Detector R&D Issues

Jim Brau
Boulder, CO
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Our goal is to be prepared to submit a detailed technical proposal for an experiment in a few years (when the accelerator proposal is ready.)

- What do we need to develop or demonstrate?
  - subsystem by subsystem
    - some of the R&D will be more advanced than others.
- How do some detector choices constrain other aspects of the detector choices?
- How do we integrate subsystem issues into full detector constraints?
**Desirable Detector Features**
(Keith has discussed this in more detail on Thursday)

**NLC Detector will benefit from good:**

- Hermeticity
- Charged track momentum resolution
- Charged track impact parameter resolution
- Electromagnetic & hadronic calorimeter energy resolution
- Granularity (calorimeter segmentation, 2-track separation)
- Electron/muon identification

**Special needs of the NLC Detector:**

- Very high B field to curl up beam-induced pairs
- Accurate differential luminosity measurement
- Subdetectors that correctly handle 90 bunches/train at 2.8 ns separation

**Special constraint:**

- Final focus quad (2 meters from I.P.) that must be anchored to bedrock
Reminder (again) of the NLC Beam Parameters

\[ E_{\text{cm}} = 0.5 \text{ Tev} \quad (L \approx 5 \times 10^{33}) \]
\[ E_{\text{cm}} = 1 - 1.5 \text{ Tev} \quad (L \geq 10^{34}) \]

90 bunches per train (bunch spacing 2.8 nsec)
120 - 180 trains/second

\[ P(\text{e}^-) \geq 80\% \]

**Backgrounds:**
- muons - < 1 \mu / train
- synchrotron rad. - collimation controlled
- \( e^+e^- \) pairs - potential problem \( \rightarrow \) large B field
- mini-jets (\( \gamma \gamma \rightarrow \) hadrons) few jets per train @ 1 TeV
  \( \Rightarrow \) timing to 1 nsec useful

**Beam spot size:**
- tiny
  \[ \sigma_{xy} \sim 4 \mu m \]
  \[ \sigma_{z} \sim 10 \mu m \]
Detector Goals

Need to measure:

- Missing Energy
- Jet-Jet reconstruction
- Lepton ID
- $b$, $c$, $\tau$ vertices

To do this:

- Highest possible level of hermeticity
  $\Rightarrow$ good forward coverage
- Excellent jet energy resolution
  $\Rightarrow$ finely segmented calorimeter
  $\Rightarrow$ tracking with good resolution and track separation
- Heavy flavor tagging (pure and efficient)
- Electron/pion separation (segmentation-trans & long.)
- Muon detection and measurement
Caveats for this presentation:

Best technological choices are coupled:

overall configuration choice

cheaper (read smaller or compact) is better

unless it doesn't do the physics

so A big question is:

Can Compact Detector Perform As Needed?

References:

Zeroeth-order Design Report for the NLC, SLAC Report 474
Physics and Technology of the NLC, SLAC Report 485
Snowmass 96, New Directions for HEP, DPF/DPB of APS
JLC Physics (www-jlc.kek.jp)
DESY 1997-048, Concept Design Report for a 500 GEV e⁺e⁻ LC.....
2nd Joint ECFA/DESY Study, Orsay (April, 1998), www.desy.de
Outline of Talk

Example of an R&D Program on one subdetector
  CCD Vertex Detector Development:
    current state-of-the-art
    desirable improvements
    plan for R&D to achieve improvements

Some comments on the R&D issues on other subsystems
  tracking
  particle id?
  calorimetry
    electromagnetic
    hadronic
  muon detection
  trigger/DAQ
  luminosity measurement
  polarization measurement
  simulation
  backgrounds

Conclusions
Three Detector Configurations Have Been Studied

**JLC Detector**

- diameter = 16 m
- CCD vertex detector
- Central Drift Chamber
- Lead/plastic Calorimeter -> EM resolution = 15%/$\sqrt{E}$ $\pm$ 1%

**ECFA Detector**

- diameter = 17 meters
- $B = 3$ Tesla (to contain $e^+e^-$ pairs)
  - $\Rightarrow$ coil inner radius = 3 meters
  - $\Rightarrow$ detector radius = 6 meters
- CCD or APS Vertex Detector
- TPC Tracker
- Shashlik Calorimeter (lead/fiber EM)

**Snowmass/NLC Detector**

- diameter = 6 meters
- CCD Vertex Detector
- silicon strip tracking
- Finely segmented EM calorimeter (silicon pads/W)

**NOTE** all three of these are conventional $e^+e^-$ detectors:
Solenoidal field with standard layout of subdetectors covering nearly 4$\pi$
Example of an R&D Program on one subdetector:

**CCD Vertex Detector Development**

Physics of NLC demands the best possible vertex detector performance

⇒ clean separation of b, c, and udsg jets, and τs

**Vertexing provides:**

* background suppression
* combinatorial reduction within events
* measurement of key branching rations

H → bb
H → cc
H → light quarks and gluons

**Optimizing flavor tag:**

⇒ track resolution

* determined by technology:
  CCDs, active pixels, ??

⇒ outer radius

* constrained by outer detector
  compact, conventional, ??

⇒ inner radius

* limited by NLC parameters and detector field
  ⇒ beam backgrounds
  ⇒ B-field to constrain

⇒ radiation immunity
* improve CCDs, or pixels

**CCDs current state-of-the-art**

- SLD with 307,000,000 pixels
- MHz readout of CCD (5 MHz operational)
- < 5 \( \mu \)m point resolution
- exceptional efficiency and purity

**Improvements are needed for NLC**

**Plan for R&D to achieve improvements has been initiated**
R&D Goals on Vertex Detector:

1. Develop Technology (or Technologies):
   - CCDs (and APS active pixel sensors?)
2. Demonstrate technical suitability and select
3. Provide 1 cm beampipe

Imagine 3 pronged approach to R&D:

- physics studies and simulations
- vertex detector design
- vertex detector R&D

Expect this work to be carried out in an international collaboration
(much of this discussion is borrowed from European collaboration - C. Damerell et al)
Vertex Detector Design (CCD based parameters)

- Maximum Precision ( < 5 μm)
- Minimal Layer Thickness
  - (1.2% $X_0 \rightarrow 0.4% \ X_0 \rightarrow 0.12% \ X_0$)
- Minimal Layer 1 Radius (28 → 12 mm)
- Polar Angle Coverage (cos $\theta \sim 0.9$)
- Standalone Track Finding (perfect linking)
- Layer 1 Readout Between Bunch Trains (4.6 msec)
- Deadtimeless Readout (high trigger rate)

Vertex Detector - CCD Detector R&D

- increase readout speed to 50 MHz
- develop thinner ladder (0.12% $X_0$)
- improve radiation hardness (supplementary channels)
Vertex Detector - Physics Studies and Simulations

- Apply heavy quark tag performance to physics channels
- Investigate stand-alone track finding
  background tolerance
  layer 1 issues
- Develop detailed CCD signal simulation
  how can the point resolution be improved even
  further?
- Create detailed GEANT model of vertex detector and
  investigate impact of material on overall NLC
  detector performance
- Continue studies of the issues impacting systems outside
  the vertex detector (machine backgrounds, solenoidal
  field, etc.)
Plan for International LC Vertex Detector R&D

LC Vertex Detector R&D should be conducted in a "border-less" collaboration

Japan + US + Europe + others?

Share ideas, software, hardware, problems and solutions

⇒ PLAN this effort to maximize yield of R&D and physics capabilities
Rundown on other subdetectors
and "incomplete" list of R&D issues

**tracking**
Is outer tracking one technology or more?
What technology is it?
straw tubes (inner?)
scin fibers (inner?)
silicon strips ← Snowmass/NLC
TPC ← ECFA
Drift ← JLC

Note: each of these layouts has
\[ \sigma(1/p_T) \sim 10^{-4} \text{ GeV}^{-1} \text{ at high } p_T, \]
How important is low \( p_T \) resolution

GEM
MSGC
Occupancy
Forward Tracking

**particle id?**
Is there any?
If so, what?
Presampler?
calorimetry

Goals:
- electron and gamma measurements
- jet measurements
- missing energy measurement

Strategy for jet measurement
- energy flow analysis
  - tracking + $E_{\text{EM}}$ ($E_{\text{HAD}}$ correction)
  - $\rightarrow$ "Aleph"

- $E_{\text{EM}} + E_{\text{HAD}}$ (tracking correction)
  - $\rightarrow$ "Zeus/H1"
calorimetry (cont.)

key issues:
  energy resolution
  granularity
  longitudinal segmentation

requirements
  granularity
  resolution
    high energy
    $H \rightarrow \gamma \gamma$
  tolerance to high magnetic field
  cost containment

electromagnetic technologies
  silicon-tungsten
  Pb-scintillator
  crystals

hadronic

A BIG issue for calorimeter group
  there are many options with different advantages
  need to define relative importance of parameters
Muon detection
volume (cost) driven by inner detector choices

Trigger and DAQ
flexibility

Luminosity measurement
Could be difficult to fit in

Polarization measurement
Compton, presumably
Detector location for background immunity
Chromatic effects

Backgrounds

Simulation

General issue for all systems: Timing
does an individual subdetector try to
keep track of signal times well enough
to make its own bunch assignment or
does it rely on global pattern recognition
to sort things out later?
Conclusion

There are many issues that need to be resolved in order confidently propose an experiment for NLC.

Now is the time to get on with planning and executing the detector R&D

Next we need to develop detailed plans covering all subsystems and issues.