NN interaction study using C(e,e'pn) reaction at SRC kinematics

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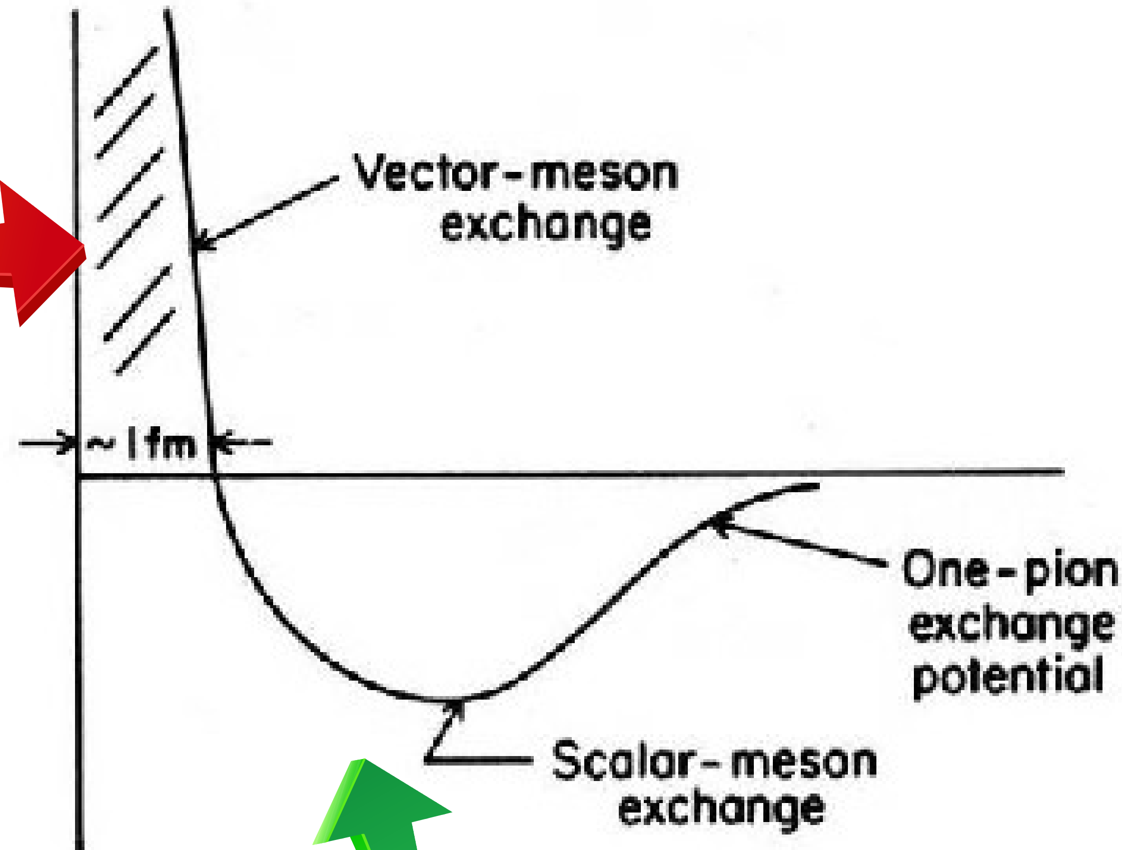
Clas collaboration meeting

June 20, 2019

General behavior of nucleon – nucleon interaction

<u>Repulsive Core:</u>

Scalar (?) nucleon - nucleon interaction



<u>Attractive Region:</u>

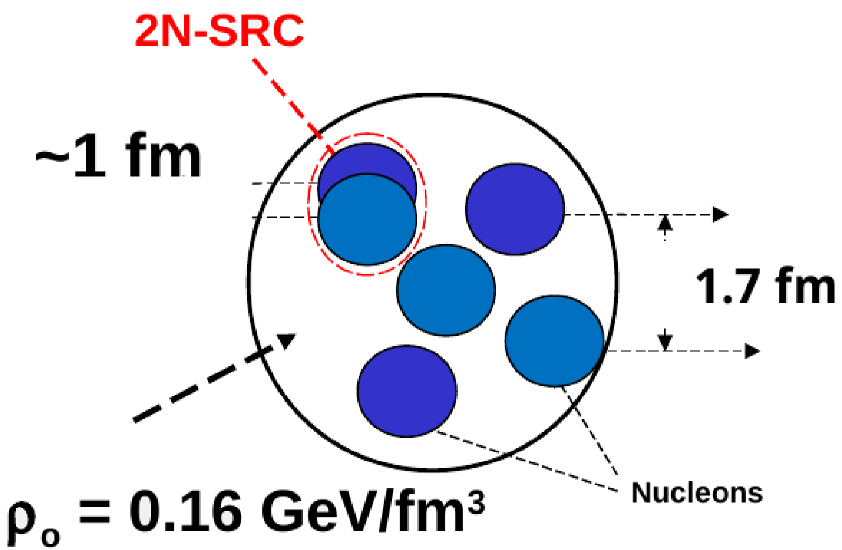
Scalar nucleon – nucleon interaction

2N - Short Range Correlation (SRC)

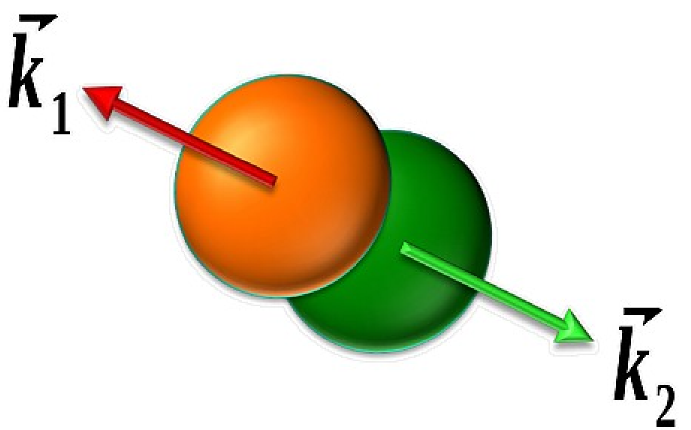
A pair with:

Large relative momentum ($k_{\mathrm{rel}} > k_{\mathrm{F}}$)

Small C.M. momentum ($k_{CM} < k_F$)

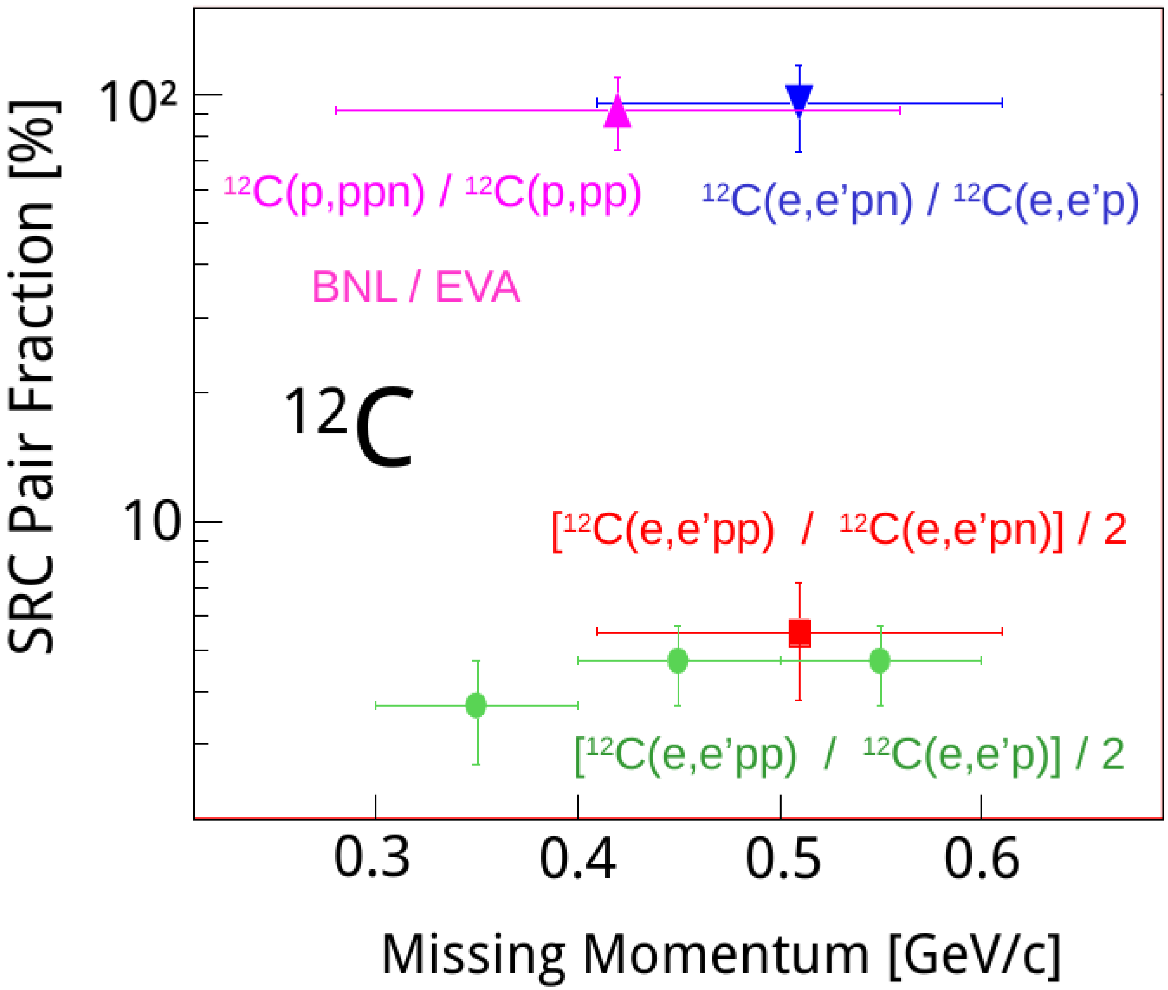


In momentum space:



$k_1 > k_F \quad k_2 > k_F \quad k_1 \simeq k_2$

np - dominance



Piasetzky et al., PRL. 97 (2006) 162504

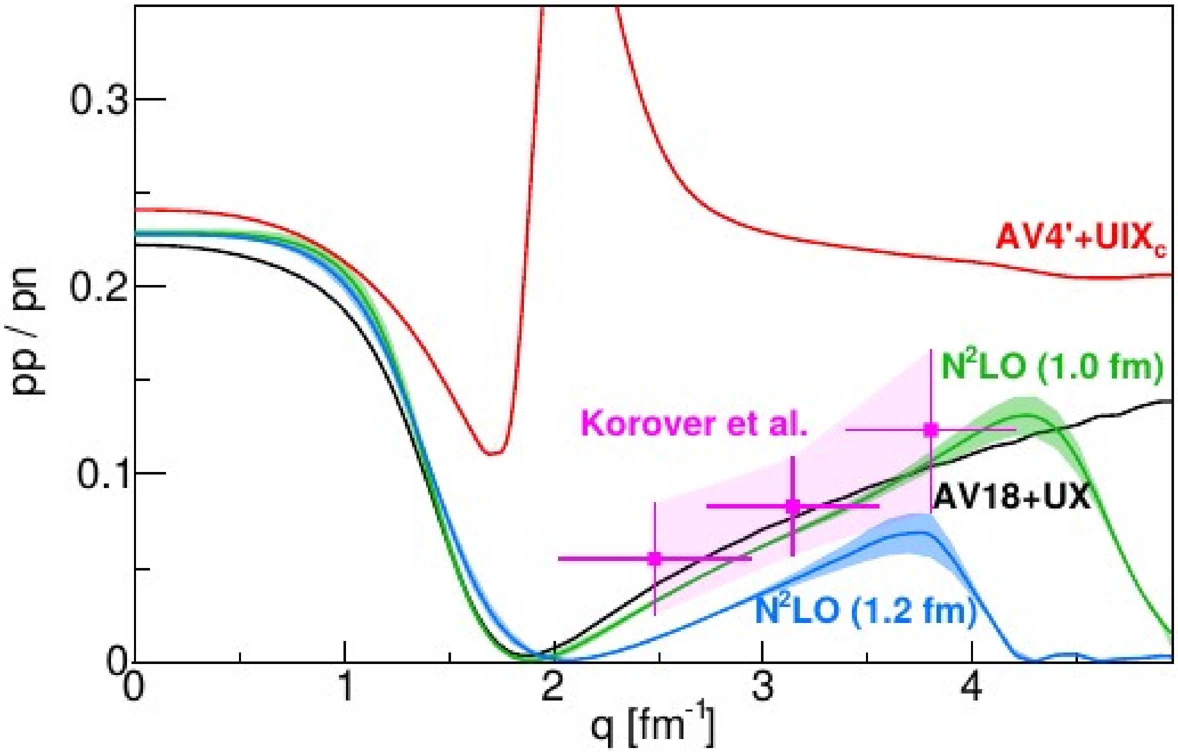
Subedi et al., Science 320 (2008)

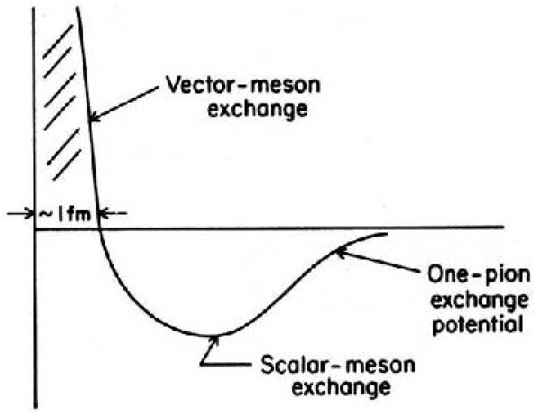
Shneor et al., Phys.Rev.Lett. 99 (2007) 072501

- High momentum tail is dominated by SRC pairs
- np - Dominance:

  ~90% np pairs
  ~5% pp (nn) pairs
- Independence from probing particle

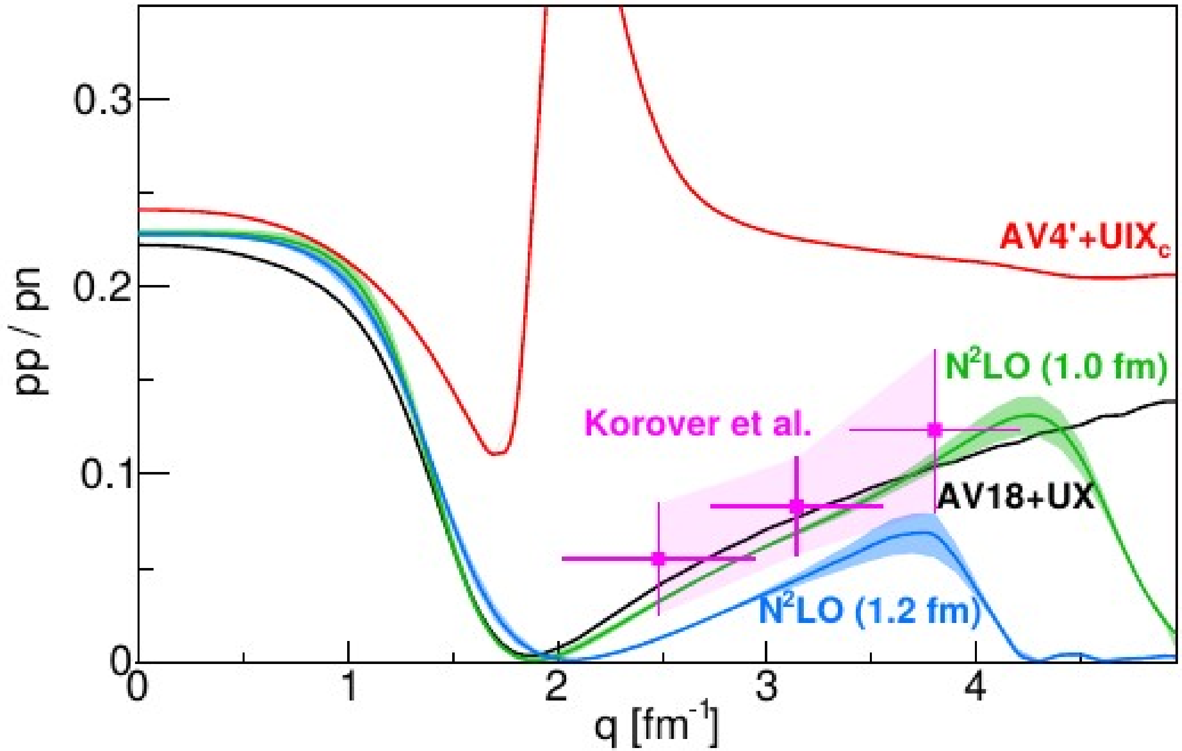
NN at large relative Momentum

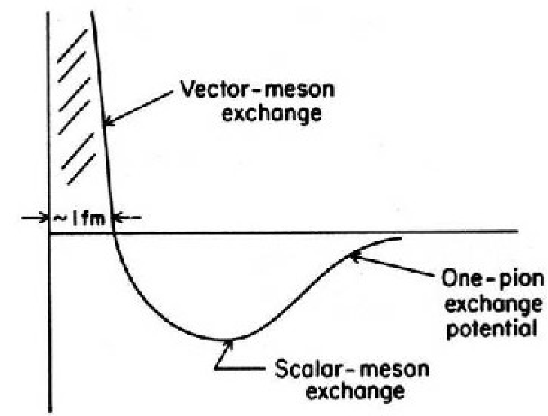




Korover *et al.*, PRL. 113, 022501 (2014)

NN at large relative Momentum

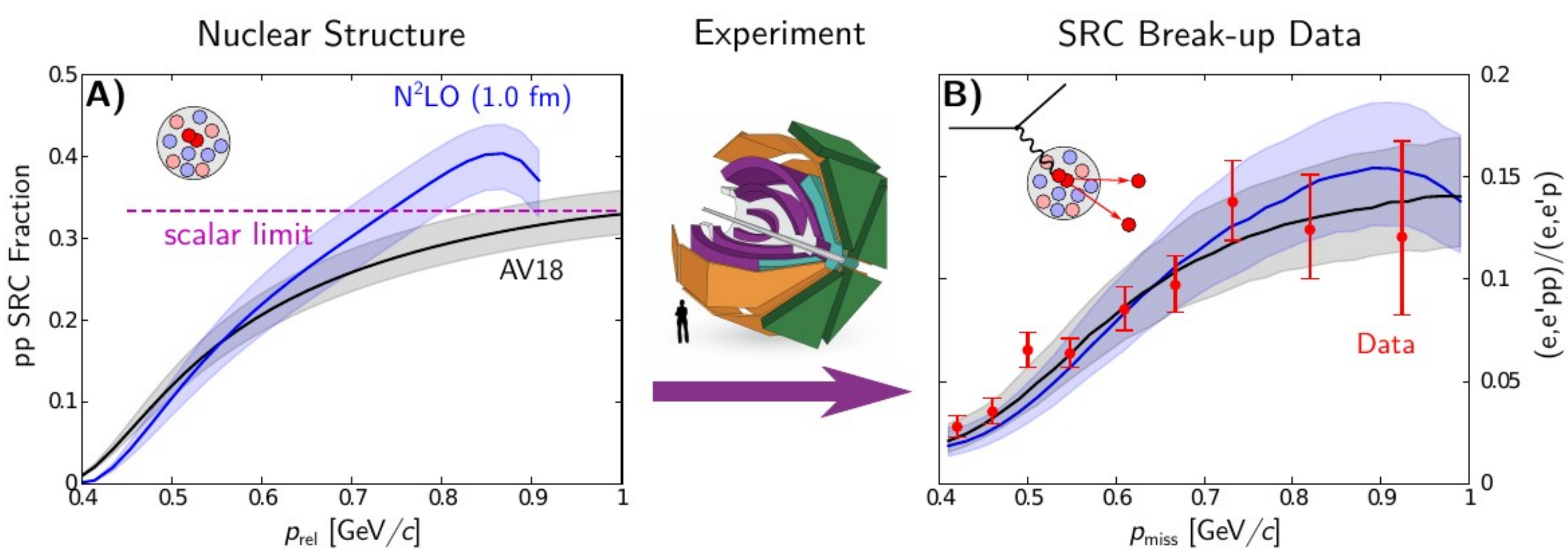




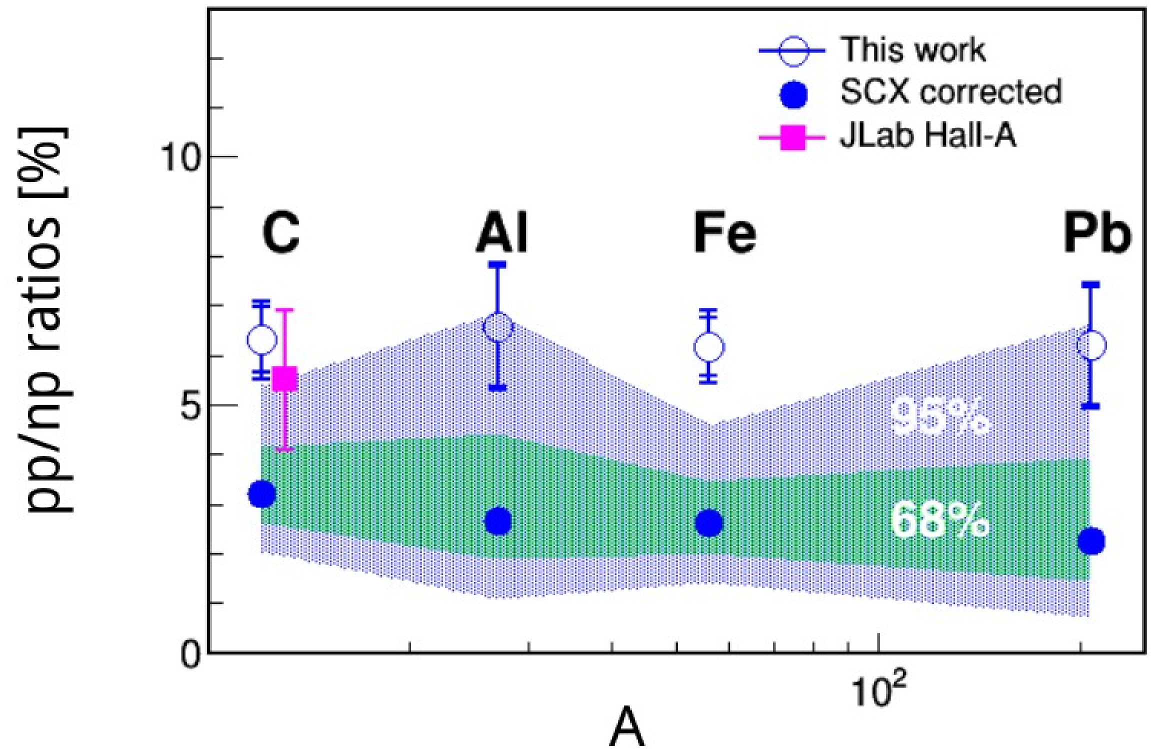
Korover *et al.*, PRL. 113, 022501 (2014)

A(e,e'pp)/A(e,e'p)

Approved CLAS analysis (see Axel's talk)



Why to also study A(e,e'pn)/A(e,e'p)?



A(e,e'pn) → Small SCX correction

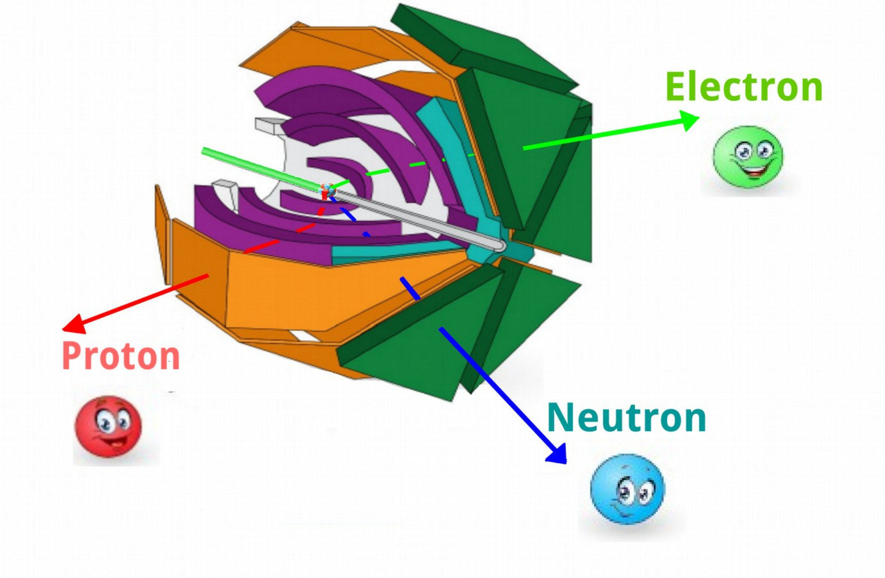
A(e,e'pp) → Large SCX correction

Study np-SRC pairs

A(e,e′np) done by Meytal Duer

Nature 560 (2018) no.7720, 617-621

Phys.Rev.Lett. 122 (2019) no.17, 172502



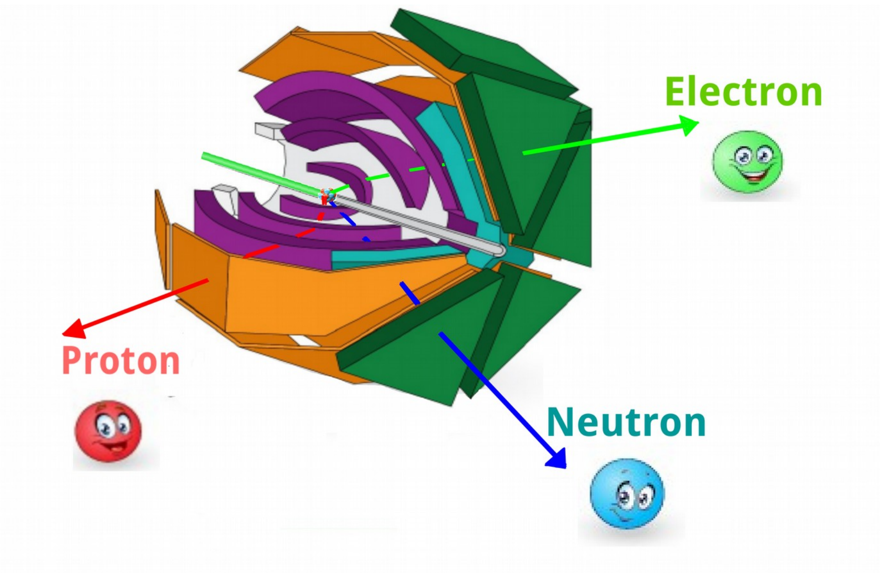
Study np-SRC pairs

This Analysis (e,e'pn)

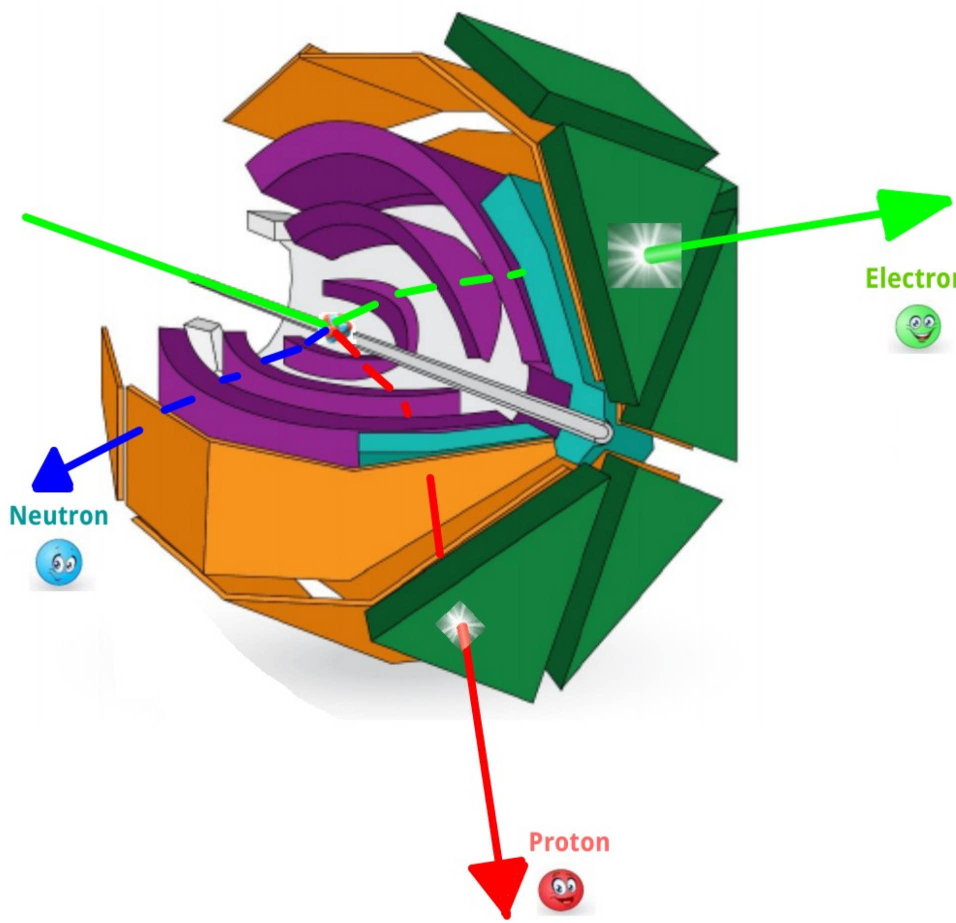
A(e,e'np) done by Meytal Duer

Nature 560 (2018) no.7720, 617-621

Phys.Rev.Lett. 122 (2019) no.17, 172502



A(e,e'pn)/A(e,e'p) as function of missing momentum.
Allows better comparison to NN-interaction calculations.



Selection of hits in TOF counter

Use of SCRC Bos bank to store the information for all hits

SCRC bos bank (or any intermediate banks) is not linked to the EVNT bos bank

Require modification to ClasTool

(with help from Gagik Gavalian)

For each event, add iterator over the intermediate banks* and store the data in the root file

*general modification also needed for Veto

Separation between charged and neutral hits

Neutron hits identical to charged hits in plastic scintillators

Veto algorithm is needed

We need detection plane before the scintillators:
Drift Chambers

Pros.

- Blind to neutral particles

Cons.

- Unreconstructed track can be selected as a neutron

Veto algorithm

Use drift chamber as a veto plane

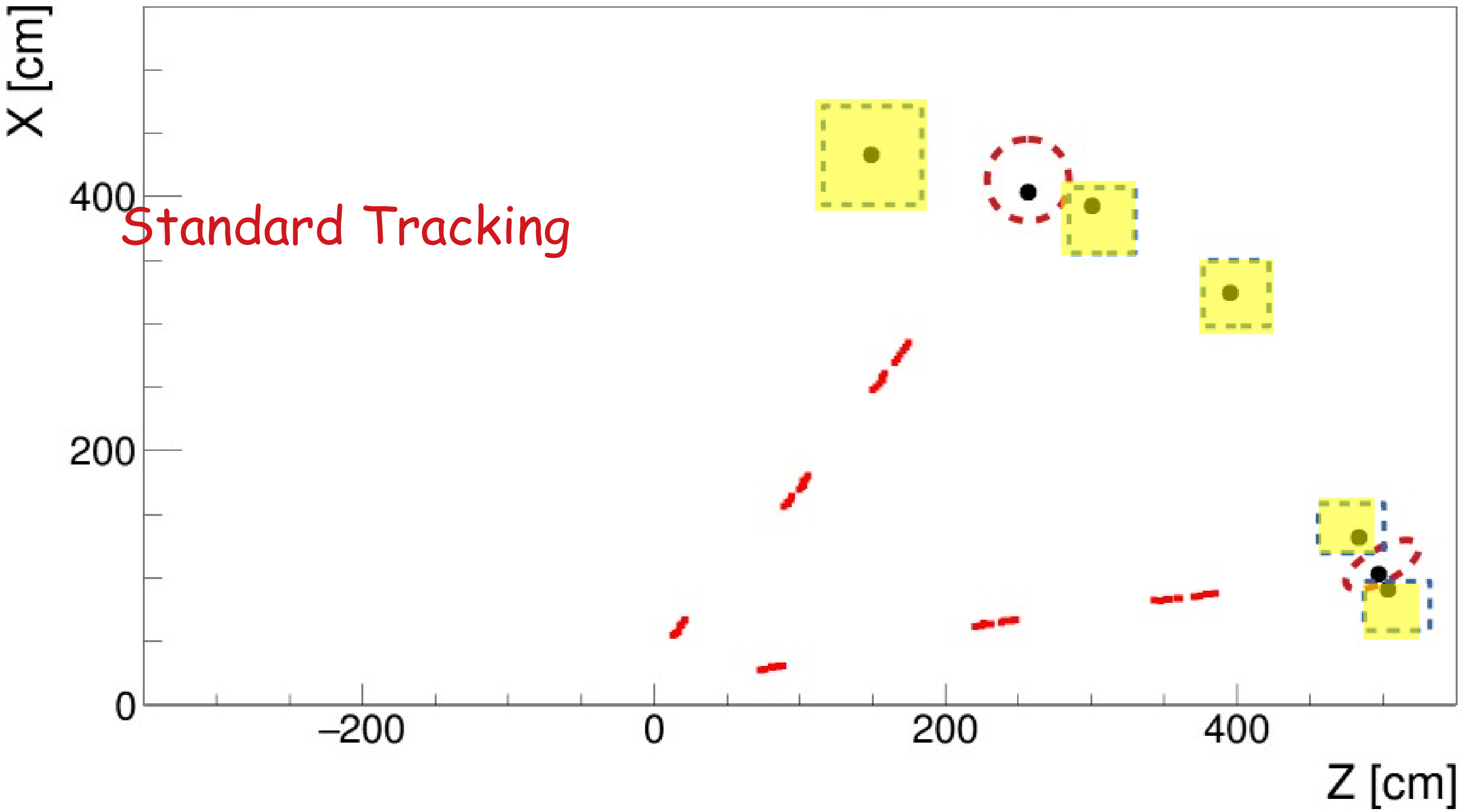
Standard bank for charged particles tracks (DCPB)

Not enough: Optimized to reduce false positive

Find tracks even if the trajectory is not good
(less drift chamber planes that are required for DCPB)

HBLA bos bank

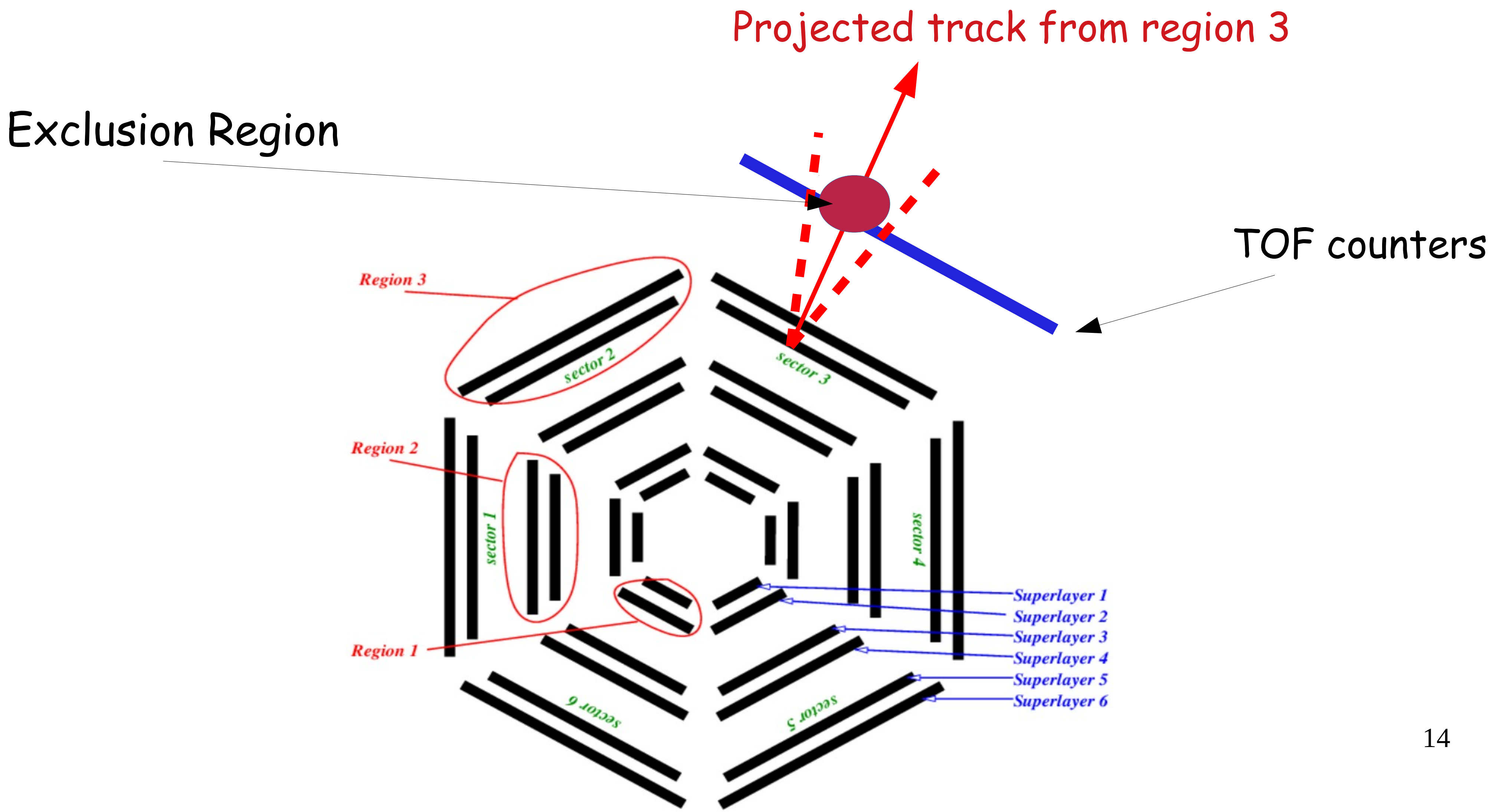
Neutron Identification using only fully reconstructed tracks



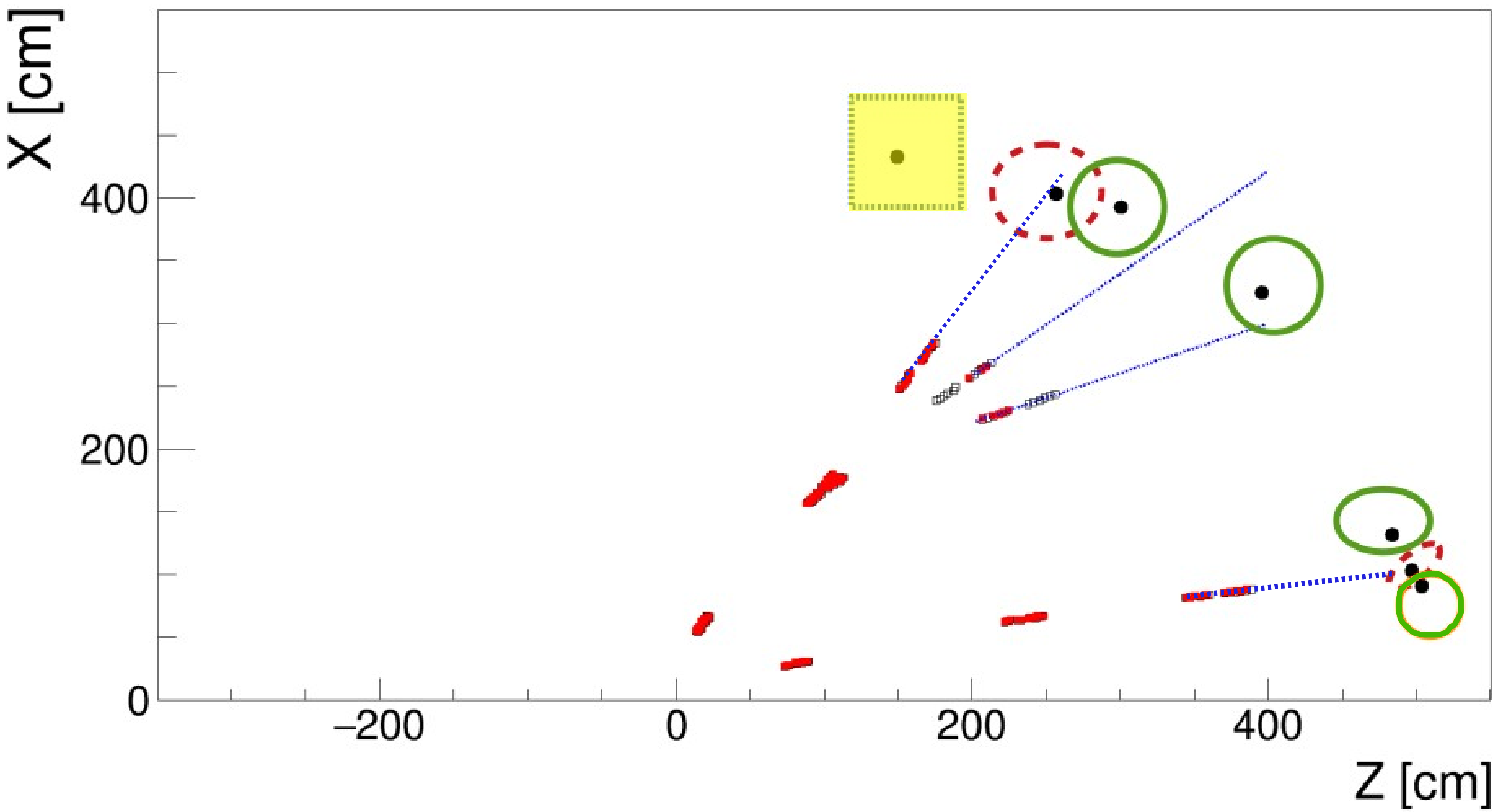
<u>5 neutral candidates identified</u>

Flow chart for extended veto algorithm

All tracks (full and partial) → Project to TOF from region 3 → Exclude hits in TOF counters that fall in the projected region

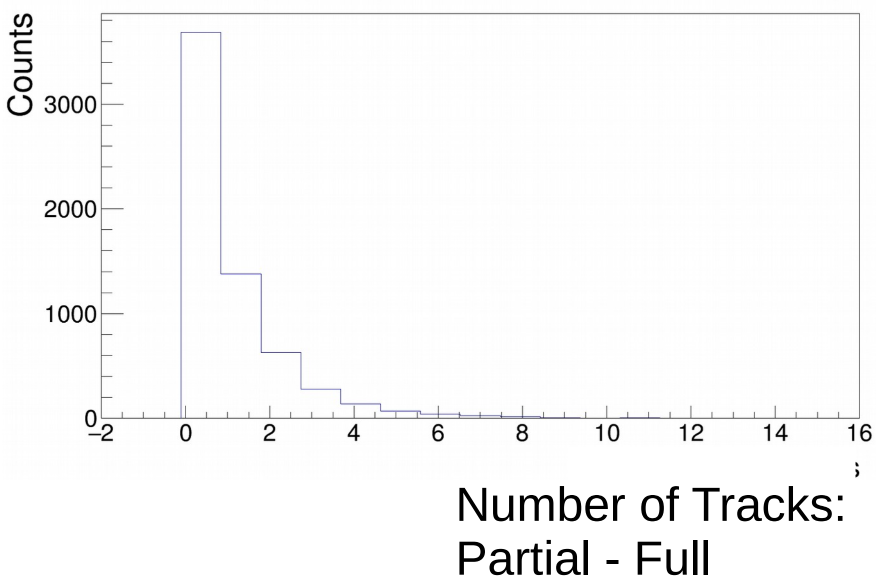


Including Partial Tracks



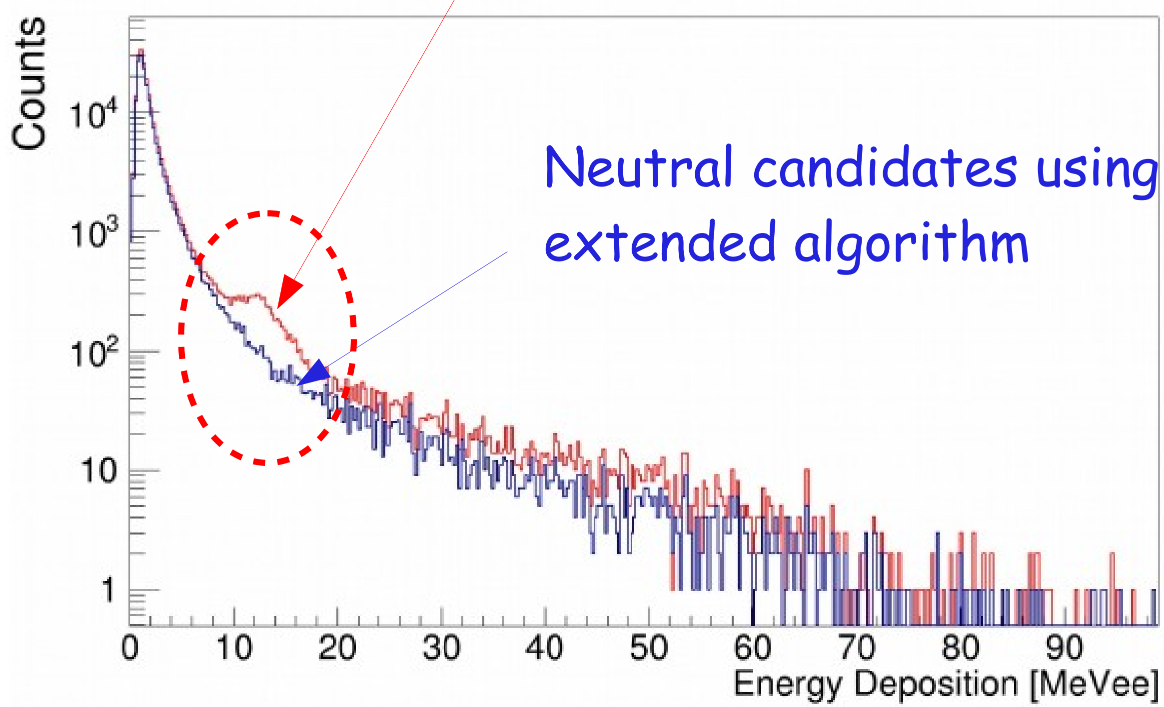
1 neutral candidate identified!

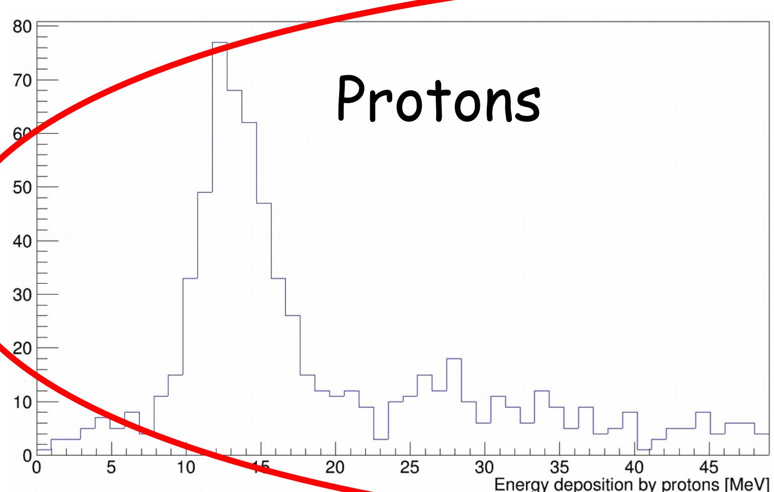
Difference between partial and full tracks

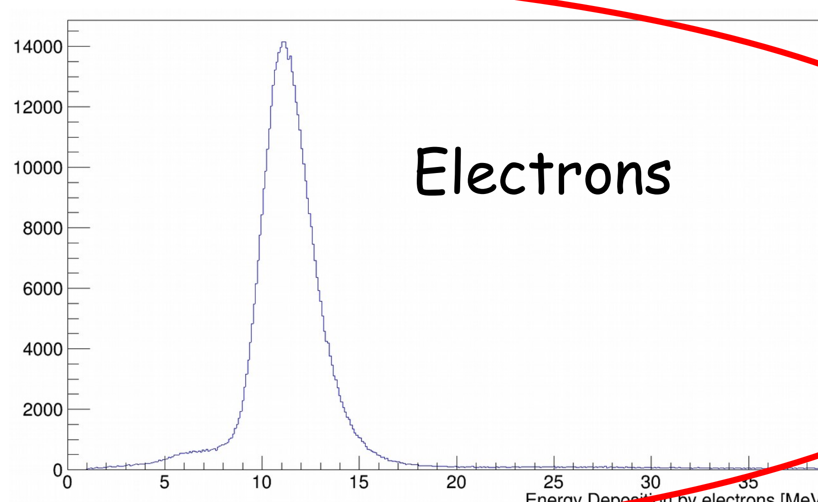


Neutral candidates using standard tracking **only**

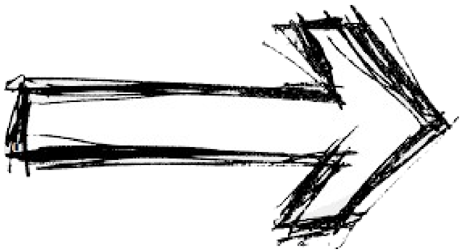
Neutral candidates using extended algorithm







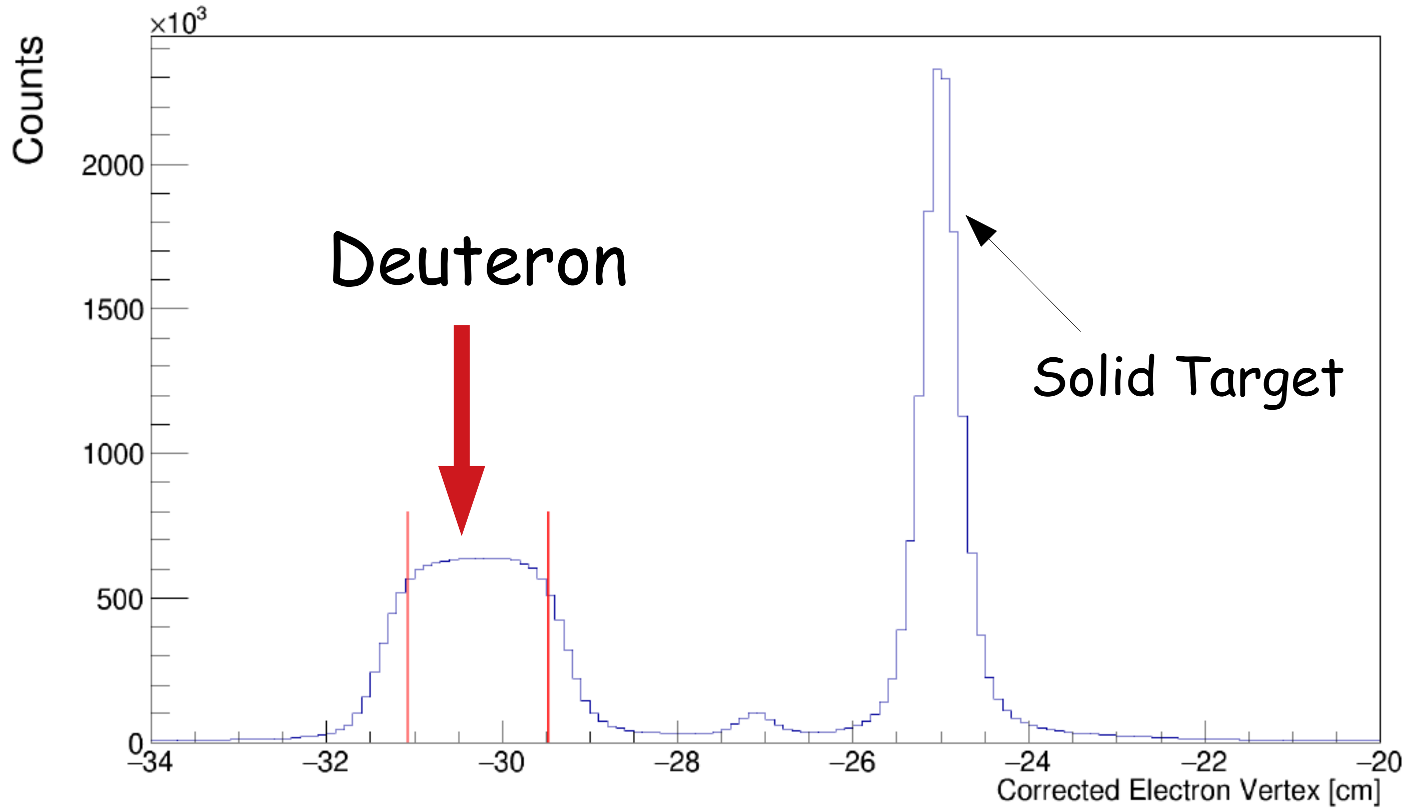
Exclusive d(e,e'pn) reaction:
Test neutron detection algorithm



- Determine momentum resolution
- Establish the neutron detection efficiency
- Check the sensitivity to Veto algorithm

d(e,e'p) selection

1. Deuteron vertex
2. Knock out protons
3. Missing mass



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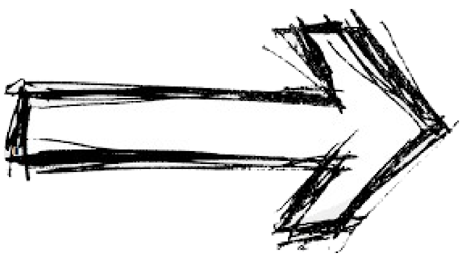

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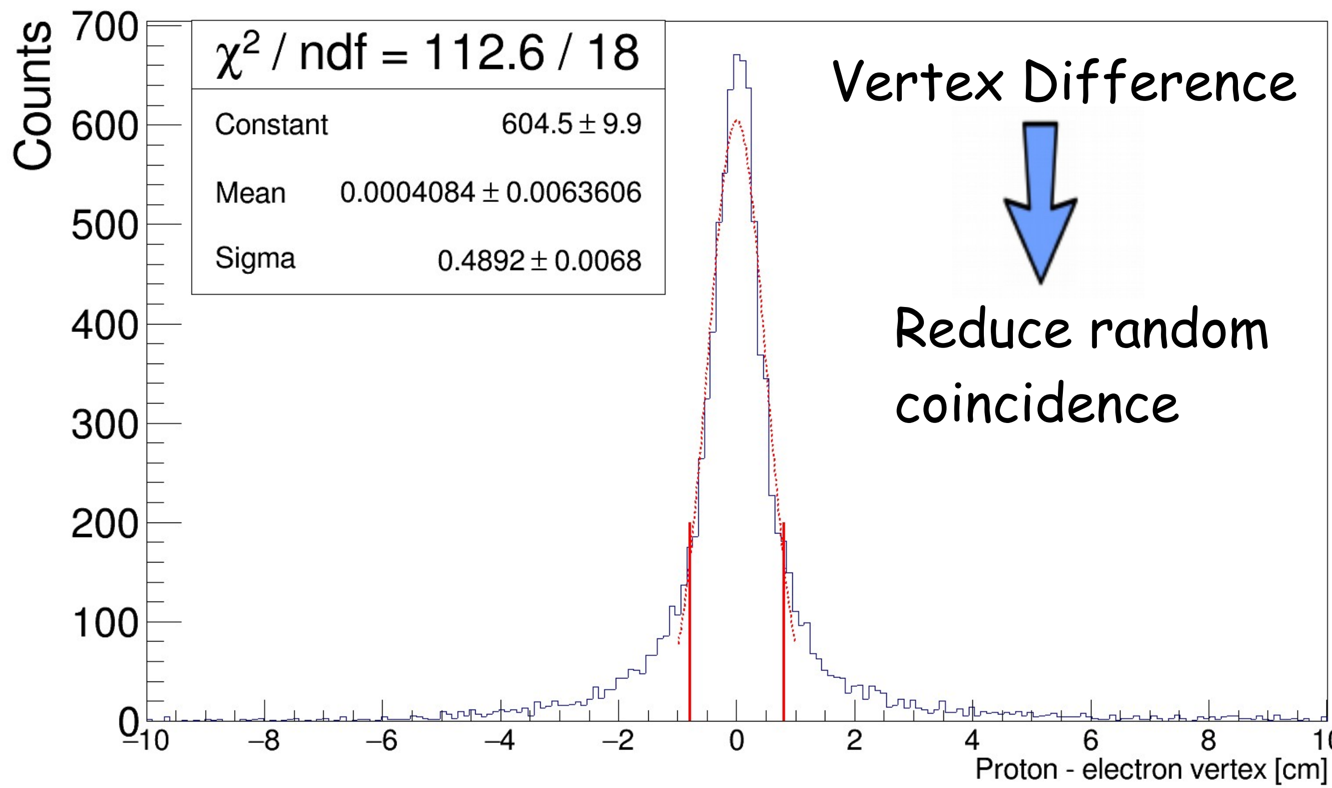

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<u>d(e,e'p) selection</u>

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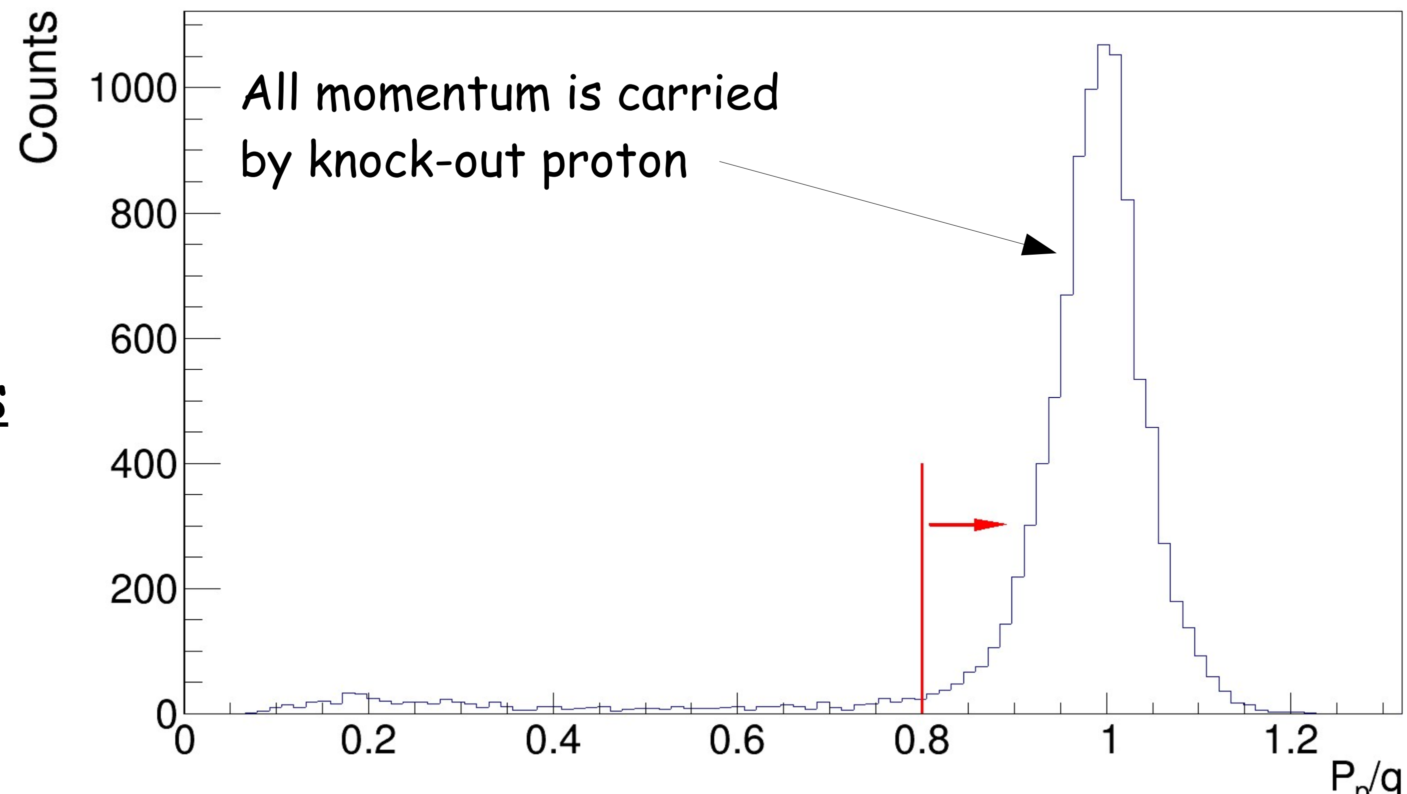

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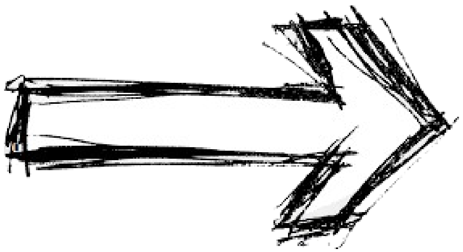

- Determine momentum resolution
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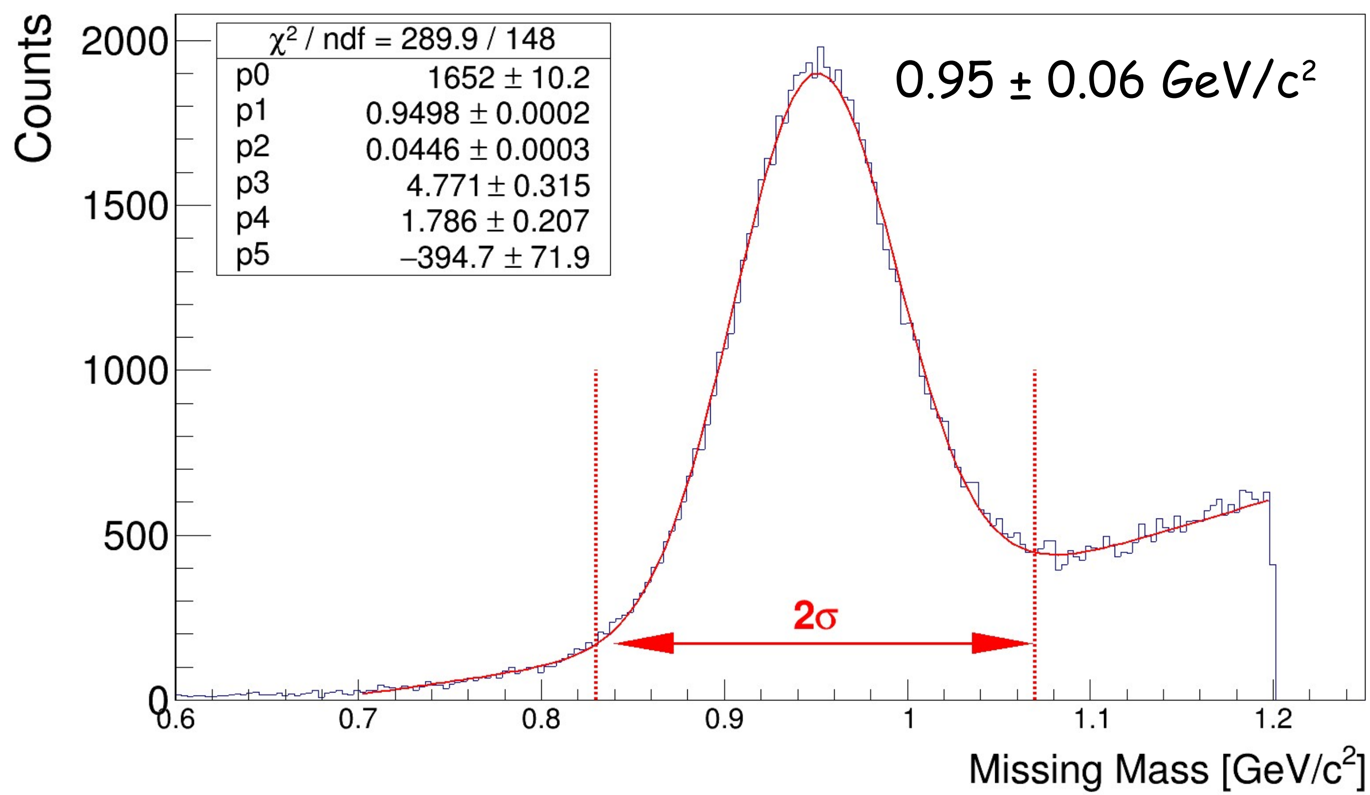
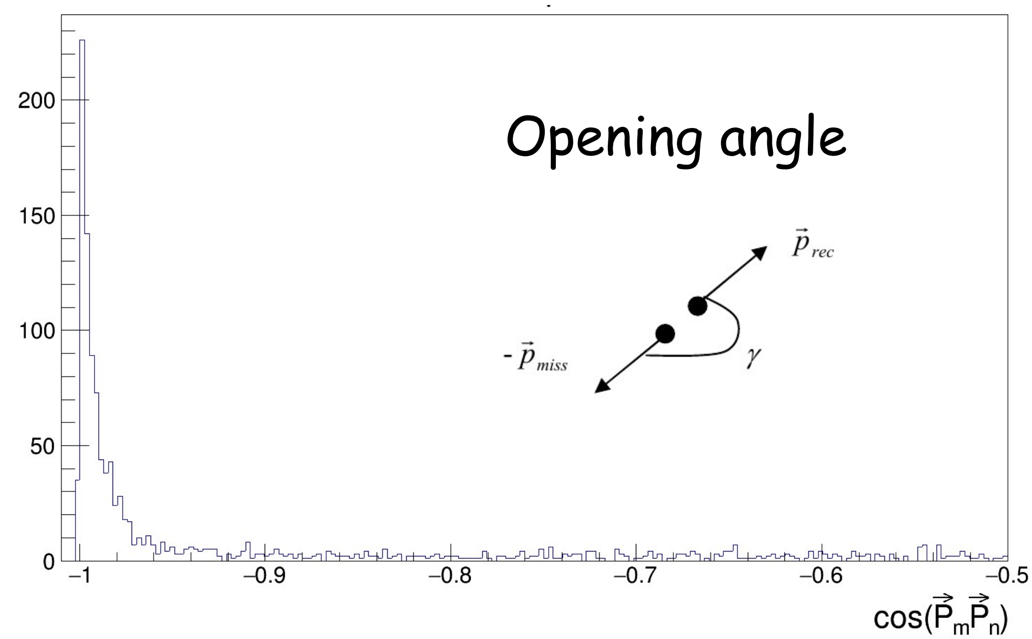
<u>d(e,e'p) selection</u>

1. Deuteron vertex
2. Knock out protons
3. <u>Missing mass</u>



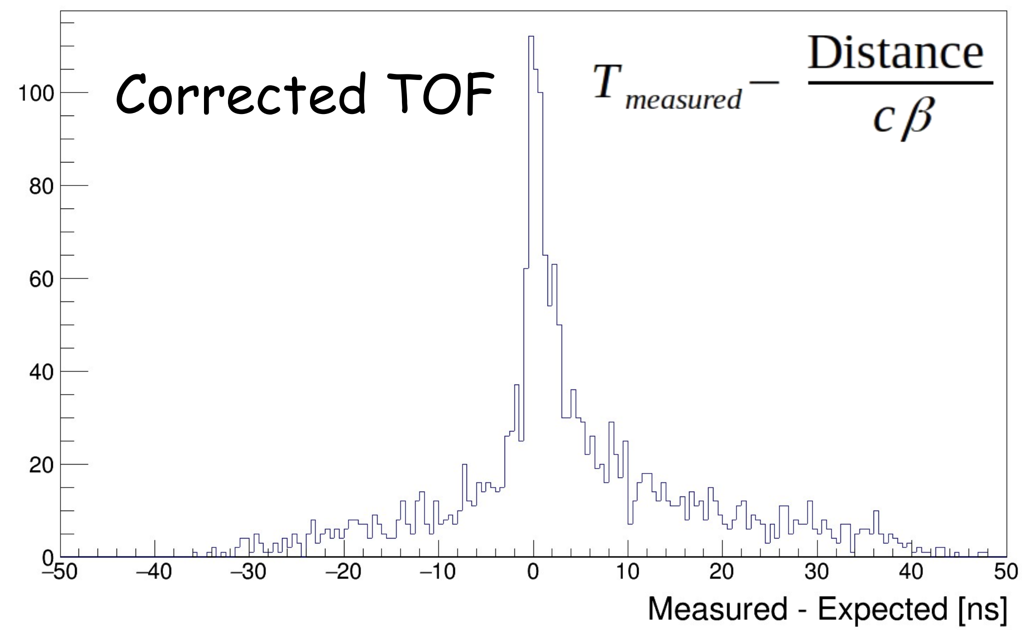
Identification of neutron candidates as neutrons

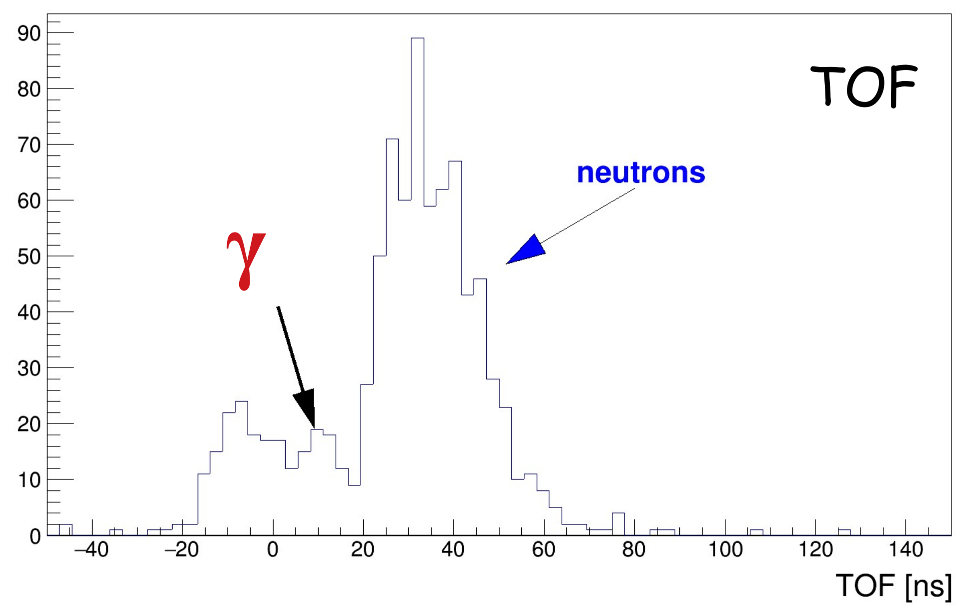


d(e,e′p)

Cuts:

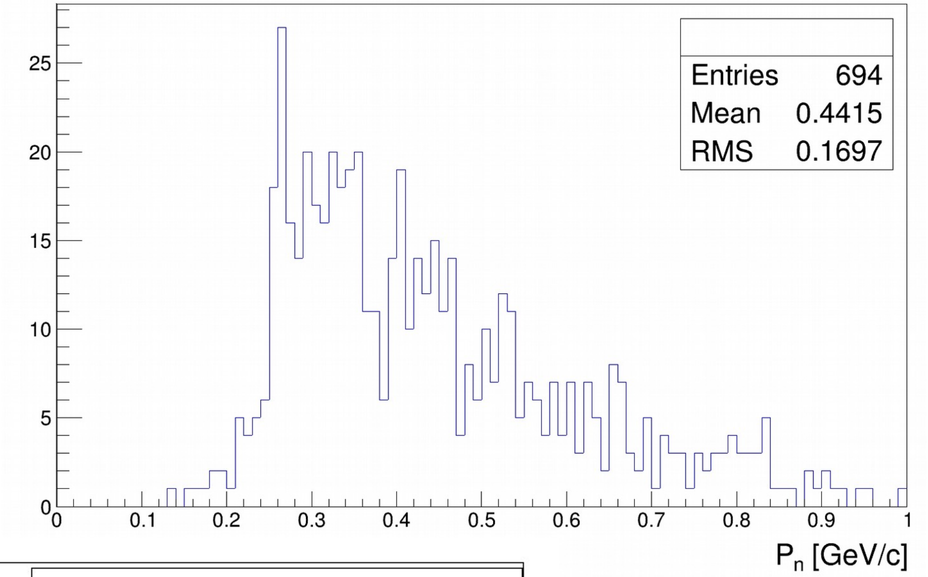
- Vertex
- Vertex difference
- Missing Mass
- Leading Proton
- Missing Momentum
- Energy deposition



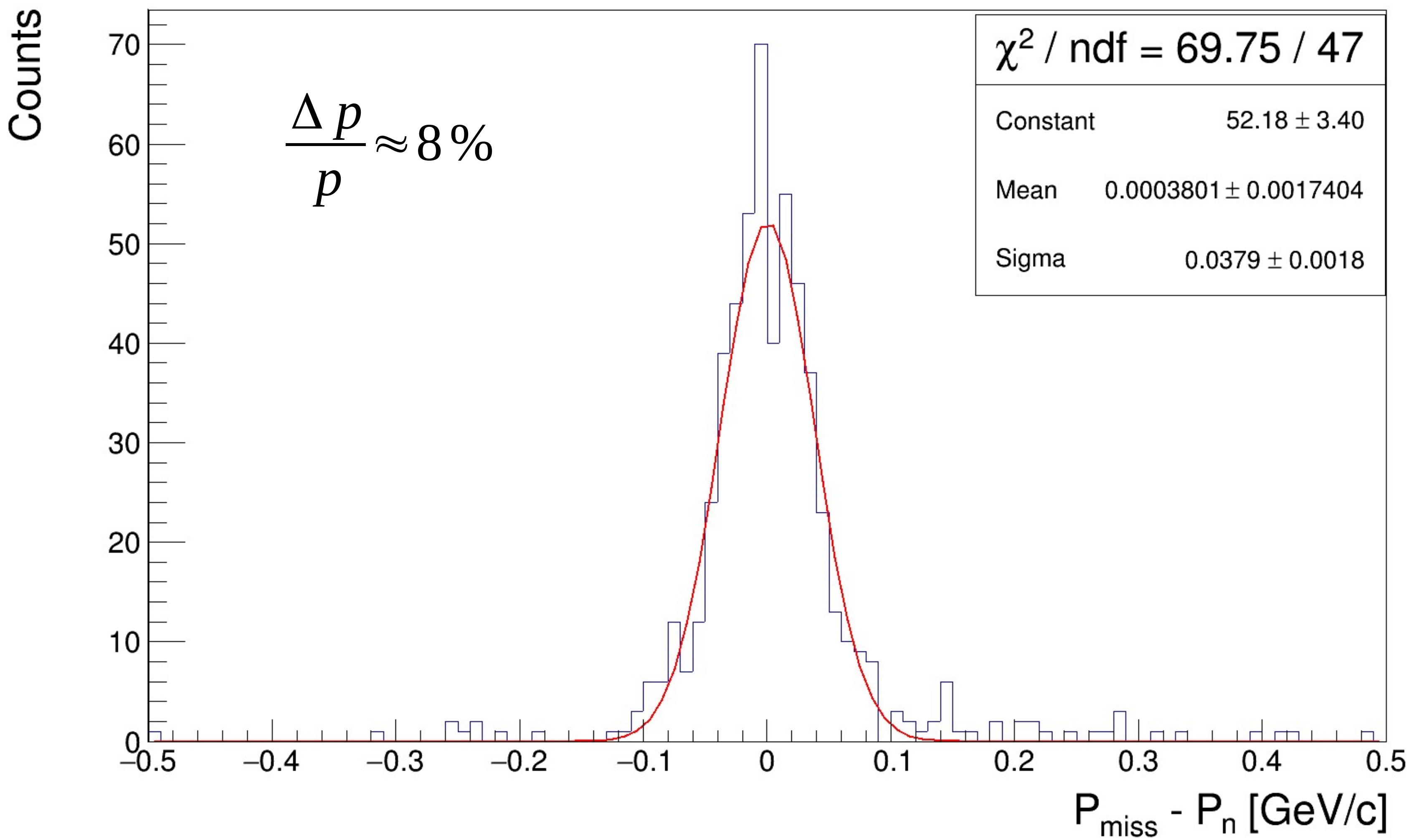


β – Calculated based on missing momentum

Neutron Momentum Resolution

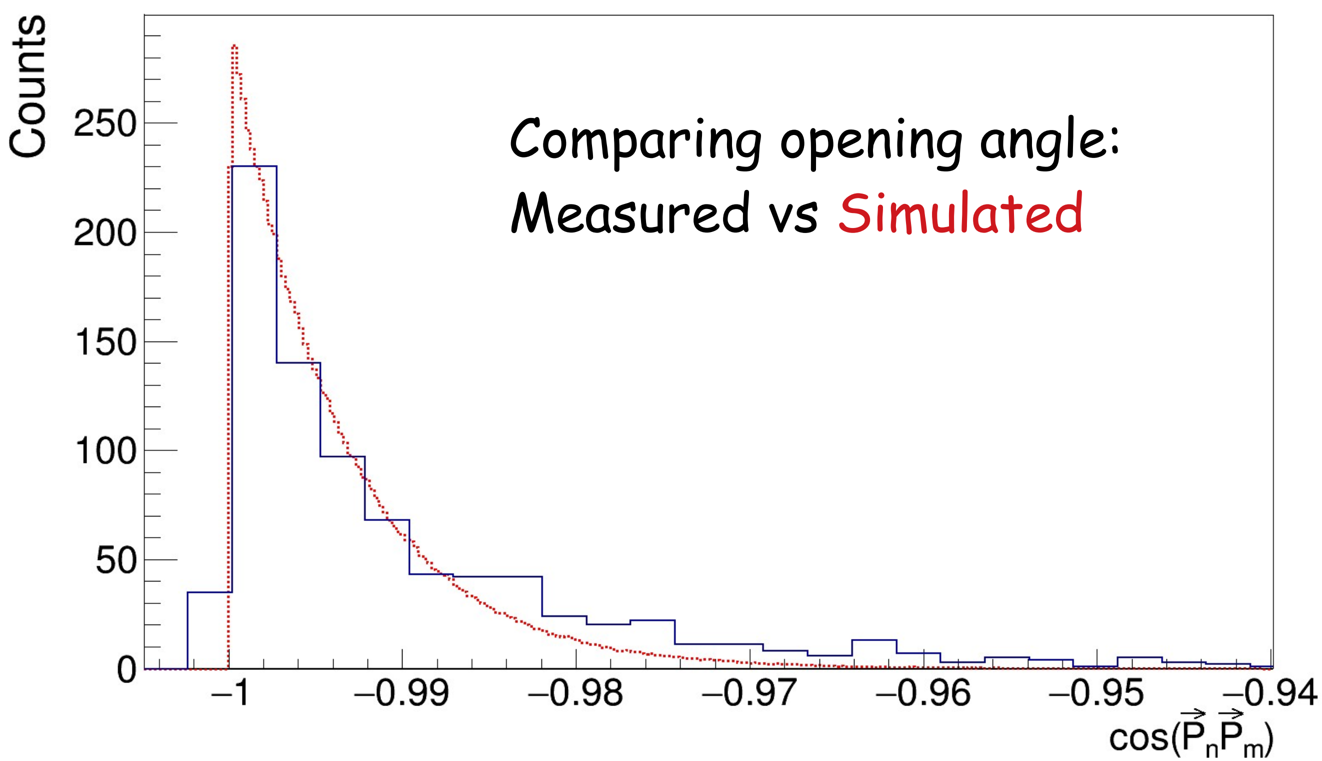


$$\frac{\Delta p}{p} \approx 8\%$$



Validating the momentum resolution

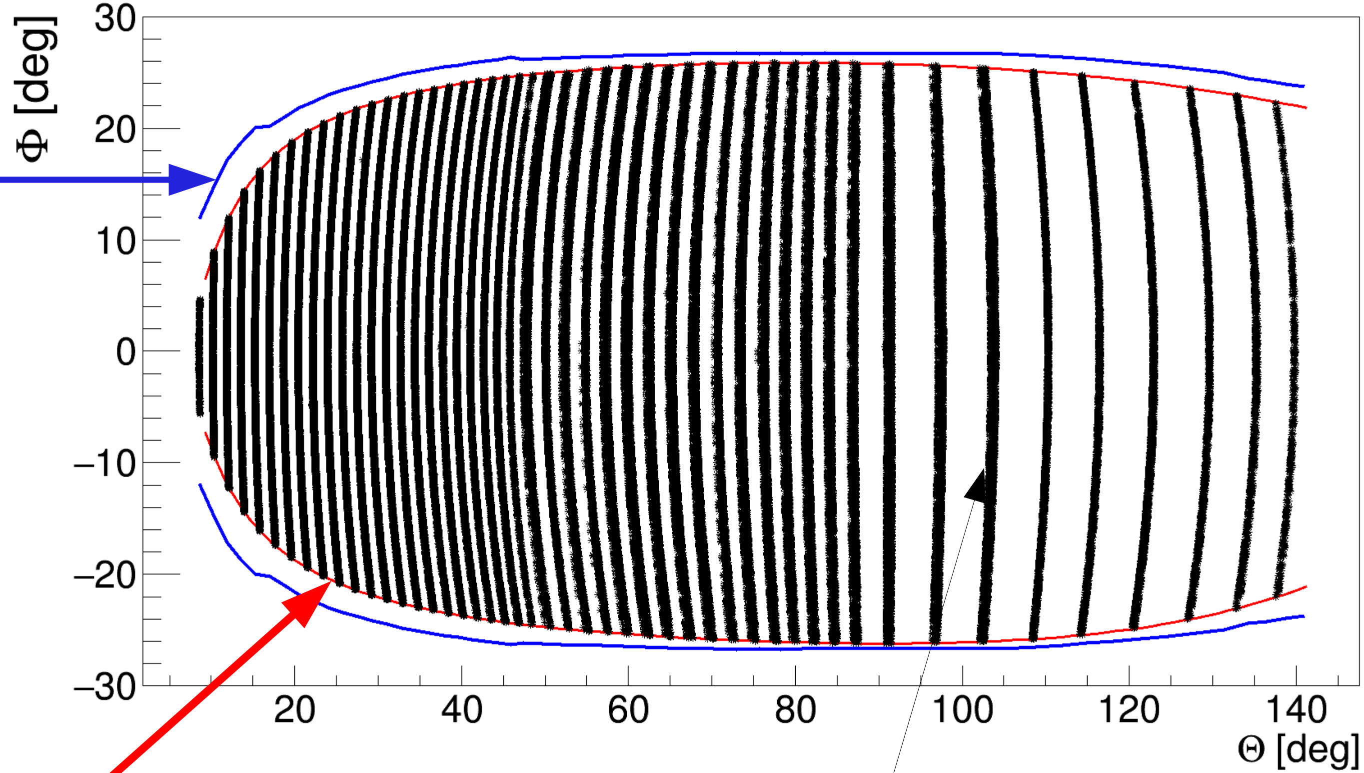
Using d(e,e'p) → Simulate back to back neutrons and smearing them with the momentum resolution



Fiducial cuts for neutrons

Paddles size from the database

E.S. Smith NIM A432, 265 (1999)



Removal of 10 cm from edge of each paddle

Actual hits position with cut out of edges

Neutron detection Efficiency

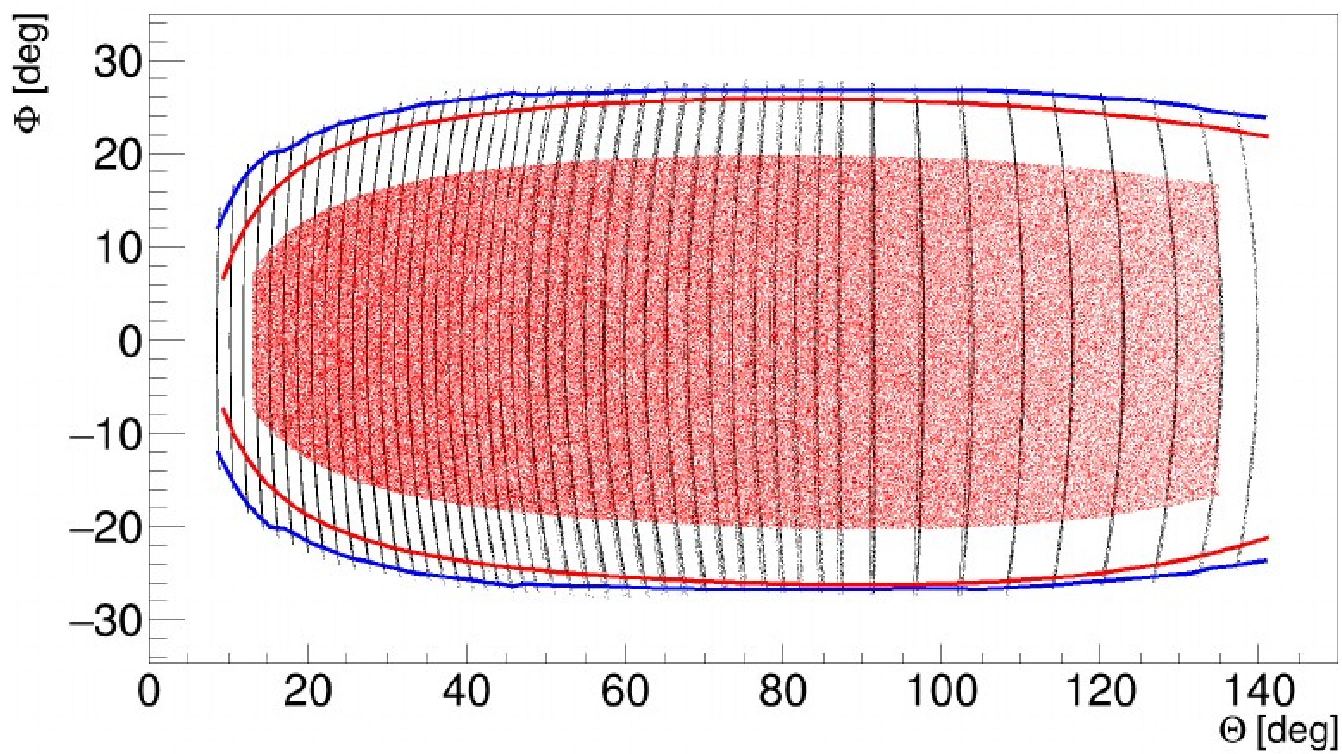
$$\eta = \frac{\# d(e,e'pn)}{\# d(e,e'p)}$$

Measured Neutrons
Expected Neutrons

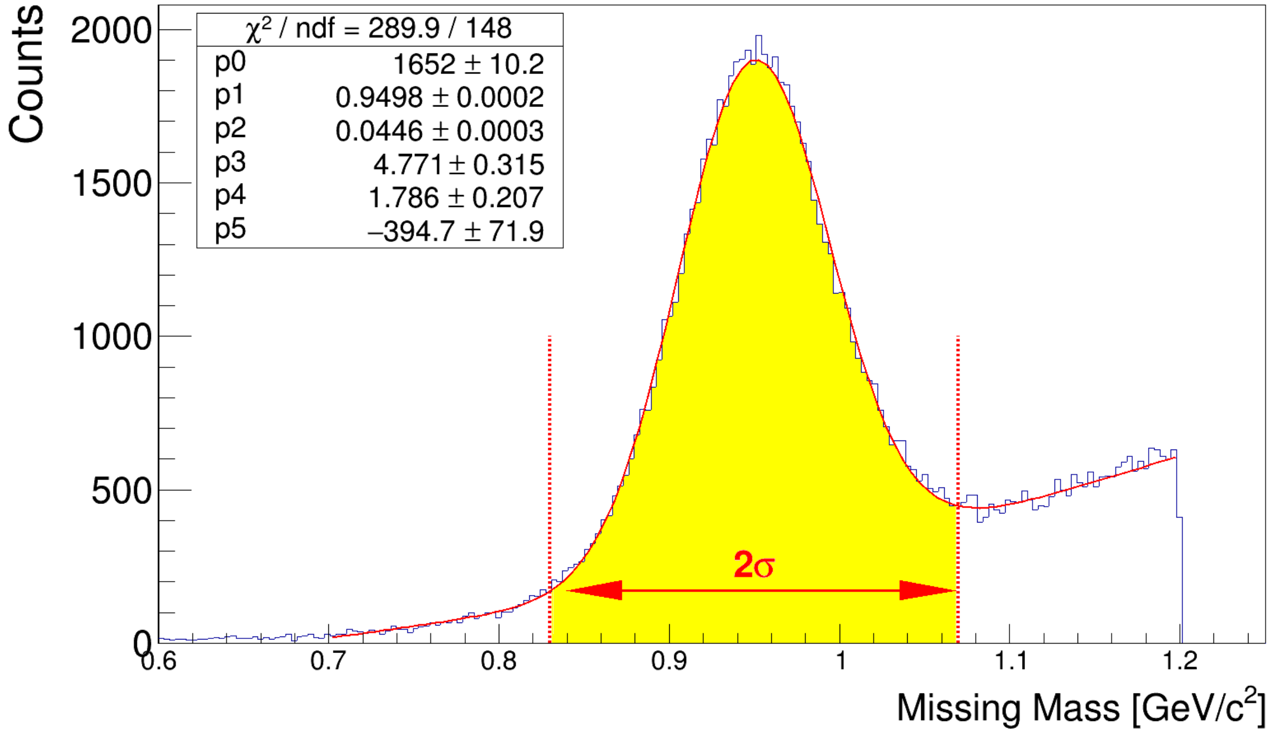
Must hit inside the detector

Projection of missing momentum from d(e,e'p) reaction,

Limit based on angular resolution, keep 2σ from the boundary.



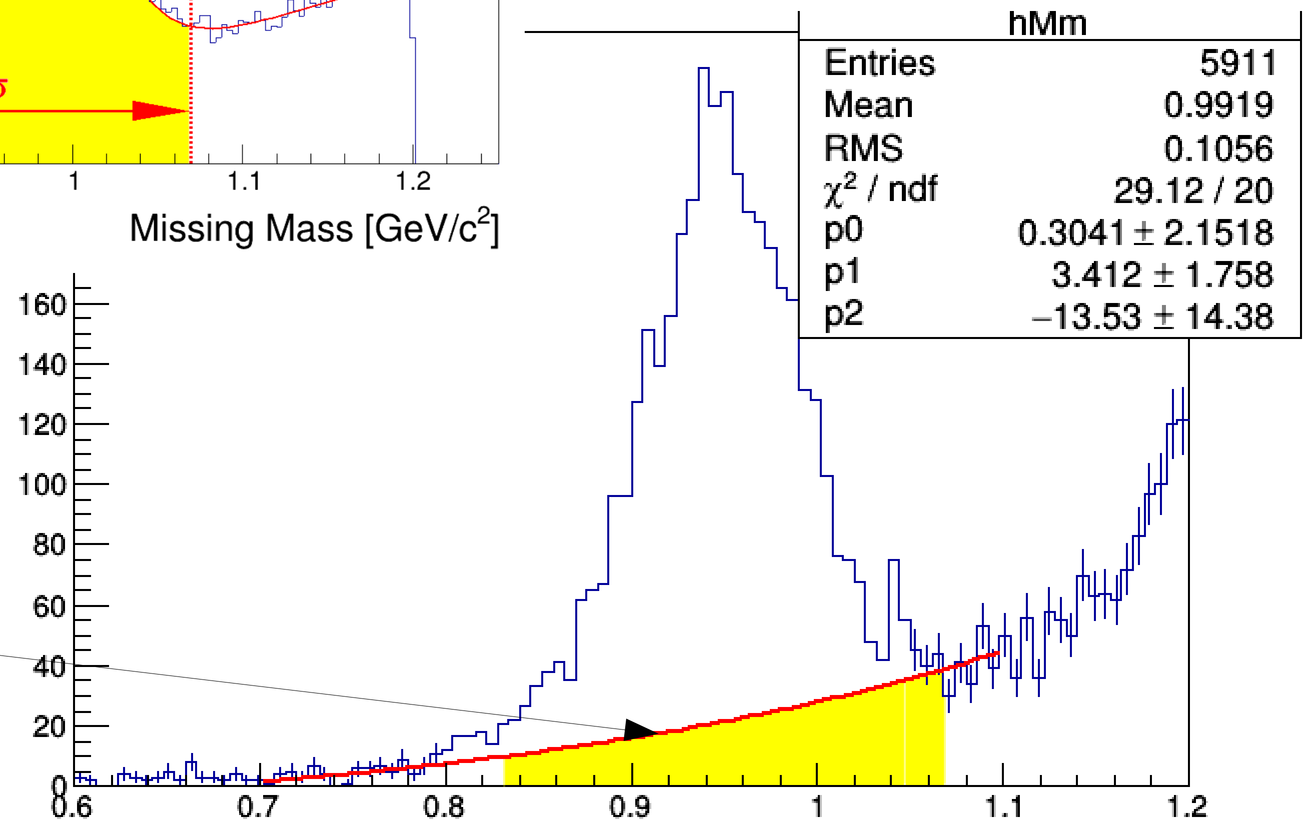
Number of d(e,e'p) events



Count number of events under the missing mass peak

Estimation of background

Empirical Fit



Number of d(e,e'pn) events

Cuts:

Vertex

Vertex difference

Missing Mass

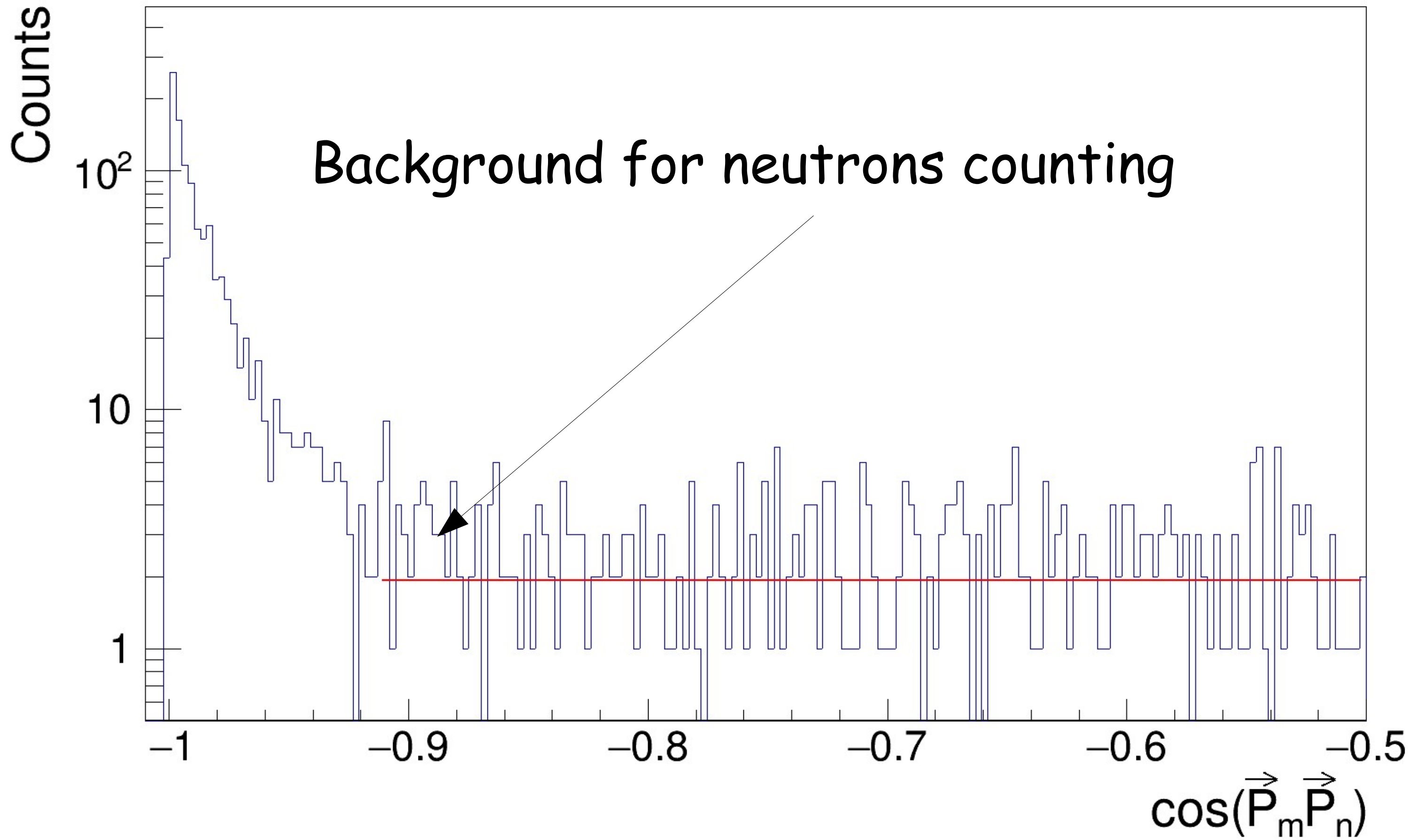
Leading Proton

Missing Momentum

Energy deposition

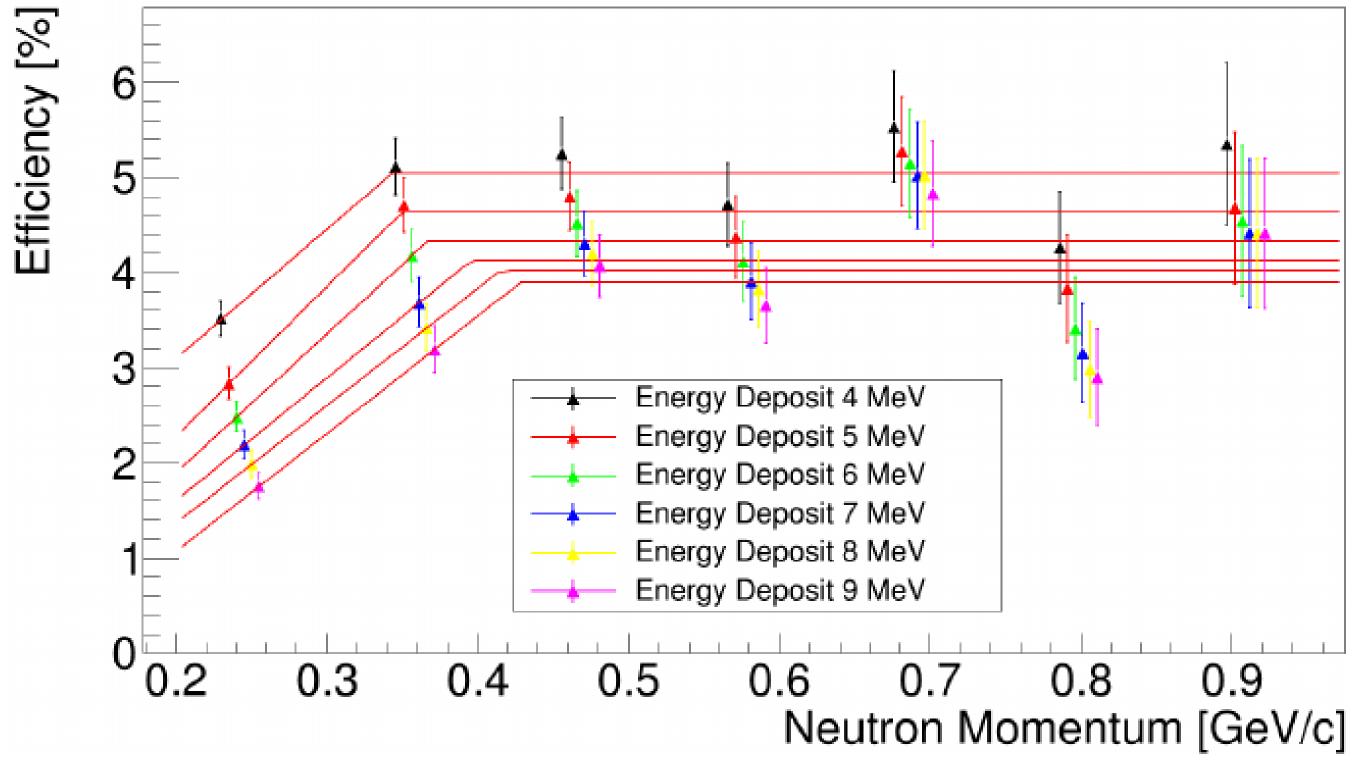
TOF

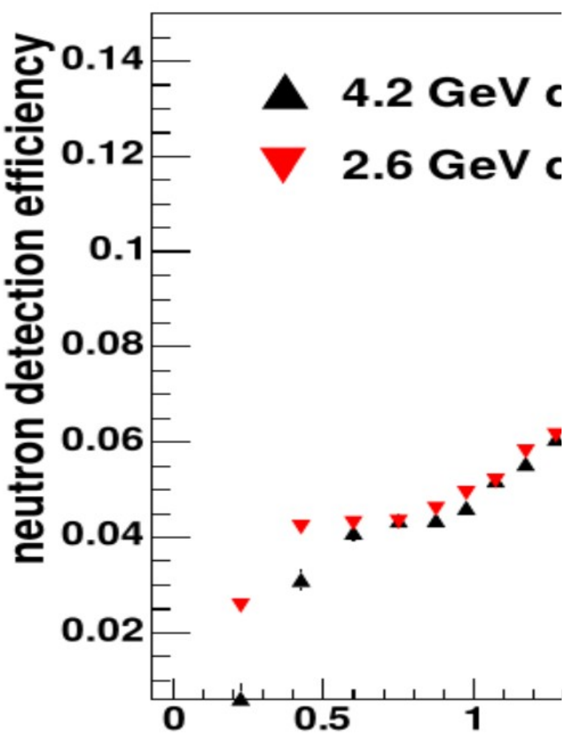
Corrected TOF



Absolute neutron detection efficiency

$$\eta = \frac{\# d(e,e'pn)}{\# d(e,e'p)}$$

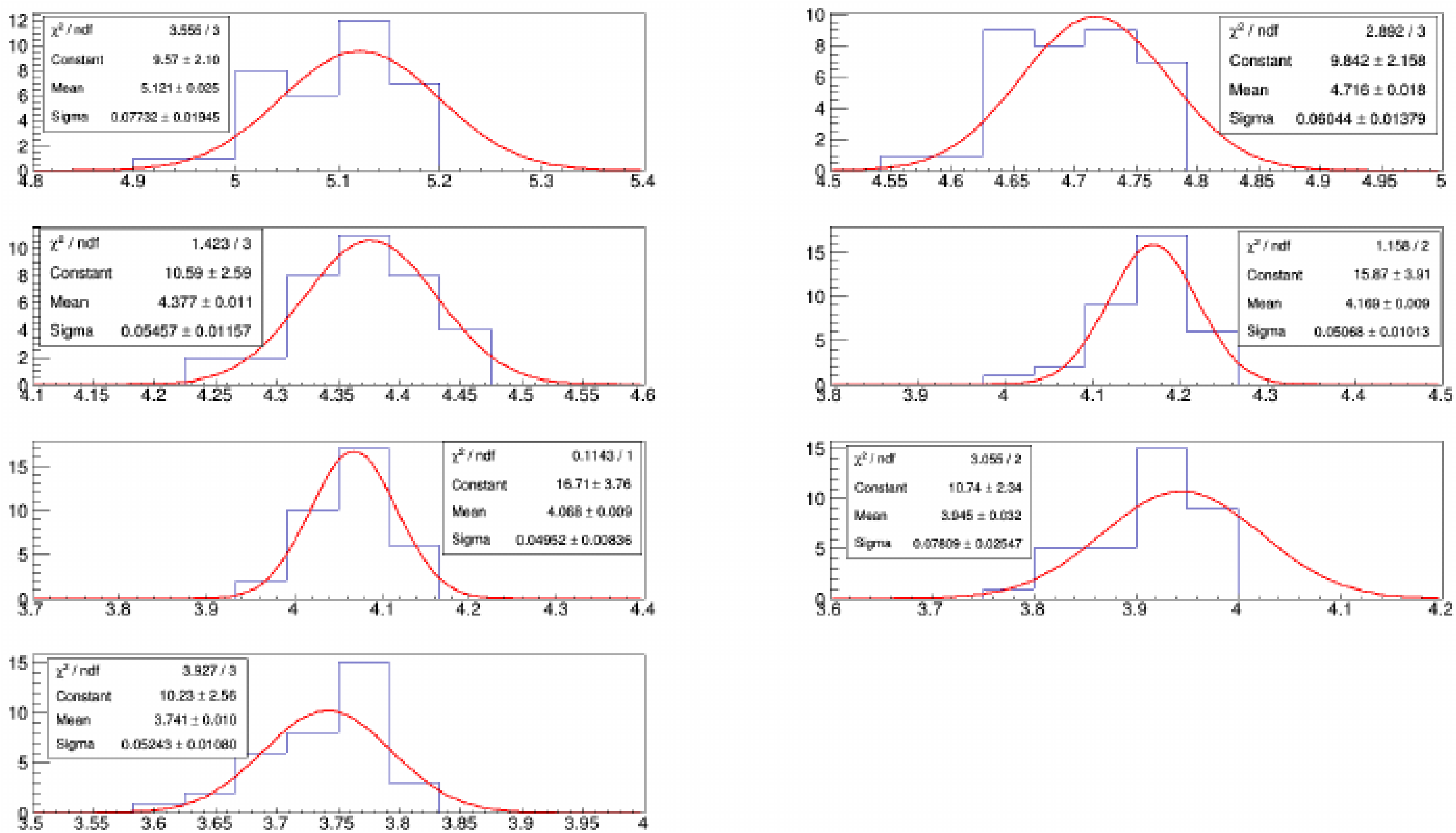




Compared to previous analysis

CLAS Analysis Note 2008-103

Efficiency sensitivity tests for different energy depositions (4 – 10 MeV)



Extraction of systematic uncertainty

Selection of C(e,e'p) events

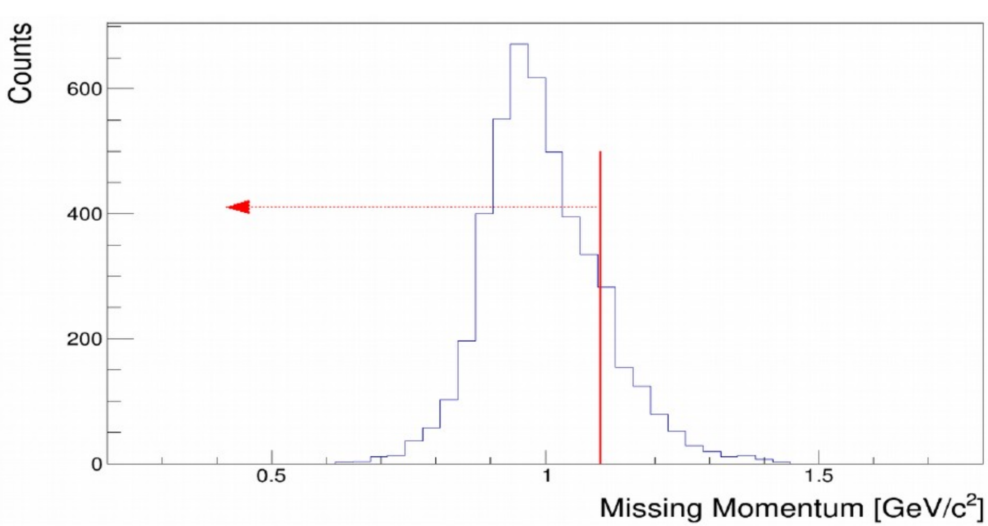
Selection of (e,e'p) events is identical to previous analysis
A(e,e'pp) and A(e,e'np)

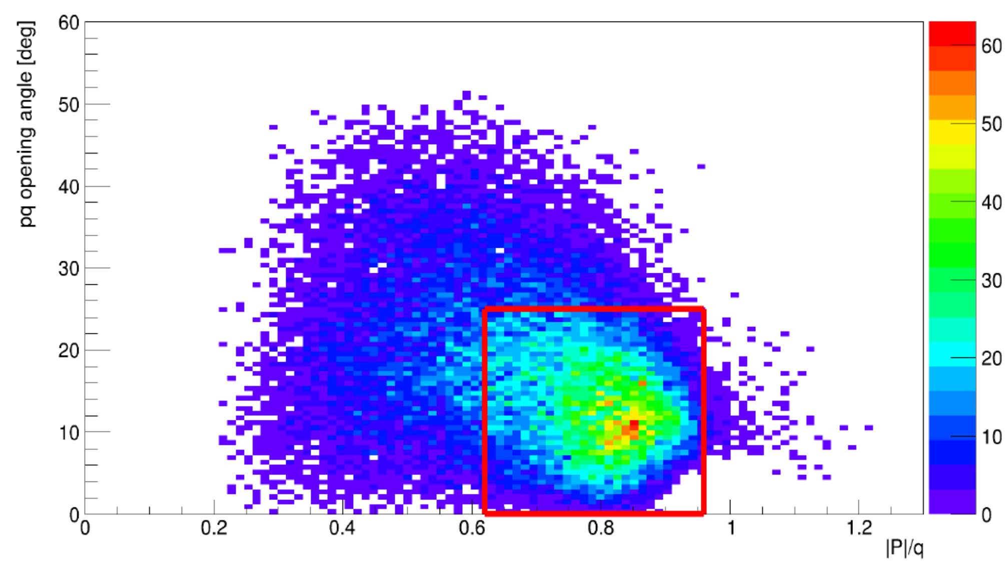
$X_B > 1.2$

Leading Proton: $0.96 > q/p > 0.62$ and acos(pq) <25

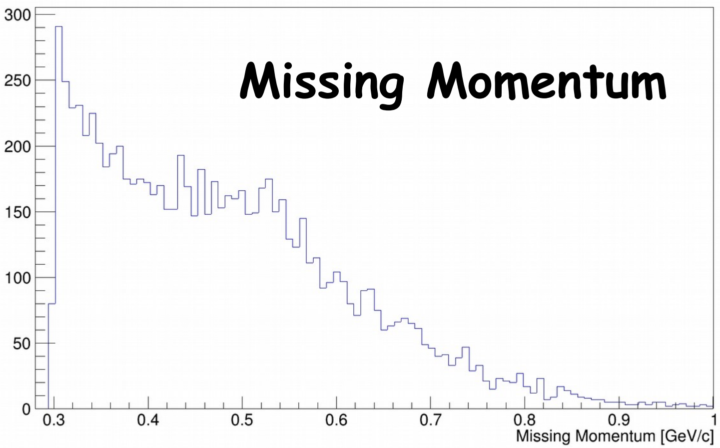
Missing Mass < 1.1

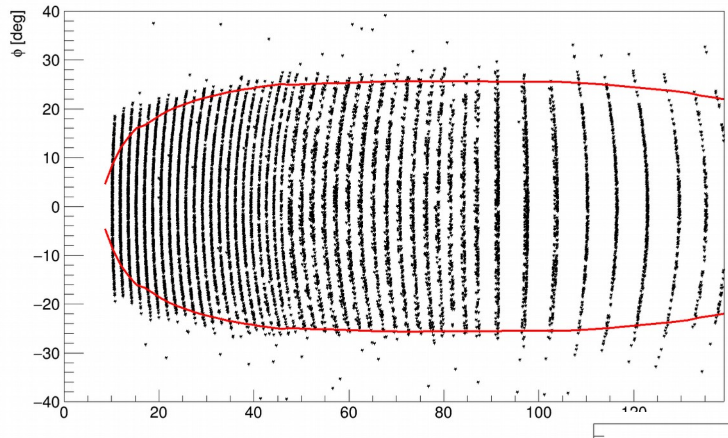
300 MeV/c < Missing Momentum < 1 GeV/c



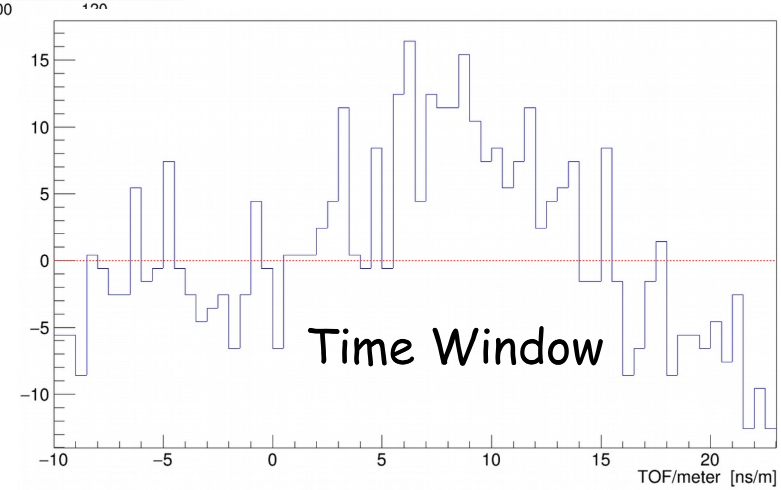


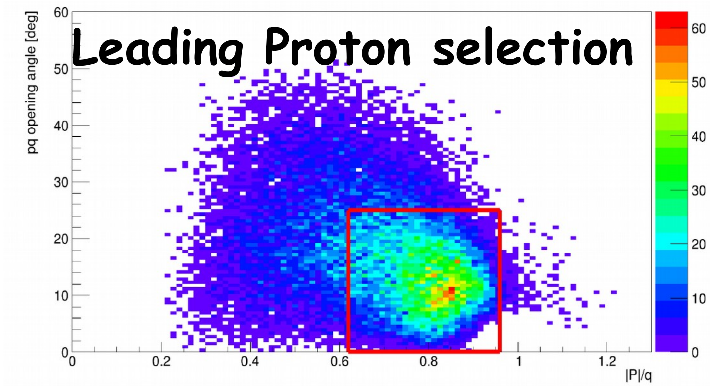
Selection of C(e,e'pn) events

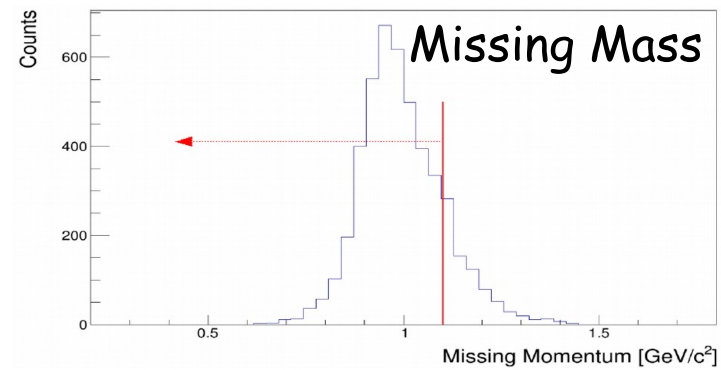


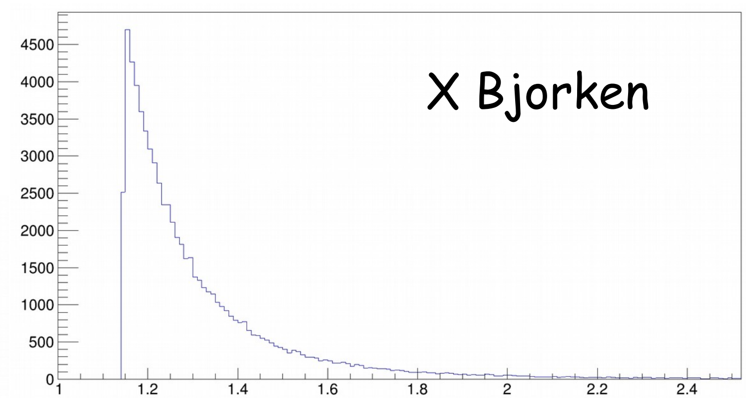


Paddle Geometry

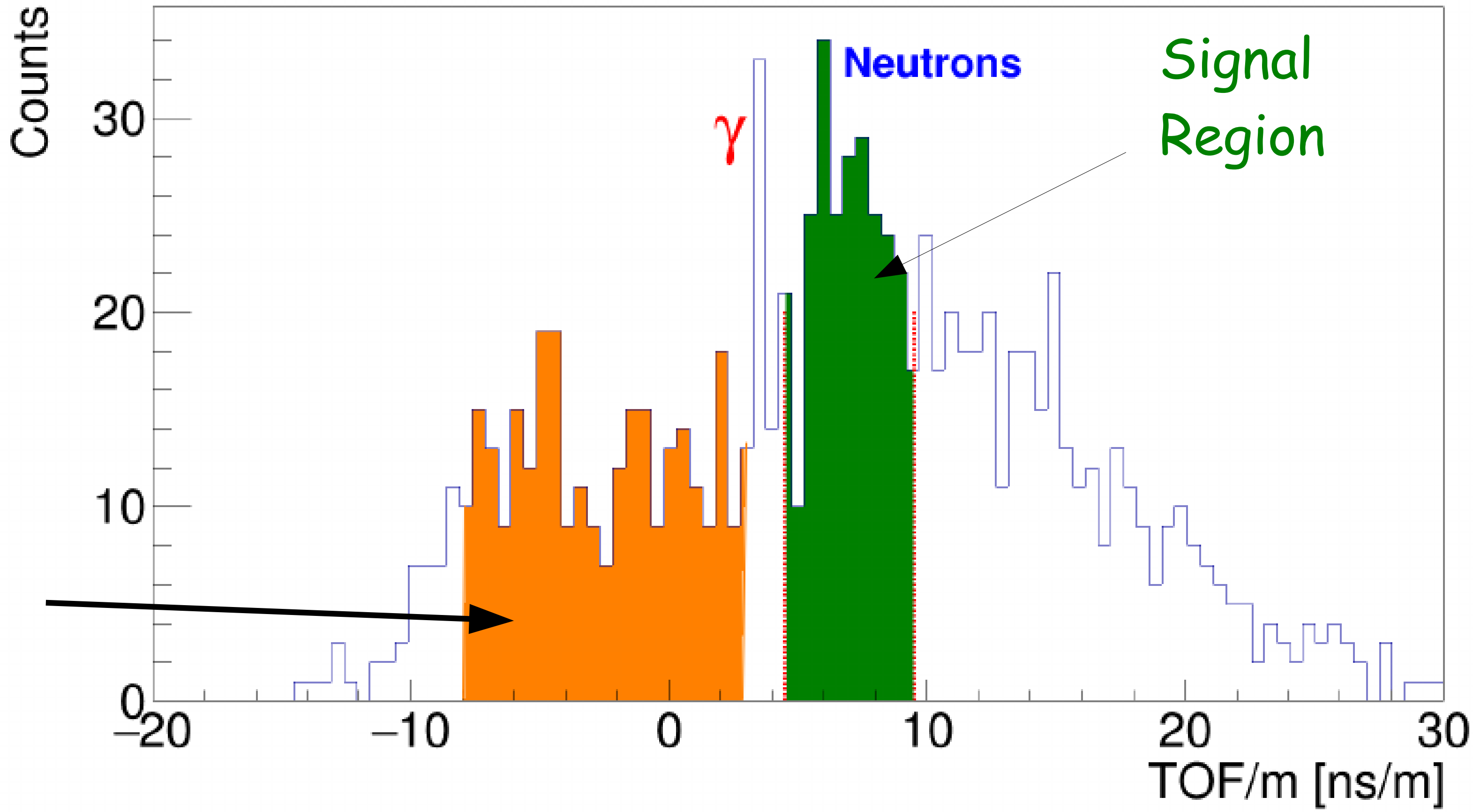








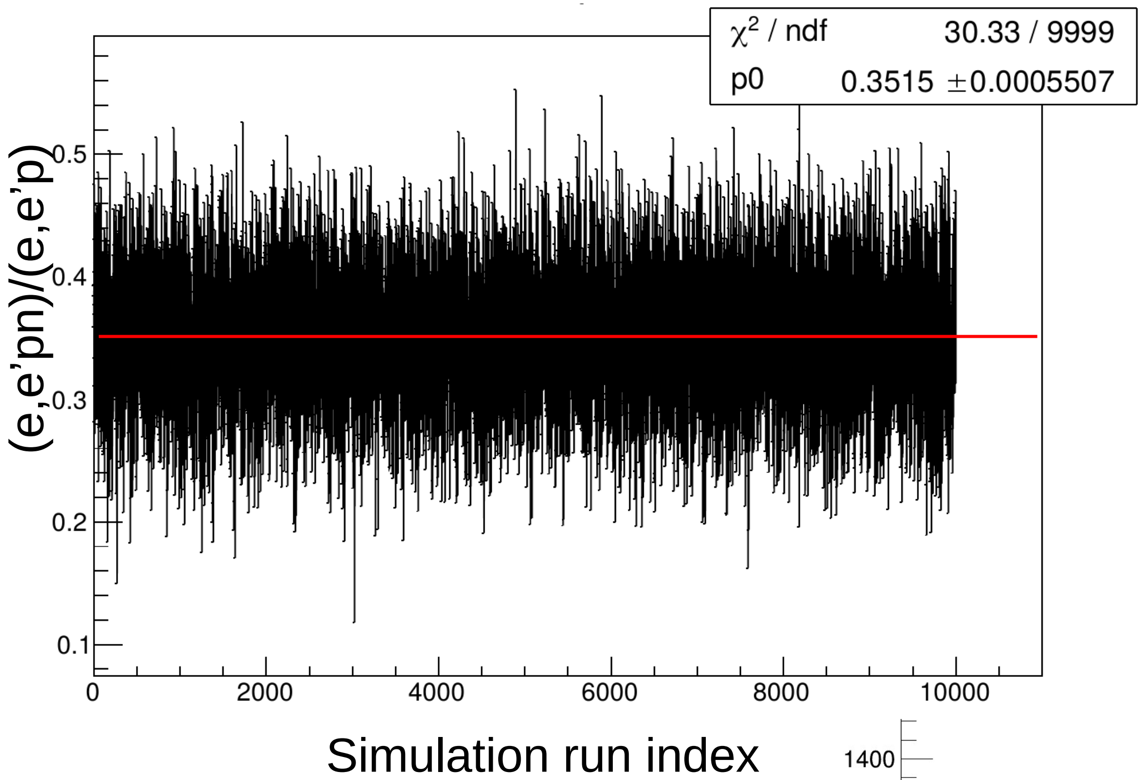
Extracting the number of recoil neutrons

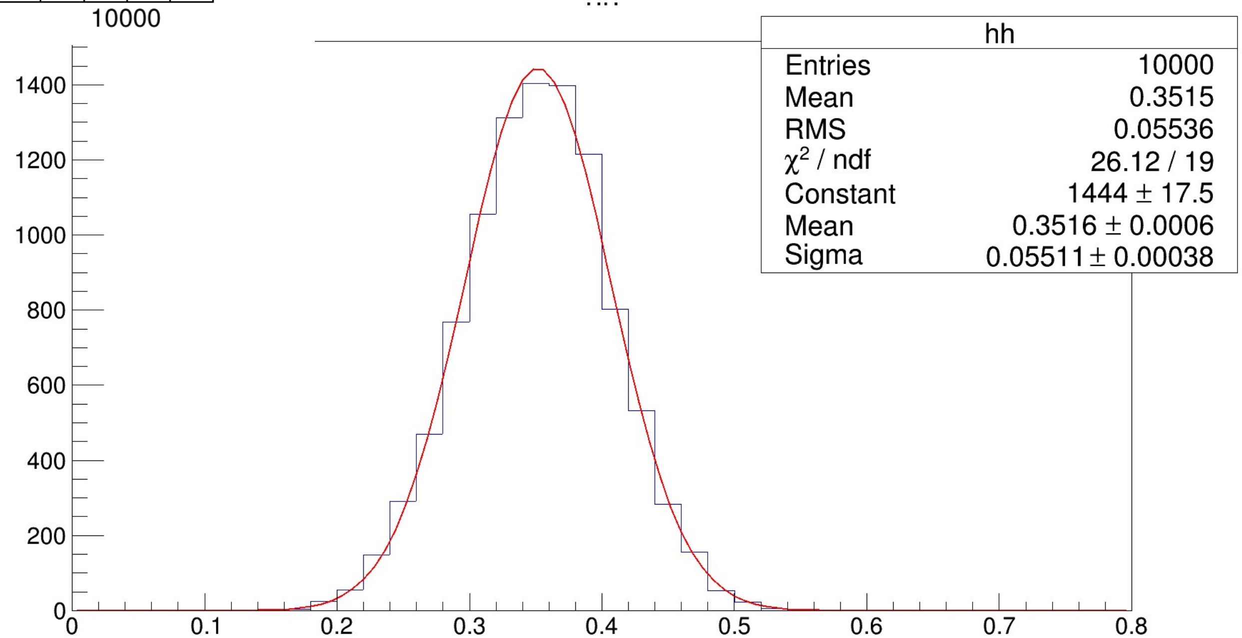


$$p_n = \frac{m}{\sqrt{\left(\frac{0.3 \cdot t}{d}\right)^2 - 1}}$$

Correcting each bin based on the neutron detection efficiency

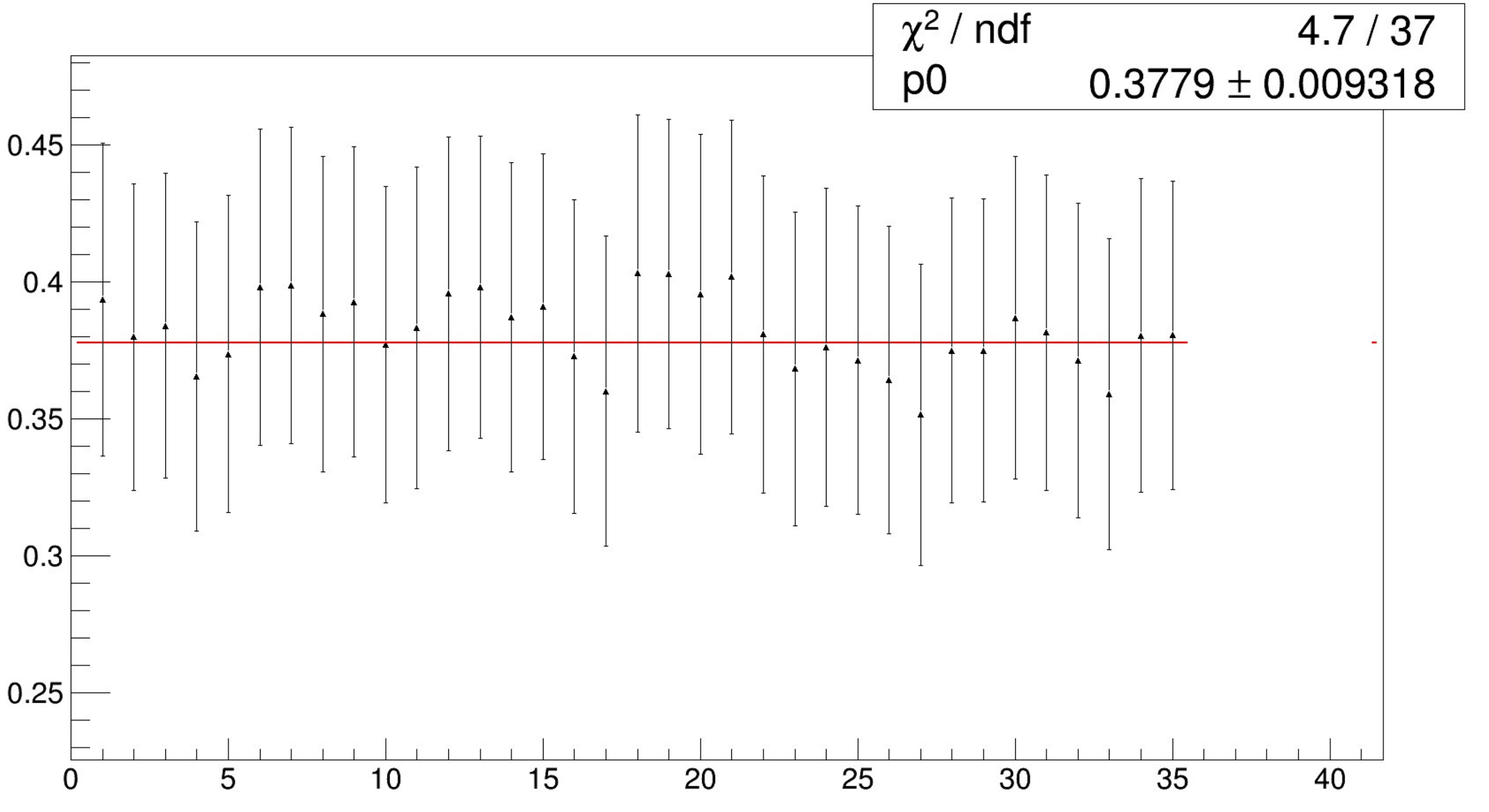
Sensitivity check of BG subtraction
10 000 realizations



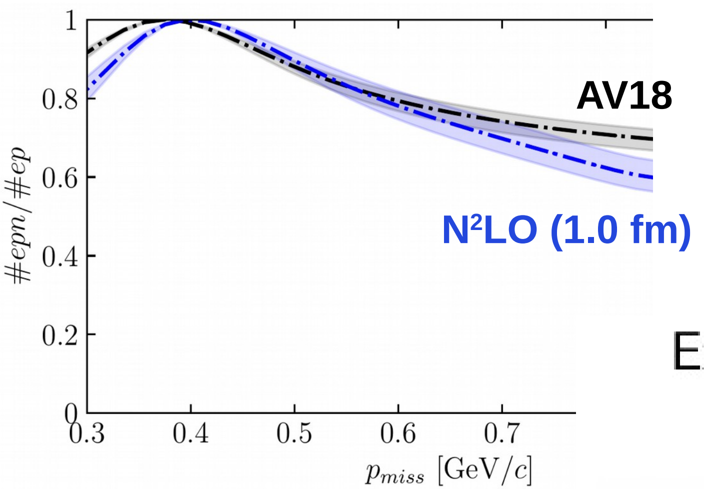


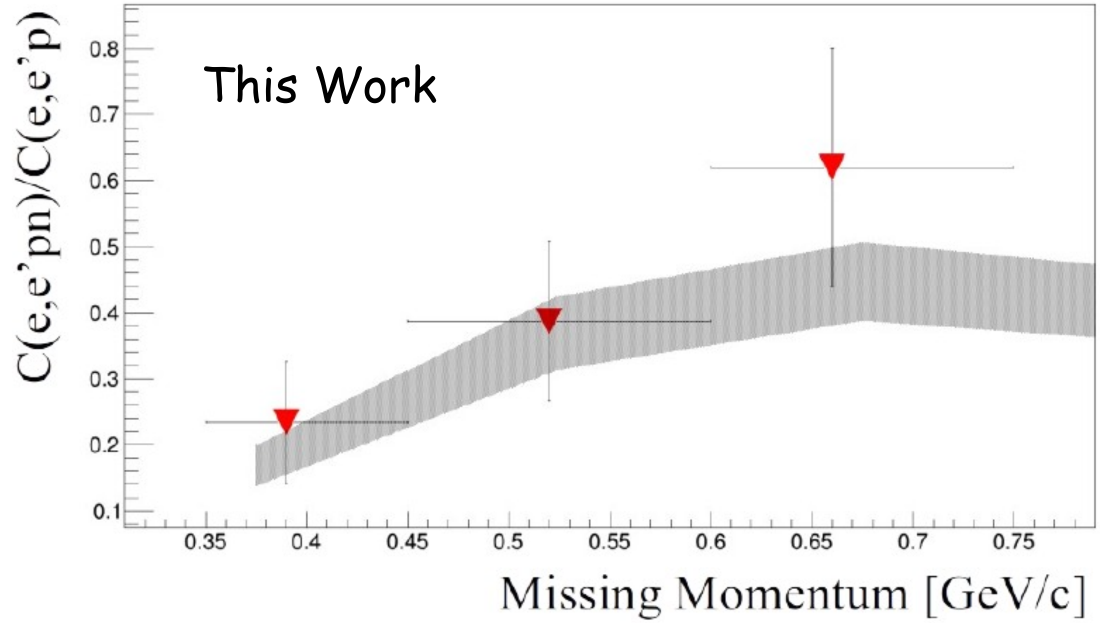
Using the background subtraction and events selection for C(e,e'pn) and C(e,e'p)

C(e,e'pn)/C(e,e'p) for whole missing momentum range

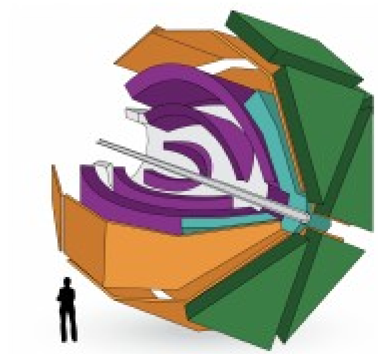


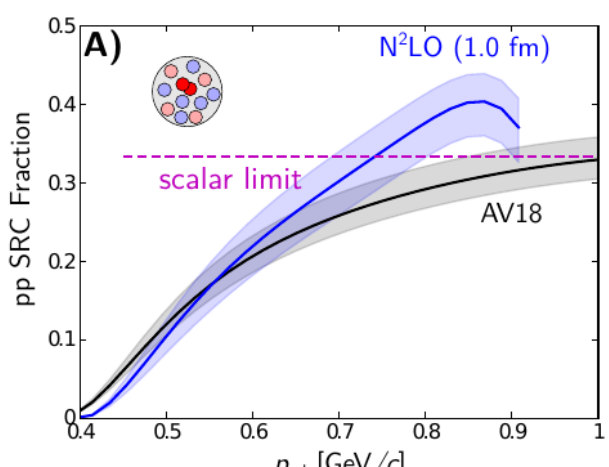
*Data is corrected to the neutron detection efficiency



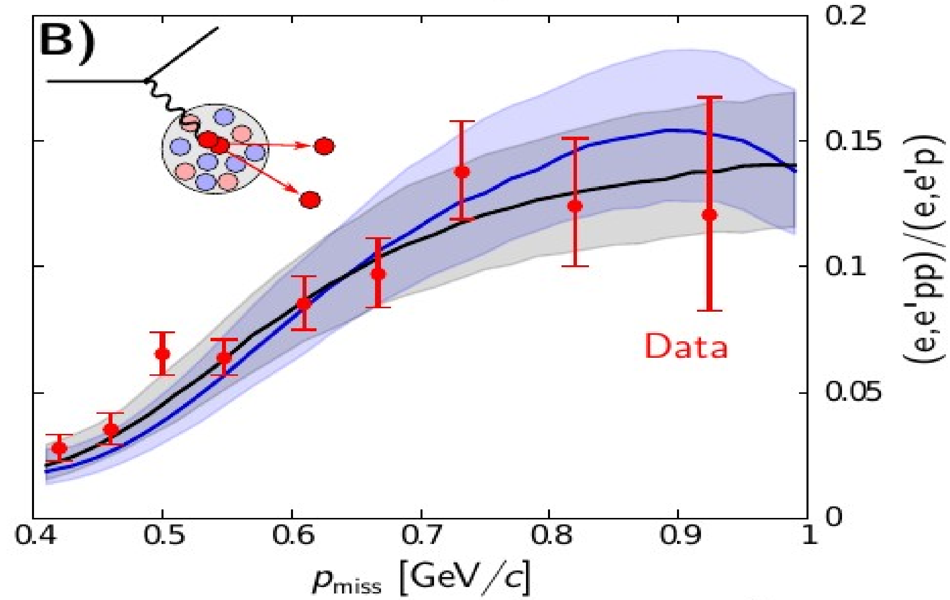


Experiment





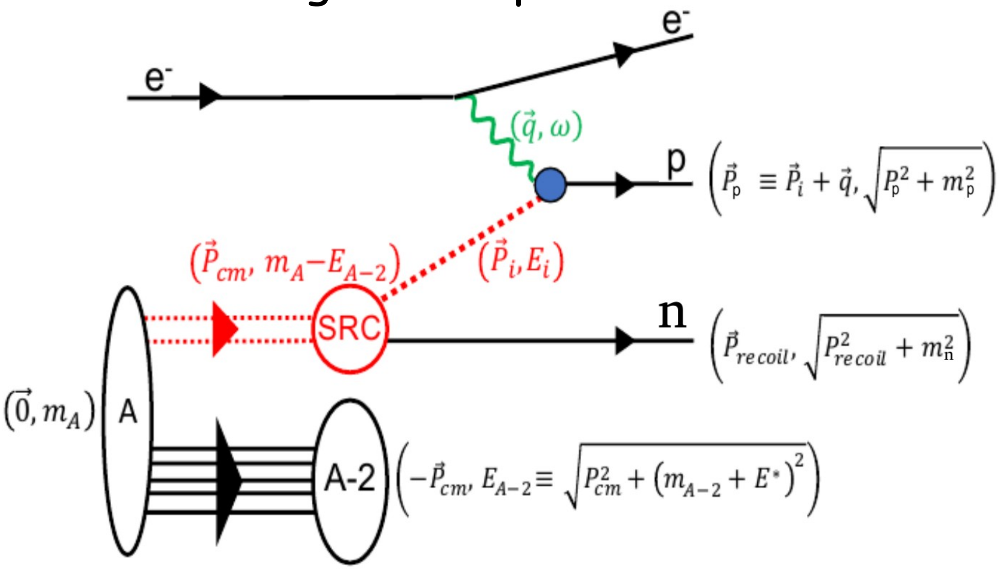
SRC Break-up Data

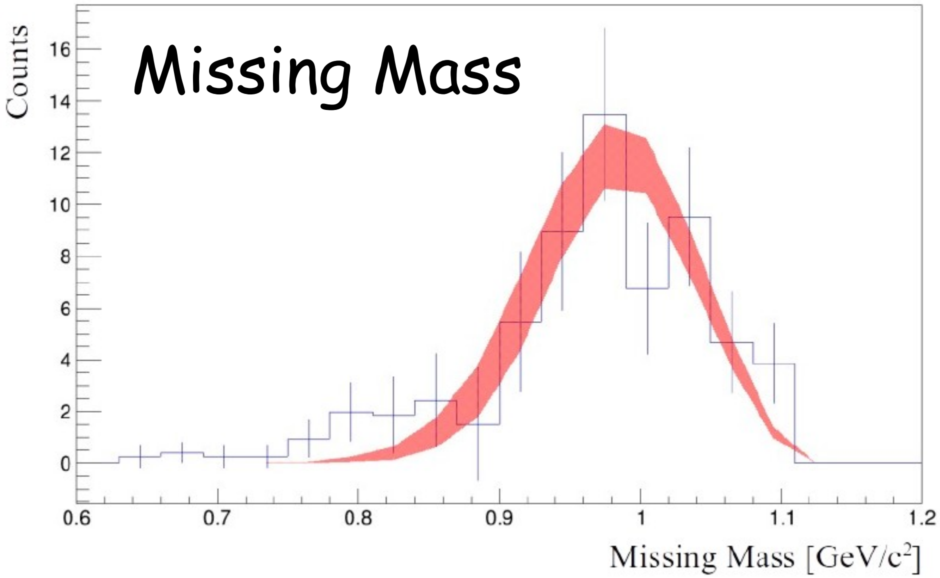


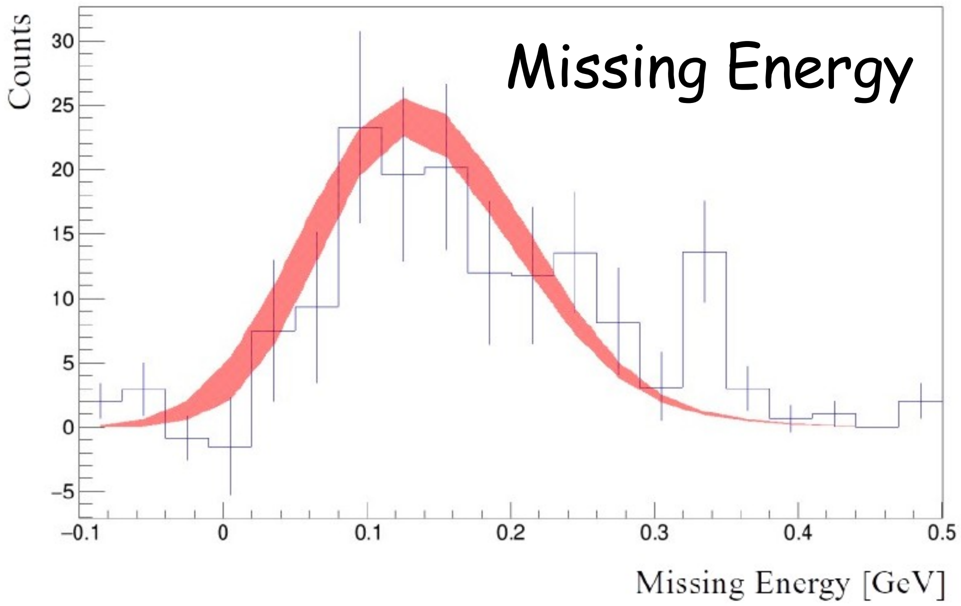
Comparison between the GCF

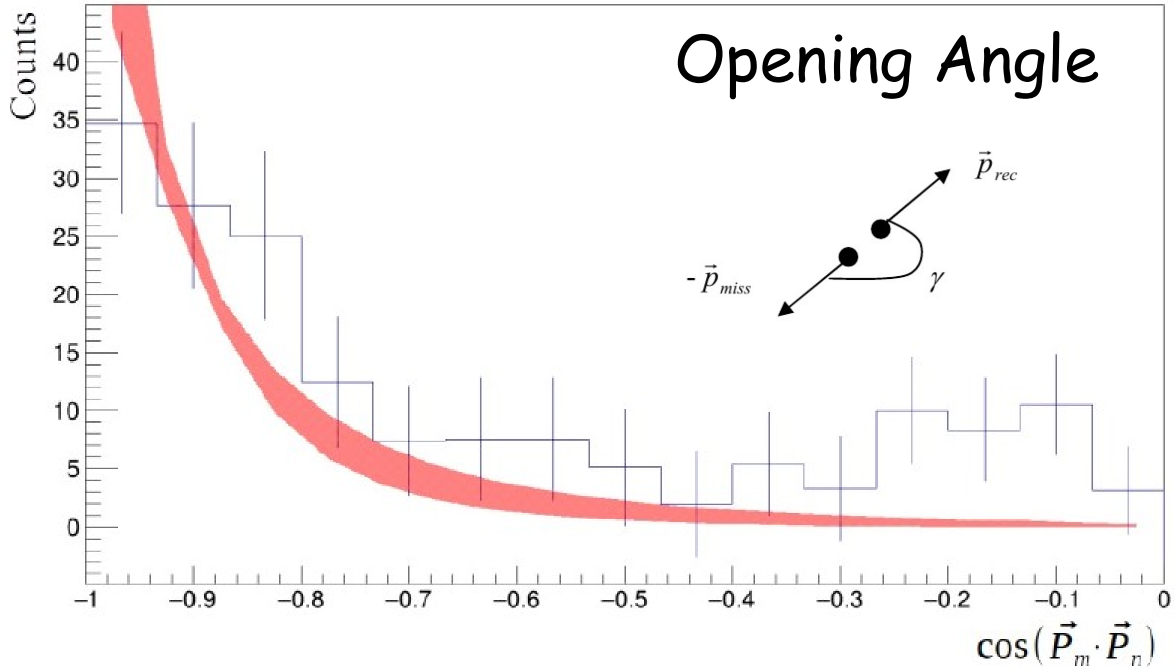
See Axel talk for details

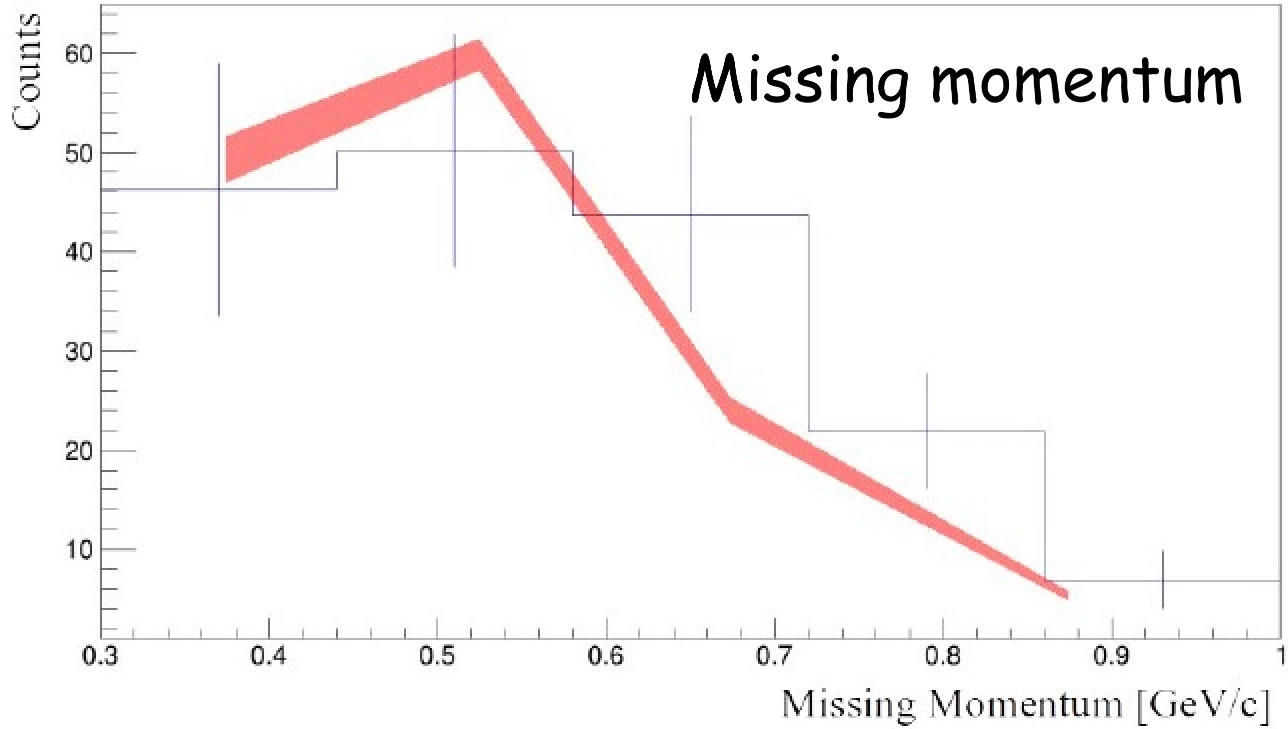
Generator using the simple reaction mechanism








Opening Angle
Counts
$\vec{p}_{rec}$
$-\vec{p}_{miss}$
γ
$\cos(\vec{P}_m \cdot \vec{P}_n)$


Missing momentum
Counts
Missing Momentum [GeV/c]

Summary

C(e,e'pn)/C(e,e'p) is complimentary to C(e,e'pp)/C(e,e'p) with less sensitive to the SCX correction.

Missing momentum dependence is consistent with the prediction of GCF model.

Analysis report will be submitted in the following weeks