The CaFe Experiment

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THE UNIVERSITY OF TENNESSEE KNOXVILLE

January 14, 2025

THE CATHOLIC UNIVERSITY OF AMERICA

Proposal: PR12-17-005

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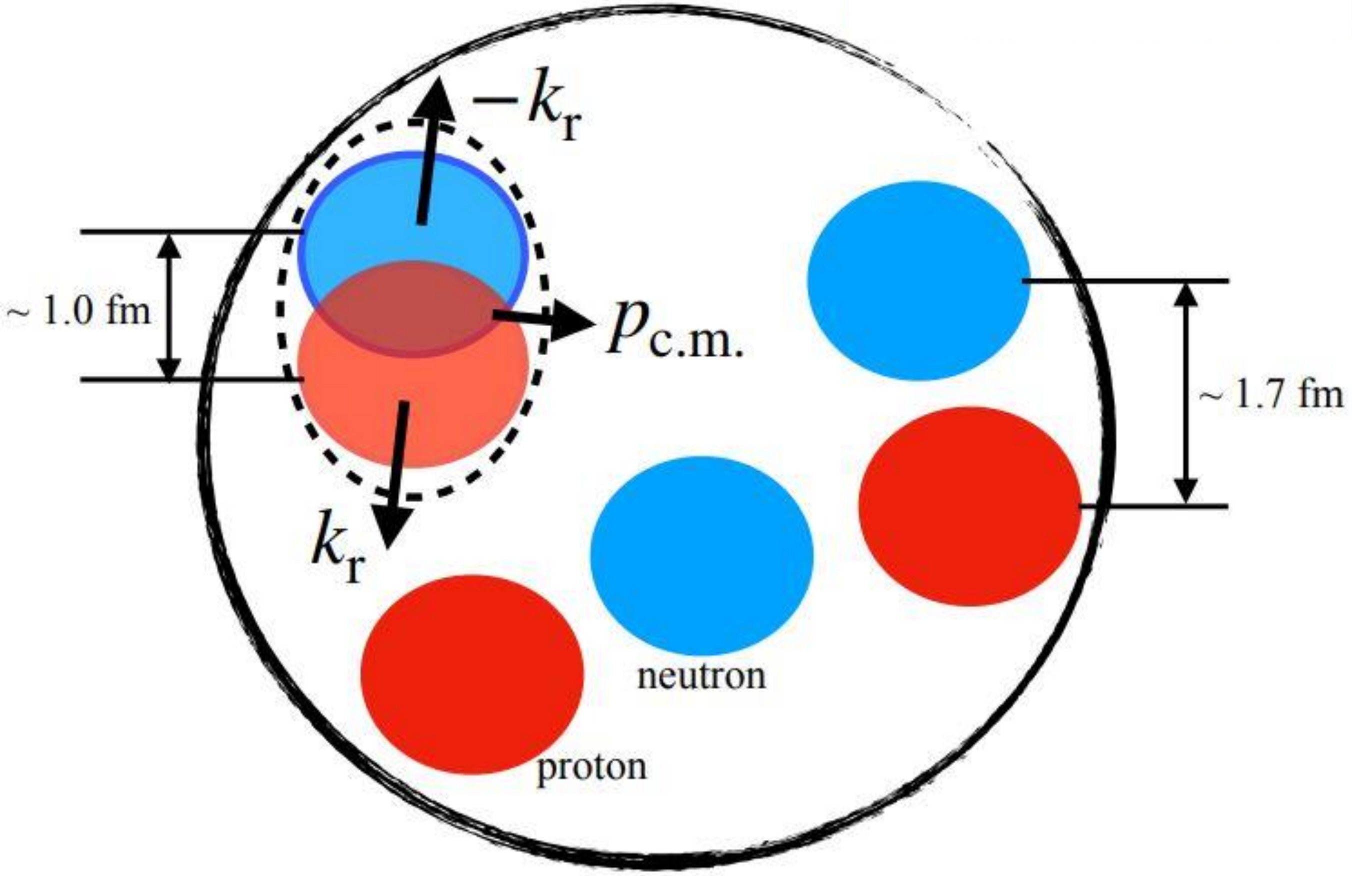
Outline

- Motivation
- Systematic Uncertainties
  - Cut Variations
  - Radiative Corrections
  - Transparency
- Results

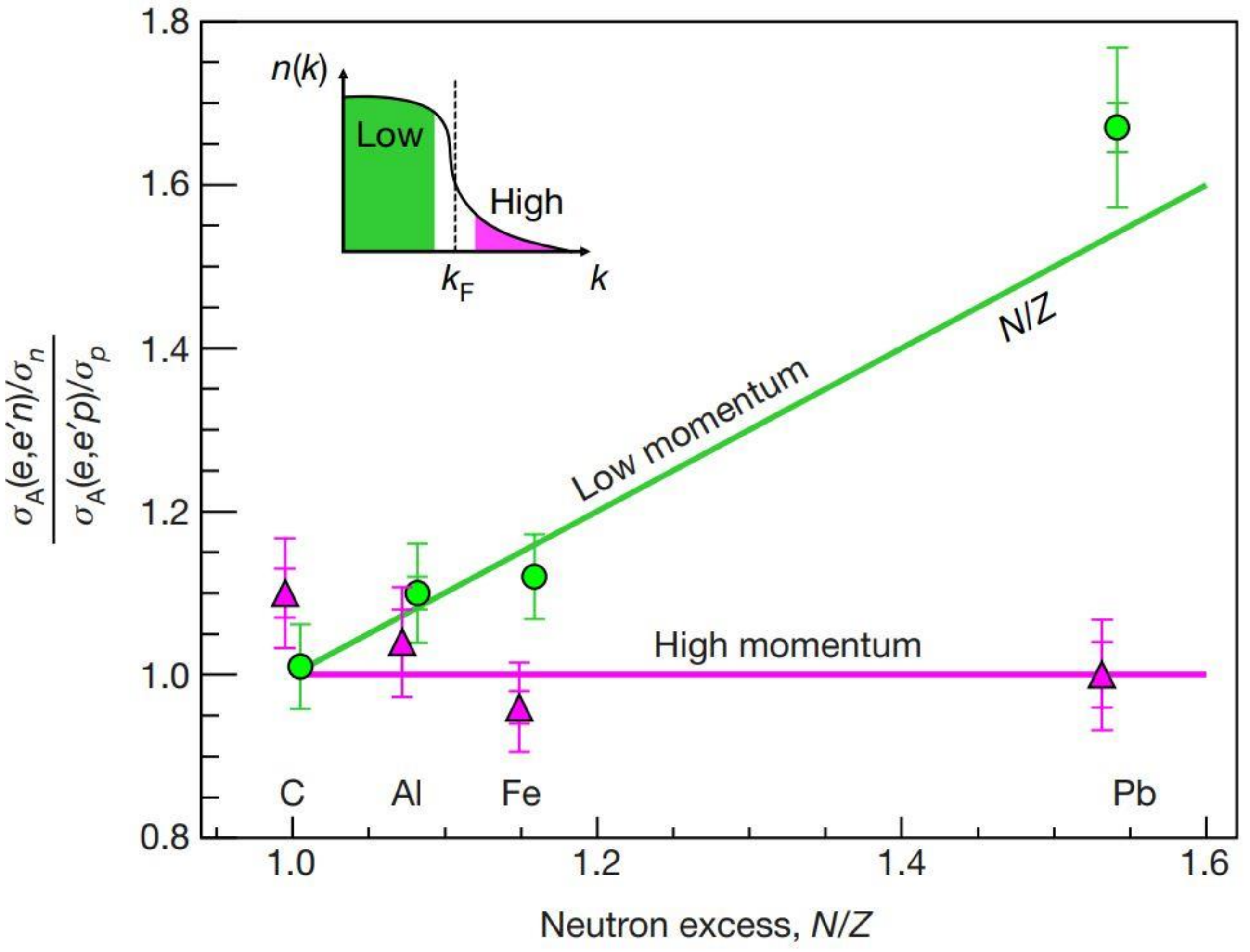
Short Range Correlations

- SRCs are temporary short distance high momentum fluctuations
- High relative momentum ($k_r > k_F \sim 250$ MeV/c)
  - Depends on the short-range part of the N-N interaction
- Unchanged center-of-mass momentum
- Open questions
  - Momentum structure
  - 3 nucleon correlations
  - Which nucleons pair



np-dominance in Asymmetric Nuclei

- A(e,e'n)/A(e,e'p) cross-section ratio
- Low missing momentum n/p ratio grows like N/Z
- High missing momentum n/p ratio is constant
- This is consistent with np pair dominance

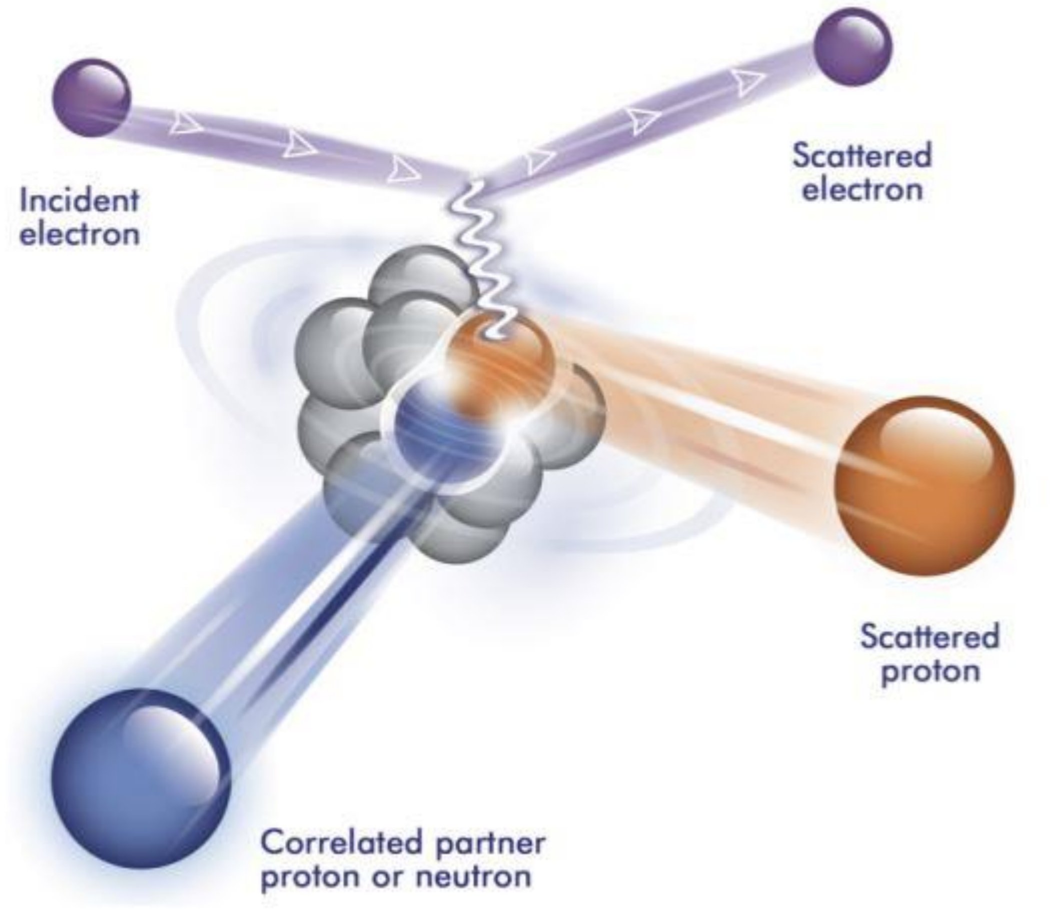


M. Duer et al., Nature 560, 617 (2018)
https://www.nature.com/articles/s41586-018-0400-z

CaFe Motivation

Which nucleons form SRC pairs?

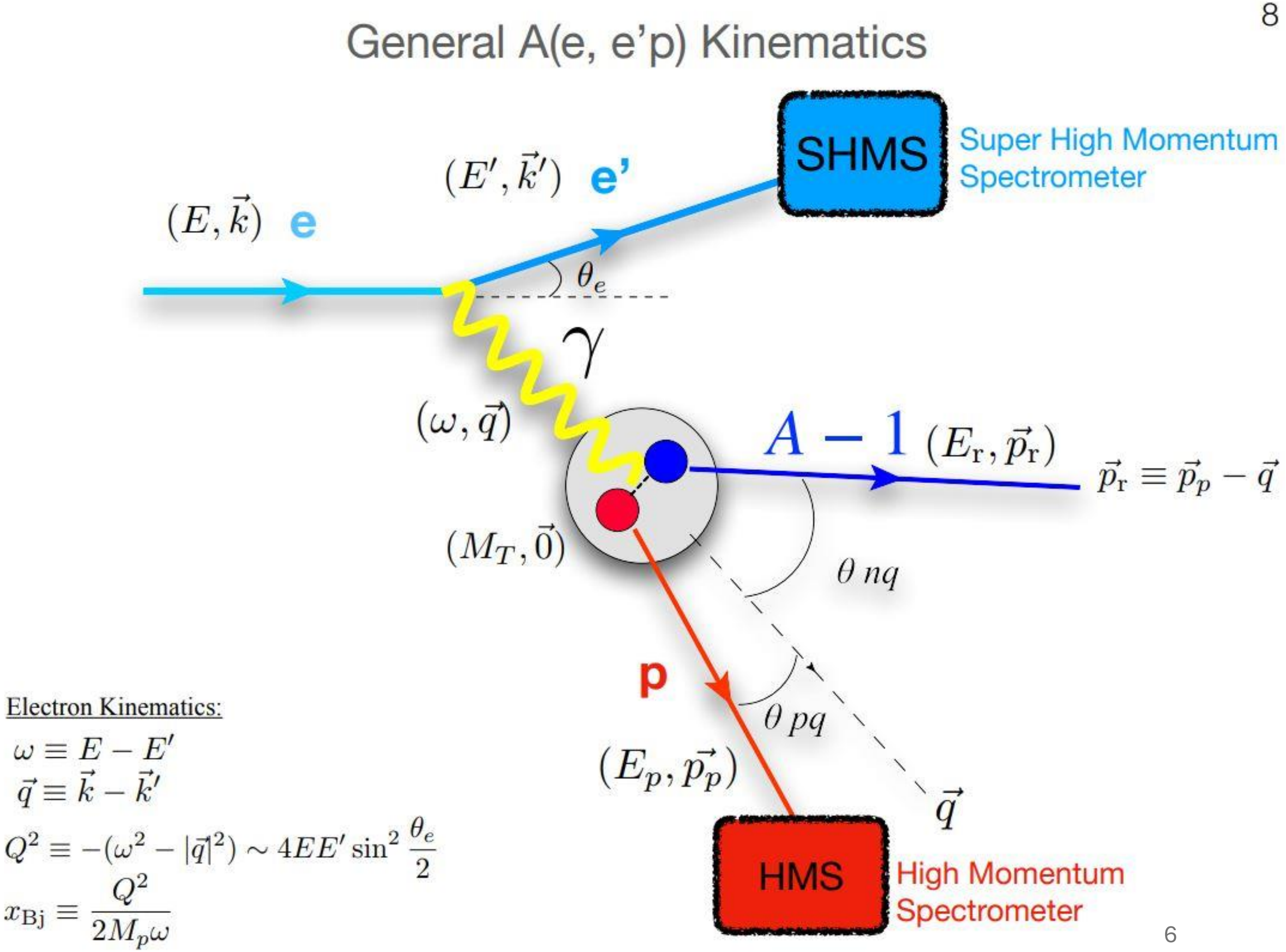
- Compare number of high-momentum (paired) protons in ^{40}Ca, ^{48}Ca, and ^{54}Fe
  - ^{40}Ca: filled 1s, 1p, and 2s/1d p and n shells
  - ^{48}Ca: add 8 $f_{7/2}$ neutrons
  - ^{54}Fe: add 6 $f_{7/2}$ protons
  - First Paper
- Measure A(e,e'p) on d, ^{9}Be, ^{10,11}B, ^{12}C, ^{40,48}Ca, ^{54}Fe, and ^{197}Au at high and low missing momentum
  - ^{9}Be-^{10}B-^{11}B-^{12}C quartet and ^{40}Ca-^{48}Ca-^{54}Fe triplet



Separate A and N/Z dependence on pairing

Hall C: Experimental Setup Cont.

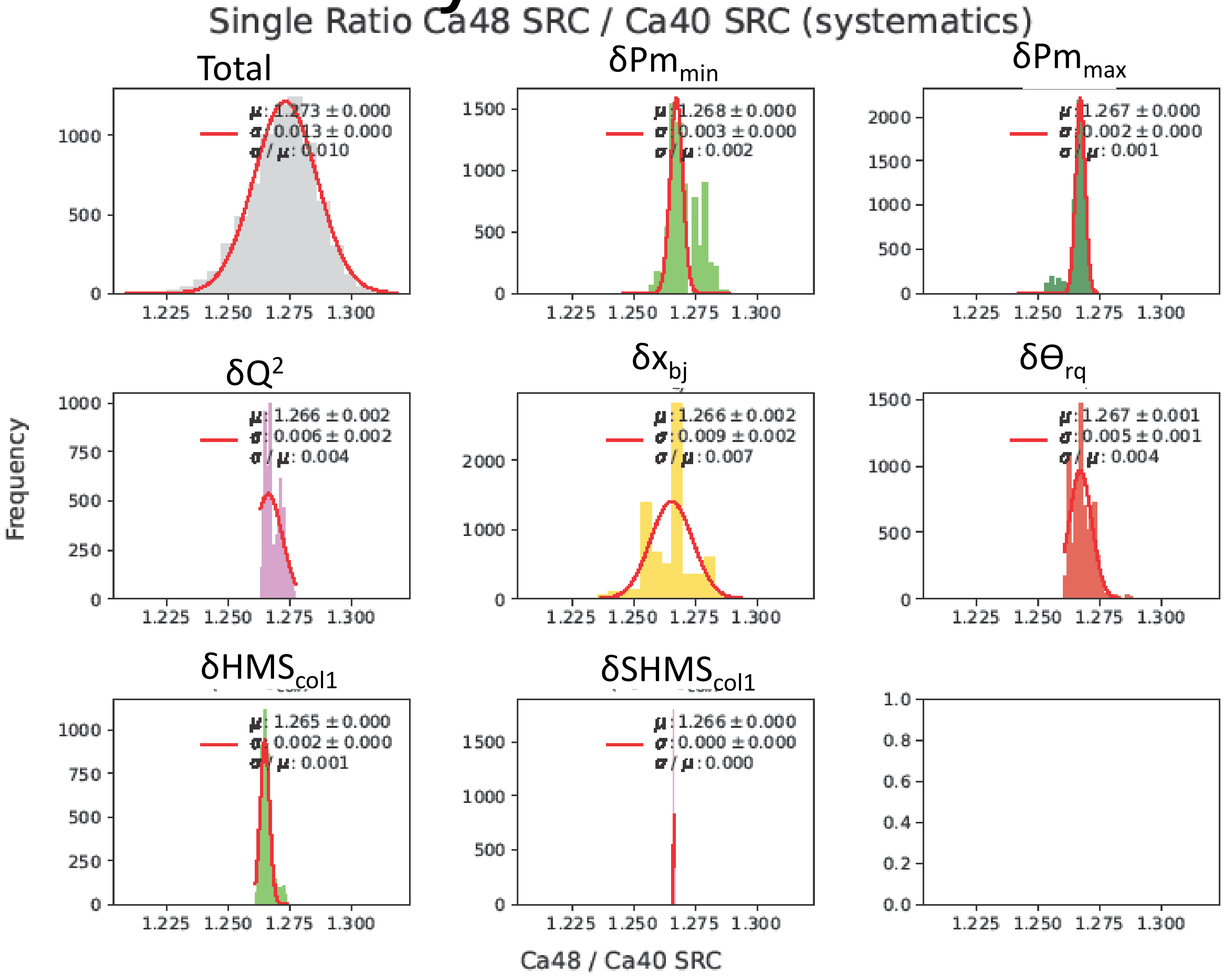
- E_o = 10.6 GeV
- E'=8.55 GeV
- Θ_e =8.3 Degrees
- Q^2 =2.1 (GeV/c)^2
- $P_{miss} \approx$ 400 MeV/c
  - $|P_p|$ = 1.325 GeV/c
  - Θ_p = 66.4°
- $P_{miss} \approx$ 150 MeV/c
  - $|P_p|$ = 1.820 GeV
  - Θ_p = 48.3 Degrees



Cut Variations

- Examine how sensitive the data is to cuts (systematic uncertainty)
- Data Selection Cuts (and 2σ cut variations)
  - PID
    - $0.8 < \frac{E_{tot}}{P_{cent}} < 1.3$
    - $-2.0 <$ ep Coin Time < 2 ns
  - Acceptance
    - Collimator Cut ± 8 %
  - Kinematics
    - $Q^2 > 1.8 \pm 0.1$ GeV/c^2
    - MF
      - $P_m < 0.27 \pm 0.02$ GeV/c
      - $-0.02 < E_m < 0.09 \pm 0.005$ GeV
    - SRC
      - $0.375 \pm 0.025 < P_m < 0.7 \pm 0.1$ GeV/c
      - $x_{bj} > 1.2 \pm 0.1$
      - $\theta_{rq} < 40 \pm 4$ deg

SRC Ratio Uncertainty



Cut Variation: Single & Double Ratios

Ratios to C							
Single Ratio (%)	Be9/C12	B10/C12	B11/C12	Ca40/C12	Ca48/C12	Fe54/C12	Au197/C12
σ/μ (MF)	0.4	0.2	0.1	0.3	0.5	0.3	0.7
σ/μ (SRC)	1.3	1.0	0.9	2.2	3.1	2.4	4.9
Double Ratio (%)	Be9/C12	B10/C12	B11/C12	Ca40/C12	Ca48/C12	Fe54/C12	Au197/C12
σ/μ	1.4	1.0	0.9	2.2	3.1	2.4	4.9

Ratio to Ca40		
Single Ratio (%)	Fe54/Ca40	Ca48/Ca40
σ/μ (MF)	0.4	0.3
σ/μ (SRC)	1.0	1.0
Double Ratio (%)	Fe54/Ca40	Ca48/Ca40
σ/μ	1.1	1

SRC uncertainties dominate and increase with larger differences between nuclei.

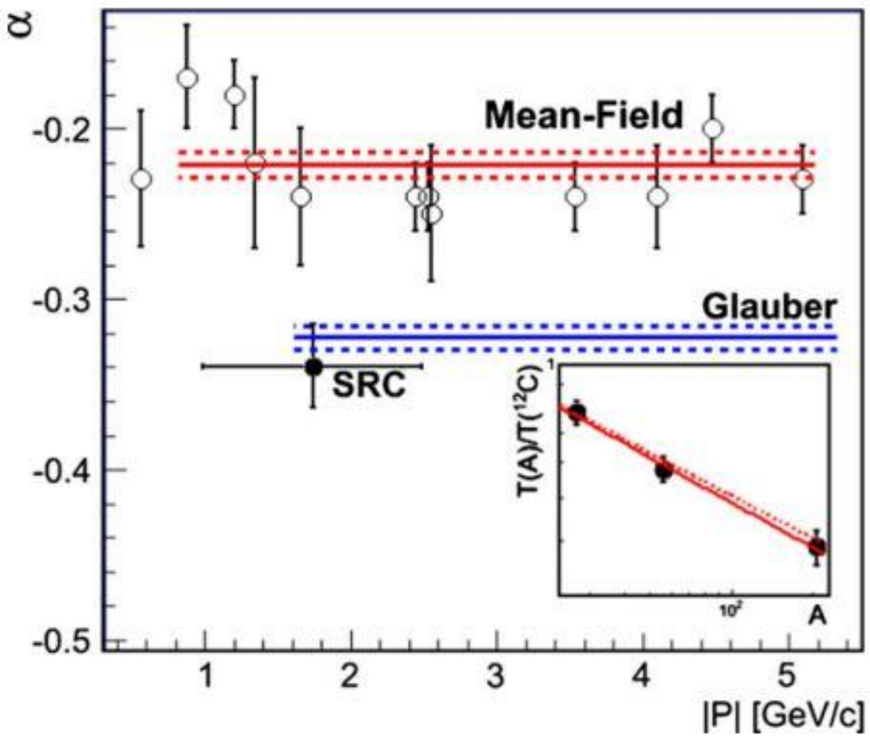
Radiative Correction Factors

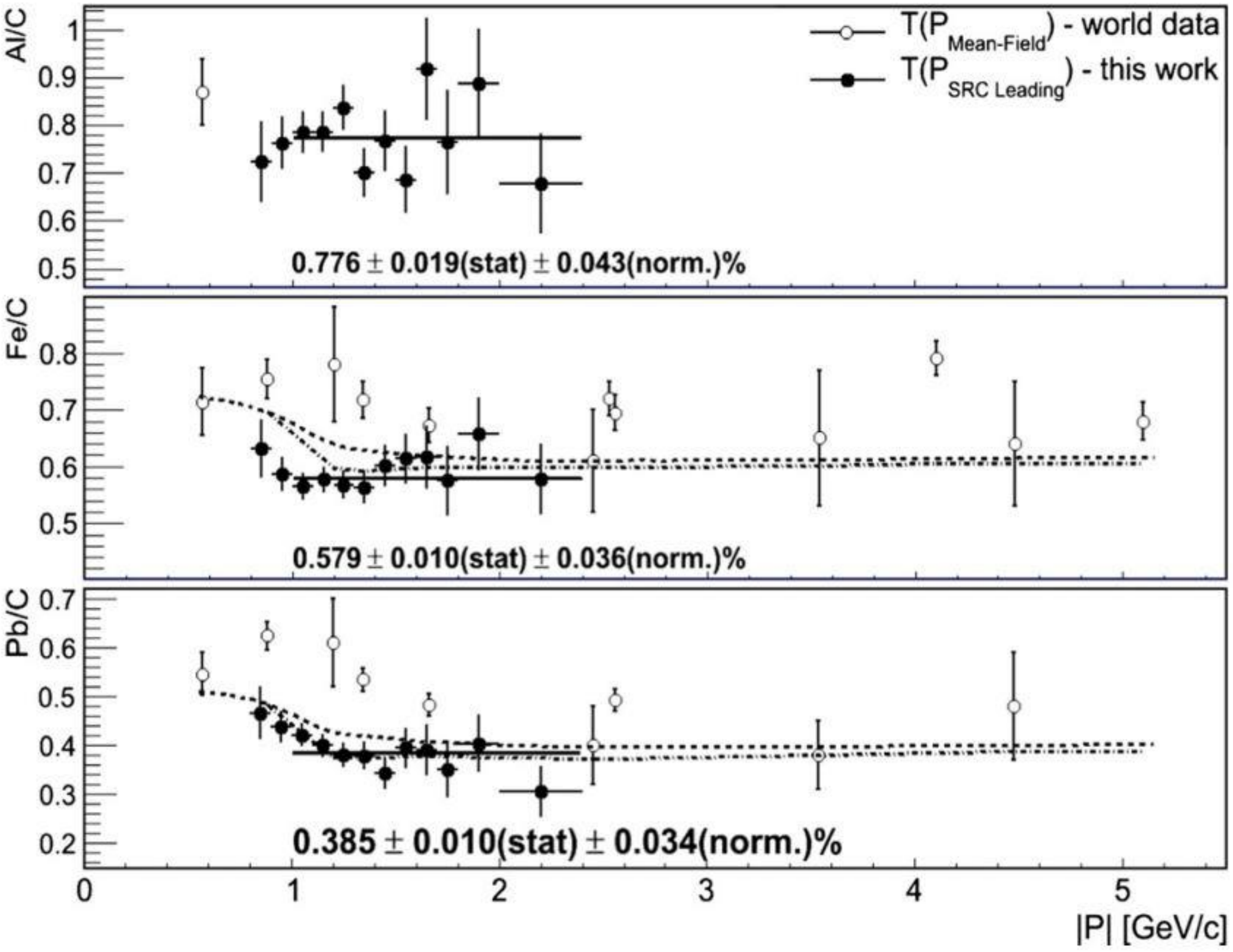
Kinematics	MF			SRC		
Target	C12	Fe56	Au197	C12	Fe56	Au197
Rad/Norad Ratio	0.618	0.577	0.451	0.742	0.734	0.604
Stat Uncertainty	0.009	0.006	0.005	0.007	0.012	0.014
Cut Var. Uncertainty	0.005	0.004	0.003	0.03	0.04	0.04

- Ratios of corrections are important
  - MF to SRC
  - Different Nuclei
  - Small A dependence implies corrections mostly cancel

Proton Transparency

- Use measured ratios to C
- $T(A) \propto A^{-0.34 \pm 0.02}$





Hen et al, Physics Letters B 722 (2013) 63–68

Systematic Uncertainties CaFe Triplet

Systematic Uncertainties (%)				
Ratio	Radiative Correction	Transparency	Cut Variation	Net
MF Single Ratio				
Ca48/Ca40	0	0.4	0.3	**0.7**
Fe54/Ca48	1.0	0.6	0.4	**1.2**
SRC Single Ratio				
Ca48/Ca40	0	0.4	0.7	**0.8**
Fe54/Ca48	1.0	0.6	1	**1.5**
Double Ratio				
Ca48/Ca40	0	0.0	0.8	**0.8**
Fe54/Ca48	1.0	0.0	1.1	**1.5**

Ratios

$$Y_A : \frac{N}{Q \cdot \epsilon_i \cdot T_N \cdot \sigma_t \cdot Z/A}$$

Y_A : nucleus A yield

N : $(e, e'p)$ coincidence counts

Q : total charge [mC]

ϵ_i : detector/DAQ efficiencies

T_N : nuclear transparency

σ_t : target thickness [g/cm^2]

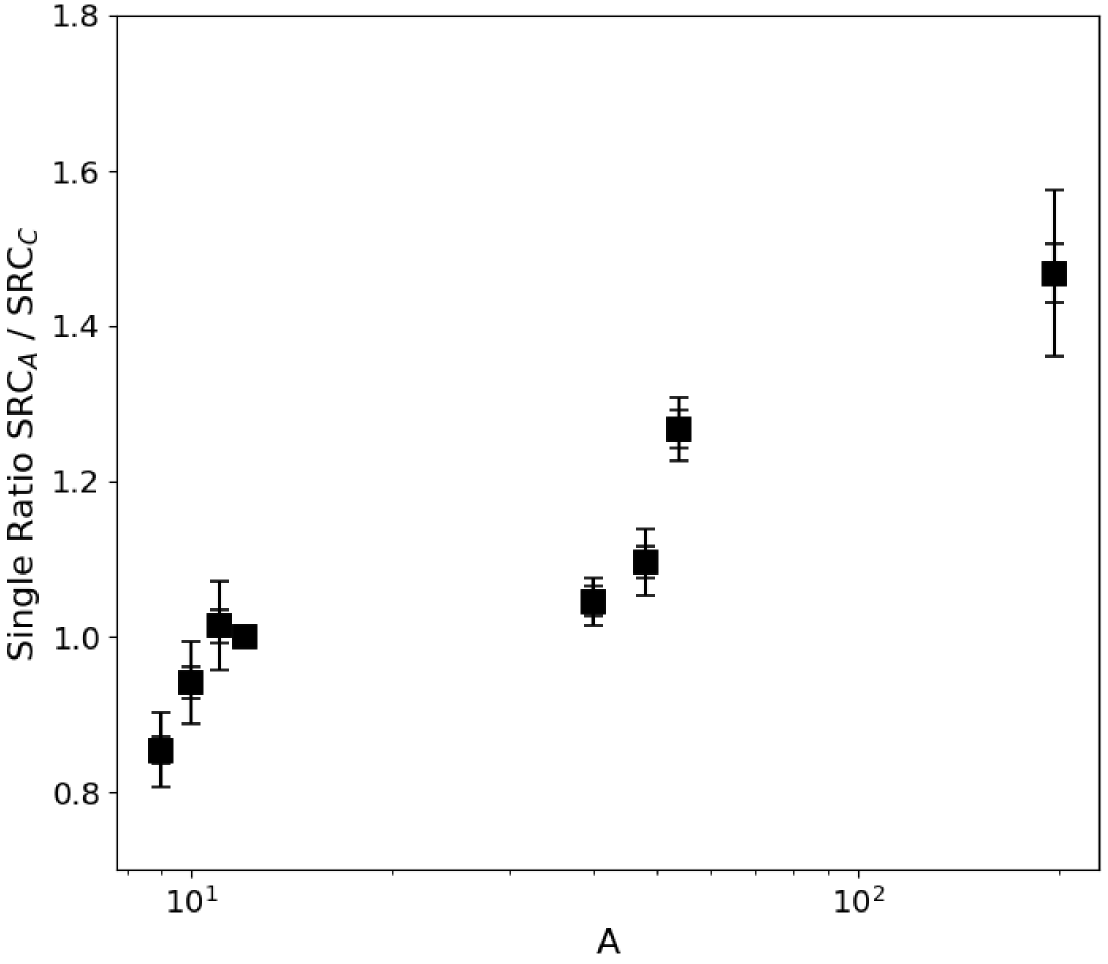
- Single
  - $\mathrm{R} = \frac{Y_A}{Y_{C12}}$
- Double
  - Normalization Factors Cancel
- MF should be proportional to number protons
- SRC should reflect probability of being in SRC
- Additional Corrections for
  - Random coincidences
  - Oil contamination (Ca targets)
  - Isotopic Impurity (Ca48 90.5%)
  - Chemical Impurity (B_4C)

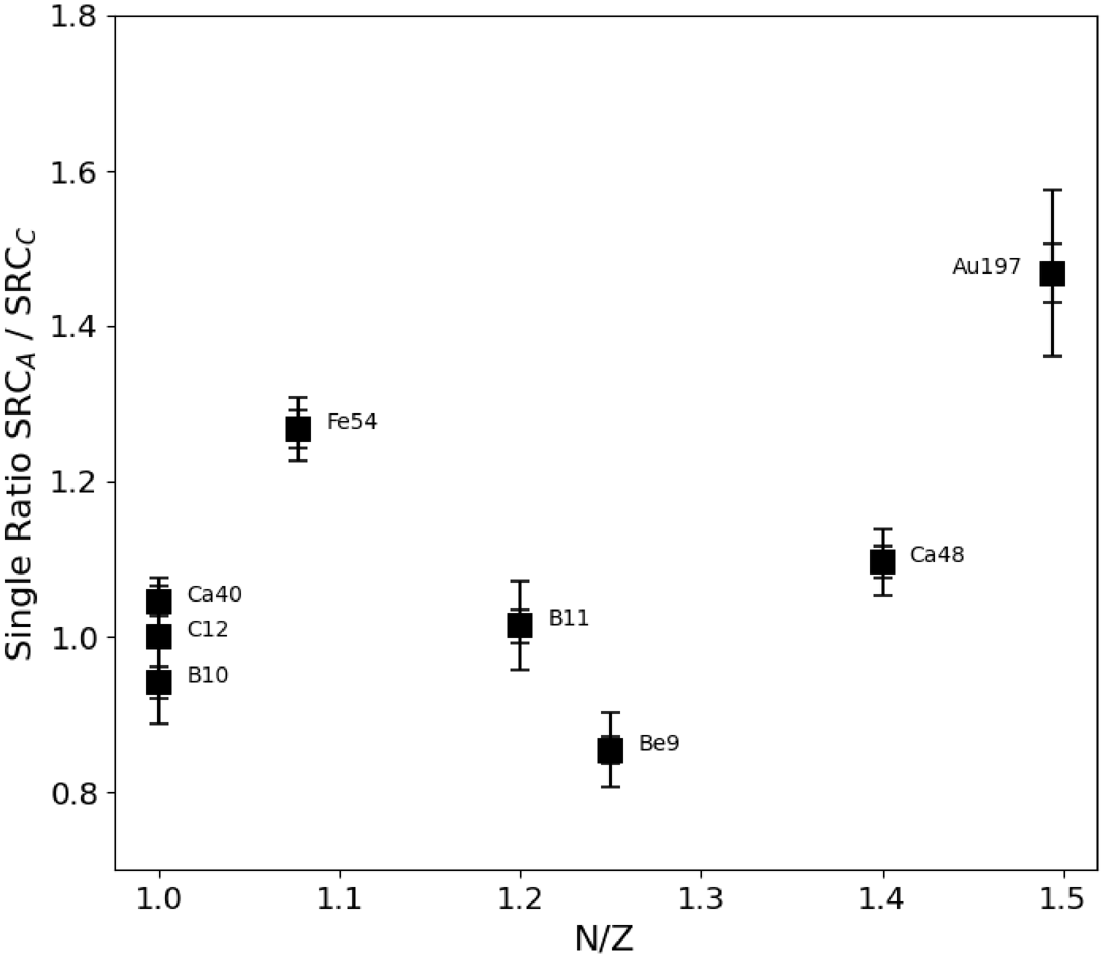
Double Ratios

$$\frac{A(e,e'p)^{SRC}/A(e,e'p)^{MF}}{^{12}C(e,e'p)^{SRC}/^{12}C(e,e'p)^{MF}}$$

Pairing depends on A (not N/Z)

SRC Single Ratio increases with A



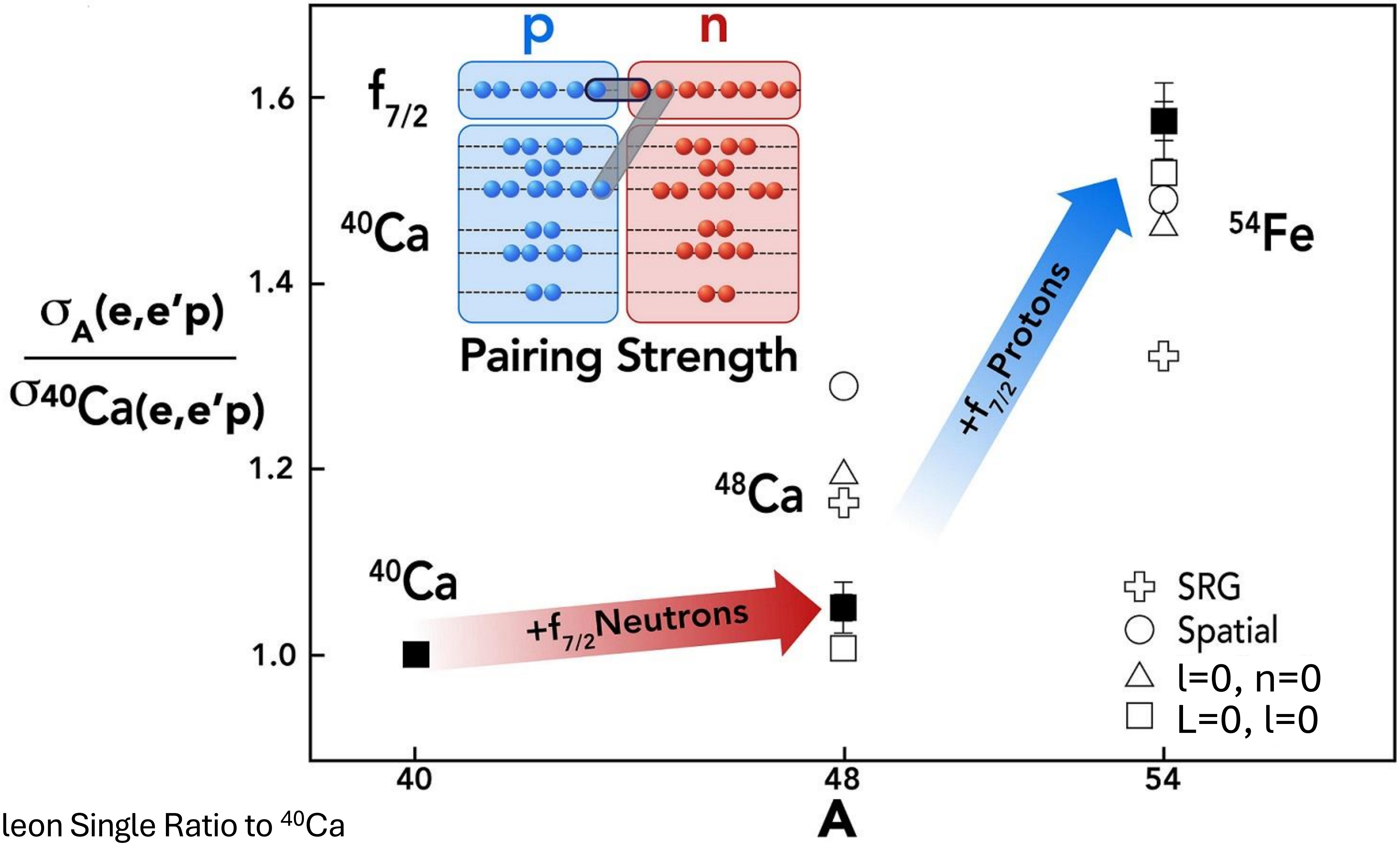


Per Proton Single SRC Ratio to C

Models

- SRG
  - Calculation of the nuclear momentum distribution
- Spatial
  - Counts the number of protons and neutrons within 1 Fermi of each other
    - A. Denniston & J. Estee, personal communication
- l=0, n=0
  - Counts the number of proton-neutron pairs in a relative l=0, n=0 state.
    - Colle et al, Physical Review C 92 (2015)
- L=0, l=0
  - Counts the number of proton-neutron pairs in a relative L=0, l=0 state.
    - Jerry Miller, personal communication

SRC Enhancement



Per Nucleon Single Ratio to ^{40}Ca

Conclusion

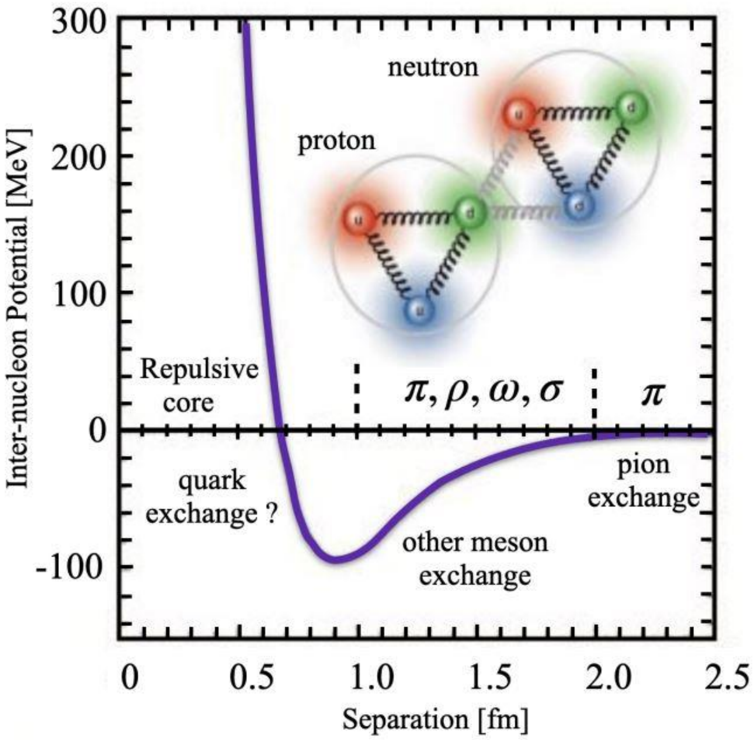
- The SRC Single Ratio is A dependent
- The $^{48}Ca/^{40}Ca$ SRC Single Ratio lower than expected
- The $^{54}Fe/^{40}Ca$ SRC Single Ratio higher than expected
- Implies
  - Strong **Intra**-shell pairing in the $f^{7/2}$ shell
  - Weak **Inter**-shell pairing between the $f^{7/2}$ shell and ^{40}Ca core

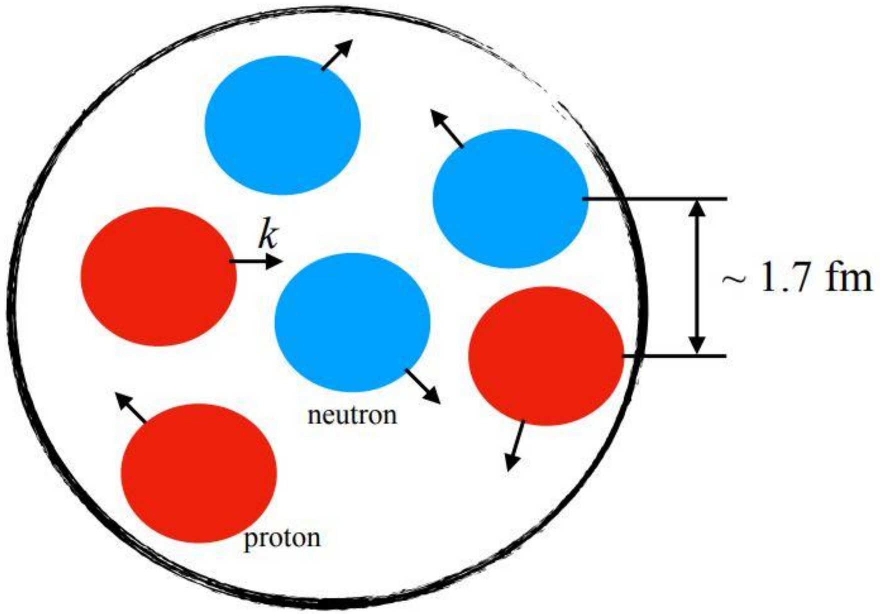
Questions?

Back up

Nuclear Shell Model

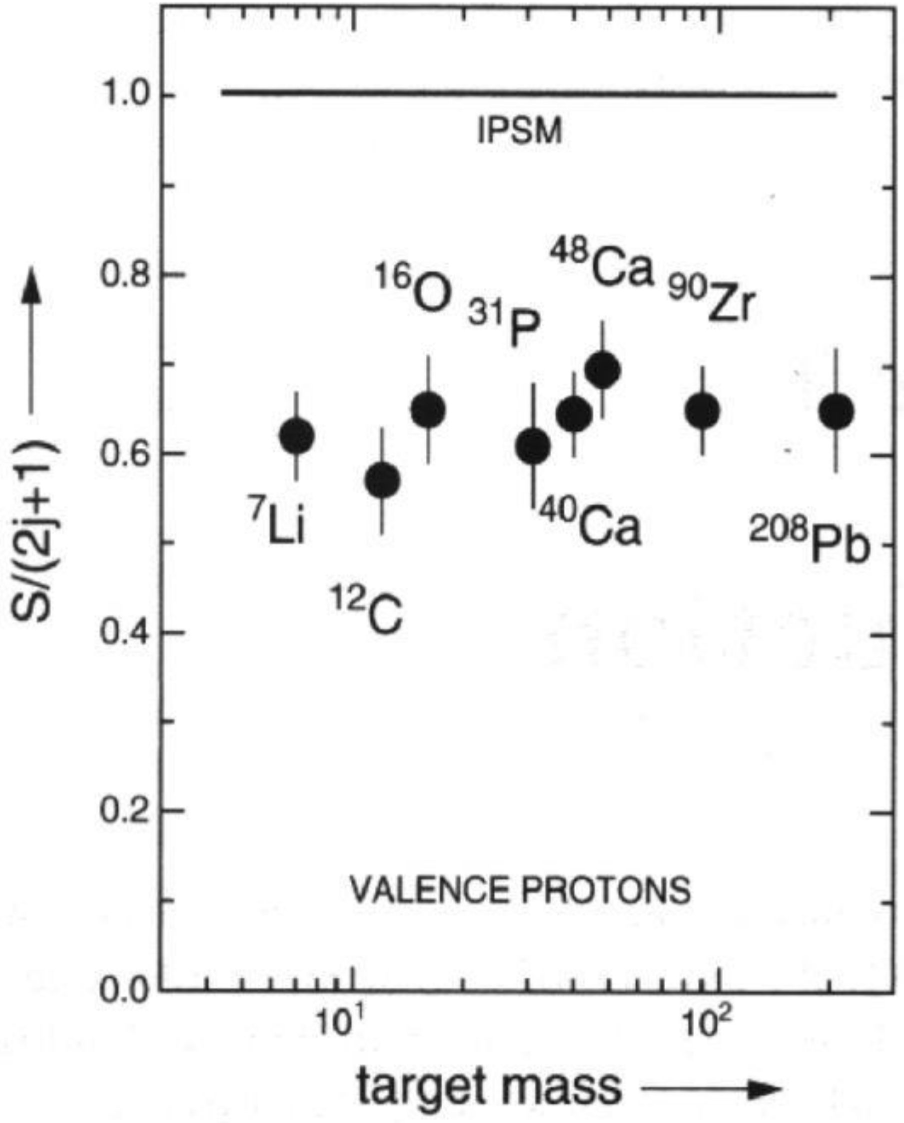
- The nucleus consists of *A* nucleons interacting via the Strong Interaction
- Nucleons move independently in a mean field generated by the other (A-1) nucleons
- Successfully describes bulk properties of nuclei
  - Shell structure
  - Excitation energies
  - Spin, parities
  - Nuclear magic numbers
- Typical momentum less than Fermi momentum, k_F~250 MeV/C





Limitations of the Nuclear Shell Model

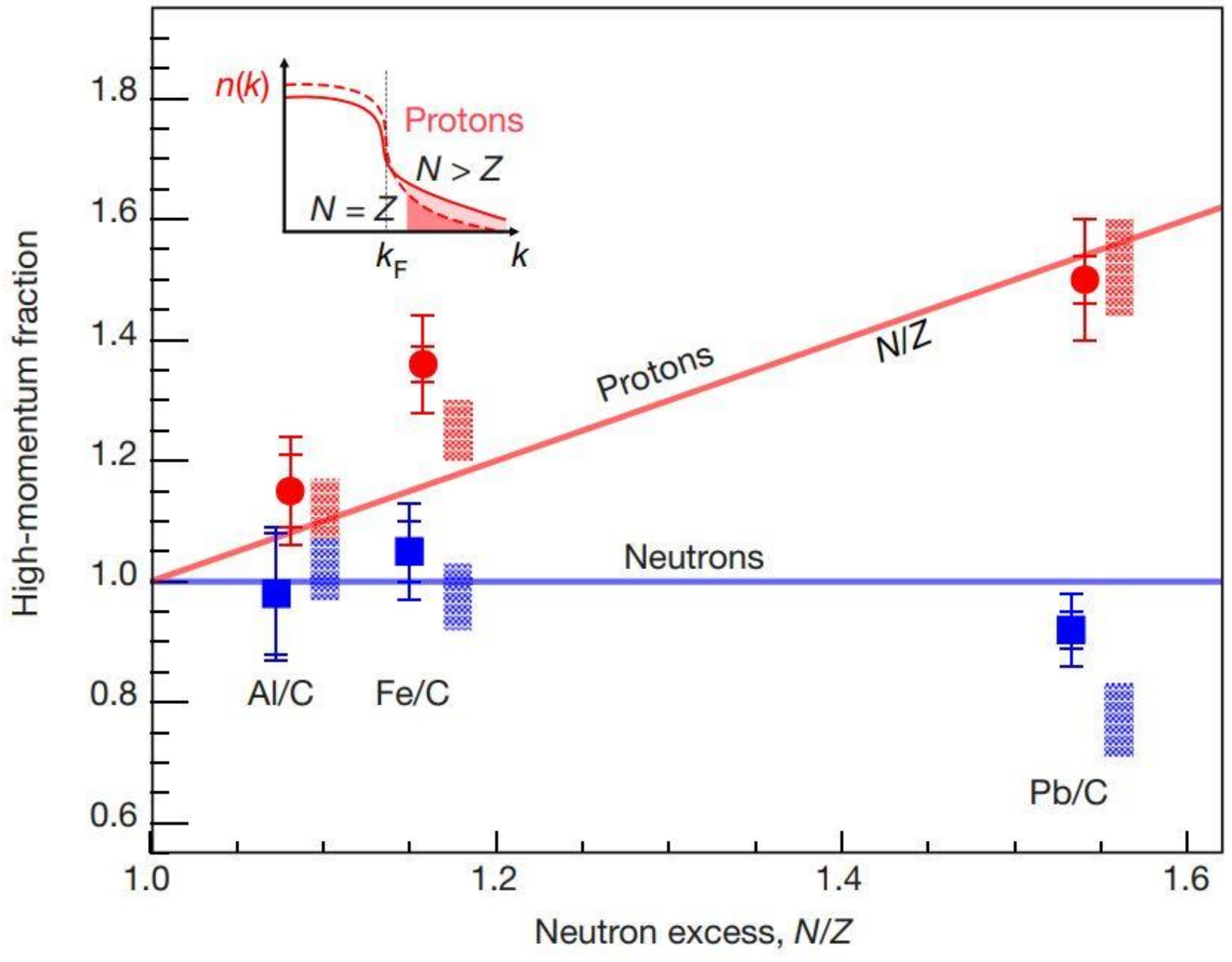
- Measured (e,e'p) proton knockout from valence shells
  - Found ~60-70% of predicted occupancy
- Corrections
  - Long range correlations
  - Short range correlations (SRCs)
    - 20-25%



O. Hen, G. A. Miller, E. Piasetzky, and L.B. Weinstein, Rev. Mod. Phys. 89, 045002 (2017). [1611.09748] Nucleon-Nucleon Correlations, Short-lived Excitations, and the Quarks Within (arxiv.org)

np-dominance in Asymmetric Nuclei Cont.

- double ratio of (e,e'p)
  - (high momentum p or n)/(low momentum p or n) for nucleus *A* relative to ^{12}C
  - Proton ratio grows like N/Z
  - Neutron ratio is near constant



M. Duer et al., Nature 560, 617 (2018)
https://www.nature.com/articles/s41586-018-0400-z

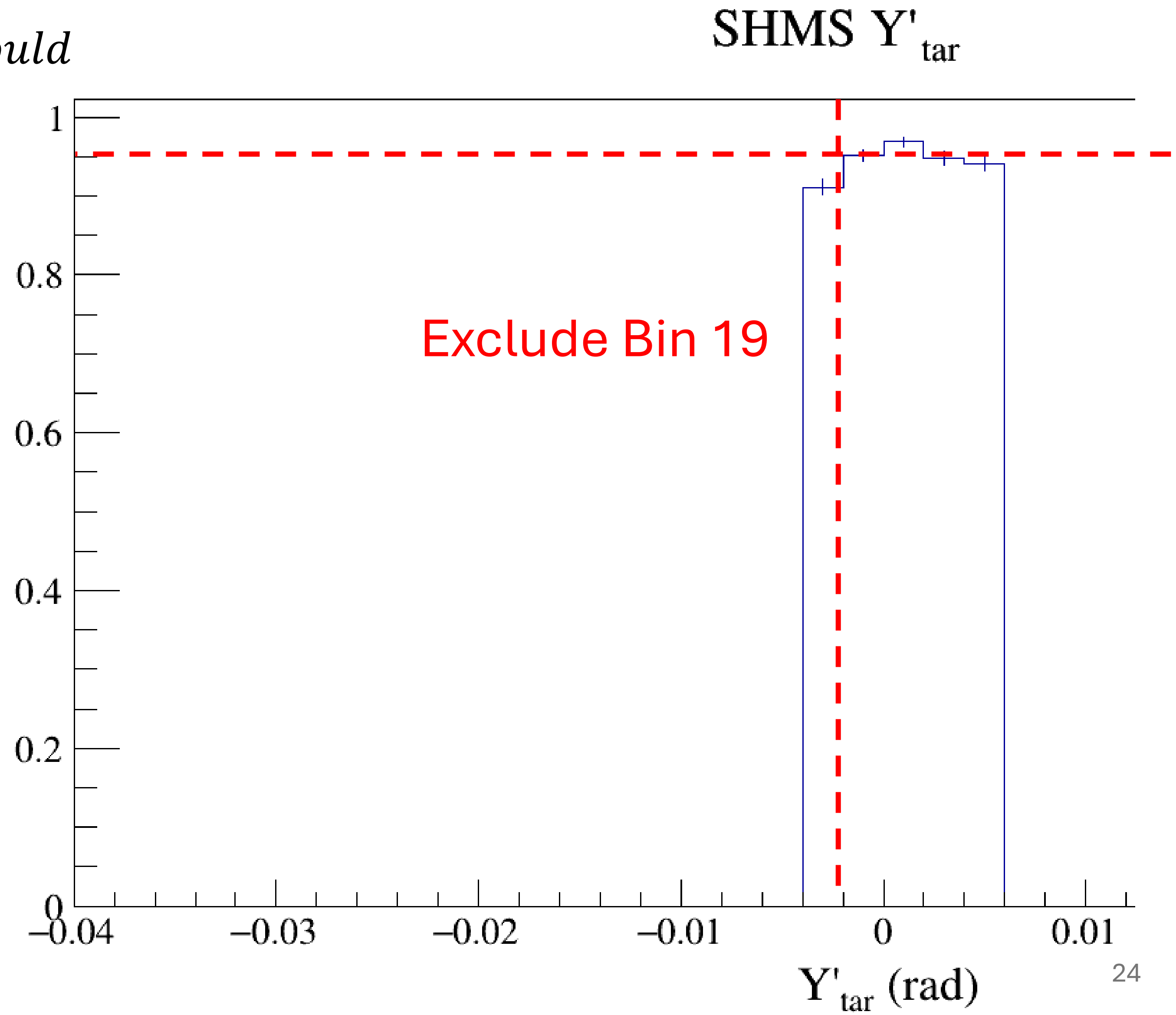
HMS Proton Efficiency

- Measure H(e,e’p)/H(e,e’)p
- Select H(e,e’) events that should have a proton in the HMS
  - $0.92 < \mathrm{W} < 0.97$ GeV
  - $-2 < \mathrm{z} - \mathrm{Target} < 2$ cm
  - $-0.01 < \mathrm{SHMS}\ \mathrm{x'}_{\mathrm{tar}} < 0.01$ rad (phi)
  - $-0.002 < \mathrm{SHMS}\ \mathrm{y}'_{\mathrm{tar}} < 0.006$ rad (theta)
  - $0.8 < \frac{\mathrm{E_{tot}}}{\mathrm{P_{cent}}} < 1.8$
- H(e,e’p) events
  - Should +
  - $-5 < \mathrm{ep\ Coin\ Time} < 5$ ns
  - $-0.02 < \mathrm{E_m} < 0.9$ GeV
- Iteratively tightened cuts until ratios became flat

HMS Proton Efficiency

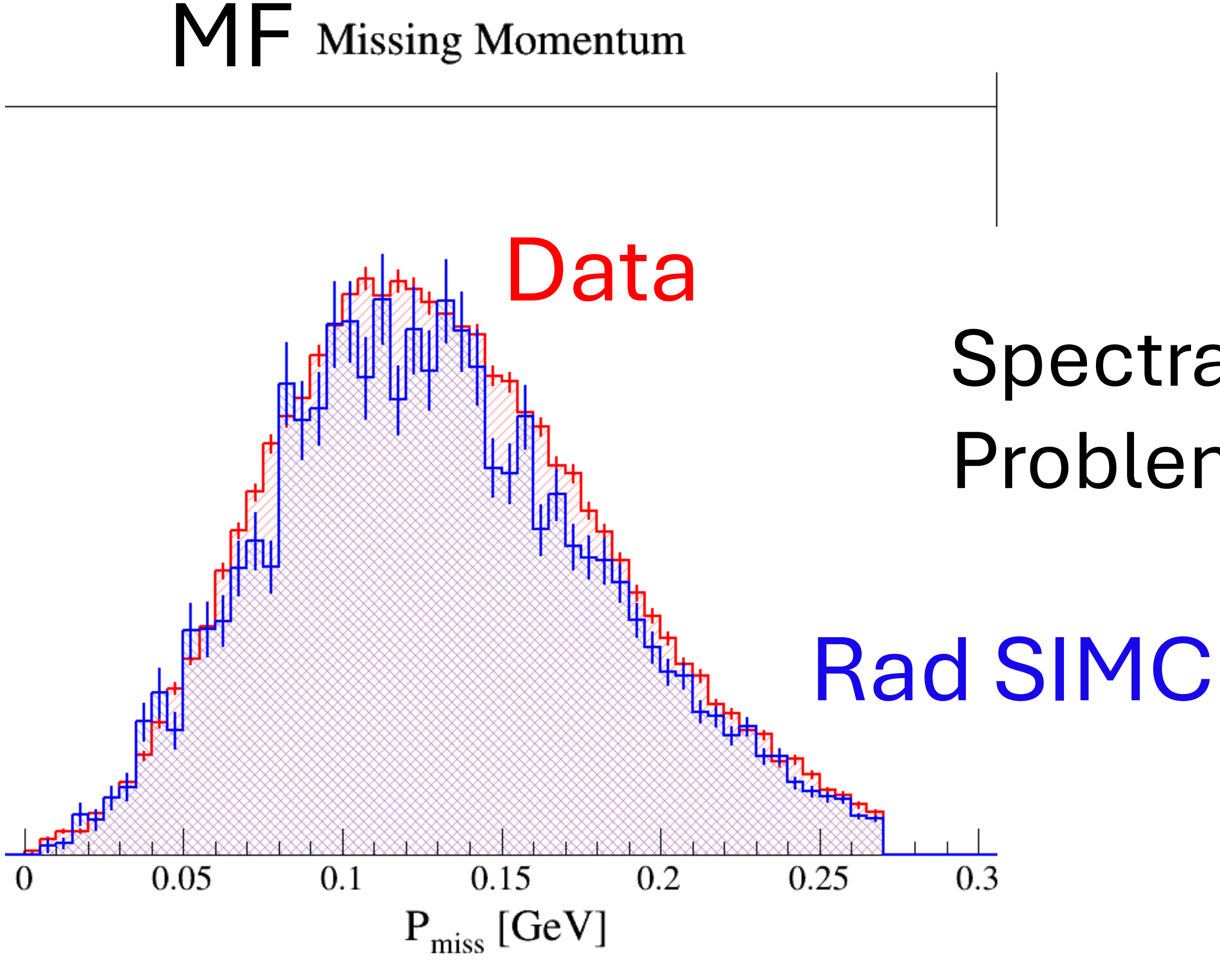
$$\sigma_{ratio}^{exact} = \sqrt{should\,\frac{did}{should}(1-\frac{did}{should})}\Big/should$$

Proton Efficiency: 0.952 ± 0.004



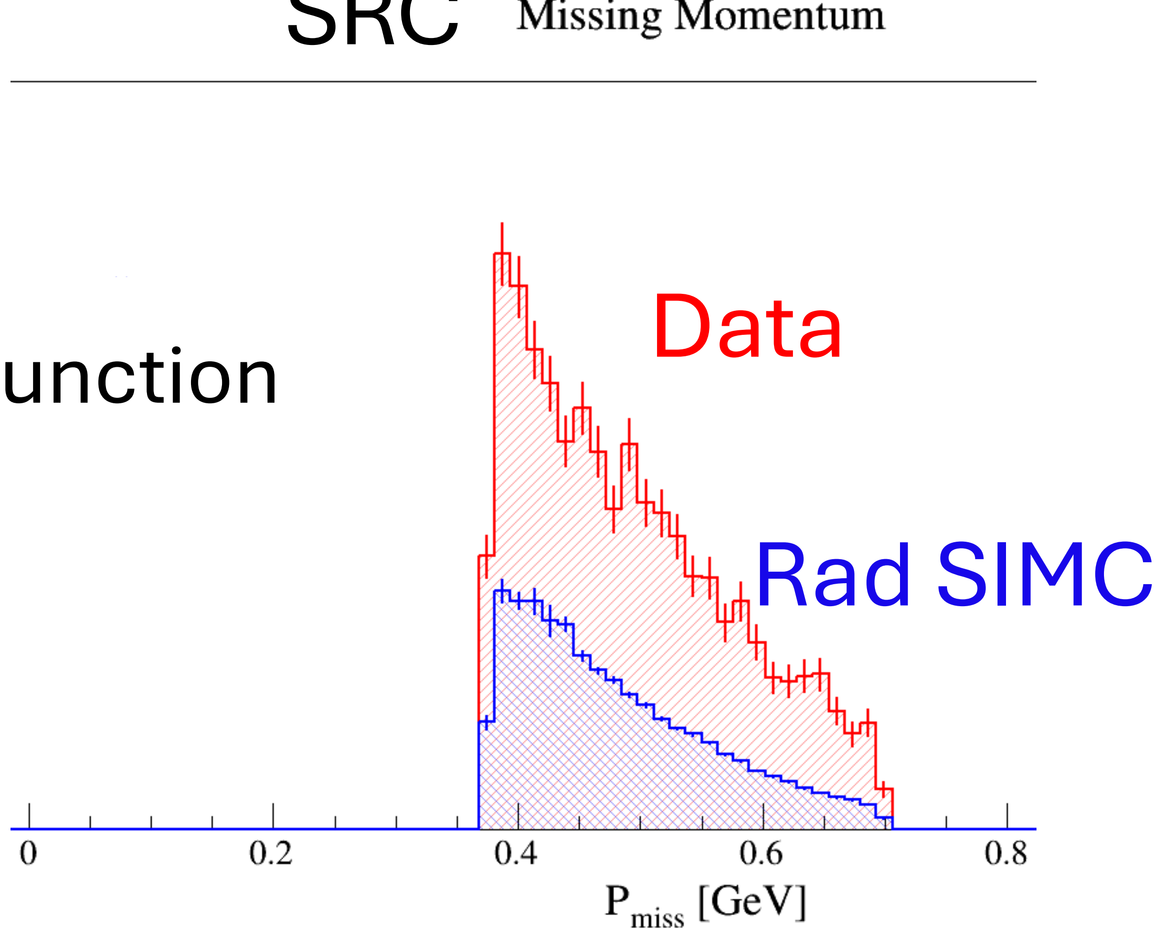
Radiative Correction: ^{12}C Benhar Simc vs Data

MF

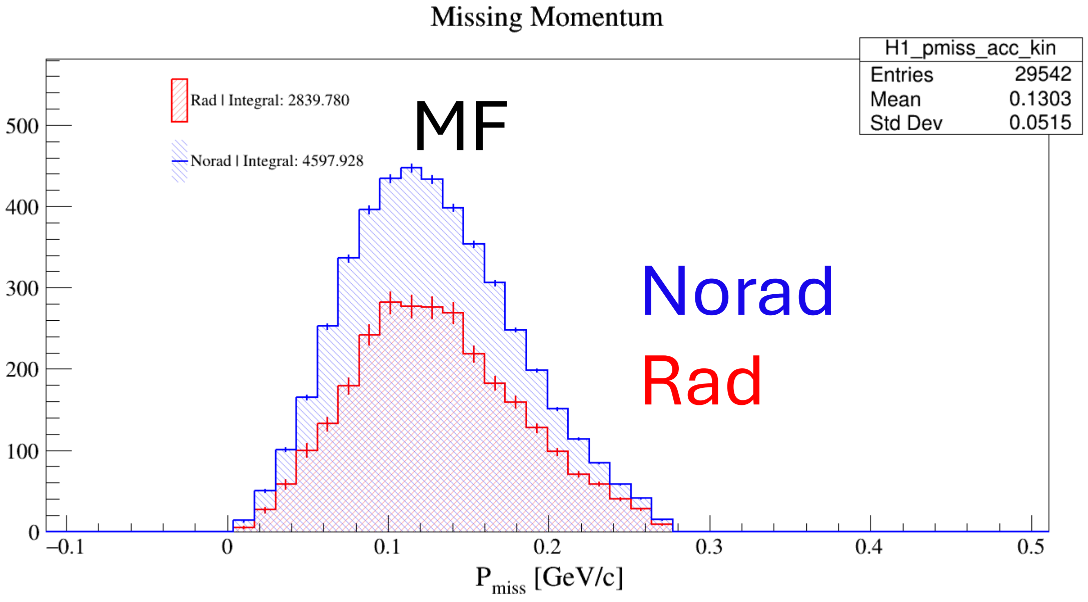


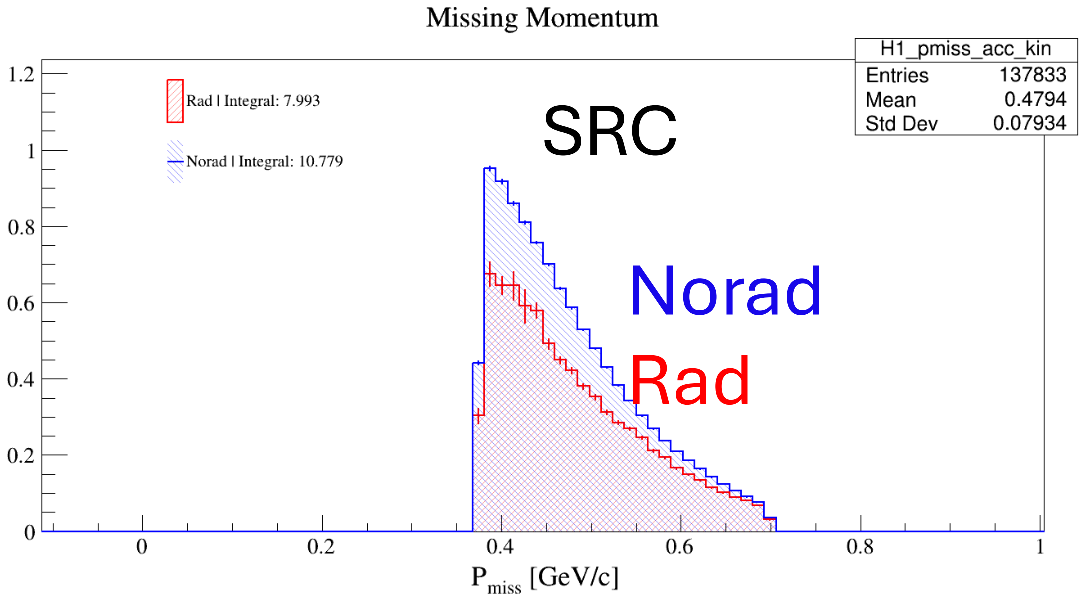
Spectral Function Problems

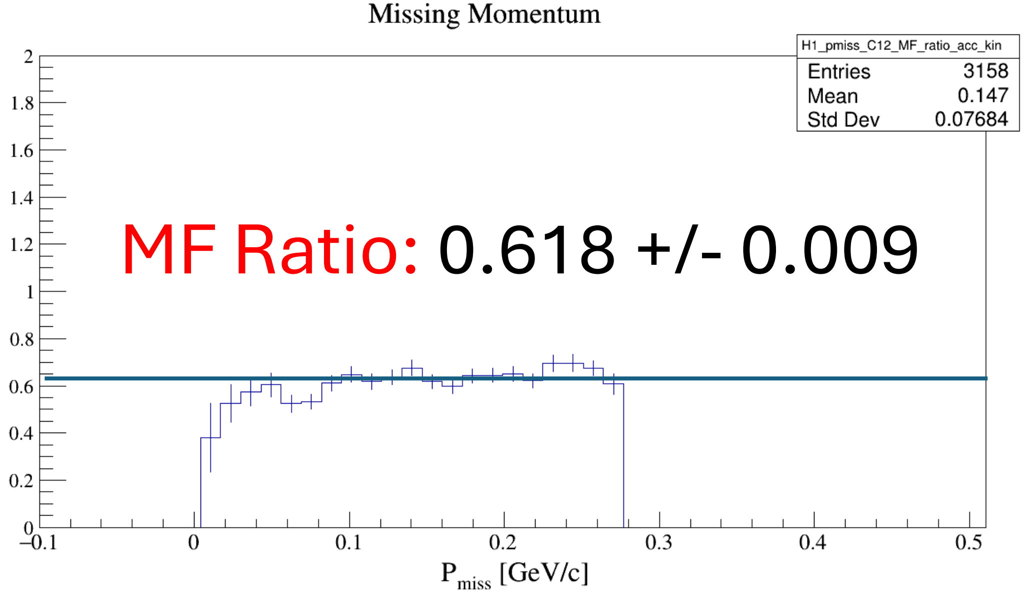
SRC

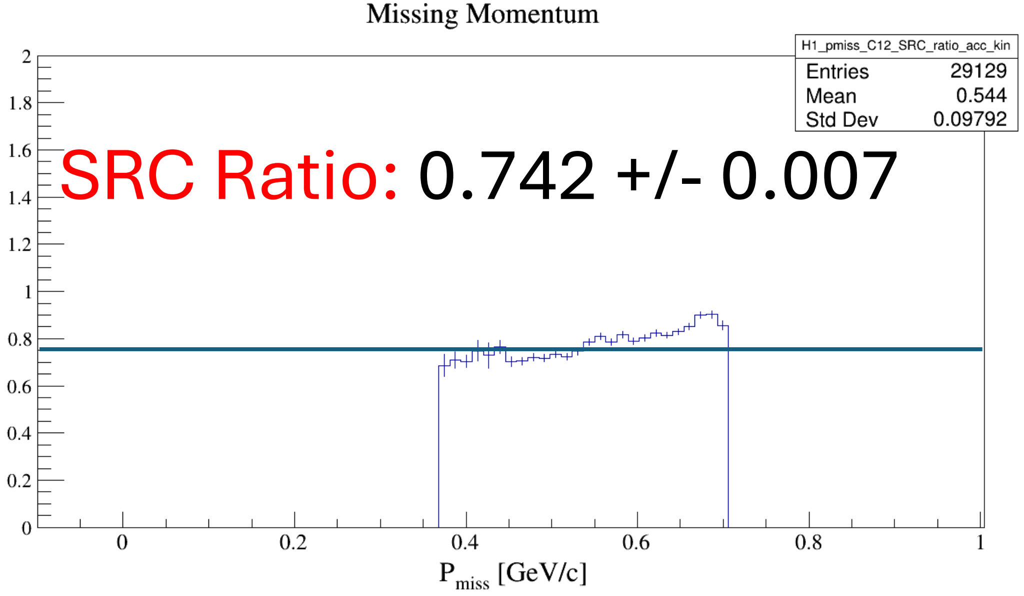


MF & SRC ^{12}C p_{miss} Radiative Correction

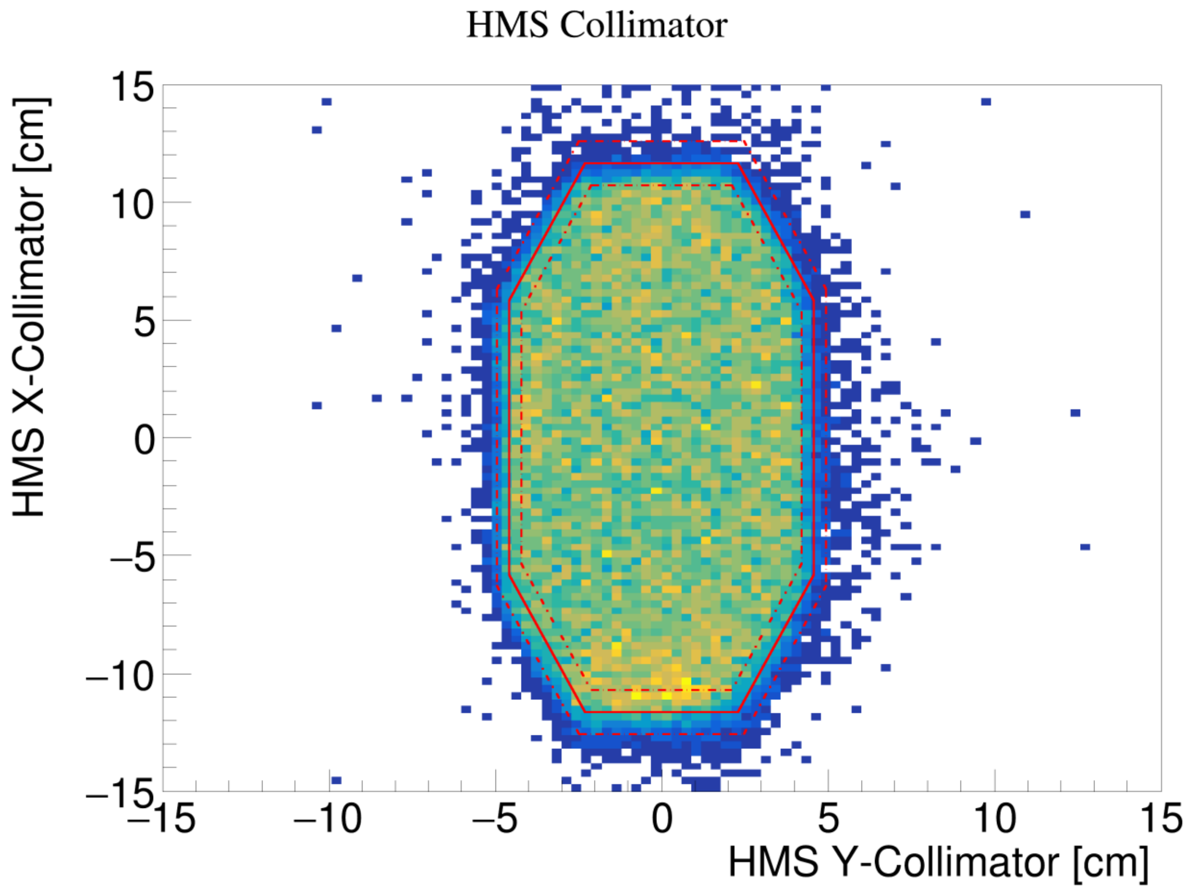


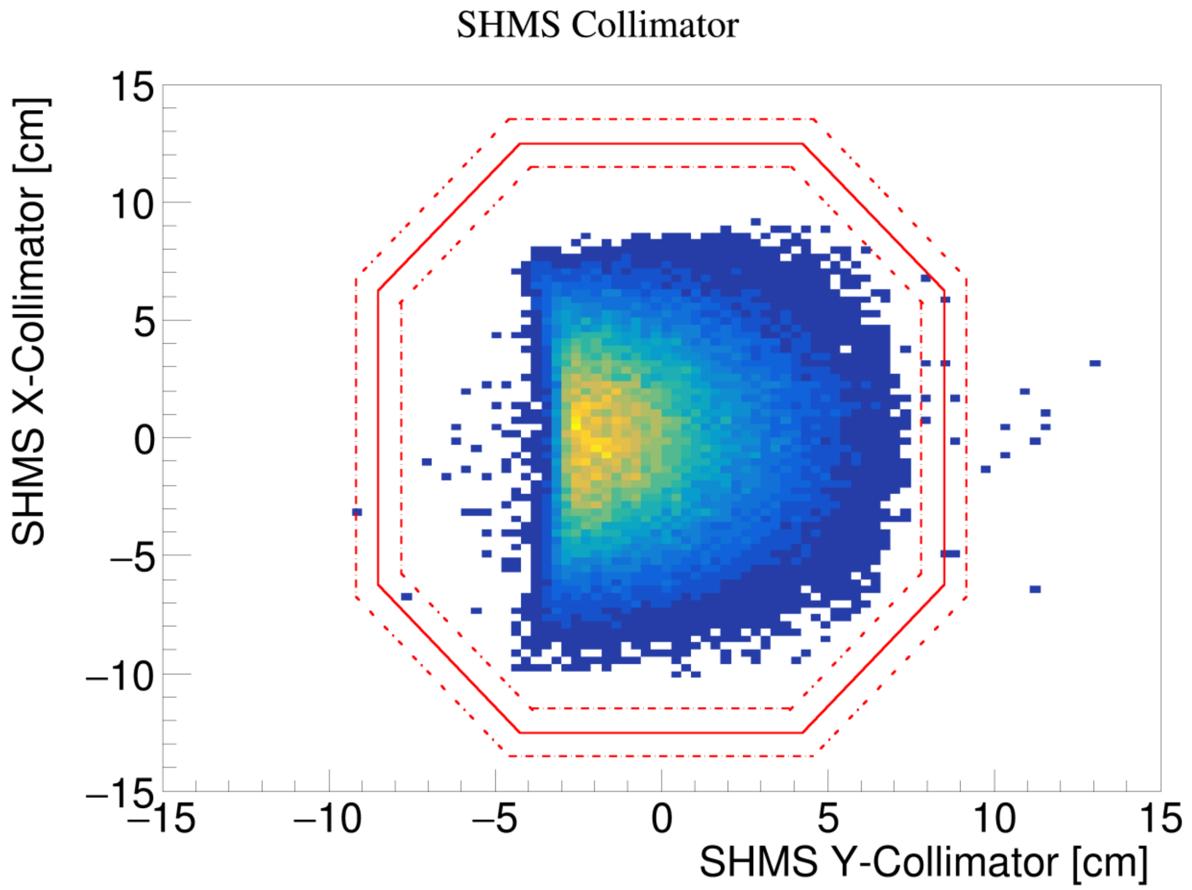




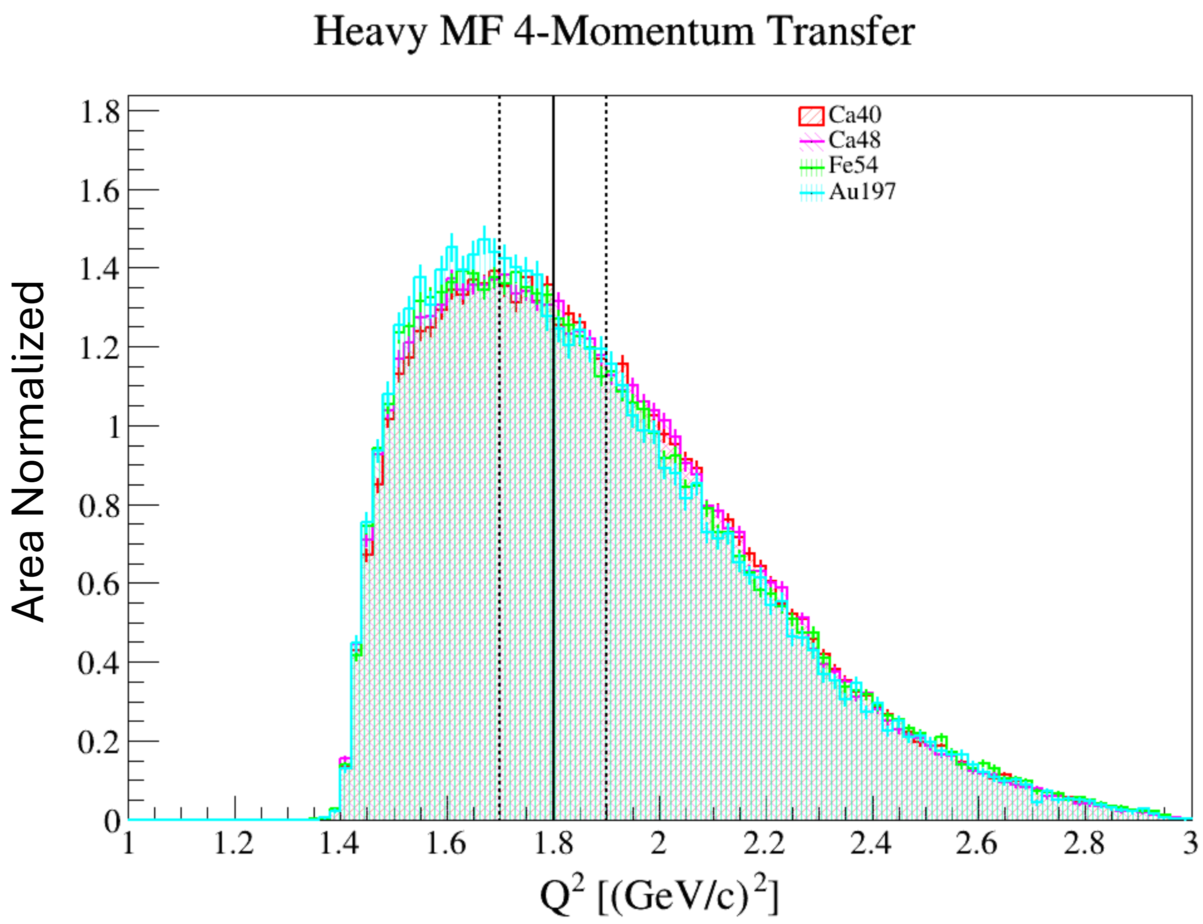


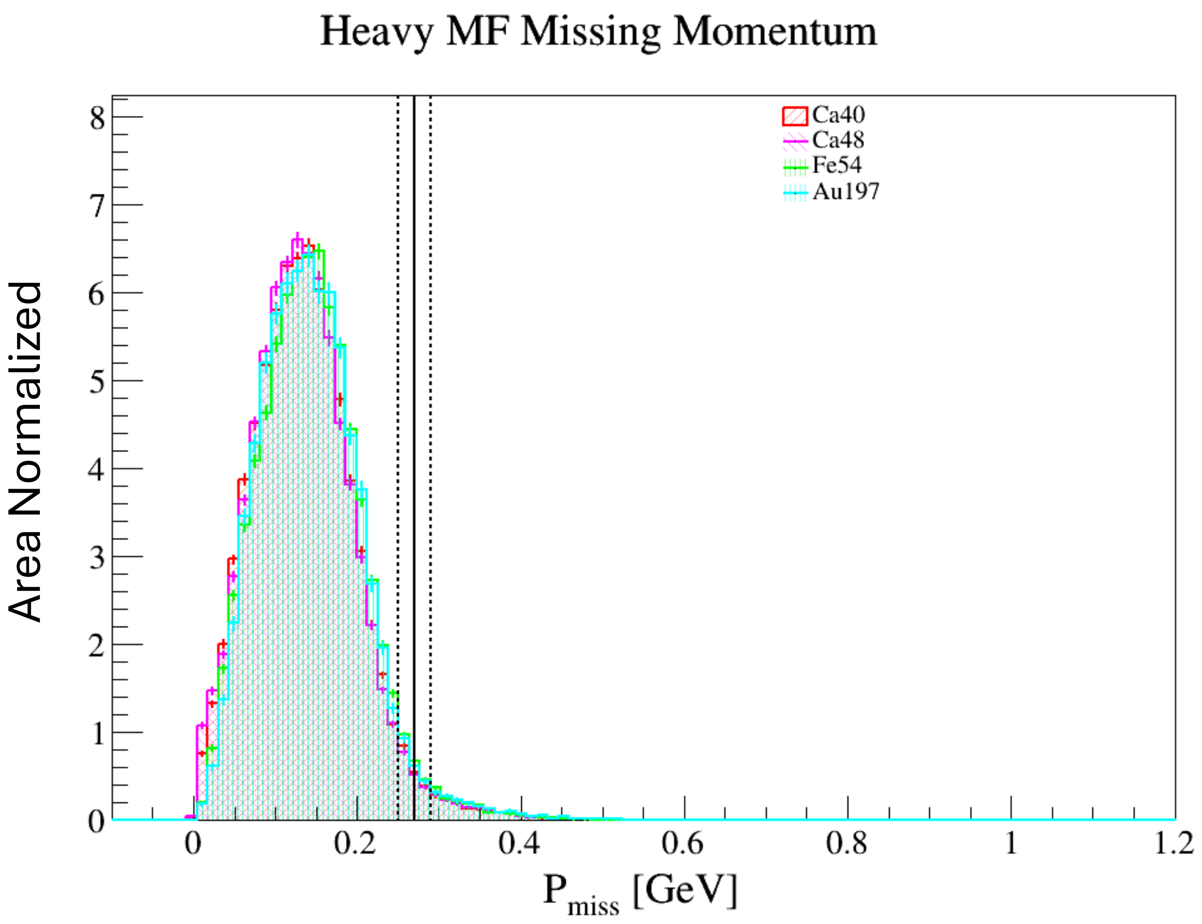
MF HMS & SHMS Collimator Cuts (±2σ)



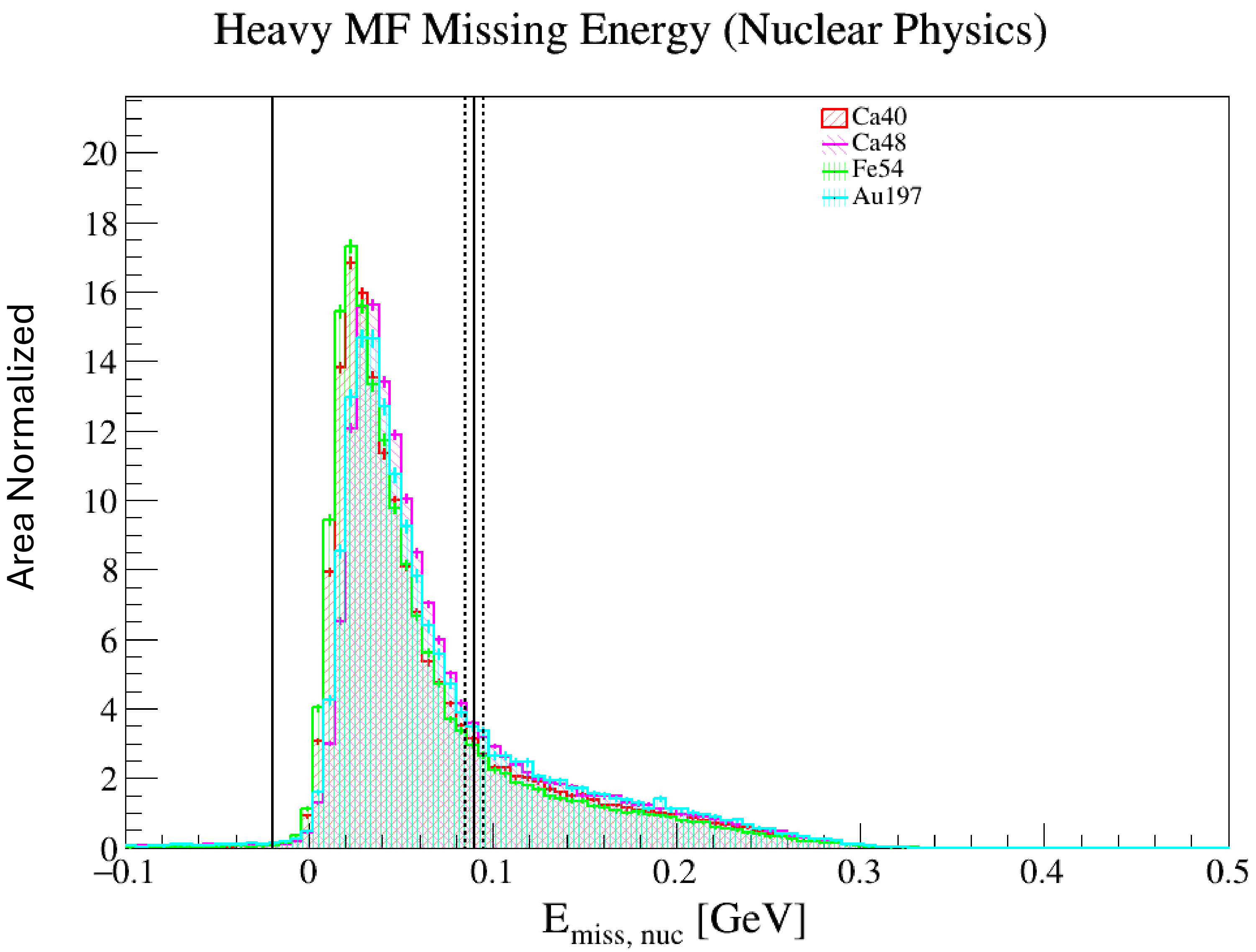


MF Q^2 & P_m Cuts ($\pm 2\sigma$)

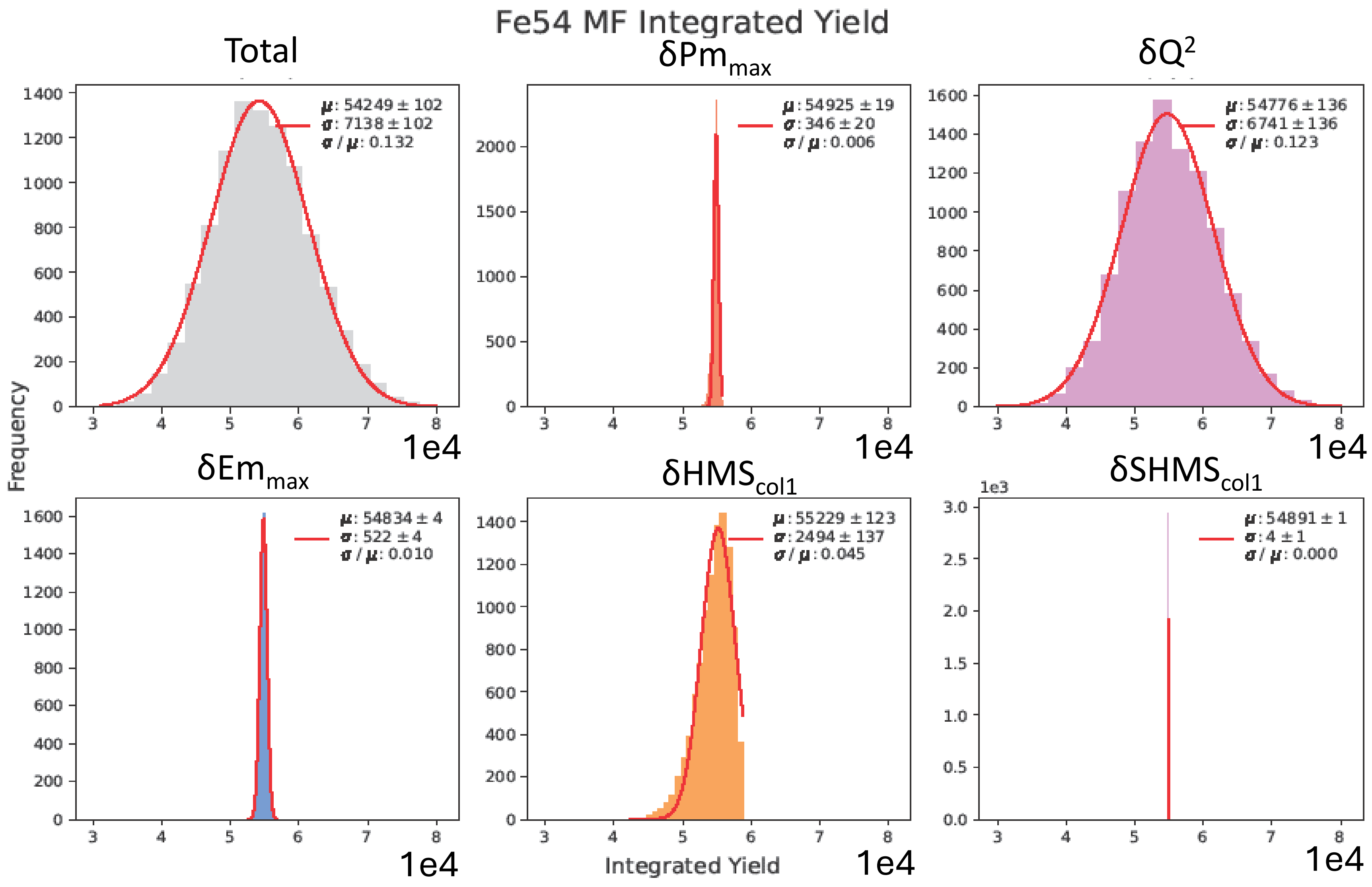




MF E_m Cuts (±2σ)


Heavy MF Missing Energy (Nuclear Physics)
Ca40
Ca48
Fe54
Au197
Area Normalized
0
2
4
6
8
10
12
14
16
18
20
−0.1
0
0.1
0.2
0.3
0.4
0.5
E_miss, nuc [GeV]

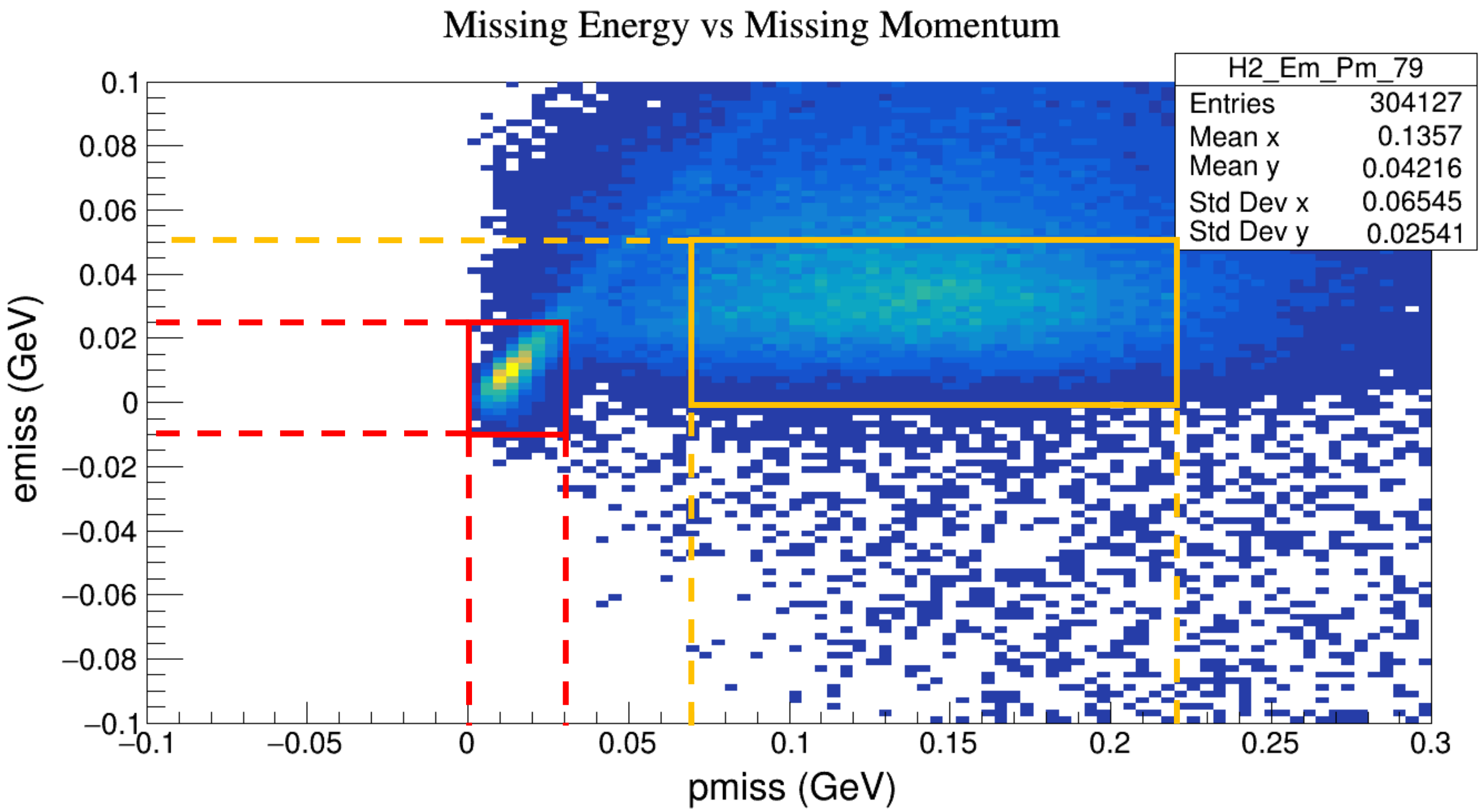
Mean and σ/mean: MF

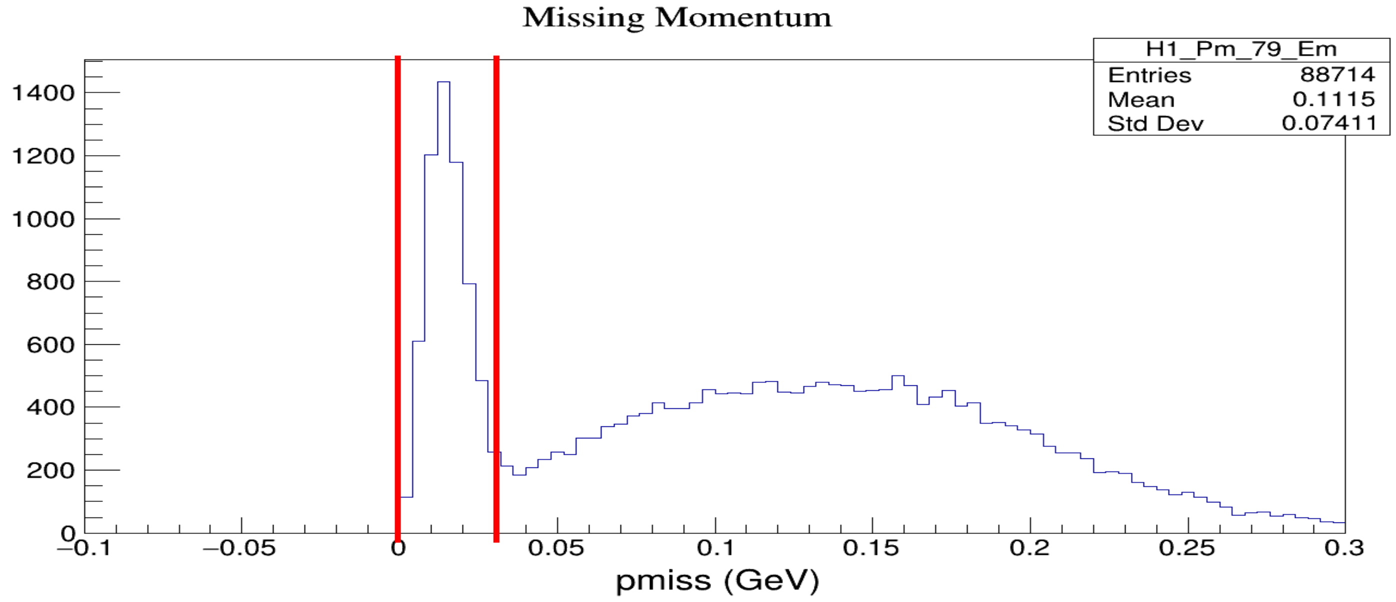


σ/mean ≈ 13% for all targets

MF ^{48}Ca Em vs Pm

- Hydrogen Peak
  - -0.01 < emiss < 0.025 (GeV)
  - 0 < pmiss < 0.03 (GeV)
- Signal Region
  - 0 < emiss < 0.05 (GeV)
  - 0.07 < pmiss < 0.220 (GeV)





^{48}Ca Contamination

MF ^{48}Ca Data			
Run	H (mg/cm^2)	Carbon (mg/cm^2)	Carbon (%)
16978	6.4	38.4	3.65
16979	5.2	31.2	2.97
17093	1	6	0.57
17094	0.9	5.2	0.49
17096	0.9	5.2	0.49

MF ^{48}Ca H-thickness (SIMC)

- $48Ca_{thick} = =1051\ mg/cm^2$
- $H_{thick} = \frac{Data\ Counts}{Data\ Q/_{Simc\ Q} * Simc\ \ Counts} * LH2\ Simc\ thickness$
- Run 16979
  - $H_{thick} = \frac{5969}{75.99mC/_{1mC} * 10857.2} * 723.1mg/cm\text{^}2 = 5.232\ mg/cm\text{^}2$

	MF ^{48}Ca Data			
	Run	Data Counts	Q (mC)	H-thick (mg/cm^2)
MF	16978	528	5.5	6.4
	16979	5969	76.0	5.2
	17093	748	49.6	1.0
	17094	165	12.6	0.87
	17096	1290	98.5	0.87

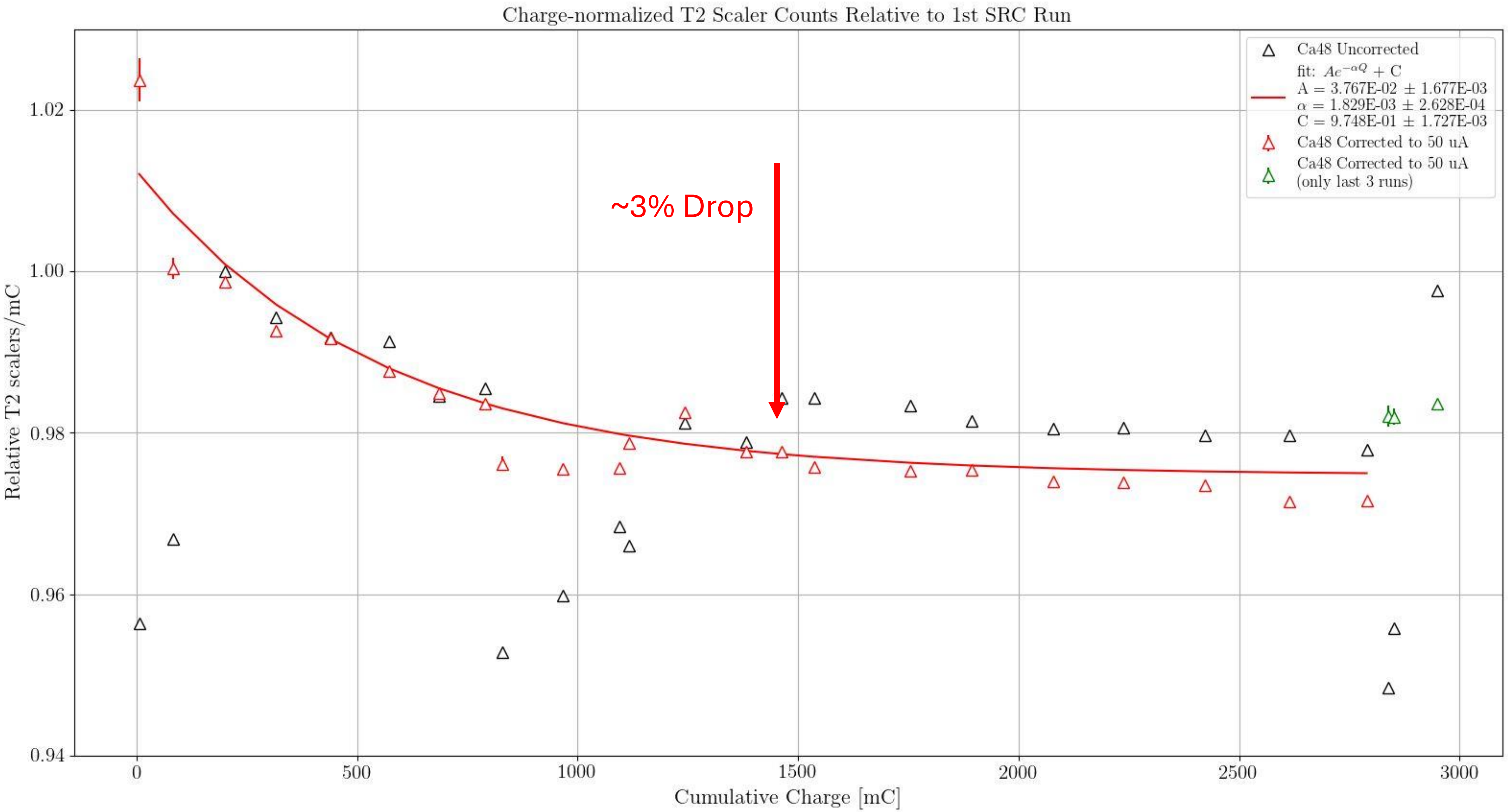
^{48}Ca: ^{12}C-thick

- $C_{thick} = H_{thick} \frac{12.011\ g/mol}{1.00794\ g/mol} * \frac{1\ C-atom}{2\ H-atom}$
- $\%C = \frac{C_{thick}}{48Ca_{thick}} * 100$

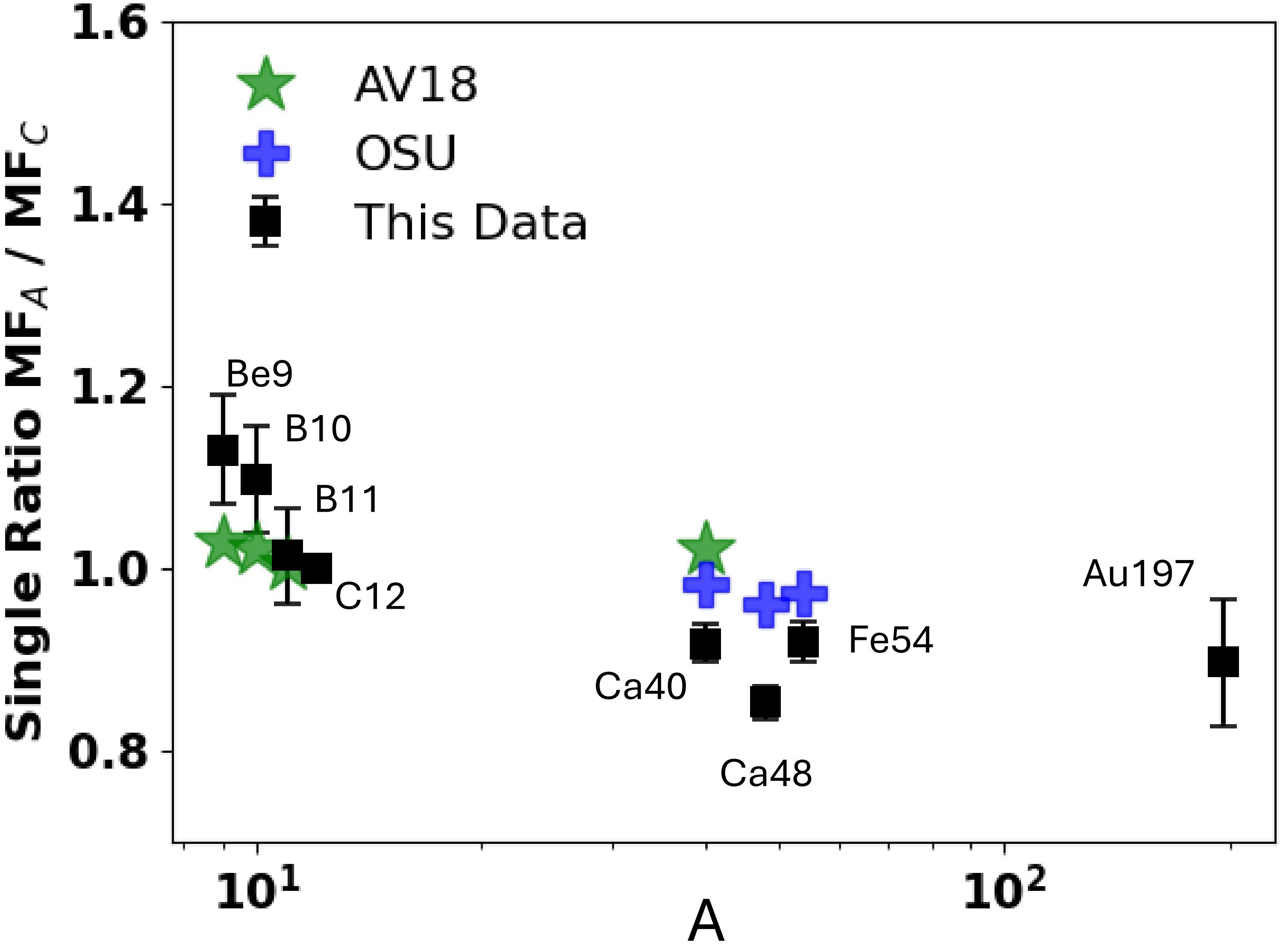
Mf ^{48}Ca Data			
Run	H (mg/cm^2)	Carbon (mg/cm^2)	Carbon (%)
16978	6.4	38.4	3.65
16979	5.2	31.2	2.97
17093	1	6	0.57
17094	0.9	5.2	0.49
17096	0.9	5.2	0.49

^{48}Ca

- A ~3% drop corresponds to the prediction of having 1 C per 2 H



MF Single Ratio to C



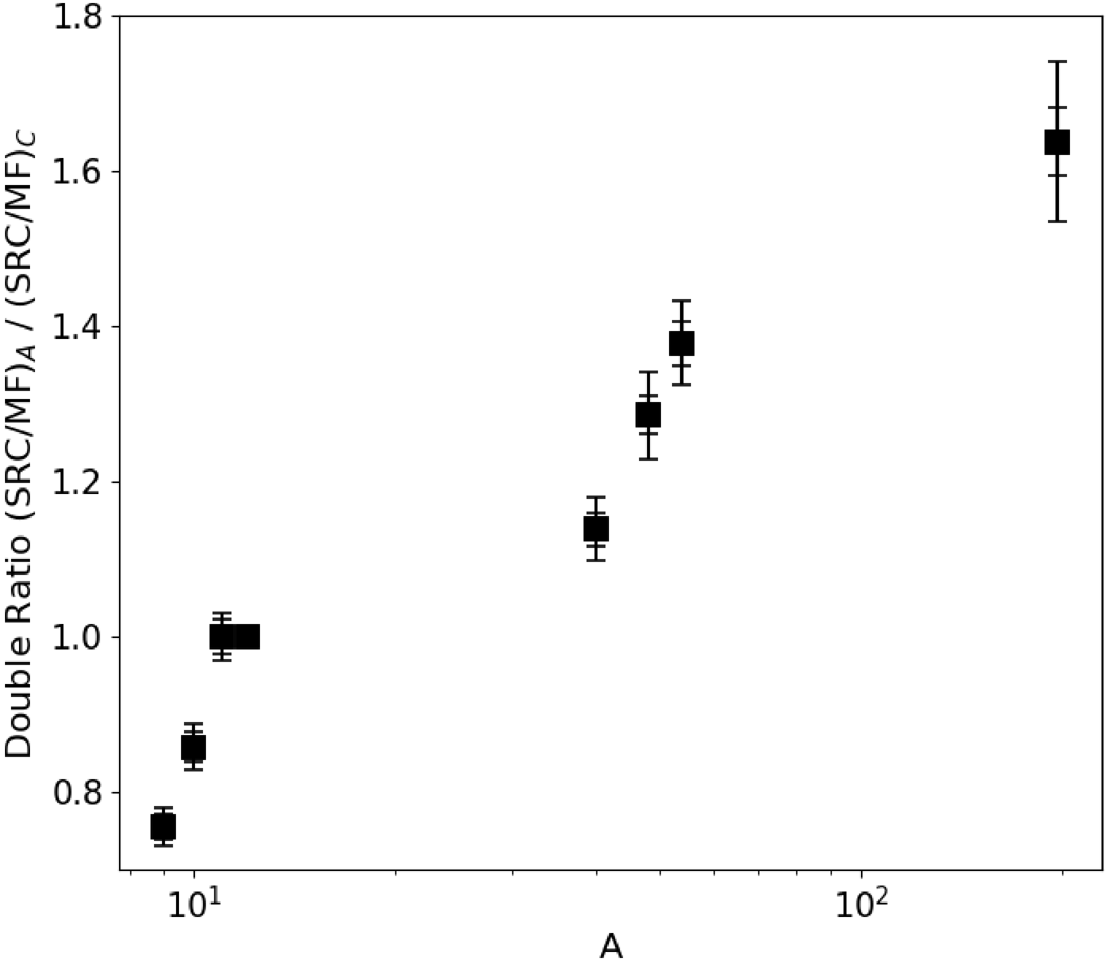
- MF Single Ratio decreases with A
- Models are flat

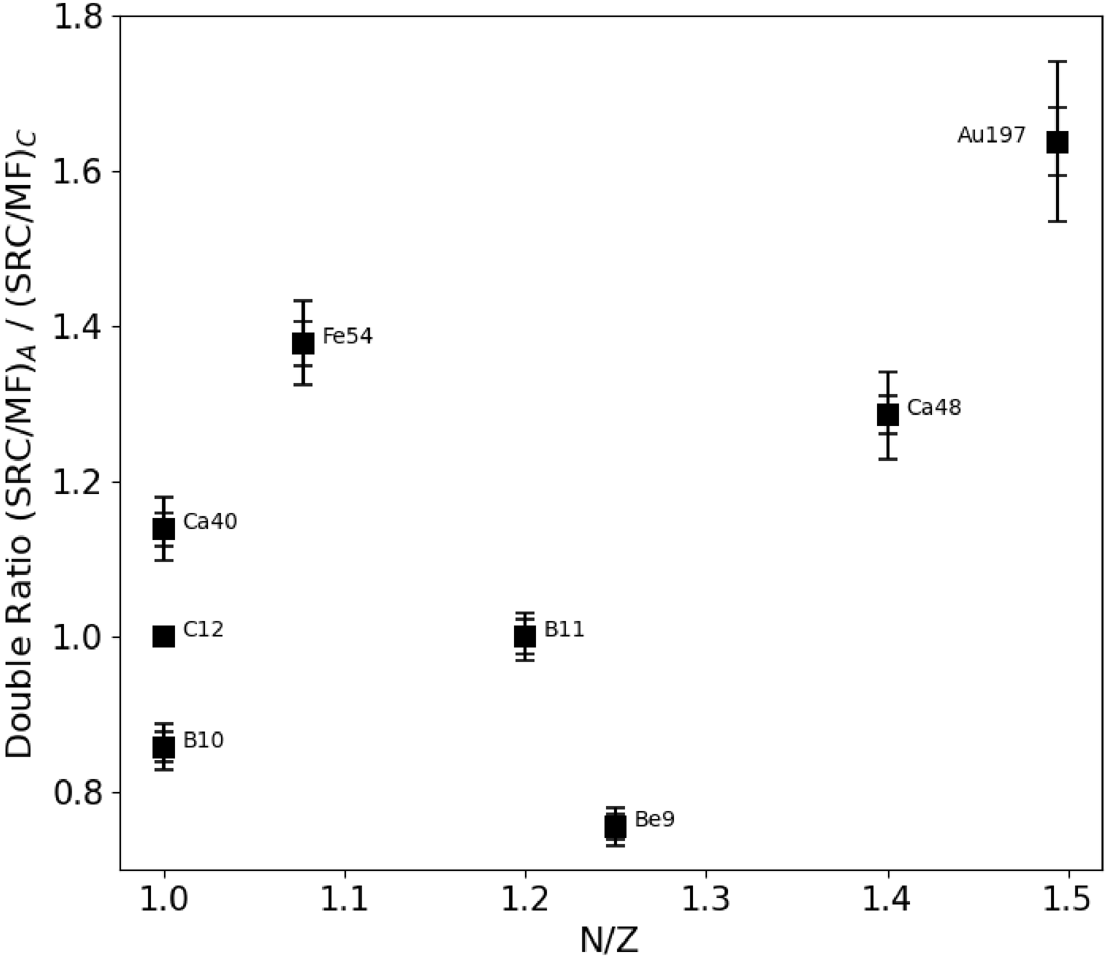
R.J.Furnstahl et al. arXiv:2402.00634v2 (OSU)

Wiringa et al. Phys.Rev.C89 (AV18)

Pairing depends on A (not N/Z)

Double Ratio increases with A





Per Proton Double Ratio to C

Calculating Electron Cross Section

- $N_{events\ into\ solid\ angle\ \Delta\Omega} = Data\ Counts\ * SIMC\ Ratio$
- $N_{incident} = \frac{Q\ (C)}{1.602*10^{-19}(C)}$
- $nx = \rho_{H2} * Target\ Length\ * N_A$
  - Target Length modified by z-Target cut
- Electron solid angle modified by hxptar and hyptar cuts

Central Kinematics

```
------------------------------
H(e,e'p) Elastics for
Beam Energy (Eb) = 10.549 GeV
e- angle (th_e)  = 8.300 deg
------------------------------
e- momentum (kf)             = 9.438 GeV/c
proton angle (th_p)          = 48.384 deg
proton momentum (Pf)         = 1.822 GeV/c
4-momentum transfer (Q2)     = 2.086 (GeV/c)^2
3-momentum transfer (|q|)    = 1.822 GeV/c
energy transfer              = 1.111 GeV
x-Bjorken                    = 1.000

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H(e, e') Cross Section @ Central Kinematics

```
H(e,e') Elastic Cross Section:
 Eb = 10549.0 MeV
 kf = 9438.0 MeV
 th_e = 8.3 deg
d_sig/d_omega_e [ub/sr] (Bosted parametrization) = 2.449E-02
d_sig/d_omega_e [ub/sr] (Arrington parametrization)= 2.409E-02
```

- Use J. Arrington form-factor parametrization (more recent)

Definition of cross section for scattering or reactions

Let $N_{incident}$ = number of incident (beam) particles

N_{events} = number of events (beam−target interactions)

n = target atoms per unit volume = $\frac{\rho N_{Avogadro}}{A}$

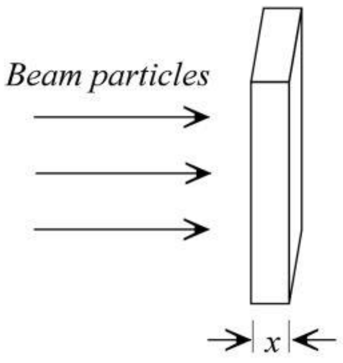
A = mass number of target (assuming a single pure isotope)

ρ = mass density of target (g/cm^3)

x = thickness of target (cm)

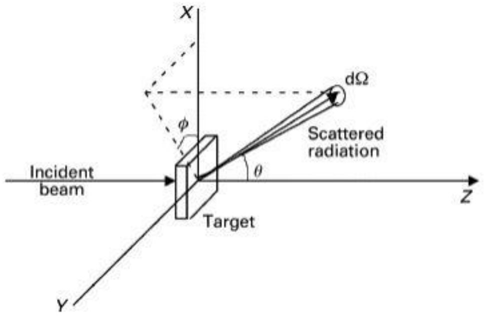
ρx = areal density of target (g/cm^2)

nx = areal number density (atoms/cm^2) = $\frac{\rho x N_{Avogadro}}{A}$



$$N_{\text{events into solid angle } \Delta\Omega_e} = N_{\text{incident}} nx \frac{d\sigma}{d\Omega_e} \Delta\Omega_e$$

Need to determine total # of H atoms per area that contaminate the Ca48 target



Ref. Physics 537/635 – D. Sober "An Introduction to Cross Sections" January 2005 (rev. 2007)

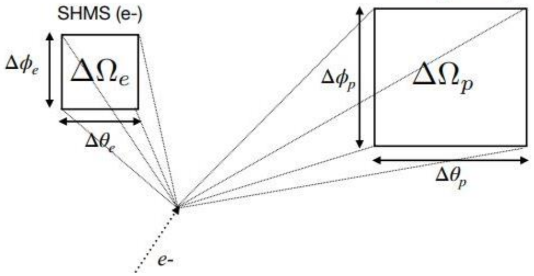
Solid Angle

$$N_{\text{events into solid angle }\Delta\Omega_e} = N_{\text{incident}}\, n x \frac{d\sigma}{d\Omega_e}\Delta\Omega_e$$

$$\Delta\Omega_e = \Delta\Omega_p \times \frac{d\theta_e}{d\theta_p} \times \frac{d\phi_e}{d\phi_p}$$

"HMS Solid Angle" "In-plane" "Out-of-plane"

Hall C spectrometers angular acceptance

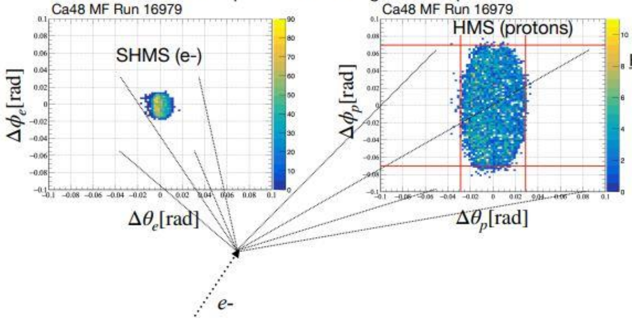


$$N_{\text{events into solid angle }\Delta\Omega_e} = N_{\text{incident}}\, n x \frac{d\sigma}{d\Omega_e}\Delta\Omega_e$$

$$\Delta\Omega_e = \Delta\Omega_p \times \frac{d\theta_e}{d\theta_p} \times \frac{d\phi_e}{d\phi_p}$$

"HMS Solid Angle"

Hall C spectrometers angular acceptance



HMS "Large" Collimator

$\Delta\theta_p = \pm 0.0275$ rad

$\Delta\phi_p = \pm 0.07$ rad

$\Omega_p = 0.00674$ sr

20

$$N_{\text{events into solid angle }\Delta\Omega_e} = N_{\text{incident}}\, n x \frac{d\sigma}{d\Omega_e}\Delta\Omega_e$$

$$\Delta\Omega_e = \Delta\Omega_p \times \frac{d\theta_e}{d\theta_p} \times \frac{d\phi_e}{d\phi_p}$$

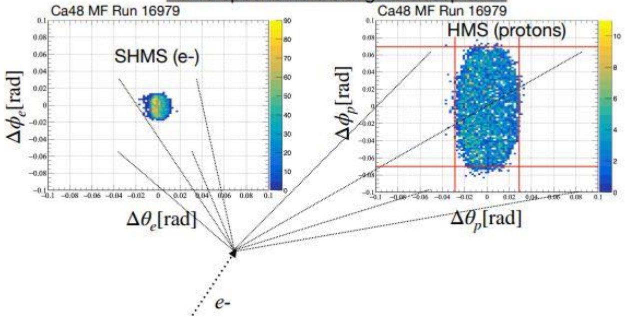
"Out-of-plane"

Momentum conservation (out-of-plane):

$$k_{i,\perp} = |k_f|\sin(\phi_e) + |p_f|\sin(\phi_p) = 0 \implies \frac{\delta\phi_e}{\delta\phi_p} \sim \frac{|p_f|}{|k_f|} = \frac{1.822\text{ GeV/c}}{9.438\text{ GeV/c}} \sim 0.193$$

"⊥ component of beam momentum is zero"

Hall C spectrometers angular acceptance



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$$N_{\text{events into solid angle }\Delta\Omega_e} = N_{\text{incident}}\, n x \frac{d\sigma}{d\Omega_e}\Delta\Omega_e$$

numerical approach

```
---------------------------------
H(e,e'p) Elastics for
Beam Energy (Eb) = 10.549 GeV
e- angle (th_e)  = 8.200 deg
---------------------------------
e- momentum (kf)           = 9.461 GeV/c
proton angle (th_p)        = 48.730 deg
```

```
---------------------------------
H(e,e'p) Elastics for
Beam Energy (Eb) = 10.549 GeV
e- angle (th_e)  = 8.300 deg
---------------------------------
e- momentum (kf)           = 9.438 GeV/c
proton angle (th_p)        = 48.384 deg
```

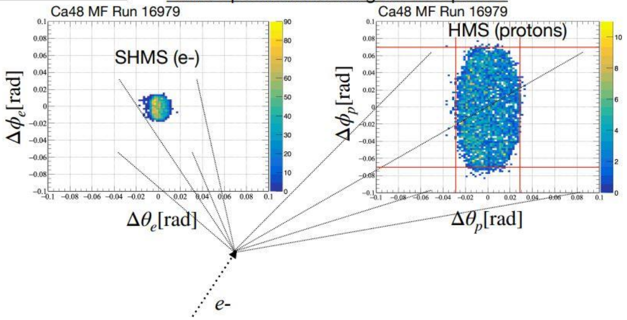
```
---------------------------------
H(e,e'p) Elastics for
Beam Energy (Eb) = 10.549 GeV
e- angle (th_e)  = 8.400 deg
---------------------------------
e- momentum (kf)           = 9.414 GeV/c
proton angle (th_p)        = 48.042 deg
```

$$\Delta\Omega_e = \Delta\Omega_p \times \frac{d\theta_e}{d\theta_p} \times \frac{d\phi_e}{d\phi_p}$$

"In-plane"

"In-plane" (numerical approach): vary in-plane (e-) angle by ~ +/- 0.1 deg and determine the variation in proton angle $\frac{\delta\theta_e}{\delta\theta_p} \sim 0.2907$

Hall C spectrometers angular acceptance



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$$N_{\text{events into solid angle }\Delta\Omega_e} = N_{\text{incident}}\, n x \frac{d\sigma}{d\Omega_e}\Delta\Omega_e$$

$$\Delta\Omega_e = \Delta\Omega_p \times \frac{d\theta_e}{d\theta_p} \times \frac{d\phi_e}{d\phi_p}$$

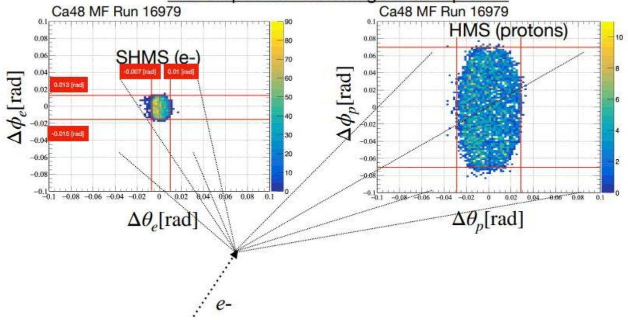
$\Omega_p \sim 0.00674$ sr

$\frac{\delta\theta_e}{\delta\theta_p} \sim 0.2907$

$\frac{\delta\phi_e}{\delta\phi_p} \sim 0.193$

$\Delta\Omega_e \sim 0.000378$ sr

Hall C spectrometers angular acceptance



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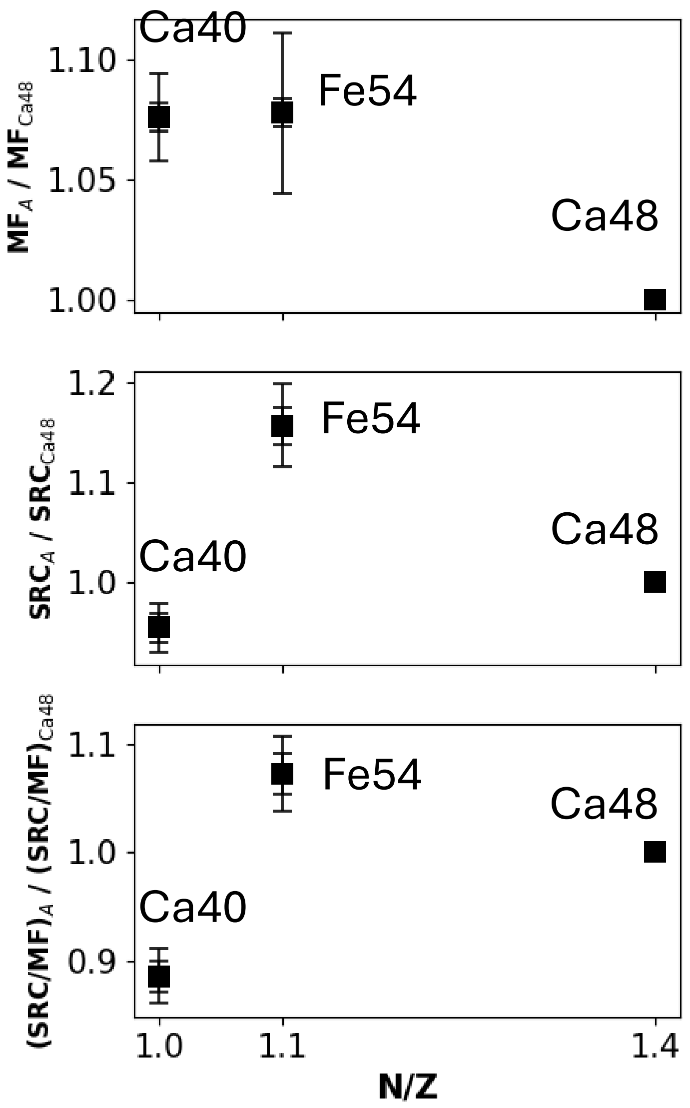
Electron Cross Section Ratio (e,e') Data

- $\frac{d\sigma}{d\Omega_e} = \frac{N_{events\ into\ solid\ angle}}{N_{incident} * nx * d\Omega_e}$

e,e'									
loose rad (e,e') cuts									
Raw Count	Norad Count	Rad Count	Rad Corr	q (mC)	Nicident	nx (atoms / cm^2)	ΔΩe (sr)	dσ/dΩe (µb/sr)	Norm
26293	410267.38	224189.82	1.83	19.284	1.20E+17	4.35E+23	3.78E-04	2.07E-02	0.859
tight rad (e,e') cuts									
Raw Count	Norad Count	Rad Count	Rad Corr	q (mC)	Nicident	nx (atoms / cm^2)	ΔΩe (sr)	dσ/dΩe (µb/sr)	Norm
2996	53625.03	29303.30	1.83	19.284	1.20E+17	1.74E+23	1.08E-04	2.37E-02	0.983

CaFe Triplet Ratios



Electron Cross Section Ratio (e,e'p) Data

- $\frac{d\sigma}{d\Omega_e} = \frac{N_{events\ into\ solid\ angle}}{N_{incident} * nx * d\Omega_e}$

e,e'p									
loose rad (e,e'p) cuts									
Raw Count	Norad Count	Rad Count	Rad Corr	q (mC)	Nicident	nx (atoms / cm^2)	ΔΩe (sr)	dσ/dΩe (µb/sr)	Norm
205041	500254.81	273363.28	1.83	26.61	1.66E+17	4.35E+23	3.78E-04	1.83E-02	0.760
tight rad (e,e'p) cuts									
Raw Count	Norad Count	Rad Count	Rad Corr	q (mC)	Nicident	nx (atoms / cm^2)	ΔΩe (sr)	dσ/dΩe (µb/sr)	Norm
30823	81242.86	44395.01	1.83	26.61	1.66E+17	1.74E+23	1.08E-04	2.60E-02	1.079

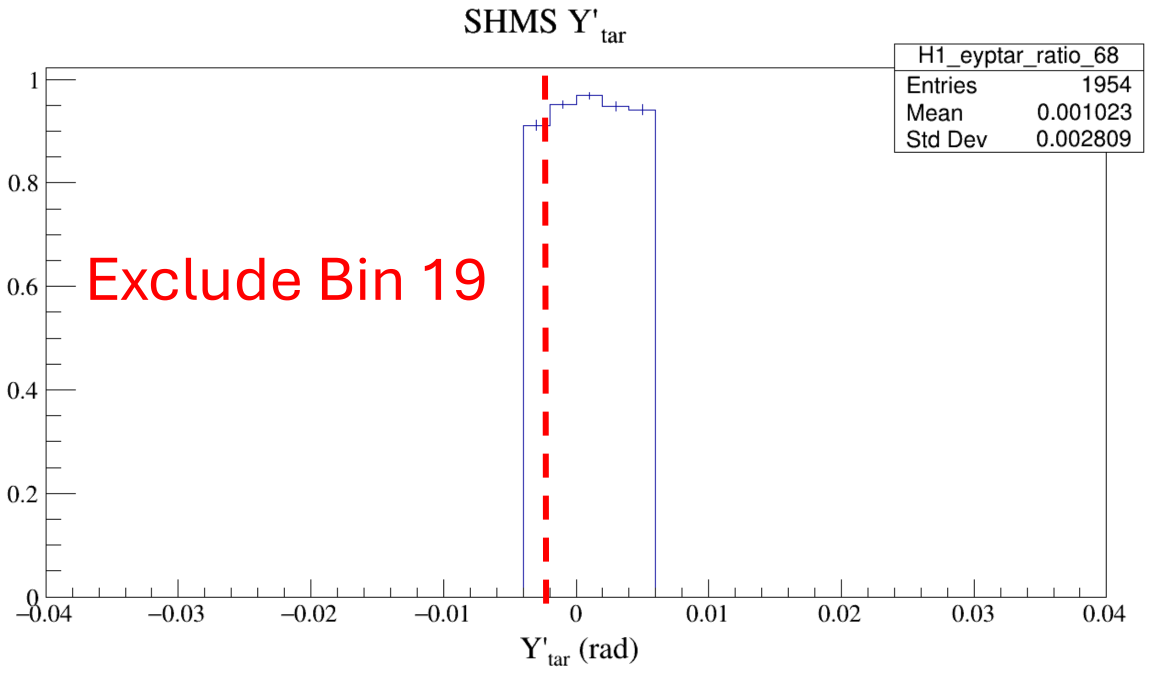
Electron Cross Section Ratio SIMC

- $\frac{d\sigma}{d\Omega_e} = \frac{N_{events\ into\ solid\ angle}}{N_{incident} * nx * d\Omega_e}$

Simulation									
loose rad (e,e'p) cuts									
Raw Count	Norad Count	Rad Count	Rad Corr	q (mC)	Nicident	nx (atoms / cm^2)	ΔΩe (sr)	dσ/dΩe (µb/sr)	Norm
1034393	442391.78	260091.86	1.70	26.61	1.66E+17	4.35E+23	3.78E-04	1.62E-02	0.672
tight rad (e,e'p) cuts									
Raw Count	Norad Count	Rad Count	Rad Corr	q (mC)	Nicident	nx (atoms / cm^2)	ΔΩe (sr)	dσ/dΩe (µb/sr)	Norm
116625	74182.28	48370.63	1.53	26.61	1.66E+17	1.74E+23	1.08E-04	2.37E-02	0.986
loose rad (e,e') cuts									
Raw Count	Norad Count	Rad Count	Rad Corr	q (mC)	Nicident	nx (atoms / cm^2)	ΔΩe (sr)	dσ/dΩe (µb/sr)	Norm
625496	429131.21	250013.25	1.72	19.284	1.20E+17	4.35E+23	3.78E-04	2.17E-02	0.899
tight rad (e,e') cuts									
Raw Count	Norad Count	Rad Count	Rad Corr	q (mC)	Nicident	nx (atoms / cm^2)	ΔΩe (sr)	dσ/dΩe (µb/sr)	Norm
70140	53874.13	31529.92	1.71	19.284	1.20E+17	1.74E+23	1.08E-04	2.38E-02	0.988

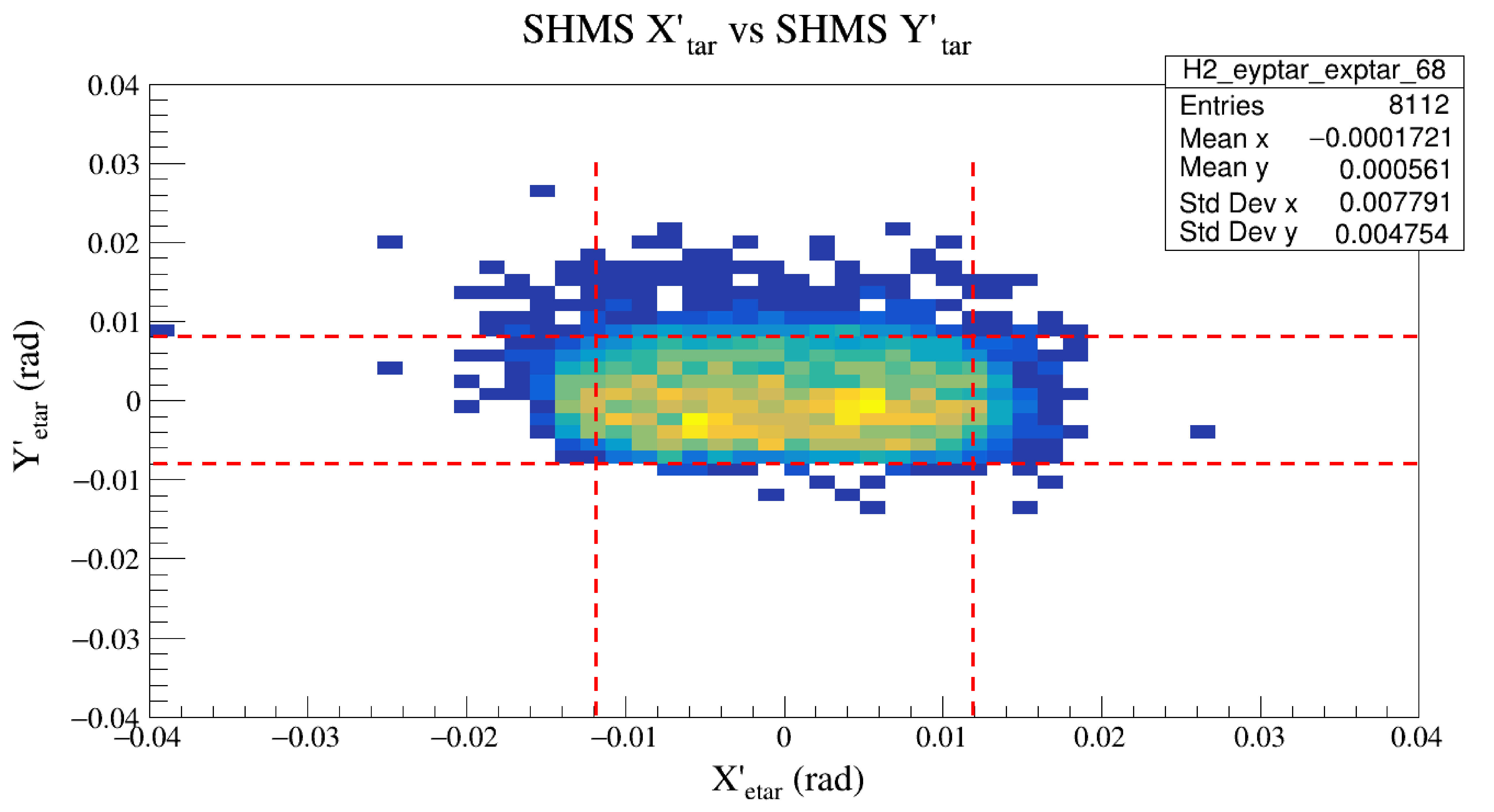
HMS Proton Efficiency

$$\sigma_{ratio}^{exact} = \sqrt{should \frac{did}{should}(1 - \frac{did}{should})} \Big/ should$$



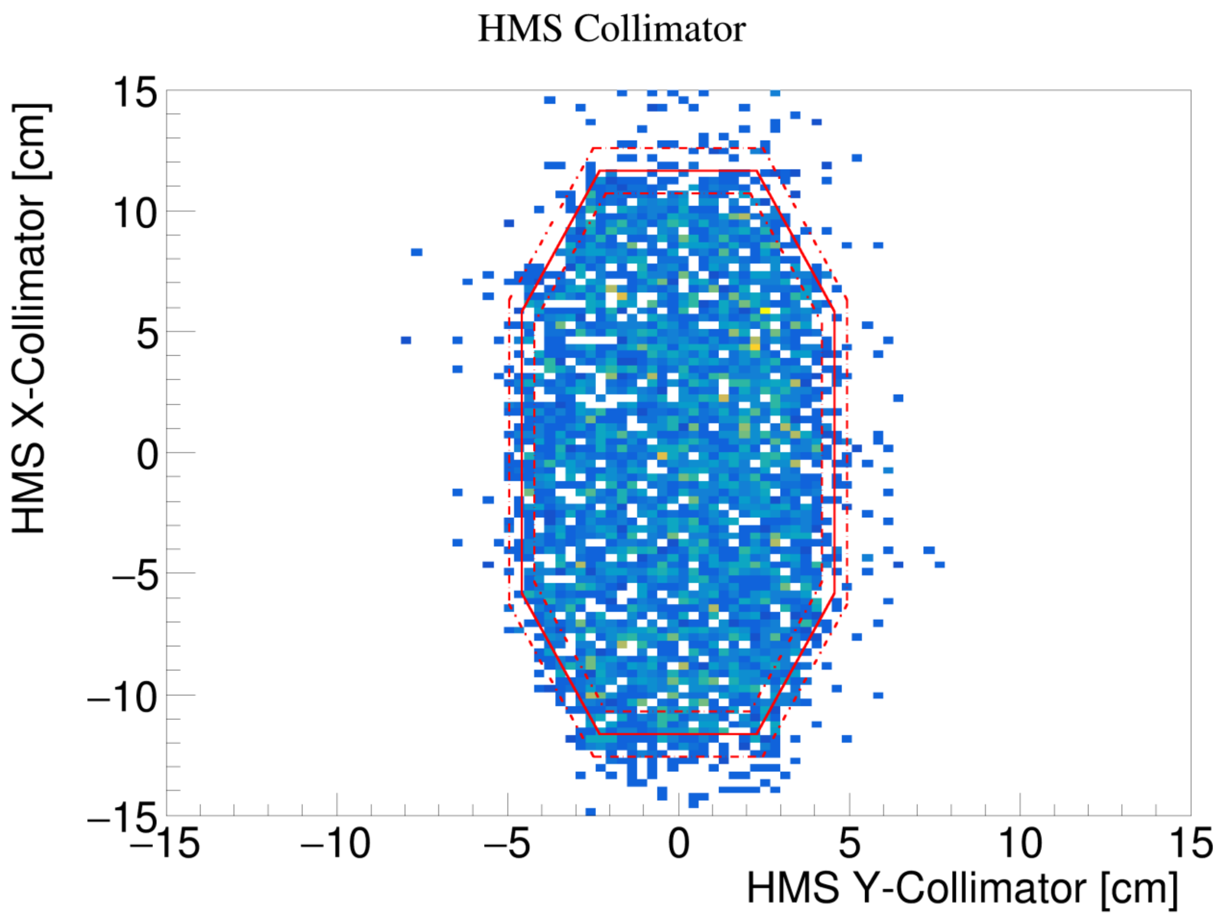
SHMS Y'tar							
Bin	Should Count	Did Count	σ_{approx}	σ_{exact}	Did/Should	Weight	Numerator
19	1012	919.8	0.009	0.009	0.91	12216.4	11102.9
20	960	907.7	0.008	0.007	0.95	18644.5	17629.2
21	873	845.5	0.006	0.006	0.97	28652.5	27751.1
22	713	680.0	0.008	0.008	0.95	16171.4	15423.8
23	669	628.9	0.009	0.009	0.94	11869.2	11157.5
Total	3215	3062.2	0.004	0.004			

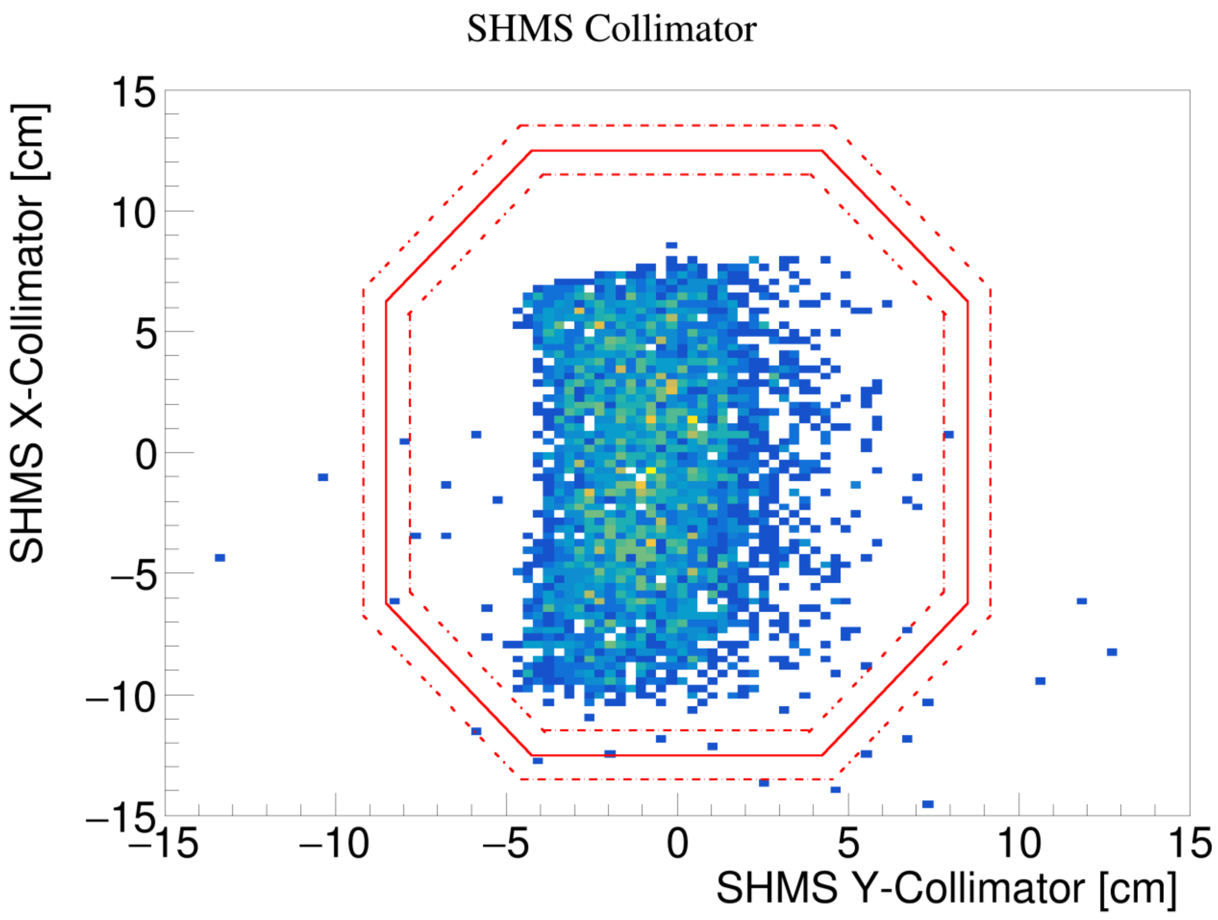
Result		
Unweighted Proton Transmission	Weighted Proton Transmission	Uncertainty
0.952	0.955	0.004



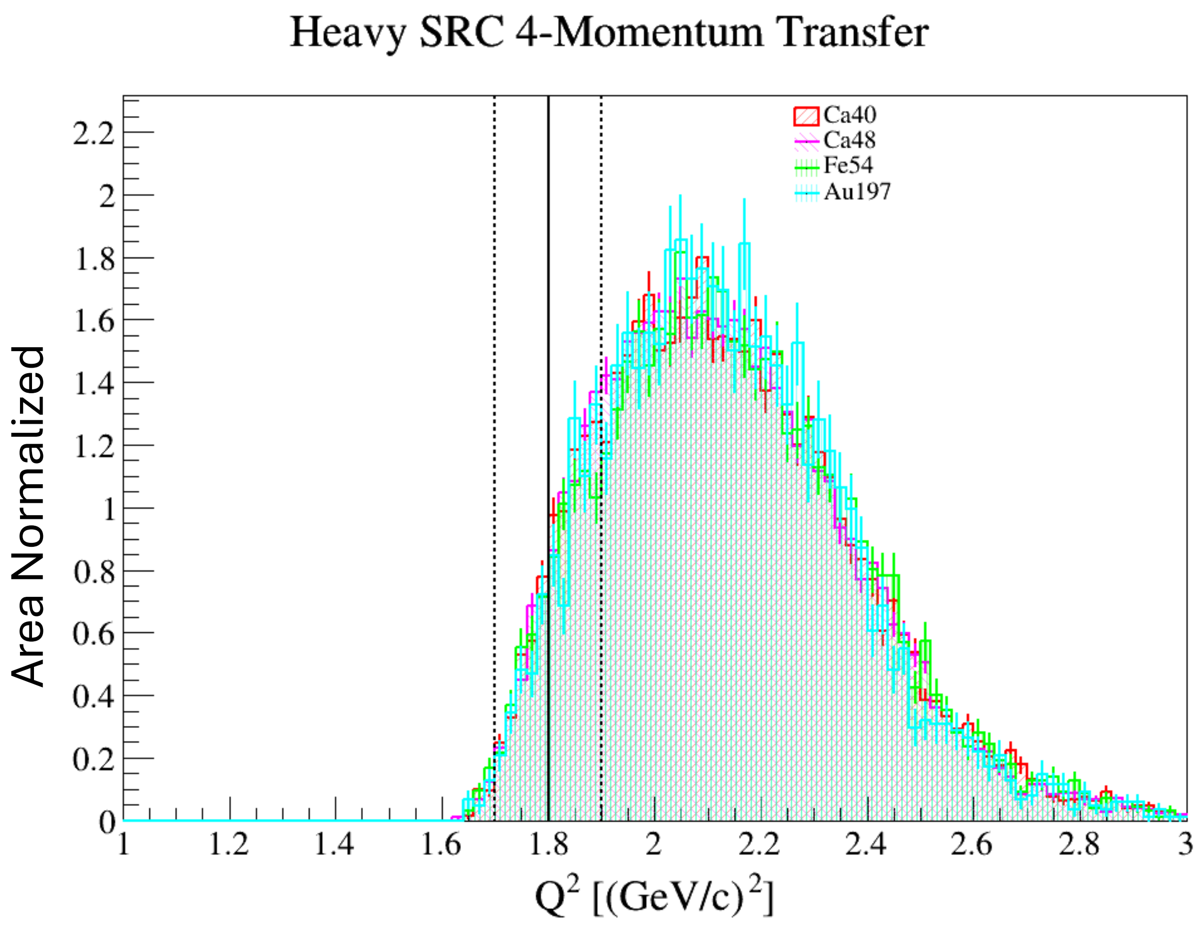
SHMS X'tar vs SHMS Y'tar
H2_eyptar_exptar_68
Entries 8112
Mean x −0.0001721
Mean y 0.000561
Std Dev x 0.007791
Std Dev y 0.004754
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
Y'etar (rad)
−0.04
−0.03
−0.02
−0.01
0
0.01
0.02
0.03
0.04
X'etar (rad)

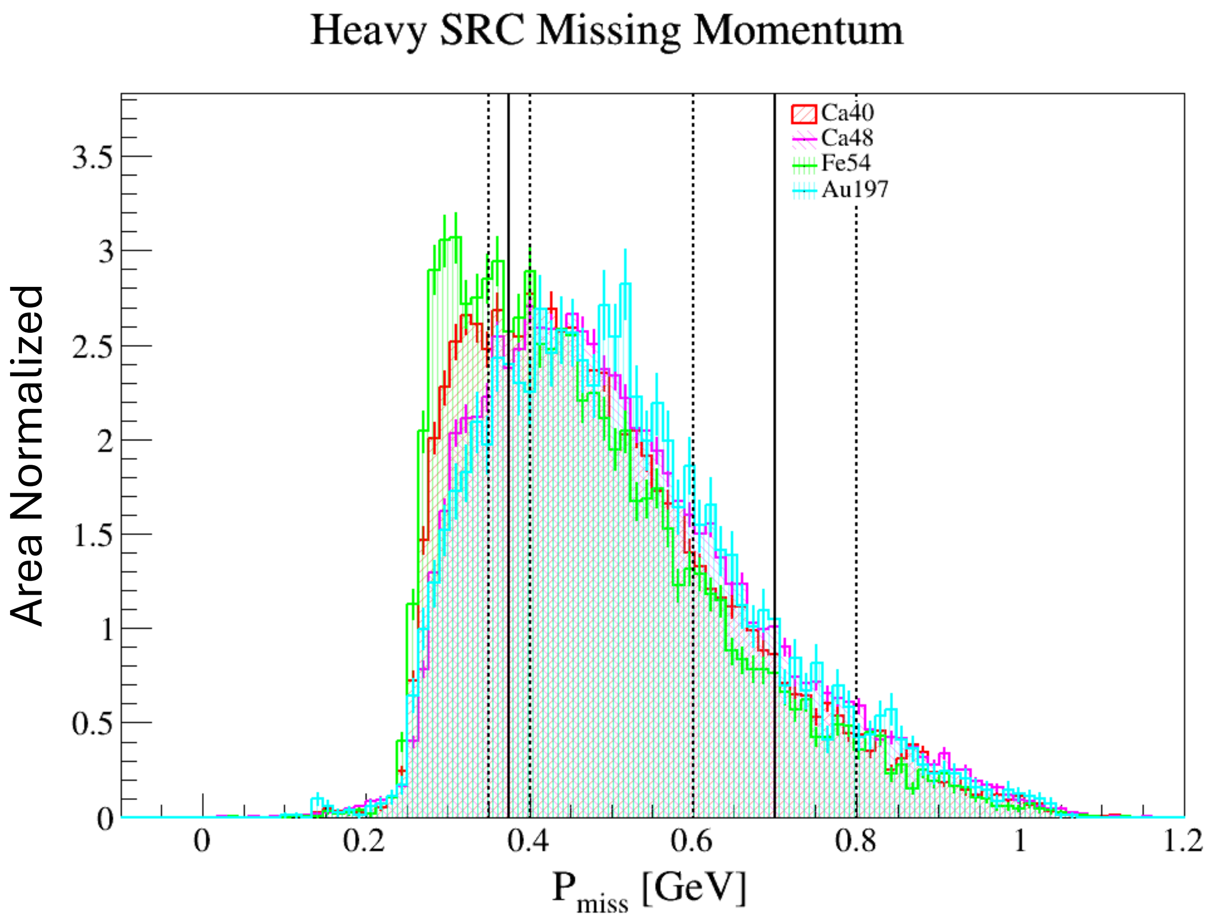
SRC HMS & SHMS Collimator Cuts (±2σ)





SRC Q^2 & P_m Cuts (±2σ)





SRC x_{bj} & θ_{rq} Cuts (±2σ)