Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Accelerator prospects for FY18 and beyond

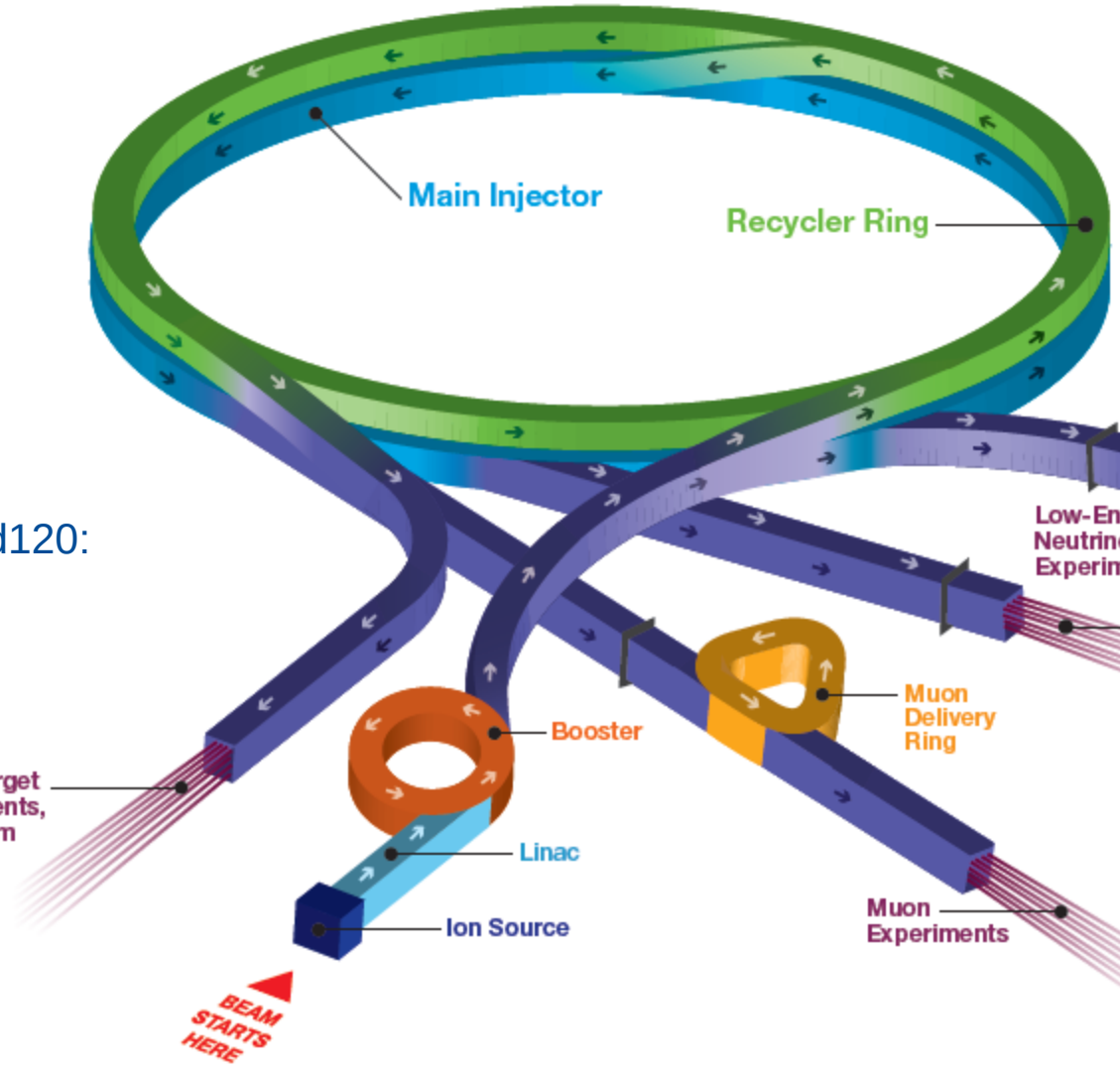
Mary Convery

PAC meeting

6 July 2017

Introduction

Fermilab accelerator complex



SwitchYard120:
SeaQuest,
LArIAT,
test beam

Short Baseline Neutrino:
MicroBooNE
(ICARUS, SBND)

Long Baseline Neutrino:
NOvA,
MINERvA
(LBNF/DUNE)

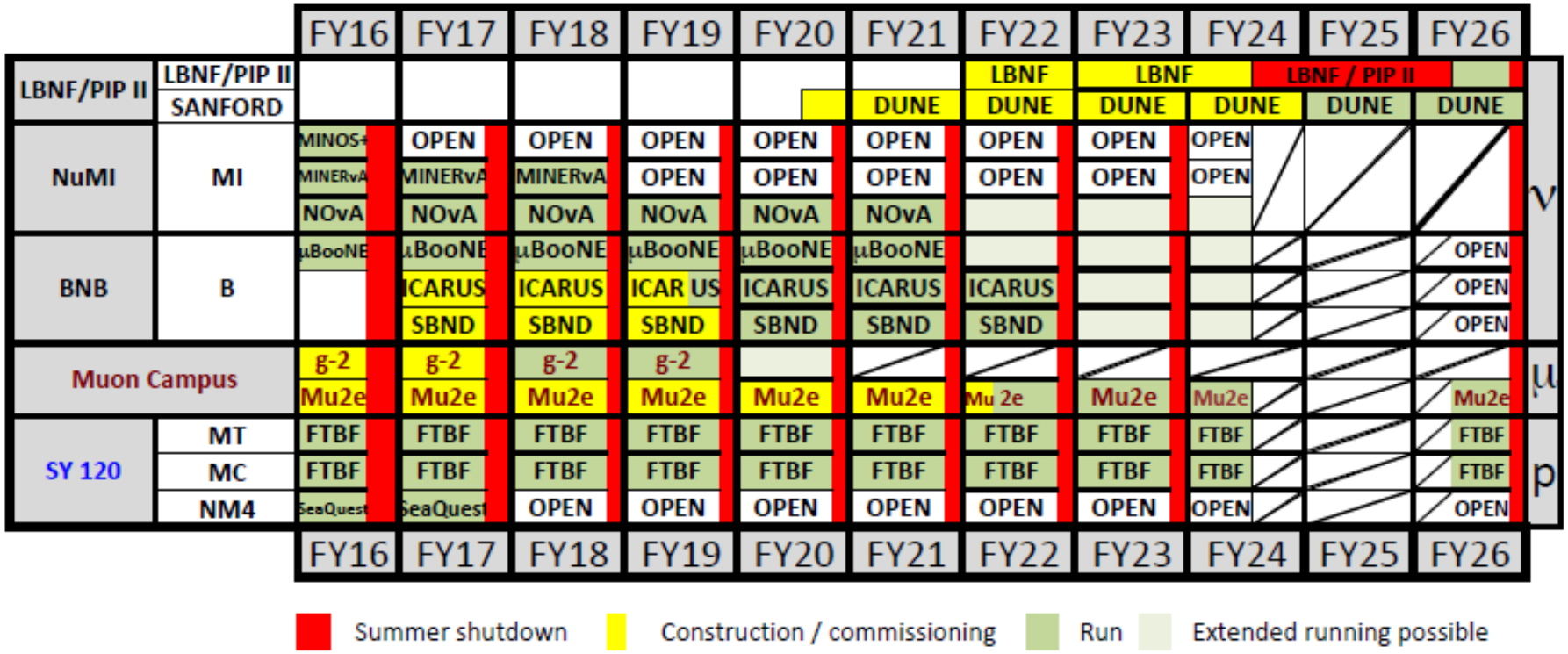
Muon Campus:
g-2, (Mu2e)

Fermilab

Fermilab experiments long range plan

Fermilab Program Planning
20-Feb-17

LONG-RANGE PLAN: DRAFT Version 7a



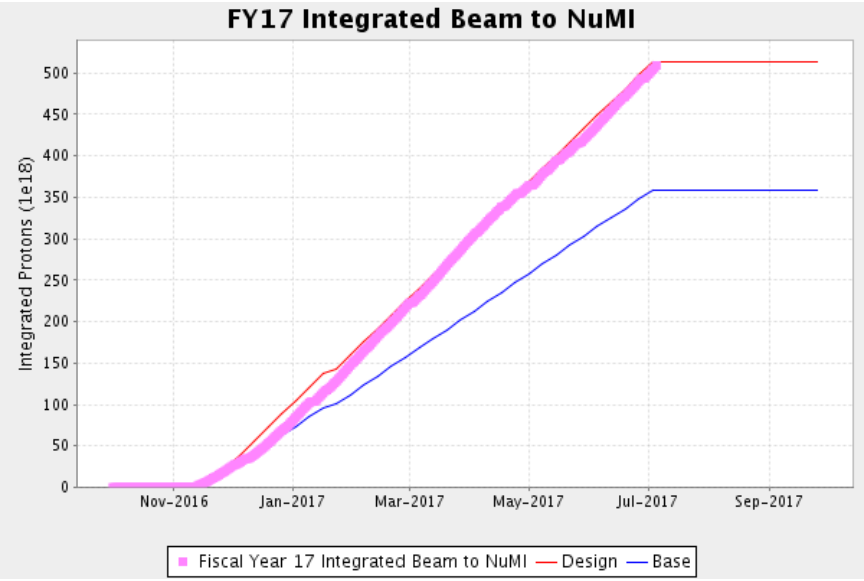
NOTES:
1. Mu2e estimates 4 year running starts mid-FY22 after 18 months commissioning
2. DUNE without beam operates in FY25-FY26

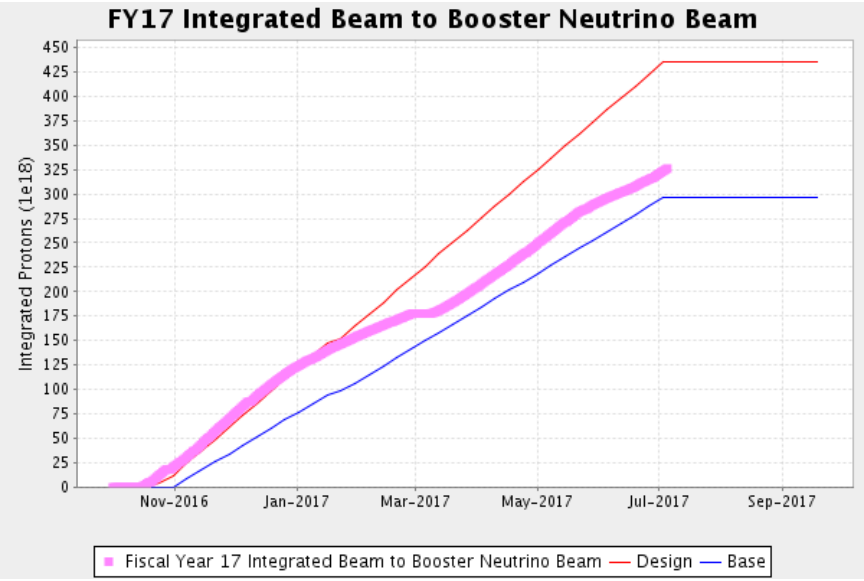
Accelerator Operations Priorities for FY18-24

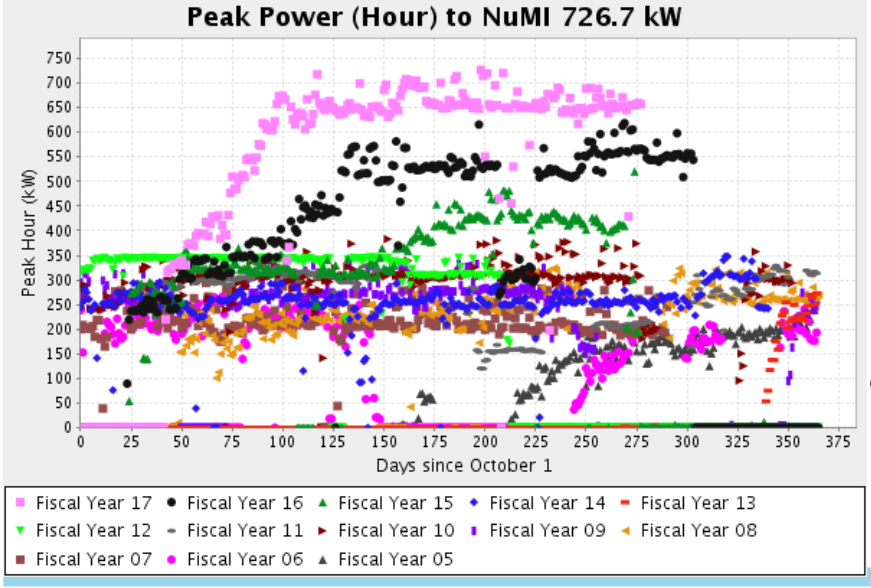
- Deliver beam to NOvA at 700+ kW beam power, achieve performance metrics, and support full experimental program
- Operate beam to the g-2 experiment and start commissioning beam to Mu2e in FY20
- Complete the Proton Improvement Plan (PIP) to ensure a useful operating life of the Linac through 2025 and the Booster through 2030
- Develop and execute PIP-I+ to increase beam power to NOvA to ~900 kW prior to PIP-II

FY17 Accomplishments

FY17 Accelerator performance goals met





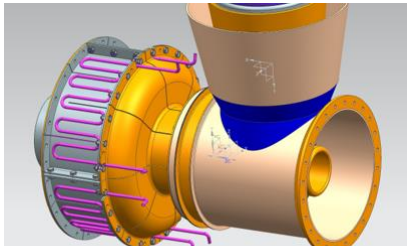


- Final modifications for new Booster shielding assessment (up to 2.7×10^{17} protons per hour) were put in place in March
- Running above 700 kW to NuMI (630 kW when 10% of timeline to SY120 fixed-target program)

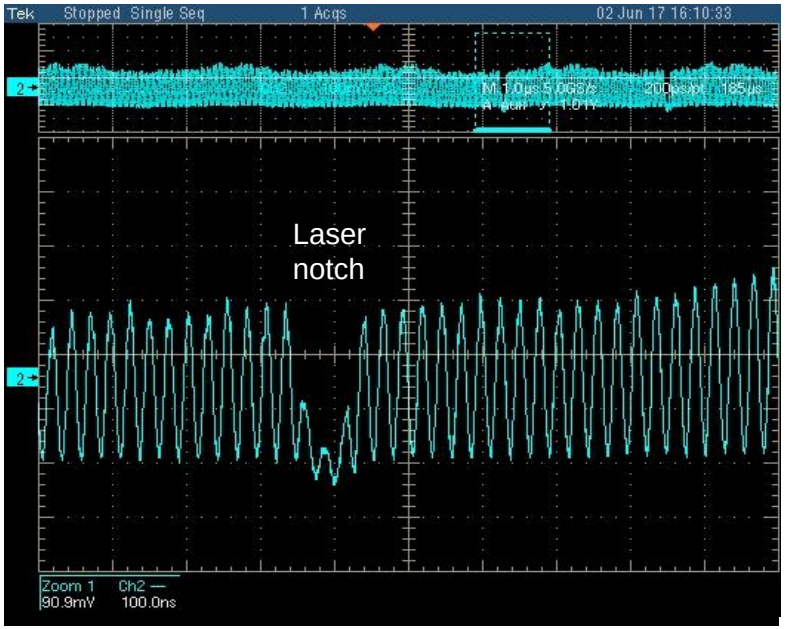
Proton Improvement Plan (PIP)

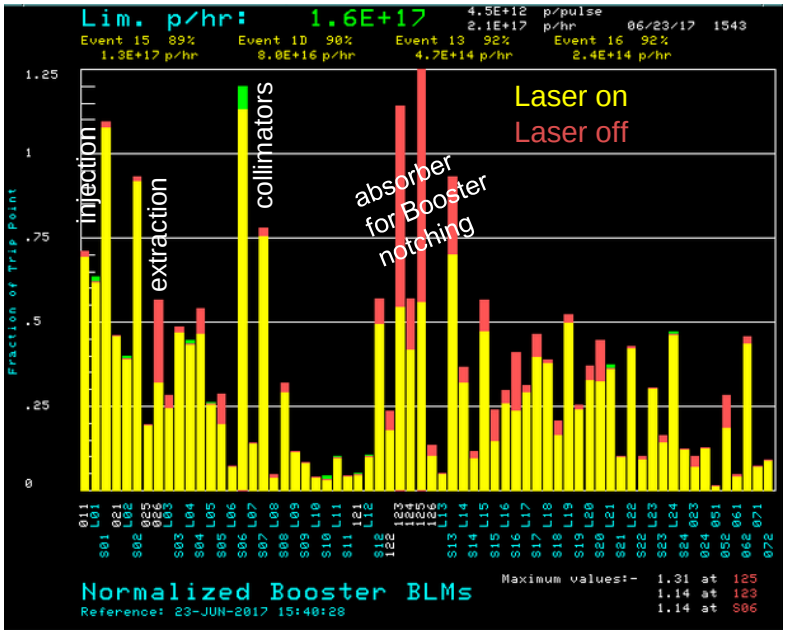
- Goals: 15 Hz (done), >2x10^{17} protons/hour (done), reliability
- Linac modulator
  - 28-cell since March 2016, 54-cell operating, install two more during summer shutdown
- Linac laser notcher
  - See next slide
- Booster beam physics improvements continue
- Booster RF
  - Total of 22 cavities by end of shutdown to increase Booster reliability
  - Prototyping 2nd harmonic perpendicular bias cavity
  - Also prototyping larger aperture replacement cavities capable of 20 Hz
  - Delay production of replacement cavities till PIP-I+
- Complete PIP in FY18

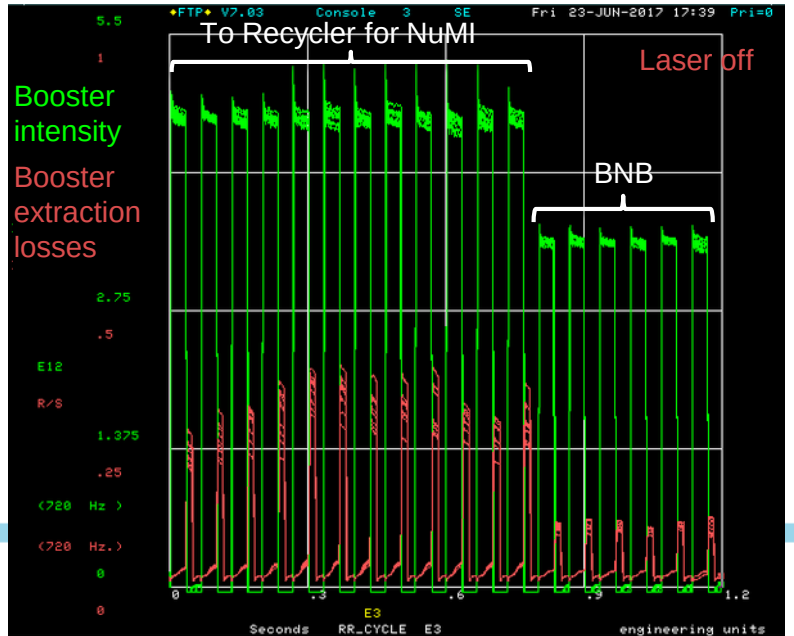

54-cell Marx modulator

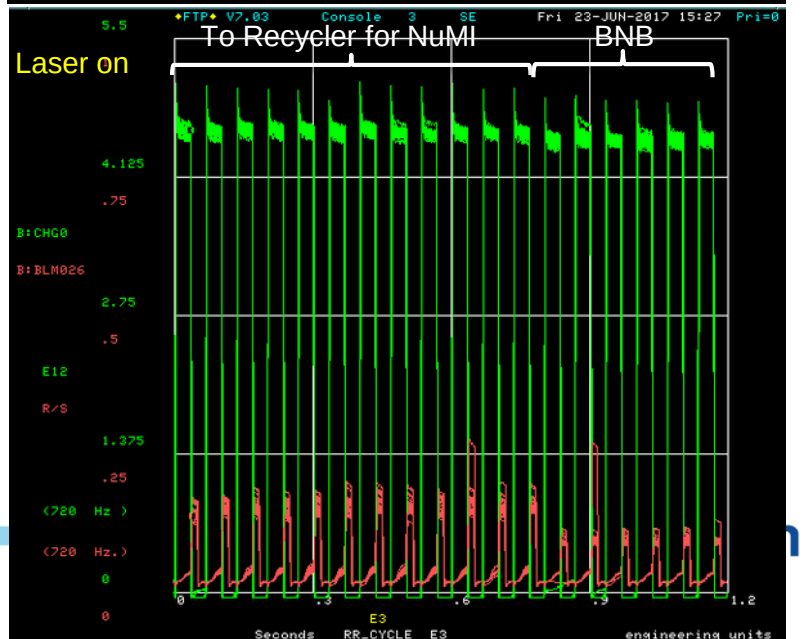

perpendicular bias cavity

Linac laser notcher and loss reduction in Booster

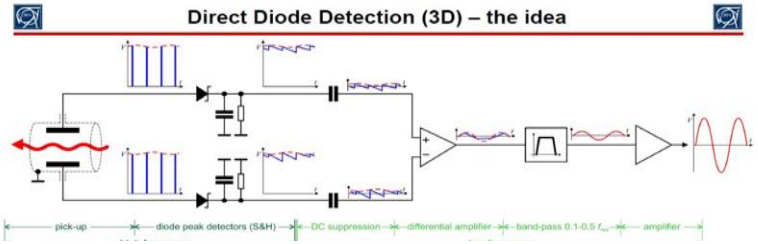




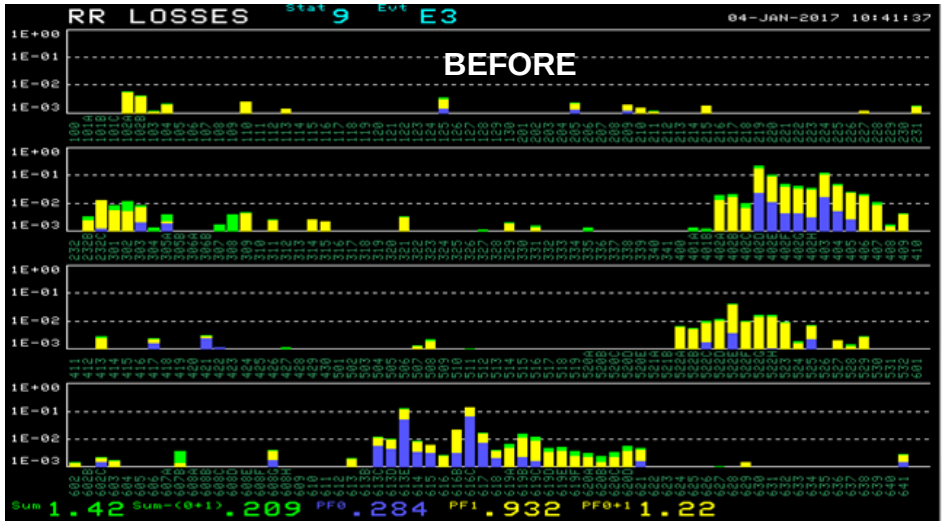


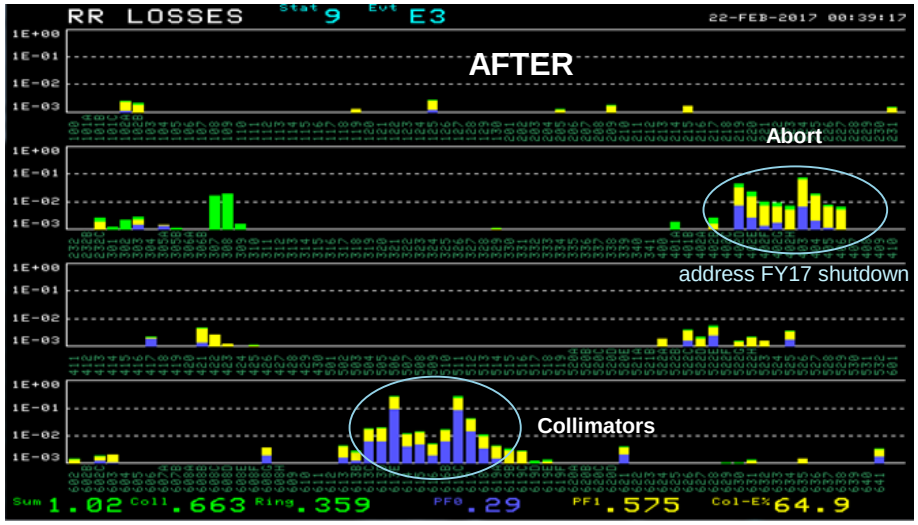


Recycler collimators and new damper (reduce/control loss)



- Bunch-by-bunch damper didn't work when bunches overlapped during slipstacking
- Implemented diode frequency damper
- No longer need for high chromaticity during slipstacking
- Reduced losses from tune shift

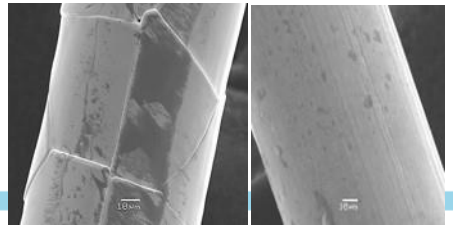




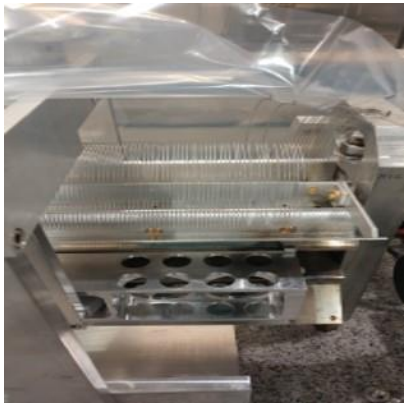
SY120 program

- Had to replace both upstream and downstream MI septa this year due to broken wires
- Have ready spare with 2 mil wires (upstream or downstream)
- Conditioning 4 mil spare (best used in downstream position)
- Preparing to rewire another septa with 2 mil wires

Examining Broken Wires



Replacing Broken Wires



Replacing Septa In MI Tunnel

Commissioning of beam to g-2

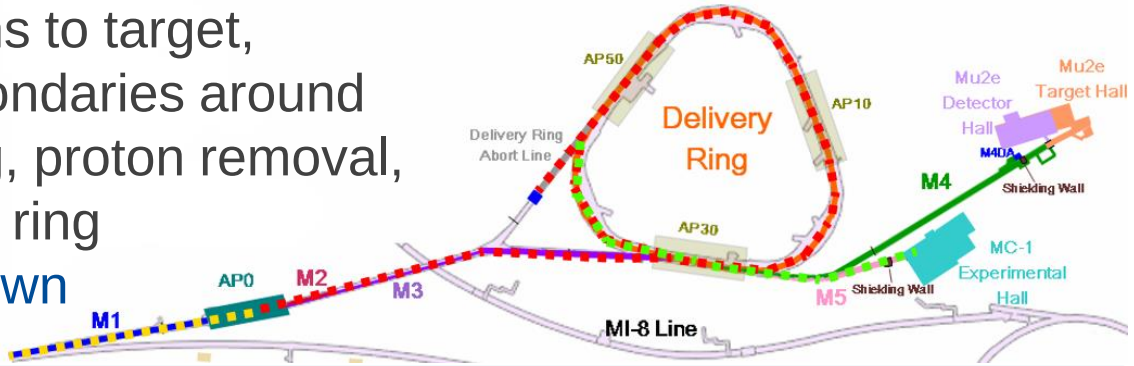
1) 8 GeV protons bypass target, through shared M4
   - If time also around Delivery Ring

✓

2) 8 GeV protons to target, 3.1 GeV secondaries to g-2 ring (100:1 protons to muons)

✓

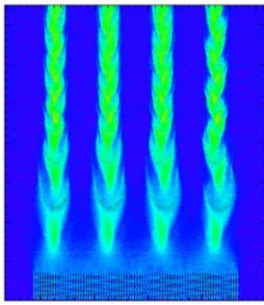
3) 8 GeV protons to target, 3.1 GeV secondaries around Delivery Ring, proton removal, muons to g-2 ring
   - after shutdown



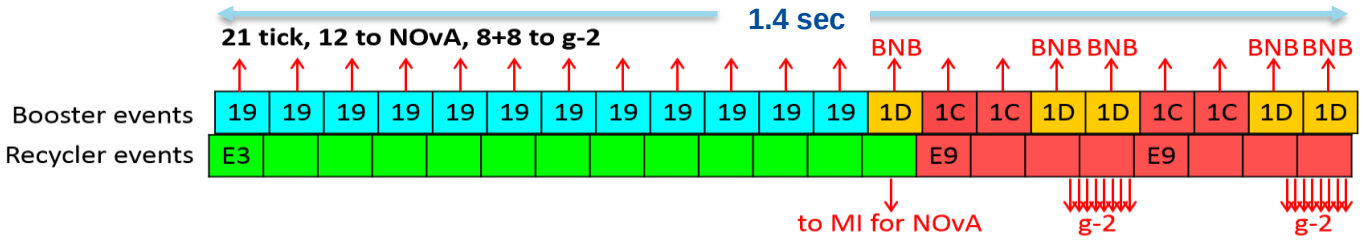
Fermilab

Commissioning of beam to g-2 (beam power)

- Currently limited by
  - Single Recycler bunch instead of 16 per 1.33s(1.4s) cycle
    - Using old Pbar pulsed septa magnets due to delay in production of new; insufficient cooling for g-2 rep rate
    - Still commissioning target station pulsed power supplies (100 Hz bursts)
  - Number of 1.33s(1.4s) cycles with beam
    - Aborting 3 of 4 bunches in Recycler because of Pbar septa
    - Have to limit irradiation of abort line (exposure during shutdown)
  - Intensity per pulse
    - Not removing protons because of inefficient transmission through the 4 revolutions around Delivery Ring (DR)
    - Protons in MC-1 trip rad detectors which limits muon intensity
- During the shutdown we will install new pulsed septa magnets, finish commissioning pulsed power supplies, check DR alignment

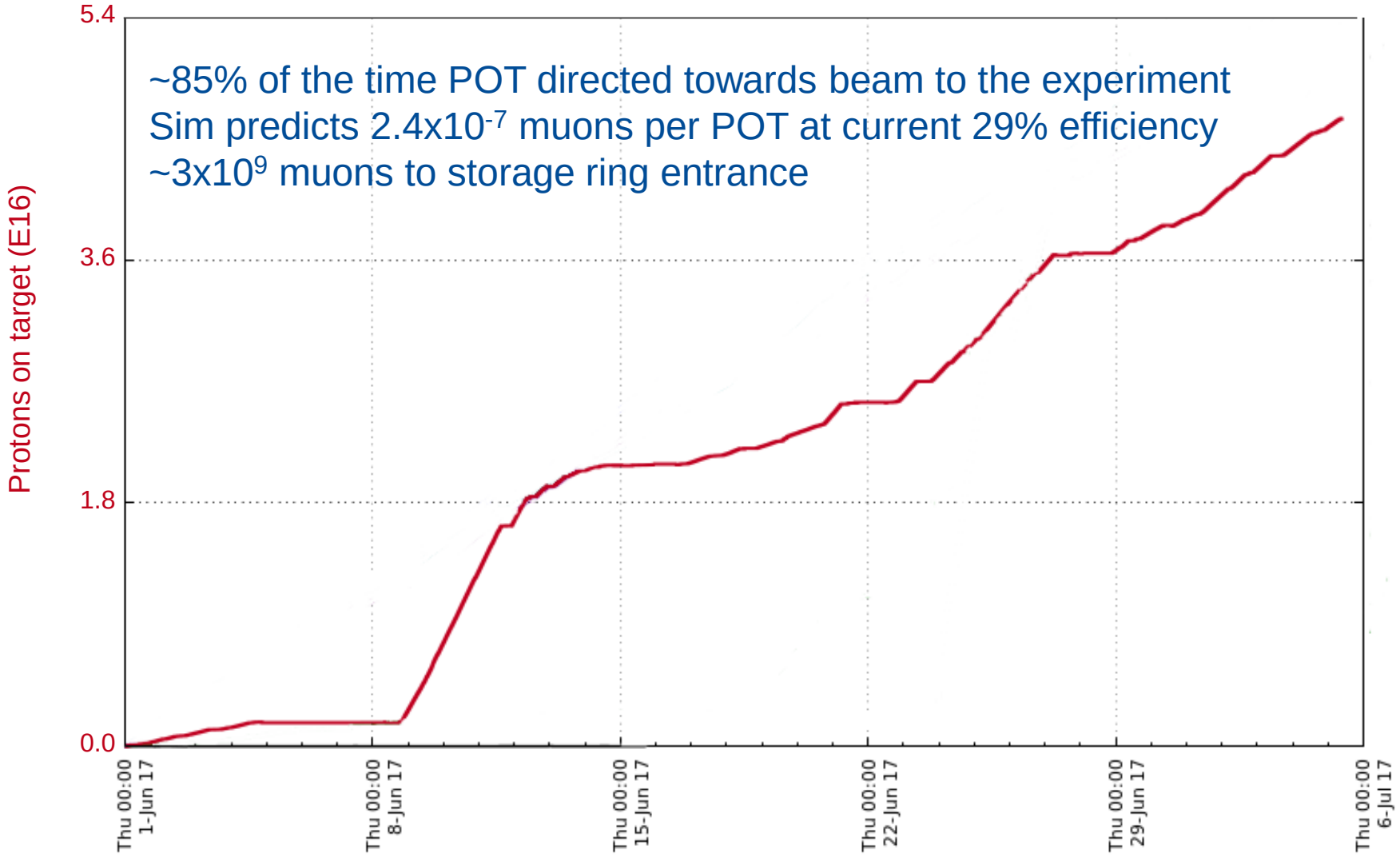


One Booster batch formed into four 2.5 MHz bunches in Recycler



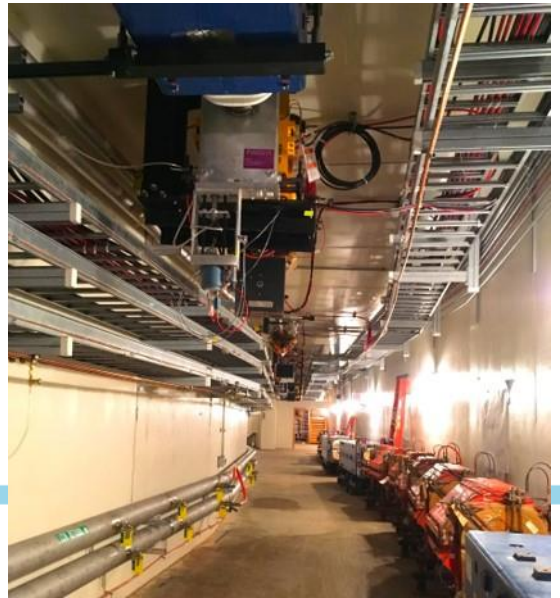
Fermilab

Beam delivery for g-2 detector commissioning



FY17 shutdown plans

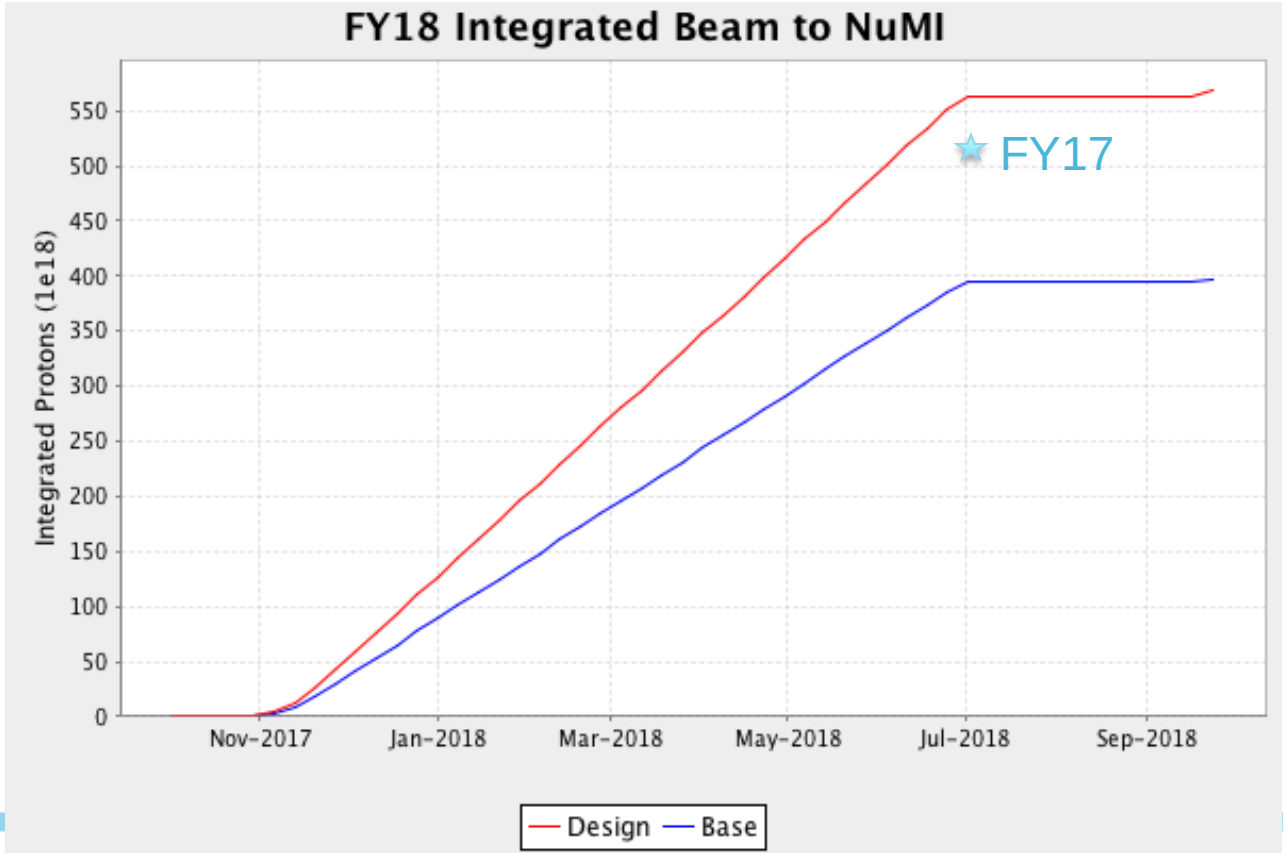
- Complete TSP2IP Recycler vacuum conversion (last of 3 yrs)
- Replace Recycler abort Lambertson with larger aperture one
  - Also larger-aperture beampipe in 52 region
- Install 2 more Marx modulators (leaves 2 for FY18 shutdown)
- Finish installation for 22 RF cavities in Booster
- Install new Muon Campus septa magnets
- Install Mu2e magnets and cabling



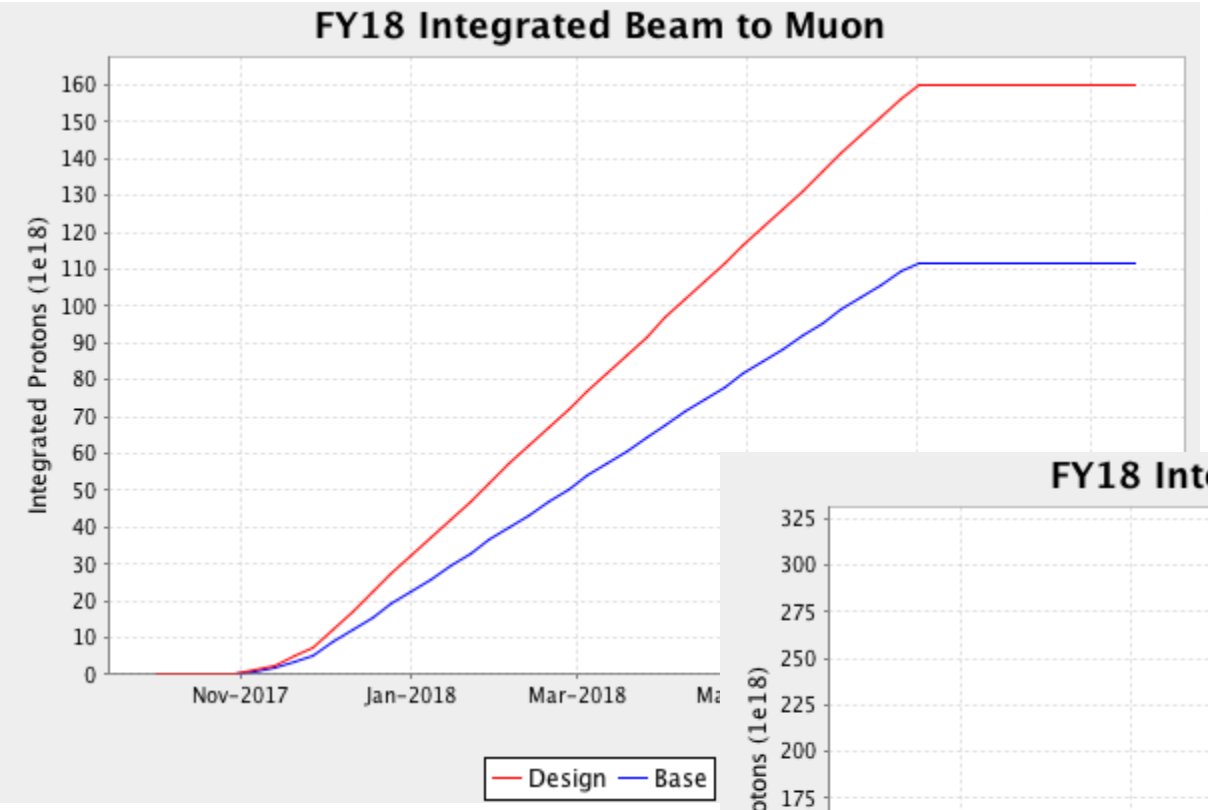
FY18 Projections

Projections for FY18

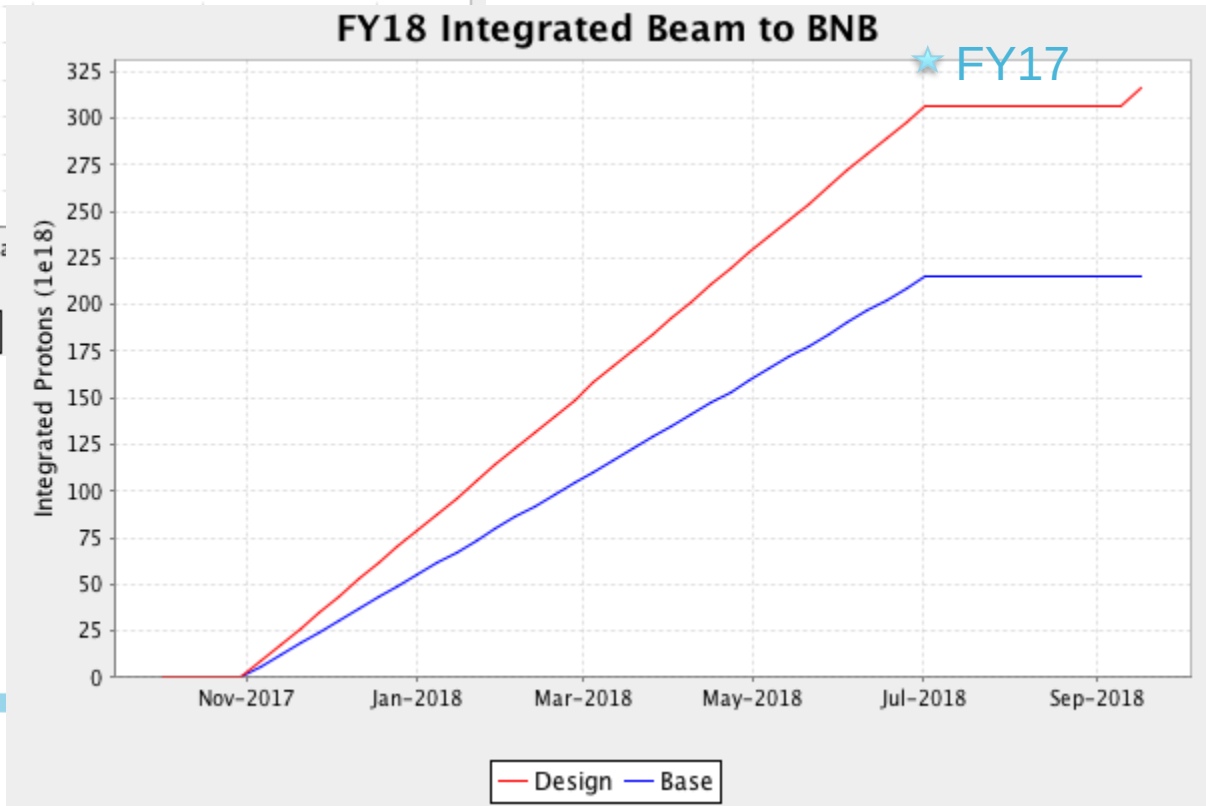
- Assume SY120 takes 5% of timeline (SeaQuest complete, test beam 12h/day)
- Increase protons per pulse to NuMI to make up for 1.33s→1.4s cycle time (for Muon Campus)



Projections for FY18 (cont)



~20-27 months at full operational beam power to reach $4x10^{20}$ POT



Plans for FY18 and Beyond

PIP-I+

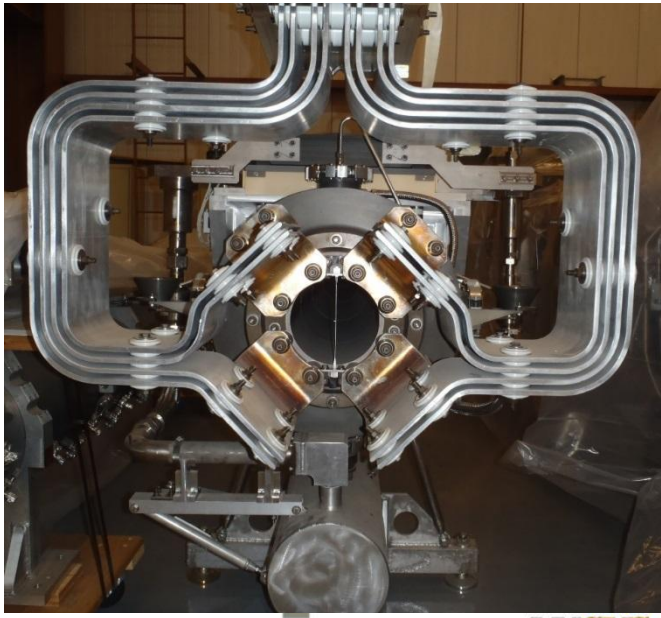
- Proton Improvement Plan (PIP) has been very successful
- PIP-I+ is proposed as a follow-on to PIP, before PIP-II
- Program of Accelerator Improvement Projects (managed like Muon Campus)
- Aim at increasing NuMI intensity to 900 kW prior to PIP-II
- Benefit of many improvements will carry over to PIP-II
- Address aging accelerator infrastructure

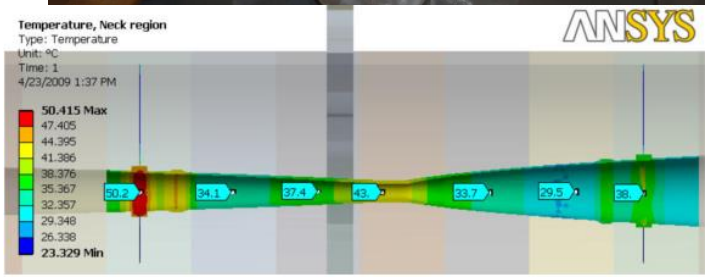
Possibilities to increase beam power to NuMI target

- Shorten MI cycle time to 1.2s
  - 11% increase from current conditions (1.33s→1.2s)
  - Cuts rate to Muon Campus in half (vs 1.4s cycle) unless also increase rep rate to 20 Hz ✘
  - May be able to use this mode between g-2 and Mu2e operation
- Increase intensity from Proton Source
  - 28% increase (4.3E12→5.5E12 protons per pulse)
  - Requires improvements to keep beam quality up and reduce losses even further than achieved by PIP
- Increase rep rate from 15 Hz to 20 Hz
  - Requires modifications to Linac ✘
  - Requires significant control system changes
  - Requires RF upgrades in Booster and MI/RR
- All of these require a target station that is robust at 1 MW

PIP-I+: Make NuMI target station robust up to 1 MW

- Can't increase beam power to NOvA without this
- Minimum 2 years
- Target window, baffle, target
  - LBNF target design
- Targetry instrumentation
- Horns, stripline
  - Cooling
- Air, water, radiation protection
- Decay pipe window
  - Corrosion observed on upstream window in 2007





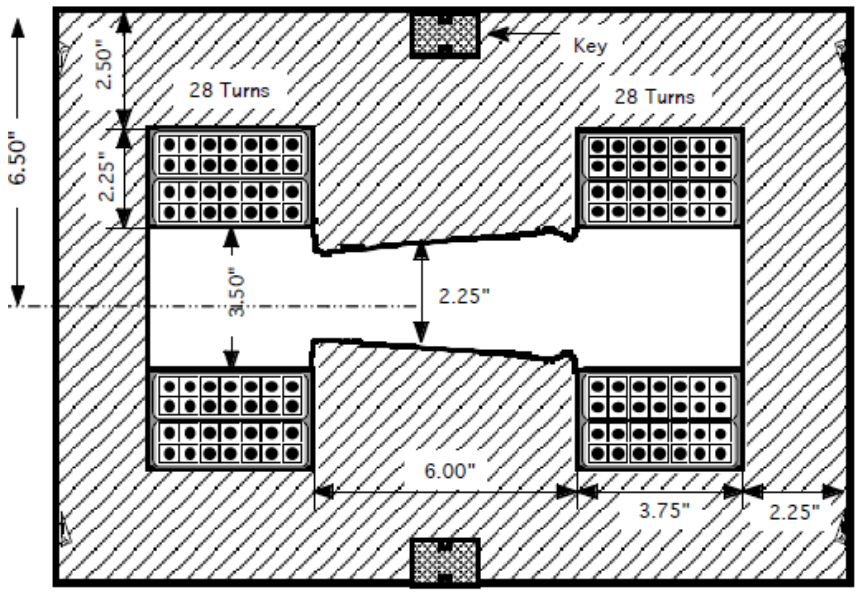
- Limit 1 MW else significantly more expensive

PIP-I+: Increase intensity per pulse from Booster

- Significant cross-over and benefits to PIP-II
- Booster collimators **(currently on PIP-II)**
  - Capture losses (reduce tunnel activation and need for new shielding)
- Booster transverse dampers **(currently on PIP-II)**
  - Lower chromaticity at injection to reduce losses
- Booster ramped doglegs
  - Ramp extraction dogleg magnets so field is near zero at injection to reduce injection losses due to lattice distortion
- Shielding assessment
  - Need to see losses after above improvements

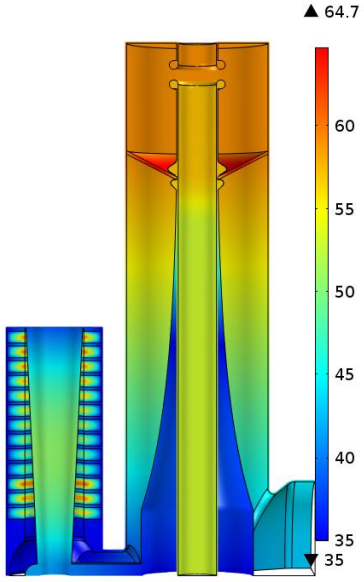
PIP-I+: Booster magnets

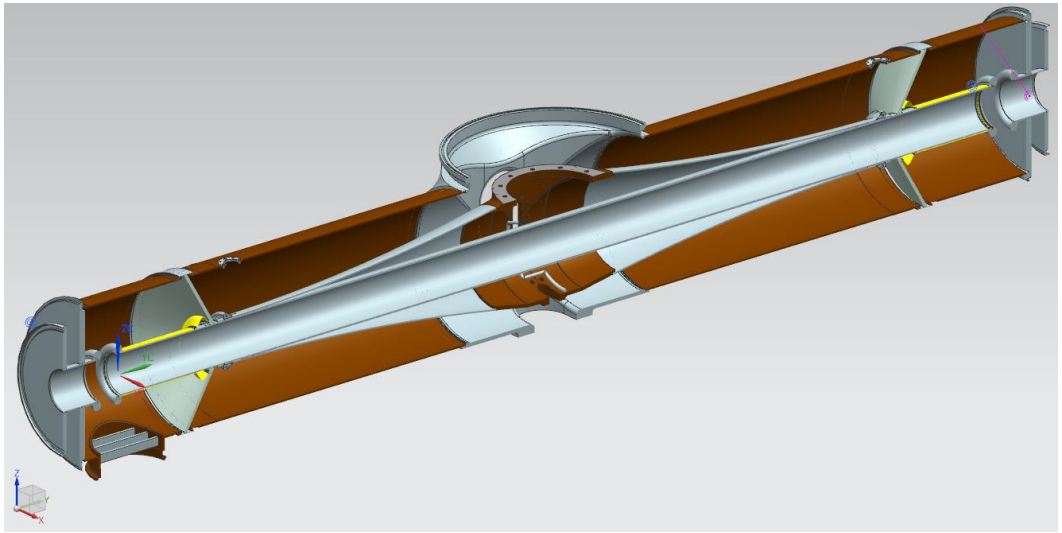
- New Booster defocusing-type combined function magnets, shorter with larger aperture
- Design benefits PIP-II, especially injection
- If done sooner, would benefit beam to NOvA
- Propose to design and build 4



PIP-I+: New Booster cavities

- Currently on PIP, but delay to get benefits of PIP-I+ sooner
- 20 cavities, 60 kV, also larger aperture
- Needed for 20 Hz running with PIP-II
- May be needed for reliable running at 15 Hz (haven't really put rebuilt cavities to the test yet)
- Complete prototyping on PIP in FY18, then build cavities on PIP-I+





PIP-I+: Main Injector

- Shielding assessment for up to 1.5 MW
  - Likely address penetrations from tunnel to service buildings
  - Install Total Loss Monitors in areas of concern

- Gamma-t jump **(currently on PIP-II)**
  - New quadrupole magnets to cross transition more quickly to reduce transition losses

PIP-I+: Infrastructure

- Controls
  - Replace obsolete controls hardware with Hot-link Rack Monitor (HRM) hardware, as has been done in recent installations such as the Muon Campus

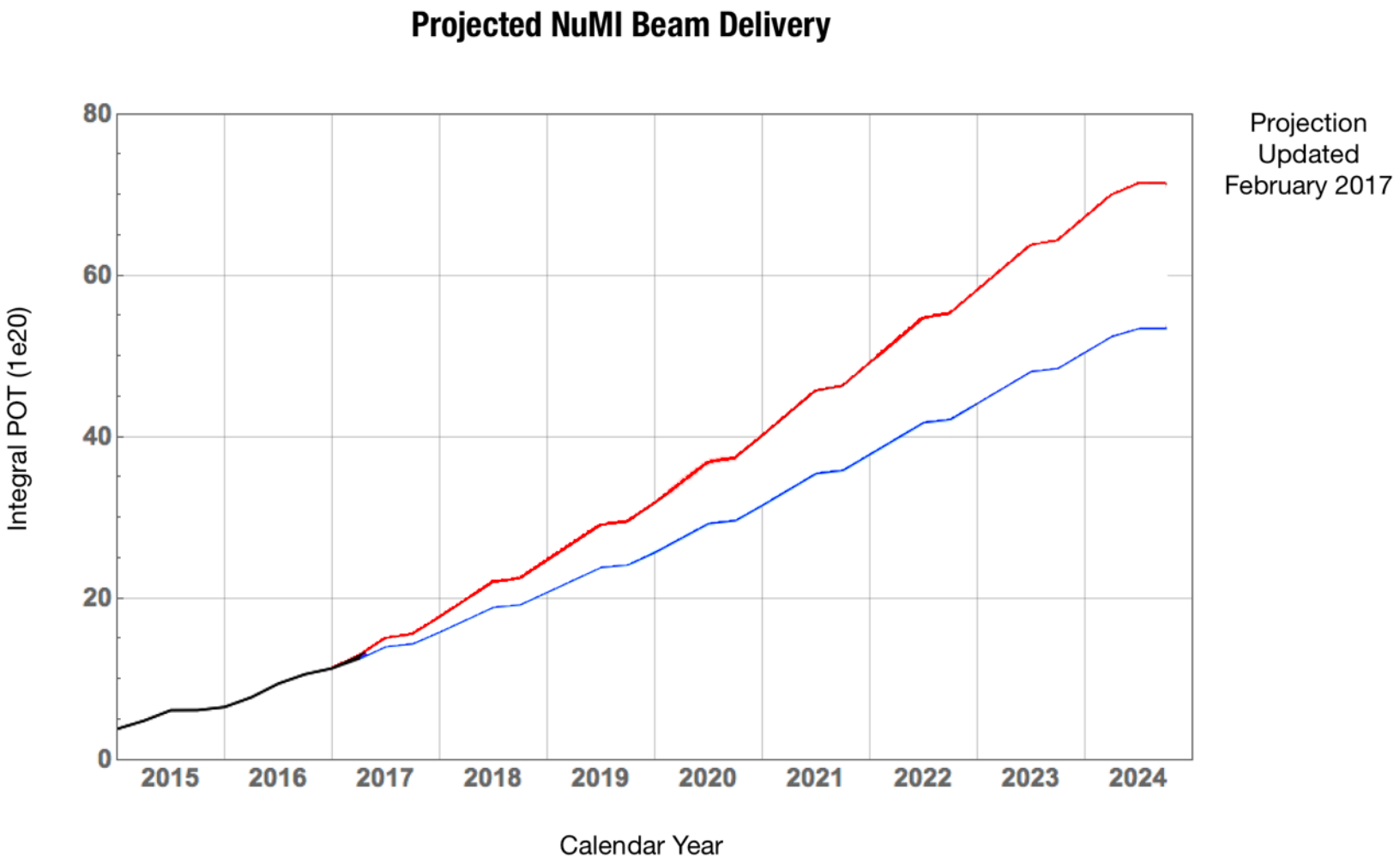
- Examining other infrastructure needs to determine if appropriate for PIP-I+

Possible PIP-I+ Schedule

	FY18	FY19	FY20	FY21	FY22	FY23	FY24
NuMI target station							
Booster intensity							
Booster magnets							
Main Injector							
Infrastructure							
PIP Booster cavities			Push off this task from current PIP schedule to allow NuMI target work				
Power (kW)	700	700	800	900	900	900	900

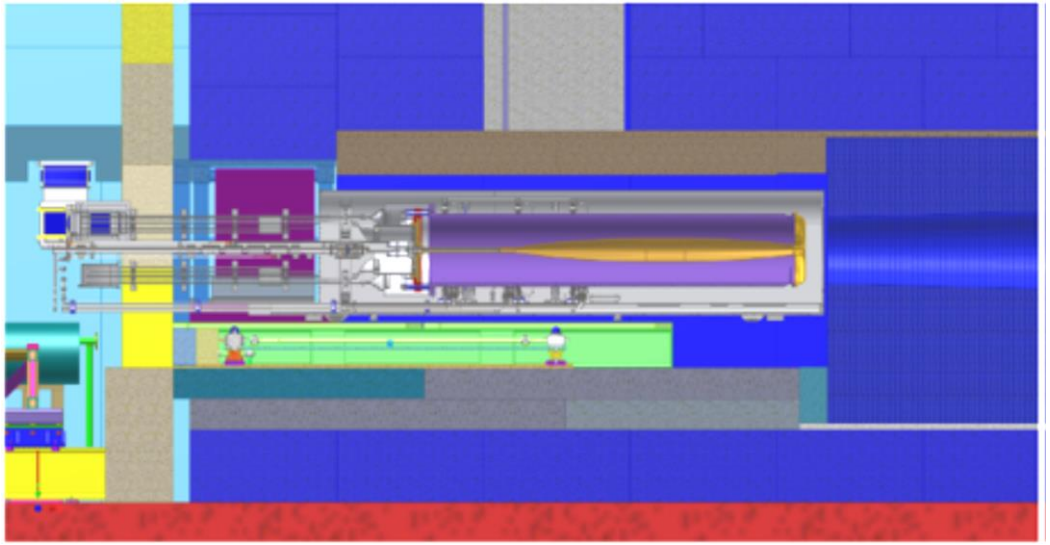
- 2-3 years to upgrade NuMI target station (resource limited)
  - May be able to increase intensity limits incrementally
- Assumed a fixed amount of funding per year
  - Not funded in FY18 under PBR
  - DOE has asked what profile we would need to finish asap
  - Working on resource-loaded schedules

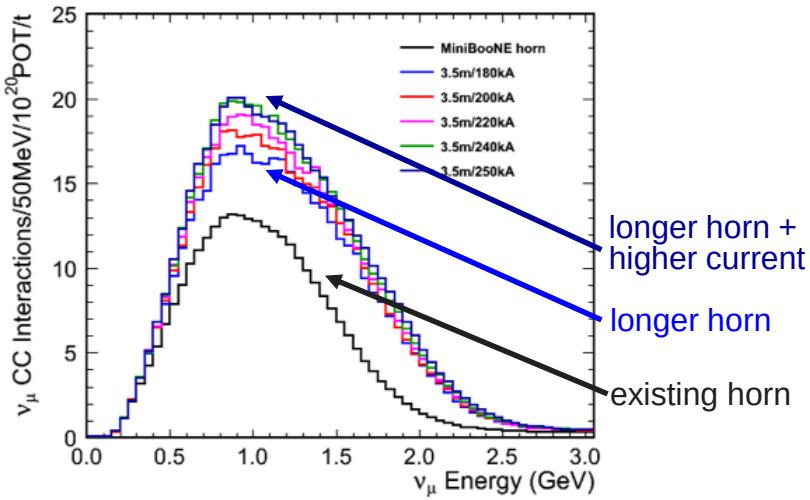
Projected Protons to NuMI with PIP-I+



Short Baseline Neutrino program

- Had considered Accelerator Improvement Projects to upgrade BNB horn and power supply





- We are not planning to pursue this; assuming limited AIP funds and that priority goes to NOvA / PIP-I+

Summary

- We have met our performance goals for FY17
- With Recycler upgrades, PIP, and g-2 beamline installation complete, we will be in a more steady-state mode, capable of operating for ~10m/yr
- Have proposed PIP-I+ to increase NuMI beam power to 900 kW over the next several years and update aging infrastructure