Radiative Correction in GENIE

Electrons for Neutrinos and more

Radiative Correction from Medium to High Energy Experiments

ECT*

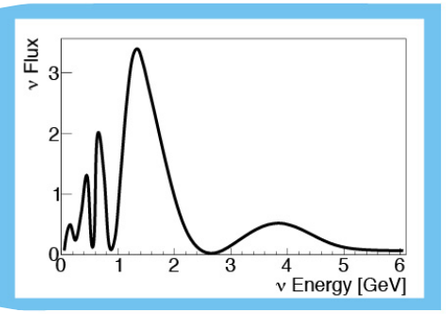
21/7/22

Adi Ashkenazi
adishka@tauex.tau.ac.il

TEL AVIV UNIVERSITY

PHYSICS PROCESS

Neutrino comes in

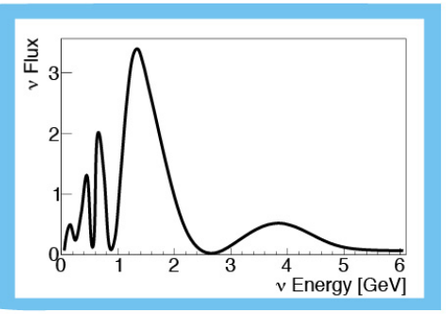


Interacts with nucleus

Particles shoot out

PHYSICS PROCESS

Neutrino comes in



Interacts with nucleus

Particles shoot out

Measure Particles

Apply Interaction Model

Reconstruct ν-Energy

Extract Oscillations

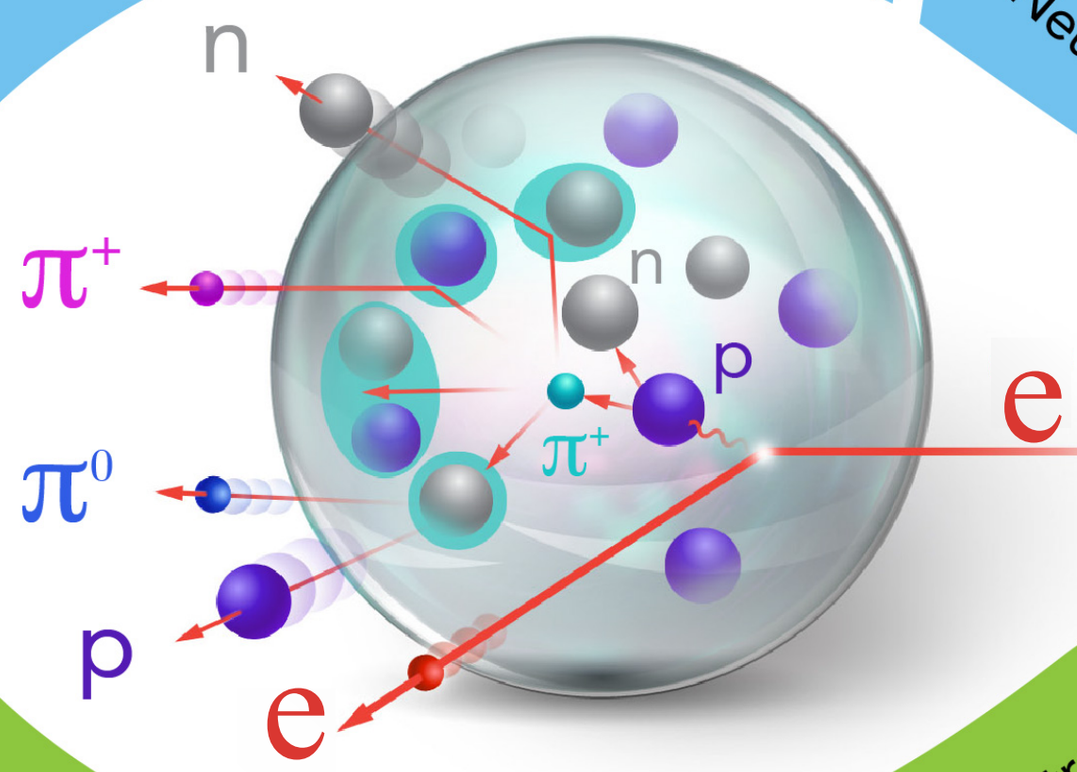
EXPERIMENTAL ANALYSIS

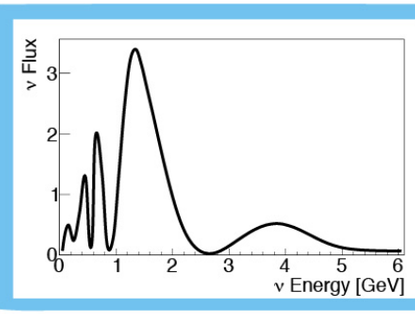
PHYSICS PROCESS

Particles shoot out

Interacts with the nucleus

Neutrino comes in





Measure Particles

Apply Interaction Model

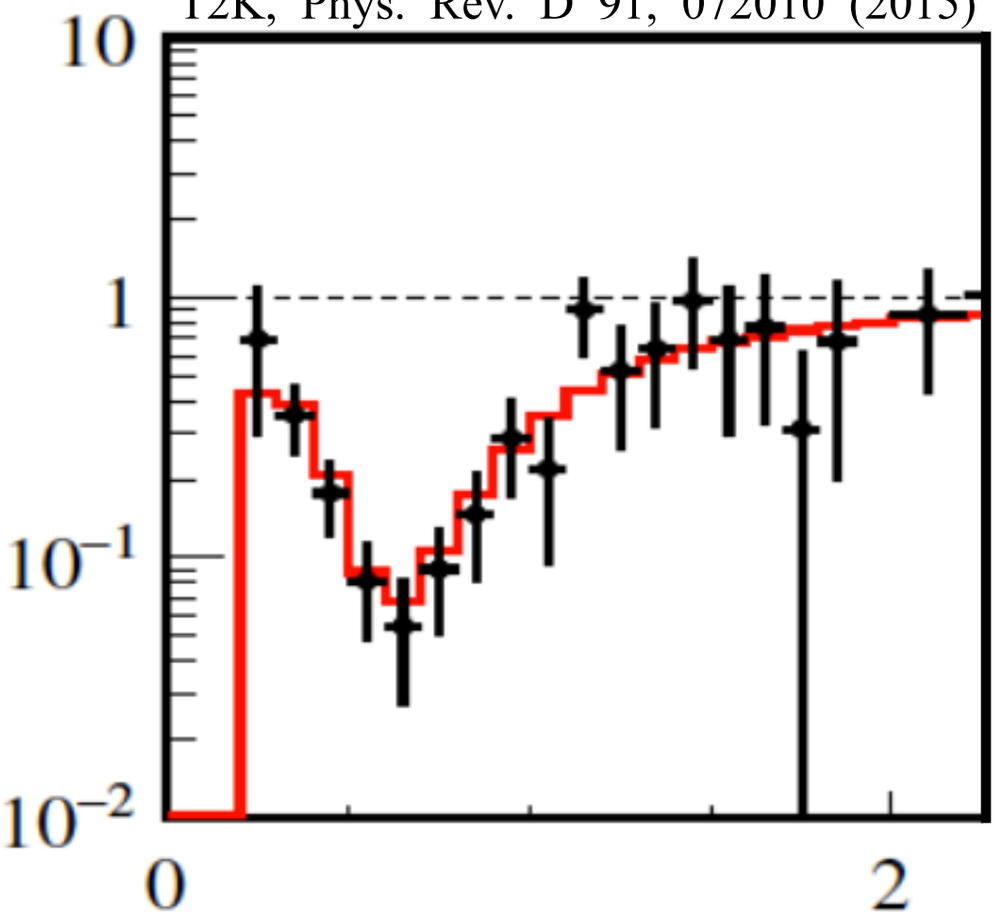
Reconstruct υ-Energy

Extract Oscillations

EXPERIMENTAL ANALYSIS

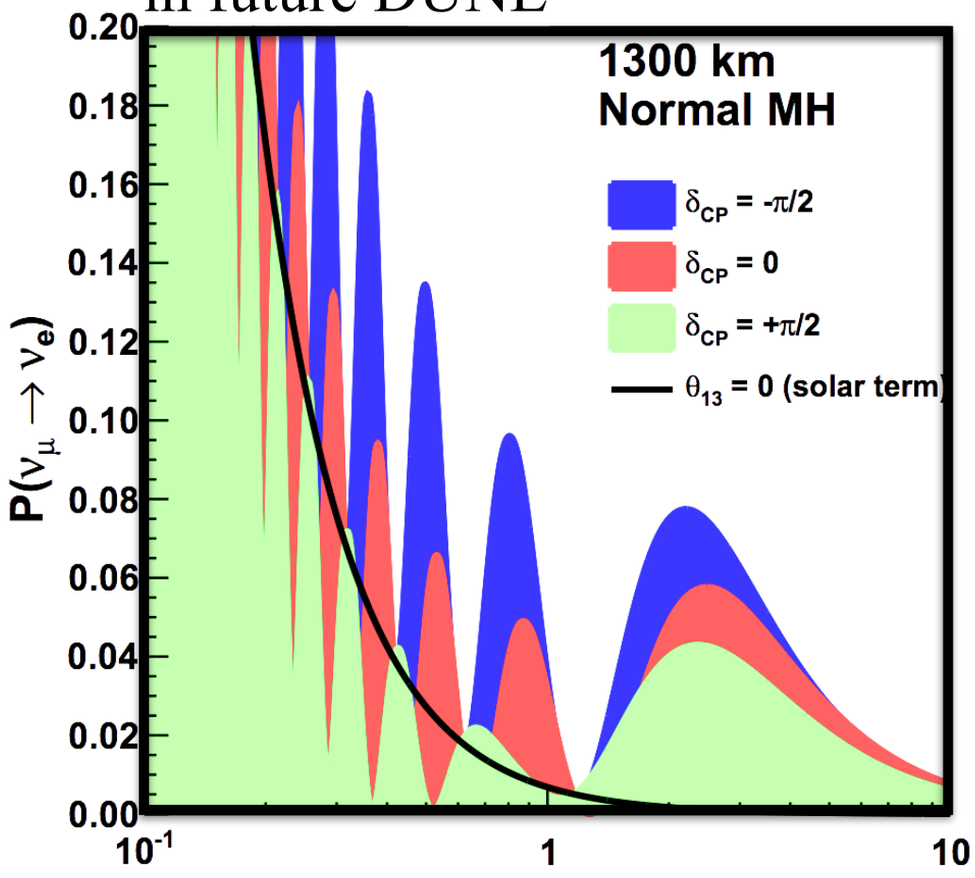
The challenge - next generation high precision

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



Neutrino Energy [GeV]

Simulation of oscillation effects in future DUNE



Neutrino Energy [GeV]

see also Oleksandr (Sasha) Tomalak talk

The challenge - next generation high precision

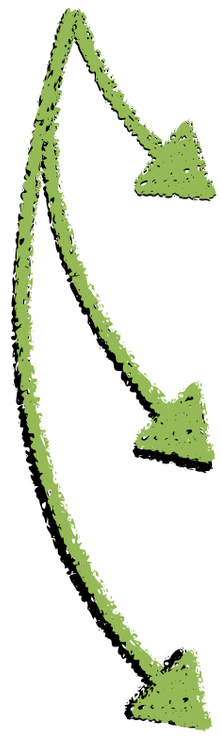
$$N(E_{rec}, L) \propto \int \Phi(E, L)\,\sigma(E)\,f_{\sigma}(E, E_{rec})\,dE$$

Measurement Incoming true flux Modelling input

The challenge - next generation high precision

$$N(E_{rec}, L) \propto \int \Phi(E, L)\,\sigma(E)\,f_{\sigma}(E, E_{rec})\,dE$$

Measurement Incoming true flux Modelling input



Improve theory

Use near detector

Use external constraints

e scattering

e4ν Electrons for Neutrinos

Using electron scattering data to reduce neutrino oscillation systematic uncertainties

- **Test neutrino energy reconstruction**
- **Constrain lepton-nucleus interaction models**

visit: www.e4nu.com

Why electrons?

Electrons and Neutrinos have:

- **Identical initial nuclear state**
- **Same Final State Interactions**
- **Similar interactions (vector vs. vector + axial)**

Electron beams have known energy

*** Needs to account for differences such as different radiative effects**

Collaboration goals

Analyse eA data

Improve lepton-nucleus models

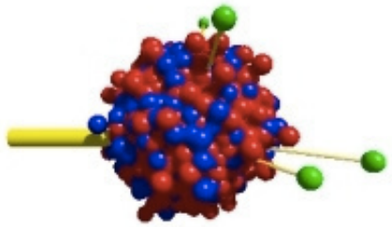
Tune existing lepton-nucleus models

Determine implications on neutrino oscillations

Lepton-Nucleus Interaction Modelling

Neutrino event generators simulating νA interaction

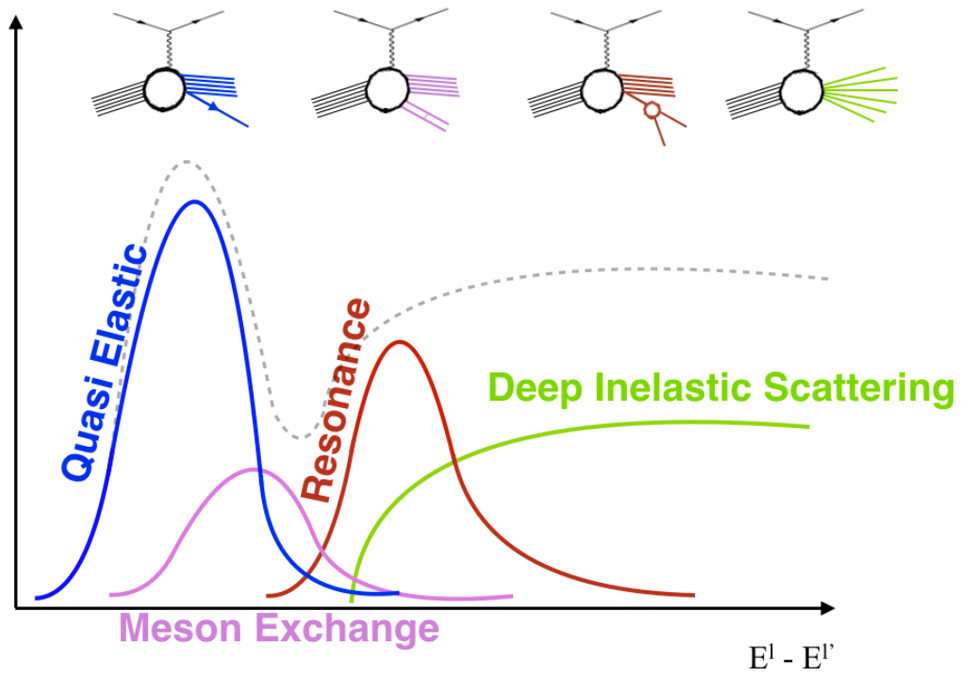
Genie



GiBUU

The Giessen Boltzmann-Uehling-Uhlenbeck Project

and more

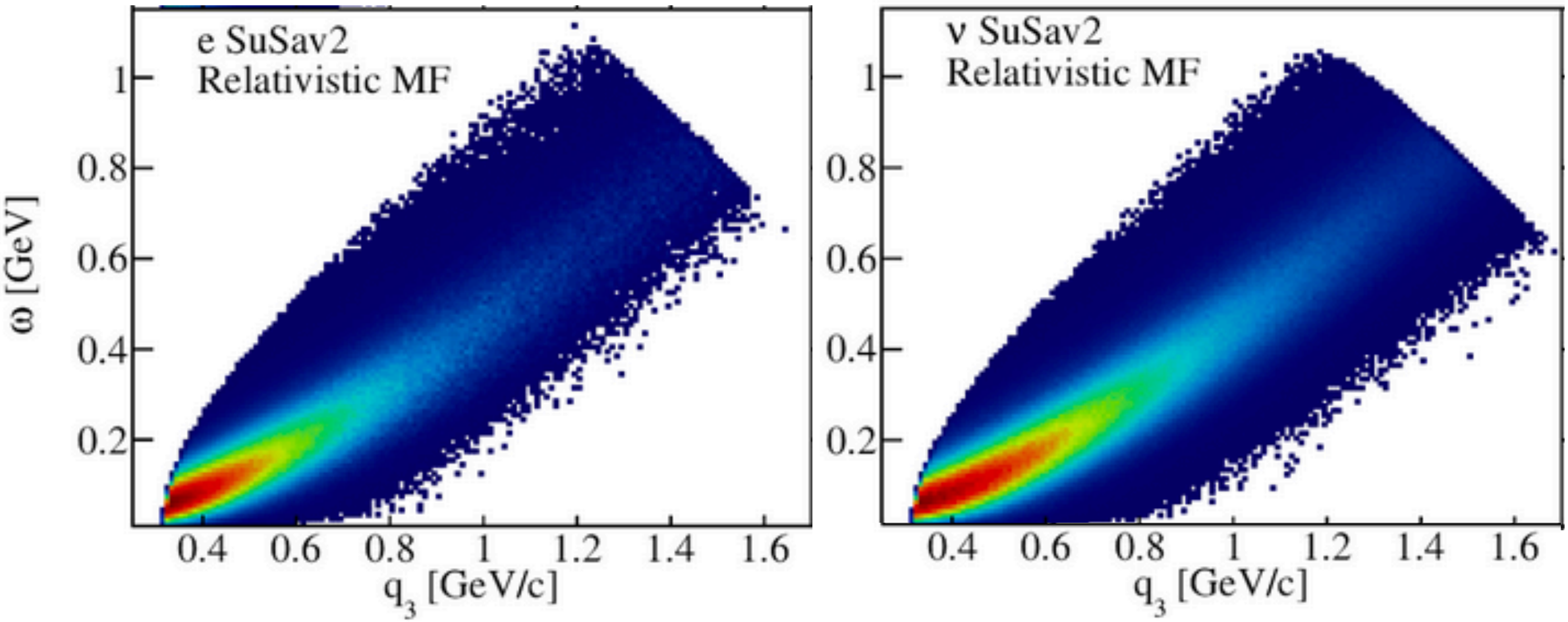


Factorisation of

- Initial state
- Each interaction mechanism separately
- Final State Interactions

Similar eA and νA Cross sections

Test on 1p0π event selection



Genie v3.0.6 SuSA

Electron were weighted by $1/Q^4$

Phys.Rev.D 103 (2021) 113003

CLAS Detector

Electron beam with energies up to 6 GeV

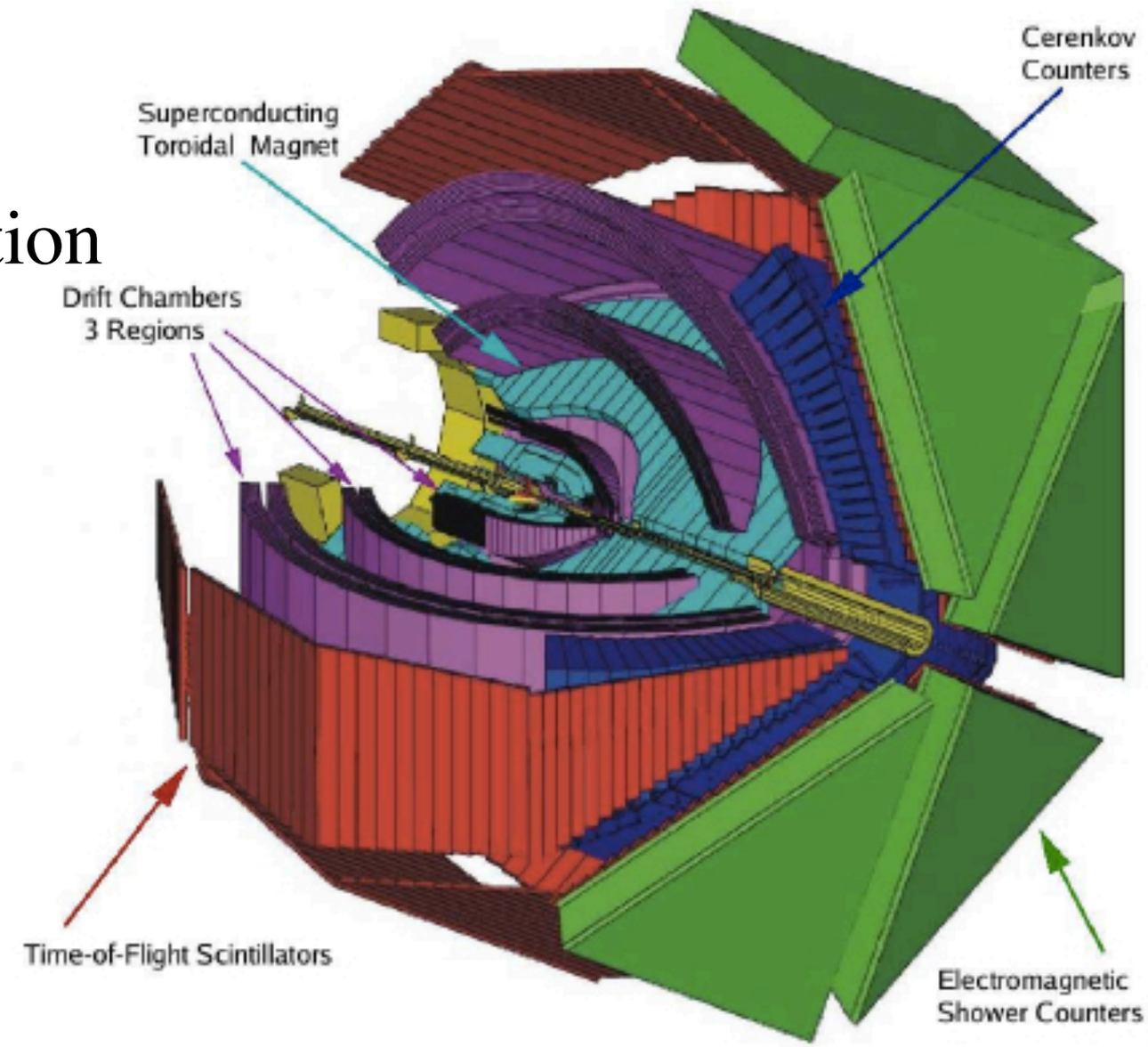
Large acceptance

Charged particles above detection threshold:

300 MeV/c for p

150 MeV/c for $P_{\pi^{+/-}}$

500 MeV/c for P_{π^0}



Open Trigger

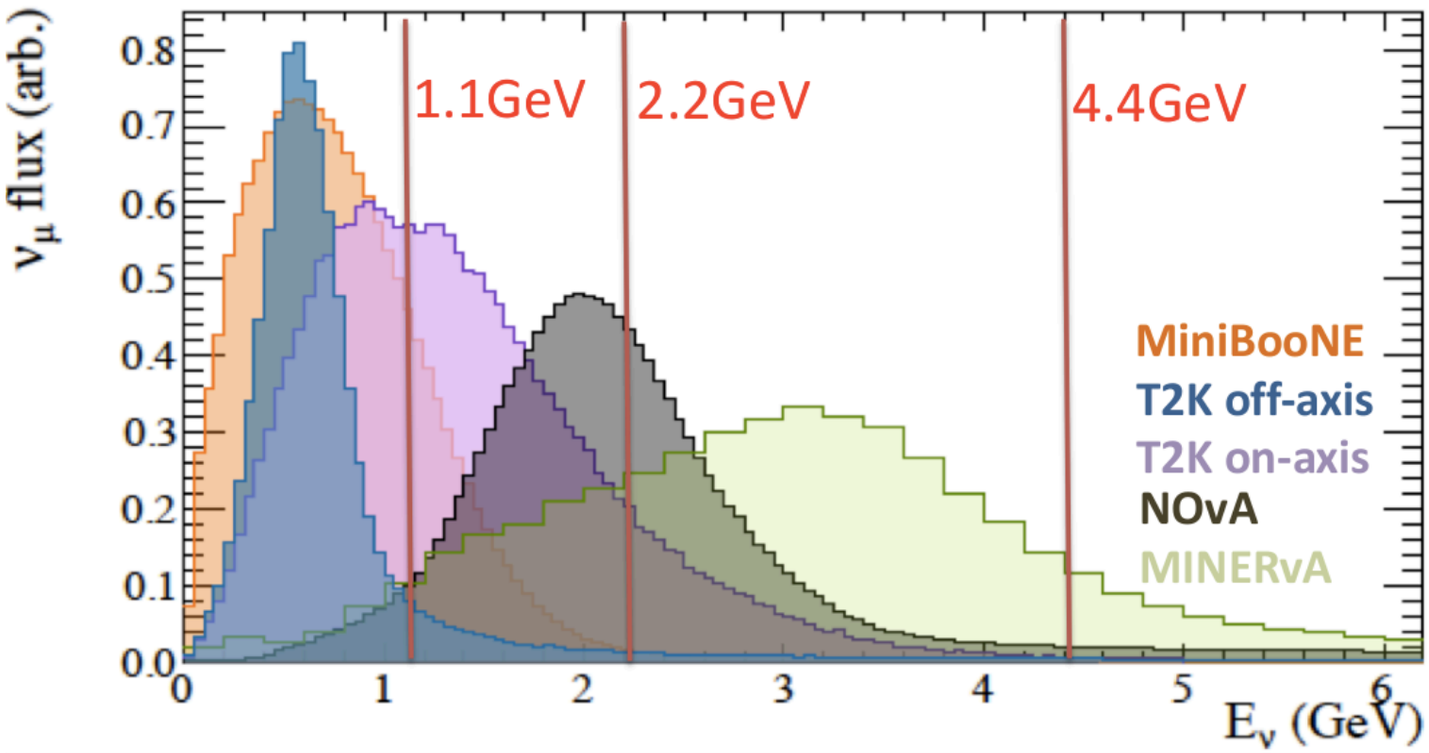
CLAS A(e,e'p) Data E2a

First test of neutrino energy reconstruction with exclusive data!

Targets: ^{4}He, ^{12}C, ^{56}Fe  (H_2O),  (CH),  (Ar)

Energies:

1.1, 2.2, 4.4 GeV



Detection thresholds:

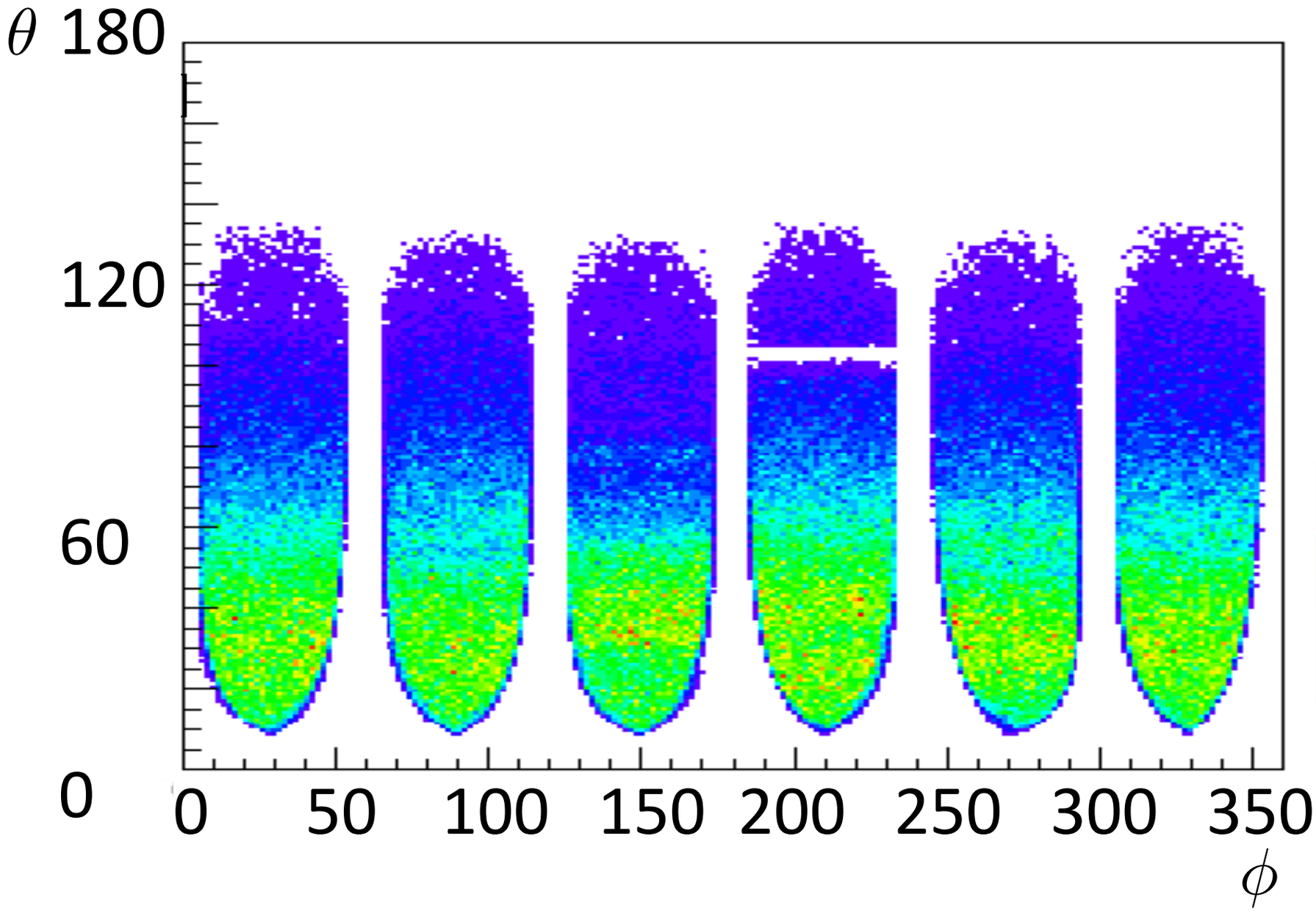
300 MeV/c for p

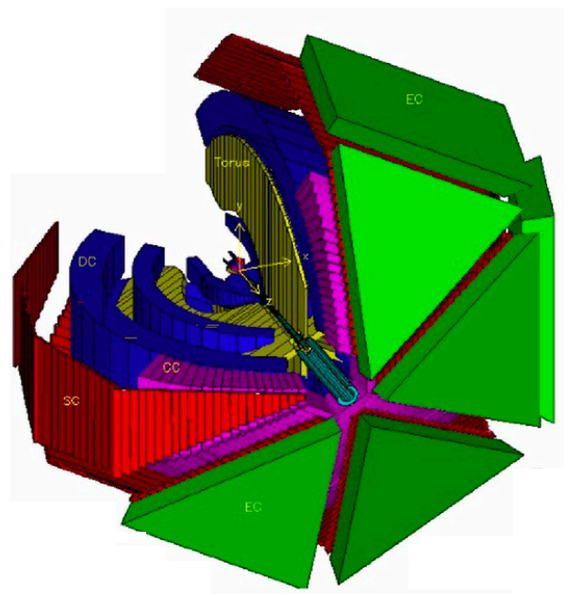
150 MeV/c for $P_{\pi^{+/-}}$

500 MeV/c for P_{π^0}

Comparable to those in ν experiments

CLAS coverage



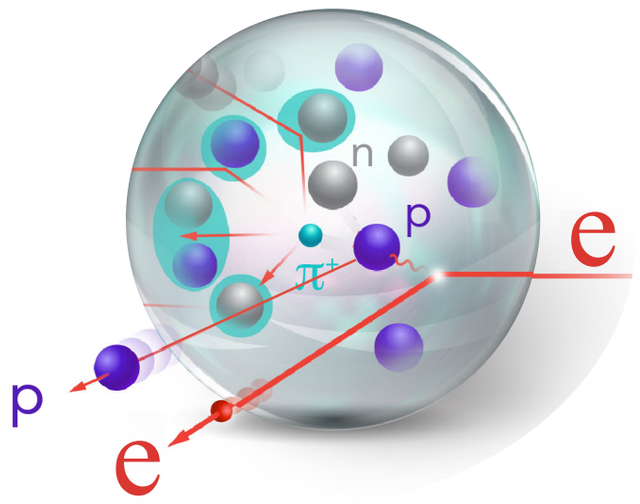


e4ν 1p0π Event Selection

Focus on Quasi Elastic events:

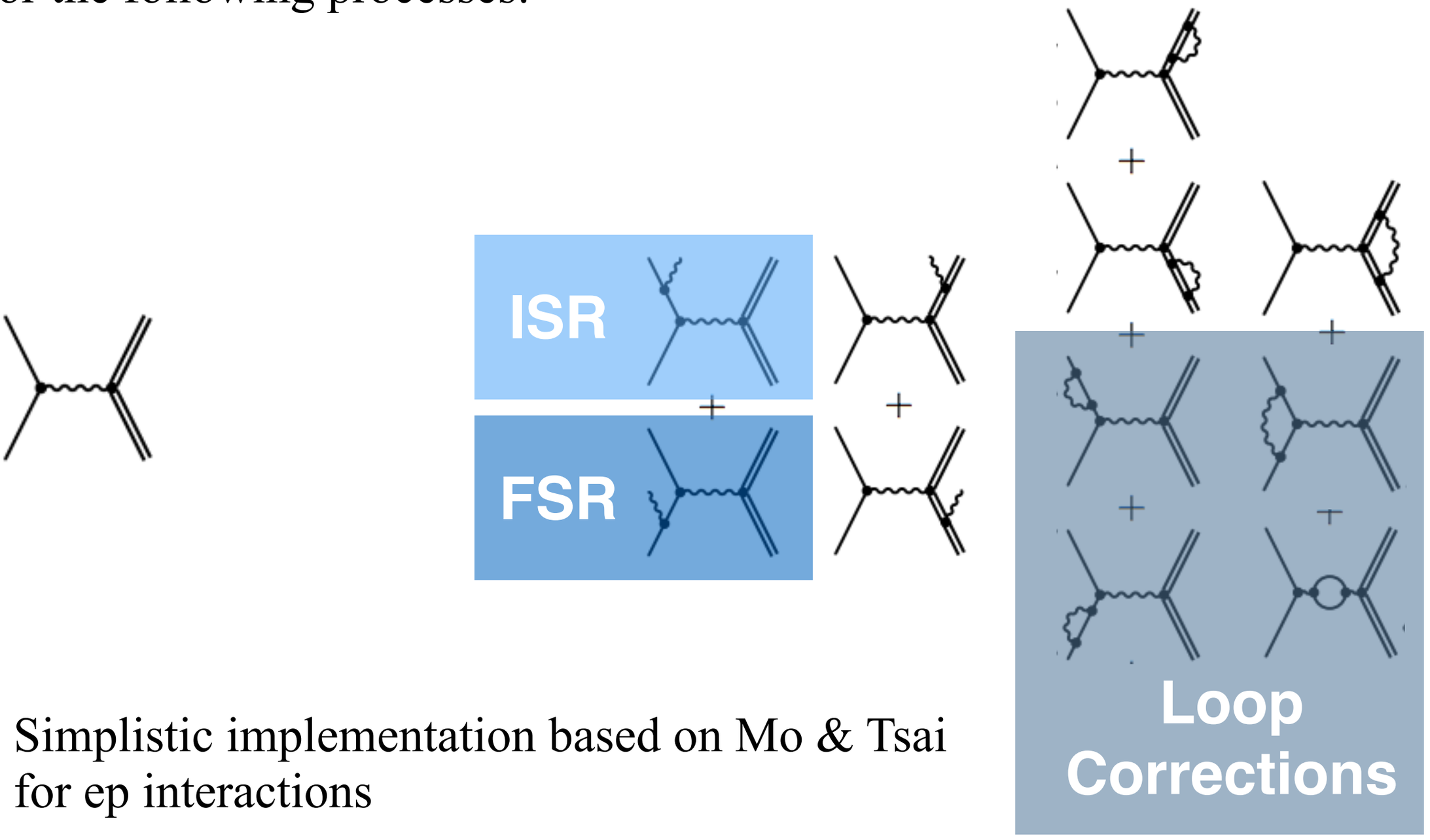
1 proton and no pions above detection threshold:

- Signal commonly used in neutrino oscillation experiment due to relatively easy reconstruction of incoming energy
- Note that 1p0π selection includes non QE contributions



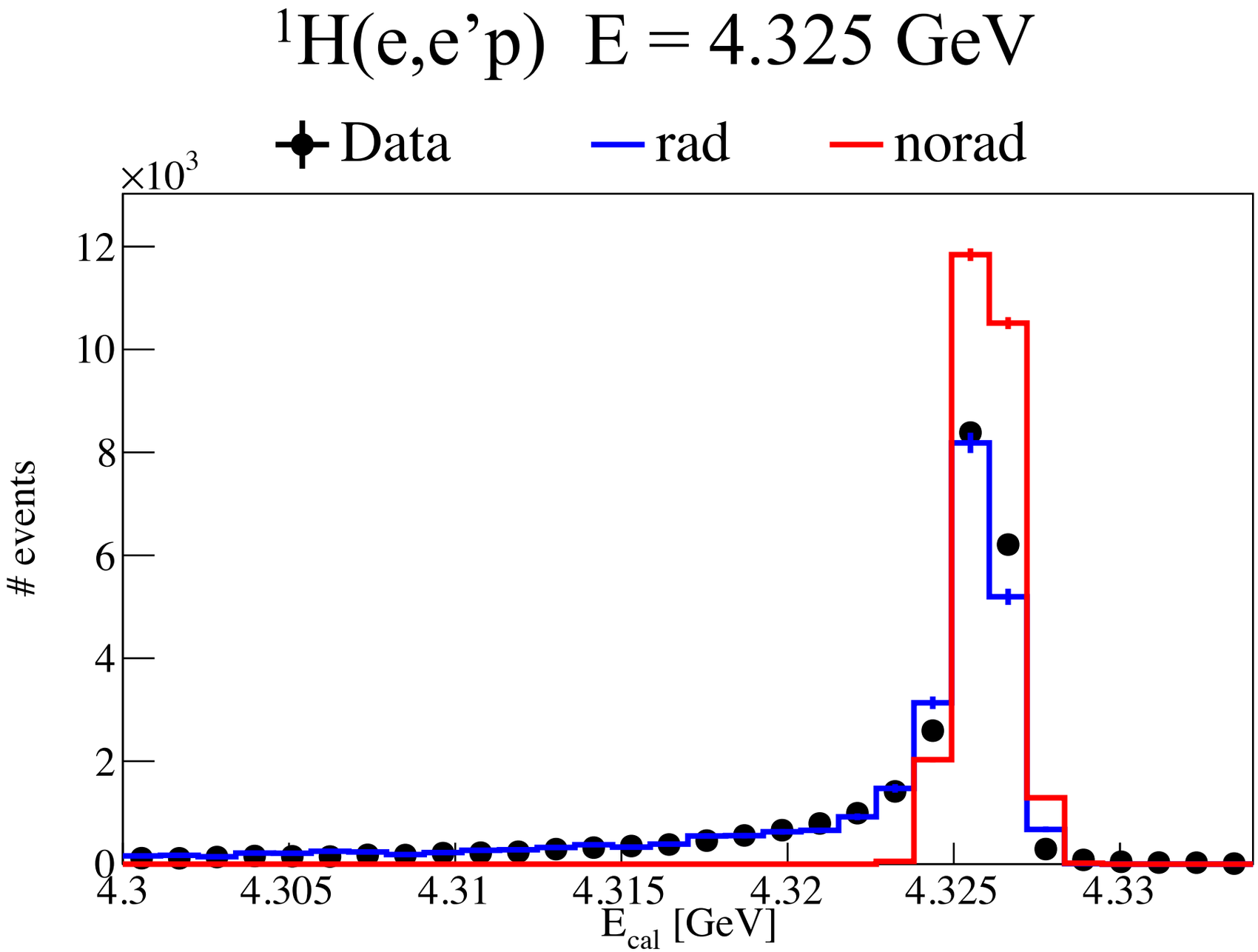
Radiative effects

A first implementation of the radiative corrections to GENIE to account for the following processes:



Simplistic implementation based on Mo & Tsai for ep interactions

Adding radiative effects to GENIE



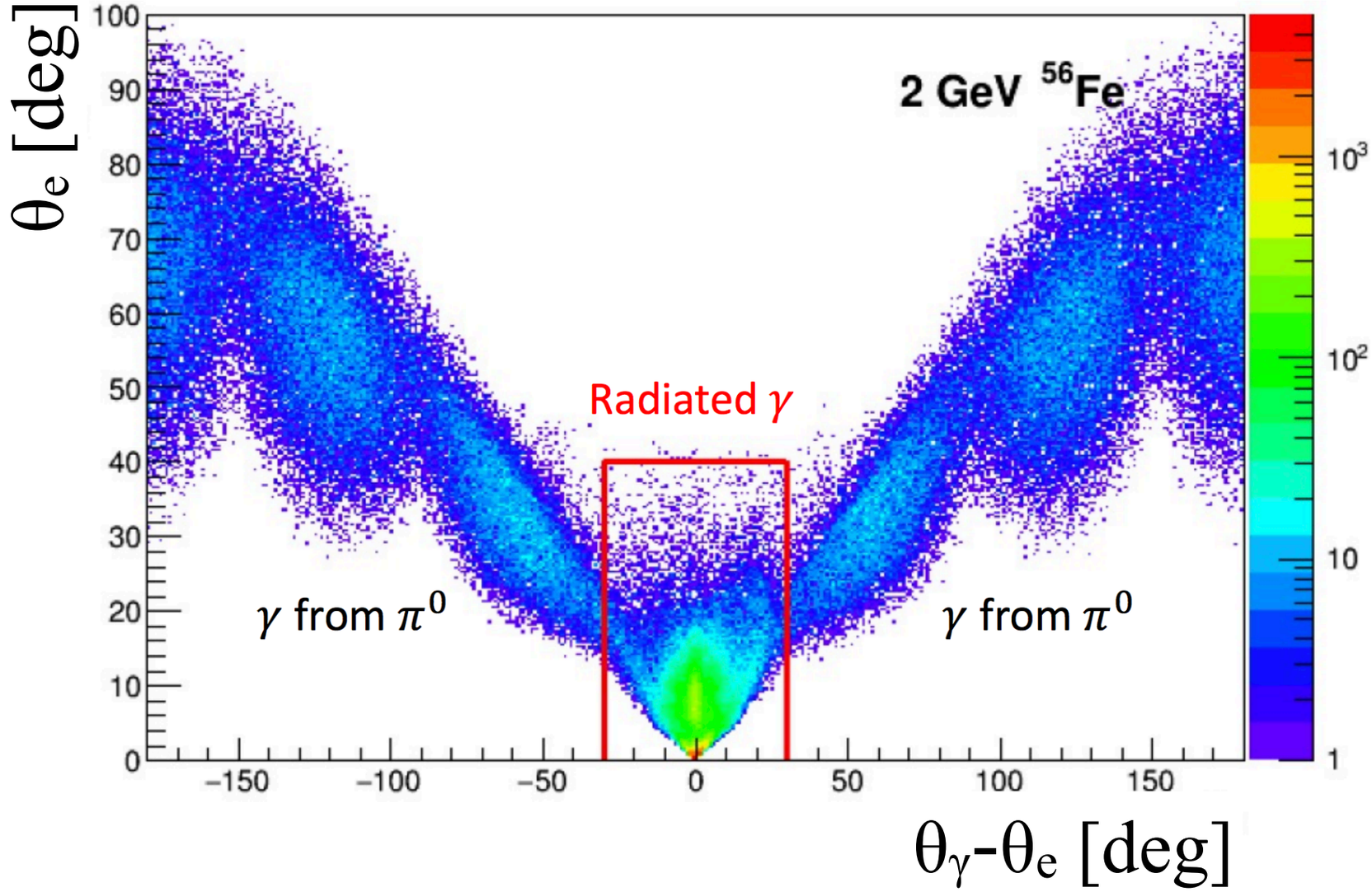
[Mo and Tsai]

Genie v3.0.6 tune GTEST19

Rejecting final state radiation events

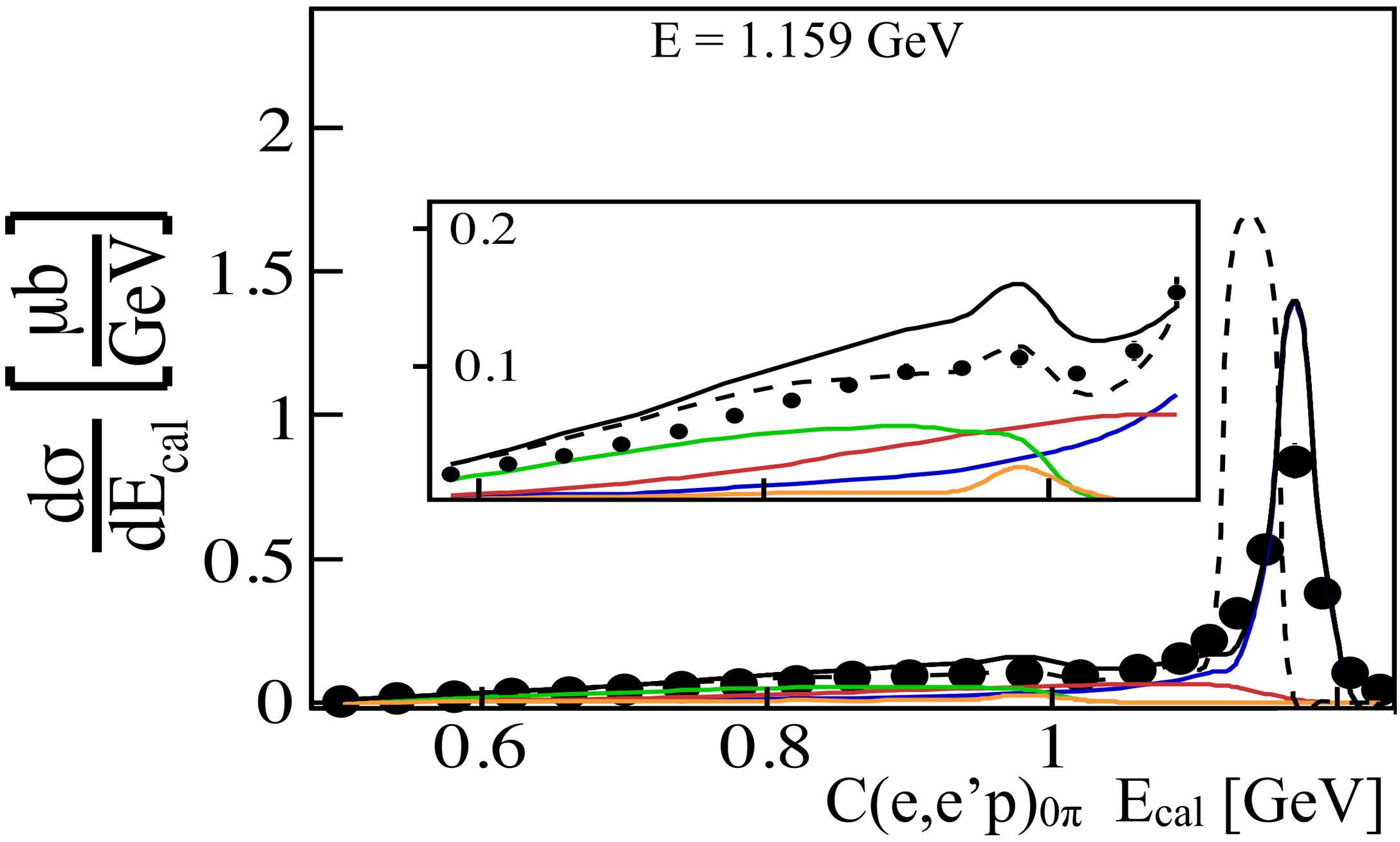
Veto events with:

- A photon close to the final state electron
- $E_e' < 0.25\ E_e$



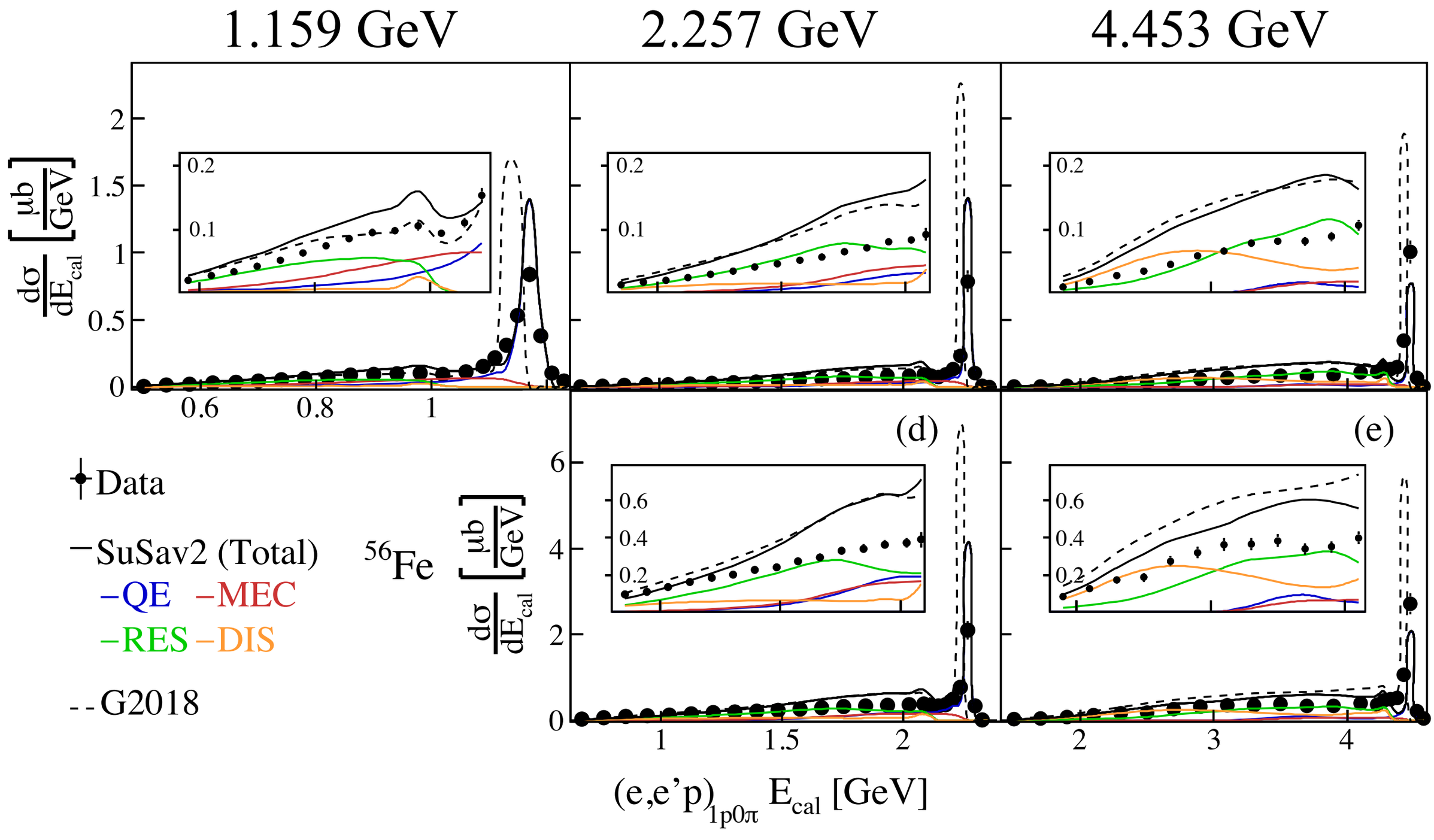
Data

Reconstructed Calorimetric Energy



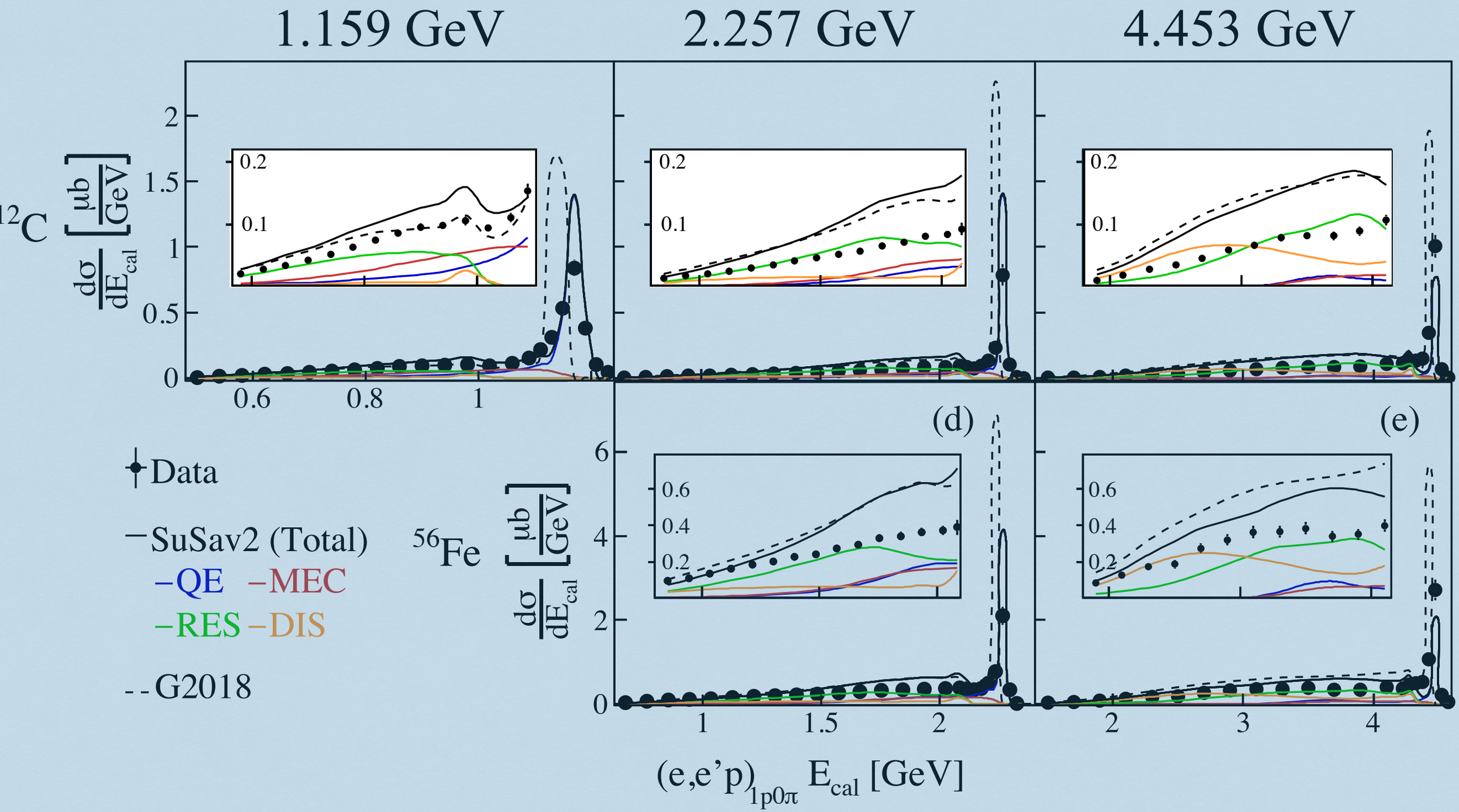
Nature **599**, 565 (2021)

Reconstructed Calorimetric Energy



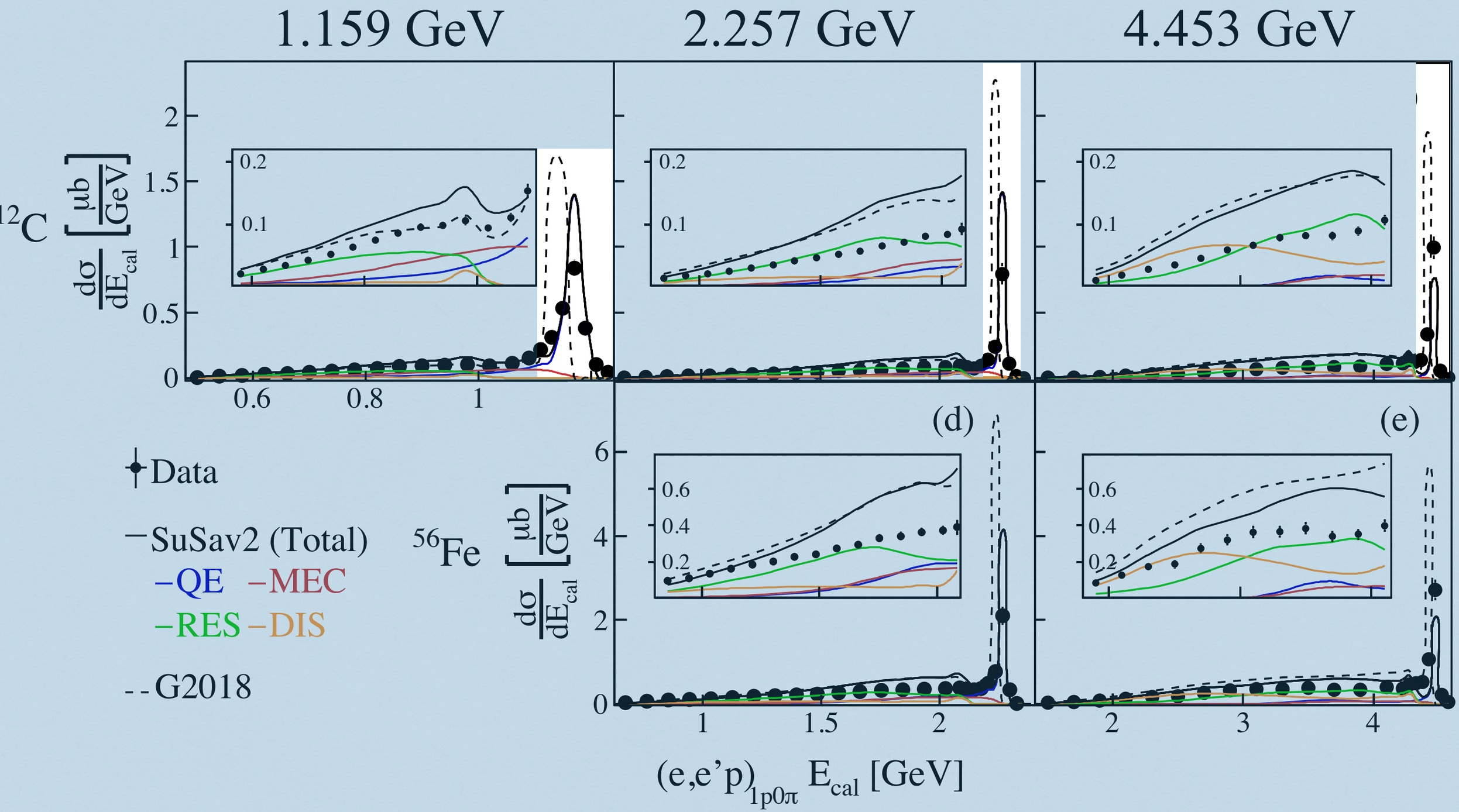
Nature **599**, 565 (2021)

Reconstructed Calorimetric Energy



Nature **599**, 565 (2021)

Reconstructed Calorimetric Energy



Nature **599**, 565 (2021)

e4ν Looking forward to new results

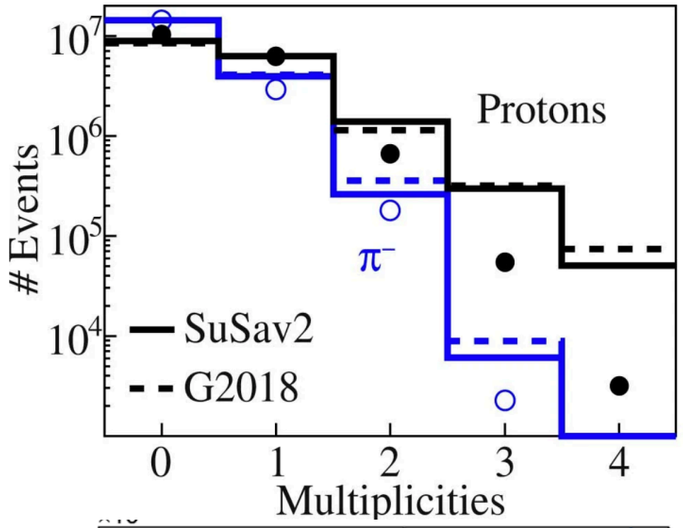
Working on:

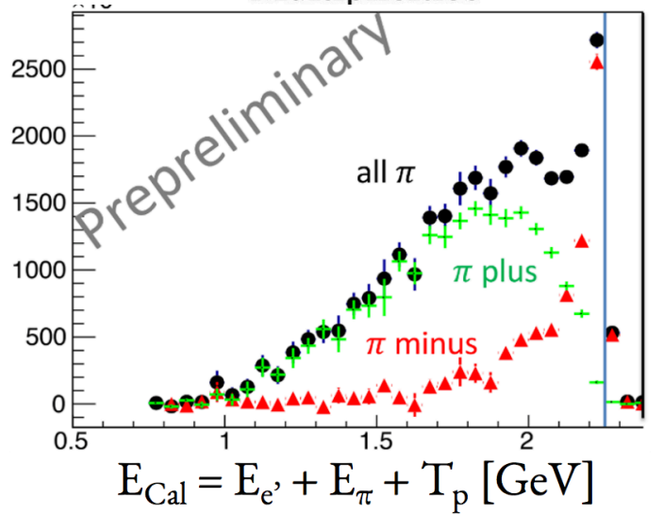
Multi differential analysis

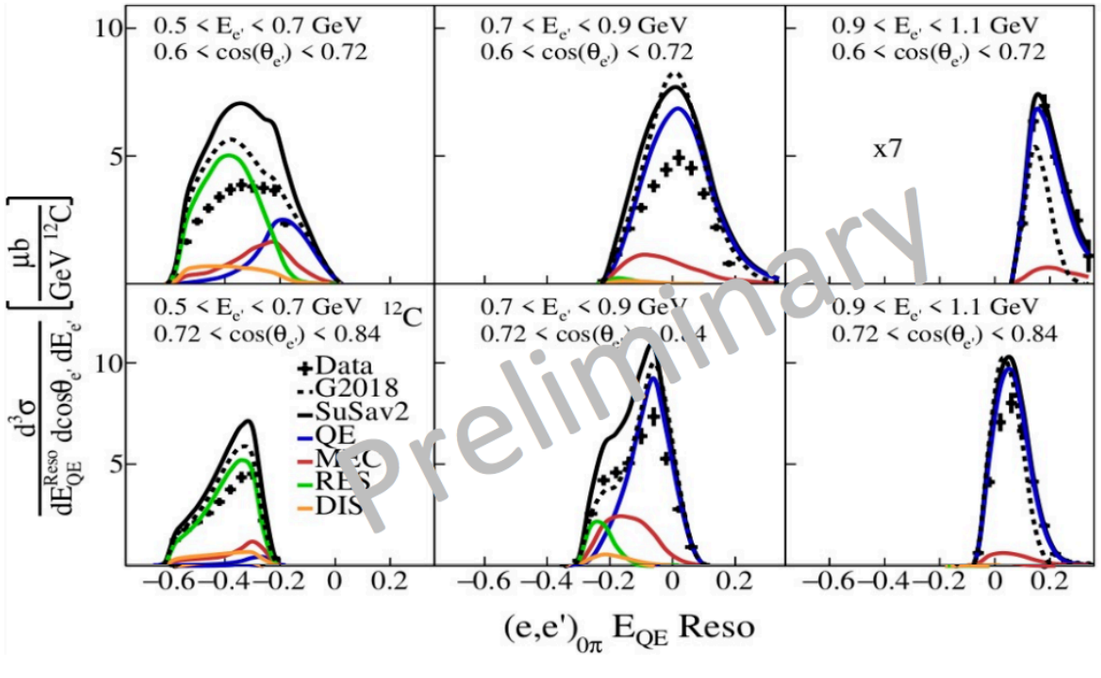
Pion production

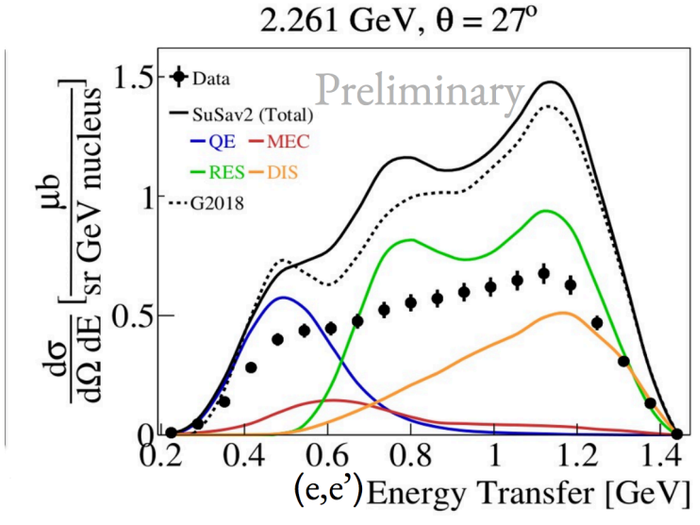
Two nucleon final state

All nuclei and energies









e4ν in need to account for radiative effects

For Exclusive non QE interaction: especially 1p1π, 2p, 1p1n

Can we implement a model?

Can we apply cuts to minimise radiative effects?

Can we assign systematic for not accounting for it?

Once implemented for the electron mode - we intend to use the same machinery for the neutrino mode as well

Thank you for your attention

CLAS6 Radiative correction to data