SRC Pairs at Low x_B

Andrew Denniston
MIT
January 22th , 2020

Agenda

- GCF on Inclusive Data
- SRC Measurements at the EIC
- Semi-Inclusive Measurements
  - Contributions to the Cross Section
  - Low x_B
  - Missing Momentum

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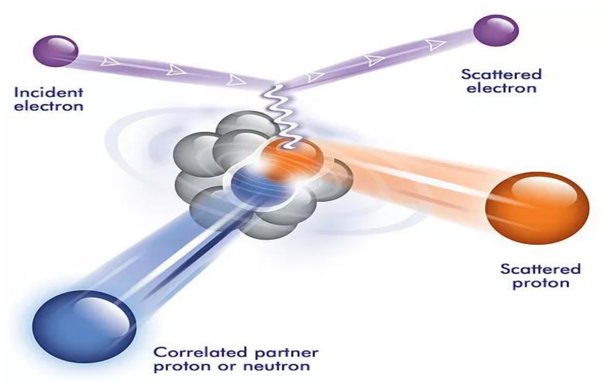
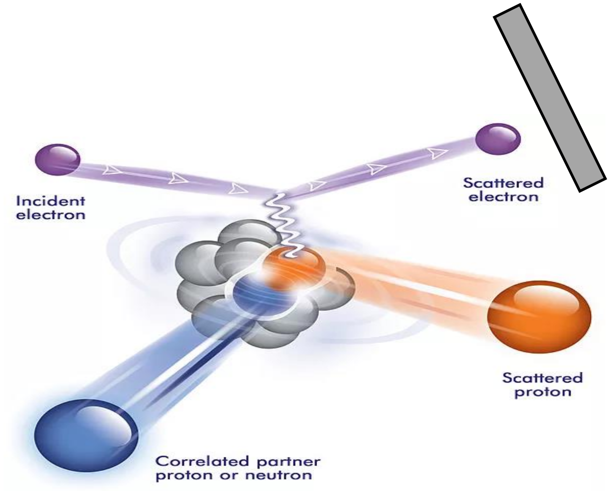
SRC Measurements



SRC Measurements



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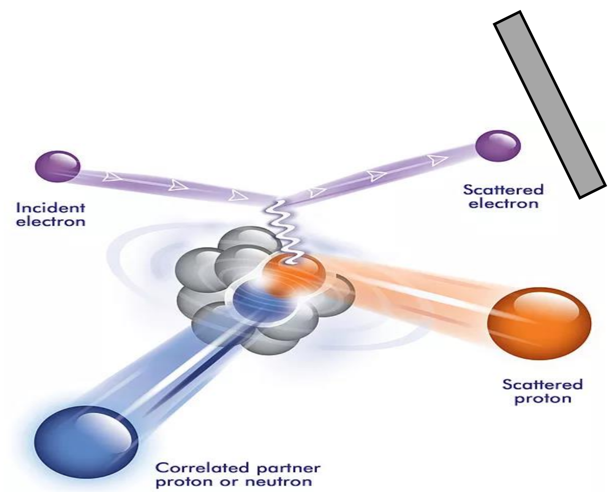
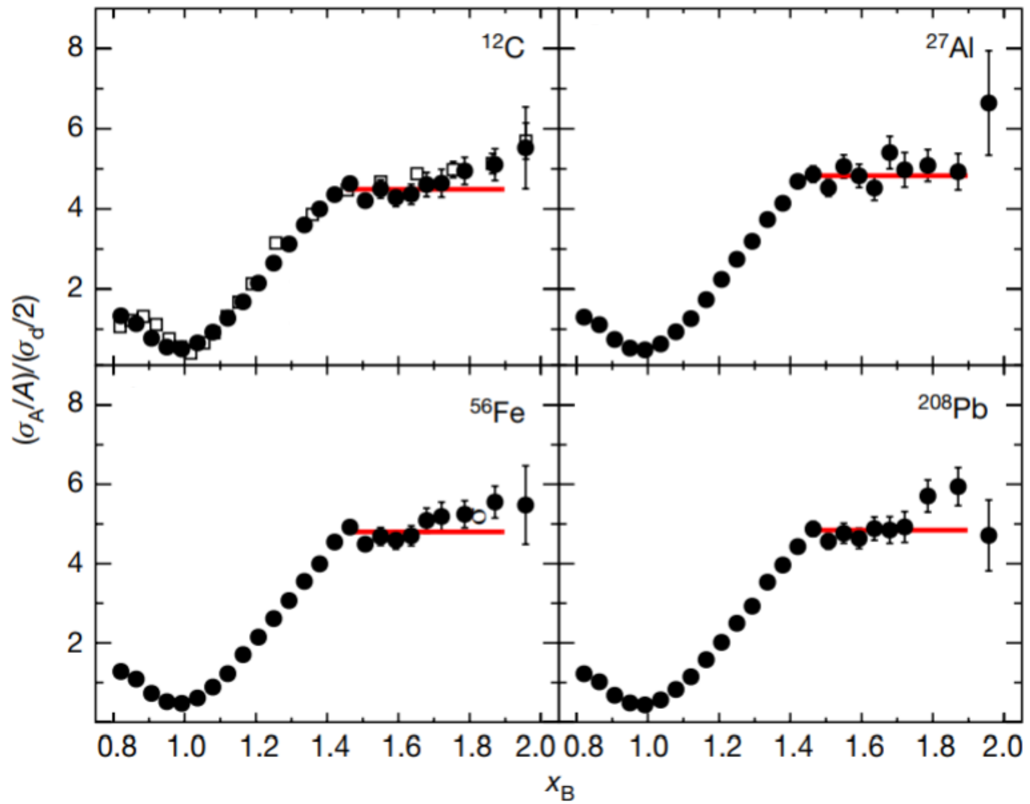
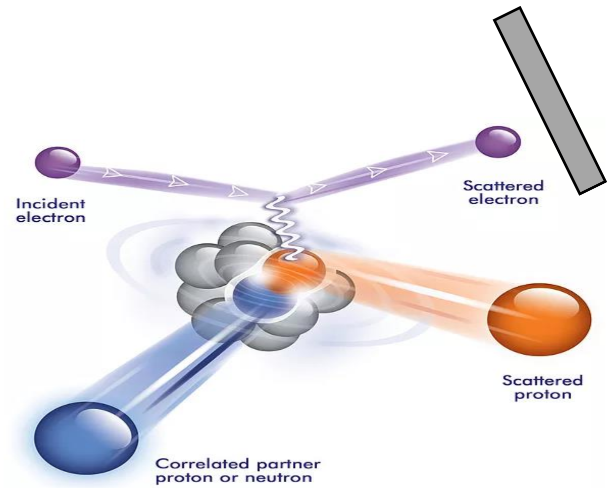


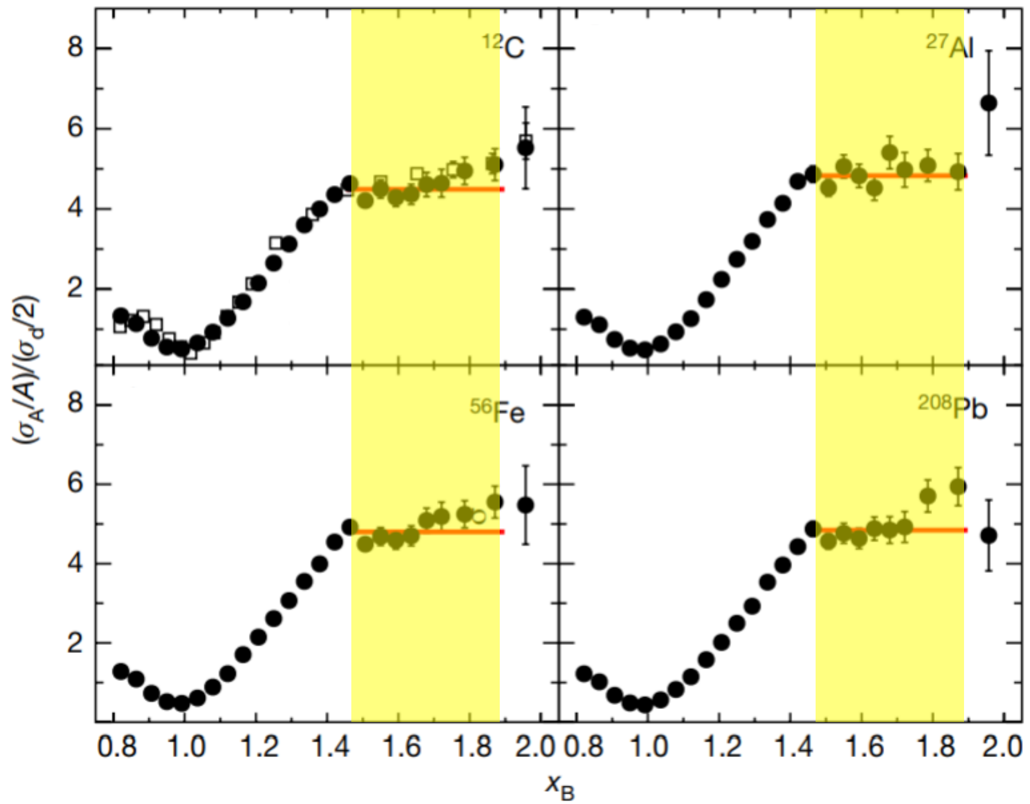


- Schmookler Nature **566**, 354-358 (2019)

$$x_B = \frac{Q^2}{2\nu m_N}$$

SRC Measurements





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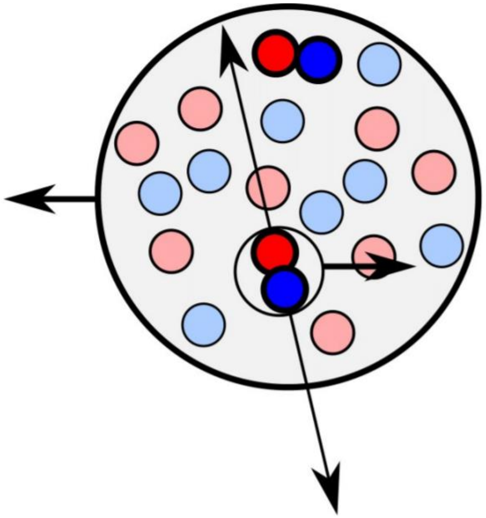
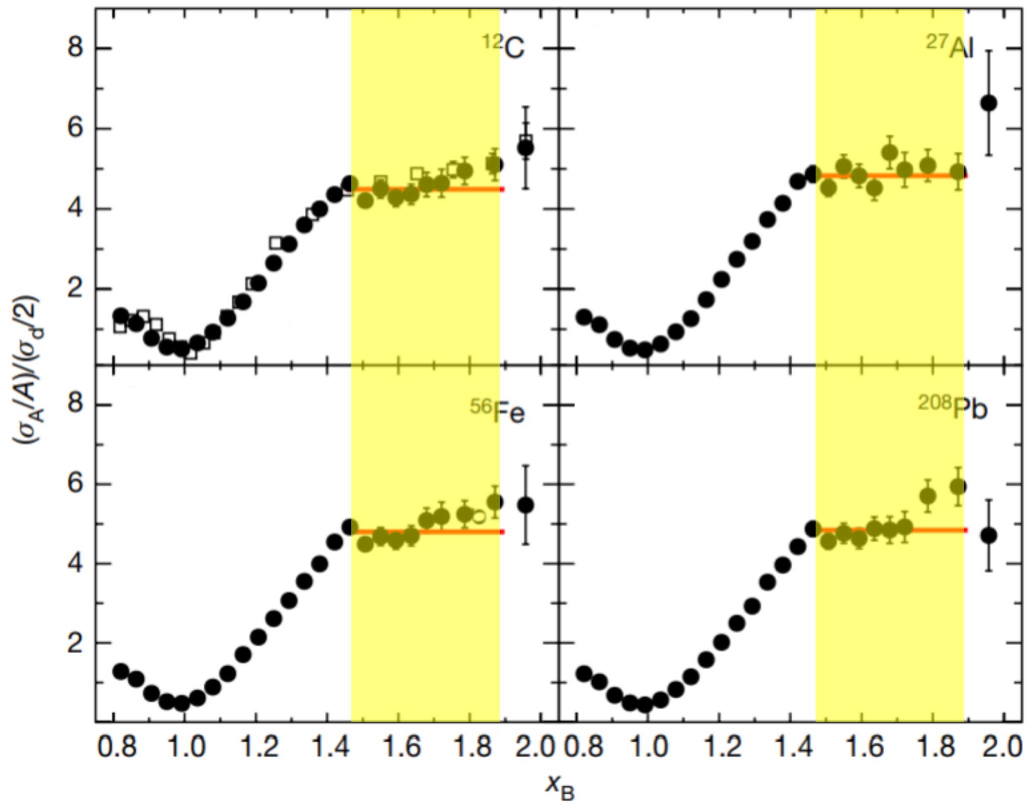
$$x_B = \frac{Q^2}{2\nu m_N}$$

Analyzing (e,e’)





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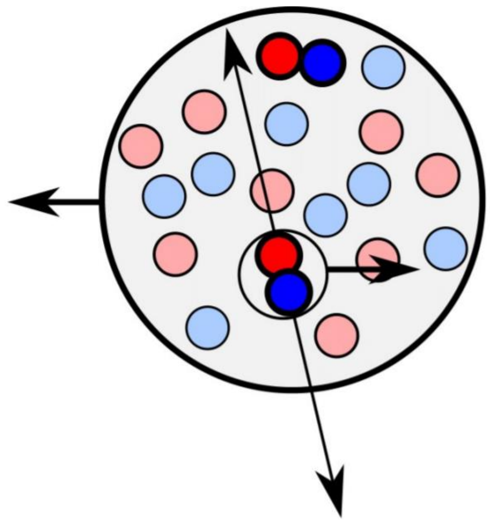
$$x_B = \frac{Q^2}{2\nu m_N}$$

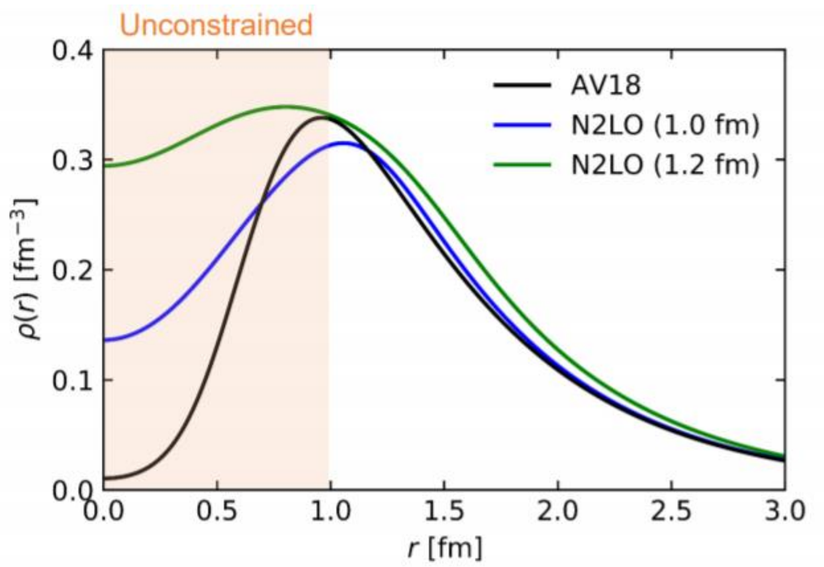
Analyzing (e,e') with GCF



Input to GCF

- Potential (e.g. AV18)
- Center of Mass Motion of the Pair: σ_{CM}
- Contacts
- Excitation Energy of Recoil Nucleus: E^*

Analyzing (e,e’) with GCF



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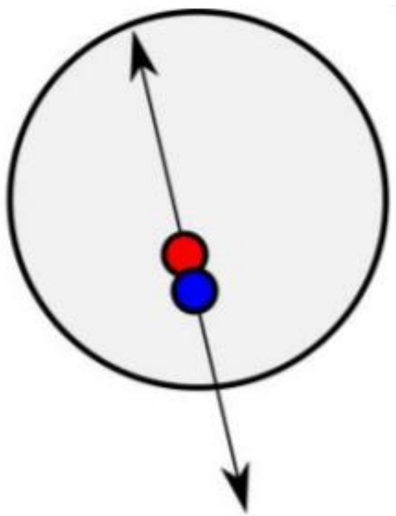

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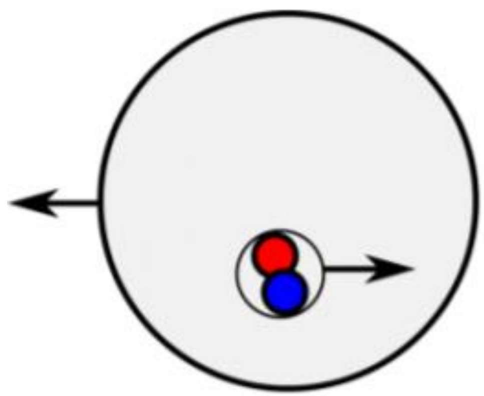

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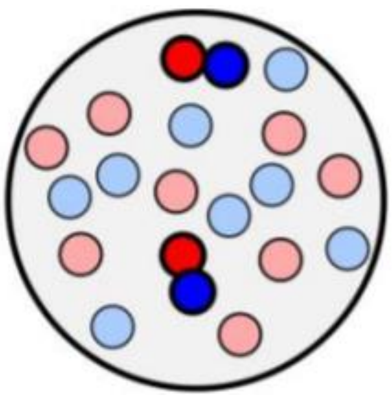

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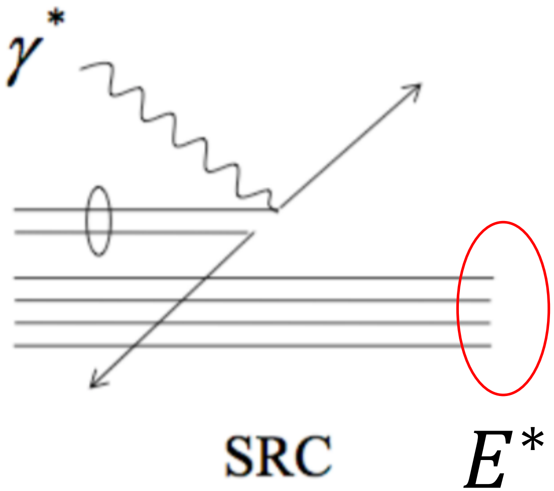
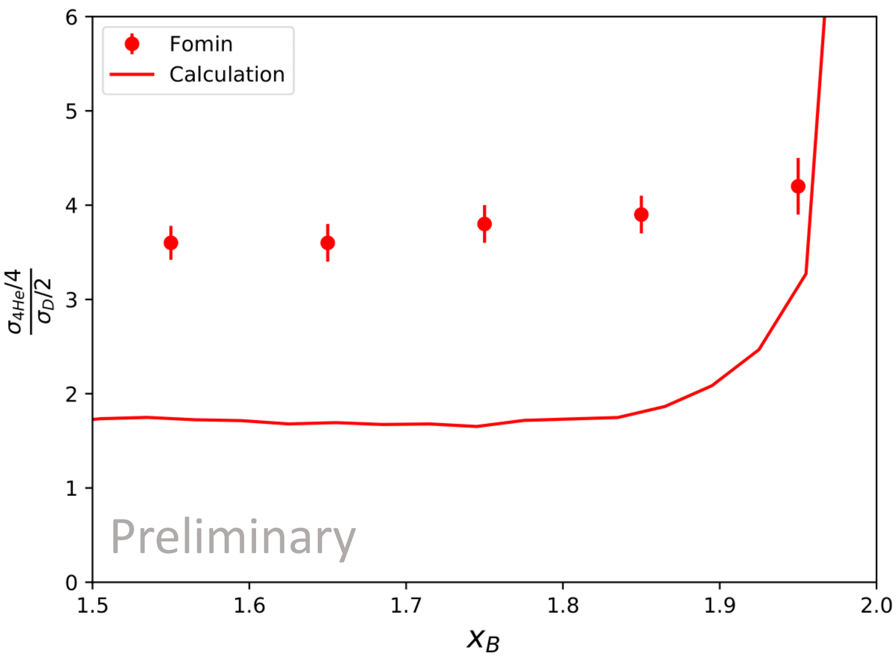


<u>Input to GCF</u>

- Potential (e.g. AV18)
- Center of Mass Motion of the Pair: σ_{CM}
- Contacts
- Excitation Energy of Recoil Nucleus: E^*

Calculating a_2 with GCF

$(e,e') \quad \theta_e = 18^{\circ}$

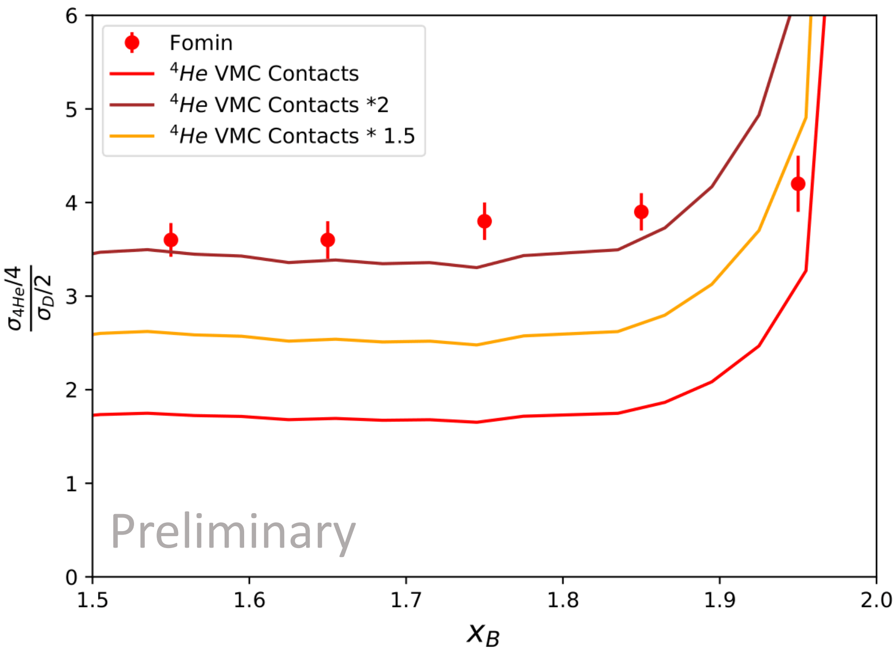


<u>Input to GCF</u>

- Potential = AV18
- $\sigma_{CM} = 100$ MeV
- VMC Contacts
- $E^* = 20MeV$

Contacts Effect a_2

$(e,e') \quad \theta_e = 18^{\circ}$

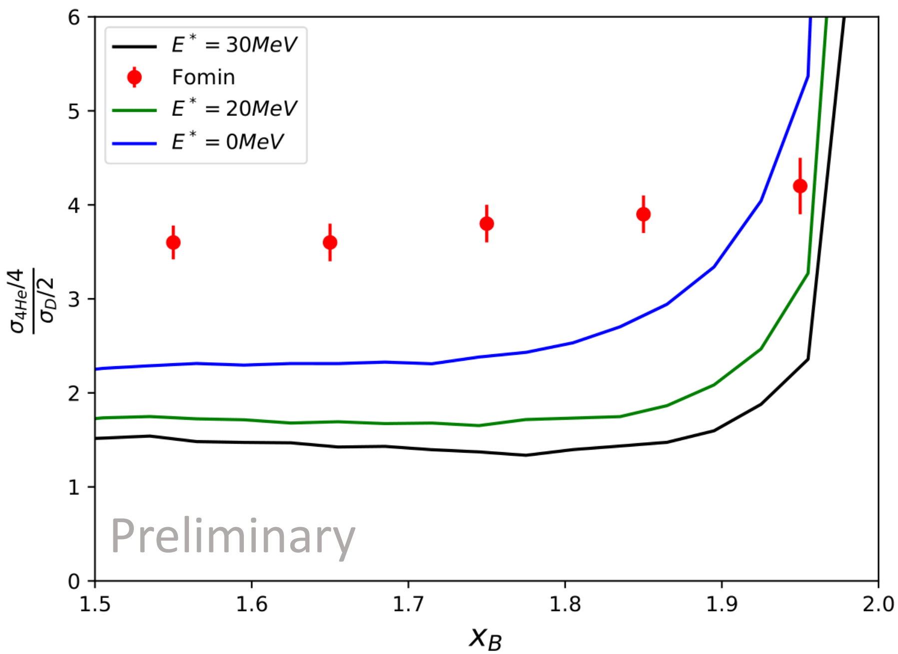


<u>Input to GCF</u>

- Potential = AV18
- $\sigma_{CM} = 100$ MeV
- **Various $^4\boldsymbol{He}$ Contacts**
- $E^* = 20MeV$

Kinematics Effect a_2

$(e,e') \quad \theta_e = 18^{\circ}$

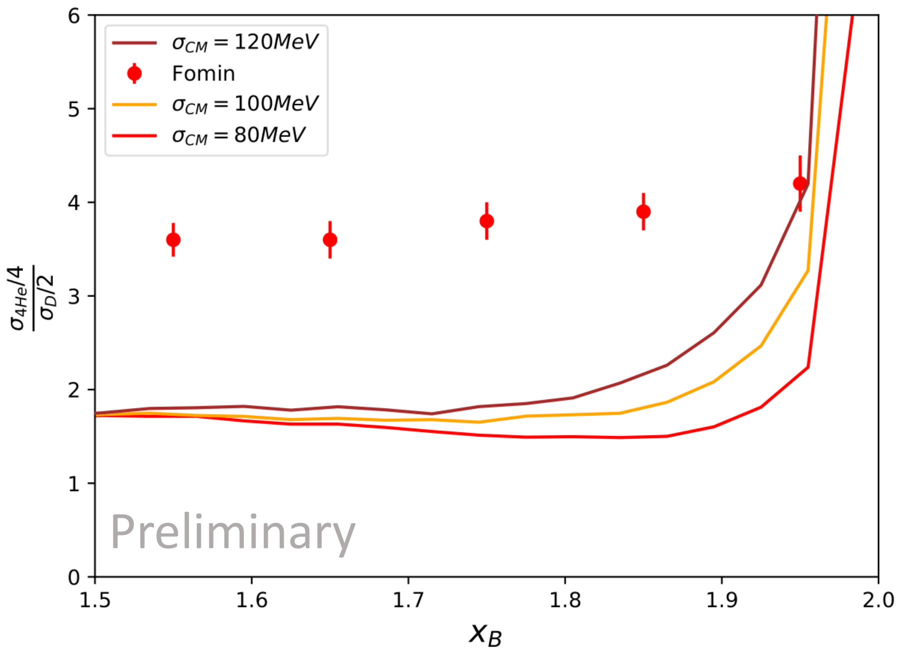


<u>Input to GCF</u>

- Potential = AV18
- $\sigma_{CM} = 100 \text{ MeV}$
- VMC Contacts
- $\boldsymbol{E^* = 0MeV, 20MeV, 30MeV}$

Kinematics Effect a_2

$(e, e') \quad \theta_e = 18^\circ$

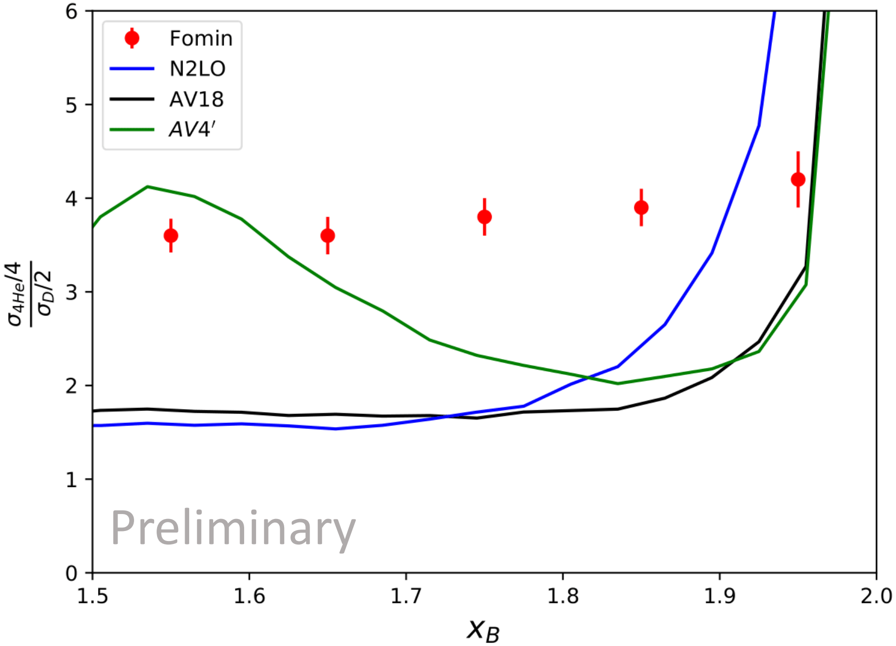


<u>Input to GCF</u>

- Potential = AV18
- $\boldsymbol{\sigma_{CM} = 80\mathrm{MeV}}$, $\mathbf{100\ MeV}$, $\mathbf{120MeV}$
- VMC Contacts
- $E^* = 20MeV$

Potential Effects a_2

$(e, e') \quad \theta_e = 18^{\circ}$

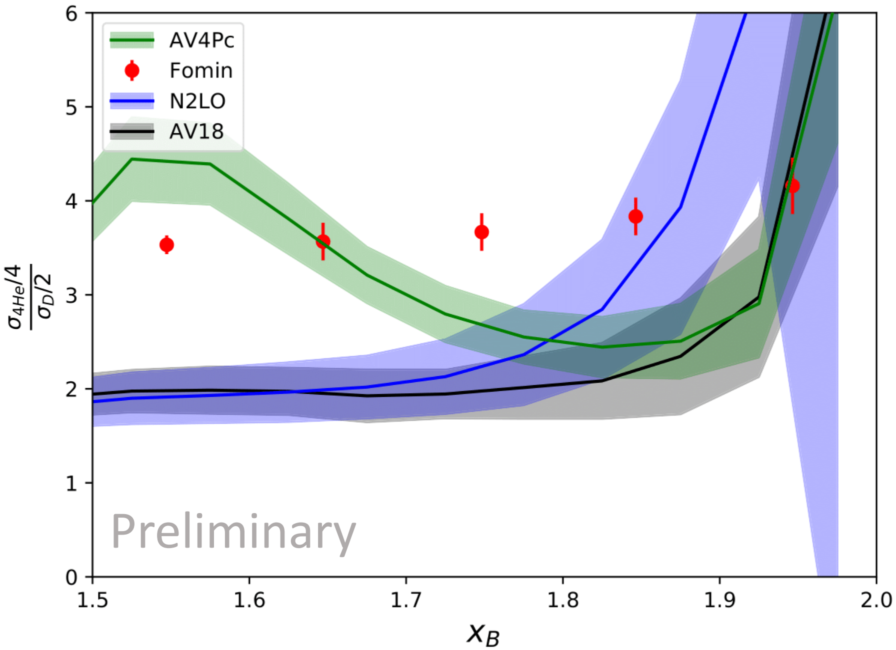


Input to GCF

- Potential = AV18,N2LO,AV4'
- $\sigma_{CM} = 100$ MeV
- VMC Contacts
- $E^* = 20MeV$

a_2 with GCF

$(e, e') \quad \theta_e = 18^{\circ}$



<u>Input to GCF</u>

- Potential = AV18,N2LO,AV4’
- $\sigma_{CM} = 100 \pm 20 MeV$
- VMC Contacts with Uncertainties
- $0 MeV < E^* < 20 MeV$

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- Semi-Inclusive Measurements
  - Contributions to the Cross Section
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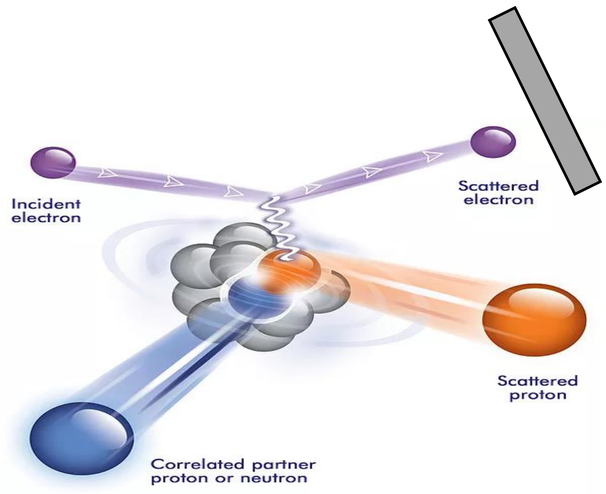
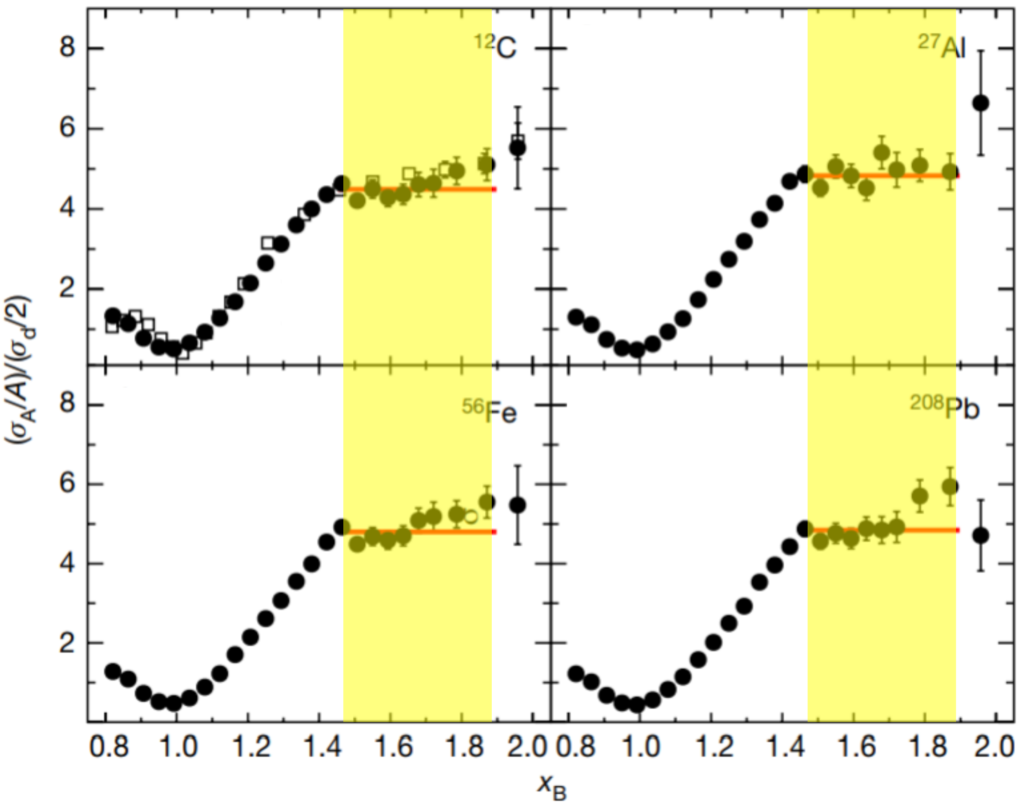
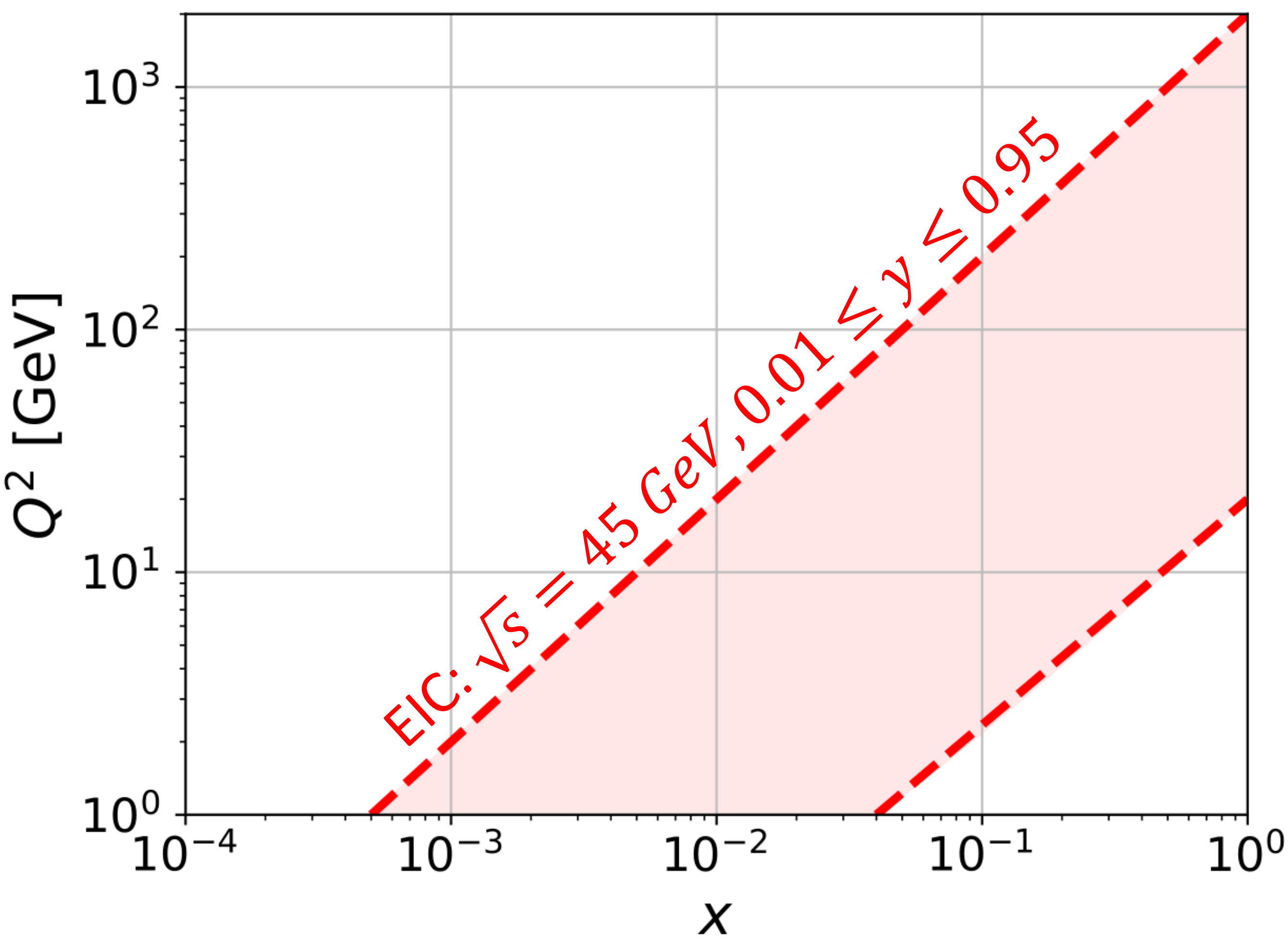
Looking for SRCs at EIC





EIC Kinematic Range



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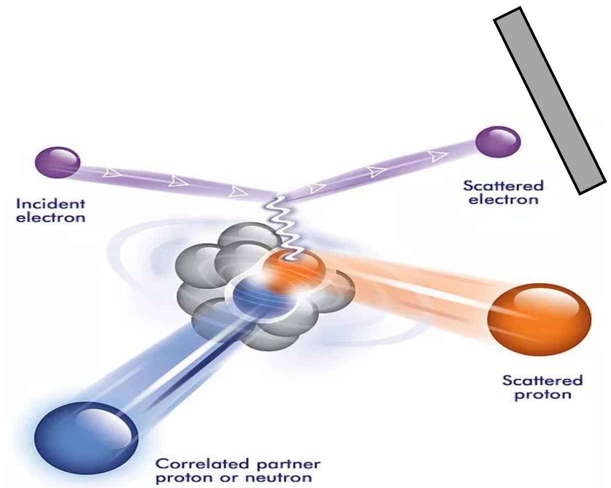

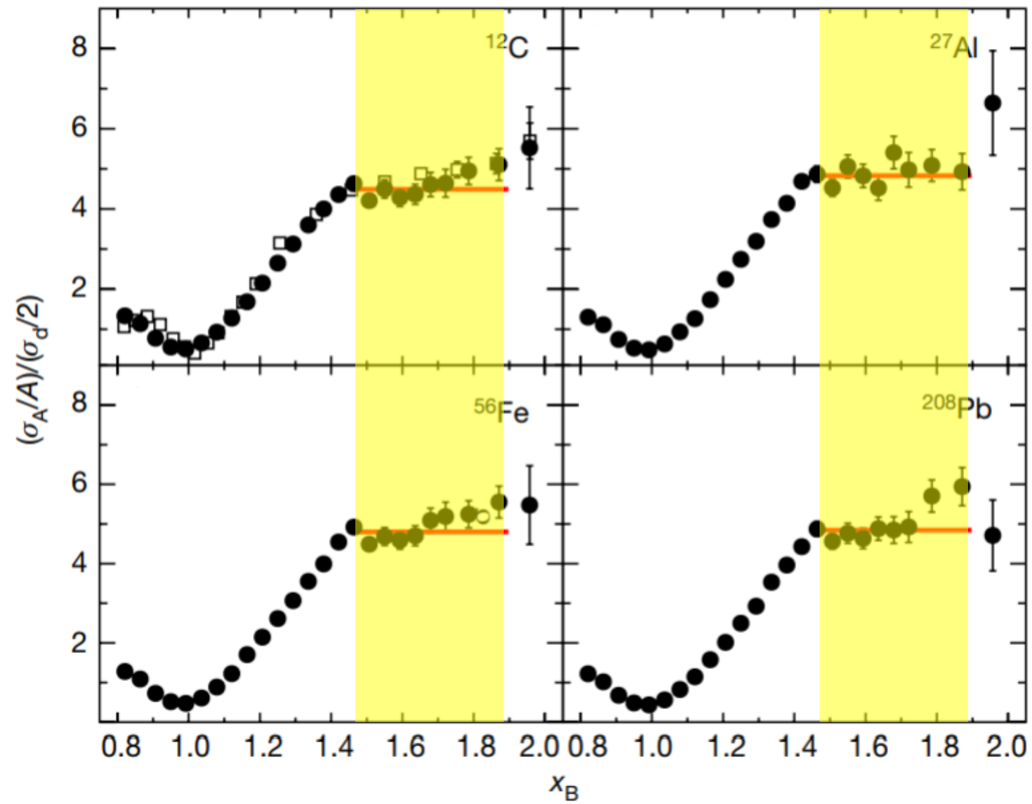

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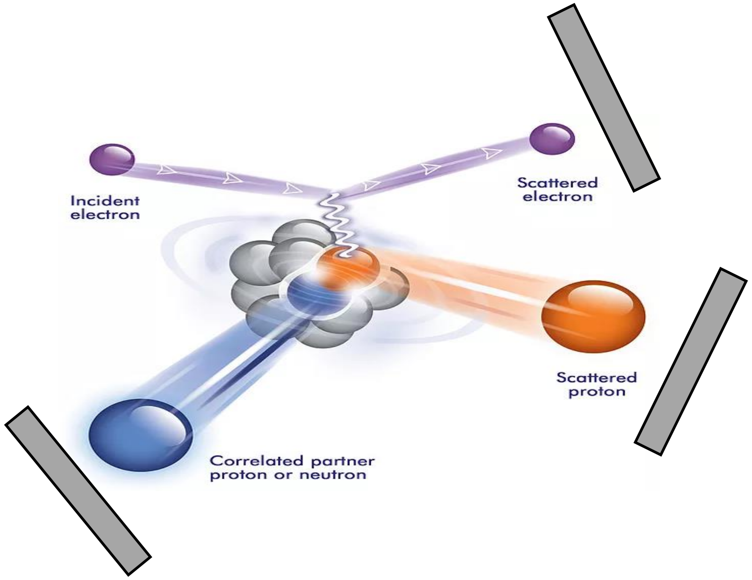

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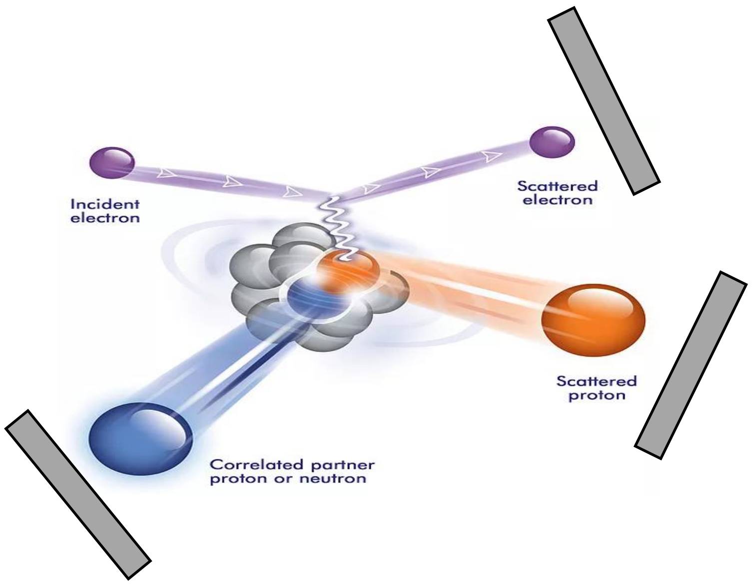

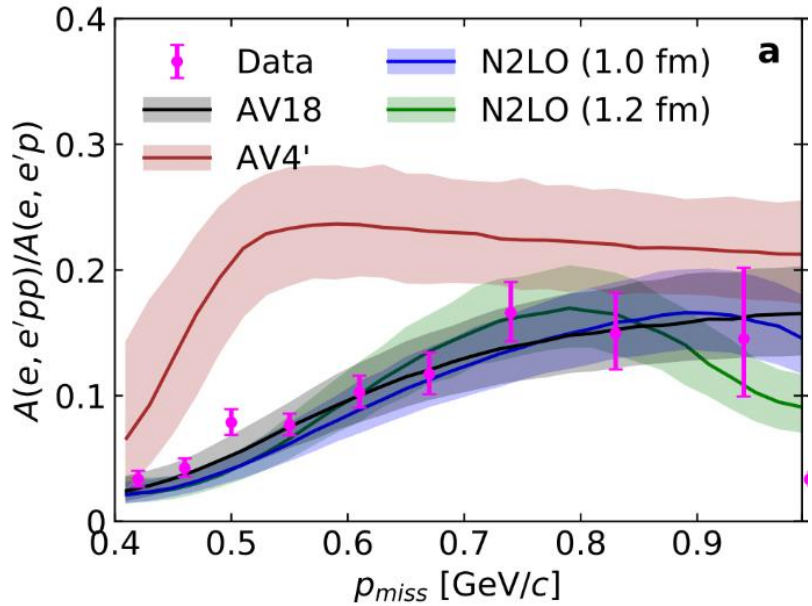

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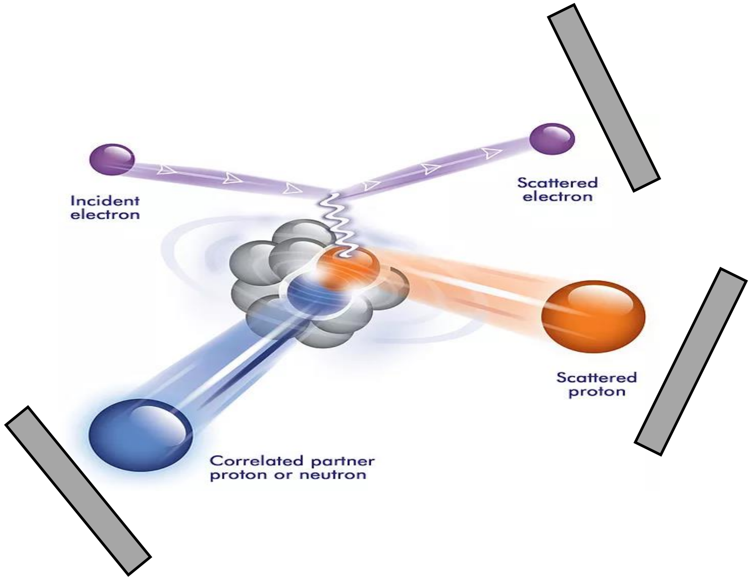
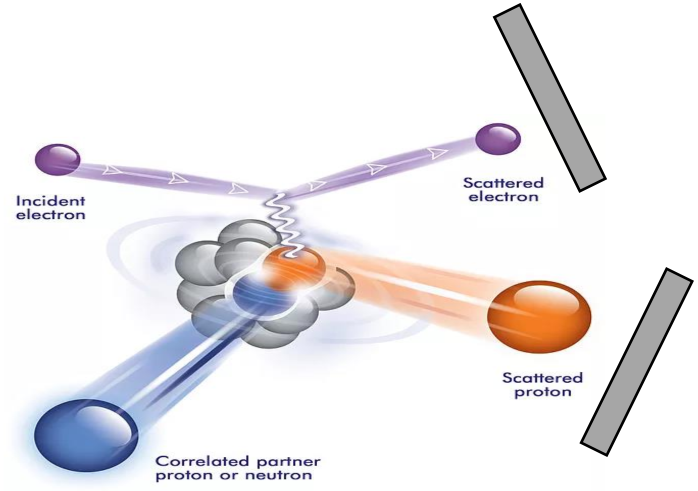


- Detect 3 coincidence particles
- Need to detect neutron for $(e, e'pn)$
- $(e, e'pp)$ events are more rare

SRC Measurements



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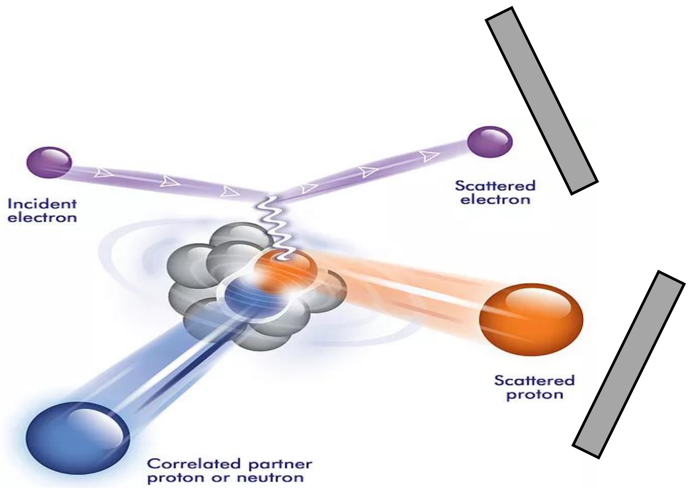
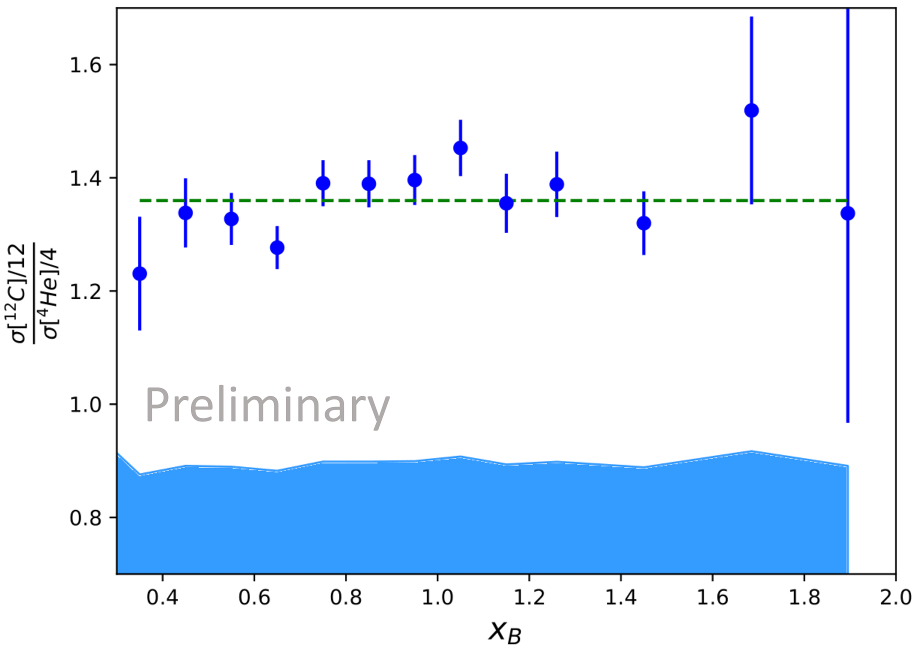
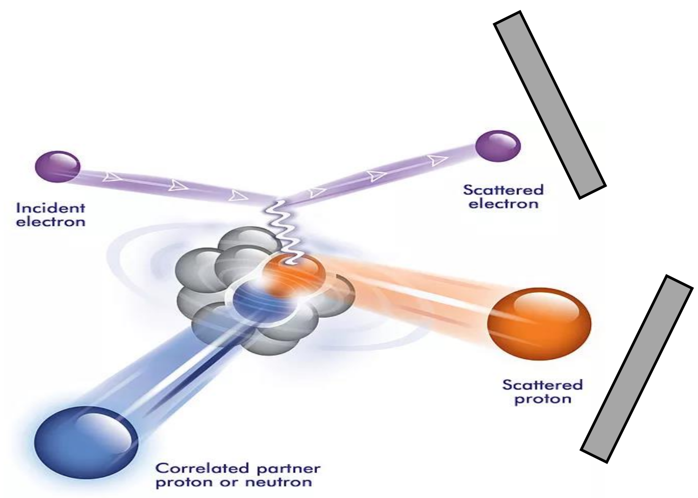


$(e, e'p)$



$$x_B = \frac{Q^2}{2\nu m_N}$$

Looking for SRCs at EIC



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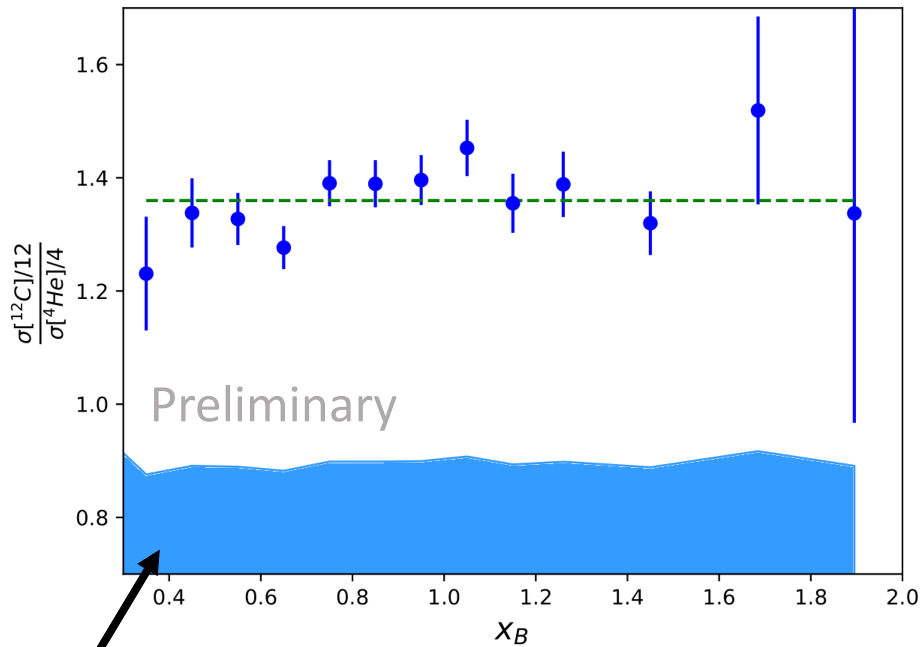
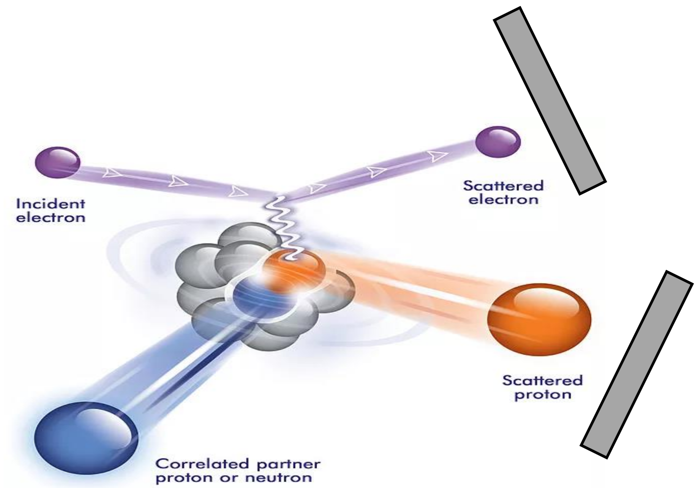


Systematic Uncertainty:
- Helium Target Density
- Nuclear Transparency

Looking for SRCs at EIC



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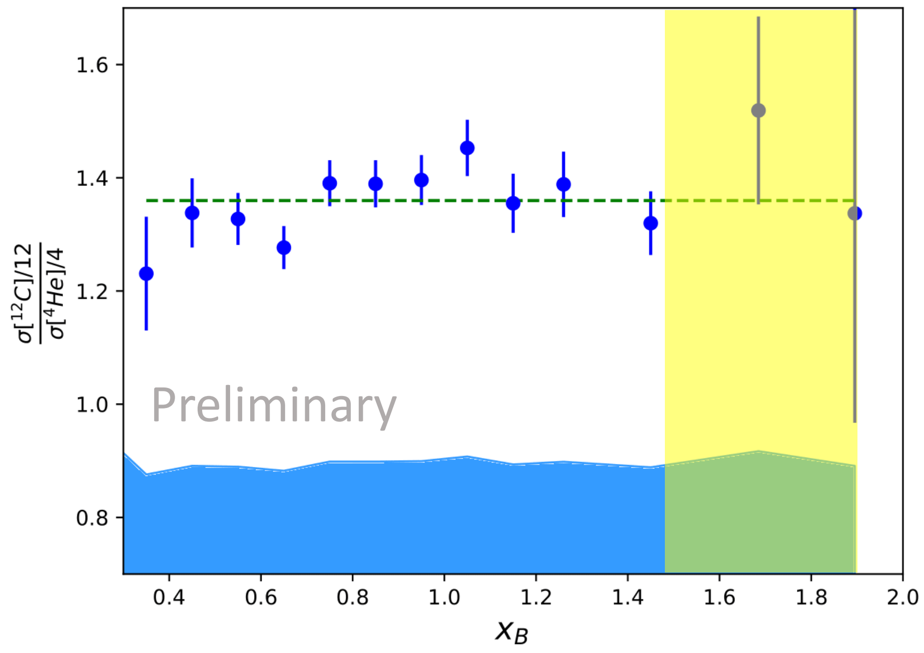

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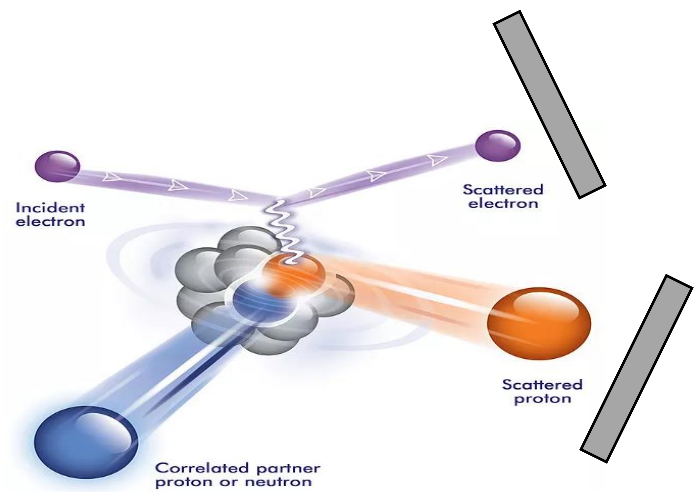

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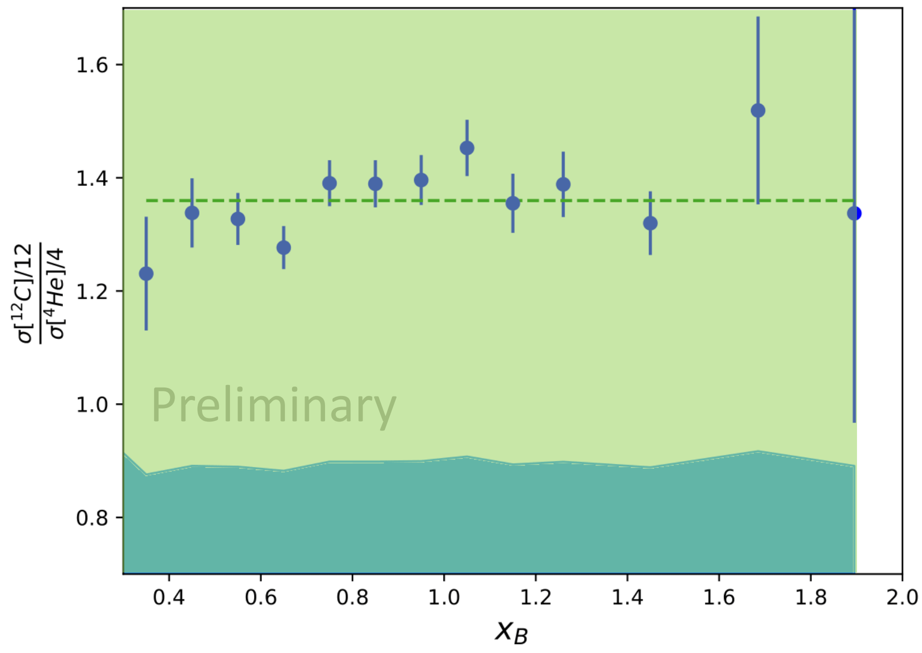
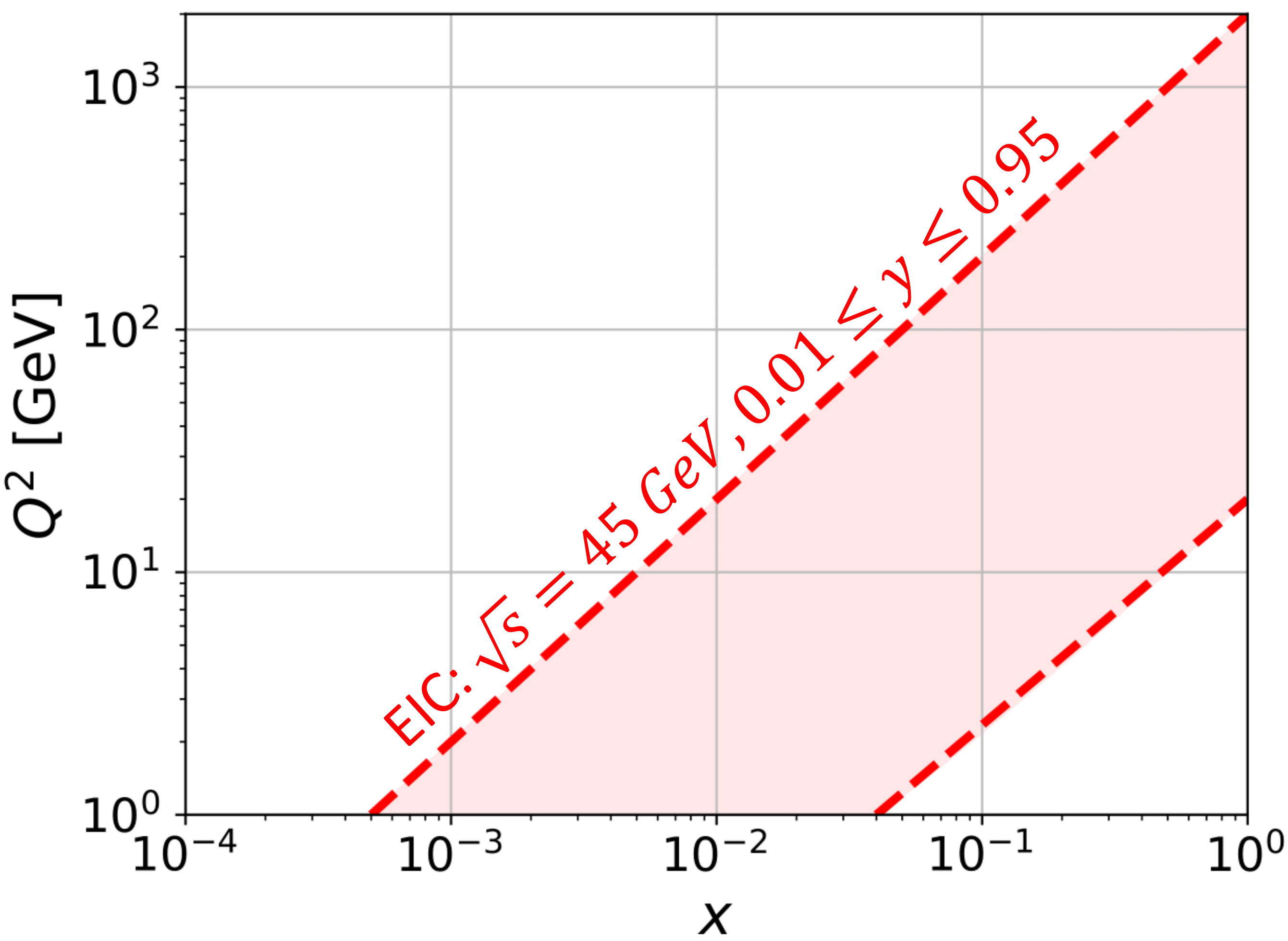


EIC Kinematic Range



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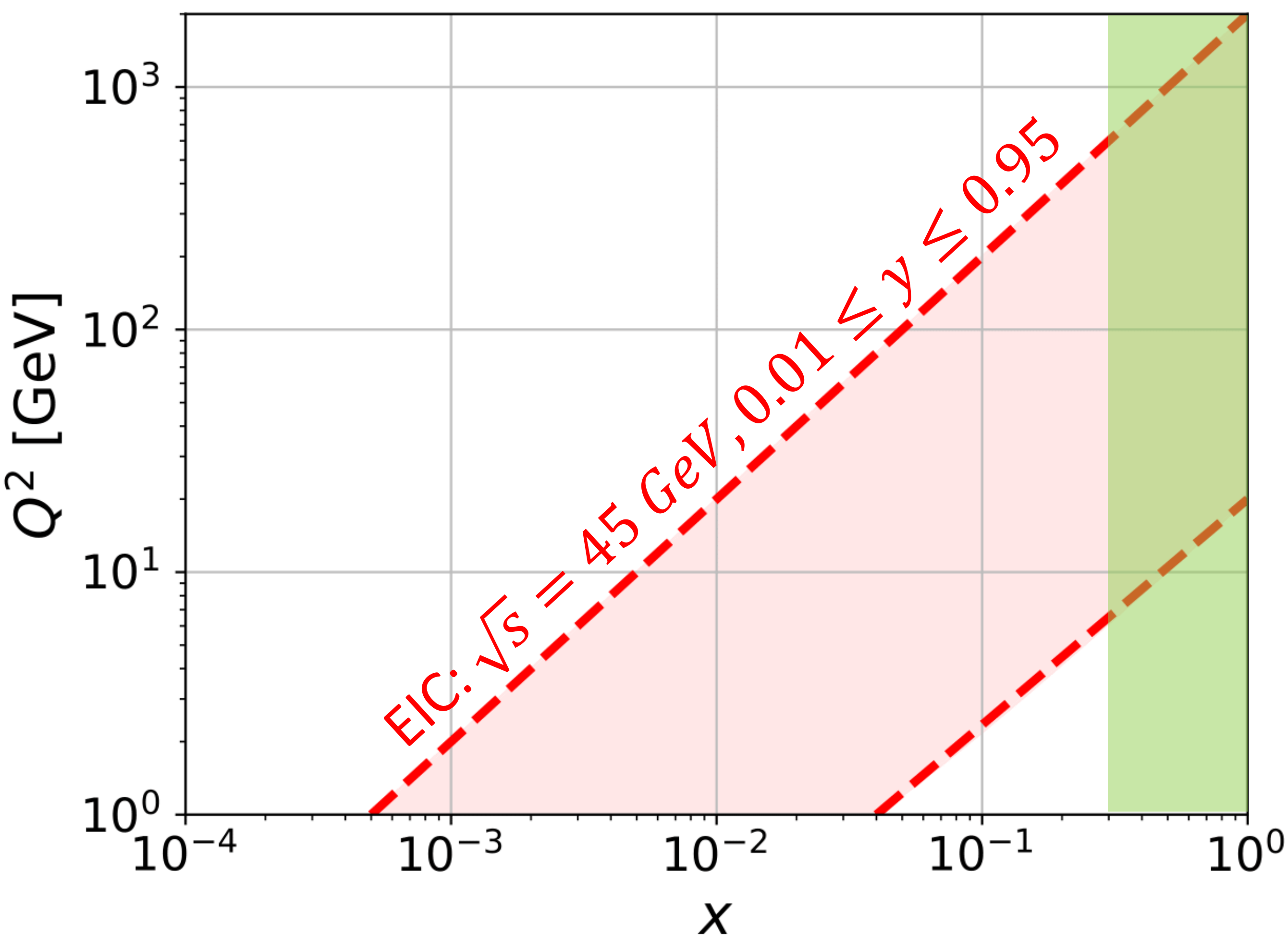

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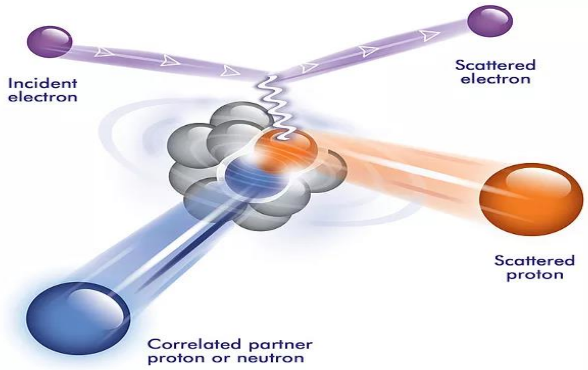
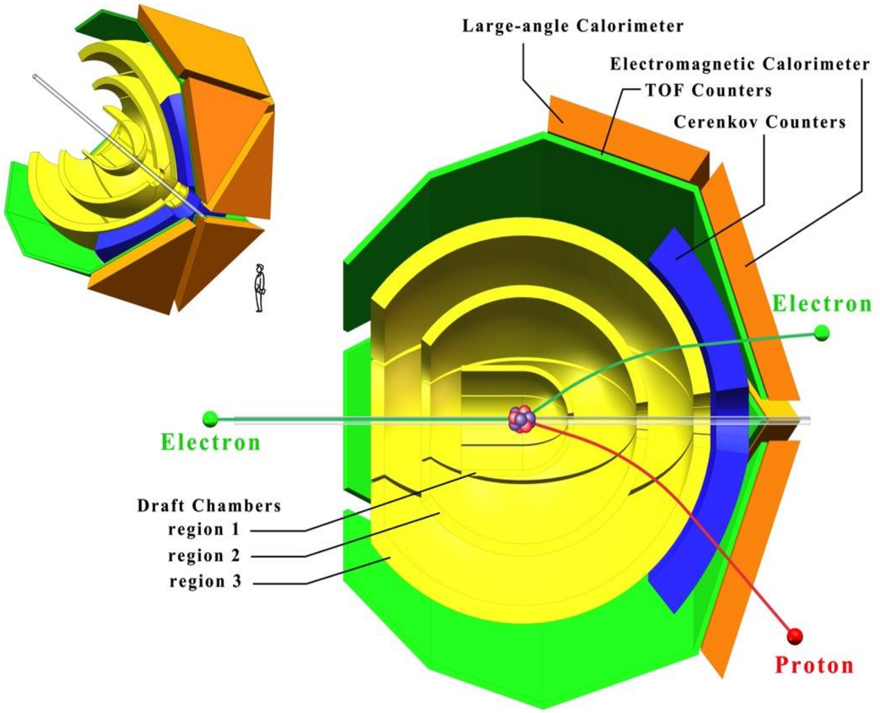
  - Low x_B
  - Missing Momentum

This Analysis

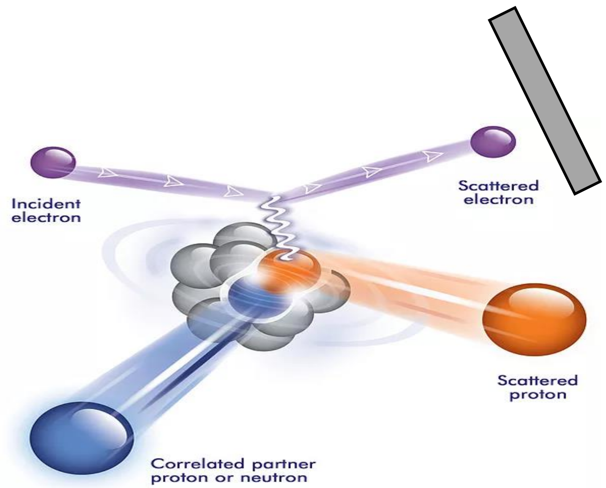
CLAS e2a

- $E_{beam} = 4.461\ GeV$
- Targets: $^{3}He, ^{4}He, ^{12}C$

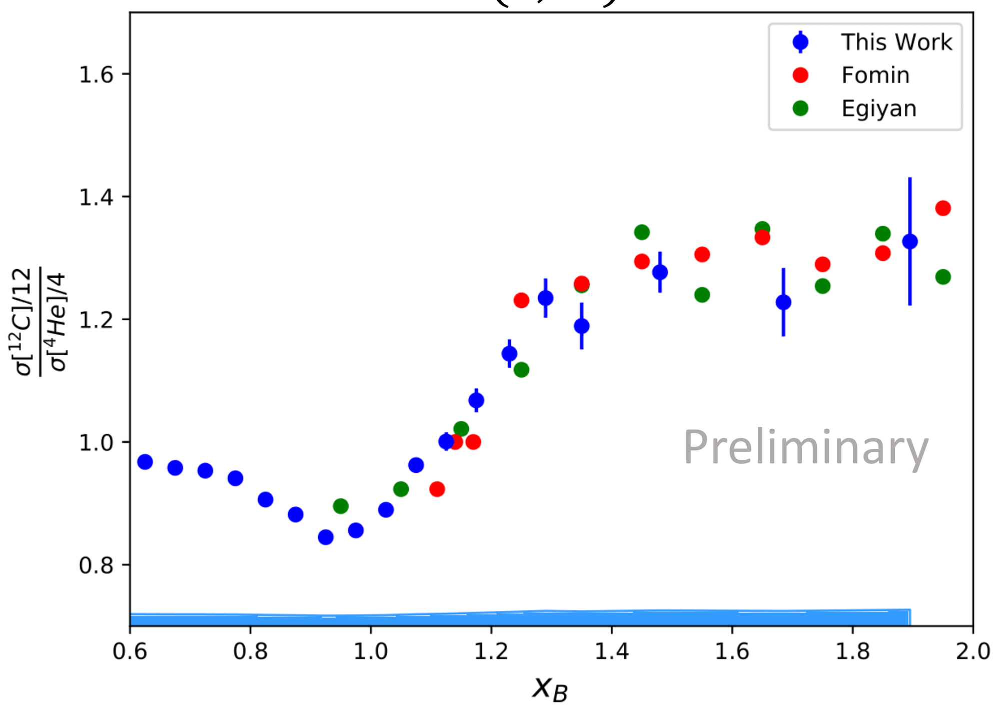




Inclusive Analysis



(e, e')



- Fomin et al. Phys. Rev. Lett. **108**, 092502 (2012)
- Egiyan et al. Phys. Rev. Lett. **96**, 082501 (2006)

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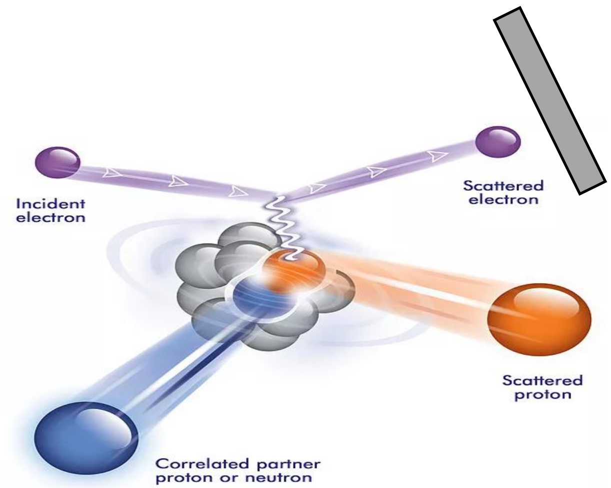

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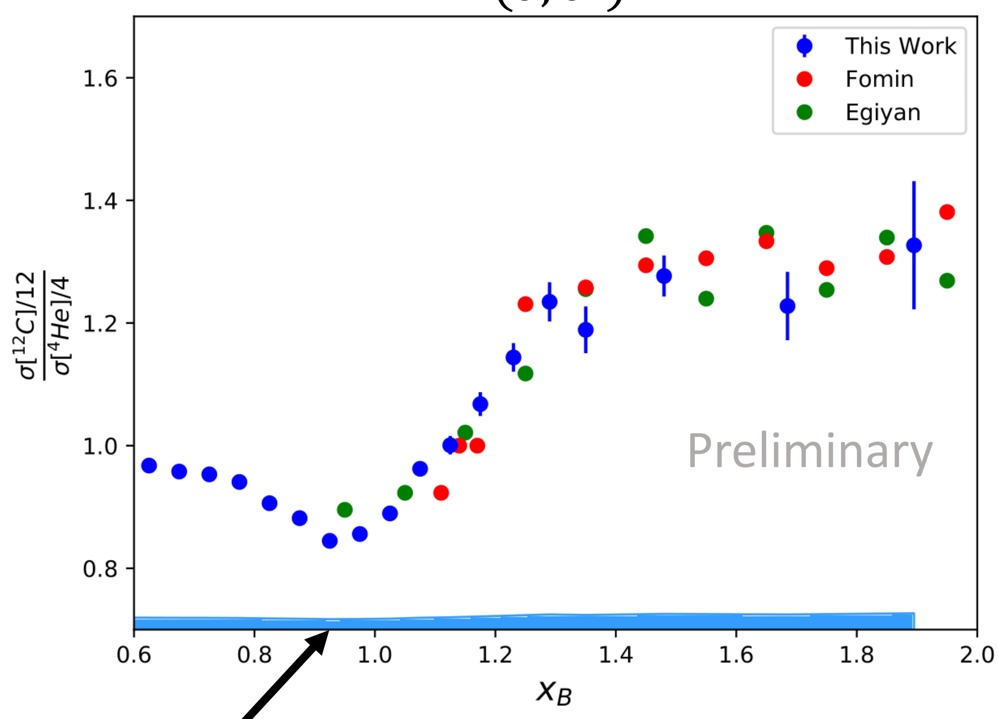
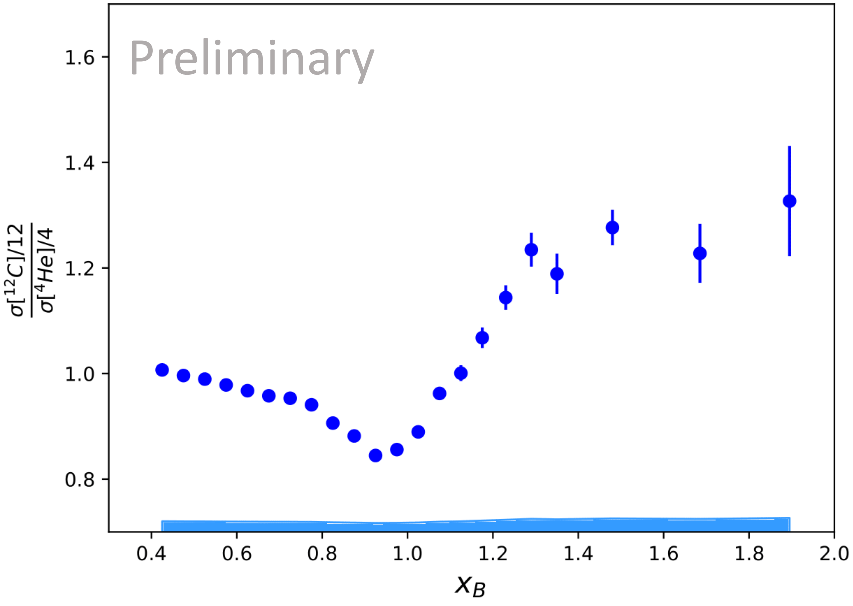


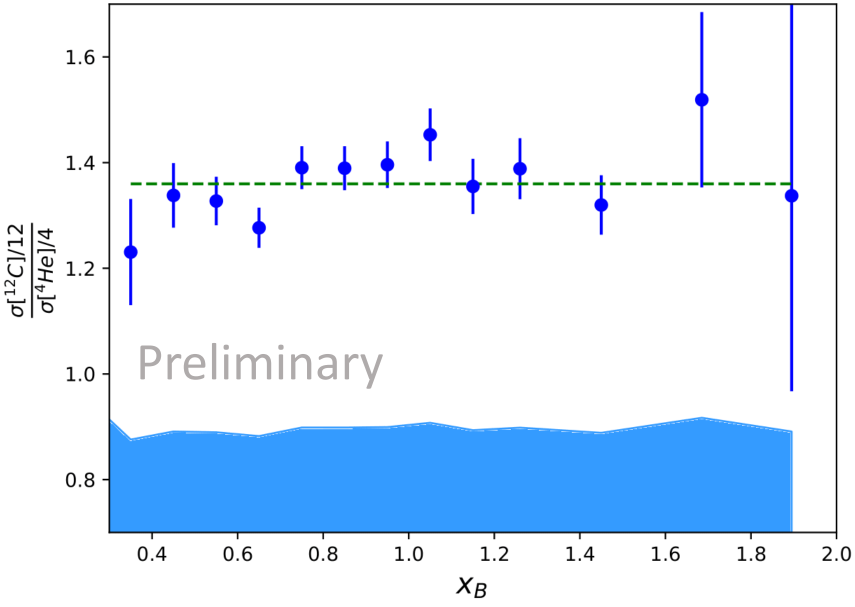
Systematic Uncertainty:
- Helium Target Density

Inclusive to Semi-inclusive

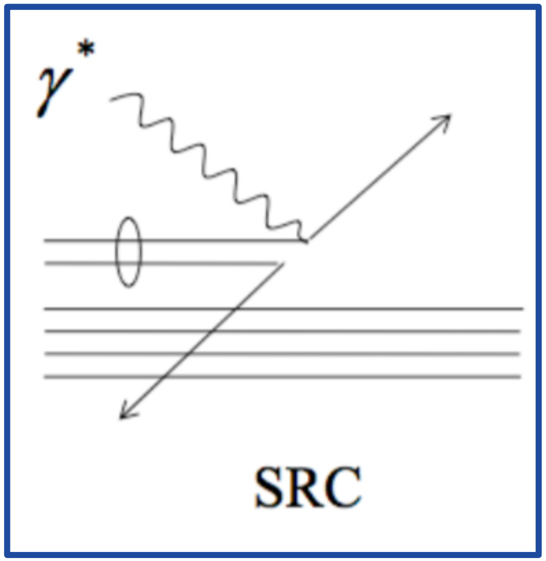
(e, e')



$(e, e'p)$



Contributions to the Cross Section



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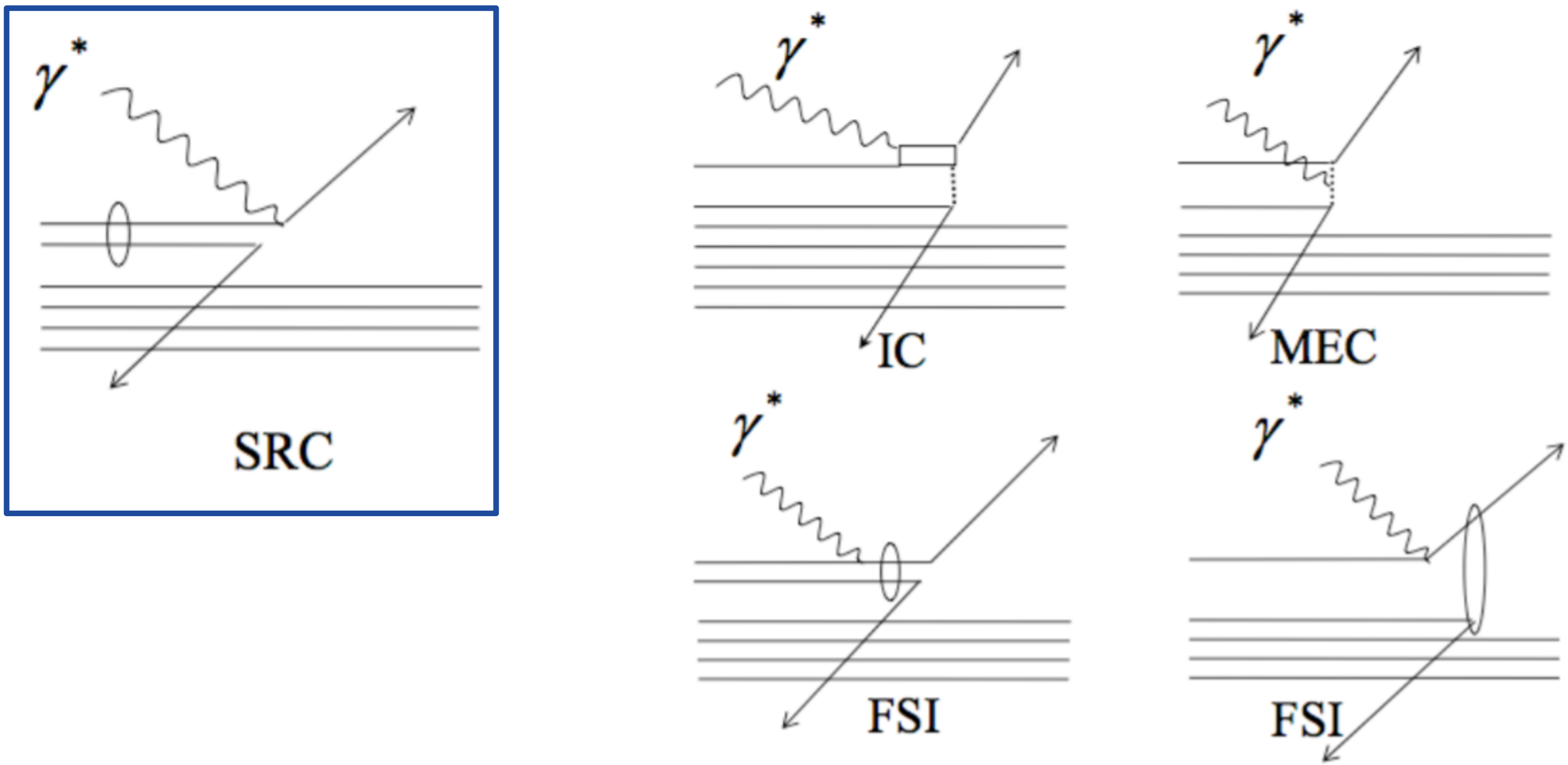

- Frankfurt, Sargsian, and Strikman PRC **56**, 1124 (1997)
- Colle, Cosyn, and Ryckebusch, PRC **93**, 034608 (2016)

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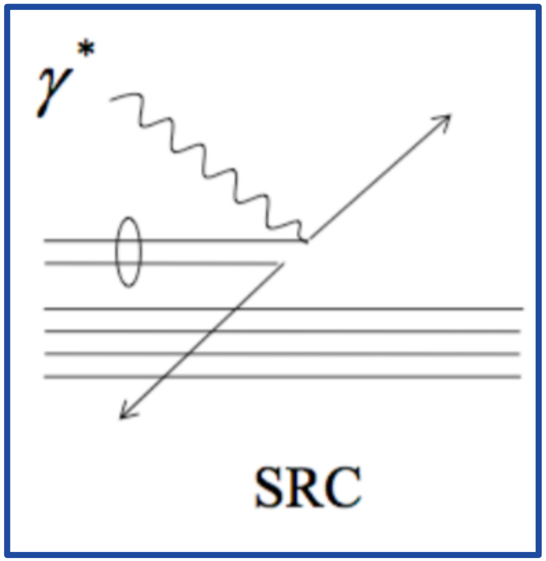

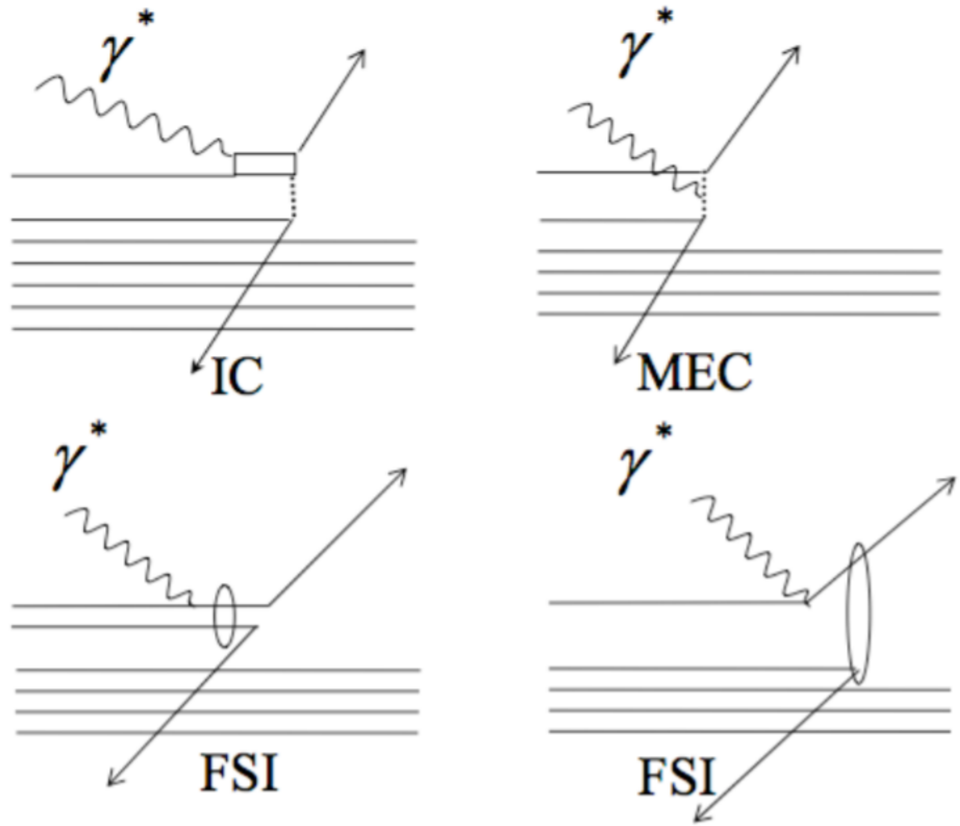

1. $1.2 < x_B < 2$
2. $0.62 < \frac{p}{q} < 0.96$
3. $\theta_{pq} < 25^\circ$
4. $0.9\ GeV < m_{Miss} < 1.1\ GeV$
5. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

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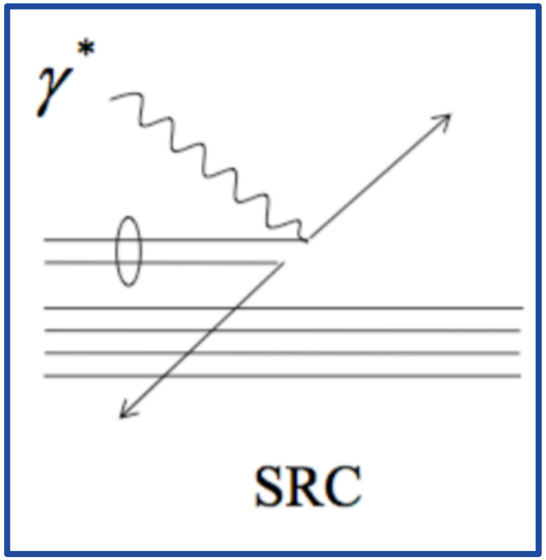

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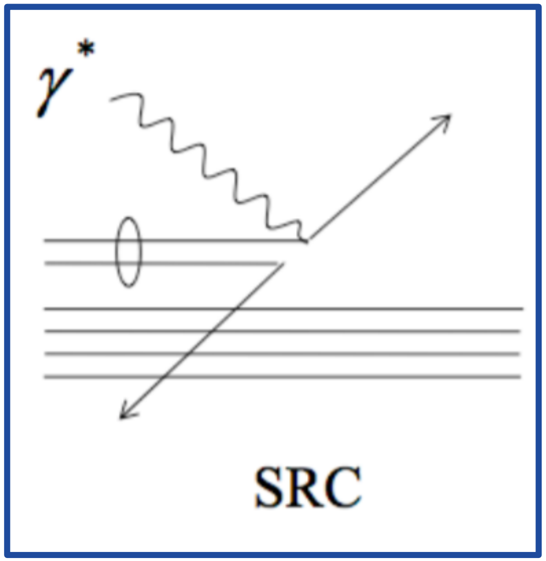
- Physics Letters B 722 (2013) 63–68
- Science 346, 614 (2014)
- Nature 560, 617–621 (2018)
- Physics Letters B 797 (2019) 134792
- Cohen et al. Phys. Rev. Lett. 121, 092501 2018
- Duer et al. Phys. Rev. Lett. 122, 172502 2019

Contributions to the Cross Section



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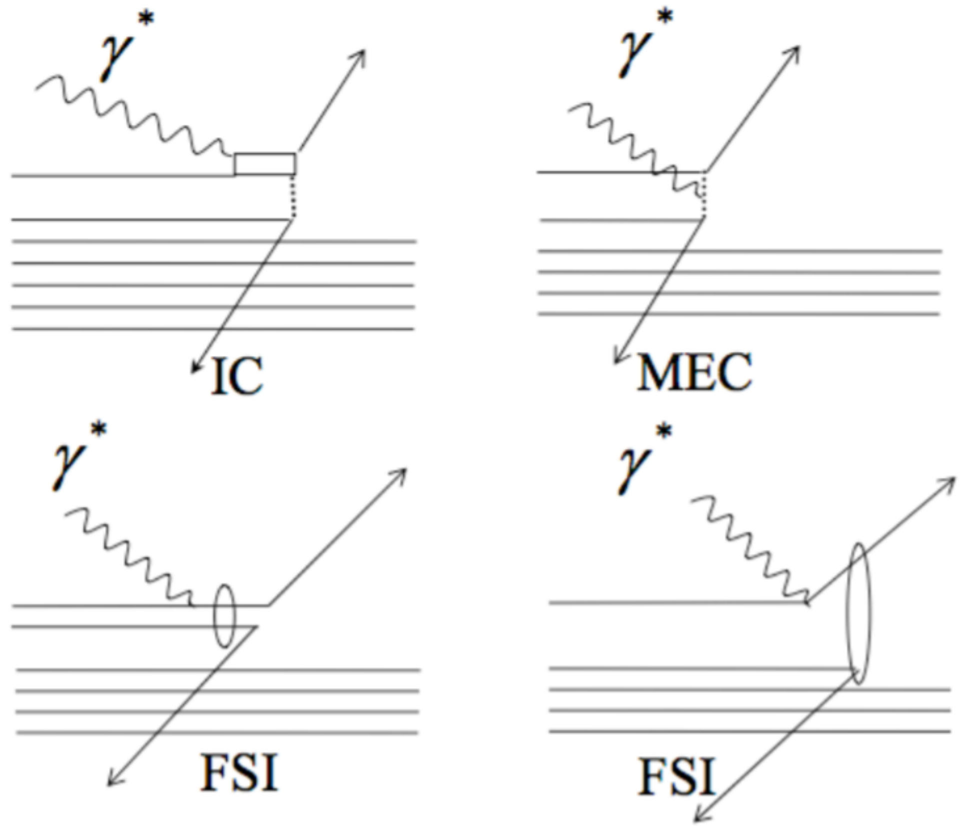

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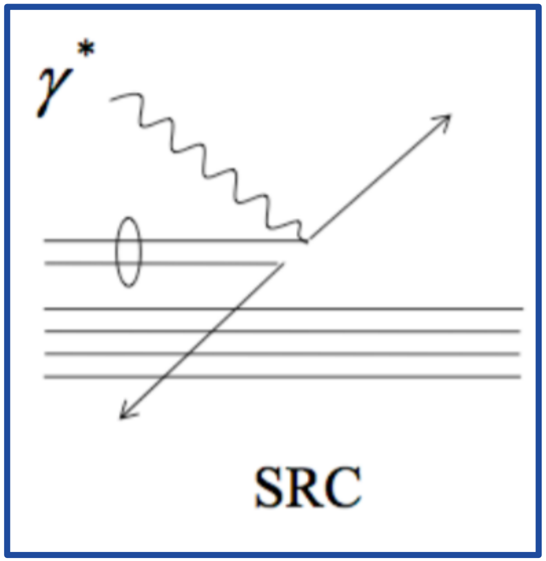

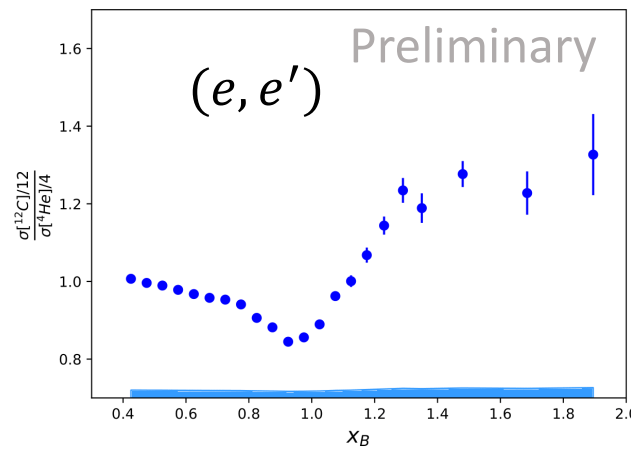

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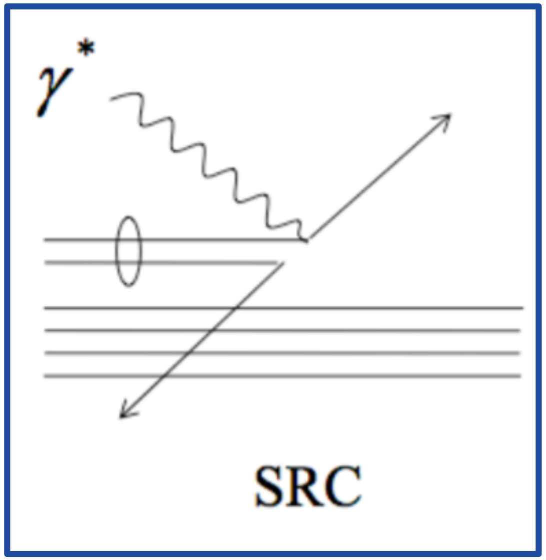
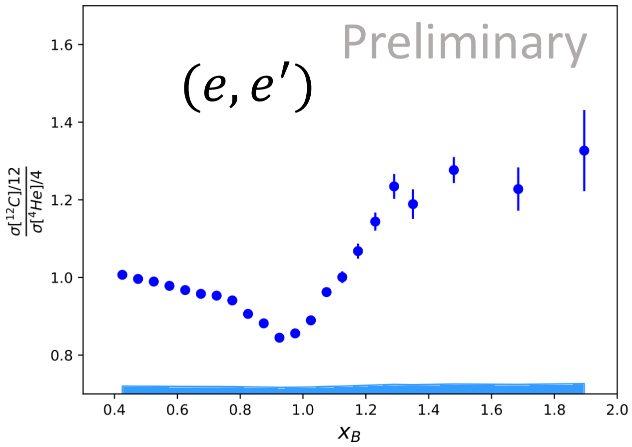
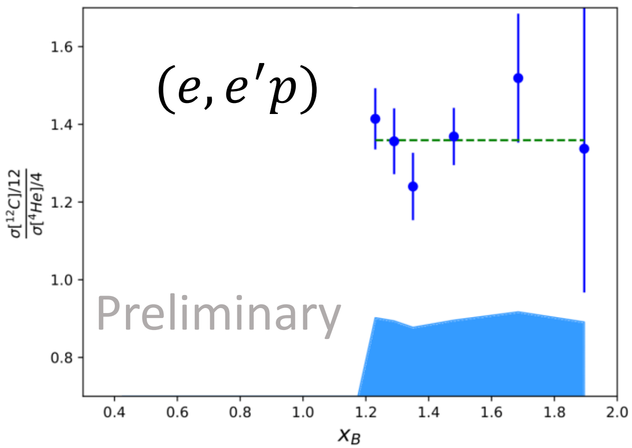
Contributions to the Cross Section



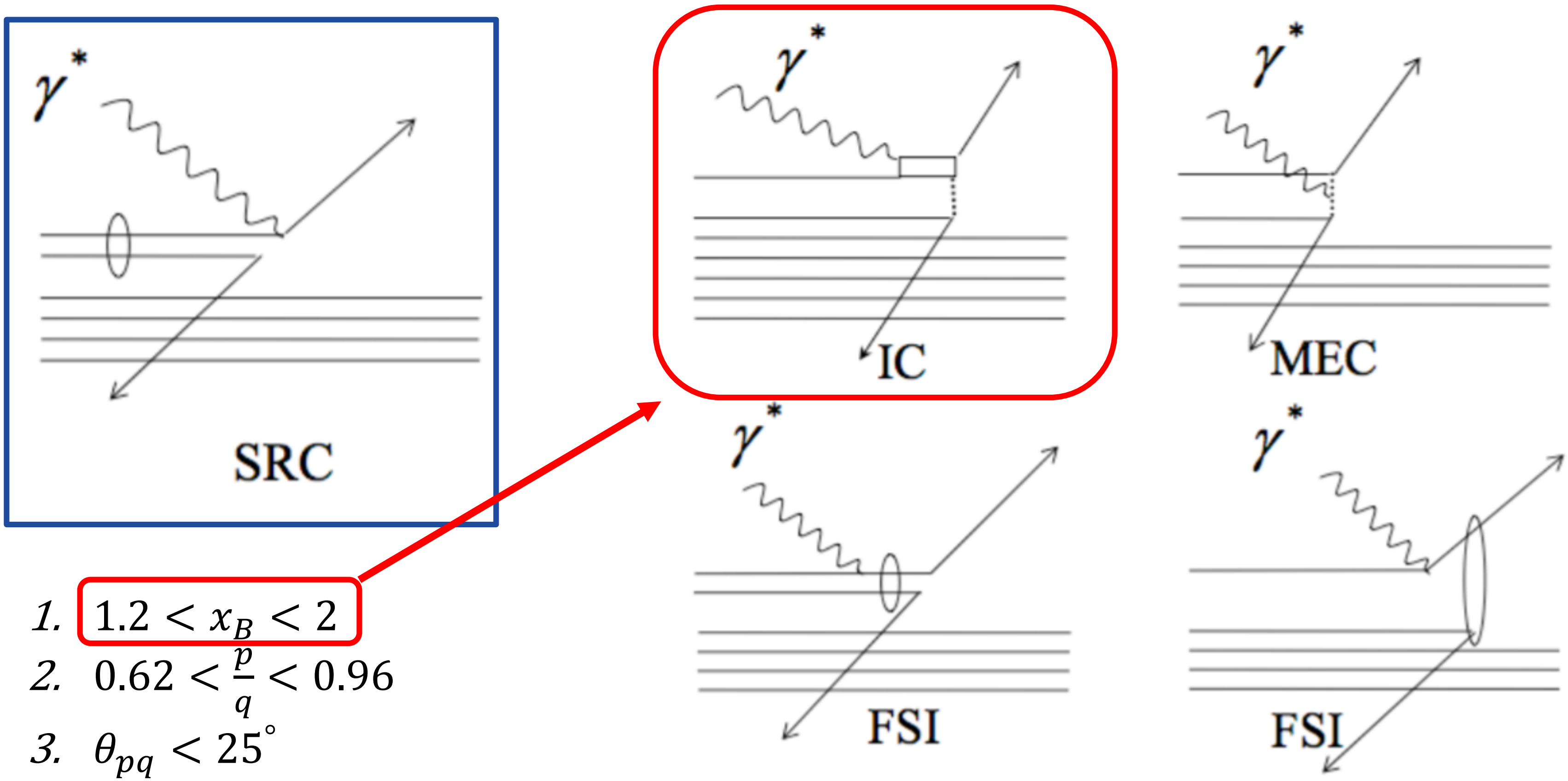


1. $1.2 < x_B < 2$
2. $0.62 < \frac{p}{q} < 0.96$
3. $\theta_{pq} < 25^{\circ}$
4. $0.9\ GeV < m_{Miss} < 1.1\ GeV$
5. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

Apply Cuts



Contributions to the Cross Section



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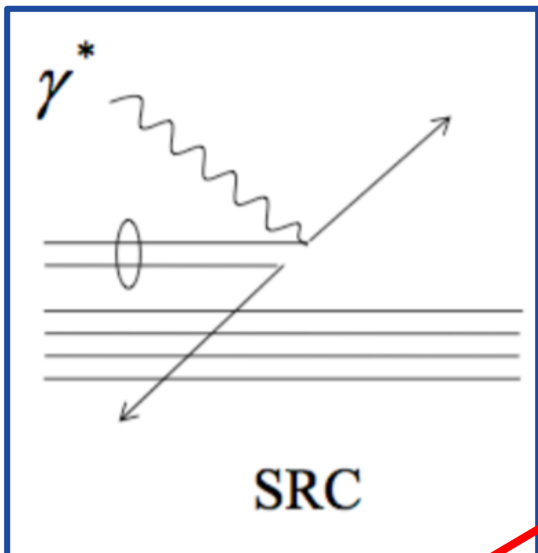

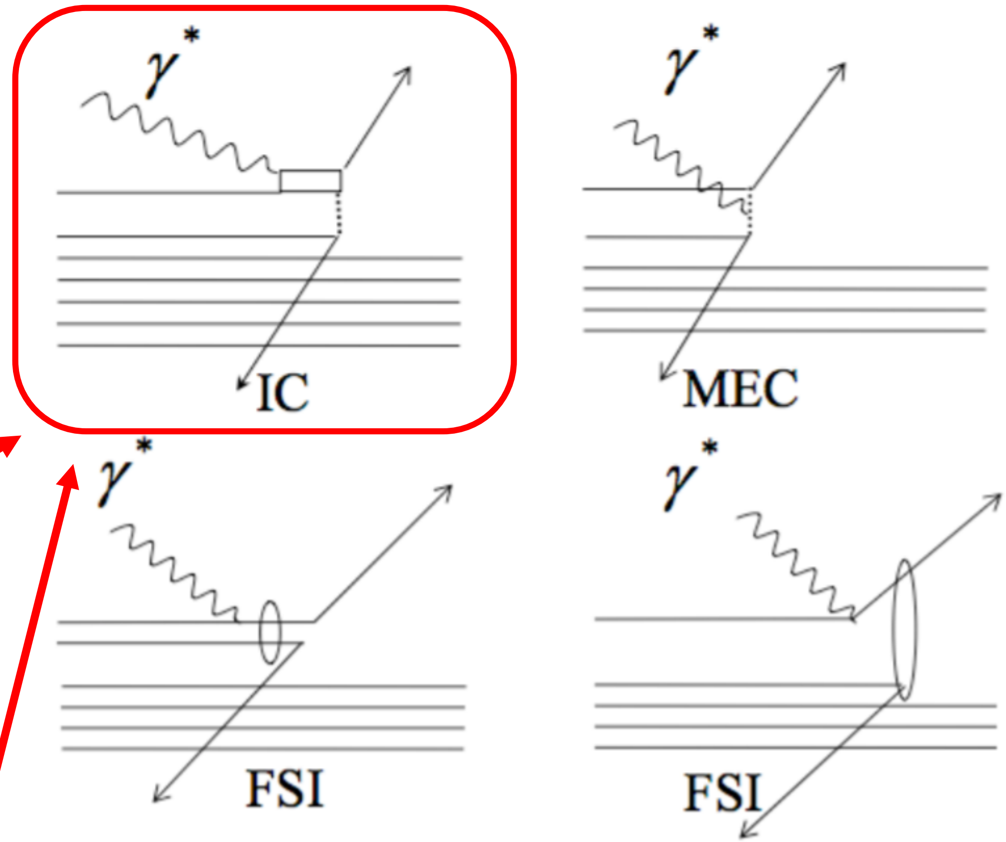

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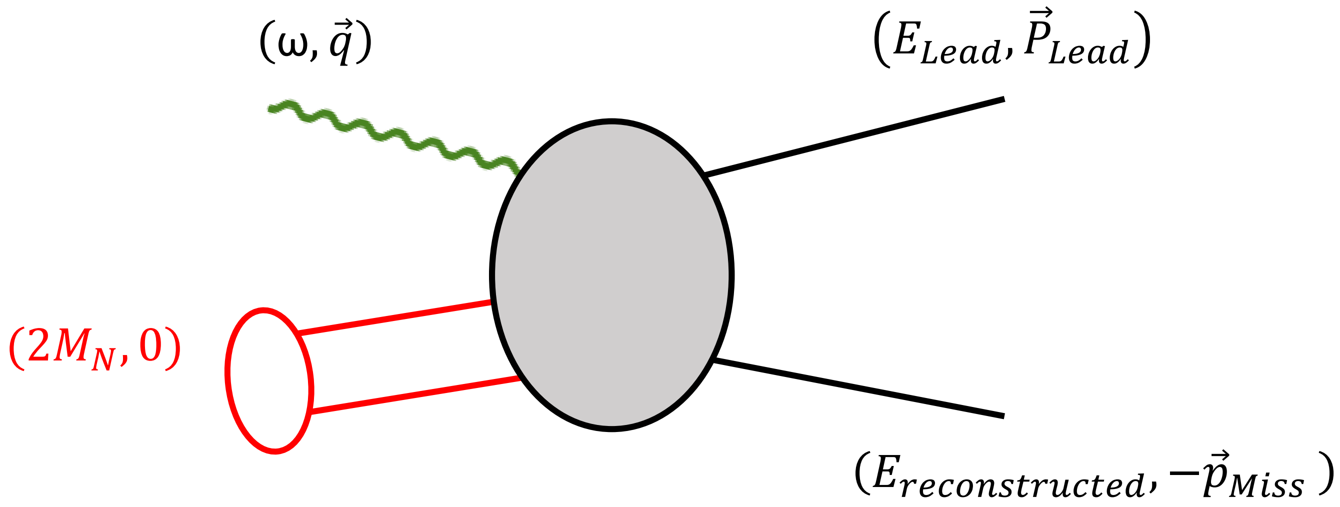
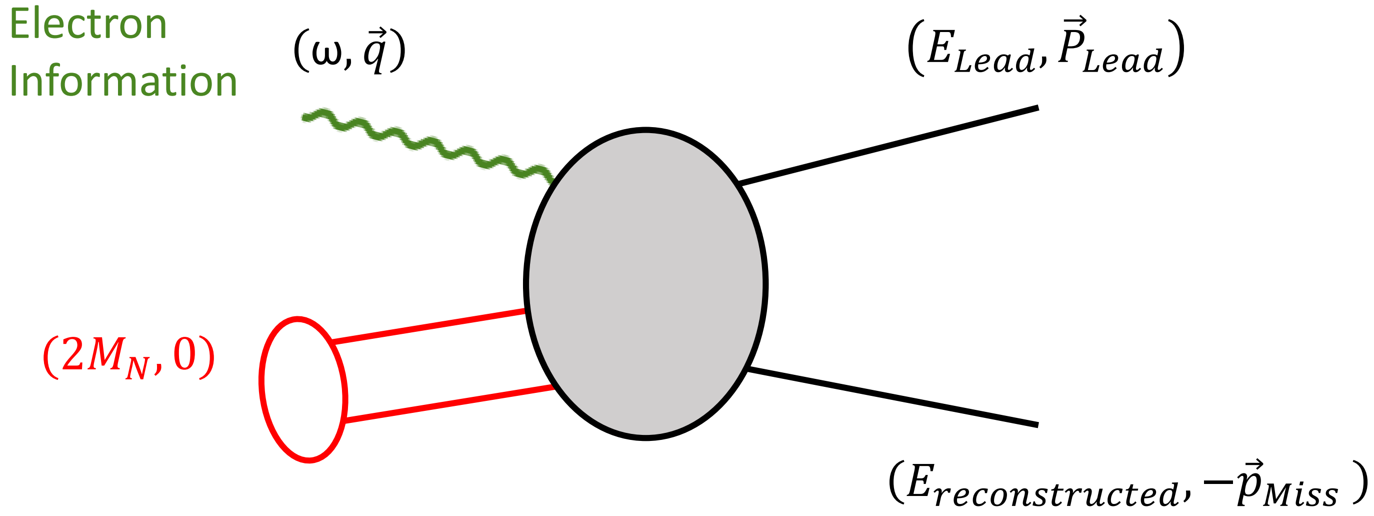
Missing Mass



$$M_{miss}^2 = \left((\omega, \vec{q}) + (2M_N, 0) - (E_{Lead}, \vec{P}_{Lead})\right)^2$$

$$M_{miss}^2 = E_{reconstructed}^2 - p_{Miss}^2$$

Missing Mass



$$M_{miss}^2 = \left((\omega, \vec{q}) + (2M_N, 0) - \left(E_{Lead}, \vec{P}_{Lead}\right)\right)^2$$

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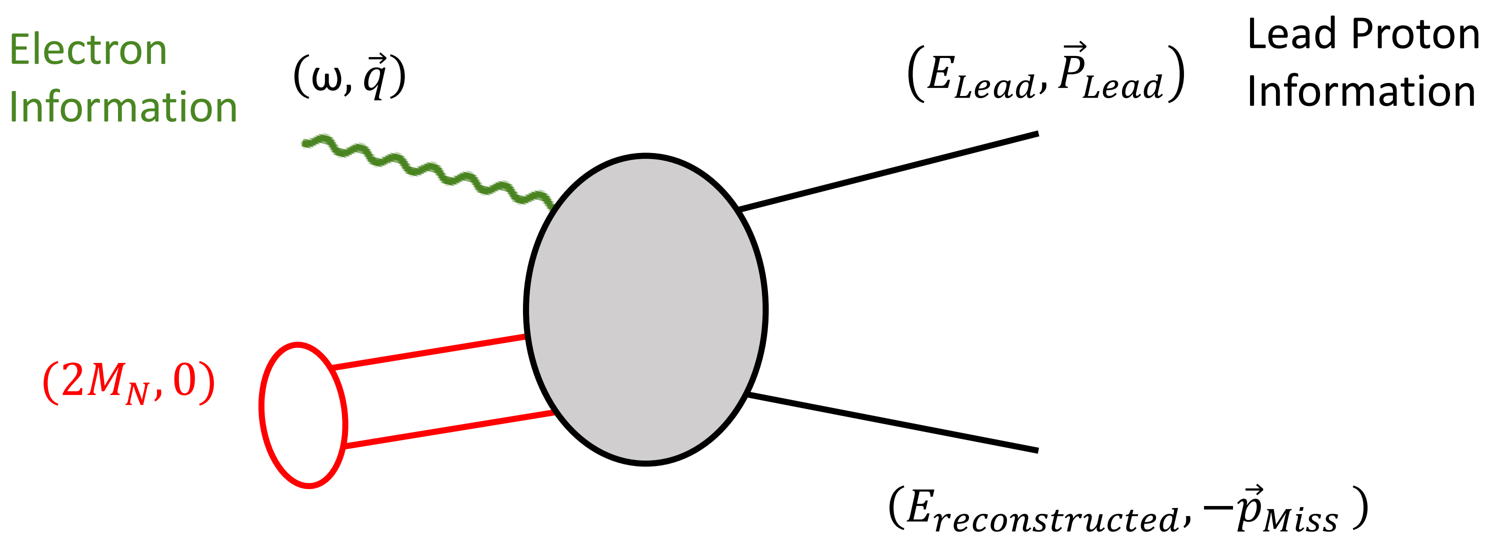
Missing Mass



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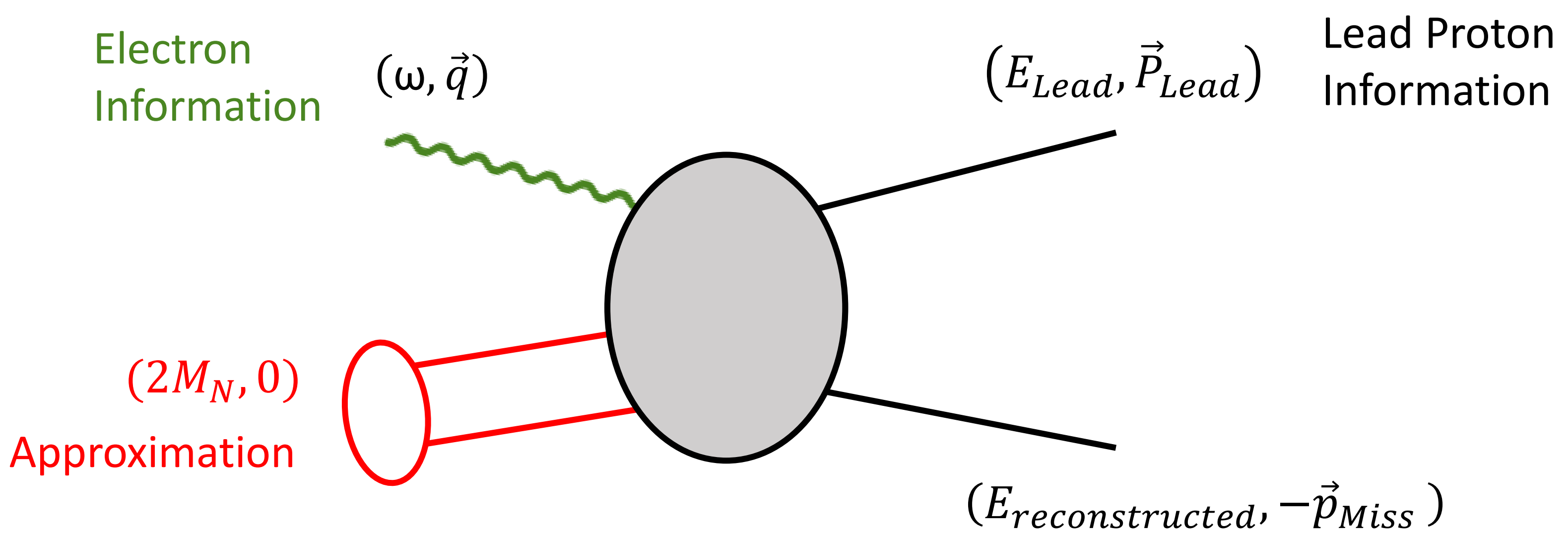
Missing Mass



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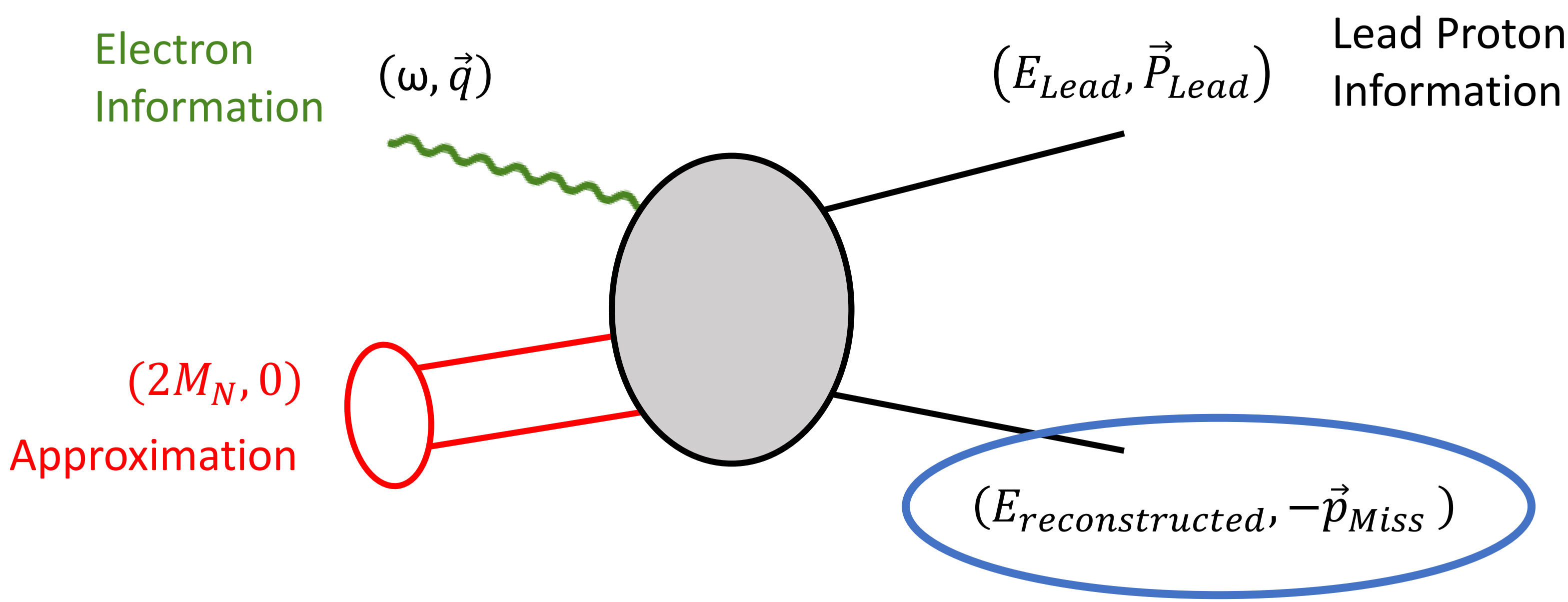
Missing Mass



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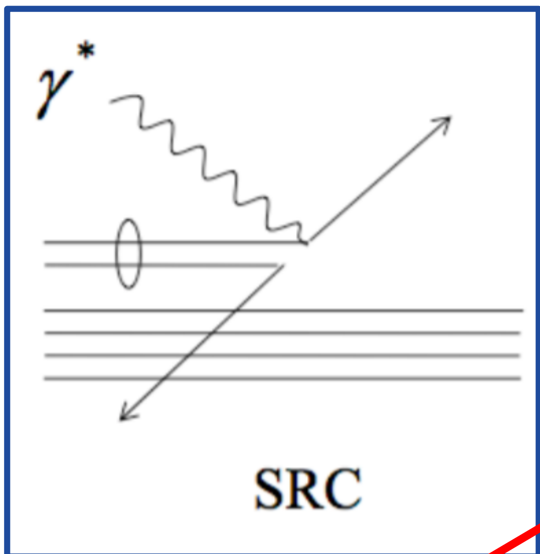
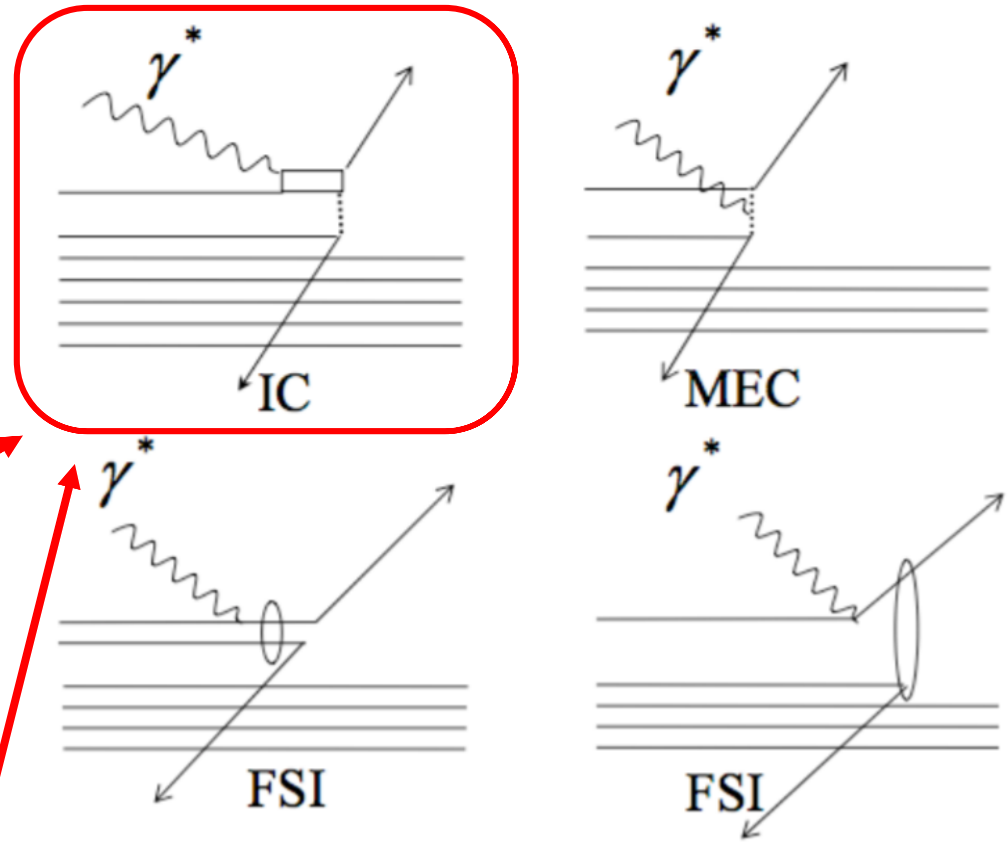
Contributions to the Cross Section





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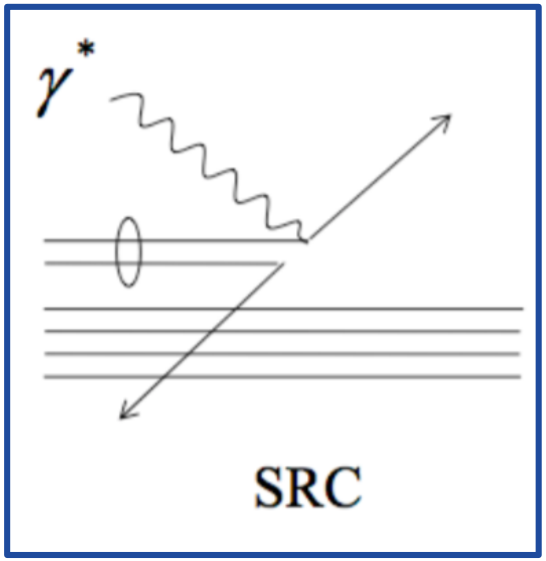
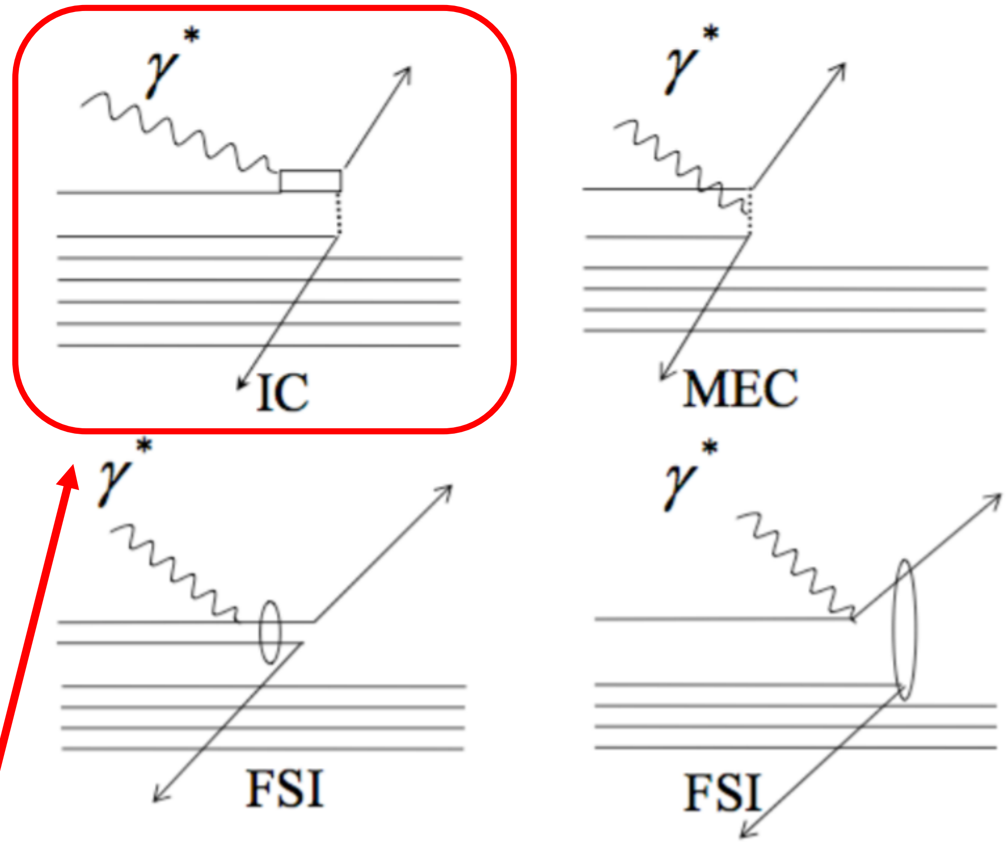
Contributions to the Cross Section





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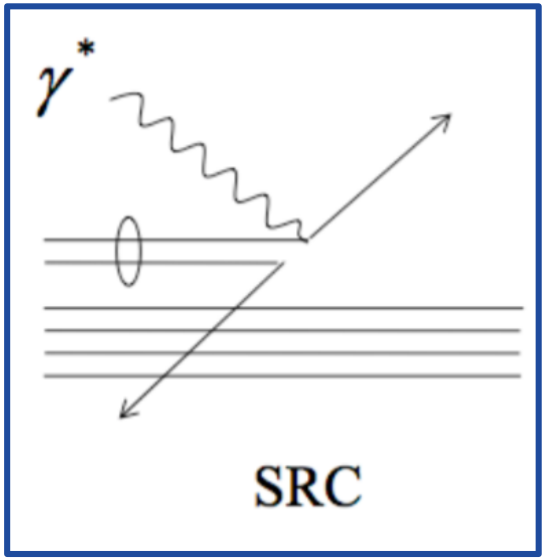

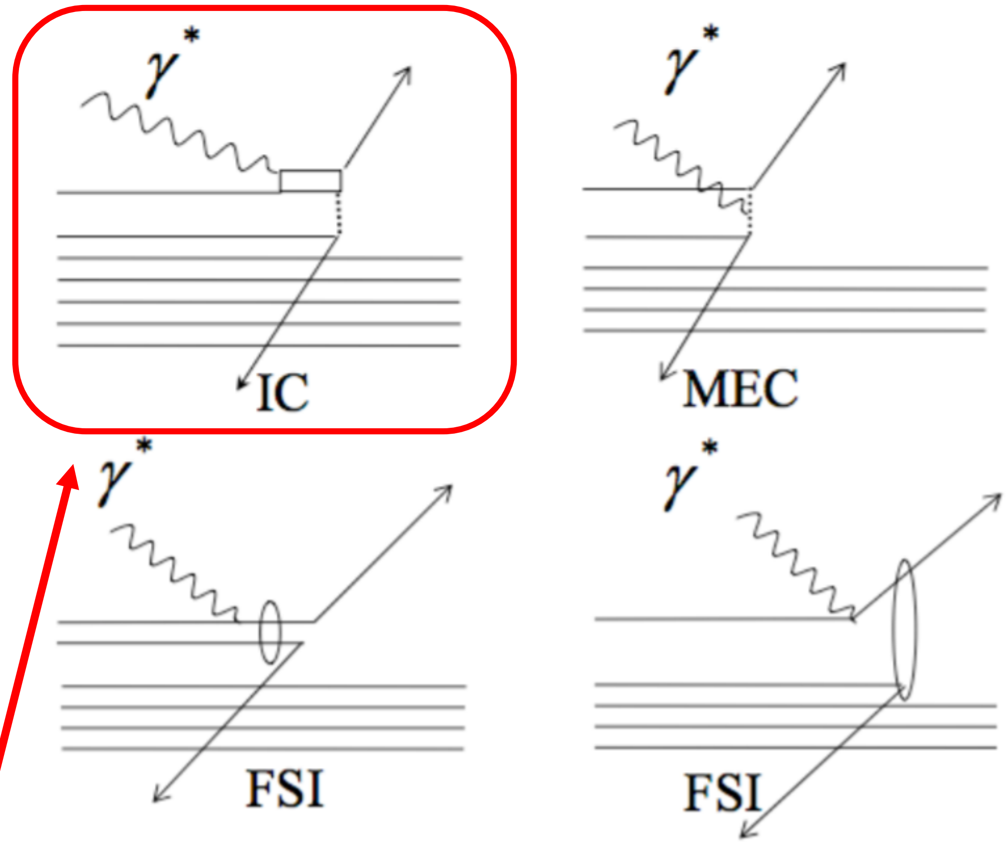

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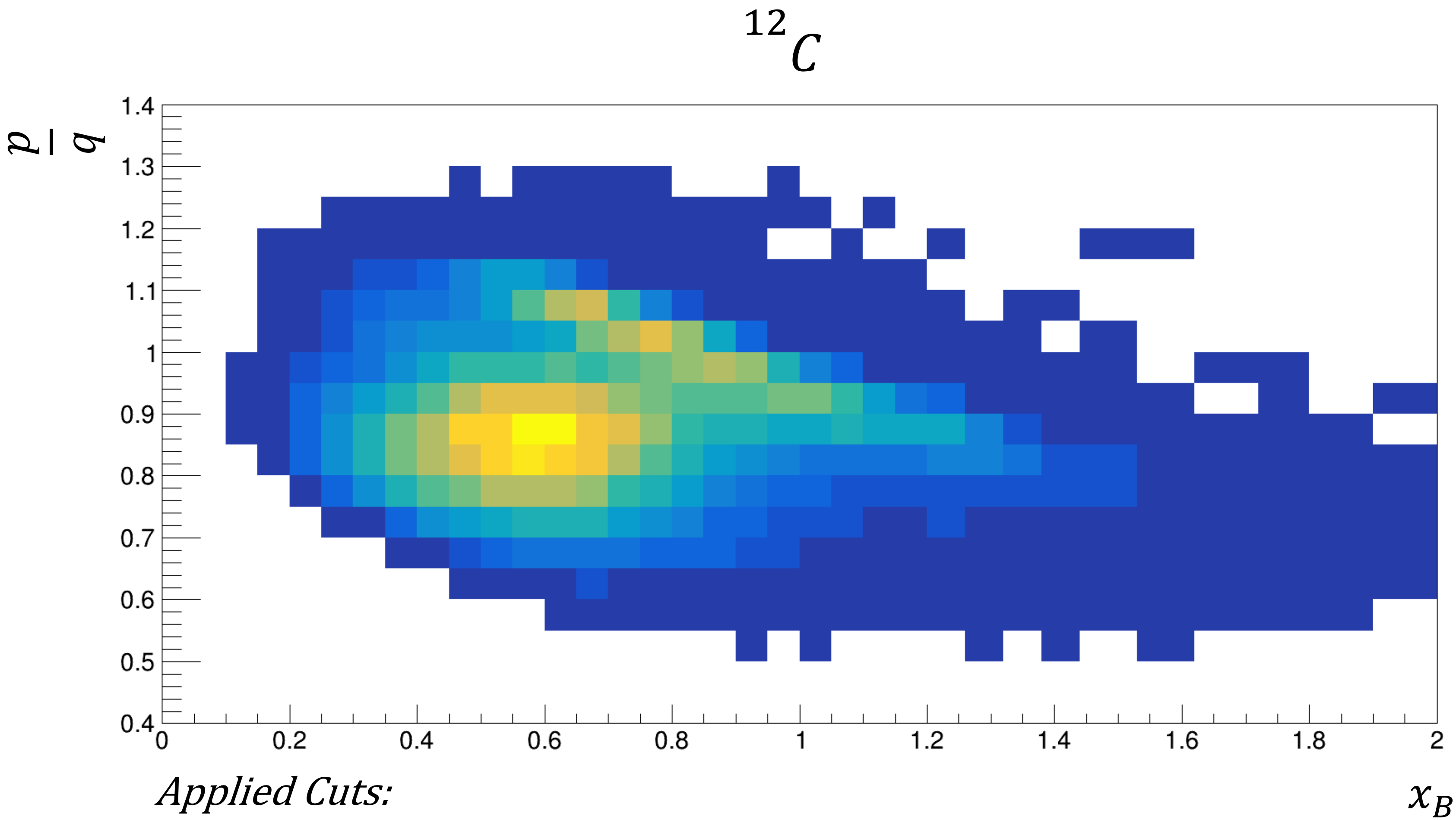
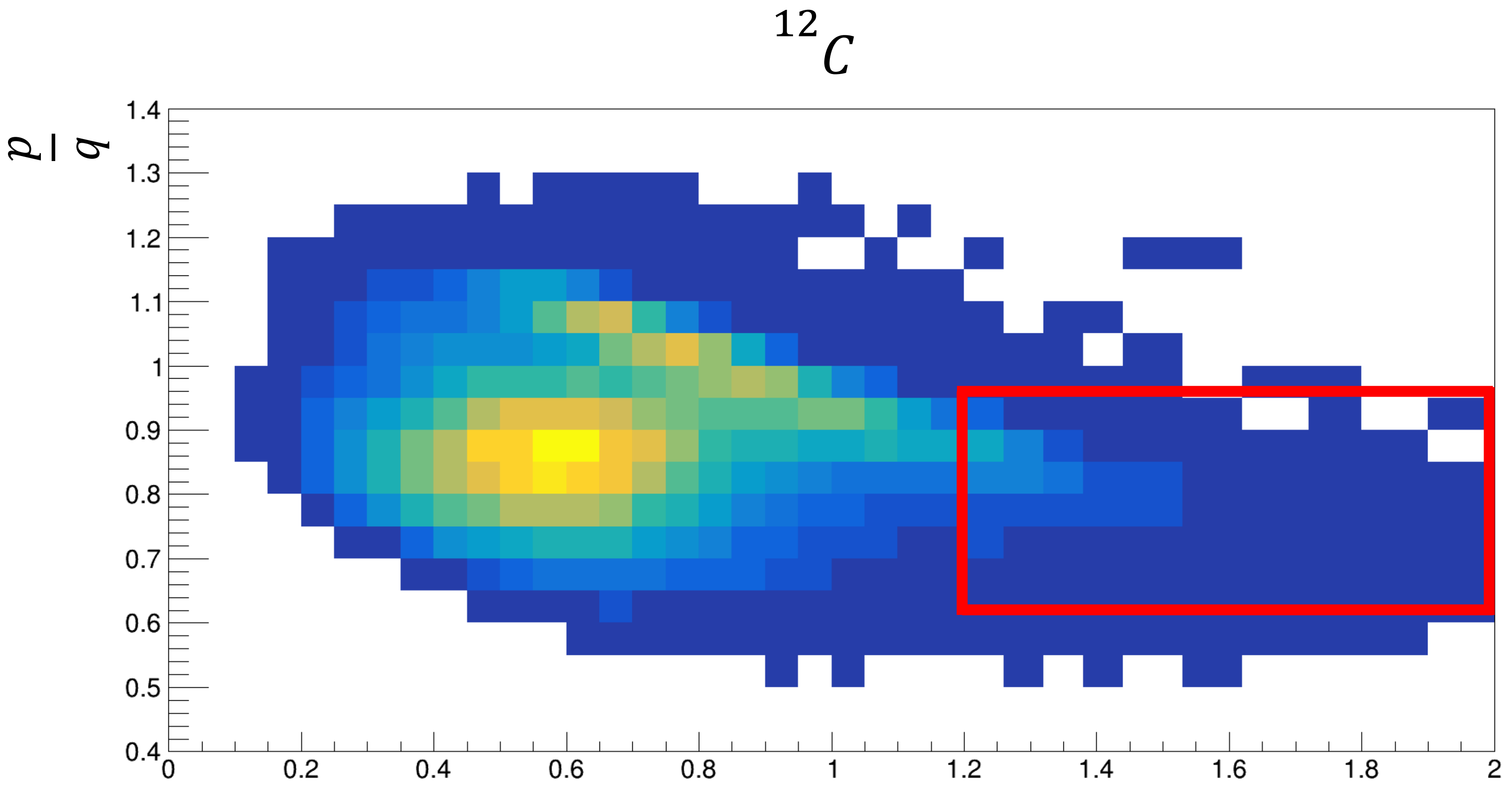
Maybe we can do better…



Applied Cuts:

- $\theta_{pq} < 25^{\circ}$
- $0.2\ GeV < p_{Miss} < 0.6\ GeV$

Maybe we can do better…



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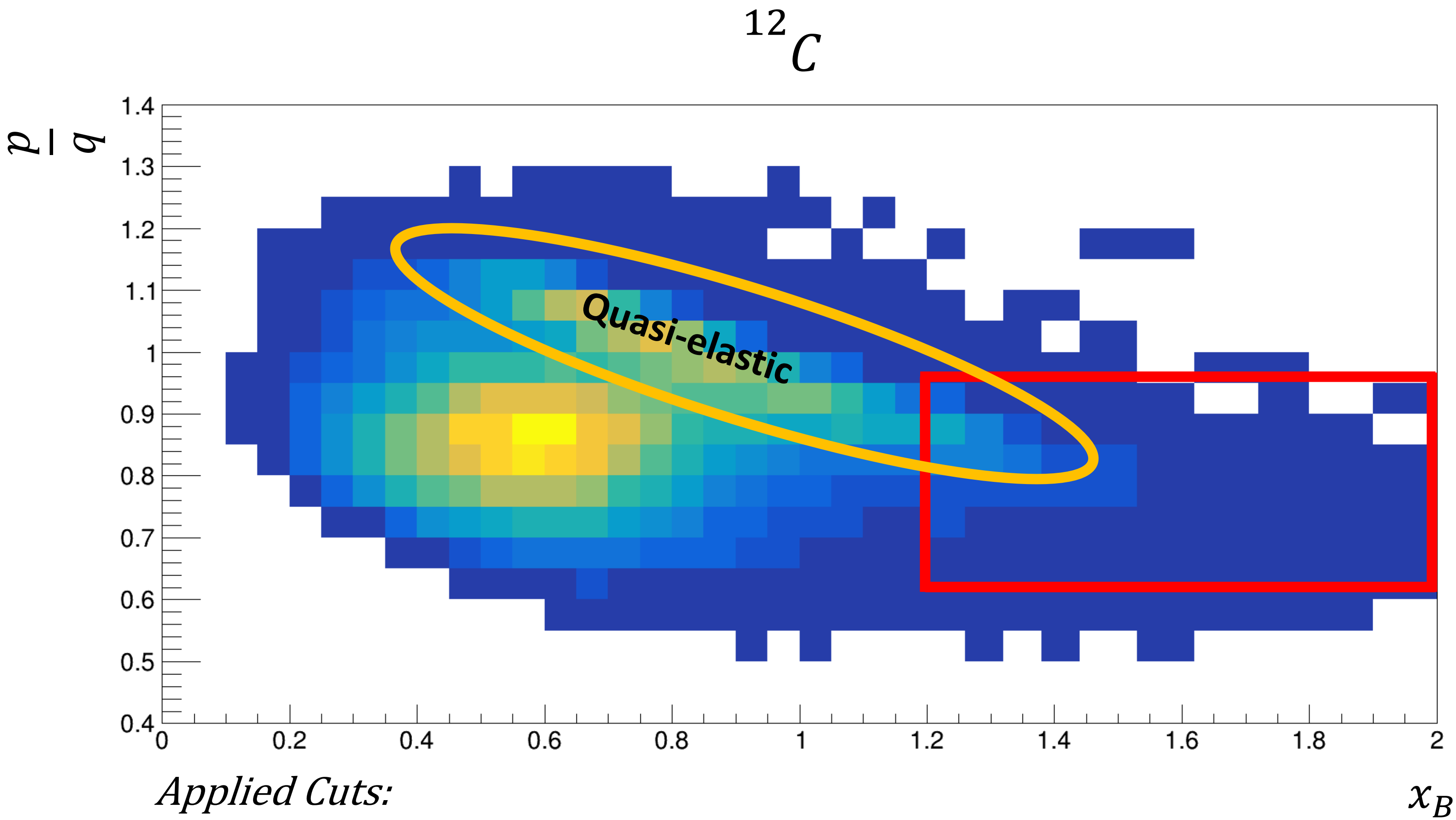

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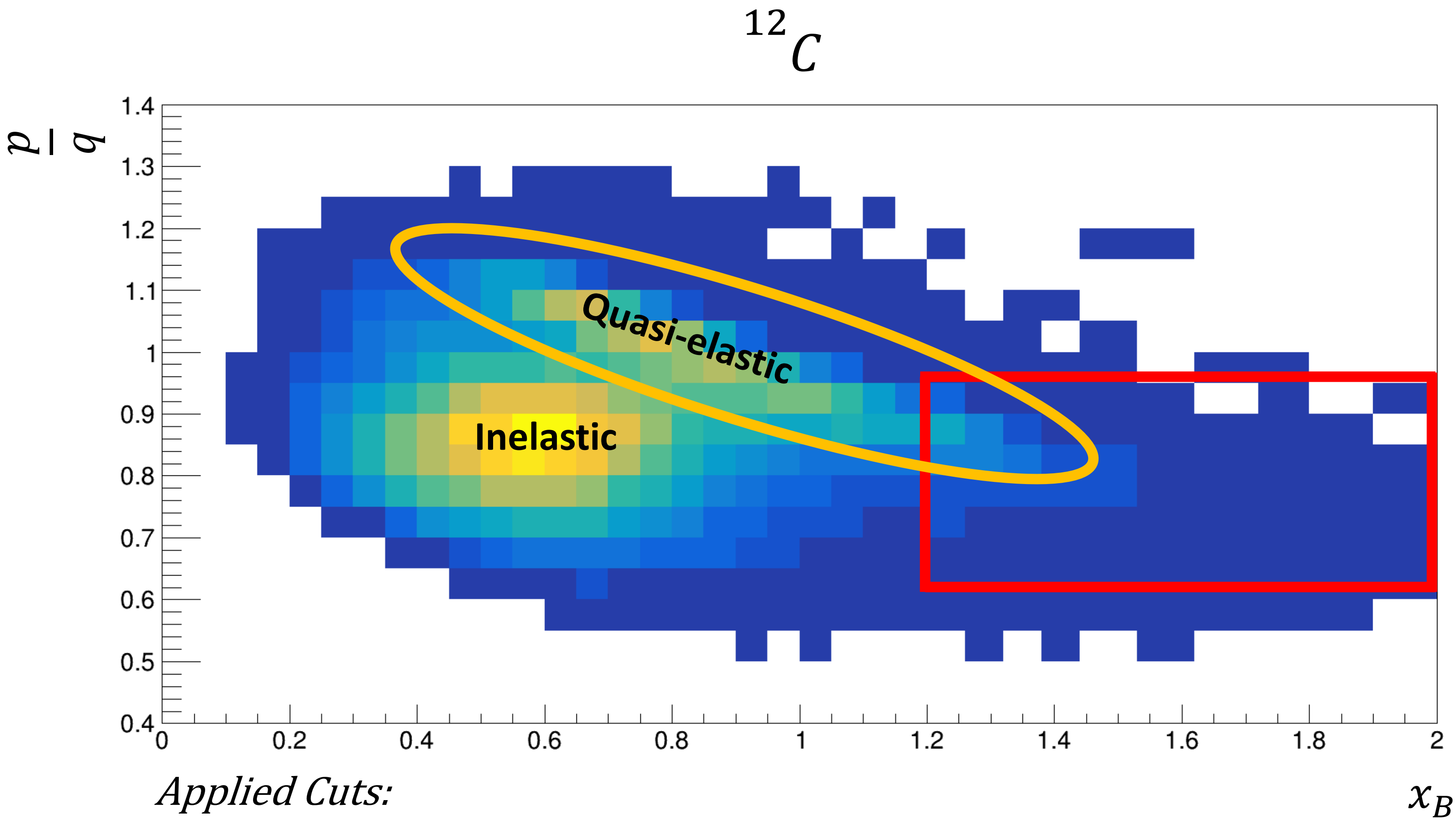
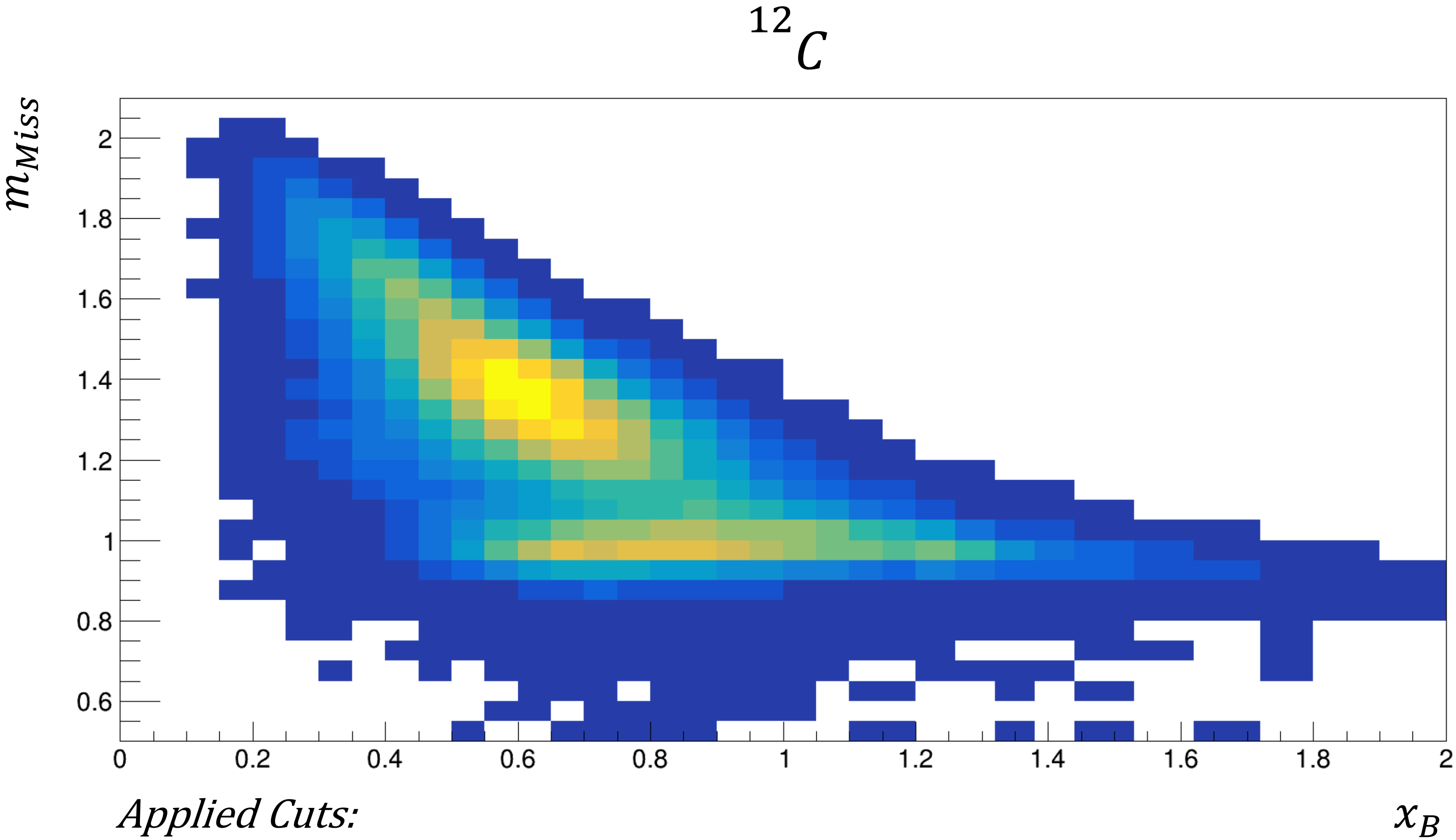


Applied Cuts:

- $\theta_{pq} < 25^{\circ}$
- $0.2\ GeV < p_{Miss} < 0.6\ GeV$

Change to m_{Miss}



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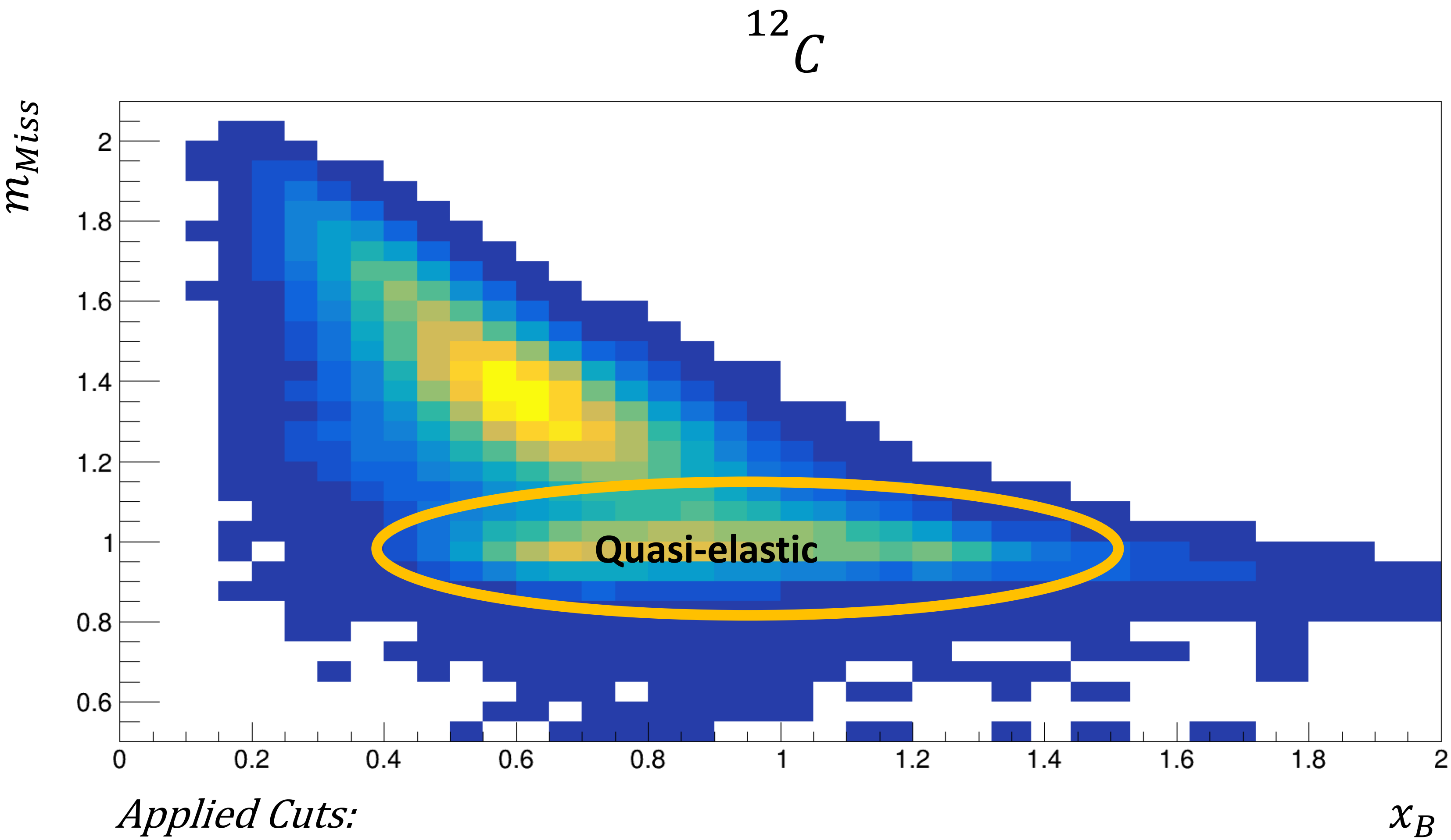

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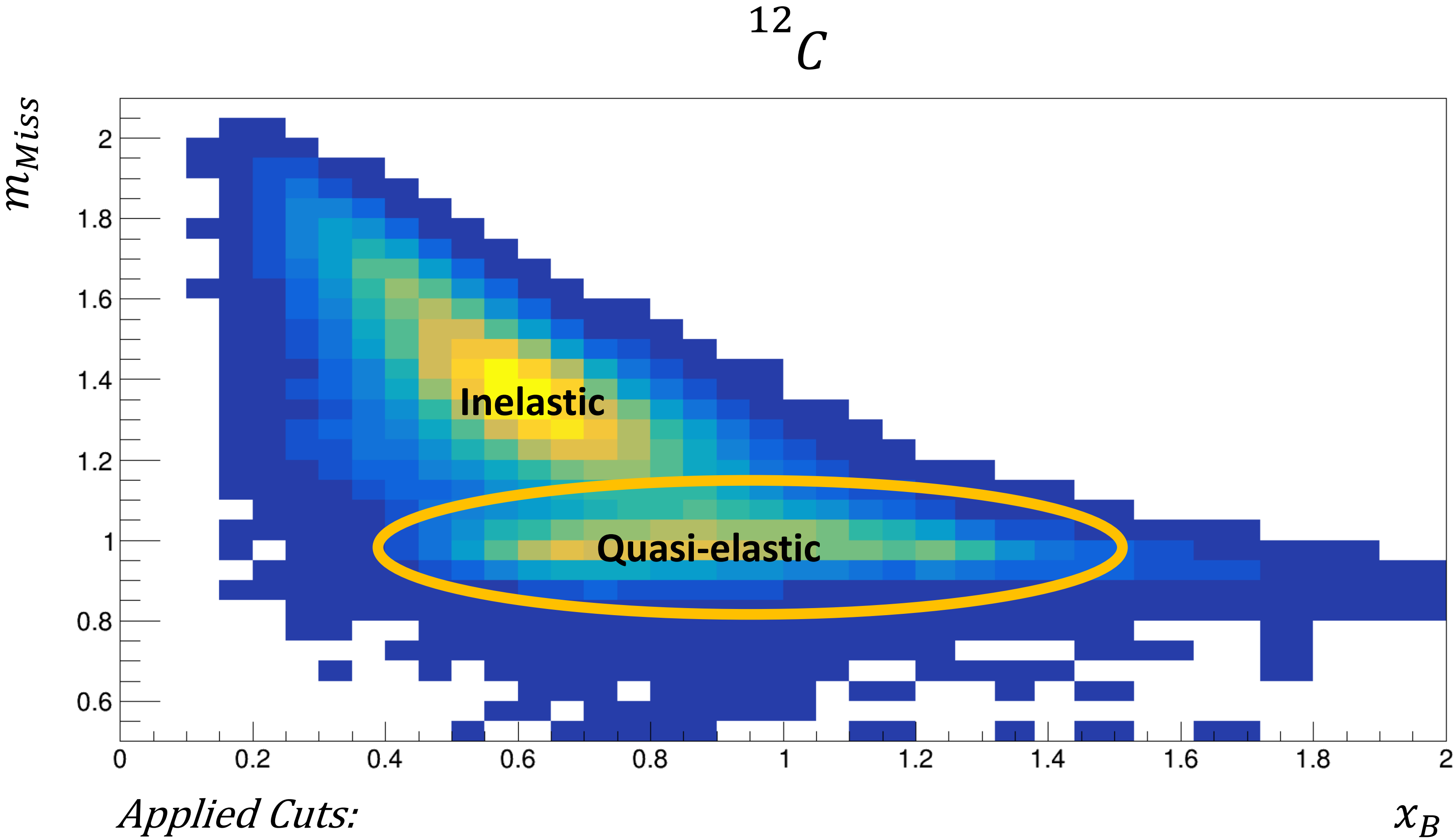

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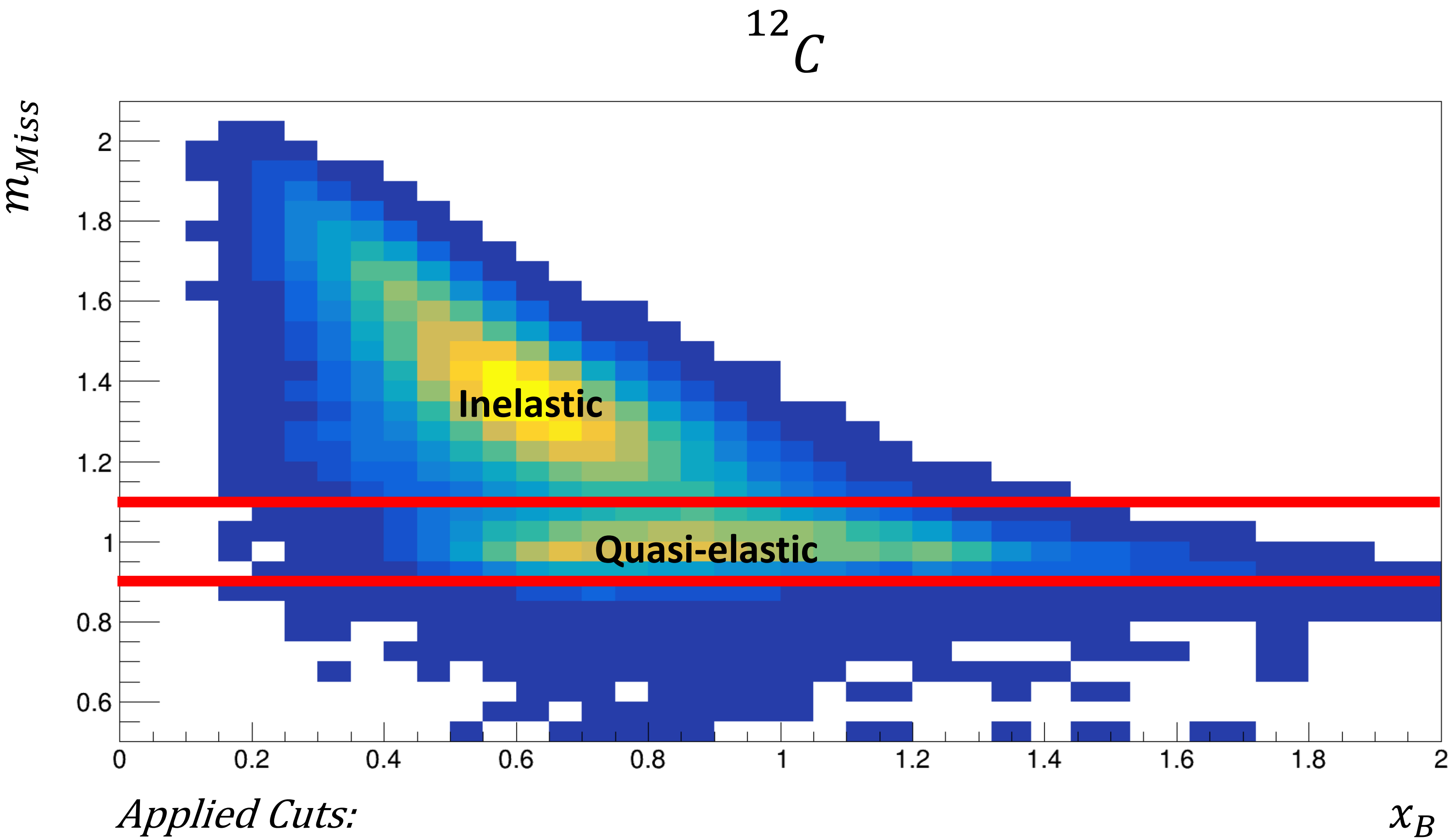

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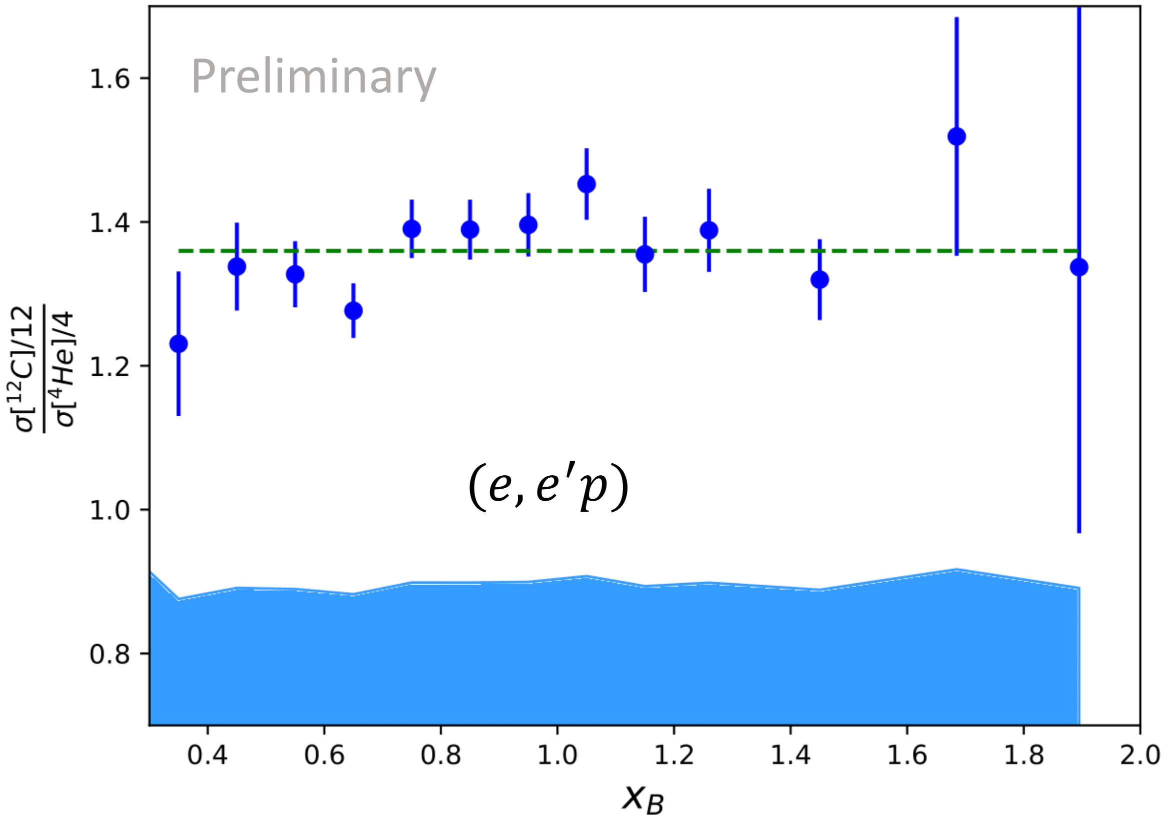
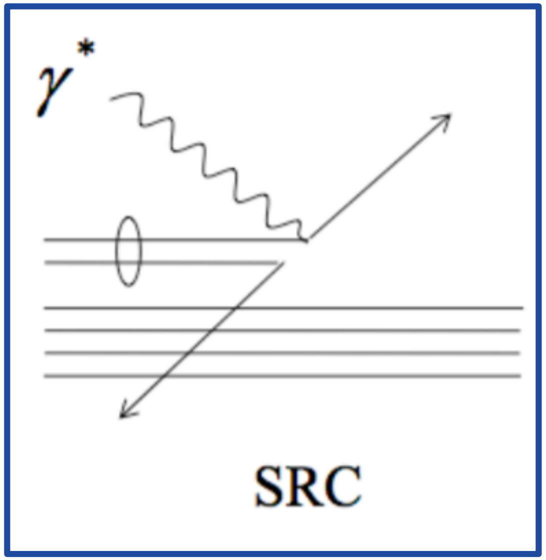
Result

$$\frac{{}^{12}C/12}{{}^{4}He/4}$$



$$x_B = \frac{Q^2}{2\nu m_N}$$

Mean Field Contribution



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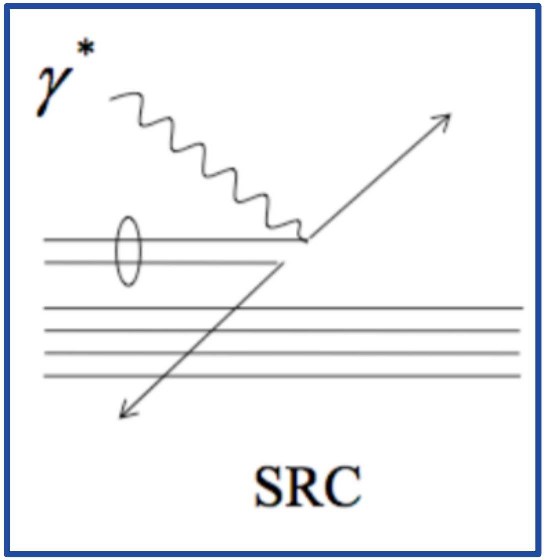

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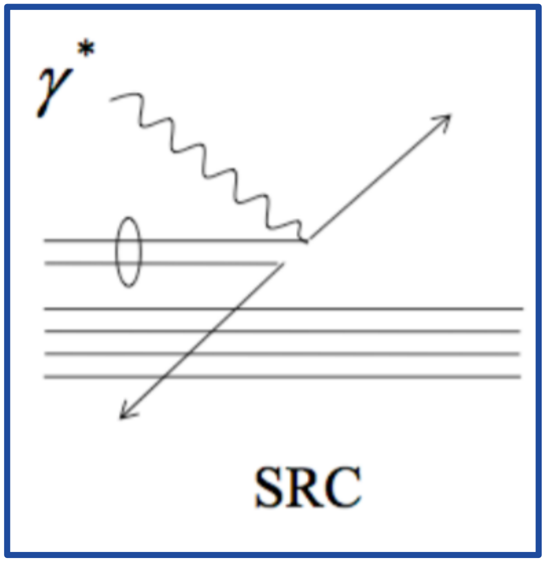

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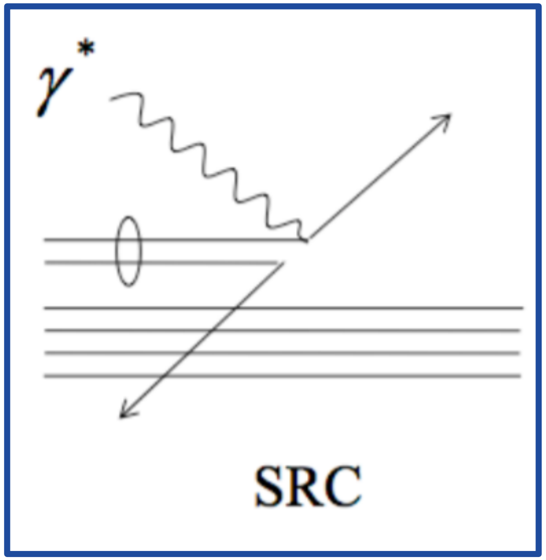
$$p_{Miss} = p_{Lead} - q$$

Mean Field Contribution



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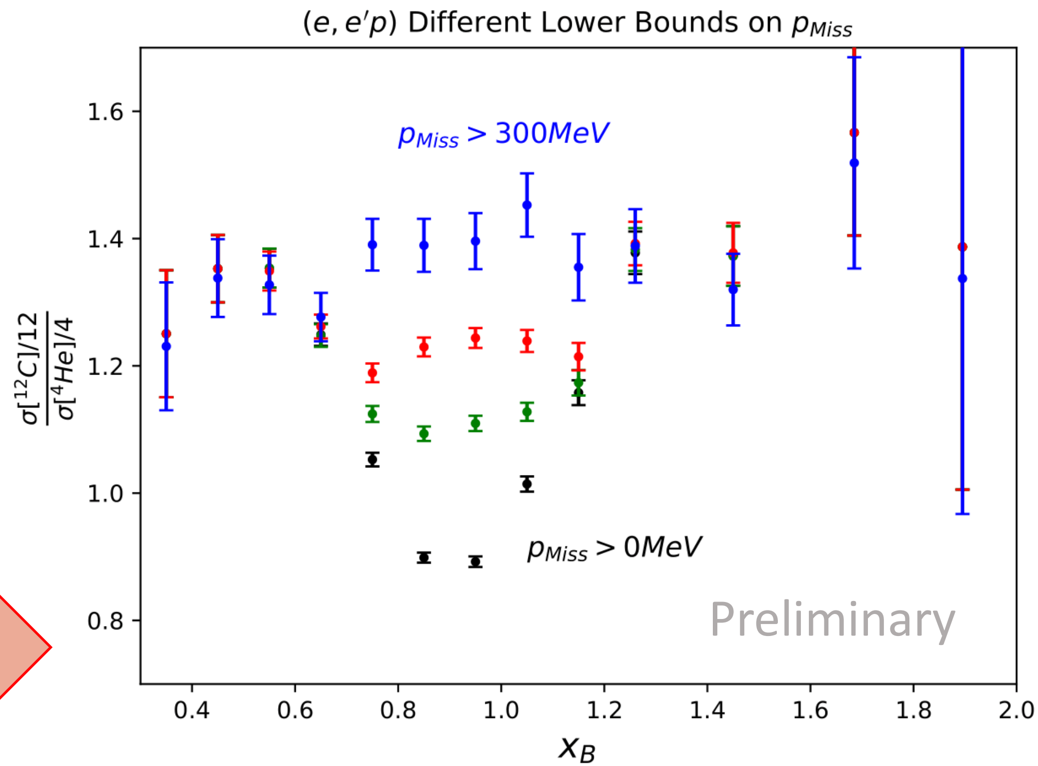
Apply Cuts

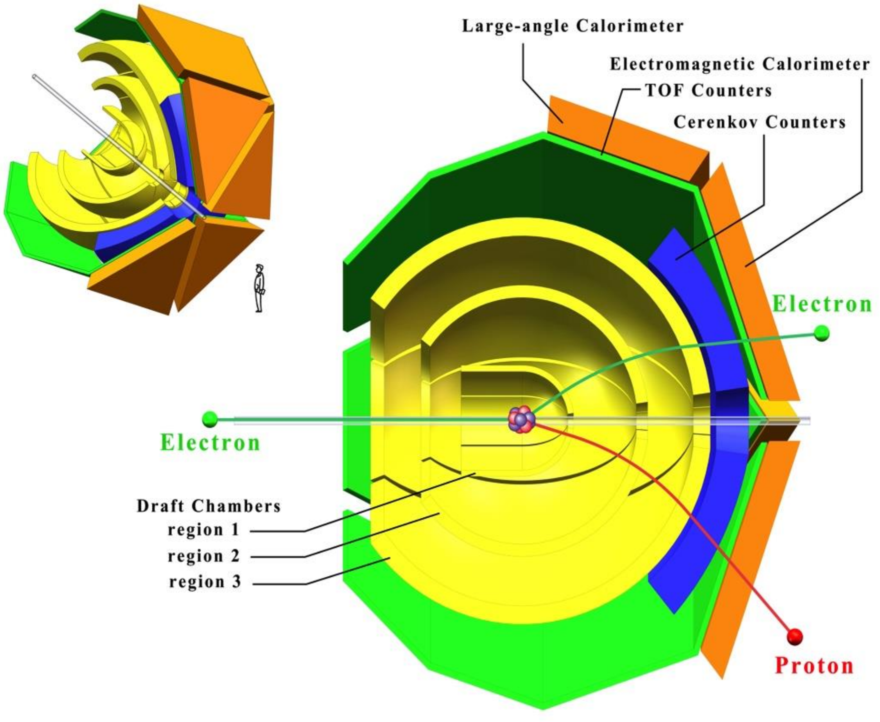


$p_{Miss} = p_{Lead} - q$

Igor Korover’s Analysis

<u>CLAS eg2</u>

- $E_{beam} = 5.009\ GeV$
- Targets: $^{2}H, ^{12}C, ^{27}A,$ $^{56}Fe, ^{208}Pb,$

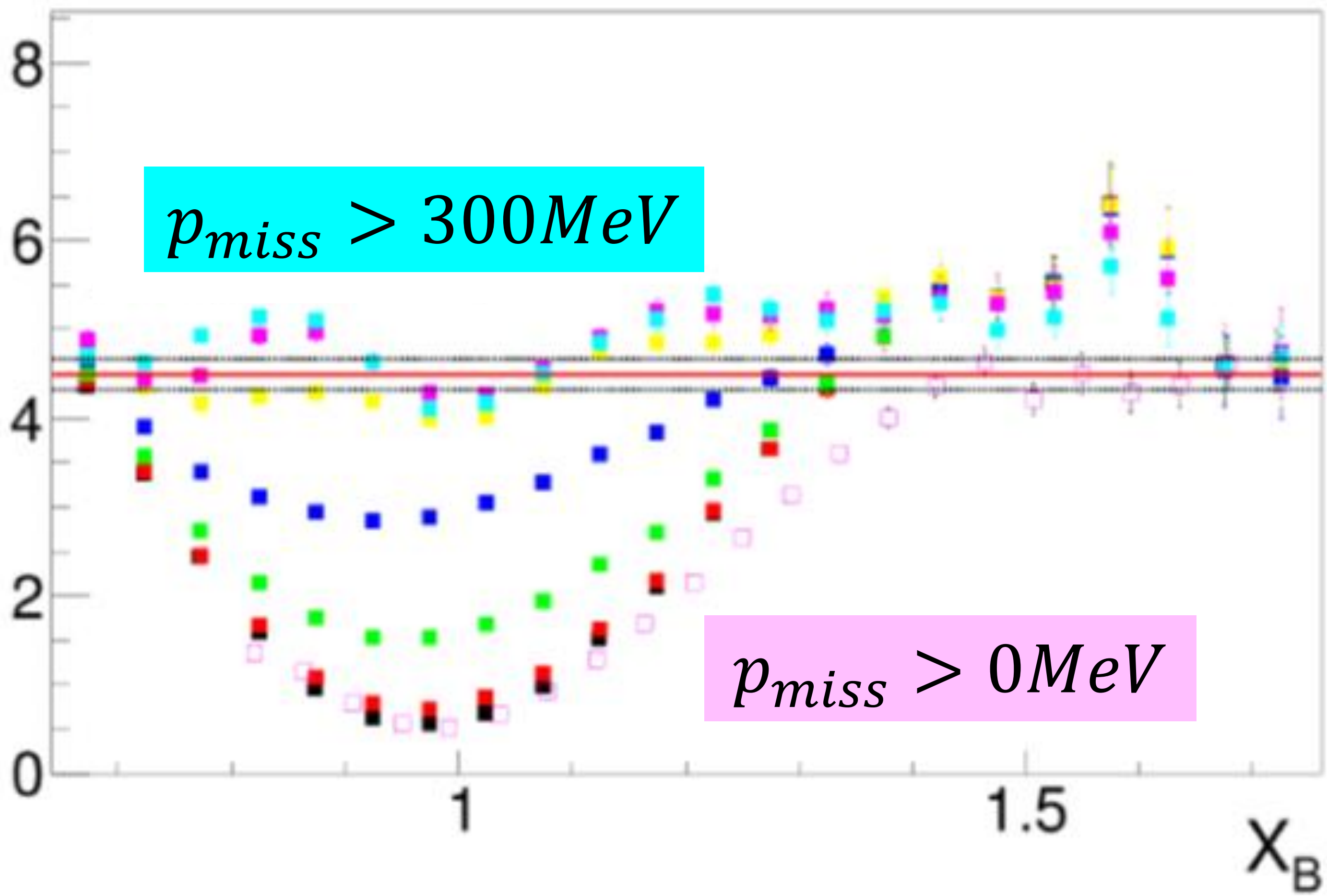


Igor Kovover

Scaling in ^{12}C

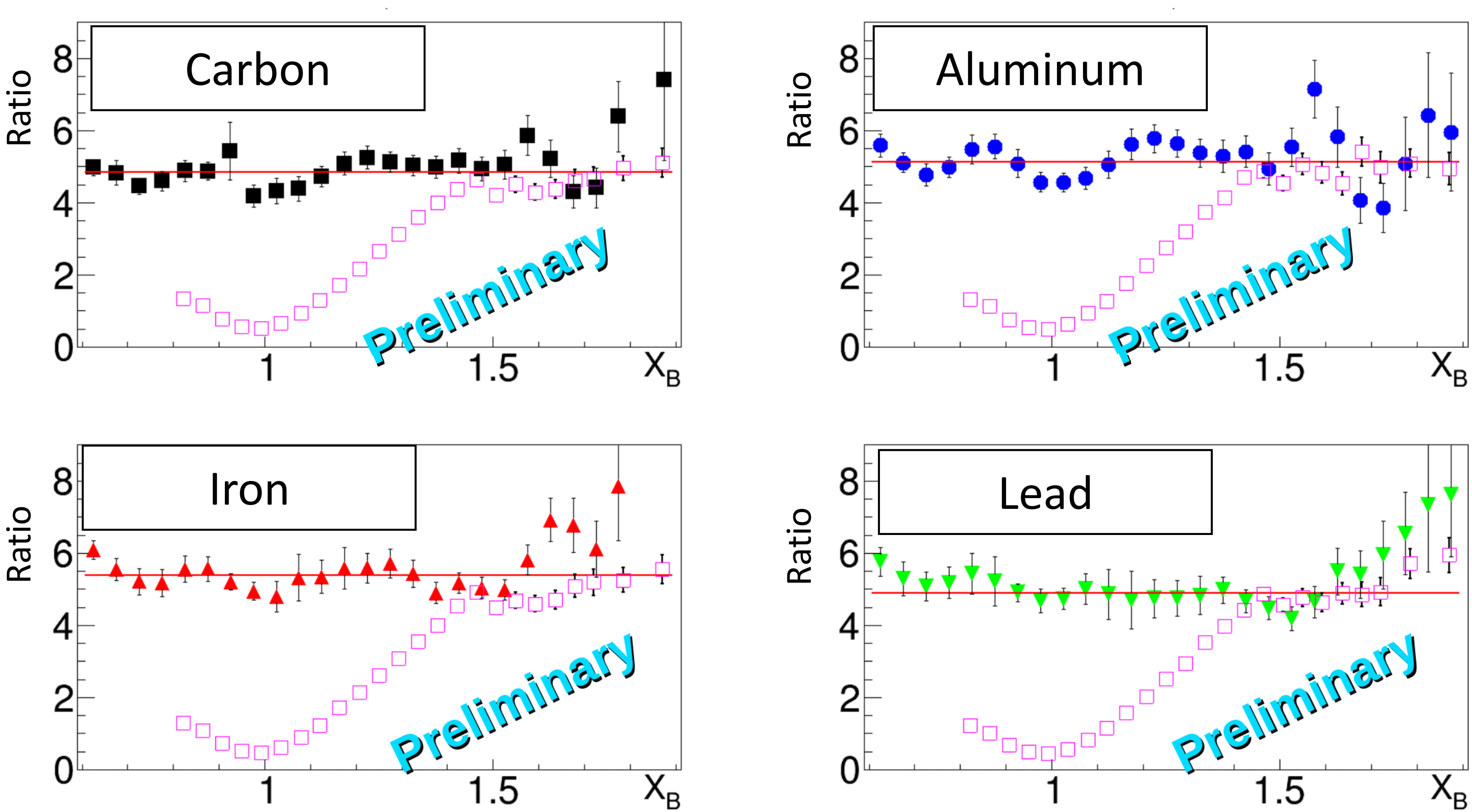
$$(e, e'p)$$

$$\frac{\sigma_C/12}{\sigma_D/2}$$



$\frac{\sigma_A/A}{\sigma_2/2}$ for Heavy Nuclei

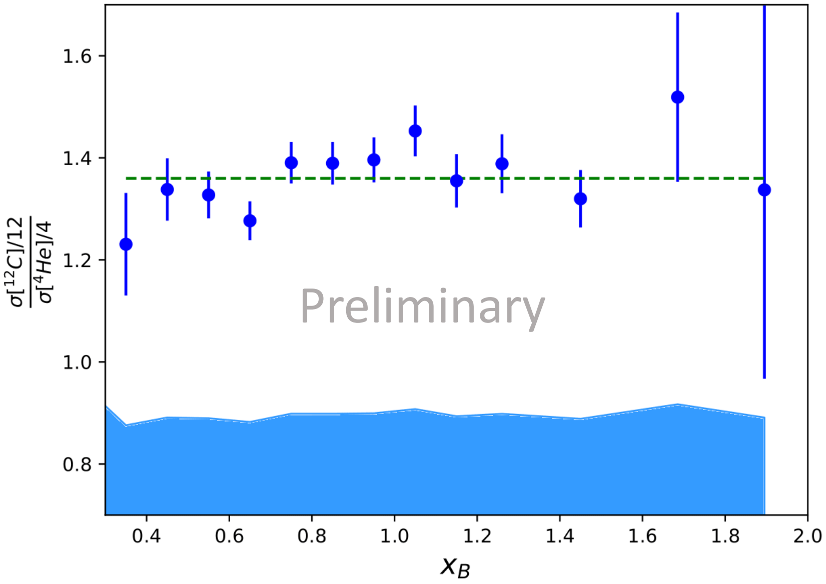
Igor Kovover



Conclusion

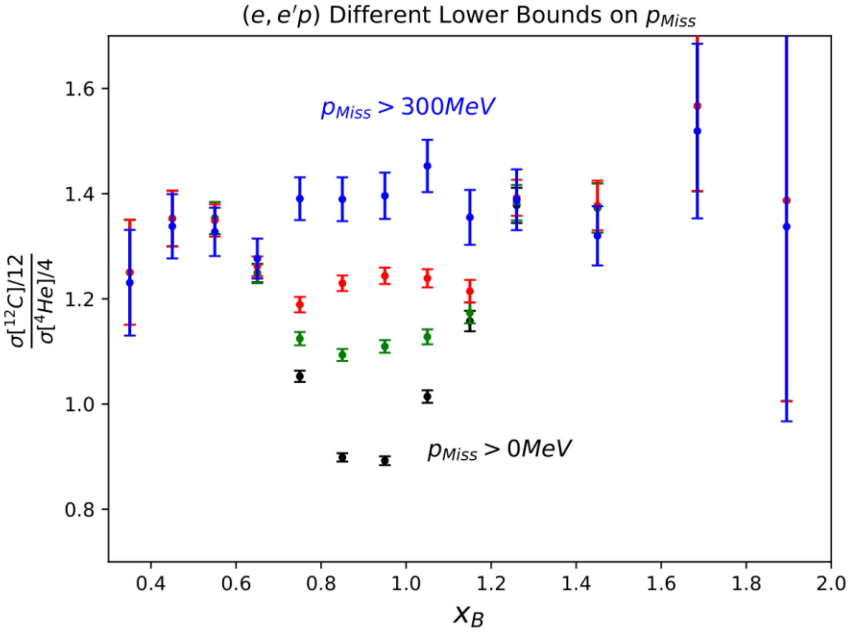
- $(e, e'p)$ allows us to see SRCs at low x_B

$(e, e'p)$



Conclusion

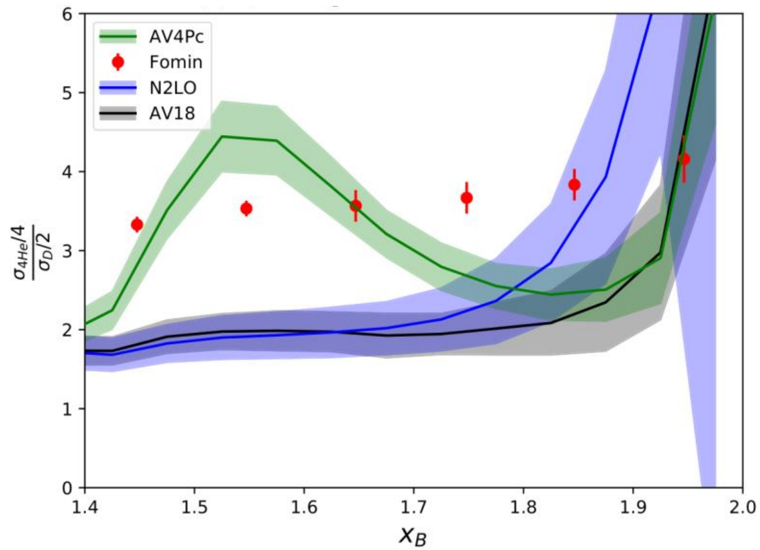
- $(e, e'p)$ allows us to see SRCs at low x_B
- p_{Miss} cuts suppress mean field nucleons



Conclusion

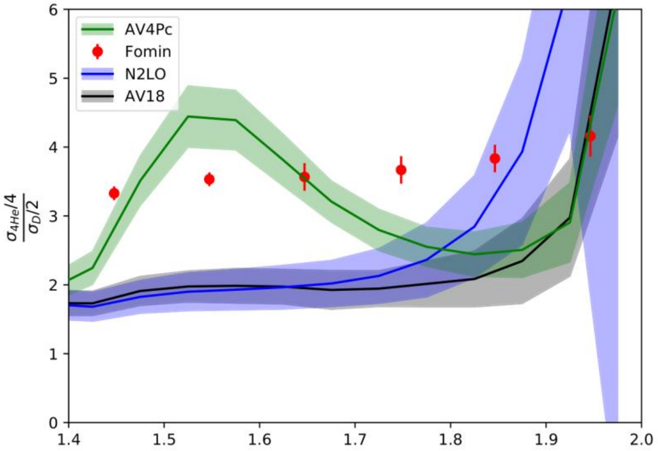
- $(e,e'p)$ allows us to see SRCs at low x_B
- p_{Miss} cuts suppress mean field nucleons
- The generalized contact formalism has been applied to (e,e')

$(e,e')\quad \theta_e = 18^{\circ}$

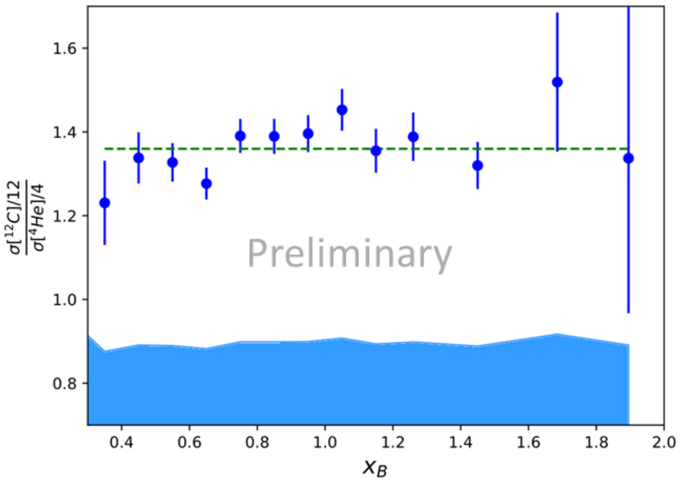


Future Work

Apply GCF to $(e, e'p)$

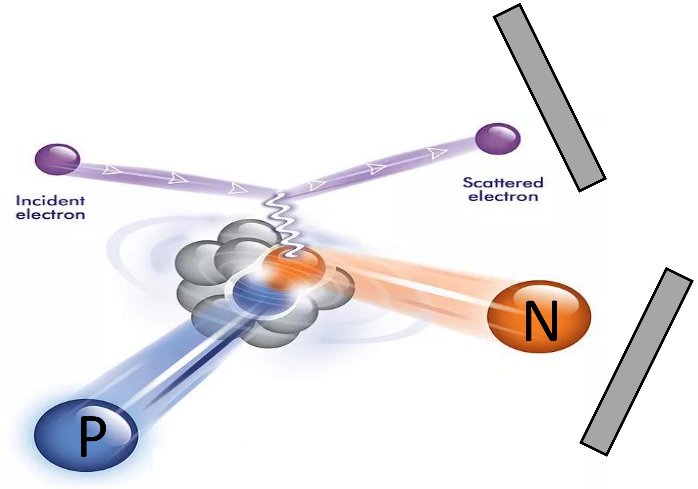


$(e, e'p)$



Future Work

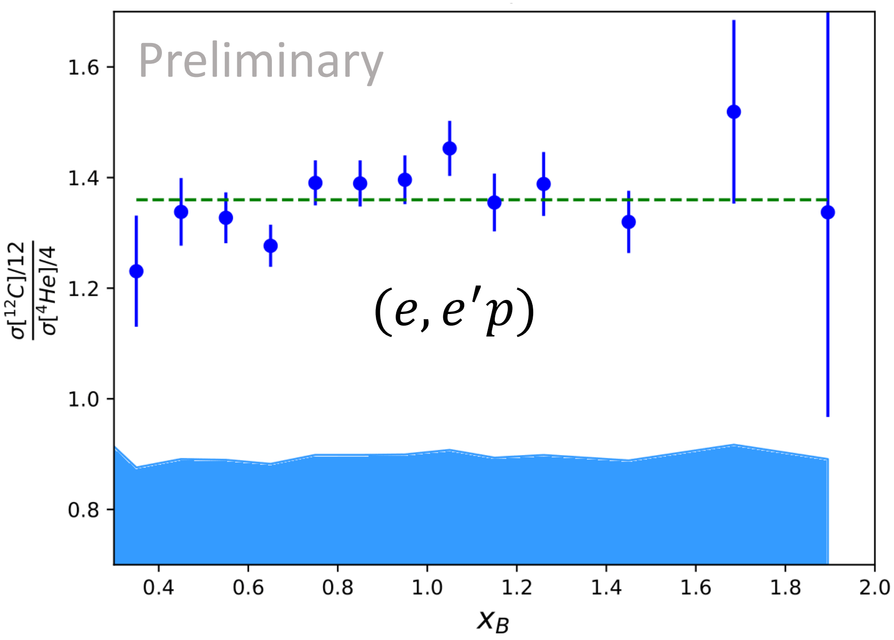
Same analysis can be applied to neutrons



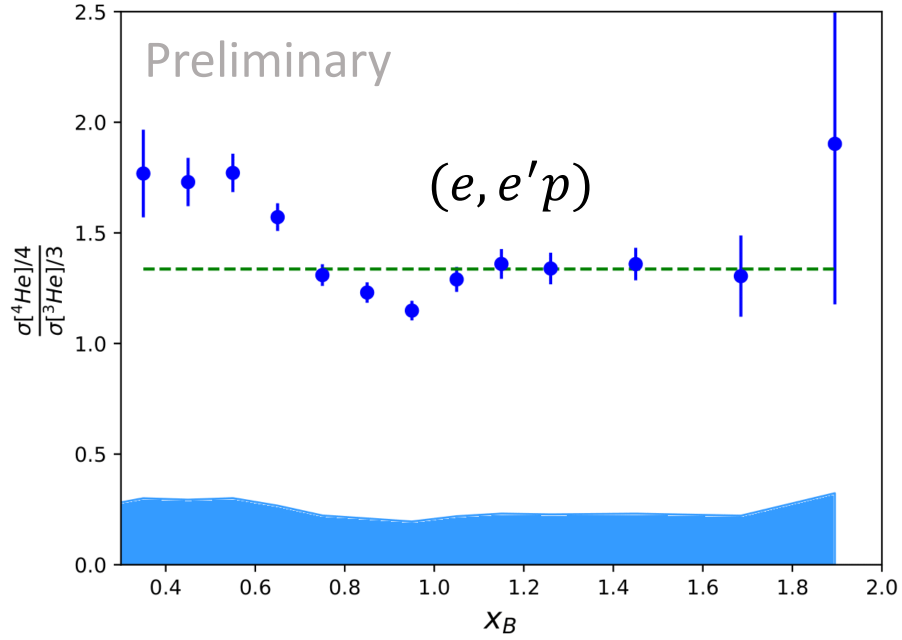
Thank you

Result

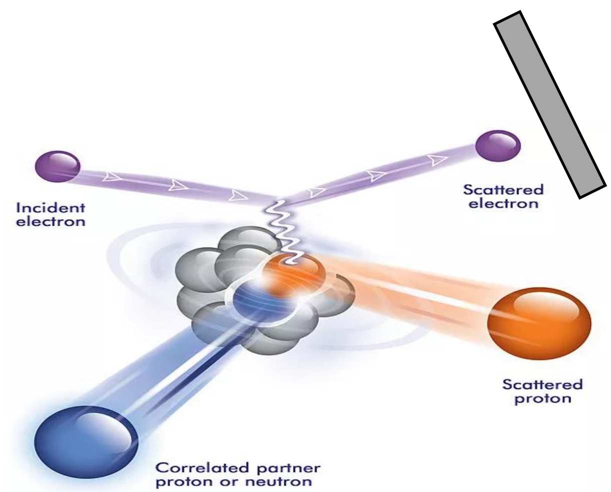
$$\frac{{}^{12}C/12}{{}^{4}He/4}$$



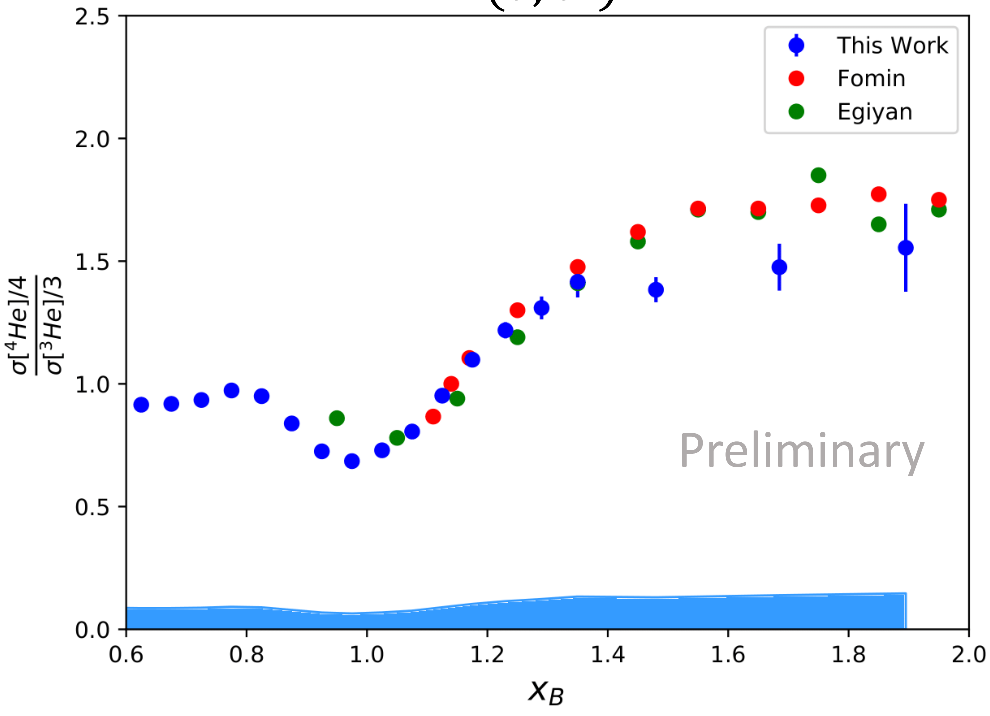
$$\frac{{}^{4}He/4}{{}^{3}He/3}$$



Inclusive Analysis

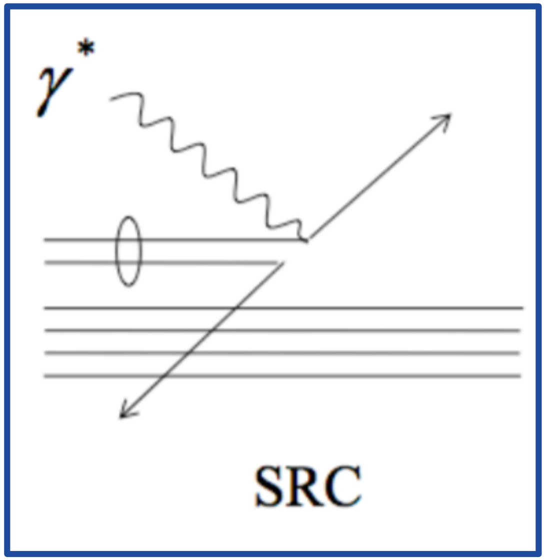


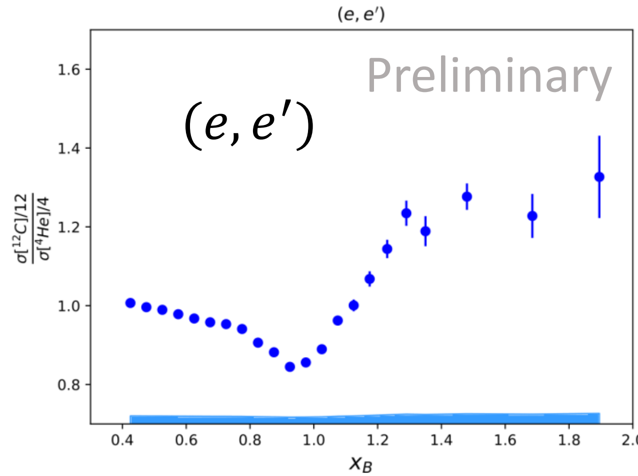
(e, e')

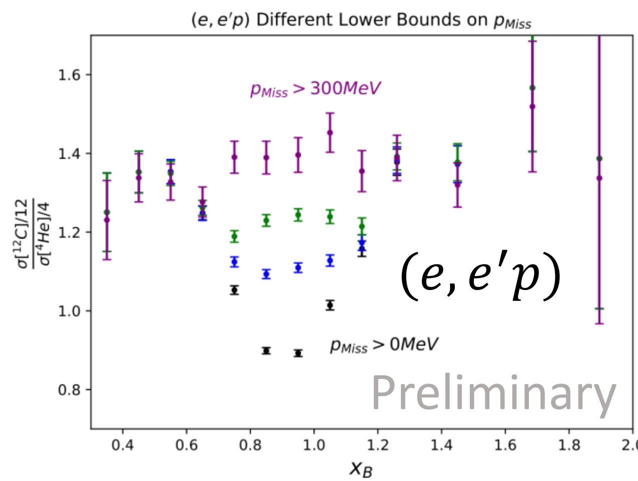


- Fomin et al. Phys. Rev. Lett. **108**, 092502 (2012)
- Egiyan et al. Phys. Rev. Lett. **96**, 082501 (2006)

Mean Field Contribution







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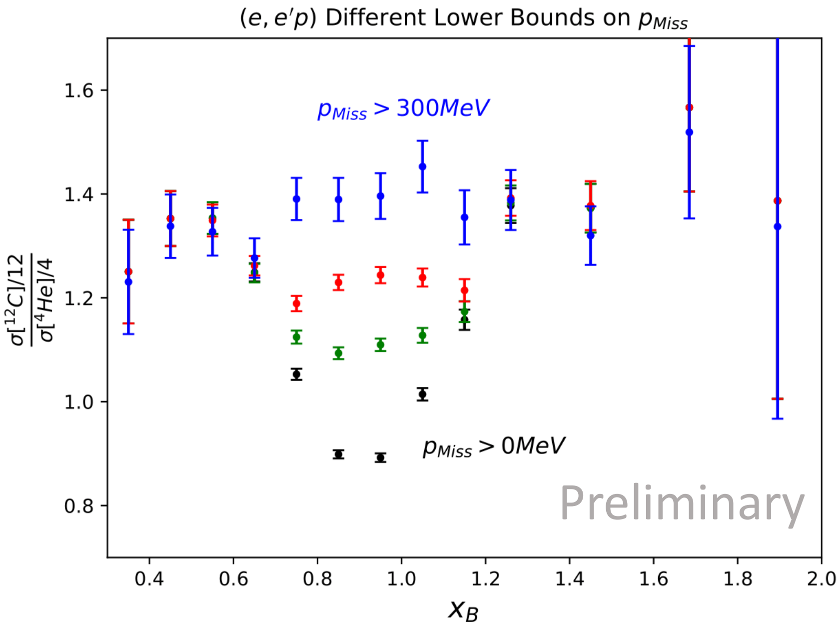
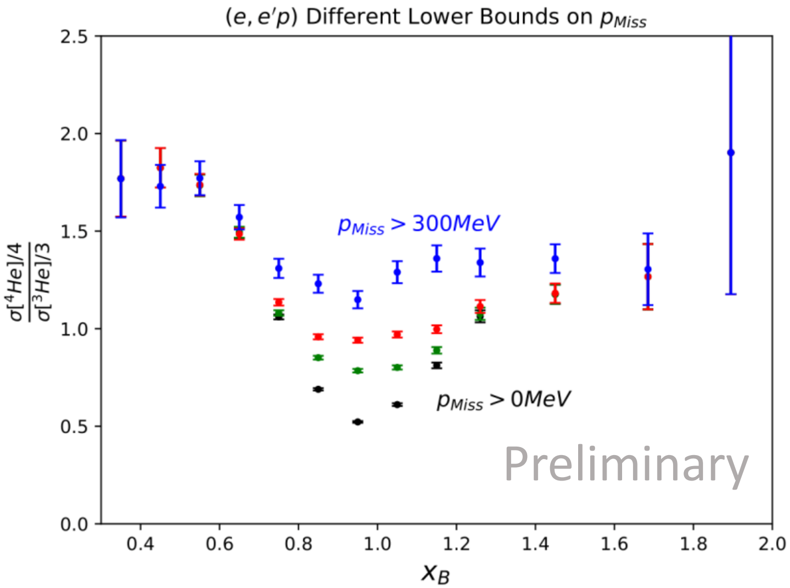
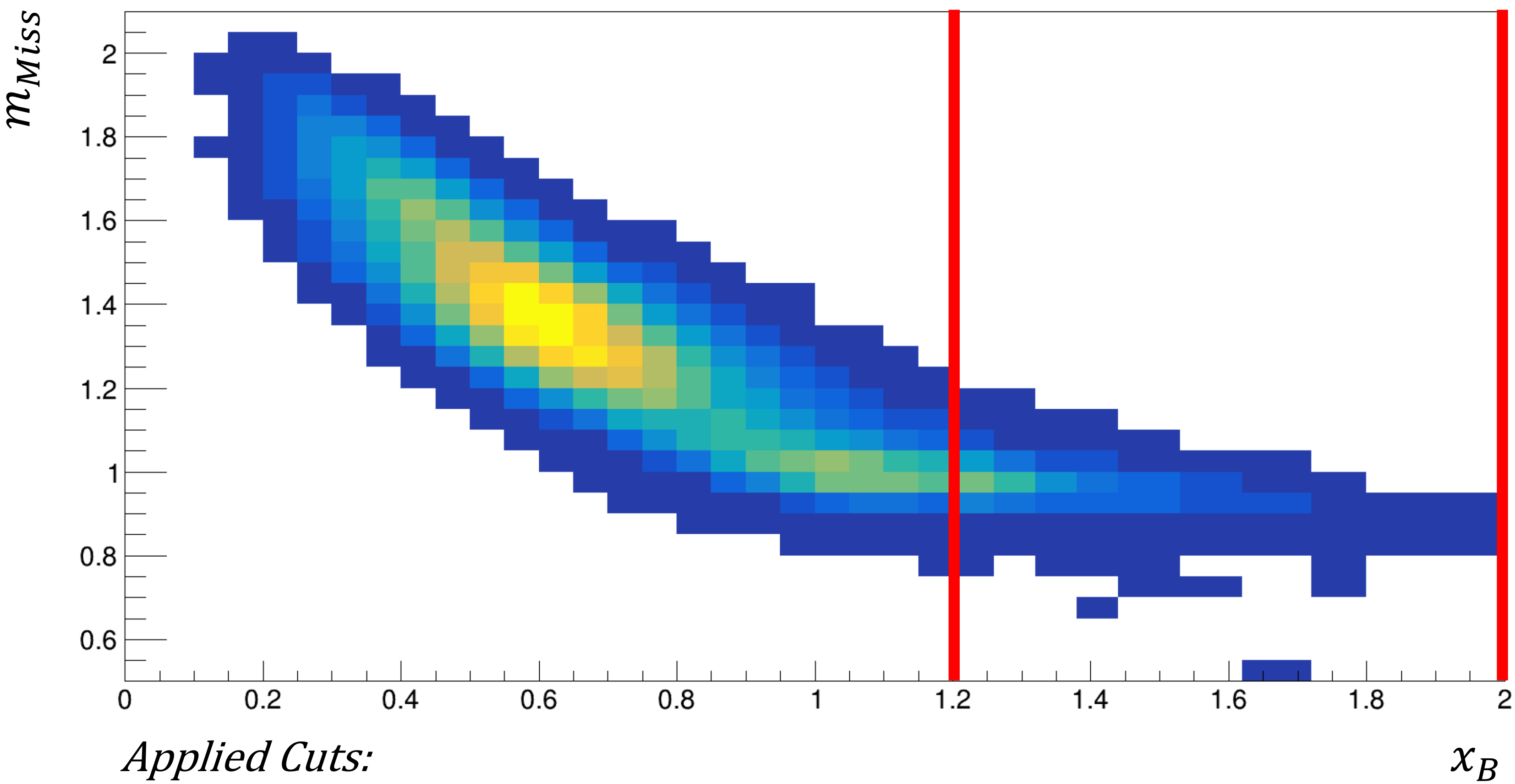
p_{Miss}


(e, e′p) Different Lower Bounds on p_{Miss}
$p_{Miss} > 300MeV$
$p_{Miss} > 0MeV$
Preliminary
$\frac{\sigma[^{12}C]/12}{\sigma[^4He]/4}$
x_B
1.6
1.4
1.2
1.0
0.8
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0


(e, e′p) Different Lower Bounds on p_{Miss}
$p_{Miss} > 300MeV$
$p_{Miss} > 0MeV$
Preliminary
$\frac{\sigma[^4He]/4}{\sigma[^3He]/3}$
x_B
2.5
2.0
1.5
1.0
0.5
0.0
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

$\frac{p}{q}$ Cut in Missing Momentum Distribution

x_B vs. m_{Miss}

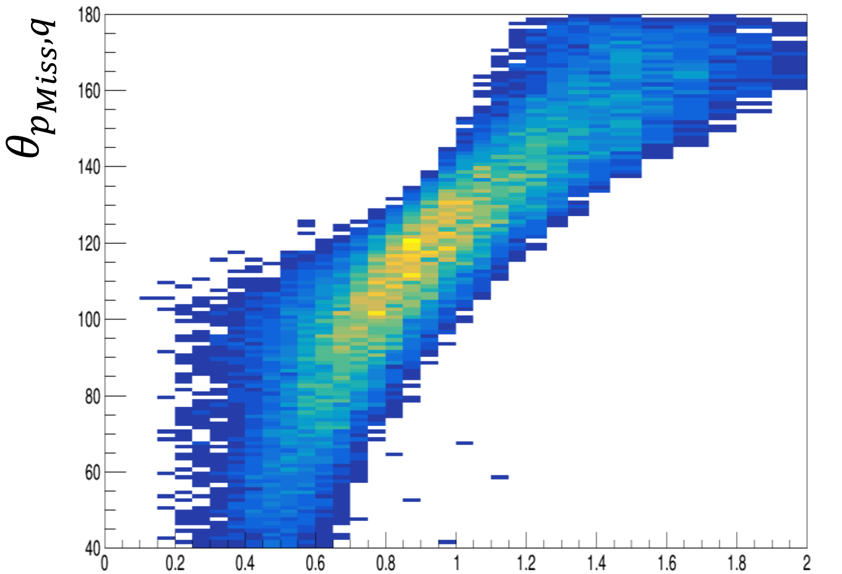


Applied Cuts:

- $\theta_{pq} < 25^{\circ}$
- $0.3\ GeV < p_{Miss} < 0.6\ GeV$
- $0.62 < \frac{p}{q} < 0.96$

Antiparallel Kinematics

x_B vs. $\theta_{p_{Miss},q}$



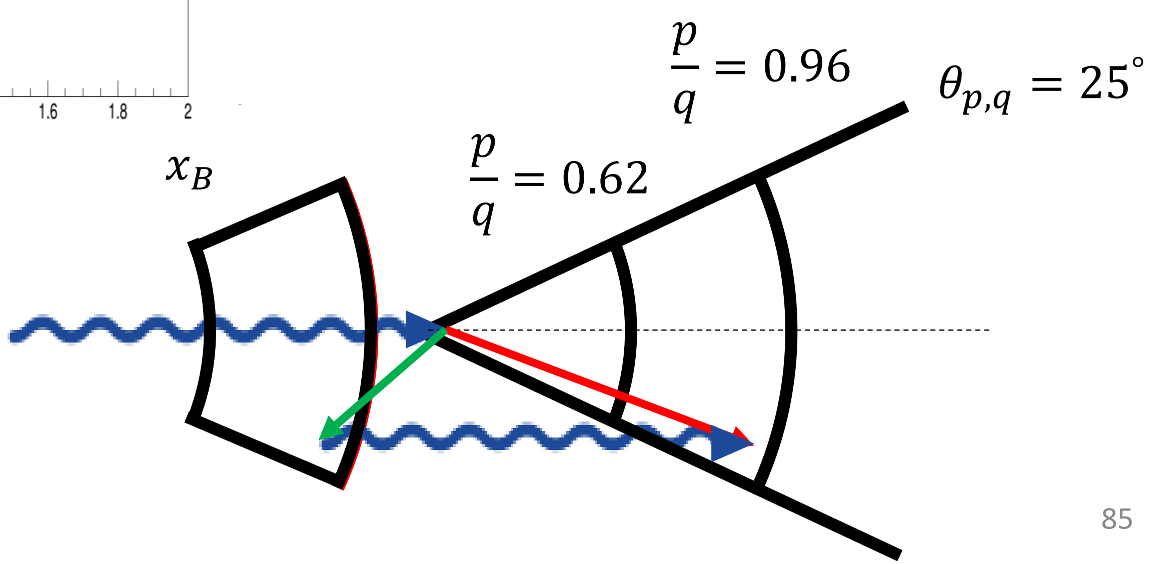
$$1.2 < x_B < 2$$

$$0.62 < \frac{p}{q} < 0.96$$

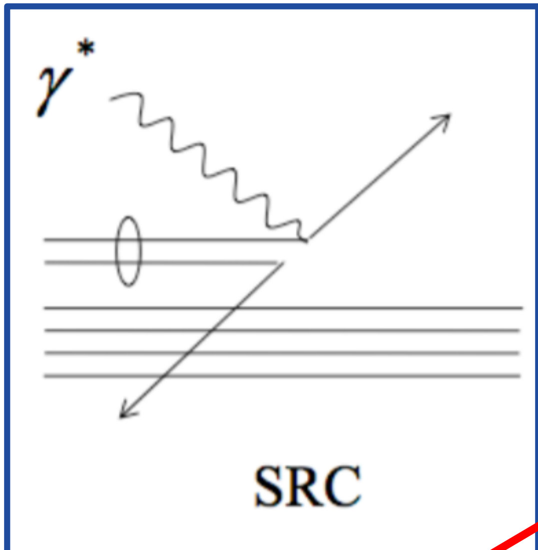
$$\theta_{pq} < 25^{\circ}$$

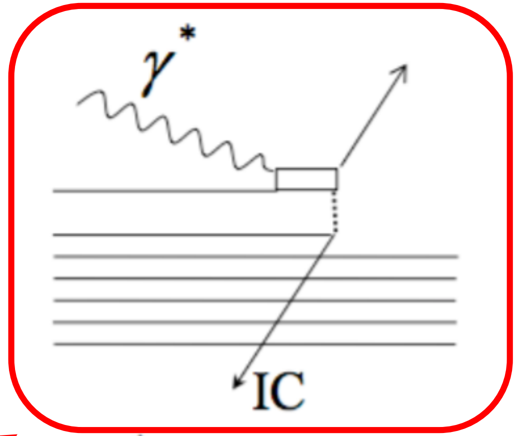
Applied Cuts:

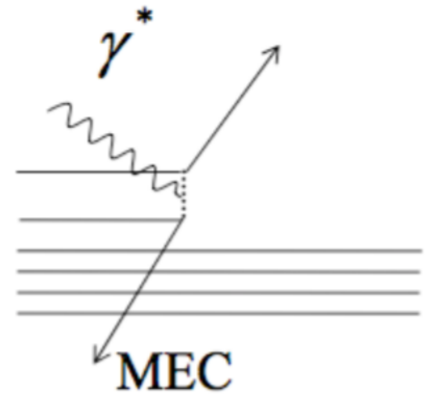
- $\theta_{pq} < 25^{\circ}$
- $0.9\ GeV < m_{Miss} < 1.1\ GeV$
- $0.2\ GeV < p_{Miss} < 0.6\ GeV$

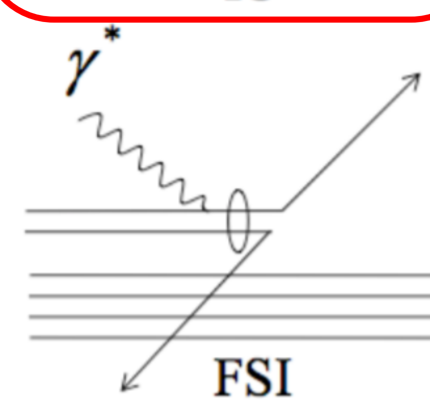


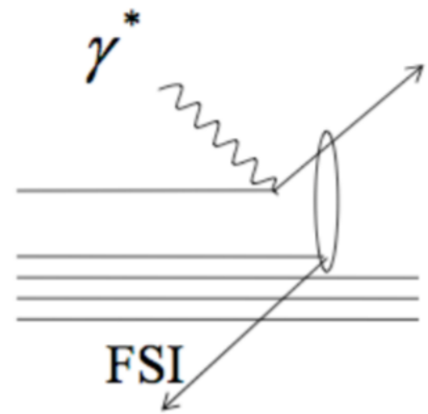
Contributions to the Cross Section





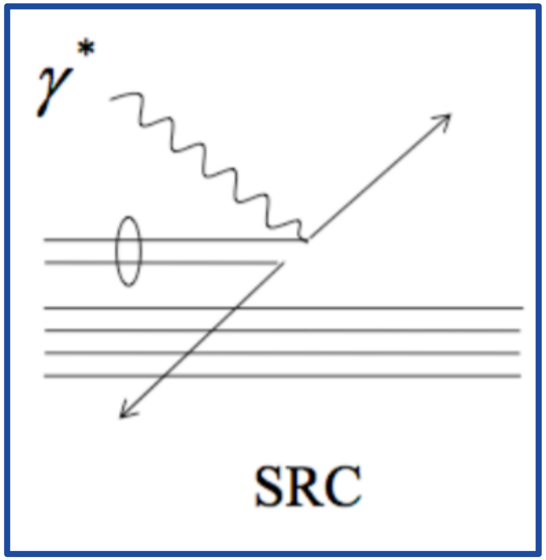






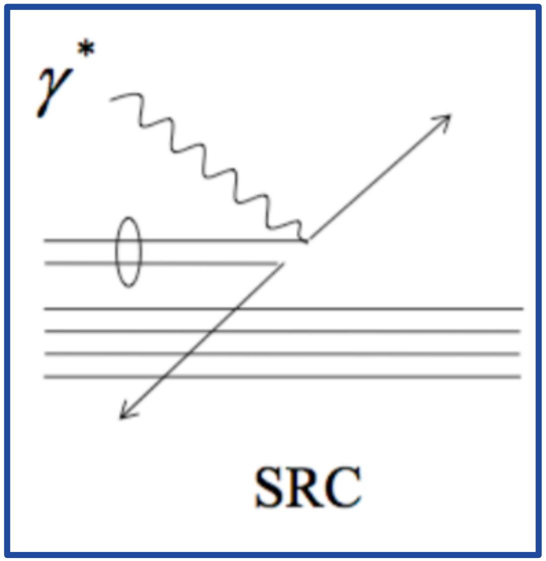
1. $\boxed{1.2 < x_B < 2}$
2. $0.62 < \frac{p}{q} < 0.96$
3. $\theta_{pq} < 25^\circ$
4. $0.9\ GeV < m_{Miss} < 1.1\ GeV$
5. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

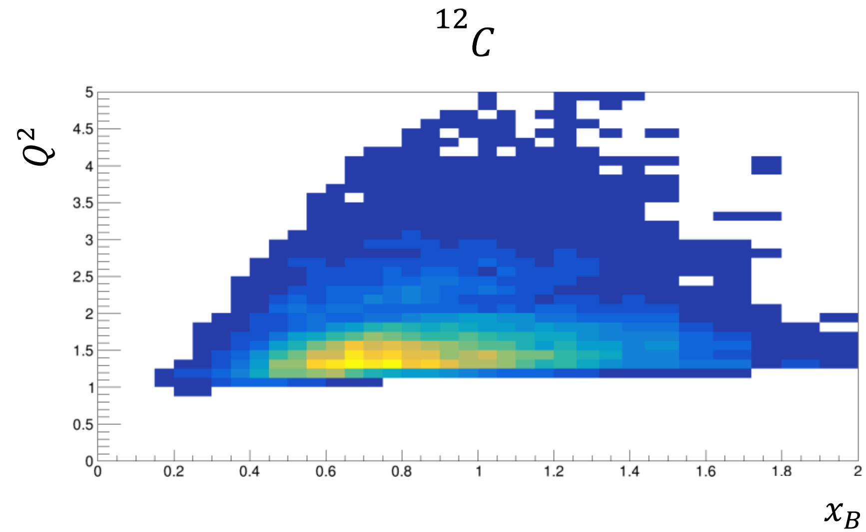
Contributions to the Cross Section



1. [redacted] $x_B < 2$
2. $0.62 < \frac{p}{q}$ [redacted]
3. $\theta_{pq} < 25^{\circ}$
4. $0.9\ GeV < m_{Miss} < 1.1\ GeV$
5. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

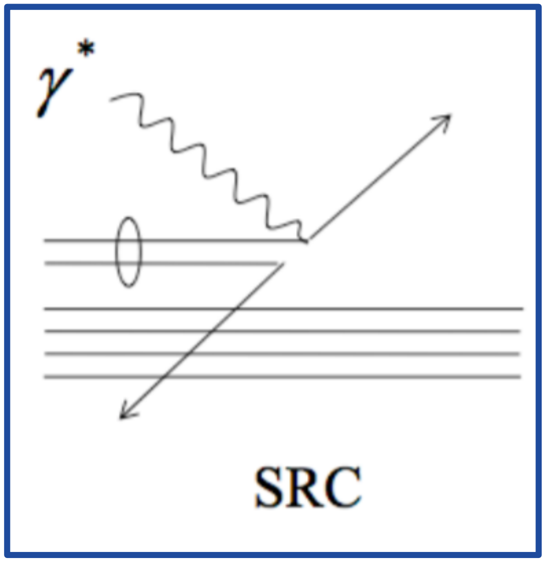
Contributions to the Cross Section

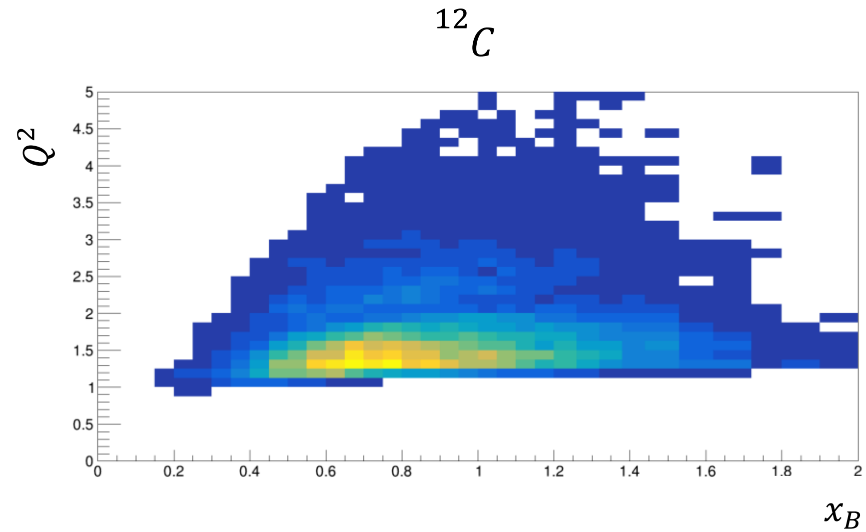




1. [redacted] $x_B < 2$
2. $0.62 < \frac{p}{q}$ [redacted]
3. $\theta_{pq} < 25^{\circ}$
4. $0.9\ GeV < m_{Miss} < 1.1\ GeV$
5. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

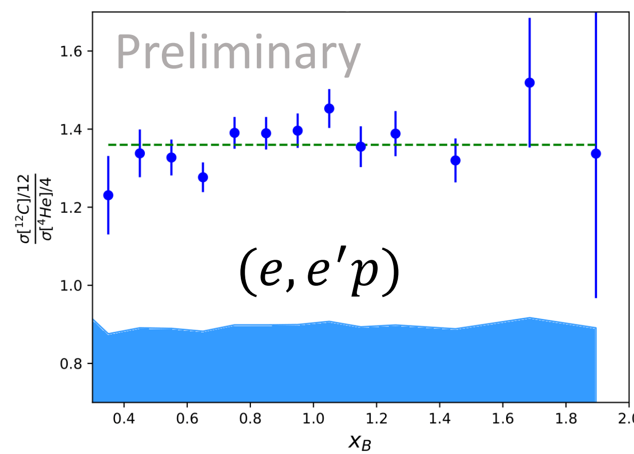
Contributions to the Cross Section





1. [redacted] $x_B < 2$
2. $0.62 < \frac{p}{q}$ [redacted]
3. $\theta_{pq} < 25^\circ$
4. $0.9\ GeV < m_{Miss} < 1.1\ GeV$
5. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

Apply Cuts



Maintaining High Q^2