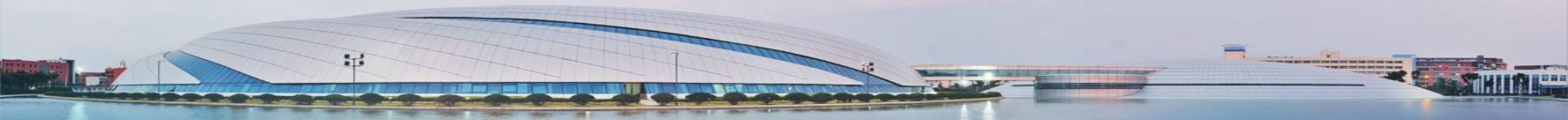
AFAD 2026 Conference

A multi-ion linac for medical isotope production

Ping Wang

On behalf of SARI team



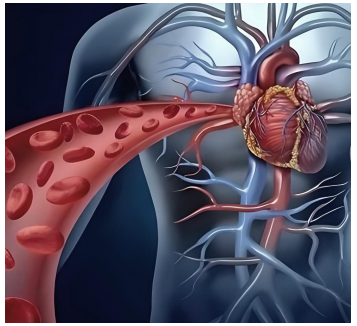
2026.10.14

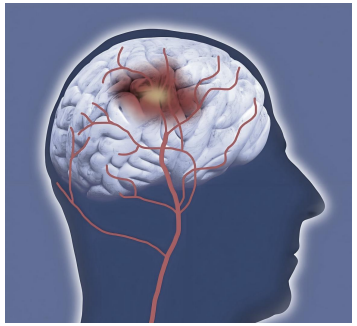
Outline

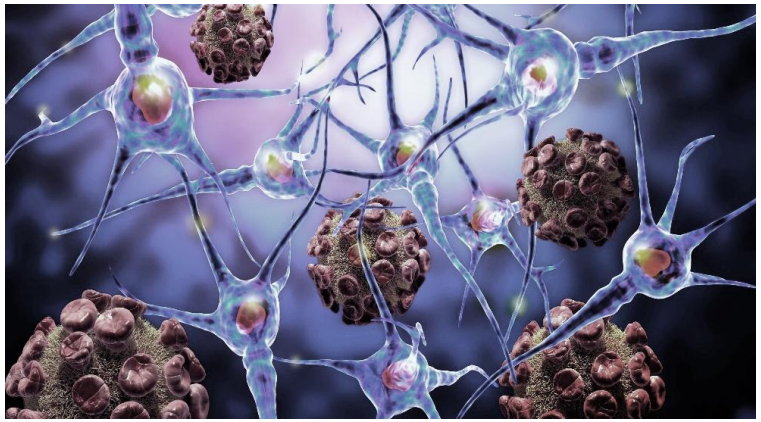
- **Background**
- Layout of the multi-ion linac
- Development of the key components
- Summary

Background

Cardiovascular and cerebrovascular disease: nearly **20 million** deaths worldwide per year





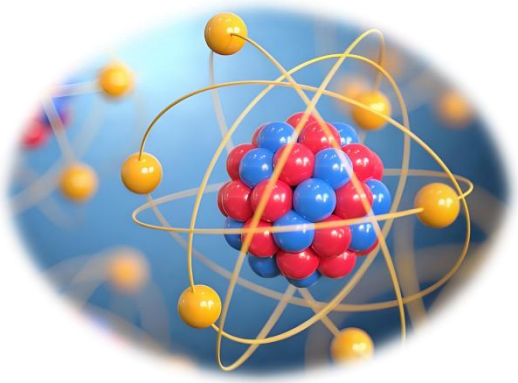


All cancers: about **10 million** deaths worldwide per year



Theranostics

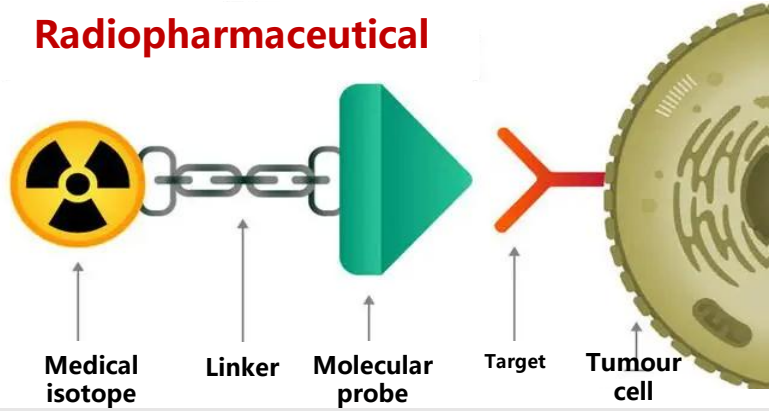
Medical isotopes
Diagnosis → Theranostics



Cardiovascular and cerebrovascular diagnosis: molecular-level blood-flow imaging



Radiopharmaceutical



Cancer care: medical isotopes enable precise targeted theranostics

Background

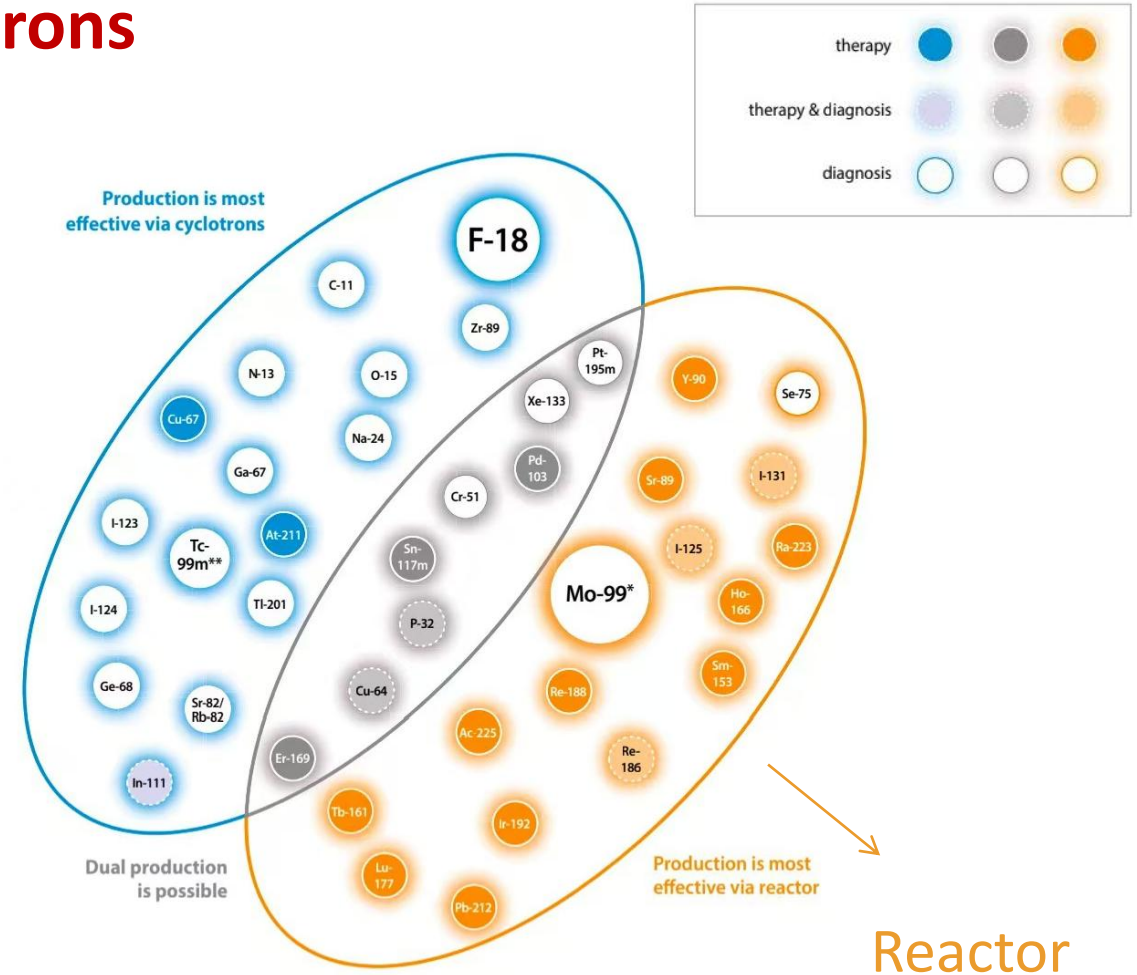
Production is most effective via proton **Cyclotrons**

■ For diagnosis (**conventional demand**)

- PET - positron emitters: ^{18}F, ^{68}Ga, ^{89}Zr, ^{64}Cu
- SPECT - single-photon emitters: ^{99m}Tc, ^{111}In

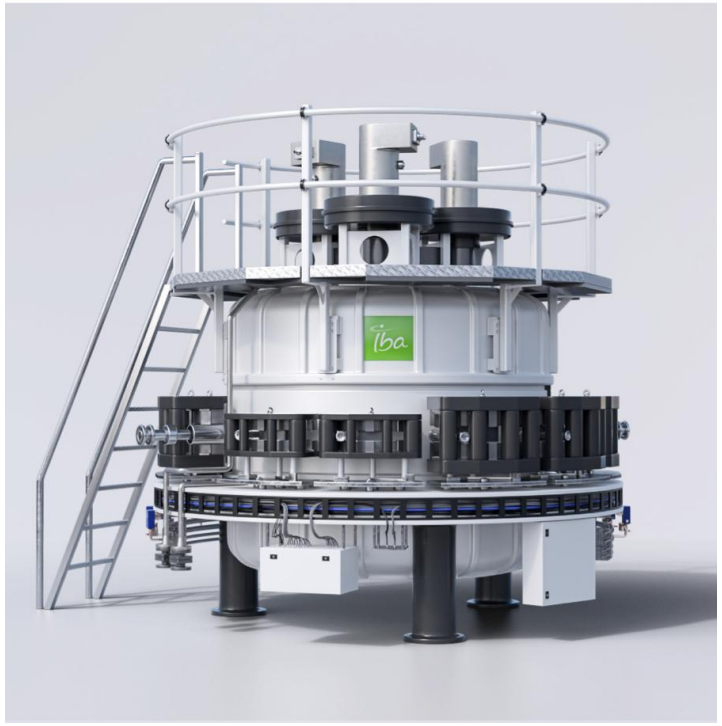
■ For therapy (**high-end, cutting-edge demand**)

- α emitters: ^{225}Ac, ^{223}Ra, ^{213}Bi, ^{211}At
- β emitters: ^{188}Re, ^{177}Lu, ^{131}I, ^{90}Y, ^{89}Sr
- α, β emitters: ^{153}Sm
- Auger-electron emitters: ^{125}I, ^{77}Br, ^{195m}Pt



Background

Rhodotron electron accelerator



Superconducting electron linac

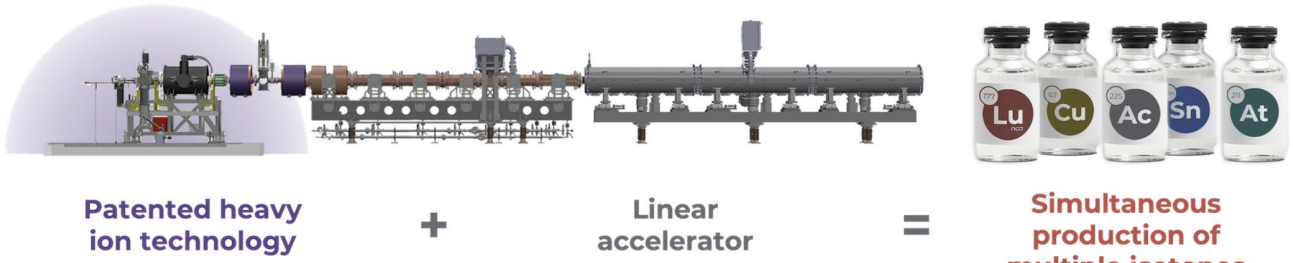


Normal-conducting electron linac

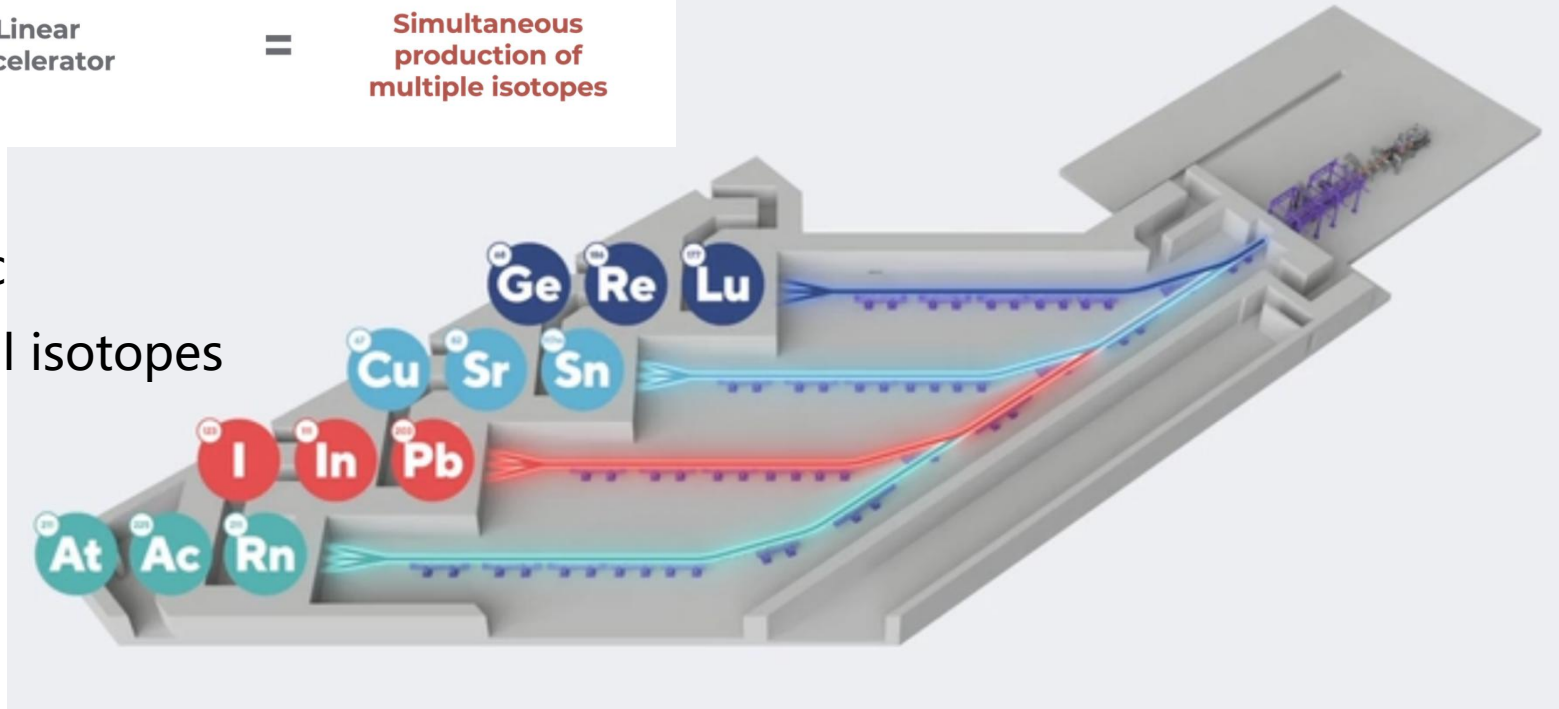


Background

Nusano (USA): a multi-ion linac producing medical isotopes

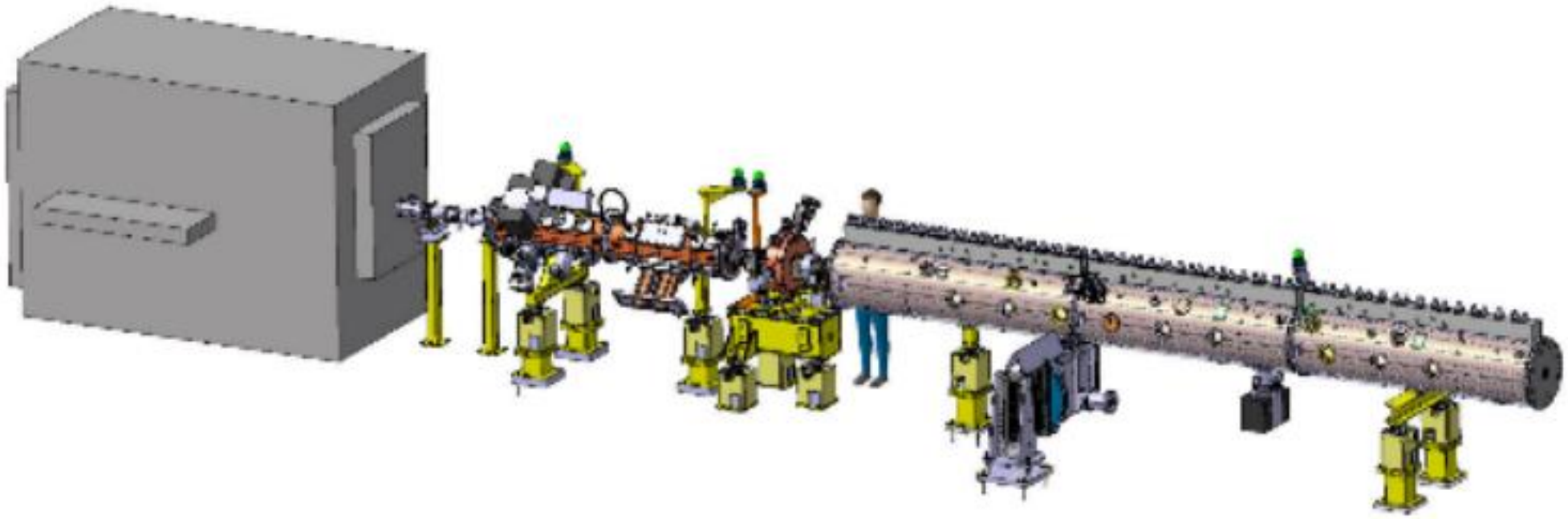


- Based on a multi-ion linac
- Produces multiple medical isotopes
- Tunable energy
- High current, high yield



Background

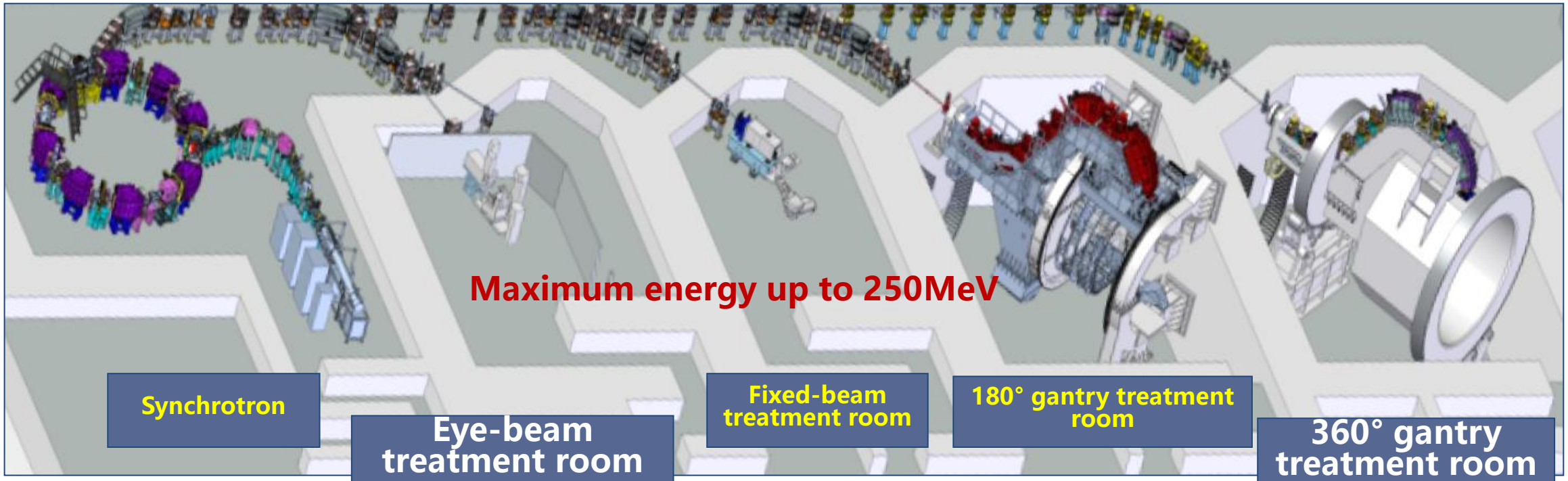
CERN proposed an RFQ+DTL linac concept delivering a 28 MeV alpha beam to produce the ^{211}**At** therapeutic isotope



M. Vretenar, et al., DESIGN OF A HELIUM ION LINEAR ACCELERATOR FOR ASTATINE PRODUCTION, IPAC2025-TUPB046

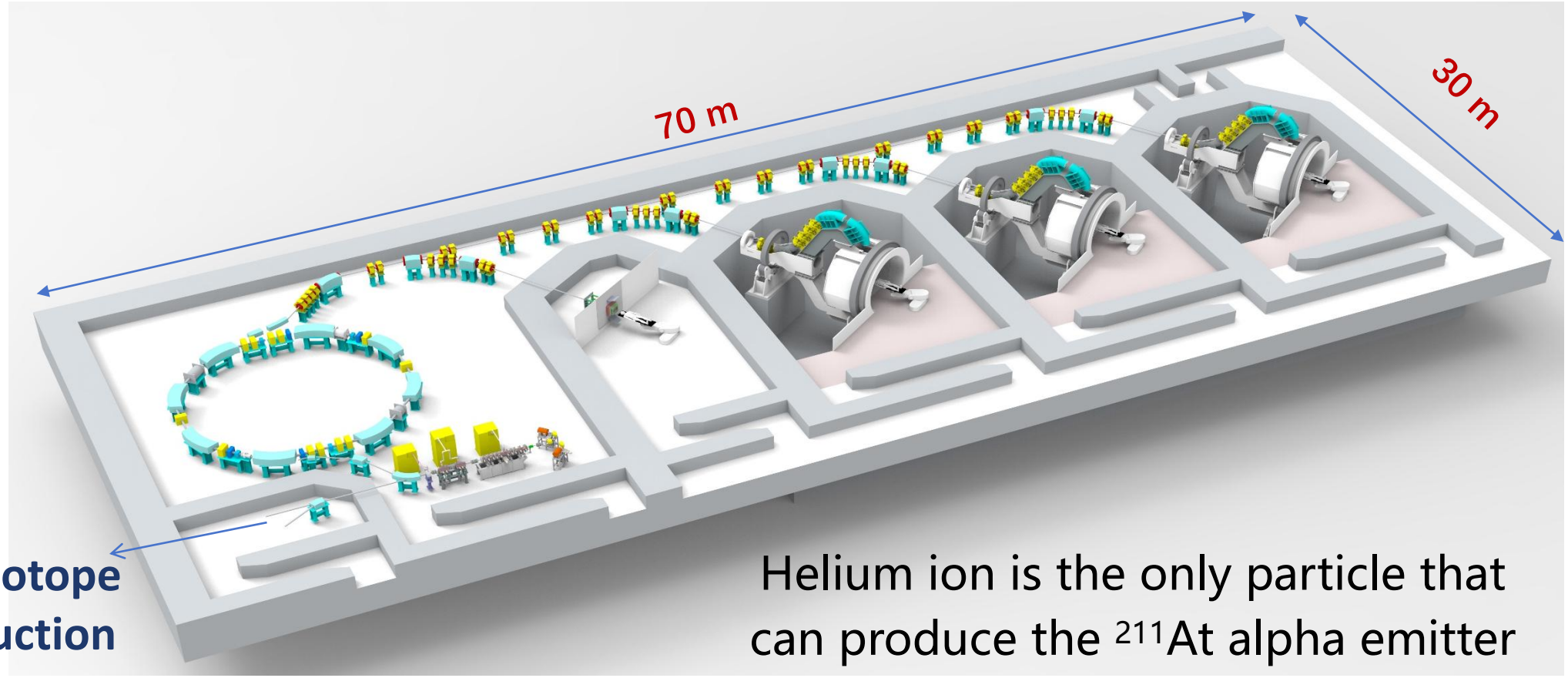
Background

Achieved: The proton therapy system developed by SARI



Background

Planed: Combined proton and helium-ion facility



For Isotope production

Helium ion is the only particle that can produce the ^{211}At alpha emitter

Outline

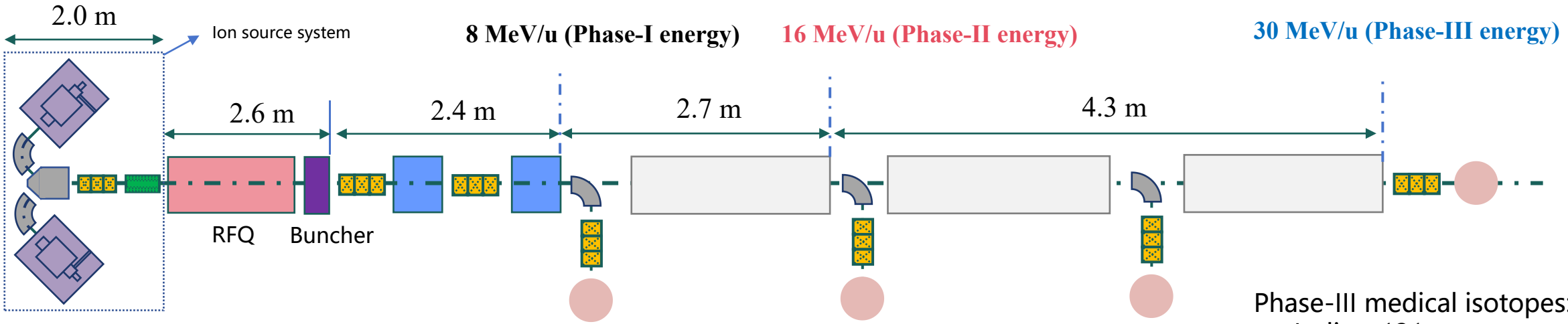
- Background
- **Layout of the multi-ion linac**
- Development of the key components
- Summary

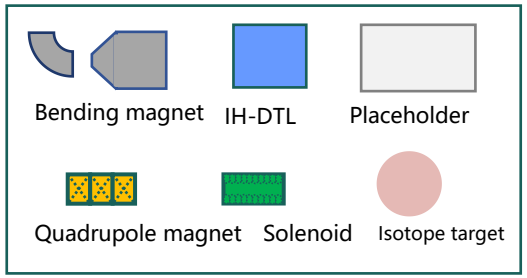
Layout of the multi-ion linac

Main components:

- H_2^+ ion source
- Helium ion source
- RFQ accelerating structure
- IH-DTL accelerator
- Low-energy beam transport
- High-energy beam transport

Protons or helium ions at different energies are flexibly extracted by bending magnets downstream of the IH-DTL accelerating structures





Phase-I medical isotopes:

- Iodine-131
- Astatine-211
- Fluorine-18
- Lutetium-177

Phase-II medical isotopes:

- Iodine-131
- Astatine-211
- Fluorine-18
- Lutetium-177
- Actinium-225

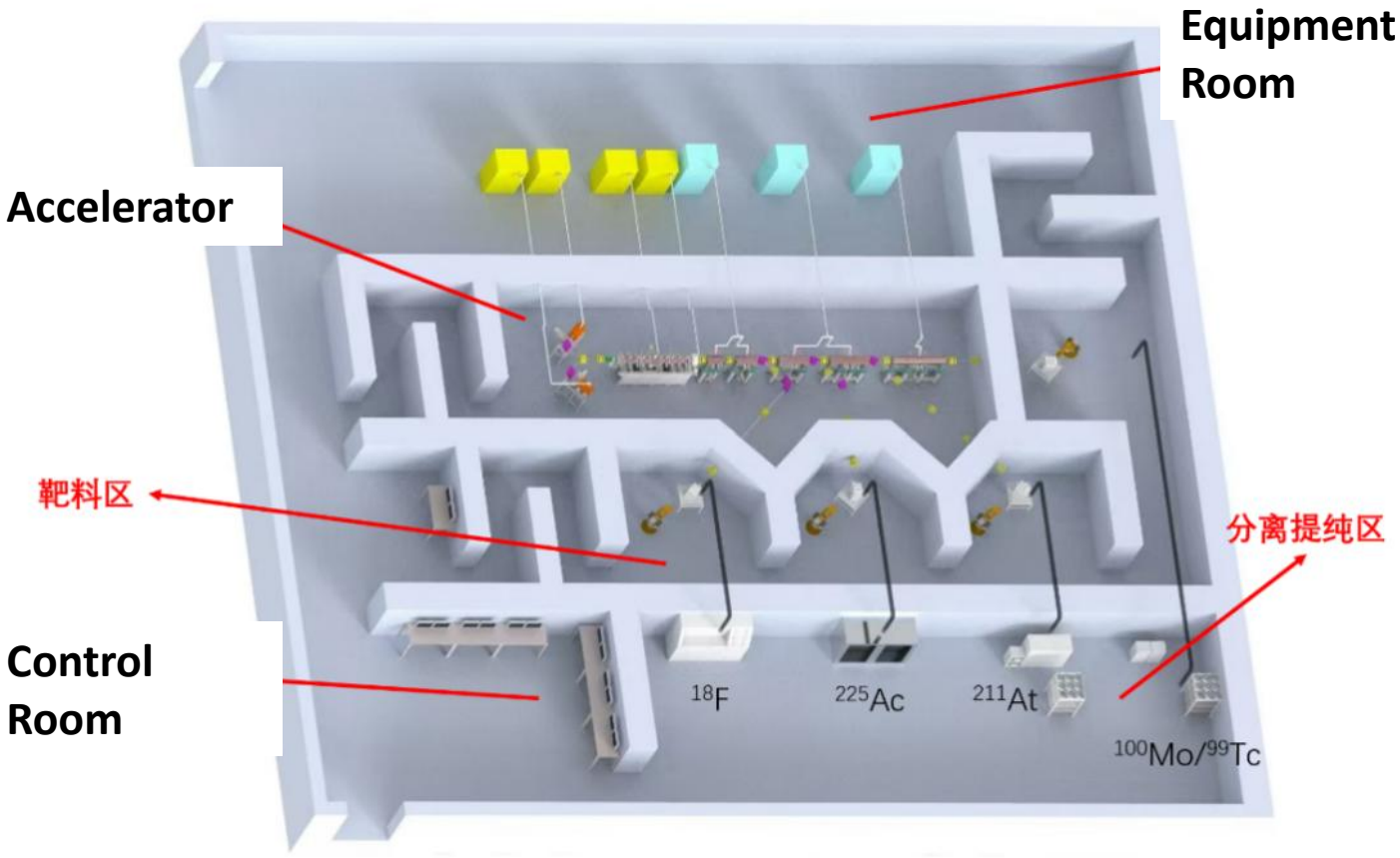
Phase-III medical isotopes:

- Iodine-131
- Astatine-211
- Fluorine-18
- Lutetium-177
- Actinium-225
- Molybdenum-99/technetium-99m

Layout of the multi-ion linac

Advantages of the linac:

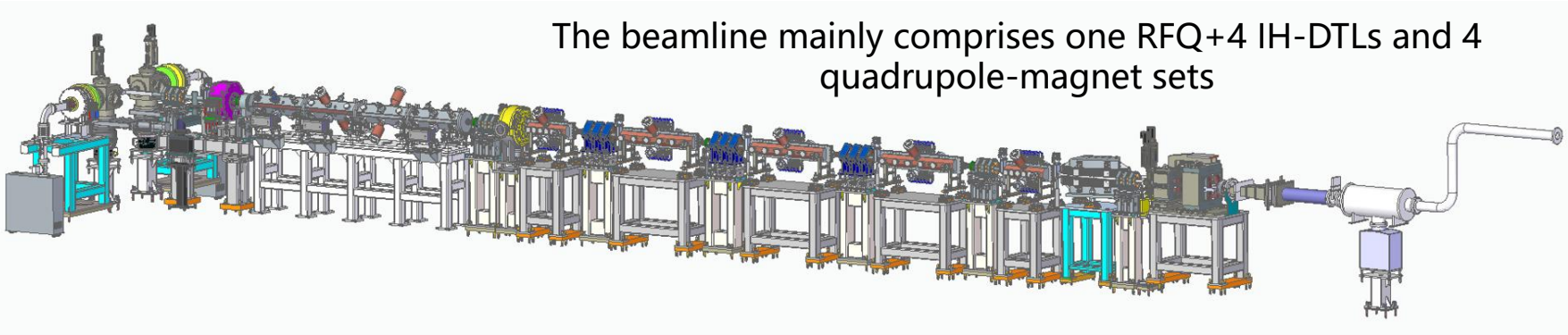
- High beam current → **high yield, good economics**
- Tunable beam energy → **full isotope range, optimal yield**
- Multiple particle species → **multi isotopes**
- Platform-based operation → **scalability, supports an industrial park**
- High technology maturity → **good reliability, easy maintenance**



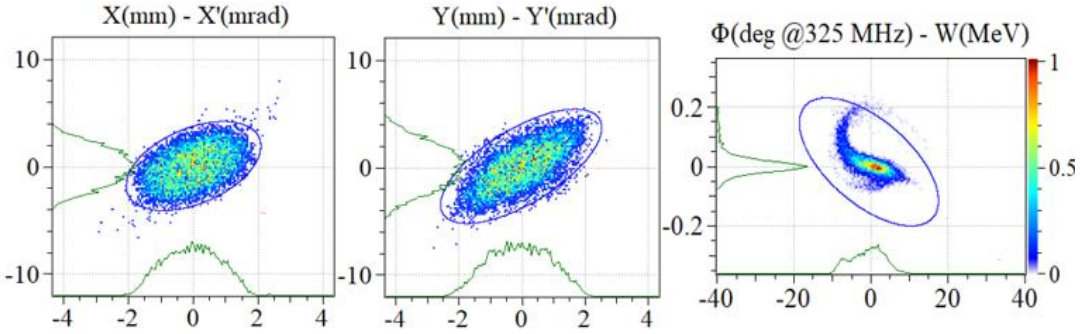
Layout of the multi-ion linac

The beamline length is about 15 m with transmission efficiency above 90%, so the design meets all specification requirements

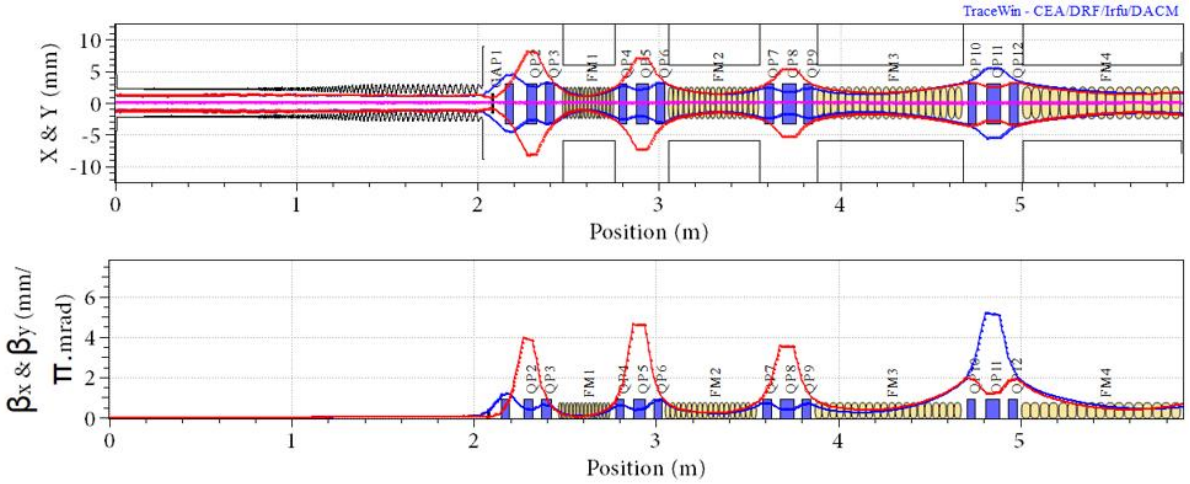
Accelerator specifications	
Beam current	1 mA
Energy	8-16 MeV



The beamline mainly comprises one RFQ+4 IH-DTLs and 4 quadrupole-magnet sets



Exit beam phase space



Beam envelope

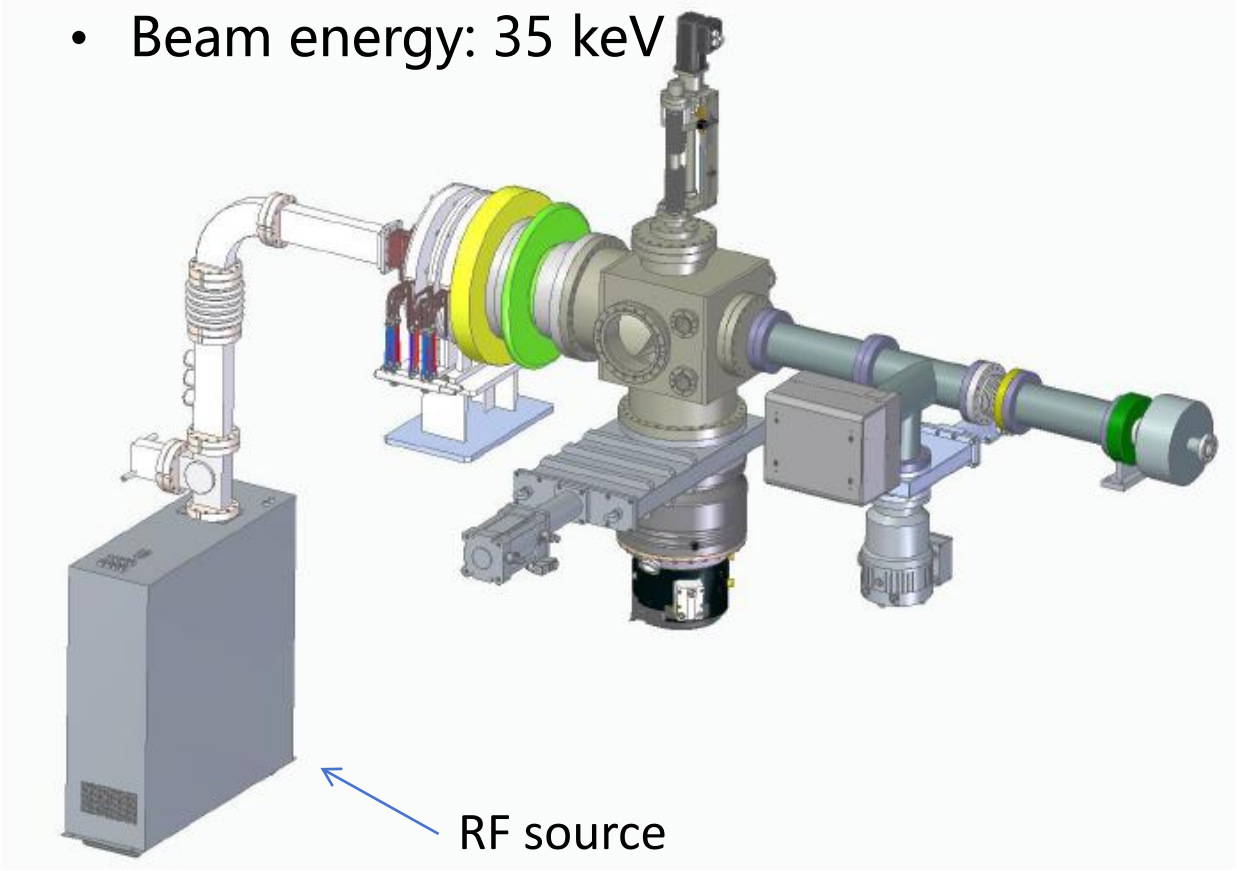
Outline

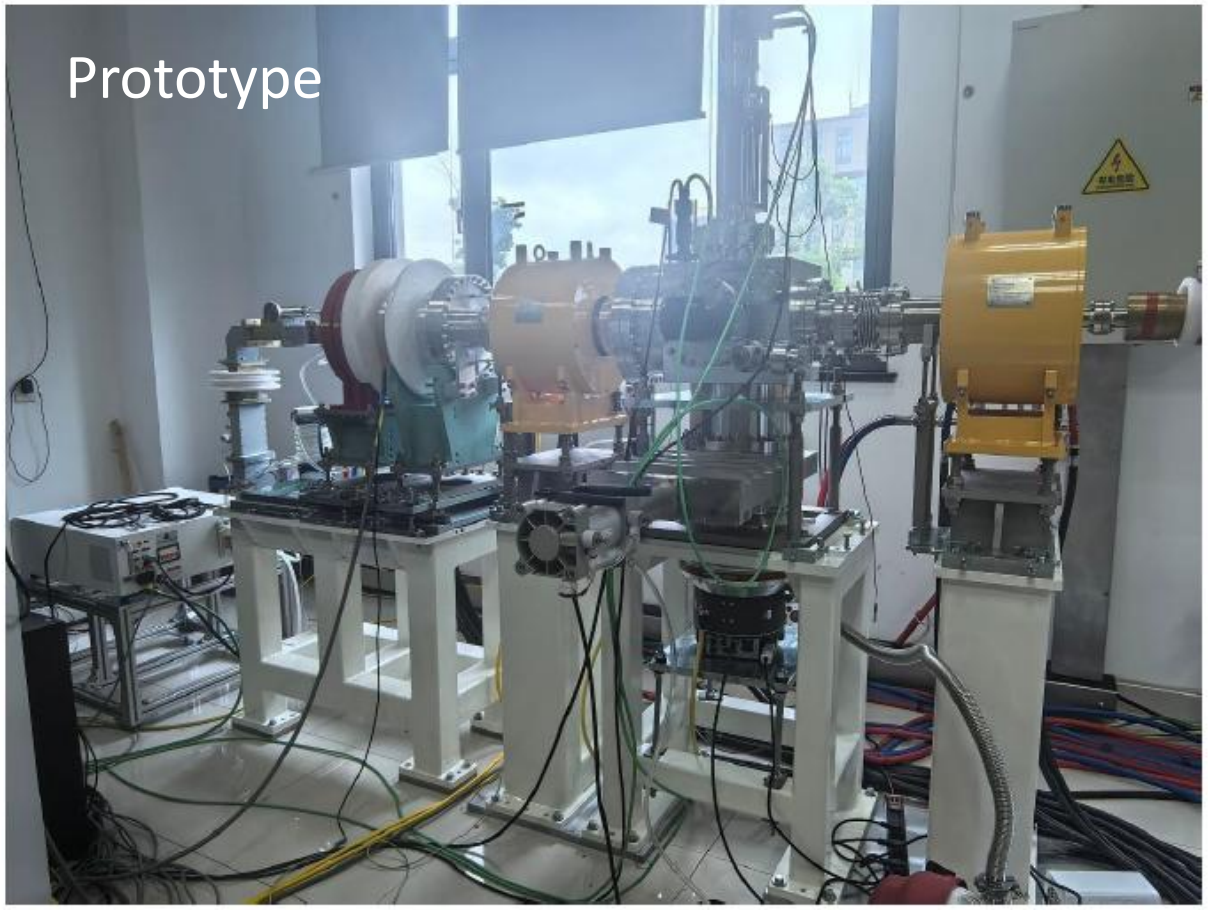
- Background
- Layout of the multi-ion linac
- **Development of the key components**
- Summary

Development of the key components-ECR-Source

ECR proton source

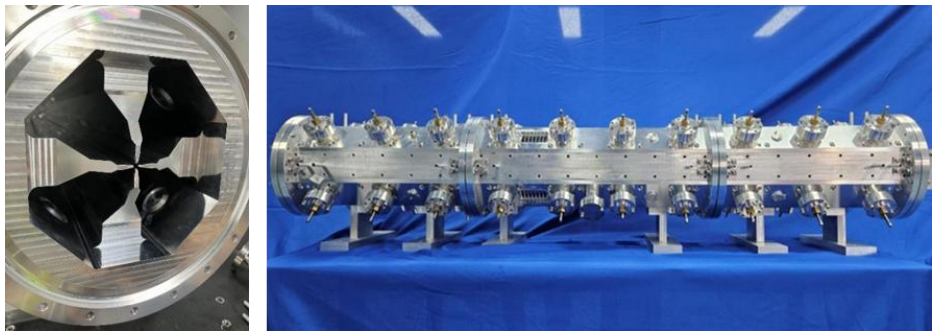
- Measured beam current :16 mA
- Beam energy: 35 keV



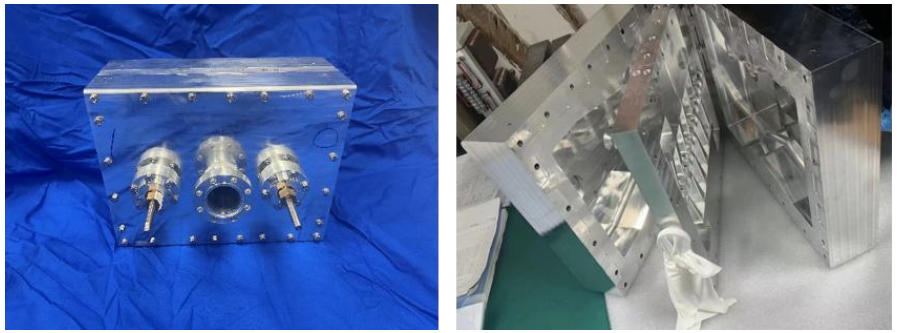


Development of the key components-Accelerating structures

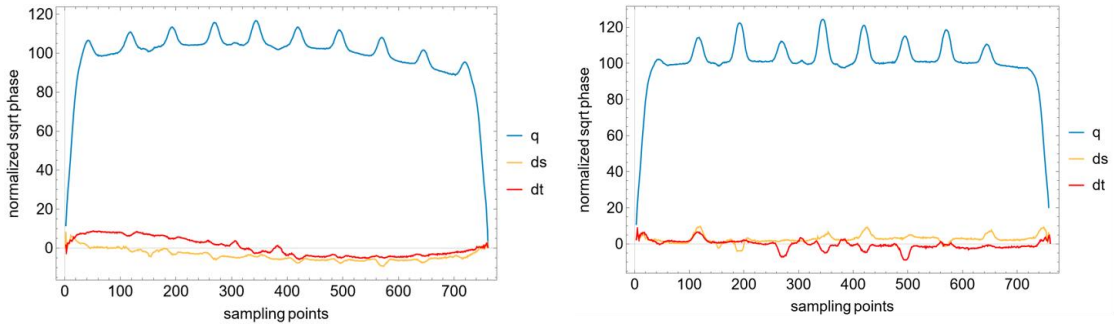
- Fabrication of the RFQ and IH-DTL prototypes
- Cold testing and tuning of the RFQ and IH-DTL prototypes



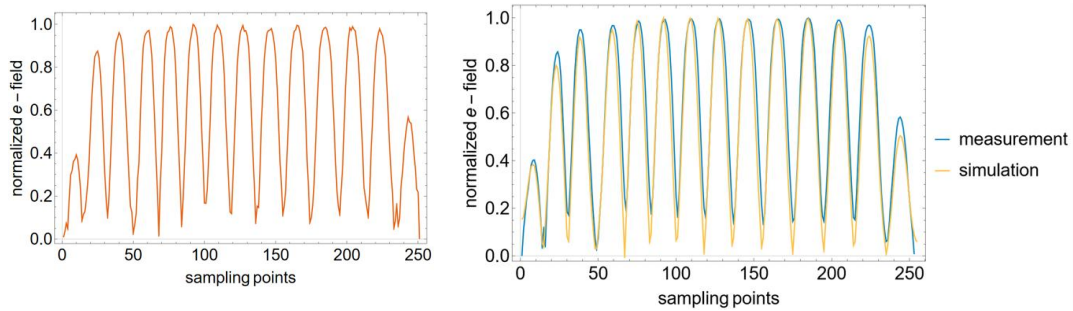
RFQ prototype



IH-DTL prototype



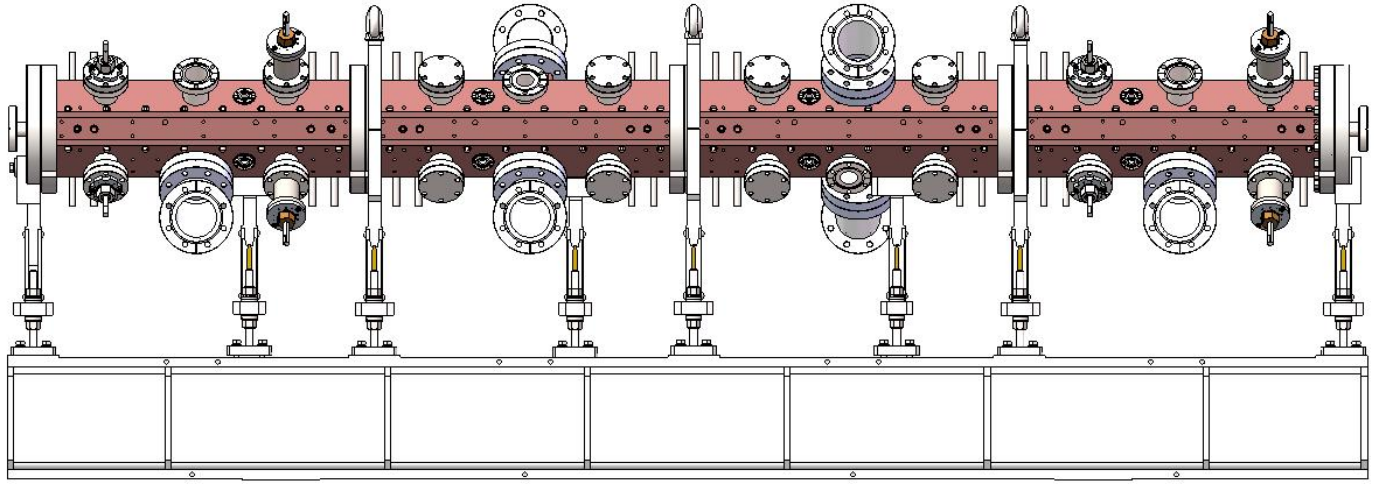
RFQ test results

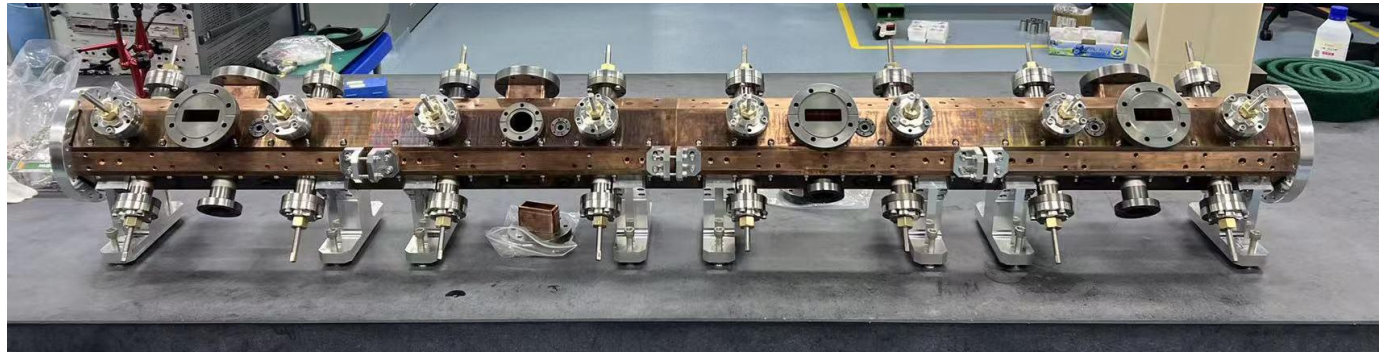


IH-DTL test results

Development of the key components-Accelerating structures

Completed machining of the key RFQ copper-cavity components

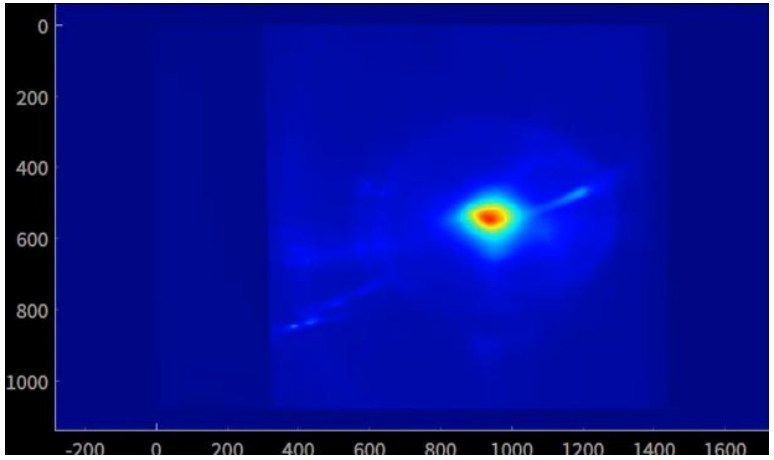




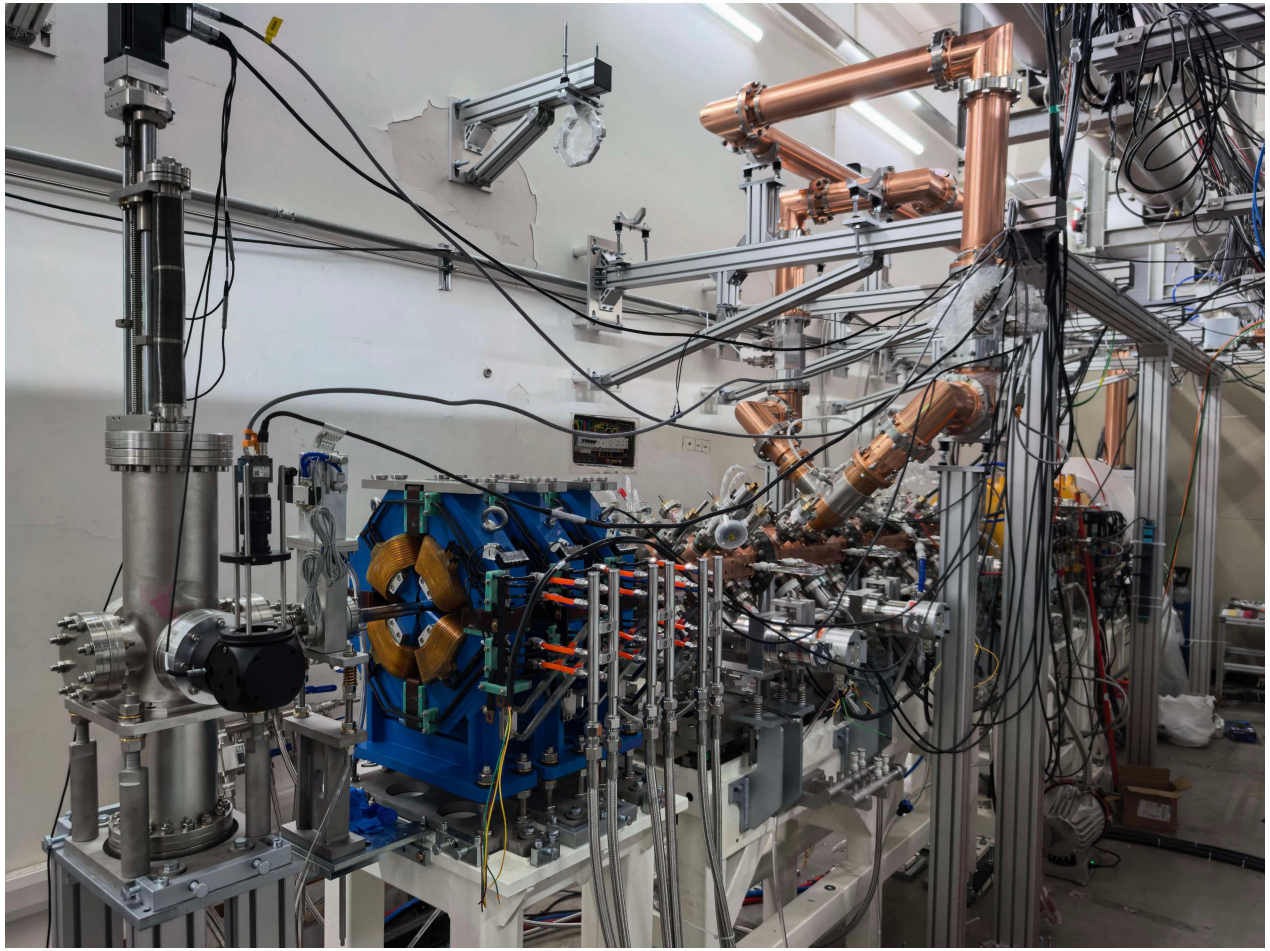


Development of the key components-Test Facility

- Ion source
- RFQ
- quadrupole-magnets
- Control system
- etc.



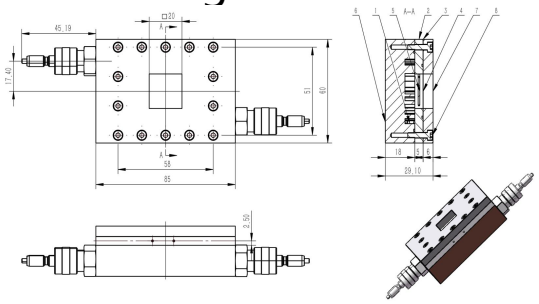
Measured beam shape

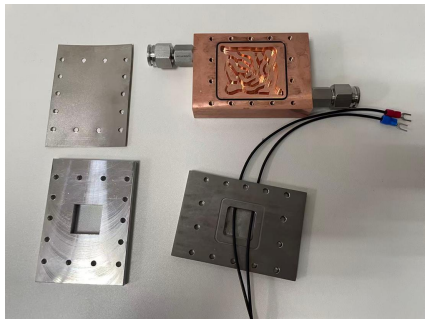


Development of the key components-Targets

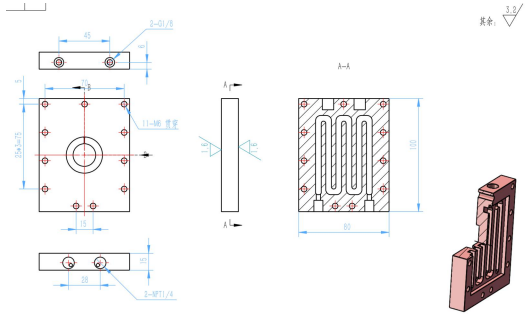
➢ Liquid target prototypes (^{18}F, ^{68}Ge)

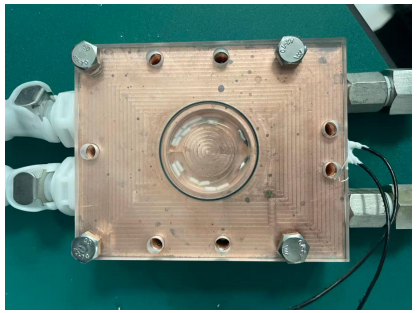
- Static liquid target with topology-optimized cooling channels





- Dynamic circulating liquid target



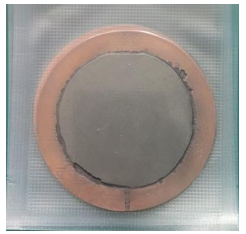


- Equivalent heat-dissipation test

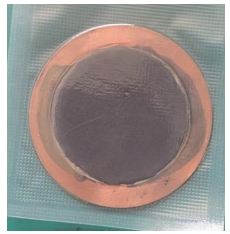
Target	Thermal power density [W/cm^2]	Temperature [°C]
Dynamic circulating liquid target	702	<37

➢ Solid target prototypes (^{131}I, ^{177}Lu, ^{211}At, ^{225}Ac)

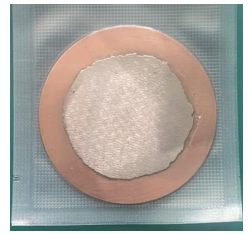
- Target fabrication by hot pressing and electroplating



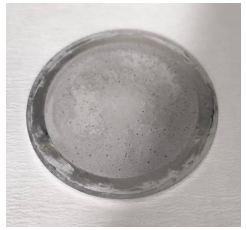
Te target(^{131}I)
0.21mm 99.99%



Yb target(^{177}Lu)
0.16mm 99.9%



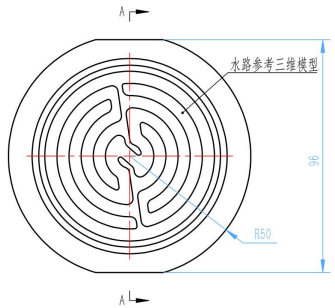
Bi target(^{211}At)
0.21mm 99.99%

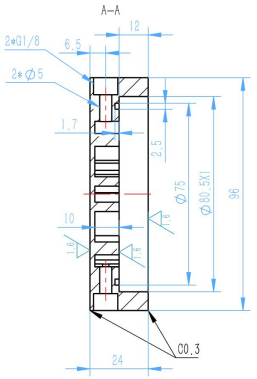


Ba/Ra target(^{225}Ac)
2 mg/cm2

- Solid target prototypes









Development of the key components-Seperation and purification

^{225}Ac separation setup and results



Separation material



Separation column



Wet-chemistry separation cold-test setup

Ba decontamination factor	Ba recovery rate	Ba purity rate	La recovery rate	La purity rate
262753.97	99.46%	99.99%	99.26%	99.14%

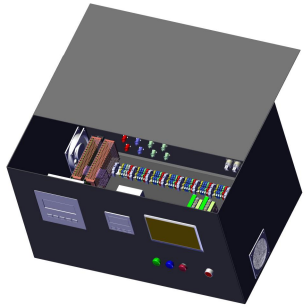
Procedure	Eluate volume (mL)		Total processing time (min)
	Ba	La	
Before optimization	120	35	340
After optimization	110	9	268

^{225}Ac automated separation and purification system

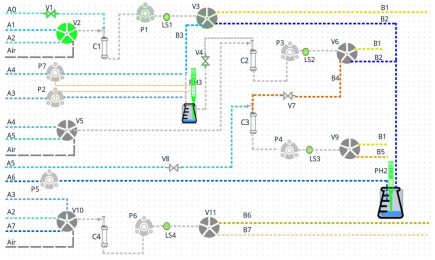
- The main components, auxiliary equipment and control system are designed separately, making them suitable for hot-cell use.
- Procedures are built in, with one-click operation that completes the isotope separation fully automatically.



Process cabinet



Control cabinet integration schematic



Control interface

Development of the key components-Seperation and purification

^{177}Lu separation cold-test setup and experiments



Separation setup

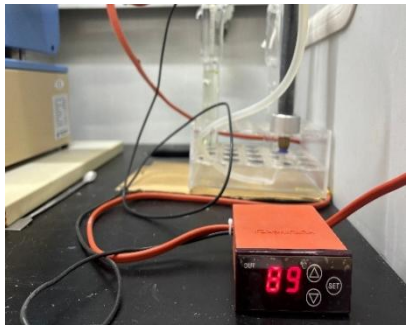
- **Conclusion:** by optimizing the separation material and process, Lu purity reached rate: **99.0%**, overall recovery rate: **52.5%**, and Yb recovery rate: **95.07%**.

类型	体积(mL)	Yb(mg/L)	Lu(mg/L)	Lu纯度	Lu回收率
原液	75	3975	2.25		
1次洗脱	100	291.45	2.83		
2次洗脱	36	4.12	3.78	99.6%	52.5%
3次洗脱	18	0.02	4.92		

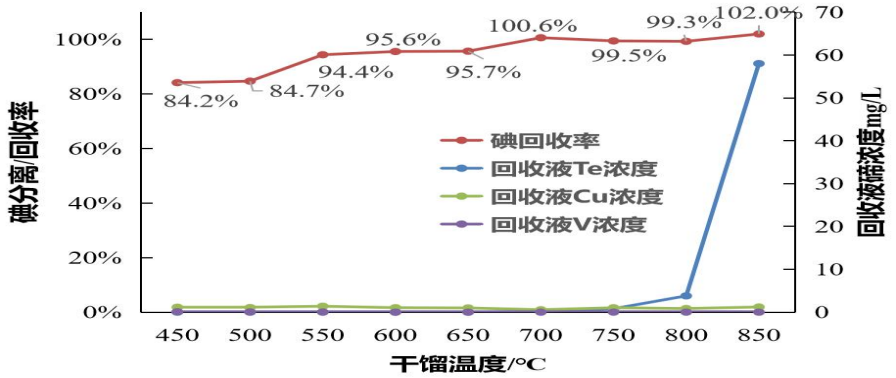
^{131}I separation setup and experiments



^{131}I dry-separation setup



^{131}I recovery system



Conclusion: using TeO_2 powder and elemental iodine to simulate the target material and 131I, at temperatures above 700 °C the recovery rate exceeded **99%**, with impurity levels **≤1 mg/L**.

Outline

- Background
- Layout of the multi-ion linac
- Development of the key components
- **Summary**

Summary

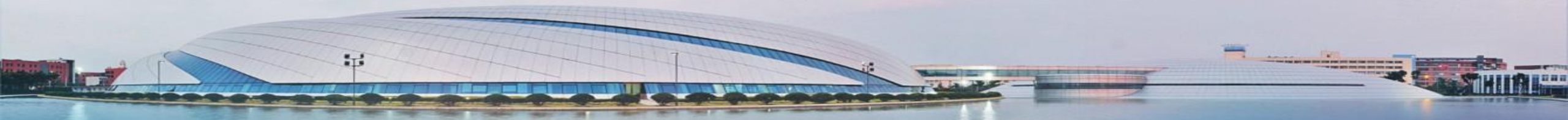
- A multi-ion linac was proposed for medical isotope production
- Many prototypes were developed for the Phase-I
- A test faclity is used to test the ion source, RFQ and etc.

AFAD 2026 Conference

Thanks for your attentation

Ping Wang

On behalf of SARI team



2026.10.14