

INTERNATIONAL SYMPOSIUM COMMEMORATING THE 40TH ANNIVERSARY OF THE HALO NUCLEI

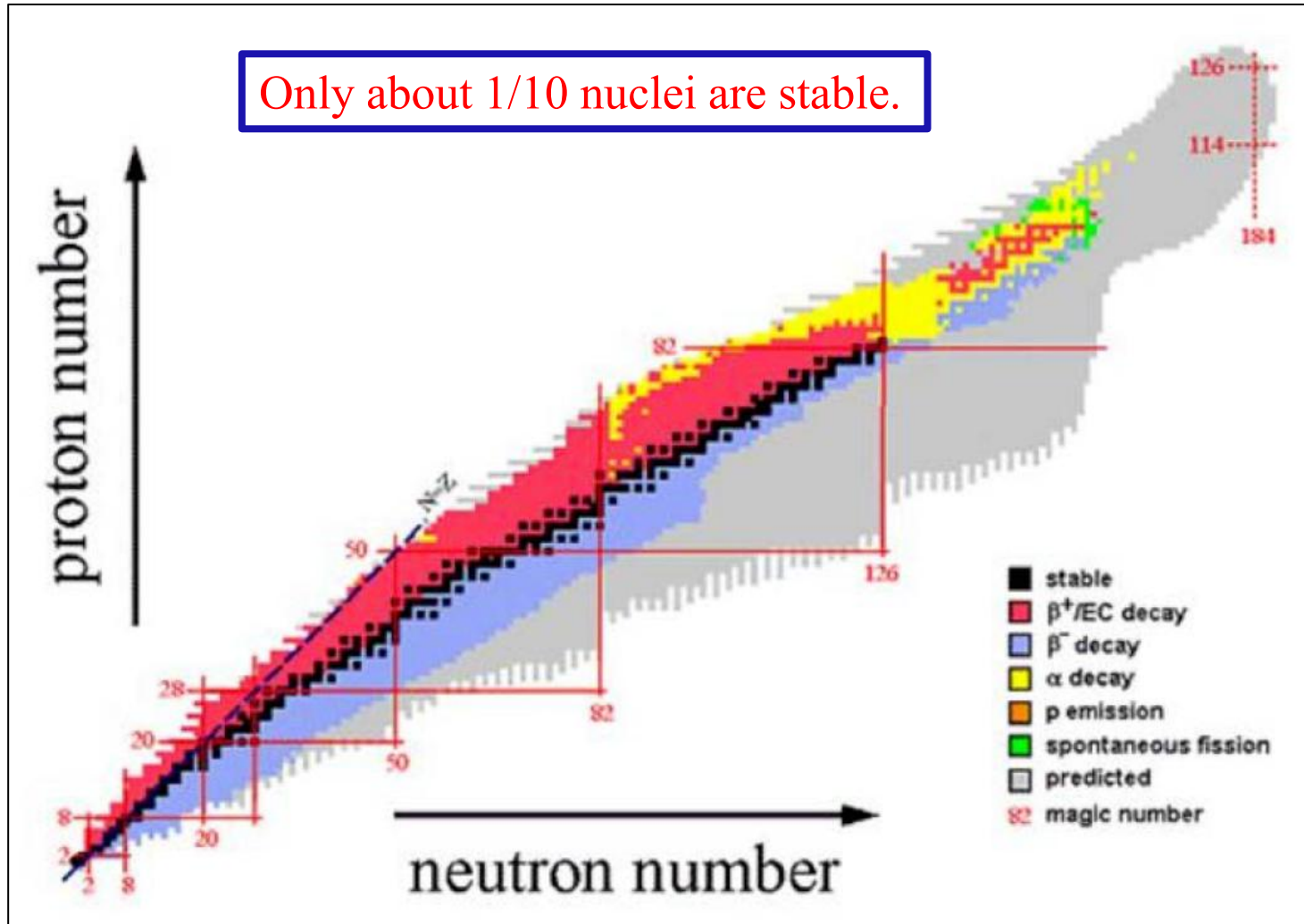
**First experiment using post-accelerated unstable ion beams at BRIF: angular
distribution of the $^{21,22}\text{Na}$ elastic scattering from doubly magic ^{40}Ca**

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Institute of Atomic Energy**

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Studies on unstable nucleus



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First generation of RIB

DECAIDES
STUDIED BY ON-LINE ISOTOPE SEPARATOR TECHNIQUES

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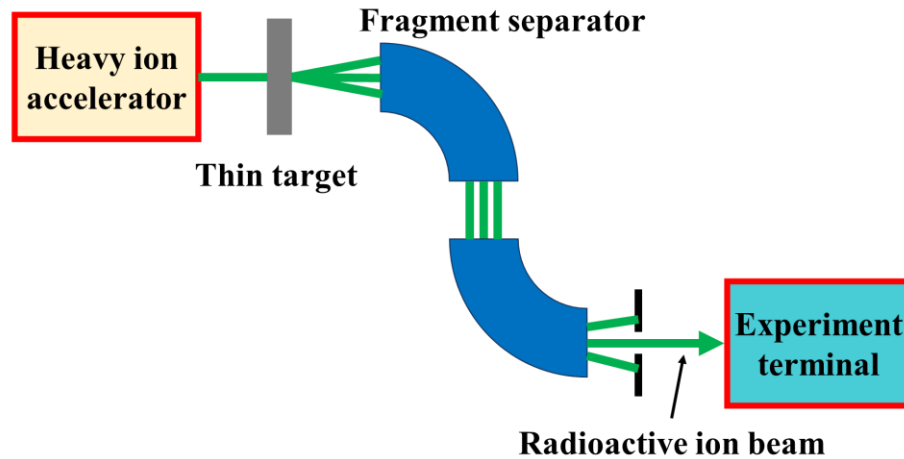
Measurement of the β -decay of ^{11}Li in the region

First using in the study of exotic nuclei

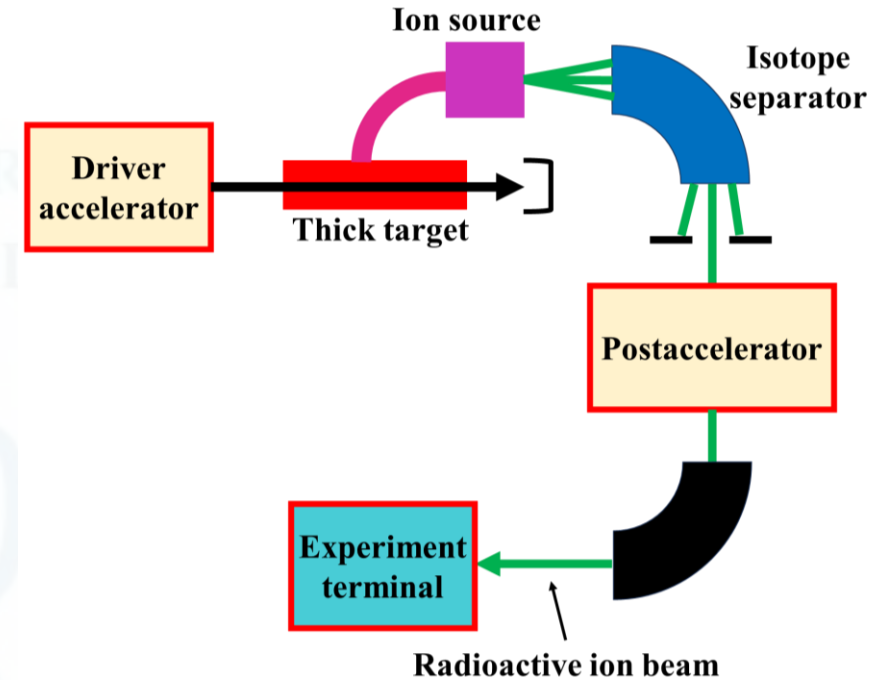
N. Takahashi
College of General Education, Osaka University, Toyonaka, Osaka 560, Japan
(Received 11 July 1985; revised manuscript received 17 September 1985)

Z. H. Li, Nuclear Astrophysics[M]. (in Chinese)

Projectile Fragmentation



Isotope separation on line



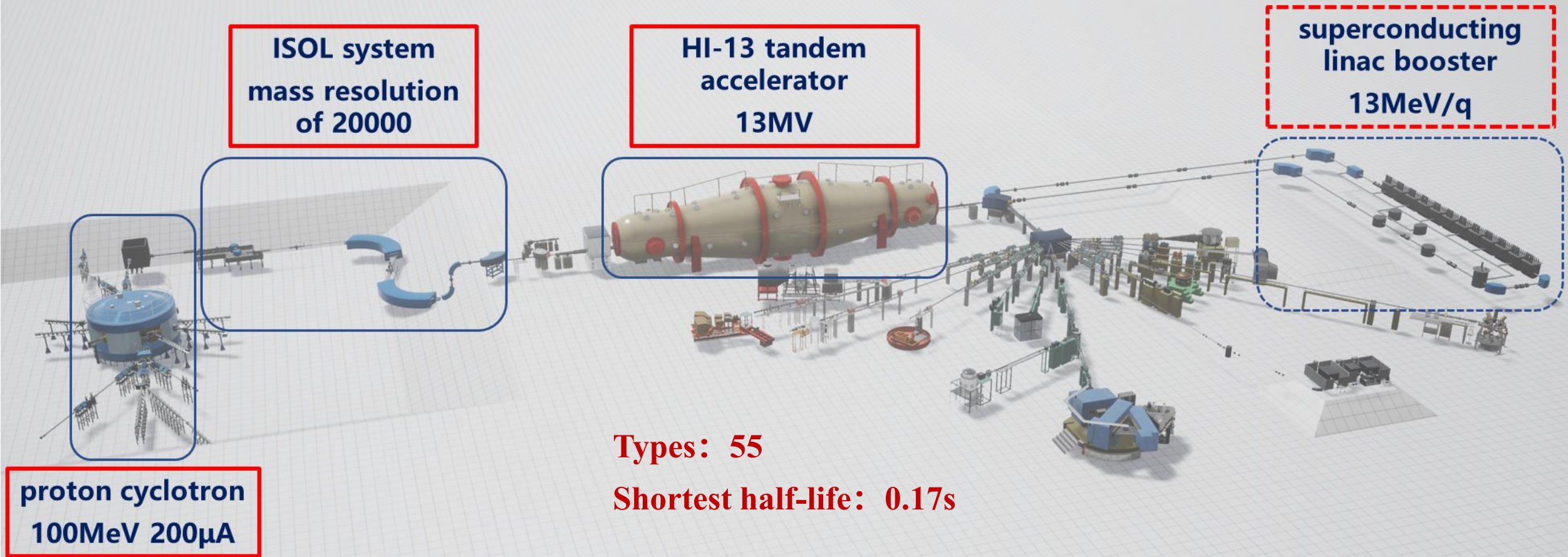
PF method can generate beam **far from stable line**, while the ISOL beam is **pure and with wide energy range**. These two methods are complementary.

One of the future development directions is the two-step method (PF+ISOL or ISOL+PF), such as **HIAF** and **BISOL**

Beijing Radioactive-Ion beam Facility (BRIF)

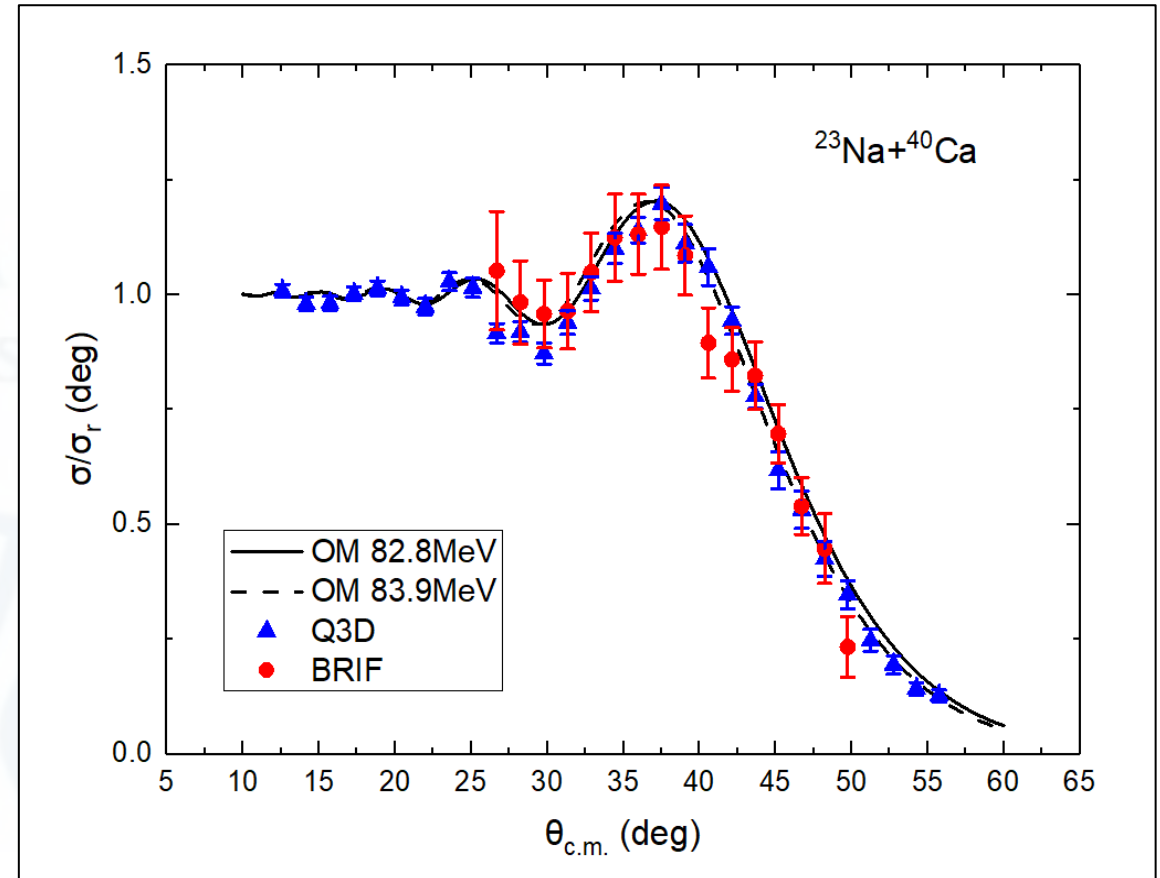
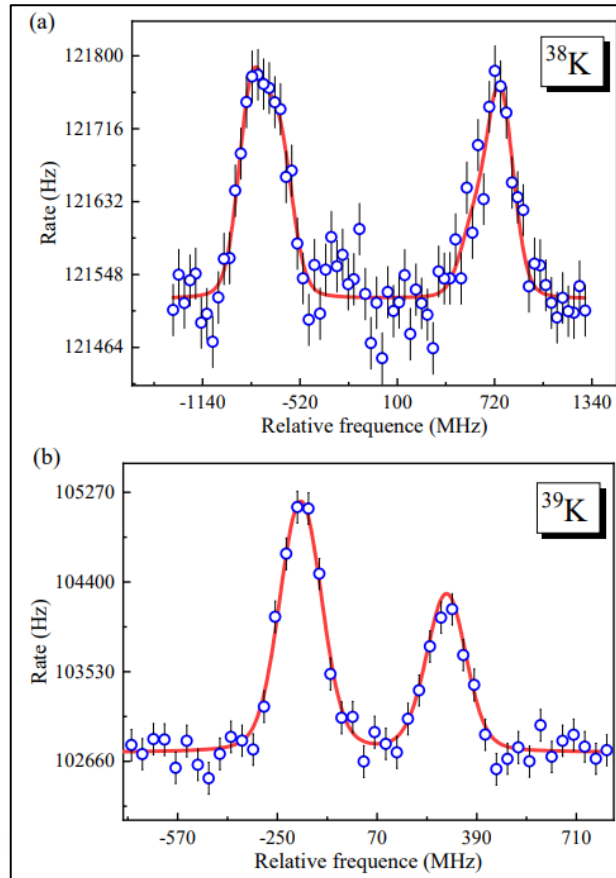
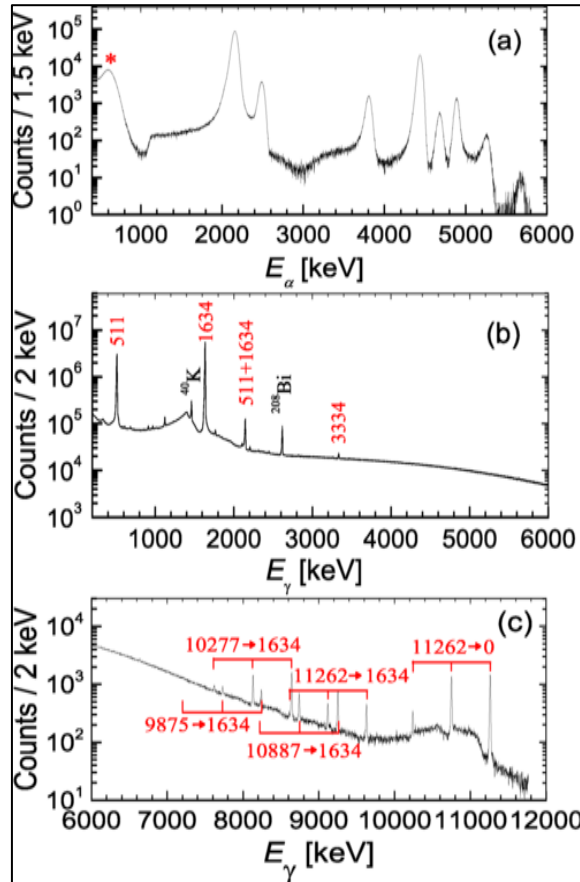
BRIF is the only ISOL facility in operation in Asia

It is a **strong complement** to the PF facility of the Institute of Modern Physics, Chinese Academy of Sciences



W. Nan, B. Guo, J. Chen, et al. Prog. Part. Nucl. Phys. 145, 104188 (2025).

Experimental results at BRIF



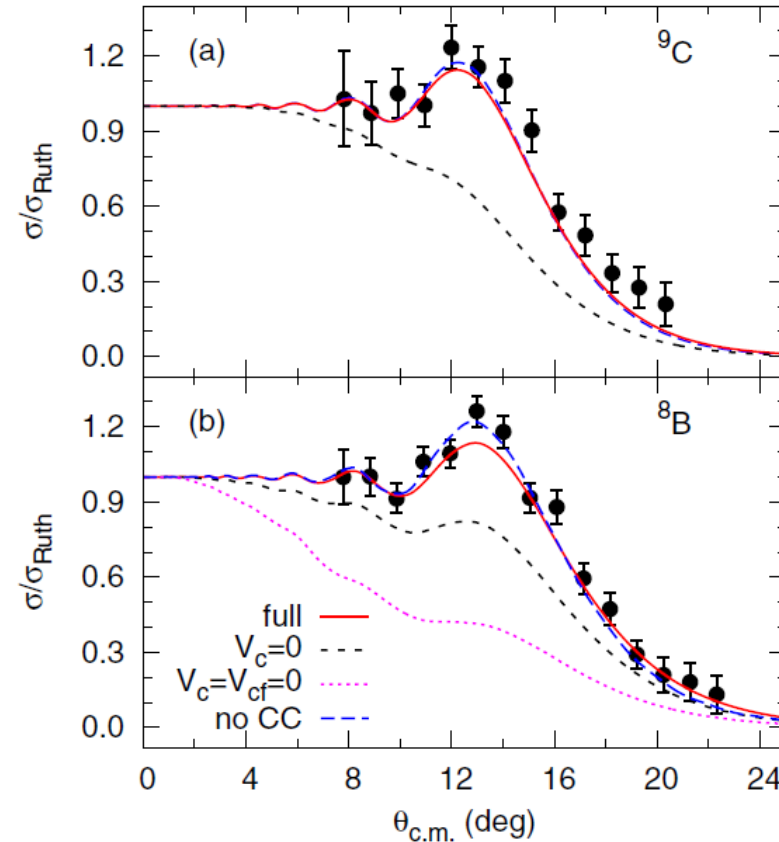
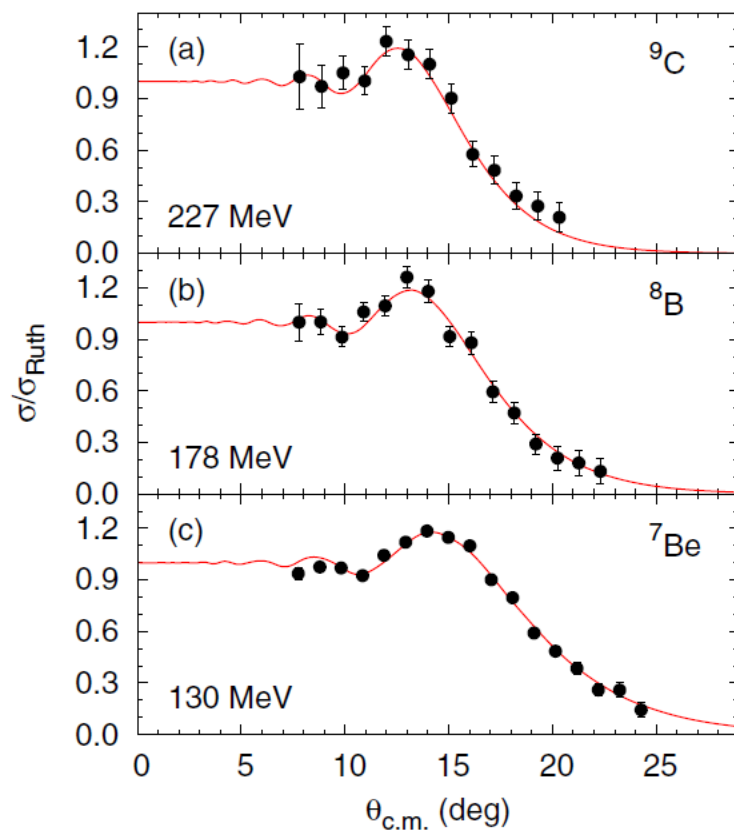
Y. B. Wang, et al. Phys. Rev. C 103, L011301(2021).

S. J. Wang, et al. NIM A, 1032, 166622 (2022).

W. Nan, et al. Nucl. Sci. Tech., 32:53 (2021).

No **post-accelerated RIB experiment** performed at BRIF yet

Elastic scattering is a probe for unstable nuclear

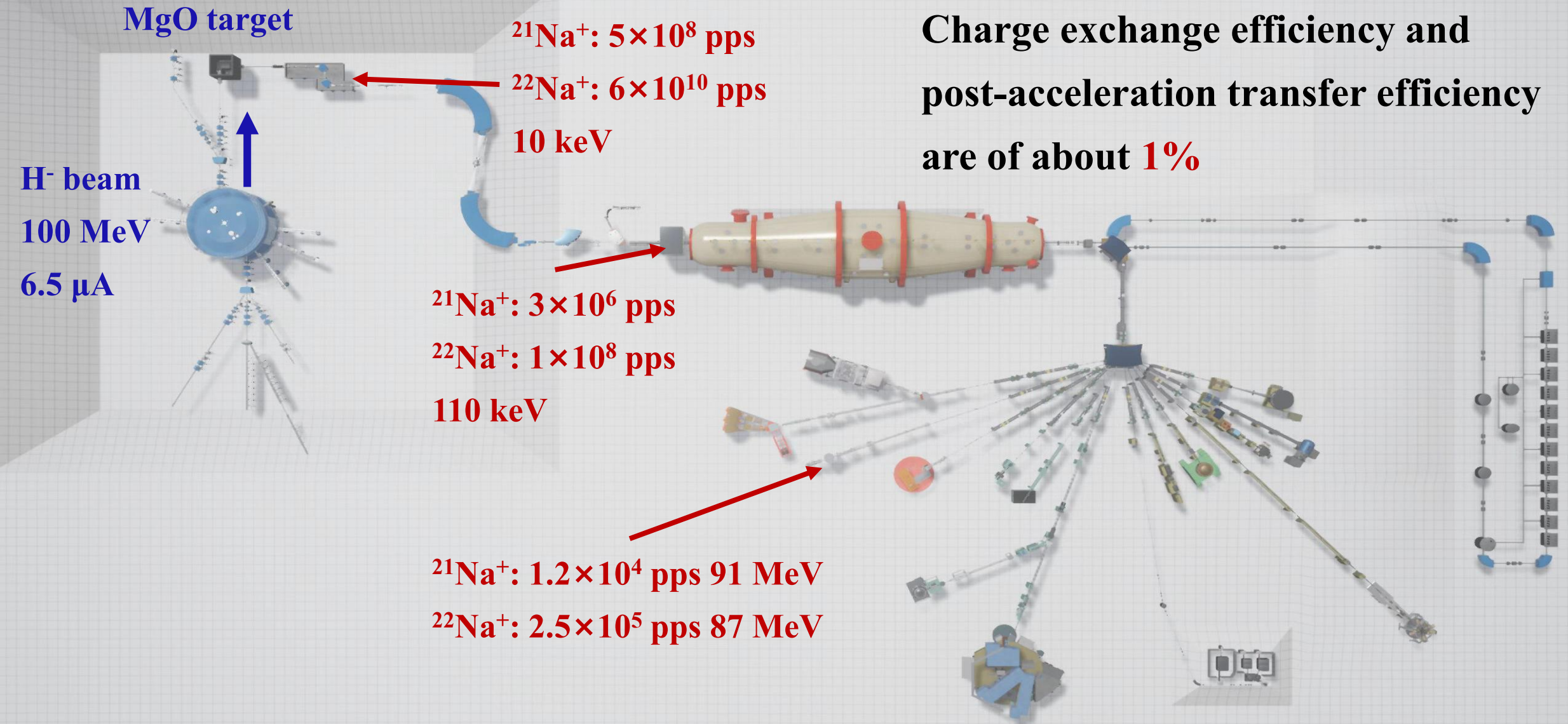


By comparing the elastic scattering angle distribution and parameters of stable nuclei and unstable isotopes, the properties of unstable nuclei can be studied

Y. Y. Yang, et al., Phys. Rev. C 98, 044608 (2018).

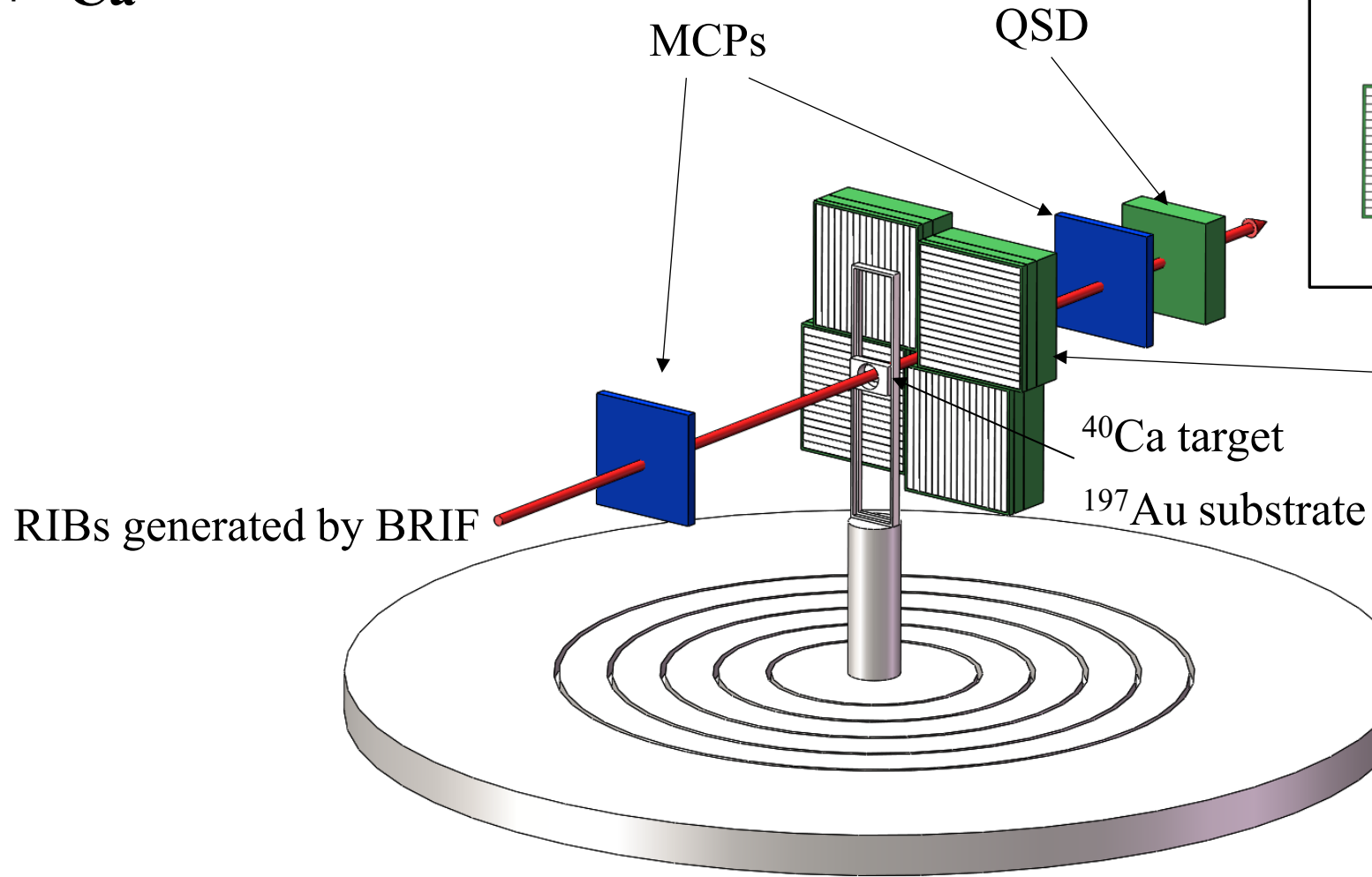


Generation of the radioactive beam

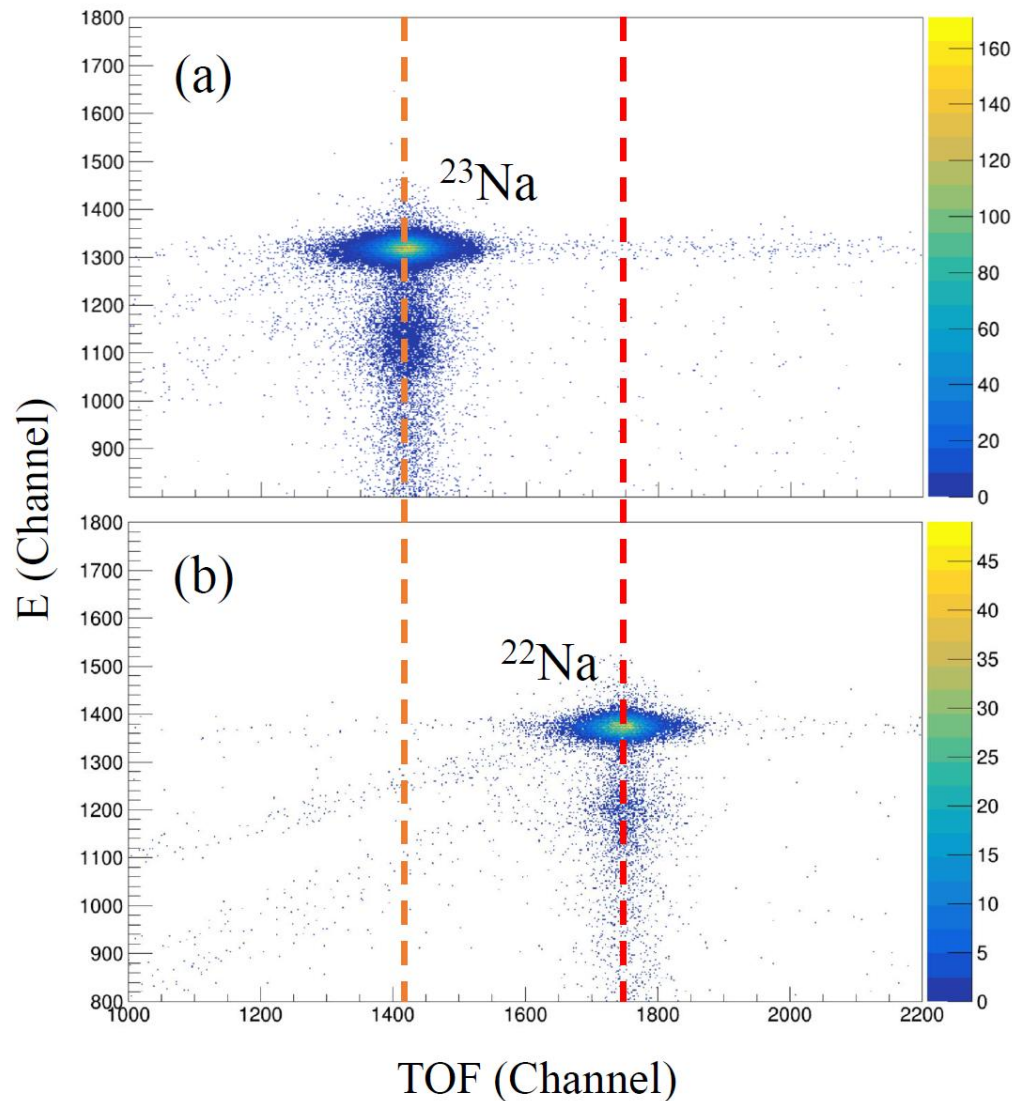


Setup of target chamber

$^{21,22}\text{Na} + ^{40}\text{Ca}$

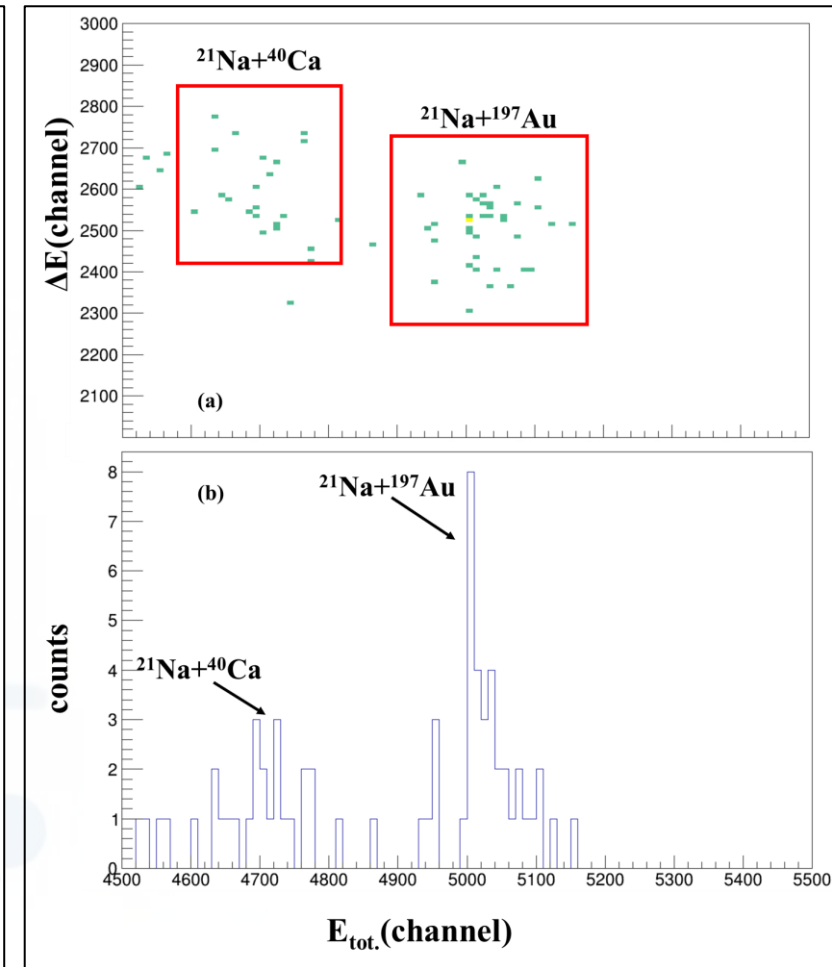
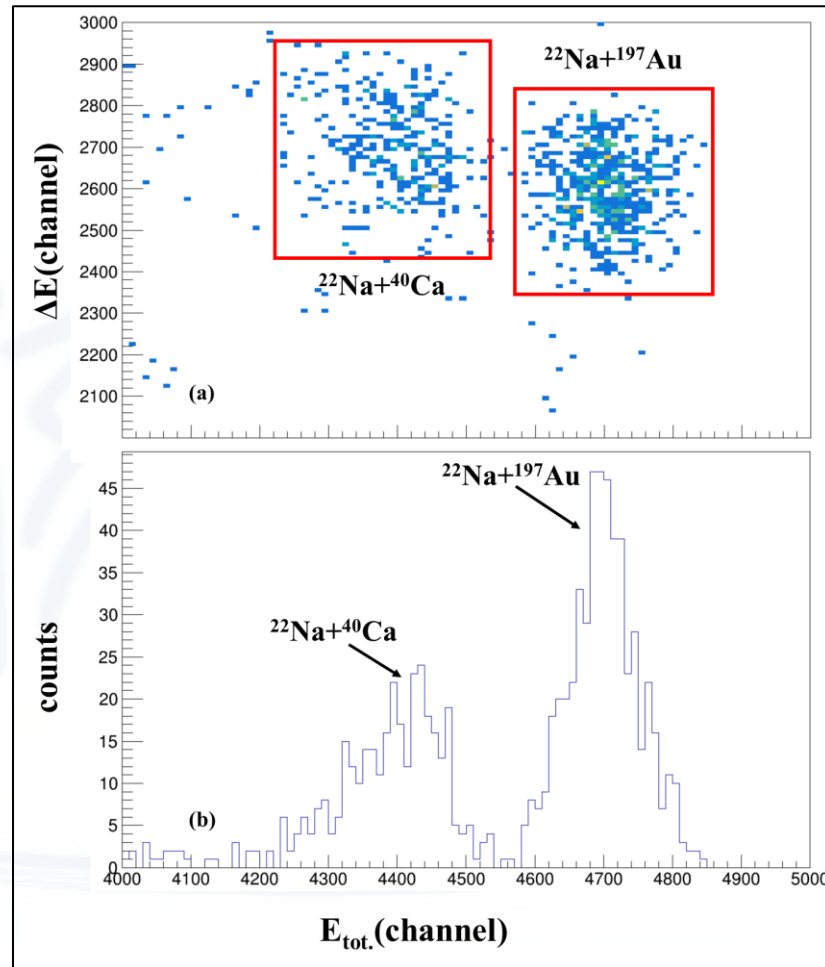
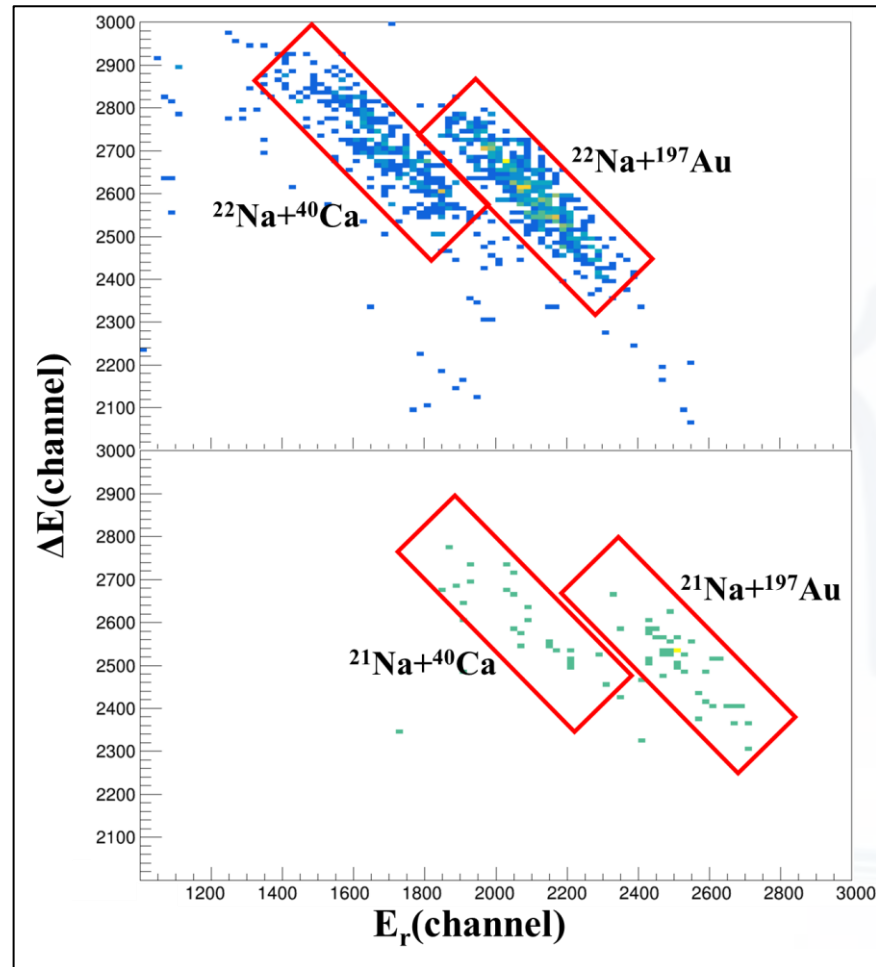


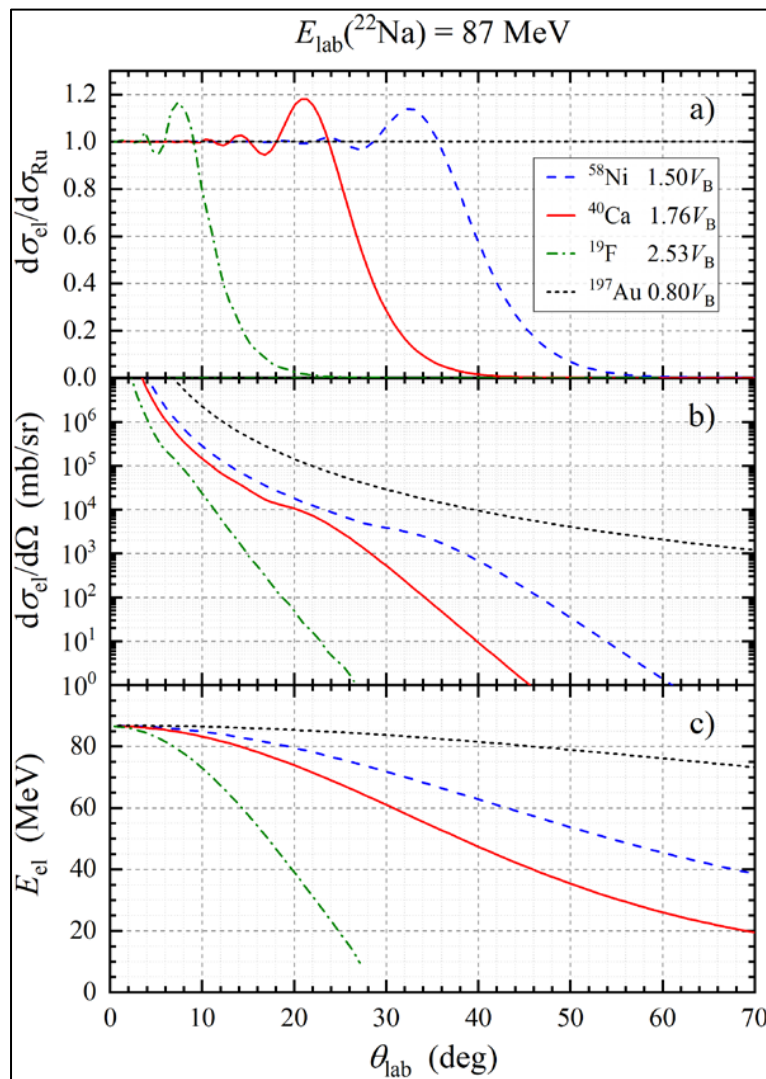
Particle identification



- Comparison of TOF spectra of 83.25 MeV ^{23}Na (a) and 87 MeV ^{22}Na (b)
- TOF signal was measured by MCPs; E_{tot} was measured by QSD at the end of the target chamber
- MCPs were removed after particle identification

Experimental spectrum





Within the range of the detector measurement, to any detection unit

$$\frac{d\sigma}{d\sigma_r^{Au}} = \frac{N^{Au}}{I N_s^{Au} \times d\sigma_r^{Au} \times \Omega} = 1$$

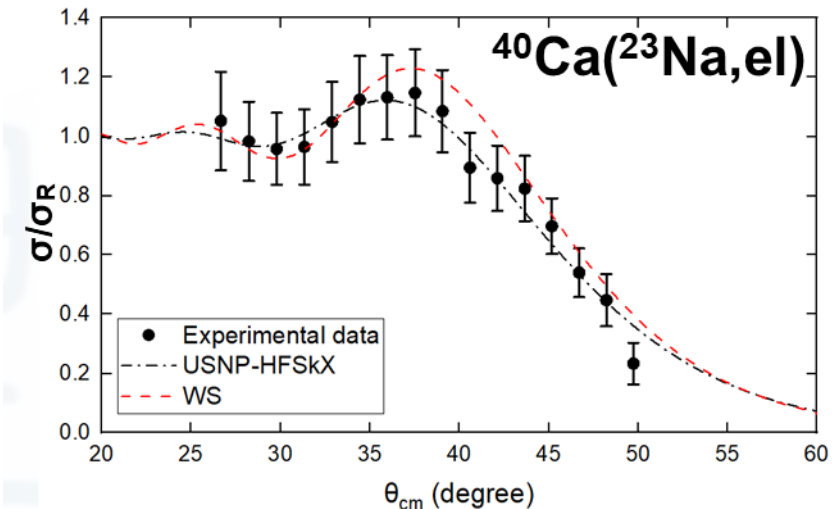
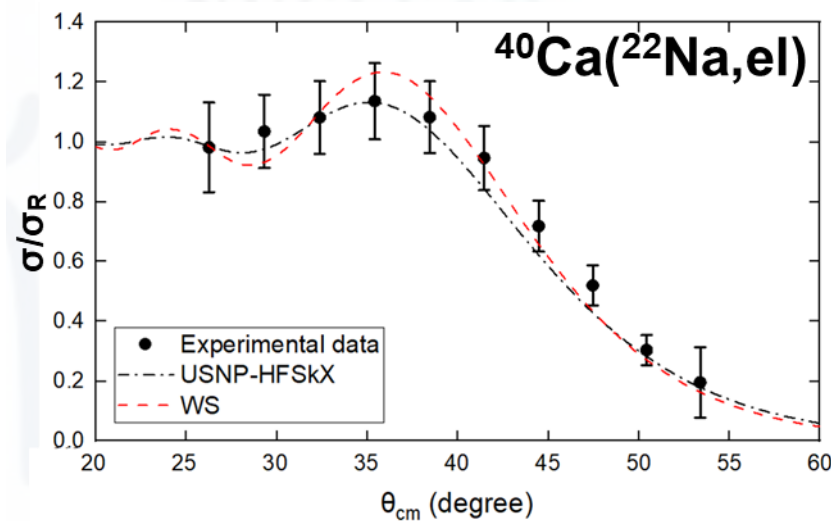
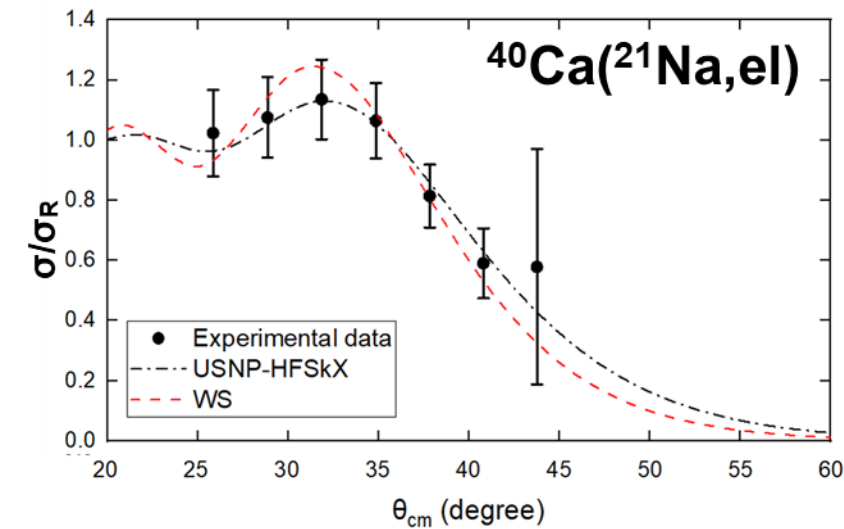
in which **N** is for yield, **I** is for intensity, **N_s** is for target thickness, **Ω** is for solid angle

$$\begin{aligned}
 \frac{d\sigma}{d\sigma_r^{Ca}} &= \frac{d\sigma}{d\sigma_r^{Ca}} / \frac{d\sigma}{d\sigma_r^{Au}} \\
 &= \frac{N^{Ca}}{I N_s^{Ca} \times d\sigma_r^{Ca} \times \Omega} / \frac{N^{Au}}{I N_s^{Au} \times d\sigma_r^{Au} \times \Omega} \\
 &= \frac{N^{Ca} \times N_s^{Au} \times d\sigma_r^{Au}}{N^{Au} \times N_s^{Ca} \times d\sigma_r^{Ca}}
 \end{aligned}$$

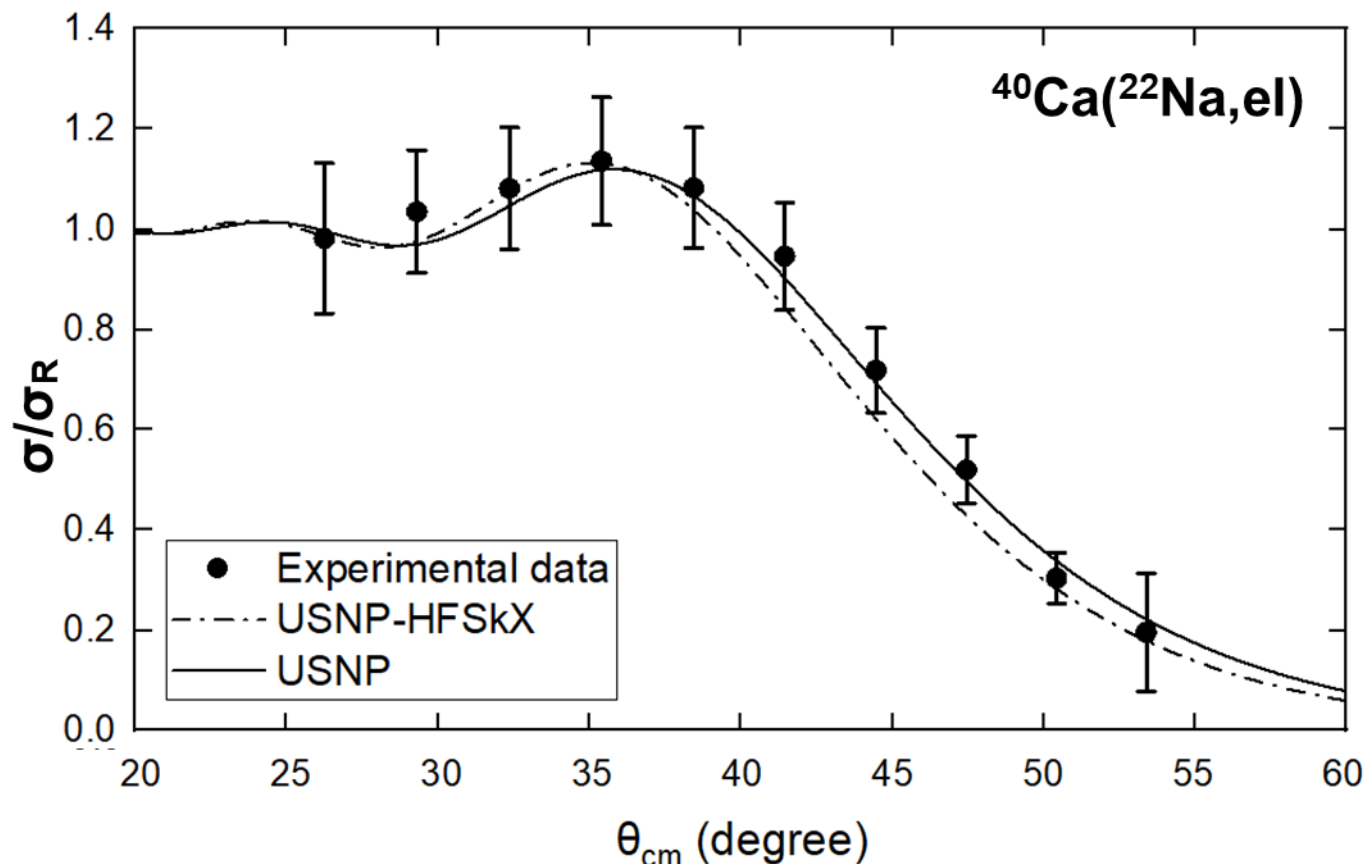
The data measured by each detector in the 2° range is synthesized into a single data point

·OMP 1: Woods-Saxon Potential
 Lin Gan, et al., Chinese Phys. C 45, 054105 (2021).

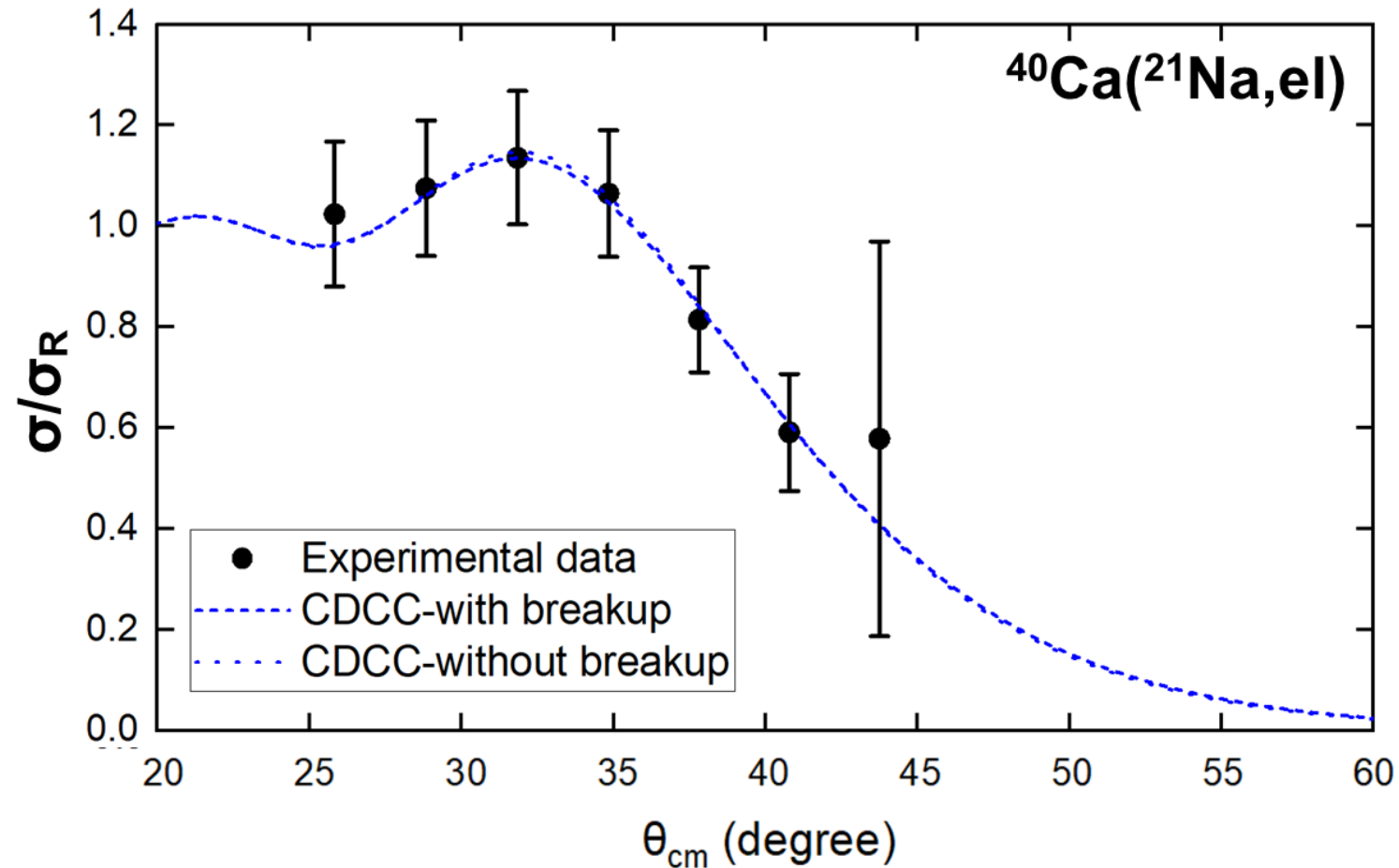
·OMP 2: Single Folding Potential (USNP-HFSkX)
 G. Yang, et al. Phys. Rev. C 107, 044603 (2023).



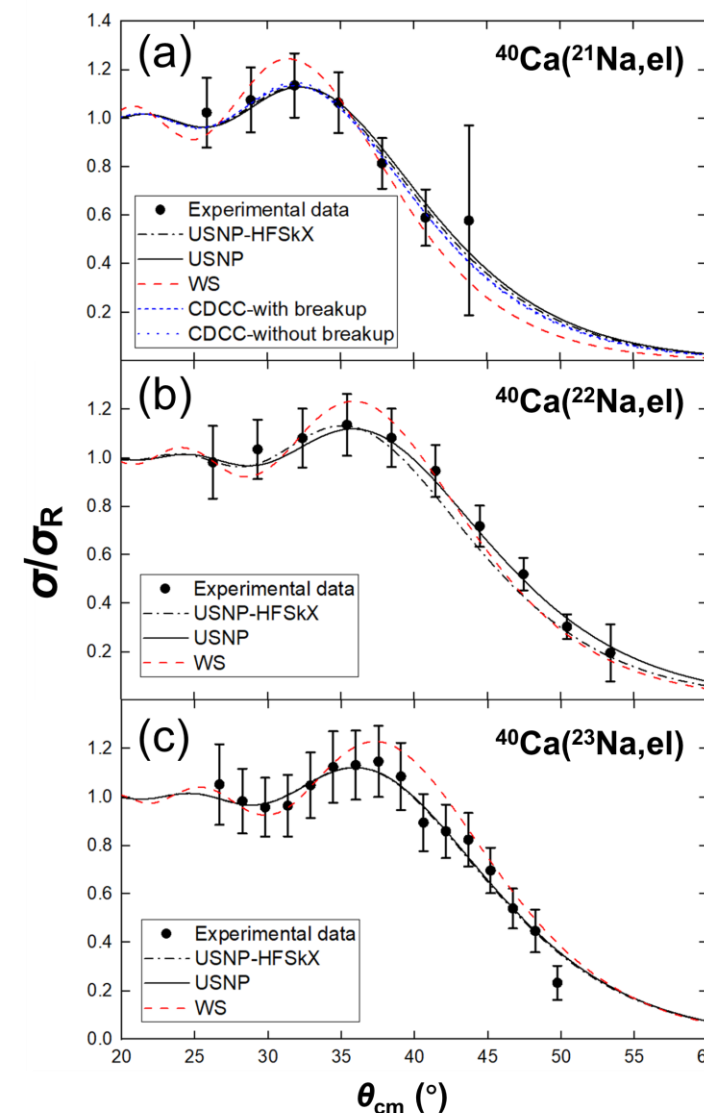
- ◆ BRIF can deliver high quality nuclear reaction data.
- ◆ This method has the prospect to discriminate different theoretical models or model parameters.



- ◆ Compared with the experimental data of ^{22}Na , the angular distribution predicted by USNP-HFSkX is offset to a smaller angle
- ◆ The rms radius of the ^{22}Na nuclear material distribution calculated by HFSkX is 2.819 fm, which is a little different from the experimental value (2.72 ± 0.04) fm, and the new angular distribution (USNP) fits better
- ◆ This method can obtain the rms radius of heavy ions from the elastic scattering angle distributions



CDCC calculations show that the breakup coupling effect is almost invisible, which echo the observations with lighter proton-rich nuclei.



- BRIF is the **only ISOL facility in operation in Asia**. We report the **first experiment using the post-accelerated radioactive beams at BRIF based on the ISOL technique**. The angular distributions of elastic scattering for the radioactive ^{21}Na (**the heaviest nuclei to date in this kind of study**) were measured for the first time.
- The present results demonstrate that **BRIF facility is reliable to deliver post-accelerated radioactive beams and investigate the properties of nuclei near the drip-lines**. These results also suggest that breakup coupling effects on the elastic scattering channel seem not to be large, within the experimental uncertainties, for the loosely bound unstable sodium isotope ^{21}Na at energy around twice the Coulomb barriers, which **echo the observations with lighter proton-rich nuclei**.
- **This work paves the way for the BRIF to investigate more exotic nuclei with post-accelerated radioactive ion beams.**

W. Nan, et al. Sci. Bull., 70: 2925(2025).

NUCLEAR
PHYSICS

核物理

Thanks for your listening!