SiD-- a compact detector for ILC

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for SiD detector concept
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Overview/Contents

Physics requirements ➔ detector requirements

Detectors being considered for LC

Concepts underlying SiD

The SiD Detector

Who is SiD?

Why do this now?

Current activities/Summary
What should ILC detector be able to do?

Identify ALL of the constituents that we know & can be produced in ILC collisions & precisely measure them.

( reconstruct the complete final state)

\(u, d, s\) jets; no ID
\(c, b\) jets with ID
\(t\) final states; jets + W's
\(\nu's\): missing energy; no ID
\(e, \mu\): yes
\(\tau\) through decays
\(\gamma\) ID & measure
\textit{gluon} jets, no ID
\textit{W, Z} leptonic & hadronic

Use this to measure/identify the NEW physics
Main Detector Design Criteria

Requirement for ILC

- Impact parameter resolution
  \[ \sigma_{r\phi} \approx \sigma_{rz} \approx 5 \oplus 10 / (p \sin^{3/2} \vartheta) \]
- Momentum resolution
  \[ \sigma \left( \frac{1}{p_T} \right) \approx 5 \times 10^{-5} \text{ (GeV}^{-1}) \]
- Jet energy resolution goal
  \[ \frac{\sigma_E}{E} = 30\% \] \[ \frac{\sigma_E}{E} = 3 - 4\% \]
- Detector implications:
  - Calorimeter granularity
  - Pixel size
  - Material budget, central
  - Material budget, forward

Compared to best performance to date

- Need factor 3 better than SLD
  \[ \sigma_{r\phi} = 7.7 \oplus 33 / (p \sin^{3/2} \vartheta) \]
- Need factor 10 (3) better than LEP (CMS)
  \[ \sigma \left( \frac{1}{p_T} \right) \approx 6 \times 10^{-4} \text{ (GeV}^{-1}) \]
- Need factor 2 better than ZEUS
  \[ \frac{\sigma_E}{E} = 60\% \]
- Detector implications:
  - Need factor \sim 200 better than LHC
  - Need factor \sim 20 smaller than LHC
  - Need factor \sim 10 less than LHC
  - Need factor \sim > 100 less than LHC

Observation: Need substantial improvement in precision
LC Physics calls for Jet Energy Resolution \( \Delta E/E = 3-4\% \) (factor of 2X better than today’s state of the art to resolve W’s/Z’s)

Particle Flow Algorithms (PFAs) promise the needed gain in jet energy resolution

**PFA Calorimetry**
- Measure charged energy in tracker
- Measure photon energy using electromagnetic calorimeter
- Measure neutral hadron energy in hadronic calorimeter
- Avoid confusion from charged tracks

Measure the energy of every particle, not the energy deposited in calorimeter
Detector concepts being considered

OD ~ 14.4m, L ~ 15m
- VTX + SI + TPC + CAL + SC Mag (3~4T) + Muon
- PFA

OD ~ 12 m, L ~ 12 m
- VTX + Si-based tracker + Si/W ECAL + HCAL + SC Mag (~5T) + Muon
- Active use of Si technology
- PFA

OD ~ 12.8 m, L ~ 15.4 m
- VTX + Cluster-counting tracker (low-mass) + CAL with dual-readout + Iron-free dual-solenoid (~1.6T/3T) + CluCou muon tracker.
- Non PFA
SiD Design Concept (starting point)

- “Jet Energy measurement = PFA” is the starting point in the SiD design
- Premises at the basis of concept:
  - Particle flow calorimetry will deliver the best possible performance
  - Si/W is the best approach for the ECAL and digital calorimetry for HCAL
  - Limit calorimeter radius to constrain the costs
  - Boost B-field (5T) to maintain BR²
  - Use Si tracking system for best momentum resolution and lowest mass (5 layers)
  - Use pixel Vertex detector for best pattern recognition (5 layers)
  - Keep track of costs
- Detector is a single fully integrated system, not just a collection of different subdetectors

Compact: 12m x 12m x 12 m

Robust in ILC operations (beam losses)
SiD Detector Overview

SiD Starting Point
Details & Dimensions

Flux return/ muon
\( R_{in} = 333 \, \text{cm} \)
\( R_{out} = 645 \, \text{cm} \)

Solenoid: 5 T; \( R_{in} = 250 \, \text{cm} \)

HCAL Fe: 34 layers; \( R_{in} = 138 \, \text{cm} \)

EMCAL Si/ W: 30 layers \( R_{in} = 125 \, \text{cm} \)

Si tracking: 5 layers; \( R_{in} = 18 \, \text{cm} \)

Vertex detector:
5 barrels, 4 disks; \( R_{in} = 1.4 \, \text{cm} \)
Calorimetry: ECAL & HCAL
PFAs call for new types of calorimeters and readout...

Si/W ECAL

Highly Segmented HCAL

Transverse Segmentation (3.6mm)
20 + 10 Longitudinal Samples
Energy Resolution \( \sim 17\% / E^{1/2} \)

13 mm\(^2\) pixels
Readout 1k pixels per Si sensor (KPiX)

Example of R&D
Machine-Detector Interface

The first step is to translate the parameters in an engineering model, formulating technical solutions, clearances and components integration.
Who is the SiD?

List of current institutions, signed EOI

Laboratories and Institutes:
- Argonne National Laboratory
- Brookhaven National Laboratory
- Fermi National Accelerator Laboratory
- Institute of Physics, Prague
- Irfu, CEA/Saclay
- LAPP, CNRS/IN2P3 Université de Savoie
- LPNHE, CNRS/IN2P3 Universités Paris VI et Paris VII
- Lawrence Livermore National Laboratory
- Max Planck Institute, Munich
- Physical Sciences Laboratory, Wisconsin
- Rutherford Appleton Laboratory
- Stanford Linear Accelerator Center

Universities:
- U. of Bonn
- U. of Bristol
- Brown U.
- U. of California, Davis
- U. of California, Santa Cruz
- Charles U., Prague
- U. of Chicago
- Chonbuk National U.
- U. of Colorado, Boulder
- Colorado State U.
- Imperial College, London
- Indiana U.
- U. of Iowa
- Kansas State U.
- Kyungpook National U.
- U. of Melbourne
- U. of Michigan
- Massachusetts Institute of Technology
- U. of Mississippi
- U. of New Mexico
- Northern Illinois U.
- U. of Notre Dame
- U. of Oregon
- Oxford U.
- U. of Pierre and Marie Curie LPNHE
- Princeton U.
- Purdue U.
- U. of Rochester
- Seoul National U.
- State U. of New York, Stony Brook
- Sungkyunkwan U.
- U. of Texas, Arlington
- U. of Tokyo
- U. of Washington
- Wayne State U.
- U. of Wisconsin
- Yale U.
- Yonsei U.

Participating or will participate in developing SiD concept
Who is SiD?

SiD organization chart

SiD DESIGN STUDY COORDINATORS
J. Jaros, H. Weerts, H. Aihara & J. Karyotakis

EXECUTIVE COMMITTEE

ADVISING COMMITTEE
All names on this chart

LOI Editors
H. Aihara, P. Burrows, M. Oreglia

R&D COORDINATOR
A. White

VERTEXING
Su Dong
Ron Lipton
Mech: W. Cooper

SILICON TRACKER
M. Demarteau
R. Partridge
Mech: W. Cooper

CALORIMETERS
A. White
ECAL: R. Frey/D. Strom
HCAL: A. White/H. Weerts
PFA: N. Graf / S. Magill

SOLENOID
H. Murayama

SOLID TRACKER
K. Krempetz

VERY FORWARD
H. Murayama

BENCHMARKING
T. Barklow
A. Nomerotski

SIMULATION
N. Graf

MUON
H. Band
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COST
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MDI
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Electronics
G. Haller

Engineering
K. Krempetz
M. Oriuna

Sept 2008

H. Weerts

SLAC SLUO meeting; Sept 18, 2008
Why do this now? and not later

Close coupling between machine ↔ detector (=one piece)
Accelerator ↔ Experiment

“Critical for machine design” B. Barish

Physics simulation = physics performance of “complex” can only be done with a machine & detector concept

Detector concepts develop frameworks to do this

Physics requirements drive detector concepts, which guide/define R&D

R&D to meet detector performance takes long time

Detector concept & development integral part of any LC.
SiD concept current activities/Summary

**R&D**
- Areas somewhat **driven by SiD**: KPiX, Si tracker, solenoid cable
- Areas more **generic**: ECAL & HCAL technologies, vertex pixels detectors.

**ILC/GDE**
- Interaction with ILC through Machine Detector Interface (MDI): detector halls, layout, connections to machine, backgrounds, push-pull, etc

**LOI**
- ILCSC/Research Director (RD) called for detector LOI's in October 2007
- SiD submitted EOI to submit LOI
- LOI's due March 2009
- Most activities guided by this due date

Expect validation through LOI process as one of the detectors to be part of the ILC technical design phase

**Ultimately build it**

Document SiD & its performance (physics)
The End