Director's Run II Review
October, 2002

Proton Source Department

Required Proton Source Role in Run II Era

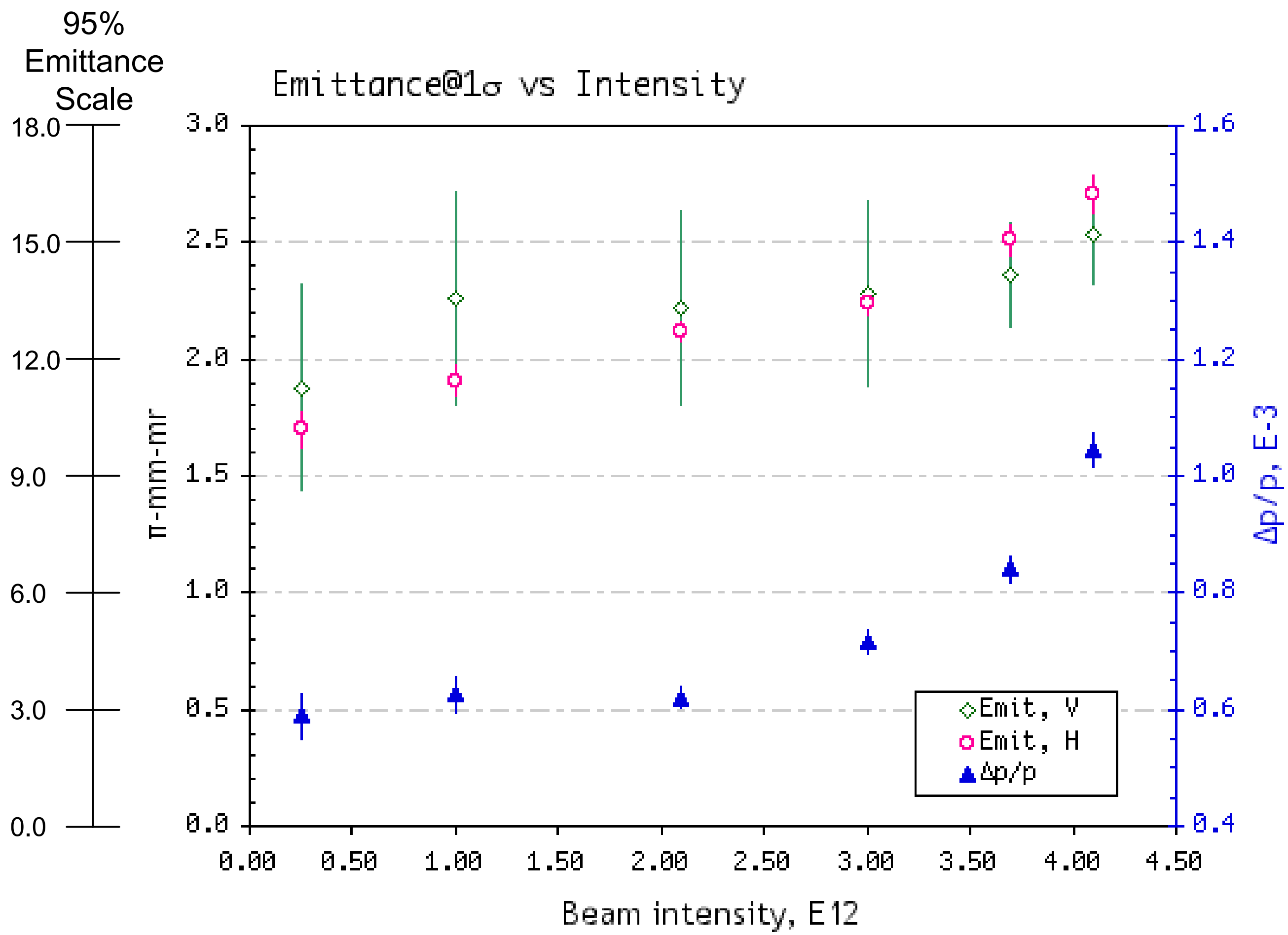
- Supply protons for antiproton production
  - 5E12 protons per pulse each 1.47 seconds for antiproton production (1.2E16 protons per hour) required
- Supply protons for Collider filling
  - 5-7 bunches of 5-6E10 protons with 0.1 eV-sec/bunch longitudinal emittance and <15 π mm-mr transverse emittance required
- Supply protons for other Laboratory programs: MiniBooNE currently and SY120, NUMI/MINOS later
  - 5E12 per pulse at 5 Hz (9E16 pph) required by MiniBooNE
- Most demanding requirements: <u>Reliability & Availability</u>
- Most difficult problem: <u>Beam loss</u> with resulting radiation and activation

Goals and Performance for Run II

Parameter	Typical Current Performance	Run II Handbook Goal	Comments
8 GeV Beam Pulse Intensity for Pbar Stacking	4.7E12/batch* = 5.9E10/bunch	>5E12/batch	Limited by Booster efficiency and residual radiation concerns
Hourly 8 GeV Beam for Run II	0.8E16	1.2E16	Limited by Pbar cooling cycle time
Transverse Emittance	15-17 π mm-mr	<15 π mm-mr	
Collider-filling Intensity	7 bunches @ 5.5 - 5.9E10 / bunch	5-7 bunches @ 6E10 / bunch	
Longitudinal Emittance	0.1 - 0.15 eV-sec / bunch	<0.1 eV-sec / bunch	Better understanding of transition crossing and improved longitudinal dampers

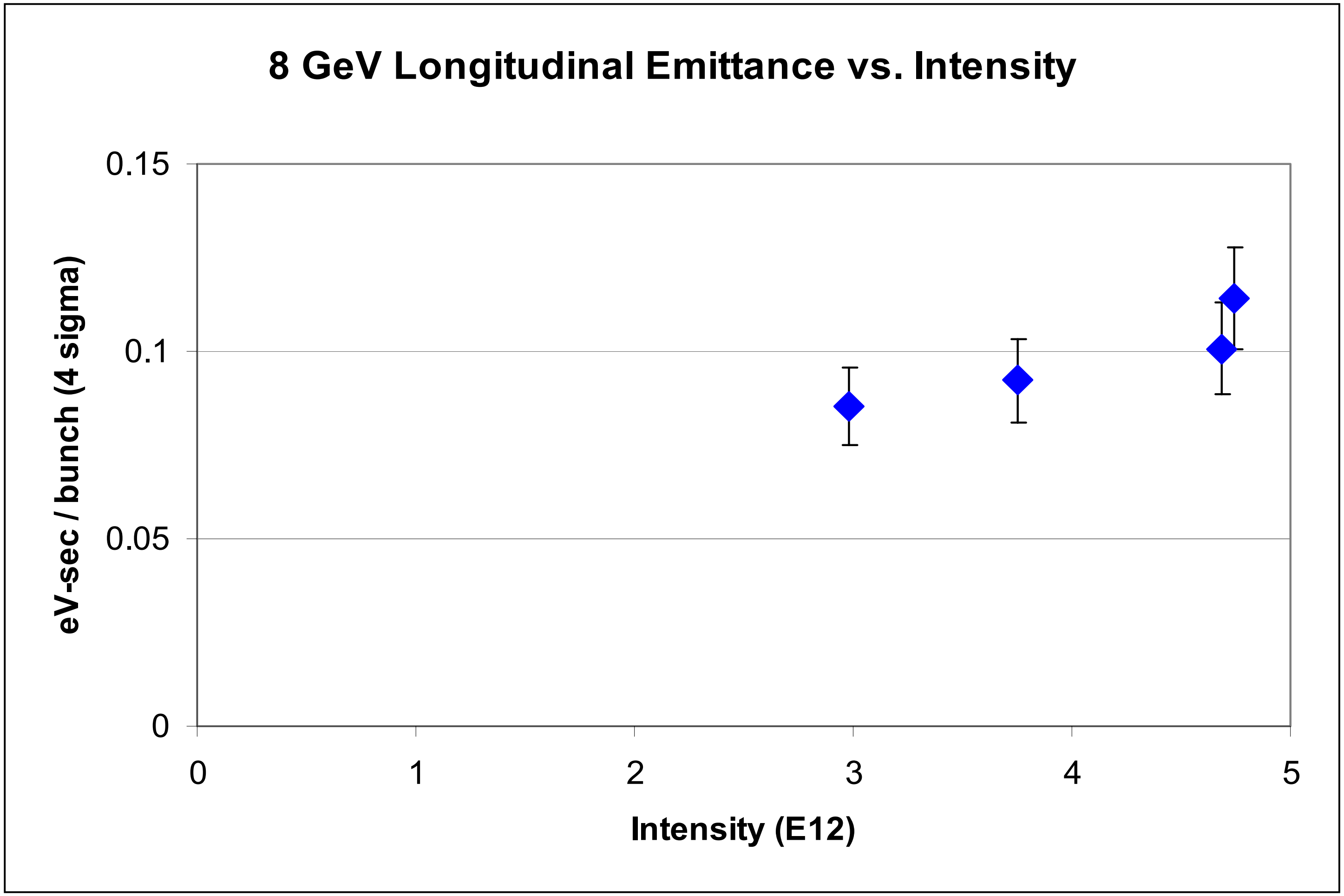
* One batch ~80 bunches (harmonic 84 with 4 bunch gap)

Emittance vs. Intensity



Data and plot courtesy of Ming-Jen Yang

Longitudinal Emittance vs. Intensity

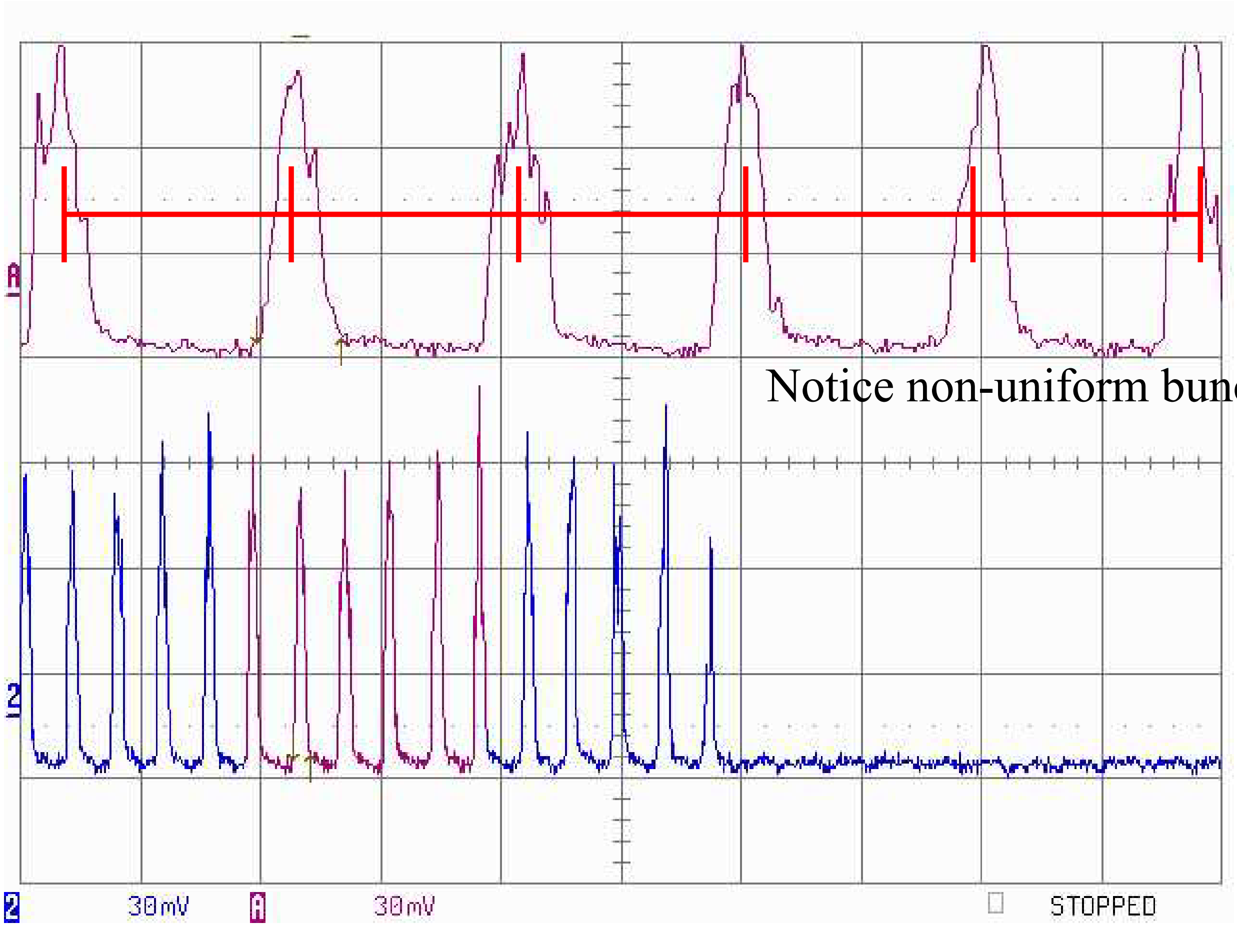


Error bars represent standard deviation of 4 measurements at each intensity

Typical Booster Bunches at 8 GeV

10 nsec/div

50 nsec/div



Notice non-uniform bunch spacing

Proton Source Run II Specific Projects (1)

- Understanding Booster Performance Limitations
  - Injection and Capture Studies (R. Tomlin et al.)
  - Space Charge Effect Studies (P. Spentzouris)
  - Transition Crossing Studies (W. Pellico)
  - Investigate Need for / Benefit of Transverse Dampers in Booster (R. Tomlin)
- Booster Longitudinal dampers (W. Pellico)
  - Re-design low level electronics system to reduce noise and facilitate maintainability
  - Dedicated damper cavity and power amplifier recently commissioned

Proton Source Run II Specific Projects (2)

- Phase Lock Improvements (W. Pellico, R. Webber)
  - Phase-locking Booster beam to Main Injector RF for transfer subjects the beam to sizeable longitudinal perturbation contributing to final longitudinal emittance of the Booster beam
  - Devise and implement hardware improvements for more “adiabatic” phase lock
  - Attempt phase lock of beam signal rather than VCO signal to MI RF reference
- Aperture and Orbit Improvements
  - Commission Ramped Correctors (E. Prebys)
  - Magnet Moves (J. Lackey)

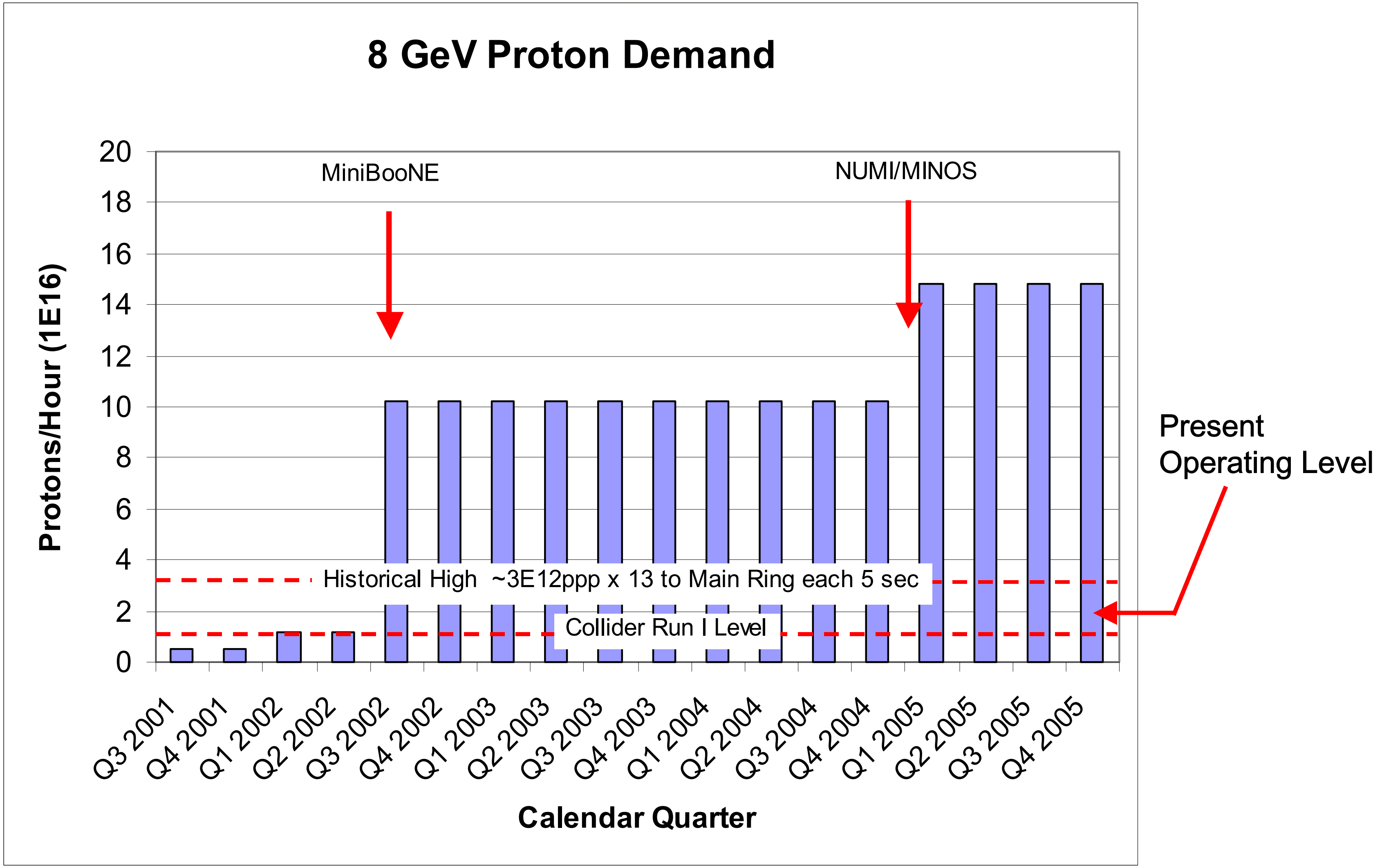
Proton Source Run II Specific Projects (3)

- Booster Beam Collimator System (J. Lackey, E. Prebys)
  - Collimation system is expected to absorb radiation load from beam losses in a location that can be well shielded.
  - This load would otherwise be carried by RF cavities and other critical beamline devices.
  - Permit increased proton delivery rate from Booster to the benefit of antiproton stacking and reduced radiation exposure to maintenance workers in Booster tunnel.
  - Collimators and absorbers are installed. Shielding must be installed before exposing collimators to high radiation doses.
    - Complete shielding design
    - Procure shielding materials
    - Install shielding
    - Commission collimation system with beam

The Proton Source in Full Context

- Reliable, 24/7, 39 week/year Proton Source operation (on TeV schedule) is crucial to Run II success
- Now less than one in three 8 GeV protons is used by Collider Run II, potentially less than one in ten
- **Total Proton Demand Is A Big Deal to Run II !**
- Increased pulse repetition rate demands on 30 year old equipment will impact machine availability
- Component irradiation and activation, especially in Booster, will potentially cause failures and ALARA steps will require extended repair times

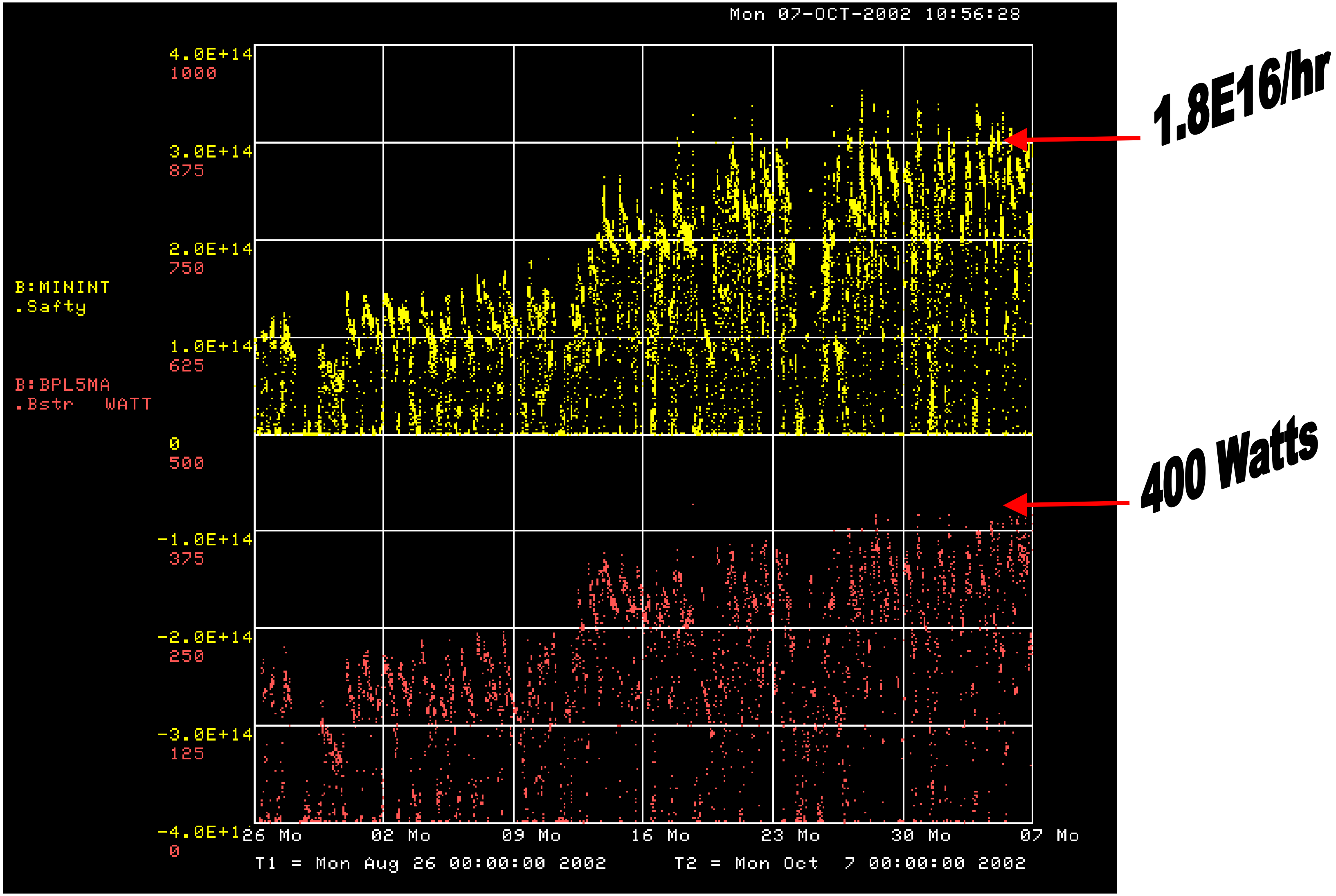
Demand for 8 GeV Protons



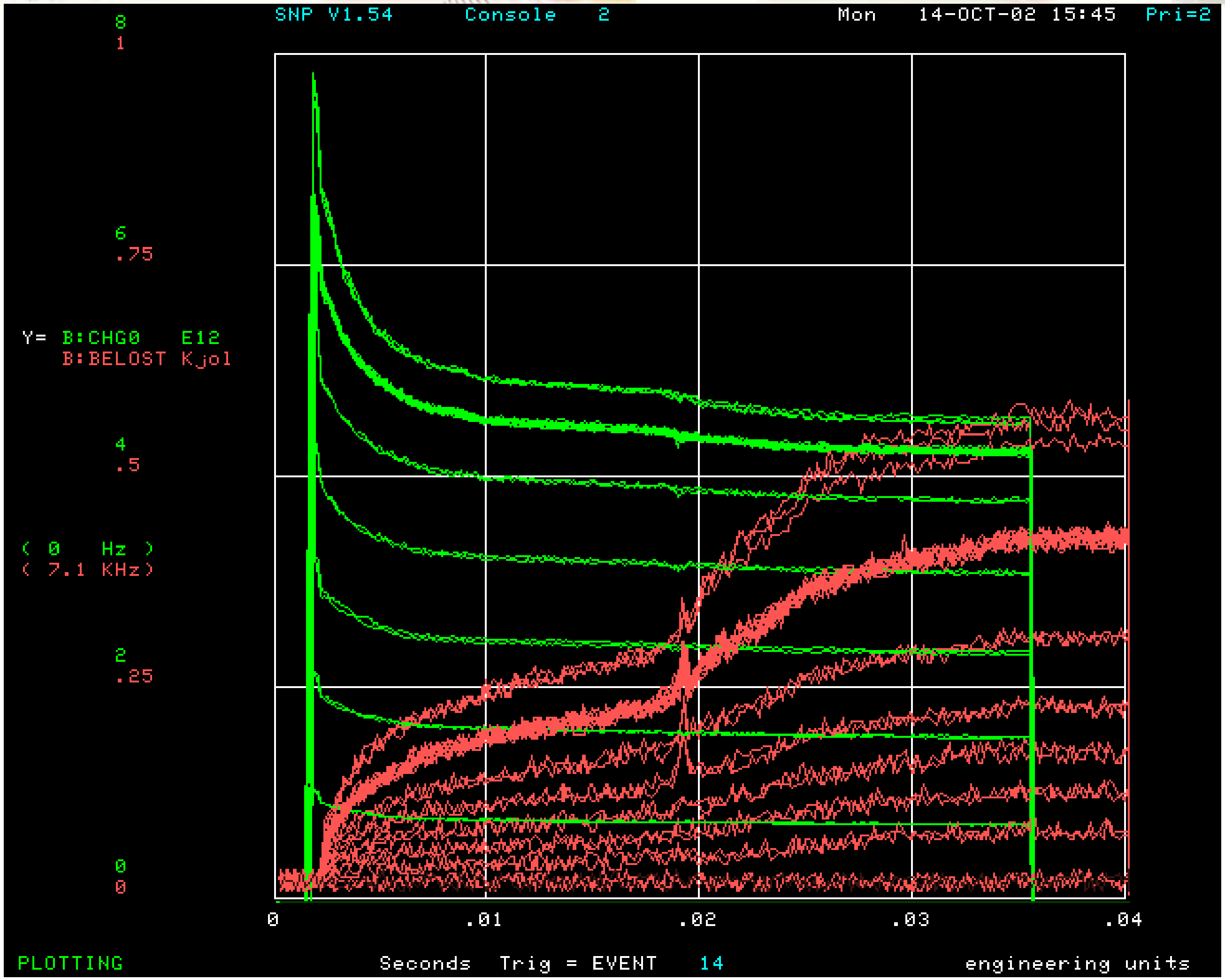
The Challenge

- To meet the increasing demand for protons from a 30 year old machine without destroying it and within the safety regulations of the Fermilab Radiation Control Manual
- Increase pulse intensity 10% and beam pulse repetition rate 5 time above current levels
- This is a challenge relevant to the entire program of this Laboratory. Every proton utilized by any Fermilab HEP experiment (Run II, MiniBooNE, NUMI, SY120) for at least the next 6 years must be accelerated by the present Booster

Recent 6 Weeks with MiniBooNE Turn-On

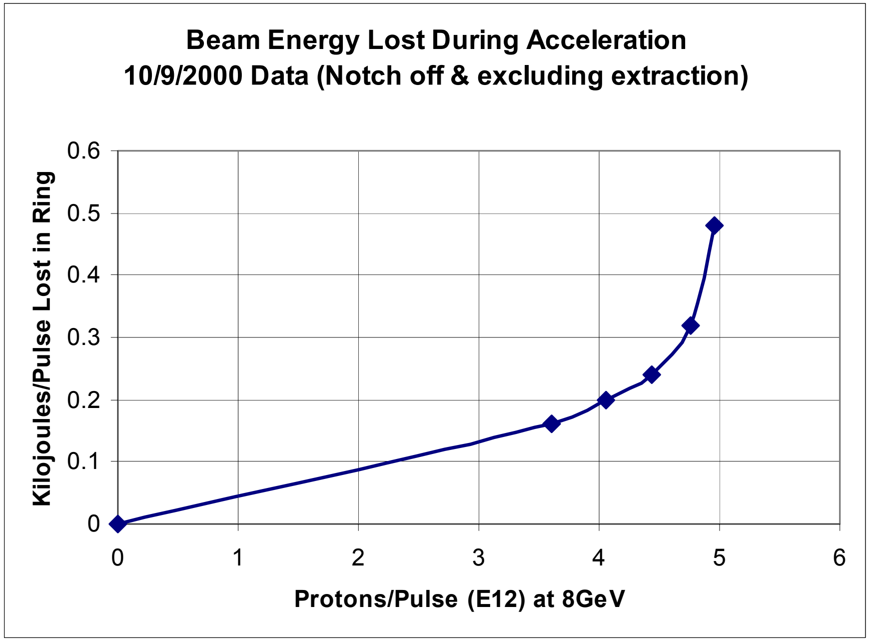


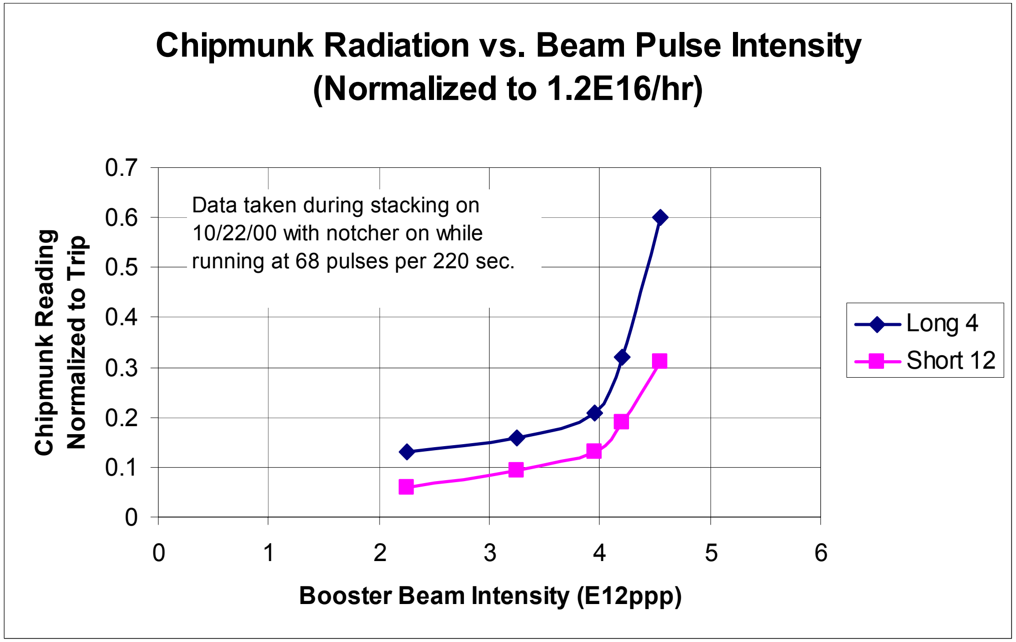
Booster Charge and "Beam Energy Lost" Family



For 0, 2, 4, 6, 8, 10, 12, 14 Injected Turns

Beam Loss Intensity Sensitivity





Projects to Meet New Demands (Not Necessarily Run II Specific)

- New Booster pulsed extraction septum magnets and power supplies to permit higher average pulse rates (J. Lackey, TD, and EE Support)
- New enlarged aperture upstream MI-8 magnets (J. Lackey and TD)
- Redesign Booster Injection Orbit Bump magnet system (T. Dombeck)
- Complete vacuum-proof prototype of enlarged aperture Booster RF cavity (J. Reid and RF Dept)
- Improved applications software to enforce better operational discipline (E. Prebys and P. Kasper)

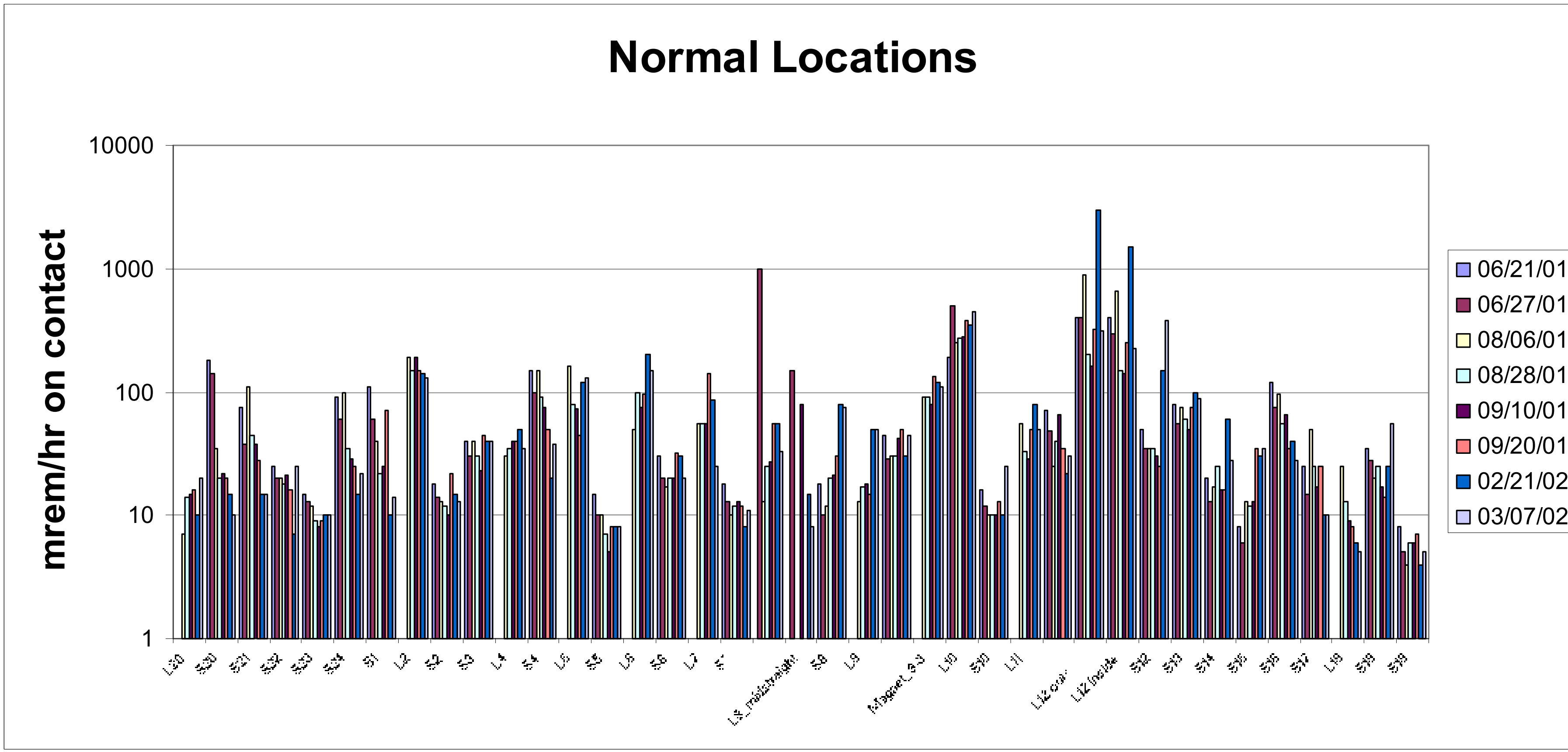
Major Systems in Need of Attention to Maintain Traditional Reliability

- Low Energy Linac water systems
- Linac 200MHz RF power systems
- Low Energy Linac pulsed quad power supplies
- 400 MeV Lambertson magnet
- 400 MeV transfer line power supply systems
- Booster Orbit Bump power supply output switch
- Booster vacuum system controls
- Booster High Power RF amplifiers and modulators
- Booster low level RF electronics
- Booster extraction kicker magnets

Booster Residual Radiation Tracking Program

- Establish "fixed" measurement locations around Booster ring
  - Selected easily repeatable measurement locations
  - Some measurements at contact (some on beam pipe some not) and some at 1 foot
- Make measurements most opportunities for access
- Typically 2-8 hours after beam is shut down
  - "fuzzy" number because operation is irregular
- Provide good "baseline" prior to MiniBooNE operation and trending during MiniBooNE

Booster Residual Radiation Data



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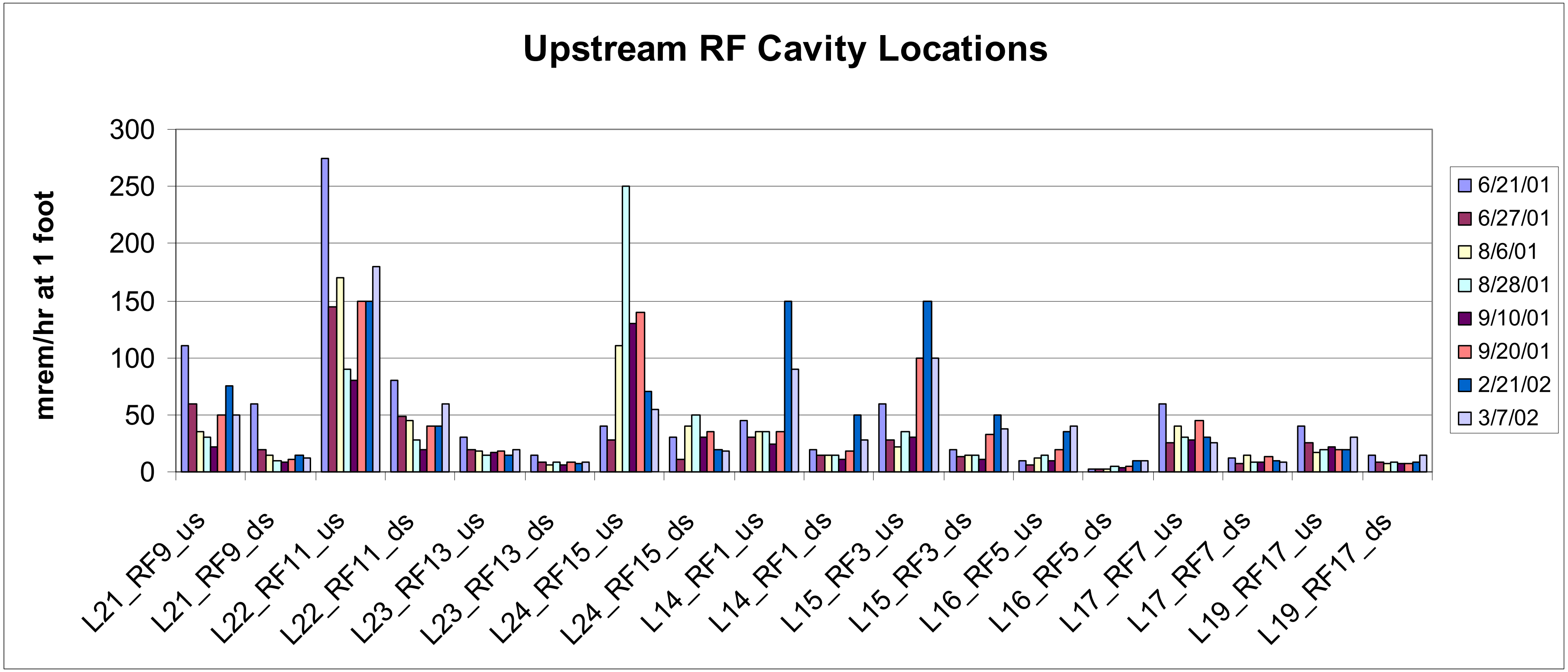
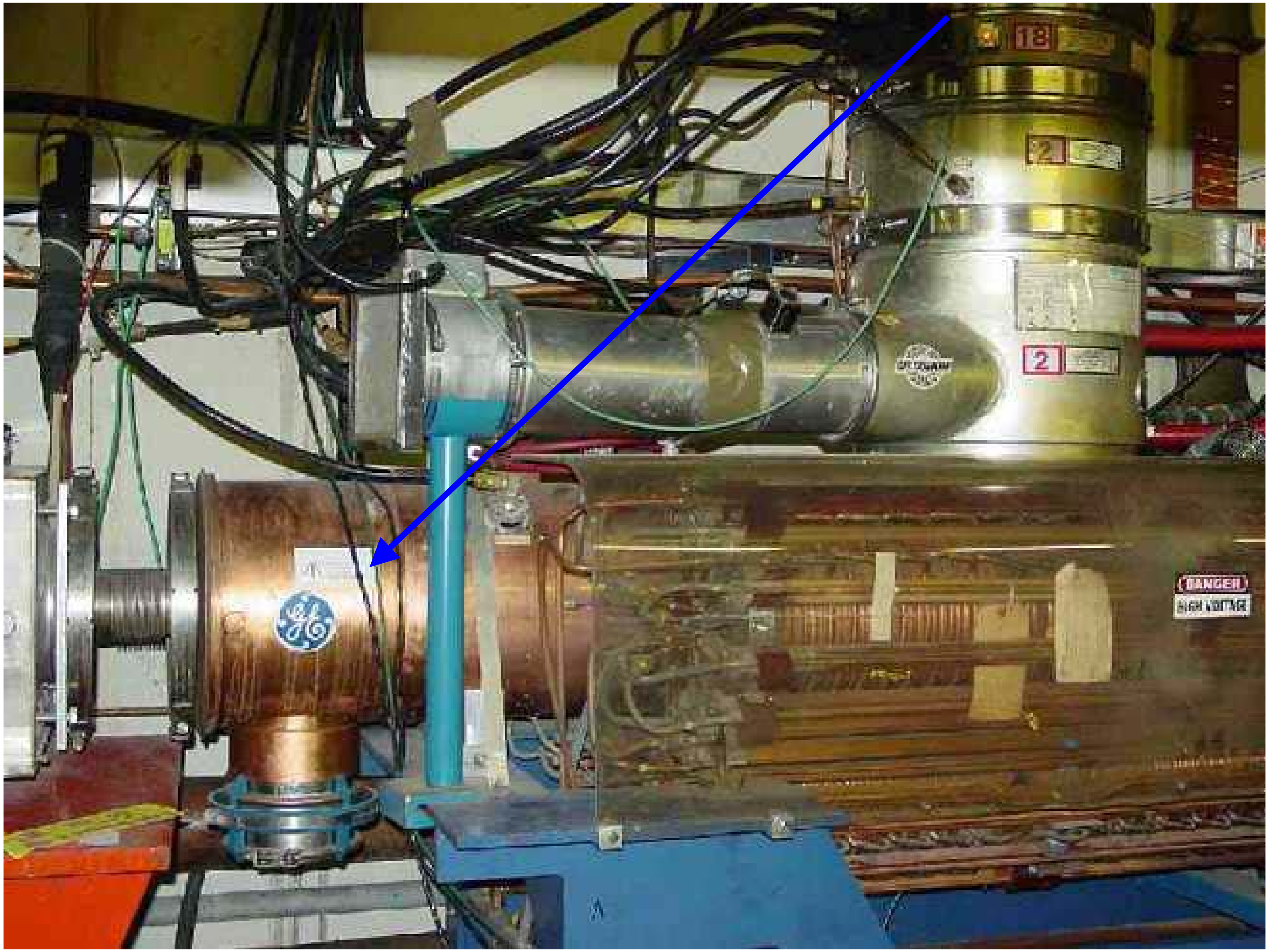
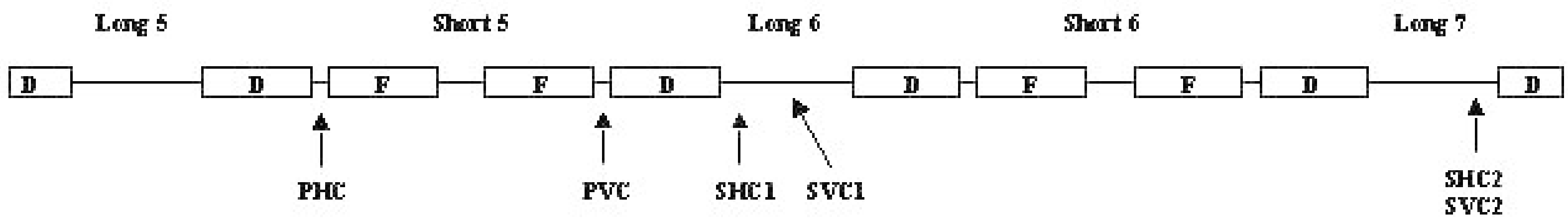


Proton Source Department

RF Cavity Survey Point (@ 1 foot)

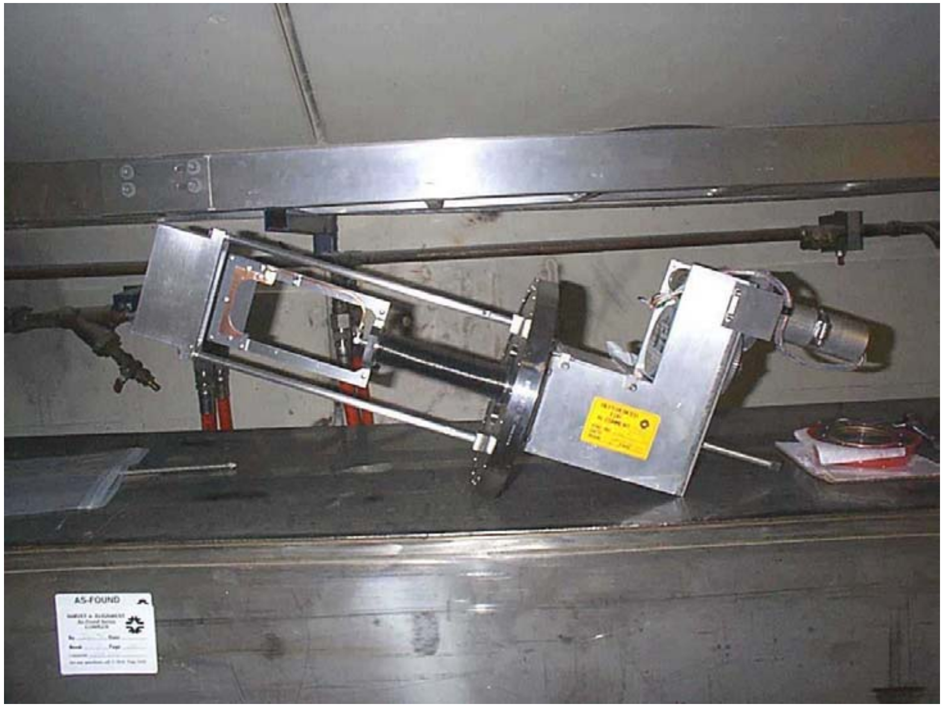


Planned Booster Collimator Layout



PHC is in upstream mini-straight section of Period 5
PVC is in downstream mini-straight section of Period 5
SHC1 is 20cm from upstream end of Long 6 straight section
SVC1 is 300cm from upstream end of Long 6 straight section
SHC2 and SVC2 are both located 60cm from downstream end of Long 7 straight section

Vertical Primary Collimator Installation



Booster Secondary Collimator Installation

Conclusions

- Proton Source is very close to meeting Run II goals and does not presently limit Run II luminosity performance
  - Improvement in beam pulse intensity at the level of 10% is needed to meet intensity goals
  - Improvement in longitudinal emittance may benefit Collider
- Accelerator component irradiation and activation is the most serious issue facing the Booster
  - Operational discipline and automated loss monitoring and data logging are important
  - Administrative operational limits are set to limit machine damage, personnel radiation exposure, and reduced machine availability
  - We will face a new era dealing with maintenance in an elevated radiation environment
- Aging equipment in the Booster and Low Energy Linac and operation at increased average beam pulse rates threaten continued operation at historical reliability levels