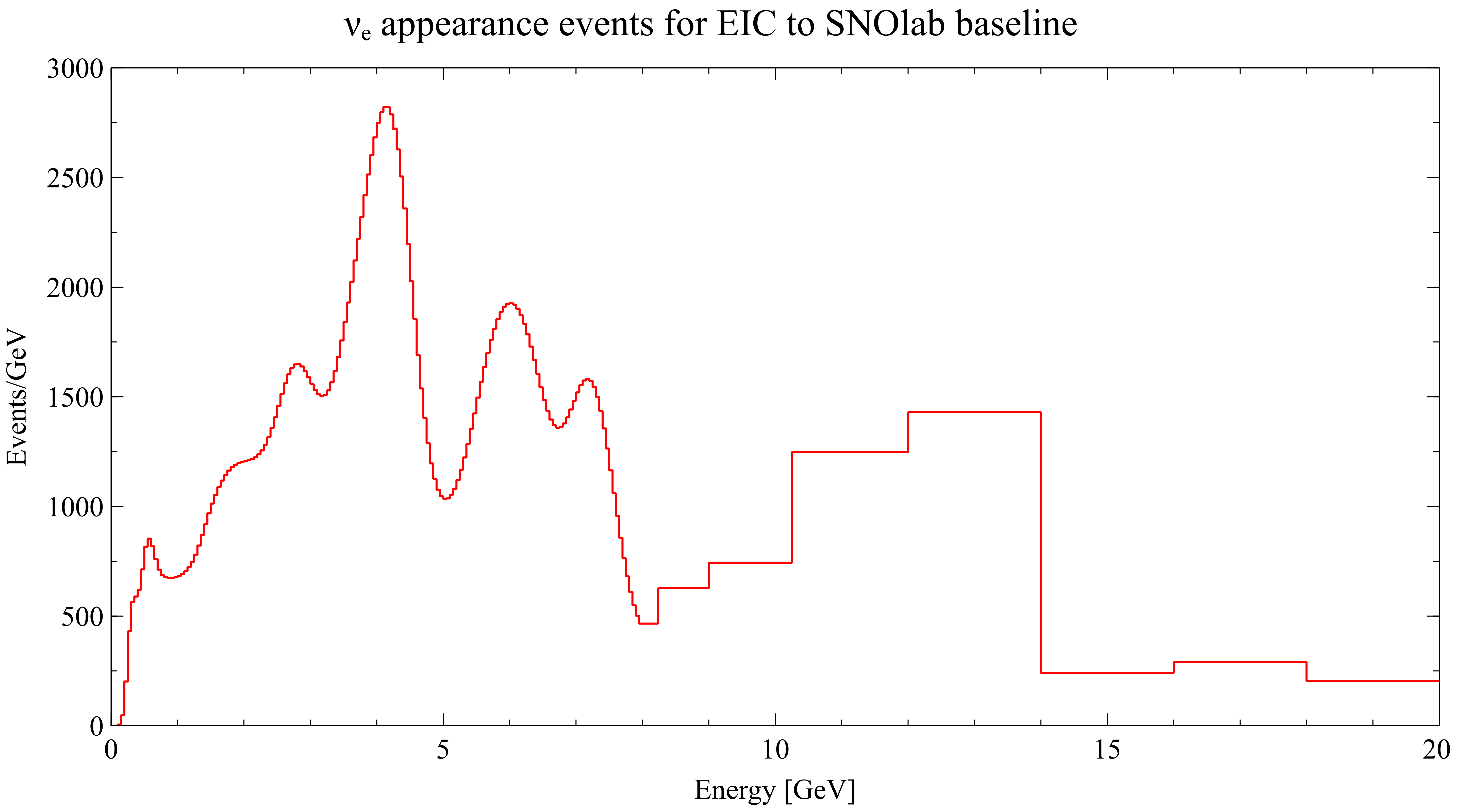


ν_μ disappearance events at SNOlab

- WbLS detector at SNOLAB
- Work in progress to incorporate refined detection efficiency and energy smearing effects

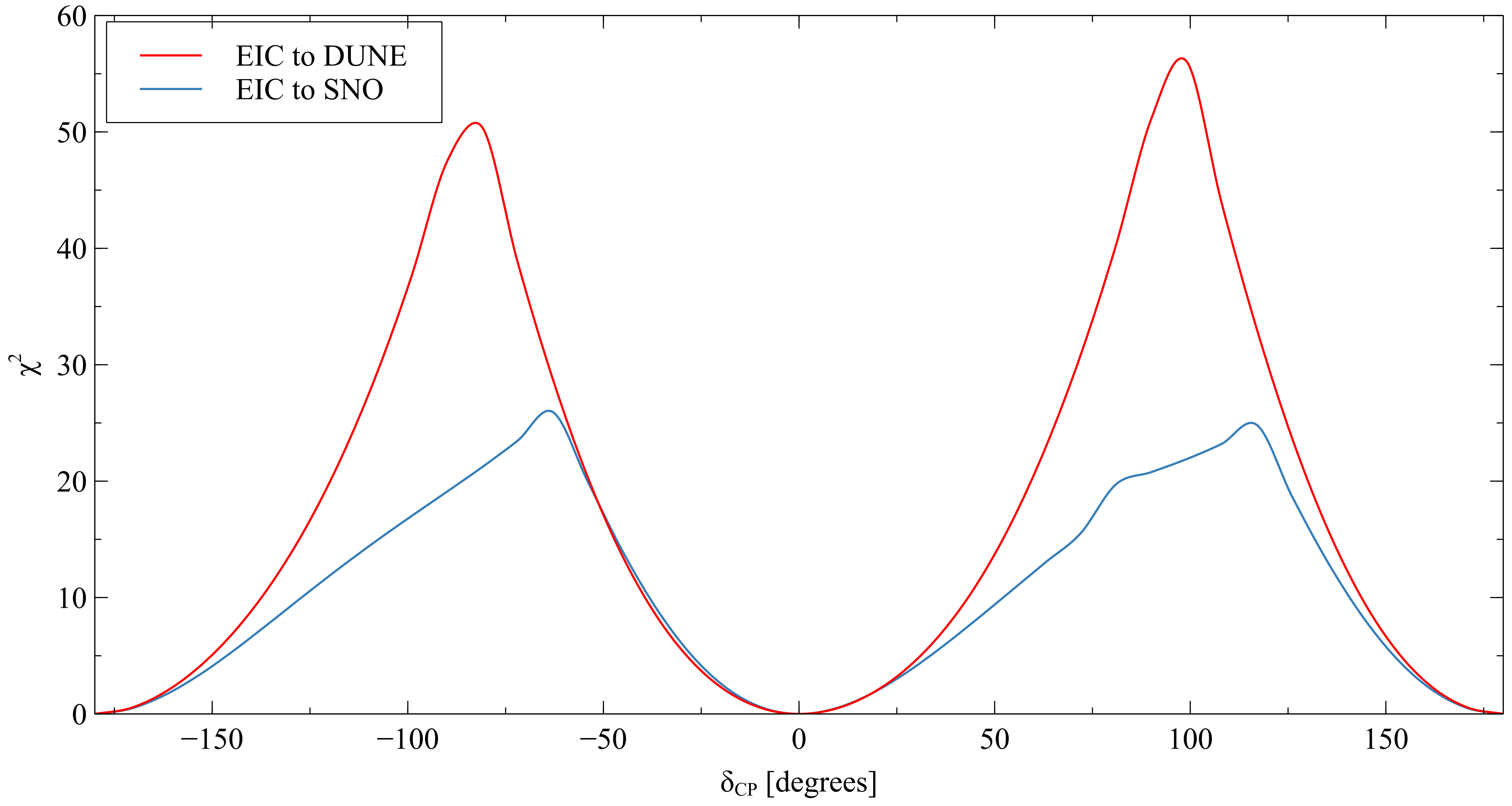


ν_e appearance events at SNOlab



- Bin widths are adjusted with energy to ensure statistical uniformity across the energy spectrum
- Smaller bin widths at lower energies allow for better resolution of oscillation patterns.
- This helps in identifying finer features of the neutrino oscillation behavior.

δ_{13} sensitivity



$$\Delta\chi^2 = Min_{u,s}\ [\sum_{bins} \frac{\{N_{data} - N_{fit}(u,s)\}^2}{N_{data}} + \frac{s_i^2}{\sigma_i^2}]$$

u: oscillation parameters

s: systematics

Fitted with $\delta_{13} = 0$ or π

Conclusion

- Simultaneous measurements at two distinct baselines using the same beam configuration help to reduce beam-related and detector-related systematic uncertainties
- Shared systematics (e.g., flux normalization, cross-section uncertainties) are better constrained
- Comparison of observed spectra at both sites improves overall measurement precision

Thank you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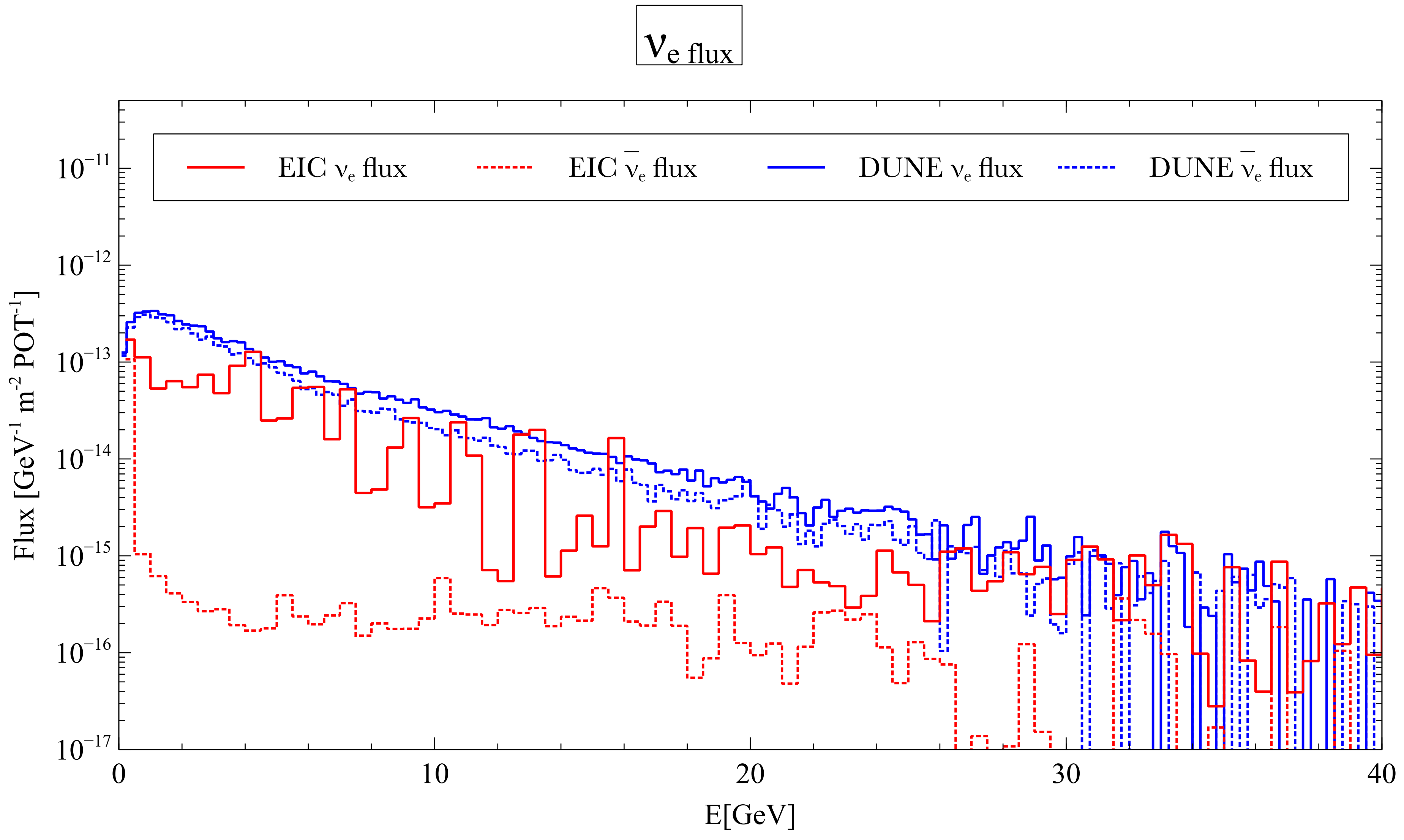
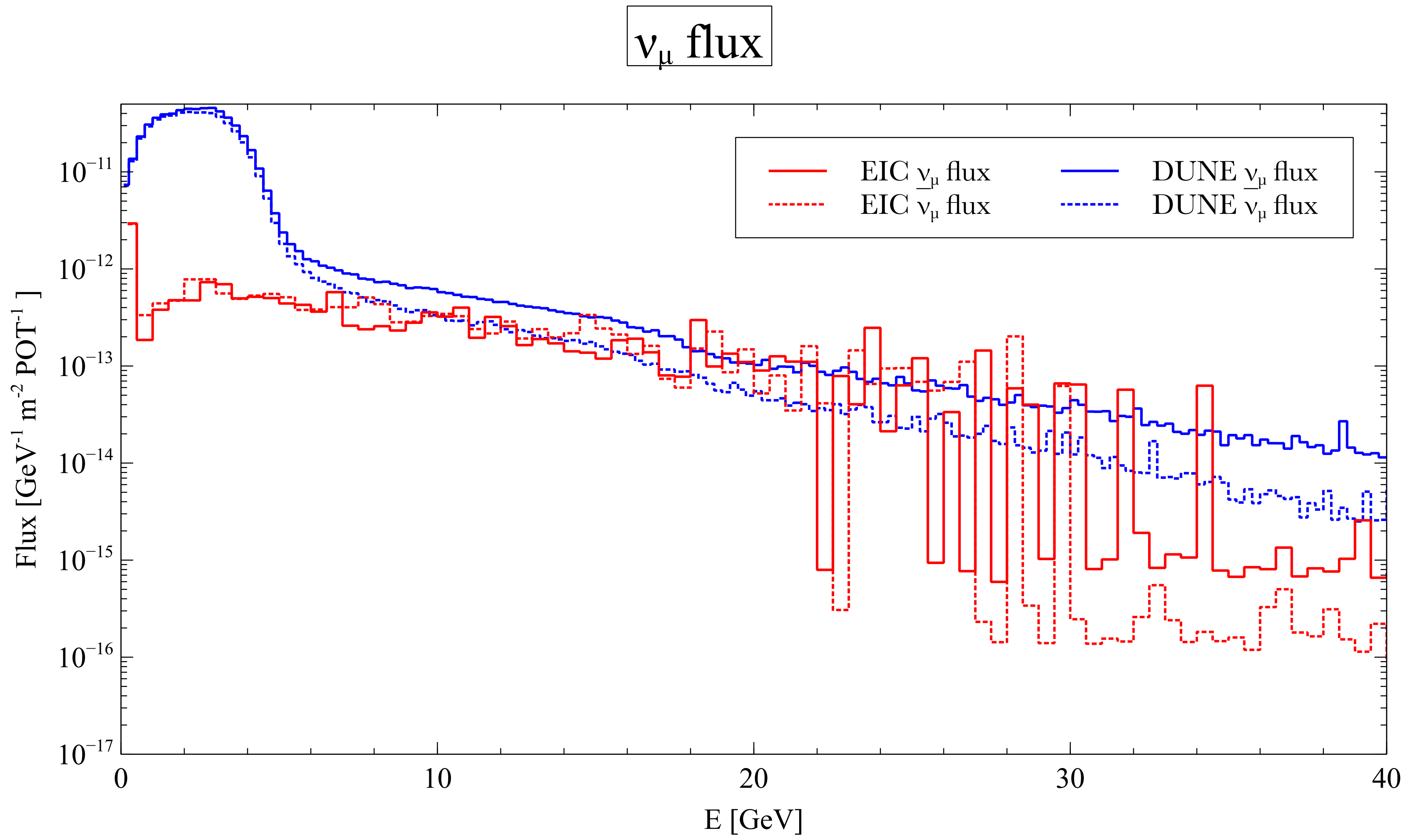


$\nu_{e\ flux}$
EIC ν_e flux
EIC $\bar{\nu}_e$ flux
DUNE ν_e flux
DUNE $\bar{\nu}_e$ flux
Flux [GeV^{-1} m^{-2} POT^{-1}]
E[GeV]



ν_μ flux
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E [GeV]