Outstanding (Si) Detector Issues

...mostly SiD issues, but some generic
...mostly tracking issues

...one message:

*US HEP needs to engage in an integrated, optimized, TDR-level detector design study if it wants its international LC driving license.*

ALCPG Workshop SLAC
January 8, 2004
John Jaros
Goal  **Fill in the details.**

*Produce a TDR-level description of an integrated and coherent LC detector design in 2 years time.*
**Silicon Detector Design Study**

**Starting Point/Assumptions**

- Use Si/W Particle-Flow Calorimetry for ECAL
- Si/W is costly; minimize the cost by limiting tracker radius and length.
- Get back BR$^2$ by raising B to 5T.
- Maintain tracker $\Delta p/p$ with Si microstrips
- Pillbox tracker shortens tracker and minimizes material: no endplate before the ECAL and little material to obscure tracking.
- 5 Layer pixel VXD ensures efficient pattern recognition.
- 5 Layer Barrel tracker measures momentum and confirms trajectories for the calorimetry.
Issue#1: Does Si/W Deliver Desired Jet Energy Resolution?

• *The* detector issue. We need full simulation demonstrations (and confirmations).

• How does performance depend on calorimeter radius, B field, transverse and longitudinal segmentation, and gap spacings?

• How does physics performance vary with jet energy resolution?
**SD Barrel Tracker Concept**

- **Si Ladders.** Build on GLAST development. Daisy-chain detectors to barrel half-lengths.
- **Axial** or Small Angle Stereo
- **Support.** Low mass C-fiber space frame.
SiD Tracking Concept

Starting Point

- Solid Angle coverage to ~100 mr
- $\Delta p/p^2 = 2 \times 10^{-5}$
- 5 Layers of CCD + 5 Layers Si $\mu$strip

Performance

- $\cos\theta = 0$
- SD Thick
- SD Thin
Issue #2: Can SiD Tracker Pattern Recognize?

Heuer’s Sermon to the Choir (LBL TPC Meeting 10/03):

End of the argument? Maybe not…

- Most TPCs don’t work at $r = 0$ (but imaging is impressive).
- Picture omits 5 layer CCD VXD which finds the tracks.
- $7 \mu$m Spatial Resolution sharpens the picture a lot
SiD Tracker Pattern Recognition

Plausibility Argument

- 5 Layer CCD VXD will pattern recognize with high efficiency
  \( \varepsilon \sim 95\% \)
  K. Harder LC-DET-2001-029
  SLD VXD3 self tracking \( \varepsilon \sim 95\% \) (3 layers; Z data)

- CCD VXD projects to barrel layer 1 with 250 \( \mu m \) accuracy.
  It has \( \Delta p/p \sim 1\% \) (!) and \( \Delta \phi/\phi \sim 10^{-4} \), hence small extrapolation errors.
  R. Partridge, SiD Tracking Study

- Pattern Recognition works if we can link VXD hits with barrel hits.
  What could prevent that in barrel 1?
  Physics occupancy 0.3 %   M. Iwasaki hep-ex/0303017
  Beamstrahlung BKG 0.5 %   T. Maruyama talk this workshop
  Detector Noise 0.2%      B. Schumm SiD Tracking Study

- A 3\( \sigma \) search region about an extrapolated VXD track will have a spurious hit 30% of the time. Not bad. Further extrapolation, to barrel 2, has 25 \( \mu m \) accuracy because \( \Delta p/p \sim 0.1\% \) for VXD+Layer 1.
  Spurious hits lead nowhere; track hits lead to more track hits.
How to Prove SiD Tracking Pattern Recognition?

• Develop pattern recognition code for simulated barrel hits, assuming VXD tracks have been found.
  
  Steve Wagner, talk this workshop

• Work toward Full Detector Simulation, including machine related backgrounds, interactions of backgrounds with detector, and realistic detector response and noise.

• Confirm VXD pattern recognition capability.
Issue #3: How bad are real machine backgrounds? How robust must tracking be?

Present background rates are LOWER LIMITS. These backgrounds are the inevitable consequence of high luminosity collisions.

At SLC, essentially all backgrounds (which were appreciable) were from sources other than beam-beam effects, especially synchrotron radiation from beam tails passing through the final quads.

We need estimates of the background levels which will arise from extra beam halo or imperfect collimation to study the robustness of pattern recognition.

We need to know what sort of high radiation dose beam accidents could occur to understand if detectors can tolerate them.

Pattern recognition in the presence of noise and Detector Lifetime are the issues.
Issue #4: What are the backgrounds from $\gamma\gamma$ processes?

See talk by Tim Barklow in the next session:

8600 e+e- pairs hit det/ NLC train

56 Hadronic Events/NLC Train
Issue #5: How to design SiD forward tracking to survive $\gamma\gamma$ background?

SiD Forward Tracking Concept

- **Extend barrel tracking philosophy forward**
  1. Pattern Recognize in 5 Layers of CCD
  2. Extrapolate tracks to forward disks for momentum measurement and reliable extrapolation to the calorimetry.
  3. Global Pattern Recognition to follow

- **Design Considerations**
  1. Extend 5 layer tracking over max $\Omega$
  2. Minimize CCD area/cost
  3. Thin the CCD barrel endplate
  4. Maximize vertexing $\Omega$
• Ω Coverage
  5 CCD layers   .97   (vs .90 TDR VXD)
  4 CCD layers   .98   (vs .93 TDR VXD)
• Shorten Barrel CCDs to 12.5 cm. Thin endplate.
• Multiple CCDs on a single 300 μm Si disk?
SD Inner Tracker Performance

Courtesy B. Schumm and LCDTRK

R-Z Impact Parameter Resolution (µm)

<table>
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<th>New SD</th>
<th>Old SD</th>
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<td>-log10(1-cosθ)</td>
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</tbody>
</table>

90  60  41.5  29  20.5  14.5  10.2  degrees
Forward Tracking Studies

Tesla FTD stand-alone tracking studies show $\varepsilon \sim 90\%$ and moderate fake rate using crossed Si microstrips. H. Bauke

SiD Occupancy Studies with pairs and photons show manageable occupancies. T. Maruyama (this workshop)

- R = 20 cm
- 25K strips

- R = 4 cm
- 5K strips

% Occ vs Fwd Layer

![Graph showing occupancy vs forward layer with two plots for strip alignment 1 and 2, one with weighted and the other without weight.](image-url)
Forward Tracking Studies (cont.)

Forward VXD Occupancy
T. Abe SiD Study

Forward Hit Occupancies are high (VXD ~.0001; EC1 ~.03) and due to pairs.

Forward Layer 1 e+/e- hits
T. Maruyama SiD Study
Issue #6: Are SiD Tracking Deficiencies Significant?

• Can $K^0$s and $\Lambda$ s be tracked?
  Does it matter for P-Flow Calorimetry?
  Find track stubs in ECAL?
• Can exotic, heavy, long-lived particles
  (which decay outside VXD) be tracked?
  Find track stubs in ECAL?
  Point back photons from ECAL?
• SiD has no dE/dx PID.
  Any physics lost?
Issue #7: Are SiD Tracking Strengths Significant?

• Superb Momentum Resolution
  Help with clean Higgs tag?

• Excellent Track Pair Resolution?
  Boost tracking efficiency in Jet Core?

• Little Mat’l in Endcaps (at least conceptually!)
  Reduce degradation of forward calorimetry?

• Stable Geometry and calibration
  No time-dependent constants?

• Robust against misbehavior of machine?
Issue#8: Can realistic SiD Tracking Designs remain thin?

Will long, daisy-chained microstrips work as needed?
Can mechanical support be stable and thin?
How to distribute power, route readout, etc.?

Issue#9: Barrel Momenter or Barrel Tracker?

Just axial layers? Or axial and stereo?
More Barrel layers?
Si Drift for Barrel?
Conclusions

• There are many outstanding Si Detector Issues needing investigation.
  
  Some are generic: Si/W; background evaluations
  Some are SiD specific: robustness of pat rec

• It’s time to address them.

• We need help with the SiD Design Study