DOE Fermilab Collider Run II Review
October 28-31, 2002

Proton Source Department

Required Proton Source Role in Run II Era

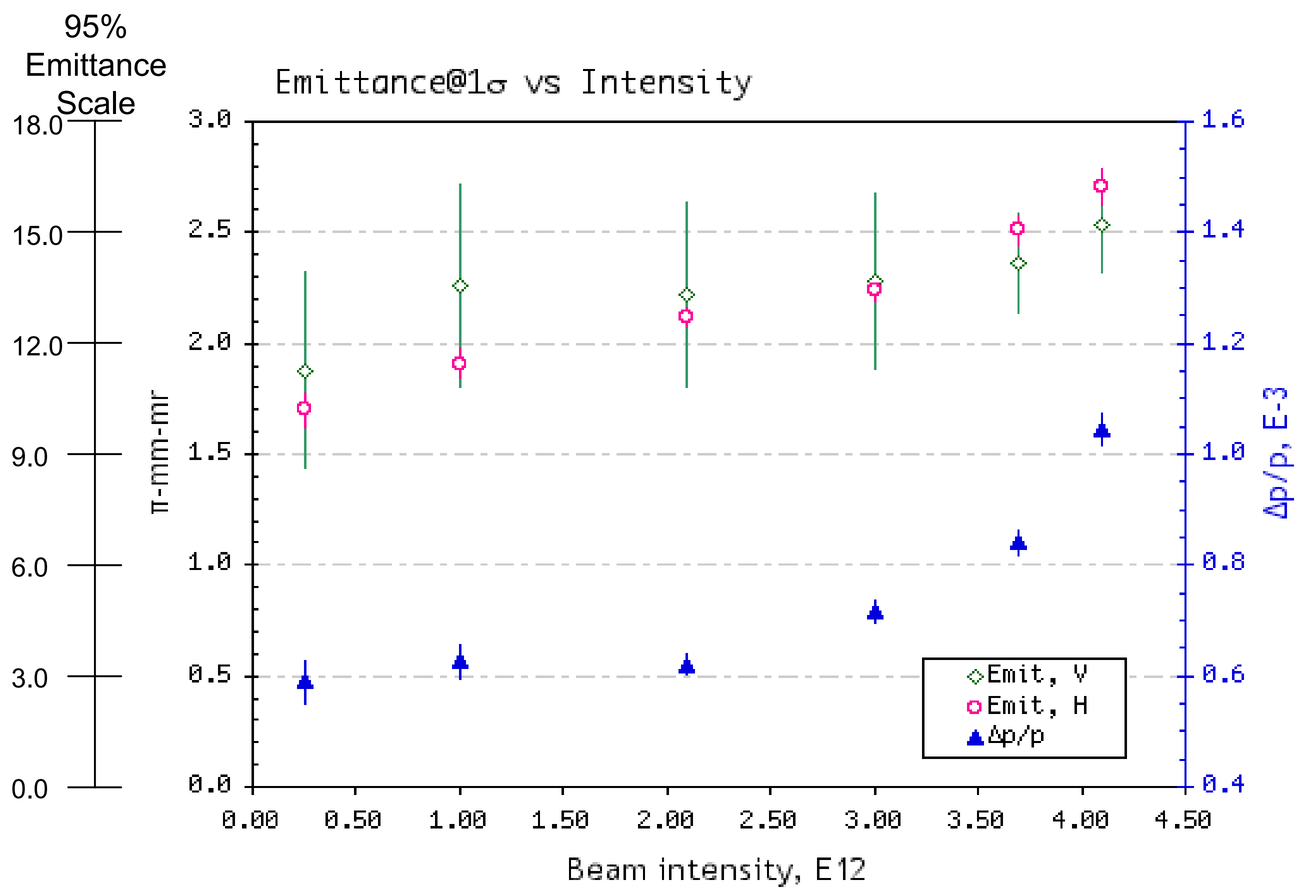
- Supply protons for antiproton production
  - 5E12 protons per pulse each 1.47 seconds for antiproton production (1.2E16 protons per hour) required
- Supply protons for Collider filling
  - 5-7 bunches of 5-6E10 protons with 0.1 eV-sec/bunch longitudinal emittance and <15 π mm-mr transverse emittance 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: Reliability & Availability
- Most difficult problem: Beam loss with resulting radiation and activation

Goals and Performance for Collider 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 cooling time in Pbar Debuncher
Transverse Emittance	15-17 π mm-mr	<15 π mm-mr	~OK
Collider-filling Intensity	7 bunches @ 5.5 - 5.9E10 / bunch	5-7 bunches @ 6E10 / bunch	6E10 times 5 not enough to make 270E9 in TeV
Longitudinal Emittance	0.1 - 0.15 eV-sec / bunch	<0.1 eV-sec / bunch	Better understanding of transition crossing and improved longitudinal dampers

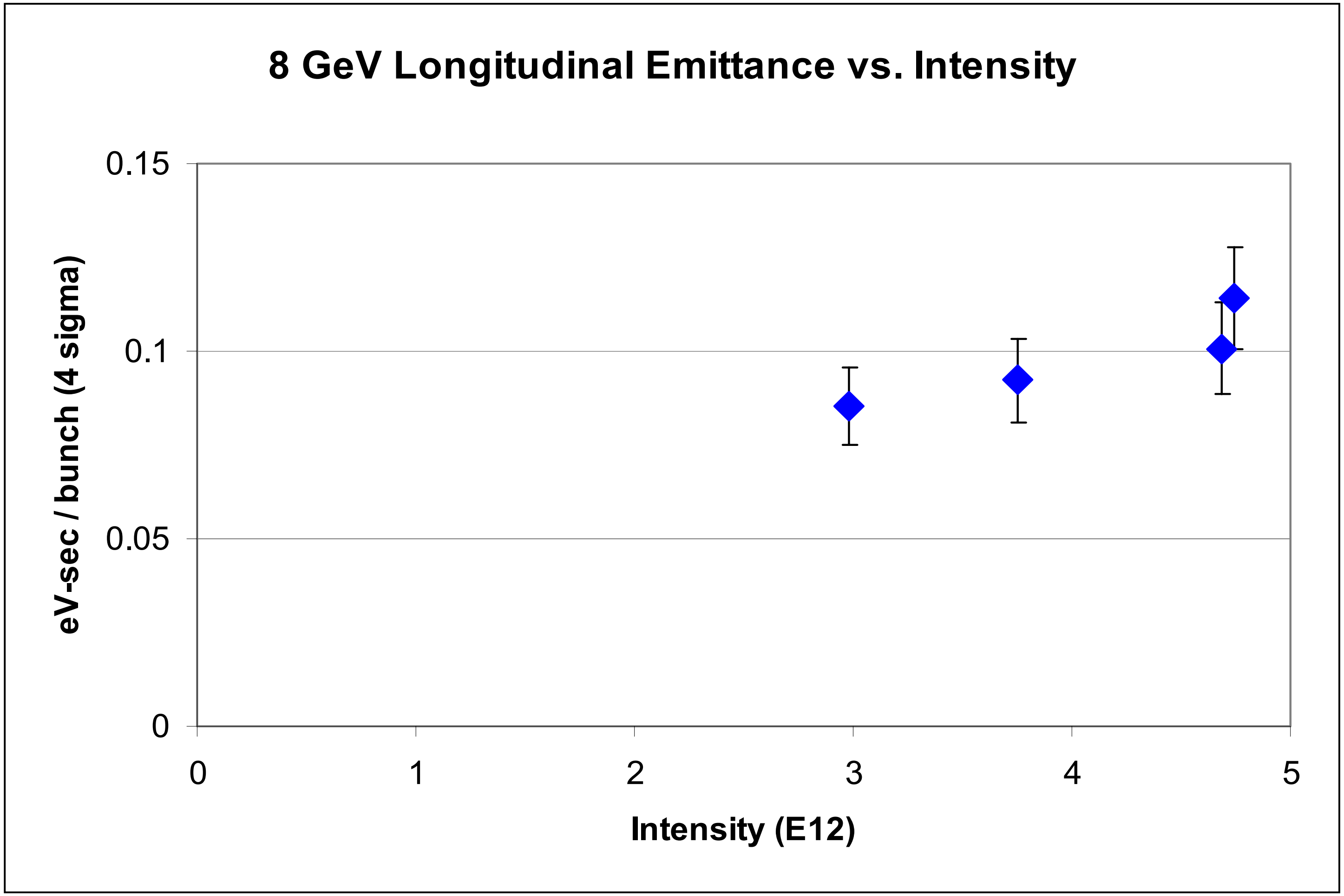
* One batch ~80 bunches (harmonic 84 with 4 bunch gap)

Emittance vs. 8 GeV Intensity



Data and plot courtesy of Ming-Jen Yang

Longitudinal Emittance vs. 8 GeV Intensity

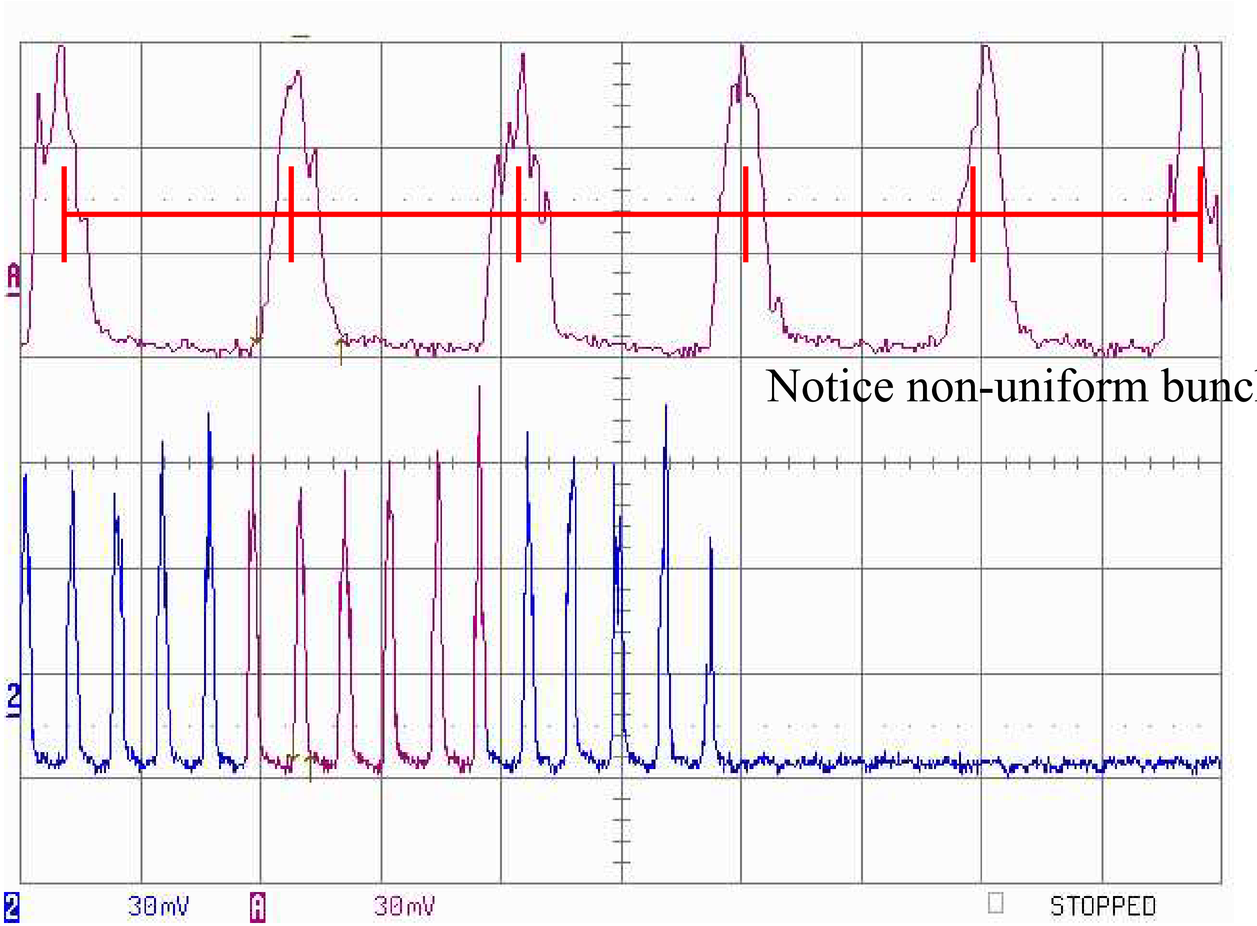


Error bars represent standard deviation of 4 measurements at each intensity

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 before transfer imparts significant perturbation to beam with some increase to longitudinal emittance
  - 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)

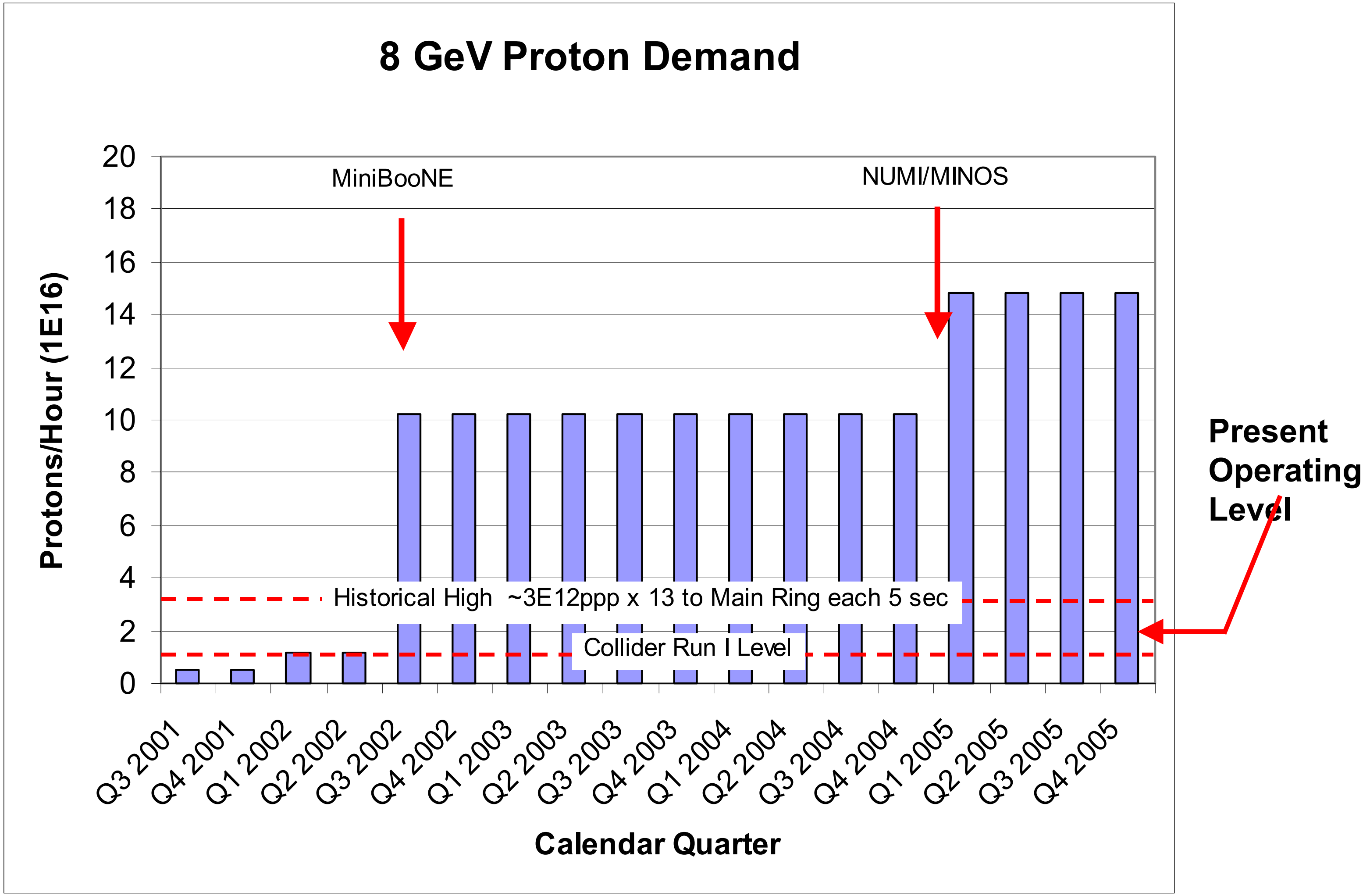
Proton Source Run II-Specific Projects (3)

- 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
  - Permits increased proton delivery rate
    - To the benefit of antiproton stacking
    - To reduce Booster tunnel maintenance worker radiation exposure
  - 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 <u>less than one in three</u> 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

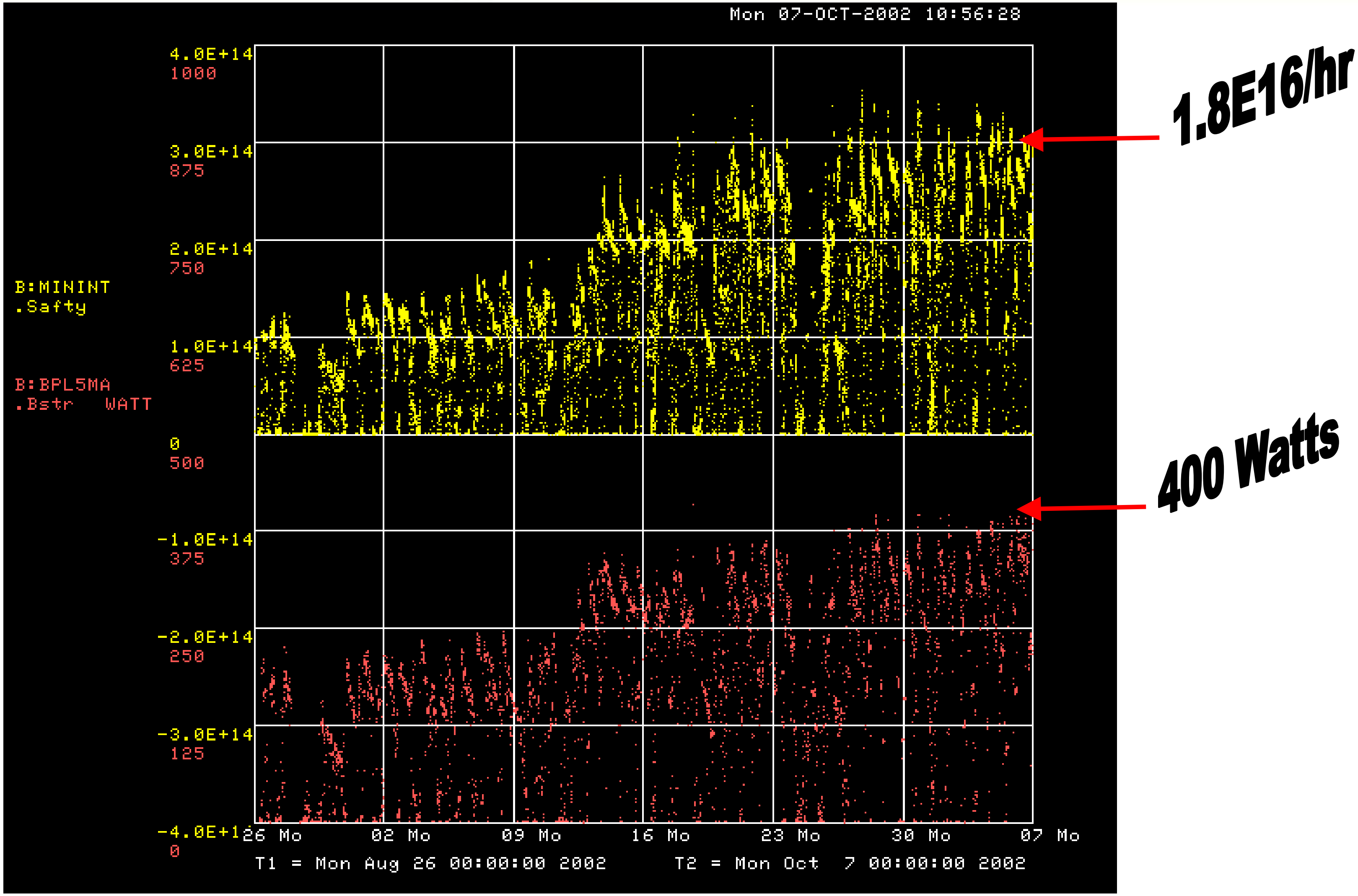
Demand for 8 GeV Protons



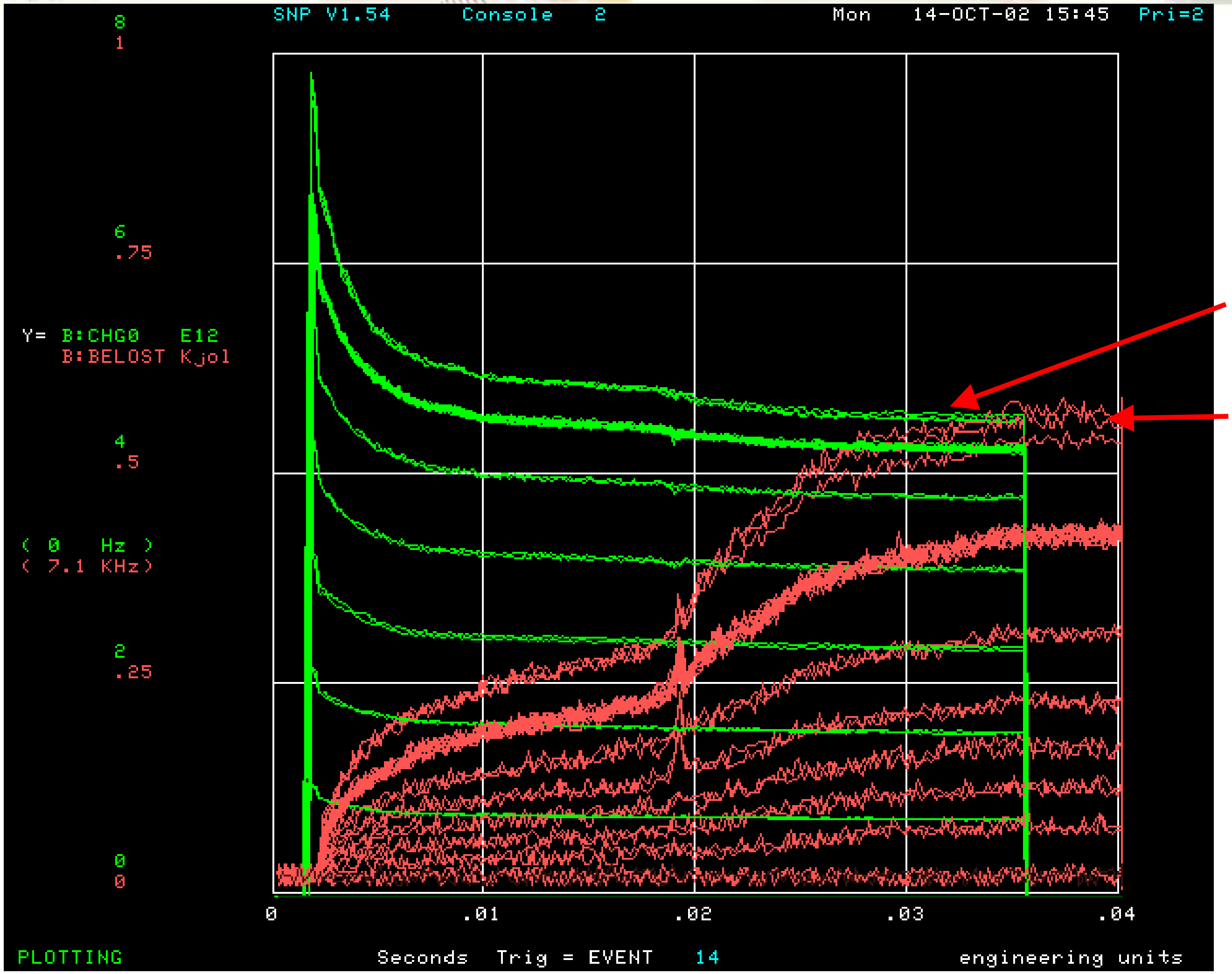
The Challenge

- 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 times 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 Linac and Booster

Recent 6 Weeks with MiniBooNE Turn-On



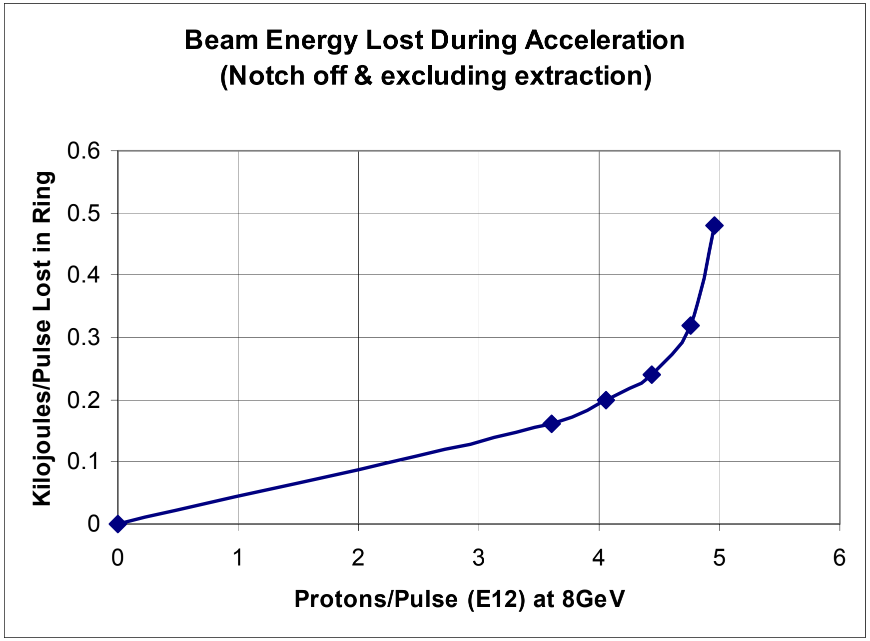
Booster Charge and "Beam Energy Lost" Family

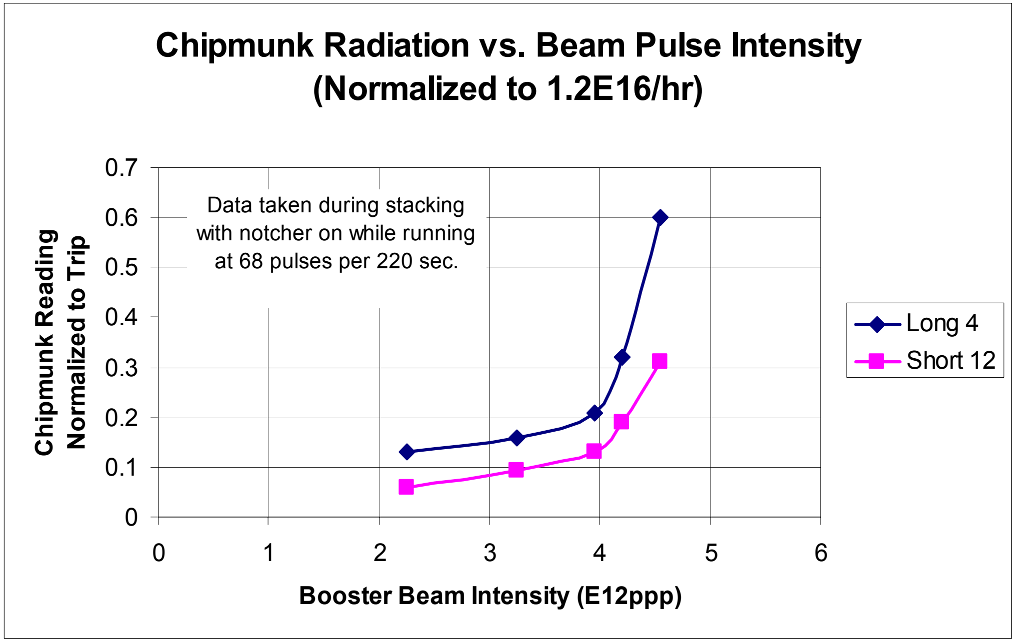


4.5E12

580 Joules

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, P. Kasper [Proton Source] and G. Guglielmo [Computing Division])

Major Systems in Need of Attention to Maintain Traditional Reliability

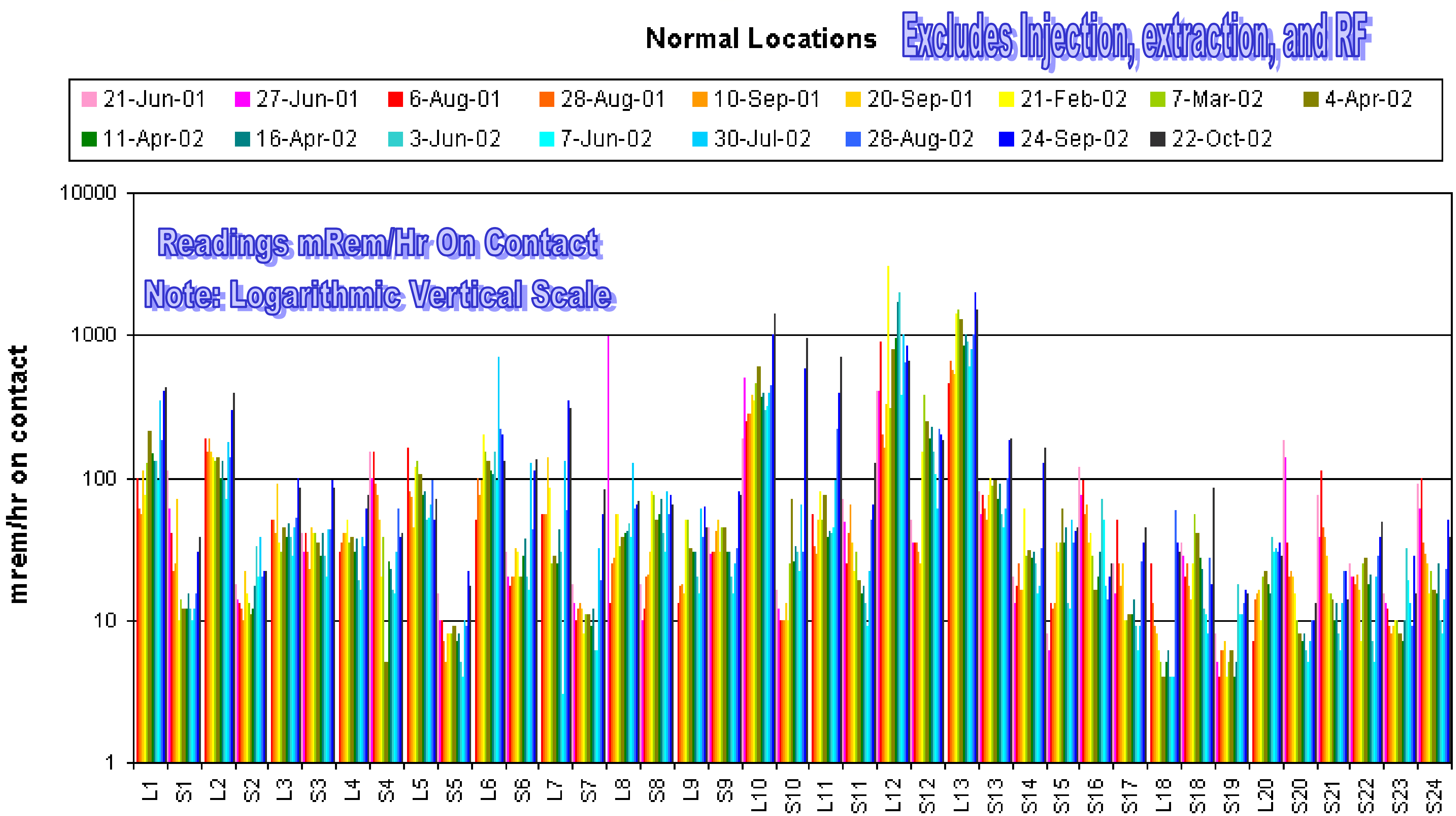
- Low Energy Linac water systems
- Linac 200MHz RF power systems
- Low Energy Linac pulsed quad power supplies
- 400 MeV Lambertson magnet
- 400 MeV transfer line power supply systems
- Booster Orbit Bump power supply output switch
- Booster vacuum system controls
- Booster High Power RF amplifiers and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

Booster Residual Radiation Tracking Program

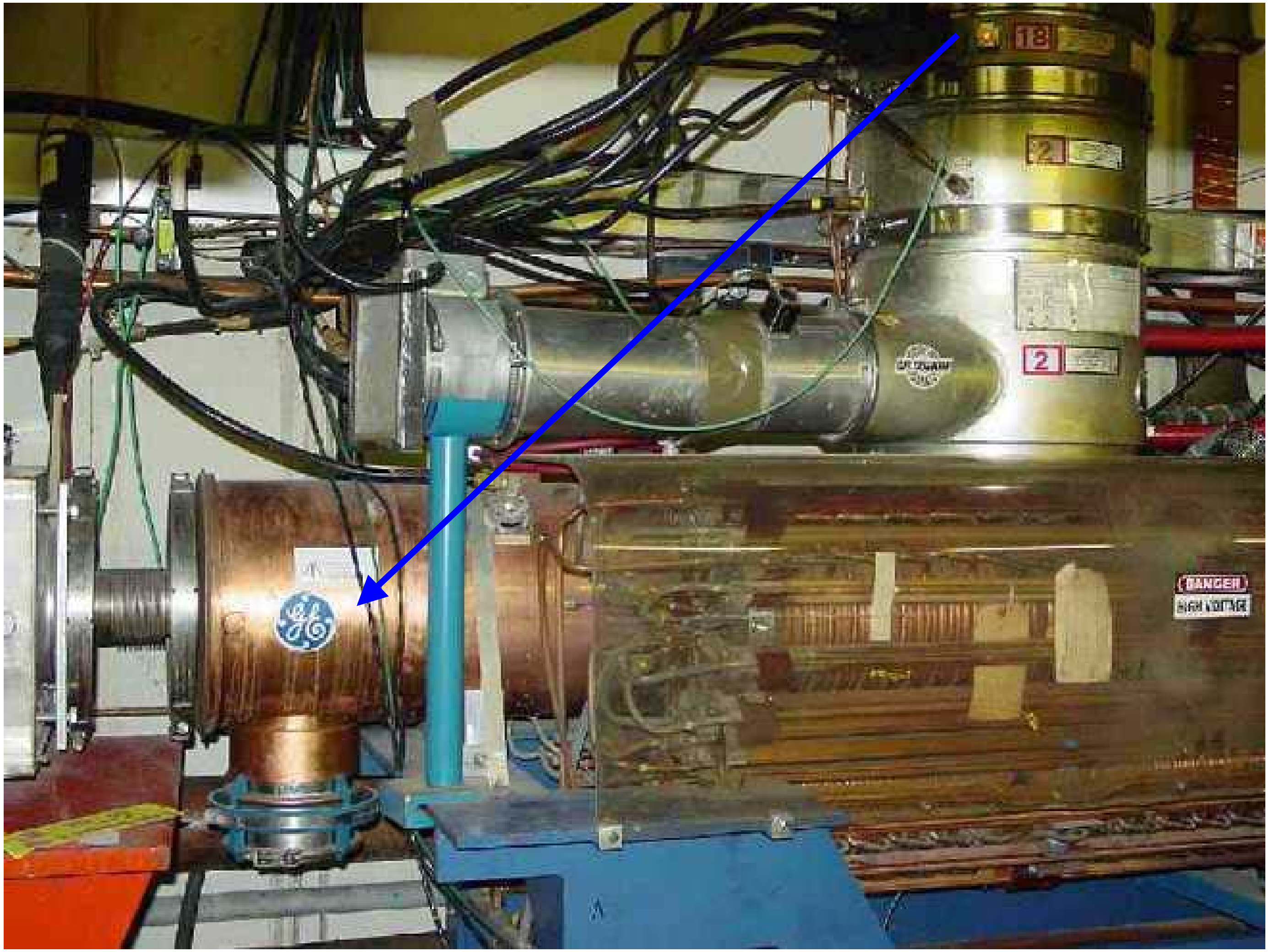
- Establish "fixed" measurement locations around Booster ring
  - Selected easily repeatable measurement locations
  - Some measurements at contact (some on beam pipe some not) and some at 1 foot
- Make measurements most opportunities for access
- Typically 2-8 hours after beam is shut down
  - "fuzzy"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

Proton Source Department

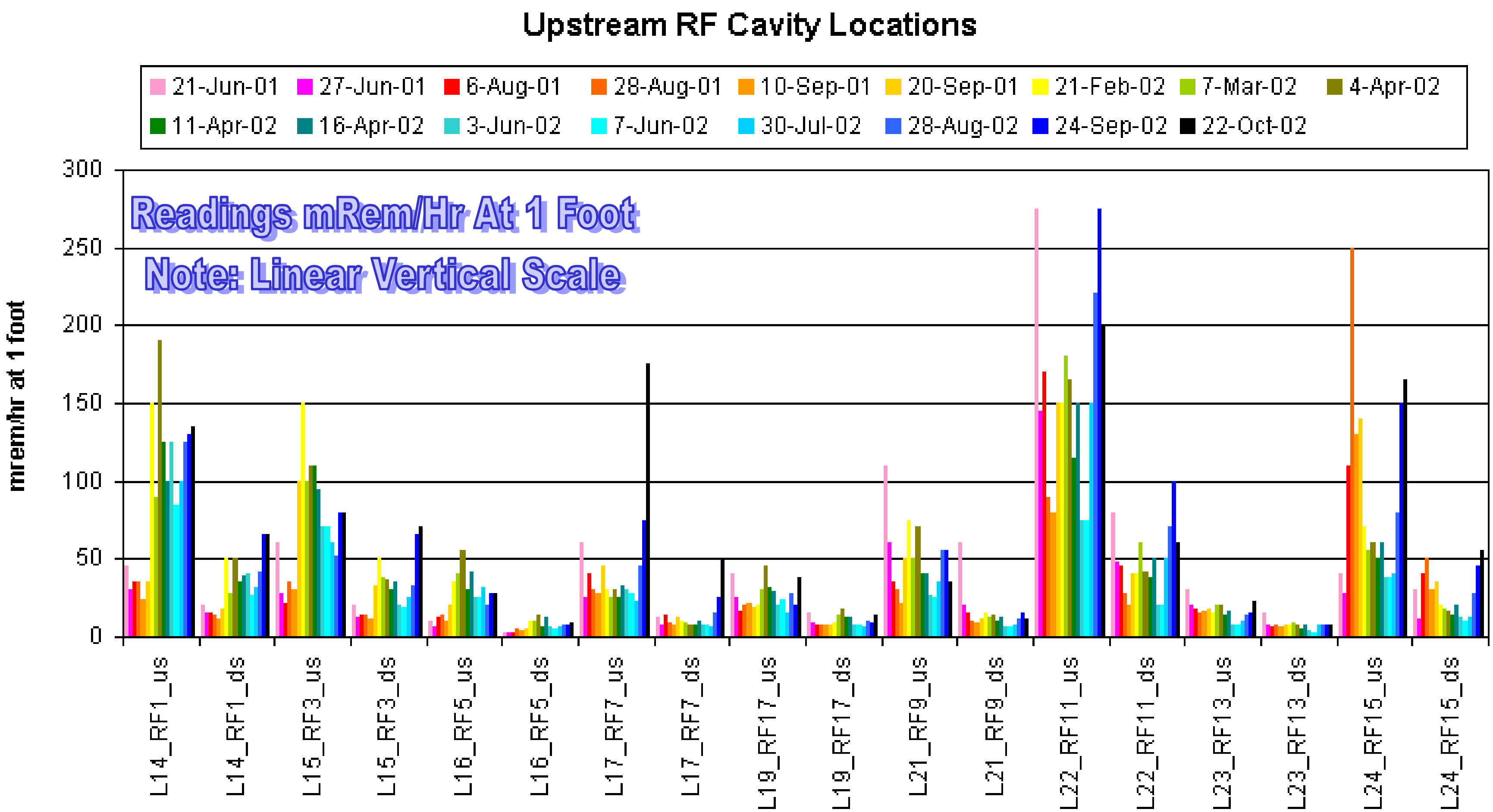
Booster Residual Radiation Data



RF Cavity Survey Point (@ 1 foot)



Booster Residual Radiation Data



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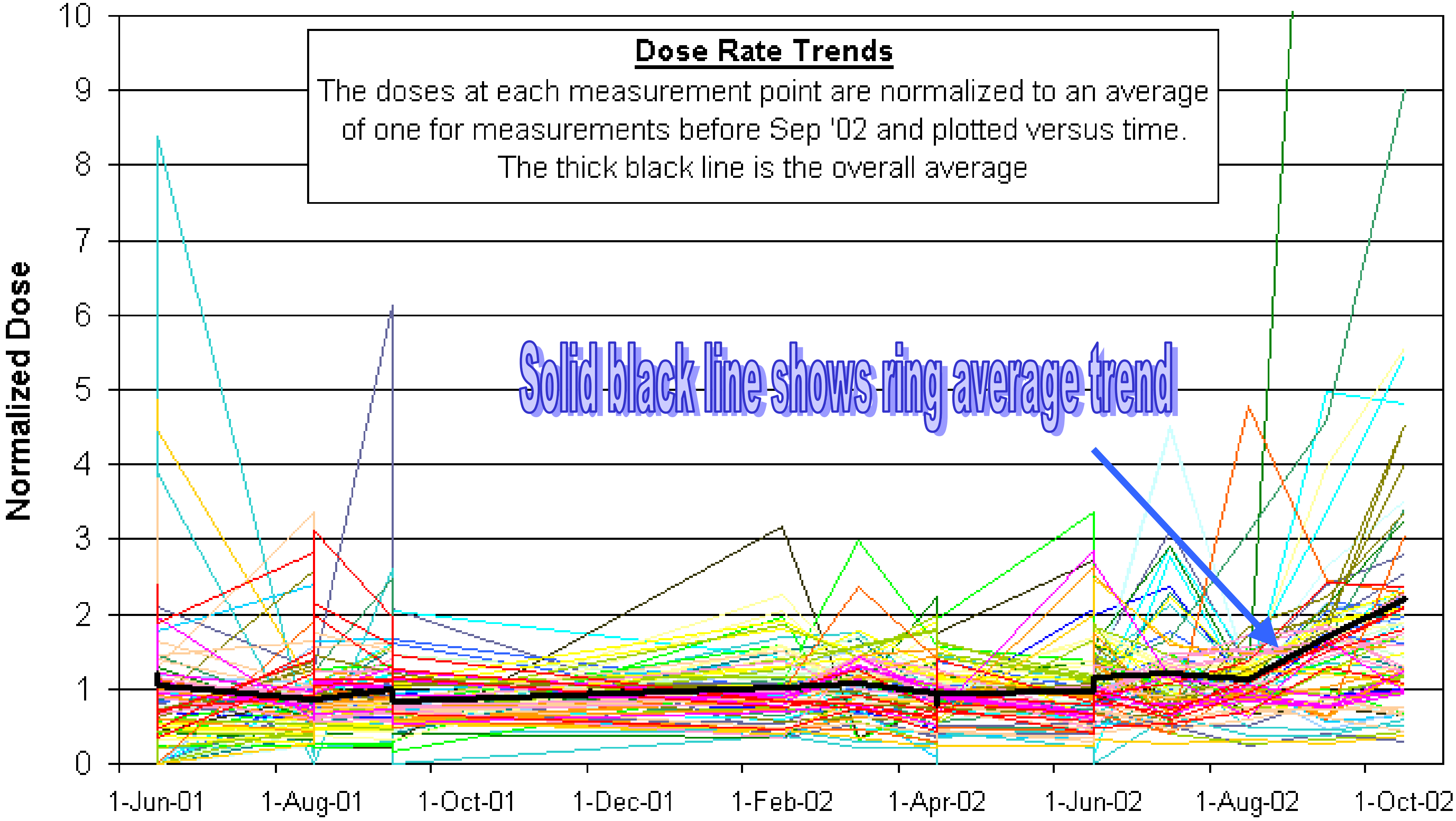
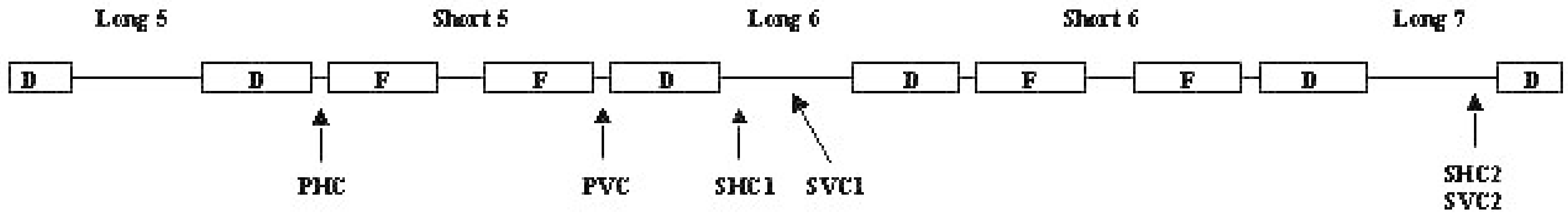


Planned Booster Collimator Layout



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
  - 10% beam pulse intensity improvement is needed to meet goals
  - Longitudinal emittance improvement may benefit Collider
- Aging Booster and Low Energy Linac equipment and operation at increased average beam pulse rates threaten continued operation at historical level of reliability
- Accelerator component irradiation and activation is the most serious issue facing the Booster
  - Operational discipline, additional dedicated scientific and technical staff, and automated loss monitoring and data logging are required
  - Administrative operational limits are set to limit machine damage, personnel radiation exposure, and reduced machine availability
  - Entering era of maintenance in elevated radiation environment