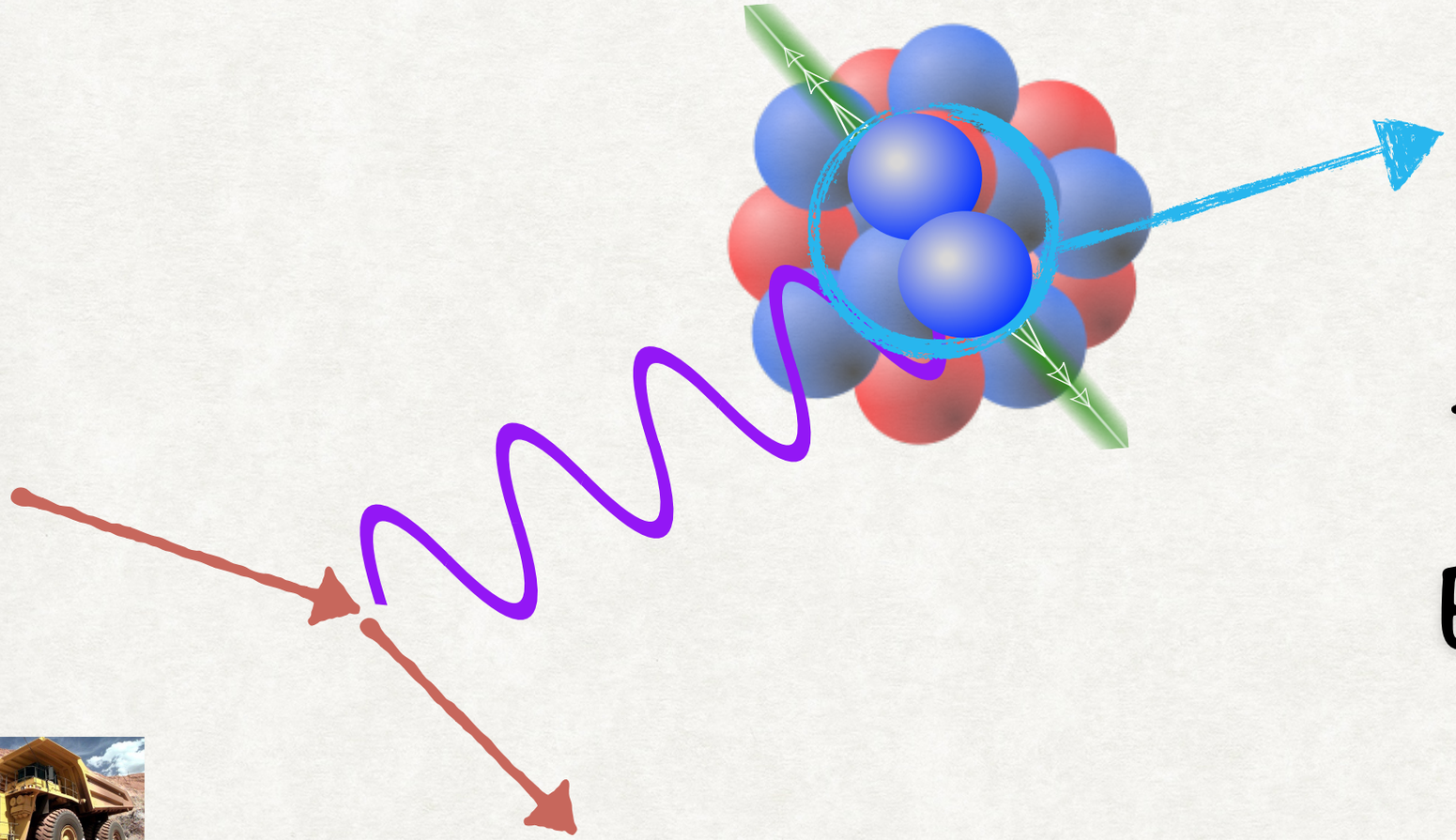
3/8/18

2N-SRC c.m. momentum distribution extracted from A(e,e'pp)



Erez. O. Cohen

Tel Aviv University

E. Piasetzky group

EG2 data-mining

CLAS col. meeting, March 2018

Outline

- Introduction and Motivation.
- data analysis of **pp-SRC @ CLAS** (EG-2 data).
- **Results.**

Introduction

and

Motivation

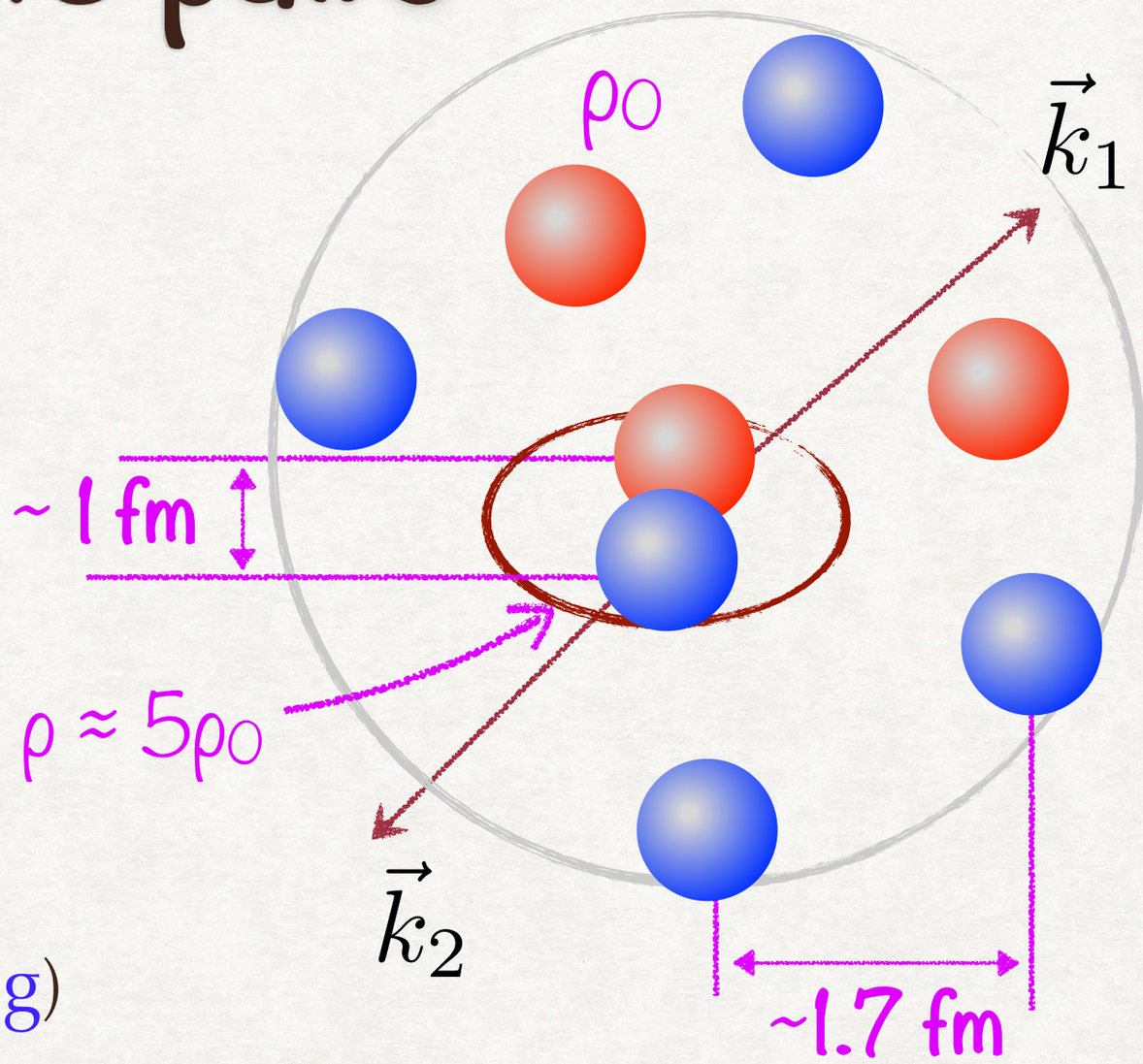
2N-SRC pairs

- Large relative & Small c.m. momentum (w.r.t Fermi).

$$|\vec{K}_{c.m.}| = |\vec{k}_1 + \vec{k}_2| < k_F$$

$$|\vec{k}_{rel}| = \left|\frac{1}{2}(\vec{k}_1 - \vec{k}_2)\right| > k_F$$

$$k_1, k_2 > k_F$$

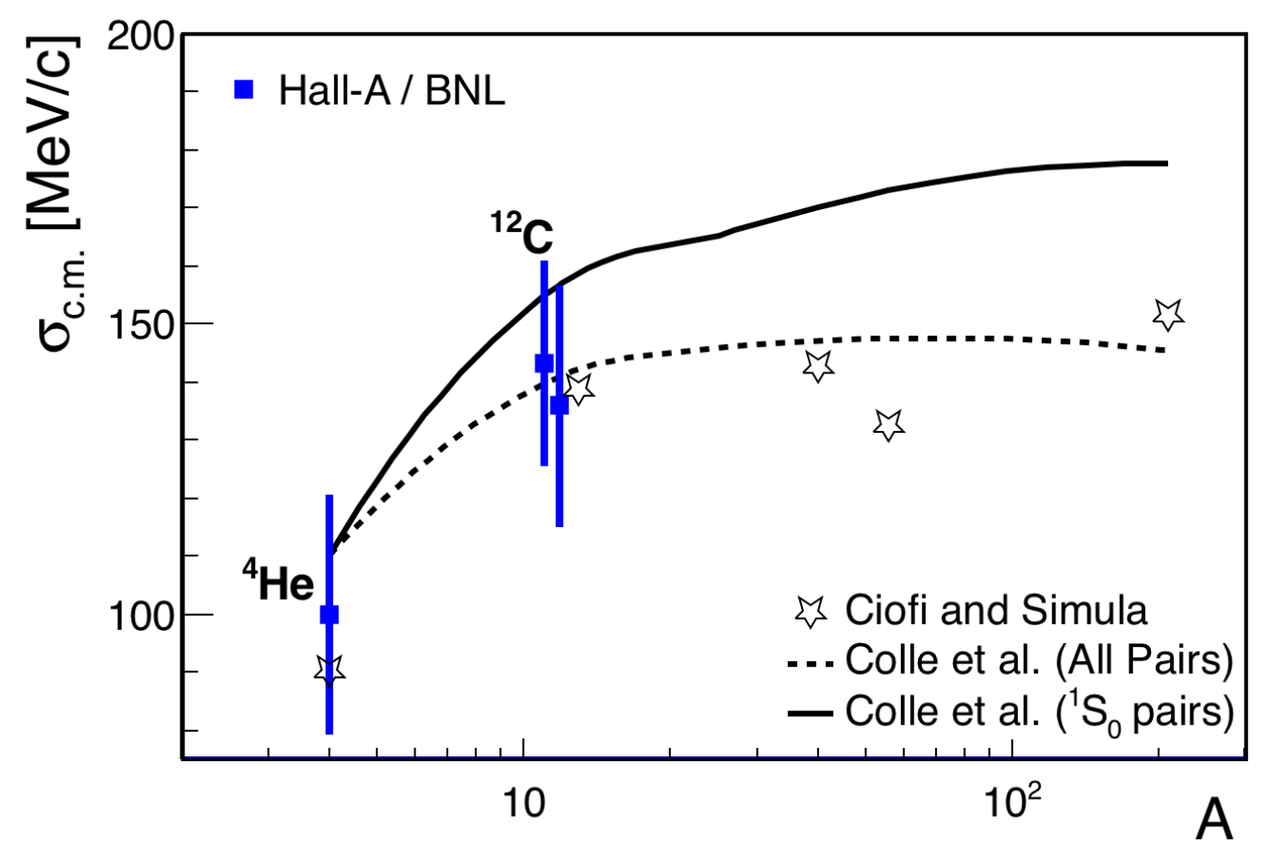


- High momentum part has the same shape for all nuclei (Scaling)

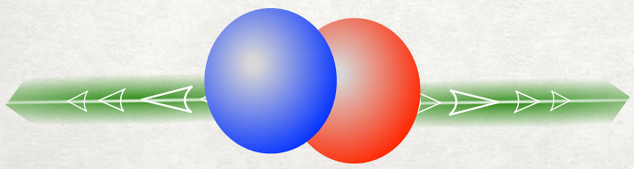
$$\psi_{2N}^{SRC}(\vec{k}_{rel}, \vec{K}_{c.m.}) \rightarrow \sum_{\alpha} \varphi_{2N}(\vec{k}_{rel}) \cdot A_{2N}(\vec{K}_{c.m.}, \{k_\alpha\}_{\alpha \neq 2N})$$

(Factorization) [R. Weiss et al. arXiv:1612.00923]

2N-SRC c.m. momentum



[Korover et al., PRL 113,022501(2014)]
[Shneor et al., PRL 99, 072501 (2007)]
[Tang et al., PRL 90 ,042301 (2003)]
[Colle et al. PhysRevC.89.024603]
[Ciofi, Simula, PRC53, 1689 (1996)]

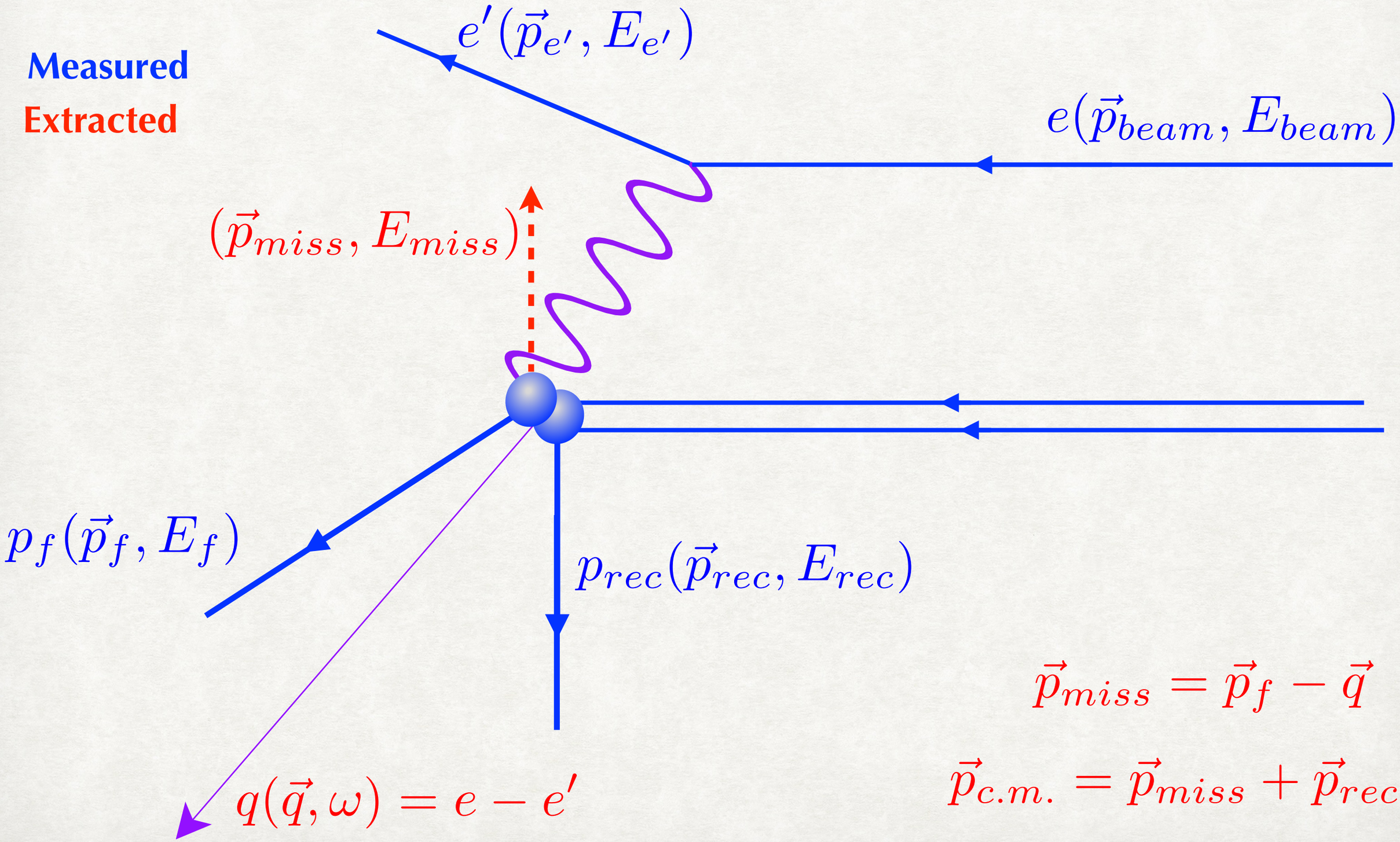


- Following Ciofi&Simula, we assume **3D Gaussian** motion of the correlated pair, and try to extract its parameters.
- **Important feature** of a SRC pair.
- Width sensitive to **pair quantum numbers**.

How do we extract p_{cm} from data

Measured

Extracted



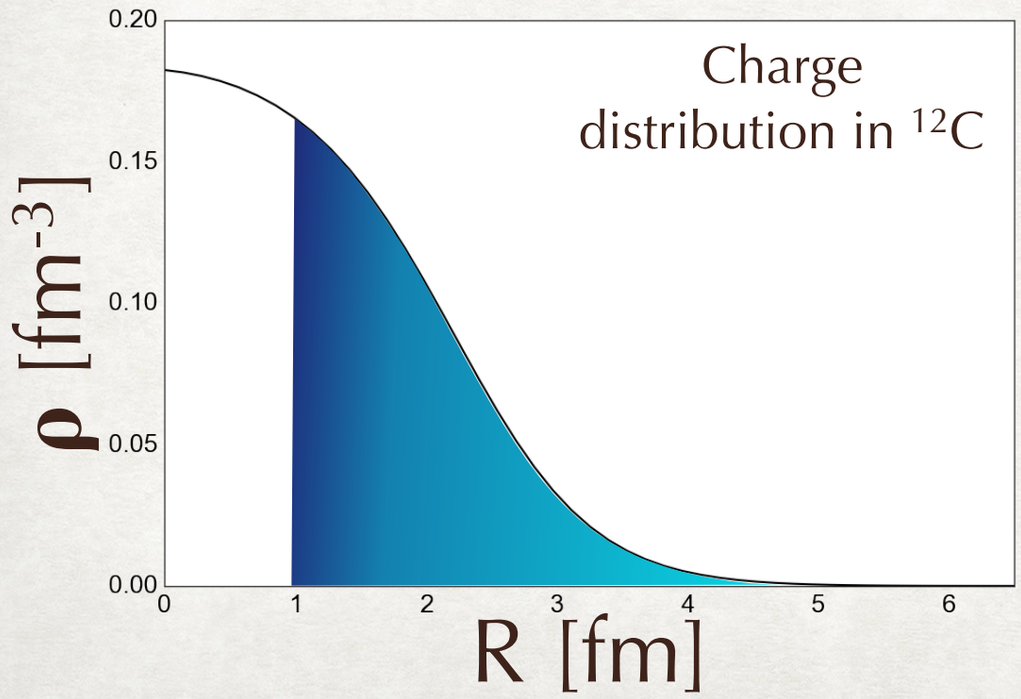
$$\vec{p}_{miss} = \vec{p}_f - \vec{q}$$

$$\vec{p}_{c.m.} = \vec{p}_{miss} + \vec{p}_{rec}$$

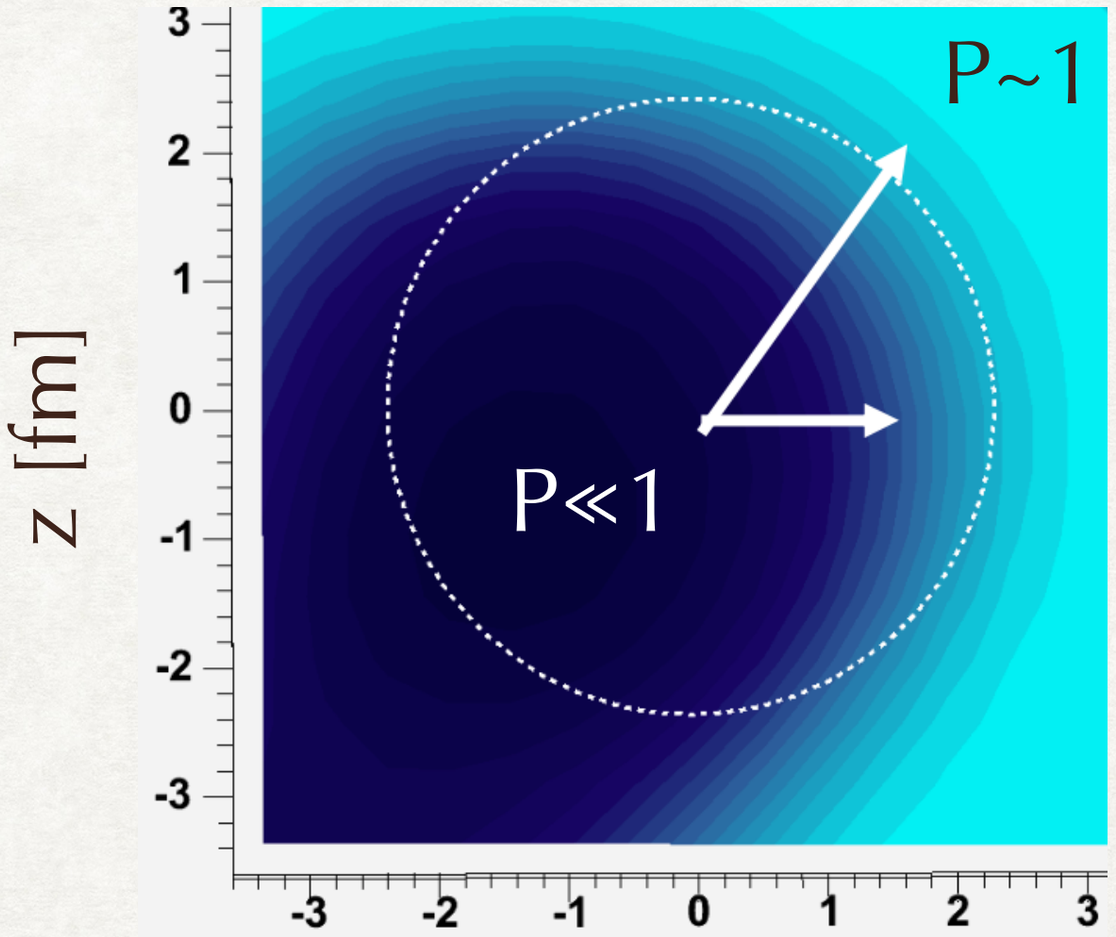
Where do our pp-pairs come from?

The effective density probed in (e,e'pp).

The combined transparency for the two protons as a function of the interaction point in the nucleus.



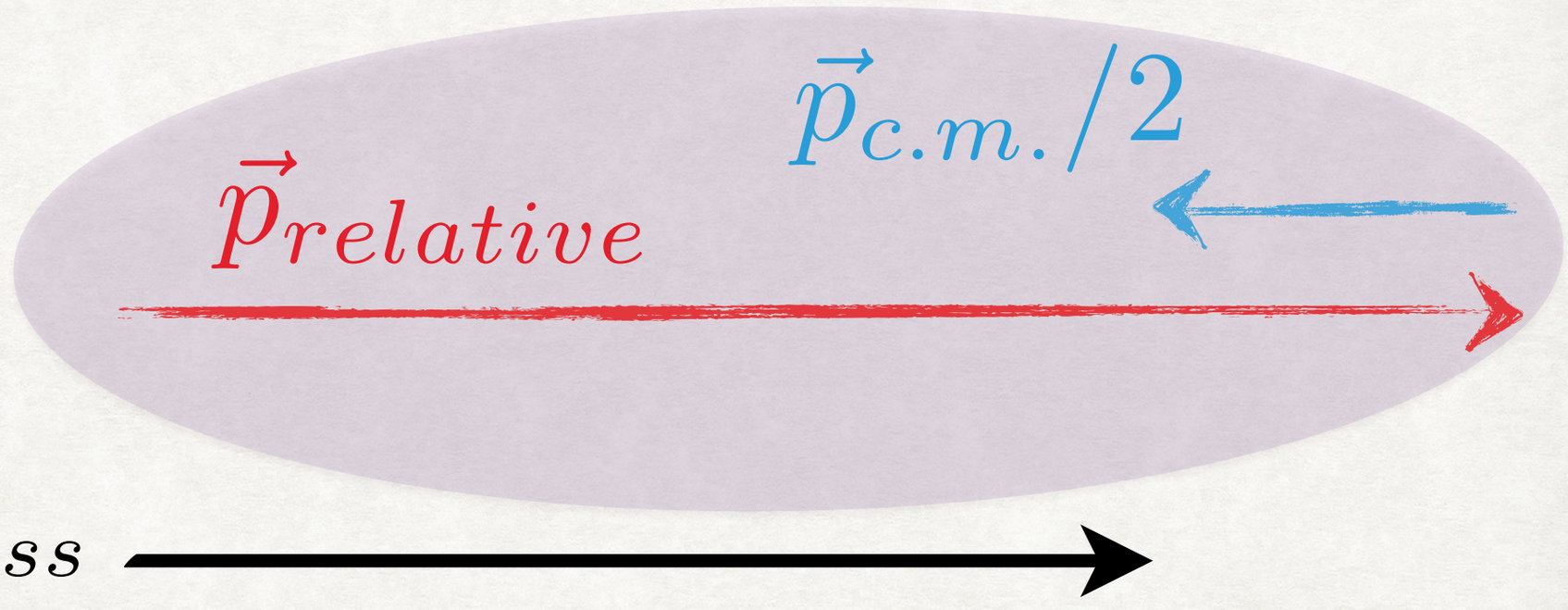
Ran Shneor, PhD Thesis, Tel Aviv U



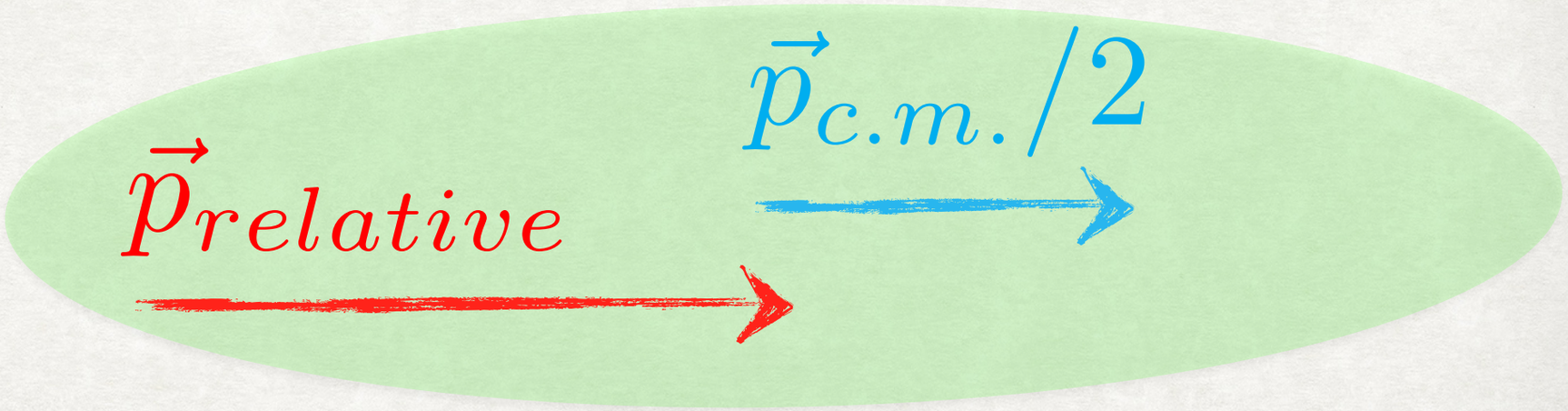
Longitudinal bias by the reaction

For high p_{miss}, more likely to probe $\vec{p}_{c.m.}$ in the $\vec{p}_{miss}$ direction (case 2).

case 1



case 2



Final state interactions

For large Q^2 and x>1, FSI is dominated by interactions within the SRC pair

Distances that highly virtual struck nucleon propagates

For large x

$$r_{FSI} \sim \frac{1}{\Delta E v} \lesssim 1 \text{ fm}$$

FSI in the SRC pair:

- conserve Isospin structure.
- conserve pair c.m. momentum.

$$\Delta E = -q_0 - M_A + \sqrt{m^2 + (p_i + q)^2} + \sqrt{M_{A-1}^2 + p_i^2}$$

[PRC 56 1124-1137 (1997), arXiv: 0806.4412]

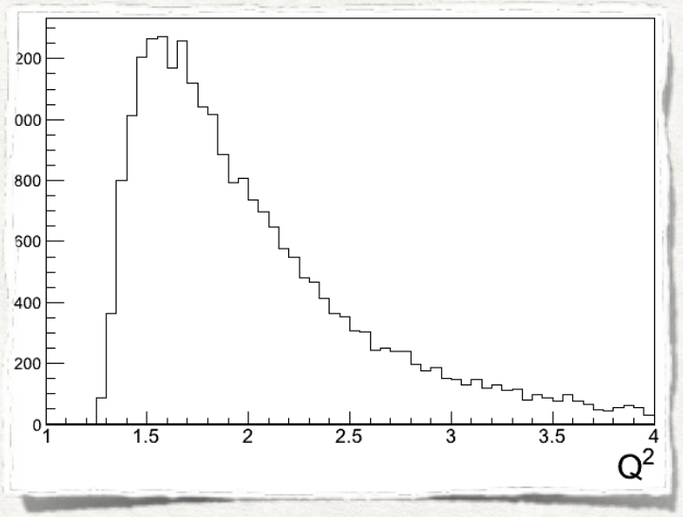
Data

Analysis

pp-SRC events selection

(e,e'p) Kinematics

- $x_B > 1.2$
- $1 > |\mathbf{p}_{miss}| > 0.3$ GeV/c
- $M_{miss} < M_p + M_\pi$

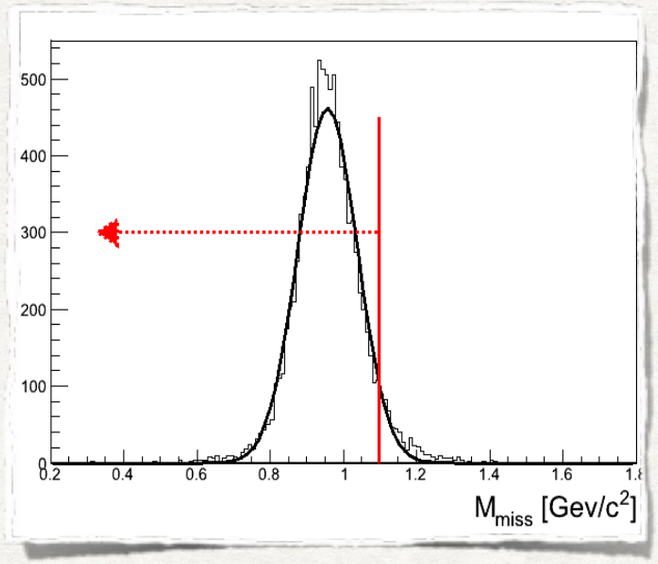


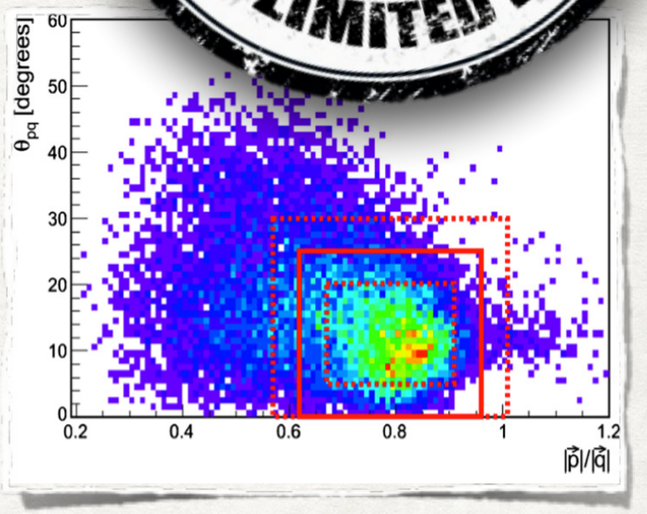
[O. Hen et al., Science, 346:614 (2014)]

[PRL 108, 092502 (2012) , PRL 113, 022501 (2014)]

(e,e'p) Leading proton

- $\theta_{pq} < 25^0$
- $0.62 < |\mathbf{p}|/|\mathbf{q}| < 0.96$





(e,e'pp) : (e,e'p) events, in which a recoil proton is detected w/ momentum > 350 MeV/c

p_{cm} data

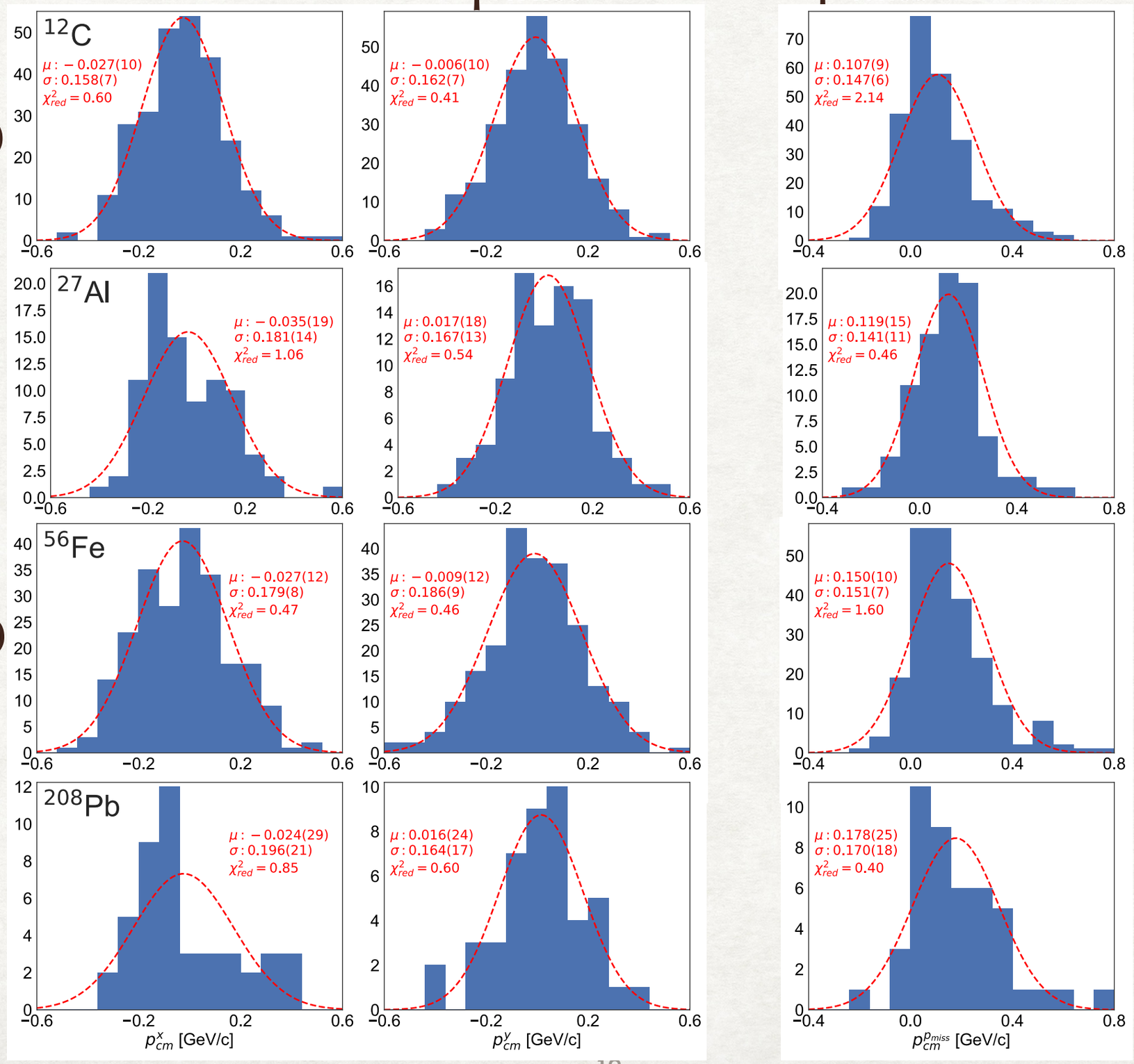
transverst to p_{miss} | p_{miss} dir.

^{12}C (266 events)

^{27}Al (88 events)

^{56}Fe (227 events)

^{208}Pb (45 events)

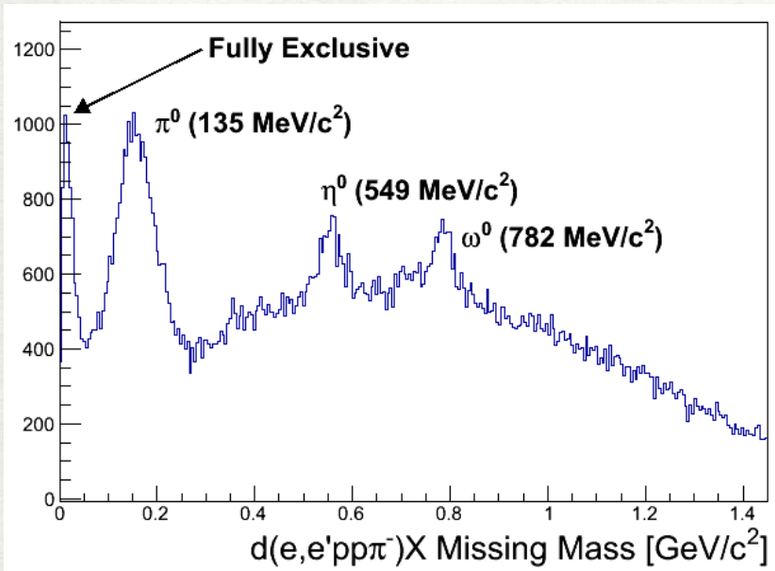


- fiducial cuts applied to the recoil protons.
- Includes broadening due to CLAS momentum reconstruction resolution.

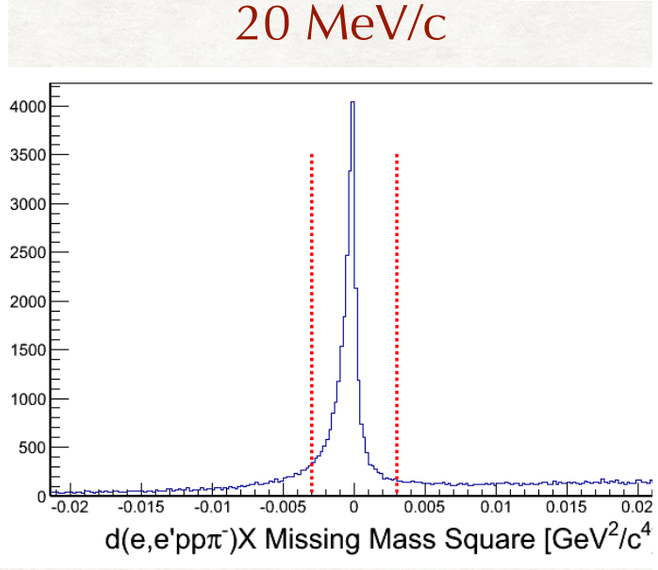
Resolution of the c.m. momentum reconstruction

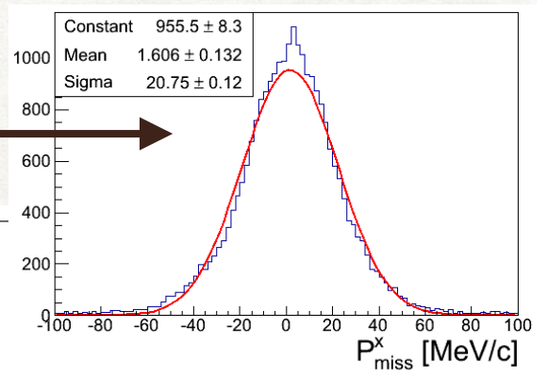
$$\sigma_{c.m.\ \mathrm{real}} = \sqrt{\sigma^2_{c.m.\ \mathrm{measured}} - \sigma^2_{res}}$$

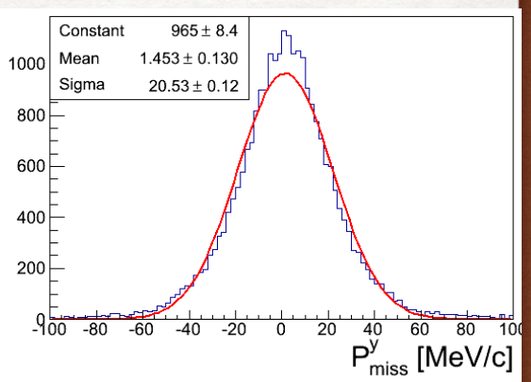
- Momentum reconstruction resolution obtained from d(e,e'ppπ⁻), in which p_{miss} vanishes, up to the finite CLAS momentum reconstruction resolution.

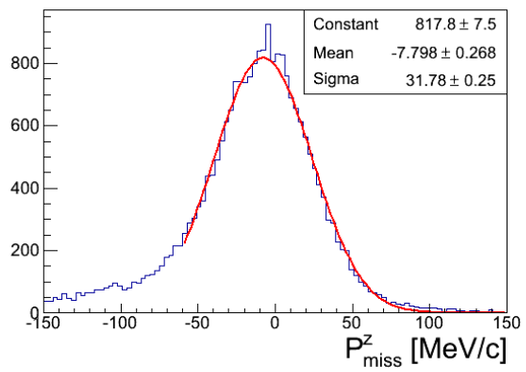


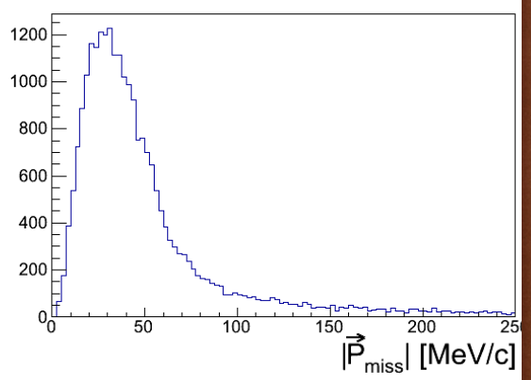
width of about 20 MeV/c











- Results:
  - σ_{res} ~ 20 MeV/c.
  - effect on the extracted $\sigma_{c.m.}$ is of the order ~ 1-2 MeV/c.

Before CLAS acceptance corrections

$$\sigma_t^{\text{before acc. corr.}} = \frac{\sigma_x^{\text{before acc. corr.}}/\Delta\sigma_x^2 + \sigma_y^{\text{before acc. corr.}}/\Delta\sigma_y^2}{1/\Delta\sigma_x^2 + 1/\Delta\sigma_y^2},$$

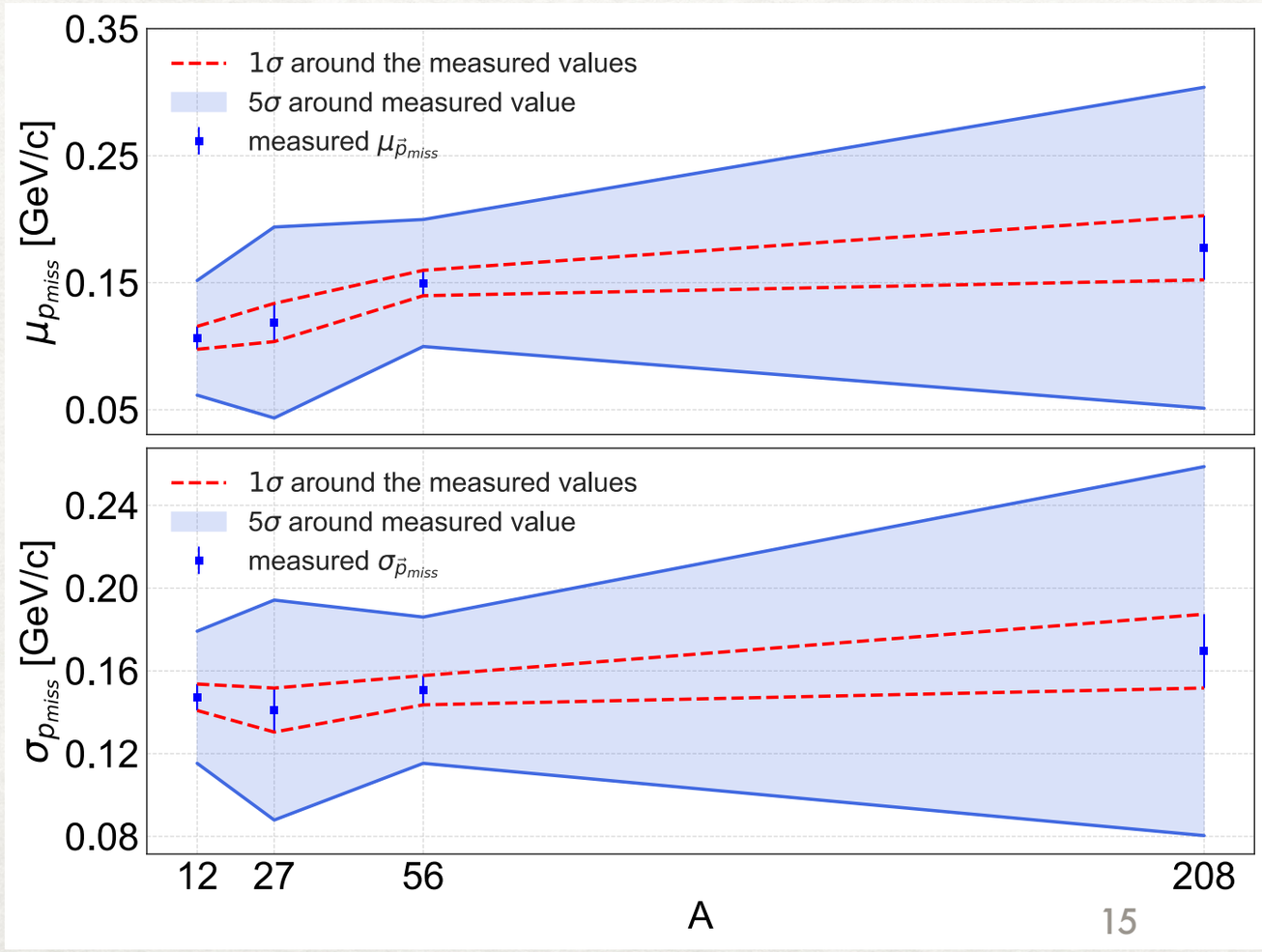
$$\Delta\sigma_t = 1/\sqrt{(1./\Delta\sigma_x)^2 + (1./\Delta\sigma_y)^2}.$$

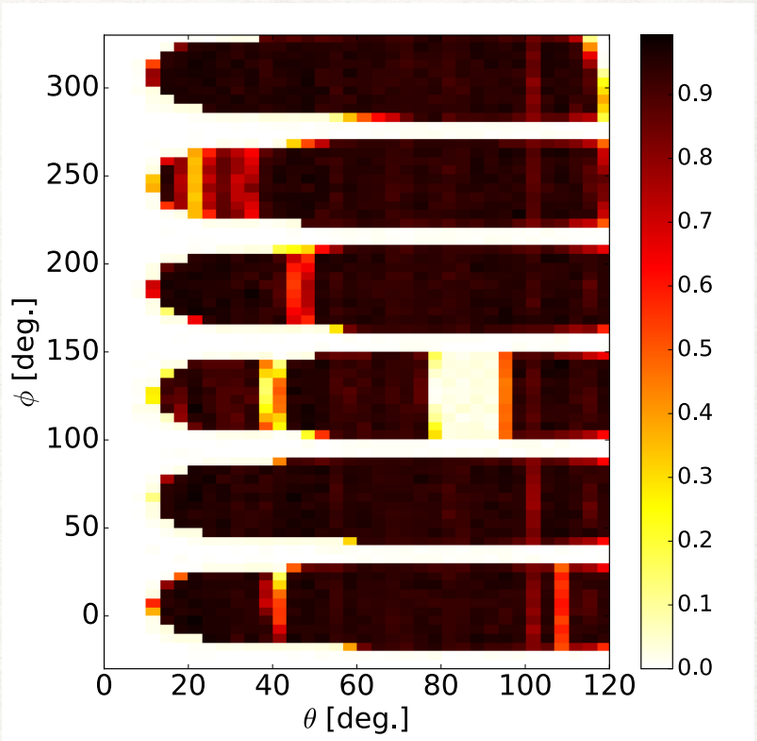
target	σ_x [GeV/c]	σ_y [GeV/c]	σ_t [GeV/c]
^{12}C	0.157 ± 0.007	0.160 ± 0.007	0.159 ± 0.005
^{27}Al	0.180 ± 0.013	0.166 ± 0.012	0.172 ± 0.010
^{56}Fe	0.178 ± 0.008	0.185 ± 0.009	0.181 ± 0.006
^{208}Pb	0.195 ± 0.021	0.163 ± 0.017	0.176 ± 0.013

Acceptance correction procedure

- protons were generated with a uniform momentum distribution between 0 and 1 GeV/c, and passed through the virtual CLAS-MC chain - to formulate an acceptance map.

- A data-driven event generator was designed with 3 parameters:
  - width of the c.m. distribution in the transverse directions $\sigma_x=\sigma_y=\sigma_t$
  - width (σ_{miss}) and the mean (μ_{miss}) in the longitudinal direction.

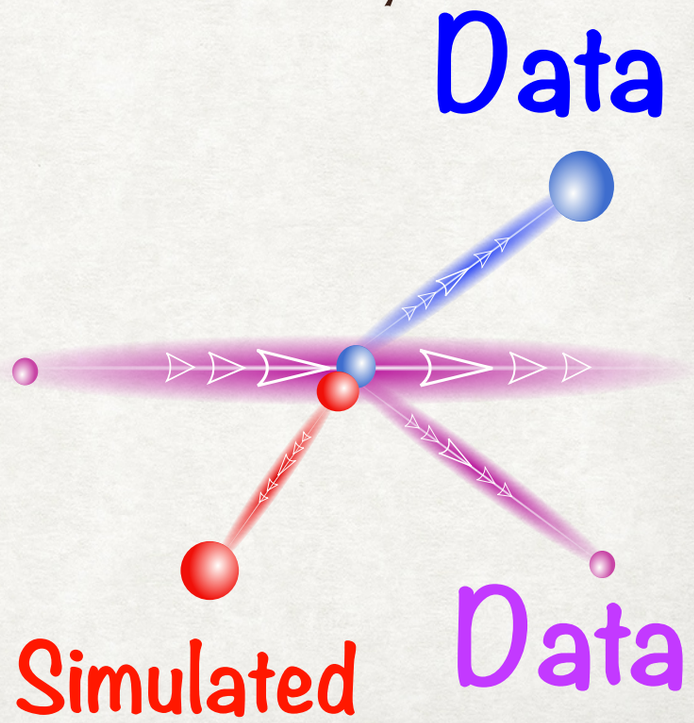




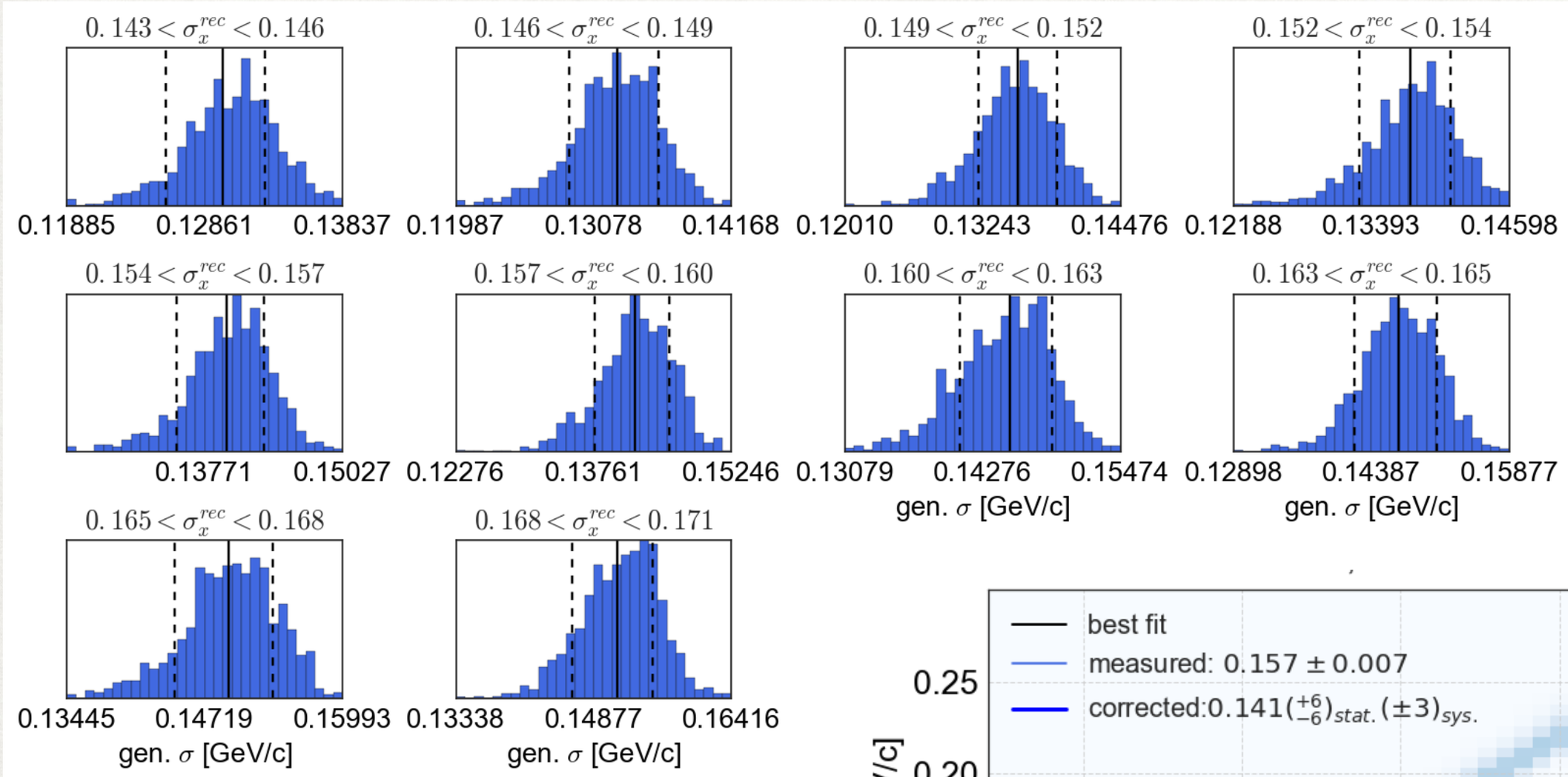
- For each set of simulations
  - σ_t was sampled uniformly in the range 0-0.3 GeV/c
  - σ_{miss} and μ_{miss} were randomly selected from a Gaussian distribution,
    - mean = measured value,
    - width = five times the measured standard deviation.

Acceptance correction procedure

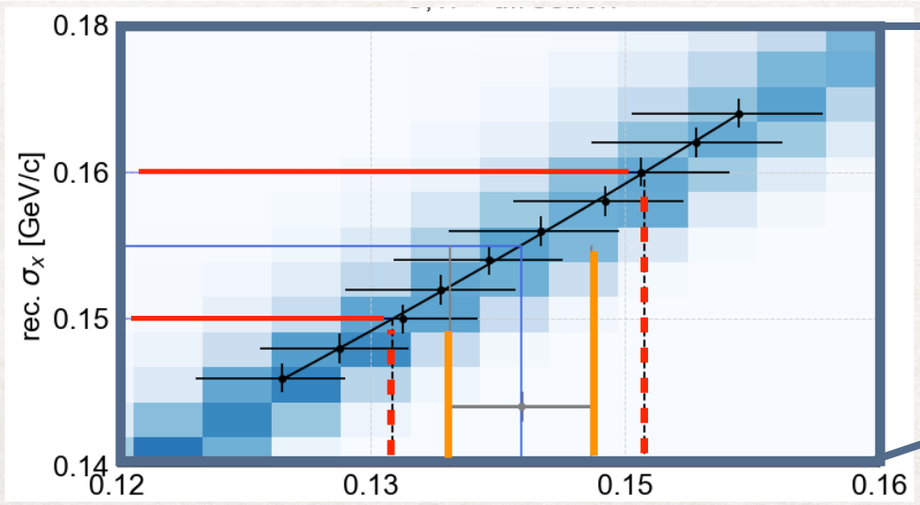
- Raffle a random value for σ_t, σ_{miss} and μ_{miss}.
- Generate a sample of (e,e'pp) events from the measured (e,e'p) event sample N times:
  - Generate $\mathbf{p}_{cm}$ and define $\mathbf{p}_{recoil} = \mathbf{p}_{cm} - \mathbf{p}_{miss}$.
  - Apply CLAS acceptance and fiducial cuts
  - Weight recoil proton with CLAS detection efficiency.
- Fit the c.m. momentum distribution of the weighted (e,e'pp) event sample to obtain the "reconstructed" σ_x and σ_y, and calculate their weighted average, σ_t.

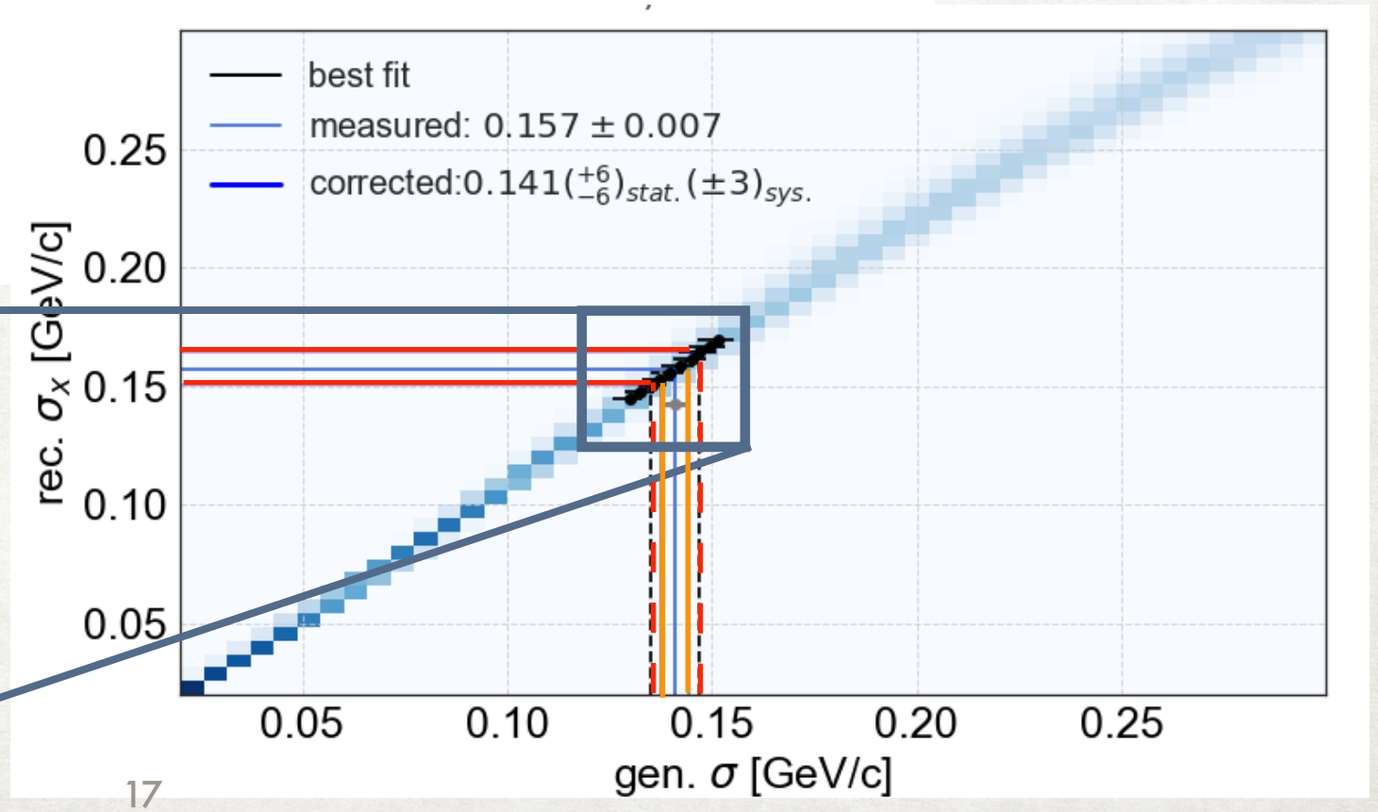


Acceptance correction procedure



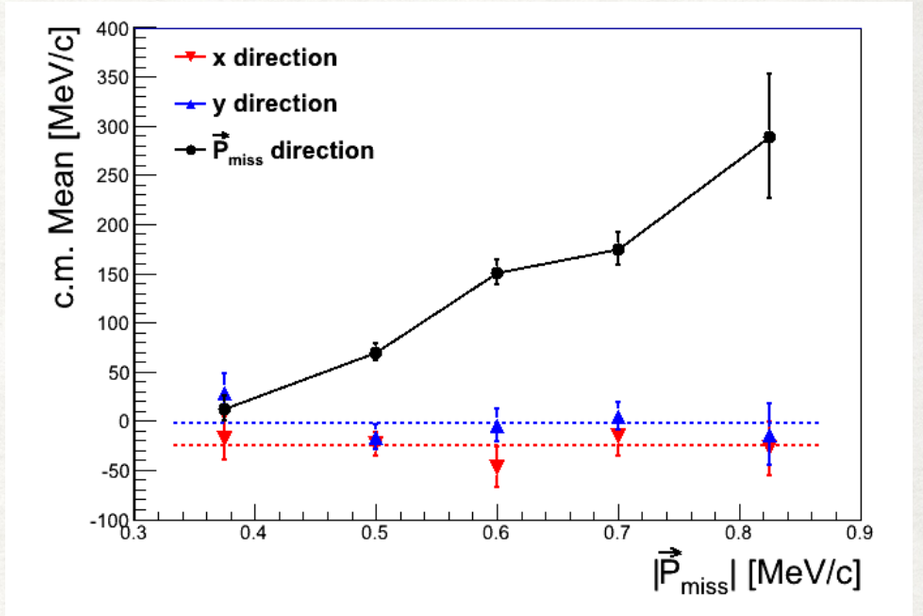
example for σ_x in carbon simulations

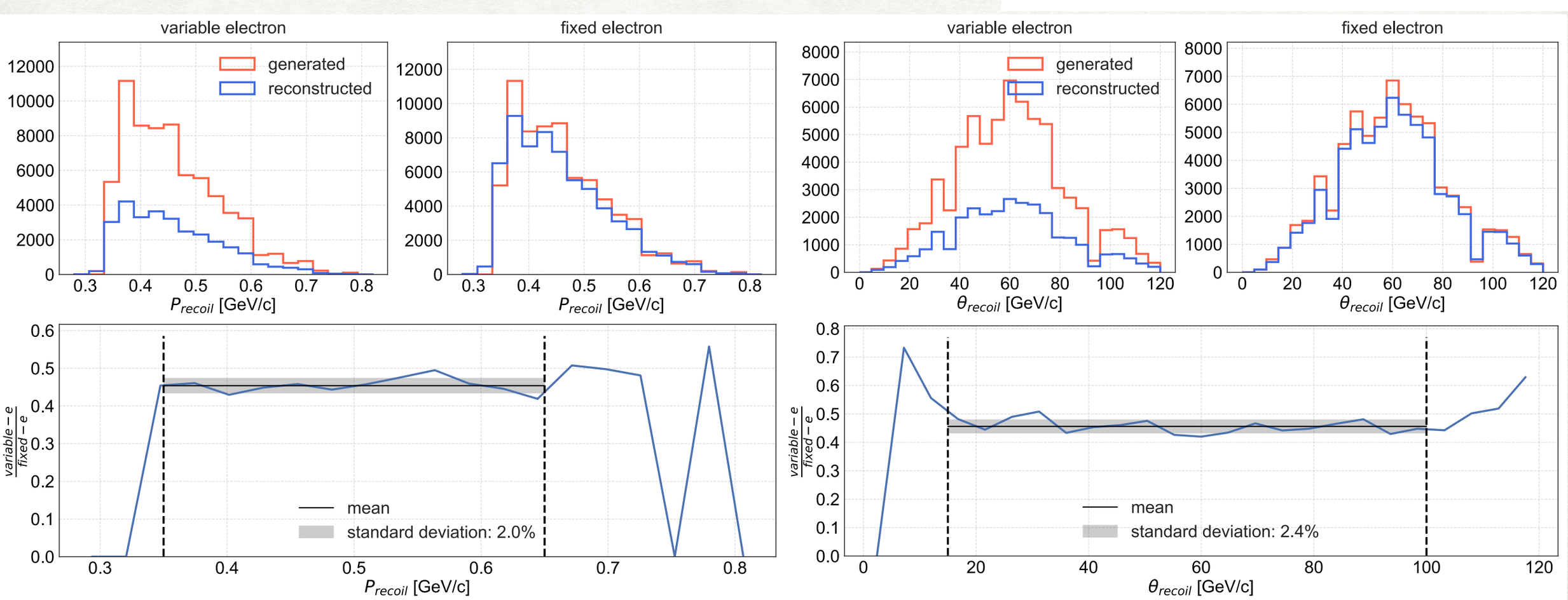




Impact of the event-kinematics on the acc. corr. procedure

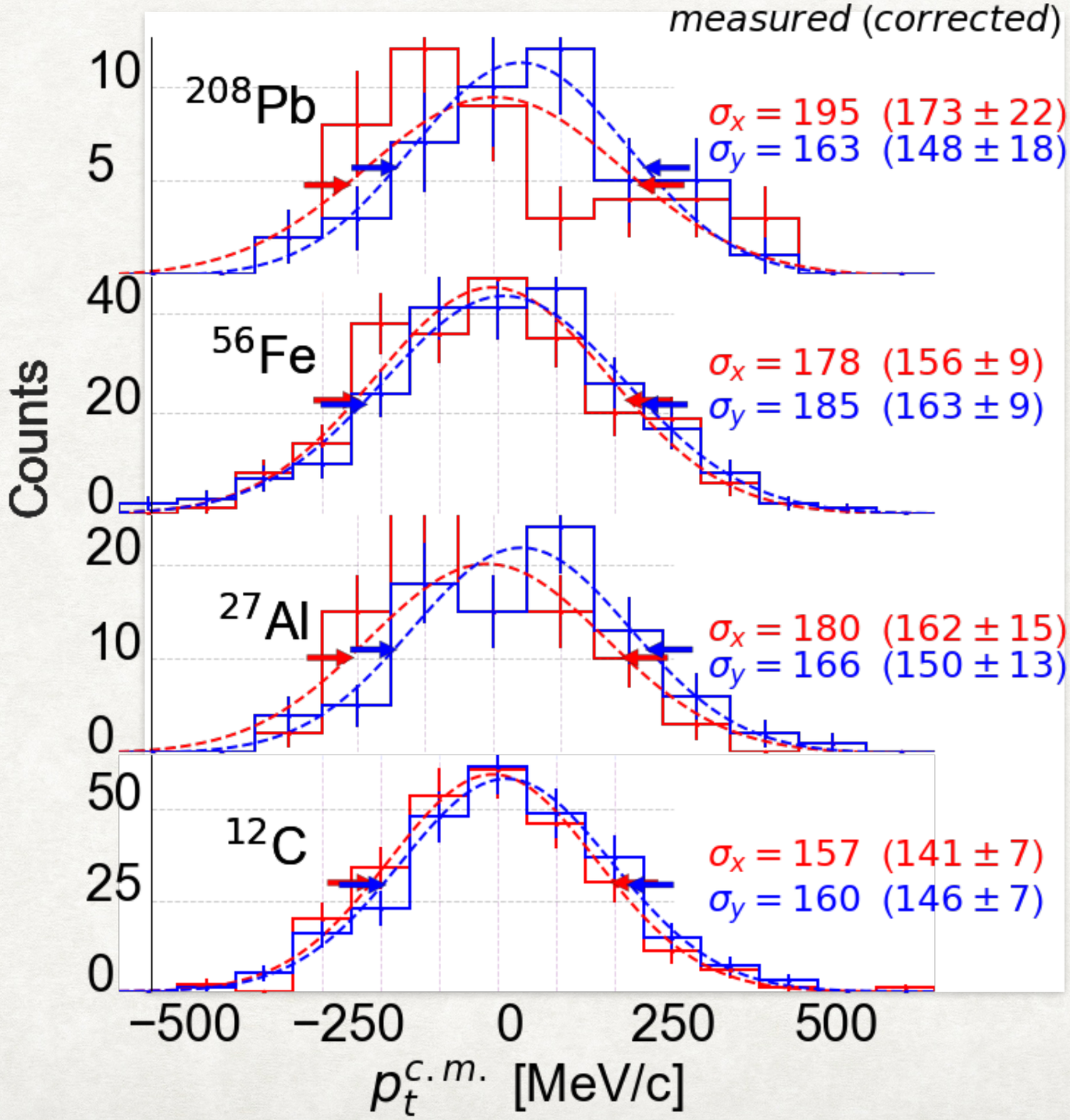
- We correct for the p_{recoil} acceptance. The correlation with the event-kinematics via for $x_B > 1$ is weak and does not affect the extracted σ_t
  - The results do not depend on the kinematics
  - p_{recoil} acceptance in a given p_{cm} bin does not depend on the kinematics.
- We verified this by calculating the acceptance-ratio for a fixed electron momentum to a varying-electron momentum.



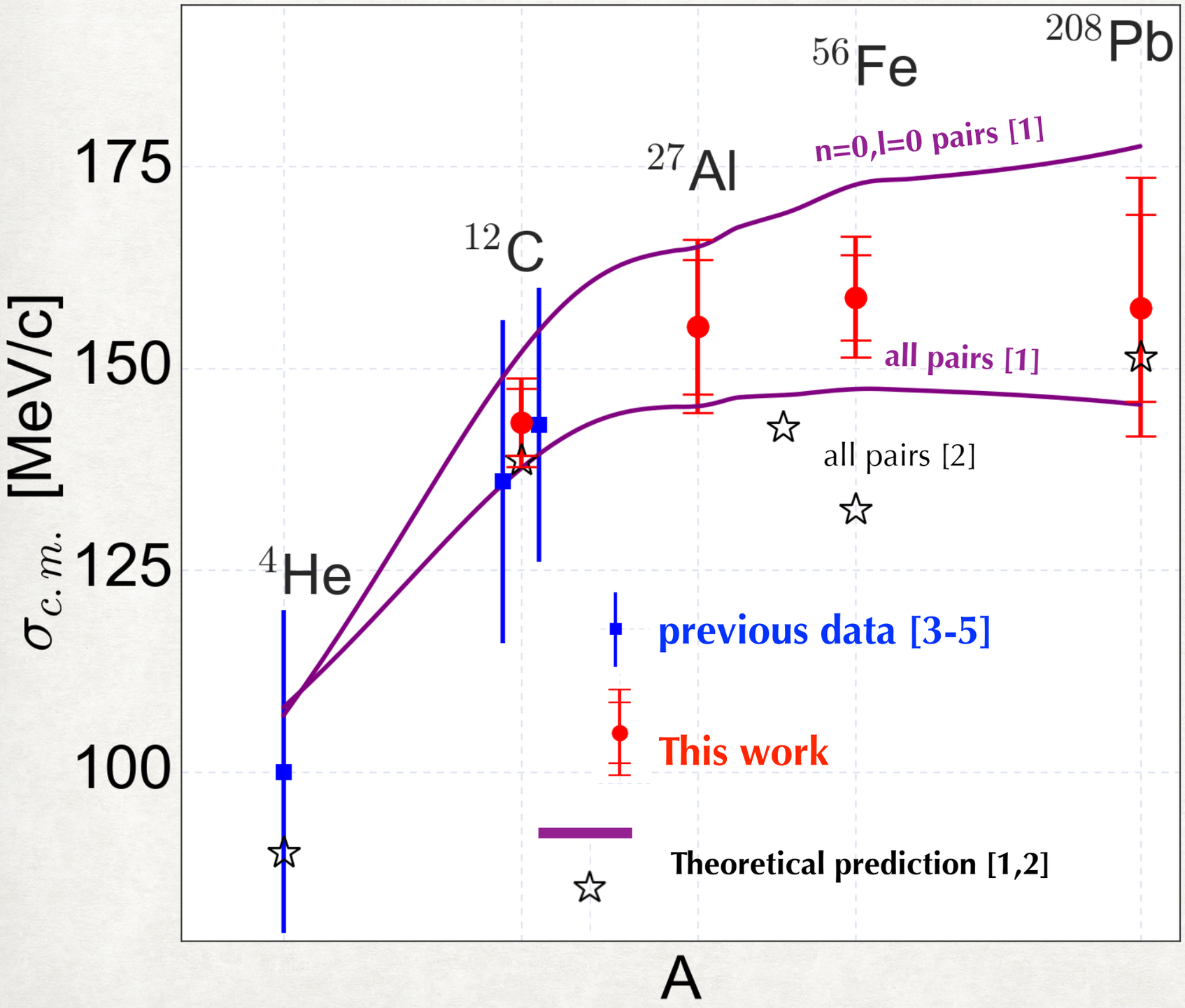


Results

results - distributions



results - A dependence



The data show:

- The width of the SRC-pair c.m. momentum is small w.r.t. the Fermi momentum.
- c.m. width saturates with mass number A.
- Selective pair matching.

[1] R. Weiss et al. arXiv:1612.00923.
[2] Colle et al. PRC 89.024603.
[3] Ciofi, Simula, PRC 53, 1689.
[4] Korover et al., PRL 113,022501.
[5] Shneor et al., PRL 99, 072501.
[6] Tang et al., PRL 90 ,042301.

draft for a paper

The center of mass motion of short-range correlated nucleon pairs studied via the $A(e, e'pp)$ reaction

CLAS collaboration

E. O. Cohen et al.,[1]

[1] *School of Physics and Astronomy, Tel Aviv University, Tel Aviv 69978, Israel*

(Dated: March 1, 2018 (v 8))

Short-Range Correlated (SRC) nucleon pairs are a vital part of the nucleus, accounting for almost all of the high-momentum nucleons and most of the kinetic energy carried by the nucleons. The small pair center-of-mass (c.m.) and large relative momenta are fundamental characteristics of SRC pairs, and indicate a small separation distance between the nucleons in the pair. While various properties of SRC pairs have been determined experimentally for a wide range of nuclei, their c.m. momentum distribution has been studied only for ^{4}He and ^{12}C. Determining this distribution in heavier nuclei is essential for understanding the formation process of SRCs in nuclei. We report here on the extraction of the c.m. momentum of proton-proton (pp) SRC pairs from measurements of the $A(e, e'pp)$ reaction in ^{12}C and, for the first time, in ^{27}Al, ^{56}Fe, and ^{208}Pb. We find that the pair c.m. momentum for these nuclei can be described by a three-dimensional Gaussian with a narrow width ranging from 140 MeV/c to 160 MeV/c, in overall agreement with theoretical predictions. The narrow width of the c.m. momentum distribution, even in heavy nuclei, supports the existence of minimal rescattering between the SRC nucleons and the residual A-2 system in the $A(e, e'pp)$ reaction at the measured kinematics. From deuterium to lead, the extracted c.m. widths are linearly correlated with the relative number of SRC pairs.

PACS numbers:

Acknowledgements

CLAS analysis review committee
S. Stepanyan (Chair), L. El Fassi, D. Watts

Convener
M. Wood

Collaborators
L. Weinstein, O. Hen,
B. Schmookler, M. Duer
A. Schmidt, R. C. Torres, S. Gilad

Thank you for your time…

Comments/Suggestions/Questions:
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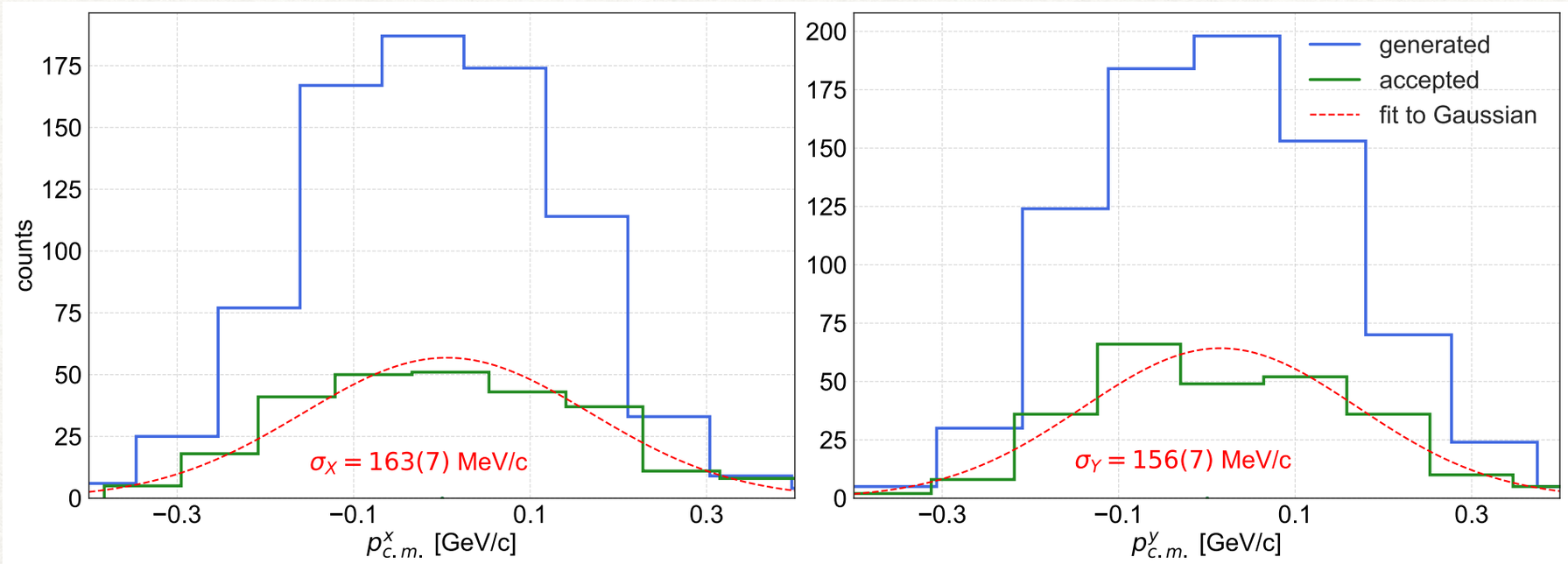
Pseudo-Data check

Validation of the process using Pseudo-Data

- A single ^{12}C (e,e'pp) pseudo-data set, input parameter: σ_t = 143, σ_{miss}=150 and μ_z=110 MeV/c.



	$\sigma_{gen.}$ [GeV/c]	$\sigma_{before\ acc.\ corr.}$ [GeV/c]	$\sigma_{acc.\ corrected}$ [GeV/c]
^{12}C	0.143	0.158 ± 0.005	0.143 ± 0.005

Validation of the process using Pseudo-Data

- A bootstrap process: multiple pseudo-data sets
  - ^{12}C
  - ^{208}Pb