Fermilab

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ACCELERATOR REPORT

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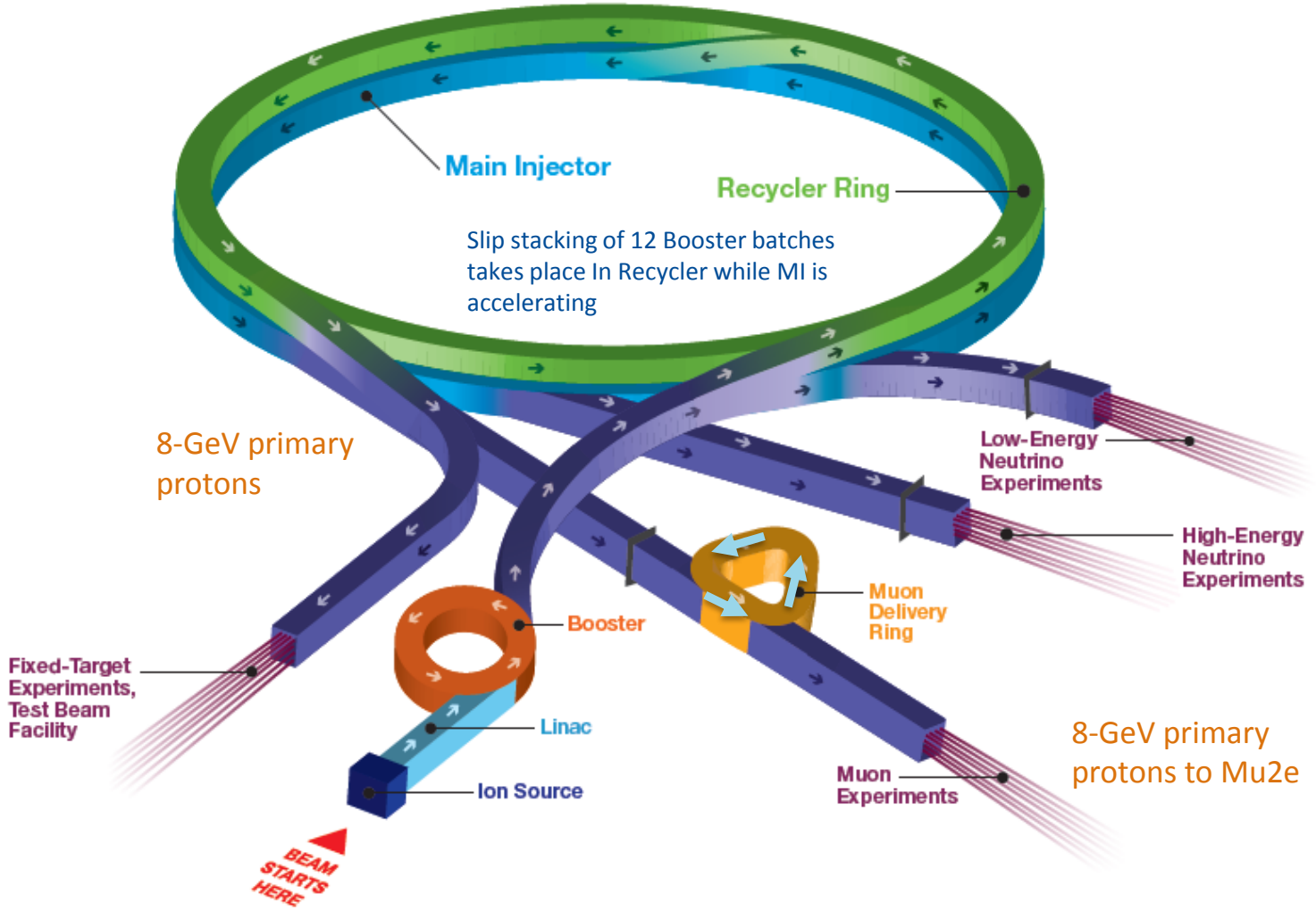
Users Meeting

06/08/2017

Outline

- Accelerator Complex
- Plans for FY17
- Accelerator Improvements/Highlights
- Accelerator Performance
- Muon g-2 commissioning
- FAST/IOTA
- PIP-I+
- Conclusions

Accelerator Complex



Our Plans for FY17

- Operate the Booster at 15 Hz delivering more than 2E17 p/hr.
  - Finish the Booster shielding assessment.
  - Reduce losses.

- Deliver 700 KW to the NuMI target.
  - Install Recycler Collimators.
  - Control losses.

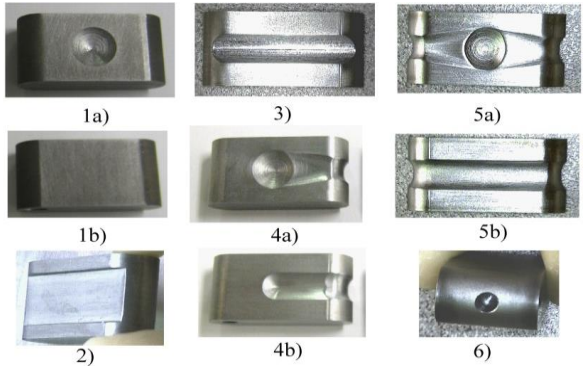
- Deliver beam to the Muon g-2 experiment.
  - Install 2.5 MHz Cavities in Recycler for bunch formation.
  - Finish the construction and component installation in the muon rings and beamlines.

Linac Highlights

- **Injector**: Have developed ion sources that operate entire year

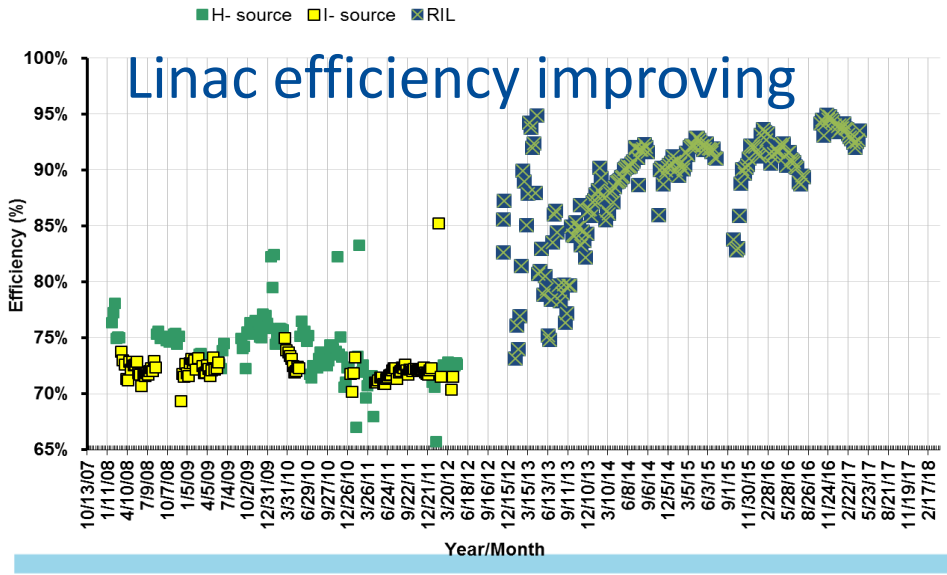
Safer and more reliable Cesium loading

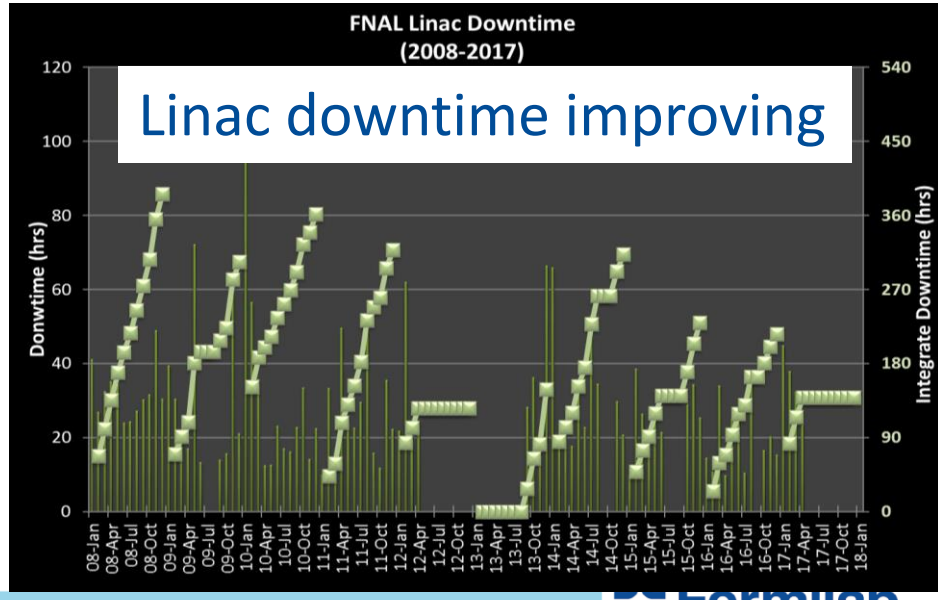
New Cesium boiler



Cathode geometries studied

- **Linac**: Upgraded reference sources, driver RF supplies and 2 modulators



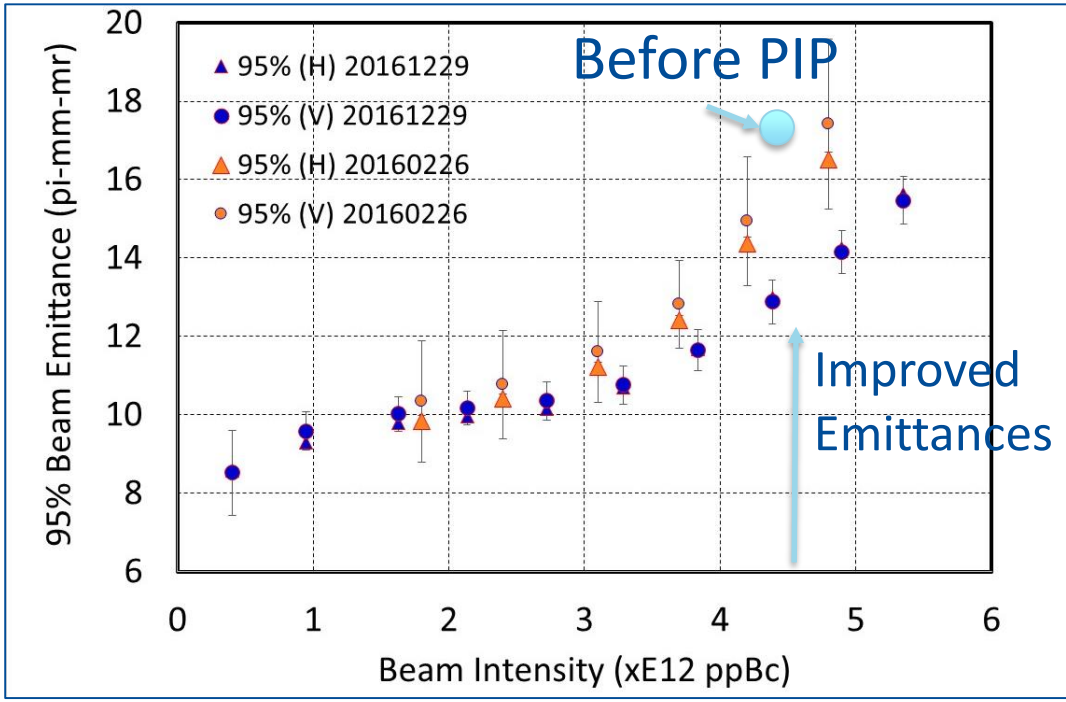


Booster Highlights

- RF cavities: 21 installed with the 22 competed by FY17 shutdown
- New low level source and control cards
- Added several more longitudinal damper modes
- Upgrade transition timing
- Improved emittances

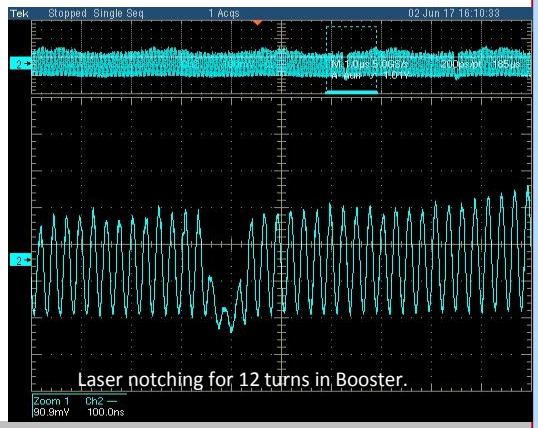
Completing the 22nd cavity

Recent emittance measurements



Recent PIP (Proton Improvement Plan) Highlights

Laser Notching



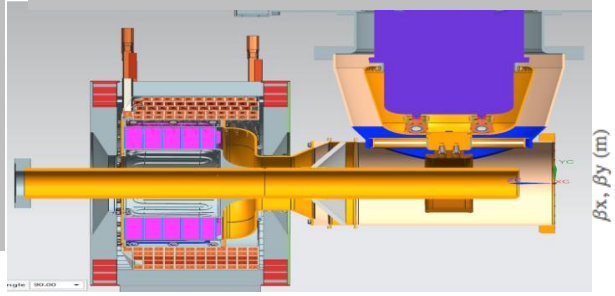
- Testing of new system under way.
- Booster efficiency improvement by 2% are expected.
- PIP Goal of 2.4E17 p/hr to be demonstrated before the shutdown.

- Operating 2 Marx Modulators.
- Laser notch studies/ops.
- Completed Booster RF cavity 21.
- Second harmonic Booster cavity for improving injection and transition crossing.
- New Booster lattice corrections
- New Booster Low Level system
- Booster Replacement Cavity (starting to build prototype)
- **Booster Shielding Assessment (New Limit of 2.7E17 pph)**

Marx Modulator

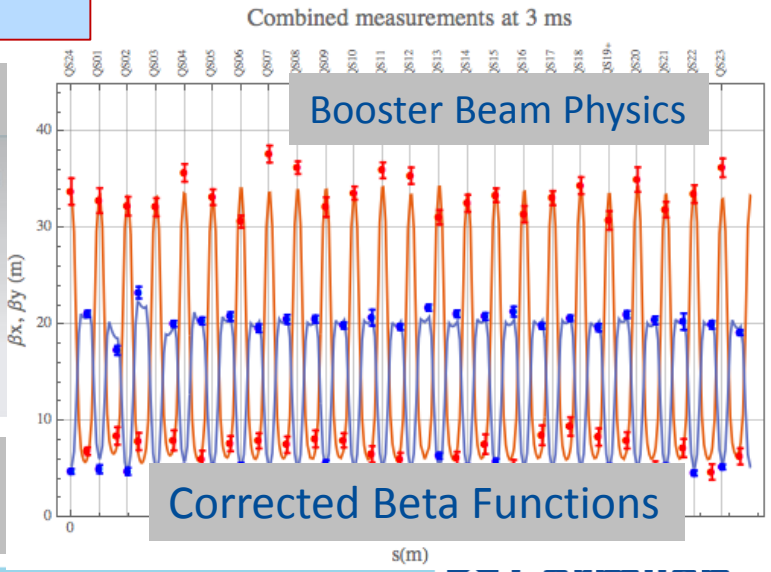
Operating in LLRF #5

2nd Harmonic Cavity



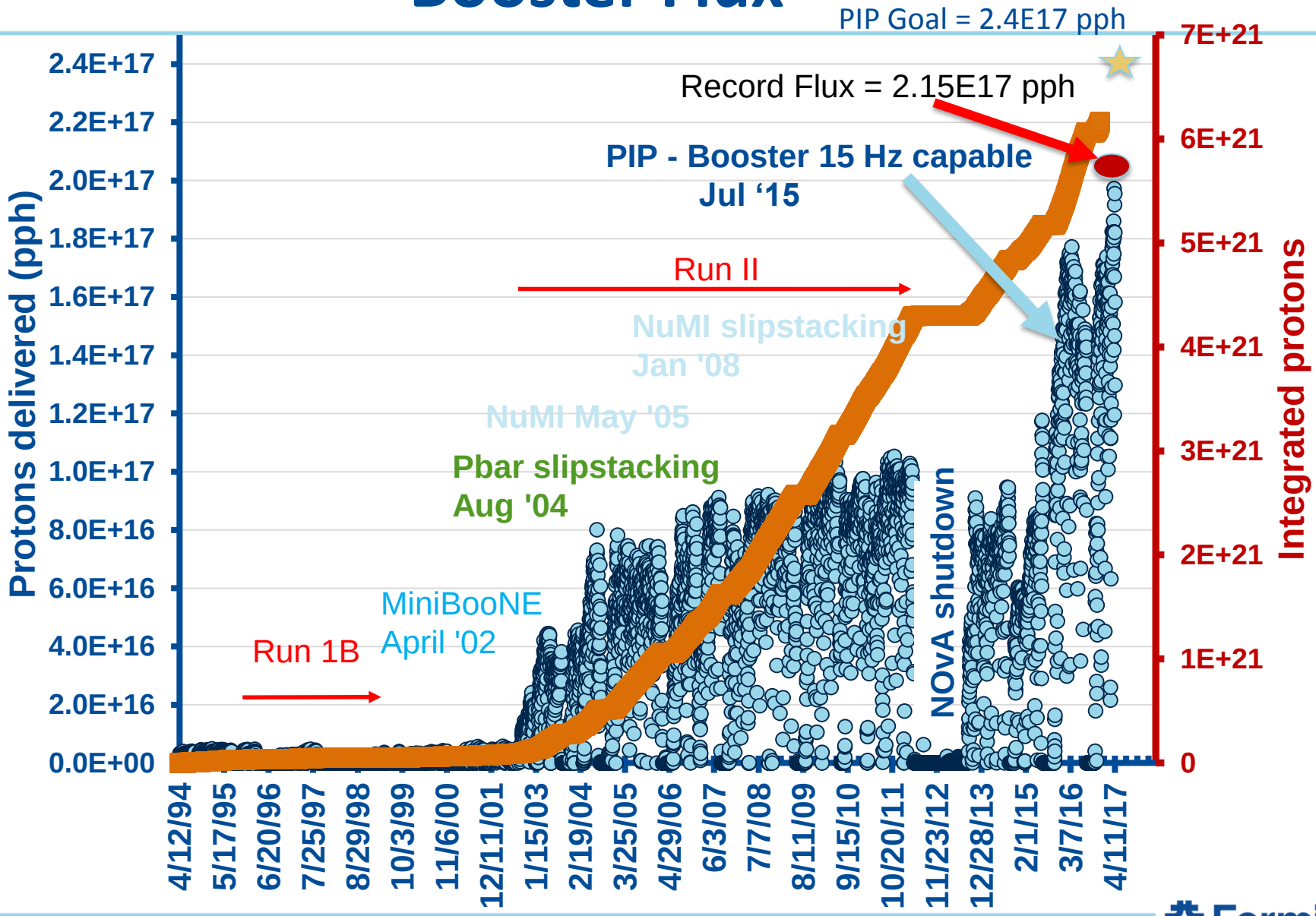
- Frequency range: 76 – 106 MHz
- Length of cavity is 27 inches
- 100 KV Gap Voltage

Booster Beam Physics

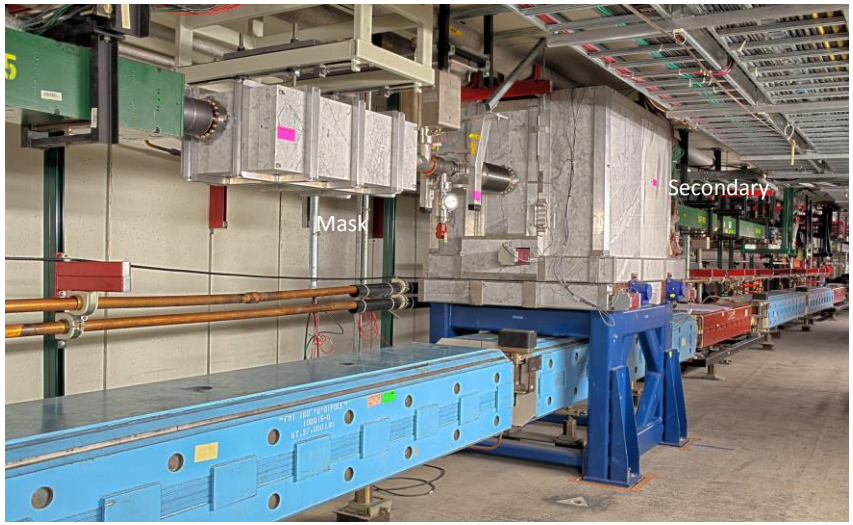


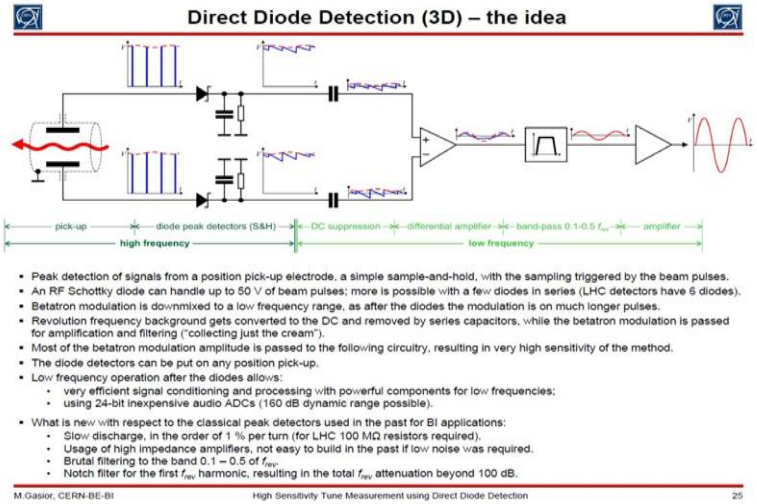
Corrected Beta Functions

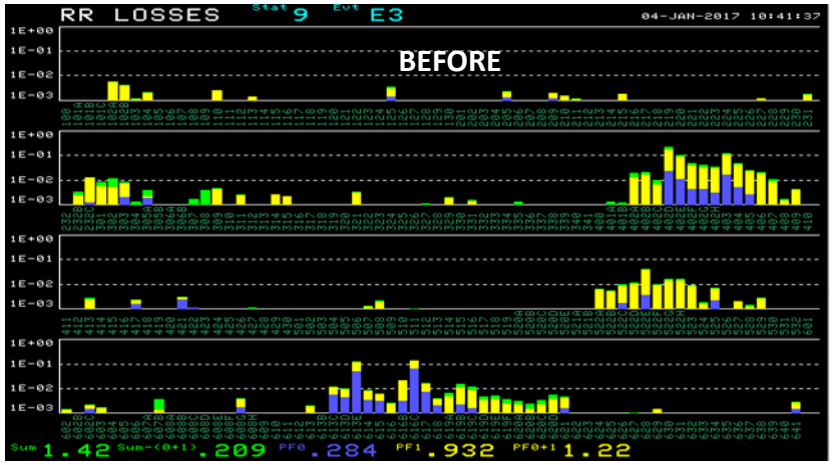
Booster Flux

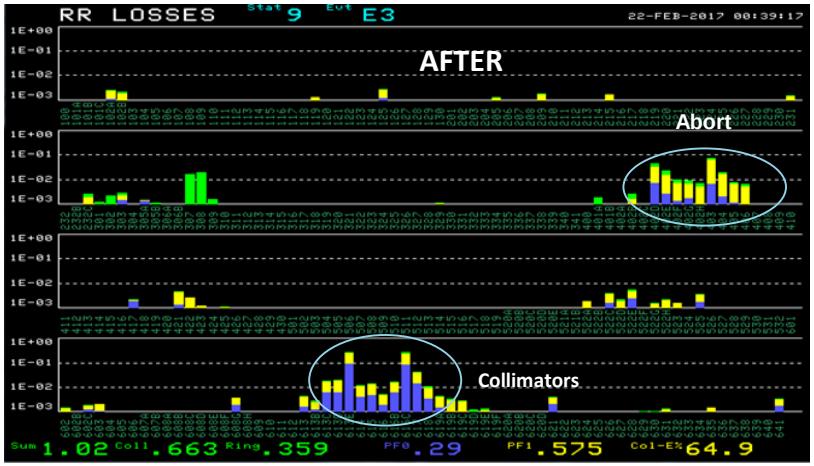


Recycler Collimators and New Damper (Reduce and control losses)



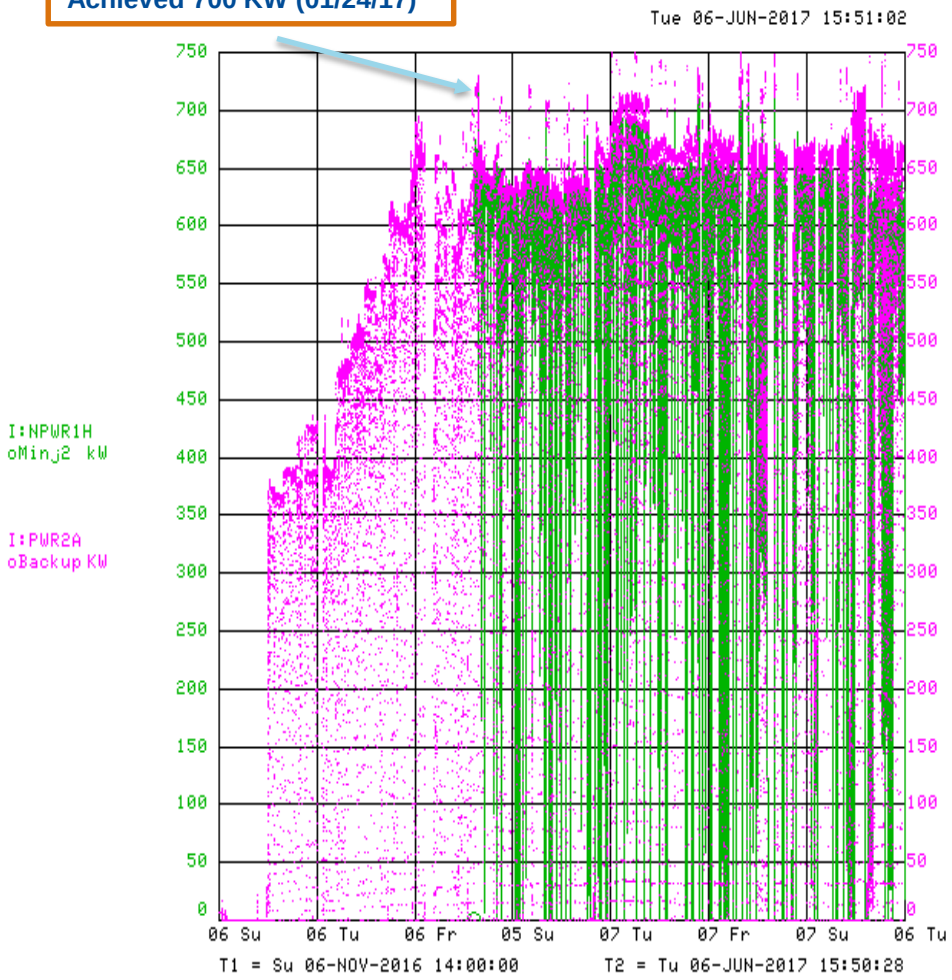






MI Beam Power in FY17

Achieved 700 KW (01/24/17)



- PWR2A: Average Power per Suprcycle (60 sec)
- NPWR1H: Average Hourly Power

- 636KW to NuMI target with SY120 is equivalent to 700KW with NuMI only.

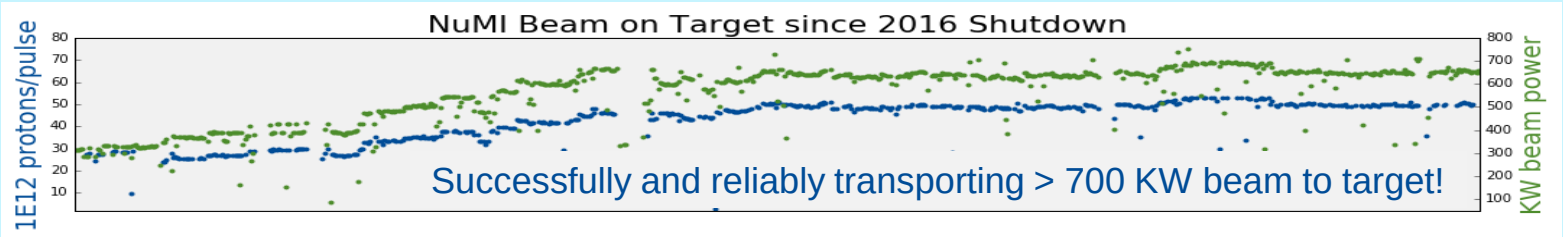
- **Record power to NuMI target : 727 KW (shielding assessment limit).**
- **Record power to NuMI with SY120: 690 KW**
- **Record beam intensity in MI at 120 GeV: 55E12 (NOvA Target Limit)**
- **Record RR Beam Intensity: 56.6E12**

Beamlines

NuMI beamline

Upgraded dipole power supply regulation to new digital system (“BμLB”), running consistently since shutdown

Updating total loss monitor instrumentation for improved reliability and redundancy

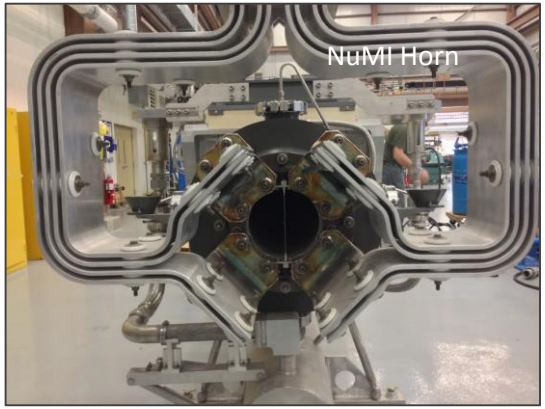


Booster Neutrino Beamline

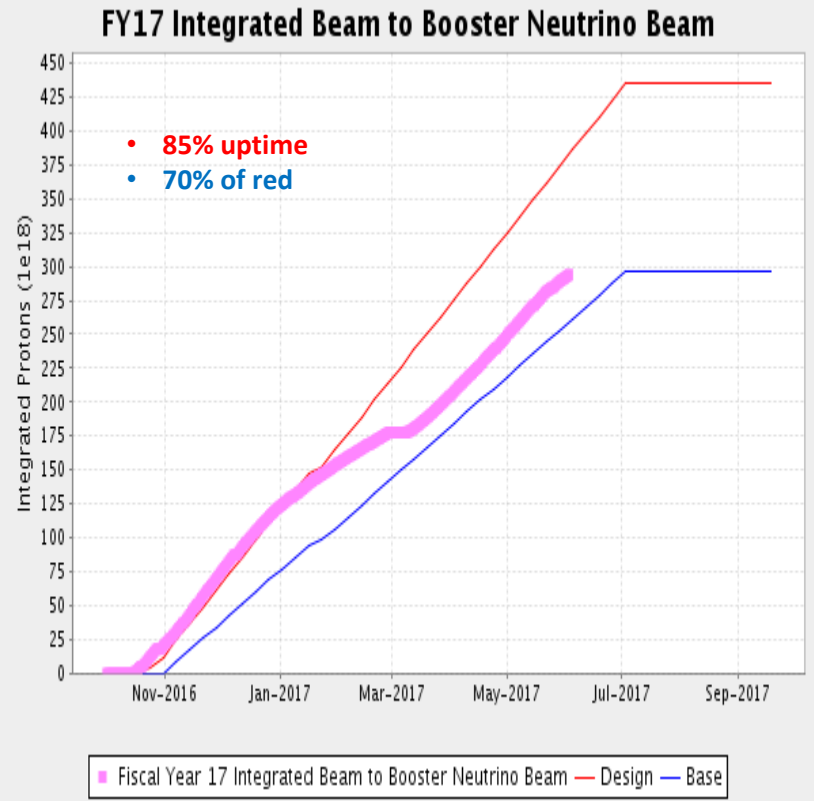
- SciBooNE Hall
- Short Baseline Near Detector
- MicroBooNE Liquid Argon Detector
- MiniBooNE Detector
- Short Baseline Far Detector

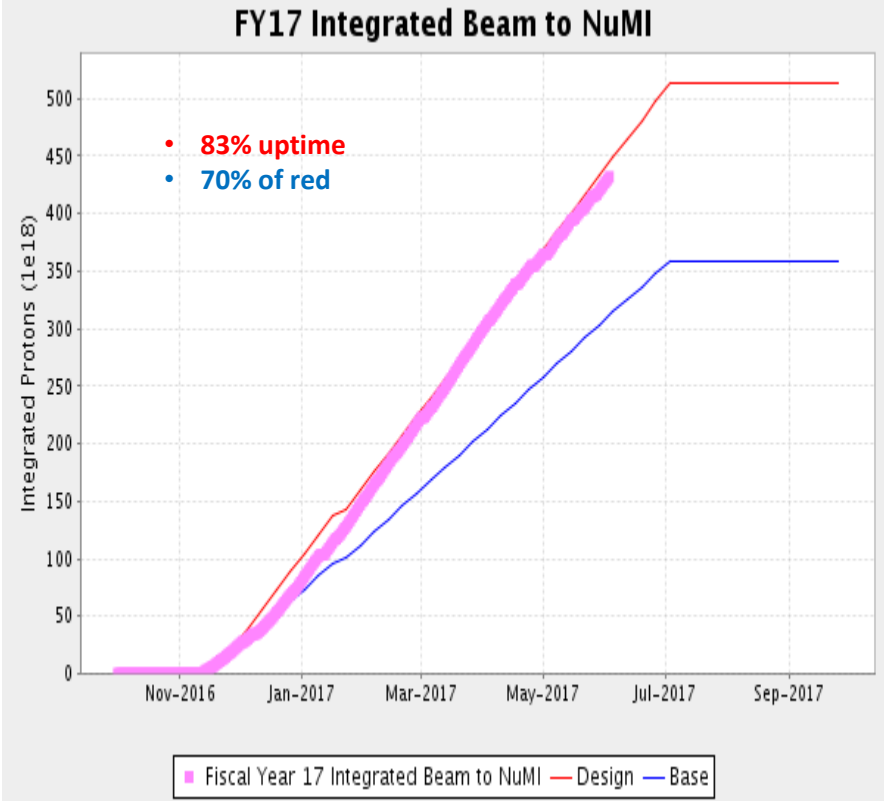
Target Systems Department: Target Halls

1. **BNB** operating at or near design limits
   - BNB-4 successfully test pulsed & nearing completion
2. **NuMI** operating at or above design limits (750 kW)
3. **Muon g-2** starting up now
   - Repurposing of the Antiproton Source AP0 hall
   - Installing new target station beam dump.



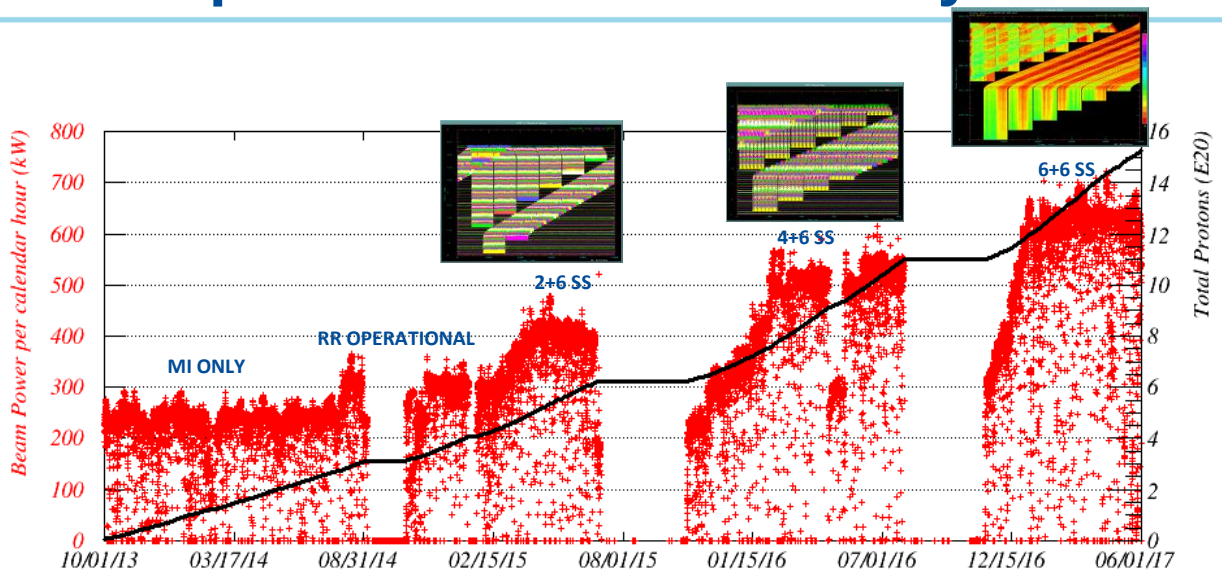
AD Operations: Goals and Performance





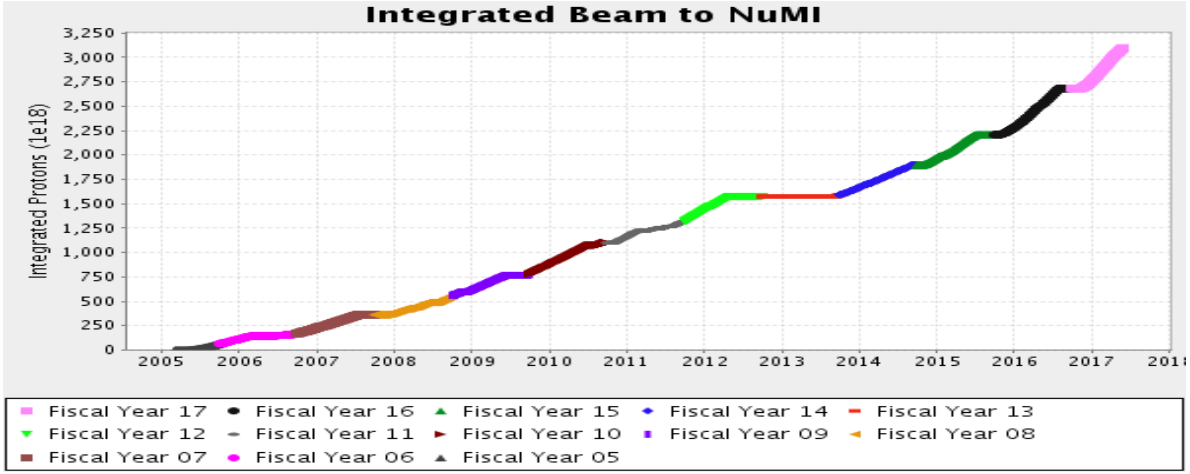
Since Jan. 2017 we are delivering 0.7E20 p/month!

MI Beam power and beam delivery to NuMI



MI Beam Power and Beam Delivered since the ANU Shutdown

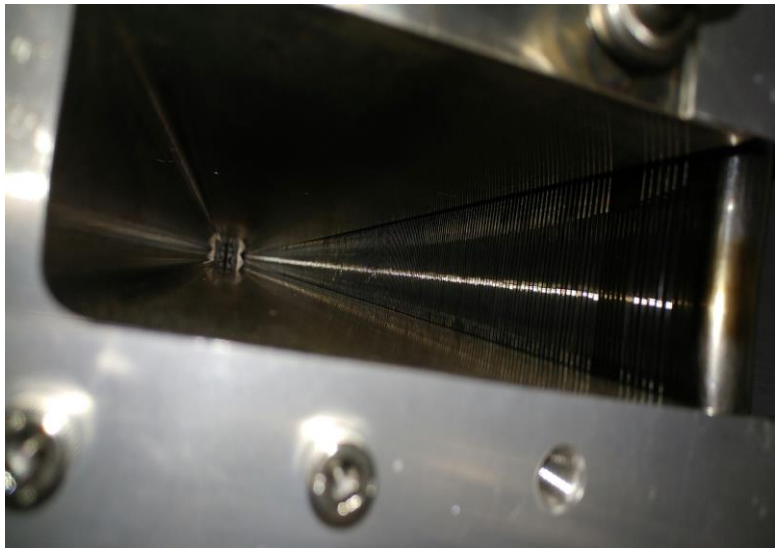
Delivered 12E20 of 36E20 approved to NOvA



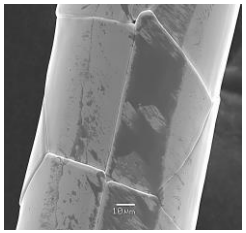
Integrated Beam to NuMI target since FY05

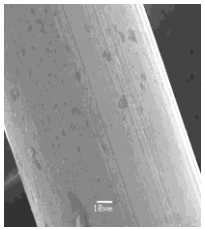
Slow Extraction Program: Replaced both septa in MI

Broken Wires

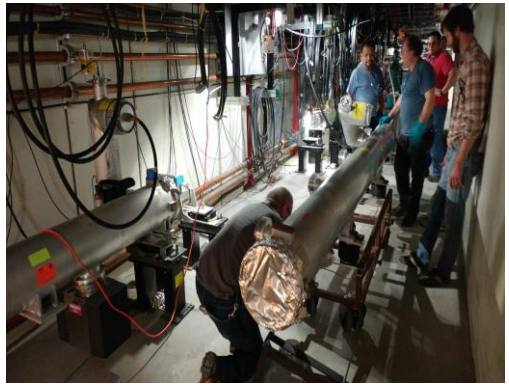


Examining Broken Wires





Replacing Septa In MI Tunnel



Replacing Broken Wires

Slow Extraction Performance

Meson and Neutrino Muon Areas

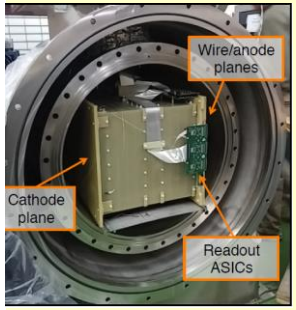
Test Beams 2016: MTEST and MCENTER

- *Users from 31 institutions; 6 countries*
  - *11 publications from FTBF experiments; 4 in progress*
- *Supported running modes:*
  - *120 GeV primary protons, 0.2- 60 GeV mixed hadron beams, 1-32 GeV mixed hadron+lepton beams*
- *Experiments and Detector R&D included*
  - *High-Luminosity LHC (ATLAS and CMS)**
  - *sPHENIX calorimeter for RHIC; also eRHIC*
  - *Detector R&D for g-2 and Mu2e*
  - *LArIAT (μBooNE, SBND, DUNE, ICARUS)*
  - *General detector R&D*

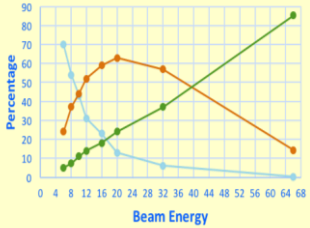
Neutrino Muon: SEAQUEST

- *From <30 to 50% increased beam duty factor*
- *Up to 1E13 ppp (60 second rep rate)*

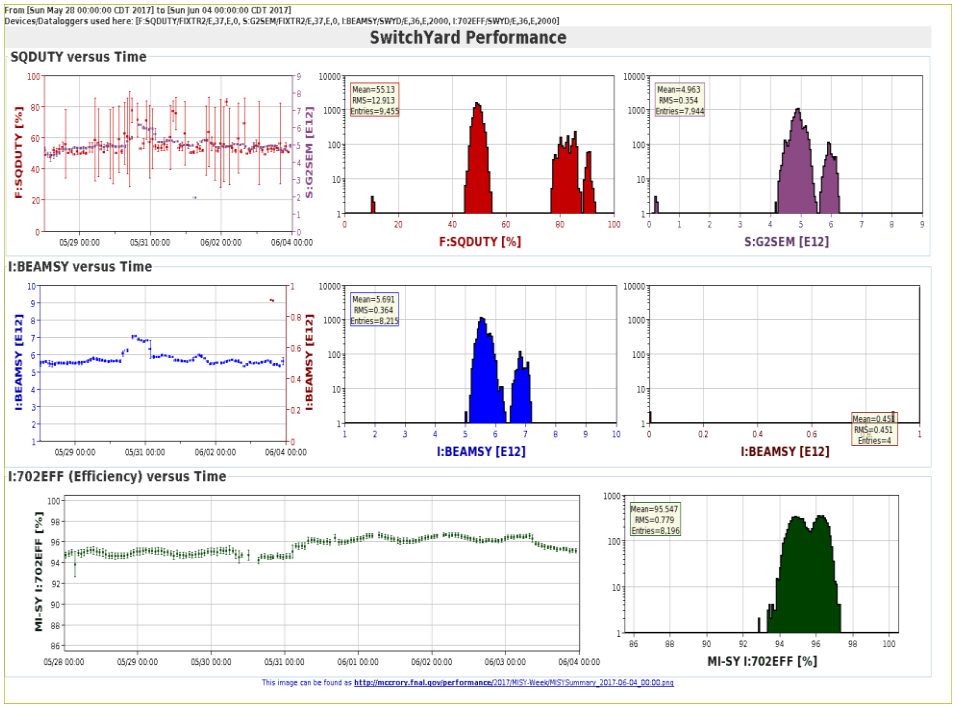
LarIAT TPC, FTBF



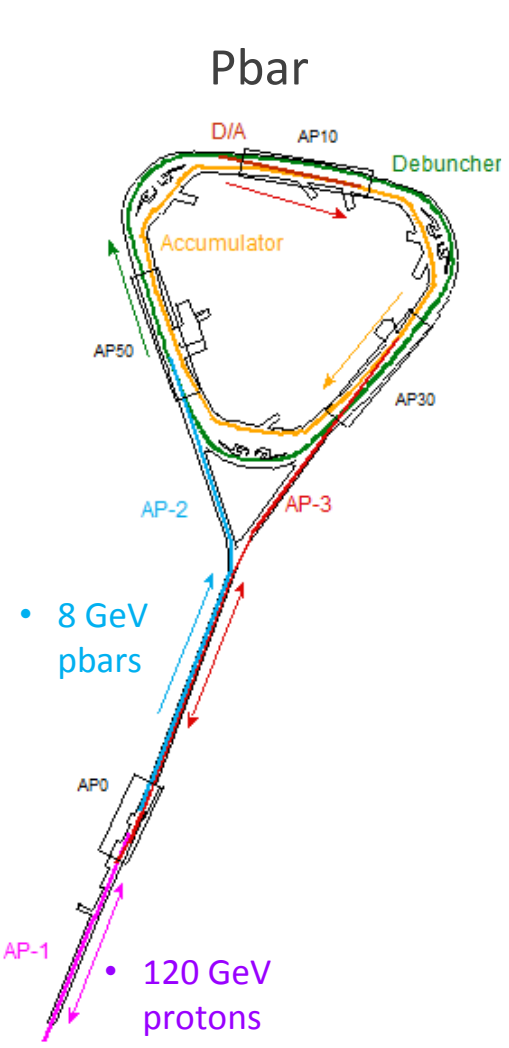
FTBF Committee Report, Nov. 2016



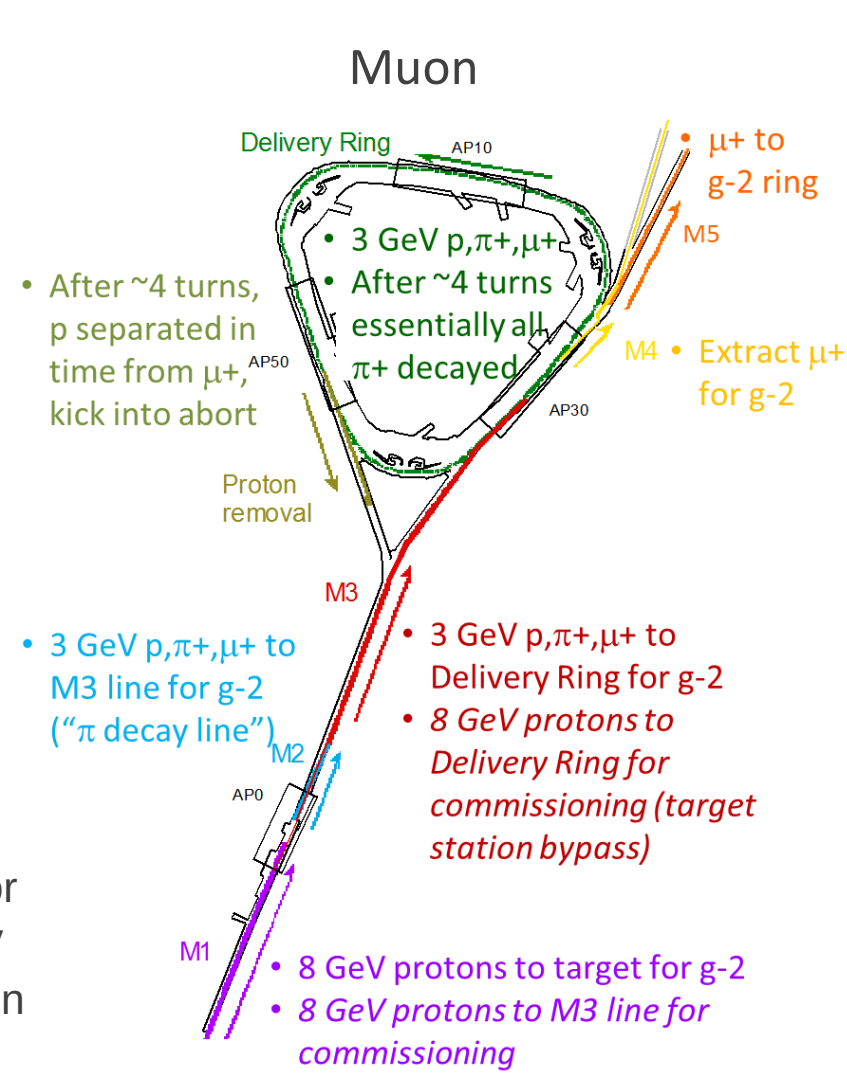
Cerenkov data >30 GeV positrons!



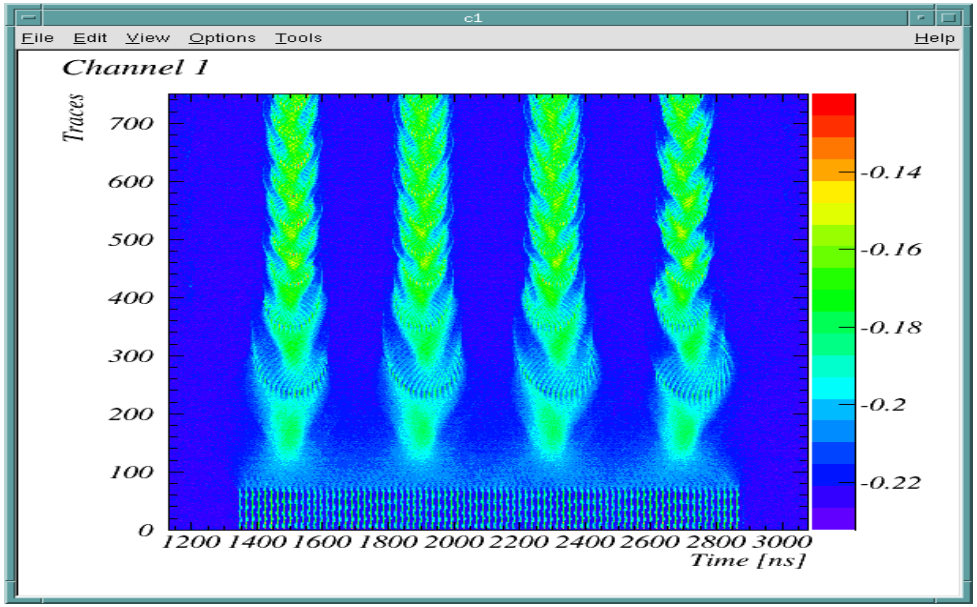
Conversion from Antiproton Source to Muon Campus



- New M4/M5 line to transport beam to g-2 muon ring
- Decommission Accumulator and use magnets for new beamlines
- Delivery Ring largely unchanged from Pbar Debuncher
- Former AP3 line connected to Accumulator – new connection from M3 to Delivery Ring
- Increase number of quads in M2/M3 lines for muon capture efficiency
- Reuse AP0 target station
- Lower beam energy



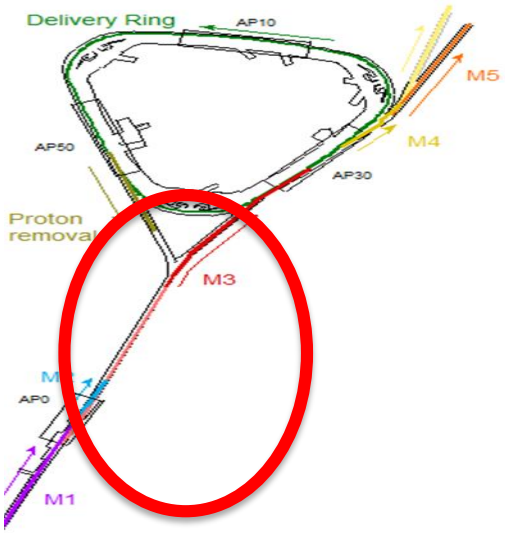
2.5 MHz Cavities in RR – getting ready for the Muon g-2

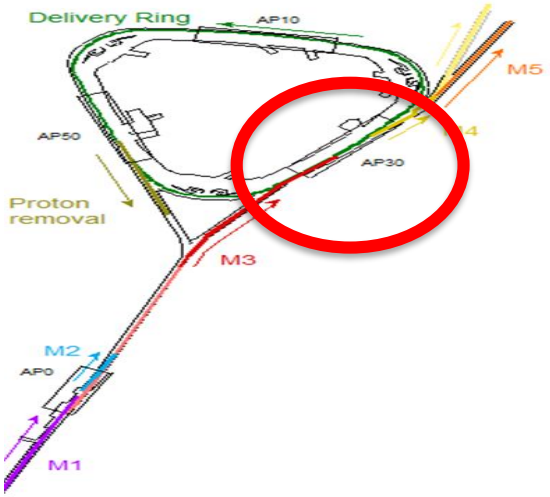


- Installed 6 2.5-MHz cavities in the Recycler for g-2/mu2e bunch formation.
- Cavities are now operational.

- One Booster batch formed into 4 2.5 MHz bunches in RR.

Muon Campus construction





Muon g-2 beam commissioning overview

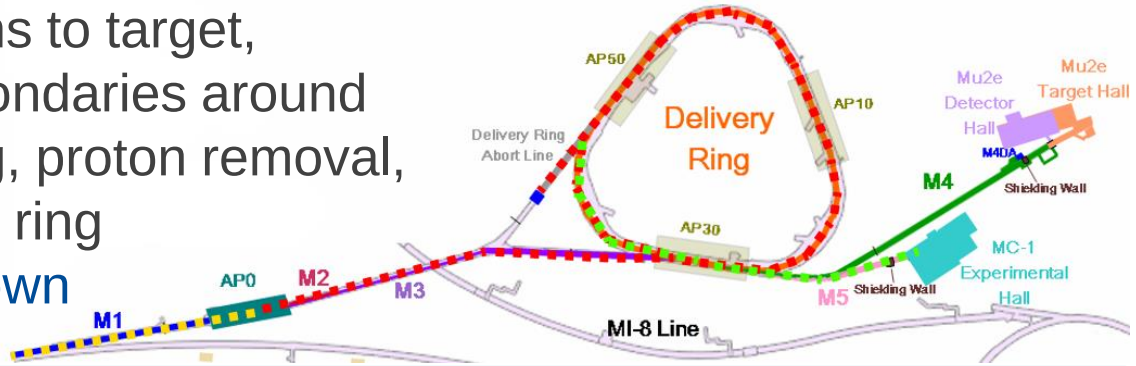
1) 8 GeV protons bypass target, through shared M4
   - If time also around Delivery Ring

✓

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



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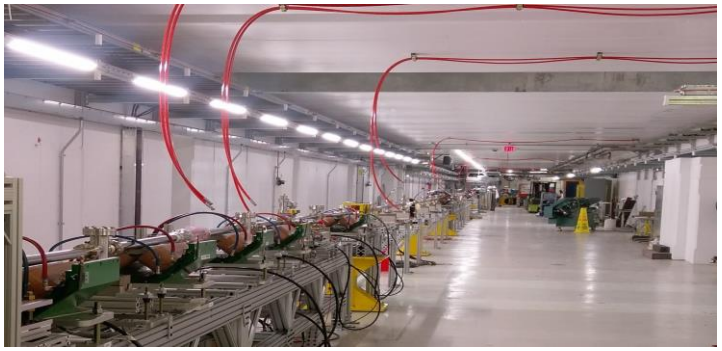
FAST/IOTA

Accelerator Test Facility for supporting Research and Development of Accelerator Technology for the next generation of Particle Accelerators



- 300 MeV electron linac nears completion-beam in July 2017
- 2-month experimental program in June-July
  - Experiments driven by external collaborators
- IOTA Ring beam to follow in 2018
- June 6-FAST/IOTA Annual Collaboration Meeting
  - 25 national and international partners

PIP-I+

- Proton Improvement Plan (PIP) has been very successful
- PIP-I+ is proposed as a follow-on to PIP, before PIP-II
  - More flexible “campaign” like PIP, not “project” like PIP-II
- Aim at increasing NuMI beam power to 1 MW prior to PIP-II
- Address many improvements needed in the accelerator complex for the PIP-II era.
- Infrastructure needs that are too big for operations budget
- Strategy
  - Upgrade NuMI target station to be robust up to 1 MW
  - Increase protons per pulse (further reduce losses in Booster)
  - Gamma-t Jump for MI/New Shielding Assessment

PIP → 0.7 MW, PIP-I+ → 1MW, PIP-II → 1.2MW, PIP-III → 2.4MW

Summary

- We are operating the Booster at 15 Hz achieving proton fluxes greater that 2.0E17 p/hr.
- We have achieved 700 KW beam power from MI.
  - 0.7e20 Protons on Target per month
- Beam has been delivered to the Muon g-2 Ring.
- We have started looking into ways to further increase the MI beam power.
  - Our vision: beam powers of up to 2.4 MW