Successful Compensation of Beam-Beam Effects on Protons with Tevatron Electron Lens

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Beam-Beam Compensation Team

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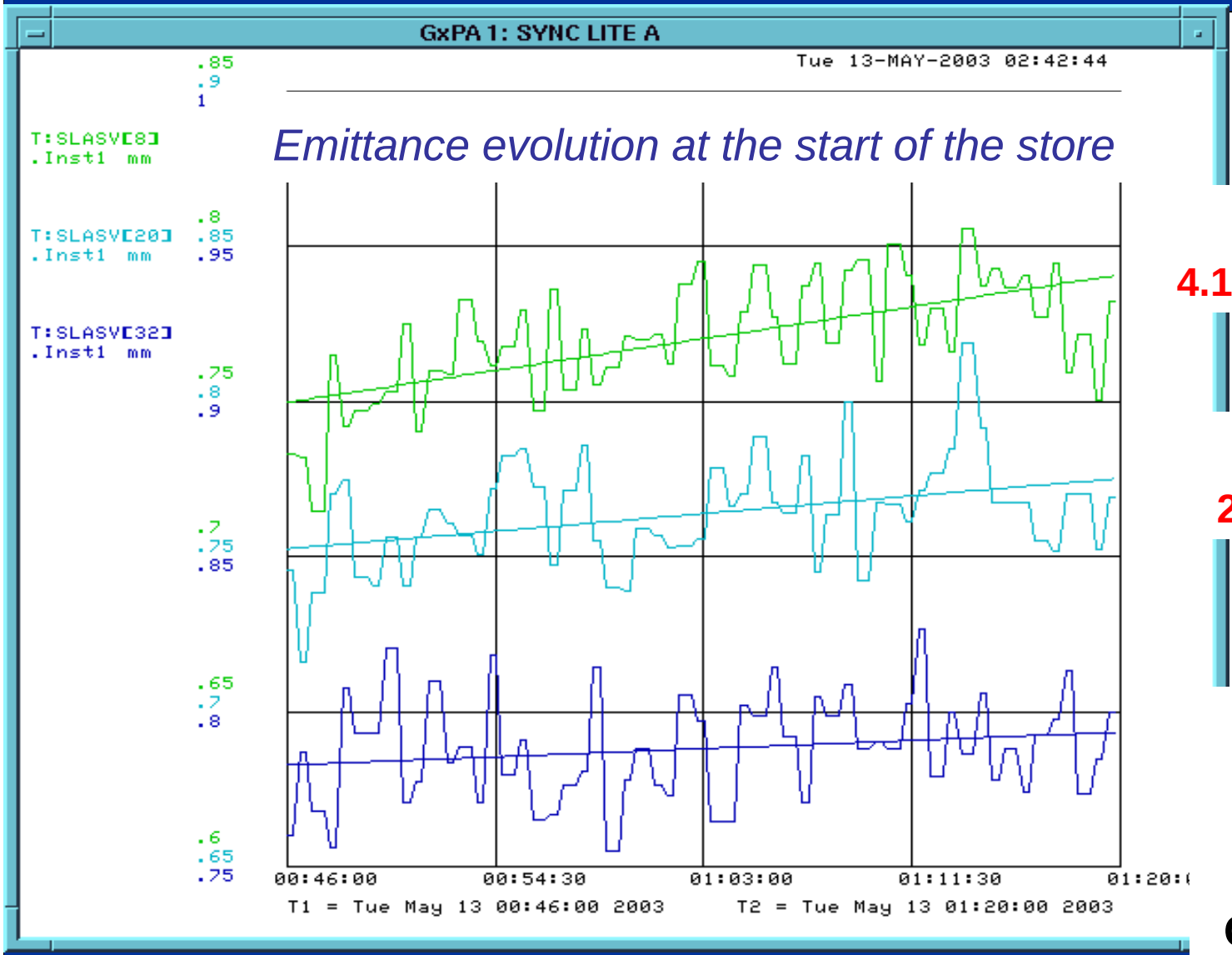
APD Meeting Jan 10, 2007

2003: Pbar Blowup Suppressed by TEL#1



Store #2540

May 13, 2003

A9

4.1 π mm mrad/hr

A21

2.2 π mm mrad/hr

A33

1 π mm mrad/hr

-TEL1 acts on it

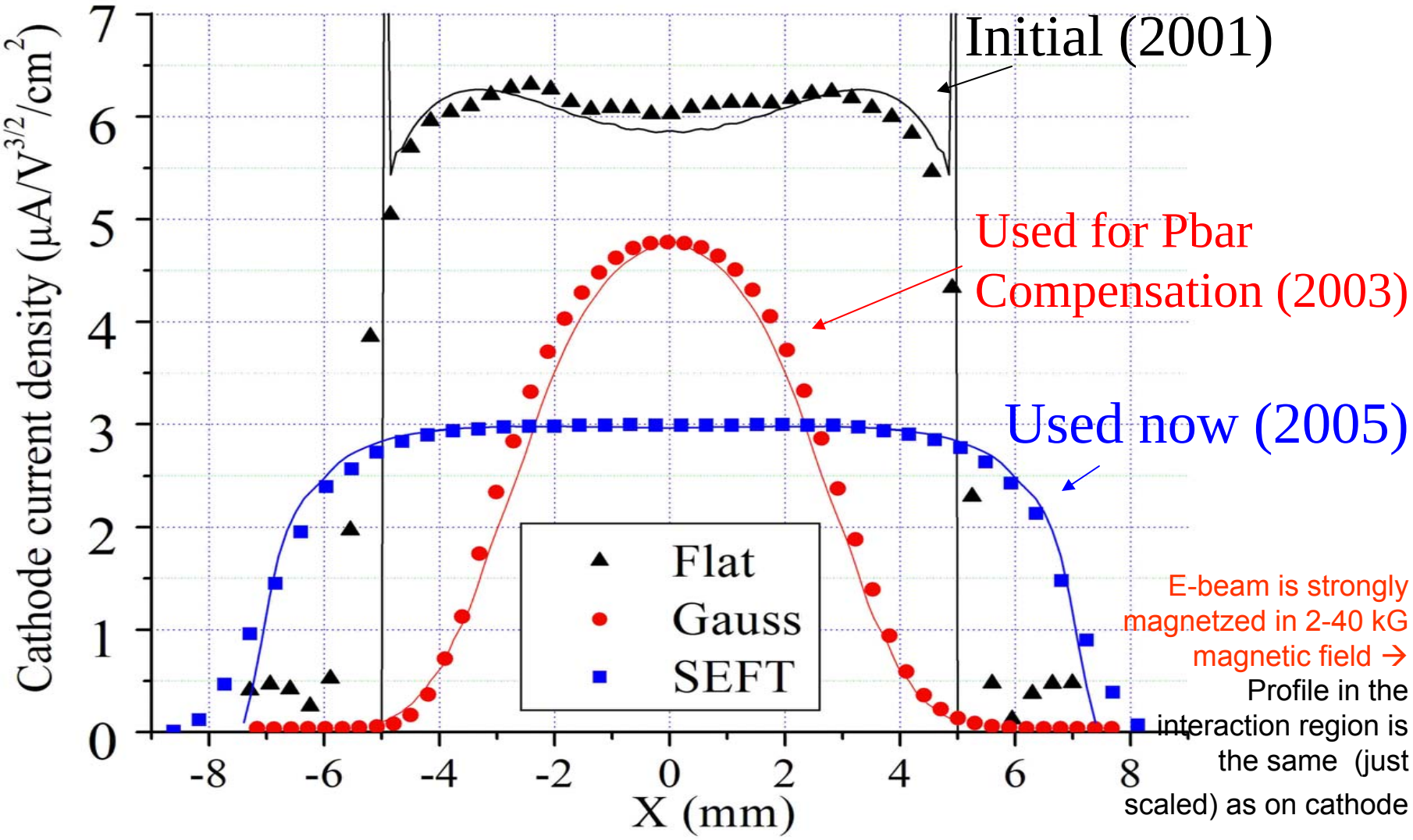
Only few stores!

→ operations

Important Changes Since Then

1. New electron guns developed with wider and optimized electron beam profiles *
2. Orbit stabilization in Tevatron, better beam diagnostics (bunch-by-bunch 1.7GHz Schottky)
3. Much better understanding of beam-beam effects
4. TEL#2 built and installed (2006 shutdown) that can be used for the studies
   (TEL#1 still works 24/7 in abort gaps)
5. Ability to work & tune up TEL2 parasitically in stores w/small e-beam on a single bunch
6. Beam-beam compensation efforts switched from antiprotons to protons **

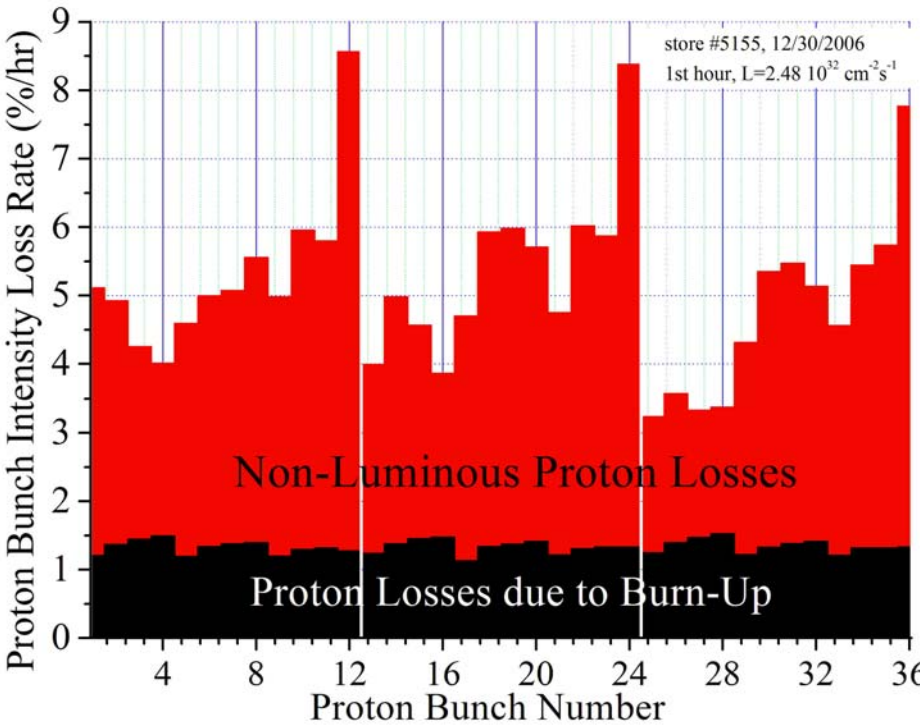
Electron Guns Developed for TELs



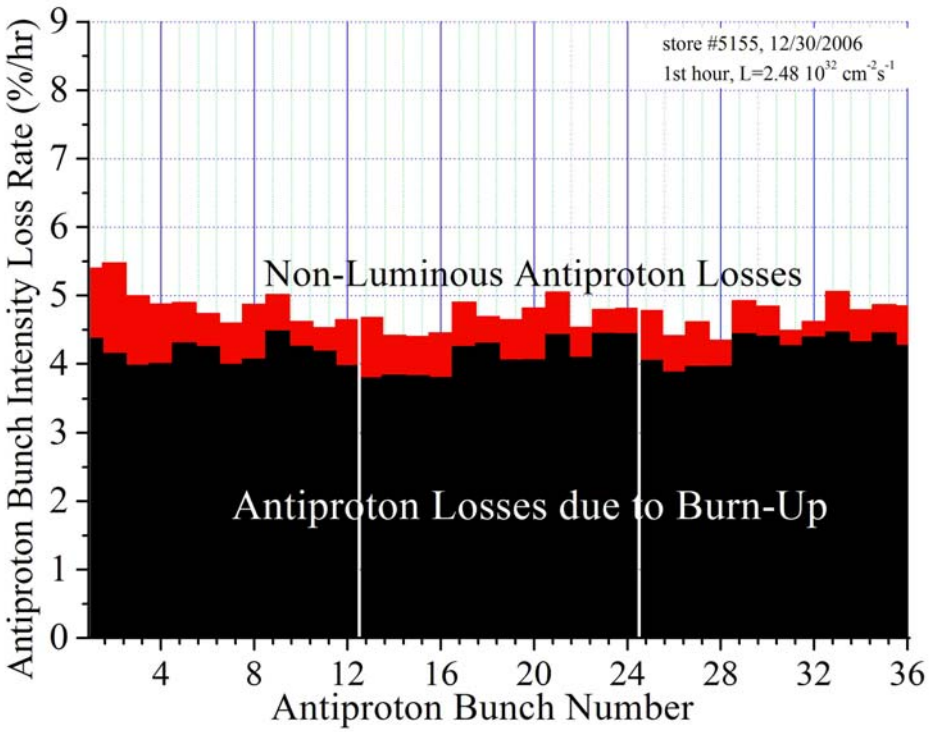
E-beam is strongly magnetzed in 2-40 kG magnetic field → Profile in the interaction region is the same (just scaled) as on cathode

What to Compensate? Protons or Pbars?

Protons



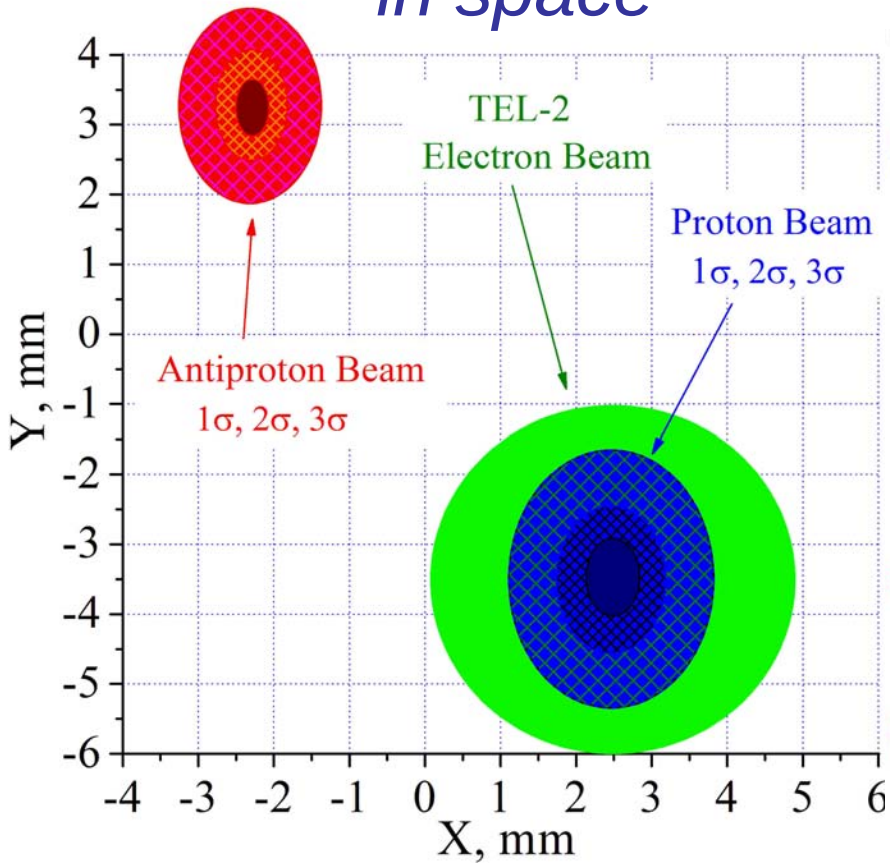
Antiprotons



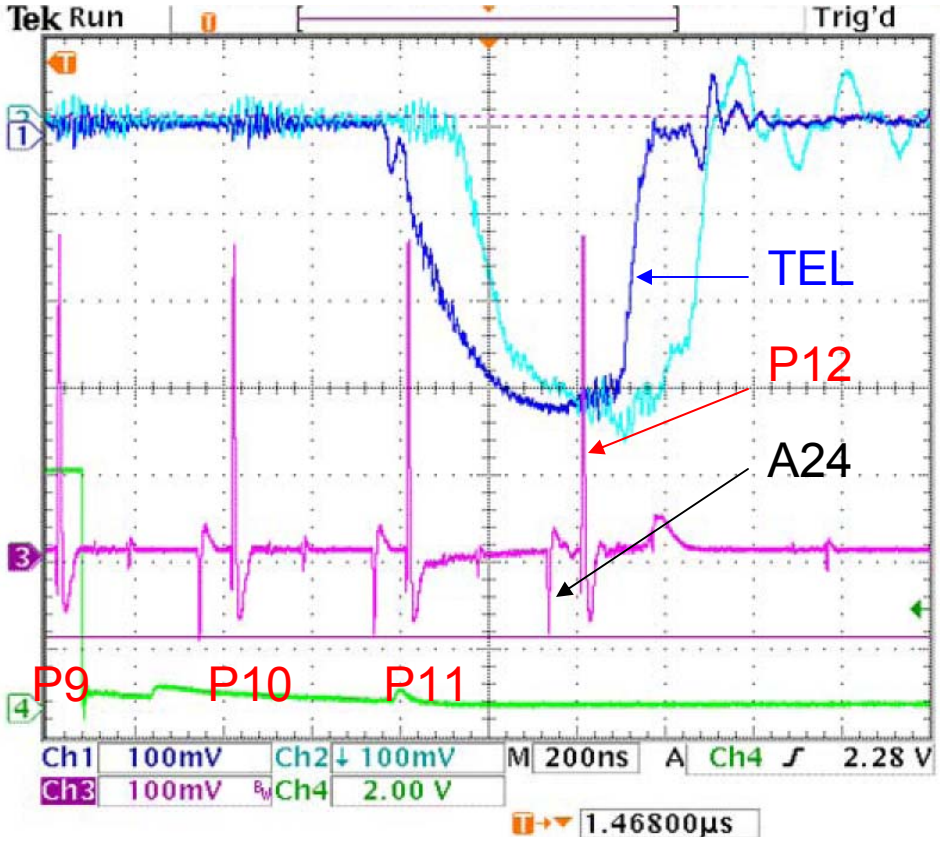
At present, beam-beam effects are relatively stronger on protons, accounting for some 10-15% loss of the integrated luminosity. Proton loss rates vary greatly from bunch to bunch. The Tevatron Electron Lens #2 aligned on proton beam.

TEL2 e-beam aligned and timed on protons

in space

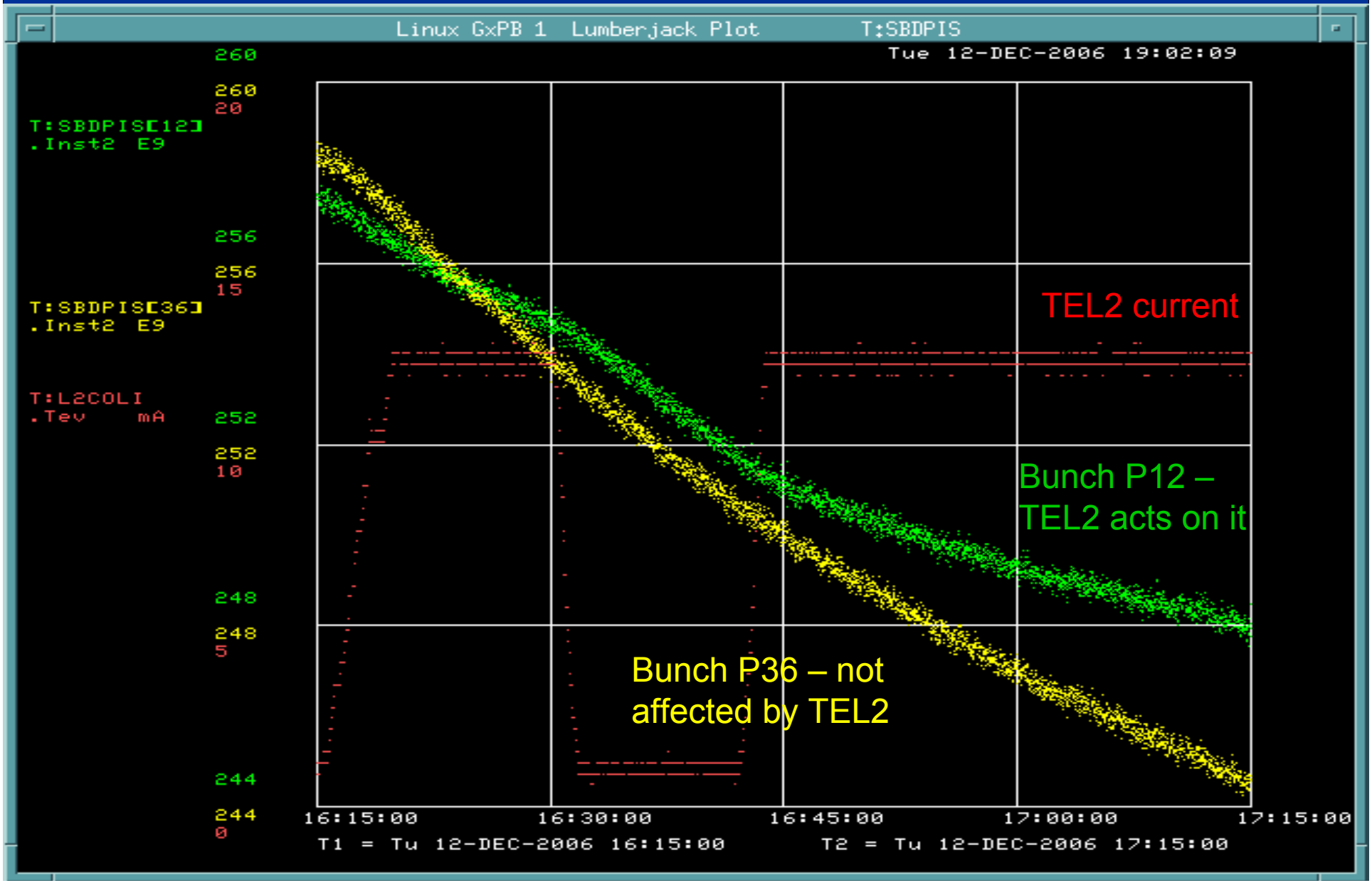


in time

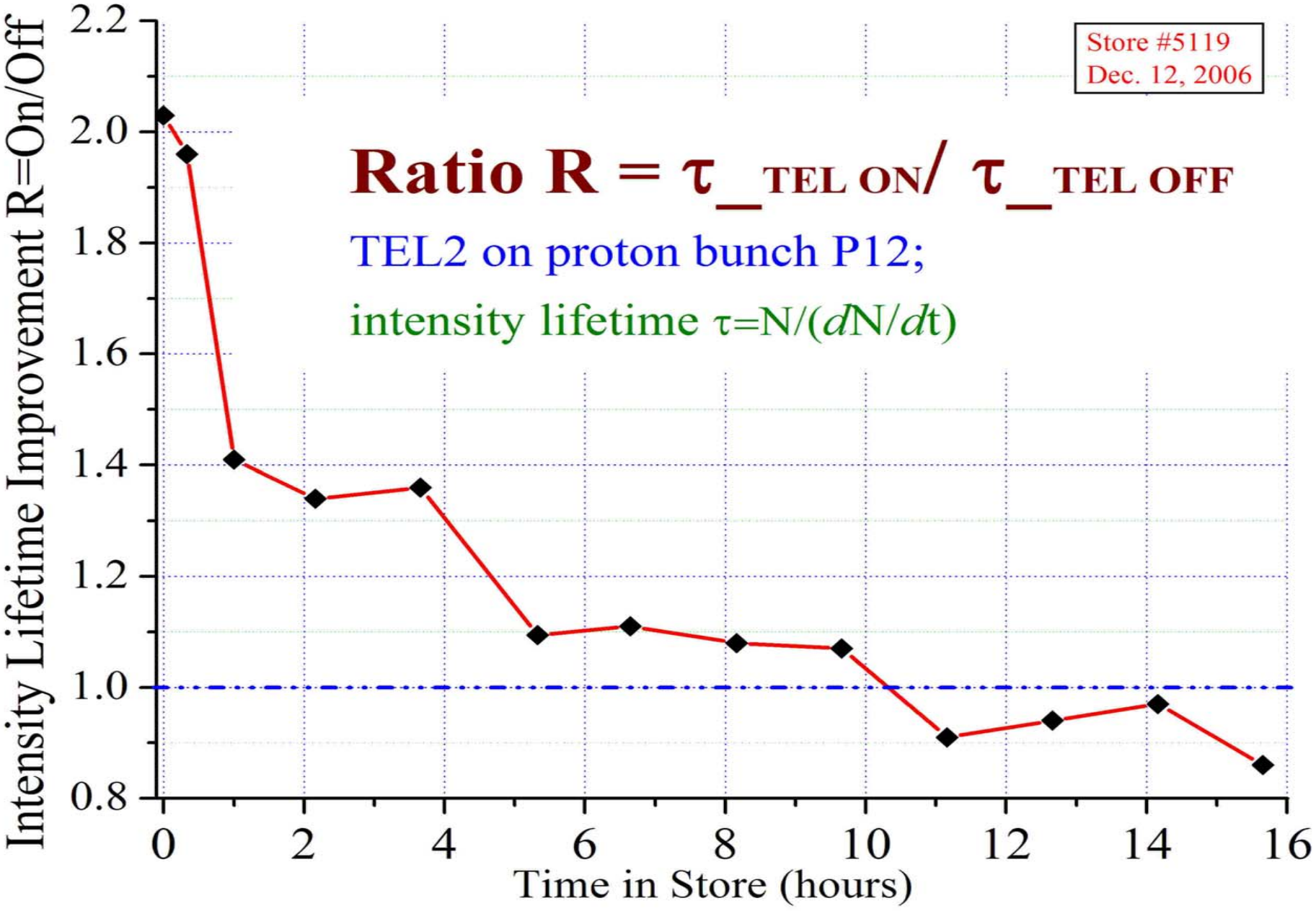


Transverse e-p alignment is very important for minimization of noise effects and optimization of positive effects due to e-beam. Timing is important to keep protons on flat top of e-pulse – to minimize noise and maximize tune shift.

TEL2 on P12: 1st hour of Store #5119



TEL2 Improves Proton Bunch Lifetime

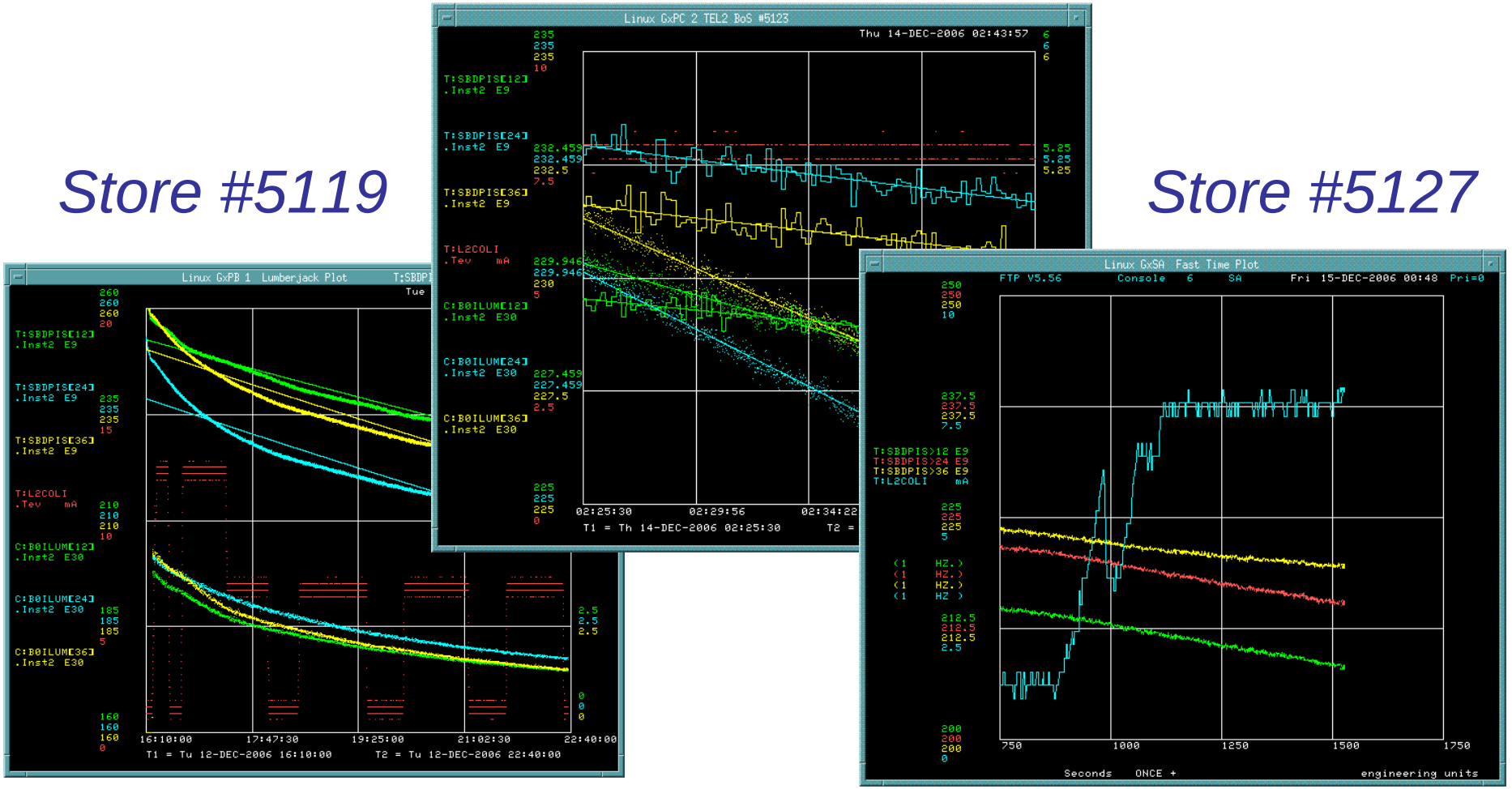


The Improvement Is Recurrent

Store #5123

Store #5119

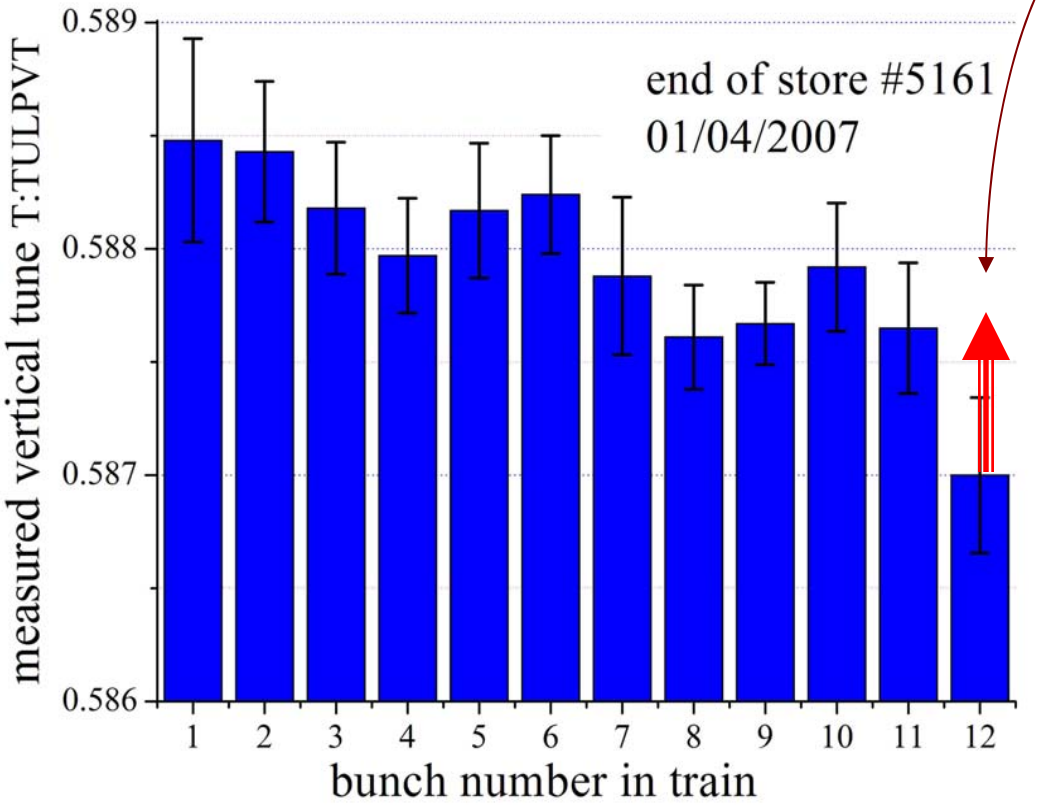
Store #5127

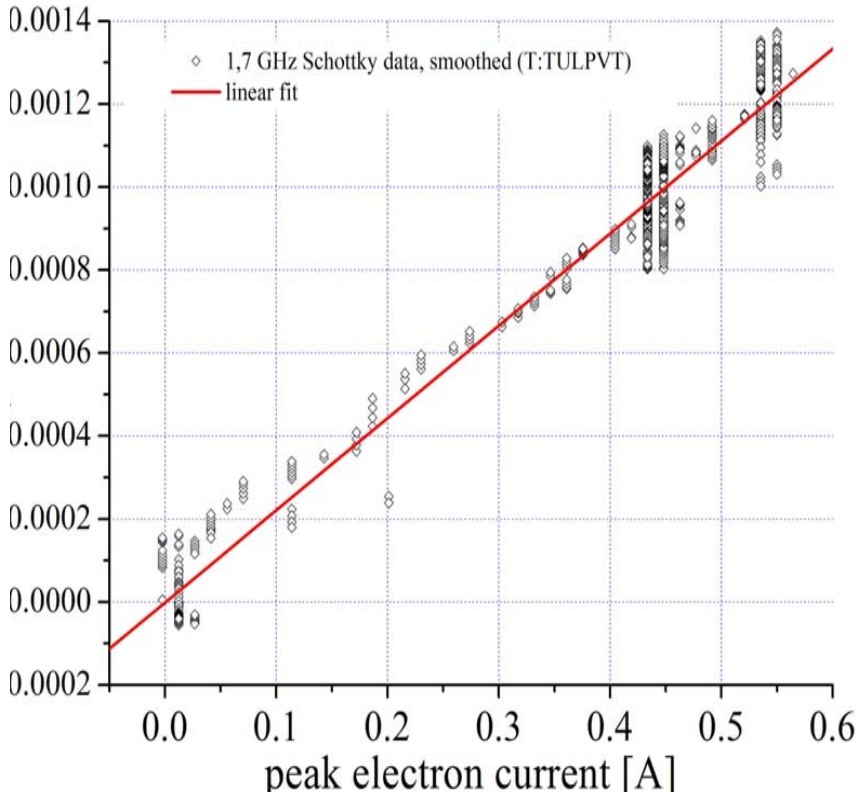


Why does that happen?

Bunches are not equal!

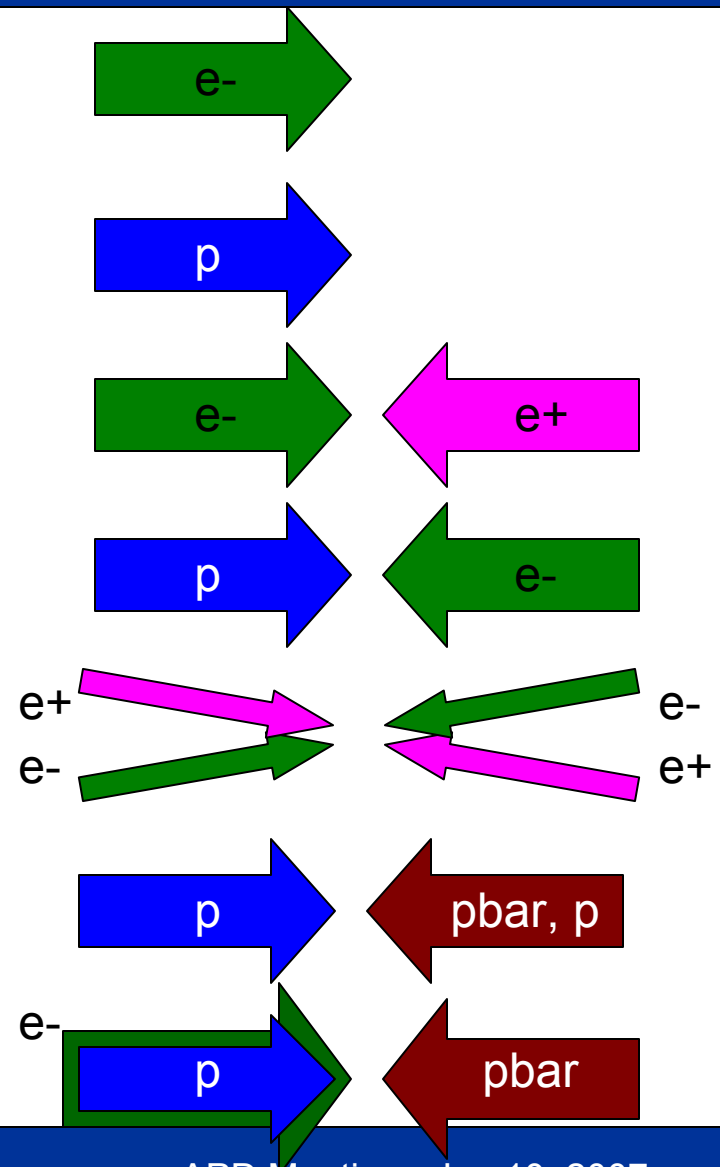
TEL2 moves Q_v up





Bunch P12 has systematically the lowest vertical tune that reduces its lifetime (too close to 7/12 resonance). TEL2 can raise the tune up by 0.001-0.002.

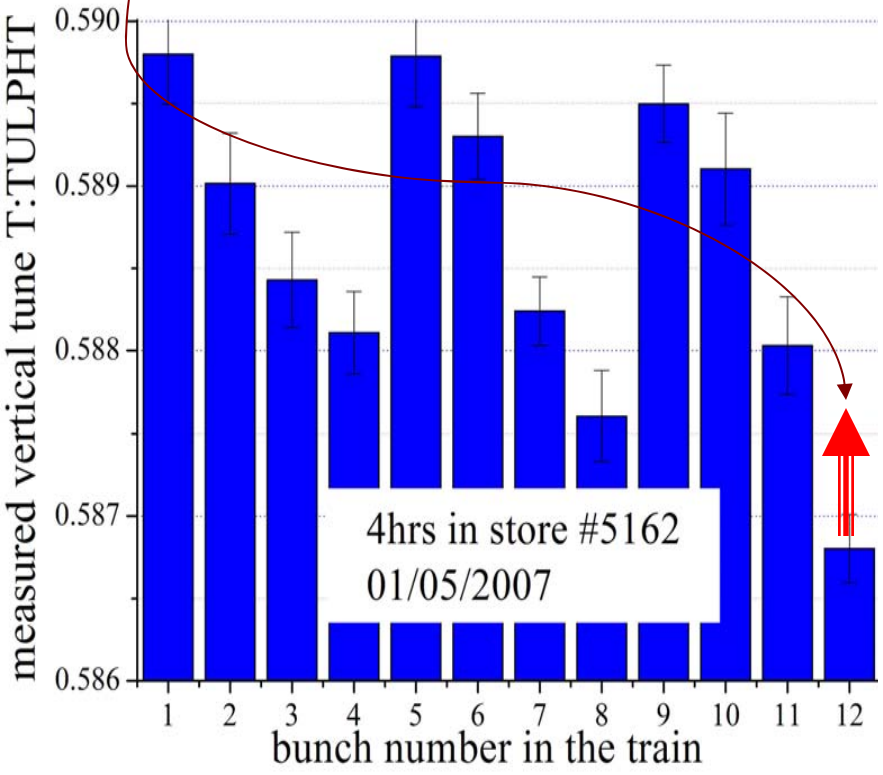
Is that hard? Complexity of Beams in *log*-Scale:

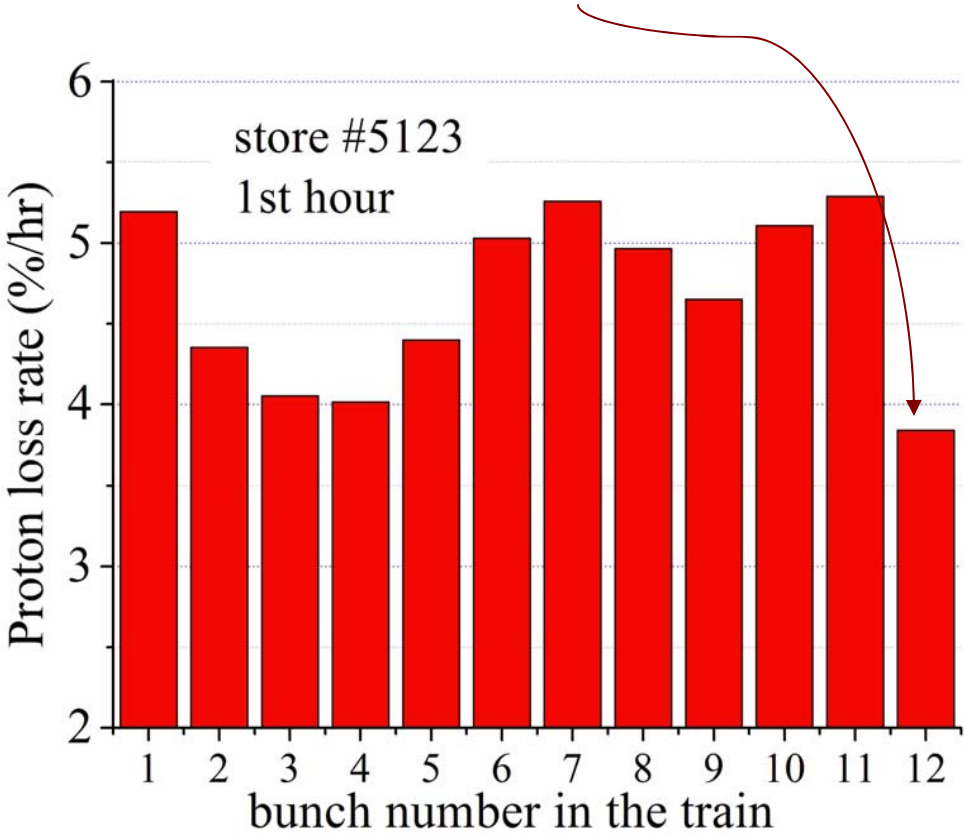


The puzzle: why so good?

Q_v up a bit by TEL2

P12 loss is THE lowest!





If only *tuneshift* matters, then the lifetime of P12 (TEL2 affected bunch) should not be better than other bunches in the train. In reality, P12 lifetime is the *best* of 36 bunches!

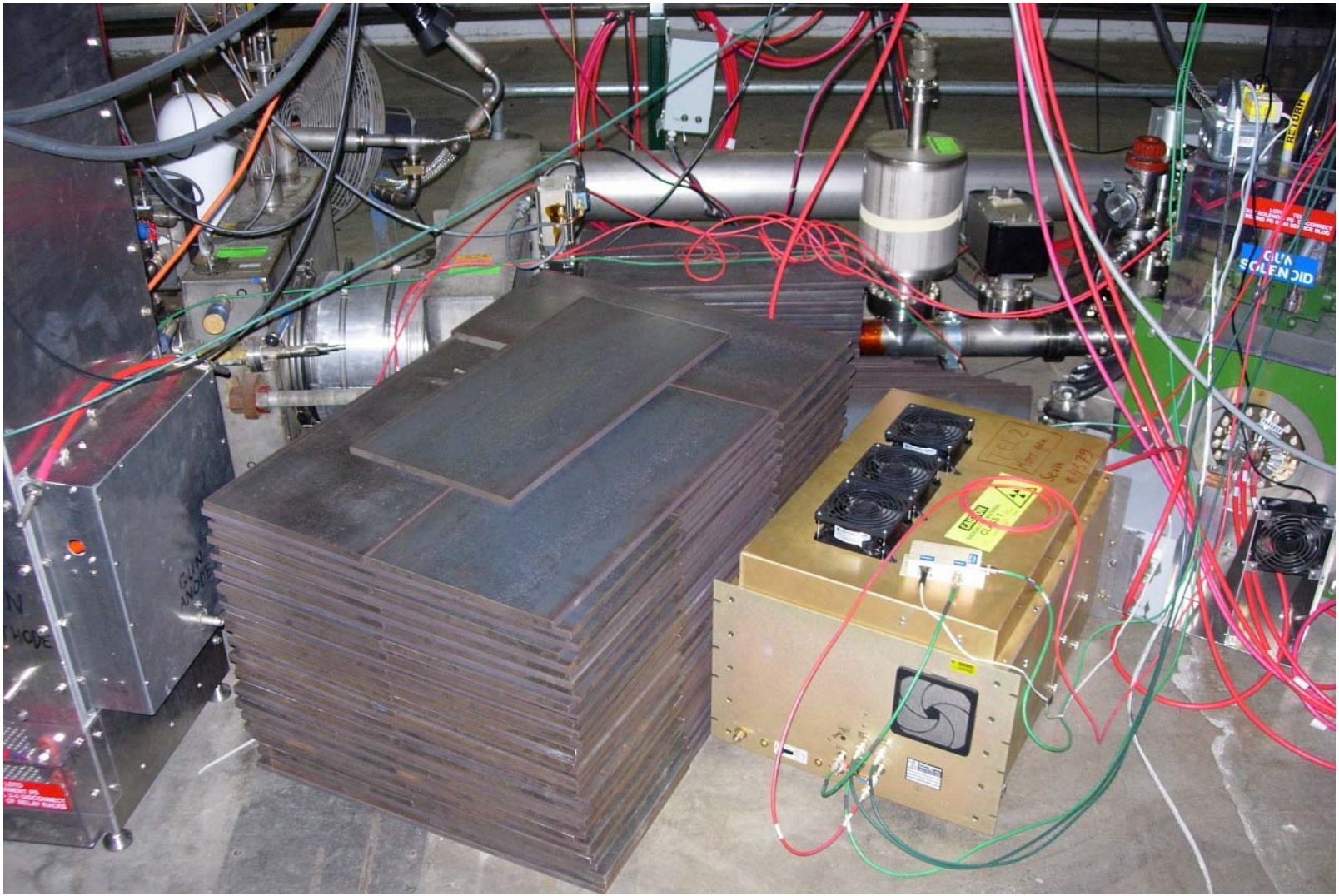
Summary

- Tevatron Electron Lens #2 was installed during 2006 shutdown and commissioned
  i) as TEL-1 backup for abort gap cleaning
  ii) as *vertical* beam-beam tune shift compensator $\Delta Q_v \sim .002$
- In a series of stores, TEL2 acted on a single proton bunch and *DOUBLED* its lifetime
- BBCompensation helps for ~10 hrs in store

Next Steps:

- Fix HV Marx generator (IGBTs die due to radiation, let them cool off, add more schielding) *
- Attempt DC beam compensation – for all the bunches
- Try TEL2 during scraping (attempt to reduce 4% loss)
- Try TEL2 on several (3,6,12) bunches
- Finish hardware improvements:
  - High power collector, gridded e-gun, MCP e-gun, TEL1 upgrade
- Formulate proposal of e-lenses for the LHC, present at the LARP collab. meeting, BBcomp workshop at SLAC, PAC'07

Marx Generator Dies of Radiation



TEL2 In The Tunnel (A0)