



Probing nucleon-nucleon correlations in atomic nuclei via (p,pd) QFS reactions

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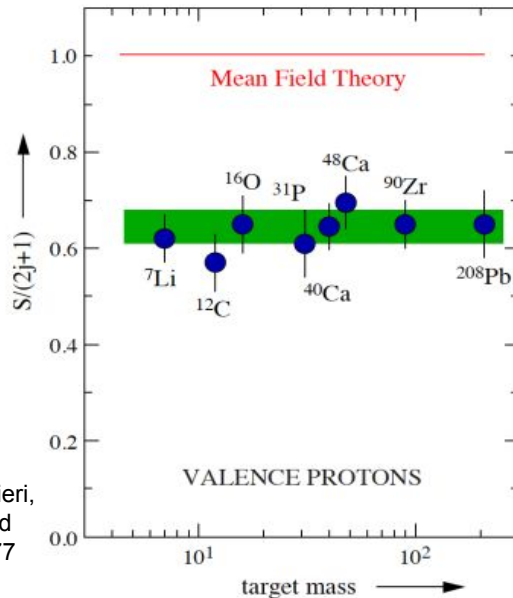
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Nucleon-Nucleon Correlations



- The independent particle model describes many properties of the atomic nucleus very well.
- However the IPM does not account for all interactions between the nucleons.
- This has been observed experimentally through the reduction in spectroscopic factors.



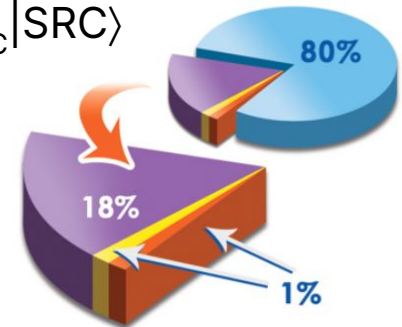
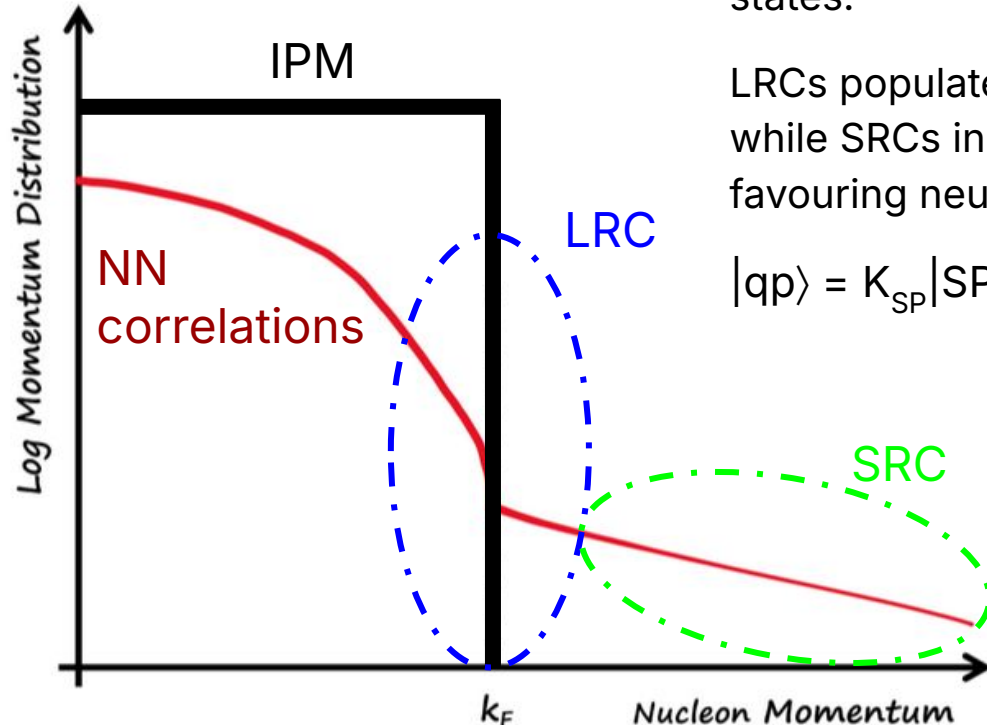
Attributed to **Nucleon-Nucleon correlations**, denoted Short (SRC) and Long Range Correlations (LRC).

Nucleon-Nucleon Correlations

NN Correlations deplete 30-40% of single particle states.

LRCs populate states close to the Fermi momentum, while SRCs induce a high momentum tail well above k_F , favouring neutron-proton pairs.

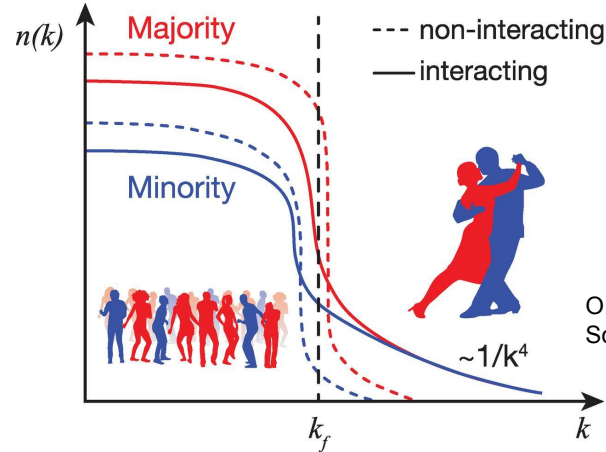
$$|qp\rangle = K_{SP}|SP\rangle + K_{LRC}|LRC\rangle + K_{SRC}|SRC\rangle$$



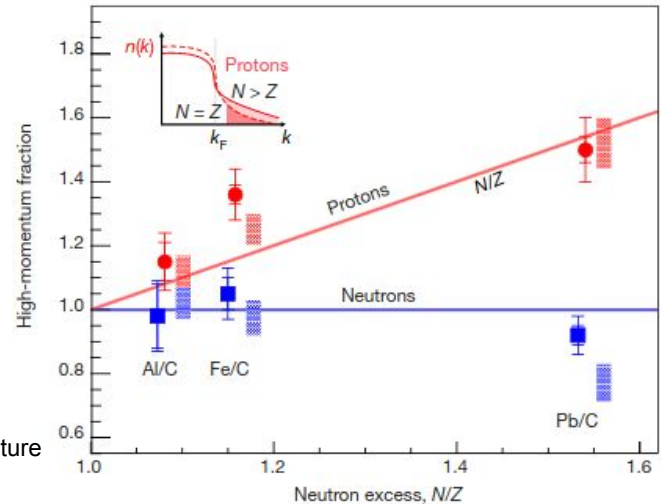
Single nucleons
n-p n-n p-p

SRCs in Experiments

- Experimental effort at JLab to directly break up and tag the SRC pair, via $(e, e'p)$ and $(e, e'n)$ reactions.
- Results suggest fraction of high momentum (SRC) protons increases with neutron richness.
- Indication of SRC dependency on isospin.
- Are there other ways to probe the SRC pair and isospin dependence?



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



M. Duer et al., Nature
560, 617 (2018).

Motivation



We follow the seminal discussions of Brueckner:

*"The evidence is that for relative distances less than roughly 10^{-13} cm, nucleon pairs in nuclei are correlated in the same way as they are in the **deuteron** or in free scattering processes"*

[from K.A. Brueckner, Proceedings of the Rutherford Jubilee Int. Conf. Manchester 1961, Ed. J.B.Birks, London, **1961**]

SRCs are a manifestation of the tensor part of the NN interaction which favours the $S=1, T=0$ (quasi-deuteron) channel.

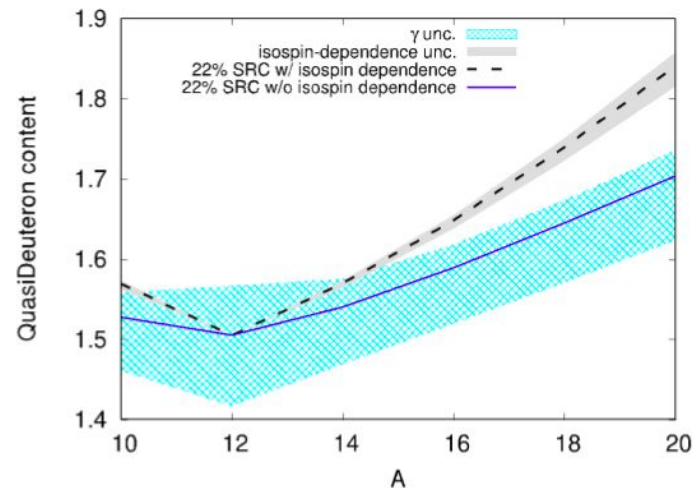
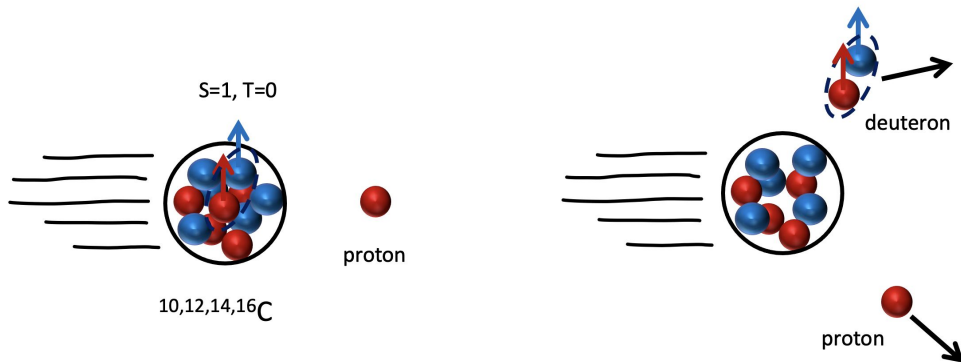
A "bare" nucleon in the presence of the SRC components of the NN interaction becomes "dressed" in a quasi-deuteron cloud, about 20% of the time with an **isospin dependence**.

$$|qp\rangle \sim 80\% |p\rangle + 20\% |h\rangle \otimes |qd\rangle$$

Probing Short Range Correlations via (p,pd) Quasi-Free Scattering Reactions

Aims:

- Investigate the SRC dependence on isospin.
- Measure (p,pd) Quasi-Free Scattering cross sections of $^{10,14,16}\text{C}$ relative to ^{12}C at 400MeV/u.

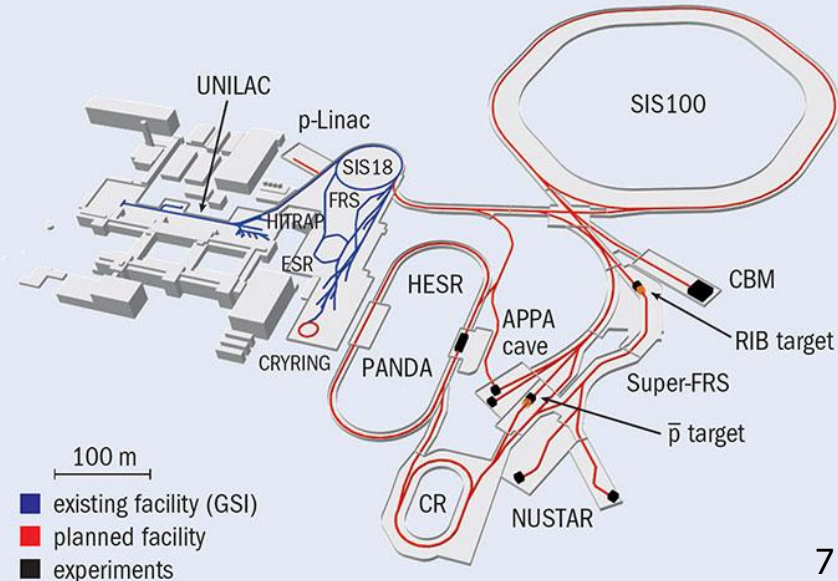
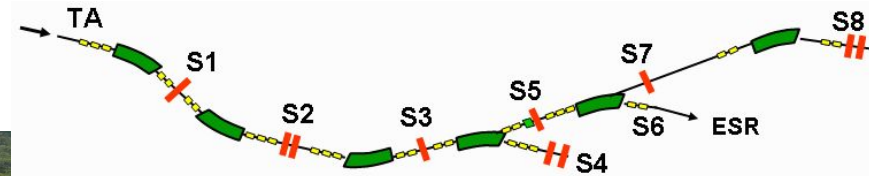


R3B @ GSI-FAIR

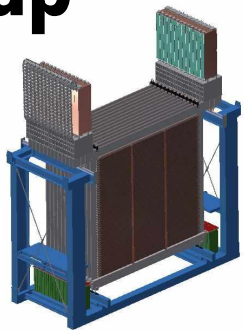
Complete kinematical reconstruction of reaction.
Fragment Separator (FRS) provides exotic
beams to R3B.



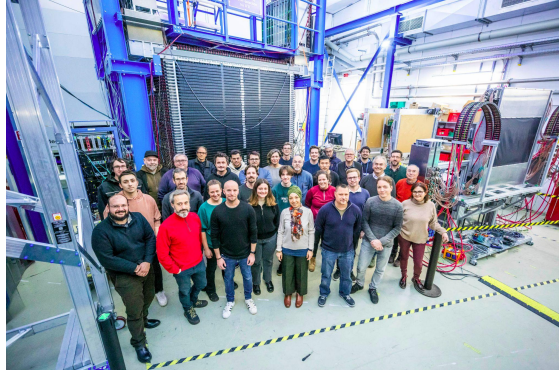
R³B



Setup

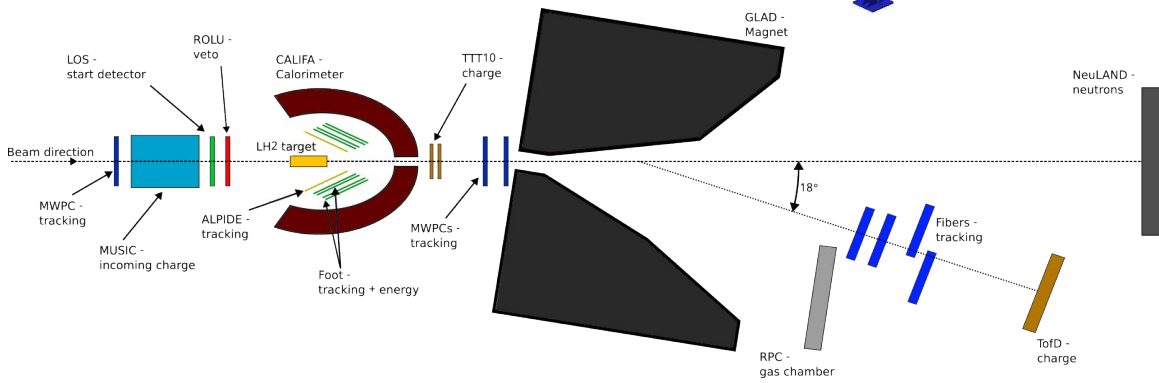
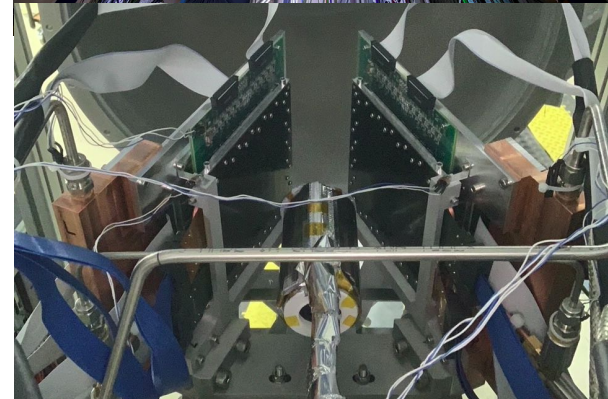
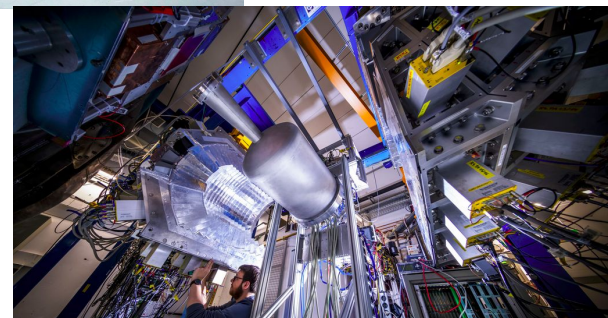
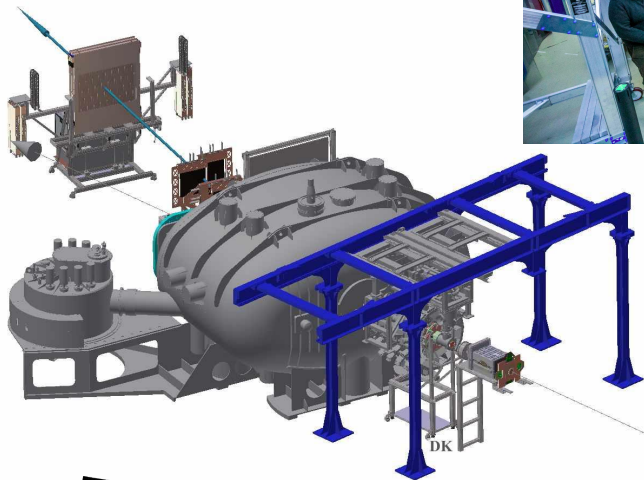


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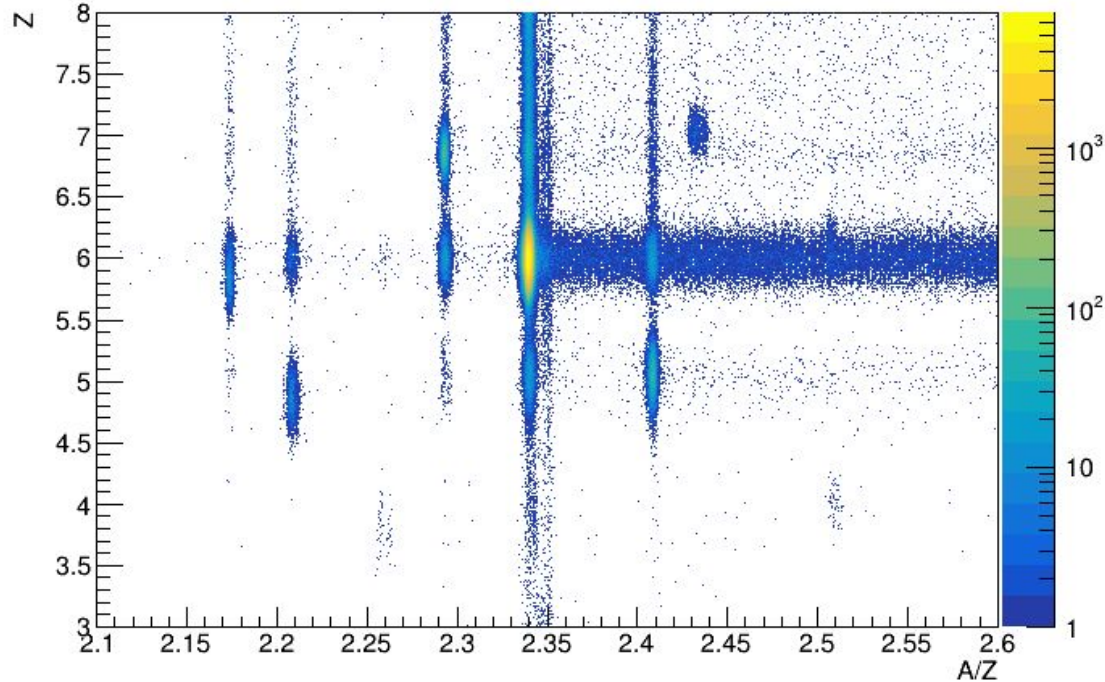
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Incoming PID

^{18}O Primary - ^{14}C Secondary

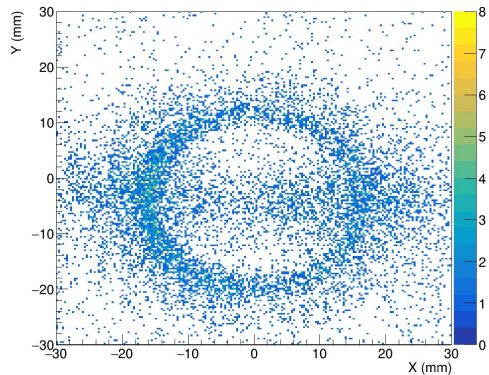


Isotope	Abundance
^{14}C	96.33%
^{12}B	1.64%
^{16}B	1.31%
^{11}B	0.20%
^{17}N	0.19%
^{13}C	0.18%
^{15}C	0.13%
^9Be	<0.01%

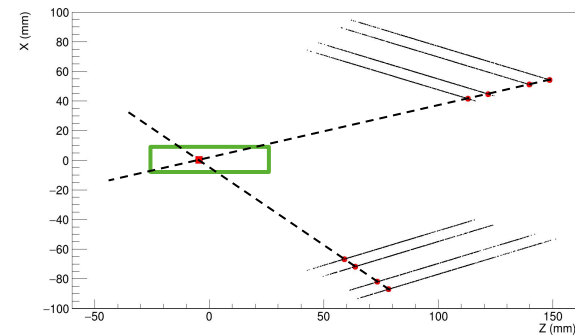
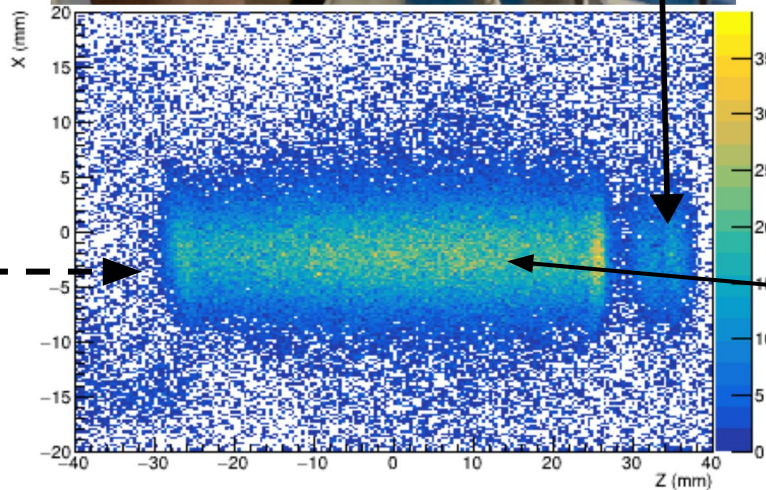
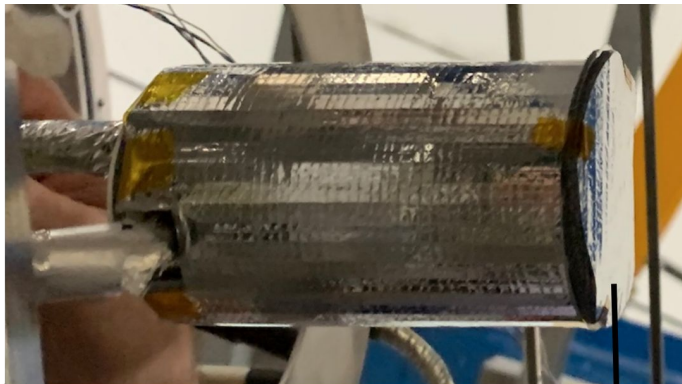


Vertex reconstruction

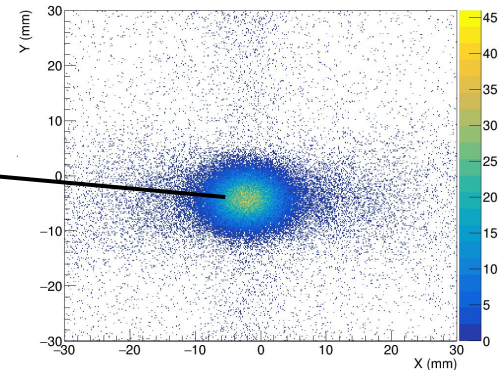
Flange halo



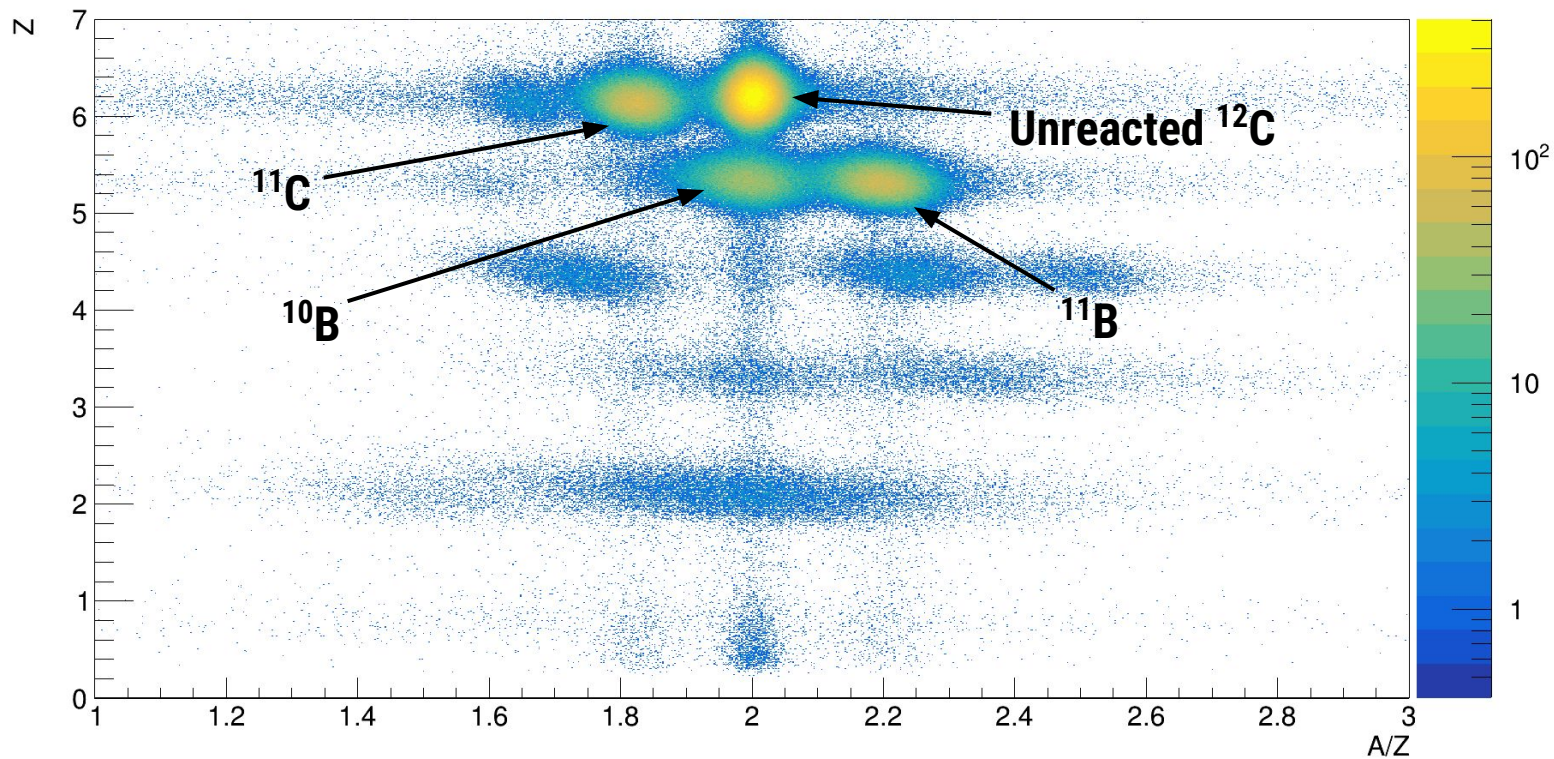
Beam direction



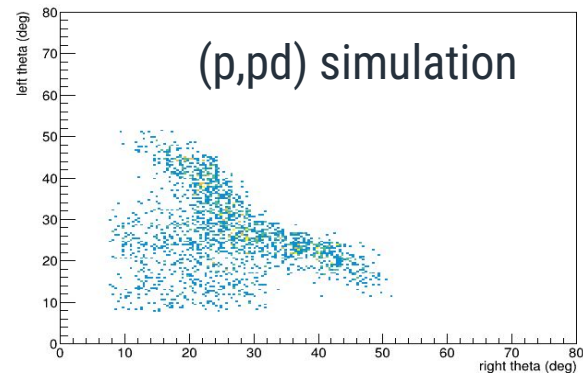
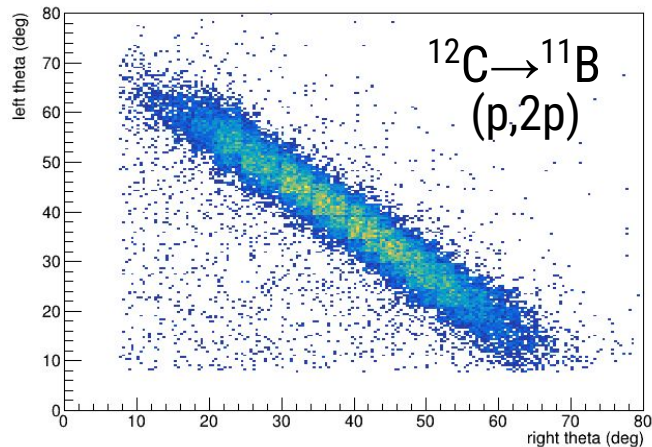
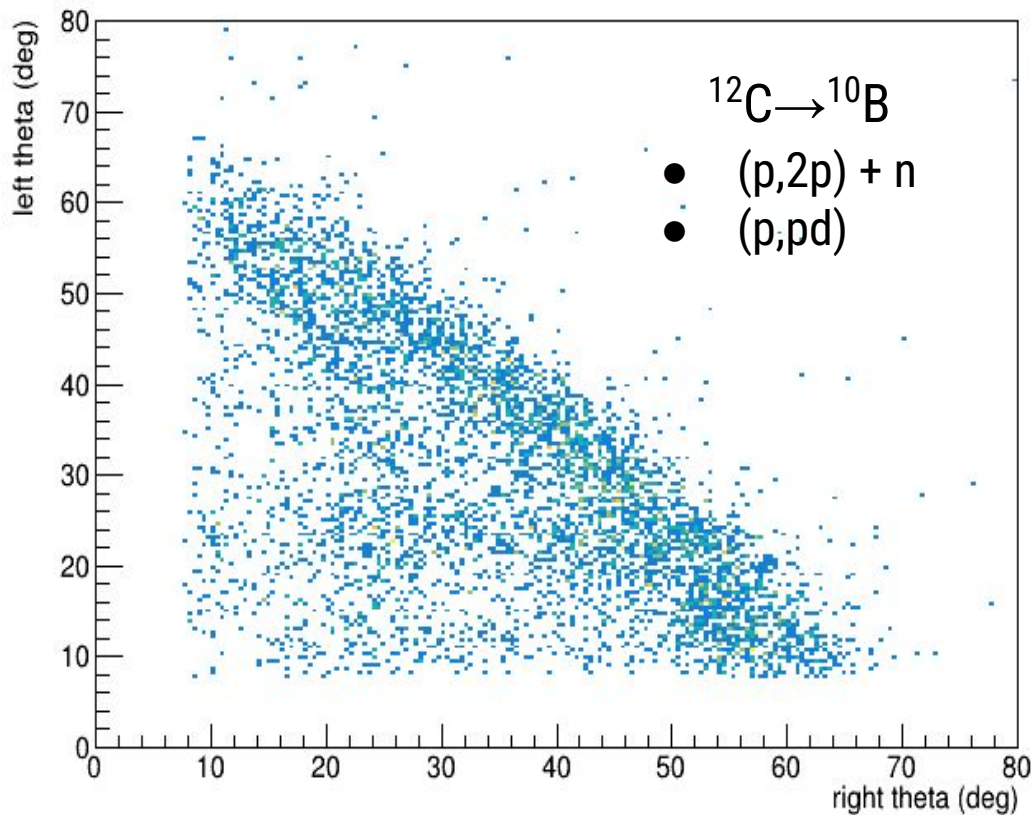
Beam spot



Fragment PID

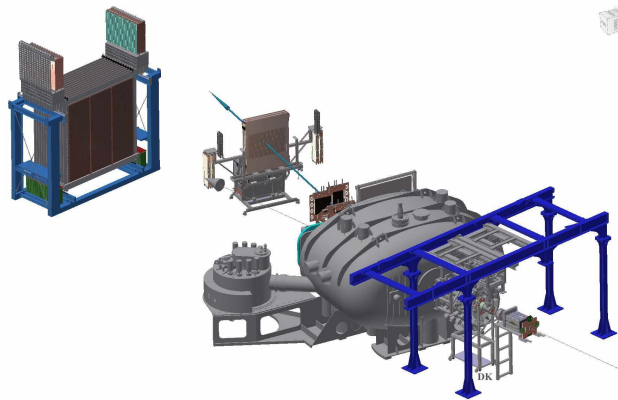
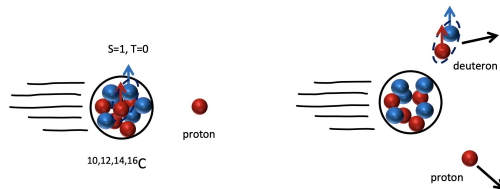


CALIFA kinematics

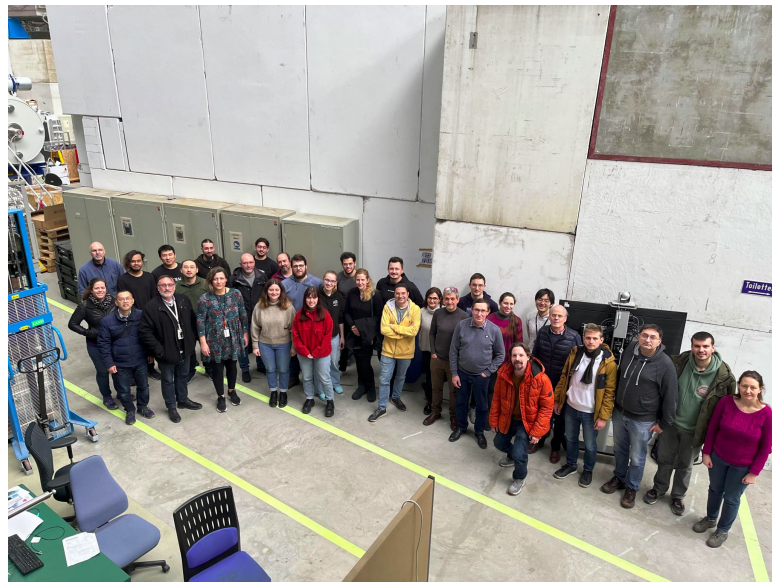


Conclusion

- Quasi-elastically knocking out deuterons to probe the number of quasi-deuterons in a nucleus and their isospin dependence:
 - $^{16}\text{C}(p, pd)$
 - $^{14}\text{C}(p, pd)$
 - $^{12}\text{C}(p, pd)$
 - $^{10}\text{C}(p, pd)$
- Analysis still ongoing - (p, pd) events can already be identified.



R³B



Thank you to the R3B collaboration!

Acknowledgements



The results presented here are based on the experiment G-22-00091, which was performed at the FRS-HTC at the GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt (Germany) in the frame of FAIR Phase-0.

This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No 101057511.

This project was supported by the UK Science and Technology Facilities Council (STFC) and The Royal Society.



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