Observation of Nuclear Scaling Below the Inclusive Limit

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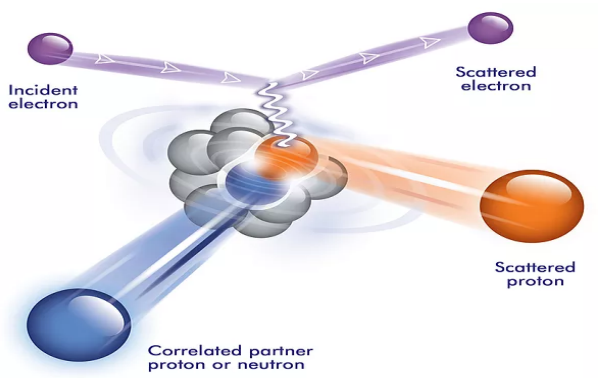
MIT

July 23rd , 2020

SRC Measurements



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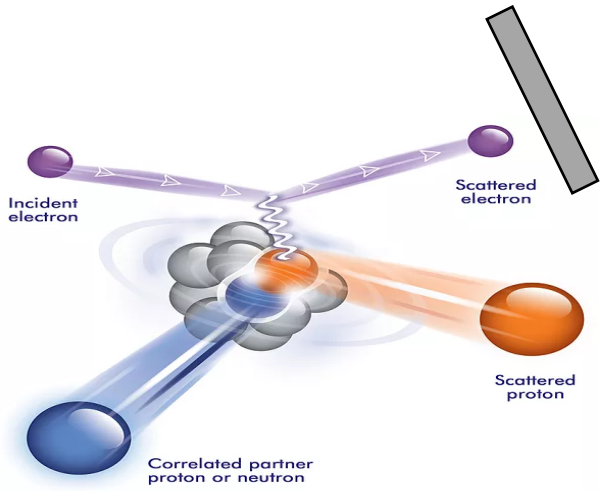

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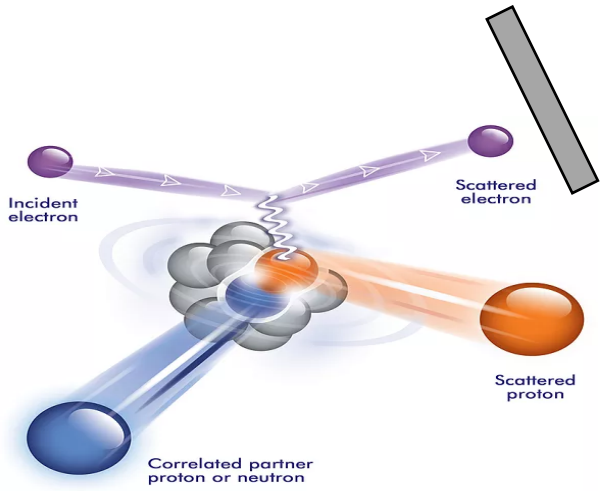

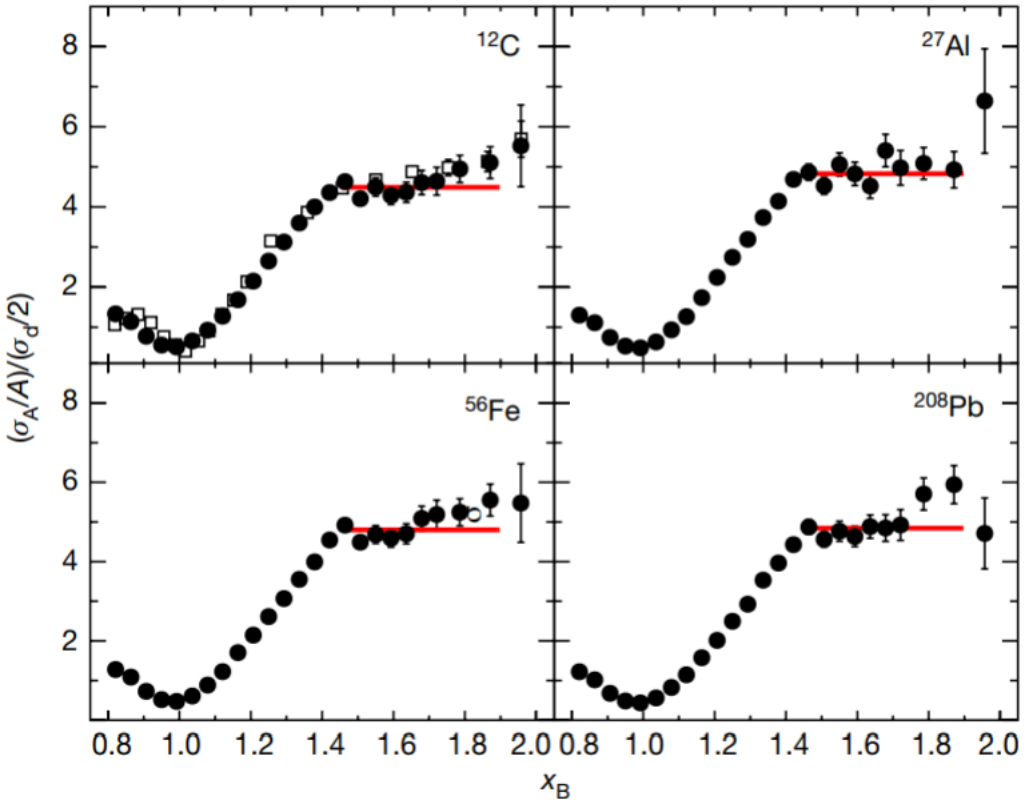

- Schmookler Nature **566**, 354-358 (2019)

$$x_B \equiv \frac{Q^2}{2m_N\omega} = \frac{q^2 - \omega^2}{2m_N\omega}$$

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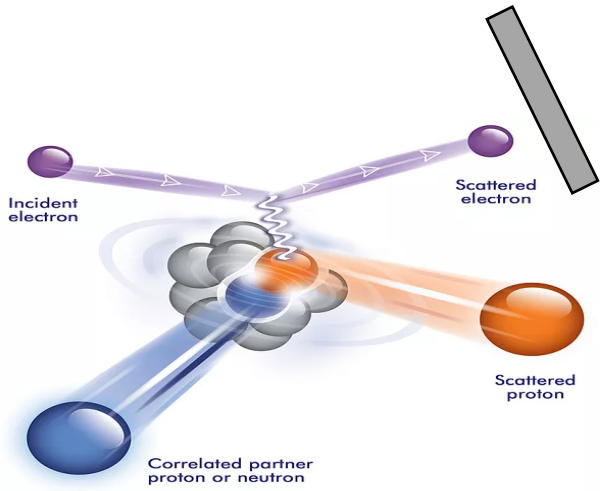

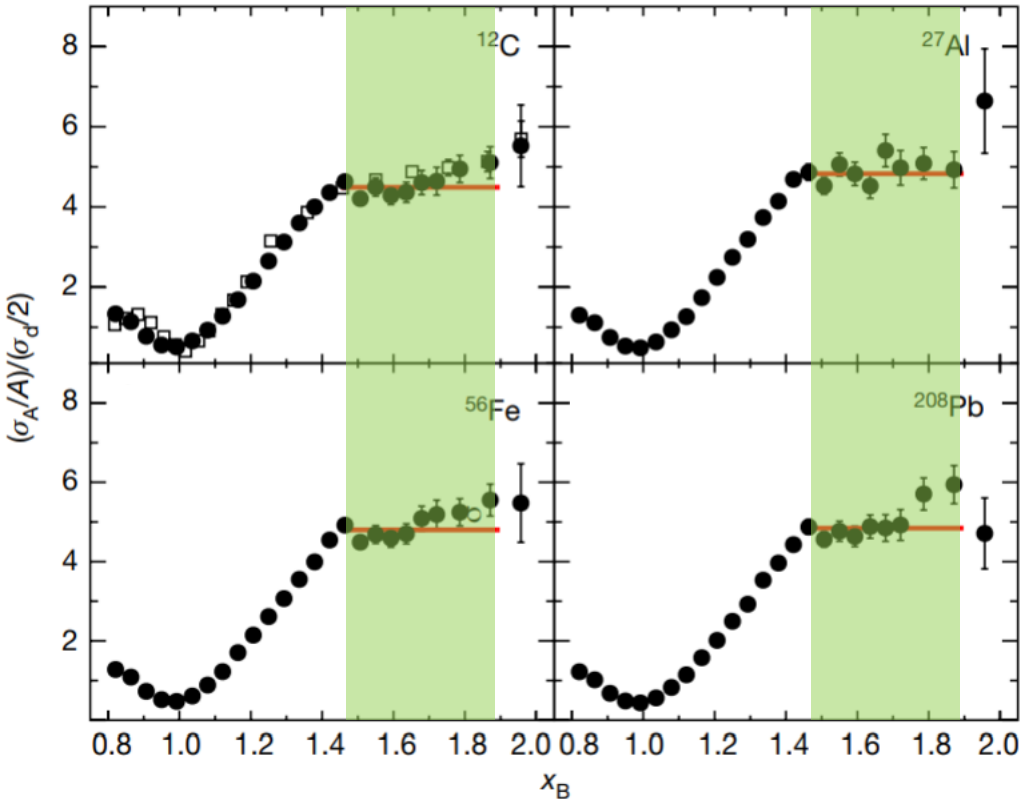

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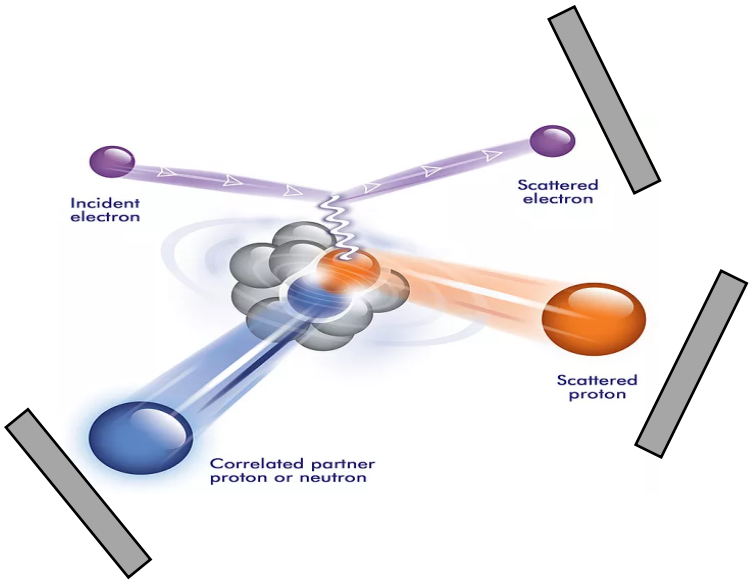

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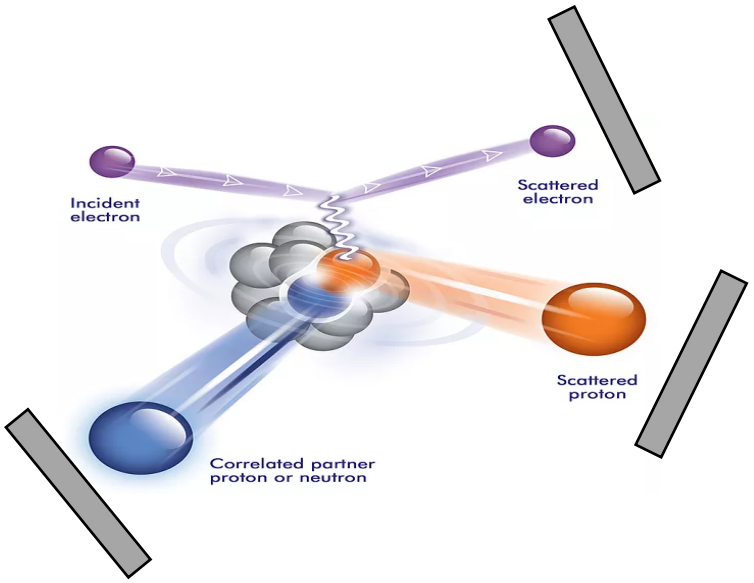

- Detect 3 coincidence particles
- Need to detect neutron for $(e, e'pn)$
- $(e, e'pp)$ events are more rare

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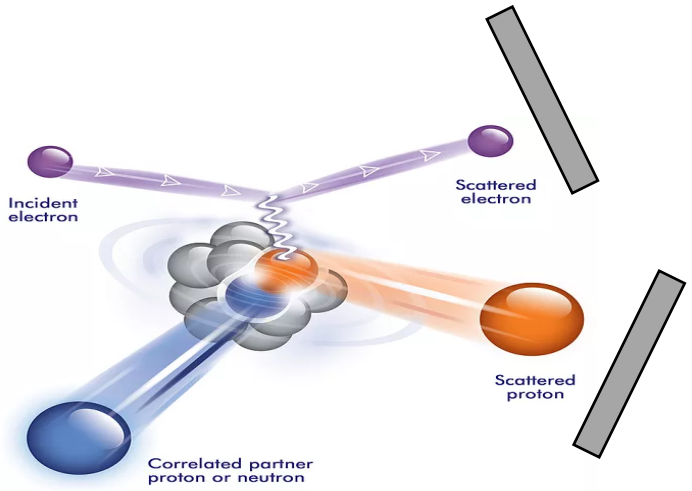

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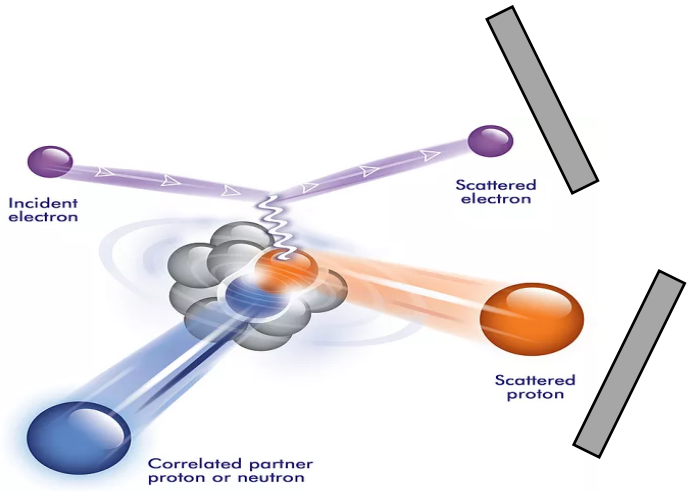

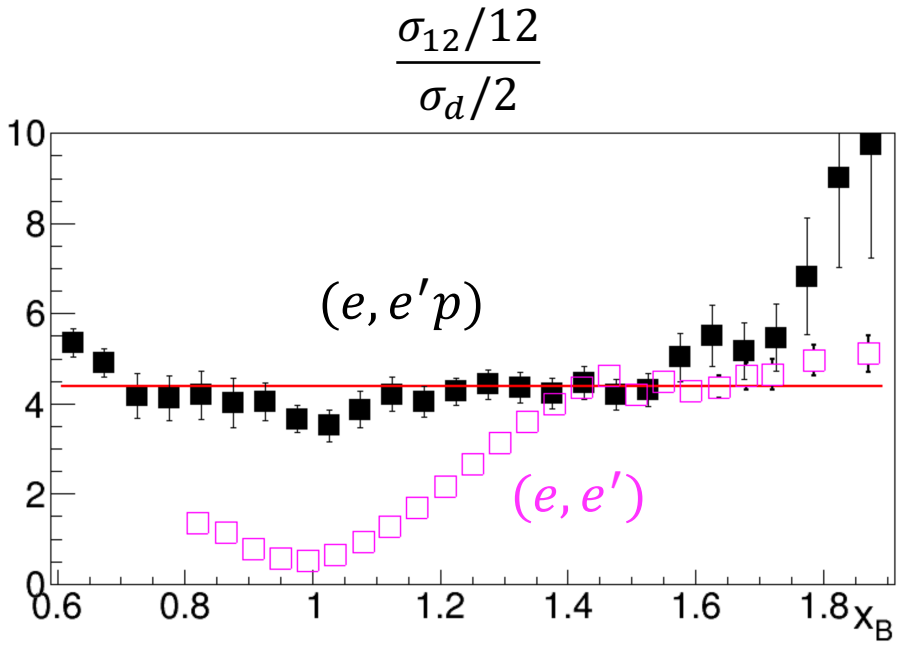

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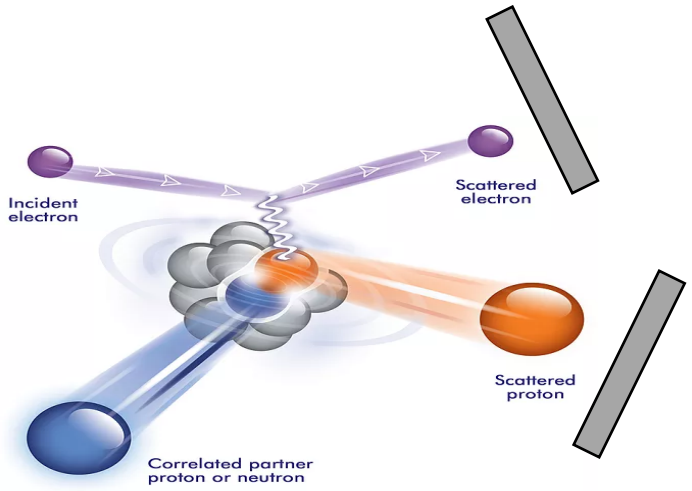
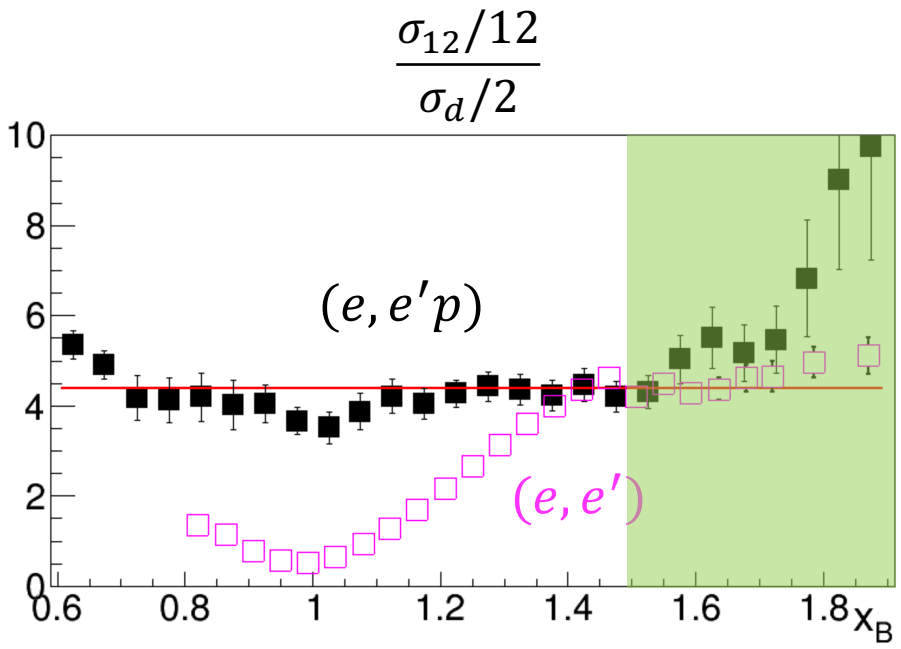
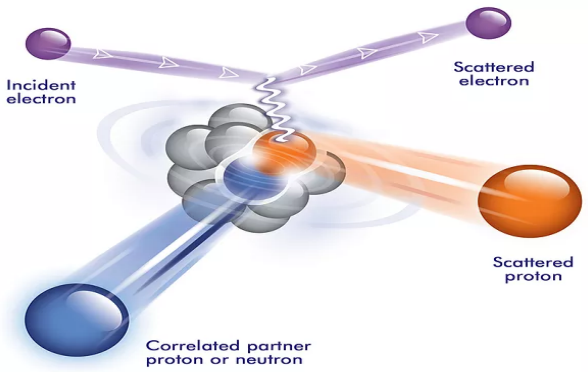


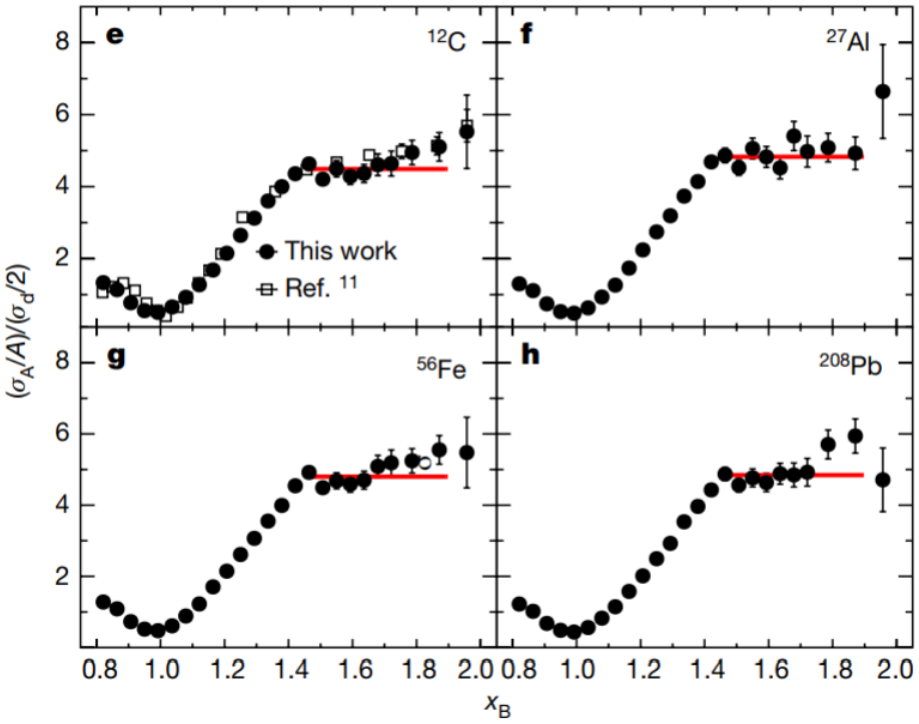


This Analysis

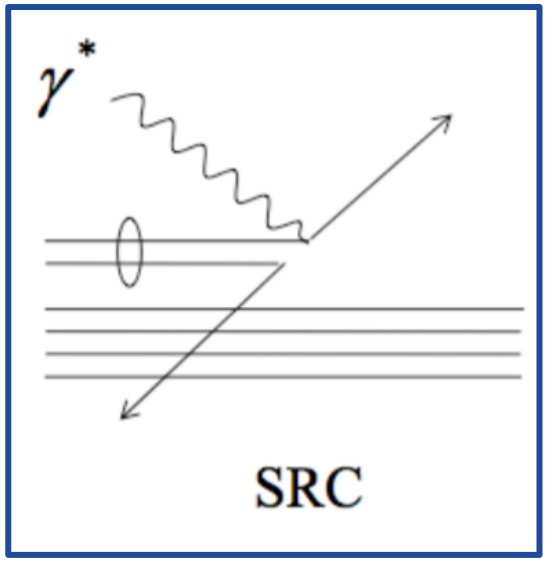
<u>CLAS eg2</u>

- 5 GeV
- (e,e'p)
- $d, {}^{12}C, {}^{27}Al, {}^{56}Fe, {}^{208}Pb$





Contributions to the Cross Section



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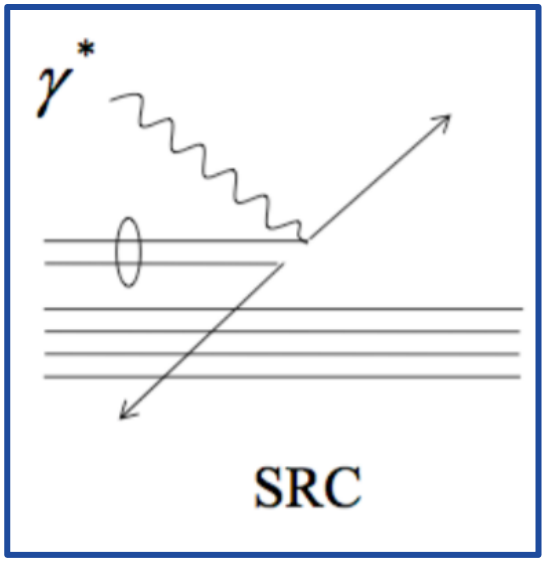

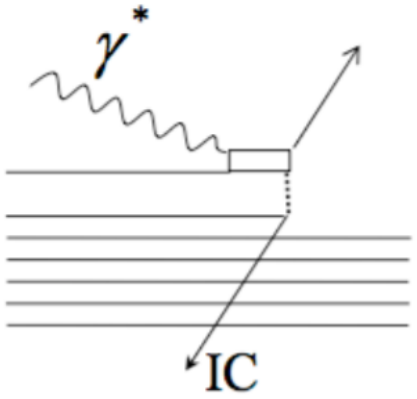

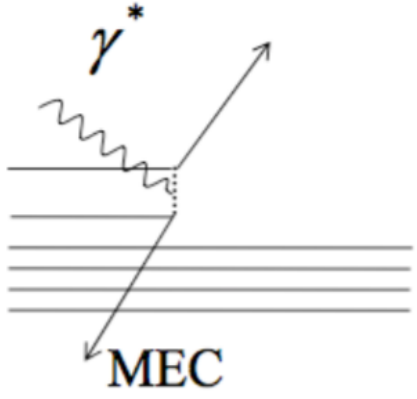

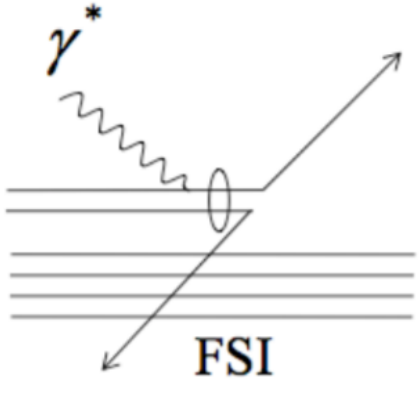

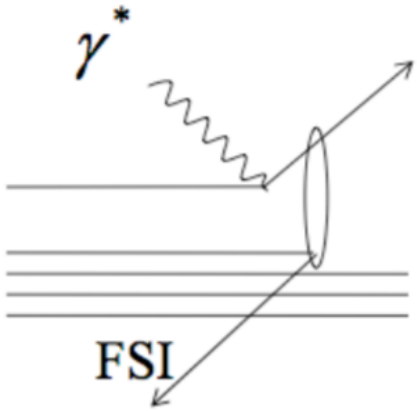

- Frankfurt, Sargsian, and Strikman PRC **56**, 1124 (1997)
- Colle, Cosyn, and Ryckebusch, PRC **93**, 034608 (2016)

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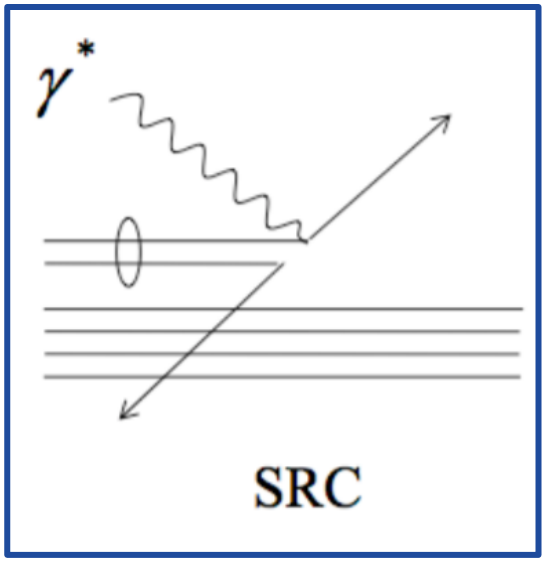

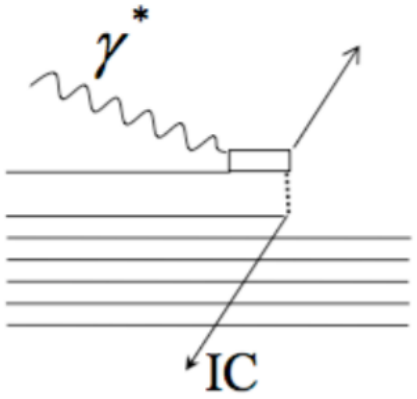

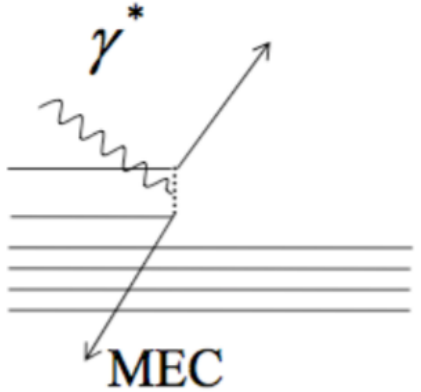

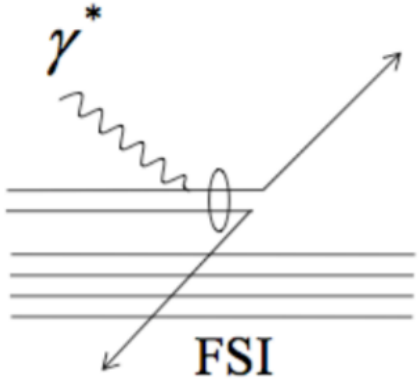

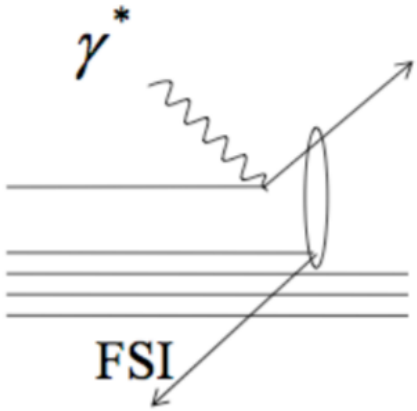

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3. $\theta_{pq} < 25^\circ$
4. $0.62 < \frac{p}{q} < 0.96$
5. $0.8\ GeV < m_{Miss} < 1.05\ GeV$
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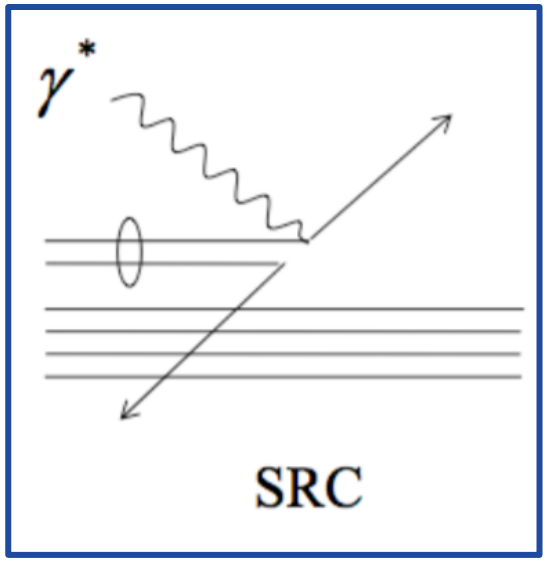

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- Physics Letters B 722 (2013) 63–68
- Science 346, 614 (2014)
- Nature 560, 617–621 (2018)
- Physics Letters B 797 (2019) 134792
- Cohen et al. Phys. Rev. Lett. 121, 092501 2018
- Duer et al. Phys. Rev. Lett. 122, 172502 2019

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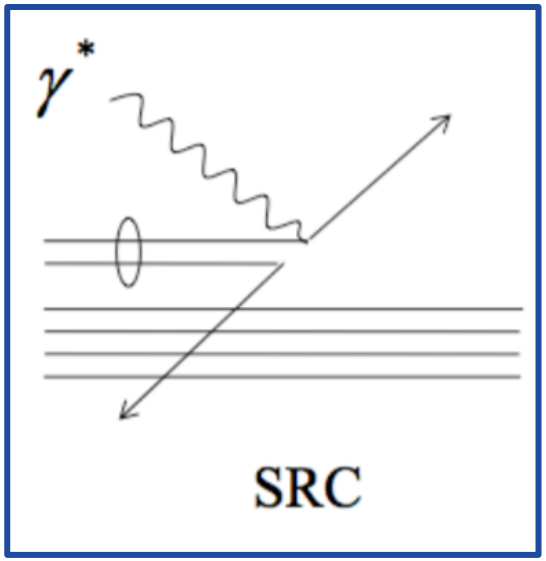

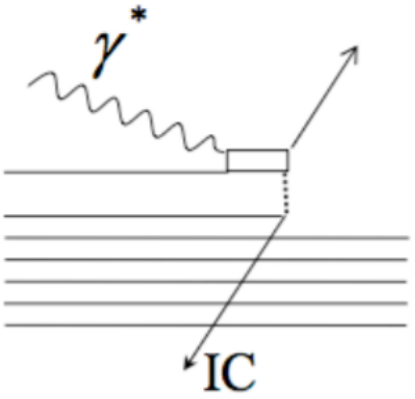

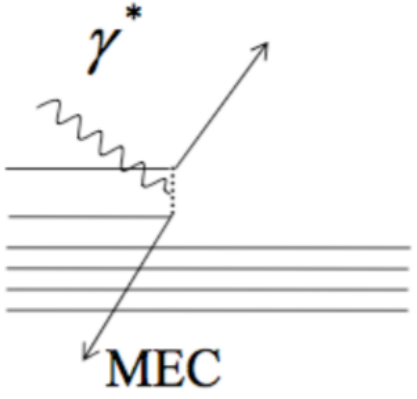

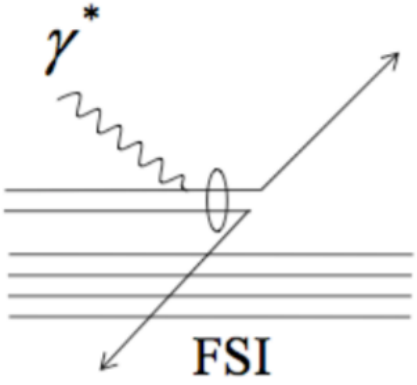

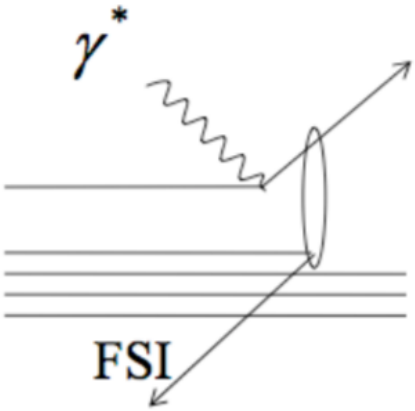

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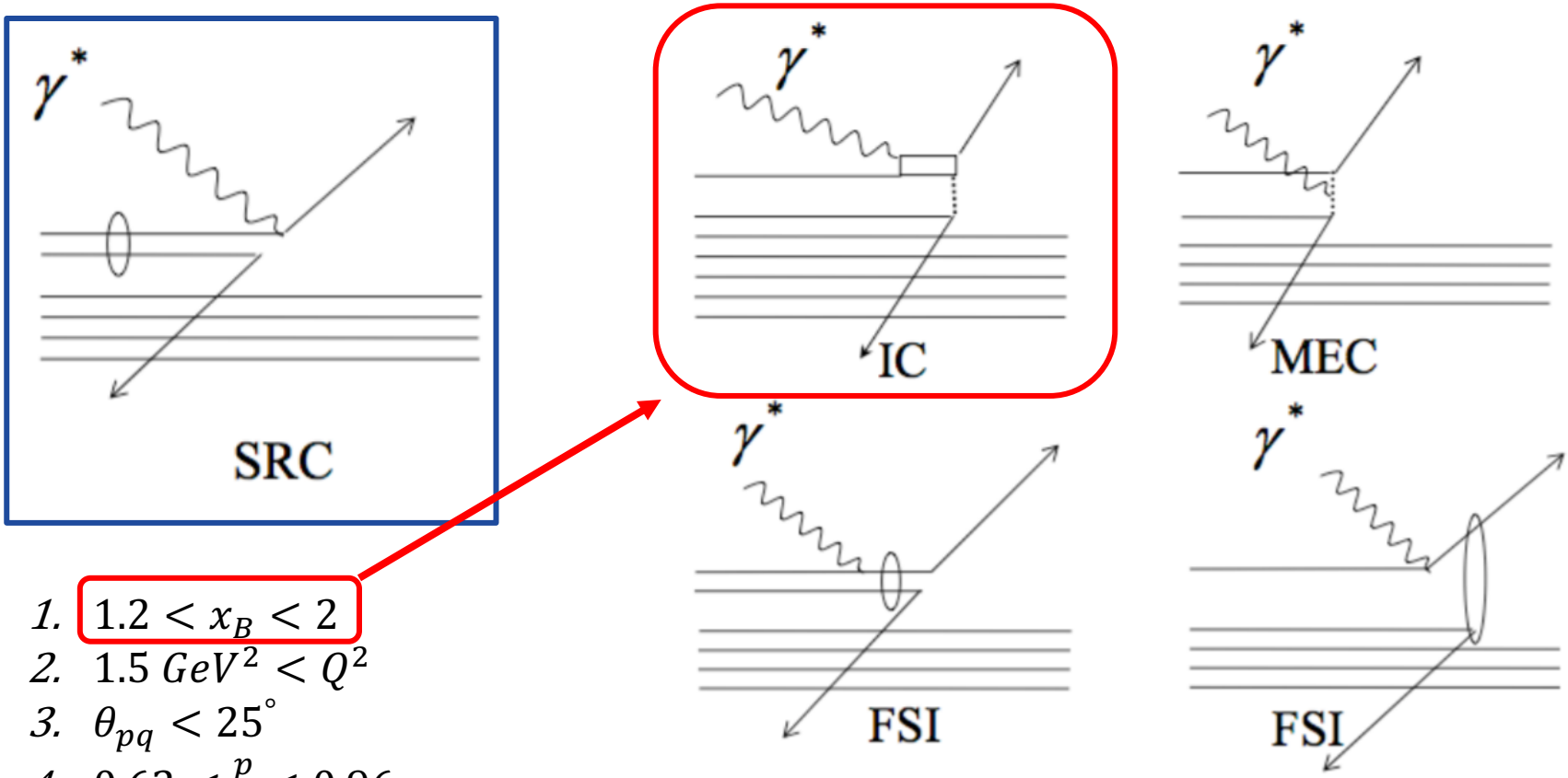

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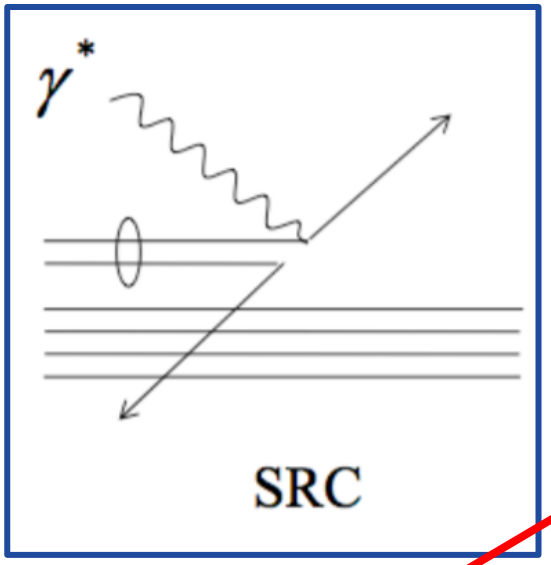

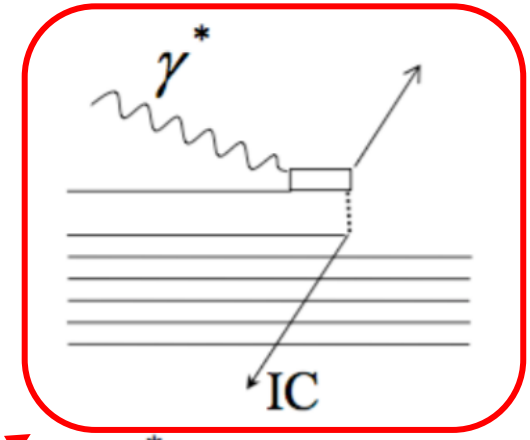

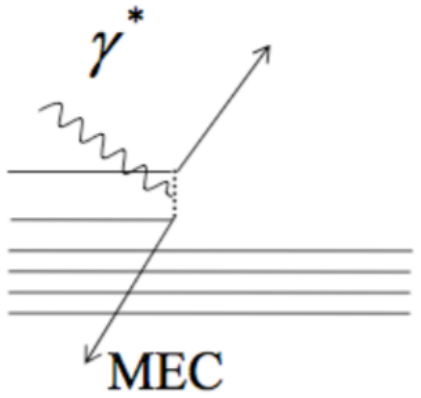

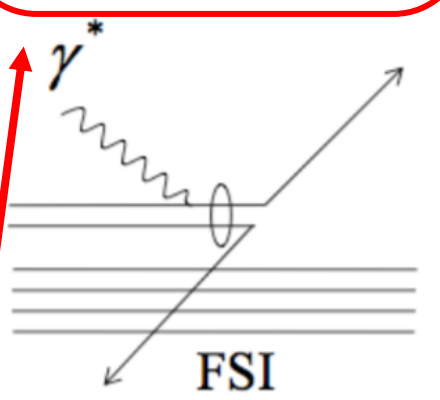

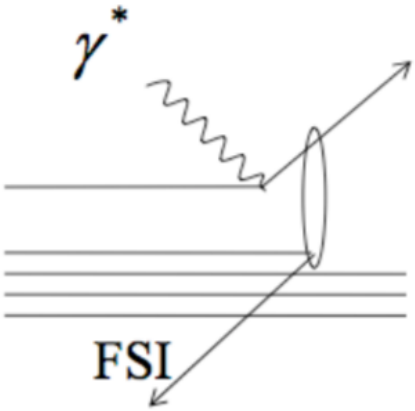

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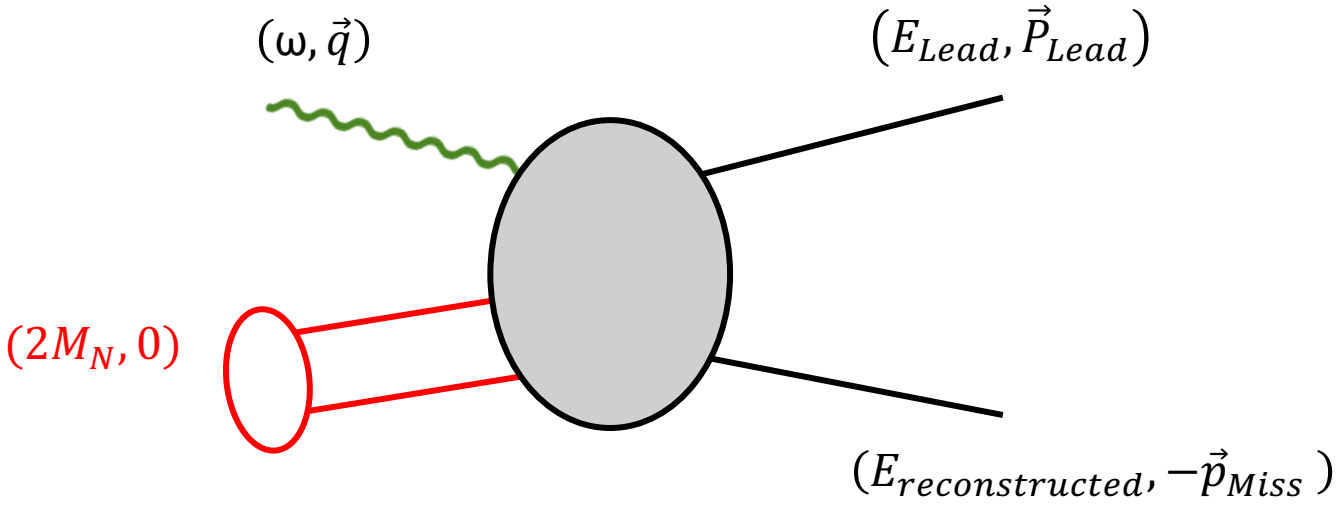
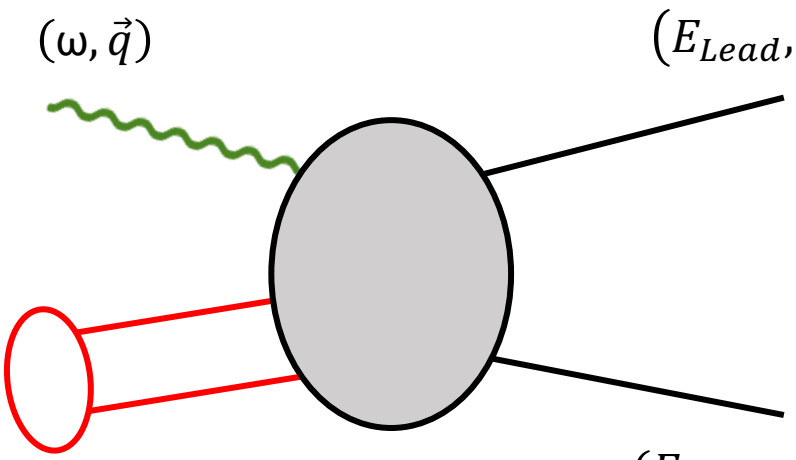
Missing Mass



Missing Mass

Know from electron measurement



Know from proton measurement

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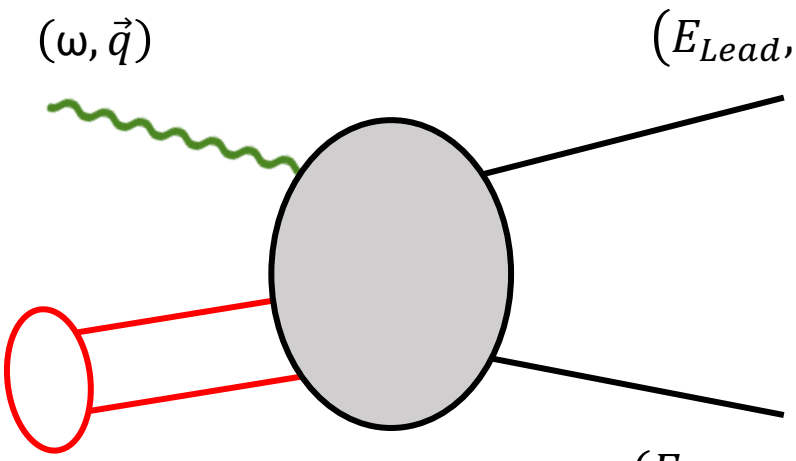

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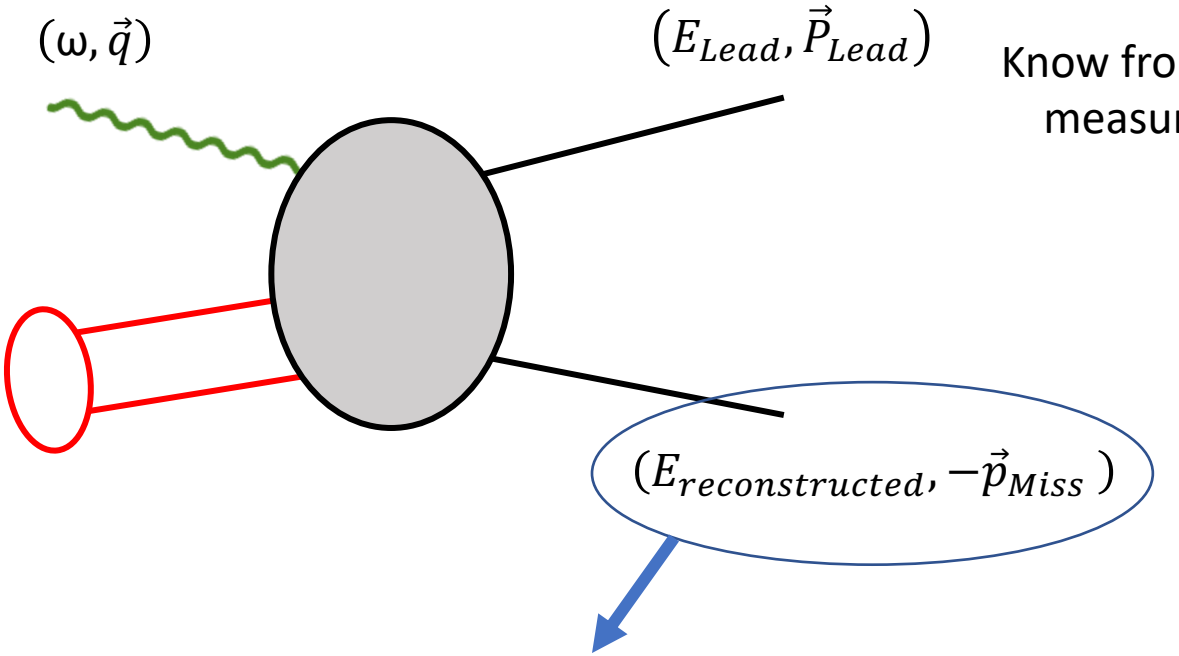
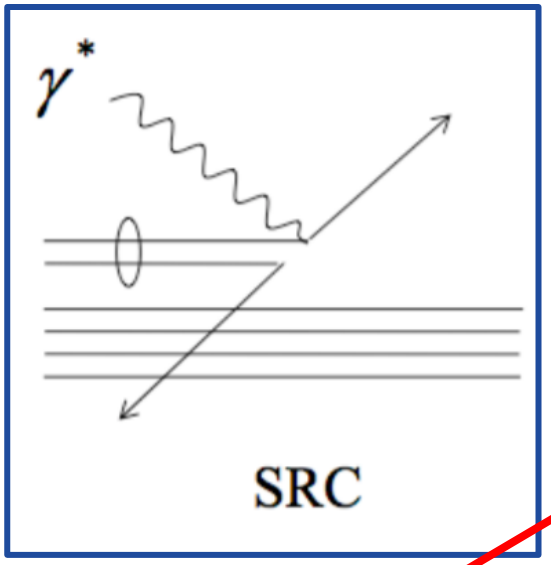


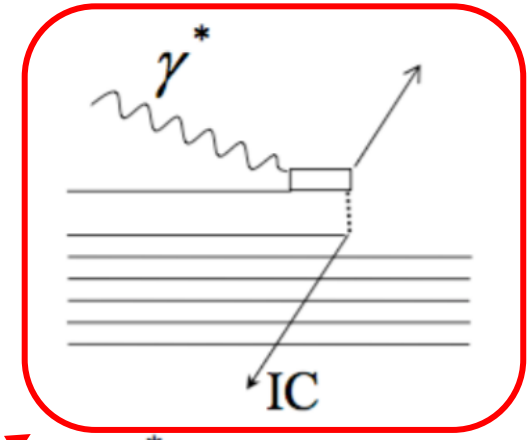
Know from proton measurement

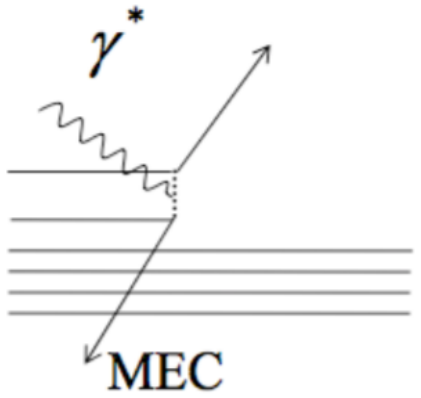
$$M^2_{miss} = \left((\omega, \vec{q}) + (2M_N, 0) - \left(E_{Lead}, \vec{P}_{Lead}\right)\right)^2$$

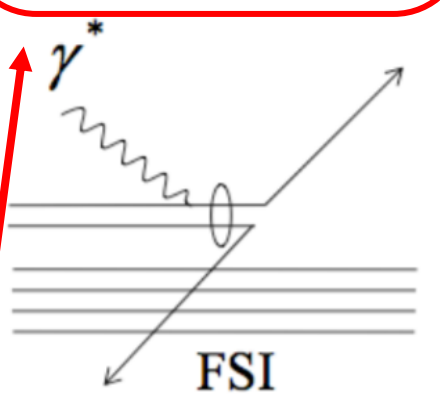
$$M^2_{miss} = E^2_{reconstructed} - p^2_{Miss}$$

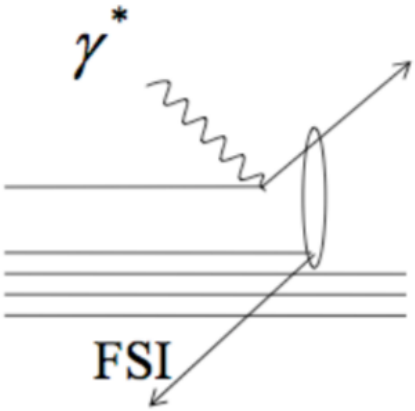
Contributions to the Cross Section











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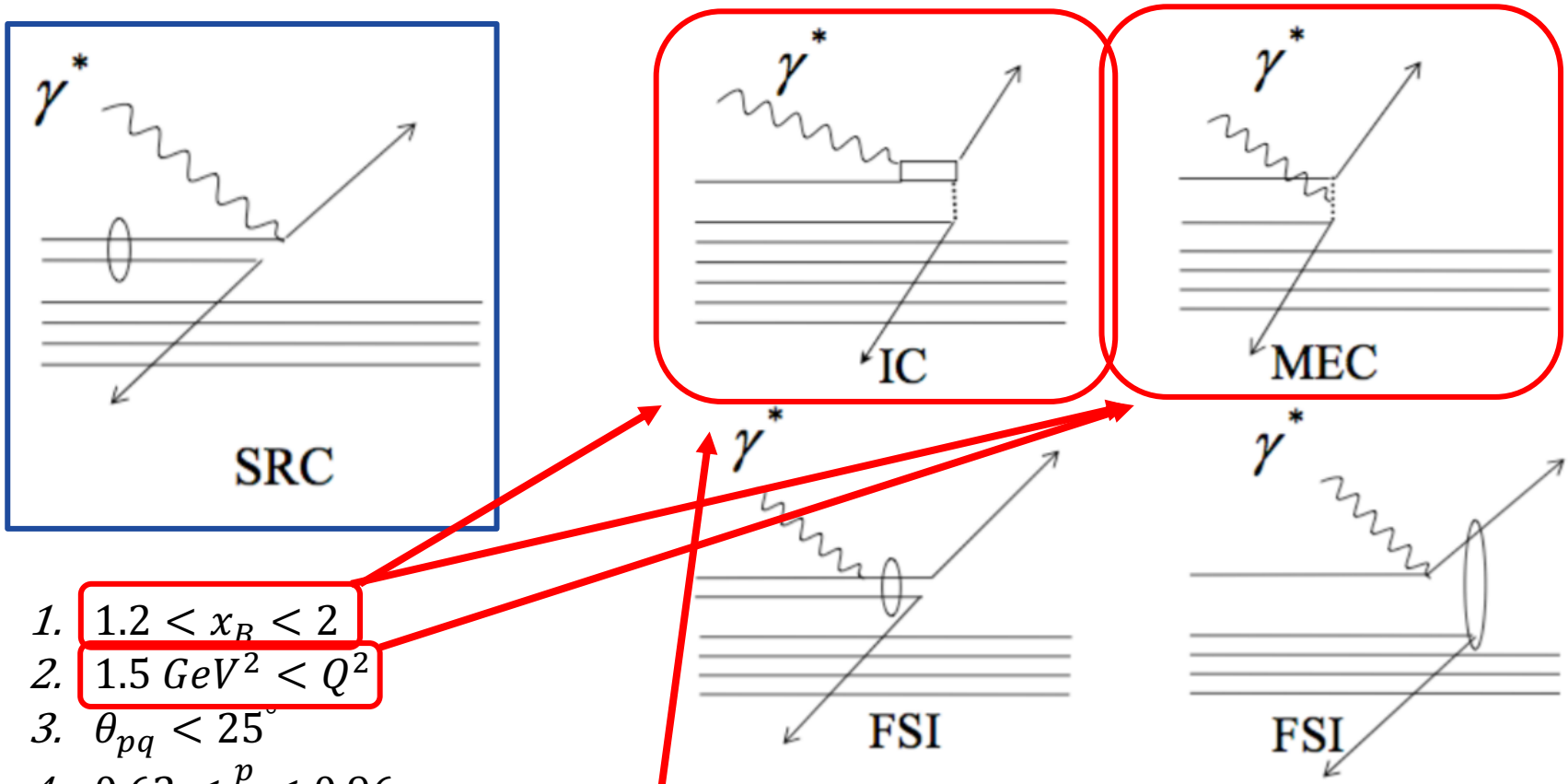

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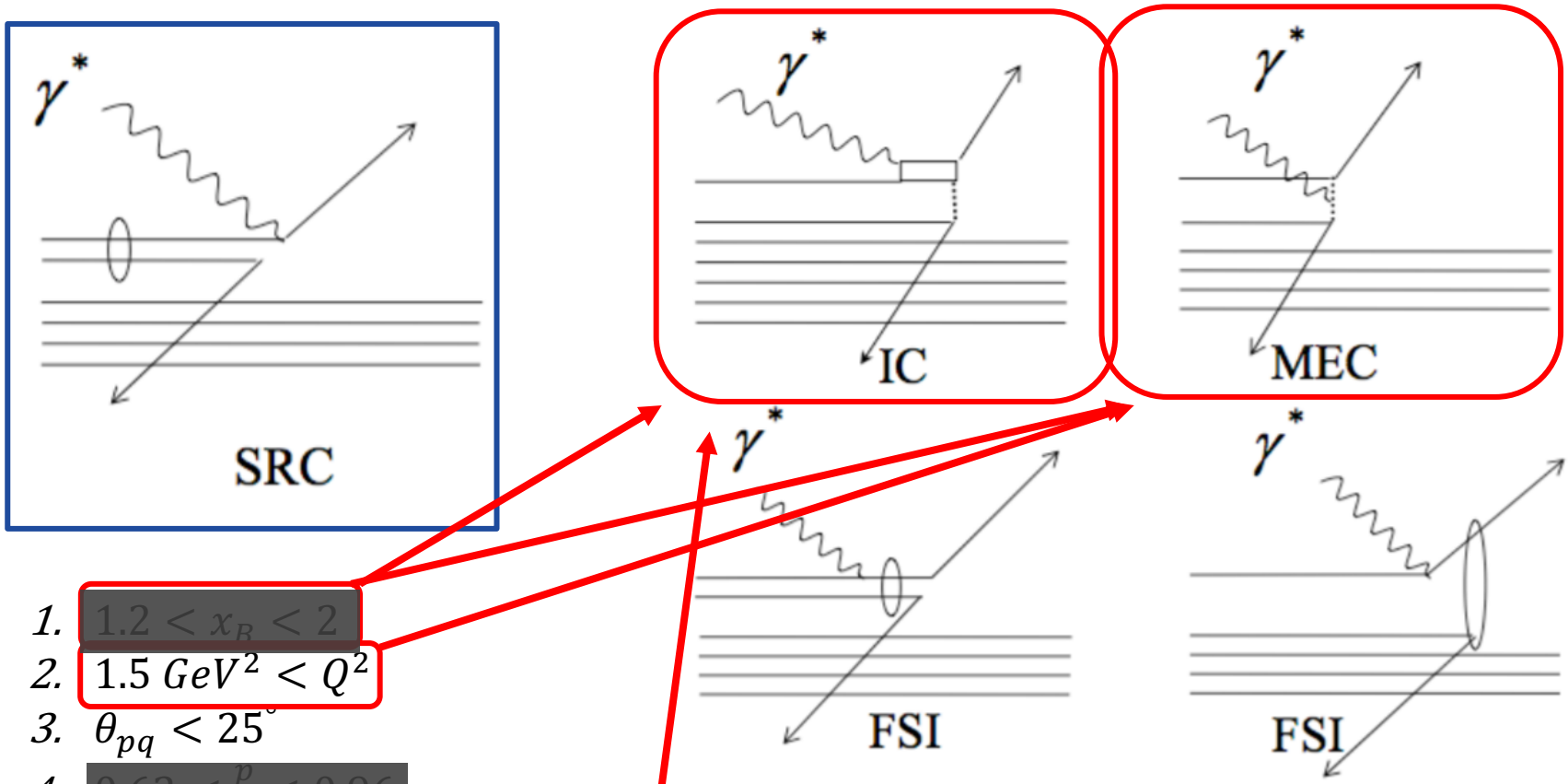

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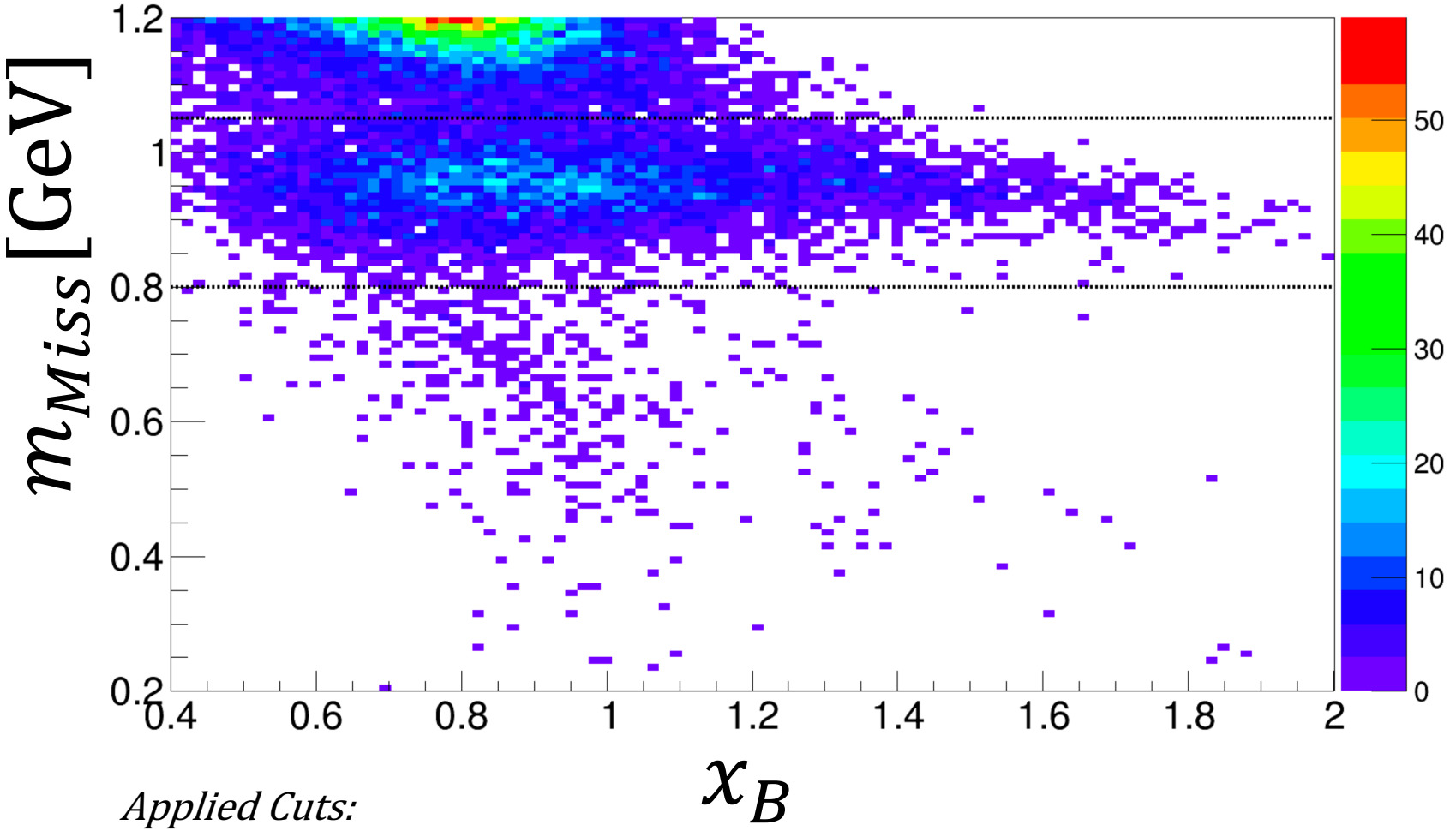
Deuterium



Applied Cuts:

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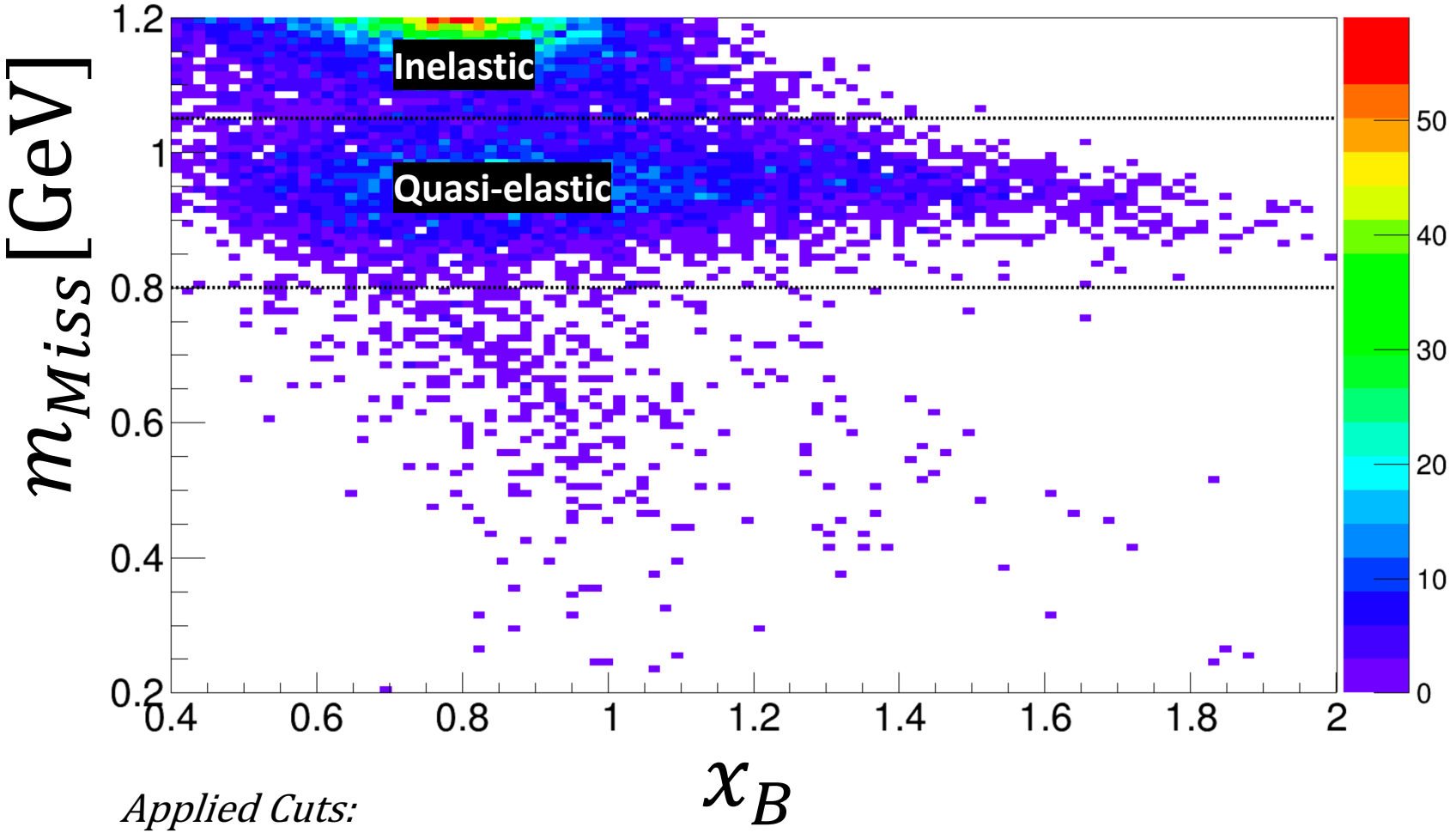

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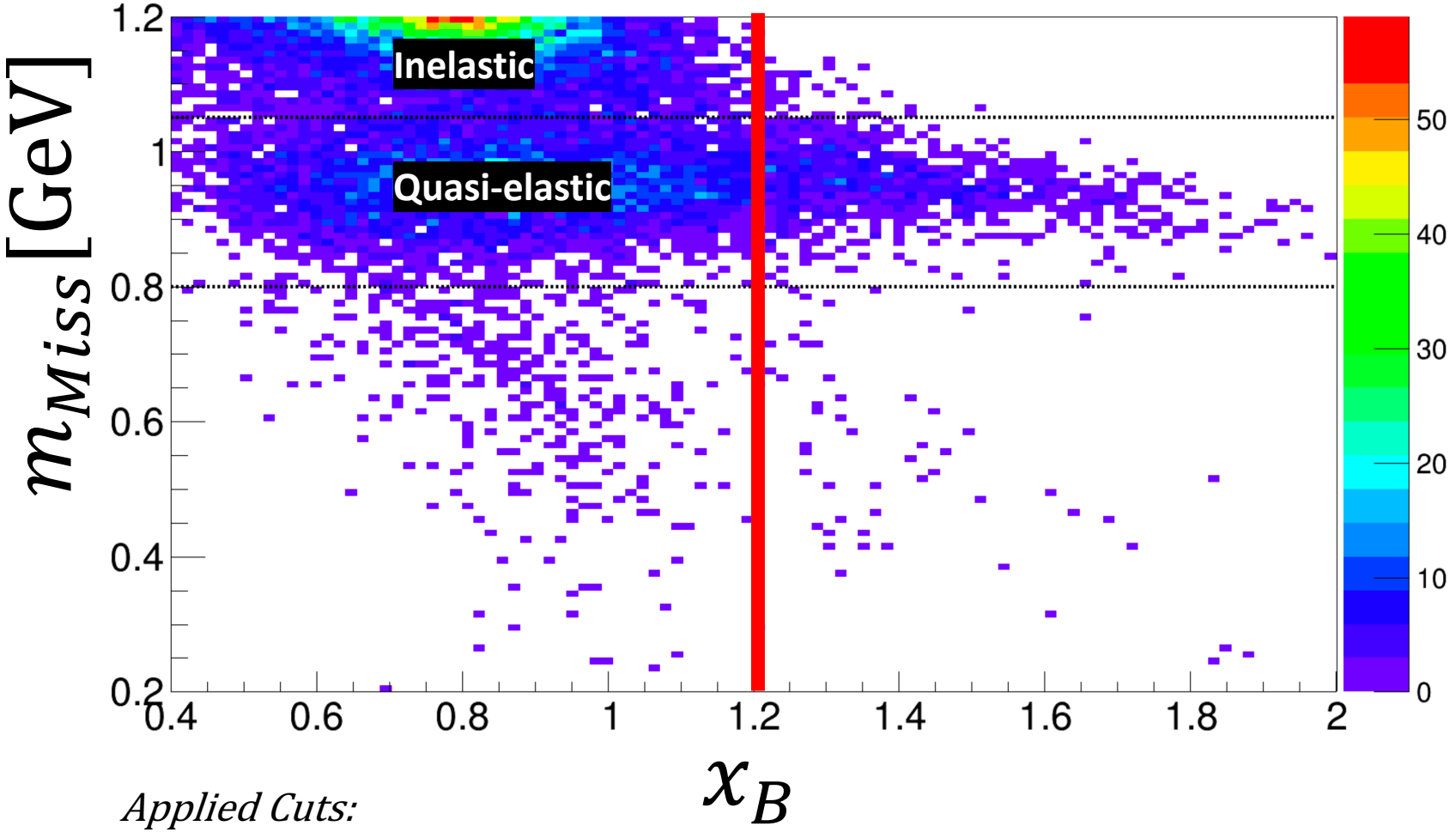
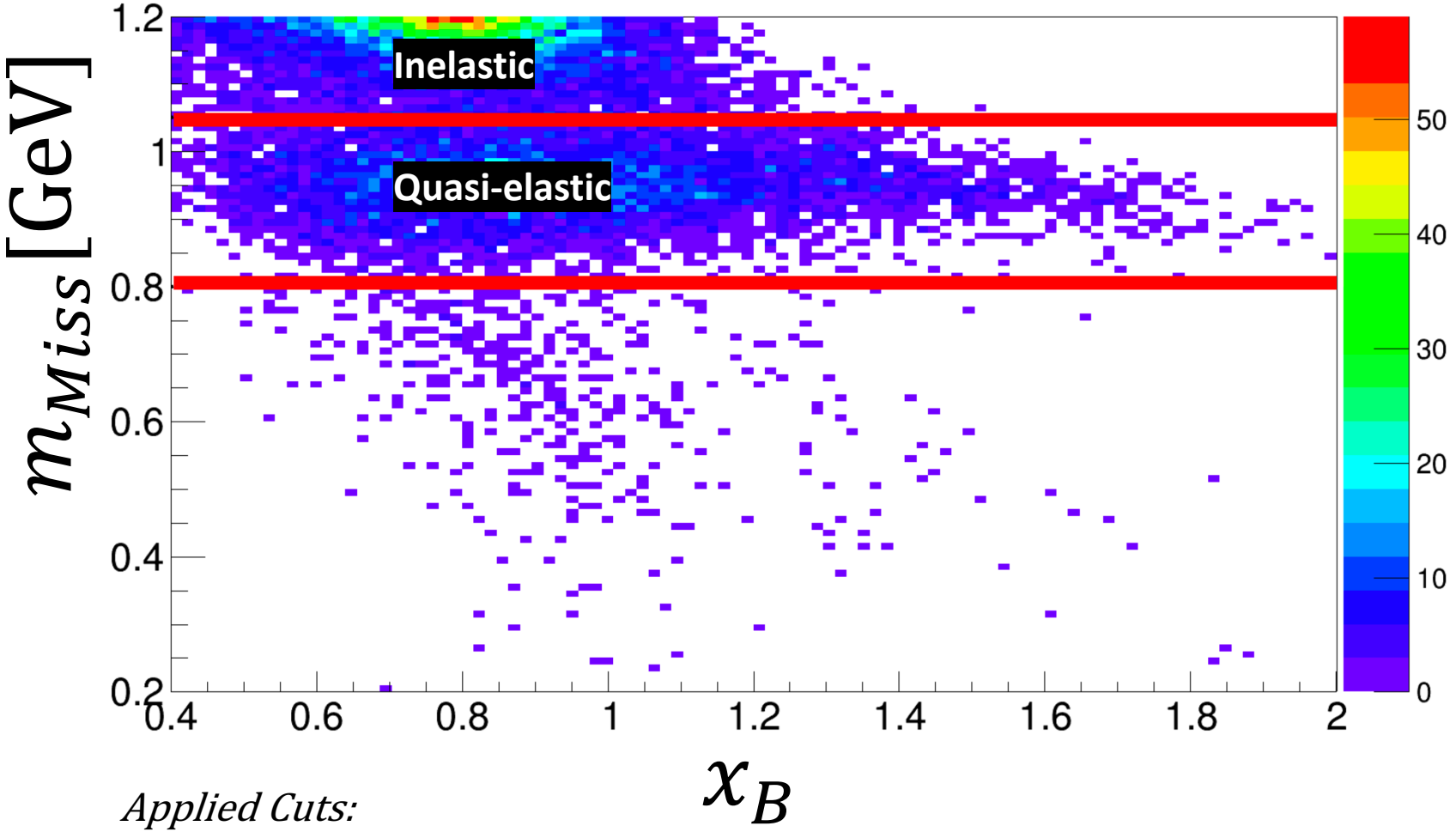
Deuterium



Applied Cuts:

- $1.5\ GeV^2 < Q^2$
- $\theta_{pq} < 25^{\circ}$
- $0.3\ GeV < p_{Miss} < 0.6\ GeV$

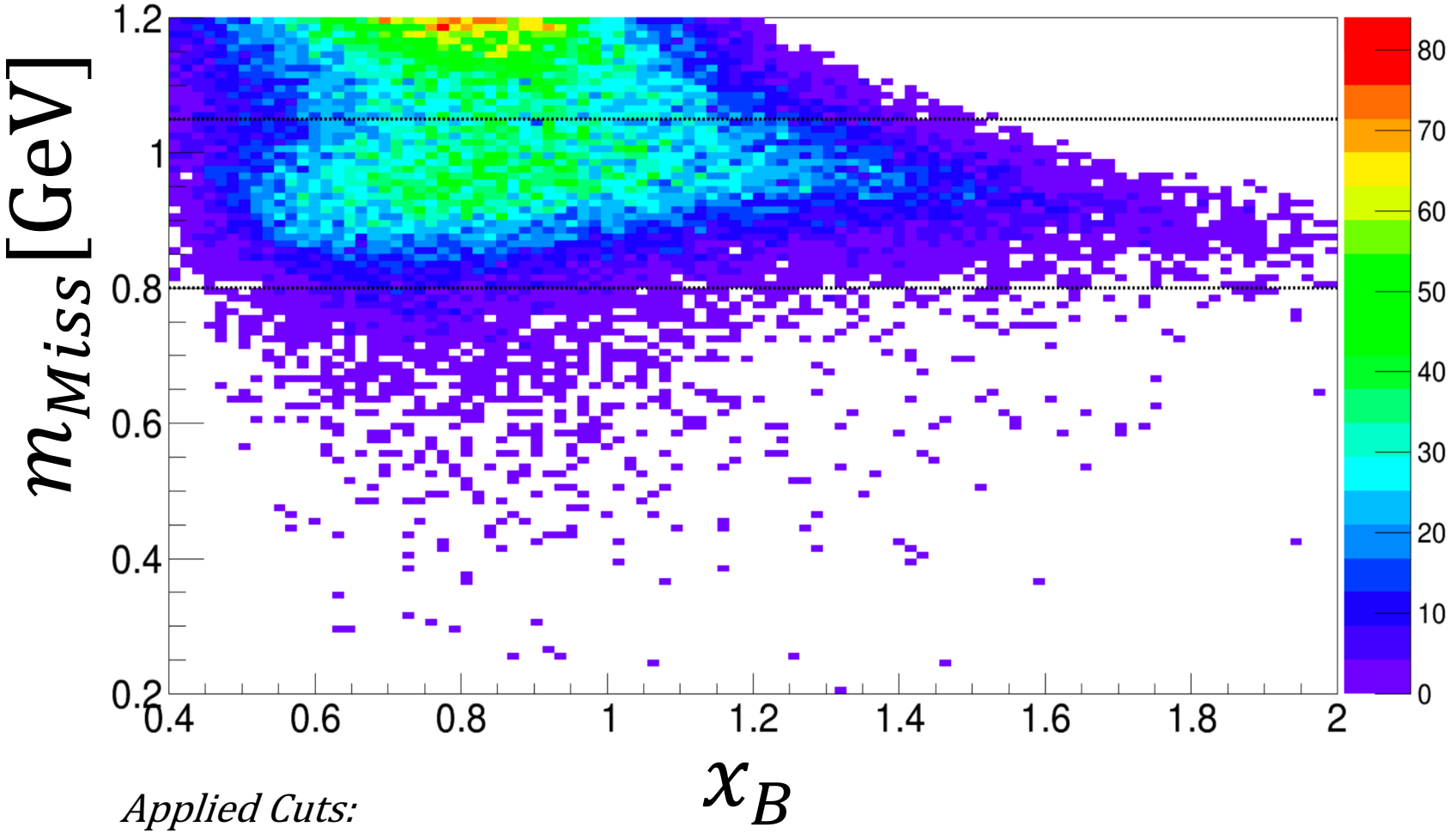
Deuterium



Applied Cuts:

- $1.5\ GeV^2 < Q^2$
- $\theta_{pq} < 25^{\circ}$
- $0.3\ GeV < p_{Miss} < 0.6\ GeV$

^{12}C



Applied Cuts:

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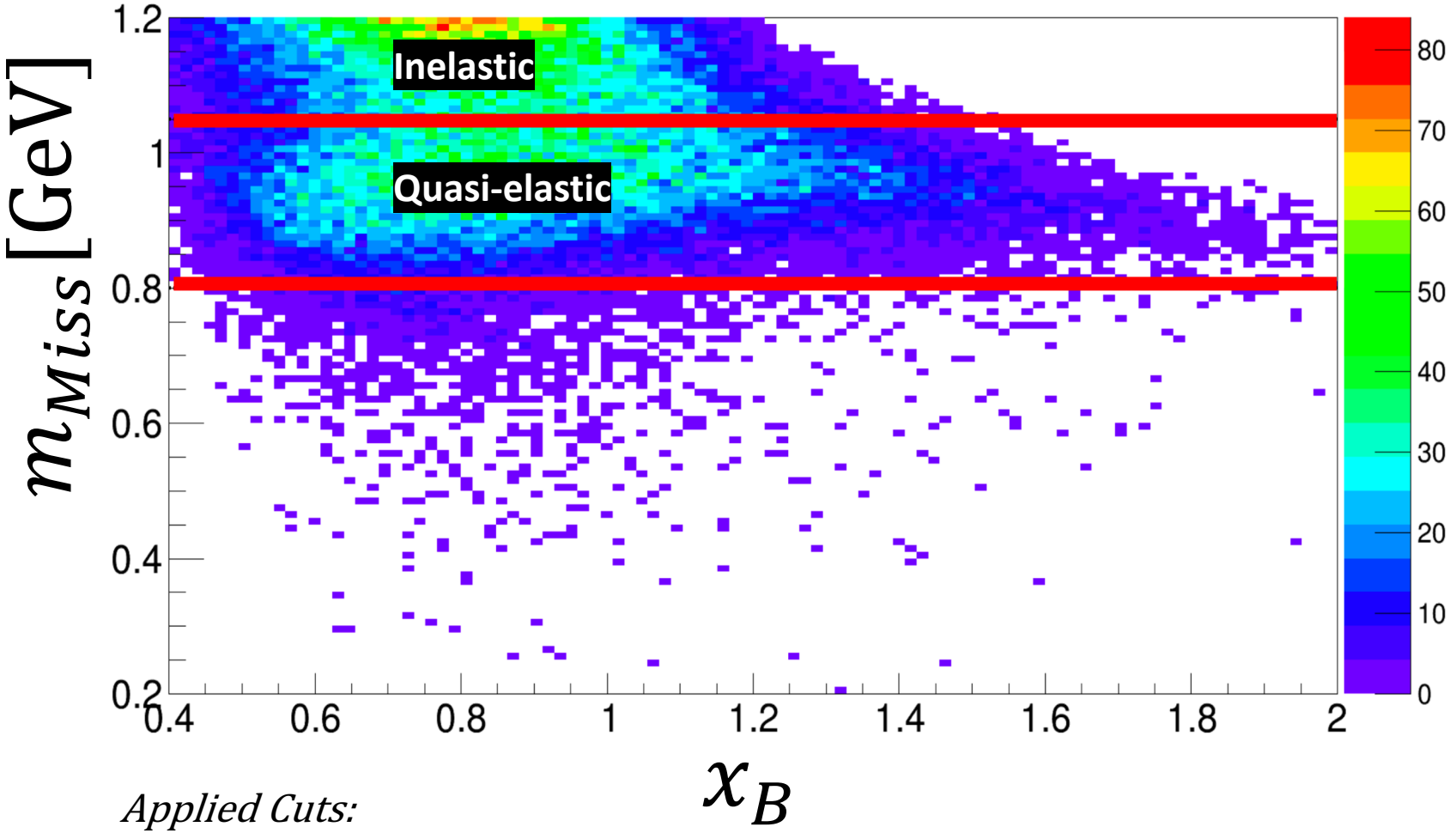
^{12}C



Applied Cuts:

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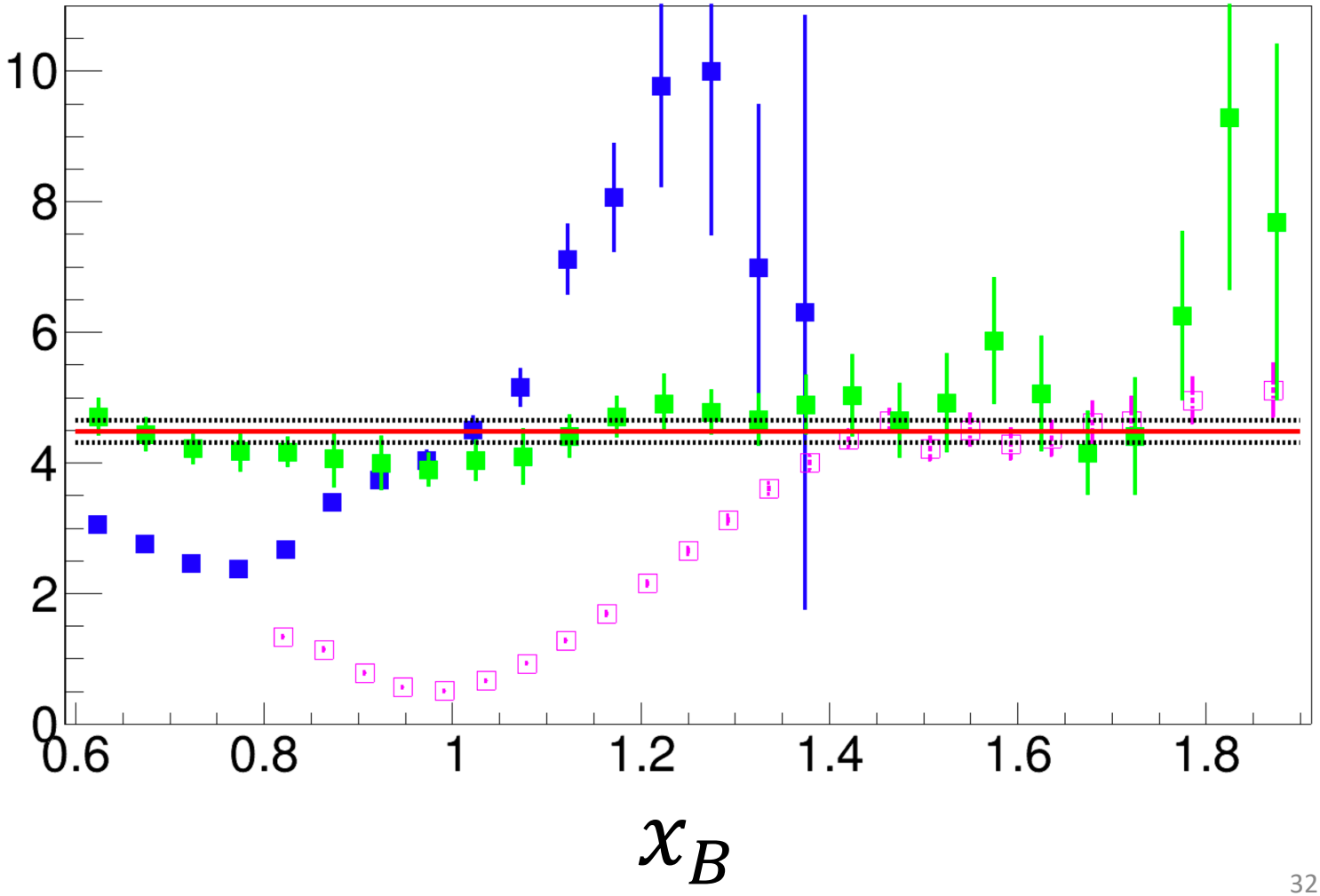
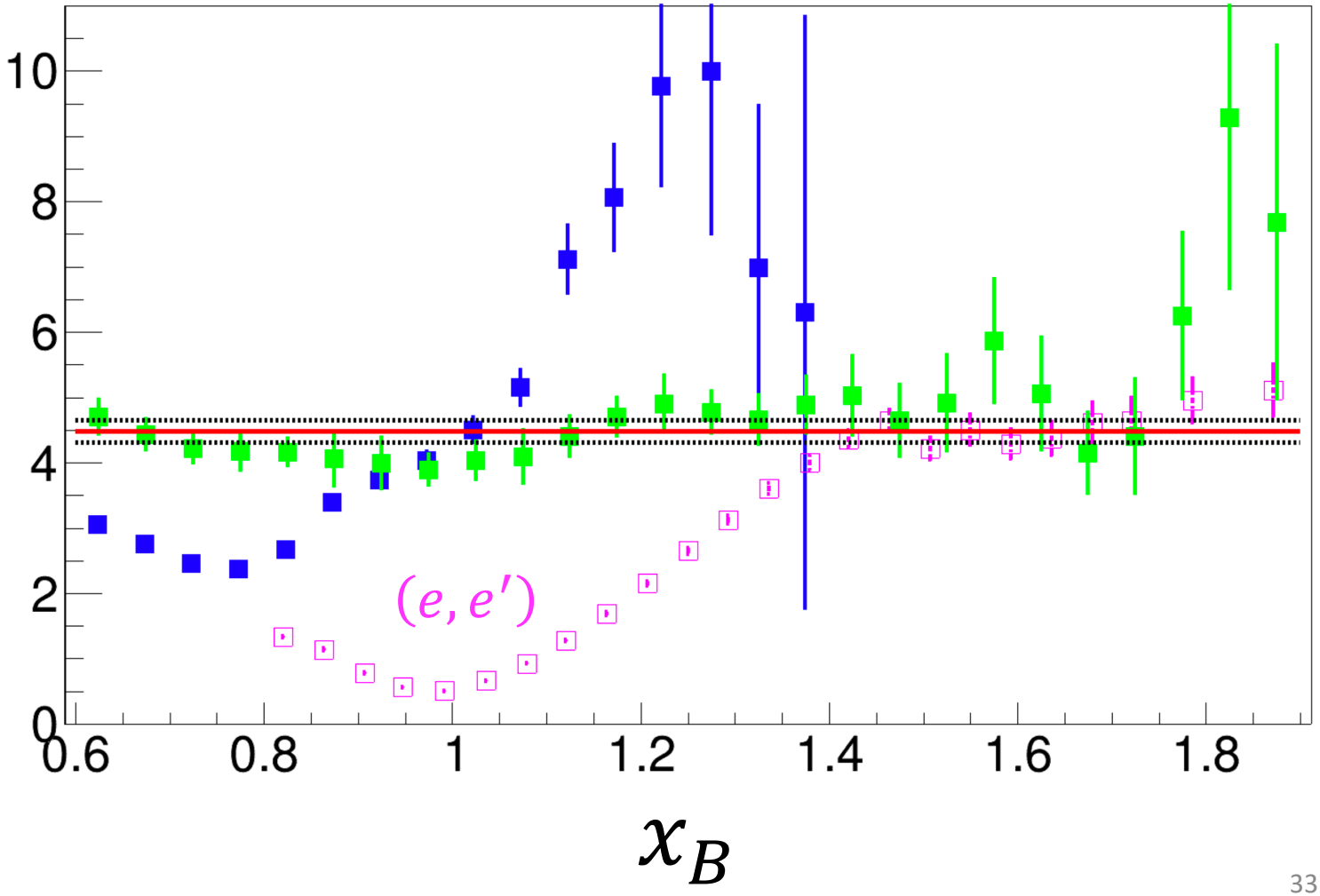
The Elastic Contribution

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



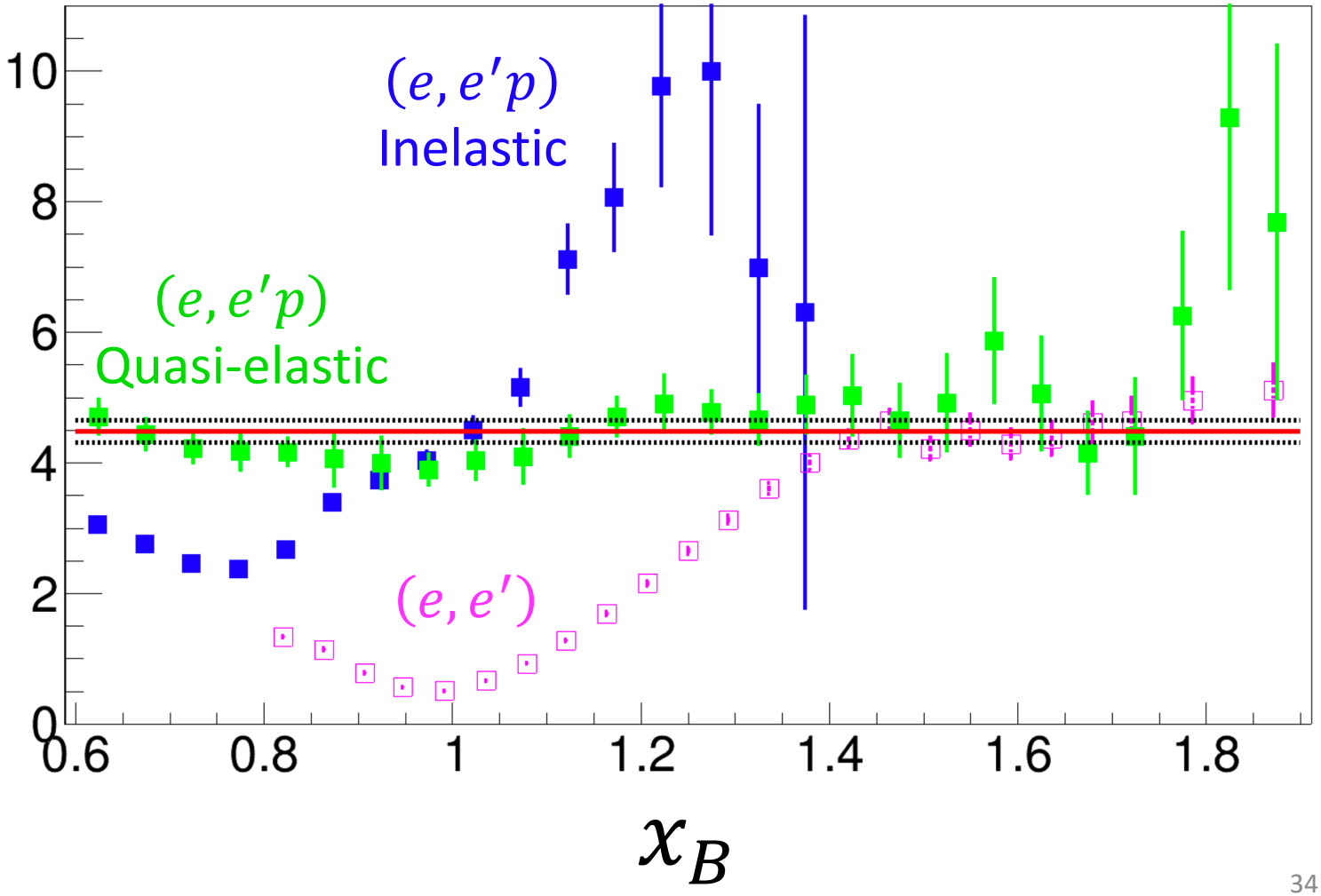
The Elastic Contribution

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

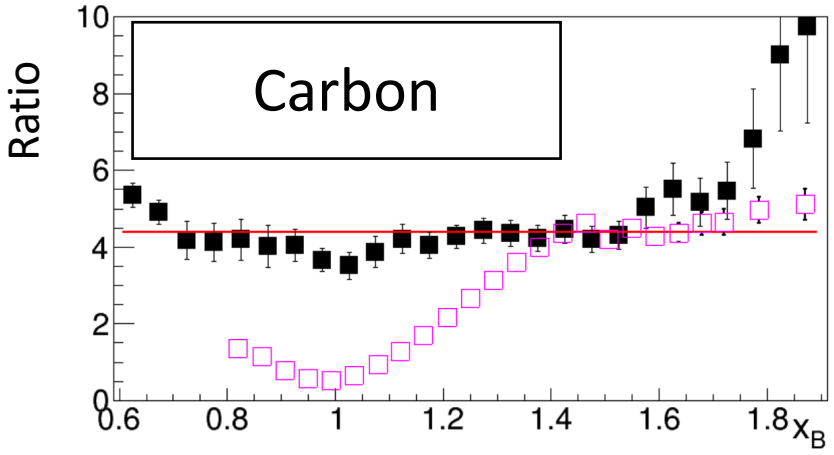


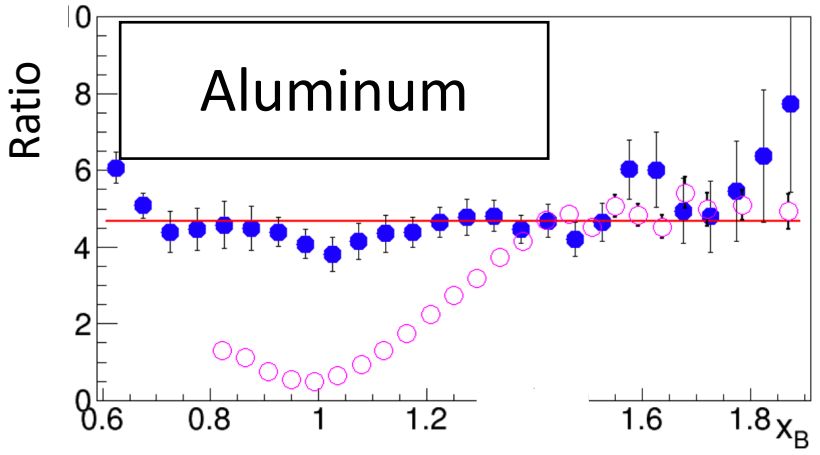
The Elastic Contribution

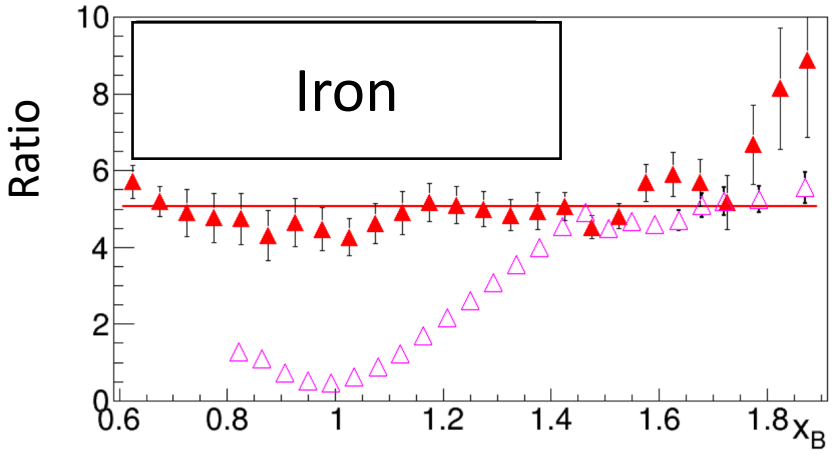
$$\frac{\sigma_C/12}{\sigma_d/2}$$

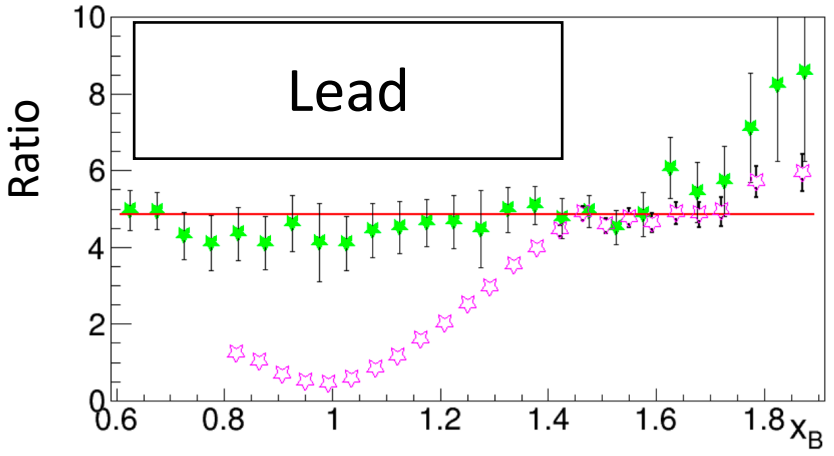


$\frac{\sigma_A/A}{\sigma_2/2}$ for Heavy Nuclei

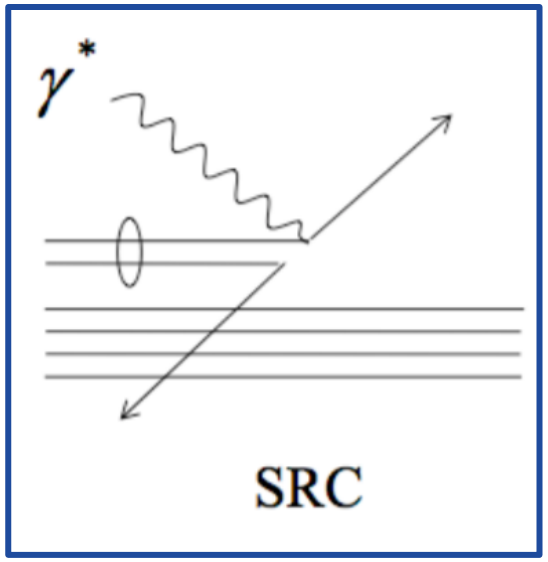






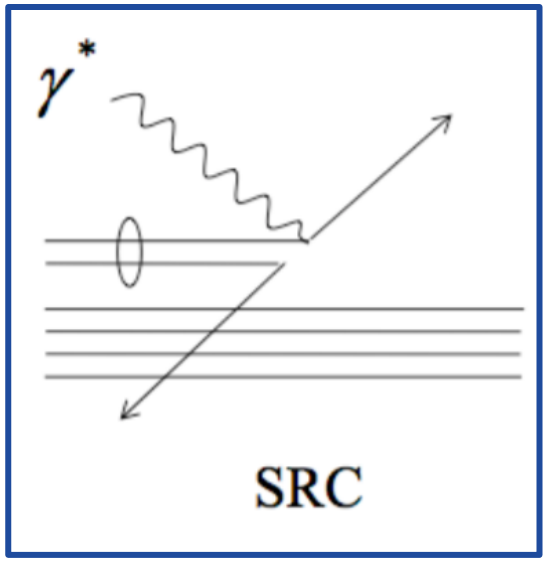


Mean Field Contribution

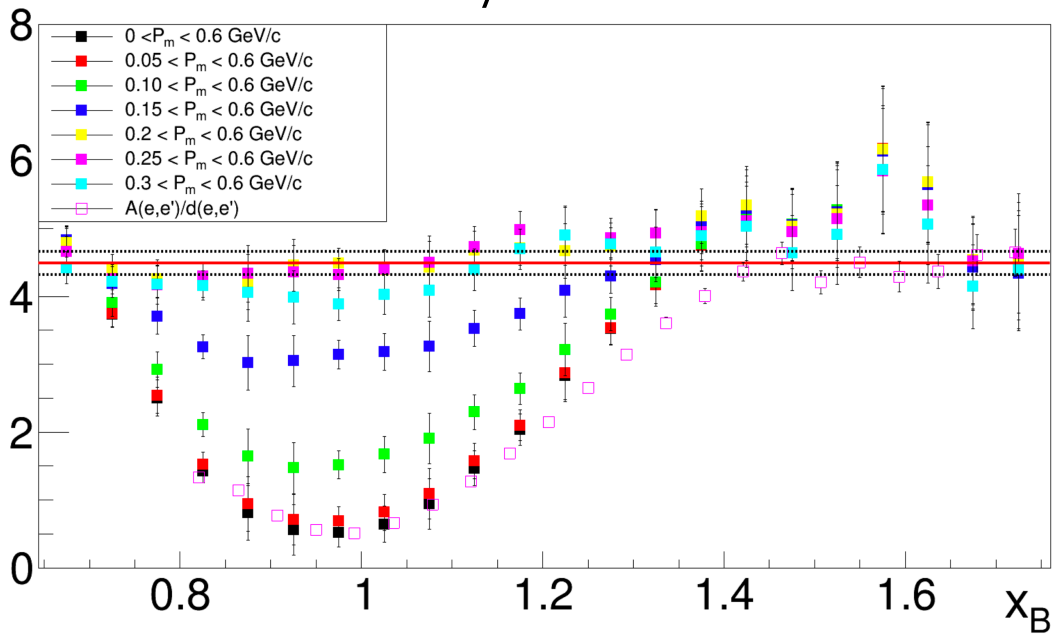


1. $1.2 < x_B < 2$
2. $1.5\ GeV^2 < Q^2$
3. $\theta_{pq} < 25^\circ$
4. $0.62 < \frac{p}{q} < 0.96$
5. $0.8\ GeV < m_{Miss} < 1.05\ GeV$
6. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

Mean Field Contribution



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



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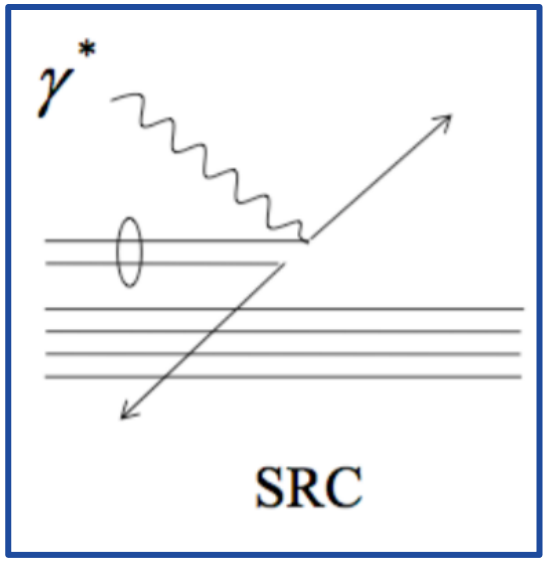
2. $1.5\ GeV^2 < Q^2$
3. $\theta_{pq} < 25^\circ$
4. $0.62 < \frac{p}{q} < 0.96$
5. $0.8\ GeV < m_{Miss} < 1.05\ GeV$
6. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

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

Mean Field Contribution



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3. $\theta_{pq} < 25^\circ$
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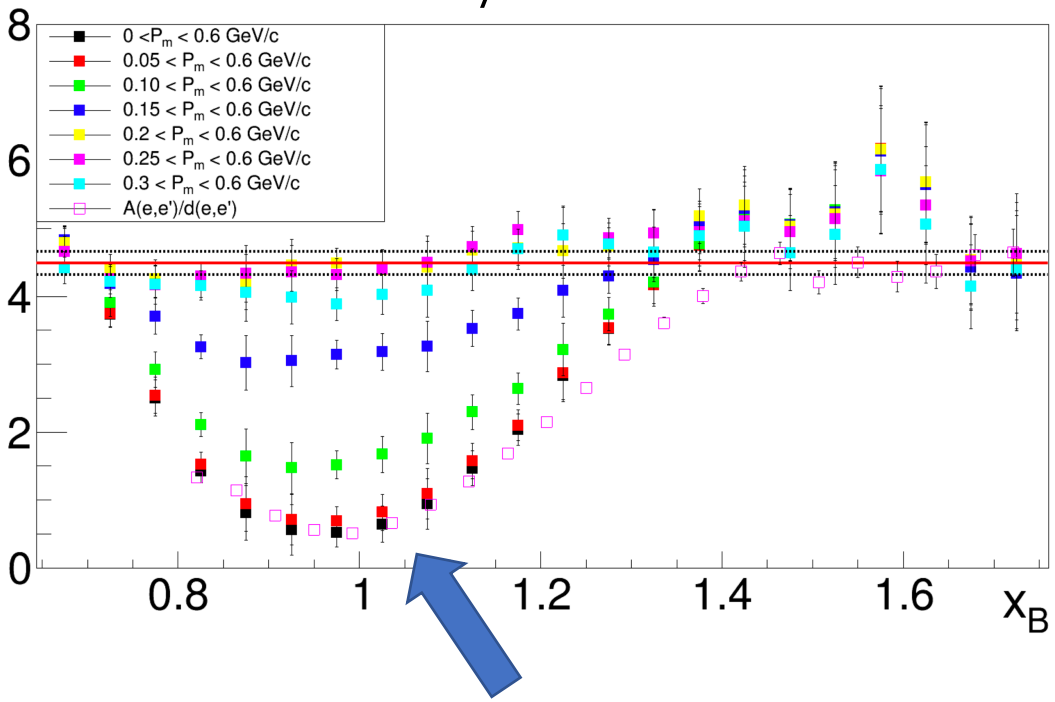
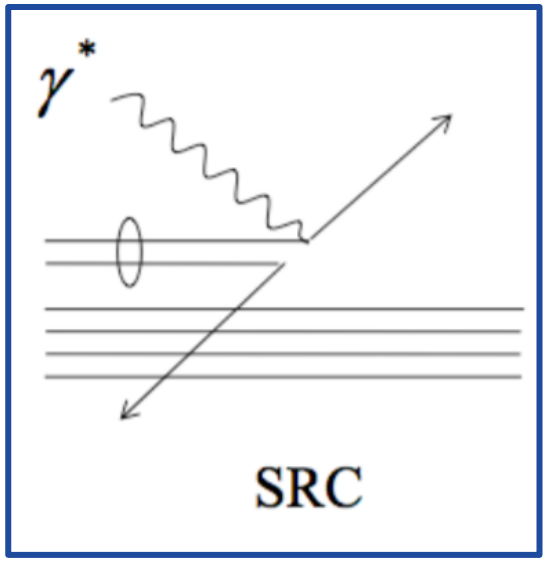
5. $0.8\ GeV < m_{Miss} < 1.05\ GeV$
6. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

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

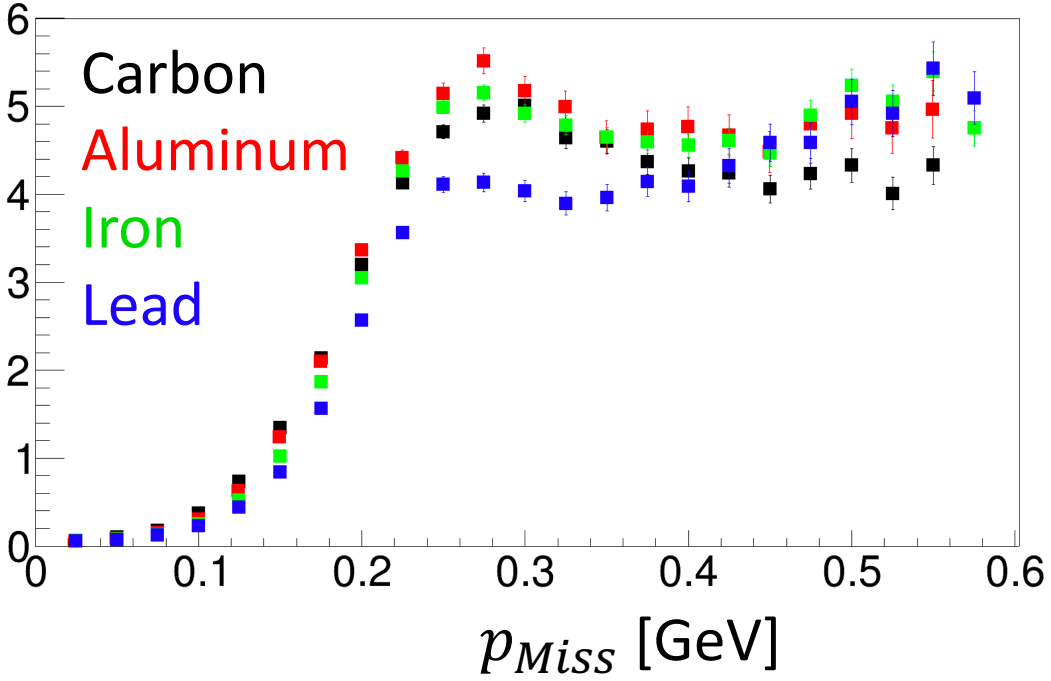


Dip only at low p_{Miss}

Mean Field Contribution

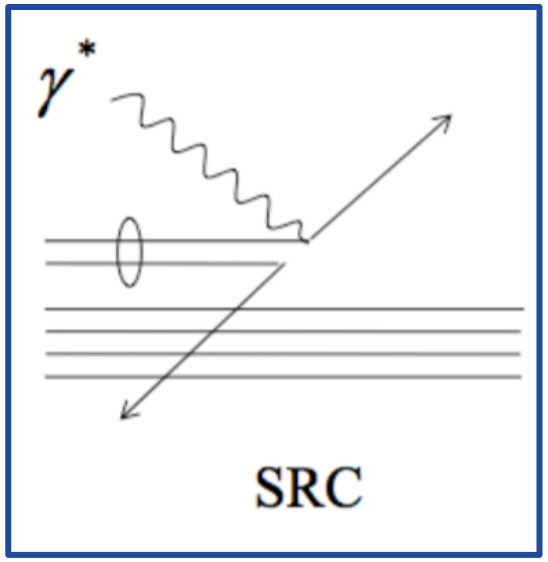


$$\frac{\sigma_A/A}{d/2}$$

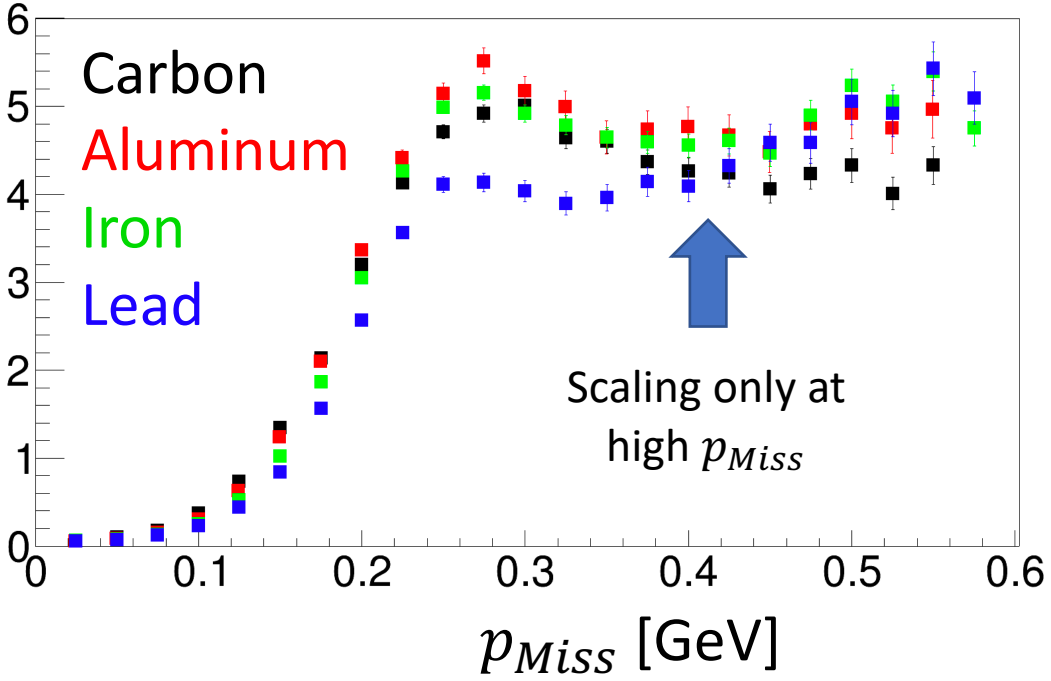


1. $0.6 < x_B < 1.9$
2. $1.5\ GeV^2 < Q^2$
3. $\theta_{pq} < 25^\circ$
4. $0.62 < \frac{p}{q} < 0.96$
5. $0.8\ GeV < m_{Miss} < 1.05\ GeV$
6. $0.3\ GeV < p_{Miss} < 0.6\ GeV$

Mean Field Contribution



$$\frac{\sigma_A/A}{d/2}$$



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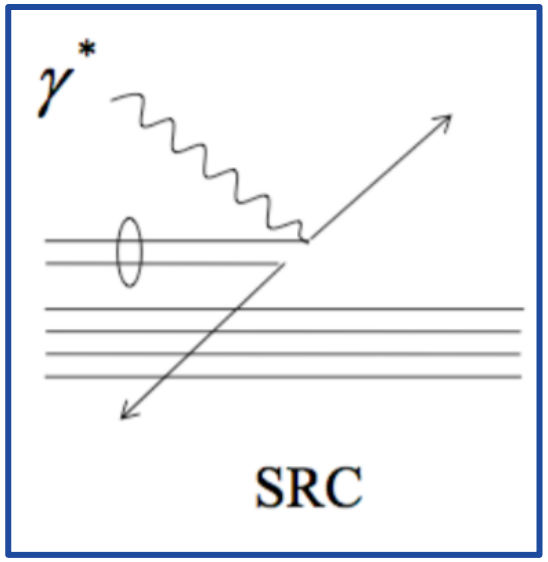
Mean Field Contribution



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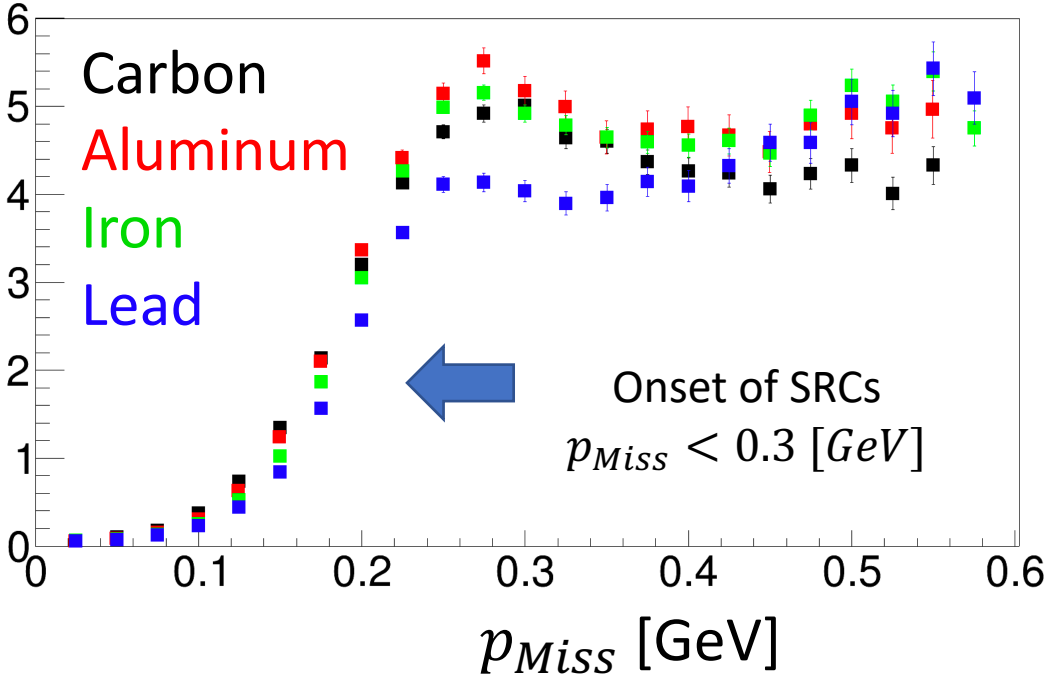
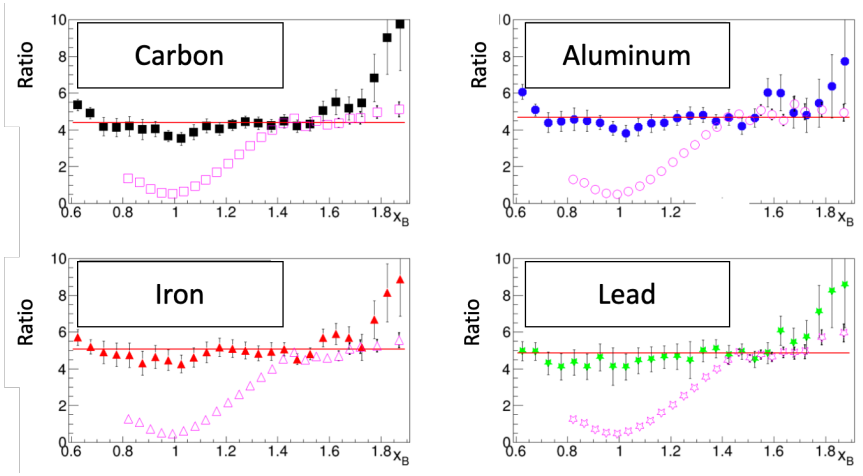
$$\frac{\sigma_A/A}{d/2}$$



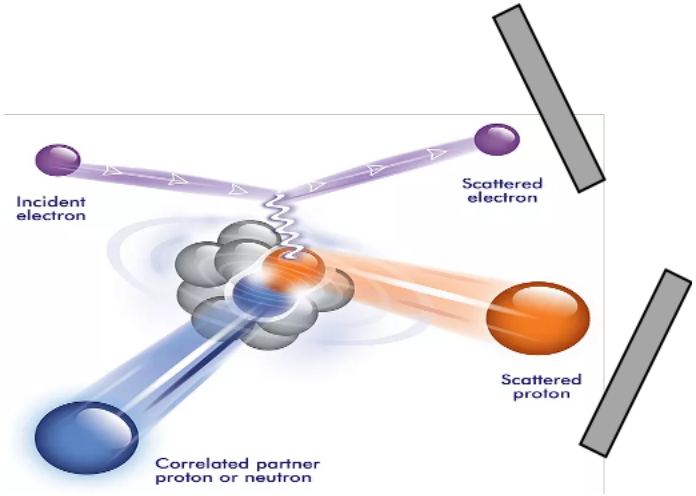
Conclusion

- We have observed SRC scaling below the inclusive limit



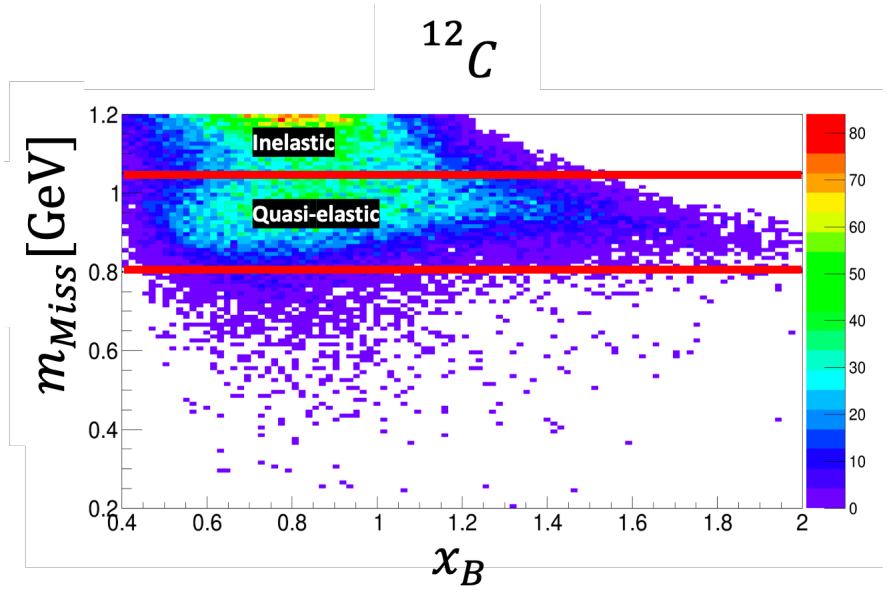
Conclusion

- We have observed SRC scaling below the inclusive limit
- This is done by moving from (e,e’) to (e,e’p)



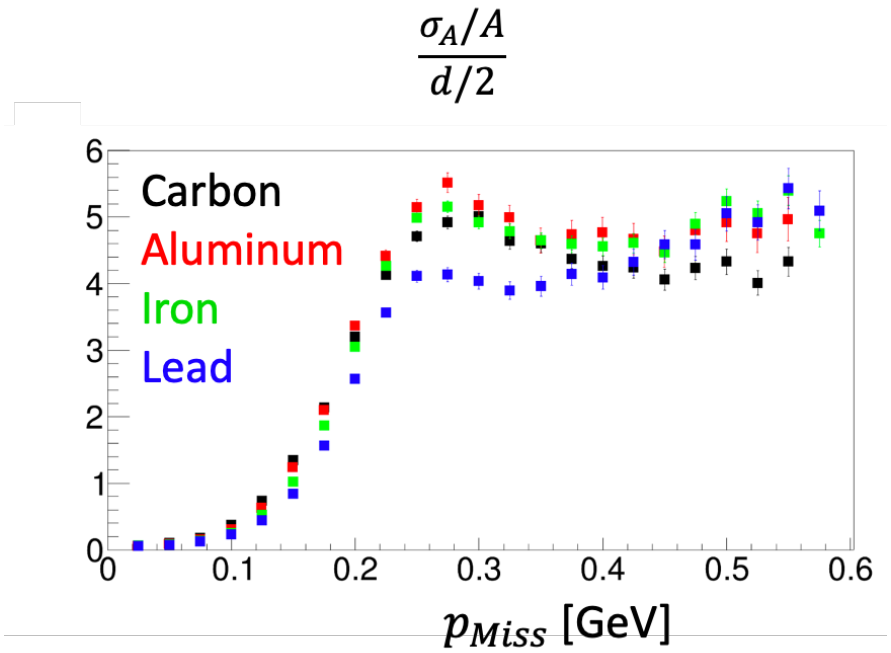
Conclusion

- We have observed SRC scaling below the inclusive limit
- This is done by moving from (e,e') to (e,e'p)
- Missing Mass cut reduces the IC contribution



Conclusion

- We have observed SRC scaling below the inclusive limit
- This is done by moving from (e,e') to (e,e'p)
- Missing Mass cut reduces the IC contribution
- Distributions in Missing Momentum can show the onset of SRCS



Thank you

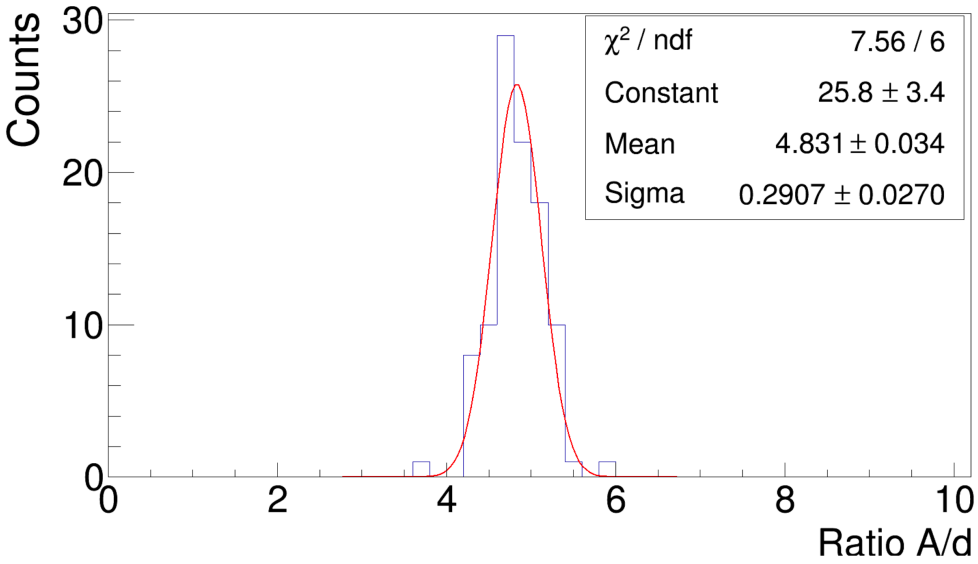
Results Table

Target	Measured	Overall Systematic Uncertainty	a_2
Carbon	4.39 ± 0.07	$\pm 10\%$	4.49 ± 0.17
Aluminum	4.68 ± 0.09	$\pm 12\%$	4.86 ± 0.18
Iron	5.06 ± 0.10	$\pm 12\%$	4.81 ± 0.22
Lead	4.85 ± 0.12	$\pm 14\%$	4.89 ± 0.20

Transparency Factors

Nucleus	Transparency	Uncertainty $[1\sigma]$
Deuteron	1	0
Carbon	0.53	0.052
Al	0.43	0.05
Fe	0.34	0.04
Pb	0.22	0.03

Systematic Uncertainties



Cut Type	Nominal Value	1σ
p_{miss} minimum	0.3 [GeV/c]	0.015
p_{miss} maximum	0.6 [GeV/c]	0.015
M_{miss} minimum	0.8 [GeV/c^2]	0.05
M_{miss} maximum	1.05 [GeV/c^2]	0.05
Θ_{PQ}	25°	0.5°
Q^2	1.5 [(GeV/c)^2]	0.01

Systematic Uncertainties

Source	Per-Bin	Overall
Beam Charge	-	1%
Target Thickness	-	$\sim 1.5\%$
Acceptance Correction	$\sim 2.5\% - 10\%$	-
Radiative Correction	$< 1\%$	5%
Coulomb Correction	$< 3\%$	-
Nuclear Transparency	-	$10 - 15\%$
Deuteron Merging	-	$\leq 1.5\%$
Event Selection	$5\% - 12\%$	-
Total	$7\% - 16\%$	$\sim 11 - 16\%$