Operational Status of CESR-c

1. Physics Motivation
2. Introduction to CESR
3. The Beam Dynamics/Lattice Design Challenge
4. Construction/Installation Milestones
5. Superconducting Wiggler Magnets
6. Operational Performance
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Physics Motivation

CLEO-c and CESR-c: A New Frontier in Weak and Strong Interactions

Unprecedented statistical precision for decays of charm-quark bound states
Increase world samples of $D$, $D_S$ and $J/\psi$ decays by more than two orders of magnitude

Take advantage of the opportunity provided by

1. CESR storage ring operation/design experience
2. CLEO detector technology
3. Cleanliness of threshold production kinematics

Depends on solving the damping-dominated beam dynamics design problem
The Cornell Electron Storage Ring Facility
Pretzel Orbits

Beams are horizontally separated at the parasitic crossing points (|||) by electrostatic separators.

Resulting beam optics distortions require careful lattice design (e.g. sextupoles) to maintain focussing at IP while reducing the parasitic beam-beam interactions.
The Beam Dynamics Challenge (I)

Consequences of reducing beam energy
5.3 GeV ($\Upsilon(4s)$) $\rightarrow$ 1.9 GeV ($\psi(3s)$)

For fixed integrated bend radius, $\epsilon_x \propto E^2$ and $\tau_{\text{damping}} \propto E^{-3}$

$\Rightarrow$ Severe consequences for

1. Horizontal emittance $\epsilon_x$ and energy spread
2. Injection repetition rate
3. Beam-beam kicks and tune shifts (parasitic crossings !)
4. Single-bunch instability thresholds
5. Intra-bunch scattering

$\Rightarrow$ Induce damping with 12 superconducting wiggler magnets at 2 Tesla peak field
The Beam Dynamics Challenge (II)

The damping effect of the wigglers

Horizontal emittance: \(30 \rightarrow 220^* \text{ nm}\)
Damping time: \(570 \rightarrow 55 \text{ ms}\)
Energy spread: \(2 \times 10^4 \rightarrow 8 \times 10^4\)

*Can be tuned with field strength and dispersion at the wigglers

The machine lattice must have sufficiently flexible design capability, e.g. independent quadrupoles, sextupoles, solenoid compensation, to compensate for the non-linear vertical focusing from the wigglers \((\Delta Q_V \gtrsim 0.1 \text{ per wiggler !})\) for 9 trains of 5 bunches each in pretzel orbits.
The Superconducting Wiggler Magnets

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<th>Pole Length (cm)</th>
<th>Number</th>
<th>Cutout Width (cm)</th>
<th>Cutout Depth (mm)</th>
<th>Main Current (Amp-turns)</th>
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7-Pole Wiggler (2.1 T Peak Field, 161 Amps) Wiggler #1

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7-Pole Wiggler (2.1 T Peak Field, 144 Amps) Wiggler #2

8-Pole Wiggler (2.1 T Peak Field, 161 Amps) Wigglers #3 #16

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Field Quality of the Wigglers

Example: Wiggler SN#6

The residual kick is less than a few gauss-meters for an absolute integrated kick of over $10^4$ gauss-meters.

The residual skew quadrupole error is less than 2 gauss-meter/cm.
Superconducting Wiggler Magnets in the Ring
Milestones

5/2001  Internal lab program review
9/2001  Installed new s.c. focussing magnets in IR
5/2002  NSF site visit and review
8/2002  **First s.c. wiggler installed in ring**
9/2002  Machine studies verify wiggler dynamics
10-12/2002  **Engineering run.**  $I_{\text{Tot}} \sim 90 \text{ mA}$, $L_{\text{peak}} \sim 1.0 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}$
3/2003  NSF project approval through 2008
7/2003  New vertex chamber installed in CLEO detector
8/2003  **Install five additional wiggler magnets**
11/03-4/04  **Physics run.**  $I_{\text{Tot}} \sim 110 \text{ mA}$, $L_{\text{peak}} \sim 3.0 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}$
4-6/2004  **Install final set of 12 wiggler magnets**
CESR-c Progress in Integrated Luminosity

Integrated Luminosity per Day (pb\(^{-1}\))

Total Integrated Luminosity (pb\(^{-1}\))
Examples of Currents and Luminosity

**Typical Running Parameters**

- $8 \times 4$ bunches
- $1.5$ mA/bunch
- $Q_H = 10.51$  
- $Q_V = 9.58$
- $\epsilon_H = 160$ nm  
- $\epsilon_V = 8$ nm
- $\beta_H^* = 68$ cm  
- $\beta_V^* = 1.3$ cm
- $\sigma_H^* = 330$ $\mu$m  
- $\sigma_V^* = 10$ $\mu$m

Crossing angle $2.7$ mrad

- $\sigma_E/E = 8 \times 10^{-4}$
- $I_{Tot} = 100$ mA
- $L = 2.5 \times 10^{-31}$ cm$^{-2}$s$^{-1}$
Summary and Outlook

→ 16 wiggler magnets have been built, tested to specification and commissioned.
→ CESR has operated with six wigglers installed on one side of the ring.
  The optical properties of the wigglers were measured to be as expected.
→ The world supply of $\psi(3770)$ decays was tripled during a 3-month physics run from November/2003 to January/2004.
→ Peak luminosities of 20% of the design goal have been obtained.
→ Theoretical limits to bunch current and b-b tune shift have yet to be reached.
→ CESR operation with the full set of 12 wigglers and the east/west symmetry of the ring restored will begin in August.
→ Experience to date indicates that mastering multibunch injection and matching/stabilizing electron and positron beam functions at the IR will be key to reaching design goals.

Major challenges ahead for beam physics at CESR-c