CHINESE ACADEMY OF SCIENCES

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

IUPAP WG9/C12 AGM and Nuclear Science Symposium 2026

HIAF status and beam commissioning

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Outline

1. General introduction
2. Construction and beam commissioning
3. Future plan
4. Conclusion

1. General introduction

One of the major national science and technology infrastructure in China, with a total budget of 2.8 billion CNY and a construction period from 2018 to 2025.

Where is the HIAF?

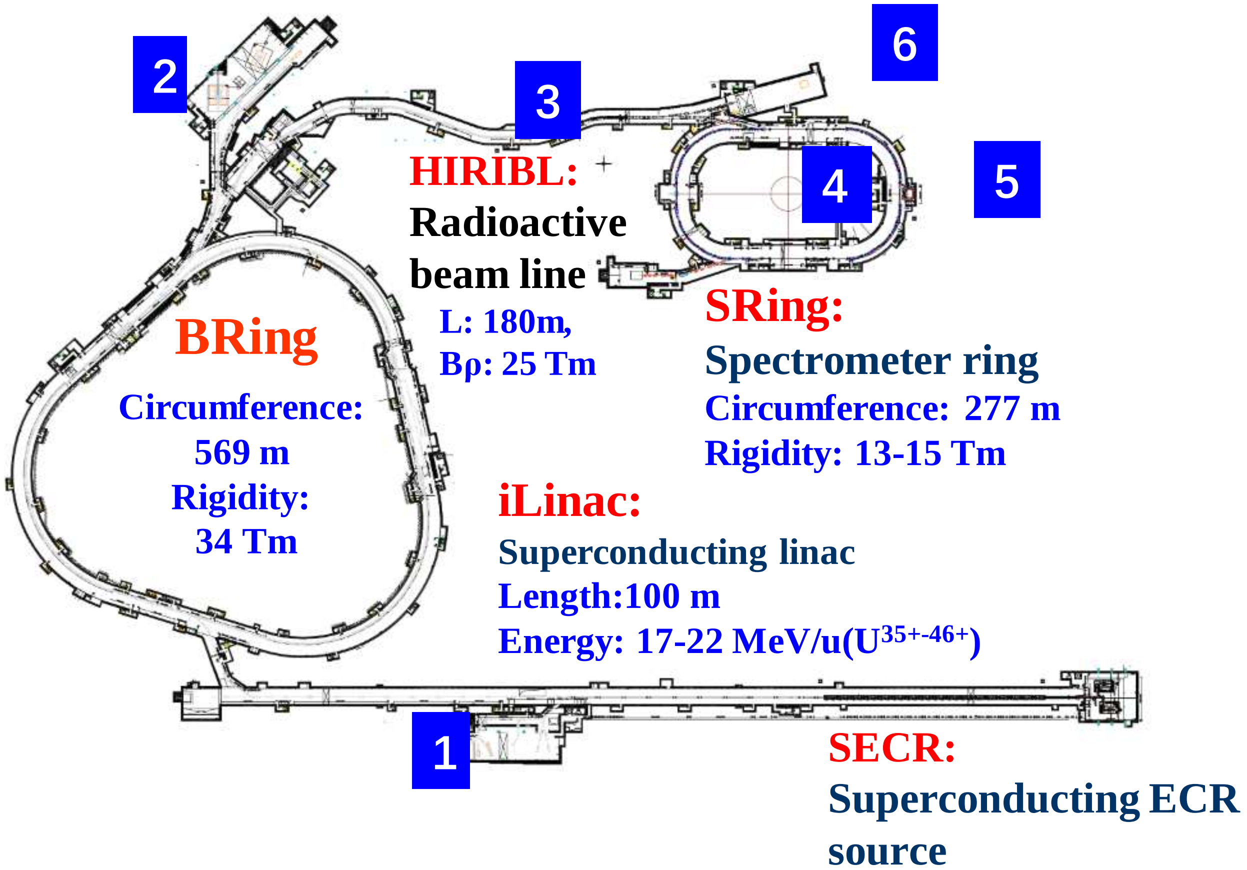
Located in Huizhou of Guangdong Province, strategically situated close to Shenzhen, Hong Kong, and Guangzhou.

Share the campus with CiADS.

1. General introduction

HIAF: High-Intensity heavy-ion Accelerator Facility

The HIAF project consists of a superconducting ECR ion source (SECR), a superconducting CW heavy ion beam linac (iLinac), a fast ramping rate synchrotron (BRing) and 6 experimental terminals



① Low energy nuclear structure terminal

② High energy experimental terminal

③ High energy fragment separator HIRIBL

④ High precision spectrometer ring SRing

⑤ Electron ion recombination terminal

⑥ Radioactive ion beam physics terminal

1. General introduction

Beam parameters and features

- High current low energy CW heavy-ion beams provided by iLinac
- highest intensity pulsed heavy-ion beams provided by BRing

	SECR	iLinac	BRing	HIRIBL	SRing
Energy (MeV/u)	0.014 (U^{35+})	17 (U^{35+})	835 (U^{35+})	800 (U^{92+})	1100 (U^{92+})
Magnetic rigidity (Tm)	---	---	34	25	15
Beam intensity of U	**1.7 emA (U^{35+})**	**1.0 mA(U^{35+})**	**1×10^{11}ppp (U^{35+}) 3×10^{11}pps (U^{35+})**	-------	**(2-5) $\times10^{11}$ppp (U^{92+})**
Operation mode	DC	CW or pulse	fast ramping (12T/s, 3Hz)	Momentum-resolution 1100	DC, deceleration
Emittance or Acceptance (H/V, π·mm·mrad, dp/p)		5 / 5	200/100, 0.5%	±30mrad(H)/±15 mrad(V), ±2%	40/40, 1.5% (normal mode)

2. Construction and beam commissioning

Civil construction

10 above-ground building and a 2 km long underground tunnel at a depth of 13 meters


BRing building


SRing building


Cryo center


Testing&Assembly hall


Linac building


Central control building

2. Construction and beam commissioning

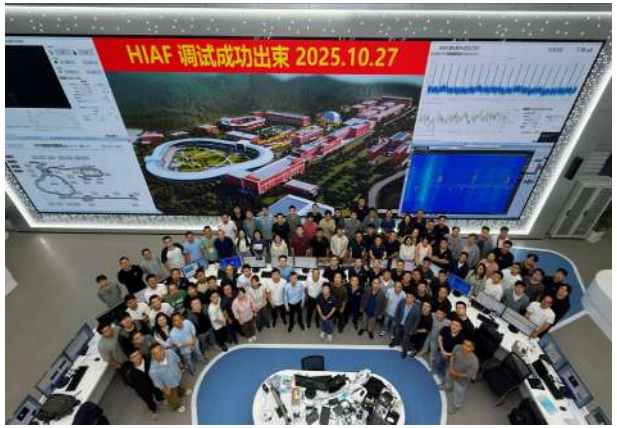
Installation schedule

19-month

27th, Mar. 2024	Aug. 2024	Nov. 2024	Sept. 2025	27th Oct. 2025
The first dipole magnet of BRing has been moved into the tunnel	The ECR ion source has been successfully installed	The installation of BRing, SRing, HFRS and beam lines has been completed	The installation of iLinac has been fully completed.	**The first beam of O^{6+} ions was successfully accelerated in HIAF**

The first dipole was moved into the tunnel in 27th March, 2024

iLinac was installed into tunnel in Sept. 2025



The first beam was accelerated in BRing on 27th October, 2025

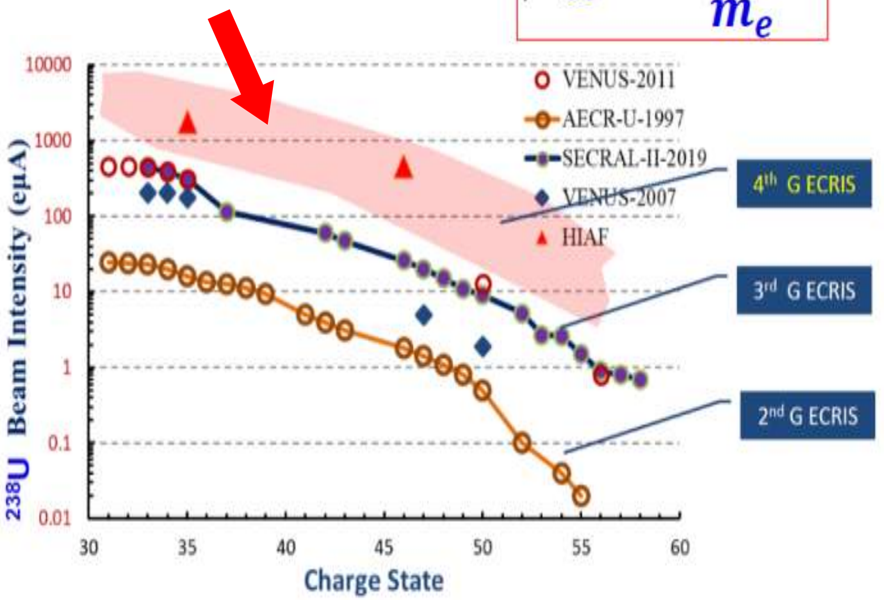
2. Construction and beam commissioning

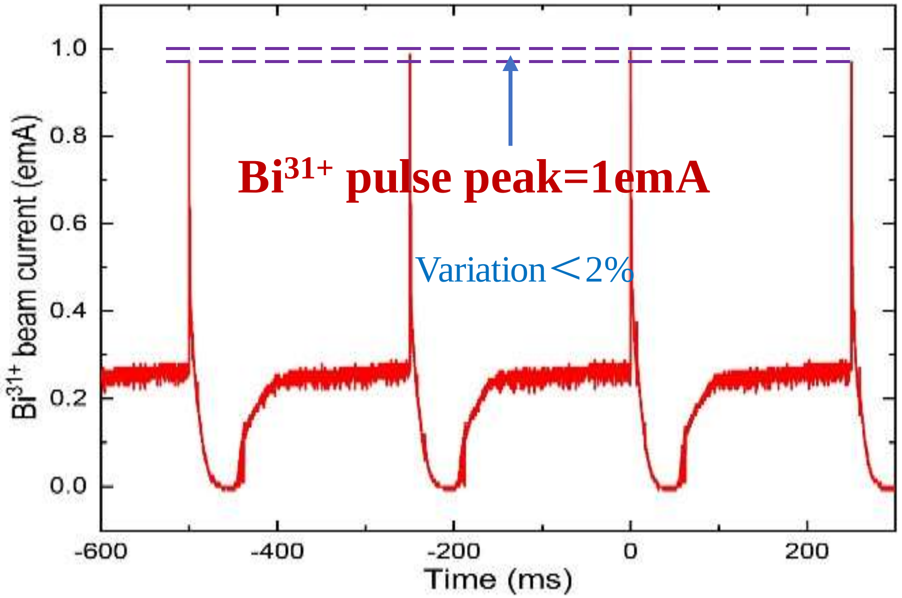
Superconducting ECR ion source for highly charged ions

- 3rd (28 GHz) and 4th (45 GHz) superconducting ECR ion source are installed

A highly charged heavy ion could be created with high magnetic field and high microwave frequency

$$\omega_{ce} = \frac{e \cdot B_{ecr}}{m_e}$$

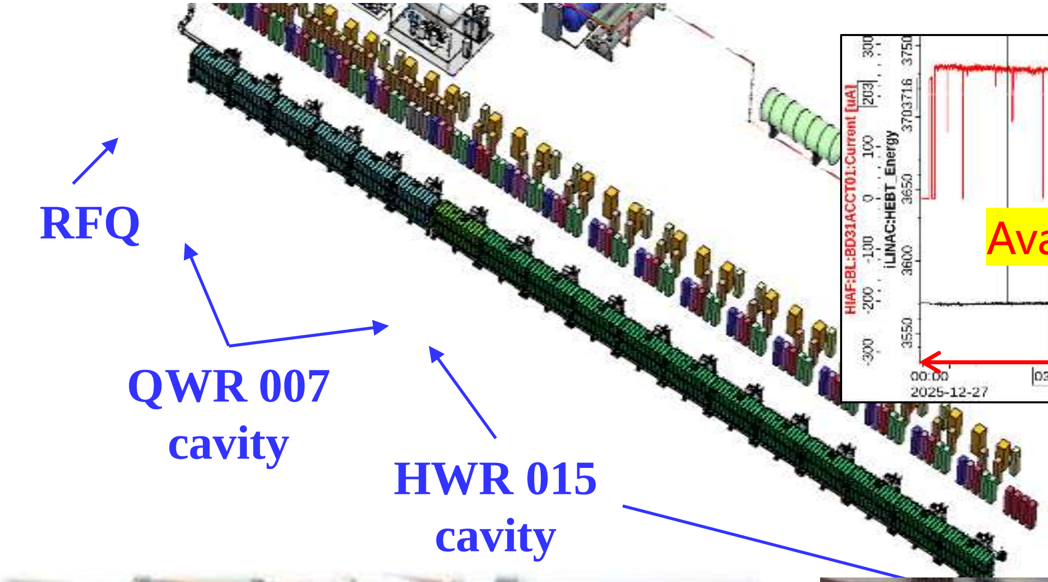


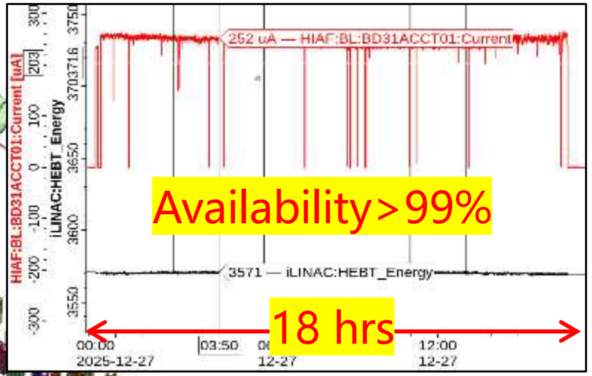


- **Bi^{35+}:** DC beam current is about 350 eμA , the new record of Bi ion.
- **Bi^{31+}:** peak current is 1 emA with the afterglow operation mode.

RFQ and SRF Linac

- Normal conducting RFQ is used to accelerated ions to 0.8 MeV/u
- SRF CW linac is used to accelerated U^{35+} to 17 MeV/u (O^{6+} to 33 MeV/u)



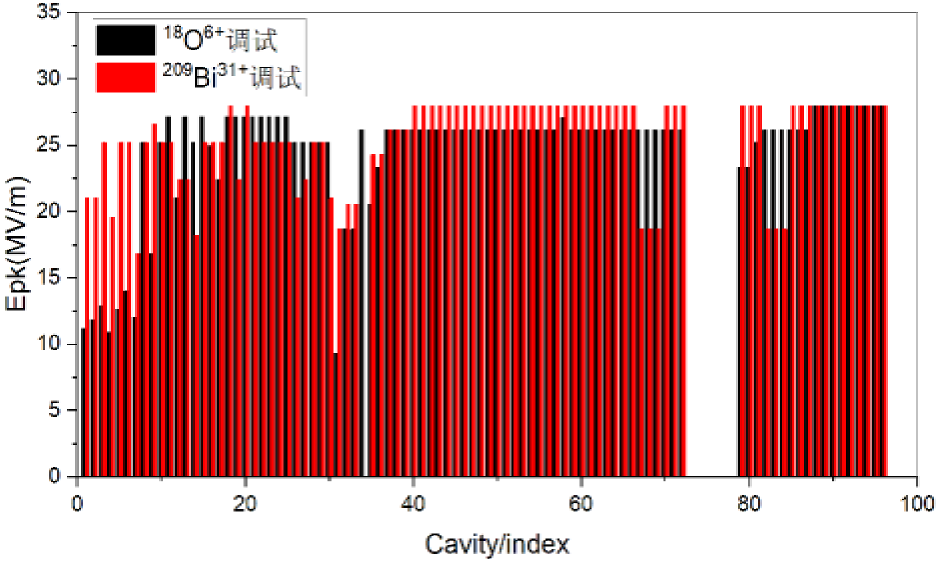


$^{209}Bi^{31+}$ commissioning:

- RFQ run at full power: 100kW 3ms@5Hz
- SRF power: QWR@25MV/m; HWR@28MV/m

RFQ

iLinac tunnel

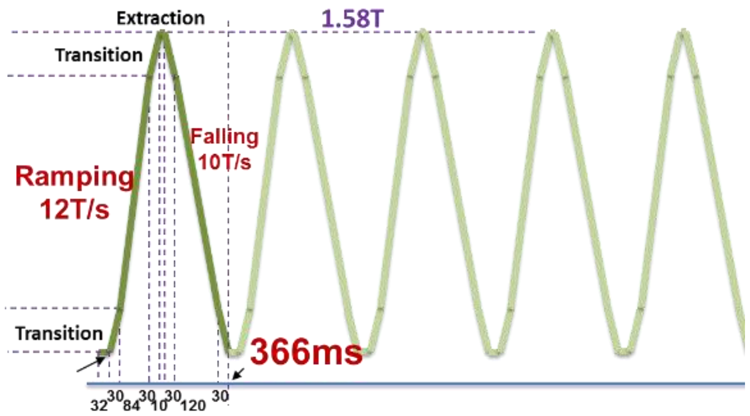


Gradient of iLinac cavities

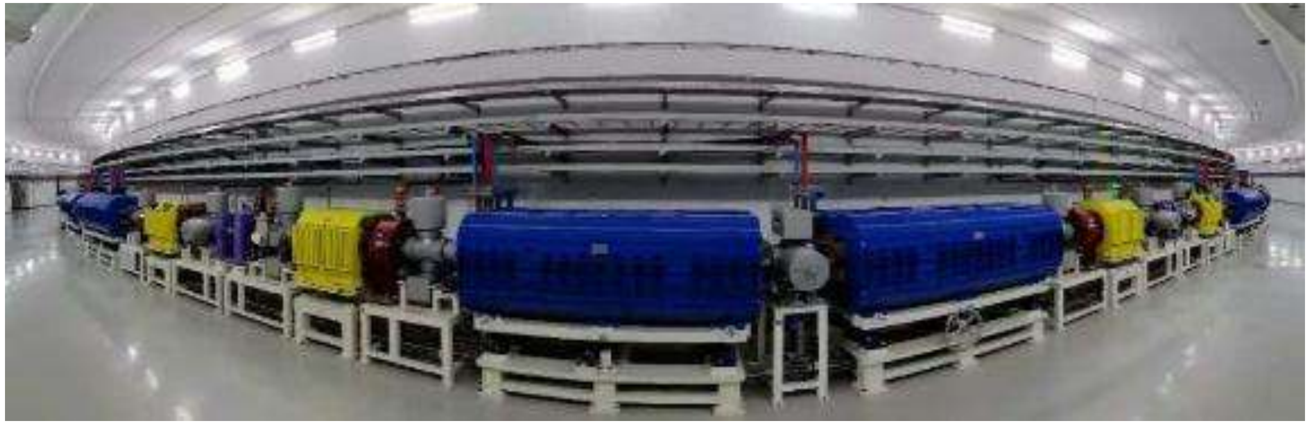
2. Construction and beam commissioning

BRing with a dipole magnetic field ramping rate of 12 T/s

Because of the space charge and dynamic vacuum effects, heavy ion beams should be launched to the high energy as soon as possible



Repetition rate： 3-5 Hz, 5-10Hz



BRing accelerator tunnel

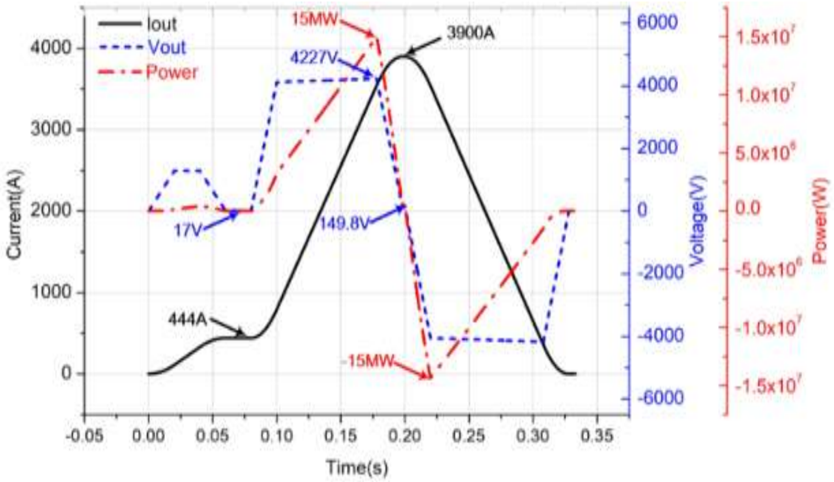
- **Challenges**

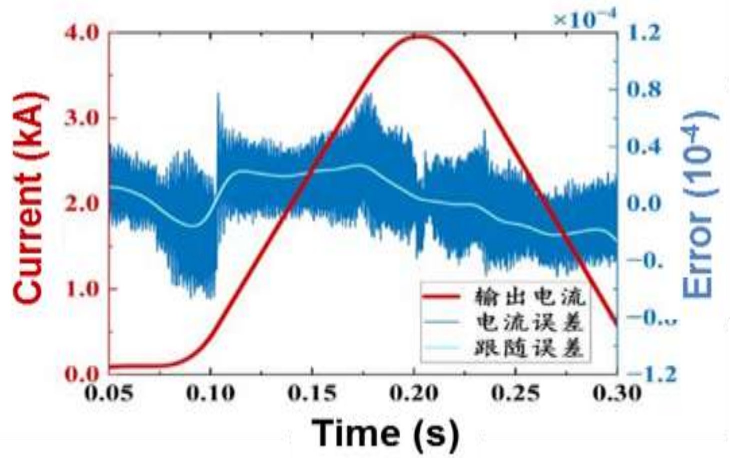
- High current ramping rate up to **38 kA/s** for dipole PS, drive 12 T/s dipoles
- High acceleration voltage up to **240 kV/turn**, satisfy to energy gain/turn
- Thin wall vacuum chamber less than **0.3 mm**, avoid distortion with eddy current

2. Construction and beam commissioning

Fast ramping rate full energy storage power supply

Requirement of magnet power converters featured by fast ramping rate: 12T/s, ±38000A/s, the peak power reaches 230MW totally at full load





---Expert Evaluation on 28/09/25

…which fully **satisfy the excitation current specifications** of pulse and DC power supplies for the HIAF facility.

- Energy **capacitor** is used to **store energy** during the falling, and provide the energy for next fast ramping
- Achieved leading level performance, and power consumption largely **reduces to 10%**

Dipole power supply

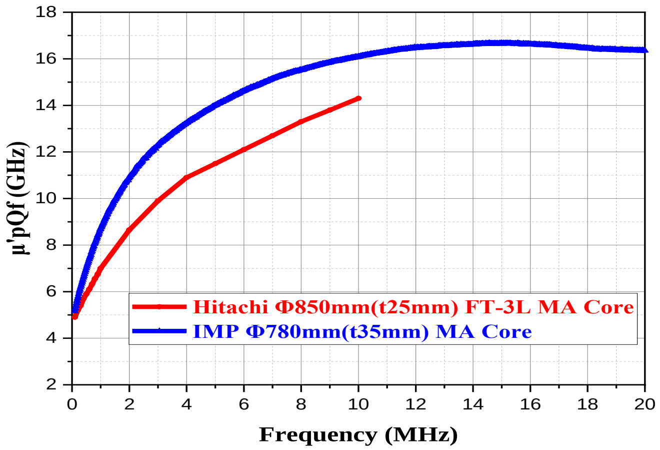
2. Construction and beam commissioning

Magnetic alloy core loaded RF system

Developed large-size nan-crystalline magnetic alloy rings, μQf value has reached the highest world level.

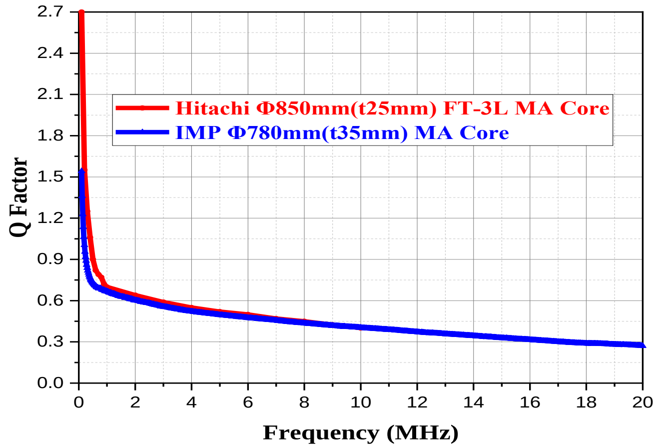
Total RF voltage is 350 kV in HIAF

---Expert Evaluation on 16/10/25



Facilities	Voltage (kV)	Length (m)	Gradient (kV/m)
JPARC-RCS	41	1.78	23
SIS18	50	2	25
HIAF-BRing	70	2	35

The measured results of the HIAF high-frequency system have all met the design specifications. … internationally advanced and **satisfies the design requirements of the HIAF facility's high-frequency system**.



2. Construction and beam commissioning

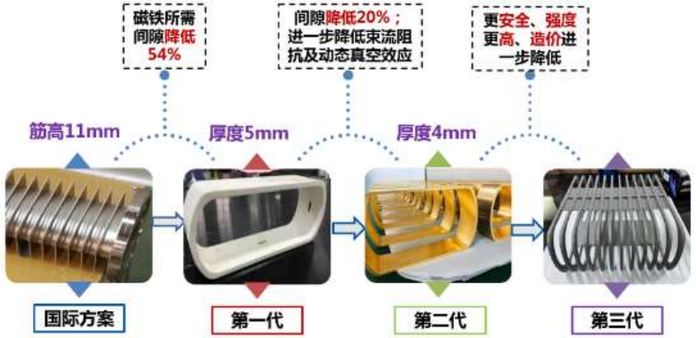
Titanium alloy-lined thin-walled vacuum chamber

Problem: fast ramping of the magnets induces eddy currents:

- The chamber walls are heated
- Generation of additional harmonics in field

Solution from GSI

Stainless steel-**0.3mm**
Rib-15mm,one side

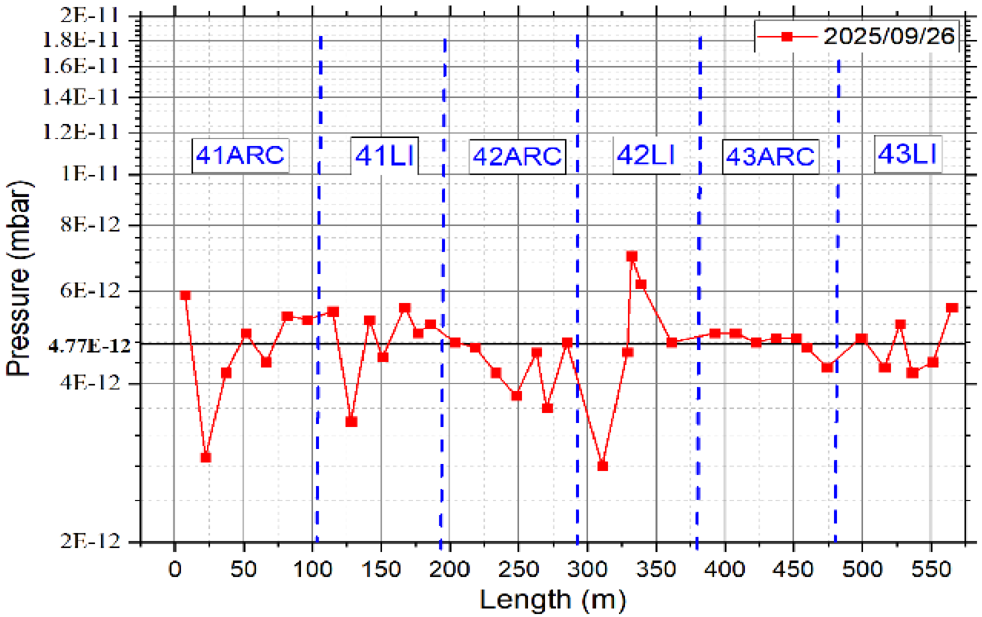


IMP: thin-wall chamber supported by rings

---Expert Evaluation on 26/09/25

Static average vacuum in 570m ring

4.7×10^{-12} mbar



...which delivers the **highest vacuum level** among comparable large international accelerators in operation, offering a key guarantee **for high-brightness, long-lifetime beam operation**.

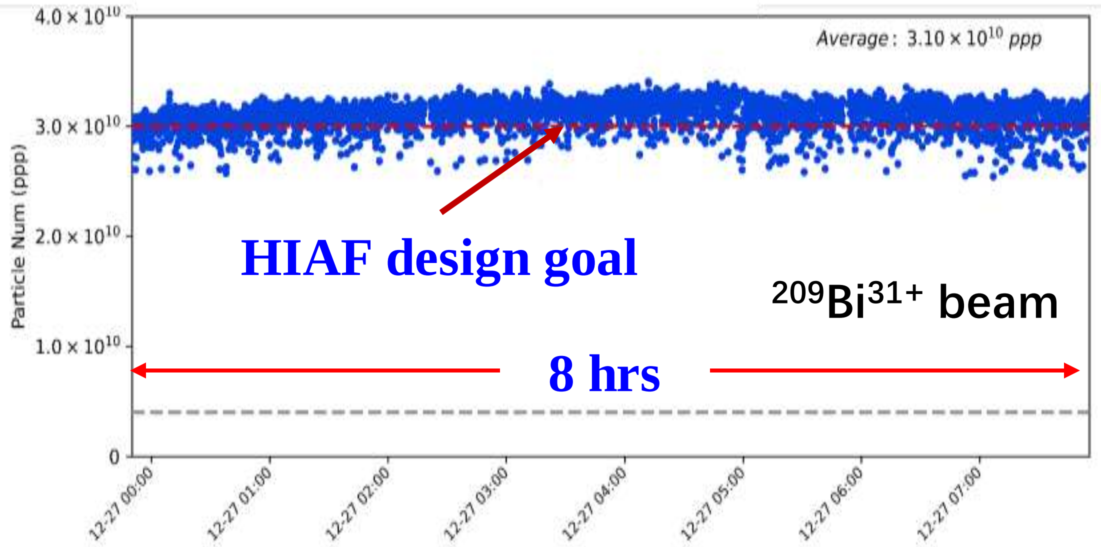
2. Construction and beam commissioning

The first beam commissioning on October 27th, 2025

- $^{18}O^{6+}$ beam was accelerated up to 2.6 GeV/u with peak current of 3×10^{11} ppp
- the 2 km-long accelerator was successfully commissioned in just **ONE day**

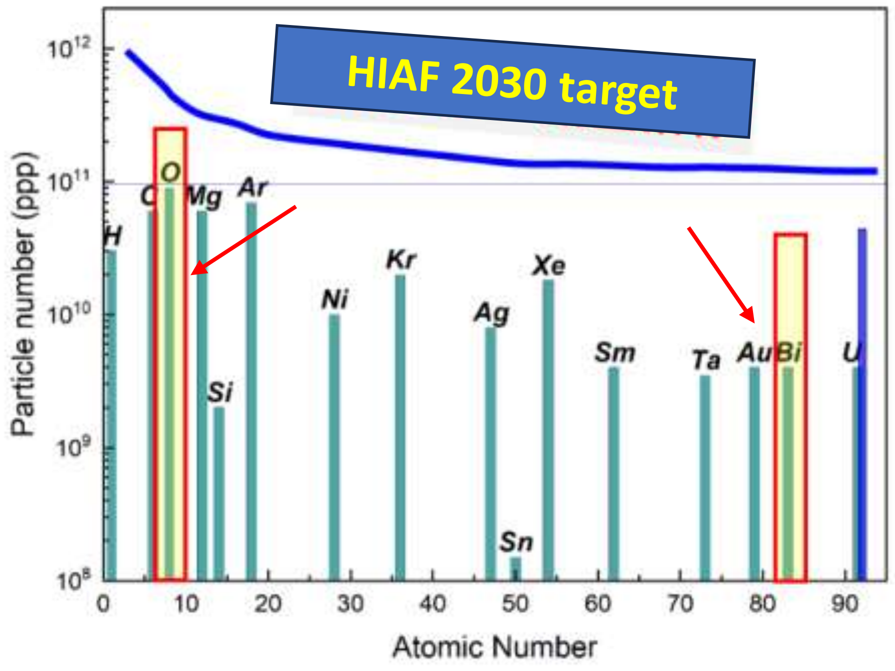
The first beam was injected, accelerated in BRing in 27th October, 2025

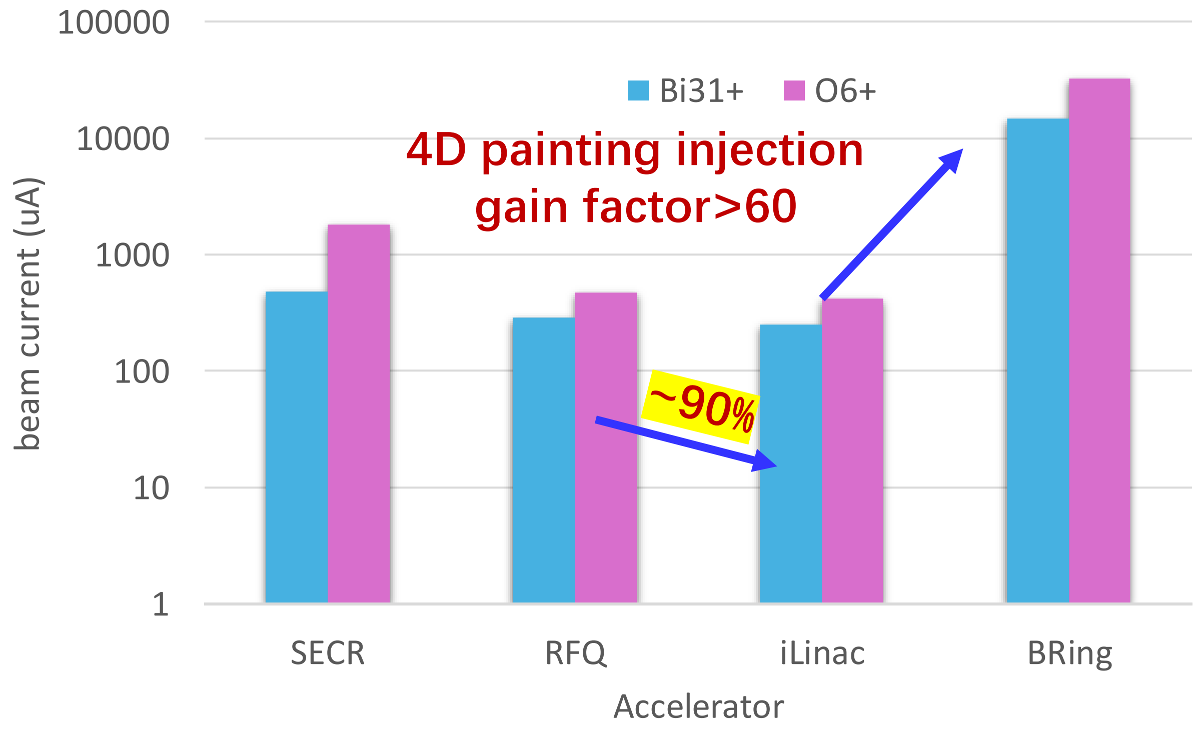
Projectile	SCL		BRing	
	$E_{proj.}$ (MeV/u)	I(pμA)	$E_{proj.}$ (GeV/u)	I(ppp)
$^{18}O^{6+}$	~33	~35pμA	2.6	2.5×10^{11}
$^{209}Bi^{31+}$	~17	~8.3pμA	0.85	3.0×10^{10}



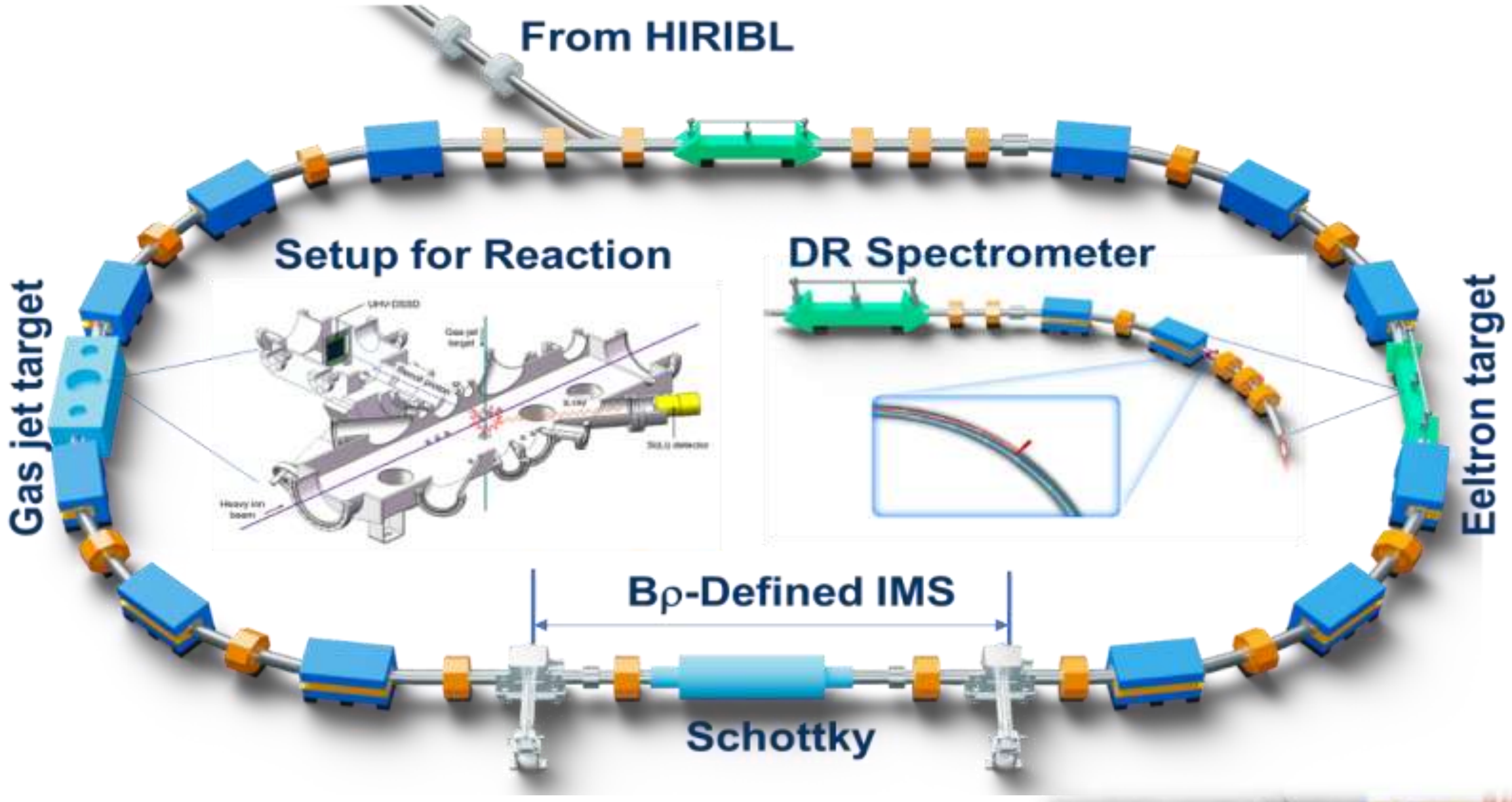
Beam intensity

- The pulsed particle number of O^{6+} and Bi^{31+} beams has exceeded the highest beam intensity record of SIS-18 at GSI
- 4D phase (H & V) painting injection gain factor larger than 60
- Intensities of all ion beams will exceed 10^{11} ppp by 2030





2. Construction and beam commissioning



Spectrometer Ring

Circumference:273 m

Rigidity: 15 Tm

Operation modes

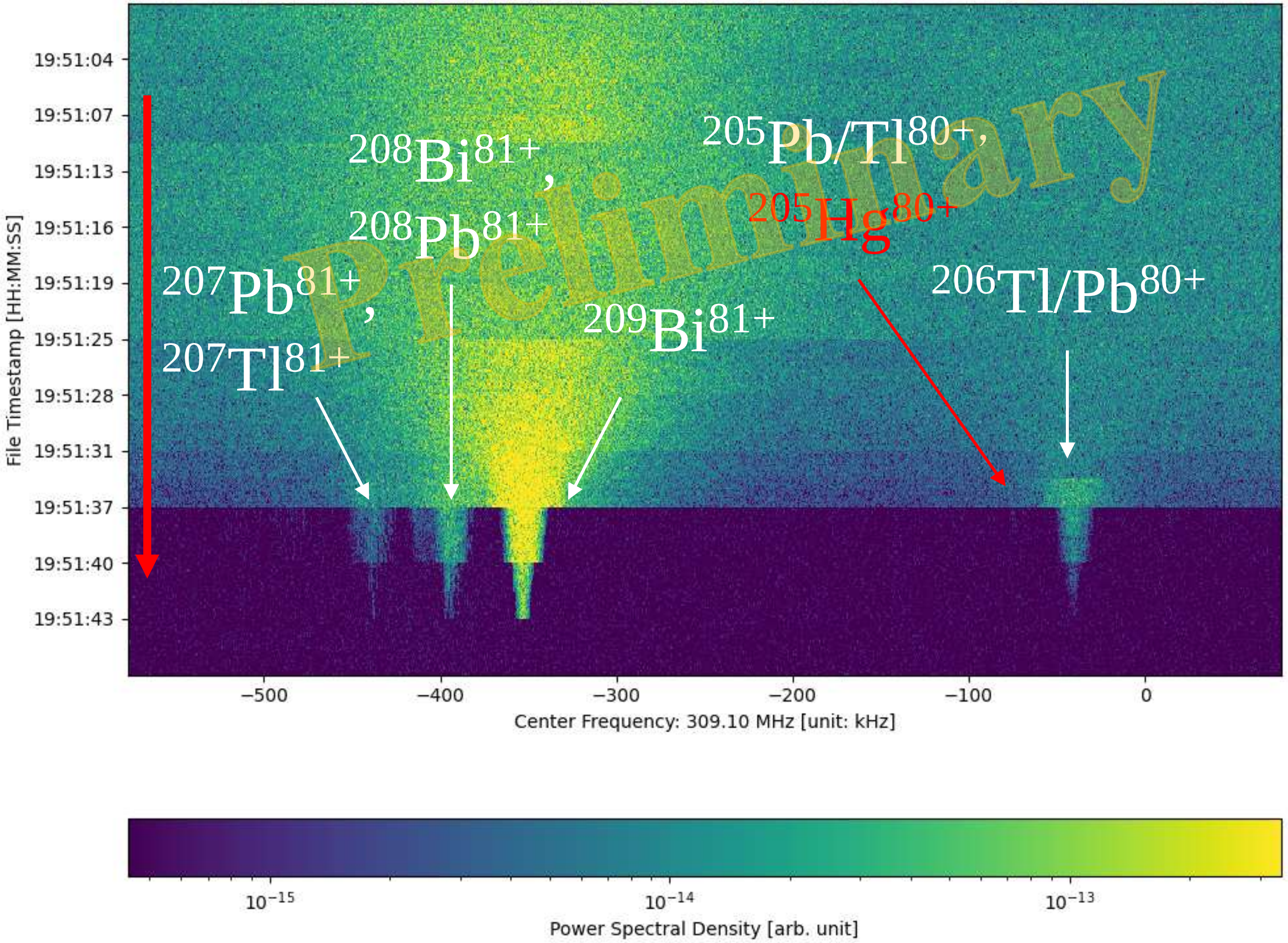
- **Isochronous mode**
- **Normal Mode**
- **Internal-target Mode**

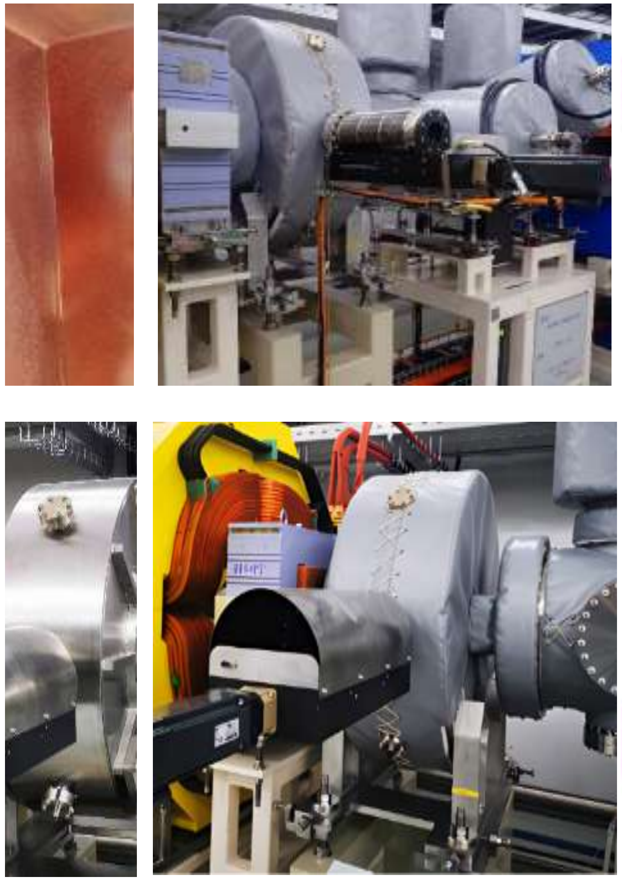
2. Construction and beam commissioning

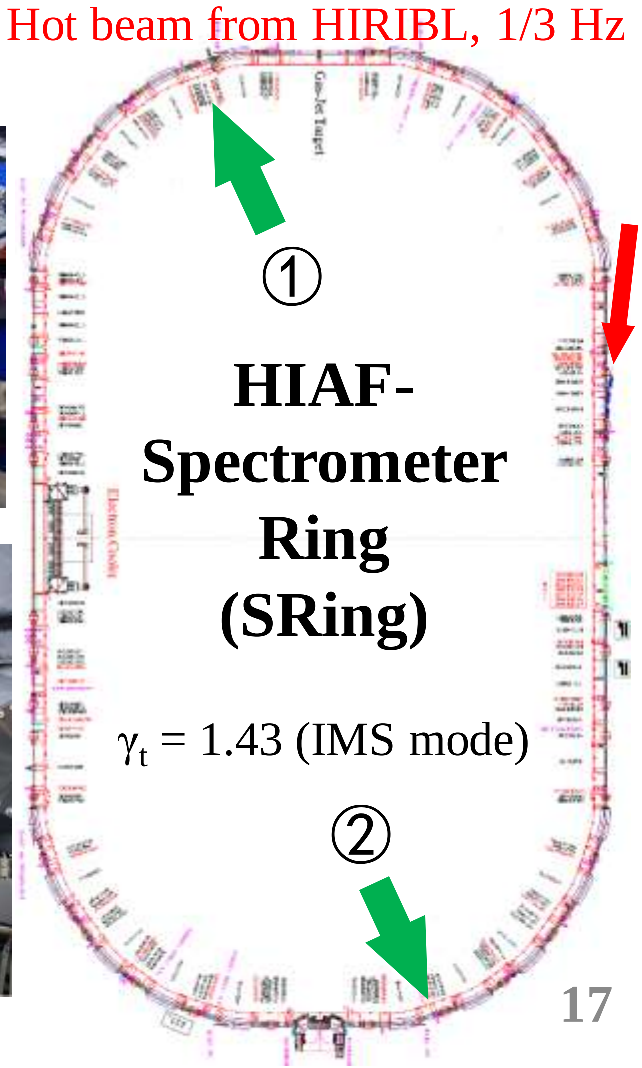
Commission run for Schottky mass measurement in SRing

Primary beam: $^{209}Bi^{31+}$ ~546 MeV/u, **particle number:** 10^{10} ppp every 3 seconds

10 mm-Graphite target







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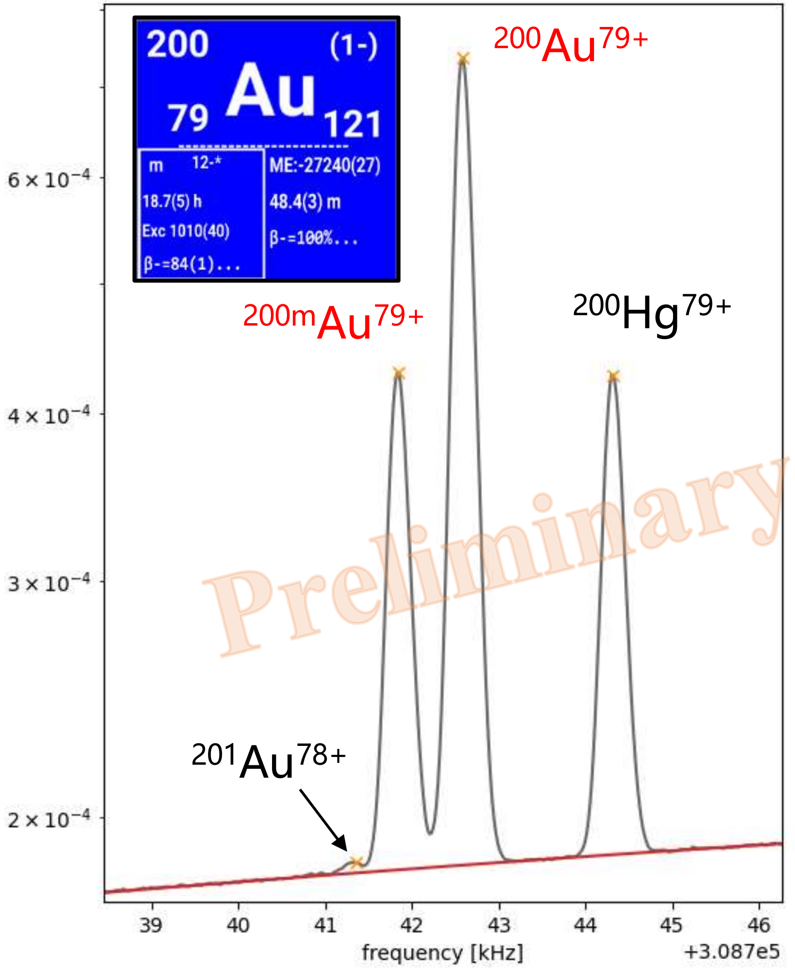

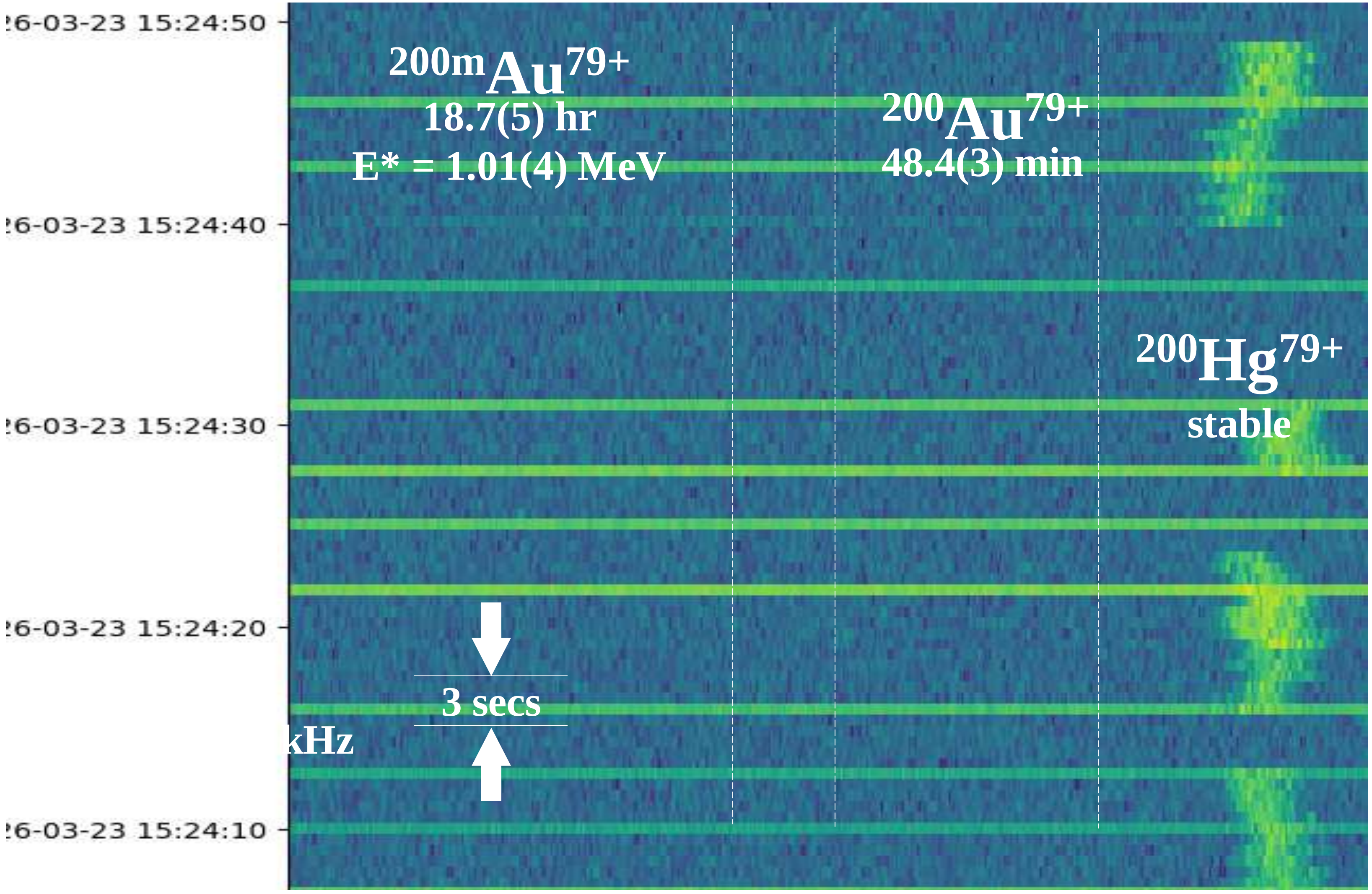

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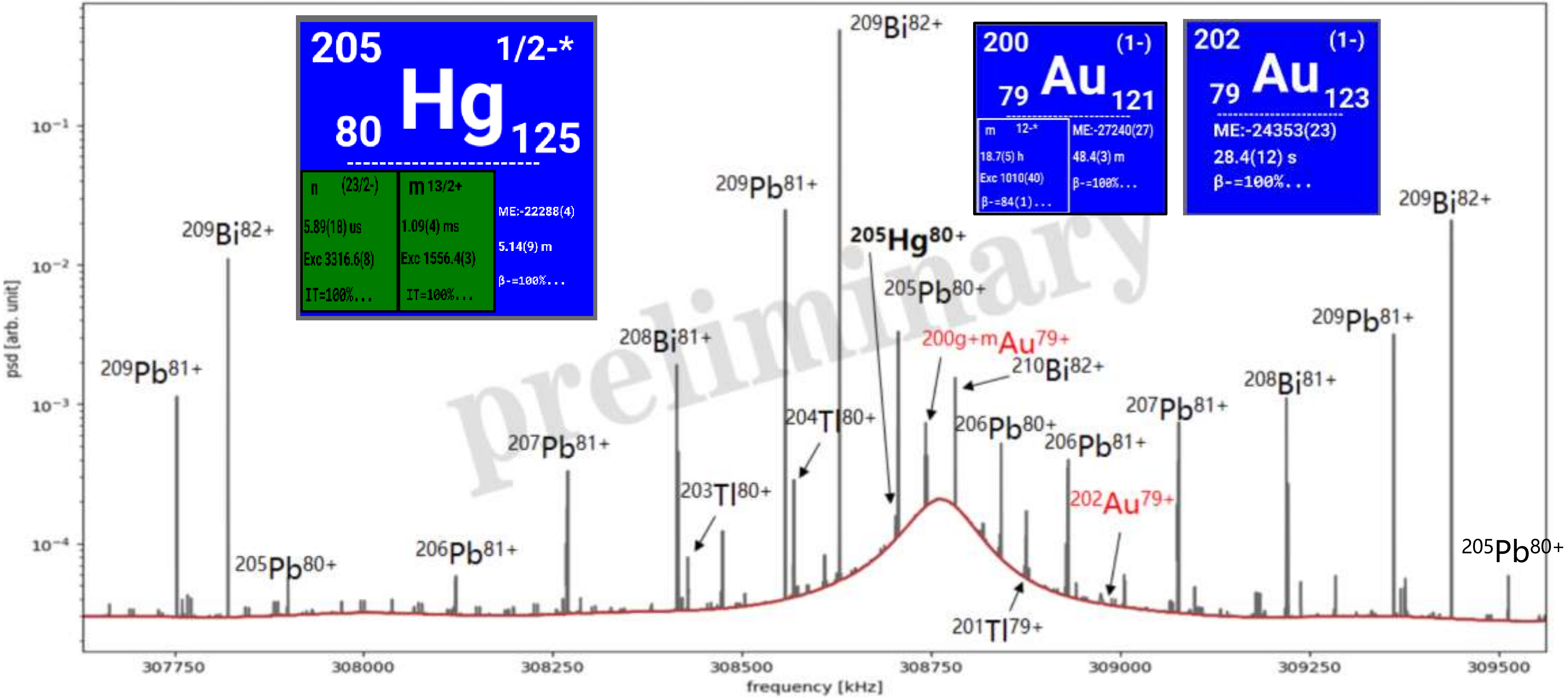

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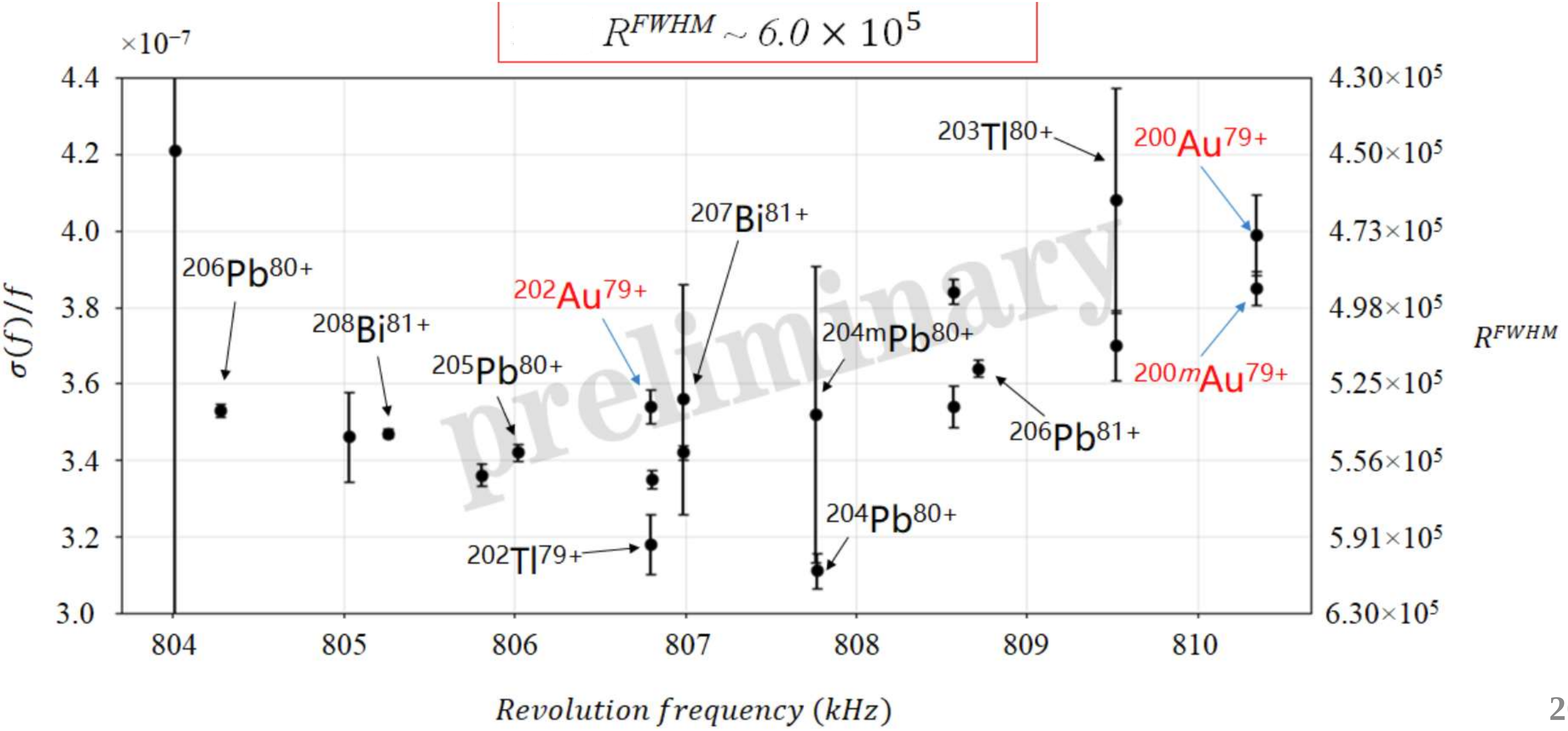
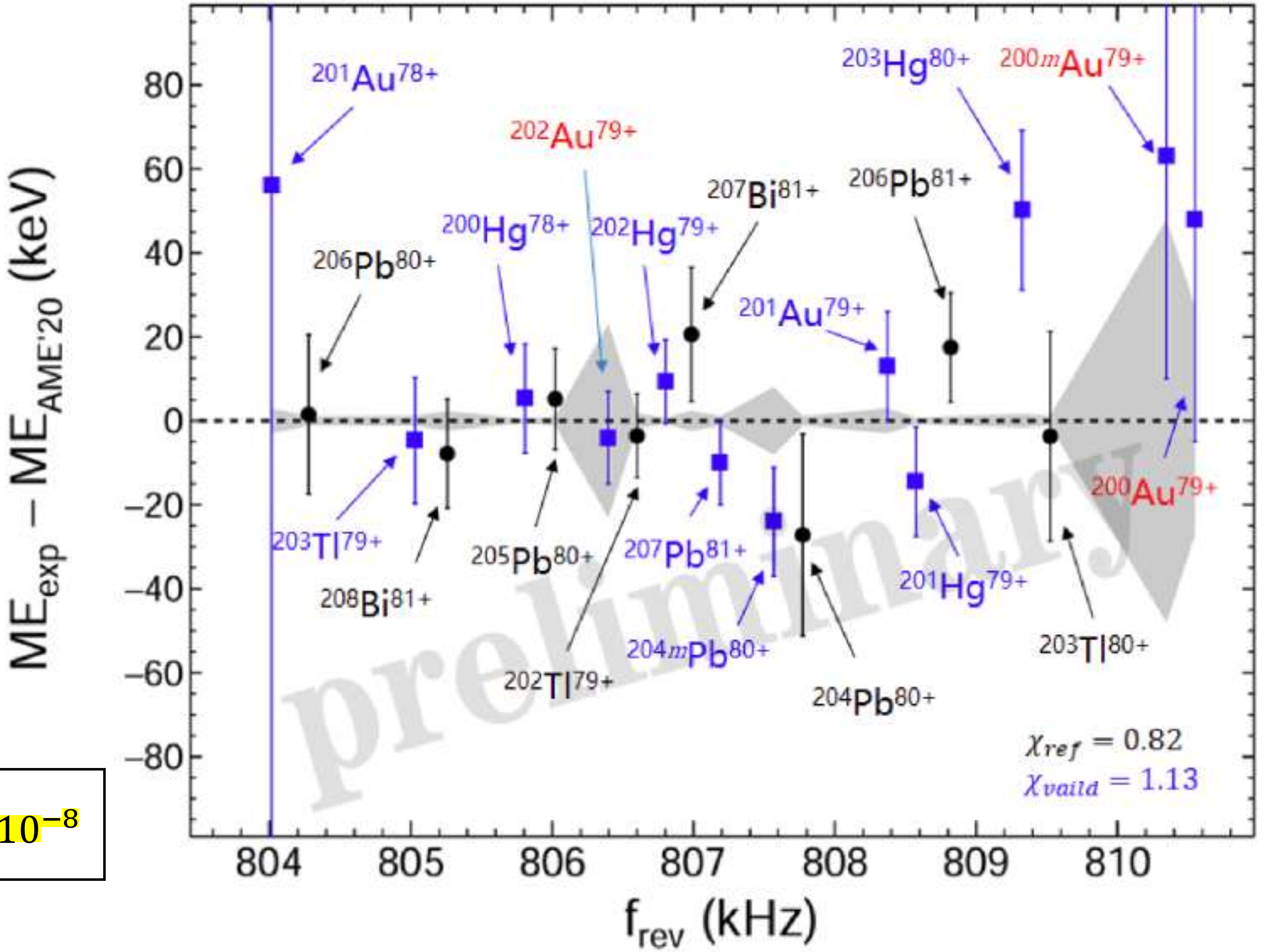


2. Construction and beam commissioning

Commission run for Schottky mass measurement in SRing



$$\frac{\sigma(m)}{m} \sim \frac{11\ keV}{202\ u} \sim 5.8 \times 10^{-8}$$

2. Construction and beam commissioning

Electron cooling

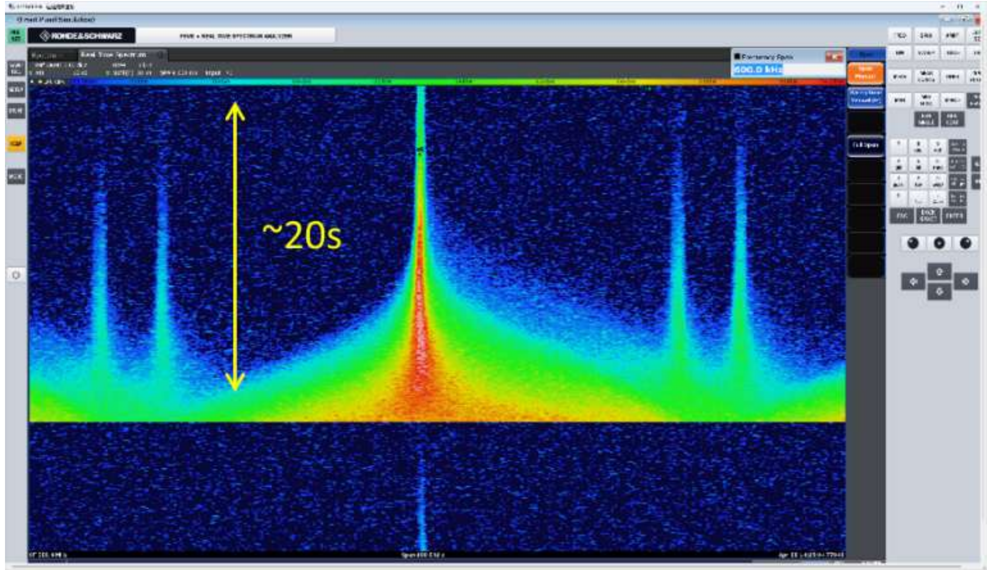
450 kV electron cooler

First beam cooling test with 81 MeV/u Bi^{31+}:

Isochronous mode:

Momentum spread before cooling : 3×10^{-3}

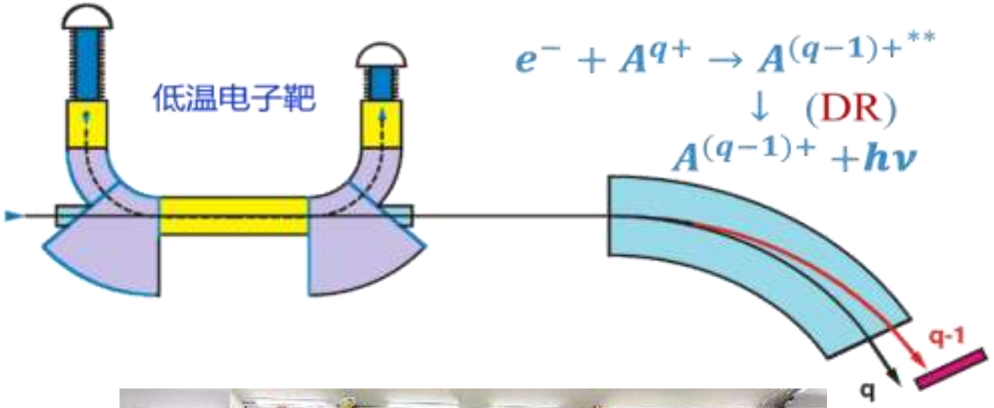
After cooling (total): 1×10^{-4}



Cooling process in longitudinal Schottky

Electron ion recombination terminal

Use separated electron cooler and electron target, to measure the dielectronic recombination rate with a wide CM range and high precision.



60 kV electron target

2. Construction and beam commissioning

Gas-filled recoil spectrometer

SC solenoid instead of quadruple magnets to get better acceptance

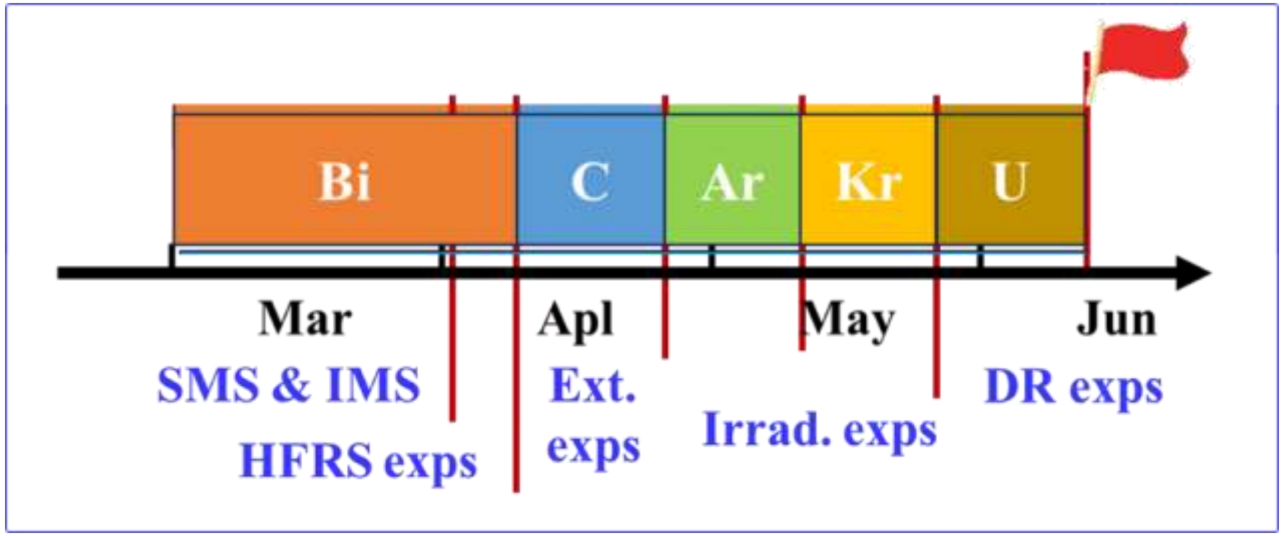
DSSD Energy Resolution: 30 keV
Si-box Det. Efficiency: 86% (α source)
MWPC Det. Efficiency: 99.8% (α source)

High rigidity fragment separator (HIRIBL)

HFRS Paramters	
$Bp_{max.}$	15~25Tm
P/ΔP	750,700,1100
ΔBp	±2.0%
ΔΩ	±30 mrad(x) ±20 mrad(y)
Beam spot ΔΦ	±1 mm(x) ±2 mm(y)

3. Future plan

- Ion beams of Bi, C, Ar, Kr and U will be provided to test the experimental terminals.



- Mostly machine tuning, have the Day-one experiments at appropriate time.
- **Pass the national acceptance inspection, probably in October, 2026**
- Change to normal operation mode, available beam time will reach 3,000 hours in 2028 and ultimately 5,000 hours by 2030

4. Conclusion

- **By providing intense heavy-ion beams, HIAF will open new opportunities for science and technology.**
- **The construction work for HIAF has been finished successfully, the first beam commissioning with O^{6+} and Bi^{31+} were carried out, and very good results were obtained.**
- **Science cannot advance without good collaboration, as an open, shared, and internationally connected research platform, we sincerely expect that more scientists can join us to explore the scientific potential of this facility and to advance our common goals in nuclear physics.**

Thanks for your attention!