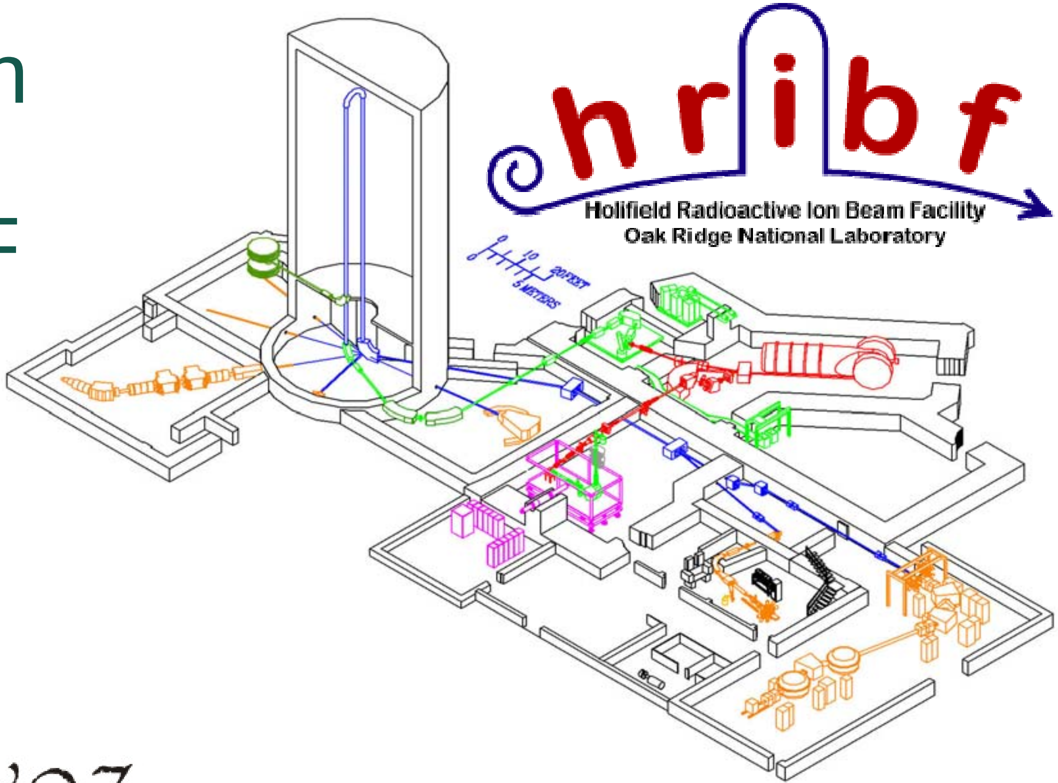
Implementation of an Electron Driver at HRIBF

B. Alan Tatum



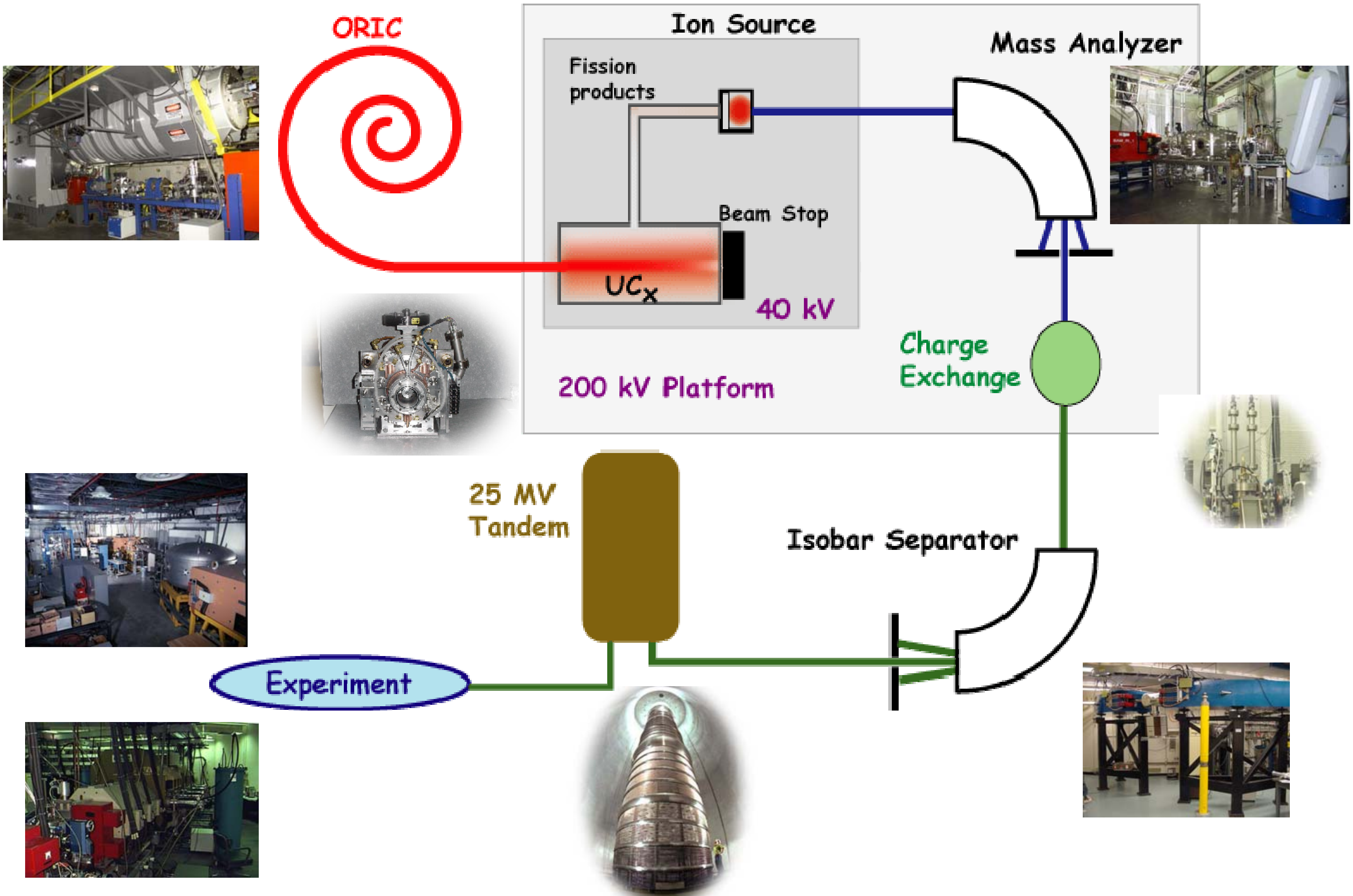
hribf
Holifield Radioactive Ion Beam Facility
Oak Ridge National Laboratory

e⁻ eRIBs'07

International Workshop on
Electron Drivers for Radioactive Ion Beams
October 10th, 2007

Marriott Hotel and Conference Center
City Center, Newport News, Virgina

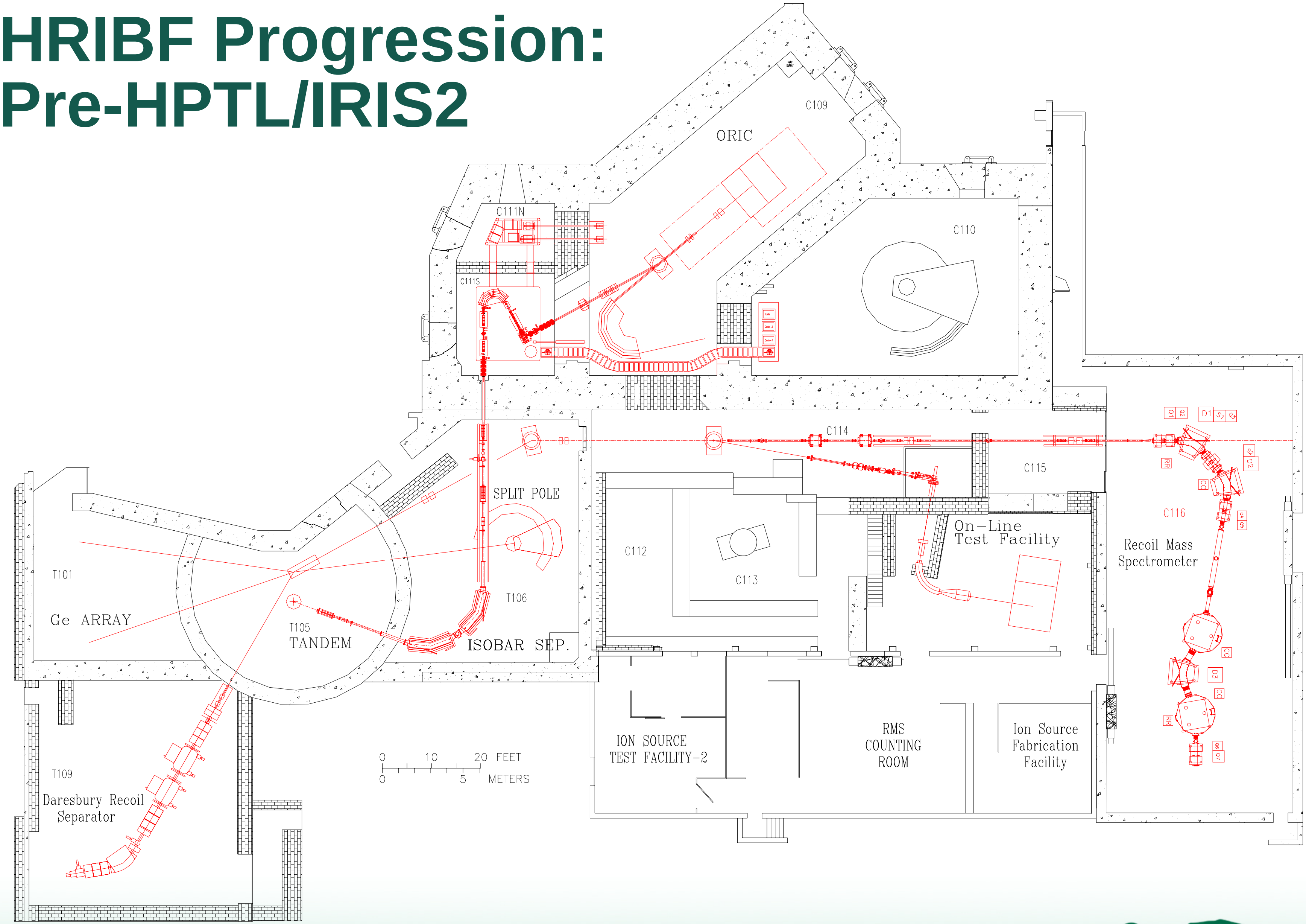
Isotope Separator On-Line (ISOL) Technique at HRIBF



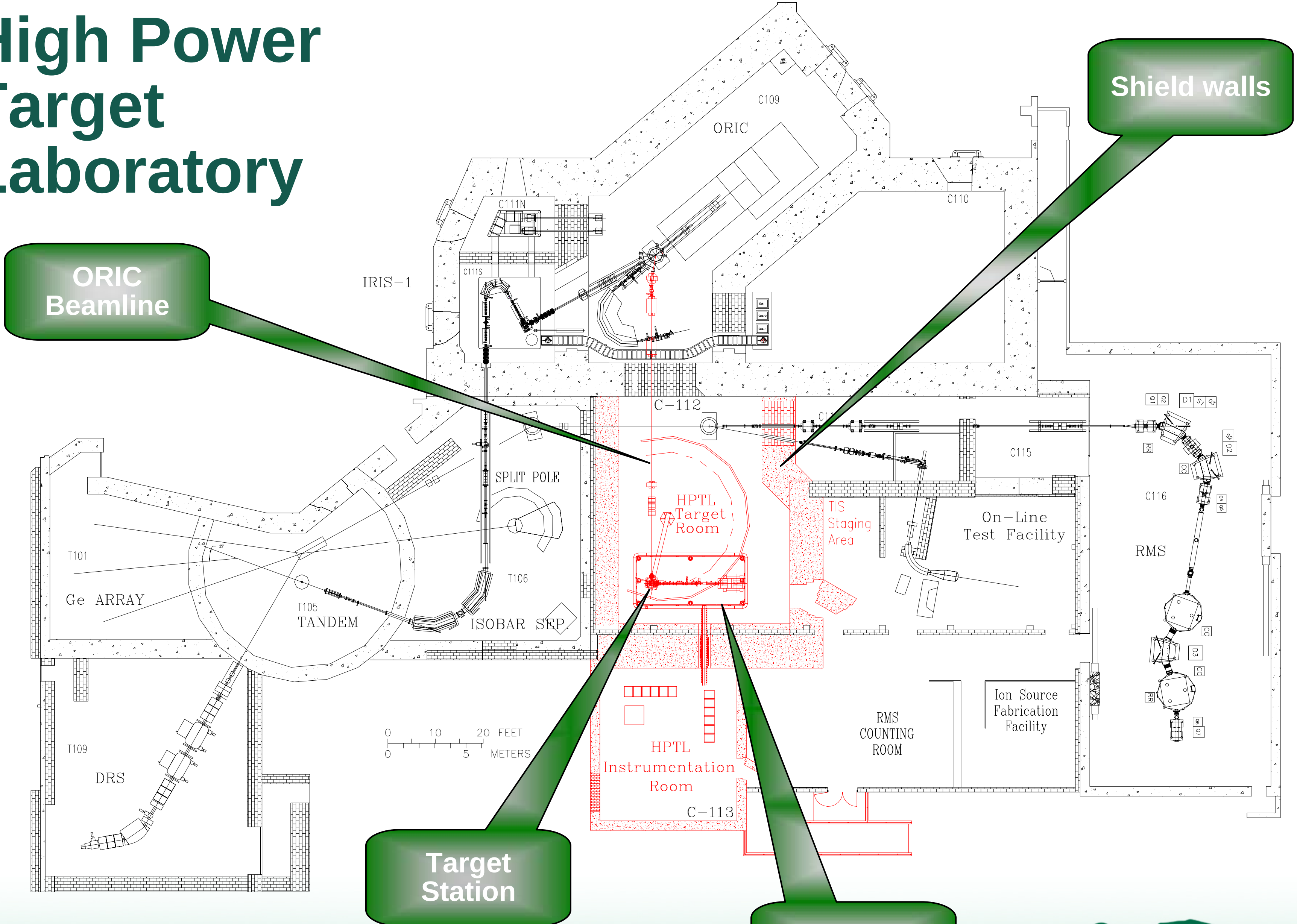
Facility Upgrade Projects

- **HRIBF management developed a long range plan for major upgrades around the turn of the century which is now well underway.**
- **Major upgrades are designed to increase the scientific output of the facility, increase reliability, and improve operational efficiency by incorporating lessons learned during our first decade as an operating ISOL RIB facility.**
- **Upgrades include:**
  - **FY03-FY05** — Complete — **High Power Target Laboratory (HPTL):** ***provides a venue for testing of new targets, ion sources, and RIB production techniques with high power ORIC beams***
  - **FY06-FY09** — In Progress — **Injector for Radioactive Ion Species 2 (IRIS2):** ***a second RIB production station for improved facility reliability designed to accommodate new ion sources, beam production and purification techniques.***
  - **FY09-FY13** — Pre-proposal — **Rhodotron or linac electron driver:** ***more reliable and cost-effective driver operation than ORIC and provides several-orders-of-magnitude increase in neutron-rich RIB intensities***

HRIBF Progression: Pre-HPTL/IRIS2

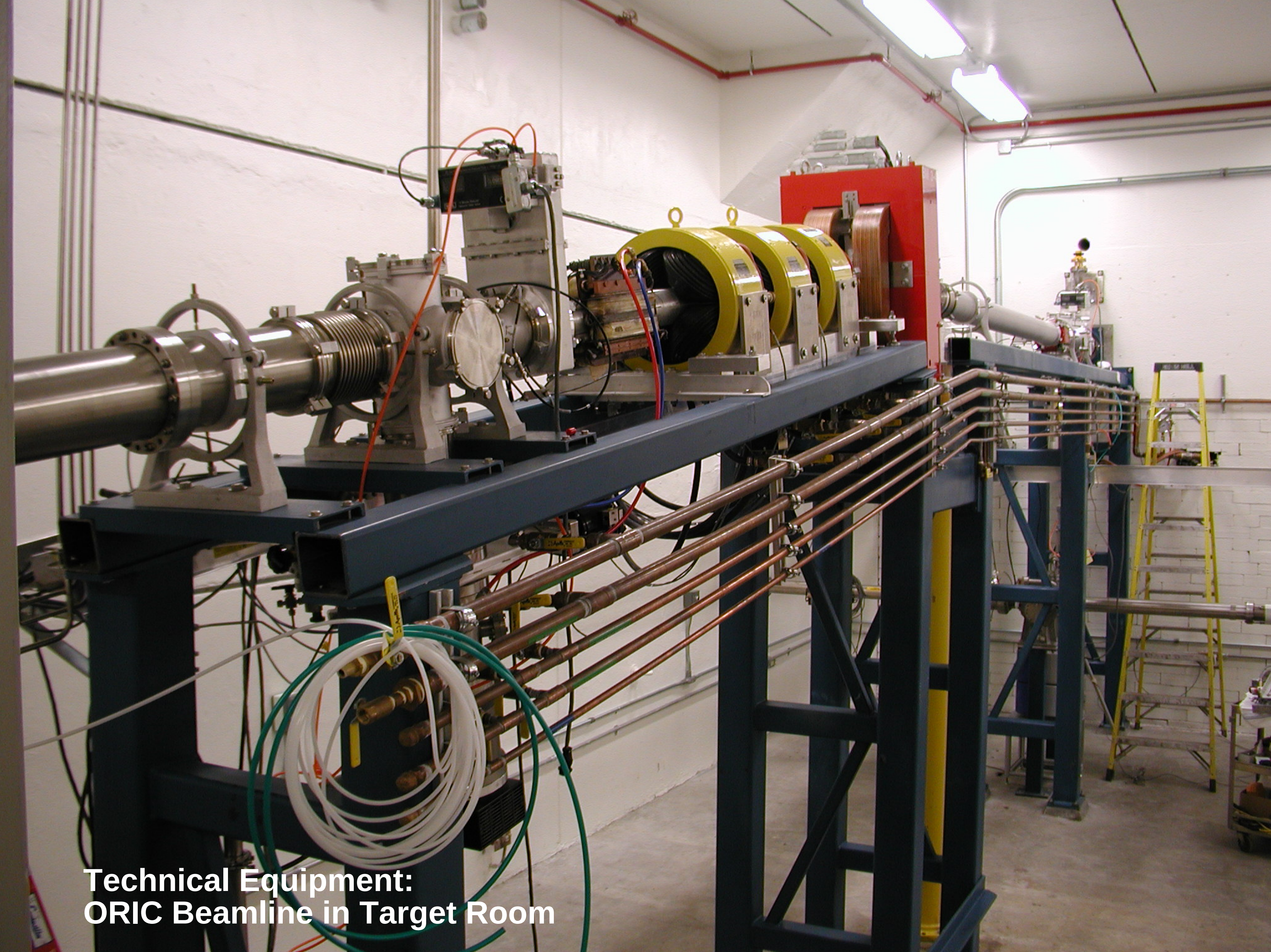


High Power Target Laboratory



Facility Modifications (exterior)
Instrumentation Room and
modified South Annex

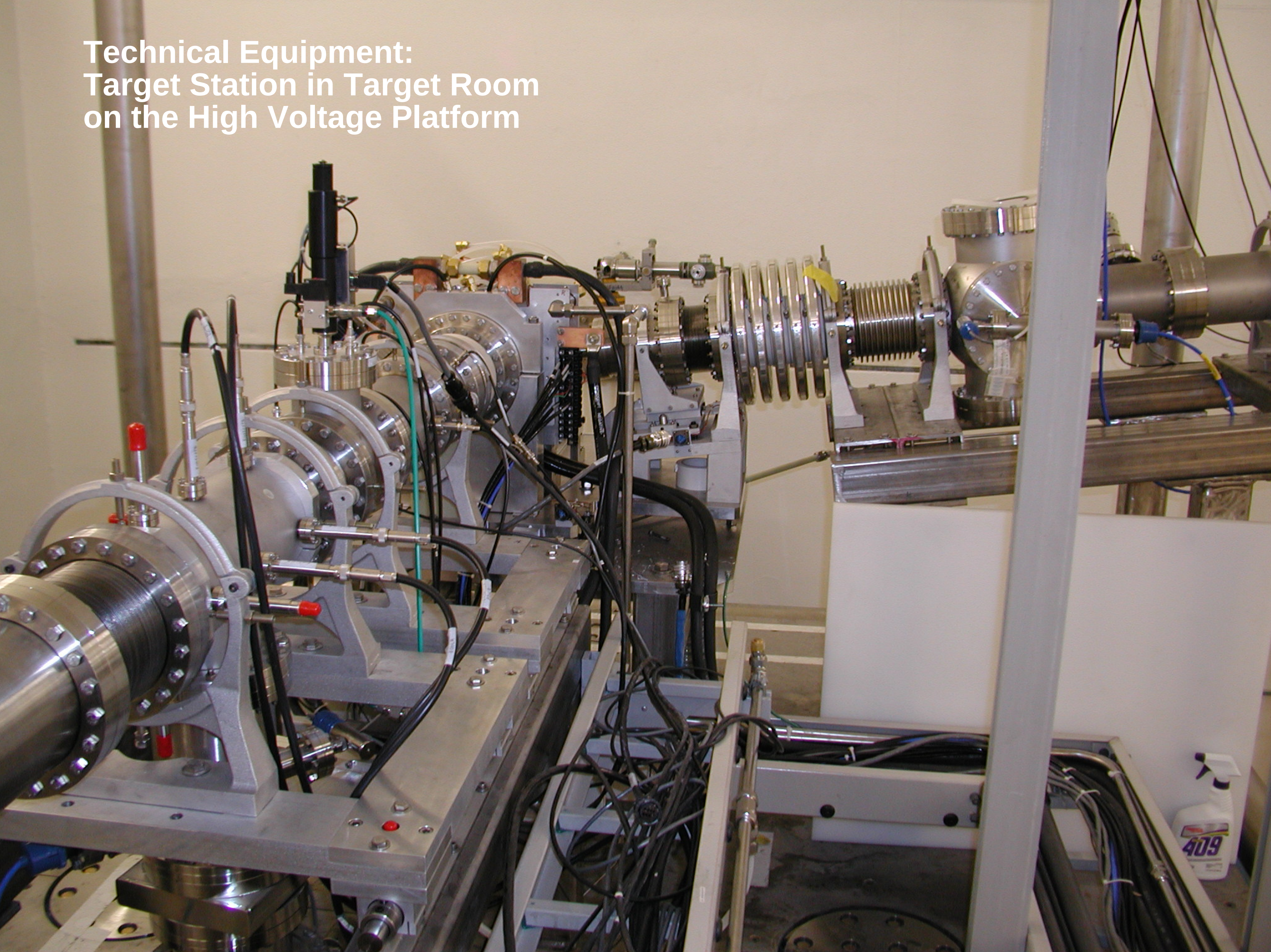
Technical Equipment:
ORIC Beamline in ORIC Vault



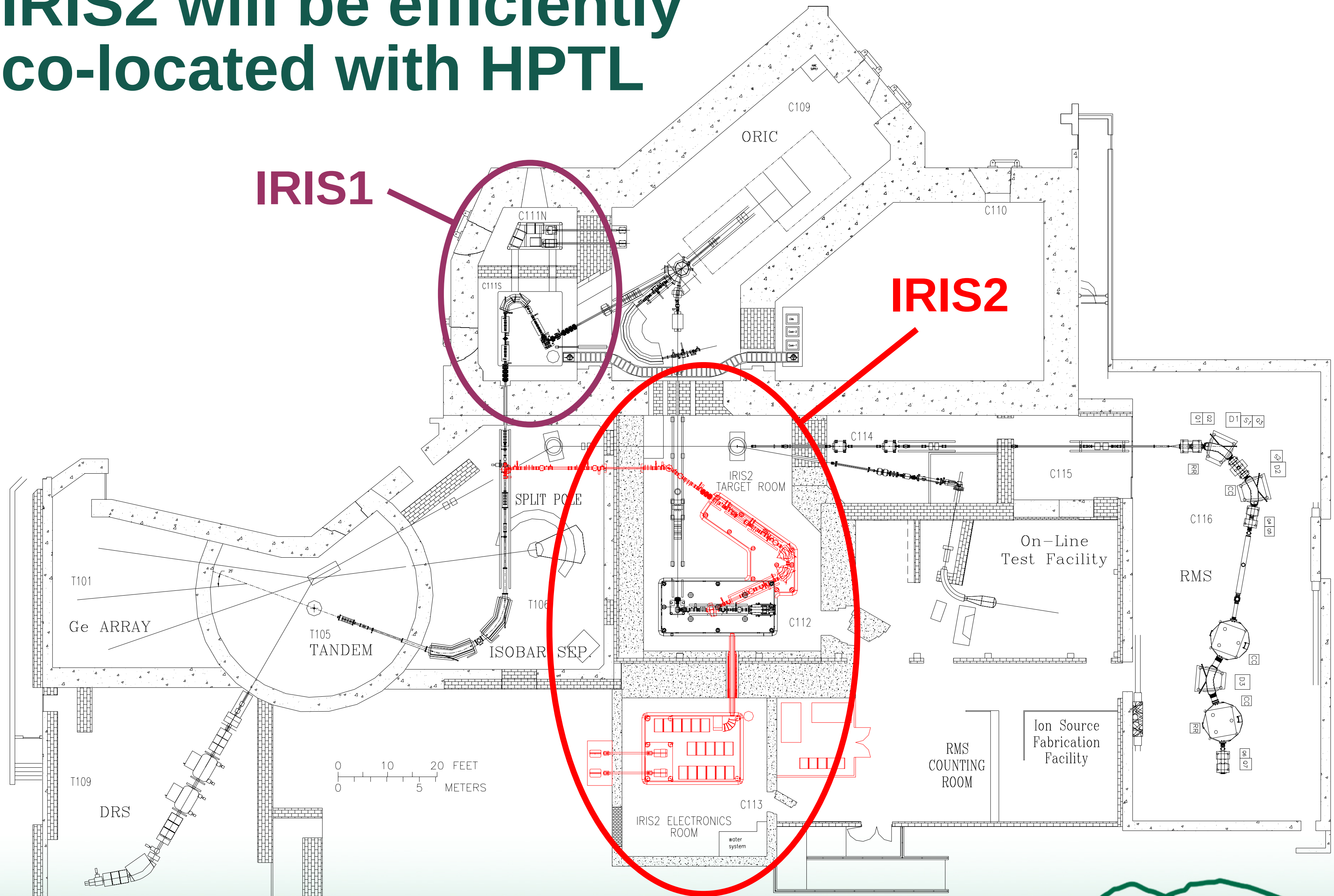
Technical Equipment:
ORIC Beamline in Target Room

Technical Equipment:
High Voltage Platform System with
RIB Analysis Beamline

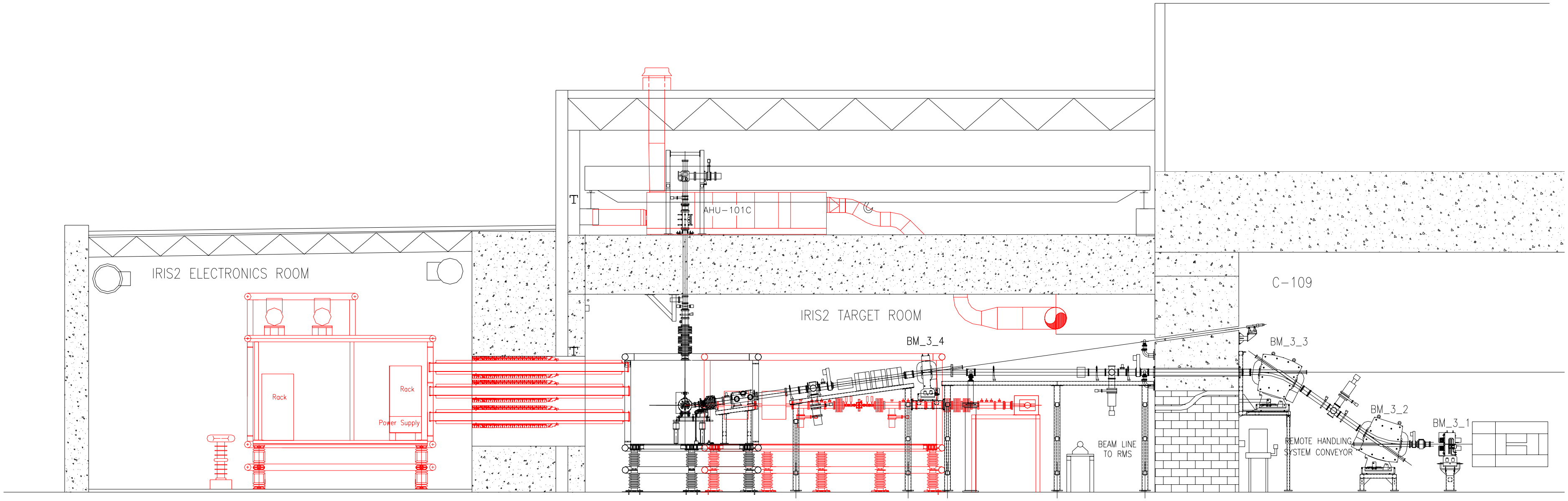
Technical Equipment: Target Station in Target Room on the High Voltage Platform



IRIS2 will be efficiently co-located with HPTL



Elevation View of IRIS2



IRIS2
Target Platform

IRIS2 Instrumentation Platform

Benefits to date

- **HPTL provided a new capability for testing targets and ion sources at full power without adversely affecting the experimental program (previous development activities took place on the IRIS1 production platform system).**
- **IRIS2 will provide much needed redundancy in RIB production systems (i.e. more efficient facility ops and facility reliability), and allow us to provide a broader array of high purity beams to the experimental program.**
- **Combined with on-going AIP and capital equipment improvements throughout the facility, we are already reaping the benefits!**
- **In FY07, HRIBF provided 1,952 ISOL RIB hours, 278 in-flight RIB hours, and 3,648 total research hours. Facility reliability was 91.2%.**

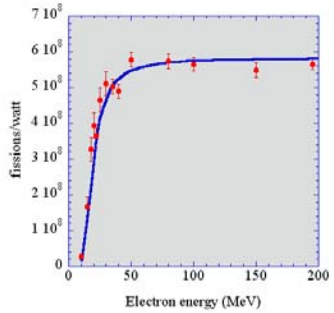
Electron Driver Upgrade

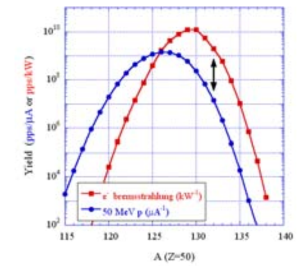
We propose to substantially upgrade the capability and further improve the reliability of HRIBF by the addition of an electron driver accelerator for the production of neutron-rich RIBs by photo-fission of actinide targets.

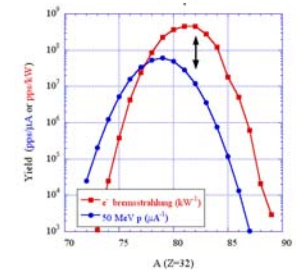
This addition can be accomplished within reasonable cost guidelines and staffing limitations.

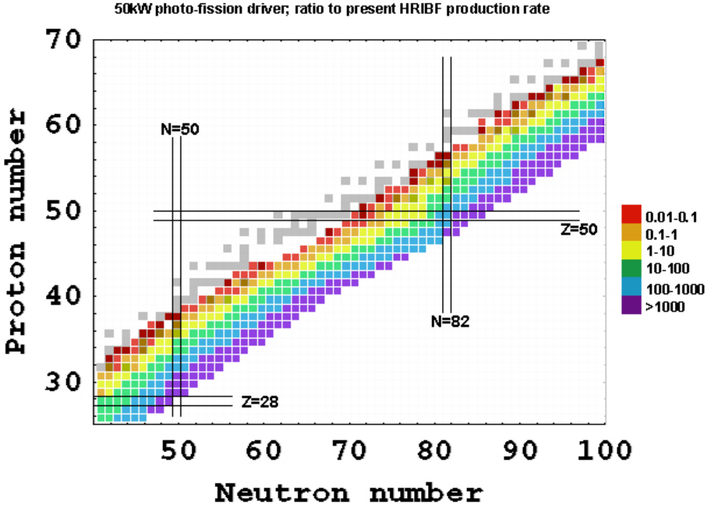
Electron Driver Upgrade

- Provides driver accelerator redundancy leading to increased operational efficiency and facility reliability.
- Would be dedicated to neutron-rich species by photo fission of actinide targets.
- Most cost effective means to achieve in-target fission rates in the mid 10^{13} /s scale.
- A turn-key electron accelerator can be implemented and operated by the small HRIBF staff with only a ~10-15% increase in operating budget.
- Capable of providing near-CW, 100kW beams at energies of 25-50 MeV.
- Target development to support ~50kW operation is well within reach (talk by Stracener).
- An improved ORIC, possibly with axial injection, would still be required to support the proton-rich program and HPTL target development activities.



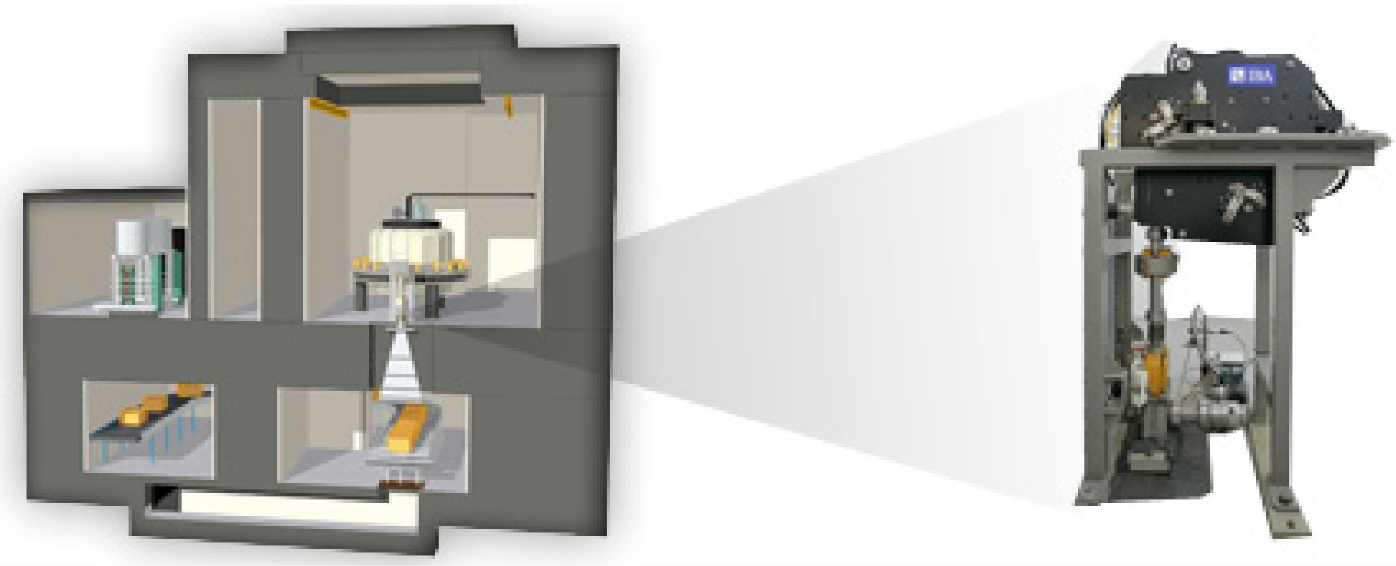






Rhodotron Overview

- An Ion Beam Applications (IBA) Rhodotron® is the preferred electron accelerator due to its compact size, high efficiency, reliability, low operating cost, and turn key implementation.
- Industrial machine typically used for medical sterilization, polymer cross-linking, food pasteurization, and mail irradiation.
- Nearly 20 of these reliable, flexible, and economical machines are installed world-wide.
- The Rhodotron® is a recirculating accelerator where electrons gain energy by crossing a coaxial-shaped accelerating cavity several times. This original design makes it possible to operate the machine in continuous mode for maximum efficiency and throughput.



Rhodotron Principle

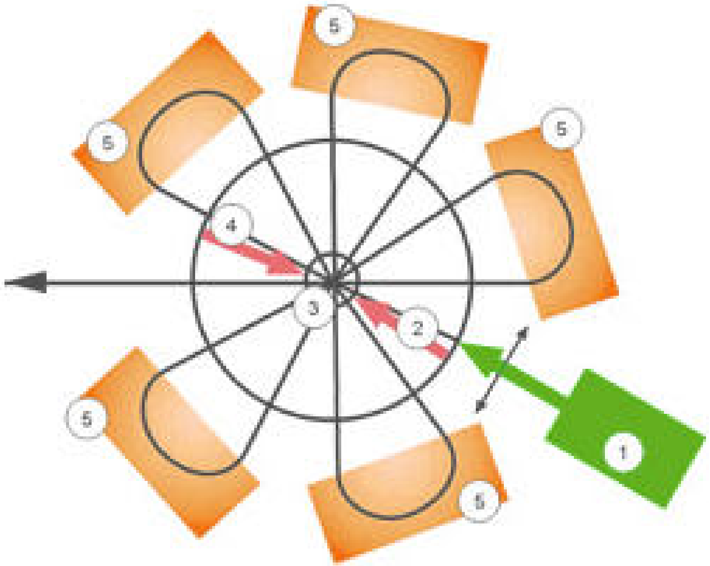
Operating Highlights of the Rhodotron®

1 - Electrons are fired by the heated filament of the electron source located at the outer wall of the cavity (1).

2 - The electrons are introduced into the cavity when the electric field is such that it will accelerate the electrons inwards, towards the hollow coaxial cylinder in the center.

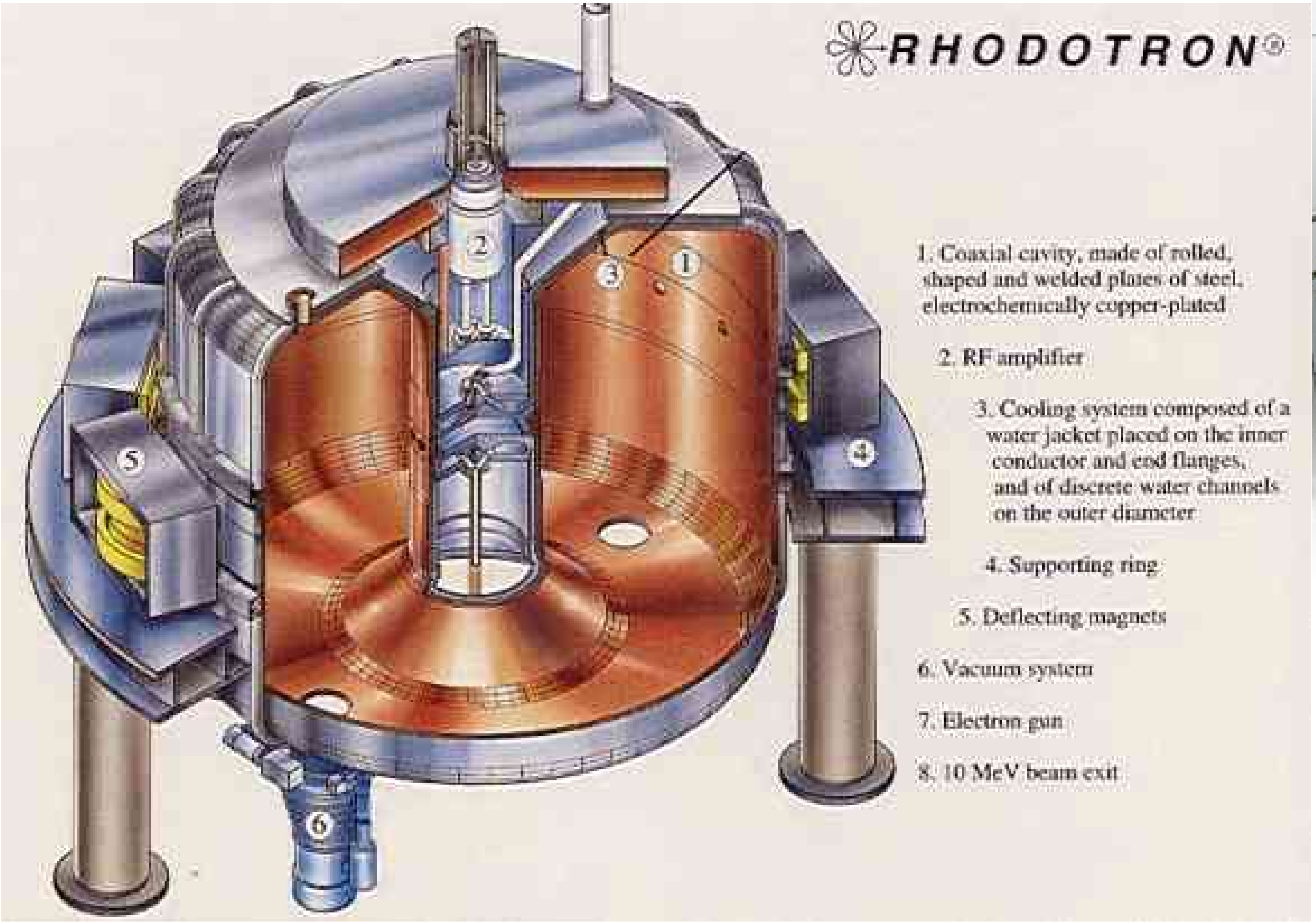
3 - The electrons pass through openings in the inner cylinder while the electric field is reversing

4 - On emerging from the inner cylinder, the electrons are further accelerated (towards the outer cavity wall) under the influence of the new reversed field.



5 - Using beam deflection magnets, the electrons are reintroduced into the main body of the accelerator for additional crossings of the cavity in order to reach the required energy level and leave the cavity through a beam line (**6**).

Components


RHODOTRON®
1. Coaxial cavity, made of rolled, shaped and welded plates of steel, electrochemically copper-plated
2. RF amplifier
3. Cooling system composed of a water jacket placed on the inner conductor and end flanges, and of discrete water channels on the outer diameter
4. Supporting ring
5. Deflecting magnets
6. Vacuum system
7. Electron gun
8. 10 MeV beam exit

Rhodotron Implementation

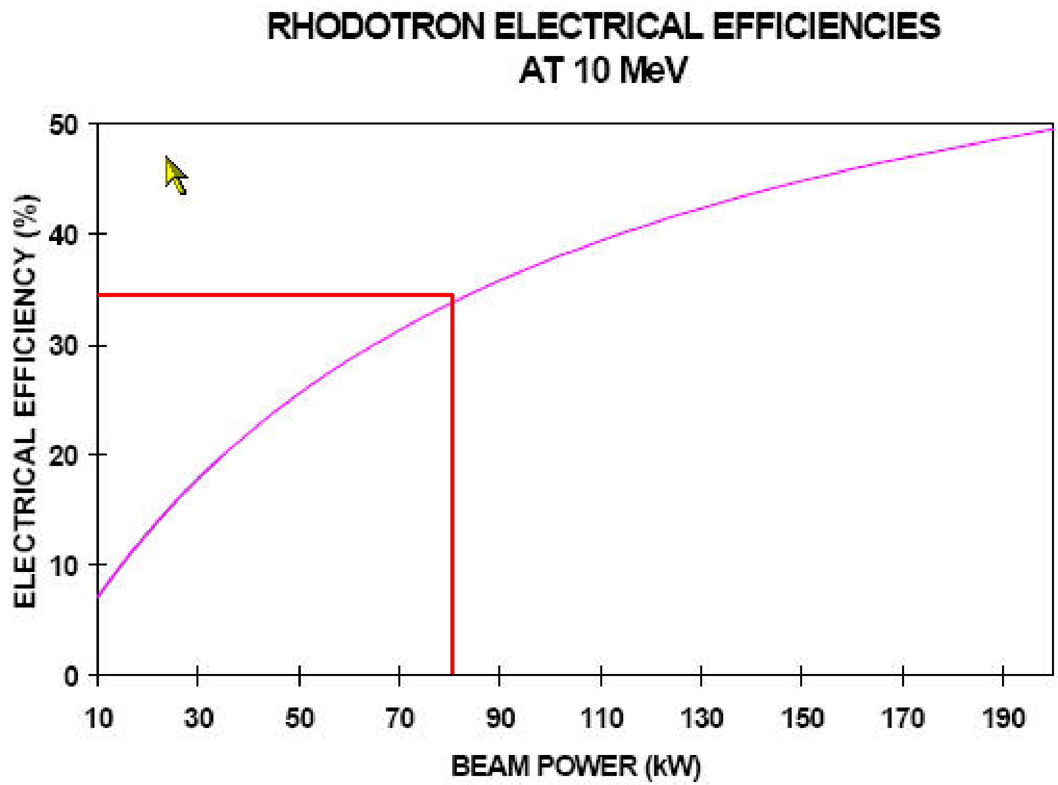
- Discussed with IBA the possibility of designing a 25MeV machine, but they believe it is too risky and requires months of extensive design effort.
- 10MeV TT200 scales easily to 12.5MeV
- IBA proposes an HRIBF layout with two 12.5MeV Rhodotron's in series
- Turnkey system includes two Rhodotrons, electron gun, scanning horn, power supplies, cooling systems, control systems, installation and commissioning at HRIBF

Technical Specifications of the various Rhodotron®'s models |

	TT100	TT200	TT300	TX400	TX1000
Energy	10 MeV	10 MeV	10 MeV	7 MeV	from 5 to 7,5 MeV
Beam Power Range	0,5 to 35 kW	0,5 to 80 kW	0,5 to 190 kW	0,5 to 280 kW	0,5 to 700 kW
Power Consumption at full energy	210 kW	310 kW	452 kW	596	1270 kW
Number of passes	12	10	10	7	6
Diameter	1,6m	3,0m	3,0m	3,0 m	3,0m
Height	1,75m	3,0m	3,0m	3,0	3,3m

Advantage: Electrical Efficiency

- **TT200 has demonstrated "wall plug to beam power" electrical efficiency of around 30%**



Advantages

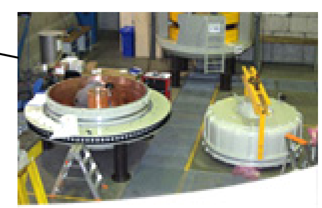
- Reliable electron gun

- Built in scanning feature
- Small footprint (~3m dia)

- All critical components outside of accelerating cavity

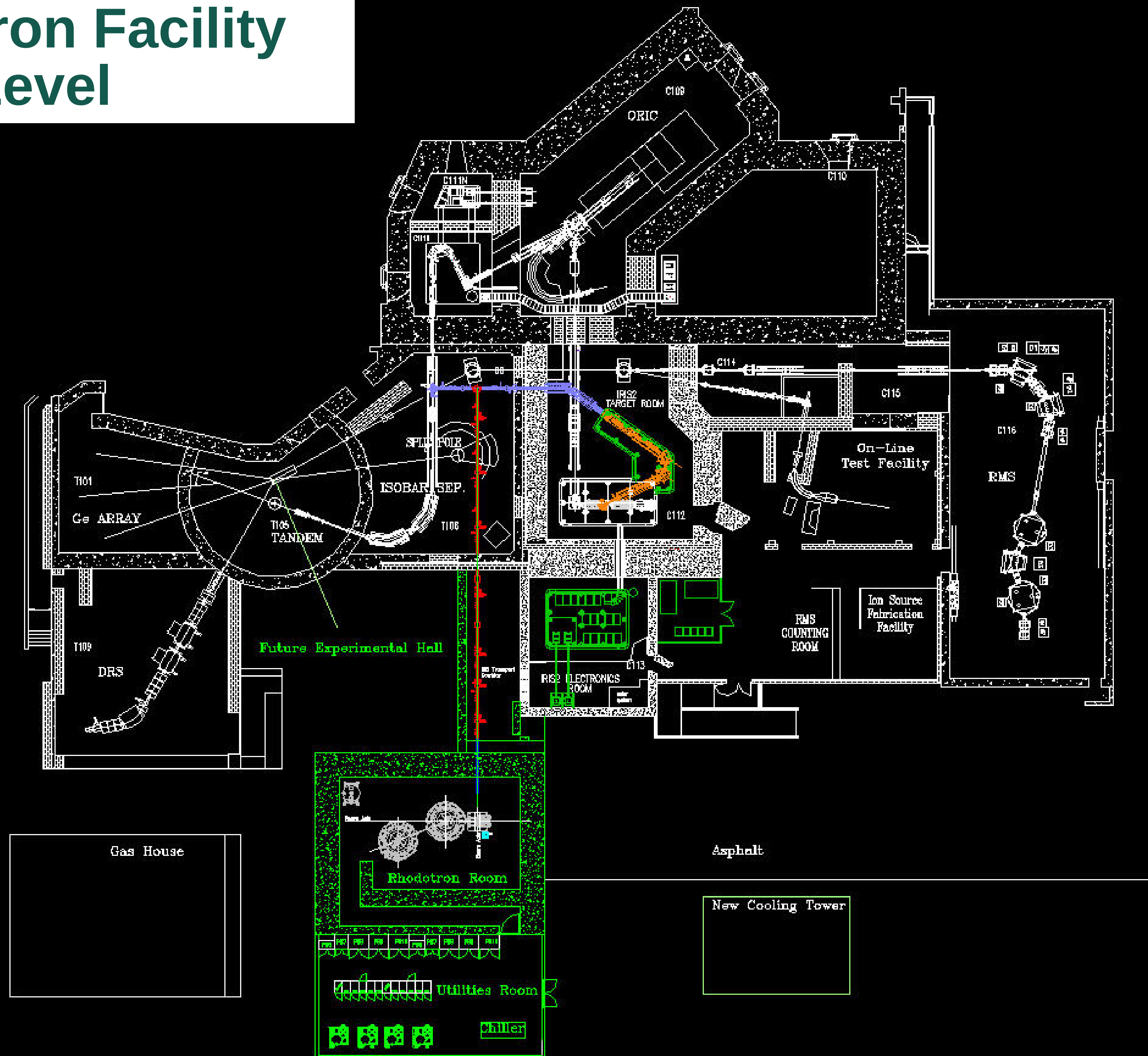
- rf uses a cathode driven tetrode rather than a Klystron (longer life, lower cost)

- Non-superconducting
- Rapid start-up and shut-down
- Top of machine lifts off by hoist for rf cavity access



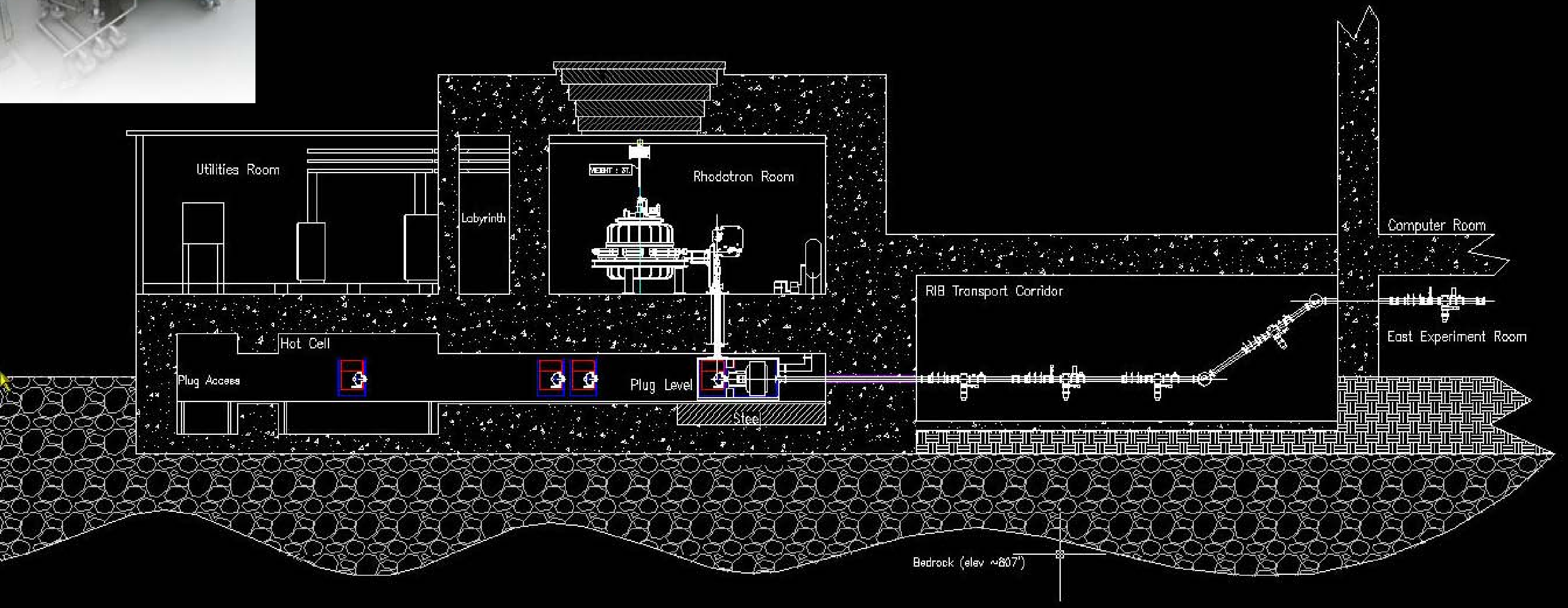
- Industrial plc controls

Rhodotron Facility Upper Level



Rhodotron Facility Lower Level

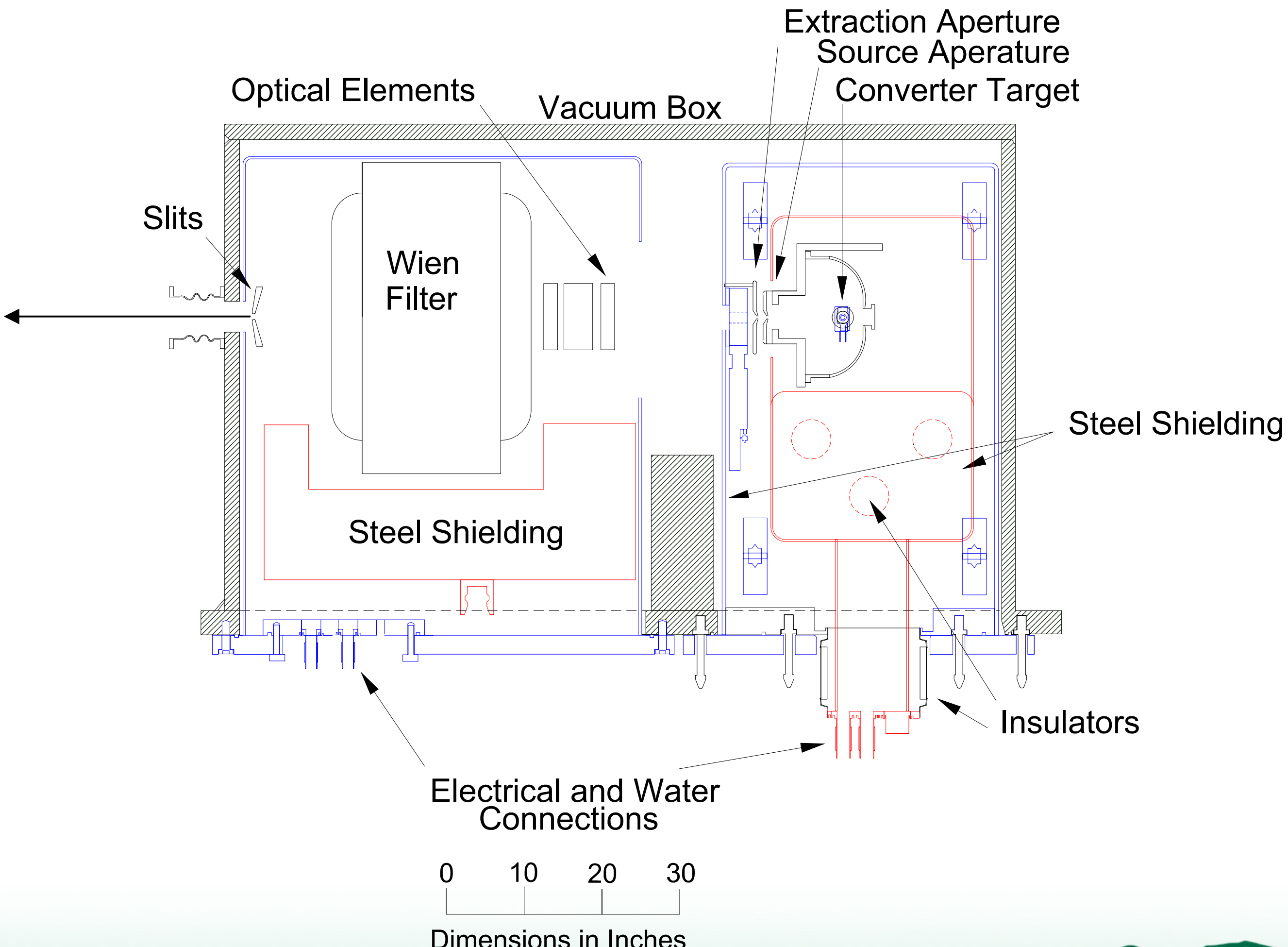
Rhodotron Facility Elevation



Source Concepts – Use Source Plugs – Same Idea as Developed for ISAC and SPIRAL II

Radioactive Ion Beam @ 40 keV

Slits serve as source point for downstream optics calculations



Design Considerations

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- Beam energy for injection into tandem
  - Presently optimized for 200 – 300 keV from existing/planned RIB and stable injectors
  - HV platform not preferred
    - Considering RFQ. Existing design study proposed locating at tandem entrance
    - Evaluating low-energy (40 – 60 keV) injection
- Isobar separation?
  - Present separator designed for 200 – 300 keV, but possible at low energies, or perhaps float on HV deck
  - Low beam energy/momentum spread and low emittance critical

Proposed Injector Line Coupling to IRIS2 Transfer Line

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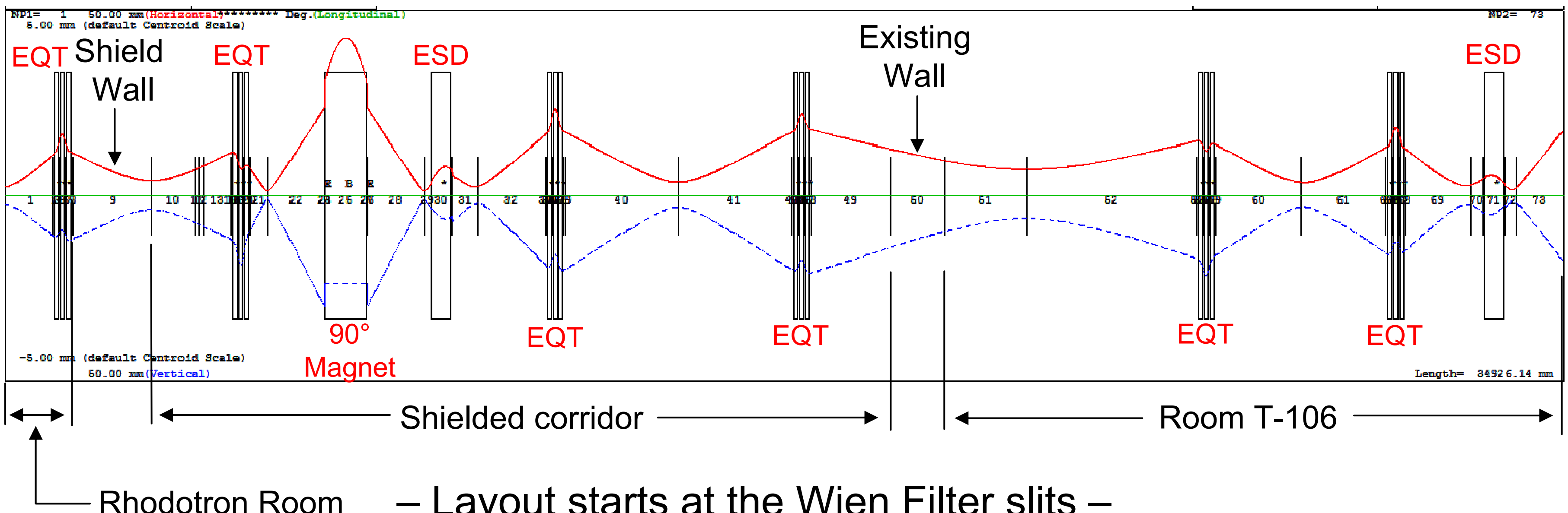

– Layout starts at the Wien Filter slits –

- Lenses are Electrostatic Quadrupole Triplets (EQT) identical to those on HPTL/IRIS2 HV platforms
- 90" elevation change + 1st-stage mass separation: 24" radius, 90° double-focusing magnet + 12" radius, 90° spherical electrostatic deflector (ESD) -- ~1/250 mass resolution
- 2nd 12" radius, 90° spherical electrostatic deflector couples into IRIS2 transfer line 63" upstream of the final IRIS2 quad.
- The beam waist after the 2nd ESD coincides with the IRIS2 designed waist location

Beam Transport thru IRIS2 & BL_12

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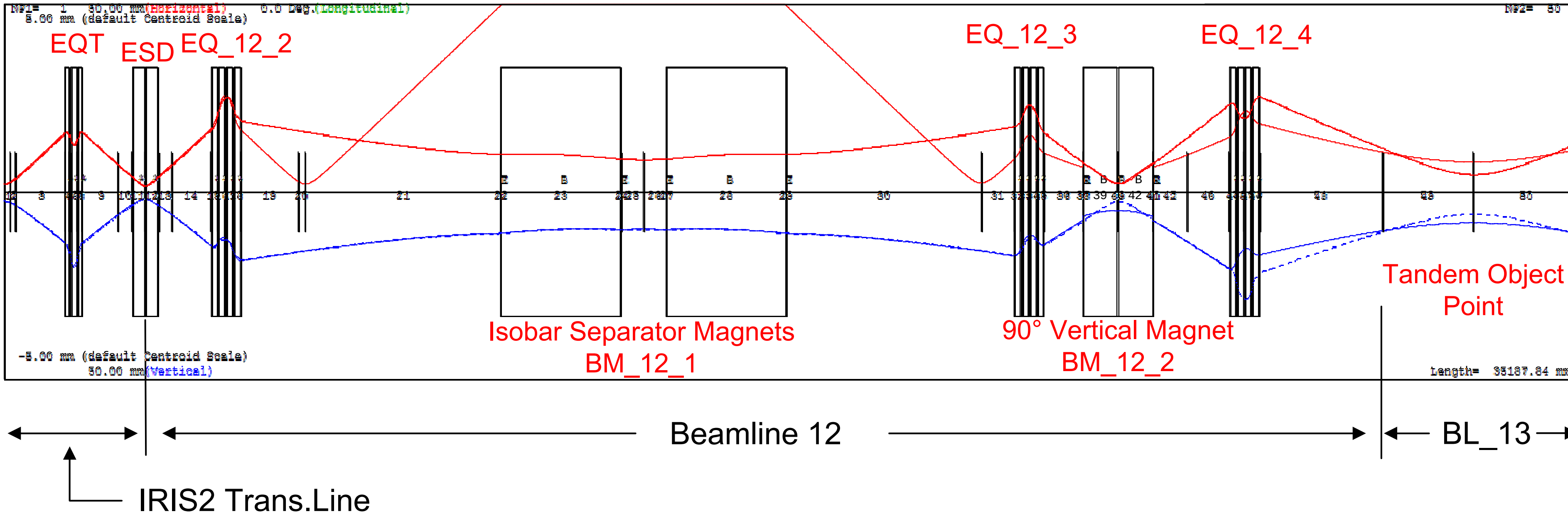
Alternate, non-dispersive tune



– Layout starts at last waist in previous calc. –

- To 1st order, transport of 40 keV beam to tandem should be possible w/ high transmission
- Optimal mass separation from BM_12_1 means either downstream charge exchange or floating the separator system at ≥ -160 kV. Either presents challenges. Cooling is also a possibility.
- One possibility to create room for downstream CEC is replacing BM_12_2 w/ much smaller radius ESD and replacing EQ_12_3 with much shorter commercial quad like those on the new line upstream

Technical Summary

- Layout proposed couples to IRIS2/BL_12 transport system
- Makes use of existing Isobar Separator
- Does not require HV platform for source (a la IRIS1&2)
  - Beam transport to tandem at 40 keV possible w/low loss
- Wien Filter & 90° Vertical Magnet provide activity filtering
- Open questions/further study
  - Location of charge exchange
  - Low-energy optics into tandem (try to avoid RFQ solution)
  - Use of beam cooling

Project Cost

- Dual-Rhodotron option (preferred): $35M (accelerator cost is ~$10M)
- Single-Rhodotron option: $24M (accelerator cost is ~$5M)

- Cost of other possible accelerators:
  - Turnkey Accel normal conducting 50MeV linac $5M ("much higher" cost for superconducting CW machine)
  - Kazimi (TJNAF) FEL-based linac estimated at $7M + cryogenics
  - SPIRAL II e-beam option linac $7.2M
  - Advanced Energy Systems (Alan Todd) turnkey FEL linac design not priced

Project Schedule

- Project duration from CD-0 through CD-4 is 5-6 years
- Presently, a proposal is being developed for DOE-NP
  - Cost and schedule being refined
  - Geotechnical study in progress
  - Target plug and handling systems (Diamond & SNS)
  - Shielding and building design (Beene, ORNL experts, A&E firm)
  - Particle beam optics studies (Mendez)