Calculation of the kick maps generated by a hollow electron lens for studies of high-energy hadron beam collimation

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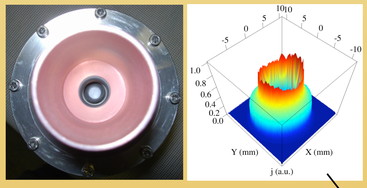
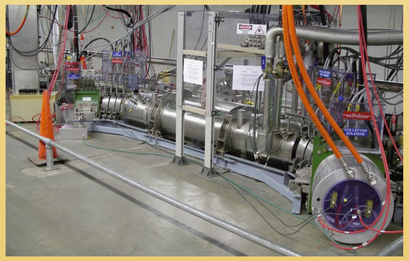
WHAT IS HOLLOW ELECTRON BEAM COLLIMATION?

An intense, low-energy, magnetically confined, pulsed electron beam with hollow current-density distribution can be used to scrape the halo of the circulating beam when beam power or impedance limit the use of conventional collimators.

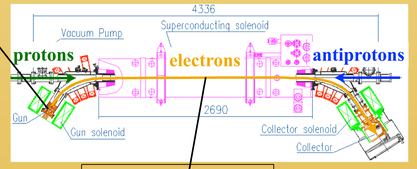
Shiltsev, CERN-2007-002
Shiltsev et al., EPAC08

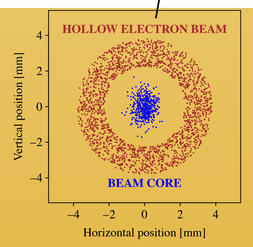


Hollow cathode and measured current density profile



Tevatron electron lens

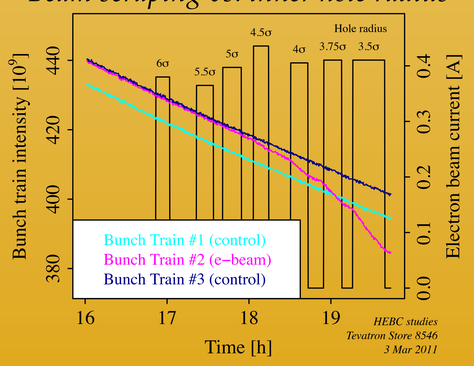




Layout of the beams

Extensive beam studies were done at the Fermilab Tevatron collider to measure scraping rates, effects on the core, halo population suppression, and halo diffusion enhancement.

Beam scraping vs. inner hole radius



This new technique is being proposed as a complement to the collimation system for the LHC upgrades.

WHAT IS THE EFFECT OF ASYMMETRIES IN THE ELECTRON CURRENT DISTRIBUTION?

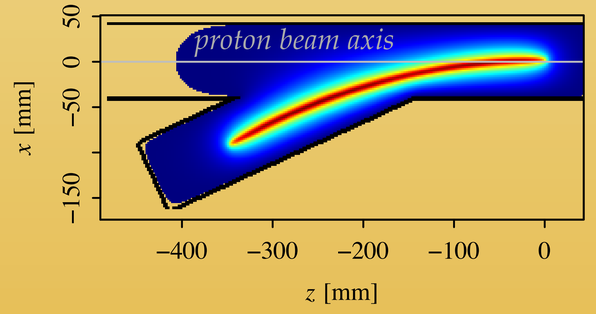
No adverse effects were observed at the Tevatron in continuous operation, but application to the LHC requires higher beam currents and different pulsing patterns. We studied two sources of asymmetry.

INJECTION AND EXTRACTION BENDS

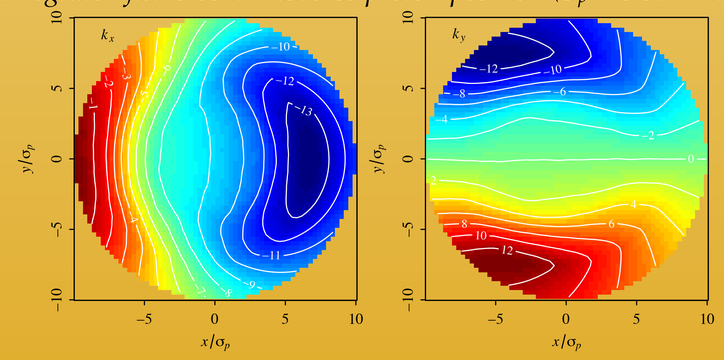
The nonlinear kicks due to the bends were calculated by integrating, over straight trajectories, the electric fields generated by a bent charge distribution:

$$k_{x,y} \equiv \int_{z_1}^{z_2} E_{x,y}(x,y,z)\, dz$$

Electrostatic potential on the plane of the bend for 1 A, 5-keV electron beam (red = -1.2 kV, blue = 0 V)



Integrated fields vs. transverse proton position ($\sigma_p = 0.32$ mm)

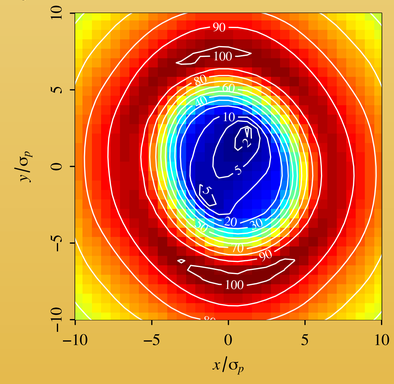


For 7-TeV protons, an integrated field of 10 kV corresponds to a deflection of 1.4 nrad.

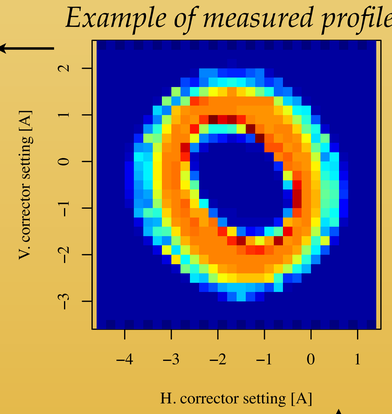
AZIMUTHAL ASYMMETRIES IN OVERLAP REGION

Transverse asymmetries can arise from space-charge evolution and from imperfections in the apparatus. Current-density profiles were measured at the Fermilab electron-lens test stand as a function of beam current and axial magnetic field. Transverse electric fields were calculated from the measured profiles.

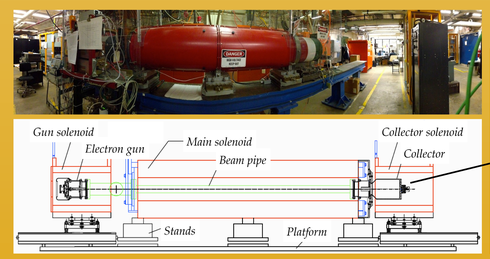
Calculated electric field [kV/m] for 1-A current, inner radius $4\sigma_p$



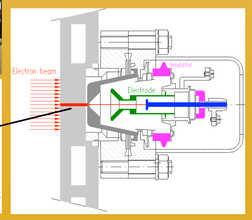
Example of measured profile



Fermilab electron-lens test stand



Pinhole for current-density measurements



All electrostatic field calculations were done with the Warp particle-in-cell code.
Kick maps are provided as inputs for numerical tracking simulations (Lifetrac and SixTrack codes) to evaluate the effects on halo removal rates, core lifetimes, and emittance growth in the Tevatron and in the LHC lattices.

Stancari, Valishev, et al., Phys. Rev. Lett. **107**, 084802 (2011)
Stancari, APS/DPF Proceedings, arXiv:1110.0144 (2011)

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