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Proton Improvement Plan (PIP)

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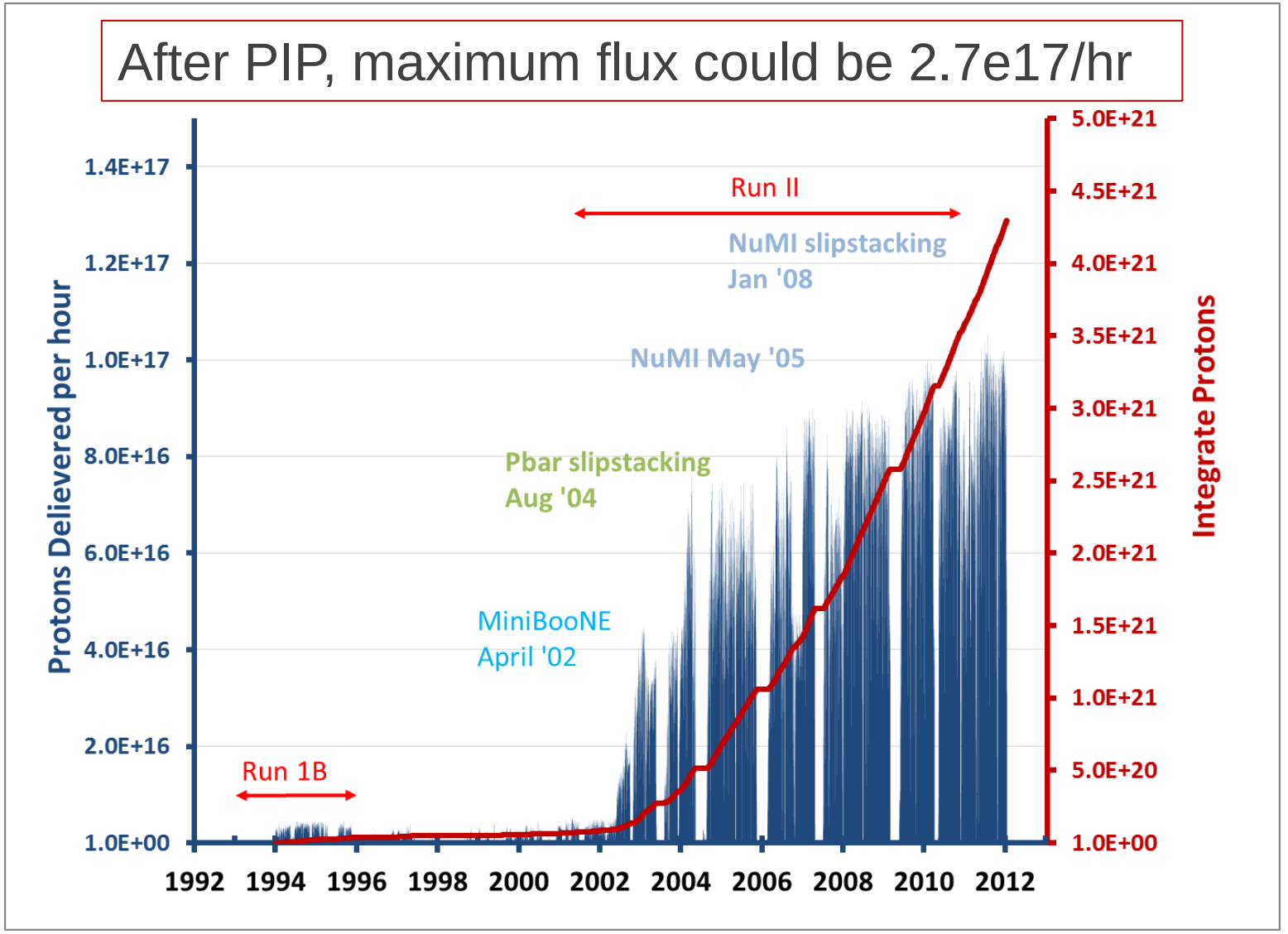
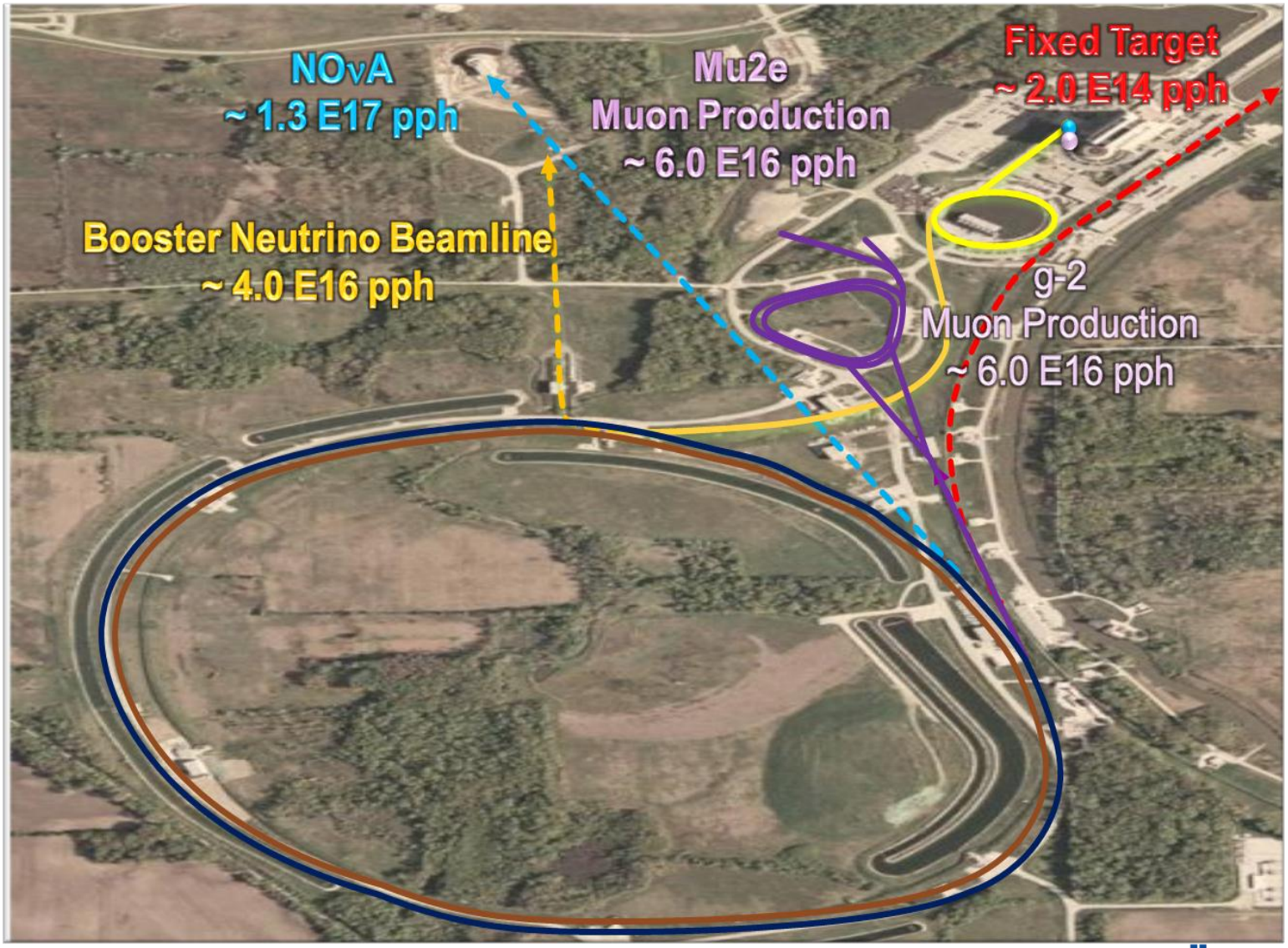
Proton Source Department, Accelerator Division

9th International Workshop on Neutrino Beams and Instrumentation
23 September 2014

Historical Beam Throughput of Proton Source Before PIP

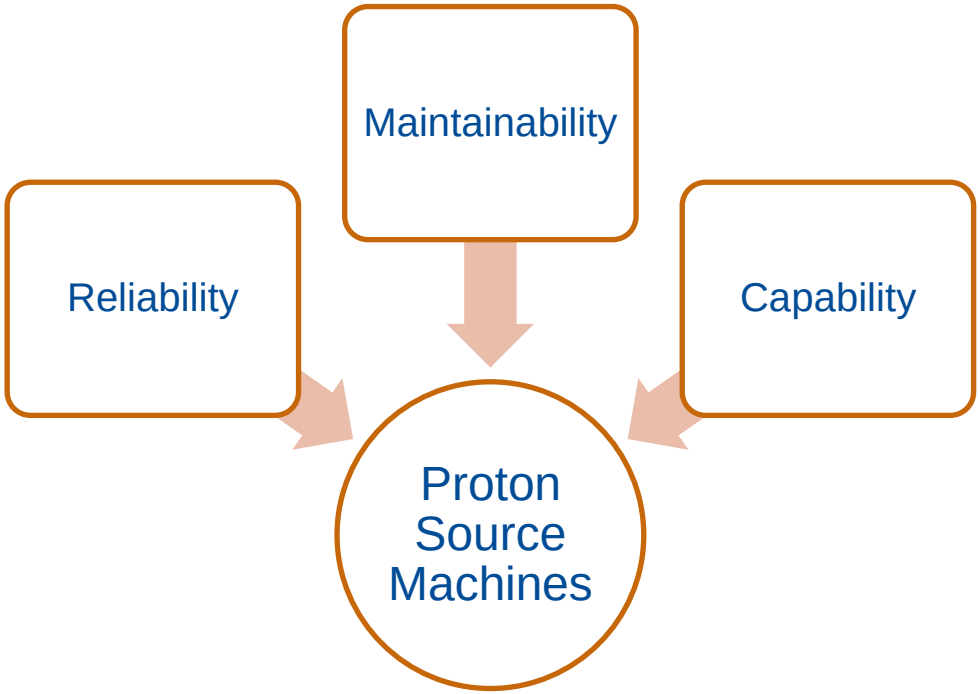


Known PIP Customers

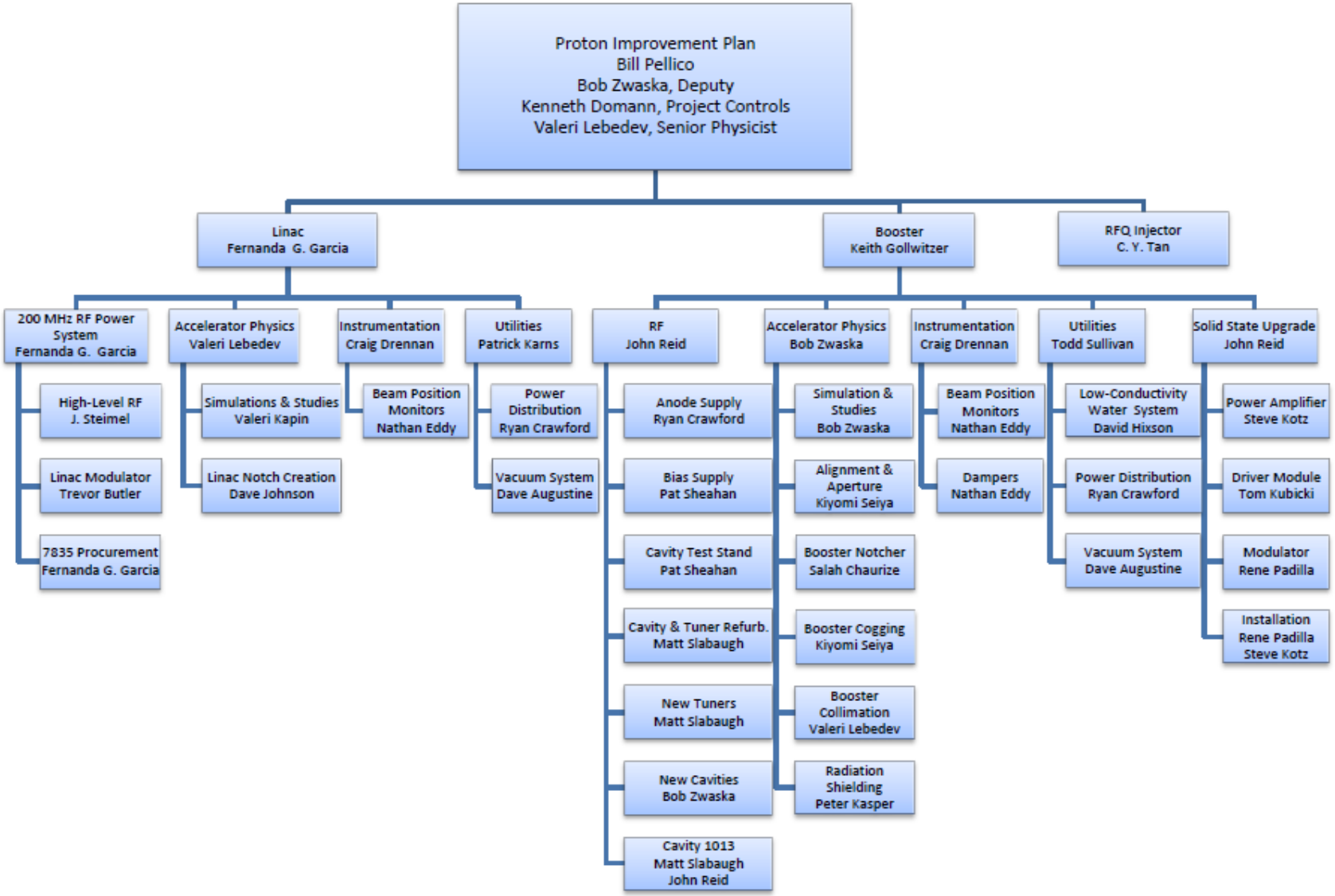


Proton Improvement Plan

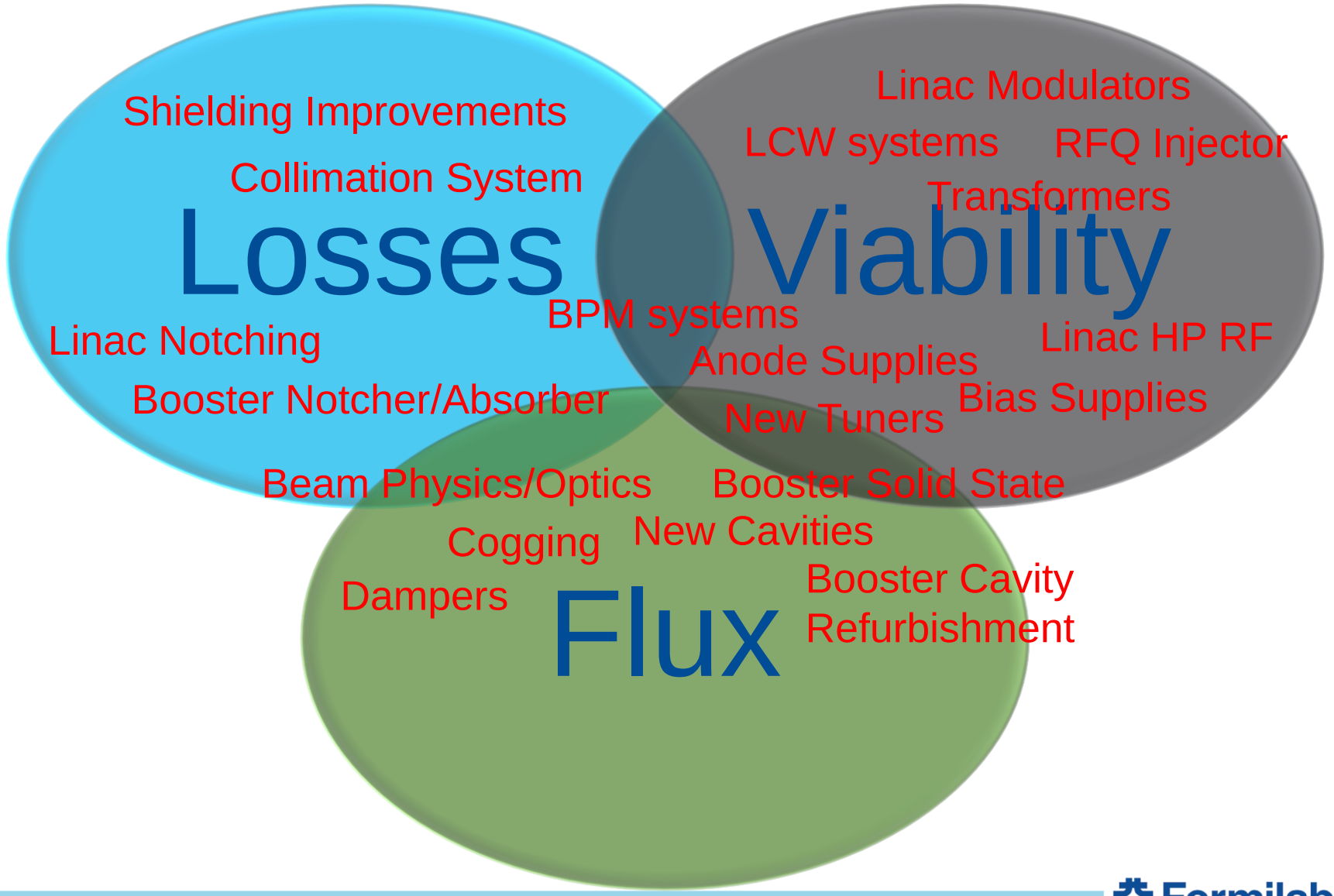
- Proton Improvement Plan (PIP) initiated in 2012 with the goal to update and improve the proton source machines to support the laboratory programmatic goals until middle 2020's



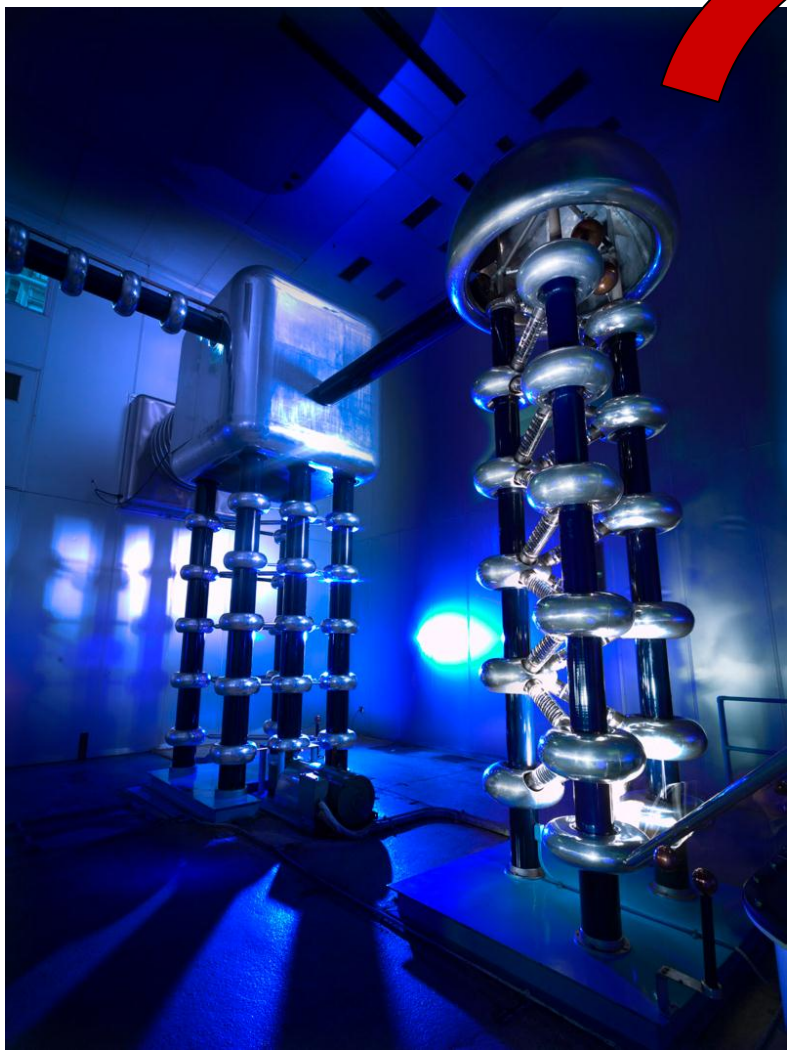
PIP consists of 31 tasks

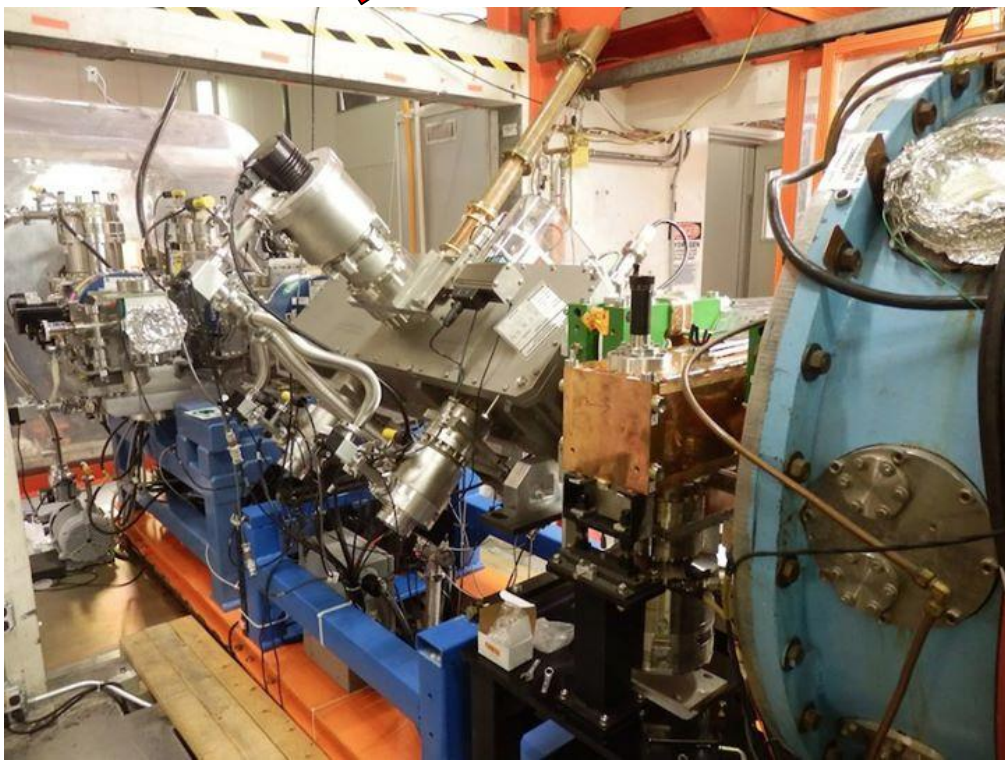


Path to Higher Proton Throughput and Reliability



Example of Modernization (Viability)





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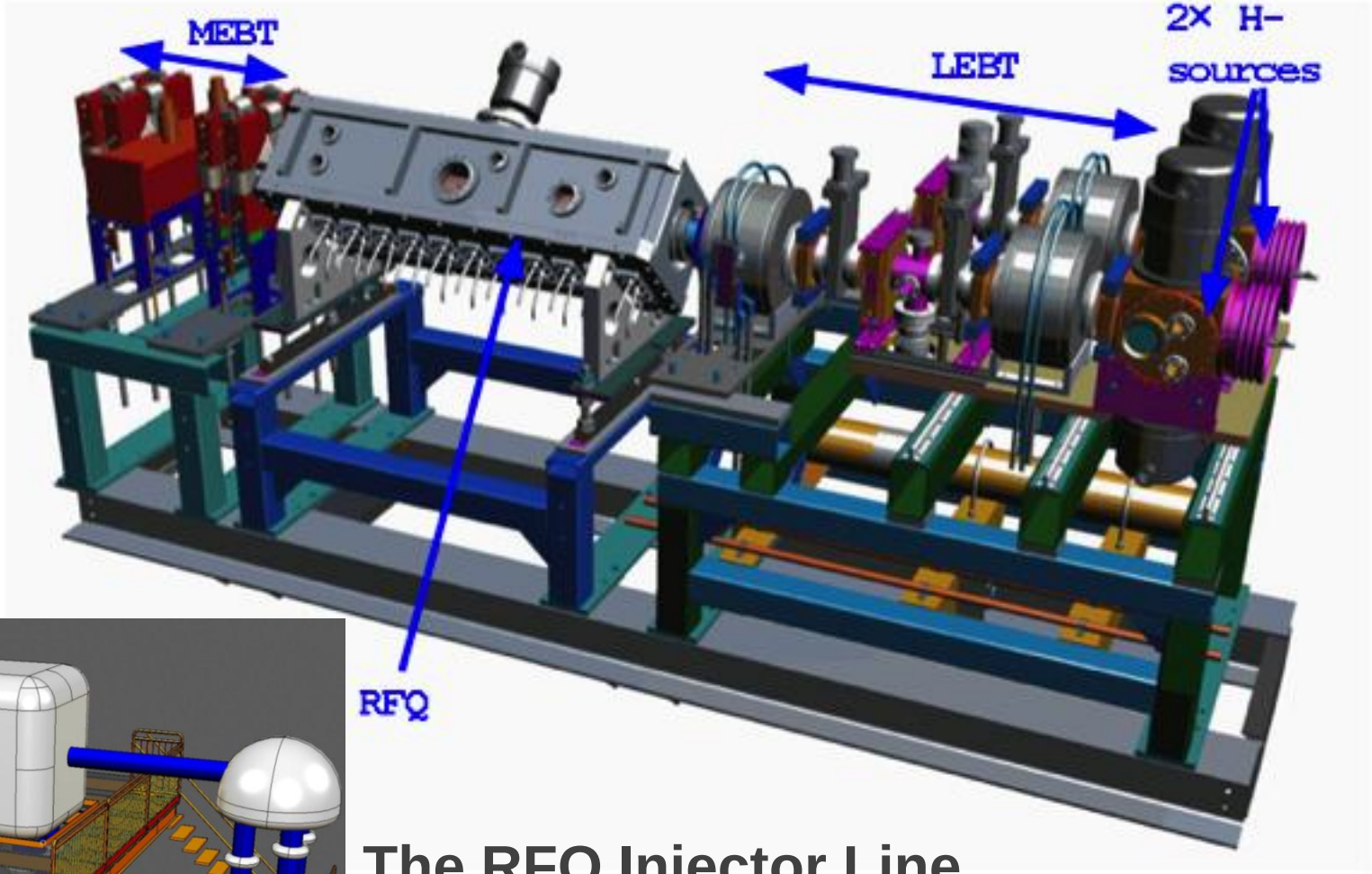

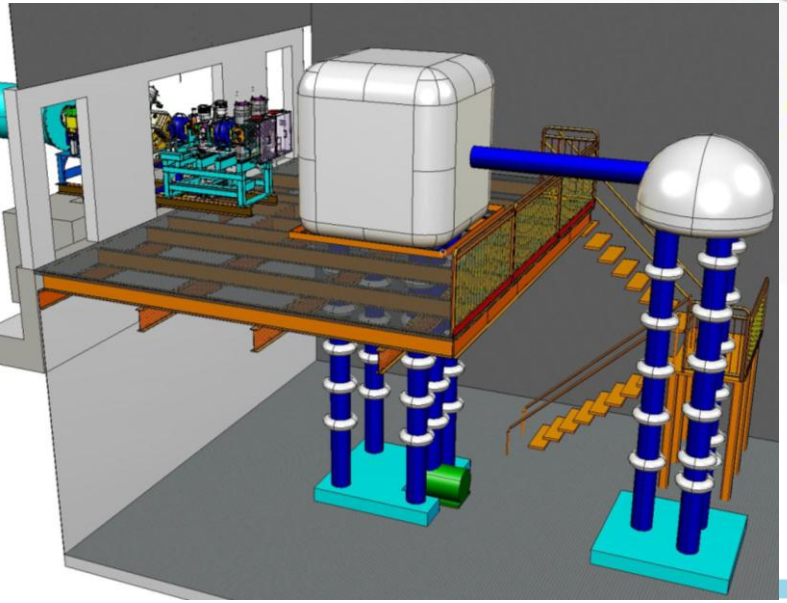

The RFQ Injector Line

Operation for more than a year

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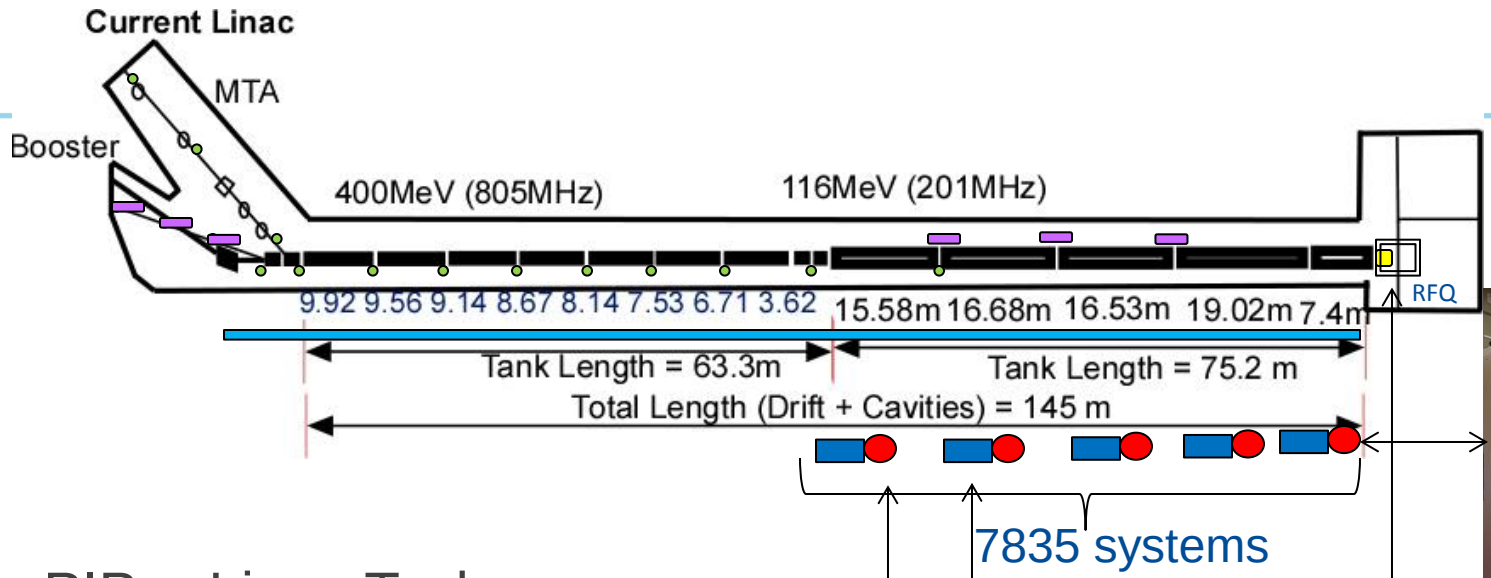
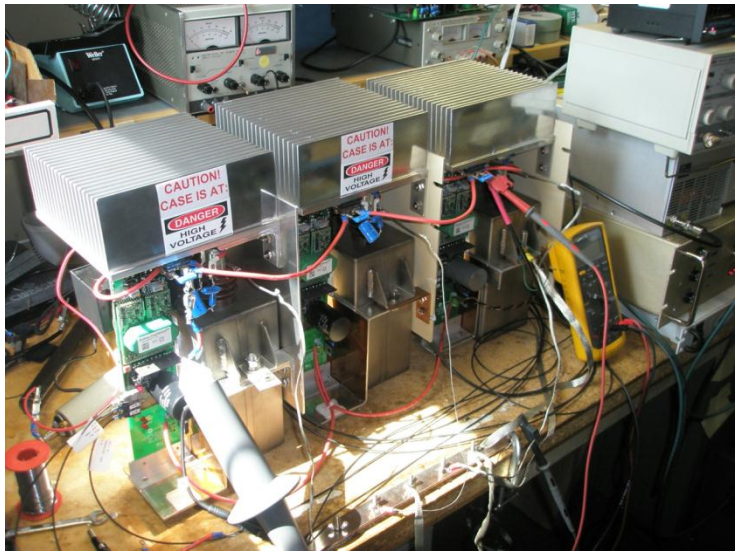


Modulator & 7835 Socket

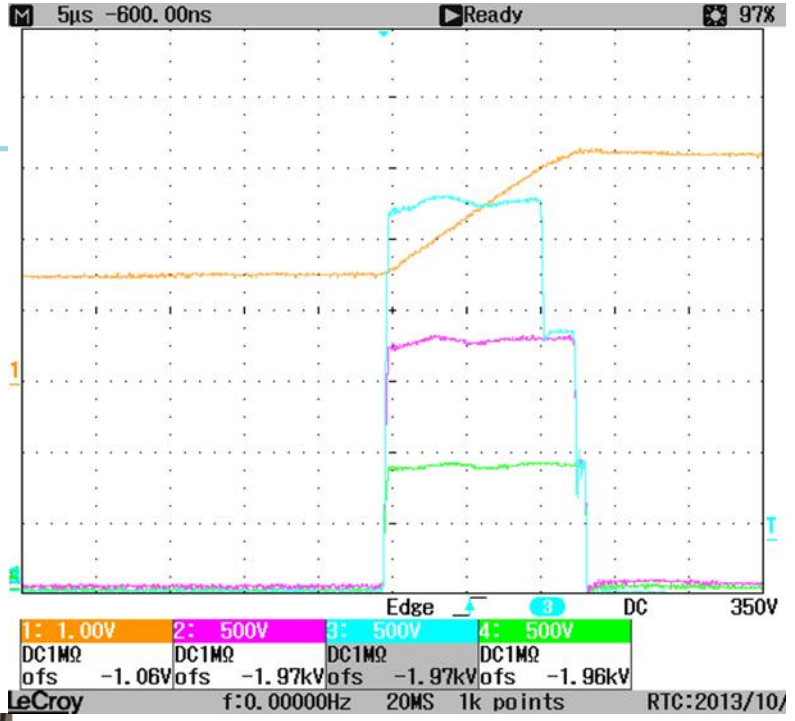
- PIP -- Linac Tasks
  - 200 MHz PS Prototype
  - 200 MHz PS Modulator
  - 7835 Tube Acquisitions
  - Laser Notching
  - Water Systems
  - Vacuum Systems
  - BPM System
  - Accelerator Physics

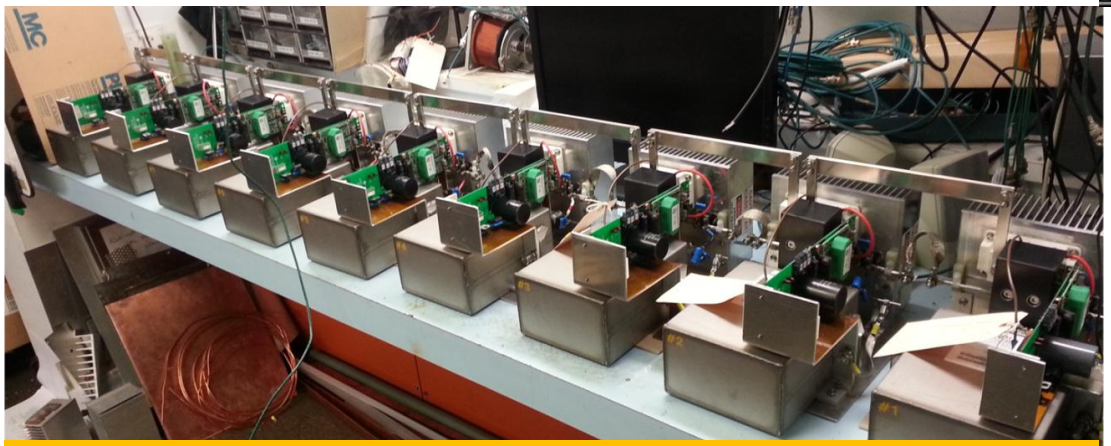
Low Energy Linac

Upgrade Linac Modulators



3-cell simultaneous turn-on at 300 amps.





9-CELL DEMONSTRATION

- 3-cell testing complete
- 9-cell testing complete
- Construction of 25-cell is underway
- Final design will be 40-cell

Replacement of Infrastructure

Roughing Station

Isolation Valve

Accessible Filtering

40+ year old items in both Linac & Booster replaced

Isolation Valve

New LCW Return System

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Electrical Transformers

Linac basement space cleared Sep 2014

Roof hatch required to lower new Linac transformer to basement

Two transformers for Booster installation within the next few weeks

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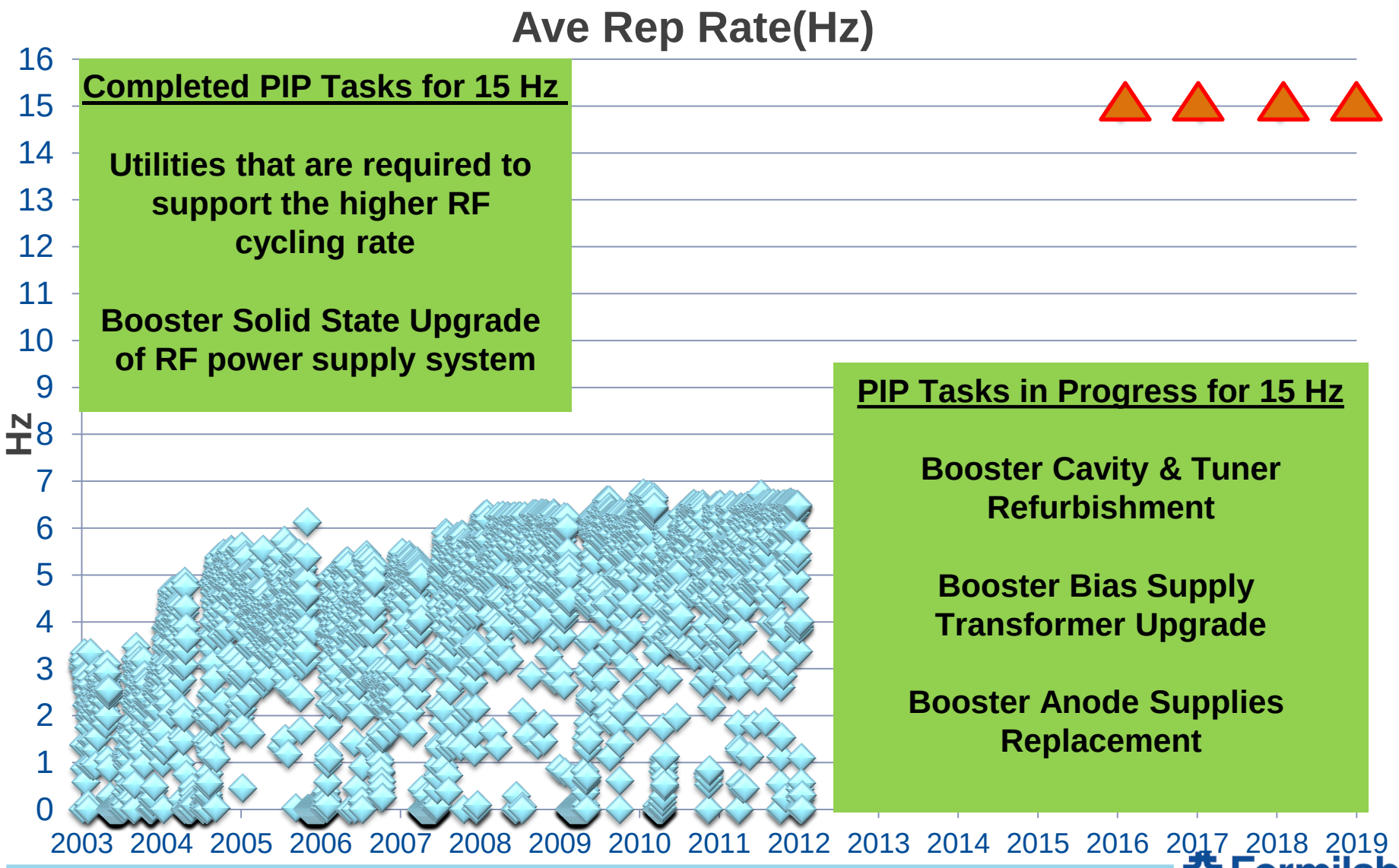
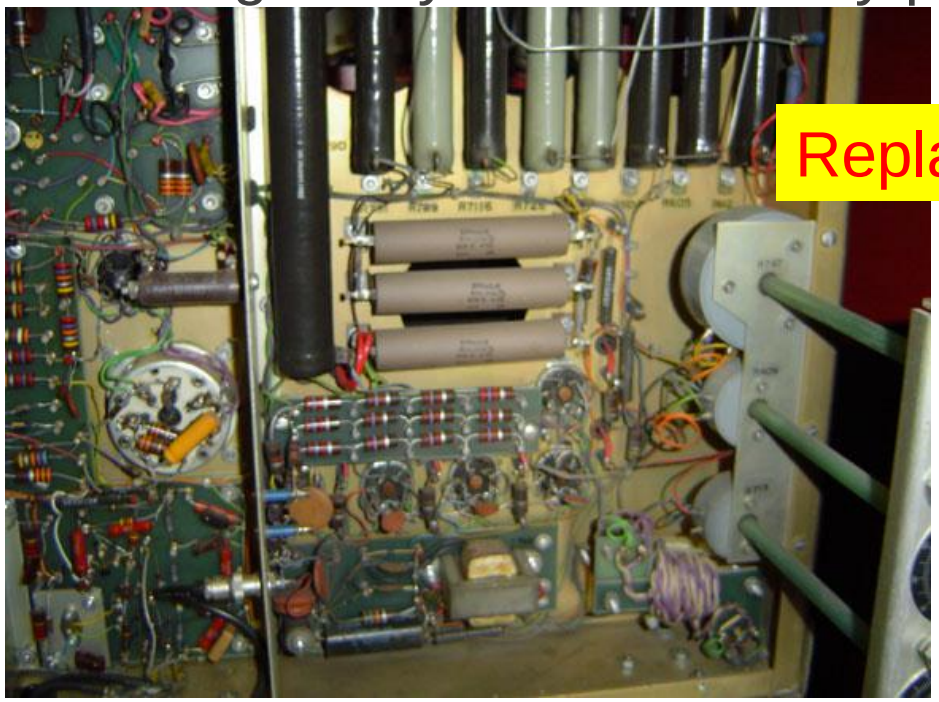
Booster RF Cycle Rate Previous to PIP & Desired



Booster RF Power System

- Original system had many power tubes

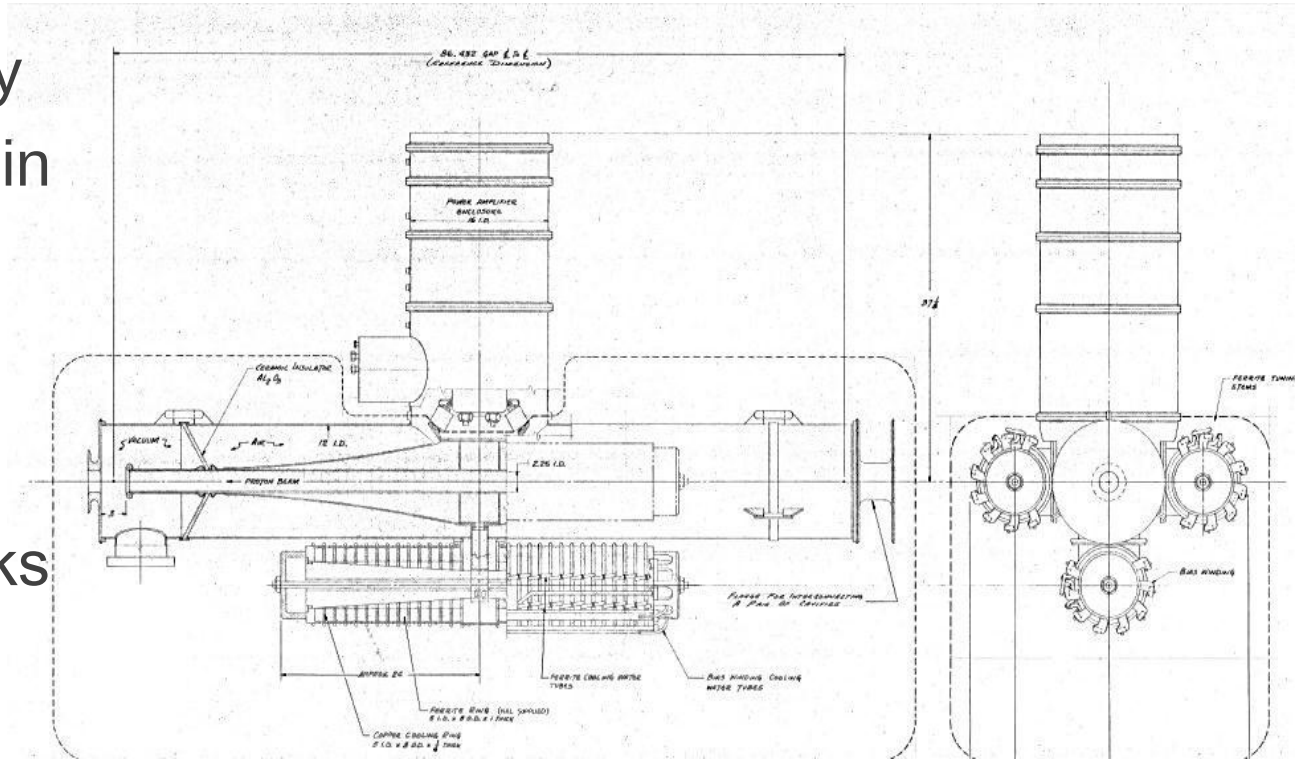


Replaced

  - Final amplification stage sat on cavity in the tunnel -- radiation environment (20 power tubes)
    - Tube lifetime issues leads to worker radiation exposure
- Replaced entire amplification chain with Solid State power system

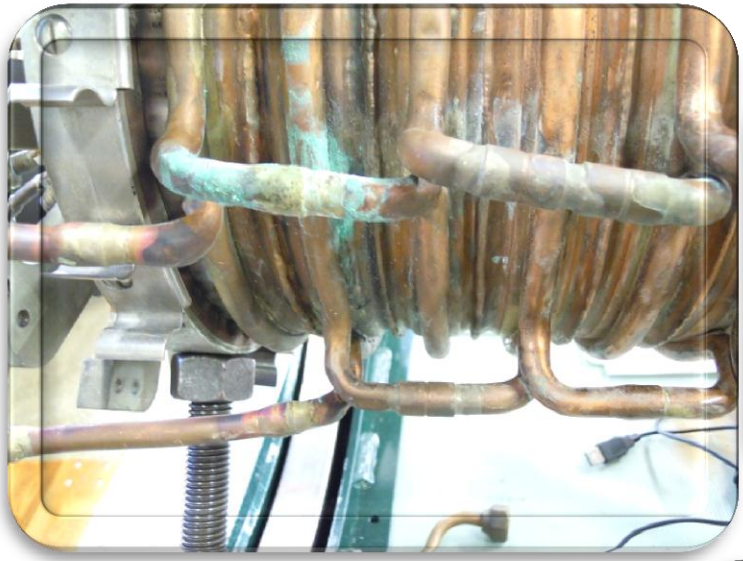
Booster RF Cavities and Tuners

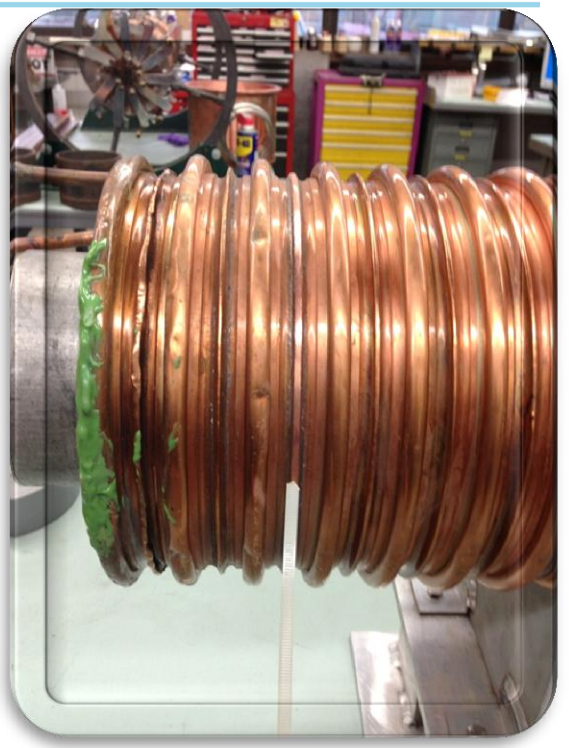
- 3 tuners per cavity
- Reworked tuners in the 1970's
- Disconnected tuners' inner-cooling lines in 1970's due to leaks and was not needed for ~1Hz

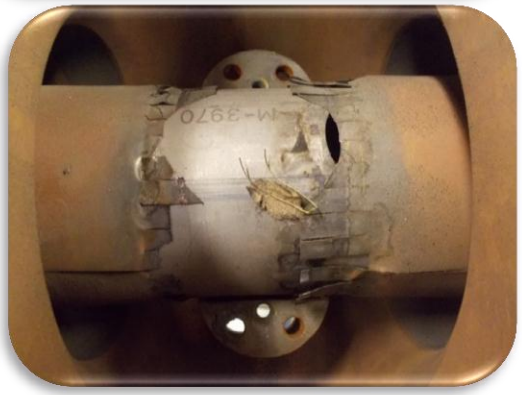


- Many in-situ fixes of vacuum and water leaks over the years
- Failures were shown to be over heating at junctions of tuners and cavity

Tuner “Findings”







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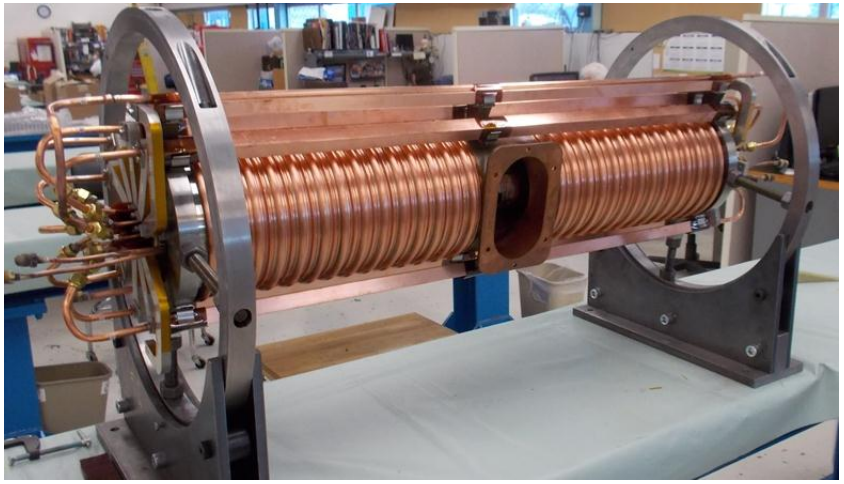
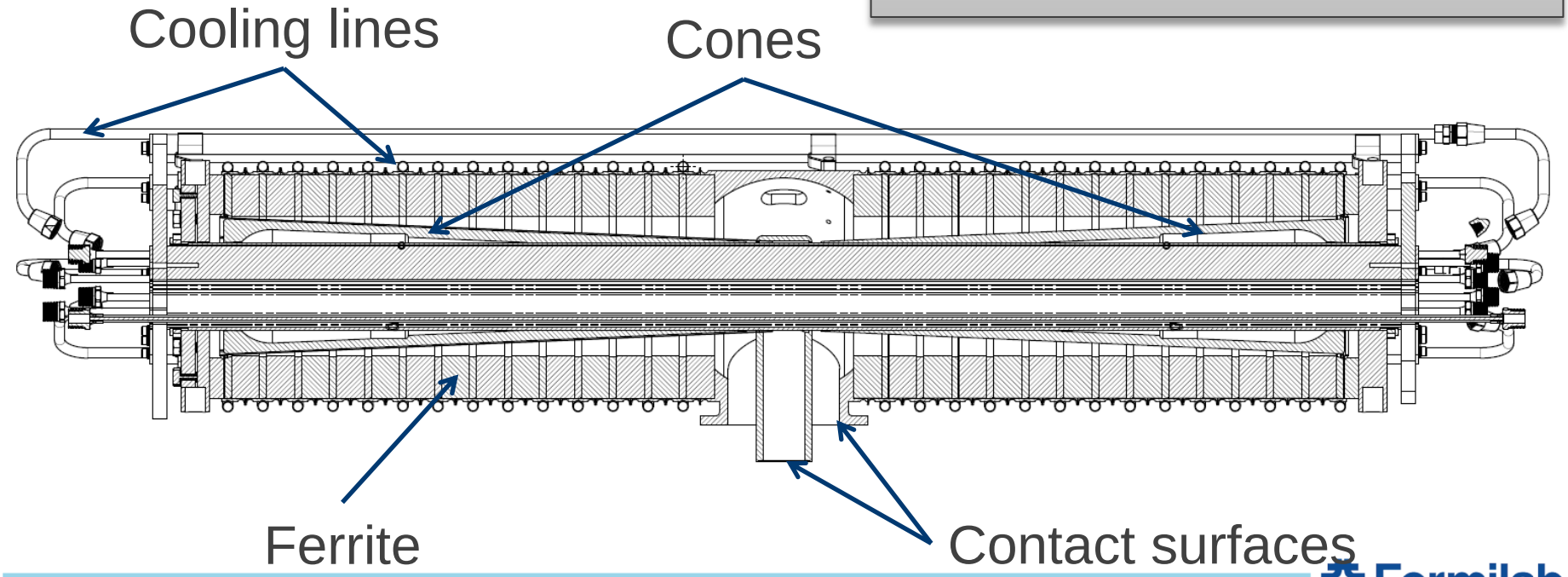
Tuners

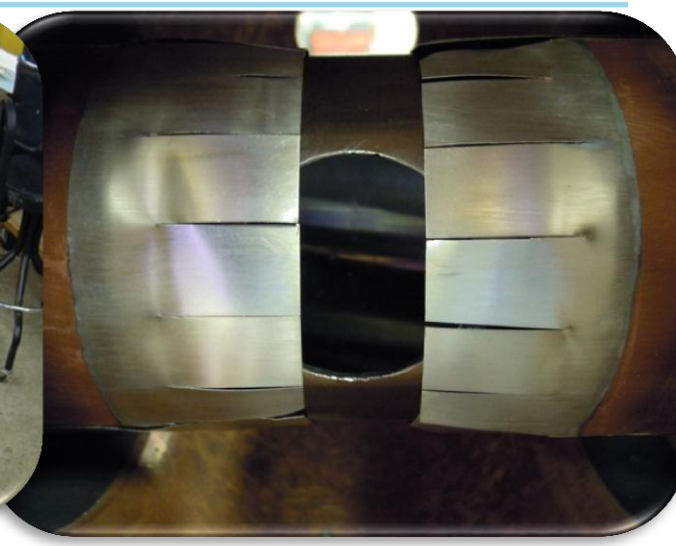


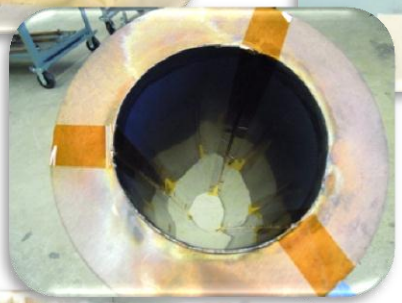
Each tuner:

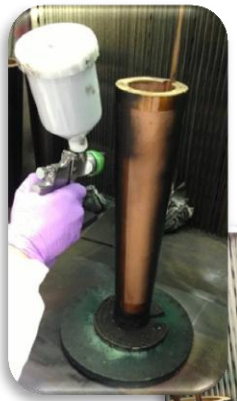
- 500+ pieces
- 150 ft+ tubing
- 50+ water connections
- 44 in long
- 650 lbs



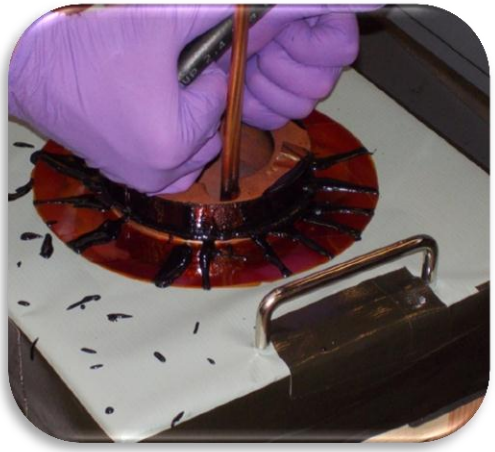
Tuner Refurbishment - Cones







A 10 step process



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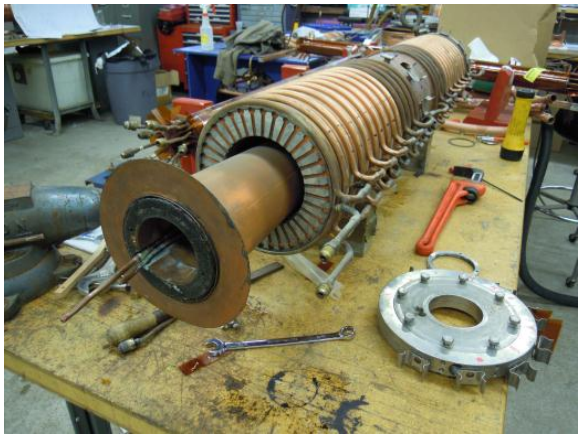
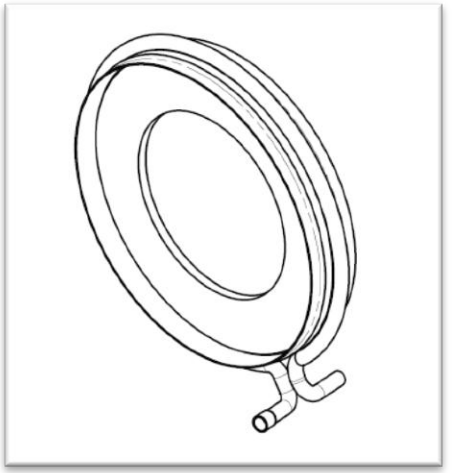
Tuner Refurbishment

- There is a copper shell with cooling line for each ferrite
- Chipped ferrite or cooling line issues can lead to grinding off welds that have to be re-welded later





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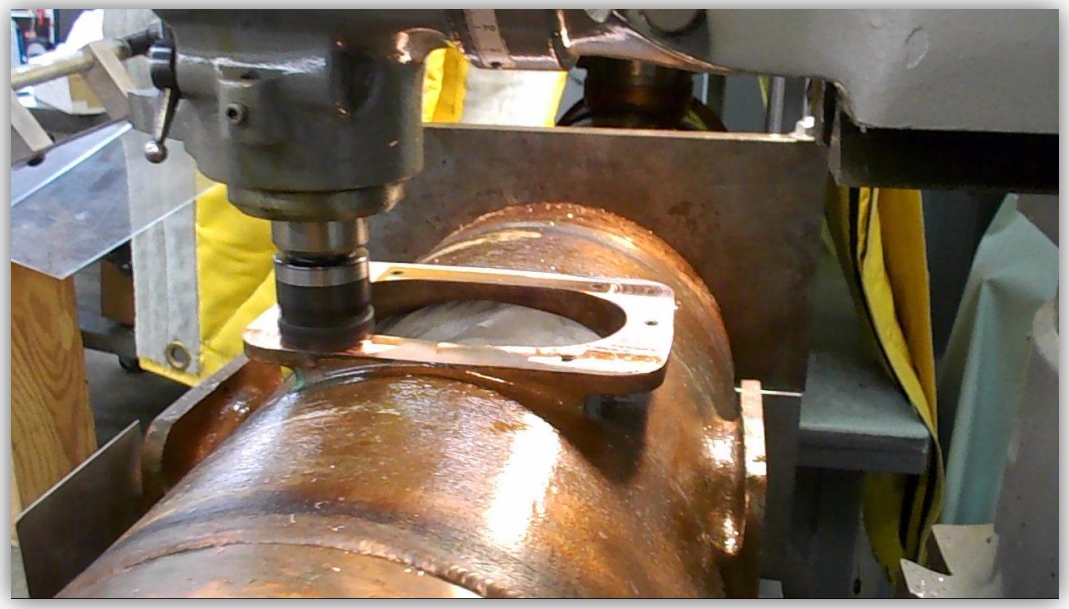
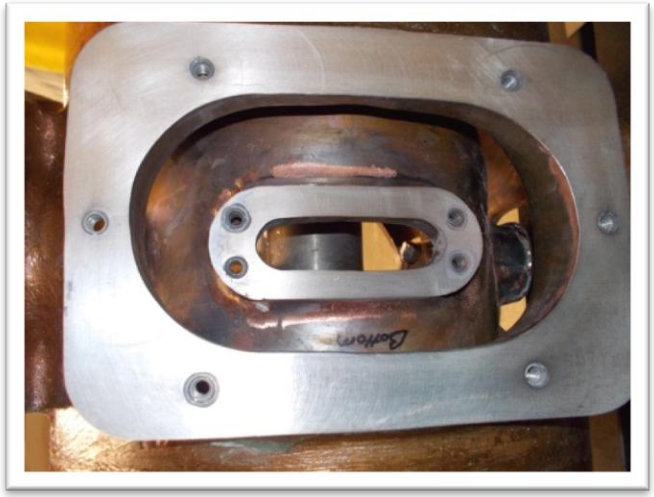
Cavity refurbishment





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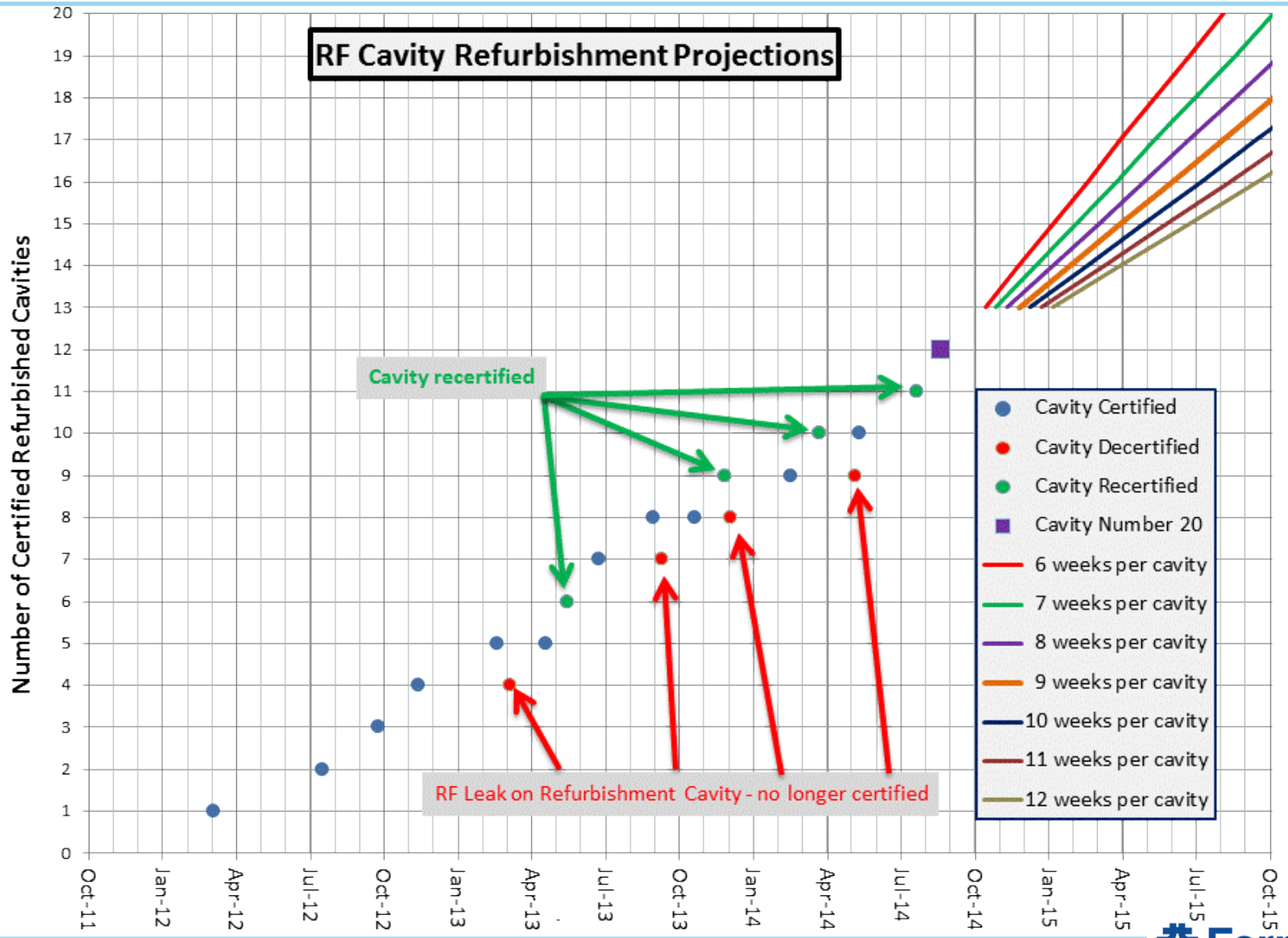
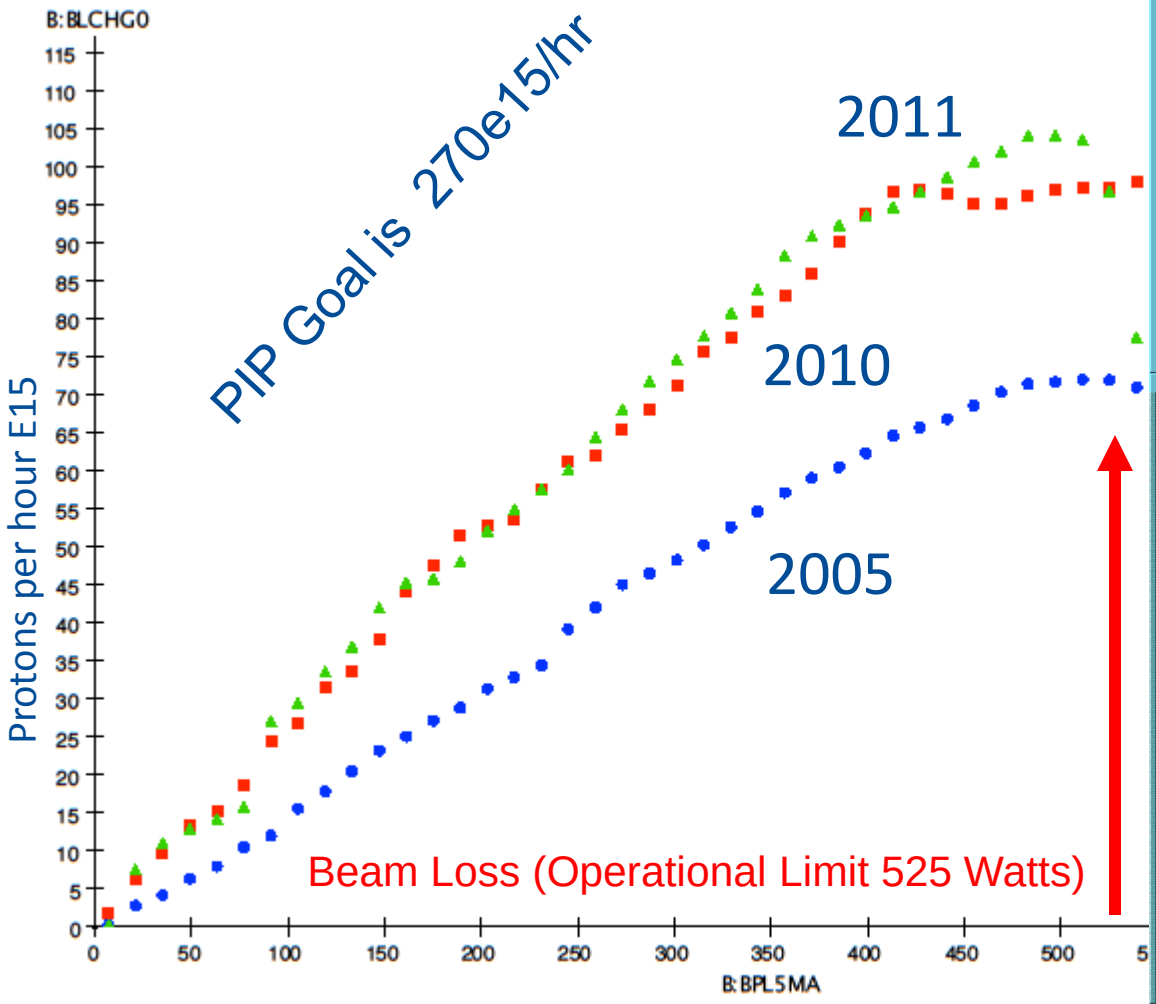
Certifying a Cavity Every 9-10 Weeks

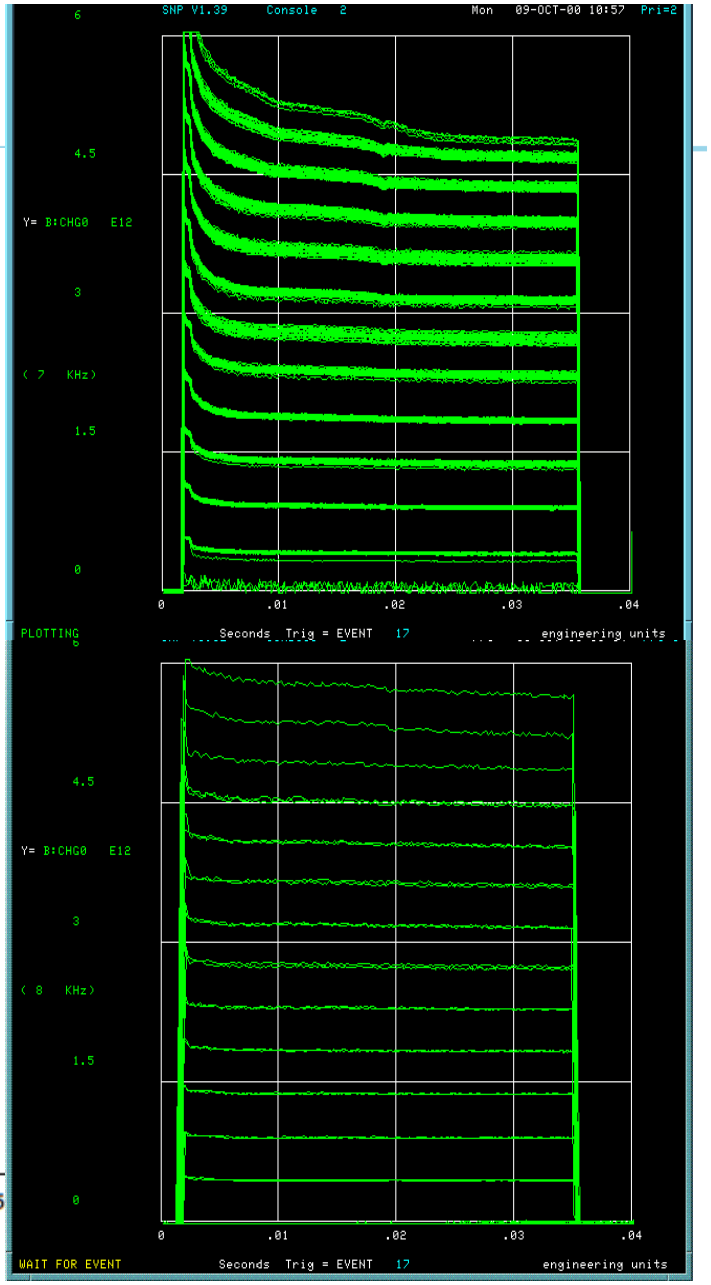


15 Hz Operations and Beam Loss

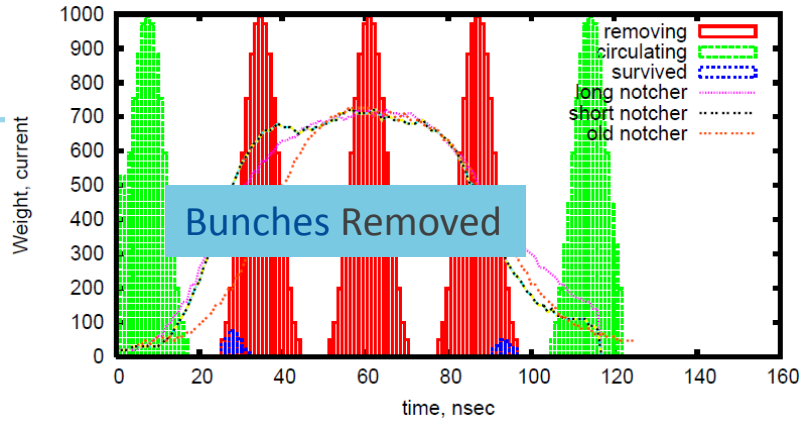
- 17 refurbished RF cavities needed to go beyond historical rate of 7 Hz
  - Anode supply replacement and bias supply upgrade also need to be complete
- Expect to reach 17 cavities summer-fall of 2015
- After new radiation shielding assessment is approved, then can
  - Increase Booster cycles with beam
  - Monitor beam loss
    - Currently ~10% of injected beam is lost in Booster
      - Doubling flux means throughput efficiency has to go from 90% to 95%

Flux increase - Losses



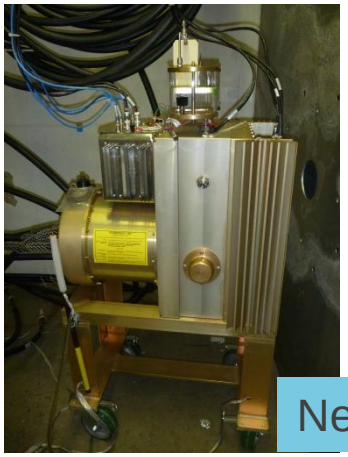


Notcher & Absorber

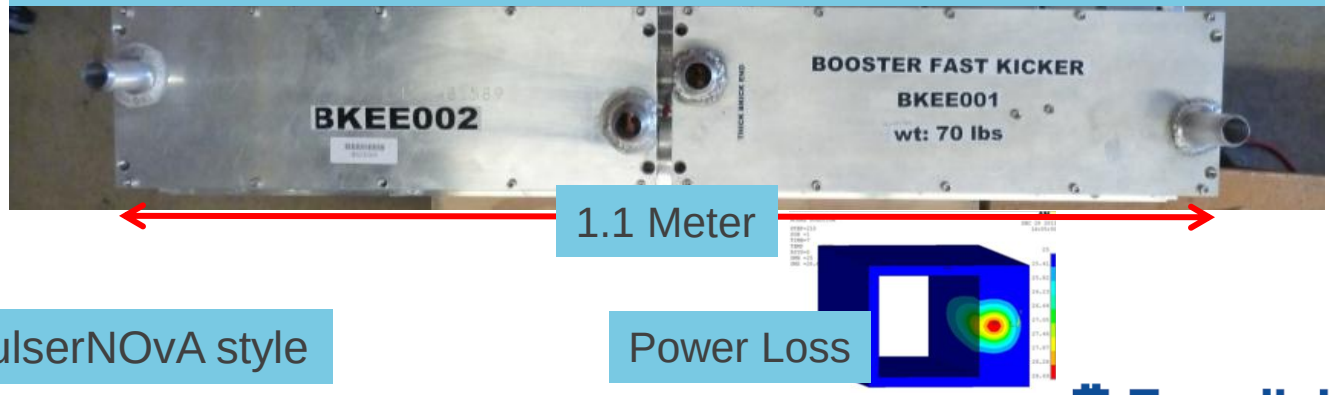


The above plot shows current notch simulation
Shorter kickers will have faster rise times, cleaner notch and reduced kick on circulating beam.
Testing complete of 4 short kickers – 2 more later

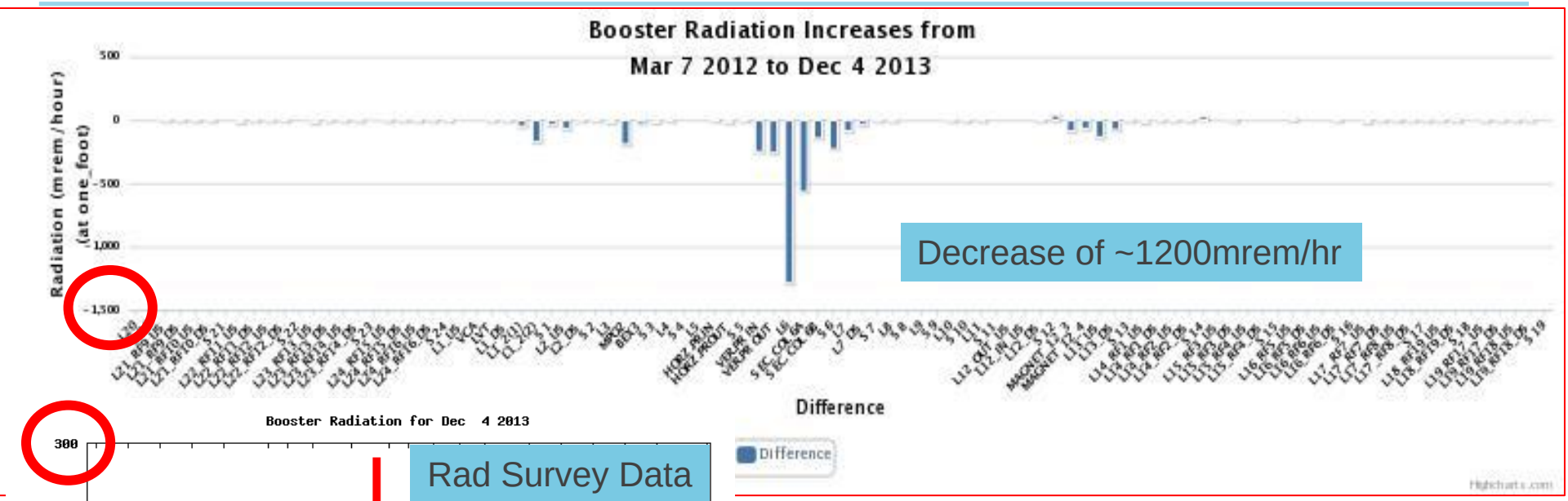
Controlling the loss at 400MeV instead of 8GeV

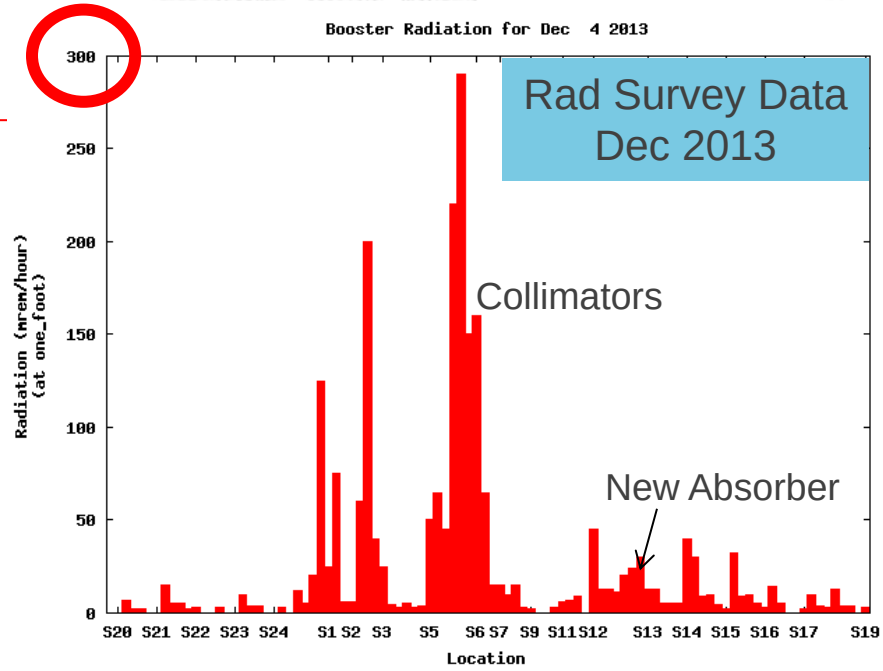


Booster Short Kickers – drop in replacements



Notcher & Absorber Controlling Beam Losses

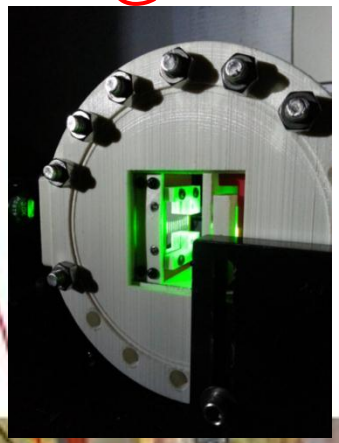


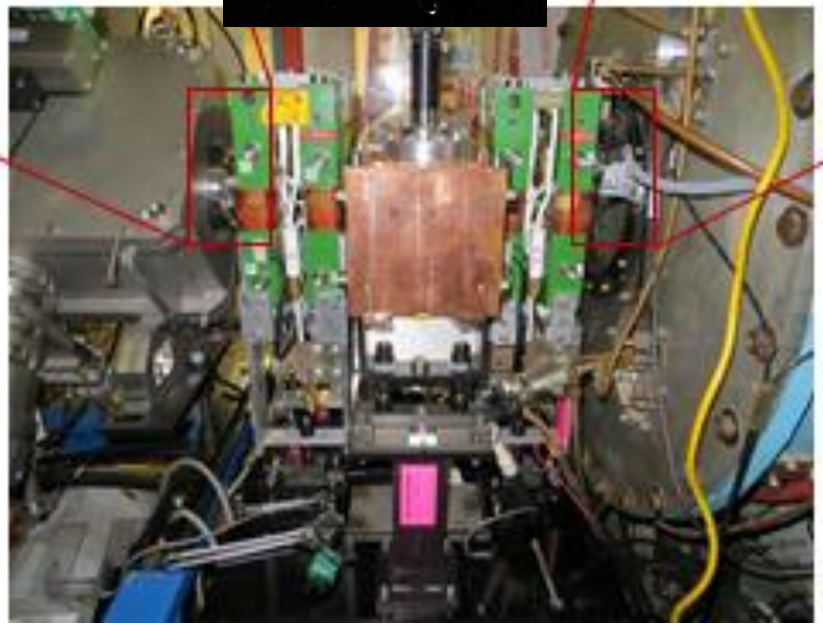


The plot above shows the difference between two rad surveys after running similar flux for a week. The new system has greatly reduced residual activation in several areas of Booster. The new absorber system directs the beam to an absorber – old system was not designed for high flux and the kicked beam 'notch' into collimators was uncontrolled

RIL MEBT Laser Notcher and Beam Valve

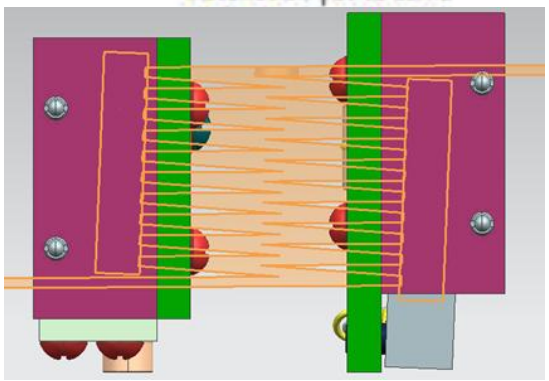
Notch @ 750 KeV





Laser notcher flange installed on RFQ upstream of MUQ1

- Electronics and test laser installation yet to come



New beam valve (L:MVV) installed on upstream of Linac DTL1, downstream of MDQ2

- PLC connection not established yet
- RIL now isolated from DTL1&2 common vacuum

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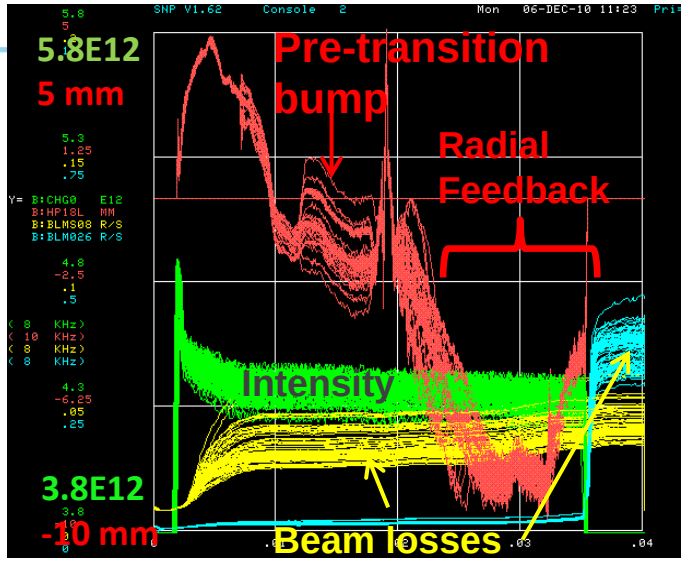
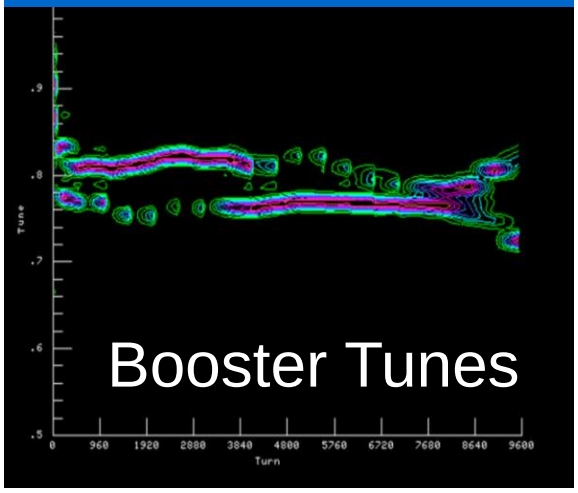
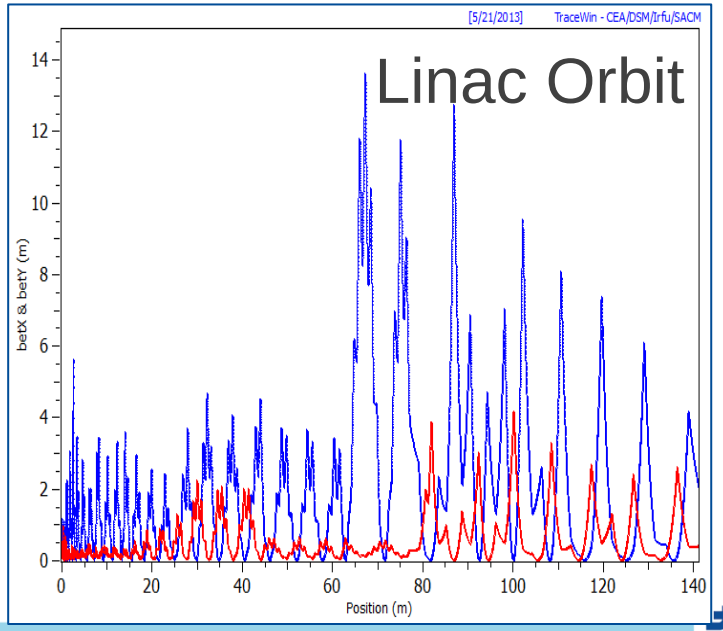
Accelerator Physics

- Aperture and orbit control
- Magnetic Cogging
- Lattice corrections
  - Beta Beating
  - Higher harmonic control – coupling, chromaticity and tunes
  - Lots of new software
- Dampers – upgrades
- Collimation
- RFQ injector lattice and capture



Better tune control at high energy





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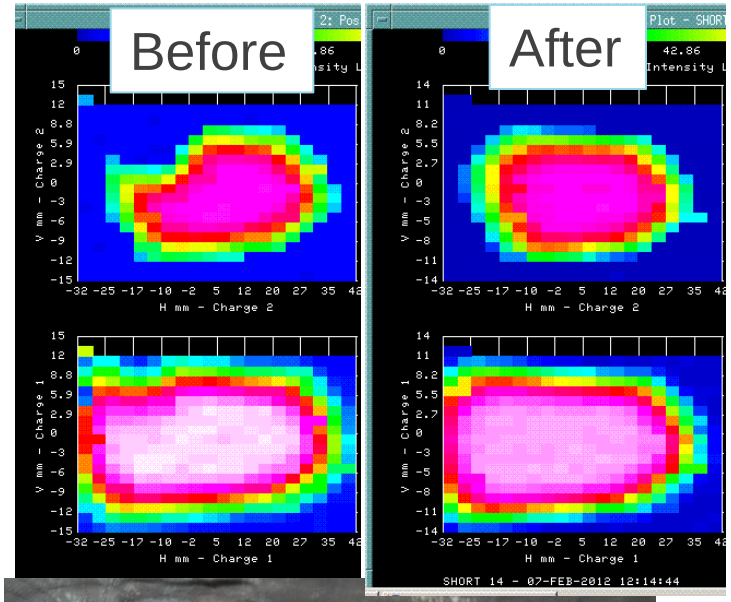
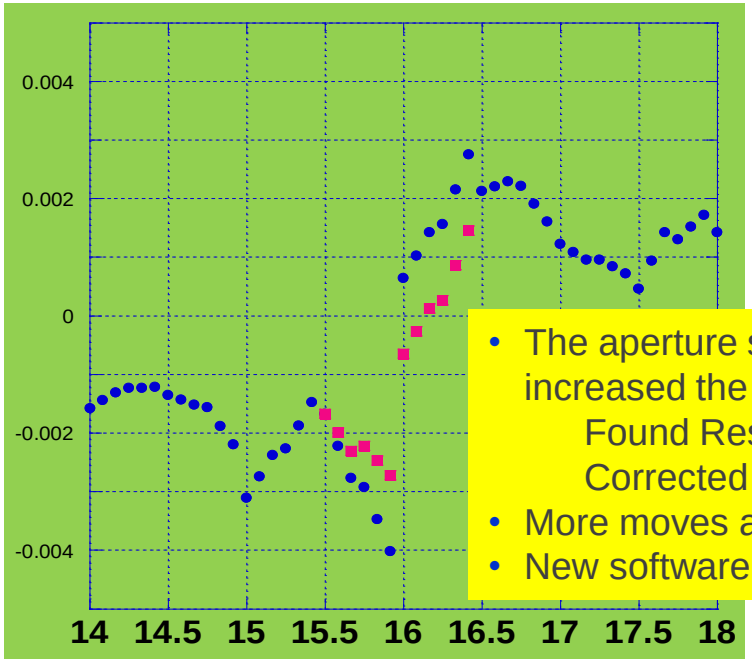
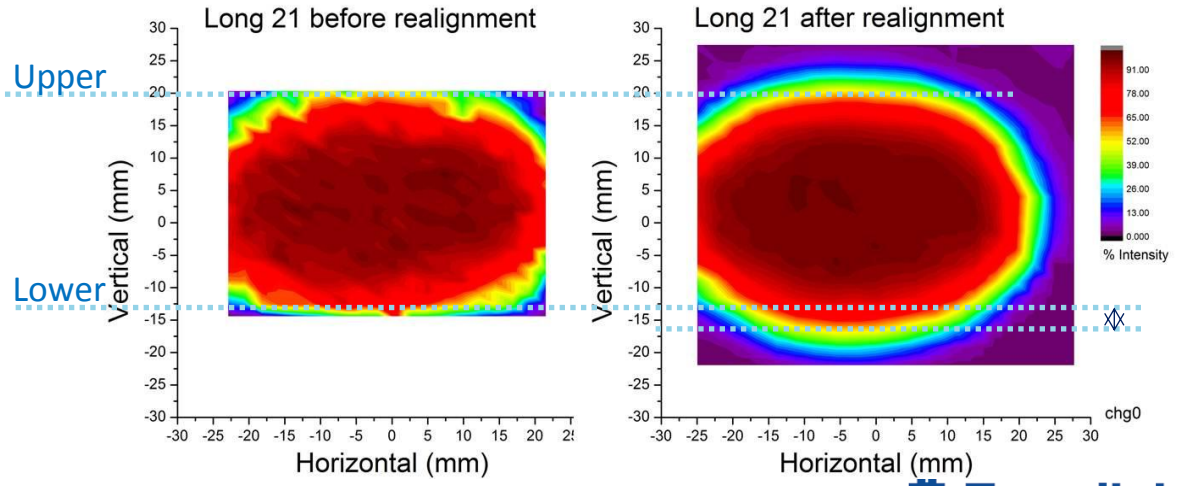
Booster Alignment/Aperture Scans





- The aperture scans has successfully increased the acceptance
  - Found Restrictions
  - Corrected Misalignments.
- More moves are planned but smaller
- New software is fast and easy to use



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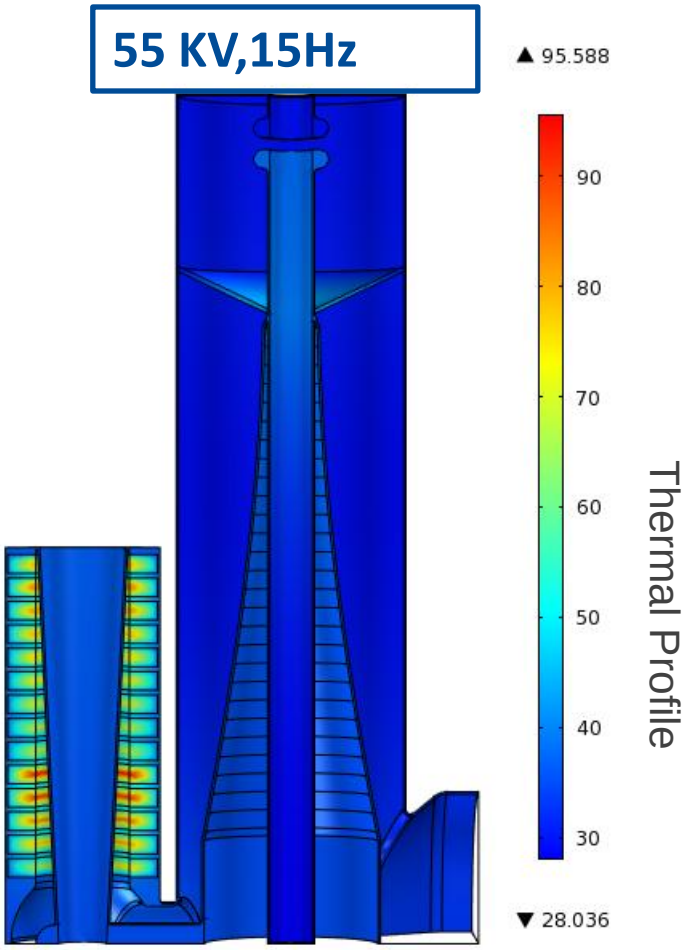
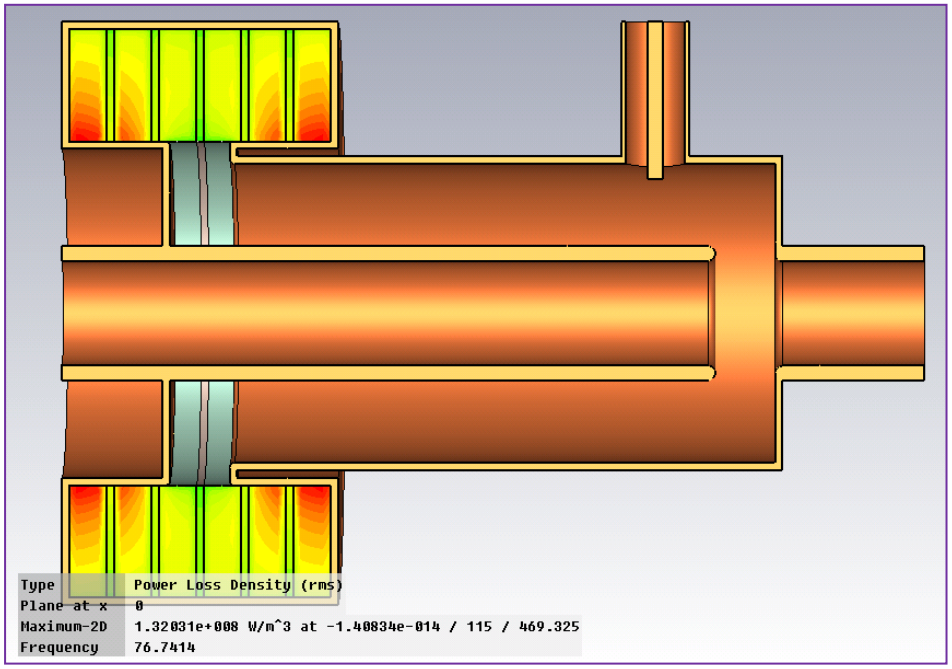
New Cavities and Harmonic Cavity

Specifications for Design of New Accelerating Cavities for the Fermilab Booster underway with testing of current cavities to confirm modeling.



Harmonic cavity work is underway to help with beam capture, transition and possibly extraction.

- Based upon work at TRIUMF and LANL
- Simulations look promising
- University interest – Illinois Institute of Technology

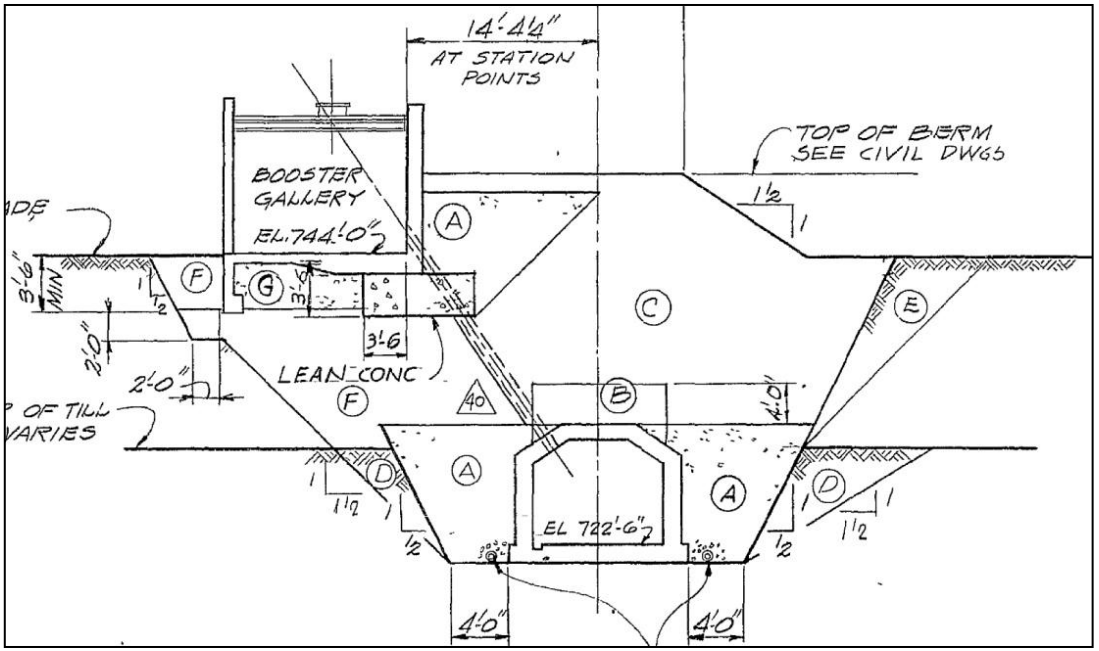


Magnetic loss density (100 kV)

Radiation Shielding

Passive Shielding is not enough
Several rounds of scans have been performed
Understanding of loss points set locations for discrete detectors
Will test Total Loss Monitor (TLM) system (Fri. morning – Leveling)

- Assessment Beam Parameters
- Shielding Requirements
- Longitudinal Shielding Summary
- Transverse Shielding Summary
- Labyrinths and Penetrations
- Air Activation
- Ground Water and Surface Water
- Soil Activation
- Muons
- Residual Dose Rates
- Active Shielding Controls



Summary

- PIP has been on going to do the following:
  - Double the flux
    - Support beam on all 15 Hz cycles
  - Keep the Proton Source viable/reliable through the middle of the next decade
    - Replace/upgrade obsolete components & technology
  - Control the beam losses such that the activation does not become worse than today
    - Will strive to control and cut beam losses to decrease worker exposure to activated equipment

- Starting in 2012, the PIP is a multi-year campaign to achieve Fermilab's physics goals for the next decade