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**
7. **Outlook**

Physics Motivation

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

Unprecedented statistical precision for decays of charm-quark bound states

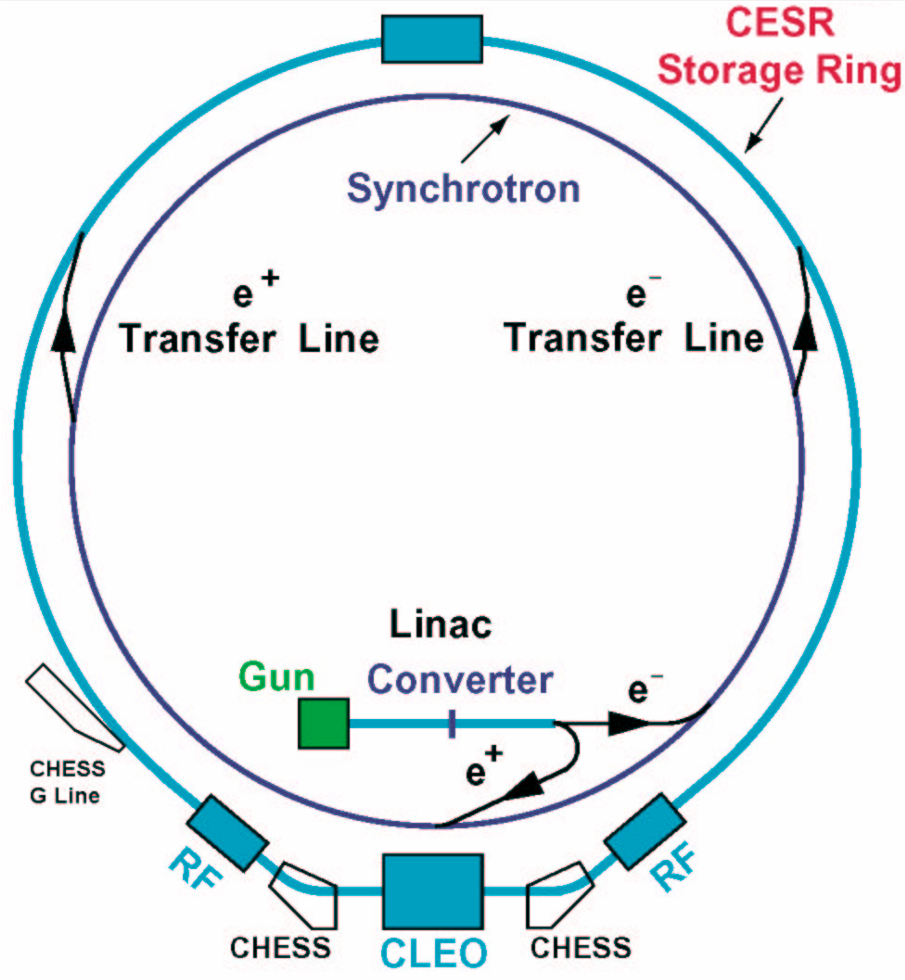
Increase world samples of D, D_S and J/ψ decays decays by more than two orders of magnitude

Take advantage of the opportunity provided by

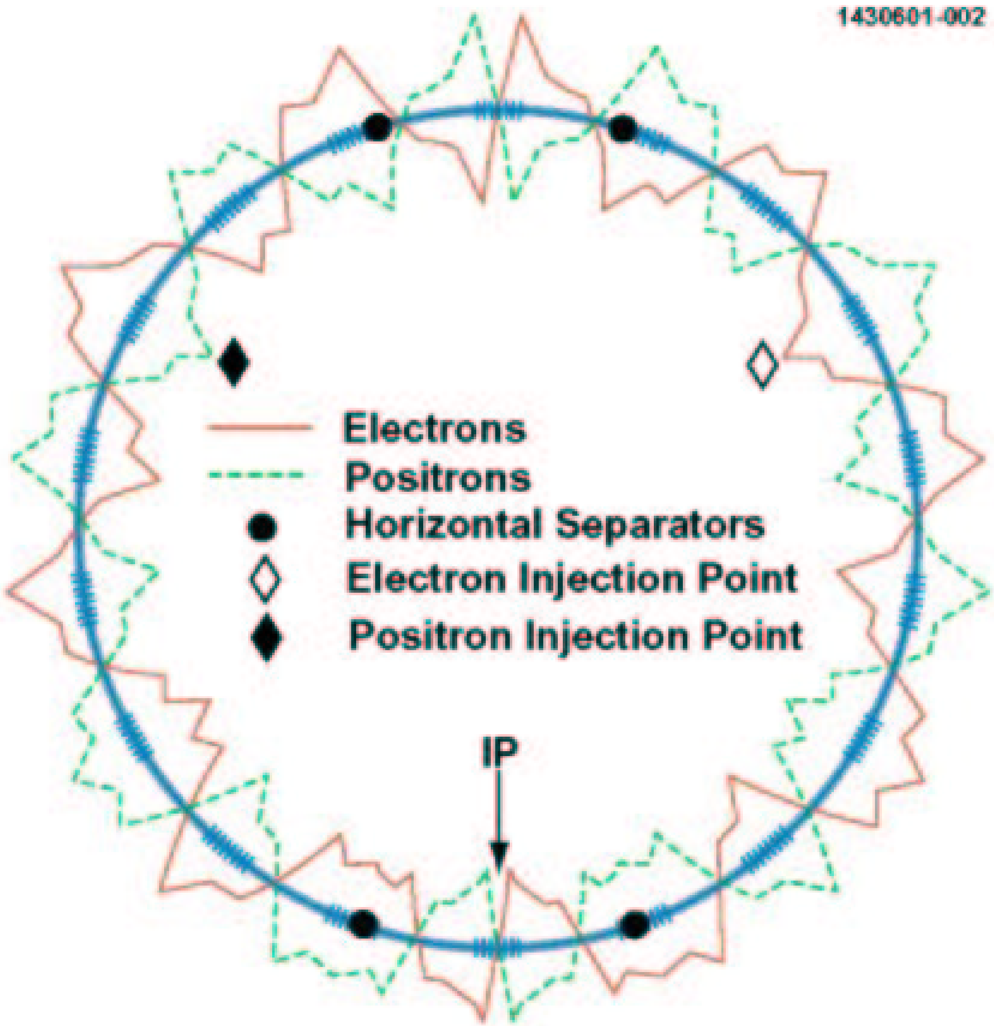
1. **CESR storage ring operation/design experience**
2. **CLEO detector technology**
3. **Cleanliness of threshold production kinematics**

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 (Υ(4s)) $\rightarrow$ 1.9 GeV (ψ(3s))

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

$\Rightarrow$ Severe consequences for

1. Horizontal emittance ϵ_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

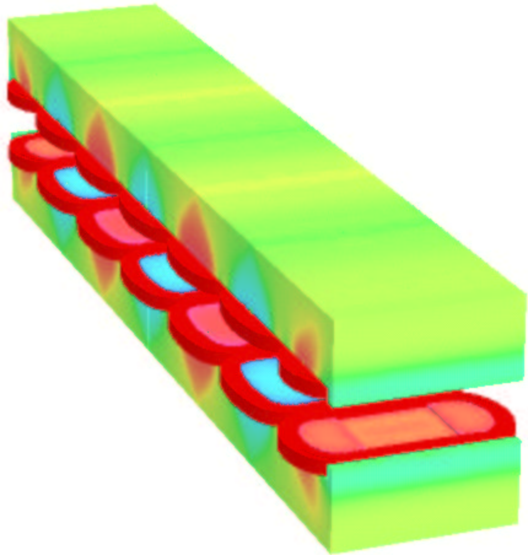
Horizontal emittance:	$30 \to 220^{*}$ nm
Damping time:	$570 \to 55$ ms
Energy spread:	$2 \times 10^{4} \to 8 \times 10^{4}$

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

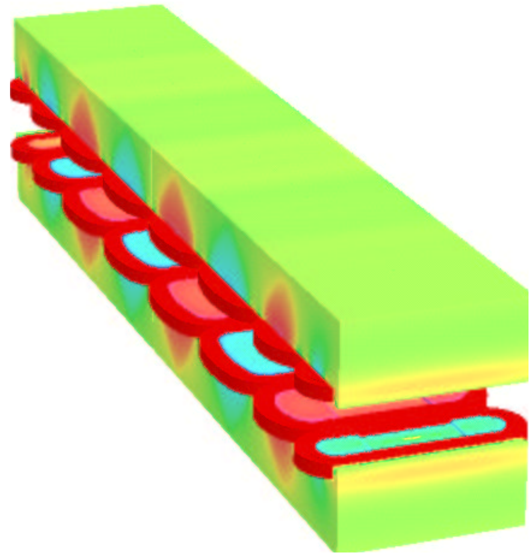
The machine lattice must have sufficiently flexible design capability, e.g. independent quadrupoles, sextupoles, solenoid compensation, to compensate for the non-linear vertical focusing from the wigglers ($\Delta Q_{V} \gtrsim 0.1$ per wiggler !) for 9 trains of 5 bunches each in pretzel orbits.

The Superconducting Wiggler Magnets

7-pole Wiggler



8-pole Wiggler

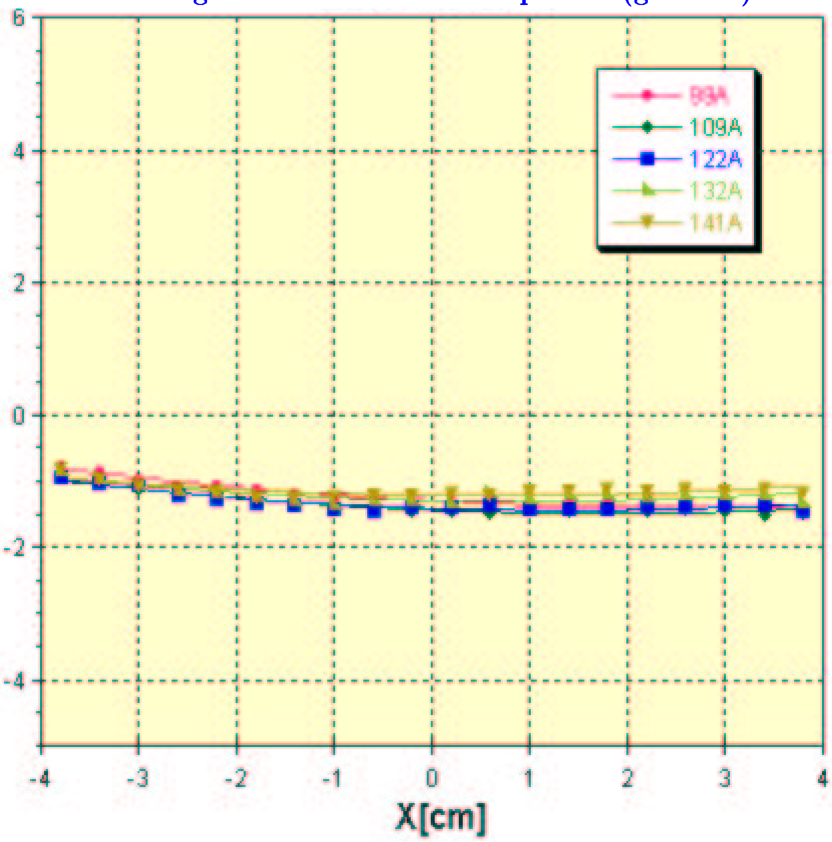


Pole Length (cm)	Number	Cutout Width (cm)	Cutout Depth (mm)	Main Current (Amp-turns)	Main Turns	Main Width (Inches)	Trim Current (Amp-turns)	Trim Turns	Trim Width (Inches)
7-Pole Wiggler (2.1 T Peak Field, 161 Amps) – Wiggler #1									
20	5	6	5.0	95.00k	588	1.000	—	—	—
15	2	6	3.5	61.07k	378	0.642	0.86k	663	0.358
7-Pole Wiggler (2.1 T Peak Field, 144 Amps) – Wiggler #2									
20	5	6	5.0	95.00k	660	1.000	—	—	—
15	2	6	3.6	57.00k	396	0.603	4.569k	684	0.380
8-Pole Wiggler (2.1 T Peak Field, 144 Amps) – Wigglers #3 – #16									
20	4	6	5.0	95.00k	660	1.000	—	—	—
15	2	6	5.5	95.00k	660	1.000	—	—	—
10	2	6	3.6	50.76k	352	0.533	0.993k	836	0.467

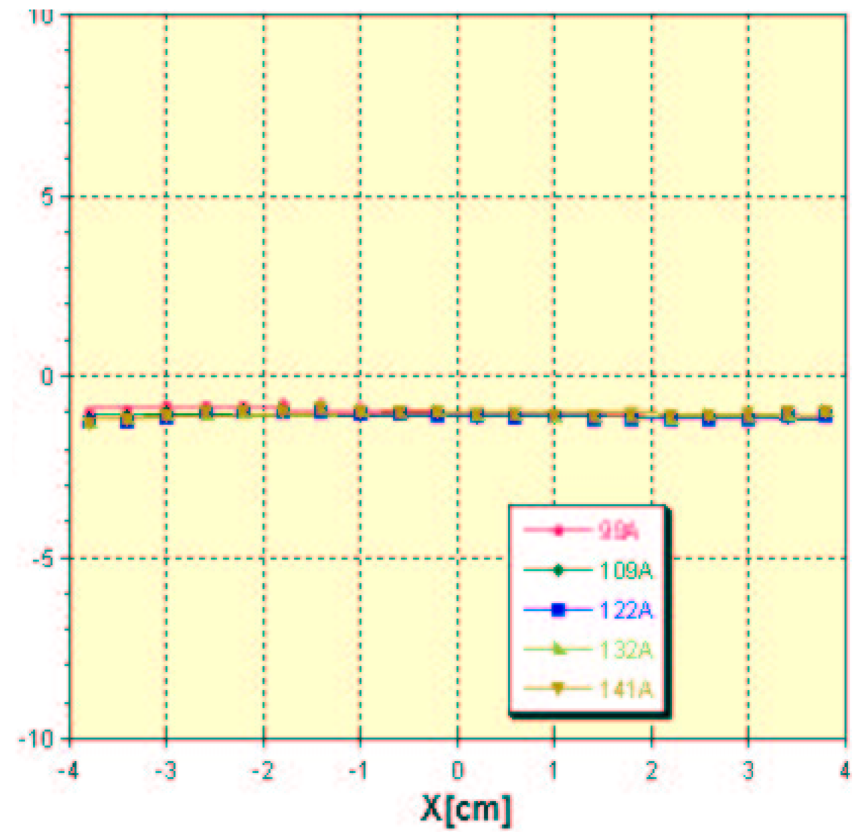
Field Quality of the Wigglers

Example: Wiggler SN#6

Integrated vertical field component (gauss-m)



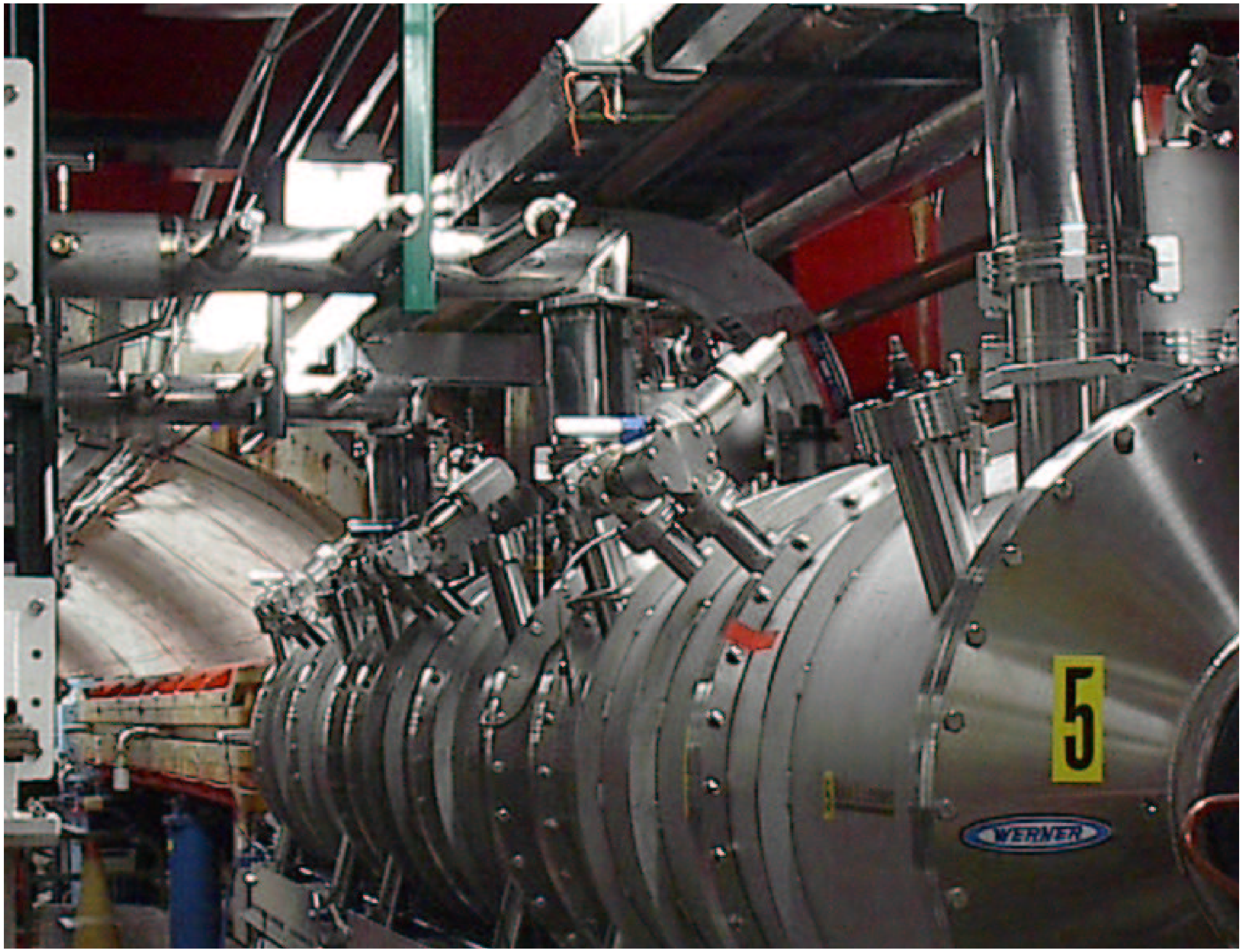
Integrated horizontal field component (gauss-m/cm)



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.

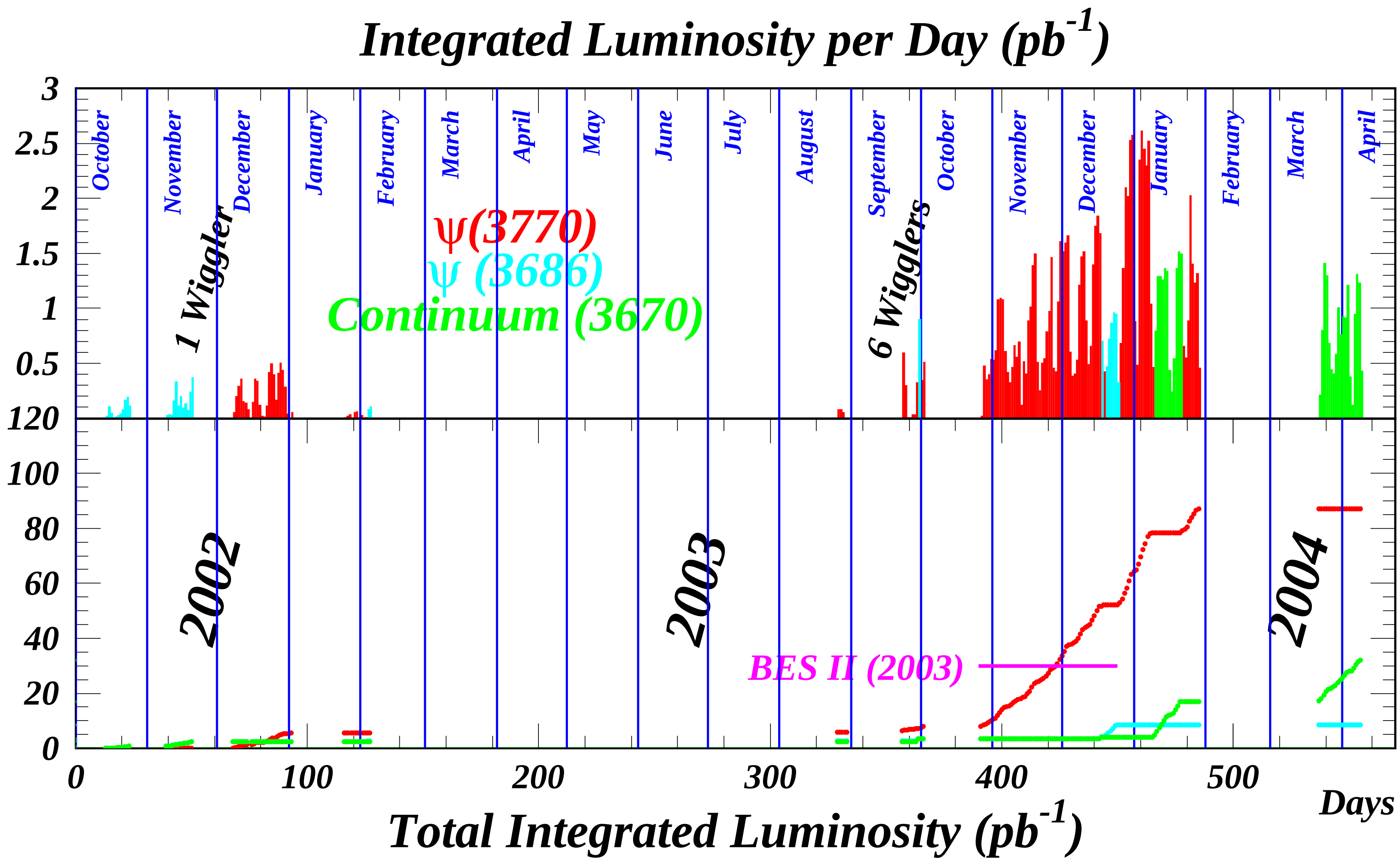
Superconducting Wiggler Magnets in the Ring



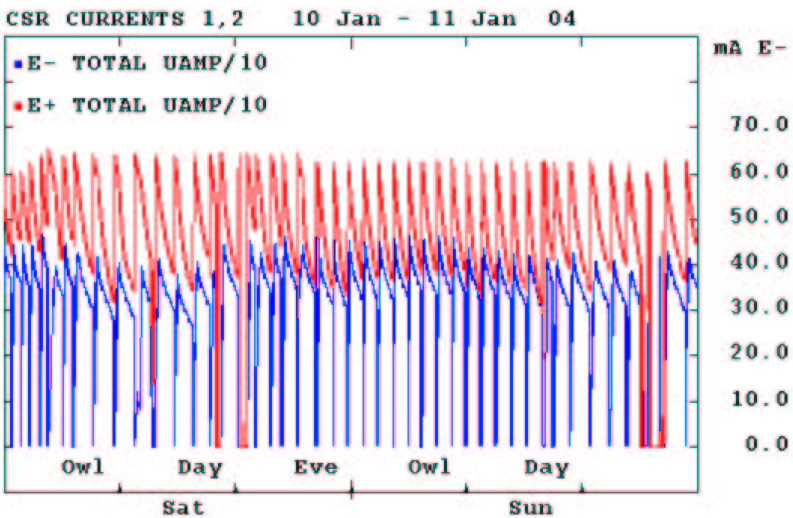
Milestones

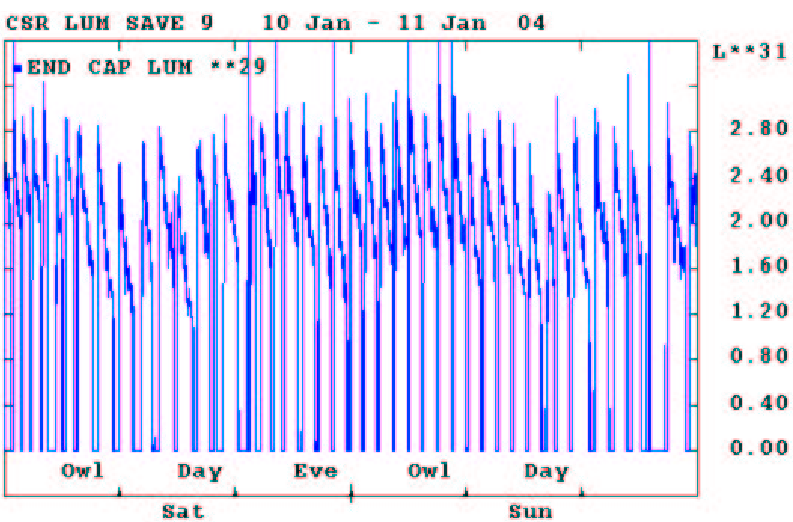
5/2001	Internal lab program review
9/2001	Installed new s.c. focussing magnets in IR
5/2002	NSF site visit and review
8/2002	**First s.c. wiggler installed in ring**
9/2002	Machine studies verify wiggler dynamics
10-12/2002	**Engineering run.** $I_{\mathrm{Tot}} \simeq 90$ mA, $L_{\mathrm{peak}} \simeq 1.0 \times 10^{31}$ cm^{-2}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.** $I_{\mathrm{Tot}} \simeq 110$ mA, $L_{\mathrm{peak}} \simeq 3.0 \times 10^{31}$ cm^{-2}s^{-1}
4-6/2004	**Install final set of 12 wiggler magnets**

CESR-c Progress in Integrated Luminosity



Examples of Currents and Luminosity





Typical Running Parameters

8×4 bunches

1.5 mA/bunch

$Q_H = 10.51 \qquad Q_V = 9.58$

$\epsilon_H = 160$ nm $\qquad \epsilon_V = 8$ nm

$\beta^*_H = 68$ cm $\qquad \beta^*_V = 1.3$ cm

$\sigma^*_H = 330\ \mu \qquad \sigma^*_V = 10\ \mu$

Crossing angle 2.7 mrad

$\sigma_E/E = 8 \times 10^{-4}$

$I_{Tot} = 100$ mA

$L = 2.5 \times 10^{-31} \mathrm{cm}^{-2}\mathrm{s}^{-1}$

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