Probing pp-SRC in ^{12}C, ^{56}Fe, and ^{208}Pb using the A(e,e'p) and A(e,e'pp) reactions

[EG2 Data Mining Analysis]

Or Hen

Tel-Aviv University

In Collaboration with:

- **H. Hakobyan, W. Brooks (UTSM)**
- **L. B. Weinstein (ODU)**
- **S. Gilad (MIT)**
- **R. Shneor, S. May-Tal Beck, E. Piasetzky (TAU)**

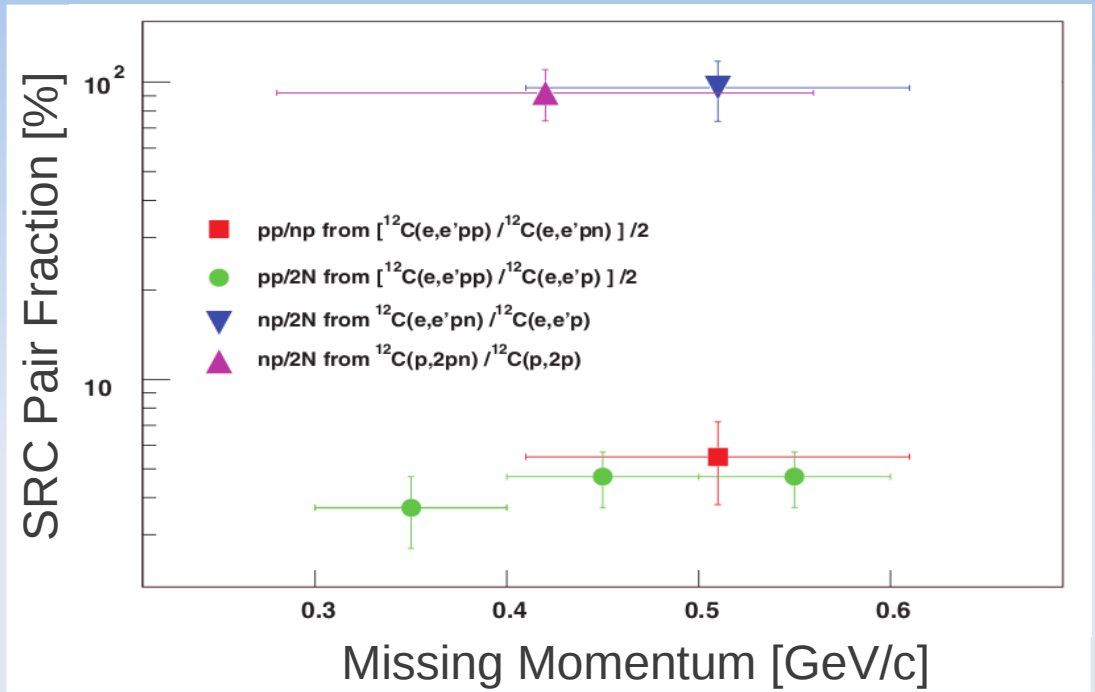
Jefferson Lab Hall-B NPWG meeting, February (2012)

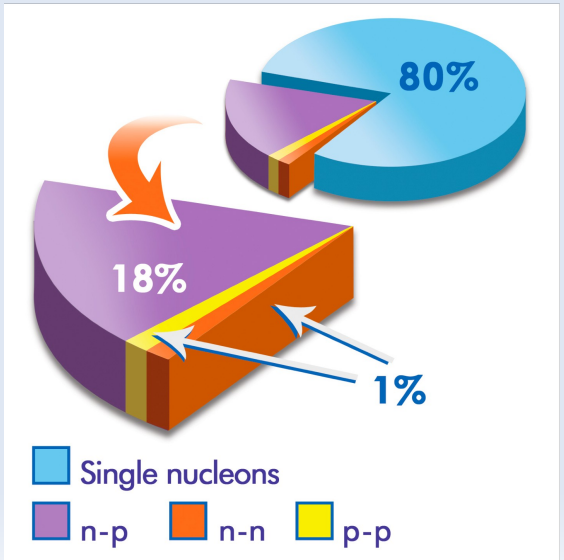
General Outline

- Two Nucleon Short Range Correlations (2N-SRC)
- EG2 data set
- Kinematics
- Events selection
- Events Characterization
- pp-SRC probabilities
- Momentum correction sensitivity study

Results From Previous Experiments

- Experiment E01-015 run in 2004 at JLab Hall-A
- Measured pp and pn SRC pairs in ^{12}C at $X_B>1$
- Confirmed BNL observation that the high momentum tail is dominated by 2N-SRC pairs
- Showed np over pp dominance for: $300<P_{miss}<550$ MeV/c





R. Subedi et al., Science, 320, 1476 (2008)

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

E. Piastzky et al., Phys. Rev. Lett. 97, 162504 (2006)

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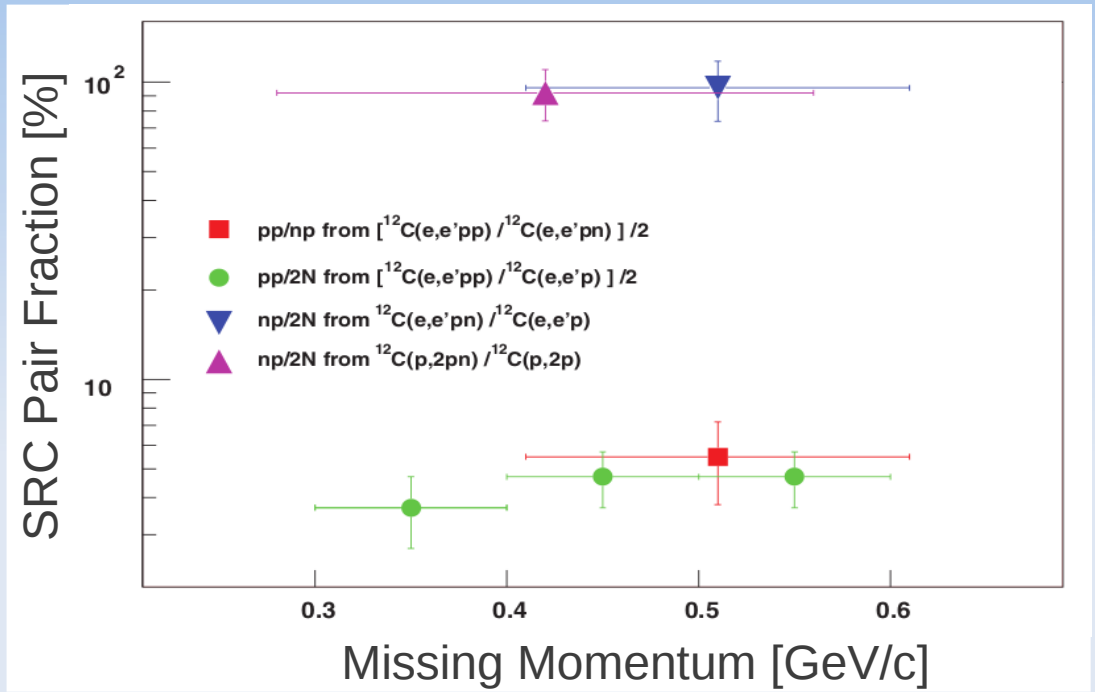

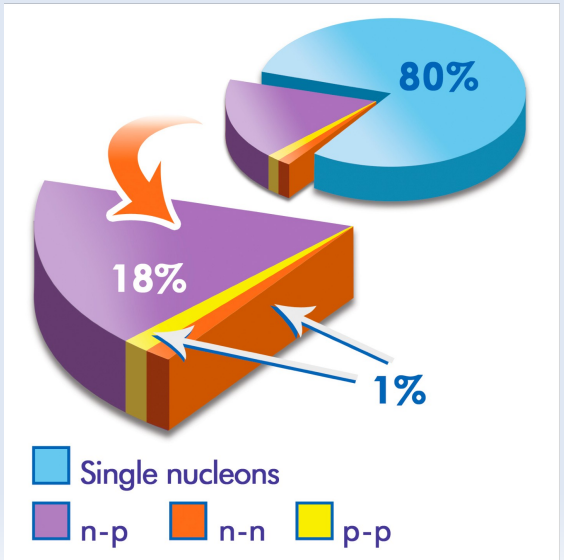

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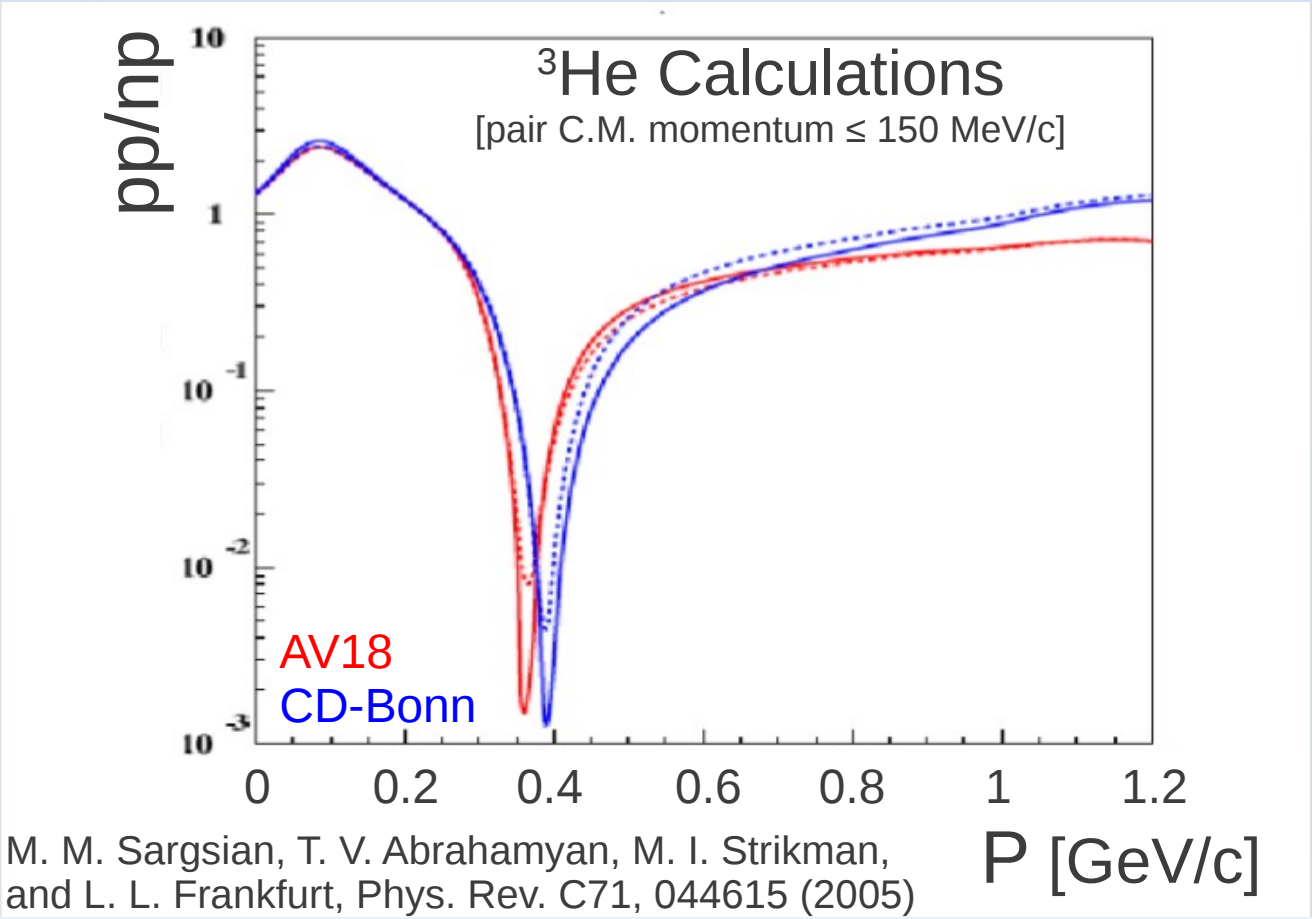
Main Open Questions

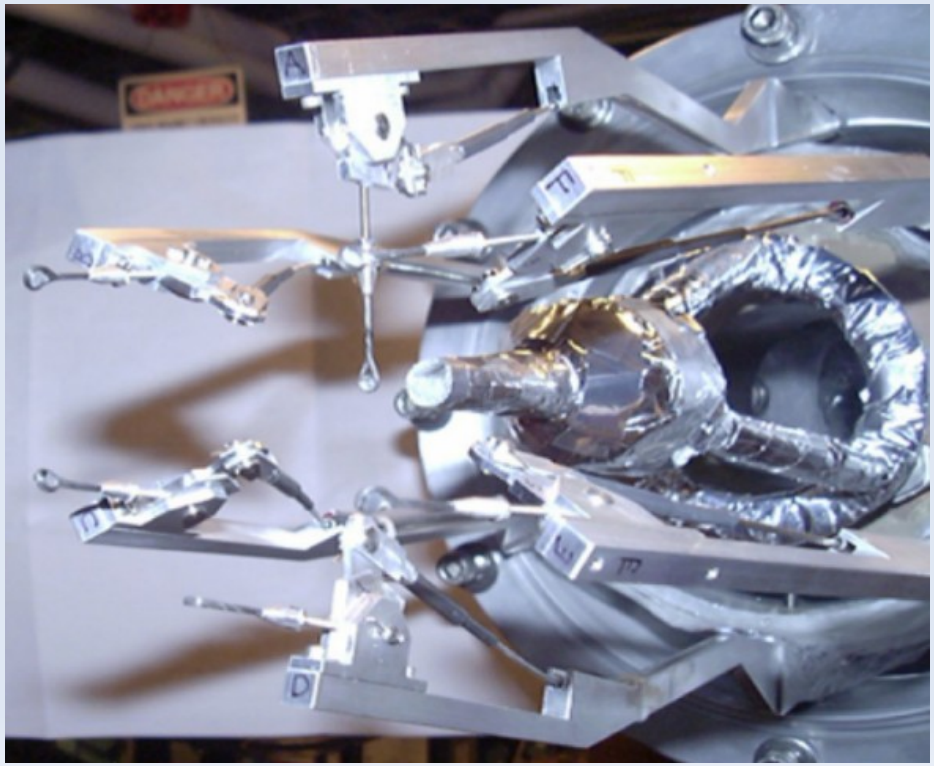
- Do the ^{12}C results hold for other nuclei ?
- What is the Isospin structure of 2N-SRC at large P_{miss} (>600 MeV/c) ?

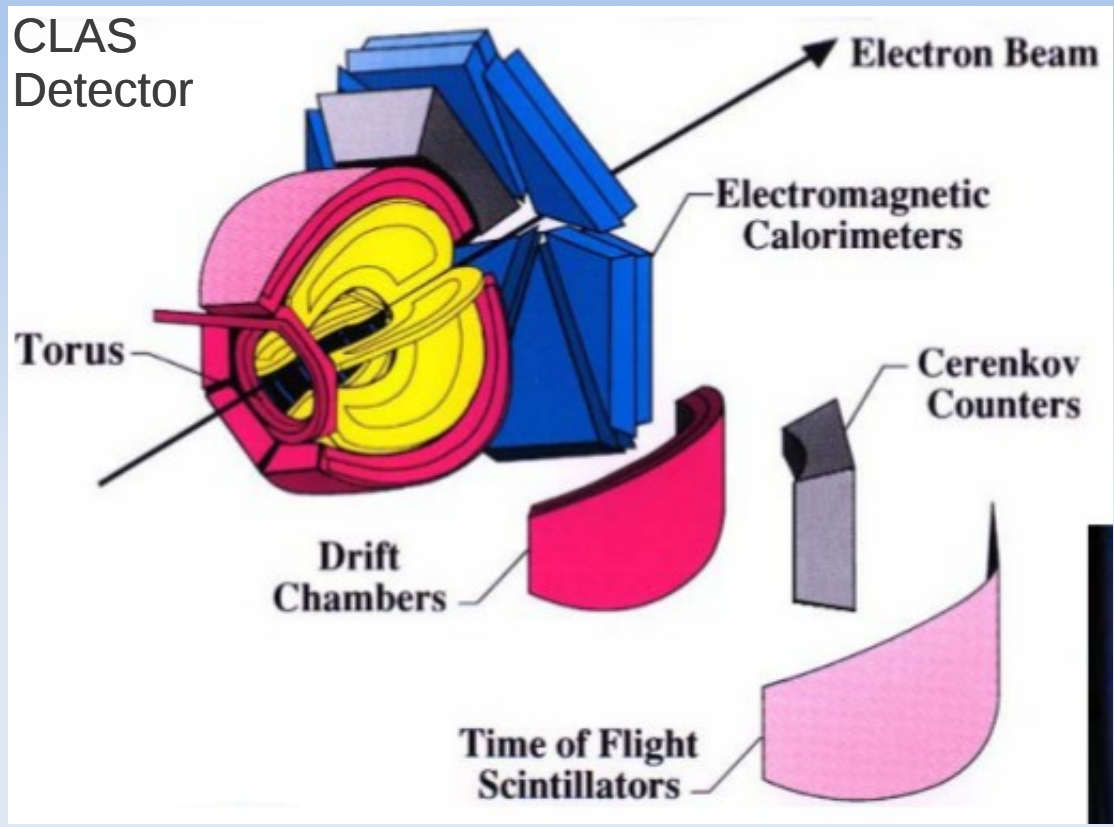


M. M. Sargsian, T. V. Abrahamyan, M. I. Strikman, and L. L. Frankfurt, Phys. Rev. C71, 044615 (2005)

EG2 Data Set

- Run at 2004 in Hall-B of Jefferson Lab
- 5 GeV electron beam
- Deuterium + Solid target simultaneously





Data collected for:

deuterium + $^{12}C/^{56}Fe/^{208}Pb$

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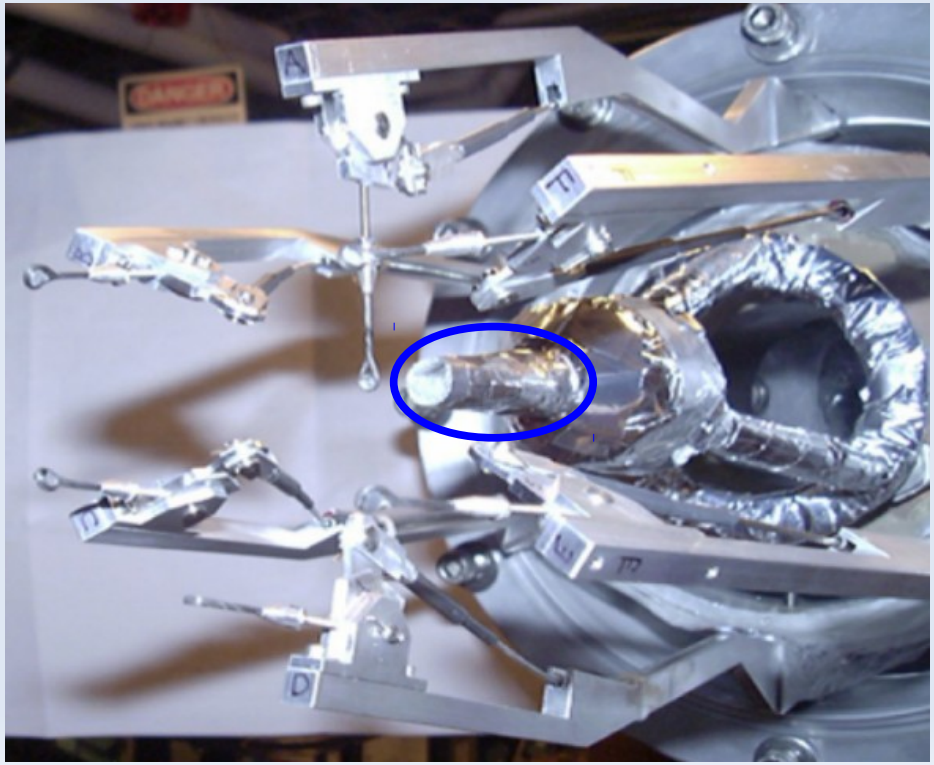

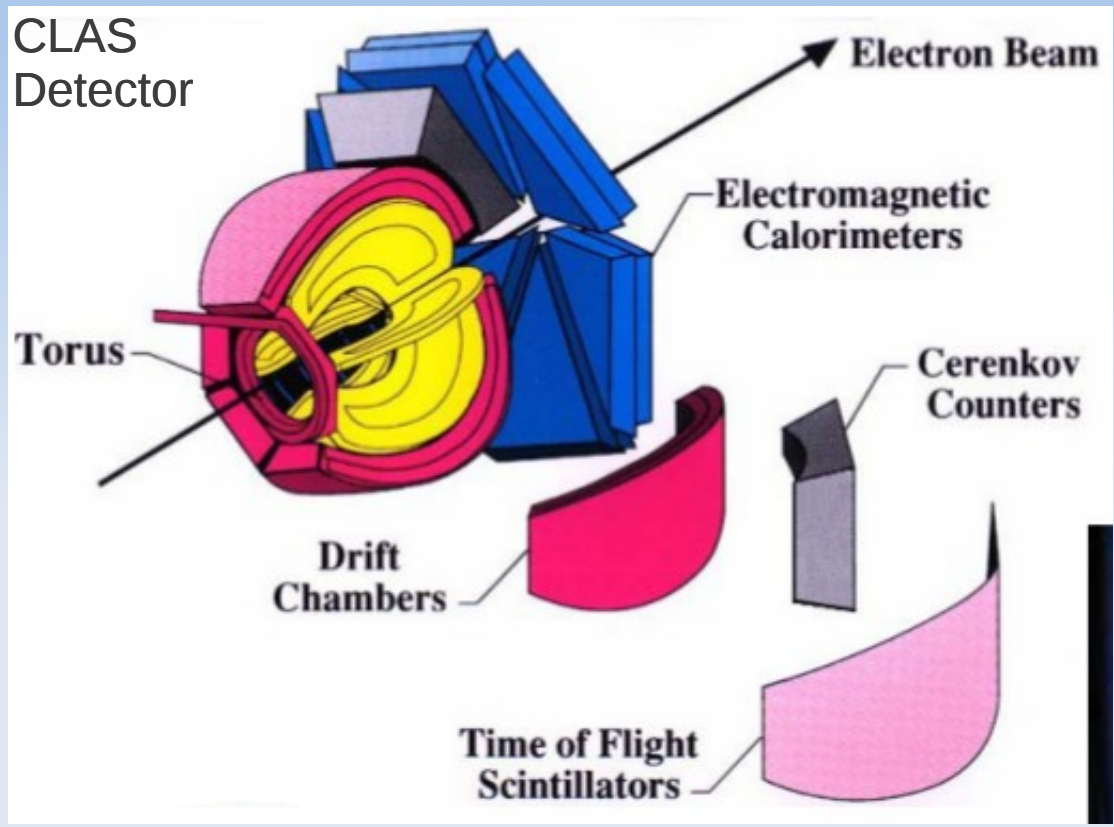

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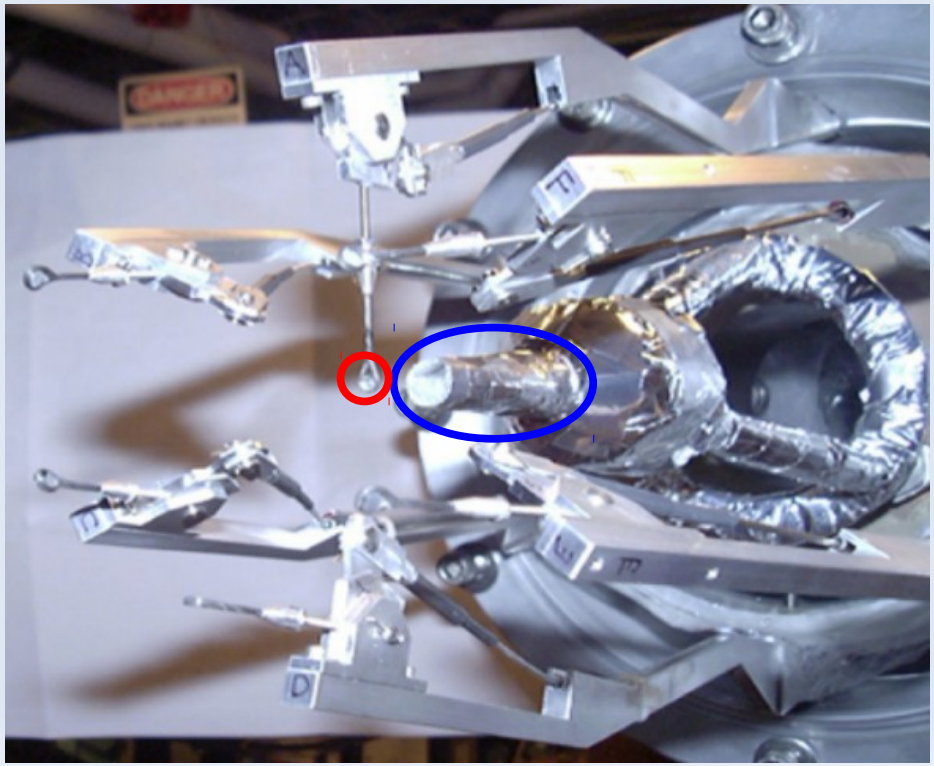

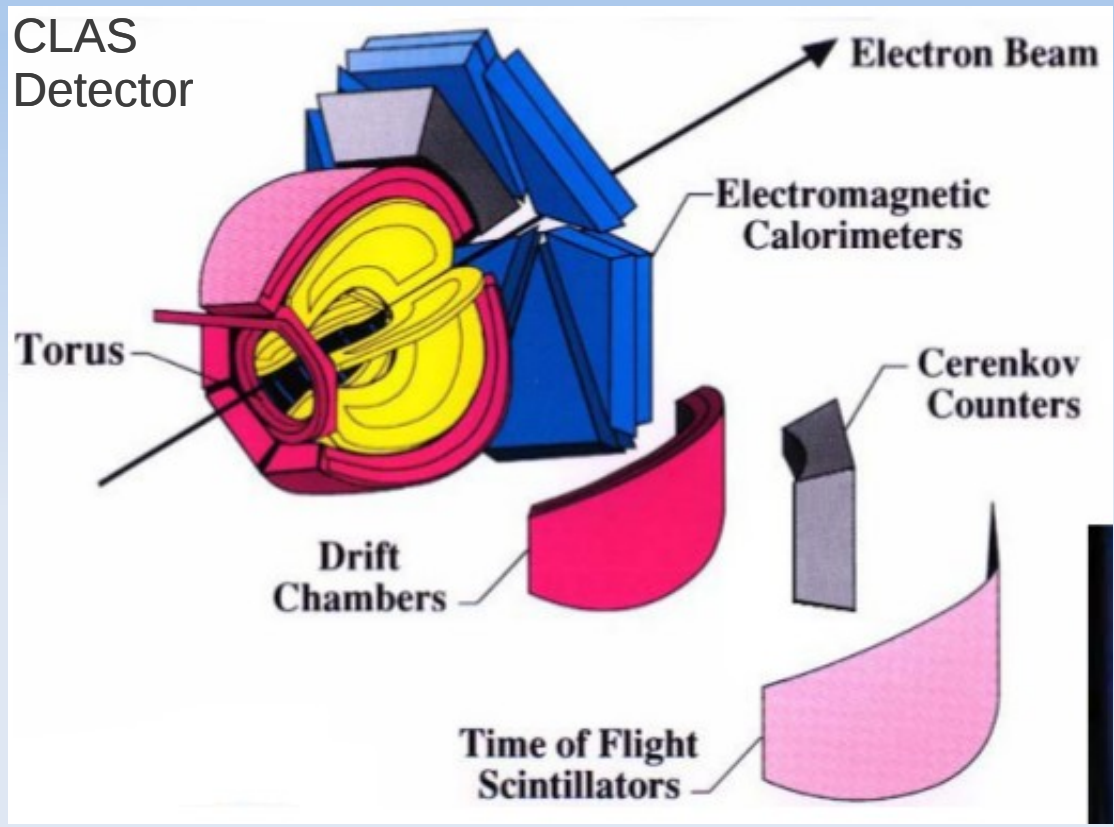

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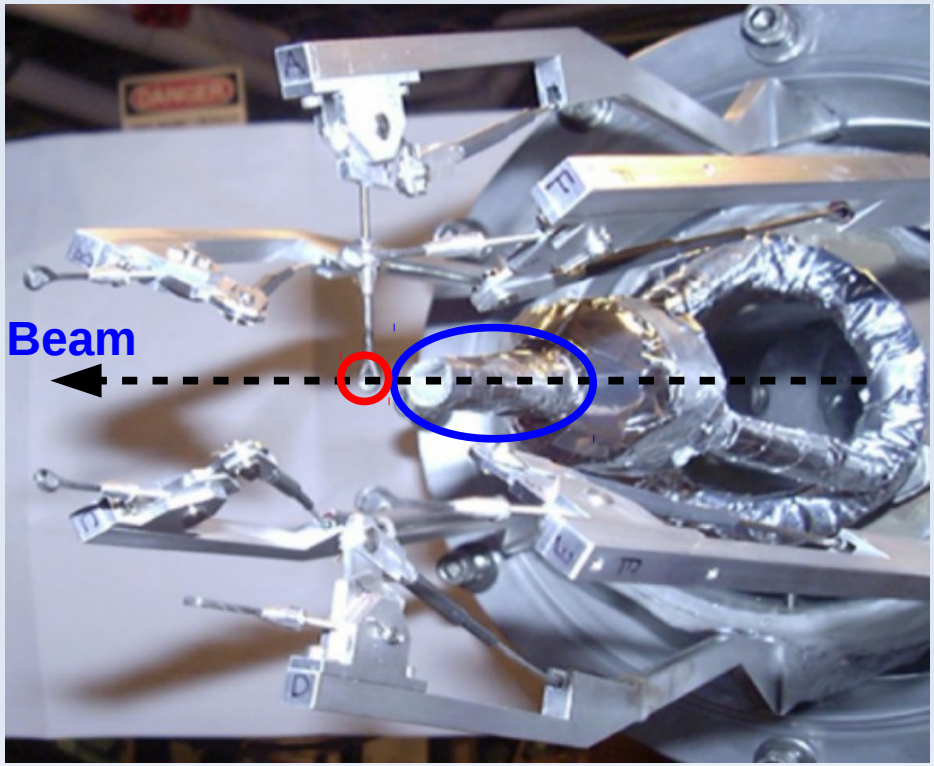

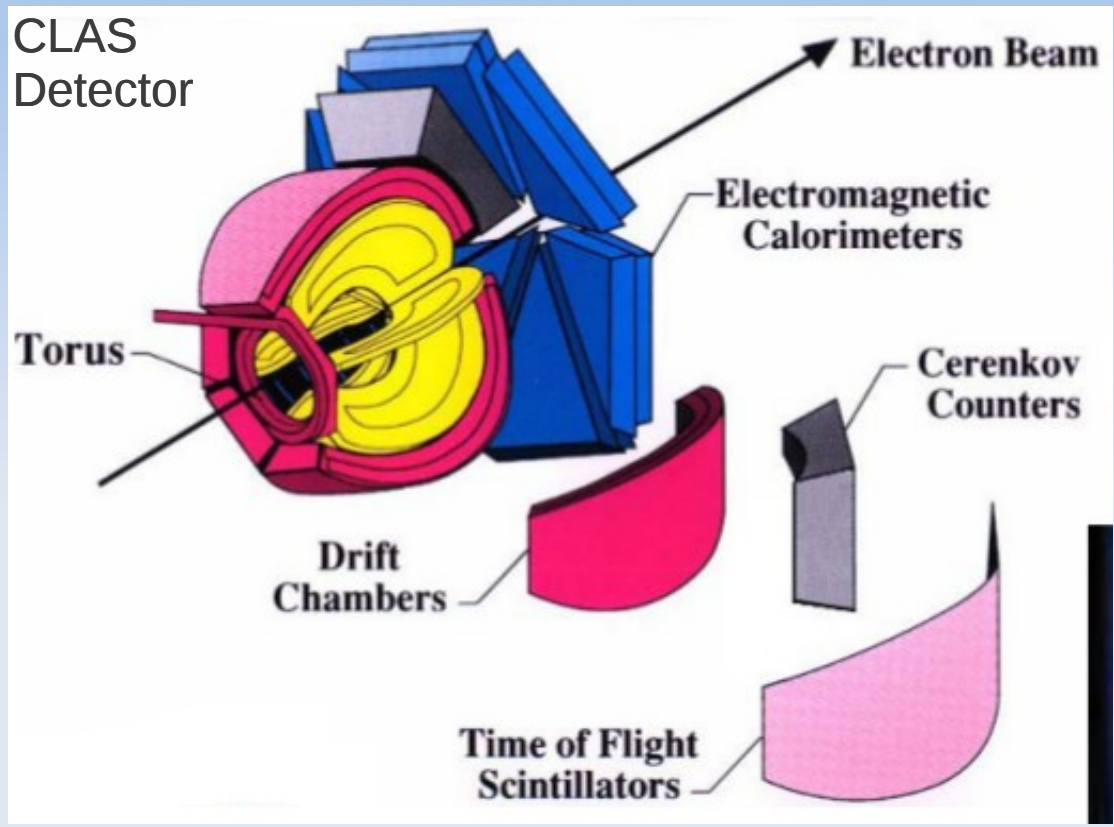

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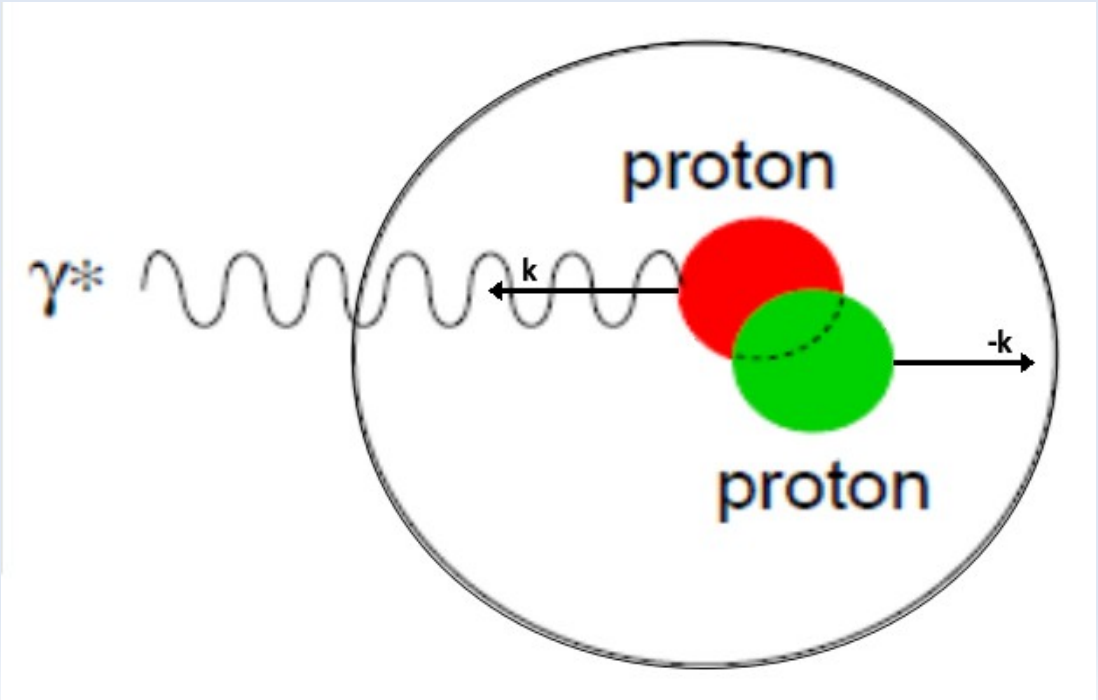
Kinematics

- Large Q^2 – suppress meson exchange currents
- High x_B (>1) – suppress isobar contributions

  – confine FSI to within the pp-SRC pair



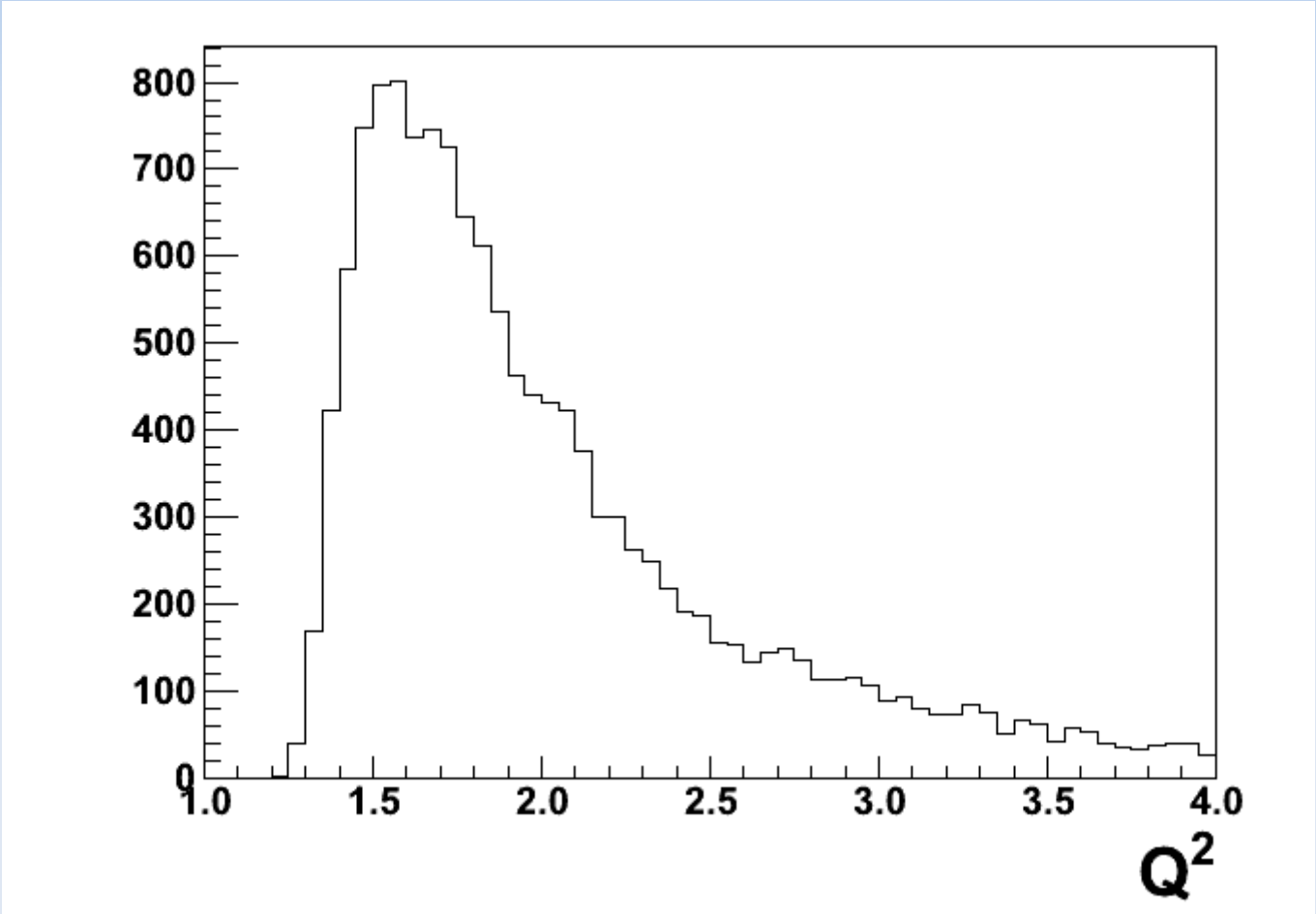
"Anti-Parallel" kinematics

$$x_B^* = \frac{Q^2}{2 \cdot M_p \cdot \omega}$$

^{12}C(e,e'p) Event Selection

1. Kinematics:

- $X_B \geq 1.2$
- $P_{miss} \geq 300$ MeV/c
- → $Q^2 \geq 1.5$ GeV^2/c^2
  [result of the x_B cut]



* $\vec{P}_{miss} = \vec{P}_{detected} - \vec{q}$

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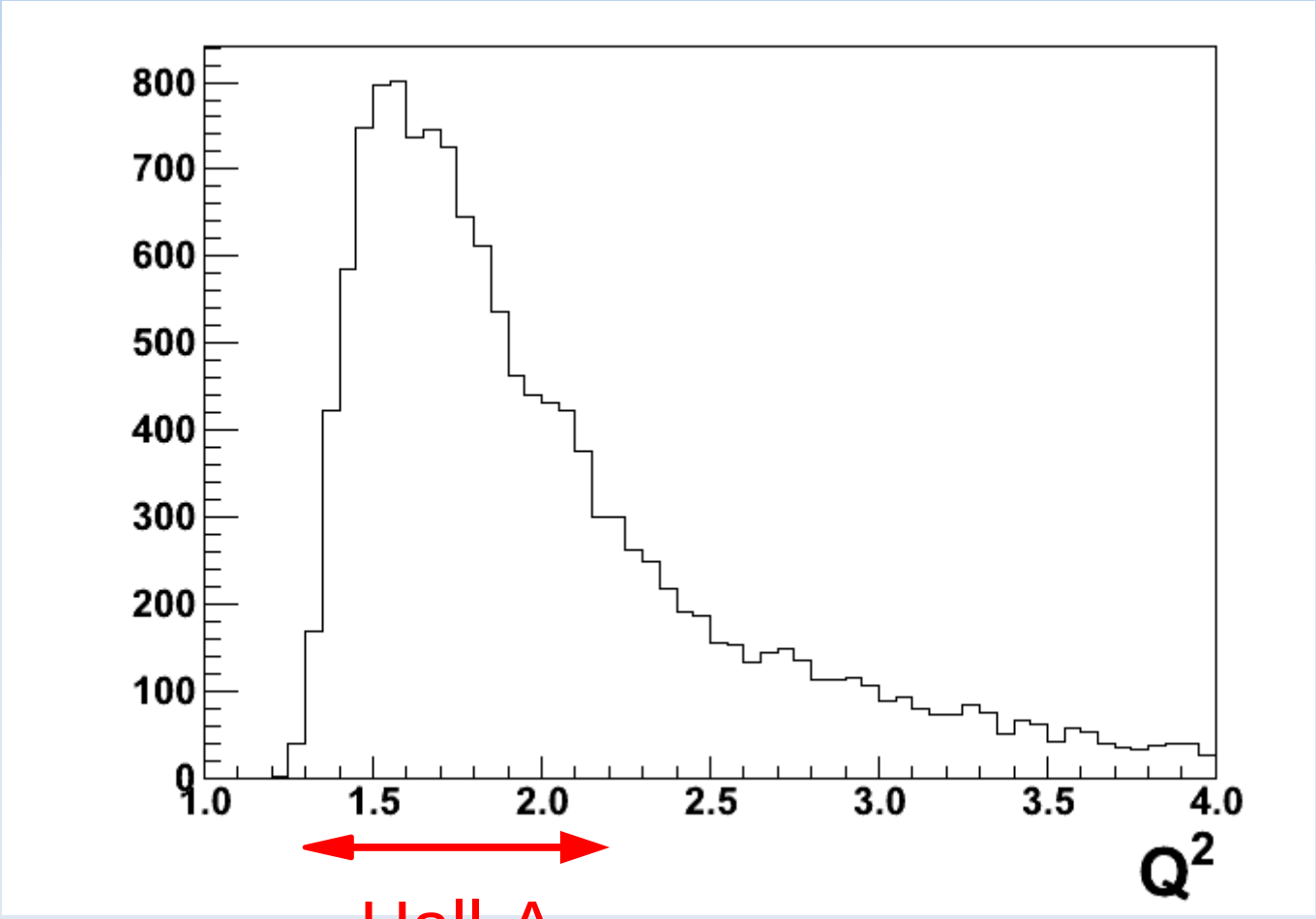

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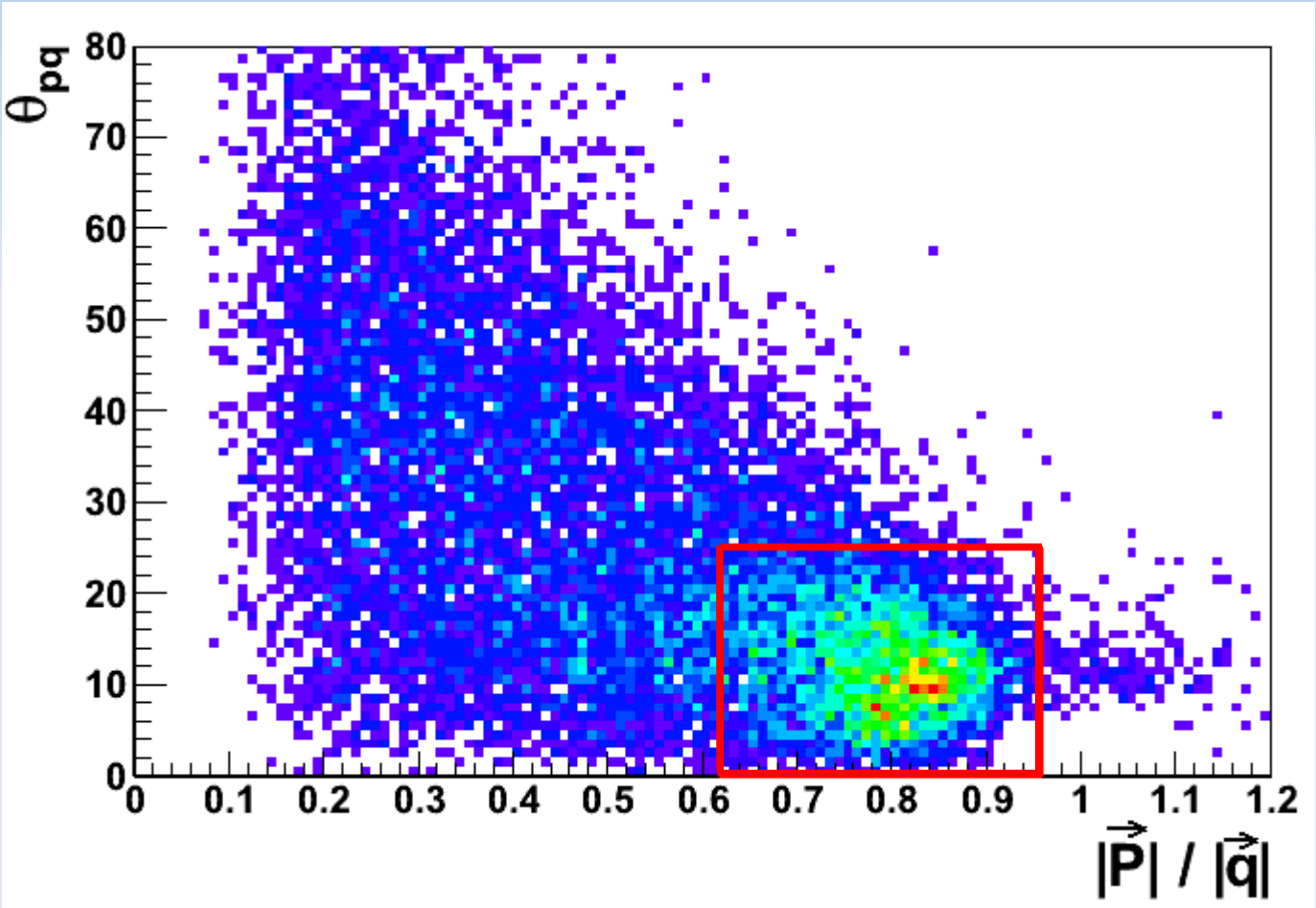
2. Leading Proton:

- $\theta_{pq} \leq 25^o$
- $0.62 \leq |p|/|q| \leq 0.96$



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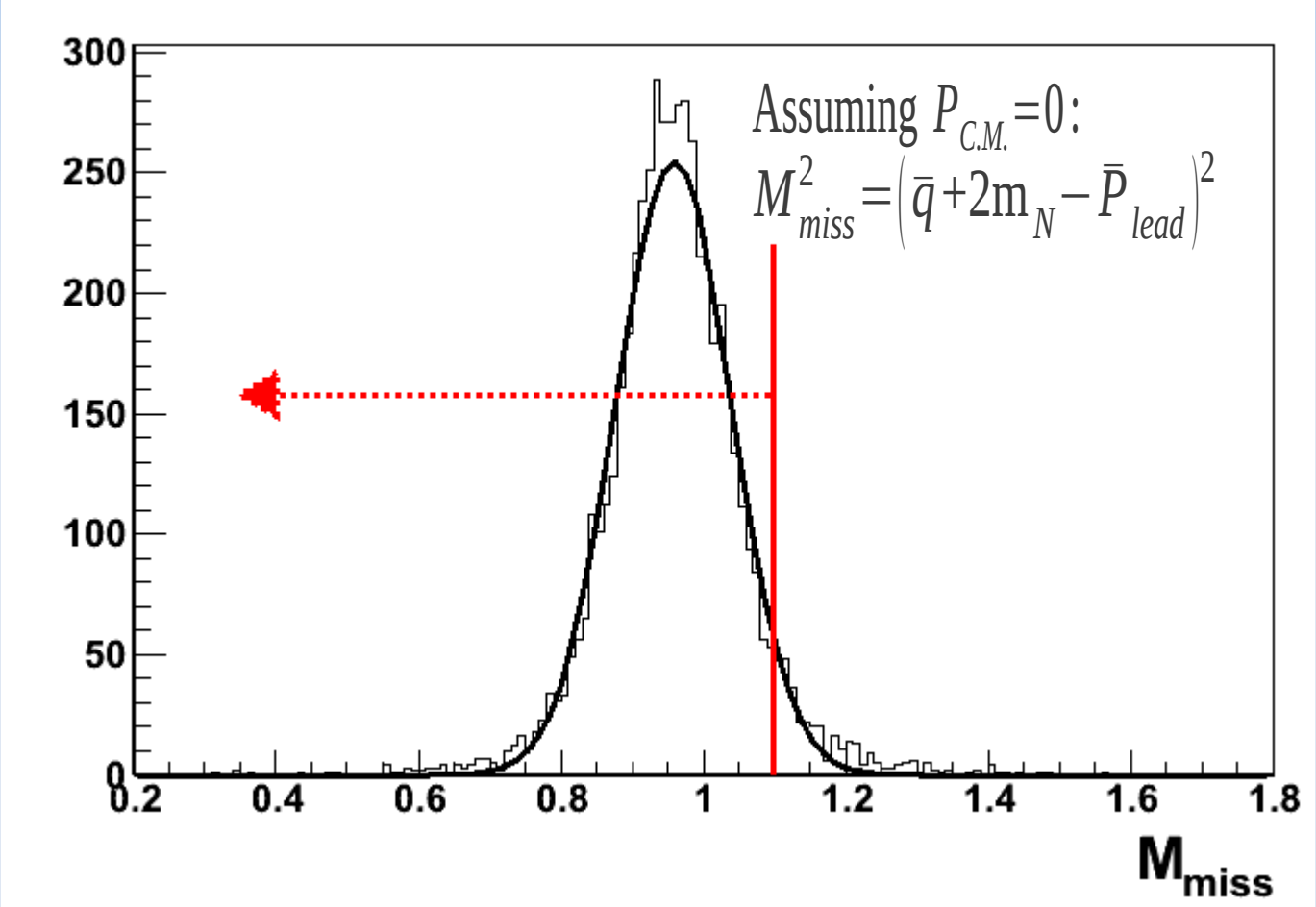
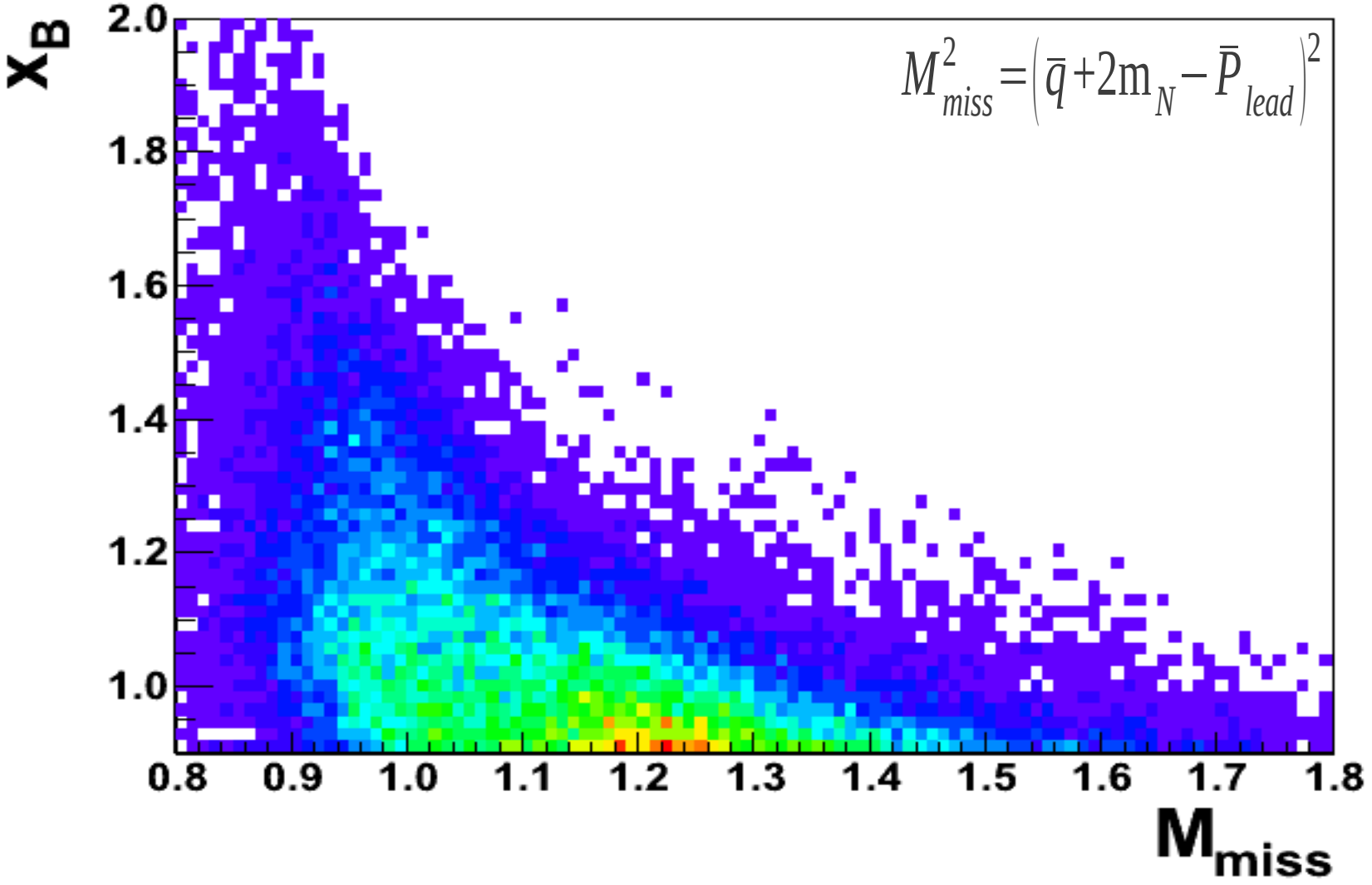
3. Missing Mass:

- $M_{miss} \leq M_p + M_{pi}$



Why high x_B?

I – Missing Mass



For leading protons with P_{miss} > 300 MeV/c

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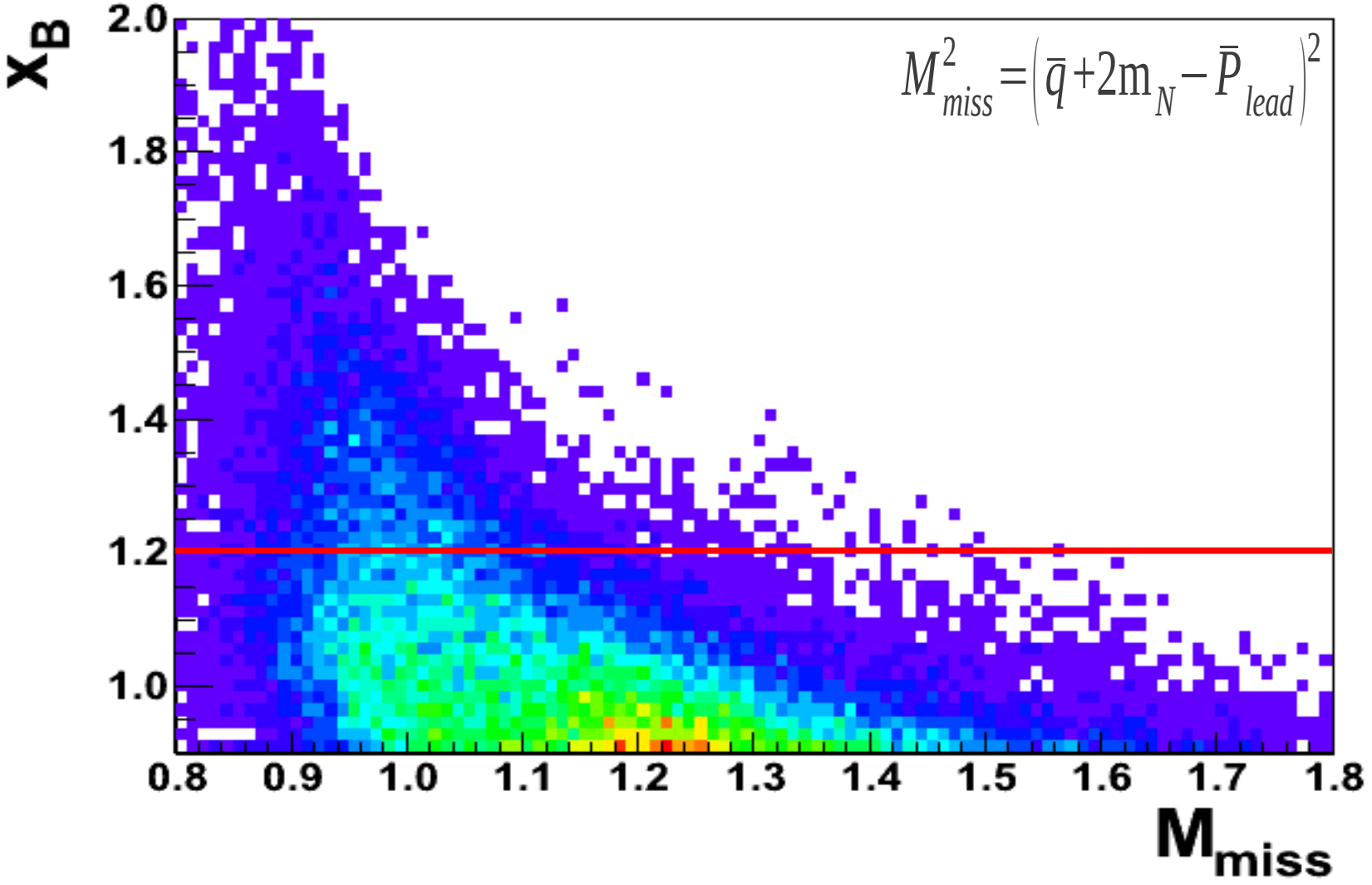

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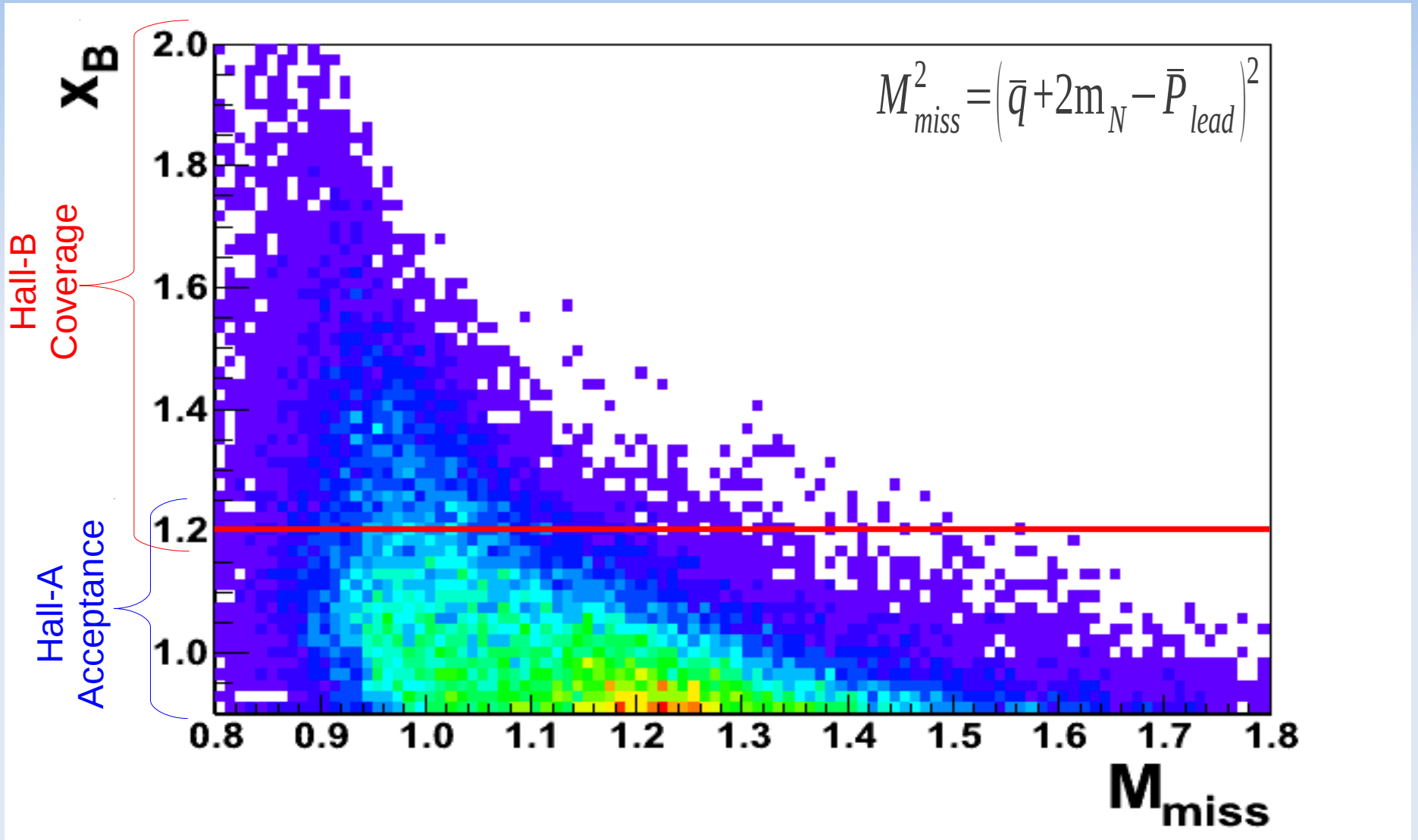
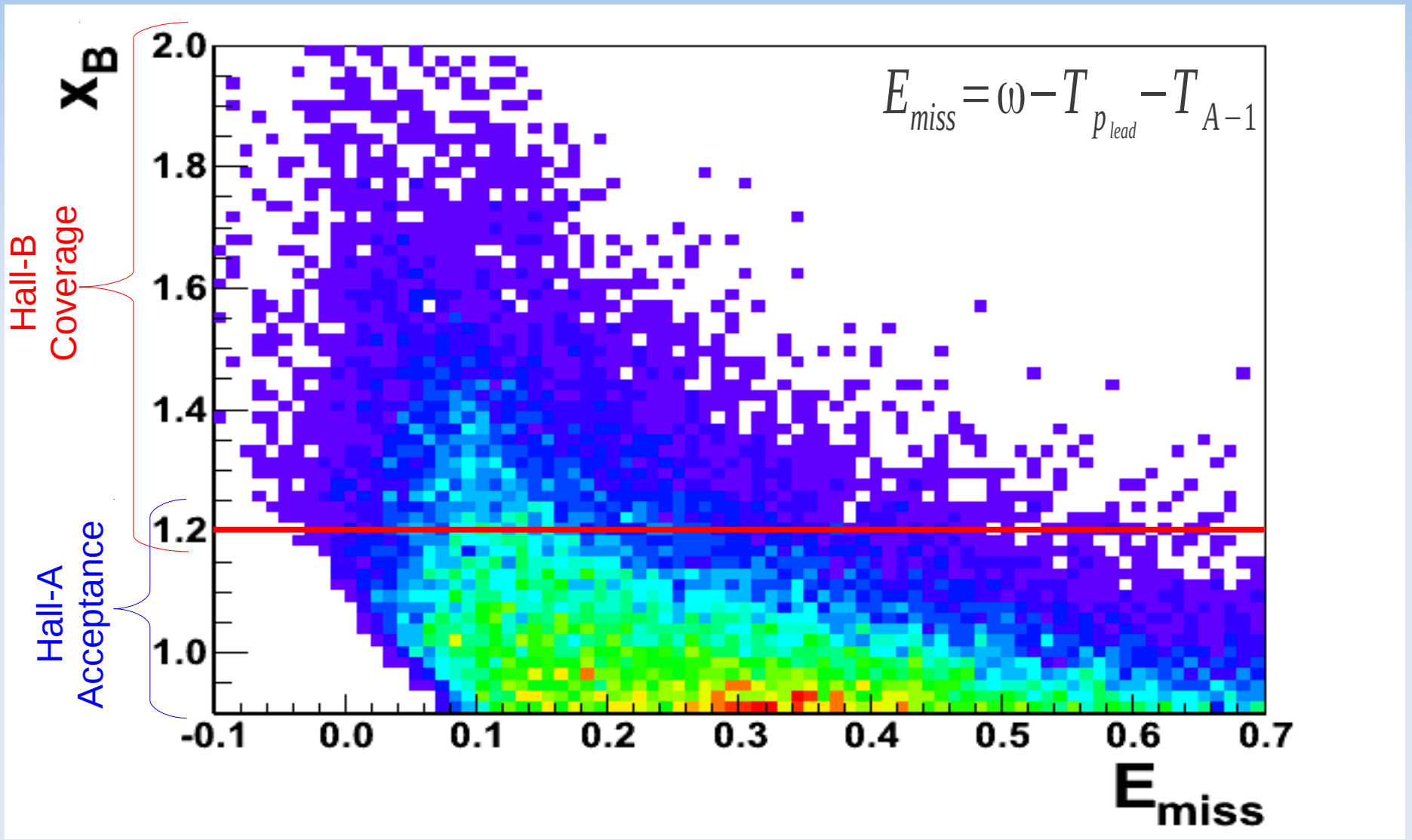


For leading protons with P_{miss} > 300 MeV/c

Why high x_B?

II – A-1 Residual System Excitation Energy



For leading protons with P_{miss} > 300 MeV/c

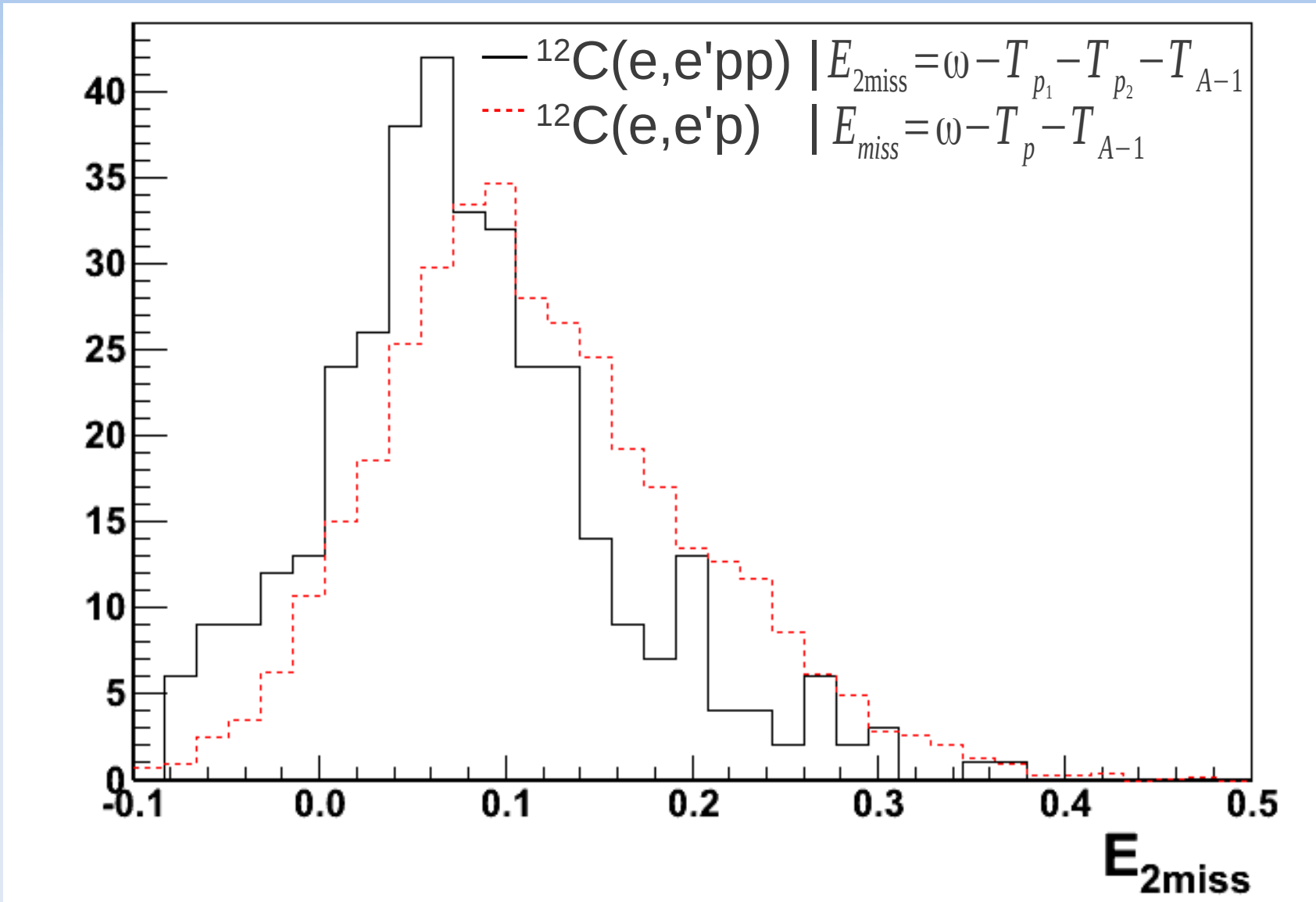
Selecting $^{12}C(e,e'pp)$ Events

- Select events with exactly two protons identified by CLAS
- Identify a leading proton
  - $\theta<25^{o}$, $0.62<|P|/|q|<0.96$
  - No events with two leading protons
  - All (e,e'p) cuts apply to the leading proton

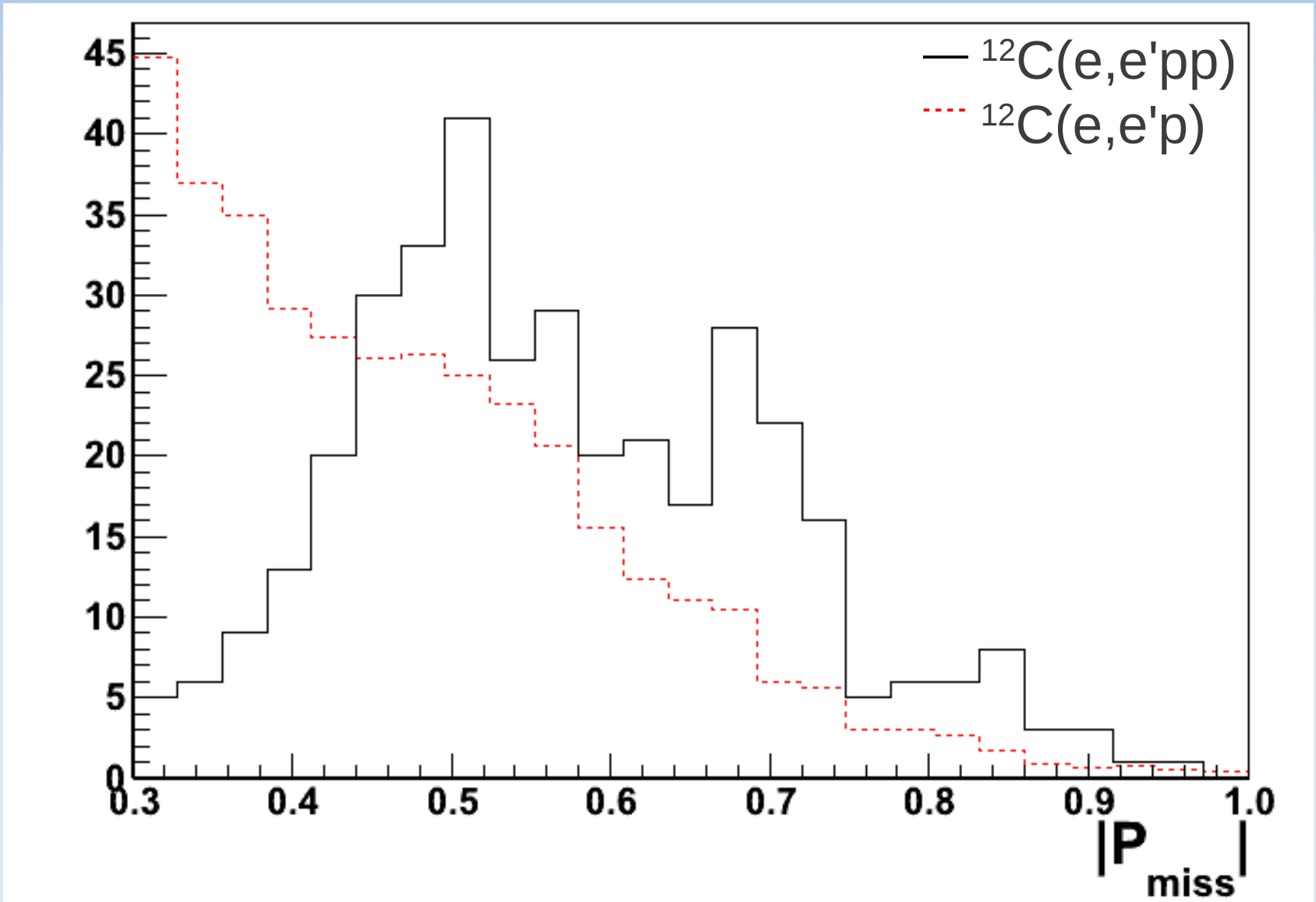
No cuts were applied on the recoil proton

Missing Energy

Excitation Energy of the A-1 and A-2 Residual Systems

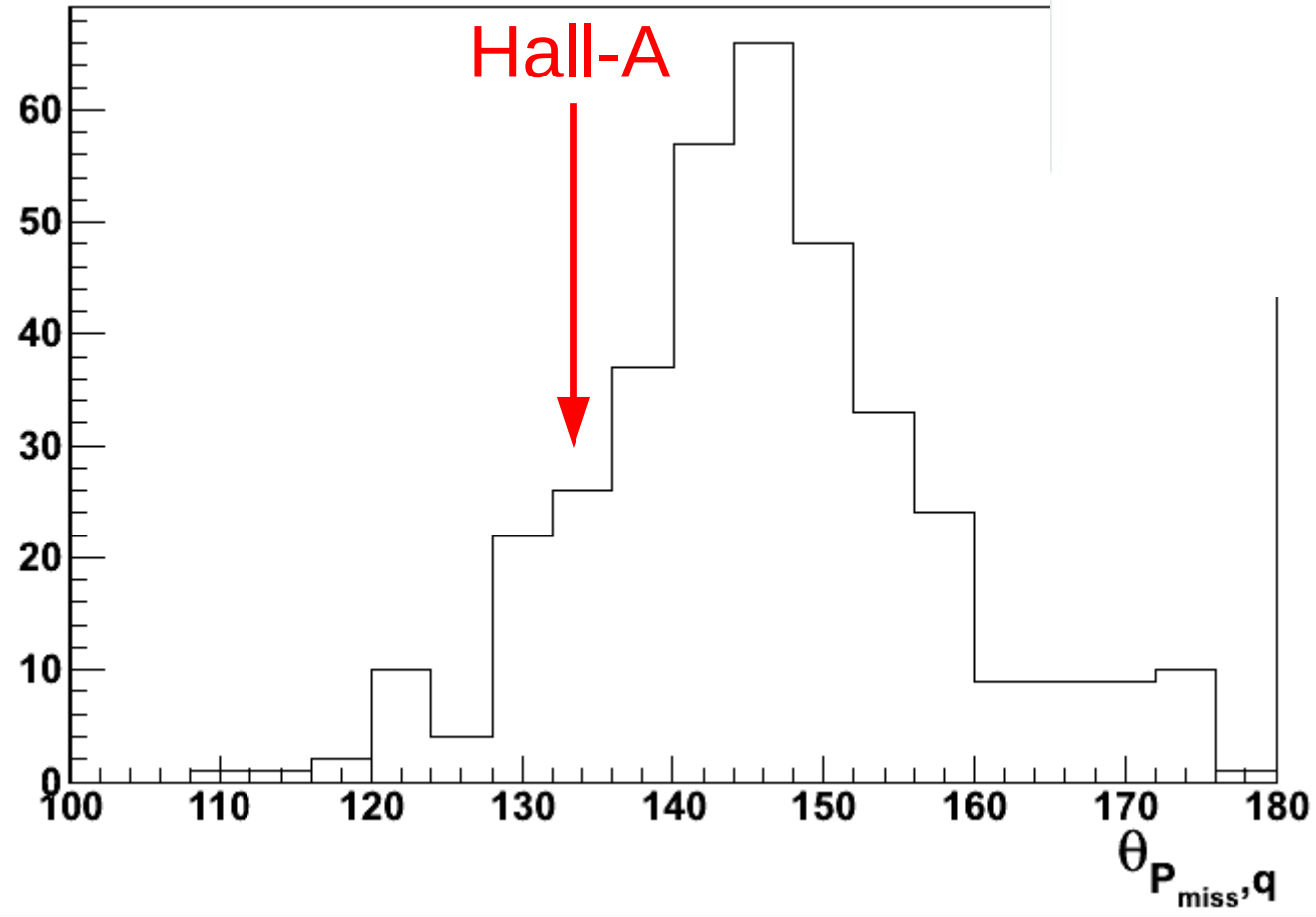


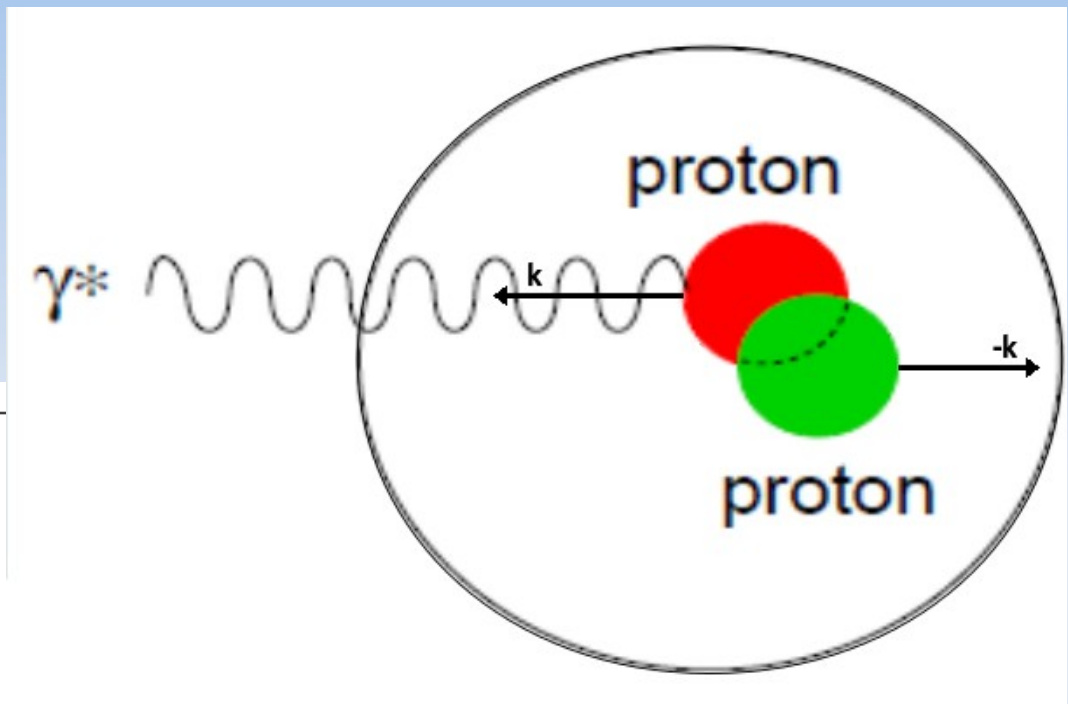
Missing Momentum Distribution



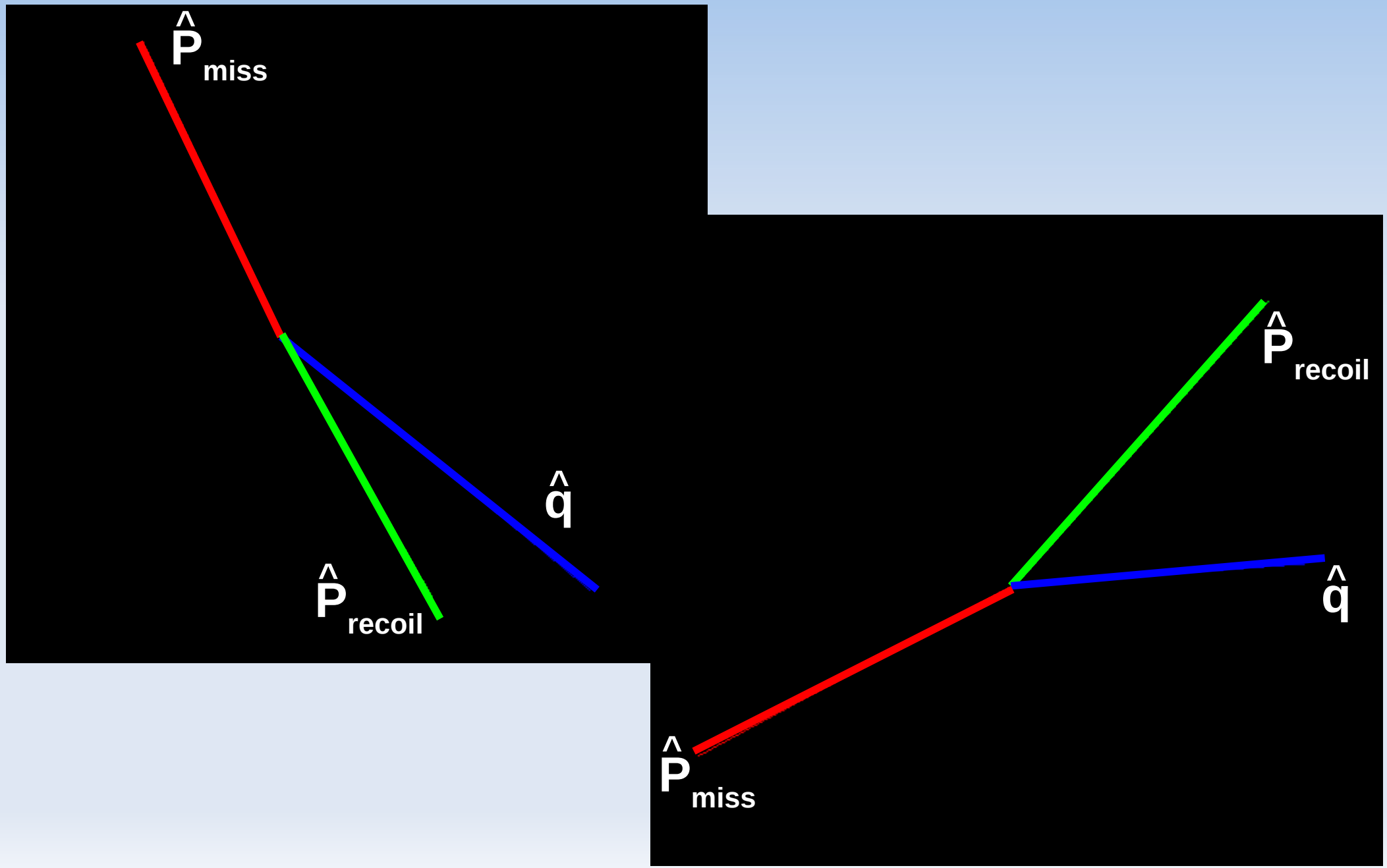
$$\vec{P}_{miss} = \vec{P}_{lead} - \vec{q}$$

Measurement Kinematics

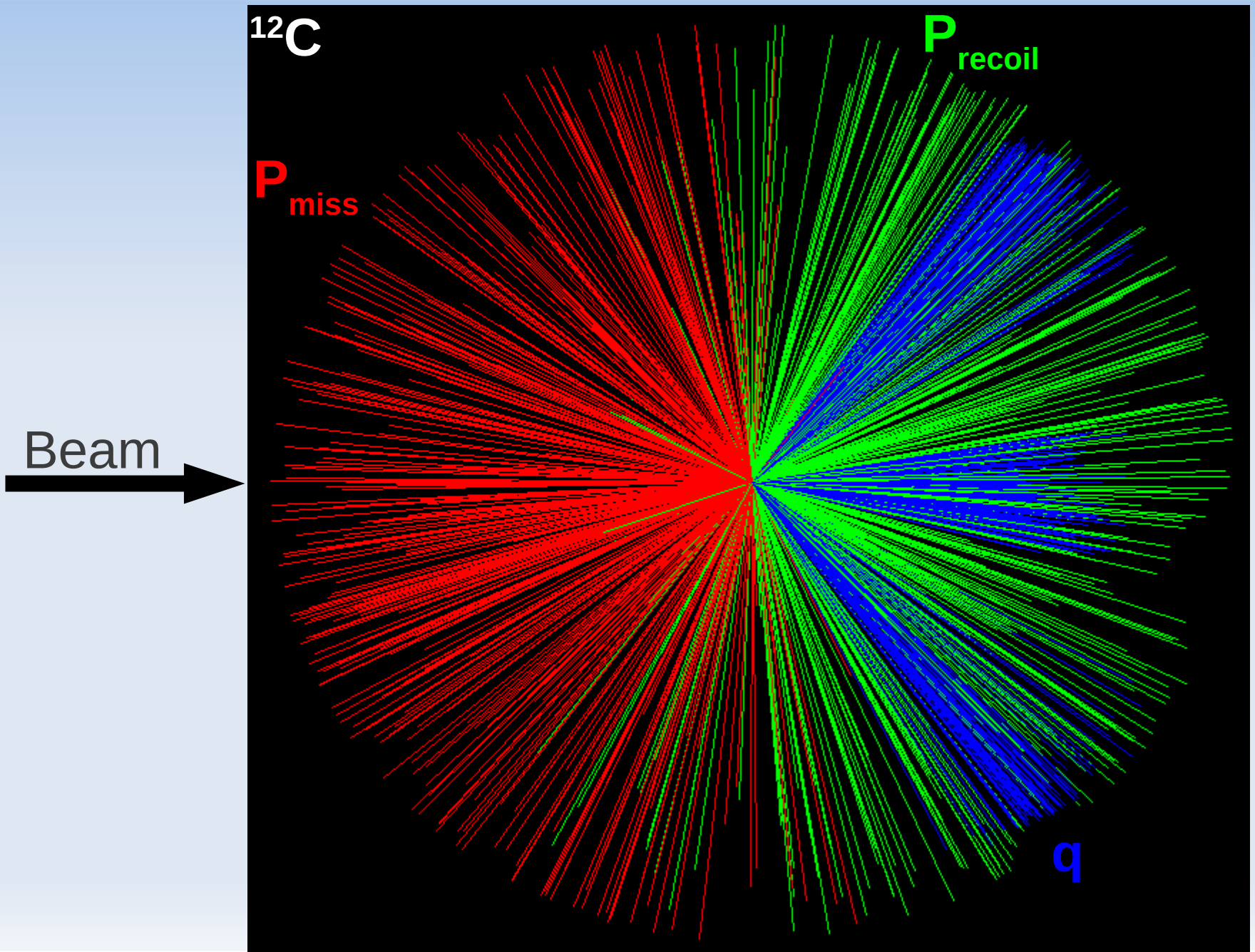




Kinematics: angles



Measurement Kinematics



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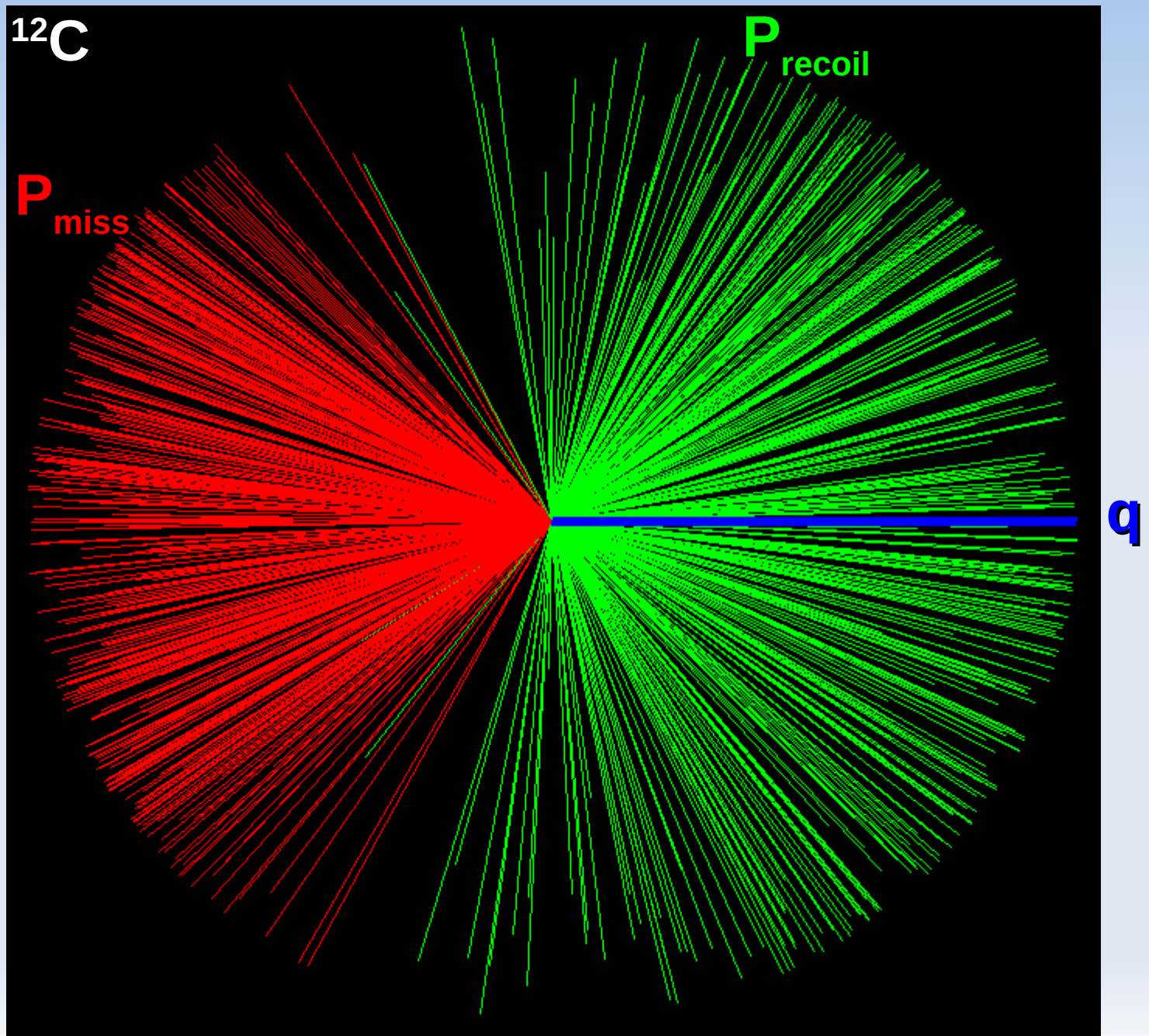
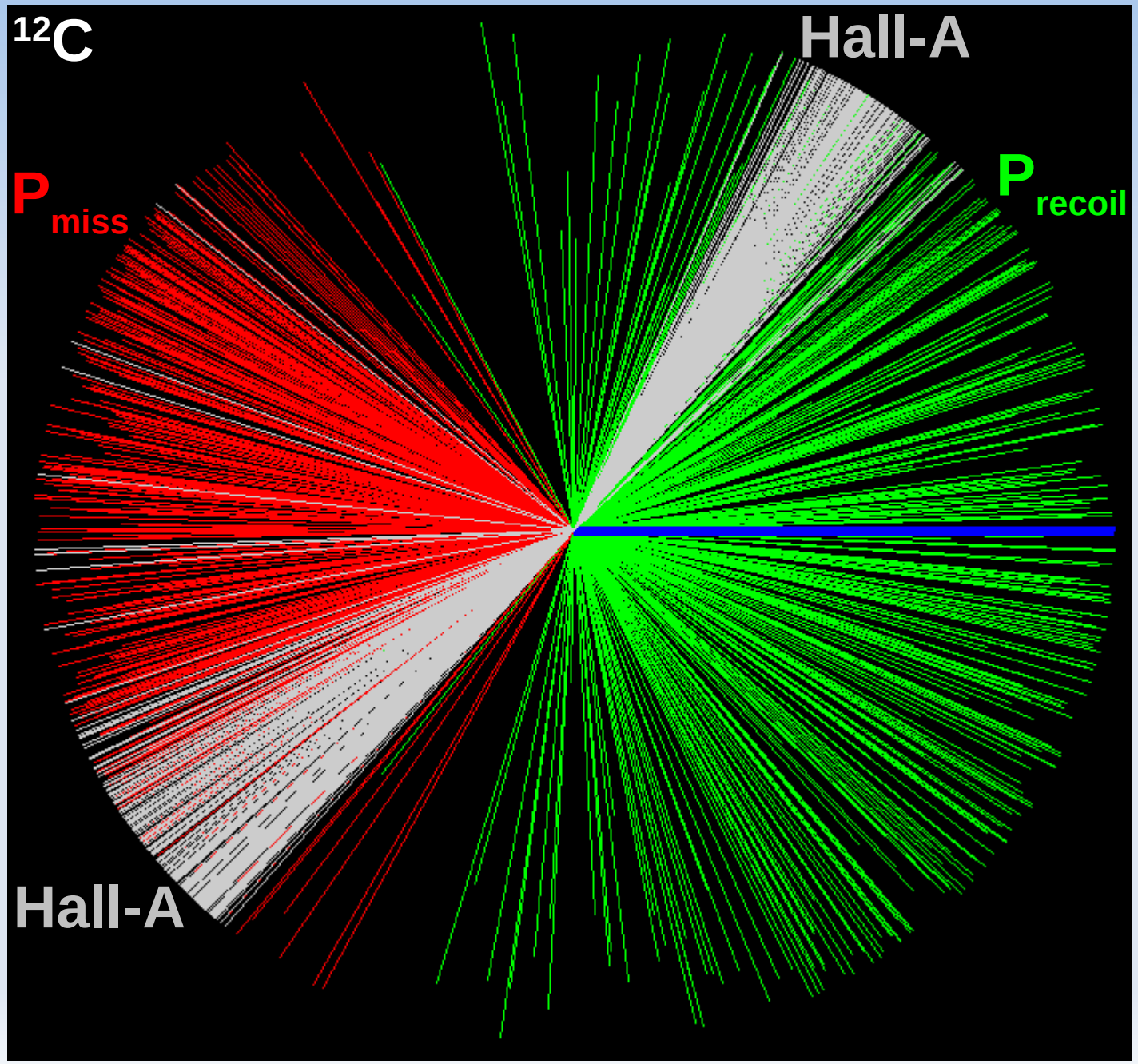


Measurement Kinematics

Comparing to JLab Hall-A E01-015



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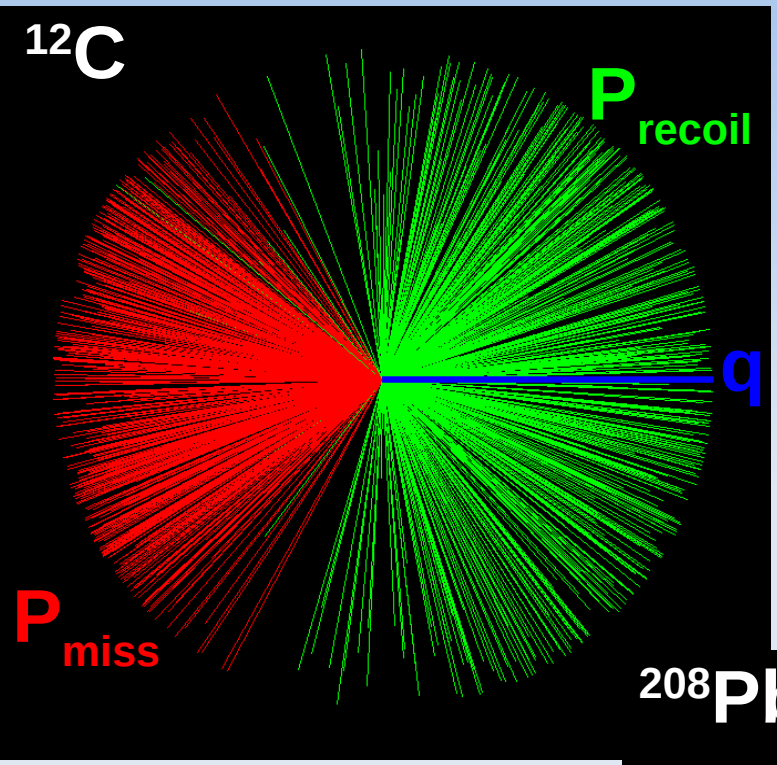
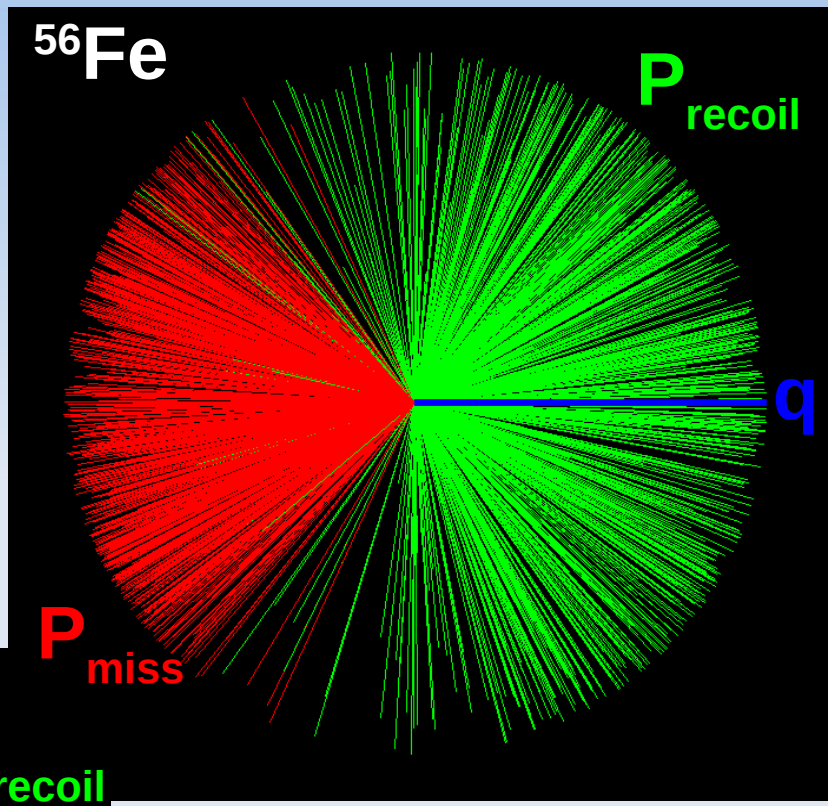
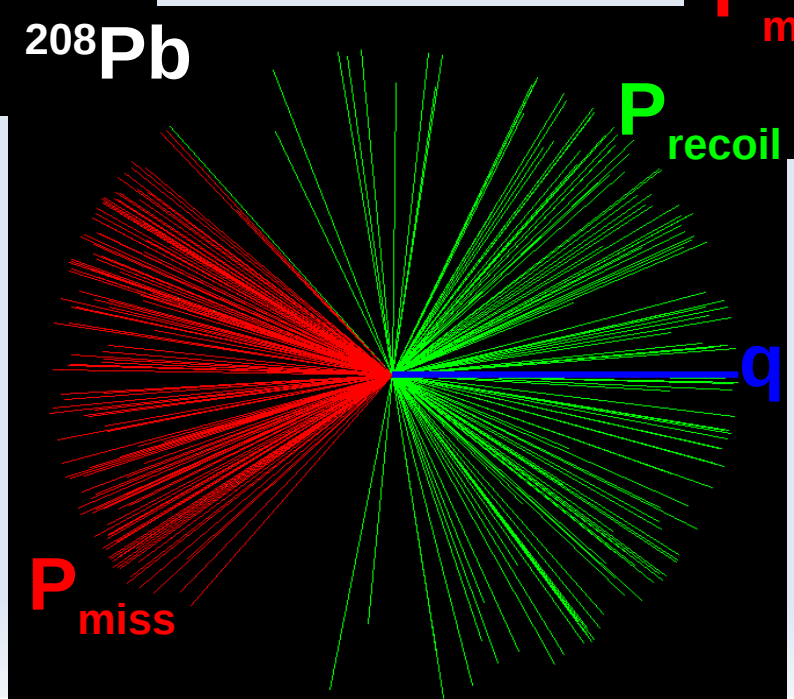
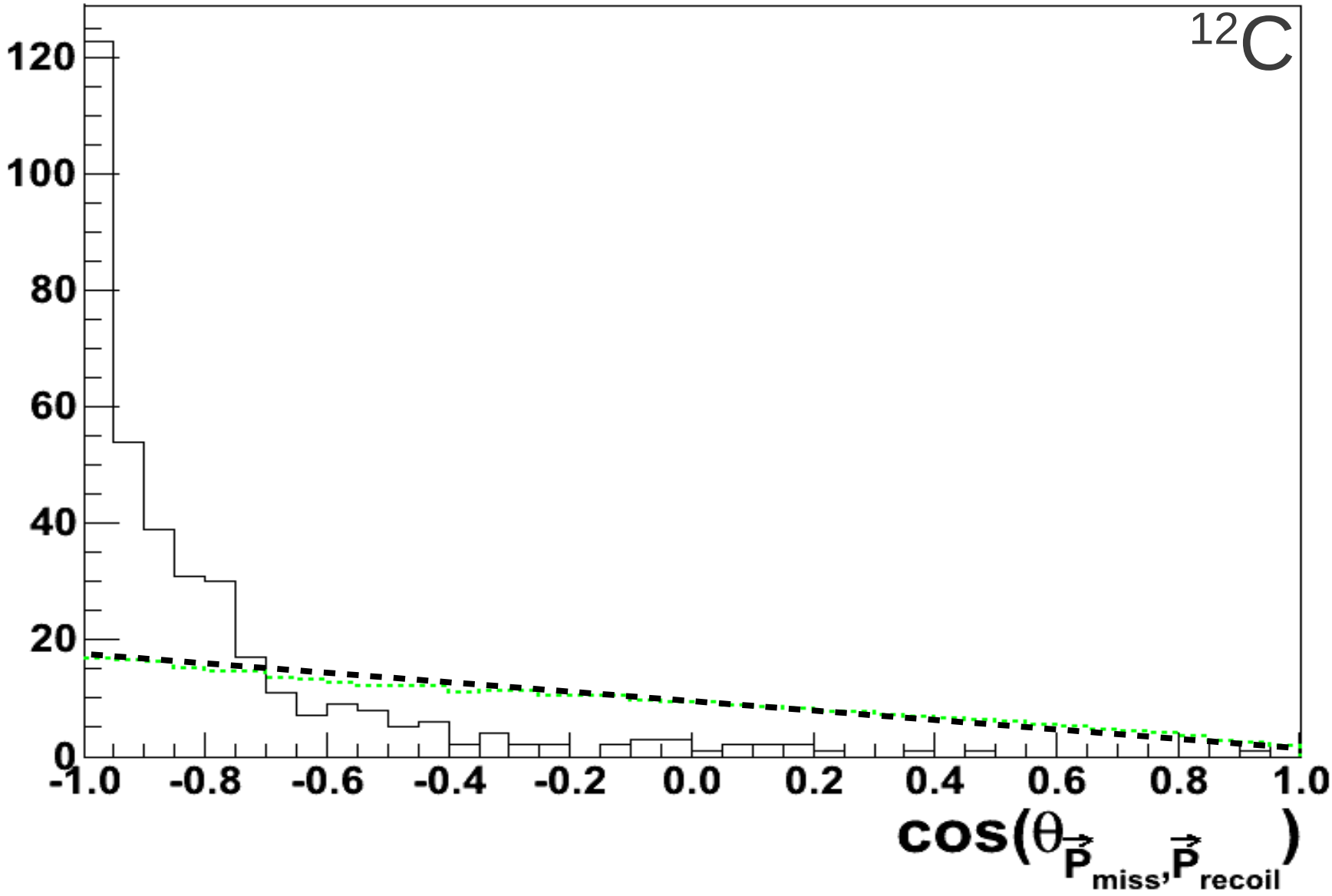






Opening Angle Distribution



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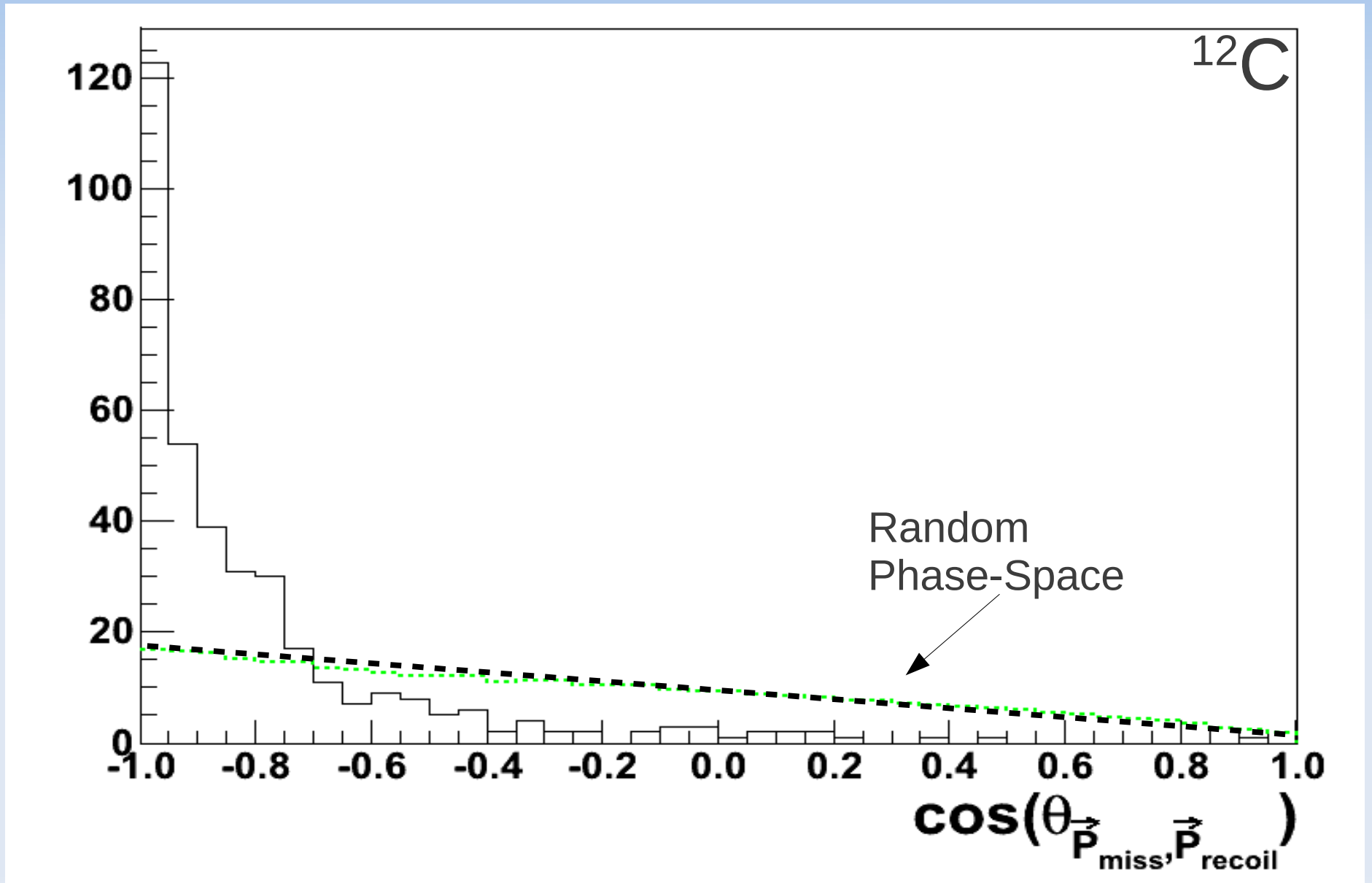

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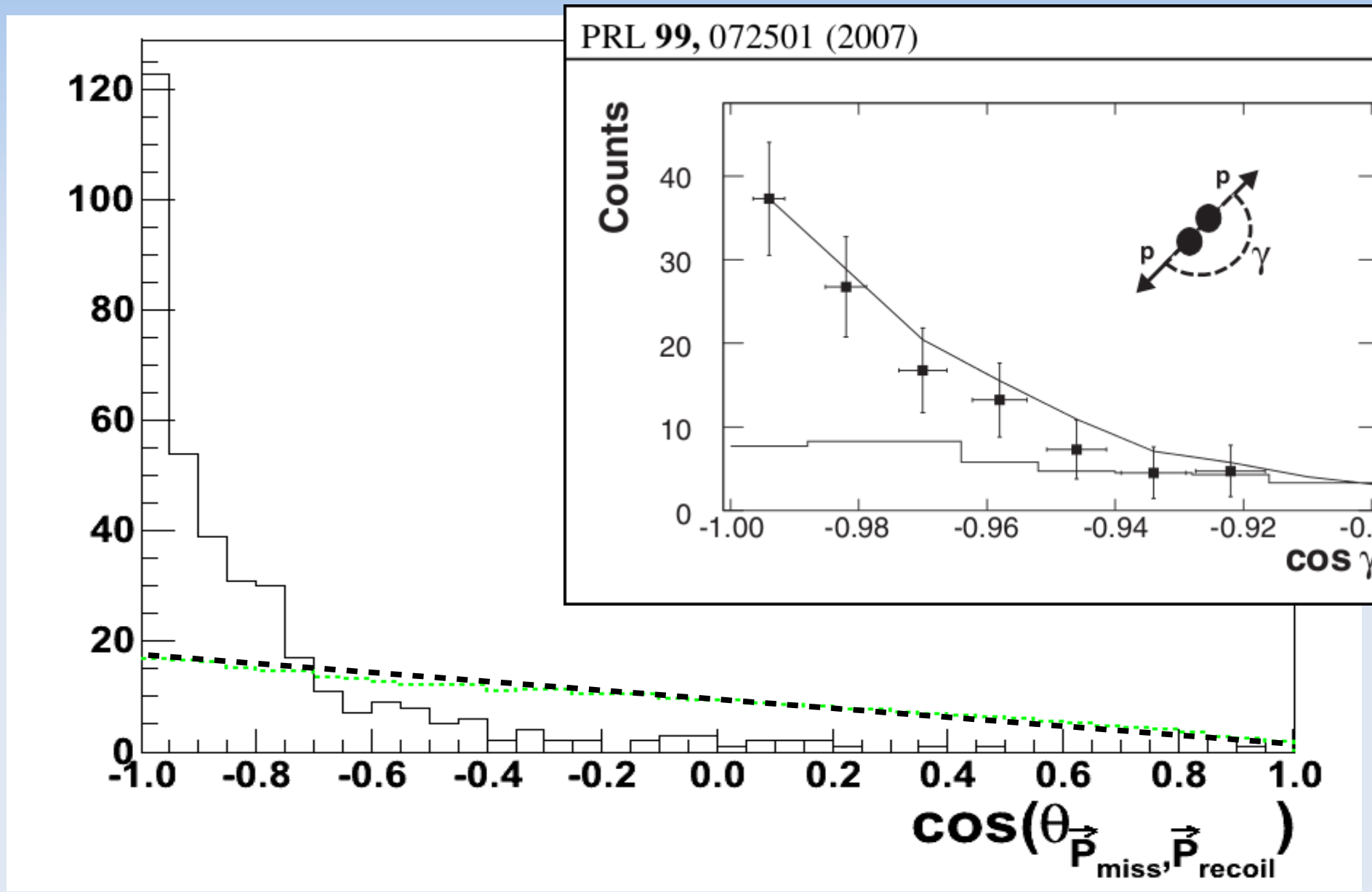

PRL **99,** 072501 (2007)

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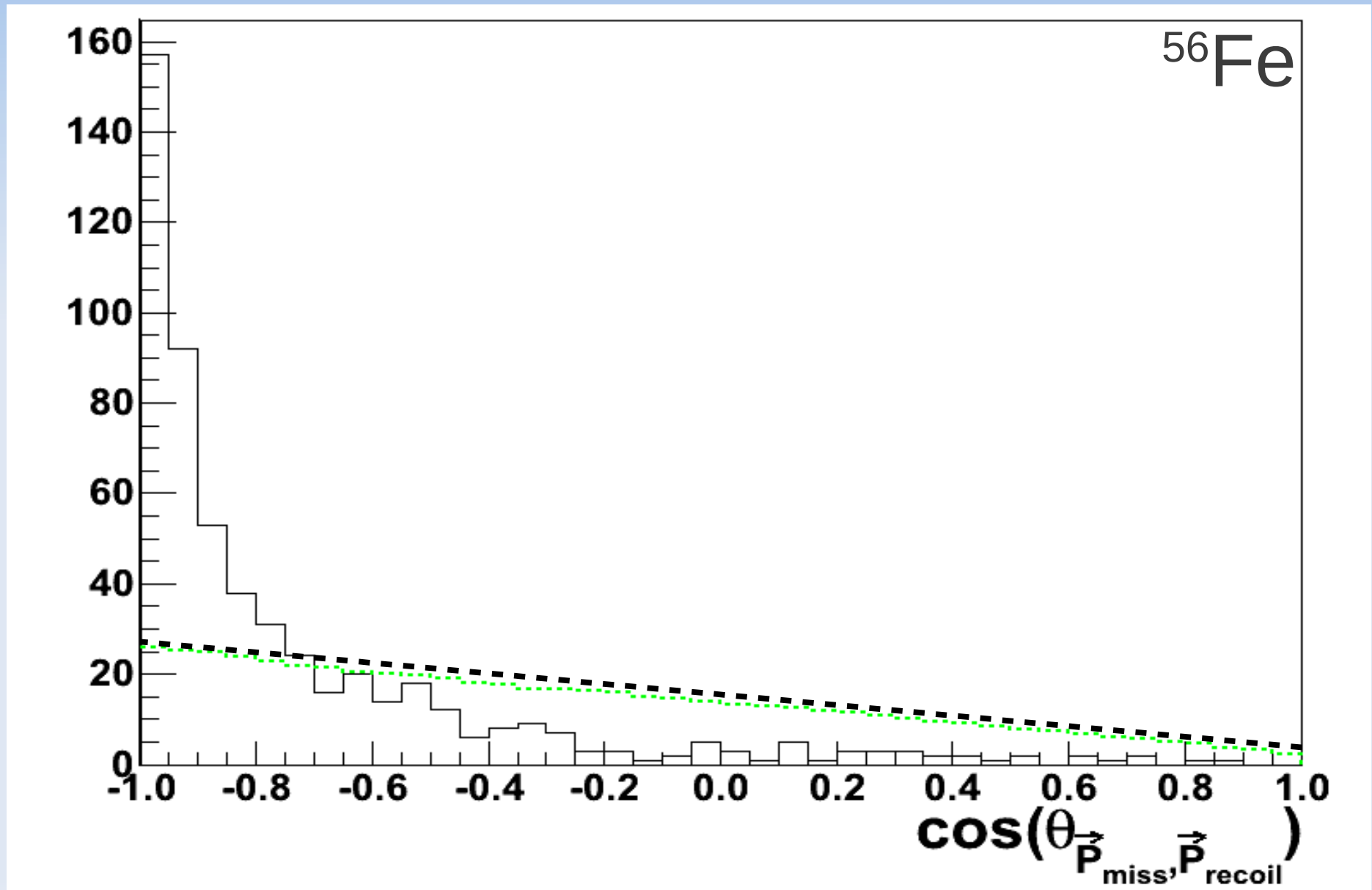

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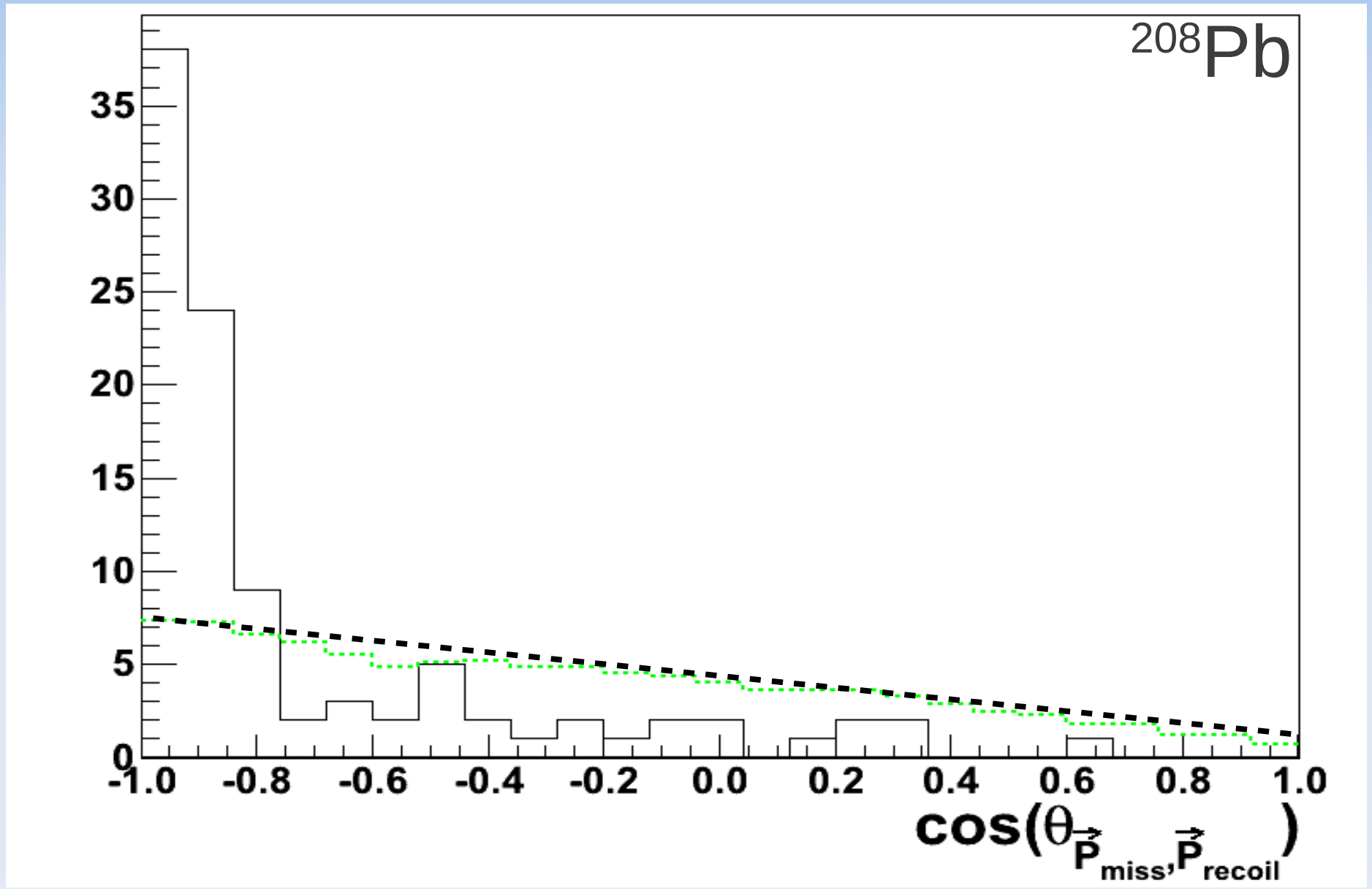
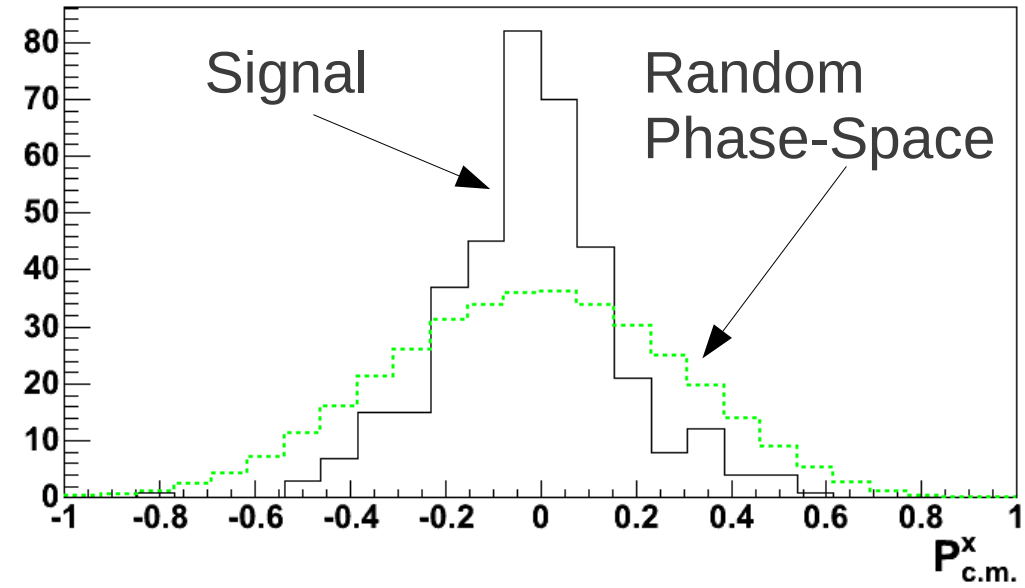
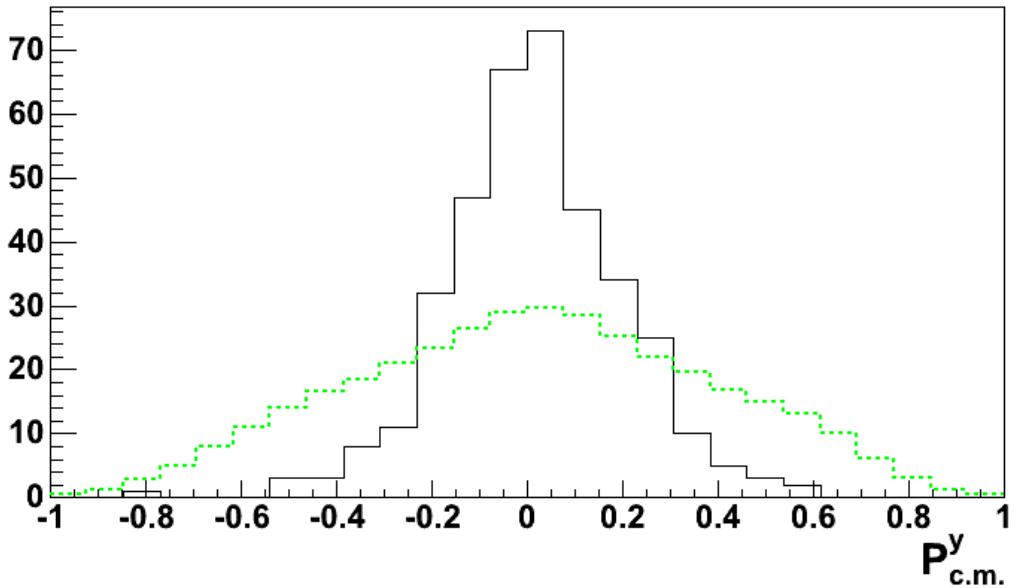
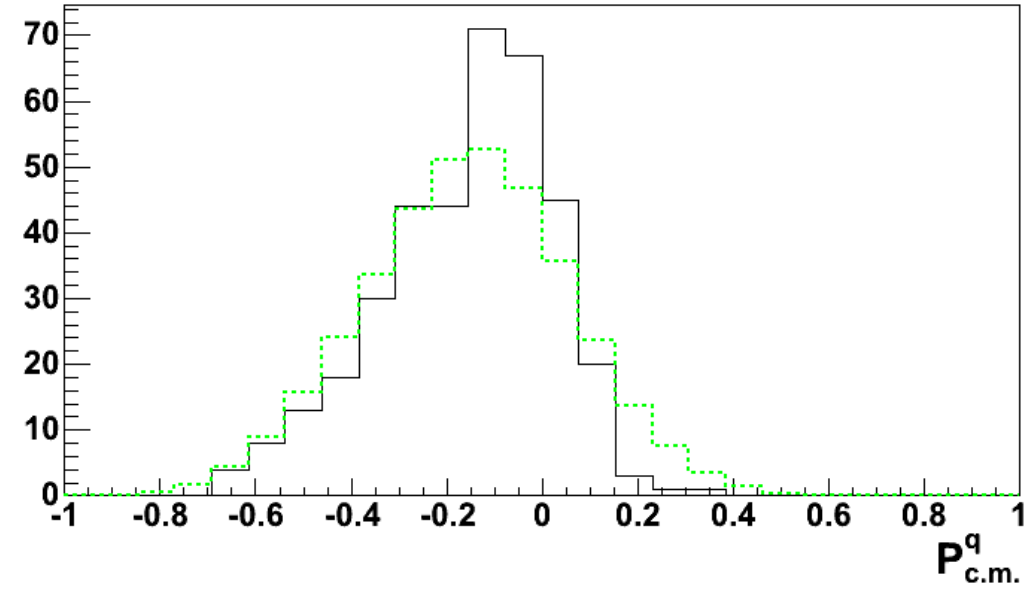


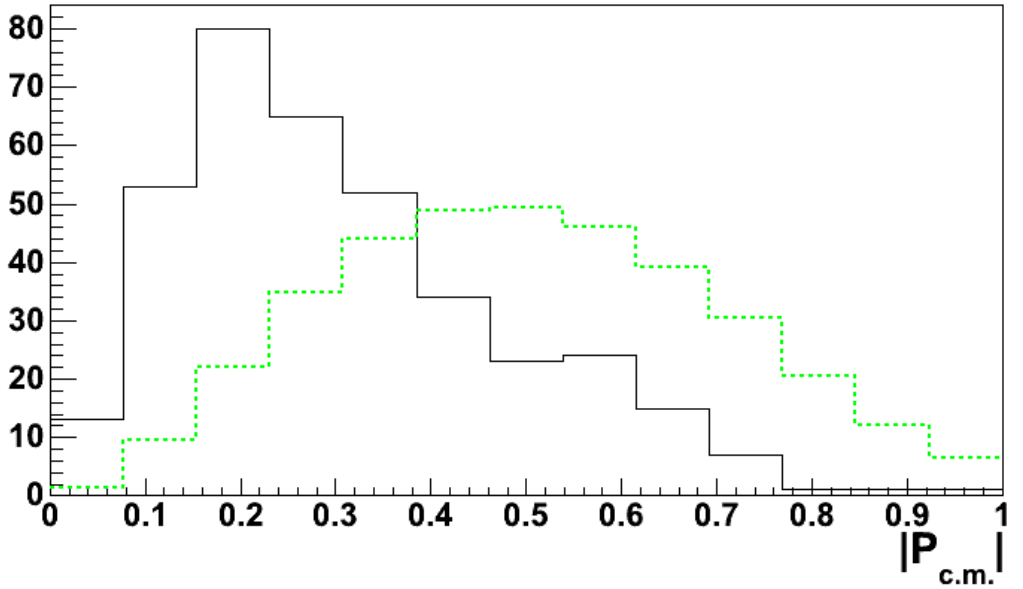
C.M. Momentum Distribution

^{12}C

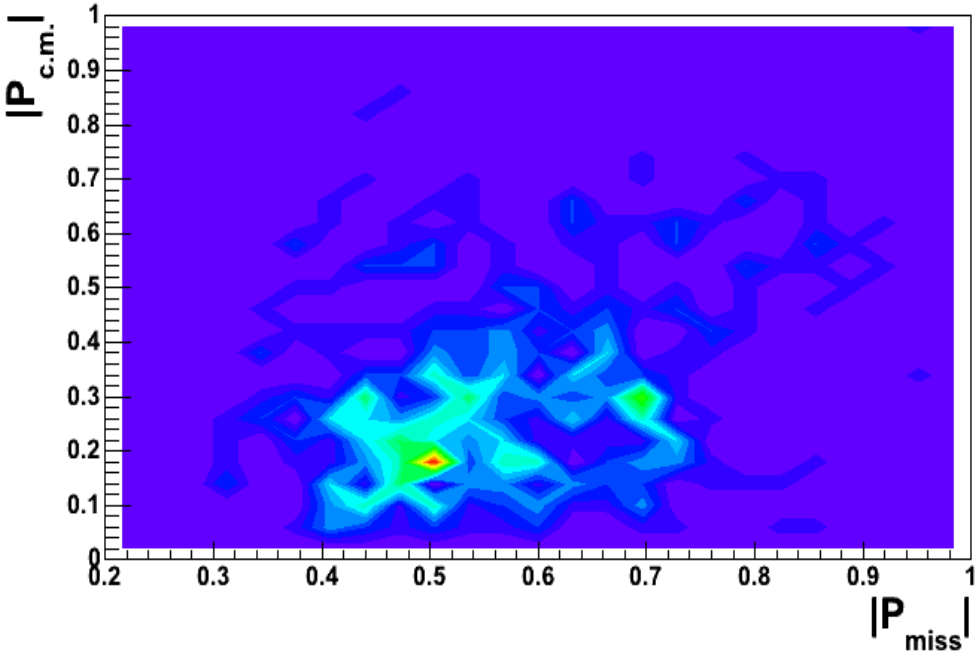


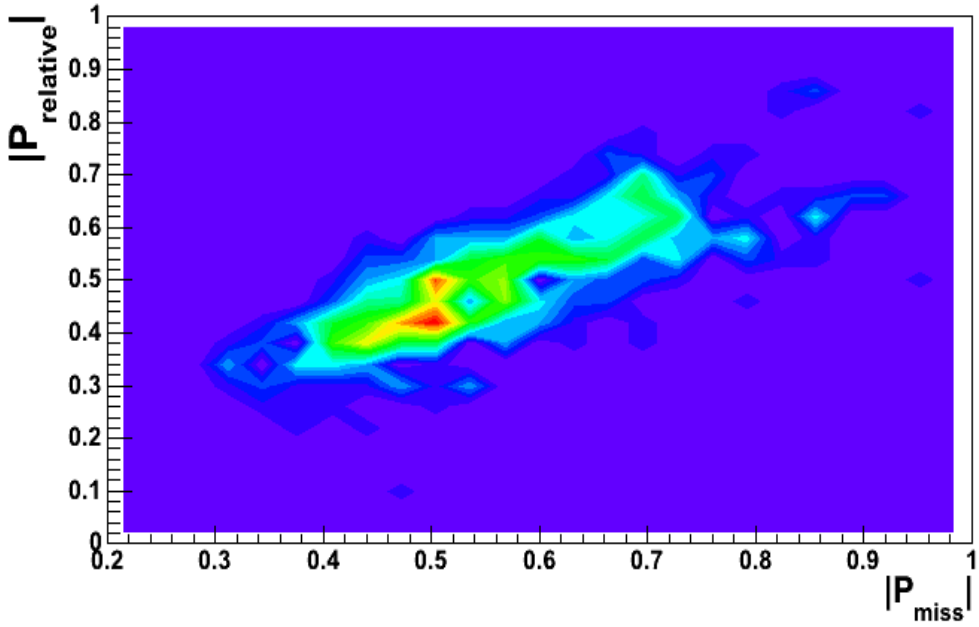


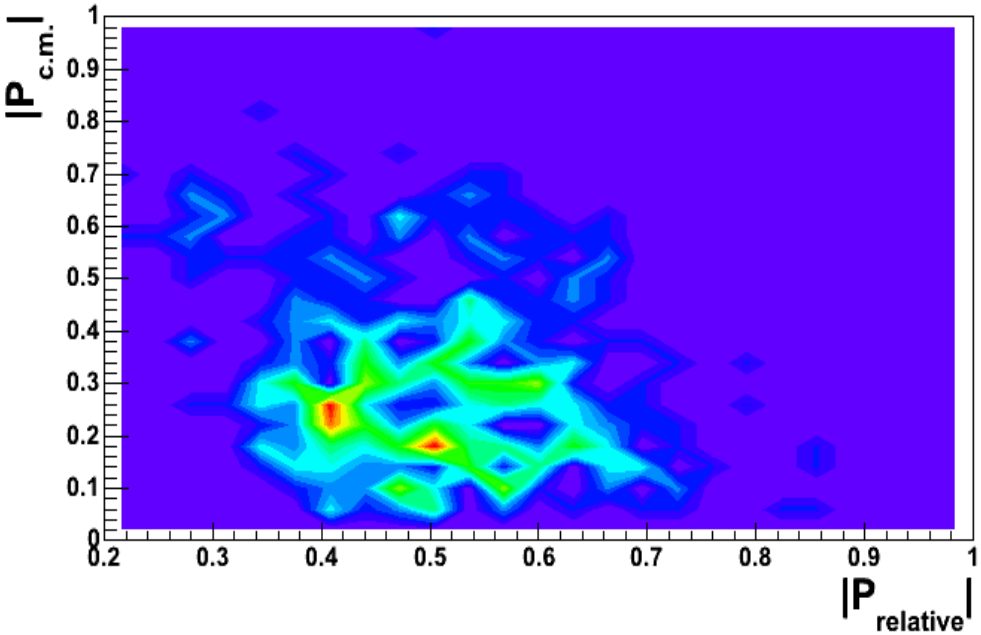




$P_{C.M.}$ $P_{relative}$ and P_{miss} Correlations



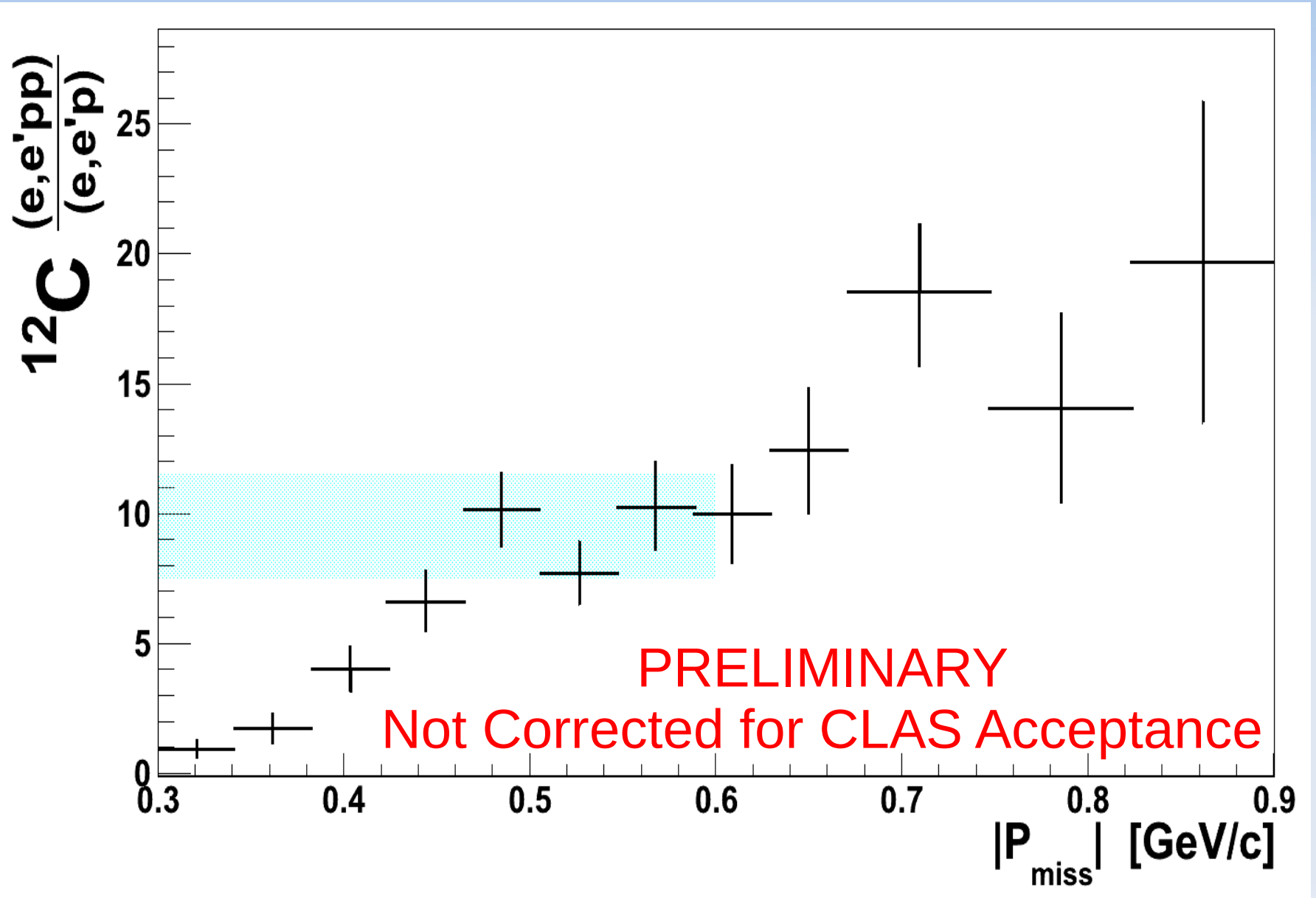




$P_{C.M.}$ Independent of P_{miss}

$P_{relative}$ proportional to P_{miss}

pp-SRC Probabilities



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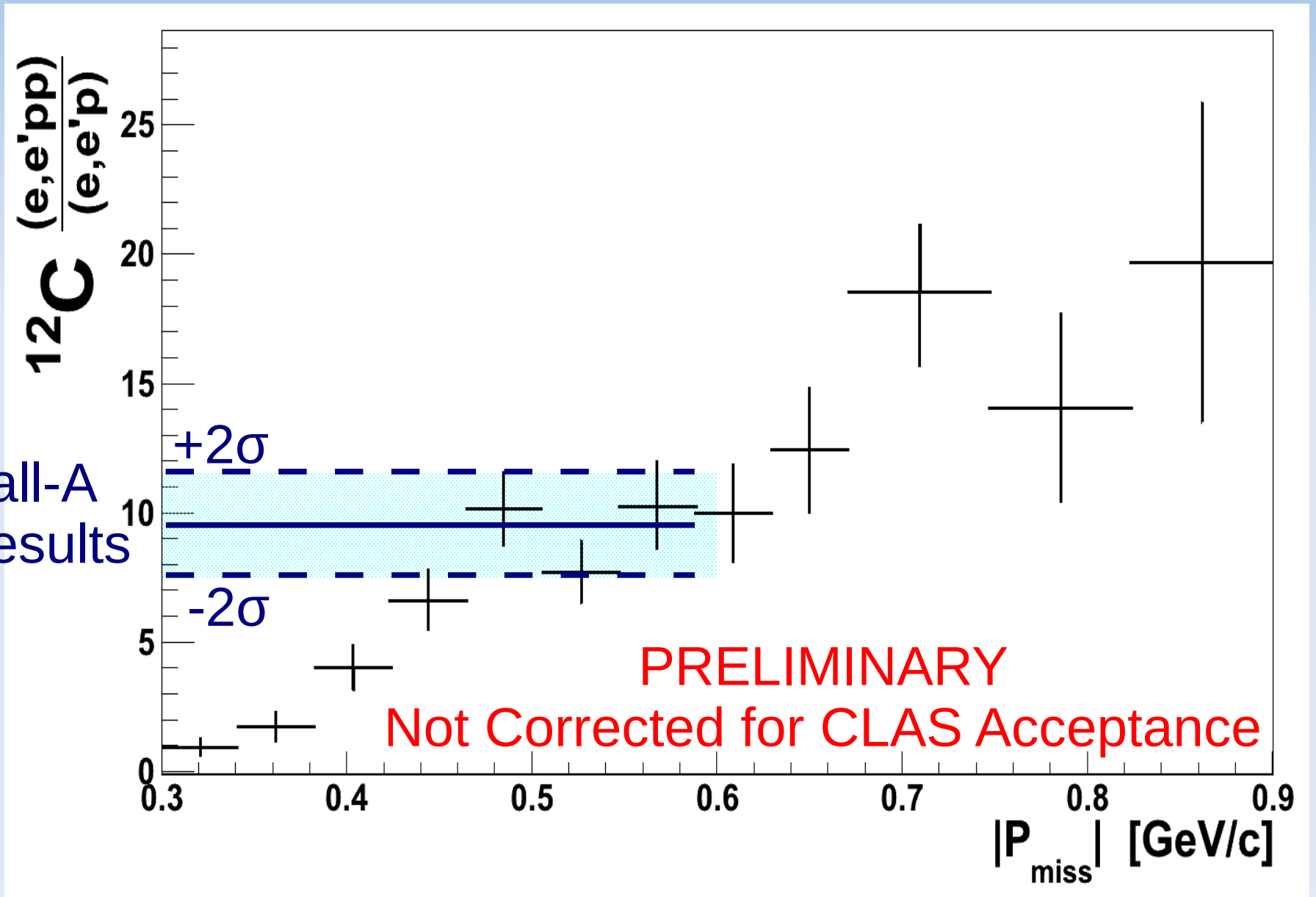

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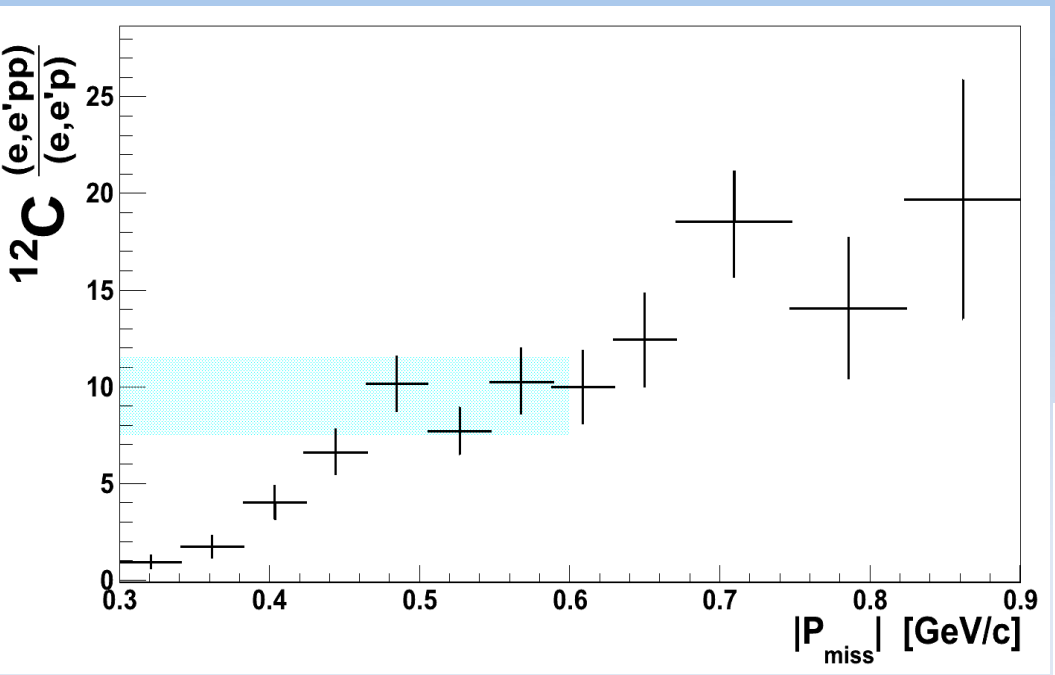
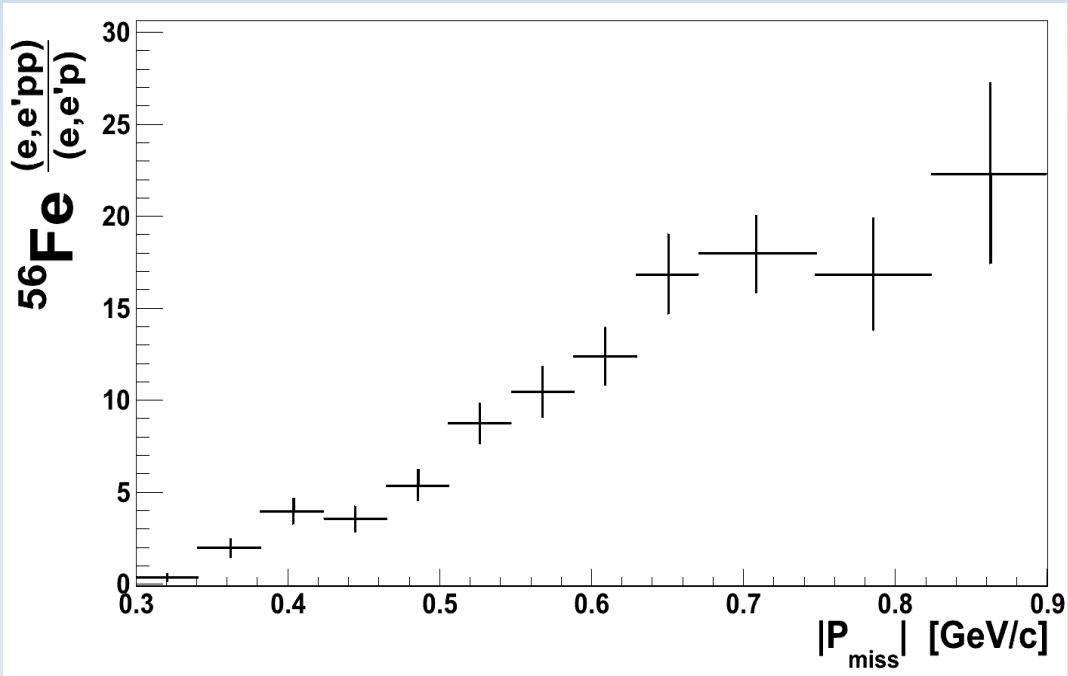
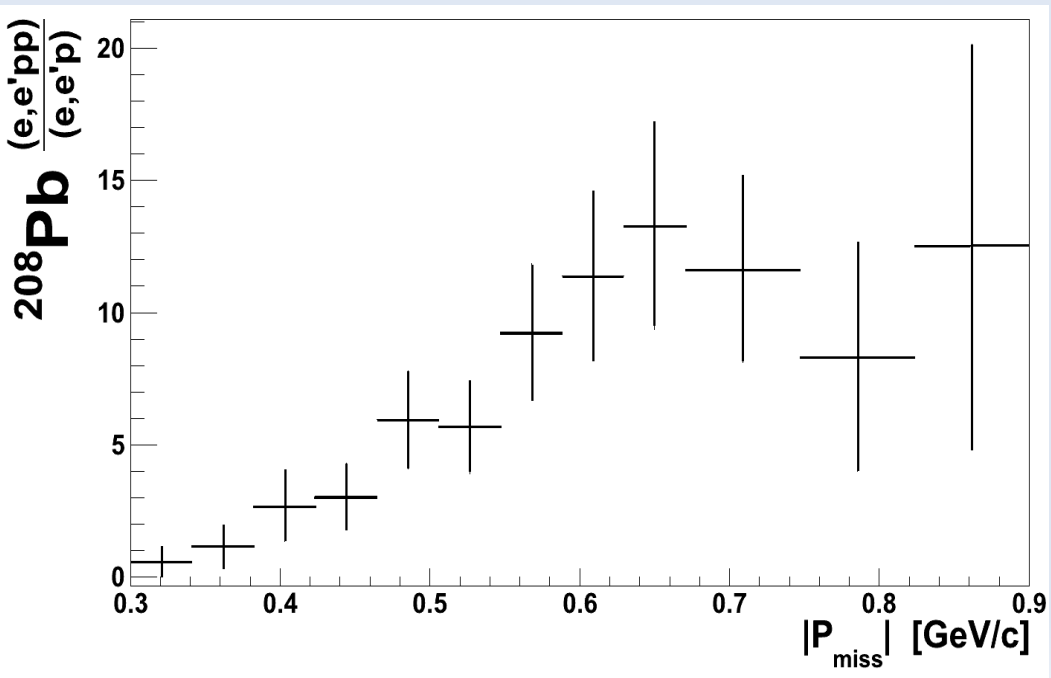


PRELIMINARY

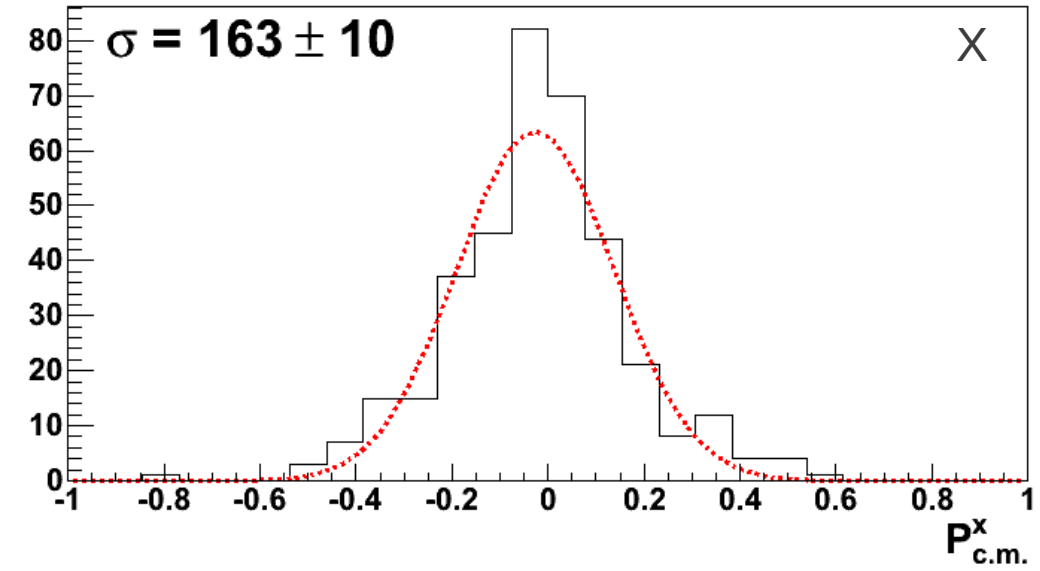
Not Corrected for CLAS Acceptance

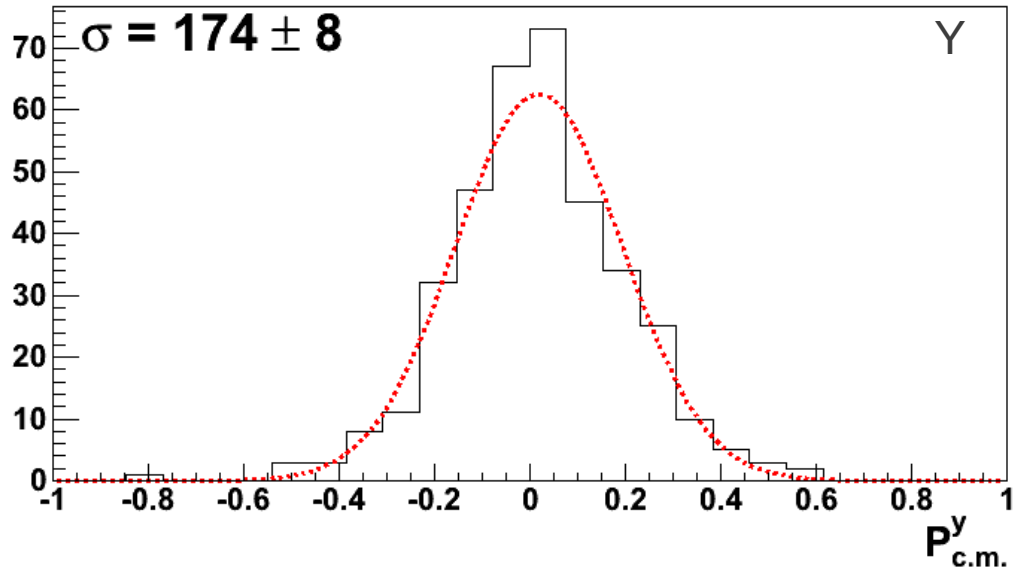


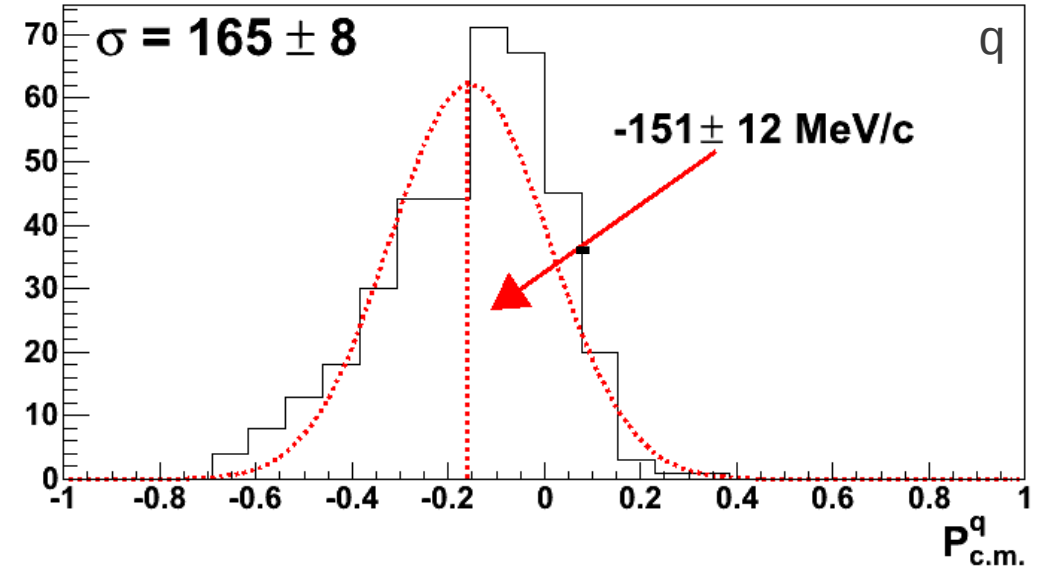


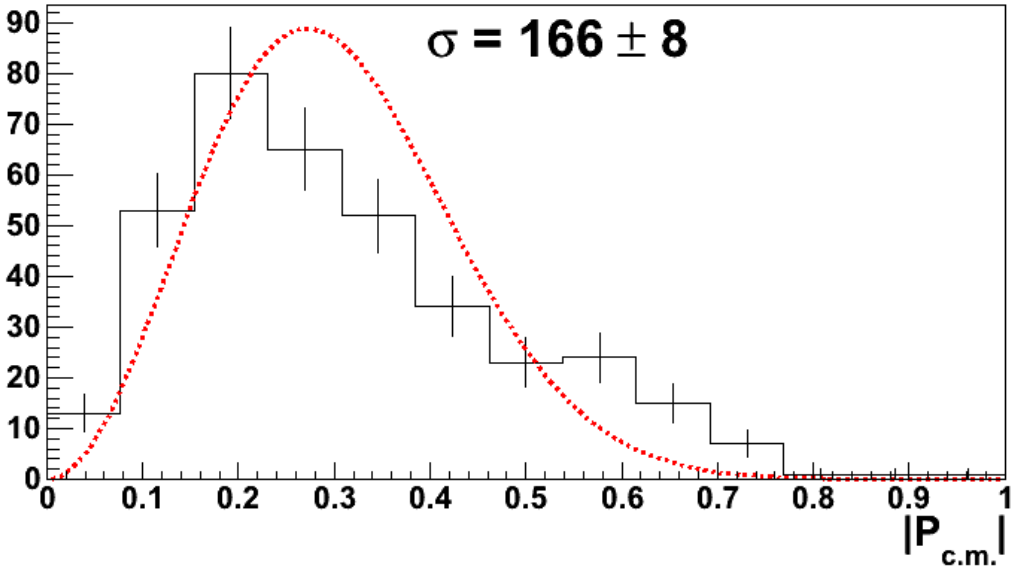
C.M. Momentum Distribution

^{12}C



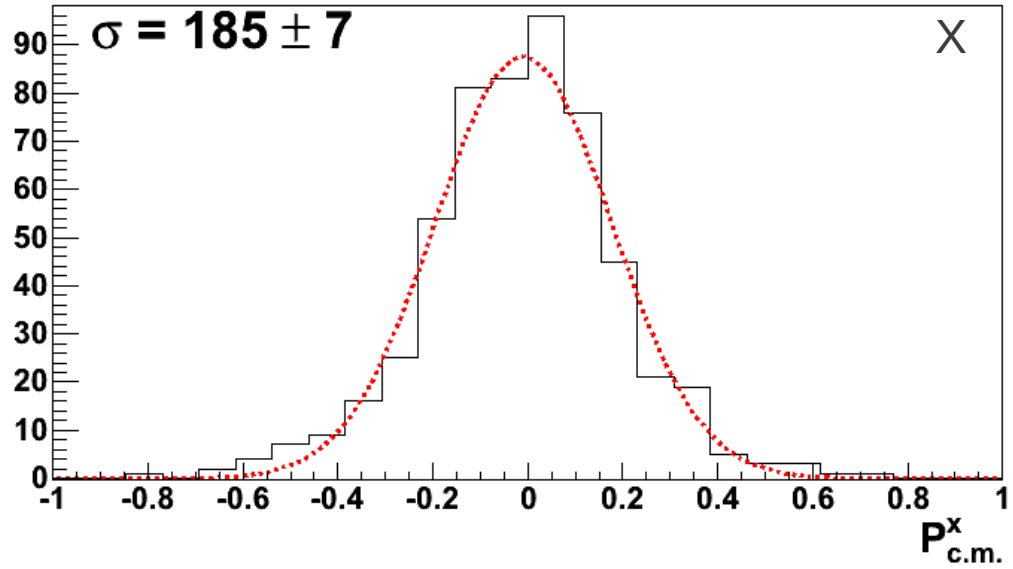


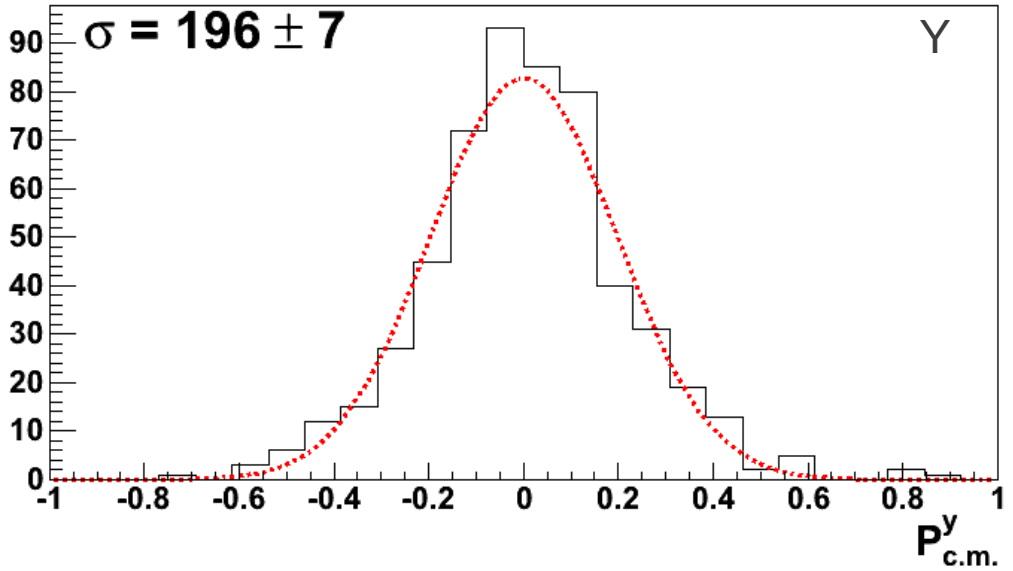


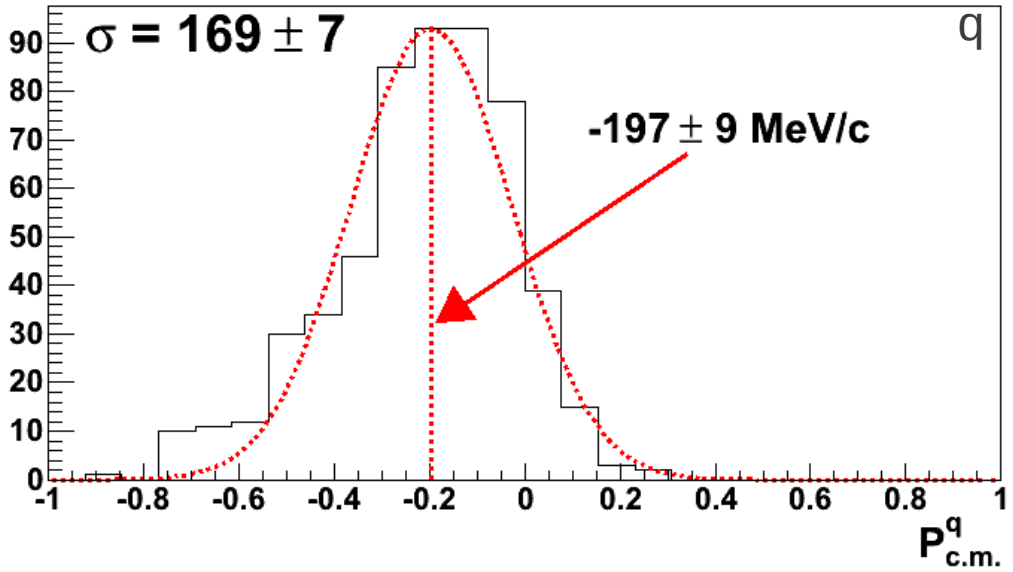


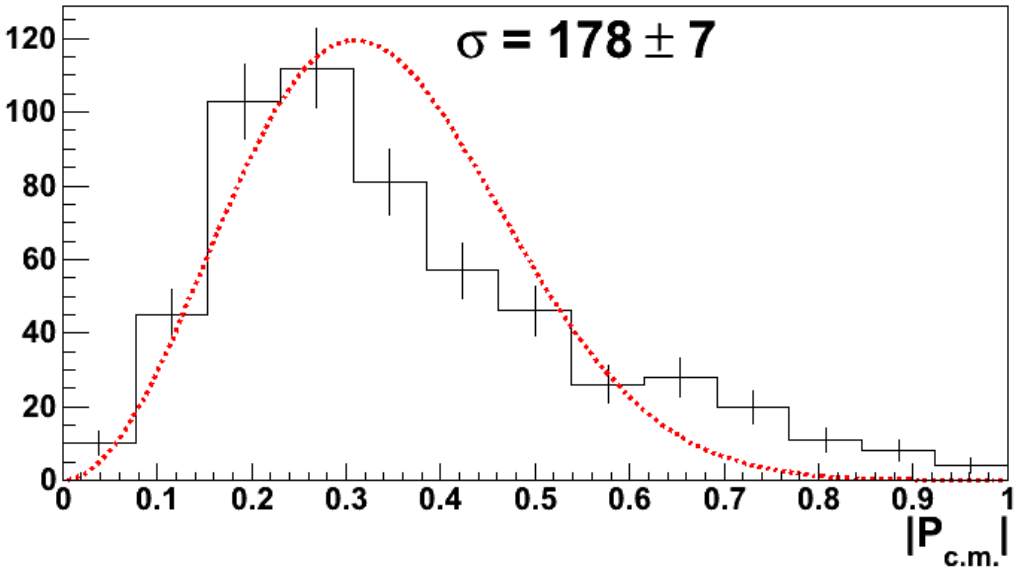
C.M. Momentum Distribution

^{56}Fe



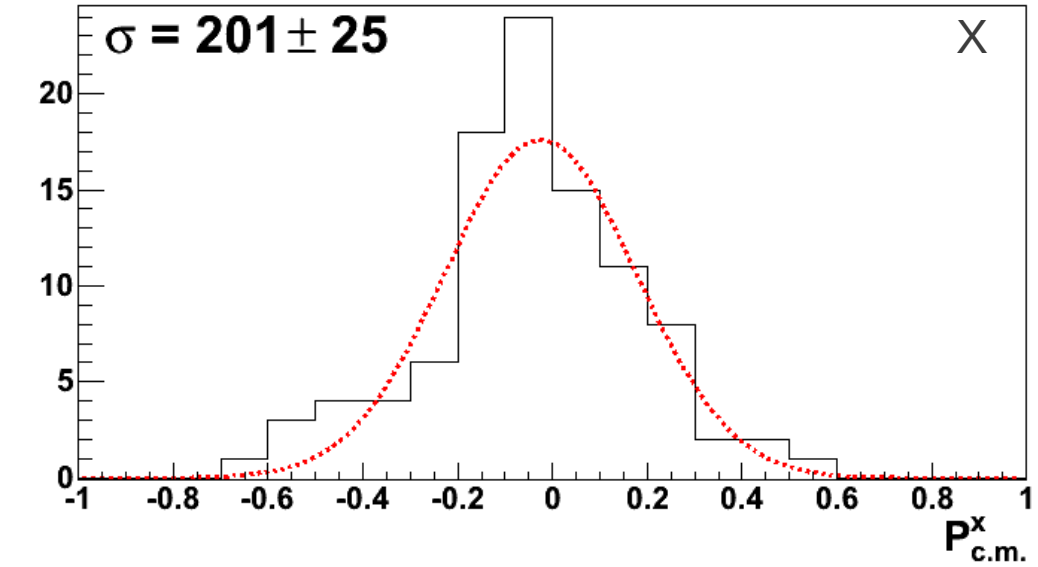


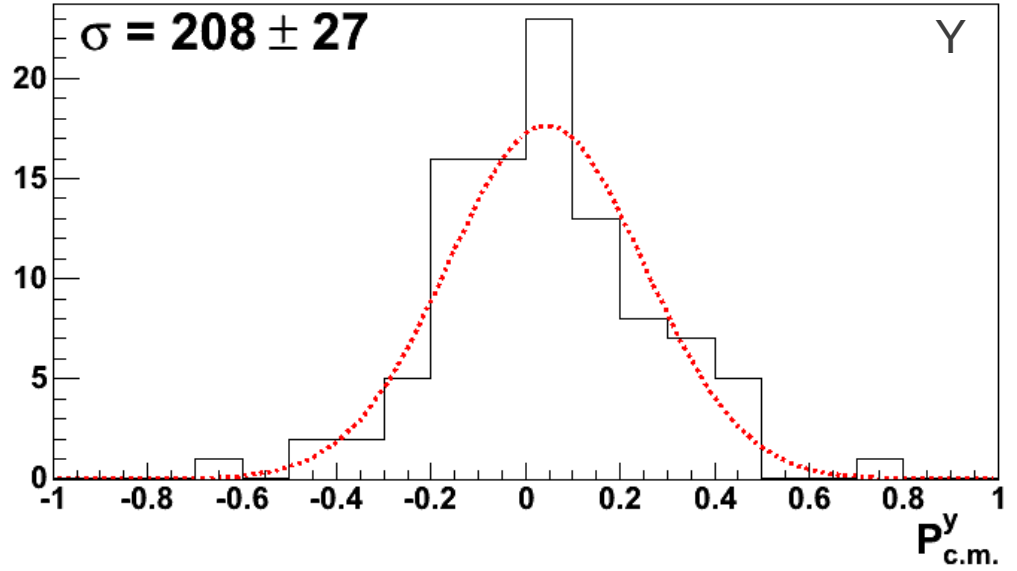


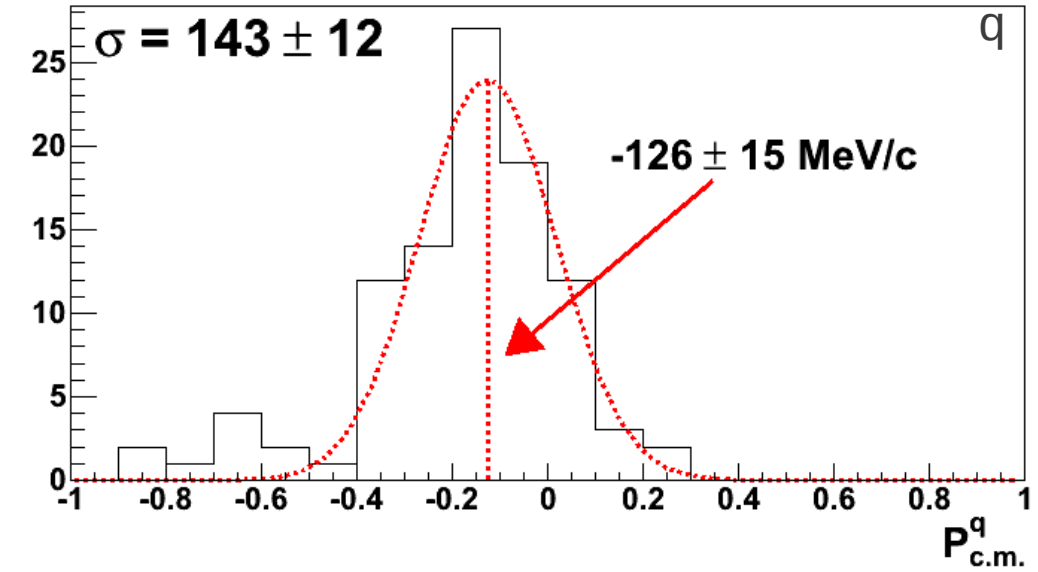


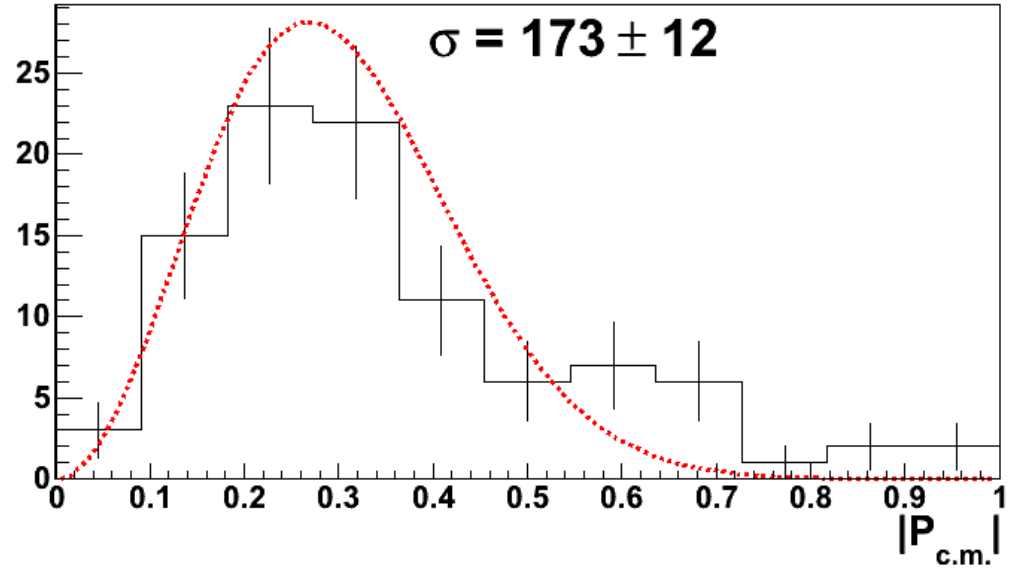
C.M. Momentum Distribution

^{208}Pb

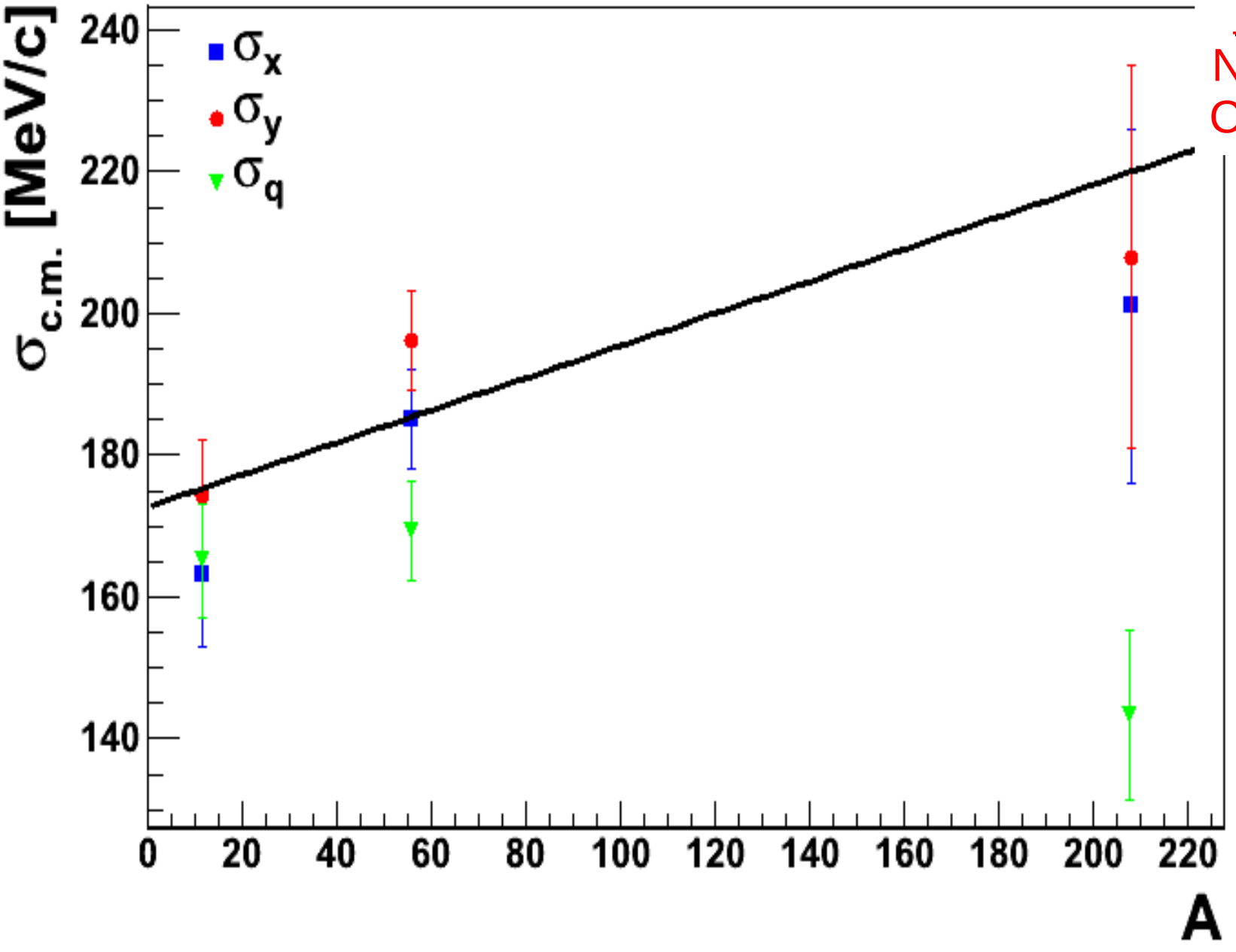








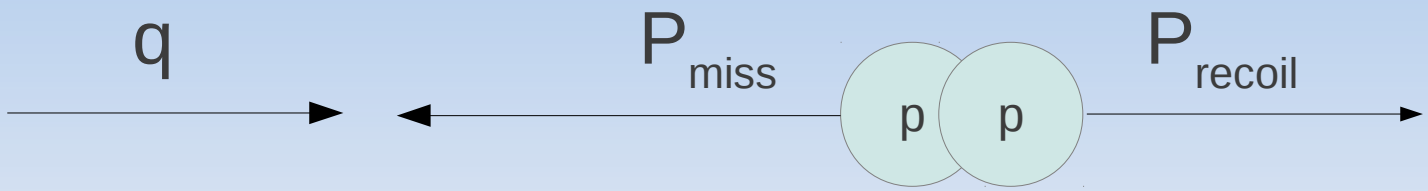
C.M. Momentum A Dependence



PRELIMINARY
Not Corrected for CLAS Acceptance

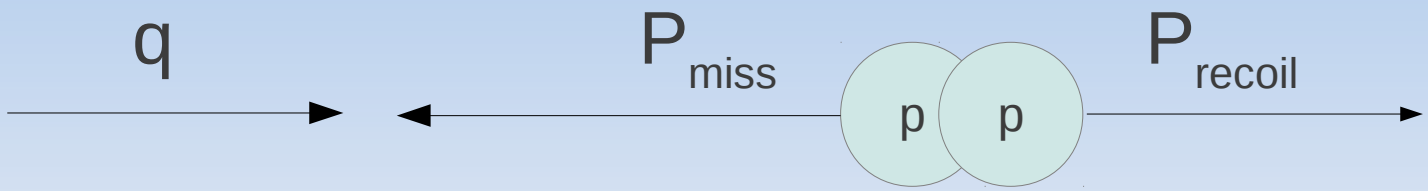
(e,e'p) cross section bias?

Scattering off 2N-SRC pair in Anti-Parallel Kinematics:



(e,e'p) cross section bias?

Scattering off 2N-SRC pair in Anti-Parallel Kinematics:



$$P_{miss} \neq P_{recoil}$$

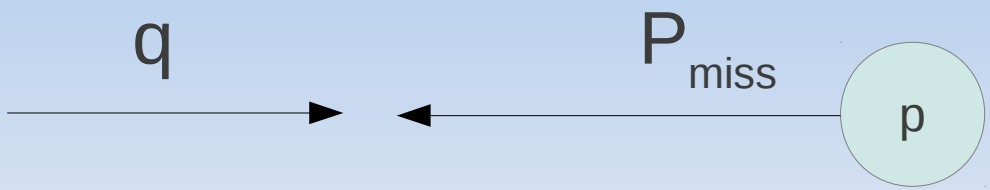
(Due to the c.m. motion)

$$P_{miss} = P_{relative} + P_{c.m.}/2$$

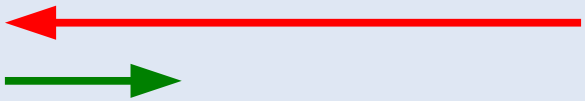
$$P_{recoil} = -P_{relative} + P_{c.m.}/2$$

(e,e'p) cross section bias?

Scattering off 2N-SRC pair in Anti-Parallel Kinematics:



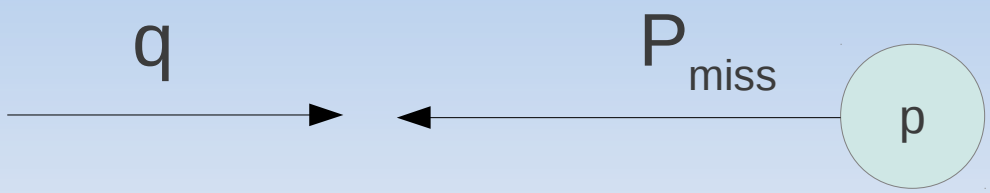
Consider two cases:

(1)  $P_{miss}=P_{relative}+P_{c.m.}/2$

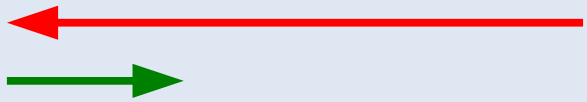
(2)  $P_{miss}=P_{relative}+P_{c.m.}/2$

(e,e'p) cross section bias?

Scattering off 2N-SRC pair in Anti-Parallel Kinematics:



Consider two cases:

(1)  $P_{miss}=P_{relative}+P_{c.m.}/2$

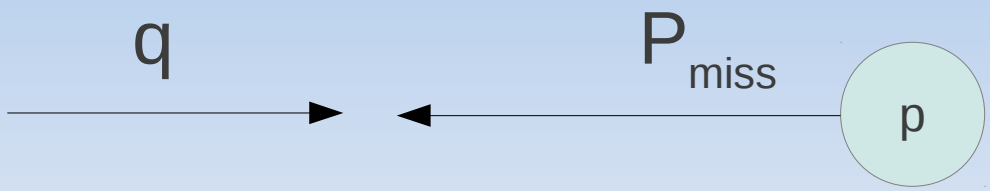
(2)  $P_{miss}=P_{relative}+P_{c.m.}/2$

We fix P_{miss} and $P_{c.m.}$ in both cases.

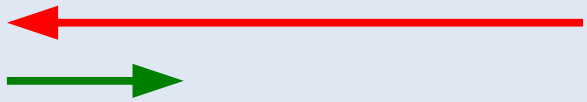
The direction of $P_{c.m.}$ determines the magnitude of $P_{relative}$

(e,e'p) cross section bias?

Scattering off 2N-SRC pair in Anti-Parallel Kinematics:



Consider two cases:

(1)  $P_{miss}=P_{relative}+P_{c.m.}/2$

(2)  $P_{miss}=P_{relative}+P_{c.m.}/2$

We fix P_{miss} and $P_{c.m.}$ in both cases.
The direction of $P_{c.m.}$ determines the magnitude of $P_{relative}$

=> For a given Pmiss, the cross section should be larger for case (2)
(Due to the relative momentum distribution falling)

Conclusions

- CLAS EG2 data were used to identify pp-SRC pairs in ^{12}C and, for the first time, in ^{56}Fe and ^{208}Pb.
  - $Q^2>1.5$ GeV^2, $x_B>1.2$ → “Anti-Parallel” kinematics.
- C.M. momentum increases slowly with A
  - Appears consistent with Hall-A results
- Preliminary (e,e'pp)/(e,e'p) ratio extracted for $300<P_{miss}<900$ MeV/c
- Acceptance corrections for the recoil proton are needed

See Next Talk

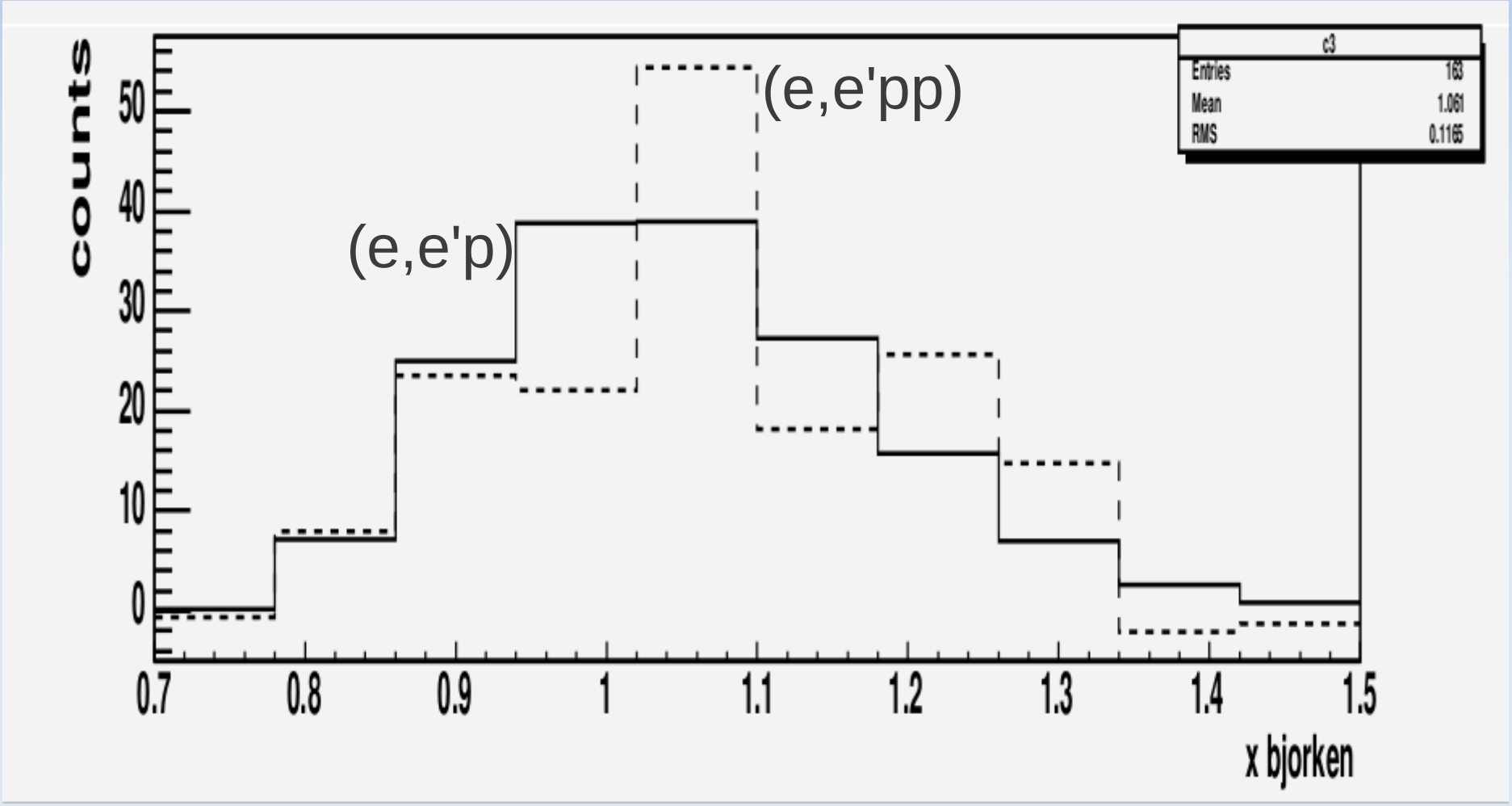
Future Plans

- Correct the (e,e'pp)/(e,e'p) ratio for the acceptance of the recoil proton
- Extract the ratio of np/pp SRC pairs for $300<P_{miss}<900$ MeV/c
  - Identify neutrons using the CLAS Electromagnetic Calorimeter
  - Identify np-SRC correlations


Thank You!

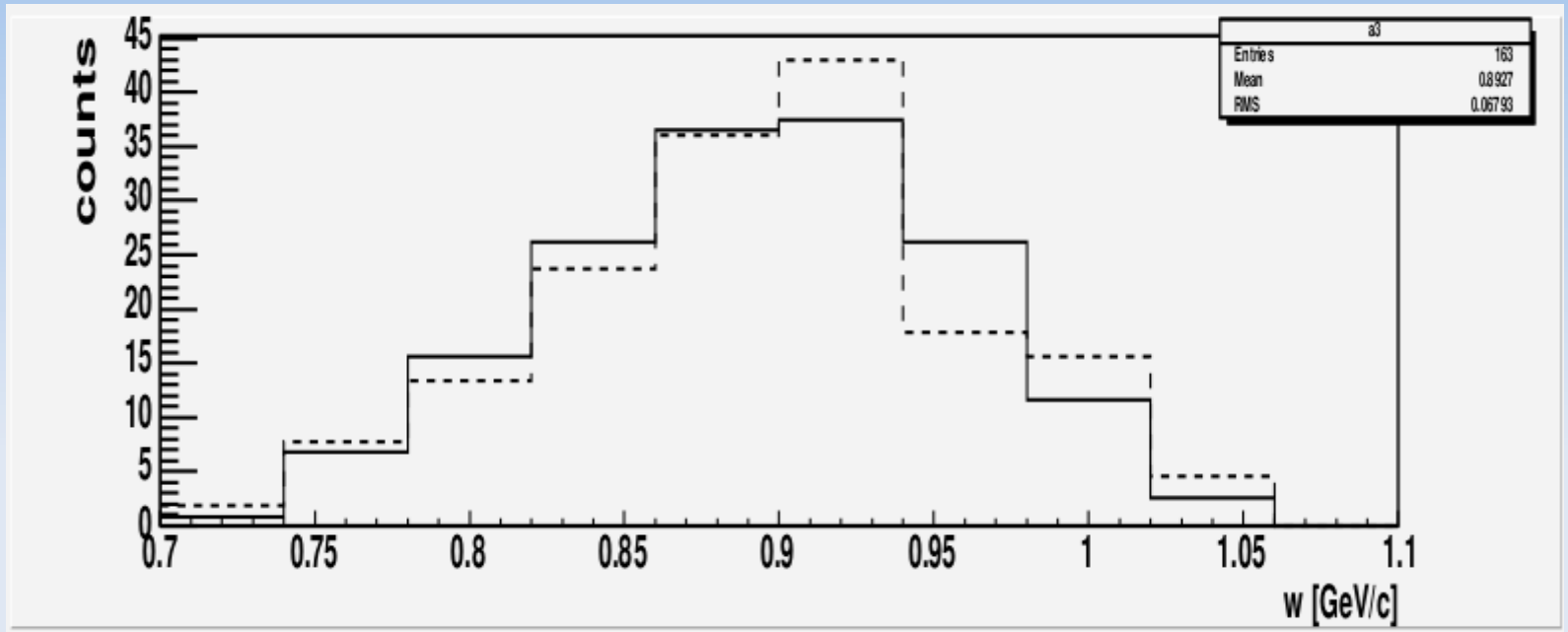
Hall-A E01-015 kinematics

x_B Distribution

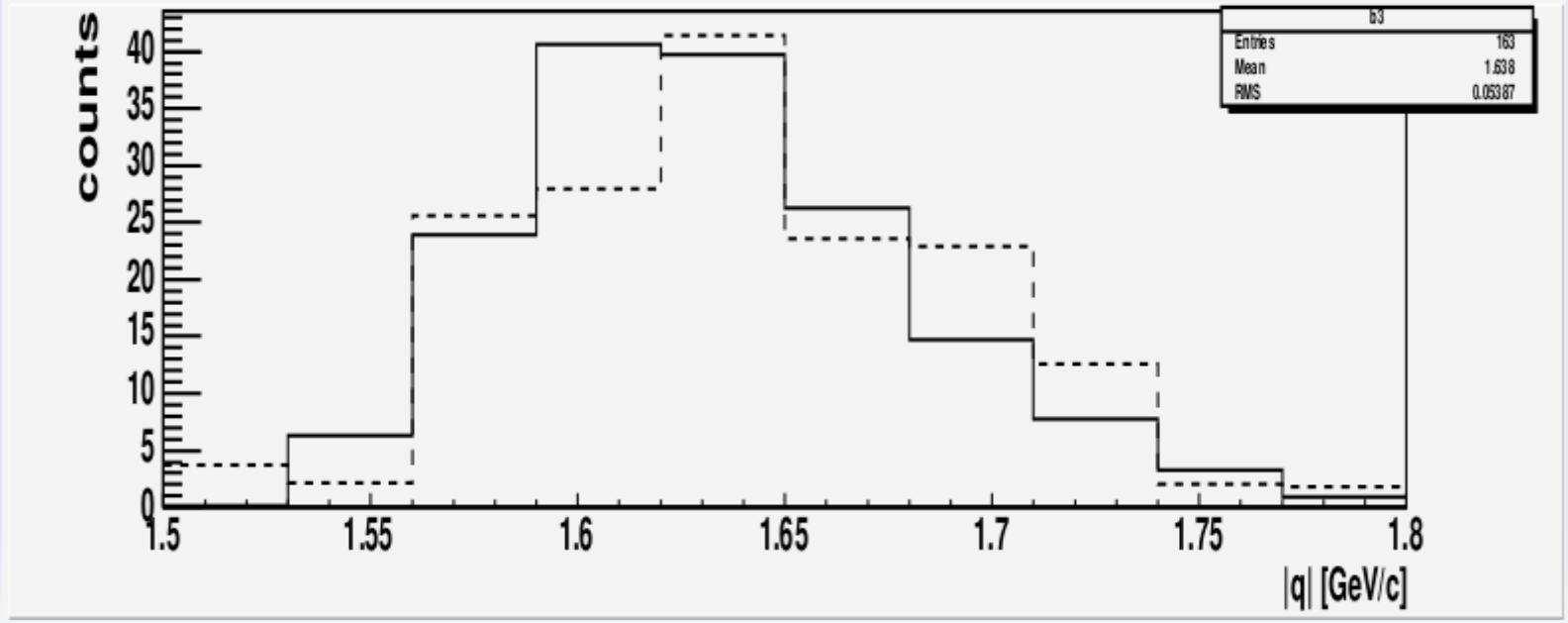


Hall-A E01-015 kinematics

Q^2 Distribution

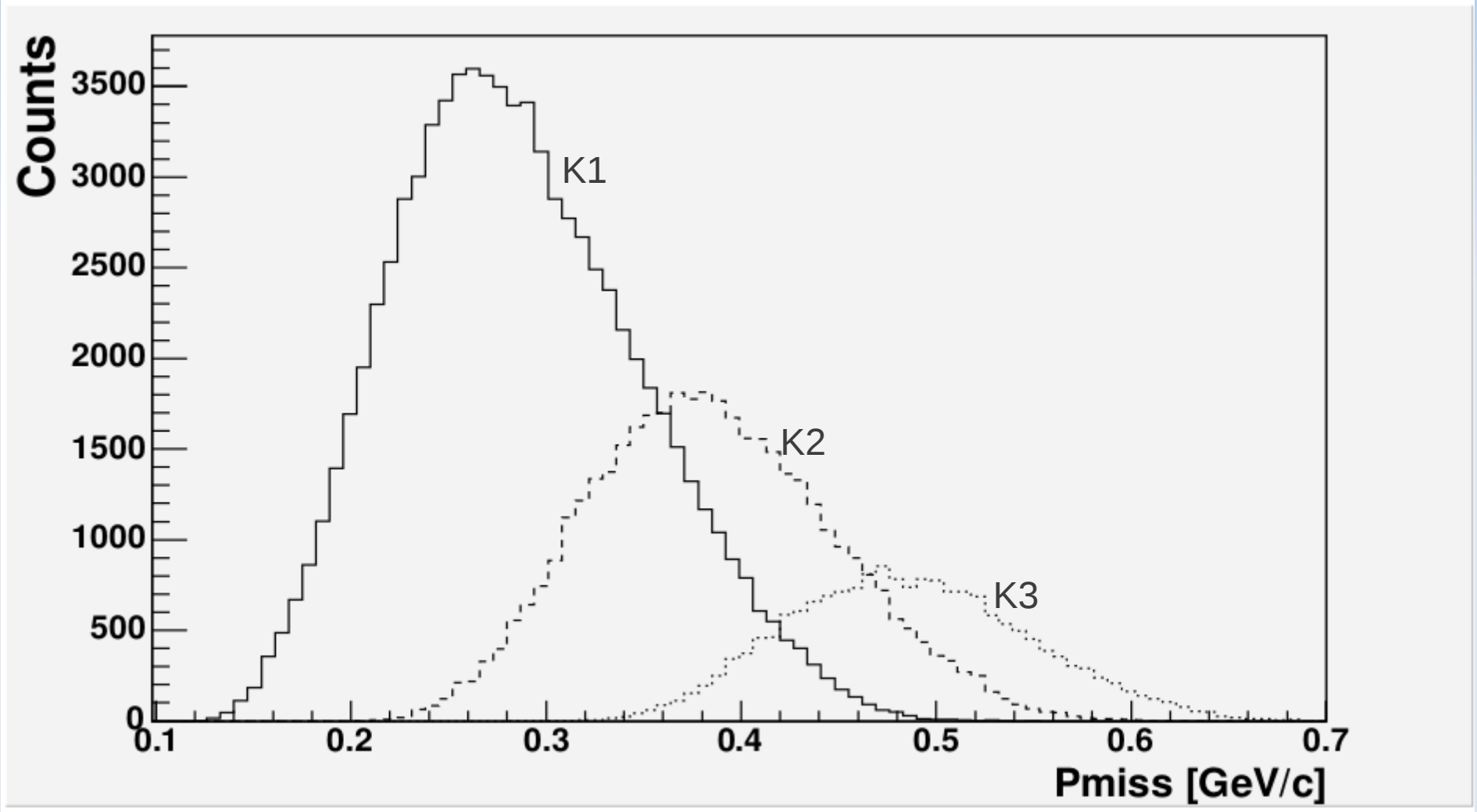


$Q^2 \approx 1.8$



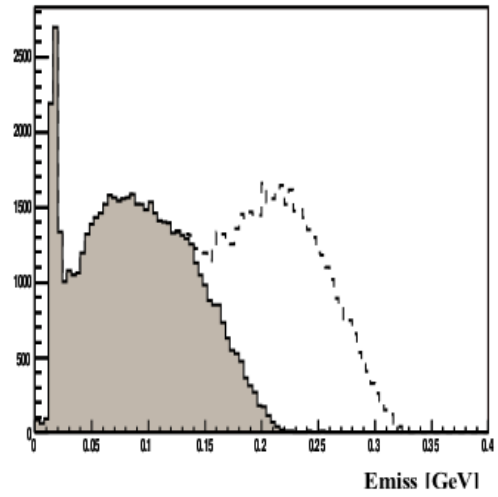
Hall-A E01-015 kinematics

$^{12}C(e,e'p)$ P_{miss} Distribution

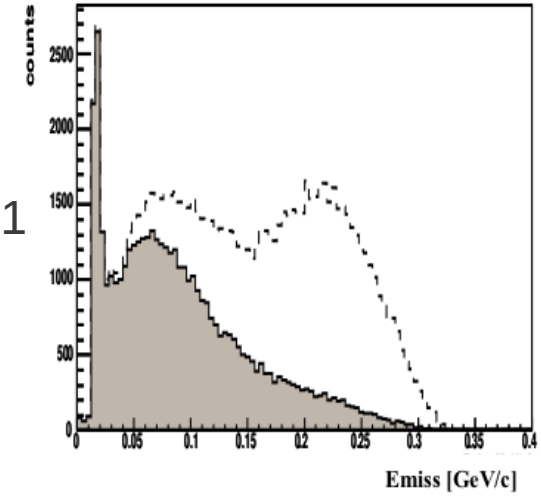


Hall-A E01-015 Delta Contamination

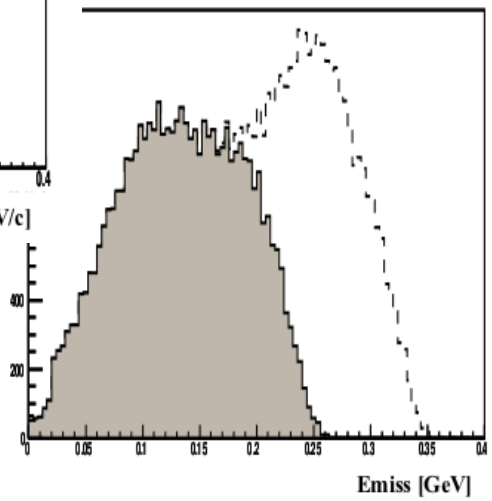
$^{12}C(e,e'p)$ E_{miss} Distribution



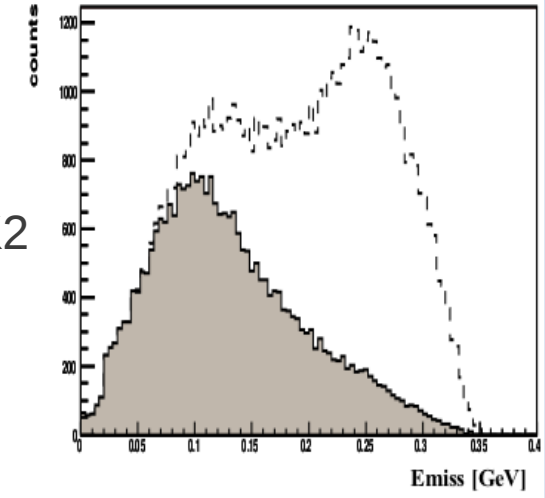
K1

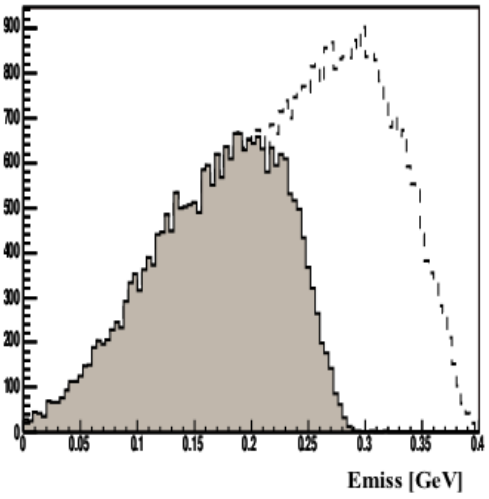


Large E_{miss} is associated with Delta production

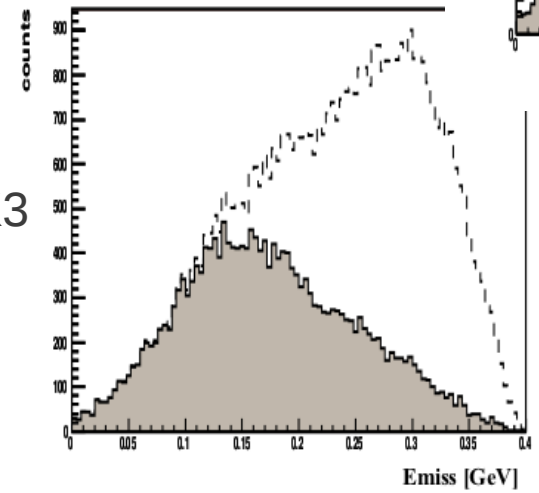


K2





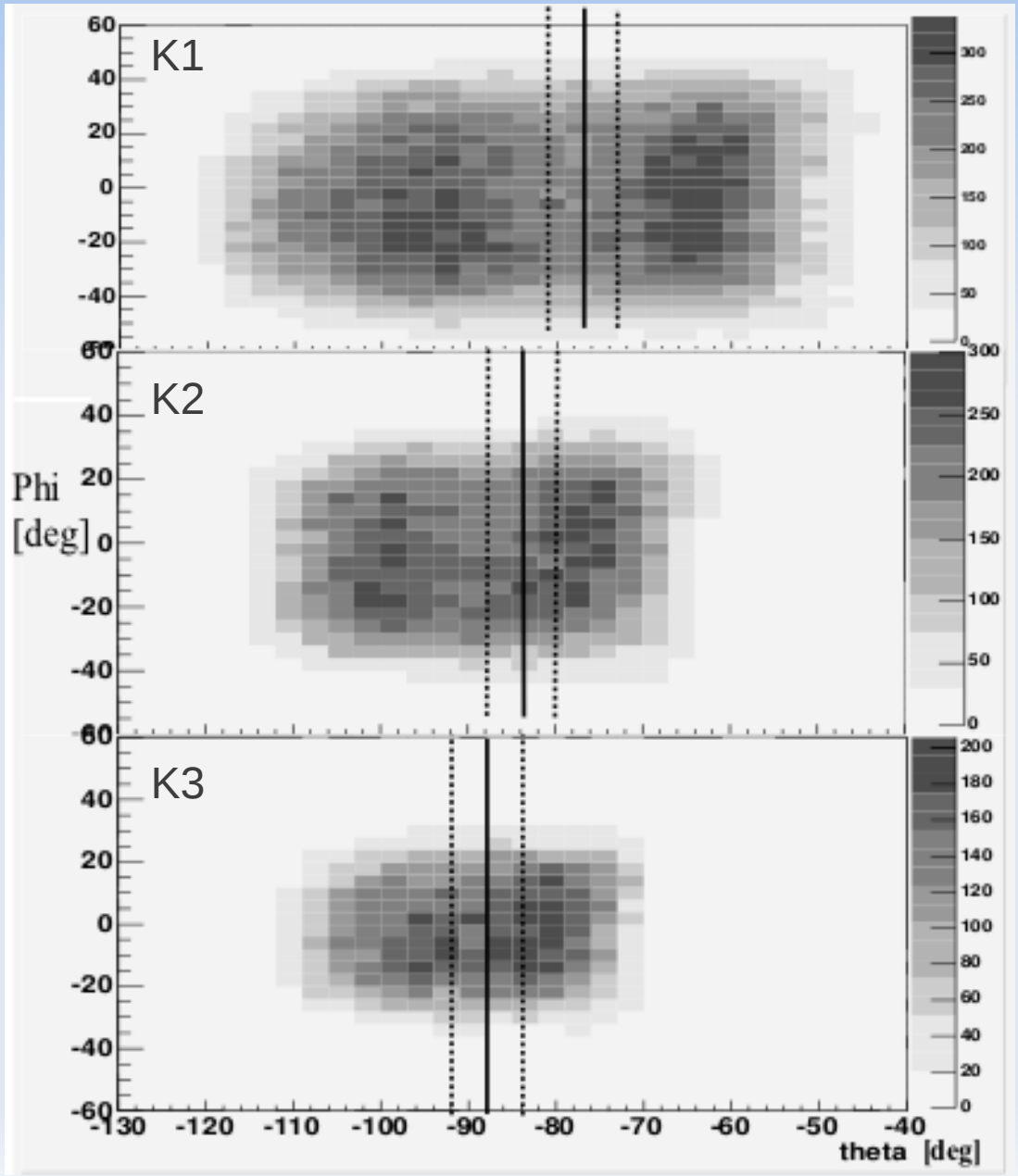
K3



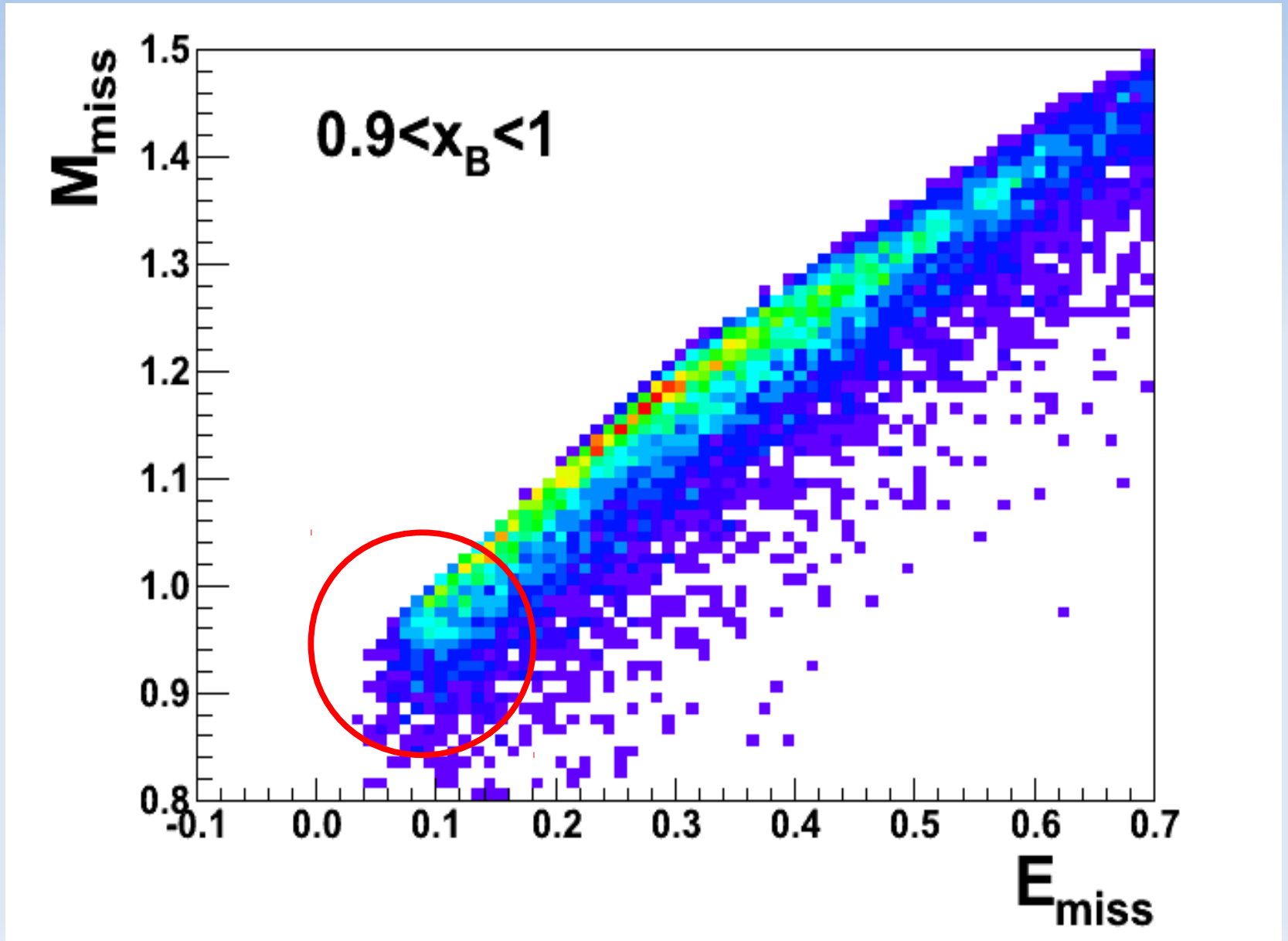
Delta events were killed by cutting on: θ_{Pmiss}**>77-88º** (left) or x_B>1 (right)

Hall-A E01-015 Delta Contamination

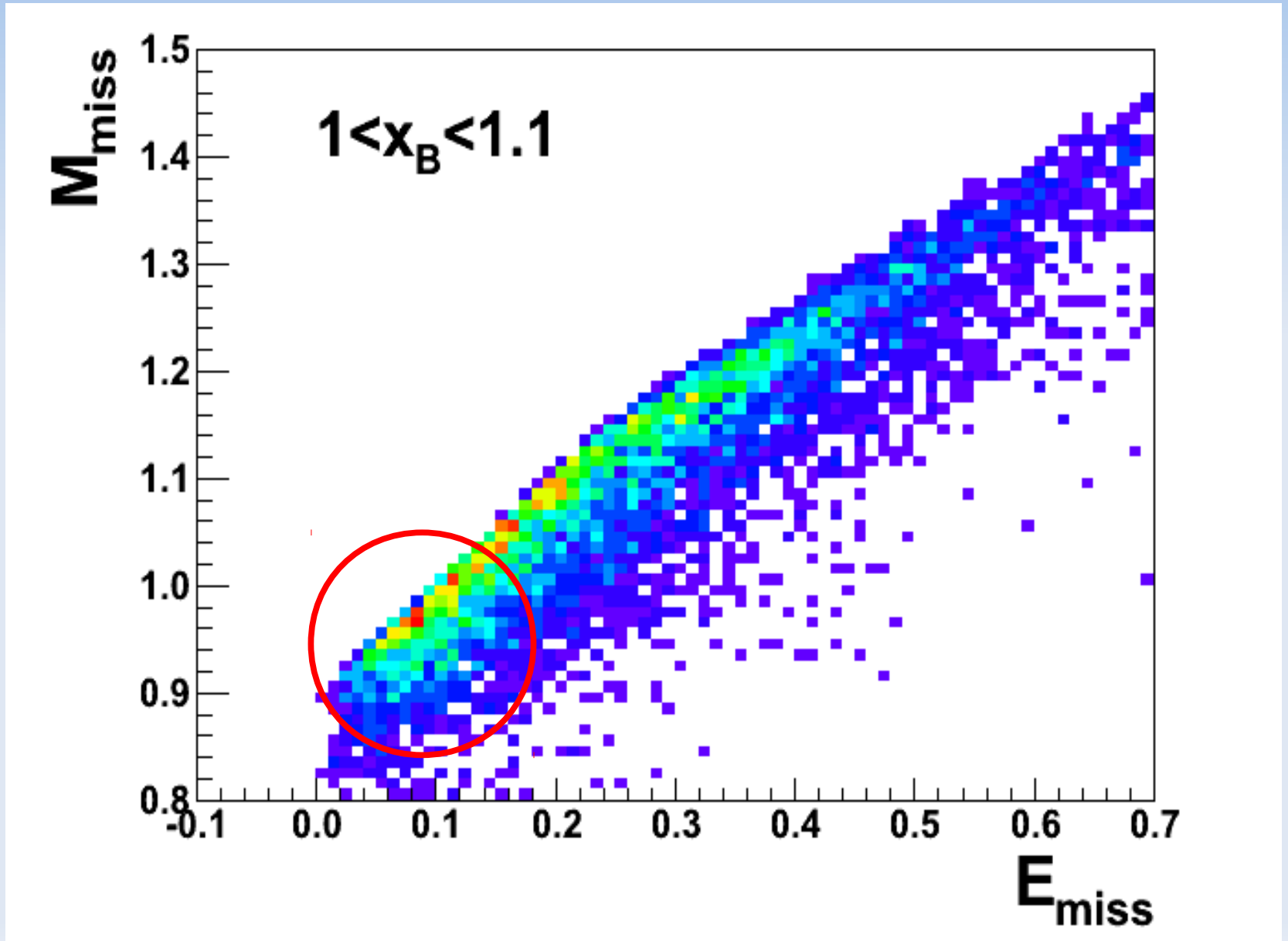
θ_{Pmiss} Cut



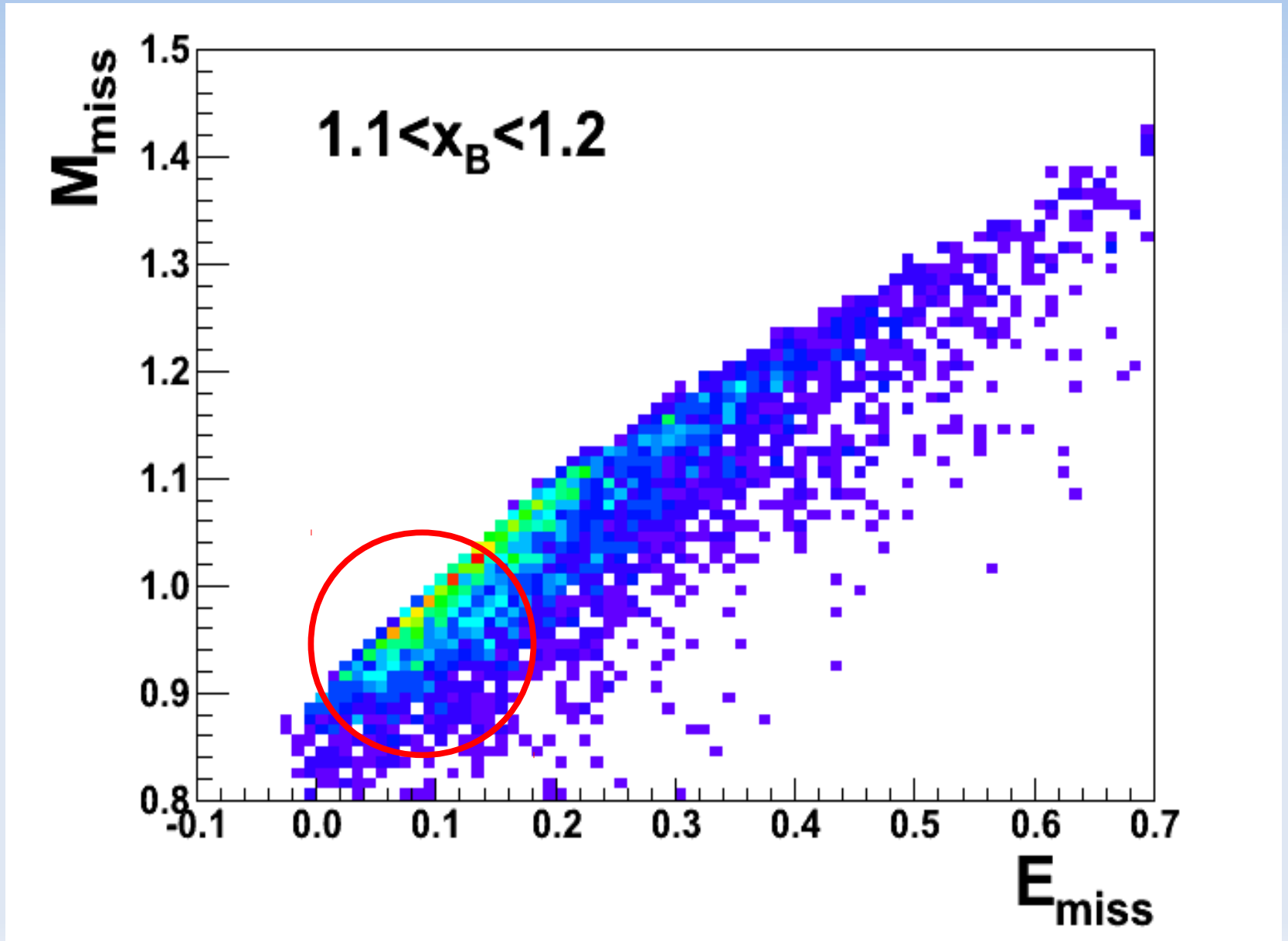
X_B and Delta Production



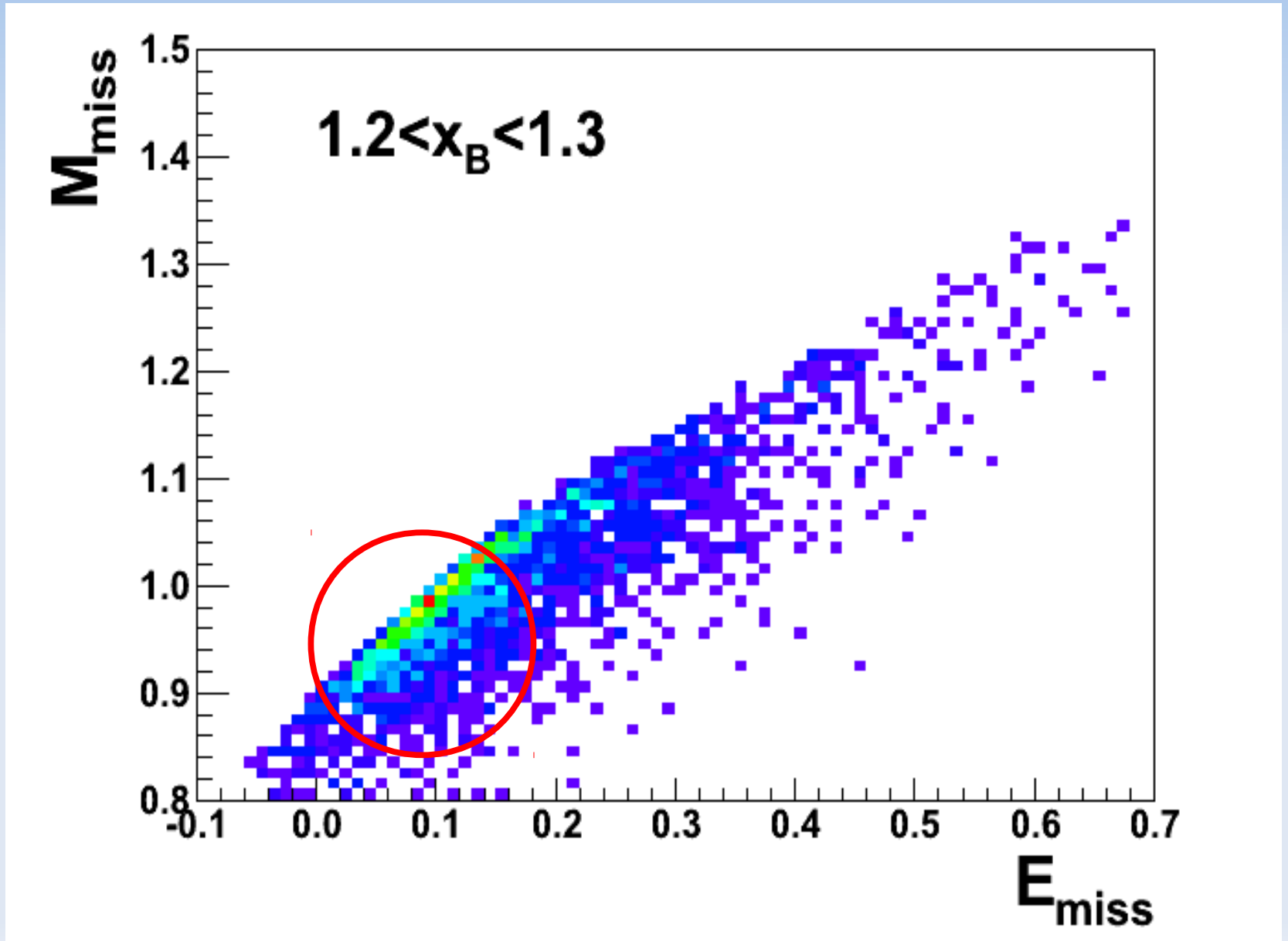
X_B and Delta Production



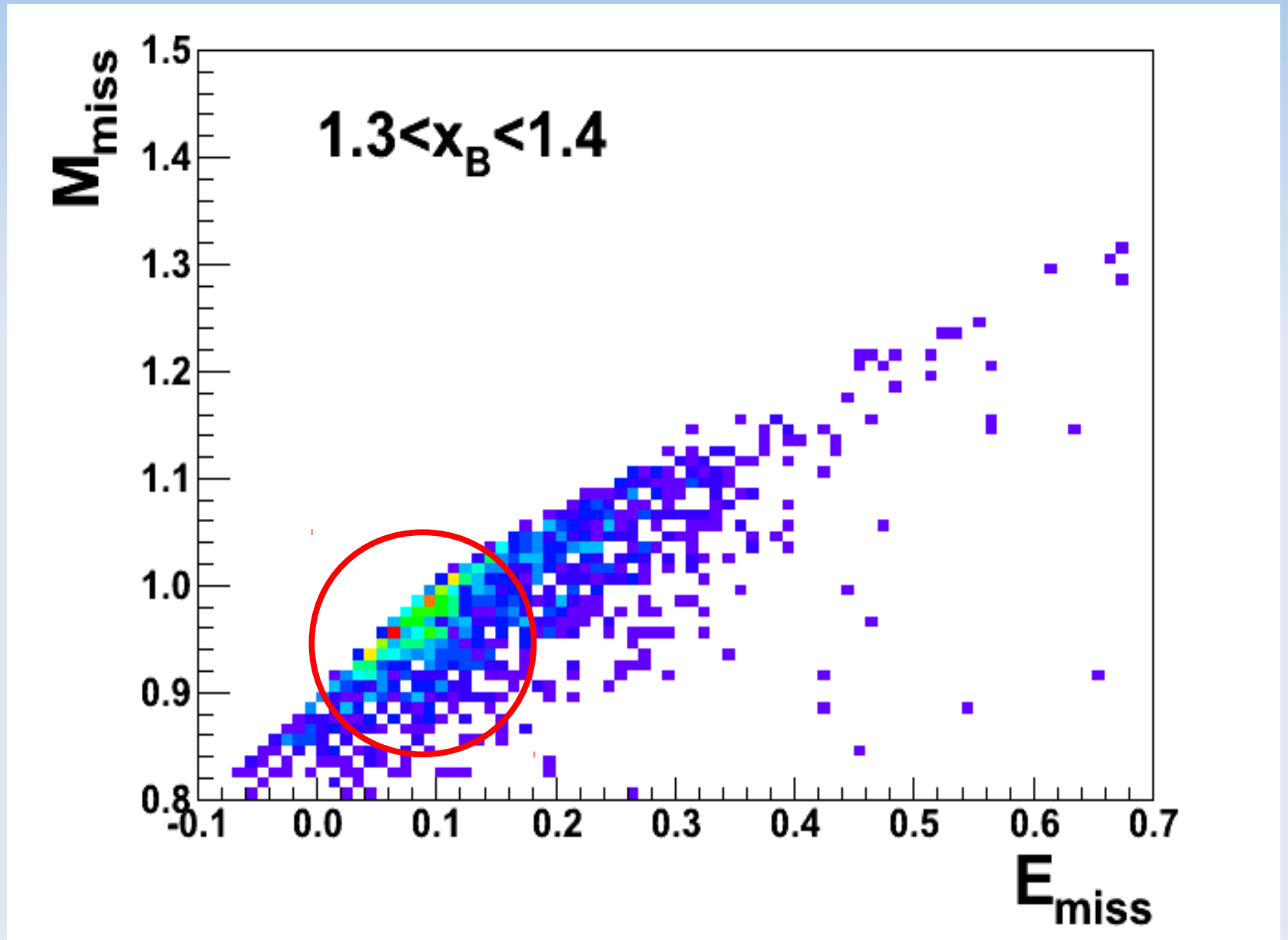
X_B and Delta Production



X_B and Delta Production



X_B and Delta Production



C.M. Momentum and 2N-SRC IsoSpin structure