The CLEO III Detector

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DPF 2000, Columbus
August 9, 2000
Outline

✔ CLEO/CESR quick facts
✔ CLEO III: upgrades & additions
✔ Key components of CLEO III: the new detectors
✔ Conclusions

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CLEO/CESR QUICK FACTS

✓ CLEO operates at CESR, the e⁺e⁻ facility at Cornell
✓ \( E_{\text{cm}} = 10.580 \text{ GeV} = m(\Upsilon(4S)) \)
  - \( I_{\text{beam}} \sim 260 \text{ mA} \)
  - \( L_{\text{max}} \sim 8.5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1} \)
✓ CLEO II and II.V accumulated some 9.6M B pairs, integrating \( \sim 9 \text{ fb}^{-1} \) on the \( \Upsilon(4S) \) and \( \sim 4 \text{ fb}^{-1} \) off.
✓ Broad program of physics in CLEO III continues...
  - \( V_{ub}, V_{cb} \)
  - \( b \rightarrow s\gamma \)
  - Rare B decays
  - Charm physics incl. D mixing, D spectroscopy
  - \( \tau \) physics

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CESR Upgrades

- Superconducting RF cavities replace conventional Cu
- New superconducting interaction region quadrupoles provide better focussing ($\beta^*$ reduced by 25%)
- Increase bunch structure from $9 \times 4$ to $9 \times 6$
- Expect: $I_{\text{per beam}} = \text{up to 500 mA}$
  
  \[ L \approx 1.6 - 2.2 \times 10^{33} \text{ cm}^{-2} \text{s}^{-1} \]
  
  $20 - 30 \text{ fb}^{-1}/\text{year}$
Why a CLEO III detector?

✔ Why not continue on with CESR upgrades alone?
  - For all measurements, running at few $\times 10^{35}$, upgraded DAQ & trigger systems necessary
  - To be competitive for many rare B decay measurements, better particle identification (PID) is essential
  - Overall, to optimize PID capability, excellent tracking necessary
  - Improved tracking & vertex capabilities
CLEO III PRIMARY DESIGN TASKS

- Keep proven parts of CLEO II where possible.
  - Magnet, CsI calorimeter, muon system.
- Provide room for new accelerator components.
  - Redesign drift chamber, integrate silicon into tracking scheme.
- Reduce material in tracking volume (drift chamber gas, structural elements at small radii, drift chamber endplates).
- Improve PID
  - Replace TOF by RICH.
  - Design driven by limited space between calorimeter and tracking volume.
Main new features:
- 4-layer Silicon vertex detector
- Drift chamber
- RICH detector
The CLEO III Detector
The new detectors

- The new detectors, Si3, DR3 and RICH are a package deal
  - Better PID requires RICH; optimal RICH PID requires excellent tracking resolution
  - More efficient DR3 is needed since the RICH takes up ~20 cm of radial space inside the CC
  - The addition of the Si3 allows for such tracking, working in tandem with DR3
    - Si3 measures z & θ; DR3 measures curvature; both obtain b & φ
- The CESR upgrades, specifically the superconducting IR quads, required a novel design for DR3, and placed constraints on Si3

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The CLEO III Detector

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New Detectors: Si3

- Goals: Efficient tracking down to 60 MeV/c - good vertexing for D and τ physics
  - high structural strength w/small amount of material: diamond mounting frame
  - four layers at 2.5, 3.75, 7 and 10.2 cm radius: 447 detectors - 61 "ladders" - 125k channels
  - 50μ strips in r-φ, 100μ strips in z
  - to obtain 15μ resolution in r-φ, and 30μ resolution in z

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New Detectors: Si3

4 layers of double-sided detectors:

<table>
<thead>
<tr>
<th>L</th>
<th>R (mm)</th>
<th>L (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>25</td>
<td>160</td>
</tr>
<tr>
<td>L2</td>
<td>27.5</td>
<td>213</td>
</tr>
<tr>
<td>L3</td>
<td>70</td>
<td>373</td>
</tr>
<tr>
<td>L4</td>
<td>101</td>
<td>533</td>
</tr>
</tbody>
</table>

DC coupled; AC coupling and biasing achieved with an R/C1C.
Noise:
400 (L1) to 900 (L4) e⁻

Resolution:

- r₀: 15 μm
- z: 30 μm

Channels:

- r₀: 62342
- z: 62342

Z ganging:

- L1: 1-2
- L2: 2
- L3: 3-4
- L4: 5

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New Detectors: Si3

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New Detectors: Si3

- Silicon commissioning completed this July
- Performance:
  - CERN beam test: 8µ track residuals
  - approaching this level in situ at CLEO:
    see Jik Lee’s talk for more details concerning current performance
  - excellent S/N: 20-30

σ = 8.4 ± 0.3 µm

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DR3 - Key Criteria

✔ Maintain good CLEO II performance while:
  - Accommodating Superconducting quads (‘weddingcake’) and RICH (outer radius reduced).
  - Extrapolation to RICH better than: \( \sigma_{\phi} \sim 100\mu m, \sigma_z \sim 700\mu m. \)

✔ Achieved by:
  - He-Propane gas instead of Ar-Ethane (also used in CLEO II.V since 1995... reduces multiple scattering while maintaining good dE/dx capability)
  - Reduce material at small radius \( \rightarrow \) load bearing at outer radius.
  - Additionally: reduce material in endplates to improve endcap calorimeter measurement \( \rightarrow \) tapered to accommodate load.

✔ Result: better tracking resolution with smaller detector

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New Detectors: DR3

31 Stereo Layers
(370 - 790 mm,
21-28 mrad)
16 Axial Layers
(132 - 342 mm)

Basic drift cell as in CLEO II:
14 mm square cells
(3:1 field:sense)

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New Detectors: DR3
New Detectors: DR3

✔ DR3 has shown very good momentum and tracking resolution

- Residuals summed over 47 DR anode layers
- Average $\sigma = 100 \mu m$ for core 80%
- Wide $\sigma = 2 \times$ narrow $\sigma$
- Total rms = 123 $\mu m$

After just ~2 months of calibration work... Already better than CLEO II. V

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Side benefits...

Reduction of material in DR3 endplate has exceptional benefits for CC resolution:

Add greatly to our capability in analyses involving neutrals.

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New Detectors: RICH

- Limited space for RICH
  - Proximity focussing (i.e. More compact, no mirrors).
  - Thin MWPC using Triethylamine (TEA) as \( \gamma \) converter
    \( (\lambda_{\text{abs}} \sim 0.5 \text{ mm}) \).
- PID Benchmark: 4\( \sigma \) \( \pi / K \) separation at 2.65 GeV - 2\( \sigma \) obtainable by \( dE/dx \) \rightarrow need 3\( \sigma \) from RICH
- With LIF radiator, \( \Theta_c \) differ by \( \sim 13 \text{ mrad} \) for \( \pi / K \) at 2.65 GeV. \rightarrow need \( \sigma_\gamma = 4 \text{ mrad} \); achievable if \( n_\gamma = 12 \) and \( \sigma_\gamma = 14 \text{ mrad} \).
- Maximize number of detected photons.

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New Detectors: RICH

LiF radiators
N₂ expansion gap
CaF₂ photosensor
entry windows
CH₄/TEA
photosensitive
medium in MWPC
Pad read-out

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New Detectors: RICH

✔ How does it work? Images are conic sections distorted and truncated by refractive effects.

✔ Total internal reflection prohibits plane radiators for perpendicular (< 6°) incidence.

→ sawtooth radiator

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New Detectors: RICH

- Performance
  - recall that our design objectives required ($>3\sigma$) $\pi$-K separation in RICH
  - thus single track $\Theta_c$ resolution required: 4 mr
  - While $\pi$-K separation is still under study, CLEO III RICH detector does show appropriate resolution:

S/N ratio is also VERY good. (e.g. For individual photons, $S/N > 40$)

- $\sigma_\gamma = 14$ mr, single $\gamma$
- $\langle n_\gamma \rangle = 10.2$
- $\sigma_{\text{trk}} = 5.2$ mr

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New Detectors: RICH

✔ Preliminary use of RICH for PID:
  - very effective in identification of D^0's
  - similar improvement in ID of D^* via D^*-D^0 mass difference

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Conclusions

✓ CLEO III had a successful engineering run this spring and began data taking in earnest in July
✓ First results from new detectors indicate excellent performance, for the most part, performing up to or exceeding specifications, so we are optimistic
✓ With improved CESR performance, and the necessary detector upgrades & replacements, we expect ultimately to obtain many competitive results in our program of b, c and τ physics.
✓ Shameless plug: for more details see
  – Jik Lee’s CLEO III Si3 talk (today, 4:00pm) and
  – Gobinda Majumder’s CLEO III RICH talk (Friday, 1:30pm)

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