



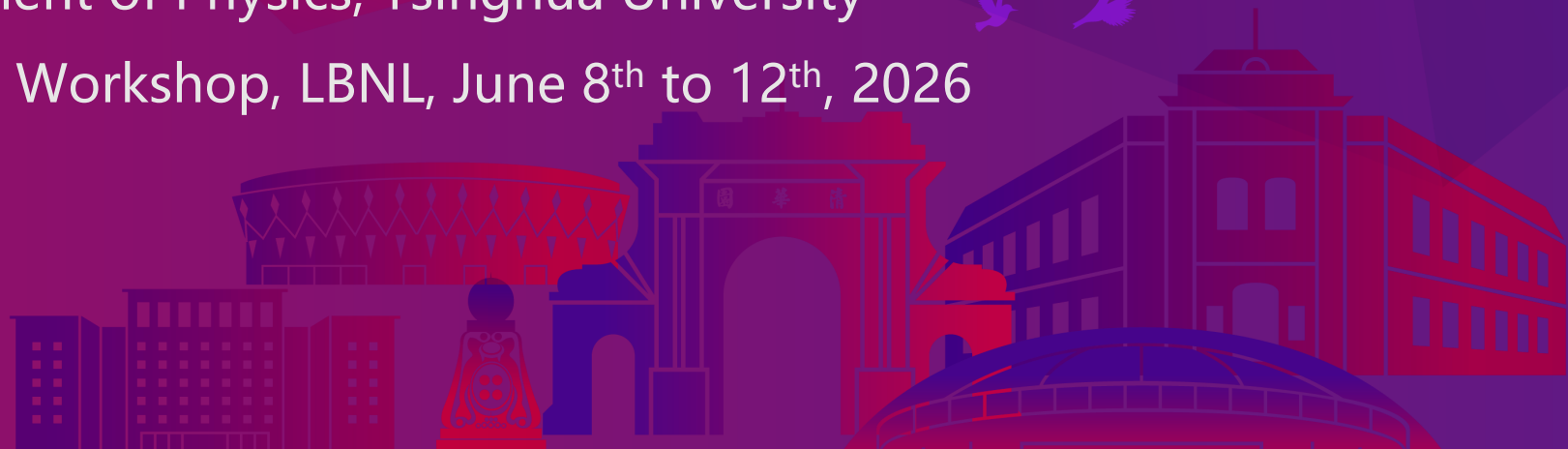
清华大学  
Tsinghua University

# Opportunities of Short-Range Correlations Study at CSR & HIAF in China

Zhihong Ye (叶志鸿)

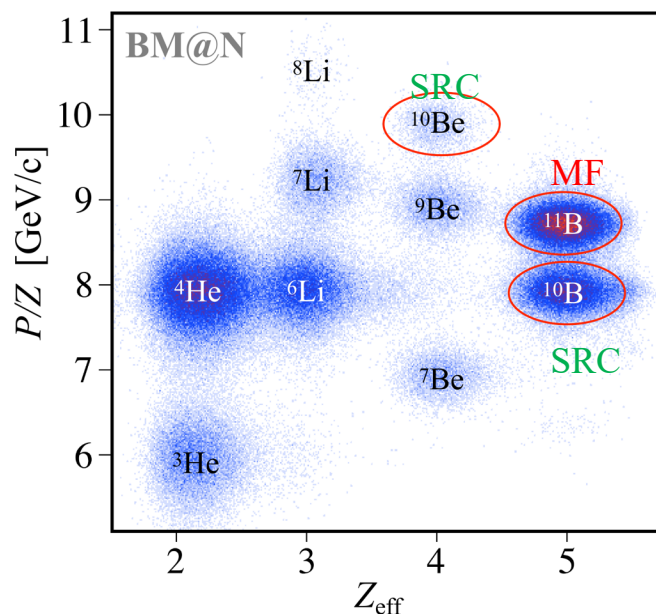
Department of Physics, Tsinghua University

5<sup>th</sup> SRC-EMC Workshop, LBNL, June 8<sup>th</sup> to 12<sup>th</sup>, 2026



## □ Test run in BM@N in 2018 and full run in 2022

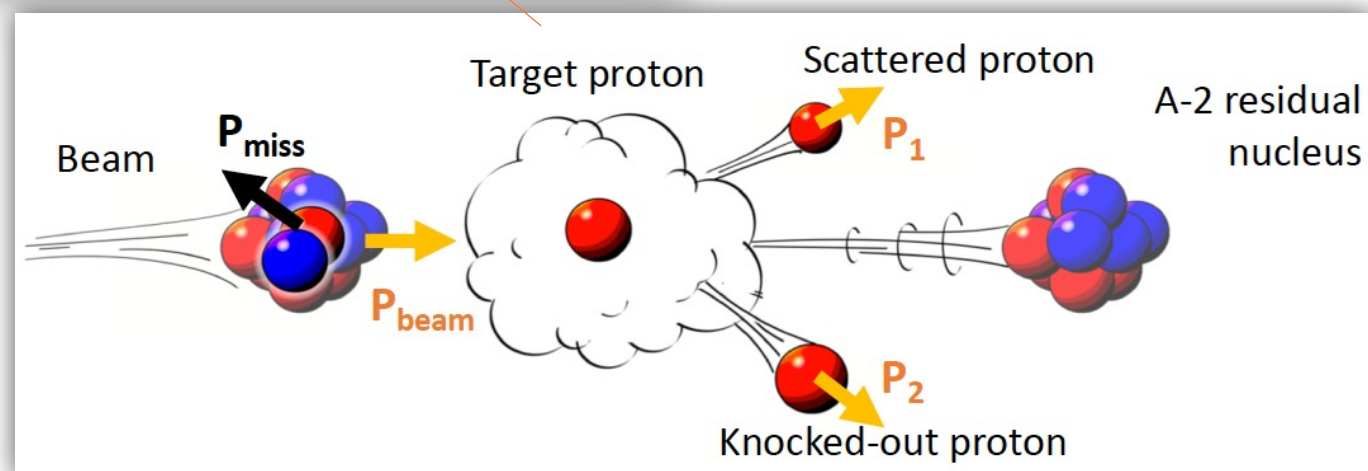
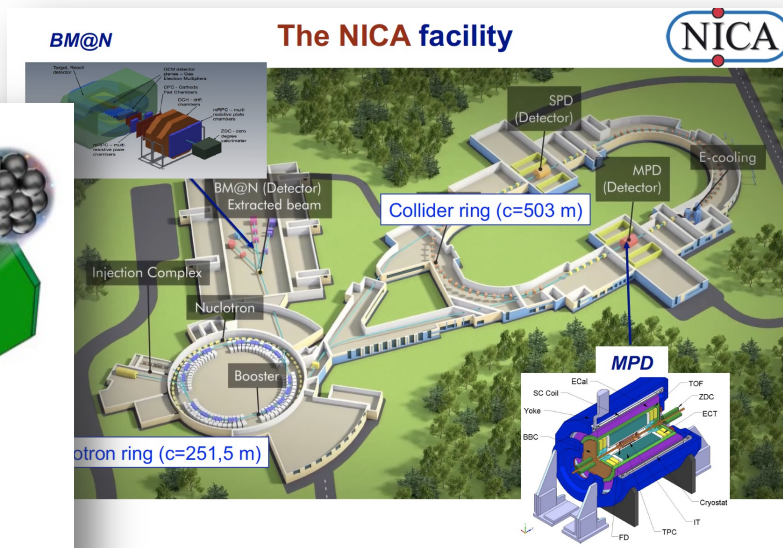
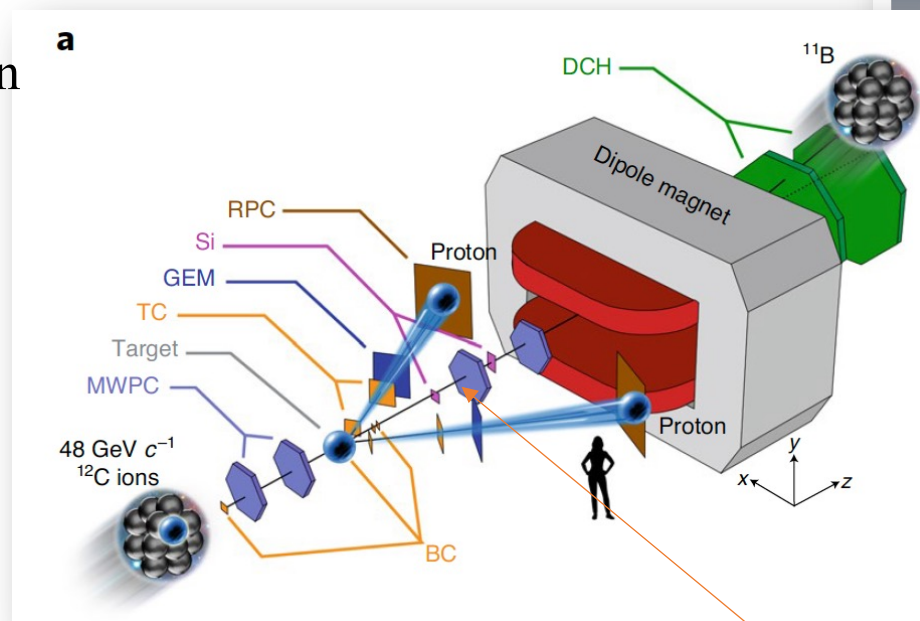
- $^{12}\text{C}$  beam, 3.5 – 4 GeV/c/nucleon
- Identify fragments:



*M. Patsyuk et al. Nature Physics 17, 693 (2021)*

- Detection of two outgoing nucleons
- Reconstruct initial nucleon momentum:

$$\mathbf{P}_{\text{miss}} = \mathbf{P}_1 + \mathbf{P}_2 - \mathbf{P}_{\text{beam}}$$

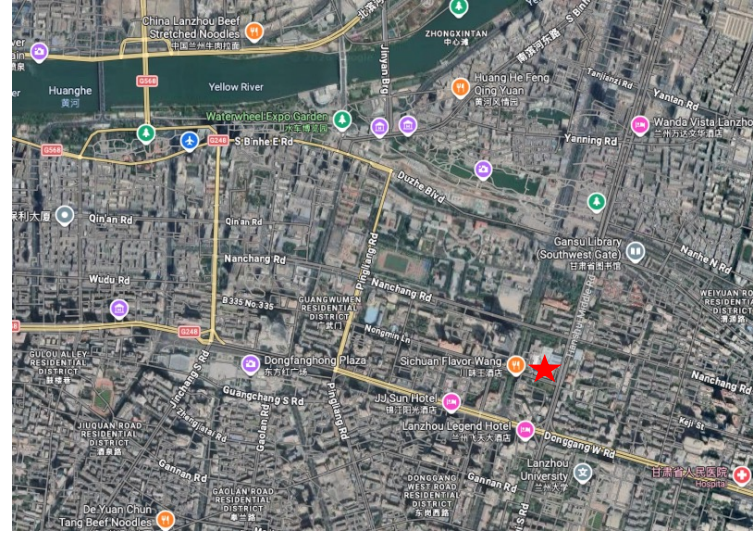


# CSR-HIRFL@IMP

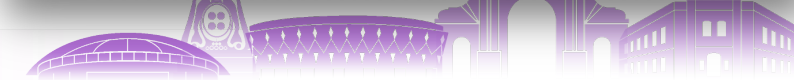
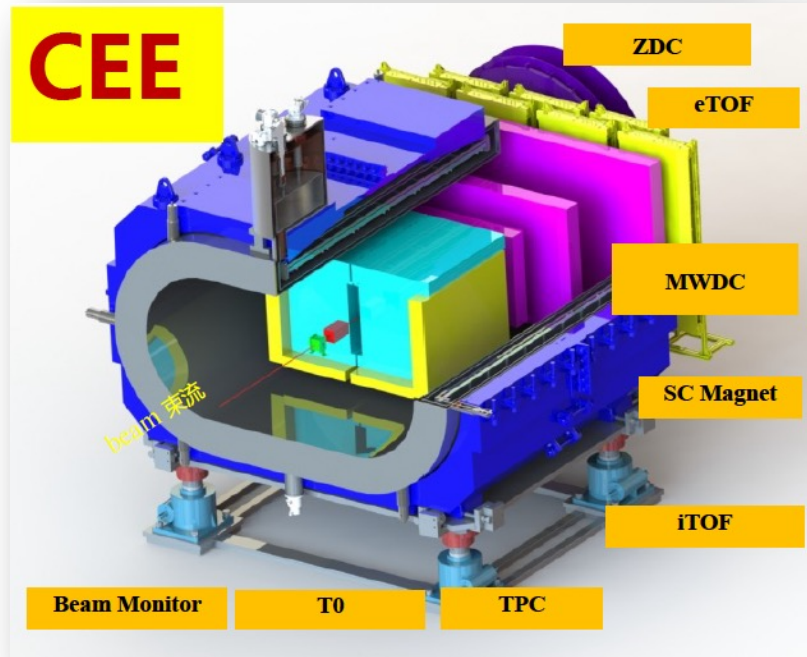


## HIRFL-CSR beam

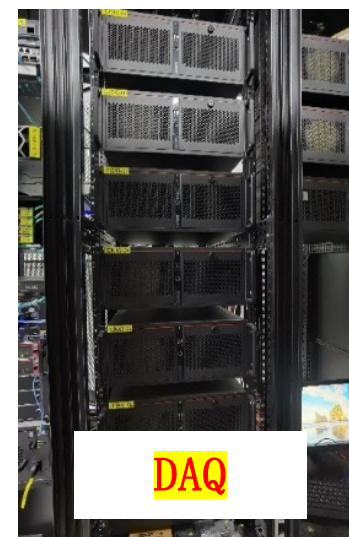
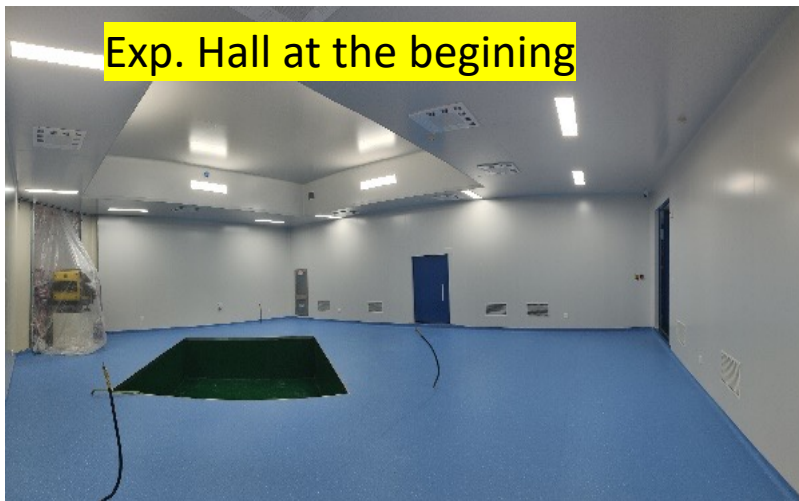
- $P: 2.8 \text{ GeV}$
- $^{12}\text{C}^+: 1 \text{ GeV/u}$
- $^{238}\text{U}^+: 0.5 \text{ GeV/u}$



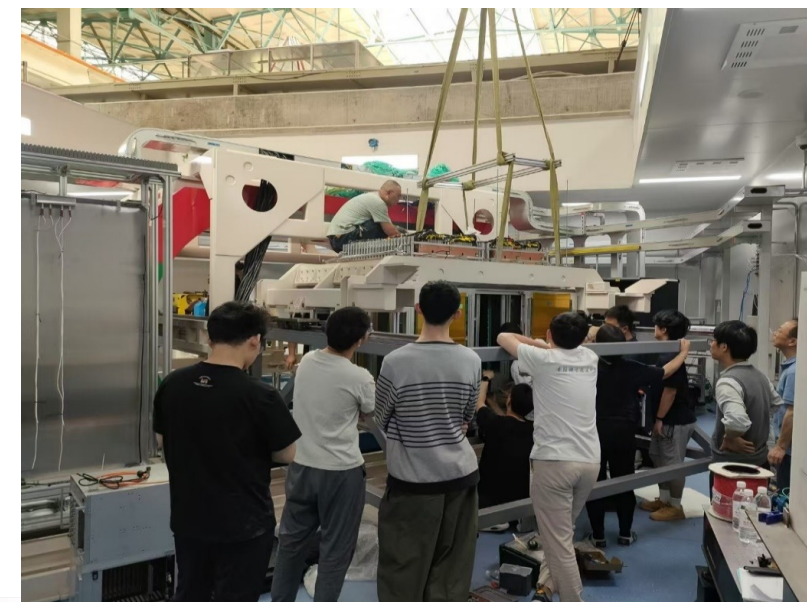
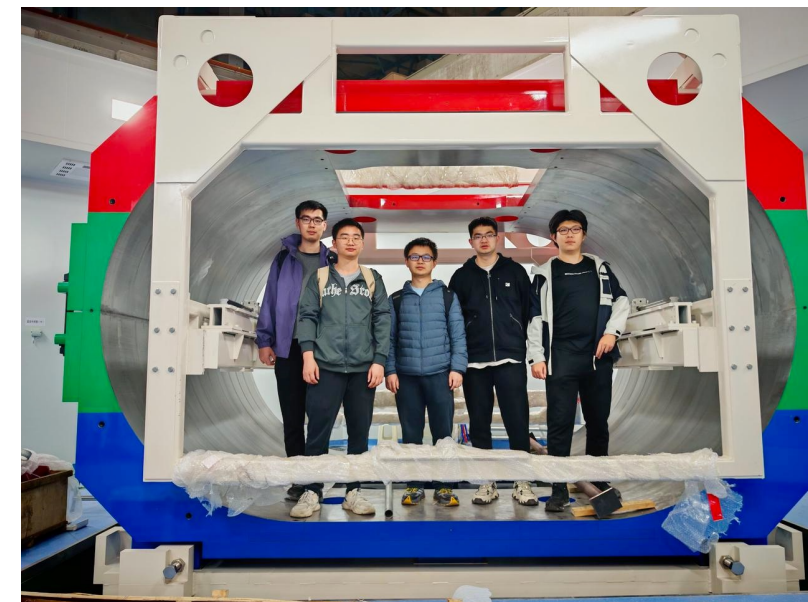
- $\Delta p/p: \leq 5\%$ ,  $\Delta t/t: \leq 80\text{ps}$
- Max. Rate: 10 kHz
- Proton acceptance:  $\sim 85\%$



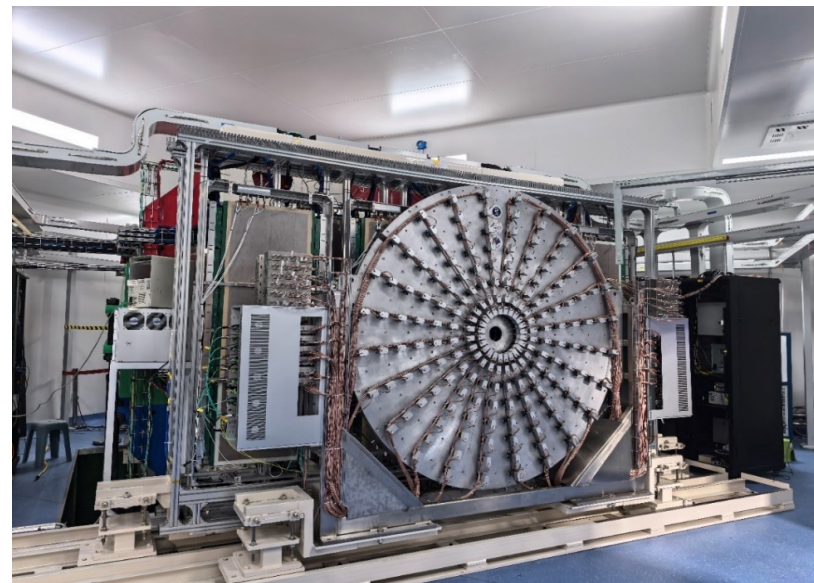
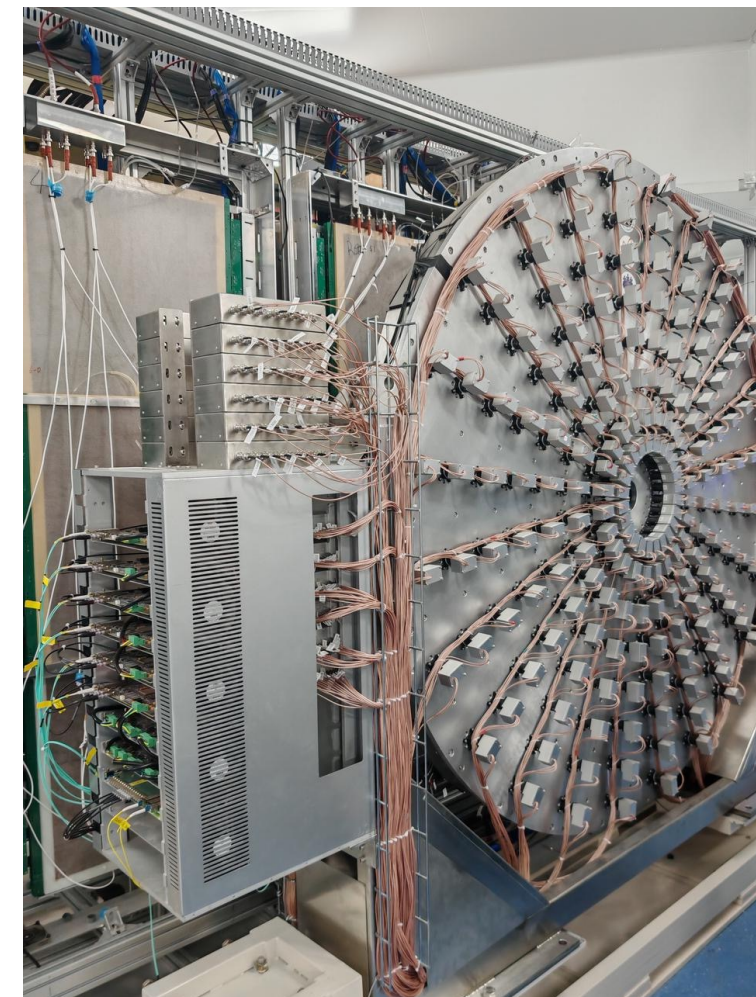
# Installation



- Detectors started installation in Spring 2025
- Commissioning in Summer 2025 w/o magnet
- Magnet coil to be installed in Summer 2026 & beam test



# Installation

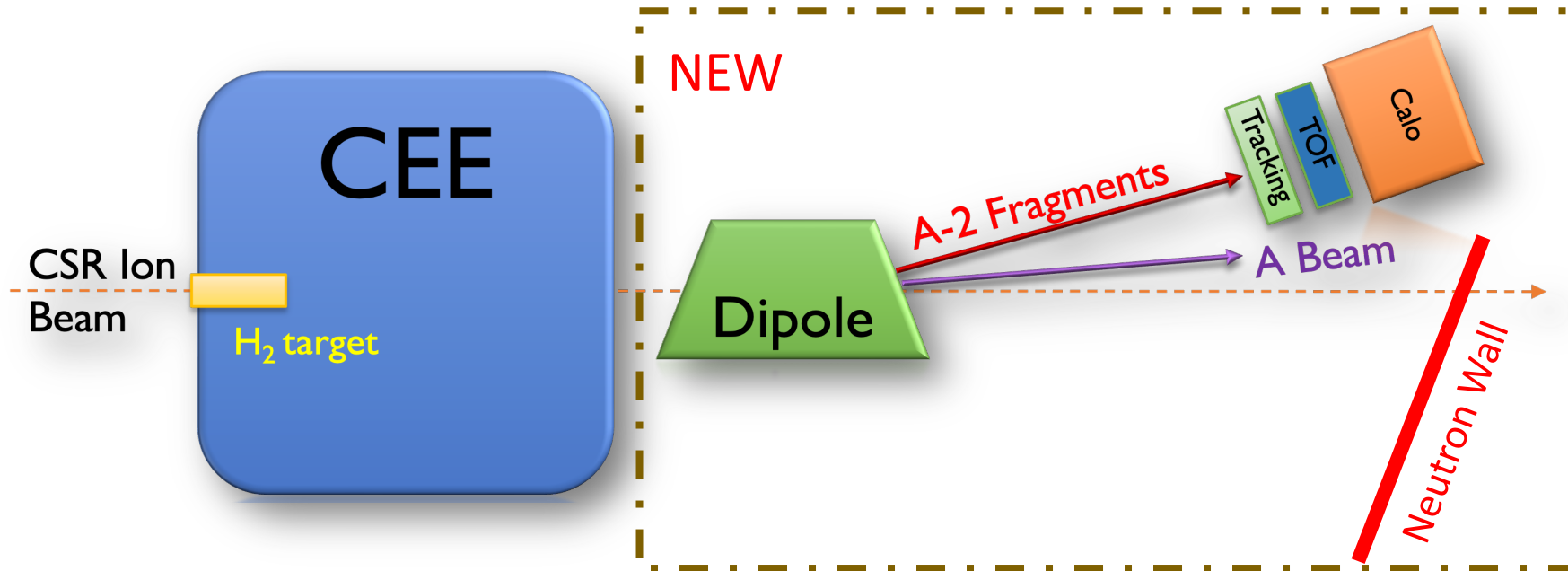
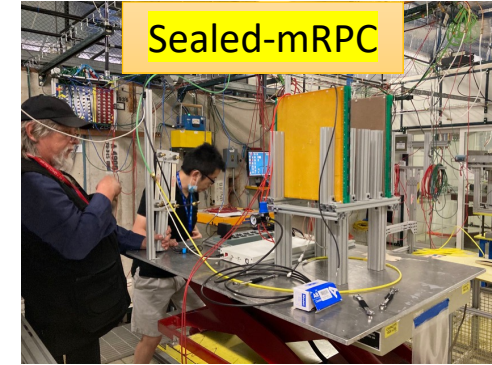
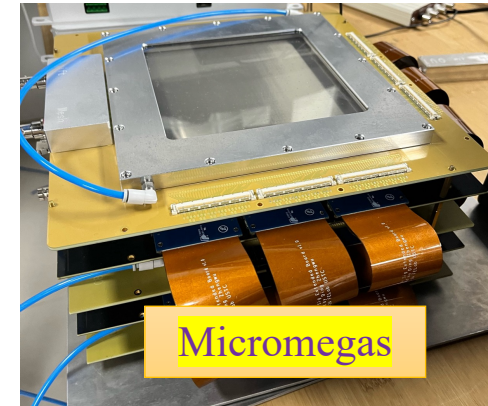


	Collision	Measurement	Physics
I	1.1 GeV/u C+C/Au (No Magnetic field)	Pion ratios (rapidity, Pt, Centrality)	EoS
		Collectivity: p, d, t, $^3\text{He}$ , $^4\text{He}$ , $\Lambda$ , K0	EoS
		Rapidity Distribution: p, d, t, $^3\text{He}$ , $^4\text{He}$ , $\Lambda$ , K0	EoS
		Correlations: pion HBT; p-p, p-d, p-t, d-d	FIS
		Hyper-Nuclei Production: $^3_{\Lambda}\text{H}$ , $^4_{\Lambda}\text{H}$	EoS & YN
		High moments of proton	PD
II	0.3-0.5 GeV/u U+U/Au+Au	Pion ratios (rapidity, Pt, Centrality)	EoS
		Collectivity: p, d, t, $^3\text{He}$ , $^4\text{He}$	EoS
		Rapidity Distribution: p, d, t, $^3\text{He}$ , $^4\text{He}$	EoS
		Correlations: pion HBT; p-p, p-d, p-t, d-d	FIS
		High moments of proton	PD



❑ Using CEE w/ additional changes/upgrades:

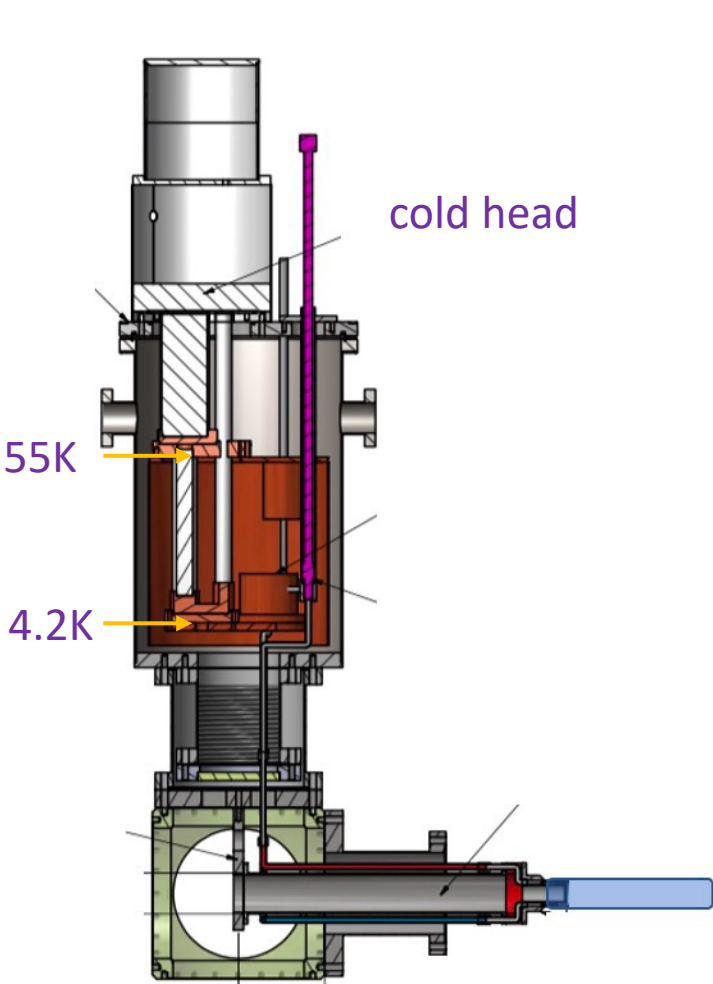
- ✓ Liquid hydrogen (LH2) target
- ✓ Replace ZDC w/ a new detectors for nuclear fragments
- ✓ A new dipole?
- ✓ Neutron wall?



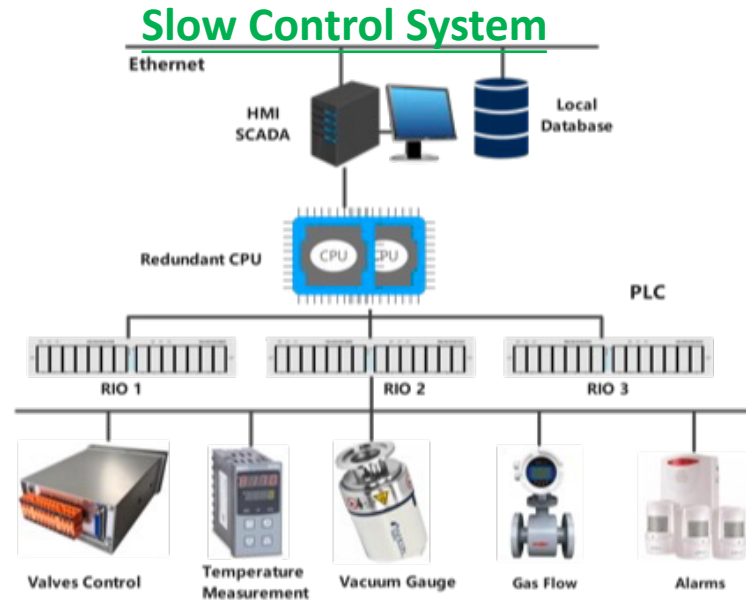
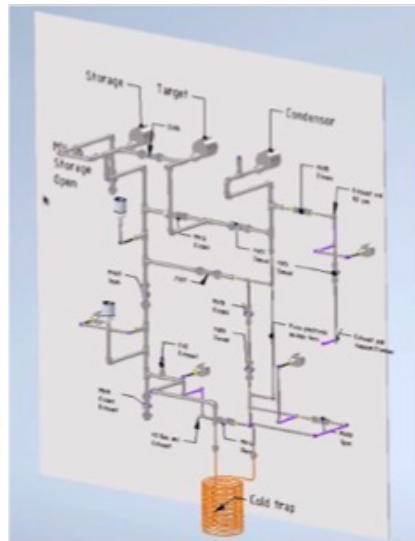
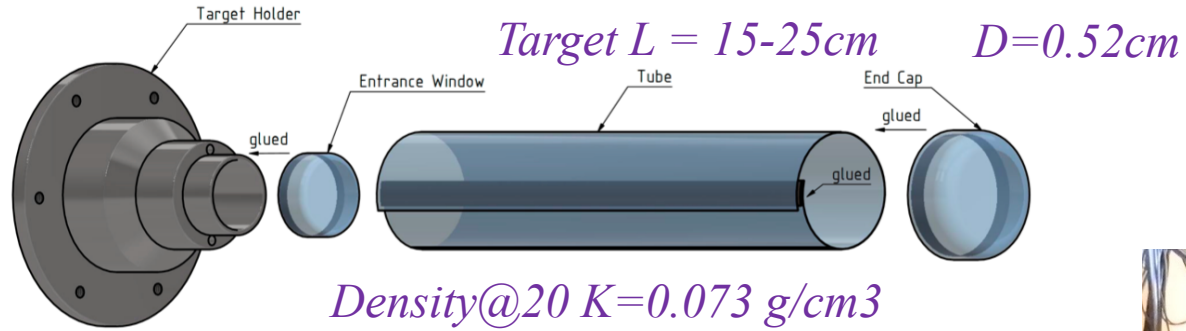
# LH2 Target

Under development by Hongna Liu, Beijing Normal University (BNU)

Commissioning in 2026



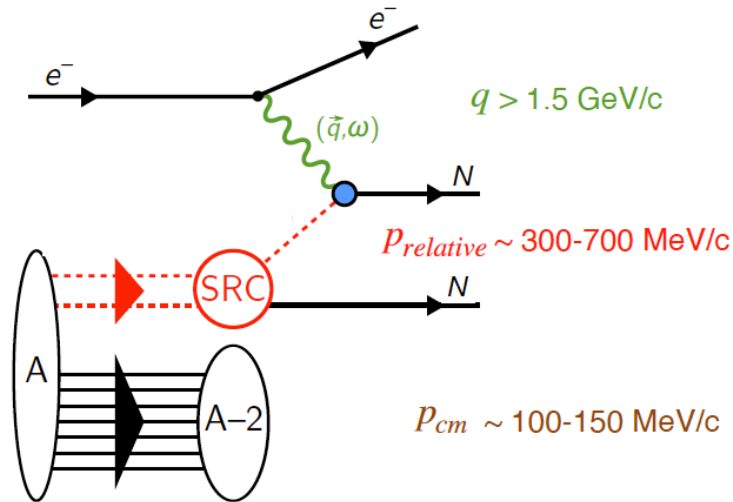
Target Chamber&Cooling



## Goals:

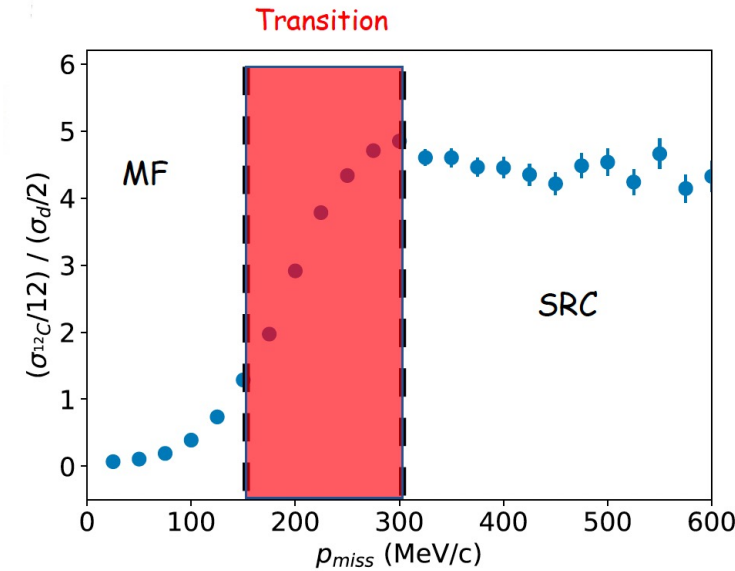
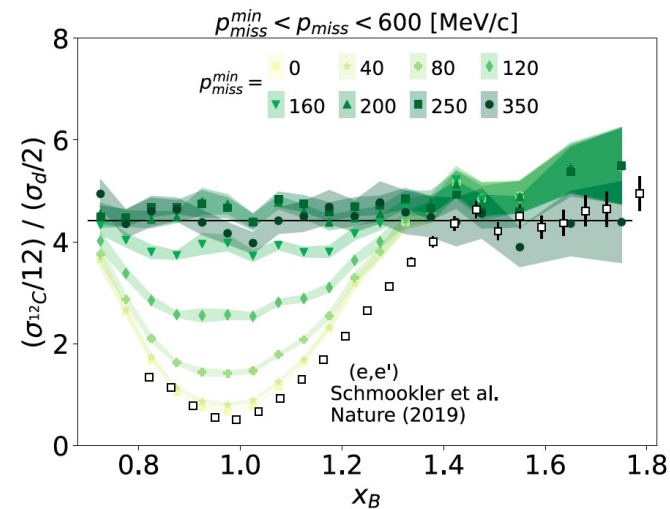
- ✓ Precision nuclear wave functions/spectroscopy factors
- ✓ Cleanly define MF & SRC transition regions for the first time
- ✓ **\*NEW\***: SRC in Heavy-Ion collision with new observations (see talks of B.A. Li & B.J. Cai, P. Li)

Scale Separation:  $q \gg P_{relative} \gg P_{cm}$



PRC 92 (2015), PLB 780 (2018), PLB 791 (2019), PLB 792 (2019), JPG 47 (2020), Nature Physics 17 (2021), PRC 104 (2021), PRC 53 (1996), PRL 119 (2017)

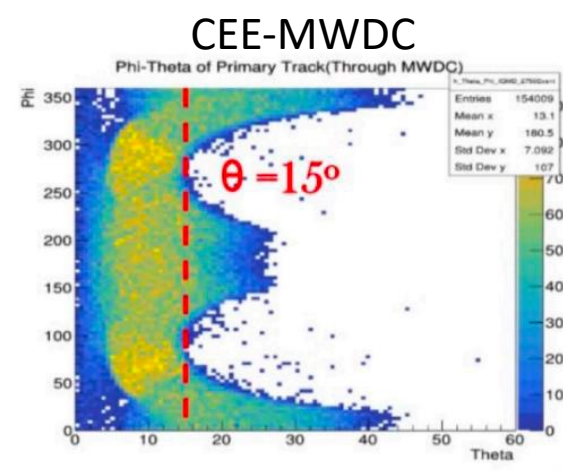
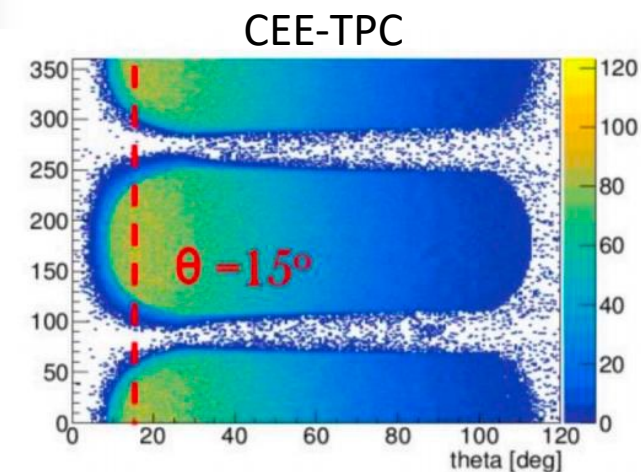
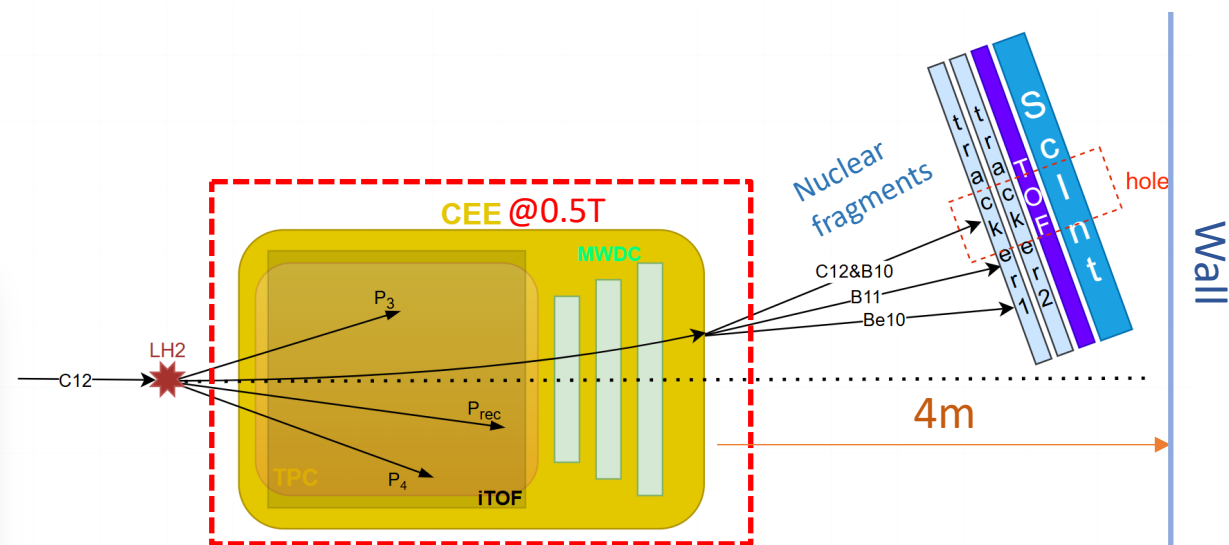
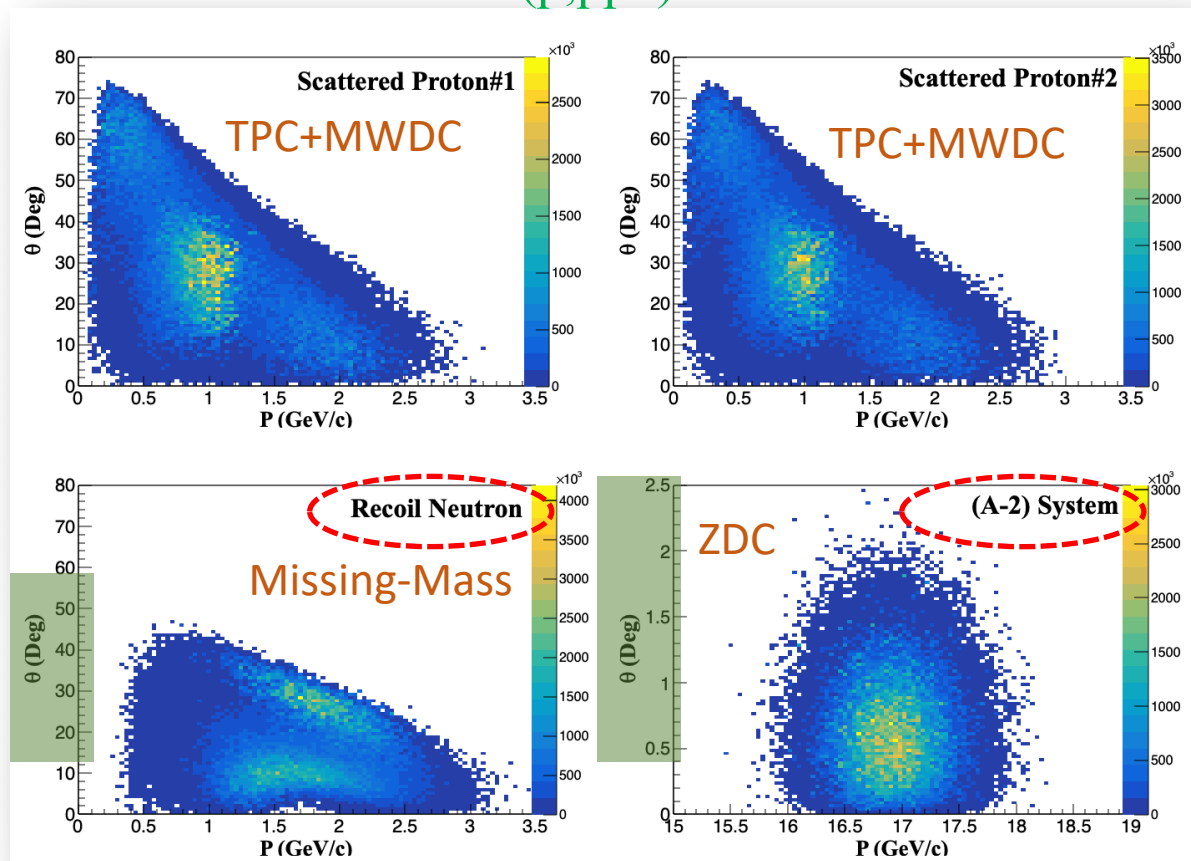
Korover PRC 107, L061301 (2023)



☐ Monte-Carlo simulation of SRC w/ CEE@HIRFL

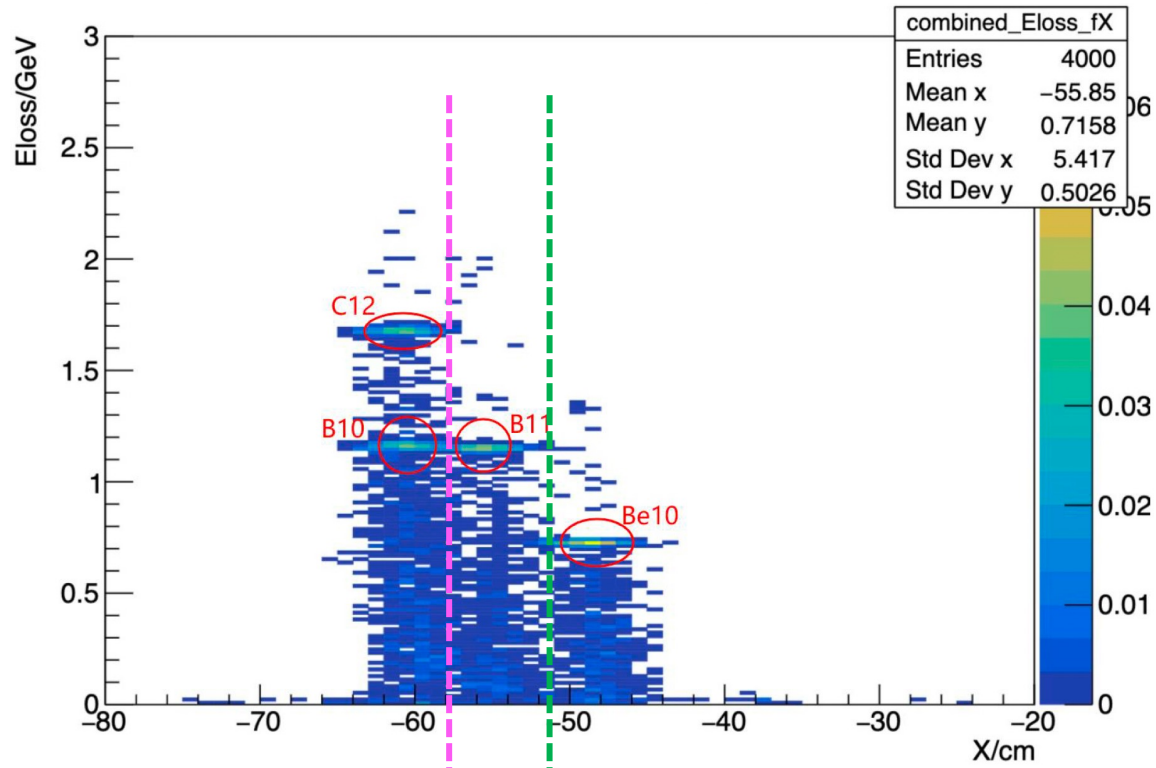
☐ Protons are within existing CEE detectors

$^{12}\text{C}^+ (p,ppn)^{10}\text{B}^+$

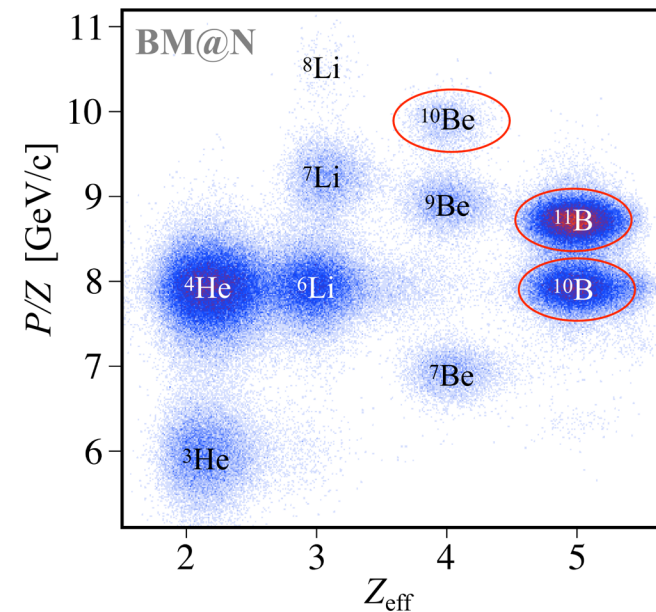
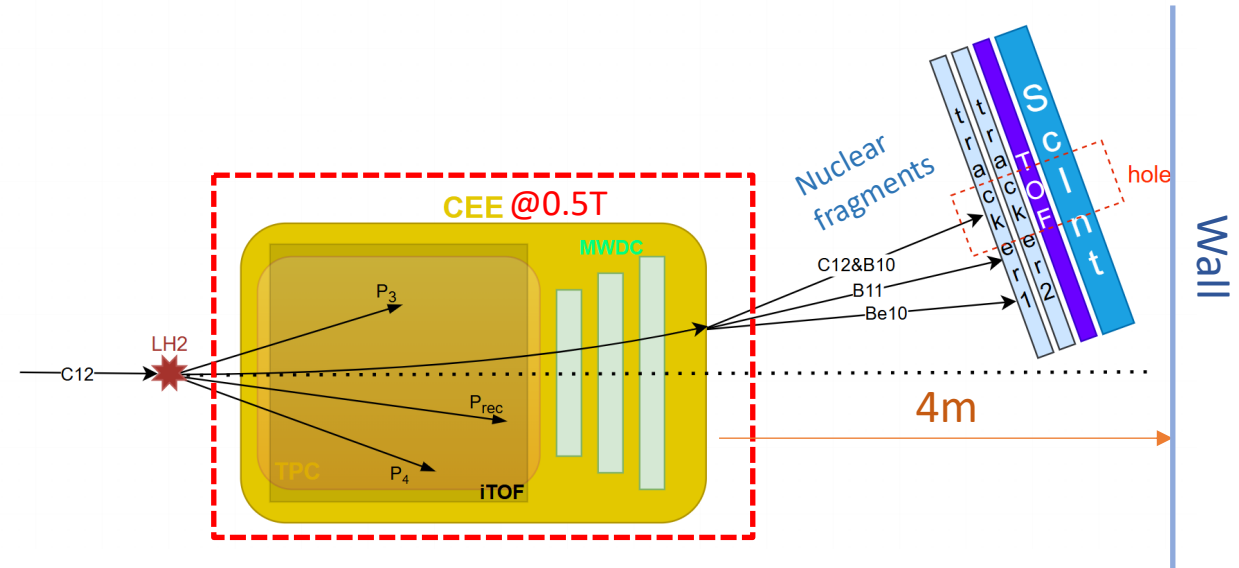


❑ Fragment detection w/ standard CEE setup

- ✓ Fragment-Detector at 4m downstream
- ✓ Same magnetic field as 0.5T



- Not yet considered:
  - Detector resolution & efficiencies
  - Background

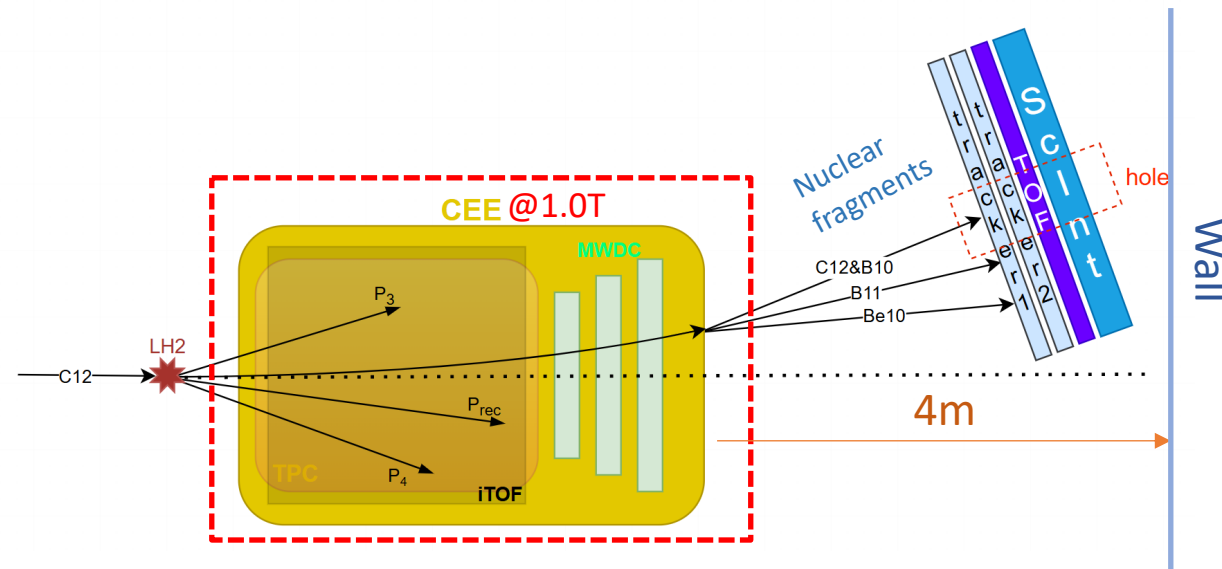
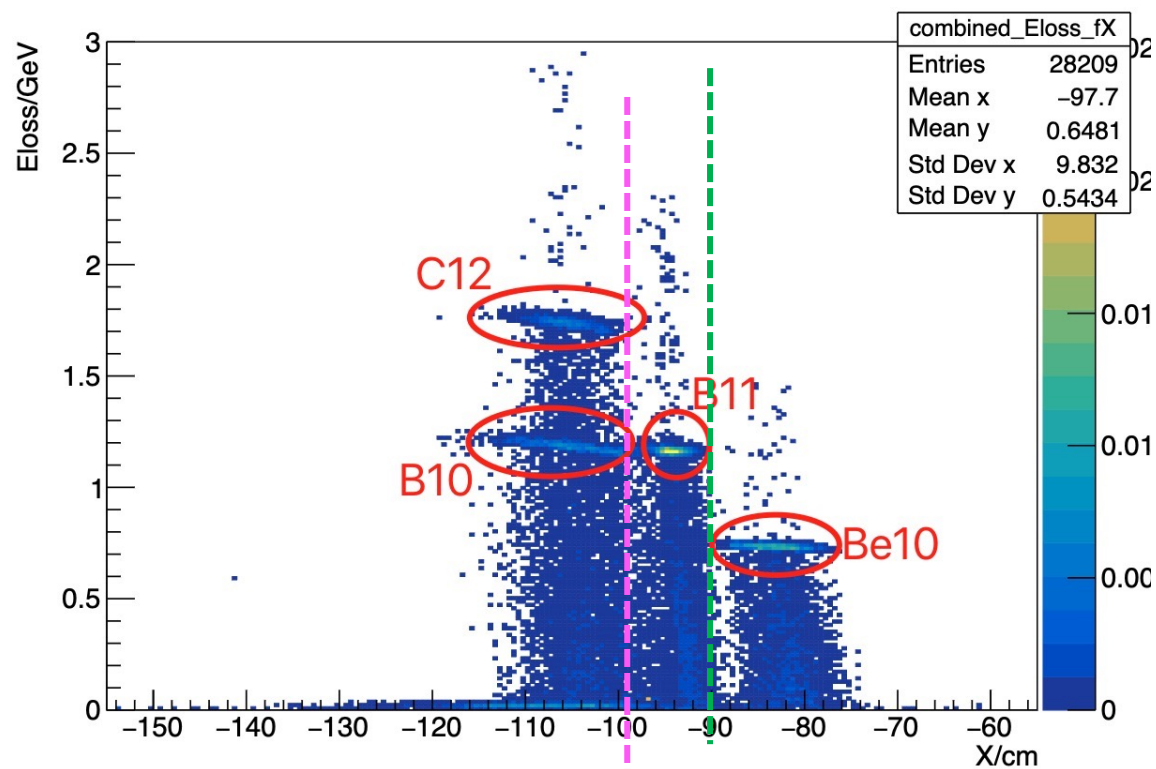


*M. Patsyuk et al. Nature  
Physics 17, 693 (2021)*

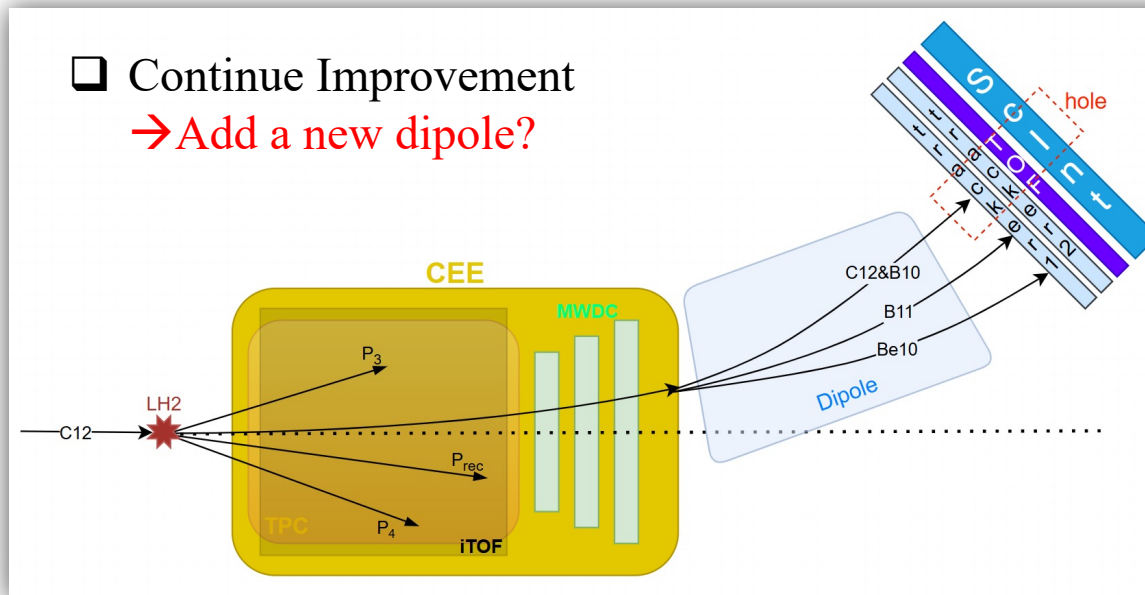


❑ Fragment detection w/ standard CEE setup

- ✓ Fragment-Detector at 4m downstream
- ✓ Increase magnetic field to 1.0T



❑ Continue Improvement  
→ Add a new dipole?





□ HIAF construction to be completed in 2025:

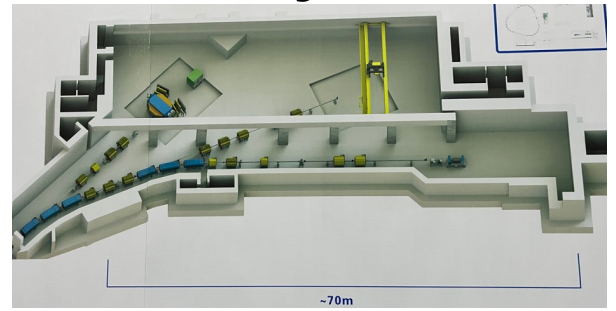
- C12,  $E=51 \text{ GeV}/c$  ( $4.25 \text{ GeV}/c/u$ )  $\rightarrow$  similar to NICA
- $1.8 \times 10^{12} \text{ pps}$  (fast extr.),  $4.5 \times 10^{11} \text{ pps}$  (slow extr.) vs.  $3.5 \times 10^4 \text{ pps}$  at JINR



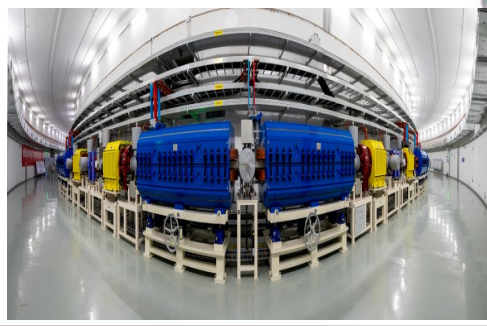
# 强流重离子加速器装置 (HIAF)



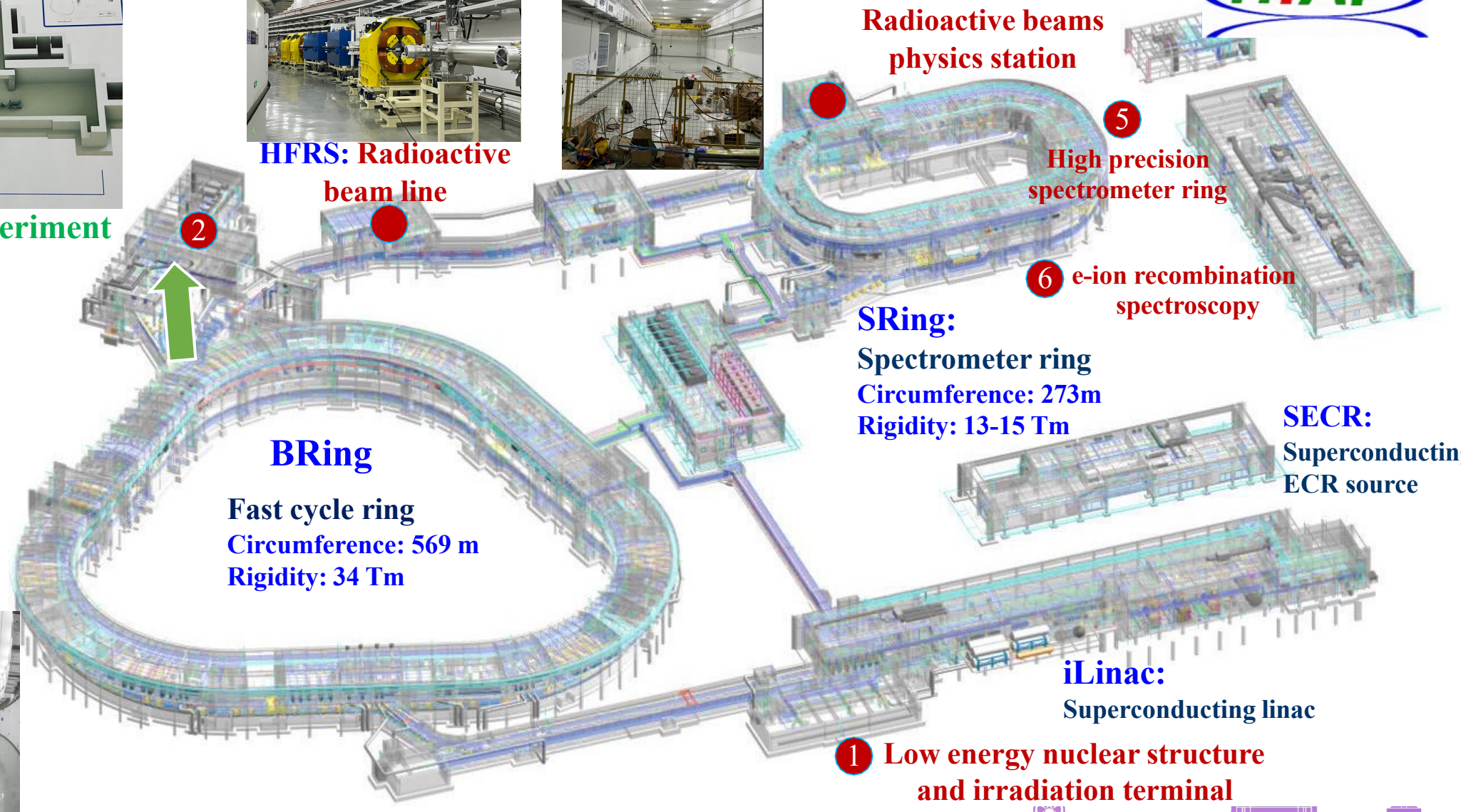
## HIAF Layout:



High energy experiment station

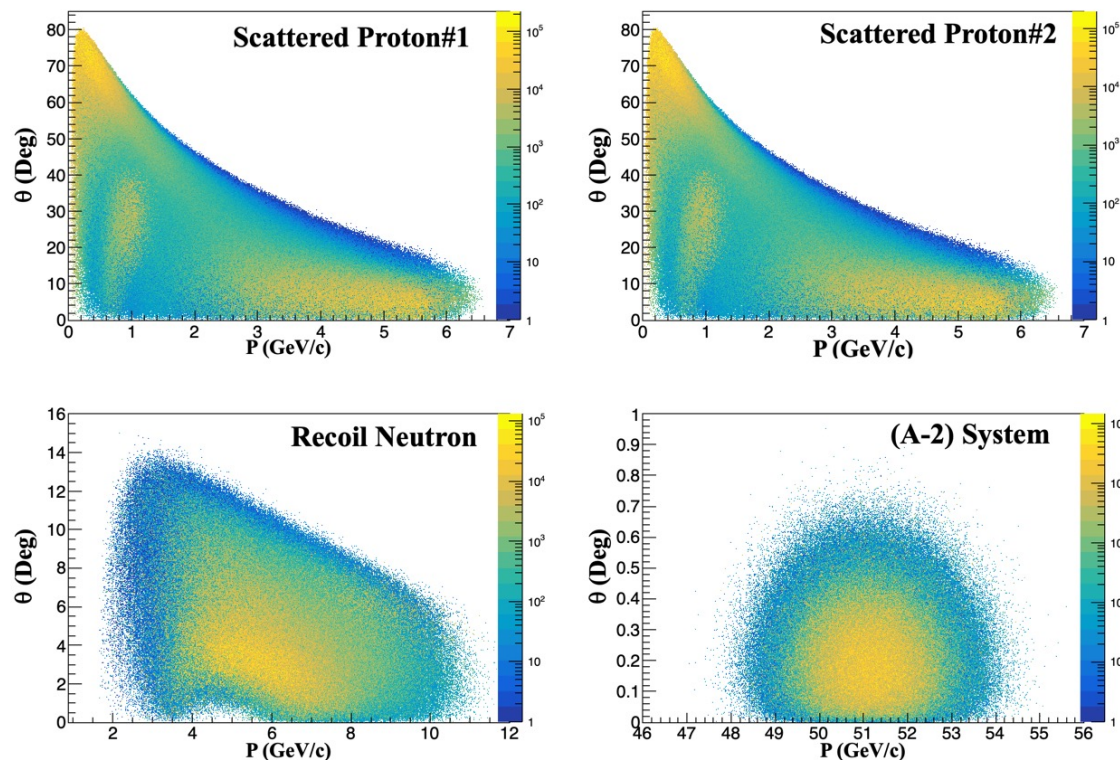


HFRS: Radioactive beam line

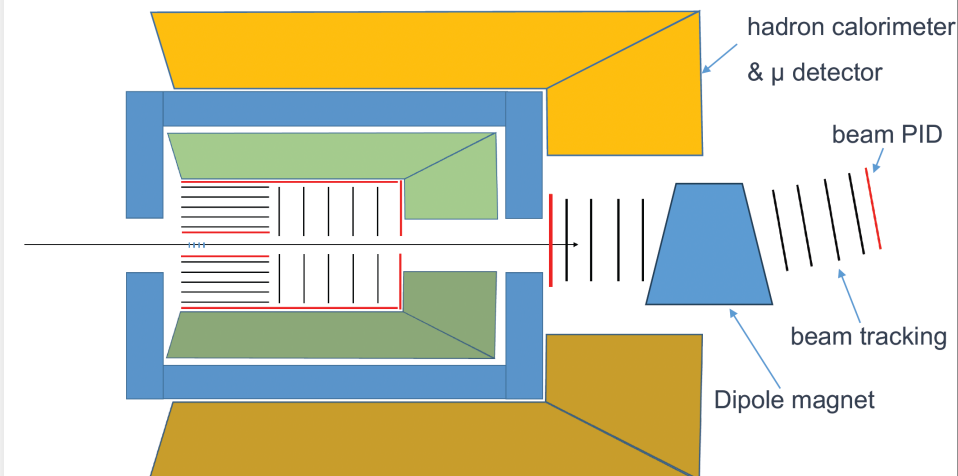


□ Precision frontier for SRC in HES:

- Mapping 2N-SRC at all kinematic
- Search 3N-SRC



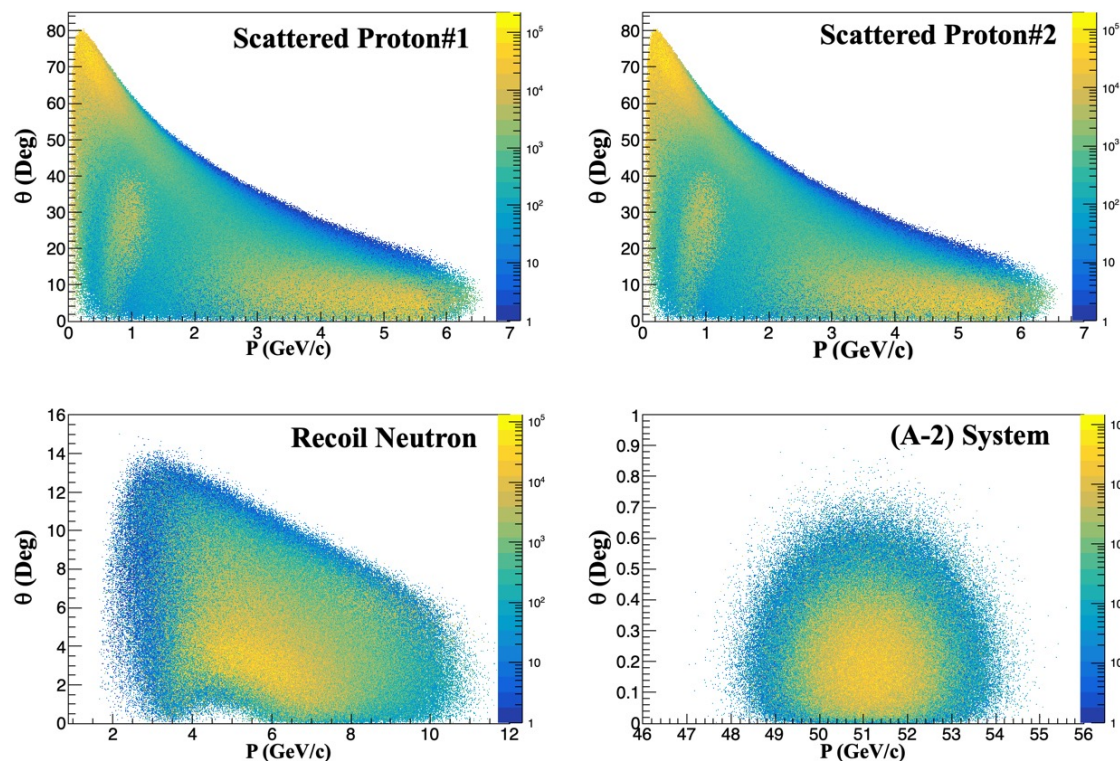
SRC with the new spectrometer  
→ preliminary thoughts



Since this spectrometer is very compact, hadron calorimeter with full coverage may be affordable

□ Precision frontier for SRC in HES:

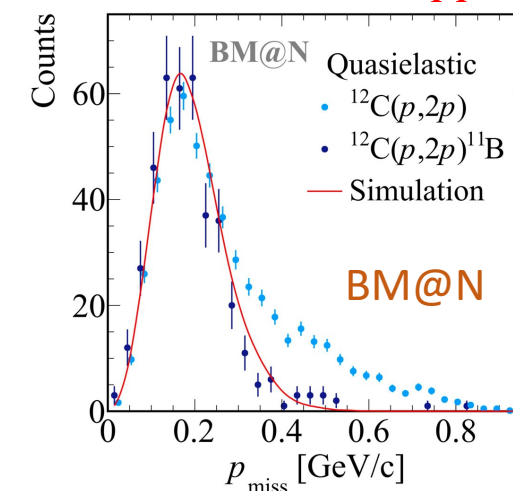
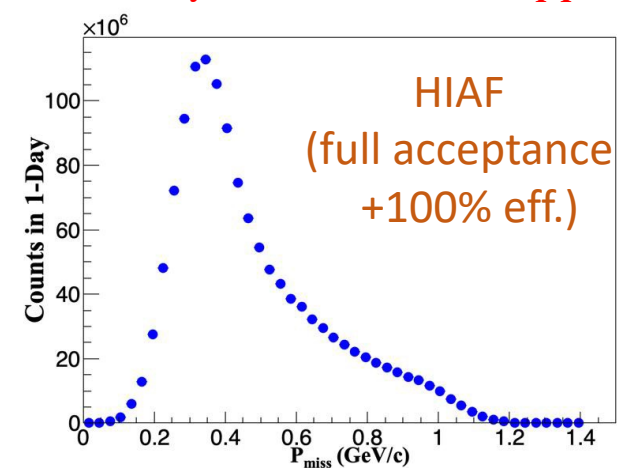
- Mapping 2N-SRC at all kinematic
- Search 3N-SRC



□ Monte-Carlo Simulation ( $^{12}\text{C}^{6+}$  at 51 GeV/c)

1-day @  $(4.5 \sim 18) \times 10^{11}$  pps

2-week @  $3.5 \times 10^4$  pps



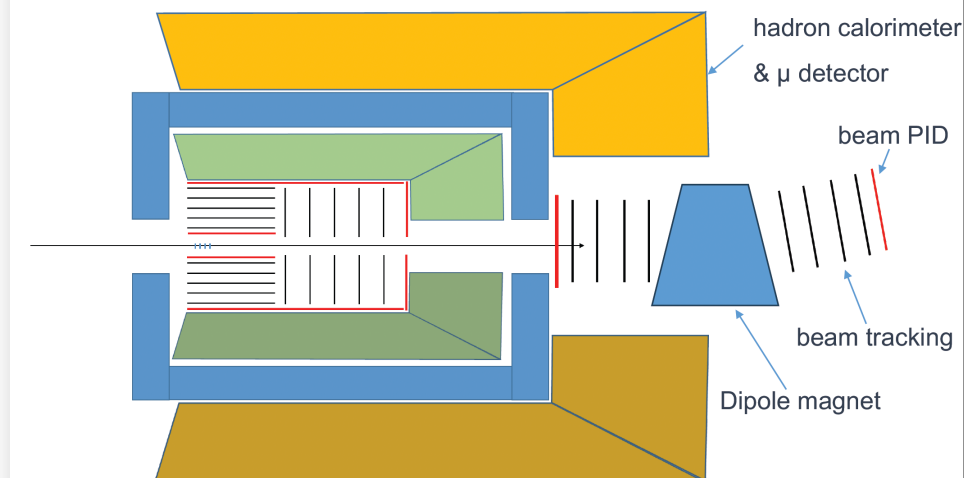
## □ Key Challenges

Luminosity is not limited by the beam, BUT by:

- Hydrogen Target
  - Liquid target (length, density, coolant power, etc.)
  - Waterfall target (Oxygen contamination)
  - CH<sub>2</sub> target (Carbon contamination)
- Detectors
  - Silicon pixel tracking rates & resolution & radiation
  - Momentum vs magnetic field
  - Neutron detectors
  - Fragment Detectors
- Readout Electronics
  - Trigger or Triggerless
  - Pipeline (e.g., CLAS12 & SoLID & GlueX DAQ @JLab)

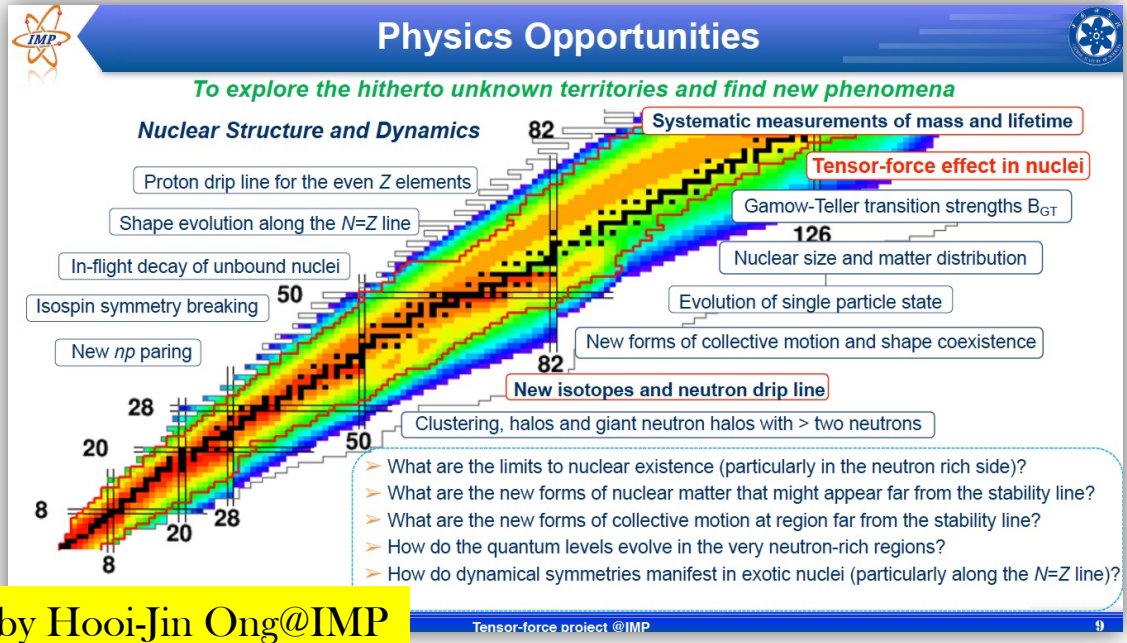


SRC with the new spectrometer  
→ preliminary thoughts

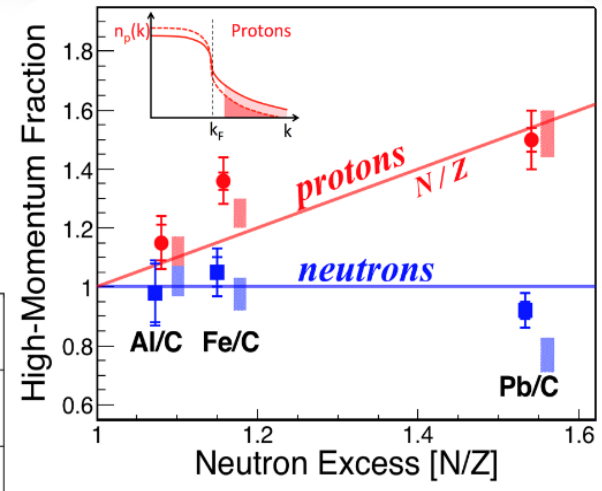
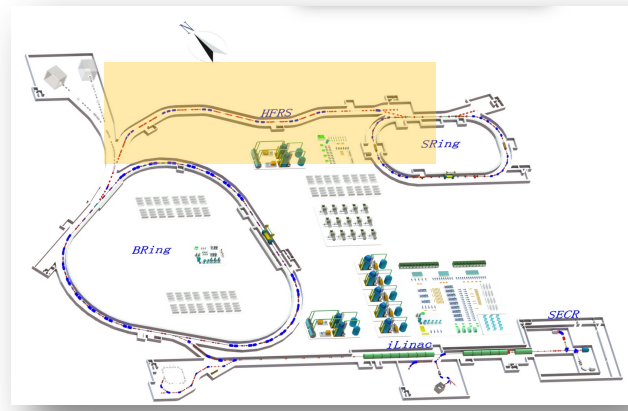


Since this spectrometer is very compact, hadron calorimeter with full coverage may be affordable

## Radioactive ion beams are produced at HIRIBL

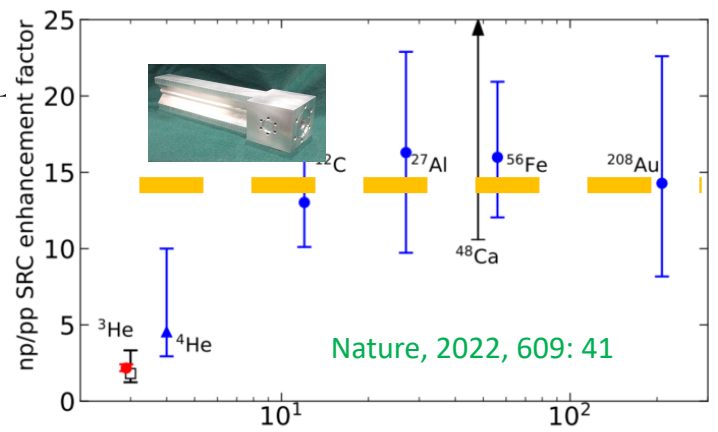


Maximum rigidity	25 Tm
Resolving power	800, 700, 1100
Momentum acceptance	$\pm 2.0\%$
Angular acceptance	$\pm 30$ mrad (x) $\pm 15$ mrad (y)
Beam size	$\pm 1$ mm (x) $\pm 2$ mm (y)
Total length	192 m



## Study 2N-SRC w/ radioactive isotopes from HIRIBL

- ✓ Light to large neutron-rich nuclei
- ✓ Cannot be done in fixed target experiments
- ✓ Need to provide a wish-list of isotopes
- ✓ **Detector concept?**



- First study of SRC in the existing CEE@HIRFL w/ small upgrades
  - ✓ CEE was designed for heavy-ion collision (EoS)
  - ✓ Commissioning CEE w/o magnetic field in 2025 and w/ field-on in 2026
  - ✓ R&D of fragment detector + hydrogen target + neutron-wall for SRC
  - ✓ Parasitic run or new beam-time request in 2027?
  
- Precision frontier SRC study with HIAF
  - ✓ Search 3N-SRC @ High-Energy Station with a full-acceptance detector
  - ✓ Study 2N-SRC in asymmetric isotopes @HIRIBL (need to develop a detector concept)
  - ✓ Initial discussion & detector design ongoing
  
- 2nd SRC-China Workshop in 2026 at Huzhou, Zhejiang province
  - ✓ Works are supported by NSFC “Joint NSFC-ISF Research Grant” under funding#12361141822

