Thin Ladders R&D

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LCFI (Linear Collider Flavour Identification) Group, UK:

- Bristol, Lancaster, Liverpool, Oxford, Queen Mary, RAL

LCFI Activities:

- Mechanical support of thin ladders
- Physics studies for detector geometry
- CPCCDs and Electronics (Nicolo’s talk)

This talk

ALCPG Workshop
SLAC
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VXD Conceptual Design and Goals for Future LC

- 5 layers of CCDs at radii 15, 26, 37, 48 and 60 mm;
- Outer layer CCDs 125x22 mm²; 6250x1100 pixels (each 20x20 mm²);
- 120 CCDs, ~8x10⁸ pixels in total;
- Thin detector, target thickness < 0.1% X₀ / layer;
- Close to the interaction point;

- High Precision, low mass support mechanics. Minimum external connections;
- Encased in light foam cryostat. Low power, gas cooled. Support fragile beam-pipe;
- Readout time: ≈ 8 ms for NLC/GLC (read between trains);
- 50 ?s for TESLA inner layer (read ≈20 times during the train);

→ Large area, high speed CCDs
Standard CCD

20 µm sensitive region
300 µm Si substrate (support)

Thin detectors

20 µm sensitive region
40 µm Si substrate

Stabilise with tension

Potentially most thin option, but...
operating at low temp,
differential thermal contraction an issue
(even if only Si, because the CCD part is different and 50 MHz may require 1µm Al on top)

FEA (Finite Element Analysis)—,
maximum deflection 0.8 mm
transverse bowing effects
Consider tensioned Be substrate

- Layer thickness $\approx 0.09\% X_0$
- Silicone adhesive: (e.g. NuSil), excellent low temperature properties
- Beryllium thermal contraction greater than for silicon
- Finite Element Analysis:
  - 60 ?m Si: distortion only few ?m
  - 20 ?m Si: distortion significant
20\textmu m silicon cooled from 20°C to -60°C (quarter of ladder shown)
What about real silicon?

- XY stage for 2-dimensional laser profiling assembled
- Resolution 1 μm
- Models made from steel + unprocessed Si have been studied
CMM metrology system surveying a test ladder at RAL
30 µm silicon after cool down to -10°C
Could also replace beryllium by some foam material – whatever gives best stiffness for least radiation length, regardless of thermal expansion properties.
Need for Low Momentum Tracking

- Track resolution in rz and r?
  \[ \sigma \approx \frac{4}{\rho \sin^{3/2} \theta} \]

- All B decay tracks required to get best b/c separation and correct B or D hadron charge (useful in reducing M_{bb} jet-jet combinatorial background)

- Requires study with realistic multiple scattering and track fitting to hits
  (current studies based on JAS3 framework)
Jet flavour tagging with VXD

based on SLD b and c-tagging with secondary vertex reconstruction

events are simulated in an LC detector and analysed with JAS3 (Java Analysis Studio)

plot shows ‘$P_T$ corrected mass’ of reconstructed vertices in event jets

$M_P$ b-jets

$M_P$ c-jets

GeV/$c^2$
b-tag efficiency in multijet LC event environment

- studied b-tag efficiency dependence on angle between jets
- found tag dependence on jet energy is more significant
- Jet-jet angle and jet energy strongly correlated for Zh events

\[ e^+e^- \rightarrow Zh \]
\[ e^+e^- \rightarrow Zhh \]
R&D for precision mechanical support of thinned CCDs at LCFI

Options that have been considered:

- Unsupported CCDs – thinned to ≈ 50 µm and held under tension.
- Semi-supported CCDs – thinned to ≈ 20 µm and attached to thin (and not rigid) support, held under tension.
  
  Good qualitative agreement between real laser survey and FEA analysis.
- Fully-supported CCDs – thinned to ≈ 20 µm and bonded to 3D rigid substrate (e.g. silicon carbide foam with good thermal match to Si).
- Nanotechnology in place of glue blobs.

Physics studies:

- Which potential processes in high energy e+e- interactions require excellent impact parameter resolution or low momentum tracking? (e.g. Zhh events with 4 b-jets to be tagged).
- How does the performance depend on the detector layer thickness and beam-pipe radius?

More information is available from the LCFI’s web page: http://hepwww.rl.ac.uk/lcfi