Electron Cloud Studies at CESR-c and CesrTA

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• Introduction

• CESR-c ⇐ CesrTA
  – Major focus on electron cloud measurements

• CESR-c Measurements
  – Instrumentation
  – Initial measurements
  – Experimental plans

• CesrTA Plans
  – Proposed ILC R&D program
  – Diagnostic wiggler chamber concept

• Conclusion

• Acknowledgments
Introduction

• Recent EC Measurements at CESR
  – Concerns about large $e^+$ emittance in HEP among other indicators
  – ILC DR interest
  – New instrumentation coming on line (CESR-c and ILC driven)

• Key CESR Parameters
  – Circumference: 768.44 m
  – Revolution frequency: 390.13 kHz
  – RF frequency: 499.76 MHz
  – Harmonic number: 1281
    • $1281/7 = 183$ bunches
  – Spacing between bunches in train: 14 ns

• Multibunch Instrumentation
  – BSM (Beam Size Monitor)
    shuttered, 32 channel linear PMT array looking at synchrotron light
    • one sample per channel per bunch on each turn
    • separate DAQ for each species samples up to 183 bunches
    • optics accommodate linear CCD array and TV camera
  – BPM (Beam Position Monitor)
    • uses four beam buttons, four channels per beam
    • one sample per channel per bunch per species on each turn
    • one DAQ samples up to 183 bunches per species
    • beam pinged for tune measurement
• CESR-c/CLEO-c HEP operations conclude March 31, 2008
• Propose to move CESR-c damping wigglers to zero dispersion regions to study ILC DR physics issues at ultralow emittance
  – 2 GeV baseline lattice with 12 damping wigglers
    • 2.25nm horizontal emittance
    • Goal is vertical emittance in 5-10pm range (in zero current limit)
    • Can presently operate with wigglers in the 1.5-2.5GeV range
    • Reconfigure so that one or more wigglers can operate at 5 GeV
    • Support operation at 4ns bunch spacings (comparable to 3.08ns of ILCDR)
  – Flexible operation with e⁻ and e⁺ beams in same vacuum chamber
    • Detailed comparison of species
    • Study both electron cloud and ion effects
  – Provide 120 days of dedicated operation for damping rings experiments per year (flexible use for collaborators in the ILC DR community)
Beam Size Monitor

BSM synchrotron light optics line for positrons
(optics line for electrons is similar)

Off-axis Parabolic Mirror, diameter 4.5”, f=445mm
Neutral Density Filters
Ground Glass Grid
Eyepiece, f=63mm
Splitter T/R=50/50
Gauss Filter 500 ± 40 nm
Expander Lens f=50 mm
Shutter

Hamamatsu linear PMT array (H7260K) followed by a 72 MHz Digital Signal Processor

Optics Box

Vertical Periscope

32 CHANNEL PMT ARRAY

TV CAMERA

Ground Glass Grid

Neutral Density Filters

Splitter T/R=50/50

Expander Lens f=50 mm

Shutter

CCD

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Optics Box

Vertical Periscope
2 GeV vertical
bunch-by-bunch
beam size for 1x45
pattern, positrons

Advancing onset of
beam instability as a
function of increasing
bunch current
Multibunch Tune Measurements at 5.3 GeV

5.3 GeV vertical tune for 1x45 pattern, positrons 
(2 kHz \( \Delta f \sim 0.005 \Delta Q \))

0.5 mA e+, 45 bunches

1.5 mA e+, 21 bunches 
(trailing bunches fell out)

Bunch #

2 kHz full scale

5.3 GeV vertical tune for 1x45 pattern, electrons 
e- tune change is much smaller than for e+ 
(but there is an effect)

0.5 mA e-, 45 bunches

1.5 mA e-, 45 bunches

Bunch #

Bunch #
Witness Bunch Studies – e\(^+\) Vertical Tune Shift

- Initial train of 15 bunches \(\Rightarrow\) generate EC
- Measure tune shift and beamsize for witness bunches at various spacings

\[
\Delta v = 0.0026
\]
\[
\rho_e \sim 1.5 \times 10^{11} \text{ m}^{-3}
\]
Ohmi, et al, APAC01, p.445

1 kHz \(\Rightarrow\) 1.9 GeV Operation
• Same setup as for positrons

• Negative tune shift and long decay consistent with EC
• Magnitude of tune shift for electron beam is \( \sim \frac{1}{5} \) of shift observed for positron beam
Witness Bunch Studies – e$^+$ Vertical Beamsize

- Rapid growth observed with >15 consecutive bunches
- Witness bunches 17-31 fall in similar size range as in middle of train
- Witness bunch 45 beam size indistinguishable from bunch 1
- $\sigma_v$(bunch 1) $\sim$ 280 $\mu$m
Witness Bunch Studies – $e^-$

- ~6% growth down length of initial train
- Slow recovery for witness bunches to nearly bunch 1 size
- $\sigma_v$ (bunch 1) $\sim$ 170 $\mu$m
Electron Cloud (and Ion) Studies

• Electron Cloud and Ion Studies Continue

• Collaborator Participation
  – Sept. 2006: M. Pivi
  – Jan. 2007:
    K. Harkay (ANL),
    J. Flanagan (KEKB),
    A. Molvik (LLNL)
    R. Holtzapple &
    J. Kern (Alfred)
• Implement 4ns transverse feedback
  – Start looking at ILC-like bunch spacings

• Install L3 Retarding Field Analyzers (RFA) for electron cloud measurements during May `07 down

• Continue electron cloud and ion studies
  – Time for tests in lower emittance configuration?

• Prepare for wiggler vacuum chamber studies
  – Collaboration: SLAC, LBNL
  – Design and construction of new vacuum chambers is a critical path item
  – Segmented RFA for high field operation
Primary ILC EDR Goals

- Electron cloud measurements
  - $e^-$ cloud buildup in wigglers with ILC-like bunch trains
  - $e^-$ cloud mitigation in wigglers
  - Instability thresholds
  - Validate the ILC DR wiggler and vacuum chamber design (critical for the single 6 km positron ring option)

- Ultra-low emittance operations and beam dynamics
  - Study emittance diluting effect of the $e^-$ cloud on the $e^+$ beam
  - Detailed comparisons between electrons and positrons
  - Also look at fast-ion instability issues for electrons
  - Study alignment issues and emittance tuning methods
  - Emittance measurement techniques (including fast bunch-by-bunch X-ray camera)
### Baseline Lattice

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E$</td>
<td>2.0 GeV</td>
</tr>
<tr>
<td>$N_{\text{wiggler}}$</td>
<td>12</td>
</tr>
<tr>
<td>$B_{\text{max}}$</td>
<td>2.1 T</td>
</tr>
<tr>
<td>$\varepsilon_x$</td>
<td>2.25 nm</td>
</tr>
<tr>
<td>$Q_x$</td>
<td>14.59</td>
</tr>
<tr>
<td>$Q_y$</td>
<td>9.63</td>
</tr>
<tr>
<td>$Q_z$</td>
<td>0.098</td>
</tr>
<tr>
<td>$\sigma_{E/E}$</td>
<td>$8.6 \times 10^{-4}$</td>
</tr>
<tr>
<td>$\tau_{x,y}$</td>
<td>47 ms</td>
</tr>
<tr>
<td>$\sigma_z$ (with $V_{RF}=15$ MV)</td>
<td>6.8 mm</td>
</tr>
<tr>
<td>$\alpha_c$</td>
<td>$6.4 \times 10^{-3}$</td>
</tr>
<tr>
<td>$\tau_{\text{Touschek}}$ (with $N_b=2\times10^{10}$ &amp; $\varepsilon_y=5$ pm)</td>
<td>7 minutes</td>
</tr>
</tbody>
</table>

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**CesrTA Baseline Lattice, $E = 2$ GeV**

![Graph of CesrTA Baseline Lattice](image)

- $\beta_x$ (m)
- $\beta_y$ (m)
- $\eta_x$ (m)

- $\varepsilon_y$ (nm) and $\eta_x$ (m) are indicated by arrows.
CESR Modifications

- Move 6 wigglers from the CESR arcs to the North IR (zero dispersion region)
  - New cryogenic transfer line required
  - Zero dispersion regions can be created locally around the wigglers left in the arcs
- Make South IR available for insertion devices and instrumentation
- Instrumentation and feedback upgrades
North IR Modifications:
- Remove vertical separators and install 6 wigglers
- Add cryogenics capability
- Instrumented vacuum chambers for local electron cloud diagnostics
- Eventual test location for prototype ILC damping ring wiggler and vacuum chambers
- Move present streak camera diagnostics area to South IR
Suppressing Electron Cloud in Wigglers

Design & test of impedance is under the way, test in PEPII Dipole & CESR Wiggler

- Strip-line type
- Wire type

Calculation of the impedance
(Cho, Lanfa)

Suetsugu’s talk

Submitted to PRSTAB

L. Wang
ILCDR06

March 2, 2007
ECL2 Workshop - CERN
The multipacting strips of electron cloud in the wigglers is more close to the beam

L. Wang, ILCDR06
• Note that CESR beam trajectory significant relative to stripe spacing at 2GeV

• Diagnostics
  – Must be capable of roughly millimeter transverse resolution
  – Longitudinal segmentation to cleanly sample stripe
CESR-c Wiggler Modifications

- Vacuum chamber tests in CesrTA
  - Remove Cu beam-pipe
  - Replace with beam-pipe having EC suppression and diagnostics
- CU/SLAC/LBNL Collaboration
- Prototype ILC Wiggler and Vacuum Chamber
  - Cornell/LBNL Collaboration

CESR vertical beam stay-clear: 50mm
ILC DR assumes 46mm diameter pipe
• Expect to make several variants to explore
  – Electrodes
  – Grooves
  – Coatings
• Preserve >45mm vertical aperture
• **Thin Retarding Field Analyzer Concept**
  – Strip pickups - copper clad kapton (flex circuit), 0.010” thickness
  – Insulator layers – 0.010” kapton
  – 3 mesh layers
    - 0.002” mesh spot-welded to 0.002” SS
    - ~25% transparency
  – Slots – 33% transparency
Conclusion

• Initial measurements in CESR show evidence for electron cloud effects with both positrons and electrons
  – Work towards detailed comparison of data with simulations is starting
  – Will install first RFAs for direct measurement of cloud in roughly 2 months

• CesrTA
  – Proposal recently submitted to NSF
  – First dedicated run expected in mid-2008
  – Major focus on electron cloud growth and suppression in wigglers and characterization of EC with ultralow emittance beams
  – Input and/or collaboration welcomed!
Acknowledgments

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  - J. Alexander
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  - D. Rice
  - D. Rubin
  - D. Sagan
  - L. Schachter
  - J. Shanks (REU)
  - E. Tanke
  - M. Tigner
  - J. Urban

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  - K. Harkay (ANL)
  - R. Holtzapple (Alfred)
  - A. Molvik (LLNL)
  - M. Pivi (SLAC)