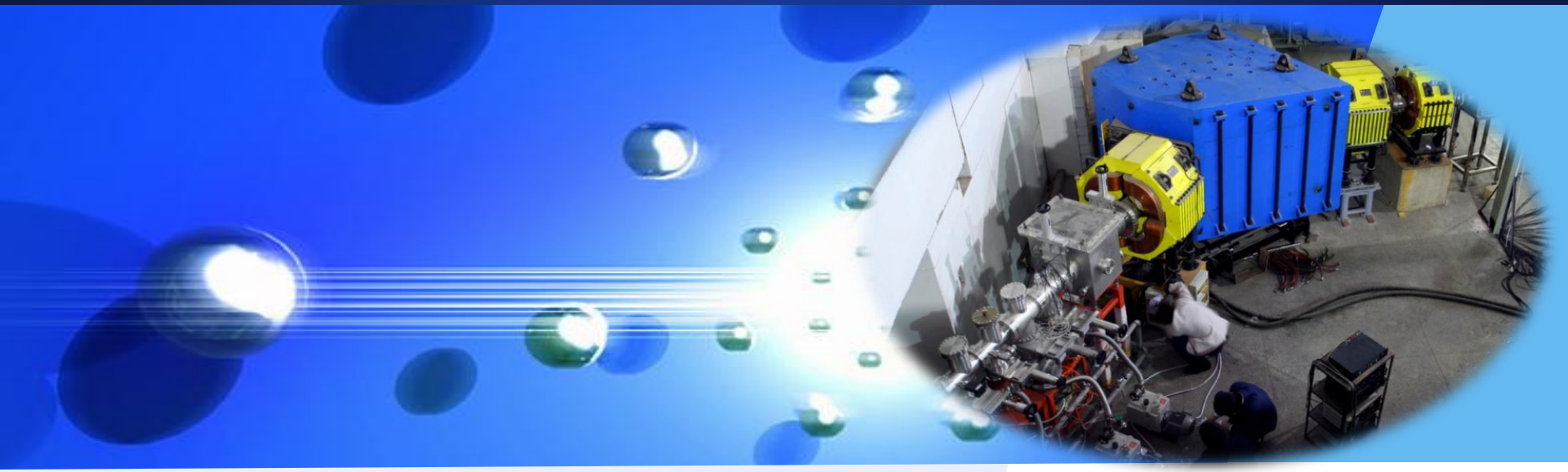
中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

Gas-filled recoil separator at IMP



GAN Zaiguo and IMP SHN group

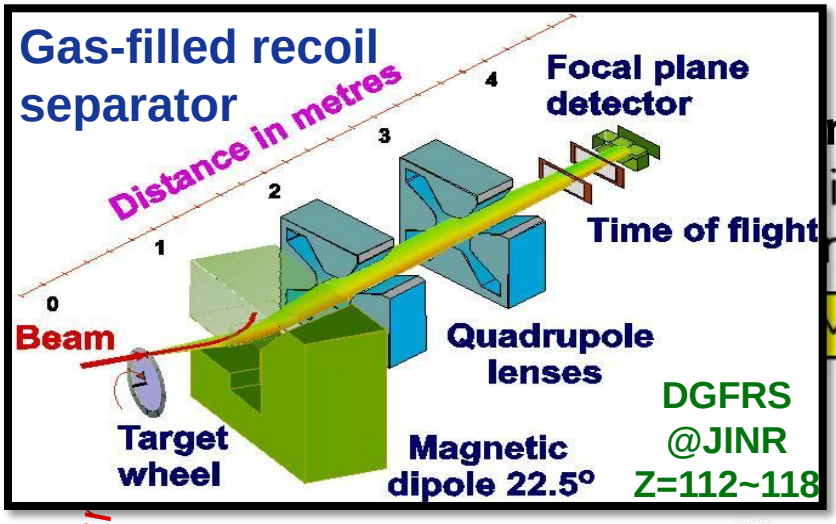
Institute of Modern Physics, Chinese Academy of Sciences

EMIS 2012

outline

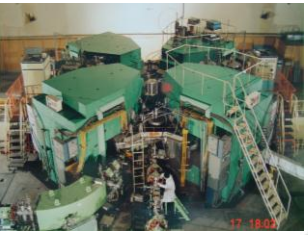
- Introduction
- Construction of Gas-filled Recoil Separator
- The test experiments
- summary

Introduction



Facilities: Heavy Ion Research Facility in Lanzhou (HIRFL)

National Laboratory of Heavy Ion Accelerator in Lanzhou



SSC(K=450)

100 AMeV (H.I.), 110 MeV (p)

SFC (K=69)

10 AMeV (H.I.), 17~35 MeV (p)

CSRe

RIBLL1

RIBs at tens of AMeV

RIBLL2

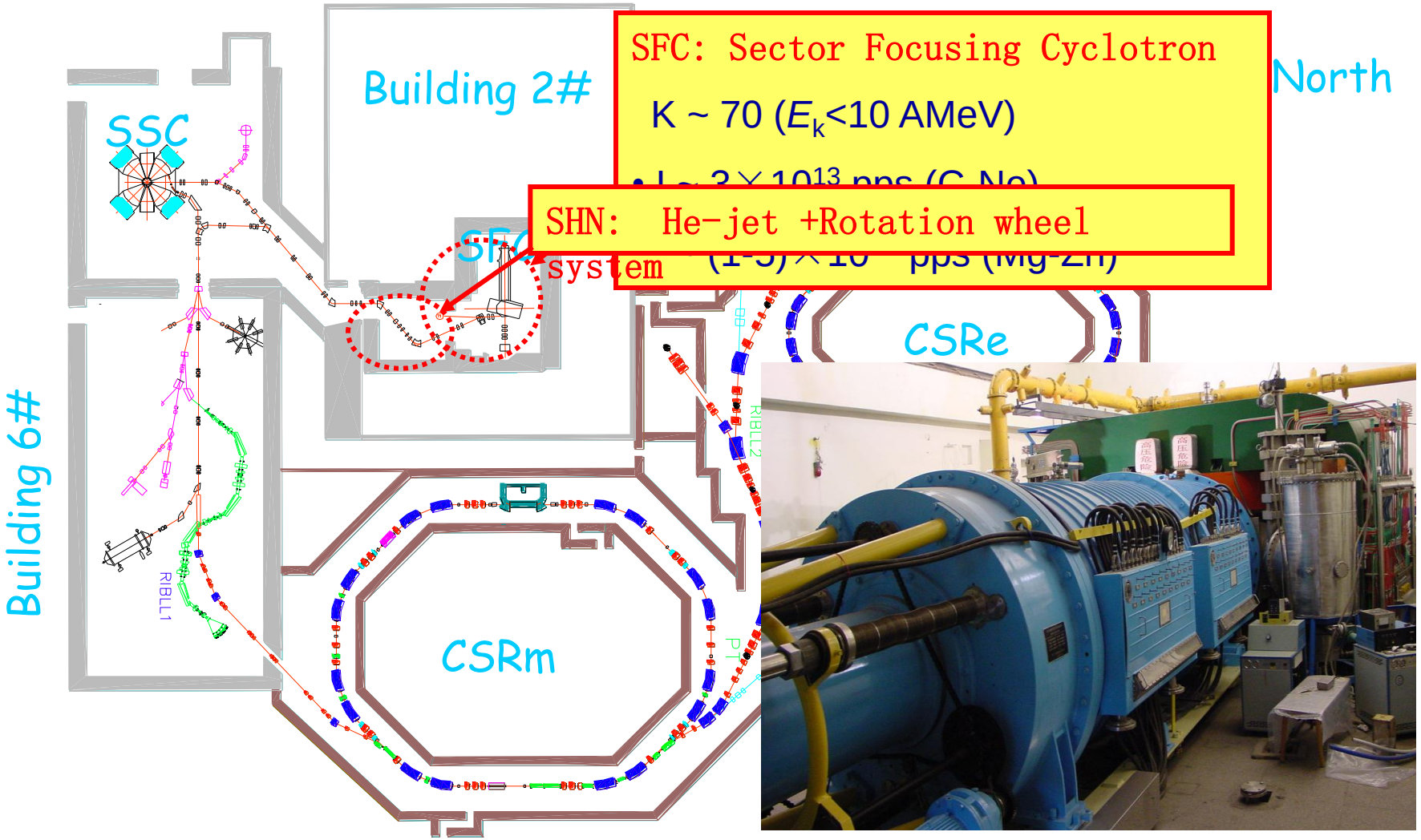
RIBs at hundreds of AMeV

CSRm

1000 AMeV (H.I.), ≤ 2.8 GeV (p)

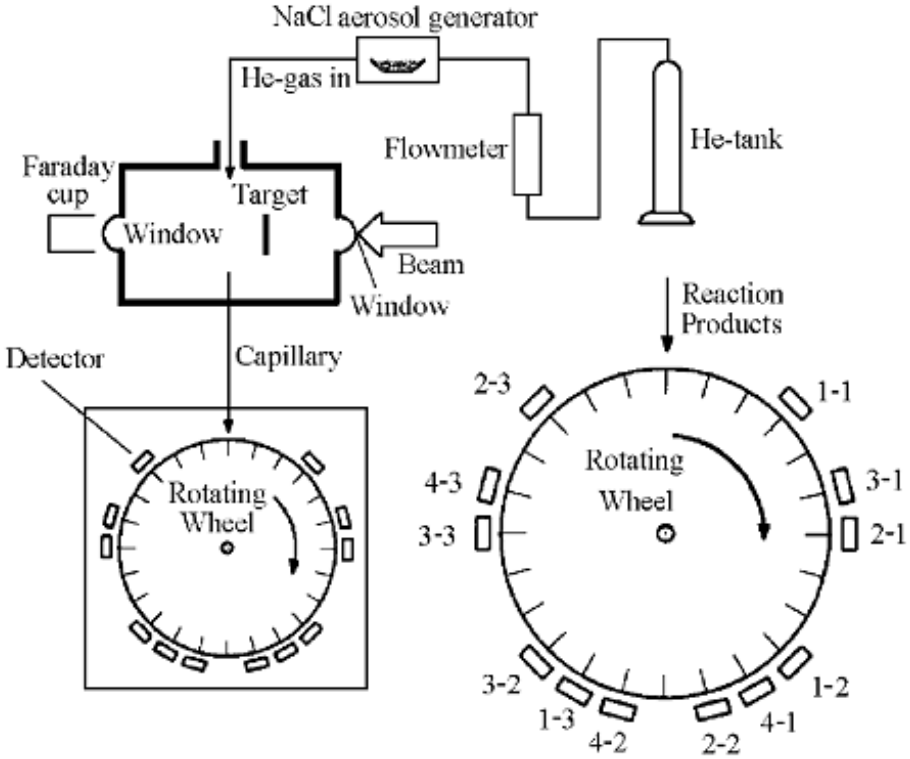
Providing stable beams and RIBs with energies from MeV/u to GeV/u

Cyclotron for Synthesis of SHN



He Jet Set-up

Measuring α from the mother nuclide
Catching the recoil daughter on the detector surface

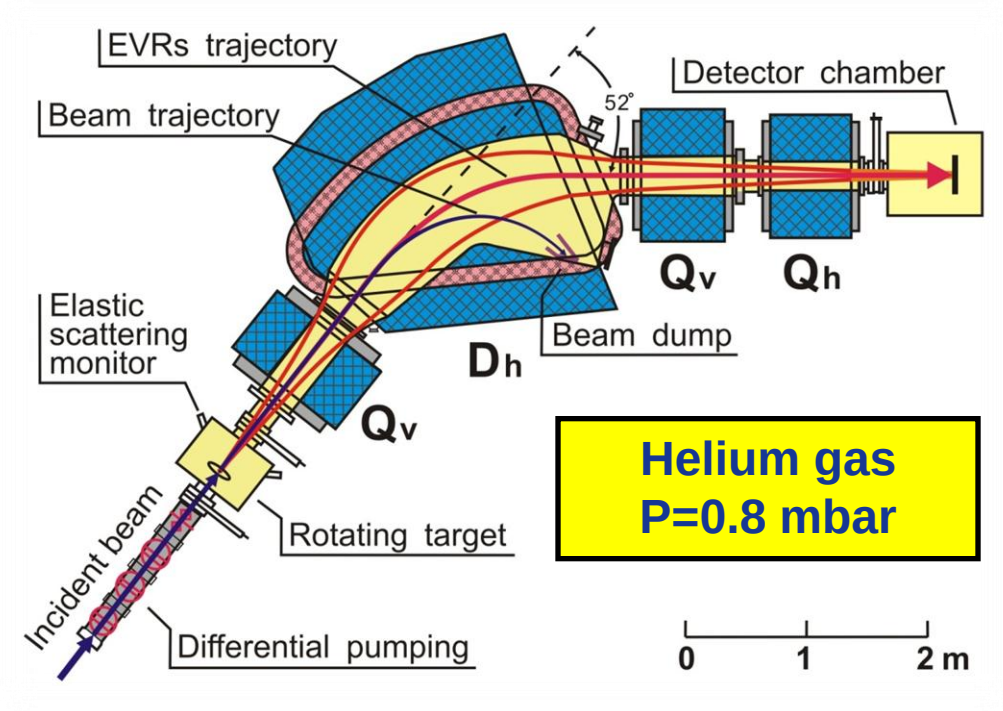


Cross section >100 pb.
Half-life> 50 ms.
Limit: α decay super-heavy nuclide with Z≤108.

Without source, measuring α from the daughter
Correlation between the mother and daughters.

Gas Filled Separator at IMP

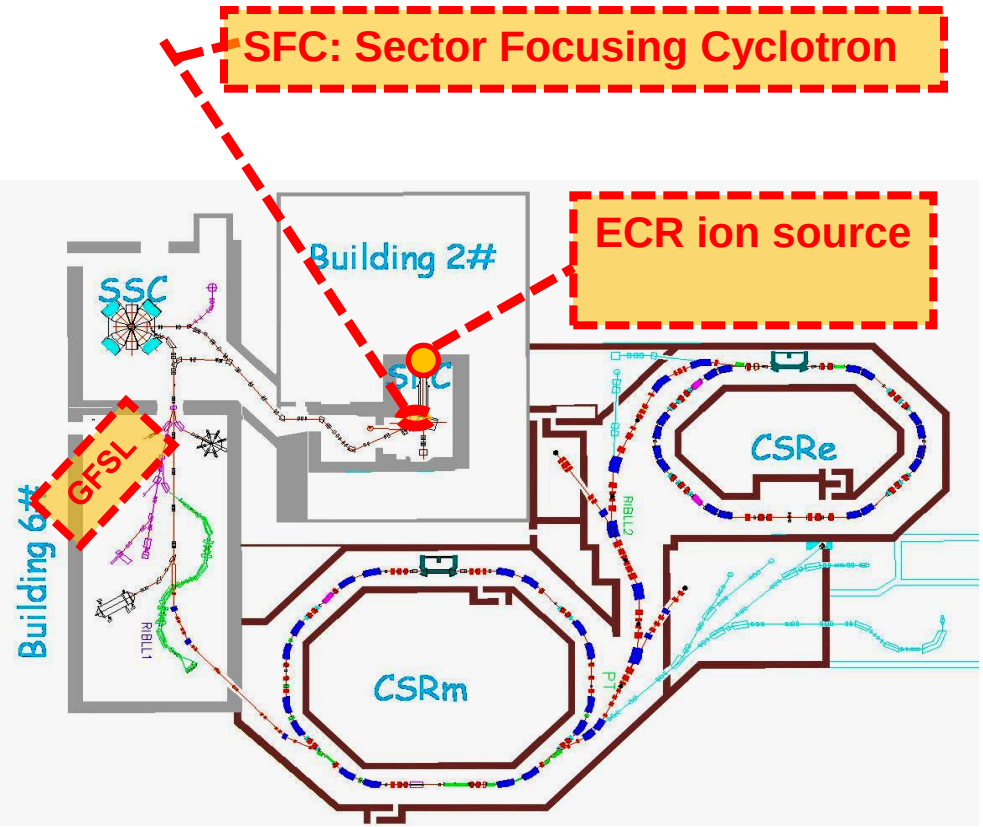
Parameters	Values
Configuration	$Q_vD_hQ_vQ_h$
Total length	6.5 m
Horizontal acceptance	±4°
Vertical acceptance	±6°
D_h magnet Certral trajectory radius	1.8 m
Angle of bend	52°
Maximum magnetic rigidity	2.88 T·m
Q_v magnet maximum field gradient	6.8 T/m
Q_h magnet maximum field gradient	8.9 T/m



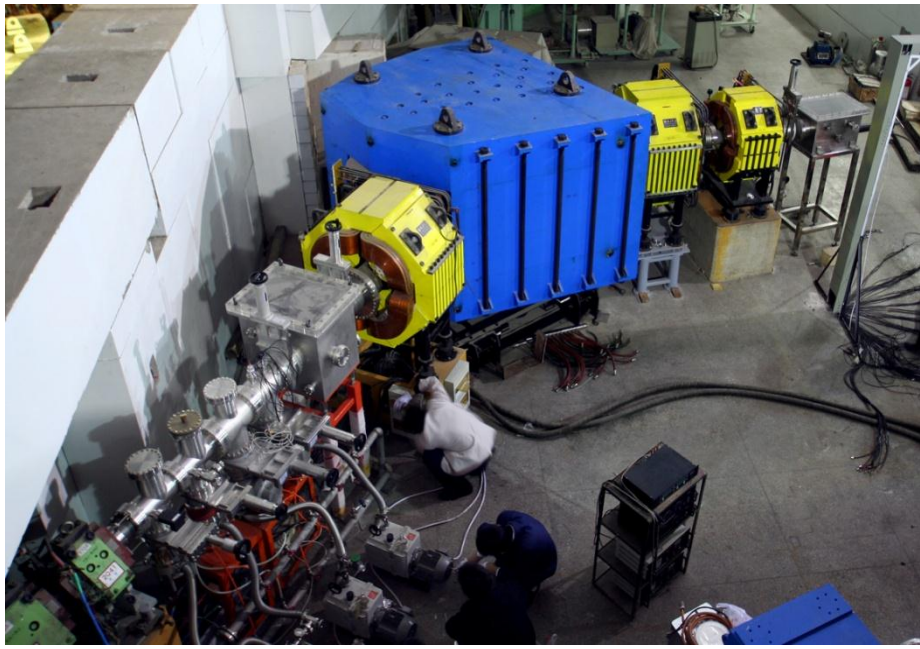
D_h : the dipole magnet with horizontally focusing ability

Q_v and Q_h : the vertically and horizontally focusing quadrupole magnets, respectively

Location

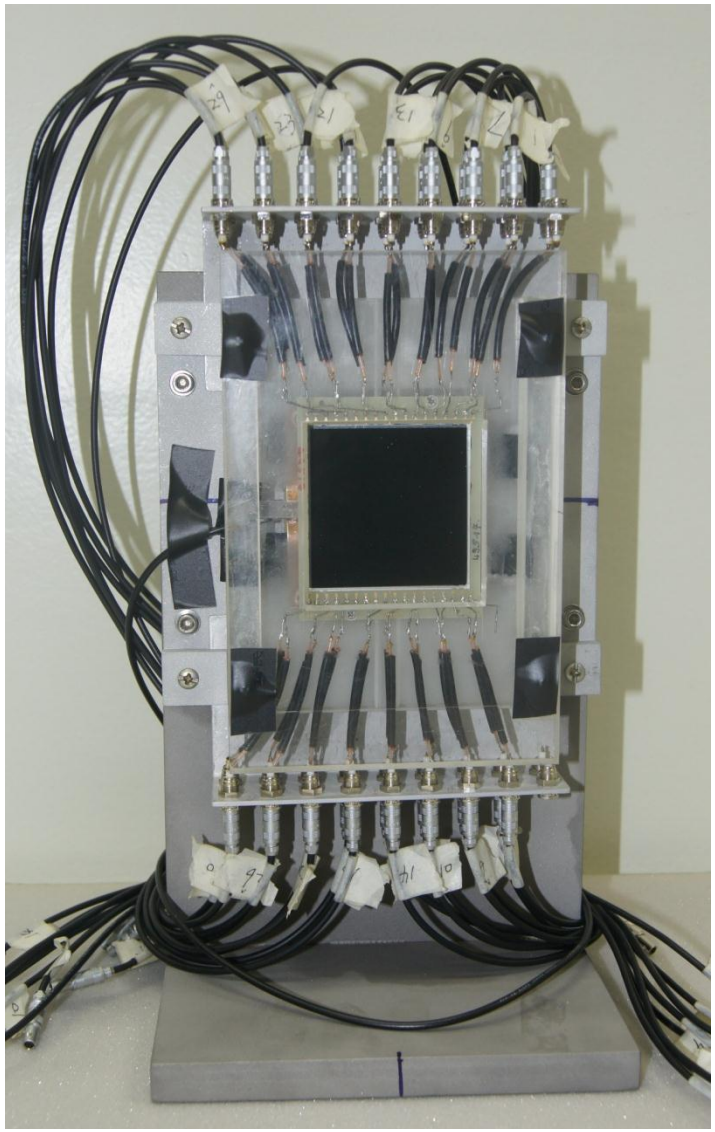


HIRFL-CSR



Gas-filled recoil separator in Lanzhou

Position Sensitive Silicon Detector



Active area：58 mm * 58 mm

Strip Number：16 (vertical)

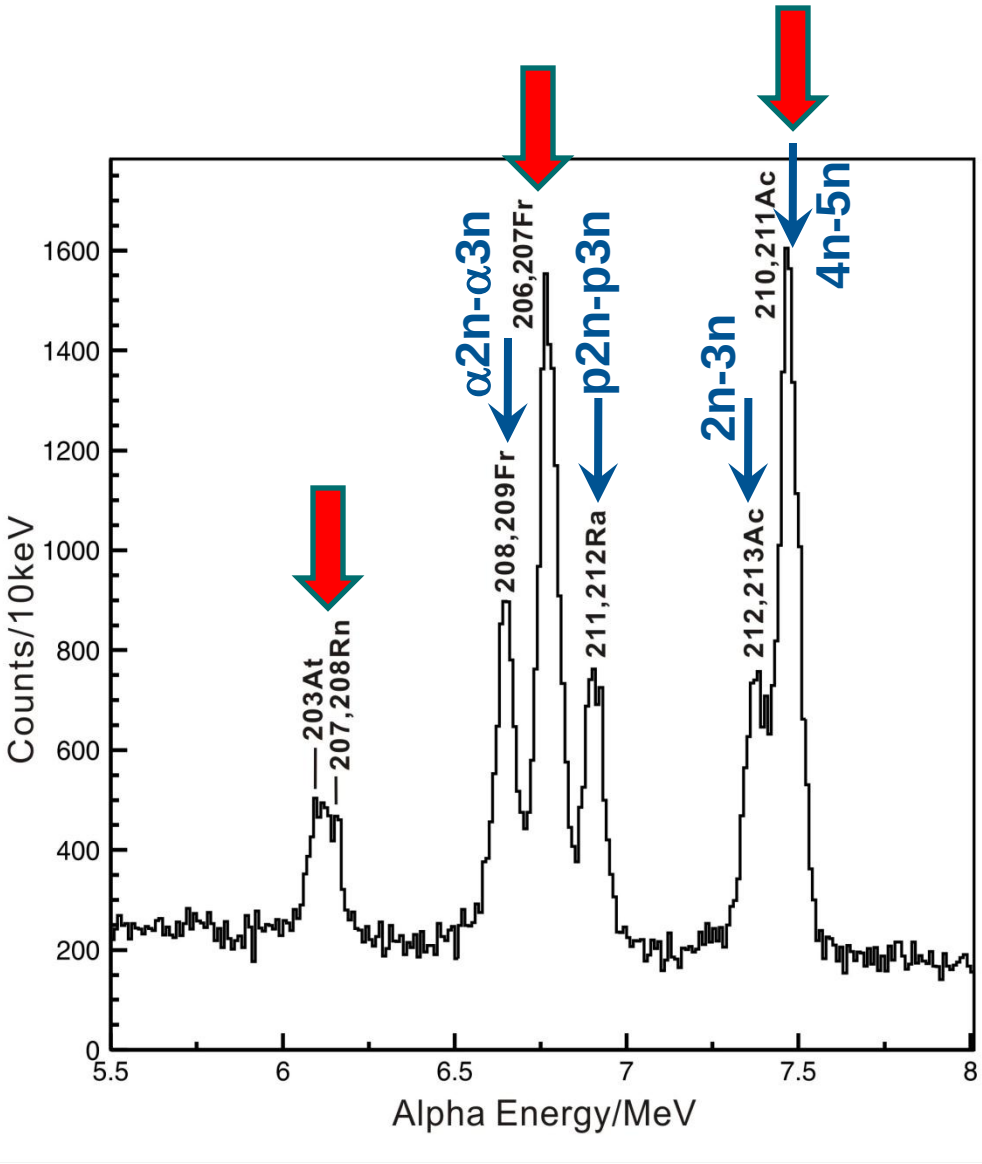
Width of one strip：3.6 mm

Thickness：300 μm

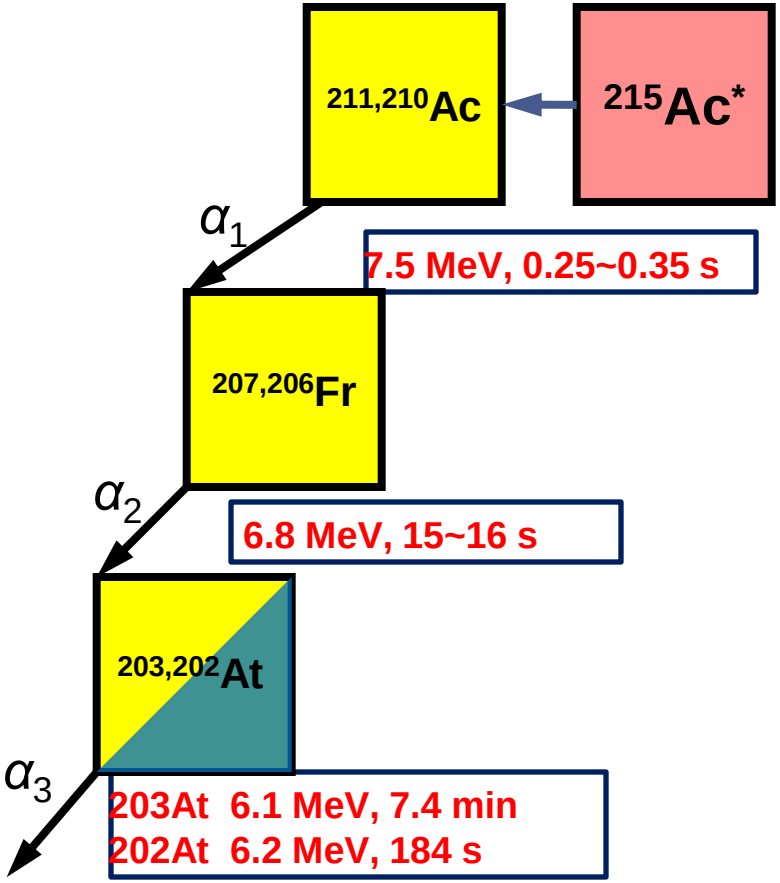
Manufacture: CANBERRA

- Energy resolution (FWMH)： ~50 keV (^{212}Po-8.785MeV)
- Position resolution (FWMH)： ~1.5 mm (ER-α)

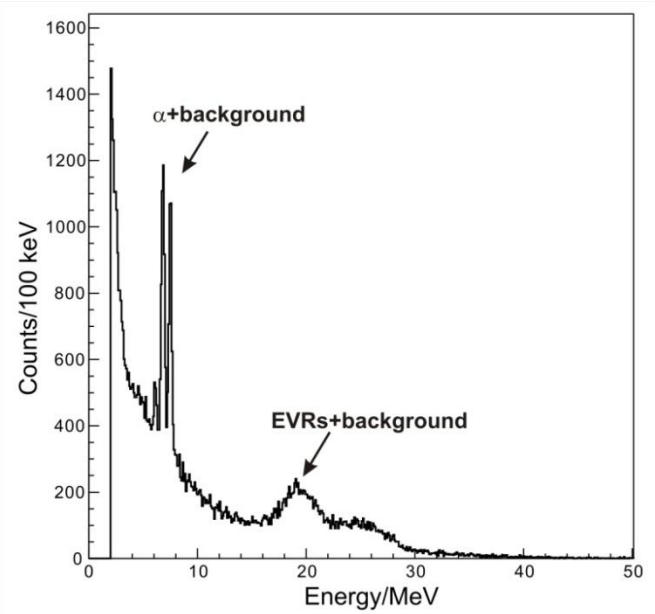
First fusion reaction experiment:
$^{40}Ar + ^{175}Lu \rightarrow ^{215}Ac^*$ (Z=89)

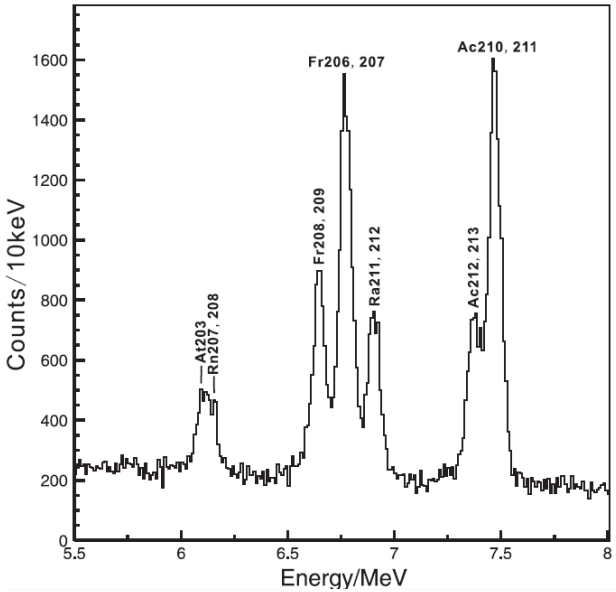


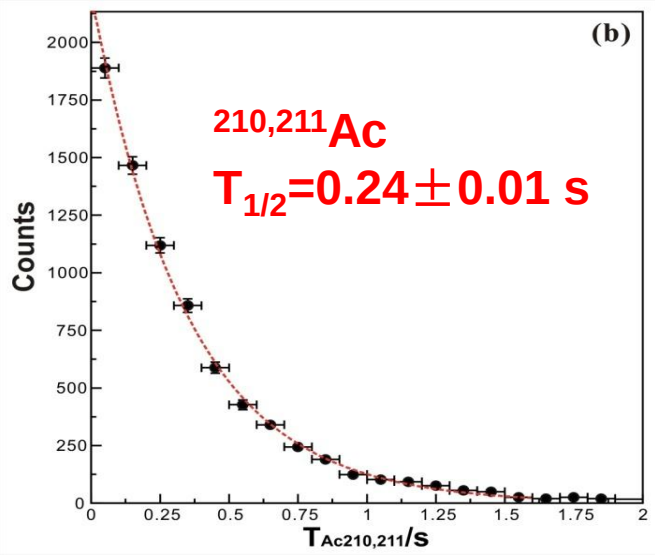
Target: 0.53mg/cm²; Bρ:~1.7Tm
Beam: 177 MeV, 2.8×10^{11}/s
He pressure: 0.7~1.0mbar

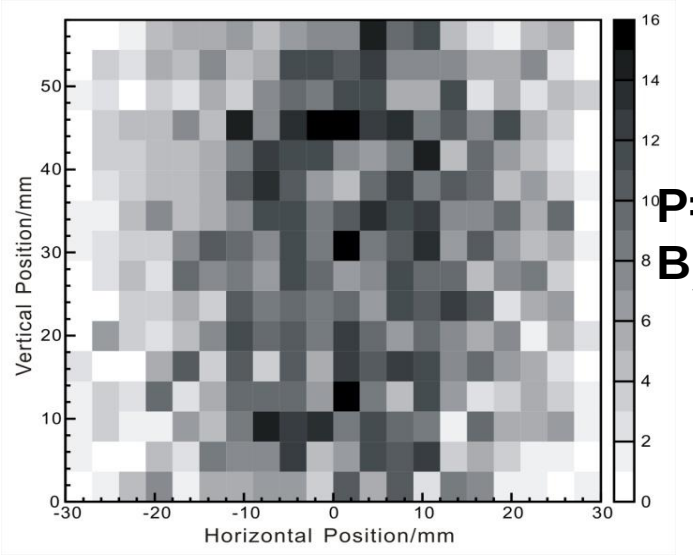


On-line spectrum





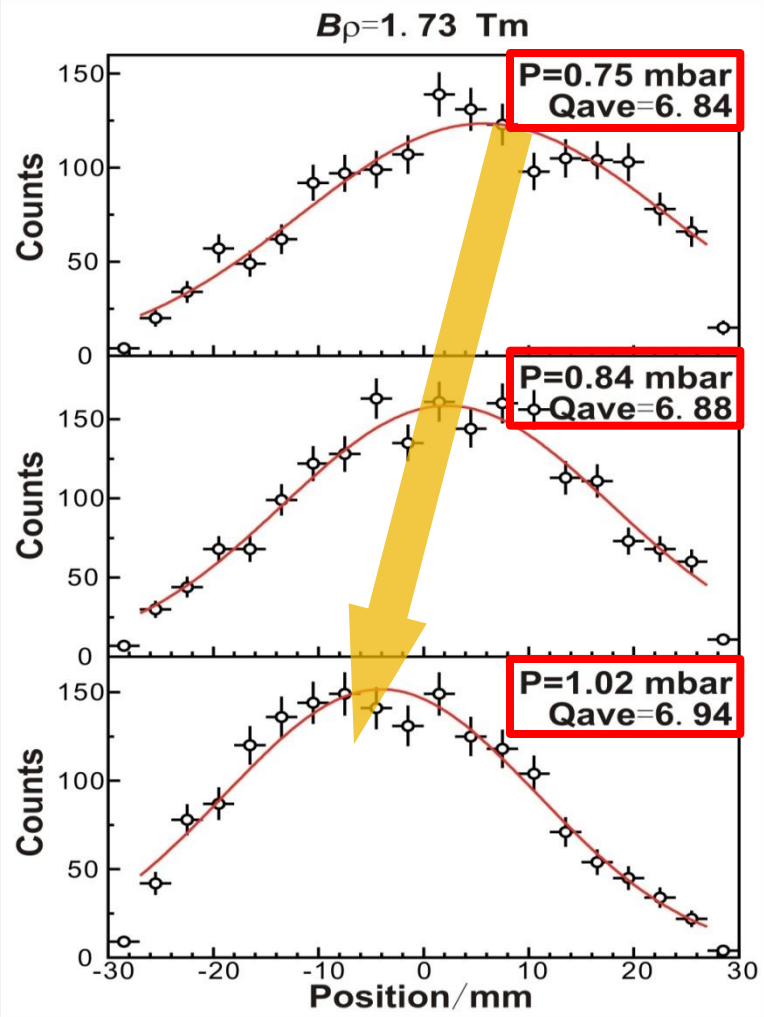




P=0.84 mbar
Bρ=1.73 Tm

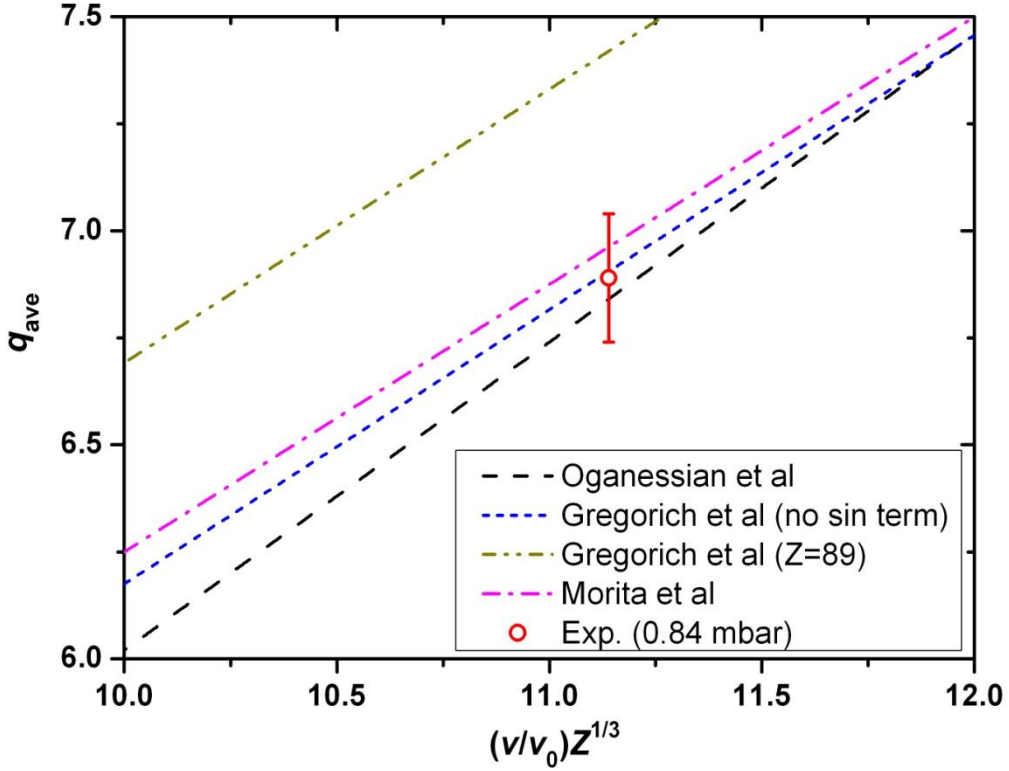
Equilibrium charge state

"density effect"



$$(B\rho)_{ion} = (B\rho)_0 \cdot (1 + x/100D)$$

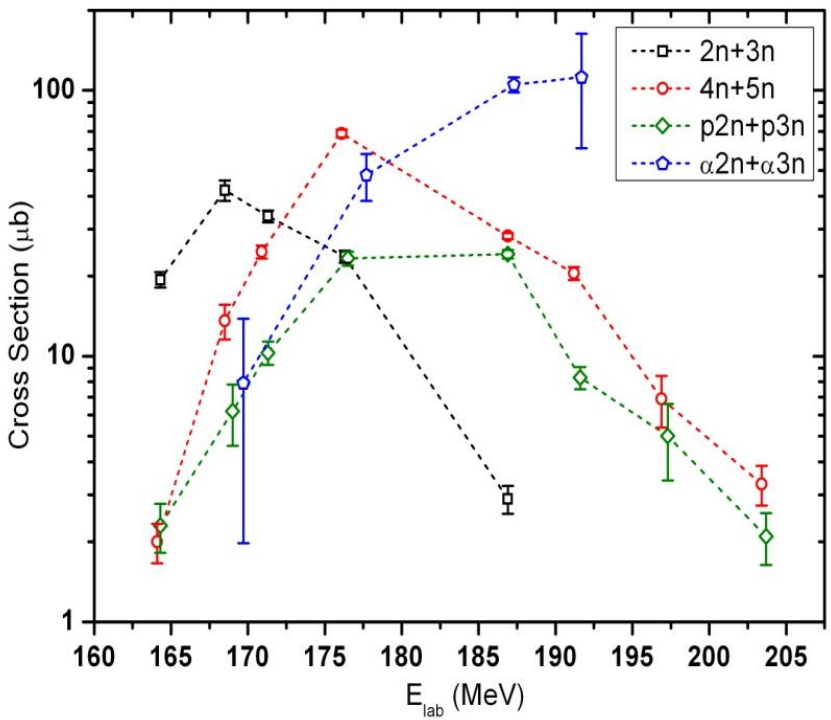
$$q_{ave} = 0.0227 \cdot A \cdot (v/v_0) / (B\rho)_{ion}$$



$$q_{ave} = 0.641 \cdot (v/v_0) \cdot Z^{1/3} - 0.235$$

Transmission Efficiency

^{175}Lu(^{40}Ar, *xn*)$^{215-x}$Ac



D. Vermeulen, et al. Z. Phys. A, 1984, 318(157).

- Beam intensity： 1 eμA
- Helium gas pressure：0.84 mbar
- Magnetic rigidity：1.73 Tm
- Counting rate of the decay of ^{211,210}Ac：300 counts/min
- Detection efficiency：50%
- Abundance of ^{175}Lu：97%
- Production cross section of ^{211,210}Ac：68.8 μb
- Transmission efficiency：14%

First test experiment:
$^{208}Pb(^{64}Ni, n)^{271}Ds$

Beam : $^{64}Ni^{19+}$ (HIRFL-SFC)

Energy : 317.1 MeV Intensity : ~100 pnA (6.6×10^{11} ions/s)

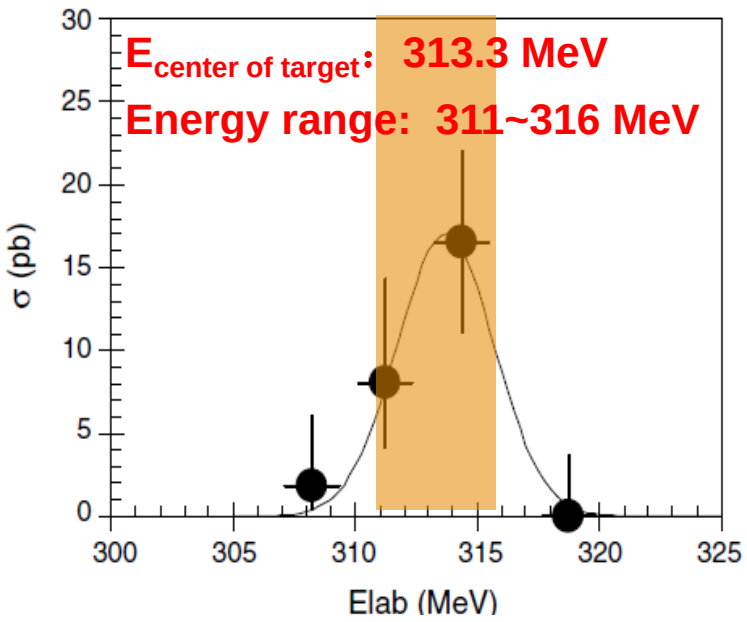
Beam time: 01/15/2011 ~ 01/21/2011 7days

03/15/2011 ~ 03/26/2011 12days

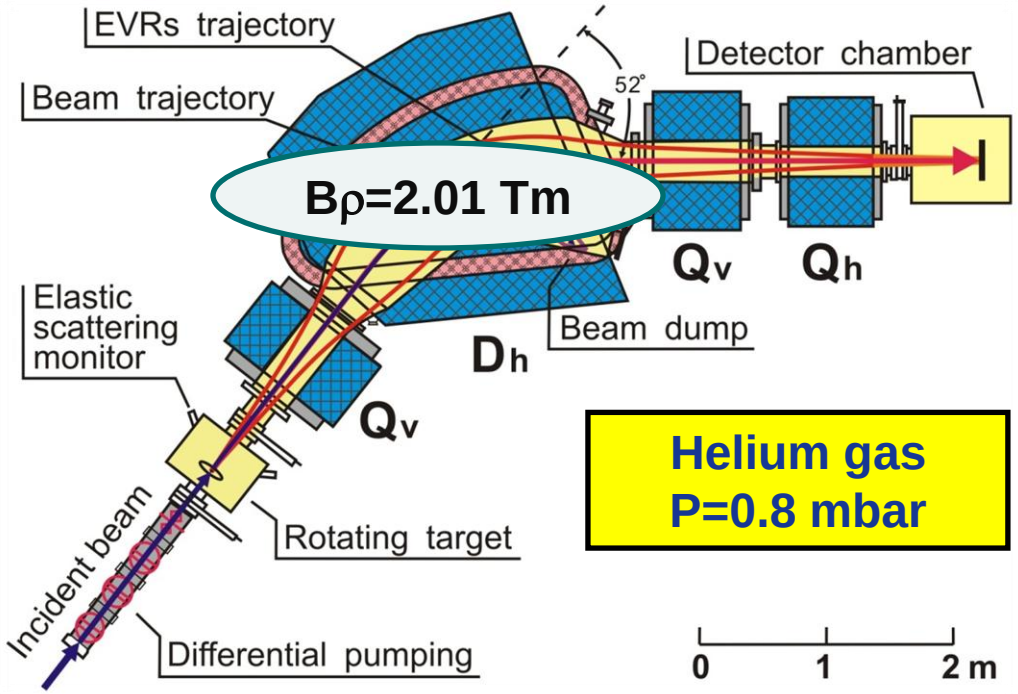
Total dose : 6.4×10^{17} ions

Beam energy at the centre of target: 313.3 MeV

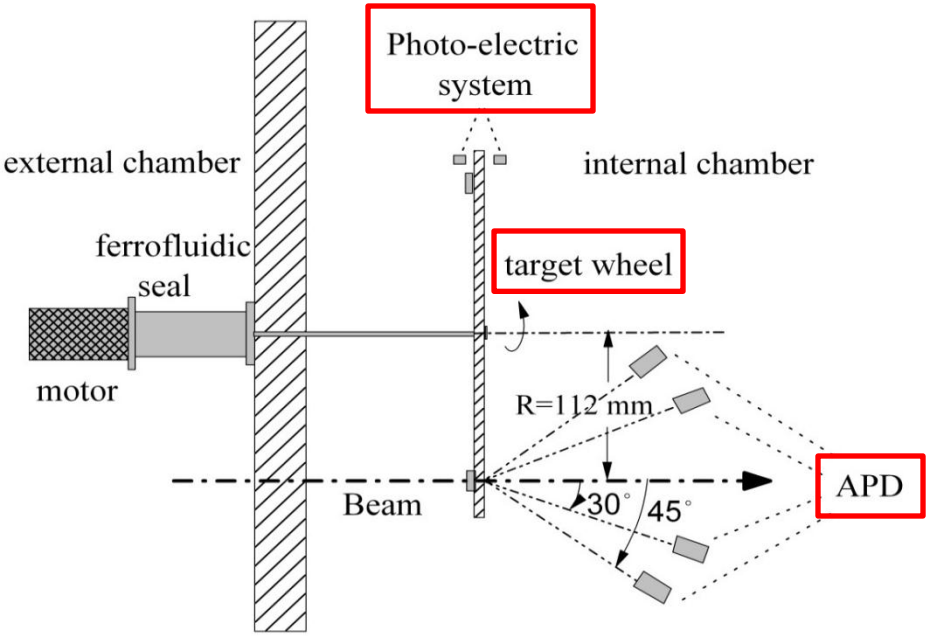
Excitation energy of the compound nucleus: 14.4 MeV



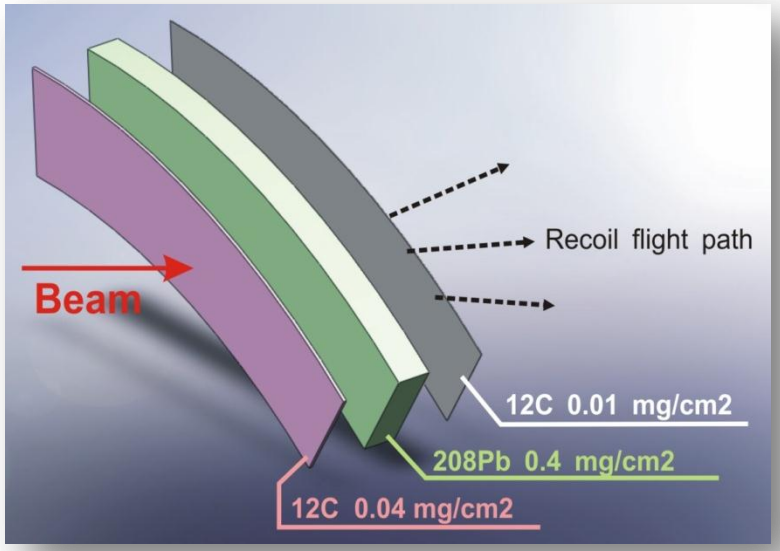
K Morita et al, Eur Phys J A 21 (2004) 257



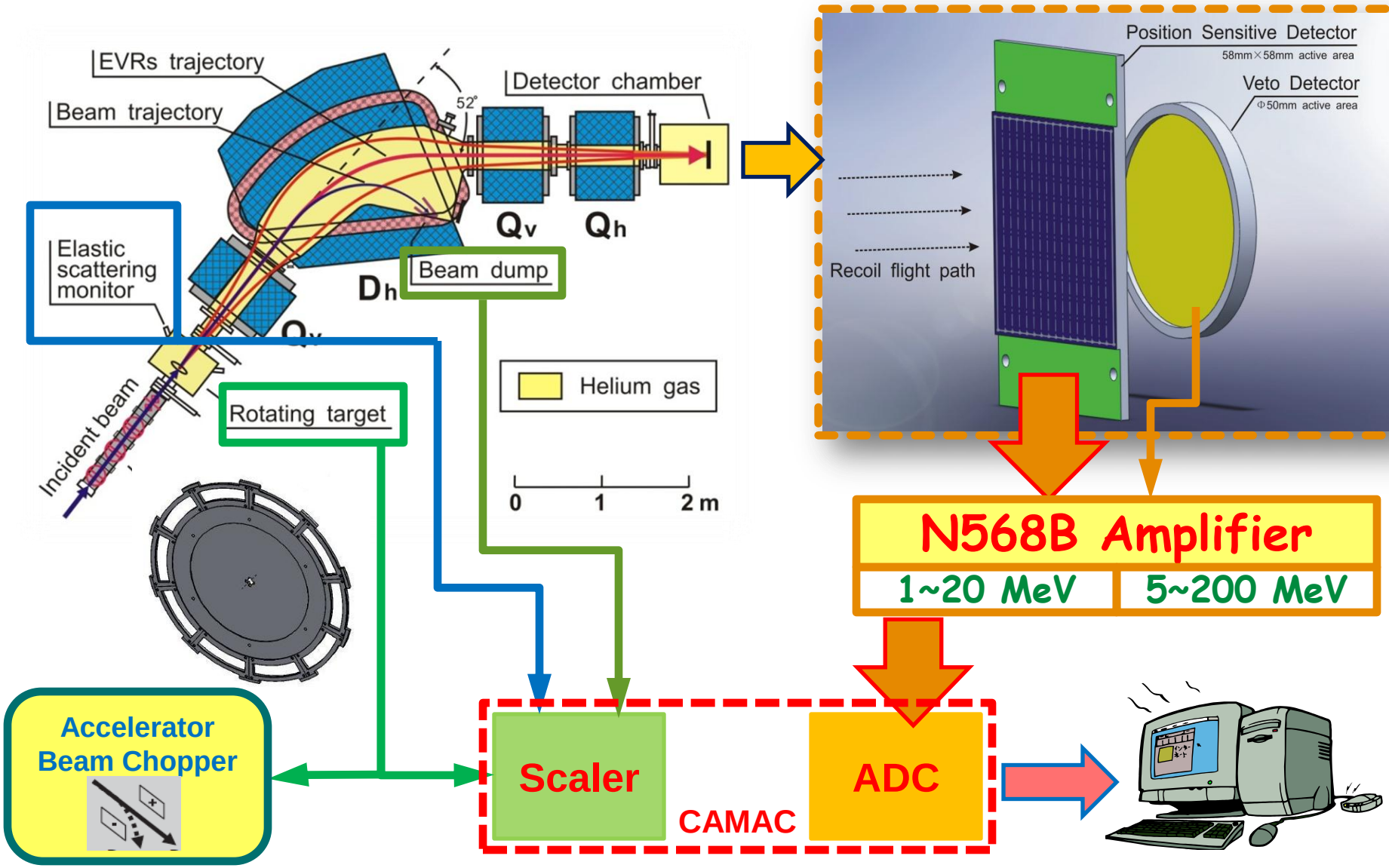
Rotating Target



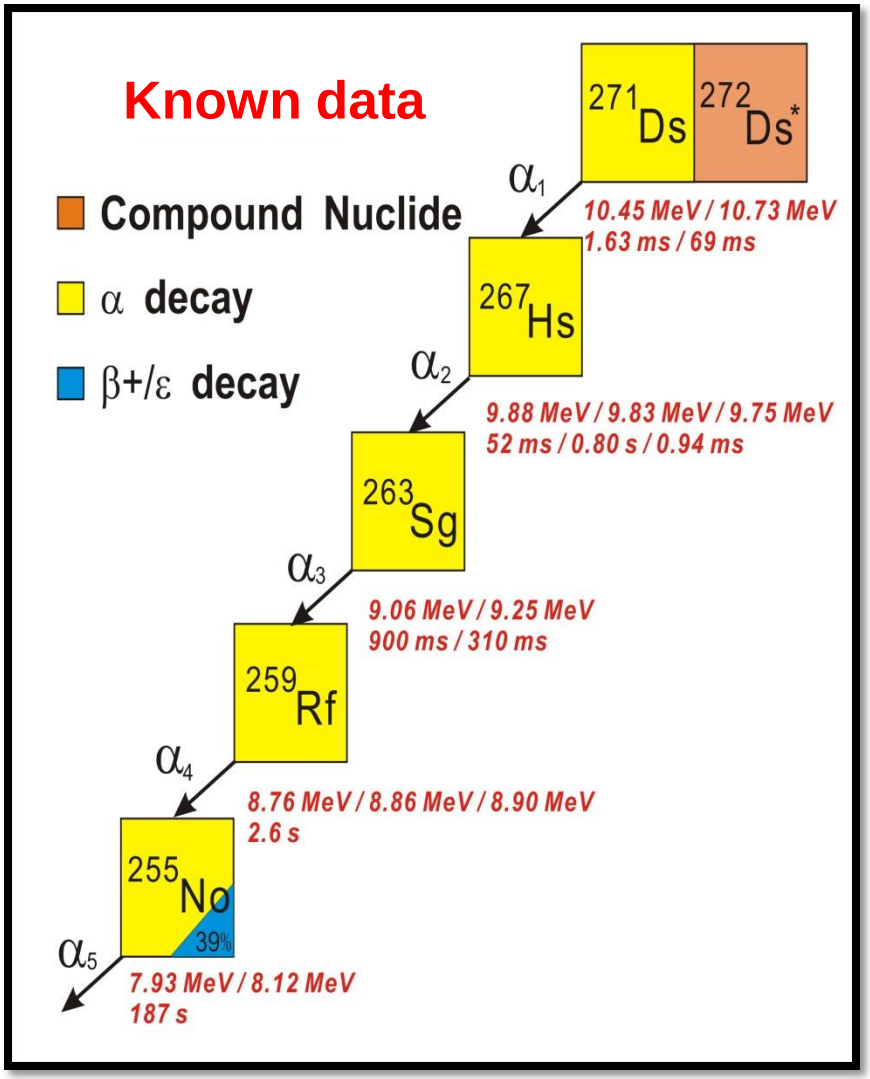
- To avoid the melting of ^{208}Pb target, the rotating target system and sandwiched targets were prepared in the experiment.
- During the irradiation, the target wheel rotated at the speed of 600 rpm.
- The simulated highest temperature of target was about 350 K lower than the melting point of lead(600 K).



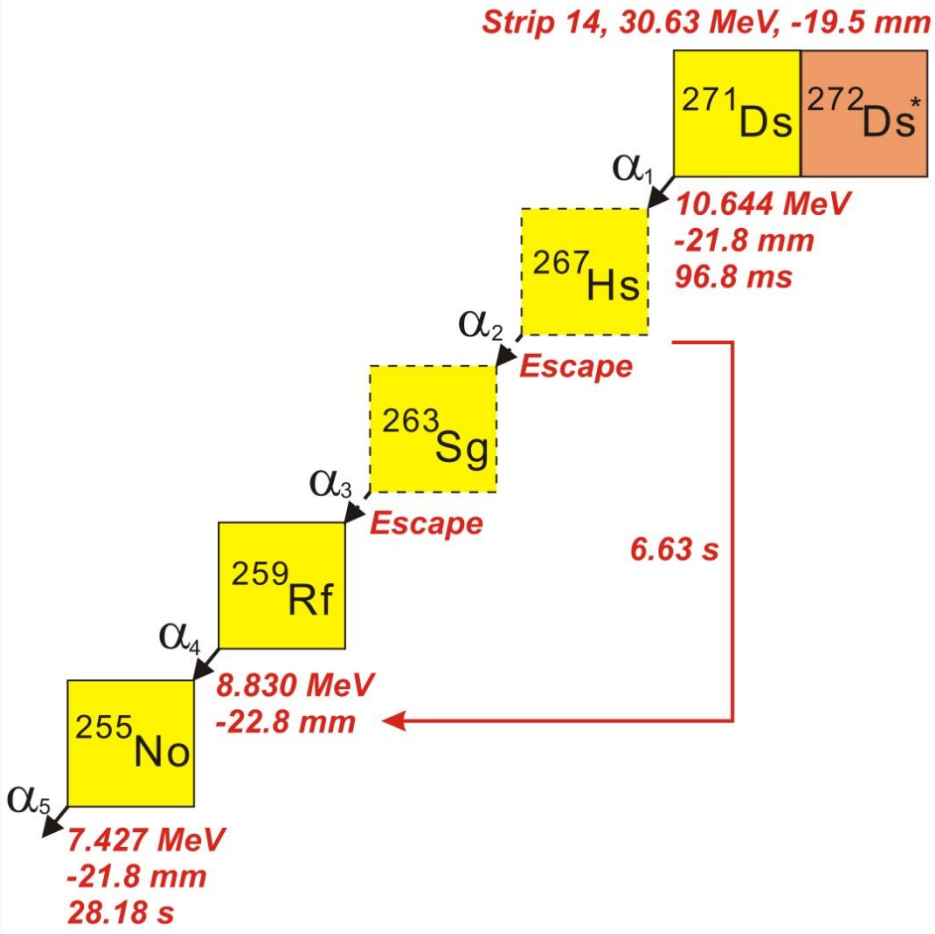
Schematic Diagram of Data Acquisition



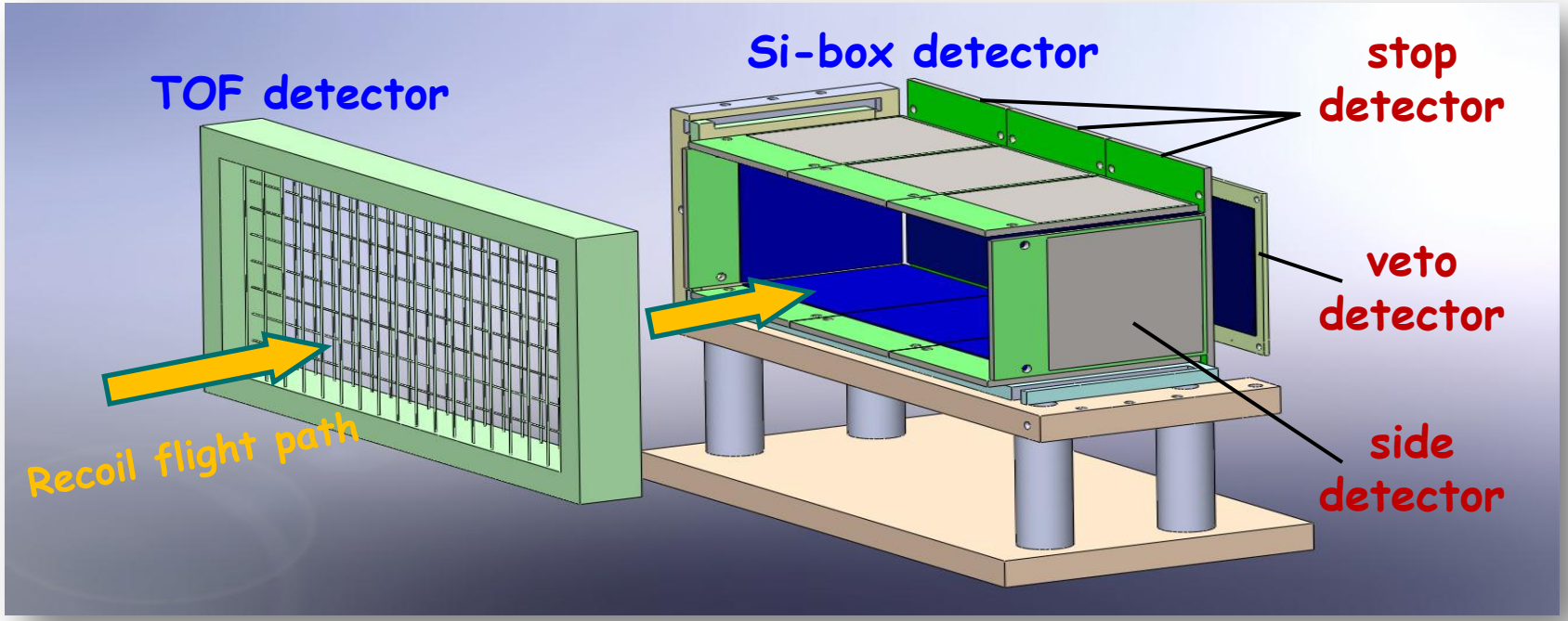
One α-decay chain assigned to ^{271}Ds



^{208}Pb(^{64}Ni, *n*)^{271}Ds (Z=110)



New Detector System



Si-box detector:

Stop detector: 3×50mm×50mm (active area), position-sensitive detectors (each has 16 vertical strips), 300μm (thickness)

Side detector: 8×50mm×50mm (active area), non-position-sensitive detectors

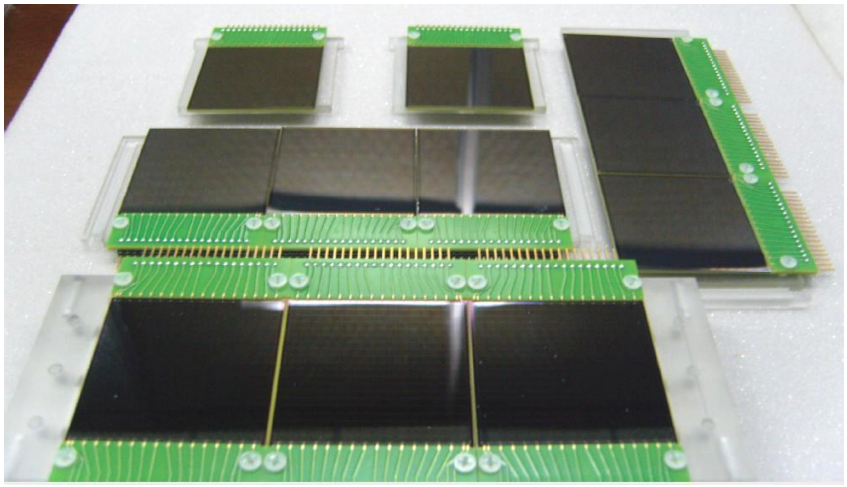
Veto detector: 3×50mm×50mm (active area), non-position-sensitive detectors

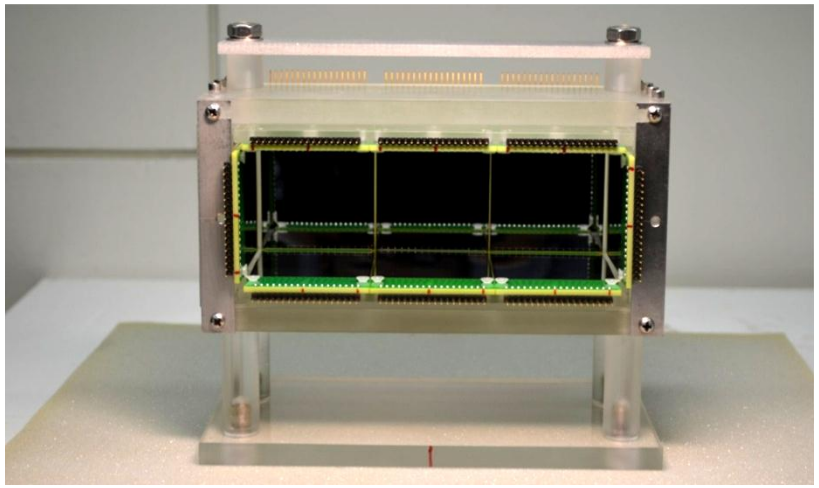
TOF detector (Multi Wire Proportional Counter):

80mm×180mm (active area), 0.5μm mylar window, isobutane gas (2 mbar)

Photos

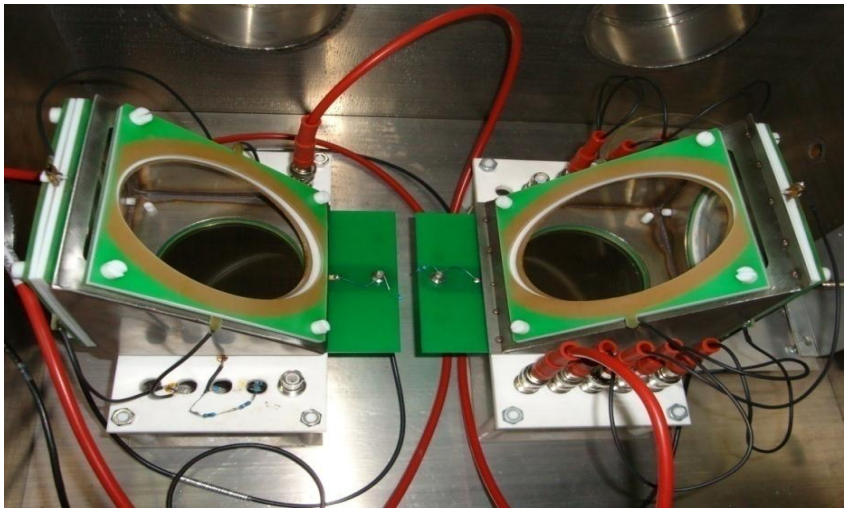
Focal plane detector



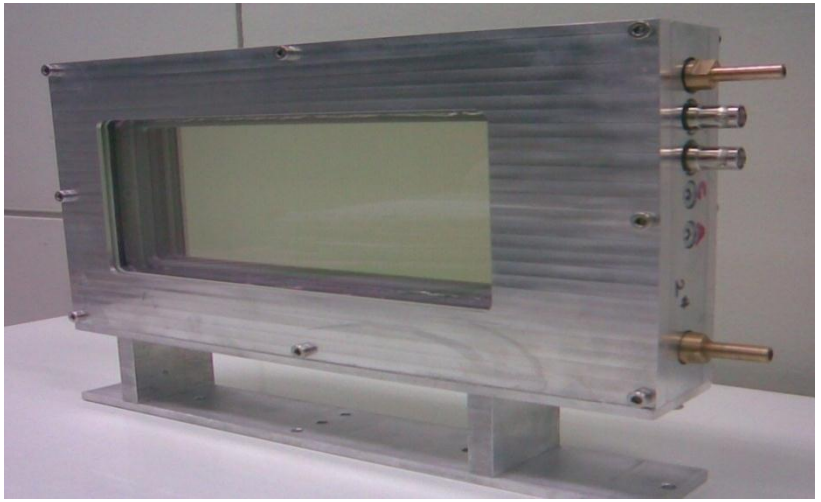


Silicon-box detector

Time-of-flight detector



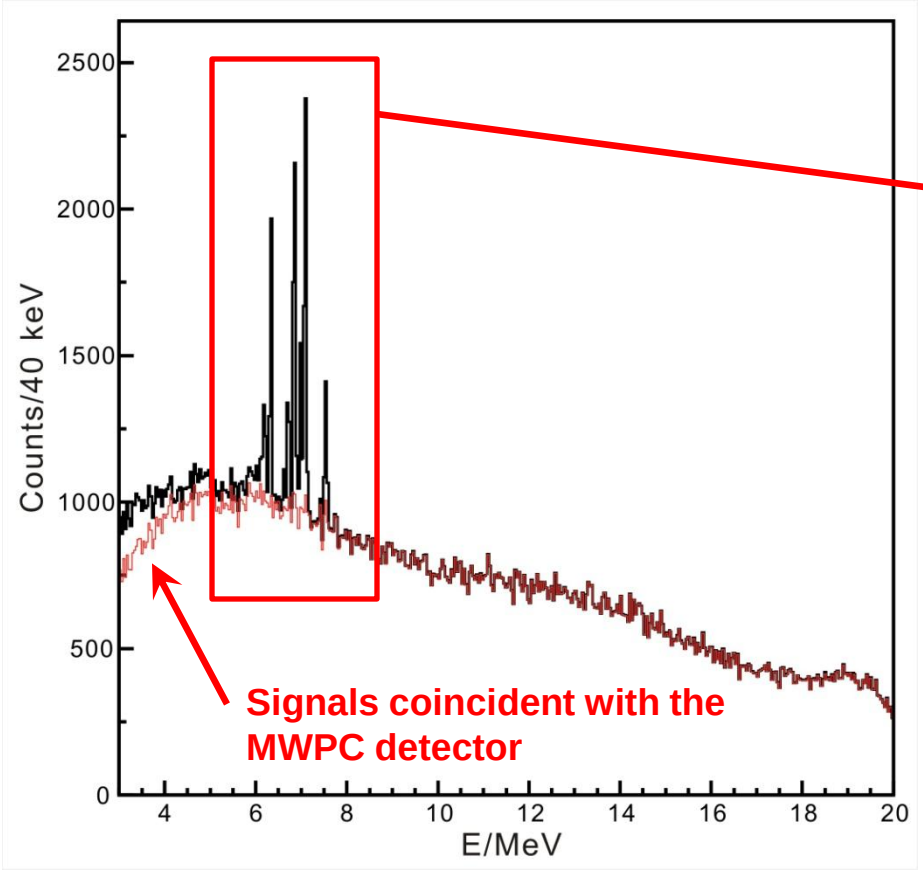
Micro-Channel Plate detector

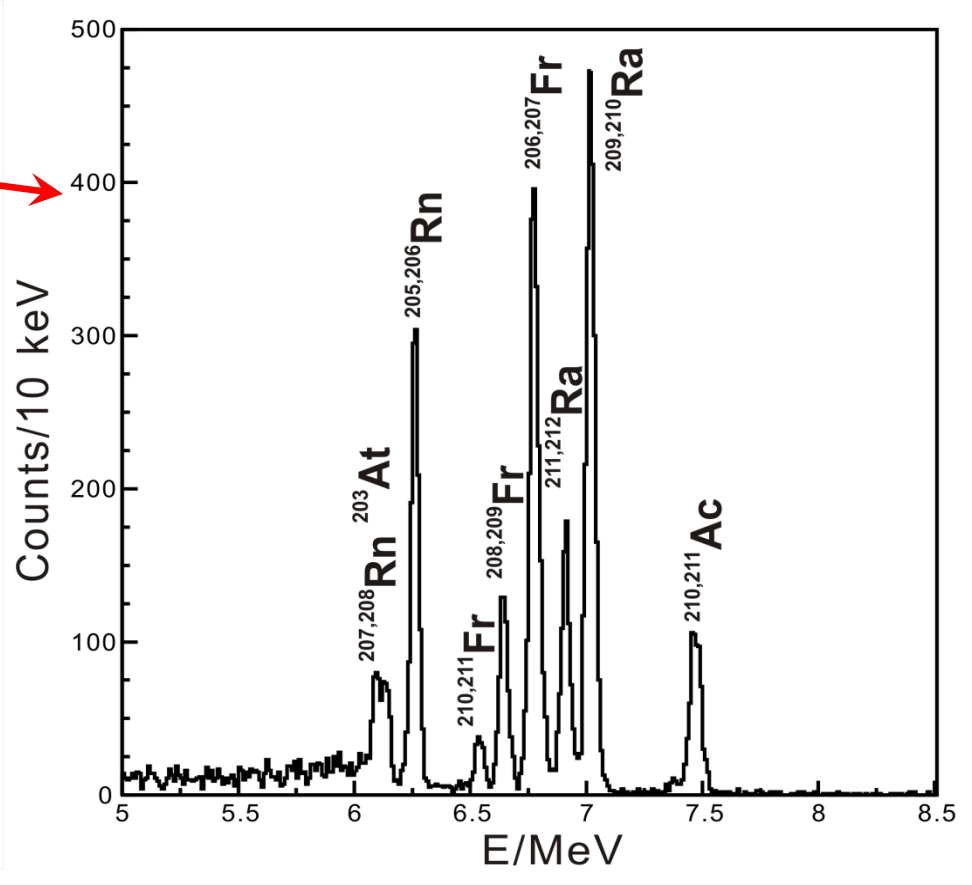


Multi-Wire Proportional Counter

$^{40}Ca+^{175}Lu->^{215}Pa^{*}$

- Observed in the bombardment $^{40}Ca+^{175}Lu$ with an energy of 4.83 MeV/u
- Without the veto detector
- With old beam dump, the total counting rate was up to 300 events/s



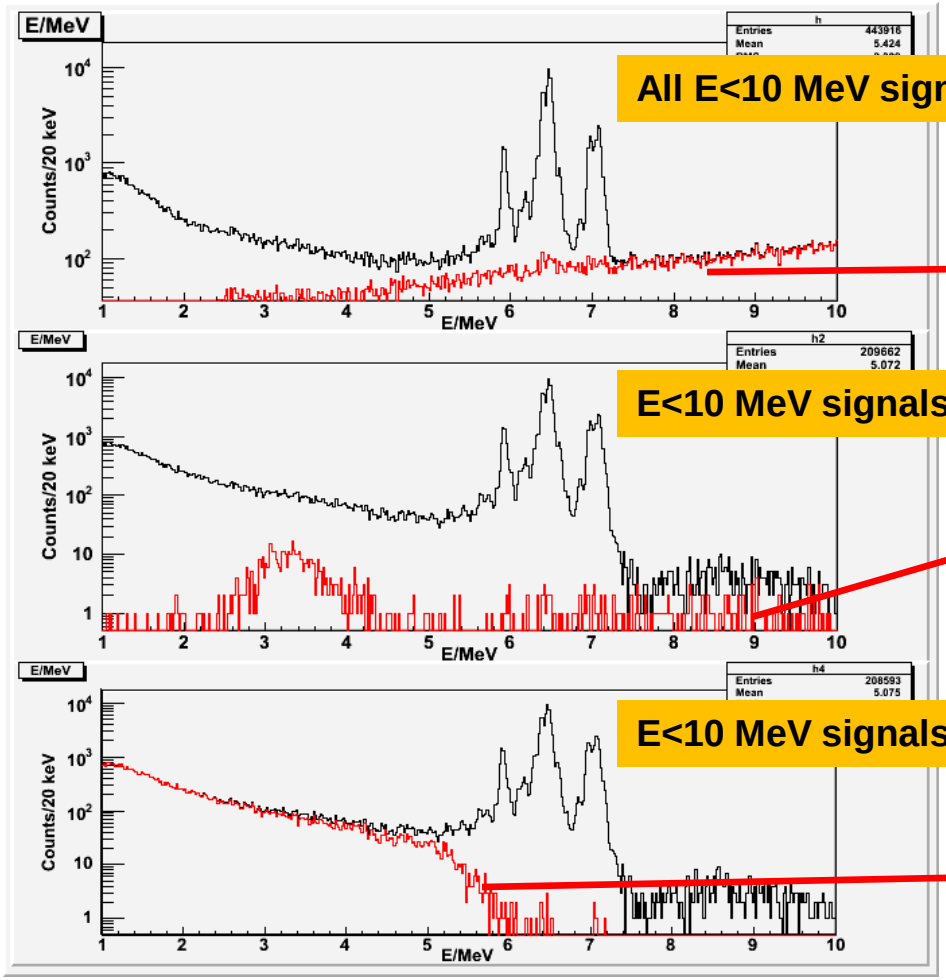


Total spectrum of silicon detector

α-decay spectrum

$^{40}Ca+^{169}Tm->^{209}Ac^{*}$

- Observed in the bombardment $^{40}Ca+^{169}Tm$ with an energy of 4.84 MeV/u
- Three veto detectors were mounted downstream of the stop detector
- With the modification of beam dump, the total counting rate decreased to 120 events/s



All E<10 MeV signals

Energy spectrum from the stop detector

E<10 MeV signals obtained from both stop detector and TOF detector

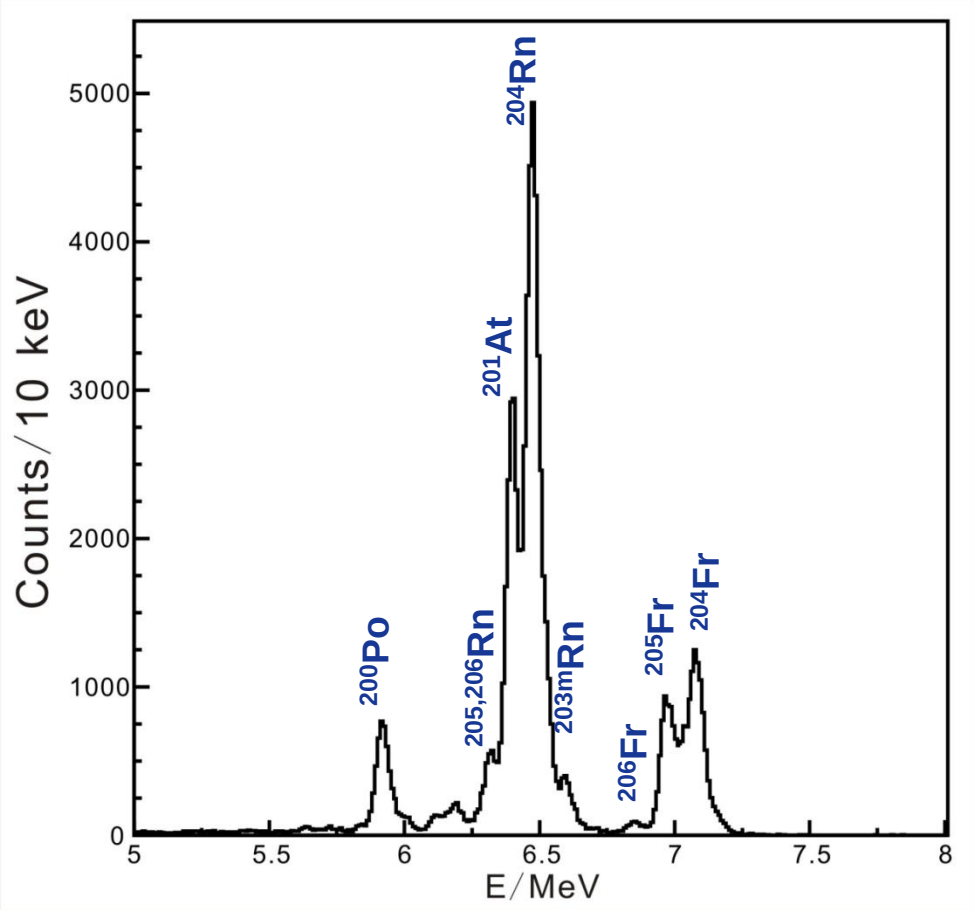
E<10 MeV signals anti-coincident with the TOF signals

E<10 MeV signals obtained from both stop detector and veto detector

E<10 MeV signals anti-coincident with the TOF and veto signals

E<10 MeV signals obtained from both stop detector and side detector

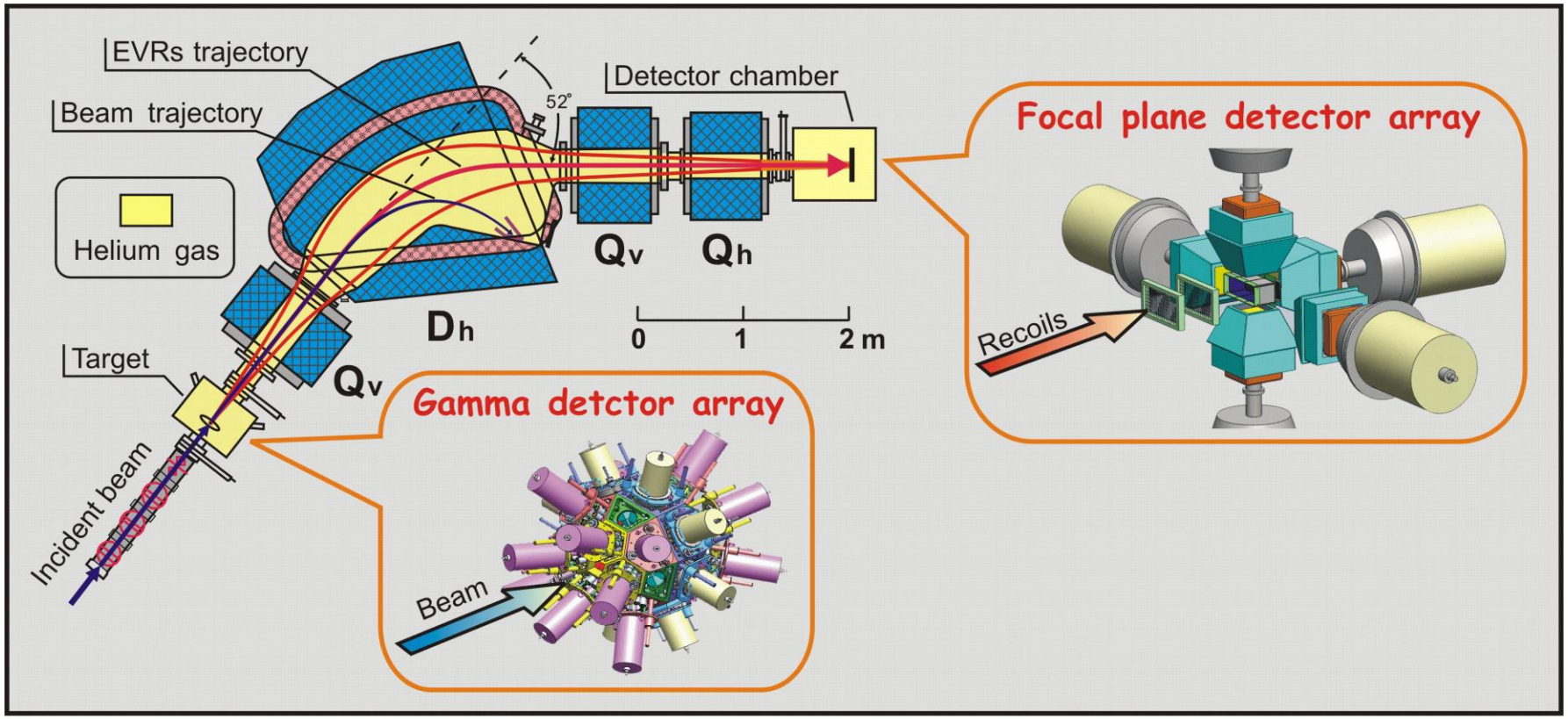
$^{40}Ca+^{169}Tm->^{209}Ac^{*}$



α-decay spectrum

The data for Ca+Lu and Ca+Tm experiments are analyzed in progress.

Future Plan

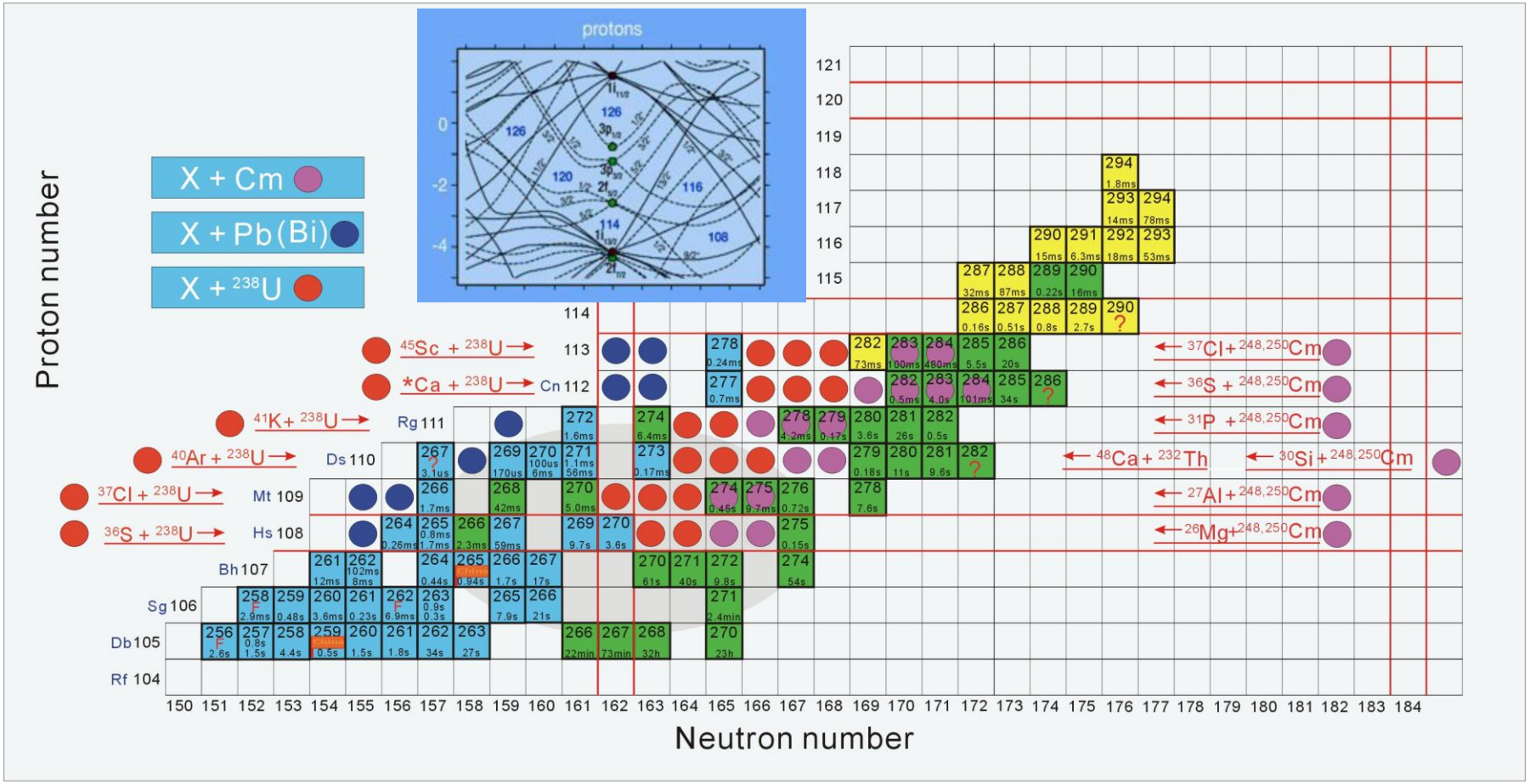


Gamma array 8 Clovers + 16 HPGes

4 HPGe 26.15^0 210 mm 4 HPGe 51.7^0 200 mm
8 Clover 90^0 180 mm 4 HPGe 128.3^0 200 mm
4 HPGe 153.85^0 210 mm

Study of Super-Heavy Nuclei

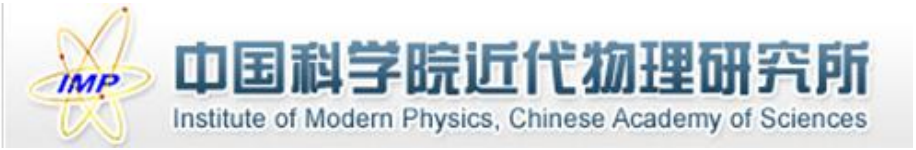
Beam intensity is about several pμA. Gas filled separator is ready.



Study the chemical properties of SHE, the reaction mechanisms to produce SHN and the structure in heavy nuclei.

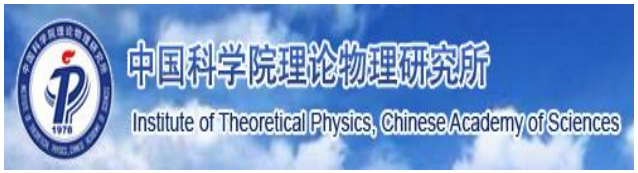
Summary

- Lanzhou gas-filled recoil separator was reported.
- In the future, with the improvement of the performance of the separator, the structure of heavy or superheavy nuclei and the synthesis of heavier nuclei will be studied.



GAN Zai-Guo, HUANG Tian-Heng, HUANG Ming-Hui, MA Long, ZHANG Zhi-Yuan, WU Xiao-Lei, JIA Guo-Bin, LI Guang-Shun, YU Lin

REN Zhong-Zhou, ZHOU Shan-Gui, ZHANG Yu-Hu, ZHOU Xiao-Hong, XU Hu-Shan,XIAO Guoqing, ZHANG Huan-Qiao,YE Yan-Lin



Thank you for your attention!