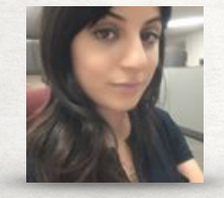
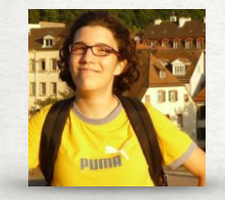
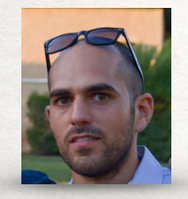
QE interactions induced by e-s and ν-s



Mariana Khachatryan, Old Dominion Univ.



Afroditi Papadopoulou, Adi Ashkenazi, MIT



Erez O. Cohen, Tel Aviv Univ.

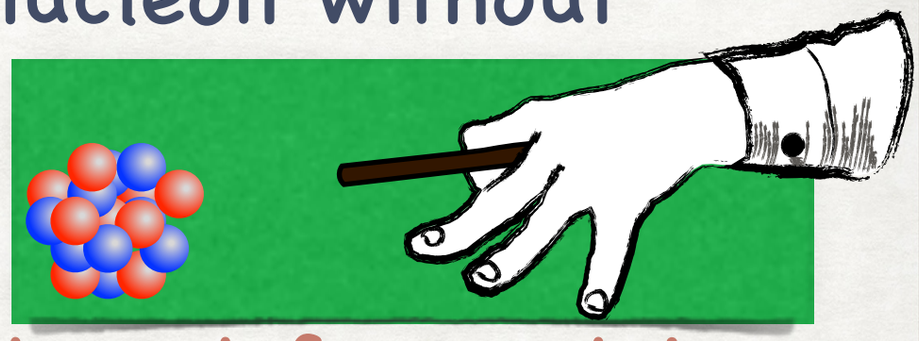
Eli Piasetkzy, Larry Weinstein, Or Hen,
Kendall Mahn, Steven Dytman,
Minerba Betancourt

11th International Workshop
on ν-Nucleus Scattering,
29 June 2017

NuINT 2017
June 23-29, 2017
Toronto, Canada

Introduction

- Quasi-Elastic (QE): knockout of a nucleon without breaking / exciting it.



- An important process in energies relevant for neutrino oscillations (E_ν=0.3-3 GeV).

- Dominates e-scattering in the same energy range.

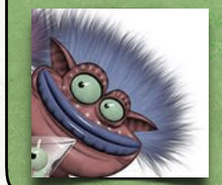
- This talk

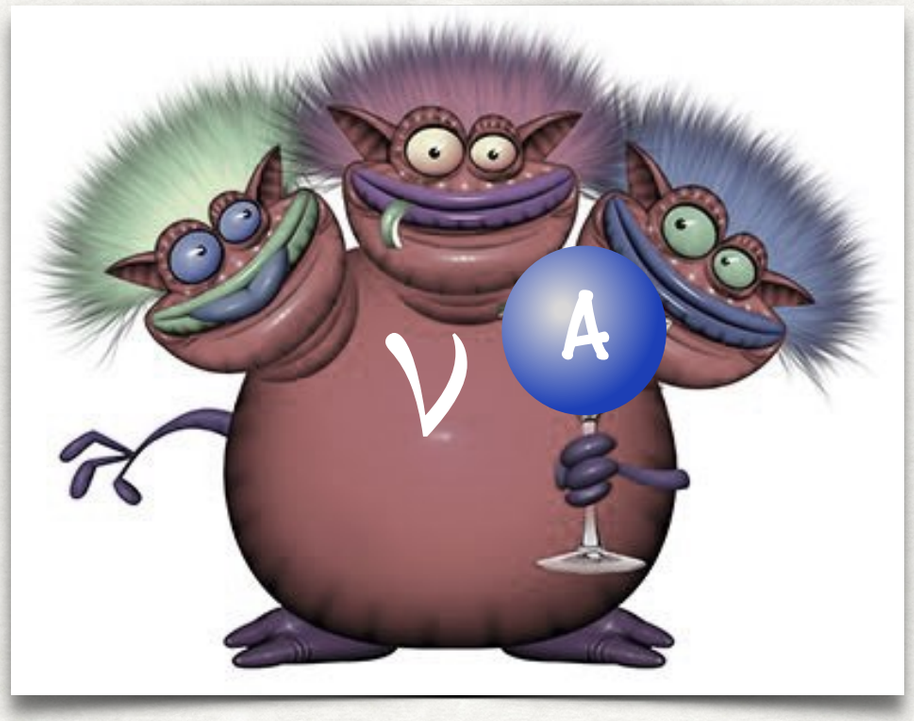
  1. Identify ν- and e- induced QE events.
  2. Reconstruct the incident beam energy.

We try to develop a global view of QE interactions

e-scattering

ν-scattering





Simulation

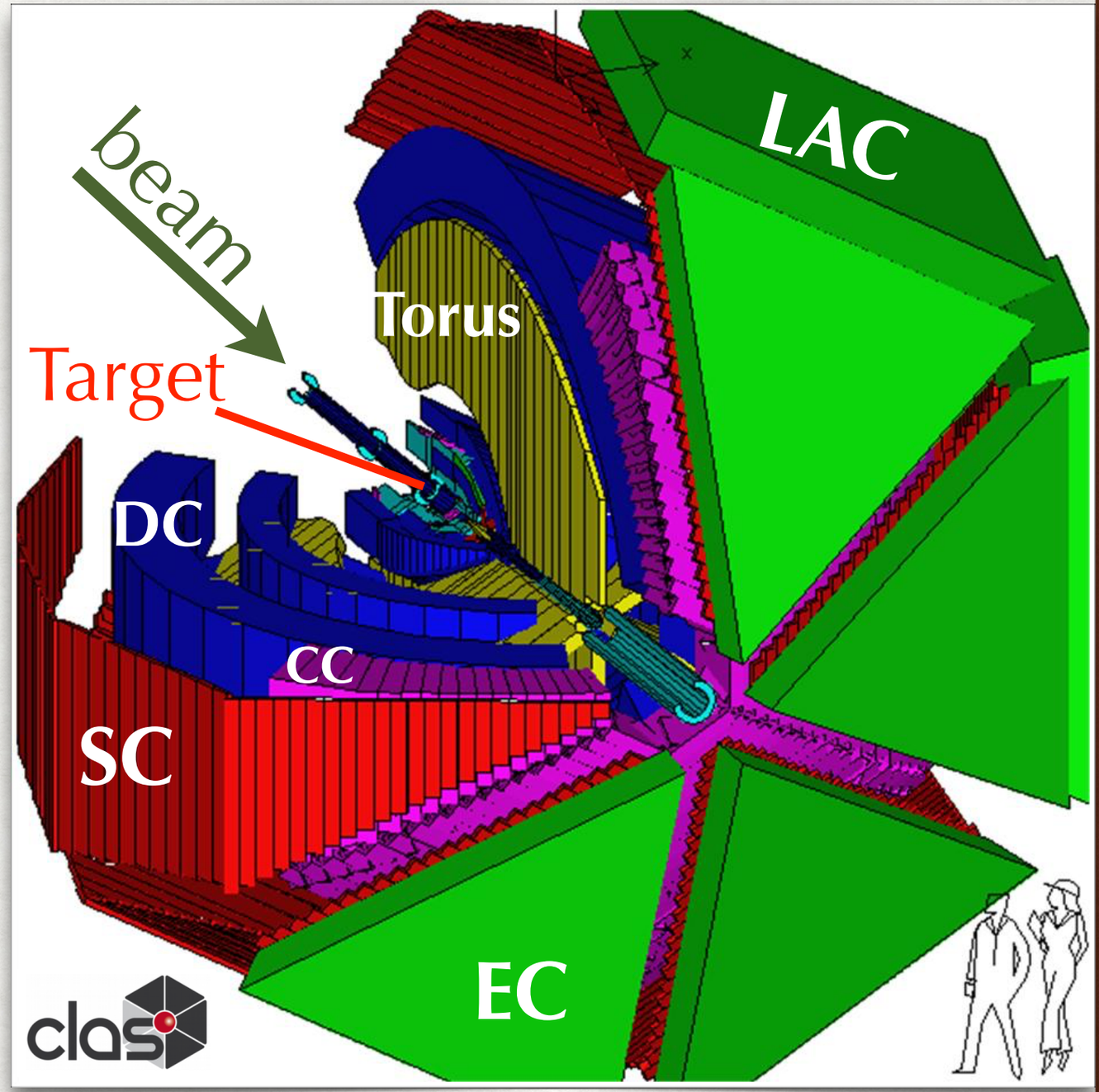
(GENIE)

electron scattering

Mariana Khachatryan

CLAS @ Jefferson Lab

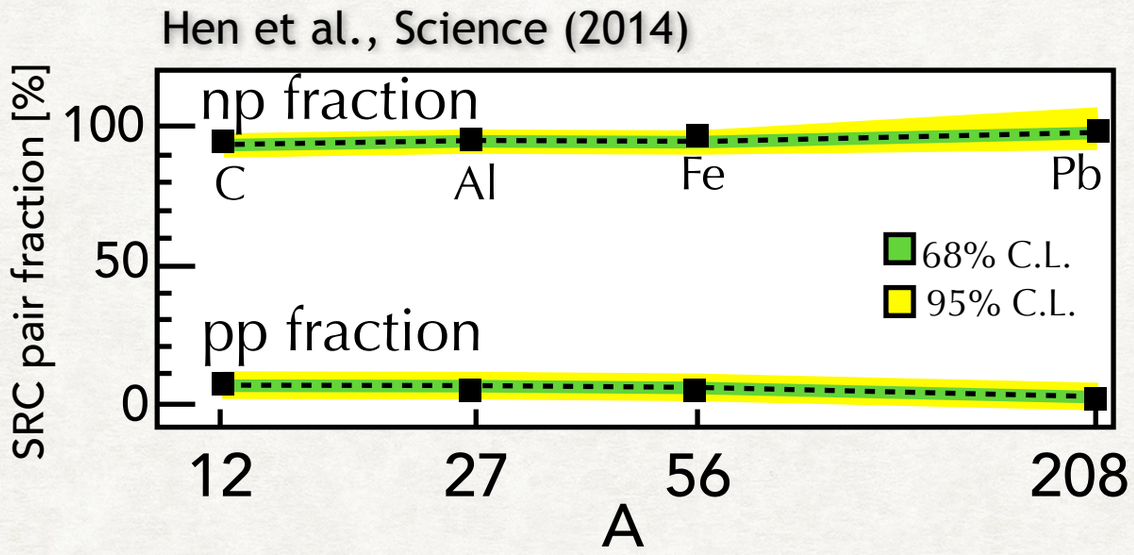
- 1 - 5 GeV electron beam.
- (almost) 4π acceptance.
- Toroidal field + tracking, TOF, Cerenkov, and EM Calorimeter
  charged particles 8-143°
- Low threshold (~300 MeV/c).
- EM Calorimeter (8-75°) and TOF (8-143°)
  Neutral particles.
- Open trigger.

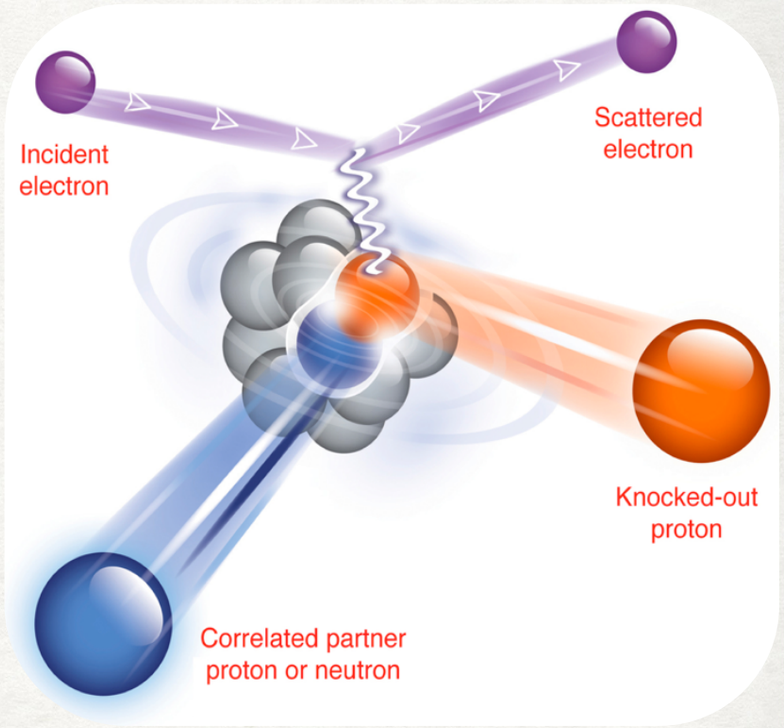


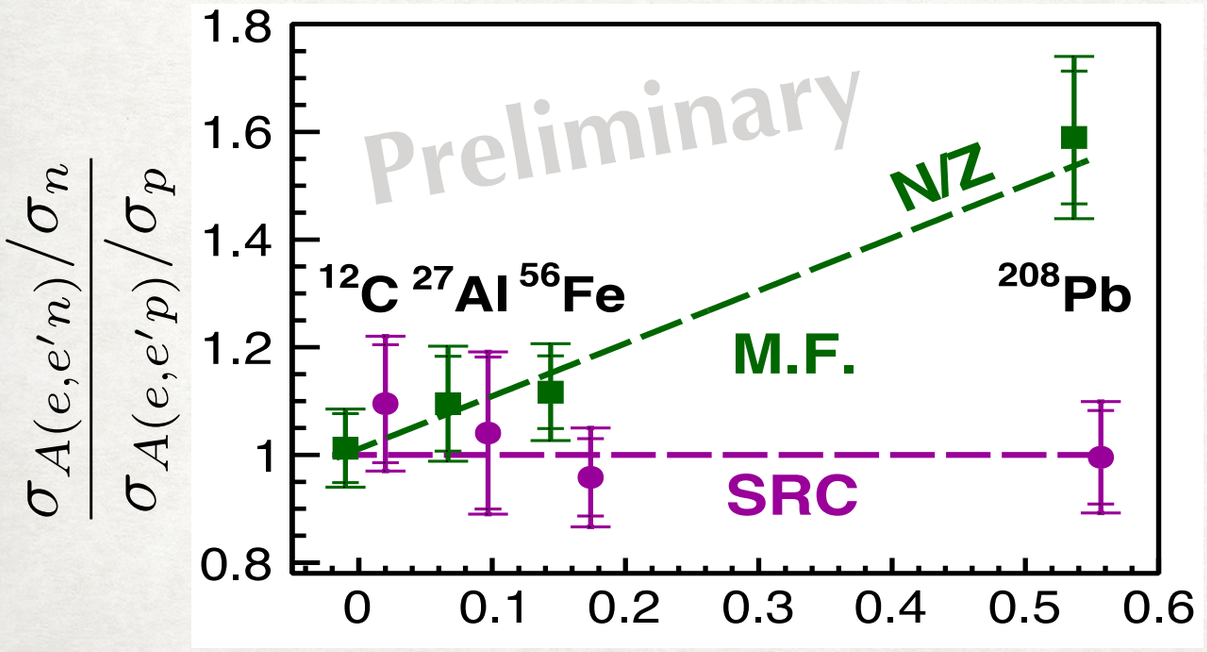
e-scattering data / σ_{Mott} = 'neutrino like' data

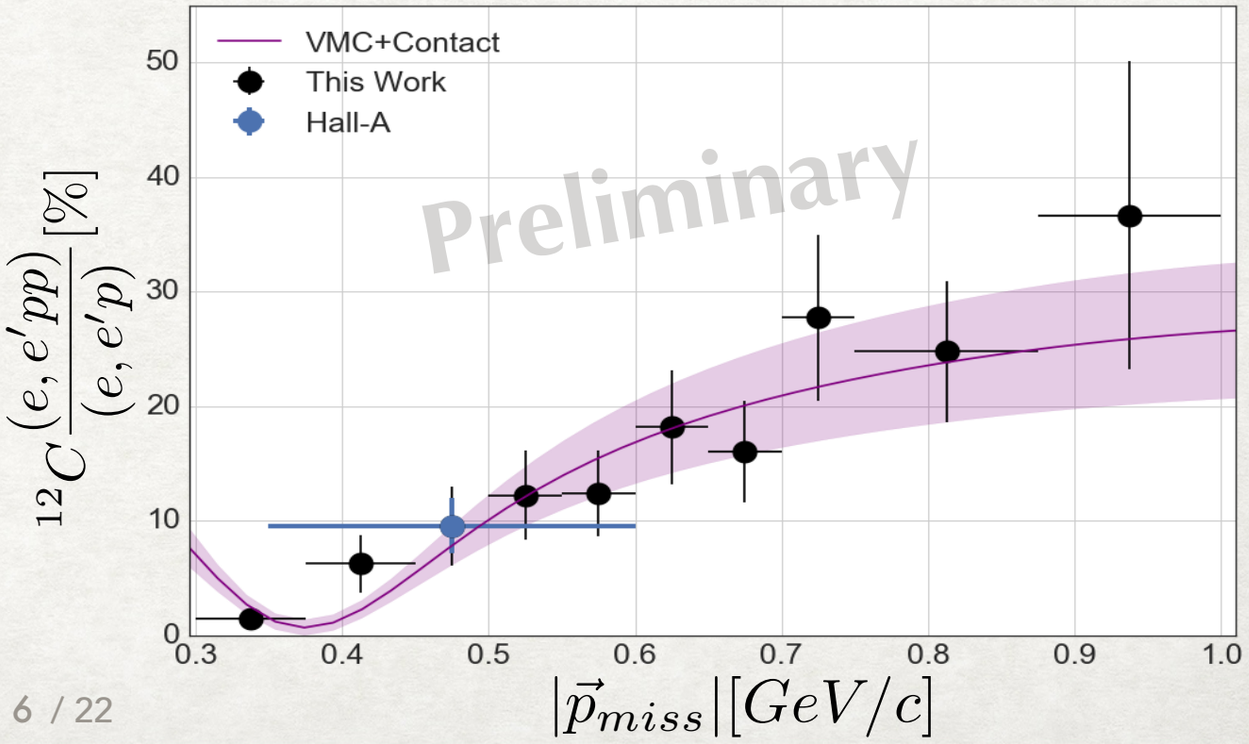
Mining the wealth of existing data

Data mining: utilizing existing CLAS data to extract physics not considered in the original proposal.

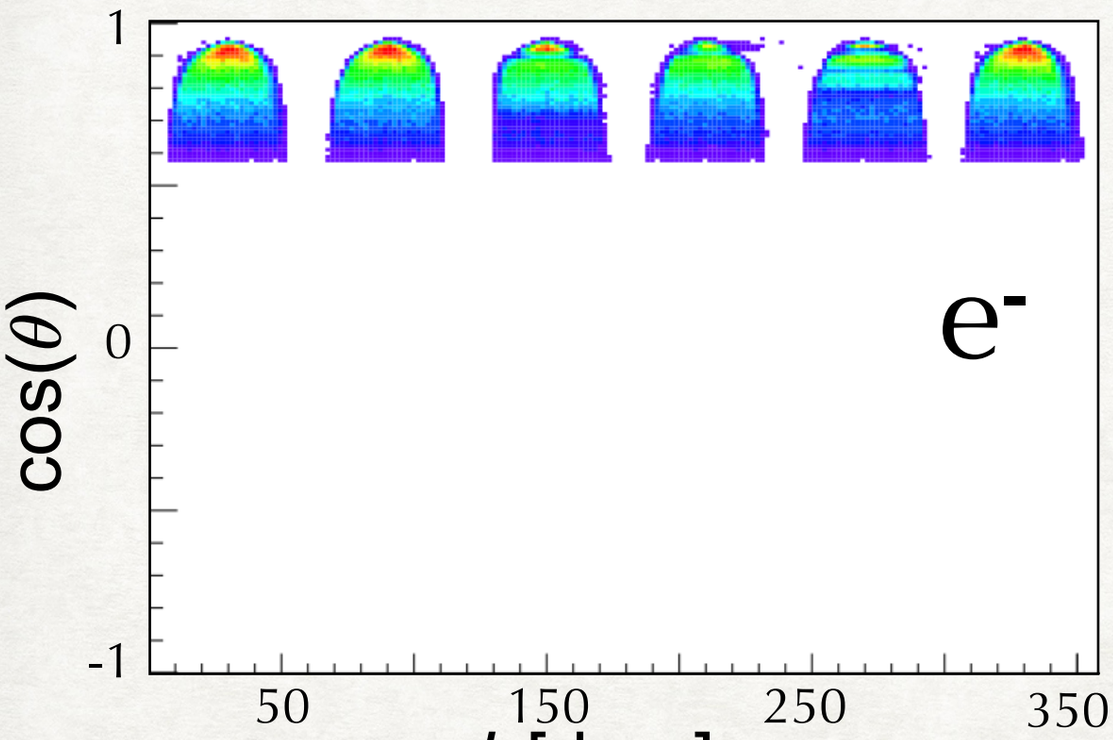


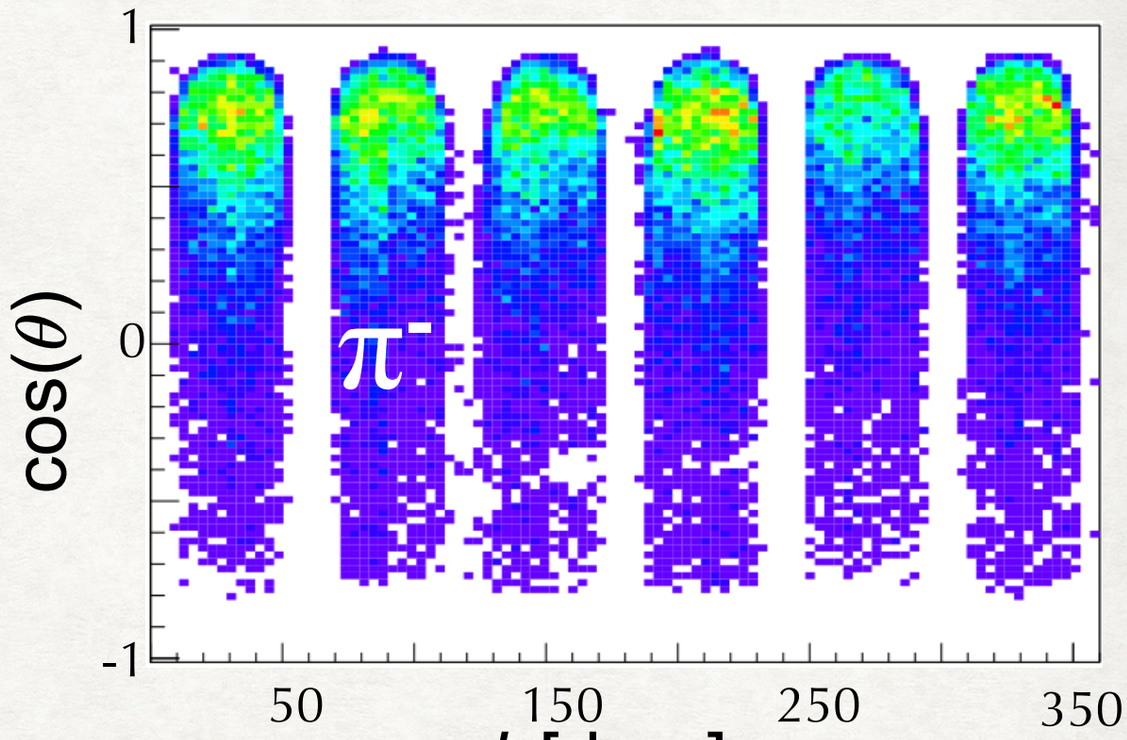




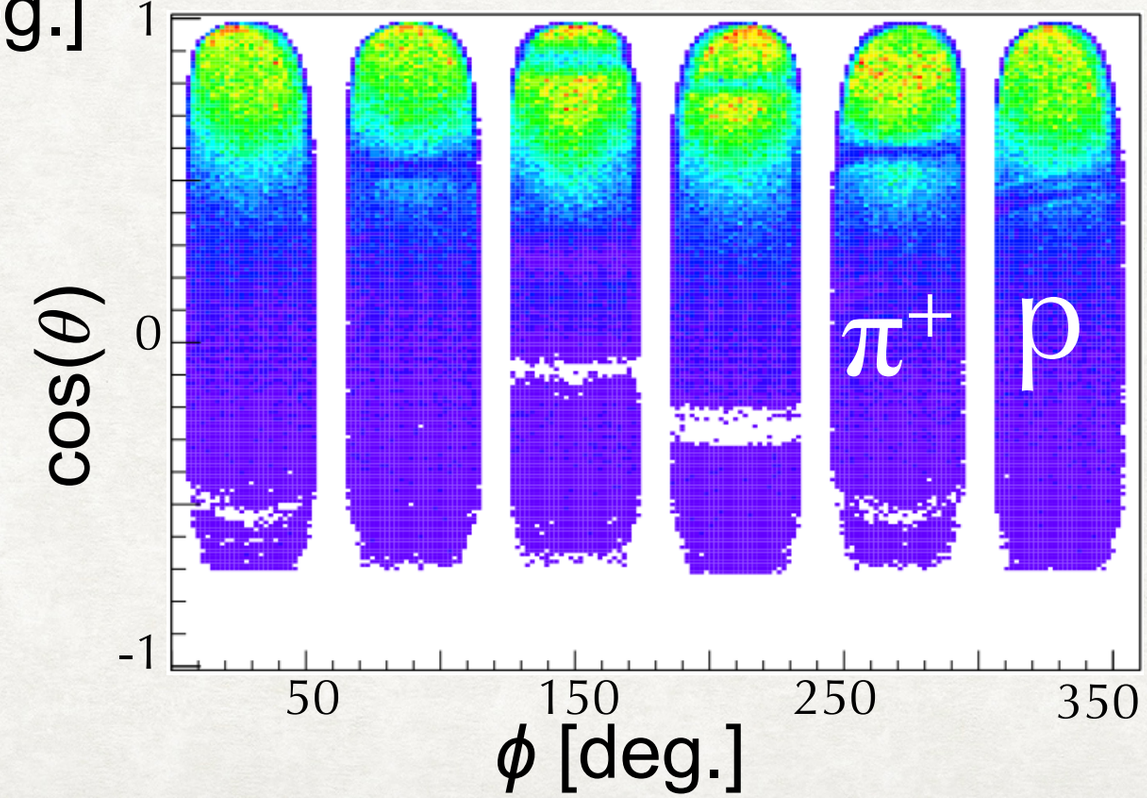


CLAS acceptance



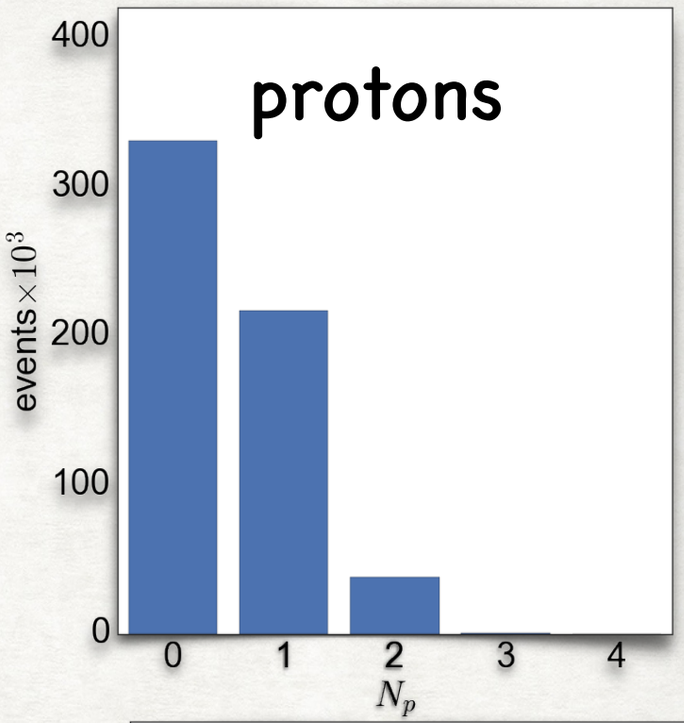


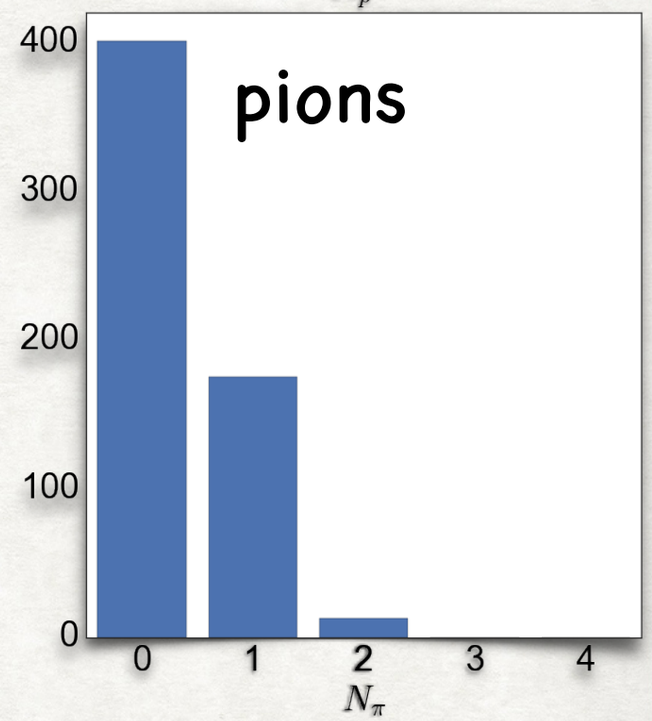
A(e,e'p) @
2.261 GeV



Event selection

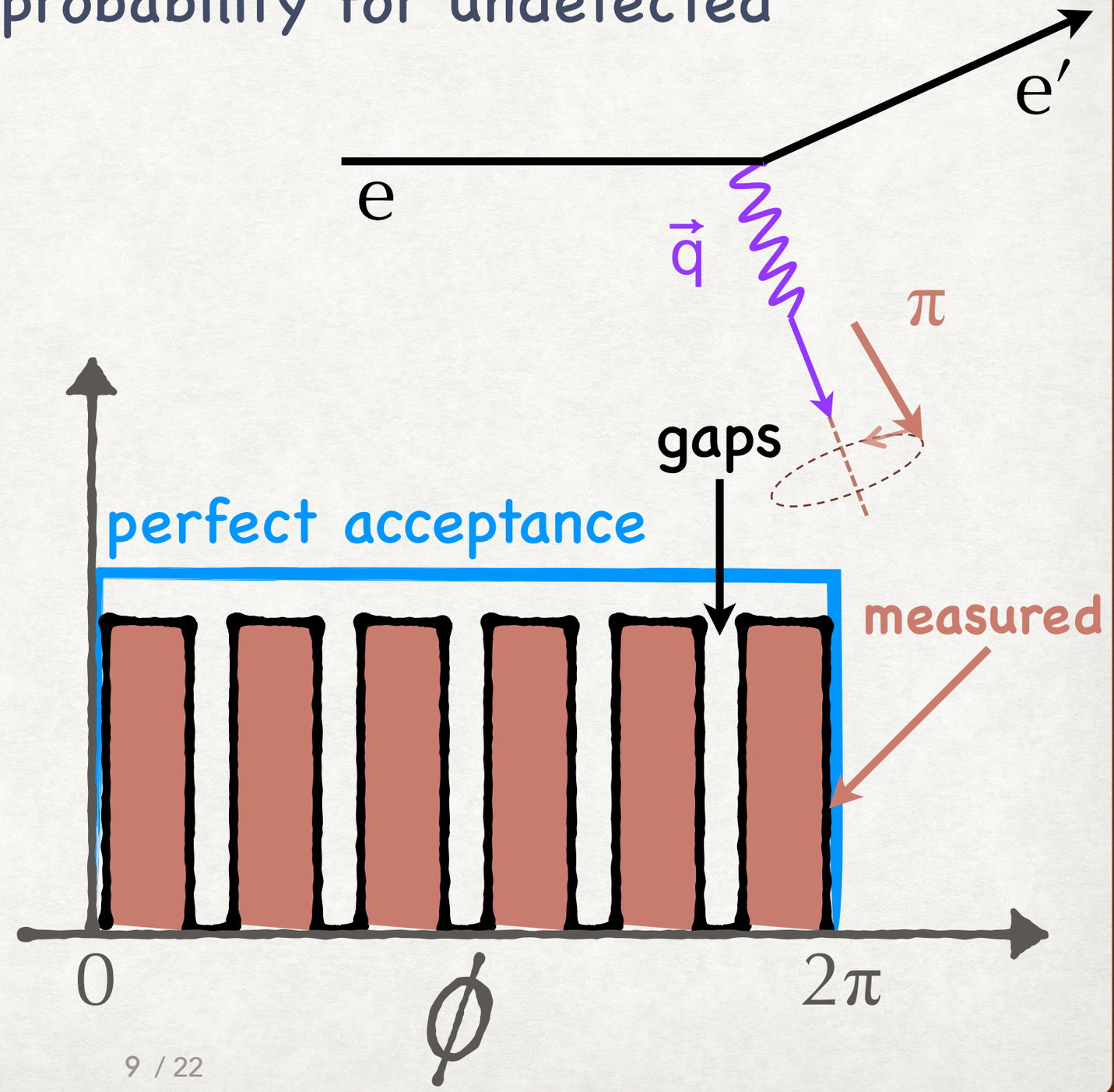
- Signal (e,e'p):
  - 1 electron
  - 1 proton (above 300 MeV/c)
  - no other charged particles (above 300 MeV/c)
  - no neutral hits in calorimeter from π^0 decay
- Background:
  - Signal criteria except with additional undetected particles (e.g. (e,e'pπ) where the π is undetected).





π subtraction

- Background subtraction: take (e,e′pπ) events, rotate π around $\vec{q}$ and estimate probability for undetected π i.e. (e,e′p)π.



Incident energy reconstruction

lepton only (QE assumption):

$$E_{beam}^{lepton-only} = \frac{2M_N\epsilon + 2M_N E_l - m_l^2}{2\left(M_N - E_l + |\vec{p}_l|\cos\theta_l\right)}$$

nucleon mass

binding energy

scattered lepton energy

lepton mass

scattering angle

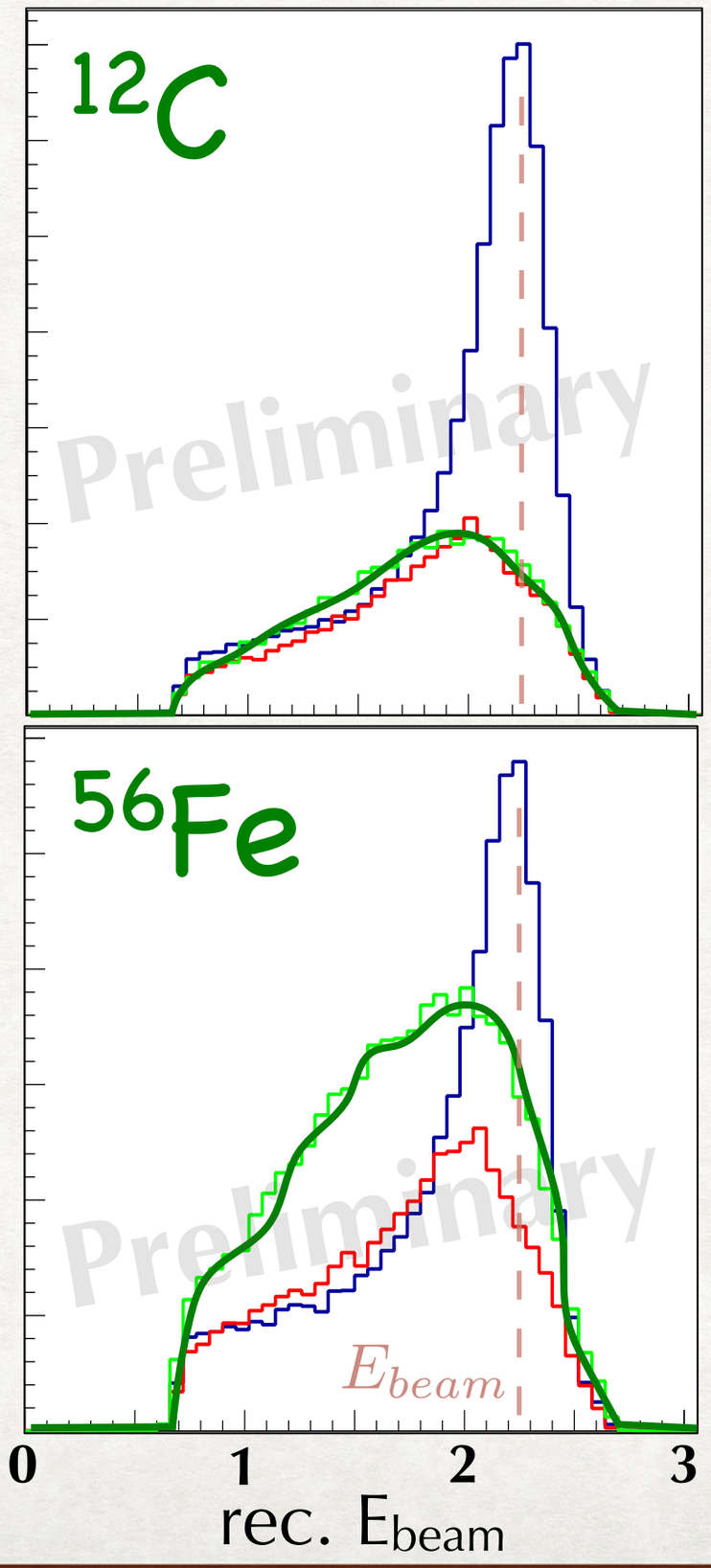
better with protons (calorimetry):

$$E_{beam}^{lepton-proton} = E_l + T_p + S_p + T_{A-1}$$

even better with cuts on transverse momentum (p_t):

$$p_t = (\vec{p}_{e'} + \vec{p}_p)_t < k_F$$

lepton only vs. lepton+proton

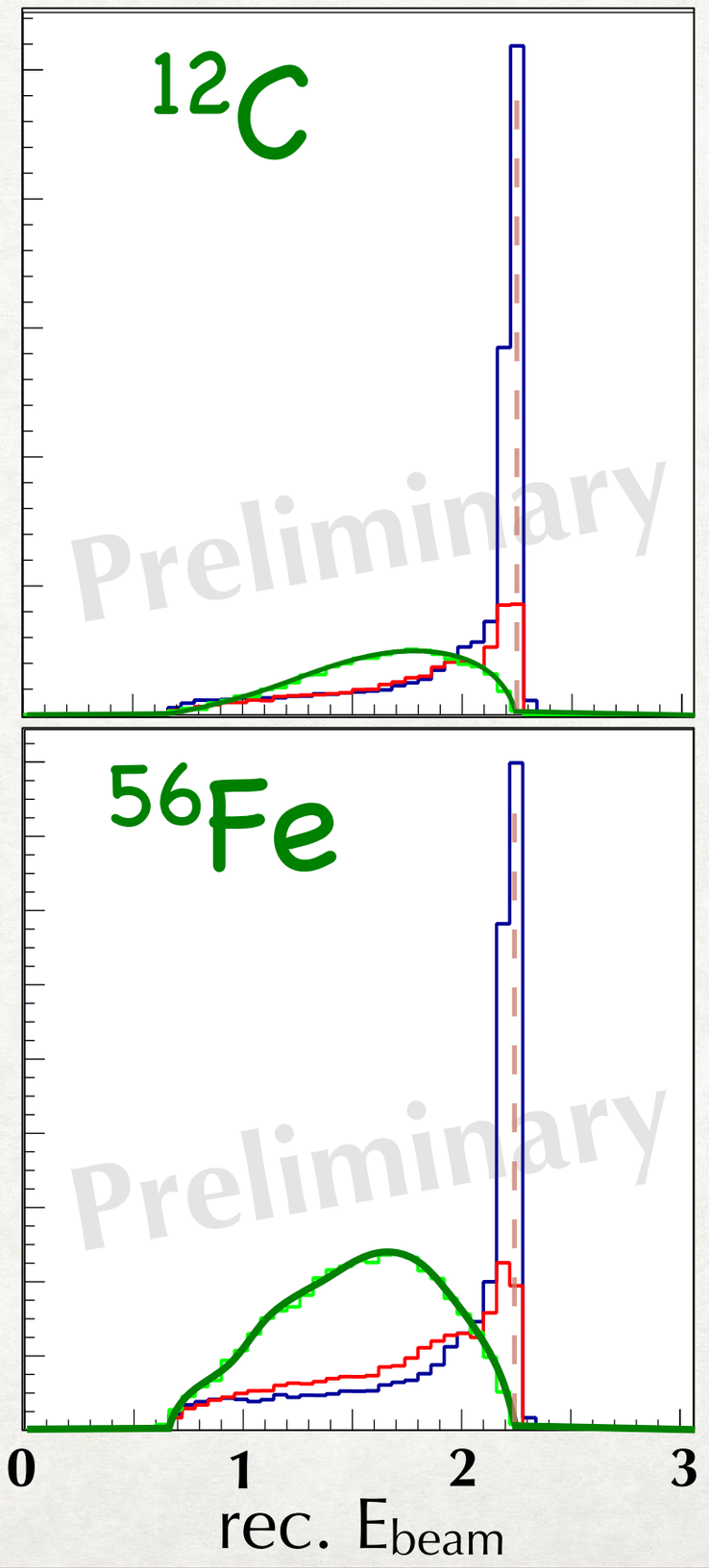


2.261 GeV data

$p_t < 0.2$ GeV/c

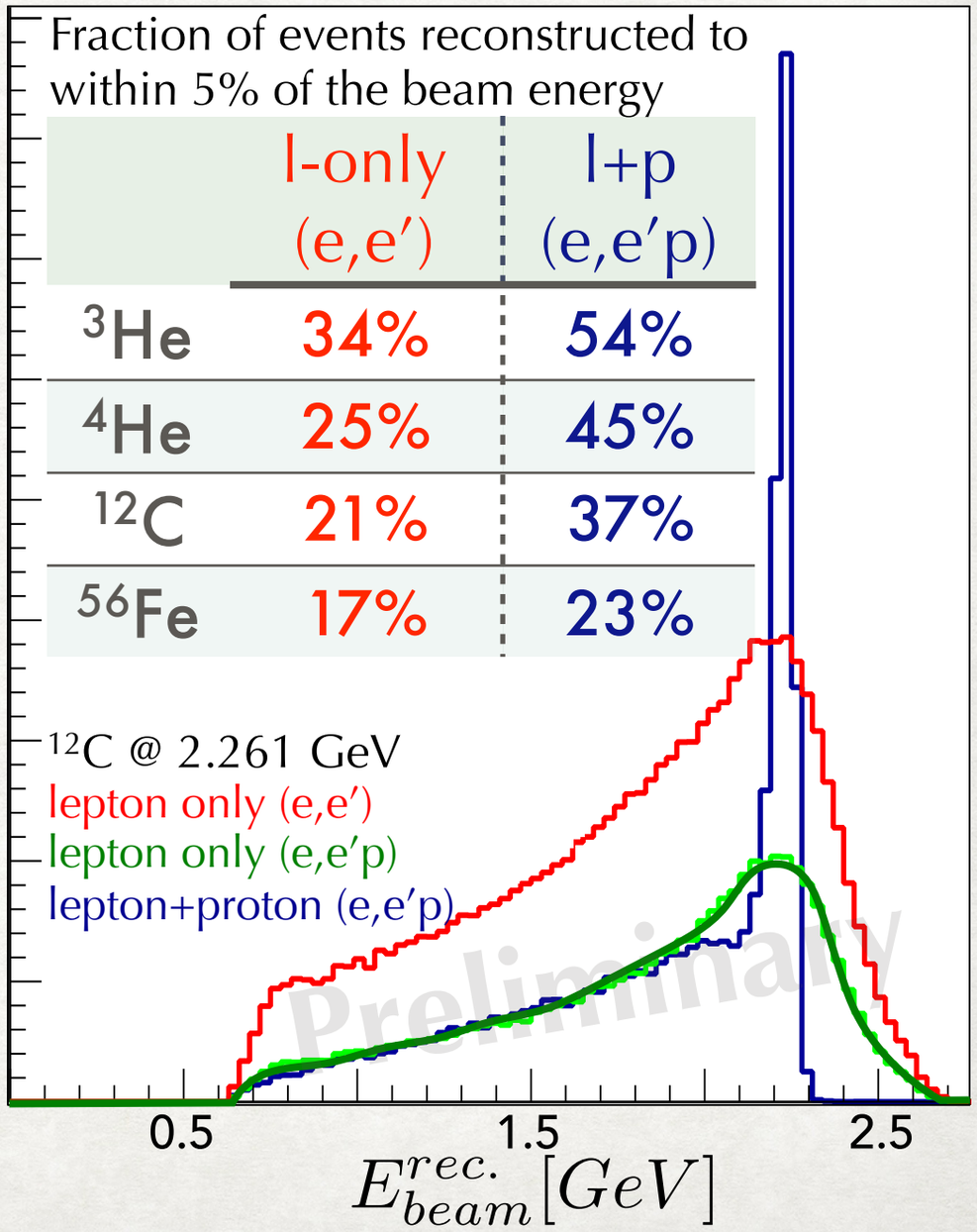
$0.2 < p_t < 0.4$

0.4 GeV/c $< p_t$



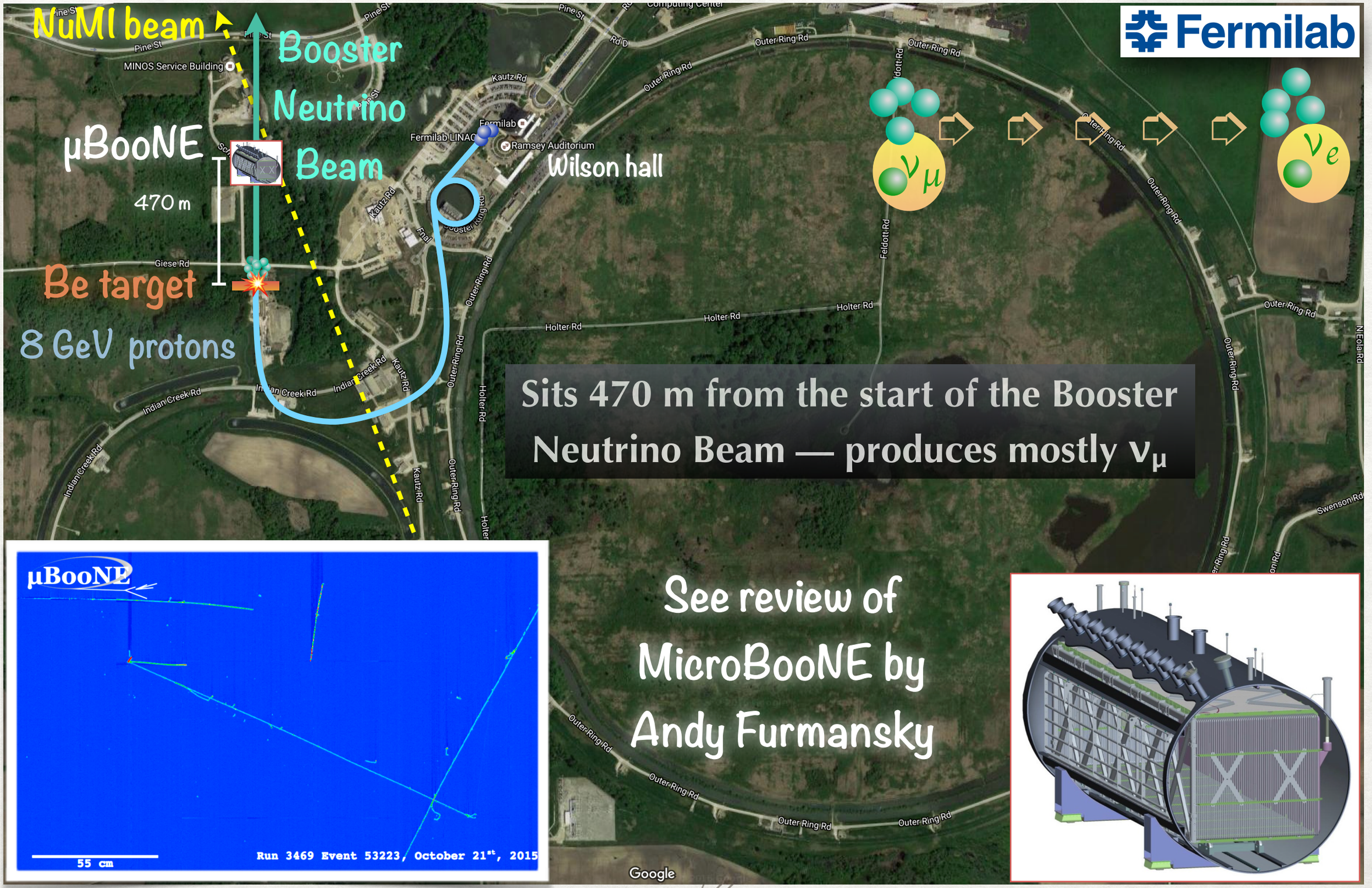
Intermediate summary

- e-data allows testing models of vector-interactions, FSI etc.
- Crucial input for high-precision ν-studies.
- CLAS data-mining offers pioneer studies. A dedicated experiment is proposed for JLAB 12 GeV.
- Only 20-40% of 0π events reconstruct the beam energy within 5%.
- Generator comparisons in progress.



neutrino scattering

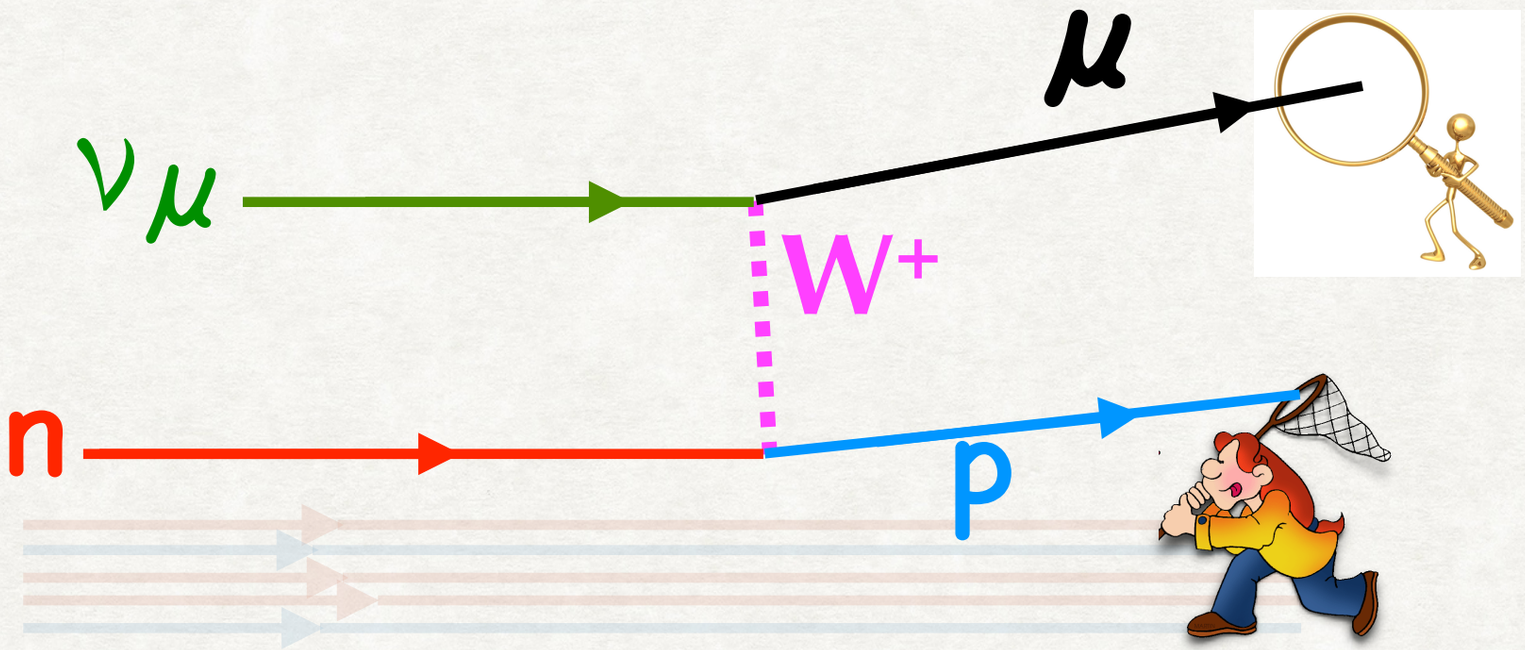
MicroBooNE


NuMI beam
Booster
Neutrino
Beam
μBooNE
470 m
Be target
8 GeV protons
MINOS Service Building
Fermilab LINAC
Fermilab
Ramsey Auditorium
Wilson hall
Fermilab
ν_μ
ν_e
Sits 470 m from the start of the Booster Neutrino Beam — produces mostly ν_μ
See review of MicroBooNE by Andy Furmansky
μBooNE
55 cm
Run 3469 Event 53223, October 21st, 2015
Google

CCQE

Charge-Current Quasi-Elastic

Knockout of a single nucleon by a charged boson without breaking / exciting the nucleon.



We discuss three samples:

- 1μ1p events: only one μ and one p reconstructed in μB.
  - events subset with a enhanced CCQE contribution.
  - events subset with good reconstructed E_ν.

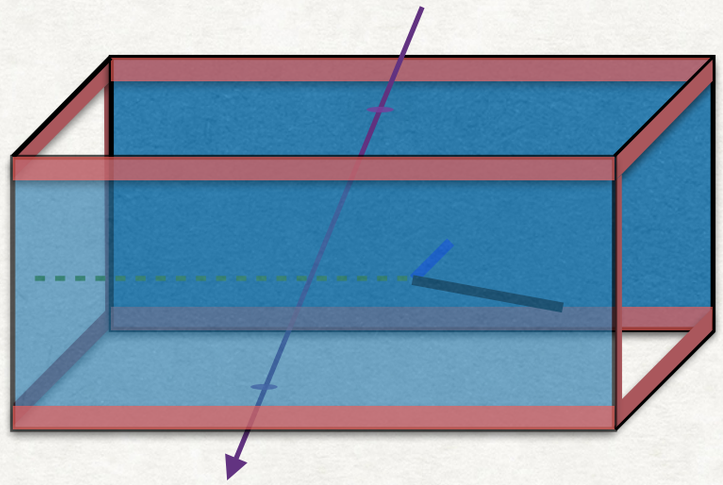
Analysis path

- Identify 1μ-1p pairs with a common vertex.
- Remove background, e.g. cosmic, other pairs, mis-reconstruction... (maximize purity).
  - Minimize the good events loss (maximize efficiency).
- compare MC and DATA to improve selection techniques and study systematics.
- extract physics observables, e.g. form-factors parameters, cross-section etc.

Methodology

- Use a cocktail of MC signal and cosmic DATA overlay, and collect all pairs of reconstructed tracks that start at close proximity

- Define a Fiducial Volume to remove cosmic background

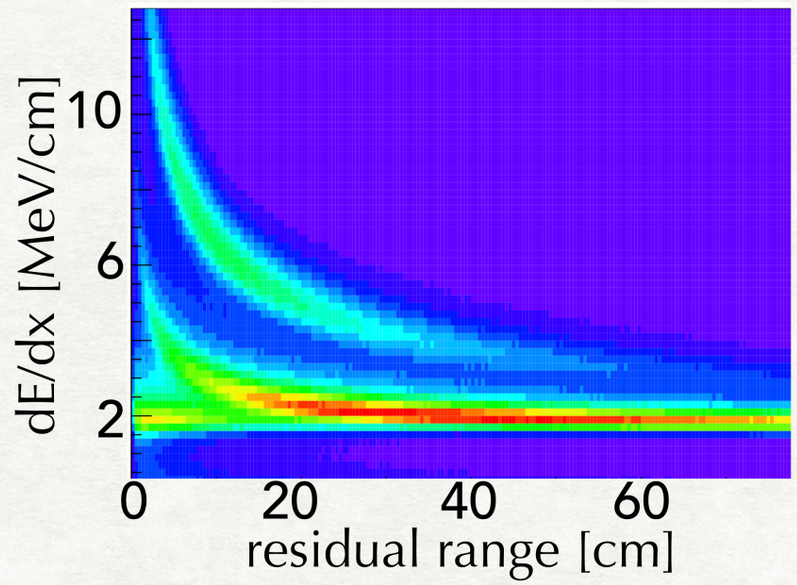


$3 < x < 250$ cm
$|y| < 110$ cm
$5 < z < 1045$ cm

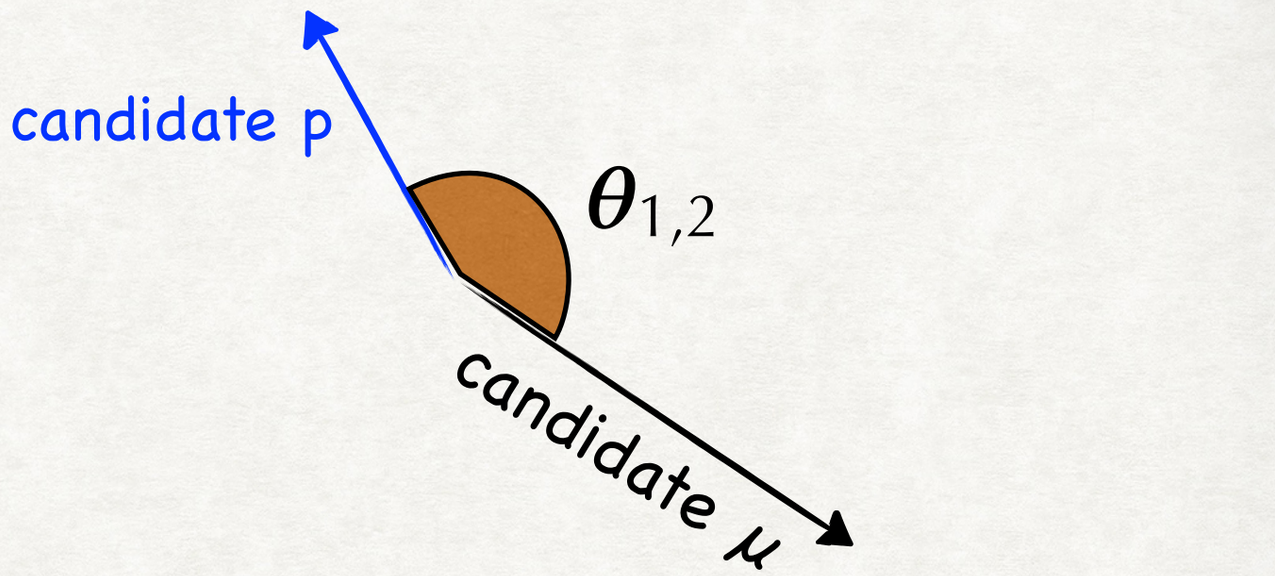
- for 1 / 1 MC signal to Cosmic data BG combination,
  Signal (1μ1p) / Background (cosmic, other pairs...) $\simeq$ 1 / 7
  i.e. very poor without application of any selection cuts.

Detector level cuts

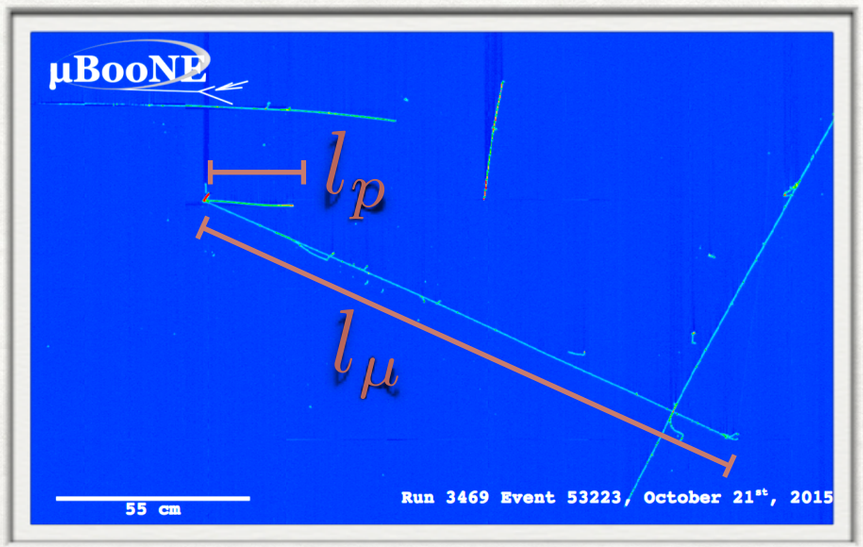
dE/dx profile



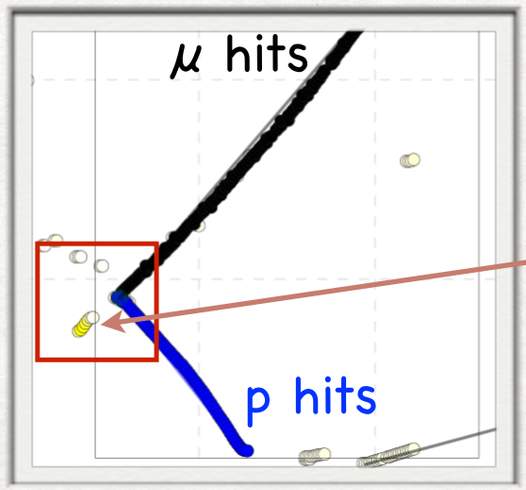
collinearity



track length



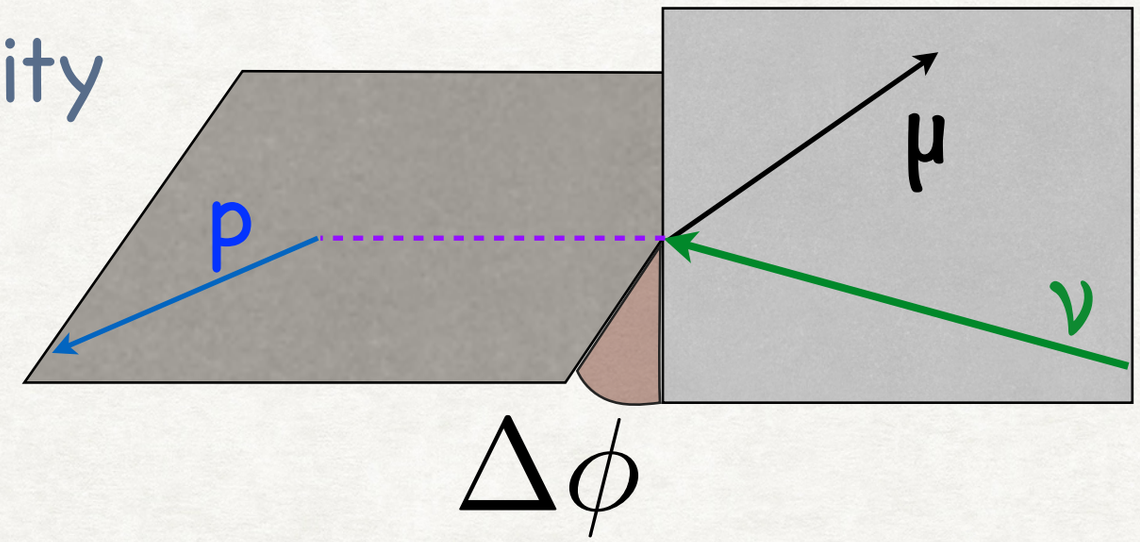
ΔQ around vertex



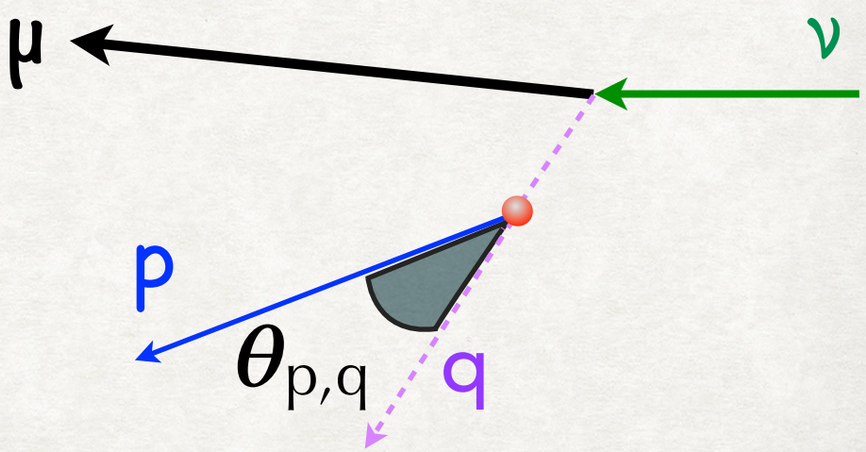
charge deposition not associated with reconstructed tracks

Kinematical cuts: signatures of QE scattering

- coplanarity



- reconstructed angle between p and q



- transverse momentum imbalance

$$\vec{p}_t = (\vec{p}_\mu + \vec{p}_p)_\perp$$

Events selection cuts

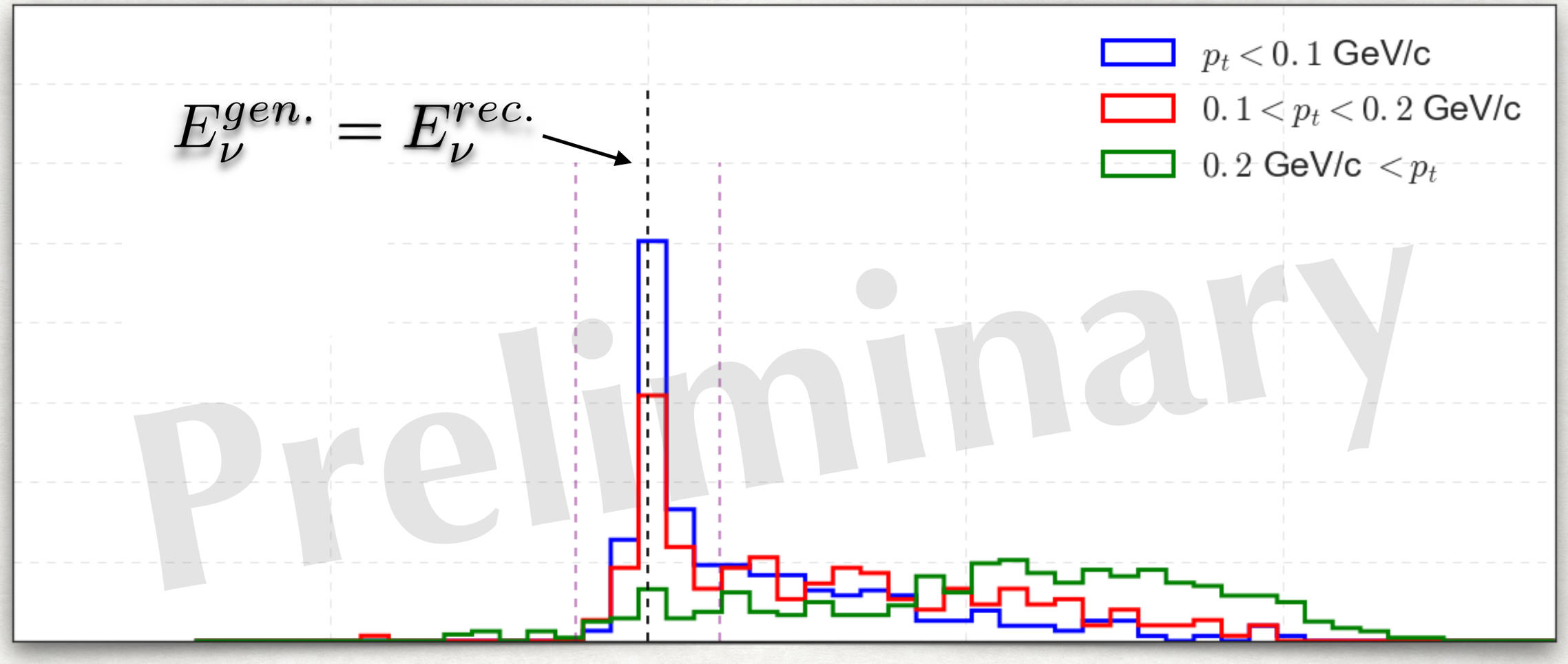
- Cocktail combination 1 MC signal/1 Cosmic data BG event

cuts	cosmic	other pairs	1μ-1p	enhanced QE	purity 1μ1p
No cuts	100%	100%	100%	100%	O(13%)
detector	few %	O(40%)	O(45%)	O(70%)	O(70%)
kinematics	<1%	O(2%)	O(20%)	O(55%)	O(95%)

- After these cuts O(95%) 1μ1p pairs in this cocktail, out of which 1/2 are enhanced QE.
- We do not consider uncorrelated cosmic backgrounds.

reconstruct Eν of 1μ1p events

$$\vec{p}_\nu \cdot \hat{z} = E_\mu + T_p + S_n + T_{A-1}$$



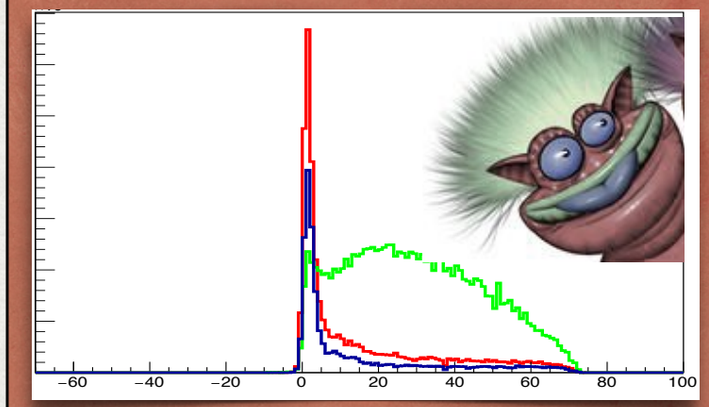
$$(E_\nu^{gen.} - E_\nu^{rec.})/E_\nu^{gen.}$$

- The tail is mostly associated with large P_t events.
- This conclusion is re-enforced by the e-scattering analysis.

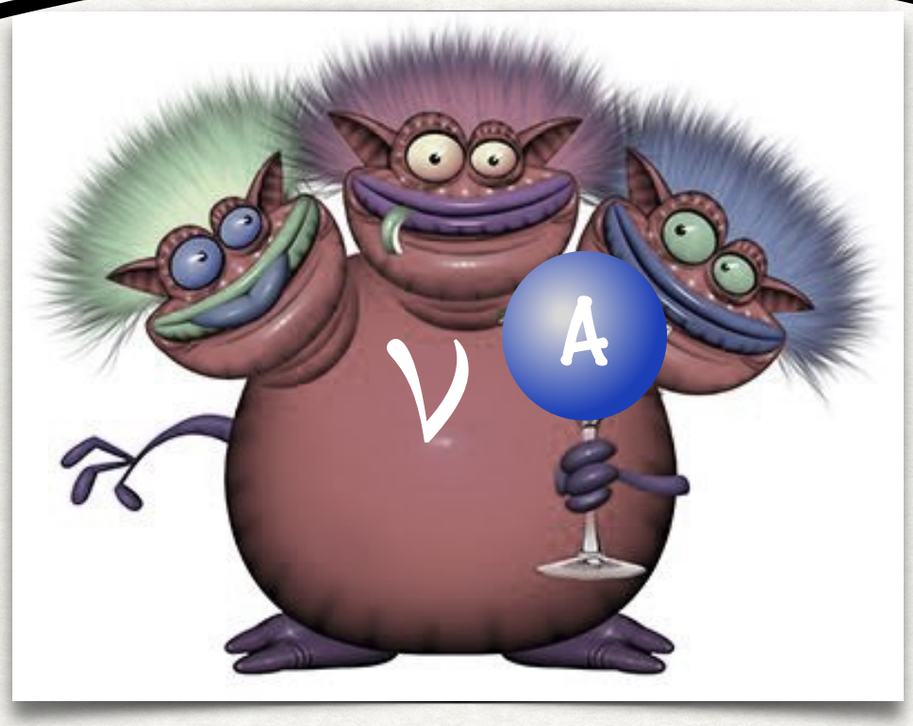
Summary

Leveraging the advantages from each direction

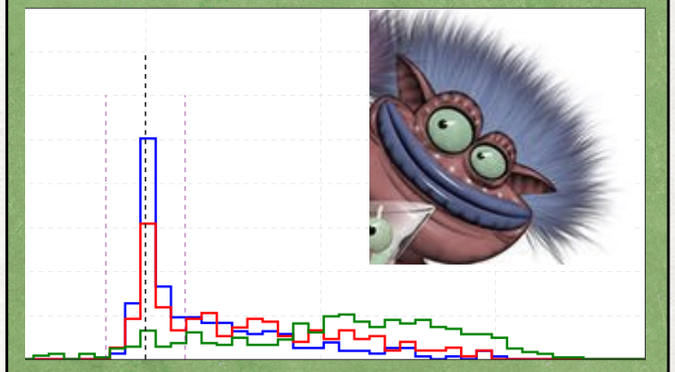
e-scattering



$(\mathbf{E}_{\nu}^{\mathrm{gen.}} - \mathbf{E}_{\nu}^{\mathrm{rec.}})/\mathbf{E}_{\nu}^{\mathrm{gen.}}$ [%]

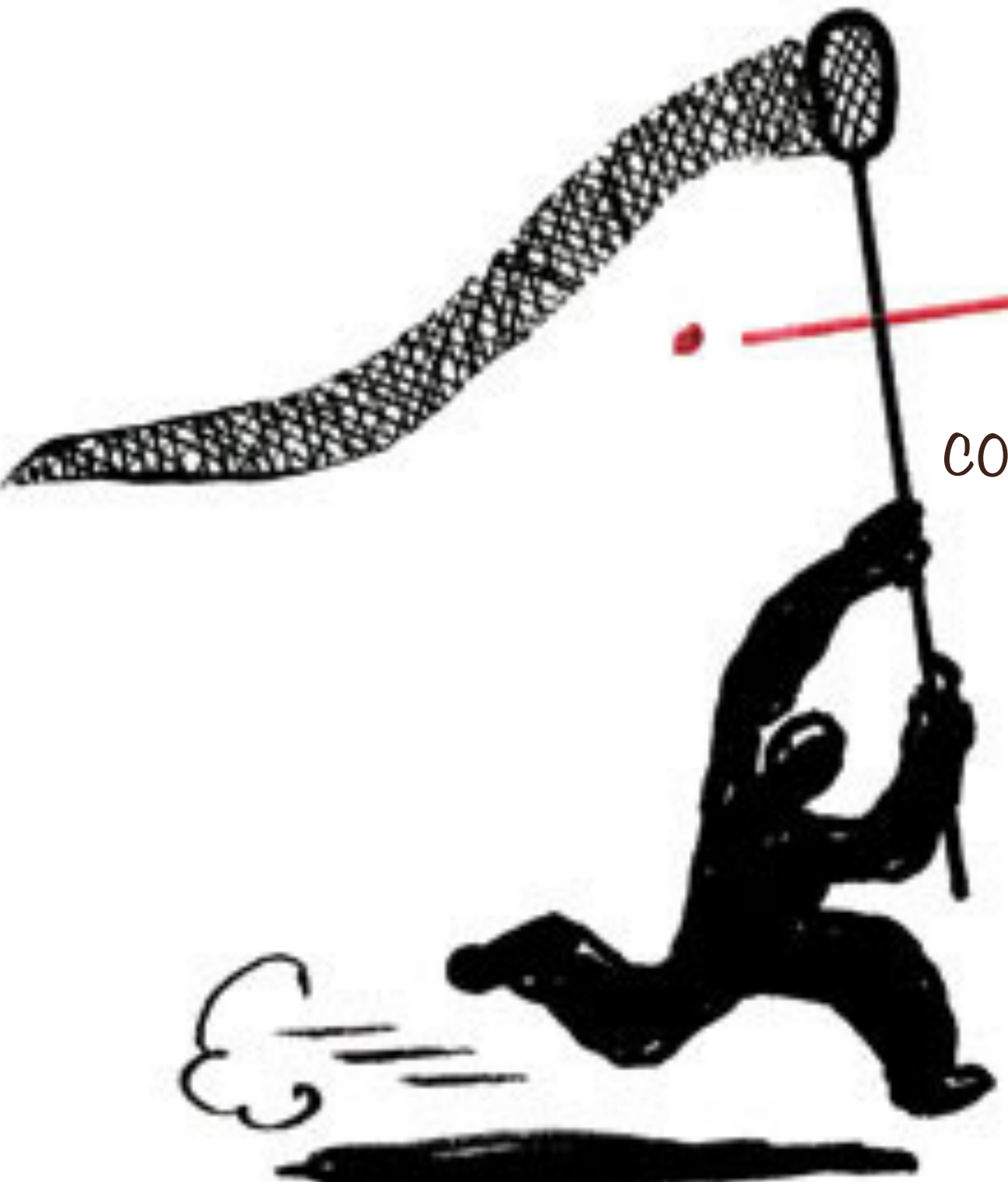


ν-scattering



$(\mathbf{E}_{\nu}^{\mathrm{gen.}} - \mathbf{E}_{\nu}^{\mathrm{rec.}})/\mathbf{E}_{\nu}^{\mathrm{gen.}}$

Simulation (GENIE)



comments/corrections/suggestions

are very welcome

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cohen.erez7@gmail.com

Backup