



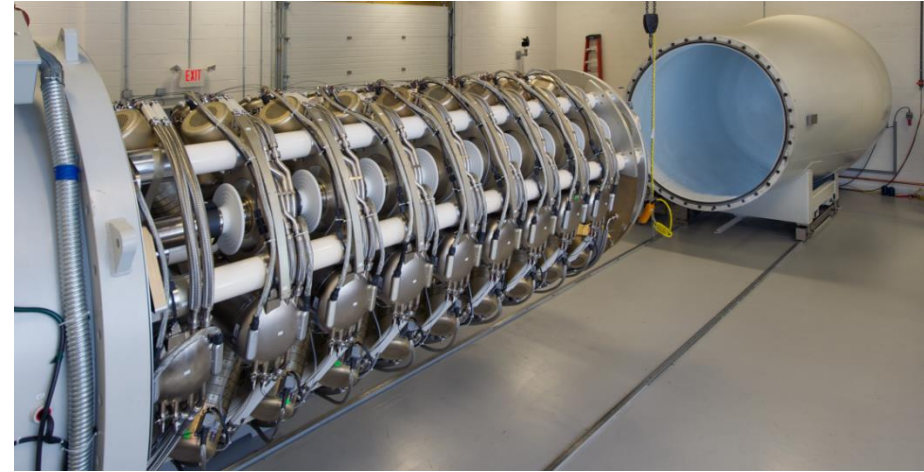
Hyperion™ Accelerator Technology for BNCT

Noah Smick

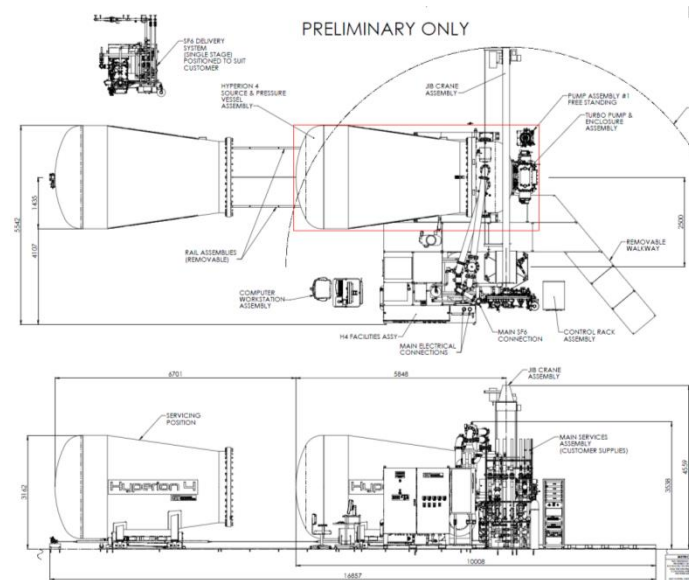
Accelerator-Based Neutron Production Workshop
Laboratori Nazionali di Legnaro, Padova, Italy
April 14, 2014

GTAT's Hyperion™ Accelerator Offering

- Design Specs (Demonstrated):
 - 2 MeV
 - 50mA H⁺
 - CW beam
- Easily extended to 2.5MeV
- Well-suited for Li(p,n) BNCT
- Designed for:
 - Manufacturability
 - Serviceability
 - Efficiency
 - Stable operation
 - Modular/configurable
 - Low maintenance
 - Cost similar to semiconductor implanters
- Ready for commercialization



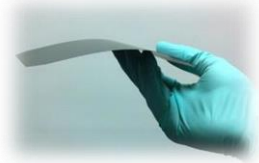
Hyperion 4: A single-ended electrostatic accelerator



Hyperion™ History / Milestones

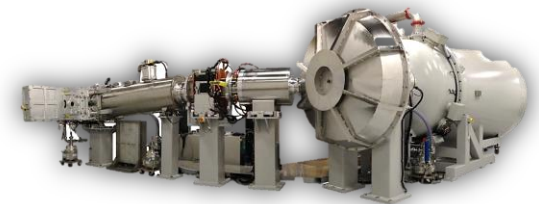
Hyperion History:

- 2008: Hyperion developed by Twin Creeks Technologies for exfoliation of silicon for solar cells
- 2011: Hyperion 3 operational at 1 MeV / 40 mA H⁺
- November, 2012: Twin Creeks assets acquired by GTAT
- 2013: Design extended to 2MeV exfoliation of sapphire for displays



Recent Milestones

- March 25, 2014: Hyperion 4 / 2MeV assembly complete
- March 29: 3mA H⁺ @ 2MeV
- April 2-3: Consecutive 7-hour days of 2mA/2MeV CW operation
- To Date:
 - 33 mA H⁺ @ 2 MeV
 - 50 mA H⁺ @ 1.87 MeV
 - 2.27 MeV terminal voltage



The GTAT Implant Group

- 20 People, Located at Danvers, MA
 - Ted Smick, VP Ion Beam Technology Division
 - General Ionex, US-AMS, IBIS, Orion, AMAT, Axcelis, Twin Creeks
 - Geoff Ryding PhD, Chief Scientist
 - Extrion (Varian), Nova (Eaton, Axcelis), IBIS, AMAT, Twin Creeks
 - Takao Sakase, Senior Scientist
 - Seiko Seki Instruments, General Ionex, Varian Semiconductor, Orion, AMAT, Axcelis, Twin Creeks
 - Paul Eide, Senior Systems Engineer, Electrical Engineer
 - Genus, Orion, AMAT, Axcelis, Twin Creeks
 - William Park, Mechanical Engineer
 - Cornell, Passport Systems, Twin Creeks
 - Noah Smick PhD, Senior Scientist
 - MIT PSFC, Twin Creeks
- Team has been largely intact through development efforts under several companies, for >25 years (IBIS, Orion, AMAT, Axcelis, Twin Creeks)
- Strong history of fast and effective commercialization of implant solutions

GT Advanced Technologies

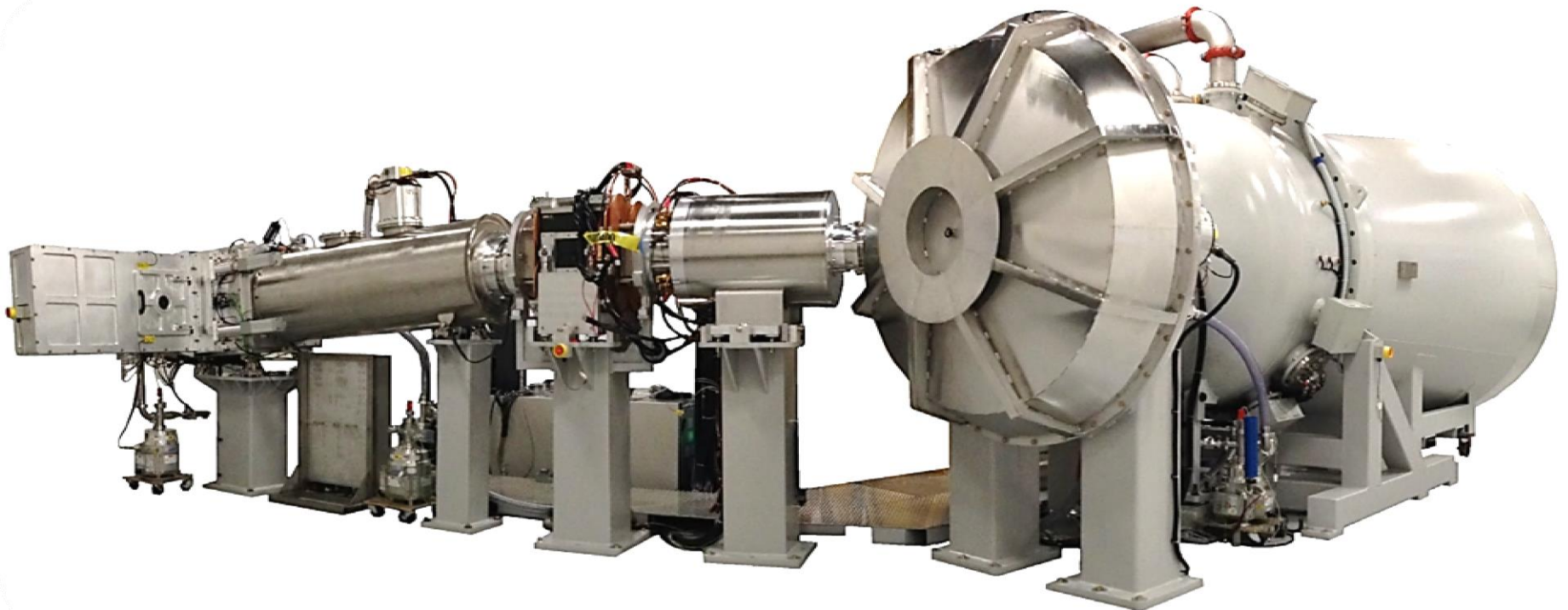


- Equipment supplier to a diverse set of markets, including:
 - Solar
 - LED
 - Power electronics
 - Consumer electronics
- Roots in crystal growth technology (Si, Sapphire, SiC...)
- Publicly owned company (NASDAQ: GTAT), <~1000 employees
- Headquartered in Merrimack, NH, USA
- GTAT is committed to diversification & innovation
 - ~\$77M invested in R&D during 2013 (26% of 2013 revenue)
 - Branched out of solar in the past 10 years through a series of strategic acquisitions, including Hyperion

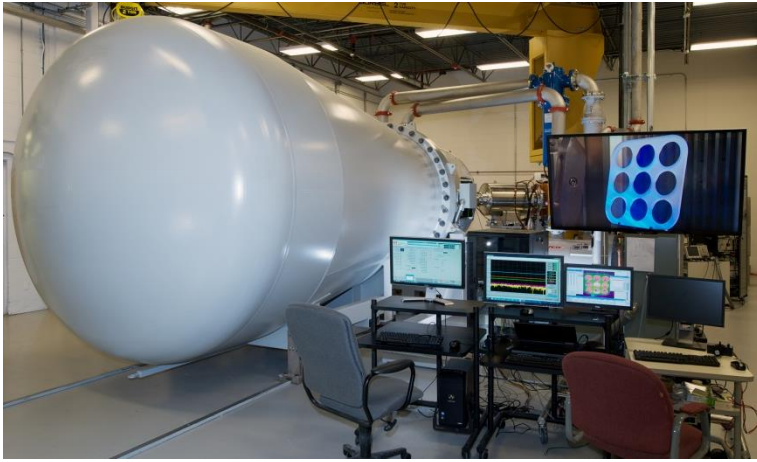


Hyperion™ 4

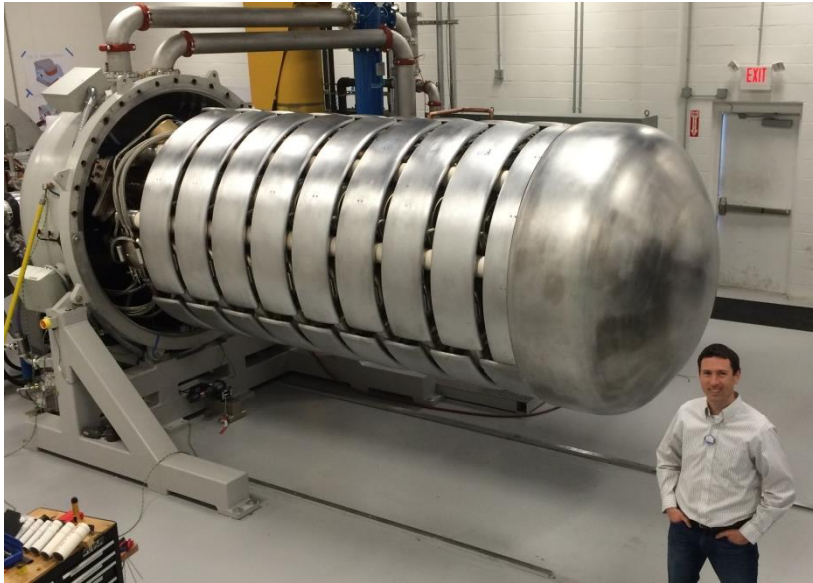
- Single-Ended Electrostatic Accelerator designed for 2 MeV
- HV power supply architecture for stable operation at 50mA
- Flexible beam-line with novel 2D magnetic scanning
- End-station for materials exfoliation process development



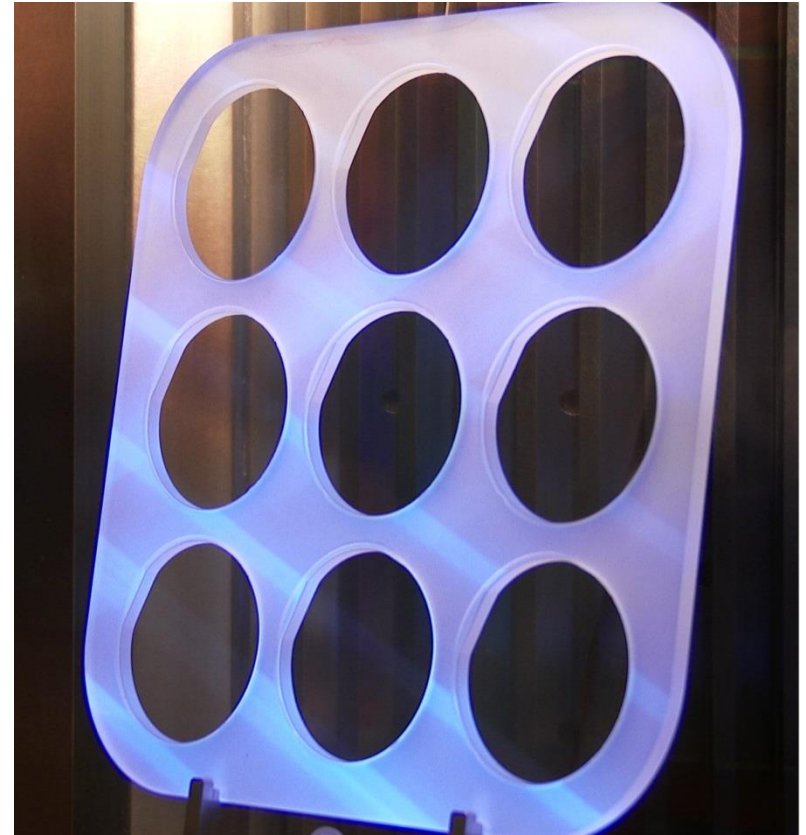
Hyperion™ 4: Pictures of Tool and Sapphire Targets



Accelerator pressure vessel

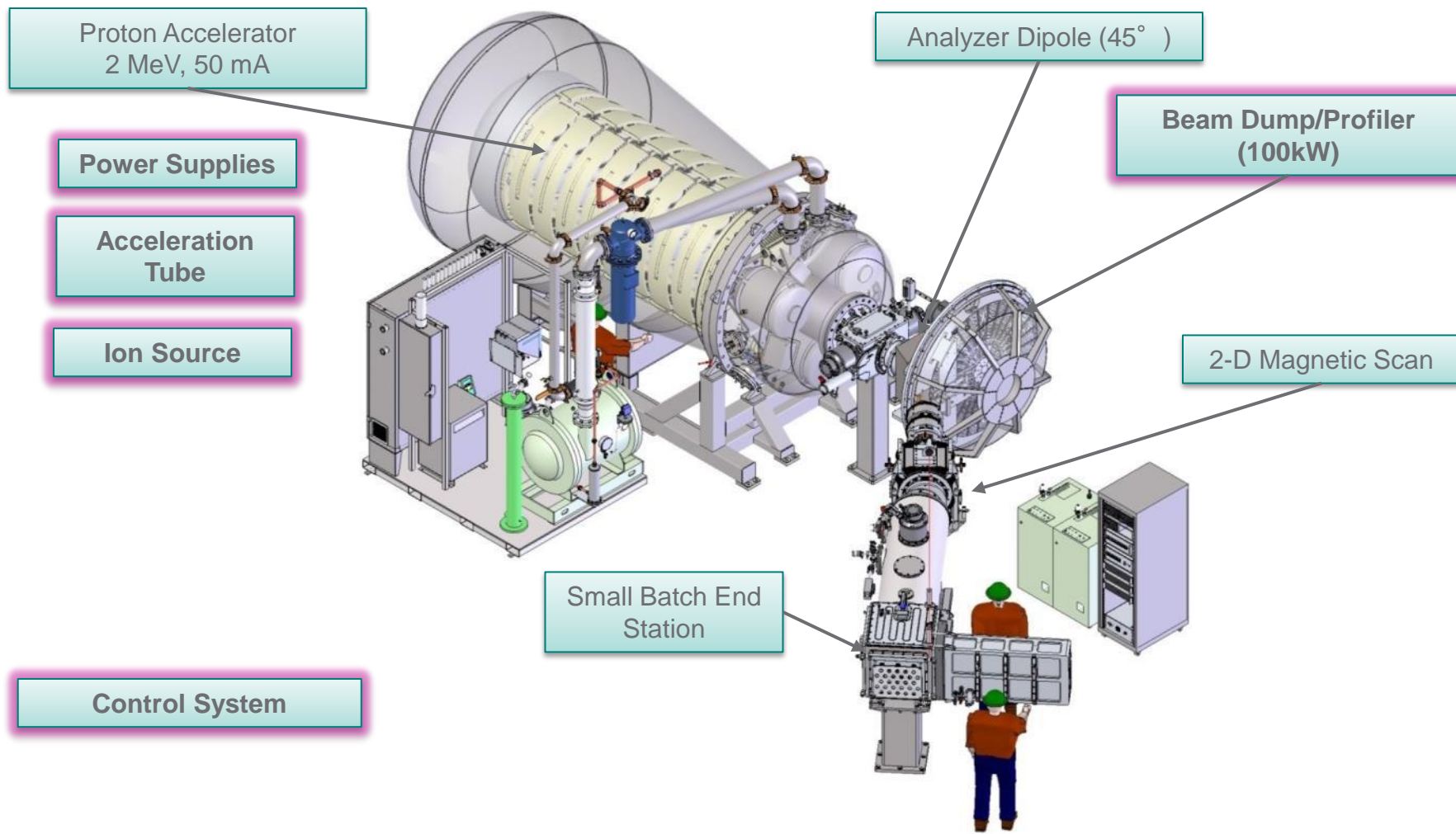


Accelerator with pressure vessel removed

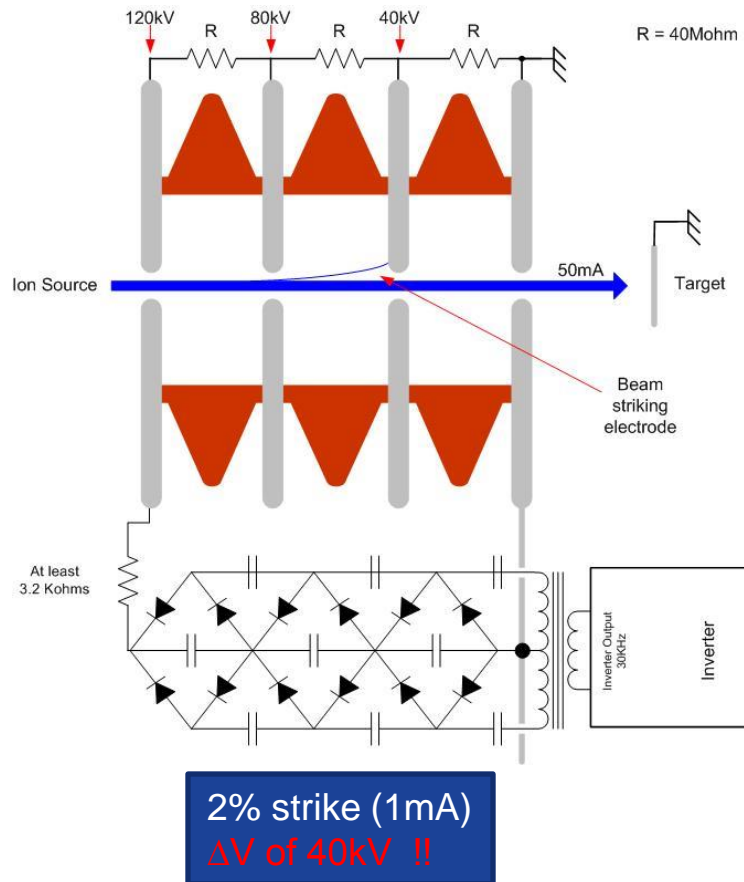


Targets under proton exposure

Hyperion™ Key Components



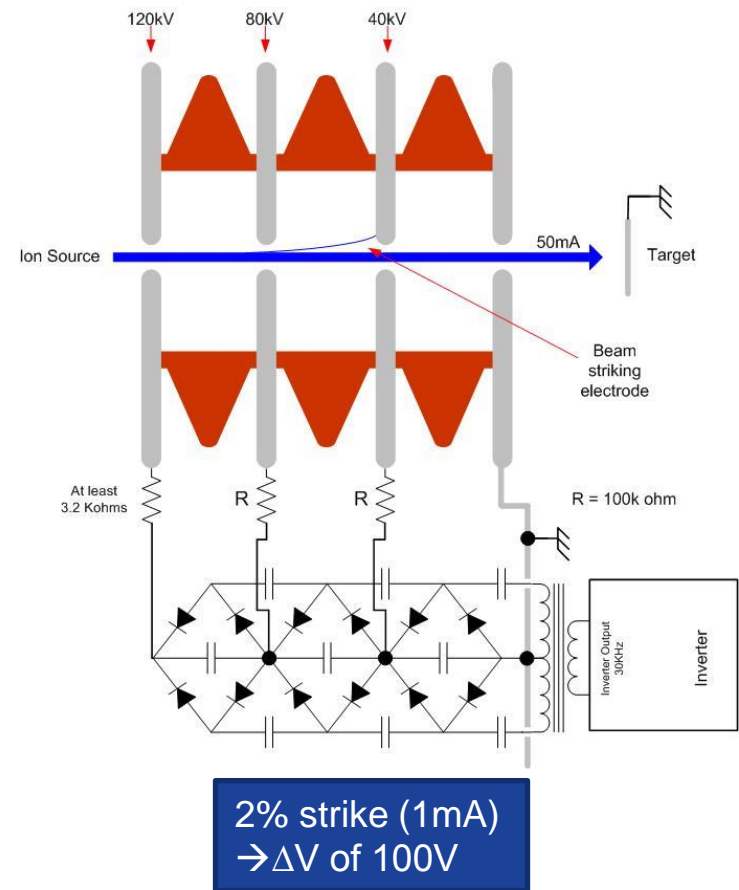
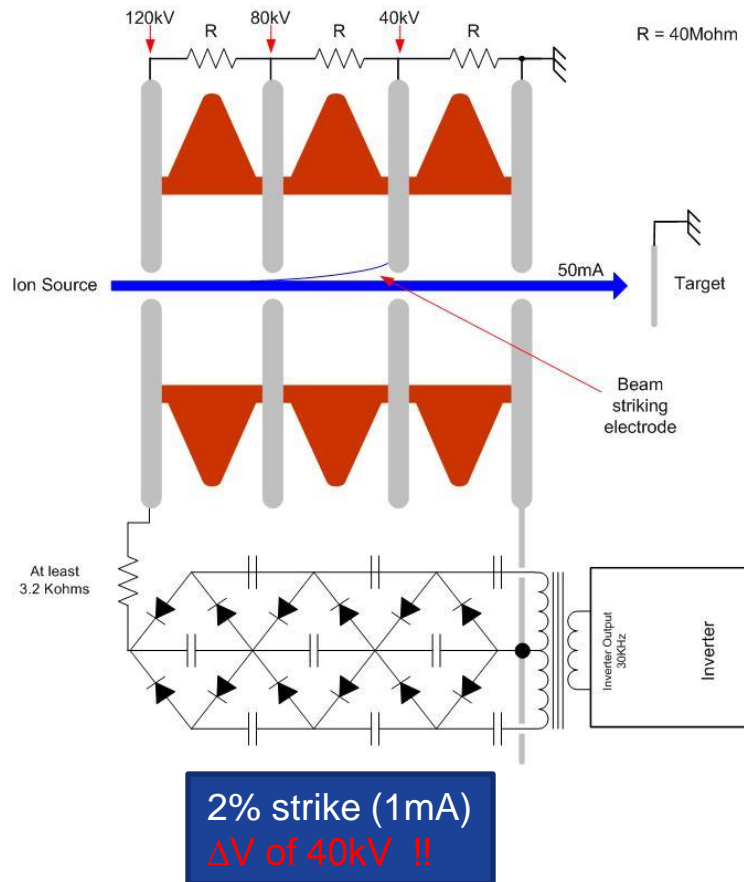
A New Power Supply Concept



High current beams:

- Expand under space charge
- Can significantly perturb resistively graded column electrode voltages with modest beam strike
- Require large drain currents

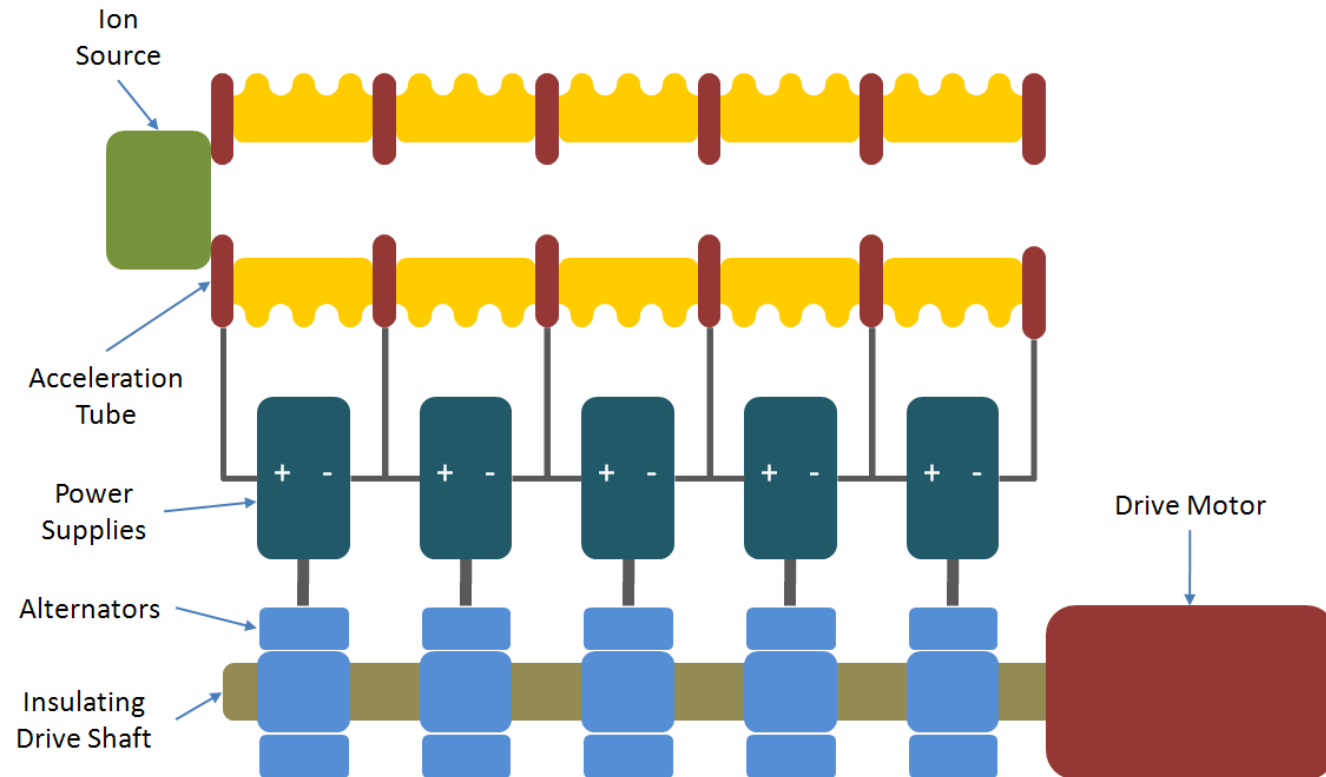
A New Power Supply Concept



Directly Driven Electrodes improve

- Stability
- Efficiency

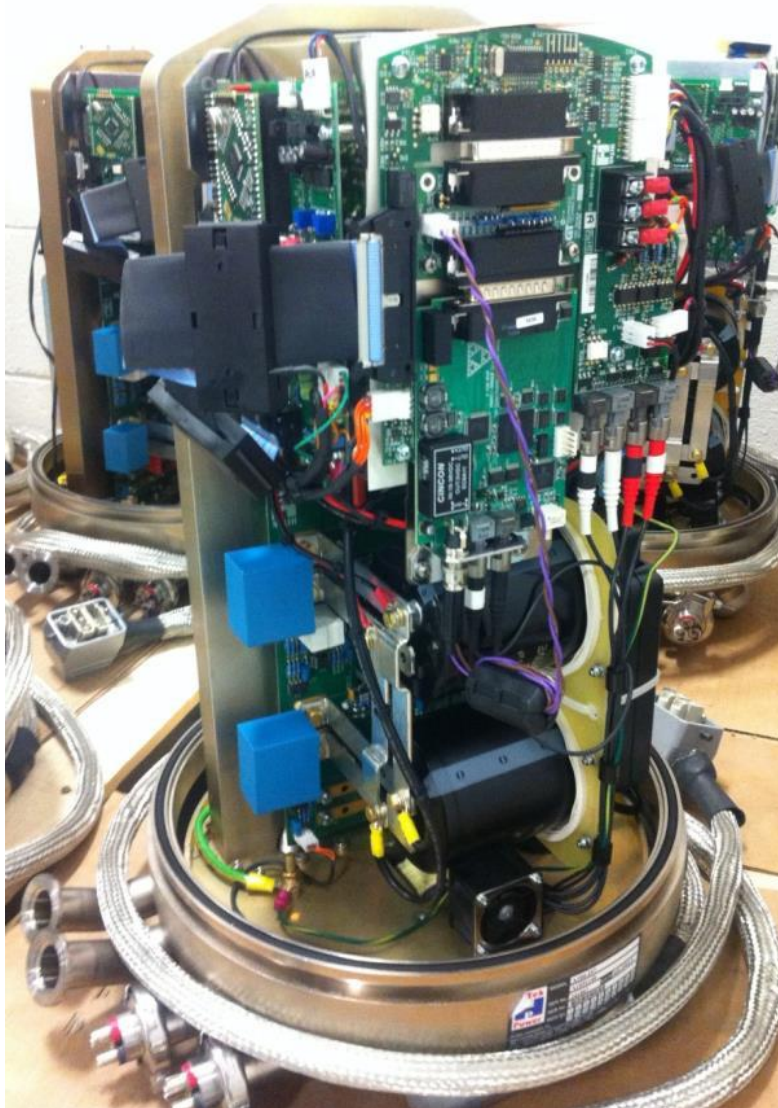
Hyperion™: A novel HV Power Supply Concept



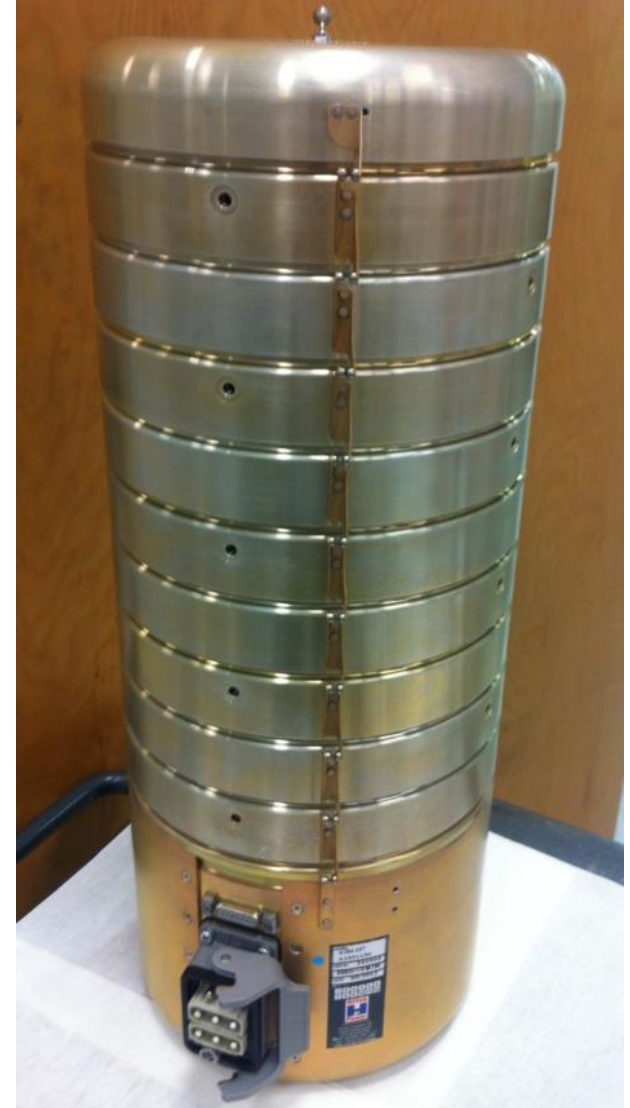
Design Benefits

- Efficiency (Wall to Beam ~70%)
- Stability
- Redundancy / Serviceability
- Off-the-shelf, IGBT-based HV power supply technology
- Low Energy Spread (<0.1%)

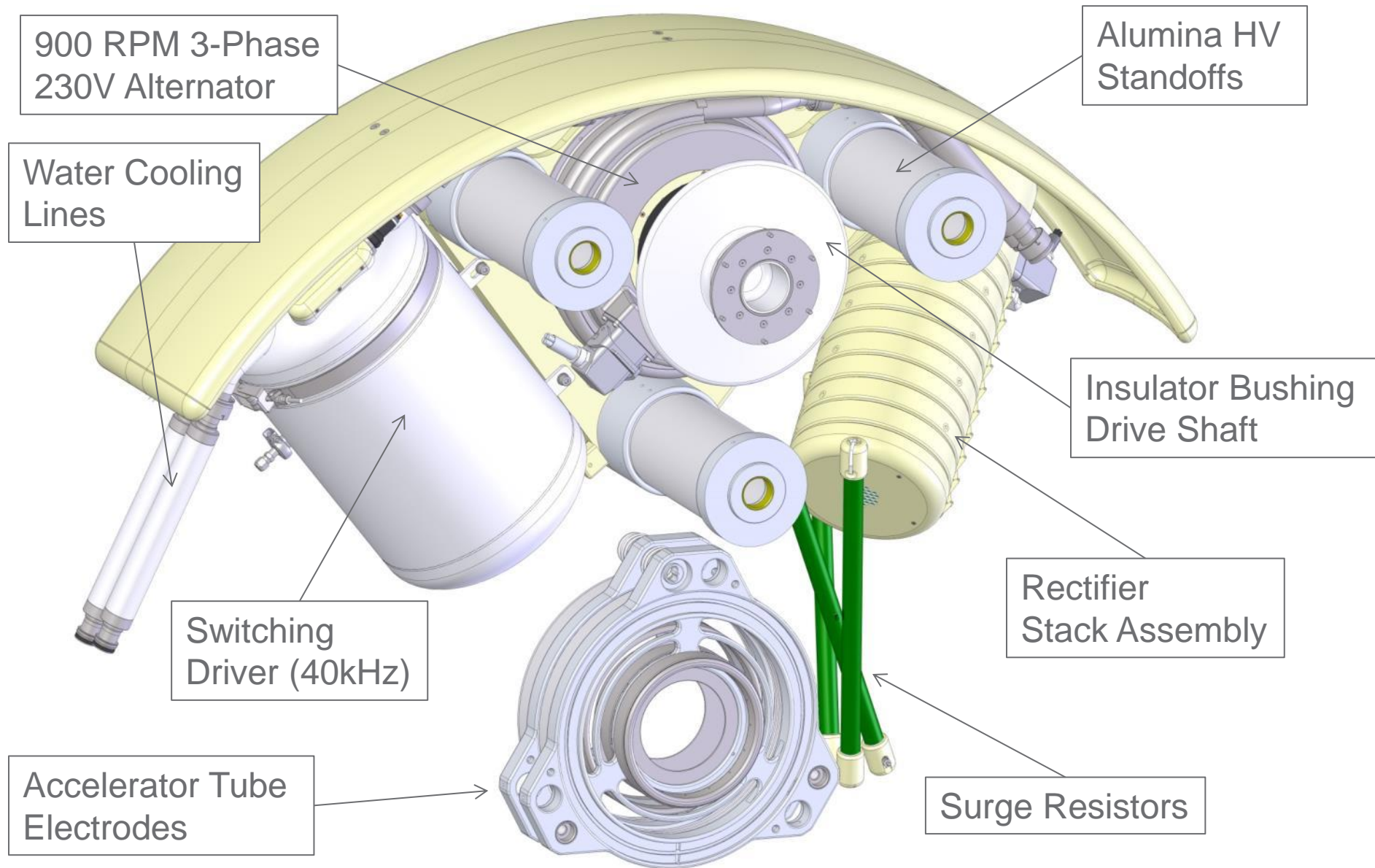
Repackaged Commercial HV Power Supply



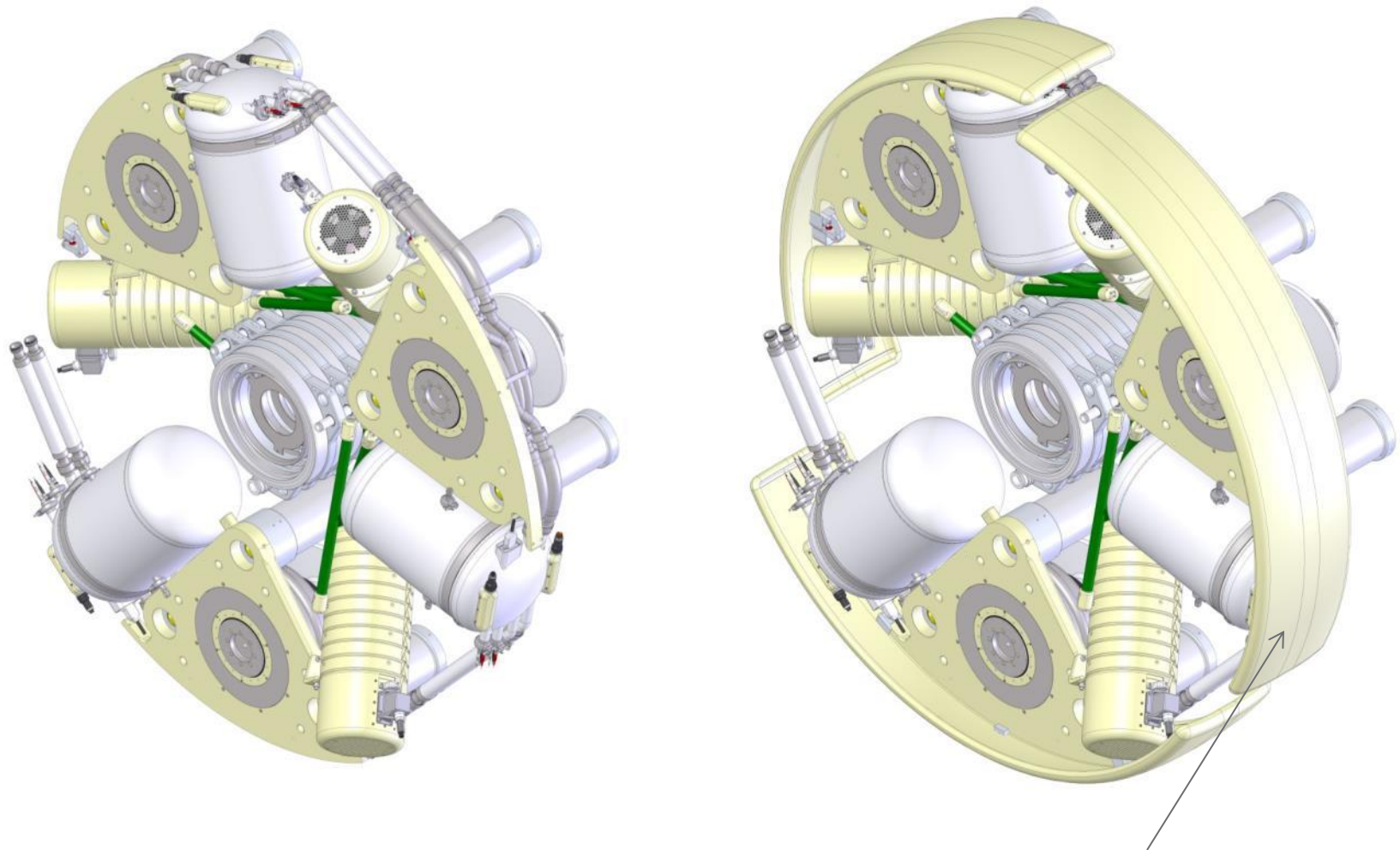
HiTek
H
P
Power



Rotary Motion to High-Voltage Output Module

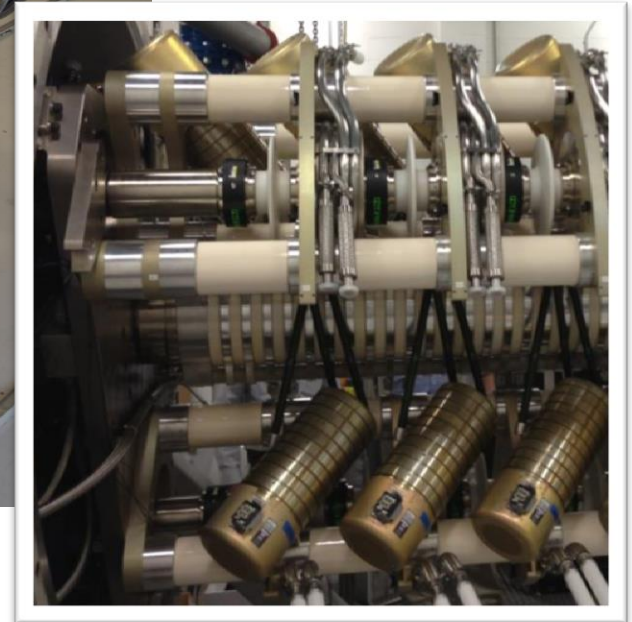
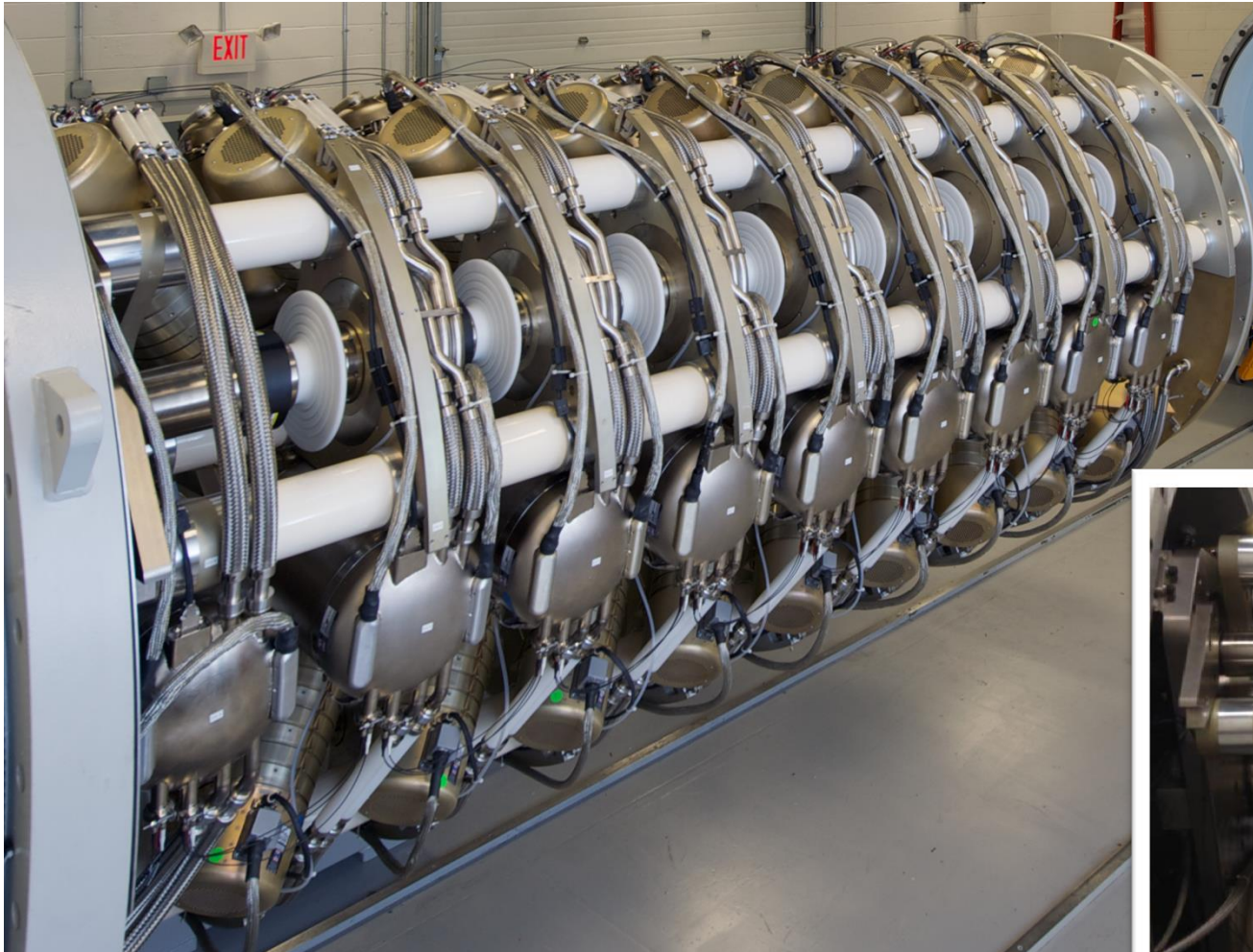


3 HV Modules / Deck

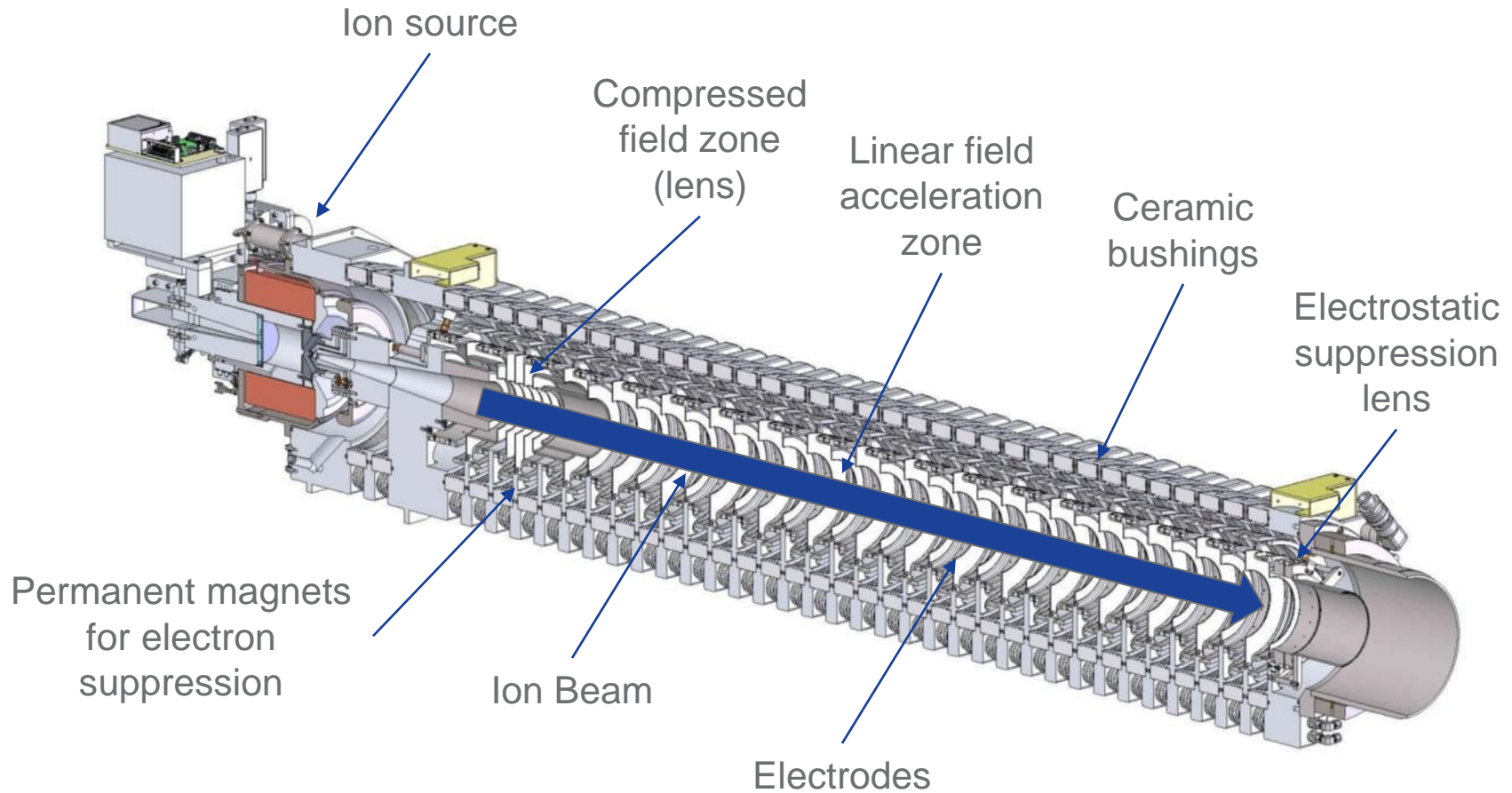


- Deck shown without / with field-smoothing shells

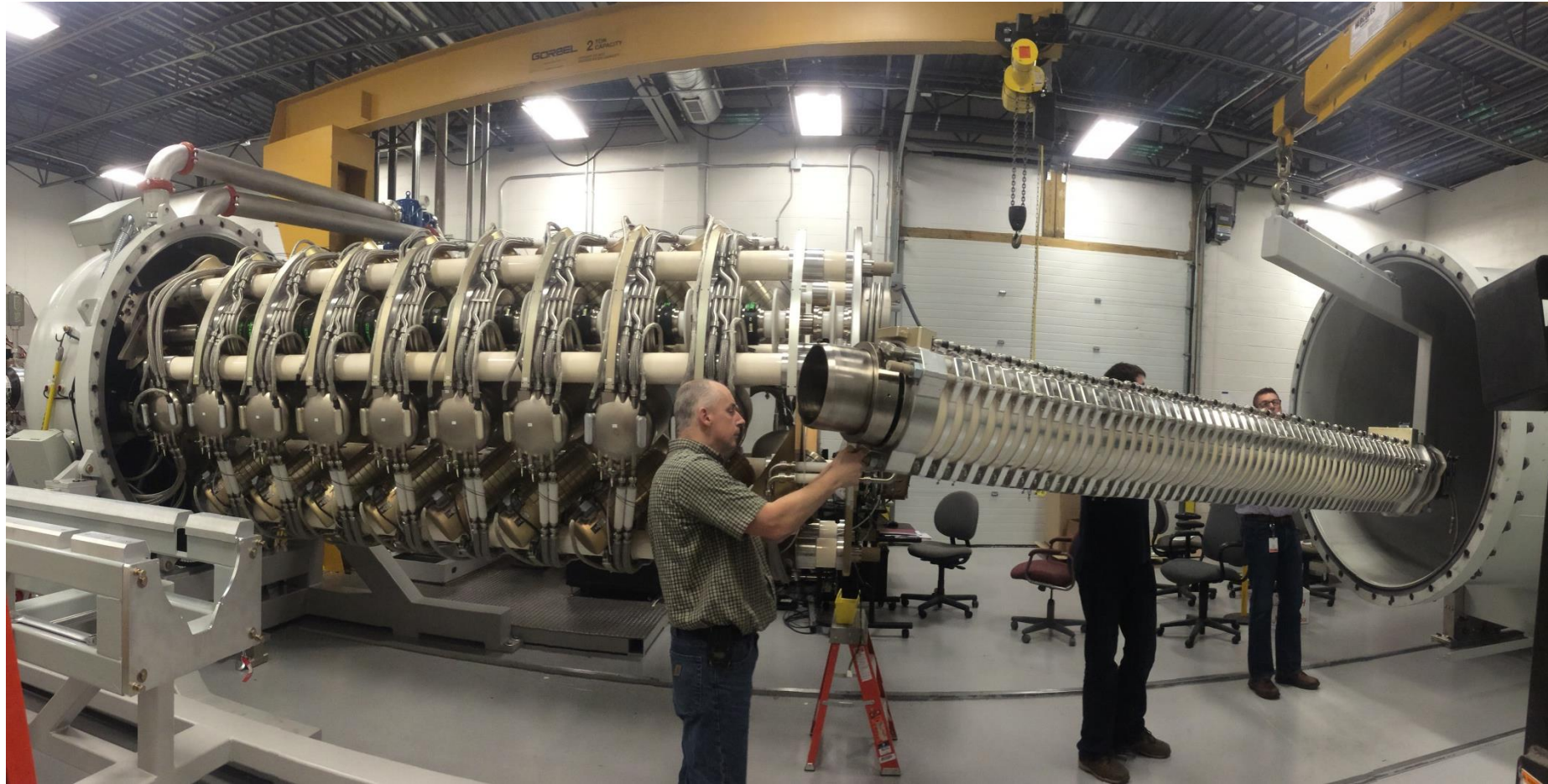
Hyperion™ 4 Acceleration System



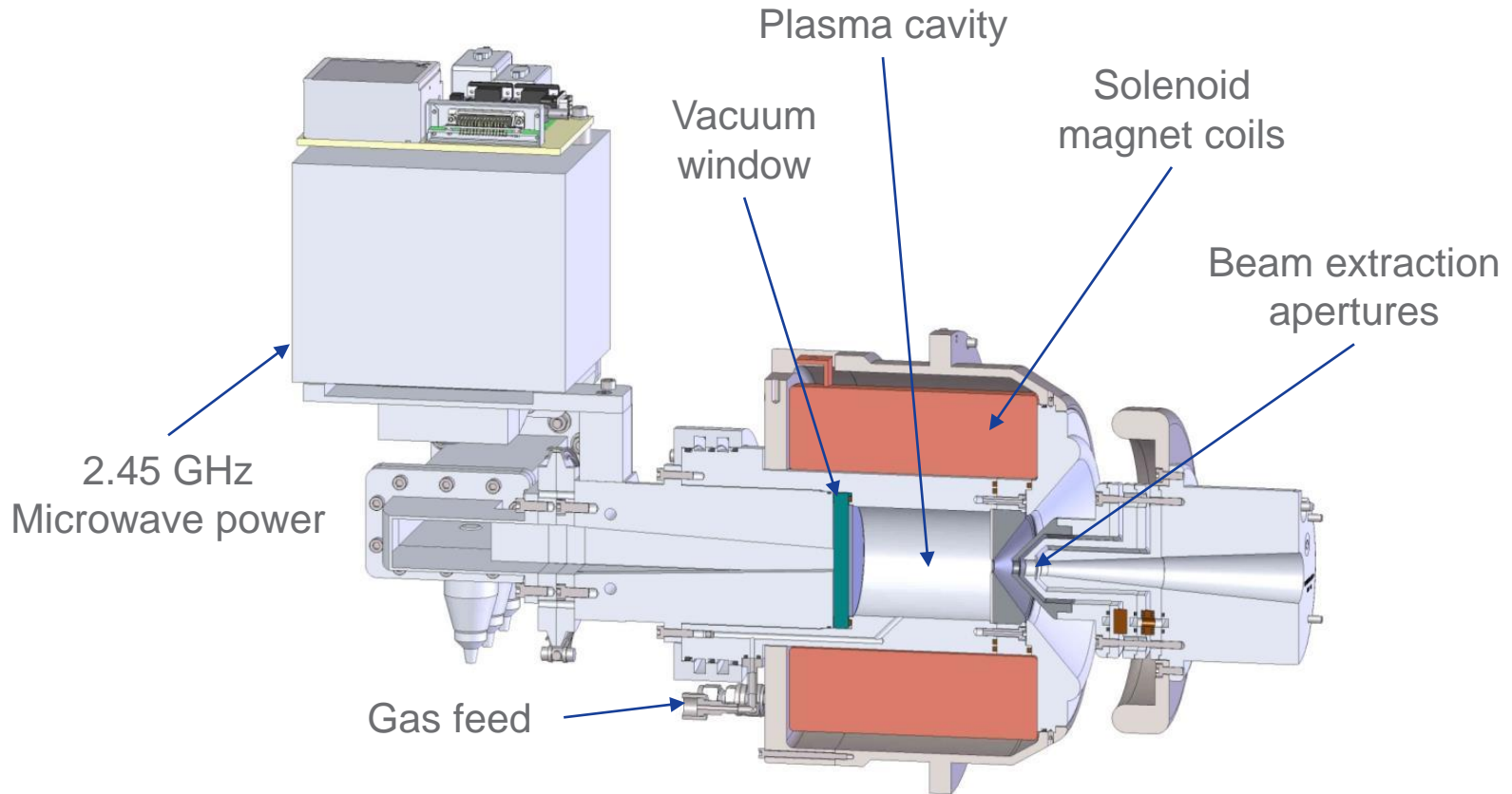
Hyperion™ Acceleration Tube



Hyperion™ 4 Accel Tube Installation



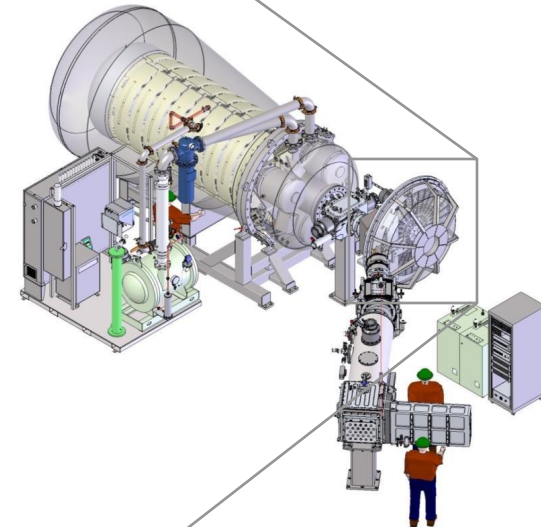
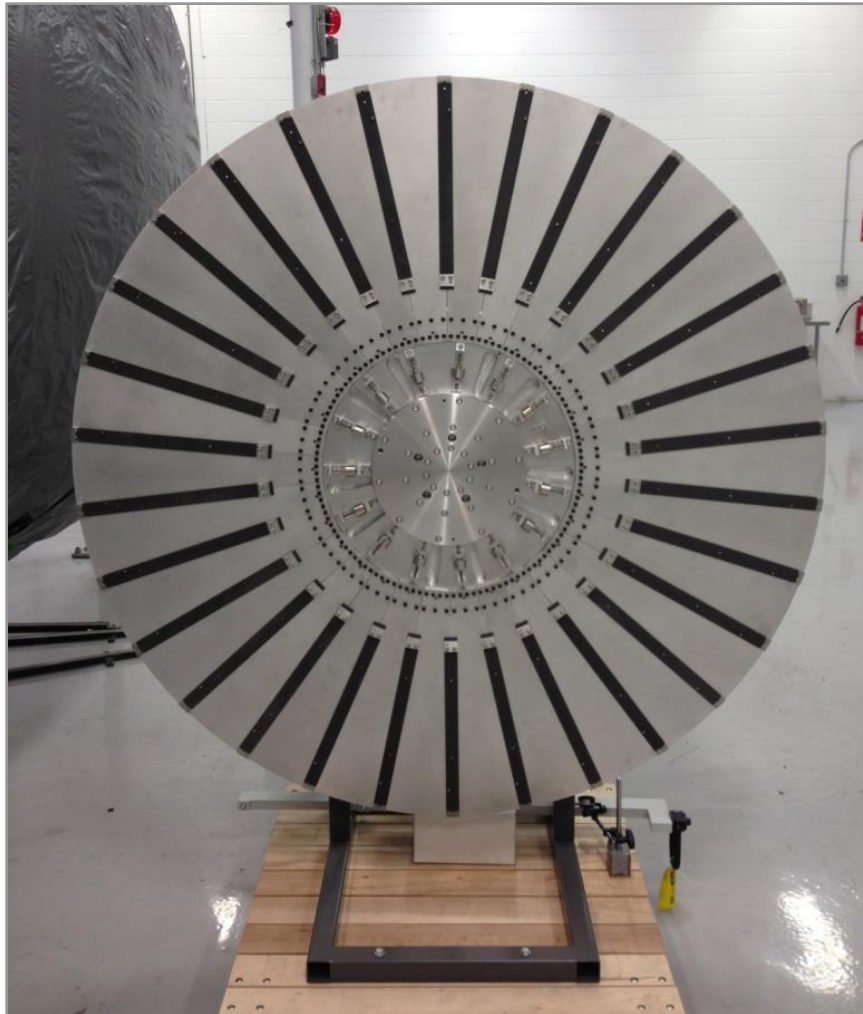
Hyperion™ Microwave Ion Source Architecture



Chalk River, Los Alamos, NTT and Ibis origins

- Capable of >100 mA extracted current
- >90% extracted H⁺ fraction
- High reliability, low maintenance

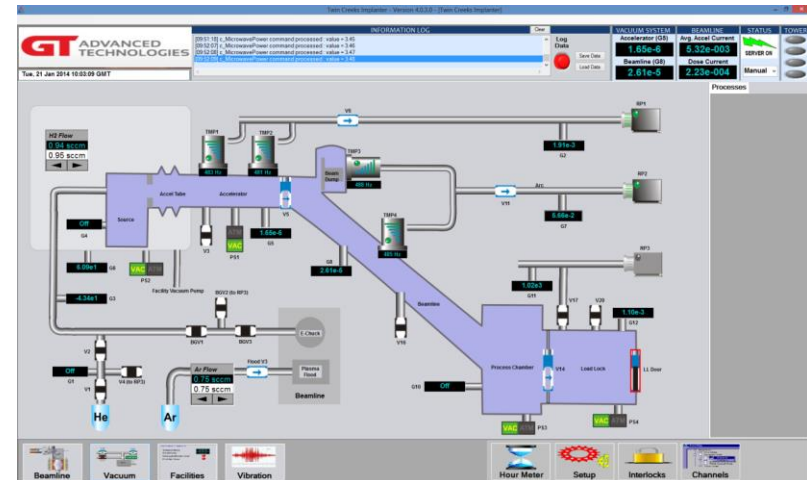
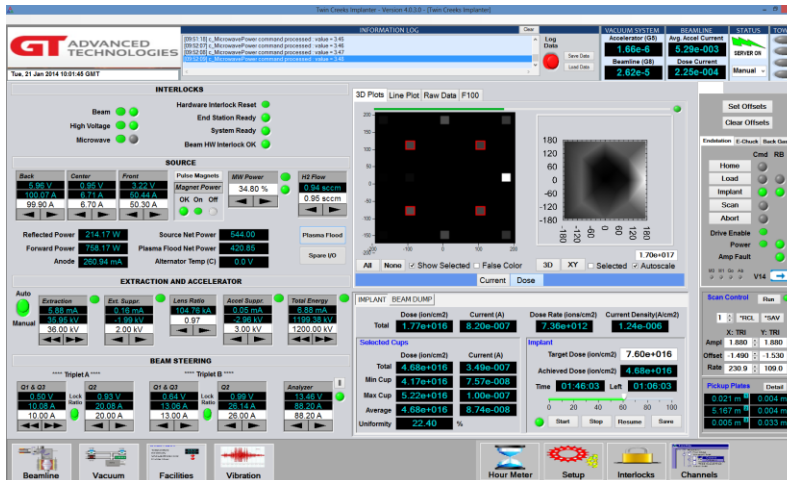
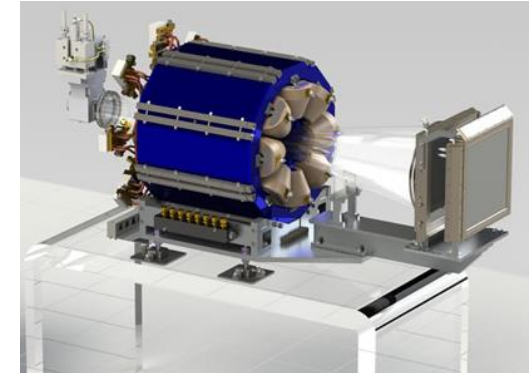
Hyperion™ 4: Beam Dump/Profiler



- Dissipates up to 100kW of beam power
- Provides 2-D beam profile measurements

Hyperion™ Control System

- Hyperion is controlled via a user-friendly GUI
- Each power supply is individually controlled and monitored via fiber optic connections
- Software support is provided by Pyramid Technical Consultants
 - Strong track record of implementing control systems for proton therapy: direct write & real-time monitoring systems



Conclusion

- The Hyperion™ accelerator is simple and reliable means of producing BNCT-relevant proton beams
- GTAT is well positioned to manufacture, deliver and support Hyperion accelerators
- GTAT can offer many of the required collaterals, including beam-line optics, beam-dump & beam-profiling components
- Hyperion is available for immediate deployment