Plans for Utilizing CESR as a Test Accelerator for ILC Damping Rings R&D

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Outline

• ILC Damping Rings R&D Priorities for the Engineering Design Report
• CESR as a Vehicle for Damping Rings R&D
  – CESR Availability
  – CesrTA Concept and Goals
  – CESR $\Rightarrow$ CesrTA Conversion
  – CesrTA Parameters
  – ILC Research at CESR – Ongoing and Planned
• Conclusion
ILC Damping Rings

  - Central damping ring complex
  - Single positron damping ring
    - For an ~6 km ring, electron cloud mitigation is a serious issue

- Engineering Design Phase
  - Engineering Design Report ⇒ 2010
  - Damping Rings R&D required as well as engineering design work

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy</td>
<td>5 GeV</td>
</tr>
<tr>
<td>Circumference</td>
<td>6695 m</td>
</tr>
<tr>
<td>RF frequency</td>
<td>650 MHz</td>
</tr>
<tr>
<td>Harmonic number</td>
<td>14516</td>
</tr>
<tr>
<td>Injected (normalised) positron emittance</td>
<td>0.01 m</td>
</tr>
<tr>
<td>Extracted (normalised) emittance</td>
<td>8 µm × 20 nm</td>
</tr>
<tr>
<td>Extracted energy spread</td>
<td>&lt;0.15%</td>
</tr>
<tr>
<td>Average current</td>
<td>400 mA</td>
</tr>
<tr>
<td>Maximum particles per bunch</td>
<td>2×10^{10}</td>
</tr>
<tr>
<td>Bunch length (rms)</td>
<td>9 mm</td>
</tr>
<tr>
<td>Minimum bunch separation</td>
<td>3.08 ns</td>
</tr>
</tbody>
</table>
ILC Damping Rings R&D Task Force

Very High Priorities

- Lattice design for baseline positron ring
- Lattice design for baseline electron ring
- Demonstrate < 2 pm vertical emittance
- Characterize single bunch impedance-driven instabilities
- Characterize electron cloud build-up
- Develop electron cloud suppression techniques
- Develop modelling tools for electron cloud instabilities
- Determine electron cloud instability thresholds
- Characterize ion effects
- Specify techniques for suppressing ion effects
- Develop a fast high-power pulser
CesrTA Concept and Goals

• CESR
  – Nearly 3 decades of colliding beam physics at Wilson Laboratory will conclude on March 31, 2008
  – It may be possible after the conclusion of HEP to carry out a program of ILC damping rings R&D ⇝ CesrTA

• CesrTA Goals:
  – Support critical damping rings R&D on a timescale compatible with EDR completion in 2010
  – Provide sufficient amounts of dedicated running time to facilitate key damping ring experiments
  – Provide an R&D program complementary to work going on elsewhere (e.g., at KEK-ATF)
Unique Features of CesrTA

• Offers:
  – An operating wiggler-dominated storage ring
  – R&D with the CESR-c damping wigglers
    • Baseline technology choice for the ILC DR
    • High-field, large-aperture wigglers with exceptional field quality
  – Flexible operation with positrons and electrons in the same ring
  – Flexible energy range
    • 1.5 GeV – 5.5 GeV
  – Dedicated experimental runs for ILC R&D starting in 2008
A number of *High* and *Very High* priority R&D items, as specified by the damping rings R&D task force, can be addressed with CesrTA

- **Electron Cloud (EC) for the Positron DR**
  - Study cloud growth in quadrupoles, dipoles, and wigglers
  - Study cloud suppression in quadrupoles, dipoles, and wigglers
  - Study instability thresholds and emittance growth
  - The decision to employ a single positron damping ring has increased the significance of these issues

- **Ion Effects for the Electron DR**
  - Study instability thresholds and emittance growth with ILC-like trains
  - Evaluate suppression methods

- **Ultra Low Emittance Operation**
  - Evaluate:
    - Alignment and survey issues
    - Beam-based alignment techniques
    - Optics correction techniques
    - Ultra low emittance measurement and tuning
  - Demonstrate ultra low emittance operation with positron beams

- **System and Component Testing**
  - For example: ILC prototype wiggler, injection/extraction kickers, etc
Proposed CESR modifications:

- Place all wigglers in zero dispersion regions
  - 6 wigglers must move from the CESR arcs to the L0 interaction straight
  - Remaining 6 wigglers are already located in short straights which can be configured for zero dispersion
- Eliminate the CLEO IR optics
- Modify the vacuum system...
  - For wiggler move
  - For EC growth diagnostics
  - For EC suppression in selected chambers
  - For flexible installation of test devices
- Upgrade instrumentation to...
  - Achieve and measure ultra low emittance beams
  - Characterize dynamics of ILC-like bunch trains
- Upgrade feedback system for 4 ns bunch train operation
Baseline Lattice

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<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>1.9 T</td>
</tr>
<tr>
<td>$\varepsilon_x$ (geometric)</td>
<td>2.3 nm</td>
</tr>
<tr>
<td>$\varepsilon_y$ (geometric) Target</td>
<td>5–10 pm</td>
</tr>
<tr>
<td>$\tau_{x,y}$</td>
<td>56 ms</td>
</tr>
<tr>
<td>$\sigma_E/E$</td>
<td>8.1 x 10^{-4}</td>
</tr>
<tr>
<td>$Q_x$</td>
<td>14.54</td>
</tr>
<tr>
<td>$Q_y$</td>
<td>9.61</td>
</tr>
<tr>
<td>$Q_z$</td>
<td>0.070</td>
</tr>
<tr>
<td>Total RF Voltage</td>
<td>7.6 MV</td>
</tr>
<tr>
<td>$\sigma_z$</td>
<td>8.9 mm</td>
</tr>
<tr>
<td>$\alpha_p$</td>
<td>6.2 x 10^{-3}</td>
</tr>
<tr>
<td>$\tau_{\text{Touschek}}$</td>
<td>&gt;10 minutes</td>
</tr>
<tr>
<td>Bunch Spacing</td>
<td>4 ns</td>
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</table>
Lattice Evaluation

- **Dynamic aperture**
  - 1 damping time
  - Injected beam fully coupled
    - \( \varepsilon_x = 1 \mu m \)
    - \( \varepsilon_y = 500 \text{ nm} \)
- Have explored alignment sensitivity and low emittance correction algorithms for various assumptions \( \Rightarrow \) results consistent with achieving our vertical emittance target of 5–10 pm

<table>
<thead>
<tr>
<th>Element Misalignment</th>
<th>Nominal</th>
<th>Worst Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quad/Bend/Wiggler Offset</td>
<td>150 ( \mu m )</td>
<td>300 ( \mu m )</td>
</tr>
<tr>
<td>Sextupole Offset</td>
<td>300 ( \mu m )</td>
<td>600 ( \mu m )</td>
</tr>
<tr>
<td>Rotation (all elements)</td>
<td>1 mrad</td>
<td>2 mrad</td>
</tr>
<tr>
<td>Quad Focusing</td>
<td>(4 \times 10^{-4})</td>
<td>(4 \times 10^{-4})</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beam Position Monitor Errors</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute (orbit error)</td>
<td>10 ( \mu m )</td>
<td>50 ( \mu m )</td>
</tr>
<tr>
<td>Relative (dispersion error)</td>
<td>2 ( \mu m )</td>
<td>10 ( \mu m )</td>
</tr>
<tr>
<td>Rotation</td>
<td>1 mrad</td>
<td>2 mrad</td>
</tr>
</tbody>
</table>

**Vertical Emittance**

<table>
<thead>
<tr>
<th>Alignment/BPM Errors</th>
<th>Mean</th>
<th>95% C.L.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>2.0 pm</td>
<td>4.7 pm</td>
</tr>
<tr>
<td>Worst Case</td>
<td>6.5 pm</td>
<td>11.3 pm</td>
</tr>
</tbody>
</table>

\( \delta E / E = 0 \)
\( \delta E / E = 0.005 \)
\( \delta E / E = 0.01 \)
IBS Evaluation (2 GeV Lattice)

- Transverse emittance growth for different contributions of coupling and dispersion to the vertical emittance
  - Baseline lattice
  - Compare different corrected optics assumptions
  - ~9 mm bunch length
- IBS effects will be significant
  - Energy flexibility of CESR and $\gamma^4$ IBS dependence offers a flexible way to study, control and understand IBS contributions to emittance relative to other physics under consideration
Ongoing R&D Using CESR

- Multi-bunch turn-by-turn instrumentation has been commissioned in CESR
  - Beam position and vertical beam profile measurements
  - See posters THPAN087 and FRPM047 for beam profile measurement details
- Example: Witness Bunch Studies
  - Initial train of 10 bunches to generate EC
  - Witness bunches placed at varying distances behind train
  - Vertical tune shift for both beams consistent with presence of EC (observed horizontal tune shifts are much smaller in magnitude)
  - Positron tune shift: 1 kHz $\Rightarrow \Delta \nu = 0.0026$
  - $\rho_e \sim 1.5 \times 10^{11} \text{ m}^{-3}$ (model of Ohmi, et al., APAC01, p. 445)
  - Electron tune shift
    - Magnitude of shift along train is $\sim 1/4$th of shift for positron beam
    - NOTE: Shift continues to grow for 1st 4 witness bunches!
Preparation for CesrTA

- Transverse feedback recently upgraded for 4 ns operation
- Work on fast x-ray beam profile monitor
  - Fast GaAs diode arrays (<50 ps rise- and fall-time)
  - Targeting a multi-bunch turn-by-turn detector with ~1 μm resolution
- Preparatory machine studies program
  - Electron cloud and fast ion studies
  - Start exploration of low emittance operations
    - CESR-c (existing machine layout) optics have been designed: $\varepsilon_x \sim 6.5$ nm
    - Early work on beam-based alignment
- First Retarding Field Analyzers (RFA) based on an APS design installed in L3 straight
- Development work for wiggler vacuum chambers
  - Collaboration: LBNL, SLAC
  - EC collector design underway (prototype this summer)
  - Will test various EC mitigation techniques
- General infrastructure preparation
  - Feedback
  - Vacuum
  - Other…
CesrTA Experimental Program

• Schedule:
  – Primary conversion down in mid-2008
  – 2 CesrTA experimental runs scheduled for 2008
  – 2009 onwards:
    • 3 CesrTA experimental runs/yr totaling ~1/3\textsuperscript{rd} of each year
    • 3 High Energy Synchrotron Source (CHESS) runs/yr totaling ~1/3\textsuperscript{rd} of each year
    • Remainder of year scheduled as down and commissioning time for hardware installation and experimental setup
    • Provides flexible scheduling of experiments for collaborators

• Experimental Focus Recap:
  – EC Growth and Mitigation Studies – particularly in the damping wigglers
    • Bunch trains similar to those in the ILC DR
  – Ultra Low Emittance Operation
    • Validation of correction algorithms
    • Measuring, tuning for, and maintaining ultra low emittance
  – Beam Dynamics Studies
    • Detailed inter-species comparisons (distinguish EC, ion and wake field effects)
    • Characterize emittance growth in ultra low emittance beams (EC, ion effects, IBS,…)
    • Demonstrate ultra low emittance operation with a positron beam
  – Test and Demonstrate Key Damping Ring Technologies
    • Wiggler vacuum chambers, optimized ILC wiggler, diagnostics, …
Conclusions & Acknowledgments

- **CesrTA conceptual design work is ongoing**
  - Program offers unique features for critical ILC damping ring R&D
  - Simulations indicate that the emittance reach is suitable for a range of damping ring beam dynamics studies
  - The experimental schedule will allow timely results for ILC damping ring R&D!

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