Detector R& D Issues

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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 quads (2 meters from I.P.) that must be anchored to bedrock

Reminder (again) of the NLC Beam Parameters

E_{cm} = 0.5 Tev   ($L \approx 5\times10^{33}$)
E_{cm} = 1 - 1.5 Tev   ($L \geq 10^{34}$)

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

$P(e^-) \geq 80\%$

Backgrounds:

- muons - < 1 μ / train
- synchrotron rad. - collimation controlled
- e^+e^- pairs - potential problem -> 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, τ 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 = $15\%/\sqrt{E} \oplus 1\%$

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 4π

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

$H \rightarrow bb$

$H \rightarrow cc$

$H \rightarrow$ 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 μm 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 ($28 \rightarrow 12$ 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

$\Rightarrow$ 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
    - $\sigma(1/p_T) \sim 10^{-4}$ GeV^{-1} 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_{EM} (E_{HAD} correction)
→ "Aleph"

E_{EM} + E_{HAD} (tracking correction)
→ "Zeus/H1"

calorimetry (cont.)

key issues:
- energy resolution
- granularity
- longitudinal segmentation

requirements
- granularity
- resolution
  - high energy
  - H → gamma gamma
- tolerance to high magnetic field
- cost containment

electromagnetic technologies
- silicon-tungston
- 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

flexibilty

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.