高能与低能核物理交叉学术研讨会

The Major National Science and Technology Infrastructure Facility in China

强流重离子研究装置HIAF简介

High Intensity Heavy-ion Accelerator Facility

Xiaohong Zhou

On Behalf of the HIAF Project Team

Institute of Modern Physics, Chinese Academy of Sciences

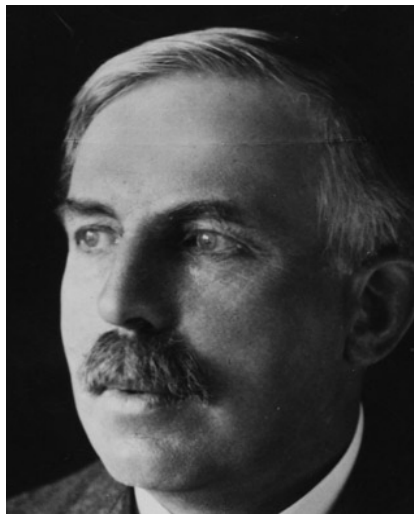


Outline

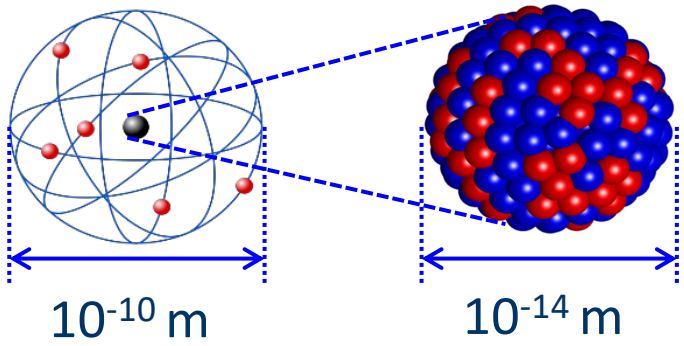
- **Brief Introduction to Nuclear Physics**
- Brief Introduction on Project Progress
- Facility Configuration and Capability
- Experimental Setups and Related Physics
- Summary

原子核物理简介

1908年诺贝尔化学奖　**划时代意义！**1911年α散射实验，**原子的有核模型**

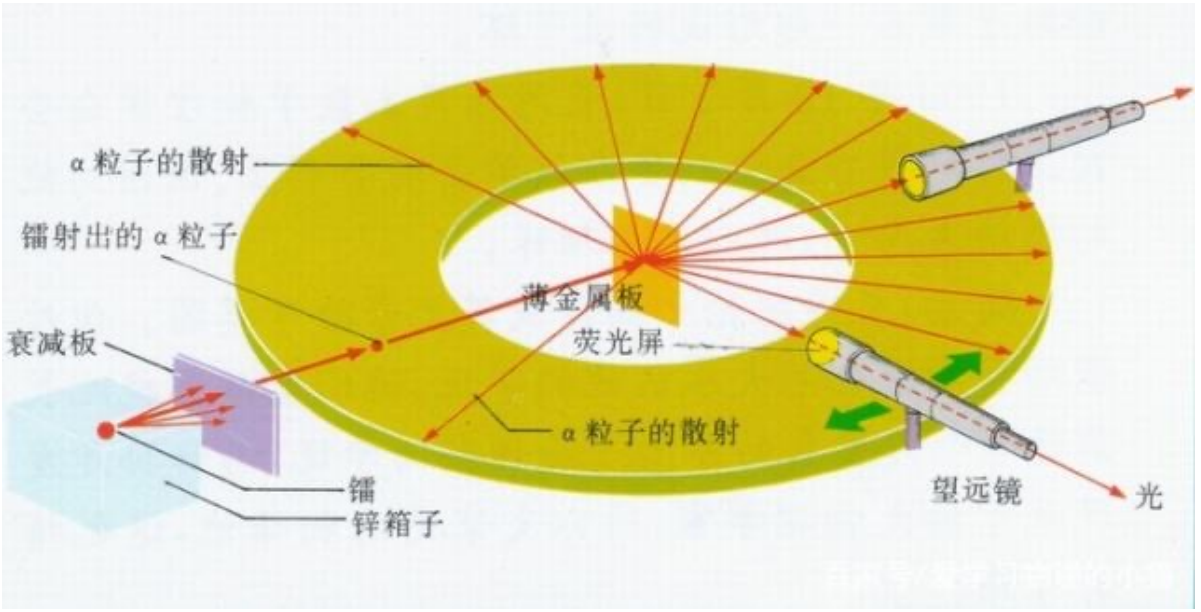


Rutherford

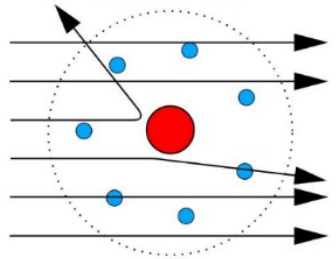


原子核带正电、体积很小

占原子质量~99.97%



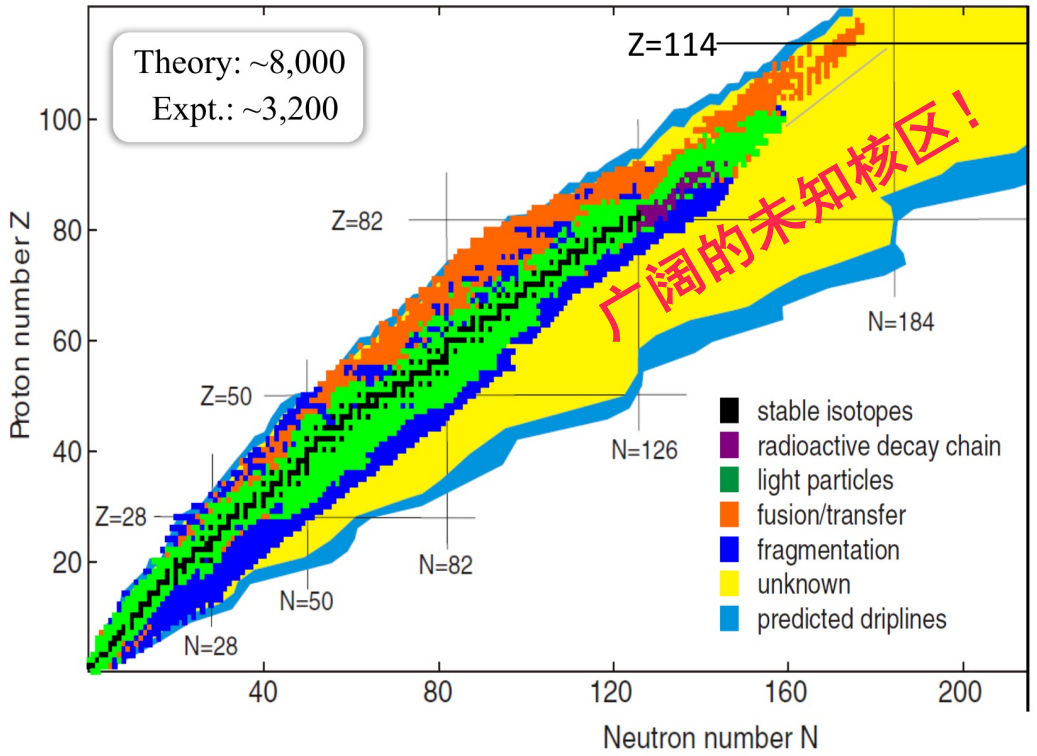
- 原子电中性、但电子带负电，正电荷在哪里以及正电荷载体？
- 原子质量是电子质量几千倍，其他质量在哪里以及这些质量载体？
- 电子可以在物质中穿行很长距离，原子内部是否非常虚空？

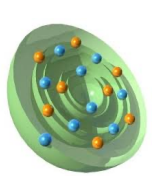


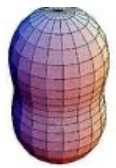
RUTHERFORD

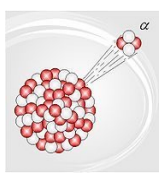
原子核物理：核心科学问题

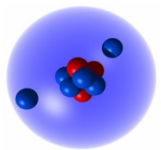
拓展核素版图、发现新现象、探究新物理

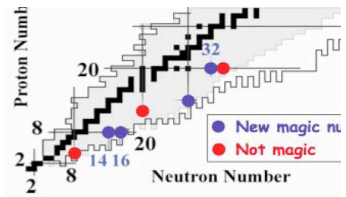










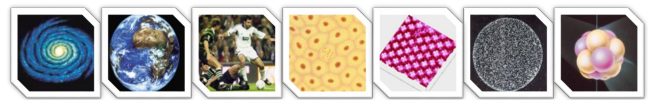


理论预言：存在~8000种原子核

原子核结构和性质、核反应机制

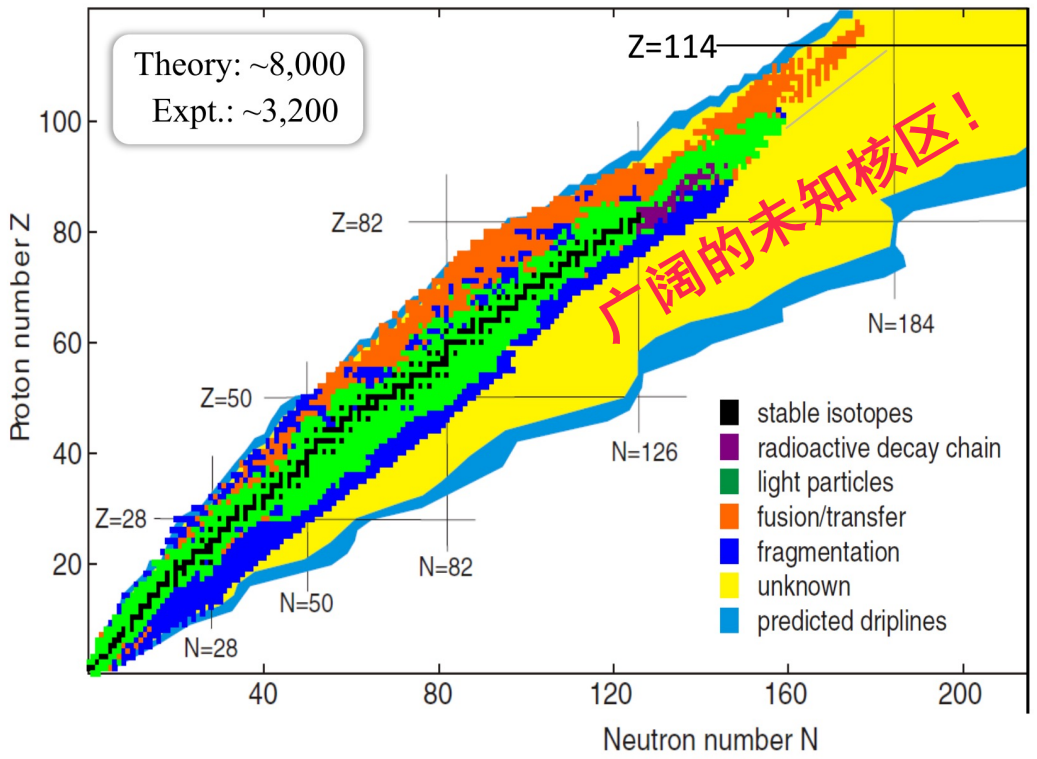
- ✓ 每一种元素存在多少种同位素？
- ✓ 原子核结构和形状如何演化？
- ✓ 弱束缚原子核具有哪些奇特结构和性质？
- ✓ 可能存在的新物质形态和性质？
- ✓ ……

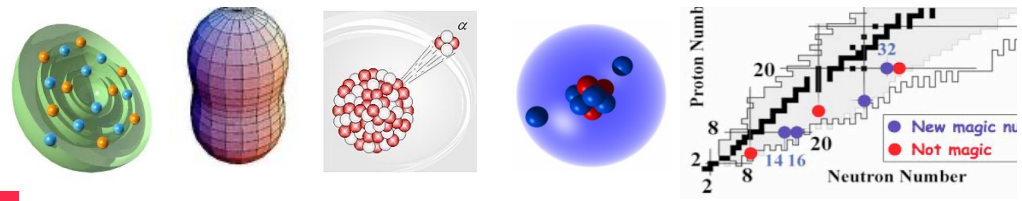
在广阔未知核区，蕴藏着重大发现机遇！



原子核物理：核心科学问题

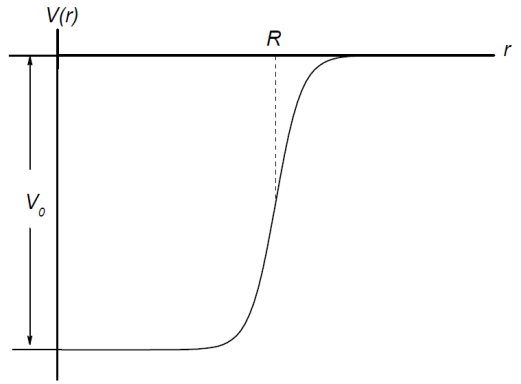
认识核内有效相互作用（核力）





目前：唯像模型 + *ab initio* 理论

Ultimate Model：描述所有核结构和反应



核力包括：

- 自旋轨道耦合项
- 张量力成分
- 三体力成分
- 同位旋相关项

Woods-Saxon 势：$V(r) = -V_0\left(1 + e^{\frac{r-R}{a}}\right)^{-1}$

普适的严格解析表示：$V(r)$？

$$\left[-\frac{\hbar^2}{2\mu}\nabla^2 + V(r)\right]\psi(r) = E\psi(r)$$

开拓核素版图

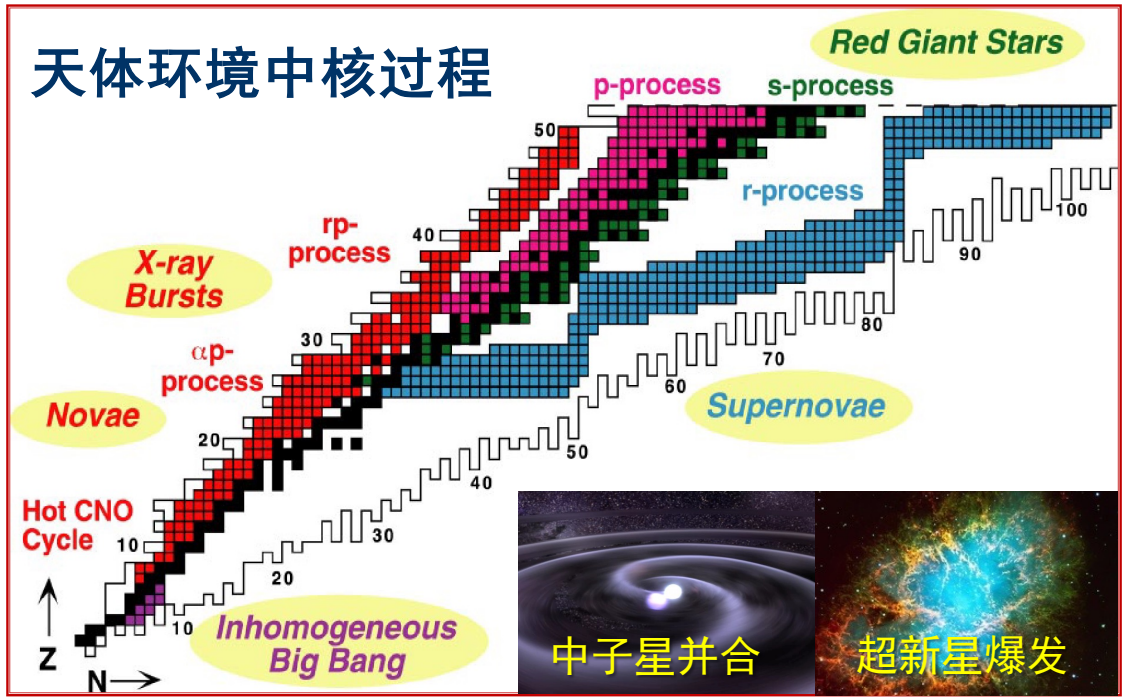
奇特核结构和性质

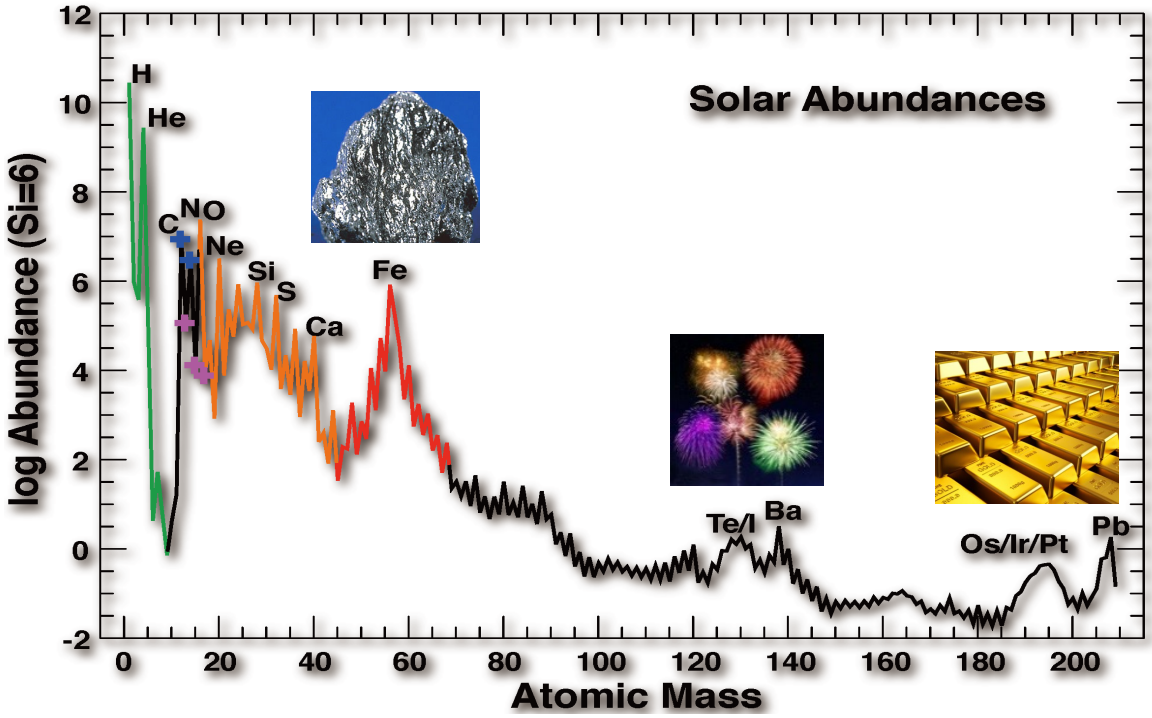
核心问题：超铁元素来源

天体环境中的核过程：驱动星体演化、产生化学元素

超铁元素：慢中子俘获和快中子俘获过程

核天体物理

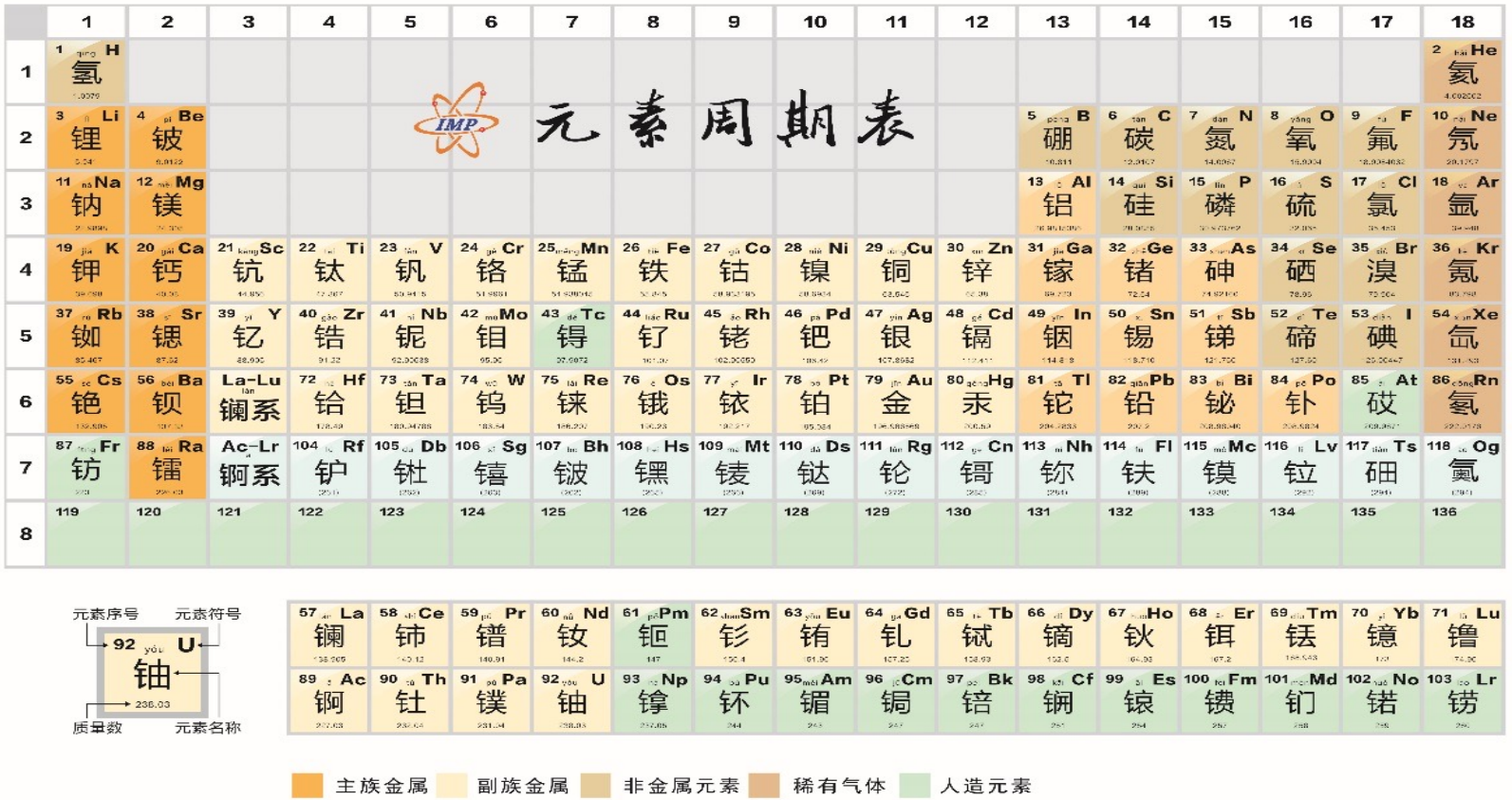




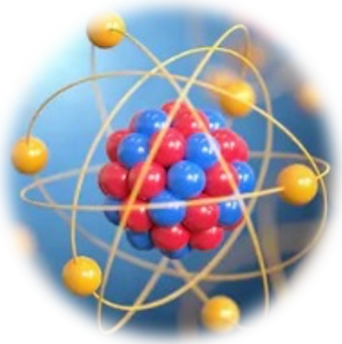
r过程：超新星和双中子星并合？极丰中子核质量、寿命、衰变性质

原子核物理：核心科学问题

能否合成119、120号元素，开启元素周期表第八周期？



- 铀是天然存在的最重元素
- 人工合成了93-118号元素



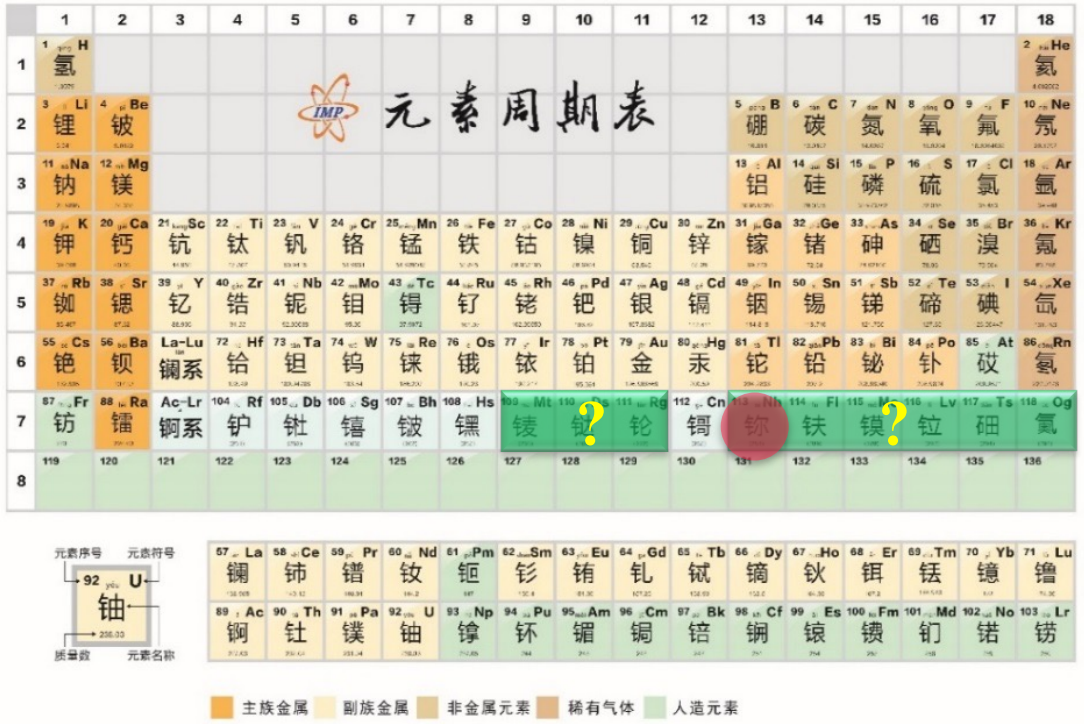
合成新元素必须有相应原子核

核物理承担着合成新元素、拓展元素周期表的科学使命！

原子核物理：核心科学问题

超重元素的化学性质：元素周期率外推的有效性？

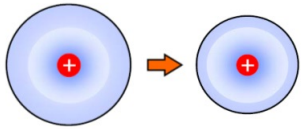
相对论效应、多电子关联、强场QED效应 ➡ 改变元素化学性质



Cn类汞；E113第13族？类铊还是类氢？

重原子中最内层轨道电子：$v \approx Zac$

电子轨道半径：$r \propto \frac{\hbar^2}{me^2} \propto r_B\sqrt{1-(v/c)^2}$



E111: $6d^9 7s^2$，Cu-Au: $(n-1)d^{10}ns^1$

s、$p_{1/2}$收缩

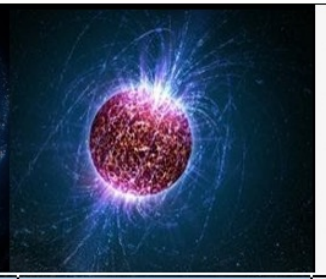
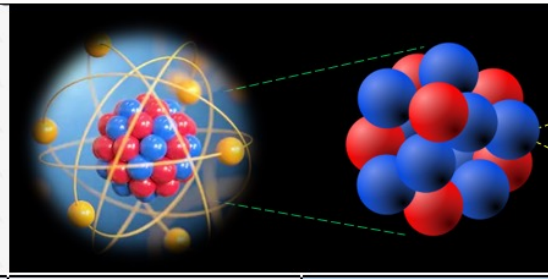
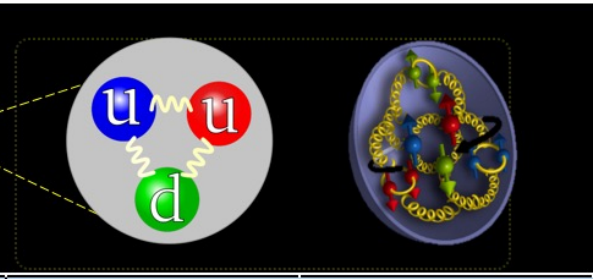
E121：$8s^2 8p_{1/2}^1$，同组Ac: $7s^2 6d_{3/2}^1$

价电子排布改变、影响元素化学性质：
氧化态、离子半径、配合物的形成等

QED-based theories calculate atomic structure, within a few hundredths of an eV

核物理及交叉学科

宇宙中几乎所有的可见物质是强相互作用核物质

万有引力（强度= 10^{-40} ）			电磁力（强度=1）	强相互作用力（强度=137）		弱相互作用力（强度=10^{-8}）	
							
大爆炸	银河系	中子星	人类	原子	原子核	核子（10^{-15}米）	
						价夸克	海夸克、胶子
宇宙起源	~10^{21}米	~10^{4}米	10^{0}米	~10^{3}eV，10^{-10}米	~10^{6}eV，10^{-15}米	~10^{9}eV，10^{-18}米	~10^{12}eV，10^{-18}米

原子核物理 →

- ✓ 核天体物理
- ✓ 核化学（放射化学）
- ✓ 高能核物理
- ✓ 中子物理、聚变物理
- ✓ 中微子物理

+

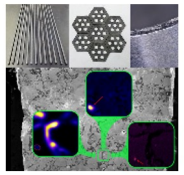
- ✓ 核武器和核能开发利用
- ✓ 核医学，诊断和治疗
- ✓ 核仪器和核电子学
- ✓ 核农学
- ✓ ……

核科学技术是大国必争的战略高地

面向国家重大需求



国家安全
核威慑力
结合能、核反应



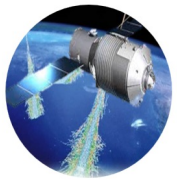
先进核工程材料
离子与物质相互作用



裂变能
聚变能
结合能
核反应



核动力
核衰变、结合能、核反应



空间辐射
单粒子效应
宇航员防护
离子与物质相互作用、电离

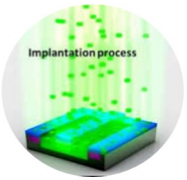


辐射诊断：X射线、CT、核磁共振、PET 离子与物质相互作用



辐射加工：材料改性（核孔膜、优质电缆、硫化橡胶等）、精密加工

离子注入：集成电路、高性能器件制造（特种光学晶体、聚合物、金属、陶瓷等）
离子与物质相互作用





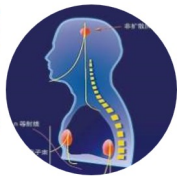
辐射育种
同位素示踪
辐射杀菌保鲜
核衰变、生物学效应



工业探伤
无损检测
离子与物质相互作用

面向国民经济主战场

放射治疗：重离子治癌
离子与物质相互作用、生物学效应

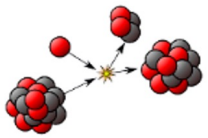




医用同位素药物、
核衰变、离子与物质相互作用

面向人民生命健康

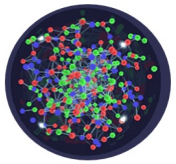
面向世界科技前沿



原子核性质研究：核结构、核反应...



核天体物理：宇宙中重元素的起源...



高密核物质：相结构、核子结构...

原理、机理研究，满足人类好奇心，支撑相关应用研究

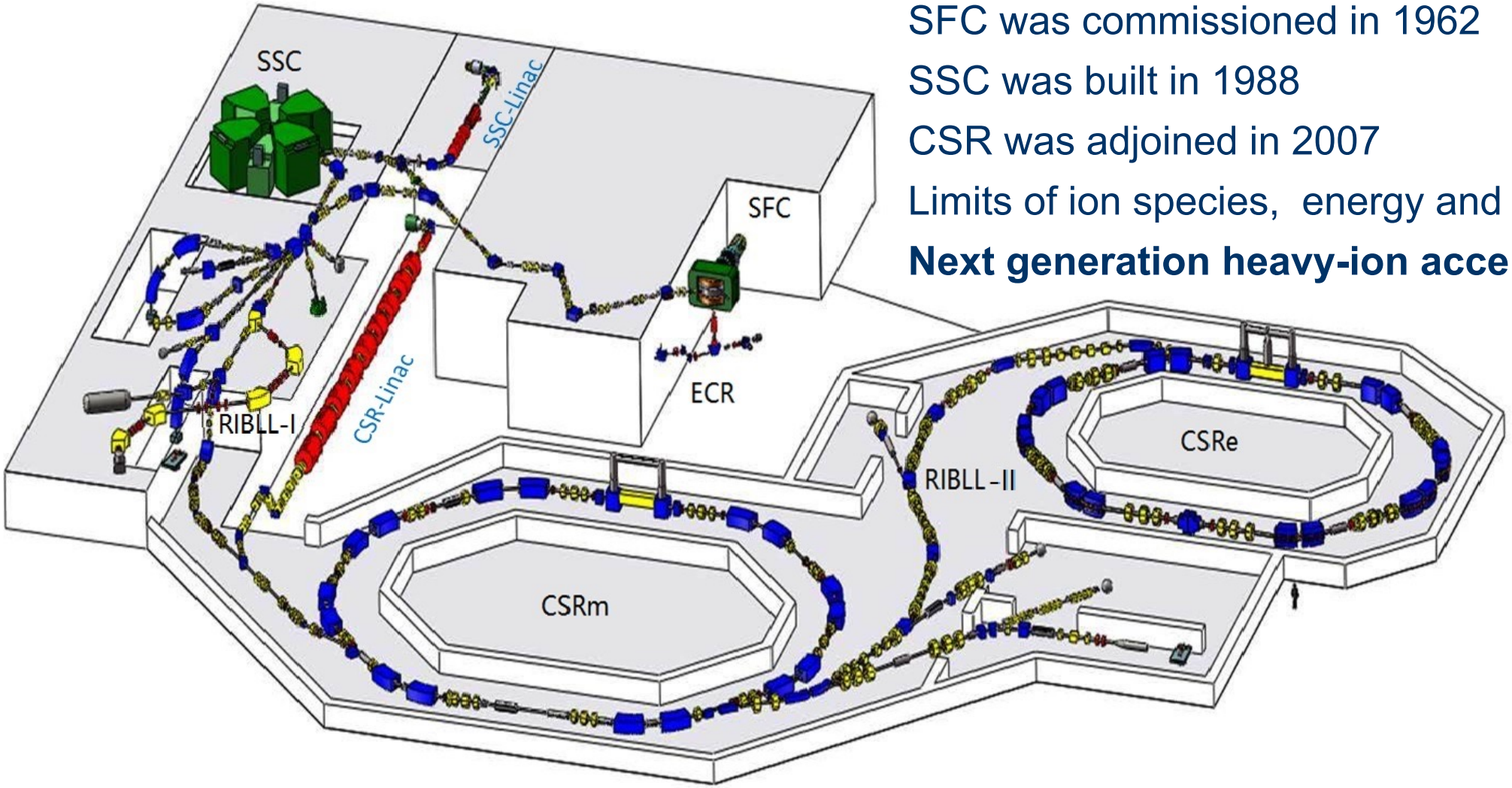
核物理基础研究为核技术开发应用提供理论、技术和人才支撑

Outline

- Brief Introduction to Nuclear Physics
- **Brief Introduction on Project Progress**
- Facility Configuration and Capability
- Experimental Setups and Related Physics
- Summary

Project Background

Heavy-ion Research Facility in Lanzhou



SFC was commissioned in 1962

SSC was built in 1988

CSR was adjoined in 2007

Limits of ion species, energy and Intensity

Next generation heavy-ion accelerator facility

Project Progress

Milestones of HIAF Project



The preliminary goals: exploration of the unknown nuclear chart and study of exotic nuclear structure and properties, synthesis of super-heavy elements and nuclides, understanding of the origin of heavy elements in the Universe, and development of new heavy-ion applications


Physics discussion



Design Review


Technical assessment


Ground-breaking ceremony

Funding agency: *The National Development and Reform Commission and local governments ,* **2.67 billion CNY**

Project Progress



Photo of HIAF campus taken by a drone

Outline

- Brief Introduction to Nuclear Physics
- Brief Introduction on Project Progress
- **Facility Configuration and Capability**
- Experimental Setups and Related Physics
- Summary

Accelerator Complex

Booster Ring:

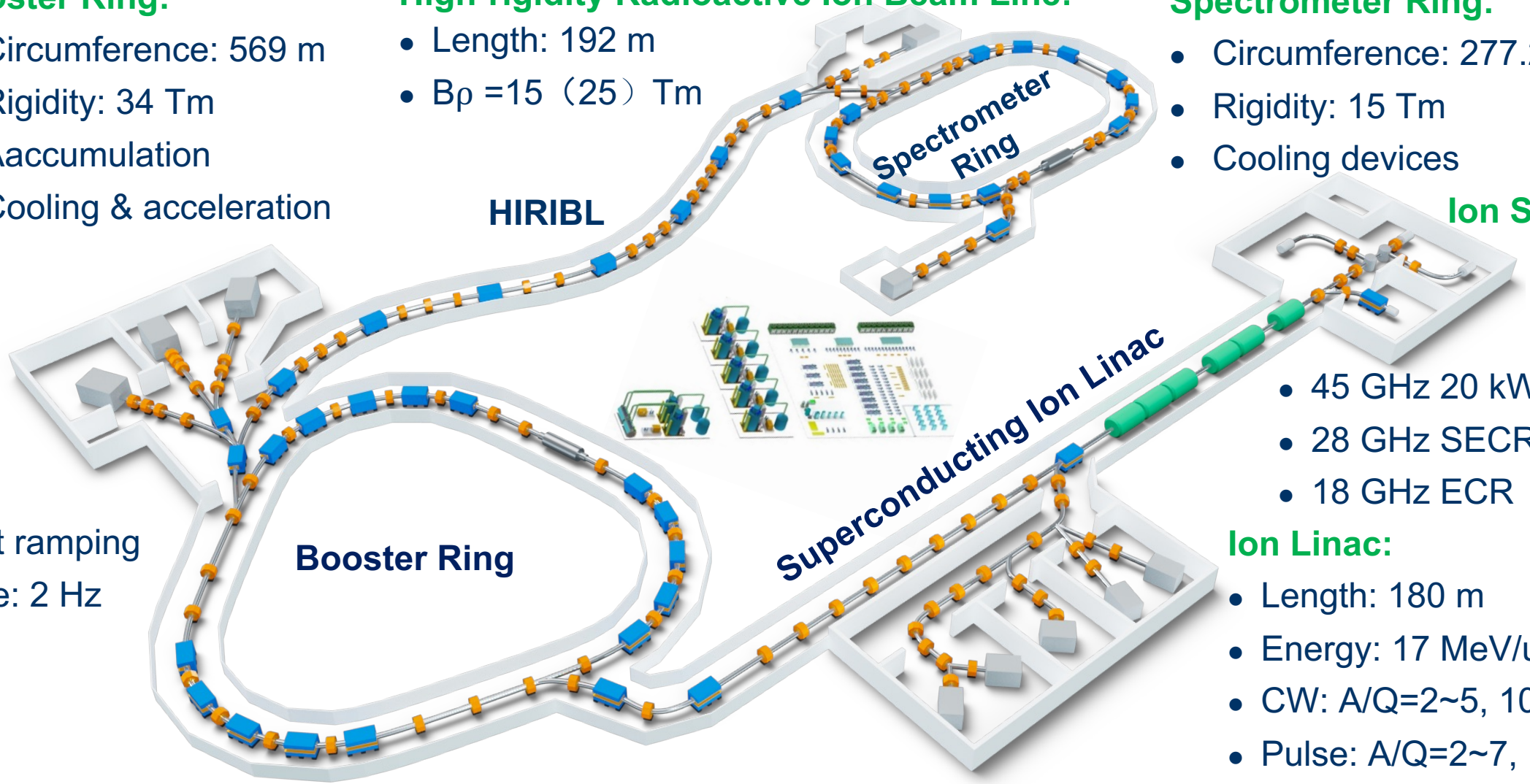
- Circumference: 569 m
- Rigidity: 34 Tm
- Aaccumulation
- Cooling & acceleration

High-rigidity Radioactive Ion Beam Line:

- Length: 192 m
- Bρ =15（25）Tm

Spectrometer Ring:

- Circumference: 277.2 m
- Rigidity: 15 Tm
- Cooling devices



Fast ramping

Rate: 2 Hz

Ion Sources

- 45 GHz 20 kW FECR
- 28 GHz SECRAL
- 18 GHz ECR

Ion Linac:

- Length: 180 m
- Energy: 17 MeV/u ($^{238}U^{34+}$)
- CW: A/Q=2~5, 10 pμA
- Pulse: A/Q=2~7, 1.0 emA

In 2400 m tunnel underground 13 meters. Power supplies of 69 MW + 32 MW

Facility Capability

Typical Beam Parameters From the Booster Ring

Ions	Energy(GeV/u)	Intensity (ppp)
p	9.3	2.0×10^{12}
$^{18}O^{6+}$	2.6	6.0×10^{11}
$^{78}Kr^{19+}$	1.7	3.0×10^{11}
$^{209}Bi^{31+}$	0.85	3.2×10^{10}
$^{238}U^{35+}$	0.835	1.0×10^{10}

Dec. 12, 2025

First beam $^{18}O^{6+}$

2.6 GeV/u

2.5×10^{11}ppp

Dec. 27, 2025

Heavy beam $^{209}Bi^{31+}$

0.85 GeV/u

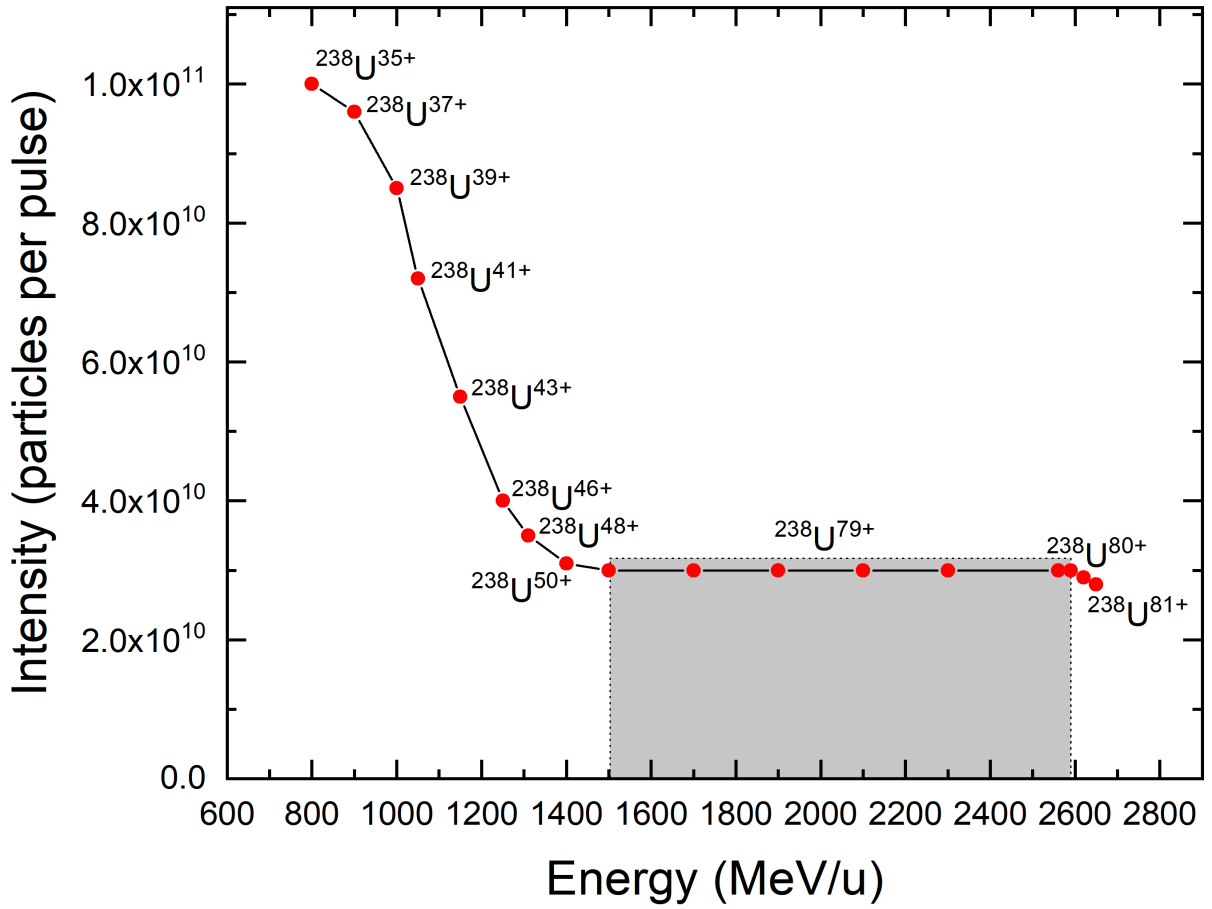
3.17×10^{10}ppp

The maximum beam intensities were estimated by optimizing the charge number

Higher beam energies available on a tradeoff of the beam intensities

Facility Capability

Intensity-energy Diagram of ^{238}U Beam Stored

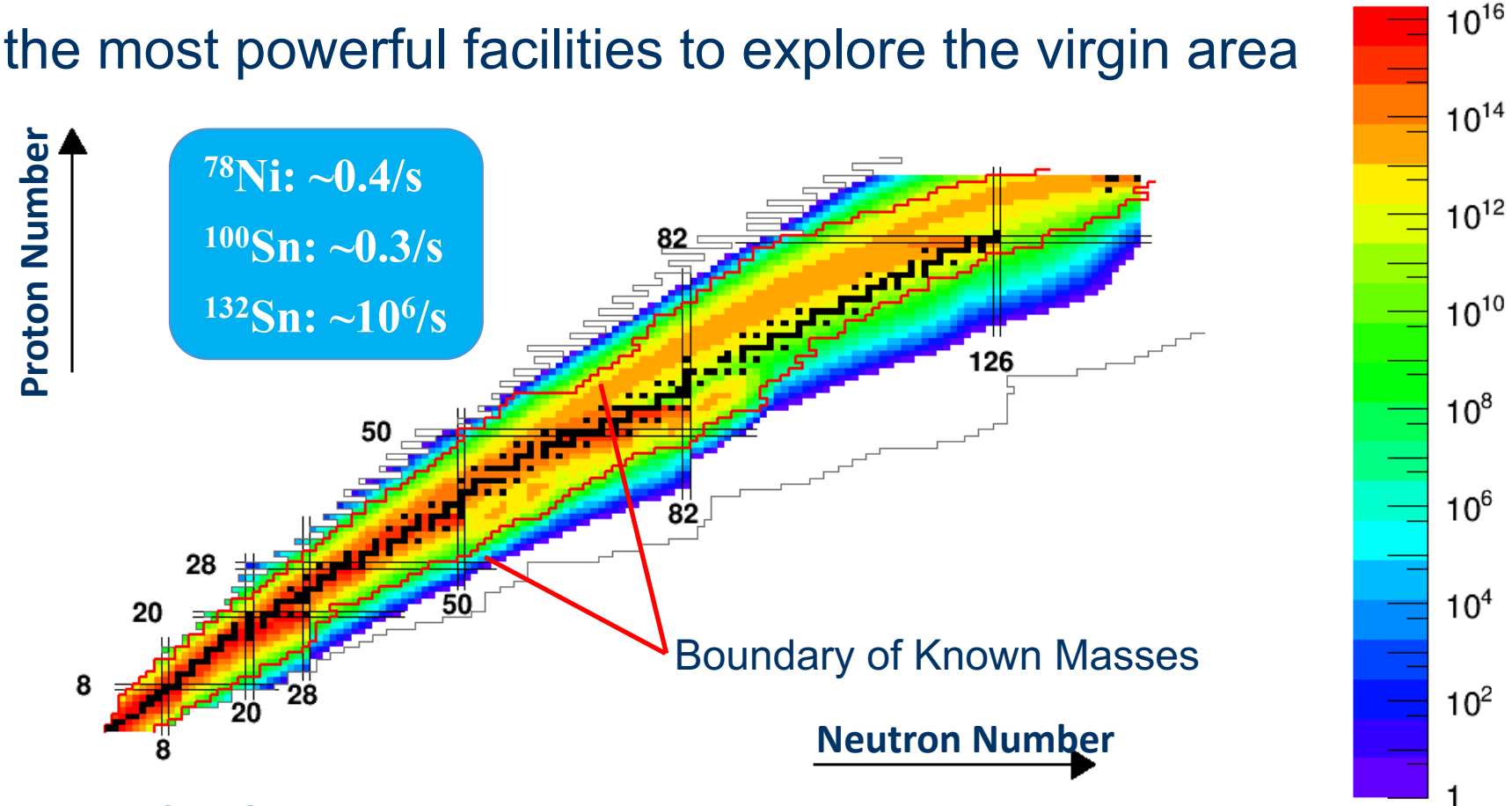


The maximum particle numbers stored at the corresponding charge states

Capability of Producing Nuclides

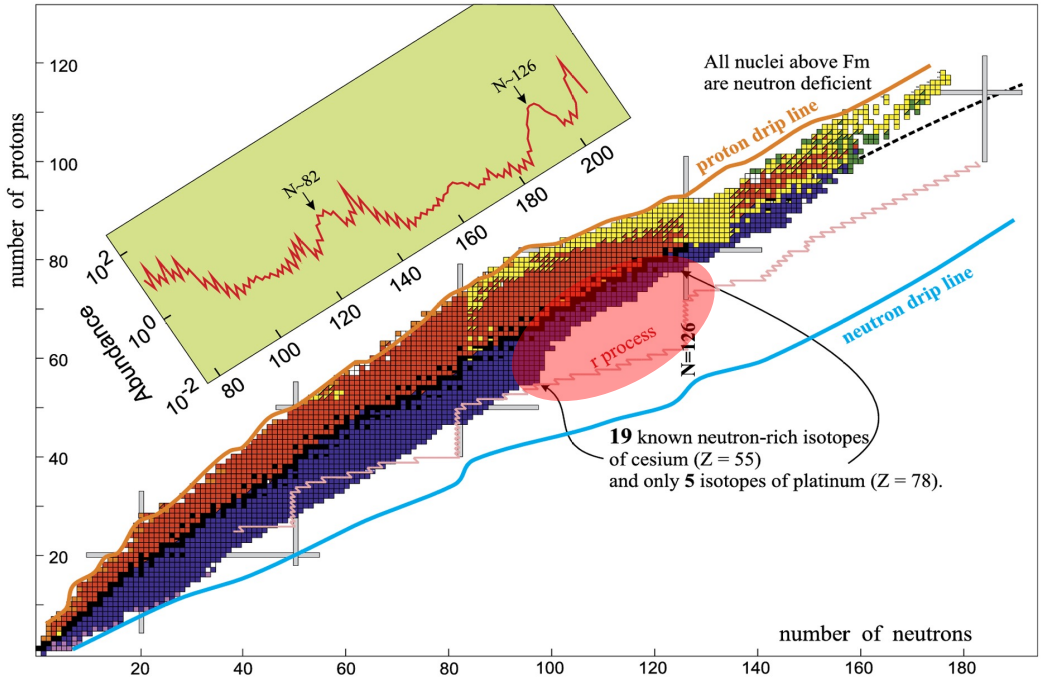
Nuclides Available (Daily Production Yield) at HIAF

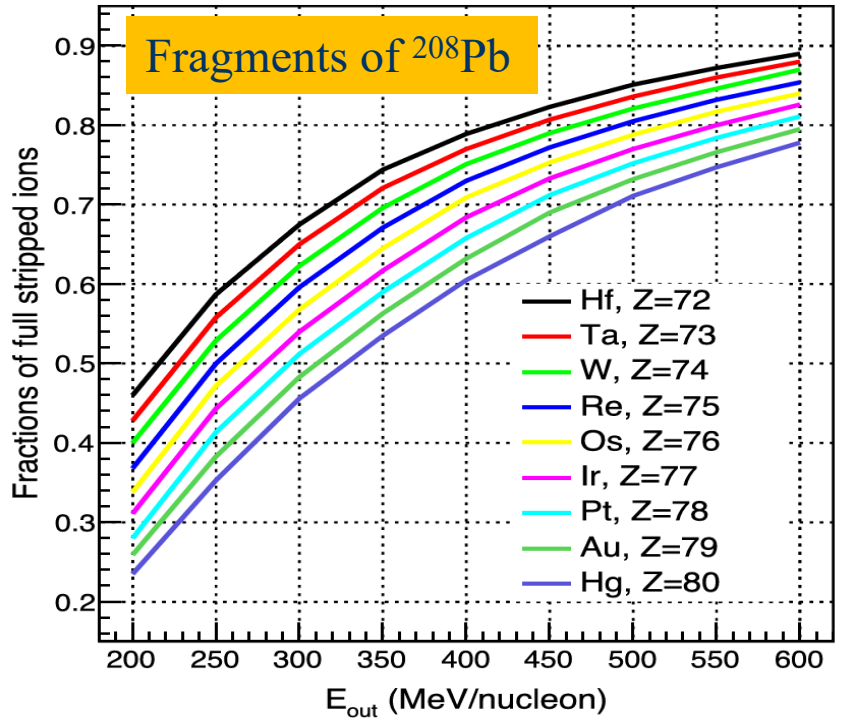
One of the most powerful facilities to explore the virgin area



Prolific nuclides far from the stability line available. The limits are the production rate of one nuclide per day, enabling the “discovery experiments”

Facility Capability



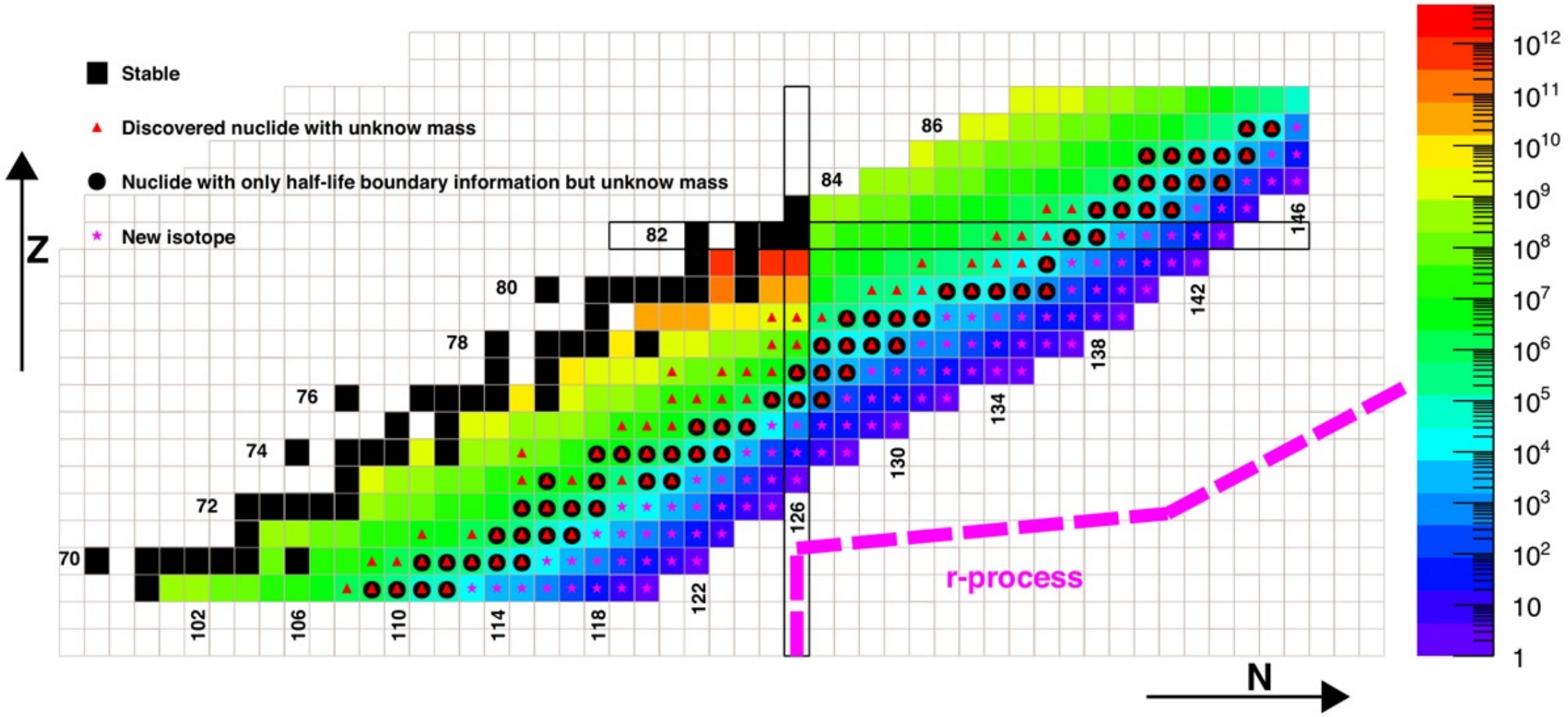


The uniqueness of HIAF: Relativistic energy heavy projectiles

- ✓ Nearly bare ions produced, and hence making particle identification easier and cleaner
- ✓ Recoiling out target in small forward angle, leading to higher efficiency of collection and transportation
- ✓ Thick target and multi-step reactions, enhancing the production yields of nuclides far from the stability line

Competitiveness: explore n-rich region south of ^{208}Pb using ^{208}Pb or ^{209}Bi projectiles

Facility Capability



Acumulated yields in a 5 day beam time assuming 3×10^{10} pps of ^{208}Pb and ^{238}U beams

Experimental Setups

High resolution Spectrometer

- Isochronous Mass Spectrometer
- Schottky Spectrometer
- In-ring Reaction Setup
- DR Spectrometer

- Setup for Nuclear Matter Study
- High Energy Irradiation Terminal
- Setup for Hypernuclear Study

High Energy Station



- Gas-filled Recoil Separator
- Low Energy Spectrometer
- Low Energy Irradiation Terminal

Low Energy Station

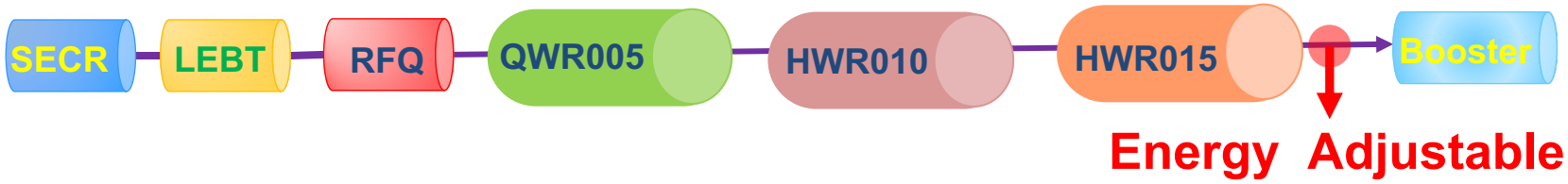
Outline

- Brief Introduction to Nuclear Physics
- Brief Introduction on Project Progress
- Facility Configuration and Capability
- **Experimental Setups and Related Physics**
- Summary

Experiments @iLinac

Low Energy Station

Pulse Mode: injector of the Booster; **CW Mode:** deliver intense beams for low-energy experiments



Pulse mode:

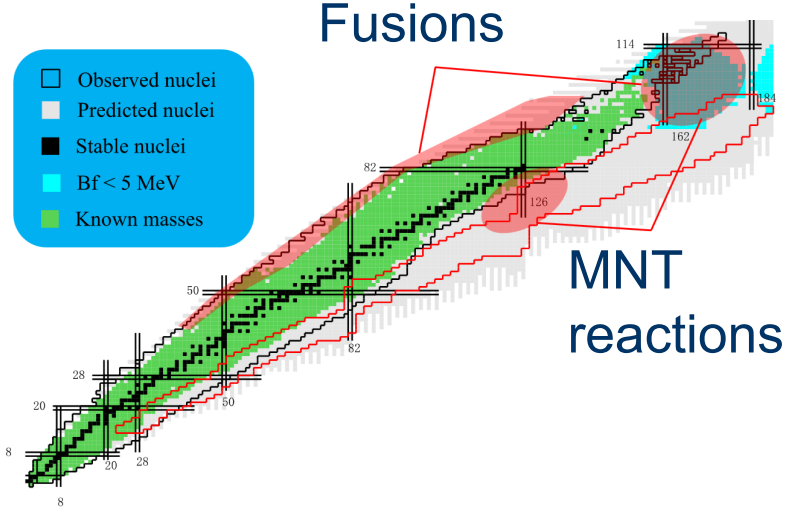
1.0 emA beams with A/Q=2~7

CW mode:

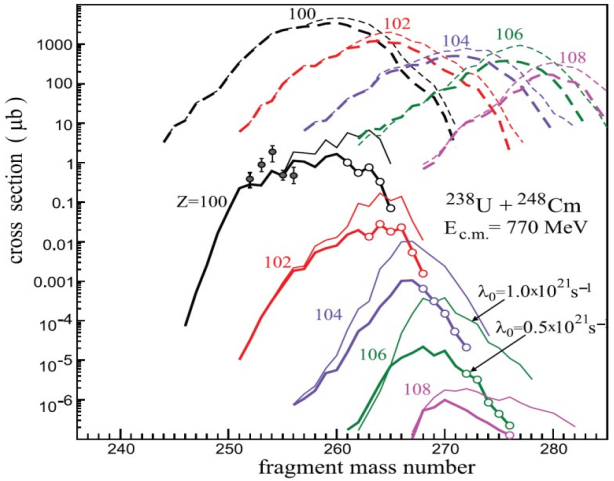
10 pμA beams with A/Q=2~5

Fusion and MNT Reactions

Fusions



MNT reactions



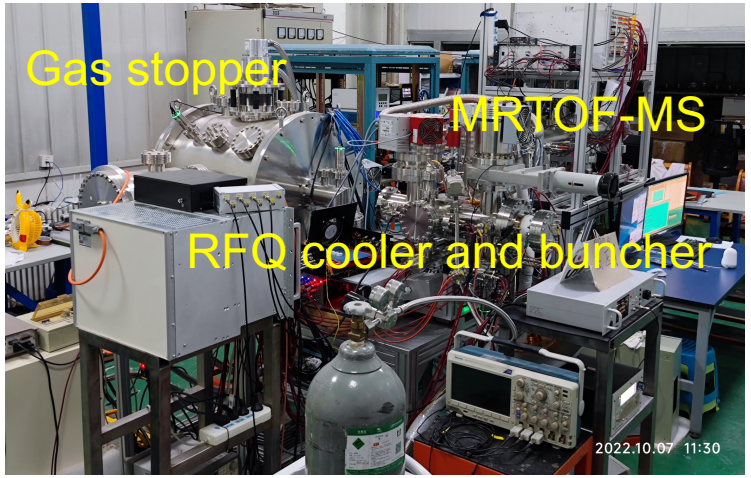
- synthesize new elements and isotopes
- measure nuclear masses and lifetimes
- build the decay schemes
- map out the drip lines
- build a bridge to the island of SHN
- simulate the *rp* and *r* processes
- study the evolution of shell structure

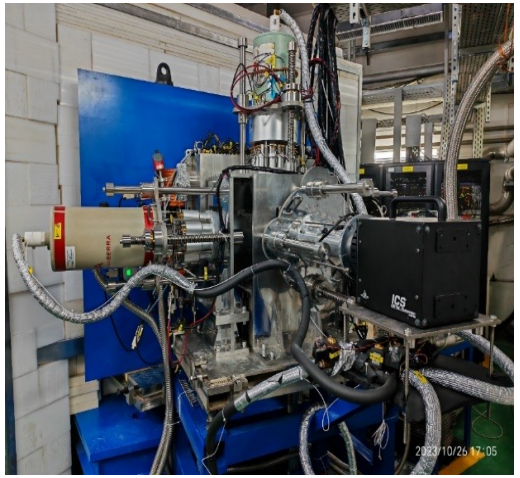
To produce heavy and super-heavy nuclei by fusion and MNT reactions

Experiments @iLinac

A high-efficient Gas-filled Recoil Separator

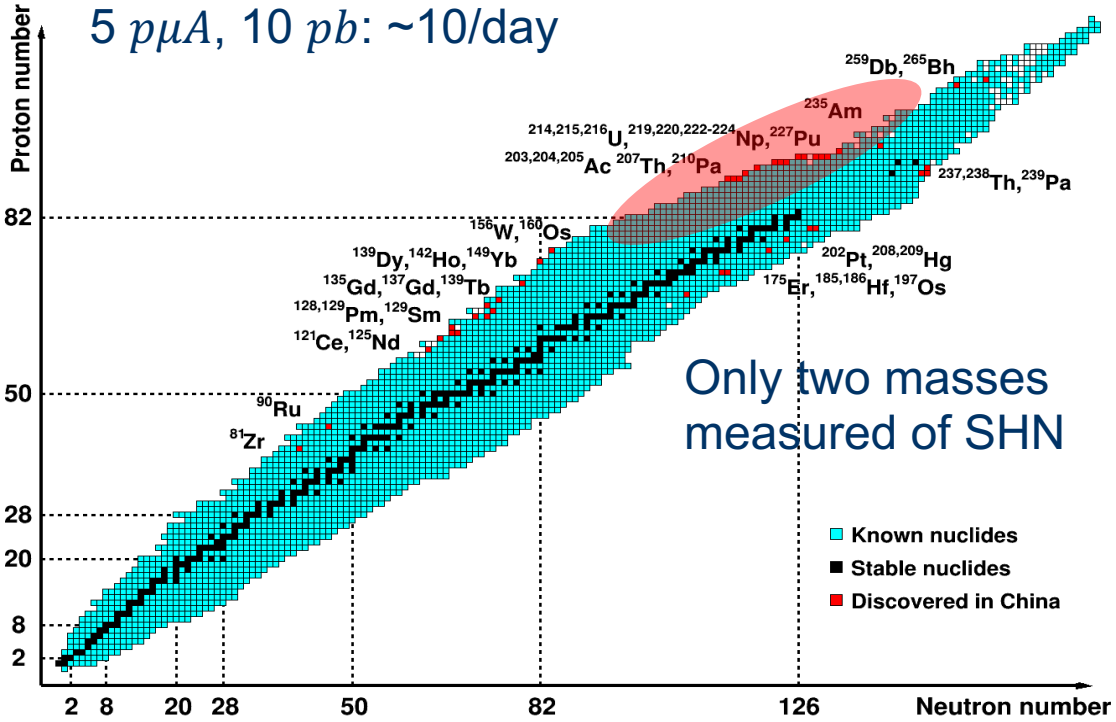






- ✓ To synthesize new elements and isotopes
- ✓ To study chemical properties
- ✓ To measure masses

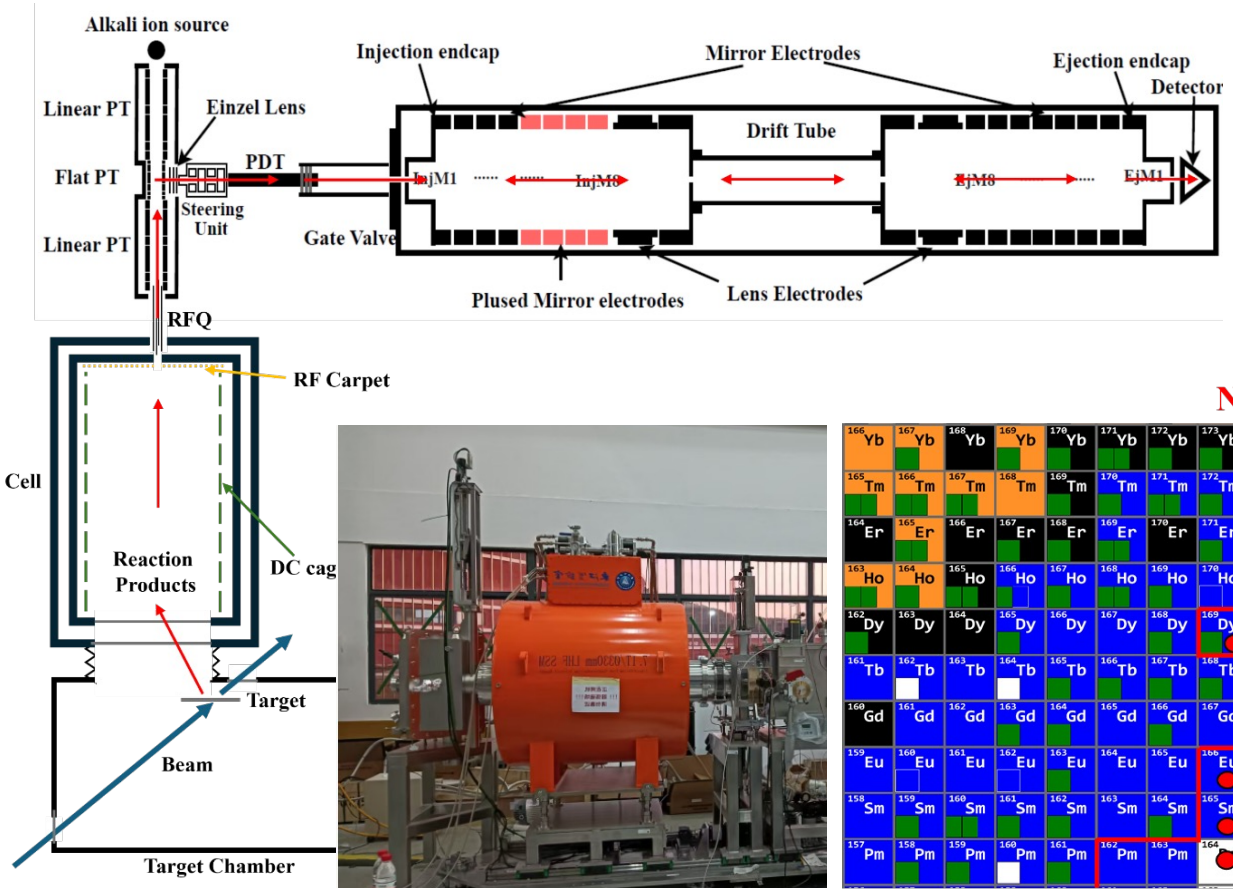
SHE production yields
5 $p\mu A$, 10 pb: ~10/day



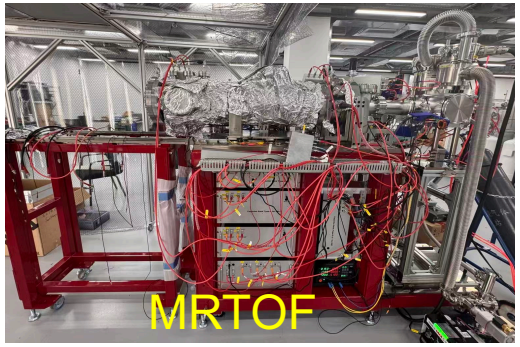
Only two masses measured of SHN

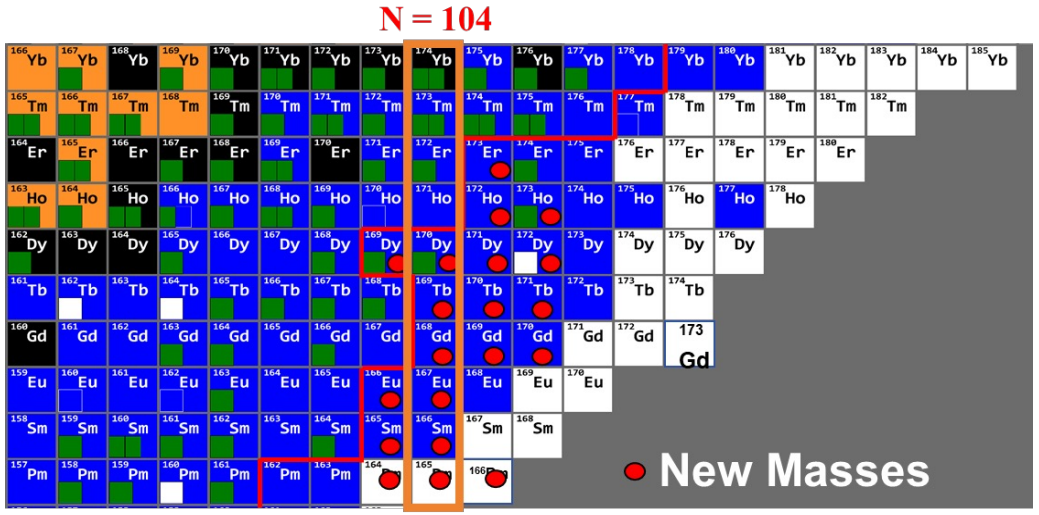
Experiments @iLinac

Separator for Products of MNT Reactions









Mass & Spectroscopy

- ✓ New masses
- ✓ β decay spectroscopy
- ✓ Chemistry of SHE

Exlpore island of SHN

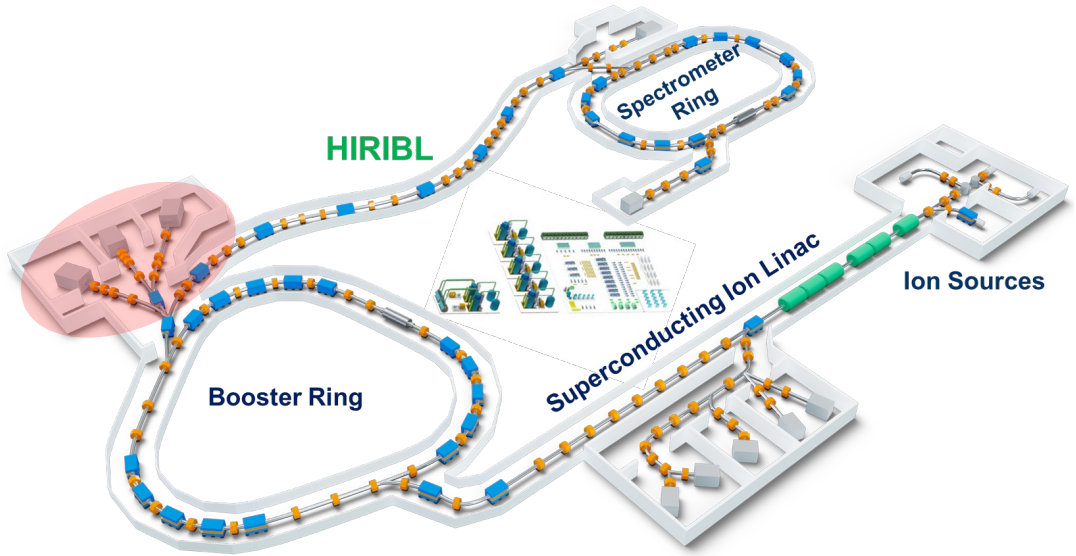
Modelling the r process

The separator provides pulsed low-energy, high-quality n-rich beams

Experiments @Booster Ring

High Energy Station

DC-type extraction from the Booster



Typical beam parameters from the Booster Ring

Ions	Energy(GeV/u)	Intensity (ppp)
p	9.3	2.0×10^{12}
$^{18}O^{6+}$	2.6	6.0×10^{11}
$^{78}Kr^{19+}$	1.7	3.0×10^{11}
$^{209}Bi^{31+}$	0.85	3.2×10^{10}
$^{238}U^{35+}$	0.835	1.0×10^{10}

Slow extraction: ~ 3s beam duration

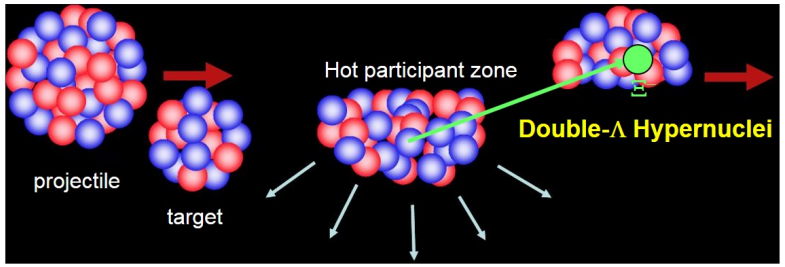
Not supported by the approved budget

The high-energy stable beams are ideal to produce hypernuclei and nuclear matter

- Properties of nuclear matter: supported already by CAS and NSFC, about 200 Million CNY
- Synthesis of new hypernuclei: seeking for financial support, international collaboration?

Moderate intensity and high energies. A/Z=2 beams up to 4.25 GeV/u available

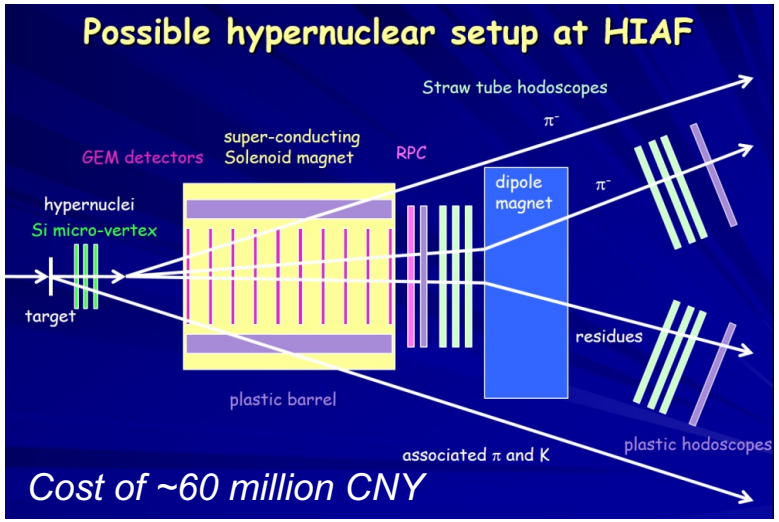
Experiments @Booster Ring



Expected reconstructed rate

- ^{20}Ne + ^{12}C at 4.25 A GeV
- Beam intensity: 10^7 /s

	Single-Λ hypernuclei	Double-Λ hypernuclei
per day	8×10^5	9×10^1
per week	6×10^6	6×10^2
per month	2×10^7	3×10^3



Courtesy: T. Saito

Synthesis of New Hypernuclei

- Hypernuclei produced in high-energy peripheral collisions
- Above 3.75 GeV/u, produce double-Λ hypernuclei

High energy & moderate intensity

Open New Domain: Hypernuclei with Double Strangeness

Production of ΛΛ hypernuclei

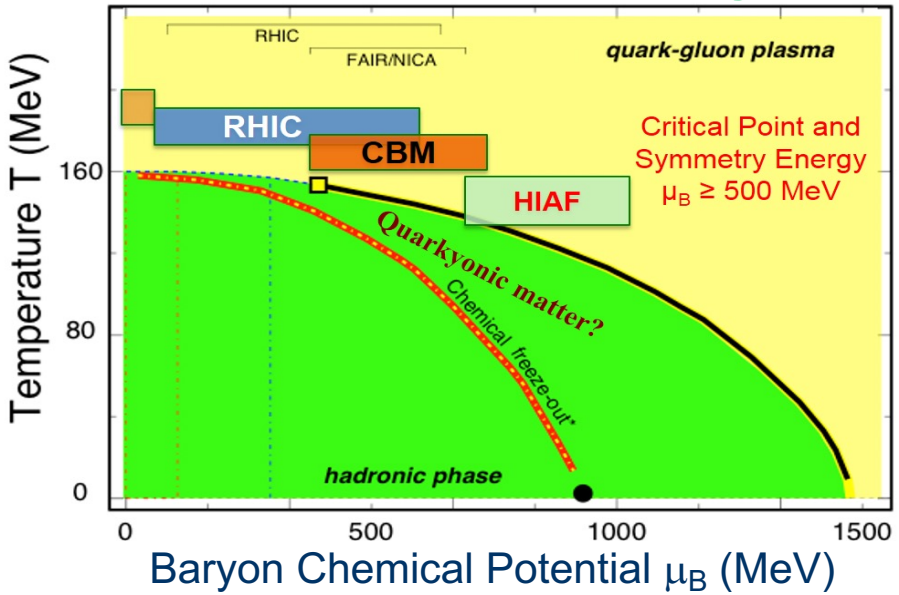
- $d + \Xi^- \rightarrow n\Lambda\Lambda$
- $t + \Xi^- \rightarrow nn\Lambda\Lambda$
- $^3He + \Xi^- \rightarrow {}^4_{\Lambda\Lambda}H$
- $^4He + \Xi^- \rightarrow {}^5_{\Lambda\Lambda}H$
- $^6Li + \Xi^- \rightarrow {}^7_{\Lambda\Lambda}He$
- $^7Li + \Xi^- \rightarrow {}^8_{\Lambda\Lambda}He$
- $^9Be + \Xi^- \rightarrow {}^{10}_{\Lambda\Lambda}Li$
- $^{10}Be + \Xi^- \rightarrow {}^{11}_{\Lambda\Lambda}Li$
- $^{10}B + \Xi^- \rightarrow {}^{11}_{\Lambda\Lambda}Be$
- $^{11}B + \Xi^- \rightarrow {}^{12}_{\Lambda\Lambda}Be$
- …

Decay of ΛΛ hypernuclei

- $n\Lambda\Lambda \rightarrow {}^3He + \pi^- + \pi^-$
- $nn\Lambda\Lambda \rightarrow {}^4He + \pi^- + \pi^-$
- $^4_{\Lambda\Lambda}H \rightarrow p + {}^3He + \pi^- + \pi^-$
- $^5_{\Lambda\Lambda}H \rightarrow p + {}^4He + \pi^- + \pi^-$
- $^7_{\Lambda\Lambda}He \rightarrow {}^7Be + \pi^- + \pi^-$
- $^8_{\Lambda\Lambda}He \rightarrow {}^4He + {}^4He + \pi^- + \pi^-$
- $^{10}_{\Lambda\Lambda}Li \rightarrow {}^{10}B + \pi^- + \pi^-$
- $^{11}_{\Lambda\Lambda}Li \rightarrow {}^{11}B + \pi^- + \pi^-$
- $^{11}_{\Lambda\Lambda}Be \rightarrow {}^{11}C + \pi^- + \pi^-$
- $^{12}_{\Lambda\Lambda}Be \rightarrow {}^{12}C + \pi^- + \pi^-$
- …

Experiments @Booster Ring

Study of the QCD Phase Structure



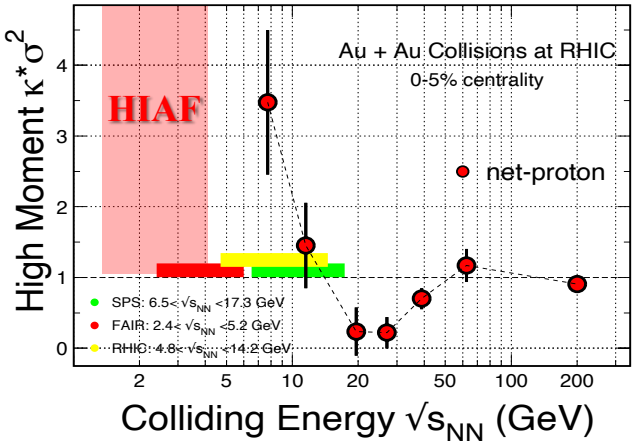
Lattice QCD: from the QGP to the hadronic phase

At μ_B~0, the smooth cross-over transition

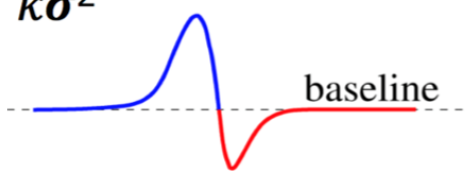
At finite μ_B, the first-order phase transition

Thermodynamically, **a critical point** must exist:

the end point of the first-order phase transition line



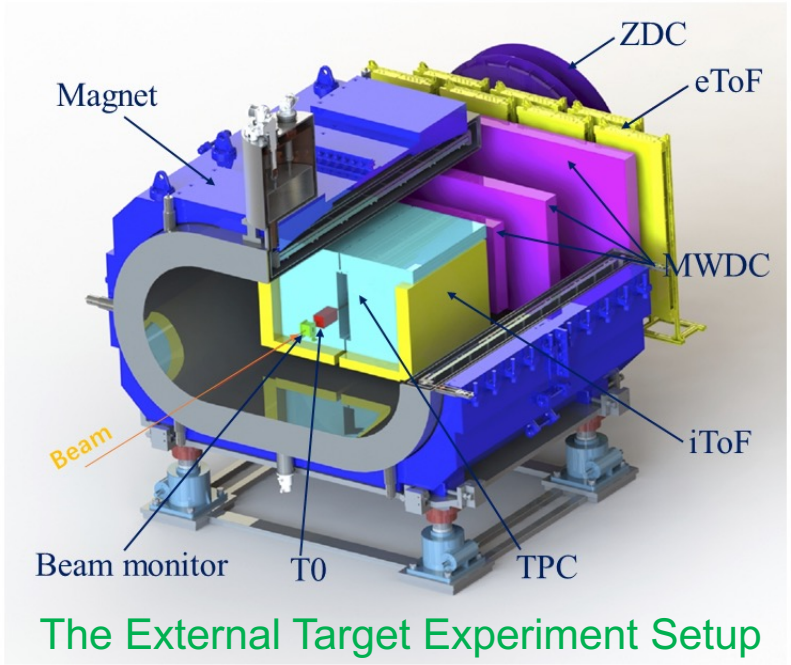
Energy scan program!



Observables:

net-proton fluctuation

net-baryon collectivity



The External Target Experiment Setup

许怒老师报告

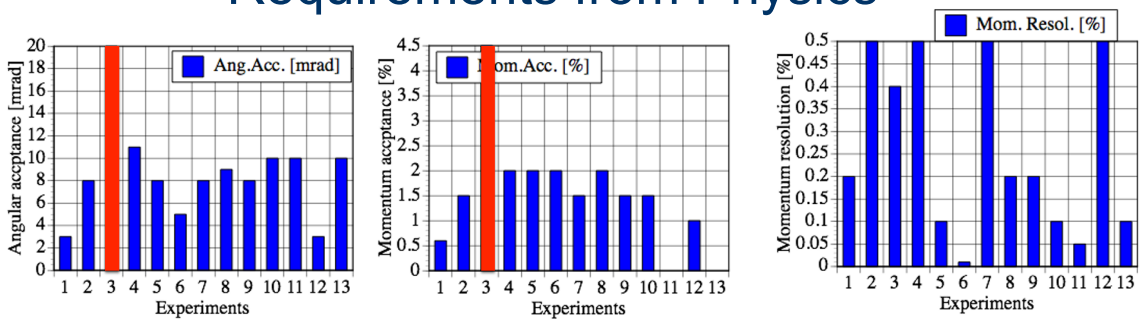
Experiments @HIRIBL

High Rigidity Radioactive Beam Line (HIRIBL)

Slow extraction and RIB produced by HIRIBL



Requirements from Physics



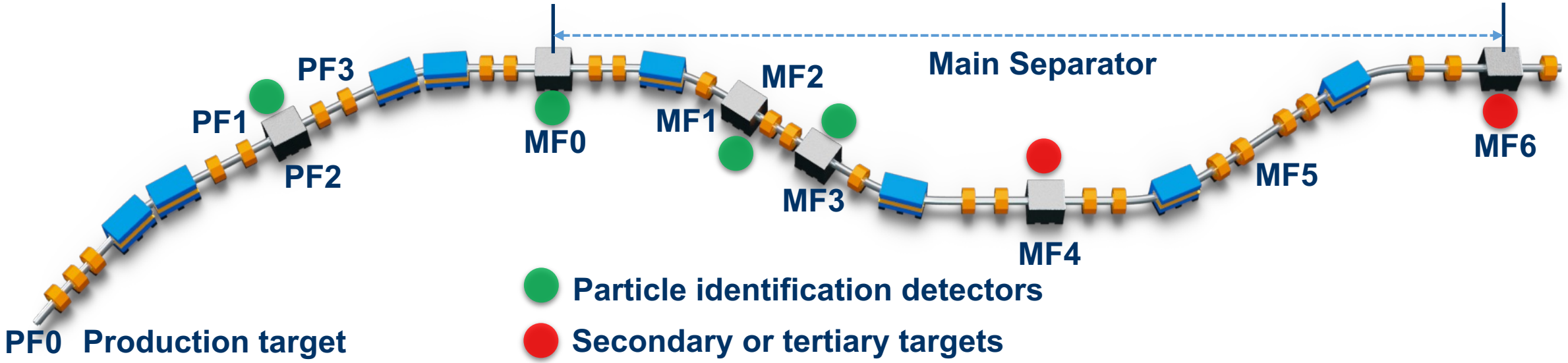
Acceptance, and Momentum Resolution

Physics Cases @HIRIBL

- ✓ New isotopes in the south east of ^{208}Pb (^{208}Pb and ^{238}U)
- ✓ Neutron dripline up to Ni isotopes (Kr and Xe)
- ✓ New isotopes by ^{238}U fission (^{238}U)
- ✓ New isotopes using two step projectile fragmentations
- ✓ Synthesis of neutron rich hypernuclei
- ✓ Study of tensor interactions: a basic change in structure model
- ✓ Particle decay in flight of unbound nuclei
- ✓ Nuclear matter radii (Interaction cross sections)
- ✓ Nuclear proton radii (Charge changing cross sections)
- ✓ Charge exchange reactions and β decay of r-process nuclei
- ✓ Nucleon excitations in nuclei
- ✓ Giant resonance of neutron rich nuclei
- ✓ Elastic scattering and transfer reactions
- ✓ Spectroscopy of meson-nucleus bound system
- ✓ …

Various experiments can be done at HIRIBL

Structure and Performance of HIRIBL



Important beam parameters:

- All elements from H to U
- Beam intensity up to ~10^{12} pps
- GeV/u beam energies
- Slow and fast extraction

Characteristics:

- $B\rho_{max} = 15\ (25)\ Tm,\ \Delta p/p = \pm 2\%$
- $\varepsilon_x = \varepsilon_y = 30\ \pi\ mm \cdot mrad$
- $\varphi_x = \pm 30\ mrad,\ \varphi_y = \pm 15\ mrad$
- $\varphi_x = \pm 30\ mrad,\ \varphi_y = \pm 15\ mrad$

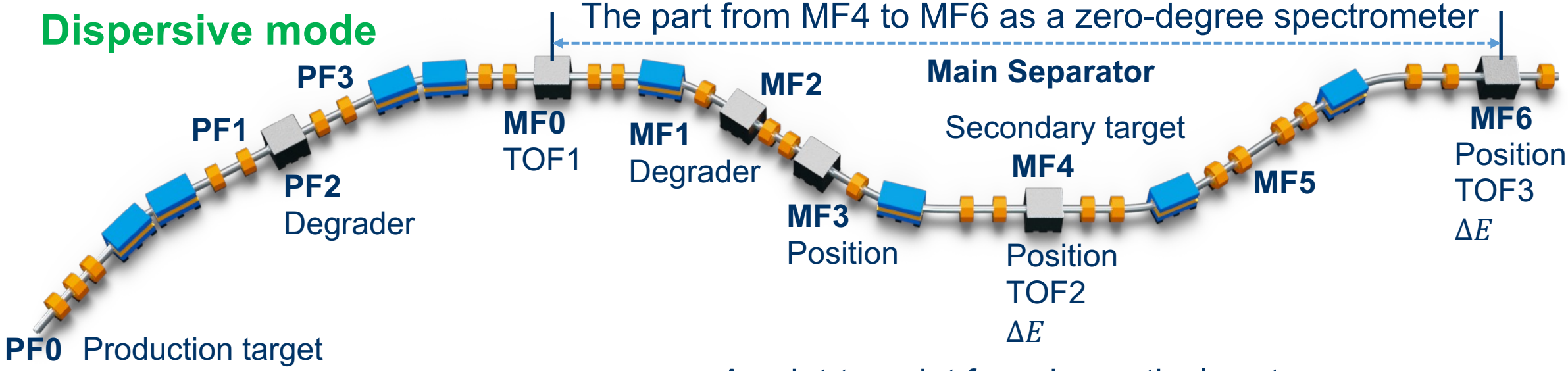
Two operation modes

Dispersive and achromatic

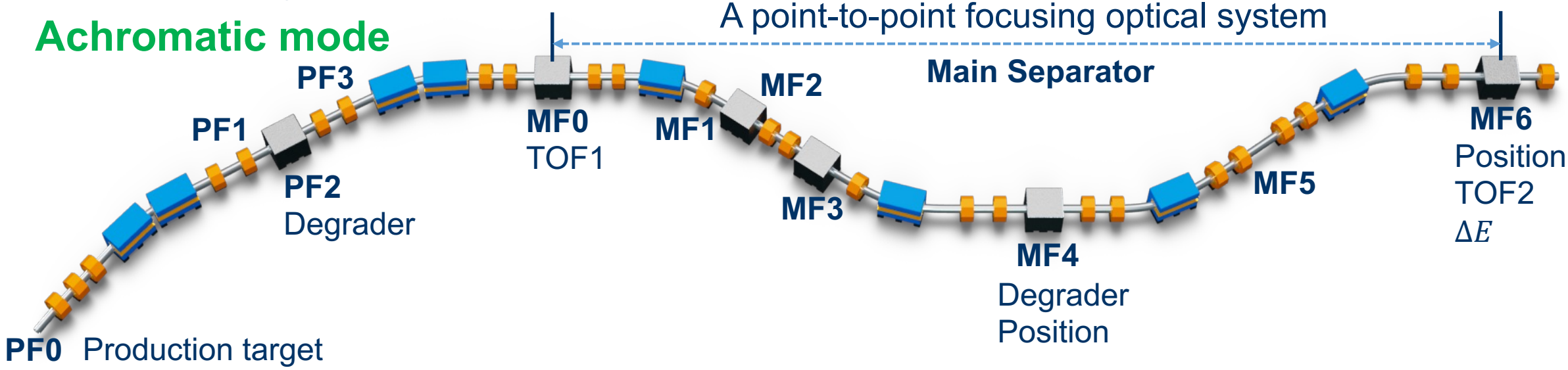
- Secondary/tertiary targets
- Degrader stations
- Ancillary detectors

Structure and Performance of HIRIBL

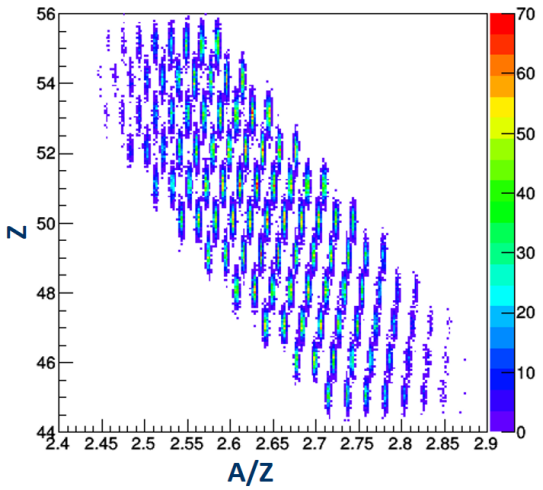
Dispersive mode

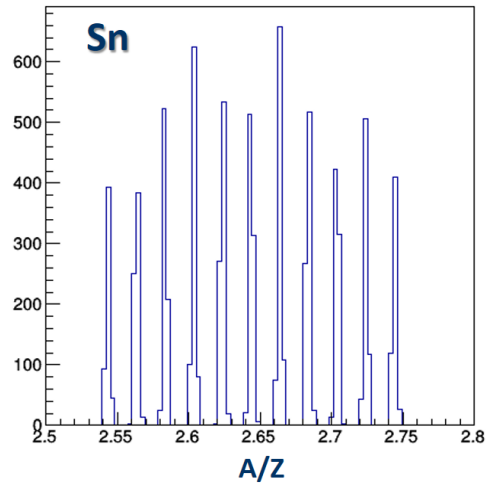


Achromatic mode



Structure and Performance of HIRIBL





In-flight fission of ^{238}U with energy of 800 MeV/u

Particle ID: $\Delta E - ToF - B\rho$

ΔE : **0.5%**； **ToF**: **40 ps**； **Position: 1.0 mm**

Under development:

- ✓ Multiple sampling ionization chambers for ΔE measurement
- ✓ Diamond detectors for **ToF** measurement
- ✓ GEM-TPC detectors for **position** measurement

The peculiarities of the HIRBL:

- A maximum Bρ=15（25）Tm, and thus high-energy secondary beams available
- High separation power, and fully stripped ions of all elements available
- Versatile spectrometer modes by different combinations of separator sections

Bρ=25Tm

Unique Experiments

- Synthesis of neutron rich hypernuclei
- Nucleon excitations (Δ resonance and N*) in nuclei
- Giant resonance of neutron rich nuclei
- Spectroscopy of meson-nucleus bound system

Physics @HIRIBL

Explore hitherto unknown territories and study new phenomena

Nuclear Structure and Dynamics

Systematic measurements of mass and lifetime

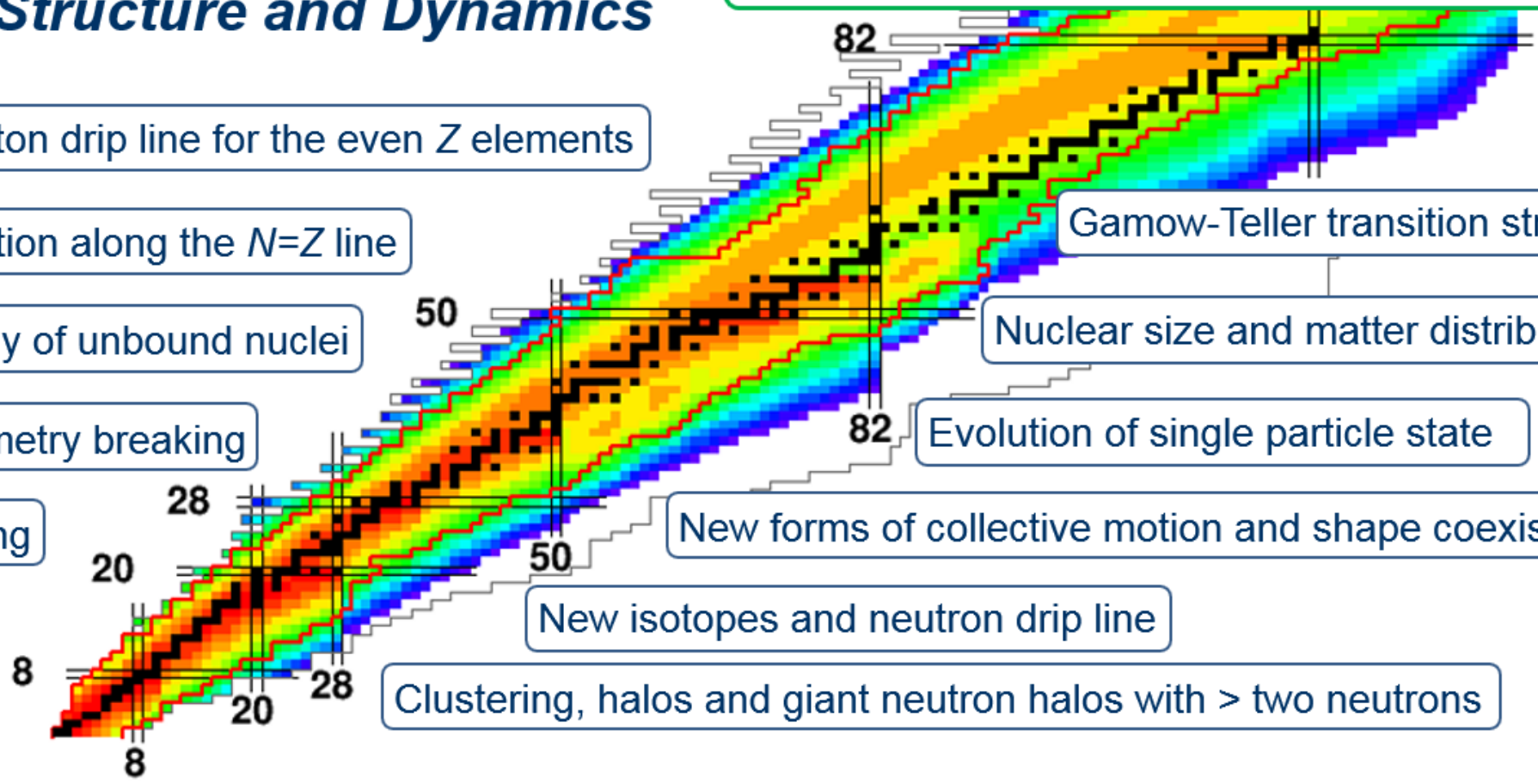
Proton drip line for the even *Z* elements

Shape evolution along the *N*=*Z* line

In-flight decay of unbound nuclei

Isospin symmetry breaking

New *np* paring



Gamow-Teller transition strengths B_{GT}

Nuclear size and matter distribution

Evolution of single particle state

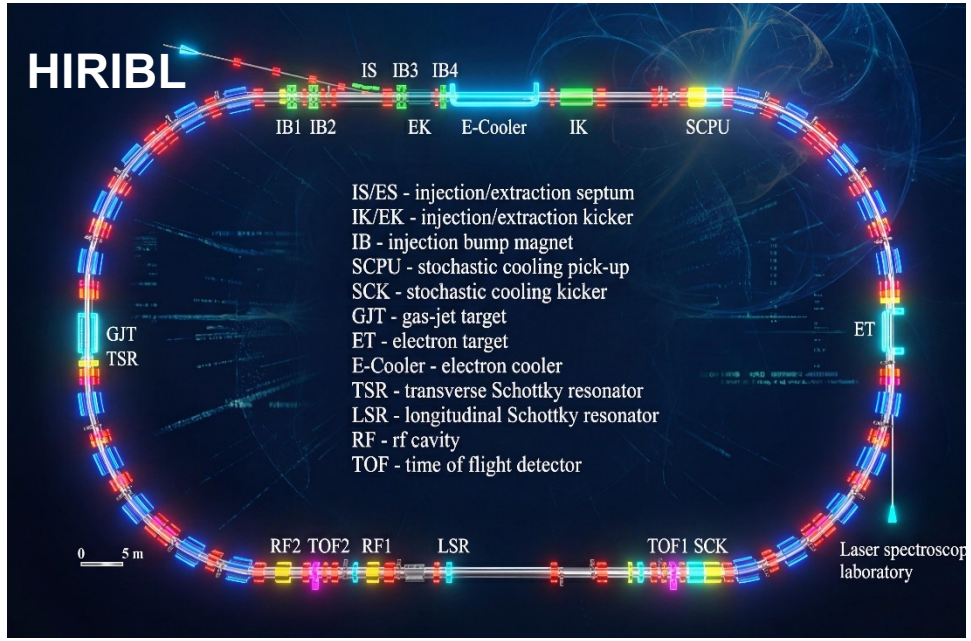
New forms of collective motion and shape coexistence

New isotopes and neutron drip line

Clustering, halos and giant neutron halos with > two neutrons

Experiments @Spectrometer Ring

Spectrometer Ring: Multi Working Modes of Storage Ring



Fast extraction. RIB and highly-charged ions

Operate in three modes:

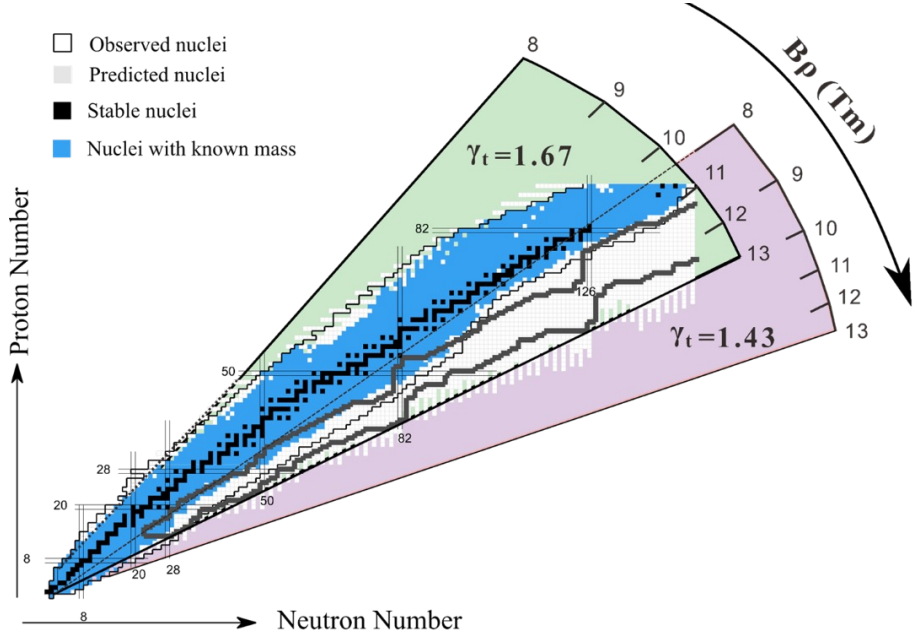
- ✓ **Isochronous:** high precision mass measurement
- ✓ **Normal:** Schottky and atomic physics experiments
- ✓ **internal target:** in-ring reactions

Spectrometer Ring:

- Orbital: 188.7 m
- 1.5~15 Tm $B\rho$ range
- Electron cooler
- Stochastic cooler

Experiments:

- Isochronous Mass Spectrometry
- Schottky Spectrometry
- DR Spectrometry
- In-ring Nuclear Reactions

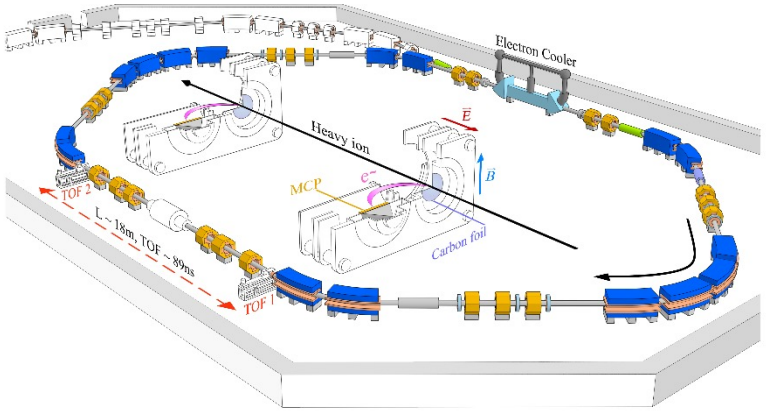


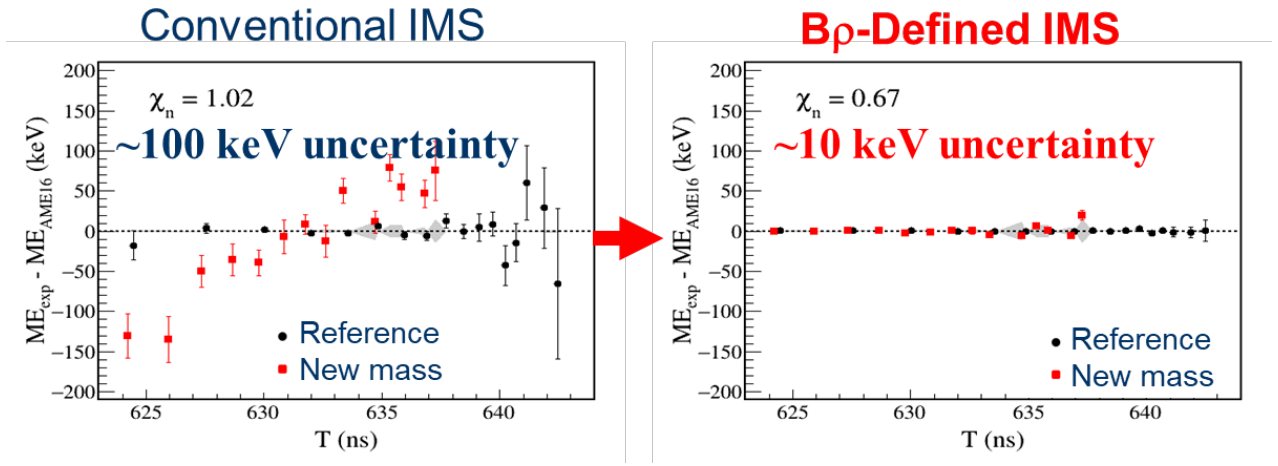
R&D at CSR

Bρ-Defined IMS

$$\frac{\Delta T}{T} = \frac{1}{\gamma_t^2}\frac{\Delta m/q}{m/q} - \left(1 - \frac{\gamma^2}{\gamma_t^2}\right)\frac{\Delta v}{v}$$

IMS: $\gamma = \gamma_t$ **Schottky:** $v \sim 0$





- ✓ Eliminate the systematic errors
- ✓ Single-ion sensitivity
- ✓ Applicable to short-lived nuclides
- ✓ Fast measurement
- ✓ High precision
- ✓ Broad band measurement

Novel Schottky spectrometry

Conventional Schottky:

- ✓ Non-interceptive prober
- ✓ Mass and half-lives
- × Long time cooling

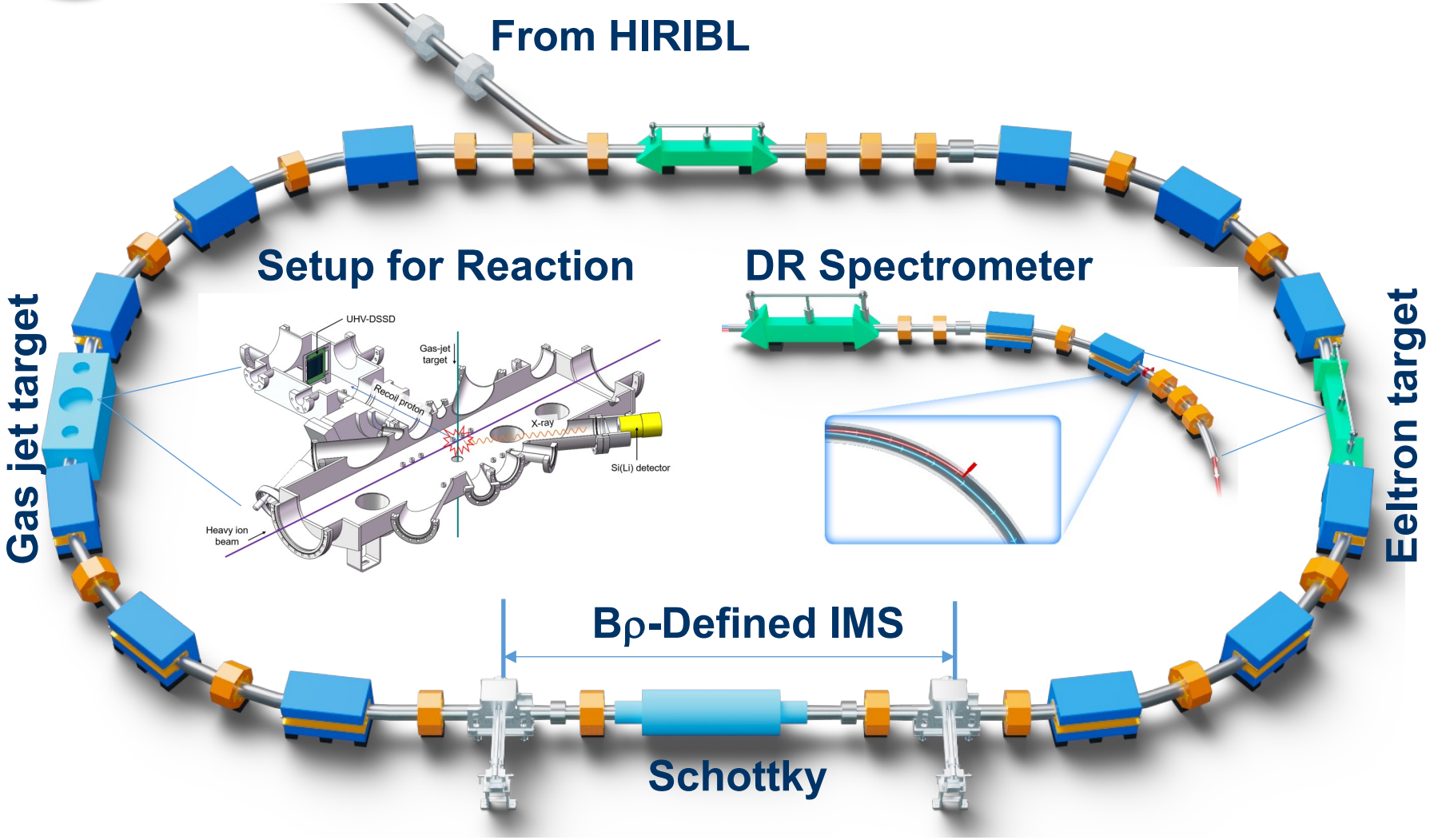
IMS: Isochronous condition

- ✓ Fast measurement
- × Interceptive detector
- × Not for half-lives measurement

Schottky Prober working in isochronous condition

Phys. Rev. Lett. 135, 012501 (2025)； Phys. Rev. Lett. 133, 222501(2024)； Nature Physics 19, 1091-1097 (2023)

Experiments @Spectrometer Ring

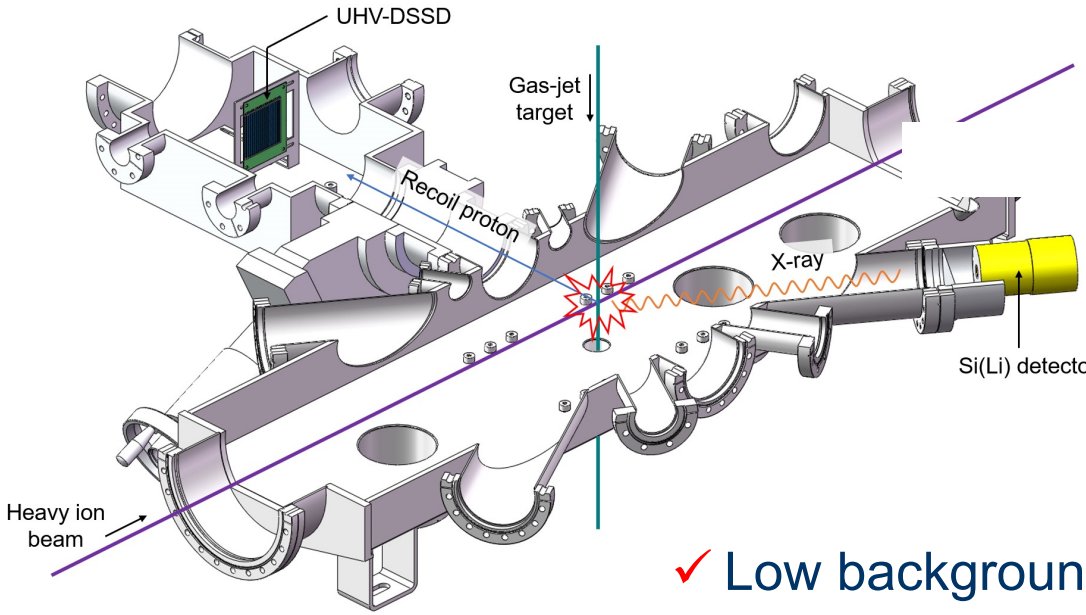




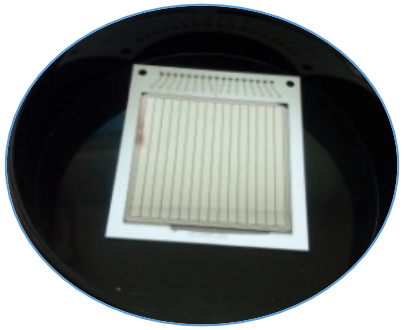


Experiments @Spectrometer Ring

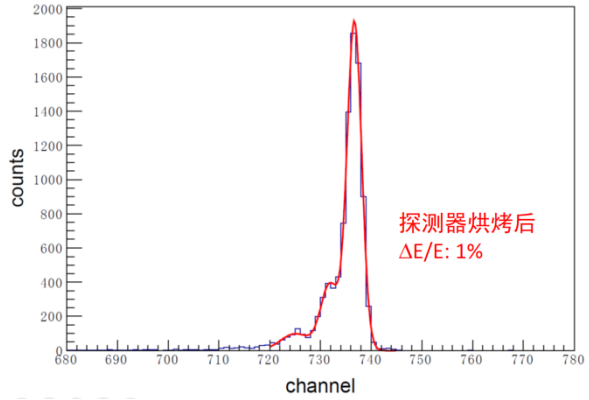
Setup for In-ring Nuclear Reactions



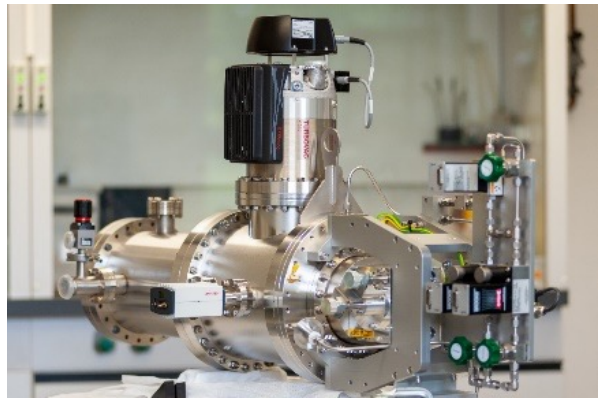
- ✓ Position-sensitive silicon detectors in ultra-high vacuum
- ✓ A gas jet target with thickness adjustable



After baking, ΔE/E: 1%



H target $\rho > 10^{12}$ atoms/cm^2



- ✓ Low background in high vacuum
- ✓ High luminosity
- ✓ High-resolution measurement

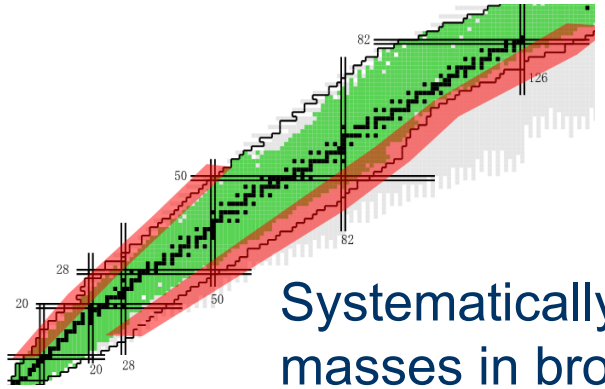
Nuclear Reactions:

- ✓ *(p, p)*, *(p, p′)*, *(p, γ)*, *(α, p)*, and *(α, γ)* reaction rates
- ✓ Solid target and active target with ion energy compensation

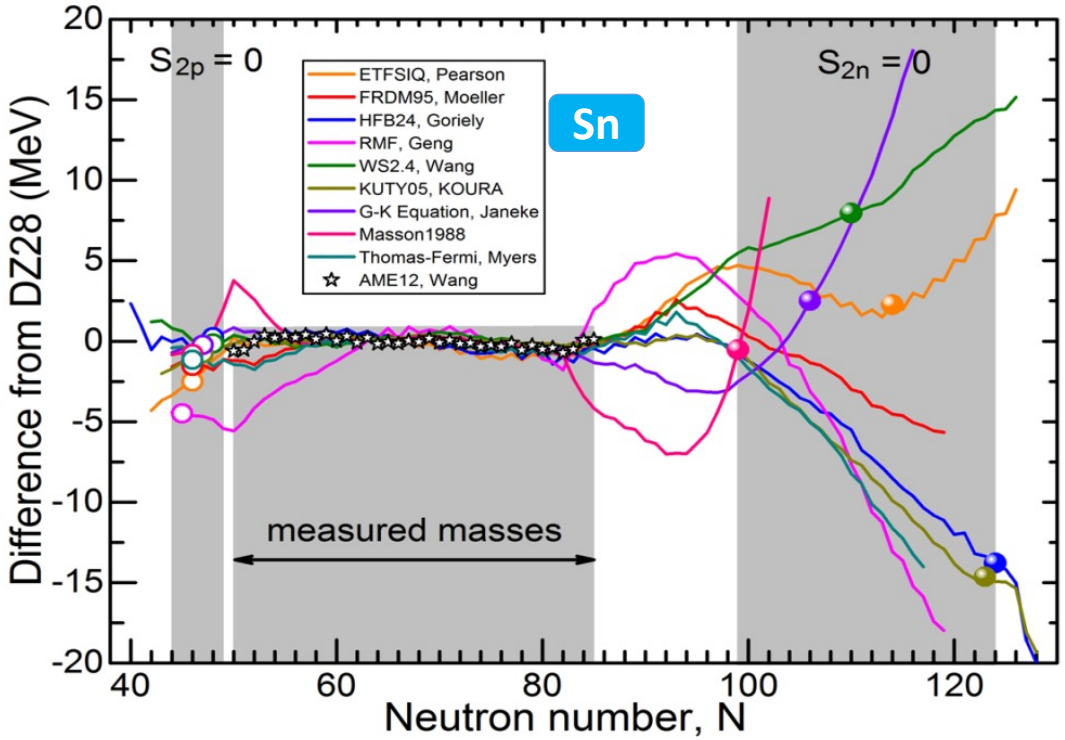
Physics @Spectrometer Ring

Experimental Measurements:

- **Nuclear Masses with Highest Priority**
- Nuclear Half-lives
- Exotic Decay Modes



Systematically measure nuclear masses in broad regions

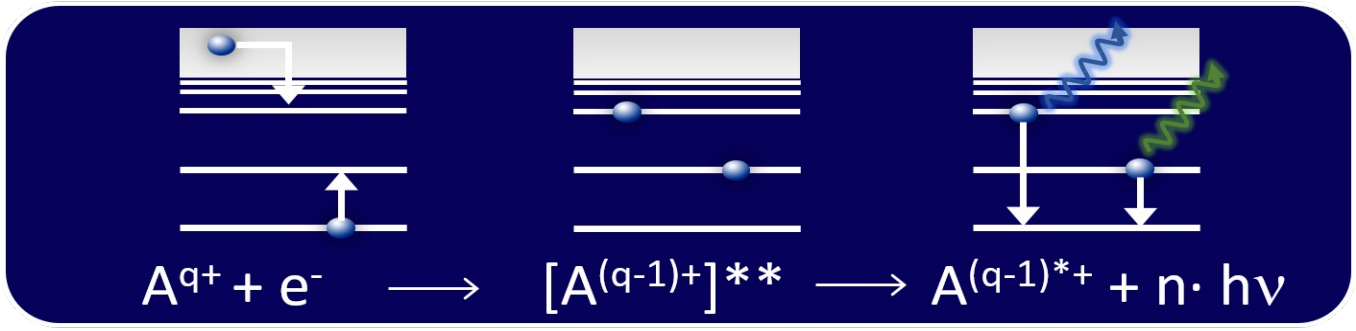


Physics:

- map out the mass surface in broad regions and determine the drip lines
- reveal the evolution of the effective interactions while changing the *N/Z* ratios
- study the quenching of the known shell gaps and development of new ones
- find out the deformation change and onset of exotic shapes along isotopic chains
- simulate the *rp* process and *r* process

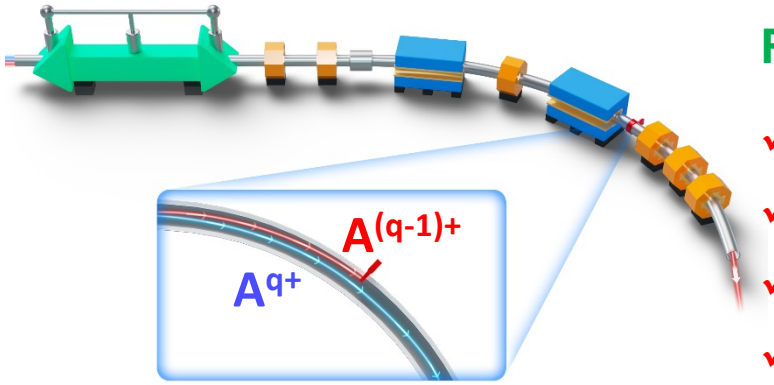
Experiments @Spectrometer Ring

Spectrometer for Dielectronic Recombination



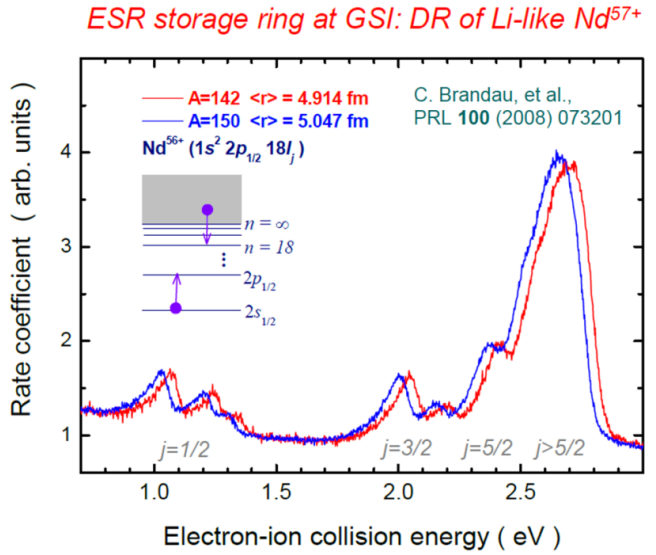
- In e-target, the electron beam has a longitudinal temperature of less than 1.0 meV
- The cooling results in a very narrow momentum spread for the ion beam of ~10^{-5}

Dielectronic Recombination: While the ion A^{q+} captures a free electron with well defined energy provided by the electron gun, a bound electron is excited simultaneously



Recombination Rate: $N(A^{(q-1)+})/N(A^{q+})$

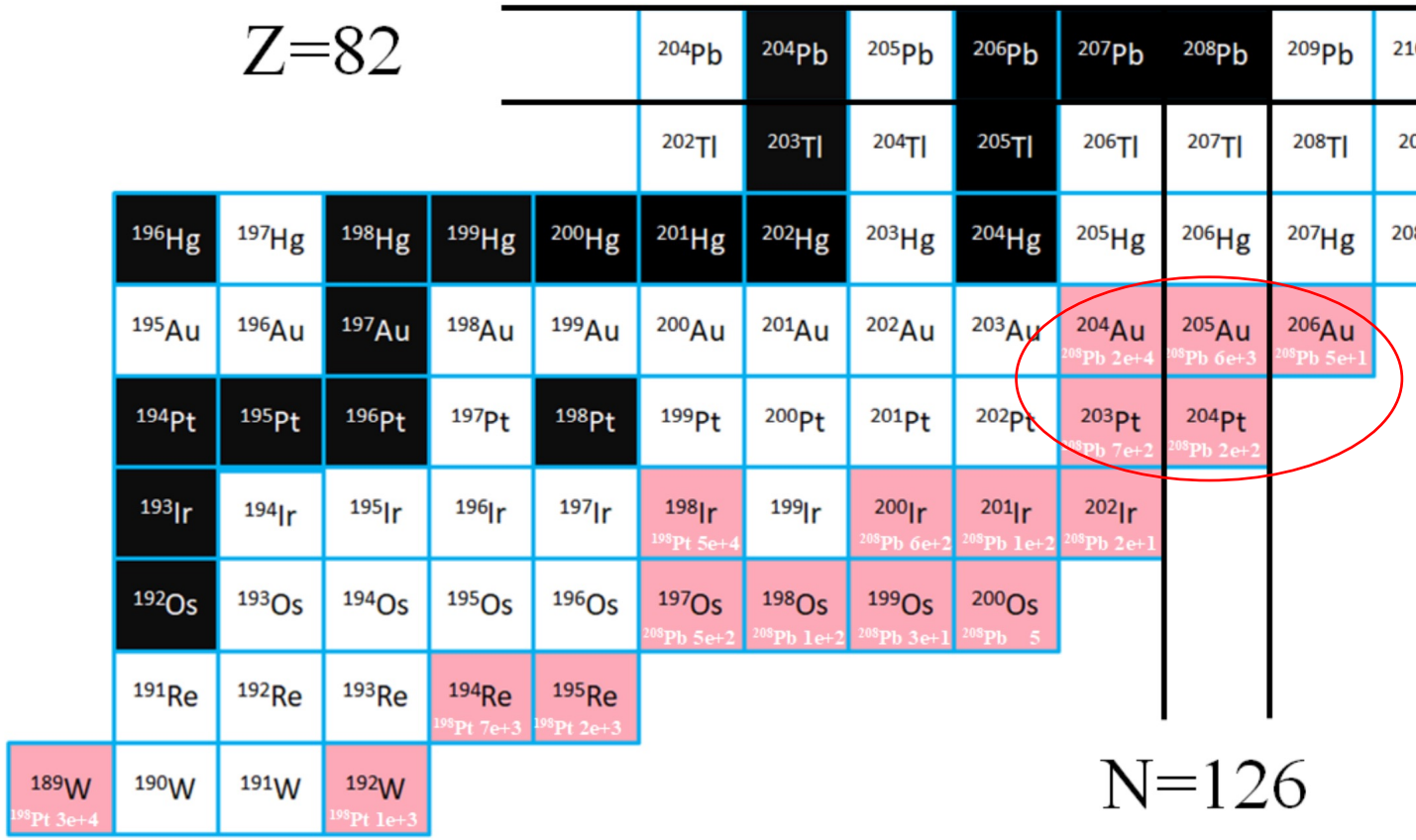
- ✓ QED effects in strong Coulomb fields
- ✓ Electron correlations
- ✓ Ultra-fast collision dynamics
- ✓ Charge radii of nuclide



To tune precisely the electron energy and count the recombined ions, fine or hyperfine spectra are obtained

First Experiment @HIAF

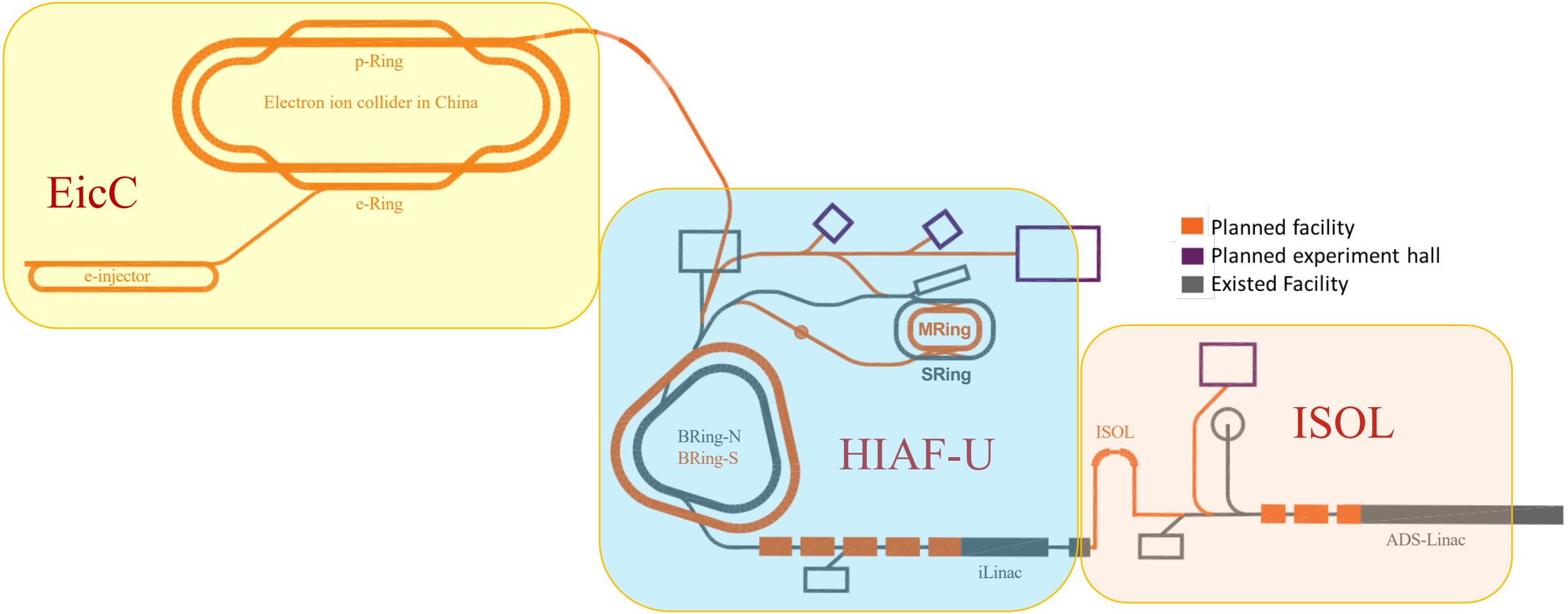
Nuclear masses around N=126 with Schottky spectrometry



$^{209}Bi^{31+}$:~3×10^{10} ppp

- ✓ To look for new isotopes
- ✓ To measure masses
- ✓ To measure lifetimes

Future HIAF


p-Ring
Electron ion collider in China
EicC
e-Ring
e-injector
MRing
SRing
BRing-N
BRing-S
HIAF-U
iLinac
Planned facility
Planned experiment hall
Existed Facility
ISOL
ISOL
ADS-Linac

Summary

HIAF is “next generation” type facility

RIBF, FRIB, RAON , FAIR and HIAF are complementary to each other

Let us work together to build a world’s leading unparalleled center for research and education in nuclear physics, accelerator physics and technology, and applications of energetic heavy ions

For details, please refer to: Status of the high-intensity heavy-ion accelerator facility in China, Zhou et al. AAPPS Bulletin (2022) 32:35

Thank you for your attention!

Acknowledgment

IMP: X.D.Tang, Zh.Liu, W.X.Huang, Z.G.Gan, J.Yang, X.Ma, Y.H.Zhang, M.Wang, X.C.Chen, X.L.Tu, Z.Y.Sun, J.S.Wang, M.L.Liu, B.Ding, Y.L.Tian, …

Beihang University: I.Tanihata, B.H.Sun, S.Terashima, …

Beijing Normal University: F.S.Zhang and K.Zhao

Peking University: Y.L.Ye, F.R.Xu, …

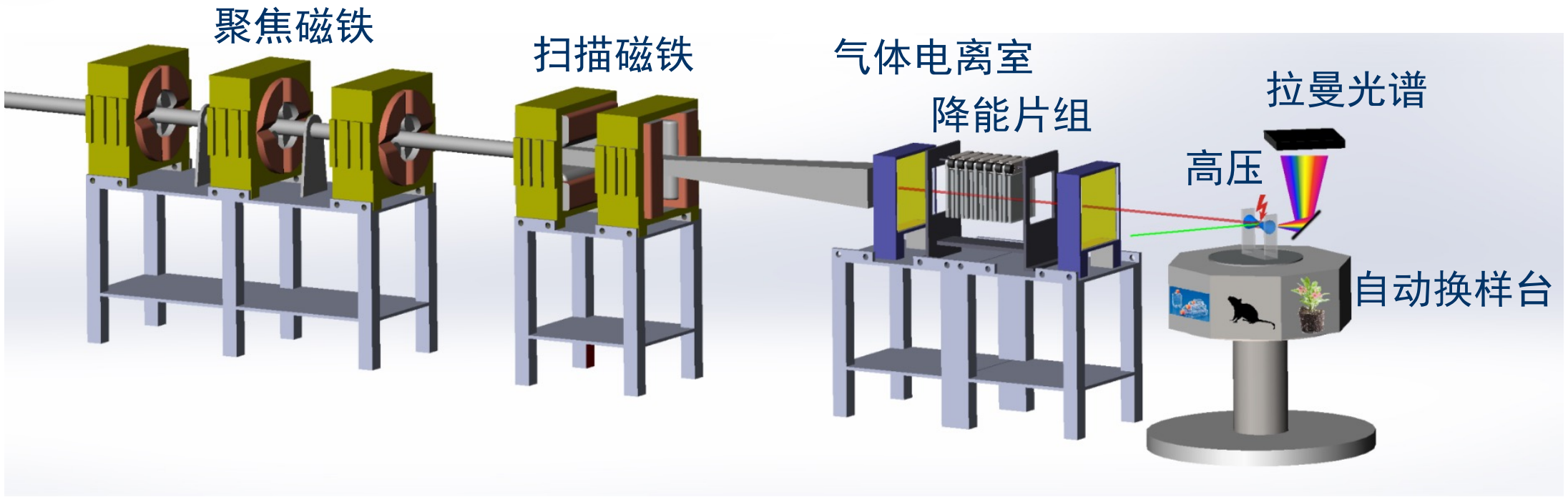
CIAE: C.J.Lin, …

CNS: S.Kubono

GSI: Y. Litvinov, T. Saito and C. Scheidenberger

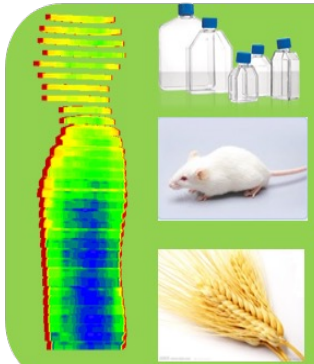
Thank you for your attention!

Heavy-ion Application

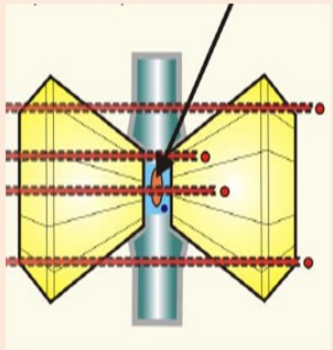




- 材料辐照效应
- 航天器件评估

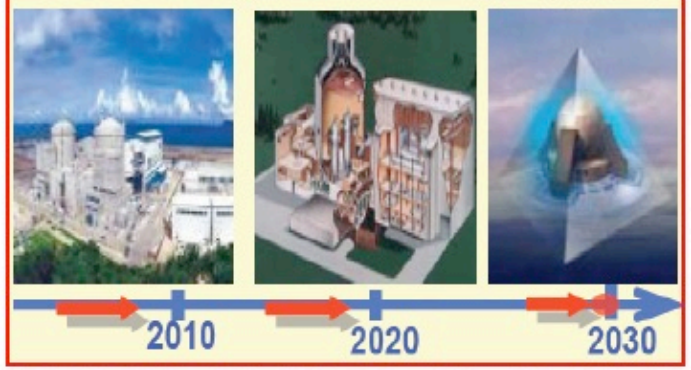


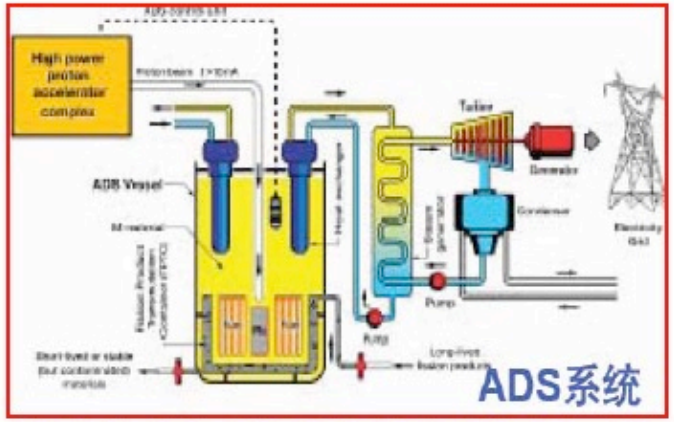
- 空间放射生物
- 放射医学研究
- 育种



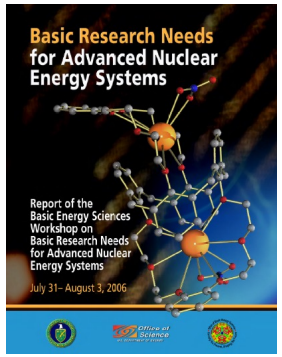
- 极端高压条件下的辐照效应
- HEDP性质研究

Heavy-ion Application

装置类别	第二代	第三代	第四代反应堆
			
	2010	2020	2030
材料耐受	温度 625-1275 K 损伤 3-180dpa, 0.1-5 ppm He/dpa 腐蚀环境	温度 > 650 K, 瞬变高应力 损伤~100dpa, 0.1-5 ppm He/dpa 腐蚀环境	温度 575-1100 K, 瞬间高热负载 损伤~200dpa, ~10 ppm He/dpa 腐蚀环境







材料成为限制先进核能发展主要瓶颈之一

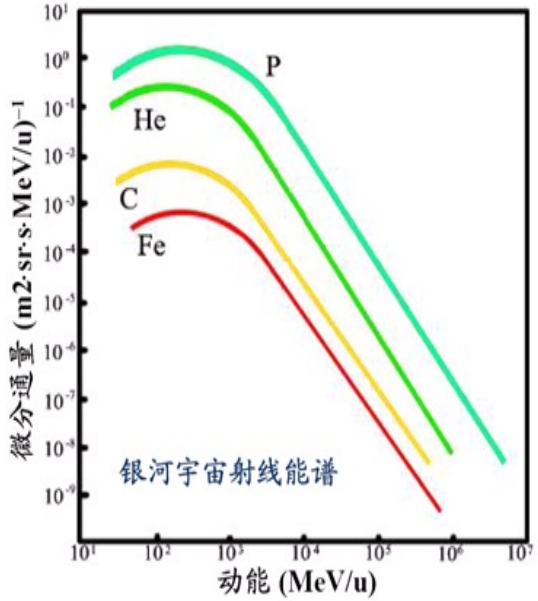
强辐照、高温、腐蚀环境等极端条件下的材料使役性能

发展在役/候选核材料快速评价新方法、研发新抗强辐照耐高温耐腐蚀材料

建造装置，形成具有自主知识产权的核能材料快速评价与筛选的方法和标准

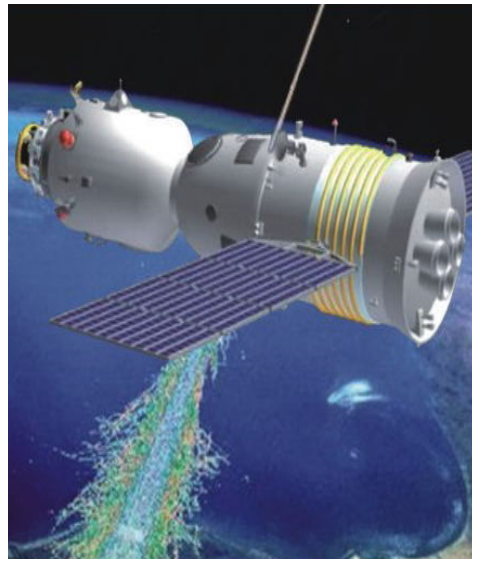
Heavy-ion Application

我国航天事业高速发展：卫星、载人航天、空间站、深空探测等



空间高能质子和重离子辐射

- 航天器安全：单粒子、总剂量效应…
- 宇航员安全：低剂量、HZE效应…



为保障航天器与宇航员的安全必须开展辐照效应研究

天基实验： 真实，昂贵、周期长、难控；**地基实验：模拟空间环境，周期短、可控**

建造空间离子辐射环境模拟平台，开展航天电子器件单粒子效应研究，为器件抗辐加固和研发提供支撑；研究空间辐射生物效应，为评价航天员健康与安全提供重要数据