Interaction Region and Beam-Beam

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Accelerator Physics Topics

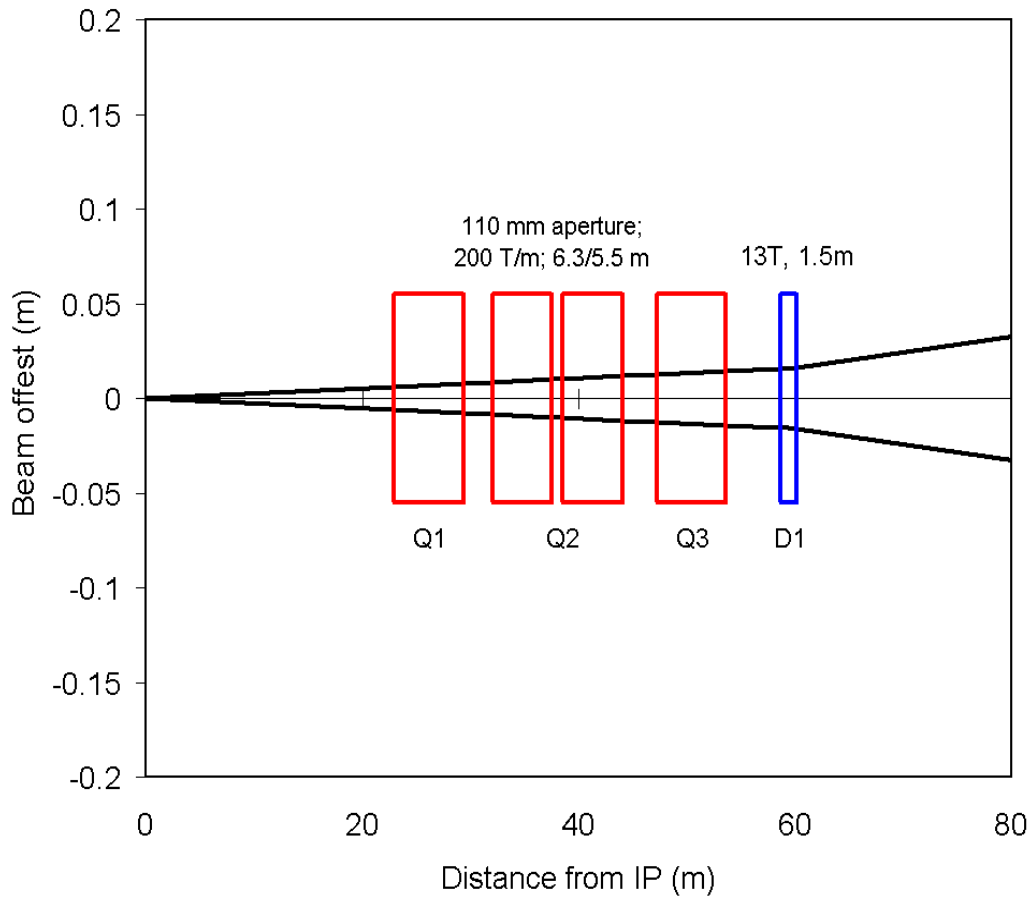
Interaction Region

- Optics design, single beam dynamics (FNAL & BNL)
- Energy Deposition (FNAL)

Beam-beam Interactions

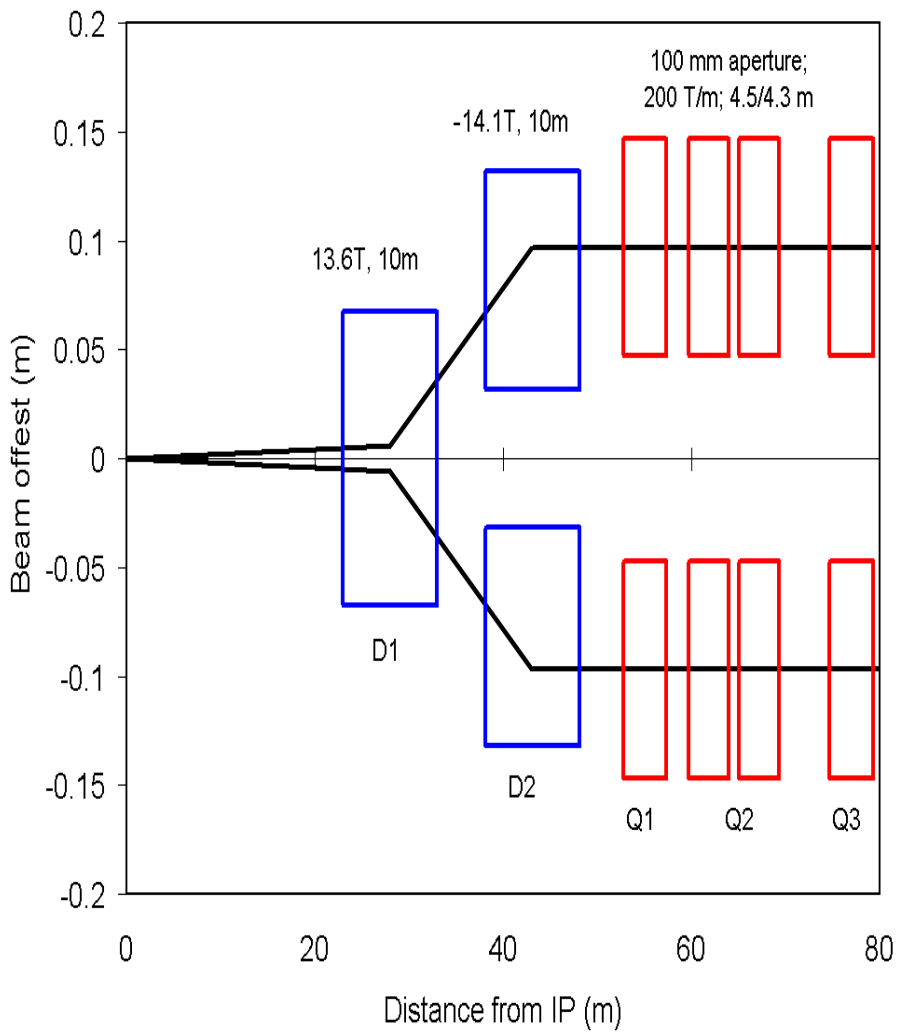
- Impact on Interaction Region design (FNAL)
- Compensation with wires (FNAL)
- Strong-strong simulations (LBNL)

Baseline Layout



- Beams go off-axis in the quadrupoles
- Correction algorithm acts on both beams
- 16 long-range interactions on either side of IP
- Quadrupoles first followed by separation dipoles

Separation Dipoles First



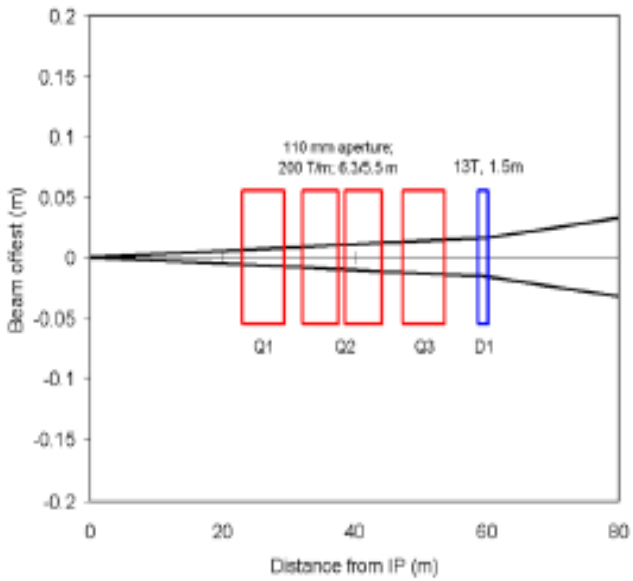
Pros

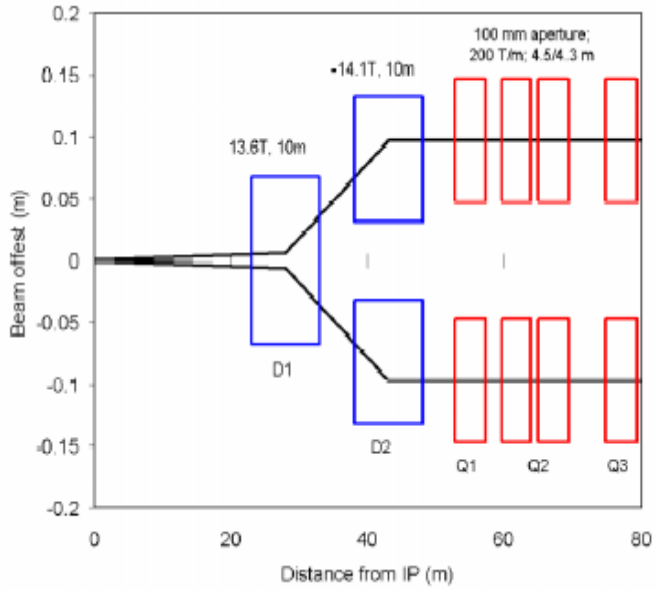
- Reduces long-range interactions 3 fold
- Independent nonlinear correction for each beam

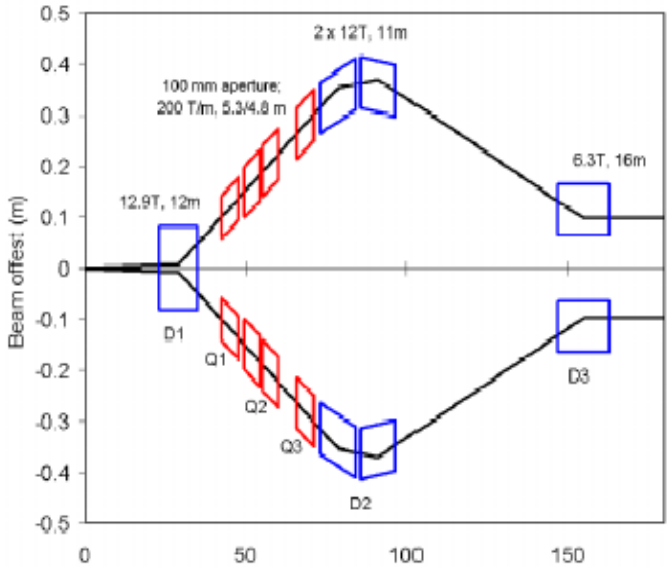
Cons

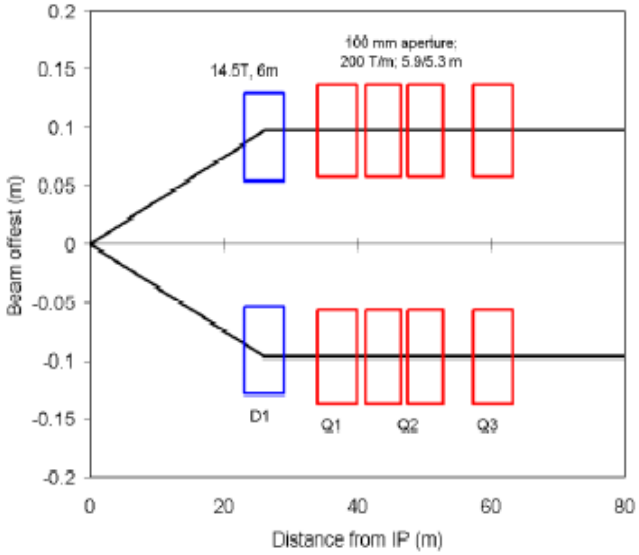
- Larger β^* for the same β_{max}
- Higher energy deposition in D1 from charged particles

Different IR Layouts

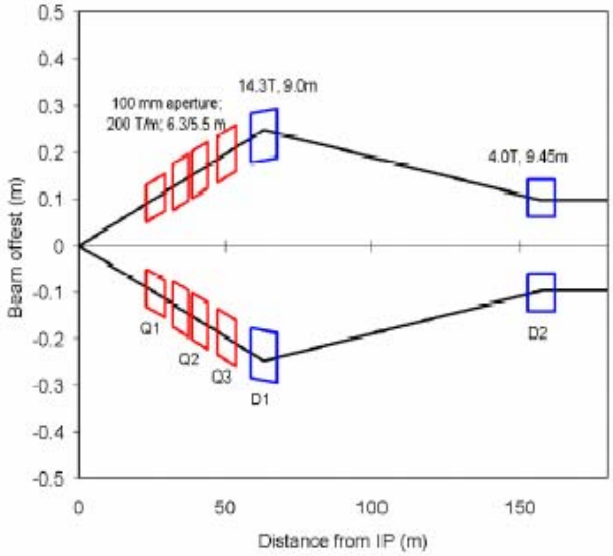








J. Strait et al.
PAC 2003



IR Design Issues

Magnet Design (dipole and quadrupole)

- Aperture, Field or Field Gradient
- Field quality: impact on dynamic aperture
- Demands on nonlinear correctors
- Energy deposition

Optics and beam dynamics

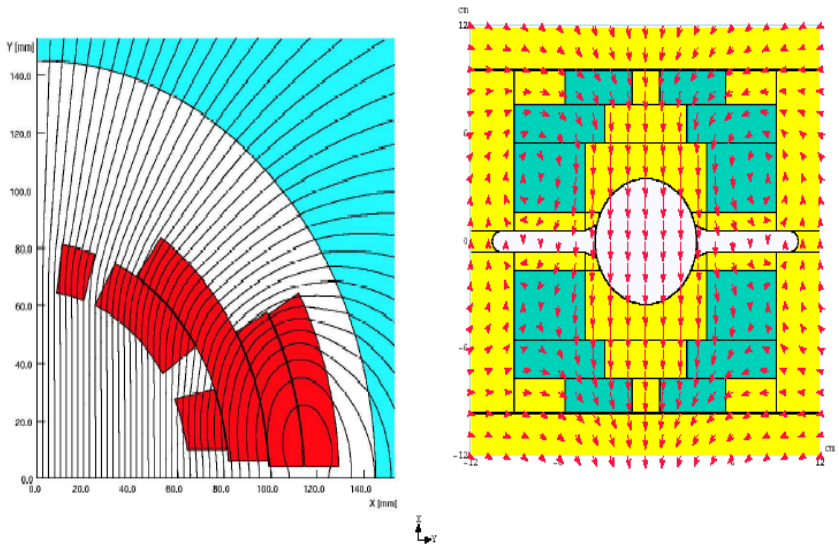
- Constraints from injection optics
- Local/non-local nonlinear correction
- Beam-beam effects

Energy Deposition

- Quench stability: peak power density in super-conducting coils
- Dynamic heat loads: power dissipated into cold magnets
- Components lifetime: peak radiation dose and lifetime
- Residual dose rates: hands on maintenance
- Operational and accidental beam loss
- IR collimators and absorbers, main collimation system

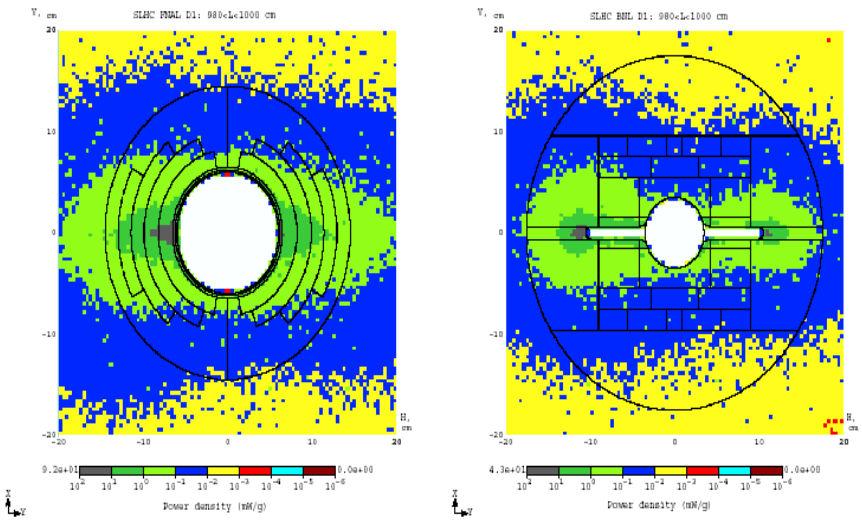
Energy Deposition: First Results

DIPOLE-FIRST MAGNET DESIGNS



Peak power density is a factor of 100 higher in SLHC dipole ($\mathcal{L} = 10^{35}$) than in LHC IR quads ($\mathcal{L} = 10^{34}$).

SLHC: DIPOLE-FIRST ENERGY DEPOSITION



Peak power density is 49 mW/g in copper spacer and 13 mW/g in SC coil (left) and only 1.1 mW/g in the SC coils of block-type dipole (right). Total power dissipated in the dipole is 3.5 kW in either design.

N. Mokhov et al., PAC 2003

Interaction Region deliverables

FY05

Basic versions of quadrupole first, dipole first

- Magnet parameters for inner triplet, separation dipoles
- Requirements on field quality (1st iteration)
- Energy deposition and radiation environment in IRs
- Modeling accidental and operational beam loss

FY06

- Iteration of FY05 optics design
- Nonlinear correction scheme (1st iteration)
- Energy deposition in IRs (2nd iteration)
- Design of IR protection system (1st iteration)

Beam-beam influence on IR design

- Choice of crossing angle Φ, β*

  Φ limited from below by parasitics

  Φ limited from above by luminosity, magnet apertures

  β* limited from below by head-on, *parasitics*, optics, bunch length

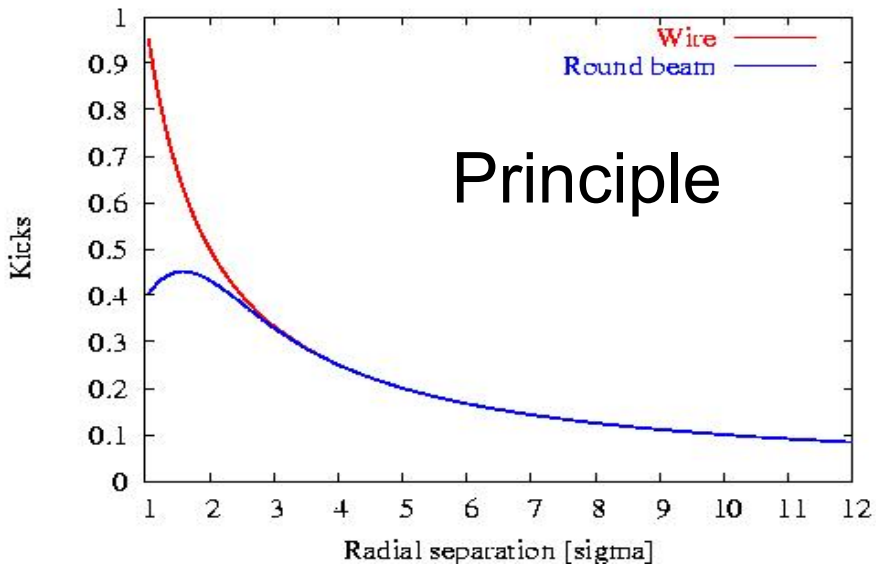
- Dispersion within IR at locations of parasitics

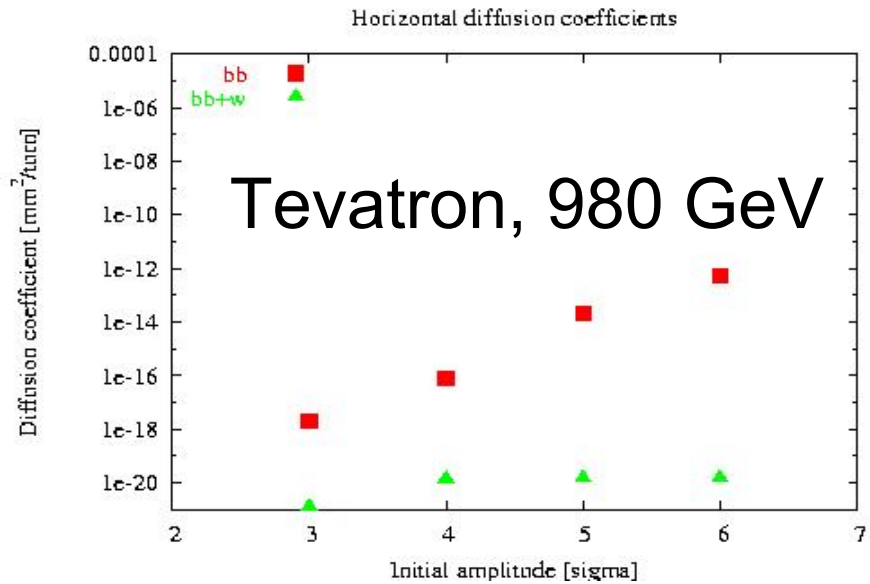
- Dynamic aperture with IR nonlinearities and beam-beam

- Halo development due to IR nonlinearities and beam-beam

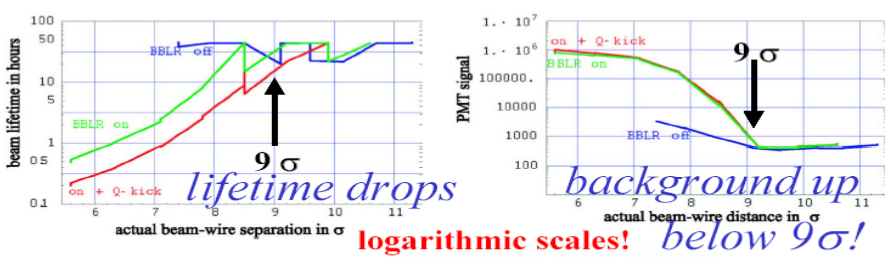
- Superbunches

Wire Compensation

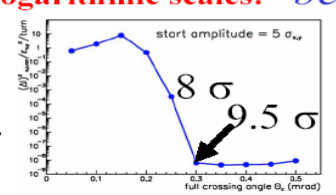




preliminary evidence for diffusion vs. beam-wire distance in SPS



compare with LHC simulation:



Tools developed at FNAL

- BBSIM – parallelized beam-beam code
- Analytical tools (resonance terms, elliptical wires, multiple wires,….)

Strong-strong simulations

BEAMBEAM3D – strong-strong PIC style code (LBNL)

- Uses a shifted Greens function method
- Initial application to luminosity monitor

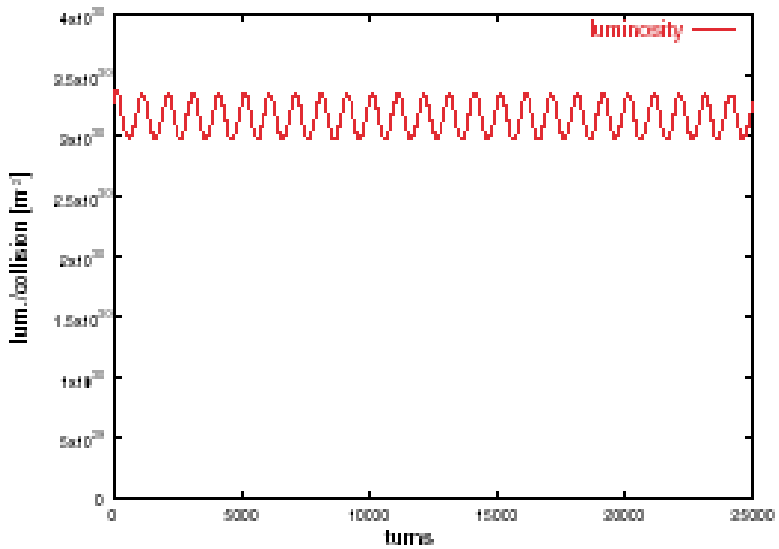


FIG. 7. (Color) The luminosity per collision as a function of turns during the sweeping process.

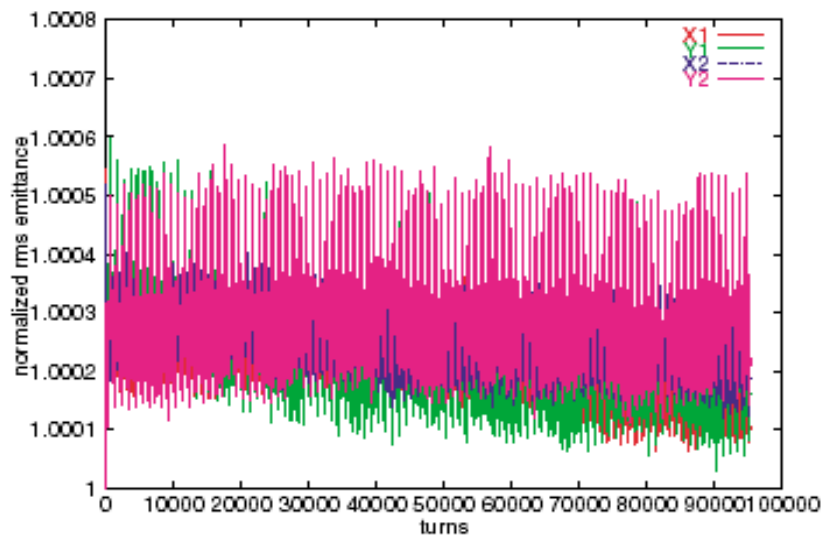


FIG. 8. (Color) The rms emittance as a function of turns during the sweeping process.

J. Qiang et al., PRSTAB, October 2002

Beam-beam deliverables

FY05

- Participation and analysis of wire experiments at SPS
- Limits on optics parameters, e.g. crossing angle vs β^*, bunch intensity,# of bunches
- LBL luminosity monitor efficiency vs integration time
- Emittance growth at long-times from high luminosity IPs

FY06

- Compensation with wires for quadrupole first designs
- Limits on optics and beam parameters (2nd iteration)
- Emittance growth at long times(crossing angle, parasitics,…)
- Benchmark LBNL code against CERN's code, observations

Level of Effort

Interaction Region and Beam-beam

	FTEs	
	FY05	FY06
IR design (FNAL, BNL)	0.7	0.8
Energy deposition (FNAL)	0.4	0.4
Beam-beam (FNAL, LBNL)	0.5	0.6