Liquid Argon Technology for Theorists

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Washington University, May 2019

DUNE

4 10-kton liquid argon TPC

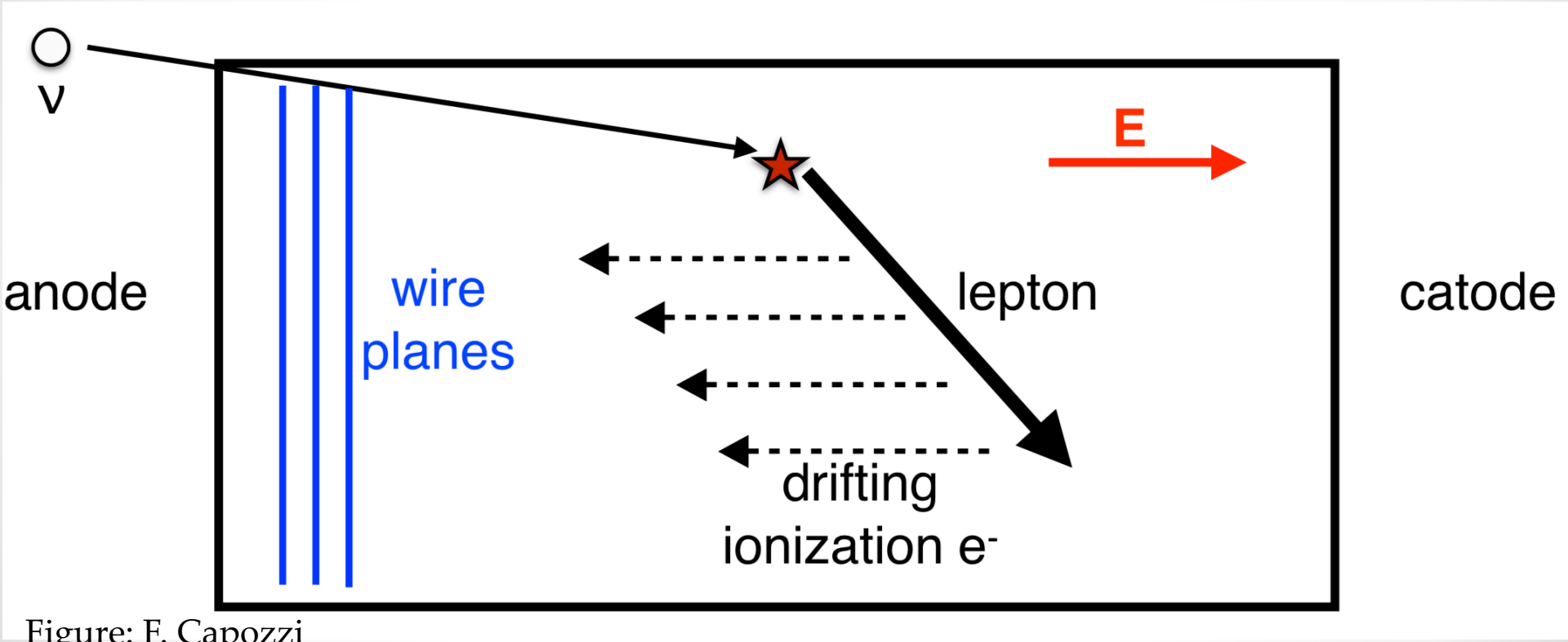


Figure: F. Capozzi
Max Planck seminar,
2017

Detects charged particles above thresholds

Official experimental setup

Physics > Instrumentation and Detectors

Experiment Simulation Configurations Used in DUNE CDR

T. Alion, J.J. Back, A. Bashyal, M. Bass, M. Bishai, D. Cherdack, M. Diwan, Z. Djurcic, J. Evans, E. Fernandez-Martinez, L. Fields, B. Fleming, R. Gran, R. Guenette, J. Hewes, M. Hogan, J. Hylen, T. Junk, S. Kohn, P. LeBrun, B. Lundberg, A. Marchionni, C. Morris, V. Papadimitriou, R. Rameika, R. Rucinski, S. Soldner-Rembold, M. Sorel, J. Urheim, B. Viren, L. Whitehead, R. Wilson, E. Worcester, G. Zeller

(Submitted on 30 Jun 2016)

The LBNF/DUNE CDR describes the proposed physics program and experimental design at the conceptual design phase. Volume 2, entitled The Physics Program for DUNE at LBNF, outlines the scientific objectives and describes the physics studies that the DUNE collaboration will perform to address these objectives. The long-baseline physics sensitivity calculations presented in the DUNE CDR rely upon simulation of the neutrino beam line, simulation of neutrino interactions in the far detector, and a parameterized

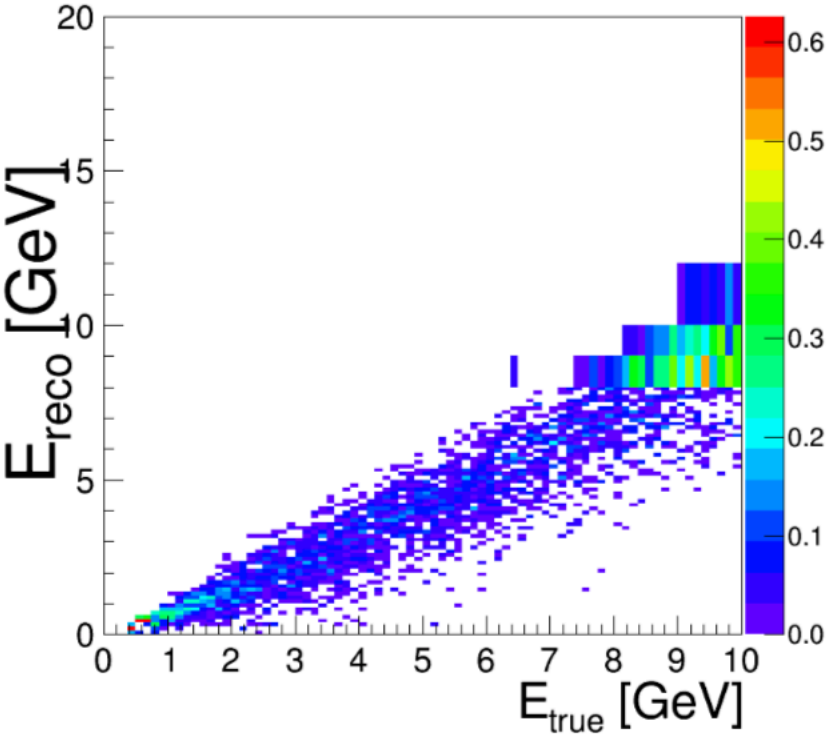
Official experimental setup

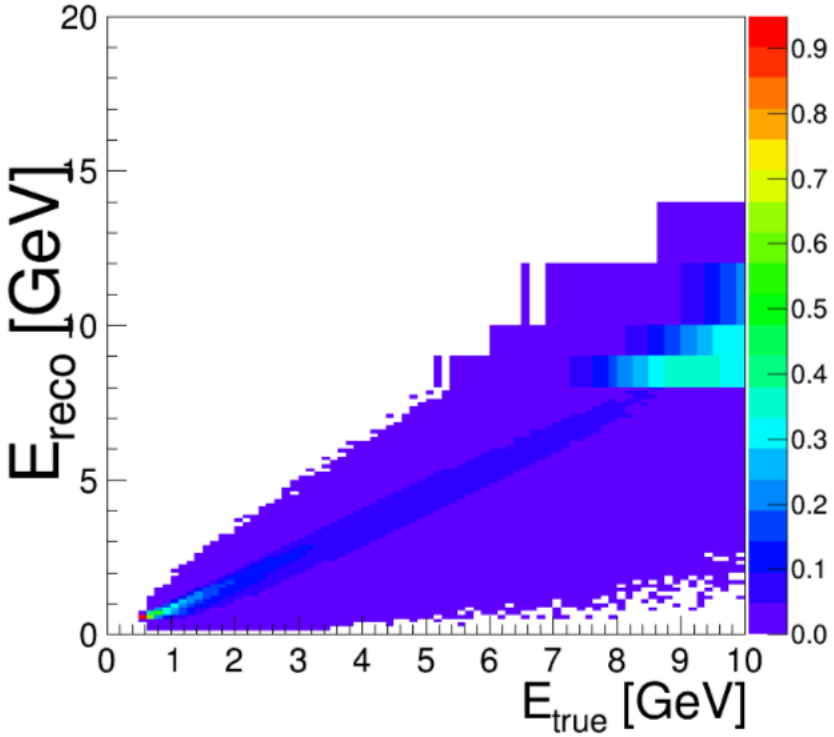
DUNE 2016

Particle type	Detection Threshold (KE)	Energy/Momentum Resolution	Angular Resolution
$\mu^{\pm}$	30 MeV	Contained track: track length Exiting track: 30%	1°
$\pi^{\pm}$	100 MeV	μ-like contained track: track length π-like contained track: 5% Showering or exiting: 30%	1°
$e^{\pm}/\gamma$	30 MeV	$2\% \oplus 15\%/\sqrt{E}$[GeV]	1°
p	50 MeV	p<400 MeV/c: 10% p>400 MeV/c: $5\% \oplus 30\%/\sqrt{E}$[GeV]	5°
n	50 MeV	$40\%/\sqrt{E}$[GeV]	5°
other	50 MeV	$5\% \oplus 30\%/\sqrt{E}$[GeV]	5°

Official experimental setup

DUNE 2016



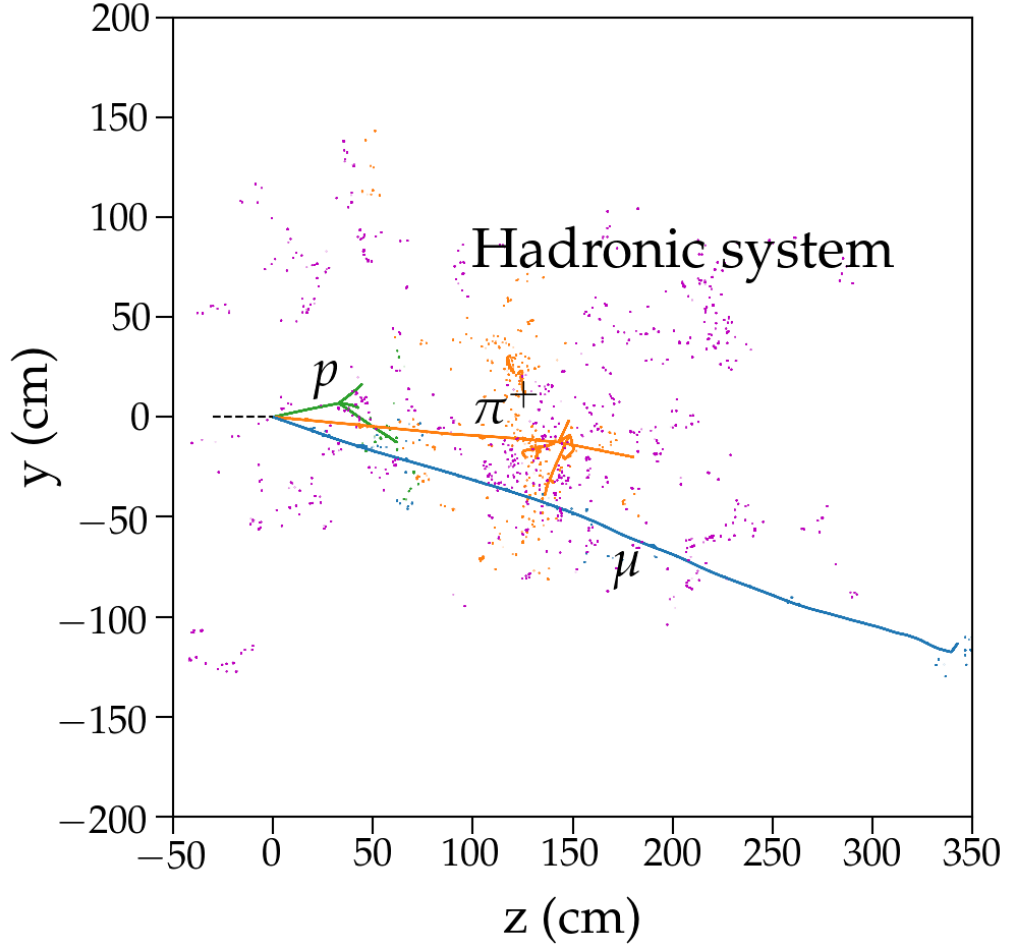



DON'T
TRUST
ANYONE

A neutrino event

Friedland & Li, 2018

Signal: $\nu_l + A \rightarrow l + X$

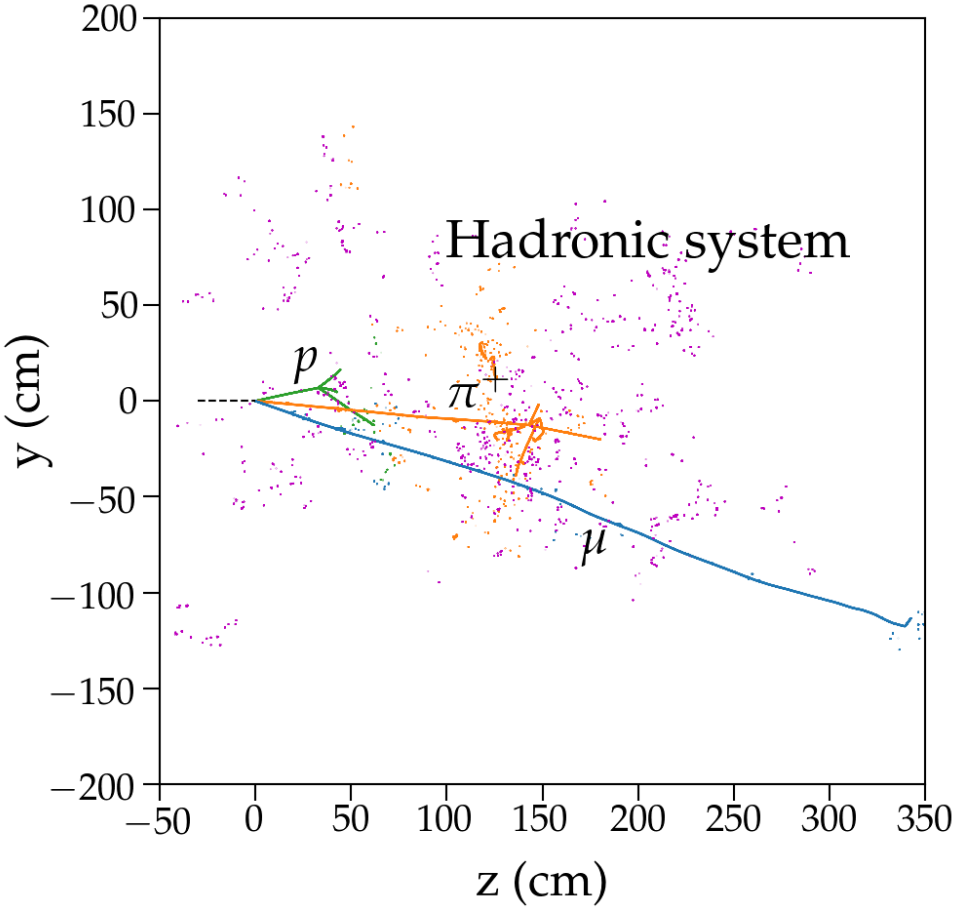


What do particles do

Ionization

Friedland & Li, 2018

dE/dx ~= 2 MeV/g cm^2

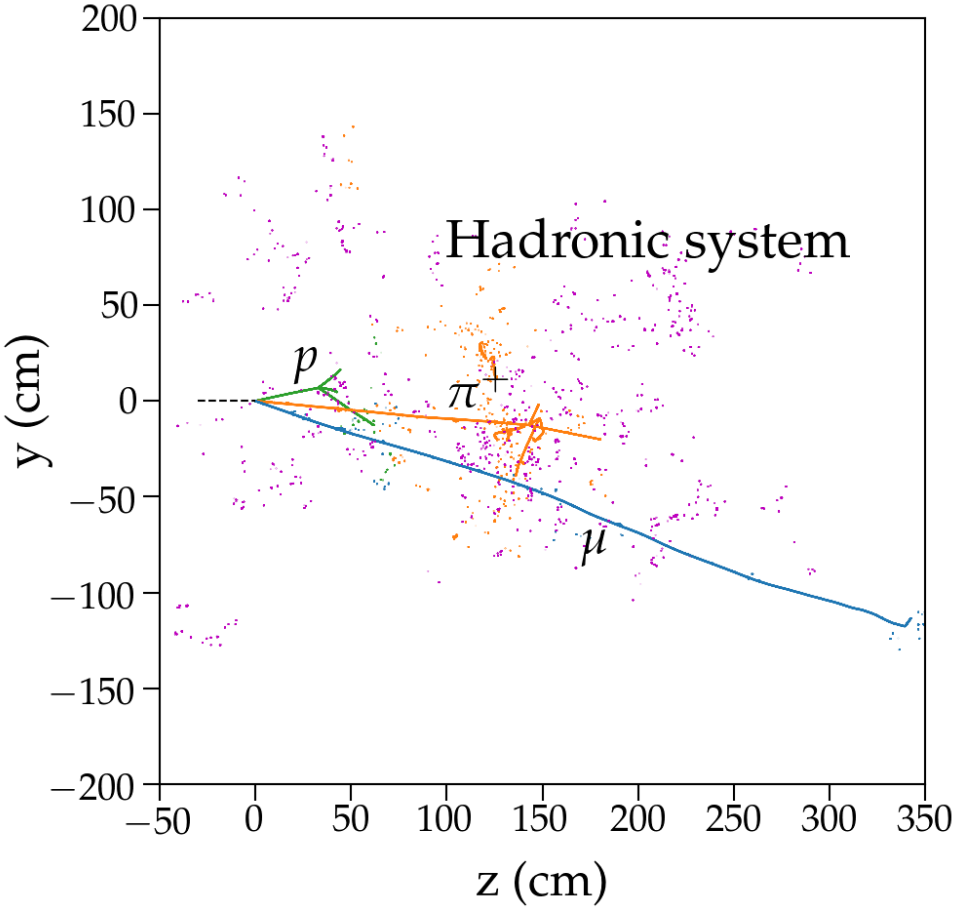


- Stable
- Energy (E) ~= Charge (Q)
- $l = \frac{E}{dE/dx}$
- Proton: large dE/dx
  - Recombination: small Q

Hadronic interaction

Friedland & Li, 2018

Interaction length ~ 1 m



- Knock out several nucleons
- 10s MeV loss to binding E
- Highly stochastic

Official experimental setup

DUNE 2016

Particle type	Detection Threshold (KE)	Energy/Momentum Resolution	Angular Resolution
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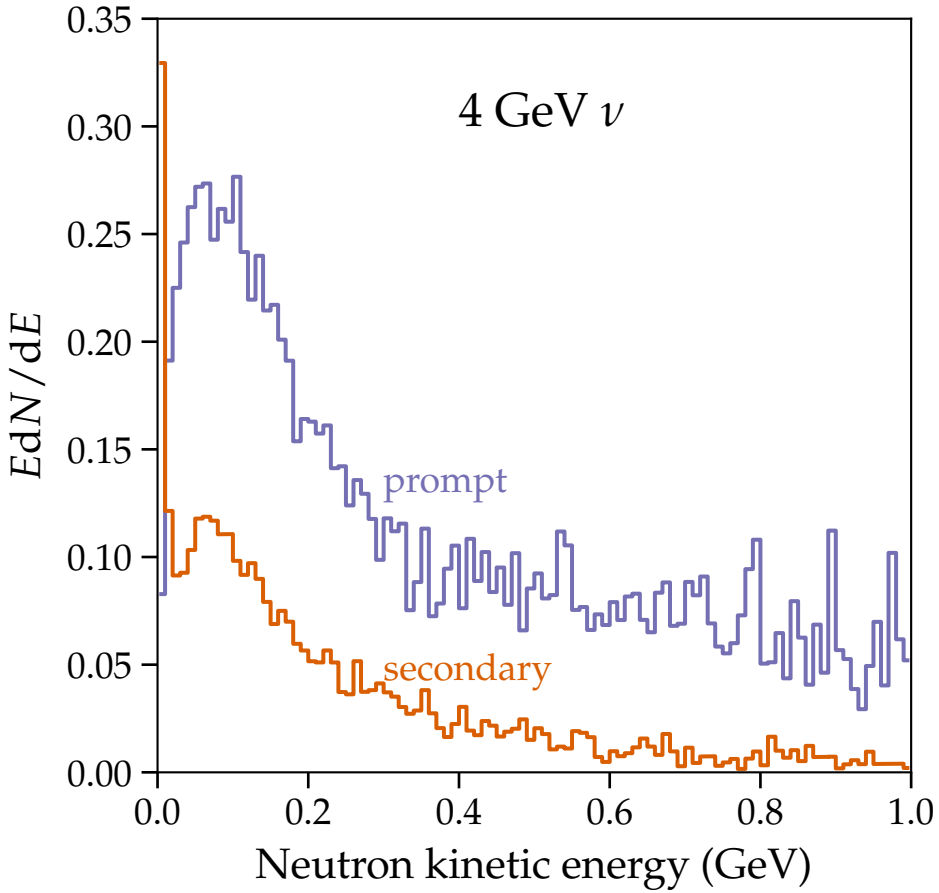
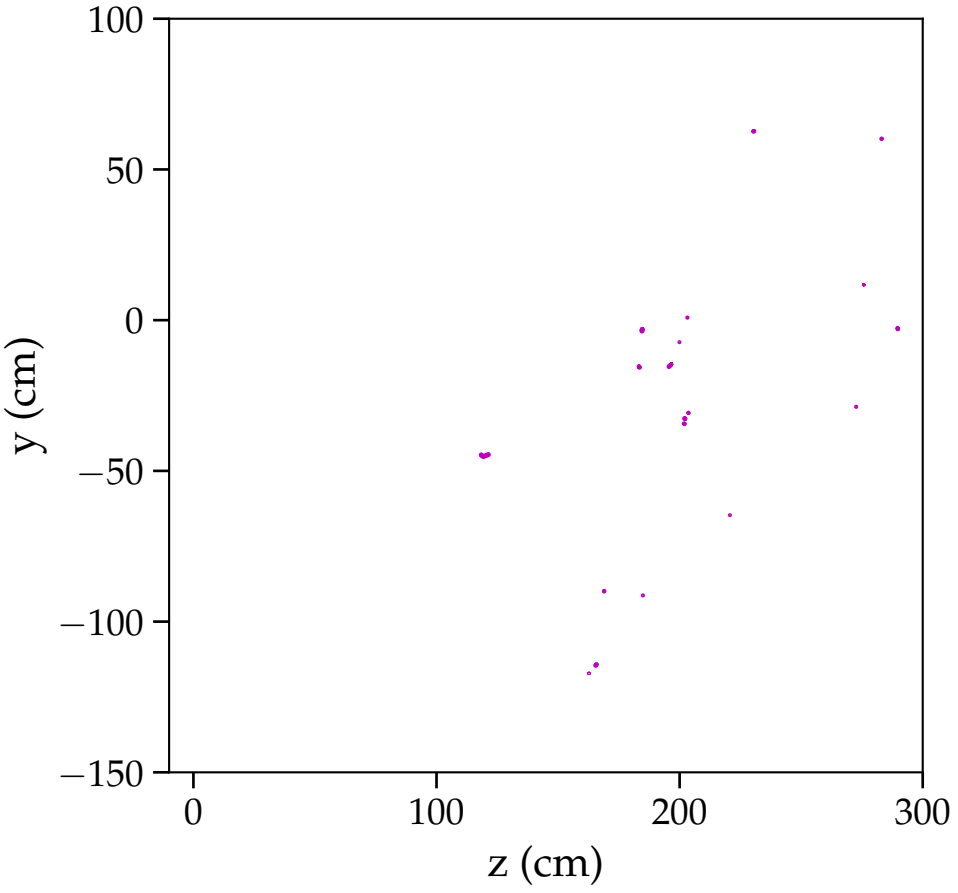
Neutrons

Friedland & Li, 2018

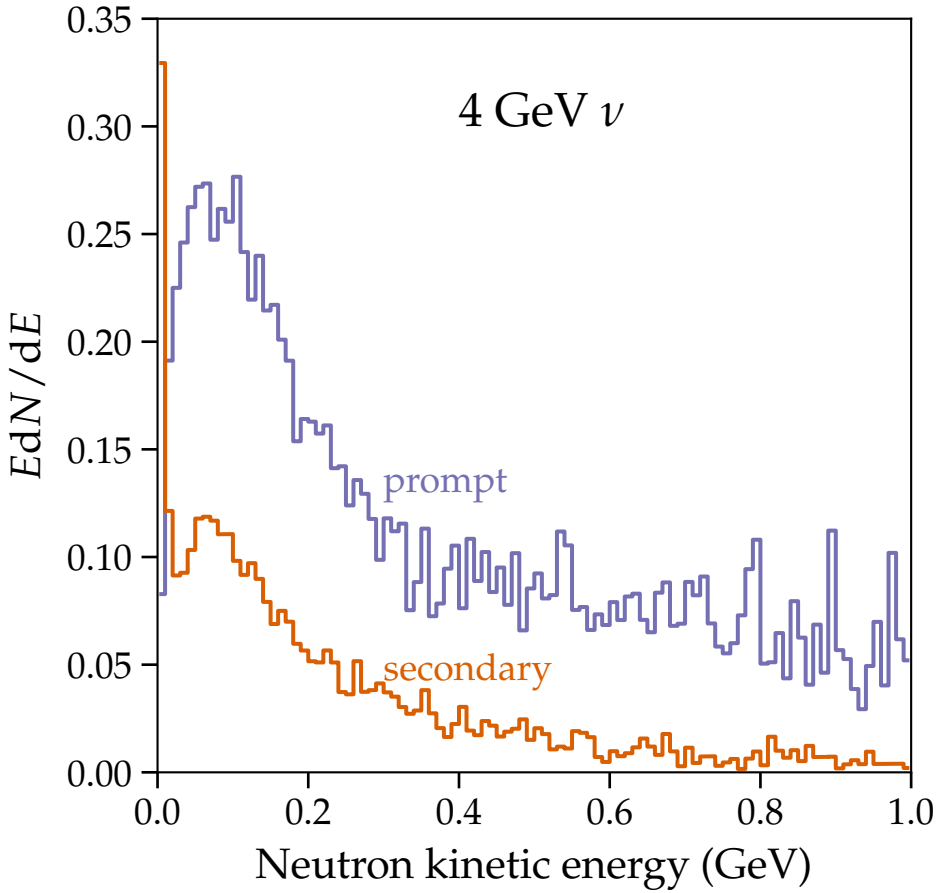


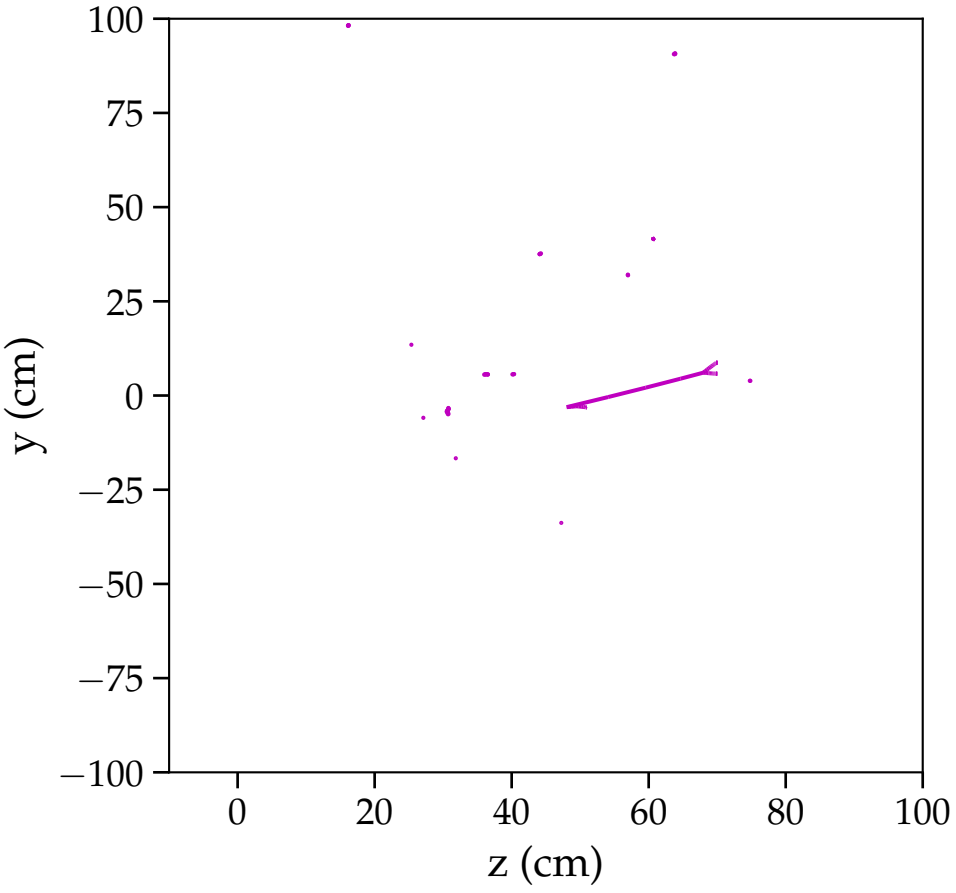


Extremely challenging to reconstruct neutrons

Neutrons

Friedland & Li, 2018





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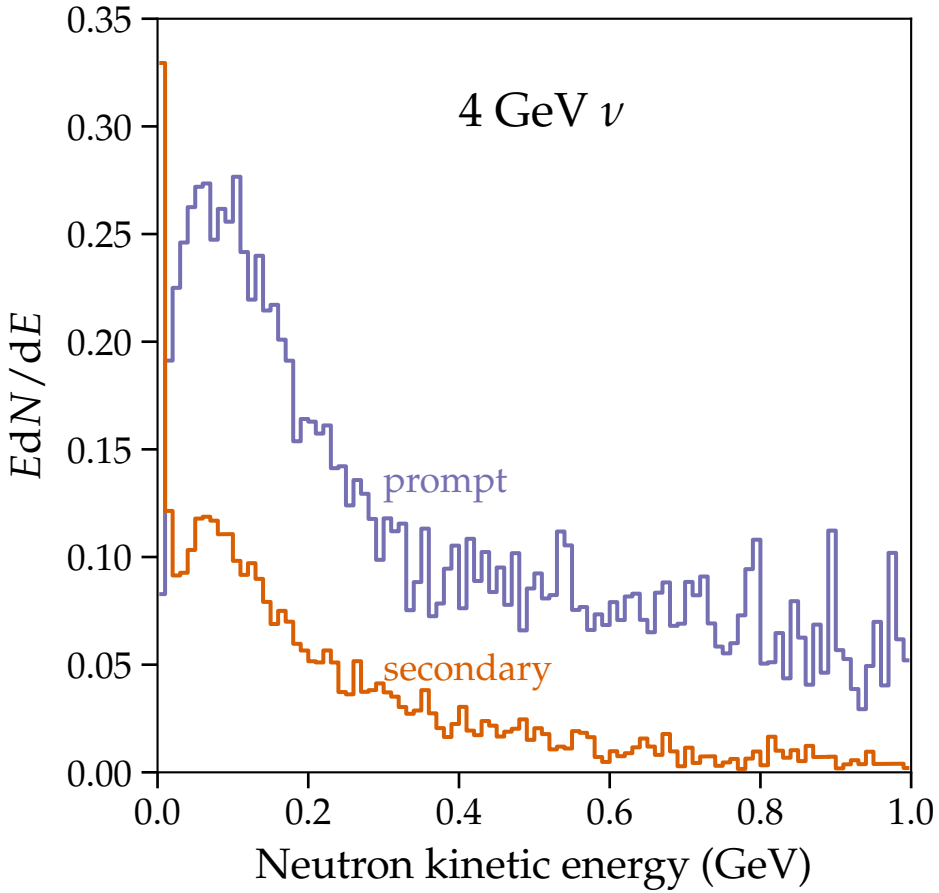
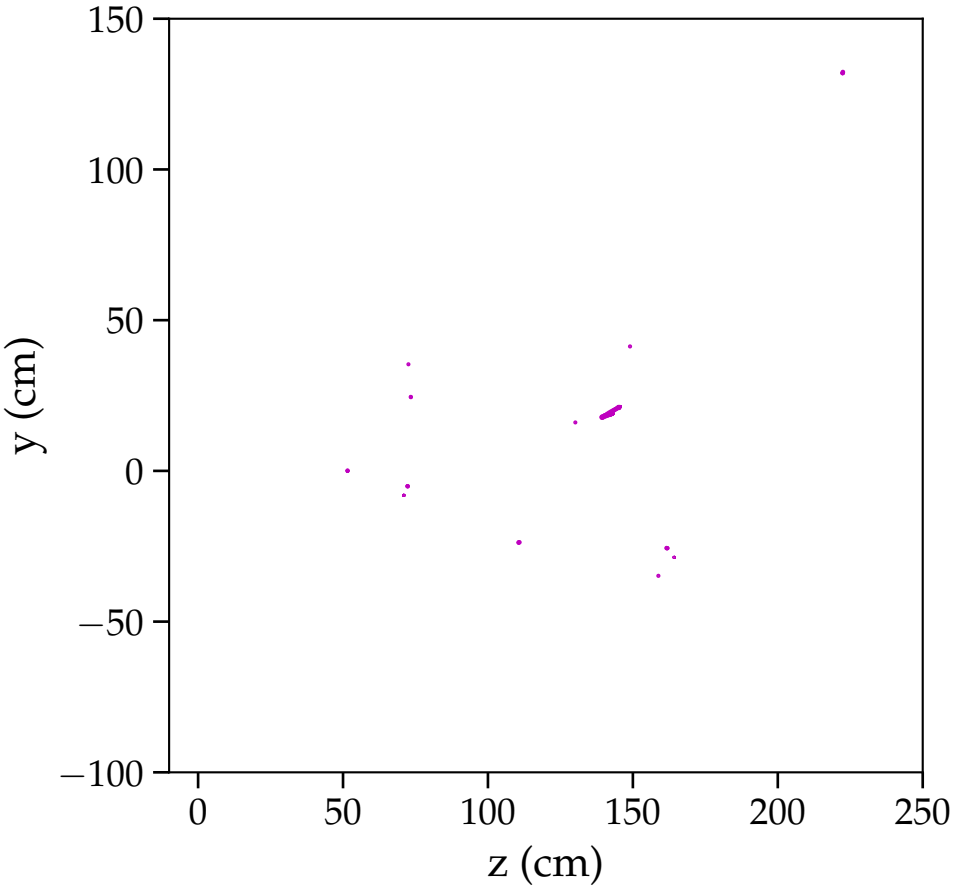
Neutrons

Friedland & Li, 2018





Extremely challenging to reconstruct neutrons

Experimental inputs

Thresholds

DUNE CDR 2

Particle type	Detection Threshold (KE)
$\mu^{\pm}$	30 MeV
$\pi^{\pm}$	100 MeV
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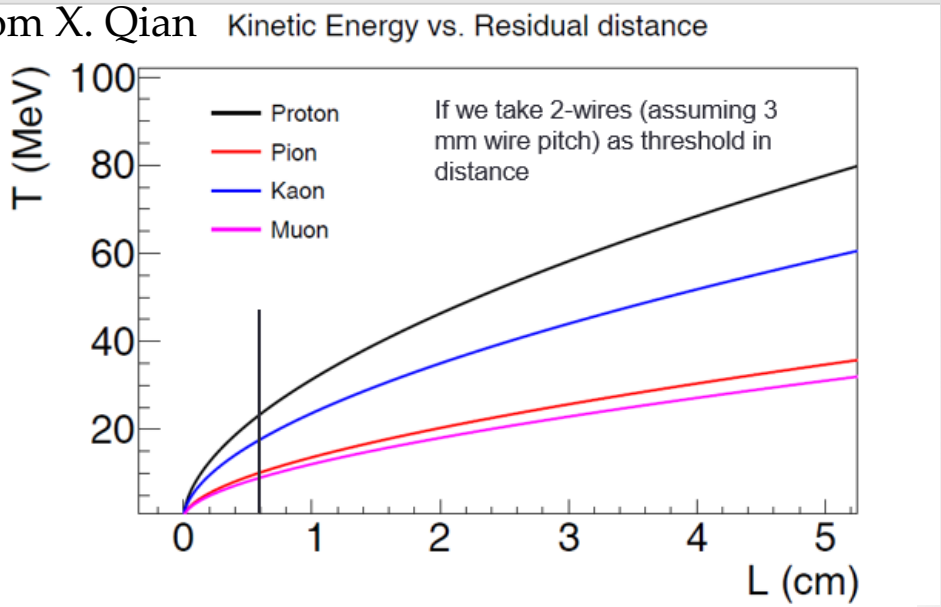
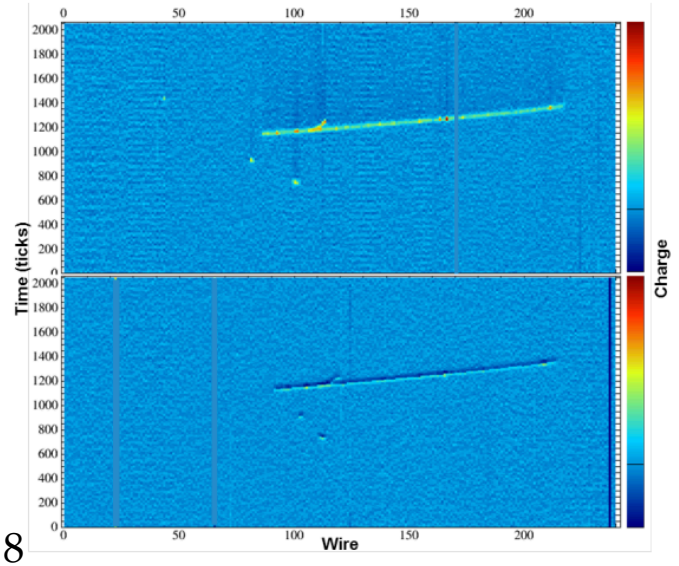
p	50 MeV
n	50 MeV
other	50 MeV

Figure from X. Qian



ArgoNeuT detect E <= 1 MeV



ArgoNeuT 2018

Experimental performance

Calorimetric energy reconstruction

Signal: $\nu_l + A \rightarrow l + X$

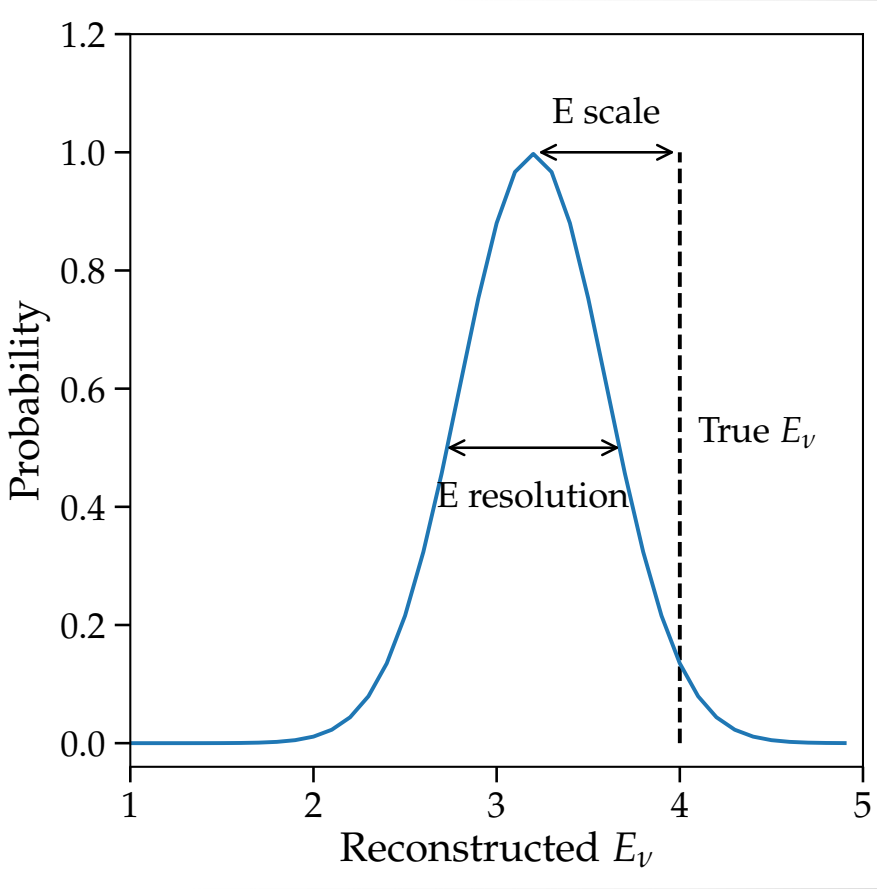
1. Separate an event into l and hadronic system
2. E_l : total collected charge -> energy
3. E_h: total collected charge -> energy
4. $E_\nu = E_l + E_h$ or $E_\nu = f(E_l, E_h)$

Calorimetric energy reconstruction

Signal: $\nu_l + A \rightarrow l + X$

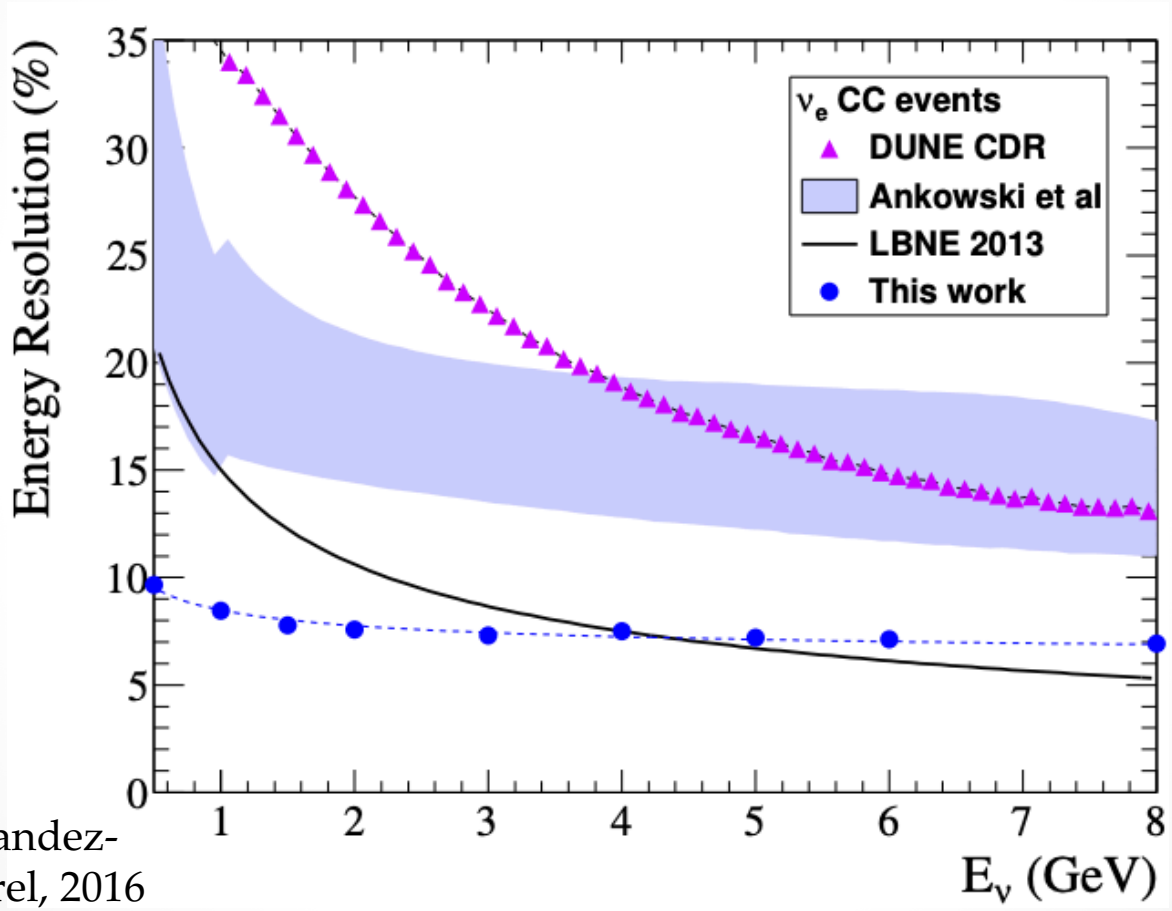
1. Should work perfectly
   if $E_l \rightarrow \frac{dE}{dx} \rightarrow Q$

2. Problem arises
   if $E_h \rightarrow \begin{cases} dE/dx \\ \text{Missing energy} \end{cases}$



No consensus in the field

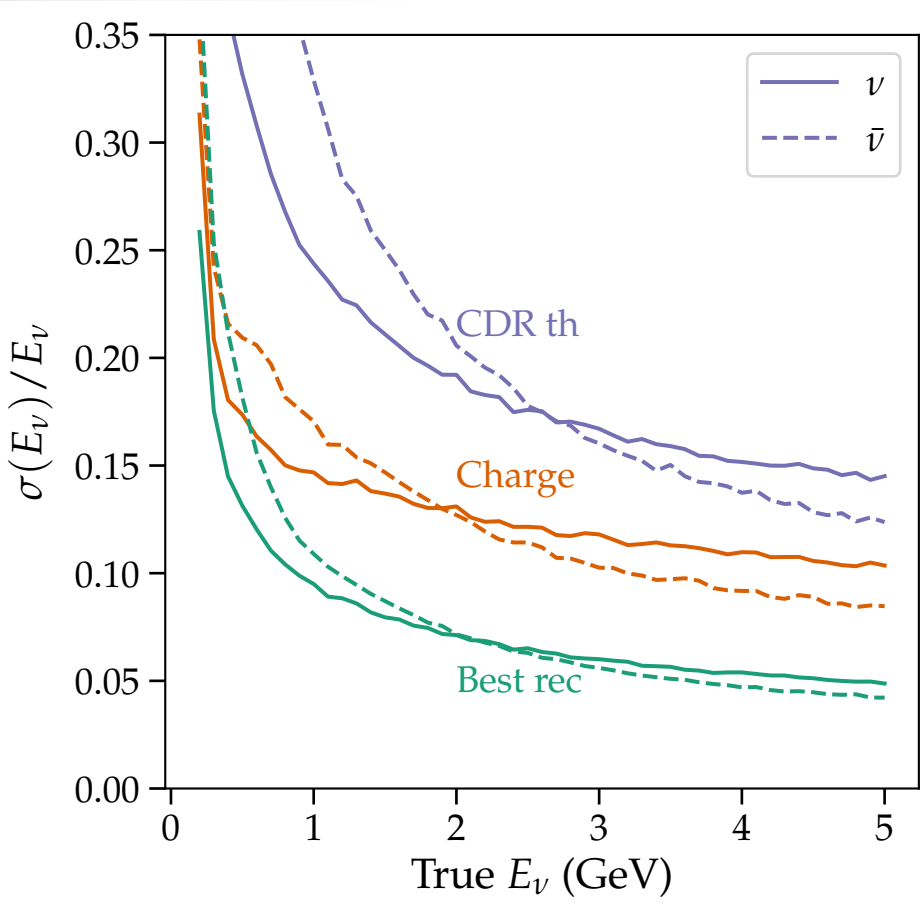
Energy resolution from prior work



Romeri, Fernandez-Martinez & Sorel, 2016

Energy reconstruction results

Friedland & Li, 2018

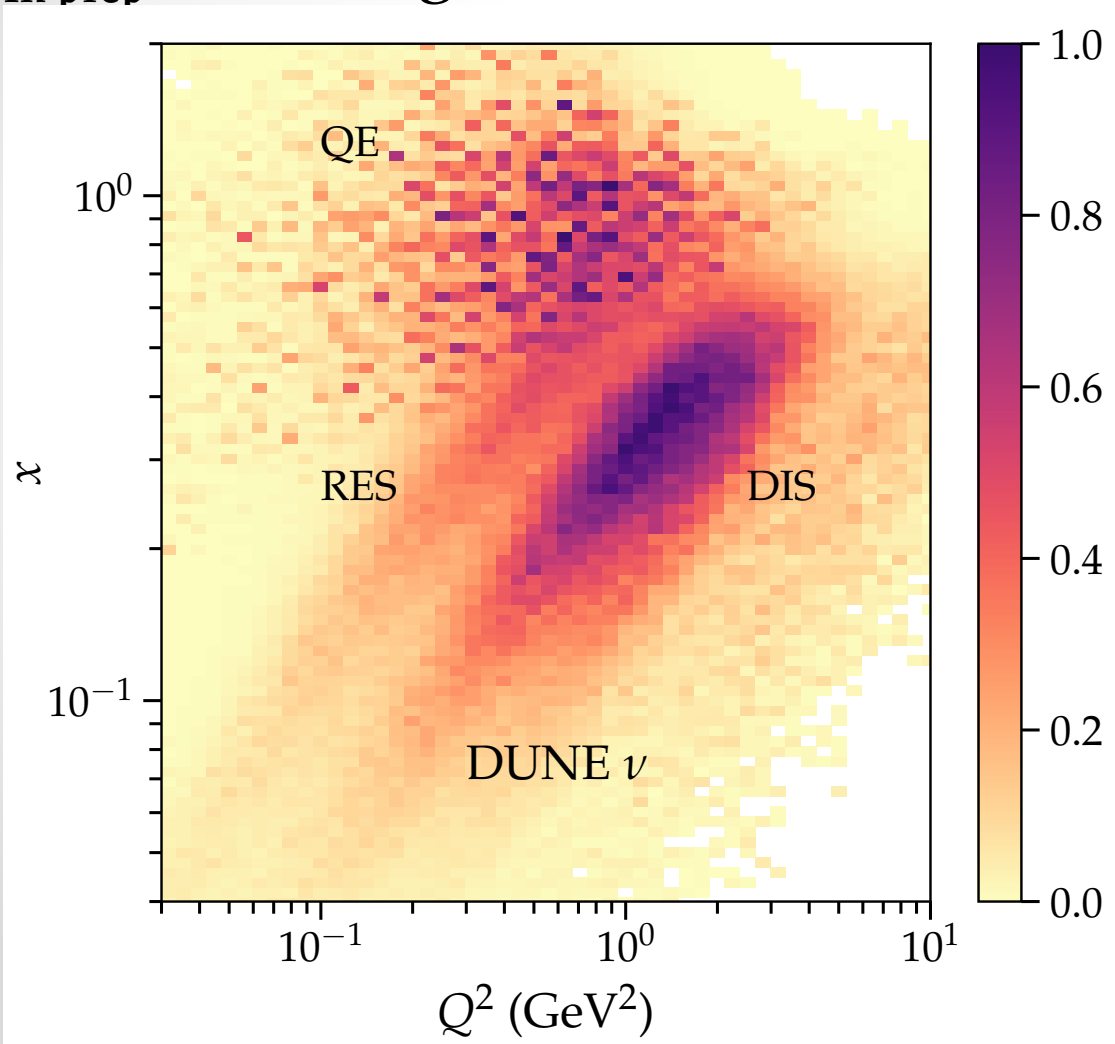


1. CDR th: method as it is
2. Charge: collect all charges with no thresh.
3. Best recon: no thresh., PID to correct for recombination

Cross section

Neutrino-nucleus interaction

Event generators: GENIE, GiBUU, NuWro, …

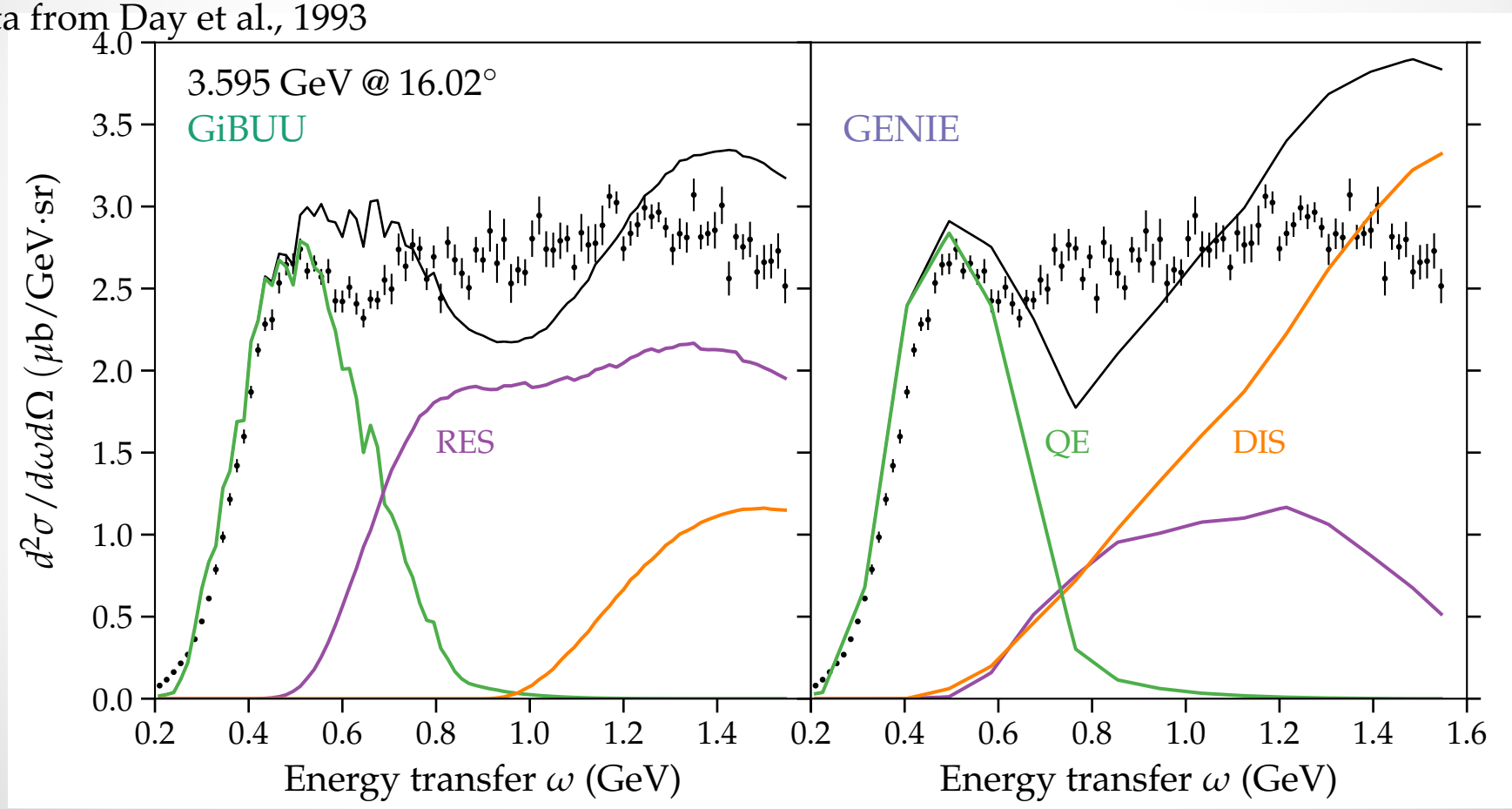


- QE: $\nu + n \rightarrow \mu + p$
- RES: $\nu + n \rightarrow u + \Delta \rightarrow$
- DIS: $\nu + d \rightarrow \mu + u \rightarrow$

Status of cross section prediction

Electron scattering: generator vs. data

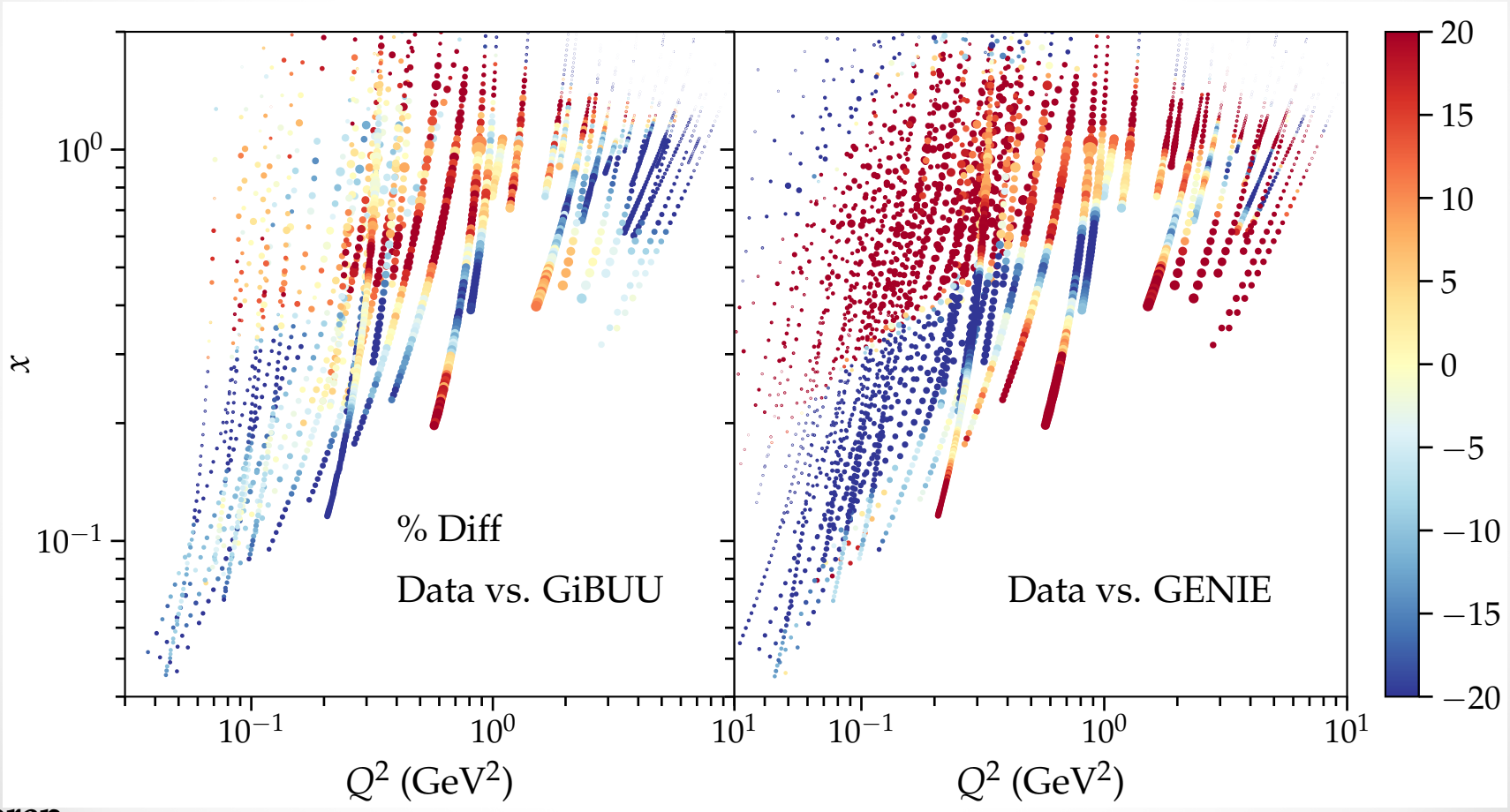
Data from Day et al., 1993



In prep

Status of cross section prediction

Electron scattering: generator vs. data

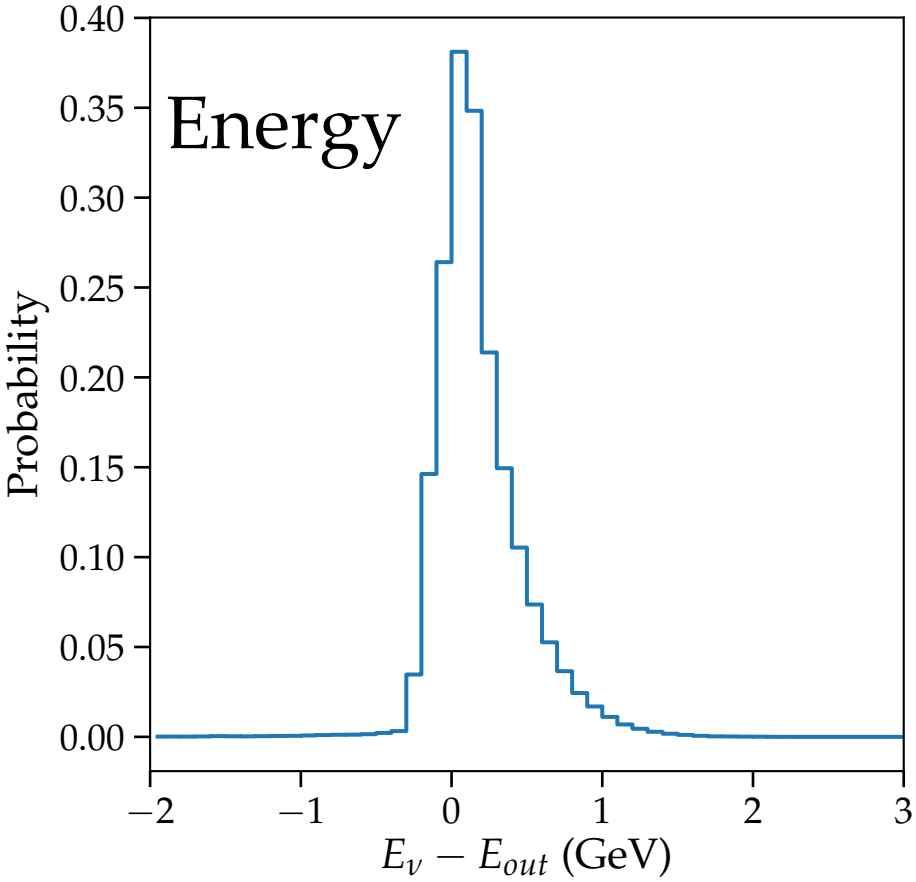


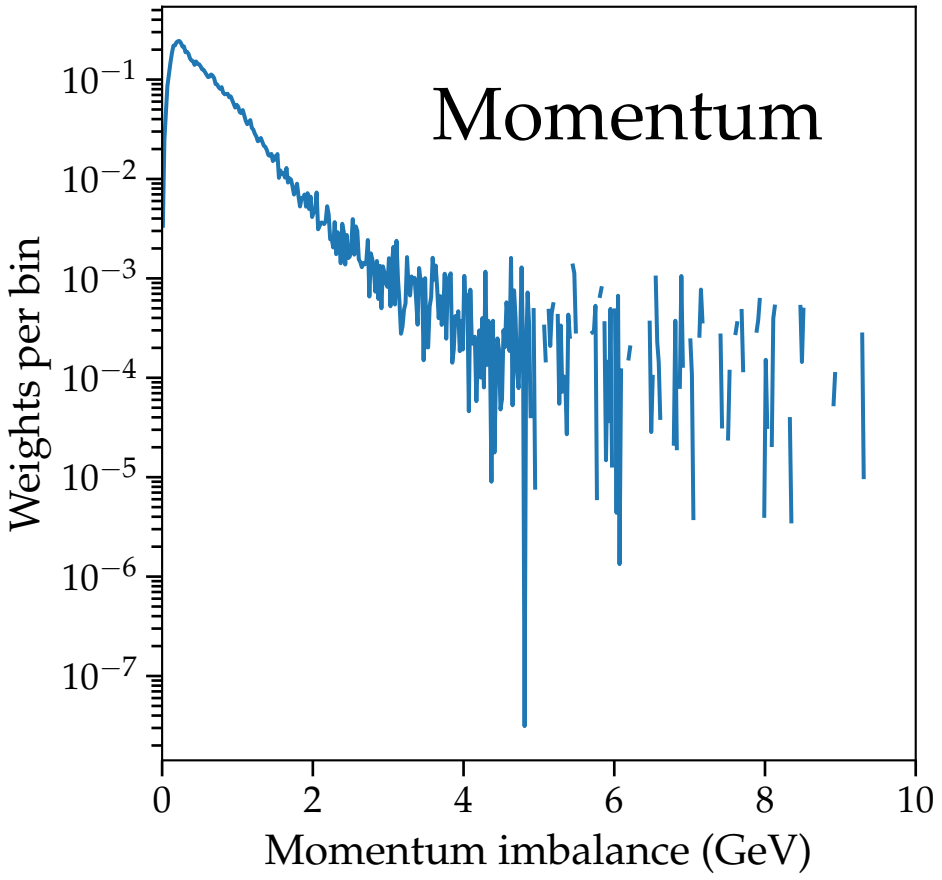
In prep

Conservation?

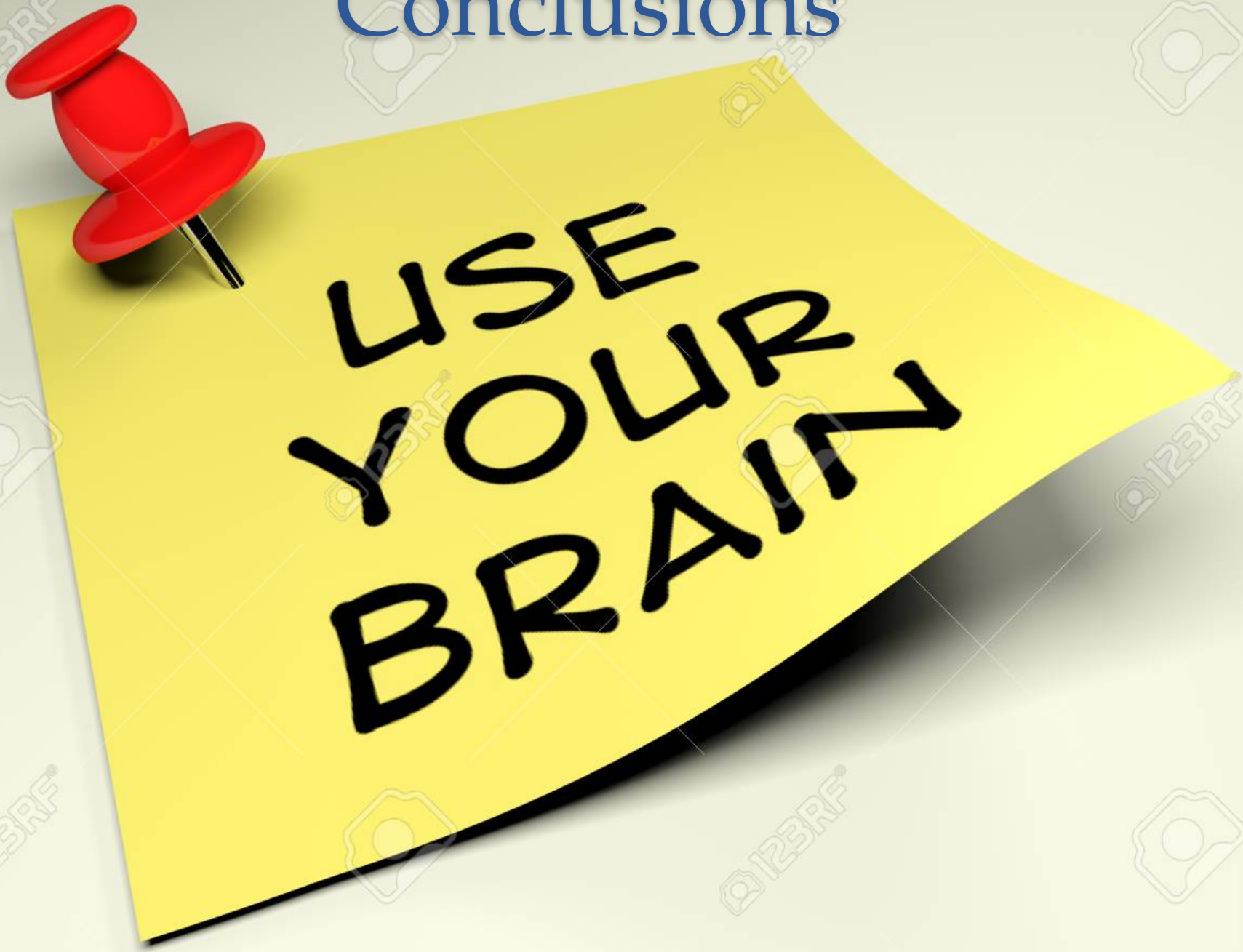
Four-momentum not conserved

In prep





Conclusions



Mailing list??

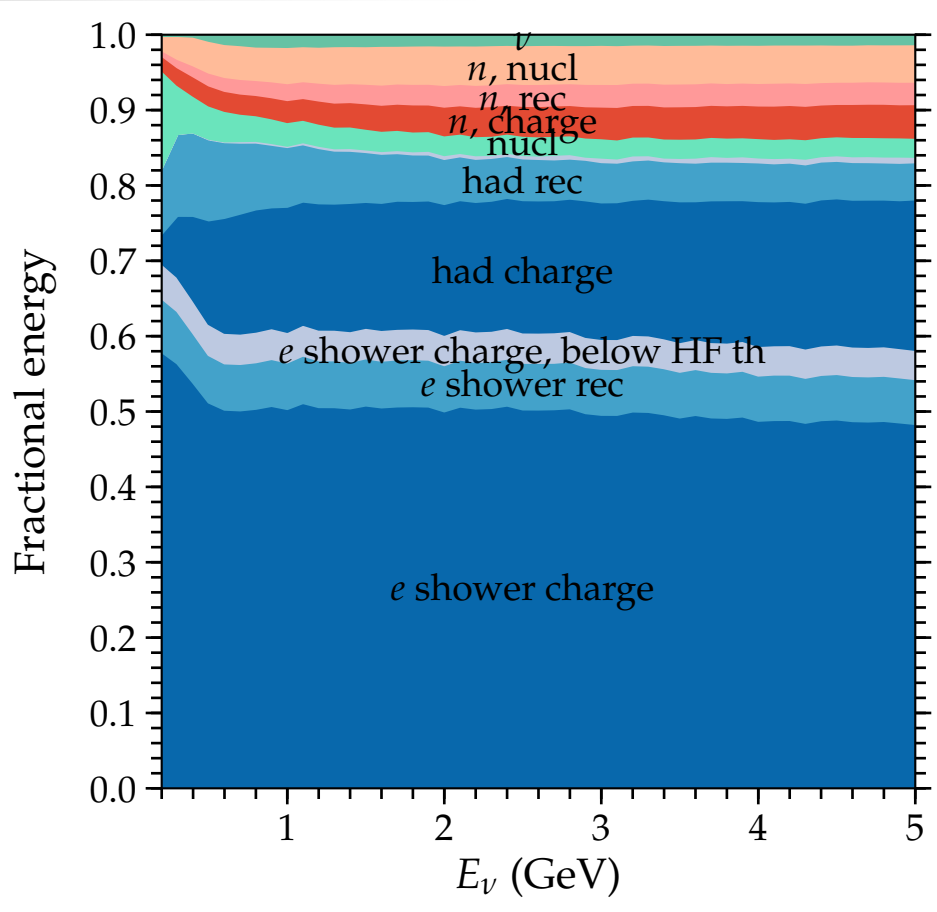
GENIE, GiBUU, NuWro

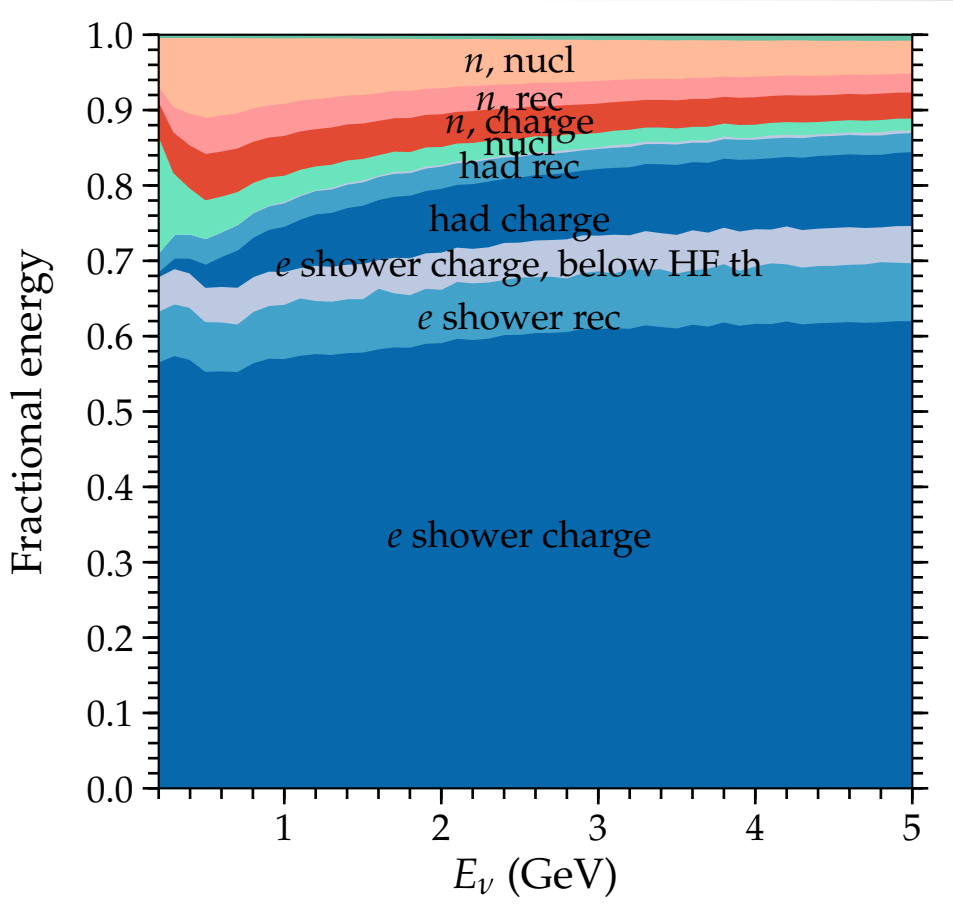
FLUKA, GEANT4

~~LArSoft~~

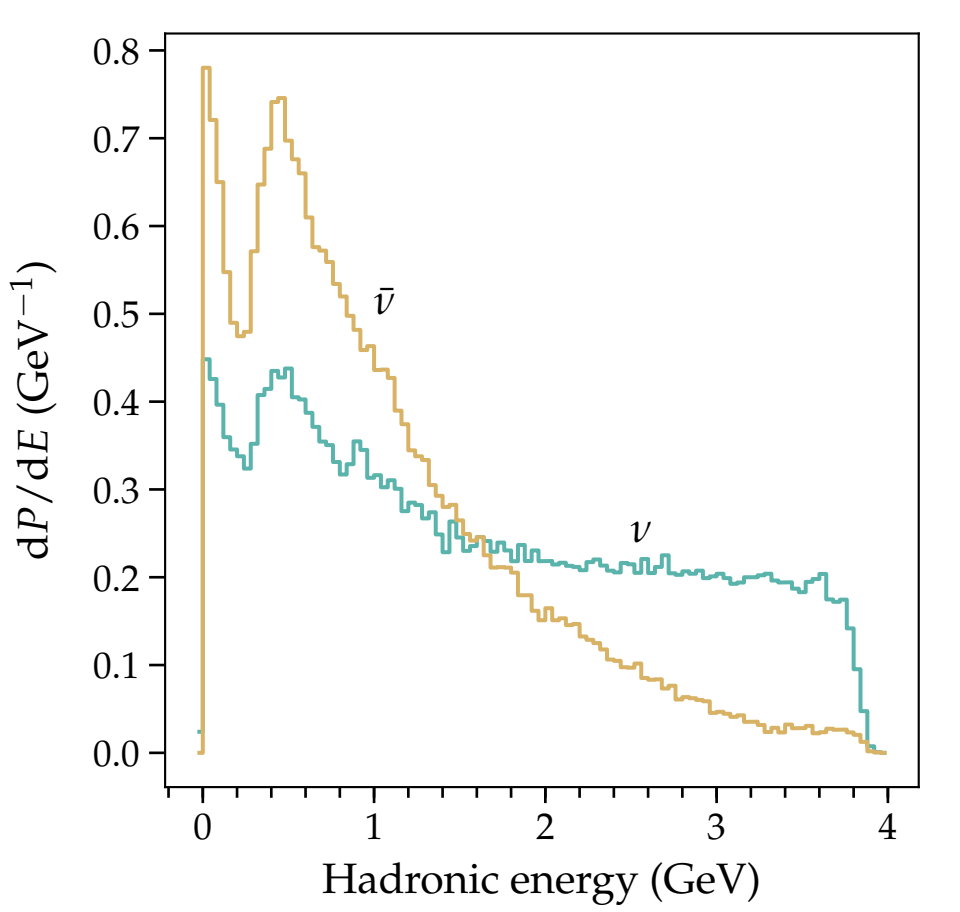
Backup

Missing energy





Hadronic energy



Hadronic interaction