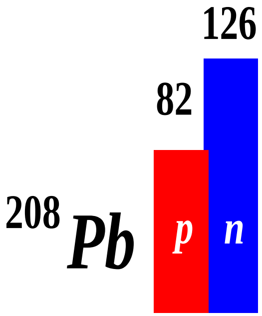
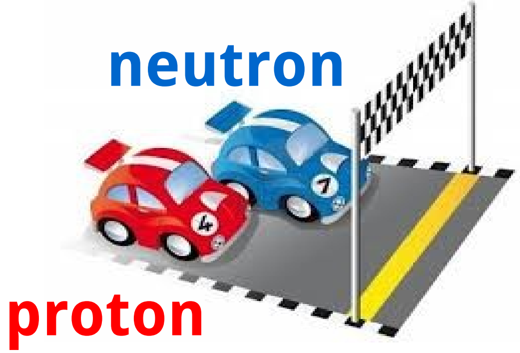




Kinetic energy of protons and neutrons in asymmetric nuclei

A data-mining project using JLab CLAS data

Meytal Duer

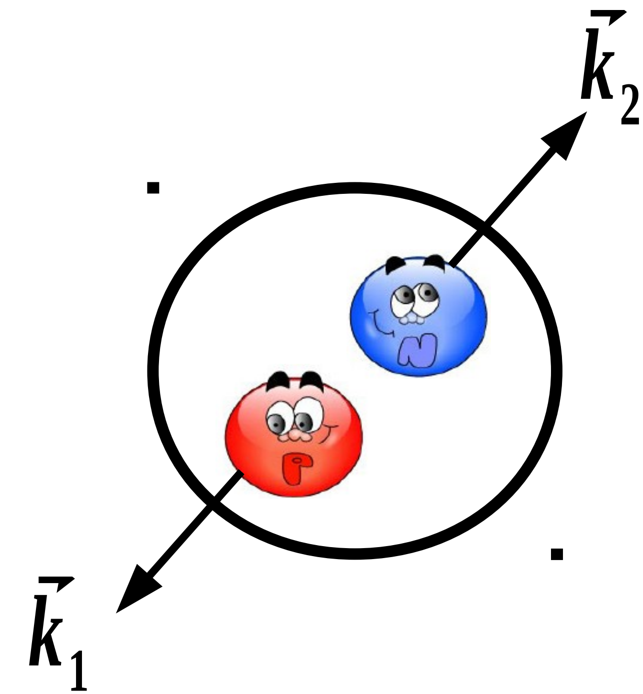
Tel-Aviv University

June 20, 2017 JLab Users Group Meeting

2N - Short Range Correlations (SRC)

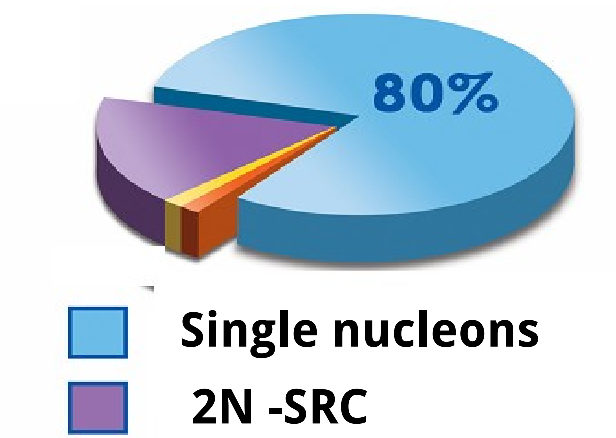
A pair with:

* Large relative momentum $\left(k_{rel} > k_F\right)$
  * Small C.M. momentum $\left(k_{CM} < k_F\right)$



$k_1 > k_F \qquad k_2 > k_F$

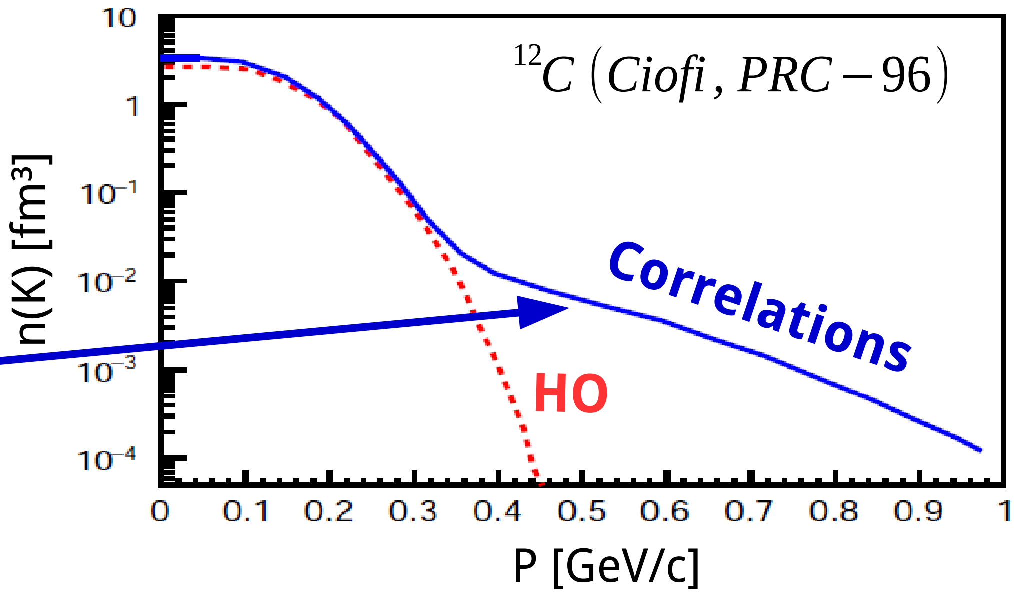
$k_1 \simeq k_2$



Momentum distribution

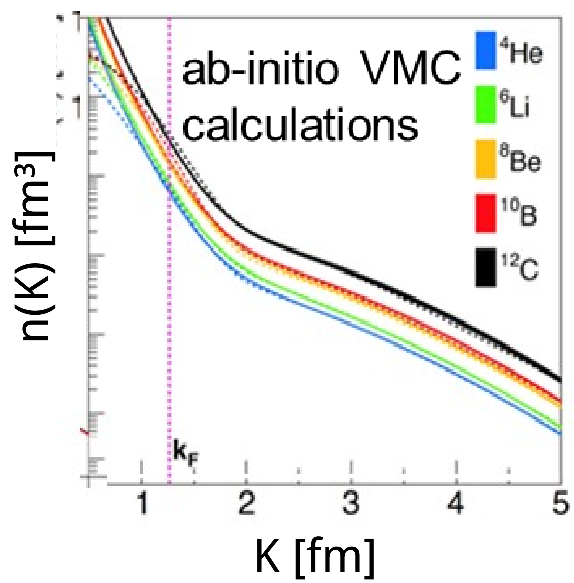
High-momentum tail:

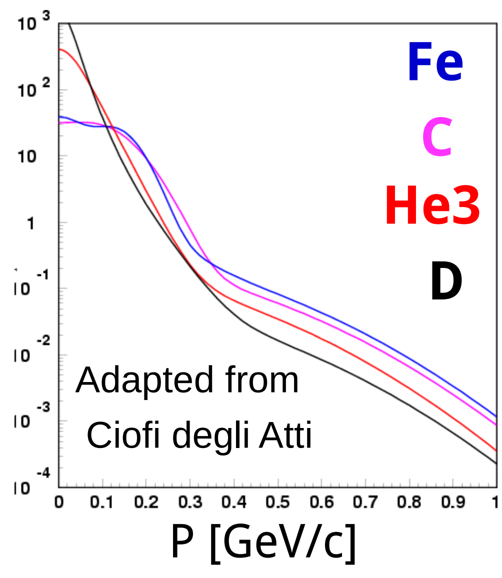
Can be explained by correlations.



Similar shape for all nuclei: SCALING.

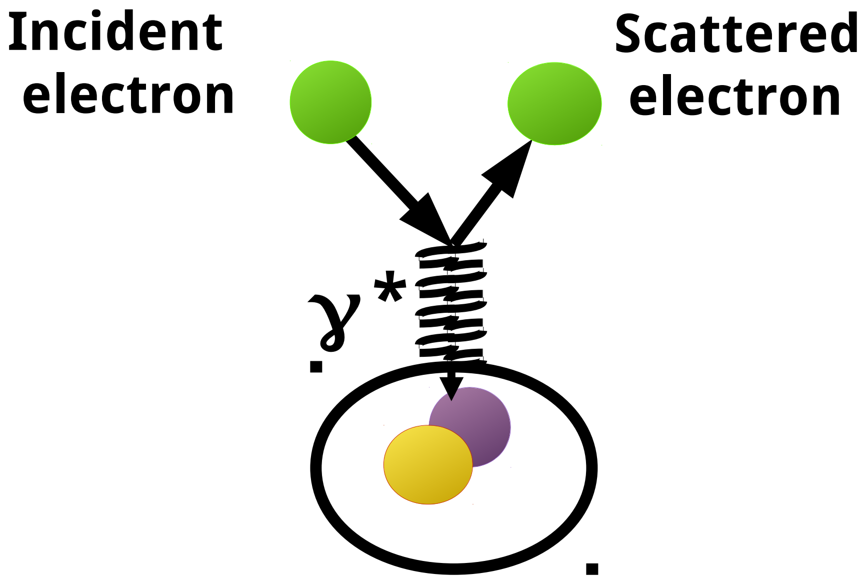
Can be explained by 2N-SRC dominance



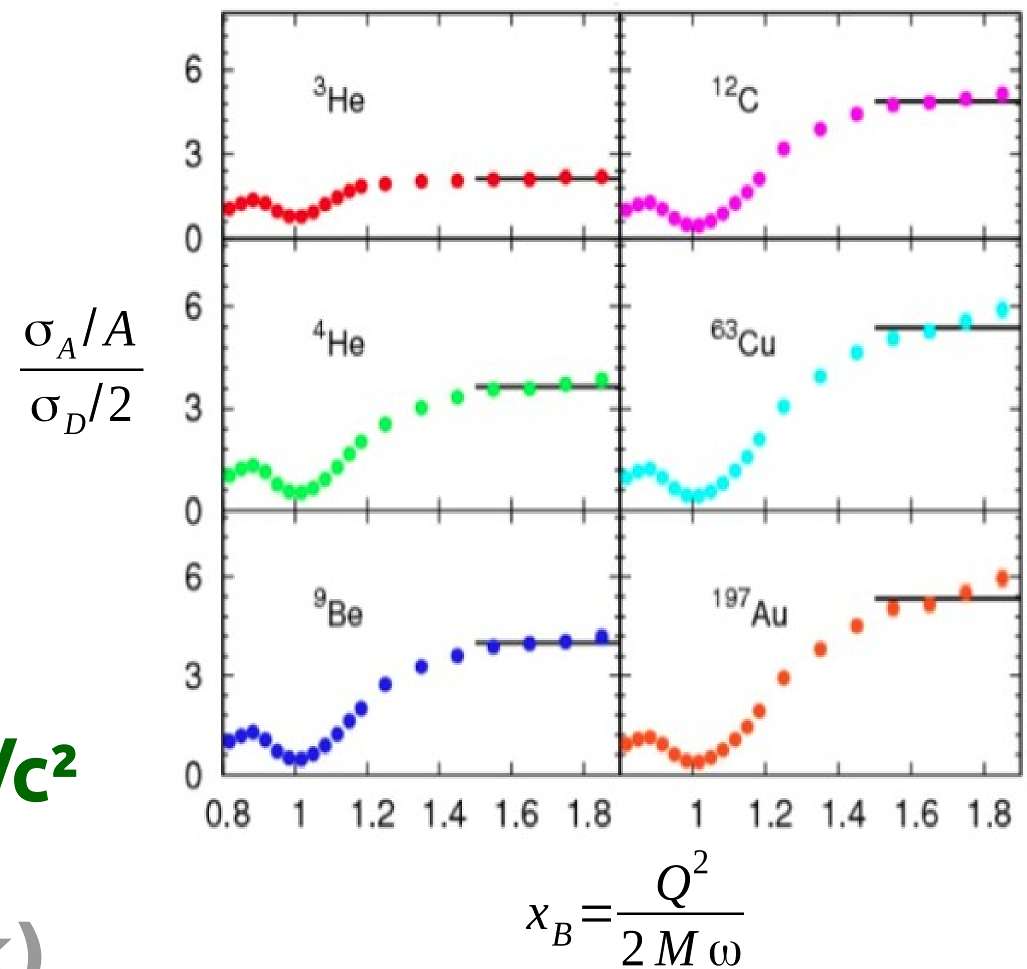


$$n_A(k) = C_A \times n_d(k)$$

Counting high-momentum nucleons



Observed scaling for $x_B > 1.5$ & $Q^2 > 1.5\ GeV^2/c^2$



$$n_A(k>k_F) = a_2(A) \times n_d(k)$$

Hall-C: Fomin et al., PRL 108, 092502 (2012)

More data:

Hall-B: Egiyan et al. PRL. 96, 082501 (2006)

Hall-B: Egiyan et al. PRC 68, 014313 (2003)

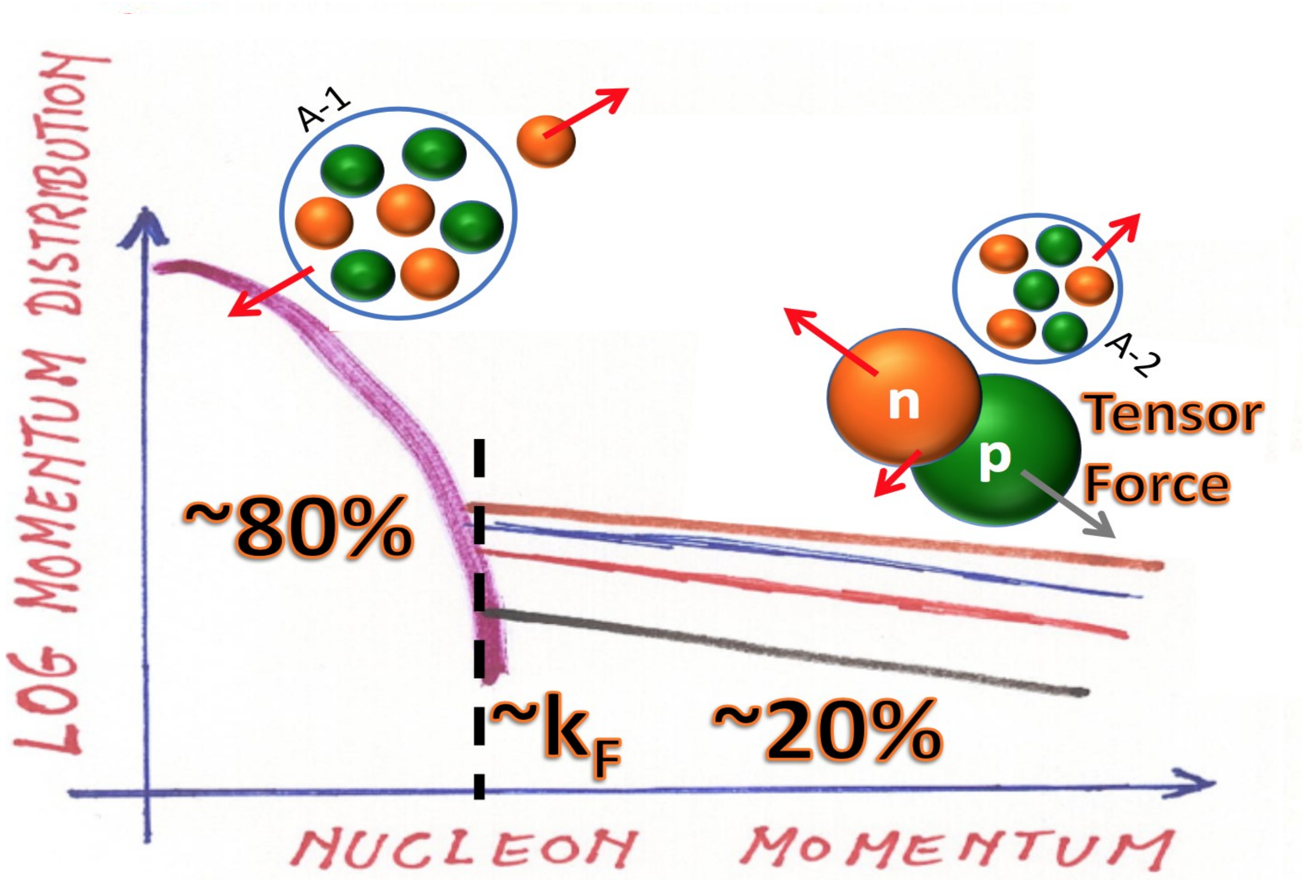
SLAC: Day et al. PRL 59,427(1987)

Counting high-momentum nucleons

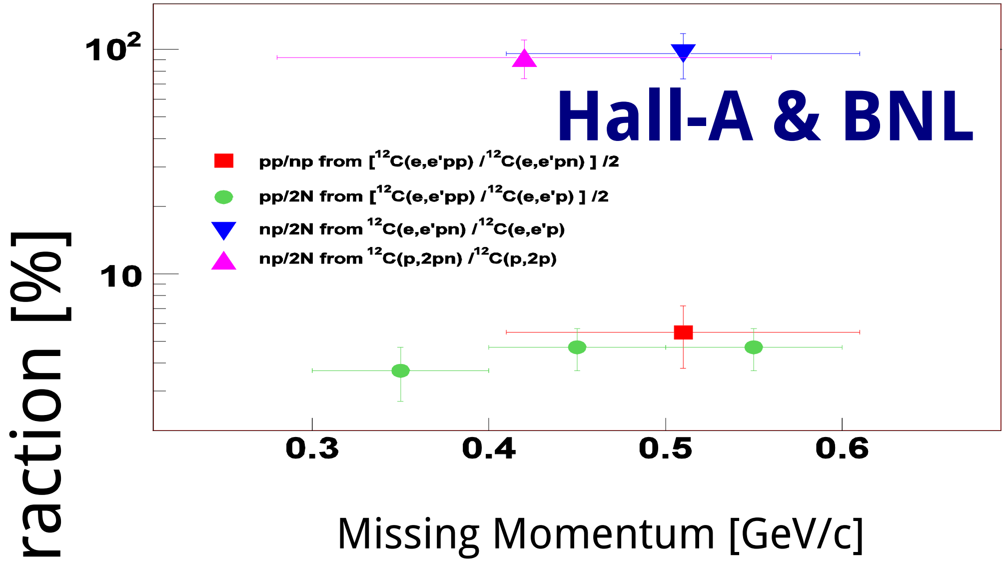
$$n_A(k>k_0) = a_2(A)\times n_d(k>k_0)$$

$K_0 \sim 1.1 k_F$

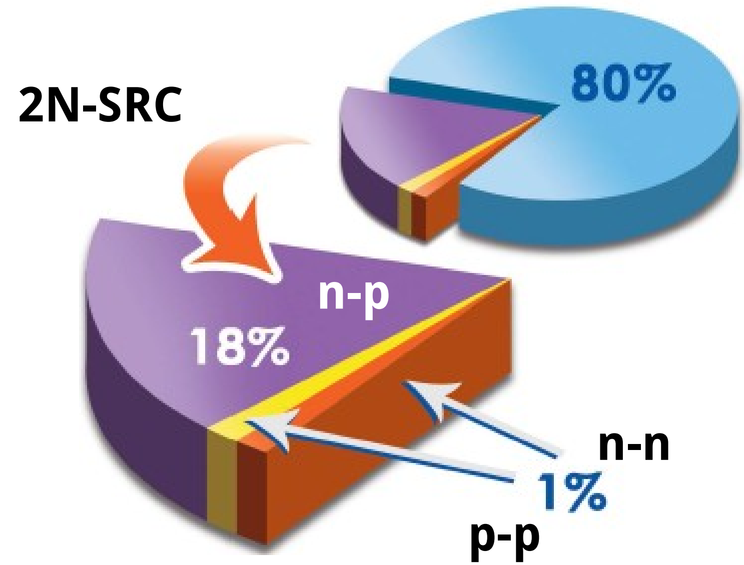
$$\sim 4\text{-}5 \times \sim 4\% = \sim 20\%$$

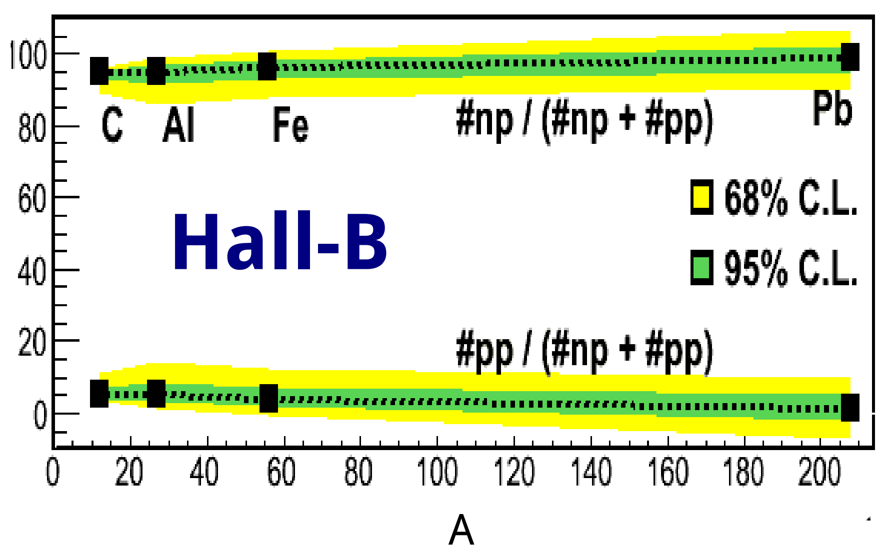


np-dominance in 2N-SRC

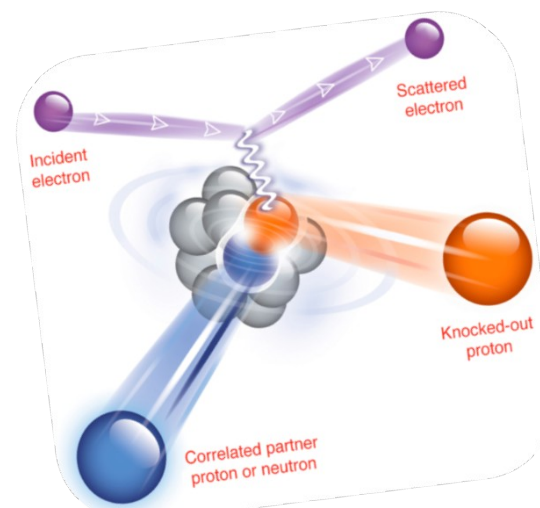


Subedi et al., Science 320 (2008).





Hen et al., Science 346 (2014)



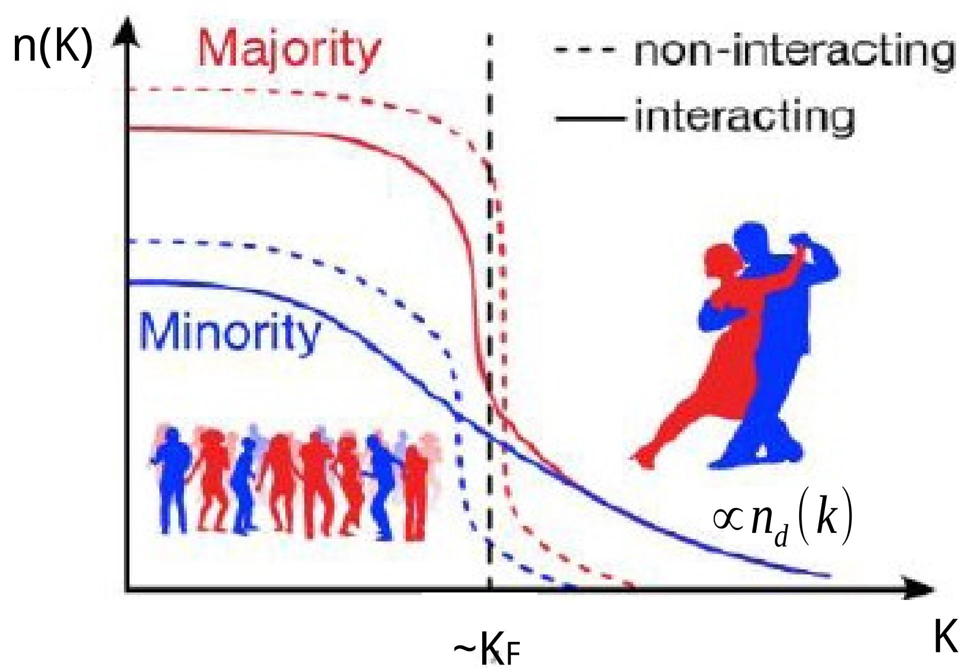
np-dominance in asymmetric nuclei

N>Z

Pauli principle → $\langle T_n \rangle > \langle T_p \rangle$

SRC → $\langle T_p \rangle \overset{?}{>} \langle T_n \rangle$

$$\langle T_{p(n)} \rangle = \int n_{p(n)} \cdot \frac{k^2}{2m} \cdot d^3 k$$



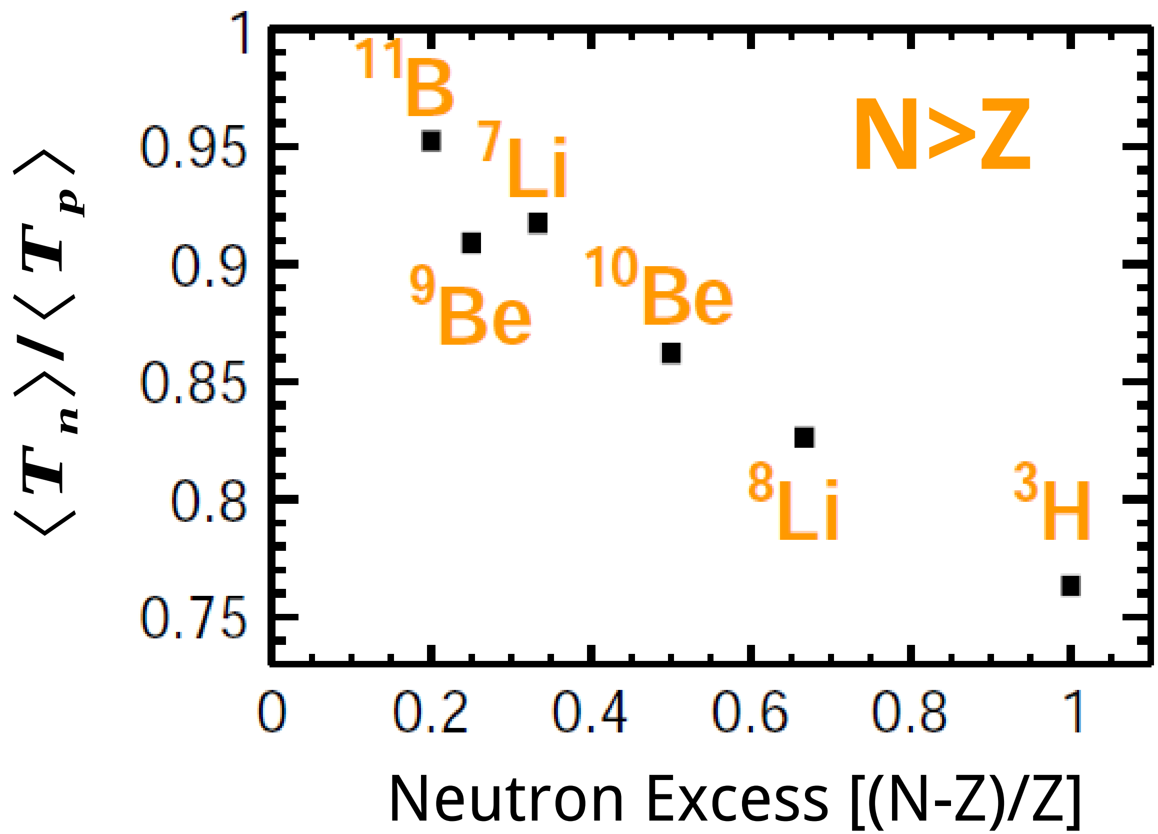
Possible inversion of the momentum sharing

Sargsian Phys. Rev. C89 (2014)

Hen et al., Science 346, 614 (2014)

Theoretical prediction -

Light nuclei (A<12)



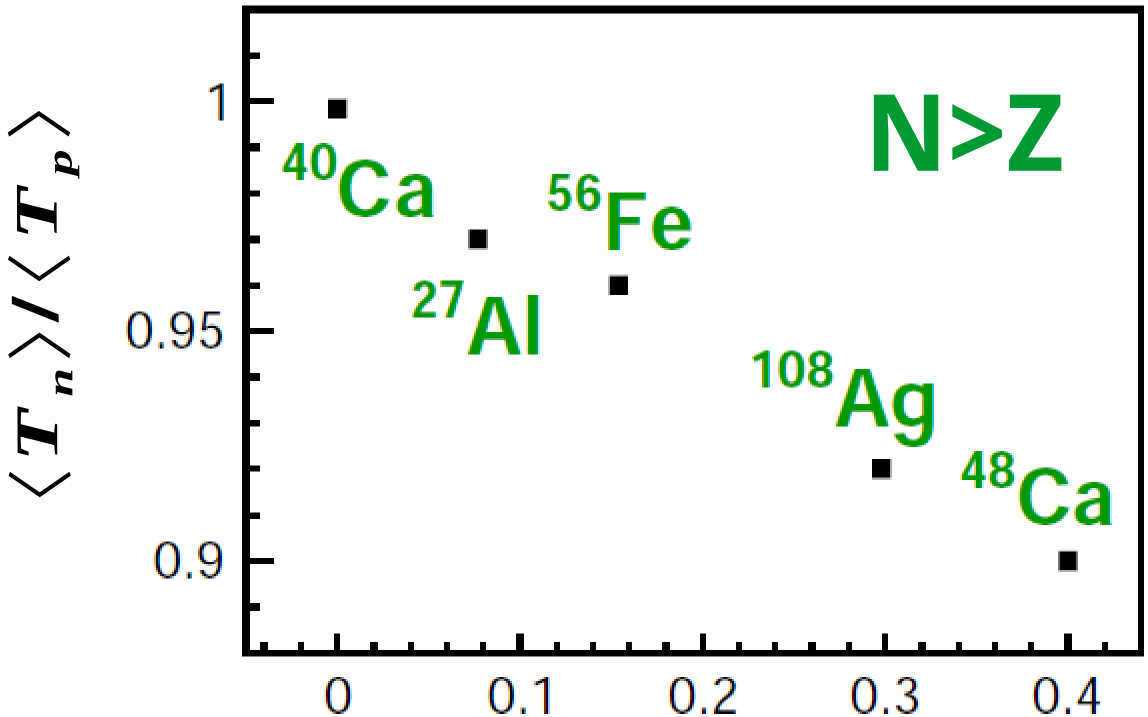
Variational Monte-Carlo calculations by the Argonne group

Z>N: ^{3}He **(N-Z)/Z = -1** $\langle T_n \rangle / \langle T_p \rangle = 1.31$

.R. B. Wiringa, R. Sehiavilla. S.C. Pieper, J. Carlson Phys. Rev. C89, 024305 (2014)

Theoretical prediction -

Heavy nuclei (A>12)



Neutron Excess [(N-Z)/Z]

Low-order Correlation operator Approximation (LCA)

Ryckebusch, J.Phys G42 (2015).

Simple np-dominance model

$$n_p(k) = \begin{cases} \eta \cdot n_p^{M.F.}(k) & k < k_0 \\ \frac{A}{2Z} \cdot a_2(A/d) \cdot n_d(k) & k > k_0 \end{cases}$$

(for neutrons: Z → N)

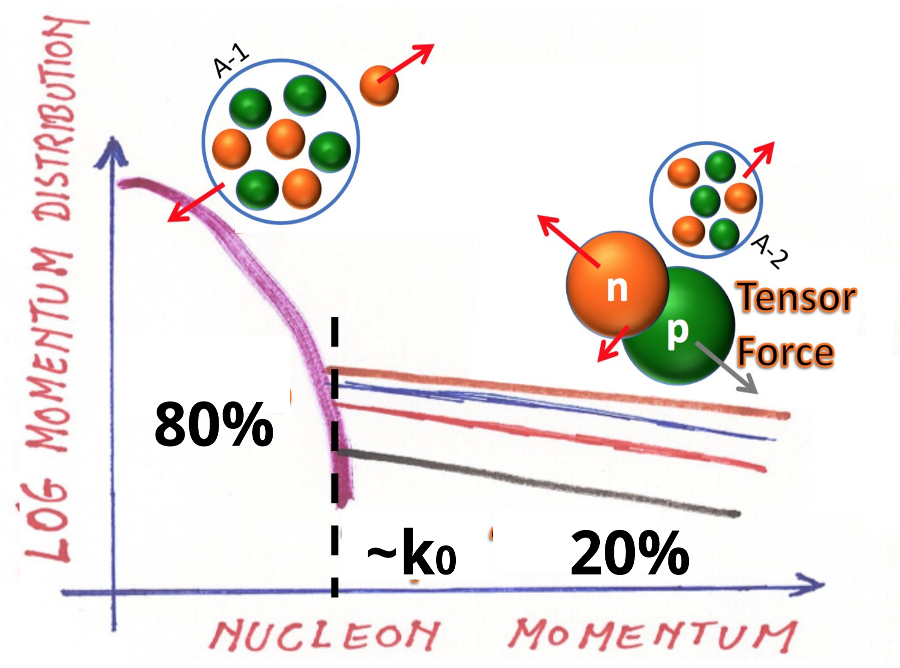
k_0: * 300 MeV/c * k_F

$n^{M.F.}(k)$: * Wood-Saxon
* Serot- Walecka
* Ciofi & Simula

$n_d(k)$: AV18 NN potential

$a_2(A/d)$: Scaling factor

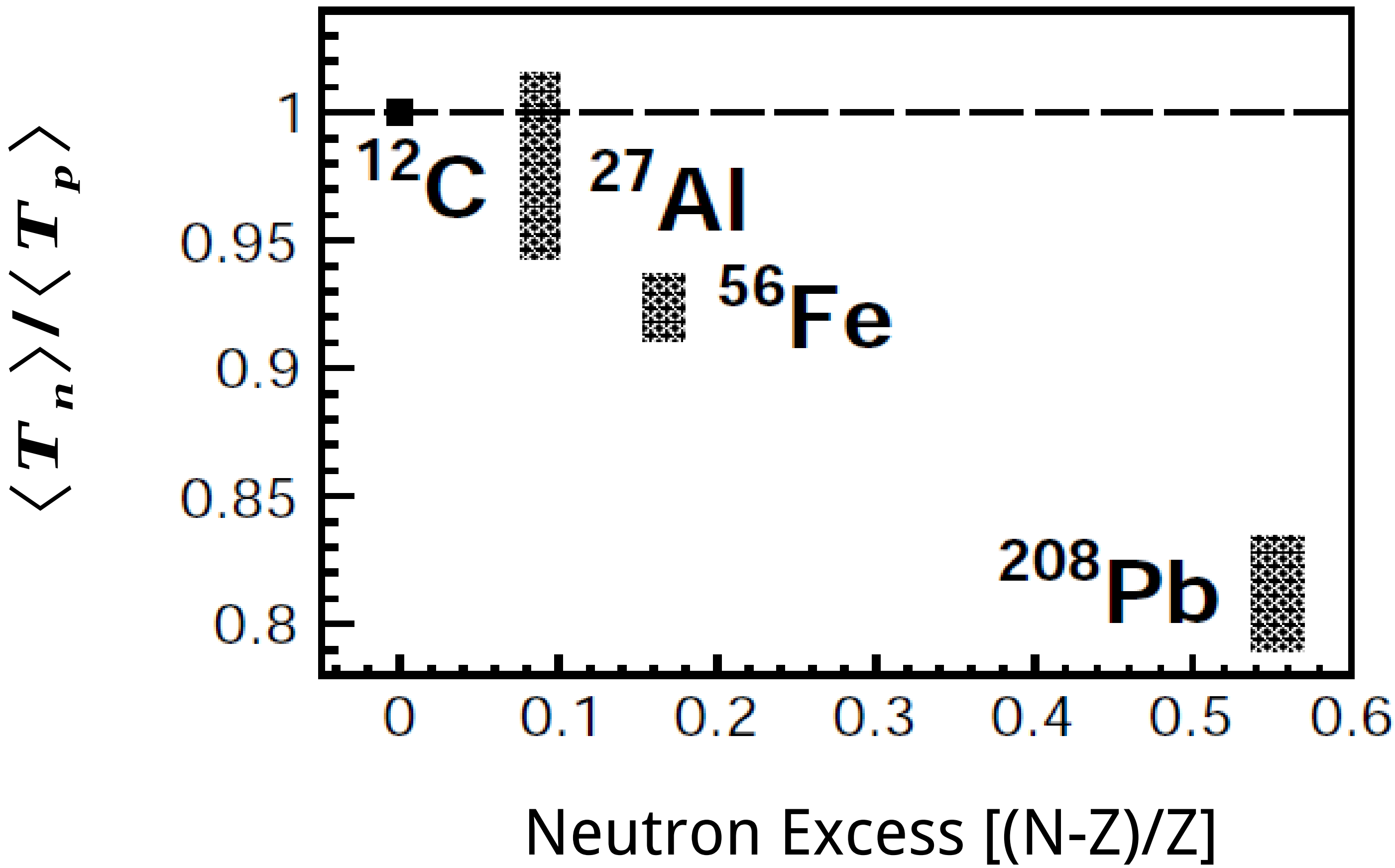
η determined by: $\int n_{p(n)}(k)\, d^3k = 1$



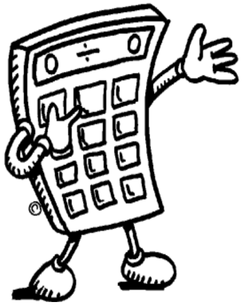
Sargsian Phys. Rev. C89 (2014)

Hen et al., Science 346 (2014)

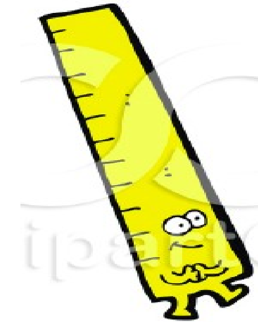
Simple np-dominance model N>Z



$$\langle T_{p(n)} \rangle = \int n_{p(n)} \cdot \frac{k^2}{2m} \cdot d^3 k$$



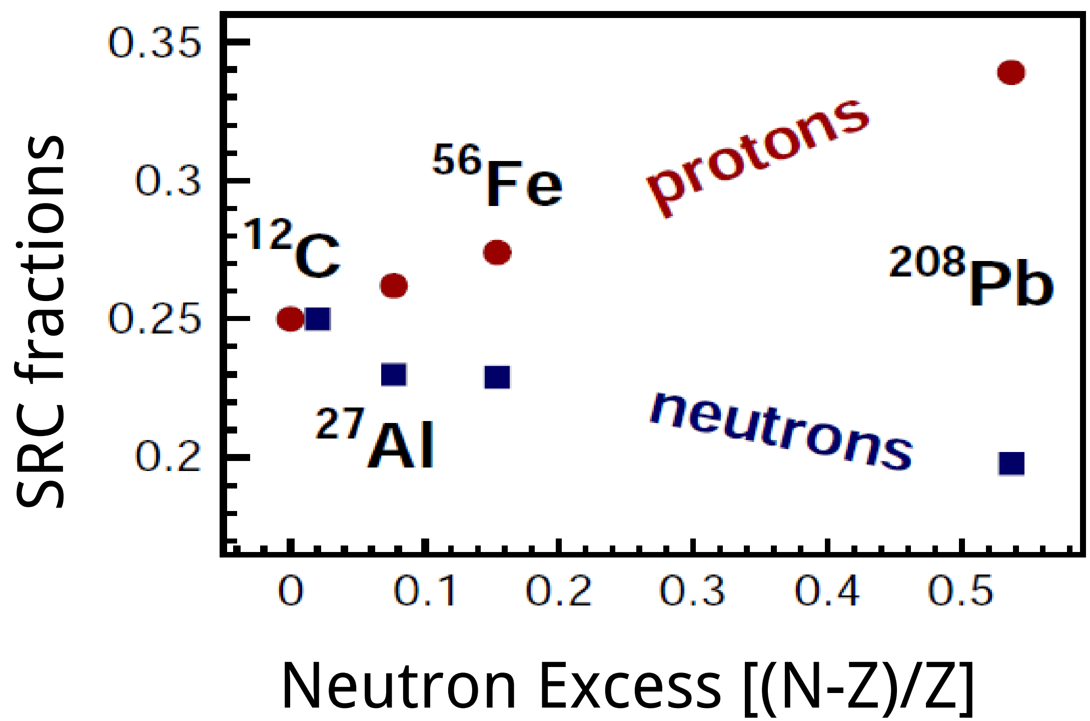
Calculation ⟶ Measurement



Simple estimate based on np-dominance

$^{208}Pb: \quad Z=82 \quad N=126$ **SRC=20%**

$$R_p = \frac{protons_{k>k_F}}{protons_{k<k_F}} \approx \frac{20}{82-20} = 0.32 \qquad R_n = \frac{neutrons_{k>k_F}}{neutrons_{k<k_F}} \approx \frac{20}{126-20} = 0.19$$



The goal:

Extracting $\frac{A(e,e'N)\ high/low}{^{12}C(e,e'N)\ high/low}$ **ratios** $(N=n/p)$

The steps:

* **Identify (e,e'N) mean-field events** $(low\ missing\ momentum)$

* **Identify (e,e'N) 2N-SRC events** $(high\ missing\ momentum)$

* **Extract ratios and their uncertainties**

Data-Mining

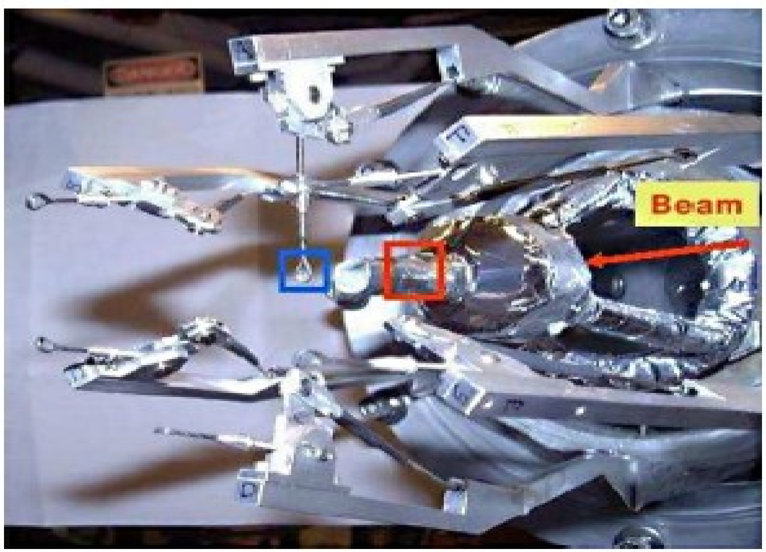
EG2 Experiment

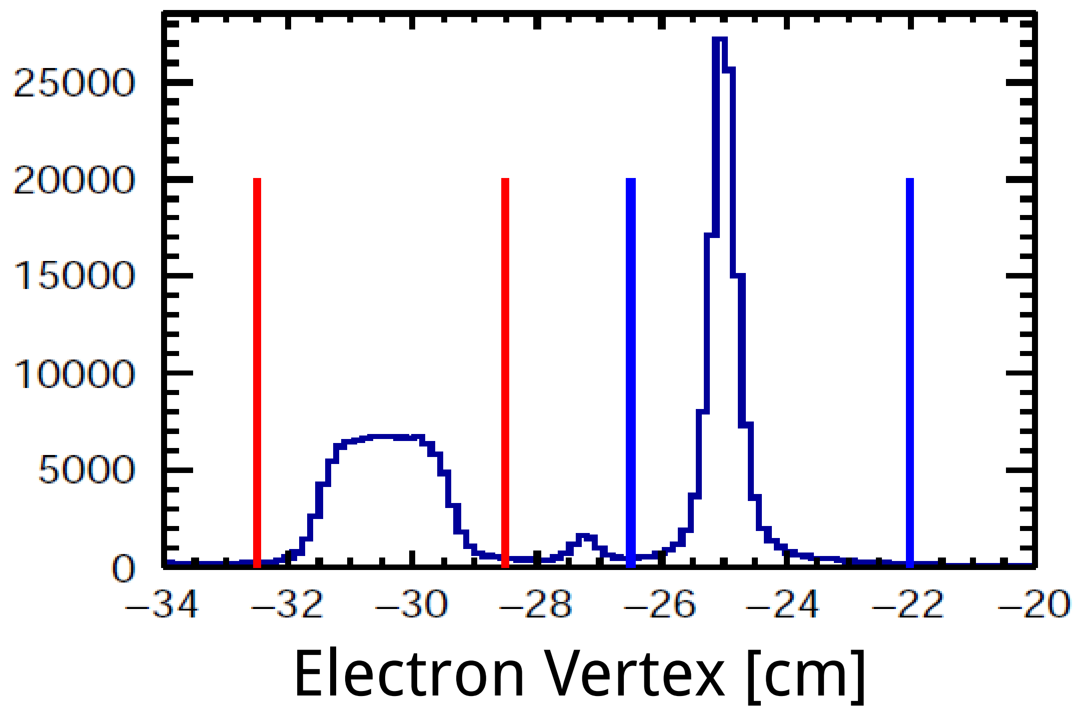
Run at 2004 in Hall-B

5.014 GeV electron beam

Data set for:

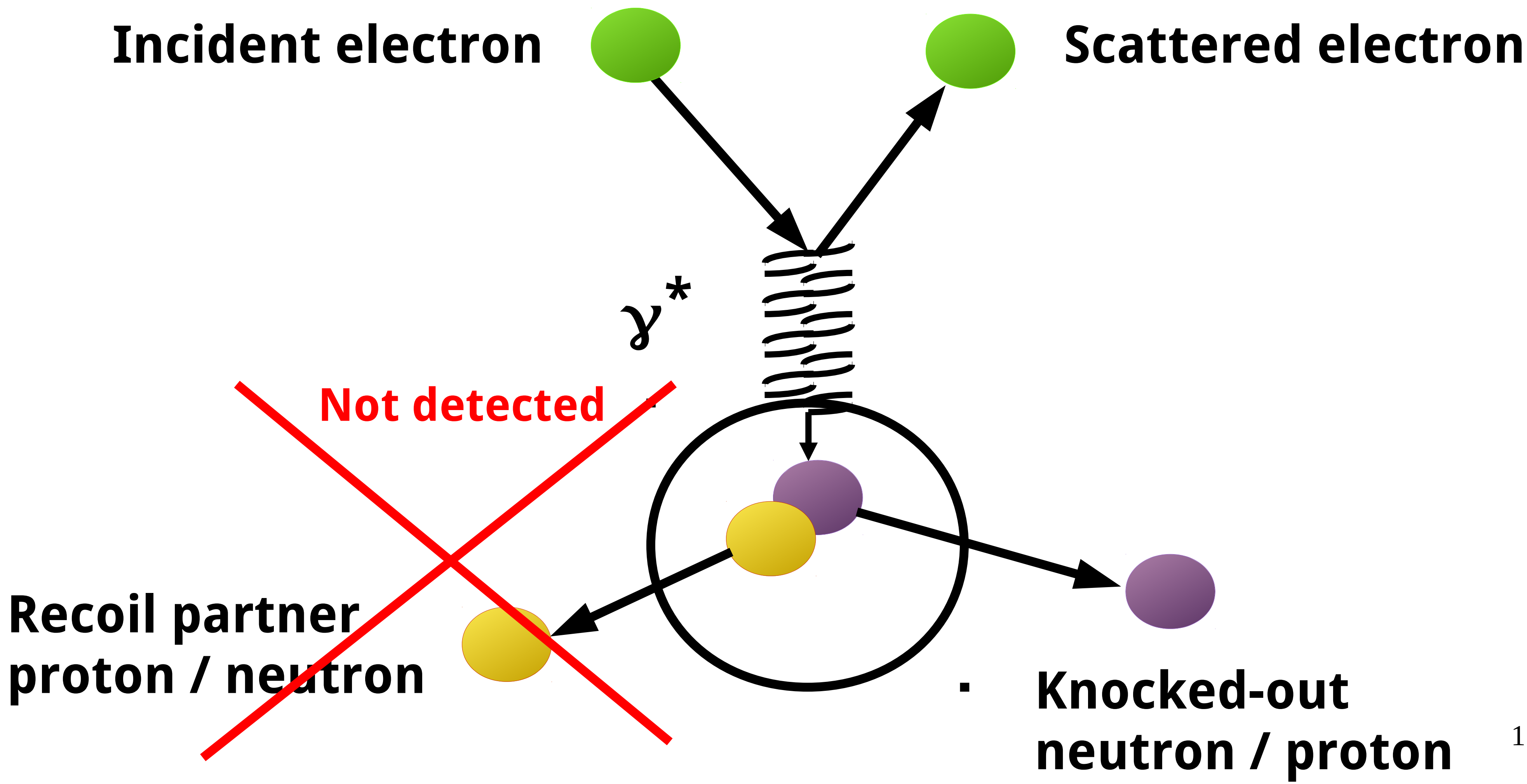
Deuterium + Solid target $\left({}^{12}C/{}^{27}Al/{}^{56}Fe/{}^{208}Pb\right)$



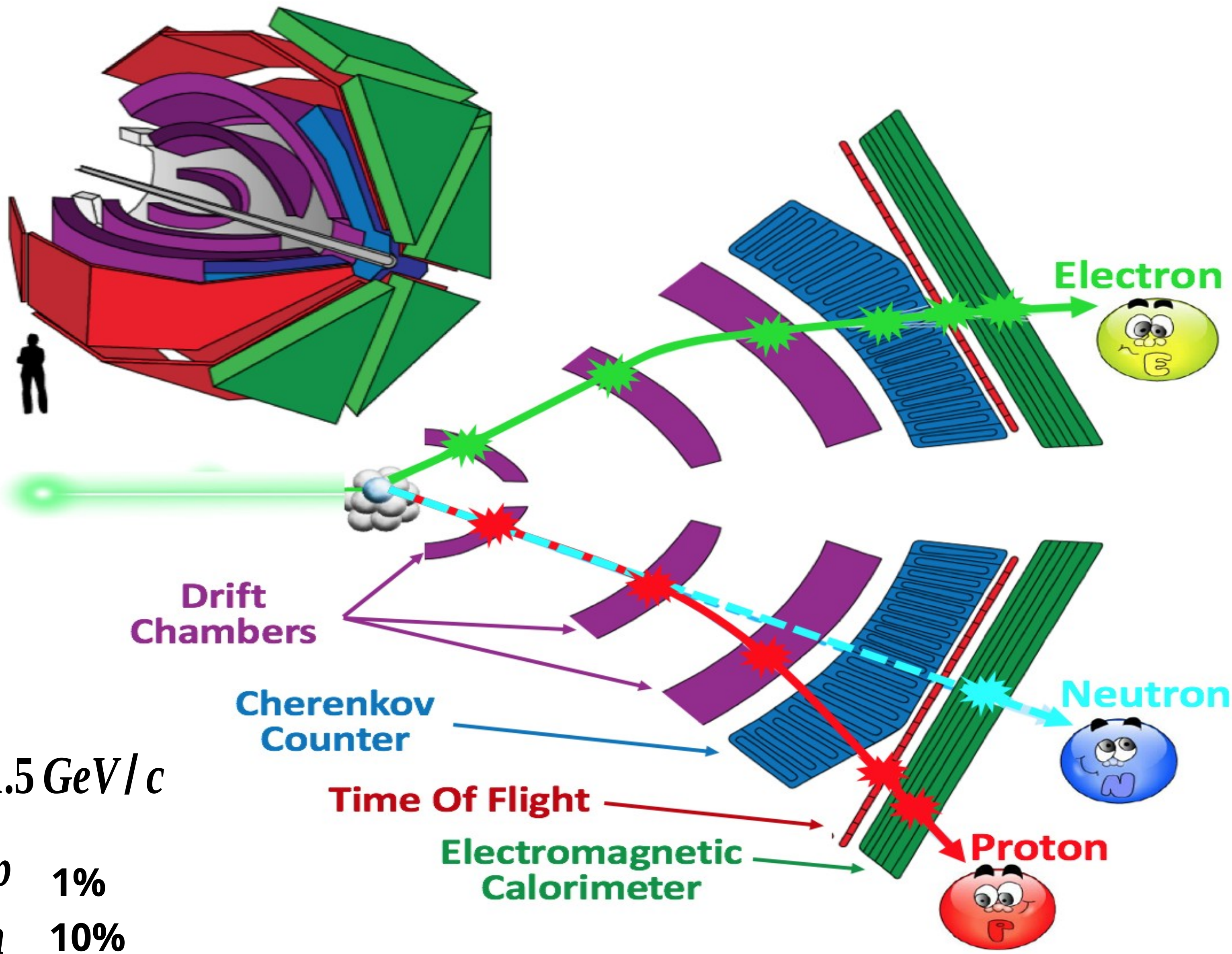


Hard knocked-out reactions

(e,e'n) & (e,e'p)



Particle Identification



$p_p = p_n \sim 1.5\, GeV/c$

$\Delta p/p$: p 1%

n 10%

El Fassi, Phys. Lett B 712, (2012) Hen, Phys. Rev. C 85, 2012 Hen, Science 346, 614 (2014)

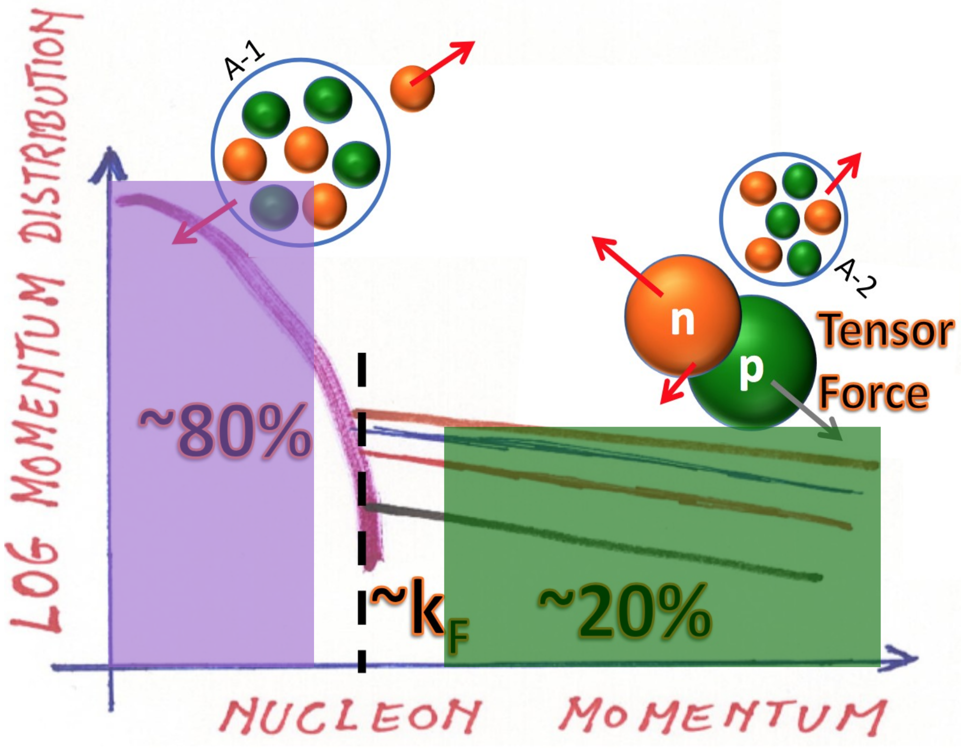
Detecting neutrons in CLAS EC (M. Braverman TAU thesis, 2014)

Analysis of QE events:

I. Identifying A(e,e'N) mean-field events

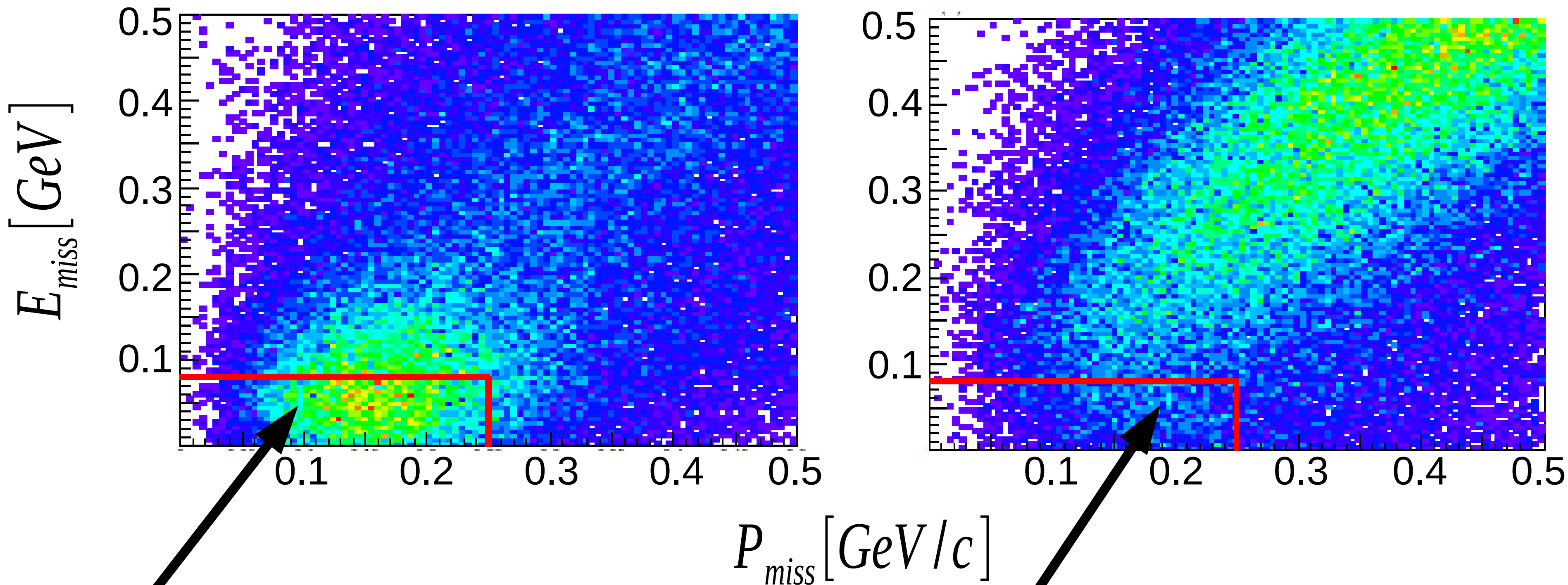
II. Identifying A(e,e'N) high-momentum events

N=n/p



Selecting M.F. QE events

protons **neutrons**



QE peak:
$P_{miss}<0.25$ GeV/c
$E_{miss}<0.08$ GeV

Problem:

Poor resolution in the EC -
$\Delta P \approx 0.1 GeV/c$

$$\vec{p}_{miss} = \vec{p}_N - \vec{q} \qquad E_{miss} = \omega - T_N - T_B$$

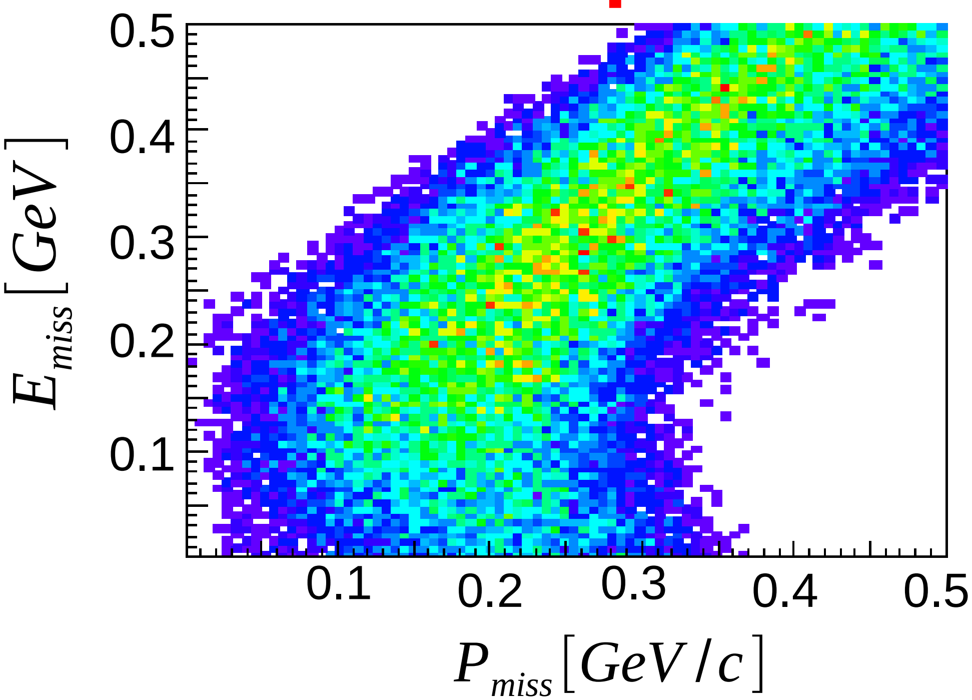
ONeill et al., Phys. Lett. B 87 (1995), Abbott et al. Phys. Rev. Lett. 80 (1998), Garrow et al. Phys. Rev. C. 66 (2002)

Solution

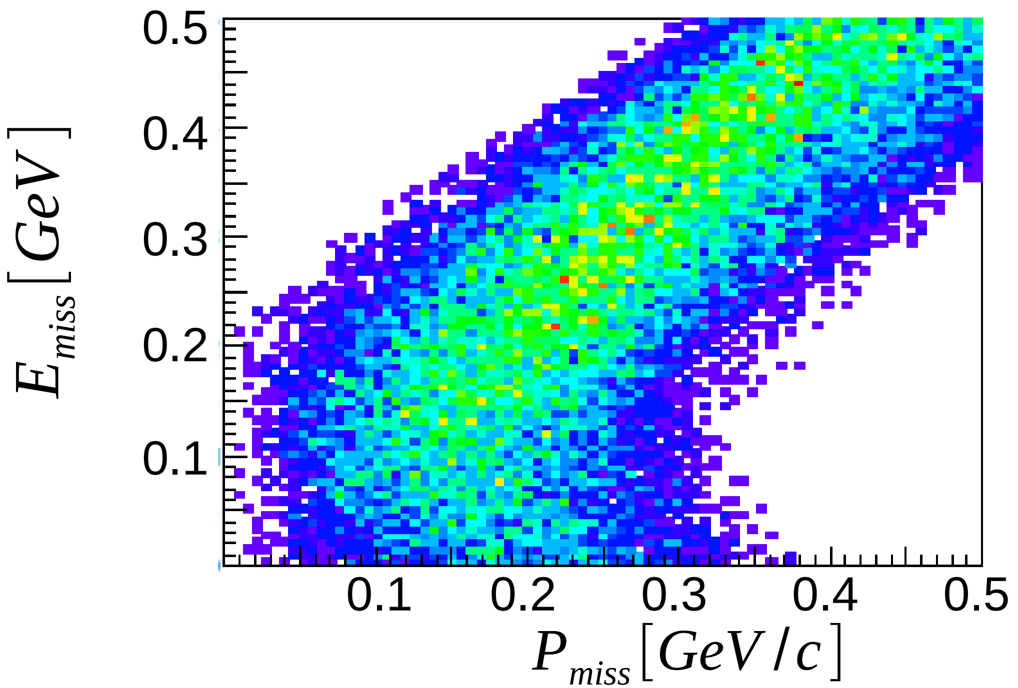
Using smeared protons to:

* Define and test the cuts
* Study bin migration

smeared protons

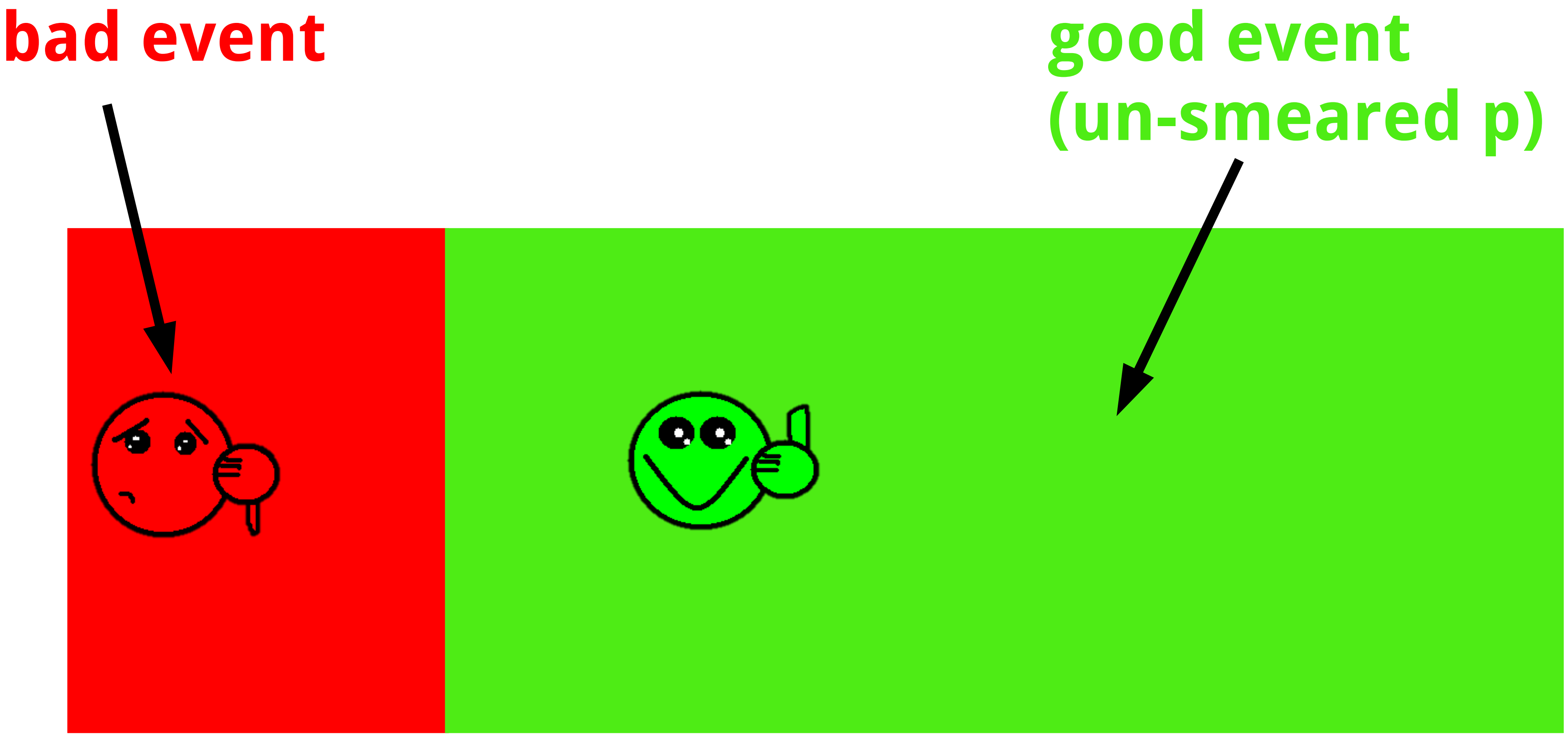


neutrons

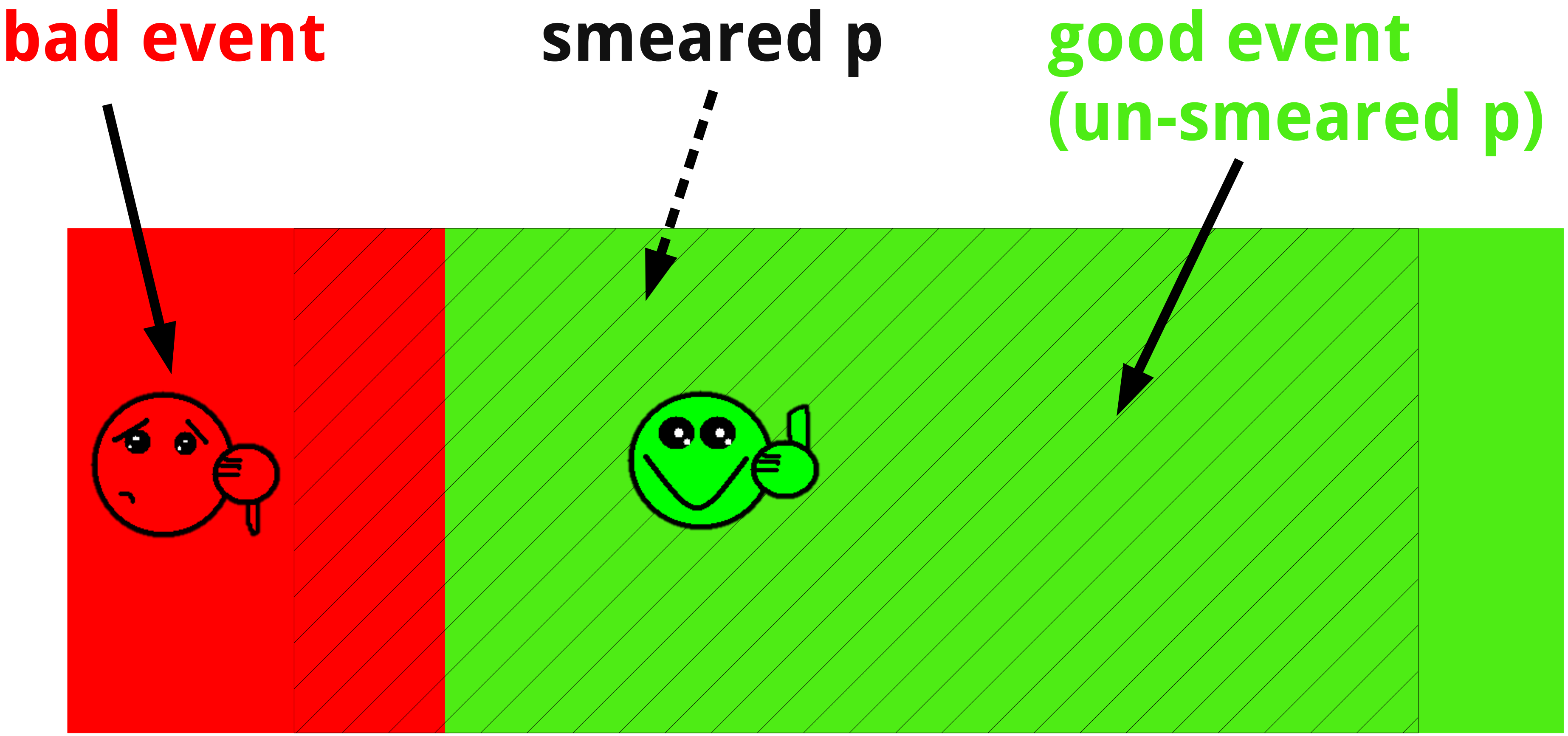


With cuts: $-0.05 < y < 0.25$ $\quad 0.95 < \omega < 1.7\,GeV$ $\quad \theta_{pq} < 8^o$

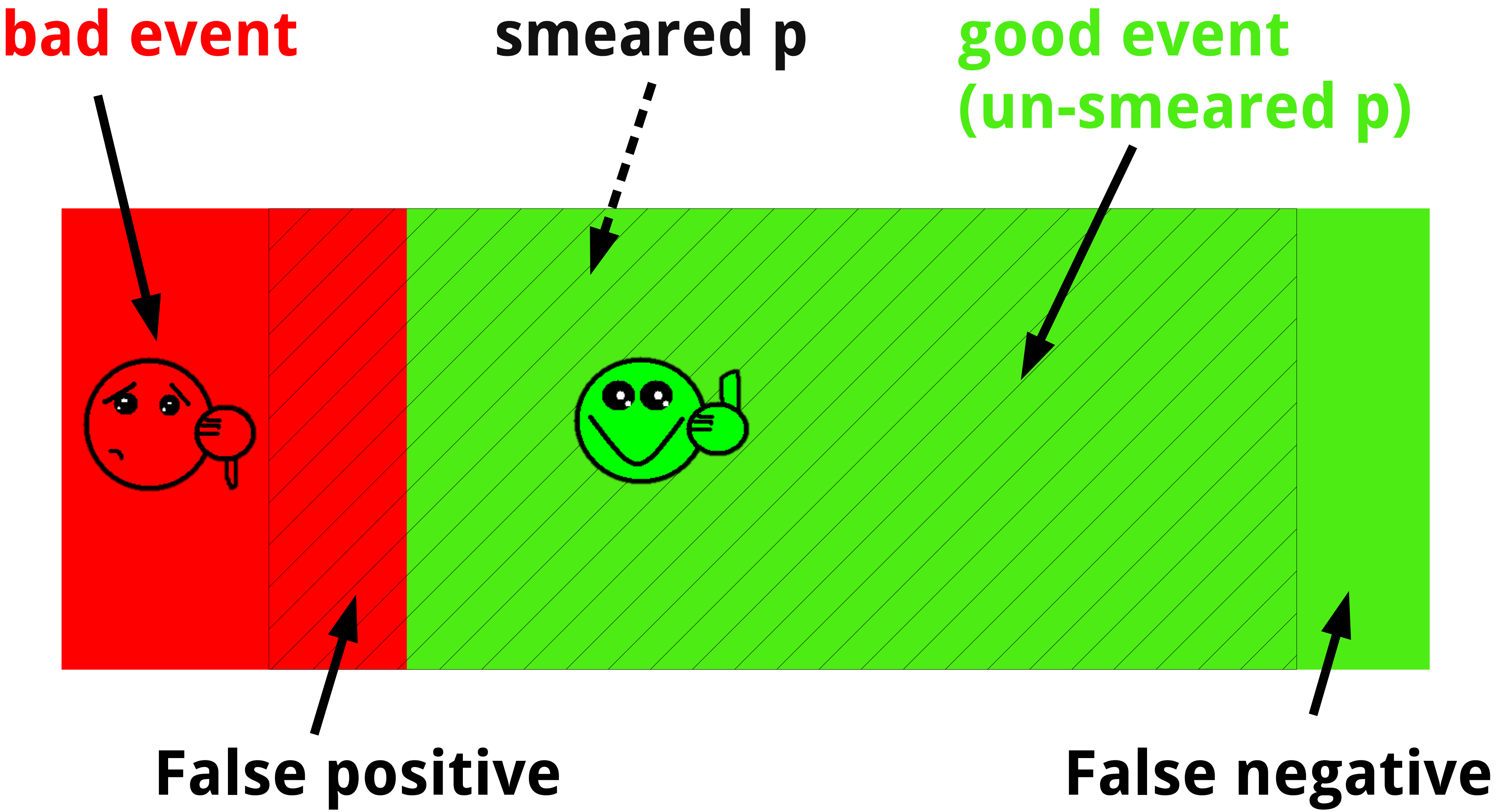
False Positive & Negative probabilities



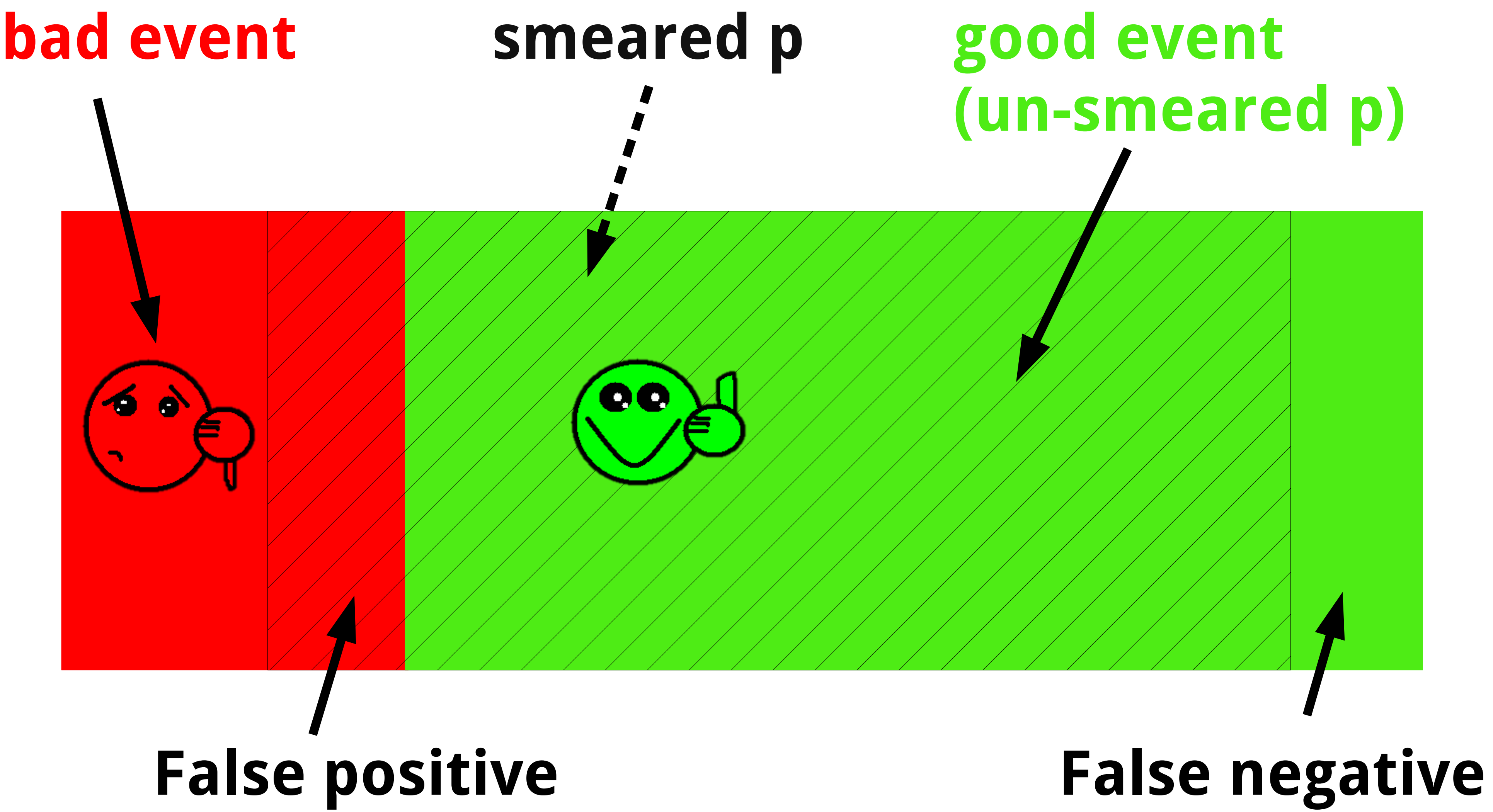
False Positive & Negative probabilities



False Positive & Negative probabilities

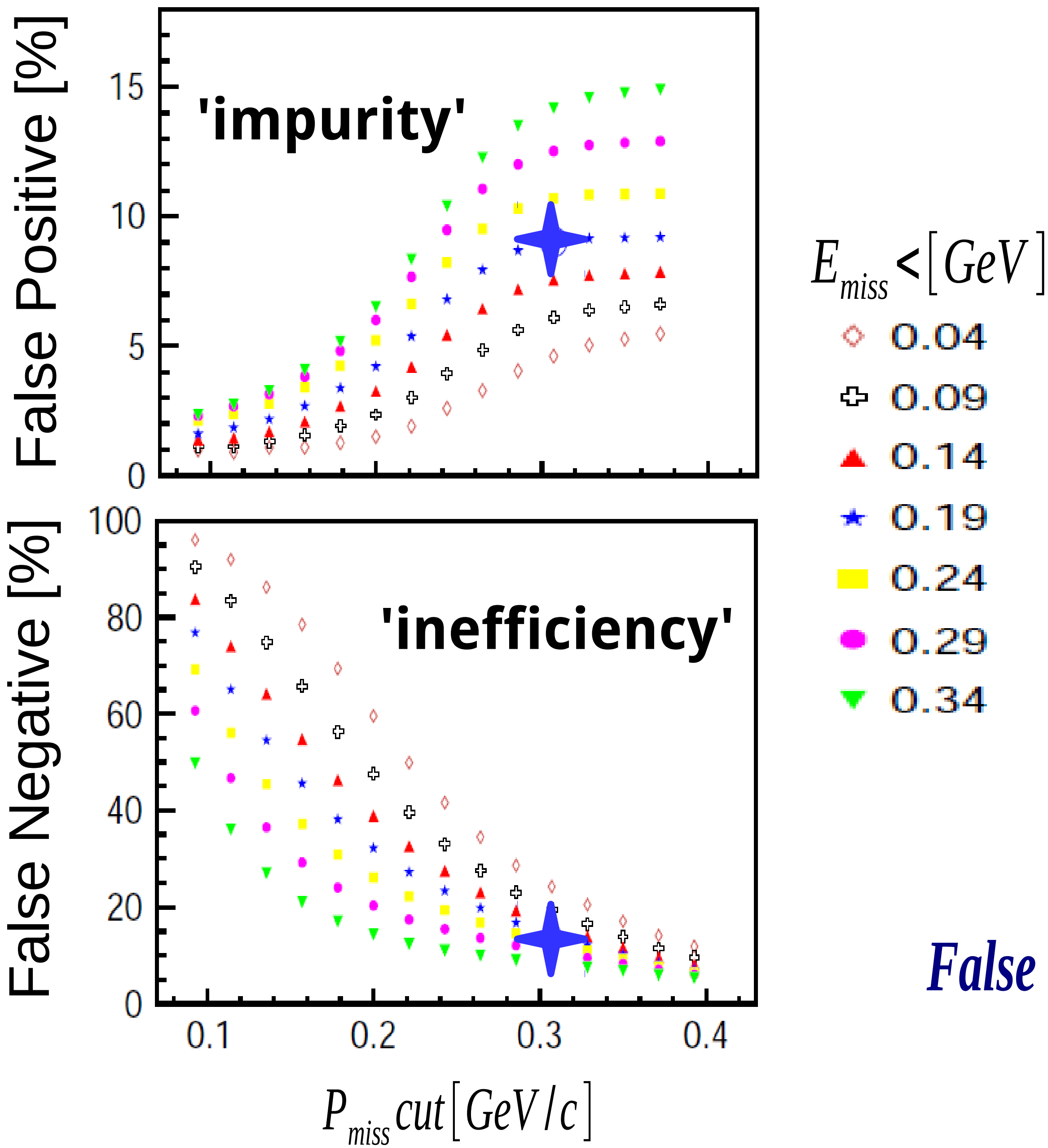


False Positive & Negative probabilities



<u>Goal:</u> Find cuts that minimize false positive & negative

False Positive & Negative probabilities



smeared p/n cuts:

$P_{miss} < 0.3\,GeV/c, \quad E_{miss} < 0.19\,GeV$

un-smeared p cuts:

$P_{miss} < 0.25\,GeV/c, \quad E_{miss} < 0.08\,GeV$

$False\ Positive \simeq False\ Negative \simeq 10\ \%$

The selected cuts:

smeared protons

$$P_{miss} < 0.3\, GeV/c$$

$$E_{miss} < 0.19\, GeV$$

$$-0.05 < y < 0.25$$

$$0.95 < \omega < 1.7\, GeV$$

$$\theta_{pq} < 8^o$$

un-smeared protons

$$P_{miss} < 0.25\, GeV/c$$

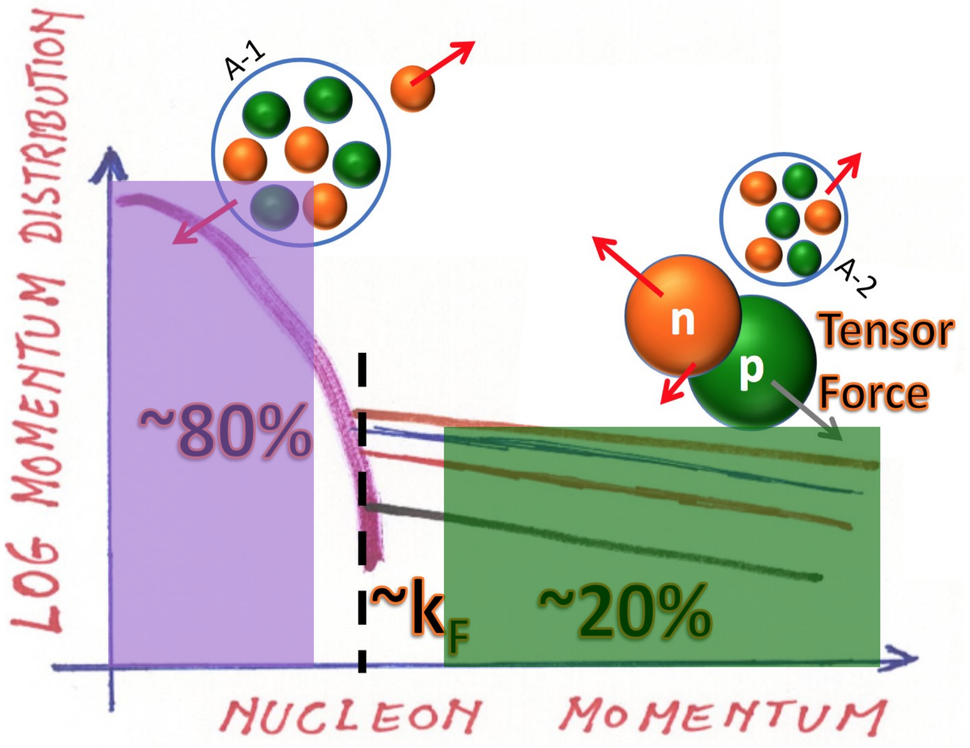
$$E_{miss} < 0.08\, GeV$$

$$False\ Positive \simeq False\ Negative \simeq 10\ \%$$

Analysis of QE events:

- [x] Identifying A(e,e'N) mean-field events
- [ ] Identifying A(e,e'N) high-momentum events

N=n/p

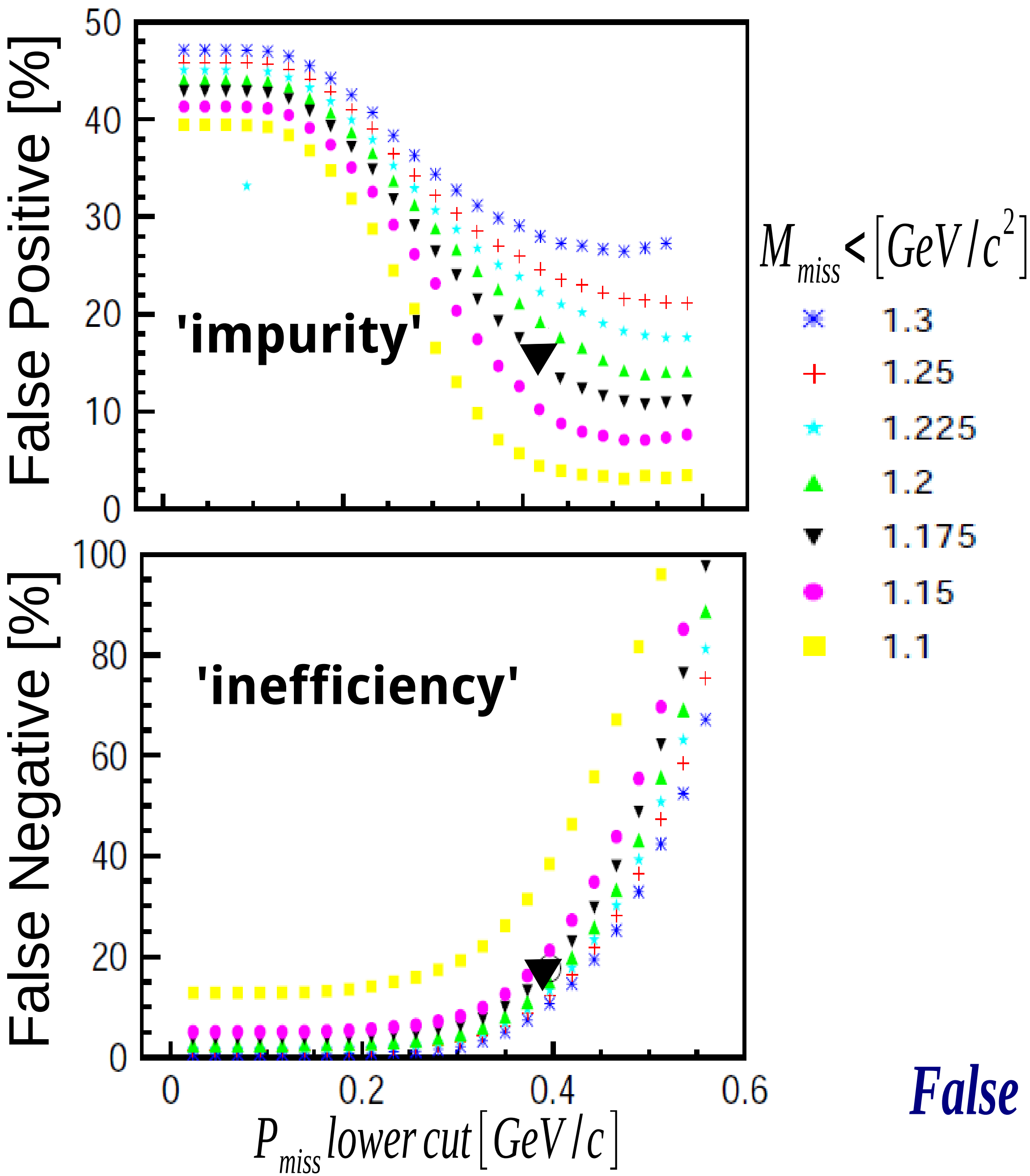


1^{st} step: (e,e'p): Identify high momentum events following analysis by O. Hen (Phys. Rev. C 85, 2012)

2^{nd} step: (e,e'n): Modifying the cuts

- * Low statistics → $x_B > 1.1$
- * Identifying the leading nucleon → $0.62 \le \frac{|\vec{P}_N|}{|\vec{q}|} \le 1.1$, $\theta_{pq} \le 25^o$
- * Poor resolution → smeared protons

False Positive & Negative probabilities



smeared p/n cuts:

$$0.4 < P_{miss} < 1 GeV/c,$$
$$M_{miss} < 1.175 GeV/c^2$$

un-smeared p cuts:

$$0.3 < P_{miss} < 1 GeV/c,$$
$$M_{miss} < 1.1 GeV/c^2$$

$$False\ Positive \simeq False\ Negative \simeq 15\,\%$$

The selected cuts:

smeared protons

$$x_B > 1.1$$

$$0.62 < \vec{p}/\vec{q} < 1.1$$

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

$$0.4 < P_{miss} < 1\,GeV/c$$

$$M_{miss} < 1.175\,GeV/c^2$$

un-smeared protons

$$x_B > 1.2$$

$$0.62 < \vec{p}/\vec{q} < 0.96$$

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

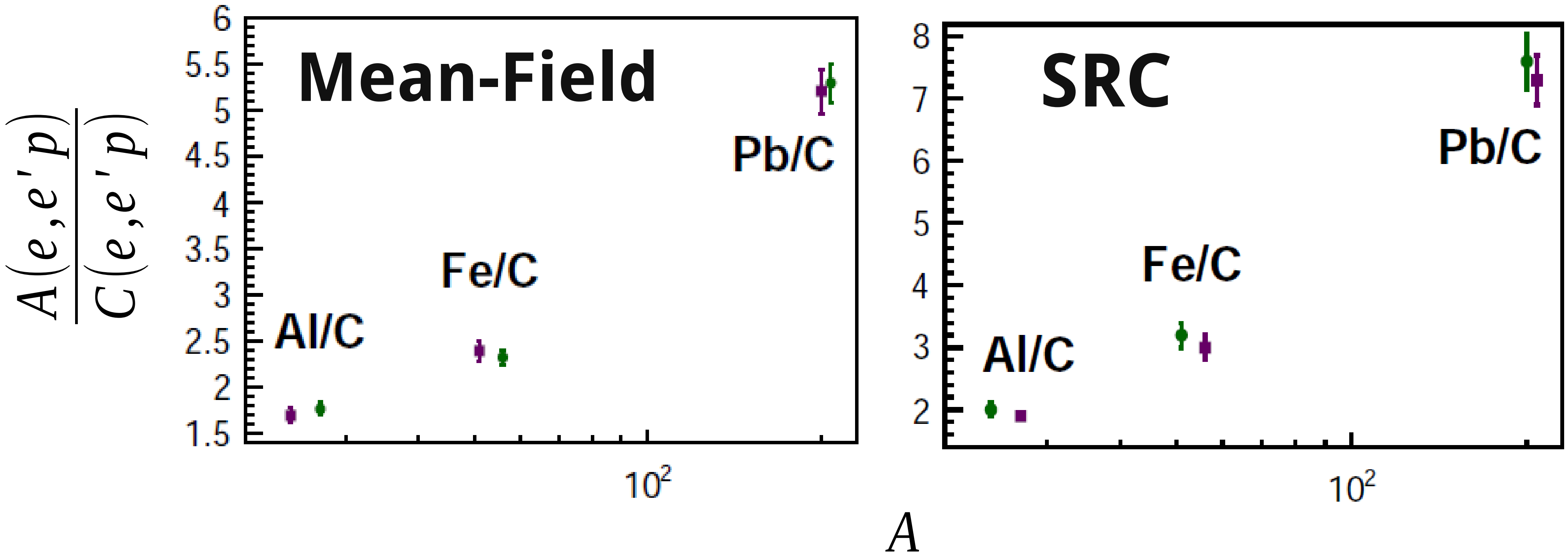
$$0.3 < P_{miss} < 1\,GeV/c$$

$$M_{miss} < 1.1\,GeV/c^2$$

$$False\ Positive \simeq False\ Negative \simeq 15\,\%$$

Compare smeared & un-smeared protons

smeared protons **un-smeared protons**



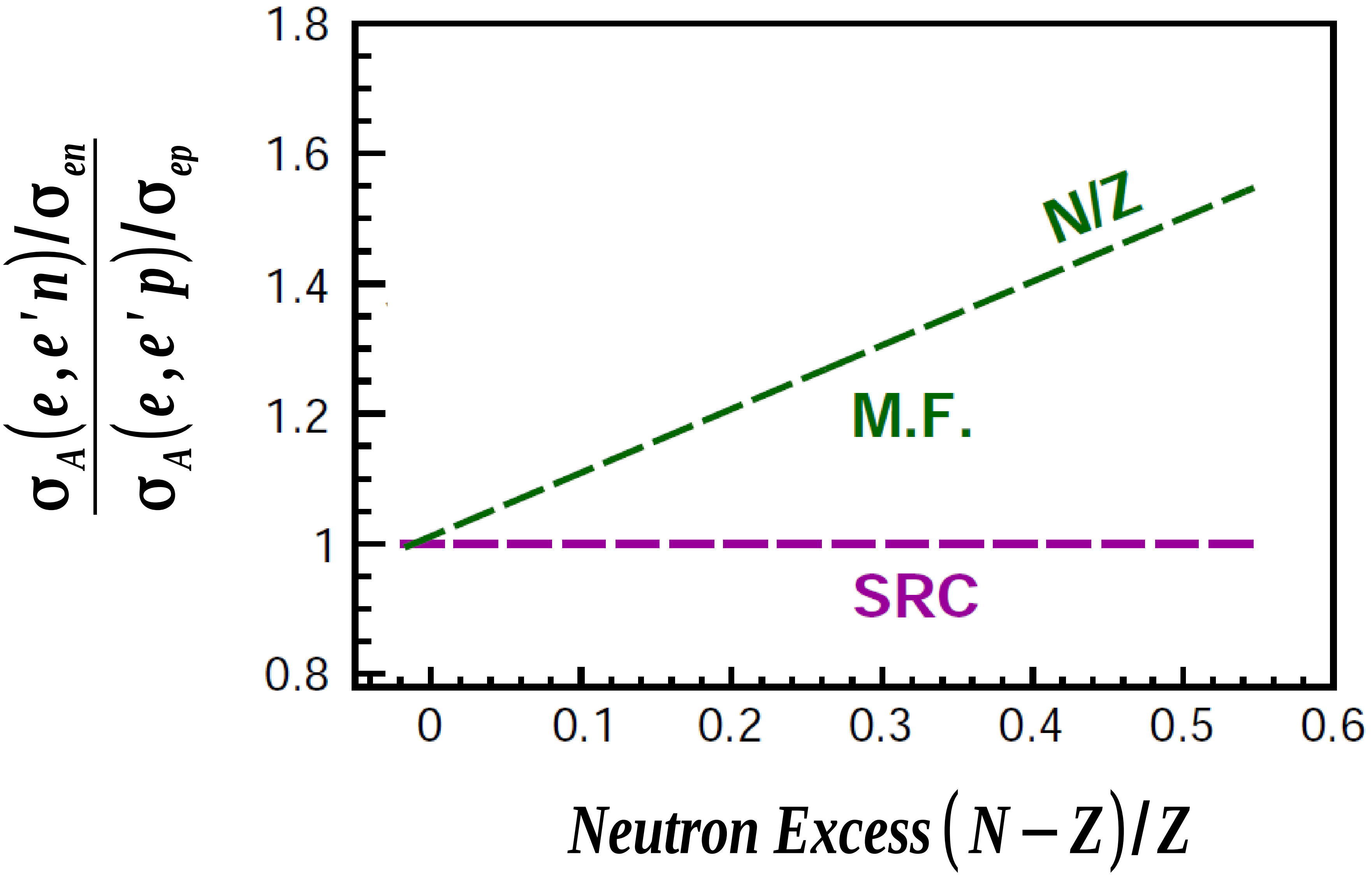
Next step:

Blind analysis for neutrons

Results

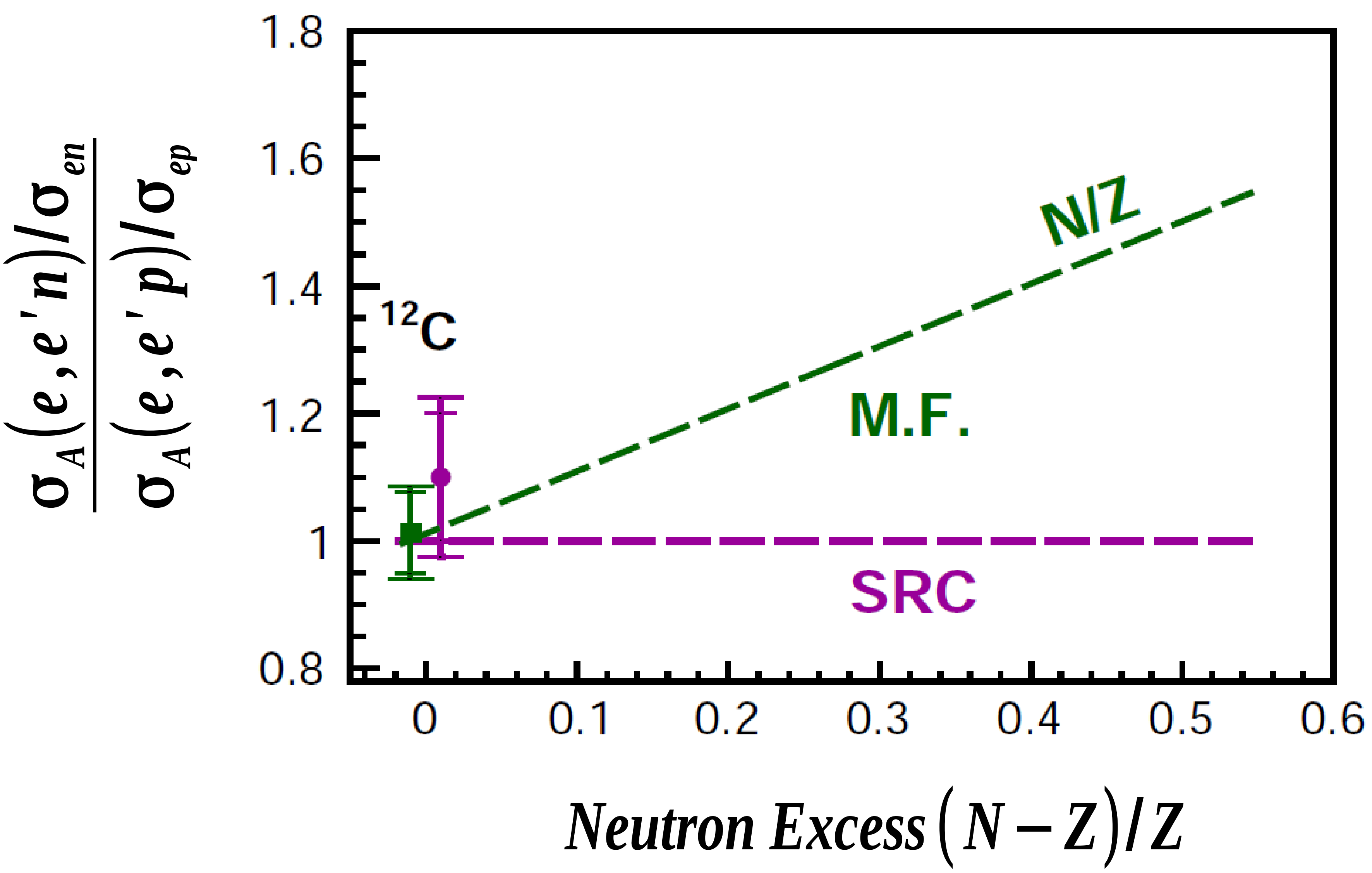
A(e,e'n)/A(e,e'p) ratios

Mean-Field **SRC**



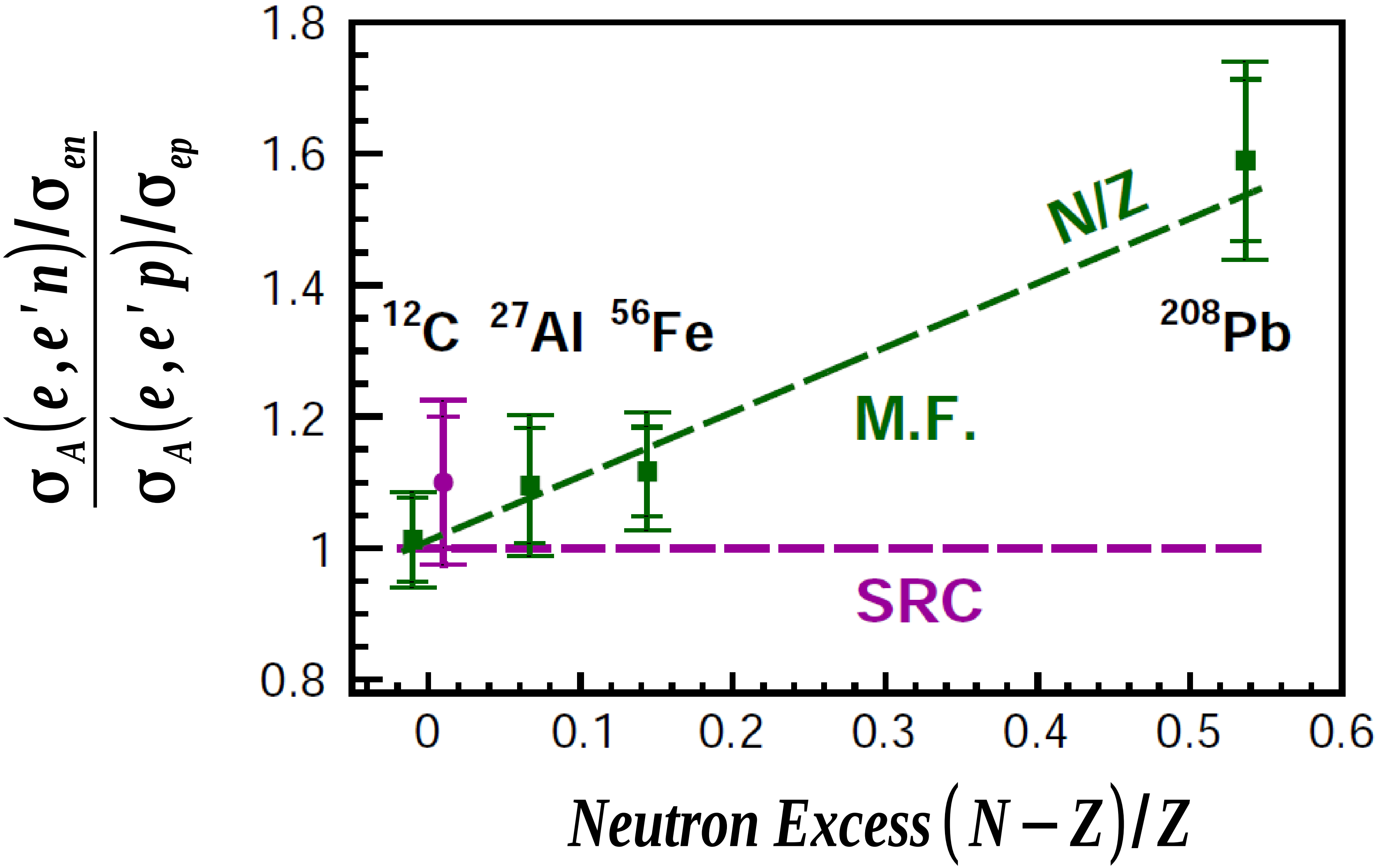
A(e,e'n)/A(e,e'p) ratios

Mean-Field **SRC**



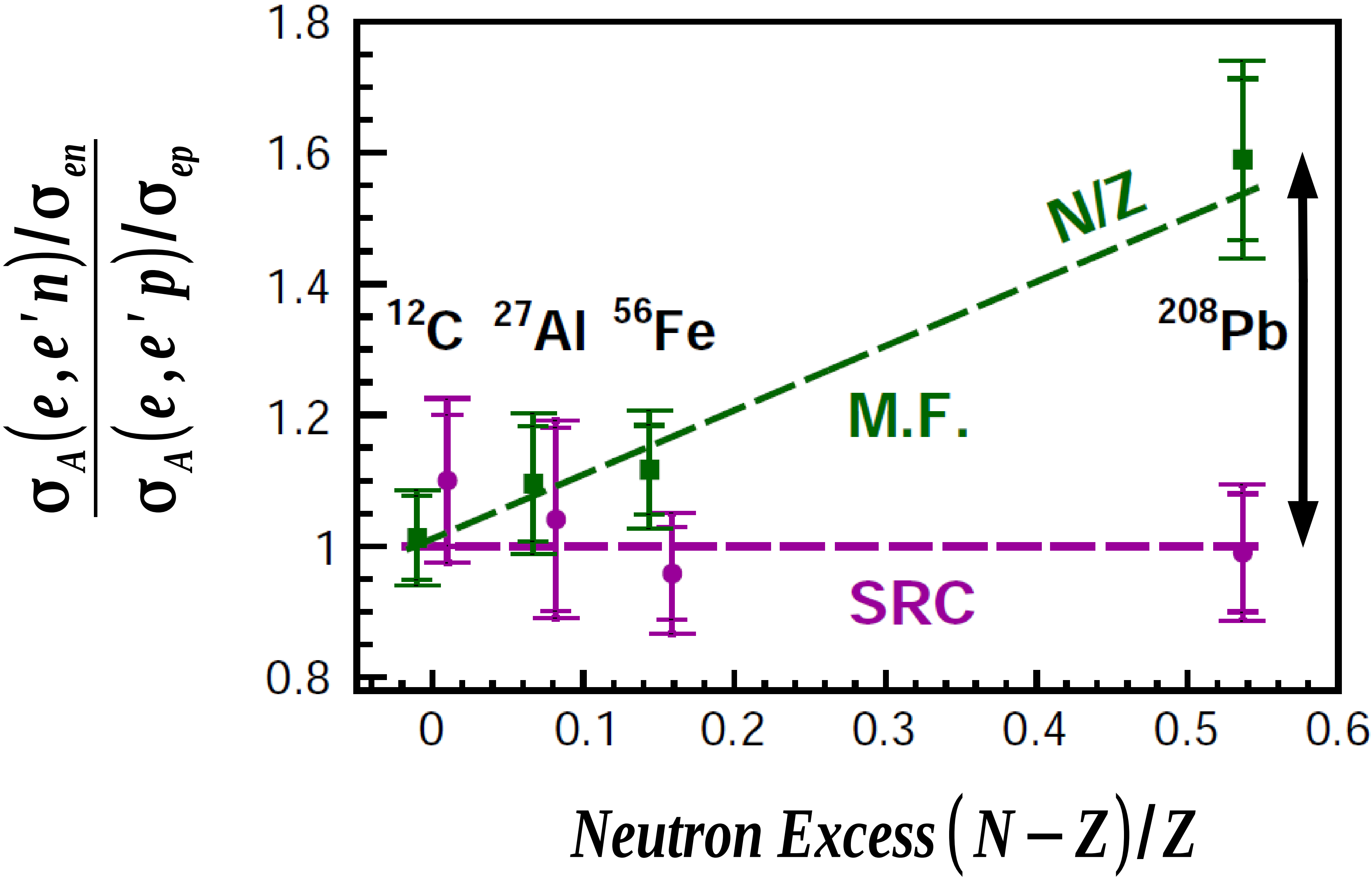
A(e,e'n)/A(e,e'p) ratios

Mean-Field **SRC**

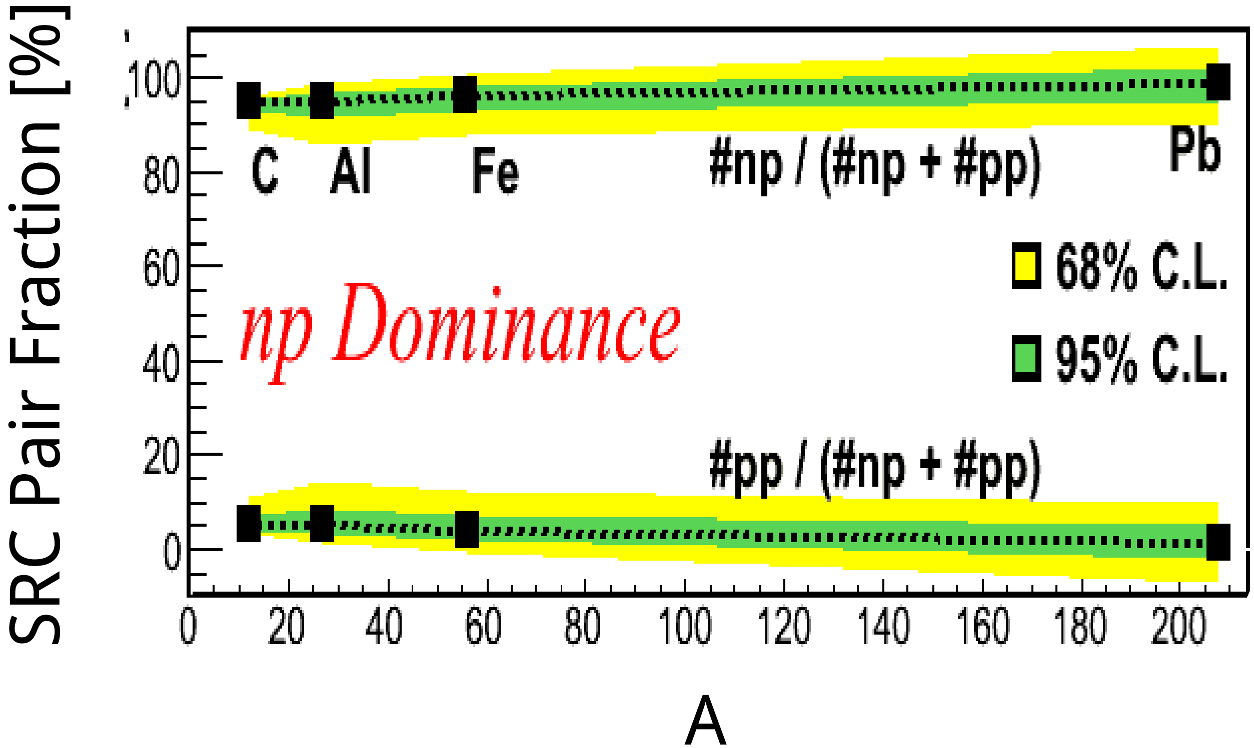


A(e,e'n)/A(e,e'p) ratios

Mean-Field **SRC**



np-dominance in 2N-SRC

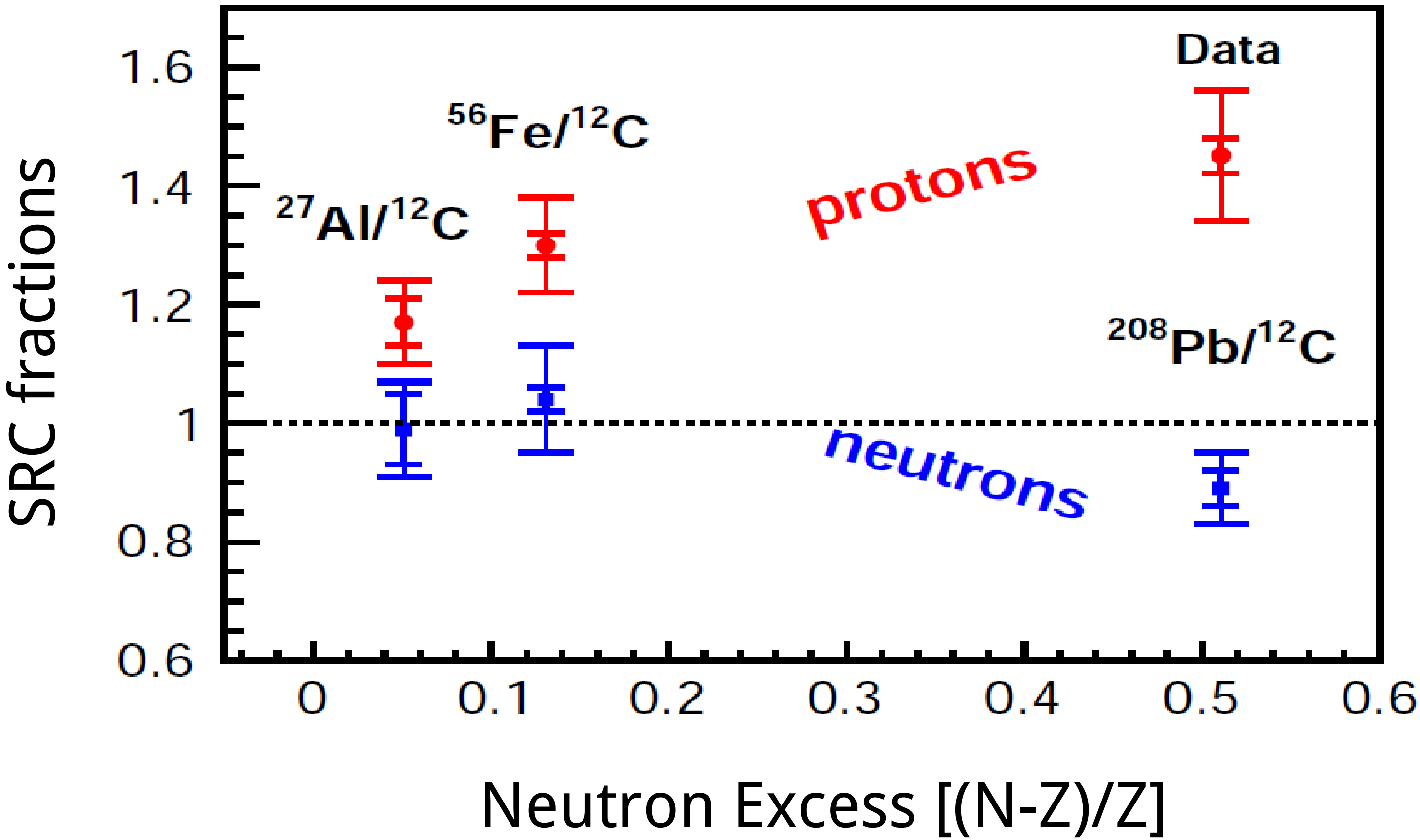


np fractions extracted from (e,e'p) & (e,e'pp) events

O. Hen et al., Science 346, 614 (2014)

Protons and neutrons super ratios

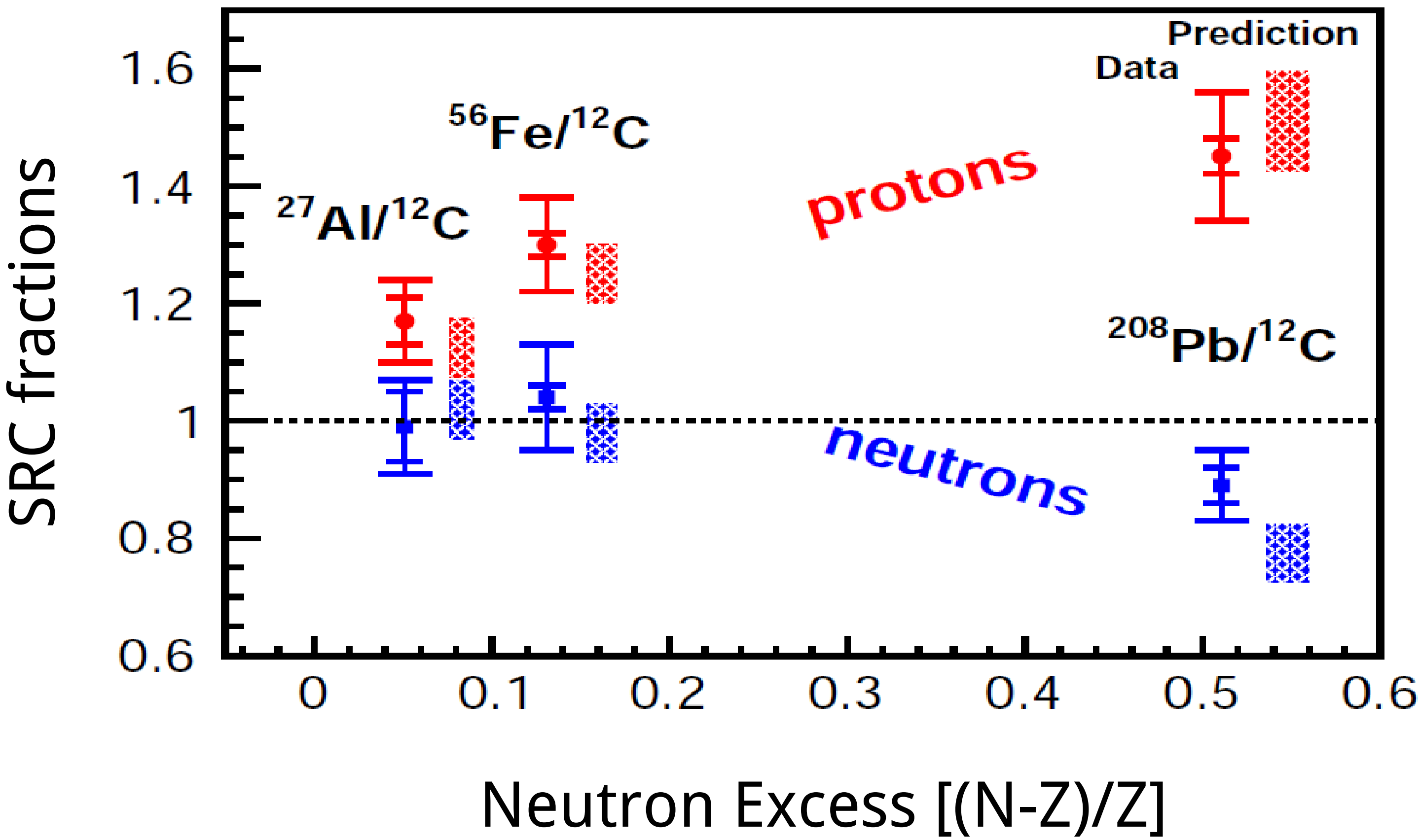
$$\frac{A(e,e'N)_{high}/A(e,e'N)_{low}}{^{12}C(e,e'N)_{high}/^{12}C(e,e'N)_{low}}$$



Correlated p go ↑ n go ↓

Protons and neutrons super ratios

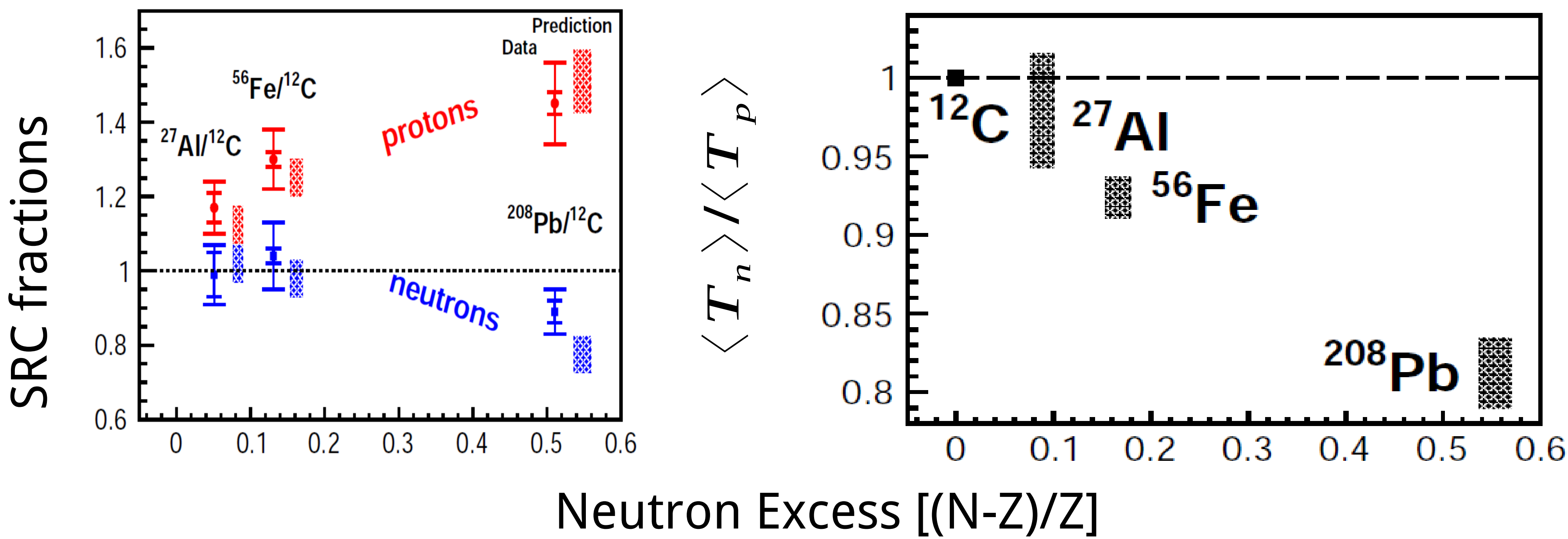
$$\frac{A(e,e'N)_{high} / A(e,e'N)_{low}}{^{12}C(e,e'N)_{high} / ^{12}C(e,e'N)_{low}}$$



Our simple model works

Protons and neutrons super ratios

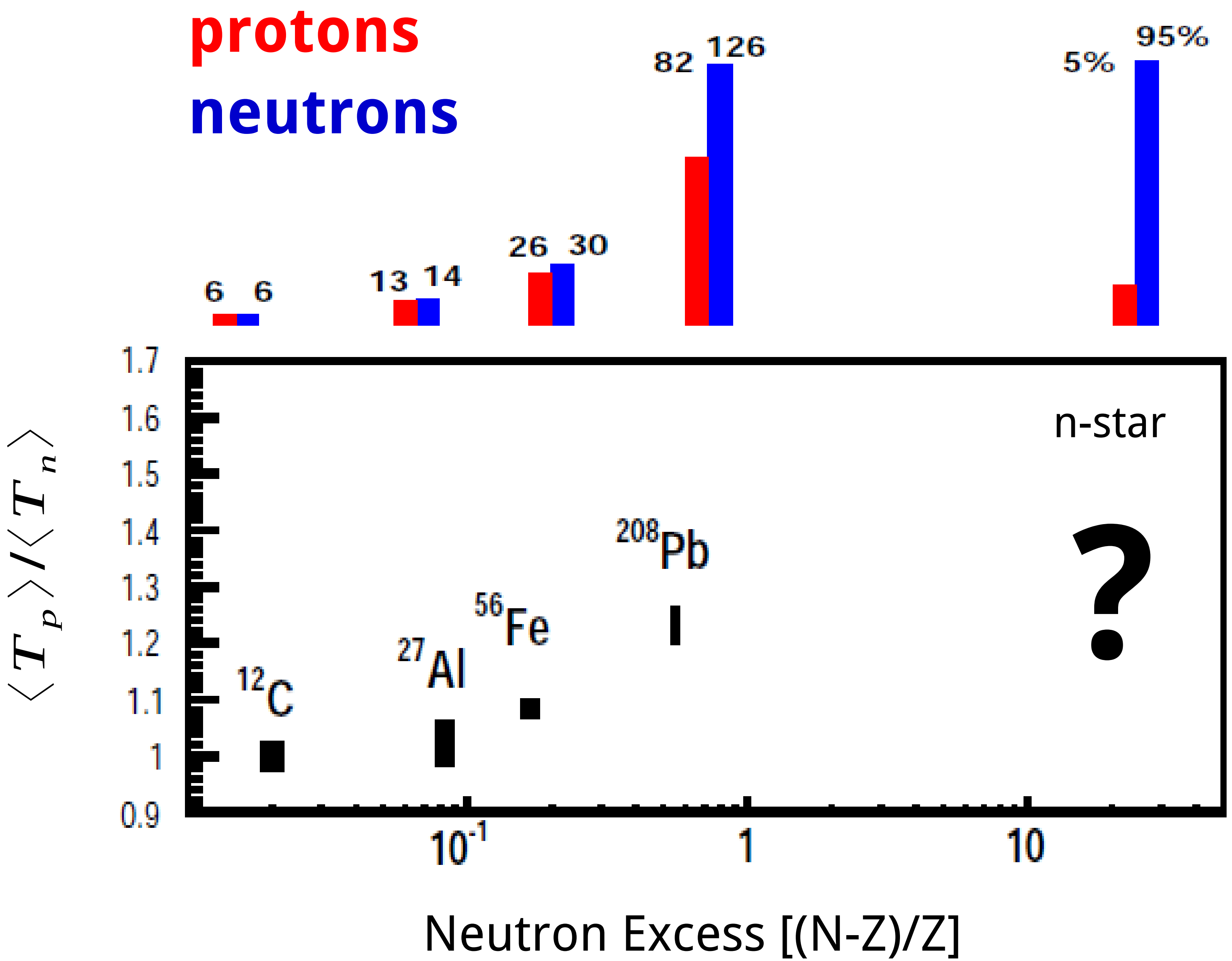
$$\frac{A(e,e'N)_{high} / A(e,e'N)_{low}}{{}^{12}C(e,e'N)_{high} / {}^{12}C(e,e'N)_{low}}$$

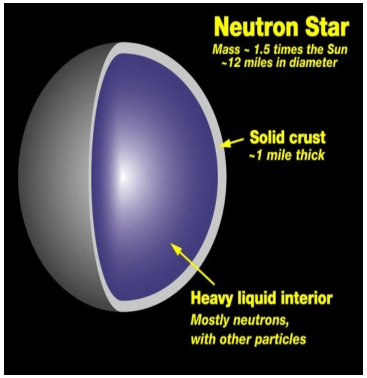


Protons move faster than neutrons in N>Z nuclei

$$\langle T_p \rangle > \langle T_n \rangle$$

What happens in N>>Z?





Acknowledgment

Data-Mining collaboration

CLAS collaboration

SRC review committee:

Stephan Stepanyan, Lamiaa El Fassi, Dan Watts

OLD DOMINION UNIVERSITY

Massachusetts Institute of Technology

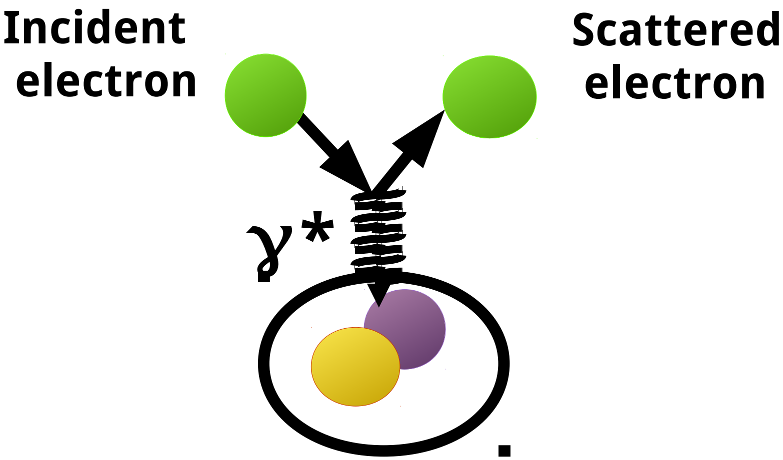
Jefferson Lab

EX UMBRA IN SOLEM

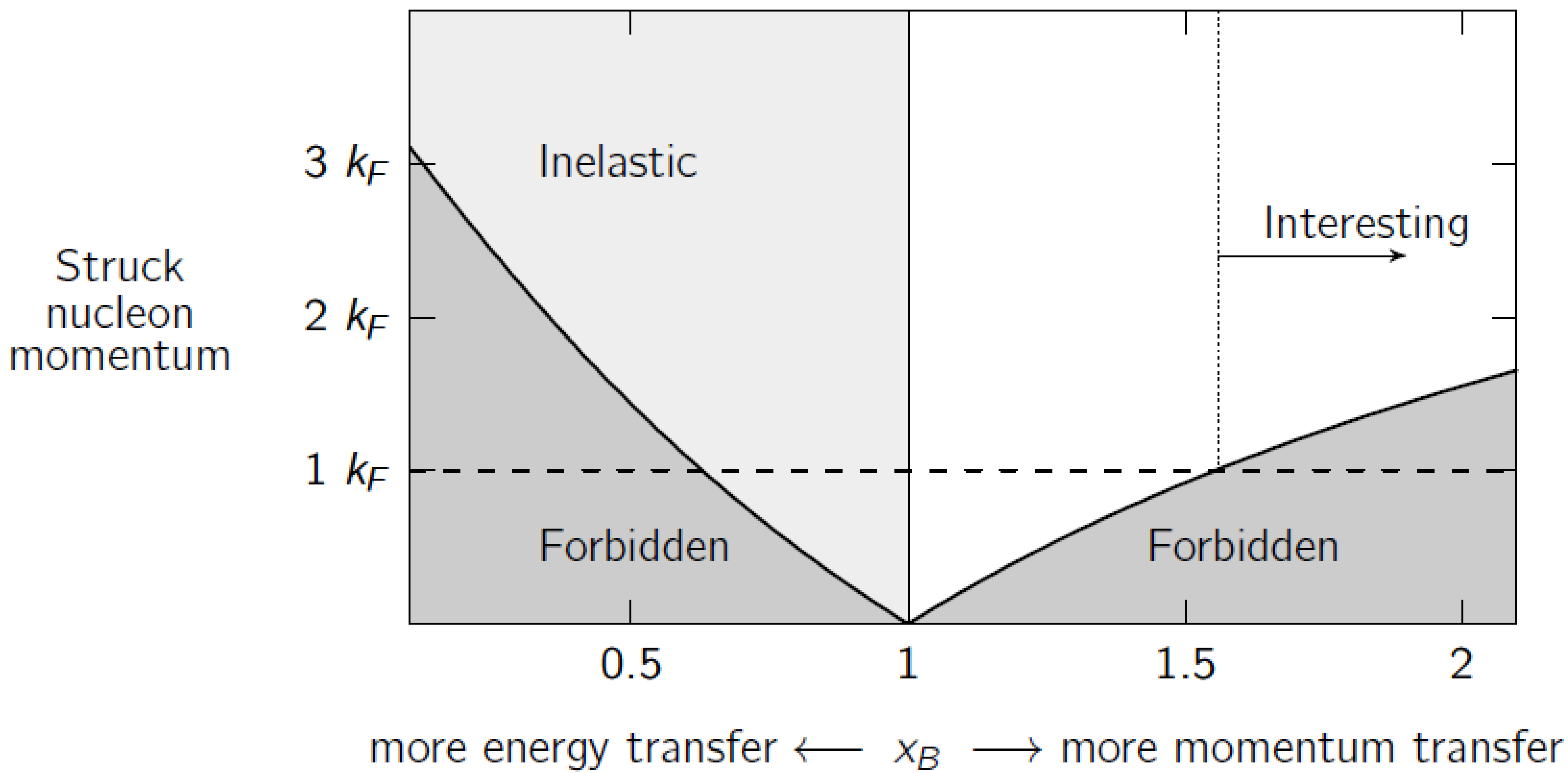
UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

Backup Slides

Counting high-momentum nucleons



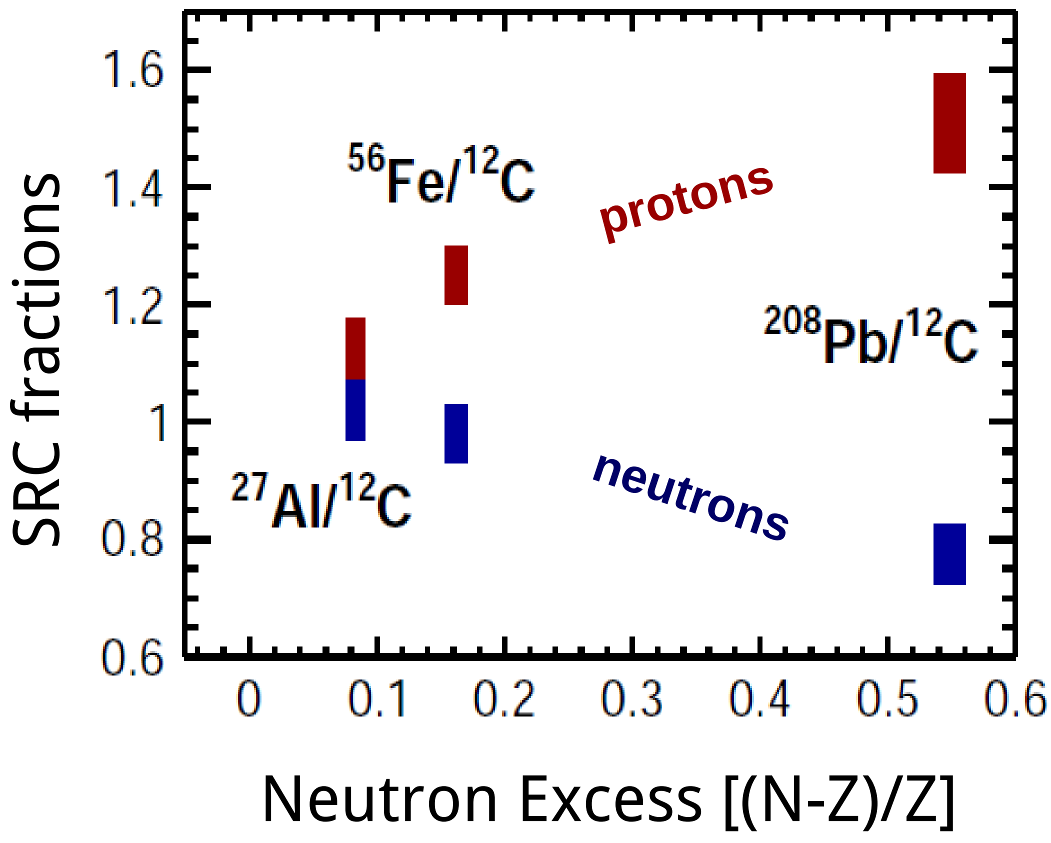
High-momentum nucleons can be selected by restricting only the e kinematics.



Simple prediction based on the np-dominance model

$$\frac{A(e,e'n)\ high/low}{^{12}C(e,e'n)\ high/low}$$

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



$$\#A(e,e'N) \propto \begin{cases} \int n^{M.F.}(k)k^2dk & k<k_0 \\ \int n^{SRC}(k)k^2dk & k>k_0 \end{cases}$$

Detecting neutrons in CLAS

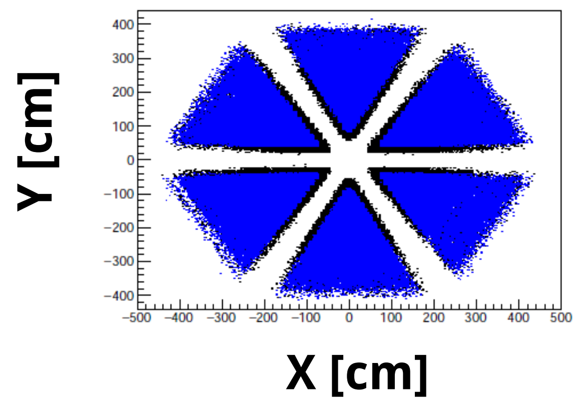
$$8^o \leq \theta \leq 45^o$$

* No signals from Drift-Chambers & Time-Of-Flight Counters

* Hit inside the EC fiducial cut

↓

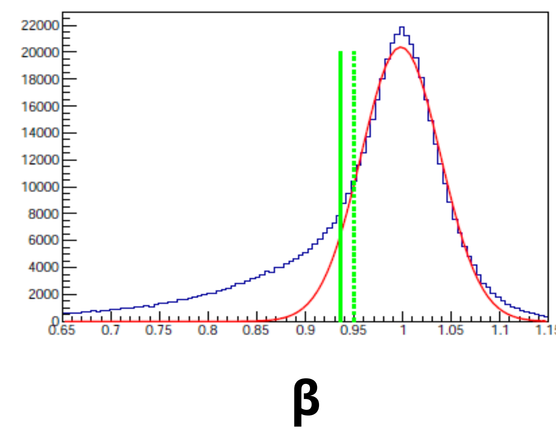
Neutral particle



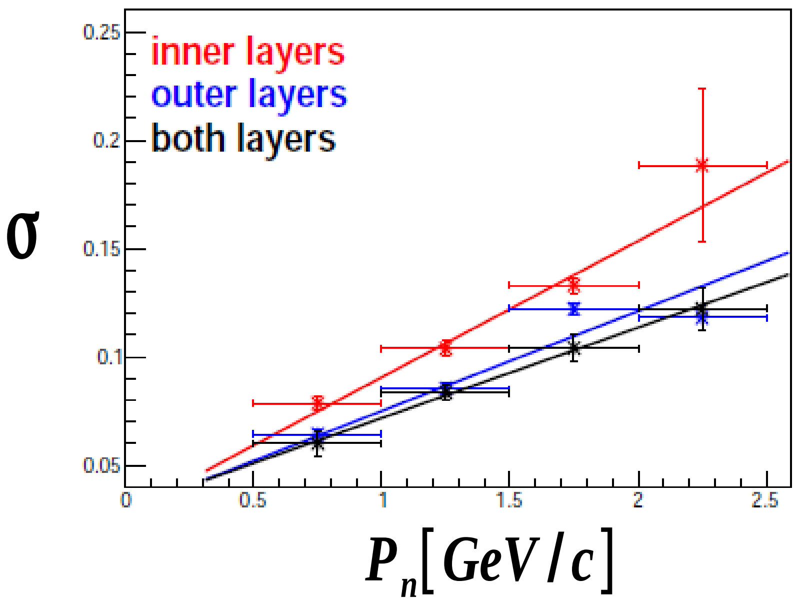
* n/γ separation: β<0.95 (β<0.936)

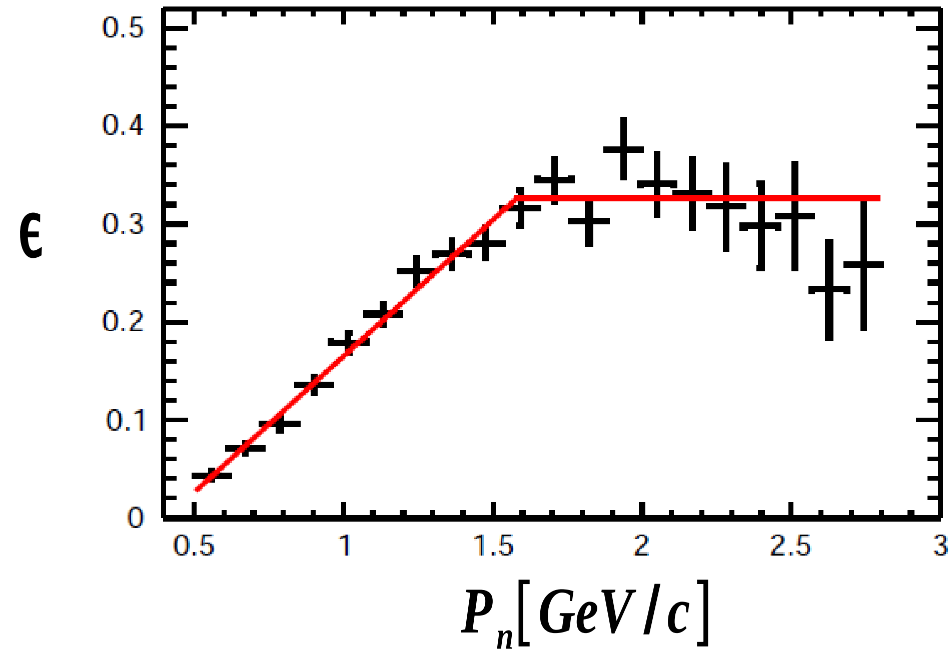
↓

Neutron



Neutron resolution & detection efficiency





$$\epsilon = \frac{d(e,e'p\pi^+\pi^-n)}{d(e,e'p\pi^+\pi^-)n}$$

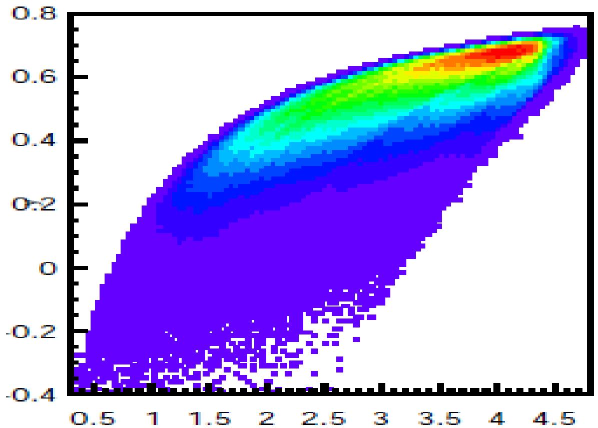
Using an exclusive reaction $d(e,e'p\pi^+\pi^-n)$

Solution I

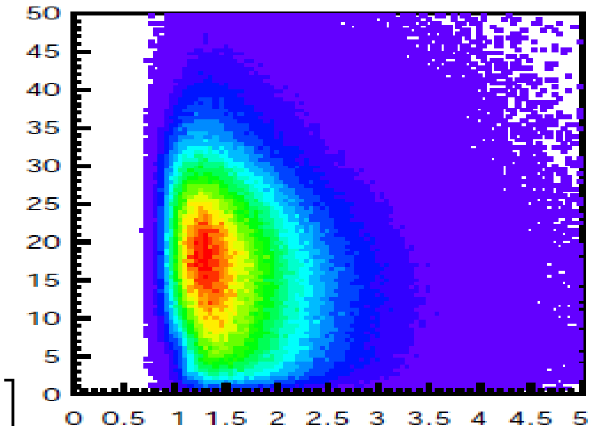
Using electron & nucleon angular cuts

Protons QE cuts: $P_{miss}<0.25$ GeV/c $E_{miss}<0.08$ GeV

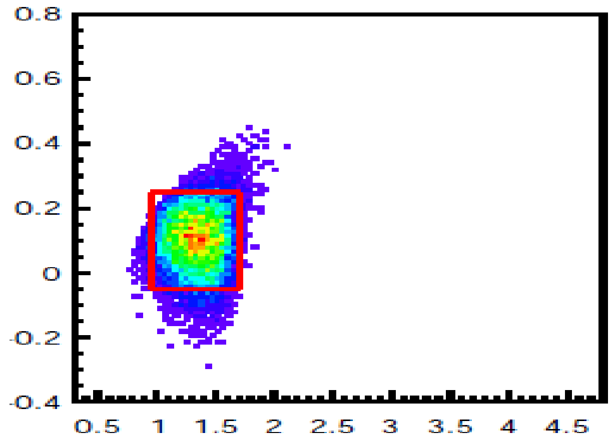
y



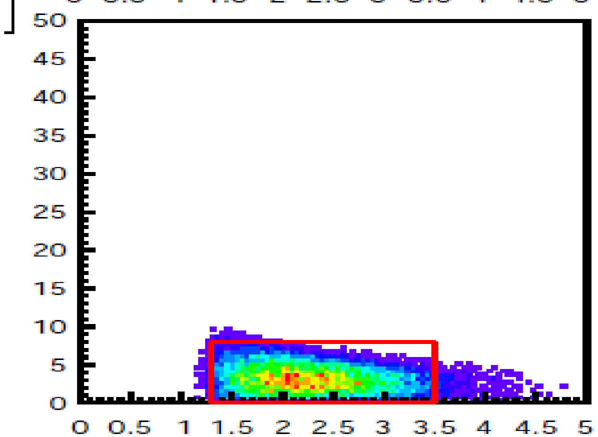
Before the QE cuts



$\theta_{pq}[deg.]$



After the QE cuts



$\omega[GeV]$ $Q^2[GeV^2/c^2]$

$-0.05<y<0.25$ $0.95<\omega<1.7\,GeV$ $\theta_{pq}<8^o$

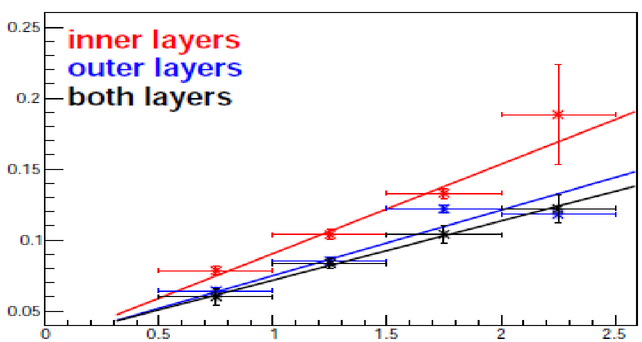
$$y\equiv[(M_A+\omega)^2\sqrt{\lambda^2-M_{A-1}^2W^2}-|\vec{q}|\lambda]/W^2 \qquad W=\sqrt{(M_A+\omega)^2-|\vec{q}|^2} \qquad \lambda=(M_{A-1}^2-M_N^2+\omega^2)/2$$

Solution II

Using smeared protons to:

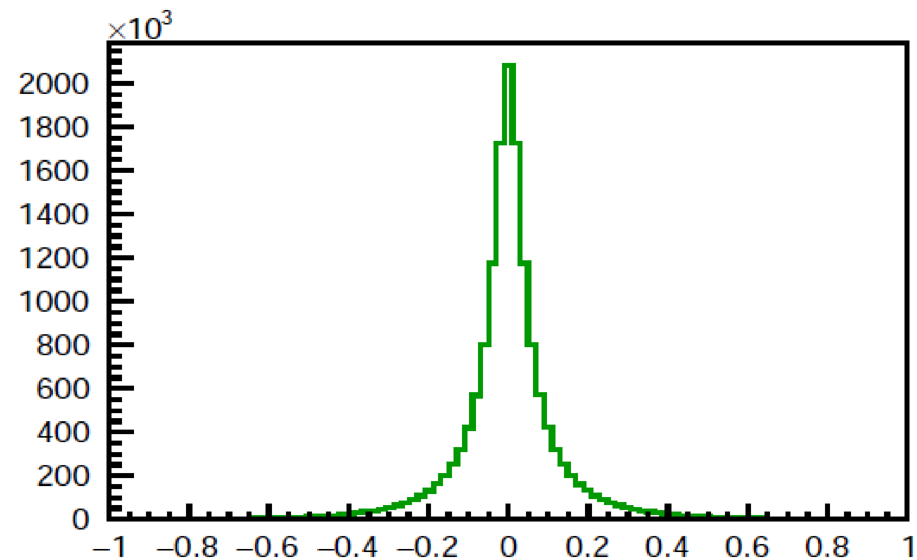
* Define and test the cuts
* Study bin migration

σ



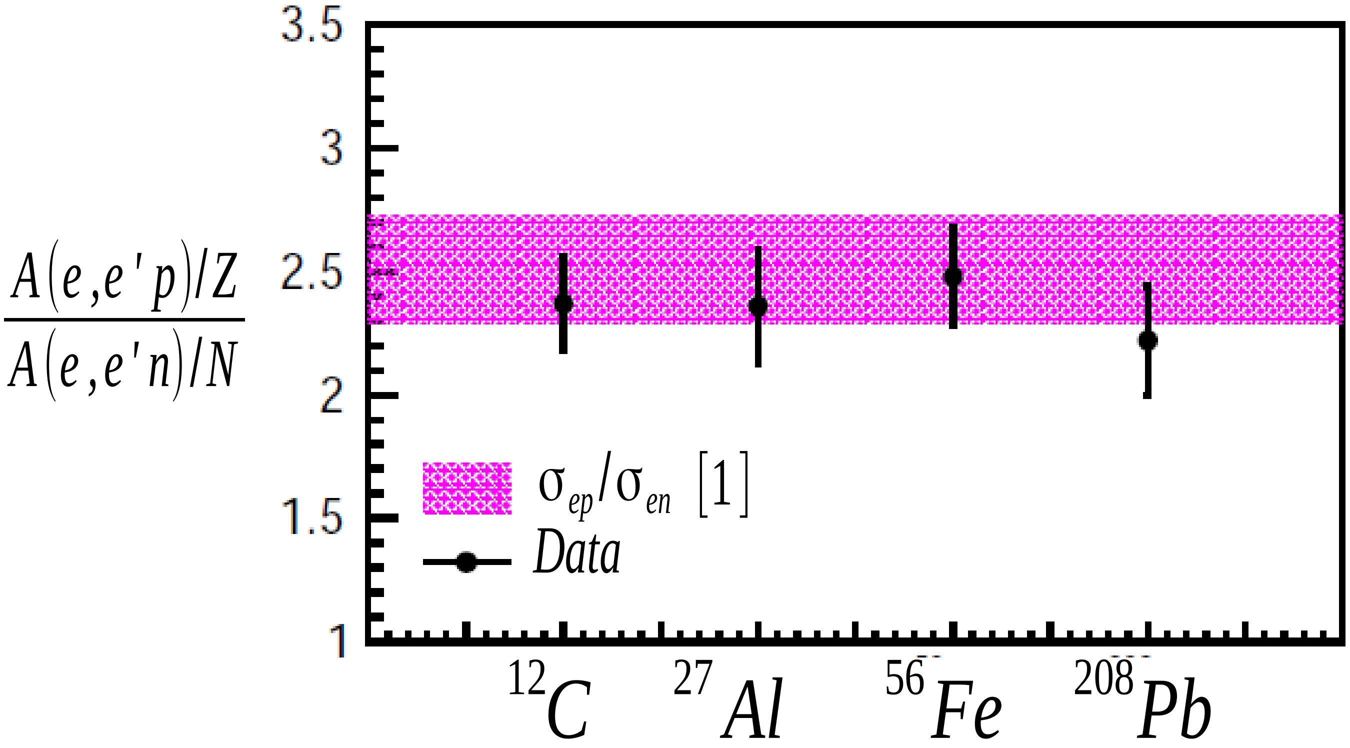
$P_n[GeV/c]$

$$P_p \rightarrow P_{smeared} = \sum Gauss(P_p, \sigma)$$



$P_p - P_{smeared}[GeV/c]$

Sanity Check: Mean-Field ratios



$$\sigma^R_{ep(n)} = \frac{\epsilon}{\tau} G_E^2 + G_M^2$$

$$\tau = \frac{Q^2}{4 M_N^2},$$

$$\epsilon = \left[1 + 2(1+\tau)\tan^2\left(\frac{\theta_e}{2}\right)\right]^{-1}$$

Taken into account:

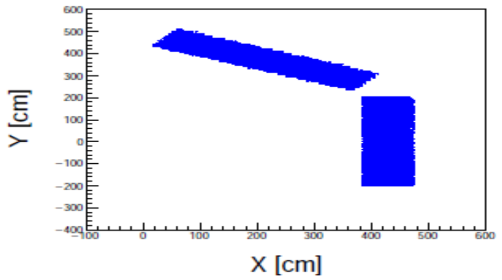
Acceptance correction & detection efficiency (different for p/n), transparency

[1] W. P. Ford, S. Jeschonnek & J. W. Van Orden, arXiv:1411.3306v1 [nucl-th] (2014)

To be continued by:

Neutrons transparency ratios

Detecting neutrons in CLAS LAC

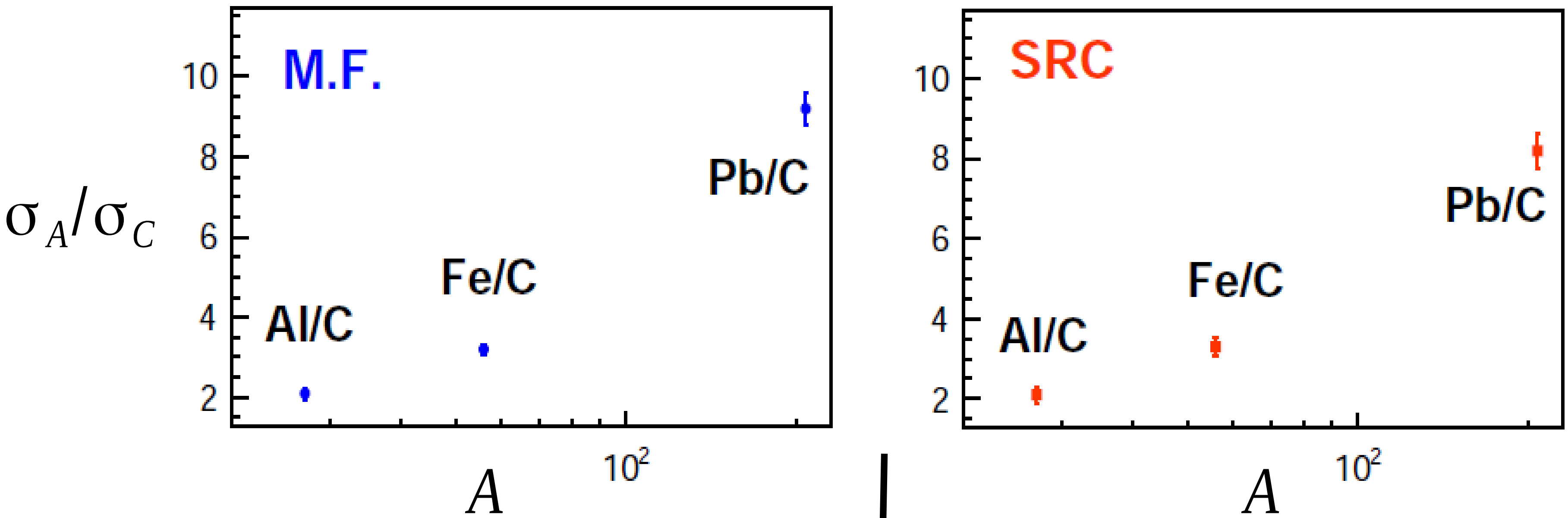


$2N - SRC$
$(e, e'np_{back})$

3N- SRC
(e,e'npp)

Blind analysis

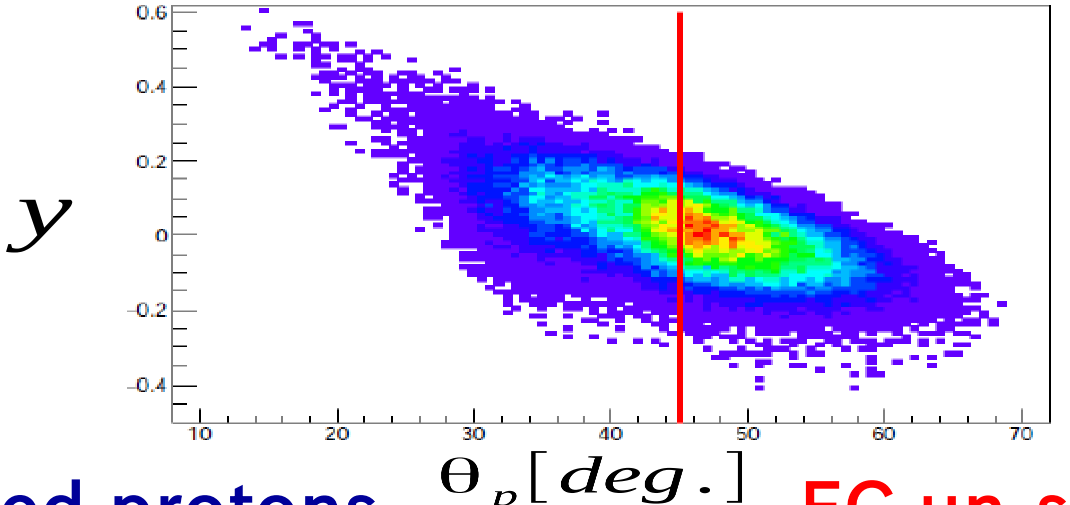
Ratios for neutrons: A(e,e'n)/C(e,e'n)



Opportunity for a 1st measurement of neutron nuclear transparency!

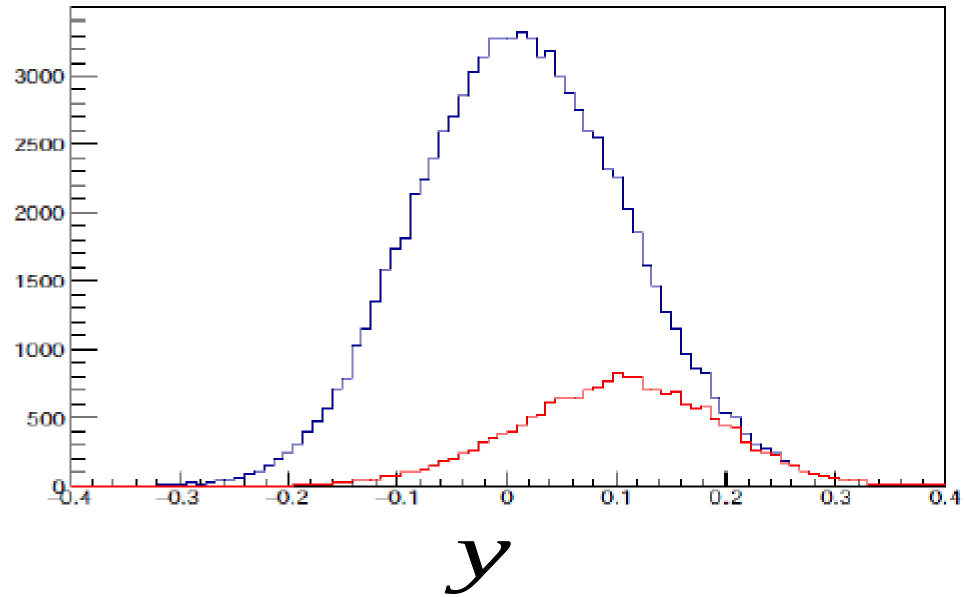
Comparing un-smeared protons

QE cuts: $P_{miss} < 0.25\, GeV/c$ $E_{miss} < 0.08\, GeV$

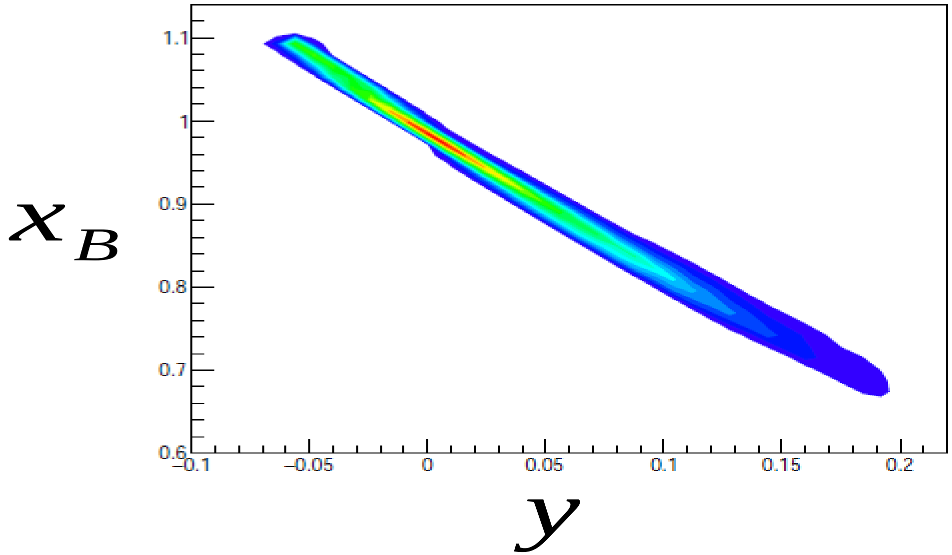


All un-smeared protons

EC un-smeared protons

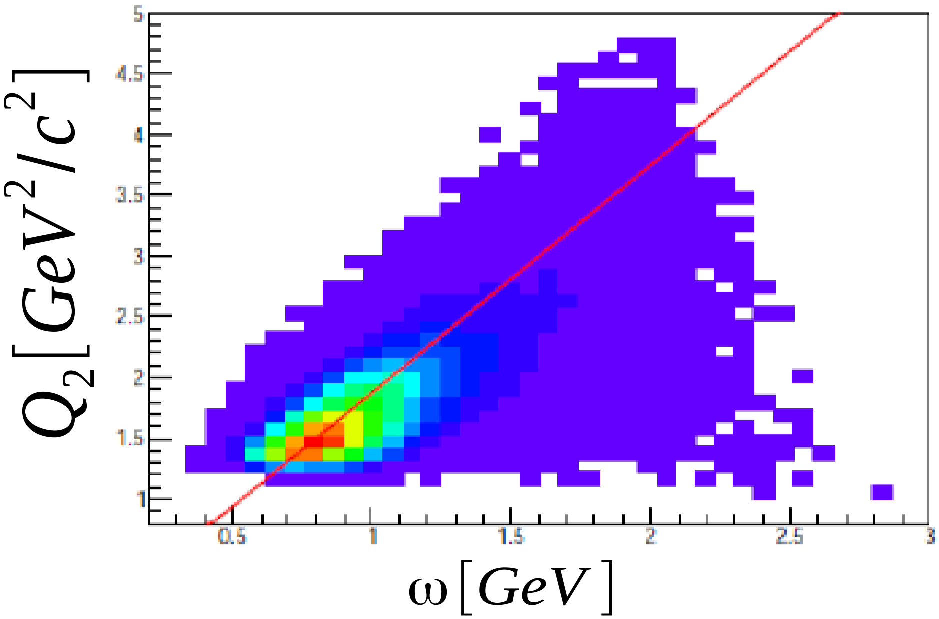


Comparing un-smeared protons

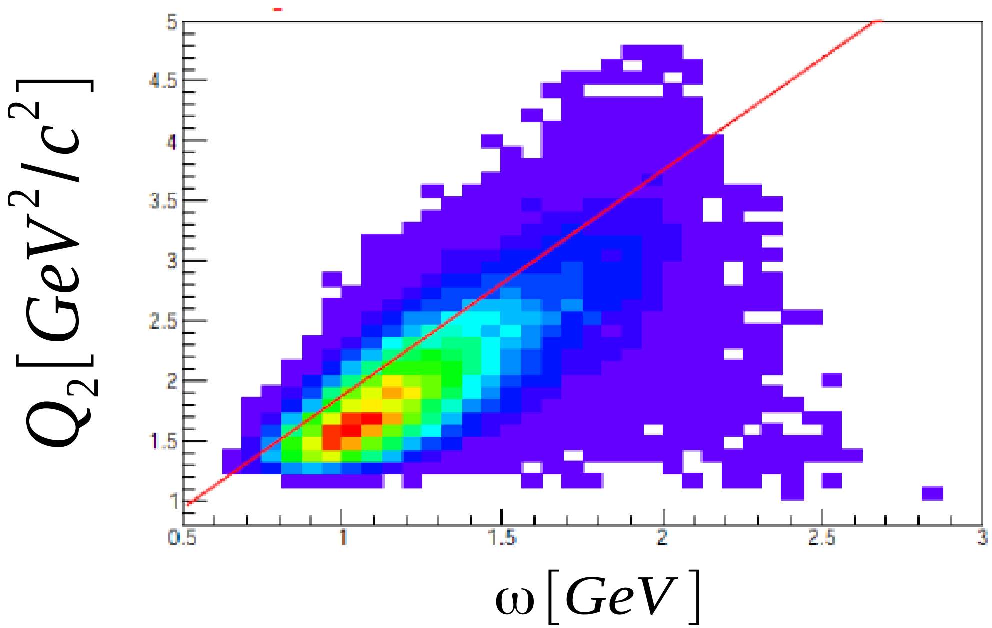


QE events → $x_b \approx 1$

All un-smeared protons



EC un-smeared protons



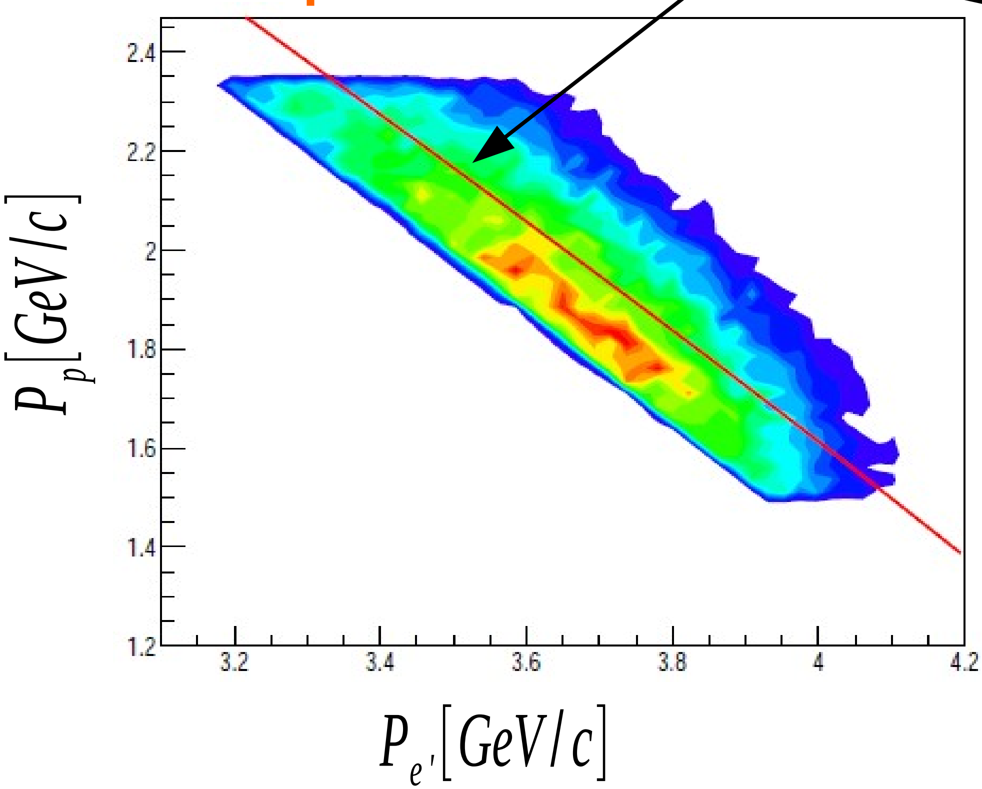
Checking the event selection

Energy momentum conservation:

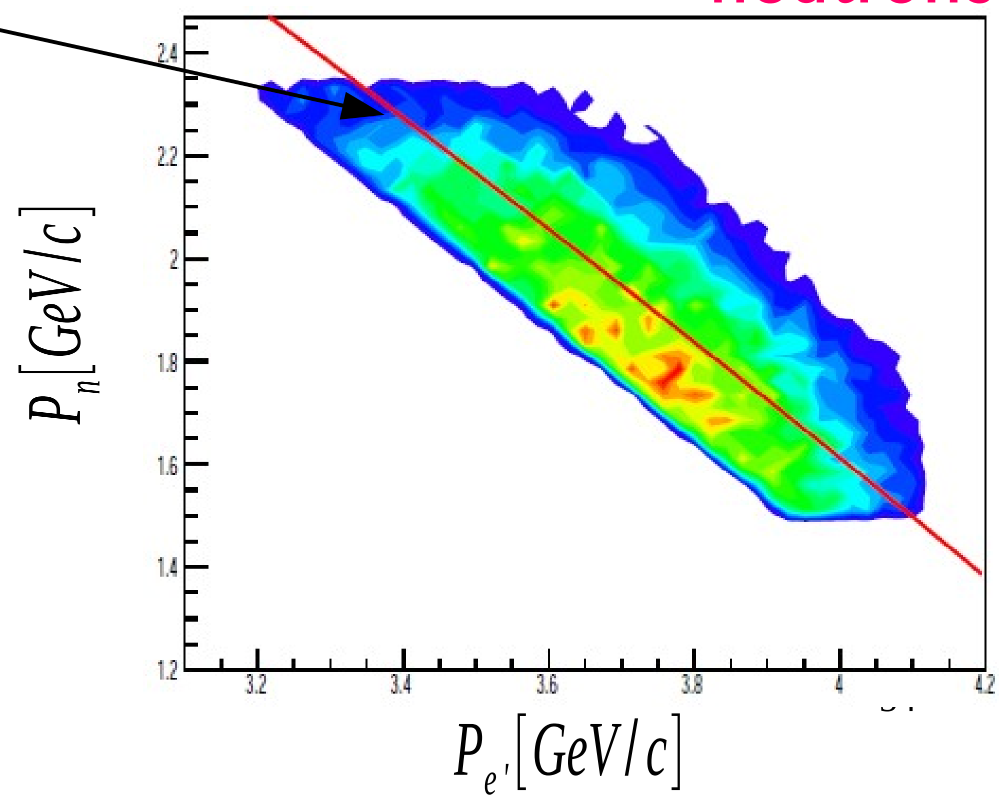
$$\left(E_{beam},\left(0,0,E_{beam}\right)\right)+\left(M_N,\vec{0}\right)=\left(E',\vec{P}_{e'}\right)+\left(E_N,\vec{P}_N\right)$$

$$|\vec{P}_N|=\sqrt{\left(E+M_N-|\vec{P}_{e'}|\right)^2-M_N^2}$$

smeared protons



neutrons

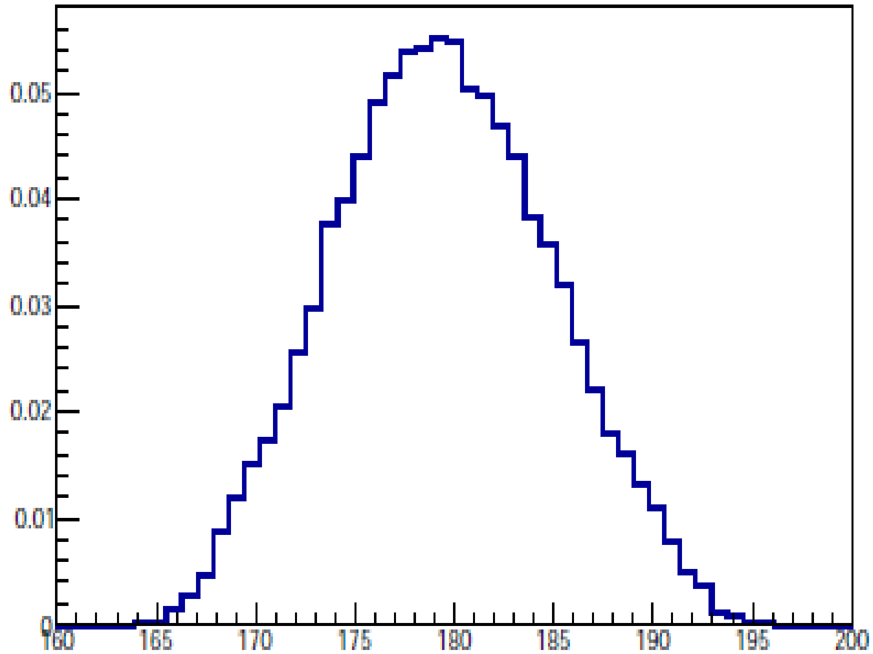


Checking the event selection

From energy momentum conservation:

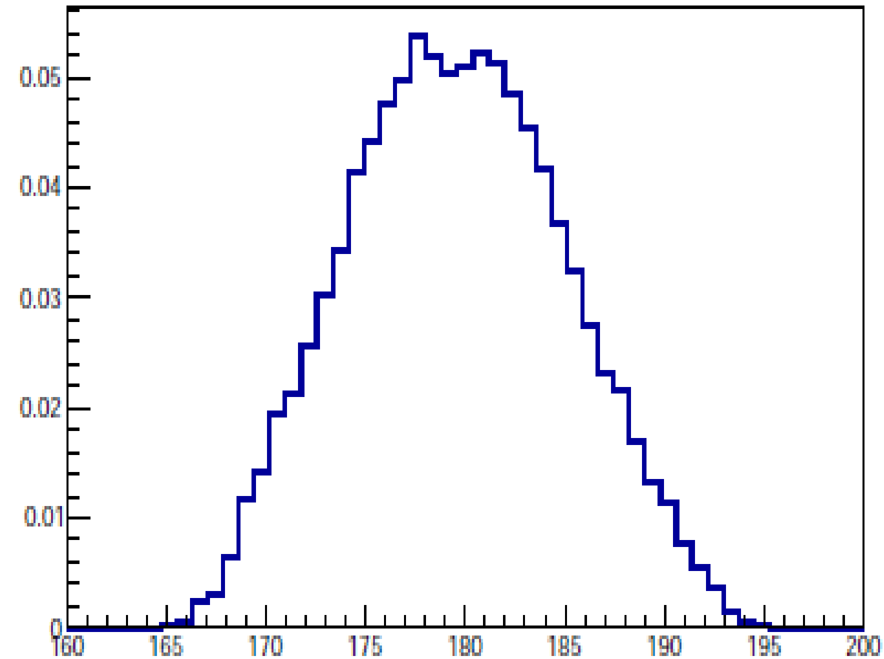
$$|\varphi_N - \varphi_{e'}| = 180^o$$

smeared protons



$|\varphi_p - \varphi_{e'}|[deg.]$

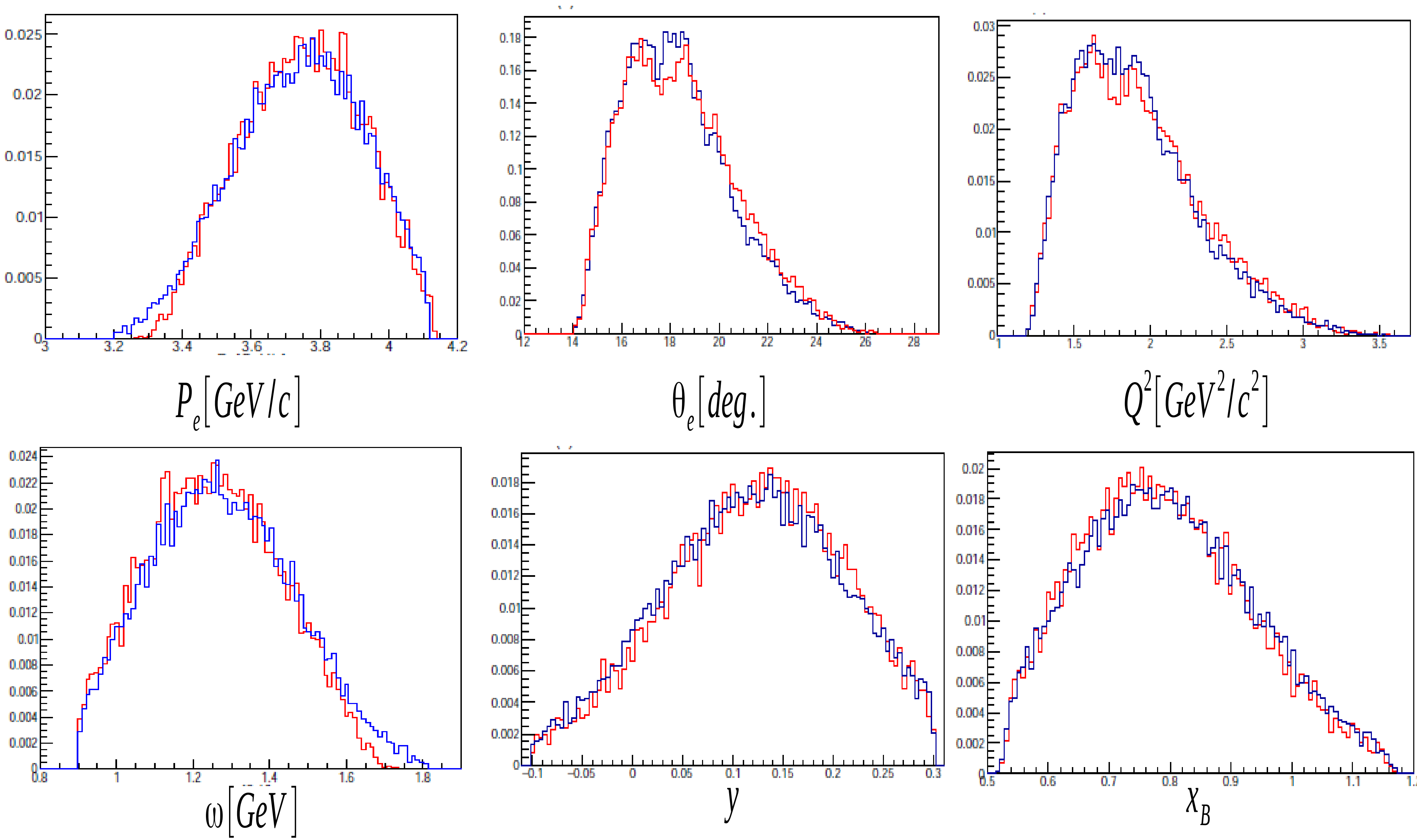
neutrons



$|\varphi_n - \varphi_{e'}|[deg.]$

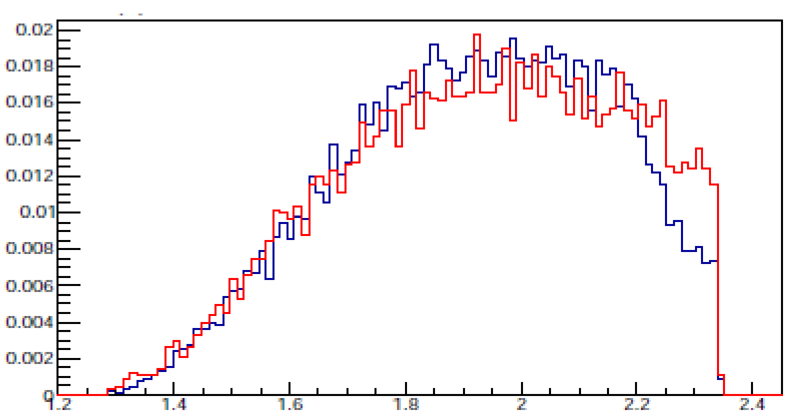
Comparing the smeared protons and neutrons

smeared protons neutrons

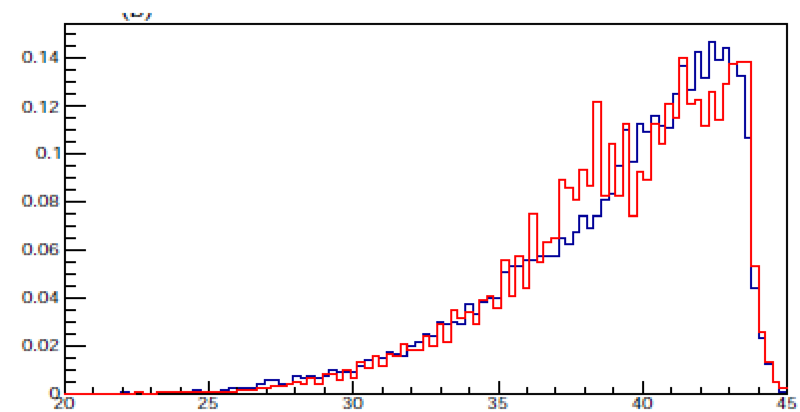


Comparing the smeared protons and neutrons

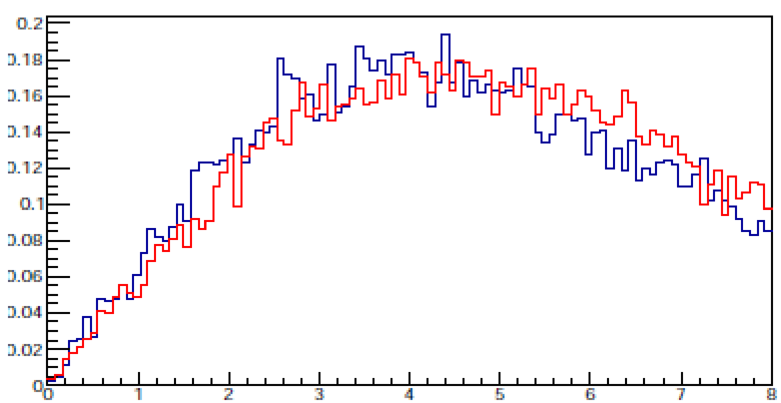
smeared protons | **neutrons**



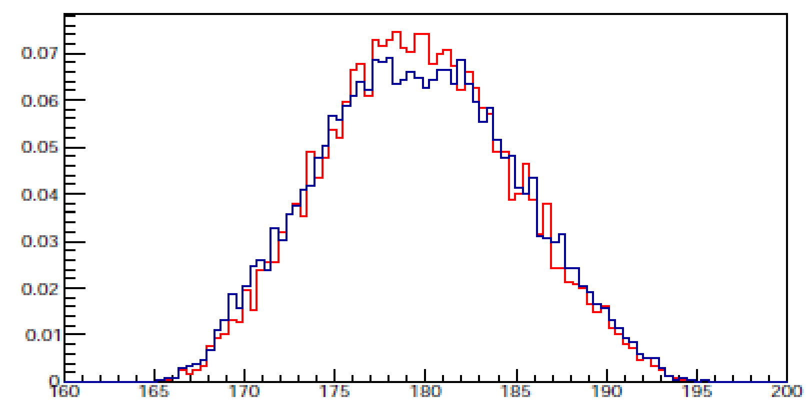
$P_{p/n}[GeV/c]$



$\theta_{p/n}[deg.]$



$\theta_{pq/nq}[deg.]$



$|\varphi_{p/n}-\varphi_e|[deg.]$

Applying corrections

protons

* Coulomb correction
* Detection efficiency
* Acceptance correction

neutrons

* Detection efficiency
* Acceptance correction

Protons simulation

* 10,000 electrons from the data.

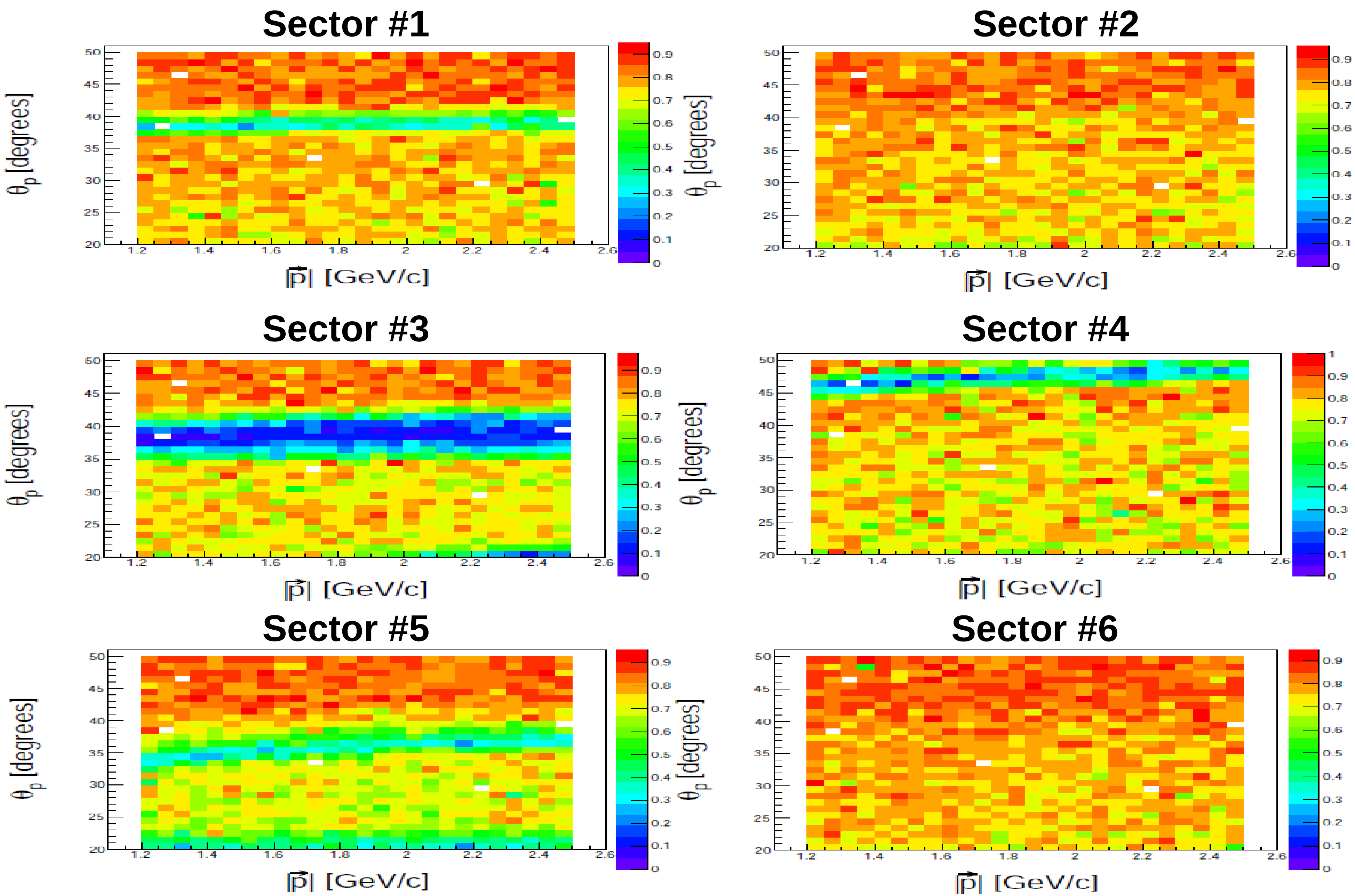
* Proton momentum & scattering angle uniformly distributed.

* 100xphi angle uniformly distributed.

* Running through CLAS MC simulation.

* Dividing event by event by the ratio of reconstructed/generated.

Protons simulation - results



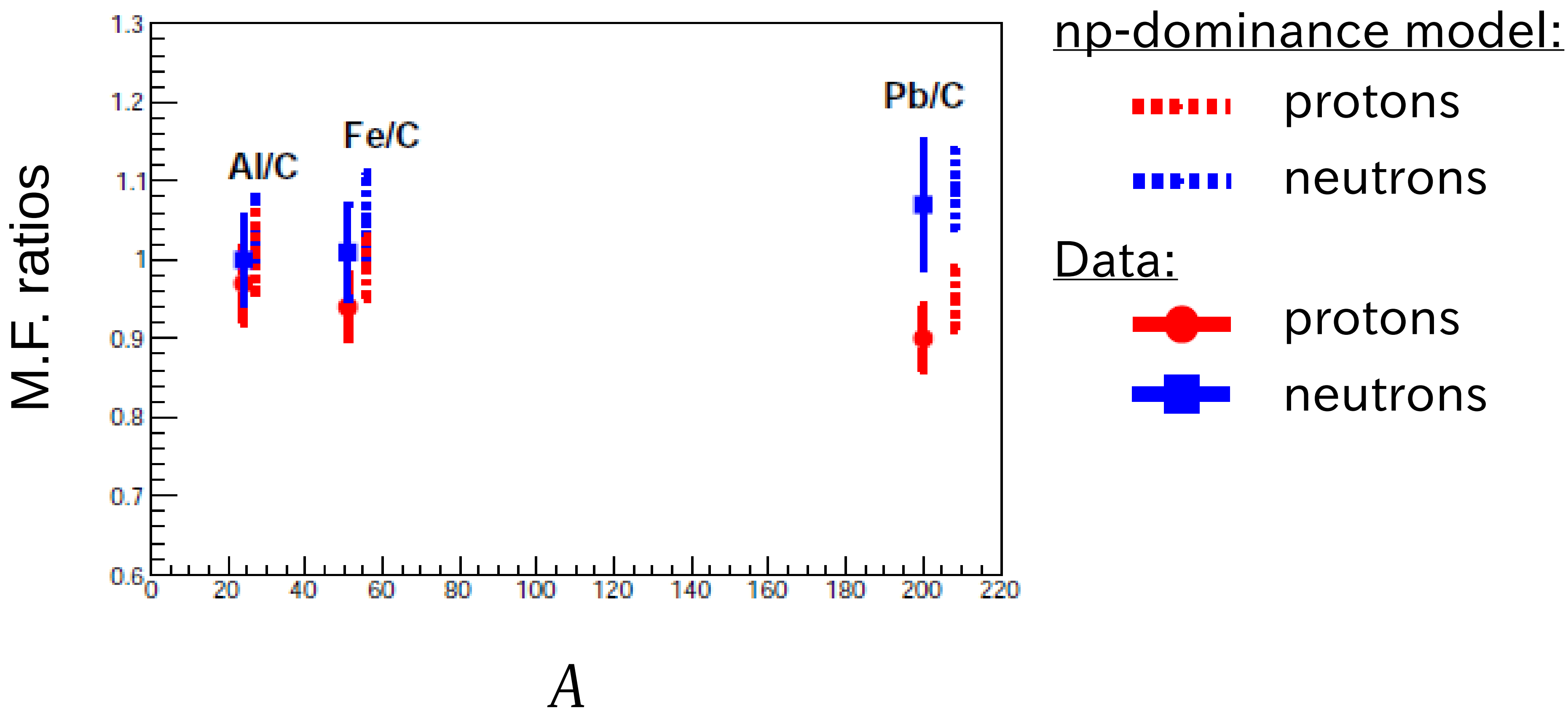
Uncertainties of the event selection

Cut	Cuts sensitivity				
	Range	**C**	**Al**	**Fe**	**Pb**
-0.05<y<0.25	±0.05	0.84%	0.83%	0.58%	0.81%
0.95<ω<1.7 GeV	±0.05 GeV	2.1%	1.9%	1.9%	1.7%
$\theta_{pq} < 8^o$	$\pm 1^o$	2.0%	1.8%	1.5%	1.4%
$1.3 < Q^2 < 3.5\, GeV^2/c^2$	$\pm 0.2\ GeV^2/c^2$	0.61%	0.39%	0.68%	0.35%
$P_{miss} < 0.3\, GeV/c$	±0.025 GeV/c	0.82%	0.49%	0.56%	0.38%
$E_{miss} < 0.24\, GeV$	±0.02 GeV	1.9%	2.2%	2.1%	2.1%
EC fiducial cut: 10 cm	30 cm	0.1%	0.11%	0.10%	0.09%

Contributions to the uncertainty

Nuclei	A(e,e'p)/A(e,e'n)	Statistics	Neutron Effic.	Simulation	Event selection
C	2.37±0.23	±0.15 (59%)	±0.07 (27%)	±0.031 (11%)	±0.19 (74%)
Al	2.36±0.26	±0.19 (73%)	±0.08 (29%)	±0.030 (11%)	±0.17 (62%)
Fe	2.48±0.24	±0.15 (62%)	±0.07 (29%)	±0.032 (12%)	±0.18 (75%)
Pb	2.21±0.24	±0.18 (75%)	±0.09 (37%)	±0.034 (12%)	±0.13 (54%)

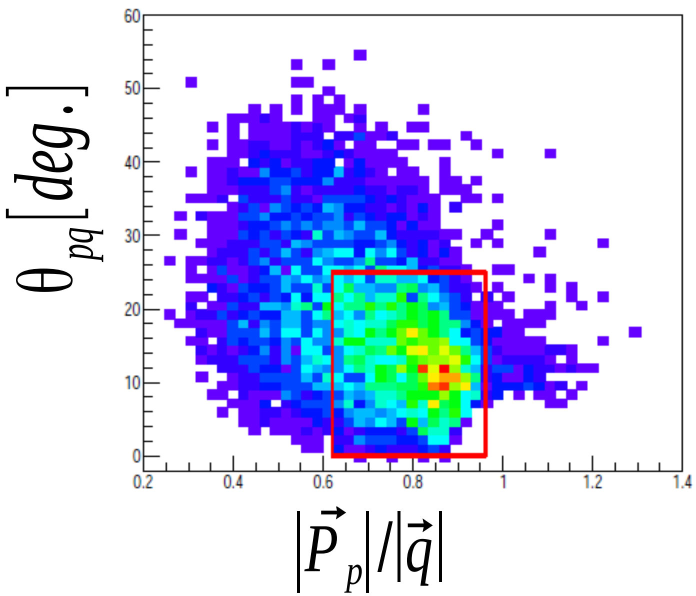
Protons and neutrons M.F ratios



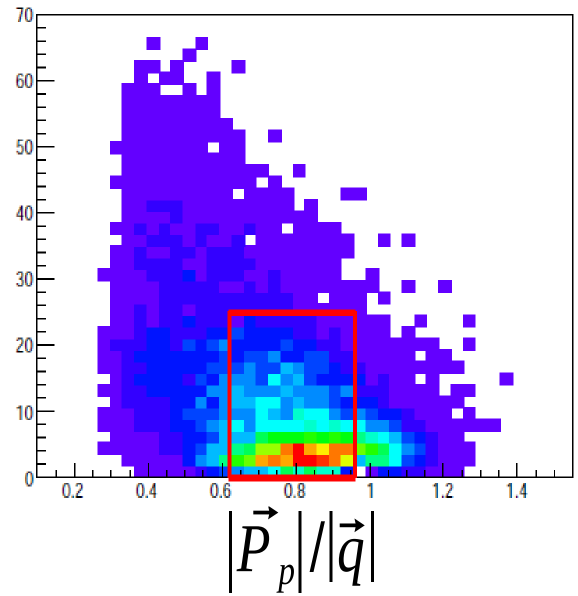
Corrected for transparency and normalized by Z (N).

Identifying the Leading Nucleon

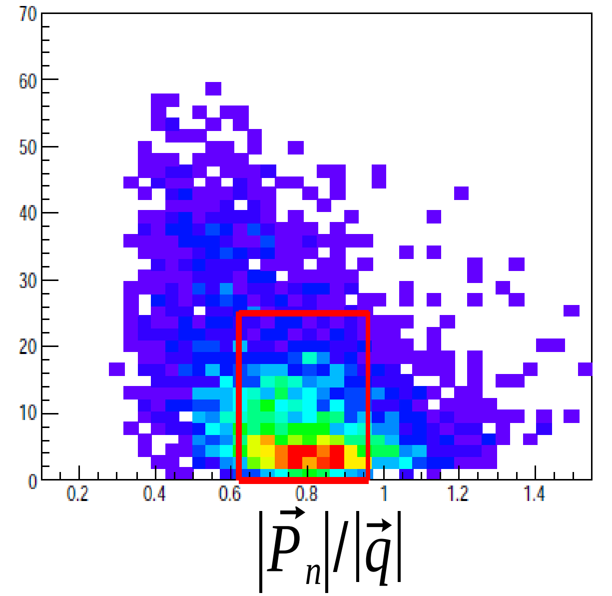
un-smeared protons



smeared protons



neutrons



We adopted the cuts (O. Hen 2012):

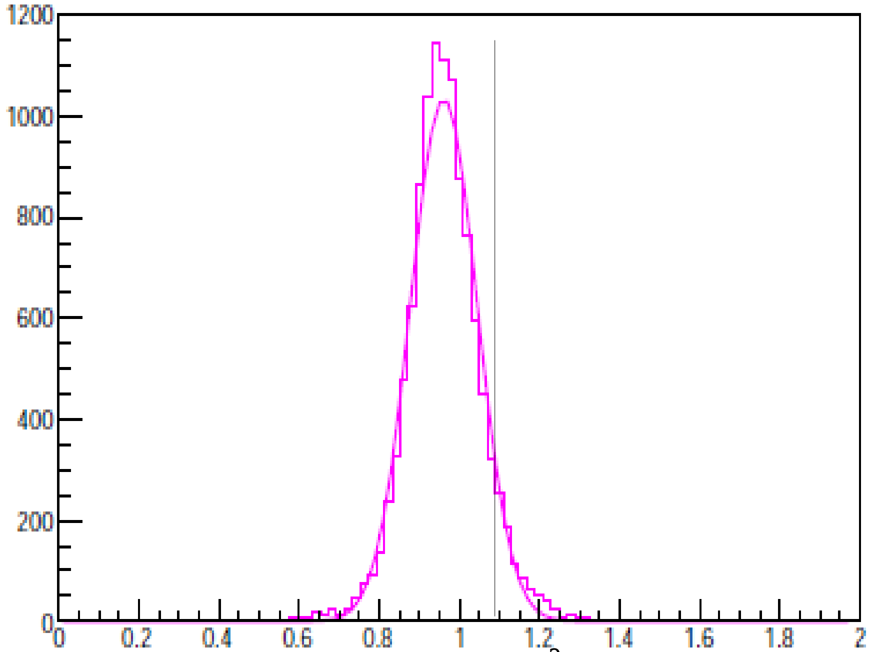
$$0.62 \le \frac{|\vec{P}_N|}{|\vec{q}|} \le 0.96 \qquad \theta_{pq} \le 25^o$$

Missing Mass cut

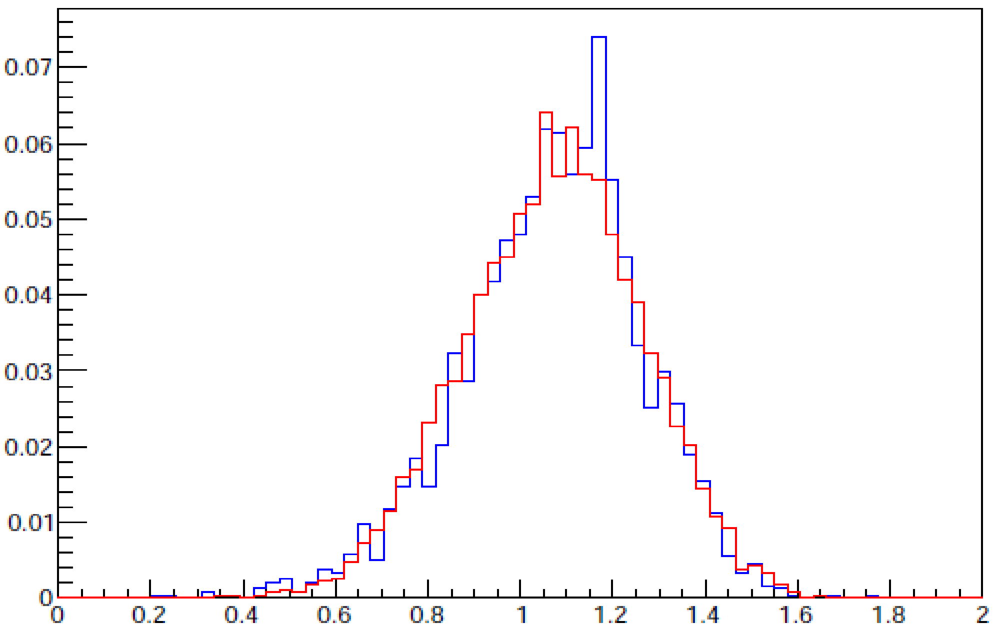
$$M_{miss}^2 = \left(\bar{q} + 2m_N - \overline{P_{lead}}\right)^2$$

un-smeared protons

smeared protons neutrons



$M_{miss}\,[GeV/c^2]$



$M_{miss}\,[GeV/c^2]$

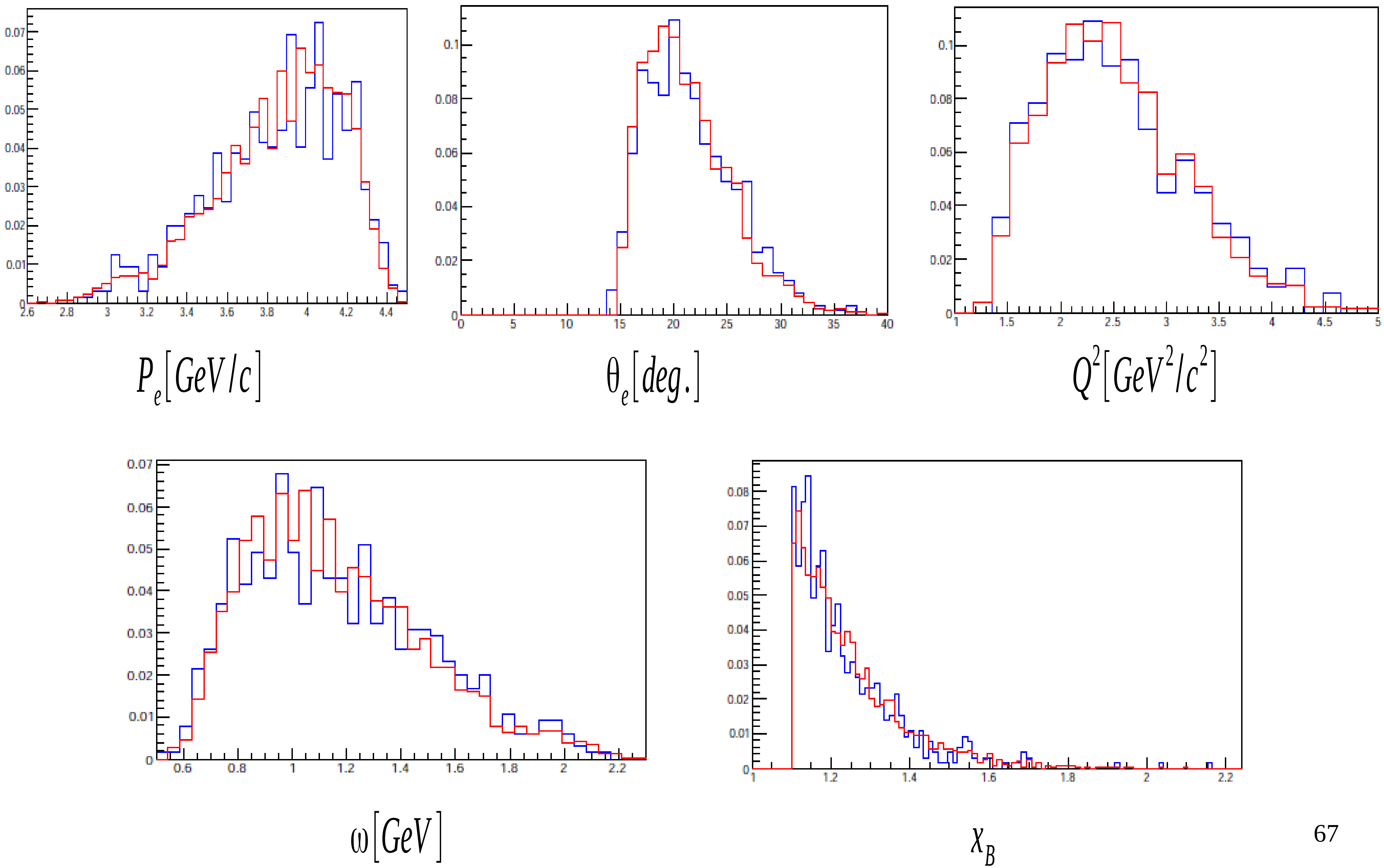
$$M_{miss} \le mean + m_\pi = 1.1\,GeV/c^2$$

$$M_{miss} < ?$$

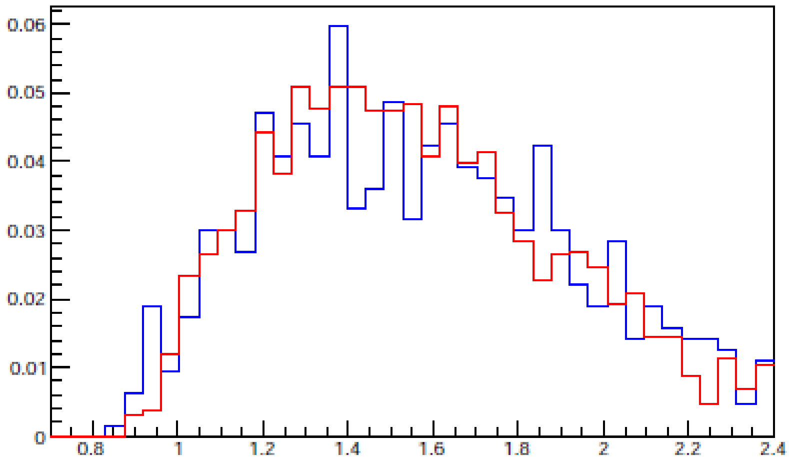
The selected events:

This analysis (smeared protons & neutrons)	Proton analysis (O. Hen et al.)
$x_B > 1.1$	$x_B > 1.2$
$0.62 < p/q < 0.96$	$0.62 < p/q < 0.96$
$\theta_{pq} < 25^o$	$\theta_{pq} < 25^o$
$M_{miss} < 1.2\,GeV/c^2$ $0.4 < P_{miss} < 1\,GeV/c$	$M_{miss} < 1.1\,GeV/c^2$ $0.3 < P_{miss} < 1\,GeV/c$

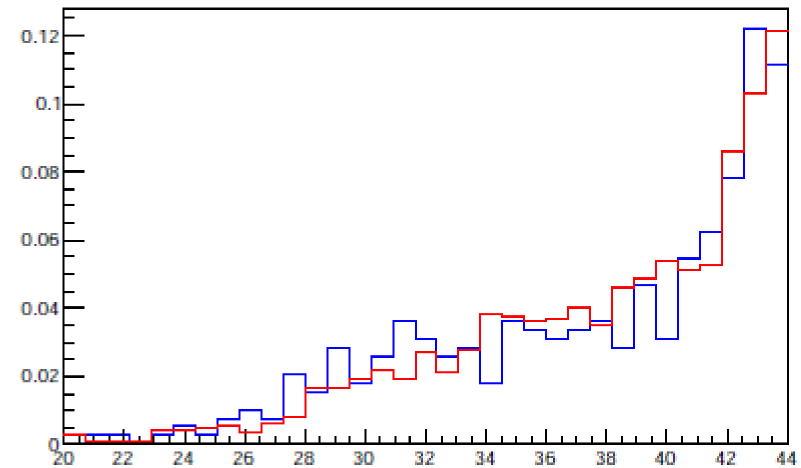
Comparing smeared protons & neutrons distributions:



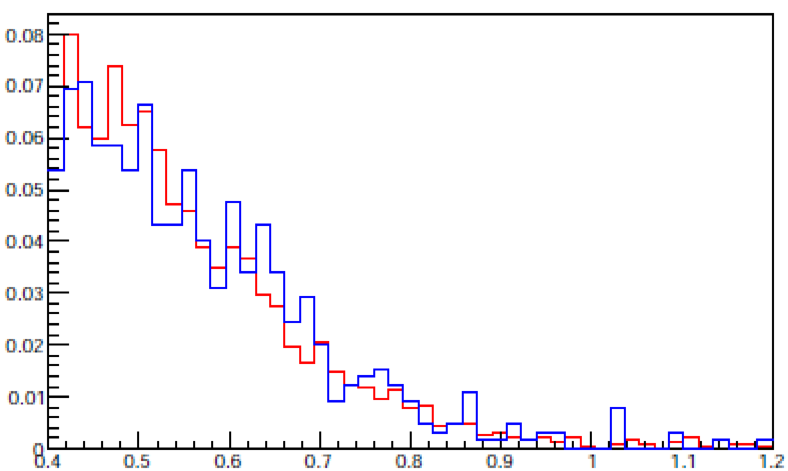
Comparing smeared protons & neutrons distributions:



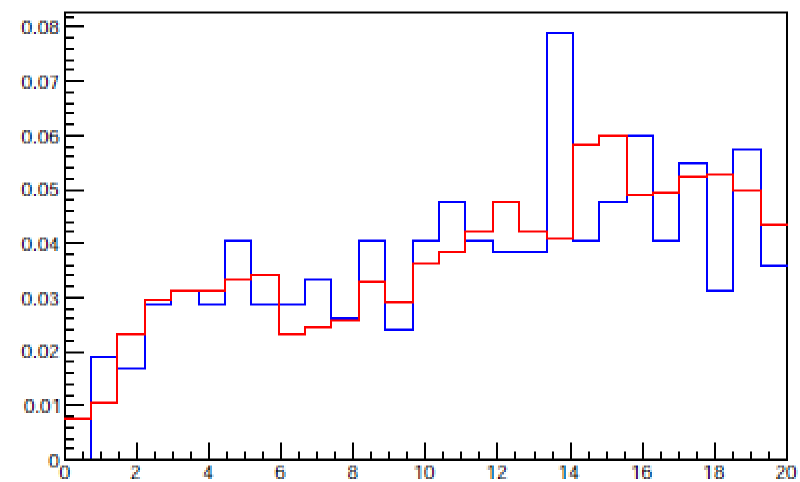
$P_{p/n}[GeV/c]$



$\theta_{p/n}[deg.]$

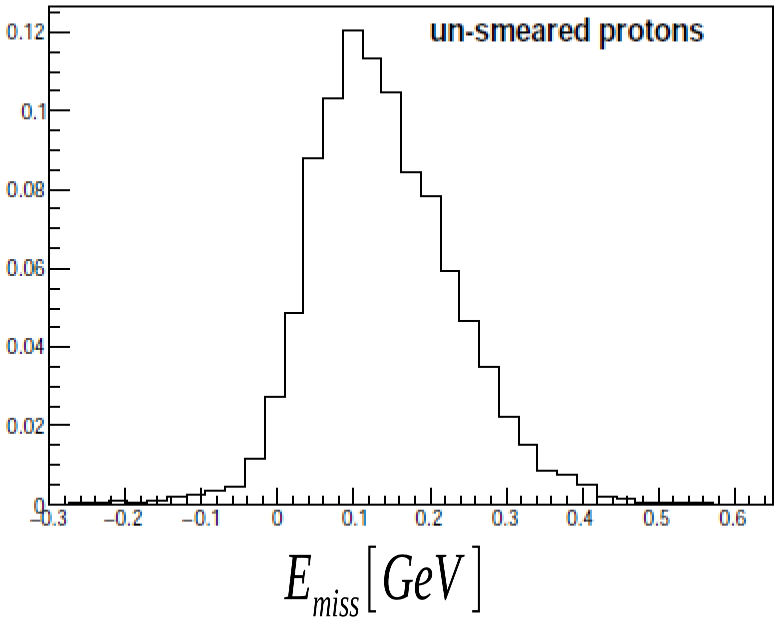


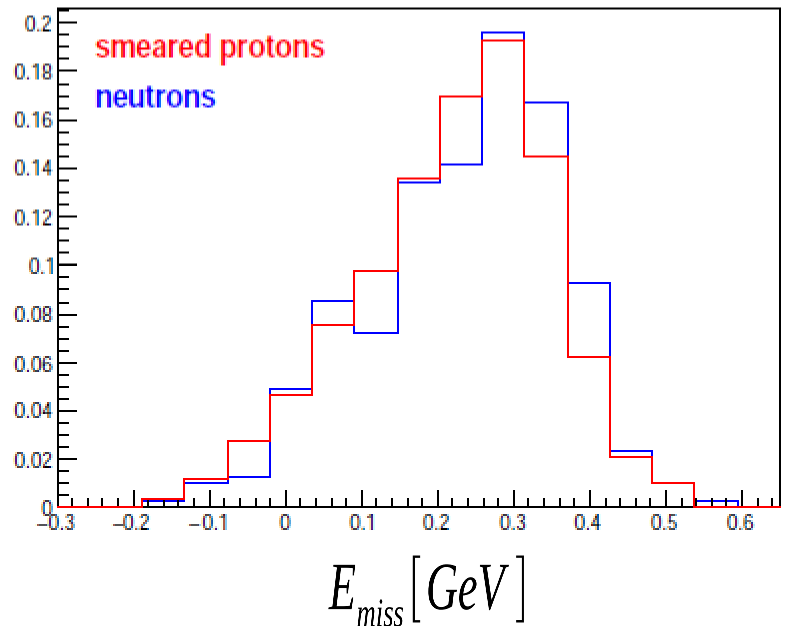
$P_{miss}[GeV/c]$

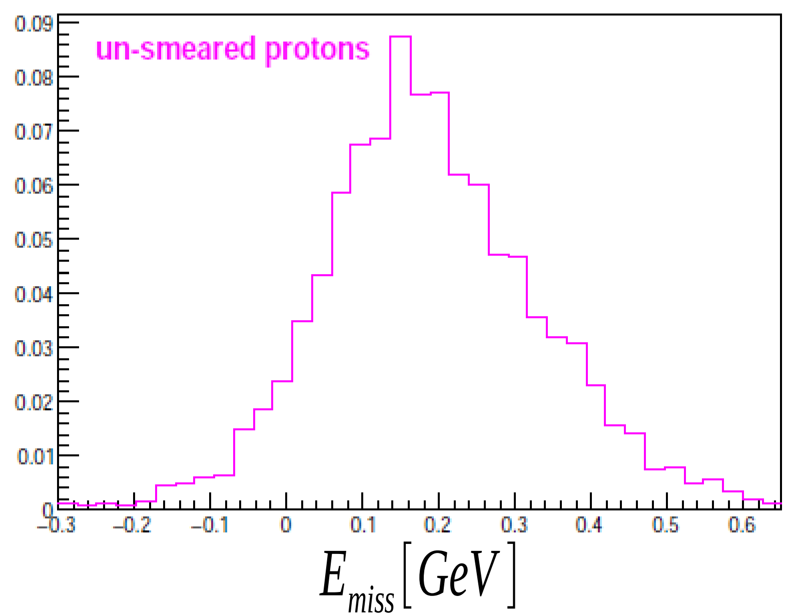


$\theta_{pq/nq}[deg.]$

Missing energy distribution







A(e,e'p)/C(e,e'p) ratios

(for smeared protons)

Corrections:

1. Normalization: target density & beam charge (FC)

	C	Al	Fe	Pb
Beam charge	3581.8	2719.4	5632.3	5079.6
Thickness [g/cm^2]	0.3	0.156	0.315	0.159

2. Radiative correction

3. False positive & negative probabilities

	C	Al	Fe	Pb
False positive [%]	15.1	14.5	15.0	14.2
False negative [%]	14.9	14.7	14.8	14.6

Radiative Correction

Done using Misak code (CLAS NOTE 90-007) for inclusive (e,e') processes

Input file:

```
INCIDENT    ELECTRON     5.014   0.000   0.000   0.000   0.000   3.000
TARGET      PB         208.000  82.000   0.260  25.000   0.025   0.010
RAD_EFFECT  YES          0.14   0.020   0.010   0.010   0.050   0.010

SWELLING    V2           0.000   0.200   0.000   0.000   0.000   0.000
EMC         NES          0.000   0.000   0.000   0.000   0.000   0.000

ELEC_SPECT               0.000   0.000   0.000   0.000   0.000   0.000
Ee` -RANGE  NES          2.710   3.430   0.015   0.000   0.000   0.000
THe -RANGE               0.000   0.000   0.000  22.500   0.000   0.000
Q0  -RANGE  NES          0.830   0.840   0.010   0.000   0.000   0.000
W   -RANGE  NO           0.900   0.910   0.025   0.000   0.000   0.000
X   -RANGE  YES          1.10    1.78   0.025   0.000   0.000   0.000

INTEGRATION              0.000   0.001   0.001   0.001   0.000 200.000
```

Output file:

$\theta_e[deg.]$	$E'[GeV]$	σ	σ_R	σ_R/σ	x_B
13.5000000	4.42063046	4.43465996	3.27398014	0.738270819	1.10000038
13.5000000	4.43228626	4.22524166	3.08815813	0.730883181	1.12499964
13.5000000	4.44349337	3.98750830	2.88599110	0.723758042	1.14999974
13.5000000	4.45427656	3.72525787	2.67181277	0.717215538	1.17499924
13.5000000	4.46466017	3.43619990	2.44445562	0.711383402	1.19999981
13.5000000	4.47466516	3.12433052	2.20719647	0.706454217	1.22499967
13.5000000	4.48431253	2.80245376	1.96815252	0.702296138	1.25000024
13.5000000	4.49362087	2.47654080	1.73224092	0.699459851	1.27500081
13.5000000	4.50260735	2.16126084	1.50825989	0.697861135	1.30000043
13.5000000	4.51128817	1.86491084	1.30000114	0.697084904	1.32499838
13.5000000	4.51968002	1.59822047	1.11500192	0.697652161	1.34999883
13.5000000	4.52779675	1.36697018	0.955449700	0.698954284	1.37500083
13.5000000	4.53565025	1.17481065	0.823031425	0.700565159	1.39999974
13.5000000	4.54325438	1.02072394	0.716113329	0.701573968	1.42499936
13.5000000	4.55062103	0.903844237	0.633903861	0.701341927	1.45000100
13.5000000	4.55775976	0.818772256	0.572003424	0.698611140	1.47499907
13.5000000	4.56468248	0.759974122	0.527037442	0.693493903	1.49999964
13.5000000	4.57139826	0.721946955	0.496739984	0.688056052	1.52500010
13.5000000	4.57791615	0.687721431	0.469726115	0.683017969	1.55000007
13.5000000	4.58424473	0.595497608	0.406235248	0.682177782	1.57499981
13.5000000	4.59039259	0.522537053	0.355940789	0.681178093	1.60000086
13.5000000	4.59636641	0.463264525	0.314598382	0.679090142	1.62499917
13.5000000	4.60217428	0.413414866	0.279868931	0.676968694	1.64999843
13.5000000	4.60782337	0.370711714	0.249916166	0.674152315	1.67500007
13.5000000	4.61331940	0.333176047	0.223424718	0.670590580	1.70000076
13.5000000	4.61866808	0.299870700	0.200065240	0.667171657	1.72499883
13.5000000	4.62387705	0.269912452	0.178801313	0.662441909	1.75000262

For each target 34 files: $13.5<\theta_e<30[deg.]$

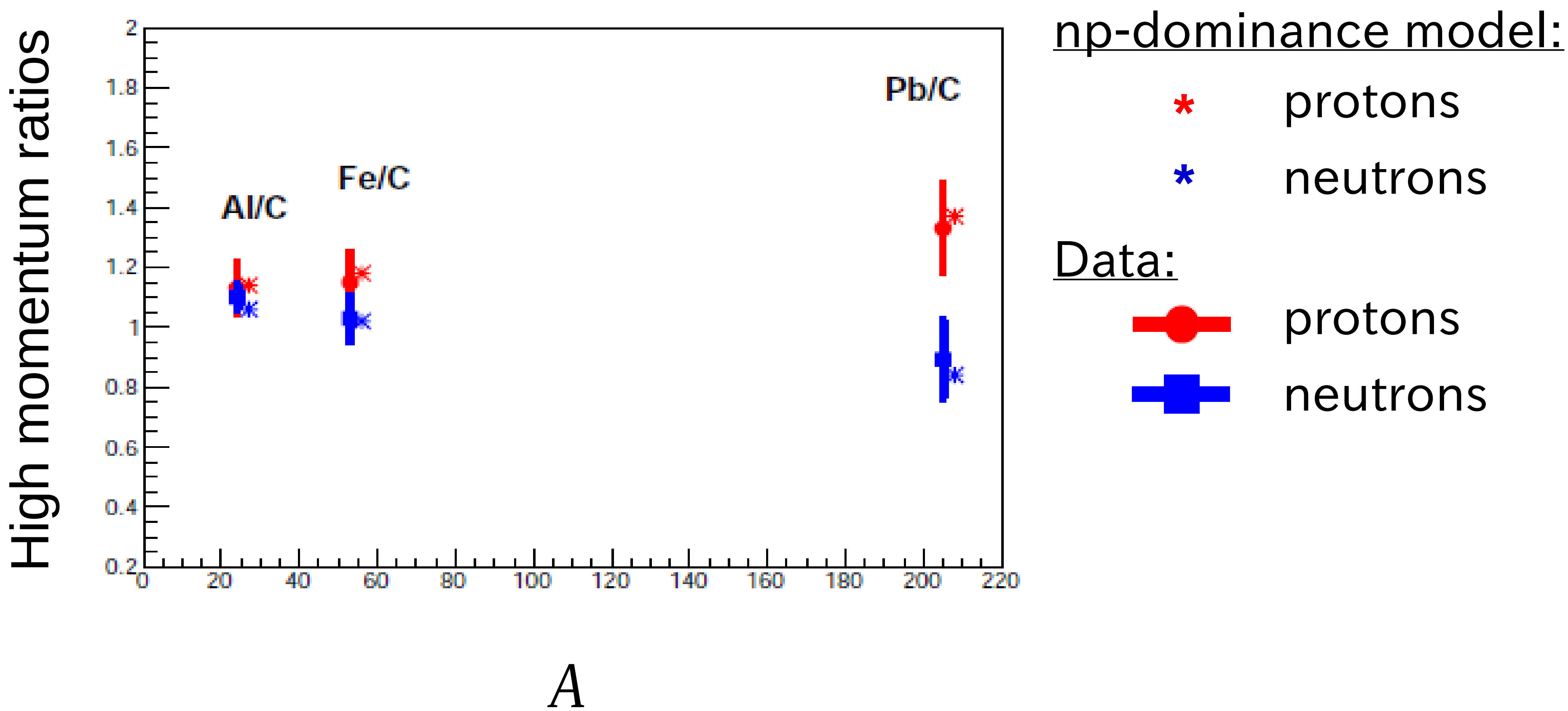
Final correction:

Nuclei	C	Al	Fe	Pb
Correction factor	0.776	0.785	0.729	0.724

Contributions for the uncertainty

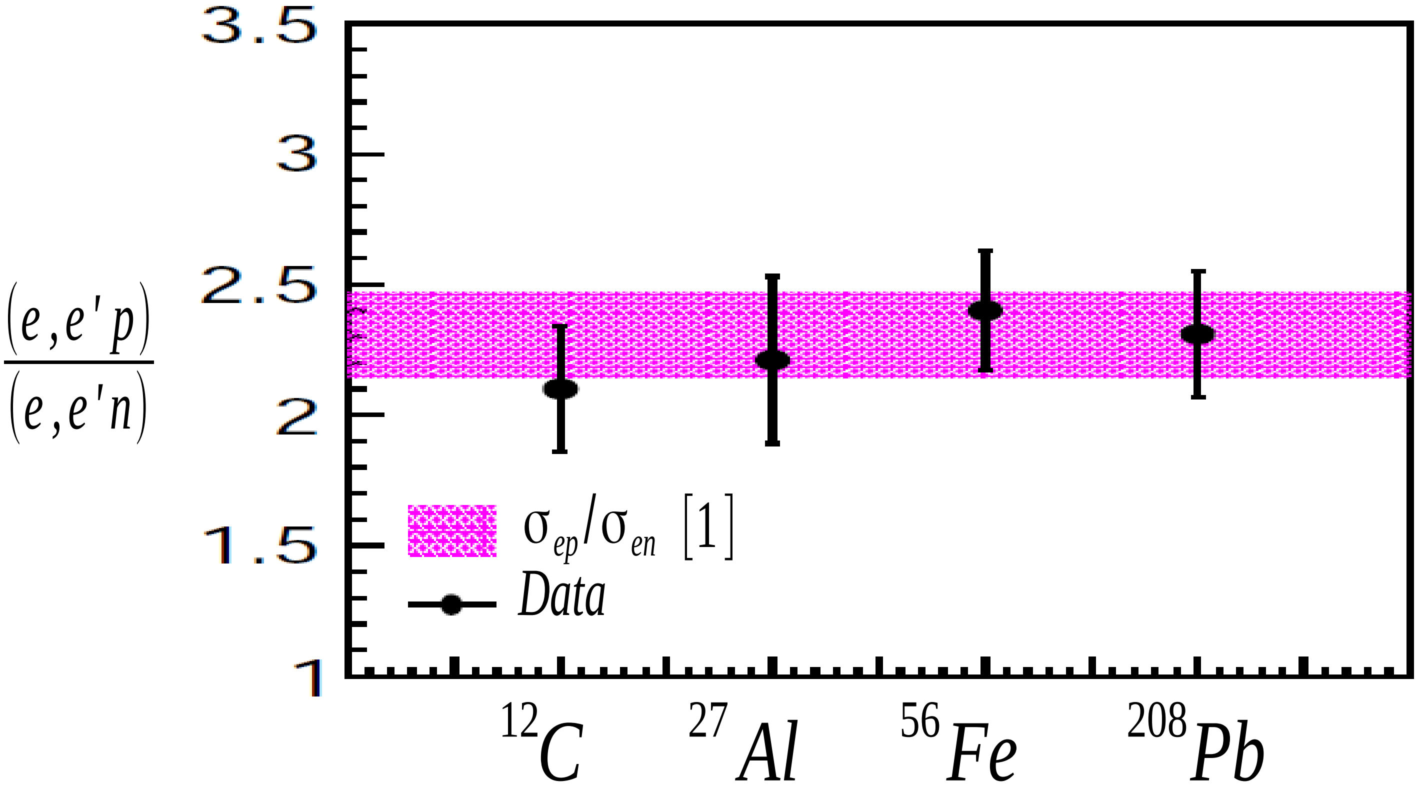
	Al/C	**Fe/C**	**Pb/C**
σ_A / σ_C	2.0±0.1	3.2±0.3	7.6±0.8
Event selection	±0.13 (92%)	±0.25 (80%)	±0.75 (93%)
False positive & negative	±0.02 (14%)	±0.03 (10%)	±0.08 (10%)
Statistics	±0.08 (57%)	±0.06 (20%)	±0.15 (19%)

Protons and neutrons high momentum ratios



Corrected for transparency and normalized by Z (N)

A(e,e'p)/A(e,e'n) SRC ratios



Not normalized by Z/N!

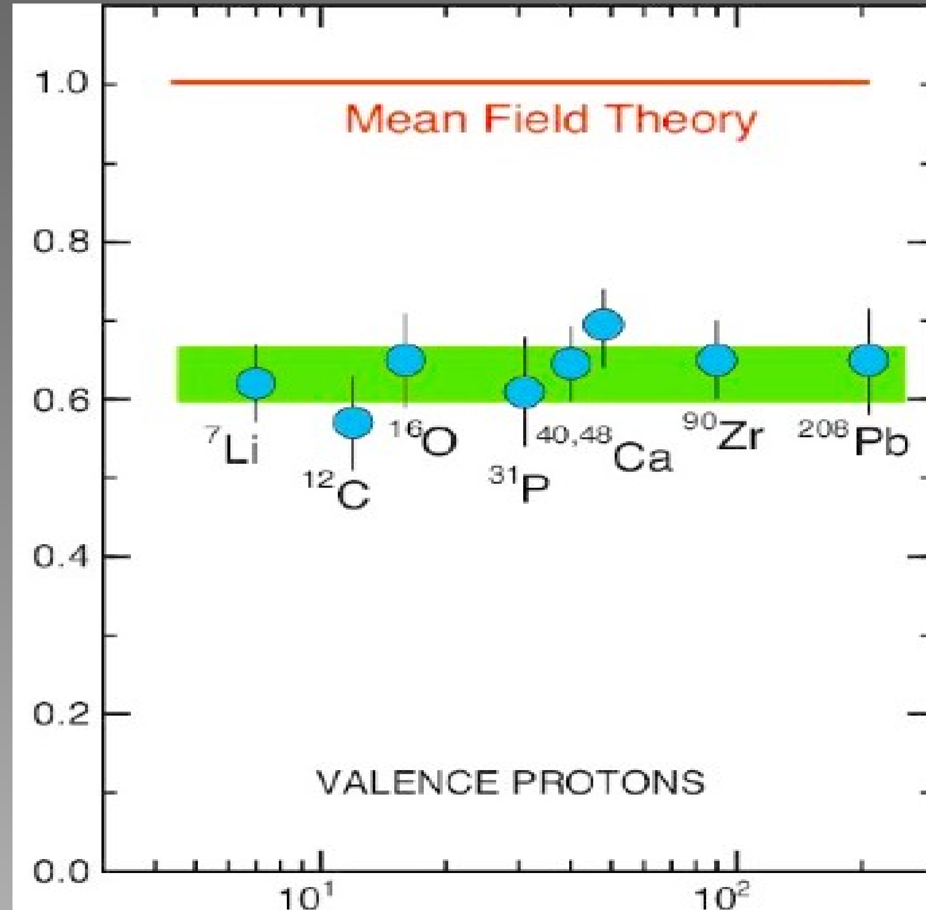
Corrections:

Acceptance correction & detection efficiency (different for p/n), transparency

[1] W. P. Ford, S. Jeschonnek & J. W. Van Orden, arXiv:1411.3306v1 [nucl-th] (2014)

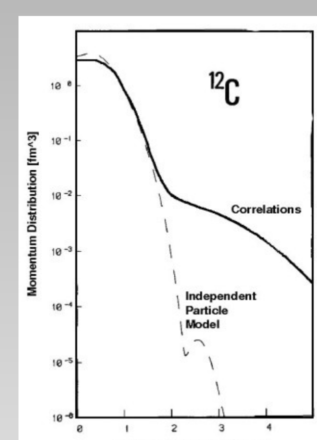
Spectroscopic factors for (e, e'p) reactions

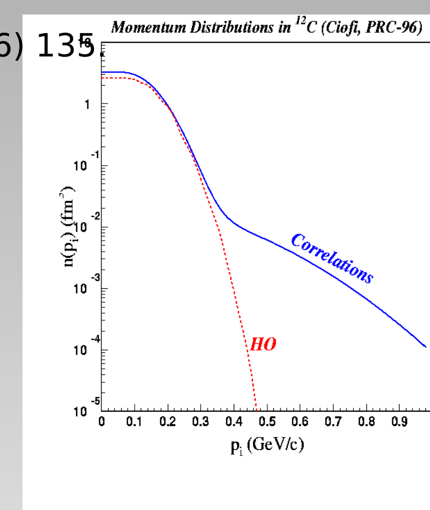
show only 60-70% of the expected single-particle strength.



L. Lapikas, Nucl. Phys. A553, 297c (1993)

Benhar et al., Phys. Lett. **B** 177 (1986) 135.

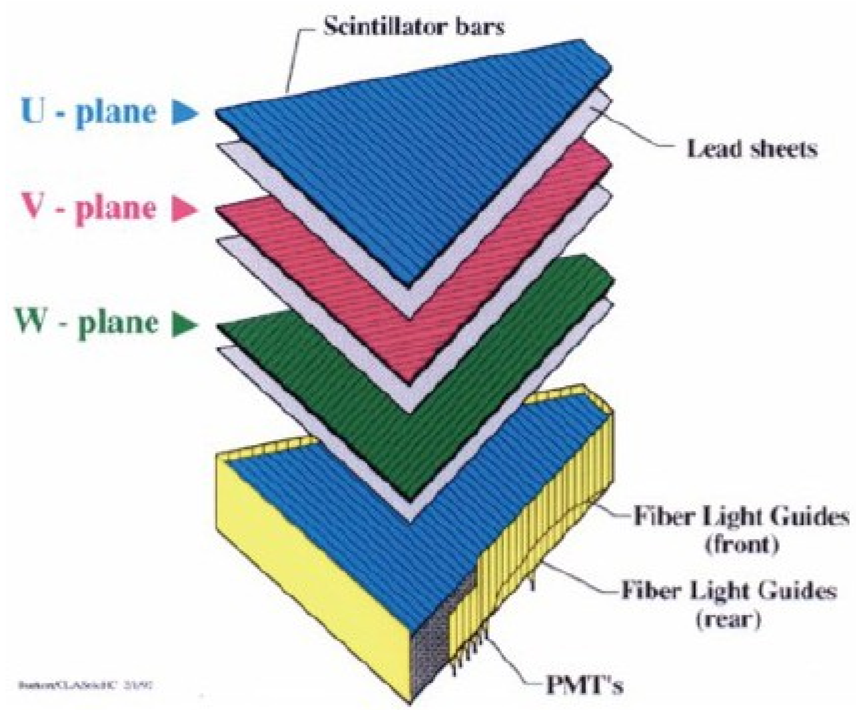




MISSING :

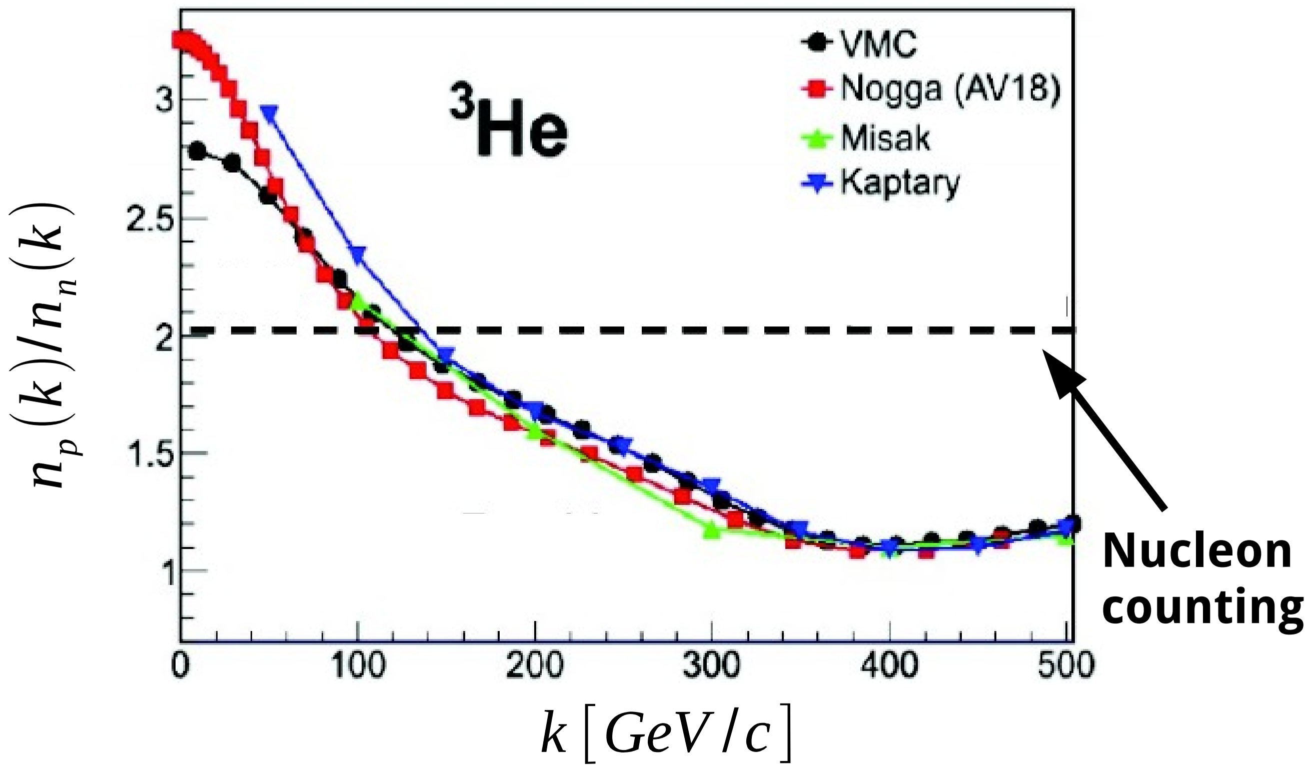
Correlations Between Nucleons

SRC $\sim R_N$ LRC $\sim R_A$

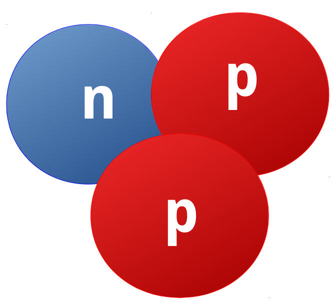

Scintillator bars
U - plane
Lead sheets
V - plane
W - plane
Fiber Light Guides
(front)
Fiber Light Guides
(rear)
PMT's

Future Experiments

Momentum distribution in A=3 asymmetric nuclei



^{3}He



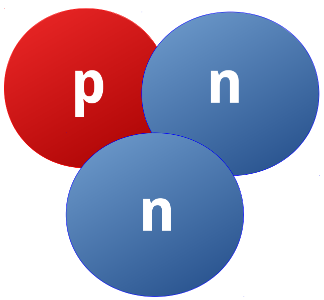
Measure ^{3}He(e,e'p)/^{3}He(e,e'n) ratio

↓

Low accuracy due to the neutron measurement

Approved experiment at Jlab Hall-A
(E12-14-011)

^{3}H

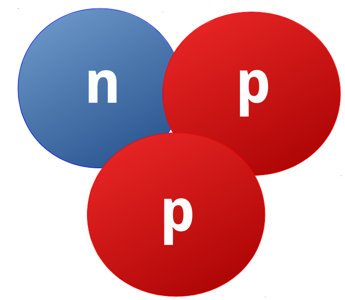


Mirror nulcei

$\Longleftrightarrow$

p in ³H = n in ³He

^{3}He



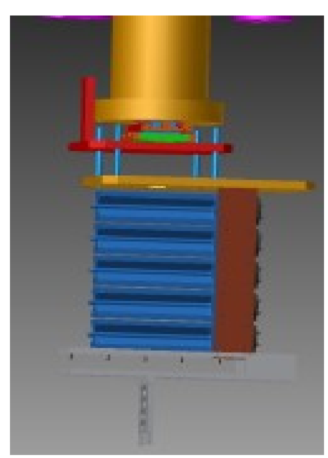
Measure $^{3}He(e,e'p)/^{3}H(e,e'p)$ ratio

$$E_{beam} = 4.4\ GeV$$

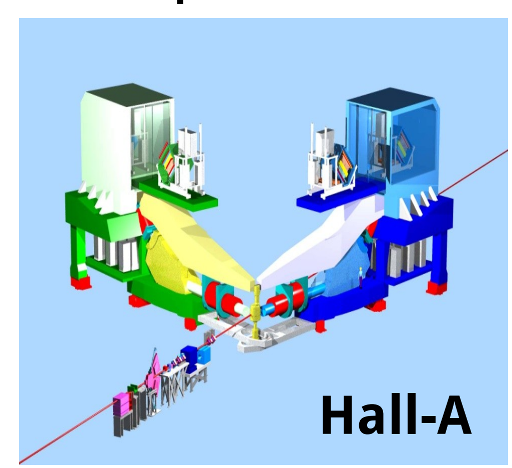
$$Q^2 = 2\ GeV^2/c^2$$

$$x_B > 1$$

MARATHON target

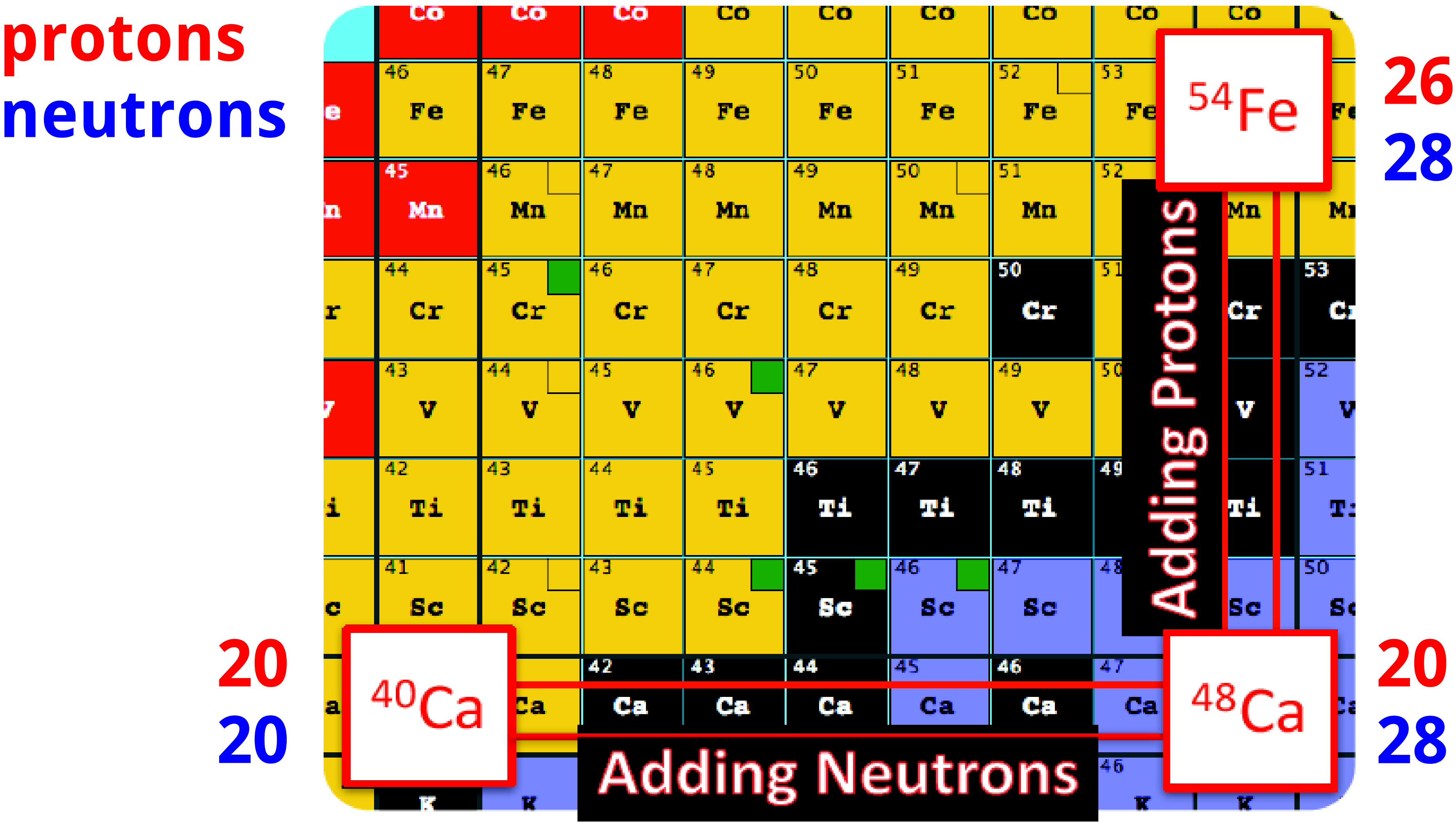


HRS Spectromter



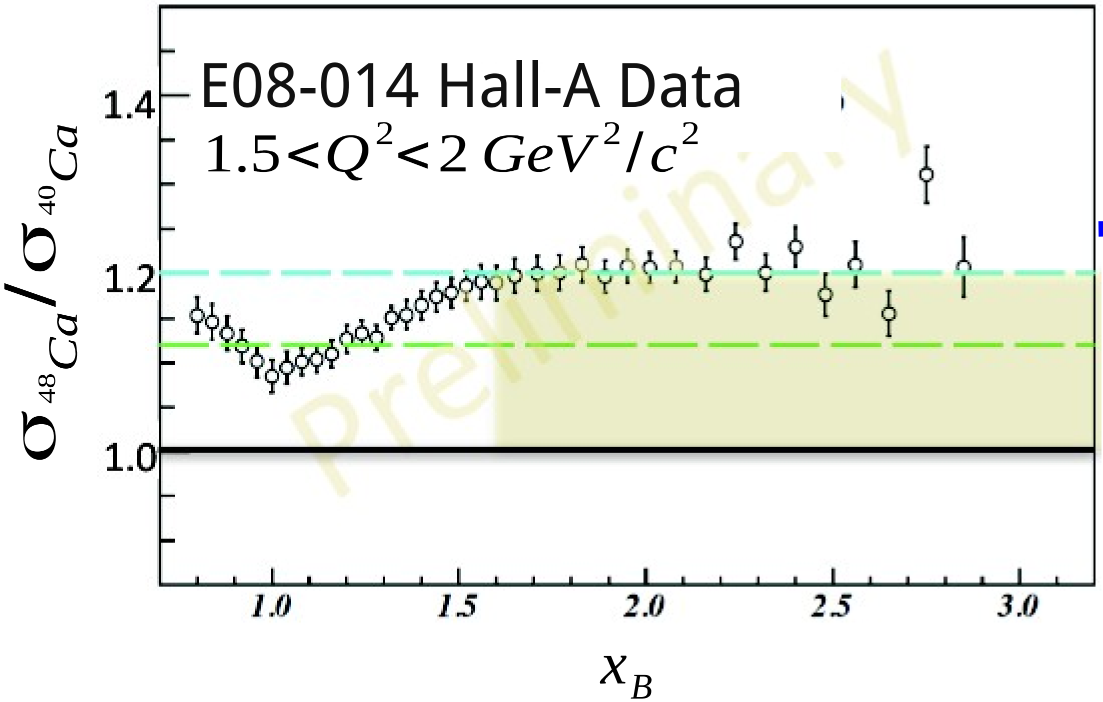
CaFe Experiment

Proposed for JLab Hall-C



What do we already know?

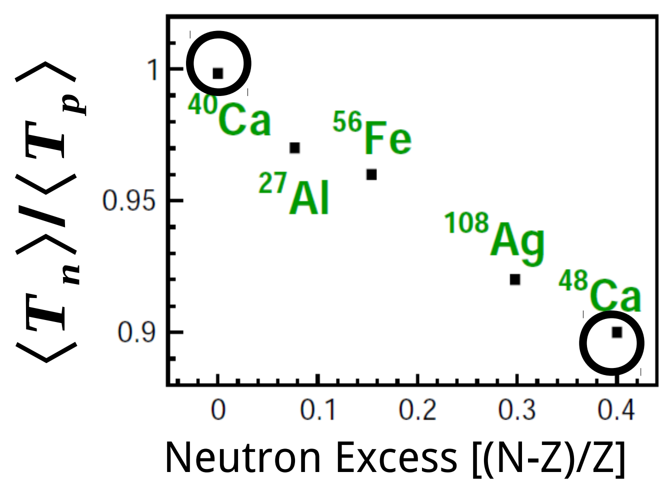
(e,e') cross-section ratios at x_B>1 are sensitive to the total number of SRC pairs



Z. Ye Ph.D. Thesis, UVA. ArXiv: 1408.5861 (2014)

^{48}Ca:
+ 20% nucleons,
+20% SRC pairs!

The (e,e') reaction can not distinguish protons and neutrons → need (e,e'p)



Ryckebusch, Vanhalst & Cosyn, arXiv:1405.3814v3 [nucl-th] (2015).

The observable

(e,e'p) cross-section Ratios for:

$$\frac{A_1(e,e'p)\,SRC/Mean-Field}{A_2(e,e'p)\,SRC/Mean-Field}$$

$$A={}^{40}Ca,{}^{48}Ca,{}^{54}Fe$$

will tell us about pairing of external nucleons with the ^{40}Ca core.

Kinematics:

$$E_{beam}=11\ GeV$$

$$Q^2\sim 3.5\ GeV^2/c^2$$

$$x_B>1.2$$