Cross Sections
WG2 overview

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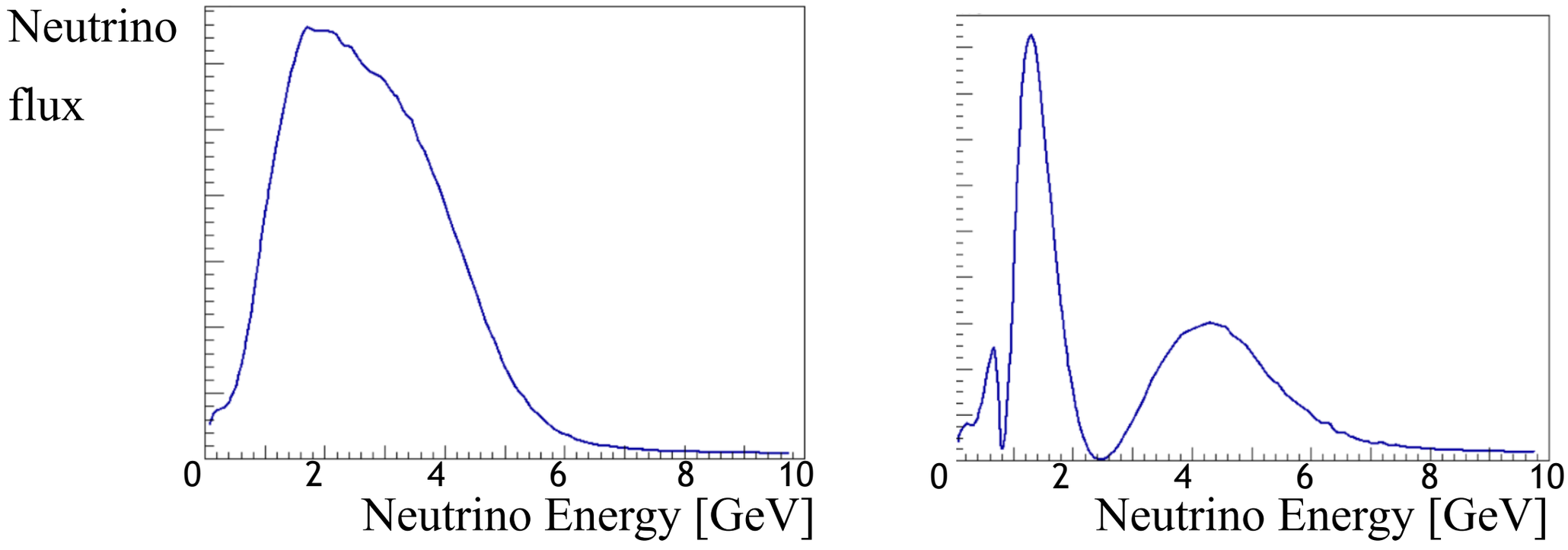
Neutrino Oscillations Experiments



Cross Section - a key ingredient for oscillations

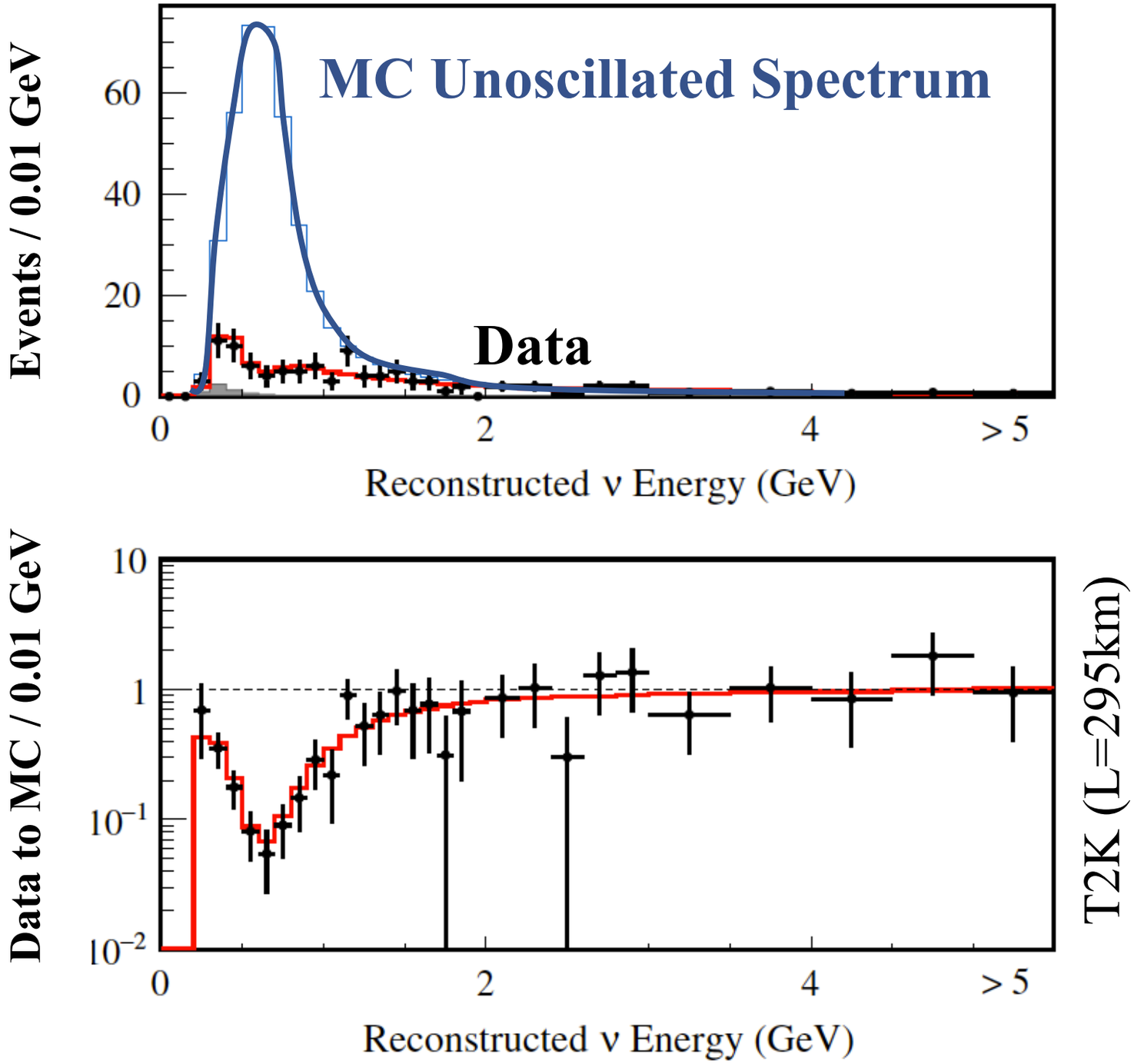
$$\frac{N^{far}_{events}(E_\nu)}{N_{events}(E_\nu)} = \frac{\int \sigma(E'_\nu)\Phi(E'_\nu)P(E_\nu|E'_\nu)P_{osc}(E'_\nu)dE'_\nu}{\int \sigma(E'_\nu)\Phi(E'_\nu)P(E_\nu|E'_\nu)dE'_\nu}$$

F. Sanchez @ NuPhys2015

The flux and cross section models are convoluted.

The cross section will not cancel out and is crucial for extraction of the oscillation parameters.

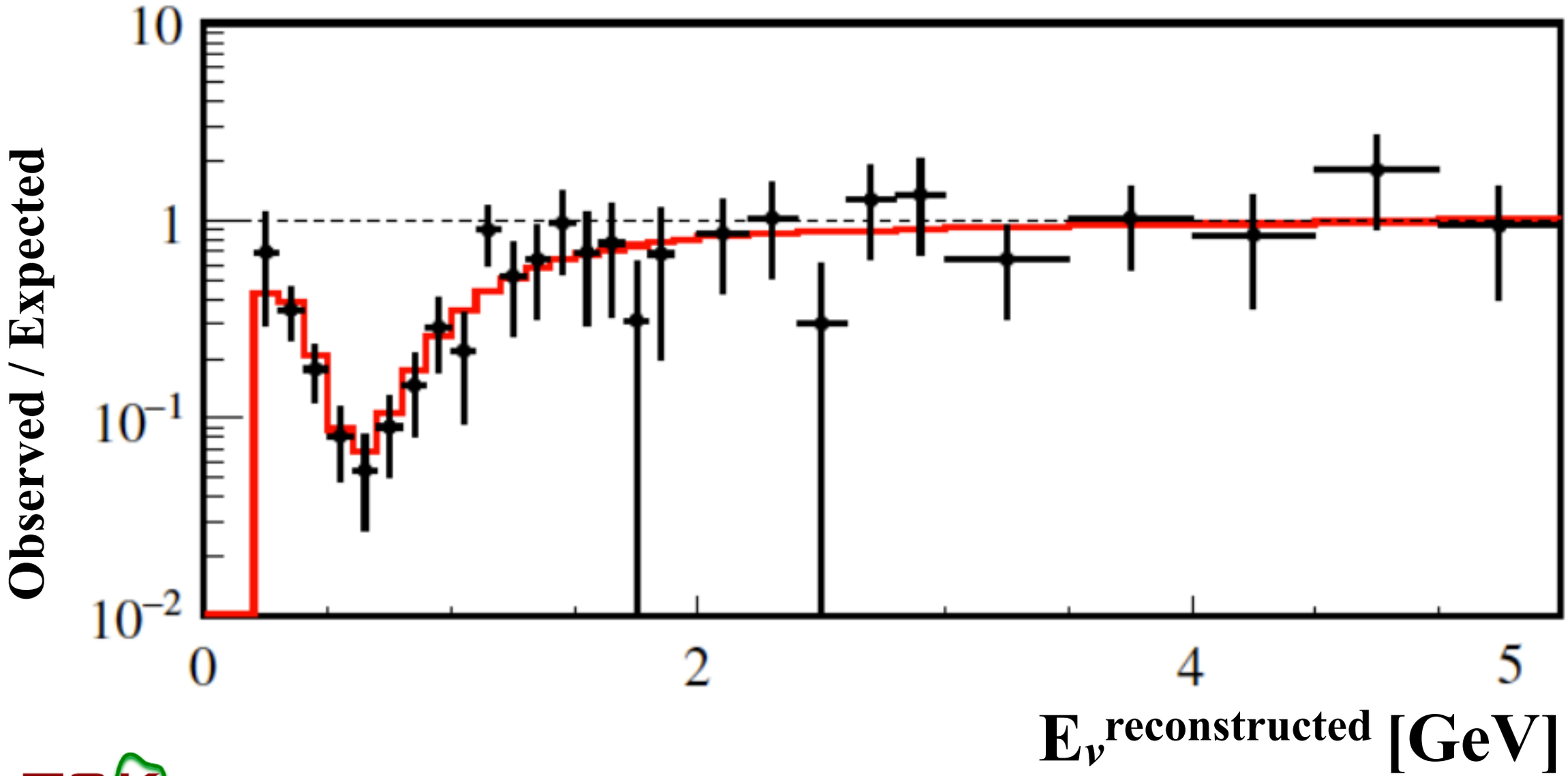
Oscillations Require incoming E_ν Reconstruction



 T2K, Phys. Rev. D 91, 072010 (2015)

Oscillations Require incoming E_ν Reconstruction

$$P\left(\nu_\mu \rightarrow \nu_x\right) = \sin^2(2\theta) \times \sin^2\left(\frac{\Delta m^2 L}{4E_\nu}\right)$$



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Oscillations Require incoming E_ν Reconstruction

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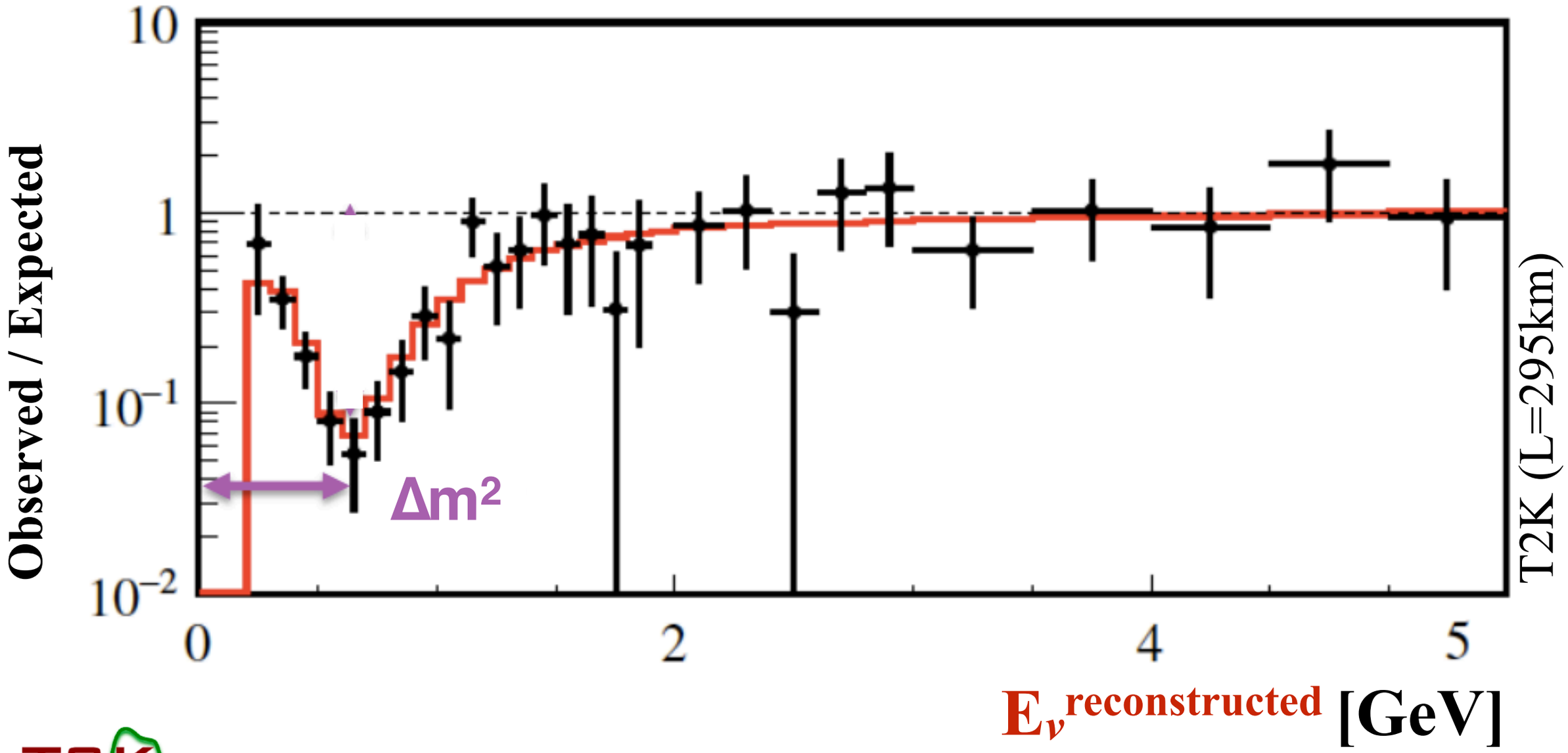

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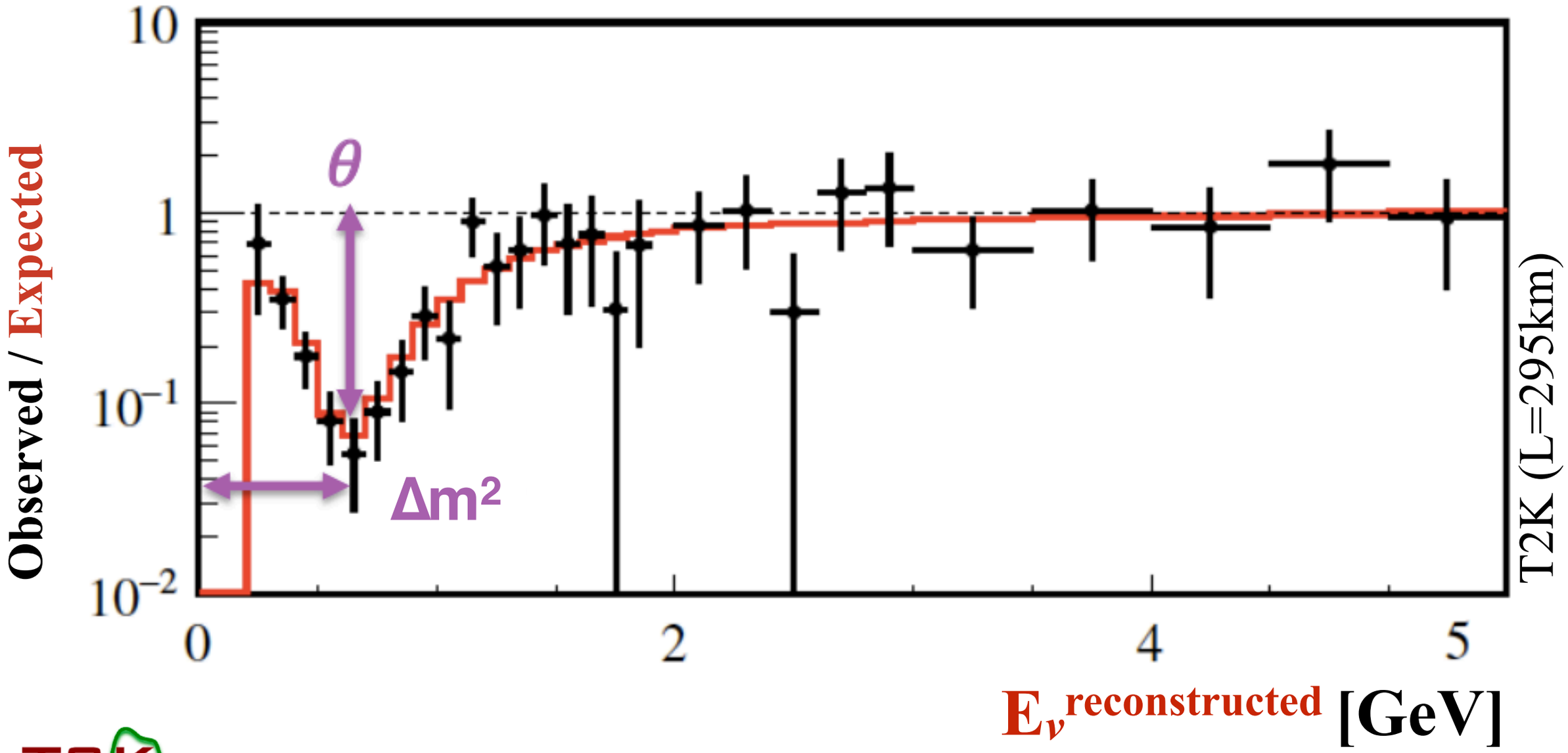
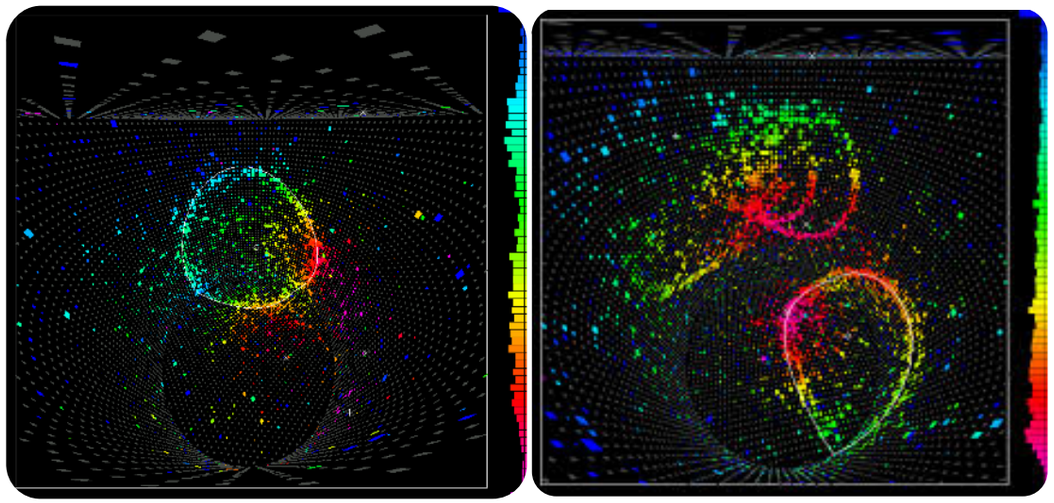


T2K, Phys. Rev. D 91, 072010 (2015)

Incoming neutrino Energy Reconstruction

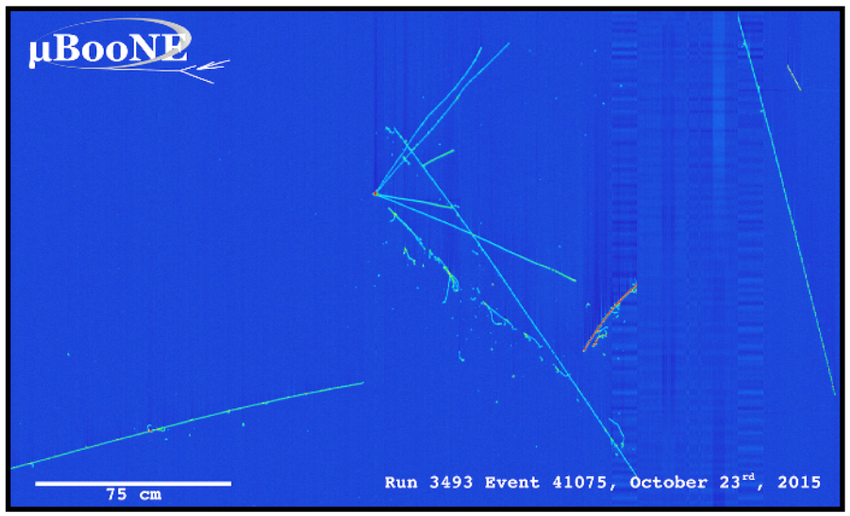


Cherenkov detectors:

Assuming QE interaction

Using solely the final state lepton

$$E_{QE} = \frac{2M\epsilon + 2ME_l - m_l^2}{2(M - E_l + |k_l|cos\theta)}$$



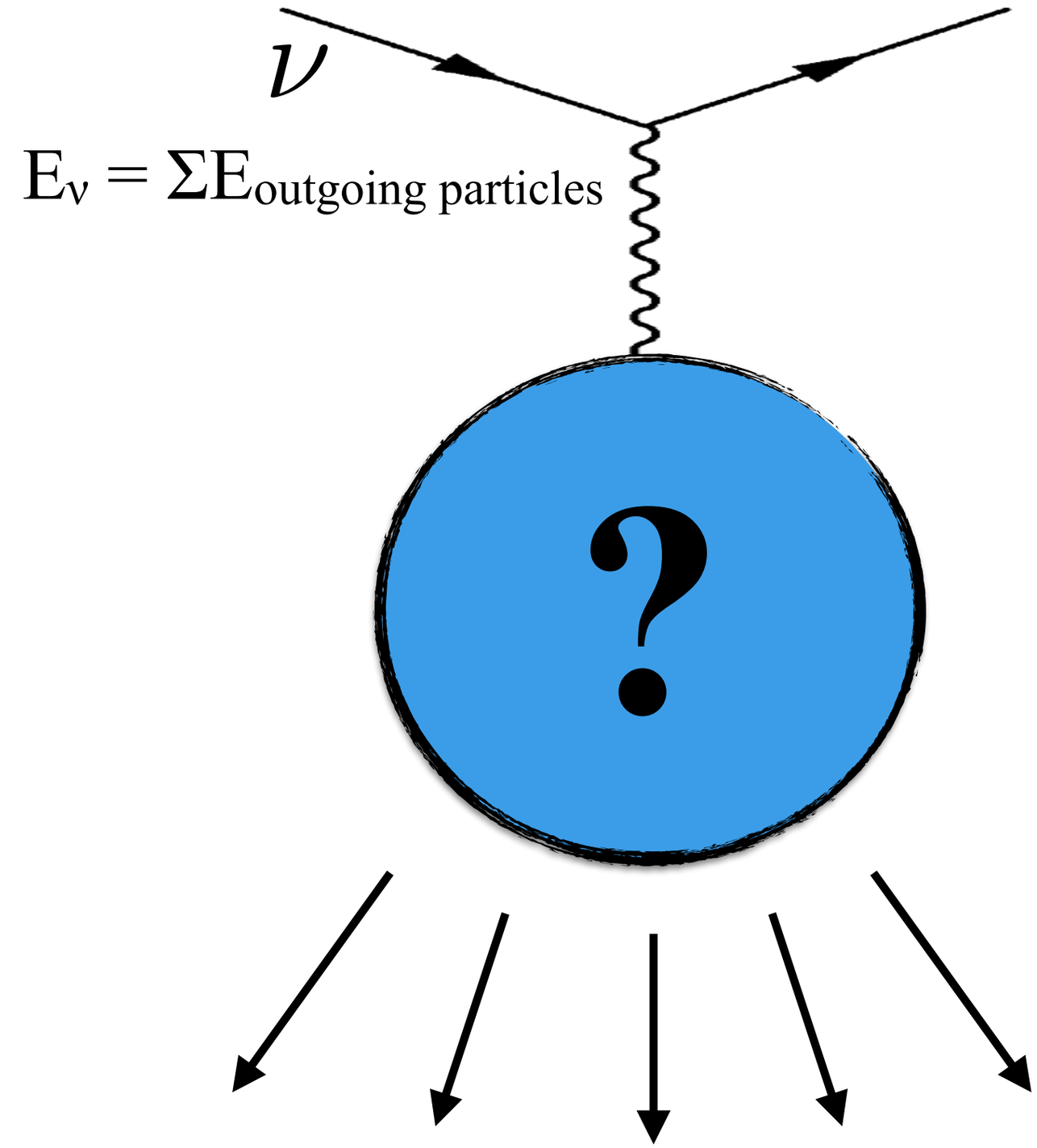
Tracking detectors:

Need good hadronic reconstruction

$$E_{\mathrm{cal}} = E_l + E_p^{\mathrm{kin}} + \epsilon$$

ϵ is the nucleon separation energy ~ 20 MeV

E_ν Reconstruction: Interaction Modeling



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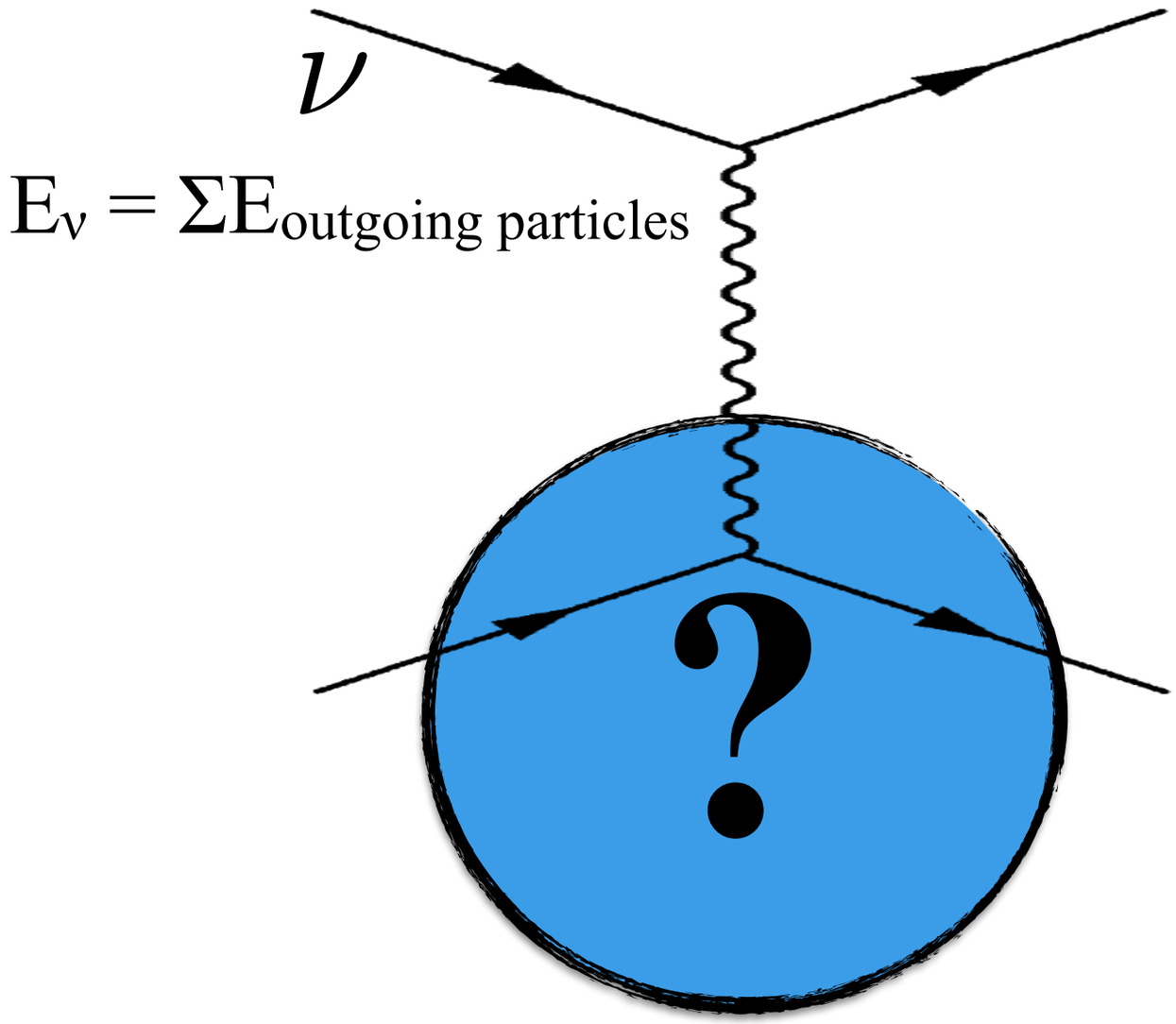
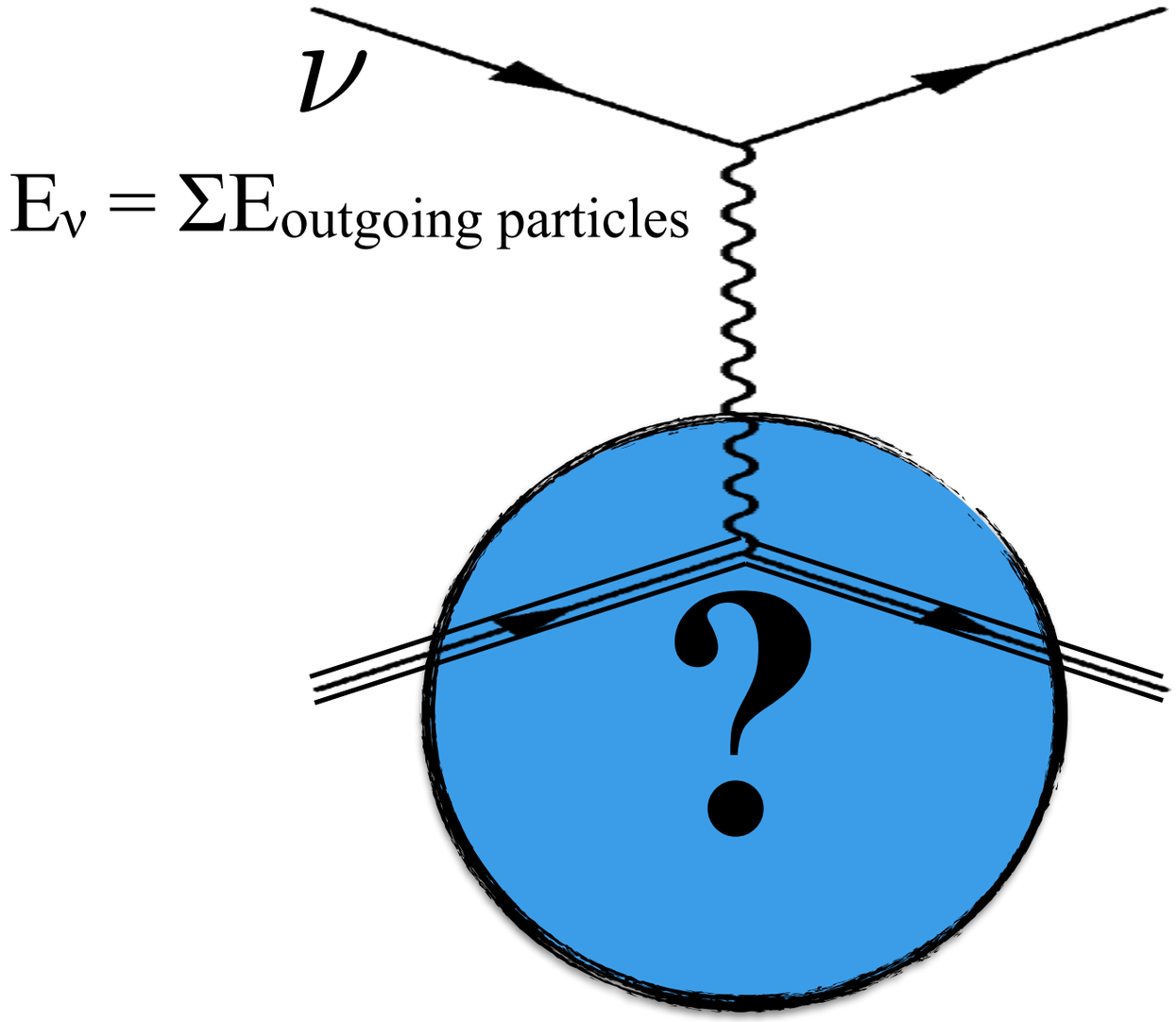


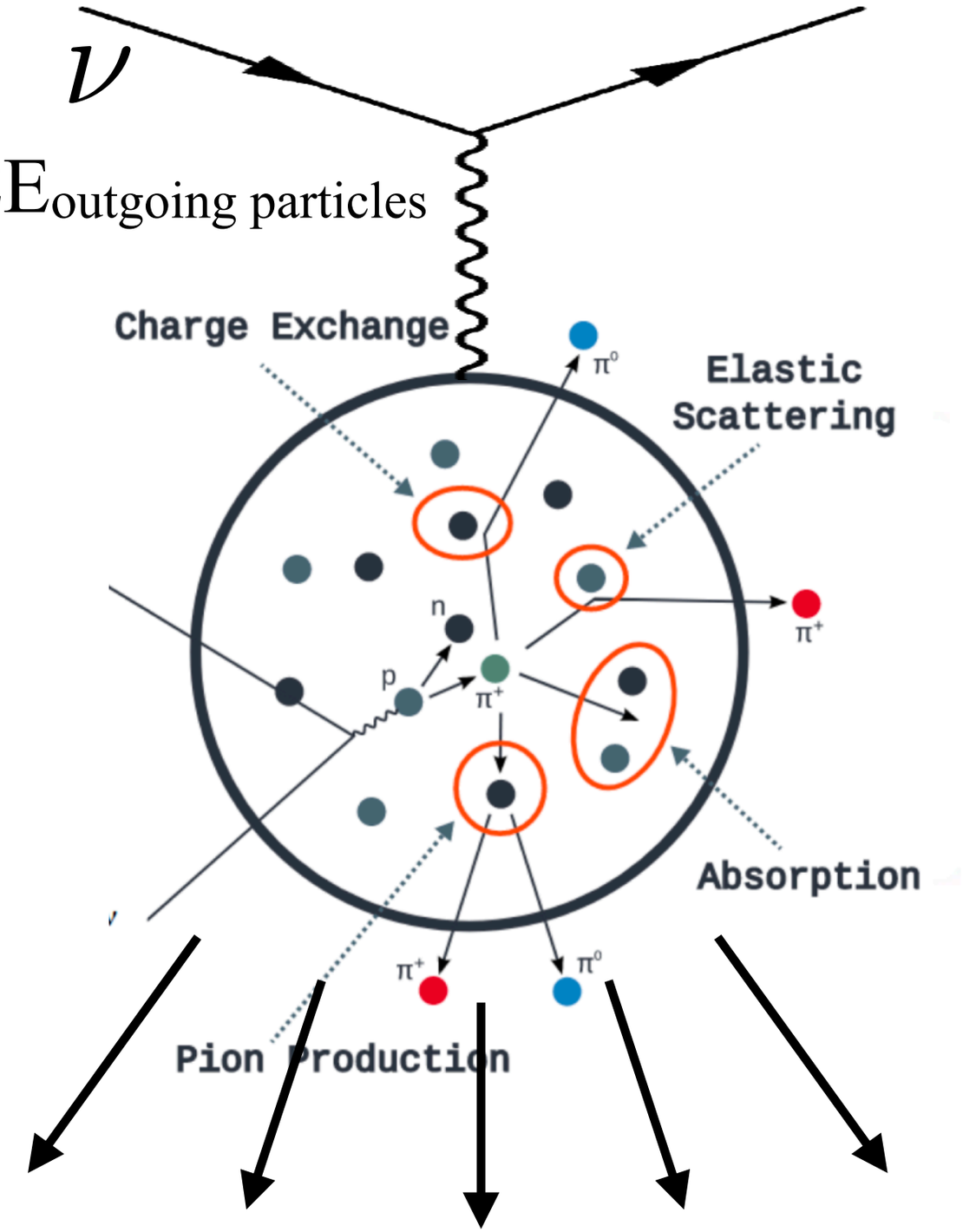
E_ν Reconstruction: Interaction Modeling



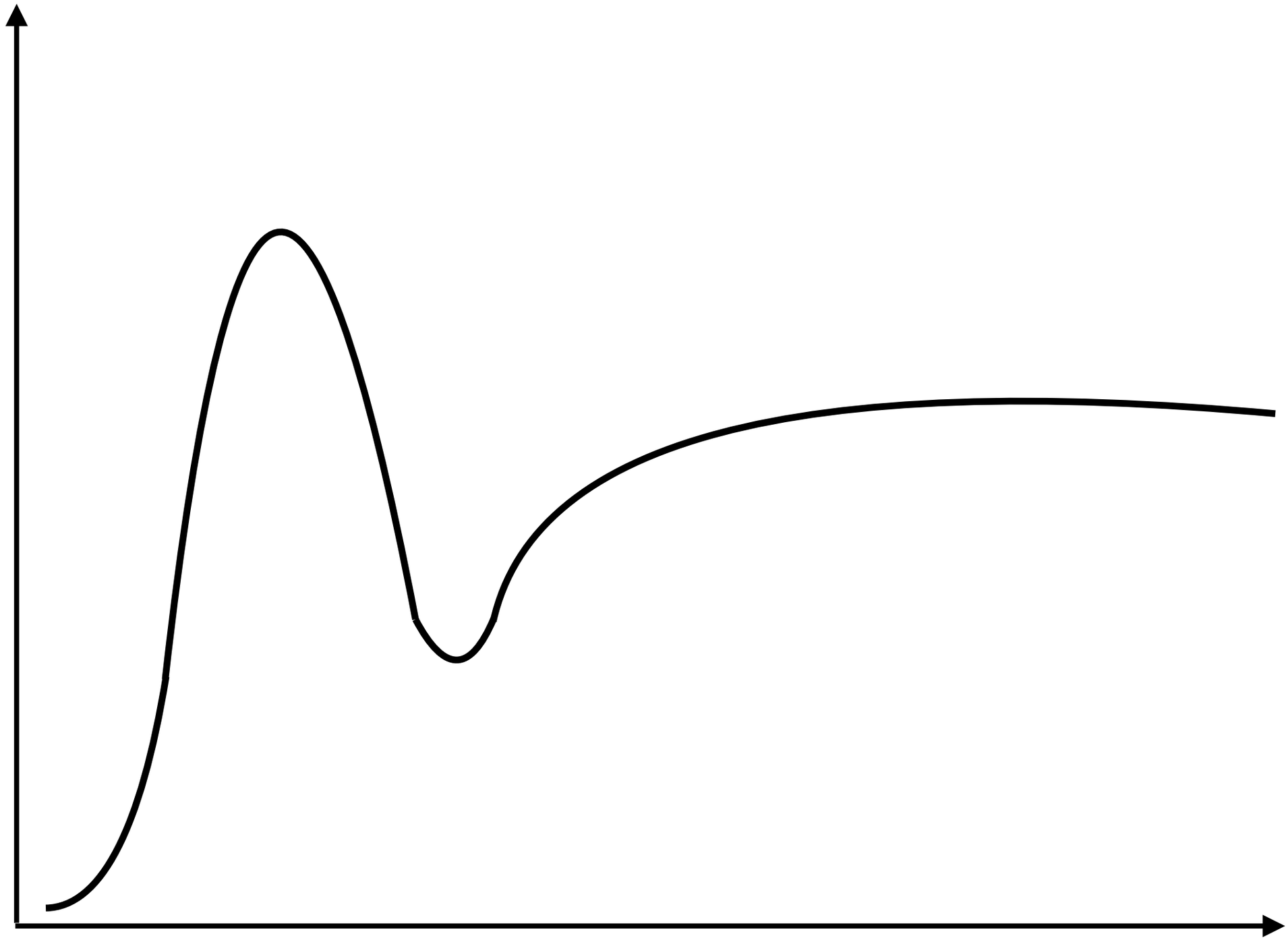
E_ν Reconstruction: Interaction Modeling

ν

$E_\nu = \Sigma E_{\text{outgoing particles}}$



E_ν Reco Requires Interaction Modeling



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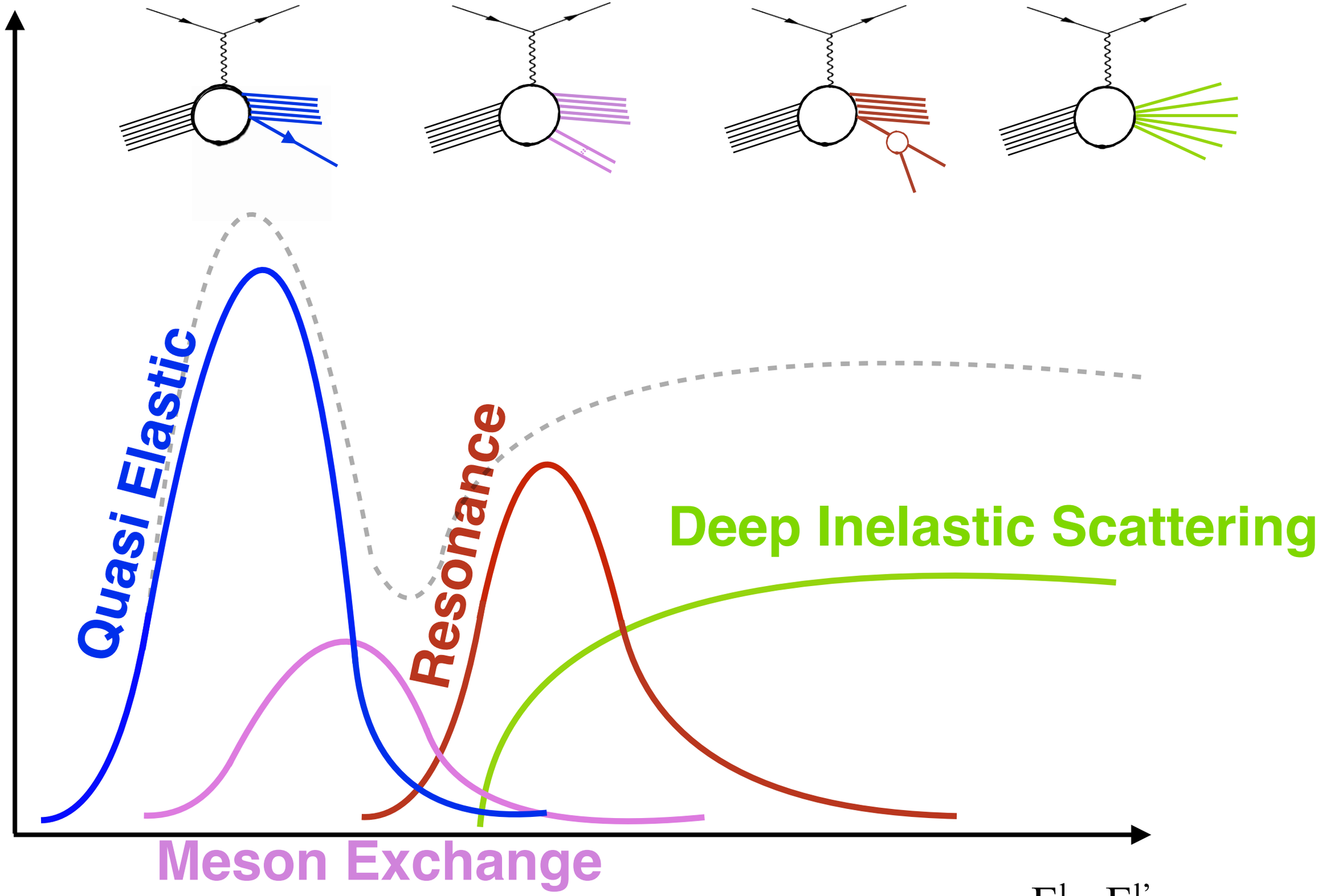


νA Interaction Modelling

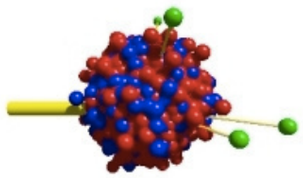
Neutrino event generators are used to simulate a νA interaction

Among those:

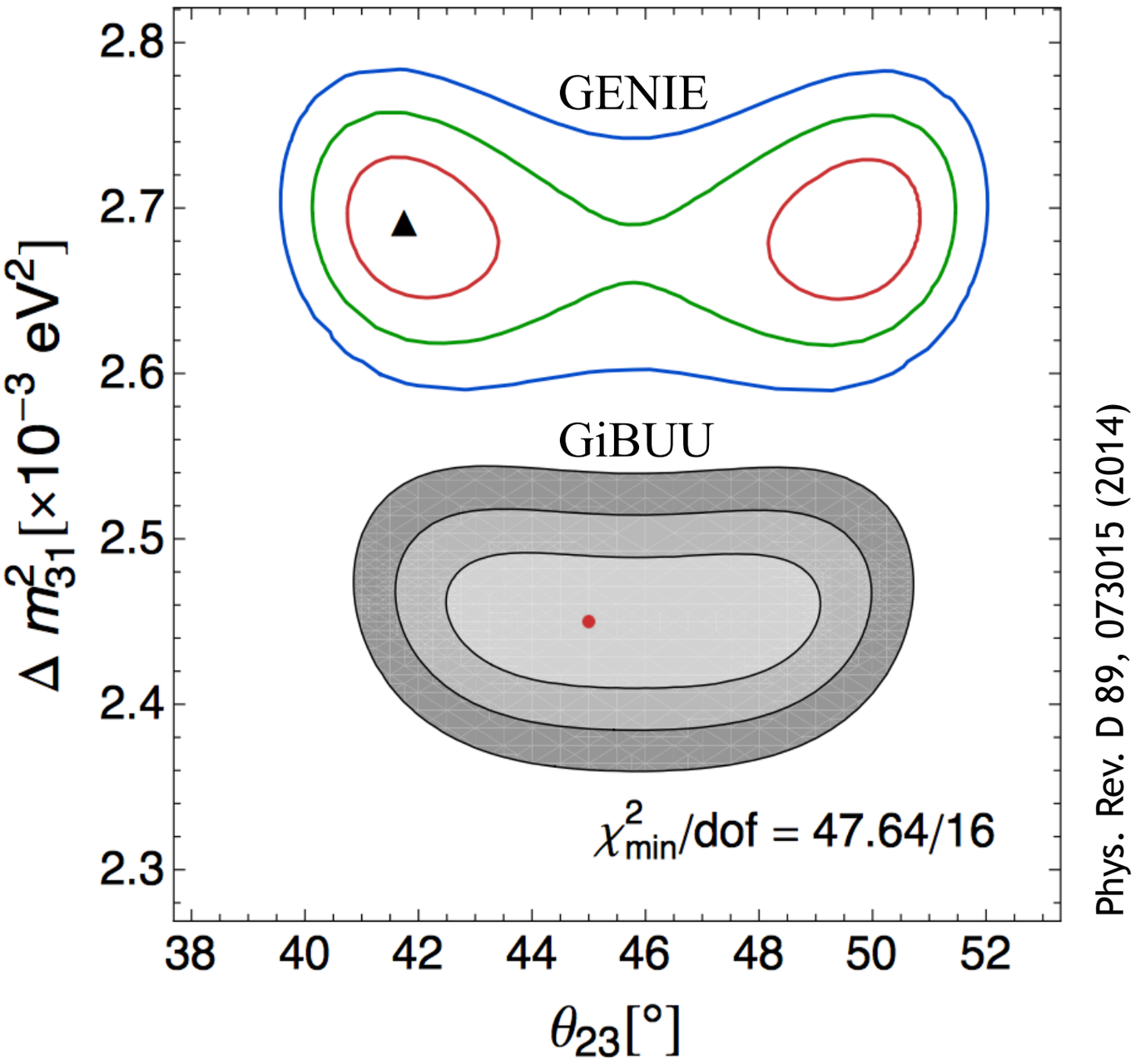
GENIE 

NEUT

NuWro 

GiBUU 

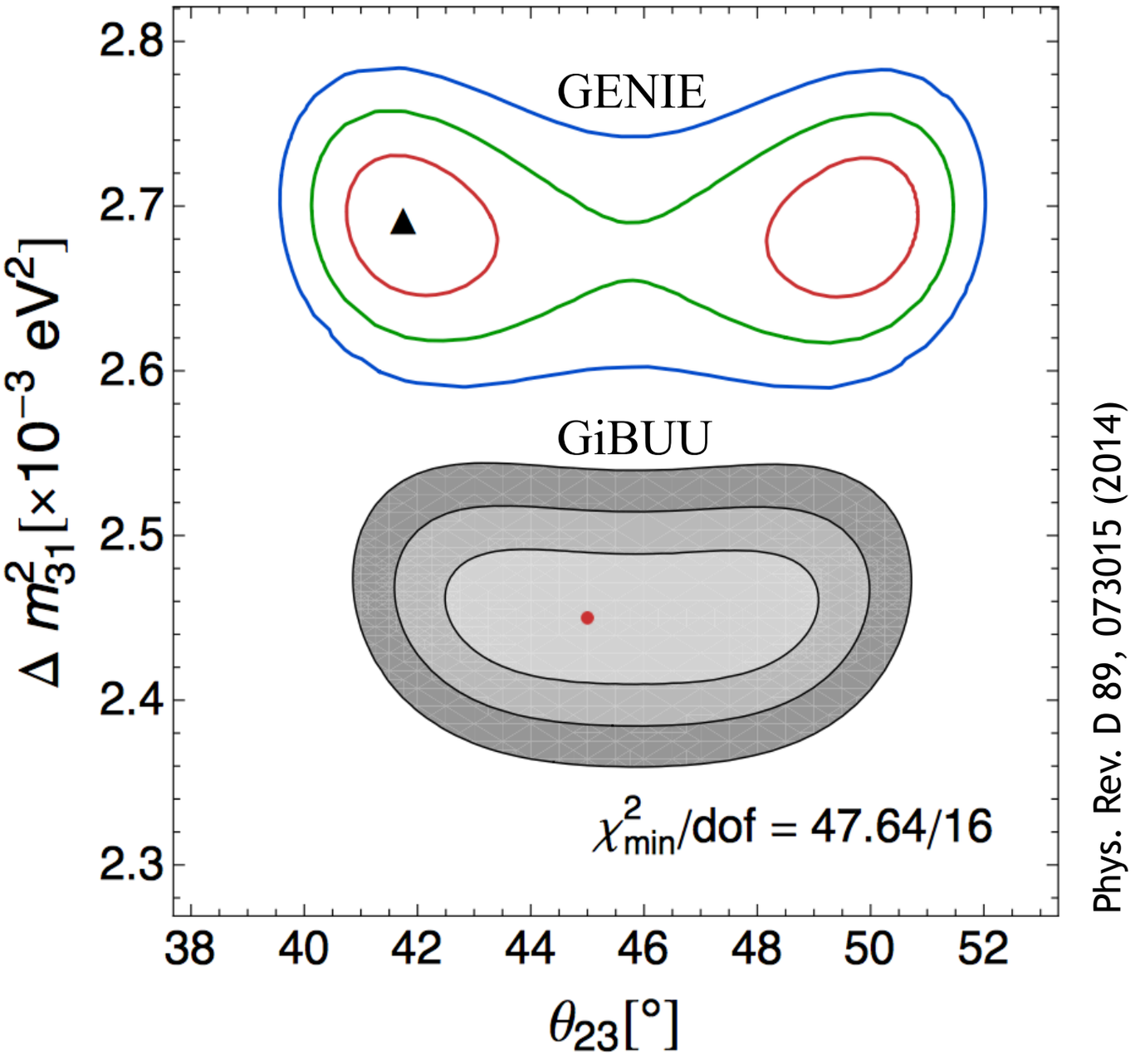
Nuclear Uncertainties are significant



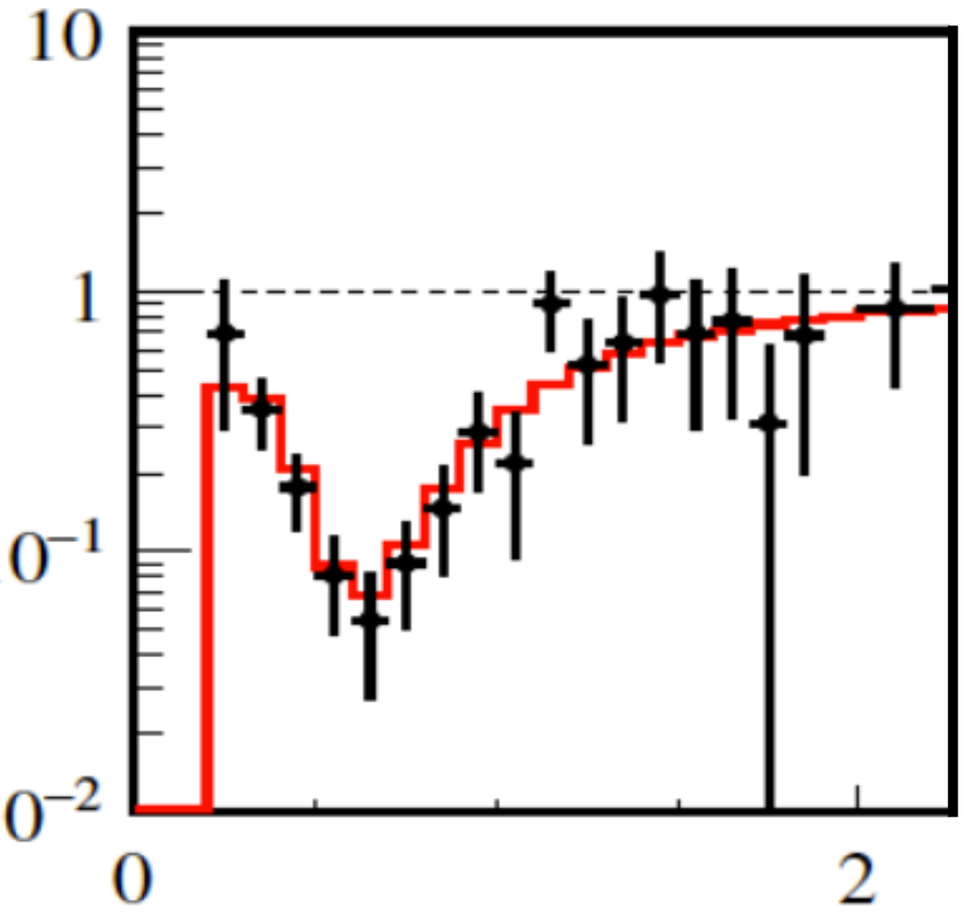
Phys. Rev. D 89, 073015 (2014)

Nuclear Uncertainties are significant

Could lead to wrong extraction of the mixing parameters due to incomplete modelling of the nuclear physics involved.

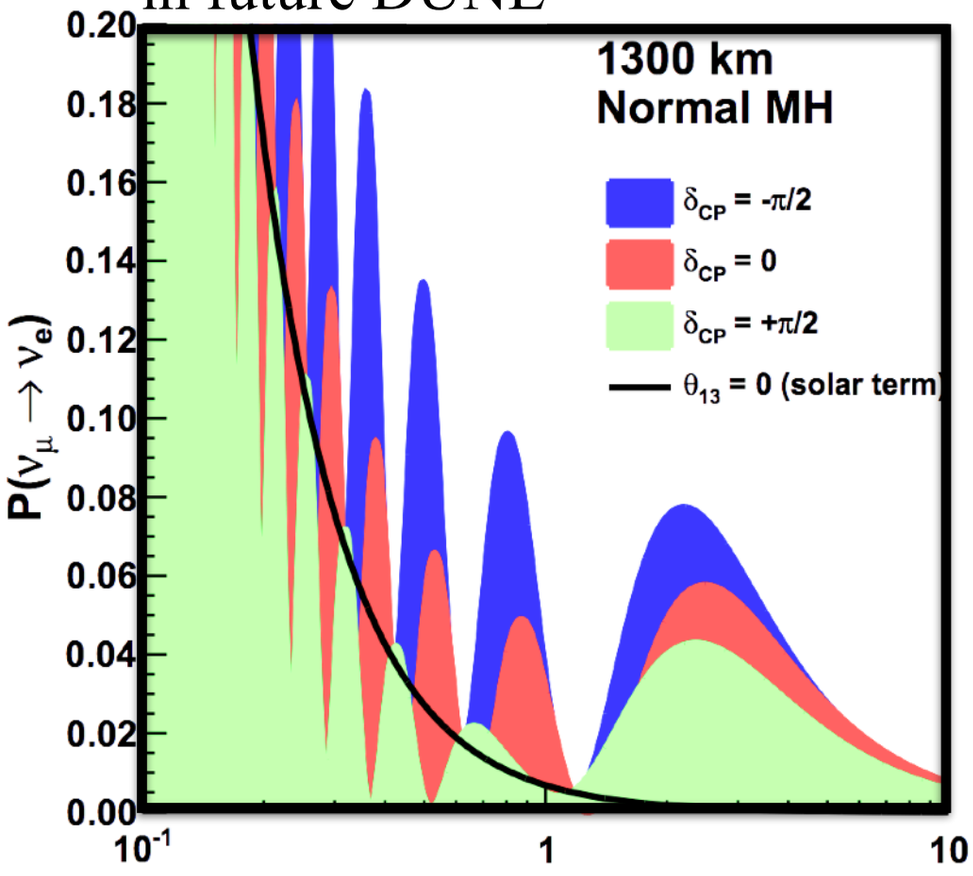


Next generation - High Precision Challenge



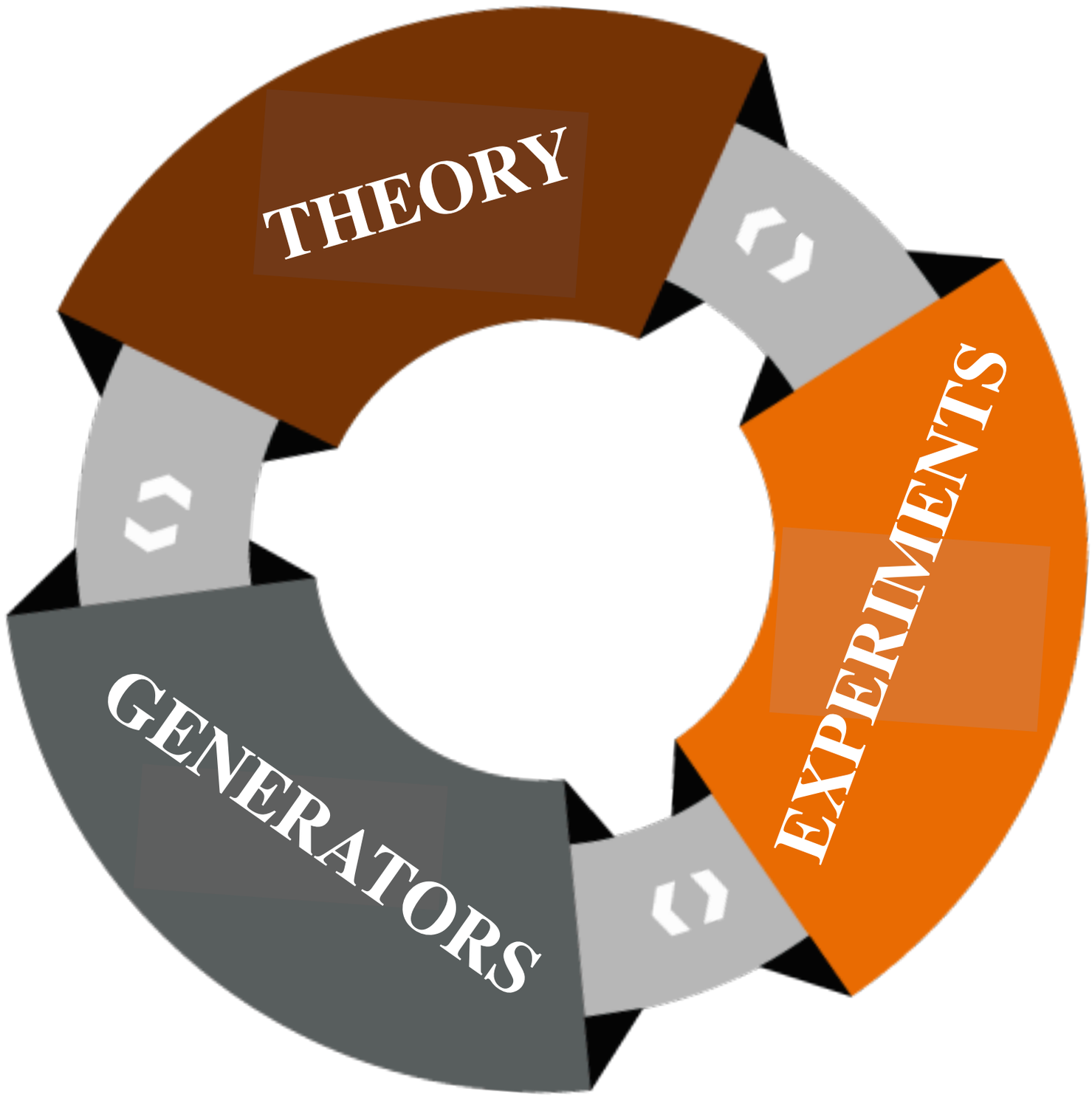
Neutrino Energy [GeV]

Simulation of oscillation effects in future DUNE

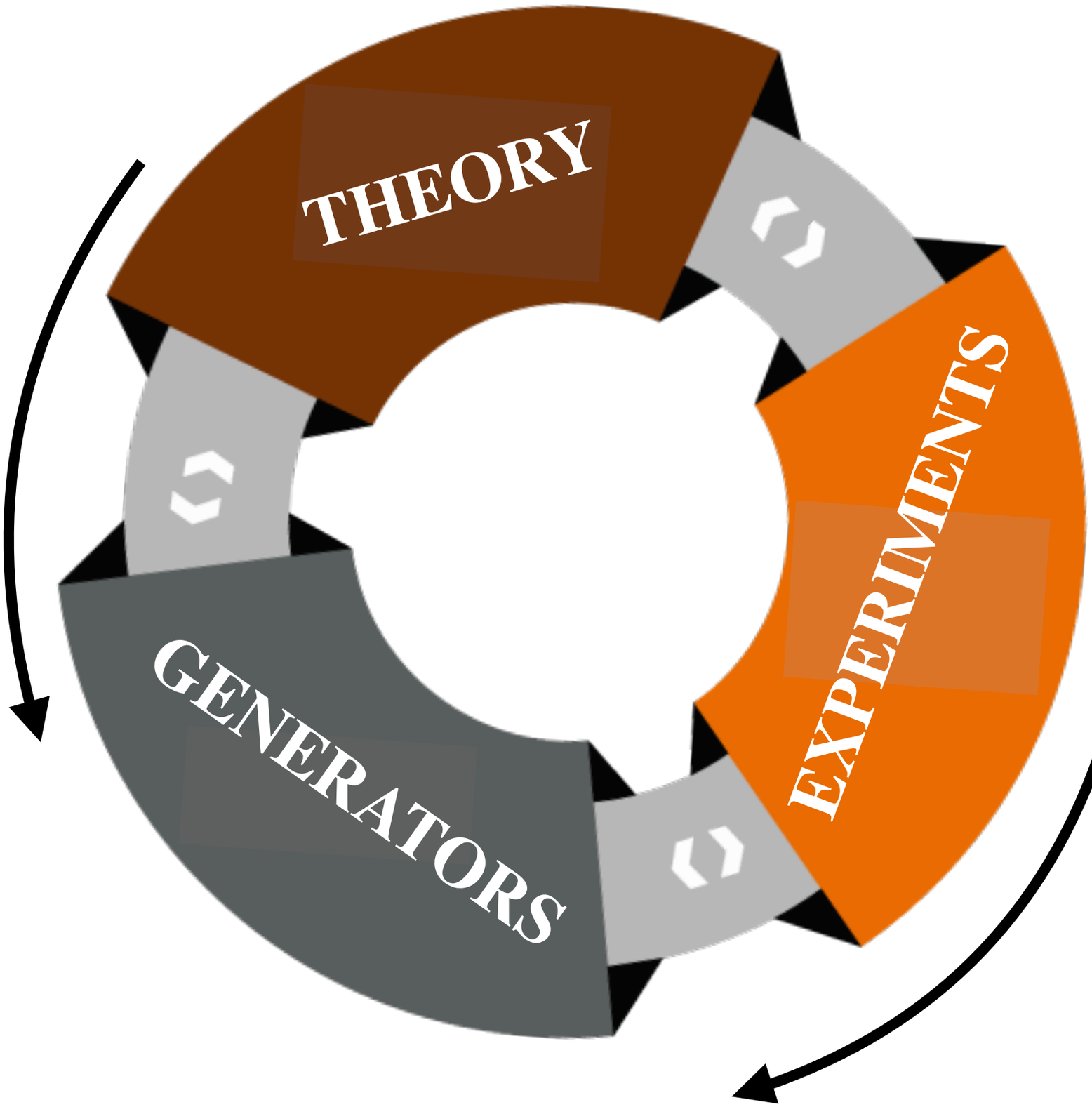


Neutrino Energy [GeV]

WG2 Cross Section Focus



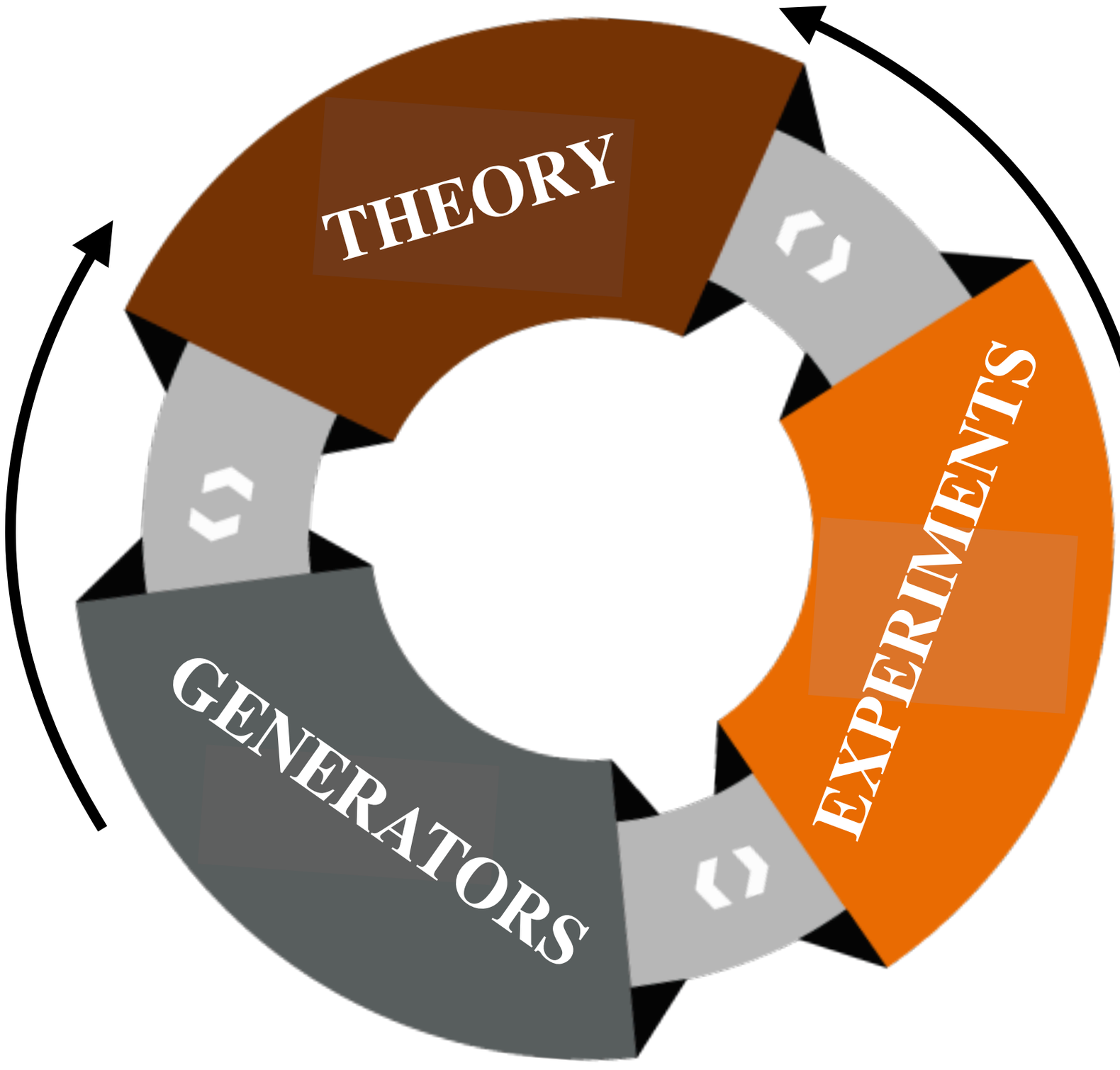
WG2 Cross Section Focus



Models

Empirical Models

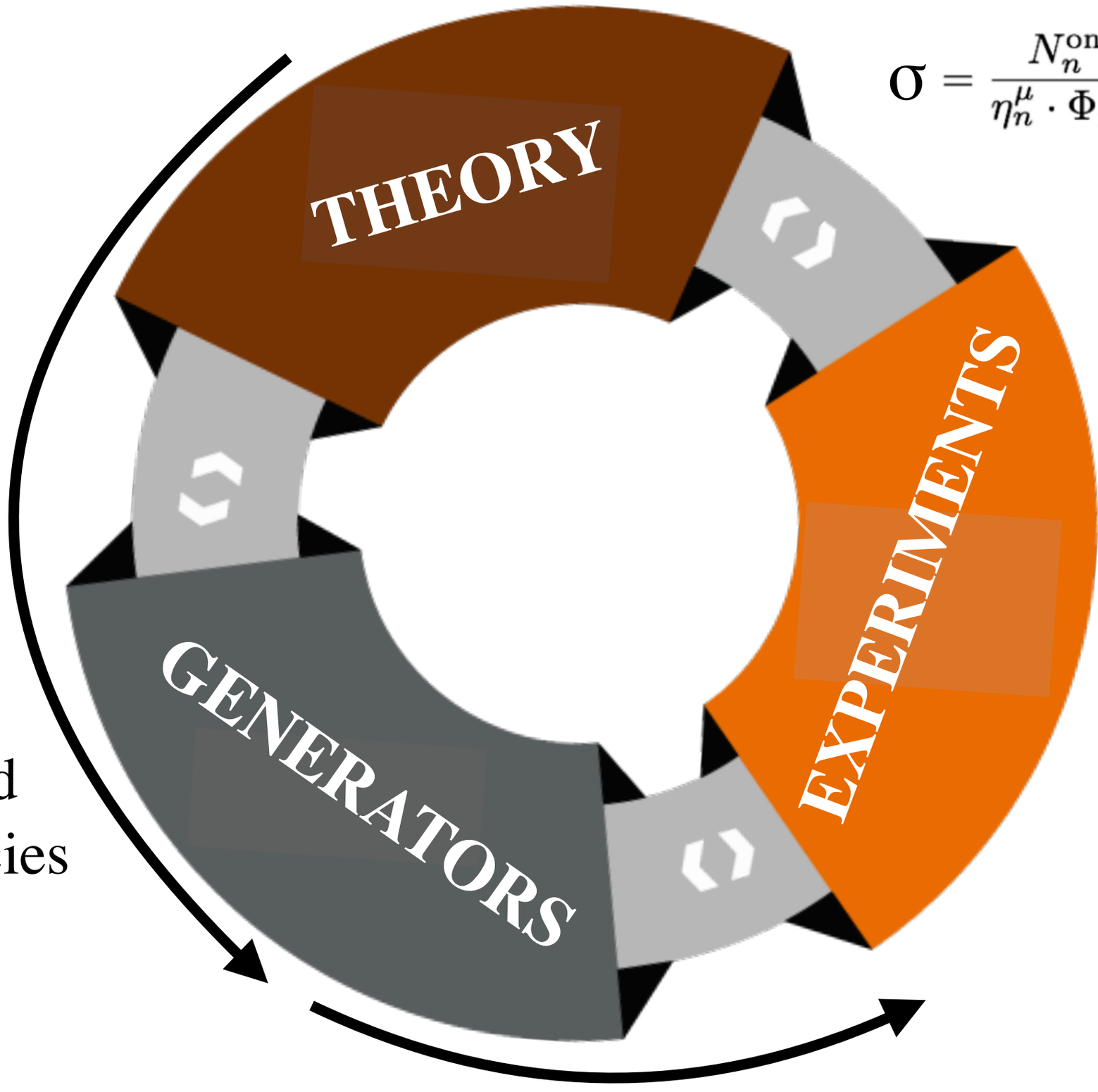
WG2 Cross Section Focus



Testing models

WG2 Cross Section Focus

$$\sigma = \frac{N_n^{\text{on}} - N_n^{\text{off}} - B_n}{\eta_n^{\mu} \cdot \Phi_{\nu} \cdot N_{\text{targets}} \cdot \Delta_n^{\mu}}$$



The background & efficiencies are model dependent

WG2 Cross Section Goals

Experimental Cross section results

Theory input - new models

Generators strategies

Goals

Experimental Cross section results

15 experiments updates

Theory input - new models

5 theory input talks **Including plenary about tensions between models**

Generators strategies

3 talks **Including plenary about status and comparison between models**

Goals

Experimental Cross section results

15 experiments updates

Theory input - new models

5 theory input talks **Including plenary about tensions between models**

Generators strategies

2 talks **Including plenaries about status and comparison between models**

External constraints

2 talks **Including plenary about e4v**

Engagement with oscillation physics

2 joint sessions with 10 talks **Also focuses on detector technologies**

Schedule

	Monday	Teusday	Wednesday	Thursday	Friday
09:00-10:30		e4v Or Hen Modelling tensions - Joanna Sobczyk µBooNE & Adrien Hourlier		Generator status - Luke Pickering	
11:00-12:30		MINERvA Tejin Cai		Theory	
14:00-15:30	T2K Francis Bench	Experiment		Joint with Oscillations	Theory + Generators
16:00-17:30	NOvA Erica Smith SBN Joshua Spitz	Experiment		Joint with Oscillations	Experiment + Discussion

Thank you