Experimental Demonstration of *Beam-Beam Compensation* by **Tevatron Electron Lenses** and Prospects for LHC

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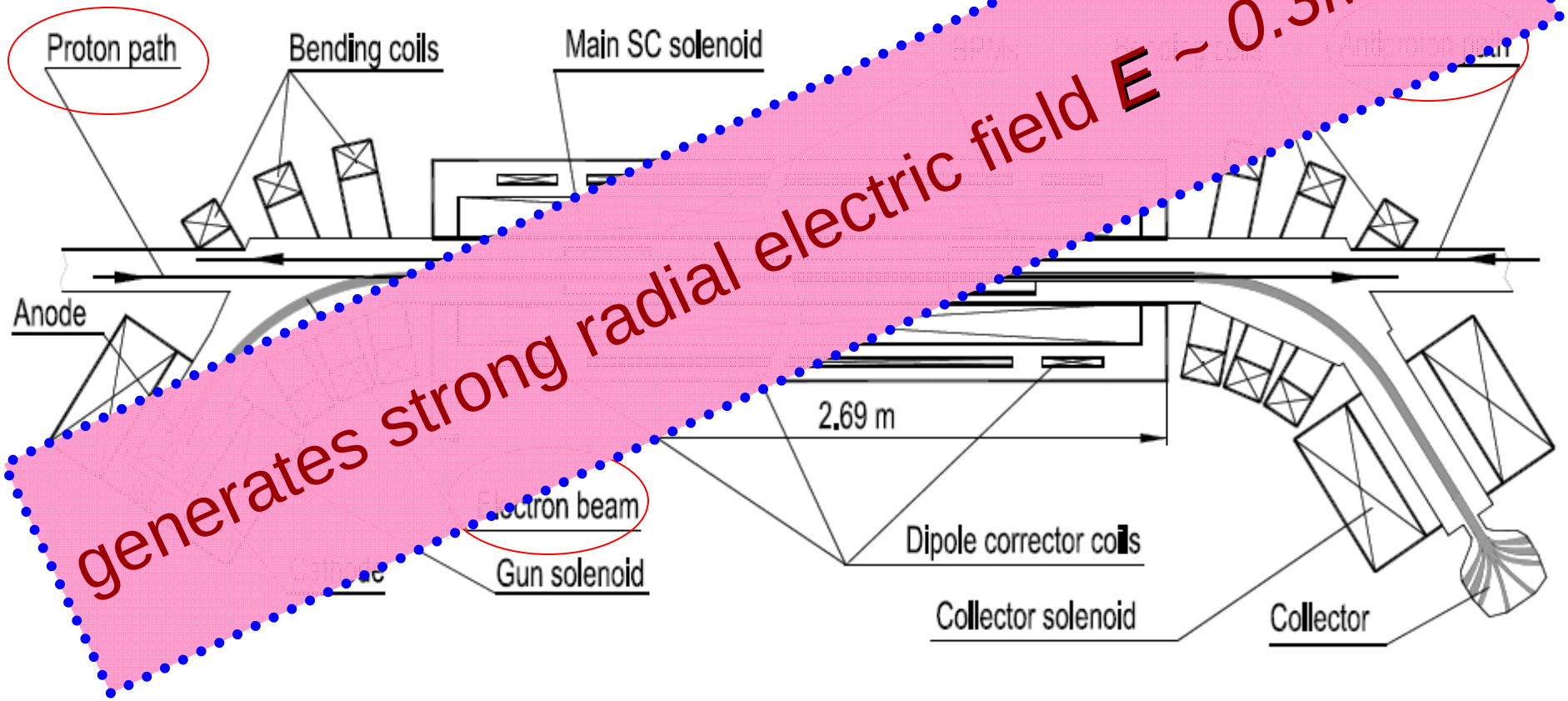
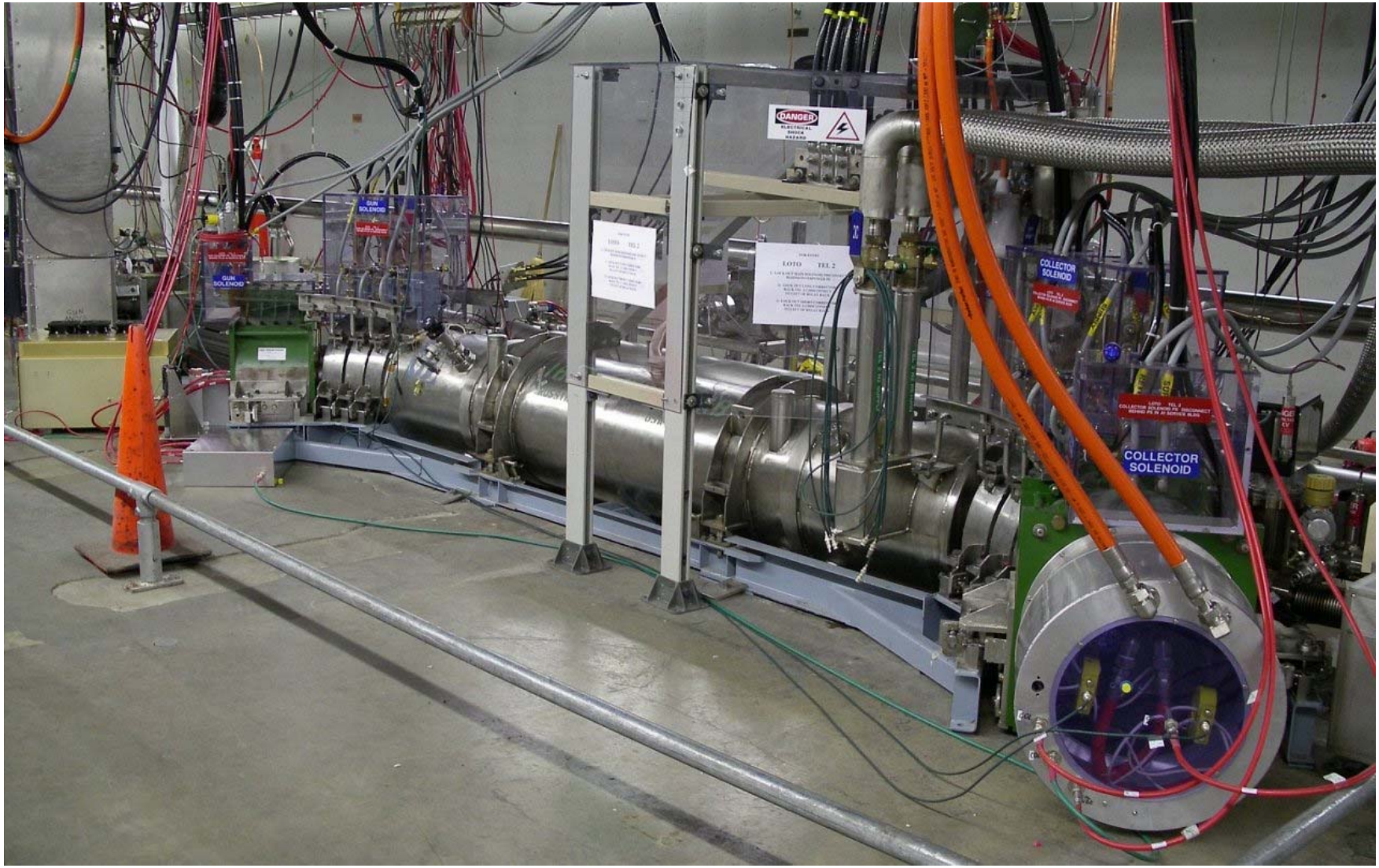
What is Electron Lens?

~2 mm dia 2 m long very straight beam of ~1[illegible] V

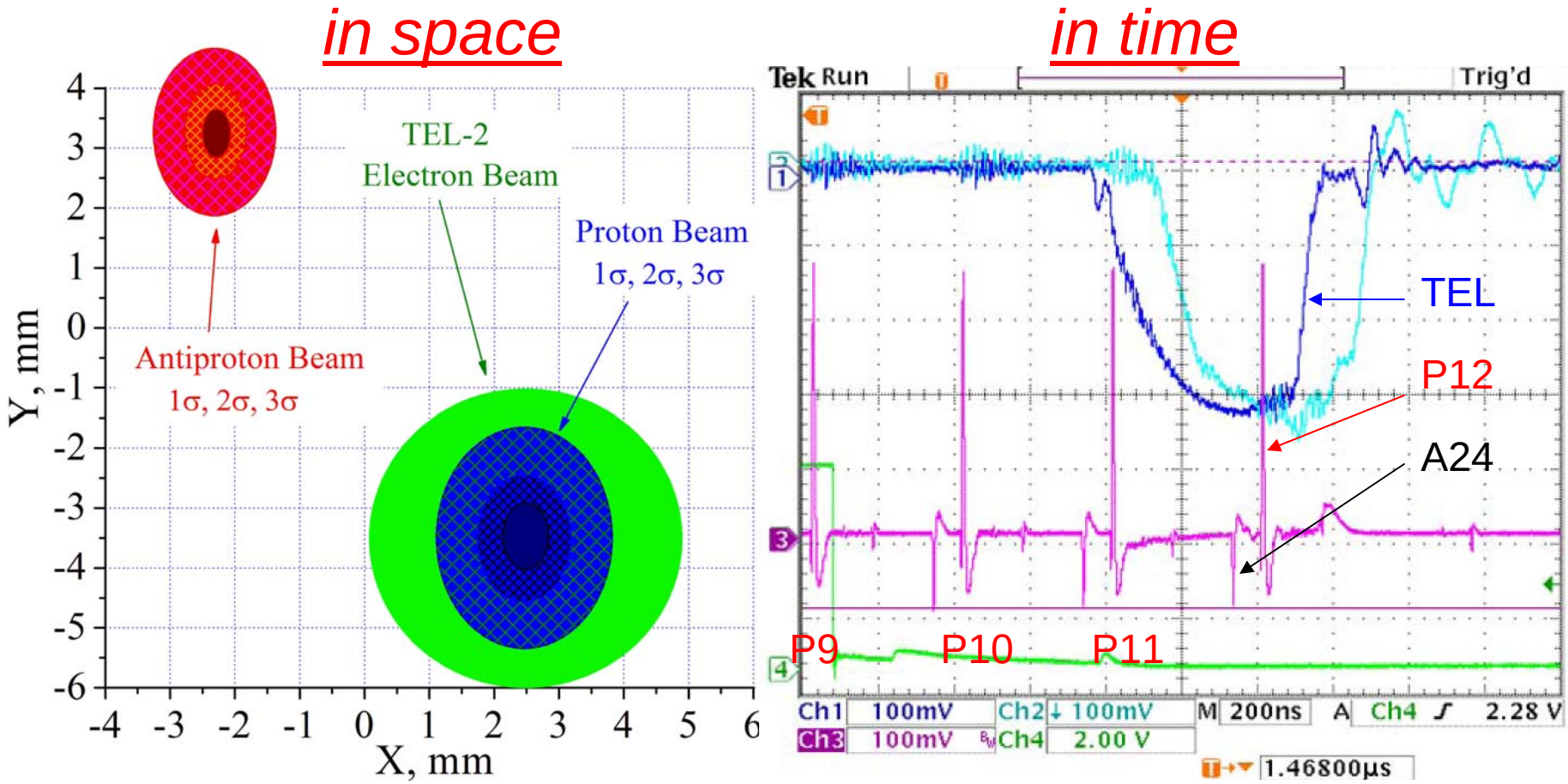
~1A electrons (~10^{12}) immersed in 2[illegible] solenoid



TEL2 In The Tunnel (A0)

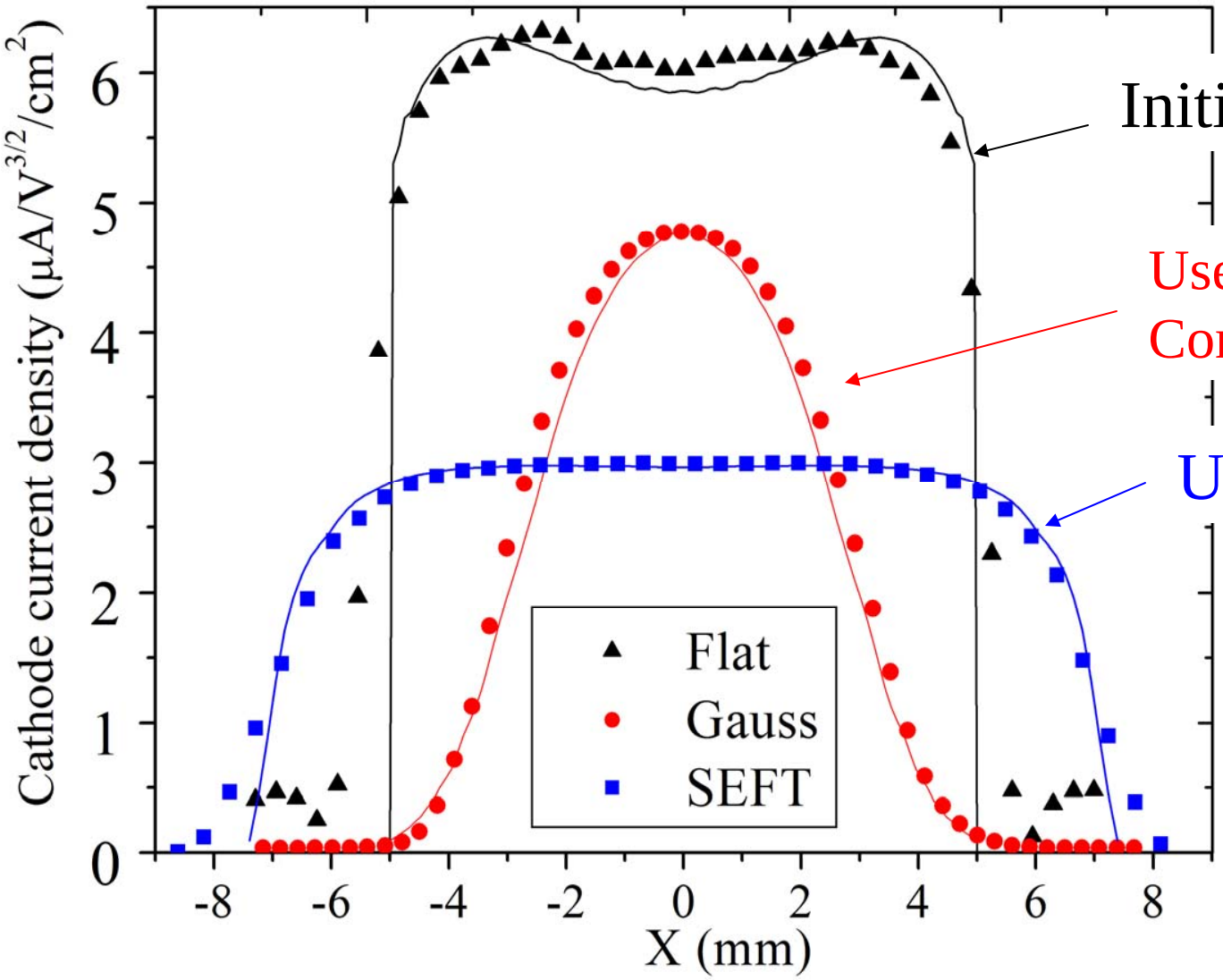


TEL2 e-beam aligned and timed on protons



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.

Electron Guns Developed for TELs



Initial (2001)

Used for Pbar B-B Compensation (2003)

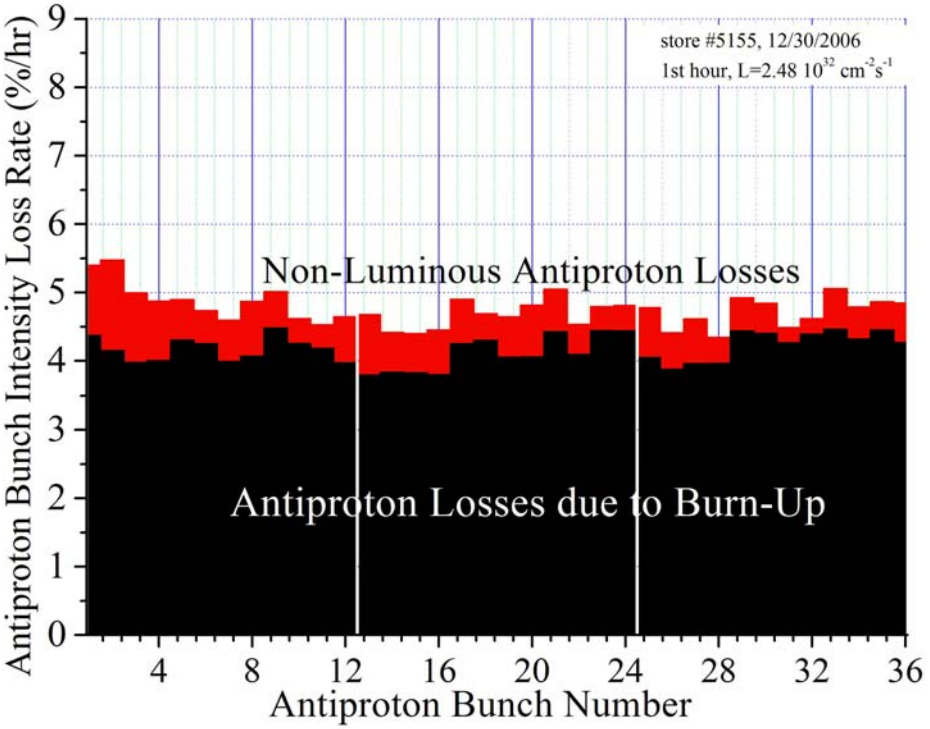
Used now (2005)

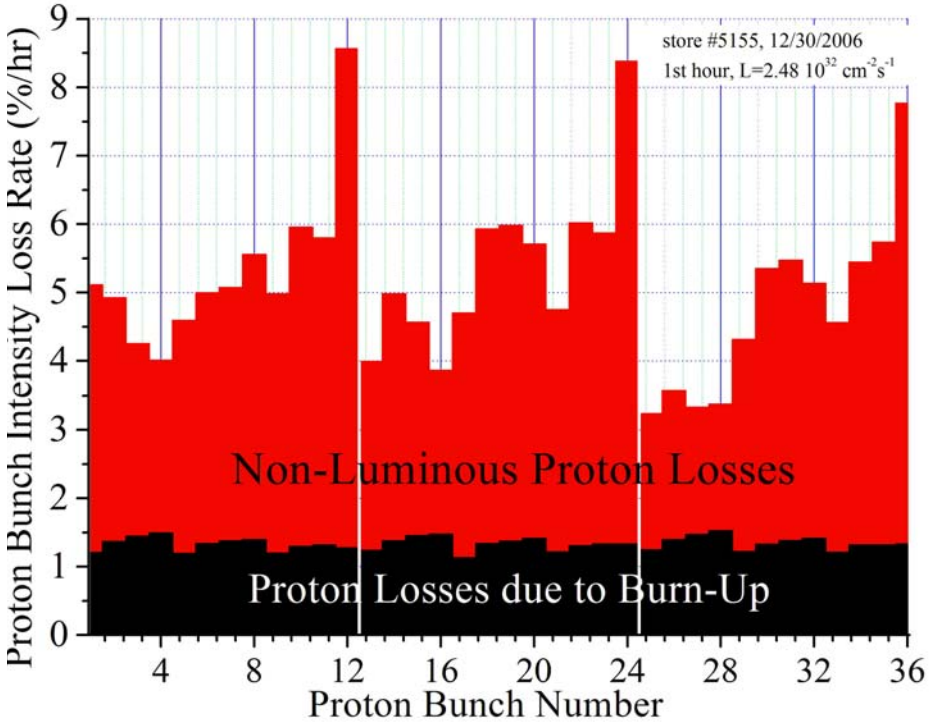
E-beam is strongly magnetzed in 4-40 kG magnetic field →
Profile in the interaction region is the same (scaled) as on the cathode

TEL Choice: Antiprotons or Protons?

Antiprotons *980 GeV :* ξ_{max}*=+0.024 ; TEL focuses*

Protons *980 GeV :* ξ_{max}*=+0.016;TEL defocuses*

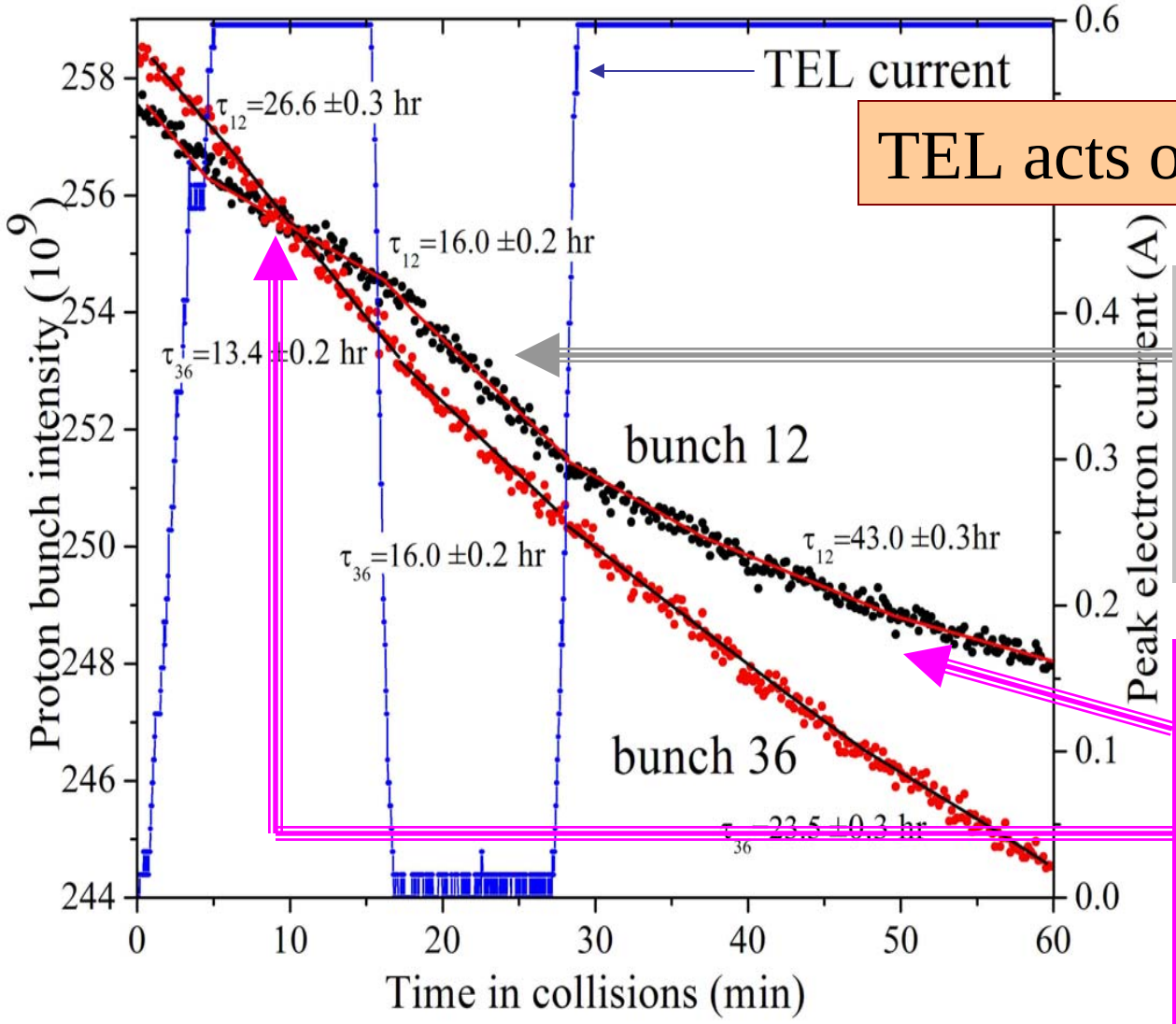




At present, beam-beam effects are relatively stronger on protons, accounting for some 10-15% loss of the integrated luminosity. Proton loss rates vary greatly from bunch to bunch. The Tevatron Electron Lens #2 aligned on ***proton*** beam.

TEL2 on P12: 1st hour of Store #5119

Dec.30, 2006

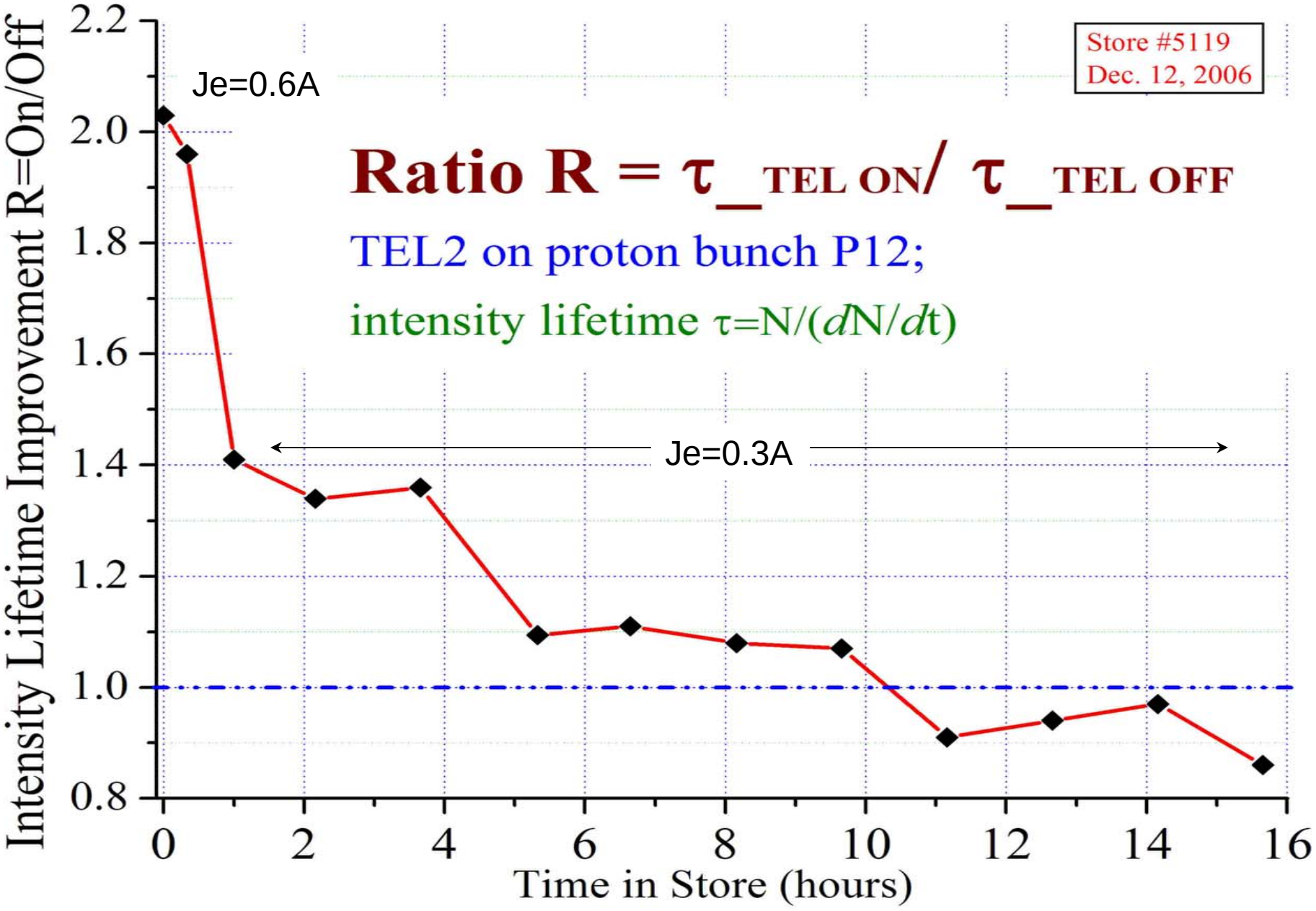


TEL acts only on bunch #P12

*When TEL **off**:*
bunches #12 and #36 have same lifetime
16 hrs and 16 hrs

*When TEL **on**:*
bunch #12 lifetime is 2x #36 lifetime:
26.6 hrs vs 13.4 hrs
43.0 hrs vs 23.5 hrs

TEL2 Improves Proton Bunch Lifetime

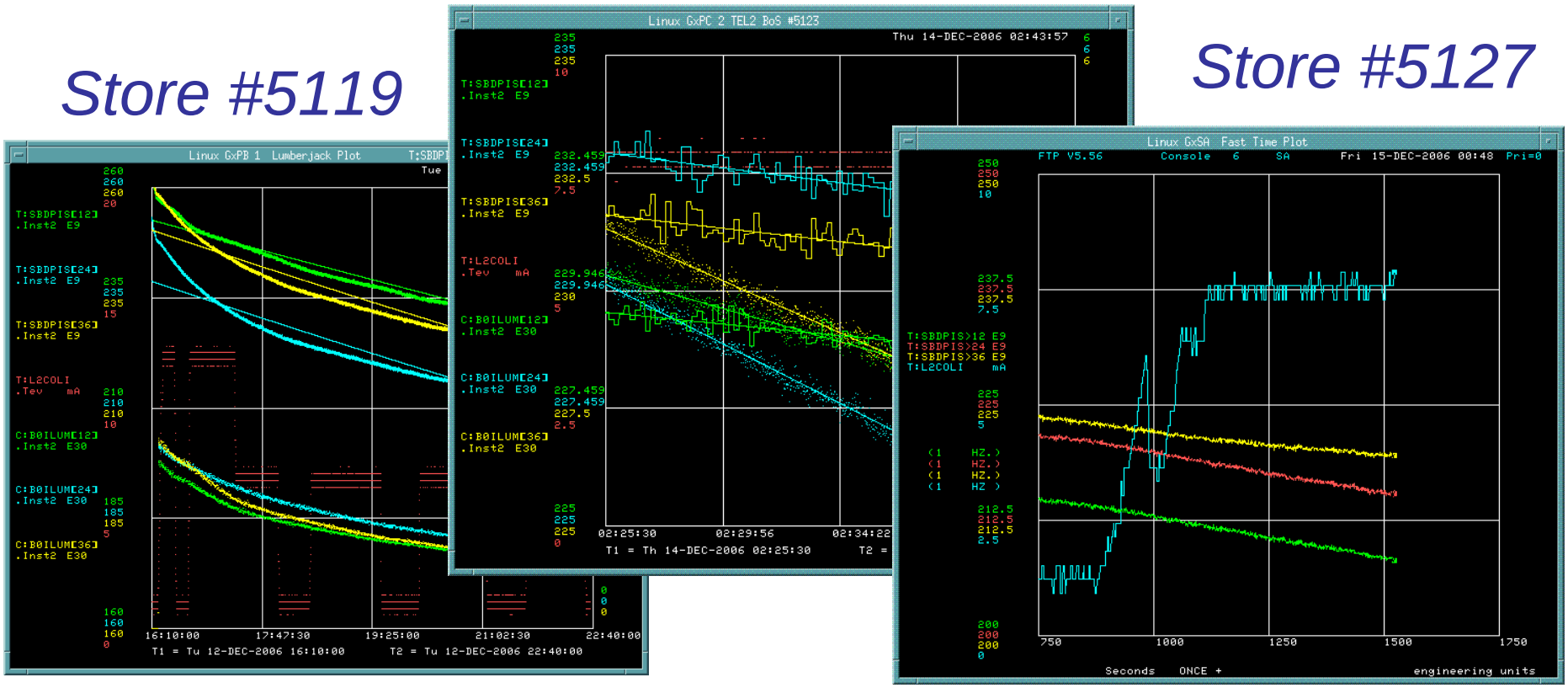


The Improvement Is Recurrent

Store #5123

Store #5119

Store #5127

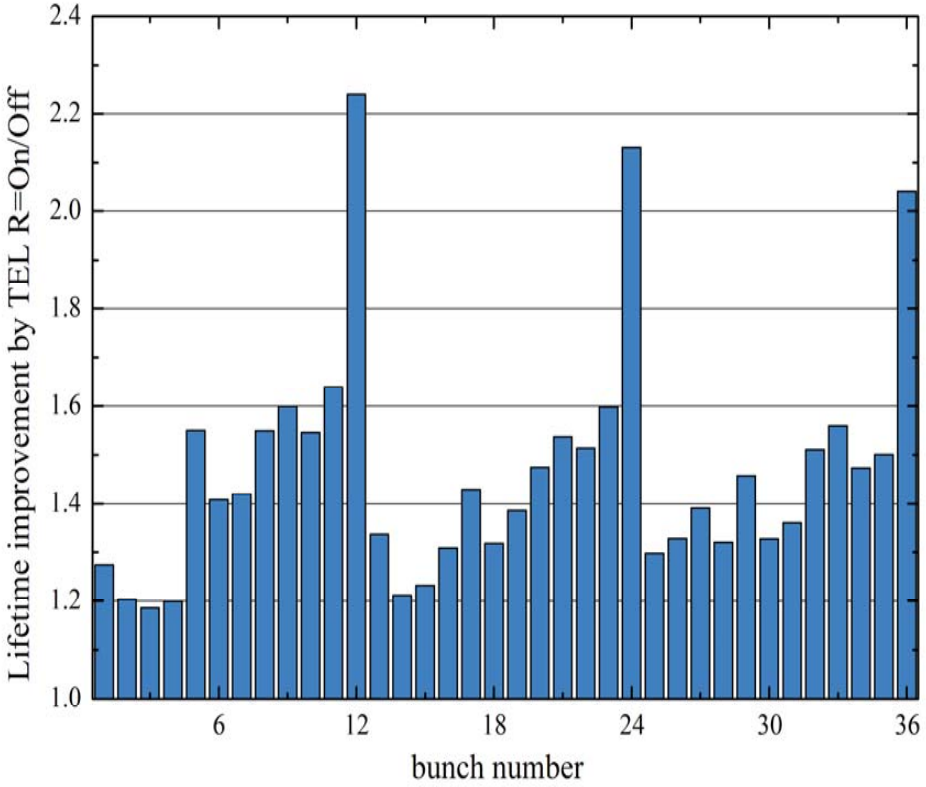


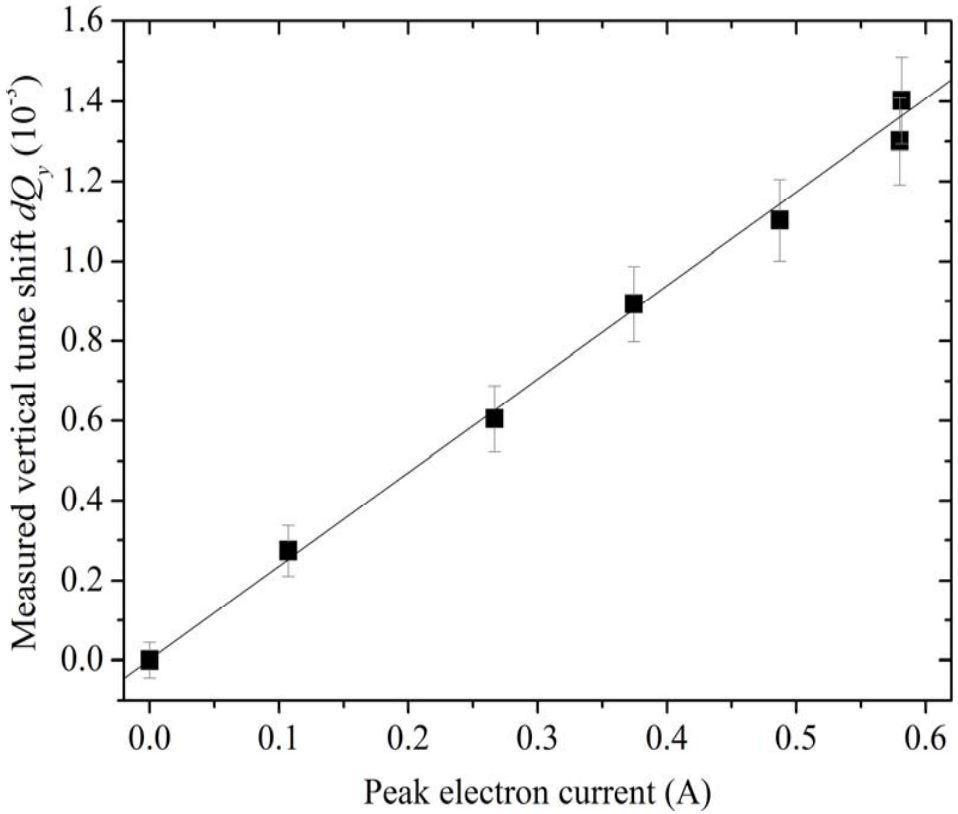
>20 HEP stores with active BBC with TELs

When TEL2 acts on all bunches (DC)

Bunches are not equal !

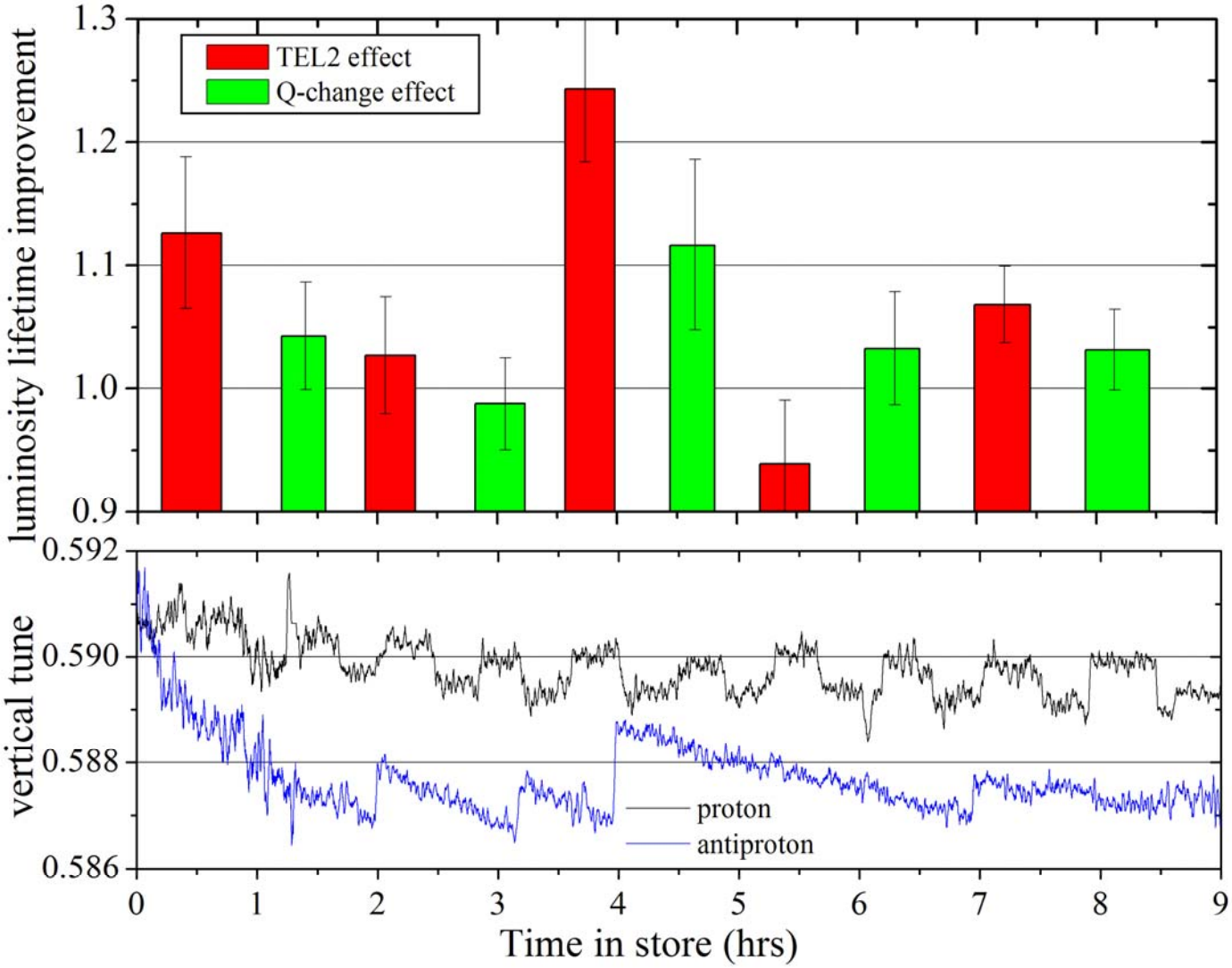
TEL2 moves Q_v up





Bunch P12 has systematically the lowest vertical tune that reduces its lifetime (too close to 7/12 resonance). TEL2 raises the tune up by dQ=+1.5e-3

12% Increase of Luminosity Lifetime



*TEL **on**:*

dQ=0.001

Effects ~comparable except TEL can affect individual bunches

Summary

- Tevatron Electron Lenses act on proton bunches and ~*DOUBLE* intensity lifetime
  - TEL1 (hor) effect varies +(20-40)%
  - Improves luminosity lifetime, too
- BBCompensation helps for ~10 hrs in store
- Will continue studies → introduce in operation
- A lot of interesting data, see:
  - TUPAS24, TUPAS25, TUPMN106, WEPMN97
- Other applications, e.g. head-on compensation
  - Gaussian profile: in RHIC, in LHC (see next slide)

LHC Electron Lens

2.4 A DC LEL with Gaussian current profile shrinks LHC footprint (Lumi-Upgrade simulations) → see TUPAN091