A(e,e'pn) detecting Neutrons in TOF counters

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Clas collaboration meeting

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Motivation

Search for Short Range Correlation using A(e,e'pn) reaction

Complimentary analysis to A(e,e'pp)

Advantages over A(e,e'np) (*knocked out neutron detected in EC*)

Better missing momentum resolution (same as A(e,e'pp) analysis)

Larger acceptance compared to A(e,e'np)

A(e,e'pn)/A(e,e'p) as function of missing momentum

A(e,e'pp) and A(e,e'pn) Allows better comparison to NN-interaction calculations (using the generator)

Selection of neutrons 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: <u>Drift Chambers</u>

<u>Pros</u>.

- Blind to neutral particles

<u>Cons</u>.

- Unreconstructed track can be selected as a netron.

Veto algorithm

Use drift chamber as a veto plane

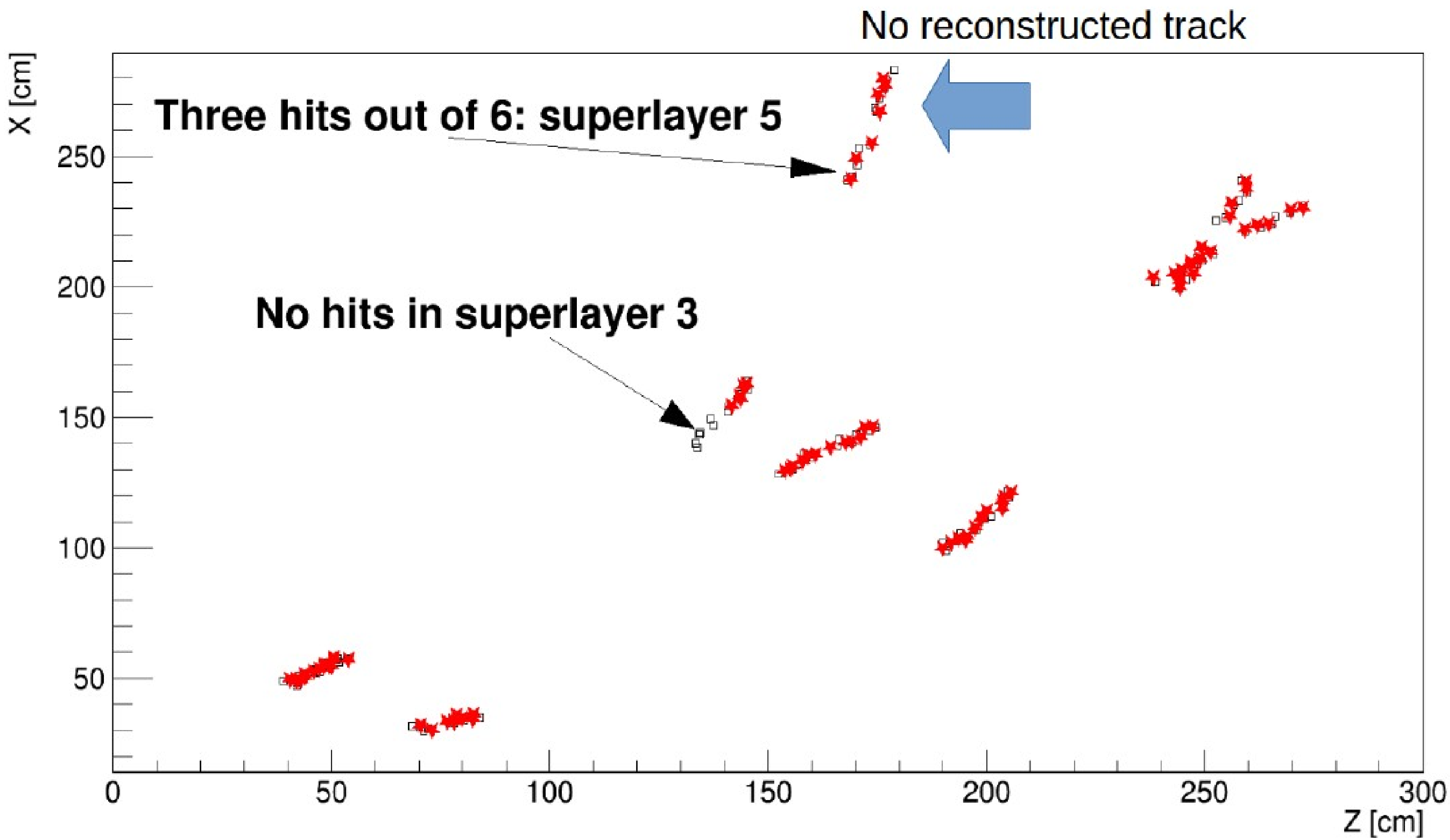
Standard bank for charged particles tracks (DCPB)

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

Example of track that is missing in DCPB bos bank



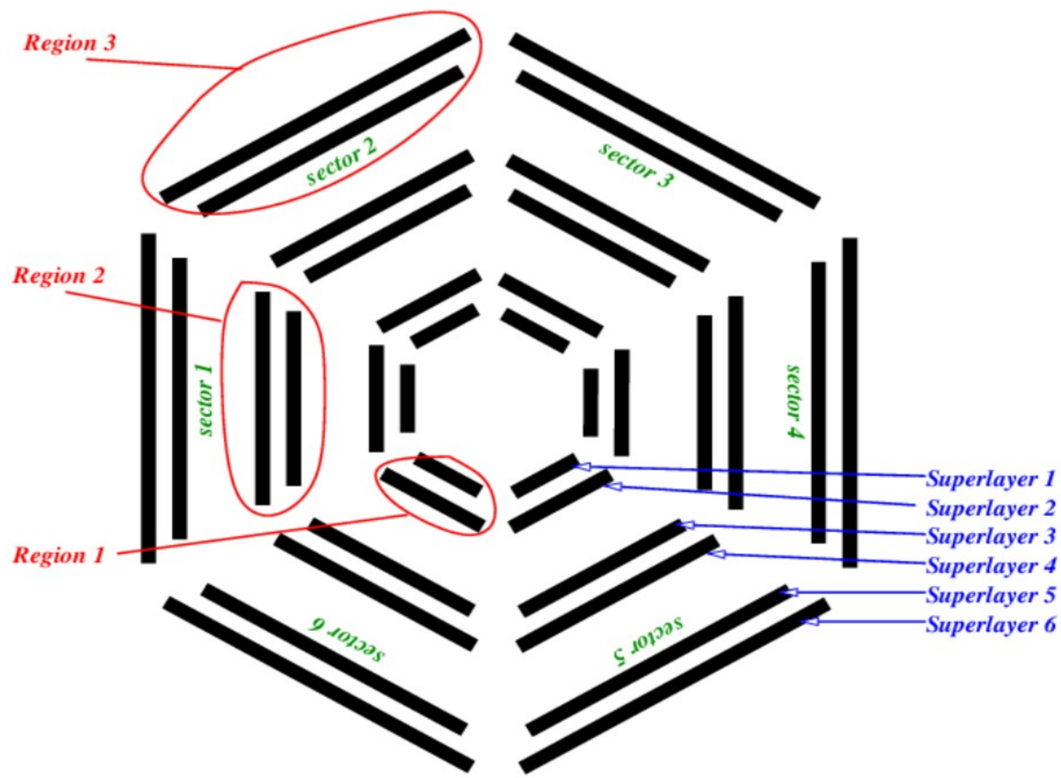
Detector structure

No magnetic field in Region 3
(Superlayer 5 & 6)

Charged particles move
in straight line

12 chamber layers

Use hits in Region 3 to project track to TOF paddles



Veto conditions

Define region on scintillators projected by charged track

DCPB bos bank

(reconstructed track)

HBLA bos bank

(un-reconstructed track)

1) The exclusion window is rectangle with different sides widths: 40 cm – 100 cm in 10 cm steps.

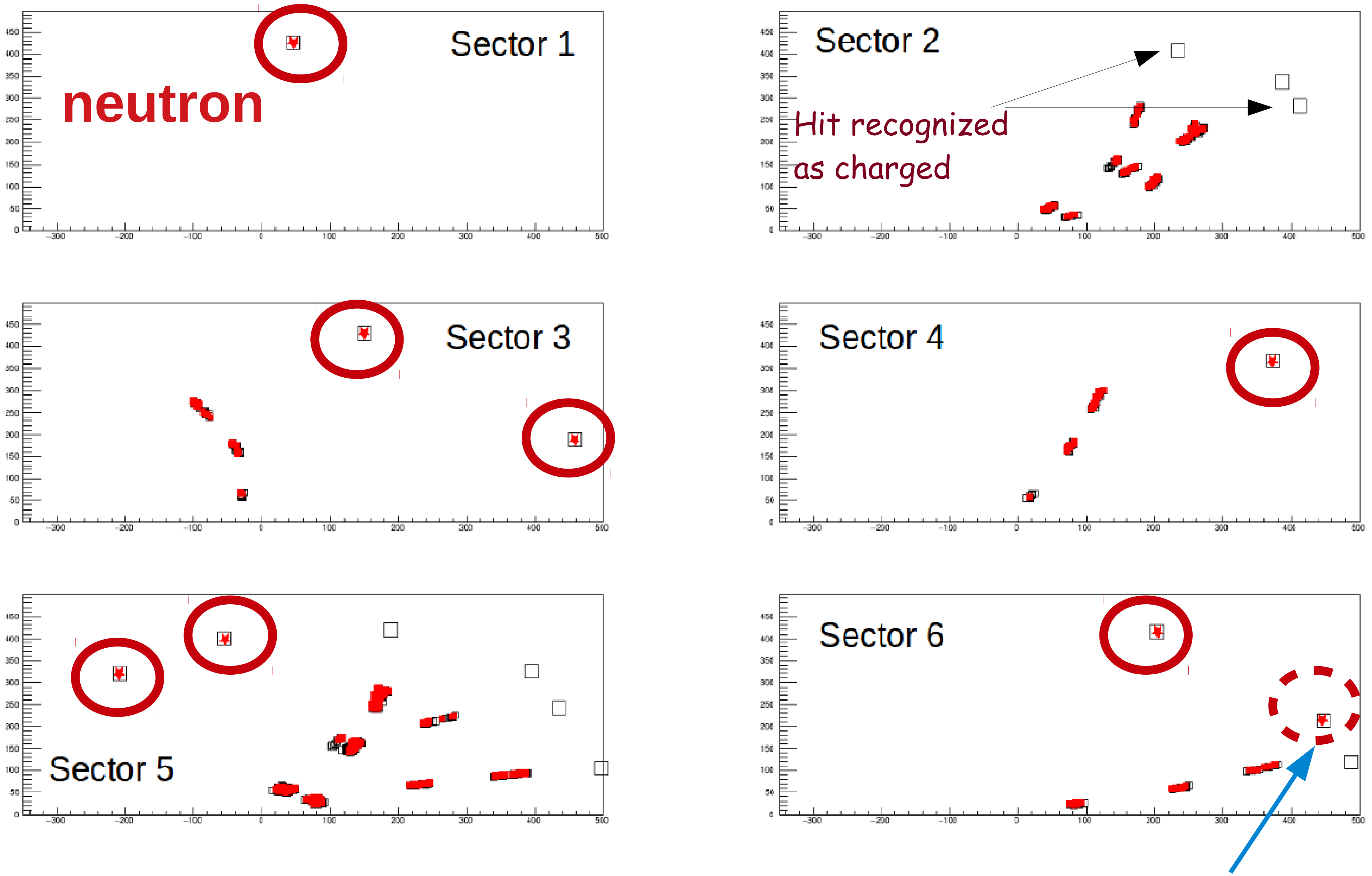
2) Exclude the whole paddle if there is a hit.

3) Exclude the whole sector.

To prevent double counting

Limit the time difference between adjacent bars with neutral hits

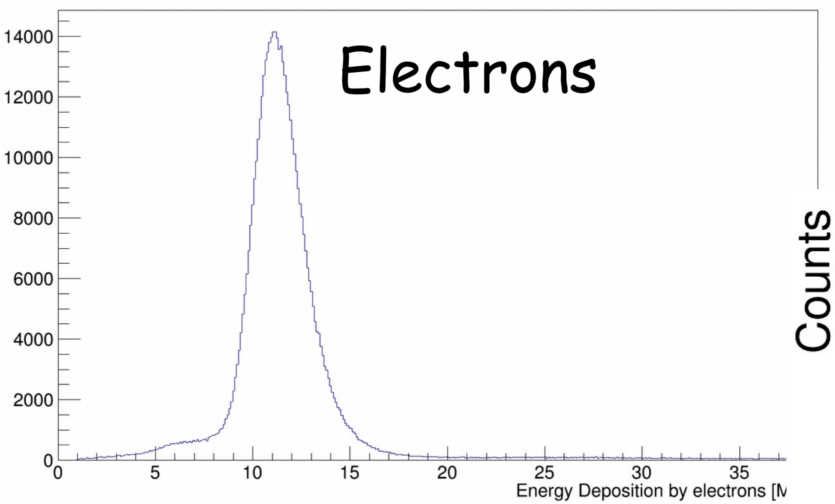
Neutron candidates after the Veto algorithm

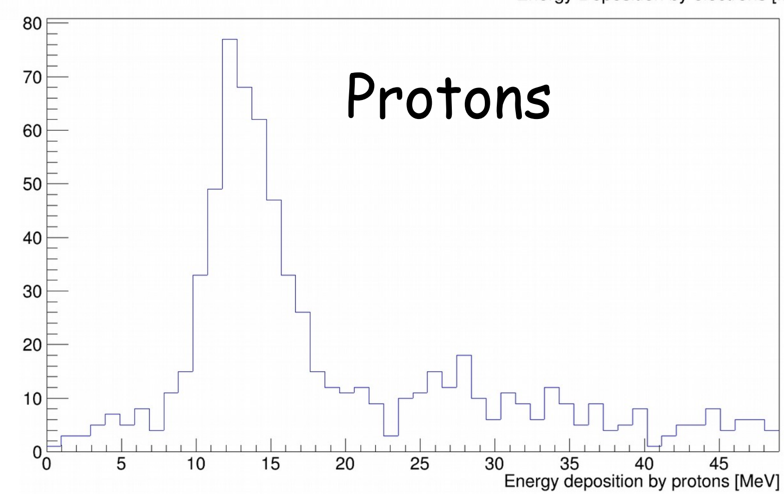


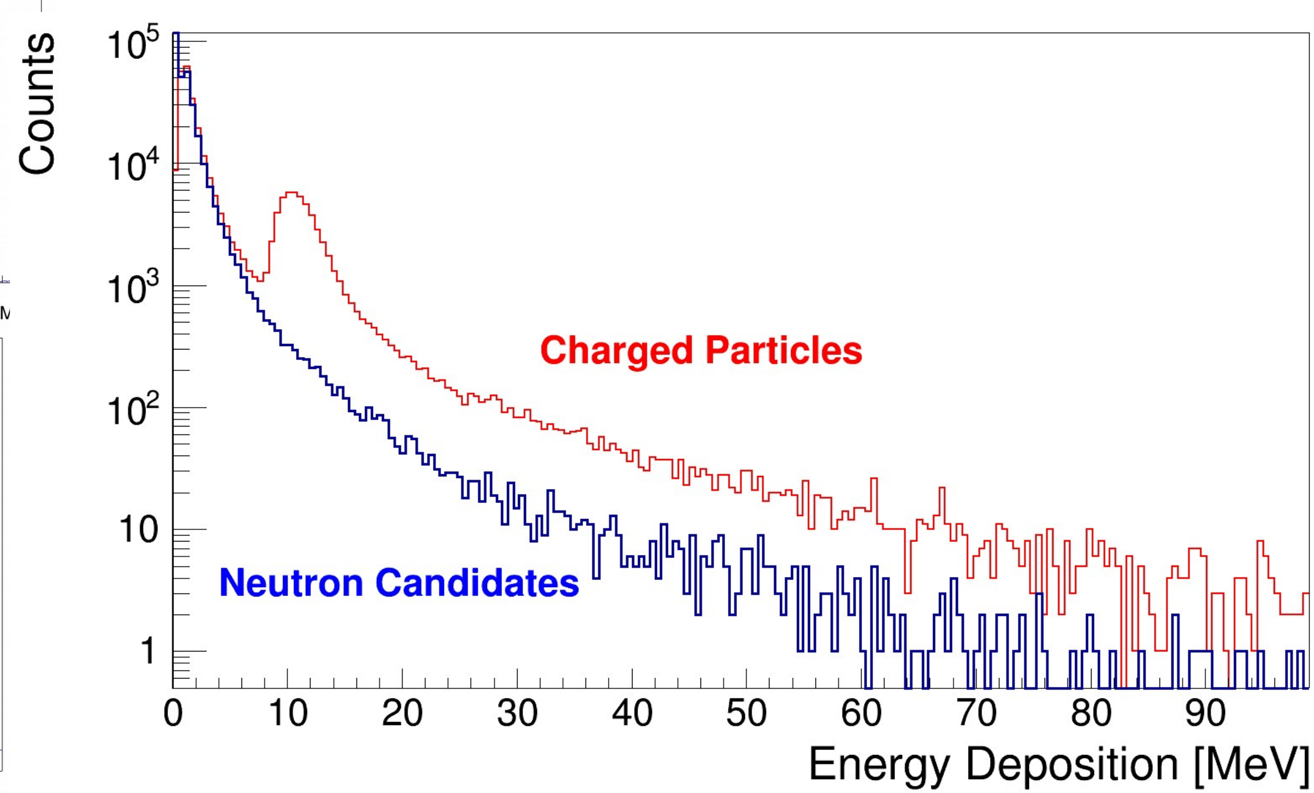
This neutron can be fake neutron
Relatively close to the track

Energy deposition

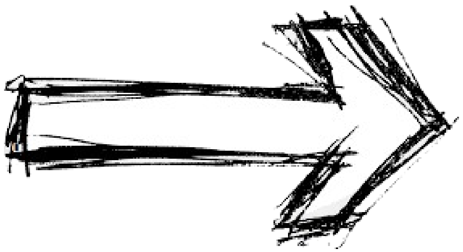
Veto algorithm remove hits due to the charged particles







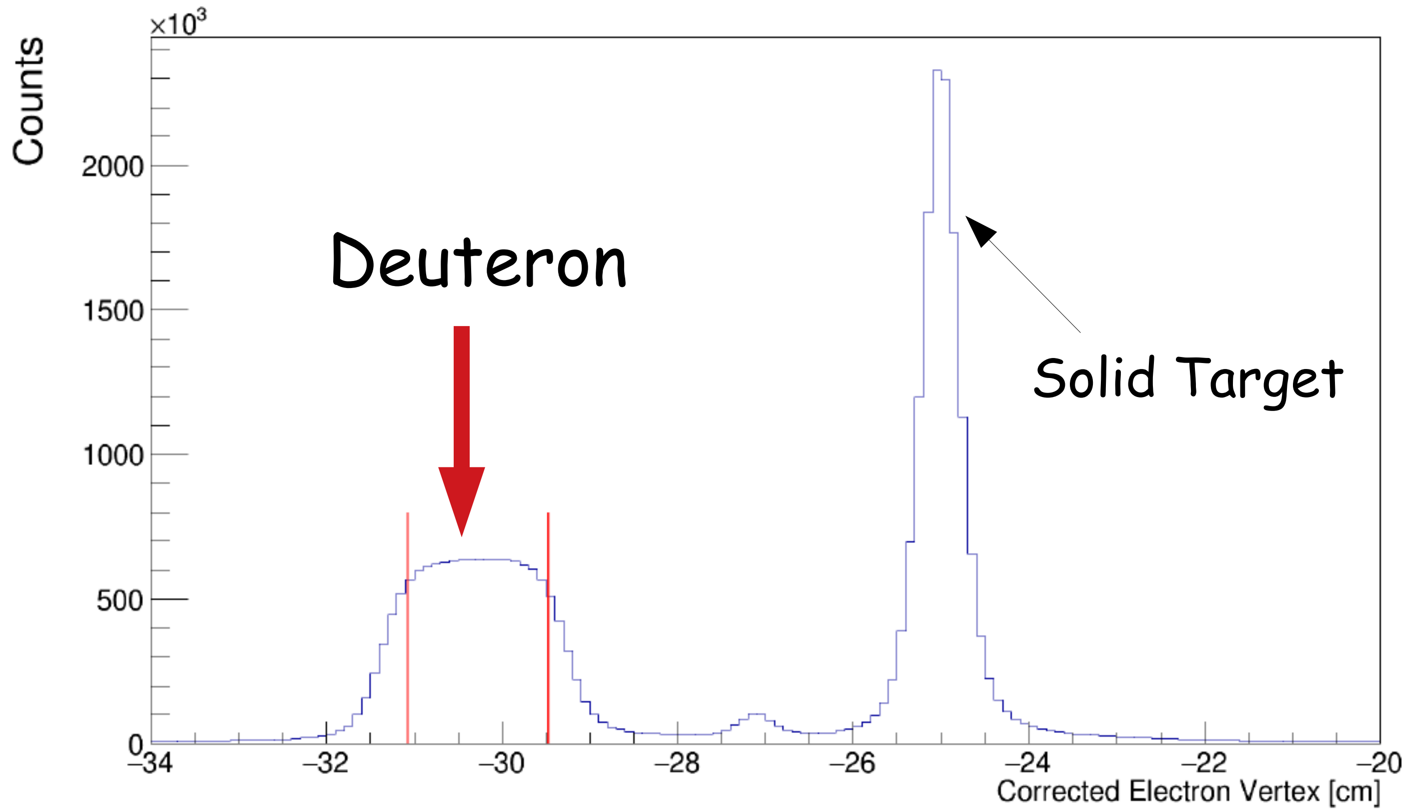
Exclusive d(e,e'pn) reaction:
Test neutron detection algorithm



- 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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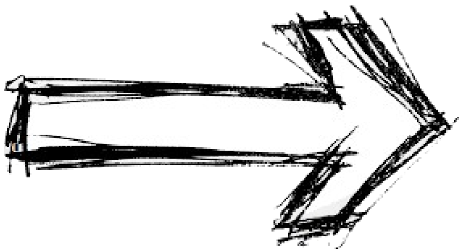

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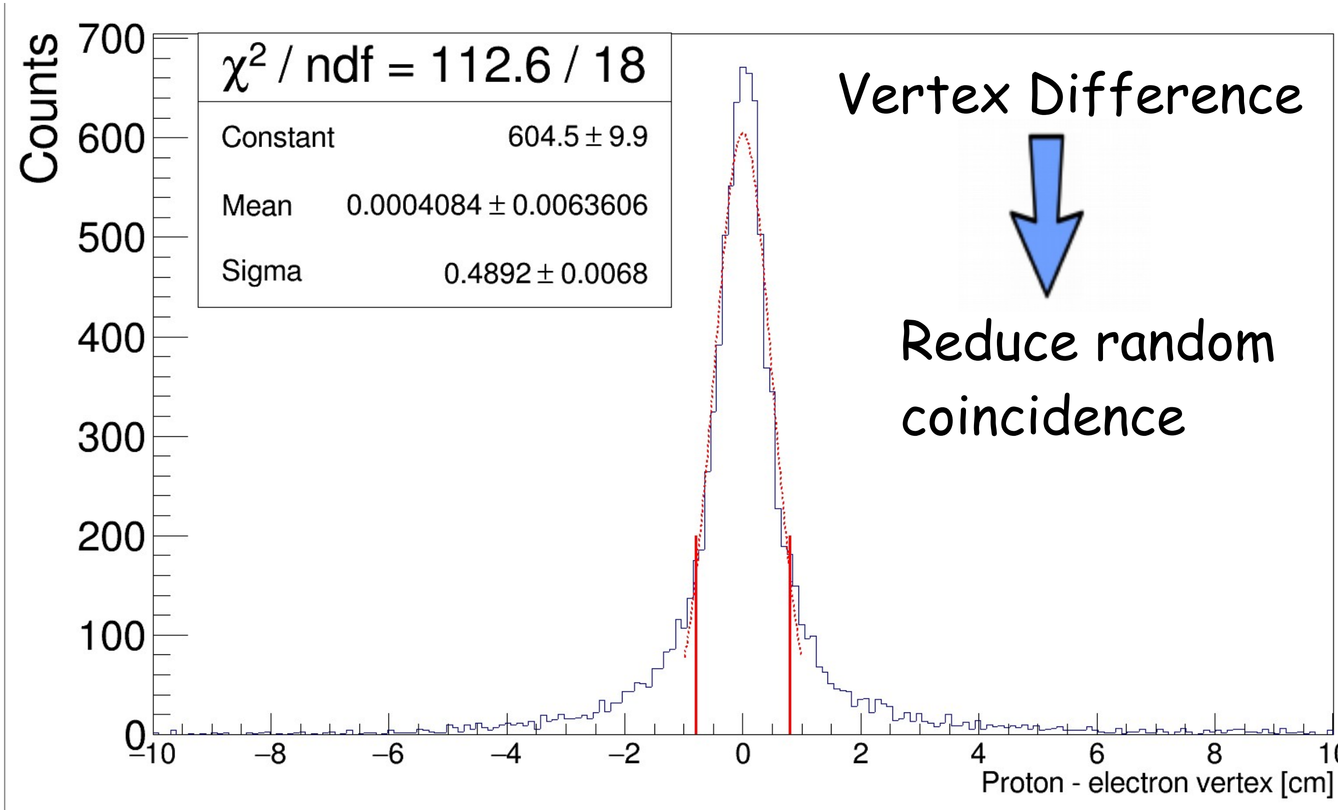

Exclusive d(e,e'pn) reaction: Test neutron detection algorithm

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

d(e,e'p) selection

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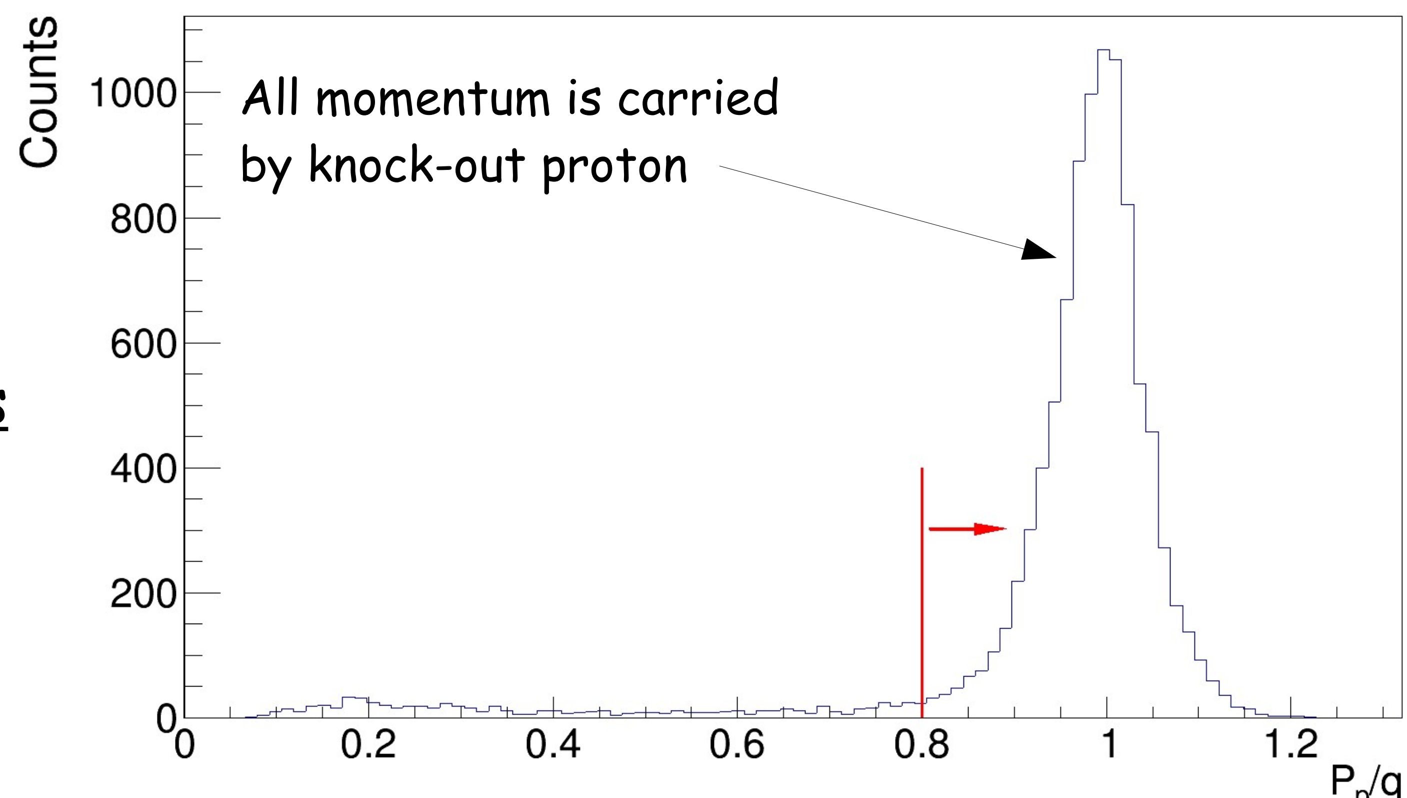

Exclusive d(e,e'pn) reaction:
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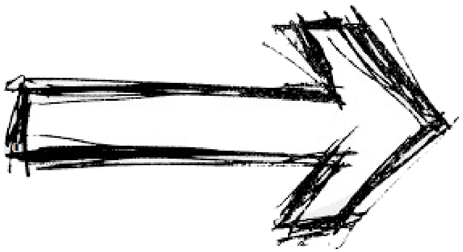

- Determine momentum resolution
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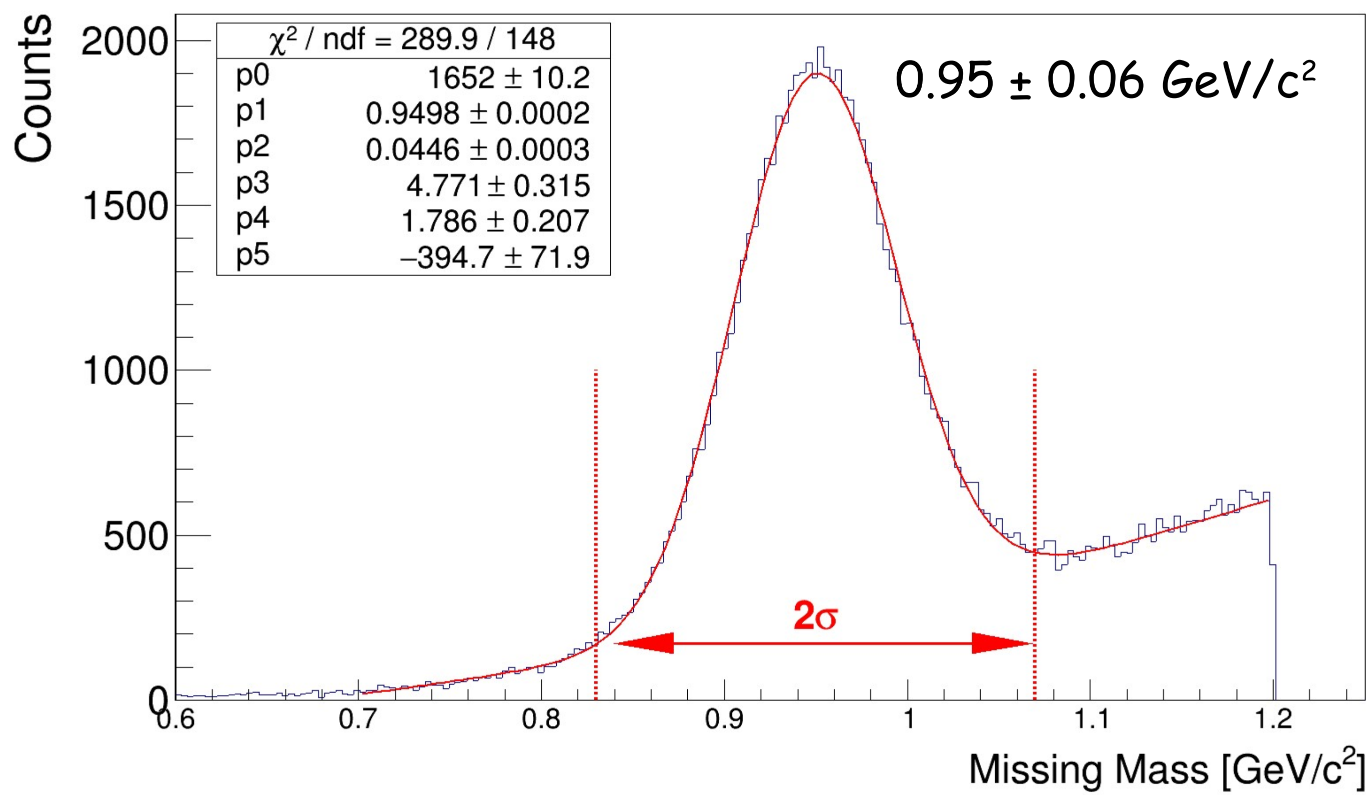
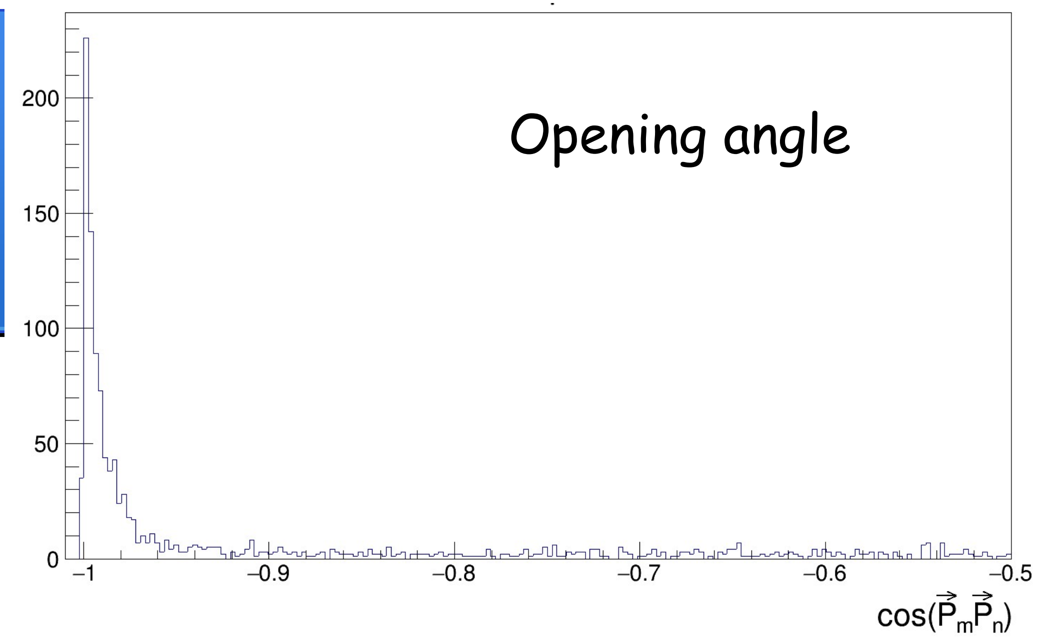
<u>d(e,e'p) selection</u>

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

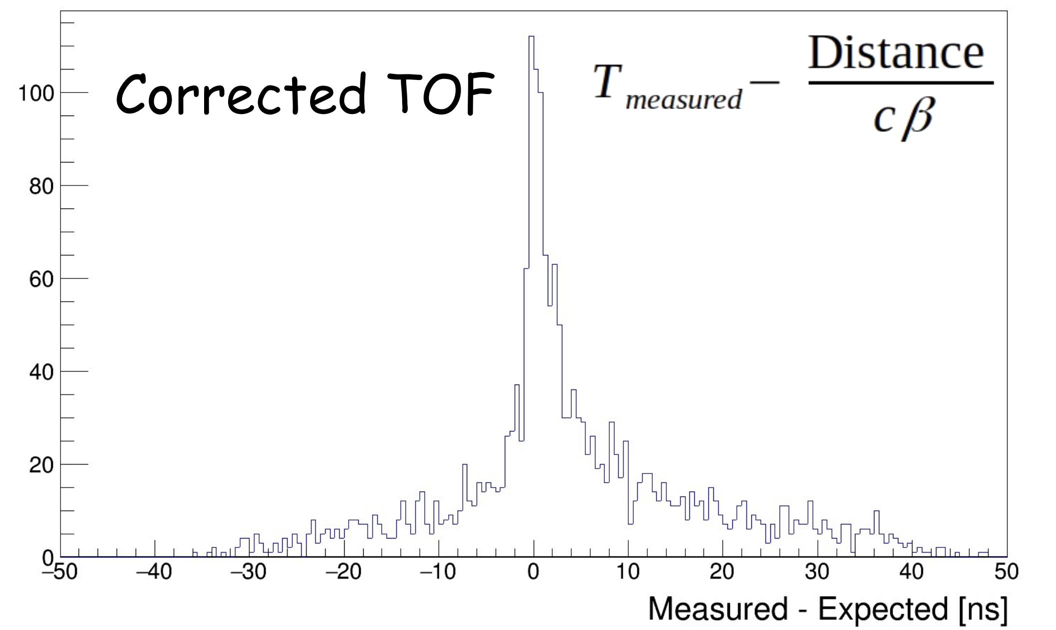


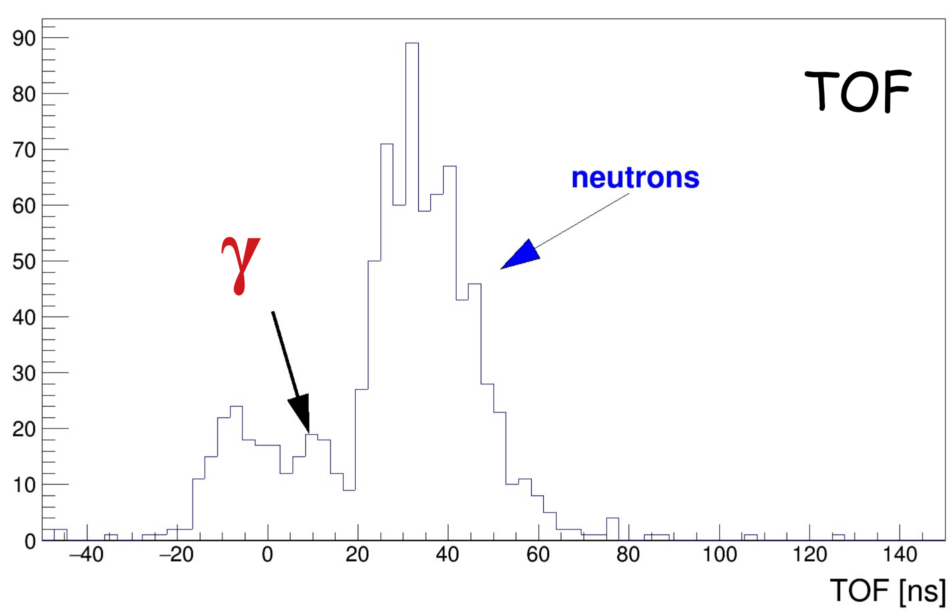
Identification of neutron candidates as neutrons



d(e,e'p)

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

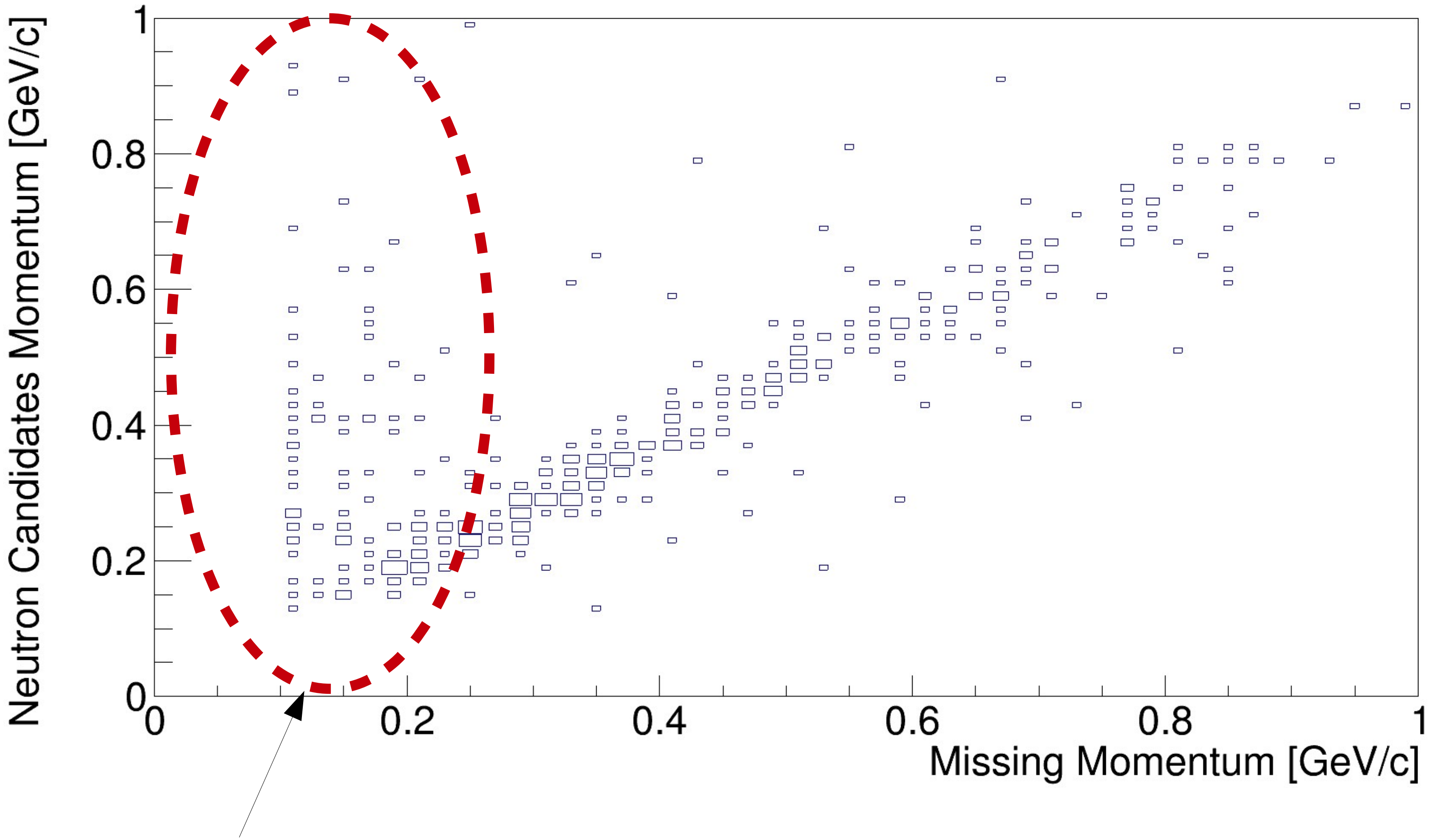




β – Calculated based on missing momentum

Missing Momentum Range

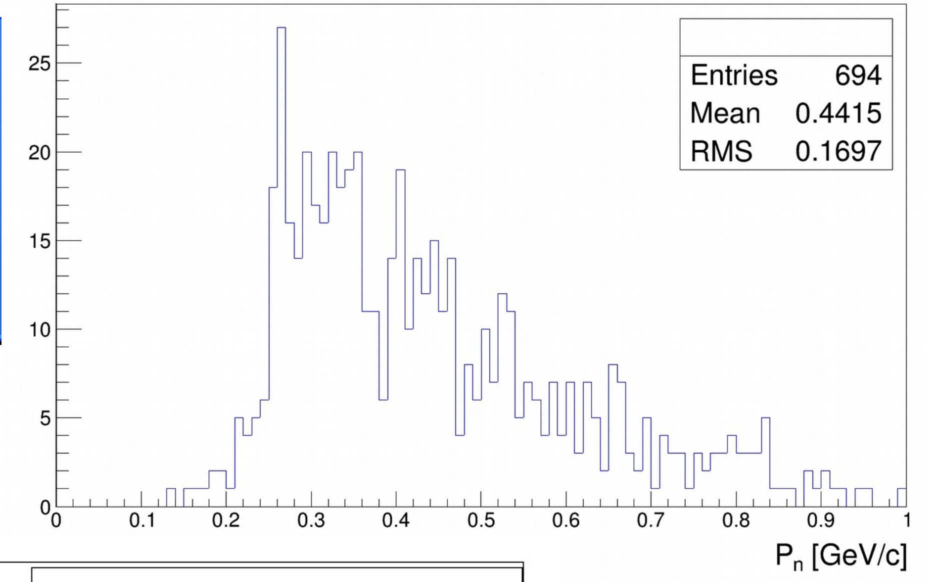
Correlation between missing momentum and neutrons

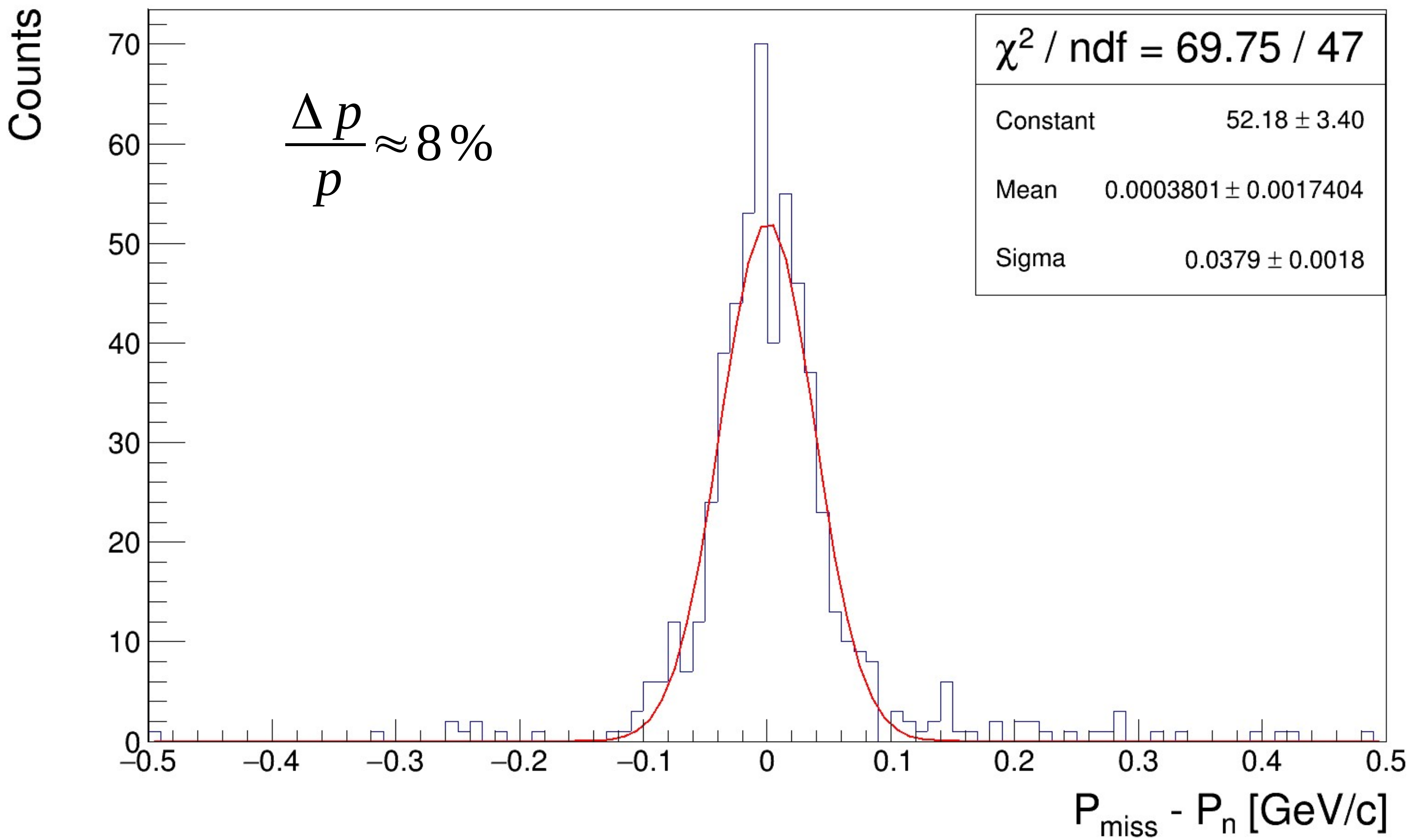


High background at low missing momentum.

Only consider missing momentum > 0.25 GeV/c

Neutron Momentum Resolution

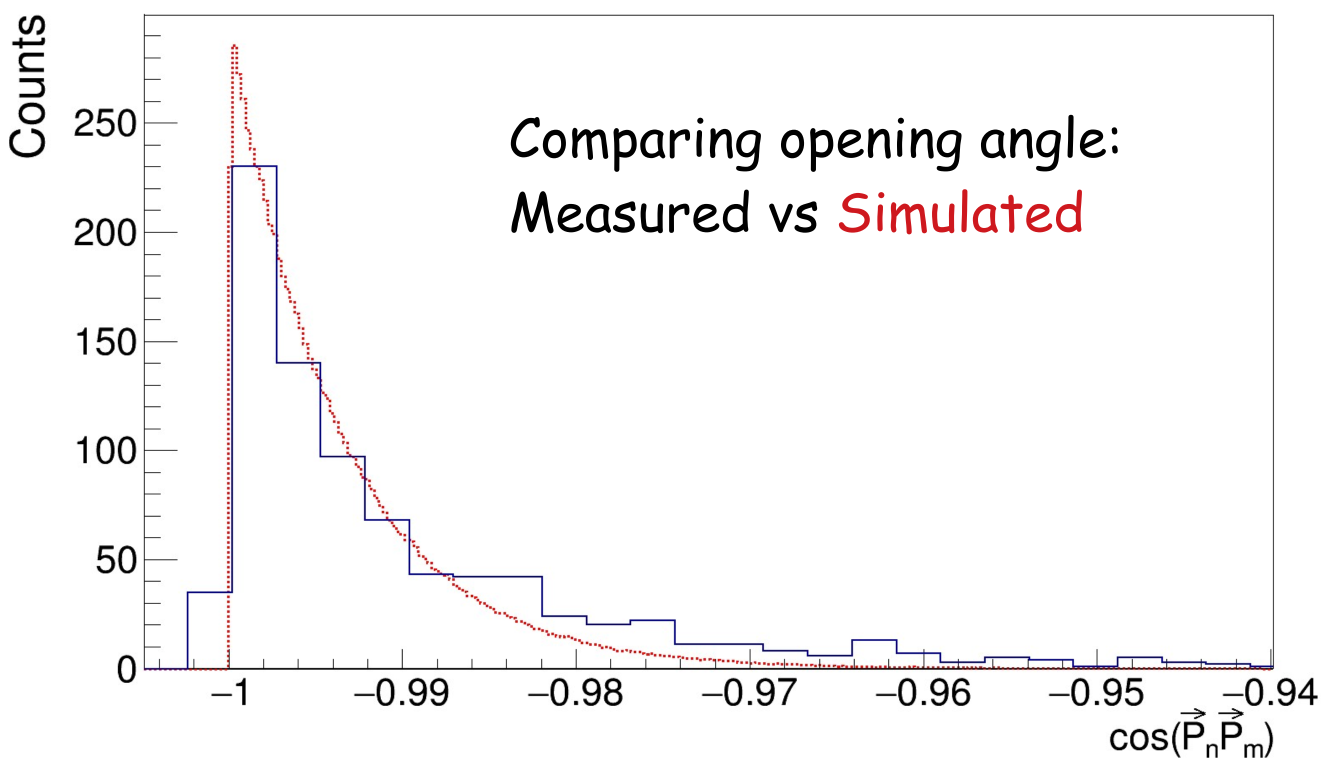




Validating the momentum resolution

Using d(e,e′p)

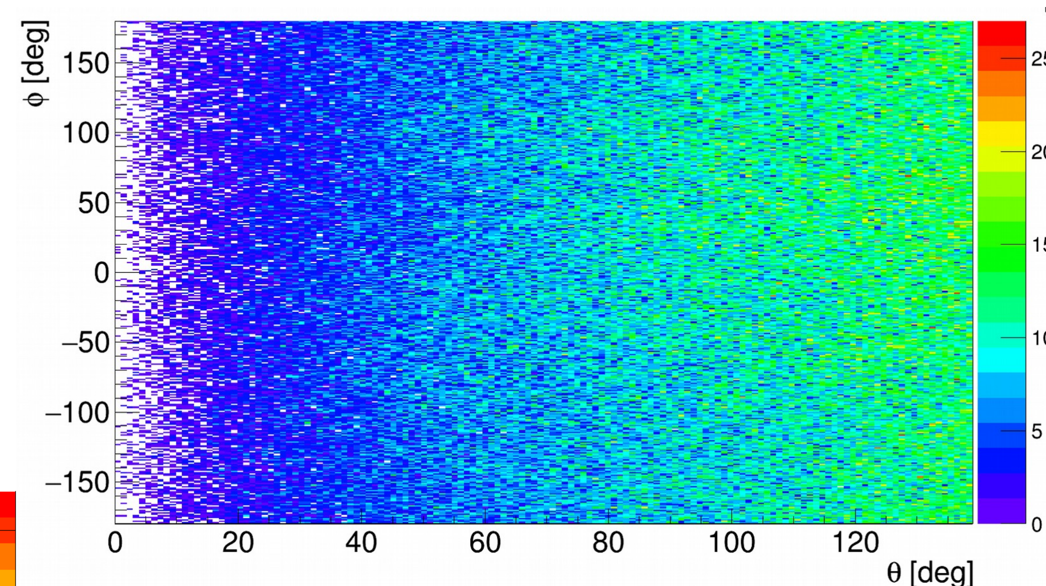
Simulate back to back neutrons and smearing them with the momentum resolution



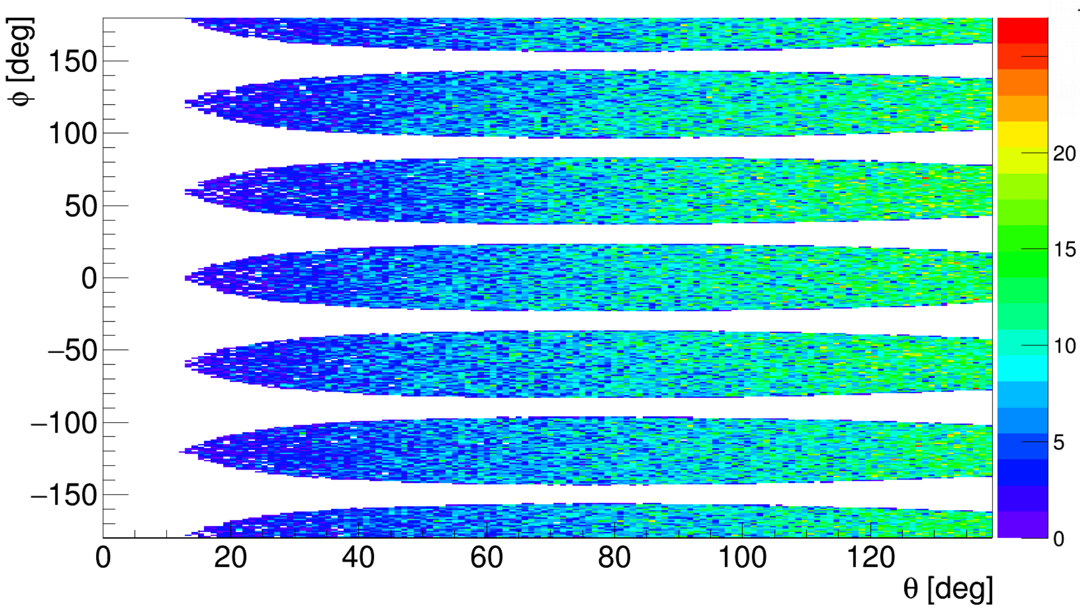
Neutron detection efficiency

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

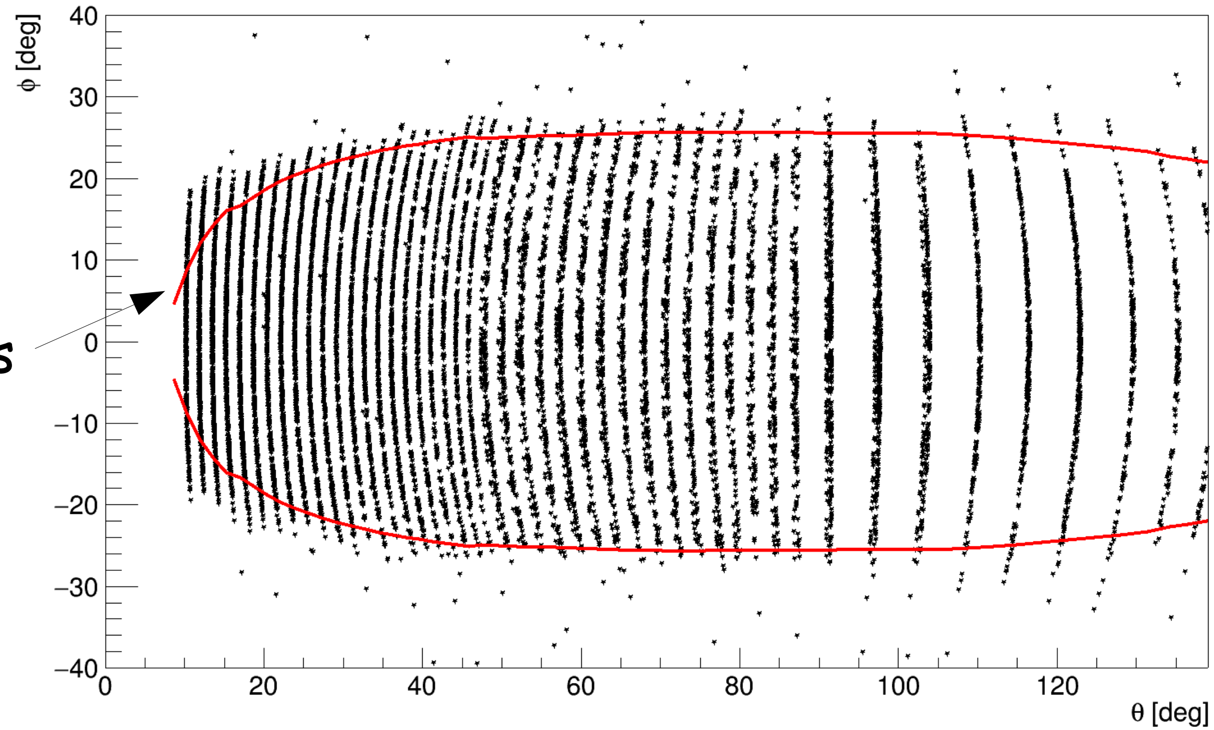
Missing momentum point to all direction



Restrict the missing momentum
to fit CLAS acceptance

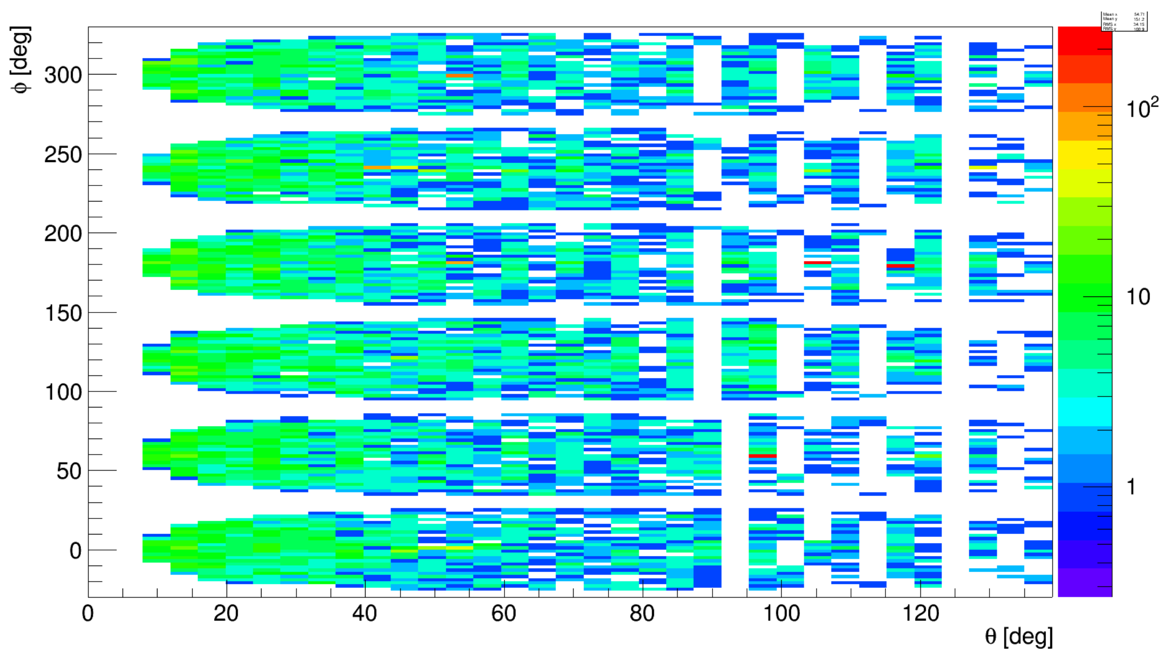


Fiducial cut for the neutrons



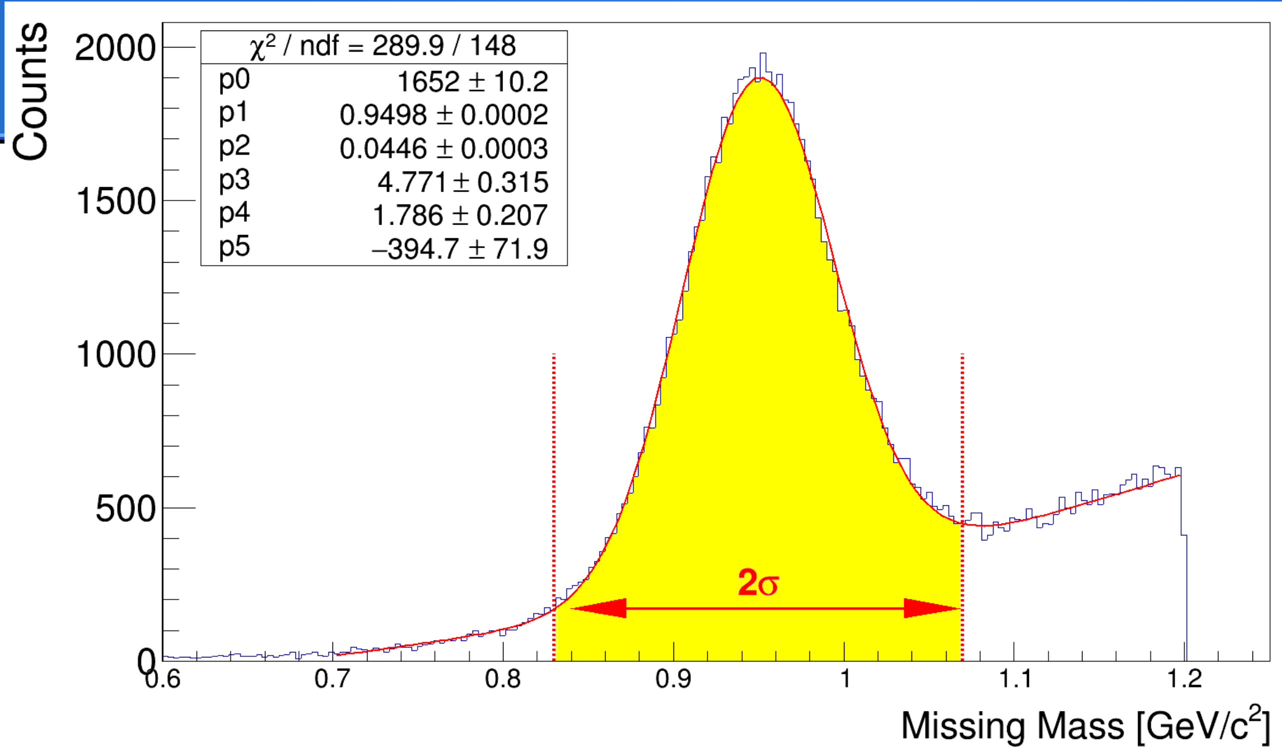
Stay away from scintillator edges

10 cm from each paddle edge

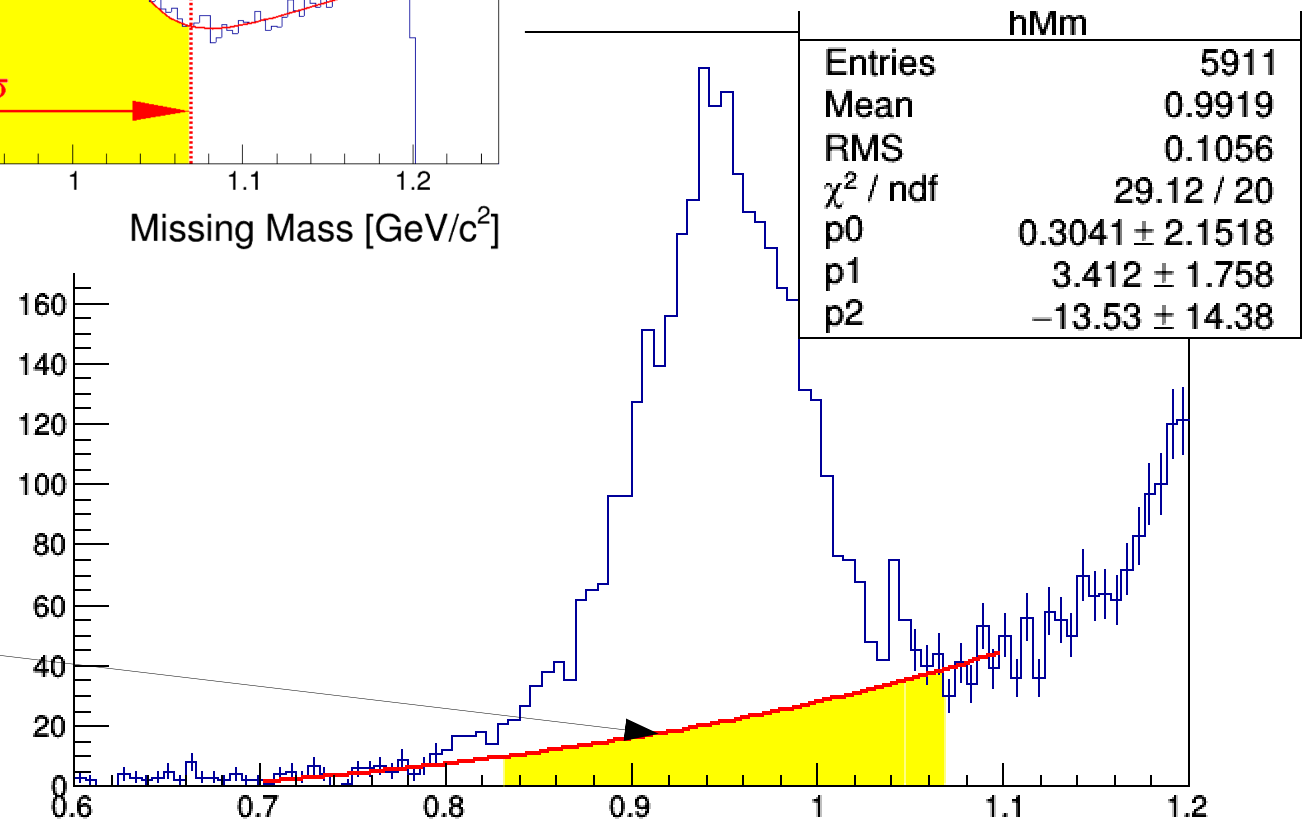


Last 16 paddle are combined in pairs in hardware

Estimation of d(e,e'p) events



Count number of events under the missing mass peak



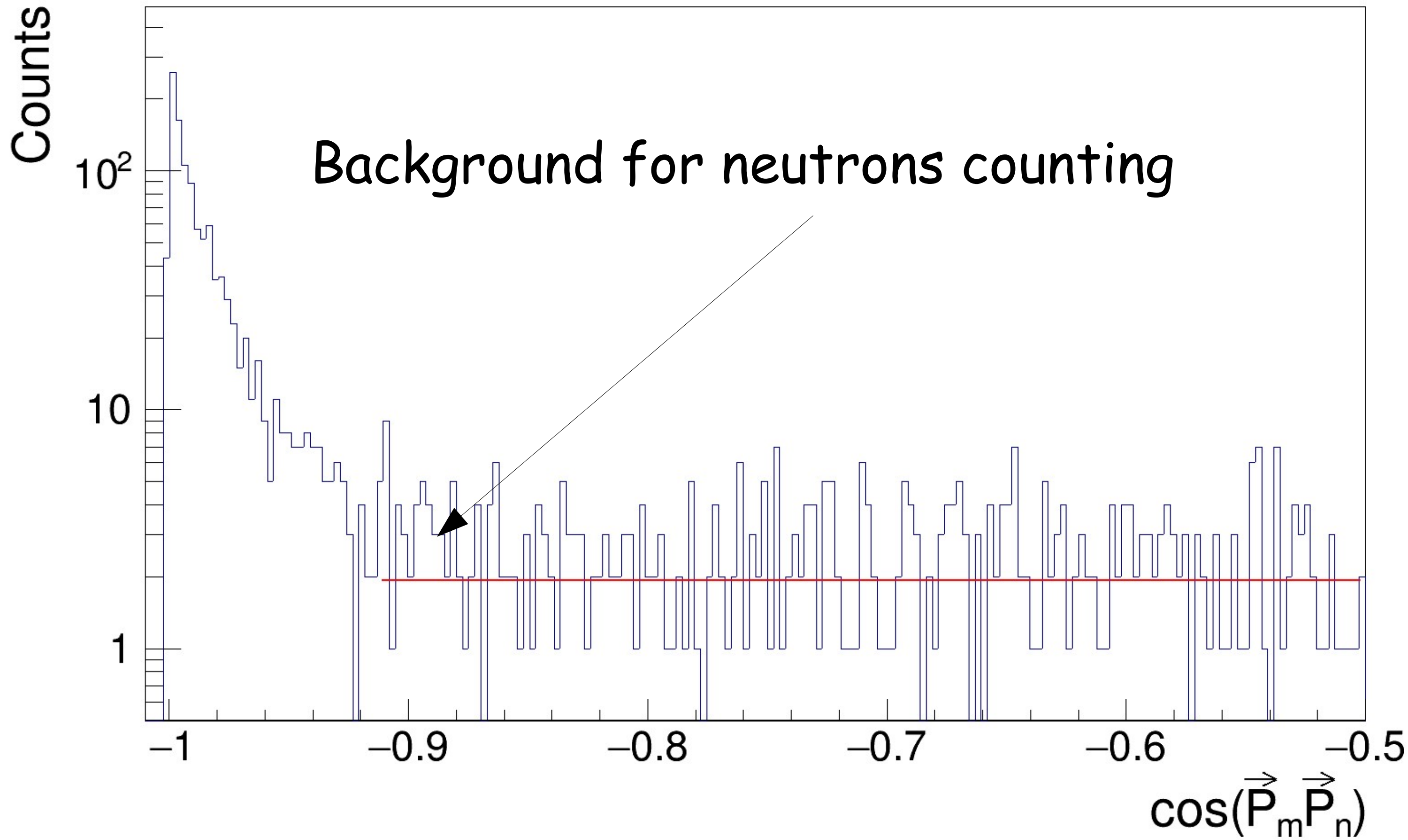
Estimation of background

Empirical Fit

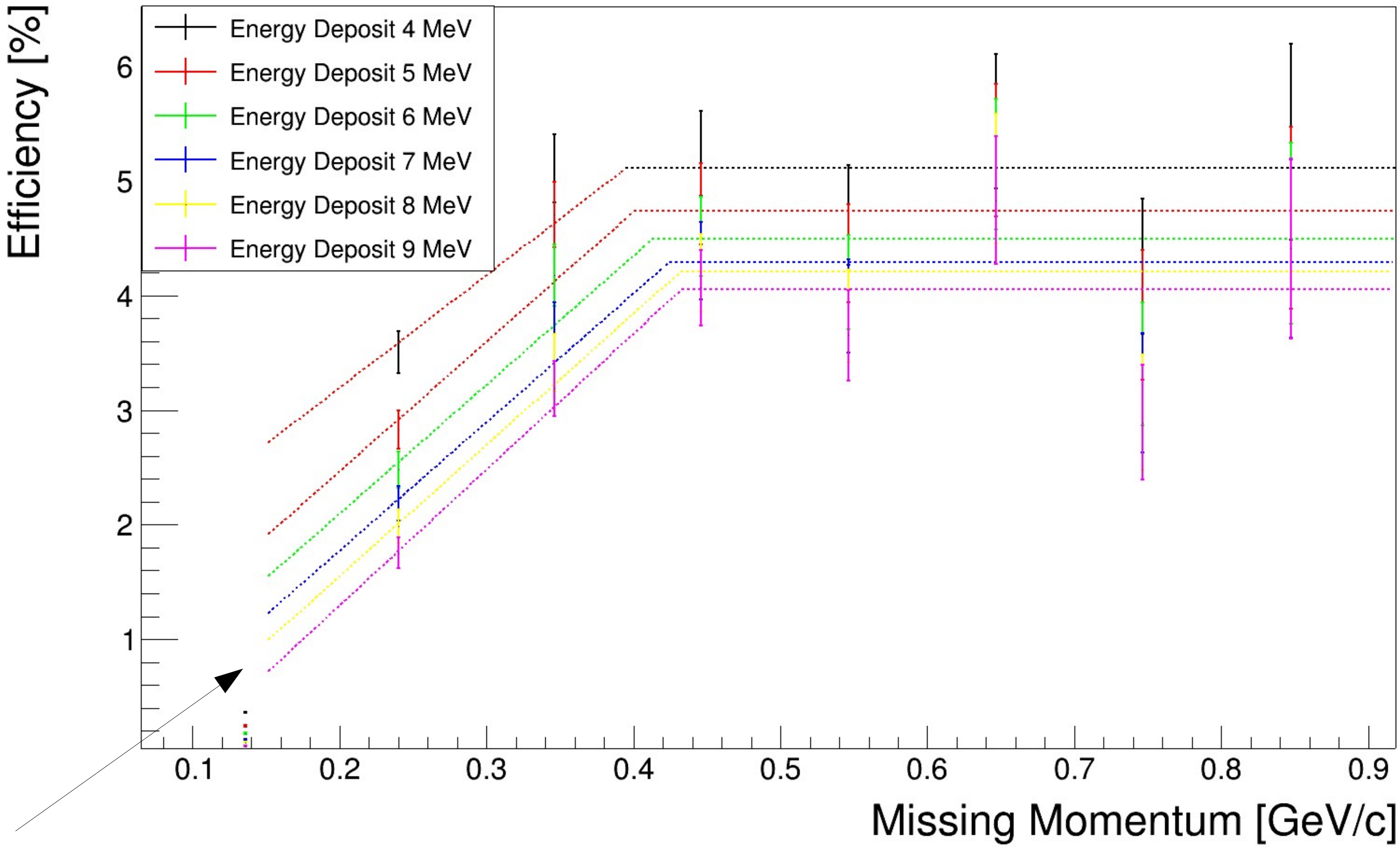
Extracting number of d(e,e'pn) events

Cuts:

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



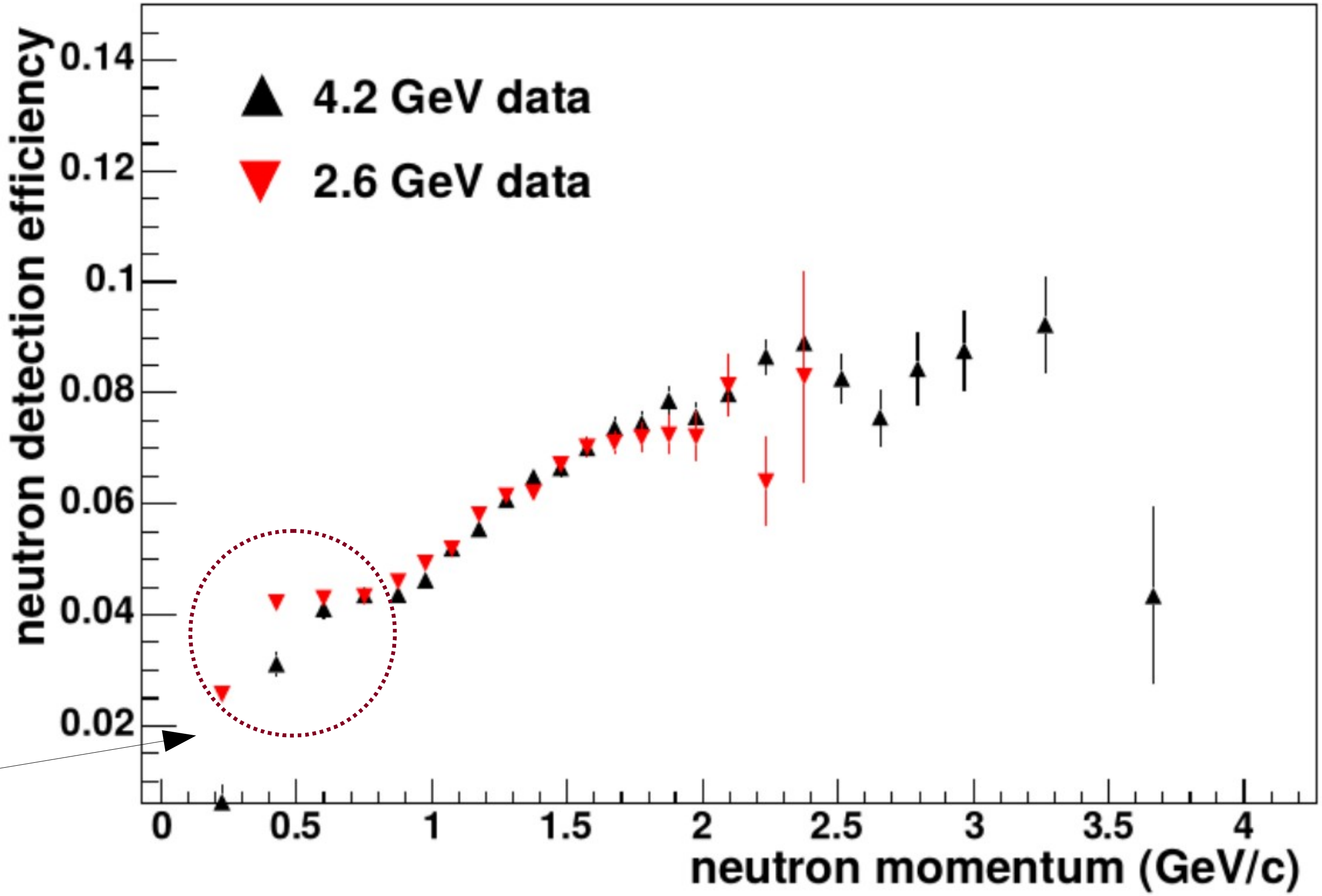
Absolute neutron detection efficiency



Efficiency measurement below 0.25 GeV/c is not reliable

Previous analysis

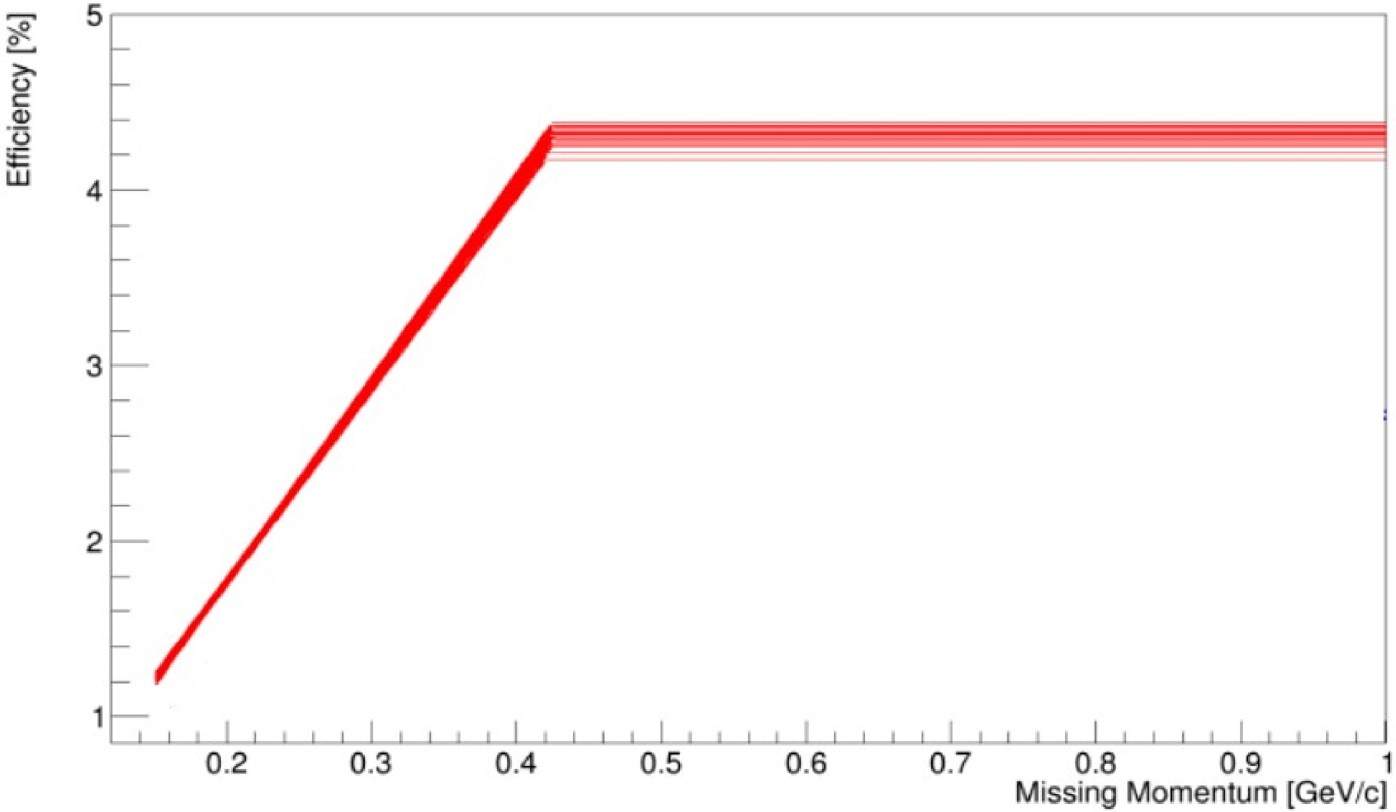
CLAS Analysis Note 2008-103



Relevant region

Sensitivity for veto algorithm

40 runs of Veto algorithm, with different side length of the exclusion window.



The width allows to determine the systematic uncertainty of the efficiency.

Selection of C(e,e'p) events

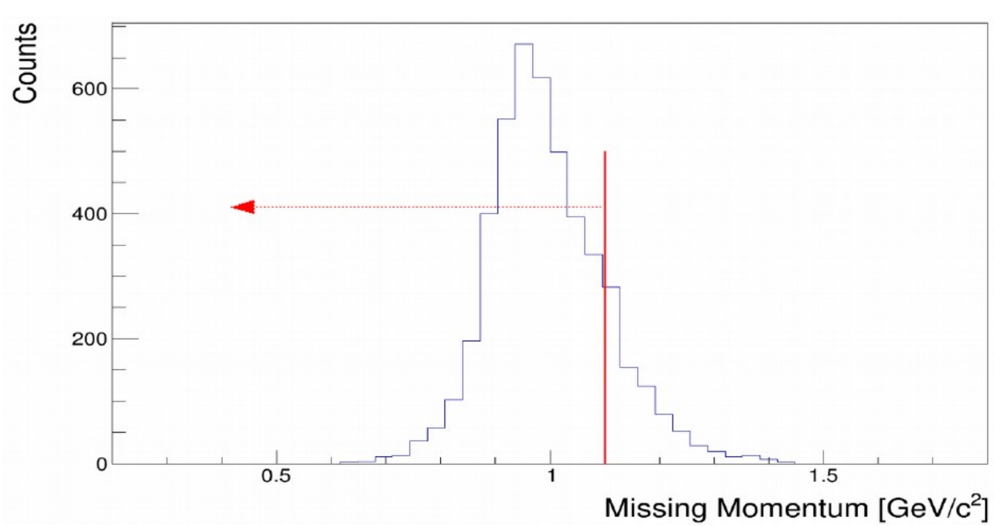
Selection of (e,e'p) events is identical to previous analysis A(e,e'pp) and A(e,e'np)

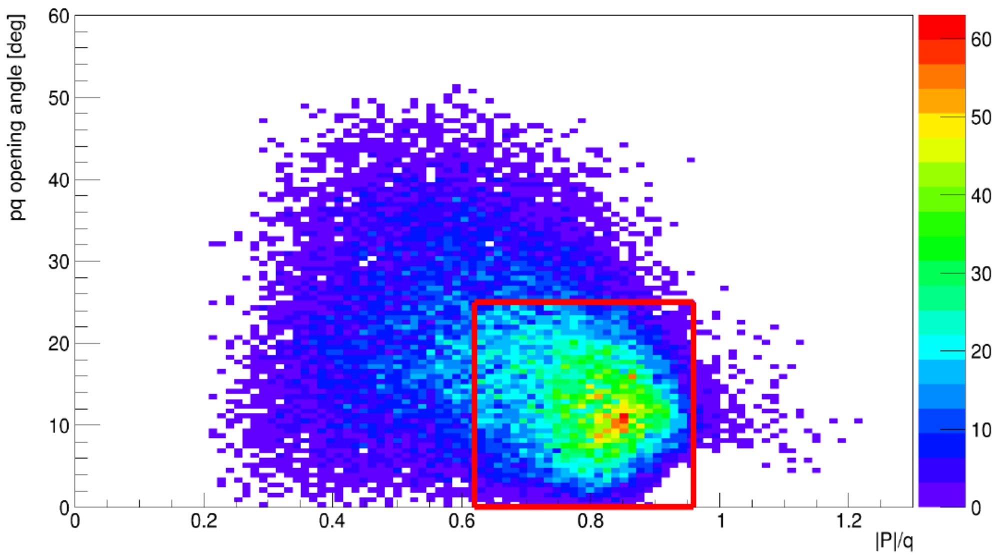
$X_B > 1.2$

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

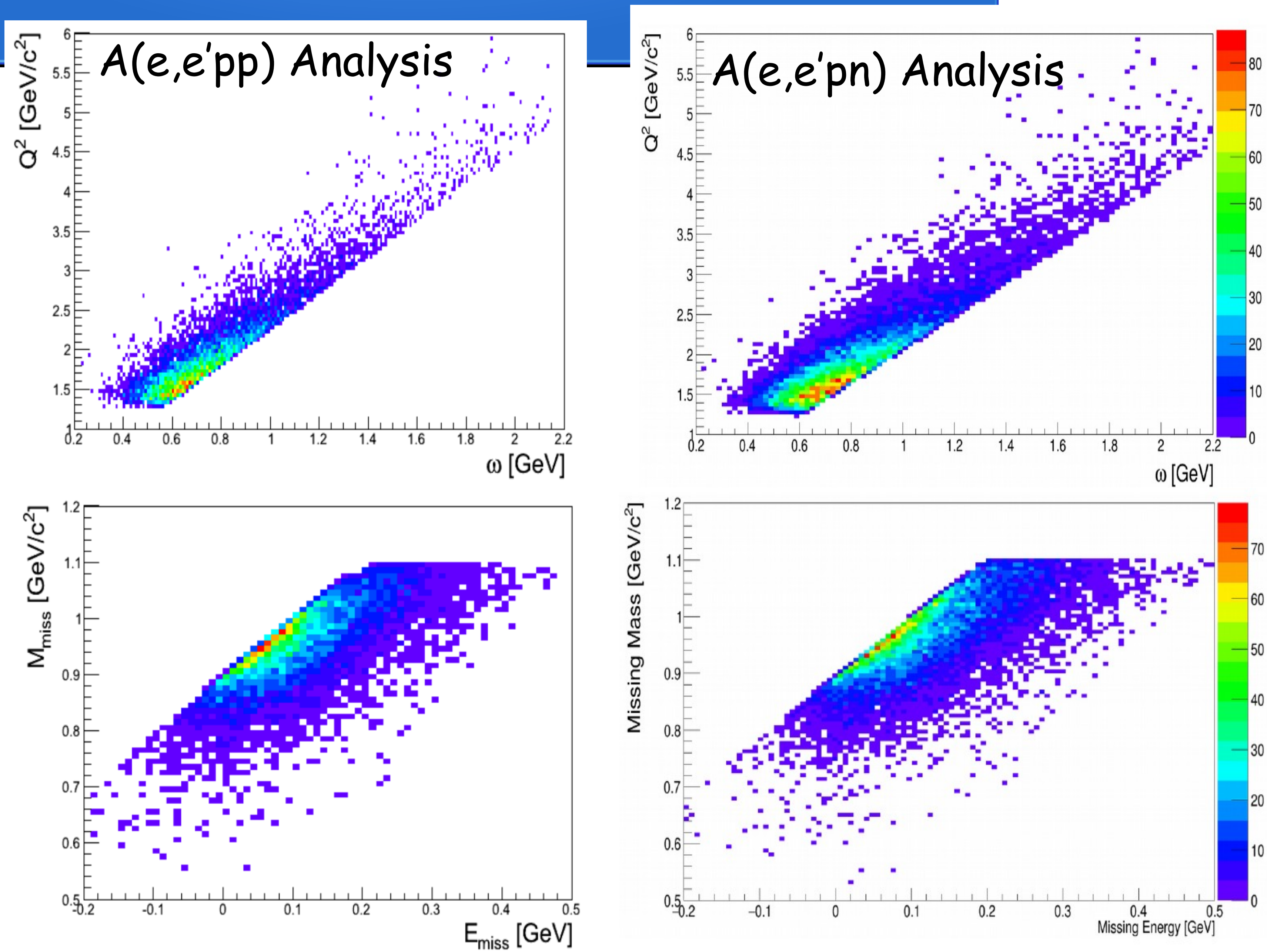
Missing Mass < 1.1

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

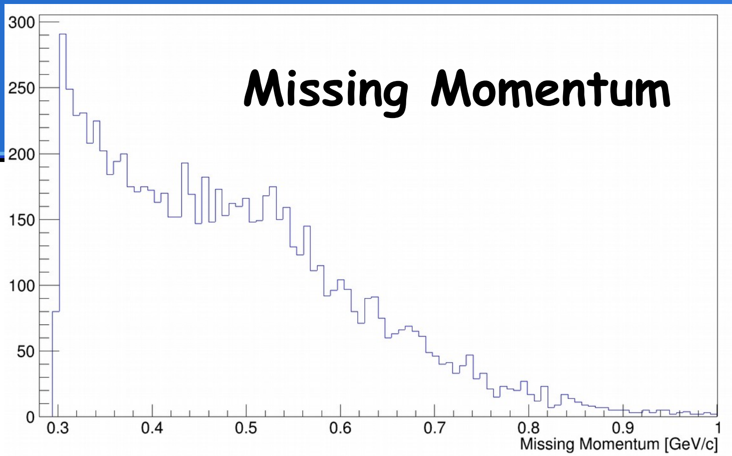


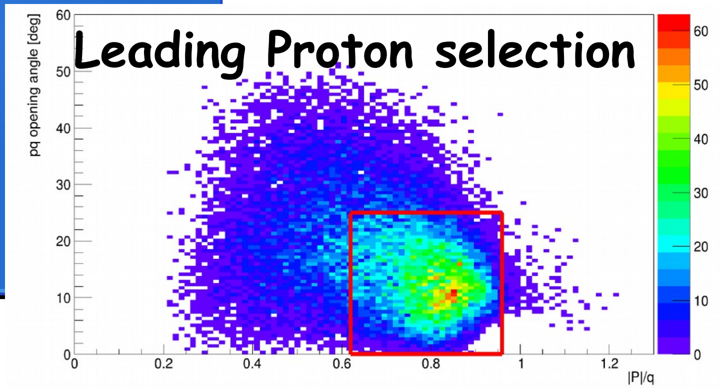


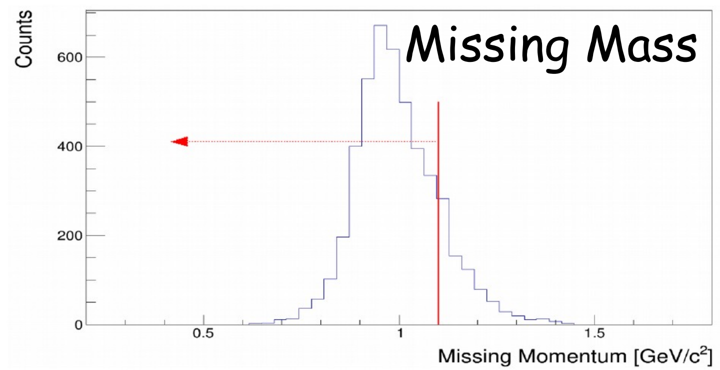
Brief comparison for C(e,e'pp) analysis

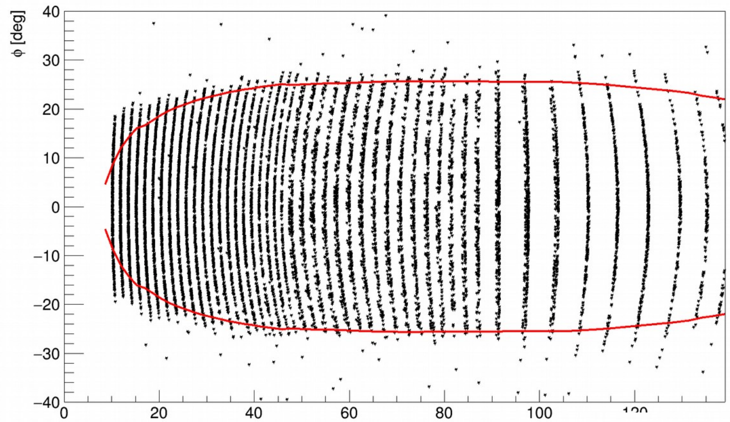


Selection of C(e,e'pn) events

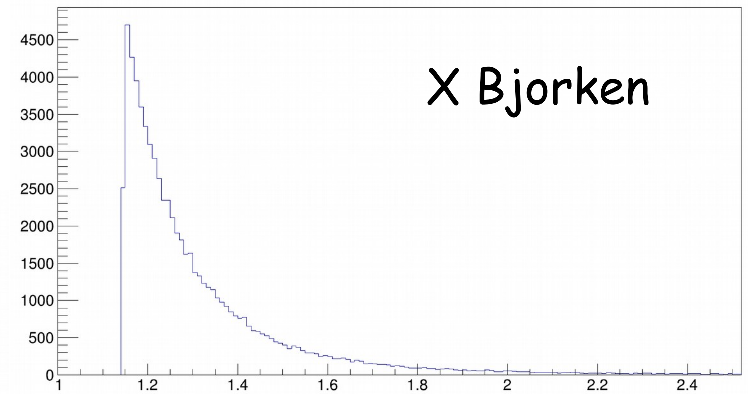


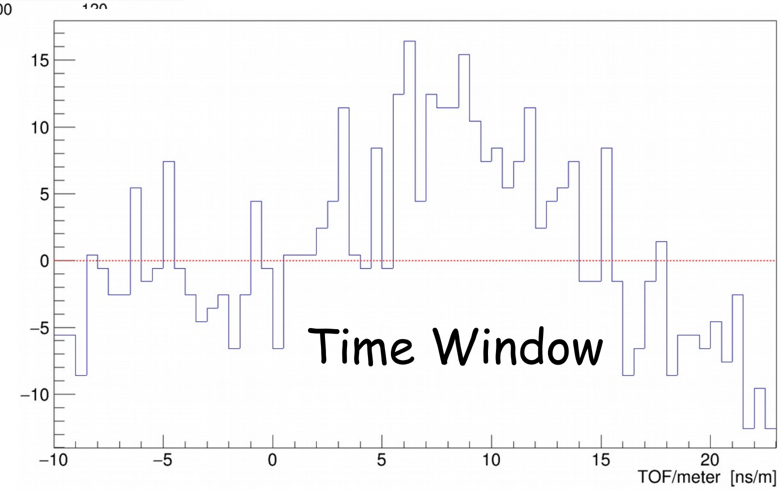






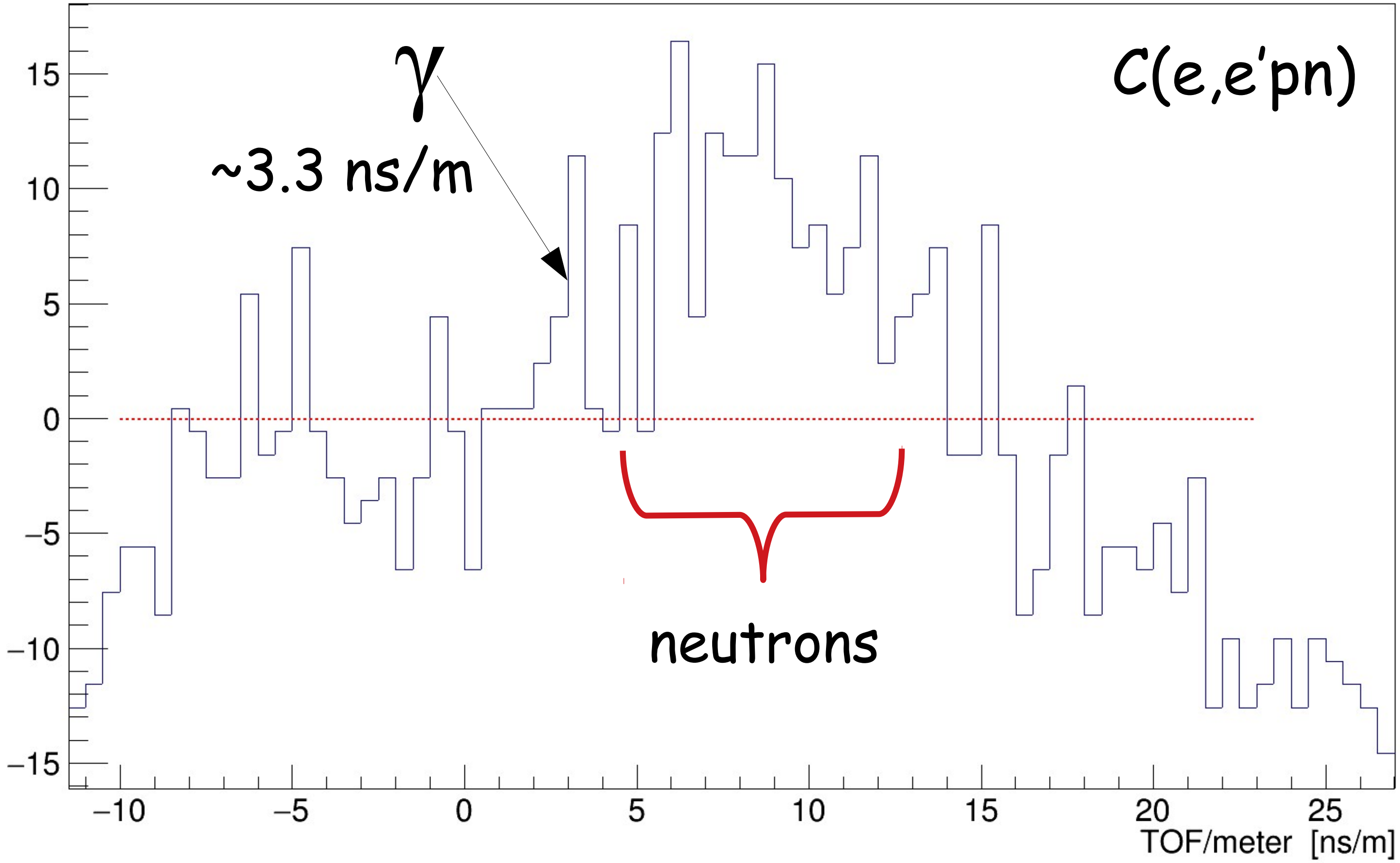
Paddle Geometry





Background

TOF per meter distribution



Neutrons in TOF counters have large background level

Neutrons: 4.5 – 11 ns/m equivalent: 0.3 – 1 GeV/c momentum

In the analysis we cut out neutrons with momentum lower than 0.35 GeV/c

BG subtraction

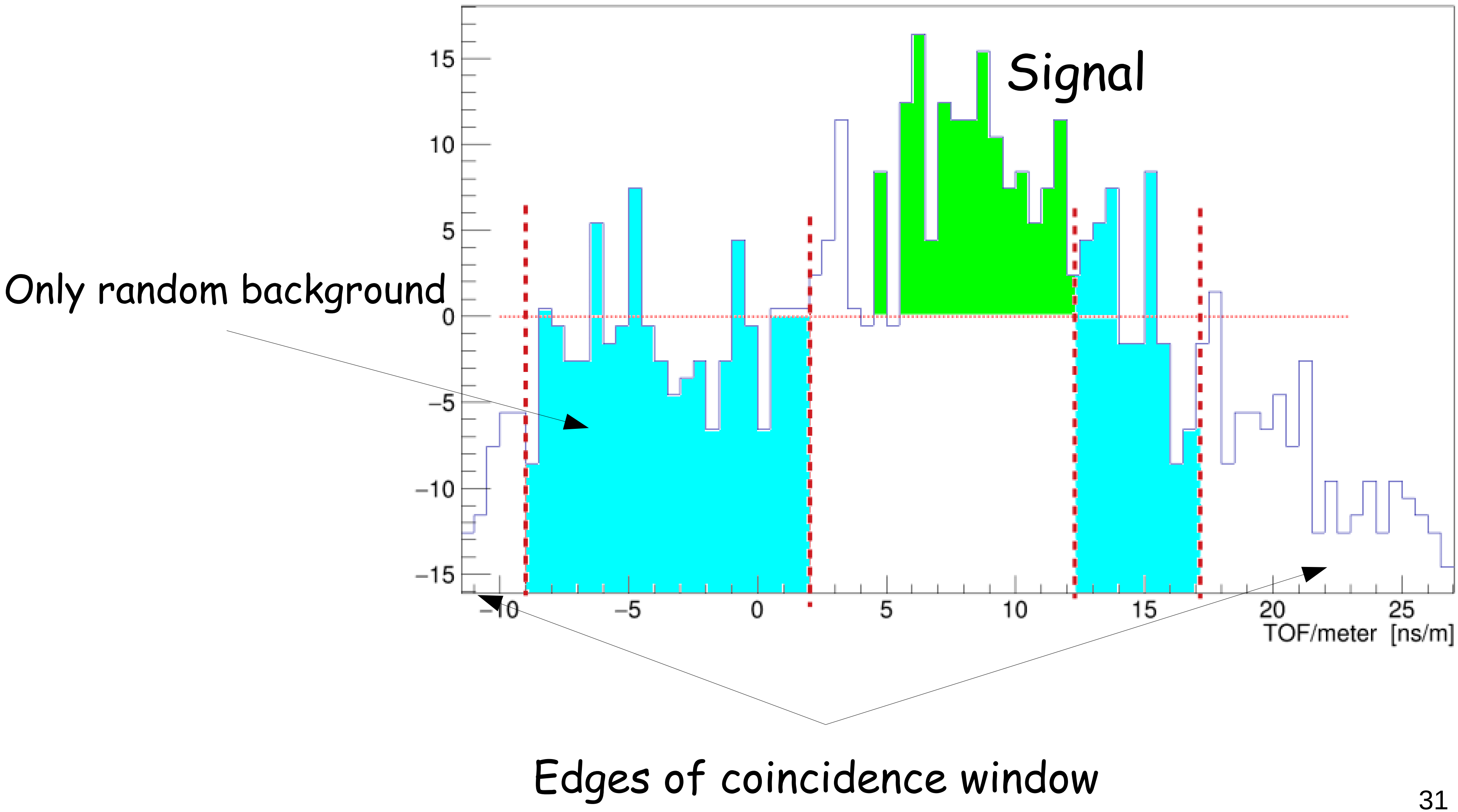
1. Event mixing technique
   - Normalization to opening angle shape
   - Normalization to out of time opening angle

Event mixing shape very sensitive to normalization.

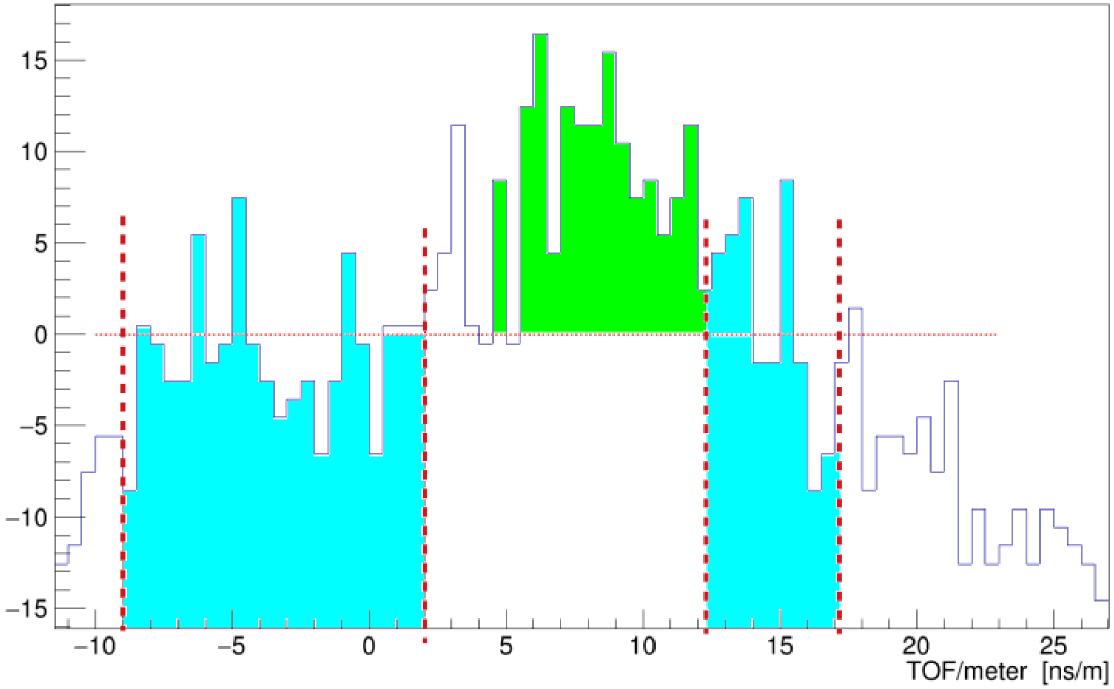
2. Out of time window/

Estimate BG using out of time window, assuming Poisson statistics

Out of time background subtraction



Background: out of time
a little bit different approach

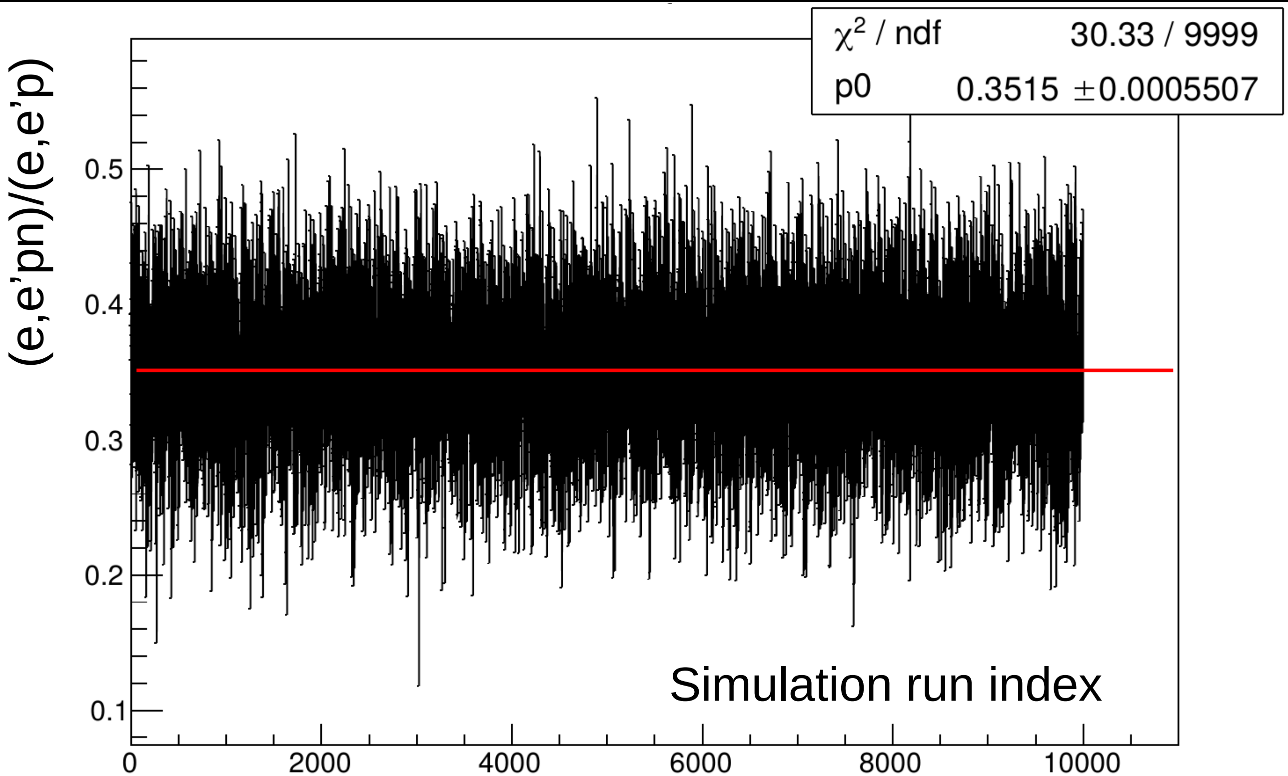


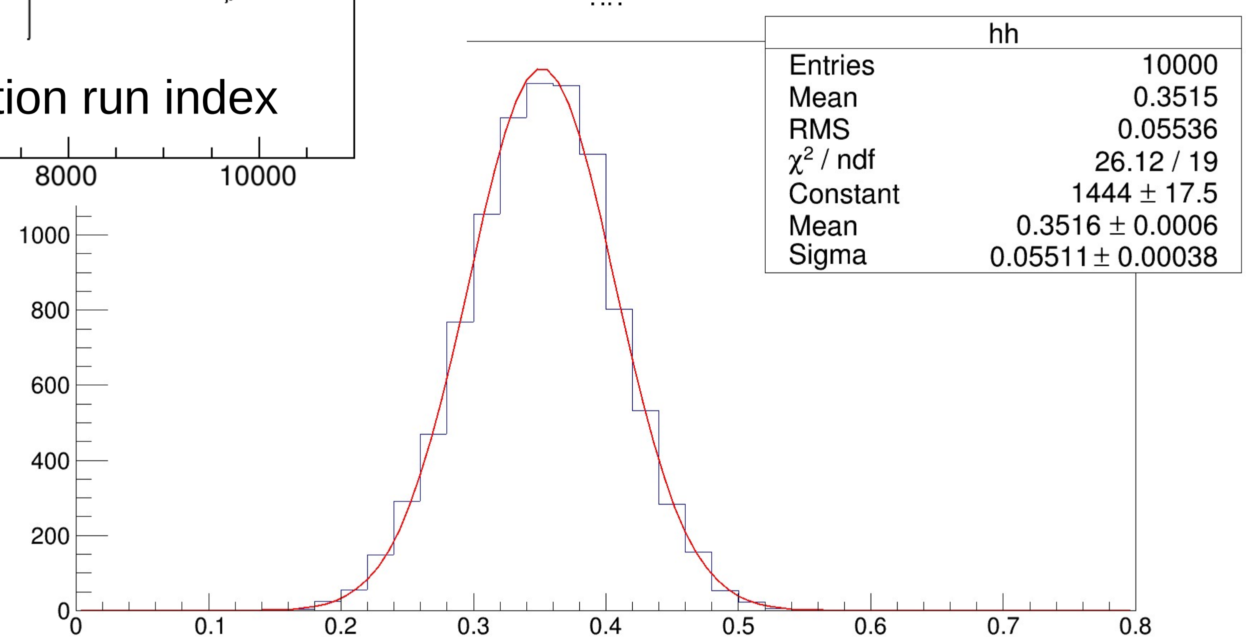
For each bin in the signal region, simulate number of BG events based on the cyan distribution.

Repeat for N times

Take the average as a number of Netto neutrons

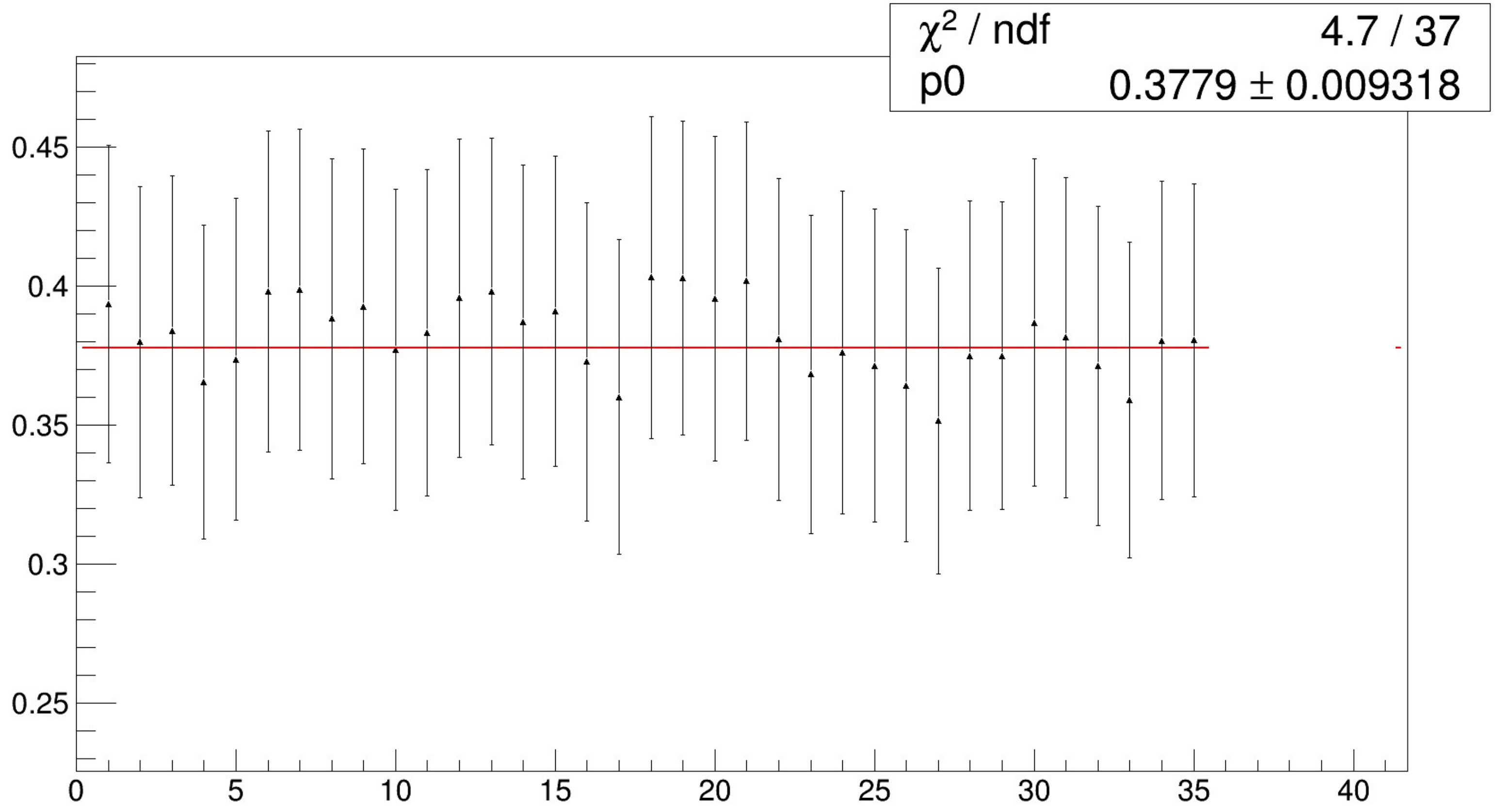
Sensitivity check of BG subtraction
10 000 realizations





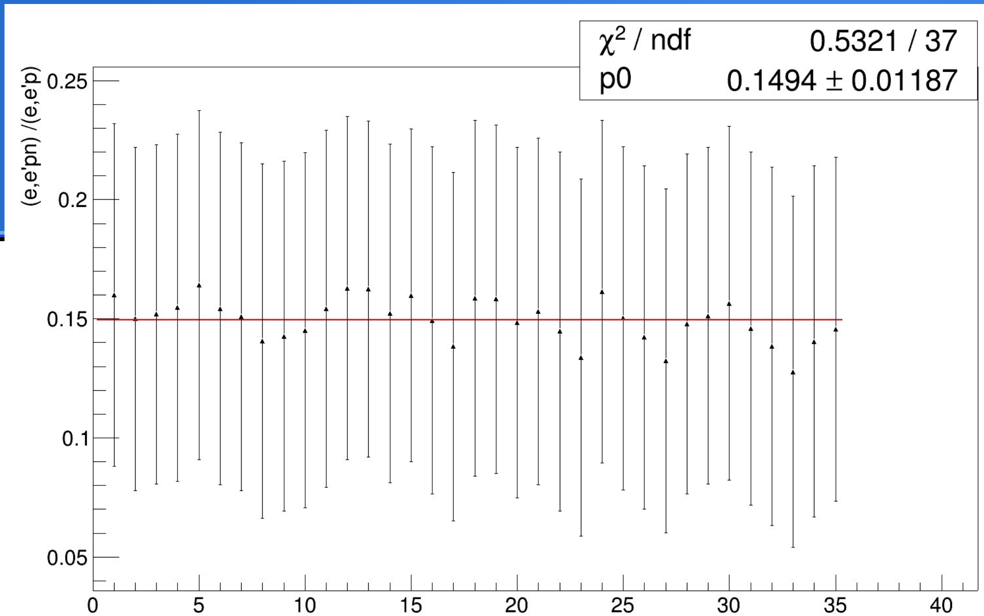
Using the background subtraction and events selection for C(e,e'pn) and C(e,e'p)

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

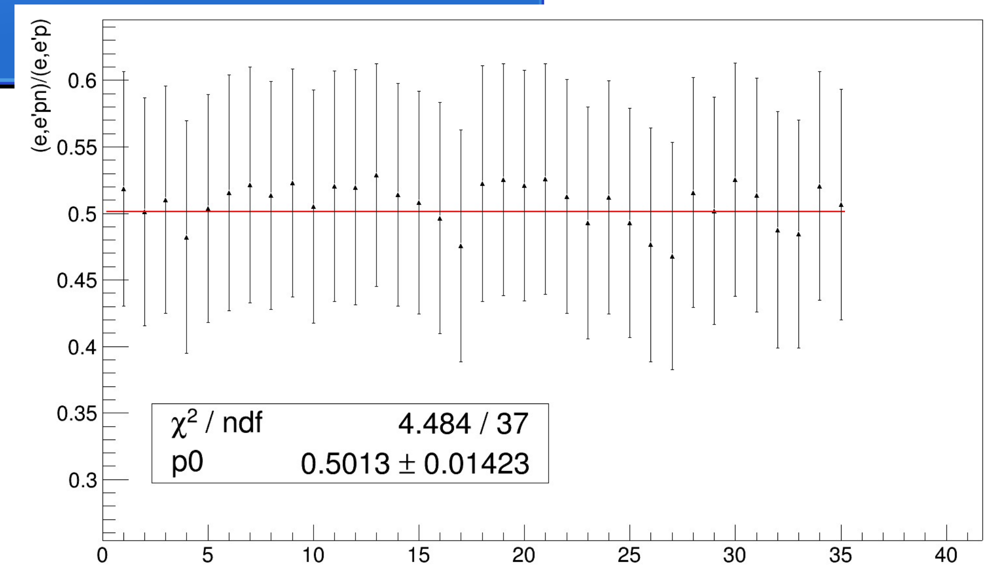


*Data is corrected to the neutron detection efficiency

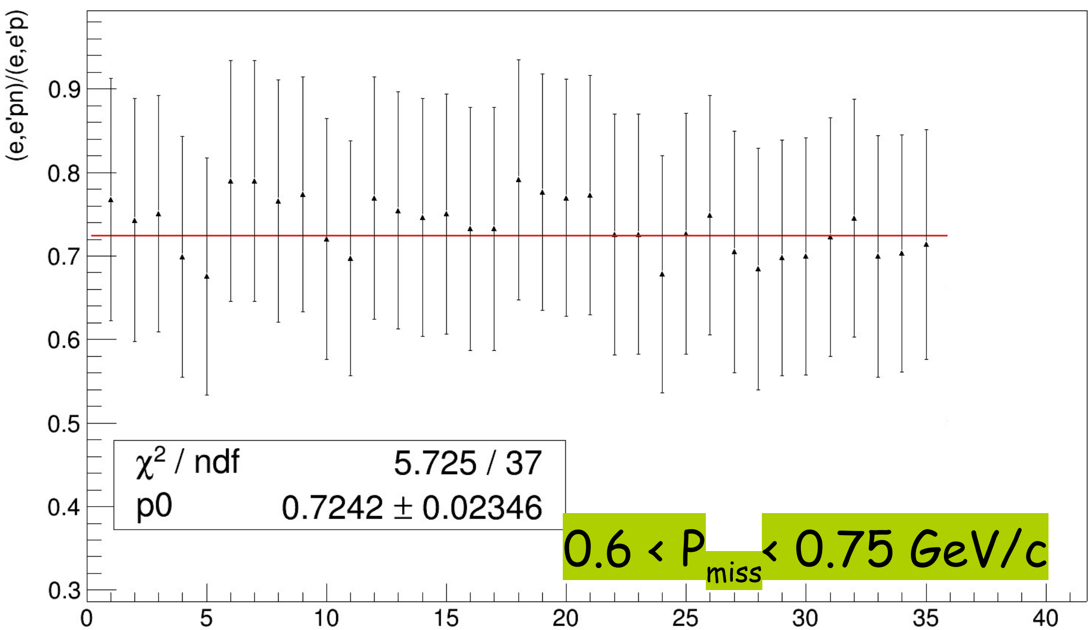
C(e,e'pn)/C(e,e'p) missing momentum dependence



$0.3 < P_{miss} < 0.45$ GeV/c



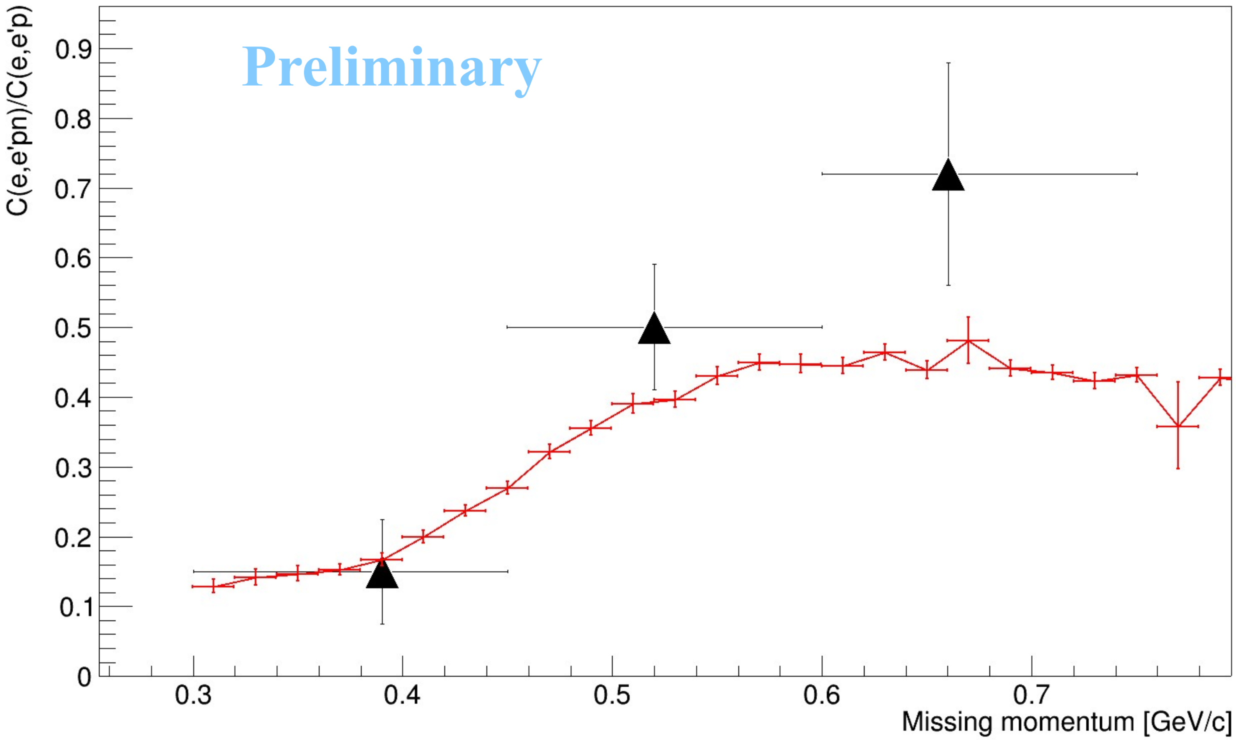
$0.45 < P_{miss} < 0.6$ GeV/c



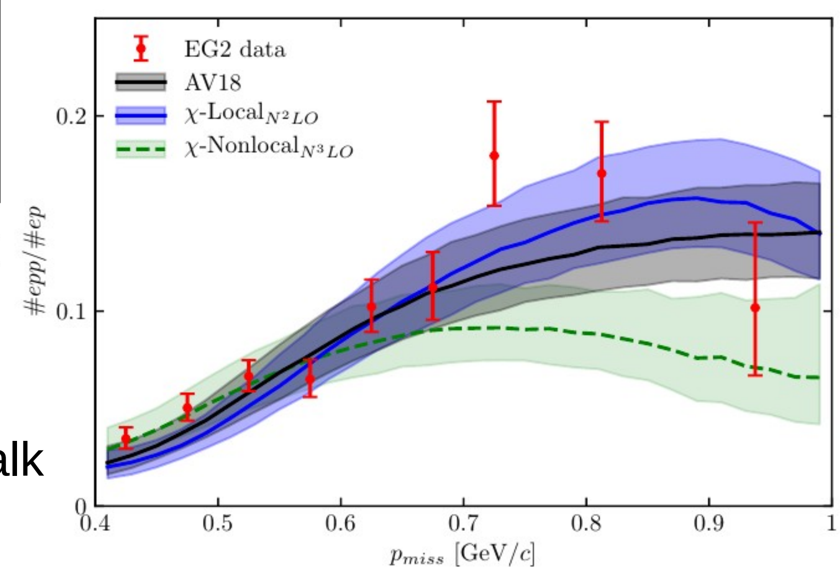
$0.6 < P_{miss} < 0.75$ GeV/c

C(e,e'pn)/C(e,e'p) Result

*Data is corrected to the neutron detection efficiency



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



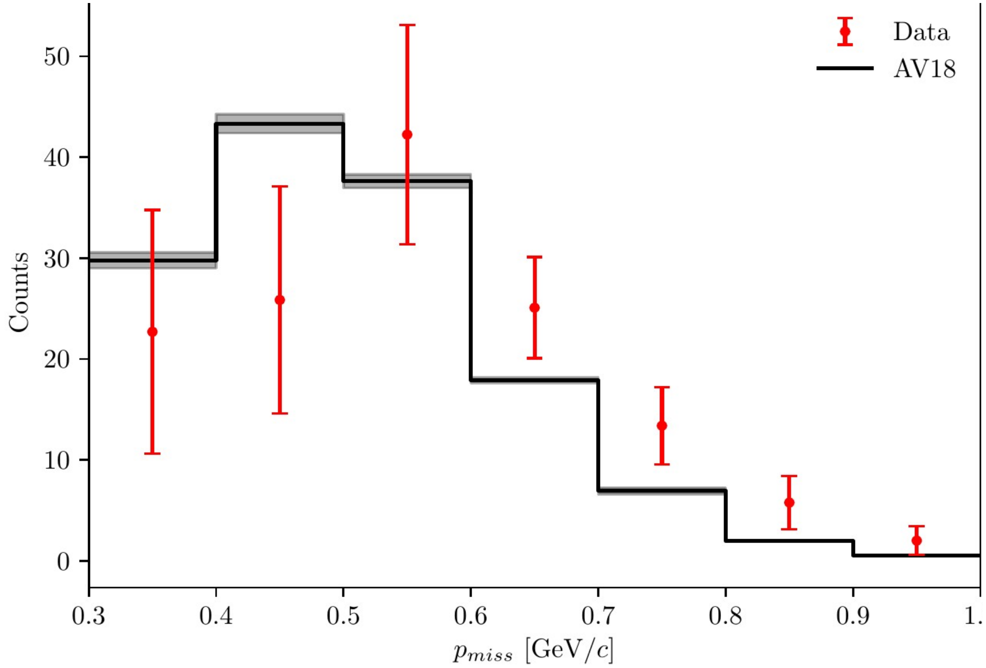
See Axel talk

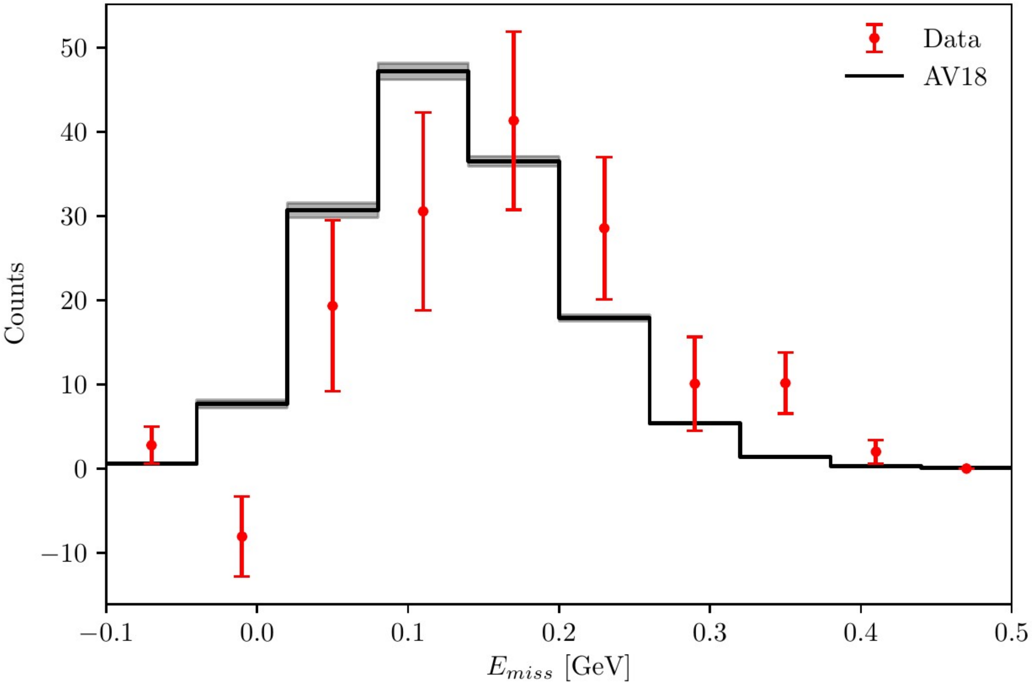
Kinematic variable comparison to the generator prediction

E_p - Energy of knocked out proton

Comparison between missing energy $$E_{\mathrm{miss}} = \sqrt{\left(\omega + m_{Carbon} - E_p\right)^2 - p_{miss}^2} + m_n - m_{Carbon}$$

Missing Momentum





Future Plans

Add Coulomb correction

Determine the systematic uncertainties

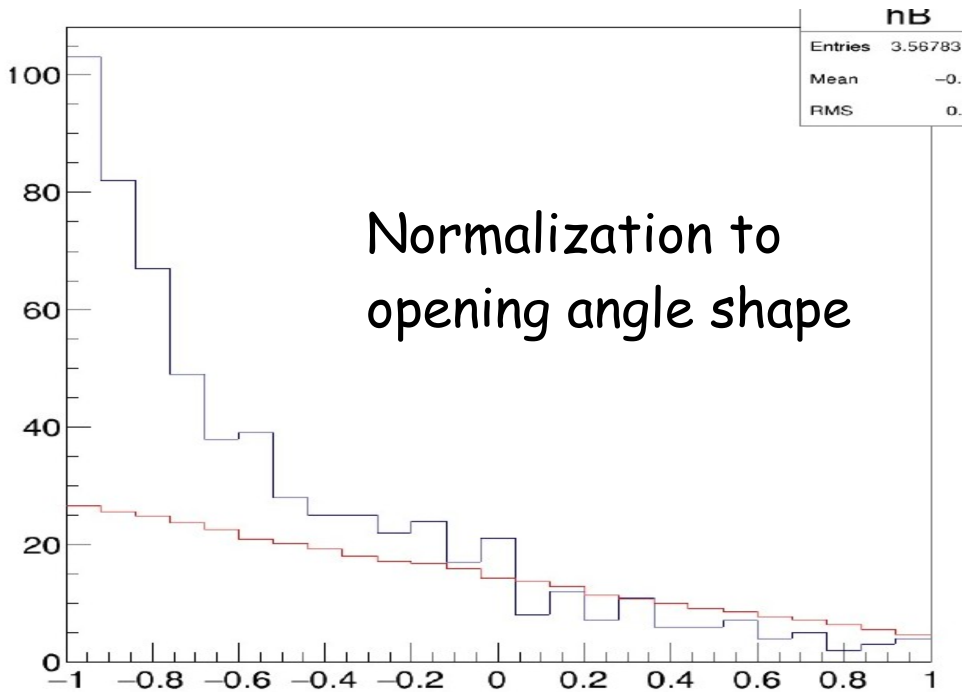
1) Veto algorithm
2) Neutron detection efficiency (energy deposit)
3) Background subtraction technique

Comparison to NN - Interaction prediction (Generator)

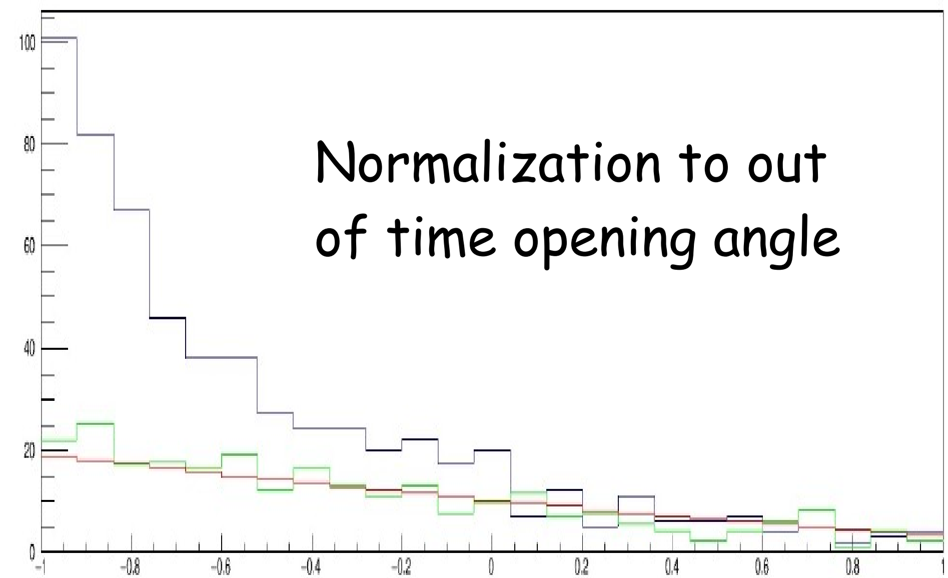
Analysis for Fe target (Al ans Pb) will not have enough statistics

Report Preparation

Backup Slides



Normalization to opening angle shape



Normalization to out of time opening angle

Xb > 1.1 (instead of x>1.2 in order to increase statistics)

Systematically above data between 0 to 1 and below from 0 to -1

Difference between missing momentum and neutron regions is due to final resolution of the neutrons