



Tracking detectors for future Linear Colliders

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2 different detector concepts: ILD and SiD – both standard HEP detectors with vertex detector, tracker, calorimeter, a solenoid and instrumented return yokes. The detector performance is optimized for particle flow analysis and Higgs-recoil measurement.

Both ILC and CLIC plan to switch between two detectors by push-pull operations.





Particle Flow Algorithm requires an efficient tracking and good two track separation also at high backgrounds. Detector is optimized for a high: BR²/ σ









The tracking system features

- Barrel: 5 layers of single sided microstrip detectors with 50 μ m pitch from R_i = 0.22 m to R_o = 1.22 m
- Endcap: 4 conical discs of double layer micro-strip detectors
- Integrated tracking approach with vertex detectors during reconstruction
- Single bunch time stamping for reliable beam background suppression







<u>Design philosophy:</u> High magnetic field B = 5 Tsmaller lever arm ($R_{_{iECAL}} = 1.27 m$)

Goal for tracking detectors: $\delta(1/p_{t}) \sim 2-5 \times 10^{-5}$ / GeV/c,









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All Silicon Tracker







Sensor area: 10×10 cm² Pitch of strips: 50 µm Thickness: 300 µm Integrated pitch adapter for 2 KPIX chips (hybridless layout)

KPIX a CMOS 1024 channel readout chip Very low power consumption. Including power pulsing: <20 mW per chip => <600 W for complete tracker => can be gas cooled low material budget: $0.9 \% X_0$ per layer in barrel Design of tracker stable for many years.











ILD

Design philosophy:



Lower B field (B = 3.5 T), but larger lever arm ($R_{iECAL} = 1.85$ m)

<u>Goal:</u> $\delta(1/p_t) \sim 2 \times 10^{-5}$ / GeV/c, efficiency: >99%

The tracking system consists of

- A large volume time projection chamber (224 space points)
- Silicon Inner Tracker (SIT)
 2 double layers of Si-strip detectors to link tracks from VXD to tracks in the TPC
- Silicon External Tracker (SET) 1 double layer between TPC and ECAL to improve the momentum resolution
- Endcap tracker (ETD)
 - 1 double layer of Si-strip detector in the endcap between TPC and ECAL
- Forward Tracker (FTD)
 7 discs of Si-pixel and Si-strip detectors around the beam pipe for forward tracks





ILD

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SIT+SET+ETD





Strong collaboration of SiLC with LHC experiments – a lot of synergy



Total number of channels: 10⁷ channels Total area: 180 m² Total number of modules: 5000 with unique sensor type but variable strip length (10-30 cm) depending module location.

Many advanced technologies are implemented in the current design:

- Reduced thickness: 500 $\mu m \rightarrow 200 \; \mu m, 50 \; \mu m$ strip pitch
- Flat sensors: no edges and int. pitch adapter
- Mechanical support by intelligent structures including cooling, cabling, services, positioning
- Staves or Supermodules: self supporting independent structures to hold 12 modules







Forward Tracking





Above 500 GeV vector boson fusion is the dominant H production process \rightarrow final state electrons and H decay products are boosted: 20-50 % of all Higgs below 30° => FTD: 7 discs (r_i = 6 cm, z = 0.2-2.2 m)

2 with Si-pixel sensors: CPS, CCD or DEPFET5 with AC coupled p-on-n microstrip sensors(2 layers/disc with stereo angle between strips)







Time Projection Chamber







Properties of a TPC

- Good spatial resolution
- Large number of measurements
 - \rightarrow continuous tracking
- True 3-dimensional detector (no ambiguities)
- High granularity
- Good energy resolution with dE/dx
- Low material budget



 \Rightarrow performance possible with MPGDs





Micropattern Gas Amplification Stages





track of high energetic particle Cathode Edrift

readout pads

Gas Electron Amplifier / GEM



- Small pitch of gas amplification regions (i.e. holes) => improves spatial resolution, reduction of *E*×*B*-effects
- No preference in direction (as with wires)
 - => all 2 dim. readout geometries can be used
- No ion tail => very fast signal (O(10 ns))
 => good timing and double track resolution
- Direct e -collection on pads
 - => small transverse width / good double track resolution
- Ion back drift can be reduced significantly
 - => Gating planned between bunch trains



pillars



universitätbo

TPC with MPGD



First collaboration to examine TPC with MPGD – many fundamental measurements and developments were done.

- GEMs: First detailed study and minimization of ion backflow (IBF)
 - Development of new GEMs (100 µm thick)
 - New way of mounting GEMs
- Micromegas: First study of IBF
 - Development of resistive cover on readout pads to spread the charge.





LC tracking, EPS, 2013



Pixelized Readout (InGrid)





Micromegas on top of a pixelized readout chip: Bump bond pads for Si-pixel detectors serve as charge collection pads.







 $100{\times}100~\mu\text{m}^2$ pixels







Summary



The future linear colliders have much more stringent requirements than previous experiments.

A lot of work has been done to optimize the detectors and new technologies have been developed.

The beam structure of the accelerators allows power pulsing reducing significantly the material budget of trackers.

The tough momentum requirements can be fulfilled.

Further optimizations and more challenging solutions to standard challenges are looked at.

But most of all – we need the accelerator!

