ASSCA2025, IHEP, Beijing

CiADS and HIAF Projects

Yuan HE

Institute of Modern Physics
Chinese Academy of Sciences

a few words on Institute of Modern Physics

Institute of Modern Physics (IMP)

中国科学院
CHINESE ACADEMY OF SCIENCES

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

- IMP was established in 1957, located in Lanzhou City, Gansu Province
- In 1991, a National Laboratory was established relying on IMP
- Employee on payroll: 979
- Researcher and technicist: 894
- Graduate student: 543

- 6 campuses located in 3 cities of 2 provinces

Research Interests

nuclear physics, accelerator–driven nuclear energy system

1. **FUNDAMENTAL RESEARCHES ON NUCLEAR & ATOMIC PHYSICS**

   Reactions with exotic nuclei, Nuclear structure, Nuclear astrophysics, Nuclear matter, Highly ionized atomic physics, High energy density physics …

2. **APPLICATIONS WITH HEAVY IONS**

   Radio-biology and medical application, mutation breeding, functional materials, single particle effect of aerospace components, ……

3. **ACCELERATOR–DRIVEN ADVANCED NUCLEAR ENERGY**

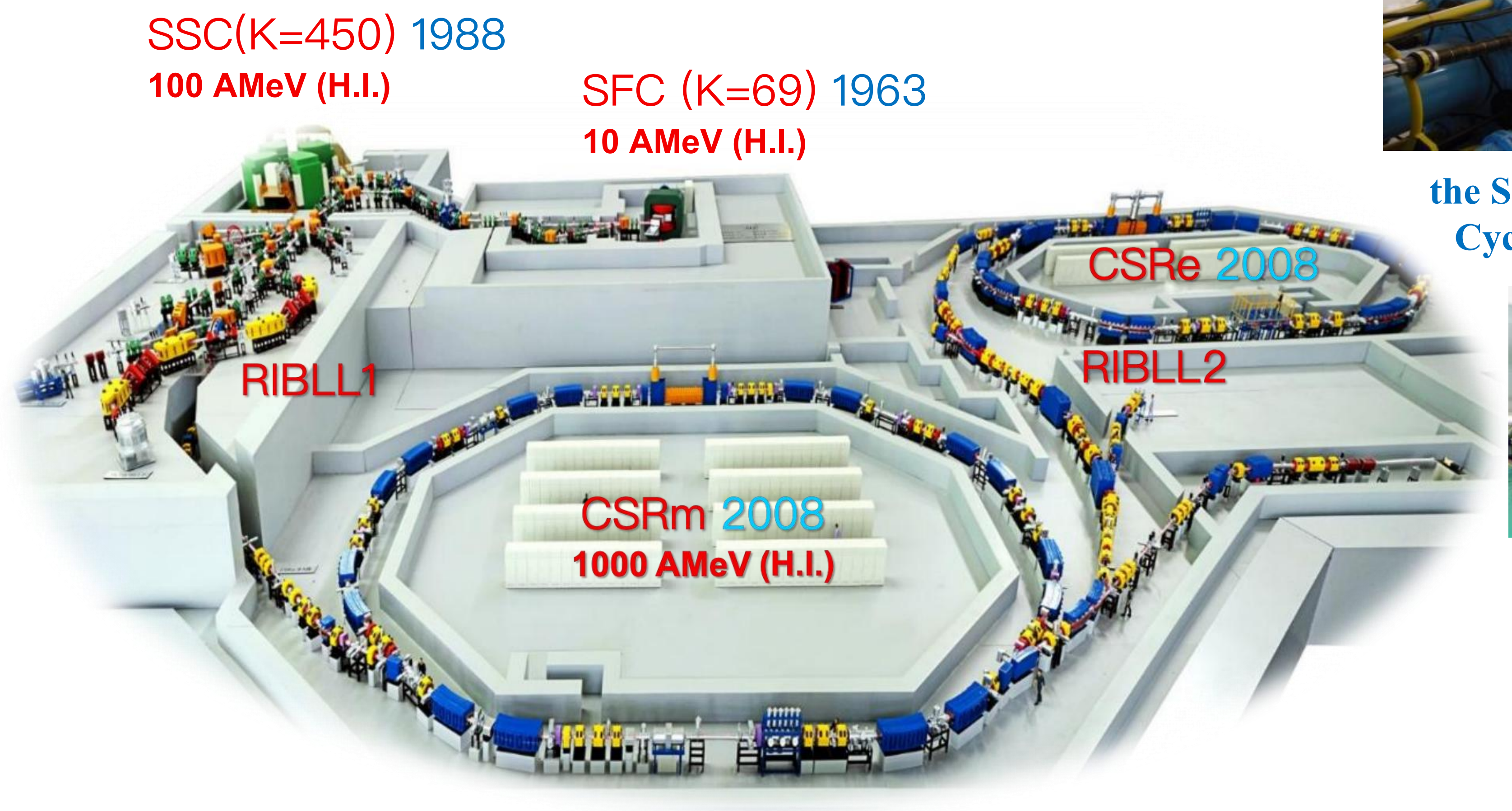
   Accelerator-driven System, cyclic utilization of spent fuel, nuclear material research, heavy ion driven high energy density physics

4. **ACCELERATOR PHYSICS AND TECHNOLOGY**

   Generation and precise control of ion beams: high intensity, high power and high quality

Research Facilities in Operation

Heavy Ion Research Facility in Lanzhou (HIRFL)



the Sector Focusing Cyclotron (SFC)

the Separated Sector Cyclotron (SSC)

the Cooler Storage Ring (CSR)

- **the largest ion–accelerator complex in operation in China**
- **more than 20 experimental terminals**

Operation status

operation time: **>7000 hrs. / year**

beam time: ~ **5000 hrs. / year**

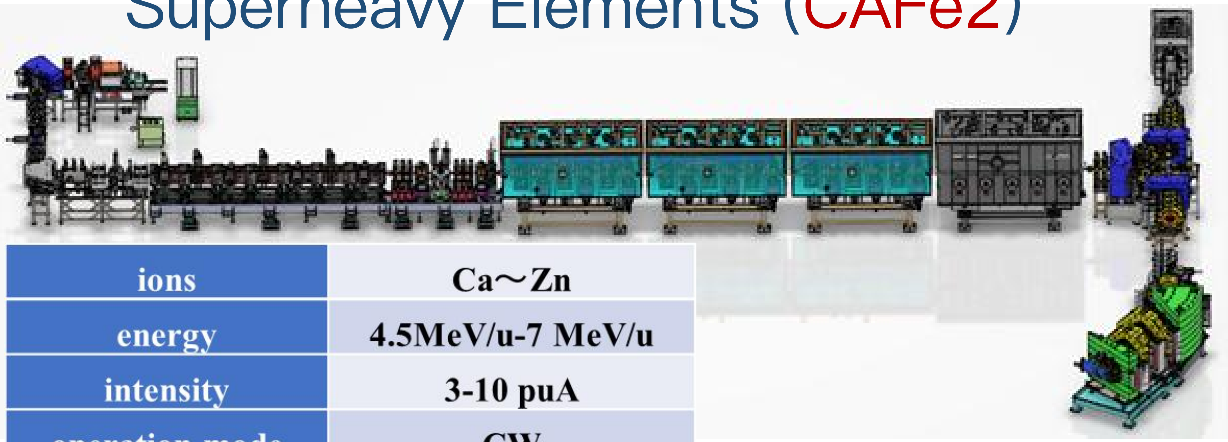
Experimental status

experiments: ~ **200 items / year**

user units: ~ **80 / year**

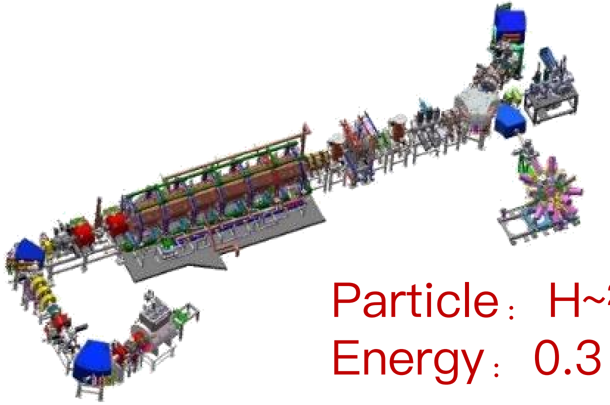
Research Facilities in Operation

China Accelerator Facility for Superheavy Elements (CAFe2)



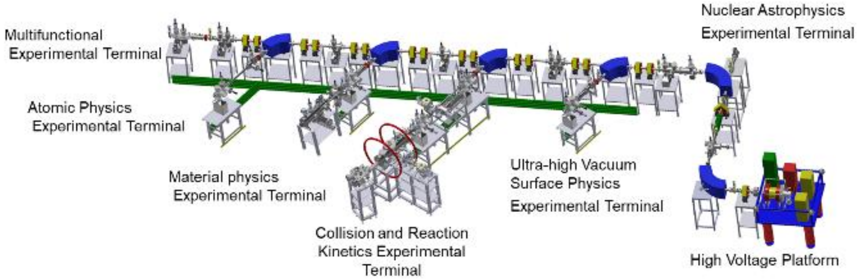
ions	Ca～Zn
energy	4.5MeV/u-7 MeV/u
intensity	3-10 puA
operation mode	CW

Low Energy intense–highly–charged ion Accelerator Facility (LEAF)



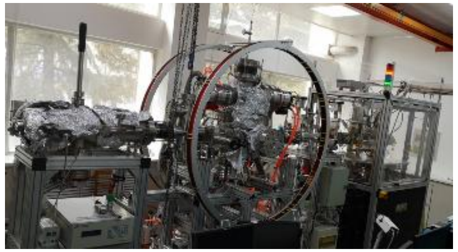
Particle： H~^{238}U
Energy： 0.3 AMeV~ 0.7 AMeV

320 kV Highly Charged Ion Beam Platform



Particle： H~^{238}U
Energy： 15 keV~10 MeV

Super Low Energy Heavy Ion Experiment Platform (EBIS)



Particle ： H He N O Ar Fe …
Energy： 500 eV~40 keV

Experimental terminals

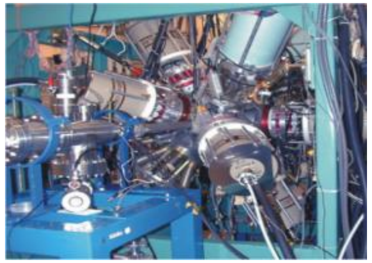
Radioactive ion beam line in Lanzhou

External target facility of CSRm

Gas-jet target experimental terminal at CSRe

Isochronous mass spectrometry at CSRe

Spectrometer for heavy atoms and nuclear structure



facility for in-beam gamma spectroscopy

- more than 20 terminals were built for the experiments
- experimental researches for heavy ion nuclear physics, nuclear technology, highly ionized atomic physics, and applied researches in the field of biology, materials and advanced nuclear energy

Dielectronic Recombination

Single Event Effects Experiment Terminal

High temperature & stress irradiation terminal

Heavy Ion Microporous Membrane Technologies

Experimental terminal for deep-seated tumor therapy and high-energy biomedical irradiation

Overview of CiADS and HIAF in Huizhou

Outline

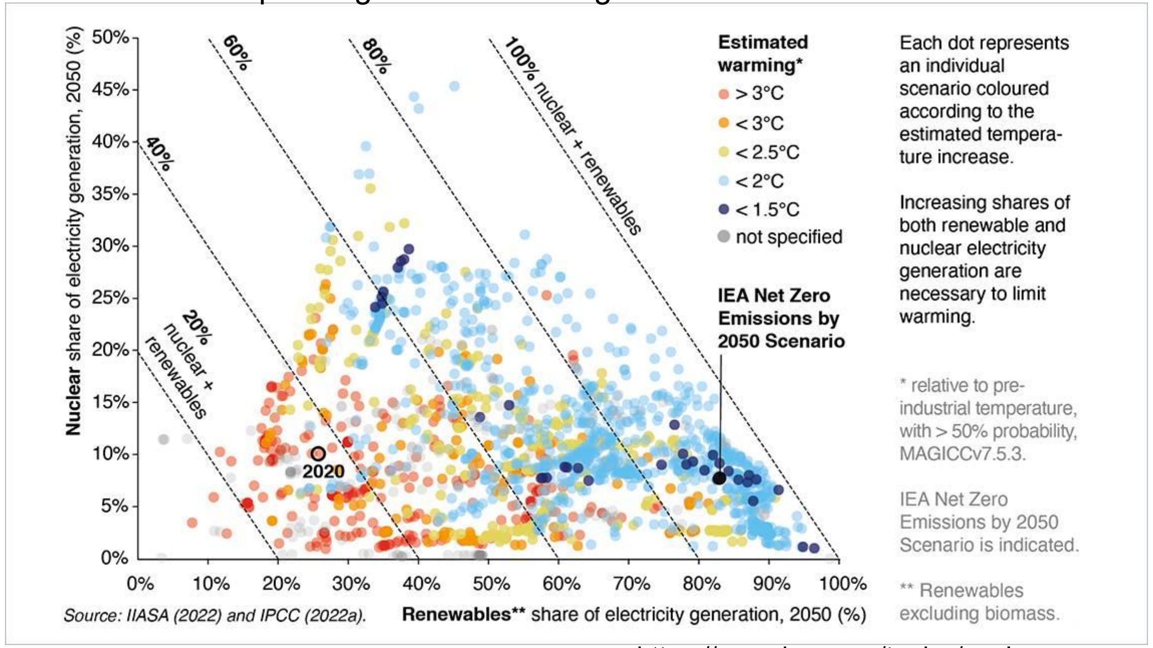
- Background of CiADS Project
- Challenges and Progress of CiADS
- Background of HIAF Project
- Challenges and Progress of HIAF
- Summary and Perspective

Carbon Neutrality and Nuclear Energy

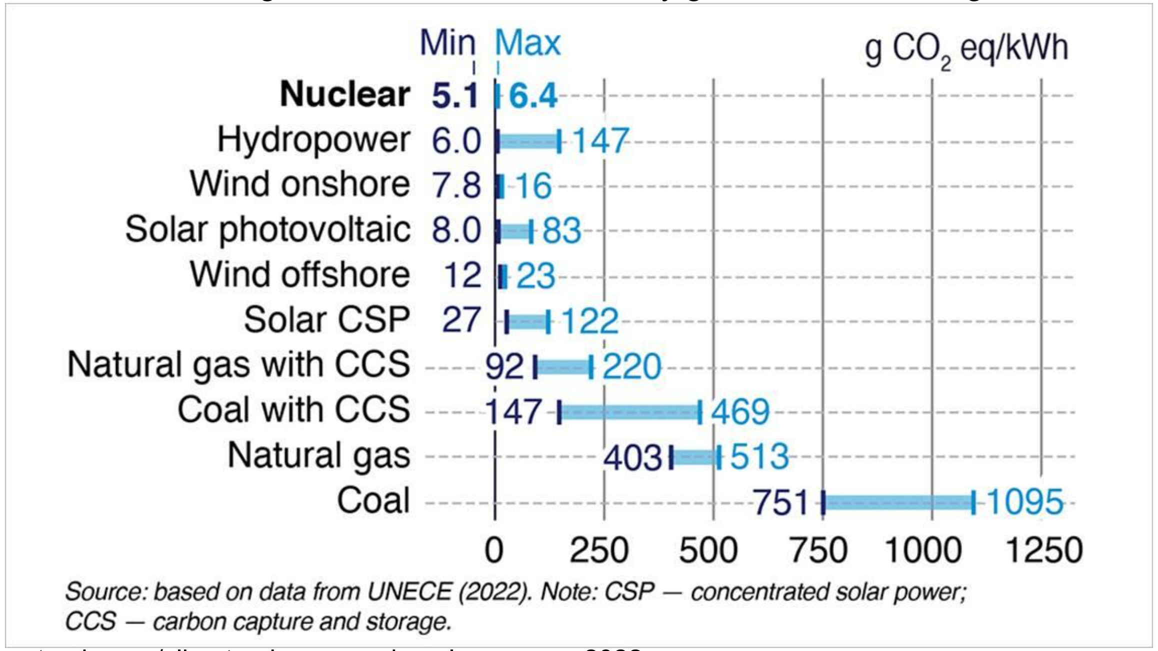
"Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels."

—— The Paris Agreement

Shares of nuclear and renewable energy in the electricity generation mix and corresponding climate warming across IPCC AR6 scenarios.



Greenhouse gas emissions from electricity generation technologies.



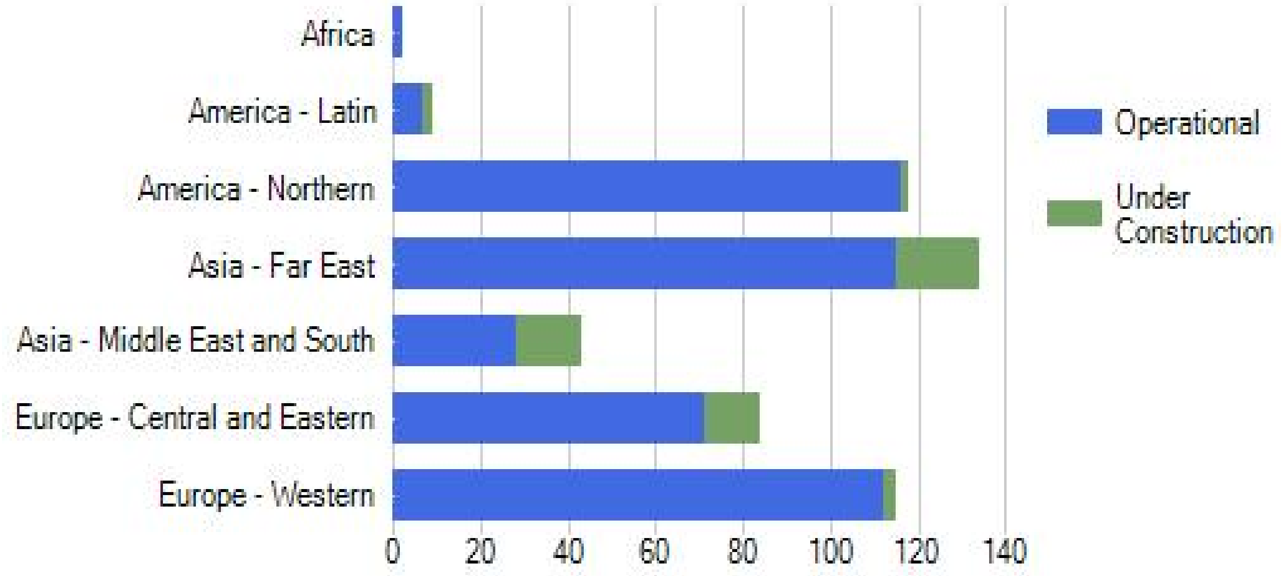
https://www.iaea.org/topics/nuclear-power-and-climate-change/climate-change-and-nuclear-power-2022

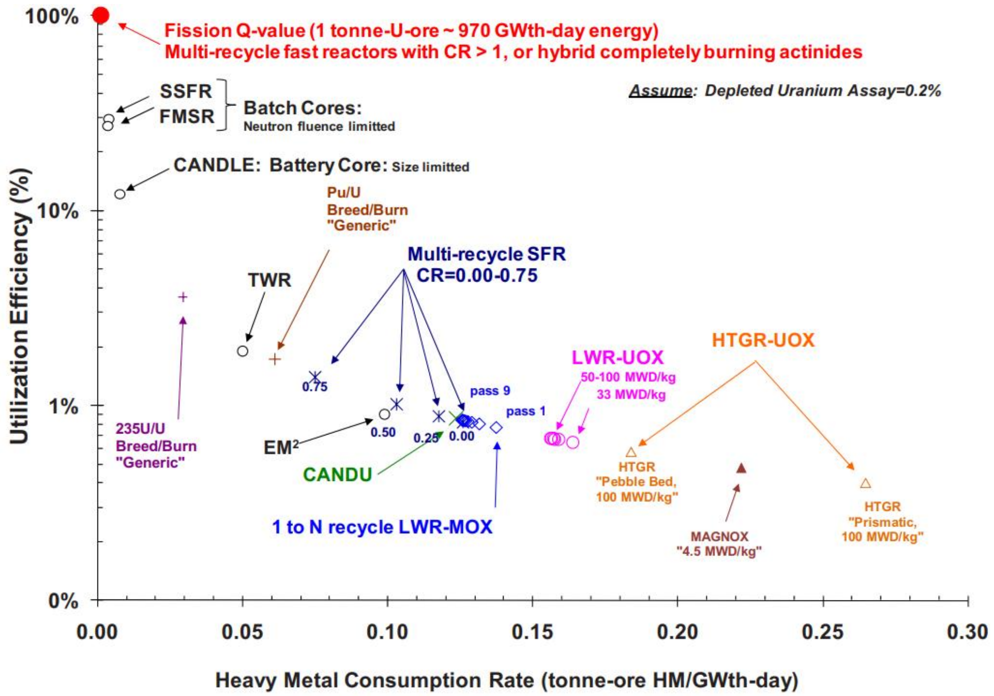
- To achieve carbon neutrality in the coming decades, a key to avoiding global warming of more than 1.5℃, investment in the energy sector must be scaled up and directed towards cleaner and more sustainable technologies that support global climate change mitigation and adaptation.
- With one of the lowest carbon footprints, 24/7 availability and the operate flexibly, nuclear power can make an irreplaceable contribution to a stable decarbonized power system and act as a regulator to renewable energy such as solar and wind.

Perspective of NE Development

Nuclear power is gaining support again after years of decline

- 52 more reactors under construction, 2/3 in Asia.
- ~30 new countries are looking at nuclear energy to meet their power and climate needs.

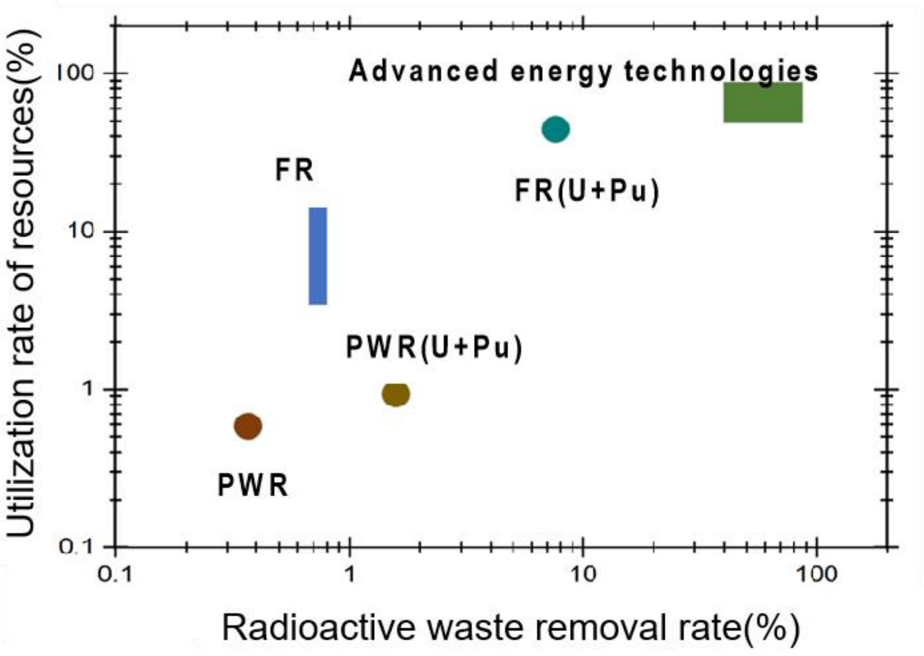


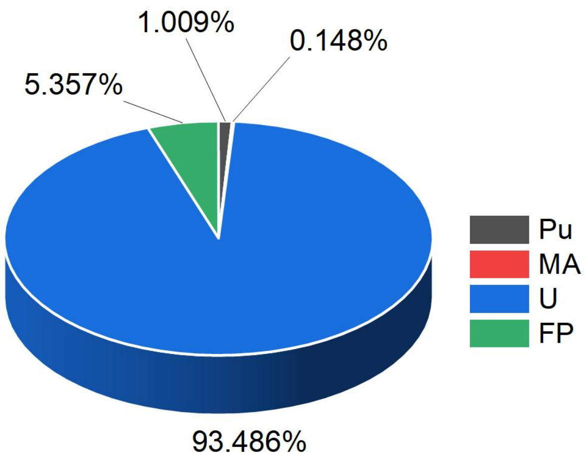


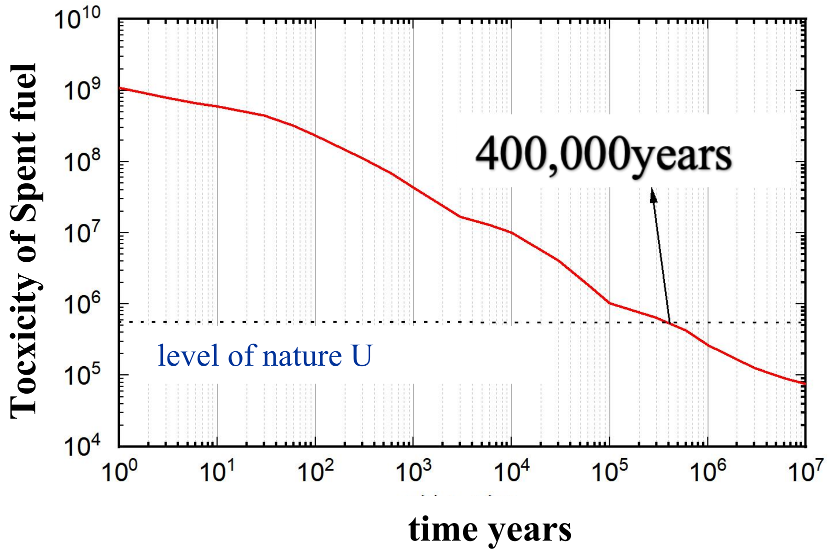
More than 22 countries to advance the aspirational goal of tripling nuclear power capacity by 2050, as well as statements by the IAEA and the nuclear industry.

But the NE technology is still far from advance.

Issues of Current Nuclear Energy



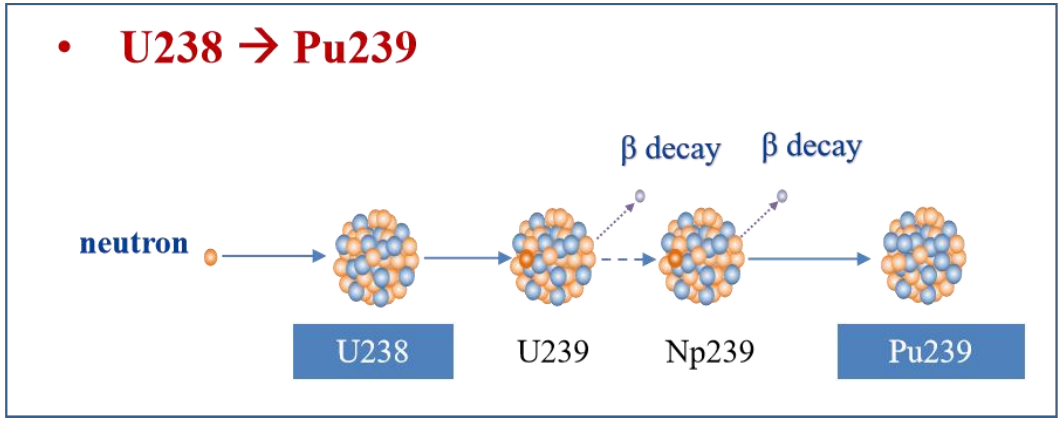




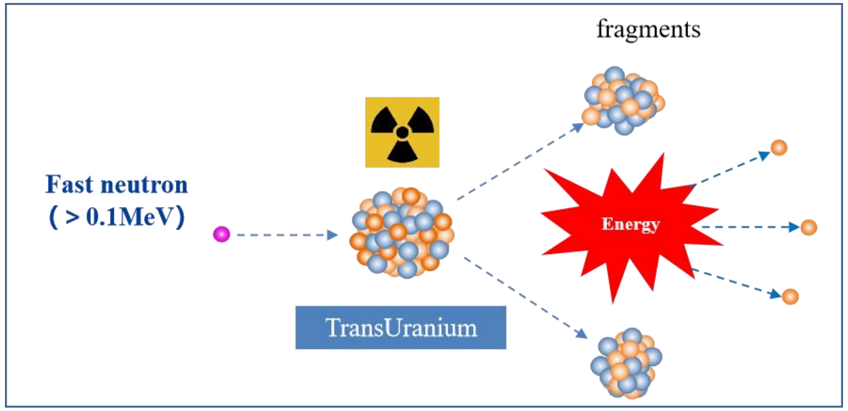
- 8 tons of natural uranium --> 1 ton of nuclear fuel -> only 50 kg is burnup into fission products
  - Reusable fuel (950kg) + depleted uranium (7 tons) has huge untapped potential for energy
- By 2035, UxC estimates that spent fuel emissions will be close to 618,000 tons, according to tripling nuclear power by 2050, that means at least 30,000 tons/y

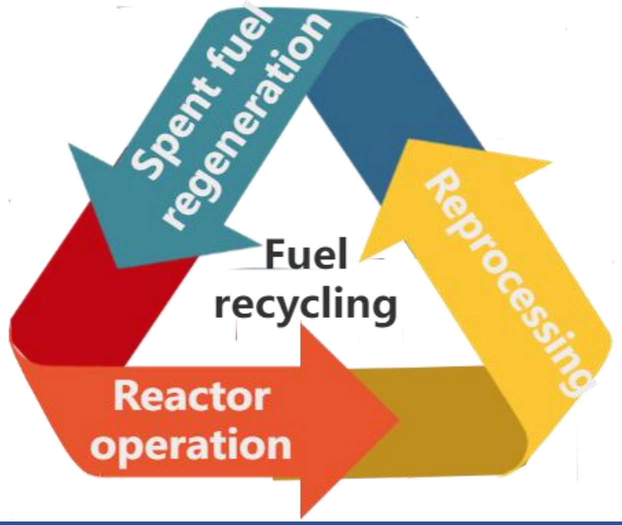
the next generation nuclear power should be sustainable

- Breeding



- Transmutation

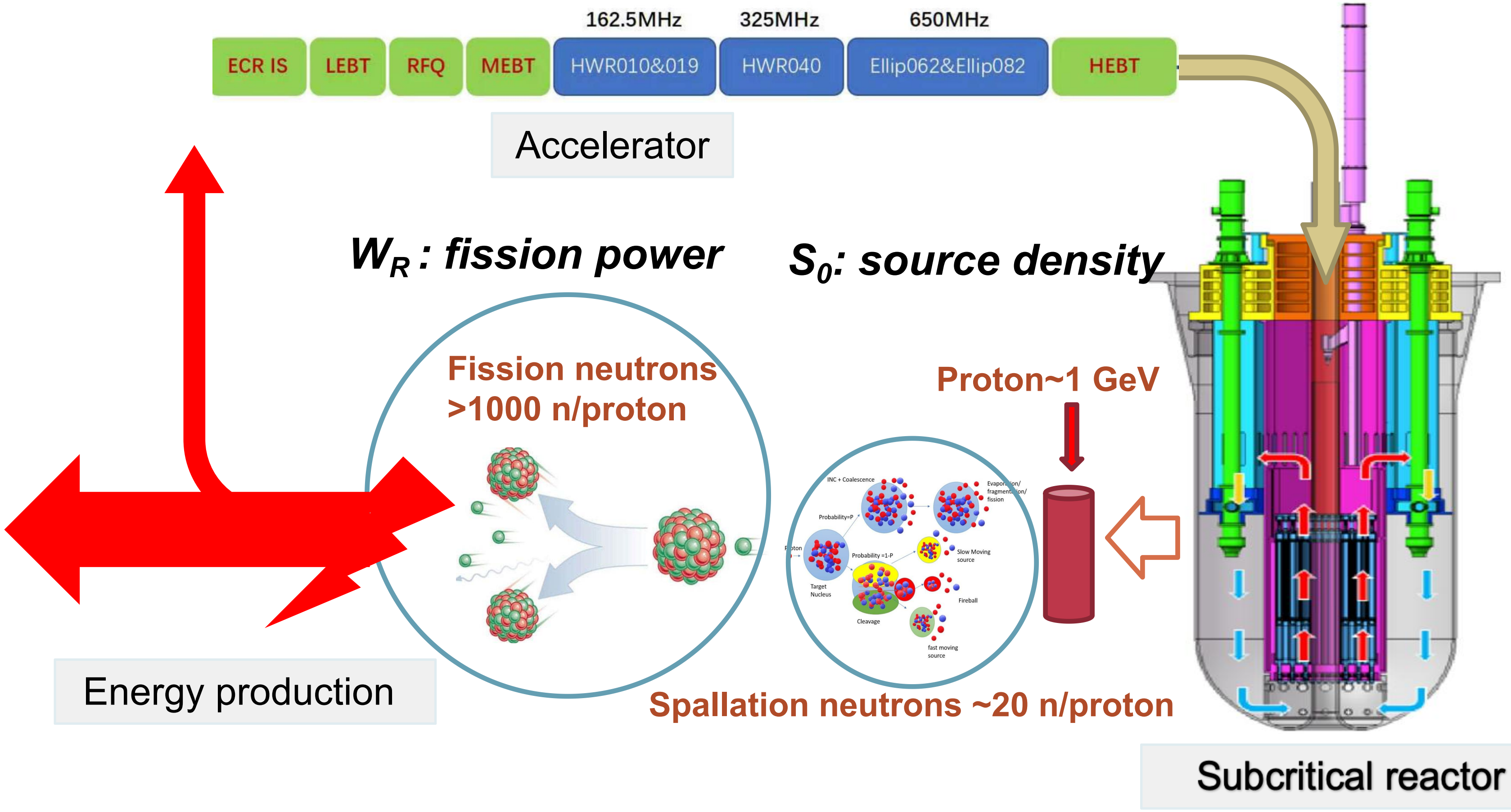




- to increase the amount of nuclear fuel by hundreds times
- to reduce the amount of nuclear waste by tens times
- to shorten the radioactive-lifetime by thousands times

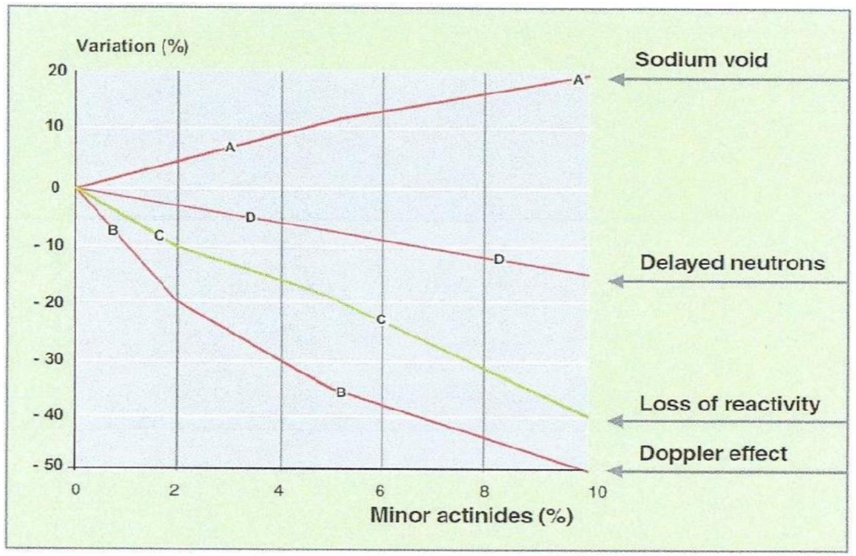
■ Principle of ADS

ADS consists of an accelerator, a spallation target, a subcritical reactor, and energy systems. The subcritical reactor is driven by a high energy proton, works like an energy amplifier.



Feasibility of dynamic in ADS Burner

◻ Effect of MAs on an FR



The relative change in core parameters is a function of the MAs content in the fuel

With the increase of MAs proportion in fuel,

- the difficulty of critical reactor control increases
- the void effect increases,
- the proportion of delayed neutrons decreases
- doppler effect and loss of reactivity decreased

◻ Reactivity control of a subcritical FR:

◻ Critical reactor：

$$W_R = W_0\, exp\left(\frac{K_{eff} - 1}{l} t\right)$$

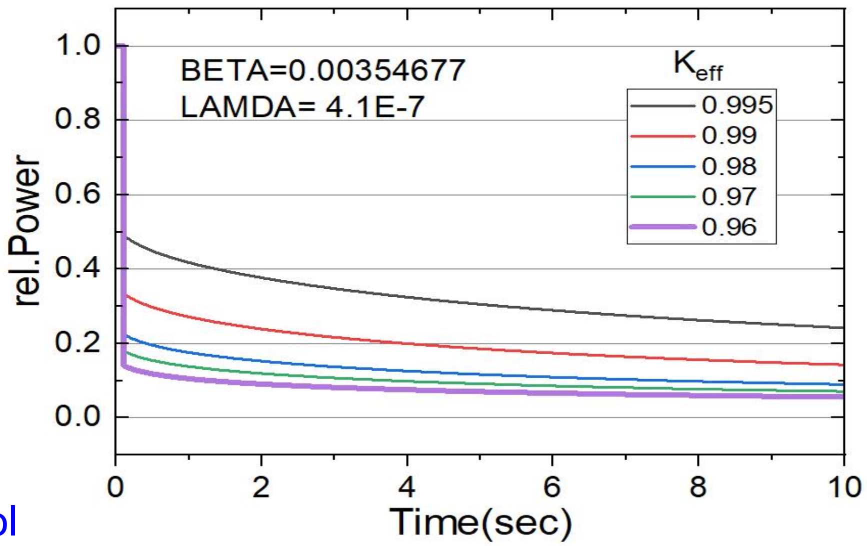
$$l = l_p + \sum_{i=1}^{6} \beta_i t_i$$

Reactivity control

◻ Subcritical reactor：

$$W_R = \frac{Q\varphi^* S_0}{\overline{\nu}} \left(\frac{K_{eff}}{1 - K_{eff}}\right)$$

External neutron source control



Subcriticality is independent of MAs content in the fuel, and reactivity is linearly related to external neutrons

The power of the critical FR is affected by the reactivity and changes exponentially after the reactivity is introduced

The ADS power is controlled by the accelerator neutron source, and the change of external neutron reactivity is linear and controllable

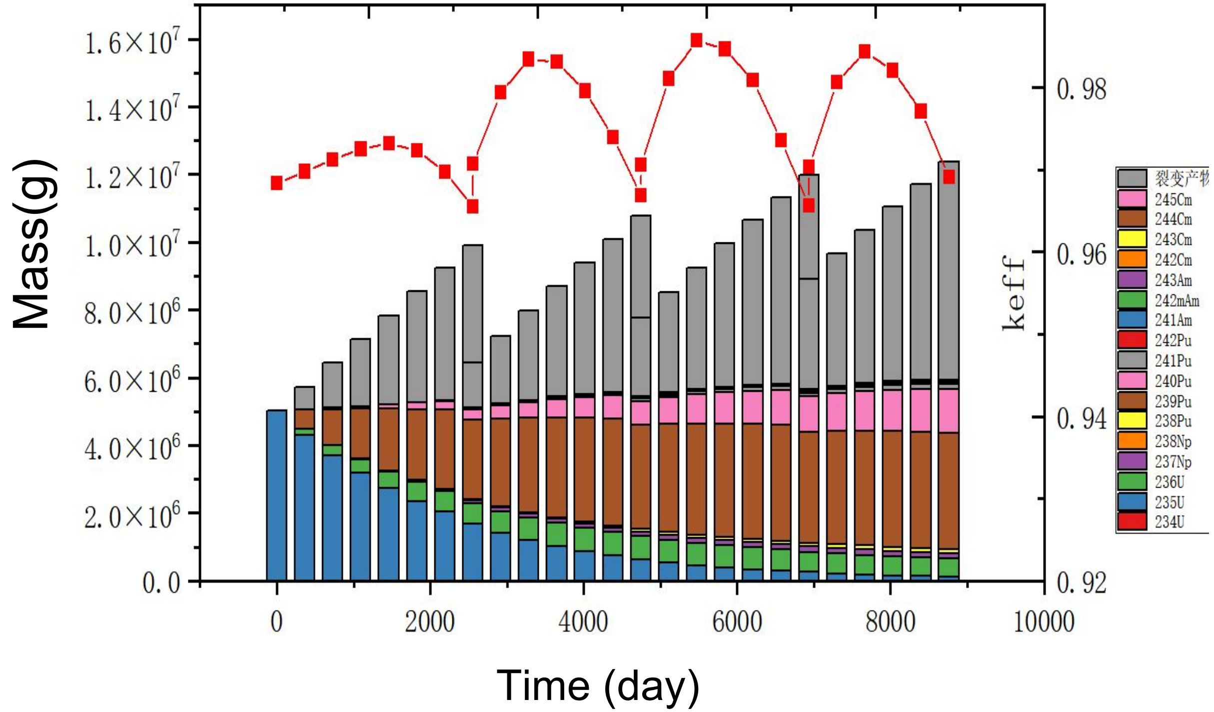
Critical reactor: Keff ~ 1, Power changes with (Keff-1) , to ensure safty, the proportion of MAs should lower than 5%

Subcritical reactor: Keff ~ 0.98, Power varies linearly with acc neutrons, the proportion of MAs is almost no limited

ADANES fuel cycle simulation

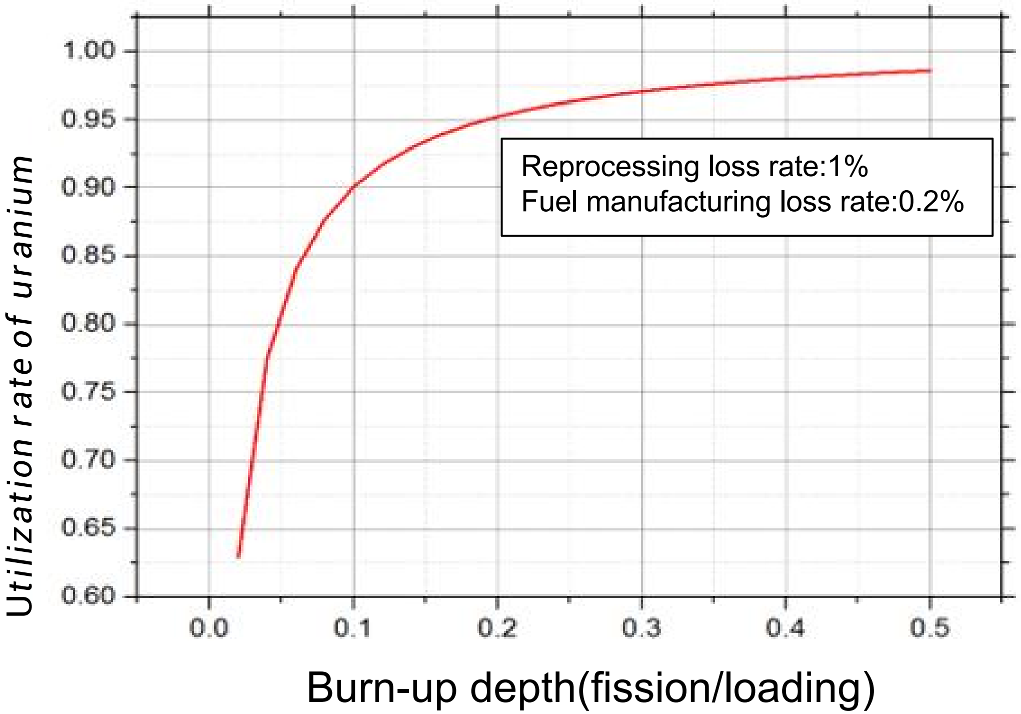
The conditions of ADANES burner : accelerator current <20mA, reactor keff <0.98

- **Preliminary reprocessing:**



- ADANES enables at least 4 fuel cycles
- The burn-up depth of a single cycle can reach 10%.
- The utilization rate of uranium resources can reach 30%

- **Advanced reprocessing:**



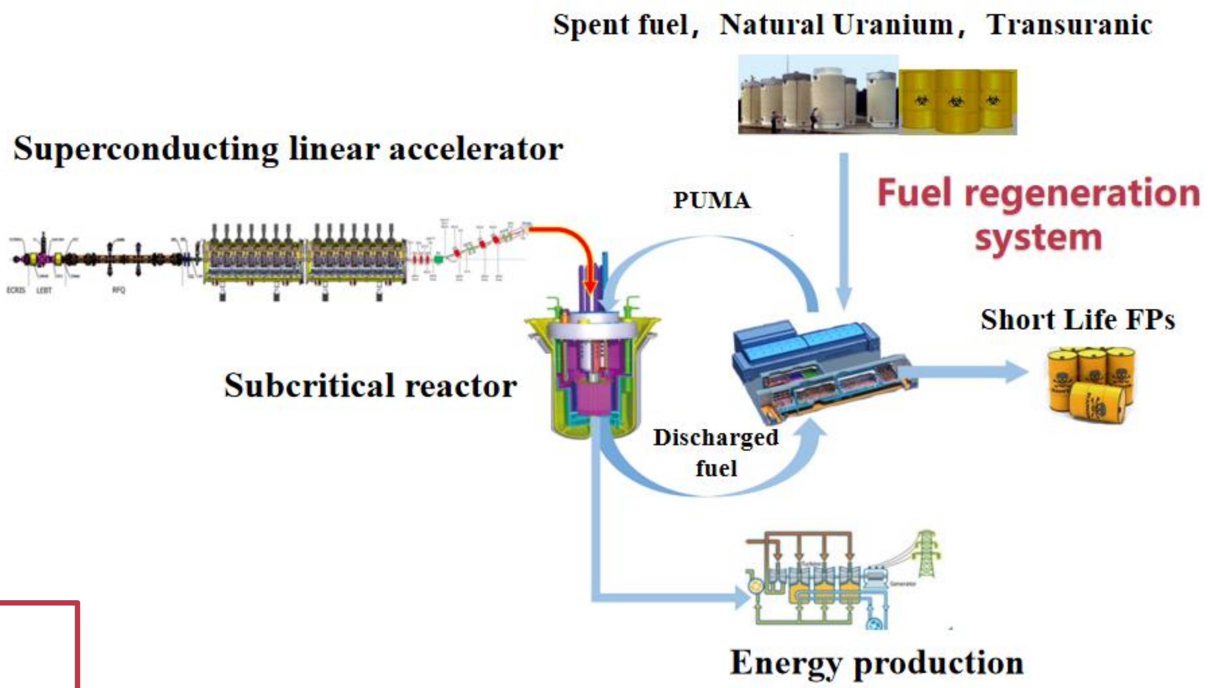
ADANES can achieve continuous fuel cycle
The burn-up depth ~10%, Uranium resource utilization ~90%
The burn-up depth ~20%, Uranium resource utilization ~95%

ADANES – a Promise Solution

To "fully" use depleted uranium, spent fuel, and "flexible" integration with the existing nuclear power industrial system

Accelerator Driven Advanced Nuclear Energy System

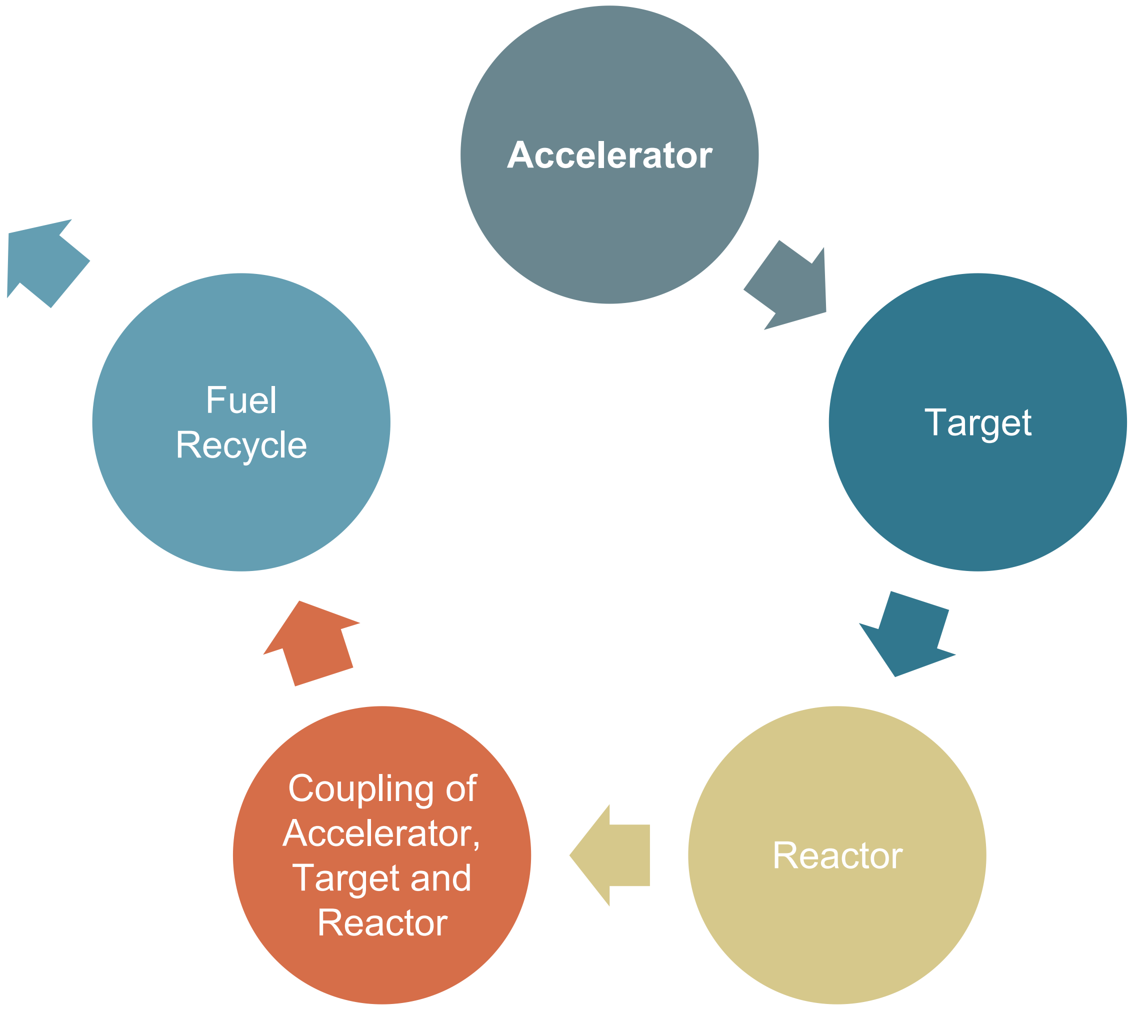
- Spent fuel reprocessing: Partially remove fission fragments from spent fuel, Mix fuel PUMA = Pu+U+MA : (**NO fine separation of uranium, plutonium, and minor actinides, even a few FP**)
- Advanced burner ADS: —— External neutron driven subcritical reactor (LFR), transmutation, breeding, and energy production



- Utilization rate of uranium resources： ~1% → ~95%
- Radioactive waste lifetime： Hundreds of thousands of years → Several hundred years
- Radioactive effluent： ~25t → ~1t（1GWe/pile year）
- Reactivity control： Critical operation → Subcritical operation

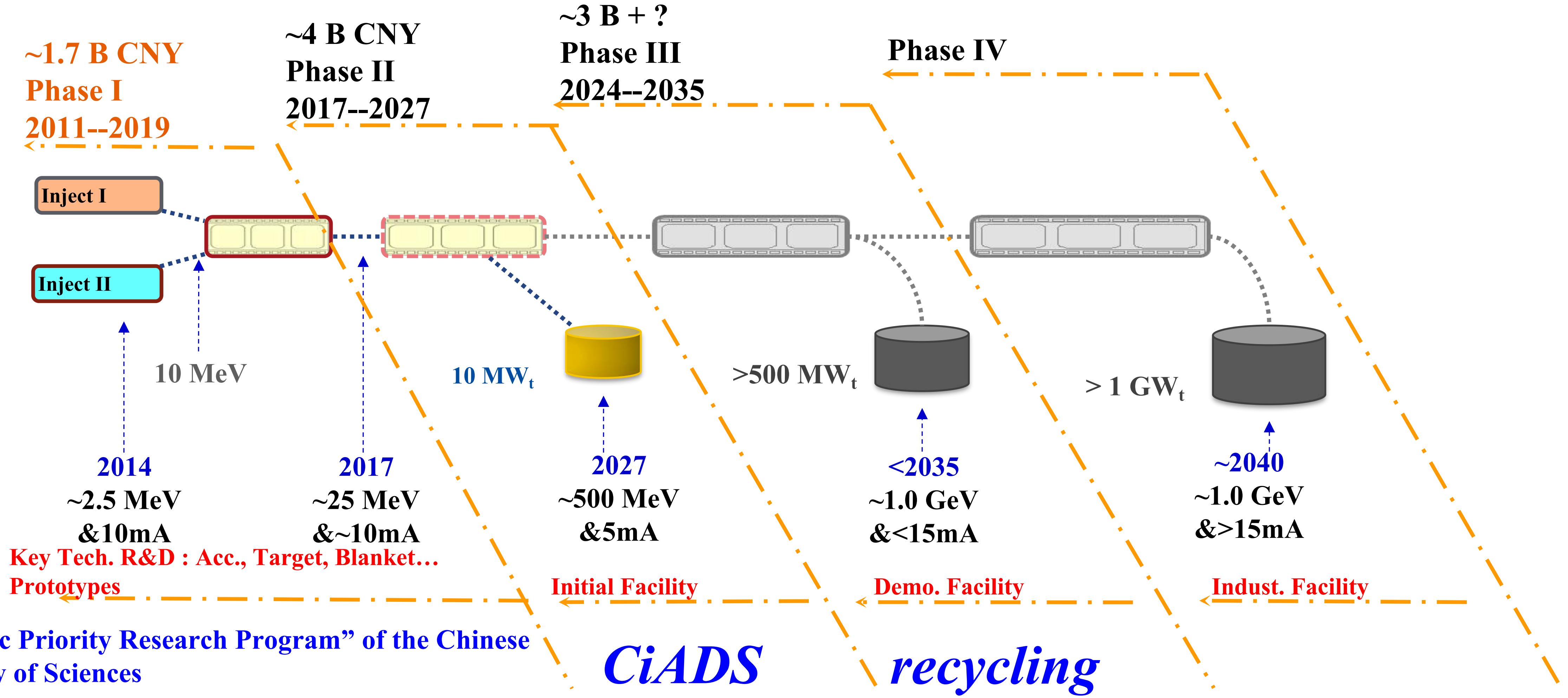
- Complete reprocess of ADANES fuel cycle
- Each time, removing the fission products, and adding spent fuel or depleted uranium

Challenges of ADANES



- **High power (tens of MW) accelerator**
  - CW beam 10-30 mA， Energy: 0.8-2 GeV
  - High availability
- **High power (tens of MW) target**
  - target window ≥ 40 dpa
  - ≥ 10-20 MW heat removal
- **Subcritical LBE reactor**
  - Fast neutron reactor
  - Material in LBE and with high dpa
- **Spent fuel reprocessing**
  - remove most of fission fragments by high temp. dry processing
  - high radiation fuel production

Roadmap of ADANES in China



"strategic Priority Research Program" of the Chinese Academy of Sciences

Phase I – China ADS Front-end (CAFe)

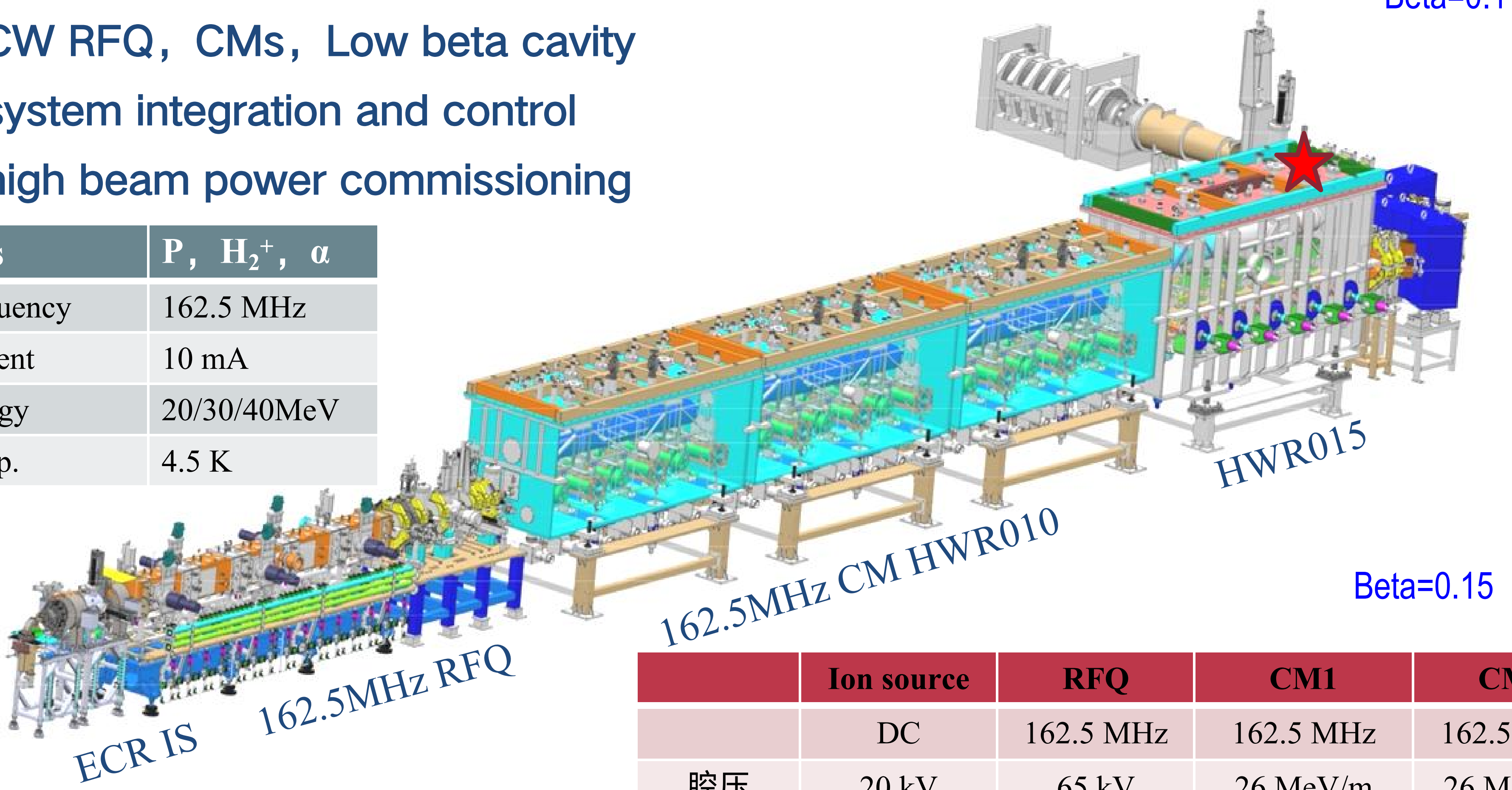
- to Demonstrated 10 mA CW proton beam:

✓ CW RFQ，CMs，Low beta cavity

✓ system integration and control

✓ high beam power commissioning

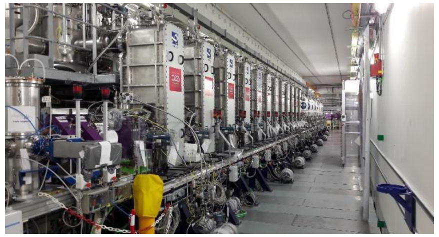
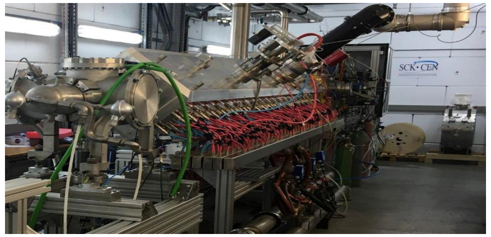
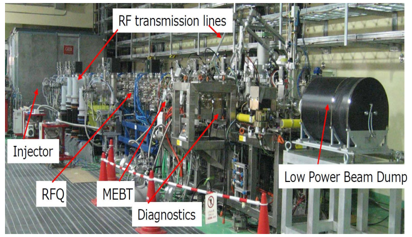
Ions	P， H_2^+， α
Frequency	162.5 MHz
Current	10 mA
Energy	20/30/40MeV
Temp.	4.5 K

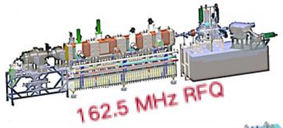


	Ion source	RFQ	CM1	CM2	CM3	CM4
	DC	162.5 MHz	162.5 MHz	162.5 MHz	162.5 MHz	162.5 MHz
腔压	20 kV	65 kV	26 MeV/m	26 MeV/m	26 MeV/m	29 MeV/m
类型	ECR	4-vane	HWR010	HWR010	HWR010	HWR015
数量	1	1	6	6	6	5

- **Supported by “Strategic Priority Research Program” of the Chinese Academy of Sciences.**

Evolution of the Demo Linac for ADS

PIPII/PXIE	EURISOL/SPIRAL2	SARAF	MYRRHA/MINERVA	IFMIF/LIPAC
				
2mA, 25MeV	5mA, 40MeV	5mA, 40MeV	4mA, 100MeV	125mA, 9MeV

1 

- ECRIS + RFQ
- Energy ~2.1 MeV
- June 06,2014, first beam

2 

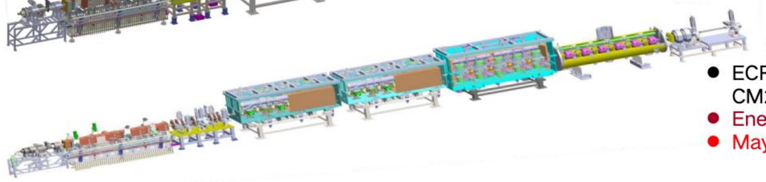
- ECRIS + RFQ + MEBT + TCM1 (single HWR)
- Energy ~2.5 MeV
- October 01,2014, first beam

3 

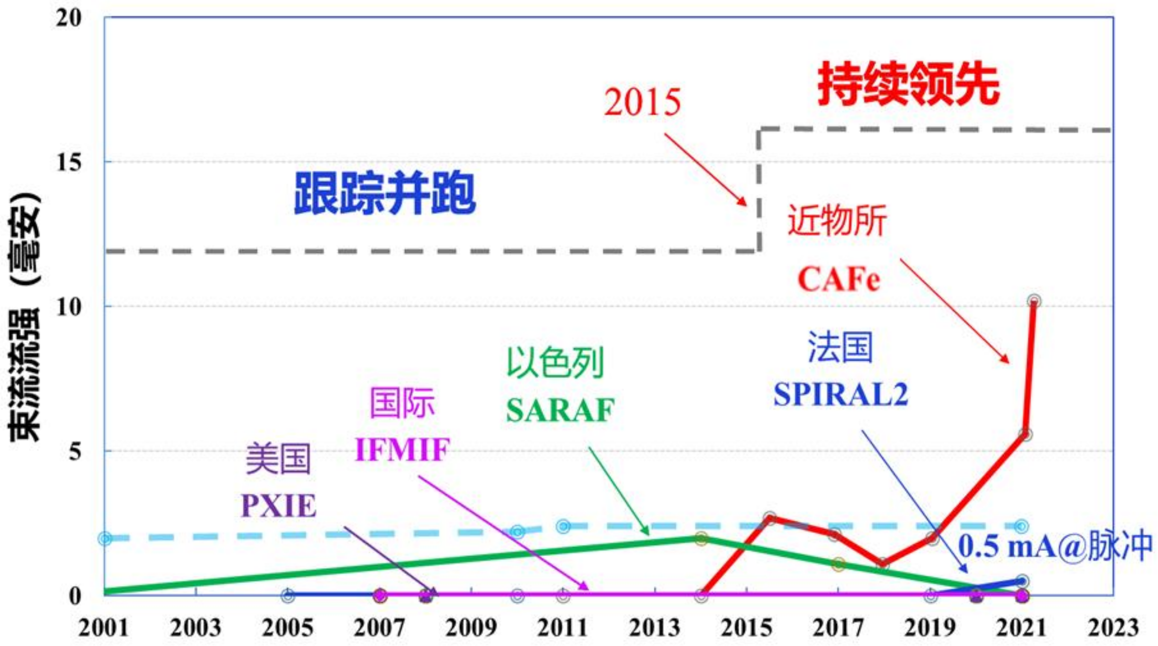
- ECRIS + RFQ + TCM6
- Energy ~5 MeV
- June 06,2014, first beam

4 

- ECRIS + RFQ + CM1 + CM2
- Energy ~10 MeV
- September 15,2016,first beam

5 

- ECRIS + RFQ + CM1 + CM2 + CM3 + CM4
- Energy ~25 MeV
- May 28,2017, first beam

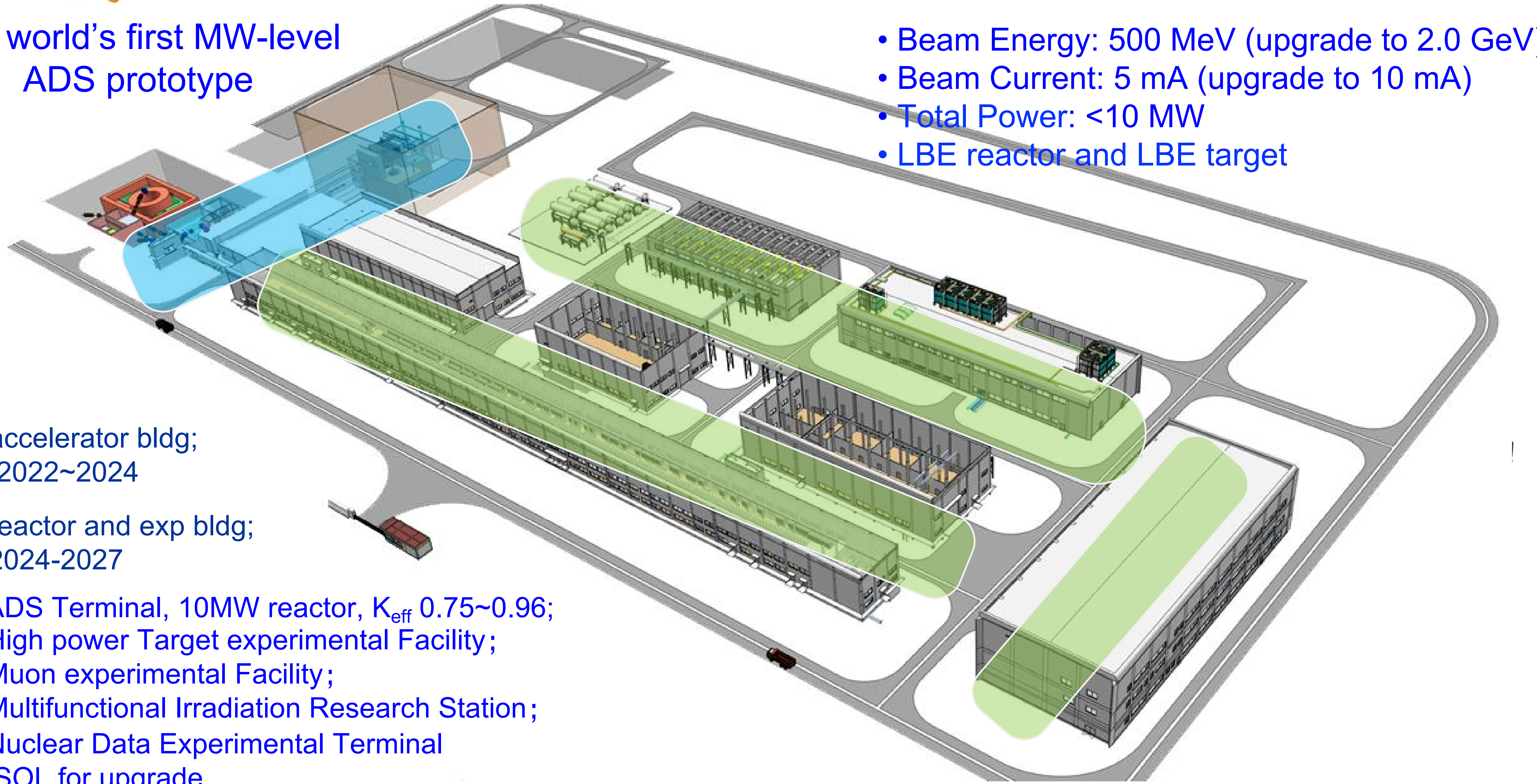


Achieved 10 mA, 20 MeV, 200 kW in 2021, the world record intensity of CW beam

Phase II - CiADS

The world's first MW-level
ADS prototype

- Beam Energy: 500 MeV (upgrade to 2.0 GeV)
- Beam Current: 5 mA (upgrade to 10 mA)
- Total Power: <10 MW
- LBE reactor and LBE target



accelerator bldg;
2022~2024

reactor and exp bldg;
2024-2027

- T1: ADS Terminal, 10MW reactor, K_{eff} 0.75~0.96;
- T2: High power Target experimental Facility;
- T3: Muon experimental Facility;
- T4: Multifunctional Irradiation Research Station;
- T5: Nuclear Data Experimental Terminal
- T6: ISOL for upgrade

Outline

- Background of CiADS Project
- Challenges and Progress of CiADS
- Background of HIAF Project
- Challenges and Progress of HIAF
- Summary and Perspective

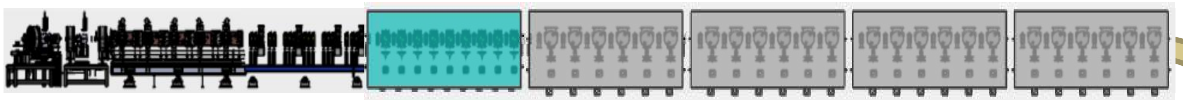
Goals and Configurations of CiADS

- CiADS is committed to the integrated coupling operation of 2.5MW accelerator, target, and reactor as a burner for ADANES.
- ADANES fuel cycle will be carried out by only removing part of the fission fragments through a simple HTD-process to obtain PUMA fuel, in order to achieve multiple cycle.
- Finally, ADANES can realized minimizing HLW accumulation and maximizing fuel utilization with other nuclear energy systems in the next hundred years.

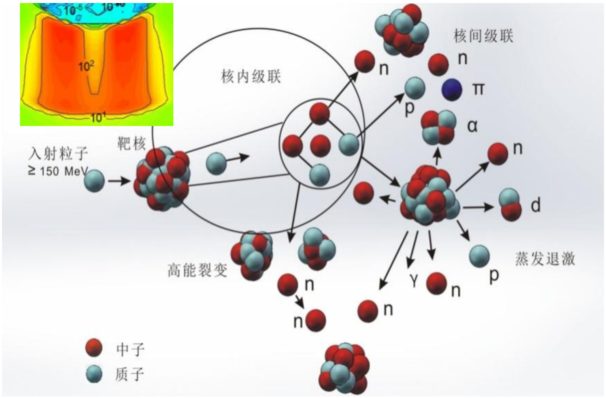
Parameter	Target	Unit
ADS		
Total power	10	MW
Designed life	20	Year
Full power time	3	Year
Proton Accelerator		
Accelerator	SC Linac	-
Beam energy	500	MeV
Beam current	5	mA
Beam power	2.5	MW
LBE Spallation target		
Neutron per proton	9	n/p
Tolerable beam power	2.5	MW
LBE subcritical reactor		
^{235}U enrichment of fuel	19.75<	wt%
k_{eff}	0.75~0.975	-
Reactor power	7.5~9.75	MW

Concept drawing of CiADS

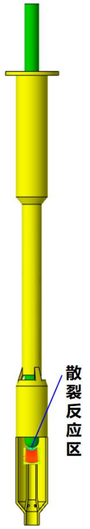
600 MeV, 5 mA, proton



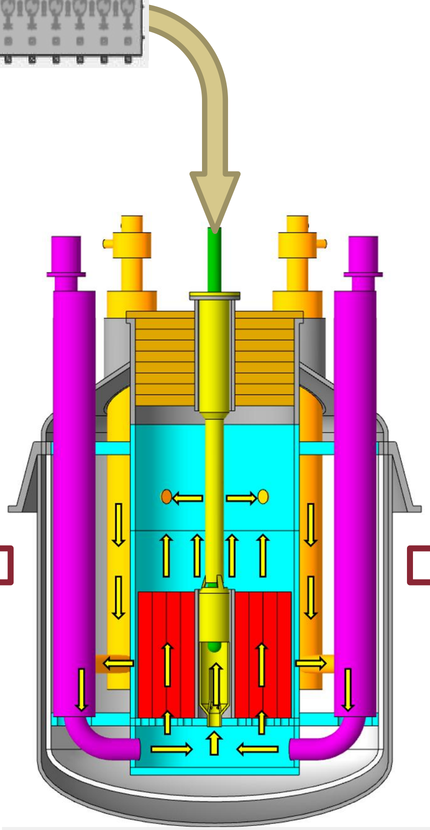
Accelerator



Spallation Reaction

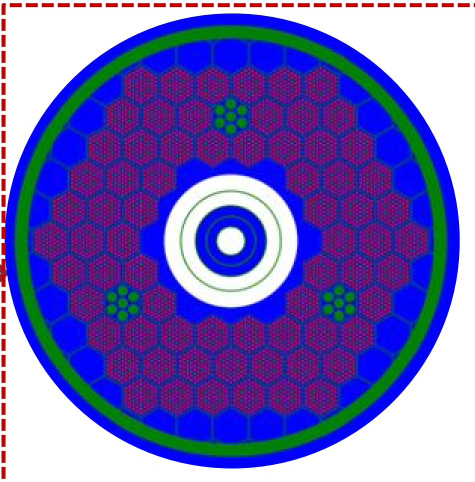


Spallation Target

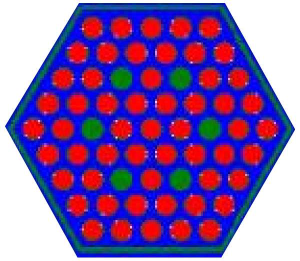


Sub-critical Reactor

Transmutation



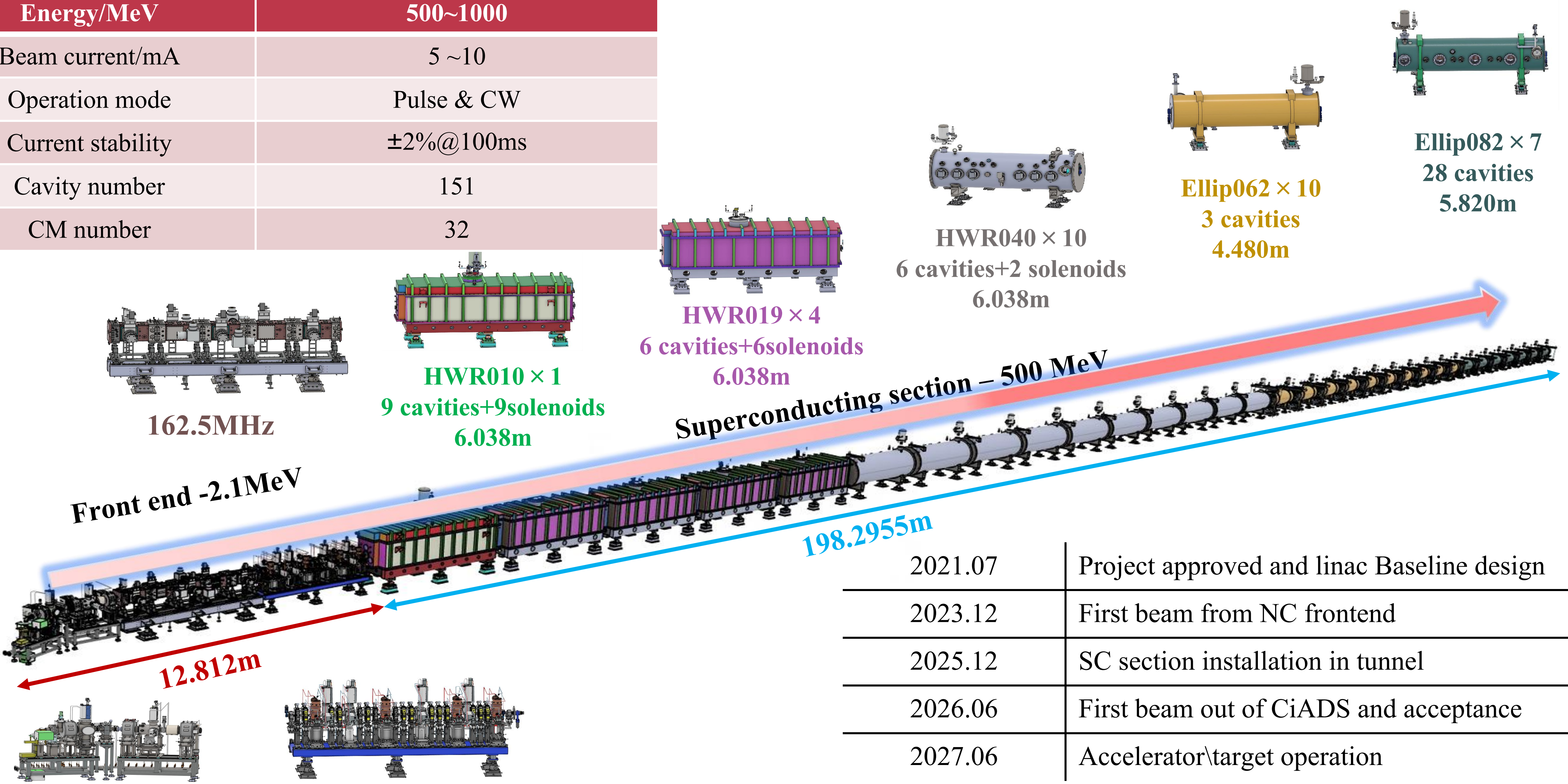
Core



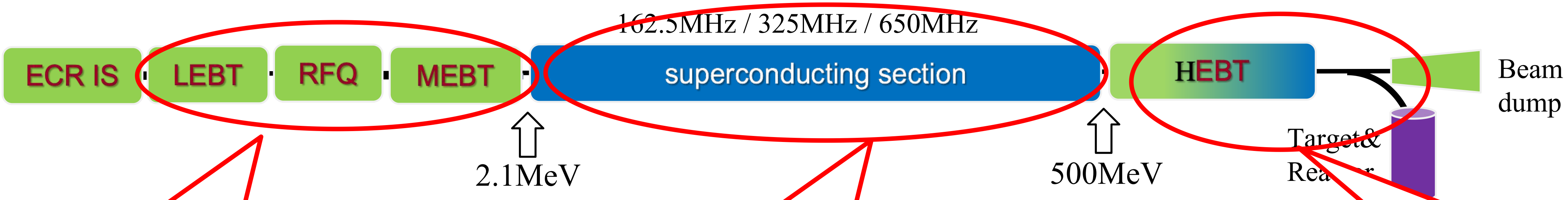
Spent fuel

Superconducting Lianc for CiADS

Energy/MeV	500~1000
Beam current/mA	5 ~10
Operation mode	Pulse & CW
Current stability	±2%@100ms
Cavity number	151
CM number	32



2021.07	Project approved and linac Baseline design
2023.12	First beam from NC frontend
2025.12	SC section installation in tunnel
2026.06	First beam out of CiADS and acceptance
2027.06	Accelerator\target operation

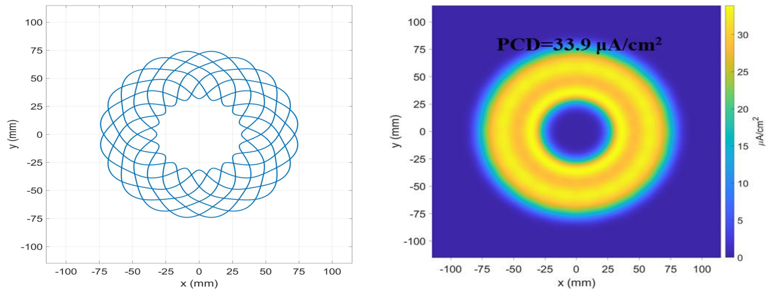


Beam quality | **Beam loss** | **Beam uniform**

- **LEBT：**Transverse beam quality control- Bend structure + beam scraping
- **RFQ ：**Longitudinal beam quality control- Full particle optimization
- **MEBT:** Beam halo control- Full space scraping

- **Low beam loss control**
  - ✓ **Lattice optimization** compact qusi-periodic structure and periodic lattice
  - ✓ **Beam matching** for mitigating halo formation and beam emittance growth
  - ✓ **Beam halo collimation** to reduce the probability of beam loss on SC elements

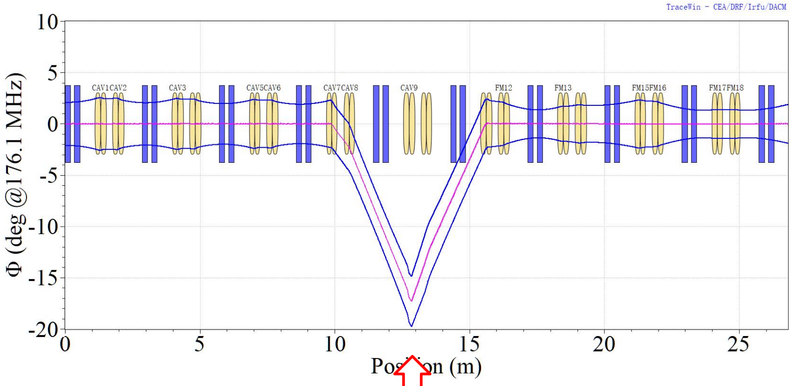
- **Beam uniformity by Multi order Sine wave scanning**
  - Fourier harmonic superposition based on scan magnets
  - Fourier harmonic superposition based on RF cavities

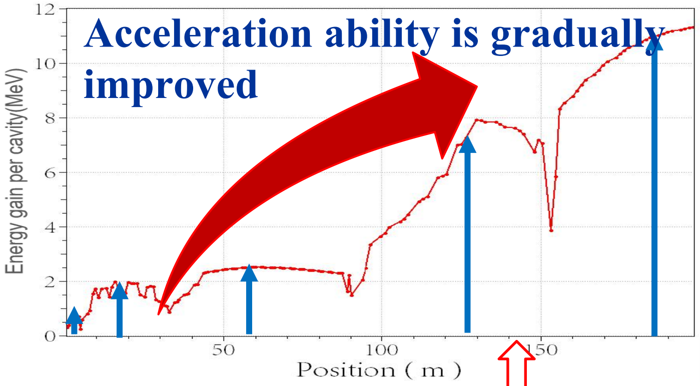


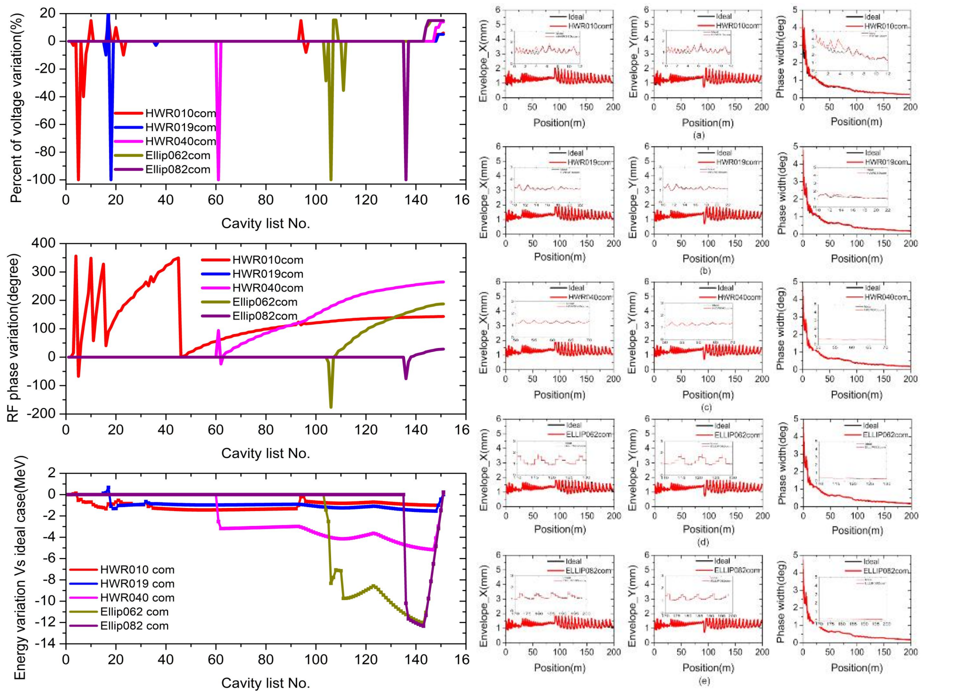
Fault recovery scheme

Rematch twiss parameters to avoid beam loss at the location where the failure occurred by adjusting the neighboring cavities and magnets of the failure cavity

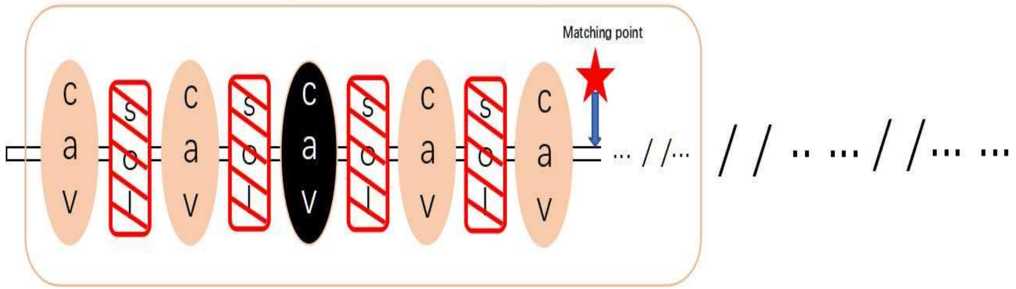
It is more effective to achieve energy compensation by cavities in the high energy part because of the greater acceleration capability of the high beta cavity



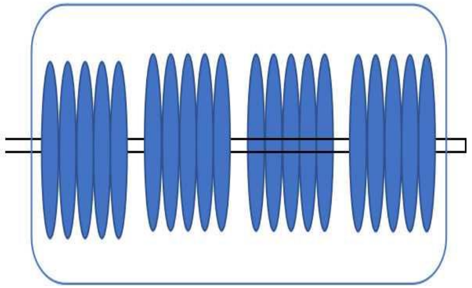


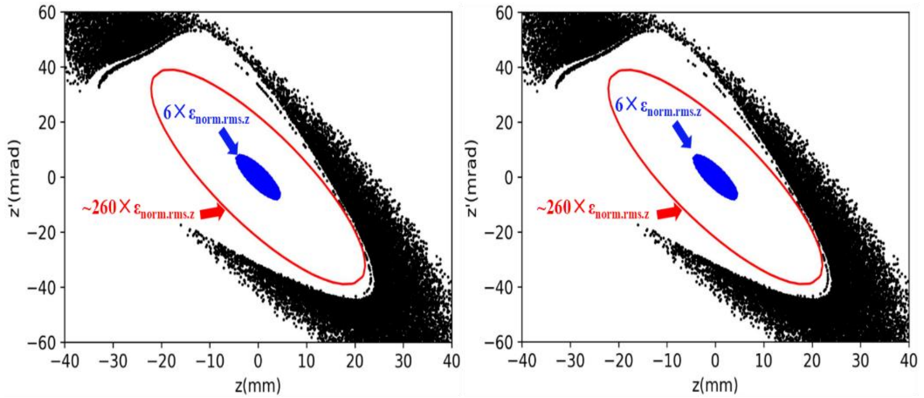


Twiss parameters matching



Energy compensation

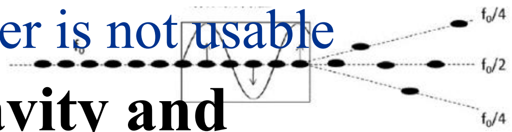




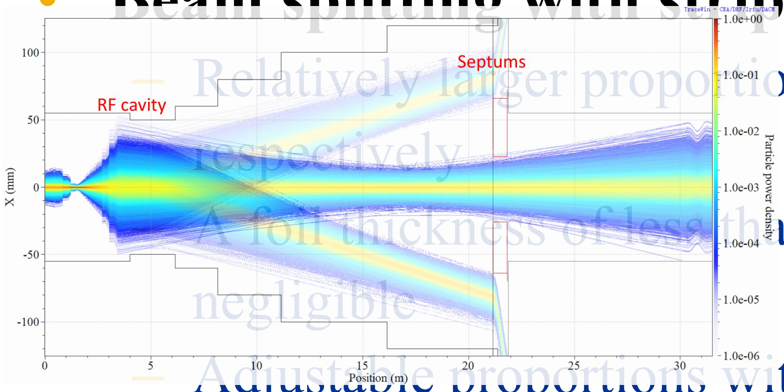
Multi terminal beam delivery

Beam splitting requirement and difficulty

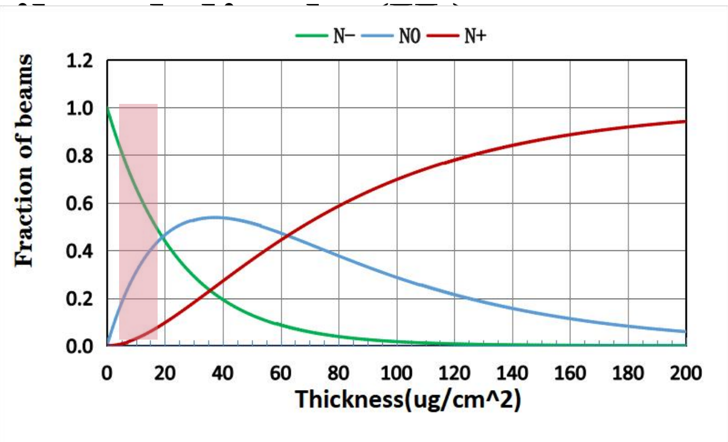
– Different terminals in experimental hall: HiTa/MIRS/NDET/MuST
– High power (2.5 MW) CW proton beam, kicker is not usable



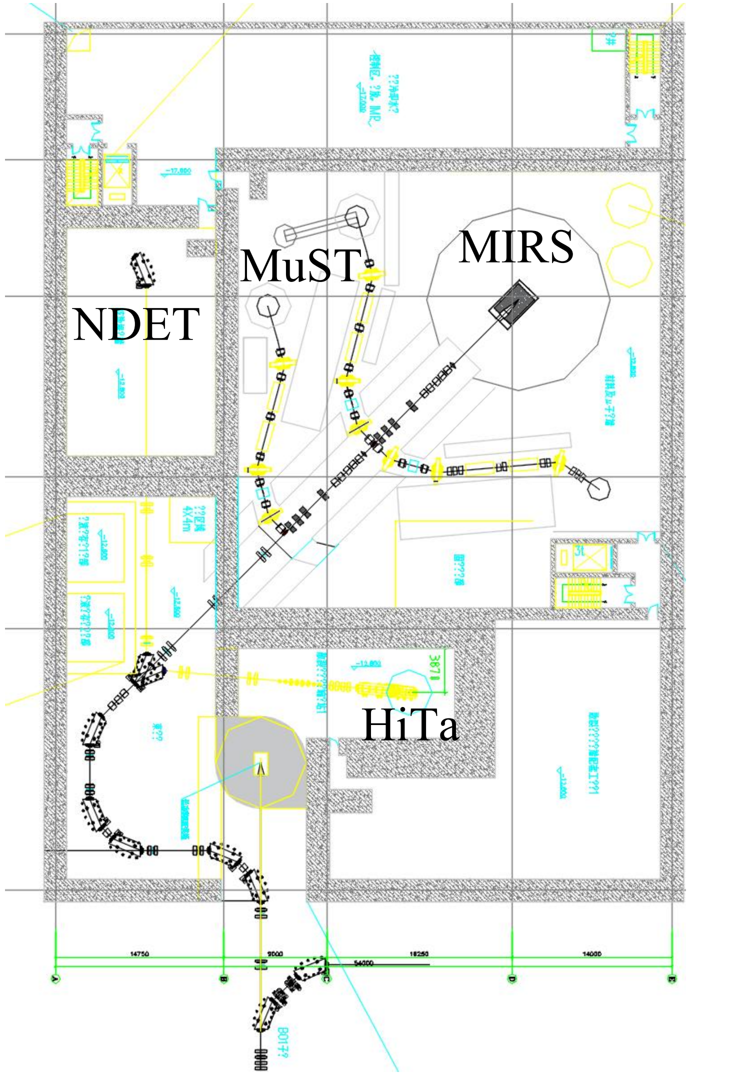
- **Beam splitting with transverse field RF cavity and septums**
  – Based on 162.5 MHz beam bunch and time structure
  – RF cavity for preliminary kicker + Septum for secondary kicker
- **Beam splitting with stripping fo**
  – Relatively larger proportions of H+
  respectively
  – A foil thickness of less than 0.1 μm
  negligible
  – Adjustable proportions with a diff



Beam splitting with RF cavity and septums



Beam splitting with stripping foil

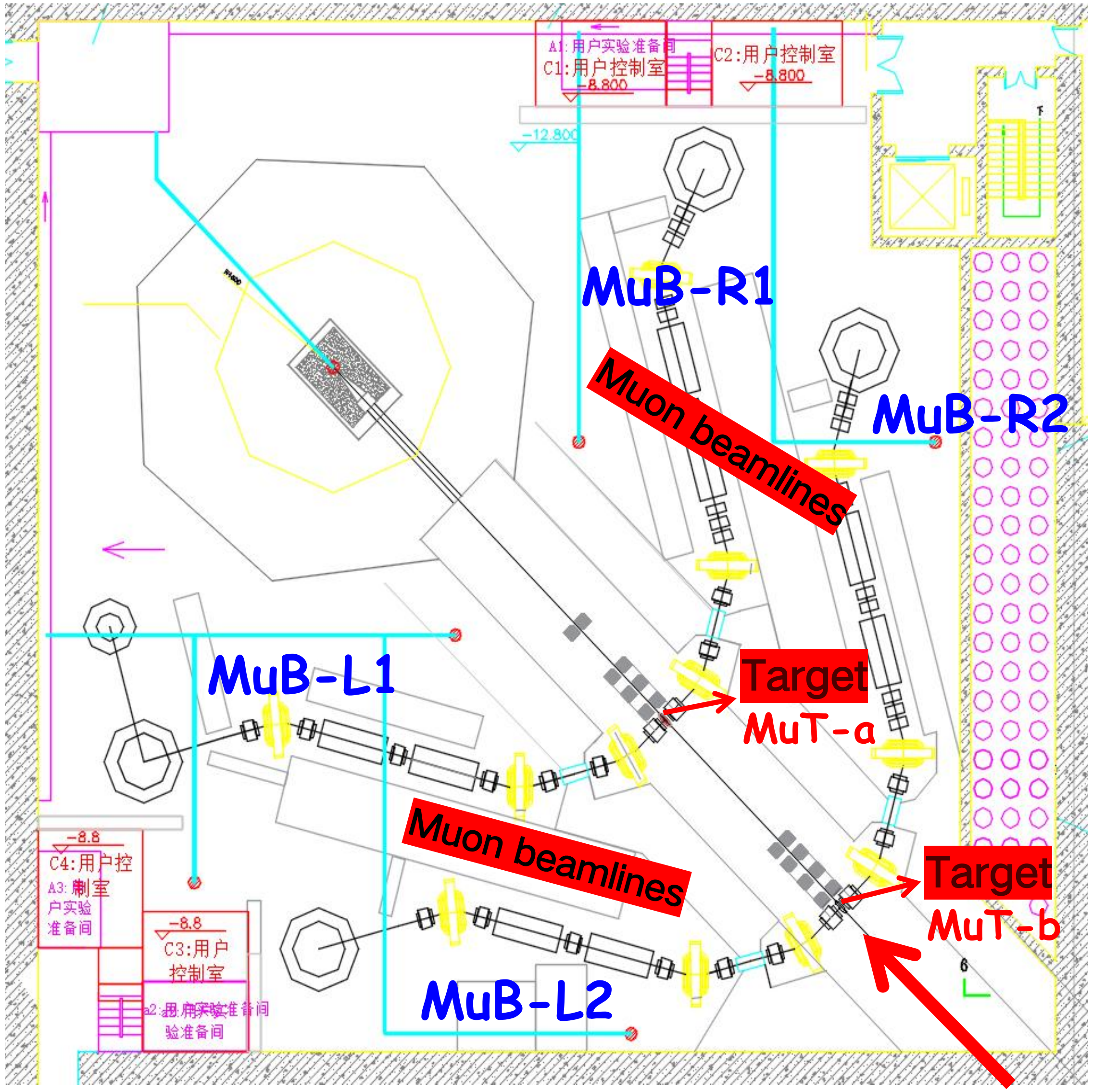


Experimental hall layout

The plan of CiADS muon source (MuST)

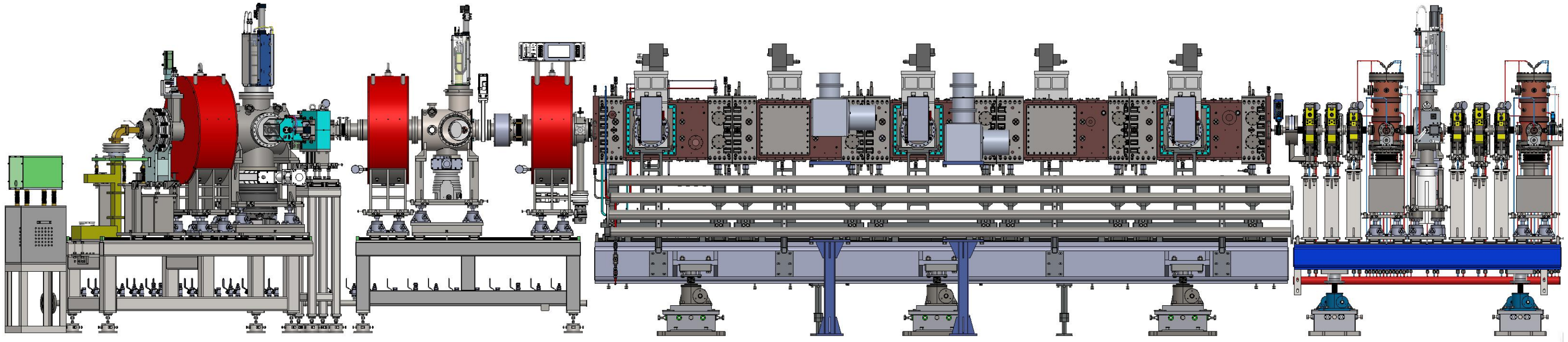
- **Muon terminal area: ~800 m²**
- **Construction plan of 2 phases**
  - Phase I (2025–2028): one target station (300 kW), two muon beamlines
  - Phase II (2029–2032): Add one additional target station and two beamlines, power upgradable to 3 MW
- **Design goals:** capable of alternating global leadership with PSI in key performance metrics

Beam power	Target	Focusing method	Muon intensity (μ^+/s)
1st phase 300 kW	Graphite rotating target	Solenoid + quadrupole	> 1E8
		Full solenoid	> 5E8
2nd phase 3 MW	Liquid lithium target	Solenoid + quadrupole	> 2E9
		Full solenoid	> 1E10



RT Front-end

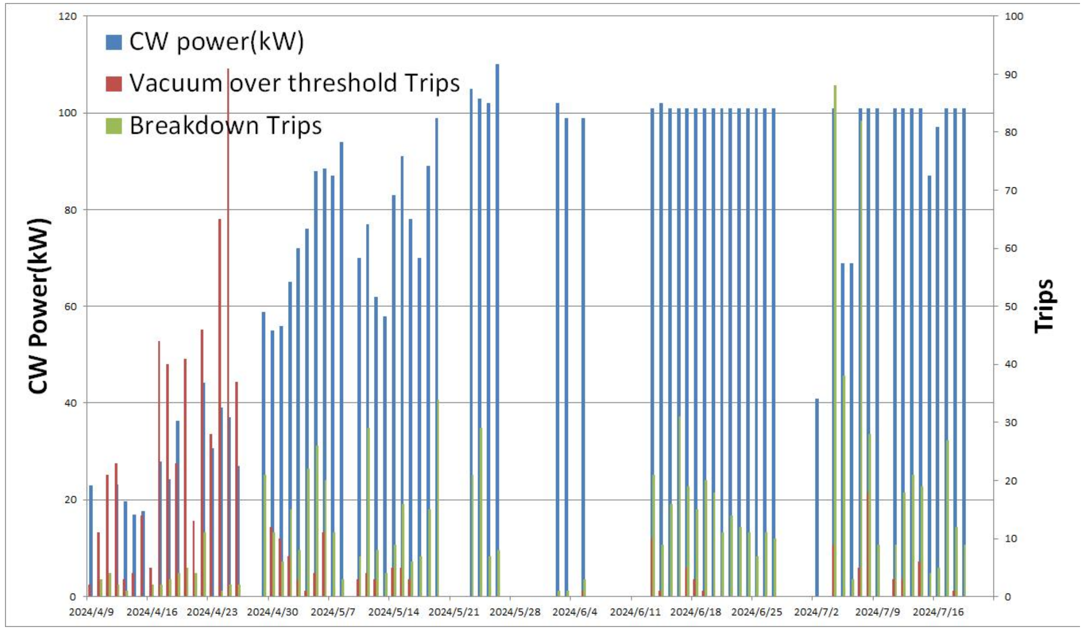
- **First beam at 2023, test-MEBT update and systematic commissioning at 2024, completed installation**



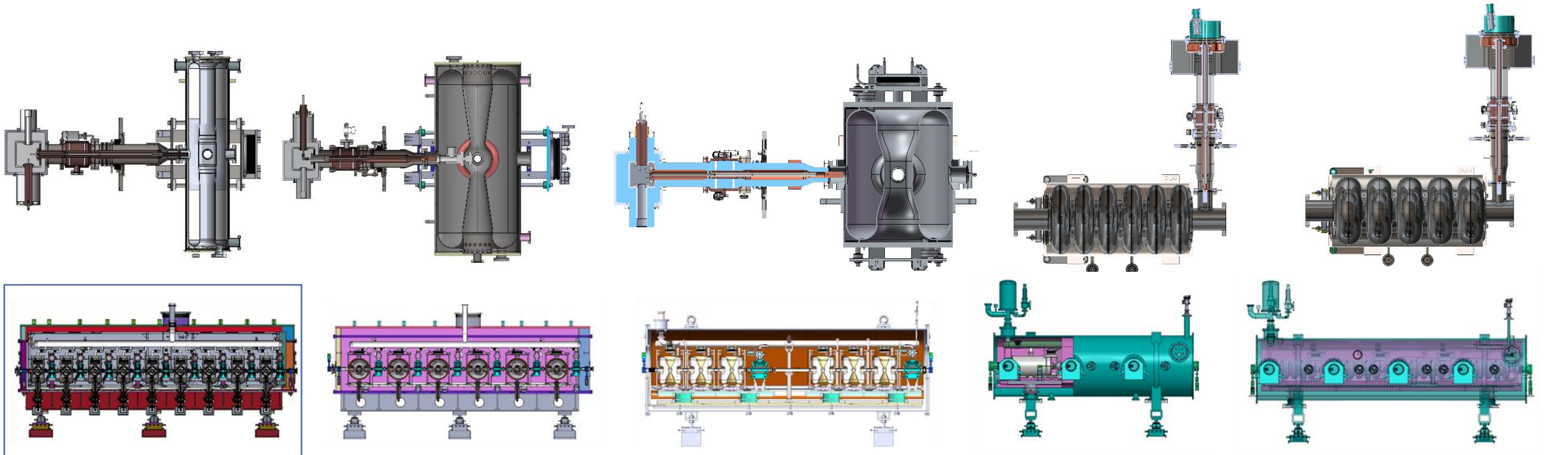
IS+LEBT RFQ Test-MEBT

Beam parameters

Parameters	data	unit
Particle	H^+	-
Energy	2.1	MeV
Current	5	mA
Frequence	162.5	MHz
Opration mode	Pulse/CW	-



High Stability of SRF



CM010
HWR cavity, beta= 0.10

CM019
HWR cavity, beta= 0.19

CM040
HWR cavity, beta= 0.40

CM062
Elliptical cavity, beta= 0.62

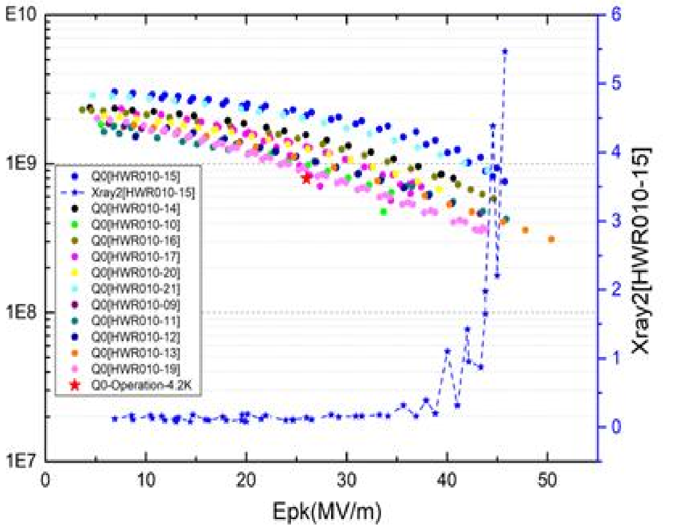
CM082
Ellipticalcavity, beta= 0.82

- Total 151 superconducting cavities with five cavity types for the CiADS linac
  - HWR010(9)/HWR019(24)/HWR040(60) & Elliptical062(30)/Elliptical082(28)
- The baseline Bulk niobium cavities show promising results
  - Prototype meets the requirement of operation at 2K
- Cu/Nb Composite Cavity as an alternative choice for 4.2K operation
  - Thermal stability, Mechanical stability

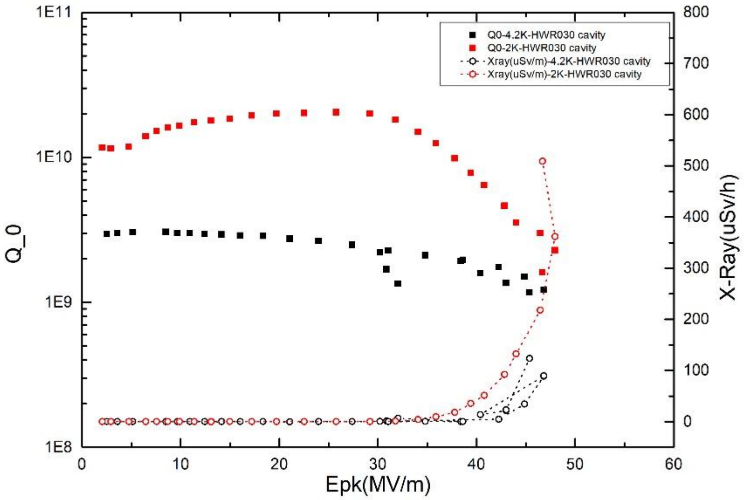
Bulk Niobium SC Cavities

- **Bulk niobium cavities have entered batch manufacturing stage**

1) All the HWR010 cavities has been fabricated,   ready for hotizontal testing in CM
2) The HWR019 cavity is in mass production
3) The prototype of 325MHz HWR shows the vertical testing result achieving the nominal specification
4) The elliptical prototype has been manufactured, prepared for VT



HWR010 test result at 4.2K



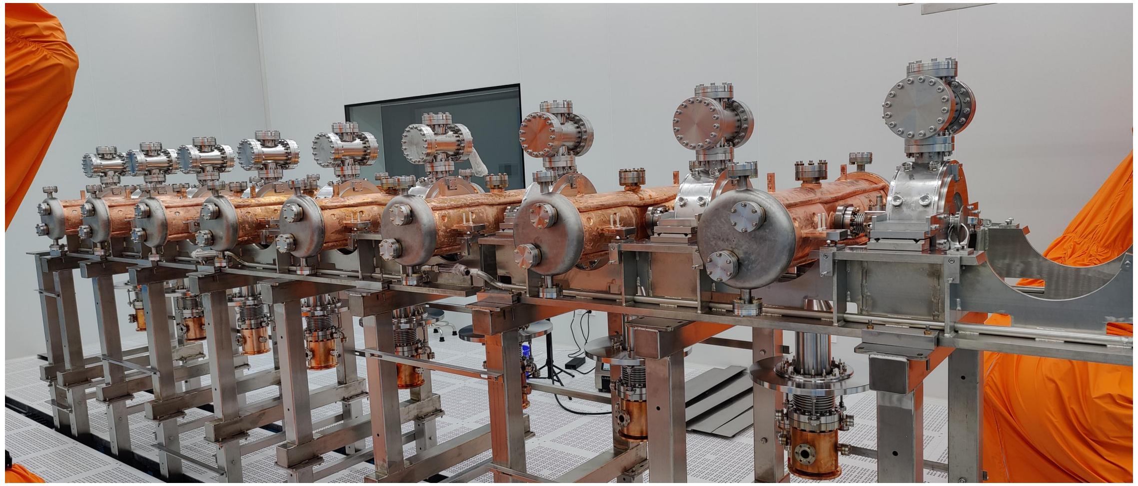
Prototype of medium beta HWR 040 and test result

Prototype of elliptical cavity

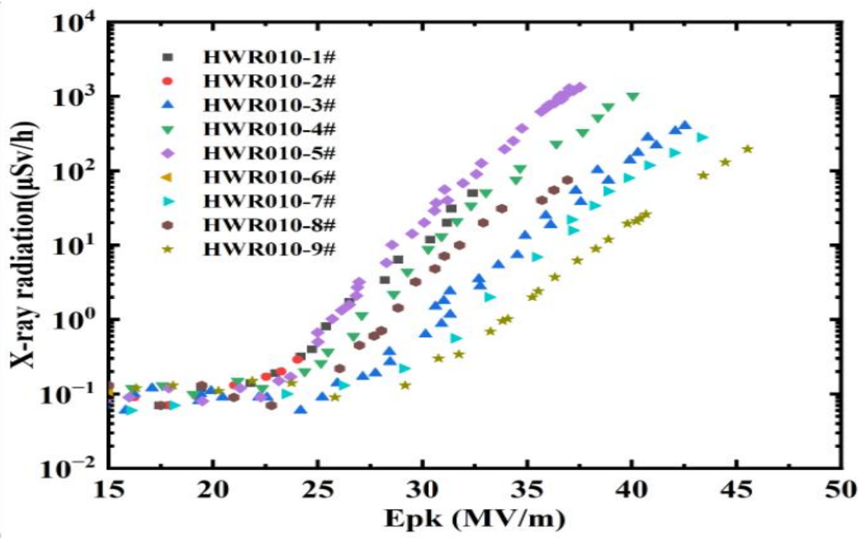
Nb/Cu Composite SC Cavities

- **Preliminary cryogenic results indicate mechanical stability**

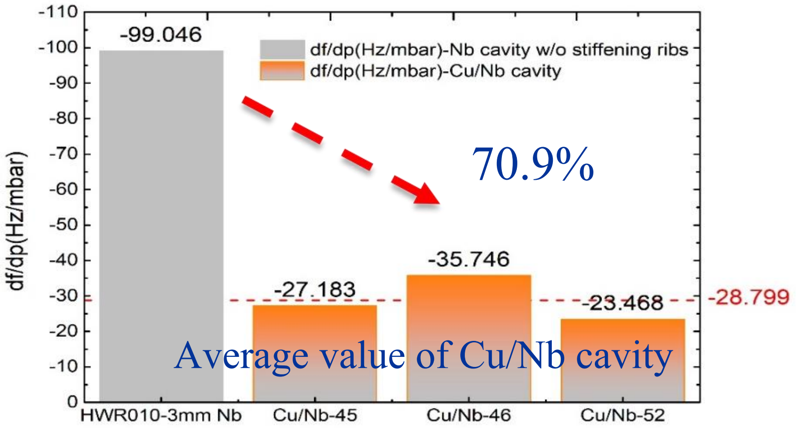
1) Cu/Nb structure: 1mm Nb+5 mm Cu ;
2) Surface treatment: 30 μm BCP, 380℃/2.5 hours heat treatment for stress relief of copper, 30 μm BCP, HPR, 120 ℃ /48 hours in clean room;
3) Slow cooling at T_c crossing of niobium adopted, ambient magnetic field < 10 mG;
4) Q_0 vs. E_{pk} at 4.2K meets the operation requirement;
5) Df/dp improved by 70.9% ;
6) LFD coeff. improved by 76.8%.



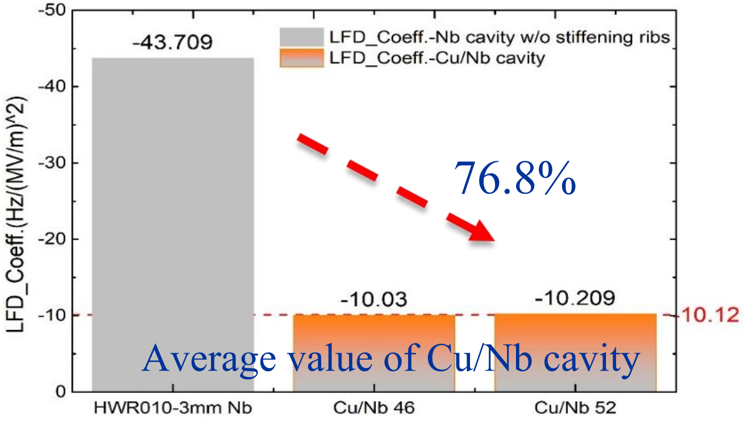
The assembled 9 HWR010 Cu/Nb cavities string



X-Ray vs. Epk



df/dp comparison between Nb cavity w/o stiffening ribs and Cu/Nb cavity



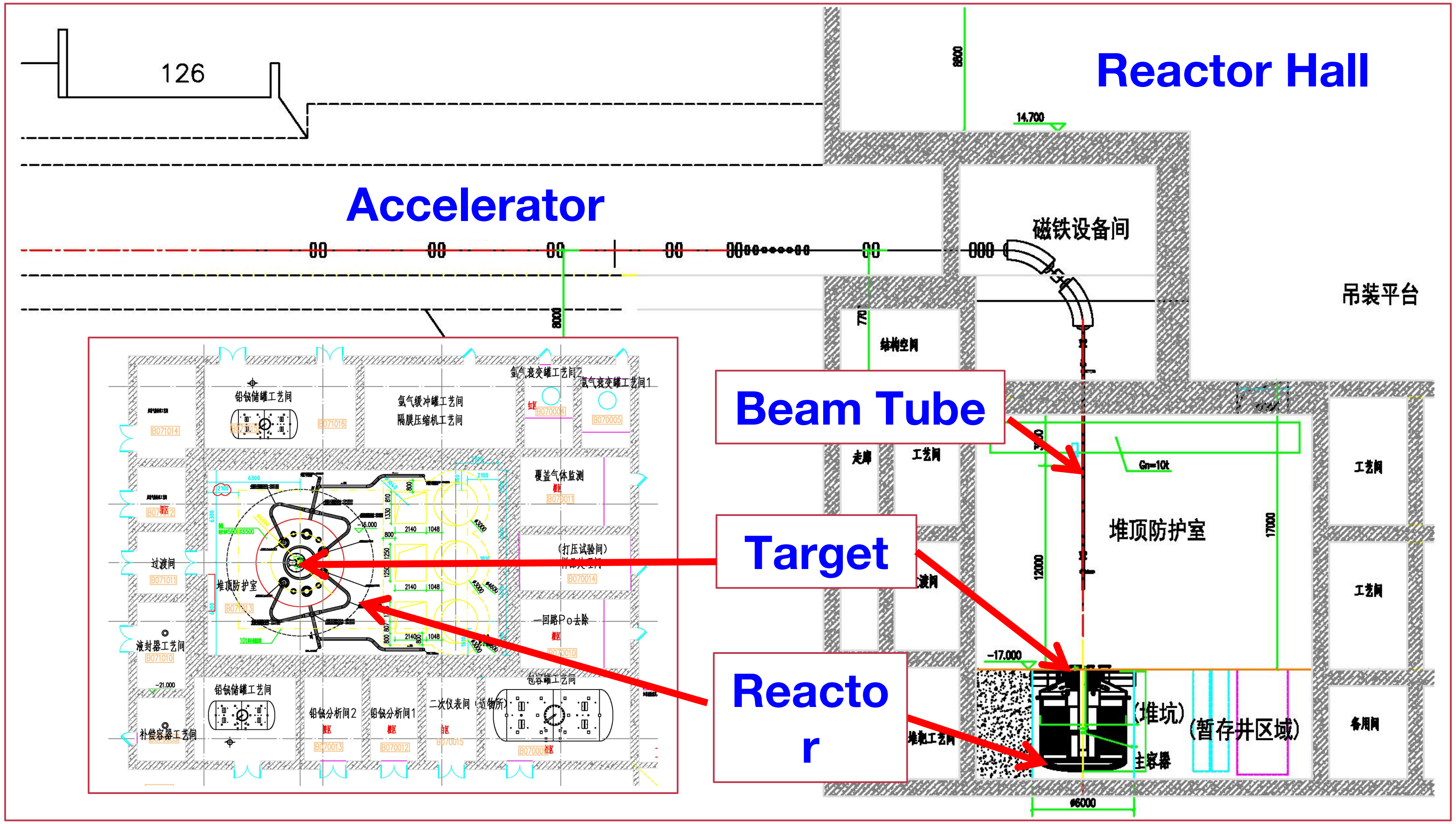
LFD coeff. Comparison between Nb cavity w/o stiffening ribs and Cu/Nb cavity

Cryogenic Plant

2.5 kW 4K (2K) system for CM testing is commissioning

18kW 4K (2K) system is delivery

distribution system for CM testing

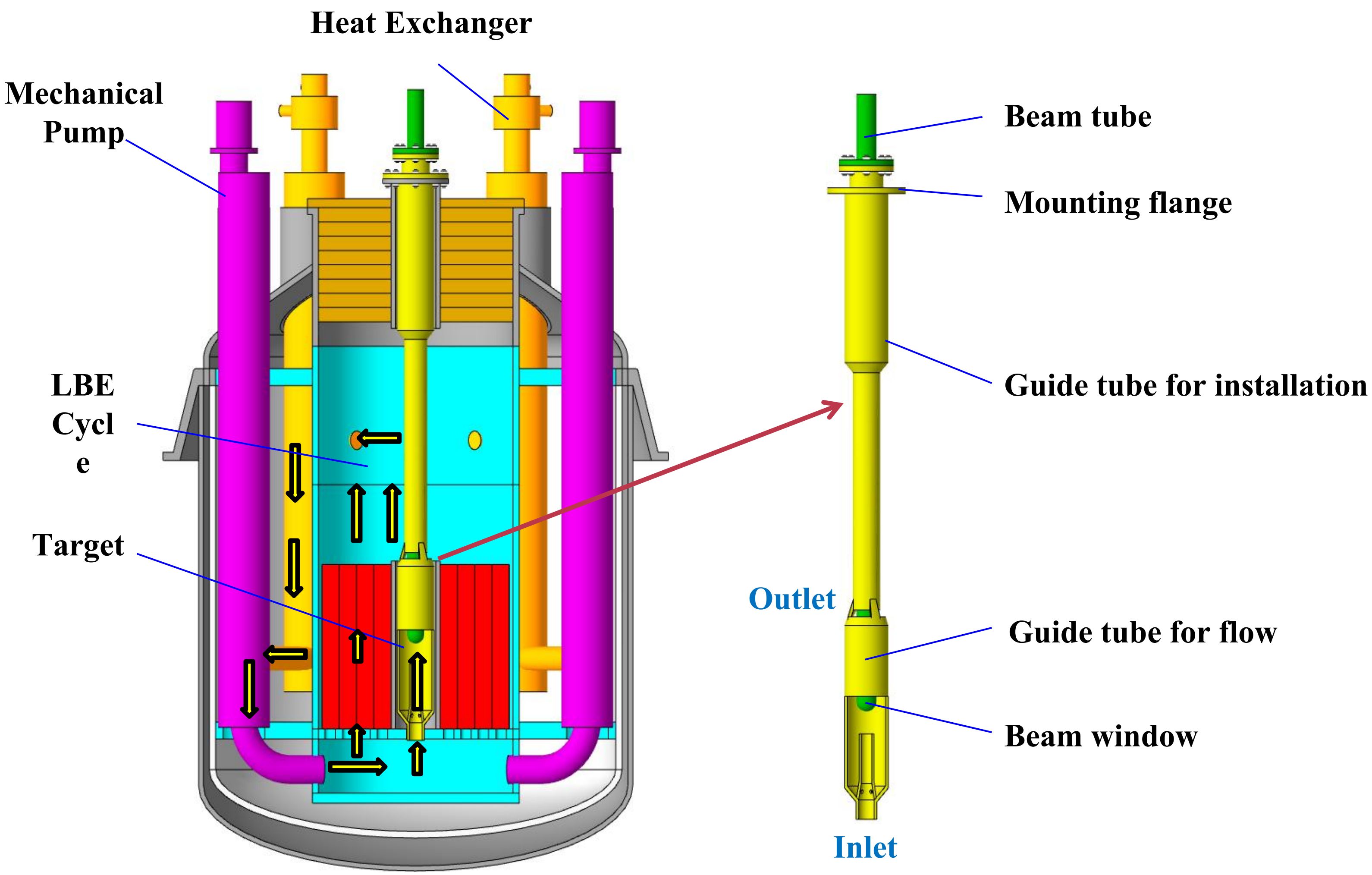


Top View

Side VieW

Main parameters of CiADS	
Thermal Output	10 MW
Linear Accelerator	
Beam	Proton
Energy	500 MeV
Max. Current	5 mA
Max. Beam Power	2.5 MW
Pulse	CW
Spallation Target	
Target Meterial	LBE
Power	2.5 MW
Sub-critical Reactor	
Primary Coolant	LBE
Power	7.5 MW

Target and Reactor Coupling



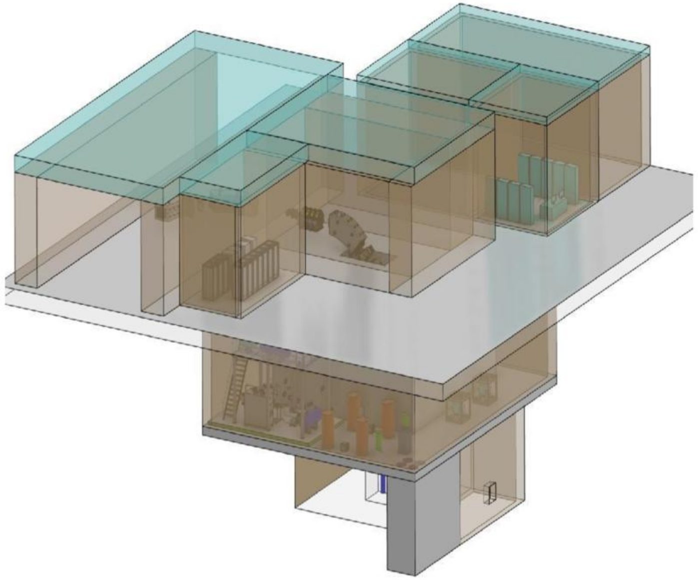
Reactor **Target**

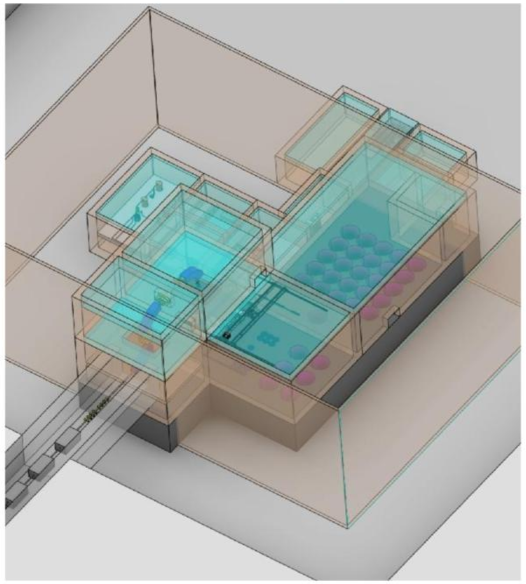
Structural features:

- The target is fixed with the reactor vessel by a mounting flange.
- The beam tube is fixed with the guide tube and connected with accelerator.
- The beam tube can be replaced separately.
- The bottom of the guide tube is constrained its radial position by the grid plate.

Planning of Spallation Target

2022年	2023年	2026-2027年	2028-2030年
Prototype Target	BW Test Loop (140 W)	On-Beam Test Target (250 kW)	Target in Reactor (2.5 MW)





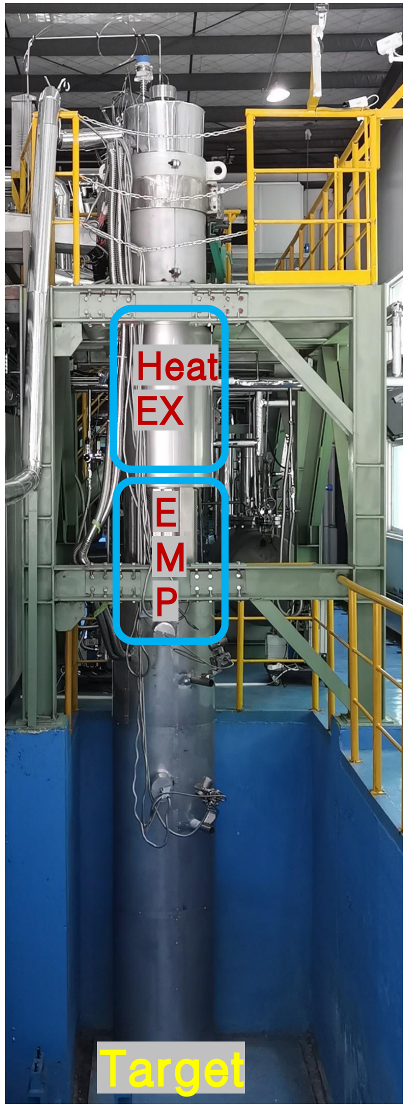
2022年 – Prototype Target
- Off-line test
- System reliability

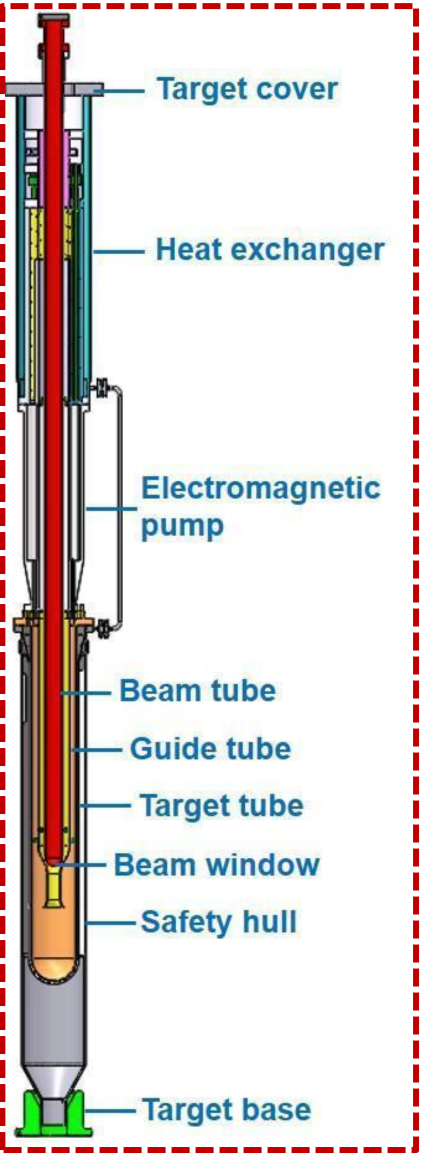
2023年 – BW Test Loop (140 W)
- Coulpled with Linac
- Estimation of Beam Window (BW)

2026-2027年 – On-Beam Test Target (250 kW)
- Accelarator-Target couple tech.
- Various target techniques

2028-2030年 – Target in Reactor (2.5 MW)
- Accelarator-Target-Reactor couple tech. (CiADS: 10MW)

Prototype1: Prototype Target System





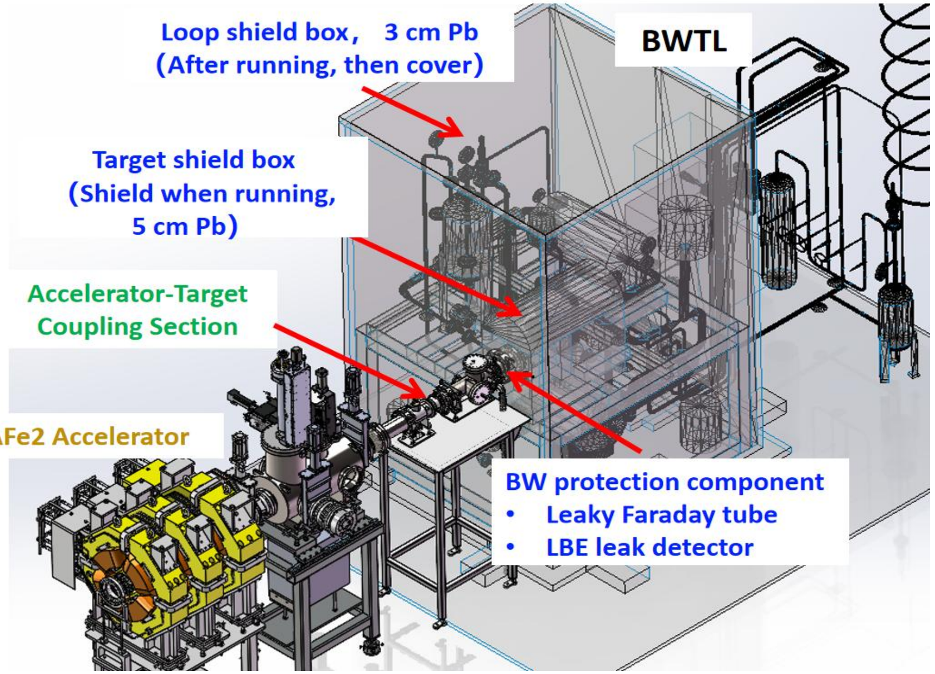
Verification:

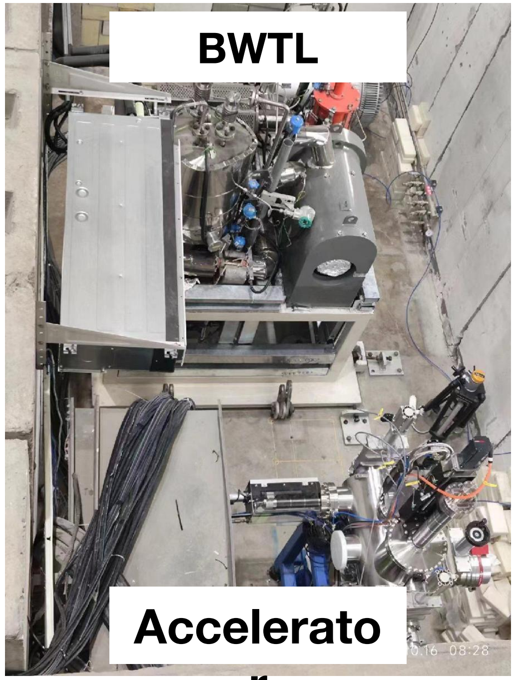
- NOT coupling with accelerator
- Thermal design verification, providing experimental data for subsequent optimization design of the target system
- Process feasibility and reliability verification
- Performance and operational stability testing of key components
- Exercise the operation process and maintenance techniques

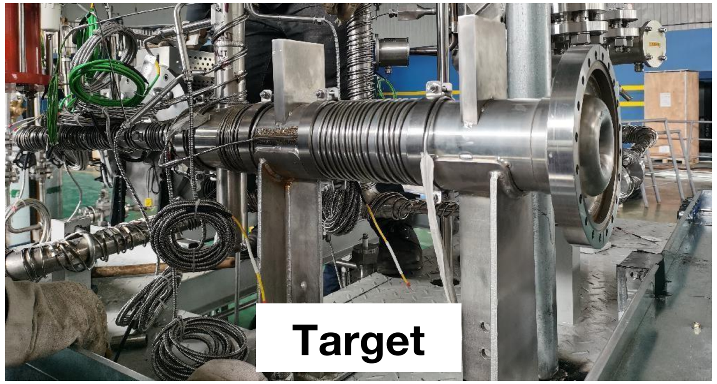
Status:

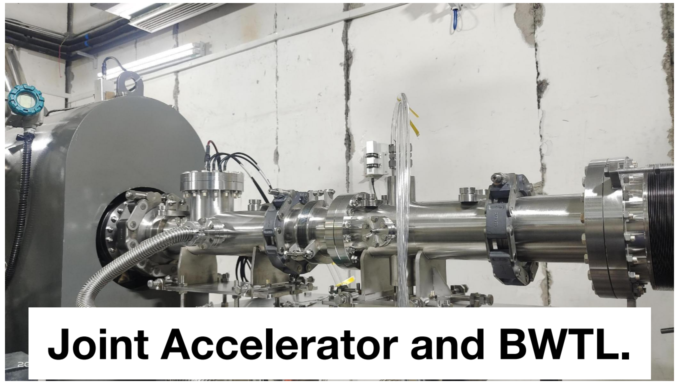
- The target has been installed in Aug. 2022.
- Testing experiments have been performed since Sep. 2022,
- Running time overed 800 hrs.

Prototype2: Beam Window Test Loop (BWTL)









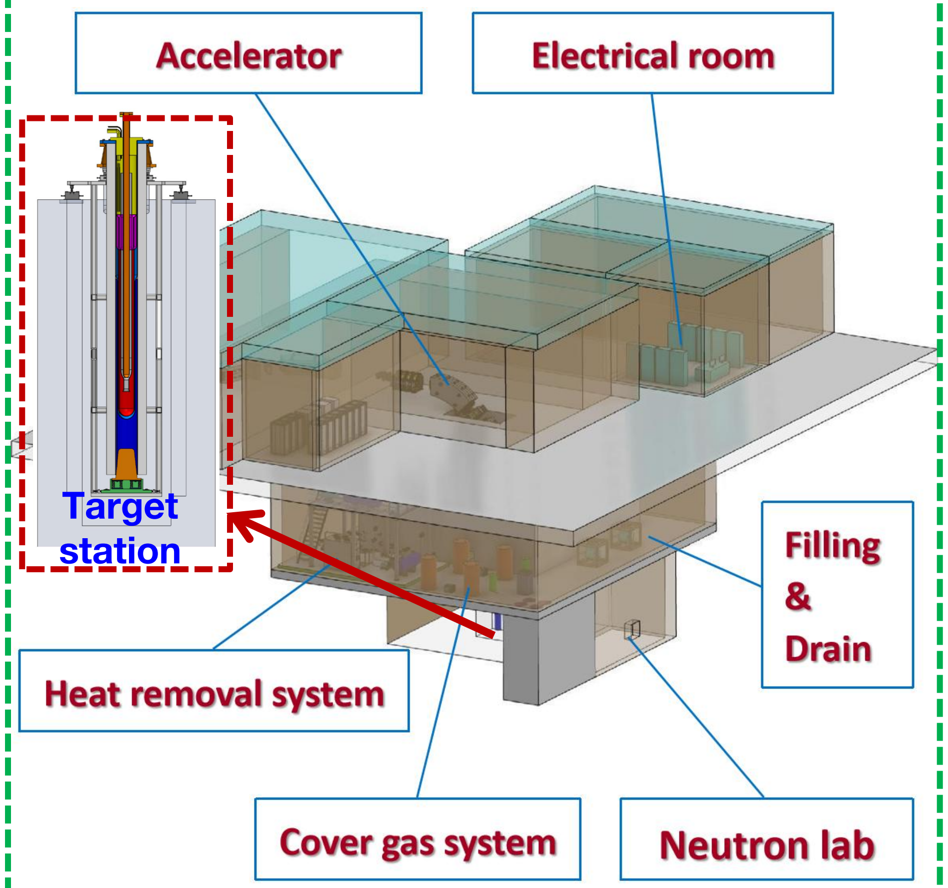
Verification:

- Coupled with accelerator (Low Power).
- To estimate the property of target beam window.
- Similar temp. rise and stress with the real target beam window.
- Under the premise of controllable risk target window performance verification experiments can be conducted under exceeding rated operating conditions.

Status:

- **BW test loop has been installed in Nov. 2023.**
- **Testing experiments have been performed during Jan. 2024.**
- **Running time overed 200 hrs.**
- **The next round of experiments will be carried out in 2025.**

Prototype3: On Beam Spallation Target



Model of the spatial arragement

Test Loop for LBE Pump

Verification:

- Bombarded by proton beams with power of 250 kW - 3MW.
- Target and beam window.
- Heat removal system.
- Shielding of the target.
- Target maintenance system.

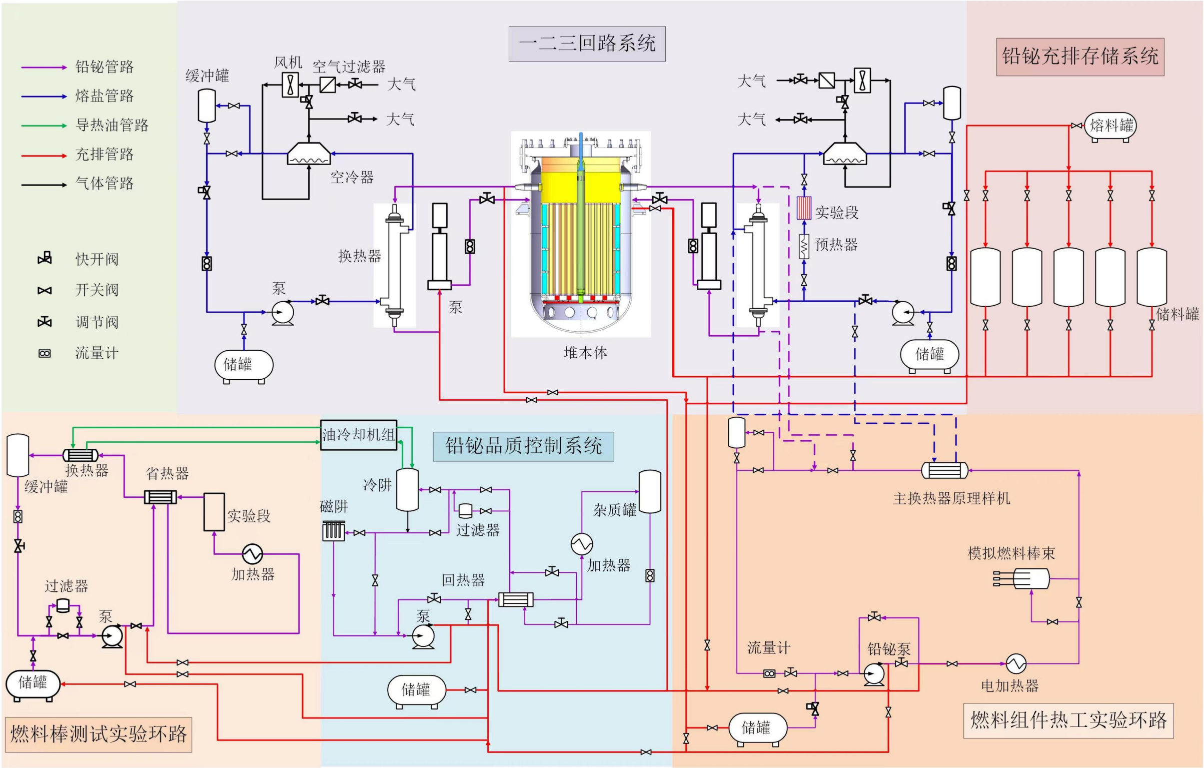
Status:

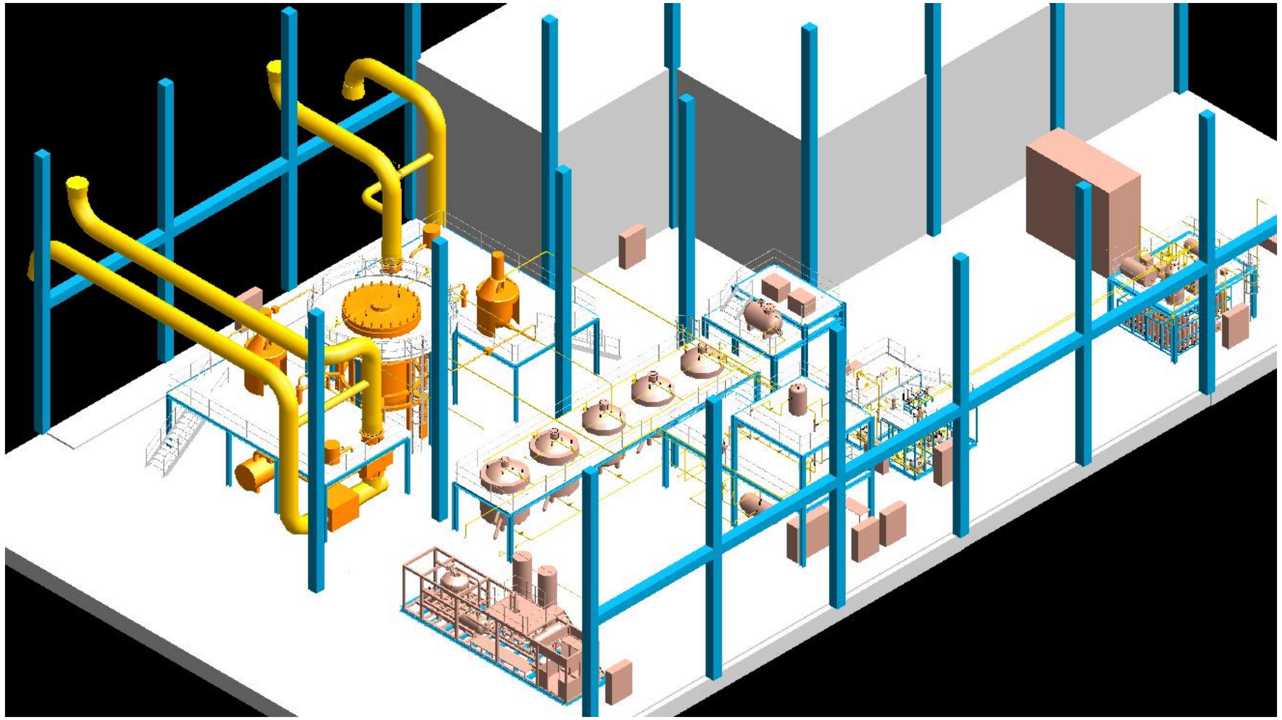
- **Test loop and pump have been produced in Dec. 2023.**
- **Engineering designs of key sub-systems have been almost completed in last year, but major technical adjustments were made this year.**
- **Fabricaiton of each component will be initiated in the beginning of 2025.**

Non-Fuel Reactor Testing Facility

◆ A facility to do hydraulic and thermal experiments for PSAR

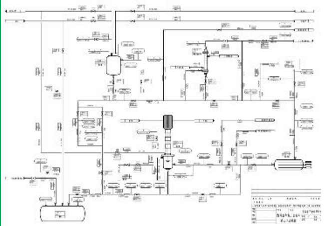
- Flowchart of main system
- 3D layout of facility



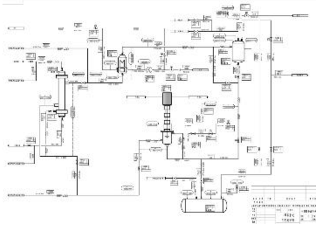


Non-Fuel Reactor Testing Facility

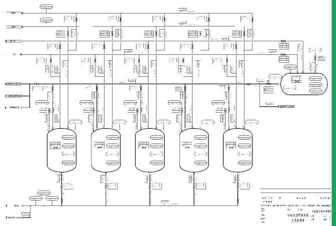
◆ The equipment installation is almost completed, commissioning will is on going.



组件热工环路



二三回路I环路



充排系统

Civil Construction is Ready for Install

Milestones of CiADS

2025 ~ 2026

Construction
Accelerator and Target

- Accelerator 25kW
- Target >25kW
- At HiTa

- ☐ Accelerator Commissioning
- ☐ Target thermal study
- ☐ Beam-target coupling

2026 ~ 2027

ADS Coupling
pre-Fuel test

- Accelerator 250kW
- Target 250kW
- k_{eff}~0.4
- Reactor~30kW

- ☐ 3 Fuel Assemblies online
- ☐ Beam-target-reactor coupling
- ☐ Accelerator stability study
- ☐ Low power test for fuels

2027~2029

ADS/ADANES demonstration
10MW system coupling

- Accelerator 0~2.5MW
- Target 0~2.5MW
- k_{eff}~0.75
- Reactor ramping

- ☐ Full fuel online
- ☐ Neutronic study of Subcritical Reactor
- ☐ Power operation study
- ☐ 2.5MW beam realization
- ☐ ADANES design demonstration

2029~2030

ADS/ADANES transmutation research

- Accelerator ~2.5MW
- Target ~2.5MW
- k_{eff}~0.75
- Reactor ~7.5MW

- ☐ 2.5MW target coupling reactor
- ☐ Fuel test in high power density and deep burnup
- ☐ Transmutation demonstration
- ☐ ADANES preliminary design report

Outline

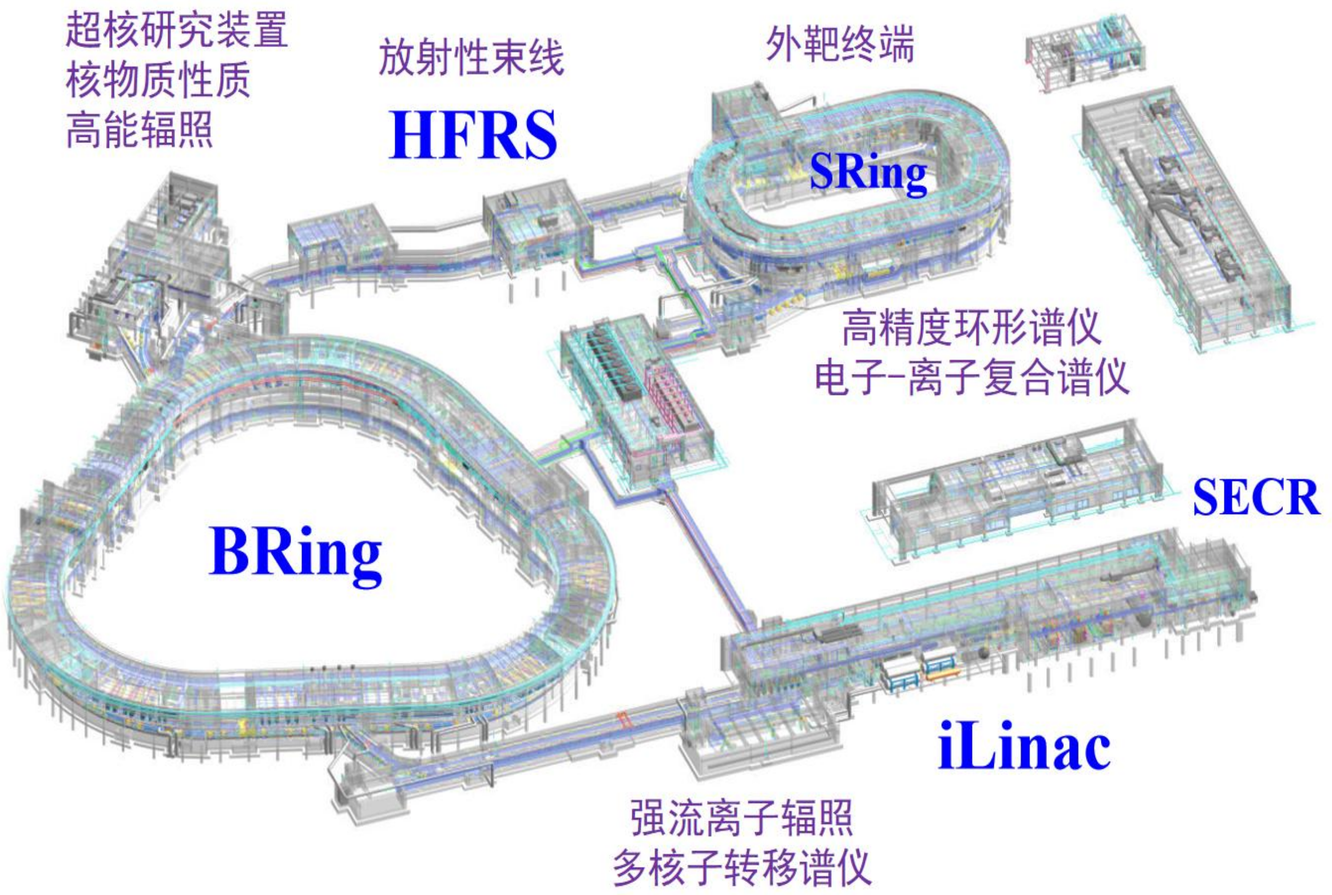
- Background of CiADS Project
- Challenges and Progress of CiADS
- Background of HIAF Project
- Challenges and Progress of HIAF
- Summary and Perspective

Background of HIAF

■ HIAF (High Intensity heavy-ion Accelerator Facility) is one of the mega-scientific projects for nuclear science constructing in China

- Mainly designed to provide high energy (~800MeV/u) and high intensity (10^{11}ppp) heavy ion beams (up to U^{35+})
- Civil construction was started in the end of 2018
- Beam commissioning date is December 2025

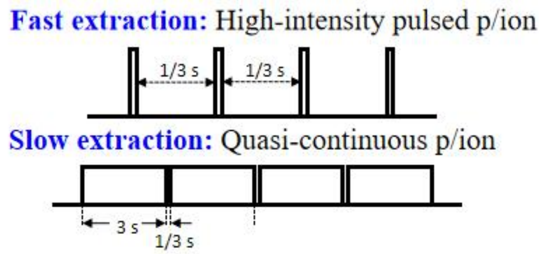
- Superconducting ECR ions source provides highly charge heavy ions
- CW linac is used as the injector of synchrotron
- The booster is used to accumulated and accelerated ions
- 6 experimental terminals will be constructed for nuclear physics, atomic physics and application studies

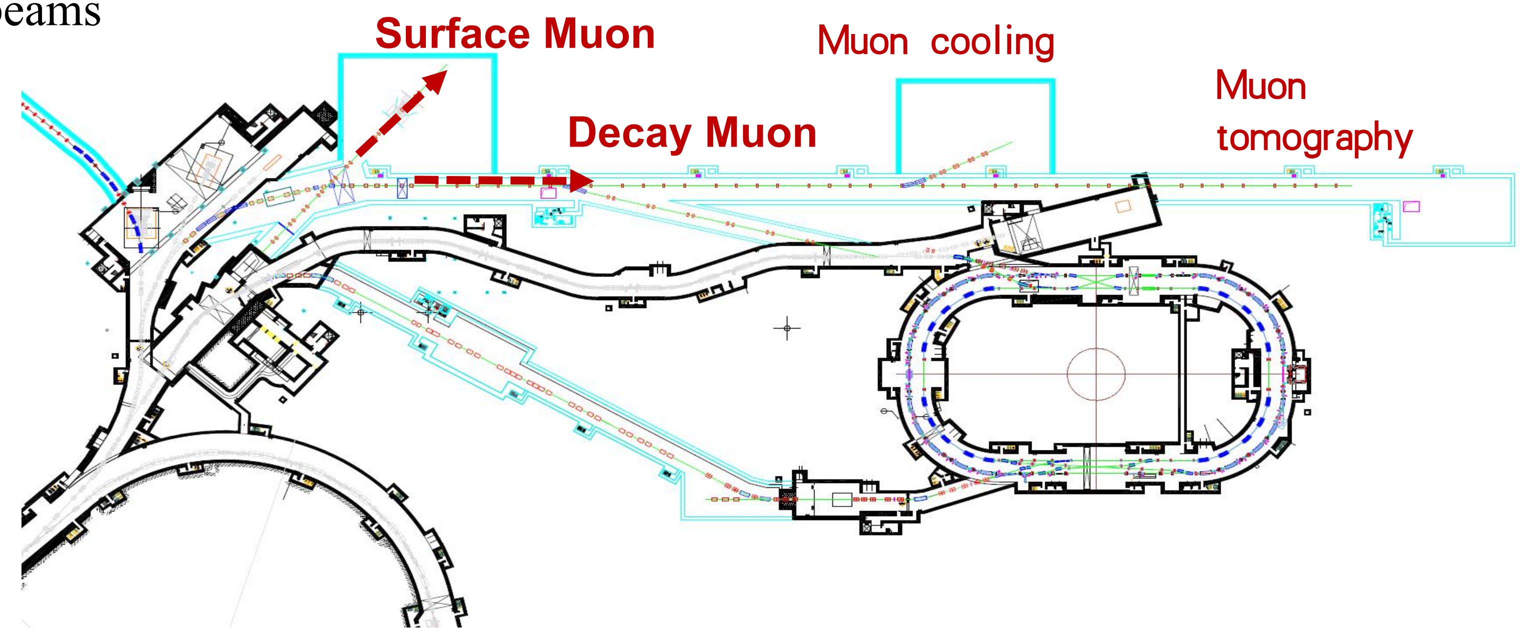


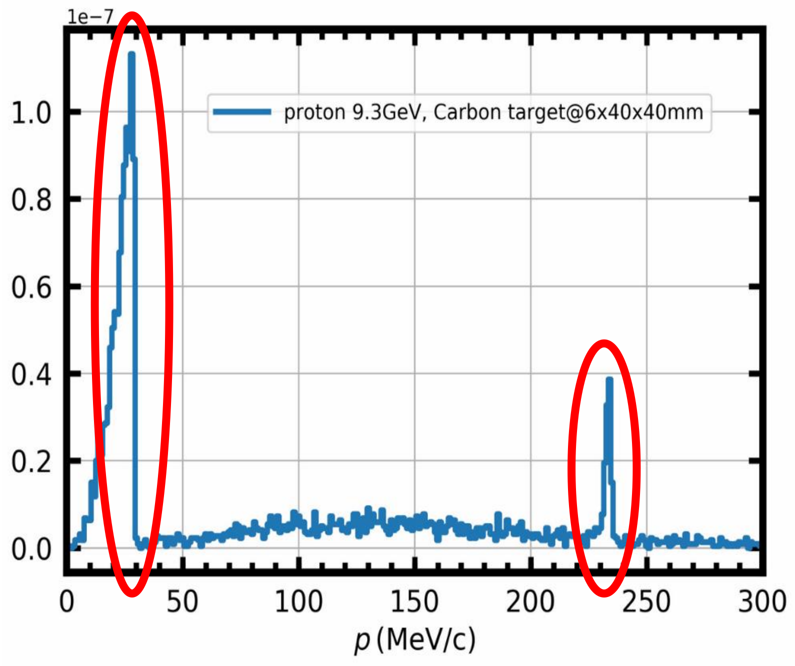
Muon source at HIAF-U

❑ muon beams with HIAF-U

- muon source with High-intensity proton/heavy ion beam
- Fast/slow extraction modes
- high-energy decay muons and surface muon beams







surface muon with HIAF—U

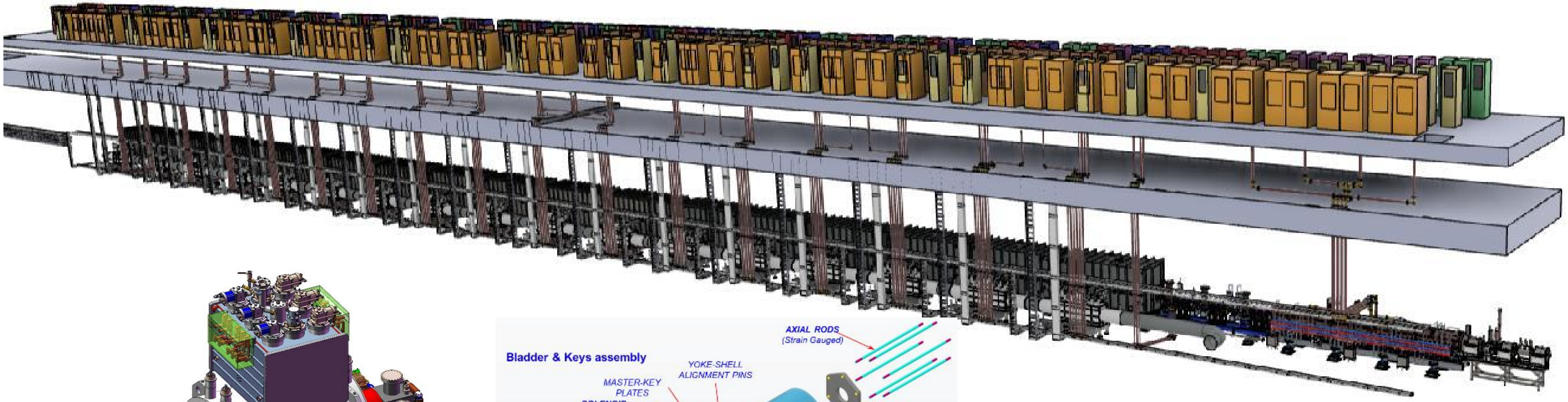
- Surface muon with momentum ~30MeV/c (pion DAR)
- Surface muon with momentum ~240MeV/c (kaon DAR)

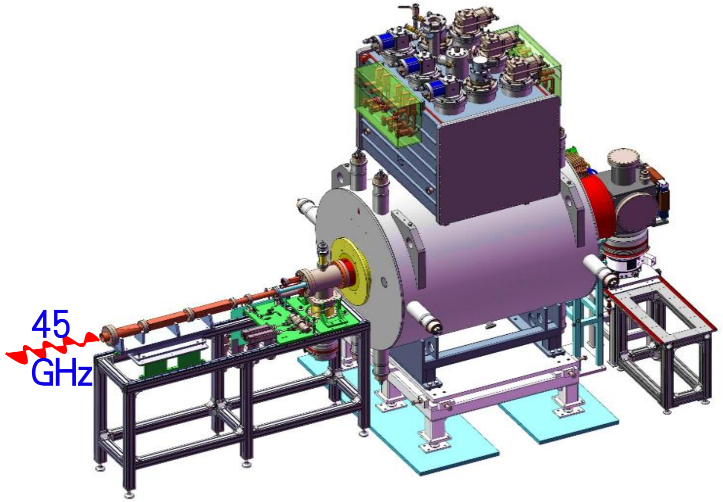
Nominal Parameters

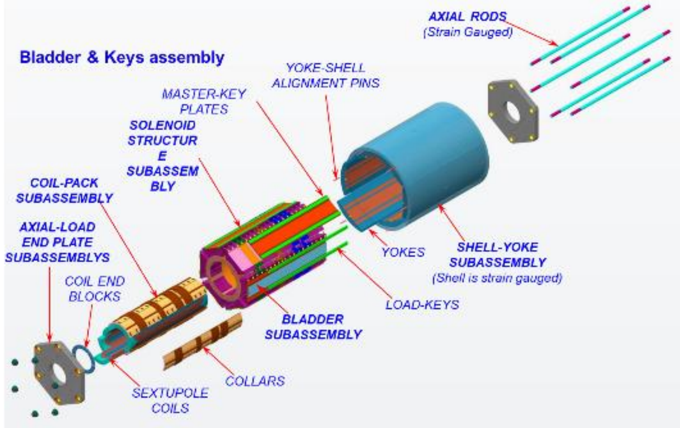
- Beam parameters, here we selected the uranium as the reference particle

	SECR	iLinac	BRing	HFRS	SRing
Length / circumference (m)	---	114	569	192	277
Final energy of U (MeV/u)	0.014 (U^{35+})	17 (U^{35+})	835 (U^{35+})	800 (U^{92+})	800 (U^{92+})
Max. magnetic rigidity (Tm)	---	---	**34**	25	15
Max. beam intensity of U	50 pμA (U^{35+})	28 pμA (U^{35+})	**1×10^{11}ppp (U^{35+})**	-------	**(2~4)$\times10^{11}$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)

- The 4th generation of ECR ion source, provide highly charge U ions with the current about mA
- A CW superconducting linac is designed as the injector of synchrotron
- Two phase painting injection and fast ramping in the booster ring (BRing)







Outline

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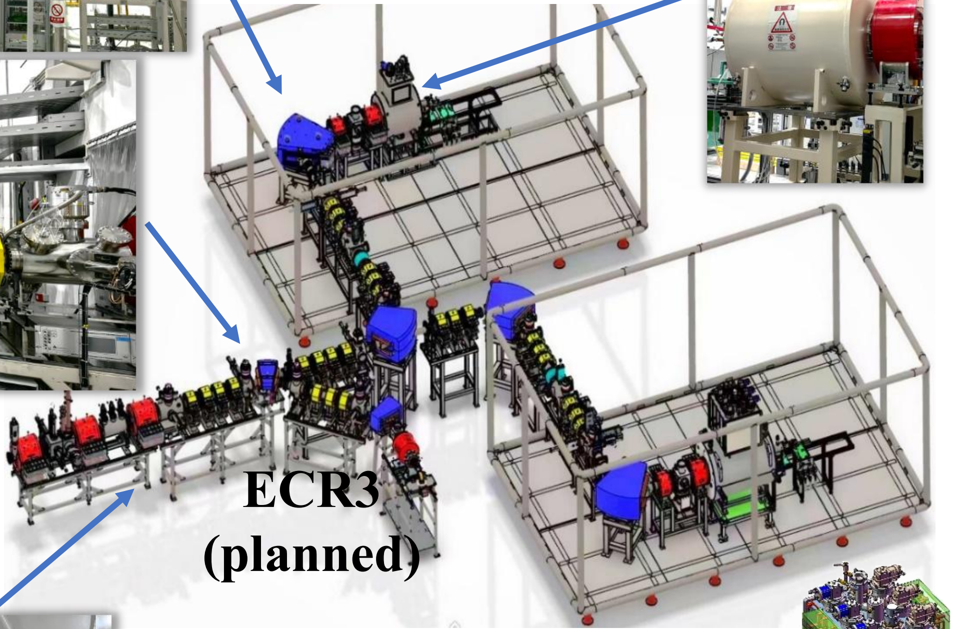
Front End - LEBT

HV platform

HECRAL ECR Ion Source

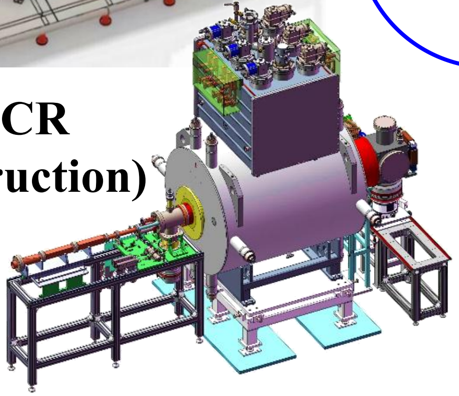
Matching Beamline



RFQ

RFQ Injection Beamline

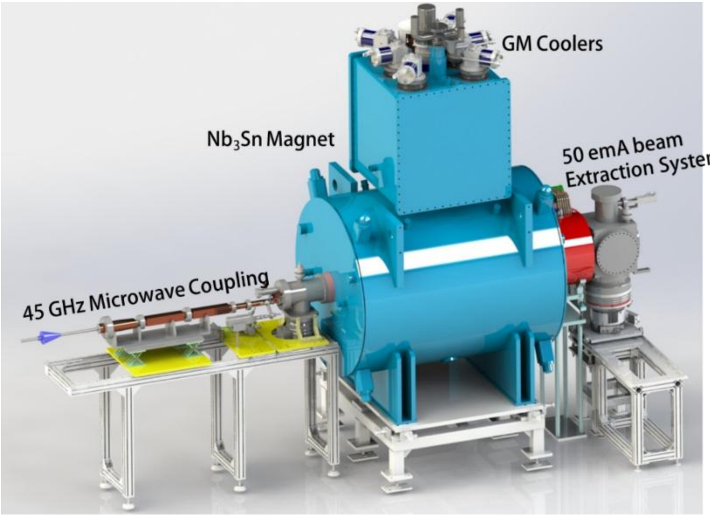
HIAF-FECR
(under construction)



- Phase I of Ion source Front End ready for beam commissioning
- All beamline sections in place and readiness check passed
- Higher performance ECRISs will be ready soon
    - 28 GHz SECRAL-IV (by 2024)
    - 45 GHz HIAF-FECR (by 2025)

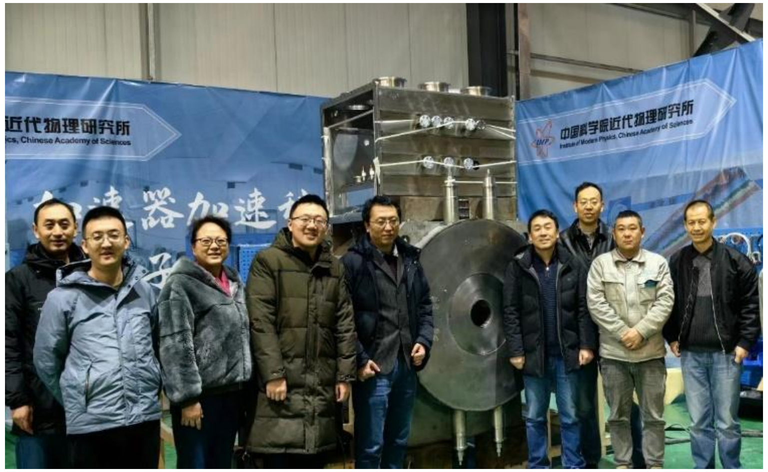
45 GHz Superconducting ECR ion source

The first 45 GHz superconducting ECR in the world: Goal 50 pμA (U^{35+})



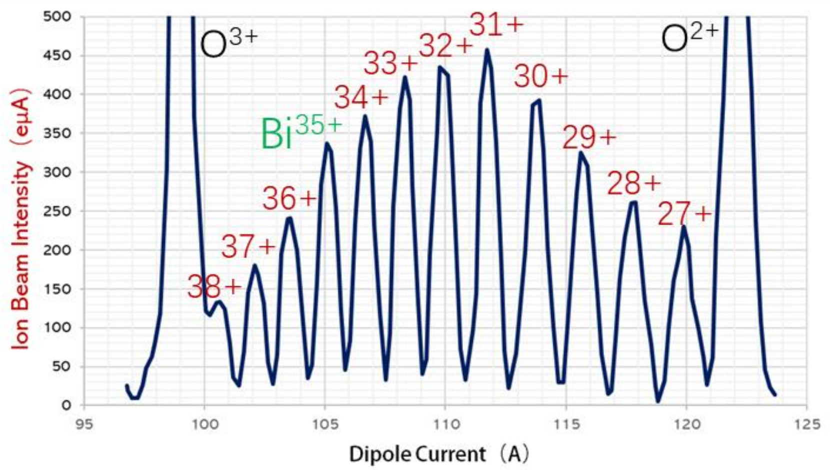
- **The first Nb_3Sn superconducting ECR ion source magnet**

Nb_3Sn + NbTi Cold mass ready



FECR magnet cryostat integration

- **FECR and its first beam @45 + 28 GHz Test Bench**



^{209}Bi

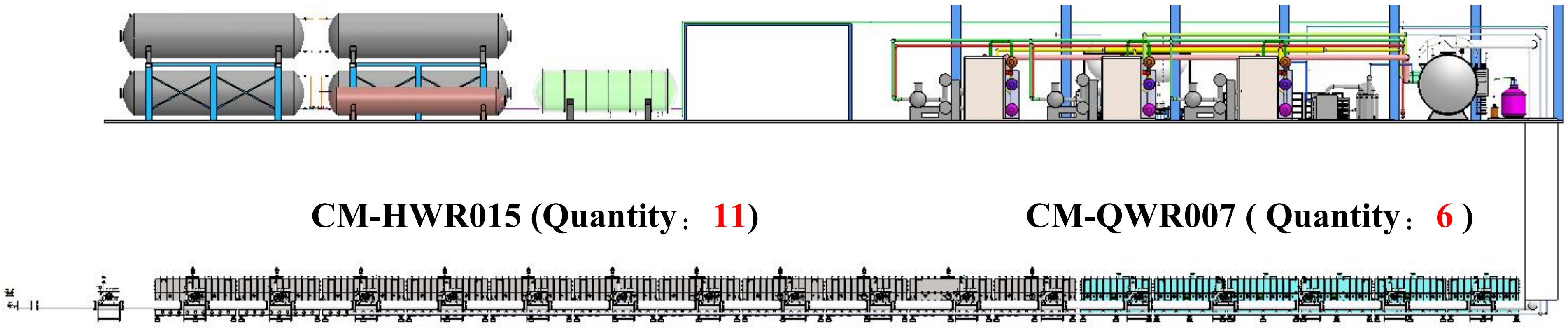
350 eμA Bi^{35+}
10 puA
@45 GHz +28 GHz

Front End – RFQ and MEBT

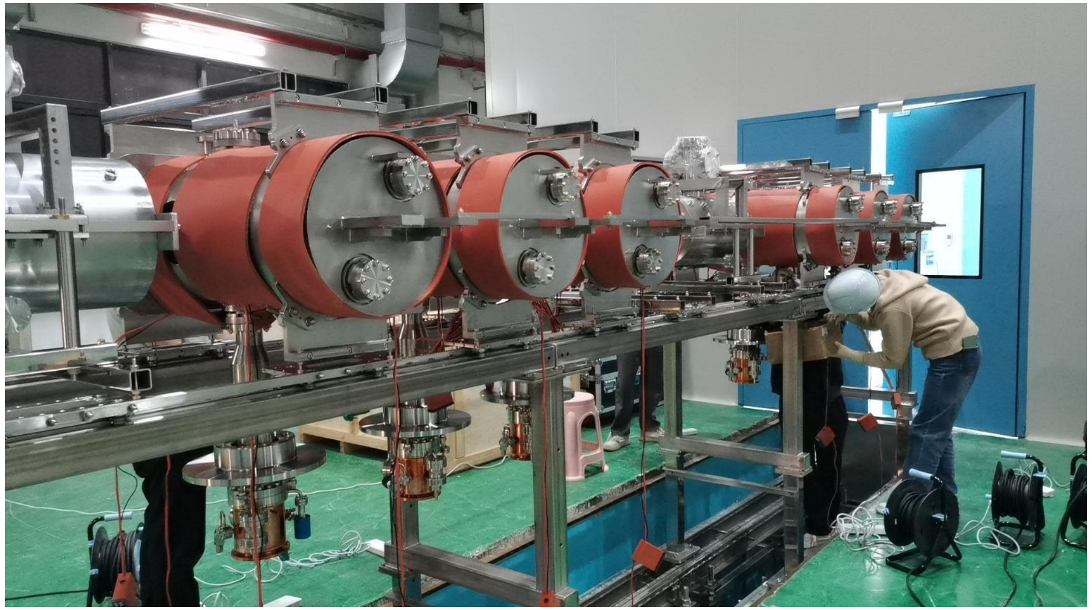
RFQ Status:

- Designed Energy: 0.8 MeV/u
- Length: ~8.7 m
- RF Commissioning:
  - ✓ Pulsed: ~98 kW for M/Q=7
  - ✓ CW: ~56 kW for M/Q=5
- First beam: October, 2024

Superconducting Linac

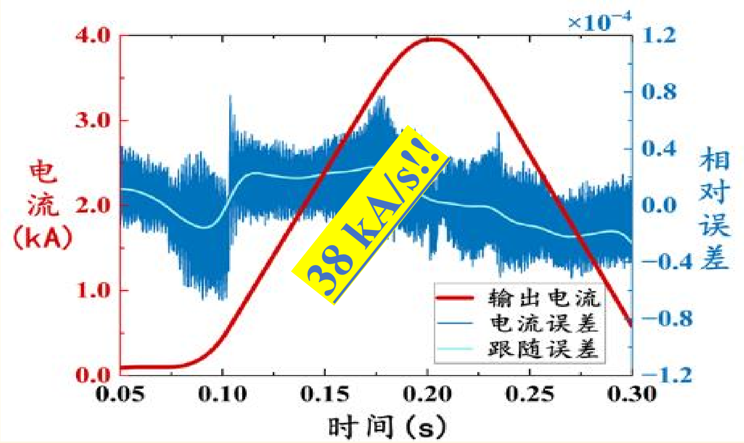


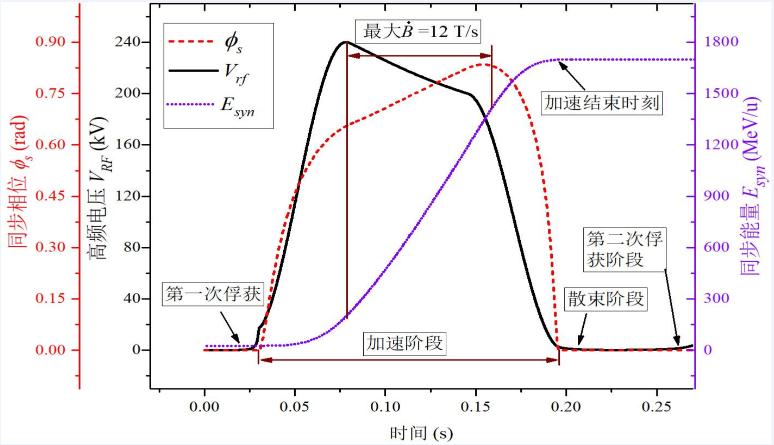
CM-HWR015 (Quantity： 11) CM-QWR007 (Quantity： 6)



BRing

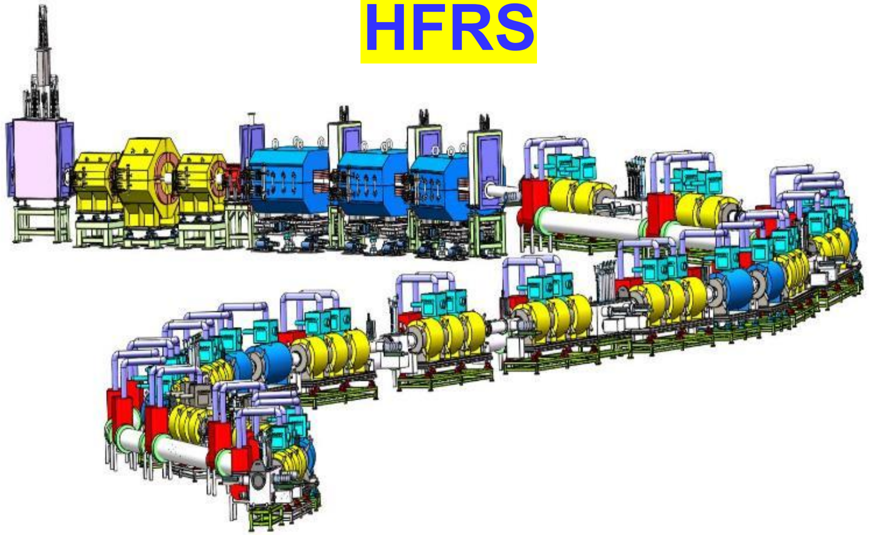
- Power supply for dipole (Full energy storage fast cycling power supply)
- Nanocrystalline soft magnetic alloy loaded cavity
- thin-walled vacuum chamber (Titanium ring supported thin wall vacuum chamber)

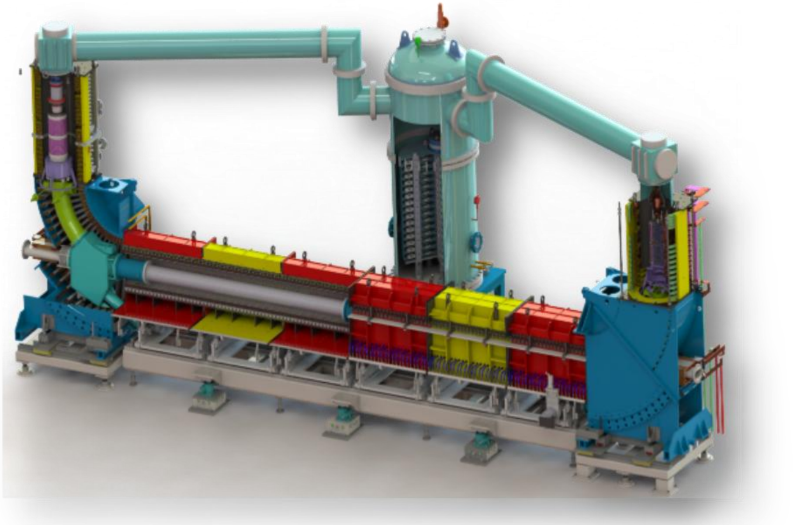




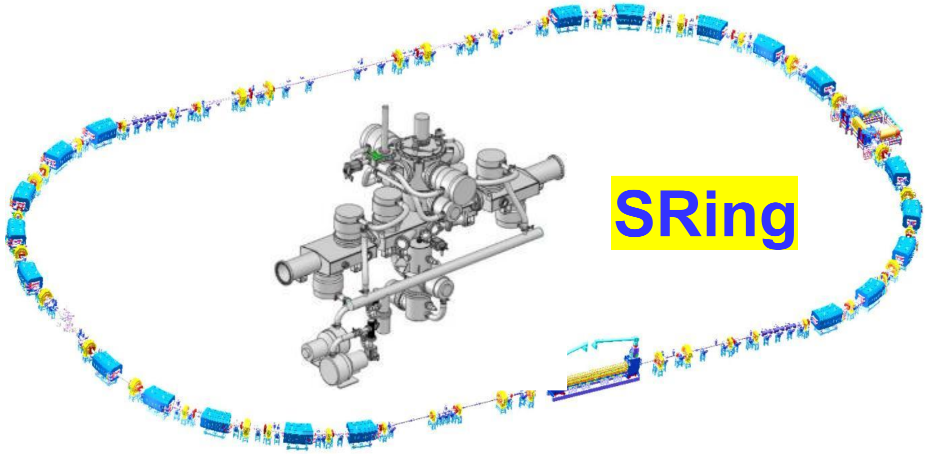
HFRS and SRing

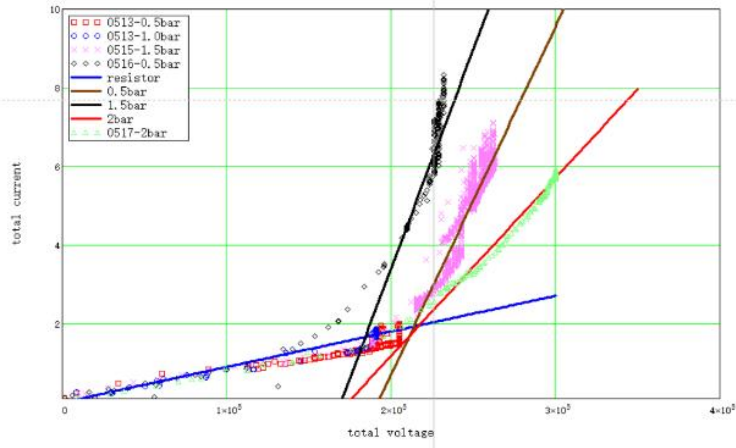
- High energy fragment separator (HFRS) and Spectrometer Ring (SRing)





450kV electron cooler





Installation and Commission

- The installation of Bring has been finished in the end 2024
- The installation of HFRS will be finished in May 2025

- The installation of iLinac will be finished in July 2025
- The beam commissioning will be in Sept. 2025
- First experiment will be in Dec. 2025

Outline

- Background of CiADS Project
- Challenges and Progress of CiADS
- Background of HIAF Project
- Challenges and Progress of HIAF
- Summary and Perspective

Summary and Perspective

- The CiADS will operate in 2027 and demonstrate the full fuel-recycle strategy in 2030.
- The HIAF will operate by the end of 2025 to start the frontier research on HED physics, QED, QCD, and so on.
- The Linac of CIADS can be a driver for Muon and ISO beam. A muon source at CiADS and ISO beam accelerated by HIAF are also the future plan.

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Thankyou for your attention!