NOvA meeting

PIP Update

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PIP Goals and Scope (Provided in 2011 – Directorate S. H. / DOE Talk)

Goals: Specific to the issues surrounding the FNAL Proton Source

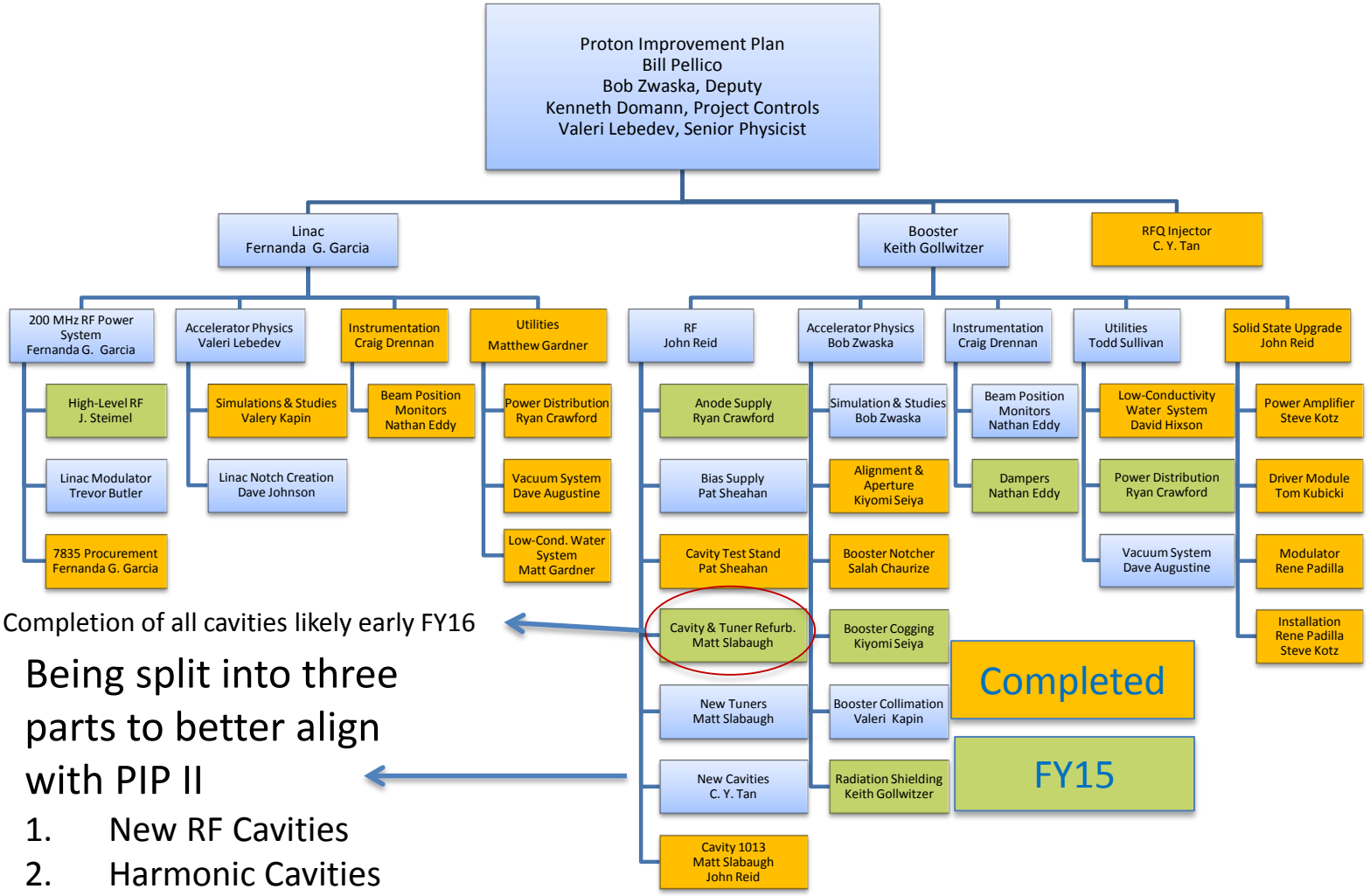
- Increase the beam repetition rate from the present **~7 Hz to 15 Hz**
- Eliminate major reliability vulnerabilities and maintain reliability at present levels **(>85%)** at the full repetition rate
- Eliminate major obsolescence issues
- Increase the proton source throughput, with a *goal* of reaching > **2E17** protons/hour
- Ensure a useful operating life of the proton source through at least 2025 – now 2030 (for the Booster)
- Align PIP to PIP II

Scope:

- Upgrading (or replacing) components to increase the Booster repetition rate
- Replacing components that have (or will have) poor reliability
- Replacing components that are (or will soon become) obsolete
- Studying beam dynamics to diagnose performance limitations and develop mitigation strategies
- Implementing operational changes to reduce beam loss

PIP – Task Structure

PIP has 32 Tasks (New Cavity being split) 16 are completed and closed 7 more tasks will be closed in FY15



Completion of all cavities likely early FY16

Being split into three parts to better align with PIP II

1. New RF Cavities
2. Harmonic Cavities
3. Reclaim/Rebuild 2 old Booster Cavities

PIP Organization Chart, Version 1.6

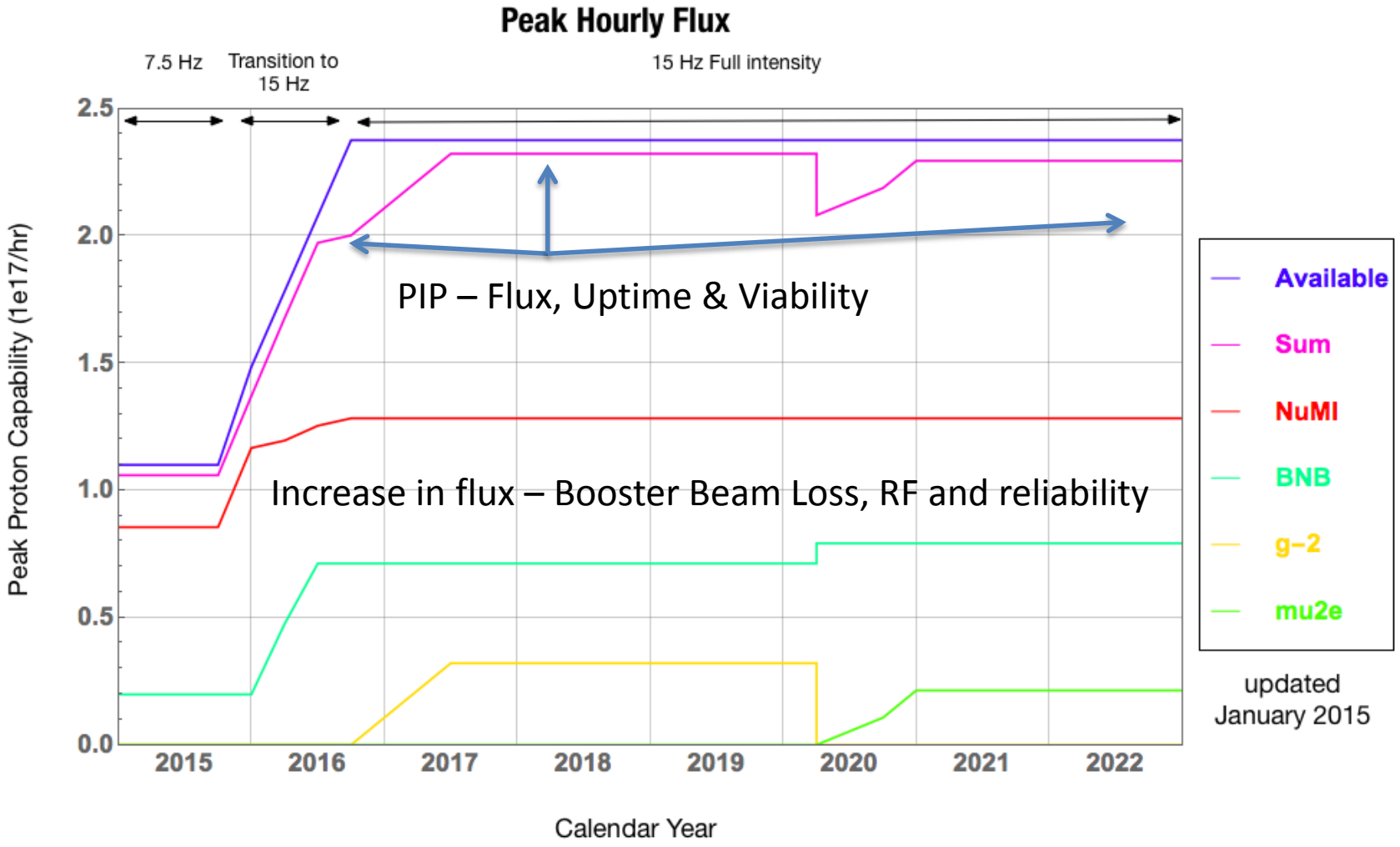
Past Year Highlights……

- RFQ/Sources are fully operational and with some small changes have become very stable
  - Fiber optics controls into HV
  - Up-graded Einzel lens
  - New operating points for gas and cesium
- Linac has closed several PIP tasks
  - Solid State drives installed (eliminated one tube)
  - Beam Optics/Physics completed
  - All of Linac Utility tasks completed
    - Power Distribution
    - Vacuum
    - Cooling systems
- Linac laser notcher successfully demonstrated

Past Year Highlights Continued….

- Booster PIP tasks have focused on RF and beam related items
  - Magnet (combined function)alignment completed
  - Booster beam notch system
    - New kickers (short – faster kickers)
    - New kicker power supply system
  - Additional Booster RF cavity rebuilt
  - Longitudinal dampers design completed and tested
  - Magnetic cogging system completed
  - 15 Hz testing of RF system has begun (East gallery)
    - West Gallery and rest of system test to begin within a week
  - New Booster tuners being built with new ferrite
  - Total Loss Monitor (TLM) system installed – testing underway

FY15: Proton Delivery Scenario (approximate, no shutdowns shown)



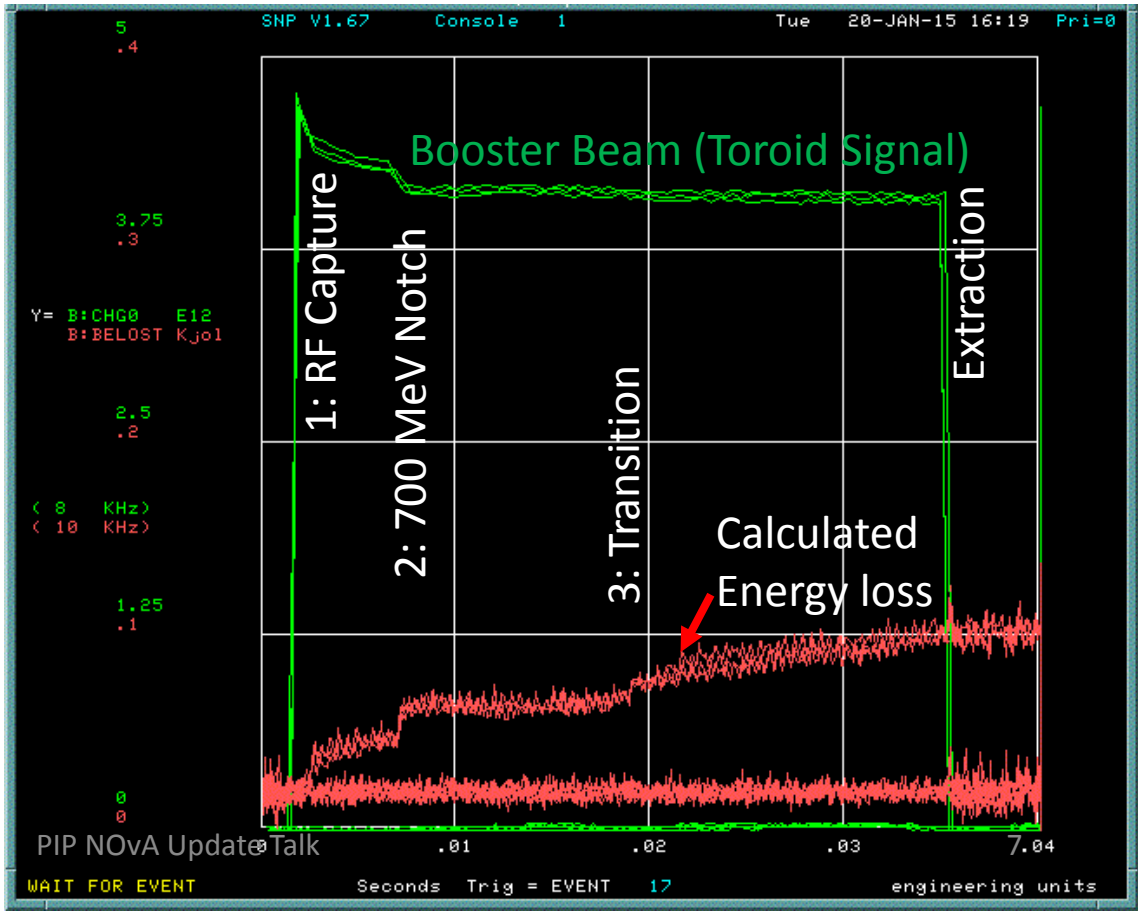
Booster Loss Profile

The present operational beam intensity at injection is about 5E12 ppp and extraction is 4.5E12 ppp. The total energy loss is 0.075 kJ in one Booster cycle and hence 1150 W when the cycle rate is 15Hz and it has to be reduced to half by 2016. Figure below shows the intensity and energy loss during a normal operation cycle. One point where significant beam loss occurs is at 6 ms after the injection when the extraction kicker gap was created.

There are basically three areas of Booster beam loss (Each contribute similar energy loss):

1. Injection: An adiabatic capture process using two sets of RF cavities is used to bunch the multi-turn injection. This process has several known loss generation issues.
2. Notching: The creation of a 3 bunch notch required to create a gap for extraction kickers rise times.
3. Transition: The transition jump and subsequent longitudinal dynamics results in both beam growth and loss.

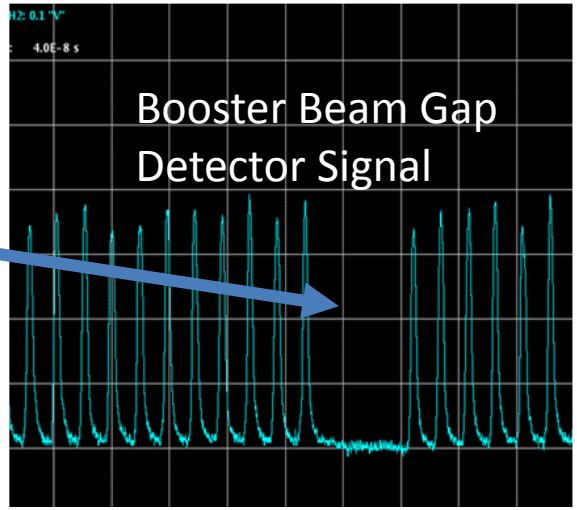
All three areas are being addressed under the Proton Improvement Plan (PIP).

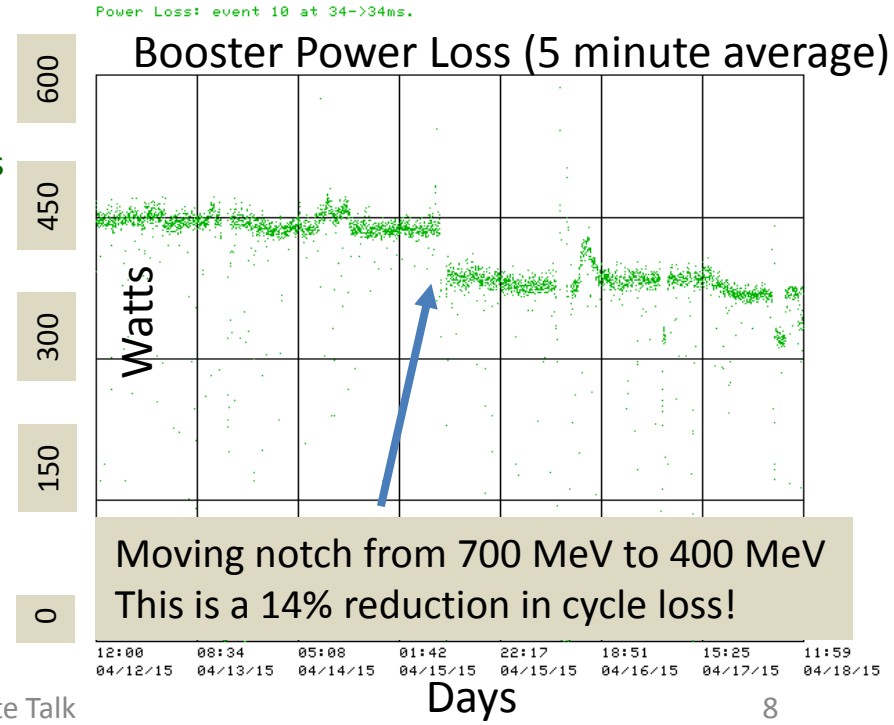


Notching Loss

- Booster beam requires a notch to allow for the rise time of extraction kicker
  - 40-50 ns notch (about 3 Booster RF buckets)
- PIP phased approach to Notch Creation
  - Phase I: notch relocation & new absorber **√ Done**
  - Phase II: kicker magnets & power system replacement **√ Done**
  - Phase III: New Cogging System **√ Done**
    - Notch was created @ 700 MeV because of limitations of old cogging system
    - New cogging system, completed 4/2015, allows only 400 MeV notching
    - Moving the notch from 700 Mev to 400 MeV – (40% reduction in notch energy loss and about 14% overall loss)
  - **Phase IIII: create notch in Linac (move loss to low energy – PreAcc)**

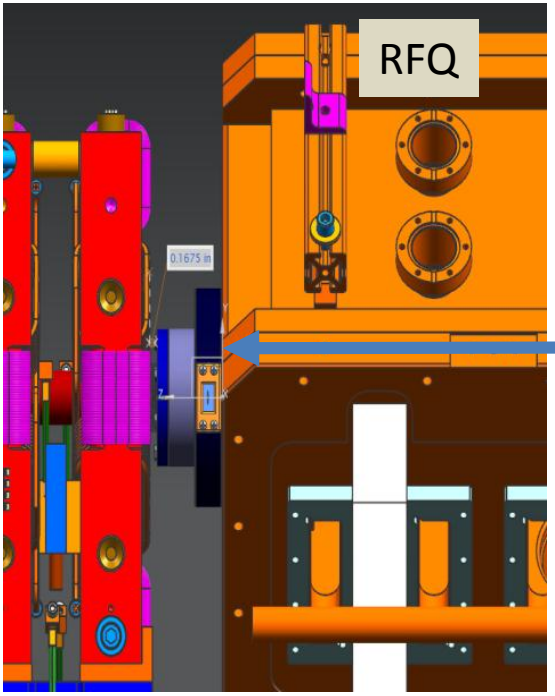
Bucket spacing at extraction energy ~ 19 nsec



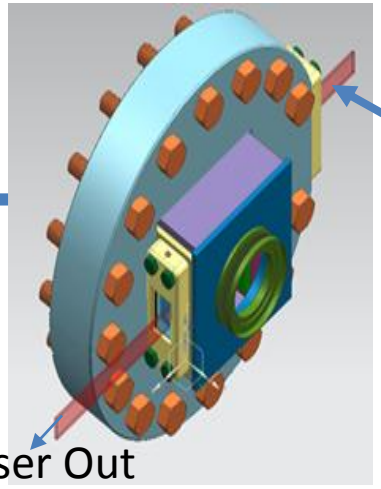


PIP – Accelerator Physics: Linac Laser Notch

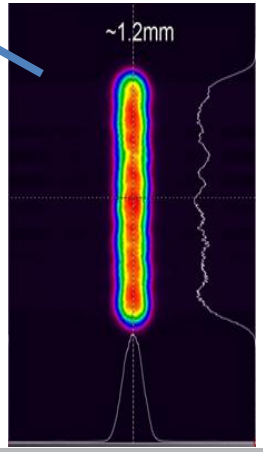
- **Phase IIII: create notch in Linac (move loss to low energy – PreAcc)**
  - **This would reduce Booster beam loss by another ~ 21%**

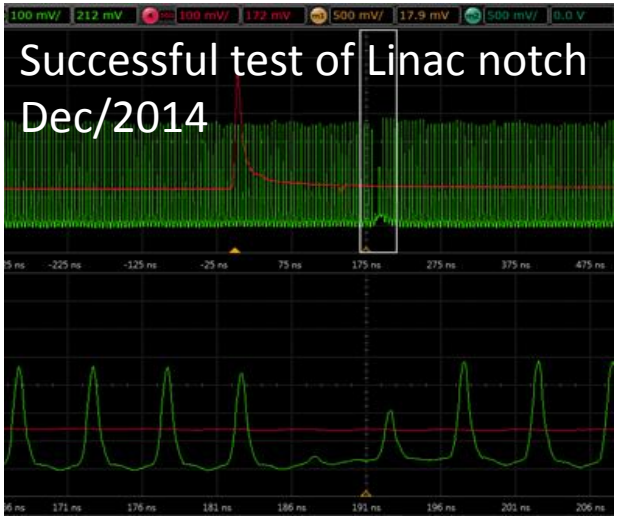


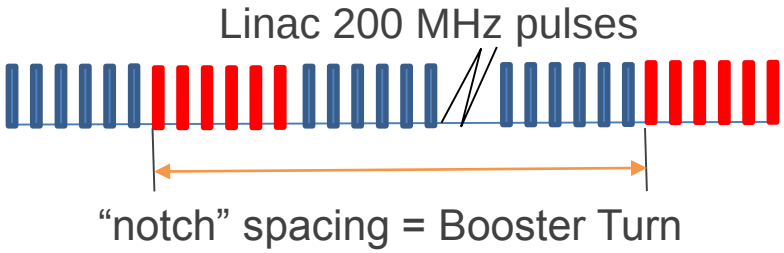
Optical cavity
(attached end of RFQ)



Laser profile



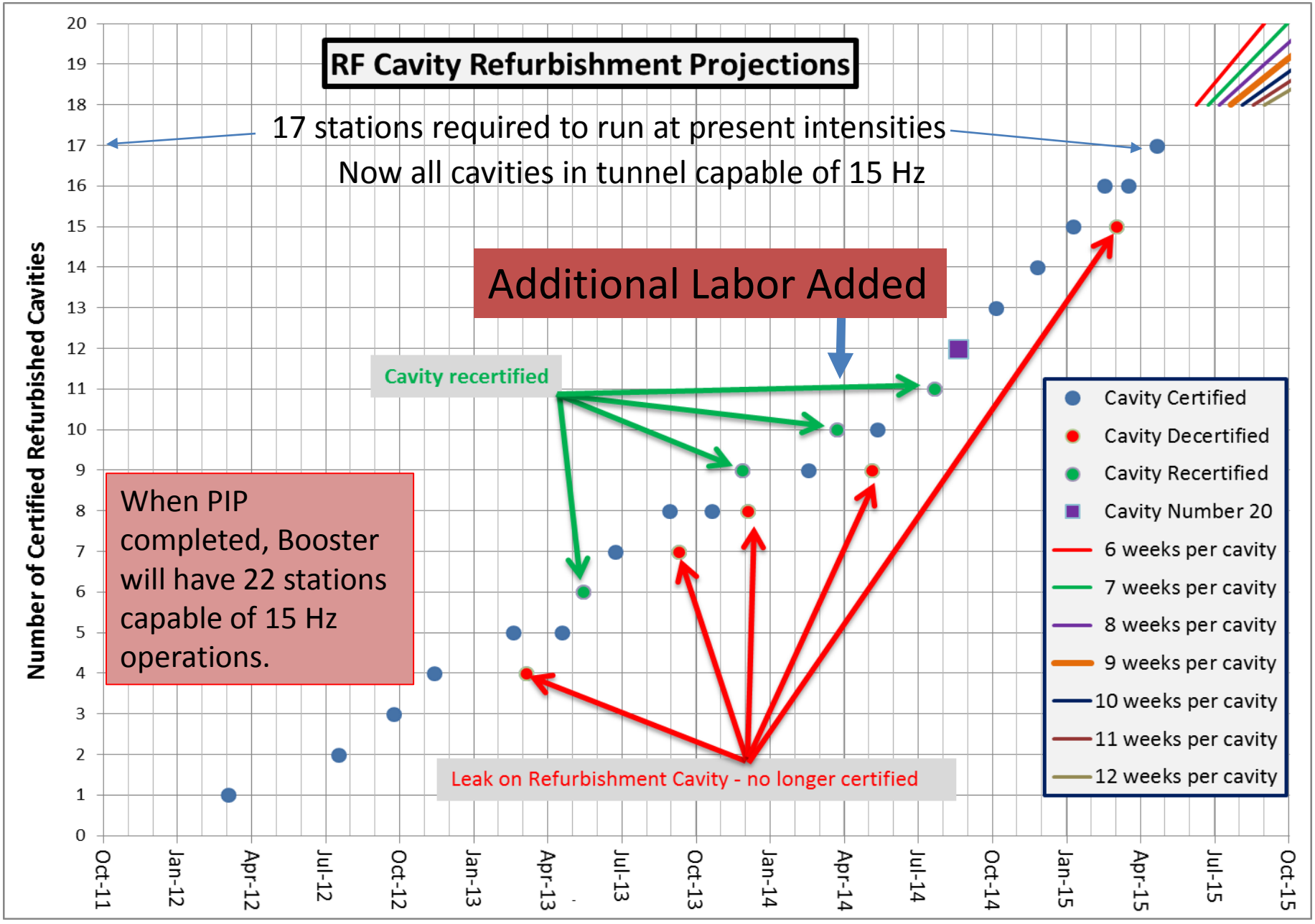




The completed system is planned to be installed this summer shutdown and commissioned in FY16.

Booster RF

- Critical for beam flux, loss, quality and reliability
  - Finished RF solid state drive system (FY13)
  - Rebuilt a reclaimed Booster cavity (#20) past year
  - Reclaiming two more Booster cavities – then will install in FY16
  - Refurbished 6 RF cavities since May of last year
    - Past week removed last un-refurbished cavity from tunnel
    - 15 Hz testing of entire system to begin within the week!
      - 15 Hz testing has been underway for half the RF stations since Jan.
    - Beam tests at 15 Hz to be demonstrated before the summer shutdown
  - New Anodes (planned to be installed this summer) nearly complete
  - Bias supplies for 15 Hz operations 80% complete


RF Cavity Refurbishment Projections
17 stations required to run at present intensities
Now all cavities in tunnel capable of 15 Hz
Additional Labor Added
Cavity recertified
When PIP completed, Booster will have 22 stations capable of 15 Hz operations.
Leak on Refurbishment Cavity - no longer certified
Number of Certified Refurbished Cavities
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Oct-11
Jan-12
Apr-12
Jul-12
Oct-12
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Cavity Certified
Cavity Decertified
Cavity Recertified
Cavity Number 20
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

What to expect – FY16

- The Proton Source will start to ramp up intensity in FY16.
  - Higher RF cycle rates: no longer limited to 7.5 Hz
- The Booster will be limited by losses and/or until a new shielding assessment is completed.
  - Beam physics and control of losses will be critical in FY16
- Reliability issues still exist
  - PIP will continue to address the issues as planned
  - Finding available resources to complete the work is always a challenge