Summary of 4s run
- Machine configuration
- Luminosity limit

Machine Upgrade
- Positron converter
- Superconducting IR quads
- x-ray beam line

Commissioning

Operation at \( \sim 1.9\text{GeV} \)

Resonance run plan
**Machine Configuration**

- Electrostatically separated orbits
- Nine trains with 5 bunches/train in each beam
- $\pm 2.5\text{mrad}$ crossing angle
- 8mA/bunch
- Bunch spacing within each train - 14ns
**INTERACTION REGION**

- **1.5m REC final focus quadrupole**
  - Solenoid compensation by rotation of IR quads
  - $\beta_v^* = 18\text{mm} \rightarrow 21\text{mm}$
  - $\beta_h^* = 94\text{cm}$
  - $\sigma_l = 18\text{mm}$

- **Parasitic crossing 2.1m from IP** -
  - Largest vertical tune shift of 89. $\Delta Q_v \sim \frac{I_b \beta_v}{x^2}$

![Graph showing beta functions for different elements of the CESR interaction region.](image)
4- single cell - 500MHz superconducting RF cavities

- \( T \): 4.5K
- \( < G > \): 6.2MV/m
- \( \hat{V} \): 7.4MV
- \( I_{total} \): 750mA
- \( P_{beam} \): 1.1 MW
- \( P_{HOM} \): 2.75kW/load
- \( P_{max/cavity} \): 294kW
Total beam current: 750mA
Non HEP time: ~6 minutes/fill
$\beta_v$: 21mm
$\xi_v$: 0.07
Peak luminosity: $1.3 \times 10^{33} cm^{-2} s^{-1}$
$\int L/day$: 73pb$^{-1}$
$\int L/month$: 1500pb$^{-1}$
LUMINOSITY HISTORY


CESR Luminosity (pb⁻¹/Month)


- 3 Bunch Operation
- 7 Bunch Operation
- 1 IR
- 2nd SRF Cavity Installed
- CLEO III Installation
- 9 X 2 IR Bunches
- 9 X 3 Bunches
- 1st SRF Cavity Installed
- Phase II
- Bunch Train Crossing Angle
- 9 X 4 Bunches
- Mini-Beta Operation
- Micro-Beta Operation

D. Rubin for CESR Operations Group
Luminosity Limits

- 9 trains with 4 bunches/train
  - $\xi_v \sim 0.07$
  - Tune shift saturates at 7.5mA/bunch
  - Beam-beam limited - increased bunch current → poor lifetime and deteriorating specific luminosity

- 9 trains with 5 bunches/train
  - $\xi_v \sim 0.065$
  - Tune shift saturates at 7mA/bunch
  - Specific luminosity decreases with increasing current
Parasitic Beam-Beam Interaction

- Uneven spacing $\Rightarrow$ bunch dependent tune and closed orbit
  - Closed orbit $x(s) \sim a \sqrt{\beta_h(s)} \sin(\phi_h(s) - \phi_0)$
  - Long range beam-beam tune shift
    \[ \Delta Q_h \sim \frac{I_b \beta_h}{x^2} = \frac{I_b}{\sin^2(\phi_h(s) - \phi_0)} \]

Bunch dependent electron positron orbit difference at IP for first 3 trains with 7.5mA/bunch. $\sigma_y \sim 4\mu$. →

Bunch dependent tune shift for first 3 trains with 7.5mA/bunch. →
Parasitic beam-beam interaction

- Horizontal tails
  - Minimum separation $\sim 7\sigma_x$
  - Tails of the bunch approach core of counterrotating bunch $\rightarrow$ large vertical tuneshift and particle losses

- Bunch dependent luminosity
  - Bunches at center of train yield 25% higher luminosity than bunches at ends of the train

Separation at parasitic crossing points in units of horizontal rms beam size
PARASITIC BEAM-BEAM INTERACTION

- Compensation of bunch dependent tune and orbit
  - Orbit correction with fast kicker
    - Adjust closed orbit independently for each bunch
    - ~ 1μm capability
    - Mixed result
  - Tune correction with RFQ
    - \( f_{RFQ} = 9 \times f_{ref} \)

- More closely space bunches
  - Reduce bunch spacing to 6ns and 8ns from 14ns
    - Sufficient separation near IP?
    - Simulation indicates tune spread increases more rapidly than total current.
- **Superconducting IR quads**
  - Energy reach

- **Positron Converter**
  - Increased positron production rate

- **x-ray beam line**
SUPERCONDUCTING IR QUADS

**Objectives**
- Extend energy reach
- Reduce $\beta_v^*$ from 18mm to $< 1\text{cm}$ and $\beta_v$ at parasitic crossing nearest IP
- Electromagnetic vs PM quad ⇒ capability for precise correction of final focus optics and solenoid compensation

**Parameters**
- V and H focus quad in each cryostat
- Gradient - 48.4T/m
- Peak field - 6 T
- $I \sim 1225\text{A}$
- Length - 65cm
- All quads rotated $4.5^\circ$ (solenoid compensation)
- Superimposed skew quadrupoles (fine tuning of solenoid compensation)
- Superimposed dipole (orbit correction)
- Support and remote positioning of cryostat by eccentric cam bearings
Superconducting quadrupole status

- Installed in IR - August-September

- Field quality
  - Skew sextupole moment in Q2 cancelled with resistive corrector located adjacent to cryostat
  - Sextupole moment in Q1 introduces tonality (differential tunes) that is corrected with chromaticity sextupoles
Alignment of IR quads is critical

0.5mm vertical displacement of Q01 → 22mm orbit error

Startup optics

- $E_{beam}=5.3$ GeV
- $\beta^* \sim 10$m
- $k_{Q1} = -0.1$ (5% nominal)

- Store beam (10/6) -
  - Low injection efficiency
  - Loss of injected particles near IR ⇒ high CLEO radiation
  - Due to high vertical $\beta$ adjacent to IR low $\beta_h$ at injection point, coupling

- Measure and correct orbit
  - Align IR quads to minimize steerings near IR
  - Zero all correctors
commissioning

- Load low $\beta$ (luminosity optics) at 5.3GeV
  - Measure and correct orbits
  - Measure betatron phase and coupling and begin analysis
  - Calibrate: Measure betatron phase and coupling vs magnet strength
  - $I > 240\text{mA}$

- Load 5.175GeV $\Upsilon_{3s}$ optics 10/15?
• New x-ray beam line
  o x-rays from electron beam accessible in already existing facility
  o x-rays from positron beam accessible in newly constructed facility, through new opening in tunnel wall

• Wiggler parameters

  Number of poles  50
  Period[cm]         12
  Peak magnetic field[T] 0.8
  Gap[cm]            4
  Pole width[cm]     11
### Υ Resonance Run Plan

$\gamma_{3S}, \gamma_{1S}, \gamma_{2S}, 11/01 \to 7/02$

<table>
<thead>
<tr>
<th></th>
<th>$\gamma_{3S}$</th>
<th>$\gamma_{1S}$</th>
<th>$\gamma_{2S}$</th>
<th>Follow up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Energy [GeV]</td>
<td>5.175</td>
<td>4.7</td>
<td>5.</td>
<td>?</td>
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<tr>
<td>Luminosity [pb$^{-1}$/day]</td>
<td>33</td>
<td>23</td>
<td>25</td>
<td>?</td>
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<tr>
<td>Start date</td>
<td>15-Nov-01</td>
<td>1-Feb-02</td>
<td>1-May-02</td>
<td>25-Jun-02</td>
</tr>
<tr>
<td>Total [fb$^{-1}$]</td>
<td>1.2</td>
<td>1.2</td>
<td>0.7</td>
<td>?</td>
</tr>
</tbody>
</table>

- August 2002 - begin transition to 1.9GeV operation with installation of first of 14 1.3m long, 2.1T wigglers
  - Installation of 14 wigglers complete June 2003
**IR**

- 20cm permanent magnet quad 
  \[ k = -5.09m^{-2} \]
- Q1 - \( k = -1.92m^{-2} \)
- Q2 - \( k = 1.32m^{-2} \)
- CLEO solenoid @ 1.0T
- All IR quads rotated 4.5° about axis
- skew quad coils superimposed on Q1 and Q2 permit compensation of coupling over wide range

**Radiation damping**

- \( \frac{1}{\tau} \propto E^3 \rightarrow 1/2 \text{ second} \)
- \( \varepsilon \propto \frac{1}{E^2} \rightarrow (\frac{1.89}{5.3})^2 \varepsilon_{5.3} \sim 25\text{nm} \)
- Lower emittance → reduced long range beam-beam
**MACHINE DEVELOPMENT - ROUND BEAMS**

\[ \xi = \frac{N_{re} \beta}{\gamma 4\pi \sigma^2} = \frac{N_{re}}{\gamma 4\pi \varepsilon} \]  

(1)

\[ \Rightarrow L = \frac{N \gamma f_c \xi}{r_e \beta} \]  

(2)

- Emittance limited by IR aperture

- Possible parameters
  - \( \varepsilon = 100 \text{nm} \)
  - \( \xi = 0.1 \)
  - \( \beta^* = 30 \text{mm} \)
  - \( E = 1.88 \text{GeV} \)

\[ \Rightarrow \]

- \( N = 1.64 \times 10^{11}, \ (I_b = 10.3 \text{mA}) \)
- \( L_b = 2.75 \times 10^{31} \text{cm}^{-2} \text{s}^{-1} \)
- \( N_b = 7, \Rightarrow L = 1.9 \times 10^{32} \text{cm}^{-2} \text{s}^{-1} \) (head on)
Solid line is displacement of closed orbit + 12σ. Vertical emittance is equal to horizontal.
August - September 2002
- Install full size wiggler prototype
- Remove one pair of arc dipoles to make space for wigglers
- Install CLEO vertex detector

October - December 2002
- Beam tests with wiggler
- Explore operation at $J/\psi$
- Run CESR at 5.3GeV for x-ray physics

January-February 2003
- Install 6 additional wigglers
- Complete installation of cryo-distribution

March - April 2003
- Beam tests with wiggler
- Explore operation at $J/\psi$, small energy spread

May - June 2003
- Install 7 remaining wigglers
- **July 2003 - June 2004**
  - $\psi''$ (3.78GeV) - 2.55 fb$^{-1}$: 255days
  - 5.3GeV/beam for x-ray physics: 110days

- **July 2004 - June 2005**
  - $\psi''$ (3.78GeV) - 0.5 fb$^{-1}$: 50days
  - Above $\psi''$ (4.11GeV) - 2 fb$^{-1}$: 205days
  - 5.3GeV/beam for x-ray physics: 110days

- **July 2005 - June 2006**
  - Above $\psi''$ (4.11GeV) - 1 fb$^{-1}$: 100days
  - $J/\psi$ (3.1GeV) - 1 fb$^{-1}$: 155days
  - 5.3GeV/beam for x-ray physics: 110days

- **June 2006 - November 2006**
  - Follow up