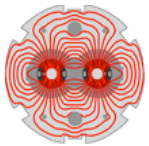


Beam-Beam Task
Where we are and where we are going

A.Valishev, FNAL

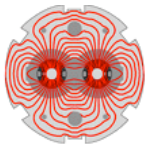
LARP CM14, 4/27/2010

Outline

- Beam-beam task scope and goals in FY10
- Status and achievements
  - Tevatron electron lens studies
  - Beam-beam simulations
    - RHIC BB and BBC
    - LHC BB and BBC
- Plans

Beam-Beam Task in FY10

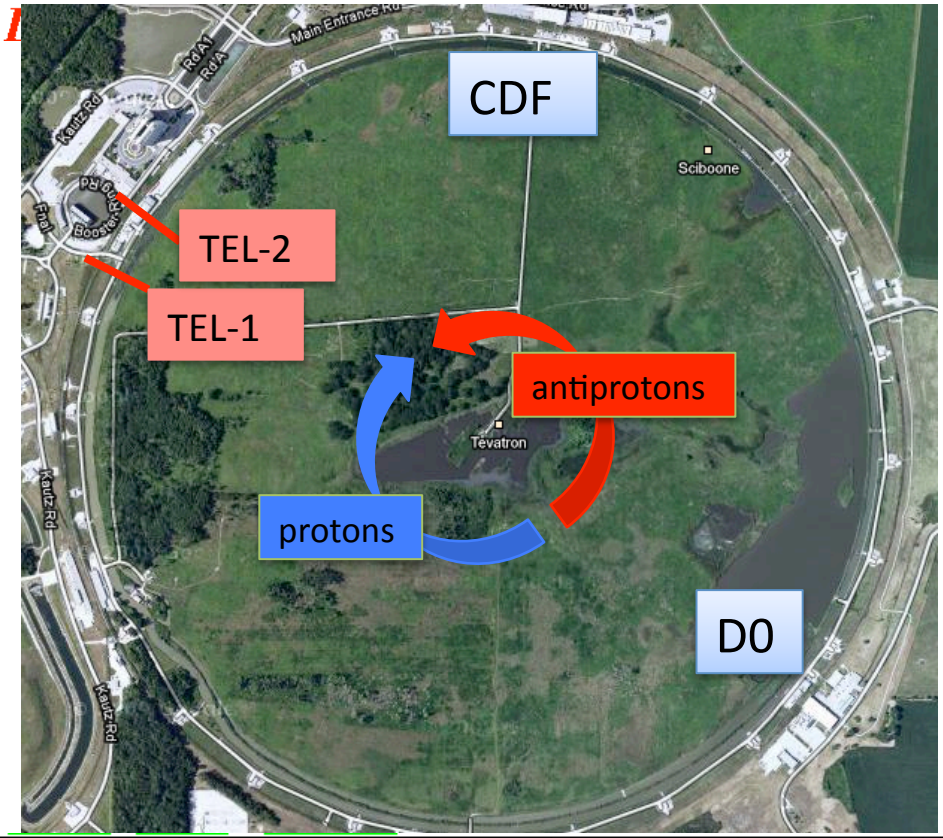
- Participants
  - BNL: W.Fischer, Y.Luo, C.Montag, G.Robert-Demolaize
  - FNAL: H.J.Kim, G.Kuznetsov, A.Romanov, G.Saewert, V.Shiltsev, T.Sen, G.Stancari, A.Valishev, X.Zhang
  - SLAC: A.Kabel
  - (LBL: J.Qiang)
- Budget: labor 206k, effort mostly supported by laboratories
- WebEx meetings



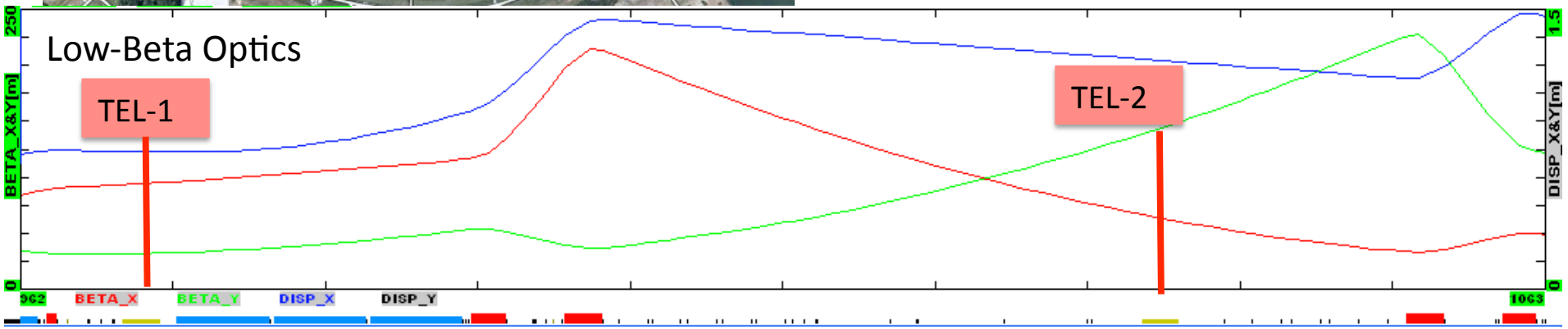
FY10 Goals

- Experiments with Gaussian EL at Tevatron
  - Observe effect of the Gaussian e- beam on proton/pbar tune spread
  - Demonstrate that HO BBC does not lead to life time degradation
  - Study effects of various imperfections
  - Provide input for simulations
- Numerical simulations of beam-beam effects and BBC
  - Develop simulation codes
  - Support design of RHIC EL
  - Simulate beam-beam effects at LHC and study prospects for EL BBC
- Development of hollow e- beam collimator
  - Numerical simulations of interaction of HEB with proton beam
  - Tests of HEBC at Tevatron

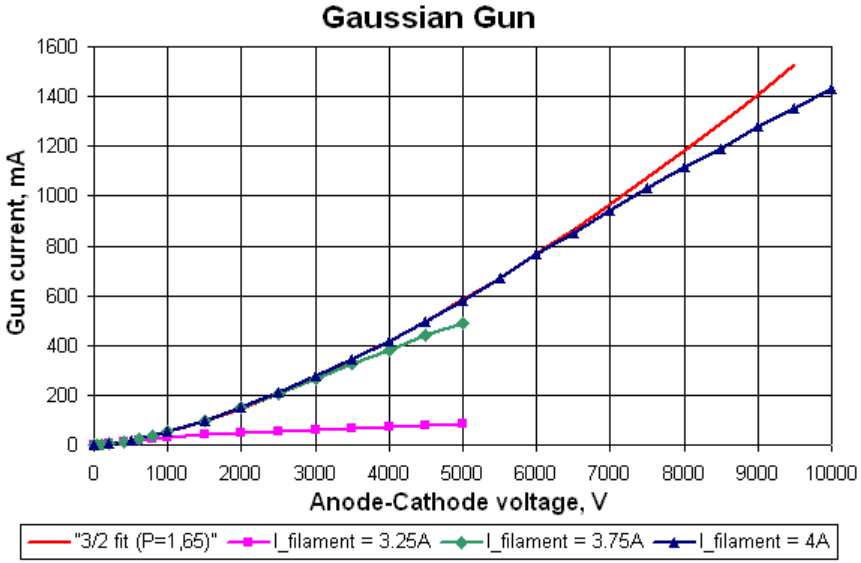
Tevatron Electron Lenses



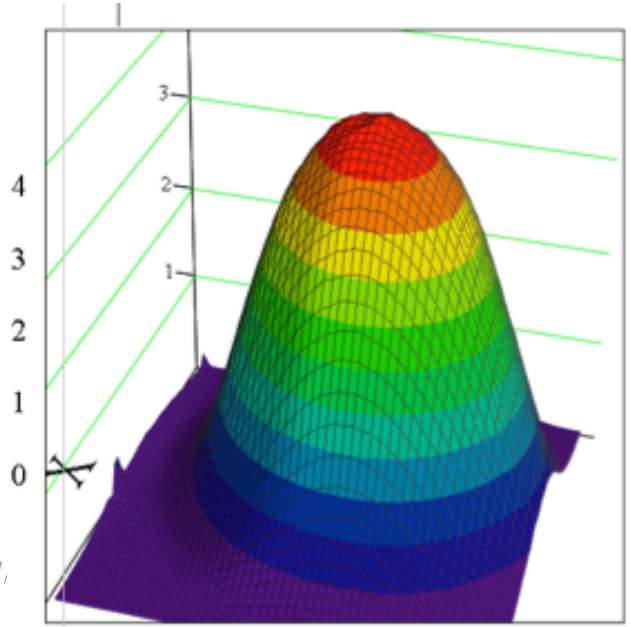
e- beam energy	< 10 kV
Peak e- current	< 3 A
Solenoid B-field	30 kG
Gun B-field	3 kG
e- beam radius (SEFT)	2.3 mm
Interaction length	2 m
TEL-1 βx/βy	95/32 m
TEL-2 βx/βy	66/160 m

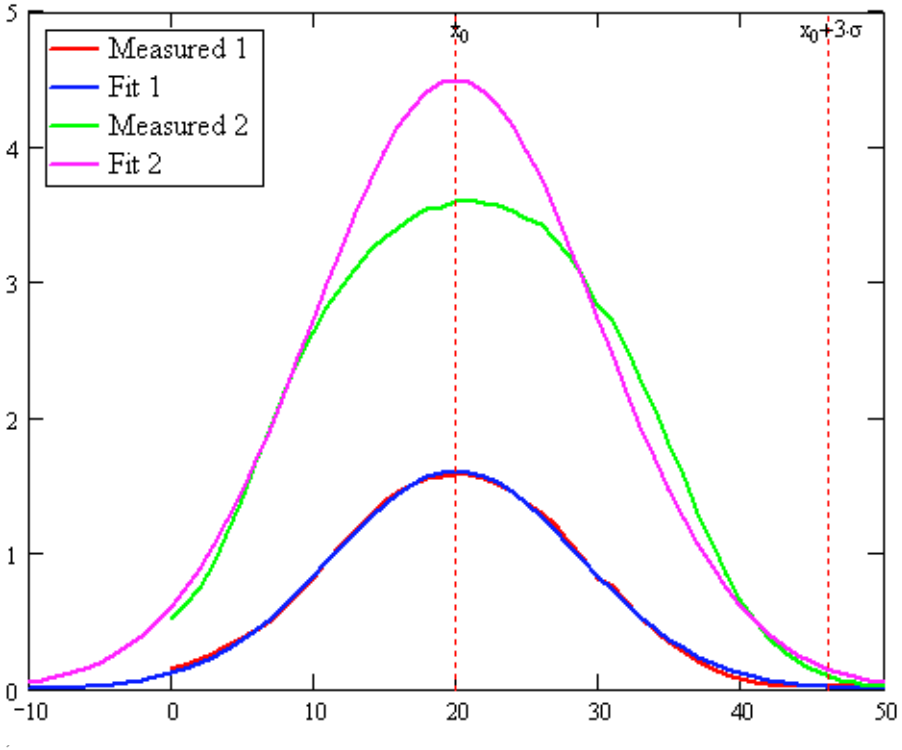


Gaussian Gun

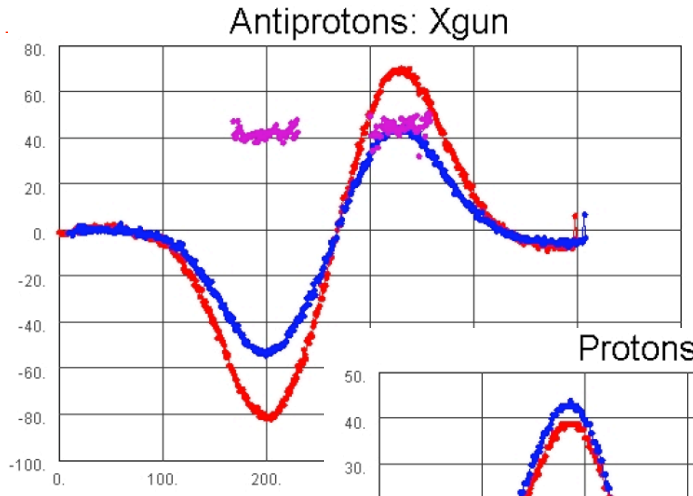


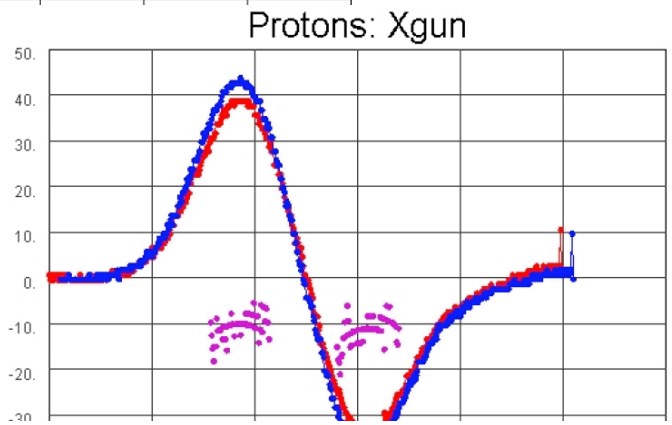
- Up to 1A current with the new modulator ($N_e=2x10^{11}$)
- Installed in TEL-2 on June 20 (Tevatron shutdown 6/15 – 9/11)





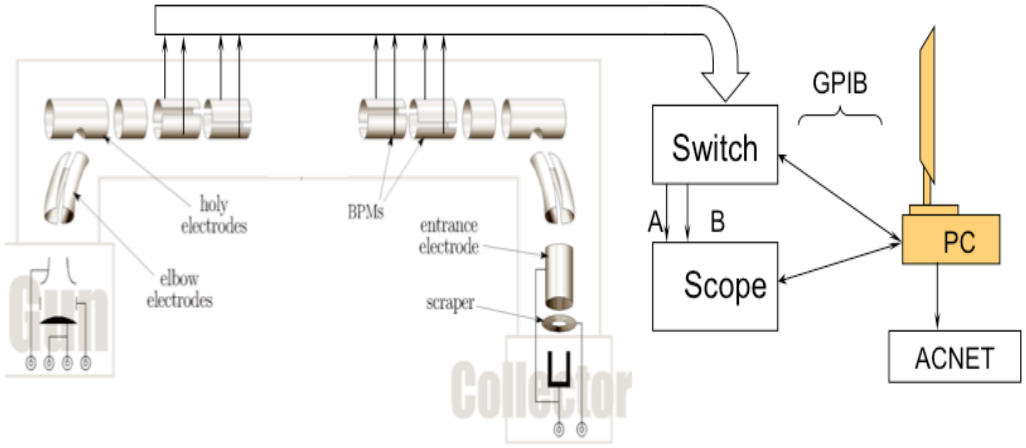
TEL Improvements: BPM Readout

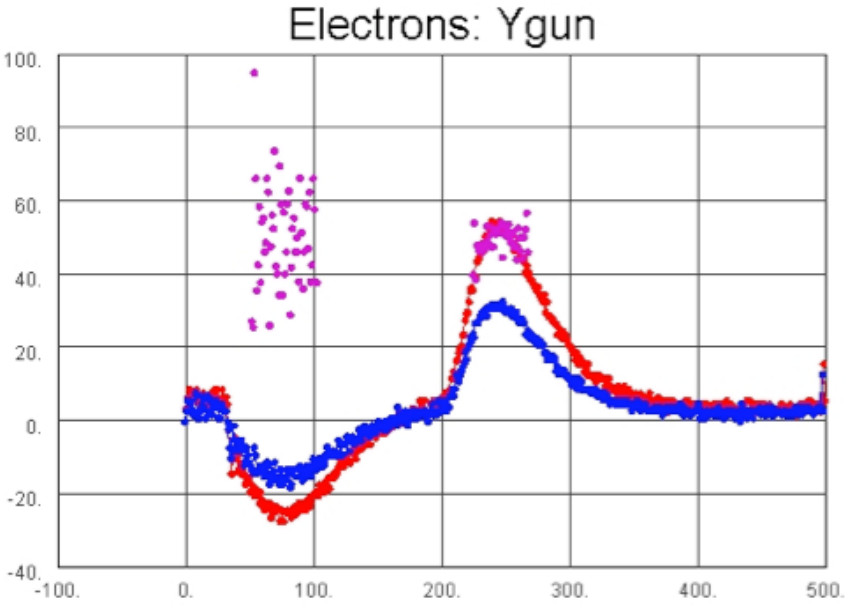




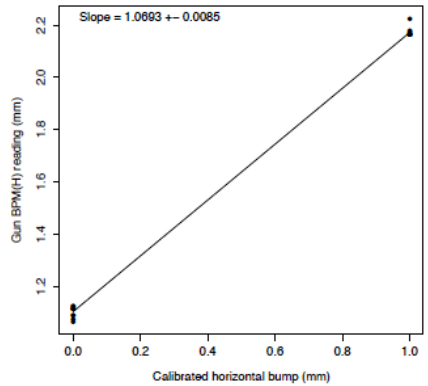
Alignment of e- and circulating beam is critical

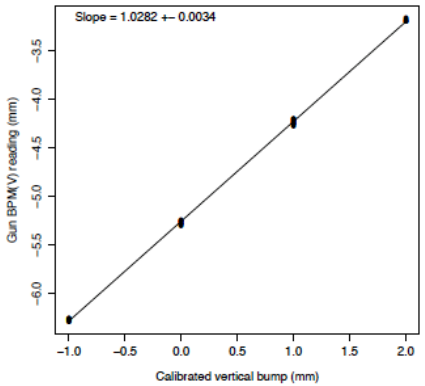
- Shorter e- pulse with new generator – closer calibrations and offsets for electrons and protons/pbars
- Old LabView program slow
- New Java program faster (response time ~20 s), uses simpler algorithm





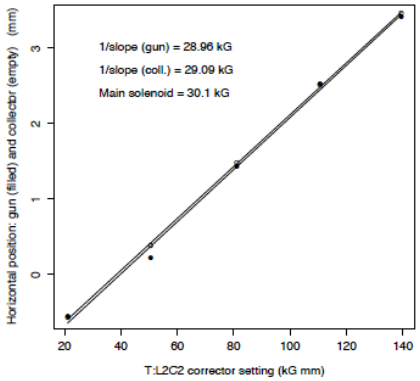
BPM Calibration

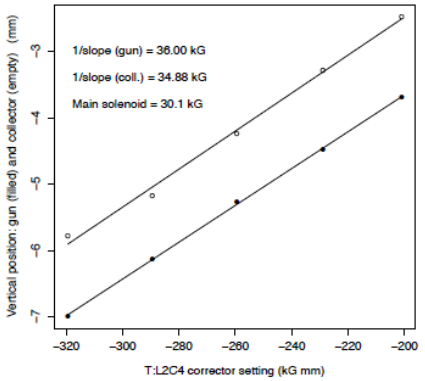




Observable	Measured / Expected Slopes
Δx gun (mm)	1.07 ± 0.01
Δx coll. (mm)	1.03 ± 0.01
Δy gun (mm)	1.028 ± 0.003
Δy coll. (mm)	1.031 ± 0.004
$\Delta x'$ (mrad)	1.10 ± 0.06

TEL-2 BPM calibration with proton beam (closed orbit bump)





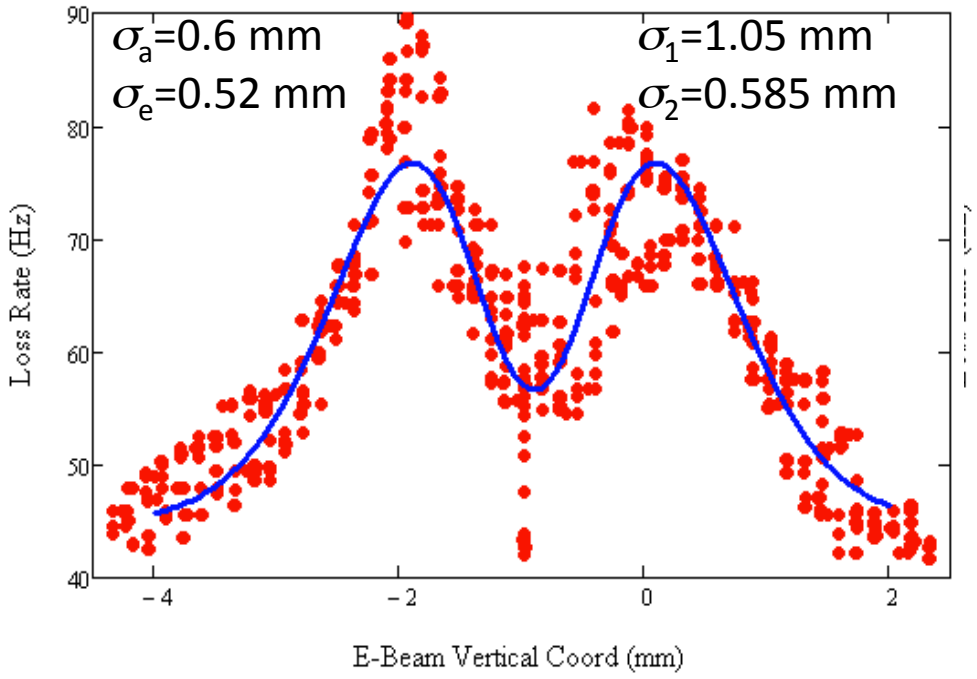
Observable	Measured / Expected Slopes
Δx gun (mm)	1.04 ± 0.04
Δx coll. (mm)	1.03 ± 0.01
Δy gun (mm)	0.84 ± 0.01
Δy coll. (mm)	0.86 ± 0.04

TEL-2 BPM calibration with electron beam

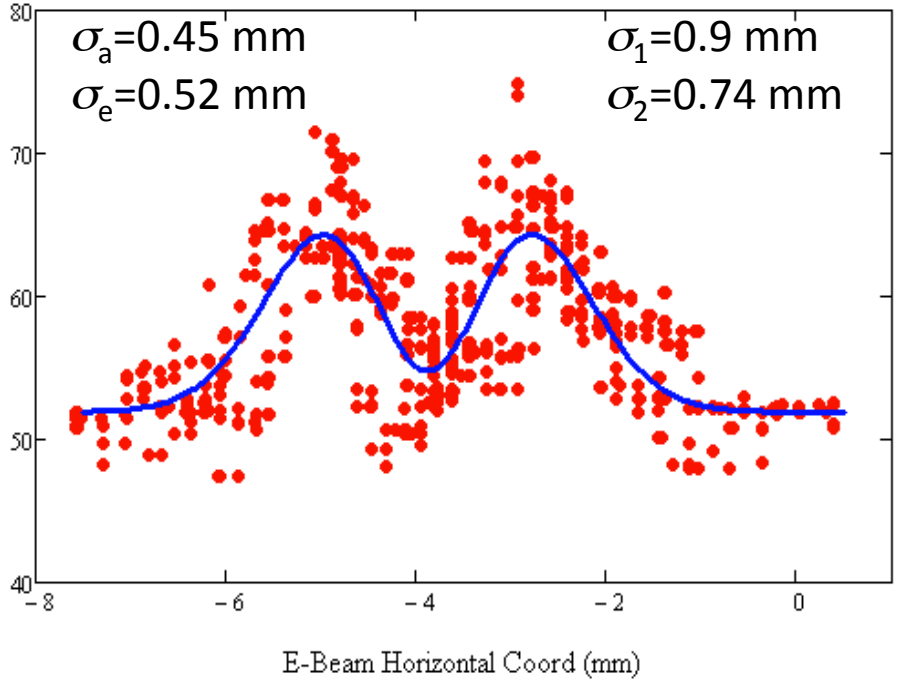
Alignment of e- and Antiproton Beams

- e- beam size is equal to the antiproton beam size at TEL-2
- Centered e- beam should not produce particle losses (in case of tune not on resonance)
- Offset by ~1σ is the worst case
- Offset scan should produce characteristic double-hump pattern

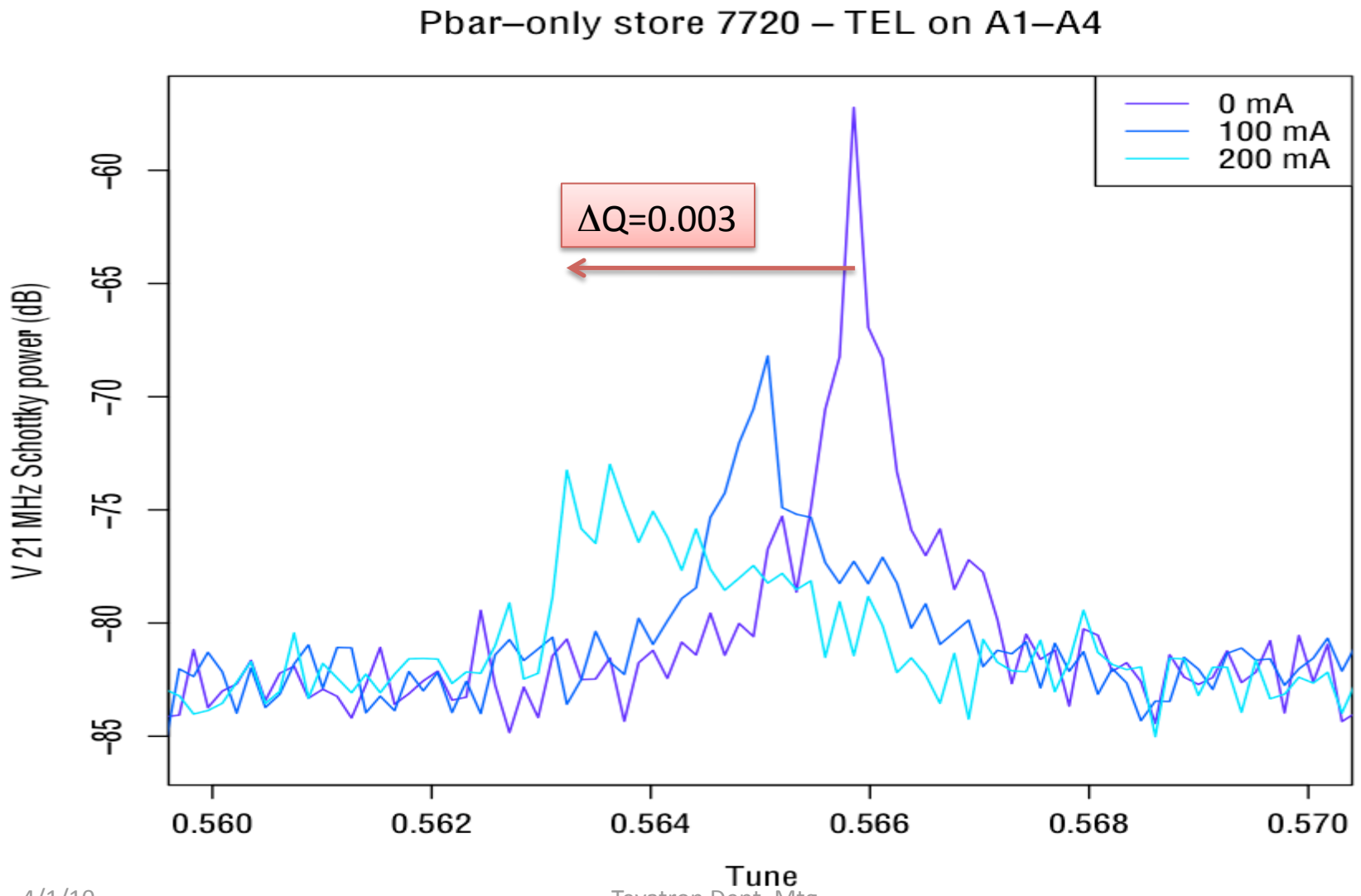
Losses during vertical e- beam position scan



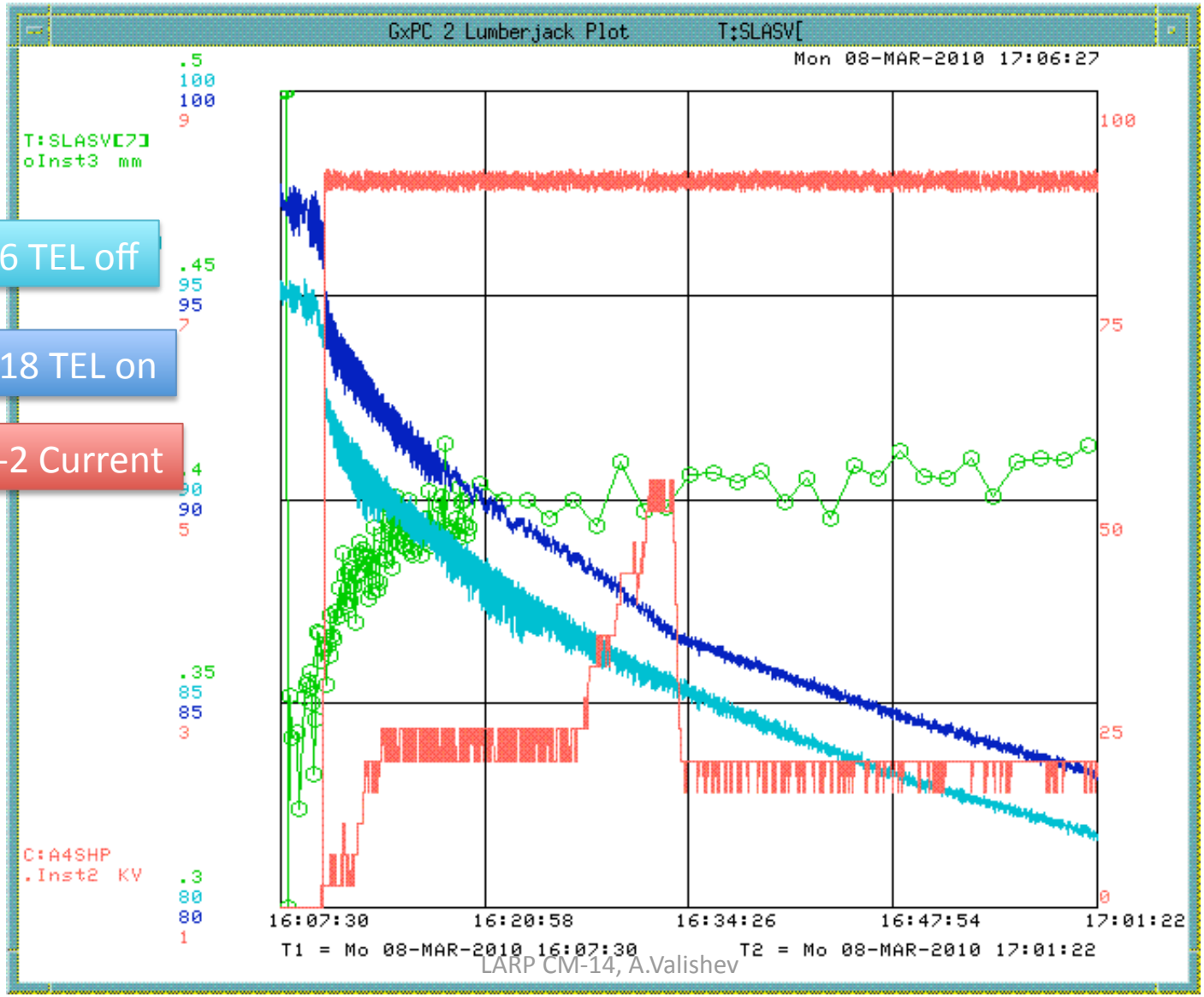
Losses during horiz. e- beam position scan



Tune Shift and Spread by Gaussian TEL-2 (antiproton-only study)



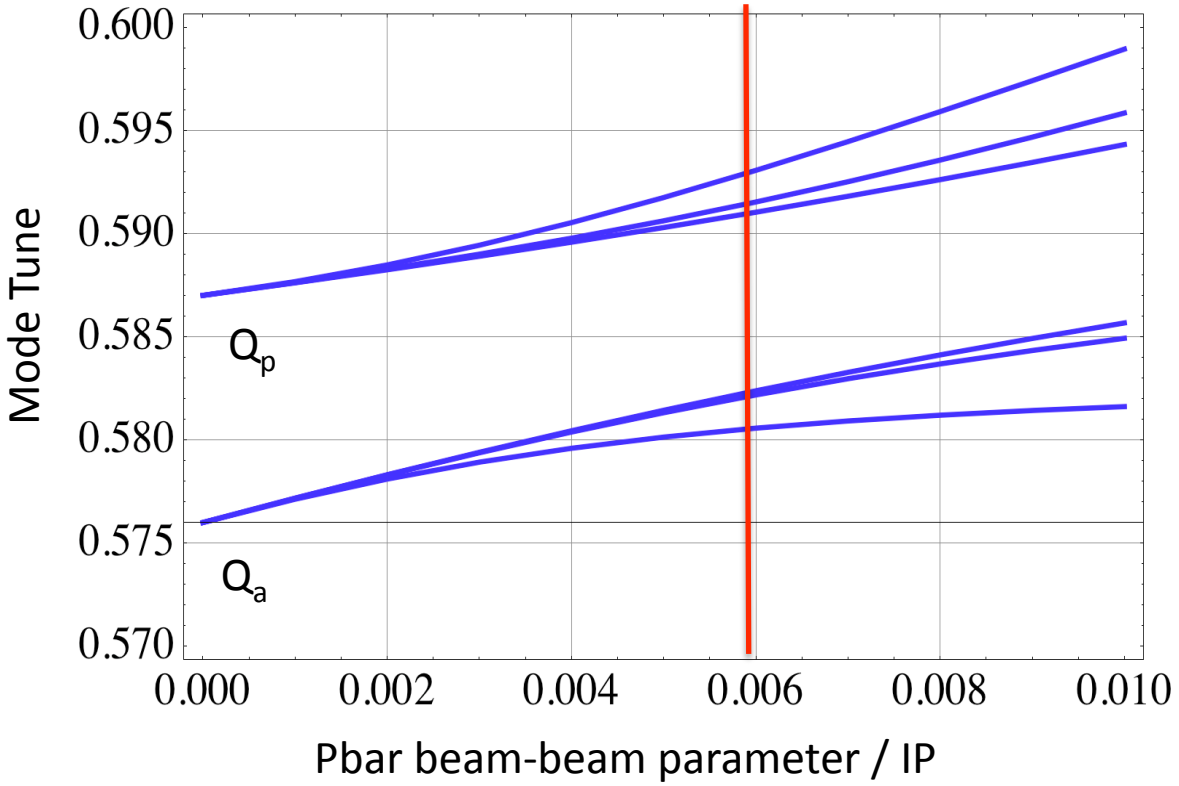
Effect of Gaussian TEL-2 on Lifetime
HEP Store 7661, $L_0=3.3x10^{32}$



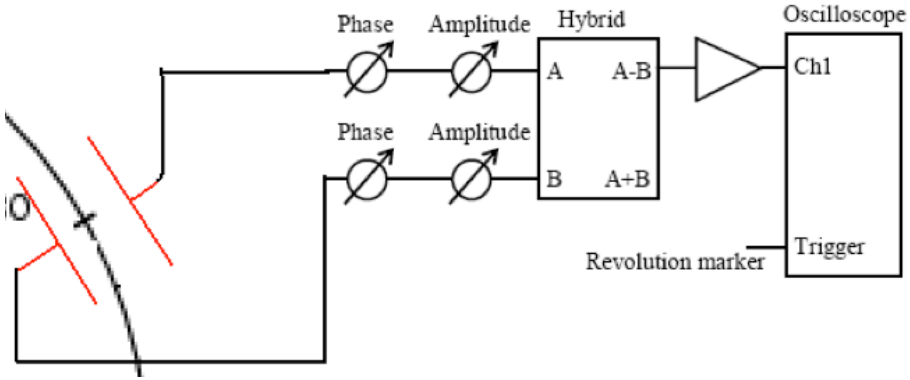
Coherent Beam-Beam Mode Tunes

Using a simplified linearized model of beam-beam interaction it is possible to compute beam-beam mode tunes

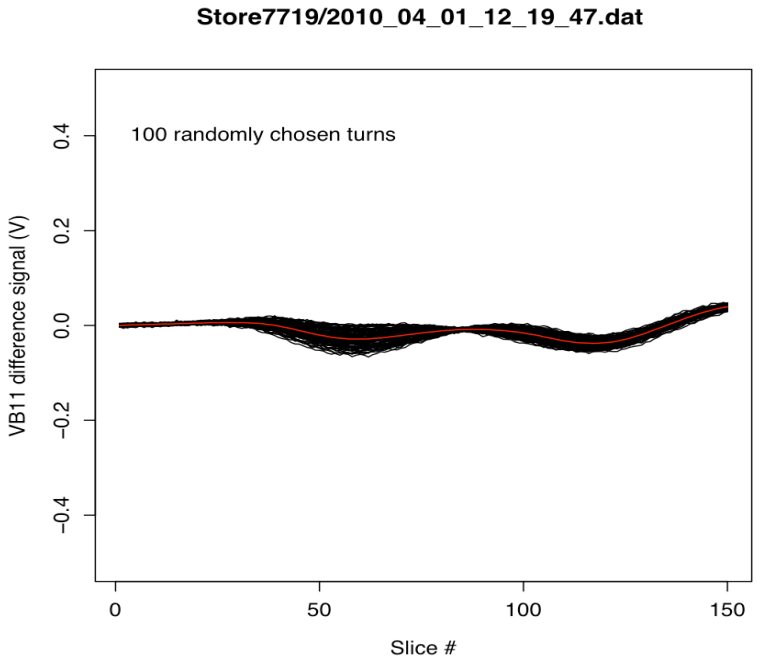
- 3x3 bunches colliding
- 2 head-on IPs (disregard long-range effects)
- Input parameters: Q_p, Q_a, ξ_p, ξ_a, Yokoya factor

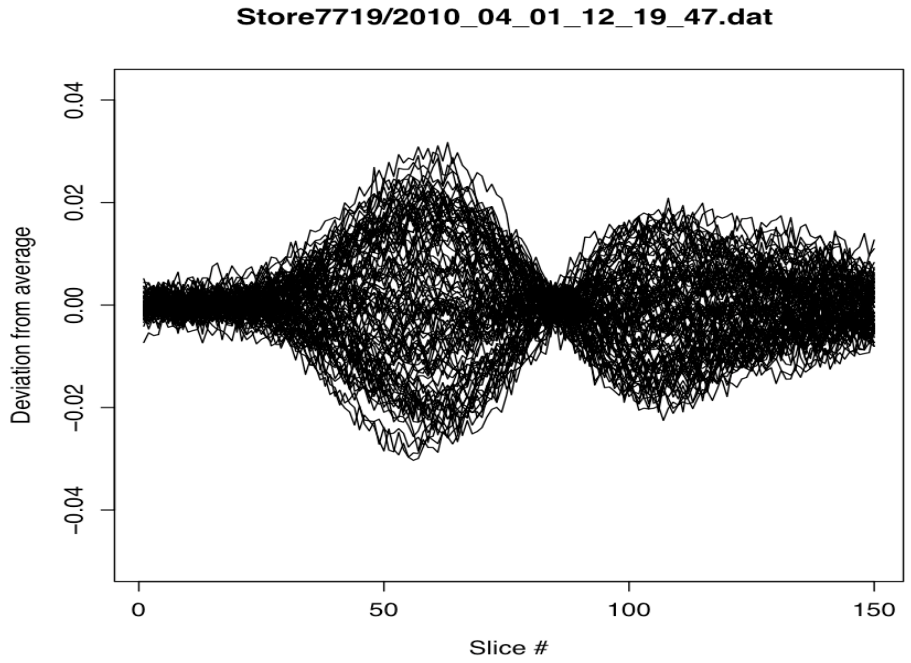


Measurement of Coherent Beam-Beam Mode Tunes

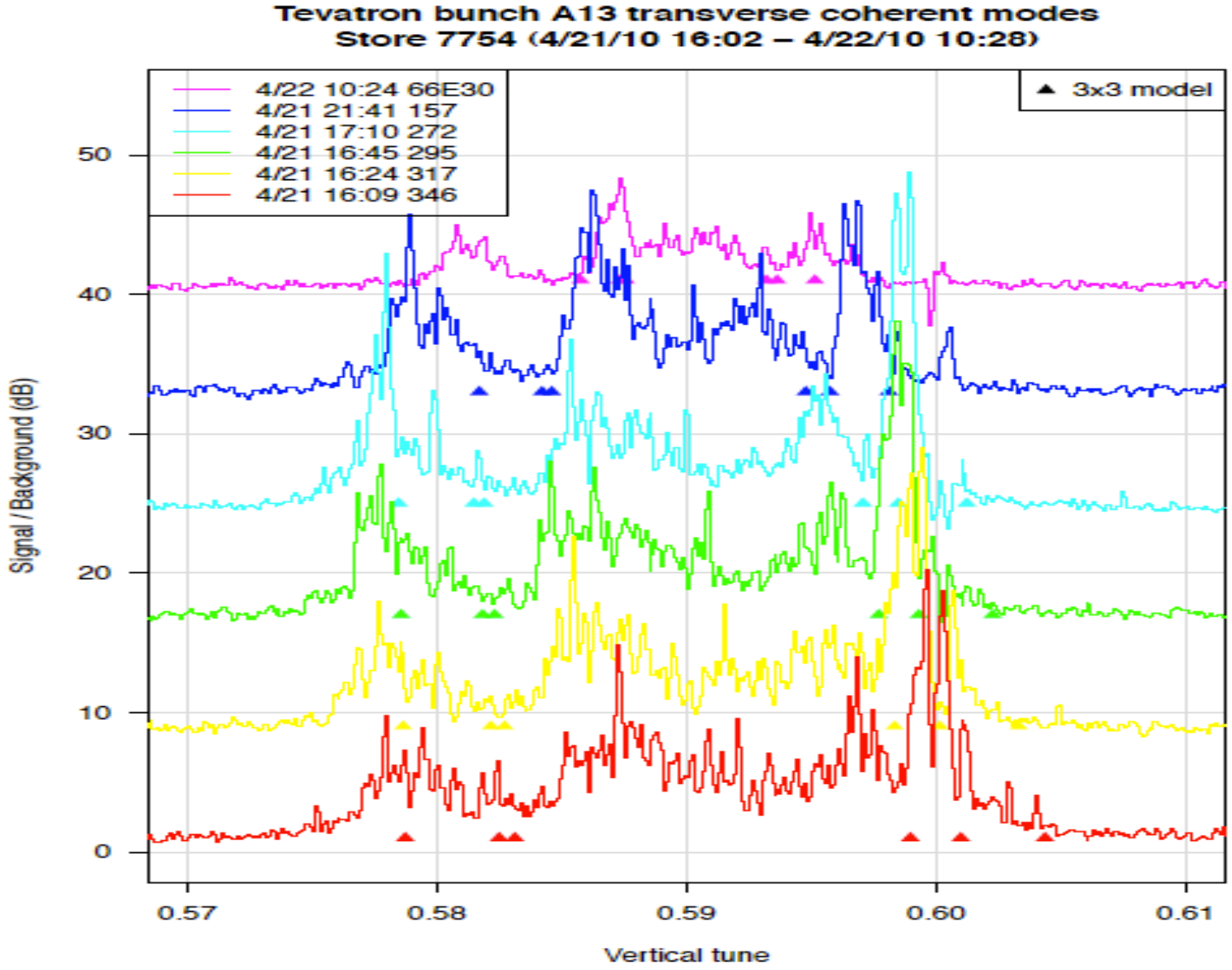


- Sample A-B signal from one bunch at 0.125ns/point for 57000 turns
- Subtract average
- FFT signal from selected slices

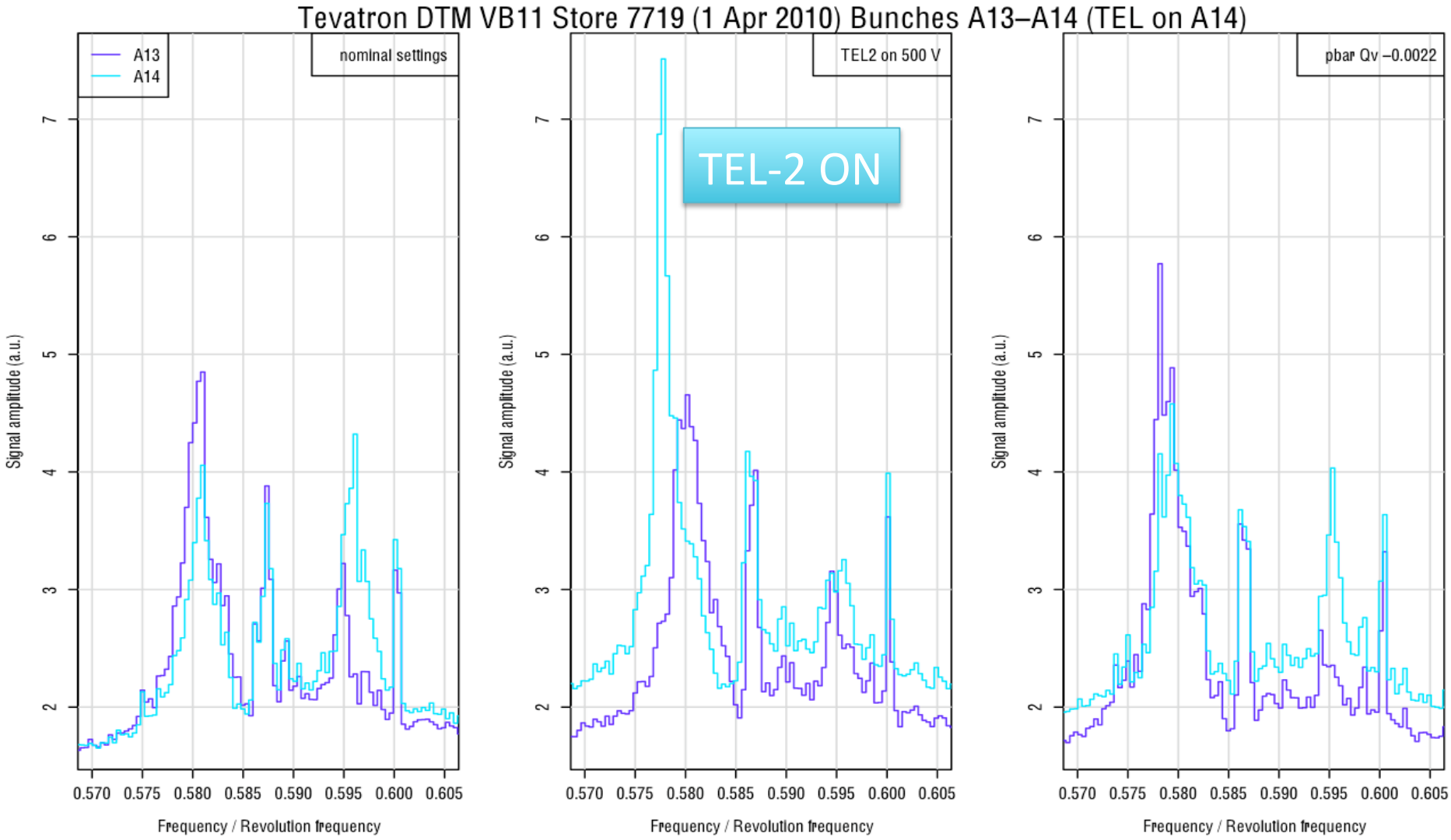




Coherent Tune Measurement in Store 7754



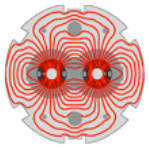
Coherent Tune Measurement in Store 7719



Gaussian TEL-2 Results

- Significant progress since CM13
- Demonstrated good alignment of e- and pbar beams
- No pbar life time degradation up to TEL current of 0.5A (if tune is off resonance)
- Observed tune shift and tune spread from TEL in a pbar only store
- Coherent modes observed in HEP stores are close to model prediction
- Observe coherent mode tune shift in pbar bunches interacting with TEL beam

- During the time remaining before Summer shutdown we plan to demonstrate nonlinear head-on BBC in a dedicated store (small number of bunches to alleviate long-range effects, and special emittance conditions to enhance head-on effect)

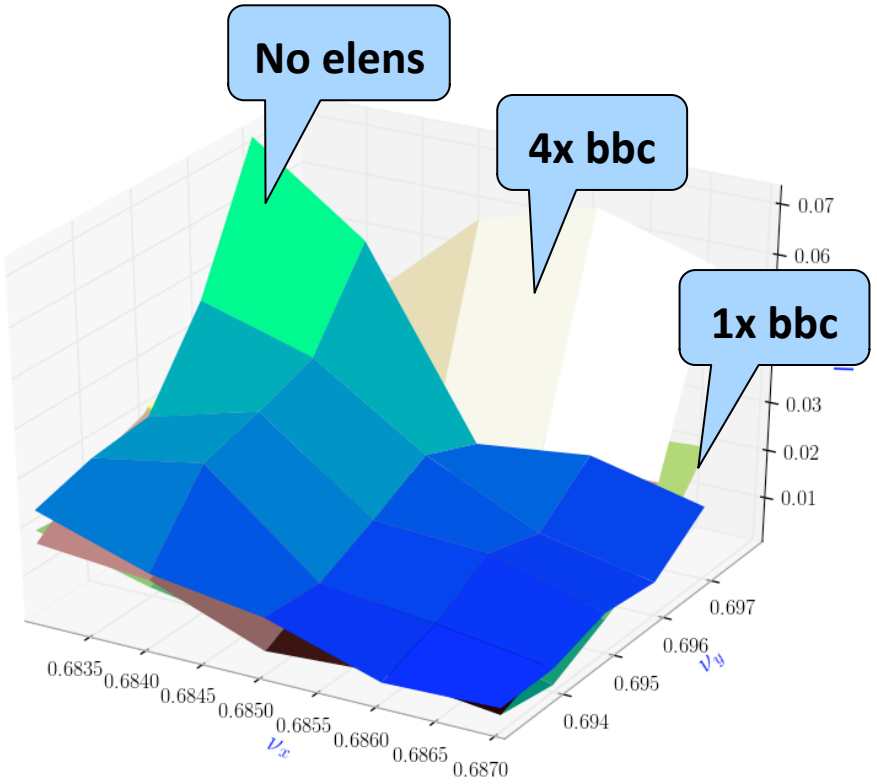


Numerical Simulations

- Benchmarked and developed codes
  - Significant progress at BNL: full 6D implementation
  - At FNAL implemented current LHC lattice with FF higher-order nonlinearities in BB simulation
- Simulations of BBC at RHIC demonstrate benefit from EL at bunch intensity above 2.5×10^{11}
- Simulations of BBC at LHC predict positive effect at Np above 3×10^{11} (nonlinearities not included)

Head-on BBC at RHIC (H.J.Kim, FNAL)

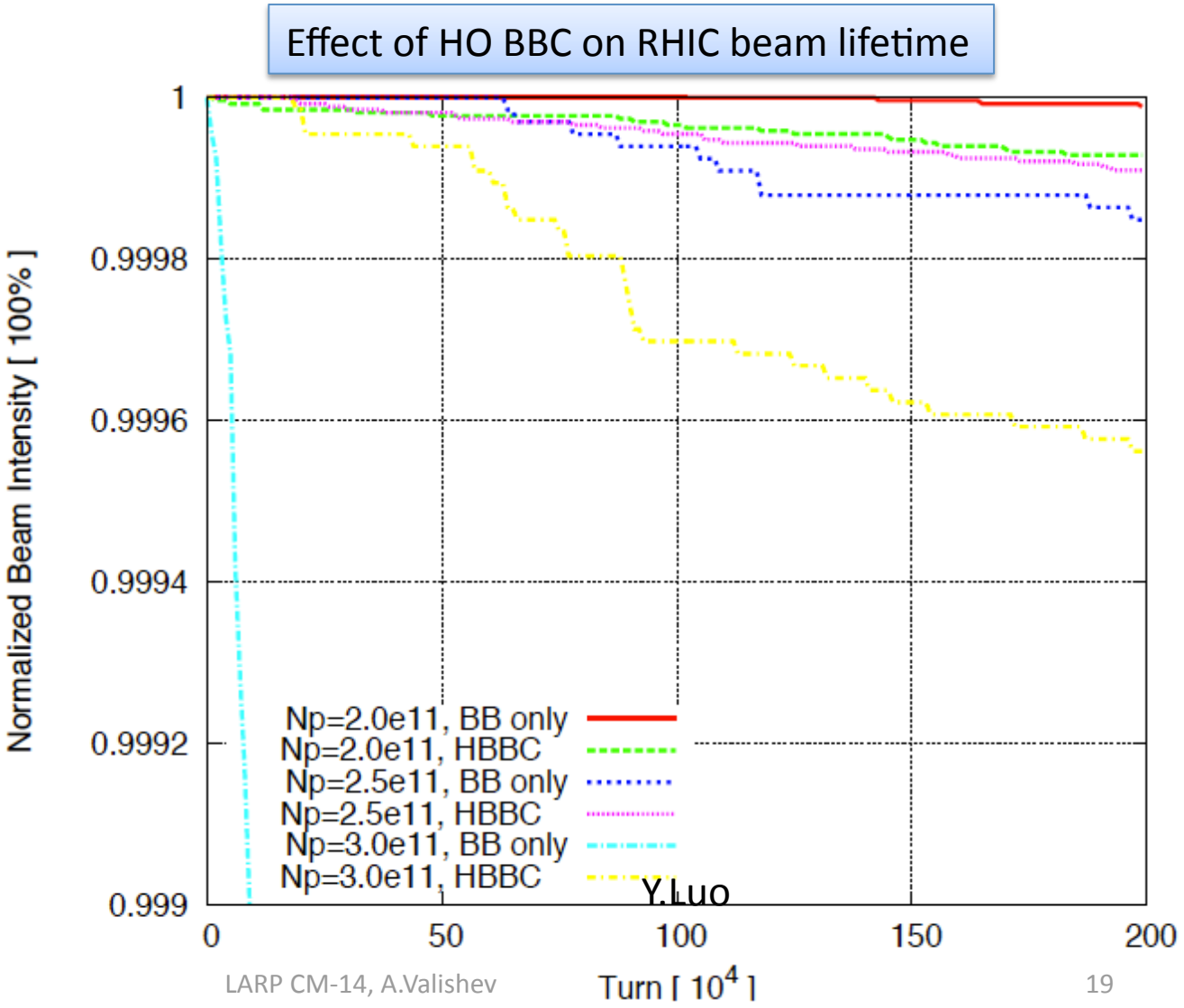
Effect of HO BBC on RHIC beam lifetime



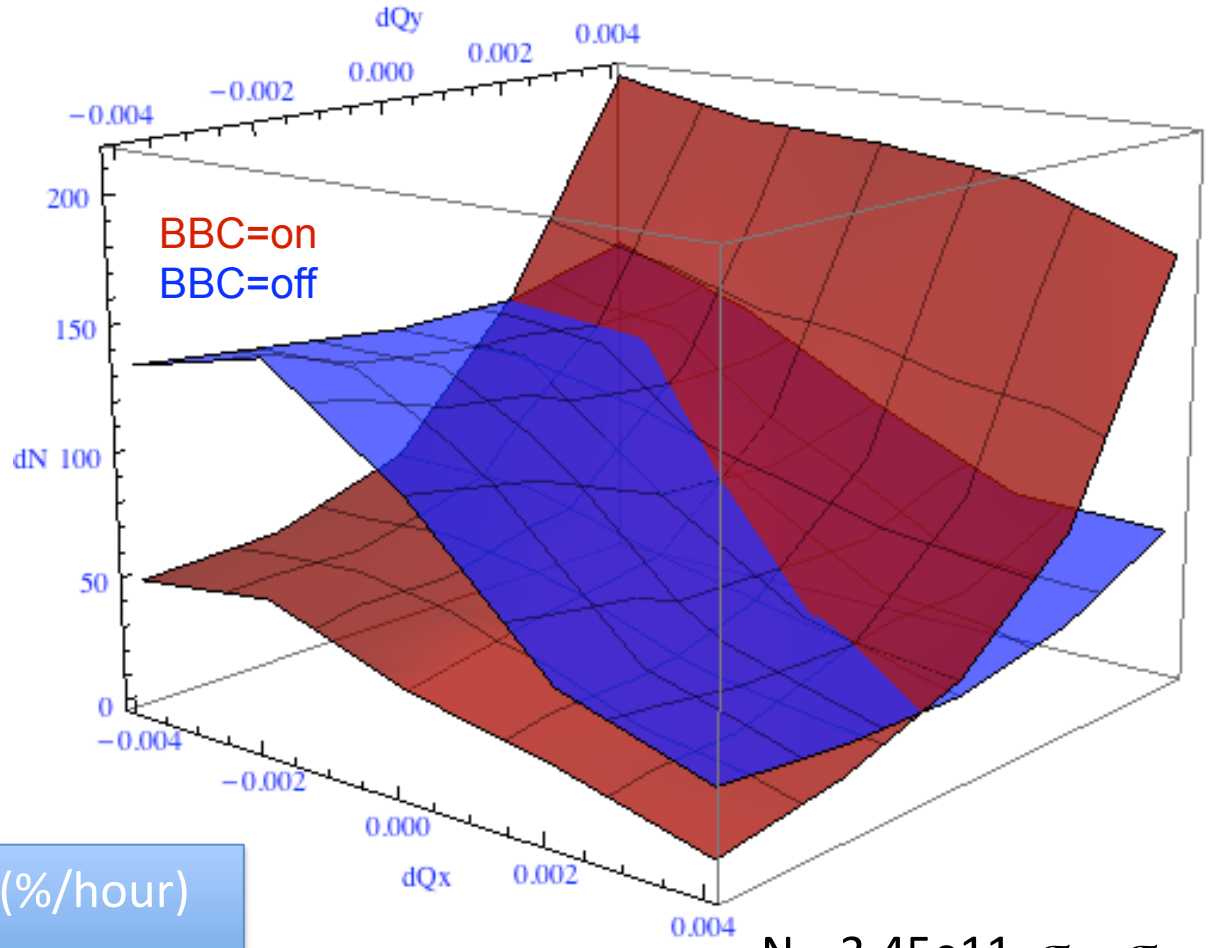
- At near (0.685,0.695), the SEFT elens does help to increase beam life time.

Head-on BBC at RHIC (Y.Luo, BNL)

Simulations demonstrate benefit from EL at bunch intensity above 2.5×10^{11}



Head-on BBC at LHC (A.Valishev, FNAL)

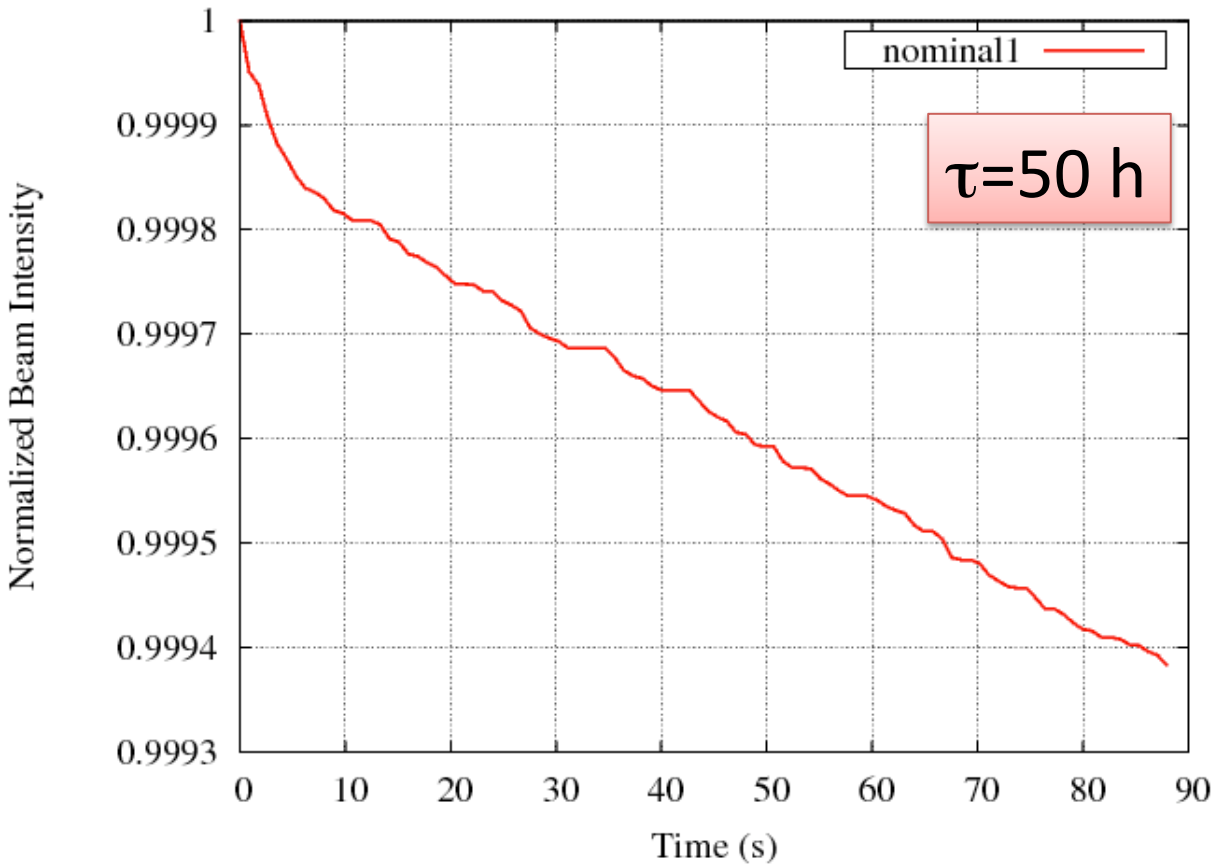


Min. loss (%/hour)
EL off 27
EL on 8

N_p=3.45e11, $\sigma_e = \sigma_p$
half compensation
Intensity loss in %/hour vs. lattice tunes

Beam-Beam Simulation for LHC (A.Valishev, FNAL)

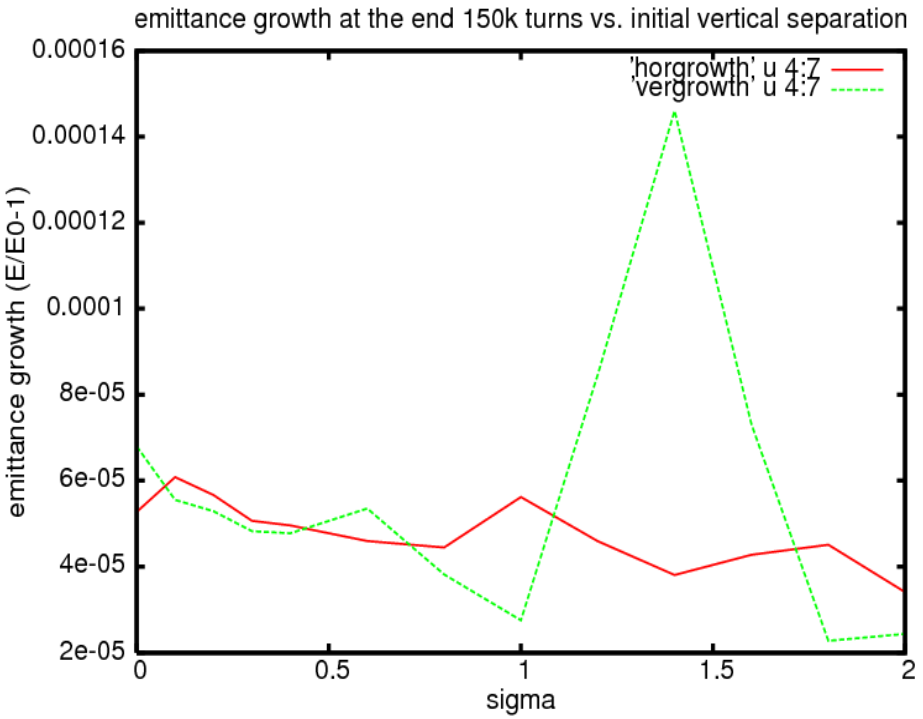
- Nominal LHC beam
- Lattice (V6.503) with nonlinearities
- Currently benchmarking vs. SixTrack results



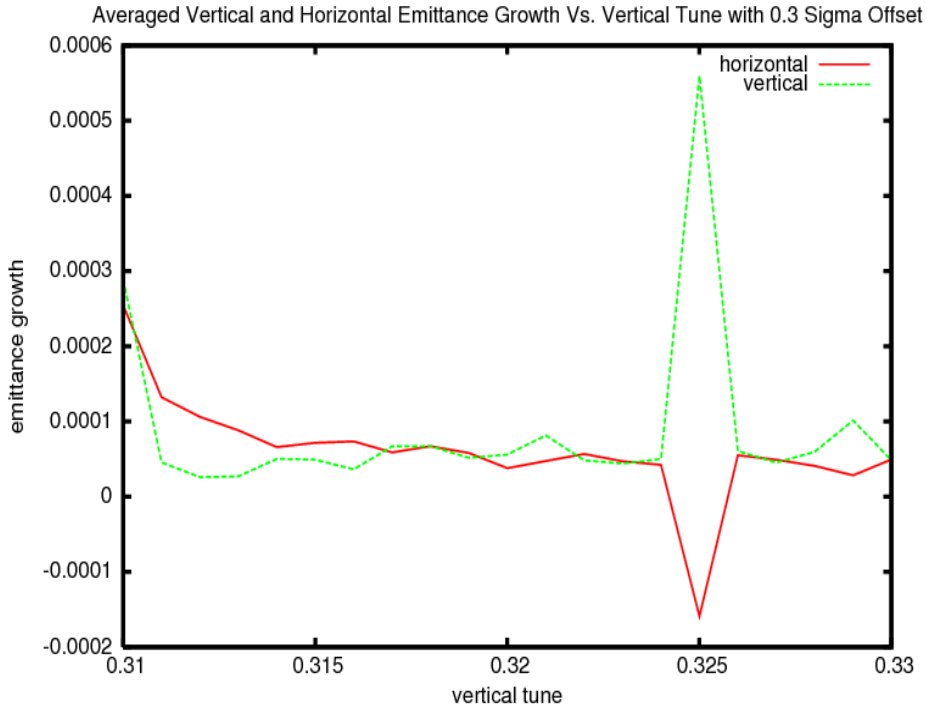
Offset Beam-Beam Collision Studies for LHC (J.Qiang, LBNL)

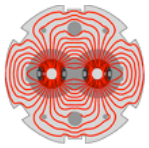
- The offset collision is unavoidable due to the different bunch collision schemes at LHC
- Such offset collision might cause emittance growth that degrades luminosity lifetime and experimental conditions

Emittance Growth vs. Offset



Emittance Growth vs. Tune





Summary and Outlook

- Gaussian TEL-2 experimental goals have been met
  - We may be able to go beyond expected and demonstrate benefit from head-on BBC at Tevatron
- Tevatron E-Lens is ideally suited for tests of hollow electron beam collimator. Hence, the plan is to shift focus in experimental work at TEL from BBC to HEBC (starting in September, 2010; see following talk by G.Stancari)
- Beam-beam simulations plan
  - Continue code development
    - implement hollow e-beam
  - Support RHIC EL project with simulations
  - Collaborate with CERN on simulations of beam-beam effects, especially as experimental data becomes available
  - Study prospects of EL BBC at LHC