Operational Status of CESR-c

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27 June 2006

EPAC 06
10th
EUROPEAN PARTICLE
ACCELERATOR CONFERENCE
A EUROPHYSICS CONFERENCE

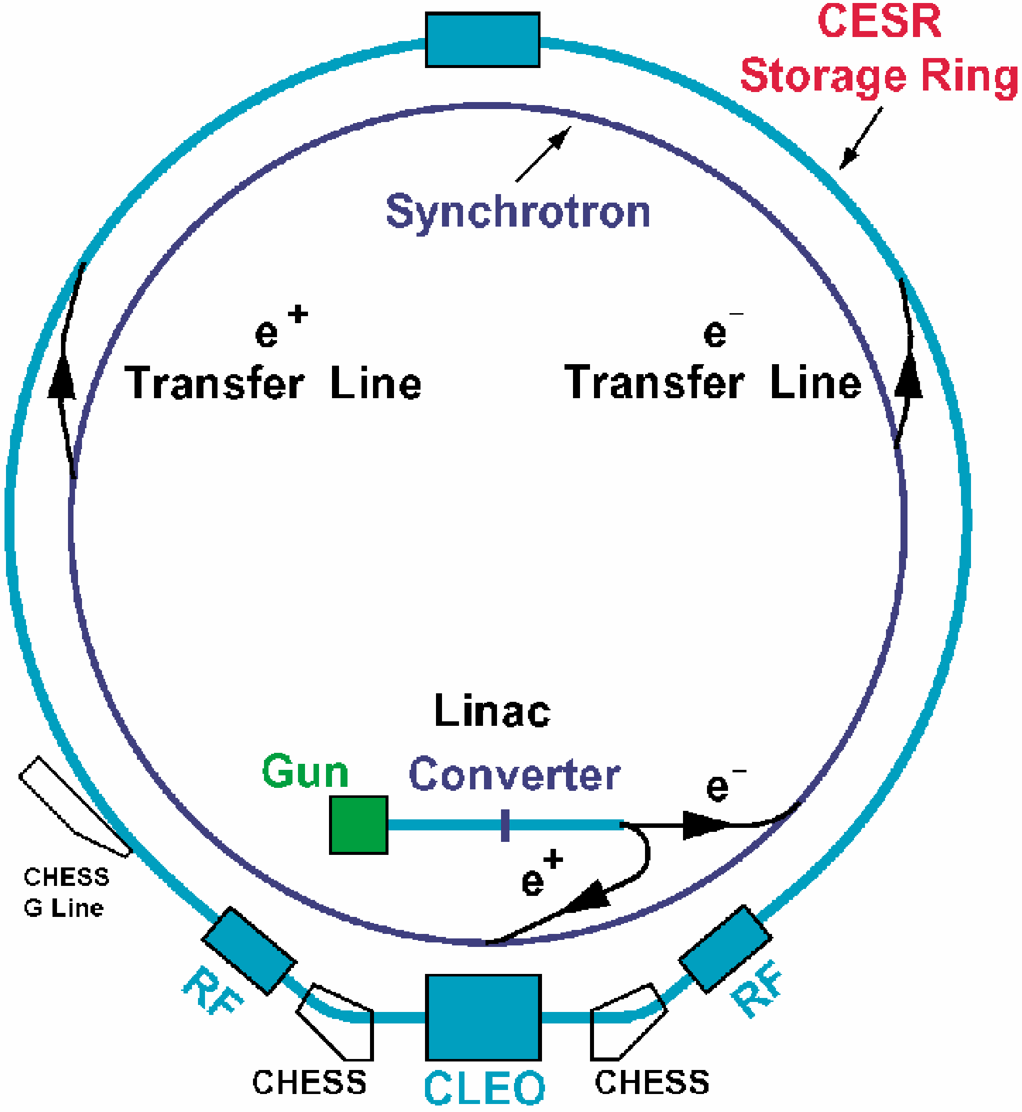
CESR Storage Ring and Injectors

**CESR-c Operation
since 2003
12 s.c. wigglers since mid-2004**

**1.5-6 GeV beam energy
Presently 2.085 GeV**

768 m circumference

**24 bunches/beam
60 mA/beam**



The electron and positron beams are separated by means of electrostatic separators.

The optical distortions introduced by this "pretzel" orbit are corrected using the lattice design flexibility afforded by 180 quadrupole and sextupole magnets.

CESR as a Charm Factory

CLEO-c and CESR-c: A New Frontier in Weak and Strong Interactions CLNS 01/1742 October 2001

Physics Motivation

Unprecedented statistical precision for decays of charm-quark bound states

Increase world data sample by two orders of magnitude

CESR provides unique opportunities

1) Decades of design and operating experience with the CESR storage ring and injectors

2) CLEO state-of-the-art detector technology

3) Threshold production kinematics

Success contingent on meeting major accelerator physics challenges

Design and operation of first wiggler-dominated storage ring

From 5.3 GeV (Υ(4s)) to 1.9 GeV (ψ(3s))

Severe consequences for lowering beam energy:

- ***Emittance*** $(\varepsilon_H \propto E^2)$
- ***Energy spread***
- ***Damping time*** $(\tau \propto E^{-3})$ ***and injection rate***
- ***Beam-beam kicks and tune shifts***
- ***Single-bunch instability thresholds***
- ***Intra-bunch scattering***

Twelve 2.1-Tesla 130-cm-long superferric wiggler magnets to restore damping

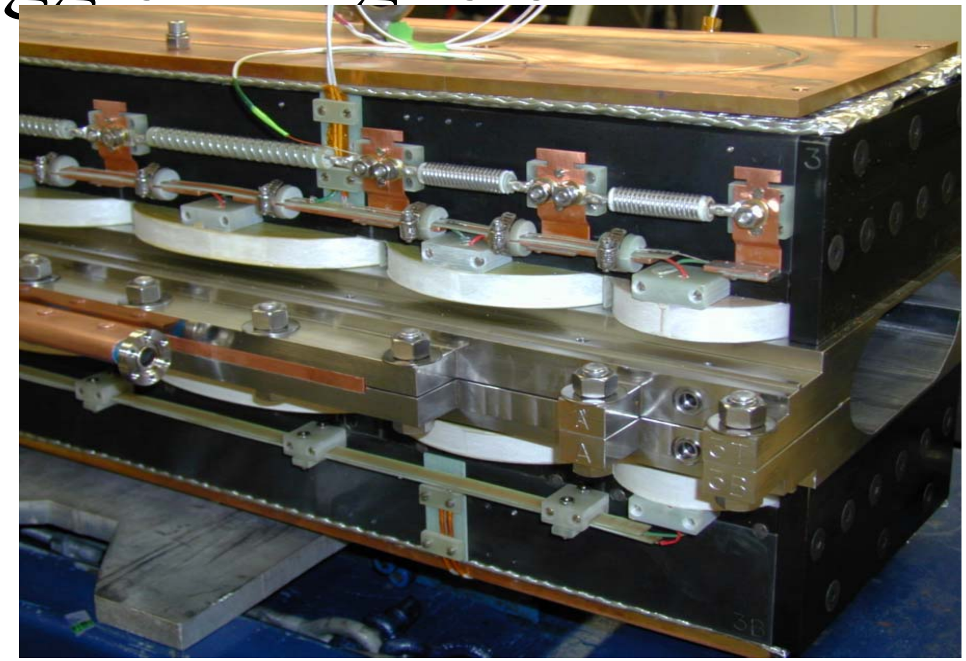
- *Emittance:* 30 → 220 nm-rad
- *Damping time:* 570 → 55 ms
- *Energy spread:* $2 \times 10^{-4} \rightarrow 8 \times 10^{-4}$

Need flexible lattice design capability

Vertical tune shift 0.1 per wiggler !

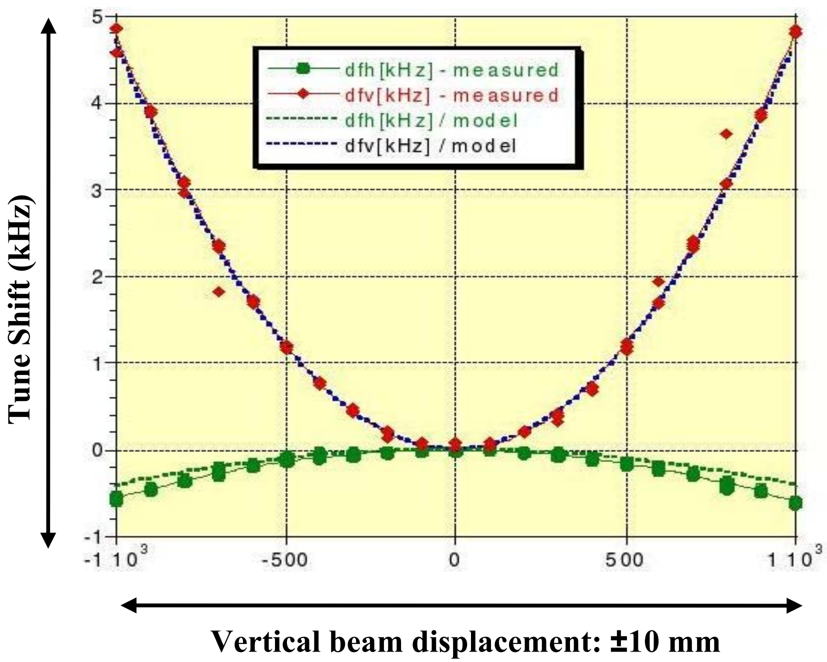
8-pole Superconducting Wiggler Magnets

Production and Testing Consideratiions for the CESR-c Wiggler Magnets
D.H.Rice et al, PAC2003



8 poles (4 x 20 cm, 2 x 15 cm, 2 x 10 cm)
Central poles: 660 turns, 95 kA
End poles: 352 turns, 51 kA (trim adjust)

In-house design & construction 2001-2004
Installation complete August, 2004



Beam-based characterization of wiggler nonlinearities accurately modeled for three-wiggler cluster in-situ. Analytic wiggler field model uses Taylor mapping for fast tracking simulation.

Field Modeling for the CESR-c Wiggler Magnets, J.A. Crittenden et al., PAC2005

Commissioning Milestones

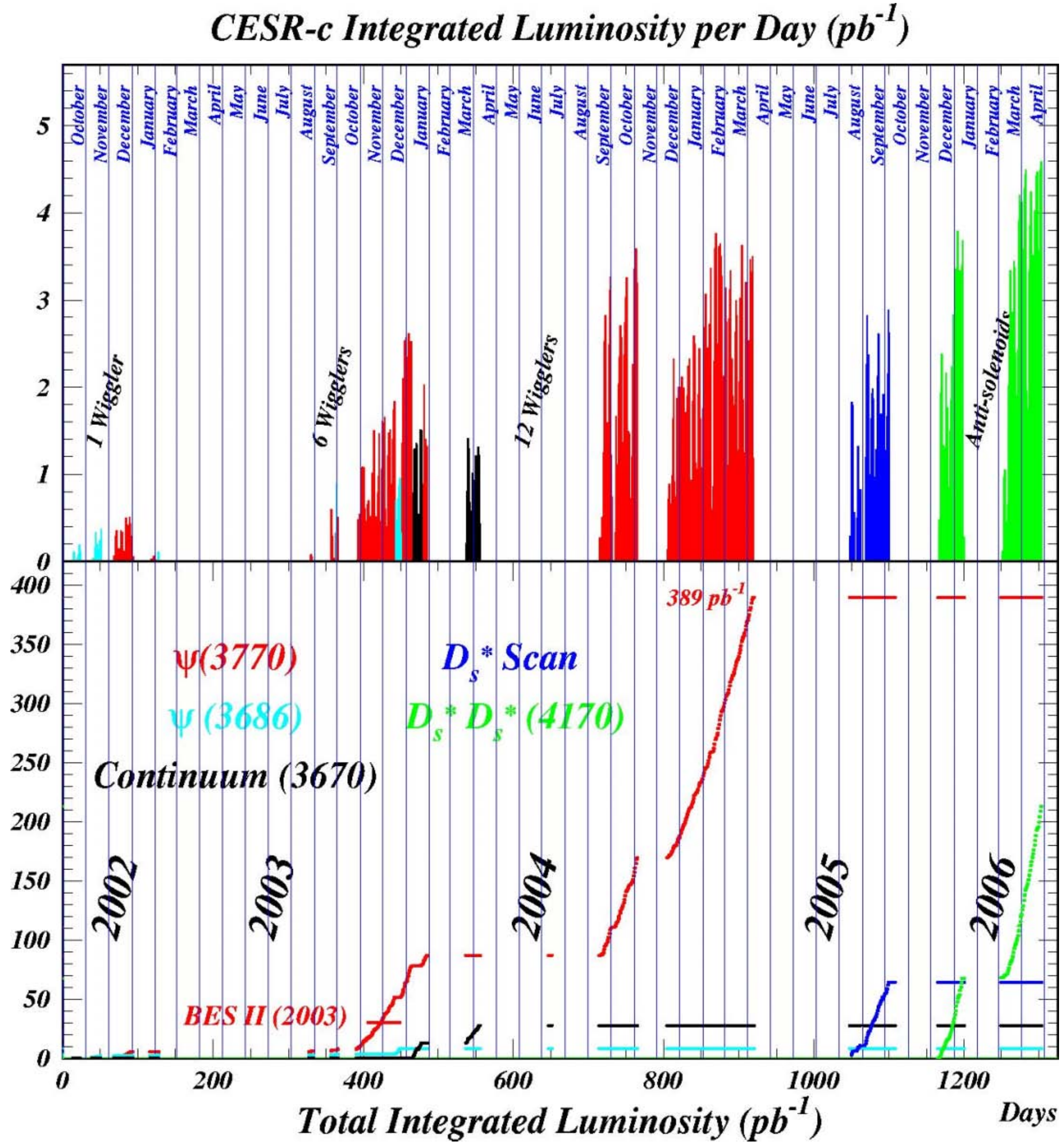
8/2002	First wiggler installed
9/2002	Machine studies verify wiggler properties
10-12/2002	Engineering run 90 mA, $1x10^{31}$
7/2003	New vertex chamber in CLEO
8/2003	Five more wiggler magnets
11/2003-4/2004	First Physics run 110 mA, $3x10^{31}$, (3x world sample of ψ(3s))
4-6/2004	Complete installation of 12 wigglers
8-9/2004	Install fast luminosity monitor
9/2004-3/2005	Production run at 3770 MeV, 160 mA, $6x10^{31}$, (ψ(3s) X 4)
8-9/2005	D_s scan
12/2005-1/2006	D_s Production (4170 MeV)
1-2/2006	Install new solenoid compensation magnets
3-4/2006	D_s Production (3X), 120 mA, $7x10^{31}$, injection into collision

Luminosity History

CESR-c: Performance of a Wiggler-Dominated Storage Ring A. Temnykh, PAC2005

Developments since PAC 2005

- *New IR Optics*
- *Electron injection into collision*
- *BBI included in lattice design*
- *Constraint on e+e- symmetry*
- *New diagnostic tools*



Diagnostics of Interaction Point Properties and Bunch-by-Bunch Tune Measurements in CESR,
G.W.Codner et al, Beam Instrumentation Workshop 2006

CESR-c Operating Parameters

	Design report 2001	4/2005	4/2006
$\mathcal{L}$ (10^{30} cm^{-2} s^{-1})	300	65	70
I_{beam} (mA)	180	75	65
Nr Bunches	45	40	24
ε_H (nm-rad)	220	135	120
ξ_V	0.04	0.024	0.029
β_V (cm)	1.0	1.2	1.2
σ_E/E (10^{-4})	0.81	0.85	0.81
$\tau_{H,V}$ (ms)	55	50	55

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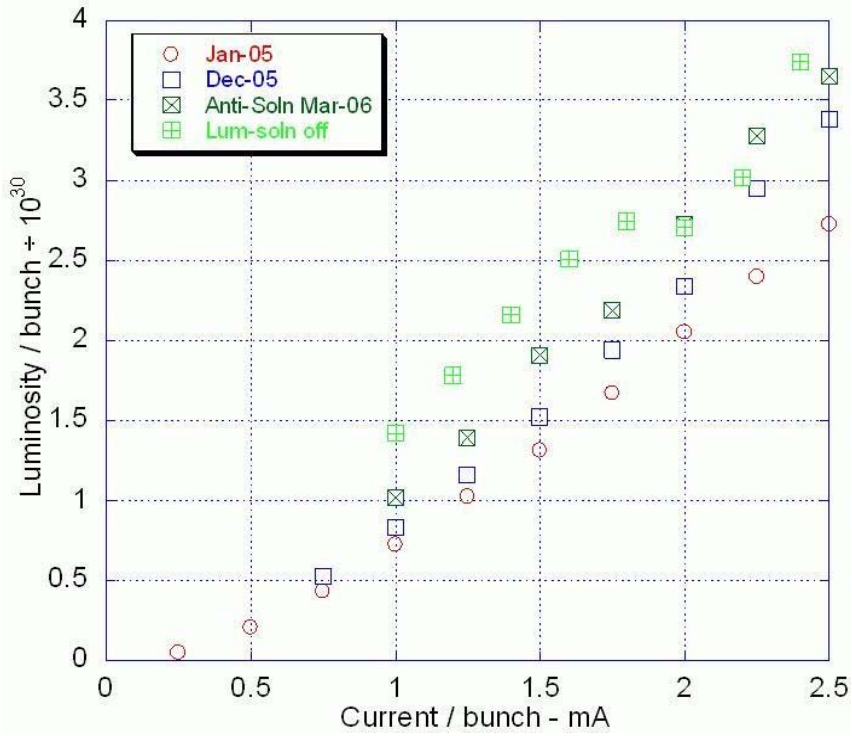
Improved Solenoid Compensation

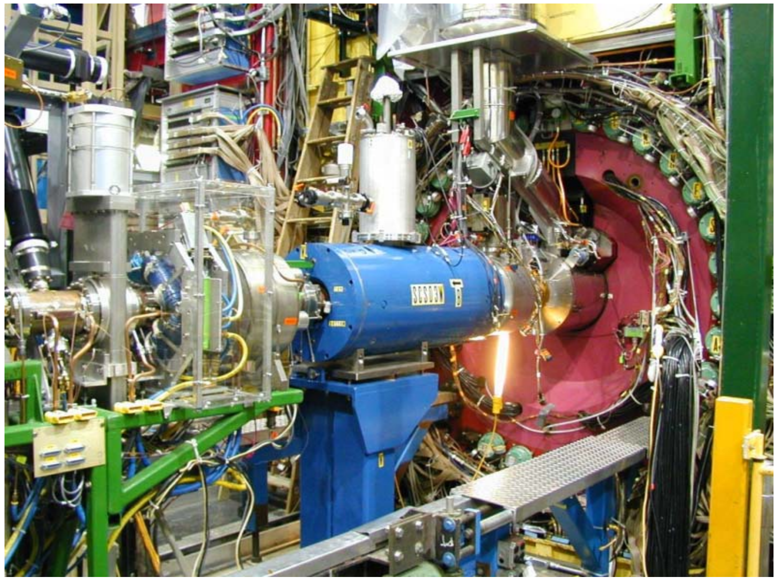


New IR Compensation Scheme 2006

Skew-quadrupole compensation of CLEO detector solenoid was implemented in 2001 and used for 5.3 GeV operation.

Full CESR luminosity modeling in early 2005 indicated that the energy-dependence of compensation is more important at CESR-c energy due to larger energy spread

Two-solenoid solution was DAϕNE-inspired, but optics design was complicated by existing permanent and s.c. quadrupoles



Two 36-inch-long 2-Tesla "anti-solenoids" installed in January, 2006

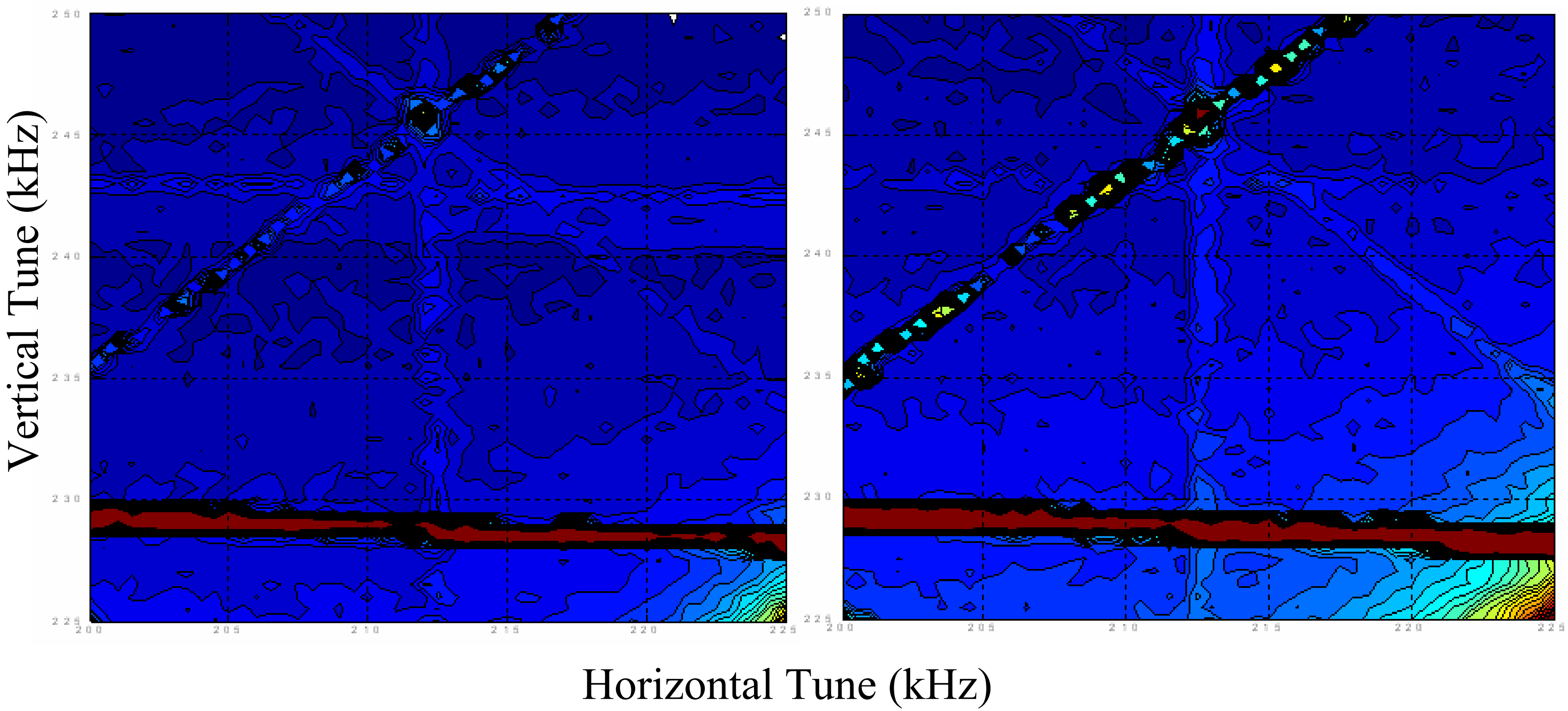
Improved Tune Plane Footprint

New solenoid compensation reduces strength of synchro-betatron resonance

→ ***improved ease of machine tuning***

Nominal Solenoid Compensation

Solenoid strength reduced 20%
Residual coupling compensated using IR skew quads



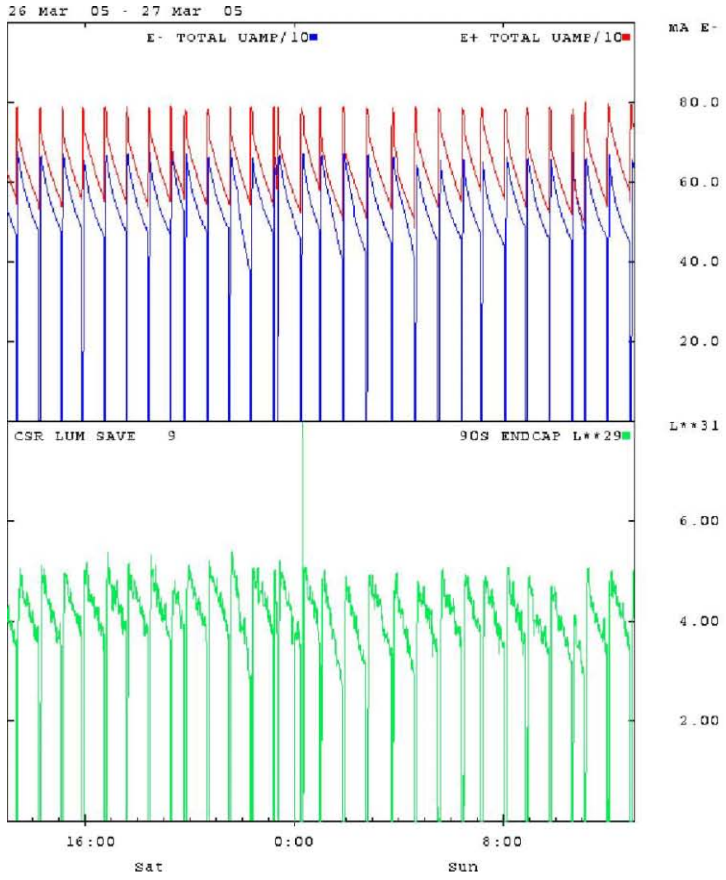
Topping Off: Reliability & Duty Cycle

Ability to inject and collide in similar optics avoids fill-to-fill thermal cycling

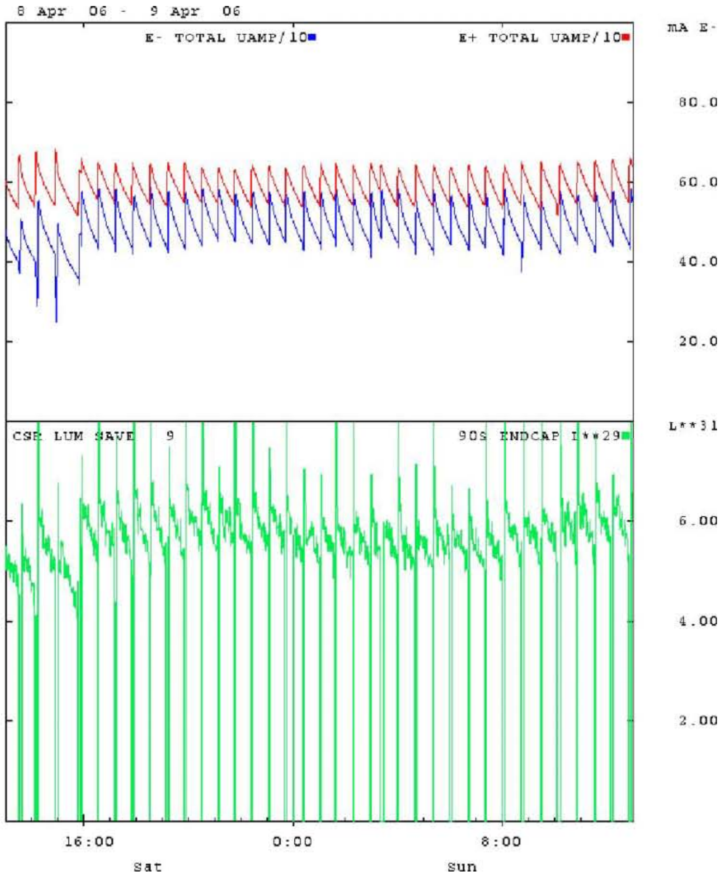
Tune excursions from BBI much reduced (less hysterisis!)

Turn-around times reduced from 4 to less than 2 minutes.

March 26, 2005



April 8, 2006

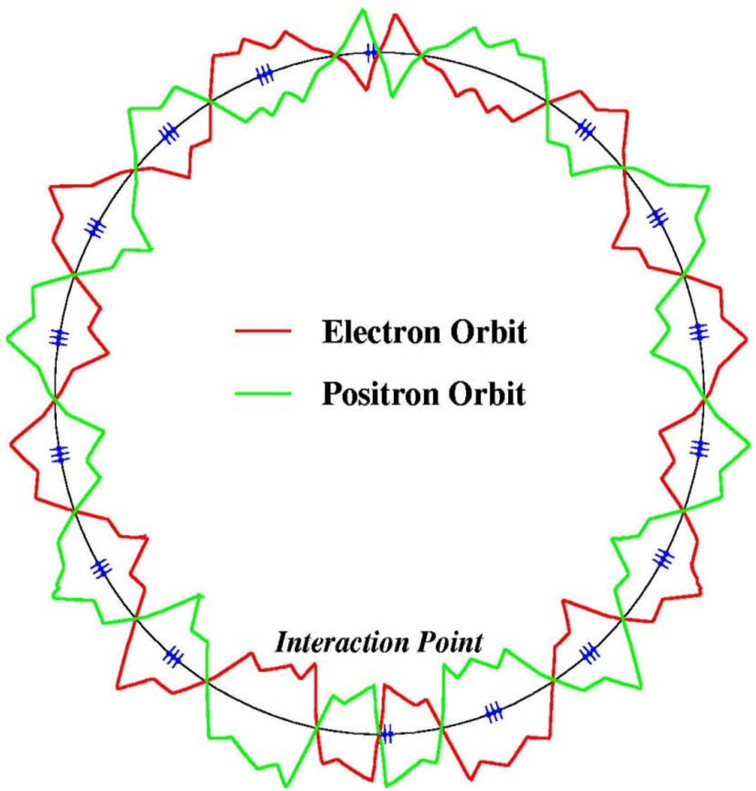


Modelling the CESR-c BBI

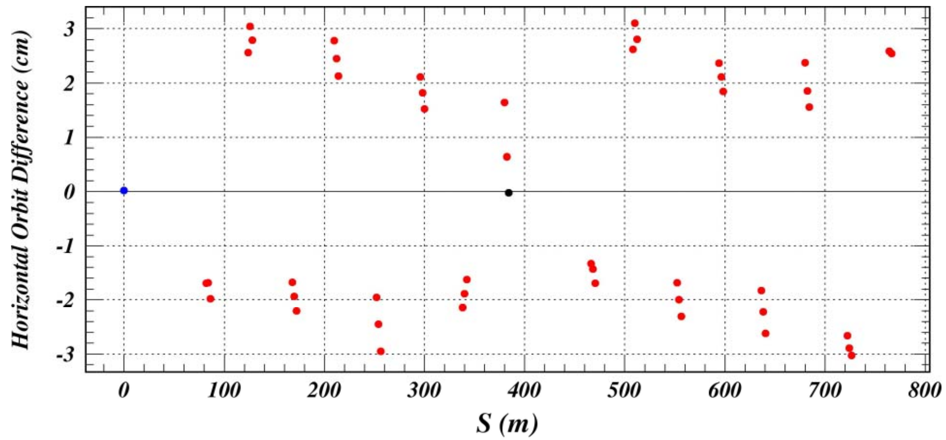
These recent improvements in IP optics, tune plane footprint and duty cycle re-emphasize the importance of finding a way to compensate optical distortions arising from the beam-beam interaction.

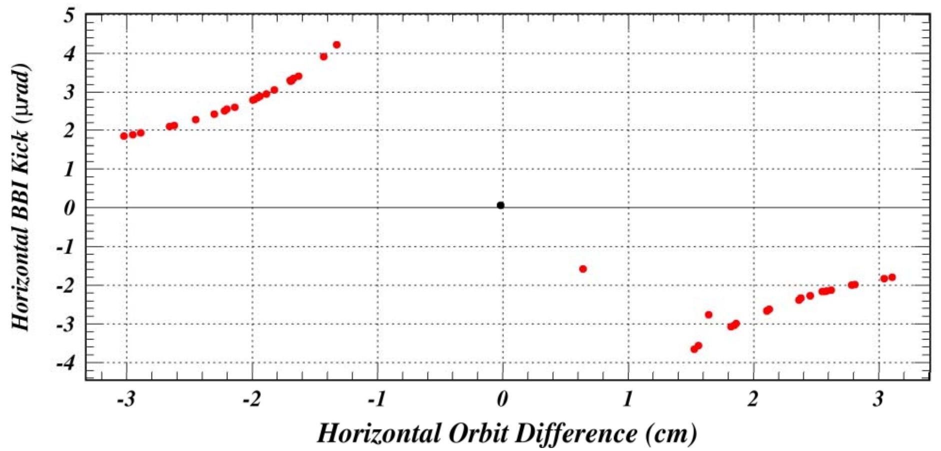
Horizontal crossing positions for electron train 1 bunch 1

Positrons: 8 trains of 3 bunches



<u>Beam-beam kicks</u>





Calculating and Compensating the Optical Distortions Arising from the Beam-Beam Interaction

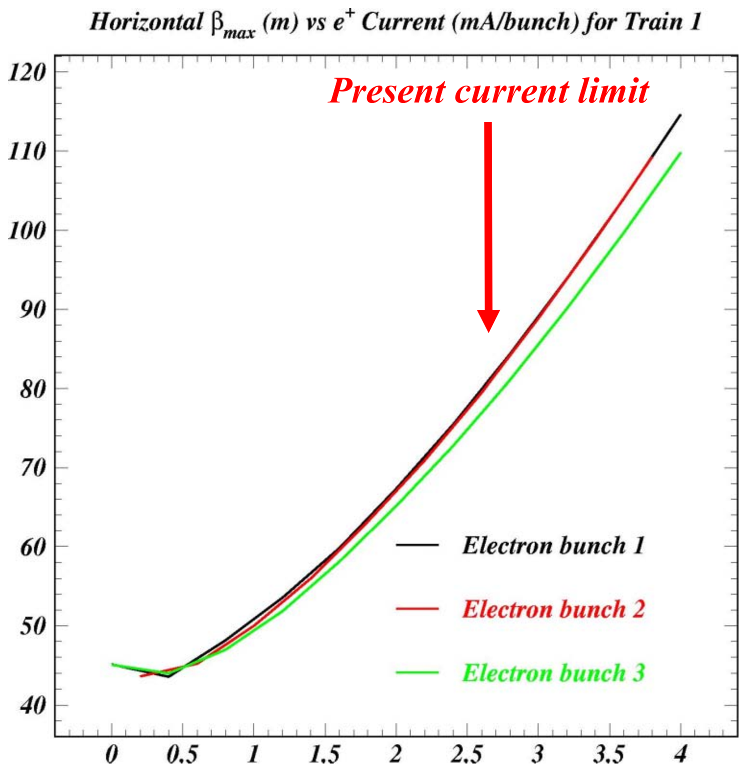
Present stored-current limit: 2.5 mA in 8x3 operation in collision, but higher if the beams are separated at the IP .

Limit on a single electron bunch into 8x3 positrons is 8 mA.

As a result, much effort has been put into modeling the beam-beam interaction both at the IP and at the parasitic crossings.

Some improvement has been obtained already by including consideration of the long-range BBI in the lattice design. Nonetheless, the distortion of the beta function is substantial, even when the tunes are held constant during filling.

Until now, operational compensation of the BBI effects has consisted of global tune corrections. We have recently developed an optics correction algorithm based on locally closed beta bumps using eight quadrupole magnets around each set of crossings. Initial results from machine studies in April, including compensation of the BBI at the main IP, are encouraging.



Near-term Improvement Plans

Machine Studies Projects July-September 2006

- *Lattice design development, e.g. pretzel optimization*
- *Tune IP BBI compensation (empirical coefficients)*
- *Tune local parasitic crossing compensation*
- *Improve e- injection efficiency*
- *Sextupole tuning to avoid resonances*
- *Study alternative working points*
- *Develop run-time tuning aids*
- *Improve hardware reliability through diagnostic tools*
- *Injector tuning*

Completion of CLEO-c Physics Program

During the past year, CESR-c operation has been improved by:

- ***new IR optics; new solenoids built and installed***
- ***lattice design optimization including new IR and BBI effects***
- ***establishing a top-off mode for electron injection into collision***

Bunch-by-bunch and turn-by-turn diagnostic tools have been commissioned.

Development of BBI compensation algorithms is underway.

CESR/CLEO continues to be major contributor to the active field of charm spectroscopy. Discovery of new bound states of charmed quarks, precision measurements of form factors, and many first-time observations coincide with increasing precision of lattice QCD phenomenology. CLEO presently dominates the world sample of $\psi(3770)$ and D_s threshold data and is on track to increase former by a factor of two and latter by a factor of four. The foreseen program also includes tripling the world sample of $\psi(3686)$ decays by the time of its completion in April, 2008.