# Linear Collider

# Detector and Event Reconstruction

# Requirements for the Electromagnetic calorimeter

# Silicon-based solution, requirements

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Meeting at HPK, Hamamatsu, 7 september 2010

*Followed by presentation by Remi CORNAT on silicon sensor design and developments*

LLR ÉCOLE POLYTECHNIQUE cnrs dépasser les frontières In2p3 CALICE Calorimeter for ILC

We are from two laboratories near Paris

* Laboratoire Leprince-Ringuet (LLR), Ecole polytechnique, Palaiseau
* Laboratoire le l'Accelerateur Lineare (LAL), University of Paris XI, Orsay

Jean-Claude BRIENT

Director of LLR, former spokesman of CALICE collaboration

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Standard Model (SM) of Particle Physics excellently describes what is seen in past and current experiments (probing energies of up to 0.1 TeV)

Open answers in particle physics:

* No direct evidence of Higgs particle
  Needed to explain particles' mass
* Strong theoretical indications that the Standard
  Model cannot be a complete theory

New non-SM effects expected at energies ~1 TeV

Several proposals for extensions to the theoretical model
  e.g. super-symmetric theories

The Large Hadron Collider (LHC) at CERN is probing physics at energy scale of up to ~TeV
→ expected to observe effects of non-SM physics

LHC probably not able to measure all aspects of new physics processes

A Linear electron-positron Collider at energies of ~1 TeV will be able to probe more details of TeV-scale physics

General world-wide consensus that next large collider project will be such a machine

Two design studies of linear electron-positron underway

ILC: International Linear Collider

- International project: Americas, Asia, Europe
- Variable energy: 0.1 → 0.5 TeV
- 30 km length
- Superconducting Radio-Frequency acceleration
  - Technique already in use @ DESY/Germany
- Technical design for 2012
- Could start 2020s

CLIC: Compact Linear Collider

- CERN-based project
- Energy up to 3 TeV
- Novel 2-beam acceleration scheme
- Longer timescale

Detector for linear collider
International Large Detector (ILD)
~500 members of design group

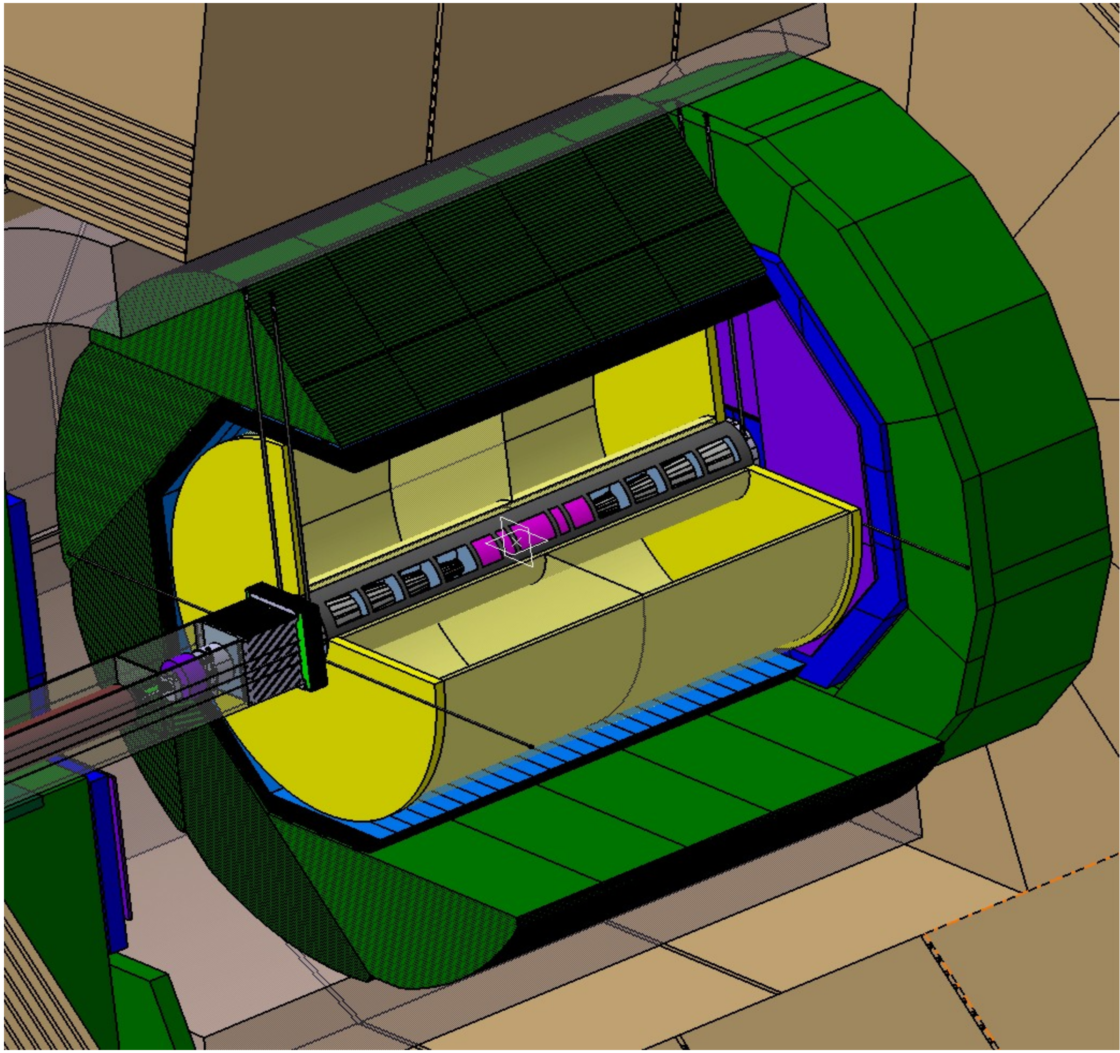
General purpose particle physics detector to identify and measure energy of particles coming out of collision

**Vertex Detector**
precisely measure production point

**Time Projection Chamber (TPC)**
Charged particle momentum

**Calorimeters: electromagnetic and hadronic**
Energy of all particles

All inside 3.5 T magnetic field, produced by superconducting solenoid

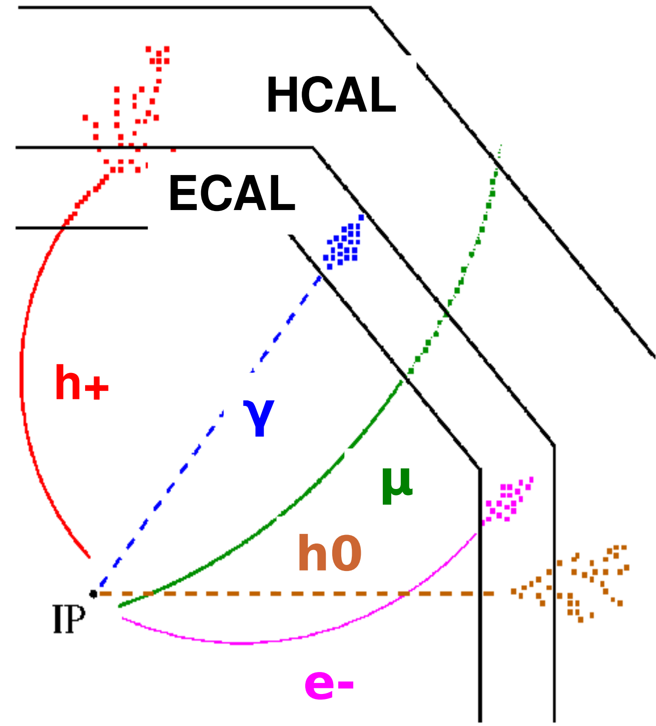


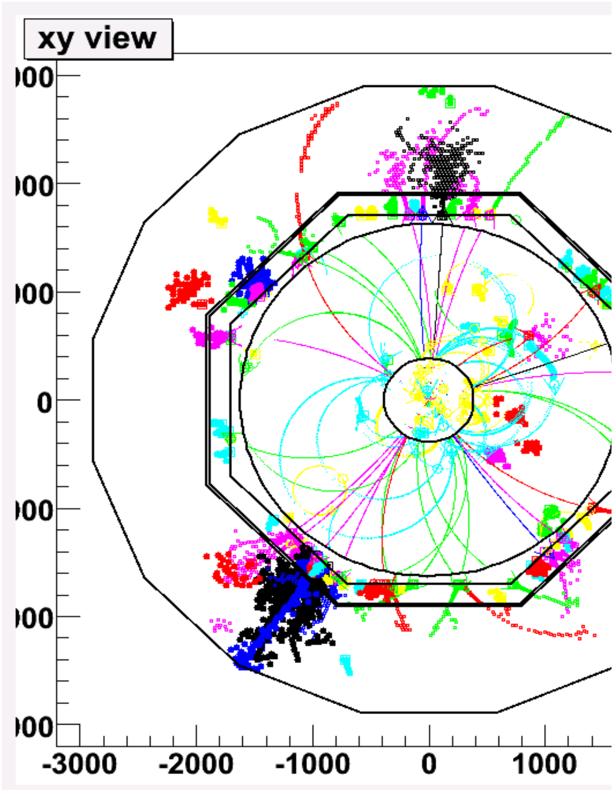
Typical collision: 10 → 100 particles in detector

* Charged particle momentum measured in tracking detector (curvature in B-field)
→ very precise measurement ~ 0.01%
* Electromagnetic Calorimeter (ECAL) measures and absorbs photons, electrons
→ medium precision ~ 5%
* Hadronic calorimeter (HCAL) measures and absorbs hadrons (particles made of quarks)
→ not very precise ~50%

Particle Flow method:

Maximise use of tracking detectors
Calorimeter used only for neutral particles
Calorimeter needs to individually measure particles
→ different to present-day calorimeters
Calorimeter must have very high granularity
→ distinguish near-by particles



CALICE collaboration researches calorimeters to be used in Particle Flow approach

>300 physicists/engineers
>50 institutes
>15 countries

Investigate a number of technical approaches to design of EM and Hadronic calorimeters

Electromagnetic calorimeter

Contain and measure electrons and photons

→ these “shower” when they hit material

Shower of many 1000s of electron/positron/photons

Number of particles in shower depends on energy of incident particle

To reduce physical size of shower, use dense, high Z material

→ tungsten

Transverse radius of shower (in pure Tungsten) ~10mm

# “Sampling calorimeter”

Measure content of shower at various points, extrapolate to entire shower
Interleave layers of Tungsten with active detection layers

Detection layers should be:
- * Thin (keep shower size small)
- * segmented readout ~5 mm (2-particle separation)
- * able to cleanly identify single charged particle
- * give unsaturated signal for ~1000 charged particles/mm$^2$

For an ILD-like detector, total active area of ~2500m$^2$,
giving ~100 million readout channels

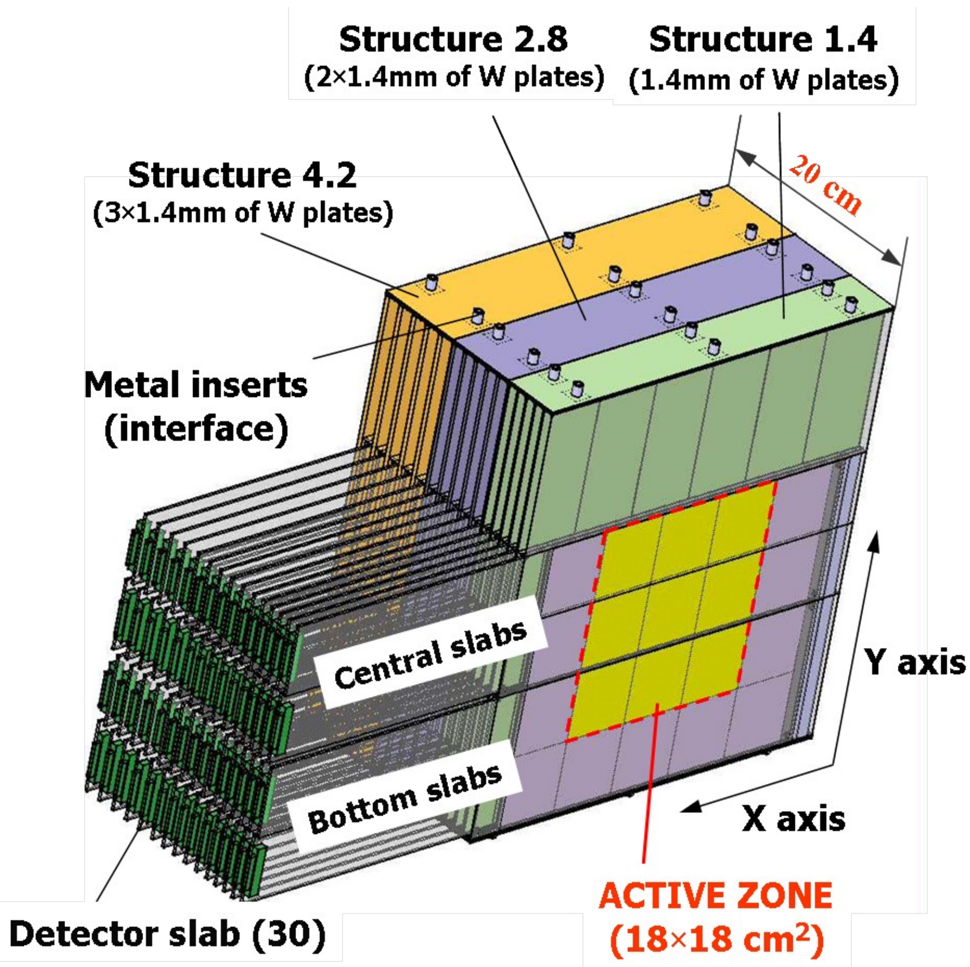
Silicon-based sensors can satisfy these requirements

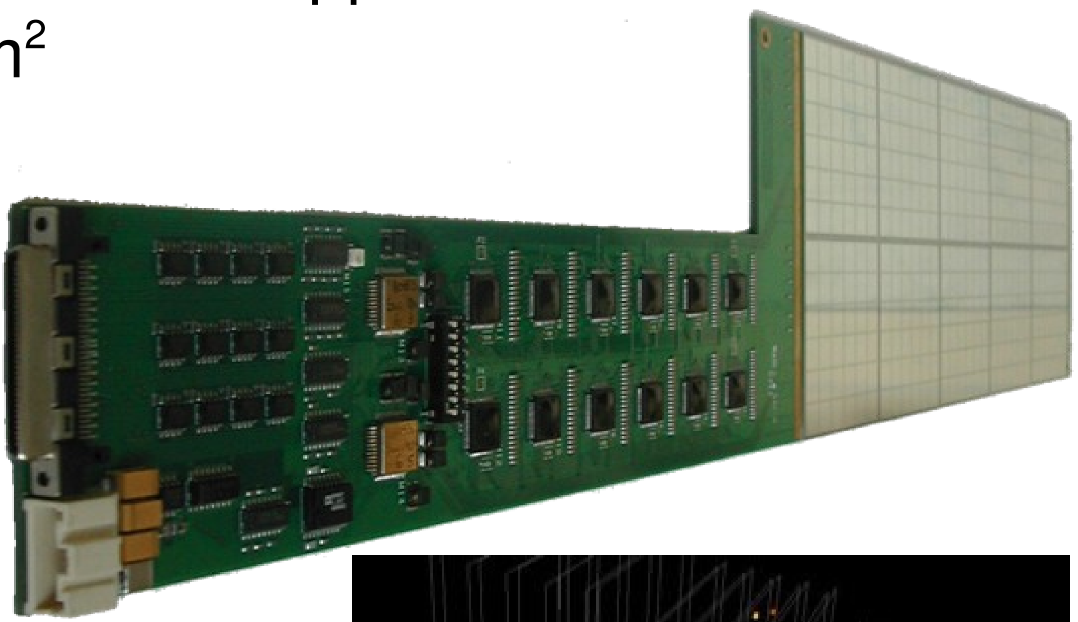
Similar ECALs also proposed for upgrades to present experiments:
ALICE, PHOENIX, e-RHIC

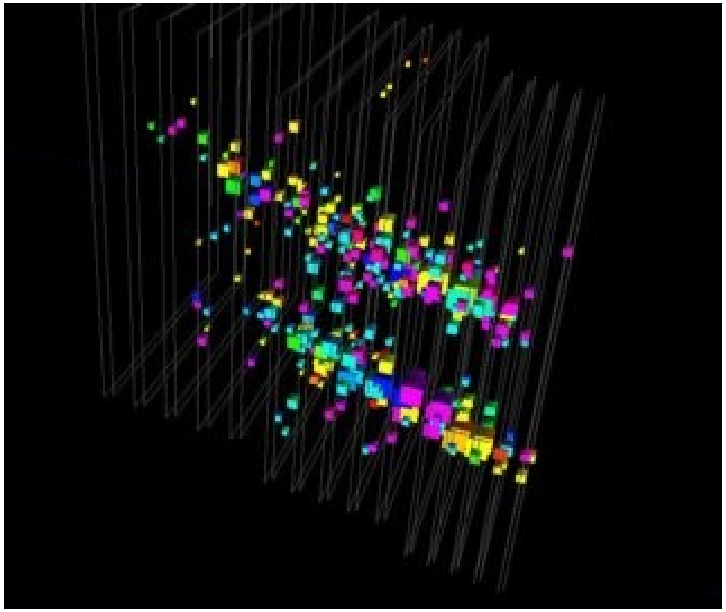
Present status of development

2005-2008: Small prototype construction and testing

- Confirm physics capabilities of approach
- 30 layers of 18 x 18 $cm^2$
- 10 mm segmentation



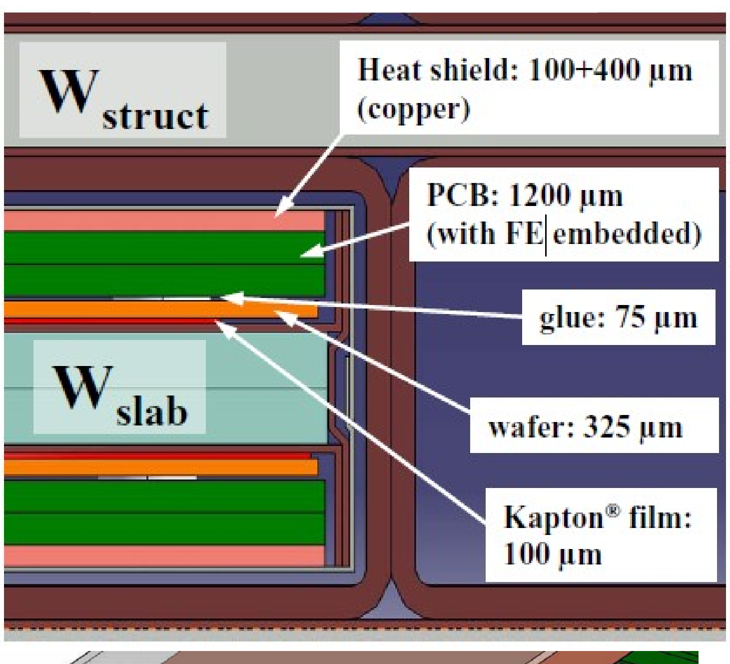


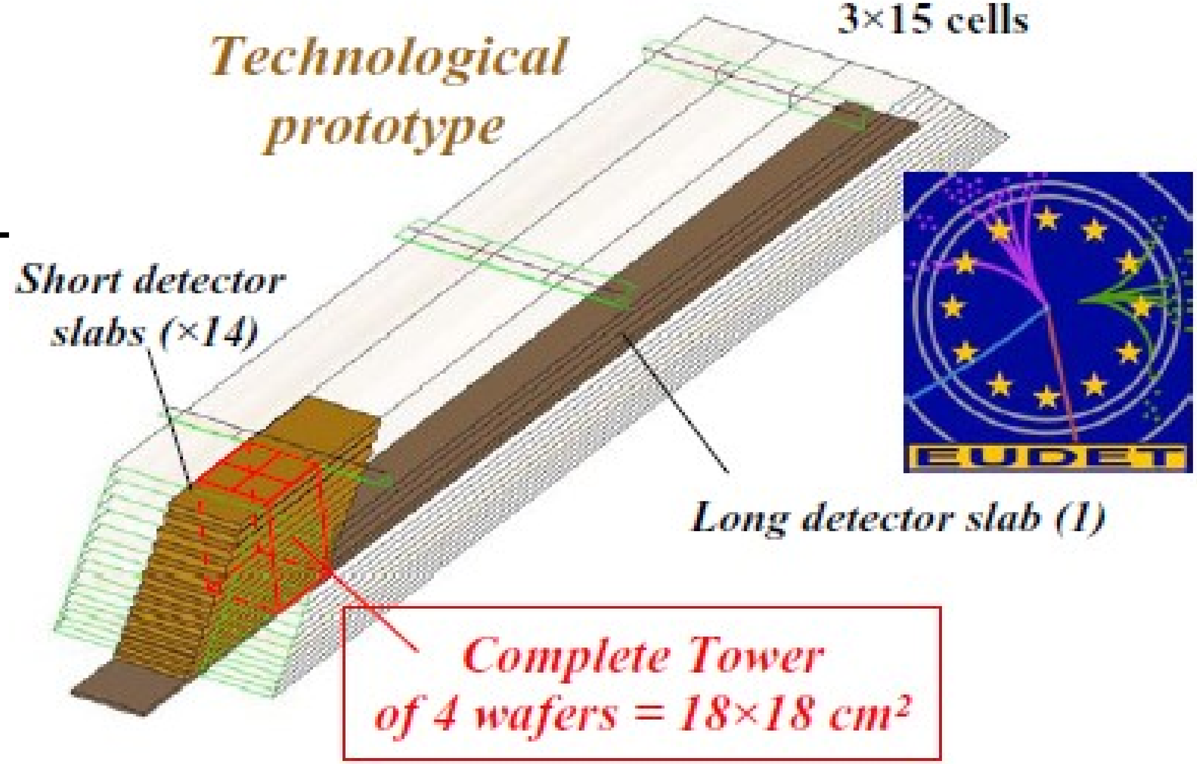
2008-present: preparation of larger scale prototype

Develop technologically realistic implementation

- Compact, low power readout electronics
- Mechanical structure, cooling...

Silicon module



# Main open question is the cost

Estimated ILC cost ~ 6 billion US$ (2007)

Typically, can expect ~10% of this to construct 2 detectors
~ 300 M$ / detector

Not reasonable to spend > 20% on ECAL detector
→ maximum ECAL cost ~ 60 M$

Ideally, would like 2500 m2 of sensors
→ smaller area would progressively degrade performance

60M$ / 2500 $m^2$ ~ 2.4$ per $cm^2$ for sensors and readout
→ upper limit of ~2$ / $cm^2$ for silicon sensors
several times less than cost of present prototypes

Is this an impossible price?
Are there technical ways we can approach it?