Vertex Detectors for the Linear Collider

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LCWS 2000
Fermilab
October 28, 2000

Physics Opportunities of the Linear Collider

- Premier physics goals of linear collider characterized by heavy-quark decays and small cross sections
  - eg.

    Higgs branching ratios

    $t\bar{t}$ (usually 6 jets, 2 b)

    $t\bar{t}h$ (usually 8 jets, 4 b jets)

    AH (12 jets with 4 b jets)

    and other reactions

Requirements of the Vertex Detector

- Highly efficient and pure b and c tagging, including tertiary vertices ($b \rightarrow c$)
- Charge tagging (eg. $b/\bar{b}$ discrimination)
- These goals are achieved by optimized impact parameter performance:
  - point resolution < 4 μm
  - detector thickness < 0.2% X_0
  - inner radius < 2 - 3 cm
  - good central tracker linking
- Also must take care with timing and radiation hardness

SLD has demonstrated the power of a PIXEL detector in the LC environment

- 307,000,000 pixels
- 3.8 μm point resolution
- pure and efficient flavor tagging at the Z-pole
  - ~ 60% b eff with 98% purity
  - > 20% c eff with ~ 60% purity

- We need a pixel solution
  - decision on option can wait
  - optimize options based on active R&D program

Options under development

- CCDs
  - system level demonstration with SLD (307,000,000 pixels)
  - R&D to advance performance
- Hybrid Active Pixels (HAPDs)
  - fast, rad-hard
- Monolithic APDs
  - fast, rad-hard

We need to pursue all of these options vigorously to ensure the best possible vertex detection at the LC

Session D3

- CCDs
  - C. Damerell (system development)
  - K. Stefanov (mech./ rad-hard devel.)
- Hybrid APDs
  - M. Caccia (prototype, charge sharing)
  - G. Alimonti (“3-D” detectors, bmp bnd)
- Monolithic APDs
  - G. Deptuch (prototype, beam test)
- Performance studies
  - T. Abe (heavy jet tagging)
  - J. Brau (Higgs BRs)
  - S. Xella (flavor tagging)
  - B. Schumm (aggressive scenarios)
  - M. Battaglia (3 Tev - CLIC)
  - A. Miyamoto (flavor tagging)

Charge Coupled Devices (CCDs)

- Chris Damerell
  - system development
    - build on SLD experience with years of operation with 307,000,000 pixels
  - 5 barrel, 799,000,000 pixels with beampipe radius of 14 mm and 3 hit coverage to cos θ = 0.96
  - thinning ladders to 0.06% X_0
  - Readout architecture
    - column-parallel readout for TESLA

- Konstantine Stefanov
  - investigating near T_{room} use
  - mechanical design studies
  - rad-hard devel. to reduce CTI
    - improves 60-100 times
    - "will survive 10 years"

Hybrid APDs (Active Pixel Devices)

- Massimo Caccia
  - readout pitch > pixel pitch
  - prototype tested
  - charge sharing efficiency demonstrated
  - next step ⇒ beam test of improved device

- Gianluca Alimonti
  - first “3-D” detectors fabricated
    - leakage currents 1/4-1 nA/mm^3 (T_{room})
    - low depletion voltage
    - active edges
  - Rad-hard XTEST2
  - bump bond yields good
  - next year ⇒ prototype system

Monolithic APDs (CMOS)

- G. Deptuch
  - prototype tested with beam
    - 64 x 64 pixel arrays
  - next year ⇒ increase size
    - ~ 10 cm
  - outstanding potential
    - rad-hard
    - high precision
    - ultra thin
    - low cost
  - issues to address
    - expand to system
    - power

Performance studies

- Bruce Schumm
  - aggressive scenarios (just to see)
    - improved resolution ($\Rightarrow$ 1 μm)
    - smaller beampipe ($\Rightarrow$ 0.5 cm)
    - greater radial extent ($\Rightarrow$ 11 cm)
    - thinner layers (and pipe) ($\Rightarrow$ 0.06% X_0)
  - conclusions:
    - good central tracking vital
    - spatial resolution and beampipe radius lead to substantial improvements
- Akiya Miyamoto
  - flavor tagging
  - conclusion:
    - significant improvement with inner radius of 1.2 cm vs. 2.4 cm

Performance studies

(continued)

- Toshi Abe
  - heavy jet tagging
  - ZVTOP installed into LCD simulation
- Stefania Xella
  - flavor tagging with neural net including ZVTOP
  - update for new TESLA geometry
  - future ⇒ ZVTOP3, vertex charge, dipole charge
- Jim Brau
  - detector parameters and Higgs BRs

Performance studies

(continued)

- Marco Battaglia
  - 3 Tev - CLIC
  - extreme energies lead to some very long decay lengths (several cm)
  - proposes counting tracks with pulse height information
  - demonstrates viability with simulation of $\sigma(e^+ e^- \rightarrow b \bar{b})$ determination

Summary of LCWS2000

- Progress continues to advance on many fronts
  - CCDs
    - R&D to advance the already demonstrated exceptional system-level performance
  - Hybrid APDs
    - prototypes with charge sharing understood
    - "3-D" detectors fabricated
  - Monolithic APDs
    - effort to capitalize on industry standards
    - first chip shows extraordinary promise
  - Performance simulations
    - tradeoffs becoming clearer

Future Directions

- Continue progress on all fronts
  - CCDs
  - Hybrid APDs
  - Monolithic APDs
- Performance simulations
  - Refine our understanding of the impact of detector trade-offs on physics performance
- We will be able to exploit the exceptional physics opportunities of the LC