Développement d’une échelle double face pour la trajectométrie en physique des hautes énergies.

Ph. D. defense

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DESY

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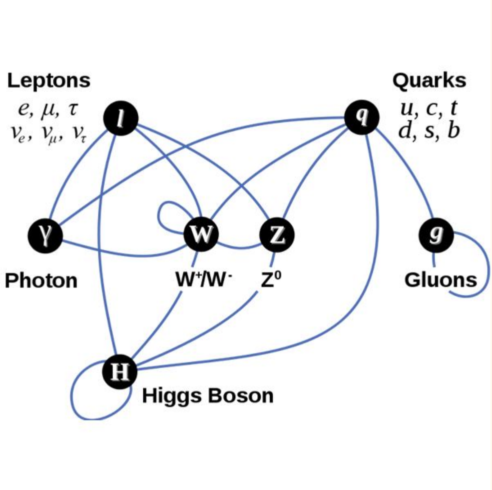
Outlines

Standard Model



Open questions

Limitations

- Free parameters
- Neutrino mass
- Dark matter and dark energy
- ...

Other theories

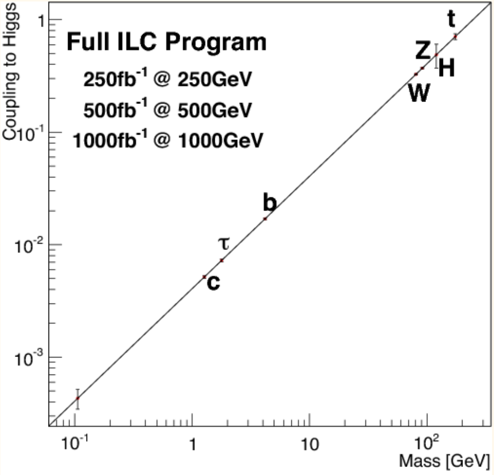
- SUSY
- GUT
- Technicolor
- ...

The Higgs boson discovery

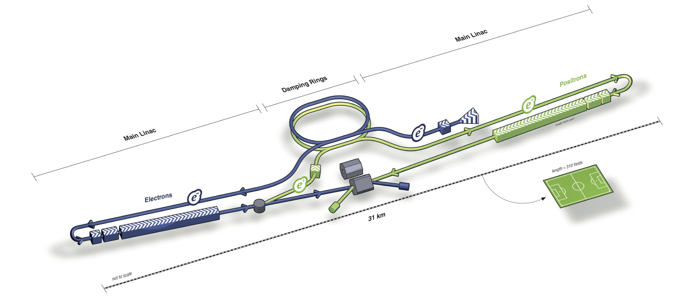
elele

- Discovery at the LHC (ATLAS and CMS)

Higgs Boson

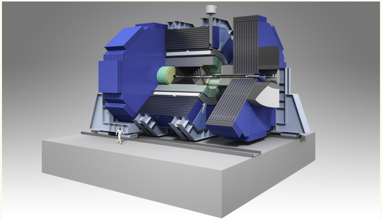

Full ILC Program
250fb-1 @ 250GeV
500fb-1 @ 500GeV
1000fb-1 @ 1000GeV
Coupling to Higgs
Mass [GeV]
t
Z
H
W
b
τ
c
1
10-1
10-2
10-3
10-1
1
10
10²

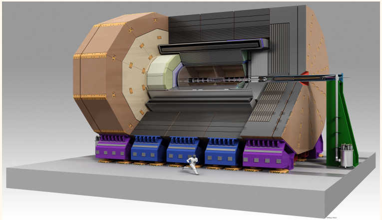
International Linear Collider



- Future e^+e^- linear collider at $\sqrt{s} = 250 - 500$ GeV (upgrade up to $\sqrt{s} = 1$ TeV)
- Polarised beam
- Luminosity $\simeq 2 \times 10^{34}$ cm^{-2}s^{-1}
- Candidate site: Kitakami in nothern Japan
- To study properties of the Higgs boson, top physics...

SiD and ILD





Silicon Detector

- Silicon tracking (radius = 1.2m)
- $B_{field} = 5$ T

International Linear Detector

- TPC + silicon envelope (radius = 1.8 m)
- $B_{field} = 3.5$ T

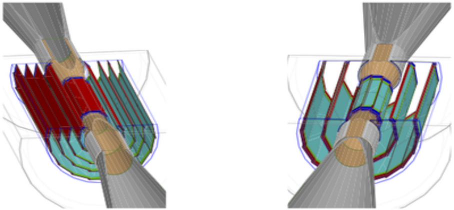
Both detectors designed for Particle Flow Calorimetry

- High granularity calorimeters (ECAL and HCAL) inside solenoid
- Low mass tracker to reduce interactions and conversions

The ILD Vertex Detector

The ILC vertex detector requirements

- Spatial resolution: $< 3\ \mu m$
- Material budget per measurement point: $\simeq 0.15\ \%\ X_0$



Two geometry options for the ILD vertex detector: 5 layers of single-sided detector (left) or 3 layers of double-sided detector (right)

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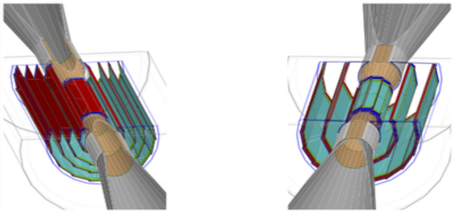


Two geometry options for the ILD vertex detector: 5 layers of single-sided detector (left) or **3 layers of double-sided detector** (right)

Outlines

Double-sided VXD: PLUME

PLUME = **P**ixelated **L**adder with **U**ltra-low **M**aterial **E**mbedding

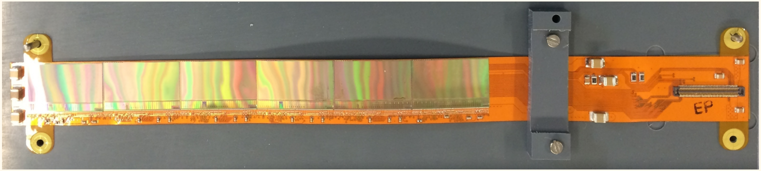
Motivation

ILD Vertex detector at ILC

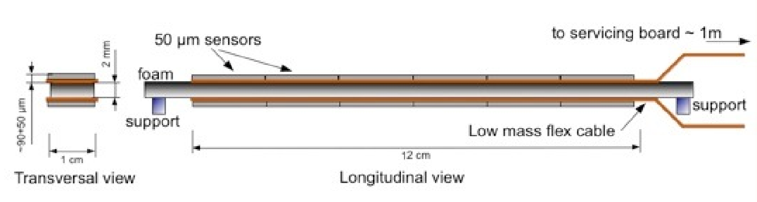
Design

- Double-sided ladder with an active area of 1x12cm^2
- On each side: six MIMOSA-26 CMOS sensors thinned to 50 μm on a kapton-metal flex cable
- 2 mm of silicon carbide foam as mechanical support and spacer between two modules

What does it look like?

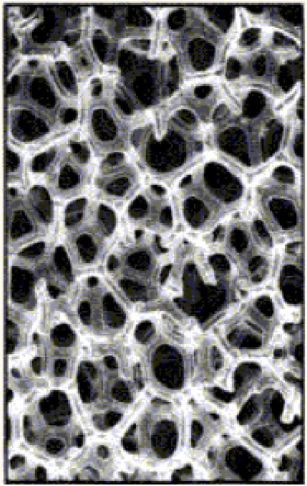


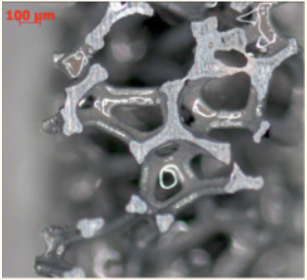
Picture of one module with copper traces.



Scheme of one PLUME ladder.

Foam support structure

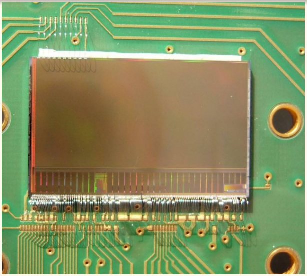


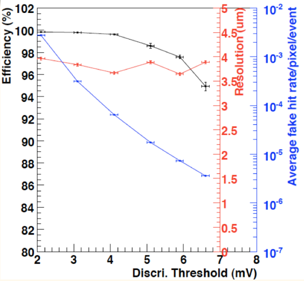


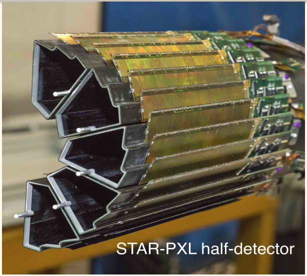
Properties

- Open-cell foam
- Macroscopically uniform
- No tensioning needed
- Density: 4 to 8 % (2-3 % possible)
- Low thermal and electrical conductivity (50 W/m/K)

MIMOSA-26 sensor







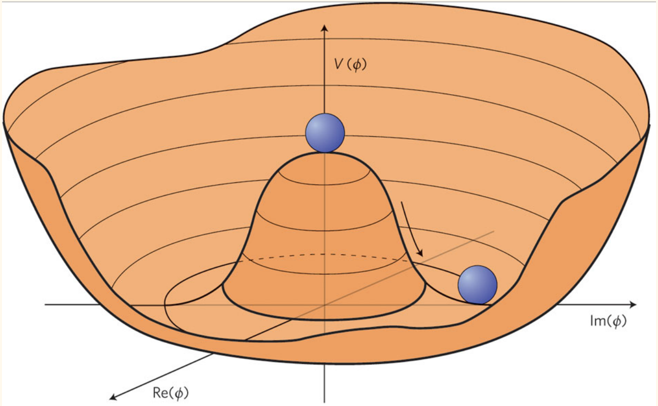
- Monolithic Active Pixels Sensor
- Pitch of 18.4 μm (square pixels)
- Active area: 10.6 x 21.2 mm^2 (576 rows x 1152 columns)
- Column-parallel readout: integration time of 115.2 μs (200 ns per line) for 80 MHz clock
- Zero suppression (to optimize data bandwith) with binary output
- Well known sensors $\Rightarrow$ used for EUDET telescope
- Extended to MIMOSA-28 exploited in STAR-PXL vertex detector @ RHIC-BNL since 2014

Main aims

- Constraint material budget $\Rightarrow \quad < 0.3\ \%\ X_0$
- Use a power pulsing (200 ms period) in a strong magnetic field with air cooling to decrease the power consumption of the ladder
- Study of the advantage to have two measurement points in the tracking of a particle (mini vectors)
- Study of the alignment and **the spatial resolution**

Thanks for your attention !!!

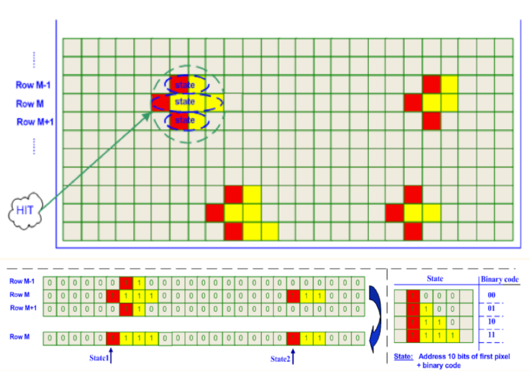
Higgs boson potential



Higgs boson physics at the ILC

- Same measurements as LHC: couplings, mass and spin
- Model independent measurement: no dependence on theory
- Total Higgs width
- $\mathrm{H} \to c\bar{c}/gg$
- Higgs self couplings

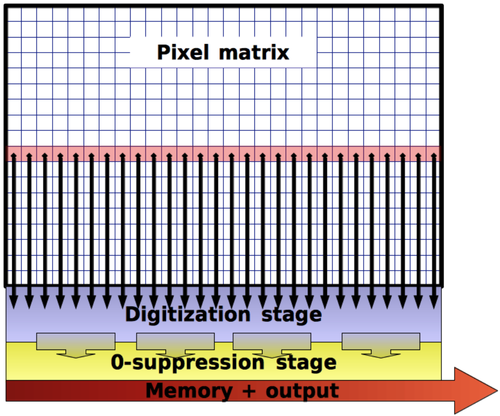
Zero Suppression logic (SUZE)



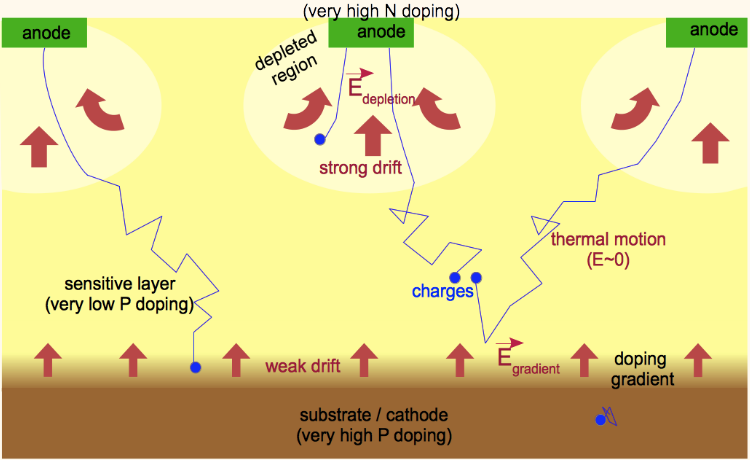
SUZE logic split in 3 blocks:

- **Sparse Data Scan (SDS)** Hit detection per line and data encoding, until 6 states consecutive pixels (1 to 4 pixels) per block of 64 columns;
- **Multiplexing Logic (Mux)** giving up to 9 states;
- **Memory storage** 2 blocks to store the states of the full frame, switching to avoid dead time (during one acquire states of event N, the other one transfer the information of frame N-1).

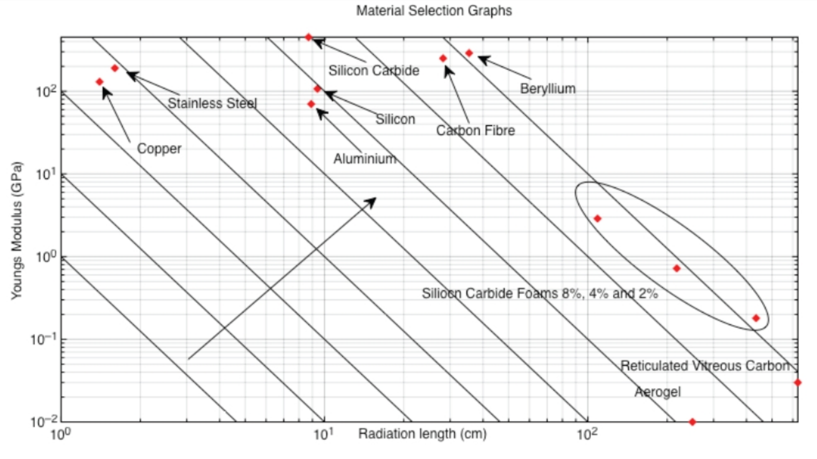
Column parallel readout



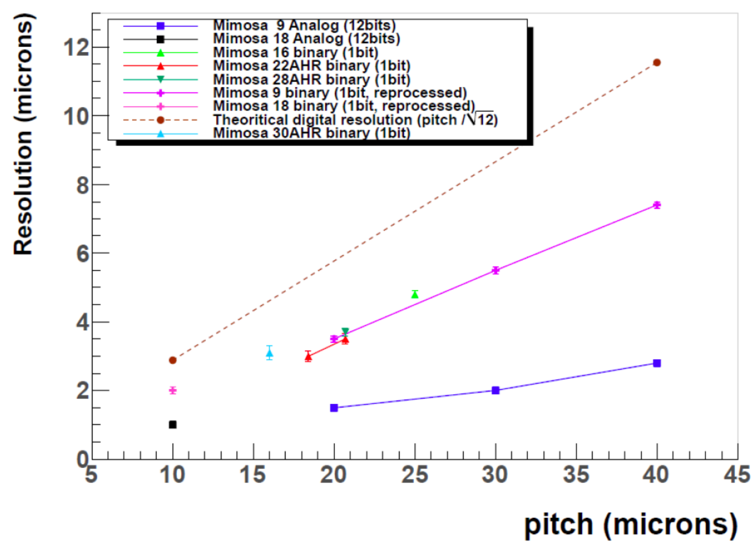
MAPS principle



Young Modulus



Spatial resolution for different pitch (IPHC-Strasbourg)



Higgs Strahlung kinematics

$$E_H = \frac{s - M_Z^2 + M_H^2}{2\sqrt{s}}$$

$$E_Z = \frac{s - M_H^2 + M_Z^2}{2\sqrt{s}}$$

$$|\overrightarrow{p_H}| = |\overrightarrow{p_Z}| = \frac{\sqrt{[s - (M_H + M_Z)^2] \cdot [s - (M_H - M_Z)^2]}}{2\sqrt{s}}$$

If $M_H = 125$ GeV, $M_Z = 91.2$ GeV and $\sqrt{s} = 350$ GeV, then:

$$E_H \simeq 185.4 \text{ GeV}$$

$$E_Z \simeq 164.6 \text{ GeV}$$

$$|\overrightarrow{p_H}| = |\overrightarrow{p_Z}| \simeq 68.5 \text{ GeV}$$

Detector performances

Vertexing

$$\sigma_{IP} = 5 \oplus \frac{10}{p \sin^{3/2}\theta} (\mu m)$$

Tracking

$$\sigma(1/p) = 2x10^{-5} (GeV^{-1})$$

Jet ernergy

$$\sigma_E / E = 0.3/\sqrt{E(GeV)}$$

Particle Flow Algorithm

- Typical jet:
  - Charged hadrons $\simeq$ 60 %
  - Photons $\simeq$ 30 %
  - Neutral $\simeq$ 10 %
- Standard approch
  - All jet components energy measured in ECAL/HCAL
  - $E_{jet} = E_{ECAL} + E_{HCAL}$
- Particle flow calorimetry
  - Measurement of charged particles in tracker
  - Measurement of photon in ECAL
  - Measurement of hadrons in HCAL
  - $E_{jet} = E_{Track} + E_{\gamma} + E_{n}$

Why a linear collider?

Limitations of e^+e^- colliders

- Synchroton radiation loss $\sim \mathrm{E}^4/r$
- Synchroton cost: $\sim$ quadratically with energy
- Power consumption

Avantages of linear colliders

- Not limited by synchrotron radiation
- Cost: $\sim$ linear with energy
- Polarisation of both beams
- Detectors close to the IP $\Rightarrow$ optimum for c-tagging