

# Recent results of SHANS2

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# TASCA 26

22<sup>nd</sup> Workshop on Recoil Separator for  
Superheavy Element Chemistry & Physics

# CONTENT

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EXPERIMENTAL SETUP



RESULTS



SUMMARY

# Gas-filled recoil separators in IMP

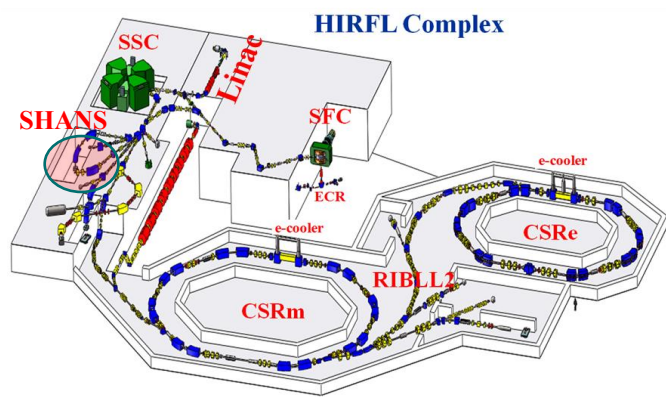
- Synthesis of heavy and superheavy nuclei
- Decay spectroscopy and nuclear structure
- Mass measurement
- Chemistry on SHEs
- ...

**Production:** Fusion evaporation reaction

**Separation:** Gas-filled recoil separators (DGFRS1&2, GRAND, TASCA, GARIS1&2&3, RITU, AGFA, BGS, ...)

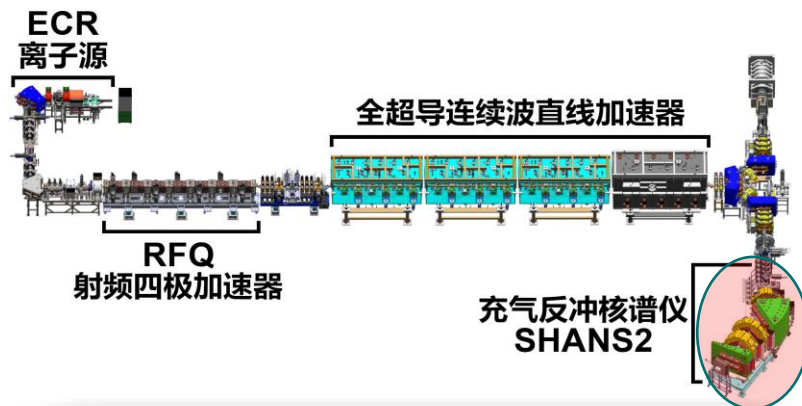
**Identification:** Correlation measurement based on, e.g.,  $\alpha$ -decay chains, RDT, exc. func., ...

Heavy Ion Research Facility in Lanzhou (HIRFL)



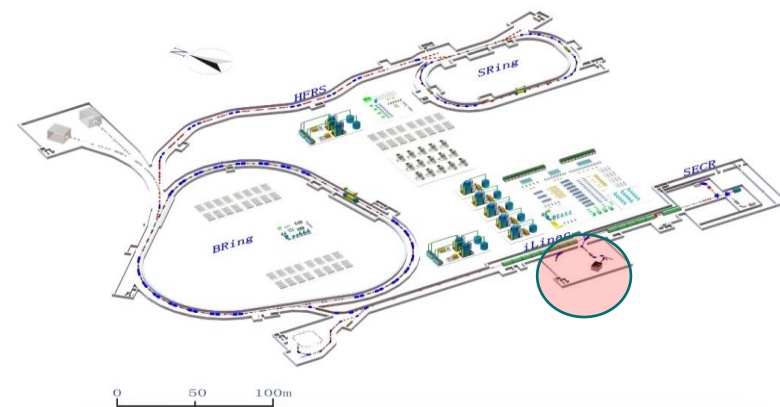
SHANS

China Accelerator Facility for Superheavy Elements (CAFE2)



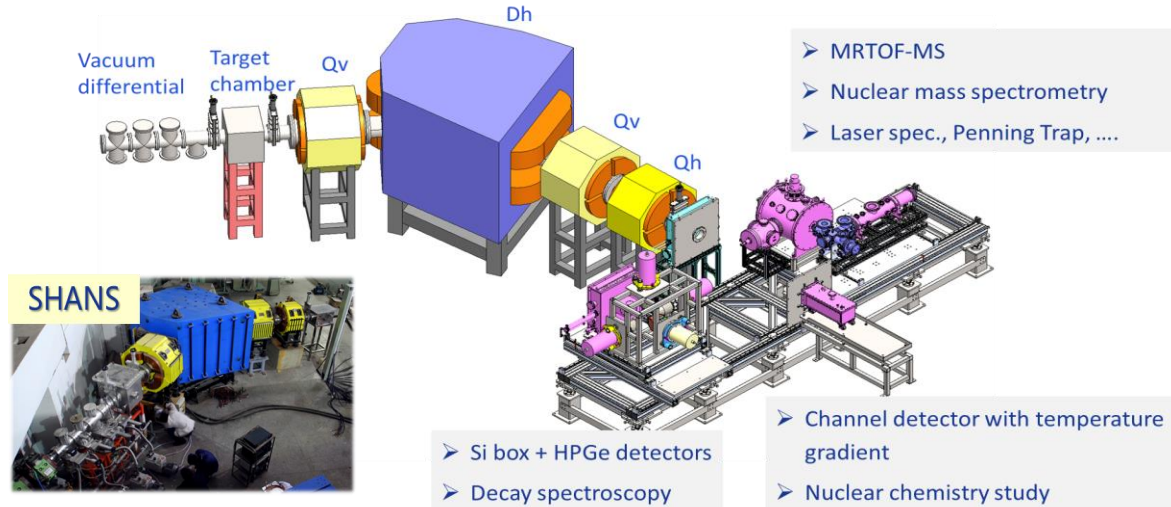
SHANS2

High Intensity Heavy Ion Accelerator Facility (HIAF)



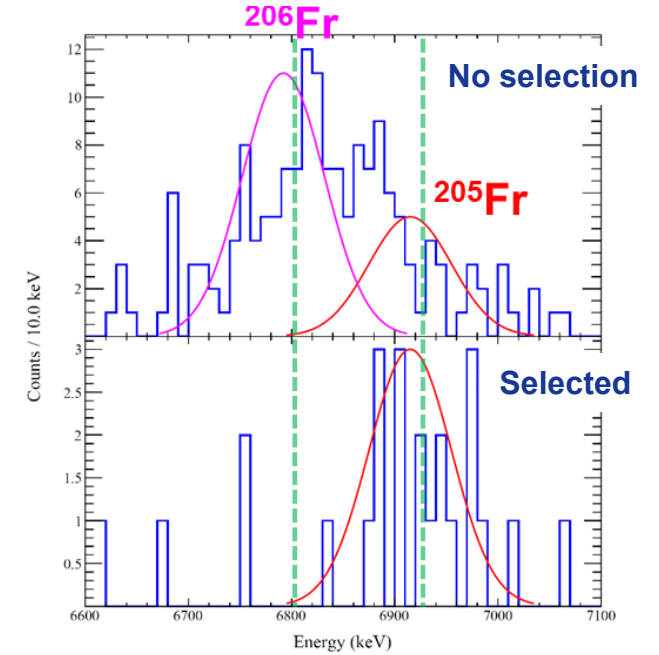
HIAF gas-filled separator

# SHANS at HIRFL

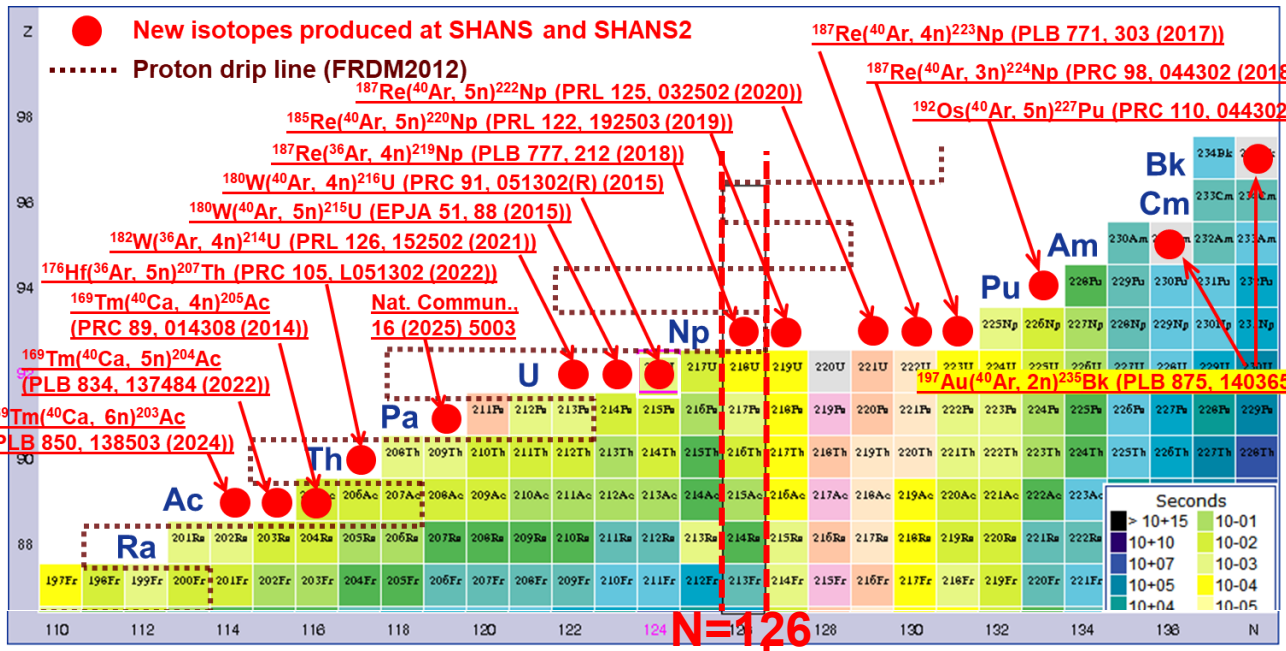


- Low cross section (pb ~ nb)
- Short half-lives (~μs or lower)
- Multi decay modes, e.g. α, EC, ECDF, ...

## α spectrum after MRTOF



X. Kong, Y. S. Wang, Y. L. Tian, et al., NIMA, submitted

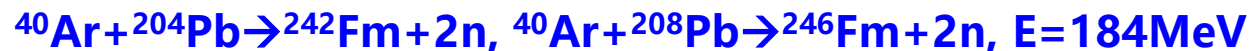
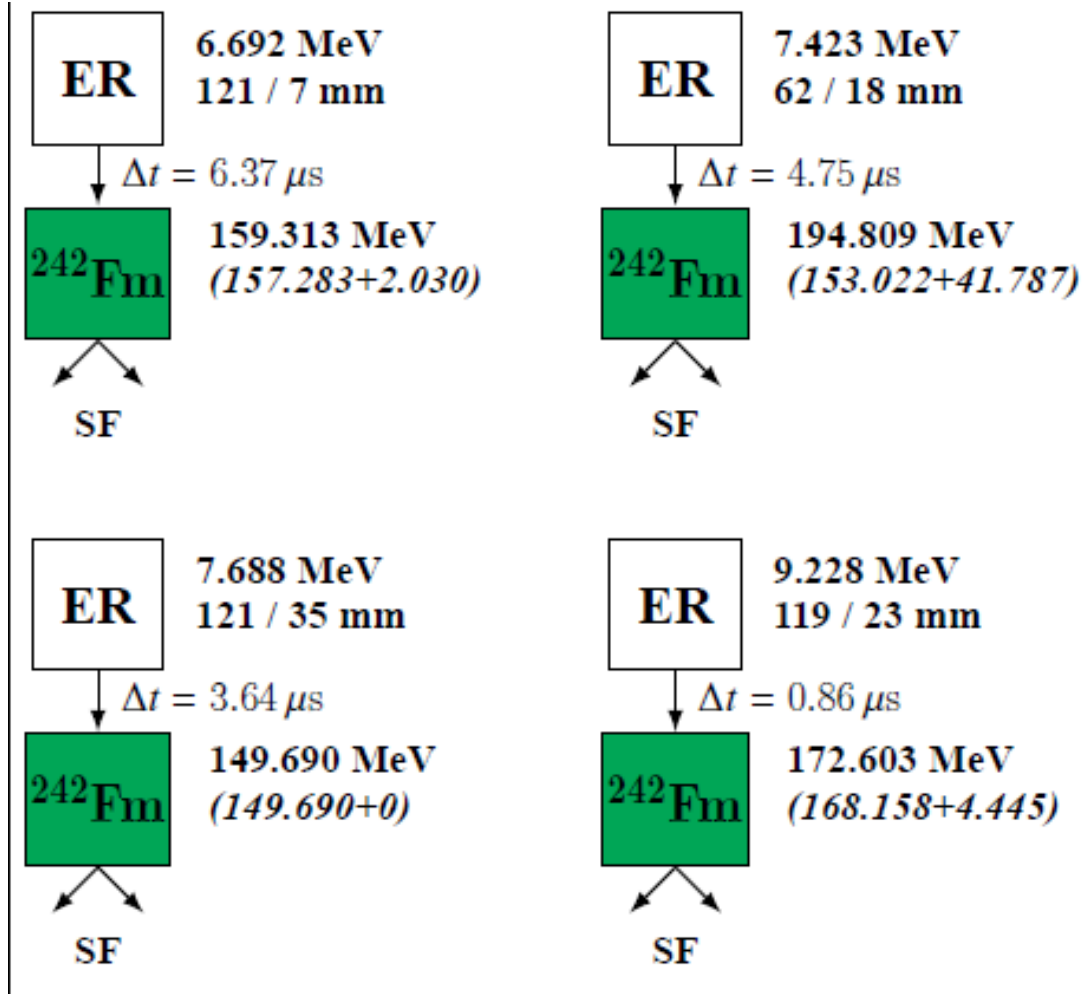
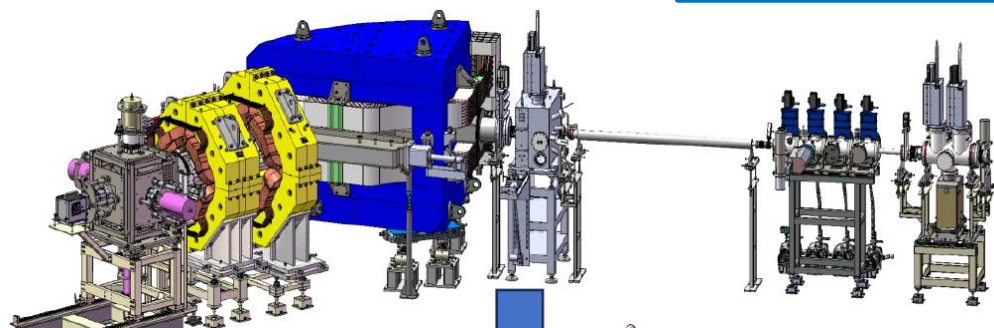
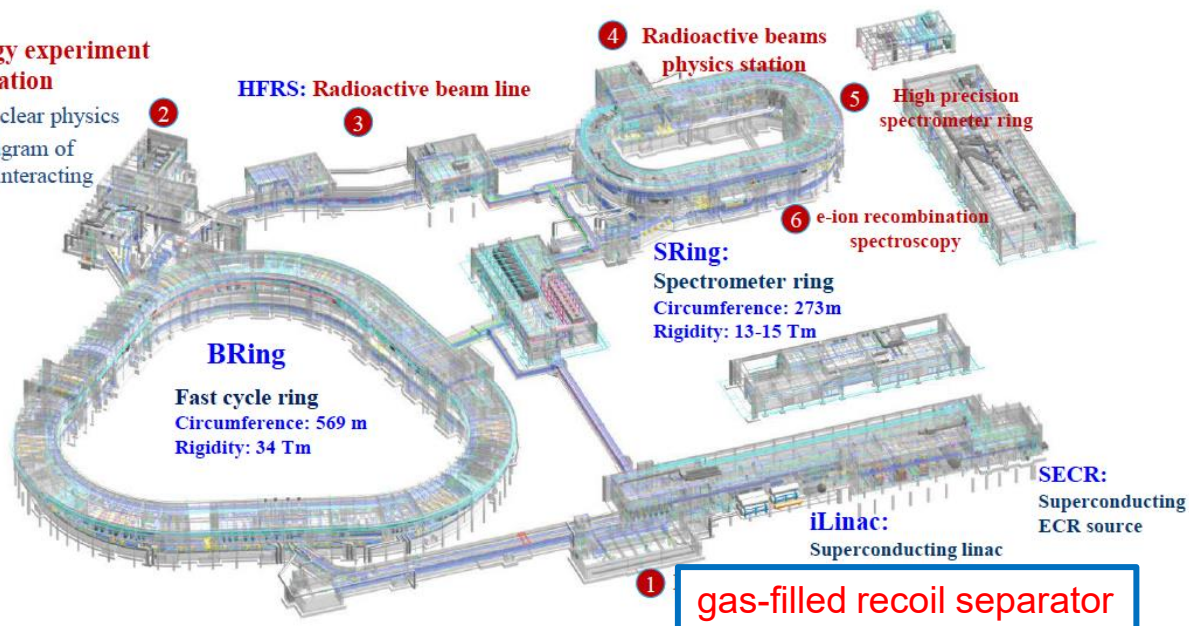


# New gas-filled separator at HIAF

## High Intensity heavy-ion Accelerator Facility (HIAF)

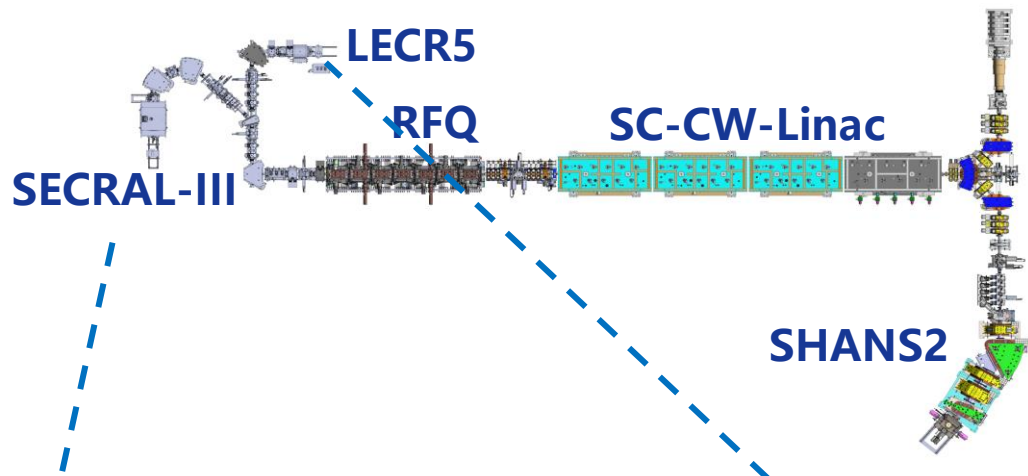
### High energy experiment station

- Hyper nuclear physics
- Phase diagram of strongly interacting matter



# SHANS2 at CAFE2

China Accelerator Facility for Superheavy Elements (CAFE2)



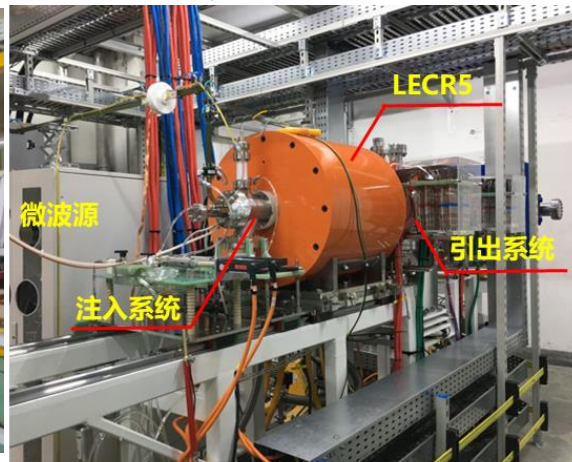
## CAFE2 running time (2022 ~ 2025)

Ions	Highest Intensity (pμA)	Beam time (h)	Ions	Highest Intensity (pμA)	Beam time (h)
$^{40}\text{Ar}^{12,13+}$	14.8	3083	$^{48}\text{Ca}^{14+}$	1.5	2352
$^{40}\text{Ca}^{13+}$	5	717	$^{52}\text{Cr}^{17+}$	1.5	1371
$^{55}\text{Mn}^{17+}$	2	134	$^{54}\text{Cr}^{17,18+}$	2	5143

Total beam time at SHANS2 > 12000 h

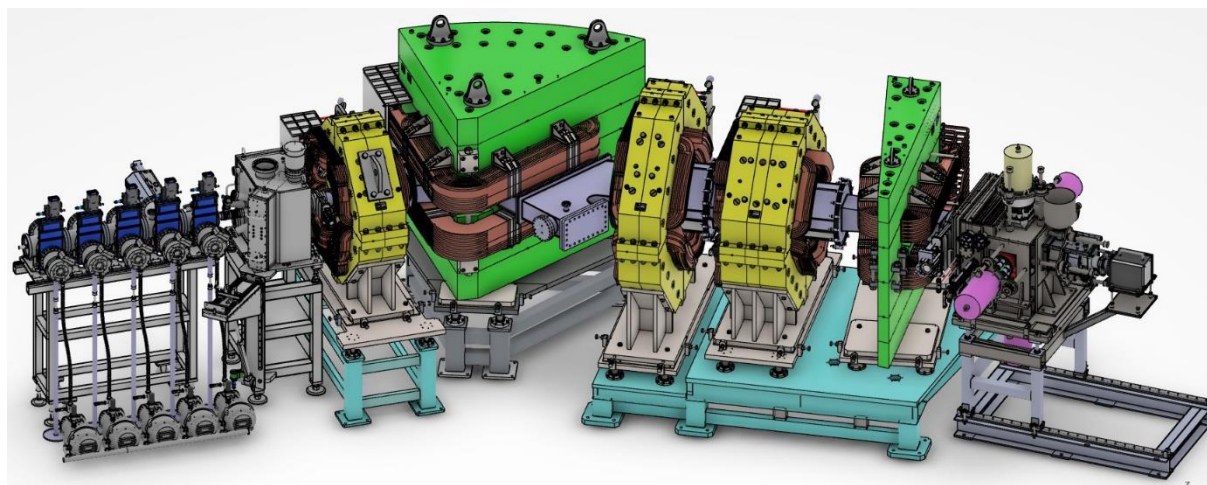


**SECRAL-III (super-conduct.)  
(2025-)**



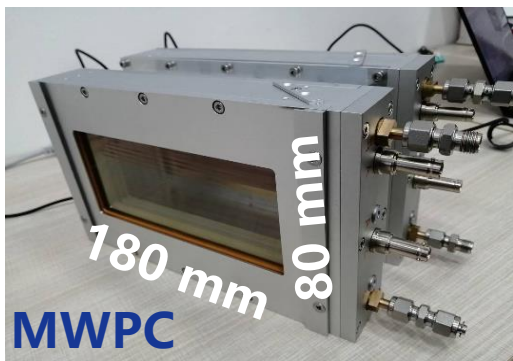
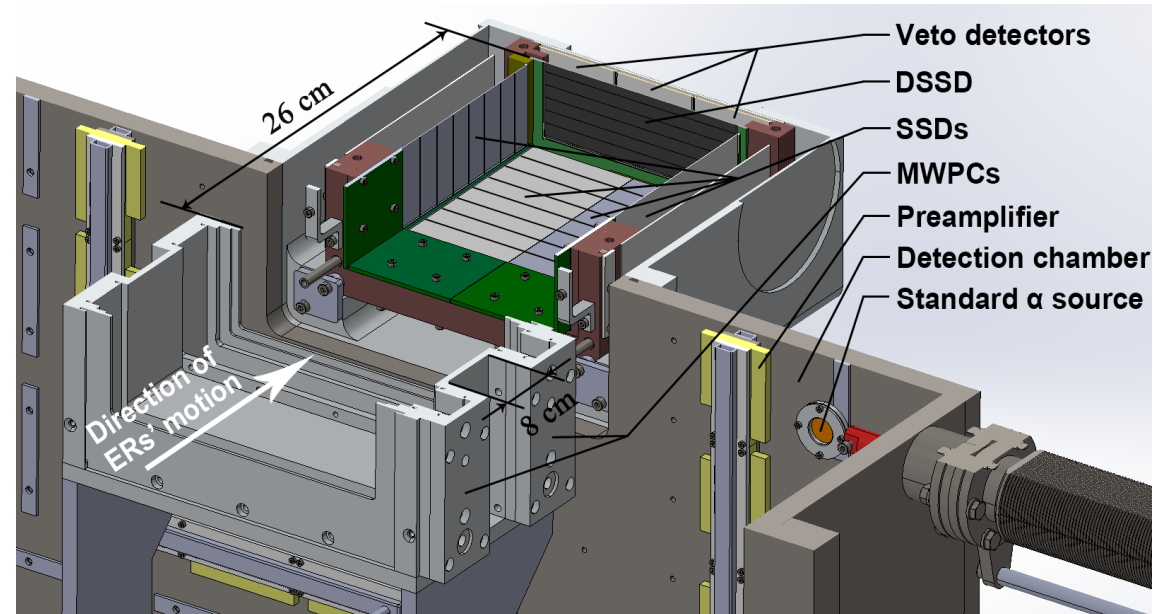
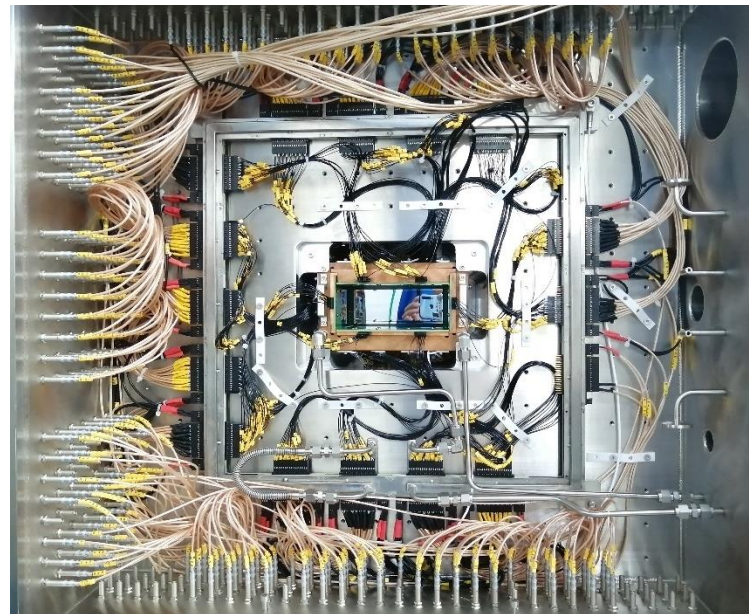
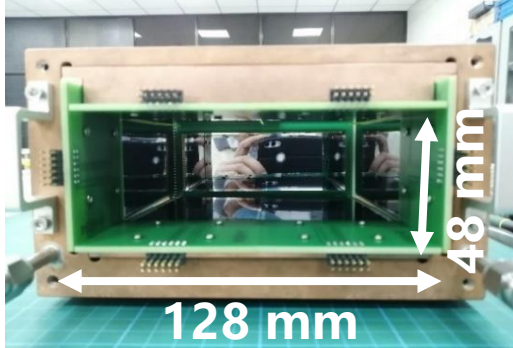
**LECR5 (room temp.)  
(2021-)**

W. Lu, et al., NIM A, 1062 (2024) 169207



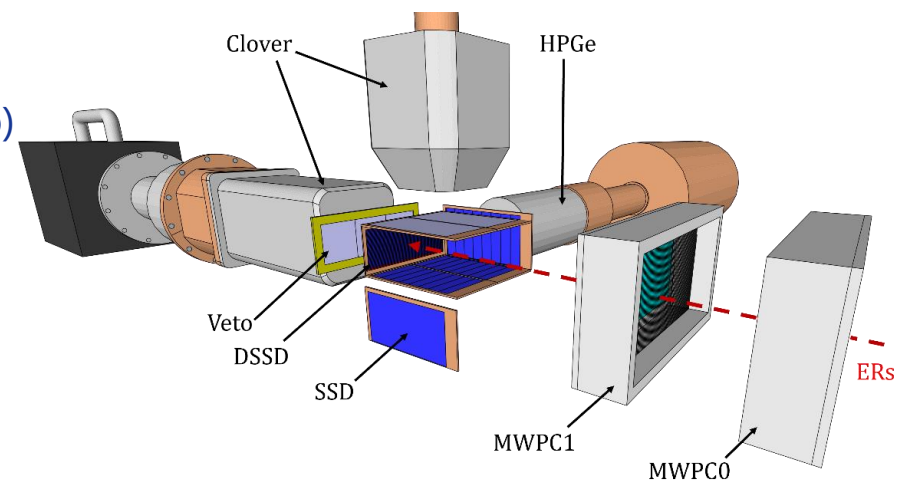
# Detection System: MWPC and Si-Box

## DSSD+SSD detectors

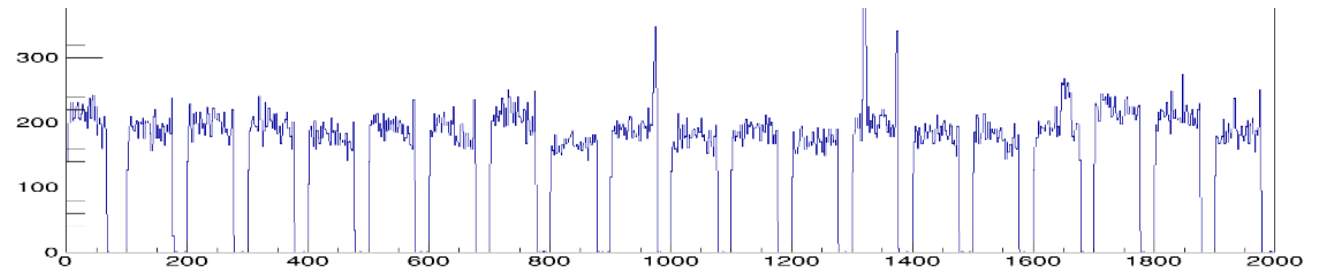
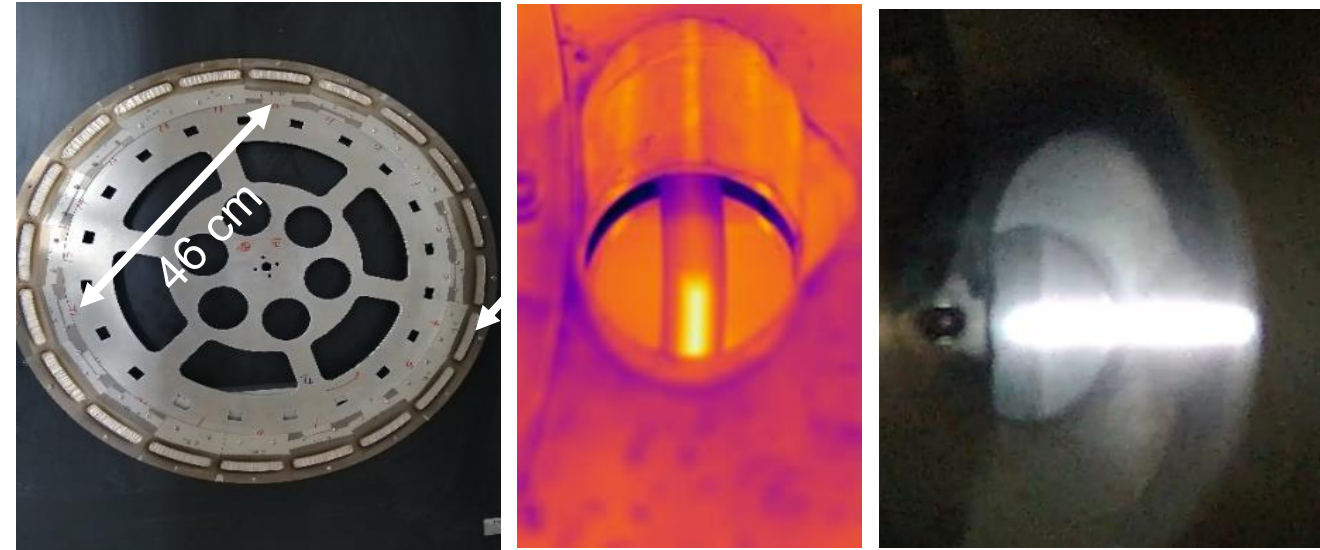


## MWPC

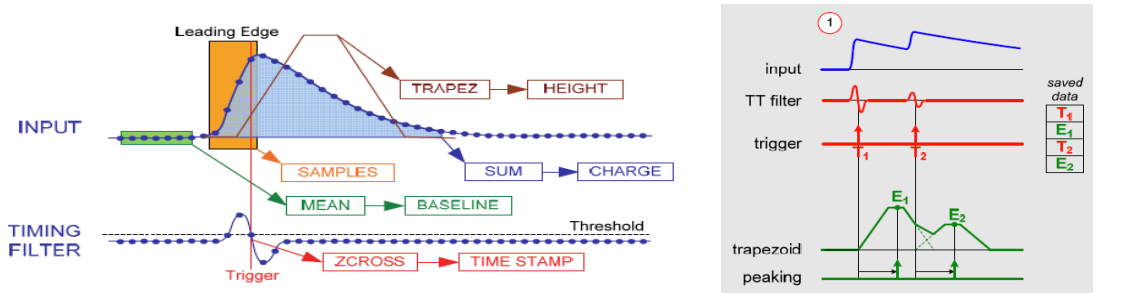
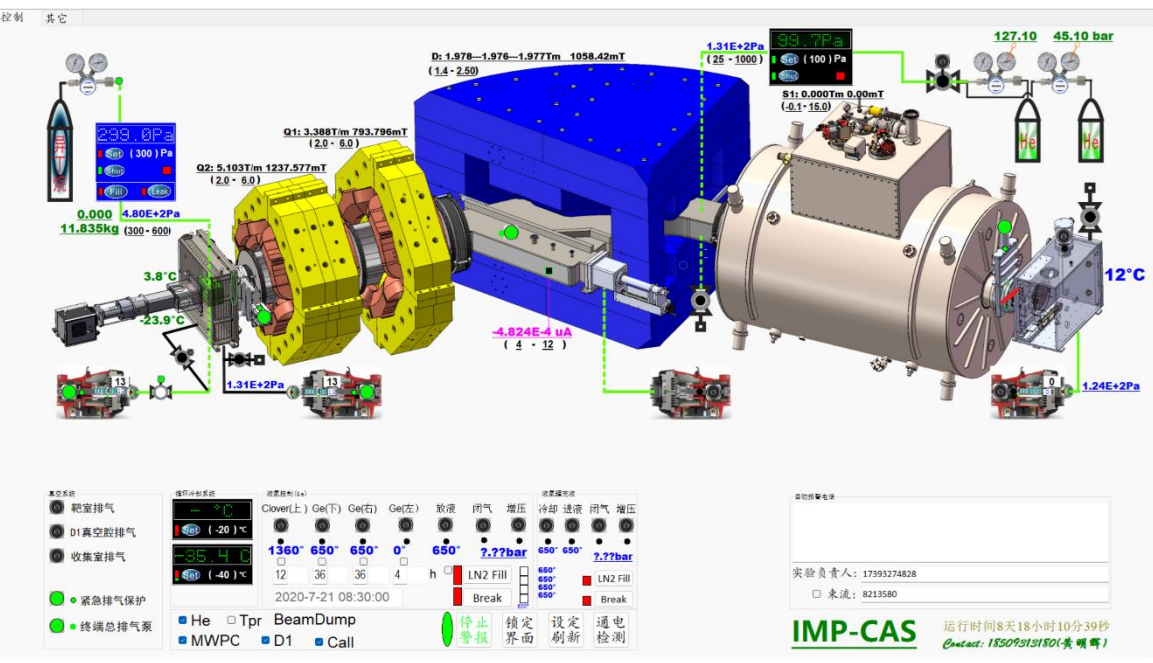
- Active area: 128 x 48 mm<sup>2</sup> (DSSD), 120 x 63 mm<sup>2</sup> x 6 (SSD), 50 x 50 mm<sup>2</sup> x 3 (Veto)
- Thickness: 300  $\mu$ m (DSSD, Veto), 500  $\mu$ m (SSD)
- Total detection efficiency for  $\alpha$ 's: 86(8)%
- Energy resolution: 30 keV (DSSD), 80 keV (DSSD+SSD)
- Cooling down to -20 °C with alcohol
- MWPC: 300 Pa isobutane; 0.9  $\mu$ m-thick Mylar window
- Digital electronics: 100 MHz, 14 bit, trace + PHA (FPGA)



## Rotating target



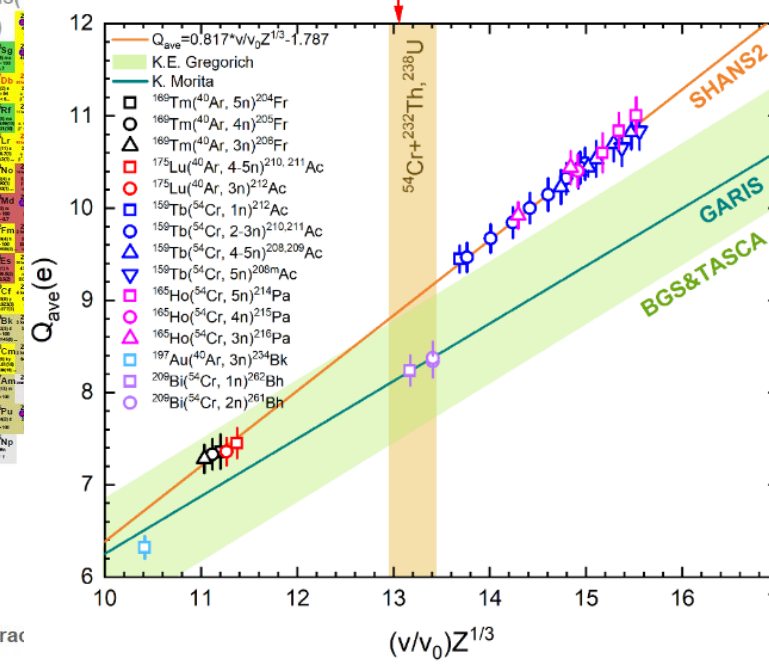
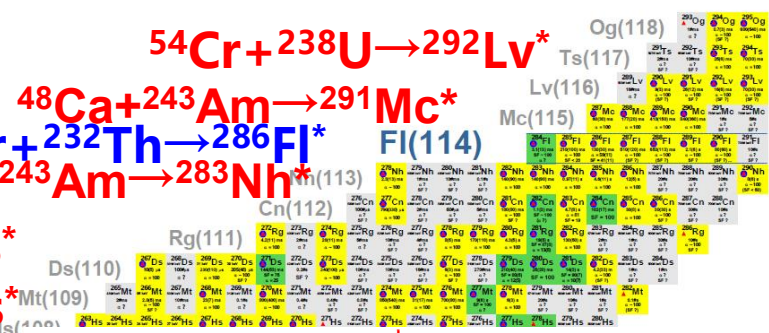
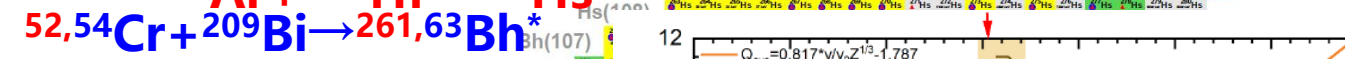
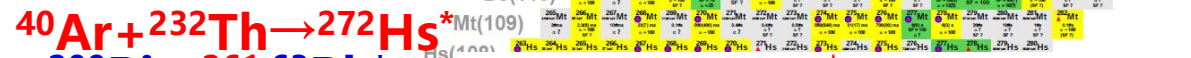
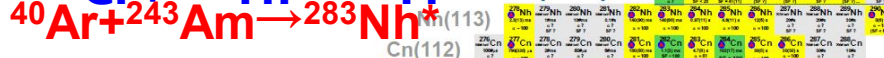
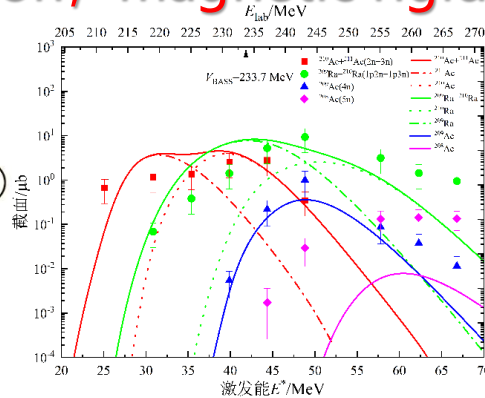
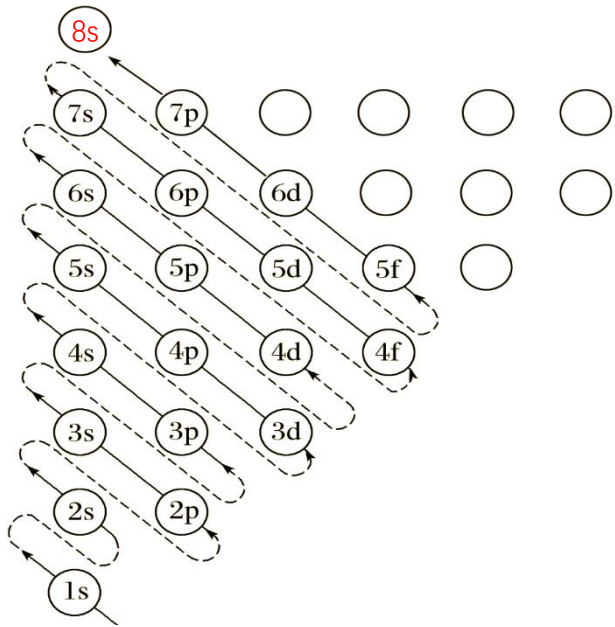
S.Y. Xu, Z.Y. Zhang, Z.G. Gan, et al., NIMA, 1050 (2023) 168113  
 L.N. Sheng, Q. Hu, H. Jia, et al., NIMA, 1004 (2021) 165348



Digital electronics: 100 MHz, 14 bit, trace + PHA (FPGA)

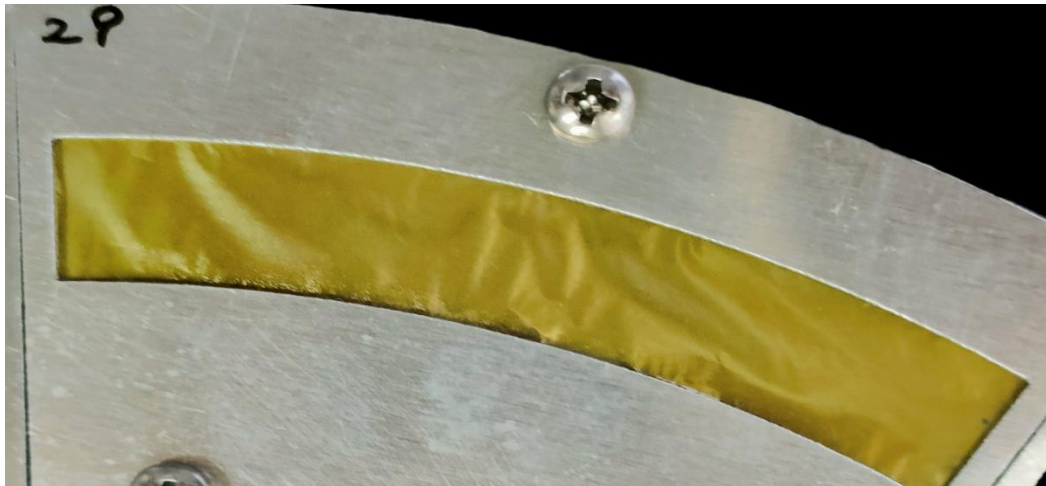
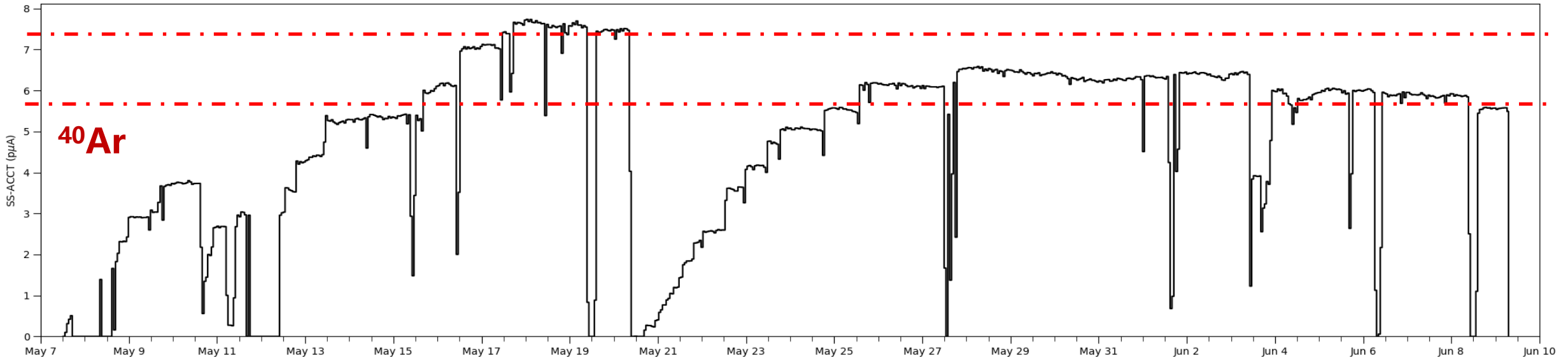
# Reaction

## Cross section, magnetic rigidity, charge state



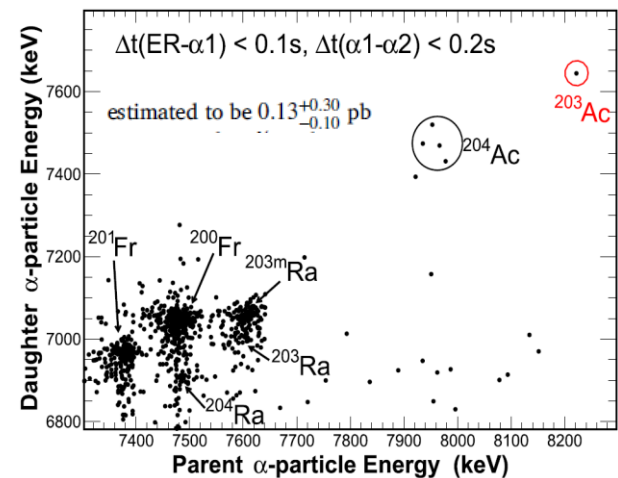
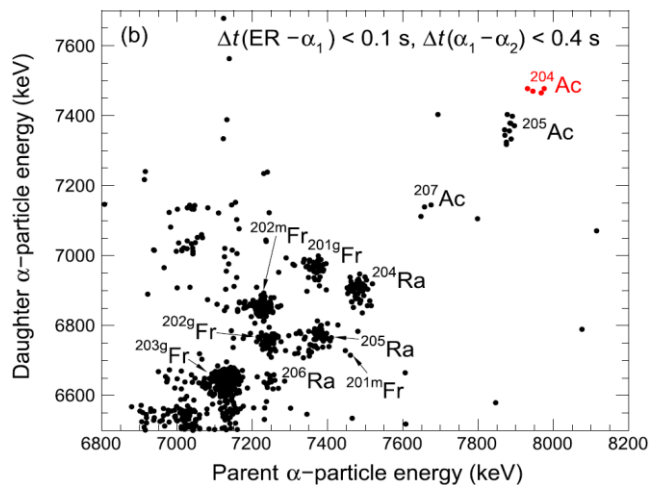
Information extract

# Beam Intensity

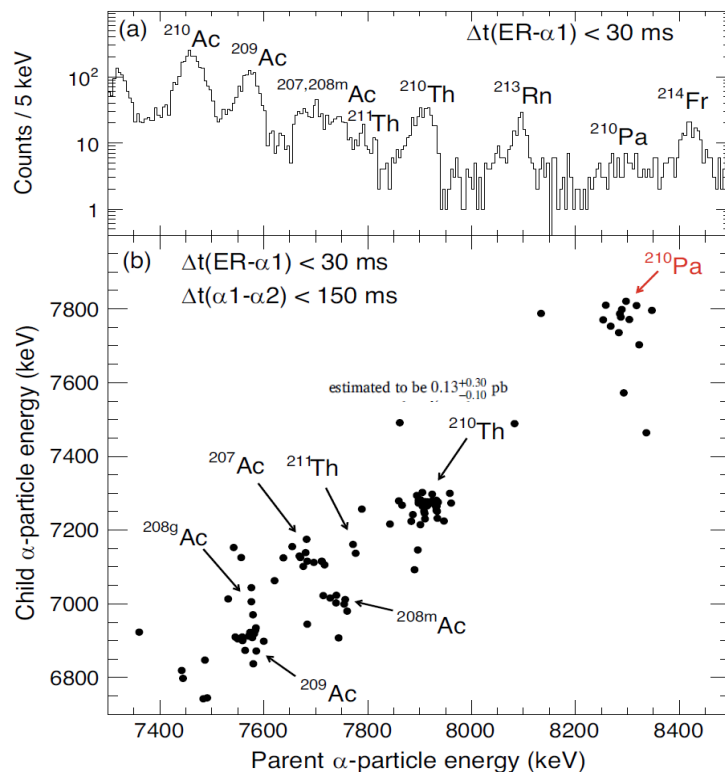


# 130fb for $^{203}\text{Ac}$

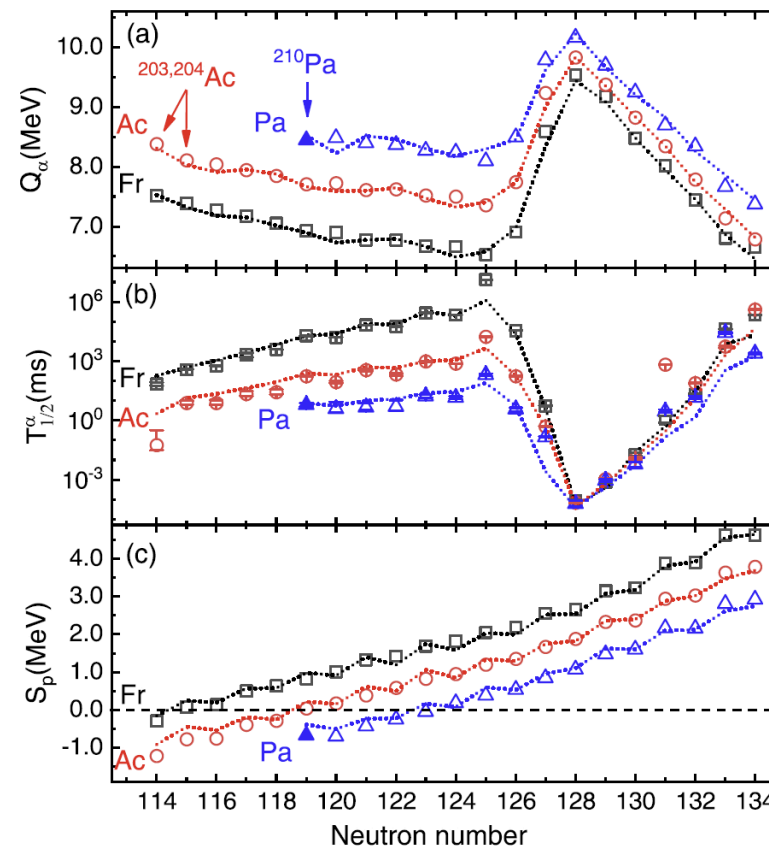
## $^{169}\text{Tm}(^{40}\text{Ca}, 5-6n)^{203,204}\text{Ac}$



## $^{175}\text{Lu}(^{40}\text{Ca}, 5n)^{210}\text{Pa}$



- Identified based on  $\alpha$ -decay chains
- Beam intensity: 1.5~2  $\mu\text{A}$
- Cross section: level of picobarn
- Beam duration: 3~5 days

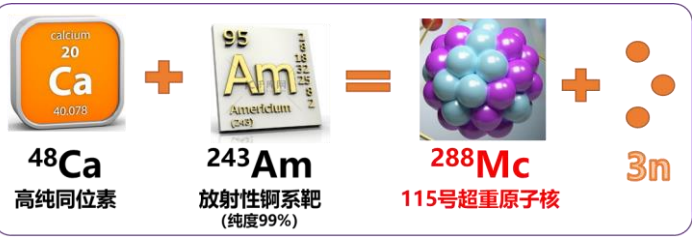


- Decay properties match well with several theoretical predictions

Nature Communications 16, 5003 (2025)

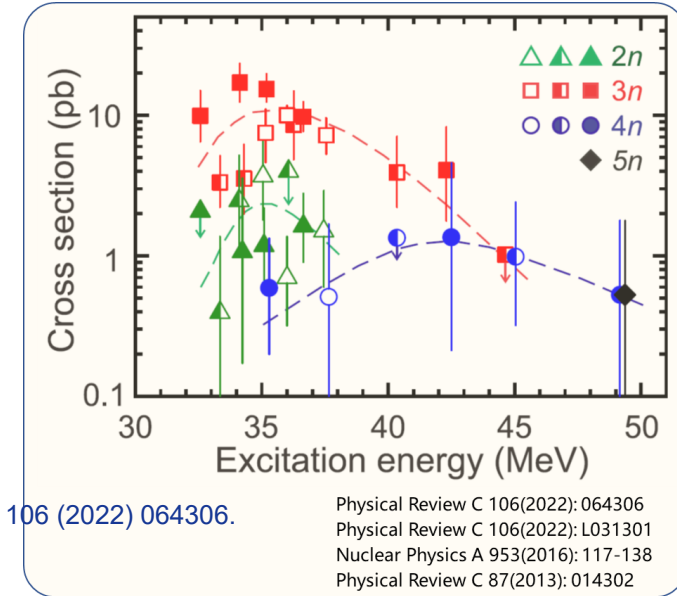
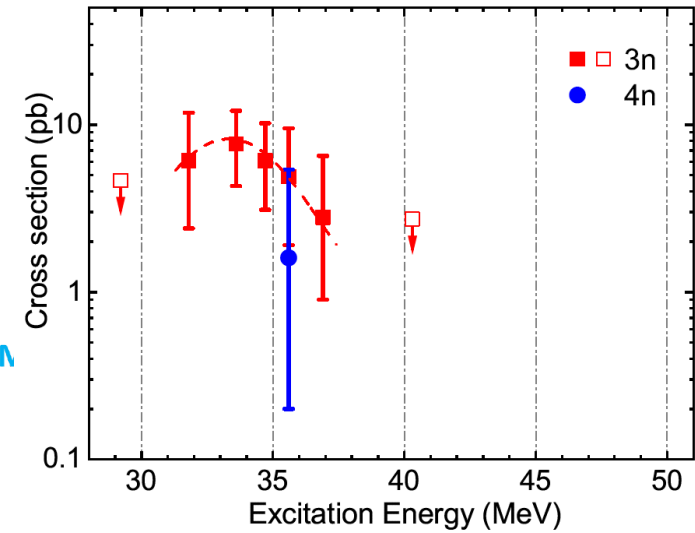
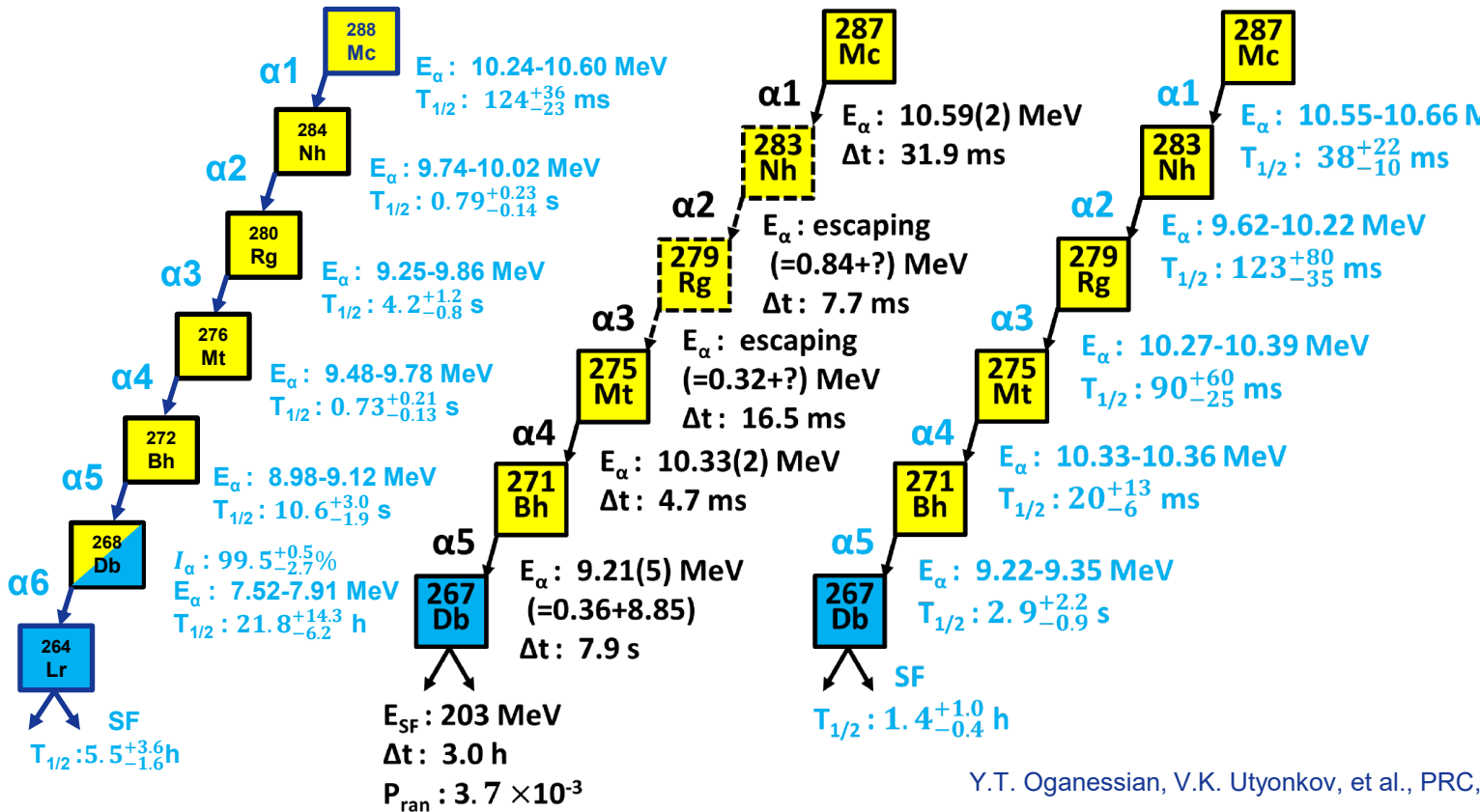
PLB 834, 137484 (2022); 850, 138503 (2024)

# Synthesis of superheavy nuclei $^{287,288}\text{Mc}$ ( $Z=115$ )



**Chain #1 (Run 242.7 MeV)**  
 $E_{\text{imp}}: 9.83 \text{ MeV}$   
 StripX: 62, StripY: 13  
 2024-10-15

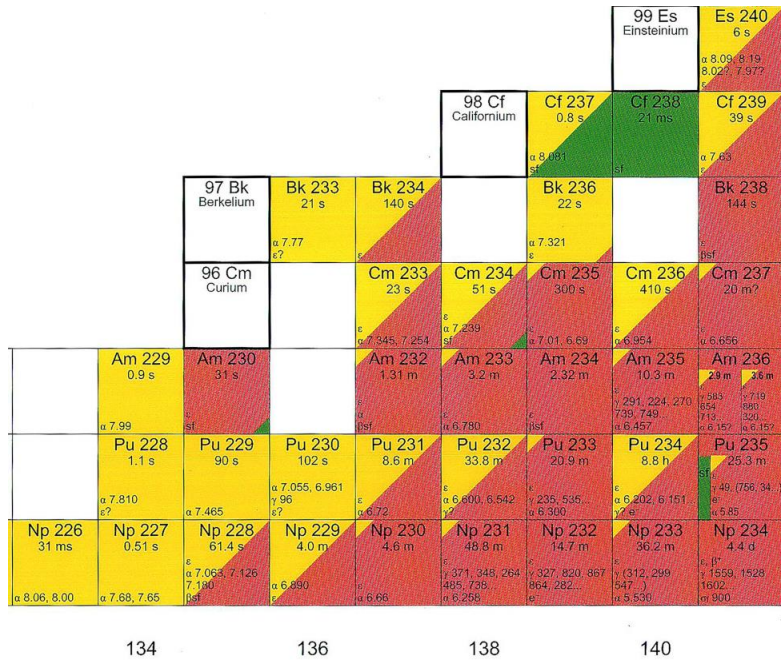
Known data  
 Reported by  
 FLNR



Y.T. Oganessian, V.K. Utyonkov, et al., PRC, 106 (2022) 064306.

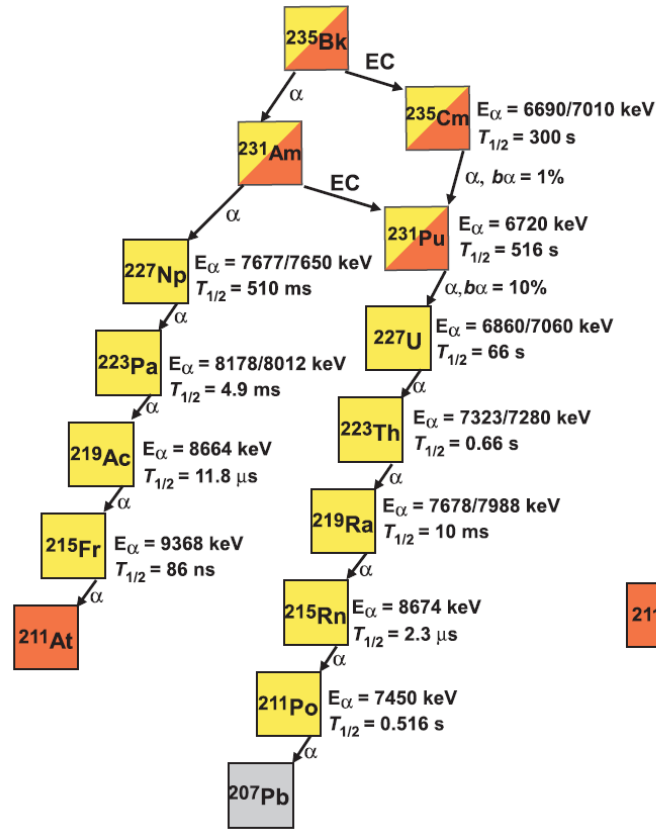
X. Y. Huang, ZYZ, et al, Chinese Physics Letters, 43, 010101 (2026)

# Synthesis of new nuclei $^{235}\text{Bk}$ and $^{231}\text{Am}$

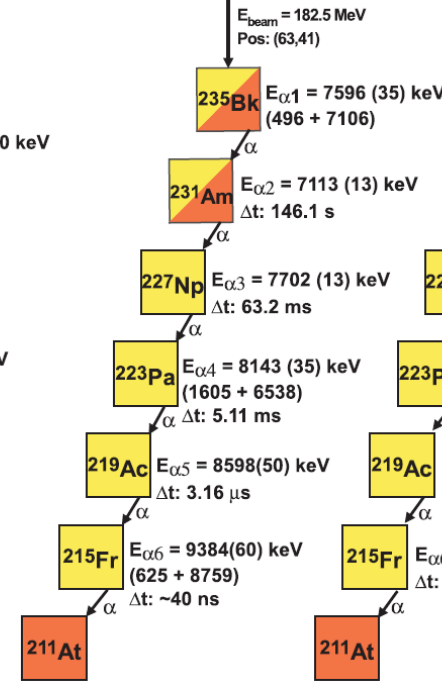


Phys. Lett. B 875 (2026) 140365

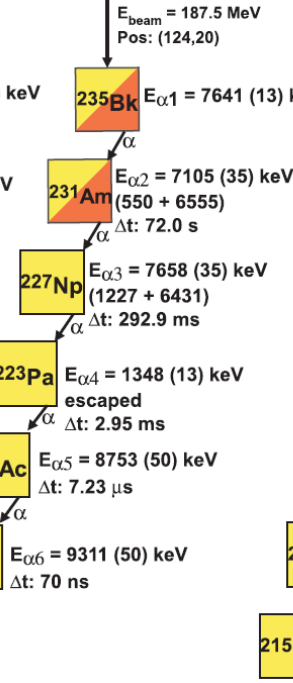
reference decay chain



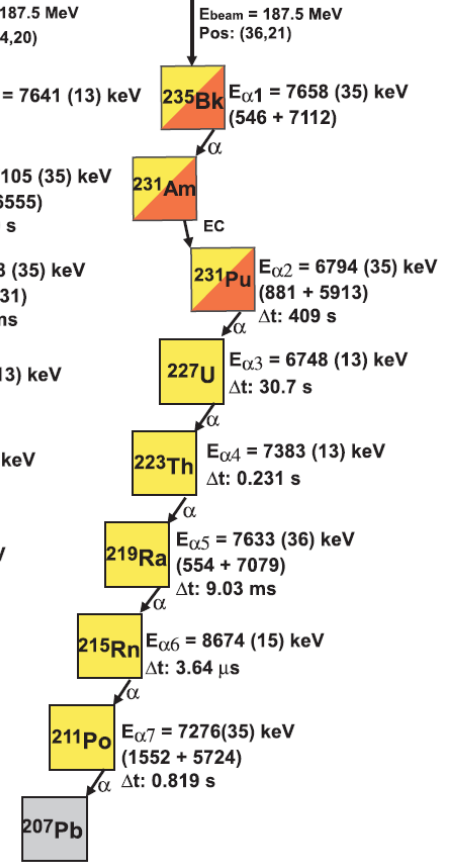
chain 1



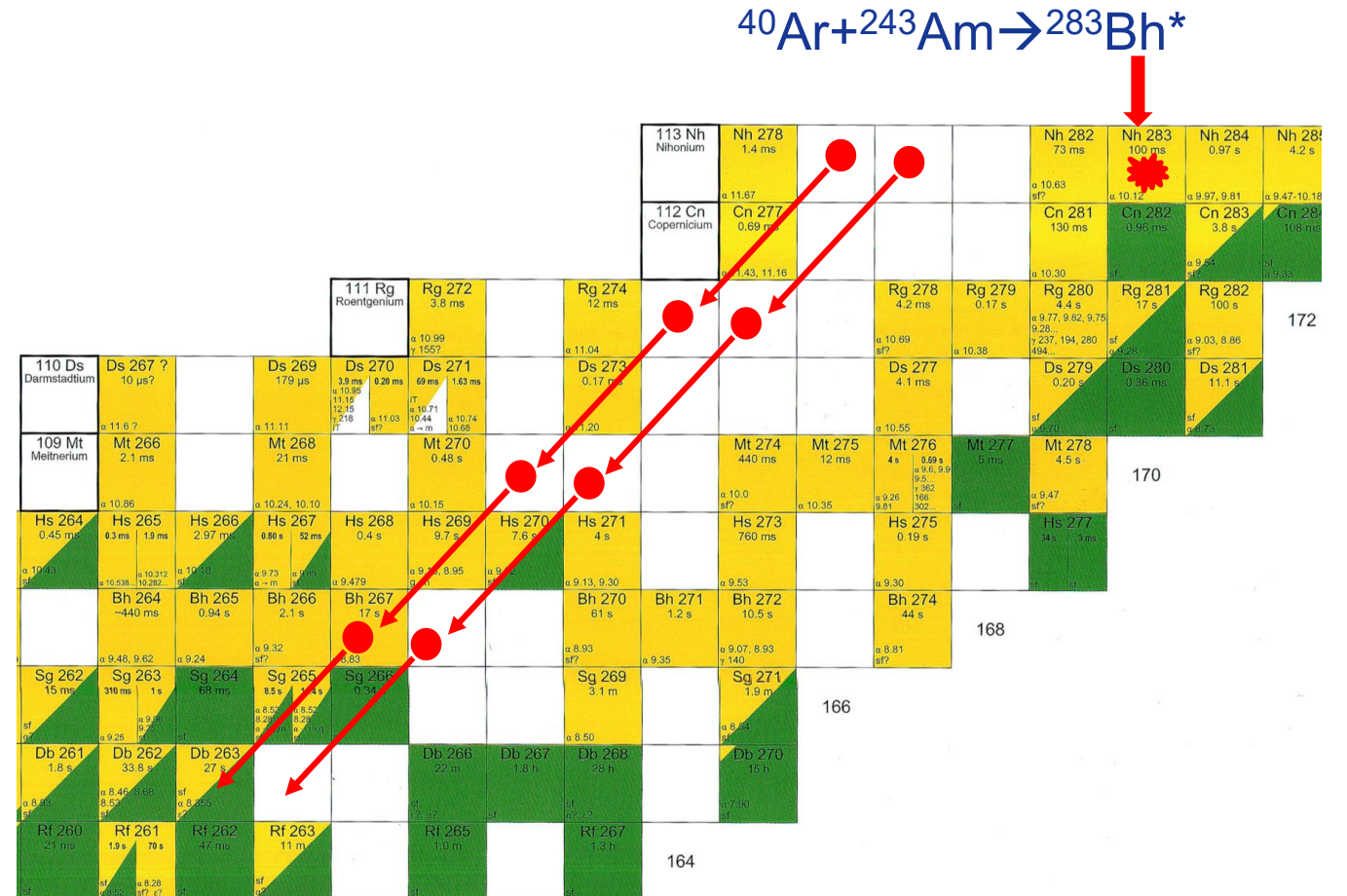
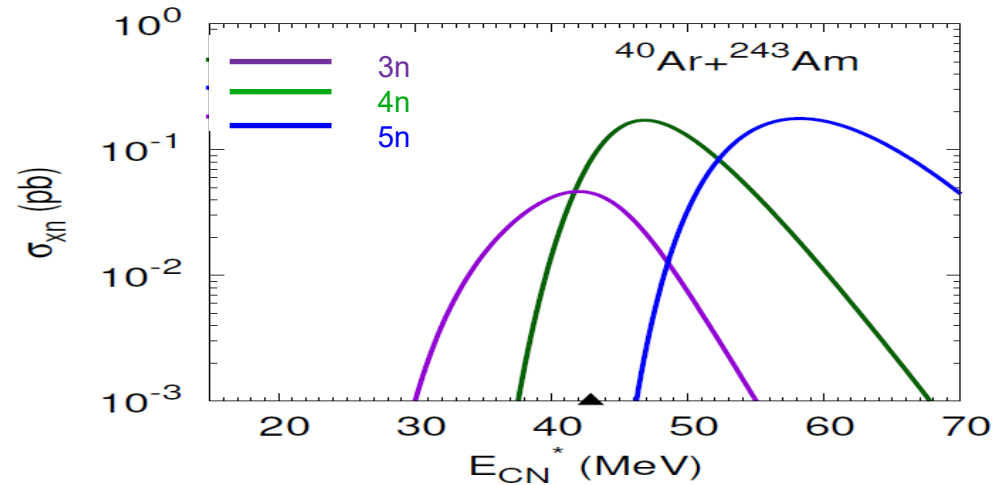
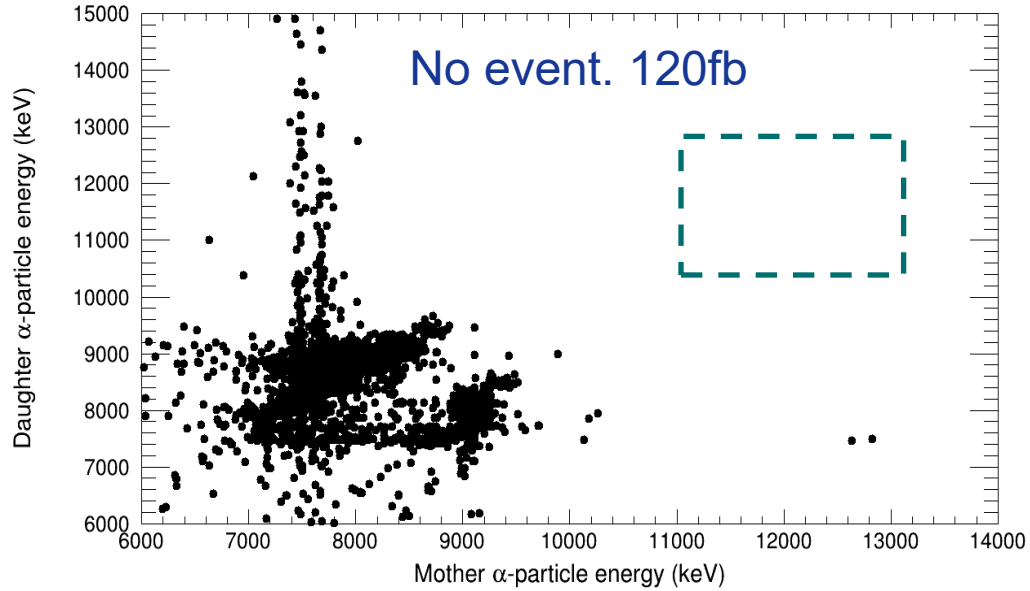
chain 2



chain 3



# $^{40}\text{Ar}+^{243}\text{Am}$ reaction



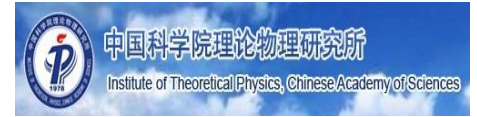
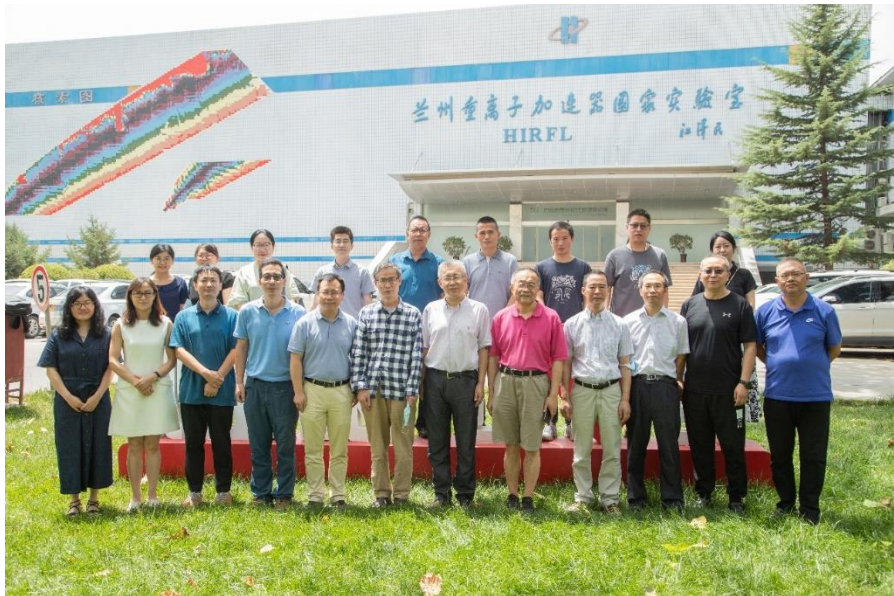
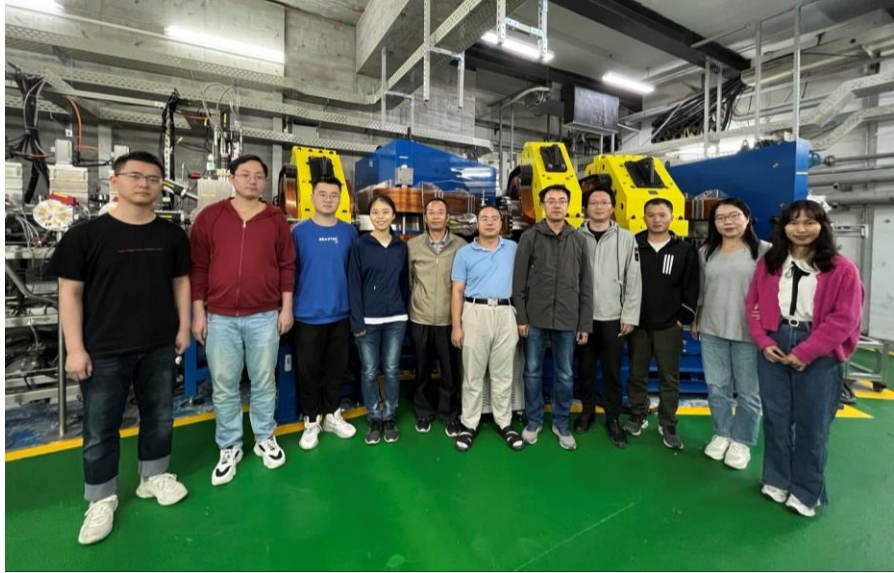


# Summary



- ◆ Some experiment are performed, and new isotopes are observed
- ◆ A new gas filled separator is been build
- ◆  $^{54}\text{Cr}+^{243}\text{Am}$

# Collaboration



Thank you for all your attention!