Summary of CYC2025 Chengdu

Lowry Conradie

CYC 2025
24th International Conference on
Cyclotrons and their Applications

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Tianjue Zhang
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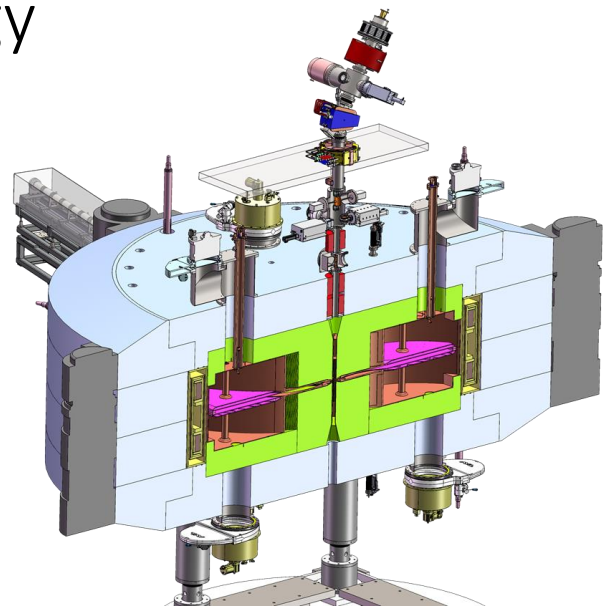
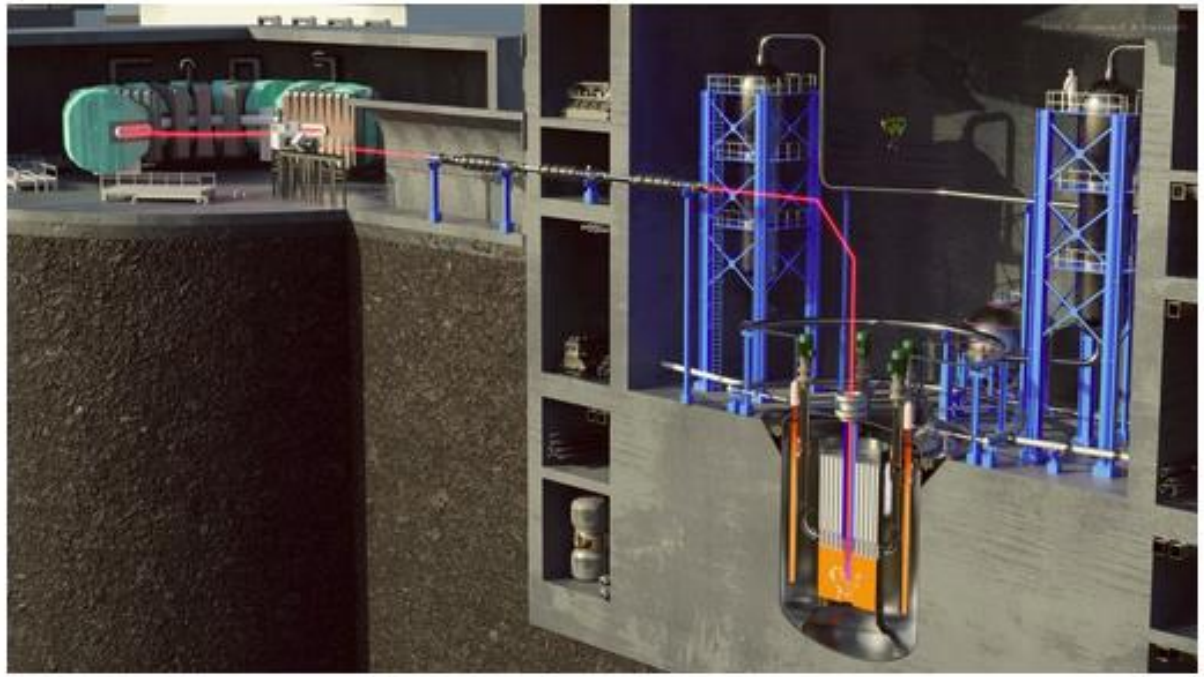
Cyclotrons and Technology

- IMP develops Compact SC cyclotron for ^{225}Ac production and nuclear physics:
  - 120 MeV/u,
  - A/Q=3
  - initially H_3^+ with ~1mA (protons)

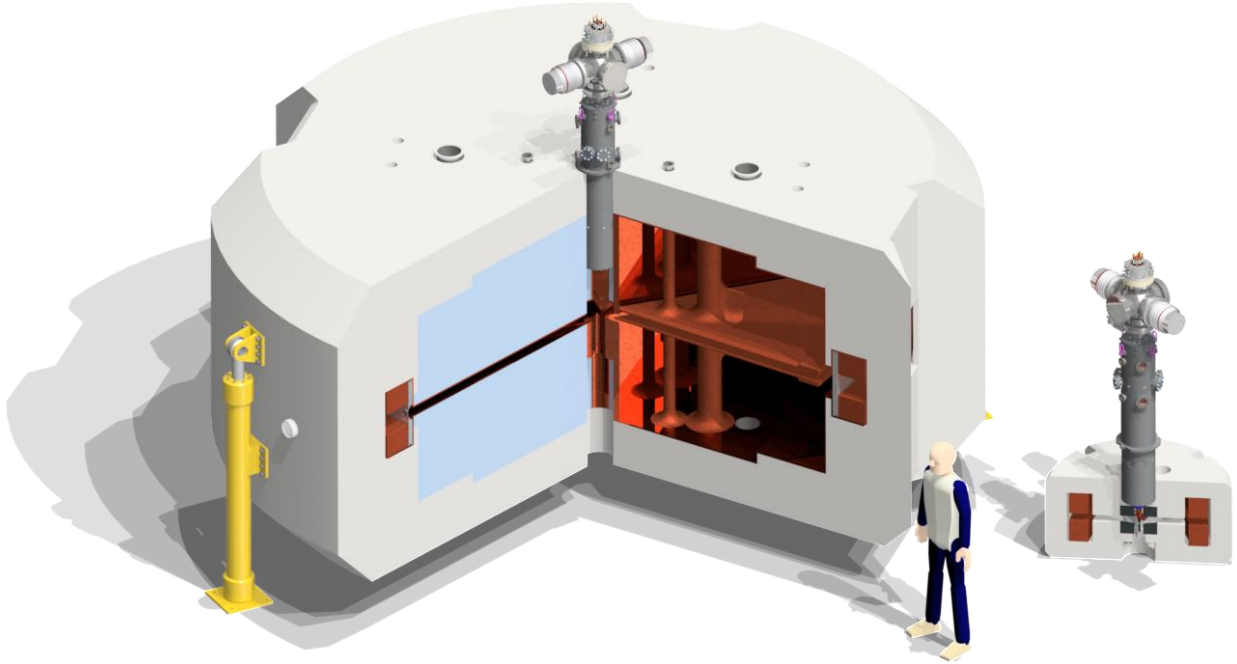


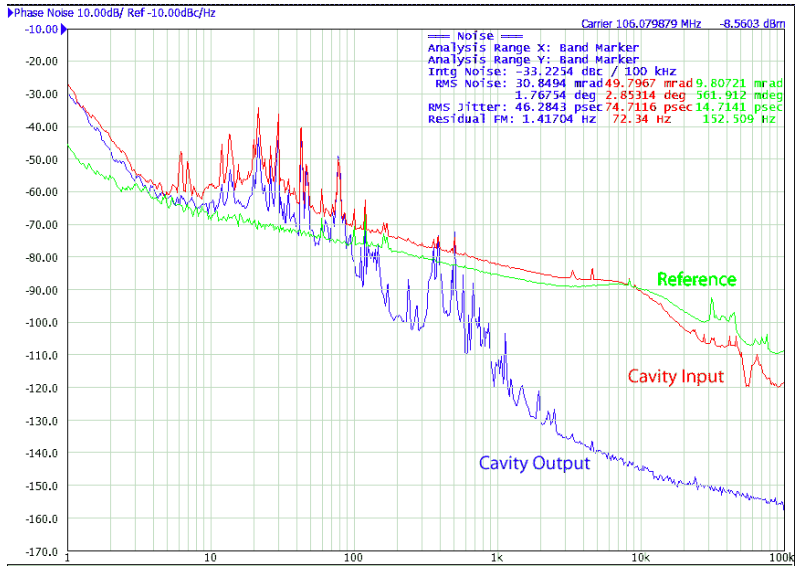
- TRANSMUTEX proposes START project (Subcritical Transmuting Accelerated Regenerative Technology) based on the PSI cyclotron configuration:
  - Cyclotron 800 MeV, 5 mA
  - Spallation Target, 4 MW molten metal target
  - Fuel: nuclear waste + Thorium



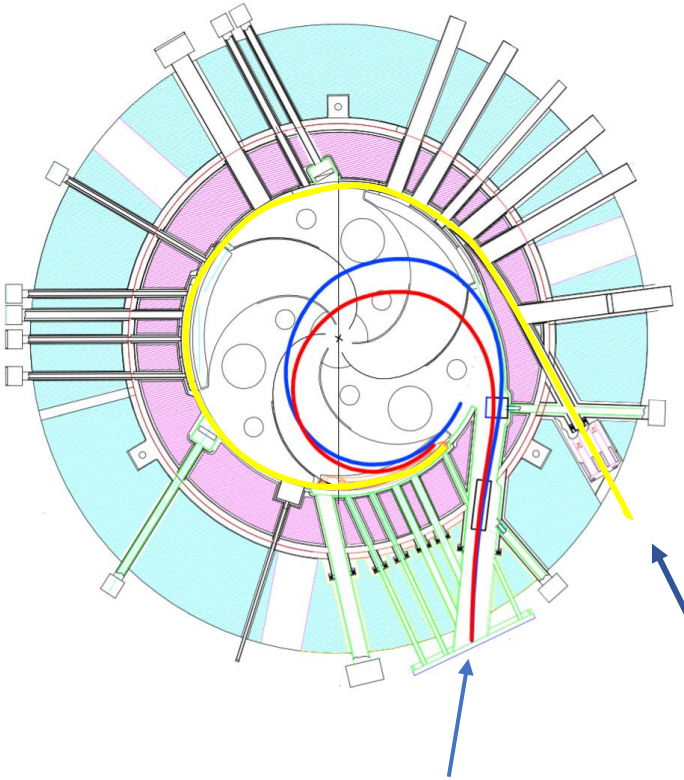
Cyclotrons and Technology

- ISODAR team focuses on validating of 5 mA of H_2^+ injection with RFQ on 1.5 MeV centre region mock-up
- Ken Fong presented a comprehensive analysis of RF frequency generation and phase noise impact:
  - Once introduced, phase noise persists indefinitely
  - Frequencies must be multiplied, never divide
  - Microphonics is a major source of additive phase noise
  - DO NOT use spectrum analyzer to measure phase noise





Upgrade of the LNS Superconducting Cyclotron
(Danilo Rifuggiato)



Ions extracted by stripping

Ions extracted by electrostatic deflection

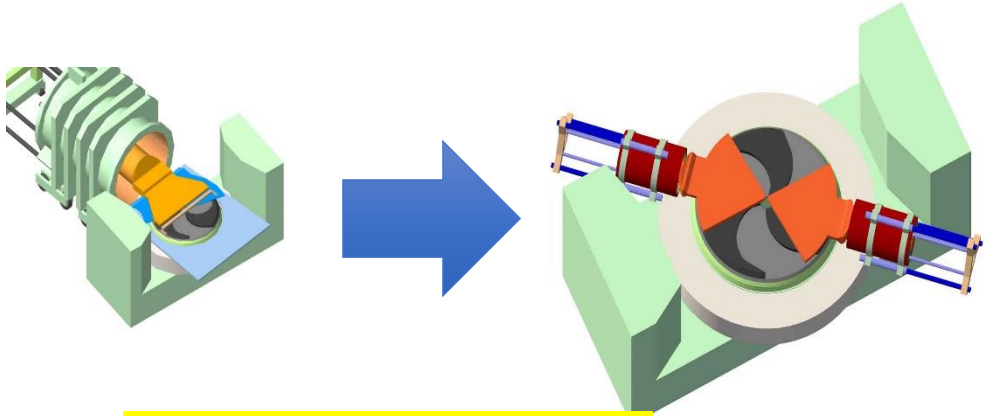
Beam commissioning with extraction by stripping (high intensity)

March 2028

Recent Upgrade of RCNP AVF Cyclotron

Upgrade of Ion Sources

Upgrade of Dee electrodesEnhance the turn separation and improve the extraction efficiency



Several tens to 100 μA

New Injection for TRIUMF 500 MeV Cyclotron

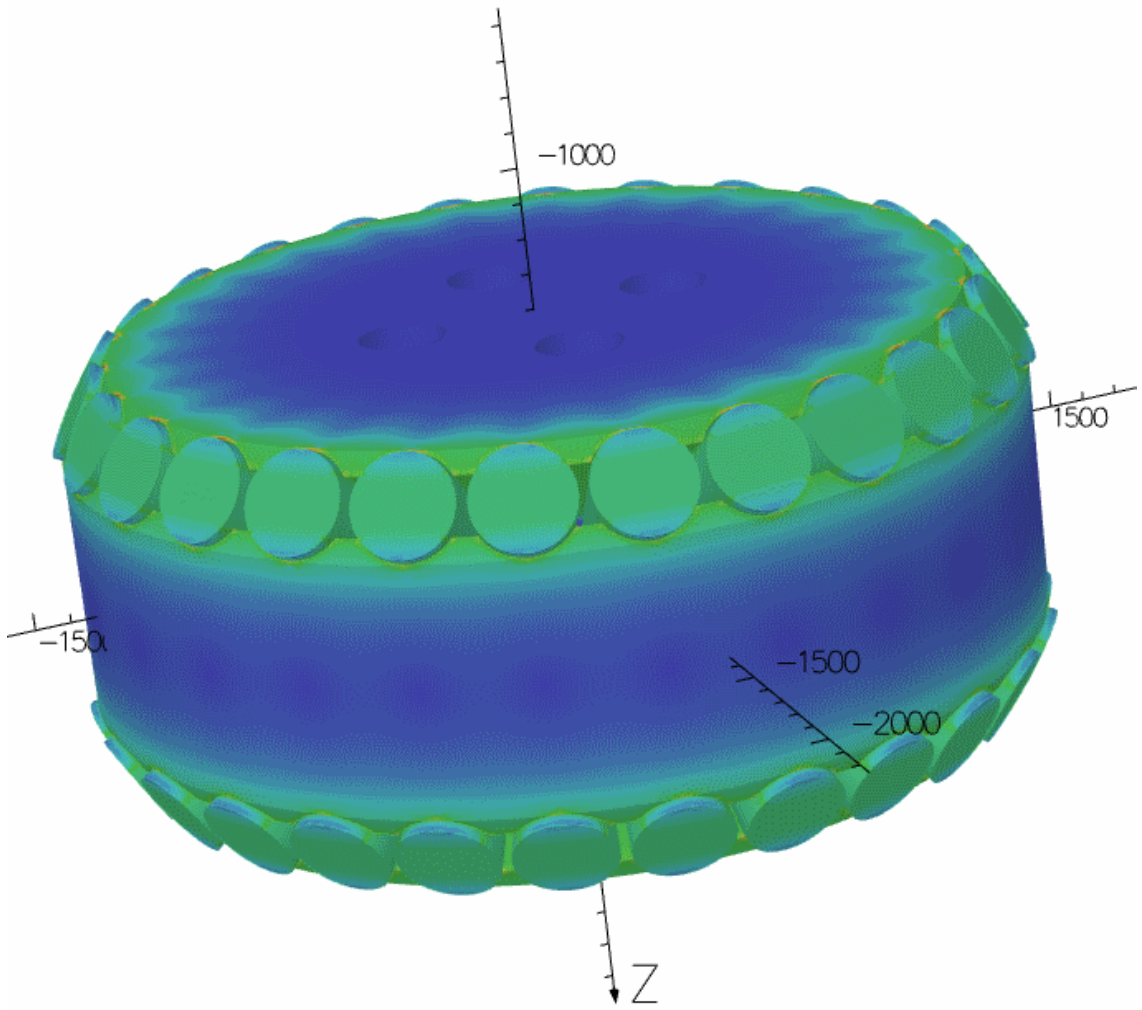
- New Ion source
- Beautiful beam diagnostics
- All new injection subsystems are controlled by EPICS based control system
- Replace old beamline with completely new one.

Upgrades for the AECR (Partrec) AGOR Cyclotron

- Cocktail beams are more controllable
- Created a monitor to follow the source performance during the delivery
- Improved intensity due to Einzel lens installation

Design of the EcoCyclone Permanent Magnet Medical Cyclotron

- EcoCyclone satisfies all feasibility tests so far:
- Overall environmental impact is not clear –
- Most useful where electricity is limited/unreliable (ie. has a scarcity) e.g. mobile cyclotron



Reinforcement Learning for Real-Time Cyclotron Tuning: Results from the Injector 2 Experiment at PSI (Dr. Malek Haj Tahar)

- a two-week experimental campaign at PSI Injector 2 was conducted to evaluate the feasibility of applying reinforcement learning (RL) for real-time beam optimization.
- very promising steps to high intensity

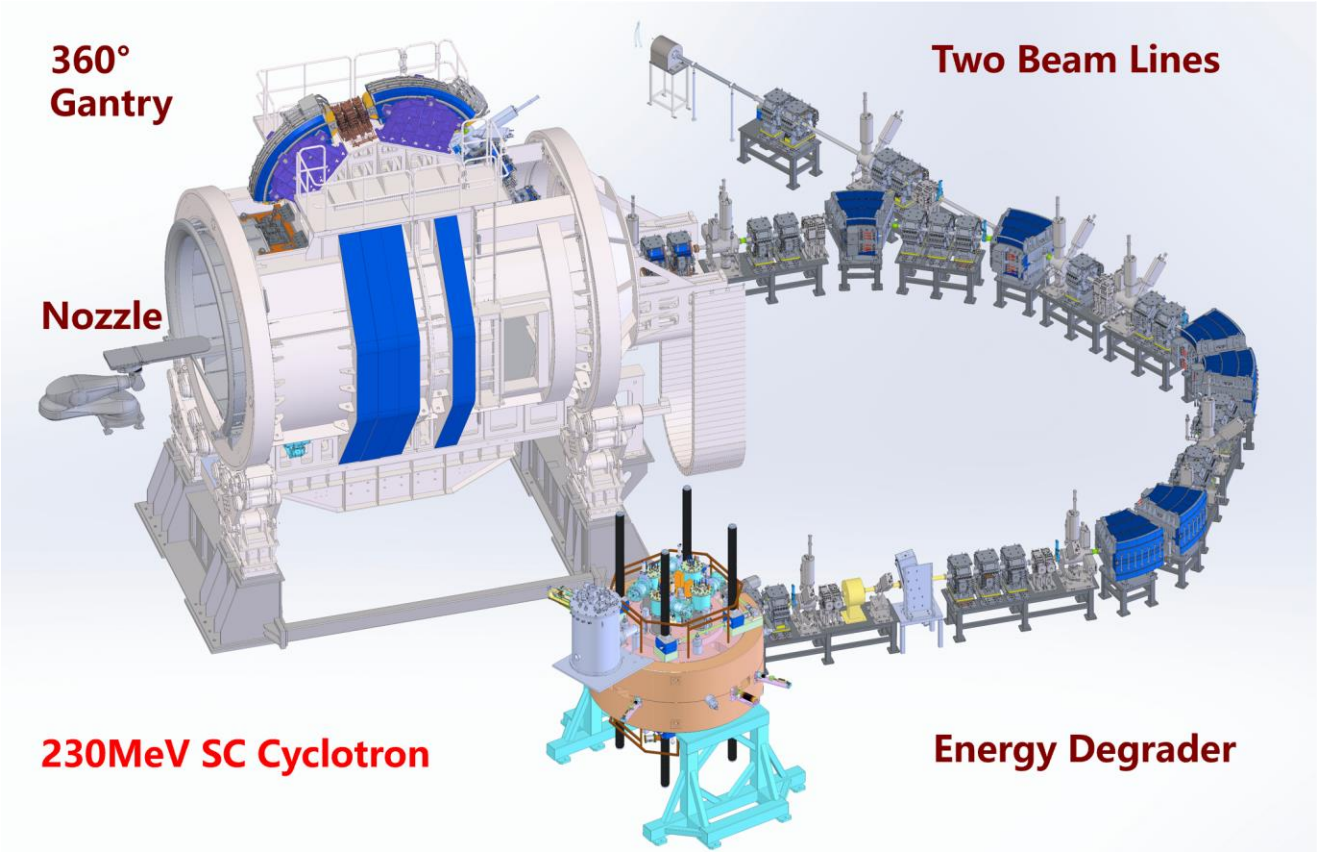
Beam current	Initial reward	Final reward	Initial losses	Final losses	Nb of steps	Nb of interlocks
50 μA	-0.14	-0.041	0.2 nA	0.2 nA	1	0
100 μA	-0.25	-0.046	2.0 nA	0.2 nA	3	0
200 μA	-0.48	-0.038	17.1 nA	0.2 nA	2	0
300 μA	-0.77	-0.060	95.0 nA	0.3 nA	3	0
500 μA	-0.33	-0.062	7.0 nA	0.2 nA	3	0
800 μA	-0.54	-0.069	23.3 nA	0.3 nA	5	0

FETS-FFA Project at RAL (Dr. Jean-Baptiste Lagrange)

- To demonstrate FFA suitability for high intensity operation, a prototype 3-12 MeV proton ring is proposed at RAL
- beam stacking, 4D painting and large dynamical aperture are key, in simulations up to 4 beams are stacked

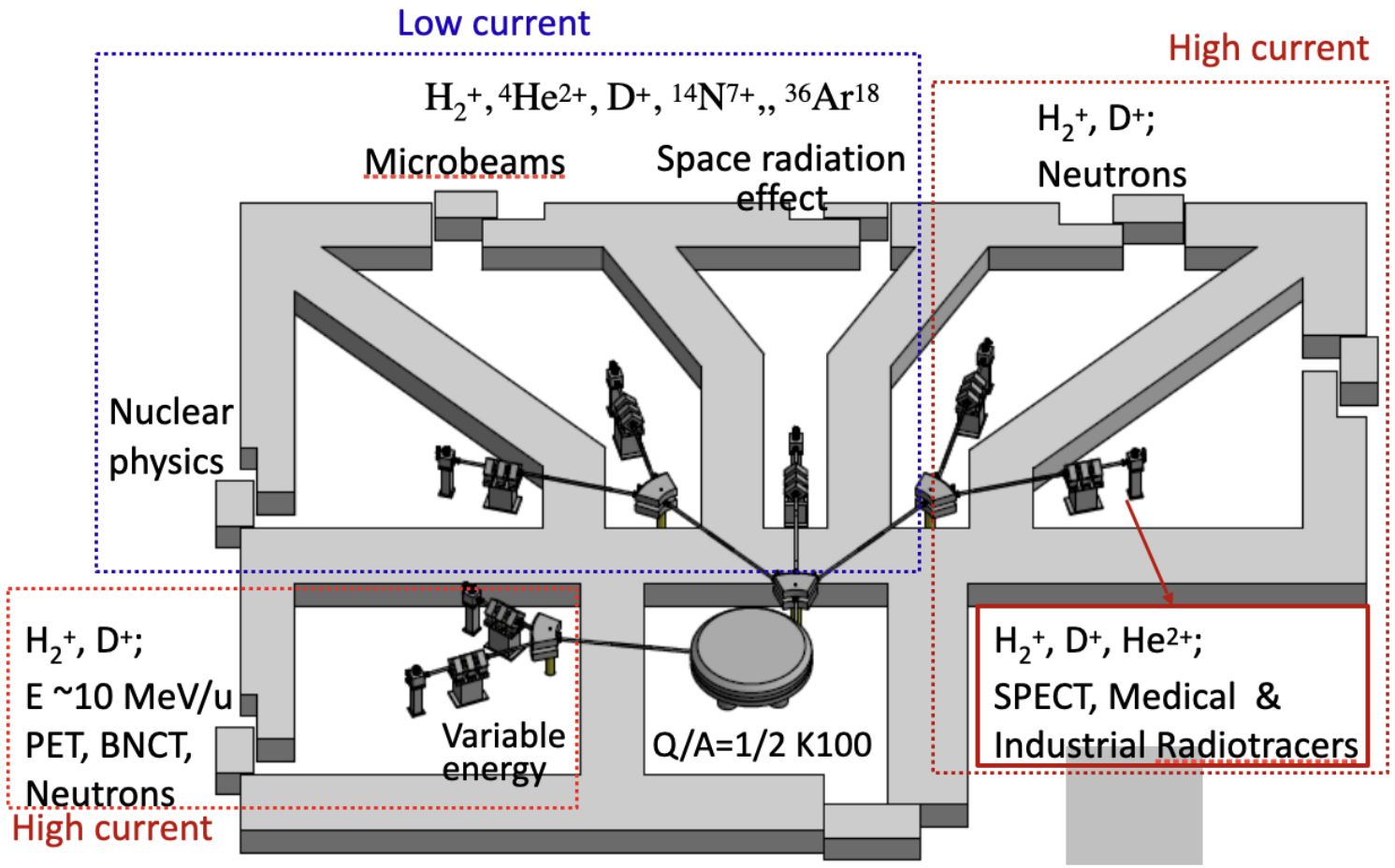
The Low-temperature and High-temperature Superconducting Cyclotrons Developed by CIAE in the Last Ten Years (Tianjue Zhang)

- SC cyclotron-based proton therapy system has been designed, constructed, installed, and commissioned at CIAE.
- a 100MeV HTS cyclotron CYCIAE-100B and a LTS α cyclotron CYCIAE-36; both have been designed and under construction.
- Continuously optimising the design of a 2 GeV high-power, high-energy isochronous FFA proton accelerator CYCIAE-2000,



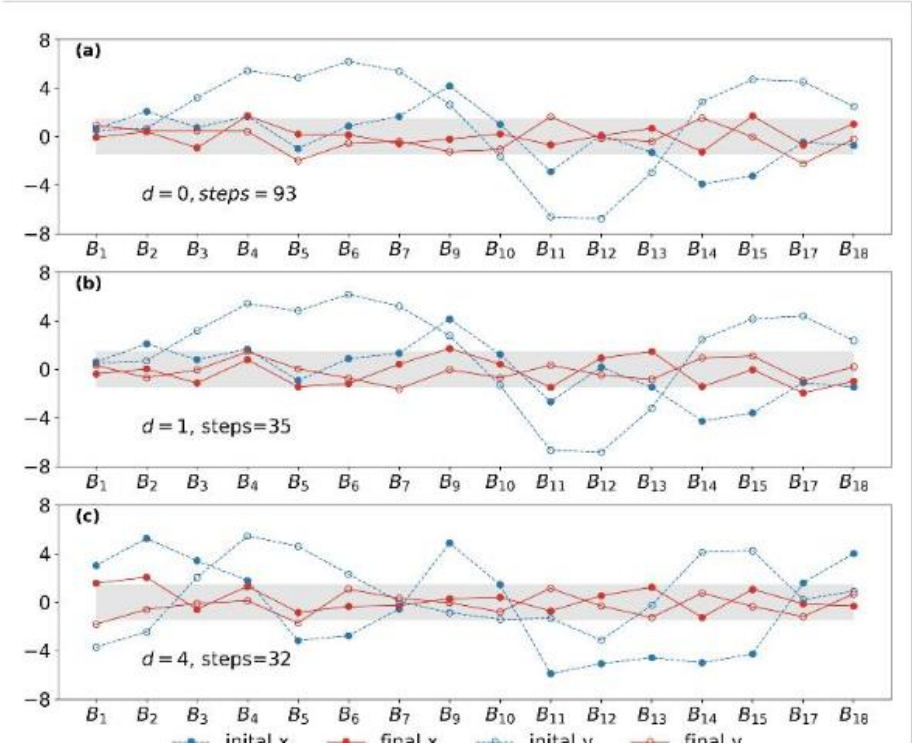
Design of q/A=1/2 K100 compact cyclotron system for heavy-ion space radiation effects and radiobiology studies (Dr. Jong-Won Kim, IBS)

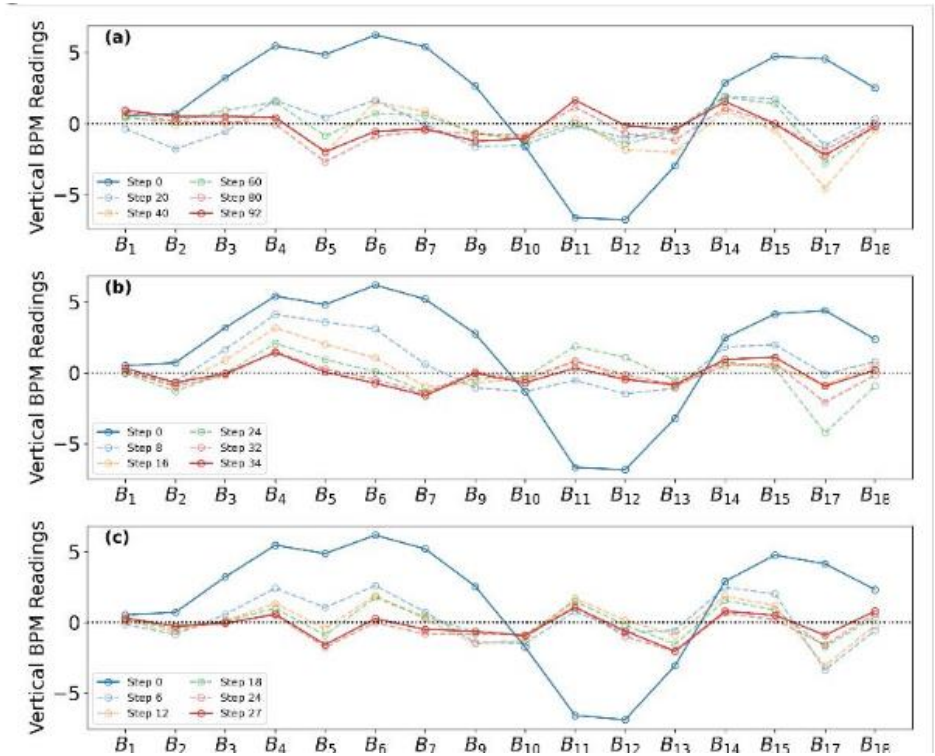
Schematic layout of the K100 facility (based on beam currents)



Machine Learning Applications in Large-Scale Accelerators
Dr. Xunye Cai

- A nice (and in this conference rare) overview of current state of the research a robust, AI-driven beam-tuning approach was presented
- A web based platform for assisted beam commissioning is shown, that allows the seamless switching of model calculations with the real machine (via EPICS)



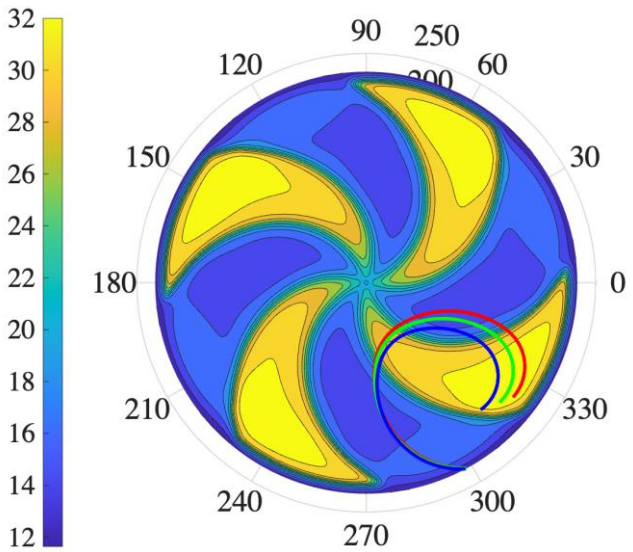


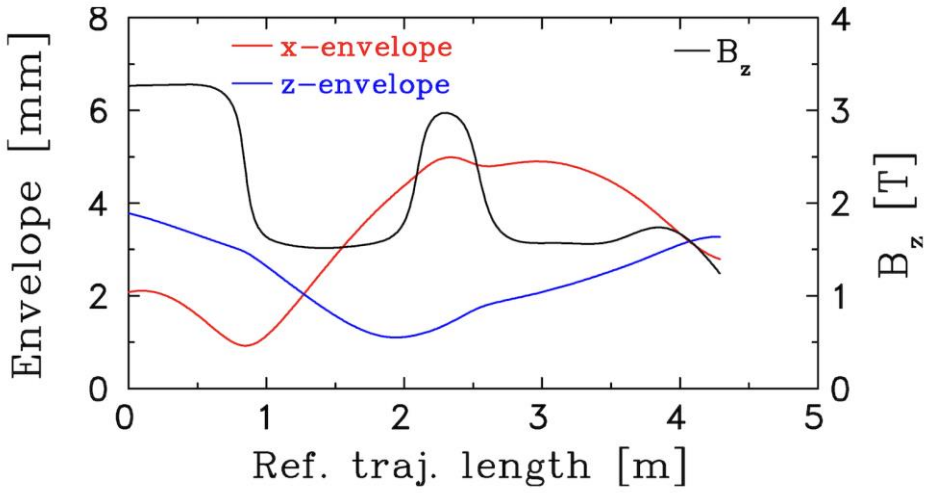
New Generation High Intensity Proton Cyclotron using H_3^+ Ions

Yi-Nong Rao, TRIUMF

- H_3^+ offers a promising route to overcome Lorentz stripping limits for high intensity compact cyclotron

- A design study of a ~340 uA, 120 MeV/u H_3^+ superconducting cyclotron has been conducted





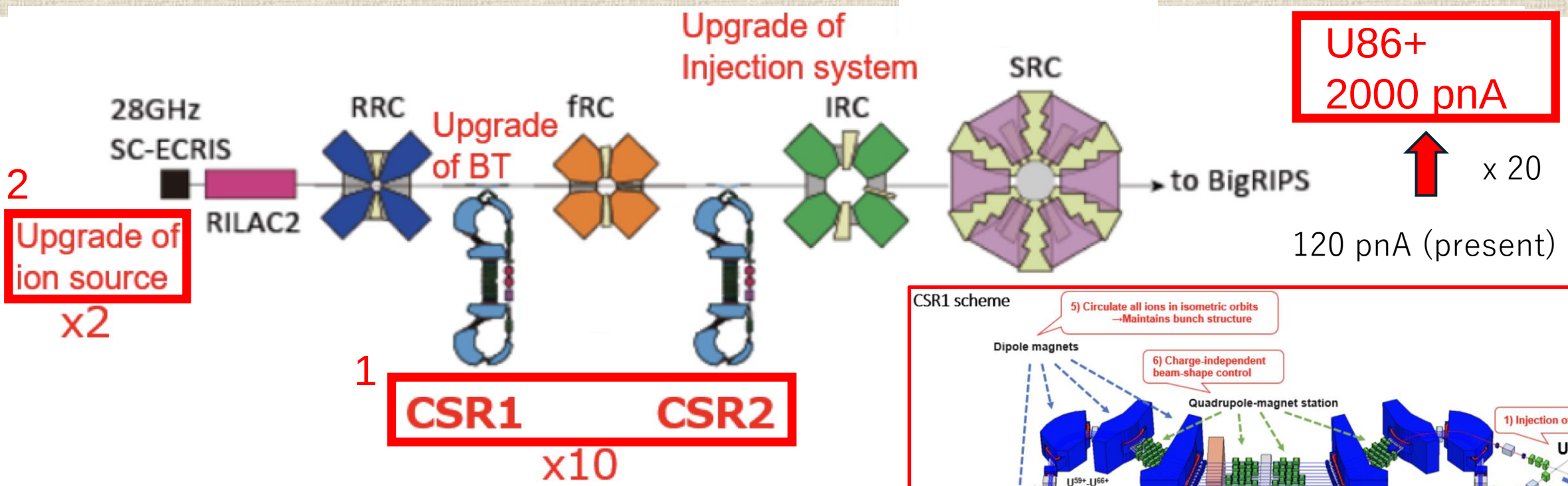
Steps towards a 1.6 micro A extracted beam of the CYCIAE230 superconducting cyclotron for proton therapy

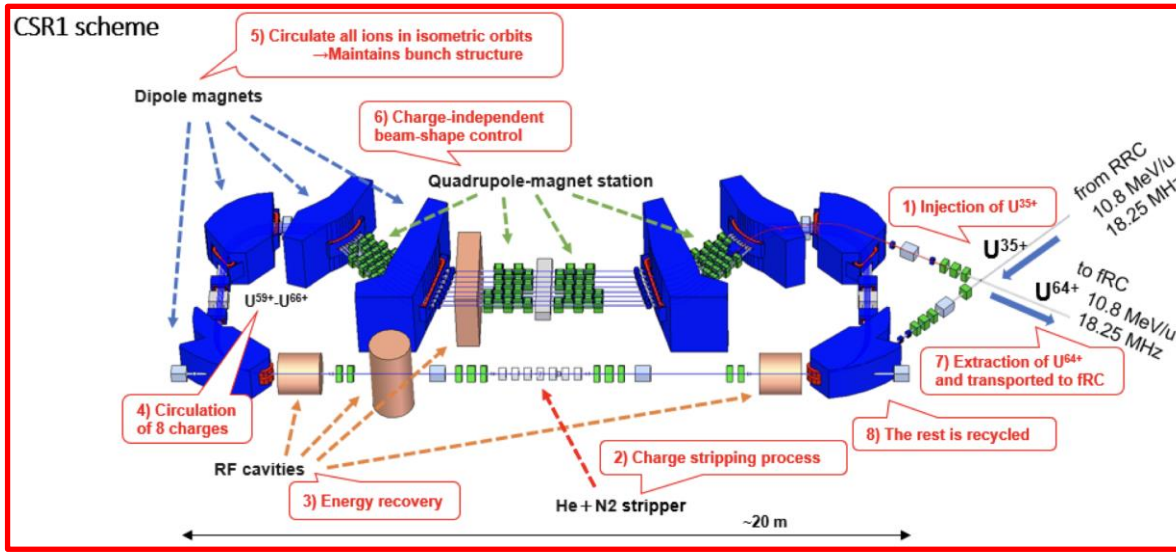
Zhiguo Yin, China Institute of Atomic Energy

A series of improvements were carried out to the superconducting cyclotron CYCIAE230 to increase its stability and beam intensity for potential FLASH usage

- Optimizing the ion source and phase selection in the central region
- Aligning the primary coil
- Adjusting the location of the electrostatic deflector
- Enhancement of the RF system
- Improvements in beam diagnostics
- New software facilitating Beam tuning

Development of High-Intensity Heavy Ion Beams for RIBF's ECR Ion Source (T. Nagatomo)

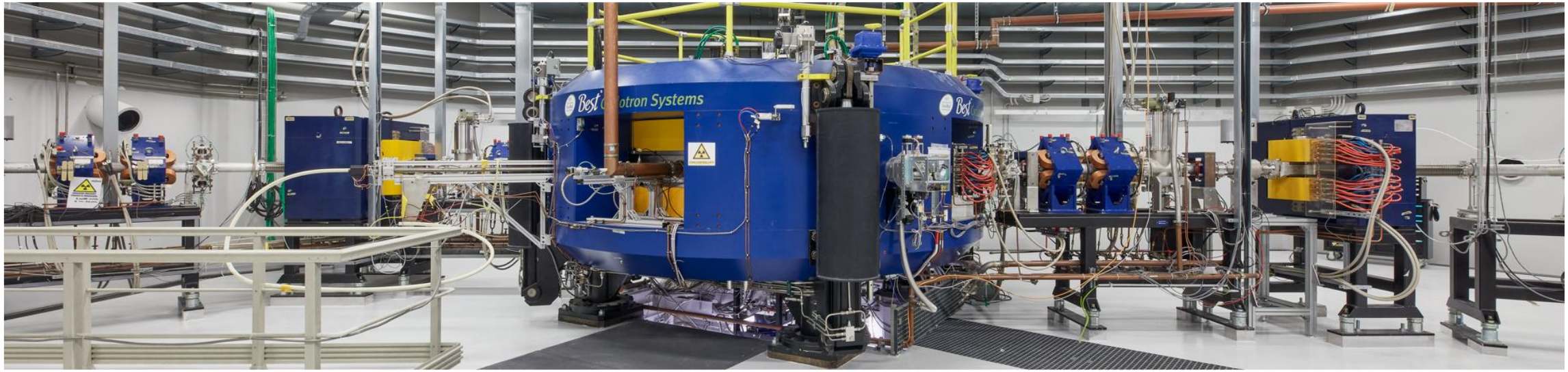




1. **Charge Stripper Rings (CSR1,2):**
   Improve the transmission efficiency
   CSR 1 and 2: 20 % and 25 % → 80 % each

2. **Upgrade of RIKEN 28-GHz SC-ECRIS**: ***To achieve the 300-eμA U^{35+} beam supply*** (twice of present)

Resume of SPES Cyclotron Operations at Laboratori Nazionali of Legnaro -INFN (MARIO MAGGIORE)



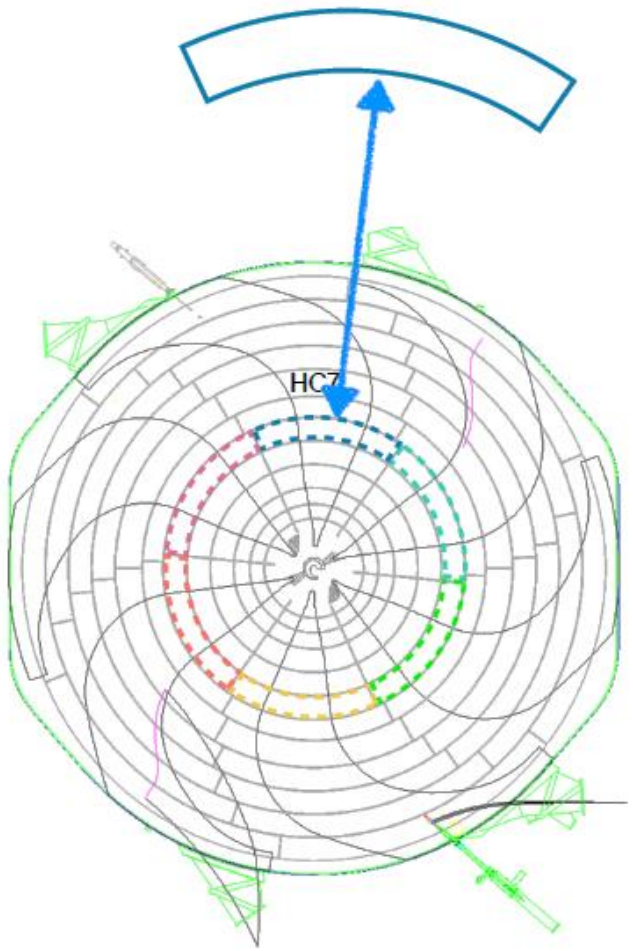
Beam commissioning of ISOL1 and ISOL2 beamline
Refurbishment of the ion source, Control system upgrade and revamping of water-cooling circuits

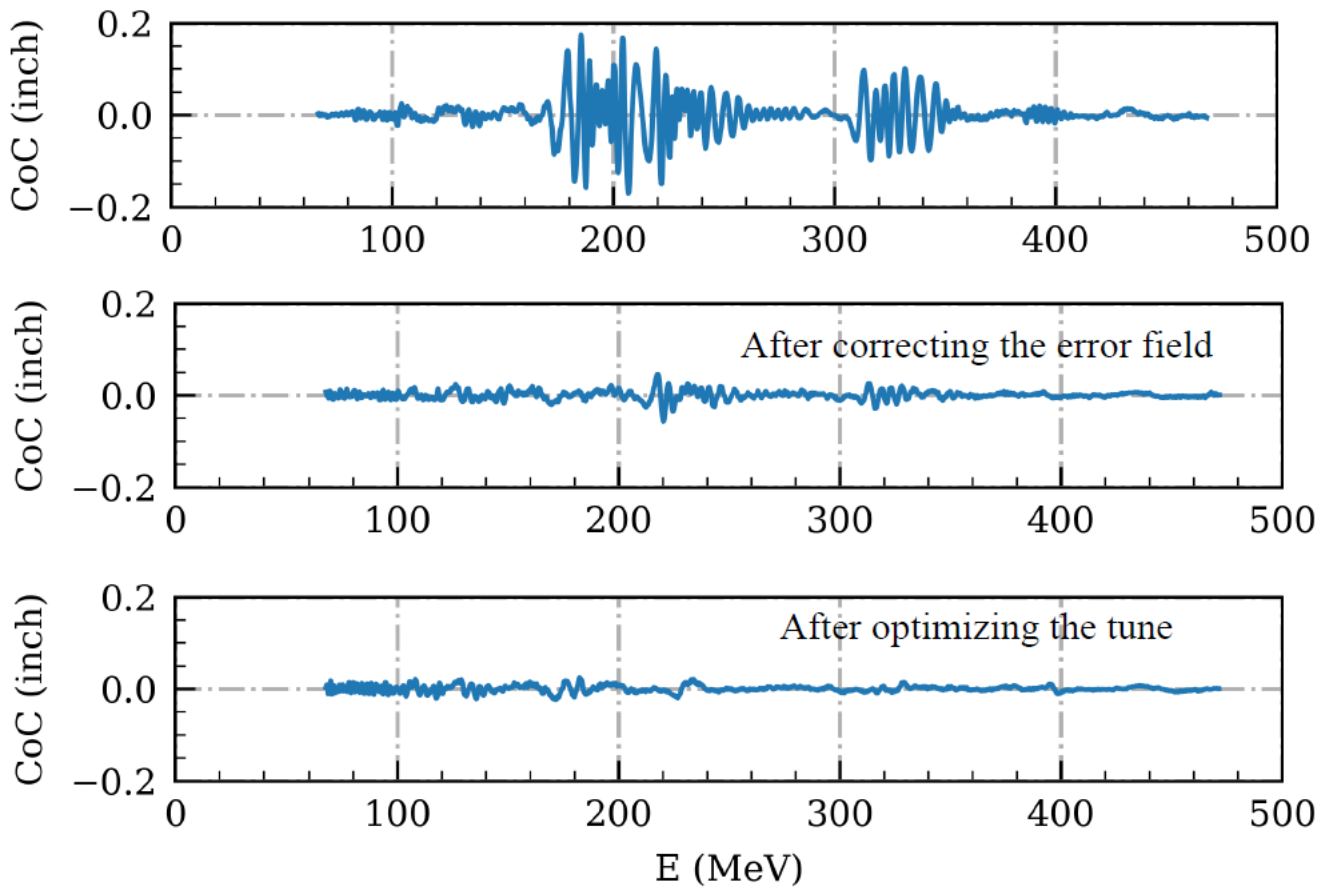
JULIC – Half a Century of Reliable Operation (Olaf Felden)

It is hard to see that such a successful facility is closed down

Recent Developments of the TRIUMF Cyclotron: Focusing on Linear Coupling Resonance (Lige Zhang)

Correcting the linear coupling resonance





SOLID state VS tube power amplifiers as one of the problematics of a wide band Cyclotron RF system (Antonio Caruso)

Vacuum Tube-based Amplifier

- High specialized personnel (difficult to find)
- Modularity and redundance (mostly NO)
- High reliability (yes if the tube is working)
- High Power up to MW (yes)
- Wide band, channel tuning is necessary
- Warmup and retuning if change tetrode
- Reflected wave full reflection (yes)
- High voltage power supply (10 kV typical)

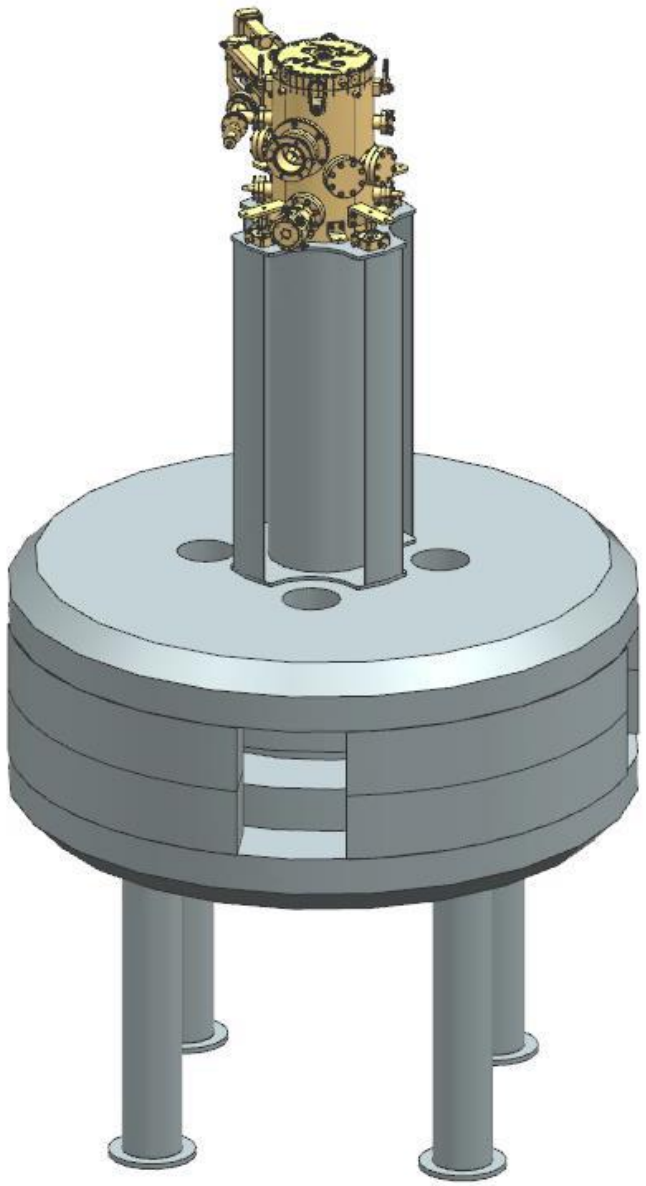
LDMOS SSA

- Maintenance and set-up accessible
- Modularity and redundance (YES)
- High reliability (YES)
- 100 kW Yes (fixed and wide band), MW (mostly fixed)
- Wide band, no tuning necessary
- No warmup, also if change a board with SSA
- Yes, if right LDMOS is selected and design accuracy.*
- Low voltage power supply (50 V typical)

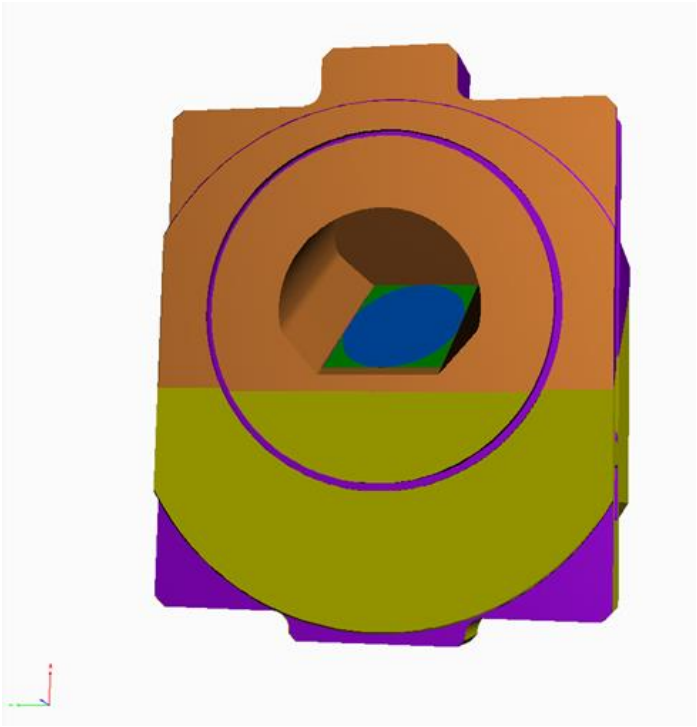
HCHC-1.5 demonstration cyclotron

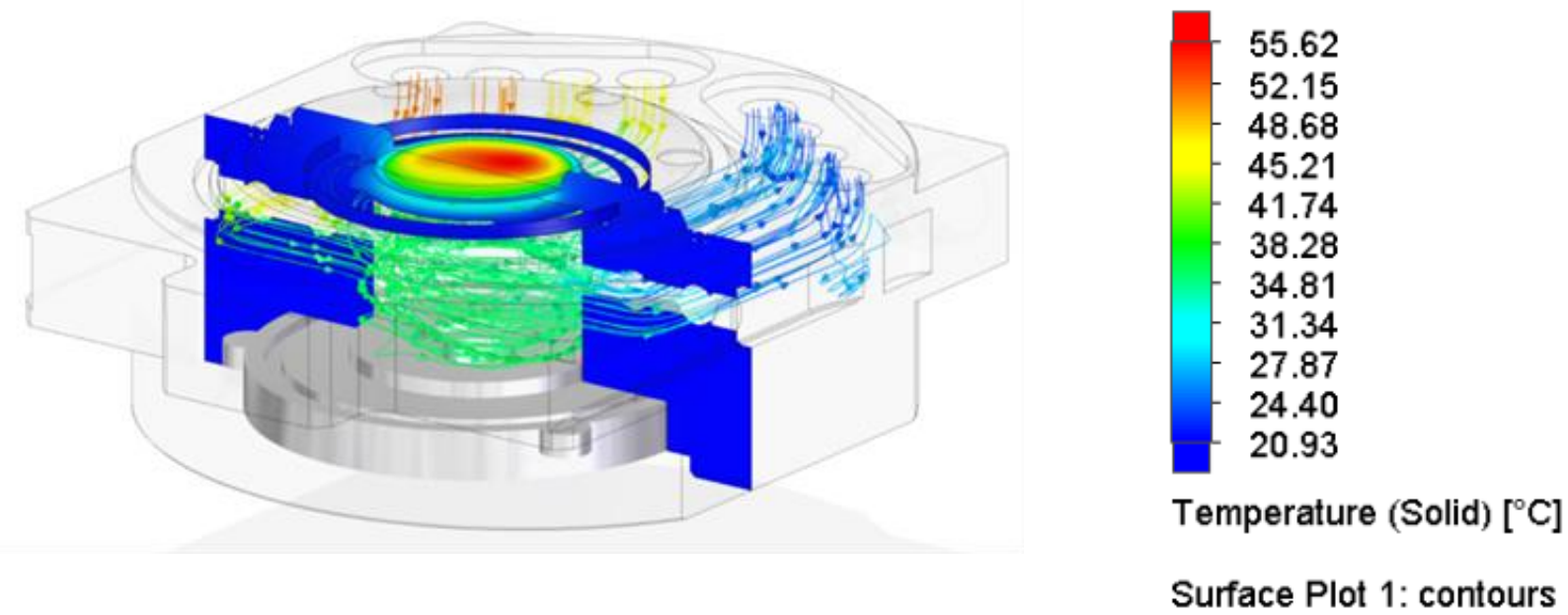
Test injection line, transmission & beam dynamics for final IsoDAR machine up to 3 MeV.

- Axial injection : same layout as in IsoDAR
- Optics matched to IsoDAR up to 3 MeV



Development of an alpha beam for 211At production at iThemba LABS (M. Sakieldien)





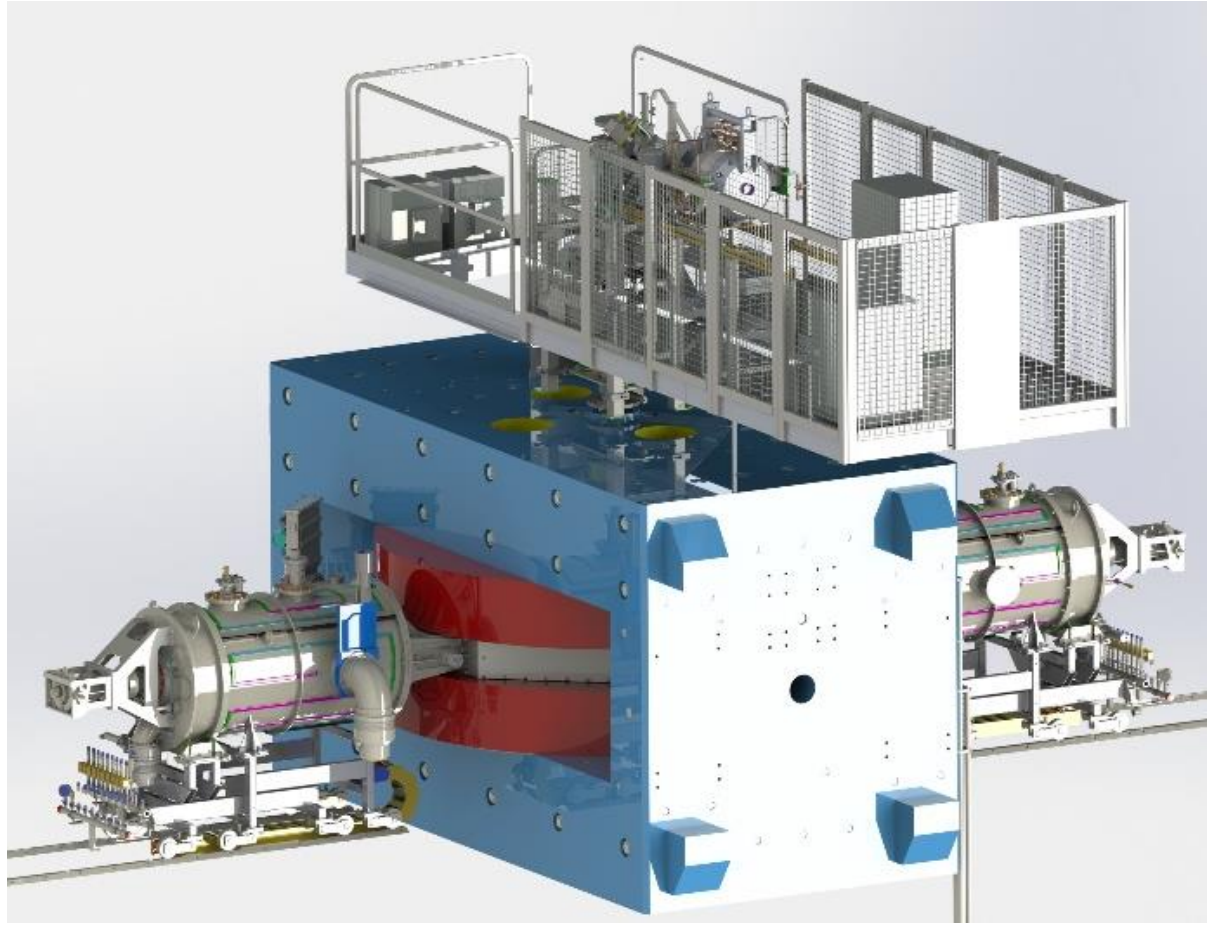
Installation of C70 Cyclotron and the Commissioning of the Sweeper Magnets for SAIF at NRF-iThemba LABS (Joele Mira)

- A C70 cyclotron and associated beam-lines have been installed and commissioned by IBA and iThemba LABS staff.
- The two target stations have been fully commissioned and are now producing isotopes.
- The sweeper magnets have been installed and tested.

FLNR JINR Accelerator Complex for multipurpose applied research (Semen Metrofanov)

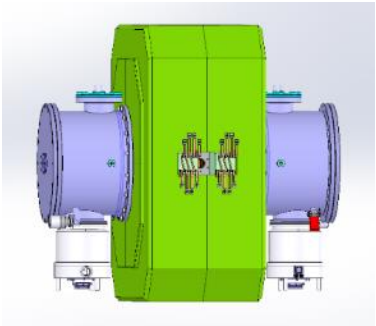
Current status of the FLNR laboratory

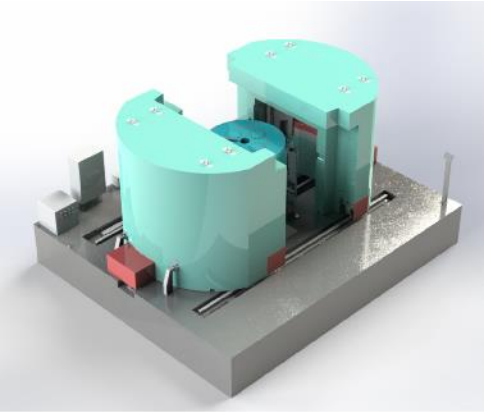
DC-140: new cyclotron for all-sort practical applications in FLNR ongoing in 2026

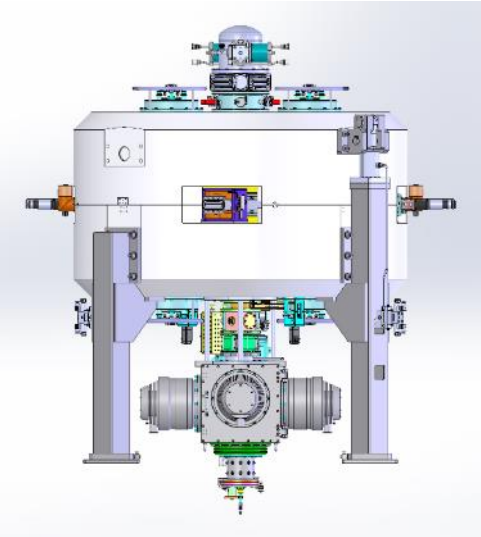


Development and Application of the Cyclotrons for the mA level beam current at CIAE (Shizhong An)

Medical cyclotrons development by CIAE







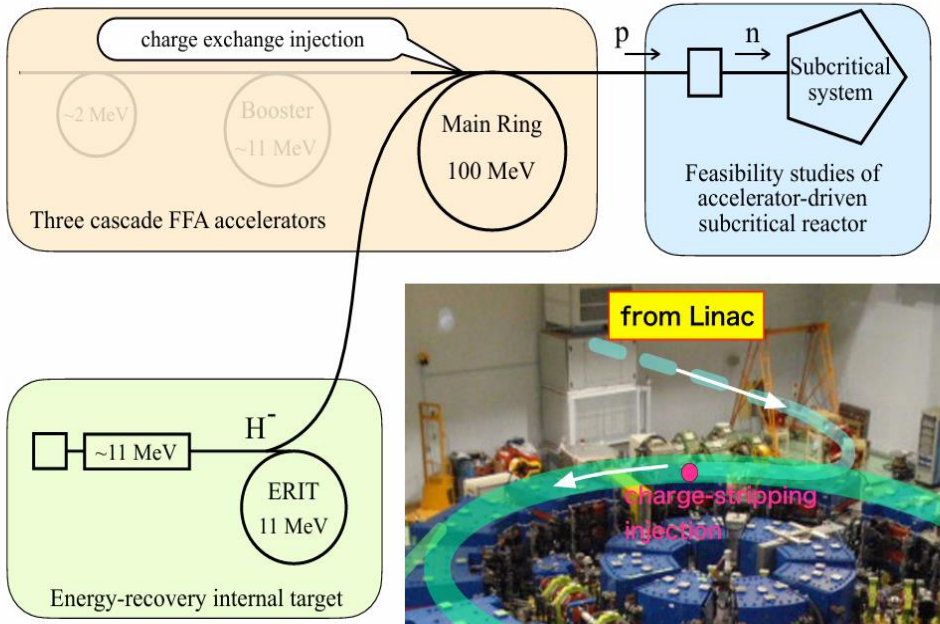
9.5MeV	16/18MeV	18MeV	30/50MeV	75/100MeV
60-100μA	60-100μA	500-1000μA	500-1000μA	500-1000μA
Pet Cyclotron Isotlope production	Isotope production	Isotope production BNCT	Isotope production BNCT	Isotope production

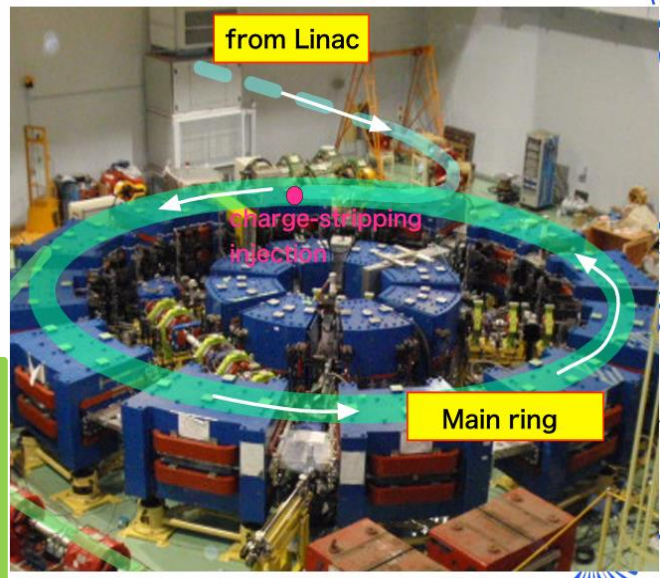
Beam stacking experiments at KURNS, Japan & ISIS, UK (J.-B. Lagrange)

KURNS FFA, Kyoto University

Successful beam stacking experiment at KURNS FFA to high energy.

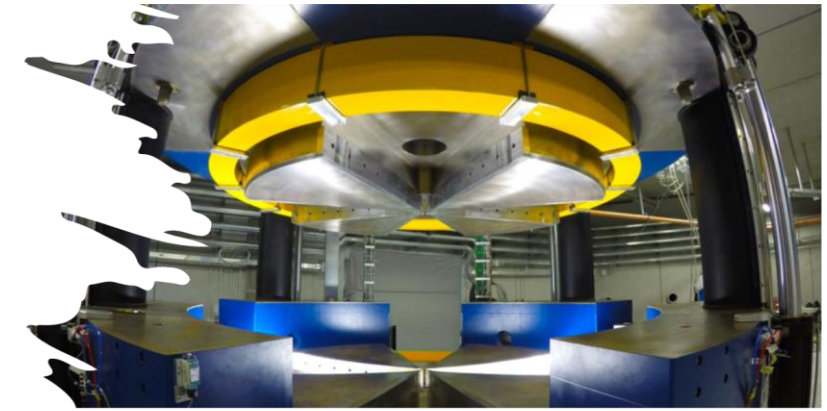
- Observation of significant loss of stacked beam due to RF knock-out.
- Experimental observation of RF knock-out in ISIS synchrotron.
- Successful experimental implementation of RF knock-out mitigation methods.
-

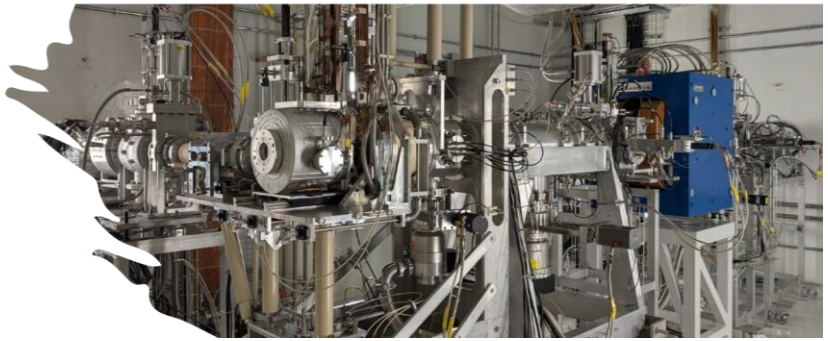


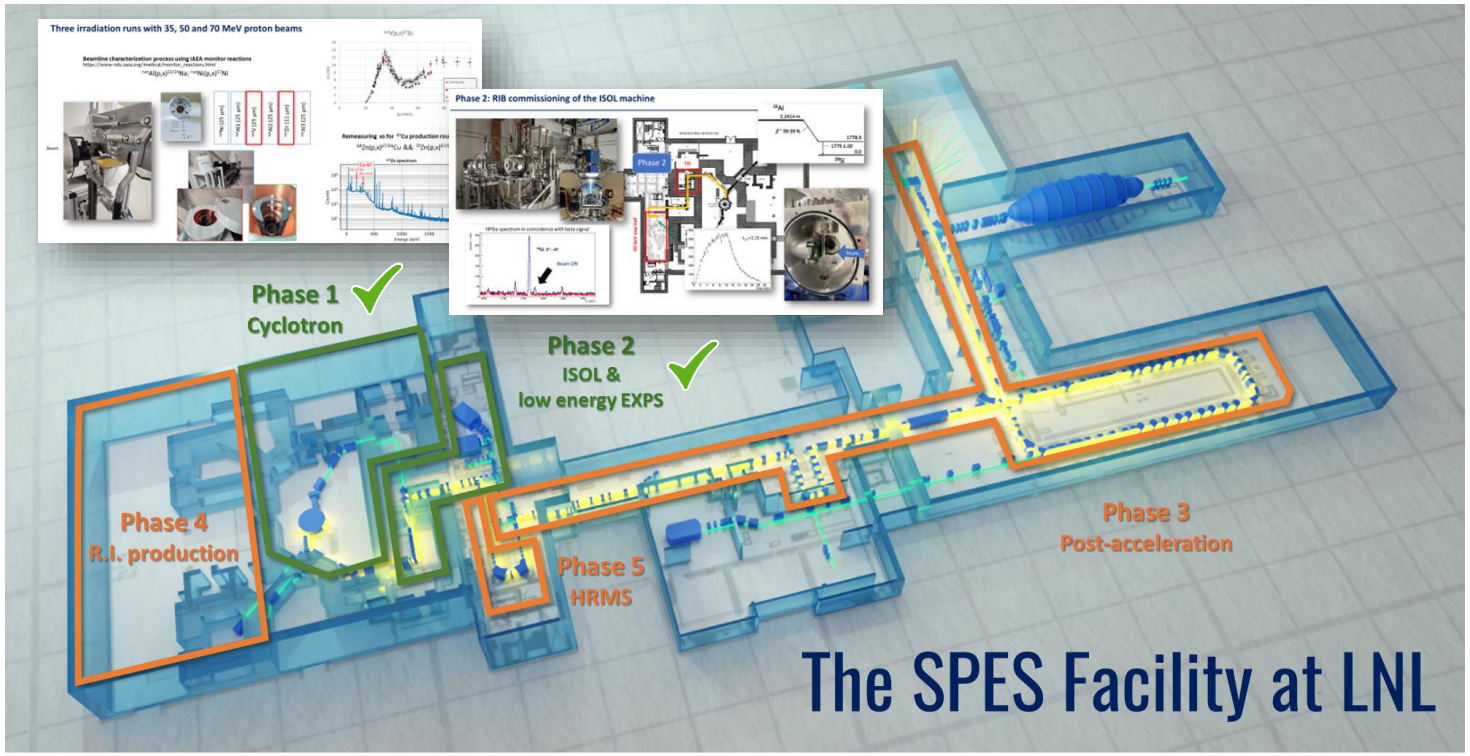


- Successful beam stacking experiment at KURNS FFA to high energy.
- Characterisation of final momentum spread of the combined beams.
- Observation of significant loss of stacked beam due to RF knock-out.

The SPES Facility at LNL: Status and perspectives (Tammaso Marchi)







- Progress well with their project
- Deliver their first radioactive beams
- Next focus on isotope production

Radionuclides production and medical applications thereof at Peking University

Back to 2016, no available radionuclide was a true bottle-neck for radiopharmaceutical R&D in China

Nuclides	Half-life	Function	2016 In China	2025 in PKU
^{18}F	110 min	Imaging	✓	✓
^{64}Cu	12.7 h	Imaging	✗	✓
^{68}Ga	68 min	Imaging	✗	✓
^{86}Y	14.7 h	Imaging	✗	✓
^{89}Zr	78.4 h	Imaging	✗	✓
^{111}In	88.8 h	Imaging	✗	✓
^{212}Pb	10.6 h	Therapy	✗	1st in China
^{212}Bi	60 min	Therapy	✗	1st in China
^{213}Bi	46 min	Therapy	✗	1st in China
^{225}Ac	240 h	Therapy	✗	1st in China
^{67}Cu	62 h	Therapy	✗	✓
^{152}Tb	17.5 h	Imaging	✗	✓
^{44}Sc	3.97 h	Imaging	✗	✓
^{56}Co	77 d	Imaging	✗	✓
^{20X}Pb	10^{x} y	Geology	✗	2026.10

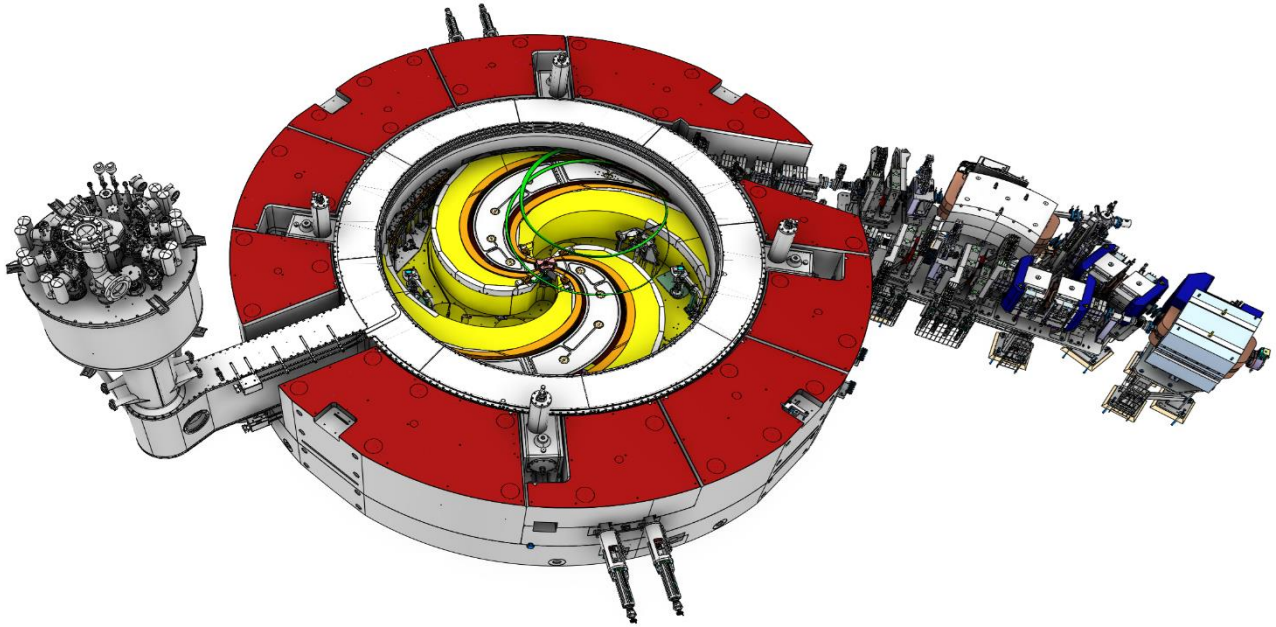
We are a team can operate cyclotron, and develop targets and purification processes for med radionuclides

This problem is being solved in China

The NHA C400 cyclotron facility for Hadron Therapy becomes a reality
Gaëlle Gérard

Coil design

- 2 main coils, each divided into 2 sub-coils (total of **4 sub-coils**)
- Superconductor material: **NbTi**
- Coils in **liquid Helium bath** at (cooled by cryocoolers)
- Max transversal field in the conductor: **≤ 4.5 T**
- Maximum current: **1140 A**
- Number of turns: **1344 total per coil**
- Ramping time **2 hours**
- Stored energy **~55.6 MJ**
- Fast coil protection in case of unexpected movement, high temperature or voltage difference



Site tests:

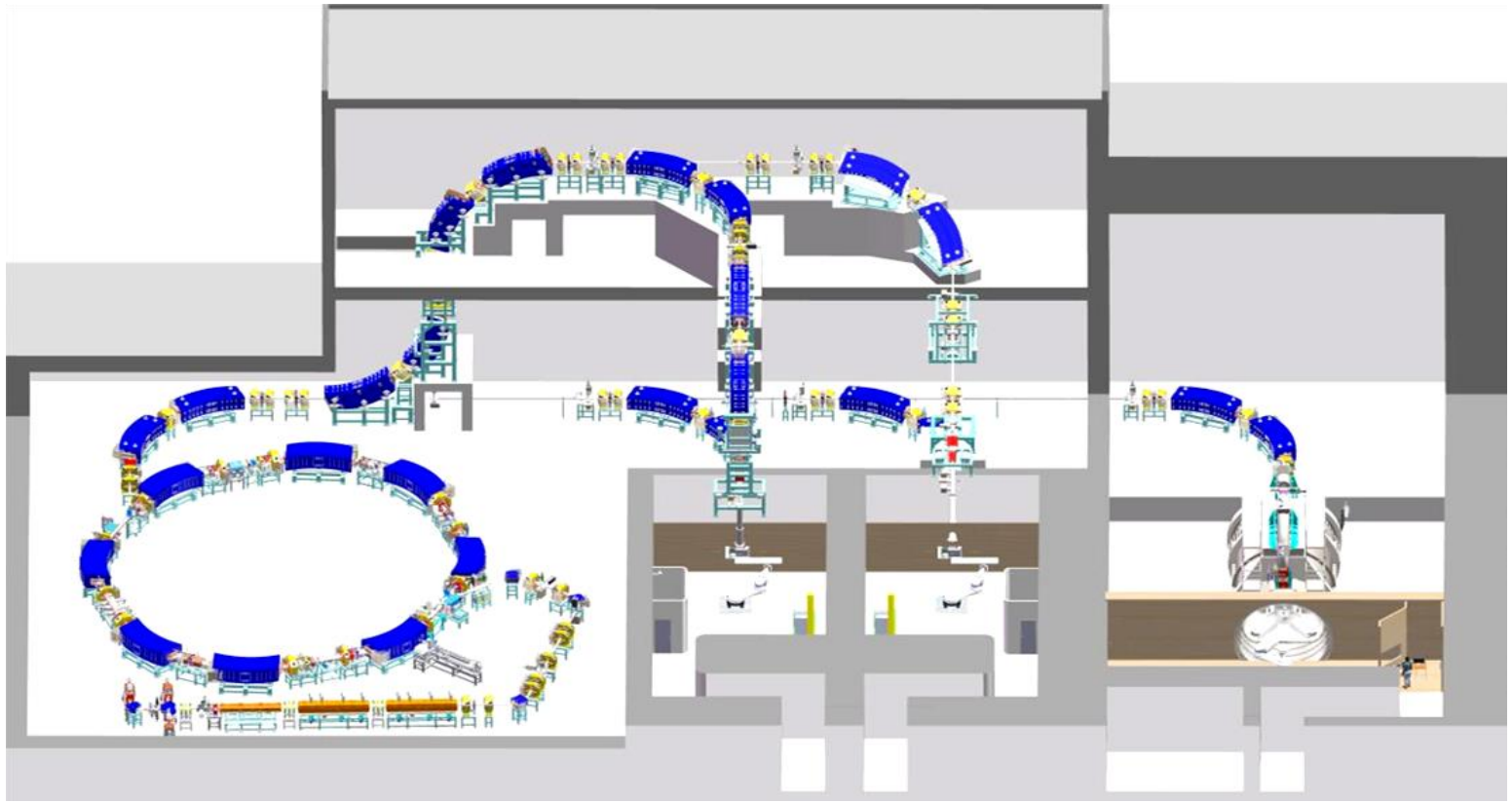
Vacuum sealing between yoke and cryostat tested
Electrical and vacuum tests performed

Next step:

Installation and alignment of the wheel inside the cyclotron
→ November 2025
Beginning of mapping measurement
→ Q1 2026

Status of Heavy ion cancer treatment facilities in China and the perspectives (Jian Shi)

- **Proton and heavy ion therapy is booming in China.**
- **China will soon have more heavy ion systems than the rest of the world combined.**
- **Lanith, a Chinese company, is expected to begin its first overseas installations soon.**

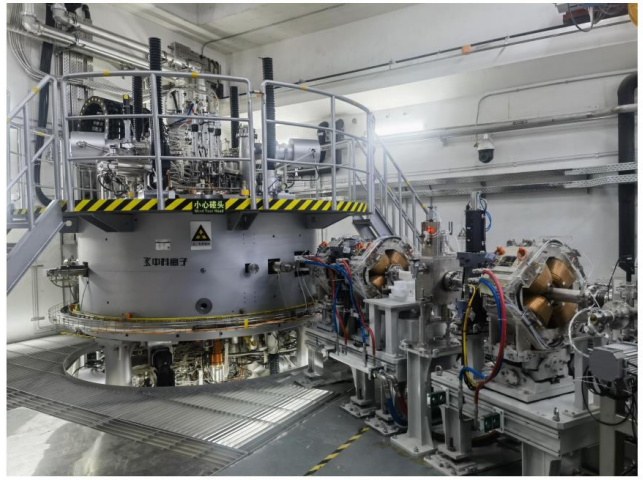


A novel 240 MeV superconducting cyclotron SC240 development for proton therapy in China (Kaizhong Ding)

- 6^+ cyclotrons have been developed and applied in proton therapy hospital and medical isotope production.

SC200 cyclotron (Hefei)
(200 MeV 300 nA)

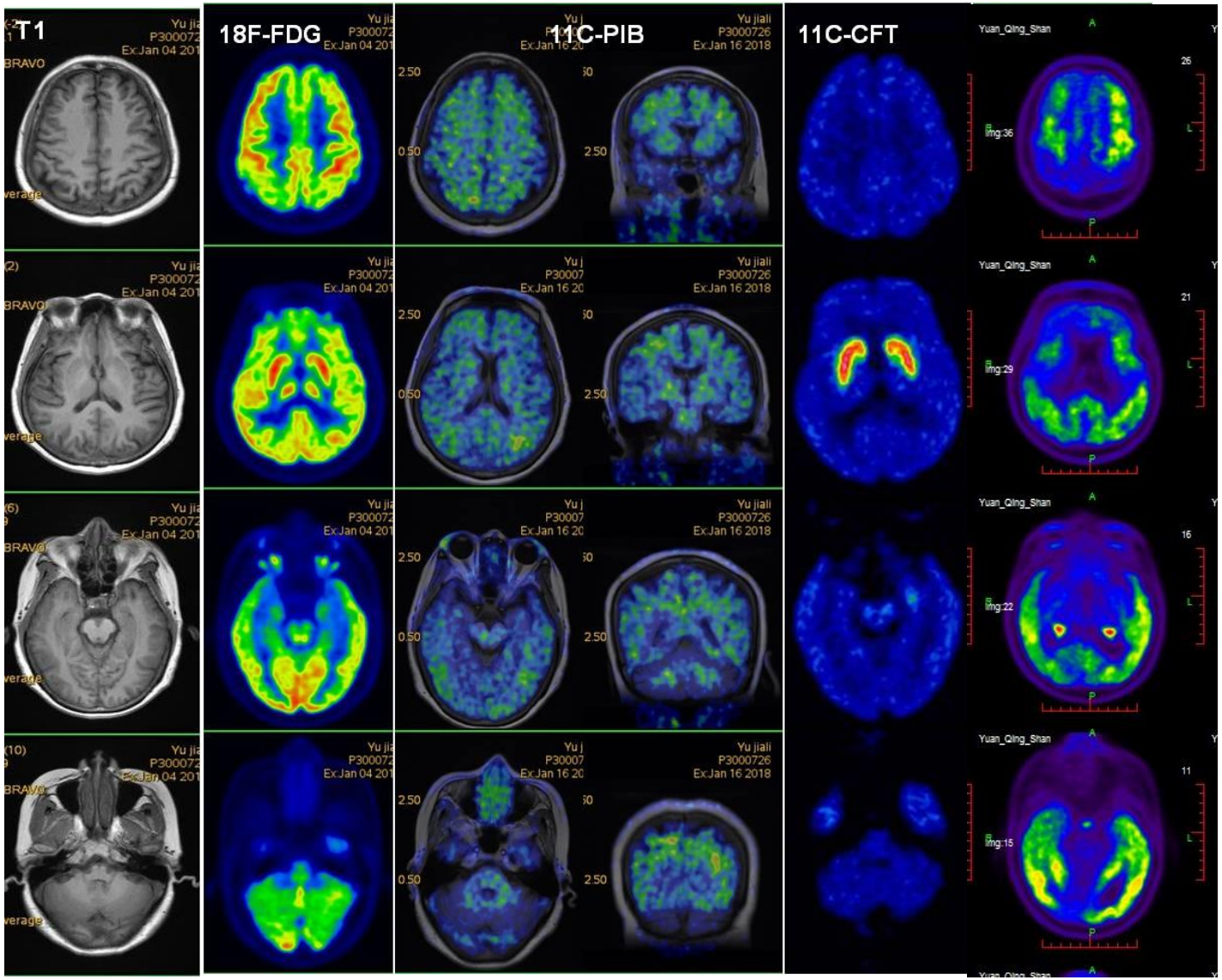
SC240-1(installed Hefei Hospital)
240 MeV 500 nA



SC240-2 (installed Wuhan Hospital)
240 MeV 500 nA

Molecular Imaging -The Road to the Future (Xiaoli Lan)

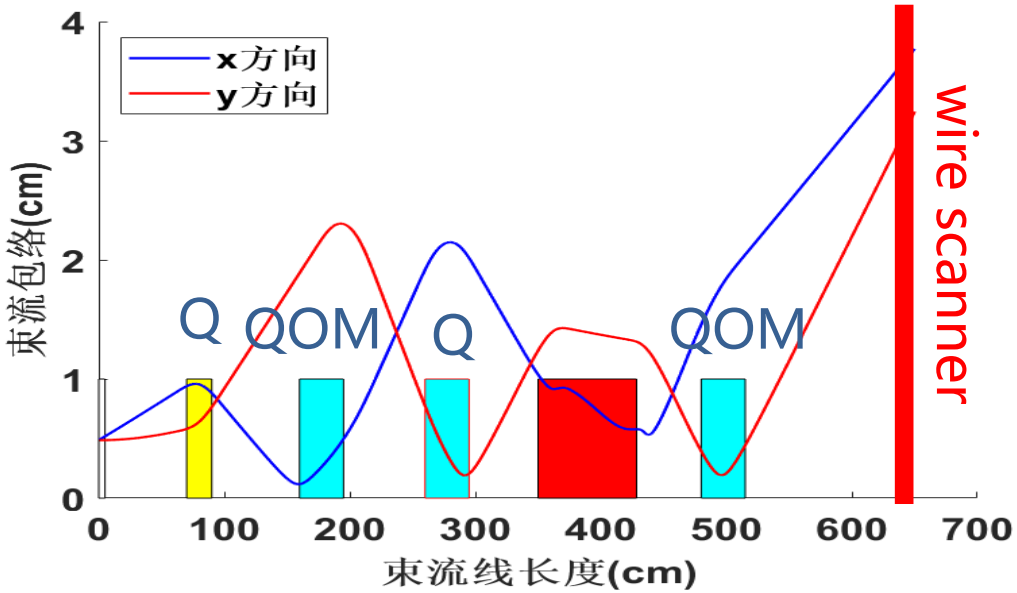
Brain imaging with different probes



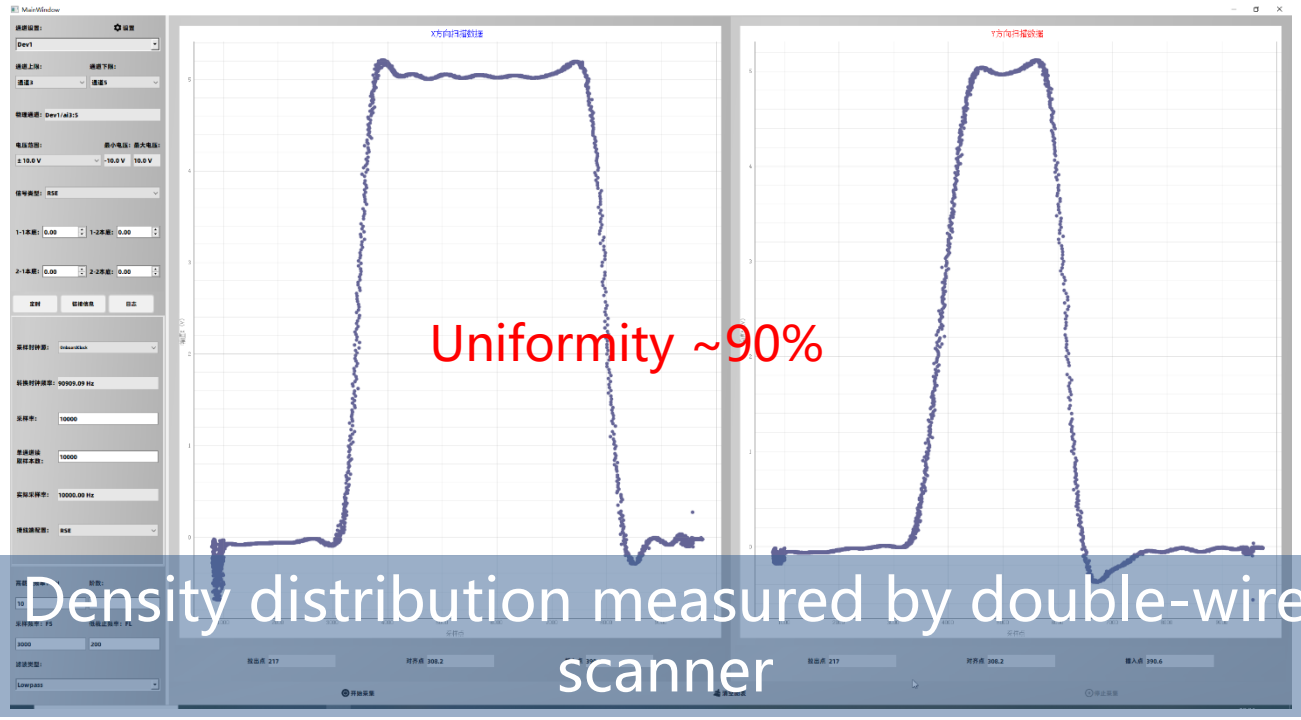
MR Glucose amyloid DAT Tau

The Start-to-End Beam Dynamics Simulation Study and Its Application in the High-Intensity Cyclotron of CIAE (Tianjian Bian)

- **Initial achievements has obtained in the 18 MeV cyclotron-driven neutron source:**
  - Maximum current 1mA. Completed multi-hour runs at >600 μA.
  - Simulation helps the beam tuning and beam loss analysis.



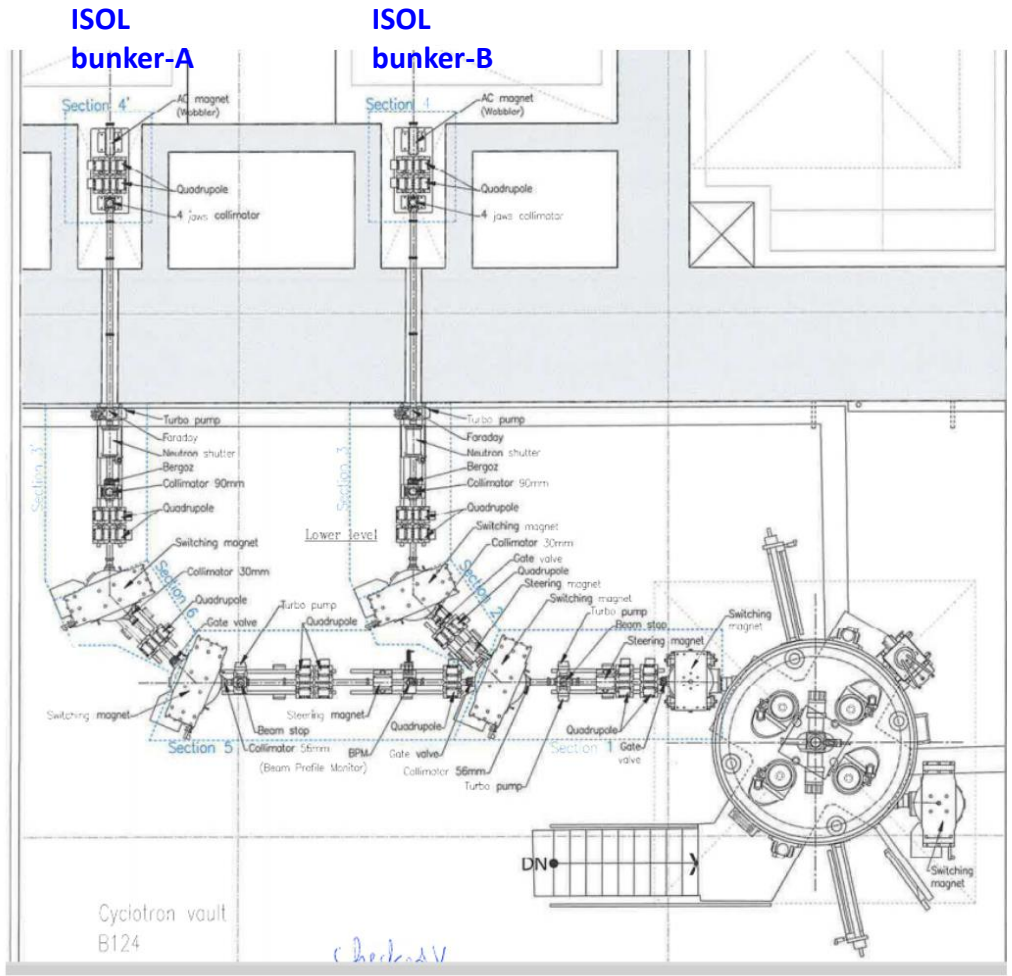
Beam envelopes

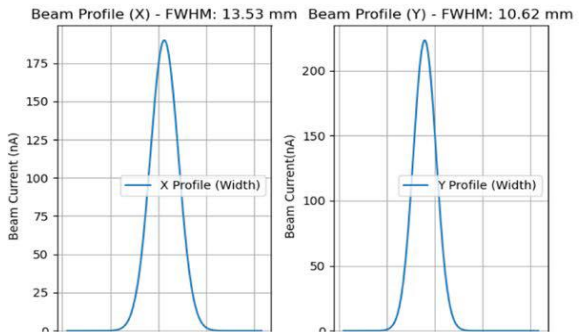


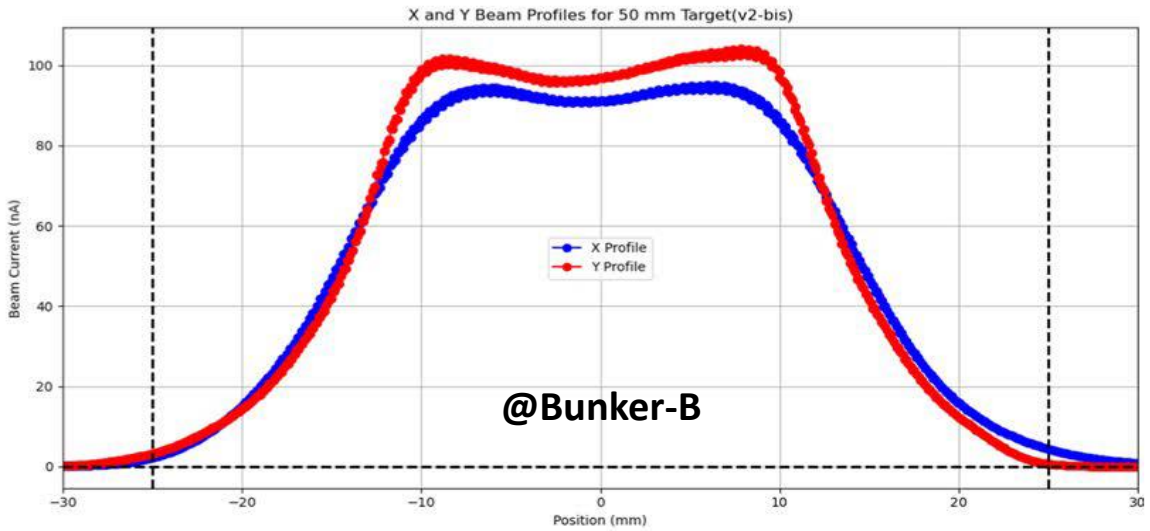
Density distribution measured by double-wire scanner

Alpha Emitter Radioisotope Development Plan from Natural Thorium Target at IRIS (Bum-Sik Park)

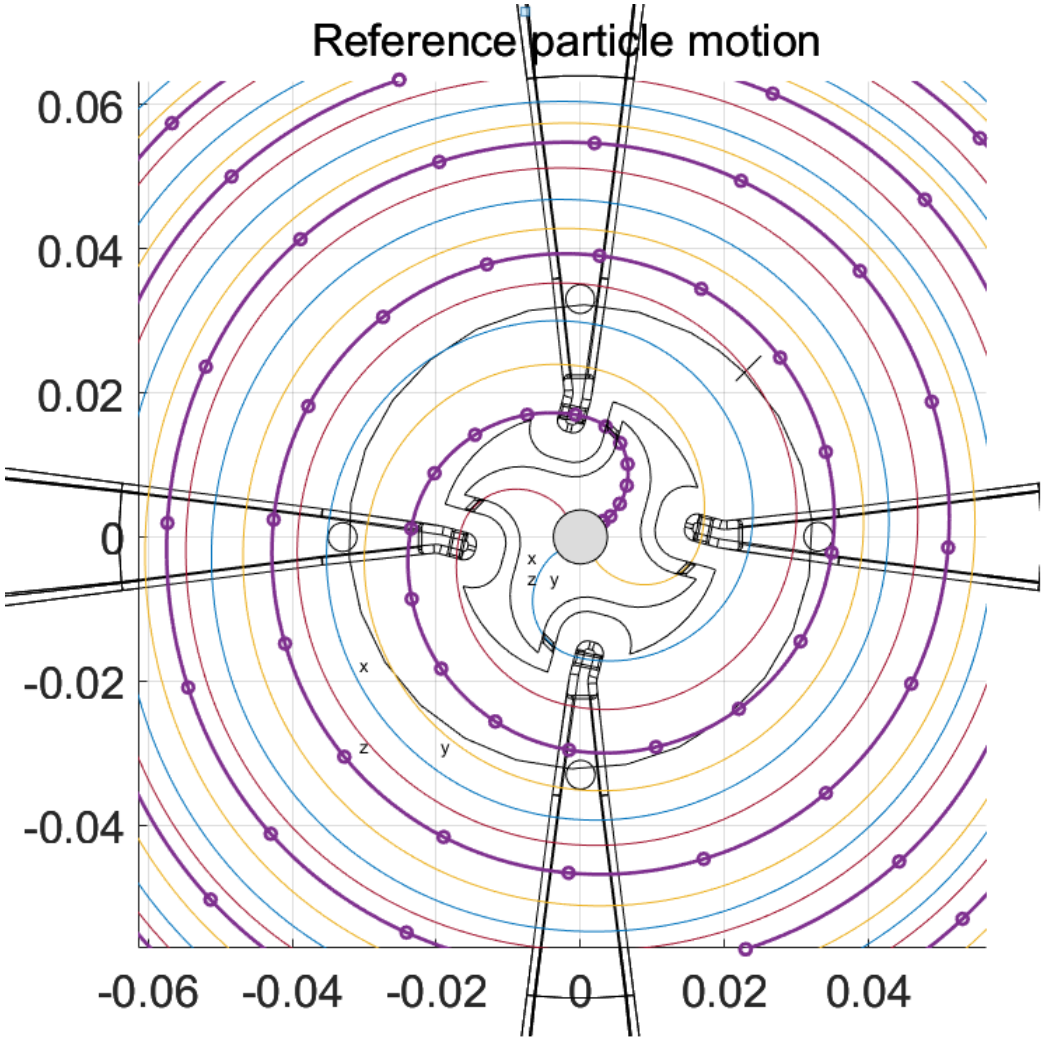
- Bunker-B will be used for produce Ac-225
- A 50 mm–diameter irradiation field was produced using a wobbling magnet.







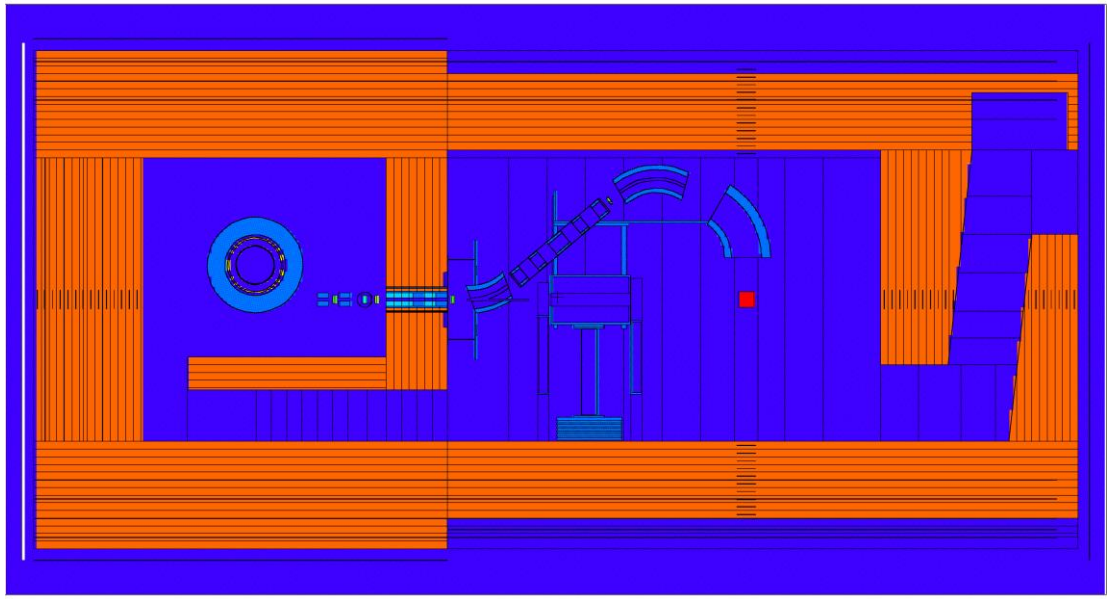
A new concept of cyclotrons for medical applications 18 to 230 MeV Oleg Karamyshev.

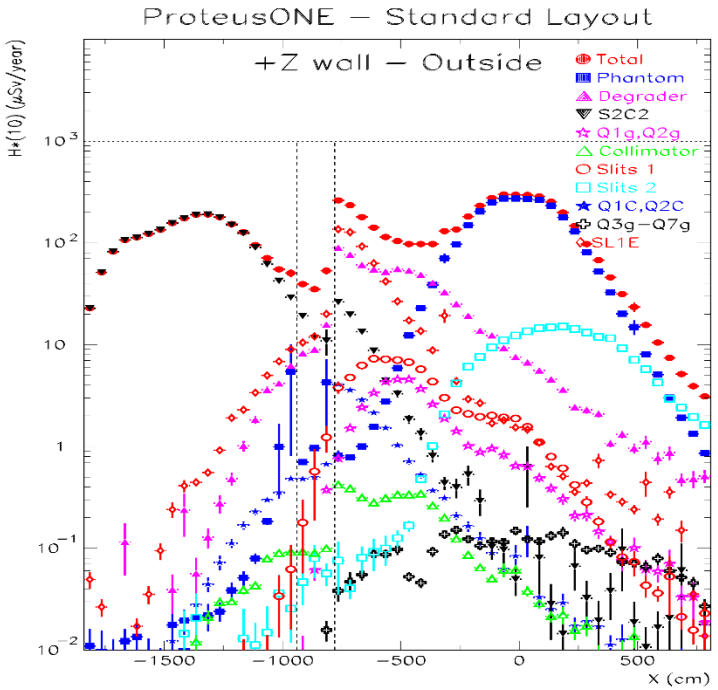


Radioprotection and Activation Studies for Compact Proton Therapy System
Frédéric Stichelbaut

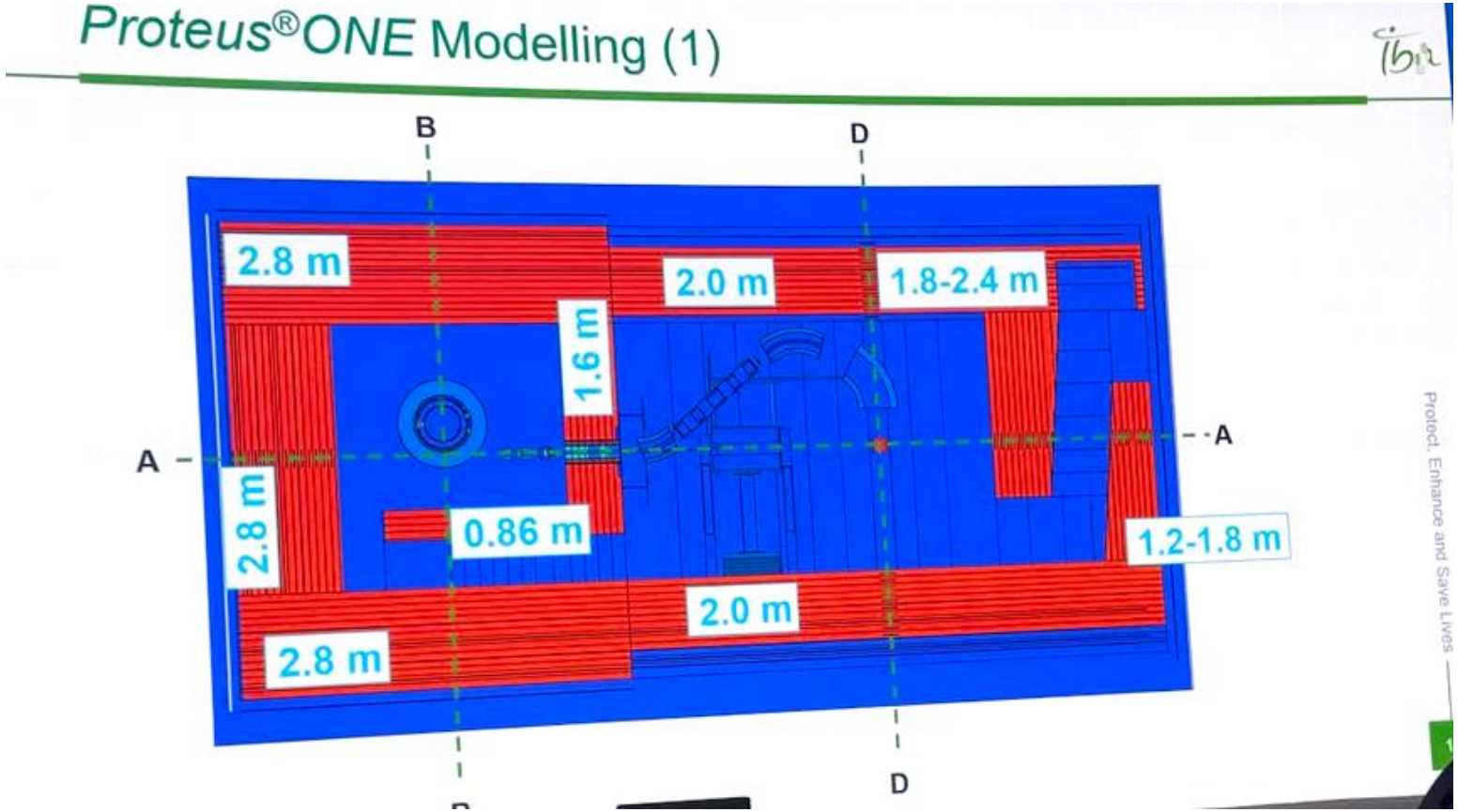
230 MeV protons interacting with matter result in complex fields of secondary neutrons and photons.

Variation of neutron properties with energy, materials, emission angles ➔ need to use complex Monte Carlo codes to accurately describe the neutron interactions and attenuation in matter.





A general approach to radioprotection and activation studies for proton therapy Facilities (Frederic Stichelbaut)



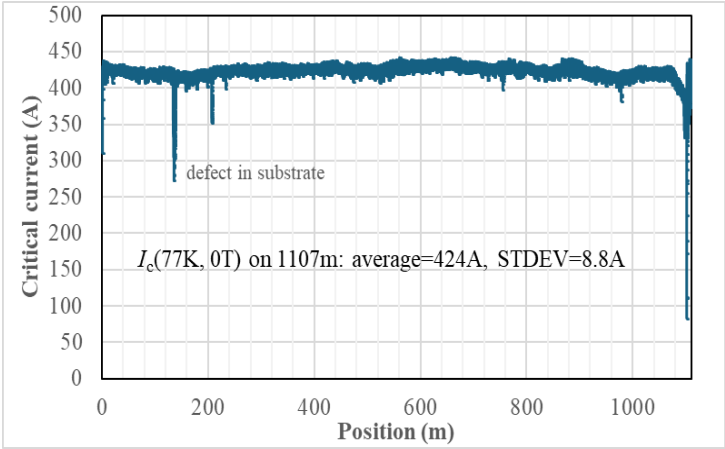
Research and industrialization progress of 2G-HTS based on MOCVD technology (Yulei Chen)

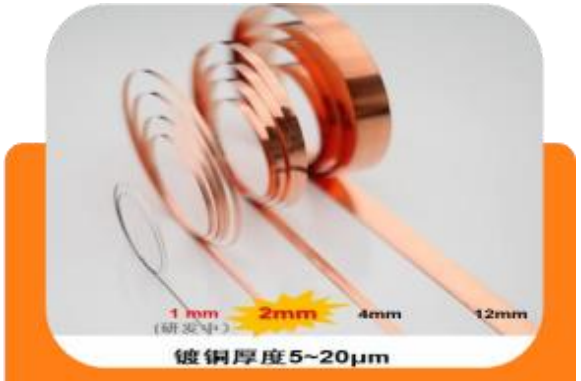
01 A technical route combining IBAD (Ion Beam Assisted Deposition) and MOCVD (Metal-Organic Chemical Vapor Deposition) is adopted to realize the mass production of REBCO superconducting tapes.

02 Based on the technical advantages of MOCVD, a variety of tape series have been developed, which can be applied to different application scenarios.

03 An online inspection system for the whole process has been developed. It can provide real-time feedback on the process status and also can provide detail data to track the status of process and quality control.

04 A production capacity of 7,000 km of 4 mm width REBCO superconducting tapes per year has been achieved.





Copper plated superconducting tape

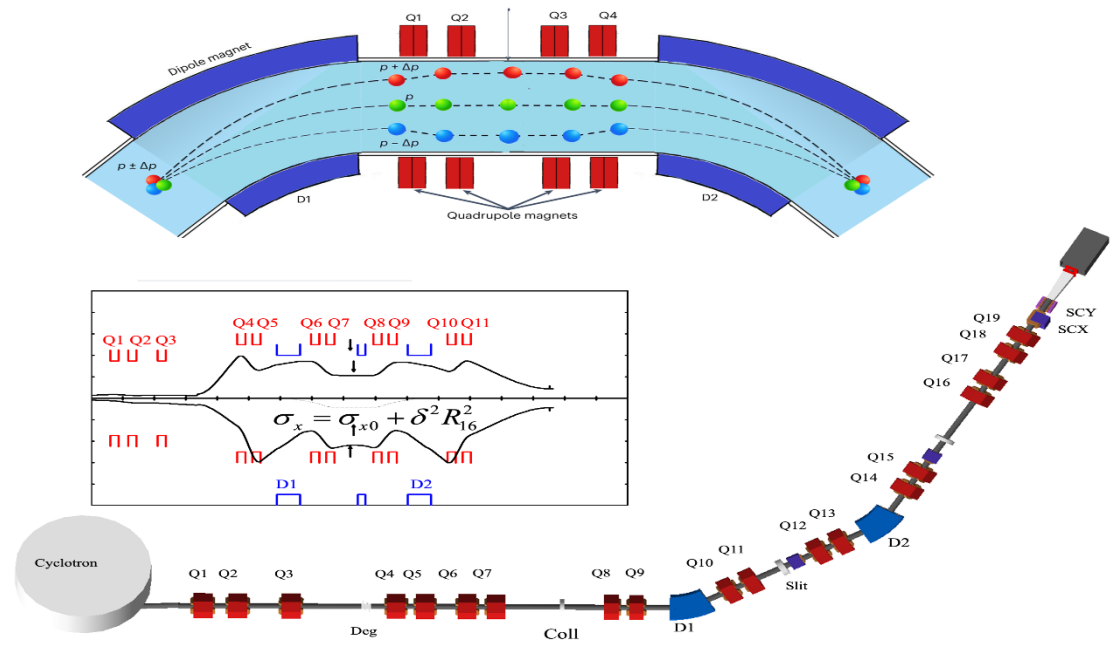
PHYSICS DESIGN OF A 30 MeV ALPHA CYCLOTRON

Shiwen Xu

- **Complete the designs study of a 30 MeV α-cyclotron, the CIM-30A, for the production of ^{211}At.**
- **For high isotope yield and high beam current, CIM-30A employs an axial injection line.**

A Practical Study on Spot and Layer Reduction in Proton Therapy: A Simulation-Based Validation for Liver Cancer Pencil Beam Scanning Proton Therapy (Shiwen Xu)

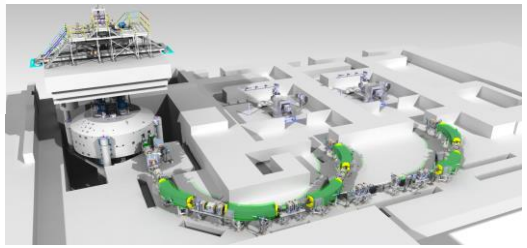
- ✓ A novel combined BDS hardware and TPS software optimization strategy was successfully developed and validated via simulation.
- ✓ The strategy achieved a **~59% spot reduction** and a **~70% dead time reduction** for liver cancer PBS-PT.

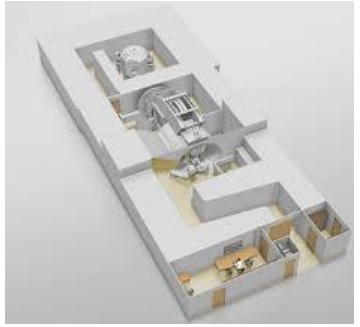


Cyclotron Design in an Industrial Environment-Continued Learning, Experience and Optimization,V.E. Nuttens

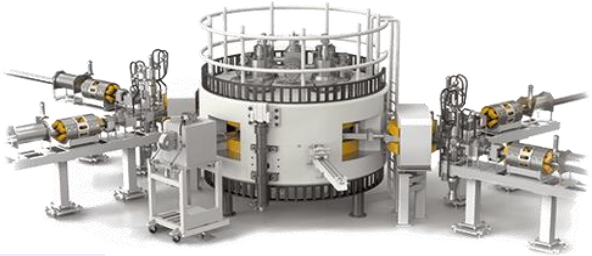
- Development of our tools enabled:
  - Fully integrated optimized system:
    - From ion source to the building
    - Sustainability evaluation
      - power, material, CO_2, …
      - lower activation of the machine and building
  - Better system performances
  - Faster magnet isochronism mapping
  - Support for a faster commissioning

C400 IONS





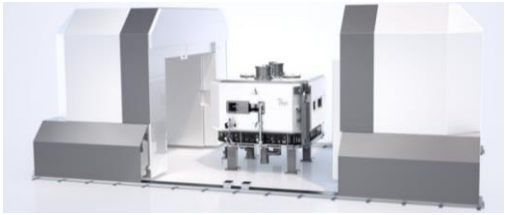
Proteus®ONE

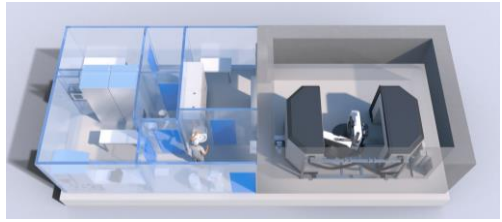


Cyclone®70

Cyclone®IKON

Cyclone®KIUBE





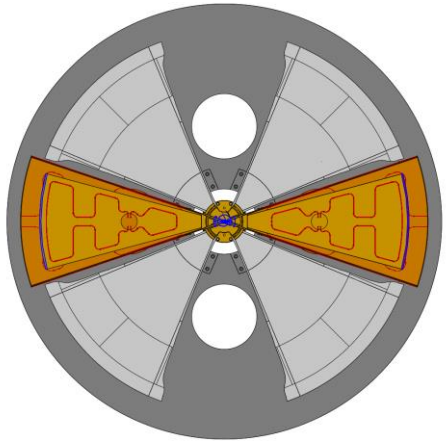
Cyclone®KEY

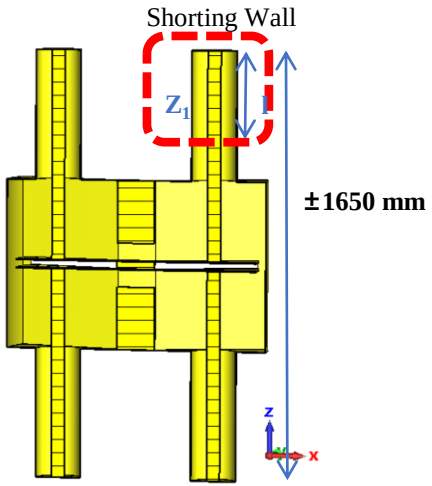
Thank You

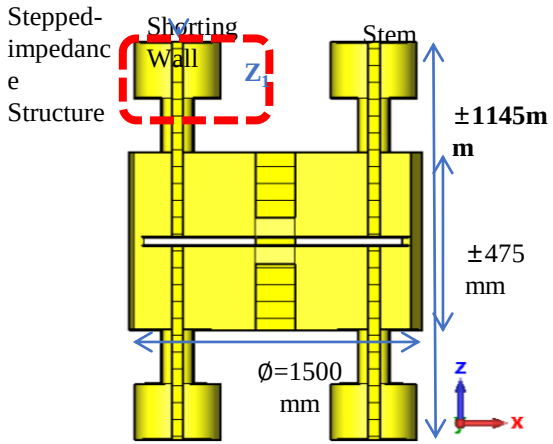
Design of the RF cavity for 30 MeV Alpha Particle Cyclotron

Xin Zhang, University of Science and Technology of China

In order to achieve the production of At-211, a **30 MeV Alpha Particle Cyclotron was designed**







7 Themes

- Cyclotron and Technology
- Theory, Models, Simulations and IA Applications in Cyclotrons
- Operation and Upgrades
- Cyclotron Applications
- Cyclotrons for Hadron Therapy and Isotope production
- FFA's and New Projects
- Session for Young Scientist

We have set 7 topics for the conference.

- **There are 19 Invited talks,**
- **32 Contributed orals and**
- **107 Posters,**
- **Total 158 Contributions**