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# Results of head-on beam-beam compensation studies at the Tevatron

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- Background
- Tevatron electron lenses
- Beam alignment

- Incoherent tune spectra
- Transverse coherent modes
- Tune scans

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# Background

Nonlinear forces between colliding beams limit the performance of colliders

Is it possible to mitigate these beam-beam effects with a low-energy electron beam?



Tevatron electron lens (TEL)



Shiltsev et al., PRSTAB 2, 071001 (1999)

### **Beam-beam compensation with electron lenses**

Pulsed electron lenses with <u>flat profiles</u> can <u>shift the tunes</u> of individual bunches by different amounts and reduce the effects of long-range collisions

Shiltsev et al., PRL 99, 244801 (2007) Shiltsev et al., NJP 10, 043042 (2008) Shiltsev et al., PRSTAB 11, 103501 (2008)

Can a Gaussian electron profile mitigate the nonlinear head-on beambeam forces acting on antiprotons?



Can the tune footprint be reduced?

Linear beam-beam parameter for antiprotons due to electrons

$$\xi_e = -\frac{N_e r_p \beta (1+\beta_e)}{4\pi \gamma_p \sigma_e^2}$$

Valishev et al., IPAC10, TUPD070 (2010)

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Results of head-on beam-beam compensation studies at the Tevatron PAC11 : 28 Mar 2011 3

# **Objectives**

- <u>Comment #1</u>: Head-on compensation requires
- geometrical configuration similar to
- interaction point (transverse and longitudinal)
- no dispersion
- ► correct betatron phase advance (integer multiple of  $\pi$ )

<u>Comment #2</u>: After the introduction of electron cooling in the Recycler Ring, head-on beam-beam on antiprotons is practically linear in the Tevatron

# **Purpose** of this research:

- Investigate technical and operational feasibility
- Observe the **effect of Gaussian electron beams** on lifetimes, emittances, tunes
- Provide experimental basis for simulation codes in view of planned application to RHIC at BNL (next talk, poster THP055)

#### The 10.8-mm Gaussian electron gun



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# Layout of the second Tevatron electron lens (TEL2)



Lattice parameters	CDF IP	DZero IP	TEL2
Amplitude functions (m)	0.30, 0.30	0.50, 0.50	68, 153
Dispersion (m)	0,0	0,0	1.2, -1.0
Betatron phase $(2\pi)$	6.84	13.85	3.22

Protons and antiprotons circulate in the same beam pipe. At TEL2, separation is 6 mm (both horiz. and vert.).

# In our experiments, electrons were aligned with antiprotons.



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# **Observations in electron beam position scan**

(1) No increase in losses with nominal tunes
(2) With tunes lowered by 0.003 (towards 7th order resonance):
- good BPM alignment and no e<sup>-</sup>/p<sup>-</sup> systematic difference
- double hump structure



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#### **Incoherent tune spectrum vs. electron beam current**

Schottky spectra during dedicated antiproton-only store.

As expected, collisions with electrons widen the tune spectrum.

Calculated linear

due to electrons  $\xi_e$ 



8

### Transverse coherent modes in regular collider store



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#### **Dedicated 3-on-3 stores**

Attempted 2 special 3-on-3 stores to eliminate long-range forces: demonstration of head-on beam-beam compensation in the Tevatron?

<u>1st store</u>: proton emittance blowup at collisions before study, unusable <u>2nd store</u>: smaller proton blowup, expected benefit negligible, used for tune scans and code benchmarking



Lifetrac simulation of decay rates and emittance growth in diagonal tune scan

### **Dedicated 3-on-3 stores**

Measurement of decay rates of antiproton bunches during diagonal tune scan



#### Average tune

- Electron sizes could not be matched with protons, beam-beam too small
- Still, no adverse effects in stable region; not enough to see improvement
- Useful for comparison with numerical simulations

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# Conclusions

- Studied basic properties of head-on beam-beam compensation with Gaussian electron lenses in the Tevatron
- Alignment of electrons with circulating beam is reliable
- With aligned beams, no instabilities or emittance growth
- ▶ No adverse effects on antiprotons at high intensity and luminosity
- Observed tune shift and tune spread generated by electron beam
- ▶ Measured lifetimes vs. tune in dedicated 3-on-3 store
- Tevatron not ideal for direct demonstration of concept
- Collected data for code benchmarking and for planned application of electron lenses to RHIC (next talk, poster THP055)

Thanks for your attention