Study of Short-Range Correlations (SRC) in exotic nuclei

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Outline

Introduction

- Short Range Correlations (SRCs);
- Quenching of the Spectroscopic Factors;
- EMC effect;
- How to probe SRCs;

JINR Experimental Program

- Dubna (JINR) test experiment;
- (p,2p) analysis.
- Derivation of observables to isolate SRC physics.

R3B Experimental Program

- Experimental Set-up;
- (p,2p) analysis;
- Derivation of observables to isolate SRC physics.

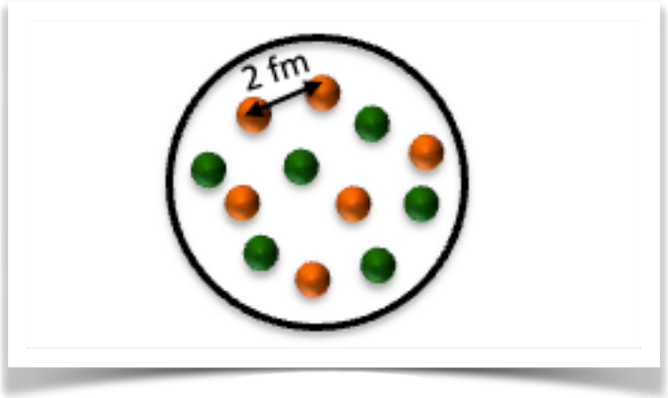
ONGOING ANALYSIS

FAIR First Physics Program

What are Short Range Correlations?

INTRODUCTION

INDEPENDENT PARTICLES



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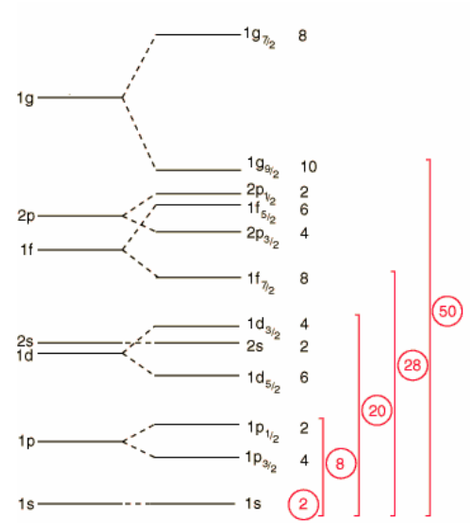

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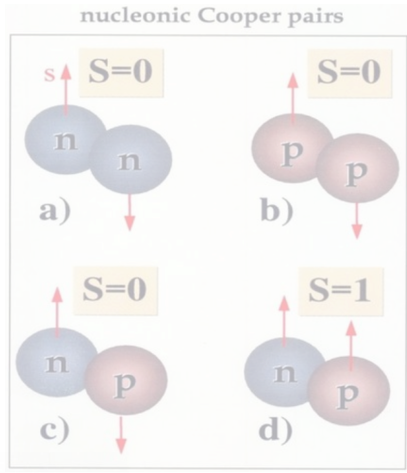

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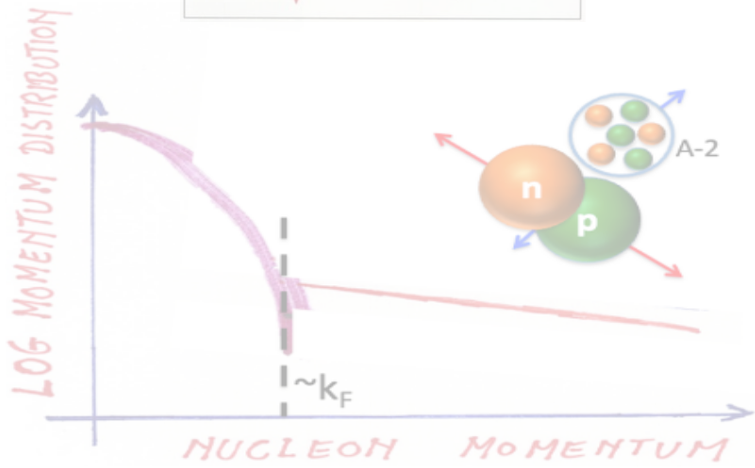

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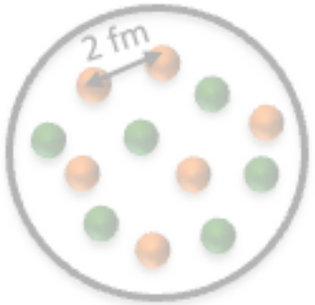

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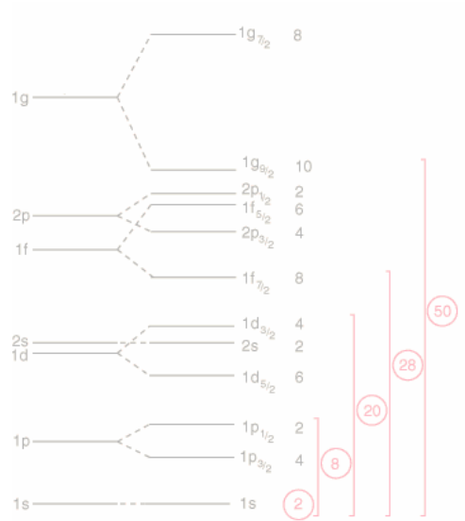

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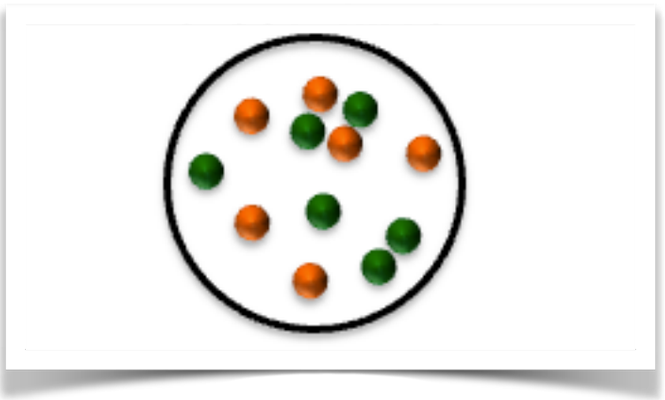

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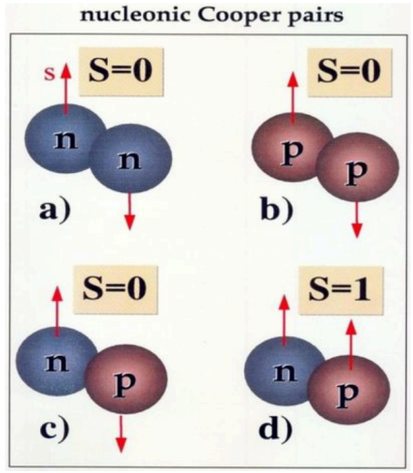

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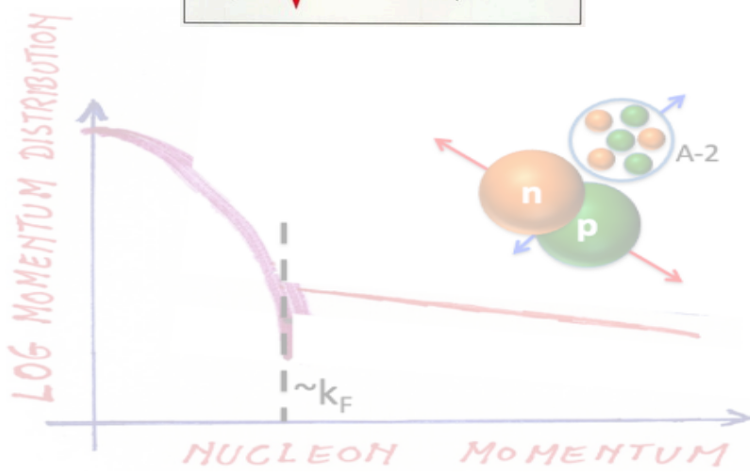

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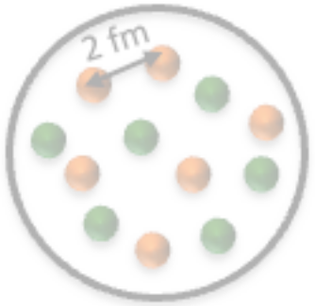

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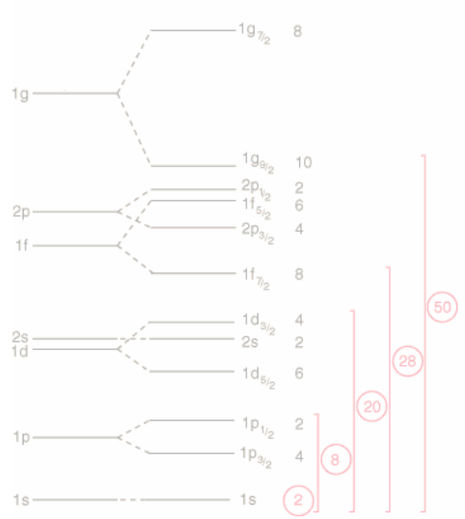

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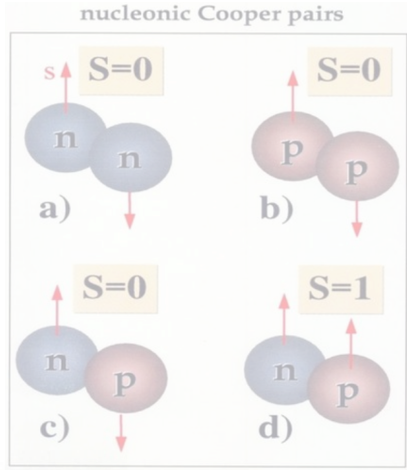

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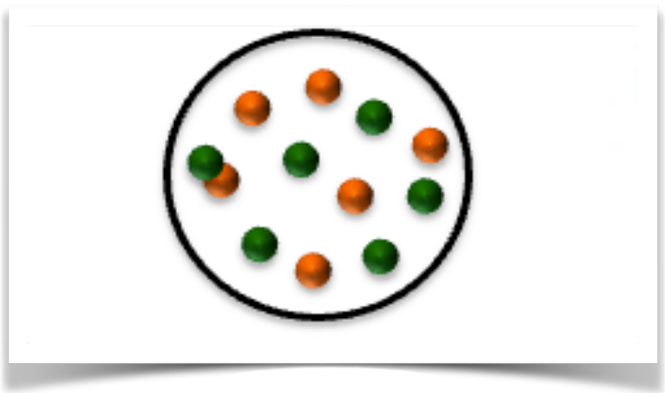

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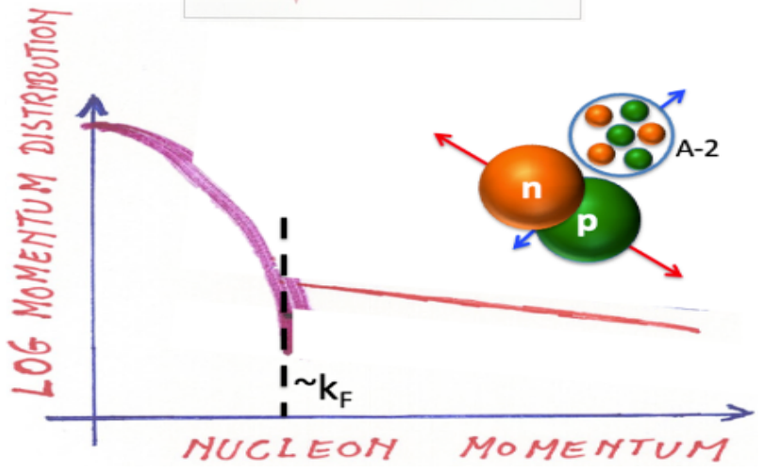

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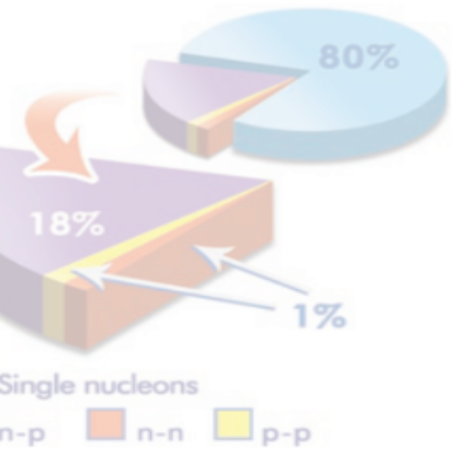
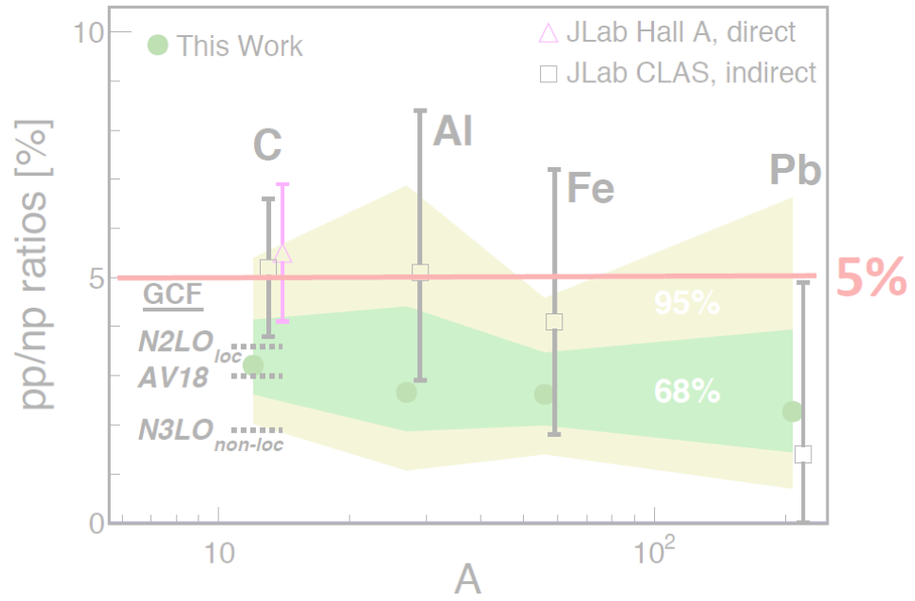


R.Saubedi,Science,Vol 320, (2008)

O. Hen et al. (CLAS Collaboration), Science, 346 (6209):614, 2014.

np Dominance



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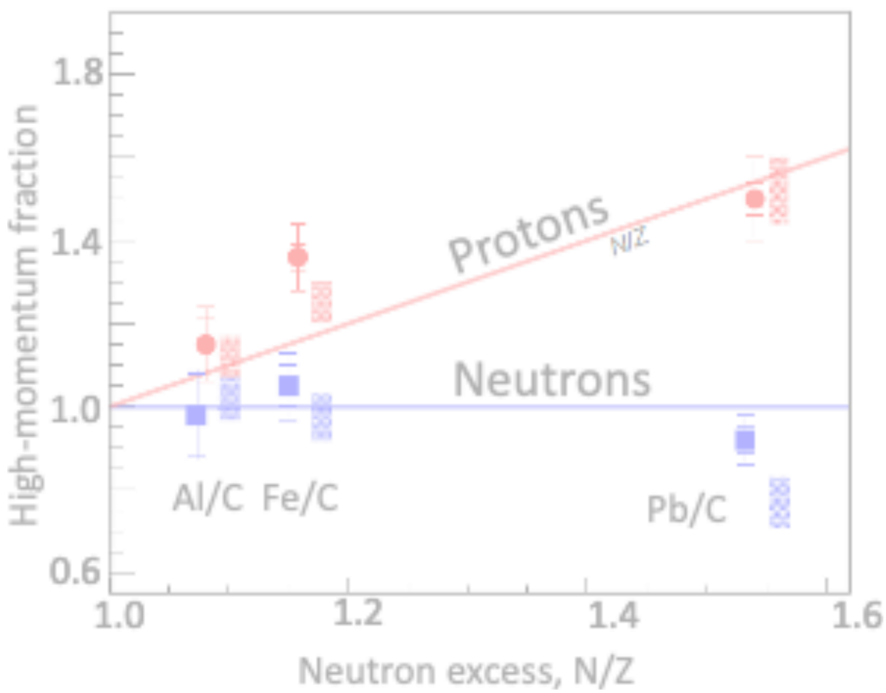

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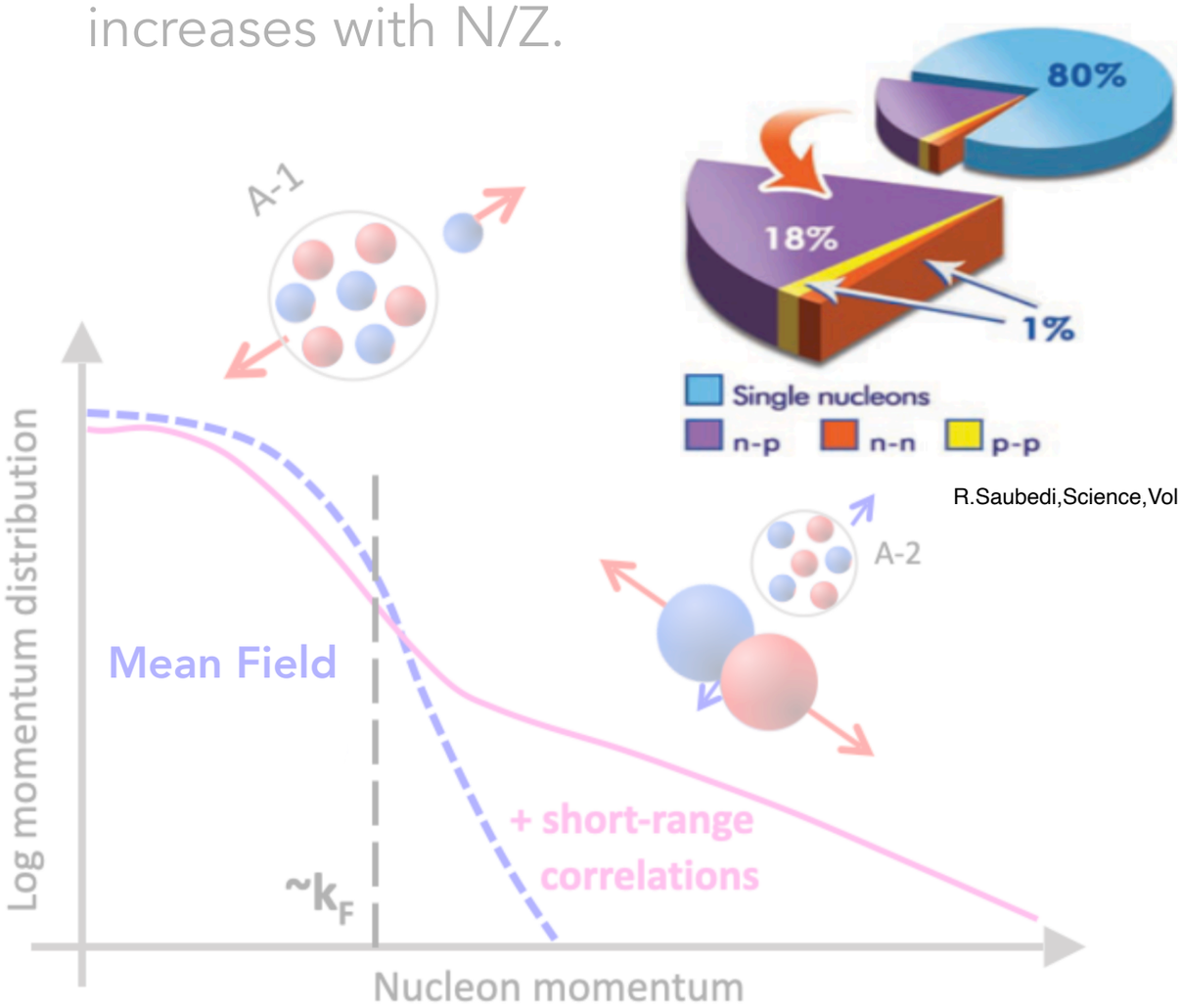

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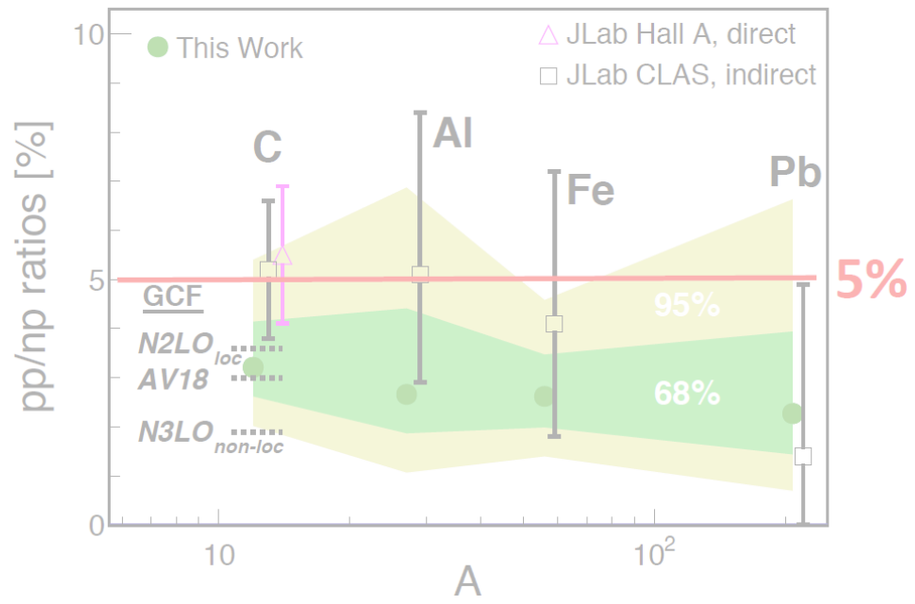

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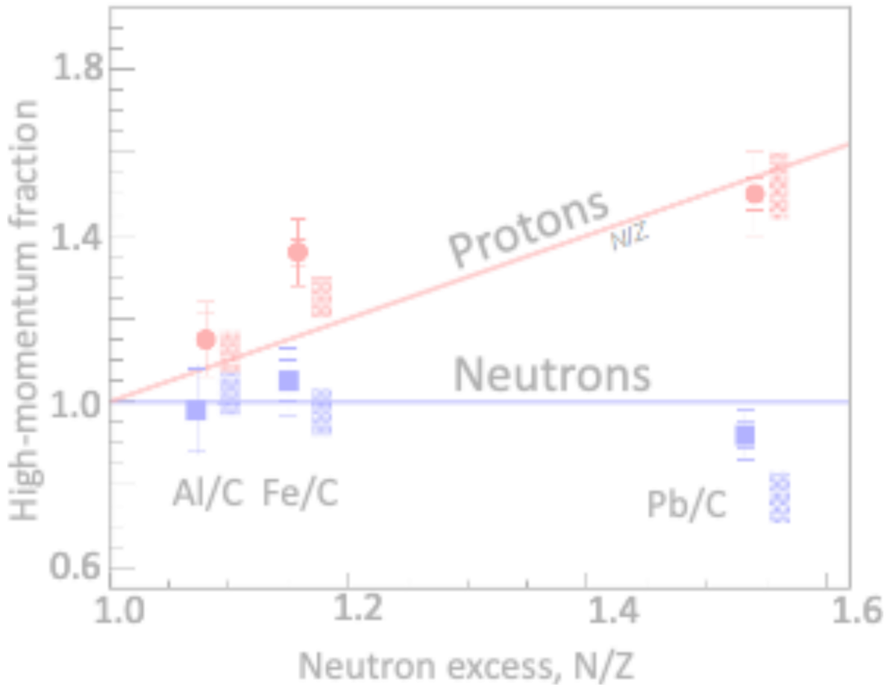

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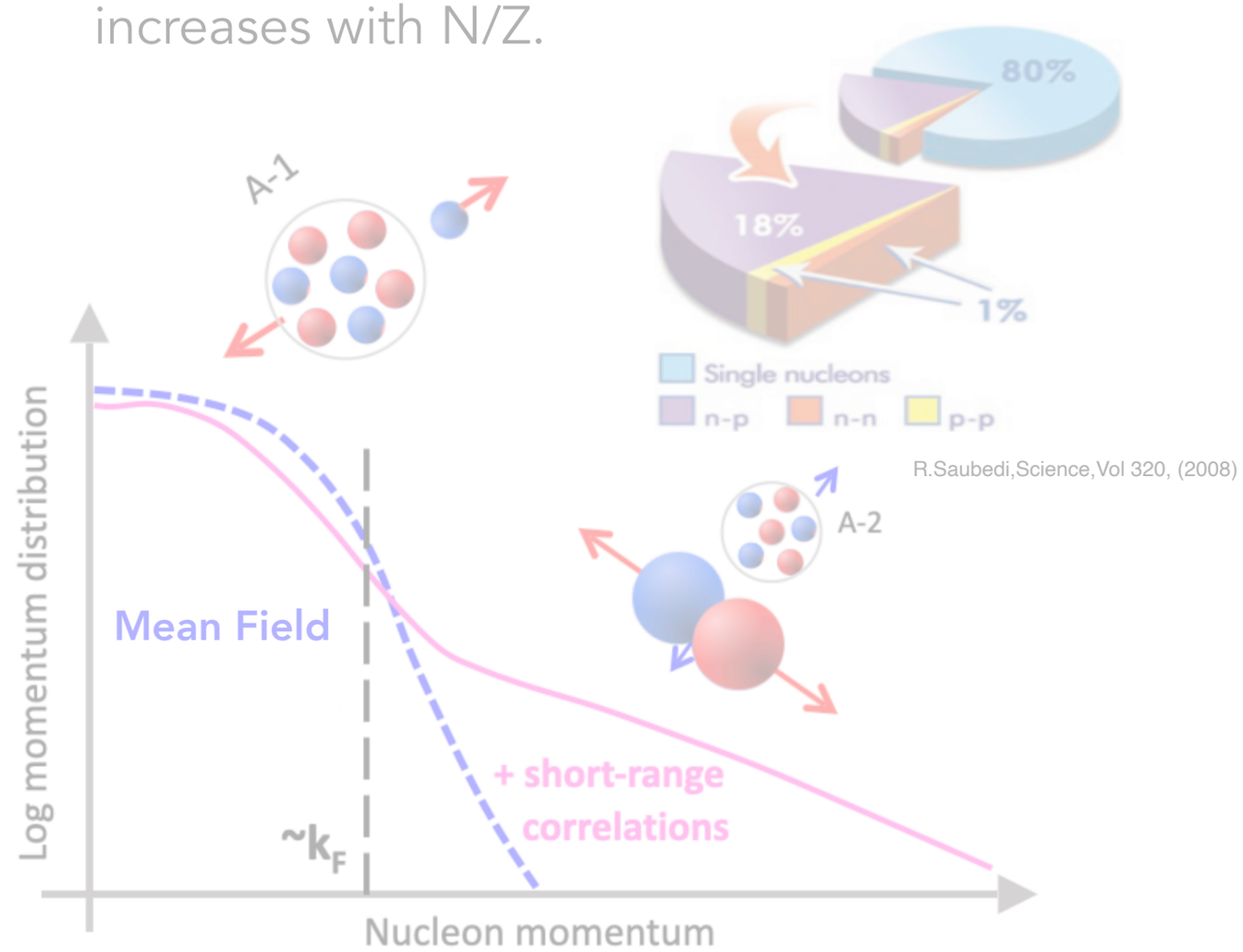

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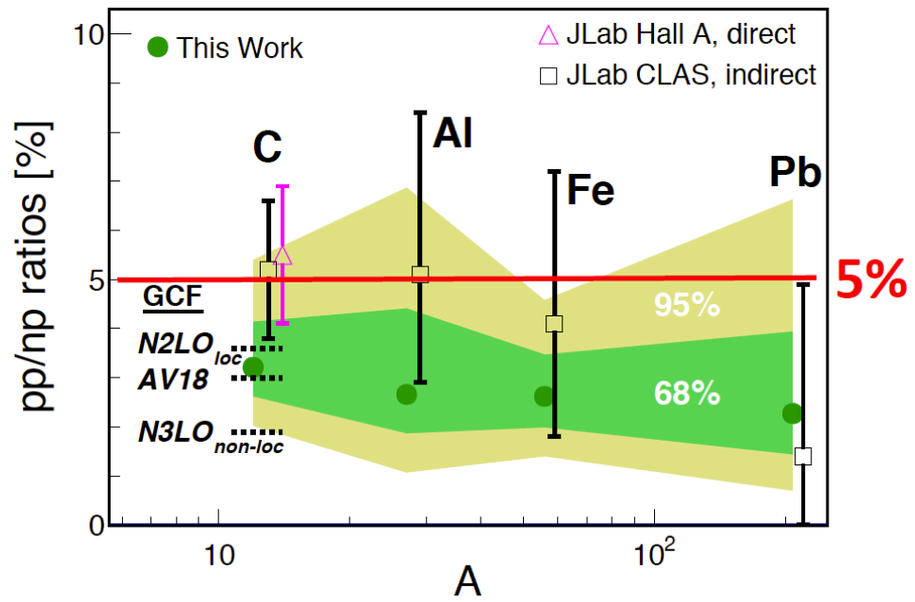

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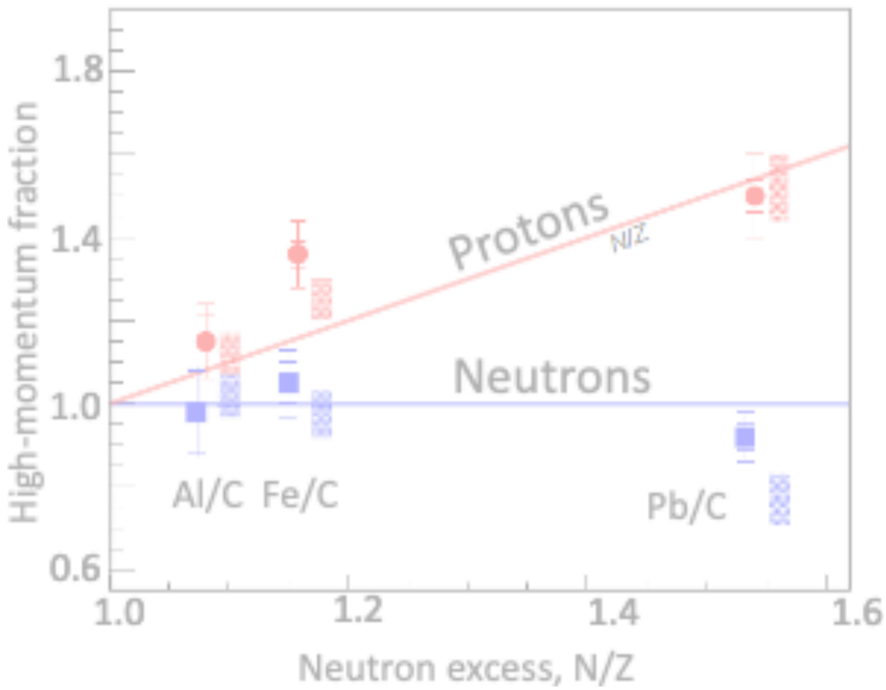

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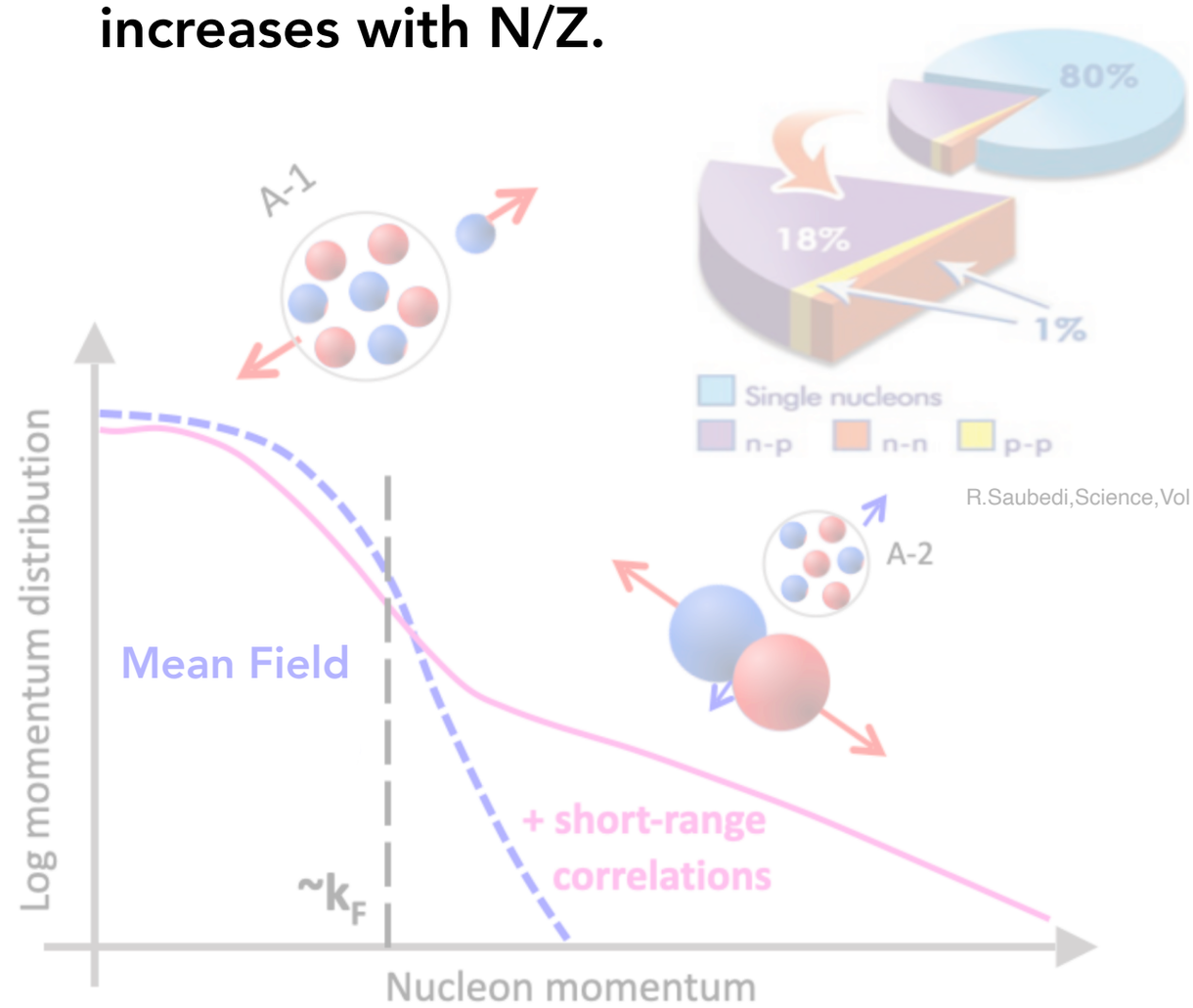

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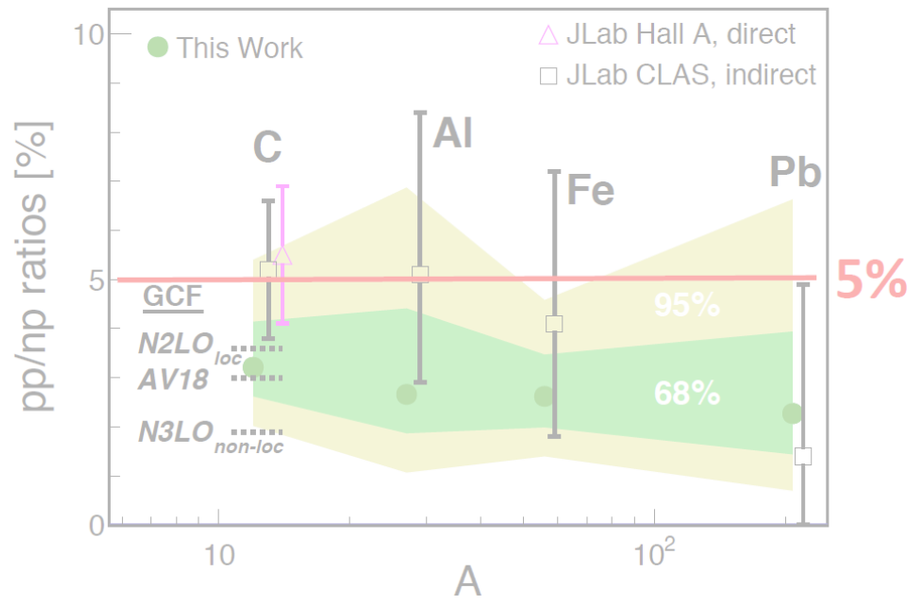

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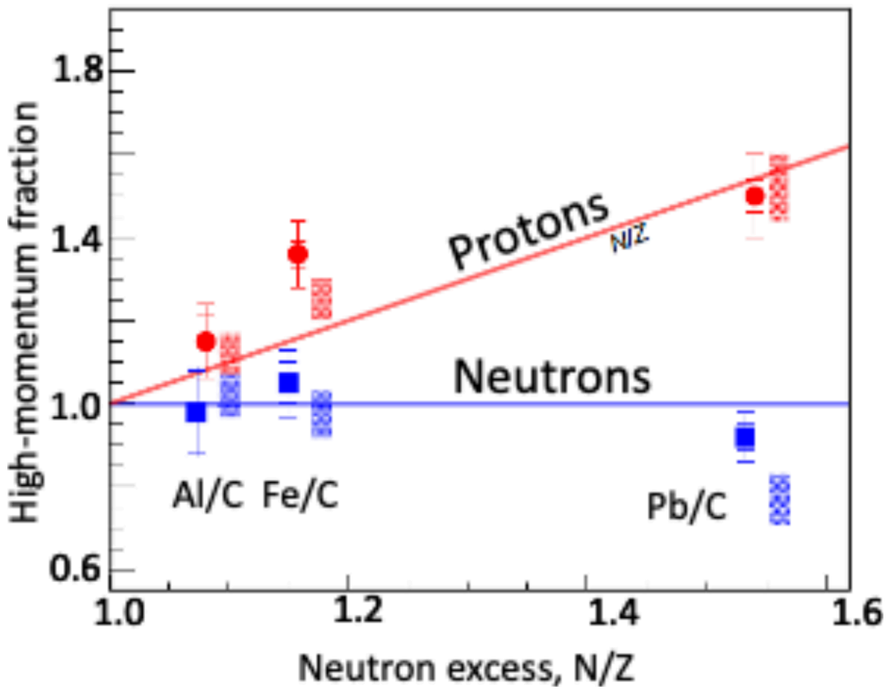

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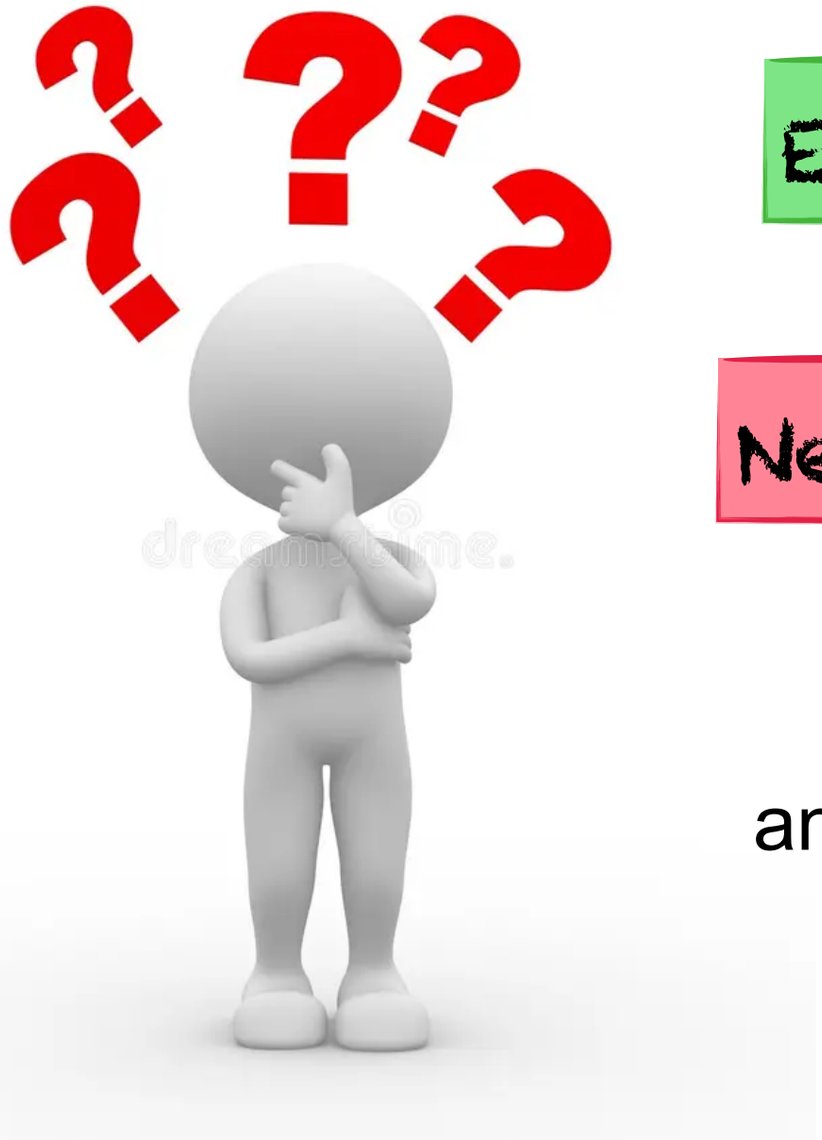
Why study Short Range Correlations?

Why study Short Range Correlations?

Quenching of the spectroscopic factors

Equation Of State



EMC effect

Neutron stars

and many more …

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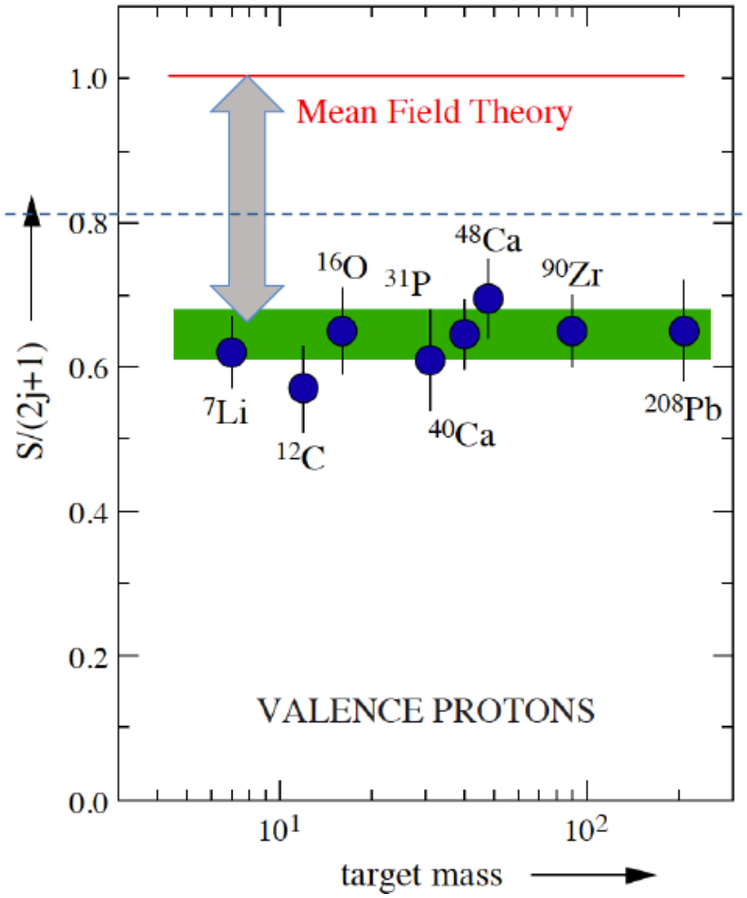
Quenching of the spectroscopic factors

Reduction of measured nucleon removal cross section with respect to the prediction of the mean-field theories

W.H. Dickhoff, C. Barbieri / Progress in Particle and Nuclear Physics 52 (2004) 377–496

Long Range

Short Range



- ***Correlations*** *between nucleons* ***modify the mean-field approximation****;*
- *About 30% – 40% of the nucleons participate in NN correlations, which are distinguished into* ***long-range (LRC) and short-range (SRC);***
- *Are thought to be the reason for the quenching of SF observed in (e,e′p), (p,2p) and transfer reactions.*
- *Depletion of the single particle states below the Fermi momentum.*

Quenching of the spectroscopic factors

- What are the **individual contributions** of LRC and **SRC** to the observed single-particle depletion?

- What is the **isospin (neutron-proton asymmetry) dependence** of LRC and SRC?

Phenomenological model that **directly connects these new SRCs results with the reduction of single-particle strength** in atomic nuclei.

Estimate the total "missing strength" in terms of contributions from LRC and SRC components.

$$R = 1 - \underbrace{(R_{PVC} + R_{PC} + R_{SRC})}_{\text{Missing strength}}$$

LRC

SRC

$$N > Z:\ R_{SRC} = \gamma\left(1 + SL^{p}_{SRC}\frac{N-Z}{A}\right)$$

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$$SL^{p}_{SRC} = 2.8 \pm 0.7$$

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Stefanos Paschalis, Marina Petri, A O Macchiavelli, Or Hen, Eli Piasetzky, Physics Letters B, 135110, 25 Nov 2019.

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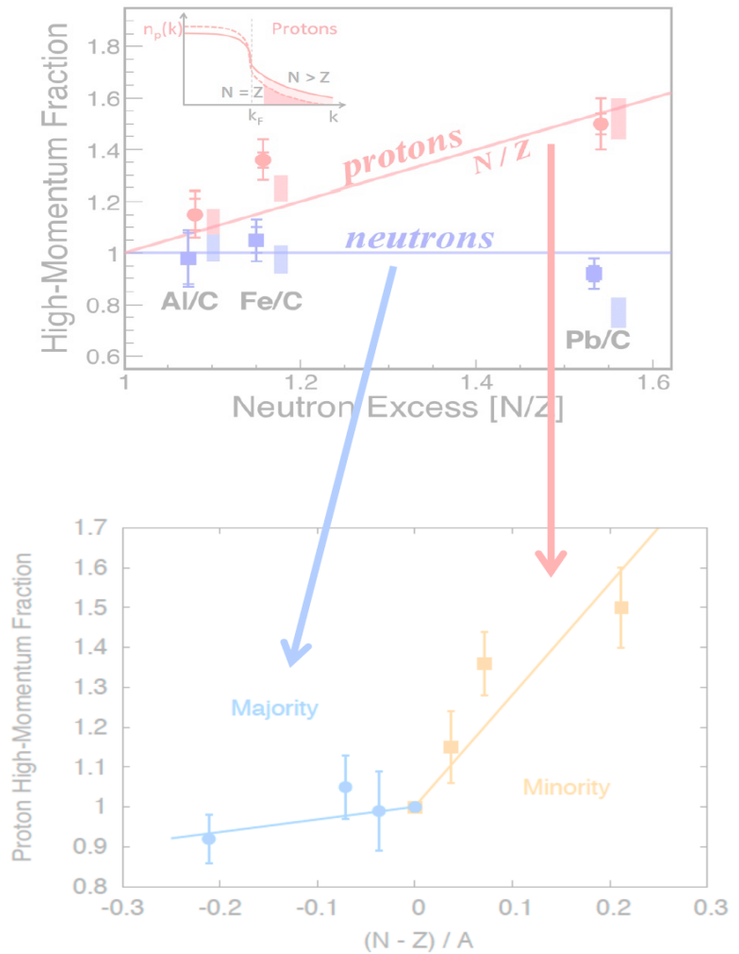

Parameterization of the dependency of the SRC component with isospin

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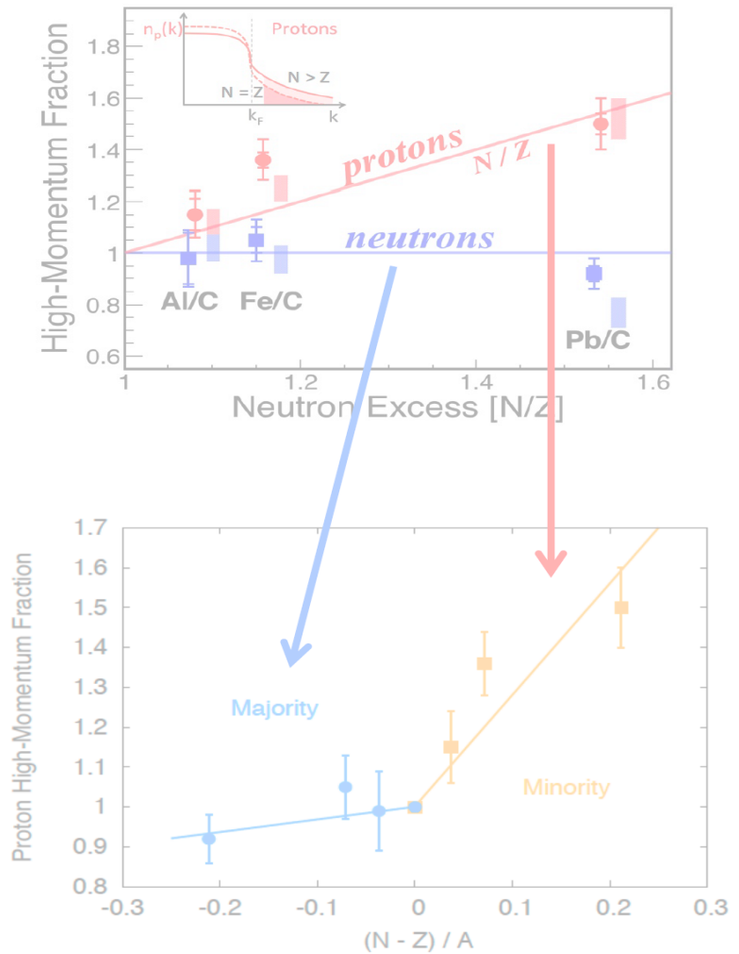

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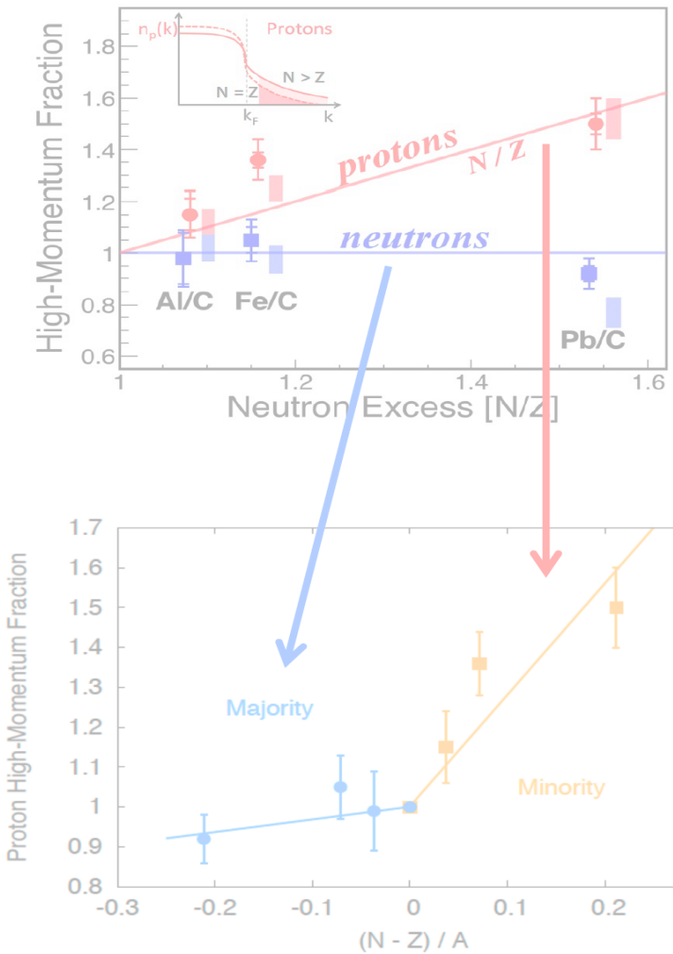

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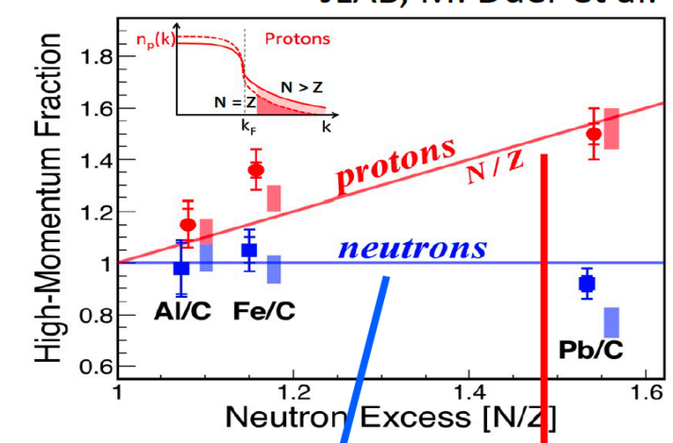

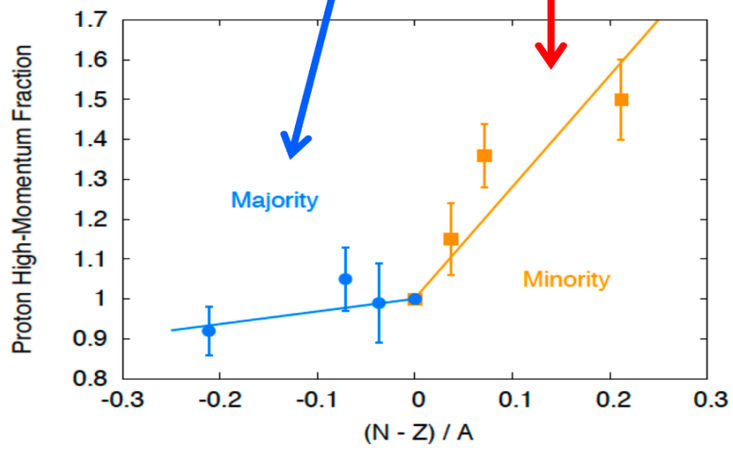

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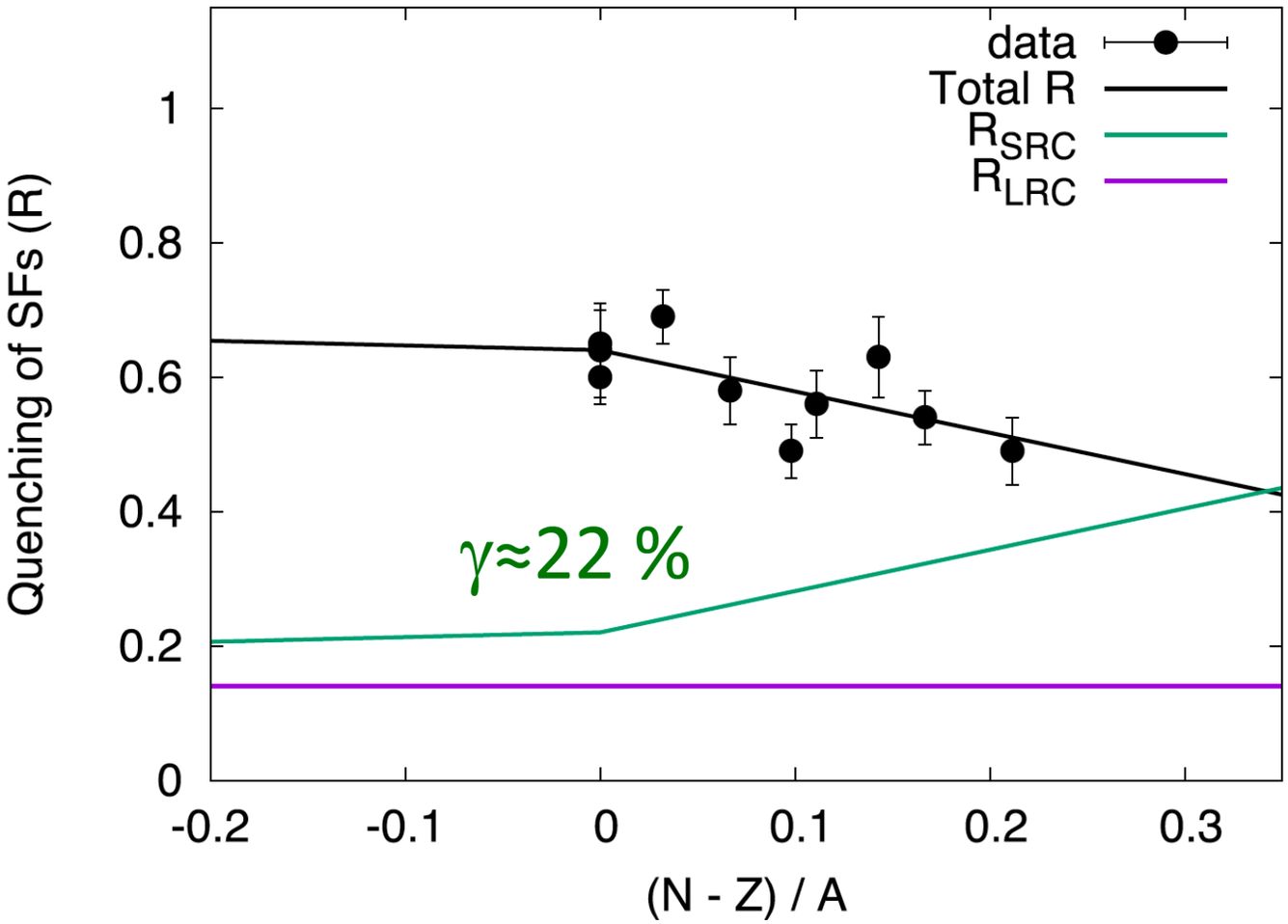

Missing strength

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LRC

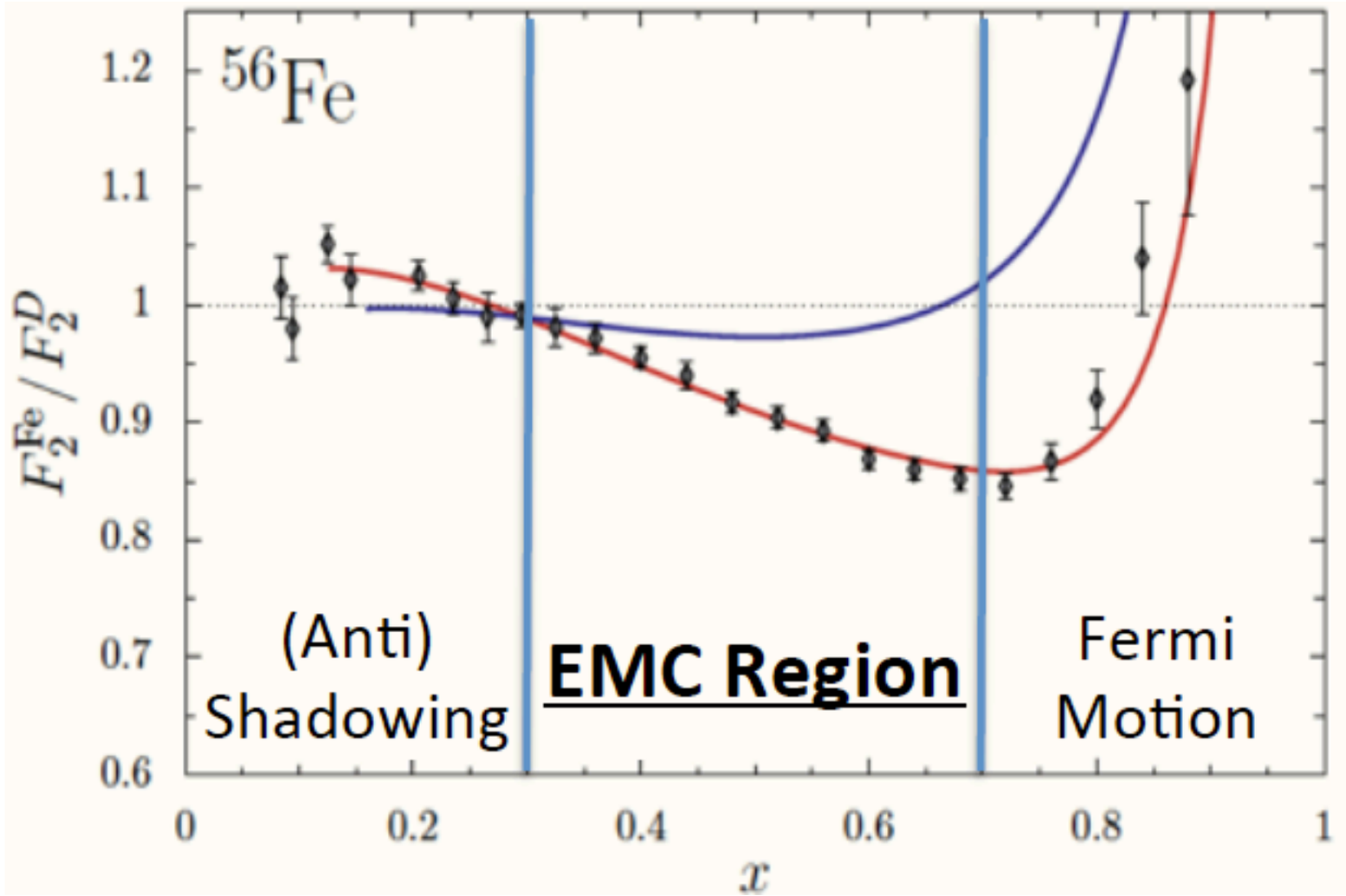
- ~ 20% of the missing strength observed in the region of N ≈ Z can be attributed to SRC, in agreement with reported expectations.

Stefanos Paschalis, Marina Petri, A.O Macchiavelli, Or Hen, Eli Piasetzky, Physics Letters B, 135110, 25 Nov 2019.

EMC effect

The European Muon Collaboration (EMC) at CERN observed a ***decrease of per-nucleon electron deep inelastic cross-section in nuclei with A>2 compared to the deuteron****.*

- *Deviation of the per-nucleon DIS cross section ratio of nuclei relative to deuterium from unity.*
- *Universal shape for 0.3<x<0.7 and 3<A<197.*
- *No fully accepted theoretical explanation.*



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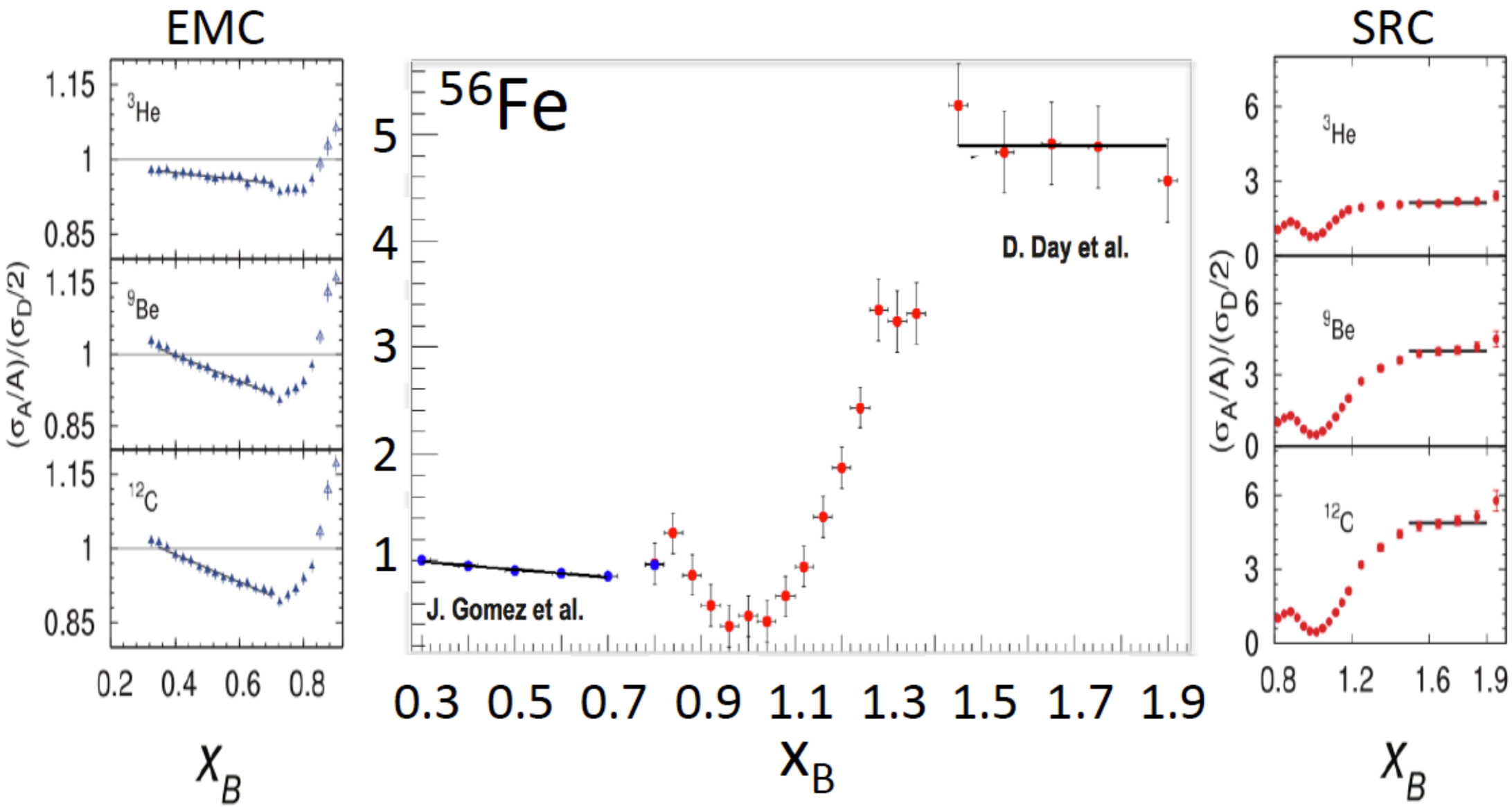

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$a_2(A/d)$

INTRODUCTION

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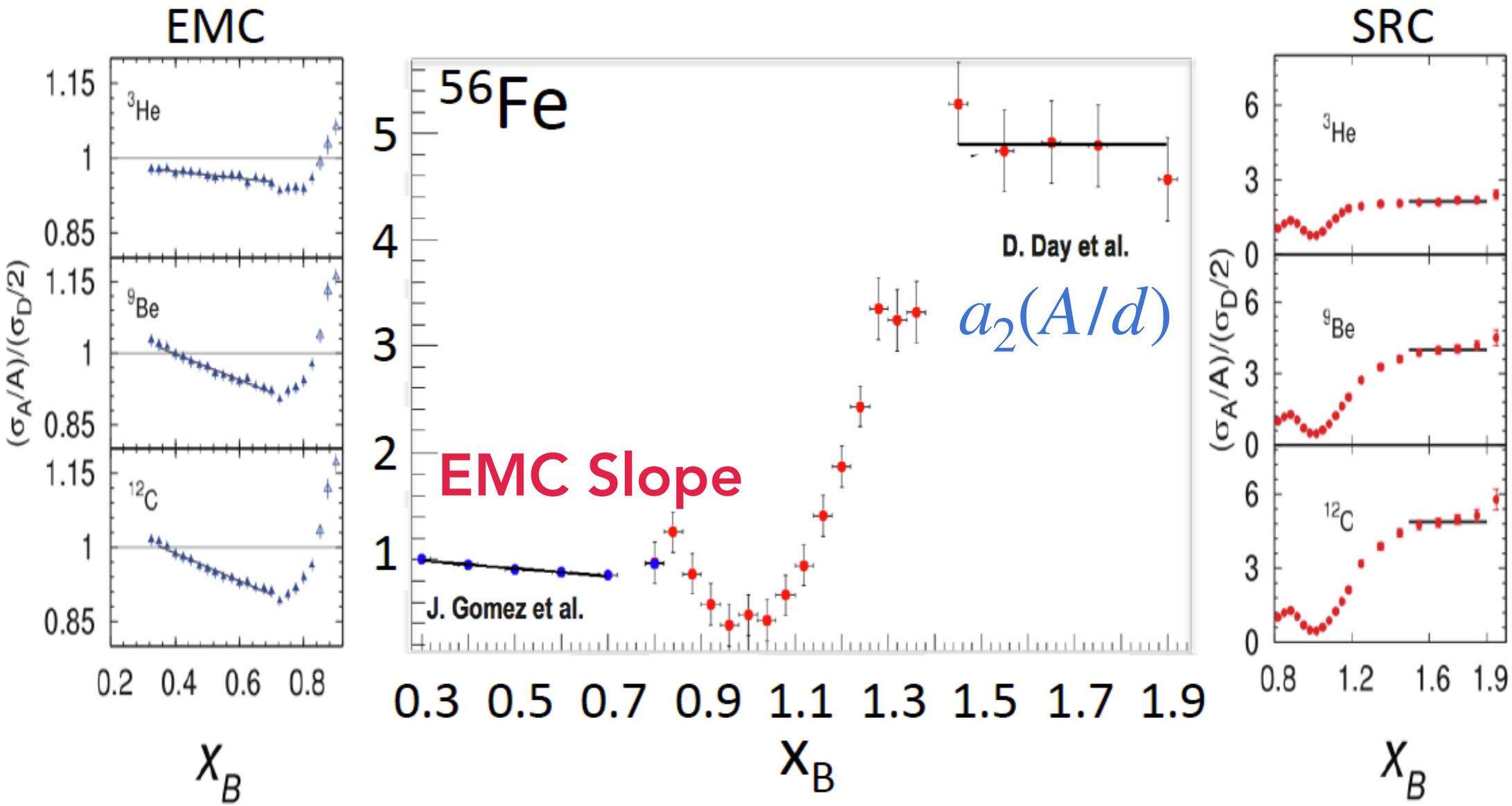

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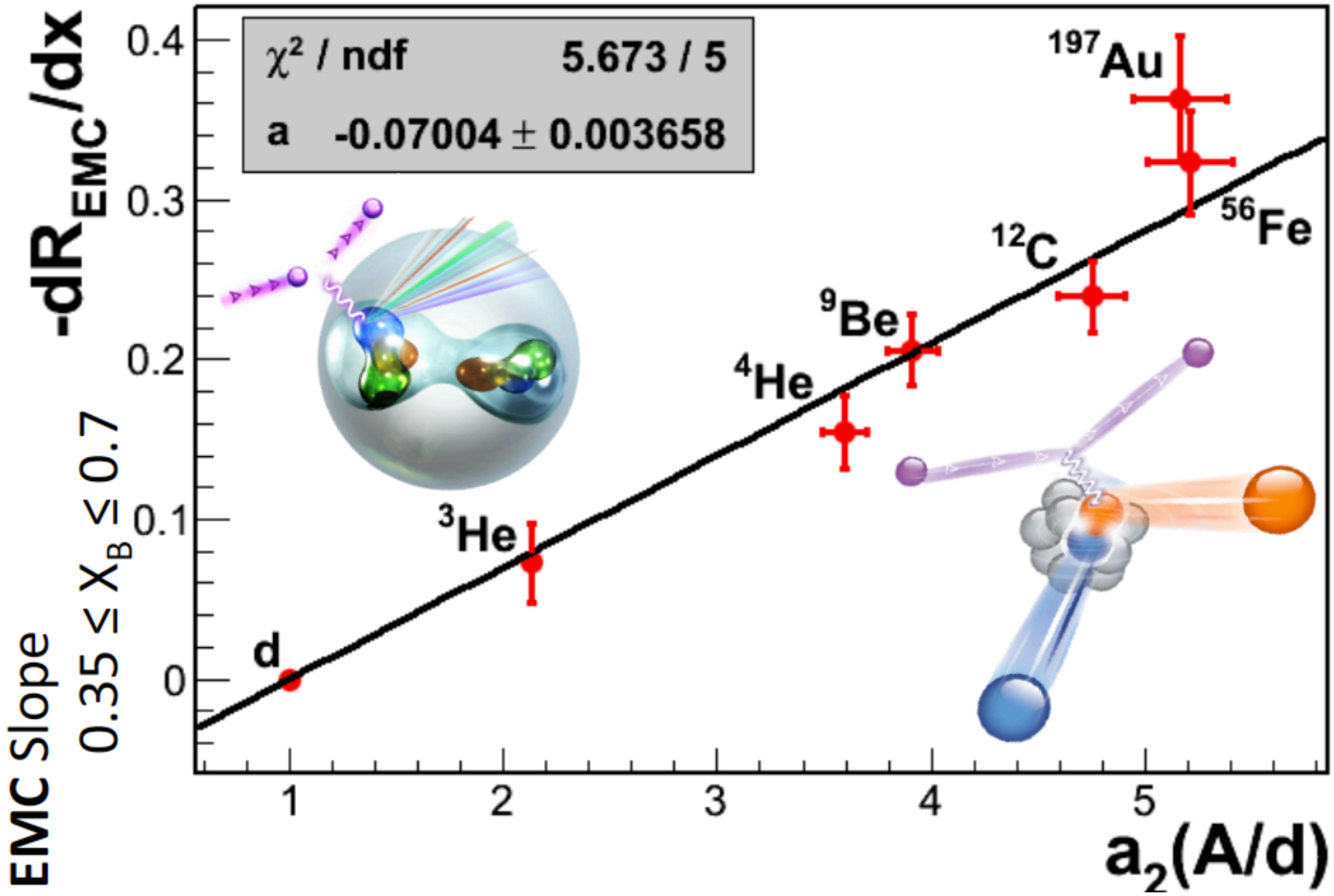
EMC slopes versus the SRC scale factors. The two values are strongly linearly correlated.



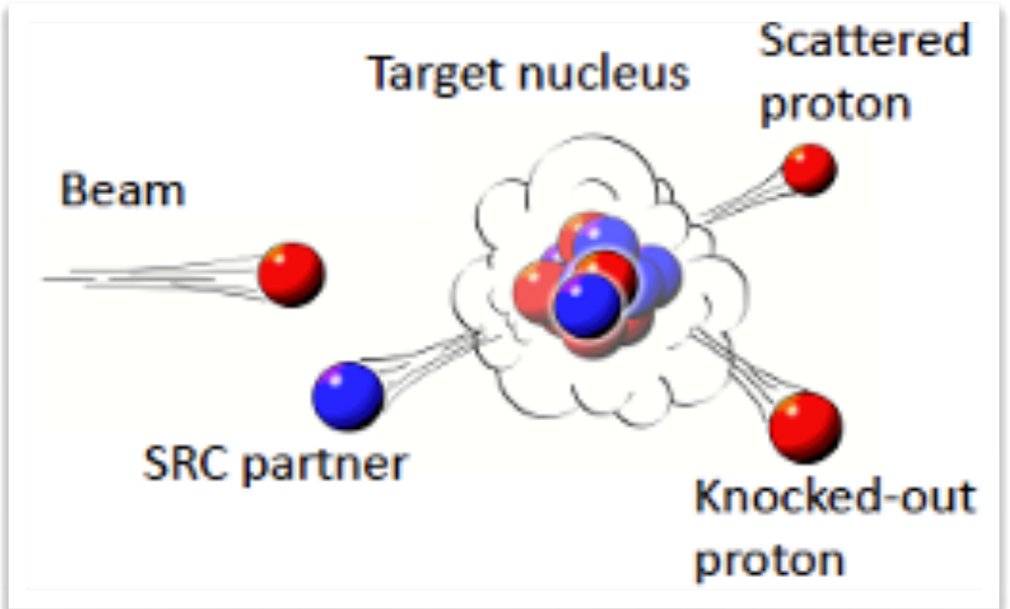
O. Hen et al., Int. J. Mod. Phys. E. **22**, 1330017 (2013).
O. Hen et al., Phys. Rev. C **85** (2012) 047301.
L. B. Weinstein, E. Piasetzky, D. W. Higinbotham, J. Gomez, O. Hen, R. Shneor, Phys. Rev. Lett. **106** (2011) 052301.

How we study Short Range Correlations?

PROBING SRC

Direct kinematics

- ☑ P_{miss}, E_{miss}, P_{recoil};
- ☑ P_{cm} (indirectly);
- ✗ Fragment ID.



Inverse kinematics

- ☑ P_{miss}, E_{miss}, P_{recoil};
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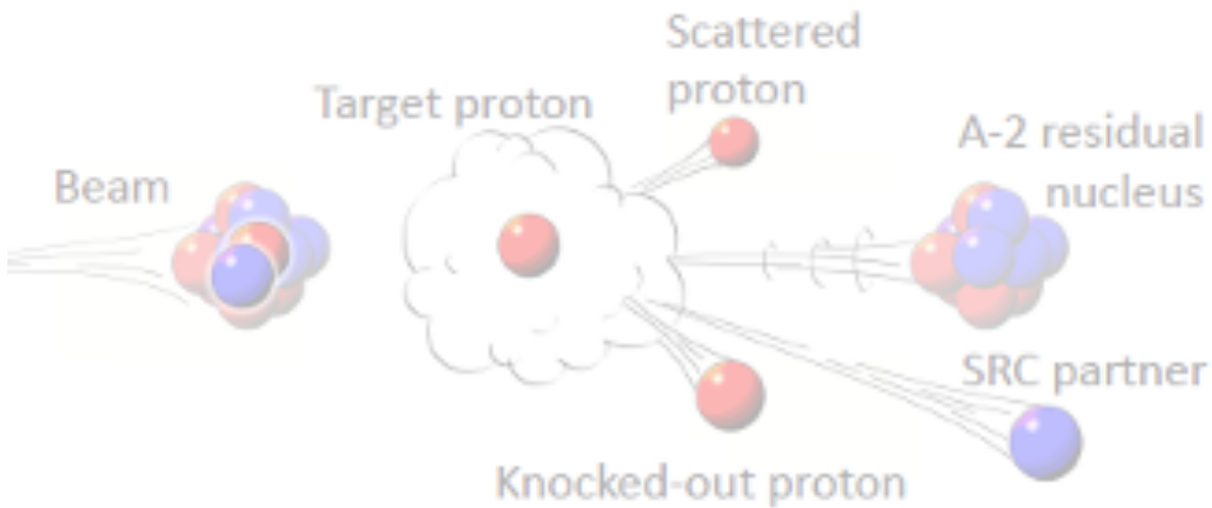
- ☑ Exotic nuclei;
- ☑ Higher cross-section for protons;
- ISI/FSI challenges data interpretation.



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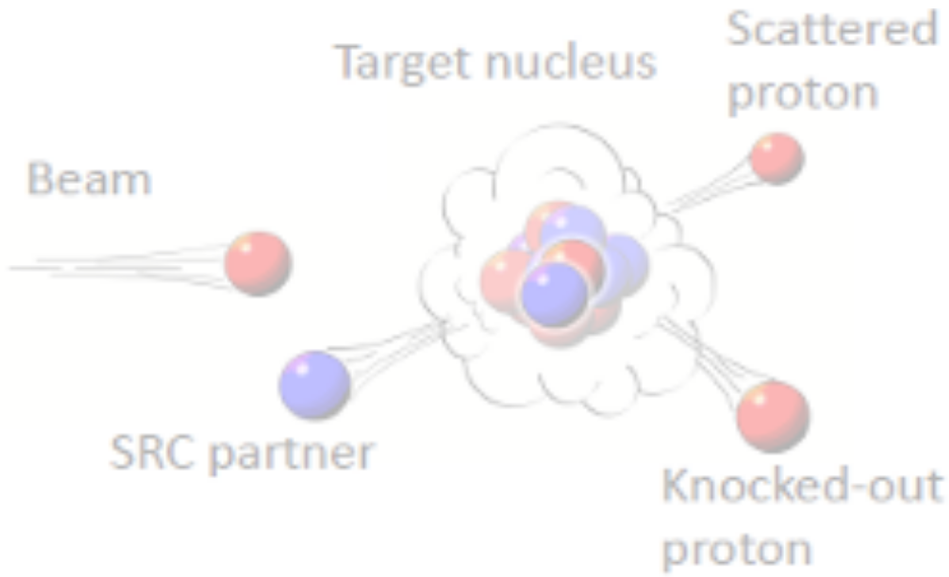

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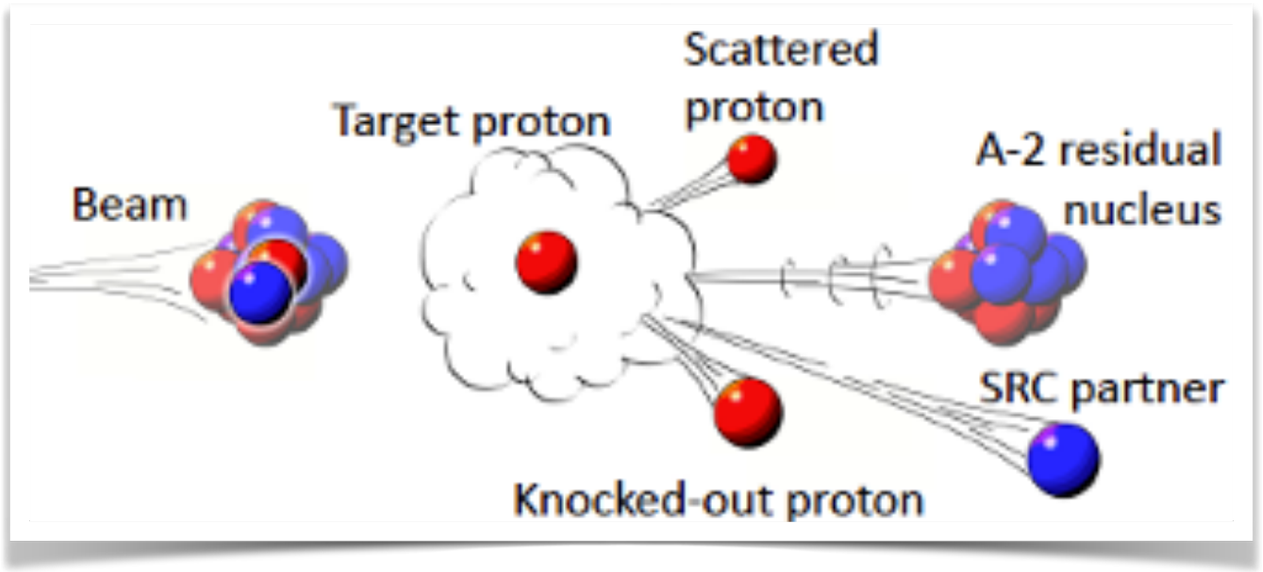

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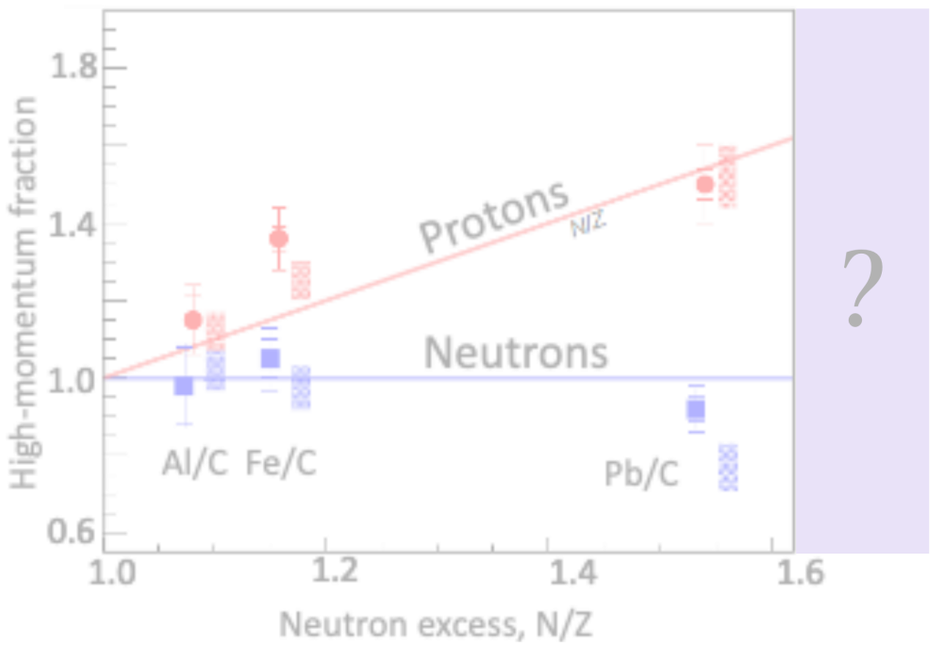


Adapted from M. Duer et al. (CLAS Collaboration), Nature, 560:617, 2018.

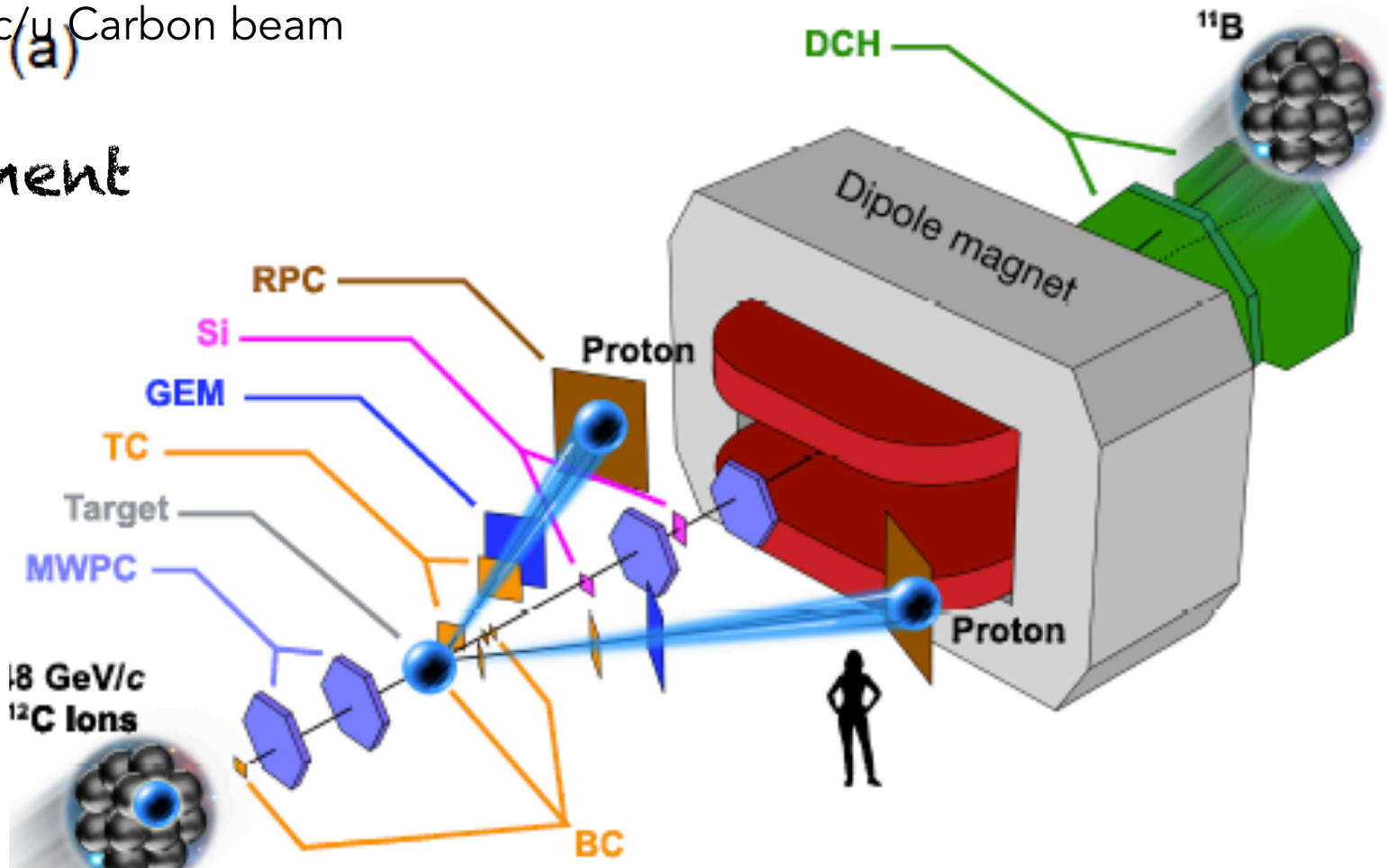
BM@N Experimental Set-up

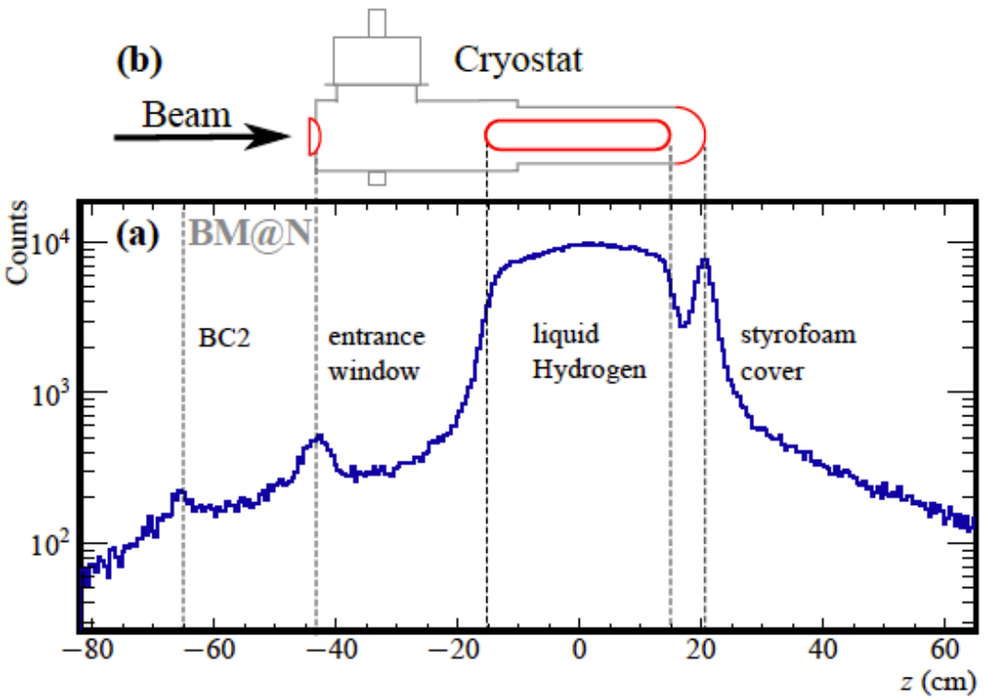
$^{12}C(p,2pN)$

Joint Institute for Nuclear Research (JINR), 4 GeV/c/u Carbon beam

Motivations JINR Experiment

- Test experiment;
- Test if SRCs are accessible in proton scattering in inverse kinematics;
- Study sensitivity to ISI/FSI induced distortions.





- tracking and momentum of the **two scattered protons** under large laboratory angles with two-arm spectrometer (TAS);
- **pair-recoil nucleon** (n or p) momentum;
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(P,2P) ANALYSIS FOR ^{12}C

- **(p,2p)** kinematics investigation with selection on ^{11}B**;**
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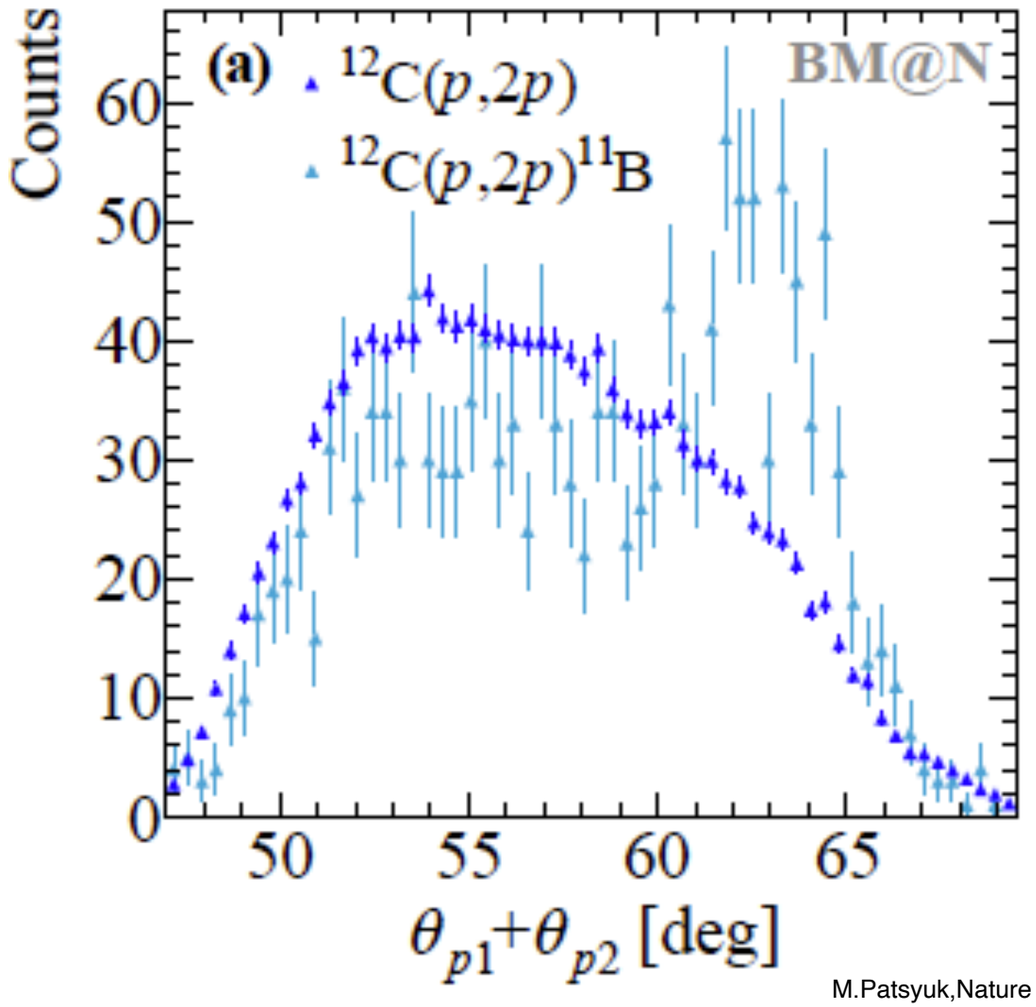
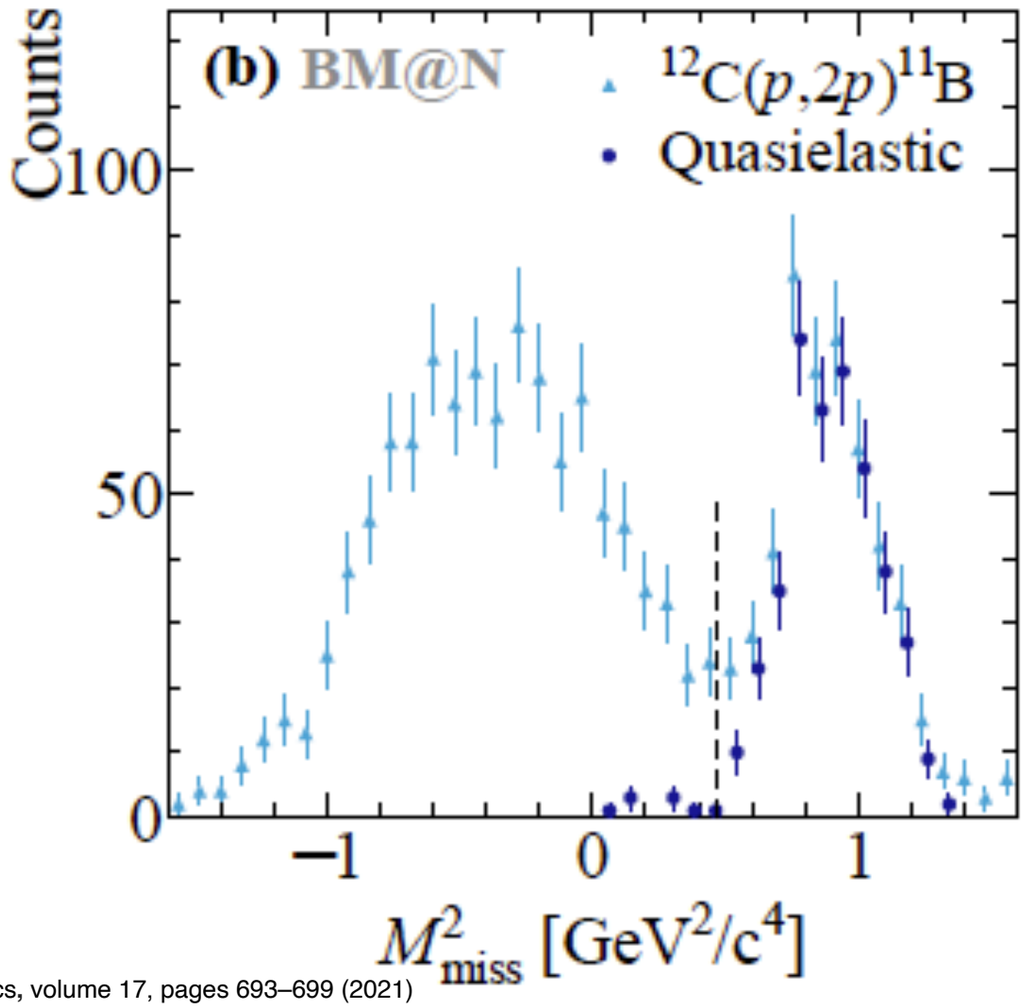
- Very strong effect for **ISI/FSI events rejection** selecting the transparent part of the reaction.





M.Patsyuk,Nature Physics, volume 17, pages 693–699 (2021)

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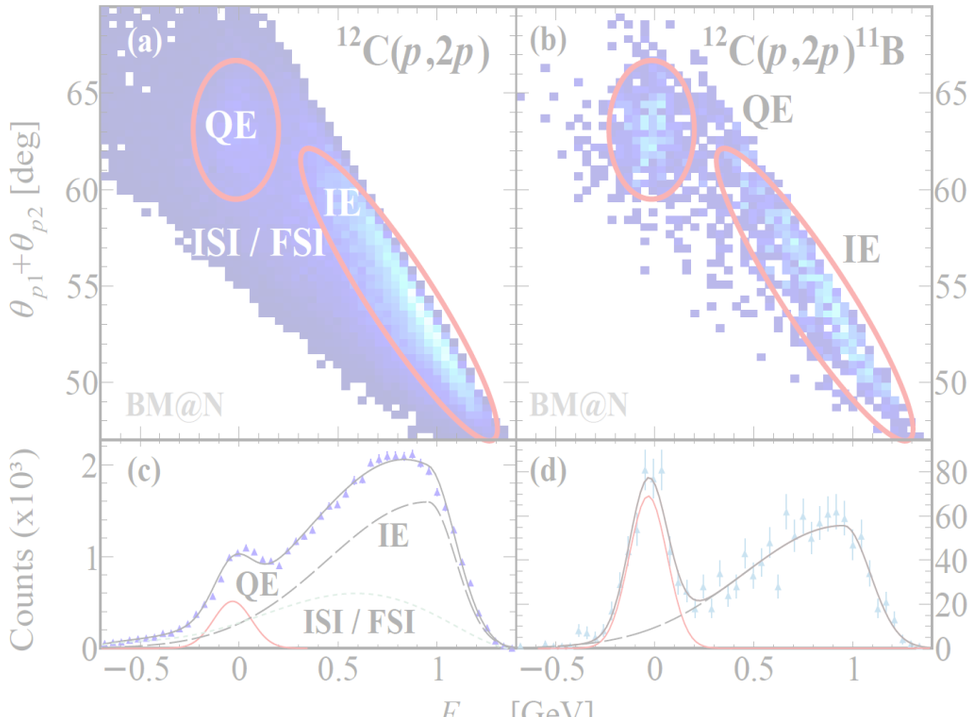

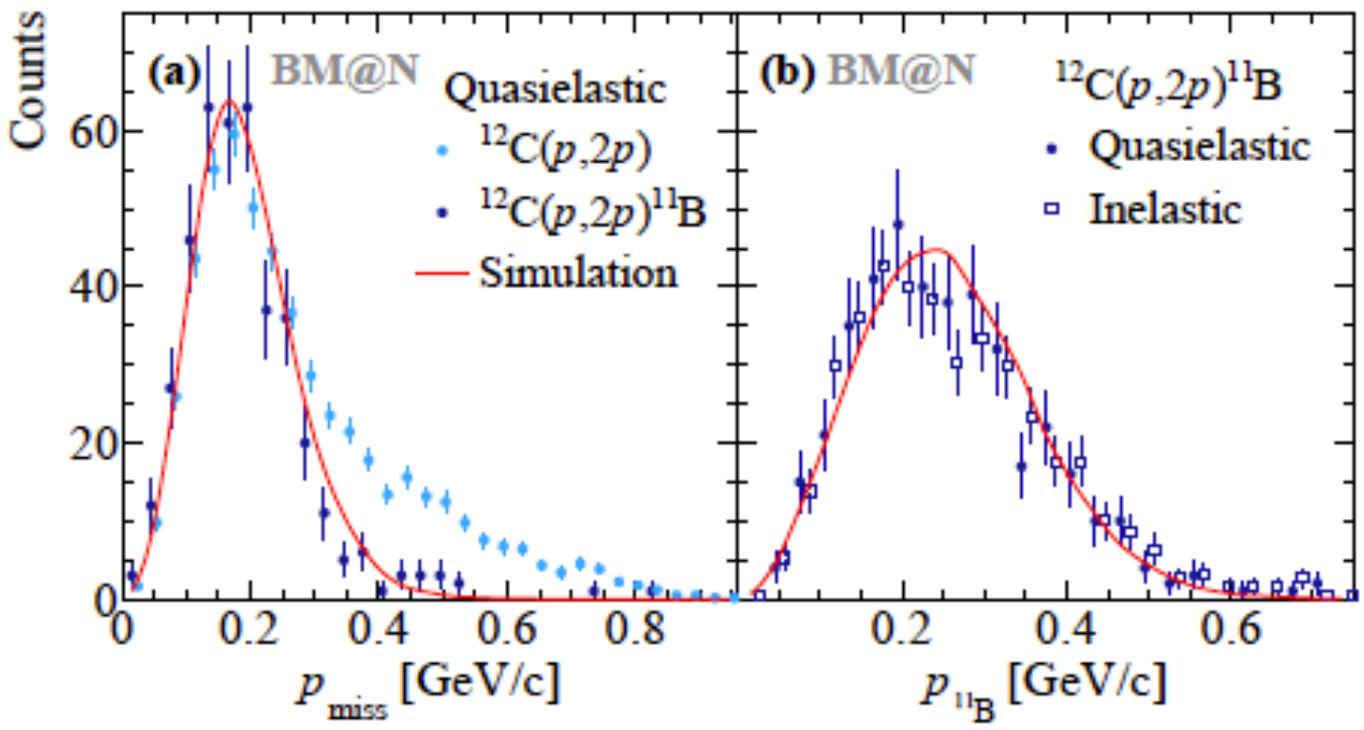

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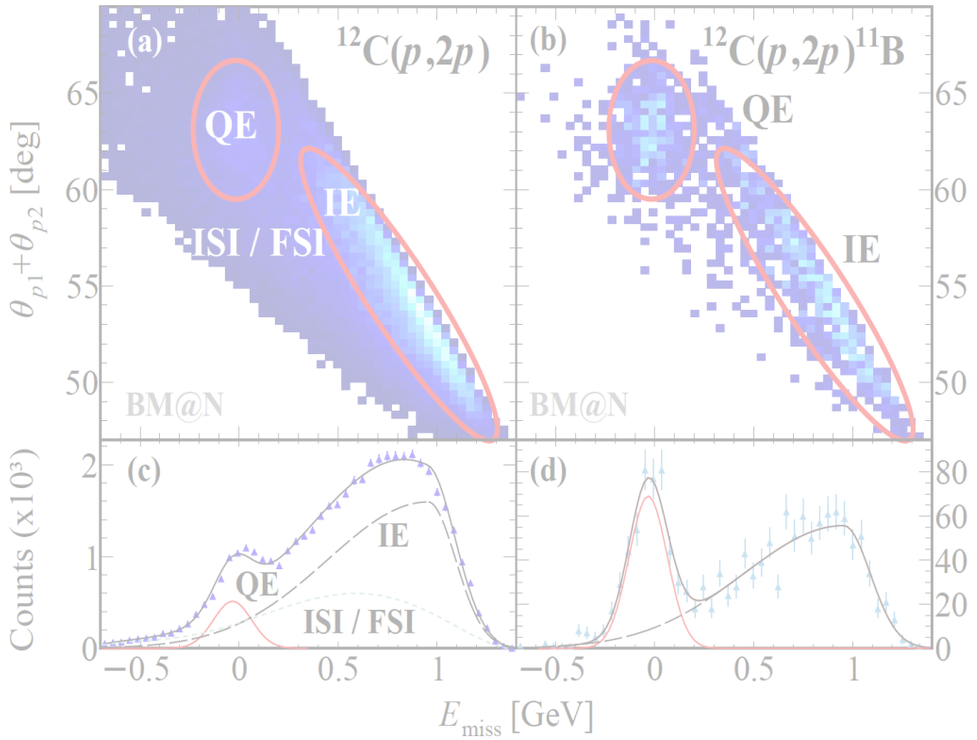

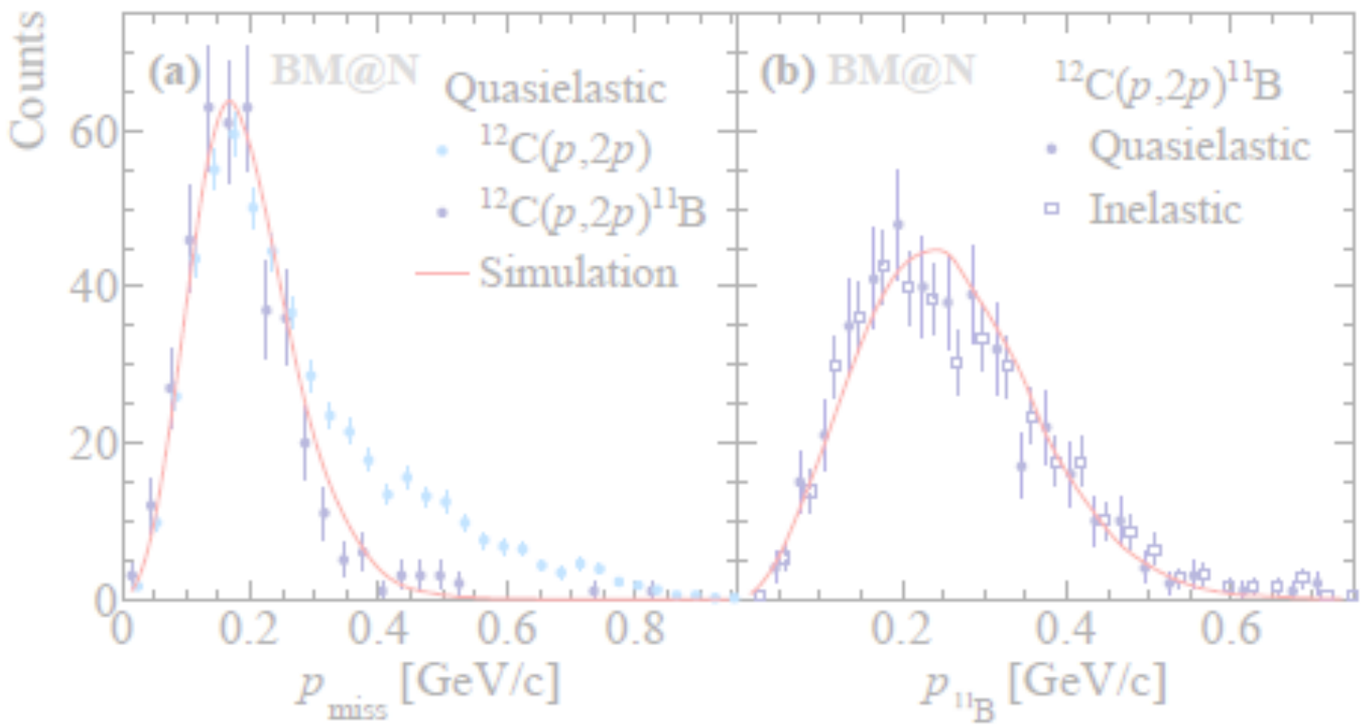

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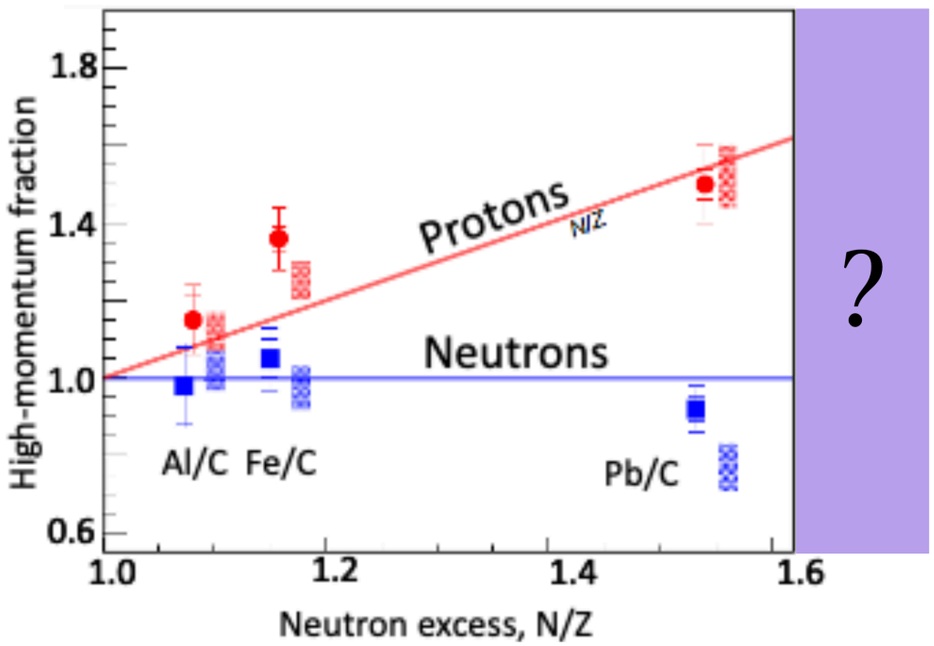

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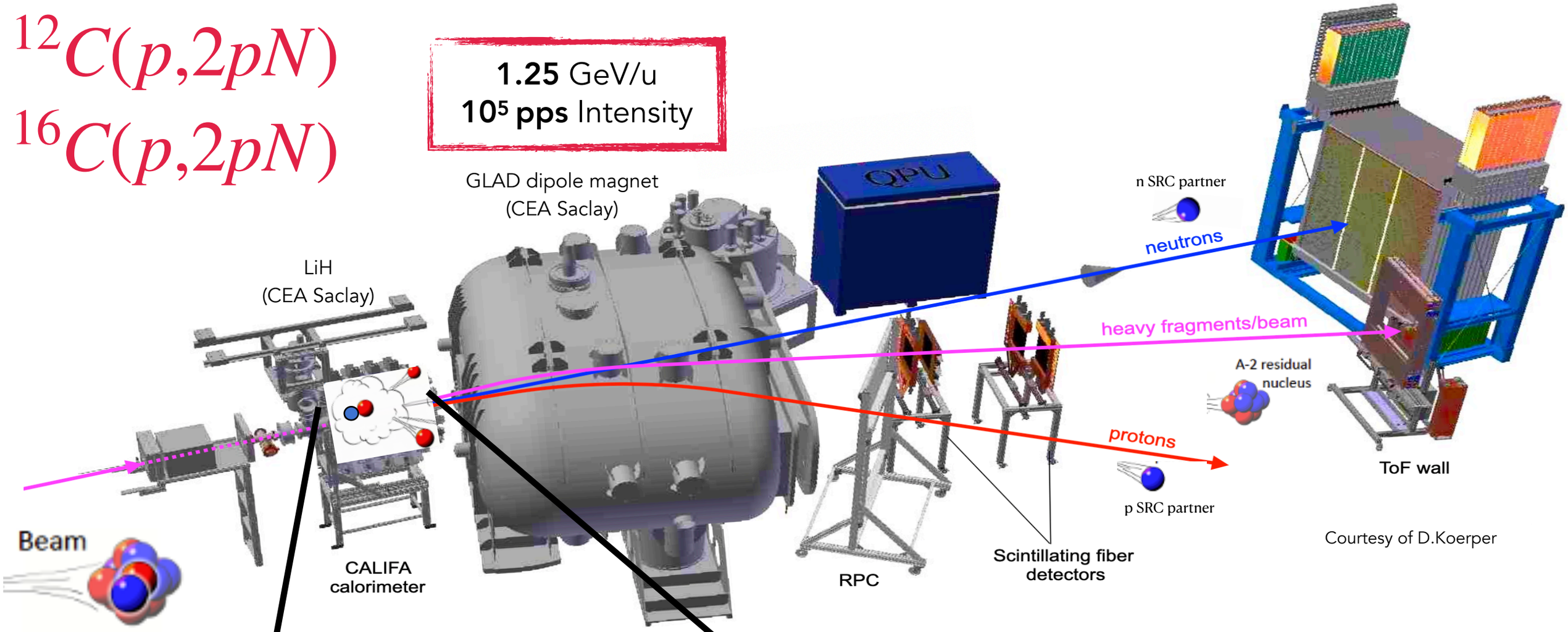
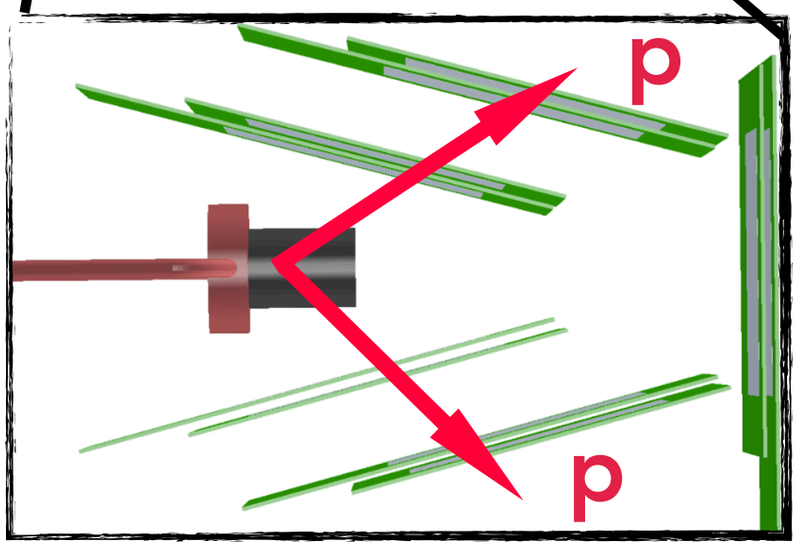
R^3B Experimental Set-up

$^{12}C(p,2pN)$

$^{16}C(p,2pN)$

1.25 GeV/u
10^5 pps Intensity





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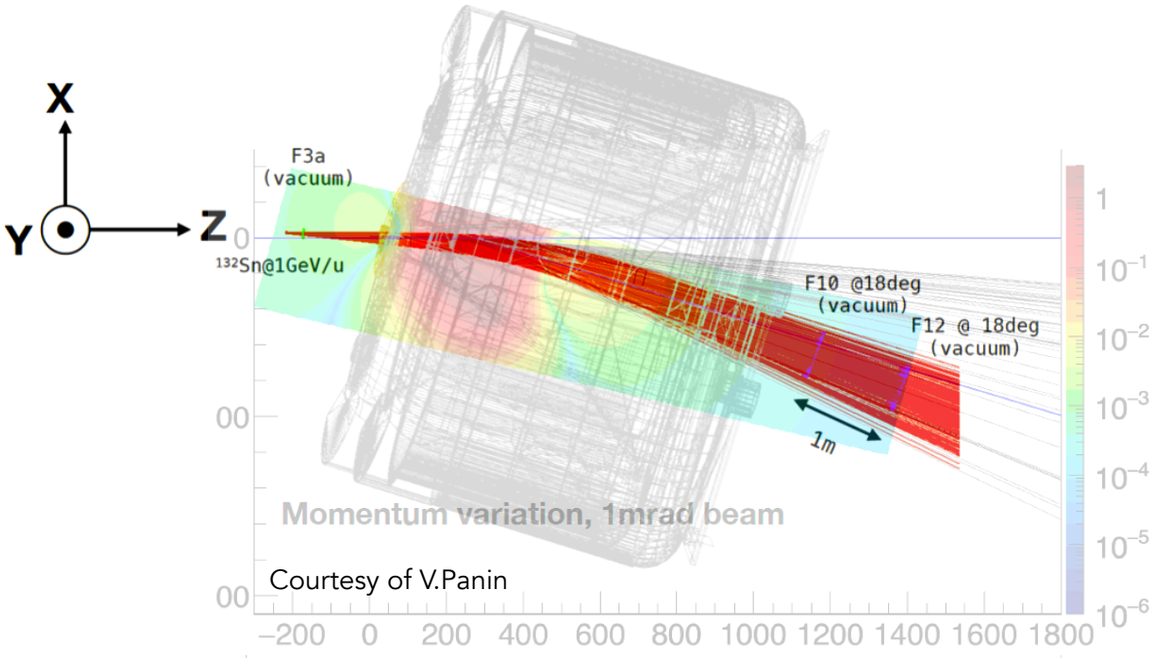
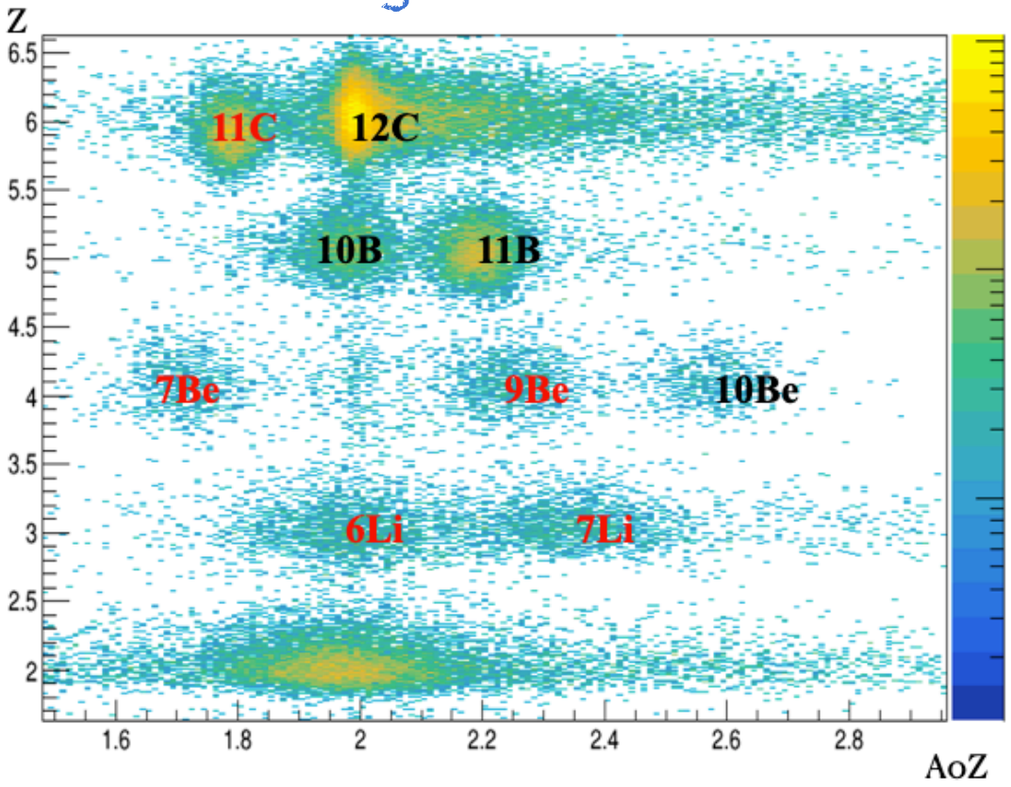
Fragment analysis: MDF Tracking



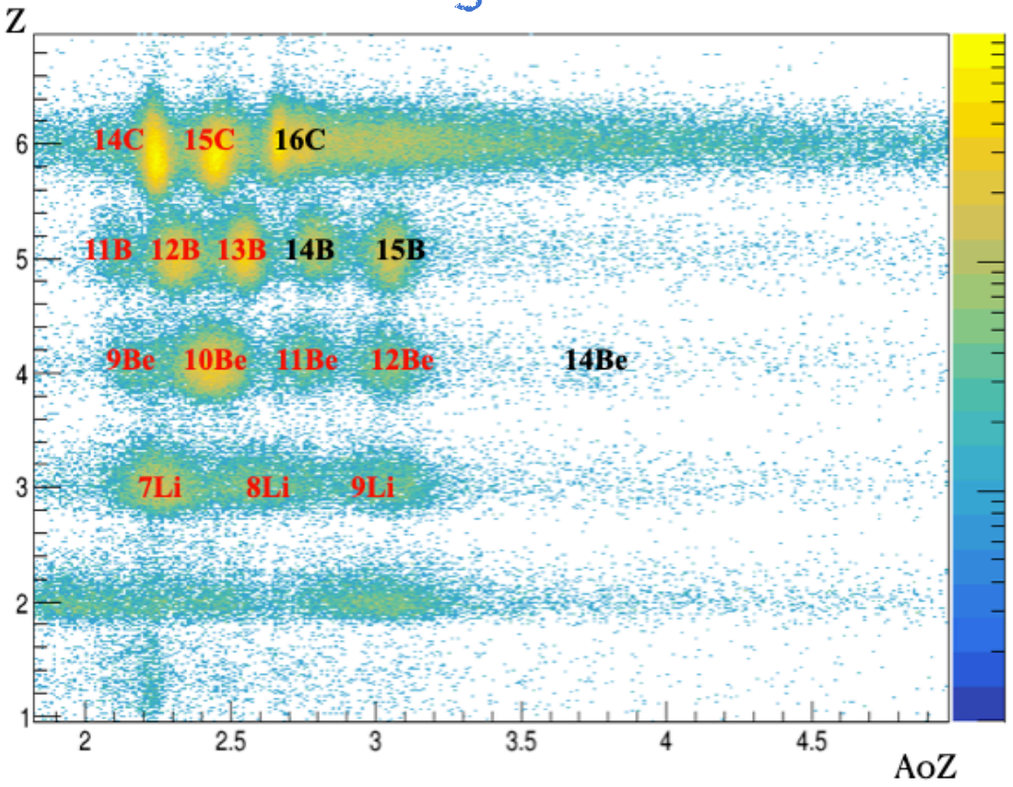
Multi-Dimensional Fit (MDF)

- Find an expression to correlate particle hit positions with their momentum;
- The function can then be used to compute the quantity of interest (**mass, momentum and angles**).

12C Fragments PID



16C Fragments PID



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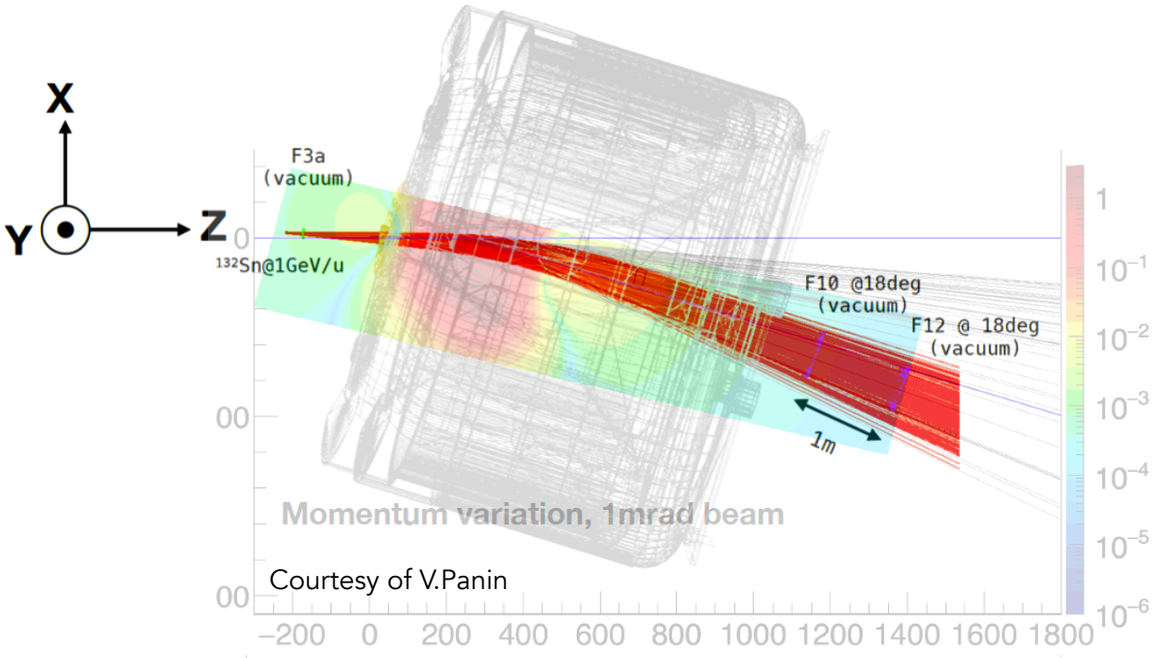

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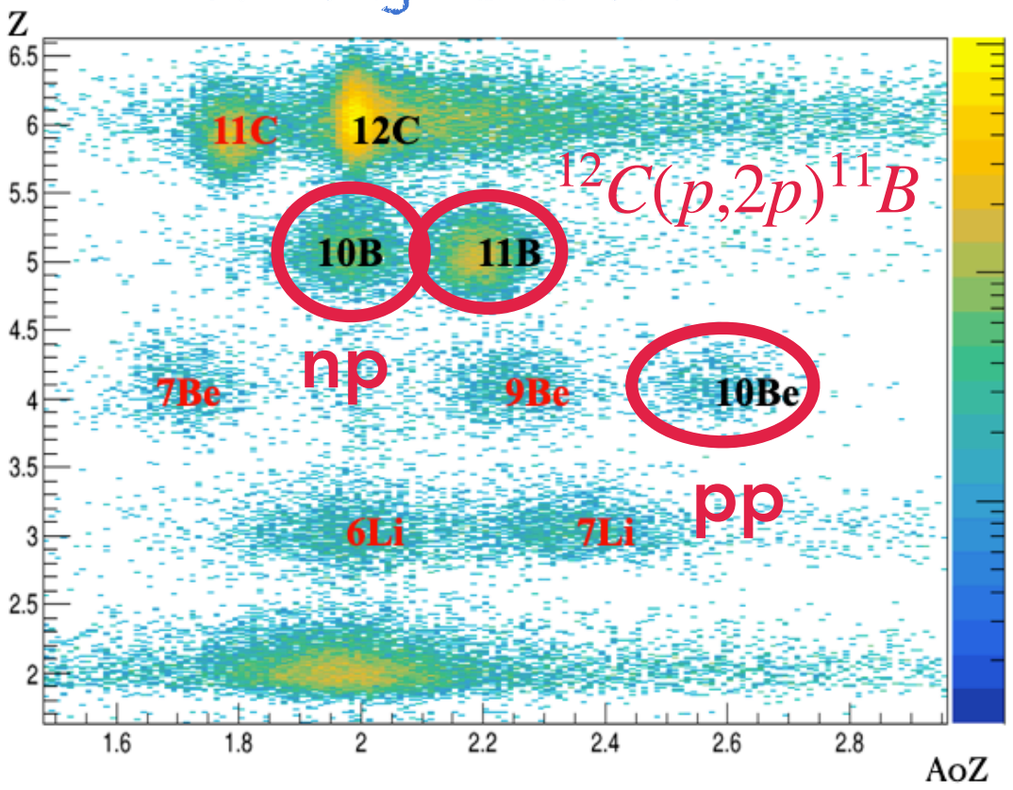

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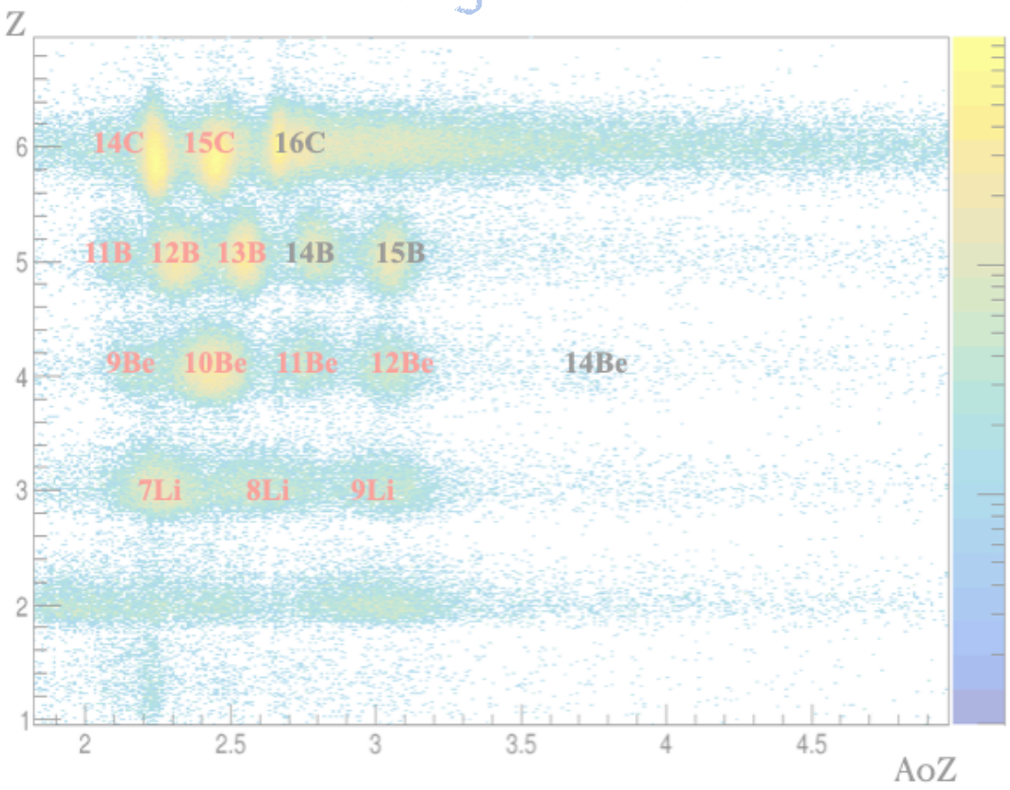

(p,2p) analysis for ^{12}C

ONGOING ANALYSIS

- **(p,2p)** kinematics investigation with selection on ^{11}B**;**
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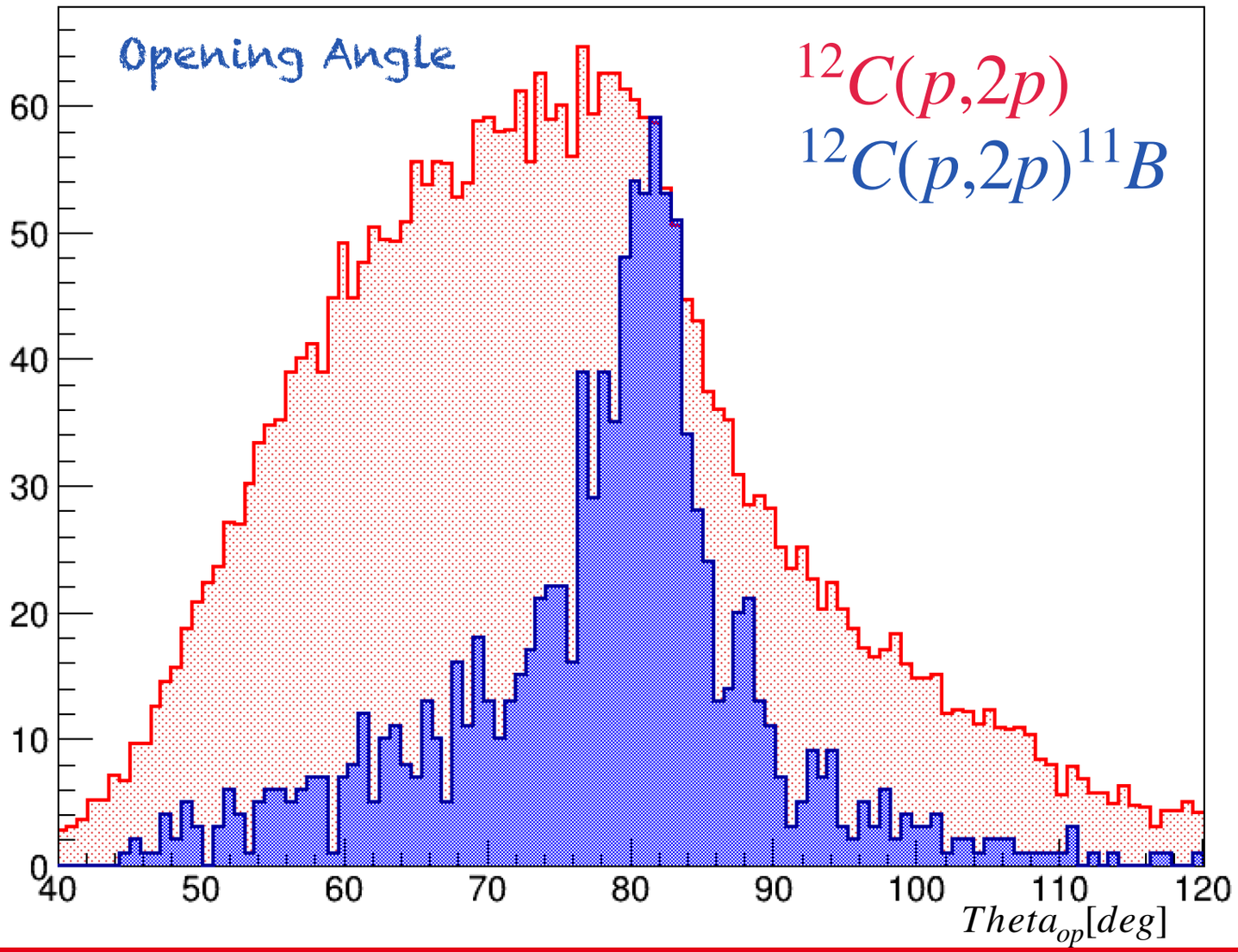

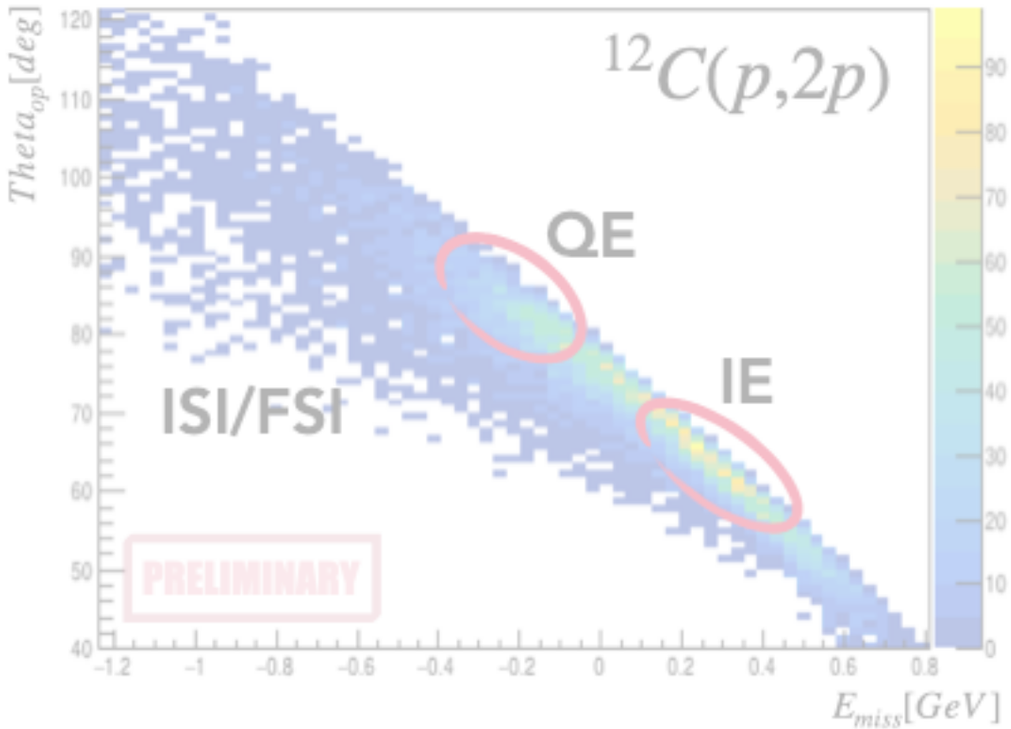

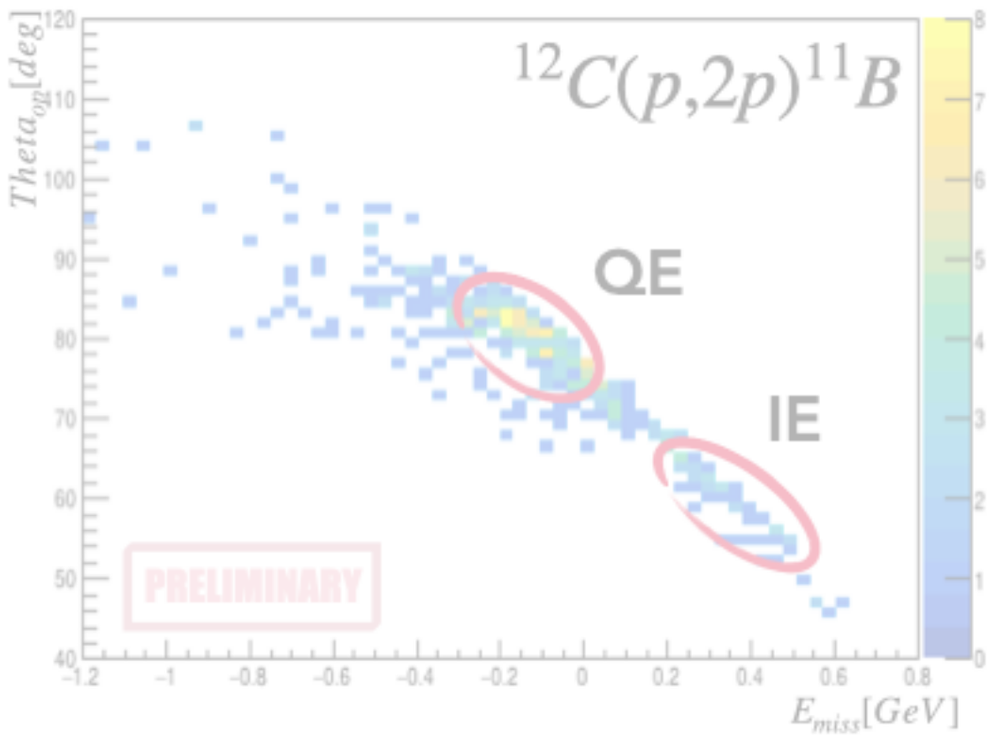

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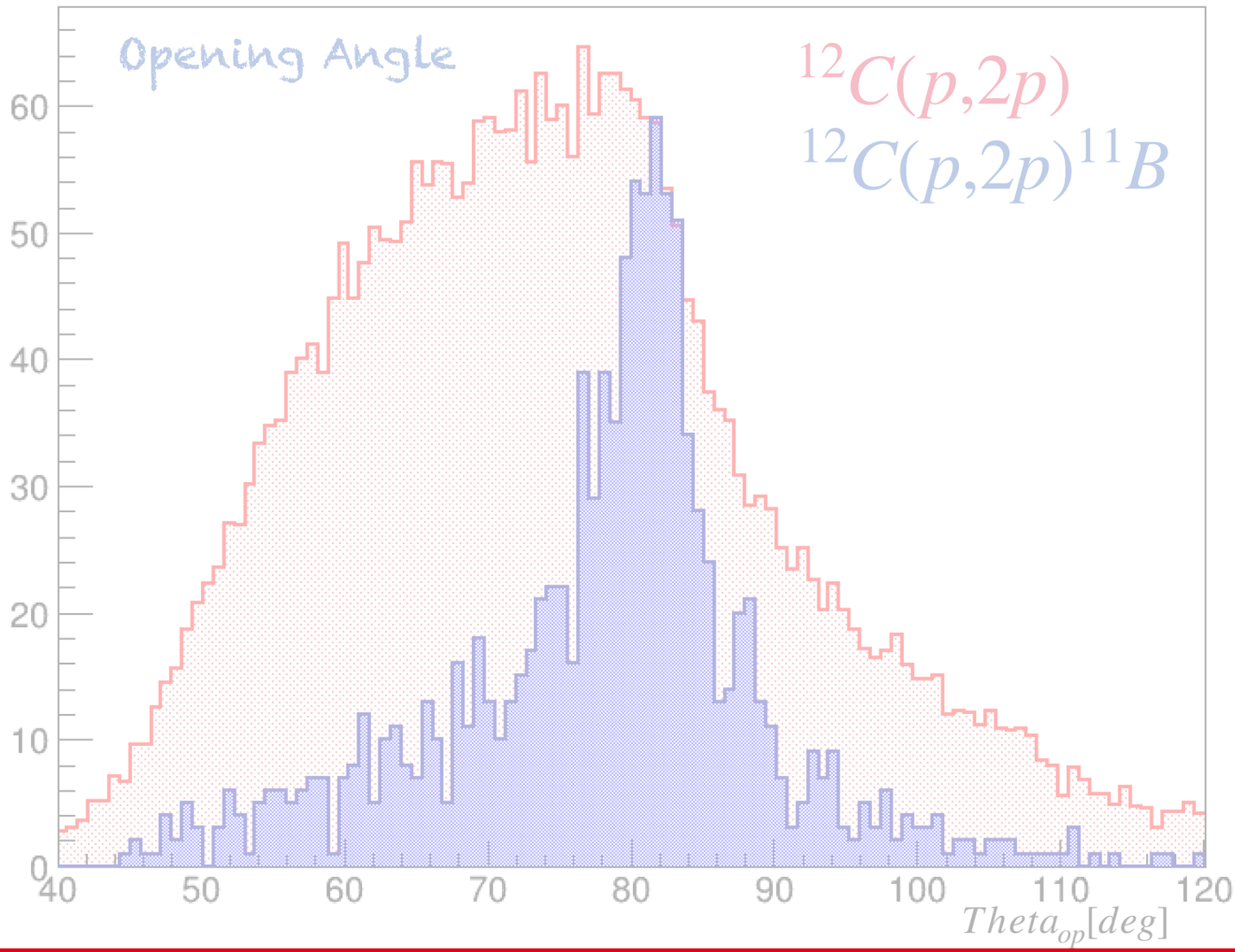

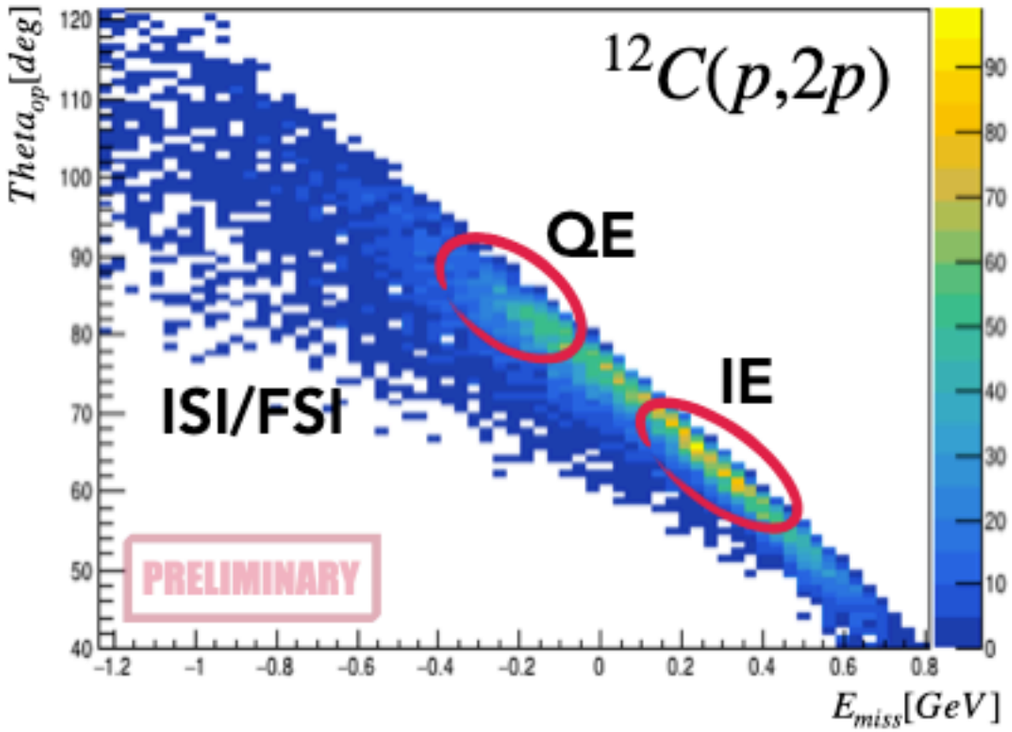

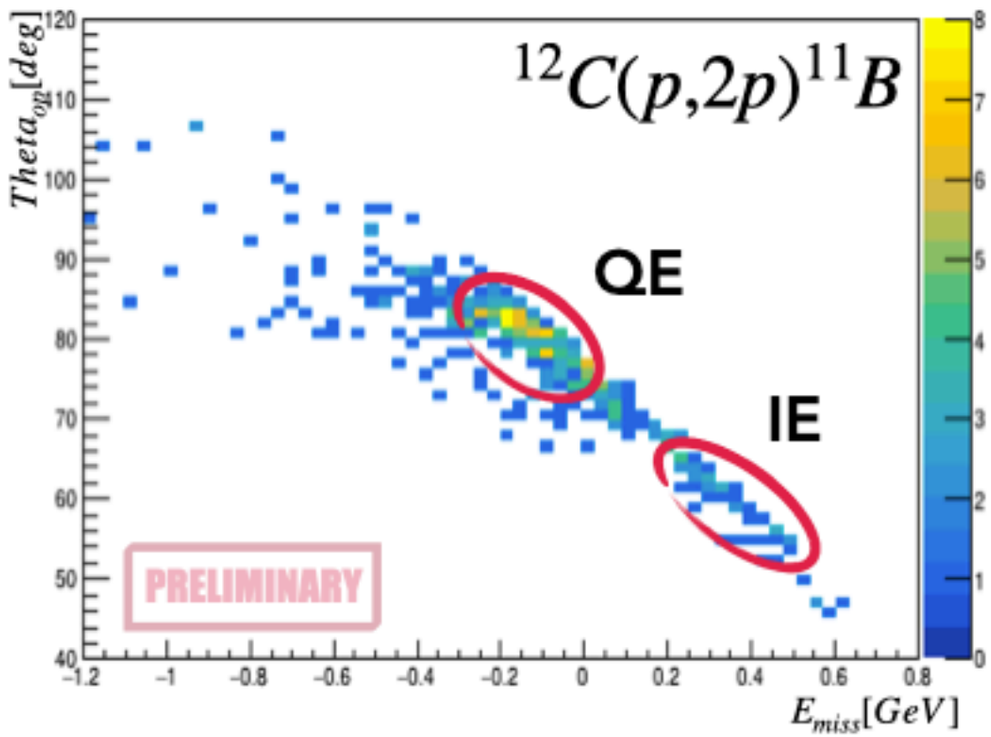

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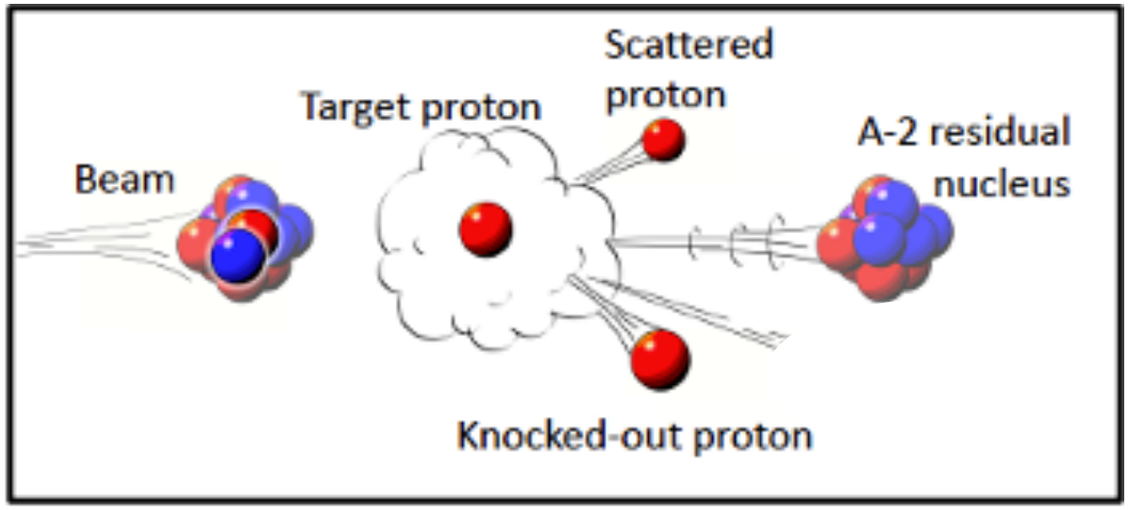

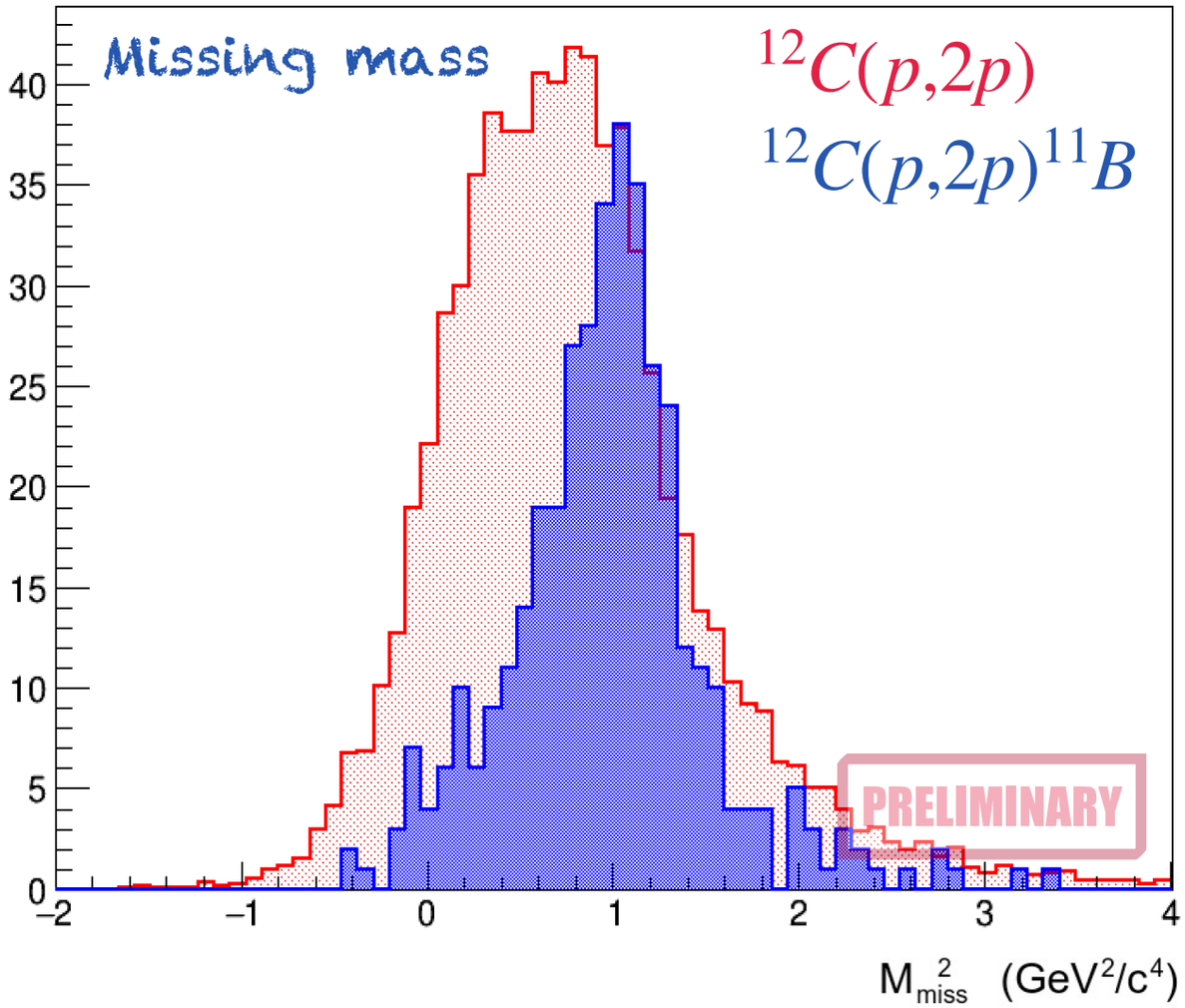

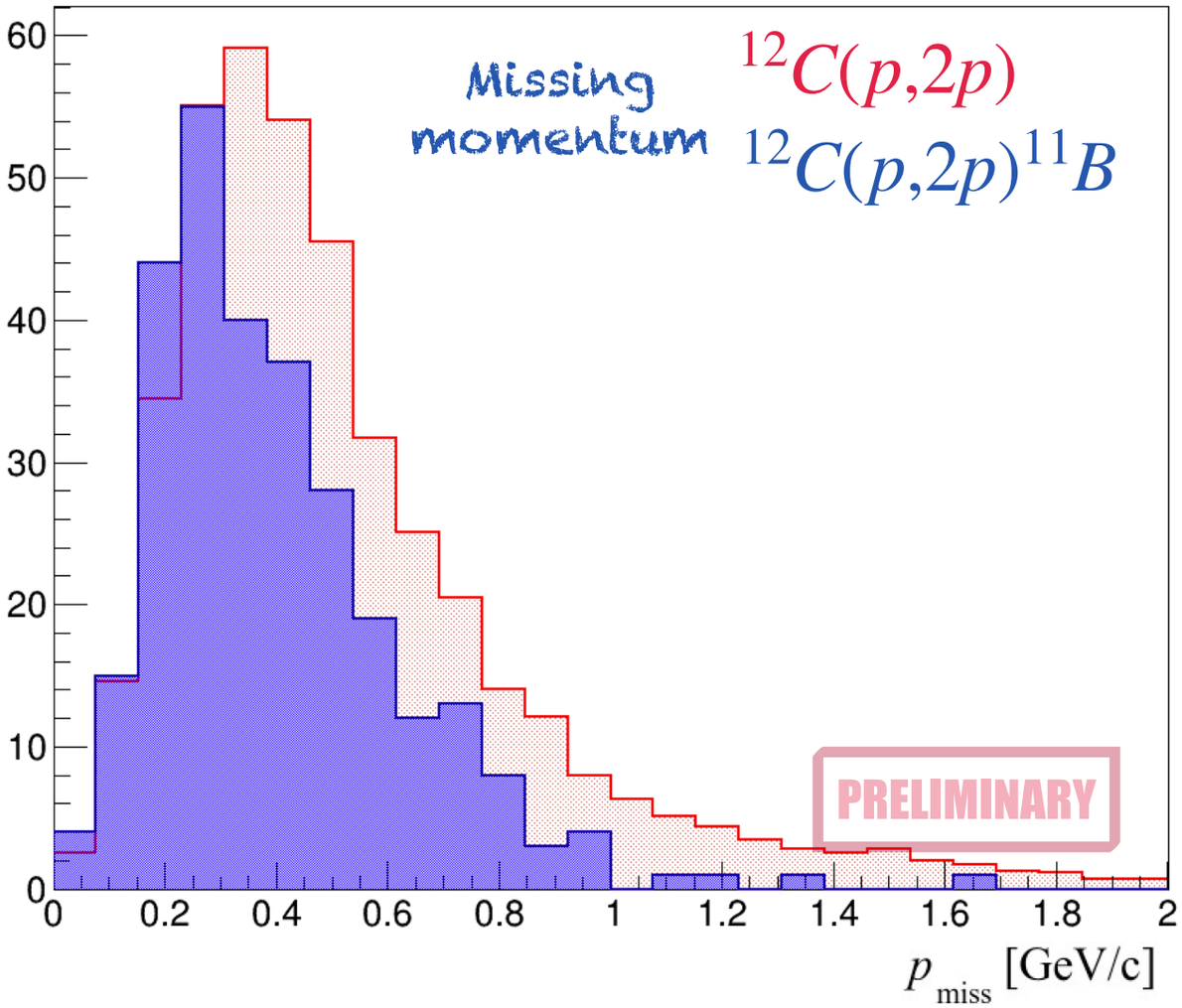

What's next?

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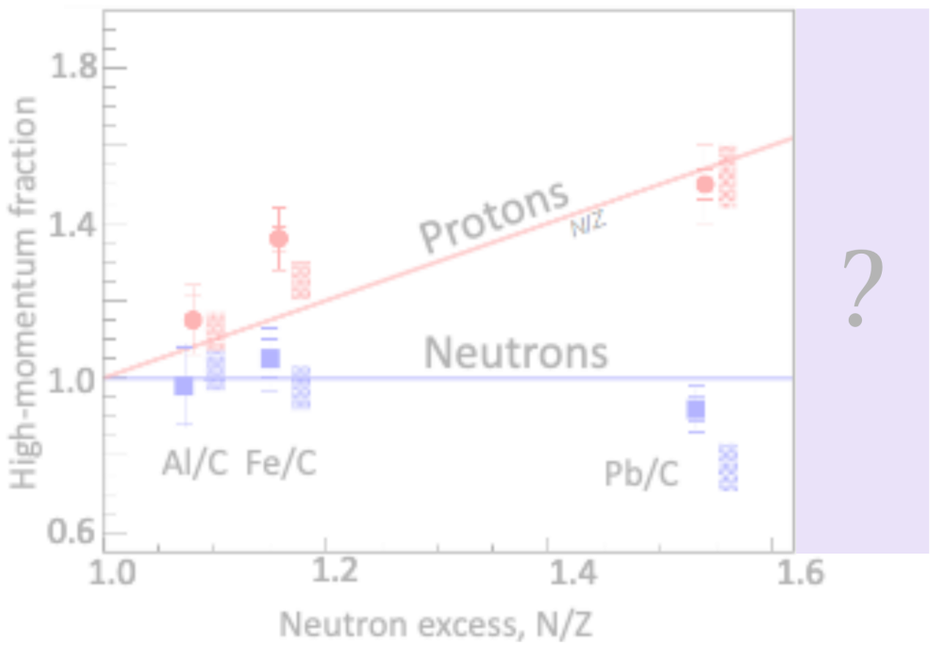

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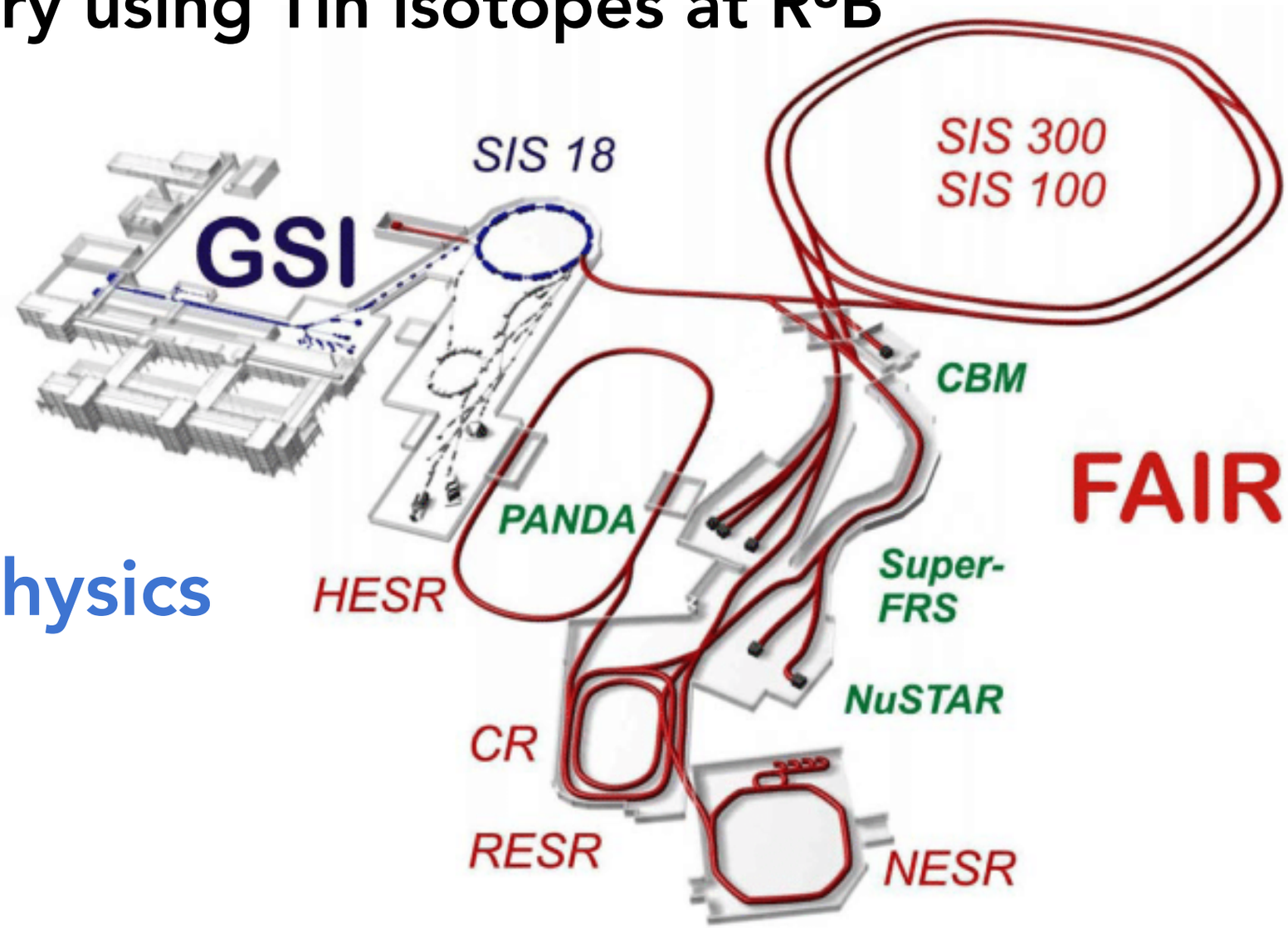
Perspectives

Short-Range Correlations as a function of mass and N/Z asymmetry using Tin isotopes at R³B



LoI for FAIR First Physics

R³B FAIR GSI

T.Aumann, M.Duer (TU Darmstadt), J.Benlliure, D.Cortina (University of Santiago de Compostela), A.Corsi (CEA Saclay), O.Hen, J.Kahlbow (MIT), V.Panin (GSI), S.Paschalis, M.Petri (York University), E.Piasetzky (Tel Aviv University), …..

Perspectives

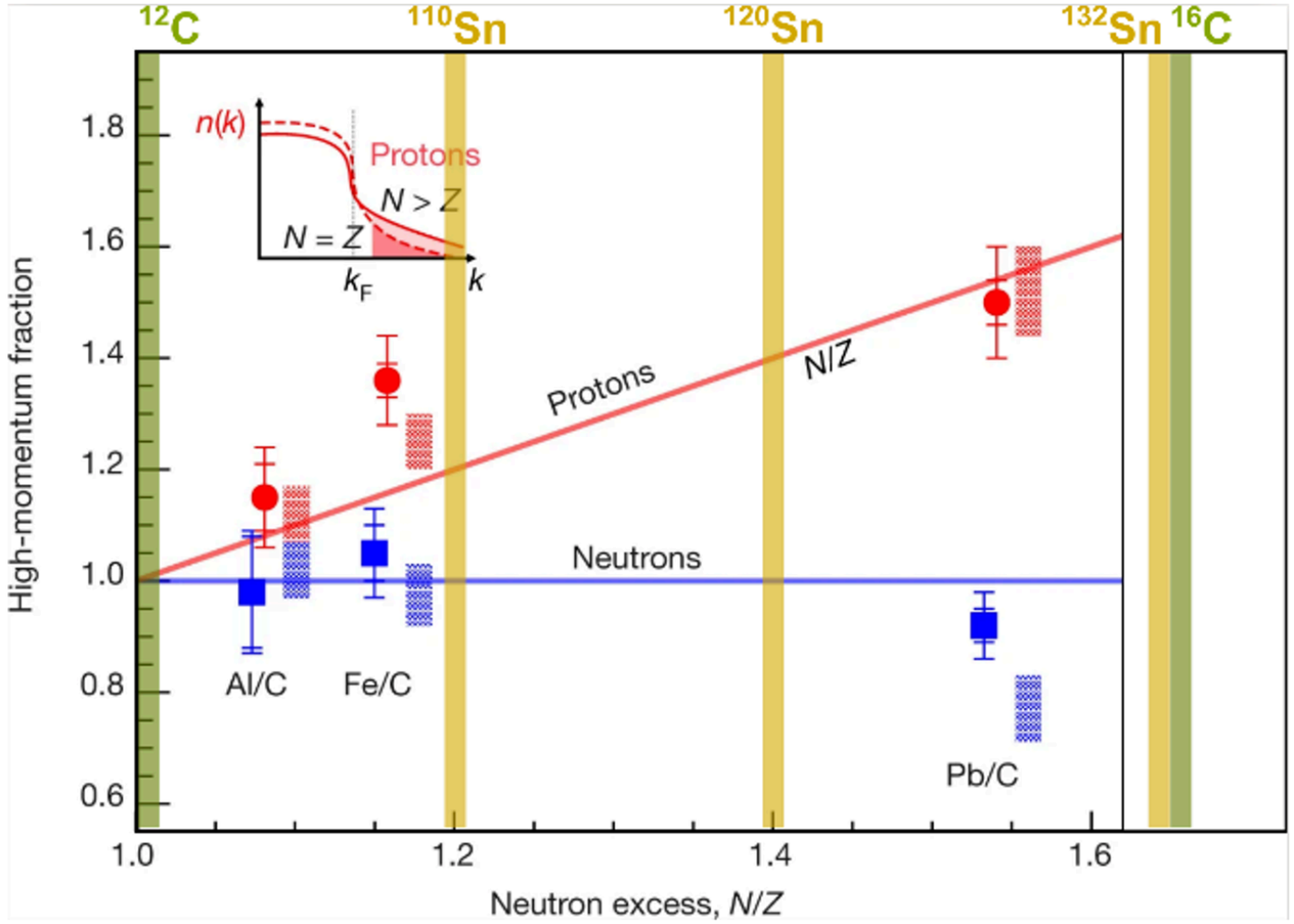
GOAL: probe pair ratios, relative and center of mass momentum, and fragment final state in at and around magic numbers, at different A and N/Z.

- ^{110,120,132}**Sn** @ 1 GeV/u on 5 cm LH2 target;
- ^{132}**Sn** from ^{238}**U coulex**, ^{110,120}**Sn** from ^{136}**Xe fragmentation.**

-**132Sn**: doubly magic, n-rich;

-**120Sn**: ref. Channel with e scattering (and same N/Z as 48Ca);

-**110Sn**: small N/Z.



Thanks for your attention!