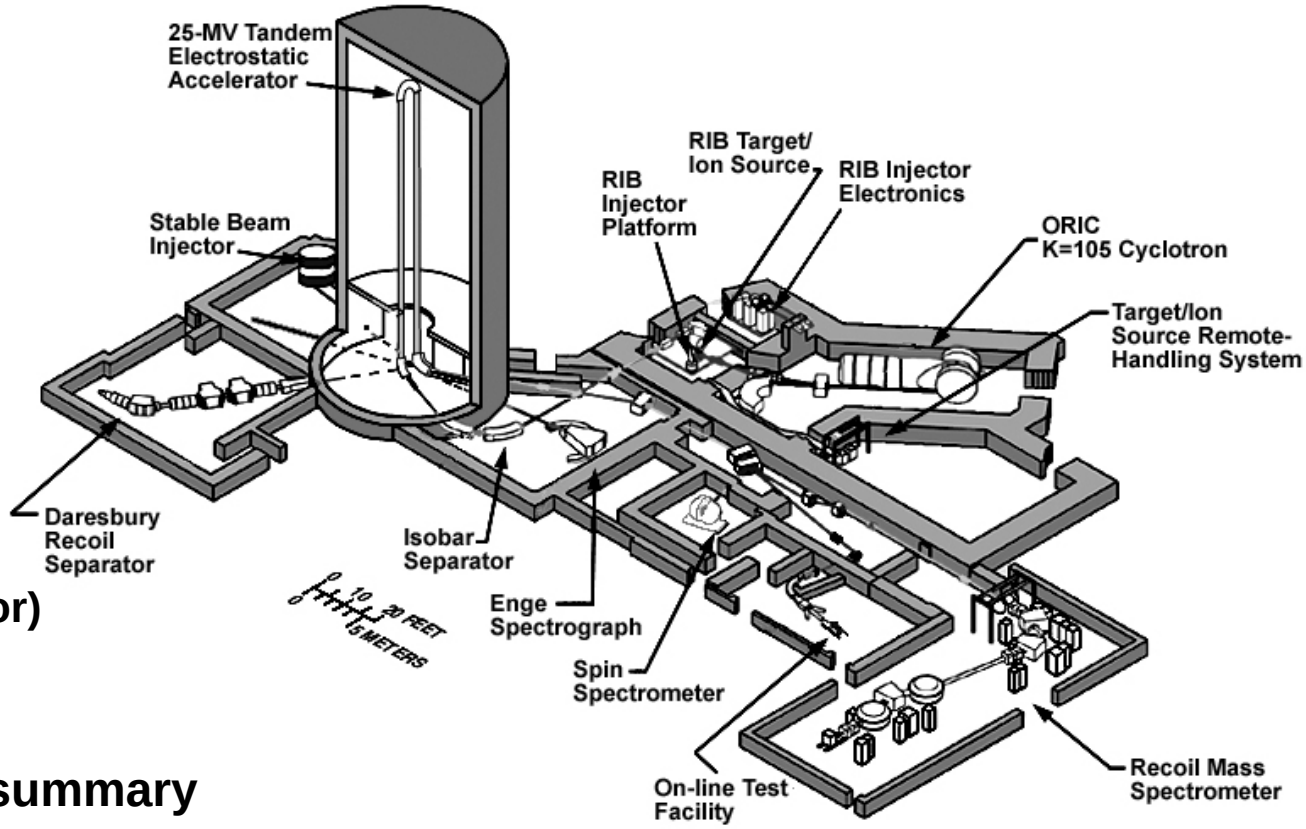
HRIBF: Present Capabilities and Future Plans

B. Alan Tatum

HRIBF Workshop - Near and Sub-barrier Fusion of Radioactive Ions with Medium and Heavy Targets

December 2-3, 2005

Outline



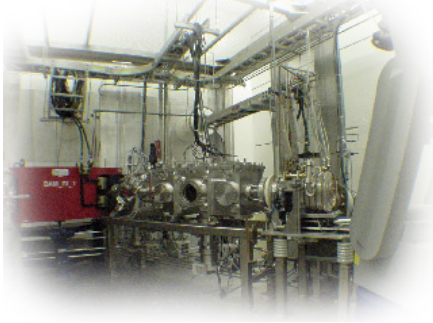
Facility Overview

- Existing Systems
  - ORIC
  - IRIS1 (RIB Injector)
  - Tandem
  - HPTL
- Operation hours summary
- Beams provided

–Future

- IRIS2
- Driver accelerator upgrades

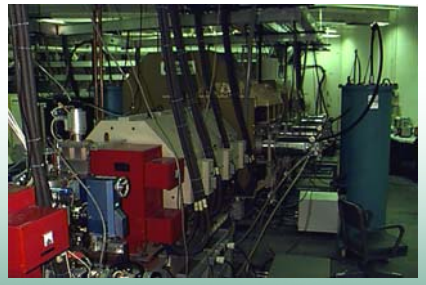
Facility Overview



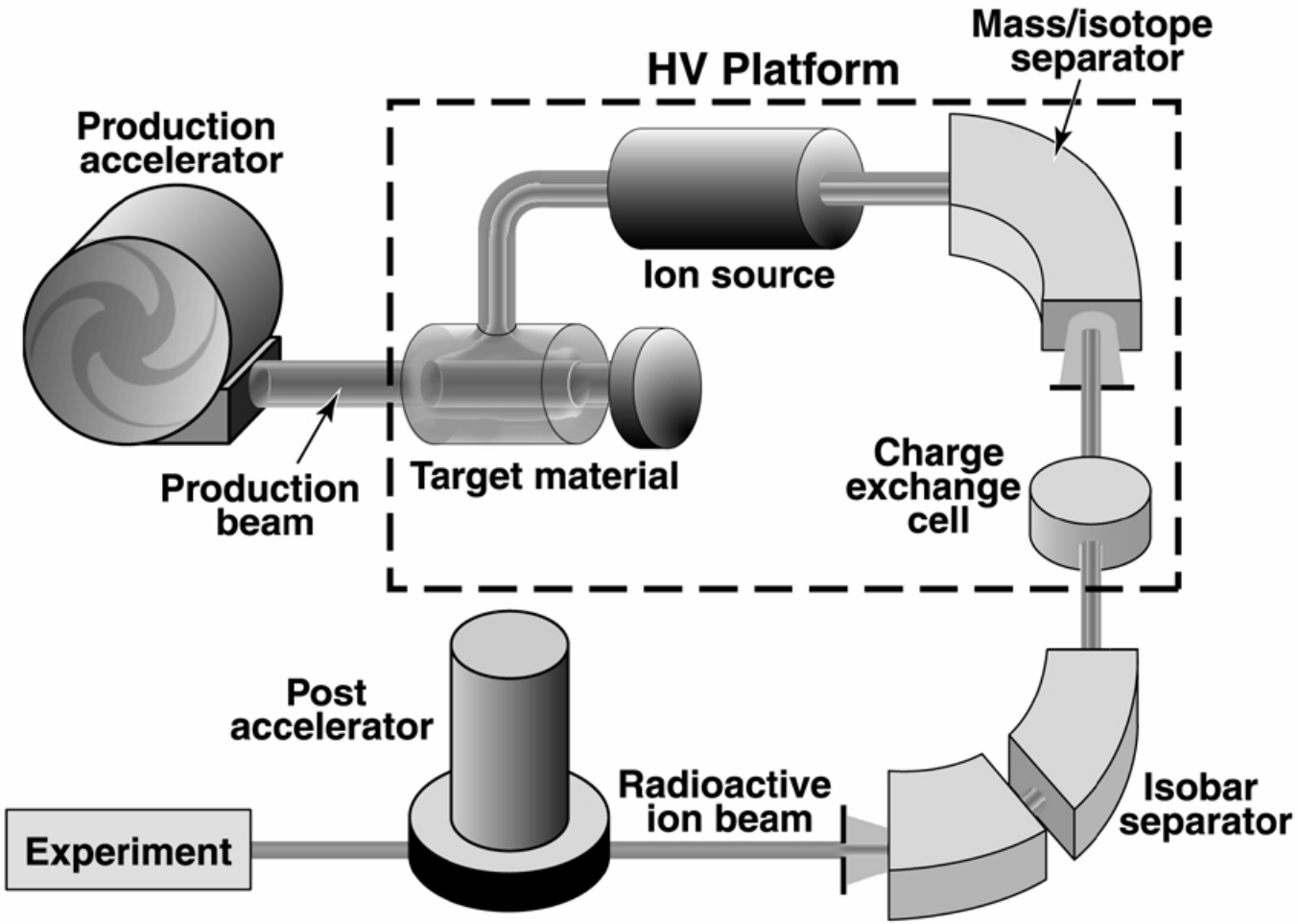
- **RIB Production:**
  - **Oak Ridge Isochronous Cyclotron (ORIC)**
  - **IRIS1: RIB production station**
  - **25 MV tandem electrostatic accelerator**

- **ISOL Development** *(D. Stracener):*
  - **2 off-line Ion Source Test Facilities (ISTF1,2)**
  - **1 low-power On-Line Test Facility (OLTF)**
  - **1 High Power Target Laboratory (HPTL)**

- **Experimental End Stations** *(C. Gross):*
  - **Recoil Mass Spectrometer (RMS)**
  - **Daresbury Recoil Separator (DRS)**
  - **Enge Spectrograph**
  - **Several general purpose end stations**

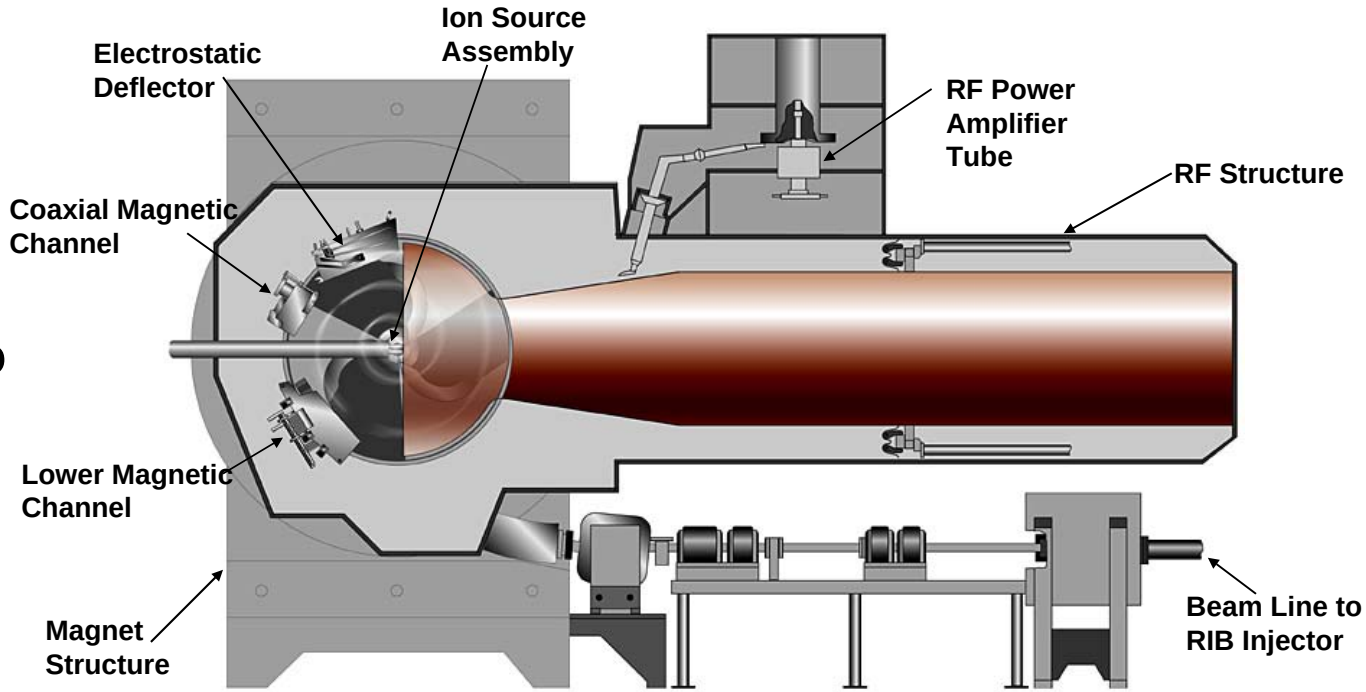


Facility Overview:
ISOL RIB Production Process



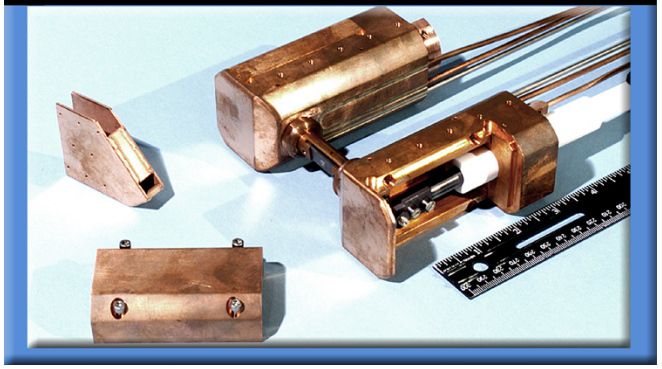
ORIC

- Provides intense light-ion beams to produce radioactive species
- Produced first beams in 1962
- 1.5m, k=100, variable energy, multi-particle
- Proton energy limited by rf system mods

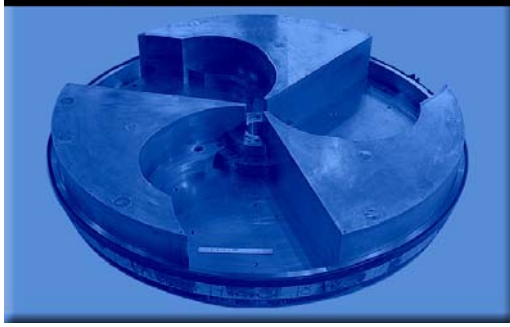


Species	Goal	Recent Max. E	Recent Max. I	Recent max. ε
p	60 MeV @50 μ A	54 MeV	20 μ A	85%
d	50 @50 μ A	49 MeV	12 μ A	75%
^{3}He	133 MeV @100 μ A	-	-	-
^{4}He	100 @100 μ A	100 MeV	6 μ A	55%

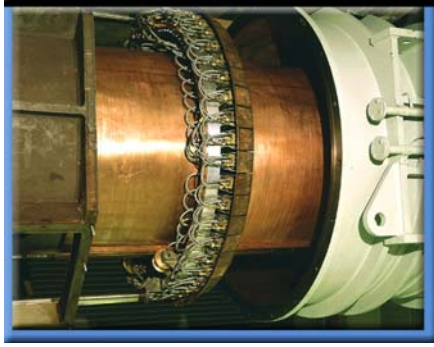
Charged particles, or ions, originate in the ion source



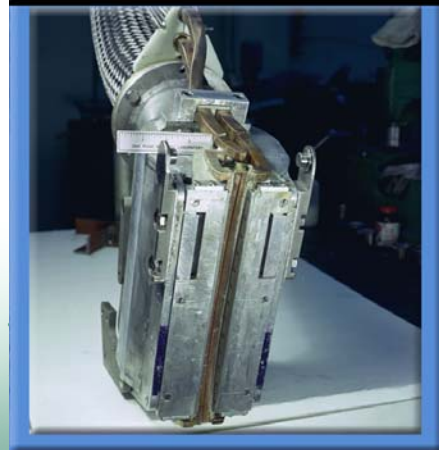
The magnet system provides a magnetic field that causes the ions to move in a circular orbit and shapes the orbit path of the ion beam



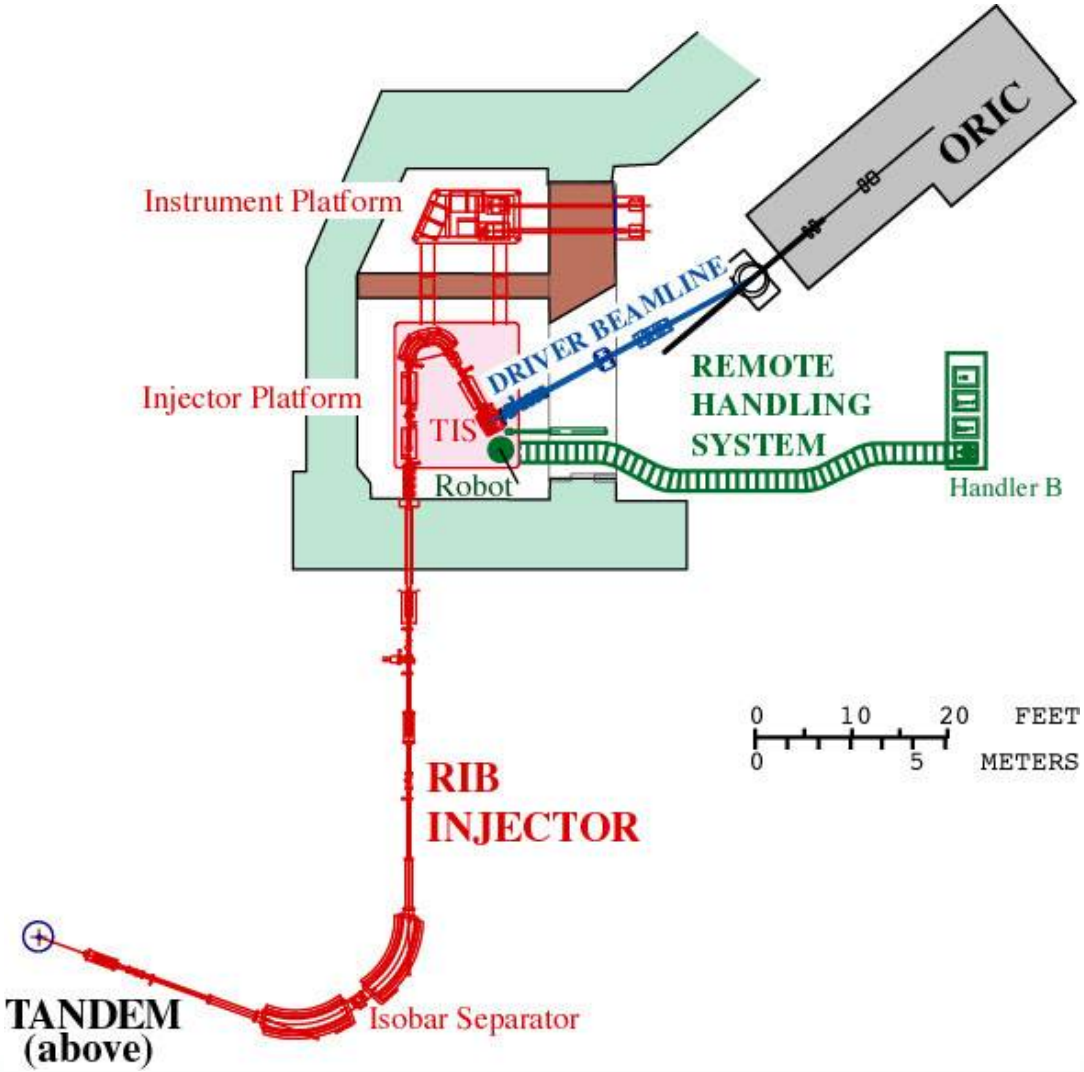
Radiofrequency (rf) system pulls the ions from the ion source and provides an electric field through which the ions gain energy, or become accelerated



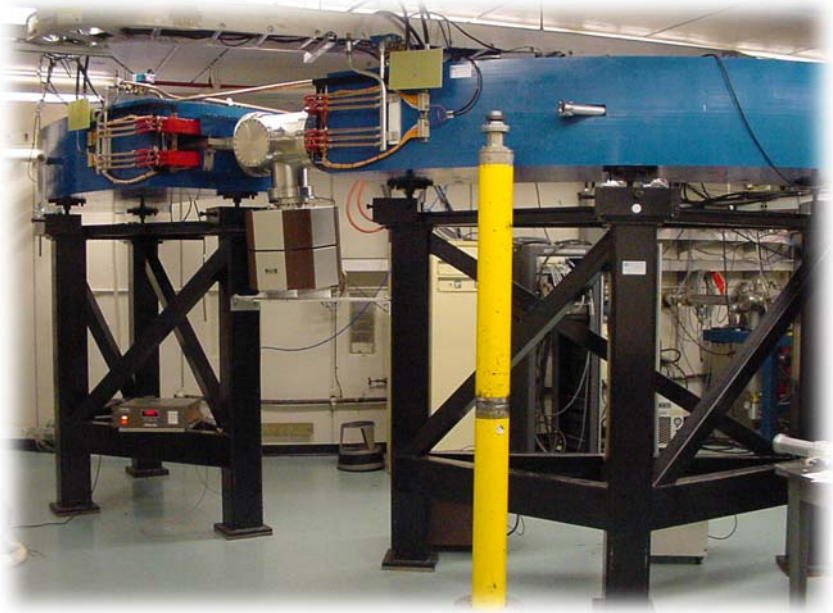
The deflected beam orbit magnetic field is reduced by the coaxial magnetic channel



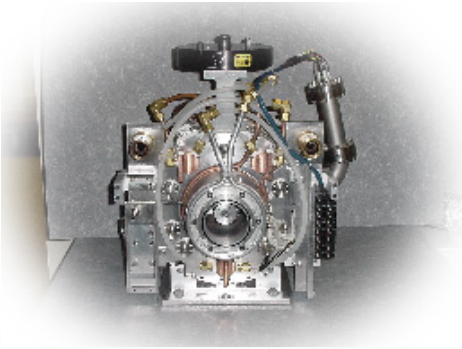
IRIS1 (RIB Injector)

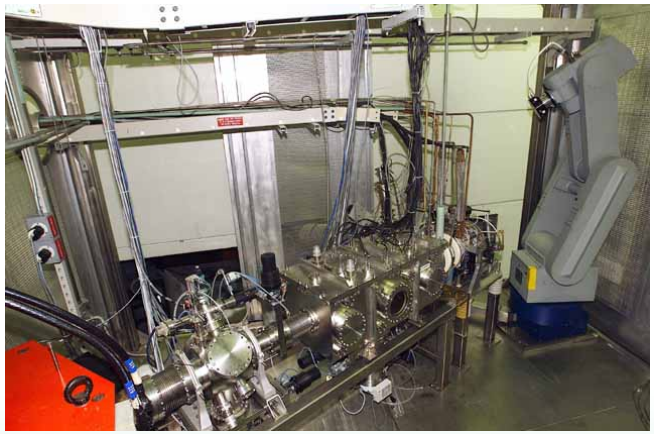


IRIS1 (RIB Injector)



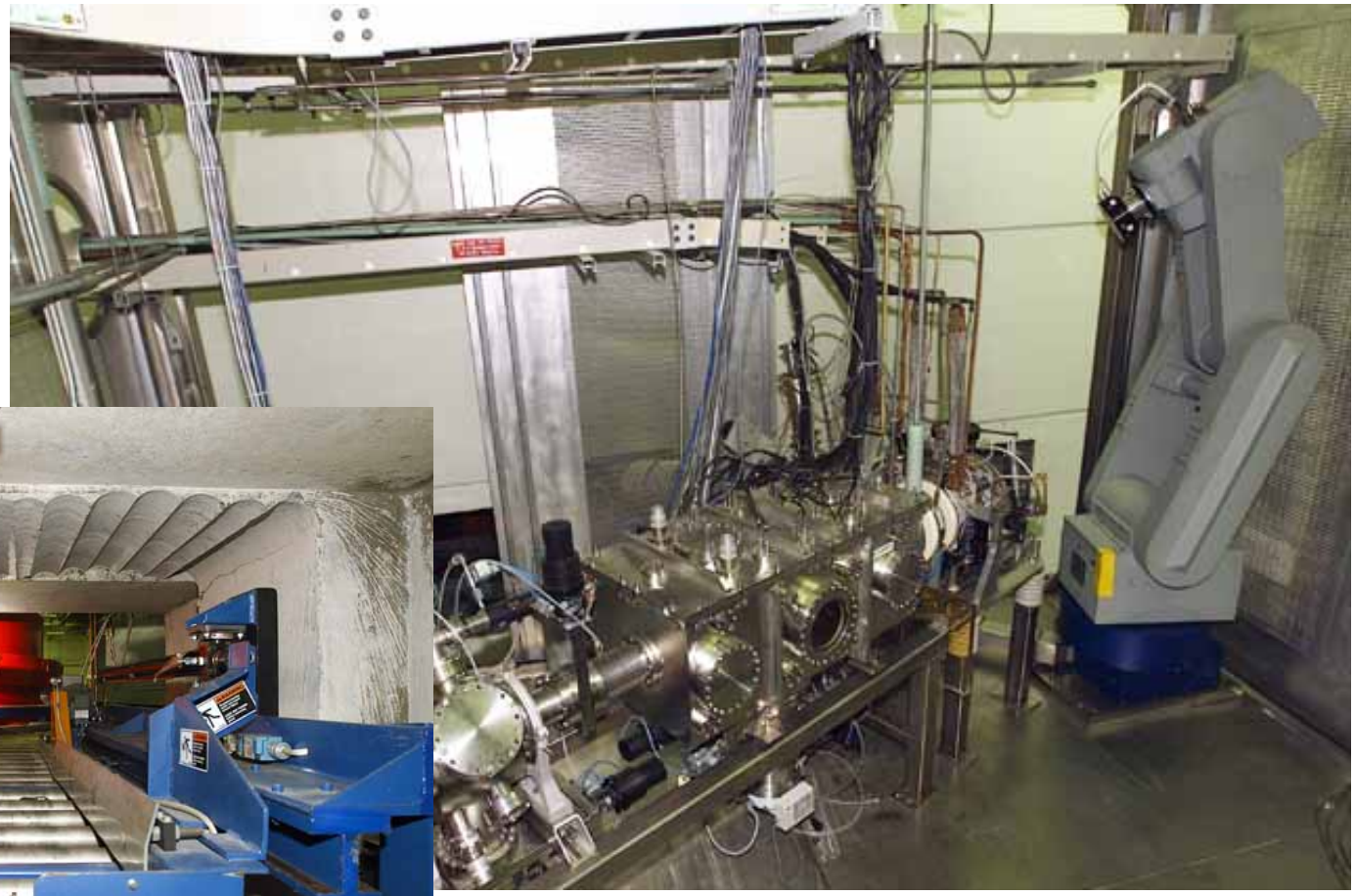
- 300 kV (design) platform
- 2-stage mass separation
  - M/ΔM ~ 1000
  - M/ΔM ~ 20000
- Robotic handling system for removal and installation of activated target ion sources
- Presently accommodates the following ion sources:
  - Electron Beam Plasma (EBP): n-rich beams (Ag, Sb, Sn, Te, etc…)
  - Kinetic Ejection Negative Ion Source (KENIS): p-rich beams (^{17}F, ^{18}F)
  - Batch mode (^{7}Be, ^{56}Ni)





Fully-Automated Handling of Activated Target Ion Sources

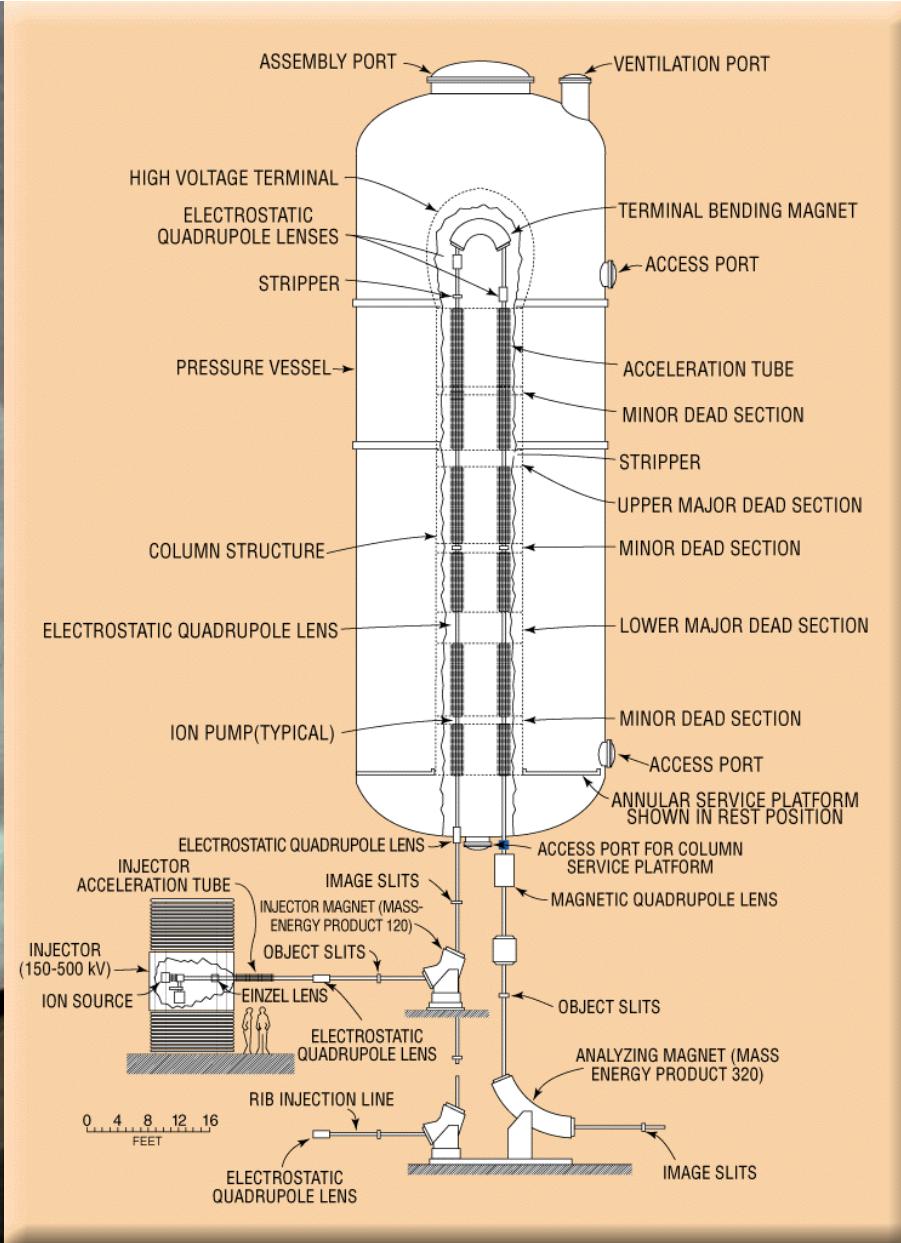
- Robot
- Conveyor
- Gantry



Tandem Accelerator

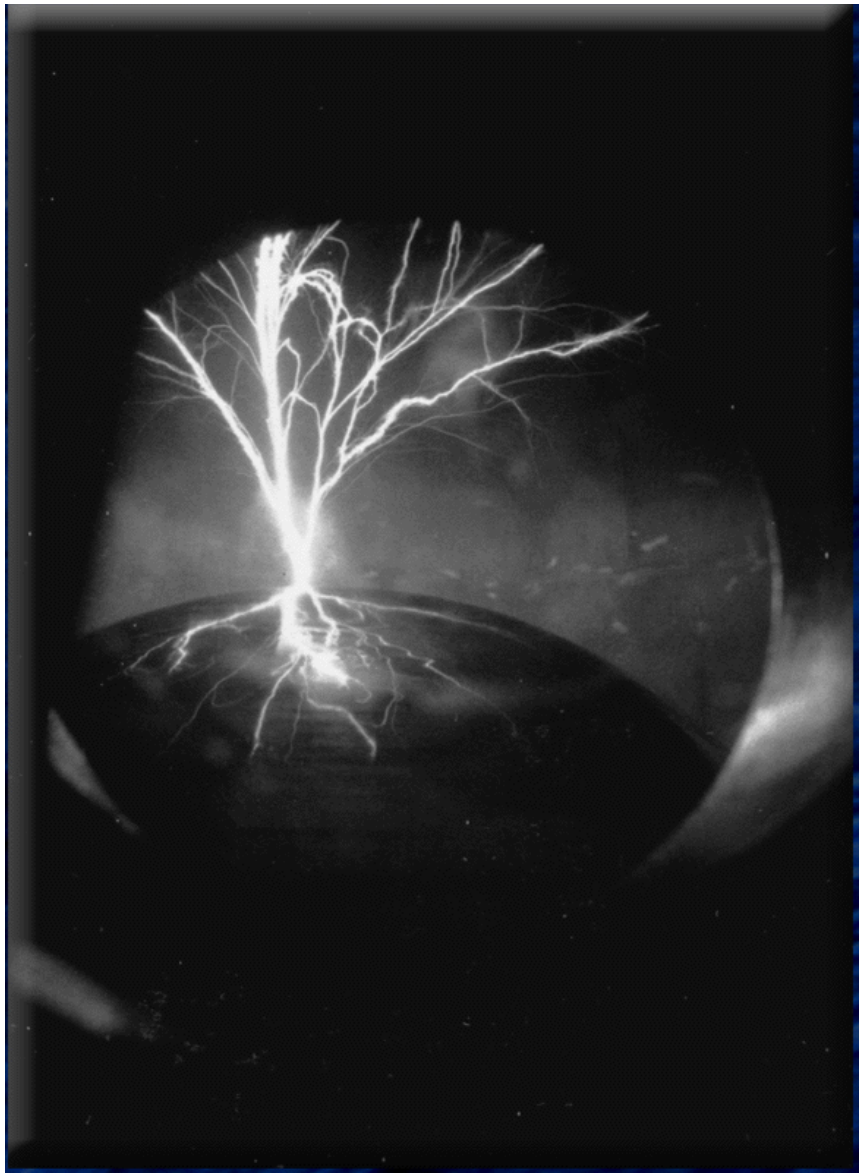
- **Largest in the World**
  - Nominal max 25 MV terminal voltage (Has operated at higher voltages)
  - "Folded" Design
  - Considerably more ion optics internally than any other electrostatic accelerator
  - Beam energy is $E_I + V_T (Q+1)$, for single stripping (E_I=inject E, Q=charge state)
  - Double stripping possible: higher energy, lower intensity
  - Maintenance access by a "central service platform" or by an "annular service platform"
- **Contained in an 80,000 ft^3 Pressure vessel**
  - Insulated with approx. 200,000 lbs SF_6 gas
  - Would hold 4,788,000 pints of beer
  - 33 ft x 100 ft (Los Angeles class submarine is 33 ft x 362 ft)

25 MV Tandem RIB Post-accelerator



–At 20 MV, stored energy is equivalent to a Volkswagen beetle dropped from 33 ft.

–Stored energy increases as the square of terminal voltage!



hribf
Holifield Radioactive Ion Beam Facility
Oak Ridge National Laboratory

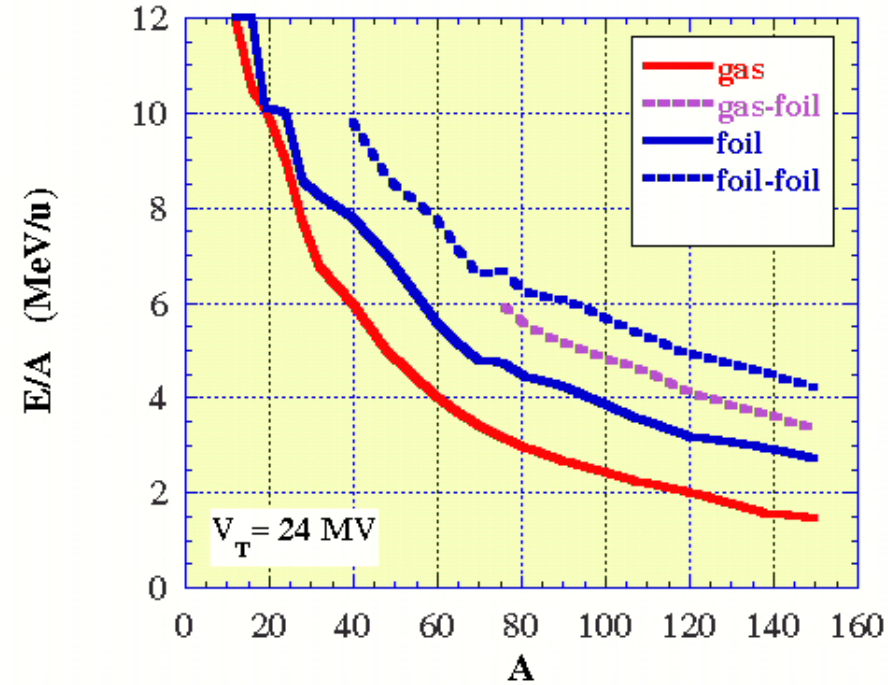
Characteristics of Tandem Accelerator for RIBs

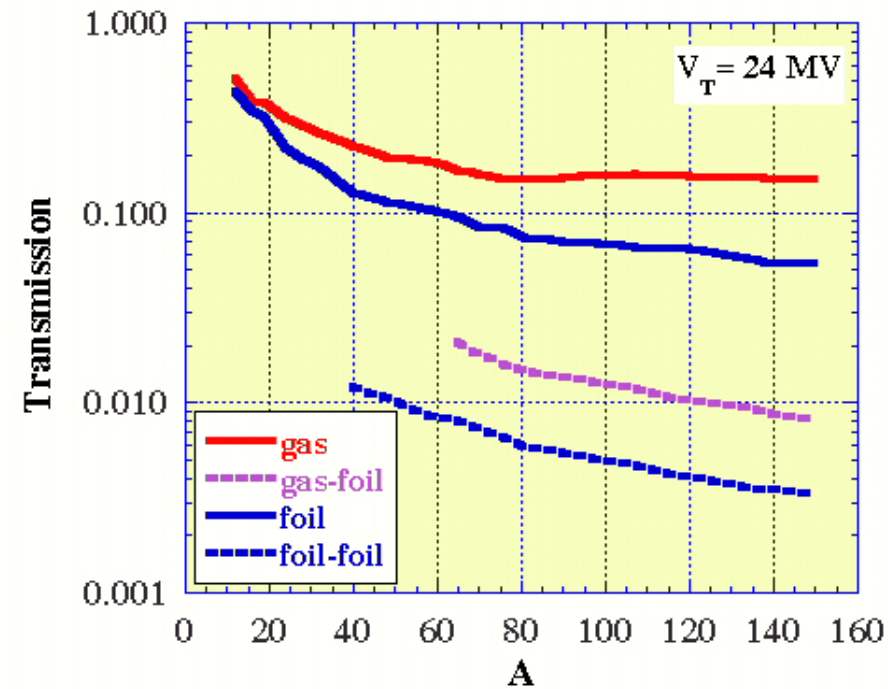
Positives:

- **Simplicity, reliability, economy**
- **Wide range of operating voltage**
  - **1MV - 26 MV**
- **Large Acceptance**
  - **Well suited to RIB source emittance**
  - **Weak dependence on injection E**
  - **Trans. eff. 15%-50% for gas stripping**
- **Excellent beam quality**
  - **Good Energy Resolution ($E/\Delta E > 10^4$)**
  - **Low emittance**
    - **0.3-0.5π mm mrad (gas),**
    - **1.0π mm mrad (foil)**
- **Easy energy variation**

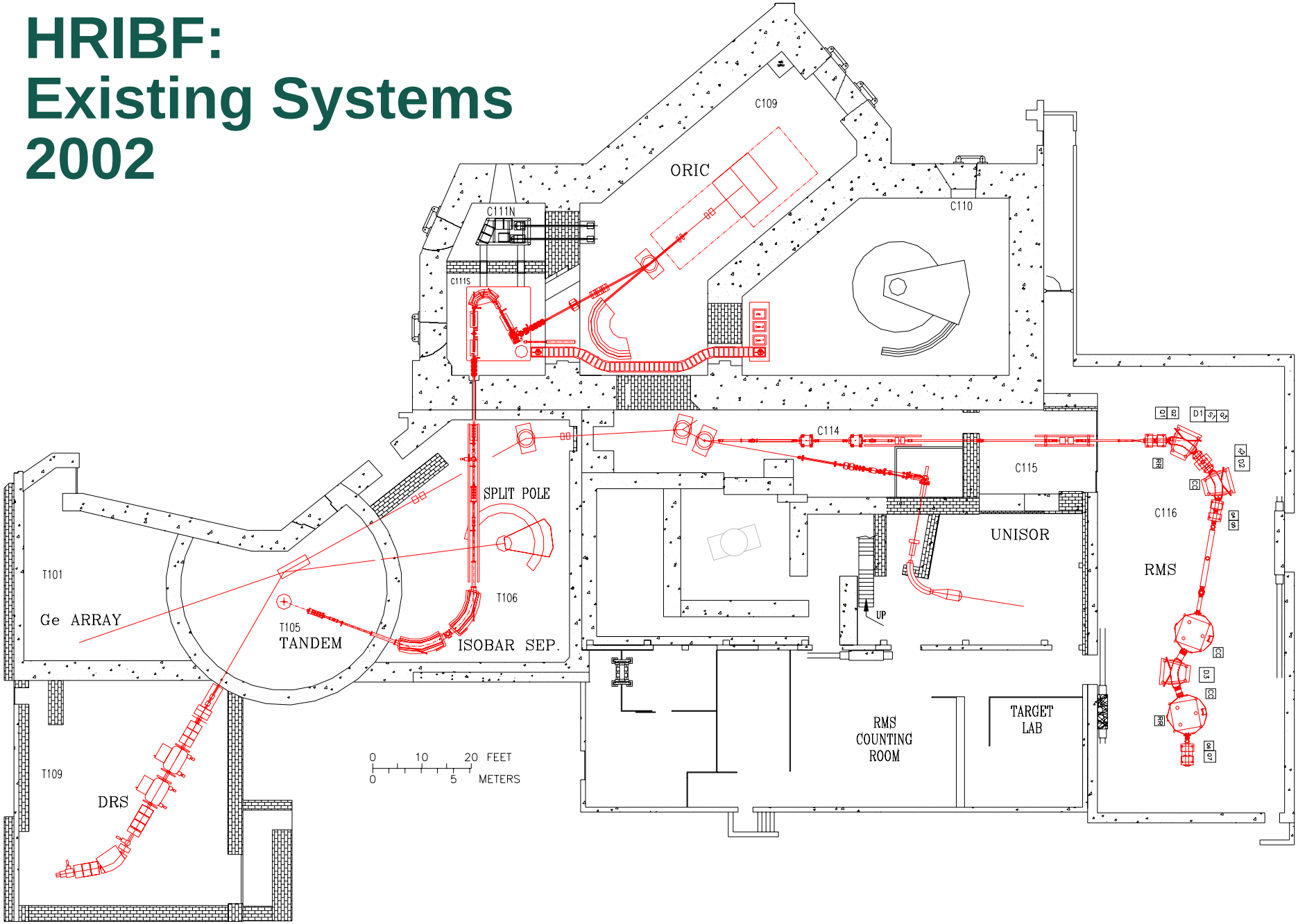
Negatives:

- **Must double strip for A>80**
  - **To reach E/A~5 MeV/u (up to ~140)**
- **Negative-ion-only accelerator**

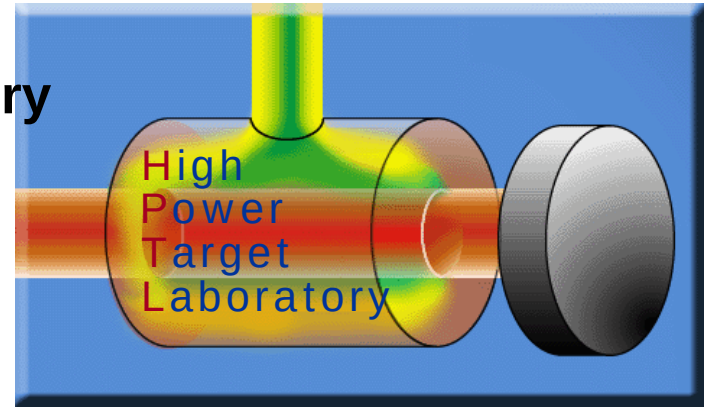




HRIBF: Existing Systems 2002



Recently Completed HPTL Project



Title: High Power Target Laboratory

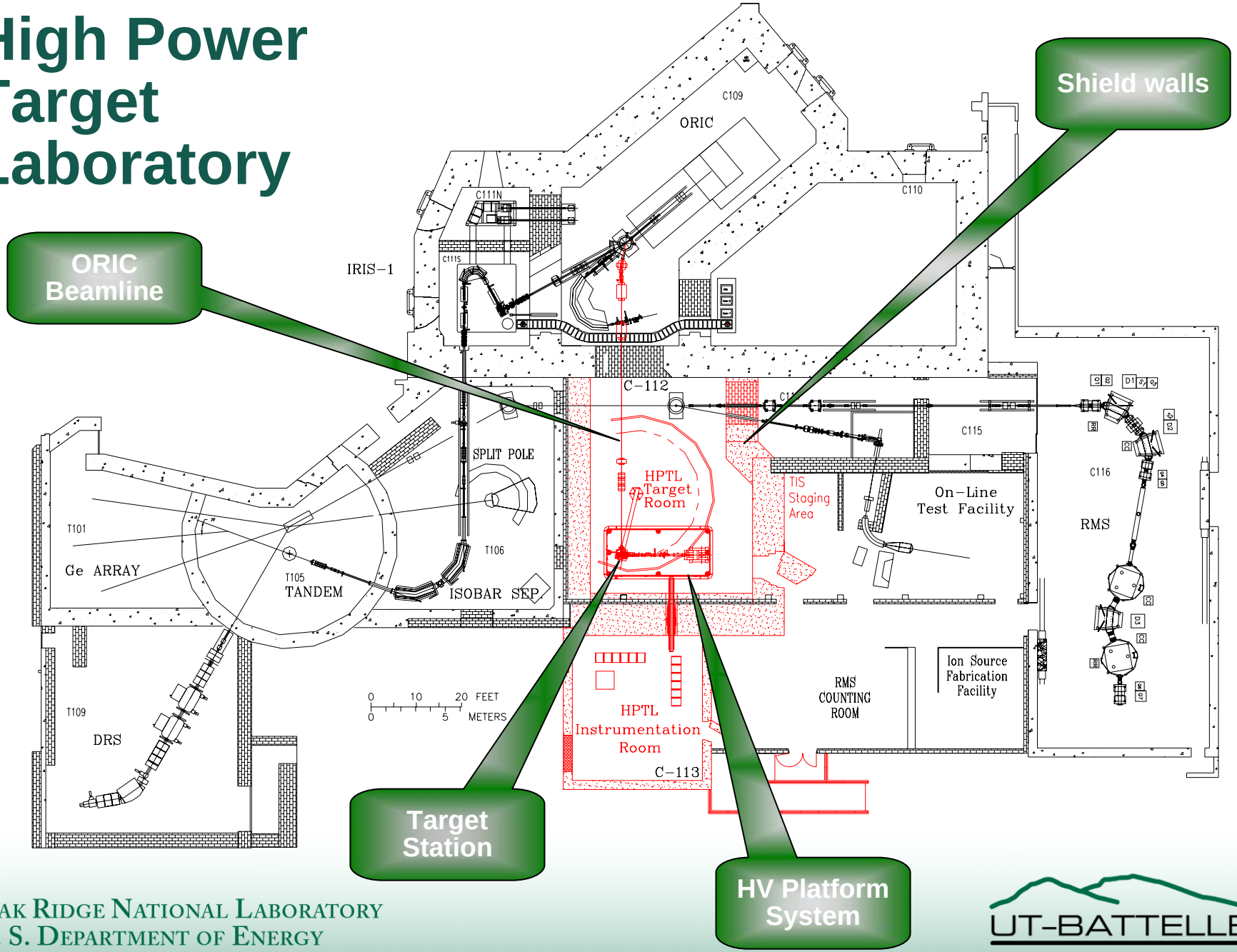
Cost: Funded at $4.752M

Schedule: FY03 (Q4) – FY05 (Q4)

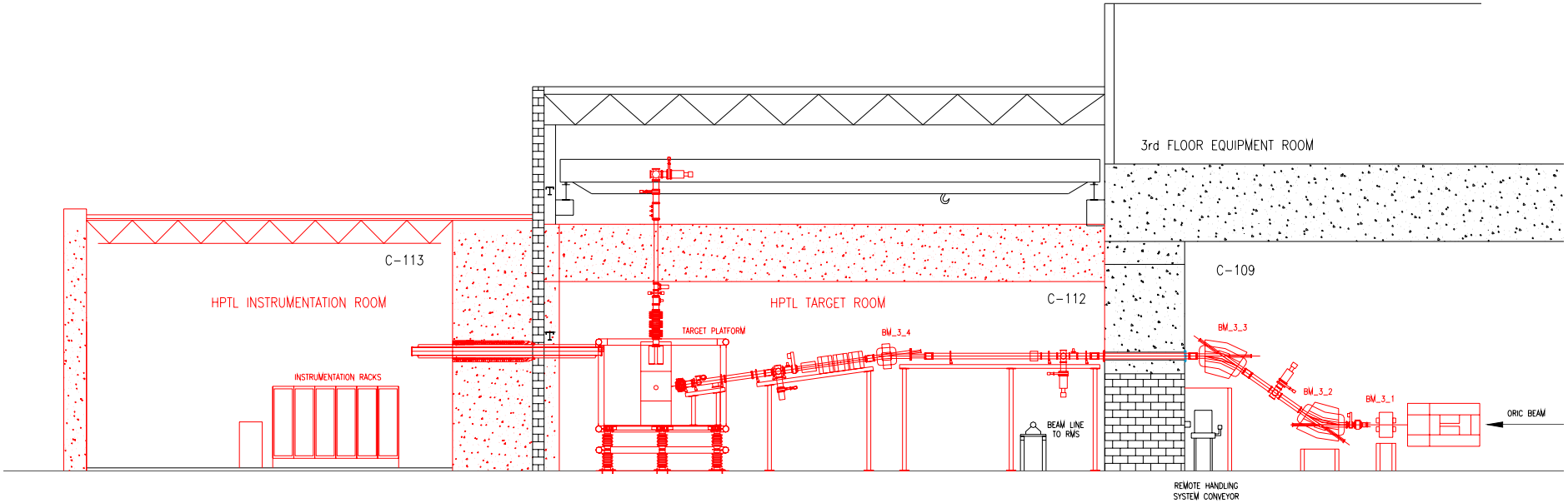
Attributes:

- Provides a dedicated facility for high-power R&D of RIB targets, ion sources, and production techniques that should result in higher RIB intensities, purities, and available species.
- Separates R&D from production
- Allows testing and optimization of novel target geometries, formats, and mechanisms for controlling high power deposition without risk to the production system
- Allows tests to monitor target behavior in real time
- Provided additional shielded space for future upgrades

High Power Target Laboratory



Elevation View of HPTL



Facility Modifications (exterior)
Instrumentation Room and
modified South Annex

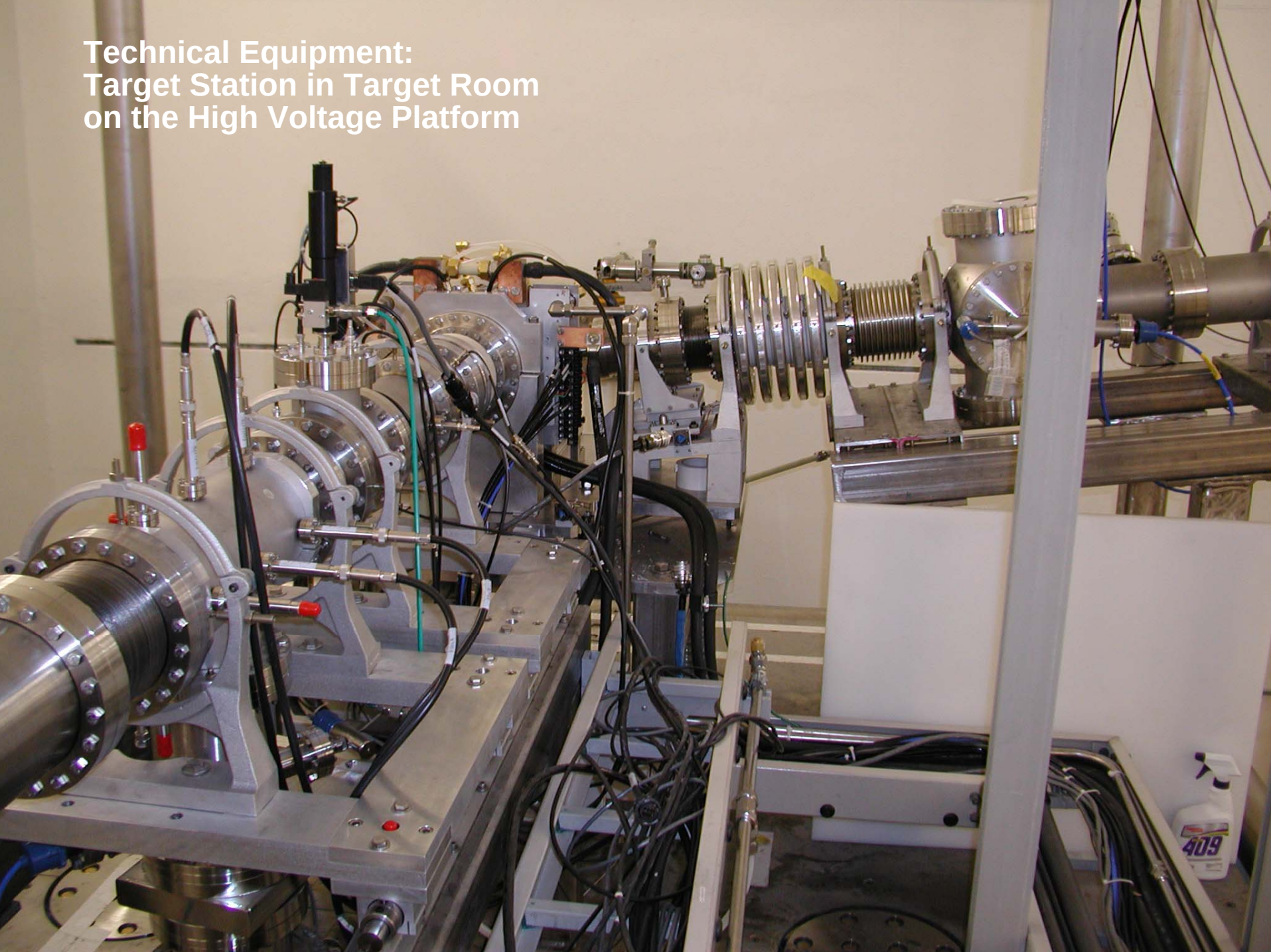
Facility Modifications (interior)
Target Room Entrance

Technical Equipment:
ORIC Beamline in ORIC Vault

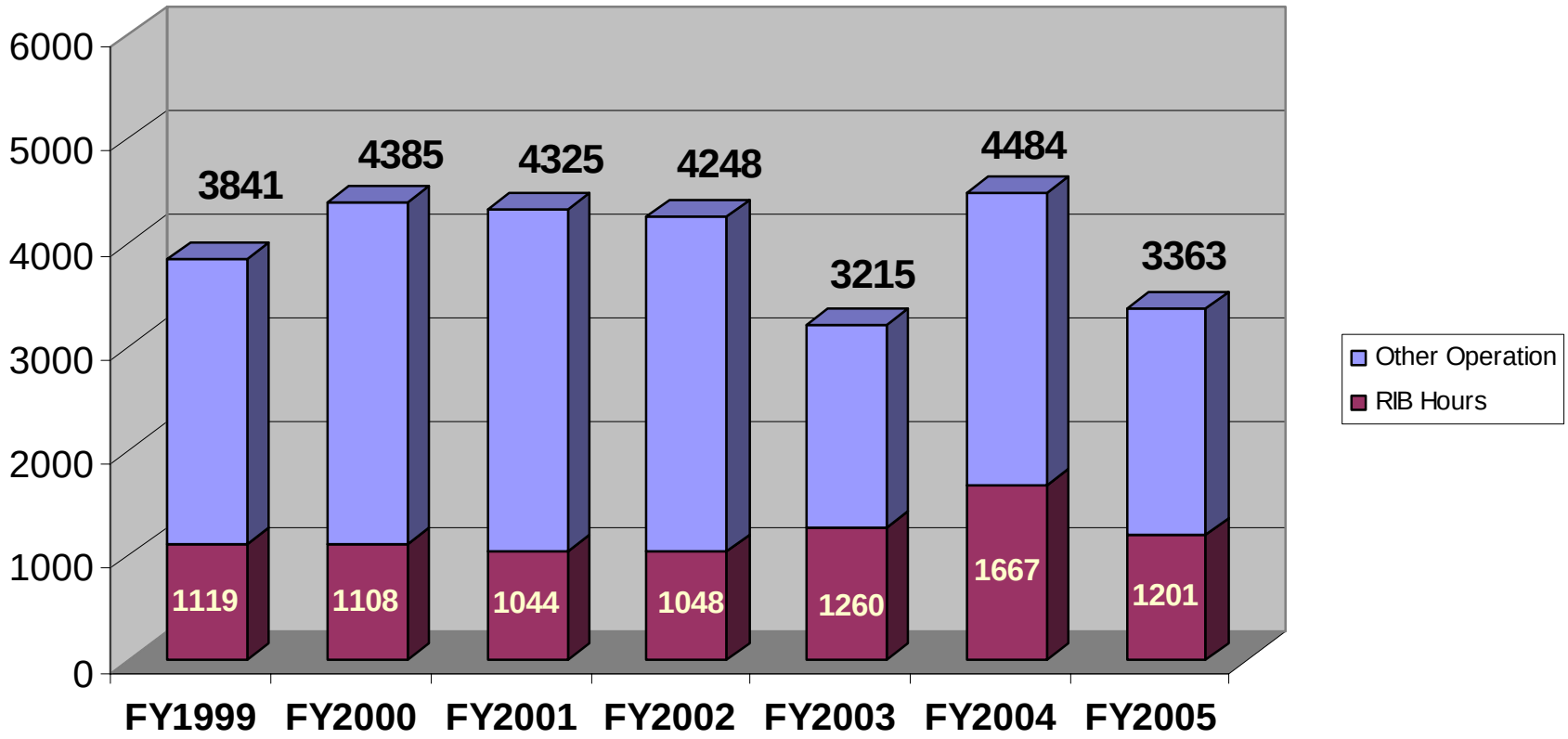
Technical Equipment:
ORIC Beamline in Target Room

Technical Equipment:
High Voltage Platform System with RIB Analysis Beamline

Technical Equipment:
Target Station in Target Room on the High Voltage Platform

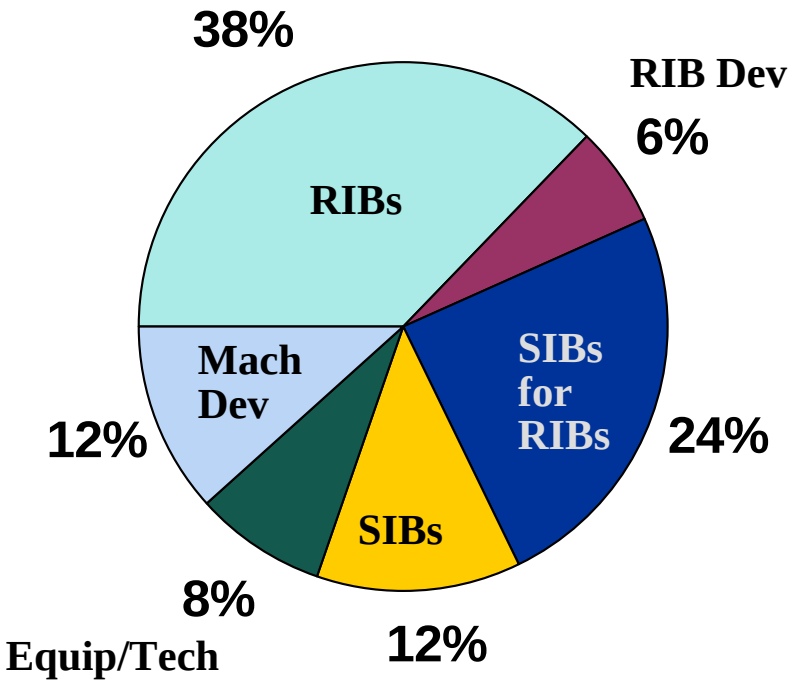


HRIBF Research Hours History



Percentage Distribution of Research Hours

FY04 (4484 hrs)



FY04 Beam Species

Species	Energy Range (MeV)
^{1}H	32-39
^{28}Si	340
^{35}Cl	249
^{36}Cl	249
^{37}Cl	235-249
^{54}Fe	225-250
^{58}Ni	292-340

SIBs

Species	Energy Range (MeV)
^{1}H	54

ORIC Beams

Species	Energy Range (MeV)
^{7}Be	4-27
^{82}Se	380
^{84}Se	380
^{118}Ag	236-340
^{120}Ag	236-340
^{122}Ag	340
^{124}Ag	340
^{125}Ag	340
^{126}Ag	340
^{129}Sb	400
^{130}Sn	550
^{131}Sn	550
^{132}Sn	400-620
^{132}Te	396
^{134}Sn	500-550
^{134}Te	396-565
^{136}Te	410-470

RIBs

Species	Energy Range (MeV)
^{2}H	40
^{7}Li	8
^{12}C	19-21
^{18}O	90
^{19}F	16-48
^{24}Mg	20-42
^{32}S	250
^{40}Ca	104
^{70}Ge	157
^{76}Ge	169-228
^{76}Se	228
^{82}Se	450
^{84}Se	315-450
^{124}Sn	400-600
^{122}Te	366
^{126}Te	378-390
^{130}Te	390-550

SIBs for RIBs

Species	Energy Range (MeV)
^{1}H	8-31
^{12}C	10-20
^{19}F	16-17
^{24}Mg	20
^{28}Si	100
^{58}Ni	110-340
^{76}Ge	170
^{82}Se	450
^{124}Sn	170

Equip/Technique

IRIS2

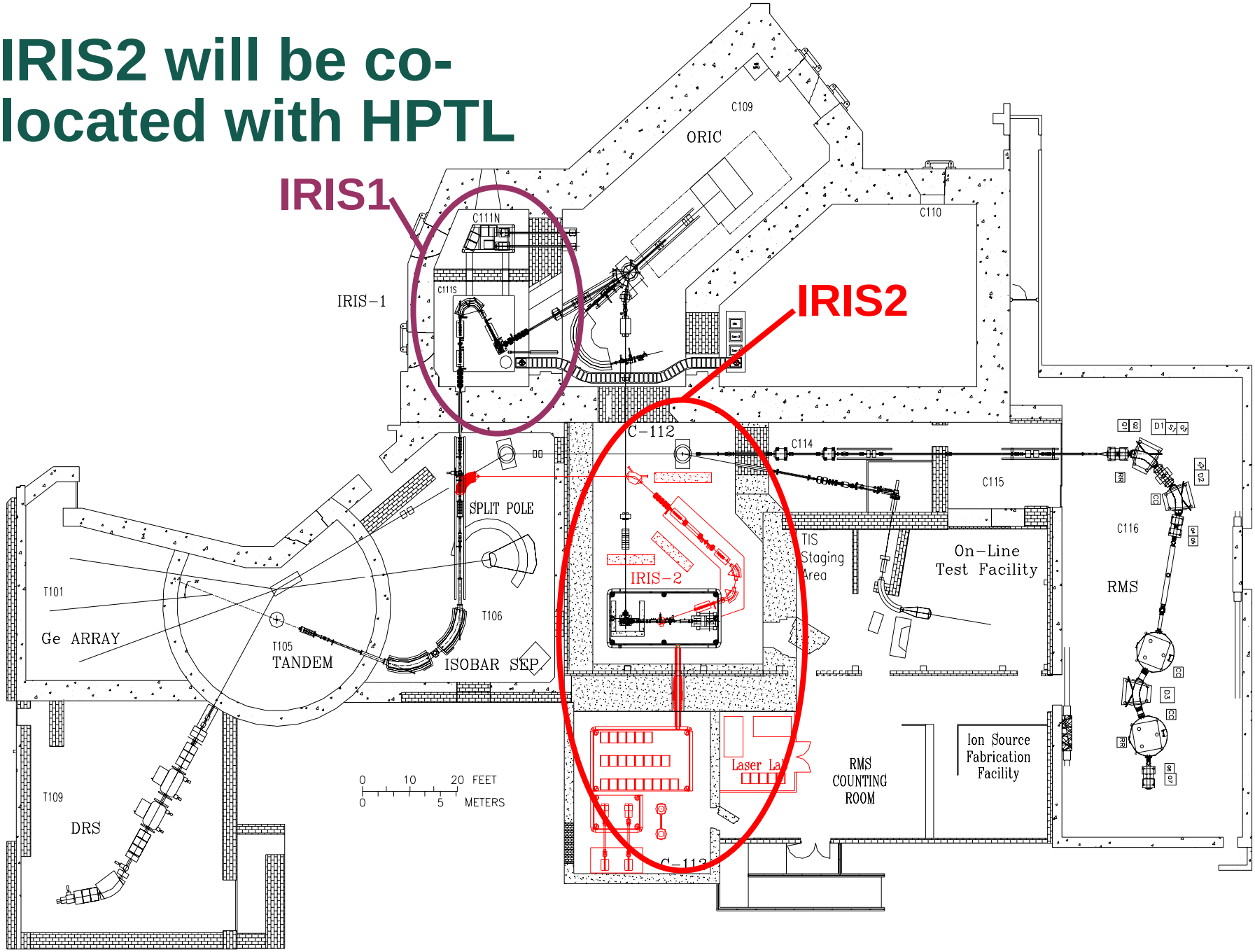
Objective:

- **Construct a second RIB production station, Injector for Radioactive Ion Species #2 (IRIS2): includes RIB generation, preparation, and selection system**

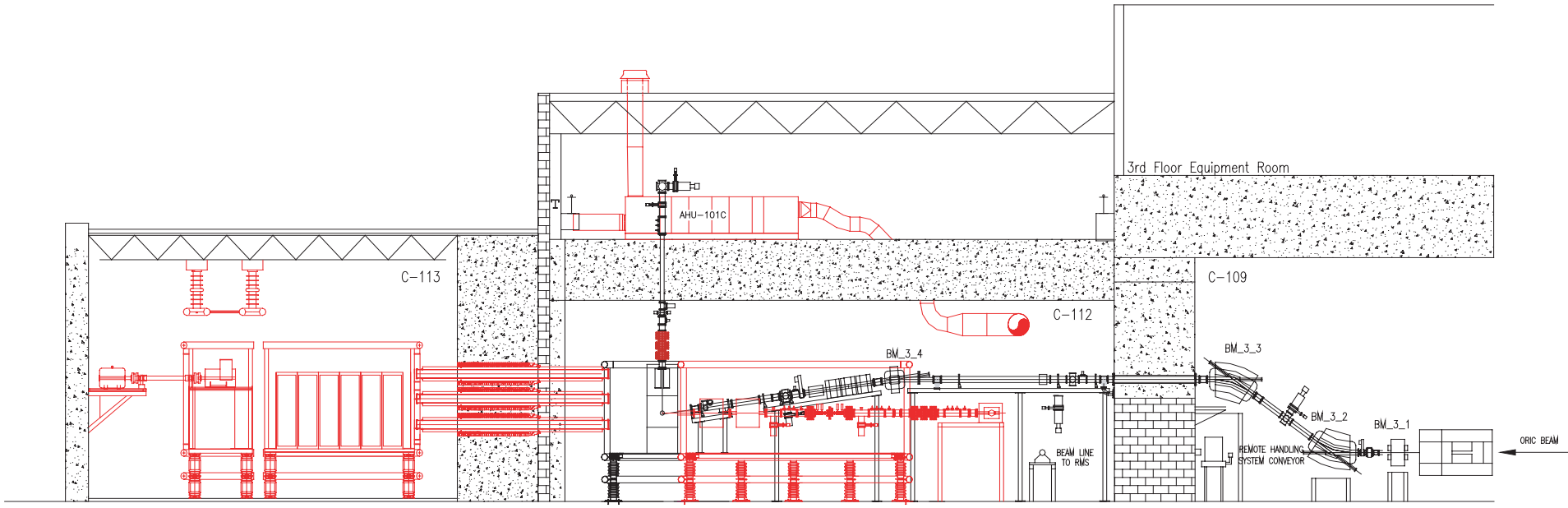
Why?

- **RIB production occurs in an extremely harsh environment at an ISOL RIB facility (e.g. high radiation, high voltage, high temperature)**
- **Equipment maintenance near the production target is challenging and time consuming.**
- **It is normal to change targets and ion sources frequently and this results in downtime at a facility with a single production system.**
- **The primary direct benefit is redundancy for improved operational efficiency.**
- **Provides a production system that will accommodate target/ion sources that cannot be implemented on the existing RIB injector due to space constraints. Examples include laser and ECR ion sources.**
- **Faster transition between experimental campaigns with different target/ion sources.**
- **Increase in RIB hours for experiments**
  - **Goal with IRIS2 implemented - 3000 h RIB on target**
- **Further increases in performance (RIB intensity, variety, purity) will follow from R&D carried out on IRIS2 / HPTL**
- **Early implementation of laser photo-detachment and RLIS will impact beam purity quickly. Laser lab "designed in".**

IRIS2 will be co-located with HPTL



Elevation View of IRIS2



IRIS2 Project Summary

Cost: ~$4.7M, funded beginning this year

Total Duration: 3 (or 4) years

Anticipated completion by December 31, 2008

- **Project has been reviewed for scientific/technical merit and has passed a Technical, Cost, Schedule, and Management Review**
- **Project Management Plan will be finalized in December and work will begin in January**

ORIC Axial Injection

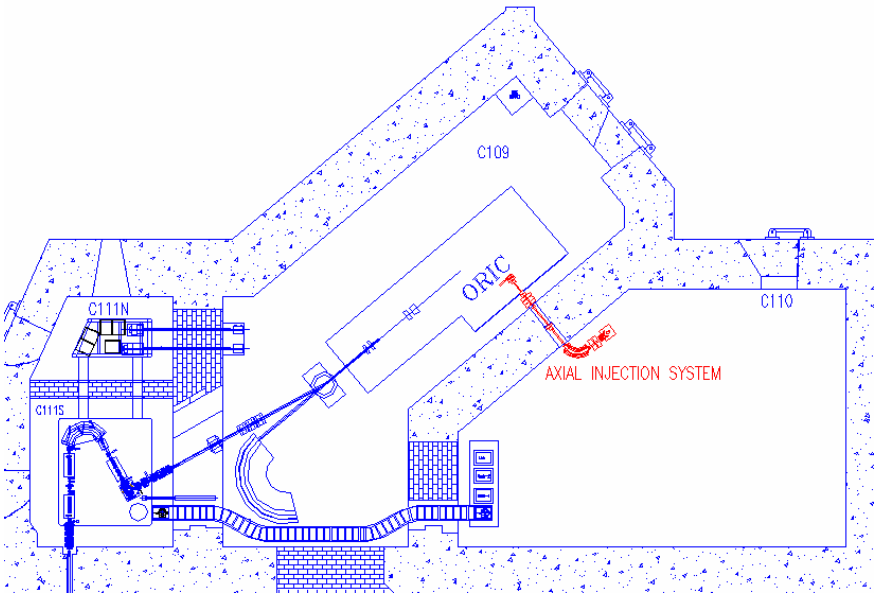
- The performance of the HRIBF driver accelerator, ORIC, is limited by aspects of the PIG-type internal ion source and the multi-stage extraction system.
- Internal ion source limitations are
  - short cathode life time when used with helium, and
  - poor beam quality
- Electrostatic deflector septum extraction limitations are
  - efficiency is low and limits the intensity of production beams
  - results in high machine activation that impedes maintenance
  - risk to internal machine components

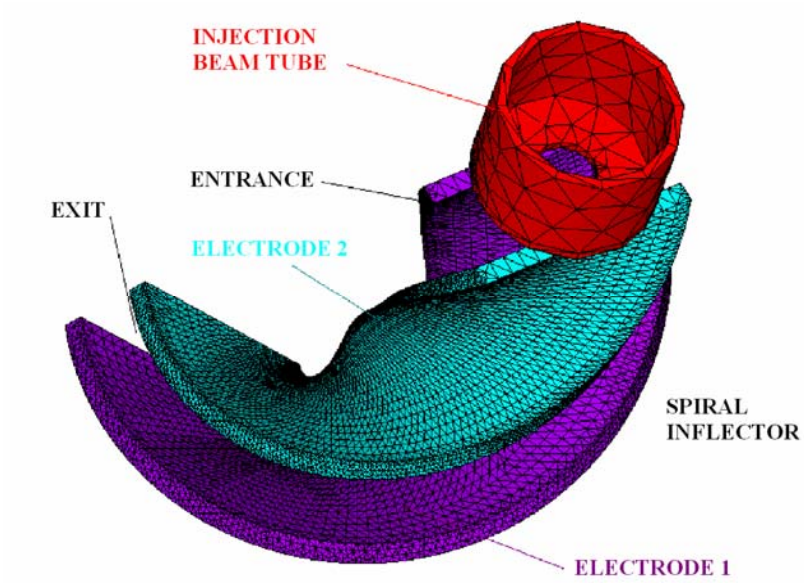
ORIC Axial Injection

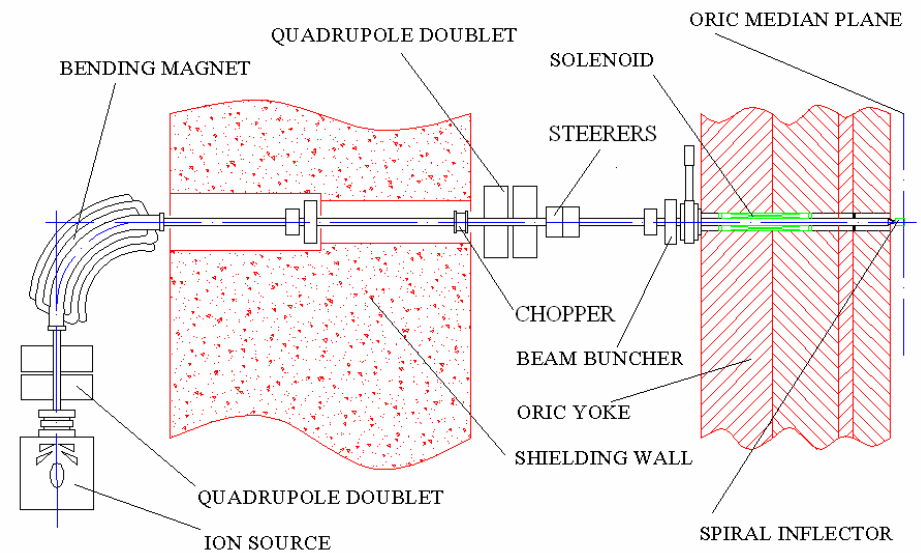
- Project Cost: $300-$500k
- 40 kV ion source platform
- multi-cusp ion source for production of high intensity H– and D– beams
- ECR ion source for He++ and heavier ions such as Li, C
- magnetic beam transport components used to address space-charge effects
- multi-harmonic (MH) beam pulsing system and a spiral inflector.

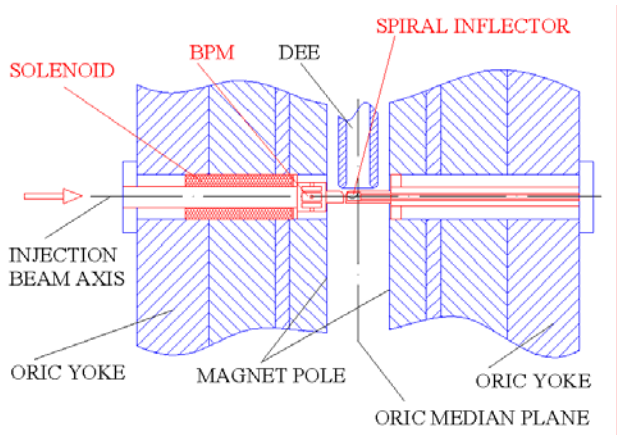
- ~ 80 % of the analyzed DC beams extracted from the ion sources will be efficiently injected into and accelerated by ORIC.
- extract light ion beams from the ORIC with intensities up to 100 μA using a newly designed foil stripping extraction system
- higher driver beam intensities combined with beam rastering will yield higher intensity RIBS

ORIC Axial Injection

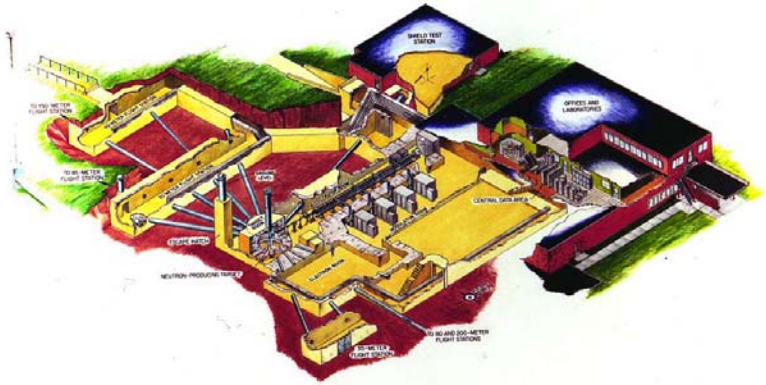








Neutron-Rich RIB Production from High Power Electron Beams

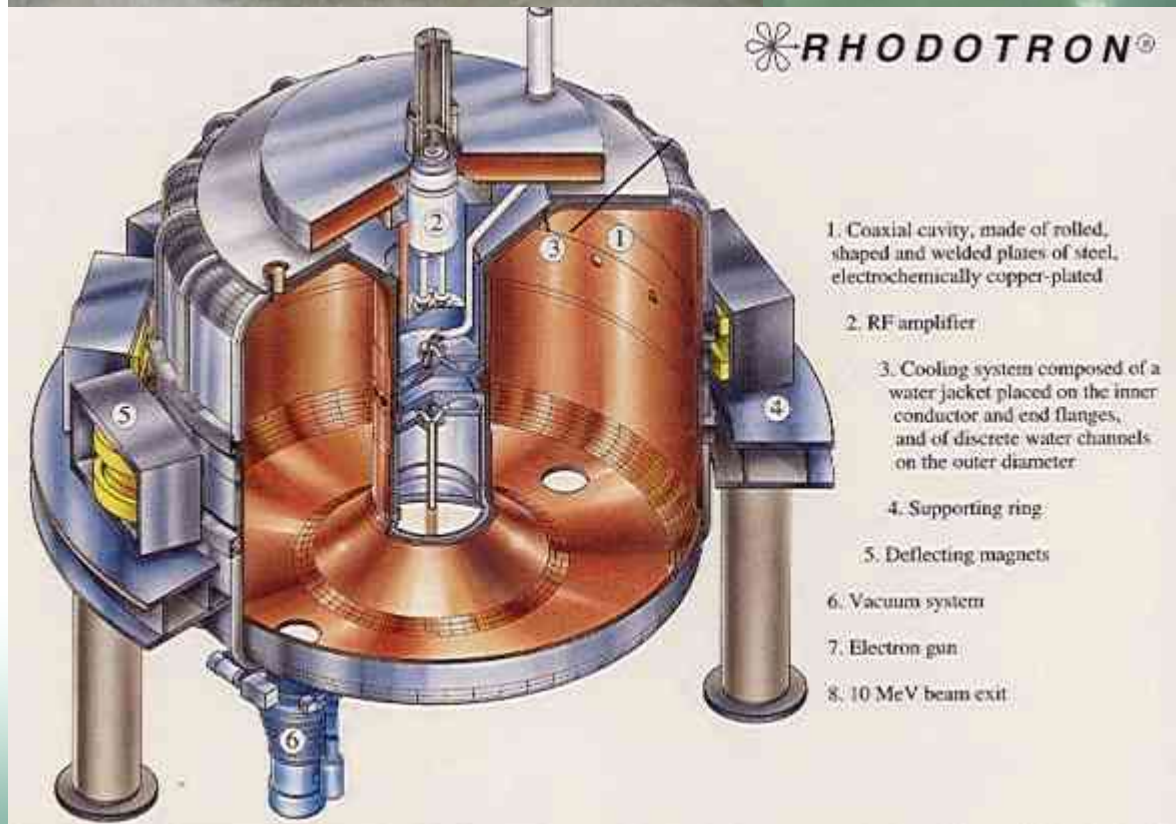


- **Bremsstrahlung from the electron beam induces photo-fission in a uranium carbide target system with a thickness of ~35 g/cm2**
- **A 50kW, 100 MeV electron beam incident on such a target would generate a total uranium fission rate 25 times greater than a 20 μA, 50 MeV proton beam, while depositing about the same power density in the target.**
- **In addition, the yield of neutron-rich species is shifted much farther from stability than for proton induced fission.**
- **This electron-driver initiative could provide extremely high neutron-rich RIB yields at a much lower cost than hadron drivers.**
- **Studies are underway with the Oak Ridge Electron Linear Accelerator (ORELA) to further explore the feasibility of using high power electron beams to produce n-rich RIBs, and to experimentally determine RIB yields.**

IBA Rhodotron

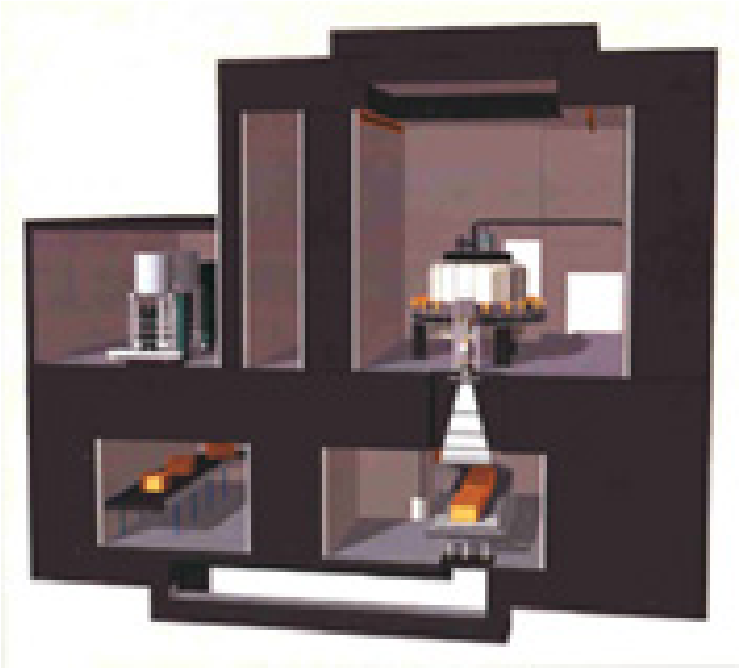
25 MeV electron accelerator

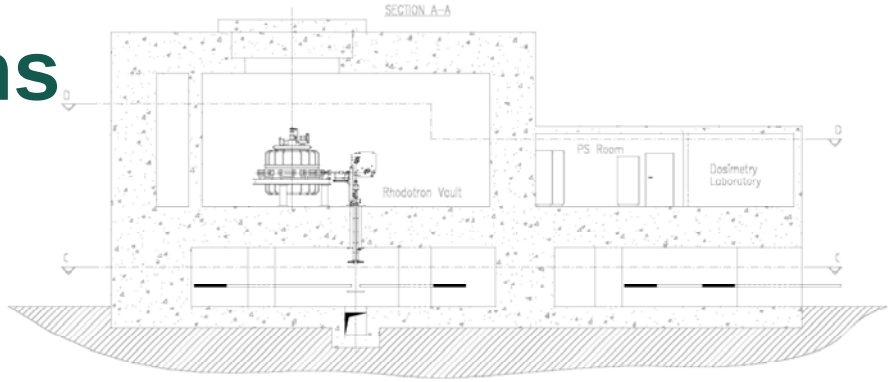
- ISOMEDIX (USA)
- STUDER (SWITZERLAND)
- A.E.0.I.(IRAN)
- ENUSA (SPAIN)
- ECI (BELGIUM)
- RISTRON (GERMANY)
- HOSPAL (ITALY)

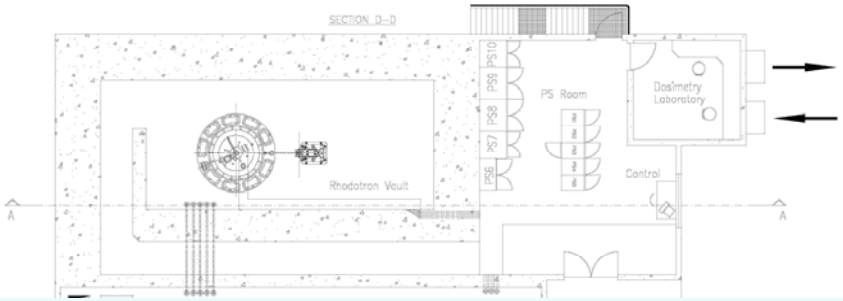


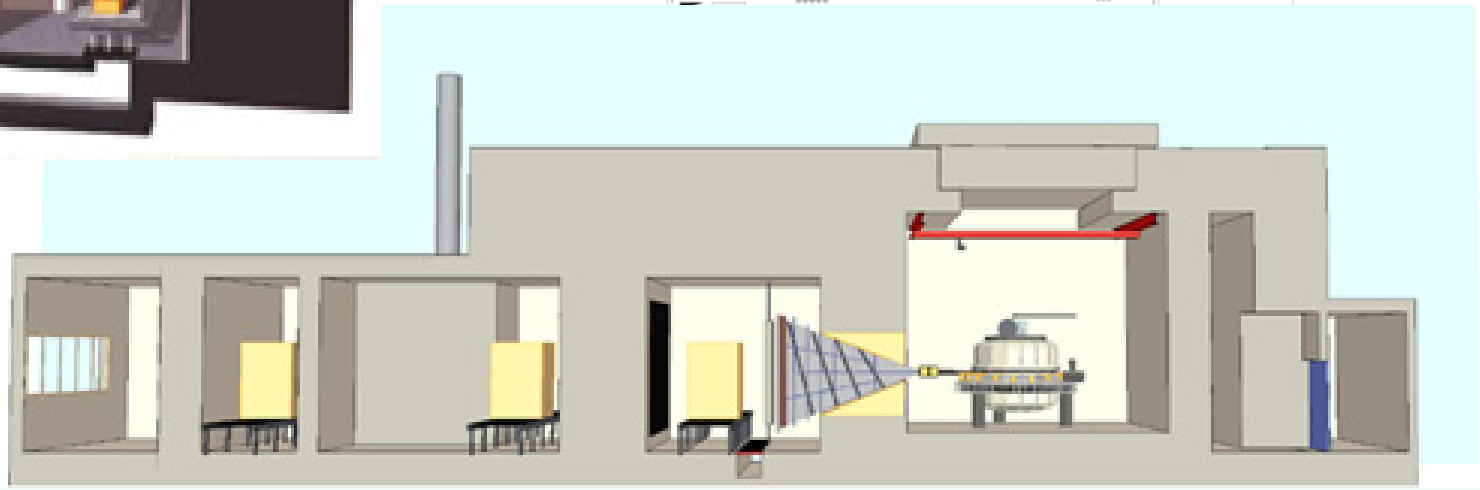
Rhodotron Installations

courtesy of IBA

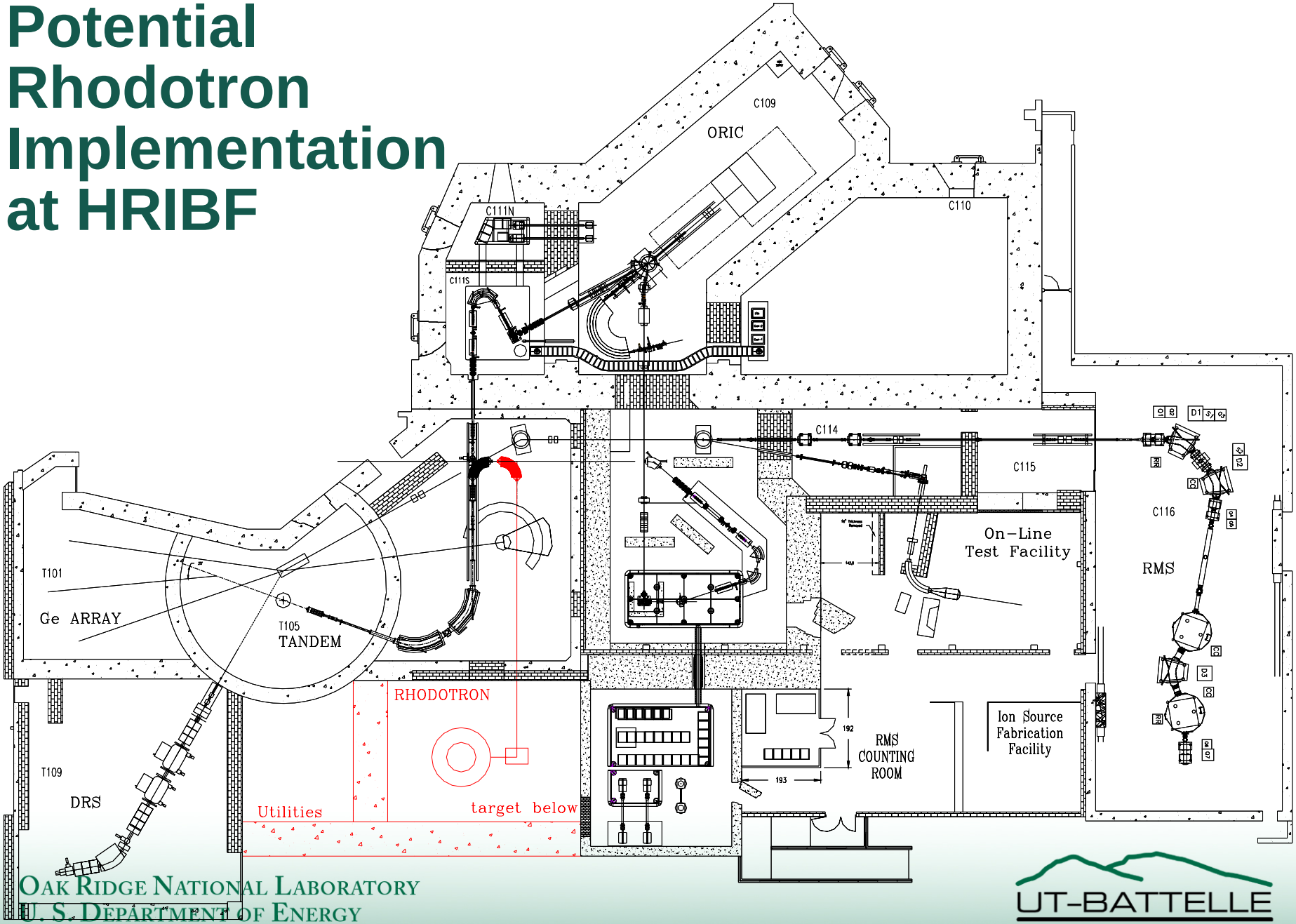








Potential Rhodotron Implementation at HRIBF



8 Year Strategic Plan for Major Systems

- **FY03-FY05** ☑ **Complete HPTL**
- **FY06-FY08** **IRIS2 & laser development**
- **FY09-FY11** **Electron driver (but > $5M)**
- **FY10-FY11** **ORIC axial injection external systems**
- **FY12** **ORIC axial injection internal systems**