Analysis of (e,e'p_{Recoil}) Reactions from ^{2}D, ^{12}C, ^{27}Al, ^{56}Fe, and ^{208}Pb using the EG2c Dataset

Barak Schmookler

Outline

- Spectator Proton Tagging for QE Events
- Spectator Proton Tagging for DIS Events

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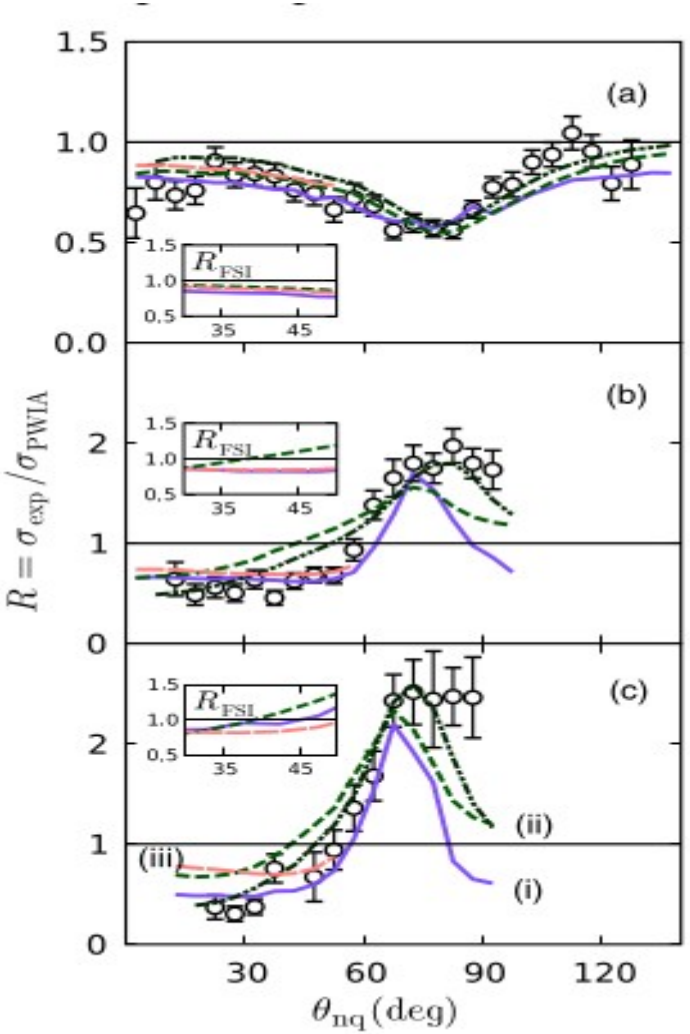
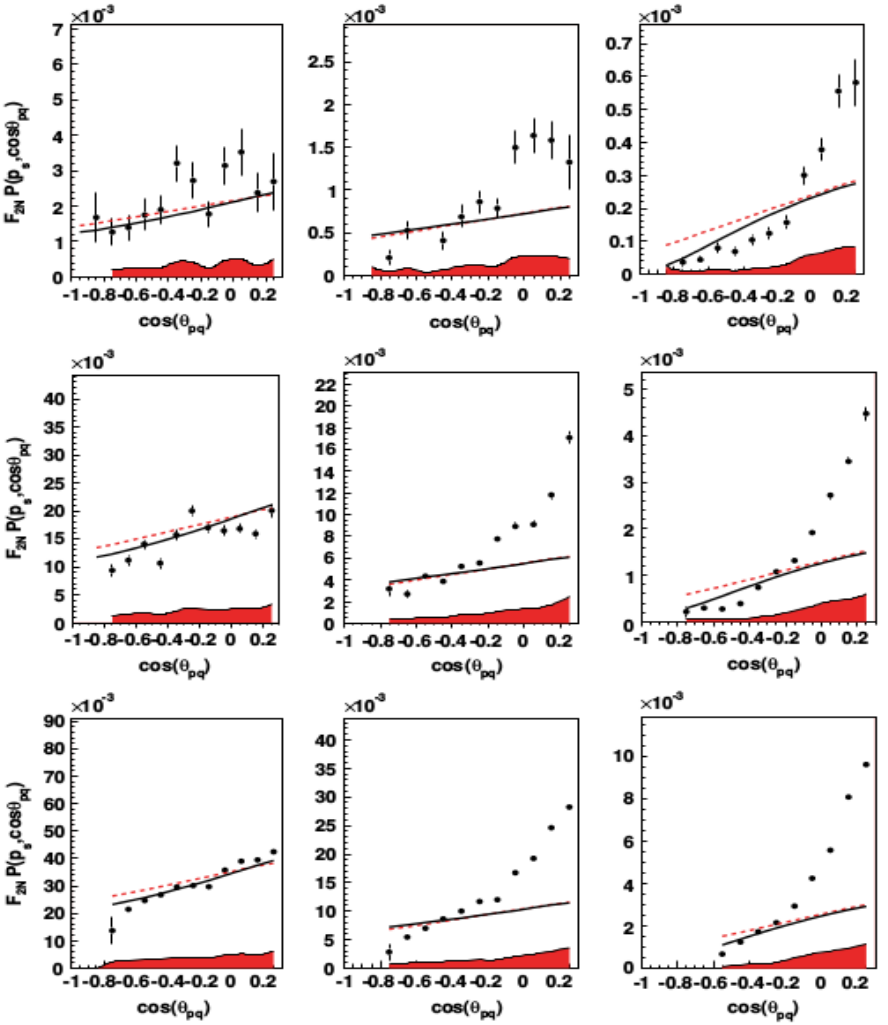
What Previous Experiments Have Done



PRL 107, 262501 (2011)



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What We Want To Do

- We want to compare deuterium cross-sections to plane-wave calculations, as well. In addition, we want to compare the deuterium cross-sections to nuclear targets.
- For QE events with a detected spectator proton, the nuclear targets will have experienced 3-body-breakup. If the detected proton has a 'high' momentum, it most likely originated from an SRC pair.

What We Expect the Ratios to Be

$$\frac{\sigma_A/A}{\sigma_D/2}(e,e'p_{Recoil}) = \frac{2}{A} \times \frac{\#np_A \times \sigma_n + 2 \times \#pp_A \times \sigma_p}{\#np_D \times \sigma_n} \times p_{Trans.}$$

What We Expect the Ratios to Be

$$\frac{\sigma_A/A}{\sigma_D/2}(e,e'p_{Recoil}) = \frac{2}{A} \times \frac{\#np_A \times \sigma_n + 2 \times \#pp_A \times \sigma_p}{\#np_D \times \sigma_n} \times p_{Trans.}$$

Number of Pairs

What We Expect the Ratios to Be

$$\frac{\sigma_A/A}{\sigma_D/2}(e,e'p_{Recoil}) = \frac{2}{A} \times \frac{\#np_A \times \sigma_n + 2 \times \#pp_A \times \sigma_p}{\#np_D \times \sigma_n} \times p_{Trans.}$$

Cross-Section
for electron-neutron or
electron-proton

What We Expect the Ratios to Be

$$\frac{\sigma_A/A}{\sigma_D/2}(e,e'p_{Recoil}) = \frac{2}{A} \times \frac{\#np_A \times \sigma_n + 2 \times \#pp_A \times \sigma_p}{\#np_D \times \sigma_n} \times p_{Trans.}$$

Proton transparency

What We Expect the Ratios to Be

$$\frac{\sigma_A/A}{\sigma_D/2}(e,e'p_{Recoil}) = \frac{2}{A} \times \frac{\#np_A \times \sigma_n + 2 \times \#pp_A \times \sigma_p}{\#np_D \times \sigma_n} \times p_{Trans.}$$

$$a_2 = \frac{\#np_A/A}{\#np_D/2}$$

What We Expect the Ratios to Be

$$\frac{\sigma_A/A}{\sigma_D/2}(e,e'p_{Recoil}) = a_2 \times \left(1 + 2 \times \frac{\#pp_A}{\#np_A} \times \frac{\sigma_p}{\sigma_n}\right) \times p_{Trans.}$$

What We Expect the Ratios to Be

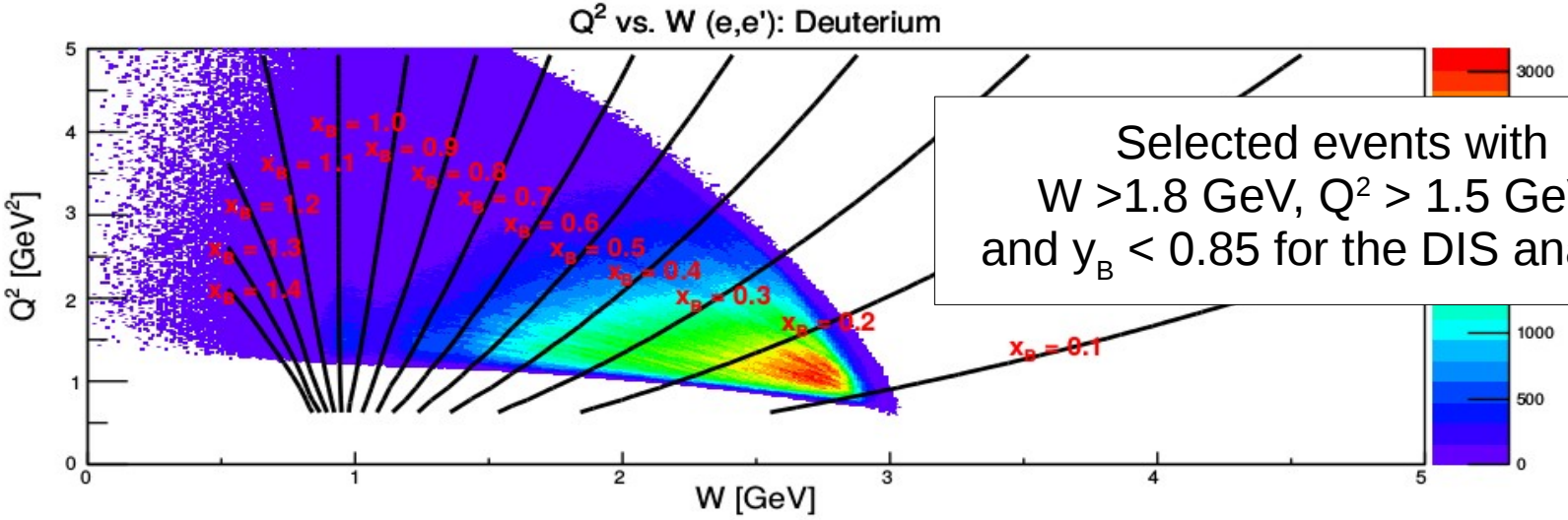
$$\frac{\sigma_A/A}{\sigma_D/2}(e,e'p_{Recoil}) = a_2 \times \left(1 + 2 \times \frac{\#pp_A}{\#np_A} \times \frac{\sigma_p}{\sigma_n}\right) \times p_{Trans.}$$

$$\frac{\#pp_A}{\#np_A} \approx 1/20 - 1/10$$

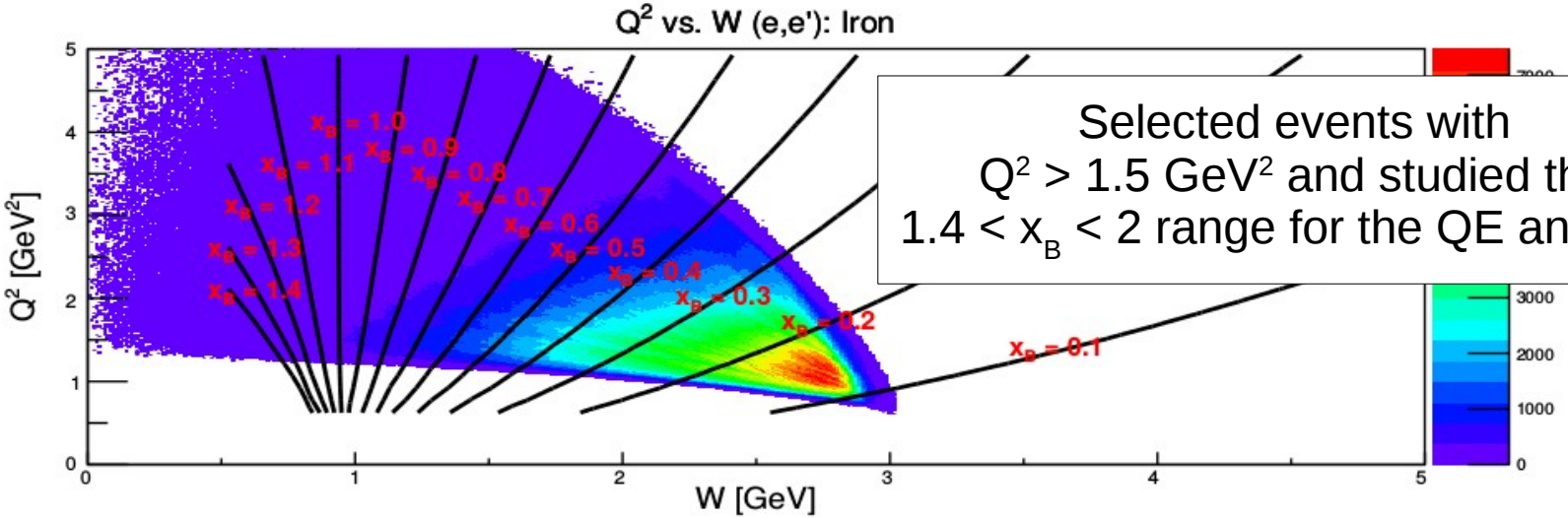
$$\frac{\sigma_p}{\sigma_n} \approx 2.5$$

$$p_{Trans.} \approx 0.3 - 0.7$$

Kinematic Coverage and Event Selection



Selected events with
$W > 1.8$ GeV, $Q^2 > 1.5$ GeV^2,
and $y_B < 0.85$ for the DIS analysis



Selected events with
$Q^2 > 1.5$ GeV^2 and studied the
$1.4 < x_B < 2$ range for the QE analysis

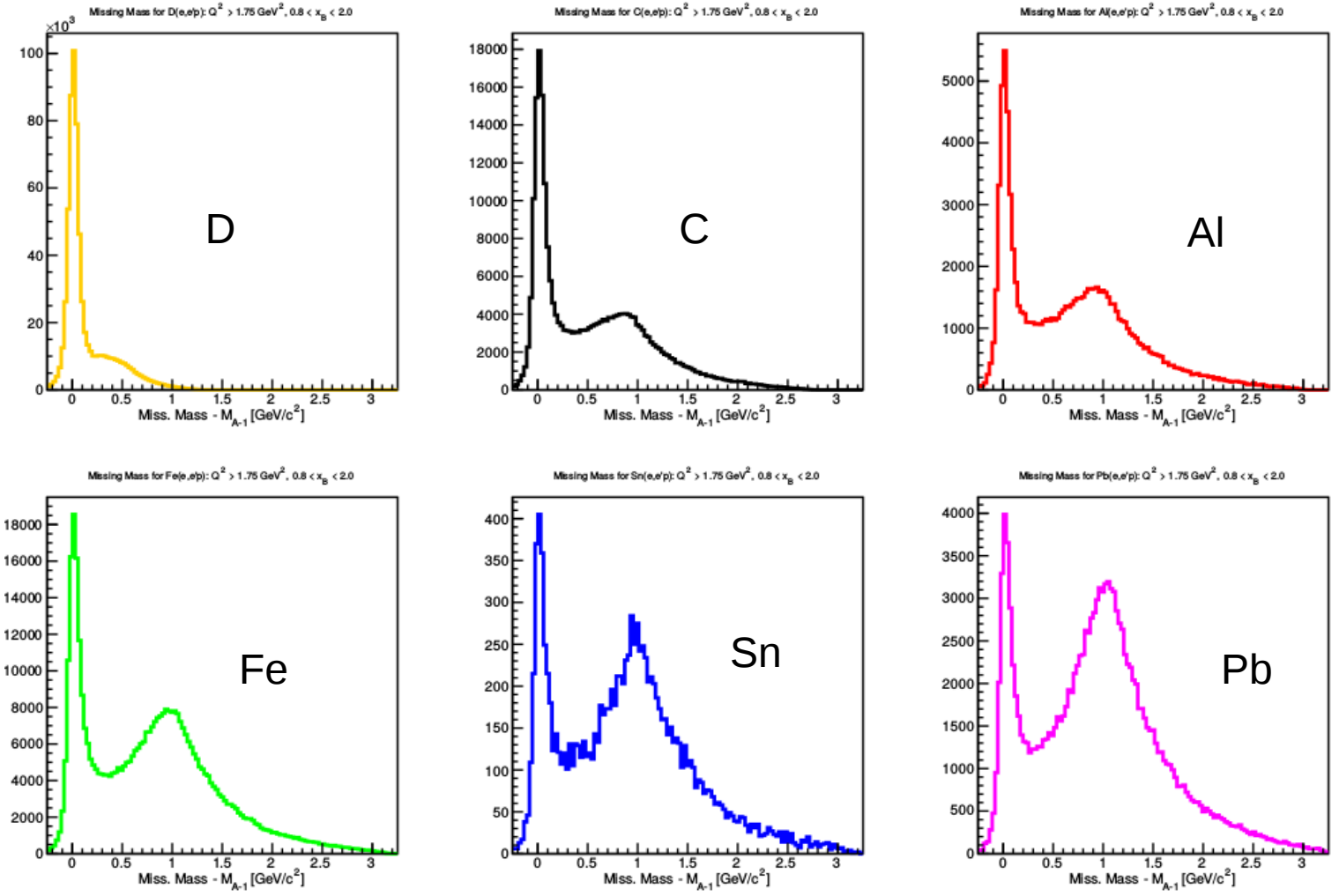
Corrections Applied when Calculating the Cross-Section Ratios

- We developed vertex, polar angle, and momentum corrections for the scattered electrons.
- In addition, we determined the beam energy using measurements taken in the Hall A arc during the data-taking.
- These corrections may be useful for other EG2c analyses.

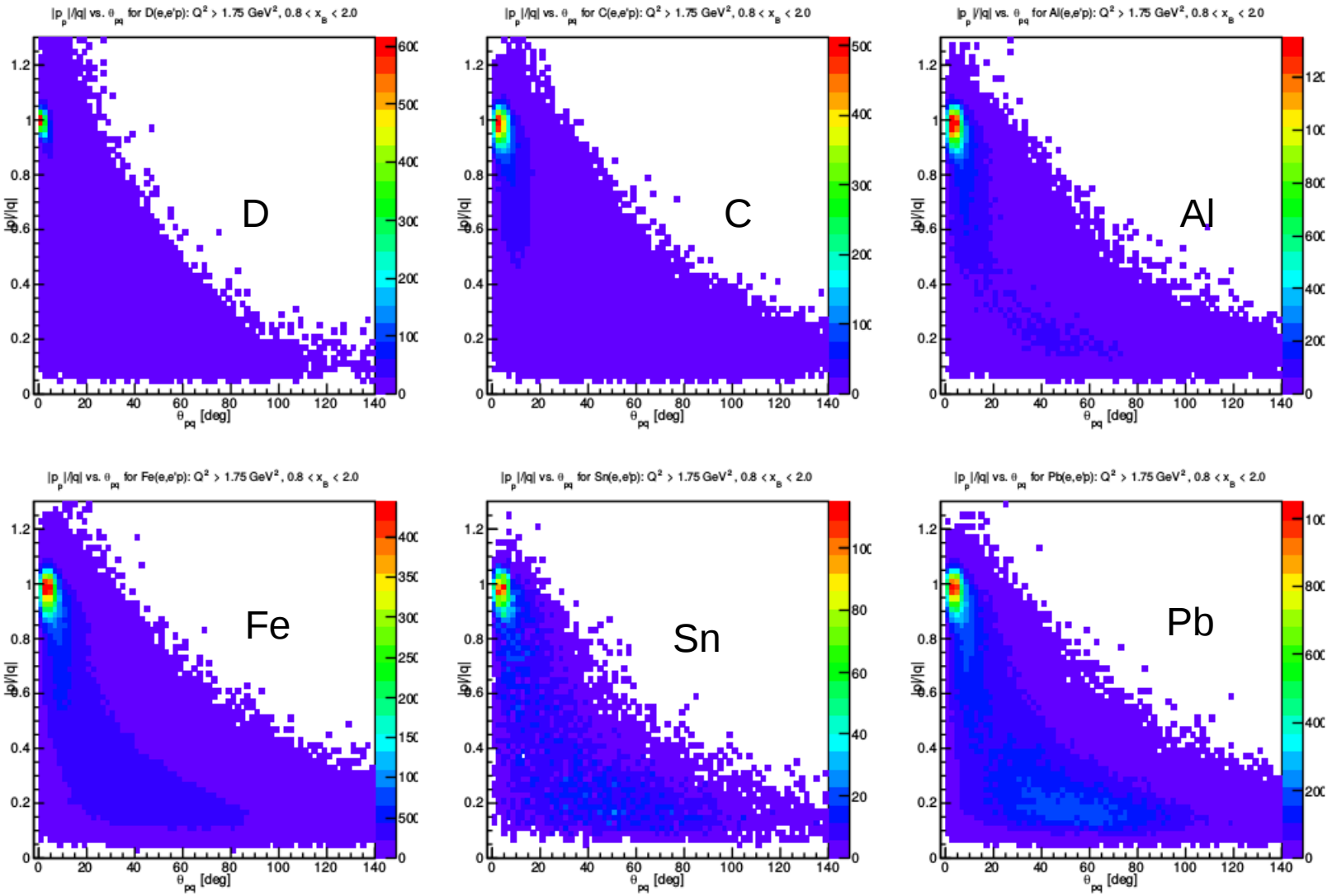
Selecting (e,e'p_{Recoil}) Events

- In QE D(e,e'p) events, the missing mass reconstructs to the neutron mass. This is true whether the detected proton is the struck or the spectator nucleon. (See section 3.3.2 of my inclusive analysis note.)
- For these QE events with low proton momentum, we compare the proton momentum vector to the q-vector.
- From here, we determine a consistent set of cuts to apply to all targets.

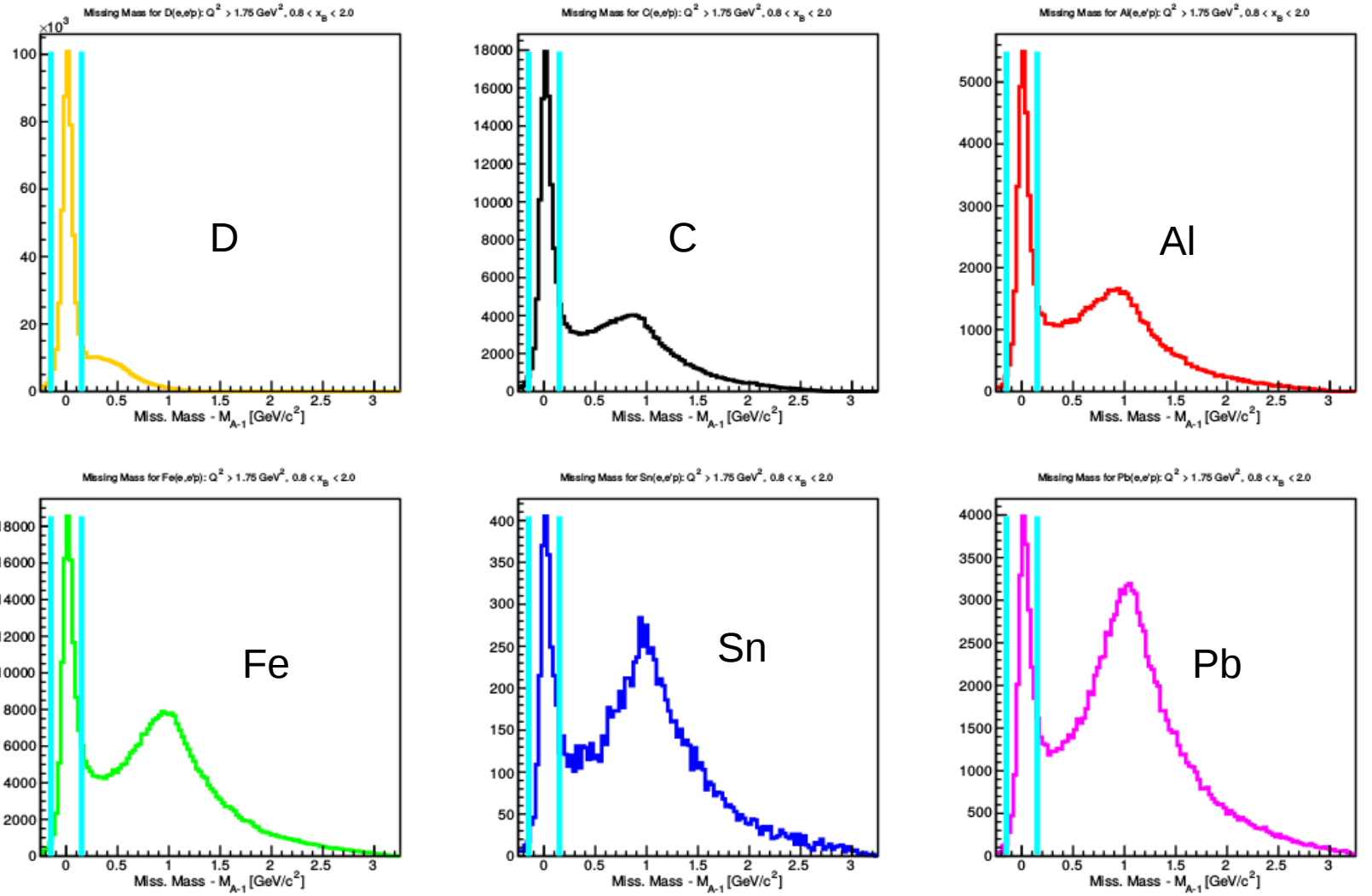
Missing Mass: (e,e'p) Events, $Q^2>1.75\ GeV^2$, $0.8<x_B<2.0$



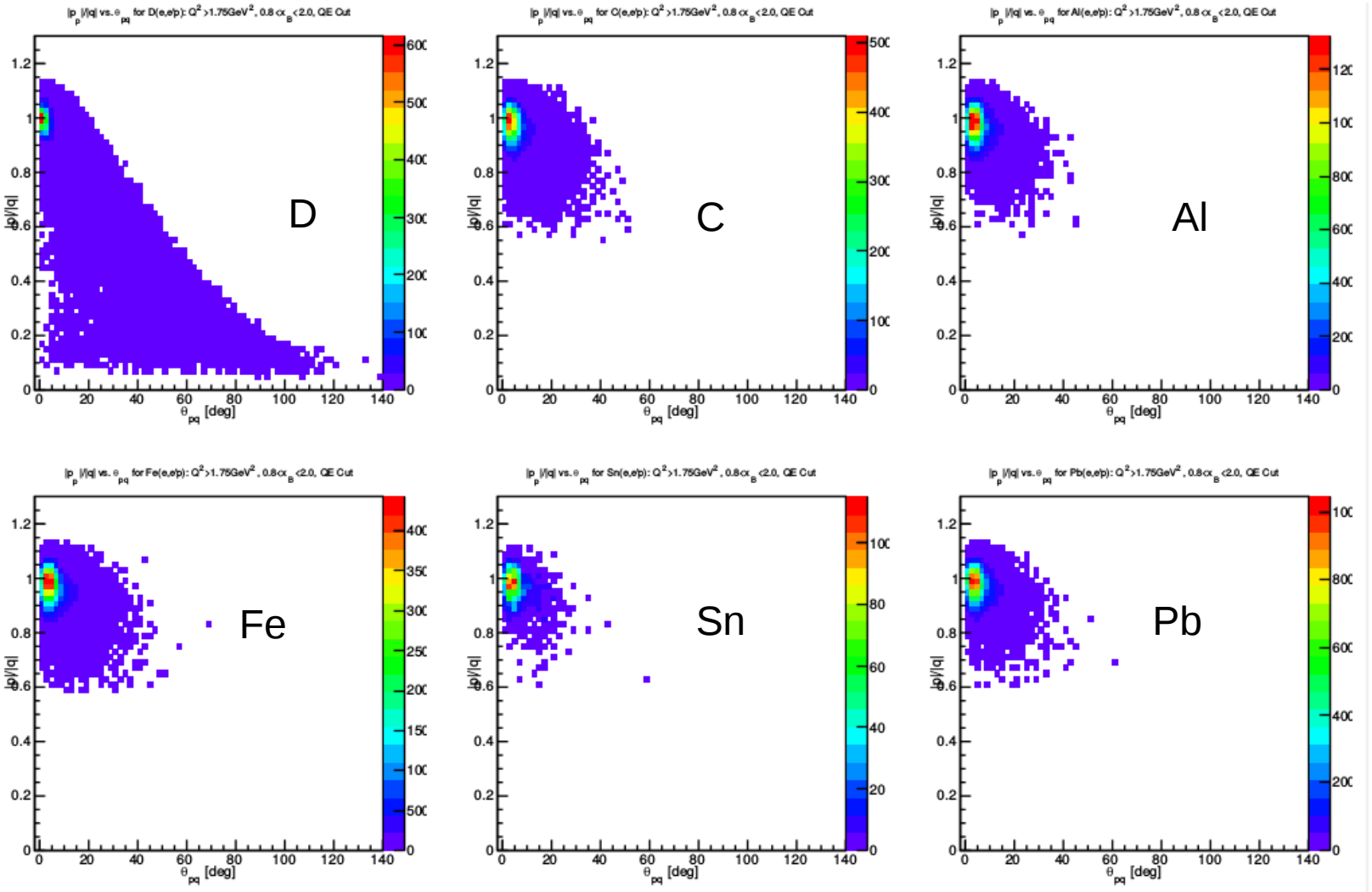
$|\mathbf{p}_p|/|\mathbf{q}|$ vs θ_{pq} for the Same Events



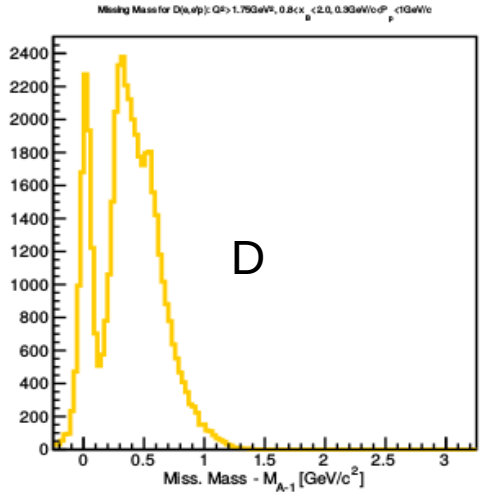
Missing Mass: (e,e'p) Events, $Q^2>1.75\ GeV^2$, $0.8<x_B<2.0$

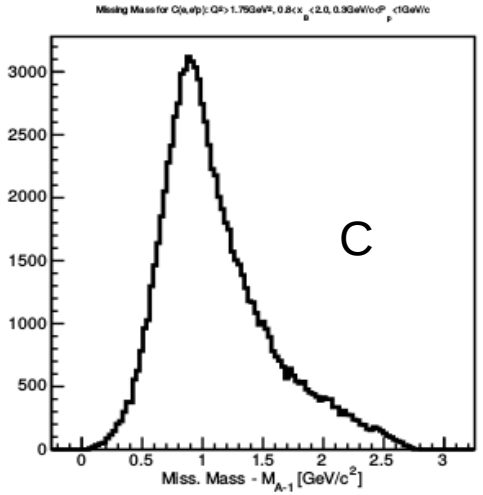


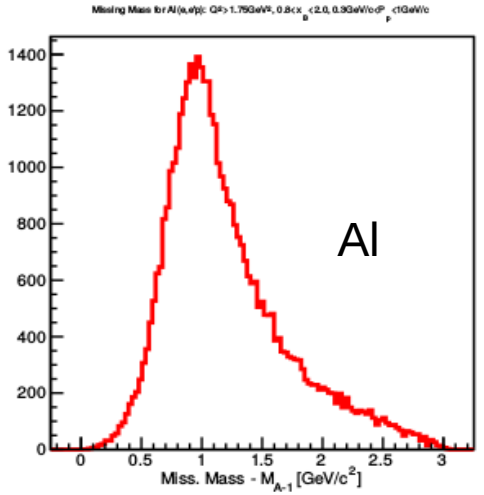
$|\mathbf{p}_p|/|\mathbf{q}|$ vs θ_{pq} after the Missing Mass Cut

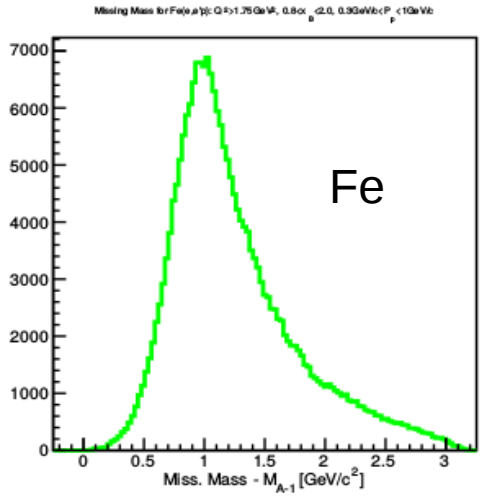


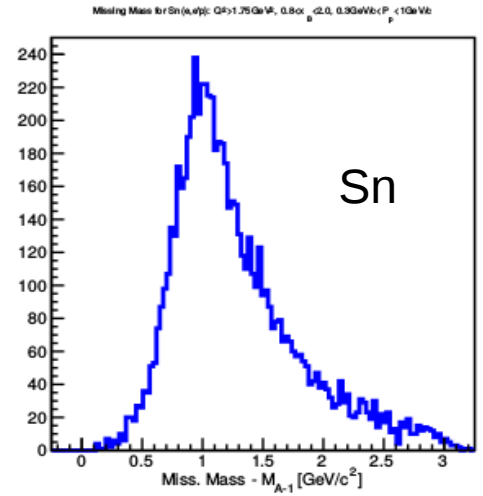
Missing Mass: (e,e'p) Events, $Q^2>1.75$ GeV^2, $0.8<x_B<2.0$, $|\mathbf{P}_p|<1GeV/c$

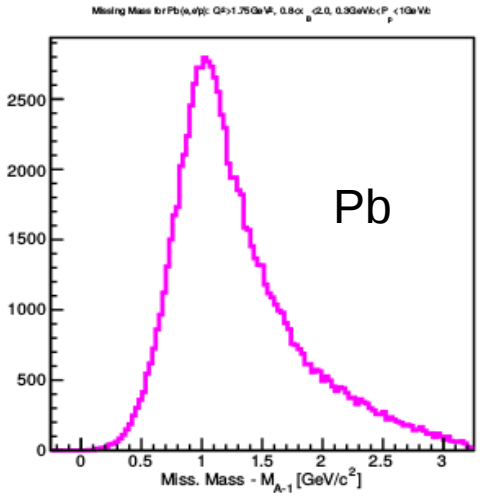




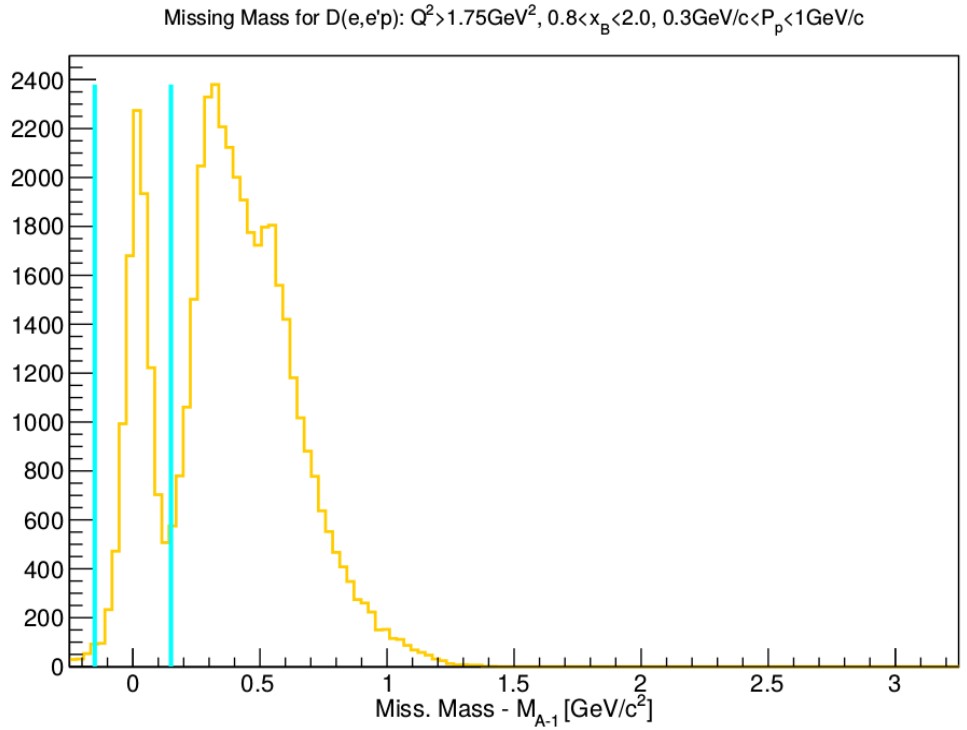


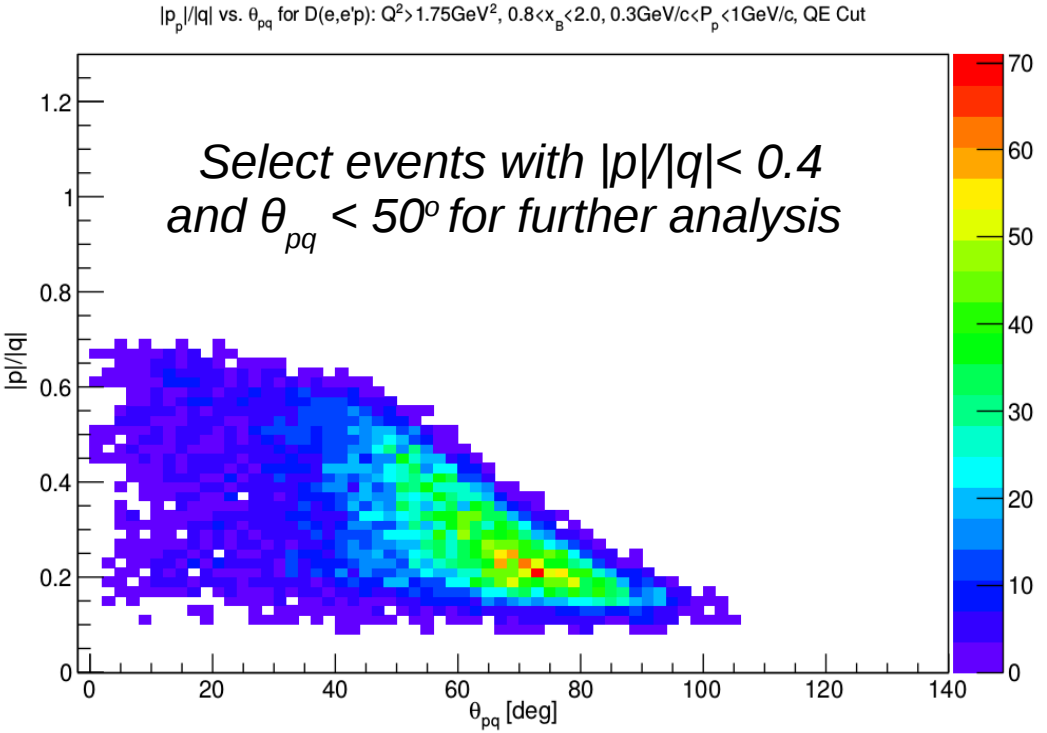






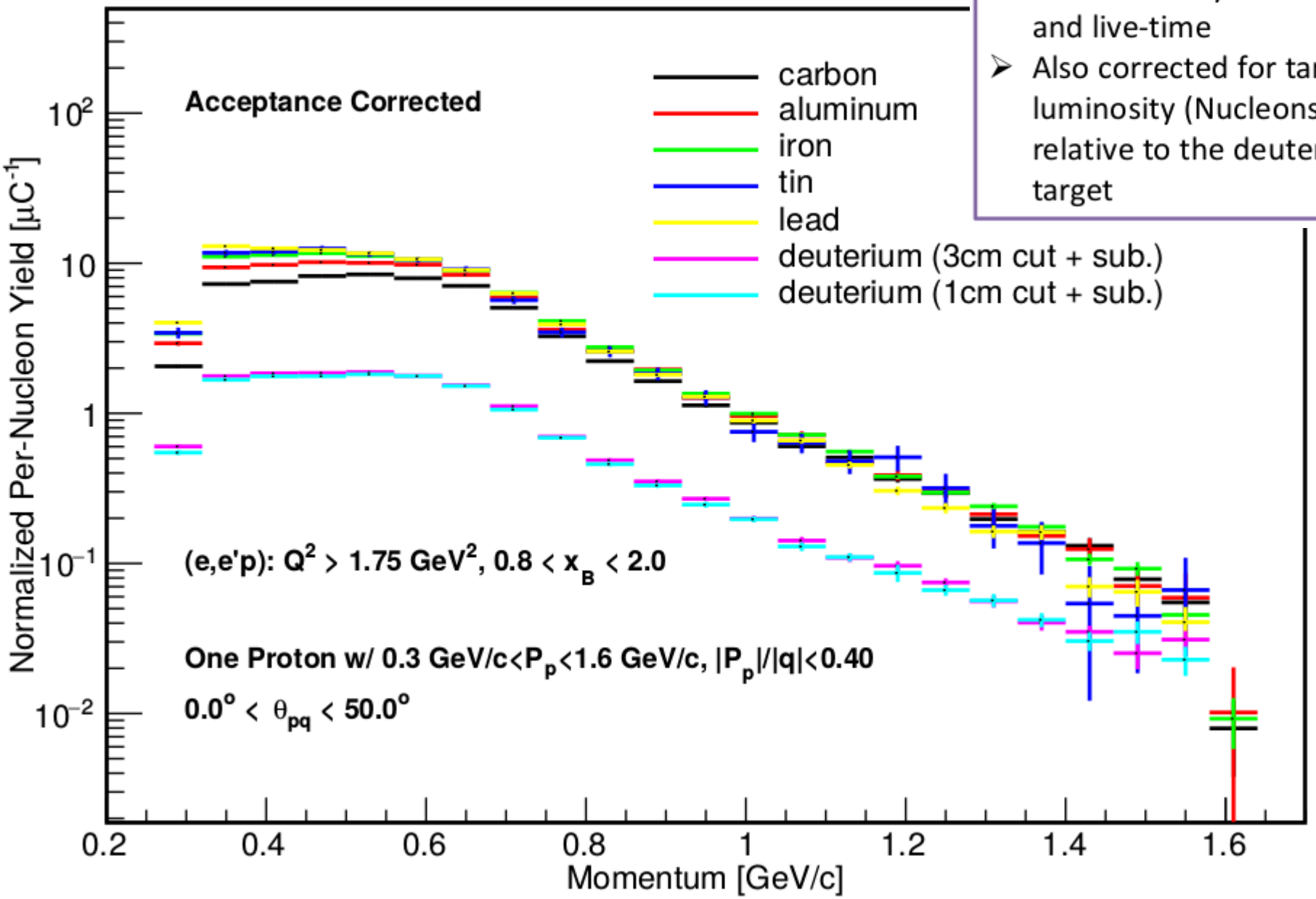
Study the Deuterium Events to Determine Cut for All Targets



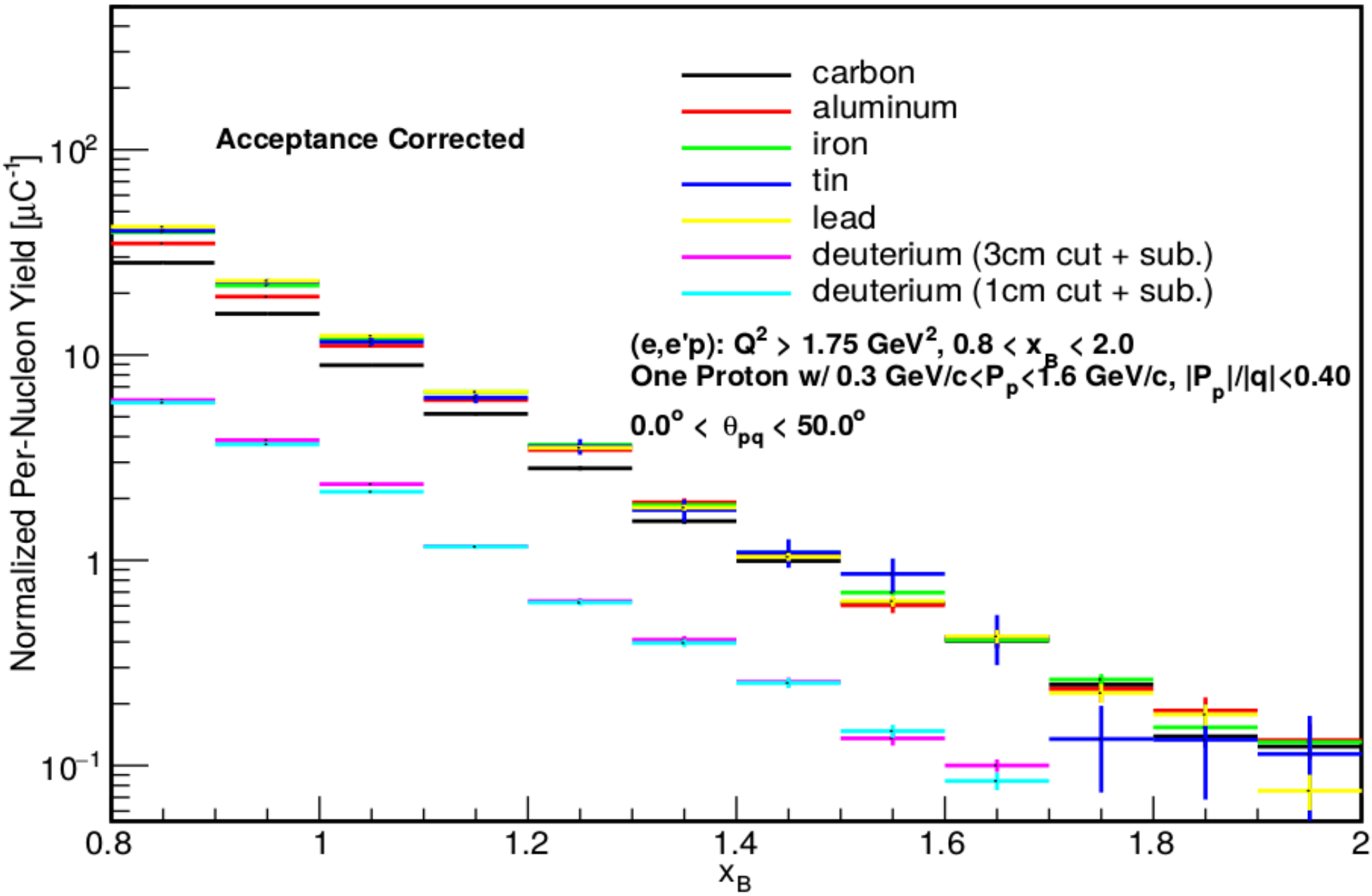


Proton Momentum

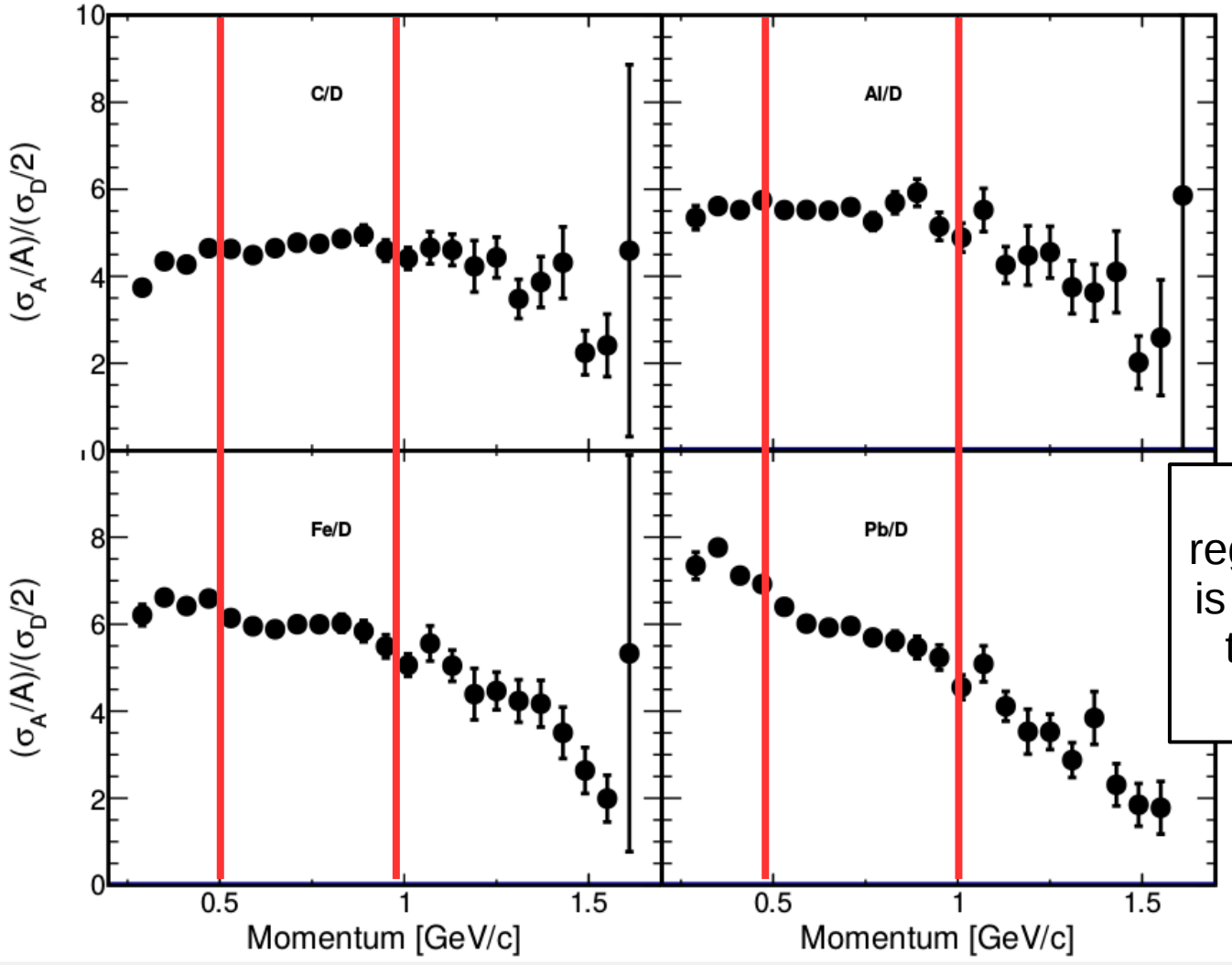
- Yields shown here are normalized by beam-charge and live-time
- Also corrected for target luminosity (Nucleons/cm^2), relative to the deuterium target



x_B Distribution

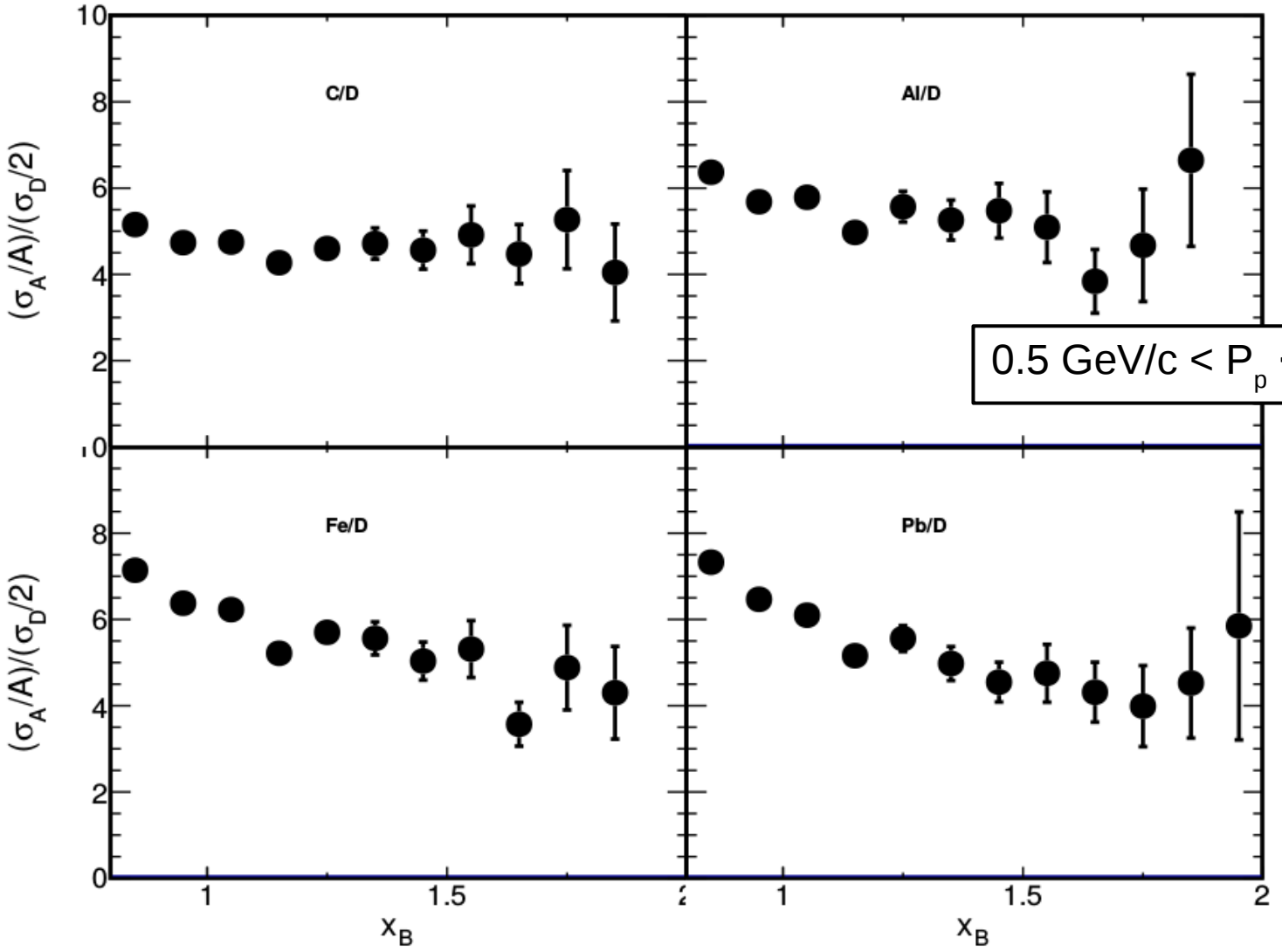


Per-Nucleon Cross-Section Ratios vs Detected Proton Momentum

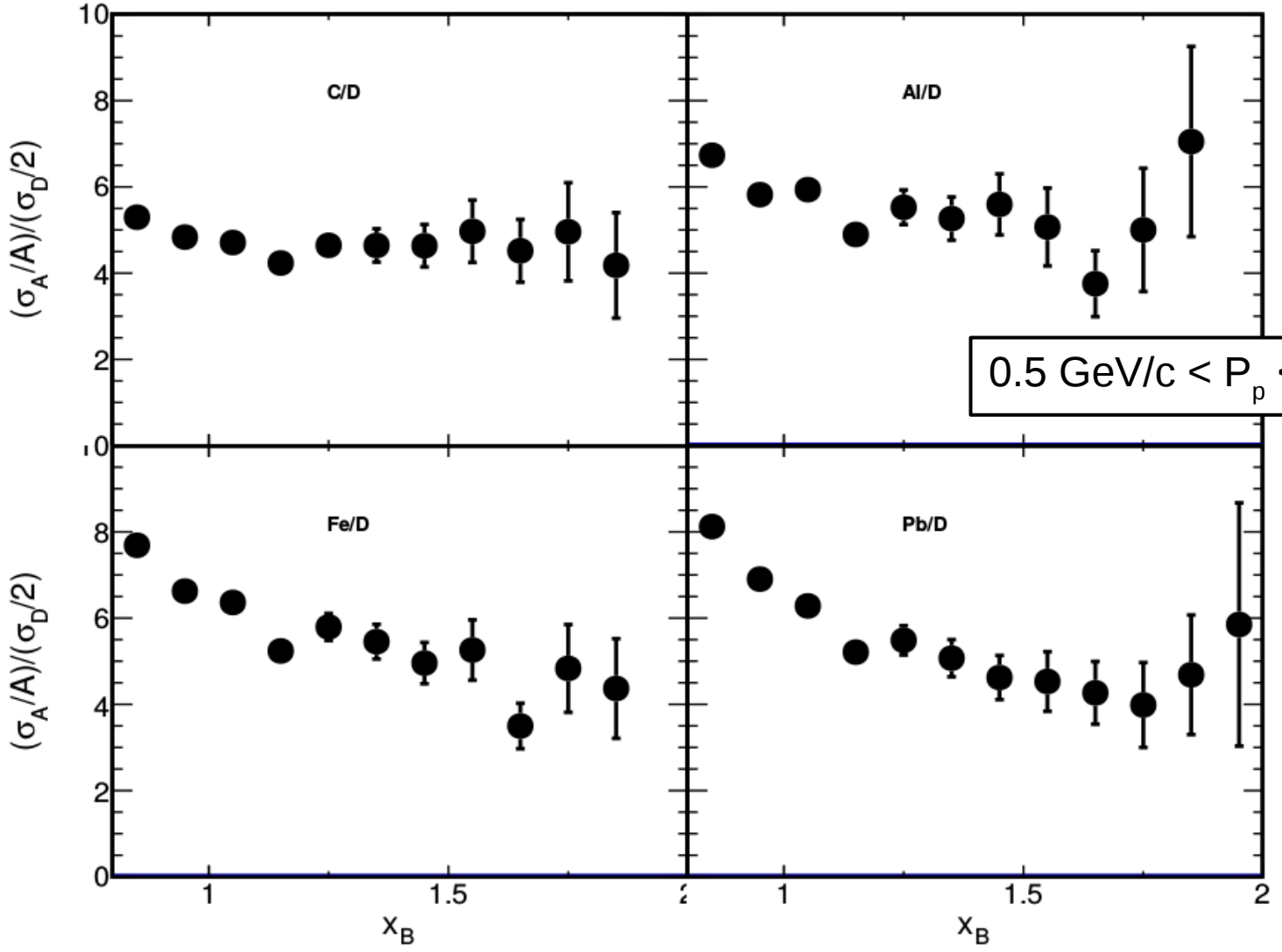


We select region where ratio is mostly flat and then look at x_B ratios.

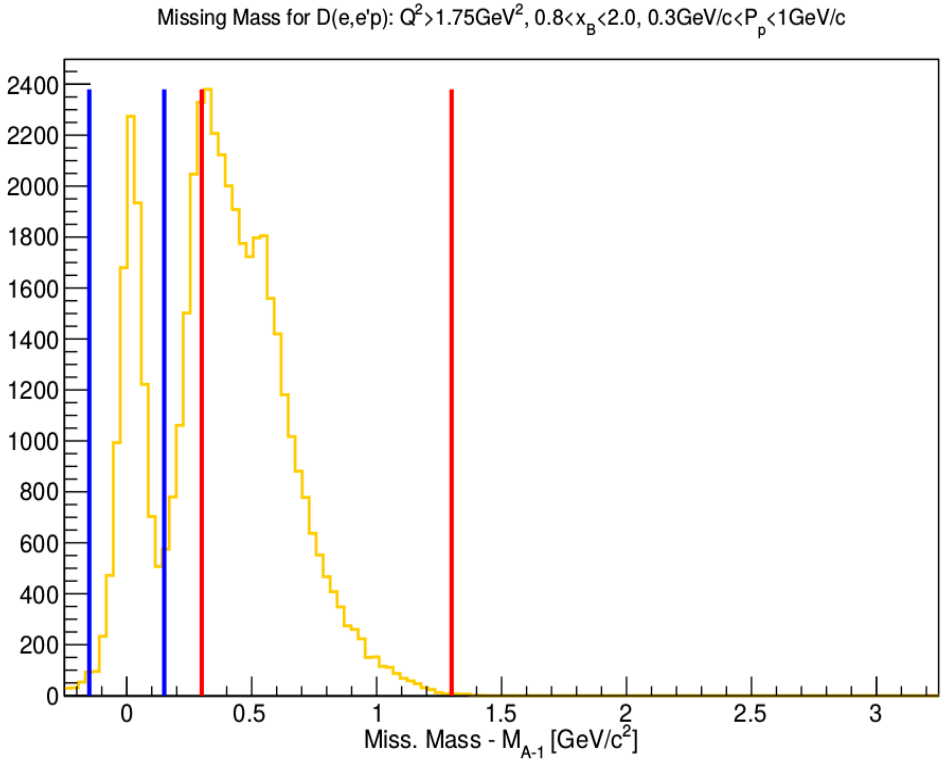
Per-Nucleon Cross-Section Ratios vs x_B for the Selected Events

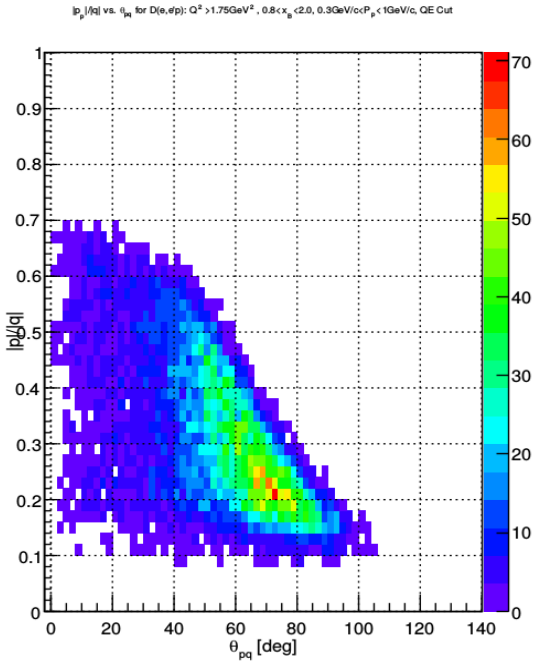


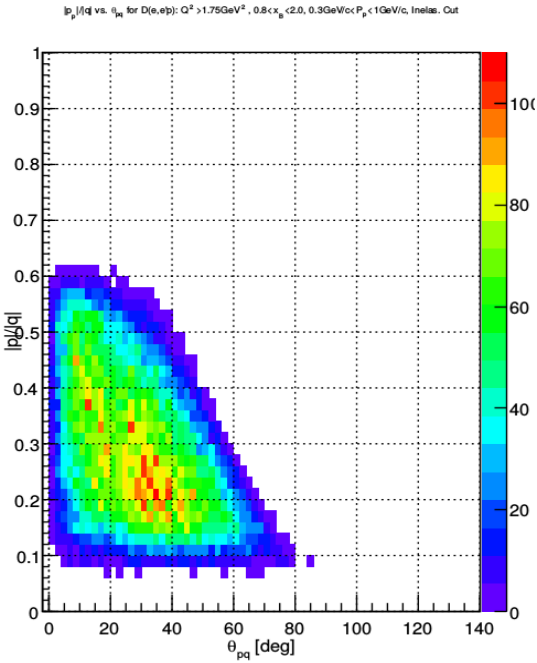
Per-Nucleon Cross-Section Ratios vs x_B for the Selected Events



Problem: Almost Impossible to Select QE Recoil Events without Missing Mass Cut







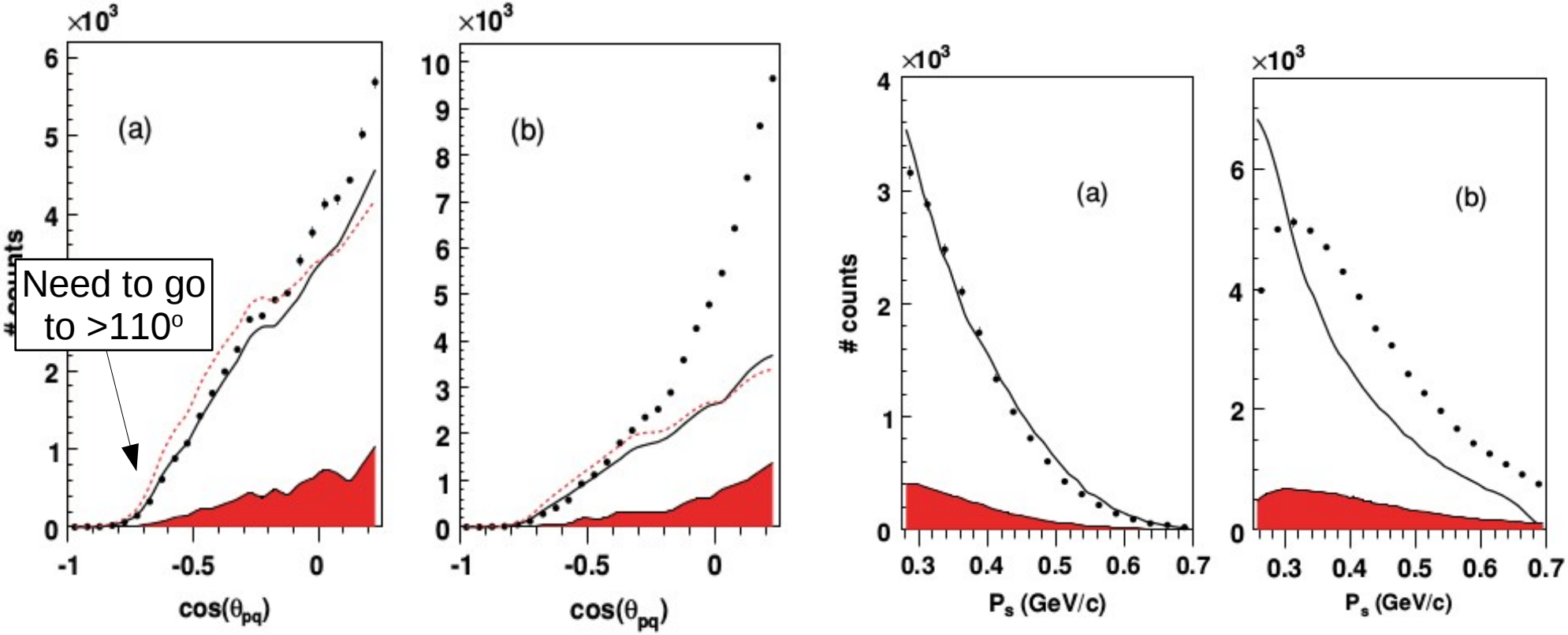
But Does it Matter?

- We need to compare the deuterium spectrum for our recoil events to plane-wave cross-sections with and without the missing mass cut.
- We need to include radiative effects (and there is a jacobian for going from cross-sections to yield).
- We can use the Hall A/C code *SIMC* to do all this. In progress...

Outline

- Spectator Proton Tagging for QE Events
- Spectator Proton Tagging for DIS Events

Previous Measurements on Deuterium



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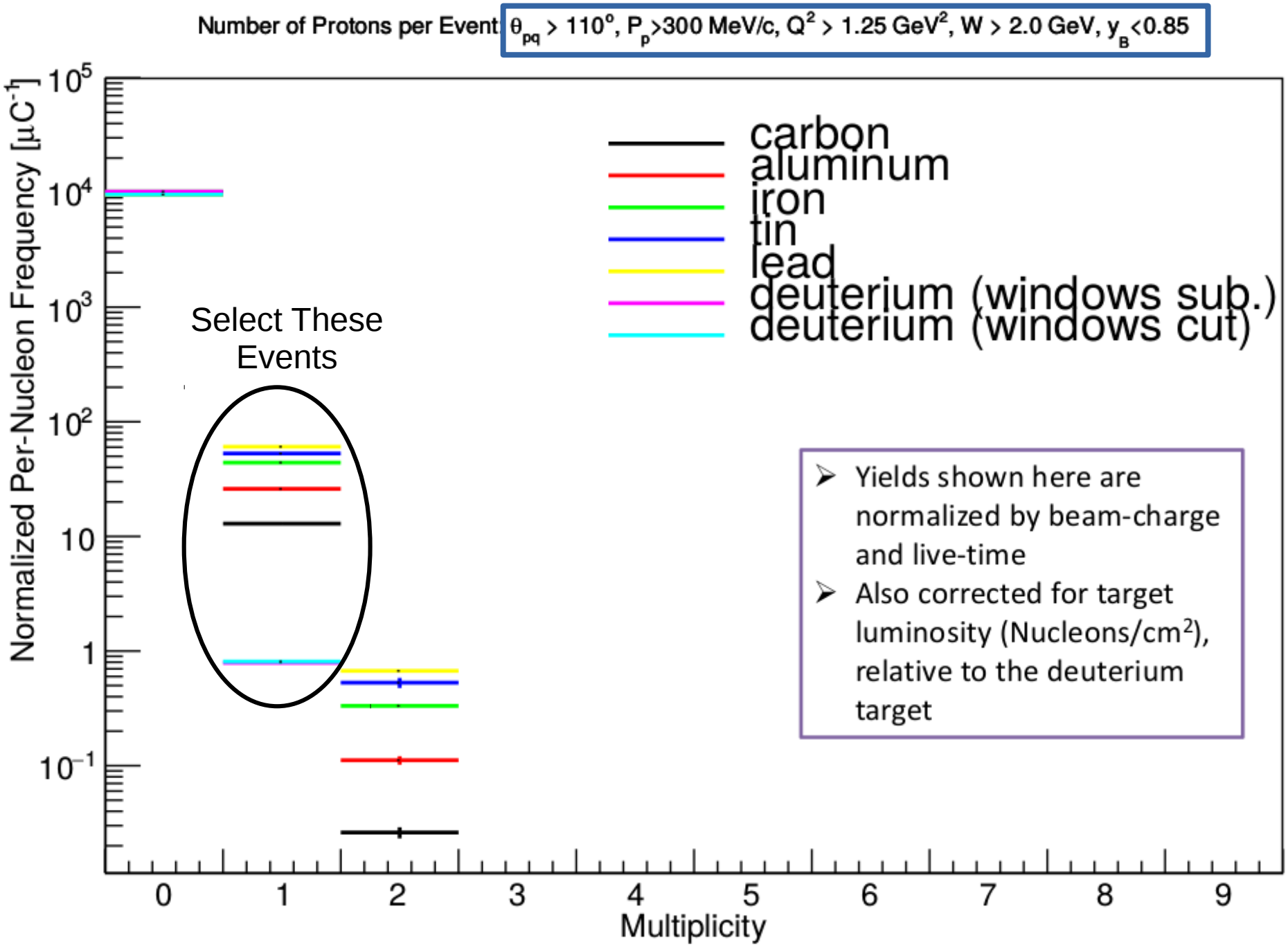
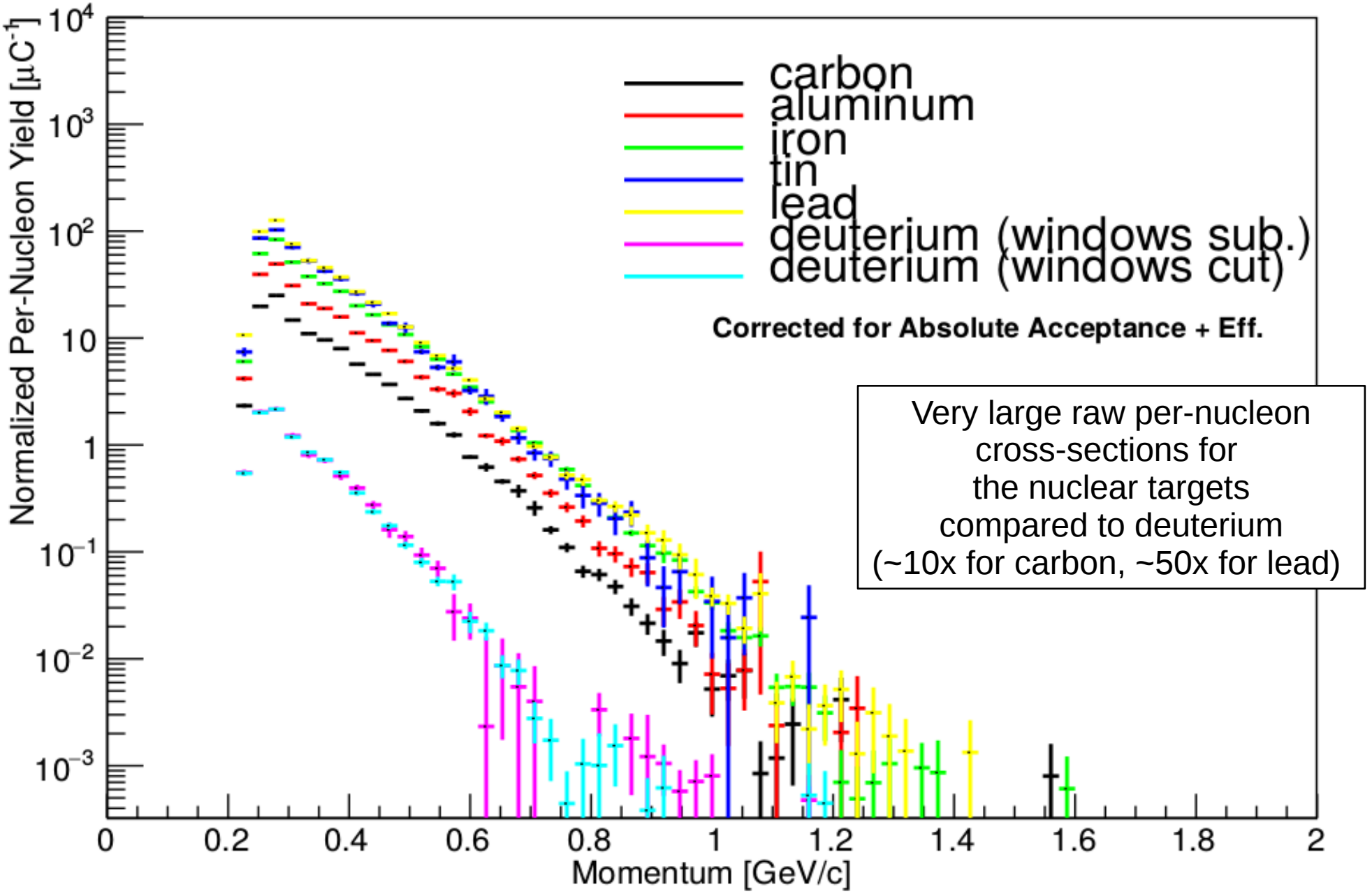
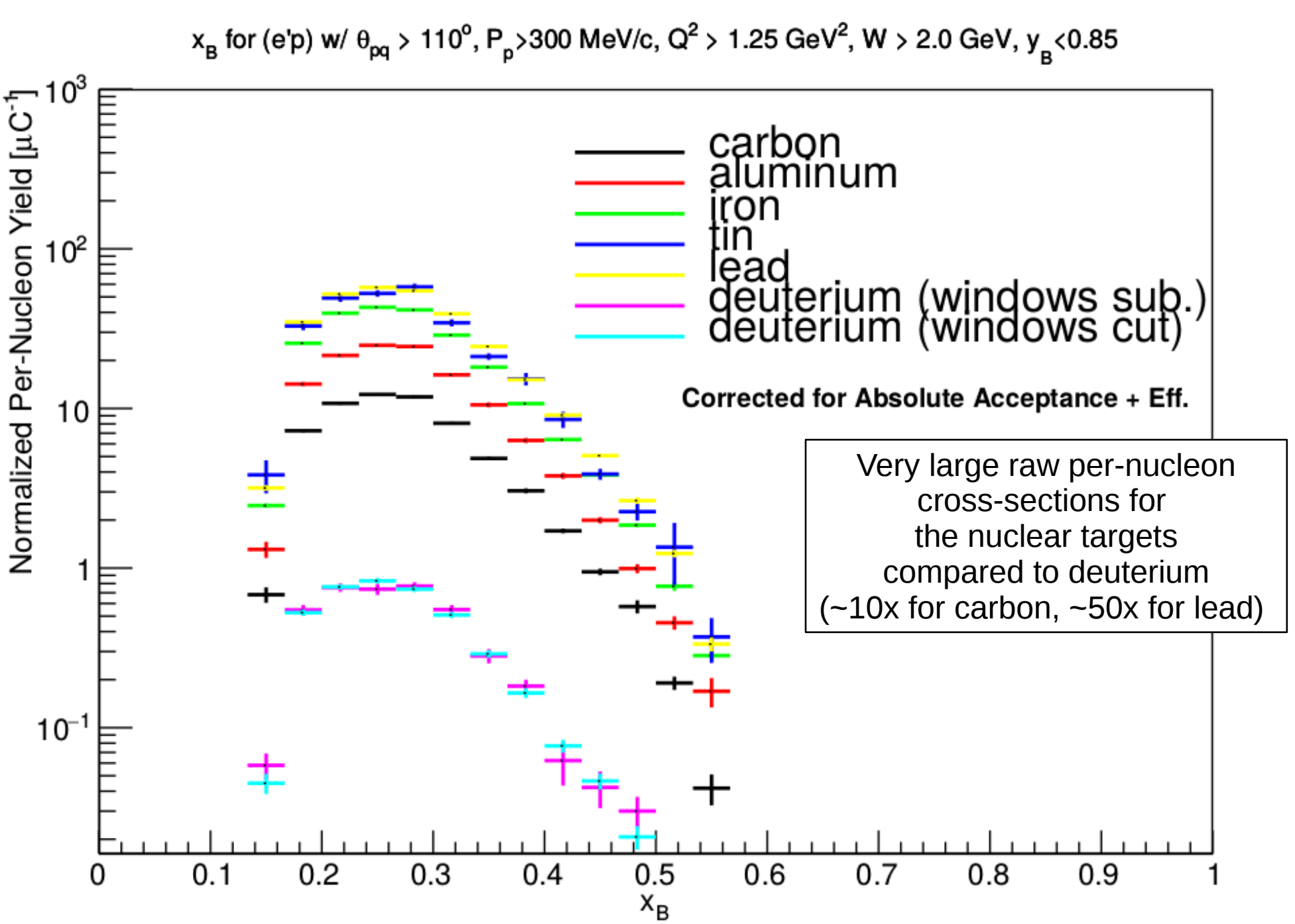

Number of Protons per Event: θpq > 110°, Pp>300 MeV/c, Q2 > 1.25 GeV2, W > 2.0 GeV, yB<0.85
Normalized Per-Nucleon Frequency [μC-1]
Multiplicity
carbon
aluminum
iron
tin
lead
deuterium (windows sub.)
deuterium (windows cut)
Select These Events
Yields shown here are normalized by beam-charge and live-time
Also corrected for target luminosity (Nucleons/cm2), relative to the deuterium target


Momentum for the proton with θ_{pq} > 110°, Q^2 > 1.25 GeV^2, W > 2.0 GeV, y_B<0.85
Normalized Per-Nucleon Yield [μC^{-1}]
Momentum [GeV/c]
carbon
aluminum
iron
tin
lead
deuterium (windows sub.)
deuterium (windows cut)
Corrected for Absolute Acceptance + Eff.
Very large raw per-nucleon cross-sections for the nuclear targets compared to deuterium (~10x for carbon, ~50x for lead)



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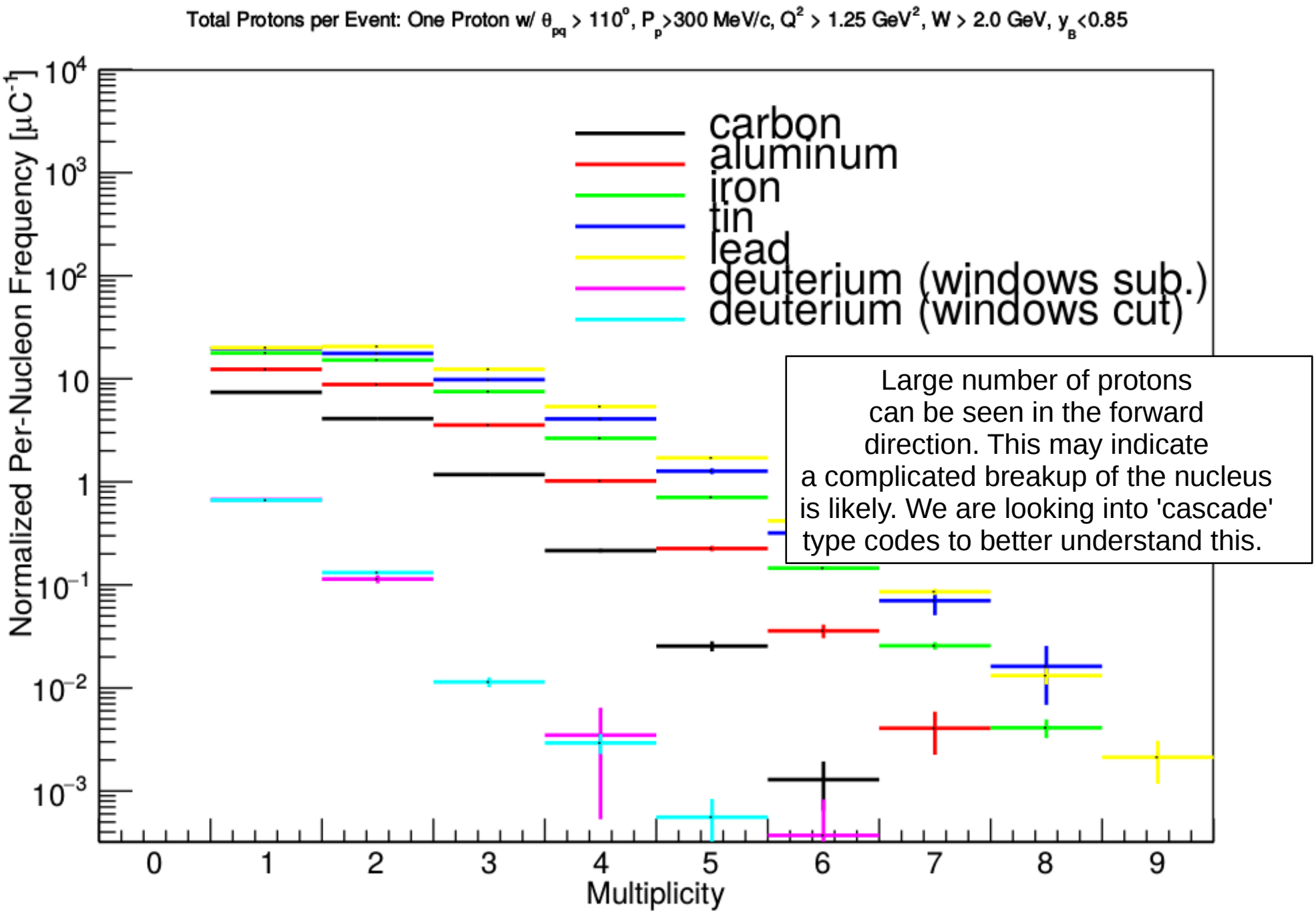
Total Protons per Event: One Proton w/ θpq > 110°, Pp>300 MeV/c, Q² > 1.25 GeV², W > 2.0 GeV, yB<0.85
Normalized Per-Nucleon Frequency [μC⁻¹]
Multiplicity
carbon
aluminum
iron
tin
lead
deuterium (windows sub.)
deuterium (windows cut)
Large number of protons can be seen in the forward direction. This may indicate a complicated breakup of the nucleus is likely. We are looking into 'cascade' type codes to better understand this.

Summary

- We have empirical results comparing the nuclear targets to deuterium when selecting a spectator proton.
- We are working with a monte-carlo code to compare the deuterium spectra to those from plane-wave calculations.
- Lastly, we are working with a 'cascade' monte-carlo to better understand our tagged DIS results.