

# Reactions with Relativistic Radioactive Beams in inverse kinematics @ the LAND/R<sup>3</sup>B setup

HGS-HiRe for FAIR  
Helmholtz Graduate School for Hadron and Ion Research



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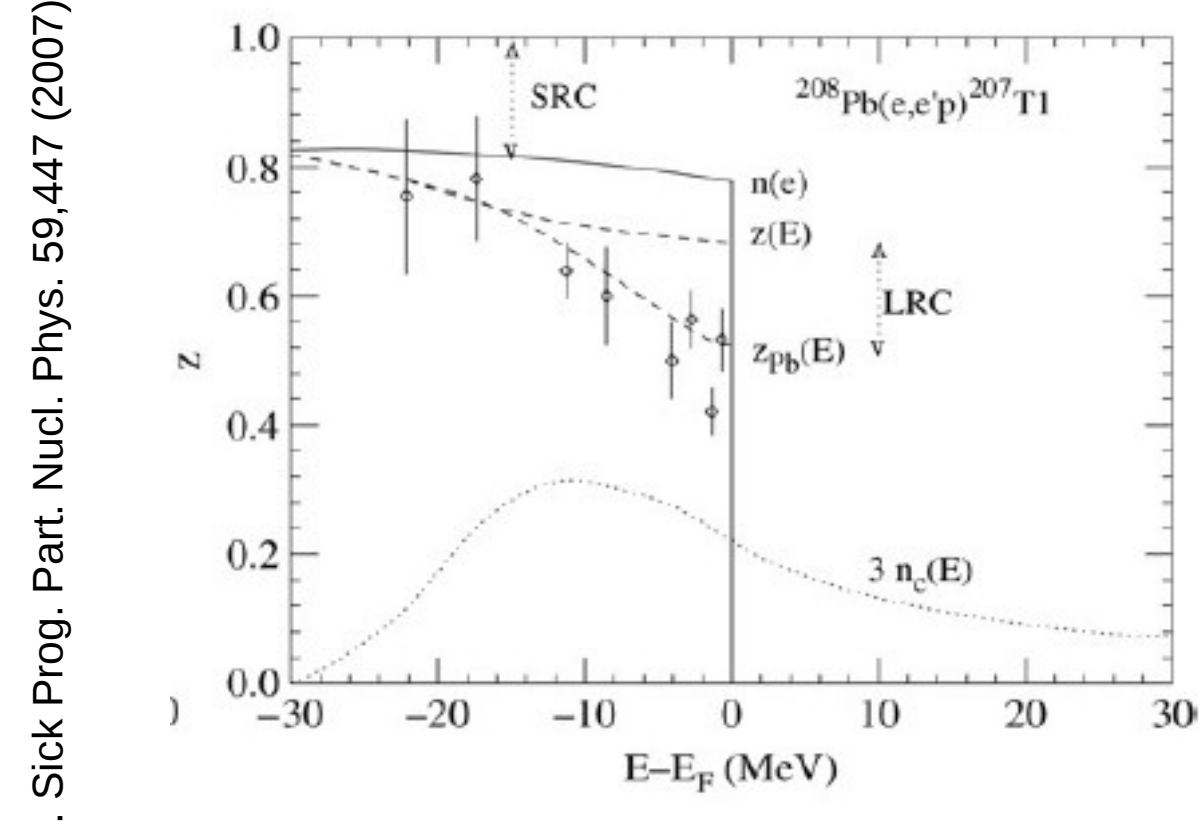
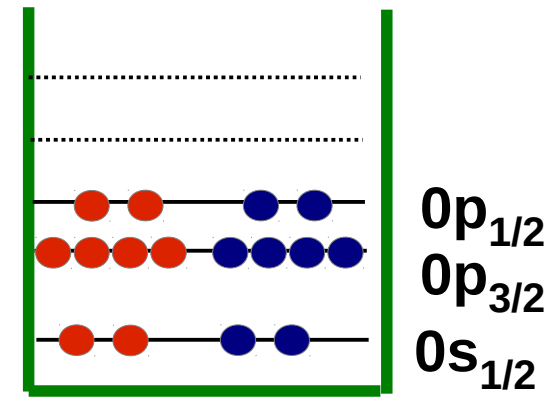
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for R<sup>3</sup>B collaboration

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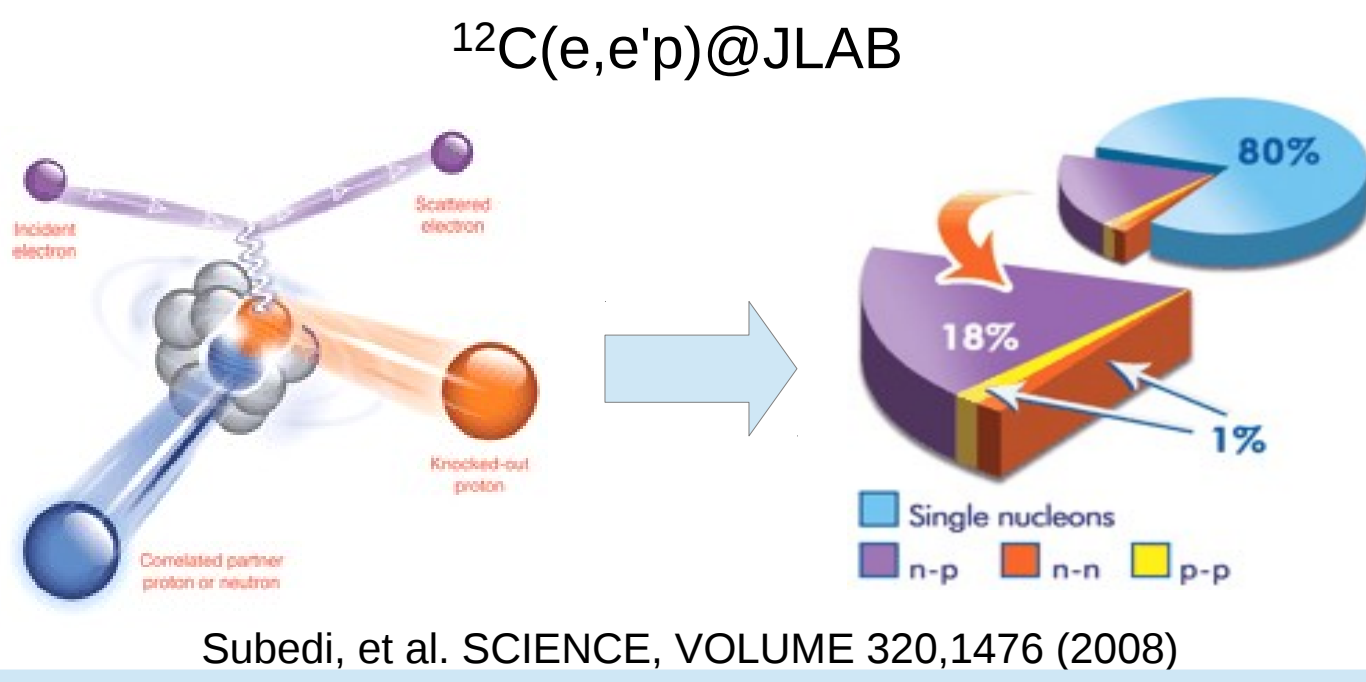


## Single Particle Structure & Correlations

► **Nuclear Shell Model** assumes protons and neutrons move independently in well-defined orbits in the average mean field created by the other nucleons.



► Deviations from the independent particle picture are described as **correlations** – like short, long range correlations, tensor forces – which are not included in the mean field theory. These correlations reduce the single particle occupancies (spectroscopic factors).

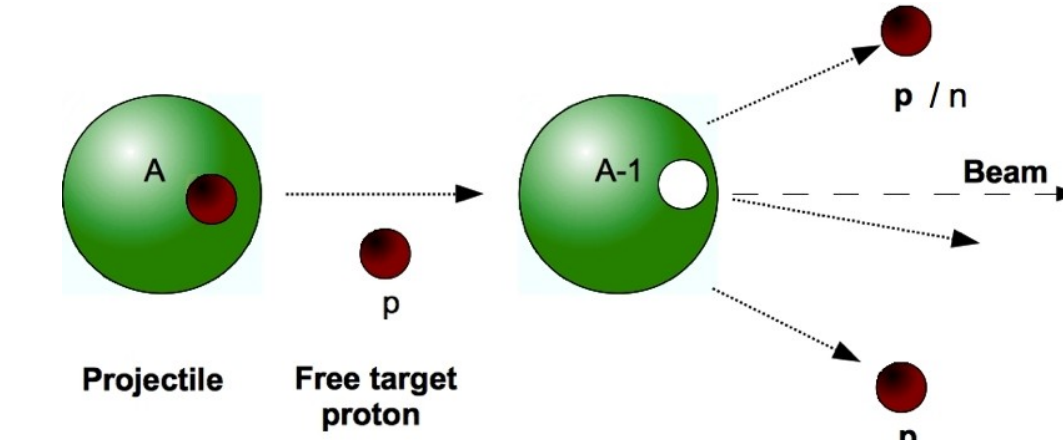
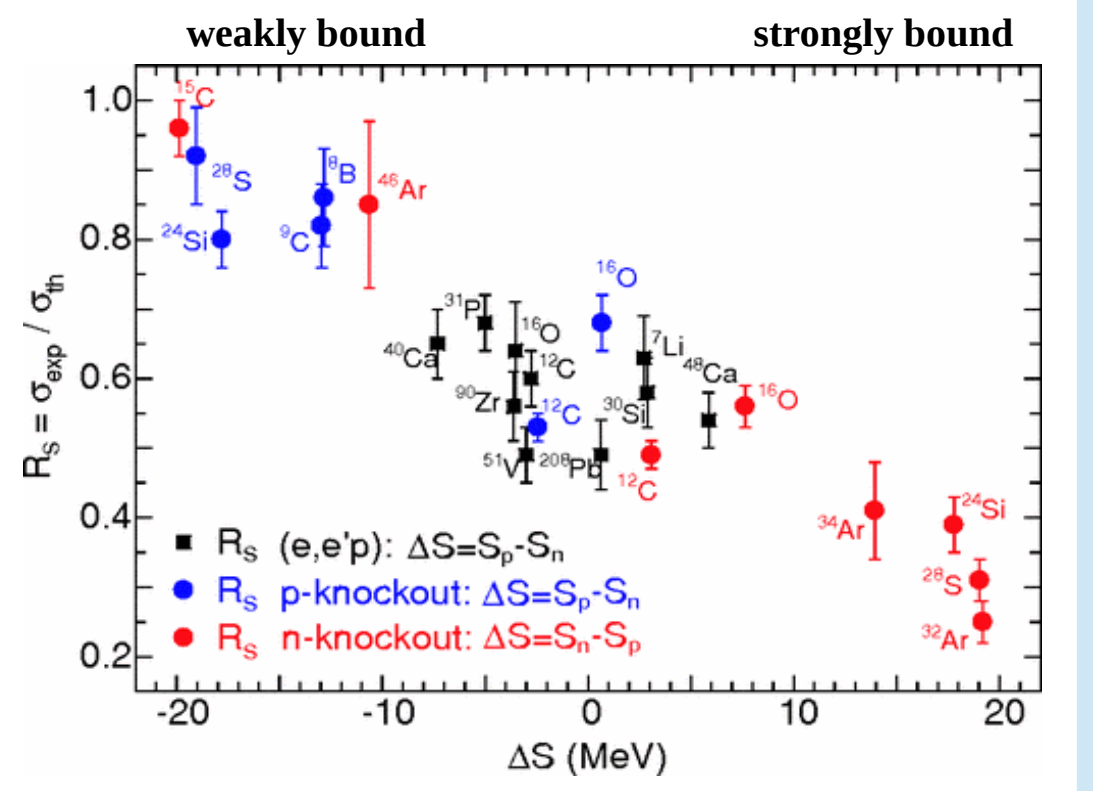


► 80% of the nucleons in <sup>12</sup>C move independently, whereas 20% builds correlated pairs, from which 90% are pn-pairs. This is a consequence of tensor forces.

Subedi, et al. SCIENCE, VOLUME 320,1476 (2008)

## Quenching of Single Particle States & Quasi-free Scattering

► Data from (e,e'p) experiments on stable nuclei shows a quenching of single particle states around 60-70% due to the correlations in compare to the independent particle picture. When going to driplines this behavior is changing, the **occupancies of loosely bound valence nucleons** have a spectroscopic factor close to 1, whereas single particle strength for **deeply bound nucleons** is suppressed.



► **Quasi-free knockout reactions** in inverse kinematics is a direct tool to obtain spectroscopic information on single particle states of exotic nuclei and study their evolution over a large variation of isospin.

► Theoretical description of the reaction based on **eikonal and sudden** approximations, assuming reactions occur very fast (10<sup>-22</sup>s) and forward focussed, with no additional scattering from nucleons of the core spectator (reaction residue).

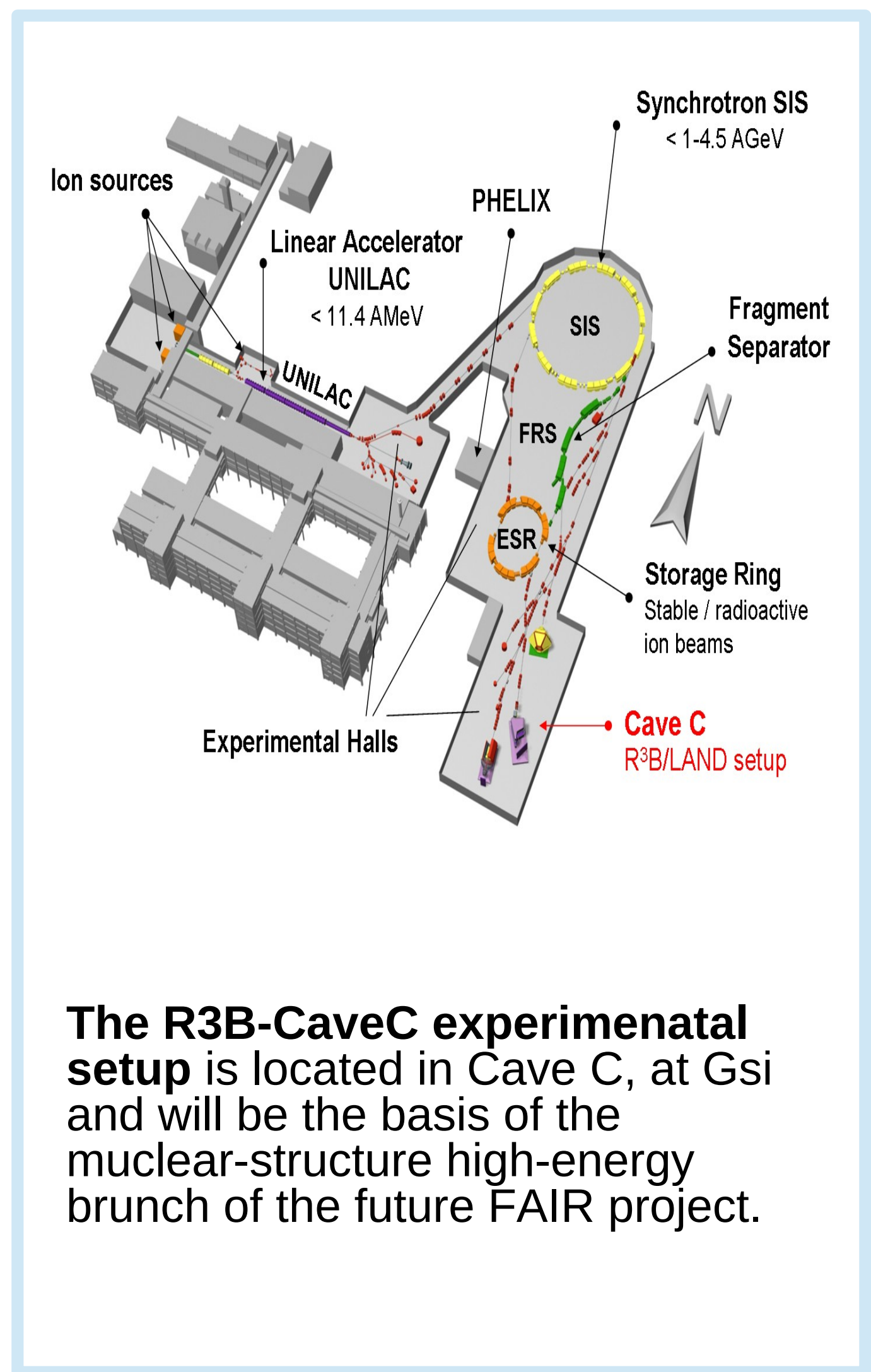
$$\mathbf{P}_{A-1} = -\mathbf{P}_{p/n}$$

Momentum distribution of residue

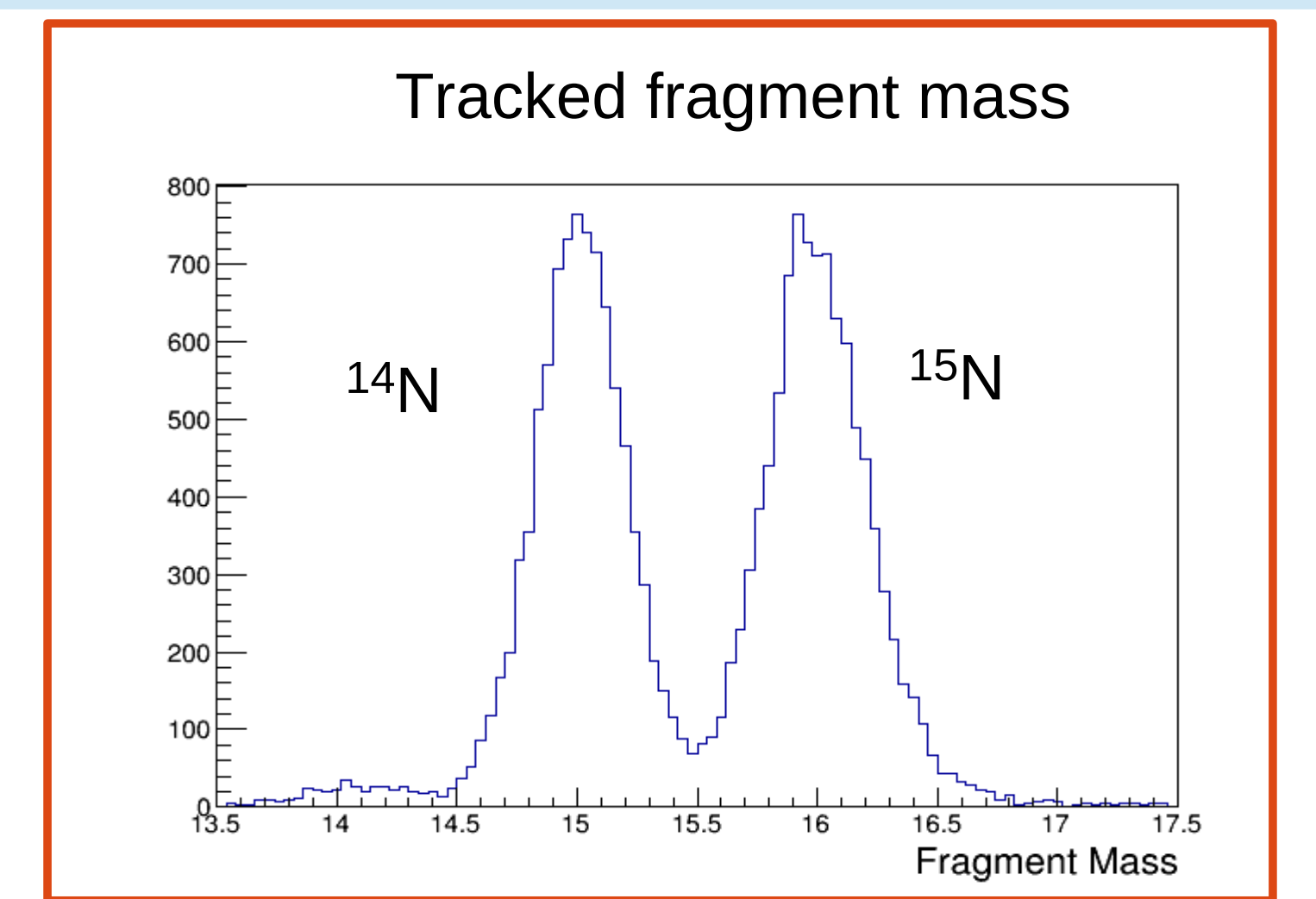
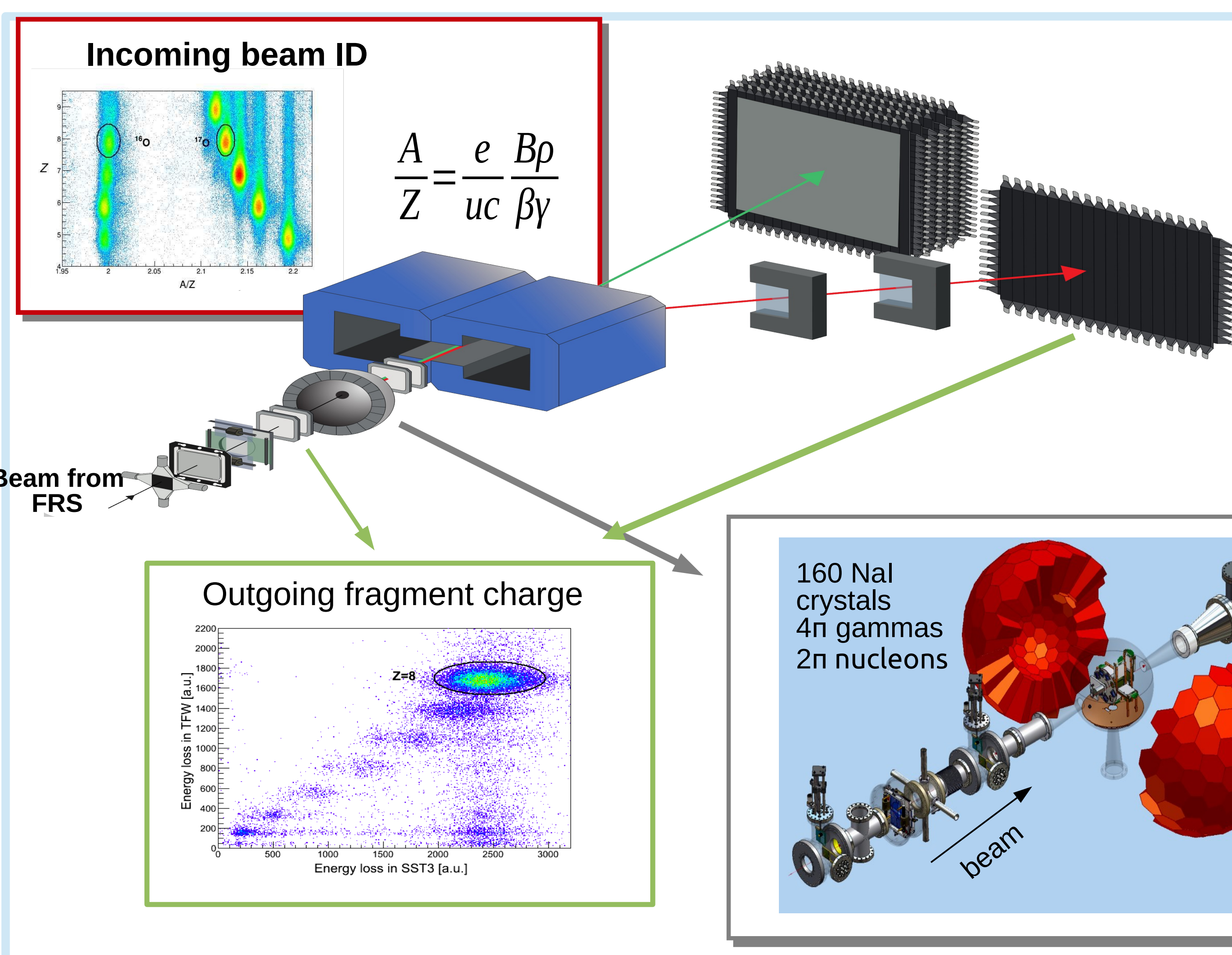
Angular momentum of removed nucleon

## GSI facility

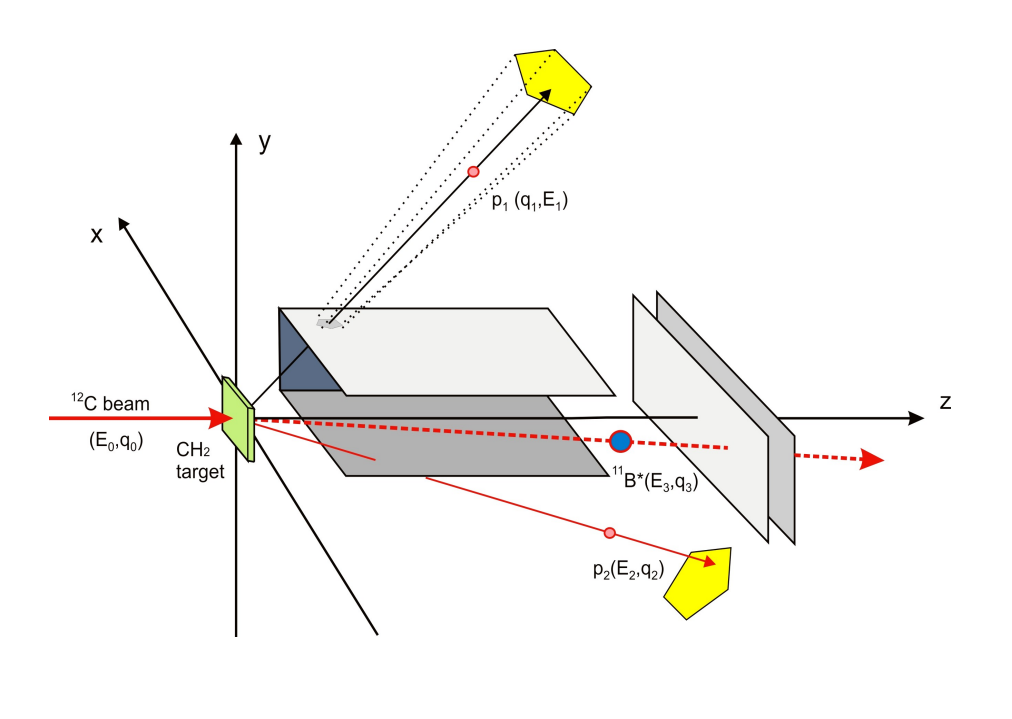
## LAND setup at Cave C



The R<sup>3</sup>B-CaveC experimental setup is located in Cave C, at GSI and will be the basis of the nuclear-structure high-energy branch of the future FAIR project.

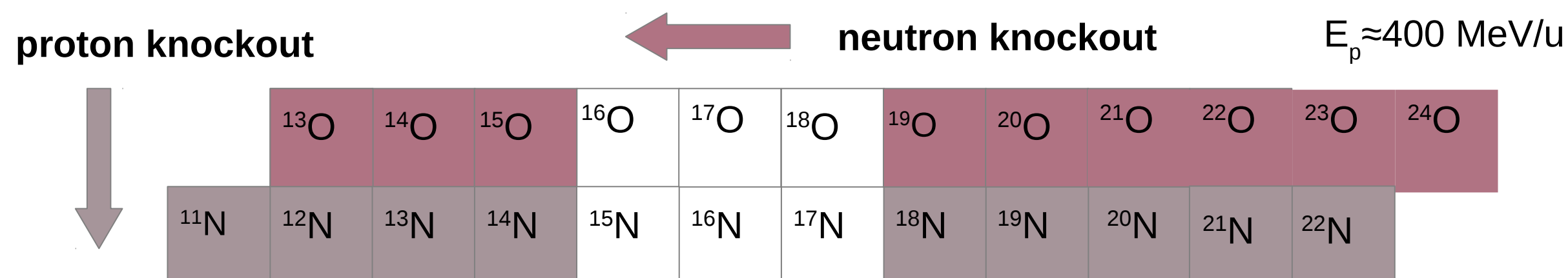


8 SSDs for tracking of charged particles



## Analysis and Results

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<sup>16</sup>O(p,2p)<sup>15</sup>N

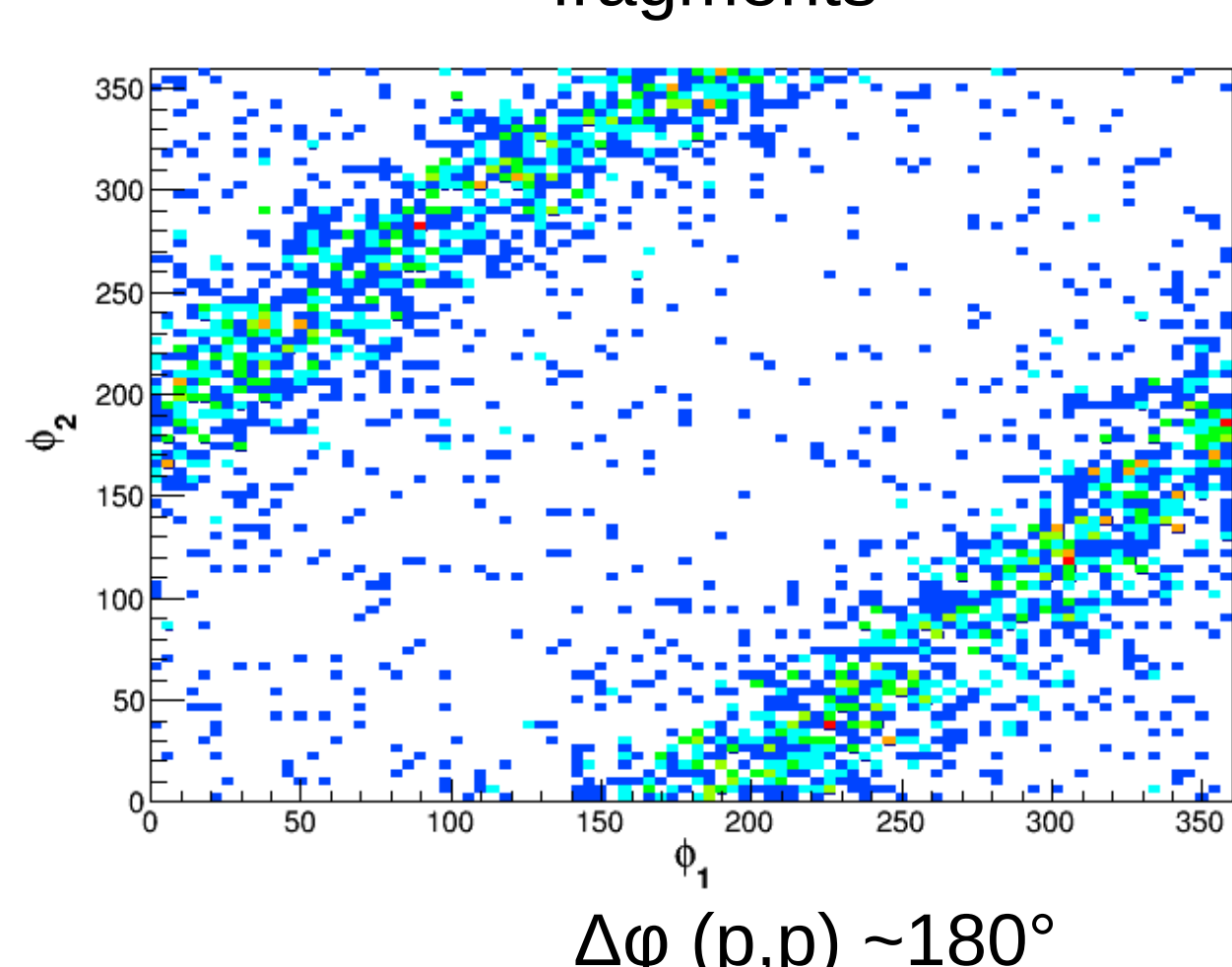
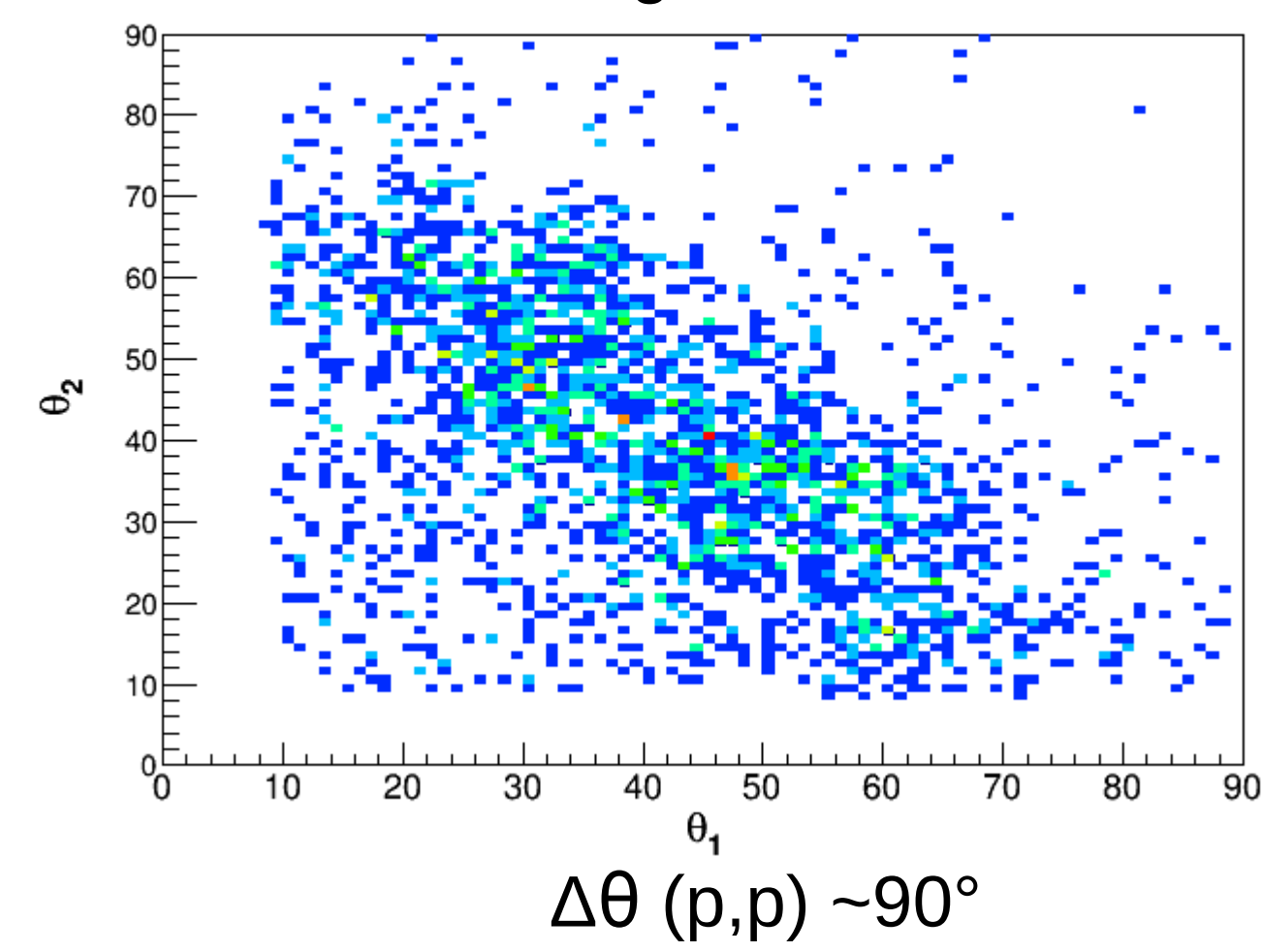
proton knockout from p<sub>1/2</sub> → <sup>15</sup>N in ground state

proton knockout from p<sub>3/2</sub> → <sup>15</sup>N in excited state

Angular correlation: Signature of quasi-free scattering

Opening angle between two outgoing fragments

Azimuthal angle between two outgoing fragments

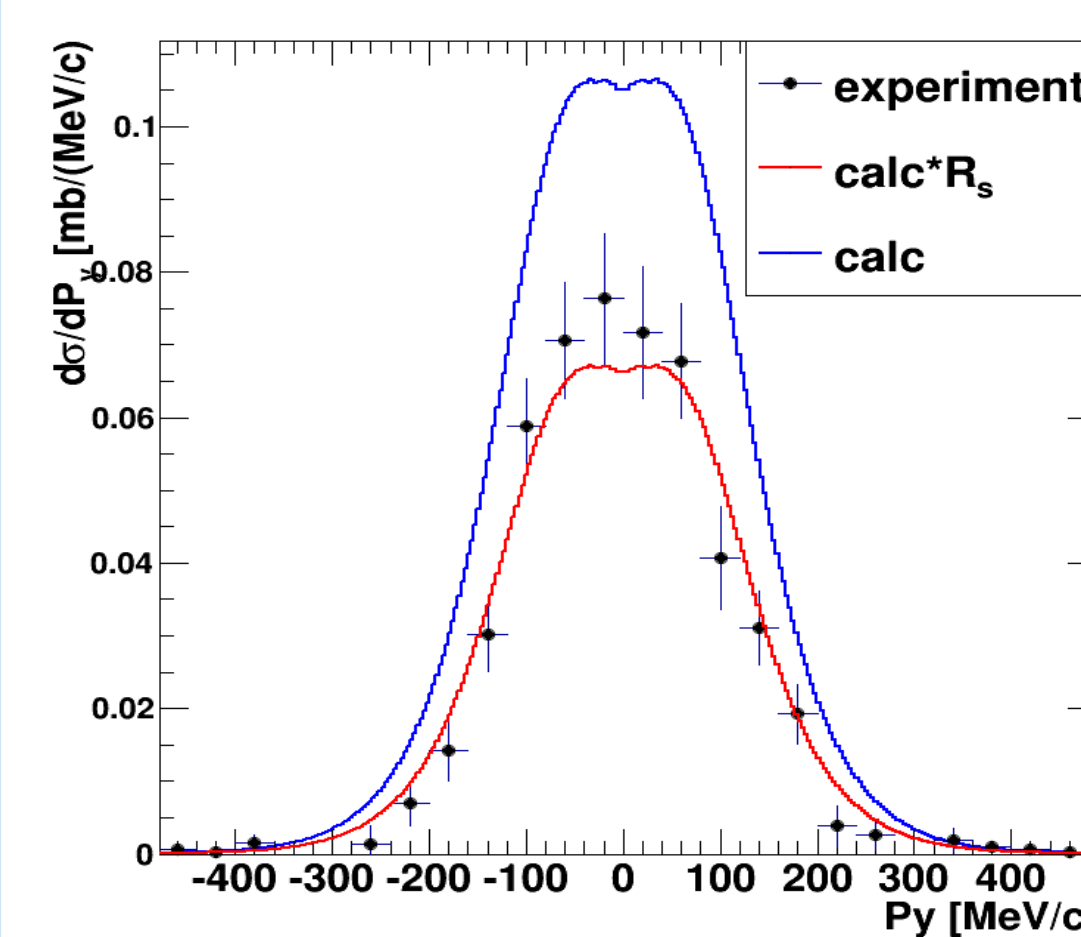


## <sup>16</sup>O(p,2p)<sup>15</sup>N inclusive cross section and momentum distribution

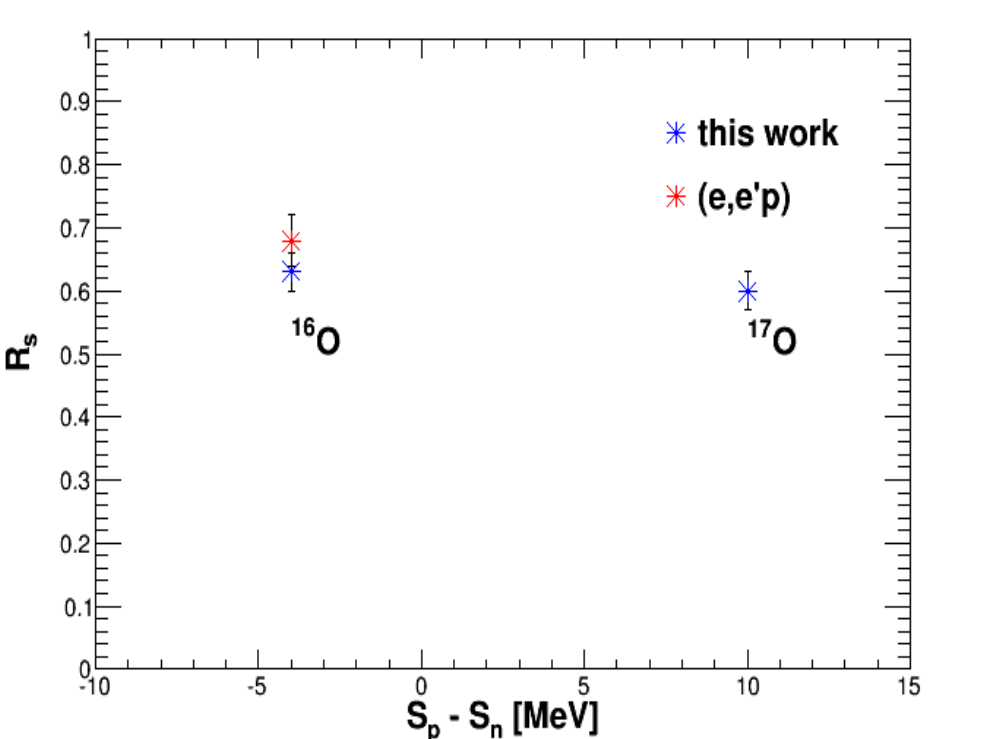
$\sigma_{\text{exp}}$ [mb]	20 ± 1
$\sigma_{\text{theo}}(p_{1/2})$	11
$\sigma_{\text{theo}}(p_{3/2})$	21
$R_s$	0.63(3)
$S_{p/n}$ [MeV]	12 / 16

reaction theory  
Glauber model in eikonal approx.(by C.Bertulani)  
Nucl.Phys.A445,124(1985)

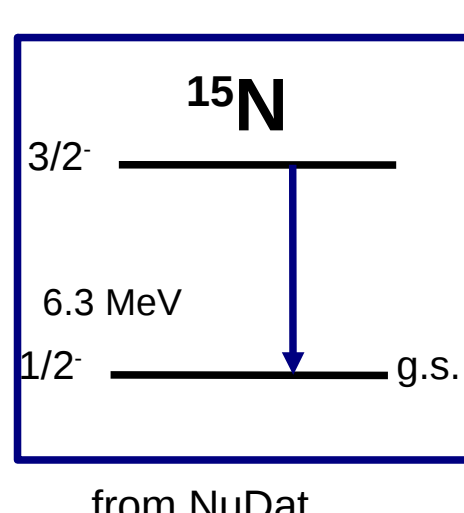
Quenching factor:  $\sigma(\text{exp})/\sigma(\text{th}) \rightarrow R_s$



Momentum distribution of the residue reflects the angular momentum of the final state of knocked-out proton.



(e,e'p): Nucl.Phys.A375 (1982) 381



Coincidence measurement of gamma-rays with residual fragment and outgoing protons allows to estimate the partial cross sections and extract the spectroscopic factors.

