Status of the Fermilab Accelerator Complex

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U.S. DEPARTMENT OF ENERGY

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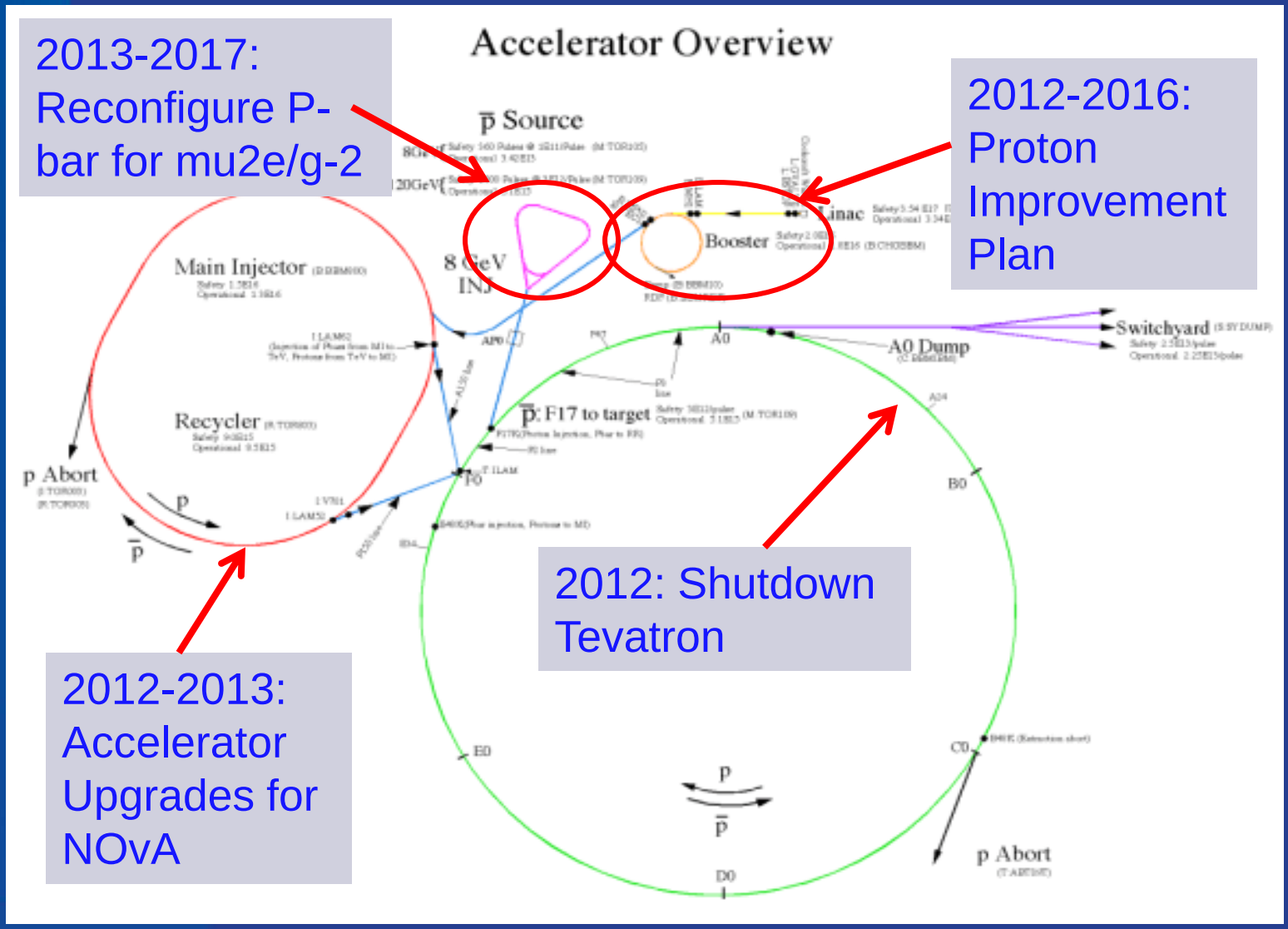
Outline

- Evolution of the Fermilab Accelerator Complex.
- Proton Improvements Plan (PIP) Upgrades.
- Proton Source Throughput.
- ANU Upgrades.
- Muon Campus.
- Start-up Plans.
- Proton Projections.
- Conclusions.

Evolution of the Accelerator Complex (through 2020)



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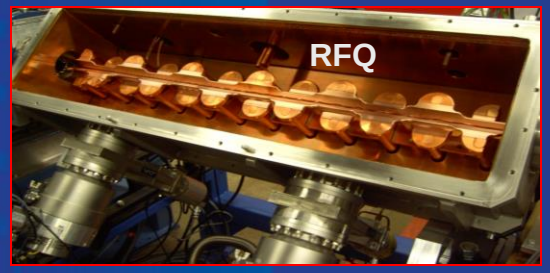
Accelerator complex in the Intensity Frontier

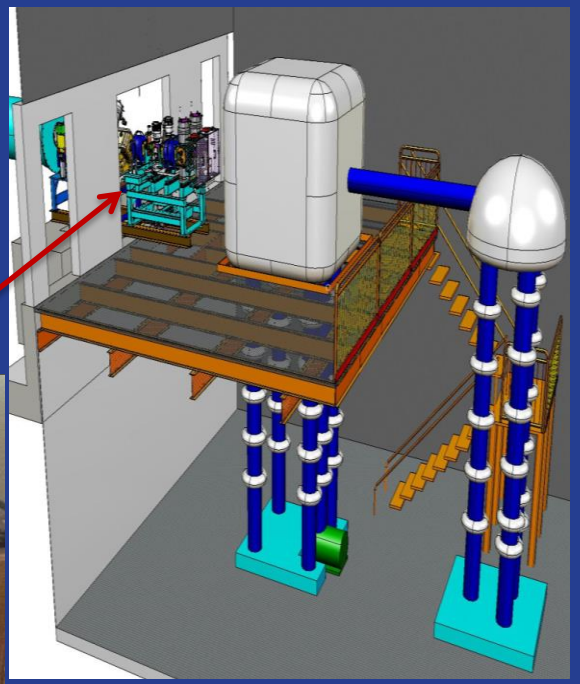
- Increase the Booster Beam Power by a factor of 2.2 by running the Booster at 15 Hz
  - Proton improvement plan provides the necessary upgrades assuring high machine availability and low residual activation.
- Increase the MI beam power by 1.7 to 700 KW by utilizing the Recycler as a proton accumulator with stacking.
  - ANU Plan provides the Recycler upgrades
  - Need to commission slip stacking in the Recycler.
- Reconfigure the pbar source into a muon campus for mu2e/g-2.
  - Series of AIPs/GPPs provide the necessary modifications required for both experiments.

Proton Improvement Plan (PIP) Upgrades

- Loss reduction
  - Lower linac emittance
    - RFQ & linac lattice improvements
  - Apertures & alignment
    - Comprehensive survey of apertures
    - Alignment where necessary (including within girders)
    - Opening apertures where possible
  - Optics adjustment
    - Comprehensive survey of lattice and coupling
    - Control of tunes and chromaticity
    - Automated orbit and optics smoothing
  - RF improvements
    - Increased voltage from amplifiers
    - Cavity modification/replacements
  - Instabilities
    - Dampers
  - Injection painting
- Orbit Control
  - Magnetic Cogging
    - Prerequisite for other work
- Loss Control
  - Rework of notching in Booster
    - Perform earlier in cycle
    - New notch kickers and absorber
    - Exploration of full or partial notching in Linac
  - Collimation system
    - Run beam near primary scatterer
    - Optimize primary scatter thickness
    - Operate as true, two-stage system
  - Adjust radiation shielding where advantageous

New RFQ Injector





New RFQ Injector

New RFQ Injector

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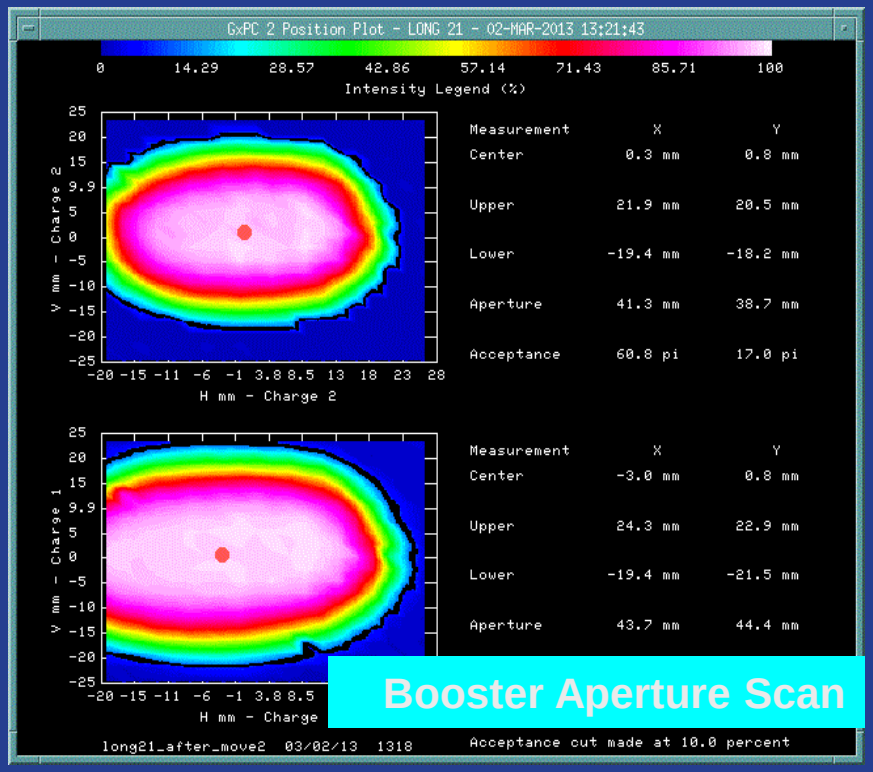
Loss Control and Aperture Improvements

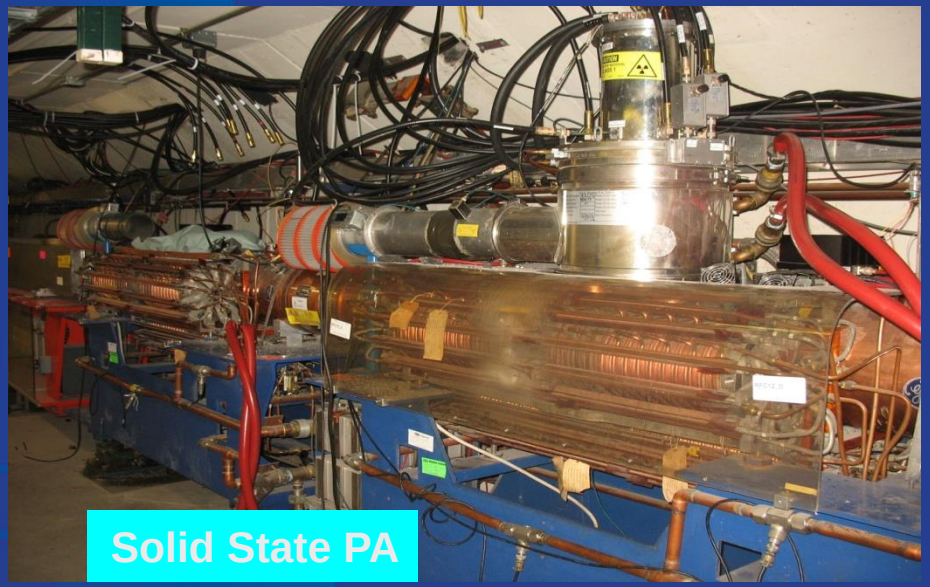
Booster Notch Beam Absorber



Booster Aperture Scan

Booster Solid State Upgrade

- Completed May 2013
- Major benefits to reliability and the cost of operation



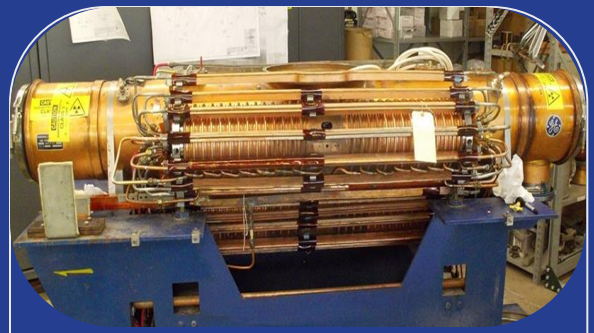
Solid State PA

Booster Solid State RF Station

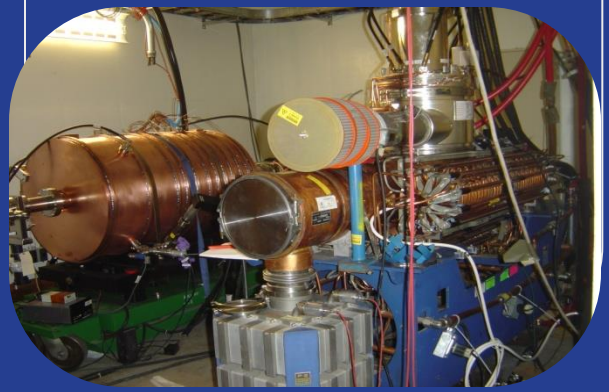
Booster Cavity Refurbishment Process

Cavity Removal - Stripping

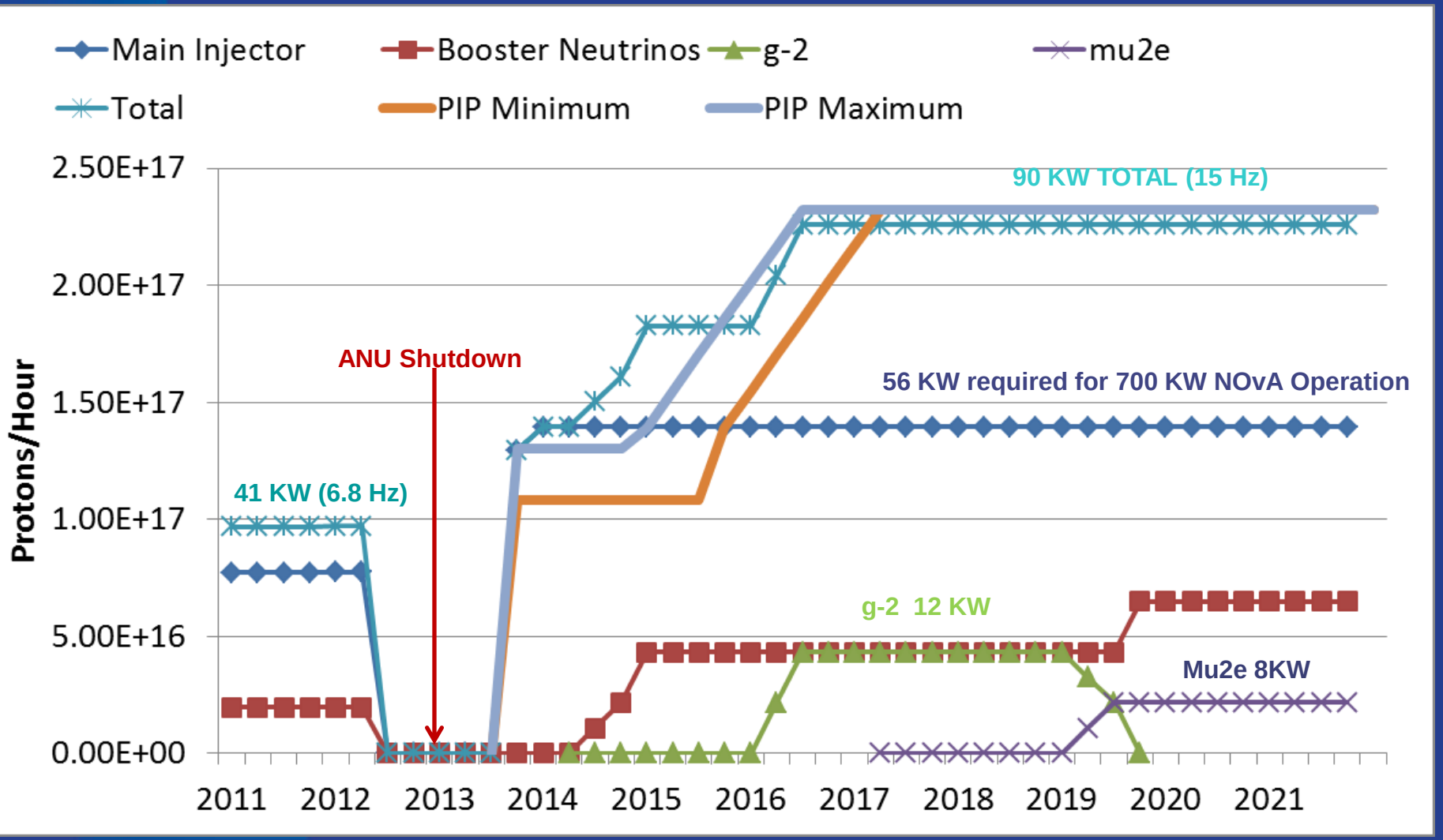
Tuners Rebuild



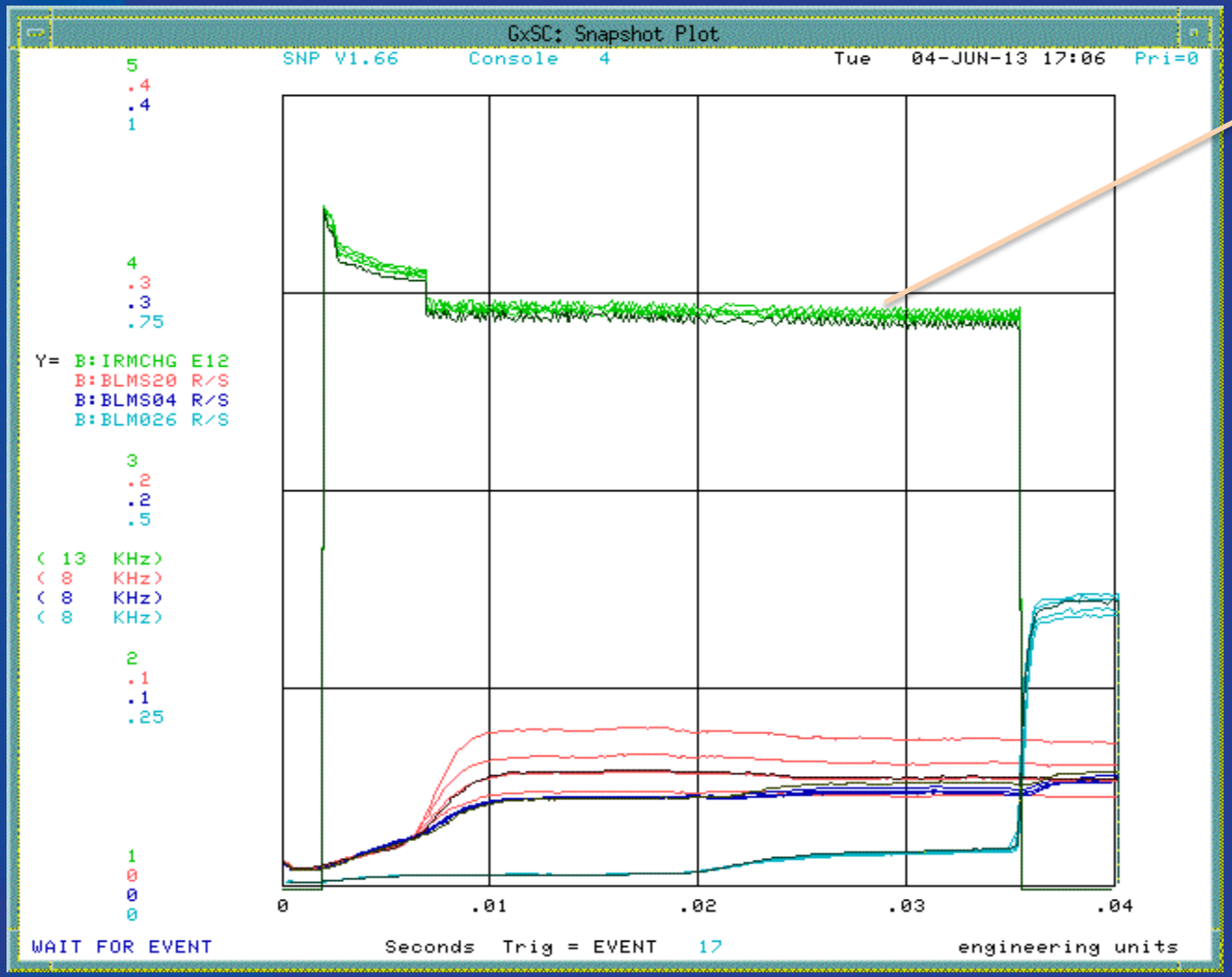
Rebuild and Test



Proton Source Throughput



Booster is up and running



Beam Intensity (E12)

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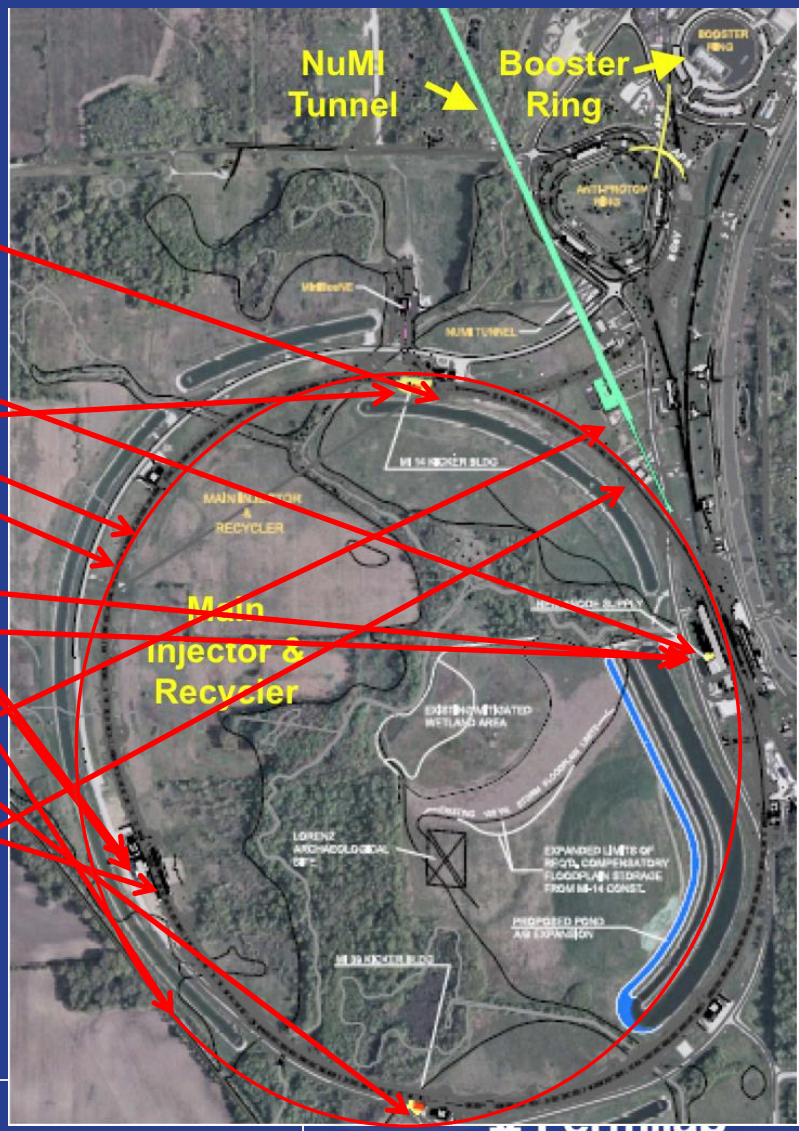
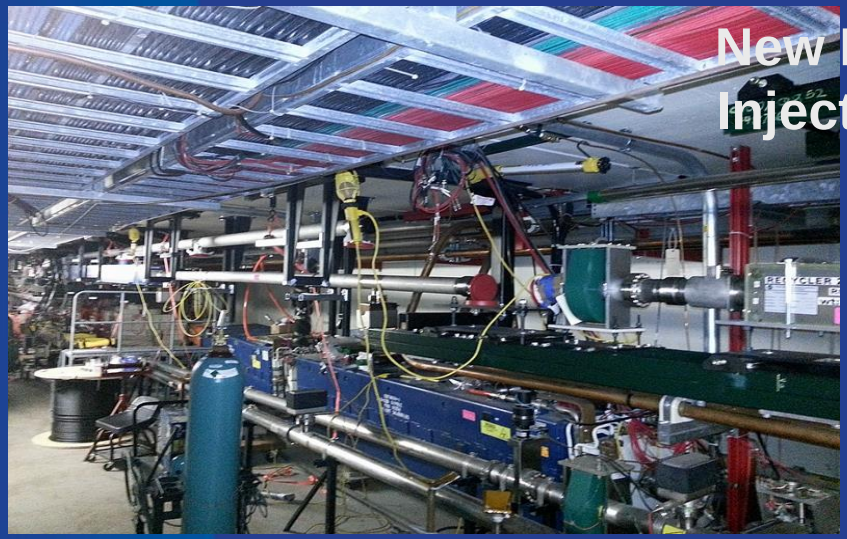
Accelerator and NuMI Upgrades for NOvA

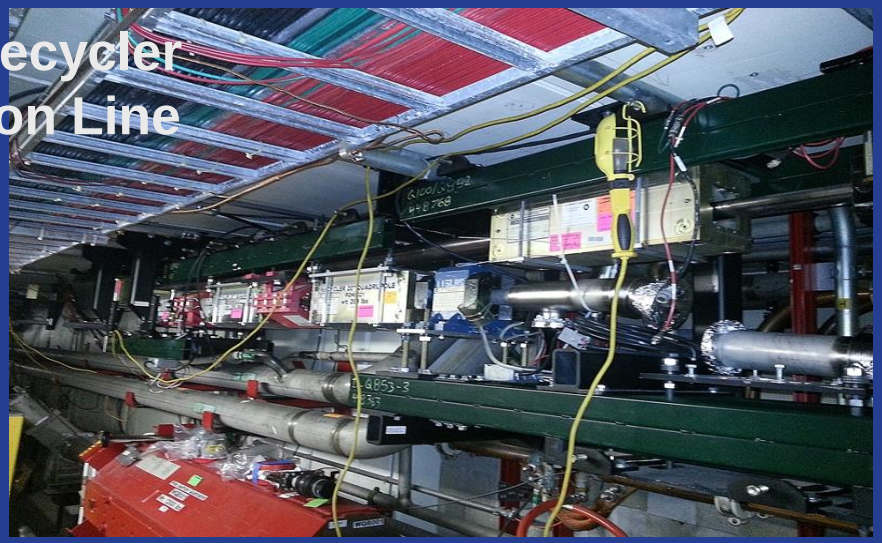
- Recycler Ring, RR
  - New injection line into RR
  - New extraction line from RR
  - New 53 MHz RF system
  - Instrumentation Upgrades
  - New abort kickers
  - Decommissioning of pbar components
- Main Injector
  - Two 53 MHz cavities
  - Quad Power Supply Upgrade
  - Low Level RF System
- NuMI
  - Change to medium energy ν beam configuration (new target, horn, configuration)
  - Cooling & power supply upgrades

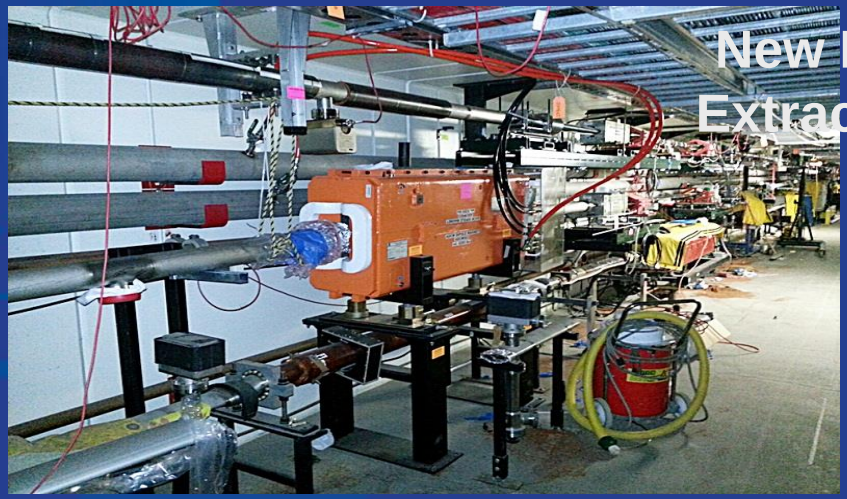


Pictures of Recycler ANU Installation



New Recycler Injection Line





New Recycler Extraction Line

Recycler 53 MHz Cavities

- **Optimized for Slip Stacking (R/Q~20 Ohms)**
- **Re-use the PAs from the TeV Cavities**

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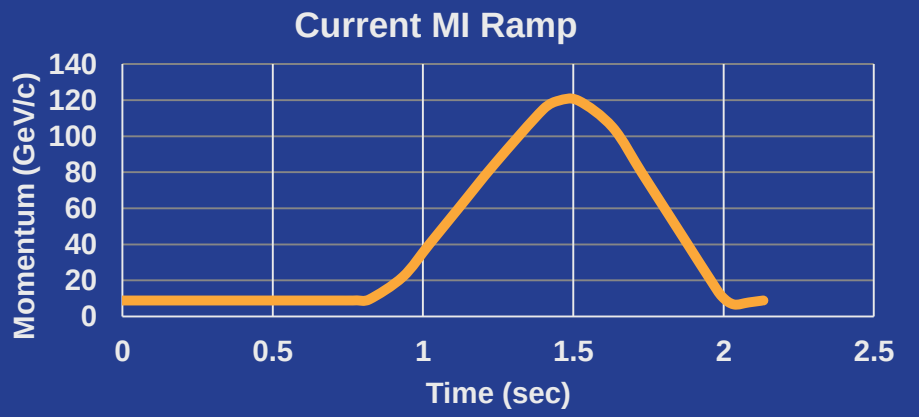
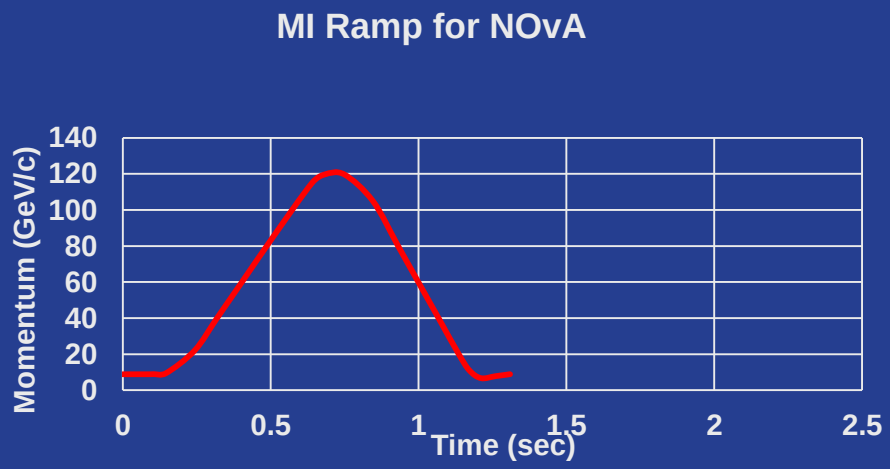
MI Operation for NOvA

- MI Cycle Reduced from 2.2 sec (33 Booster Ticks) to 1.33 sec (20 Booster Ticks).
- MI Beam Intensity increased by 9% (per bunch intensity remains the same).
- No Instability Issues are anticipated.
- Loss control is the major Issue (Power loss is increased by 80%).





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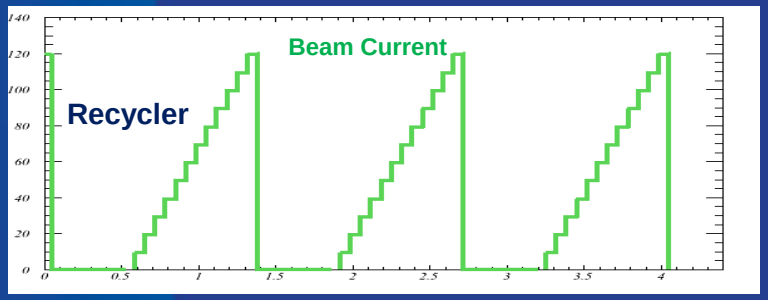
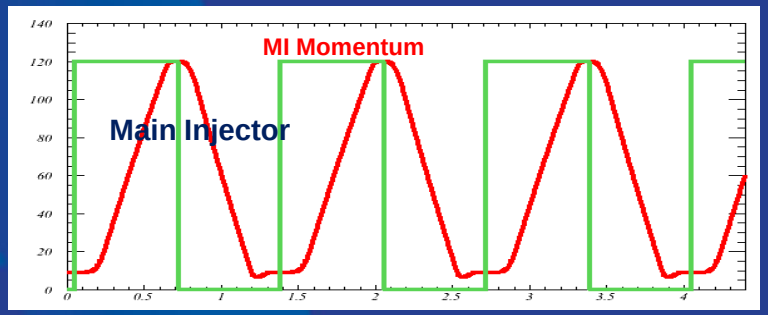
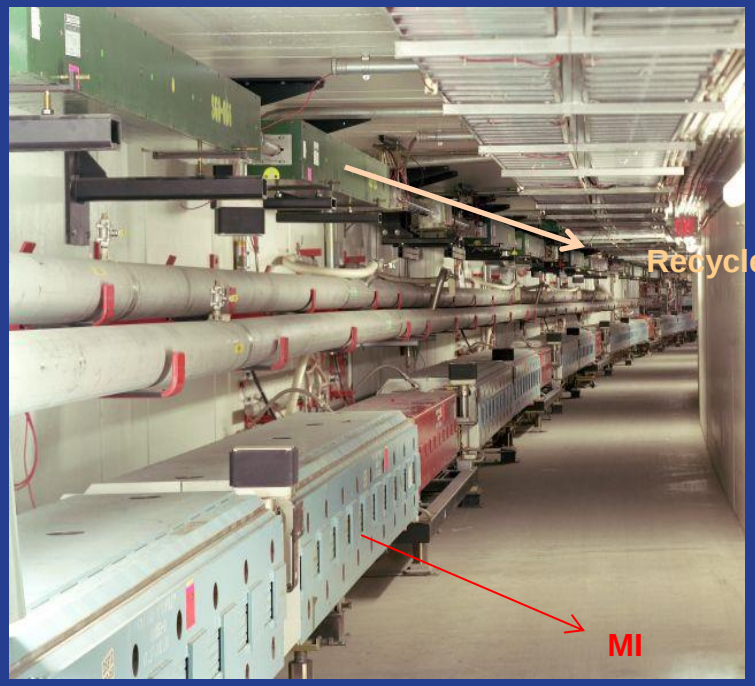
Recycler Operation for NOvA

- Injection of 12 high intensity Booster Batches for slip stacking.







- Up to 8 additional Booster batches cab be injected in Recycler for delivery to the modified p-bar Rings (Mu2e, g-2 experiments)

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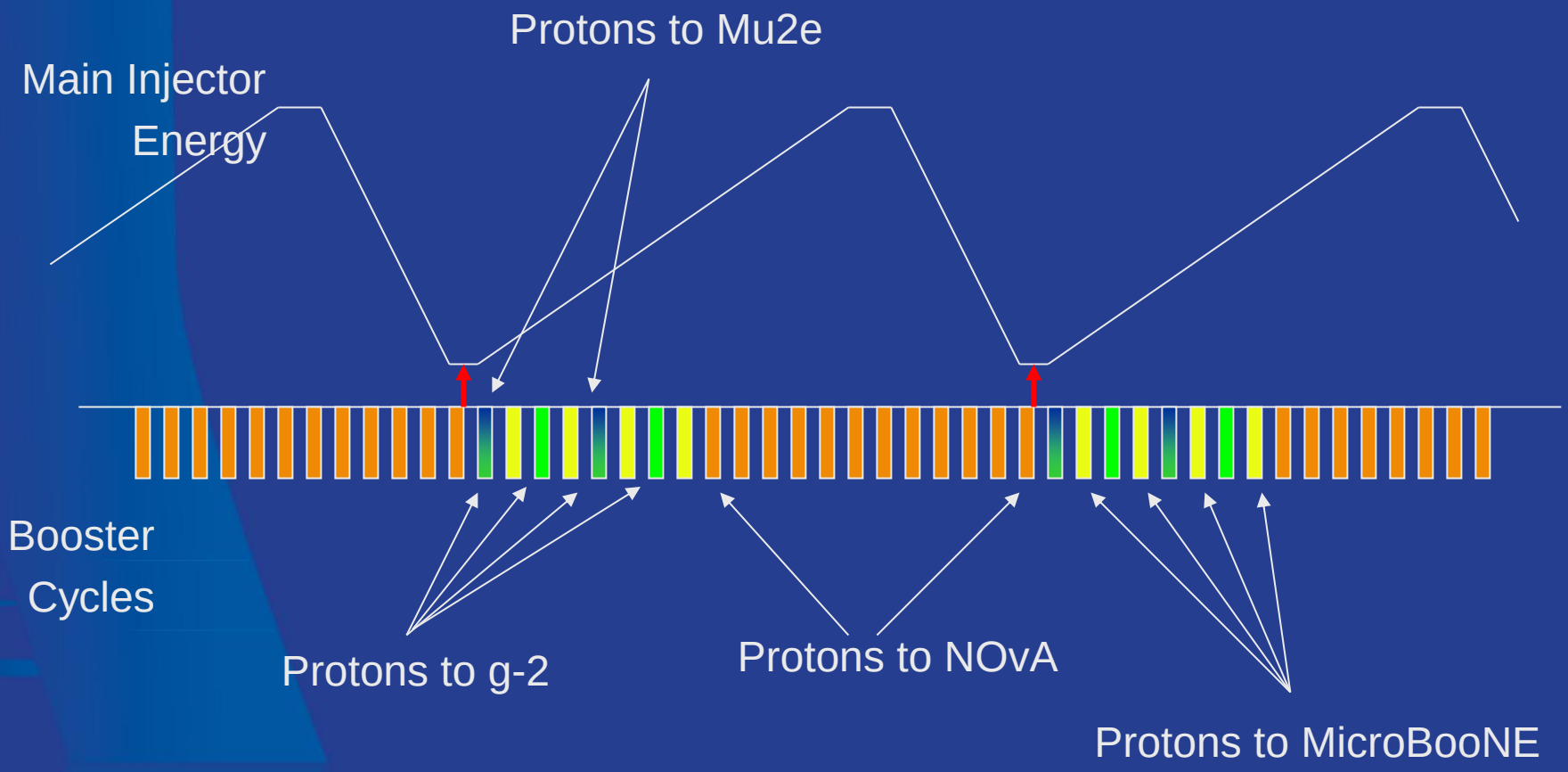
Recycler operation for Mu2e and g-2



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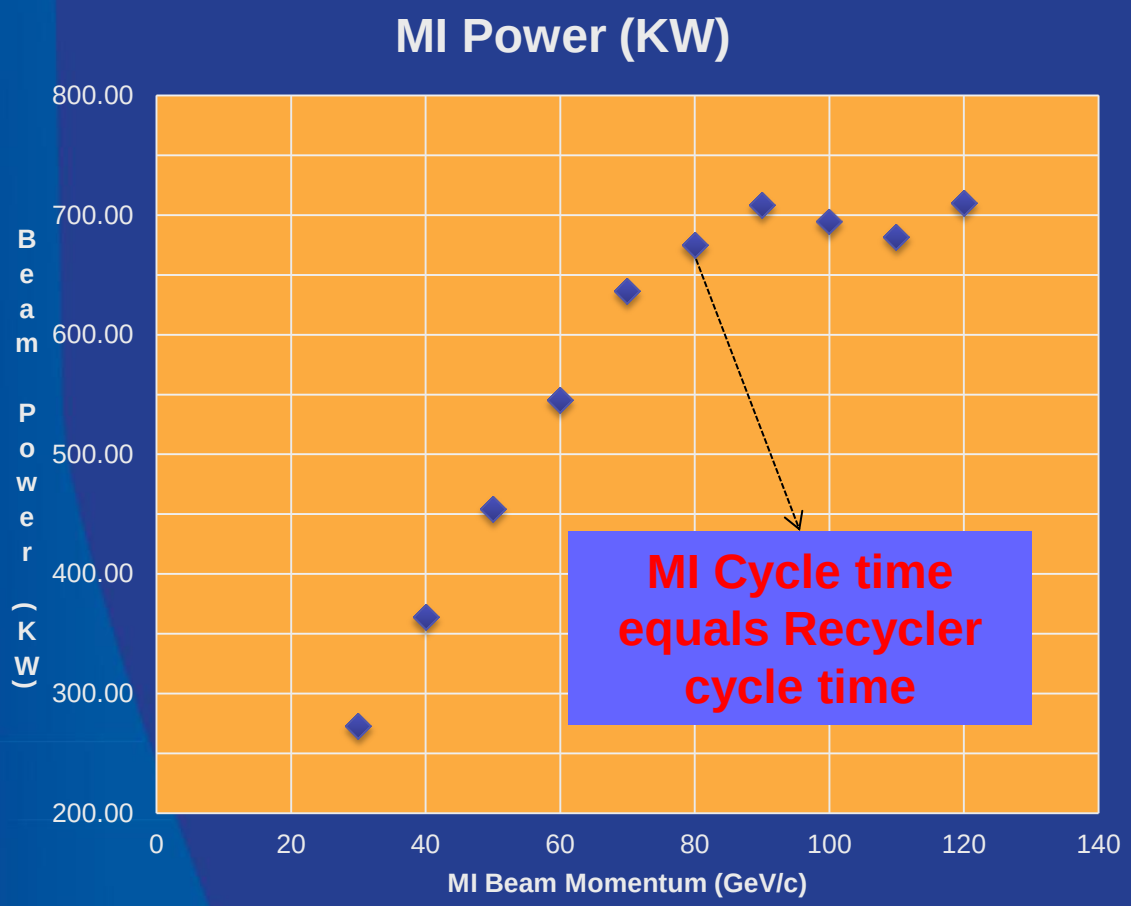
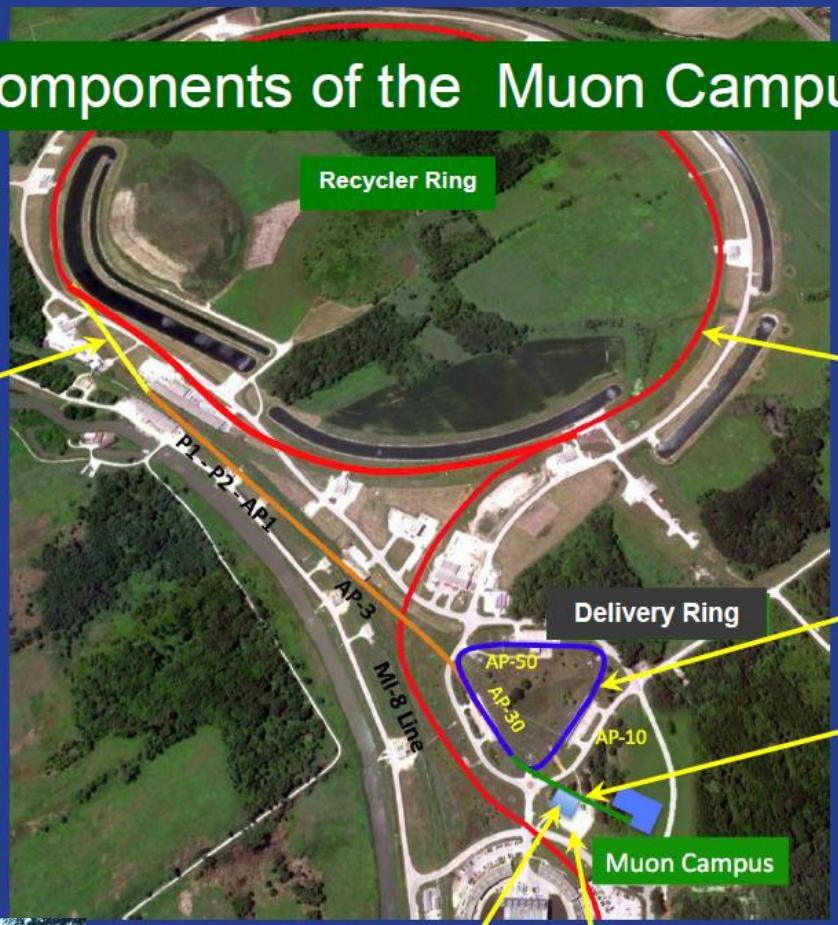
MI Injector Power vs. Energy after ANU Upgrades



Components of the Muon Campus



Beam Transport AIP:
New connection from Recycler to Delivery Ring, improve apertures

Recycler RF AIP:
Adds RF capability to Recycler meeting g-2/Mu2e specifications

Delivery Ring AIP:
Modify Delivery Ring to deliver custom beams to the muon experiments

Beamline Enclosure GPP:
New tunnel to Muon Campus

Infrastructure Upgrades:
Cooling for A0 compressors, MI-52 building extension, added feeder if needed

MC-1 Building GPP:
Houses cryo plant, power supplies for beams, g-2

Cryo Plant AIP:
Cryogenics to both experimental halls

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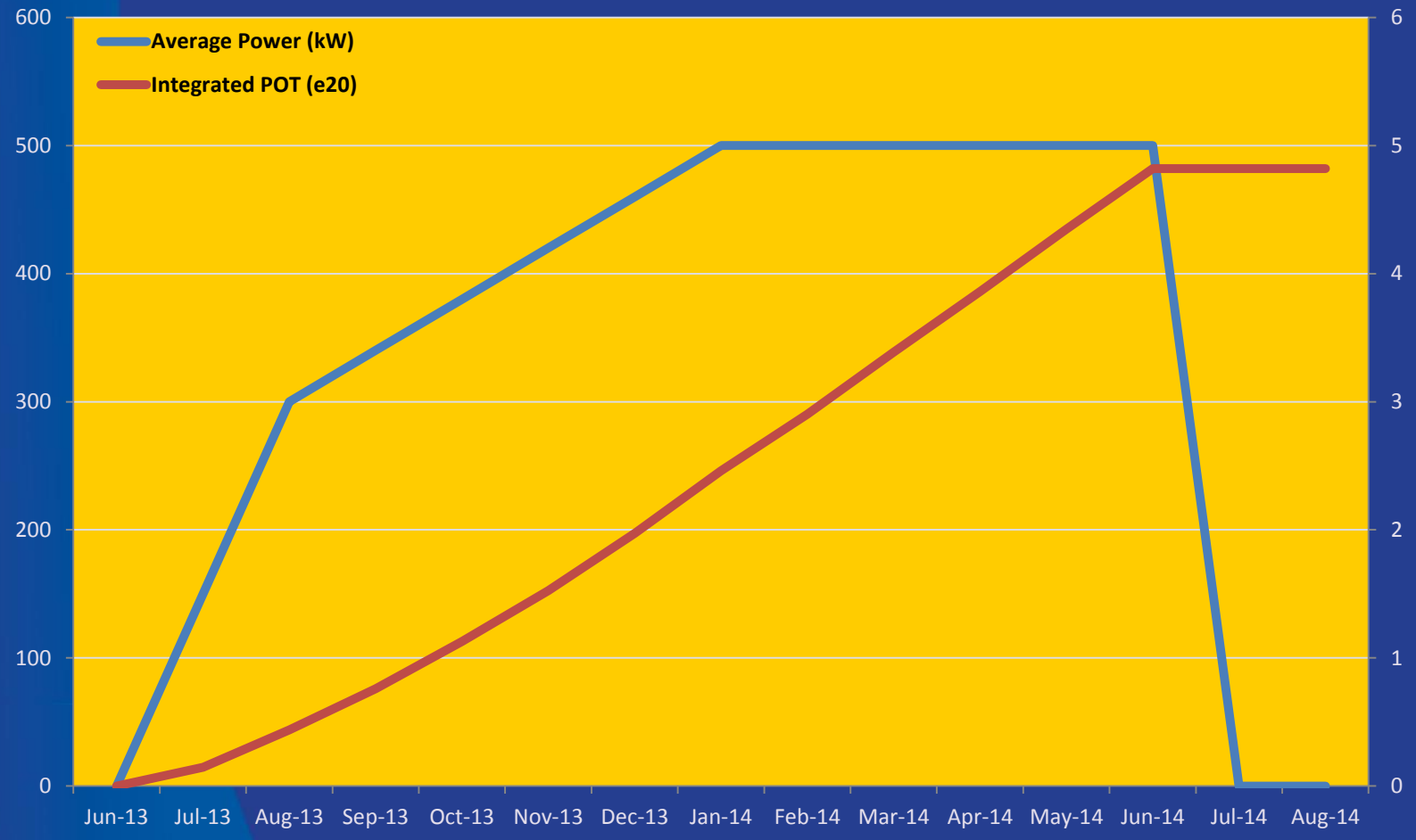
Start-up Plans (MI/RR)

- Beam to NuMI Target for tuning within 1 week from start-up (June 24?).
- Start SY120 beam studies after 1 week from start-up.
- Reach 300 KW beam power after 1 month.
  - 6 Booster batches in MI, 1.7 sec ramp, no slip stacking.
- Reach 500 KW beam power in 5 months.
  - Using slip stacking in the Recycler.
  - Assuming 7 Hz Booster operation.

Proton Projections



- **Takes into account a 10% timeline use for SeaQuest operations**

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Conclusions

- With the completion of the current shutdown the Accelerator Complex enters the Intensity Frontier.
- The Proton Improvement Plan will enable the Booster to reliably run at 15 Hz.
  - RF cavity refurbishment is the critical path
- The ANU Upgrades will enable Main Injector to provide 700 KW of beam power from 80-120 GeV.
- Plans are in place for transforming the pbar source into a muon campus for g-2/mu2e.

EXTRA SLIDES

Booster Losses

- Losses at injection
  - Poorly captured beam
- Notch creation
  - Gap for extraction
  - Created with a kicker
  - Lost in gradient magnet
- Slow losses at high-energy
  - Optics issues
  - RF variation
- Transition
  - Occasionally significant, but can usually be tuned away

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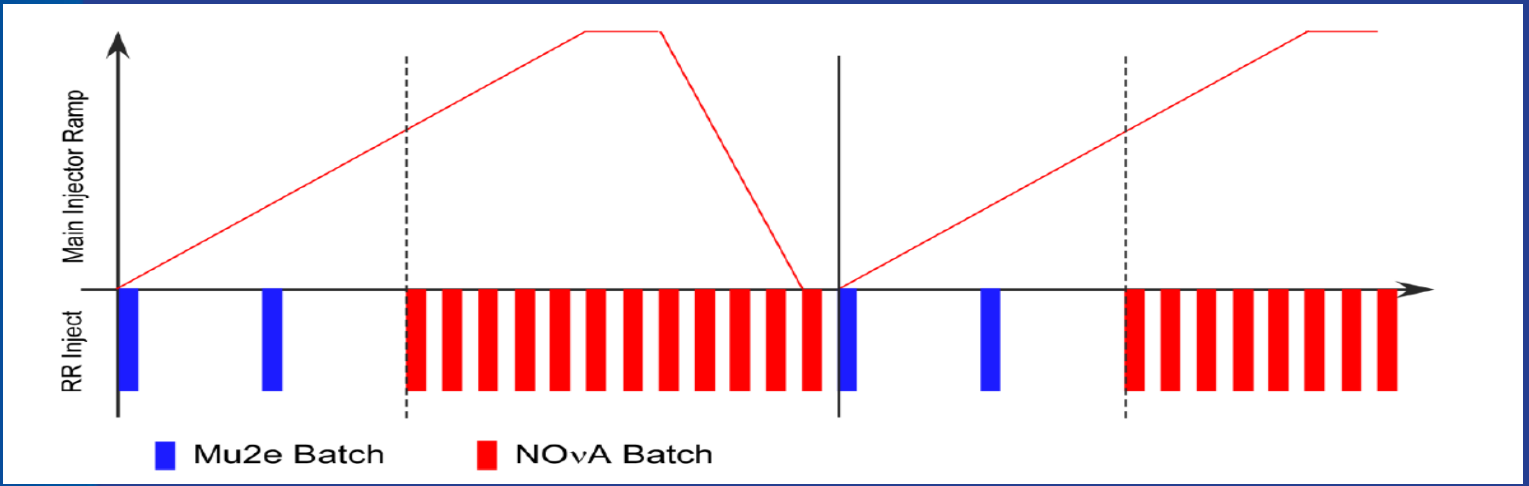
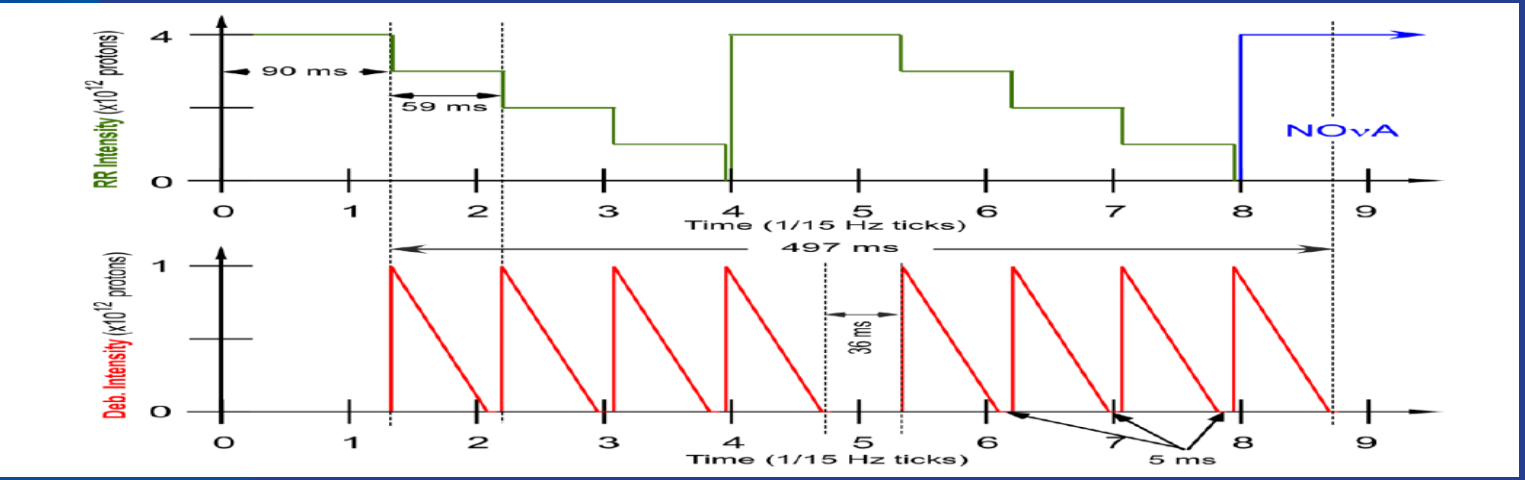
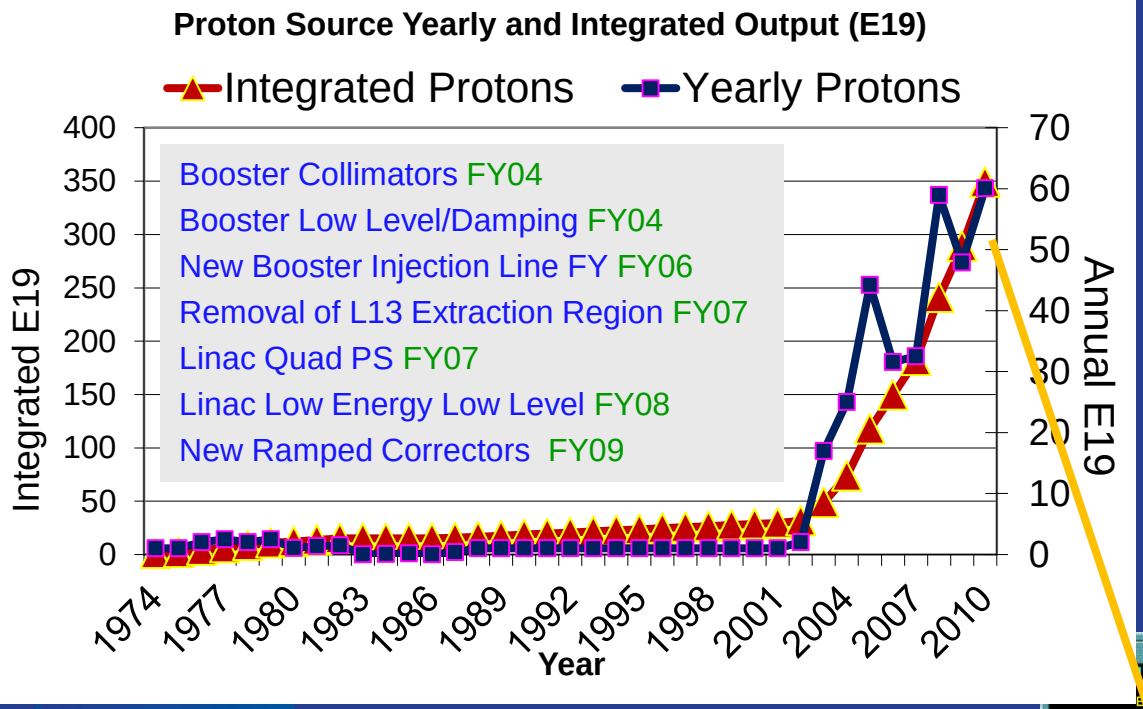
Recycler Operation for Mu2e







Neutrino Program

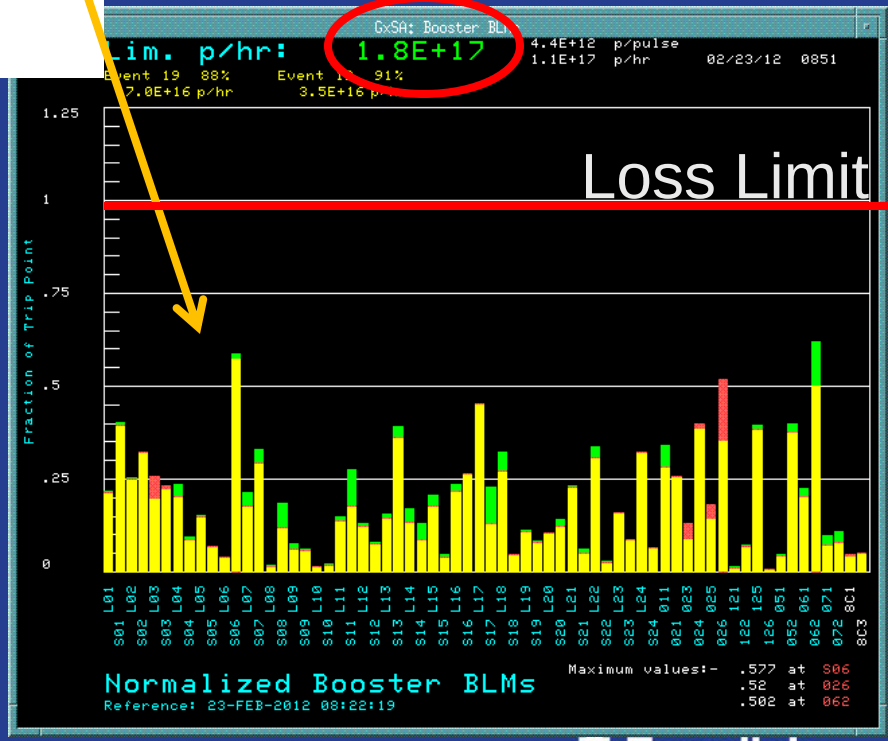
Proton Source (to 2012)

MiniBooNE Started 2001

Cycle rate up to 5 Hz

Numi Started in 2005

Cycle rate ~ 5 Hz



Typical Non - neutrino HEP Program

Proton Source to 2012

Fixed Target ≤ 11 cycle/60 sec

Recent rate 1/60 sec

Pbar Production ≤ 2 cycles/2.2 sec

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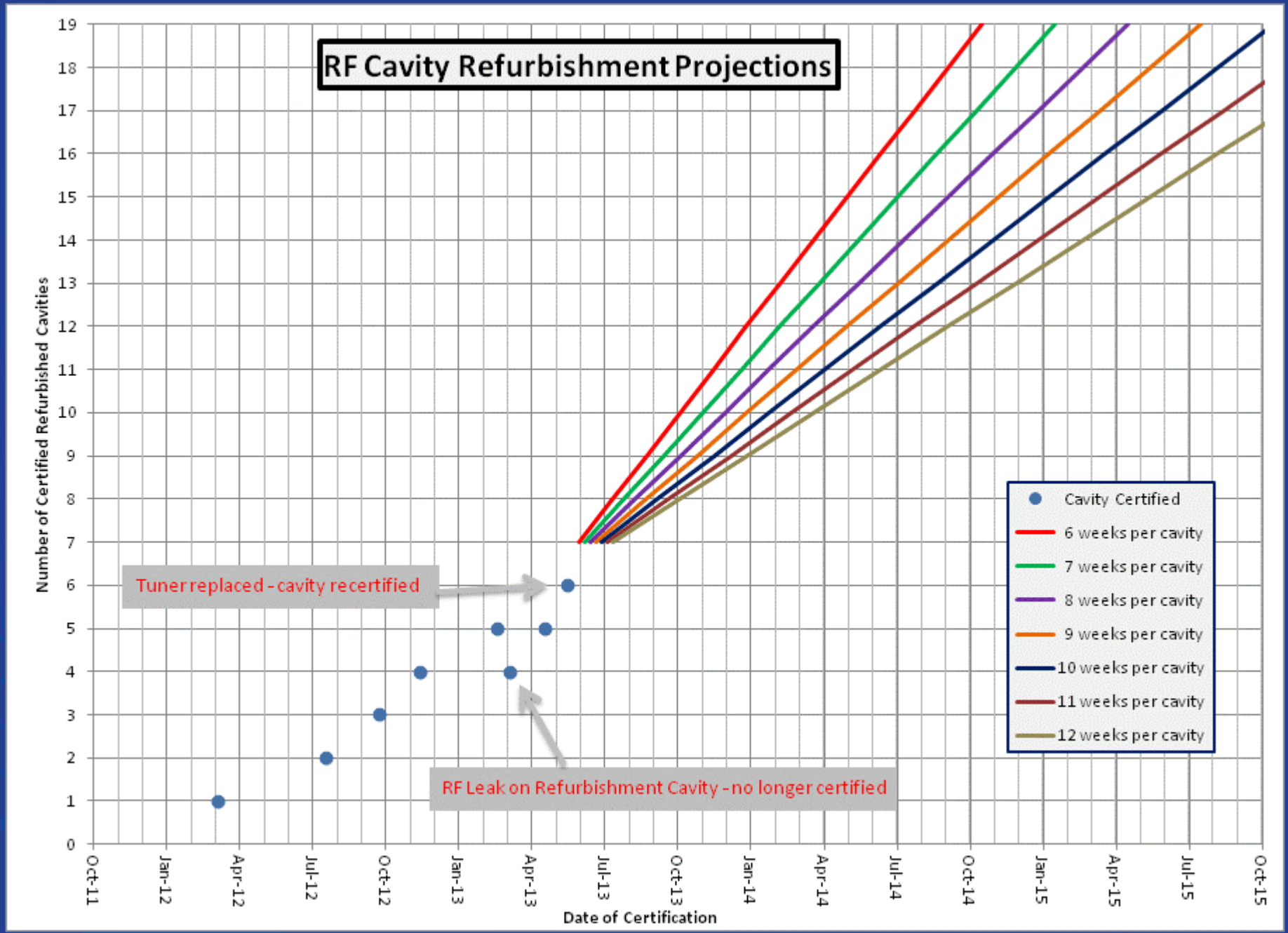
RF Cavity Refurbishment Projections
Number of Certified Refurbished Cavities
Date of Certification
Tuner replaced - cavity recertified
RF Leak on Refurbishment Cavity - no longer certified
Cavity Certified
6 weeks per cavity
7 weeks per cavity
8 weeks per cavity
9 weeks per cavity
10 weeks per cavity
11 weeks per cavity
12 weeks per cavity
0
1
2
3
4
5
6
7
8
9
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