Detectors for a Linear Collider

Joachim Mnich

DESY

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Outline

- The International Linear Collider (ILC)
    - Status of the project
    - Physics motivation
    - Impact on detector design
    - The detector concepts
- Detector R&D for key components
    - Vertex detectors
    - Tracking
    - Calorimetry
    - Towards lager prototypes
- Conclusions & Outlook

The International Linear Collider

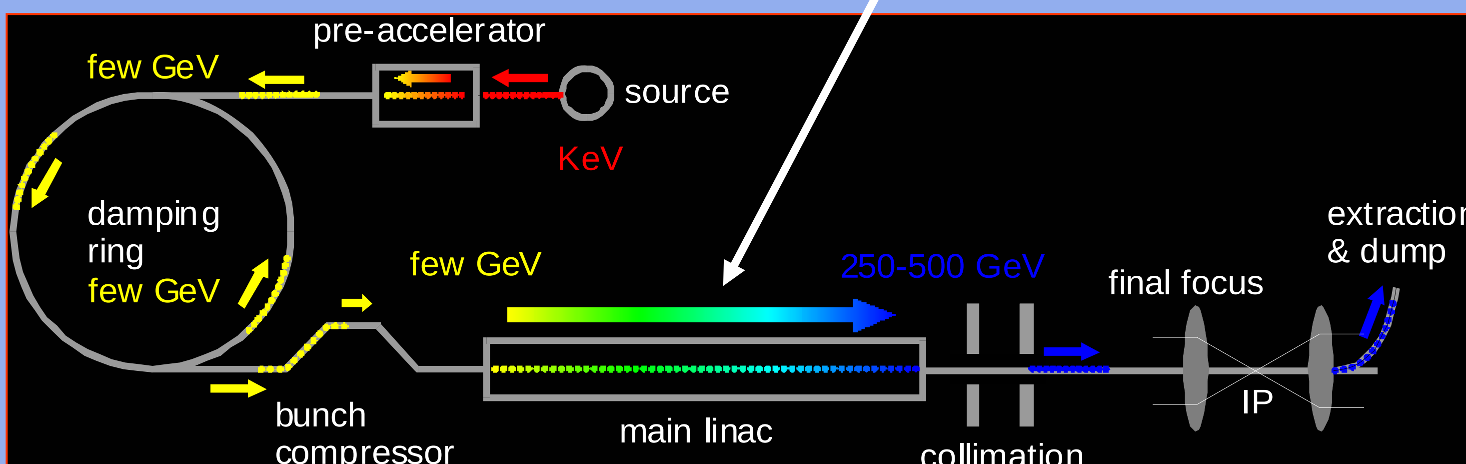
- **Electron-positron collider**
  - **centre-of-mass energy up to 1 TeV centre-of-mass energy**
  - **luminosities > $10^{34}/cm^2/s$**

- **The next large High Energy Physics project (after the LHC)**

- **Designed in a global effort**

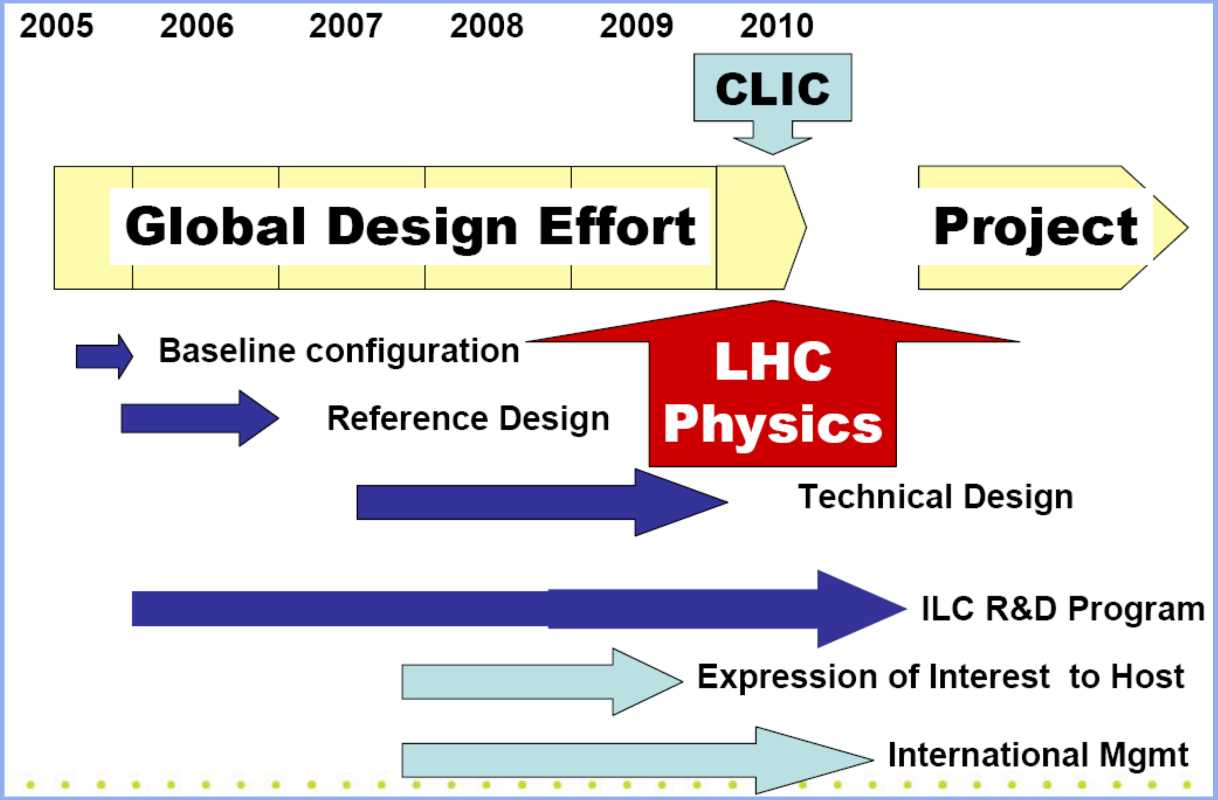
- **Accelerator technology: supra-conducting RF cavities**

- **Elements of a linear collider:**



The International Linear Collider

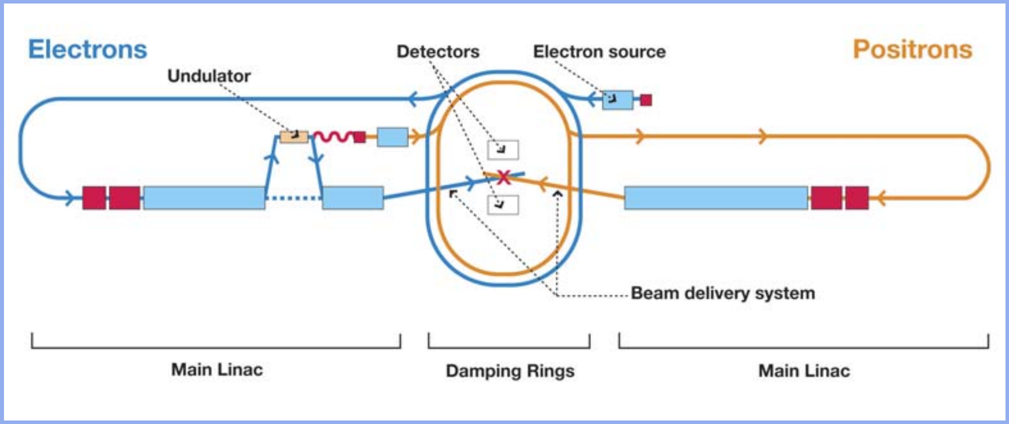
- International organisation:
  - Global Design Effort (GDE), started in 2005
  - Chair: Barry Barish
    representatives from Americas, Asia and Europe
    all major laboratories and many people contributing



The International Linear Collider

- 2006: Baseline Configuration Document
- 2007: Reference Design Report

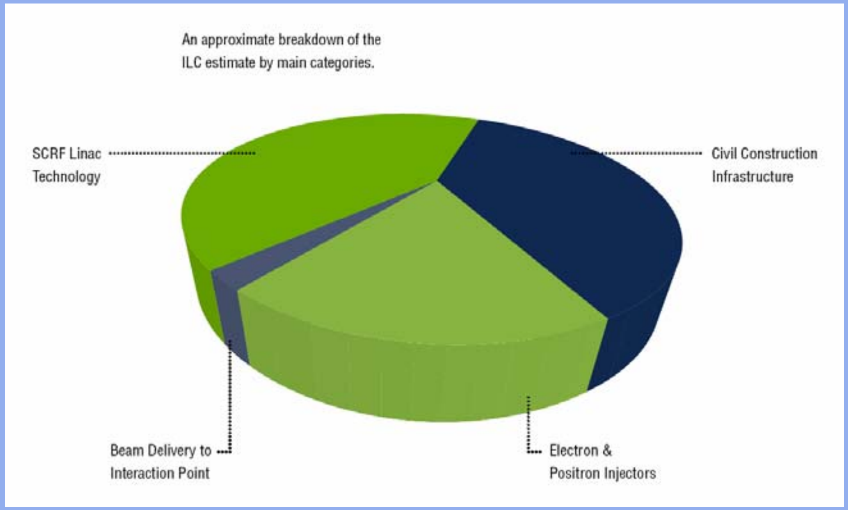
- Layout of the machine:



- 2 × 250 GeV
  upgradable to 2 × 500 GeV
- 1 interaction region
- 2 detectors (push-pull)
- 14 mrad crossing angle

- Cost estimate:
  4.87 G$ shared components
  + 1.78 G$ site-dependent
  = 6.65 G$ (= 5.52 G€)

  + 13000 person years



The International Linear Collider

- Next milestones:
  - two stage Technical Design Phase (TDP I & II) as proposed by GDE

- TDP I until 2010:
  - concentrate on main technical and cost risks main linac, gradient, electron cloud, conventional facilities be prepared when LHC results justify the programme
  - detectors: LOIs by March 2009 update physics performance

- TDP II until 2012:
  - complete technical design siting plan or process
  - detectors: react to LHC results complete technical designs

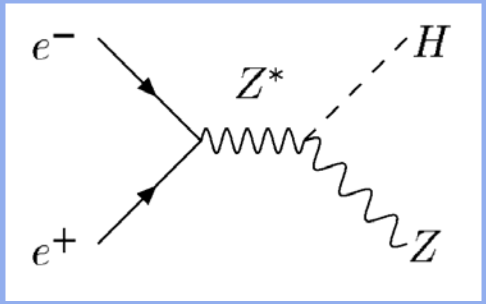
ILC Physics Motivation

- ILC will complement LHC discoveries by precision measurements

- Here just two examples:

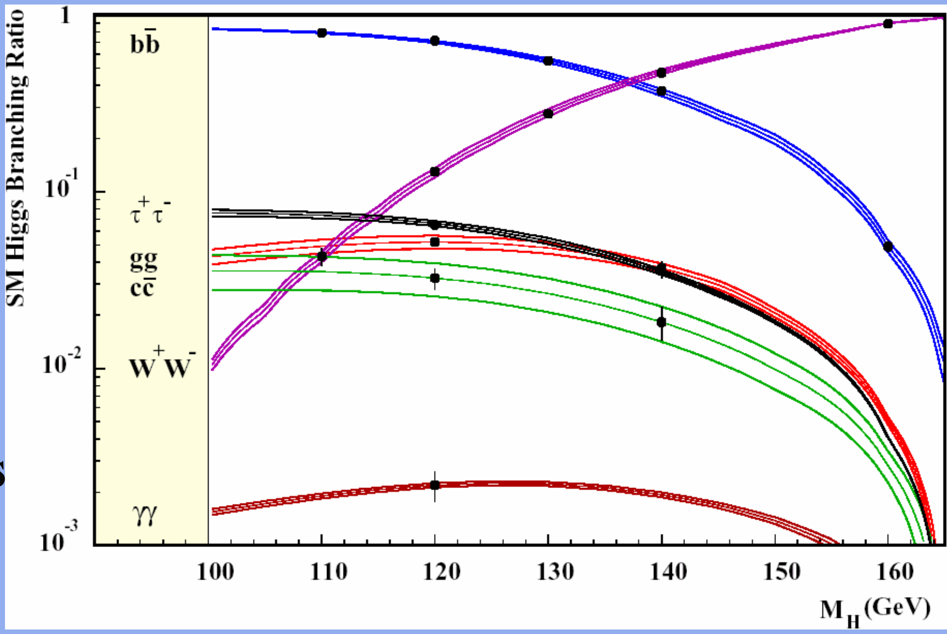
1) There is a Higgs, observed at the LHC

   - e^+e^- experiments can detect Higgs bosons without assumption on decay properties Higgs-Strahlungs process (à la LEP)



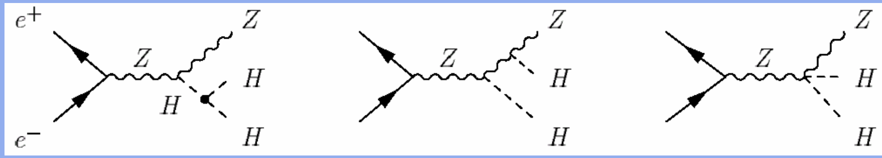
   - identify Higgs events in $e^+e^- \rightarrow ZH$ from $Z \rightarrow \mu\mu$ decay

   - count Higgs decay products to measure Higgs BRs
   - and hence (Yukawa)-couplings

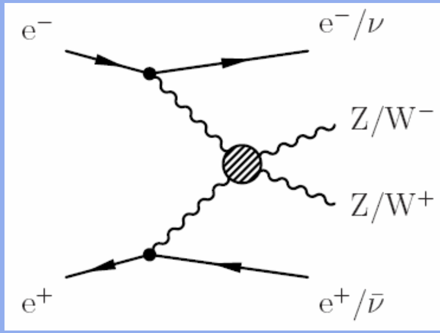


ILC Physics Motivation

- Measure Higgs self-couplings $e^+e^- \rightarrow ZHH$ to establish Higgs potential
  Note: small signal above large QCD background



2) There is NO Higgs (definite answer from LHC!)



- something else must prevent e.g. WW scattering from violating unitarity at O(1 TeV)
- strong electroweak symmetry breaking?
  → study $e^+ e^- \rightarrow WW\nu\nu$, $Wze\nu$ and ZZee events

- need to select and distinguish W and Z bosons in their hadronic decays!
  BR (W/Z → hadrons) = 68% / 70%

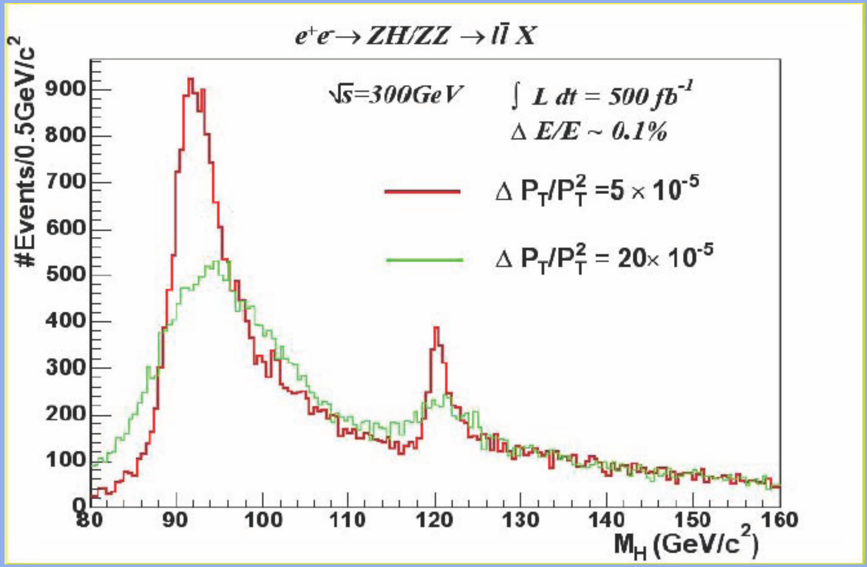
- Many other physics cases: SM, SUSY, new phenomena, …

Need ultimate detector performance to meet the ILC physics case

Impact on Detector Design

- **Vertex detector:**
  e.g. distinguish c- from b-quarks
  - **goal impact parameter resolution**
    $\sigma_{r\varphi} \approx \sigma_z \approx 5 \oplus 10/(p \sin\Theta^{3/2})$ **µm** **3 times better than SLD**
  - **small, low mass pixel detectors, various technologies under study**
    O(20×20 µm²)
- **Tracking:**
  - **superb momentum resolution to select clean Higgs samples**
  - **ideally limited only by** Γ_Z

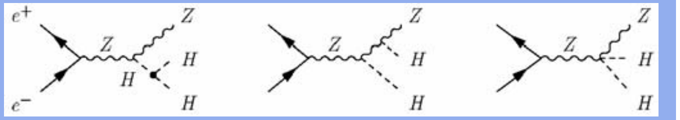
→ $\Delta(1/p_T) = 5 \cdot 10^{-5}$ **/GeV**
(whole tracking system)
3 times better than CMS

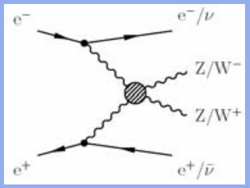


Options considered:
- **Large silicon trackers (à la ATLAS/CMS)**
- **Time Projection Chamber with ≈ 100 µm point resolution (complemented by Si–strip devices)**

Impact on Detector Design

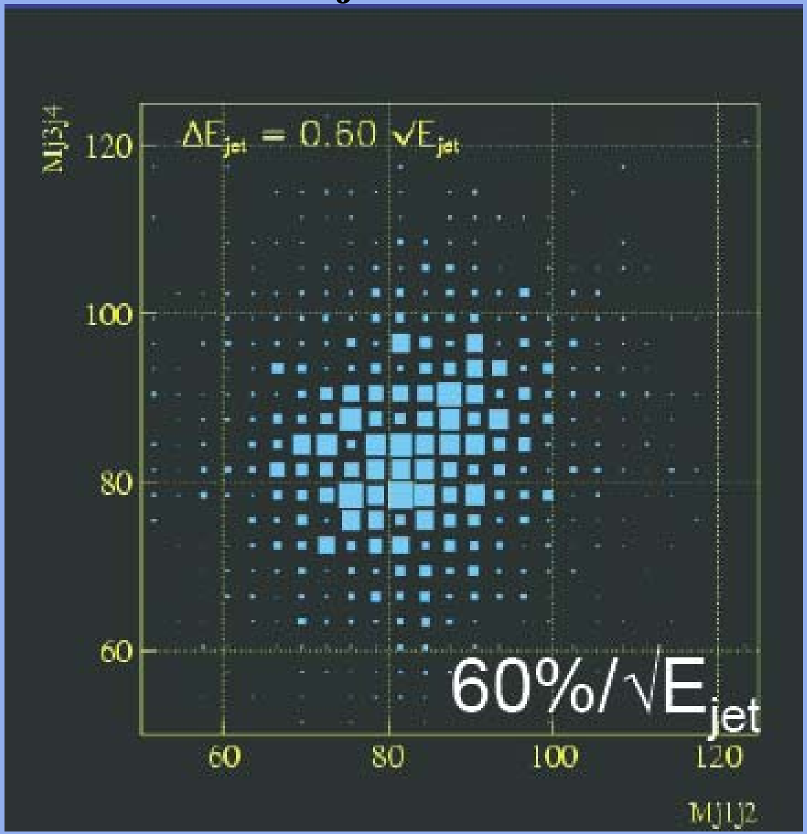
- **Calorimeter:**
  distinguish W- and Z-bosons in their hadronic decays
  → 30%/√E jet resolution!

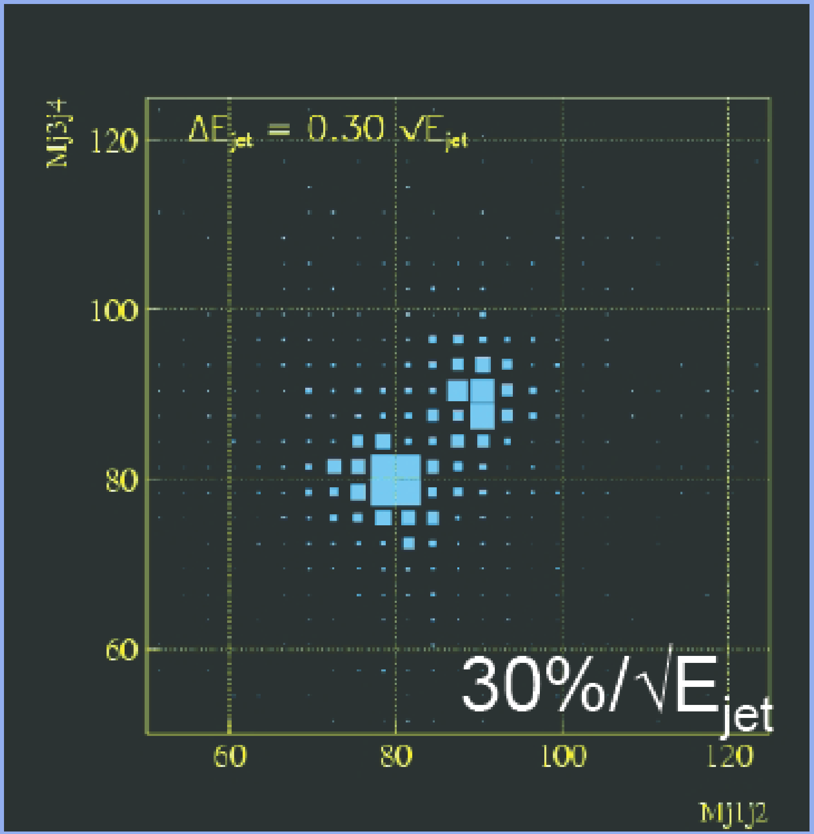




2 times better than ZEUS

- **WW/ZZ → 4 jets:**

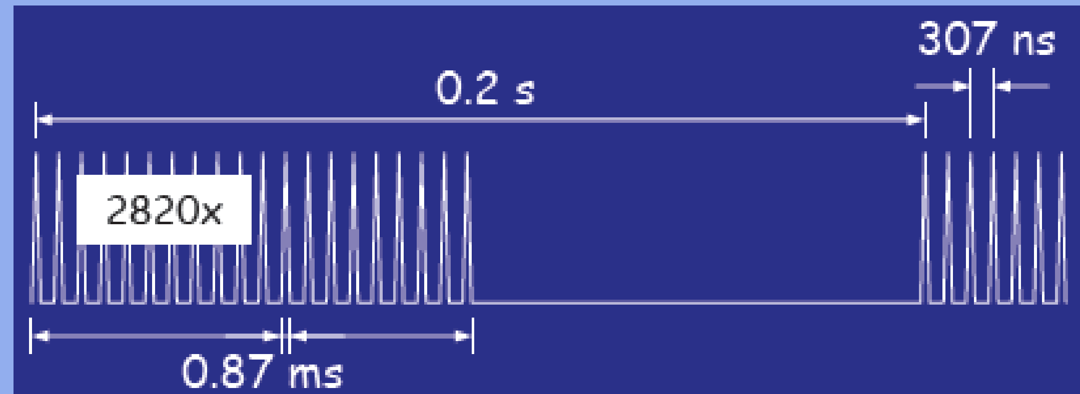




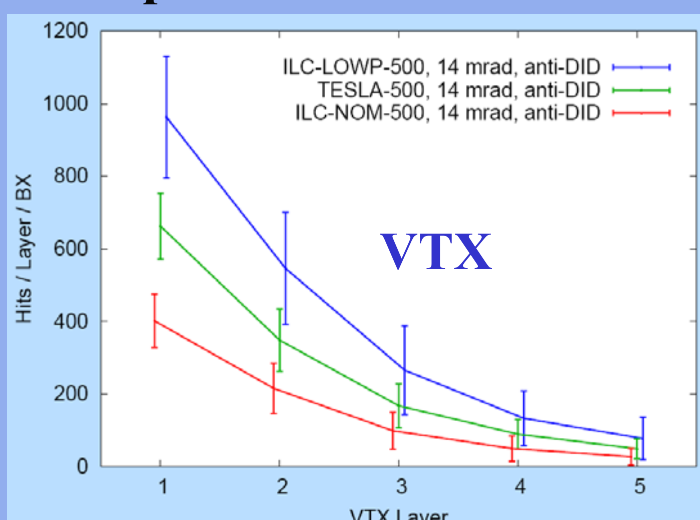
→ Particle Flow or Dual Readout calorimeter

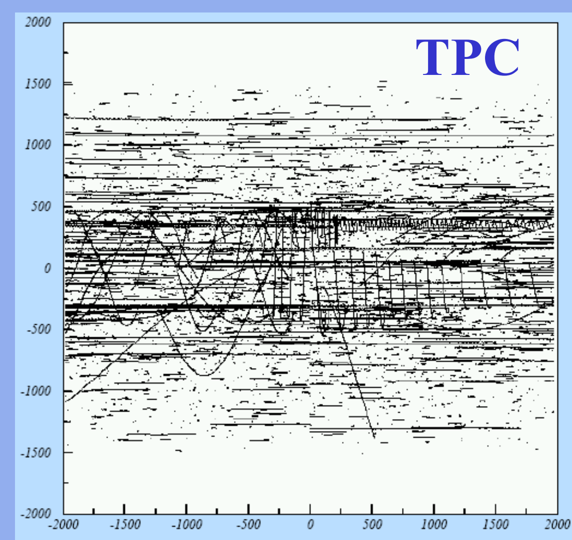
Detector Challenges at the ILC

- **Bunch timing:**
  - 5 trains per second
  - 2820 bunches per train separated by 307 ns
    - no trigger
    - power pulsing
    - readout speed
- **14 mrad crossing angle**
- **Background:**
    - small bunches
    - create beamstrahlung → pairs



backgound not as severe as at LHC but much more relevant than at LEP





Detector Concepts

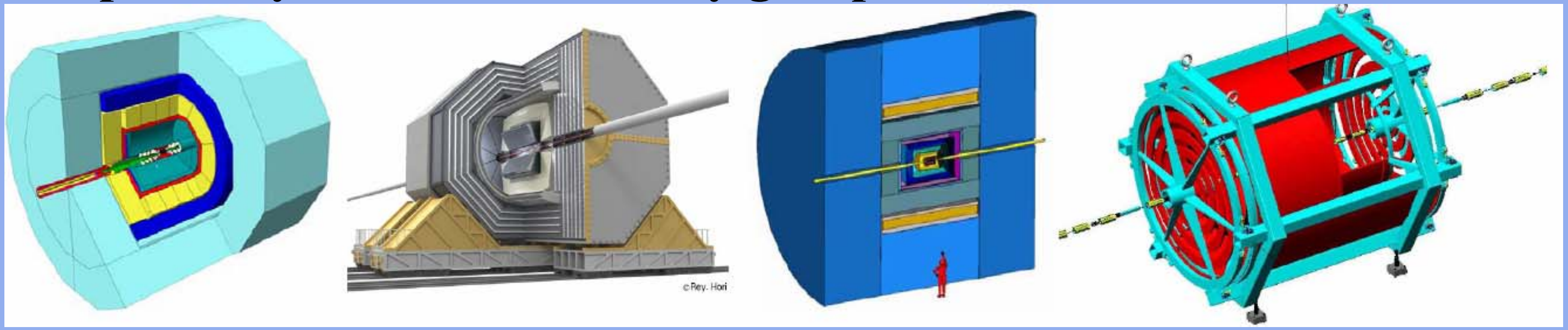
- **Four detector concepts are being investigated**
  - **GLD (Global Large Detector)**
  - **LDC (Large Detector Concept)**
  - **SiD (Silicon Detector)**
  - **4th concept**

Merging into one concept: (GLD and LDC)
(ILD) International Large Detector

- **Summer 2006: Detector Outline Documents (DOD)**
  evolving documents, detailed description

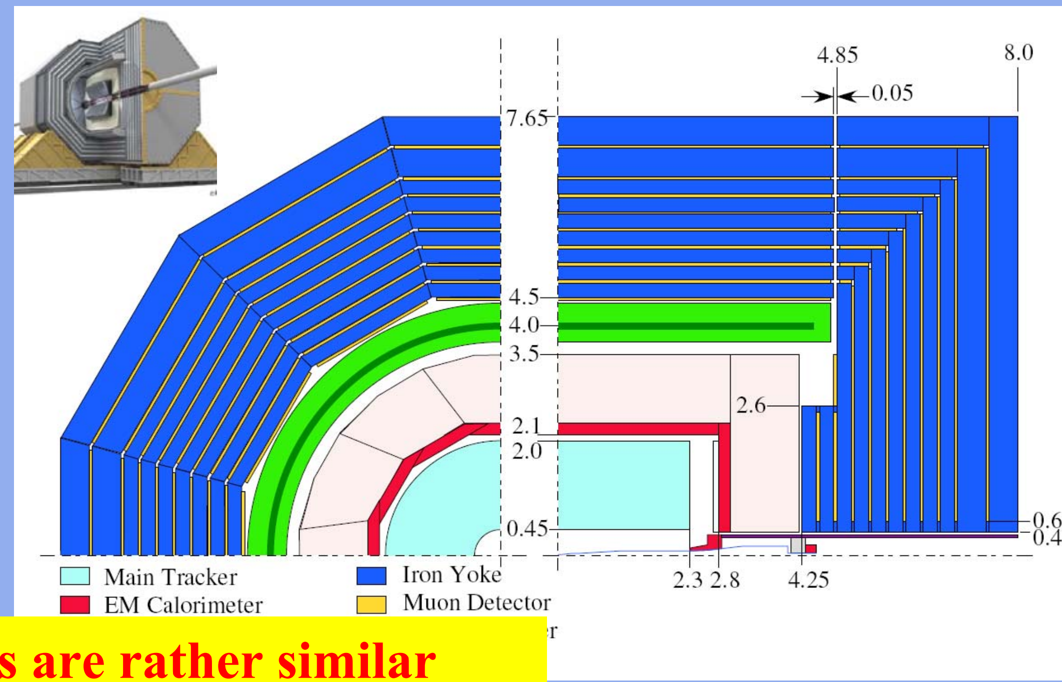
- **Summer 2007: Reference Design Reports (RDR)**
  comprehensive detector descriptions,
  along with machine RDR

- **Prepared by international study groups**



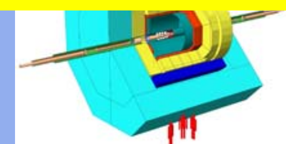
Detector Concepts

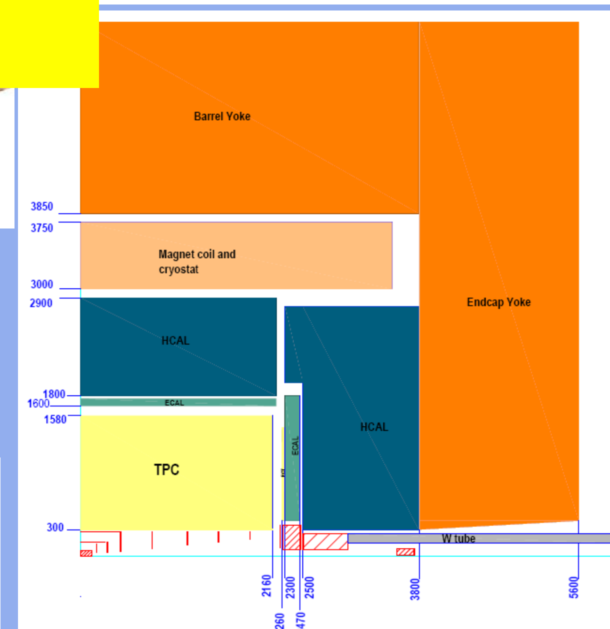
- GLD
  - TPC tracking
    large radius
  - particle flow calorimeter
  - 3 Tesla solenoid
  - scint. fibre μ detector

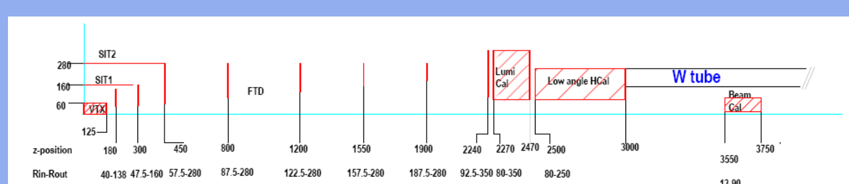


Both concepts are rather similar now merging into one (ILD)

- LDC
  - TPC tracking
    smaller radius
  - particle flow calorimeter
  - 4 Tesla solenoid
  - μ detection: RPC or others

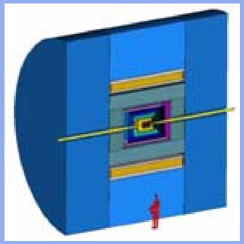


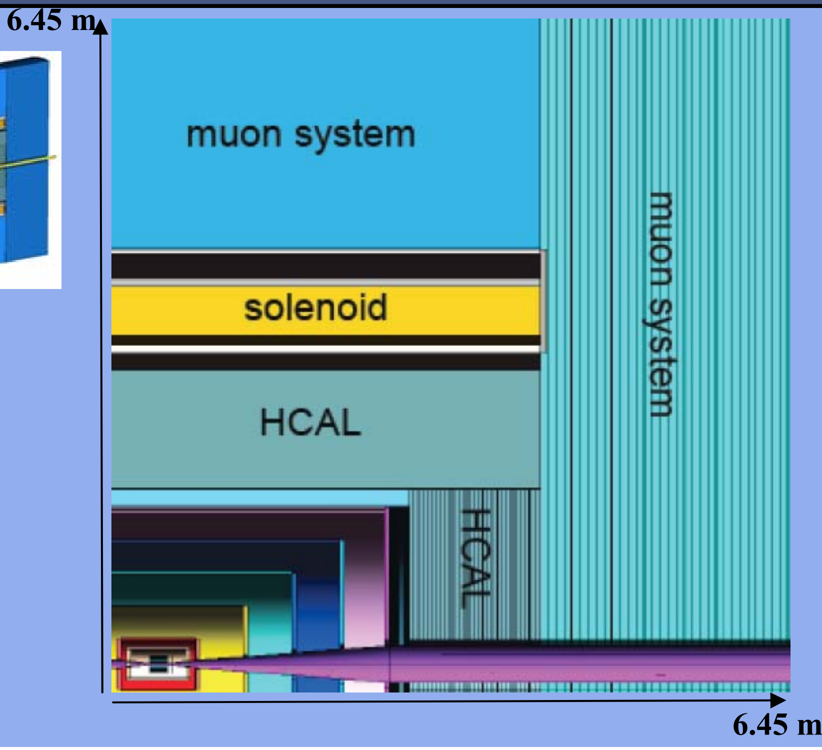




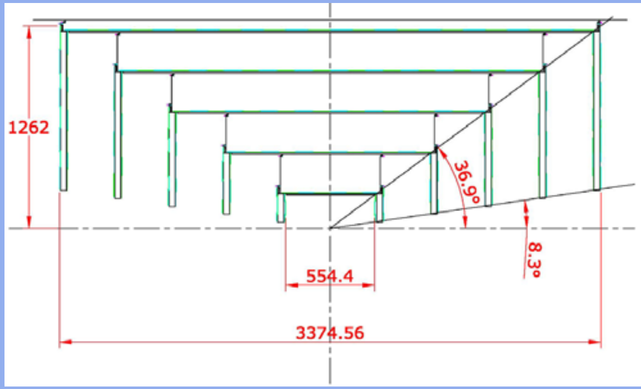
Detector Concepts

- SiD
  - silicon tracking
  - smaller radius
  - high field solenoid (5 Tesla)
  - scint. fibre / RPC μ detector

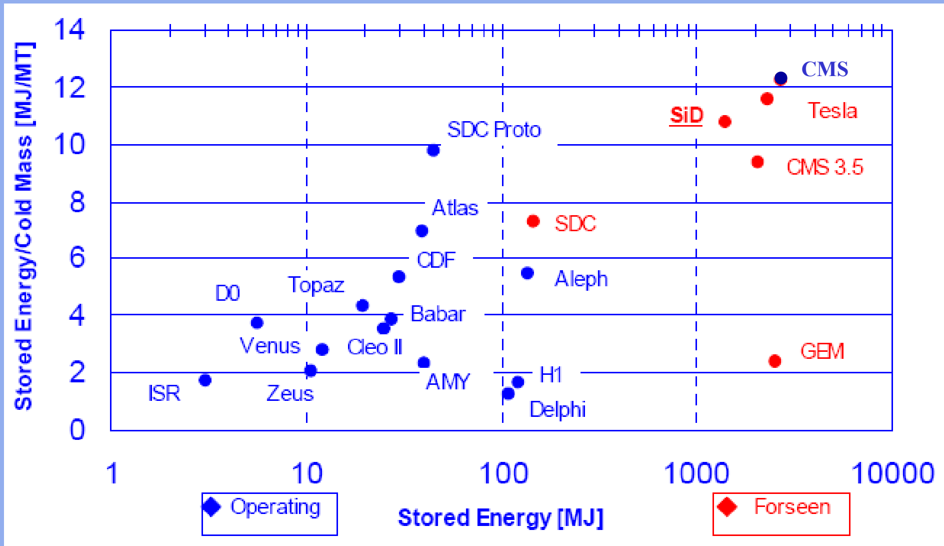




- Silicon tracker



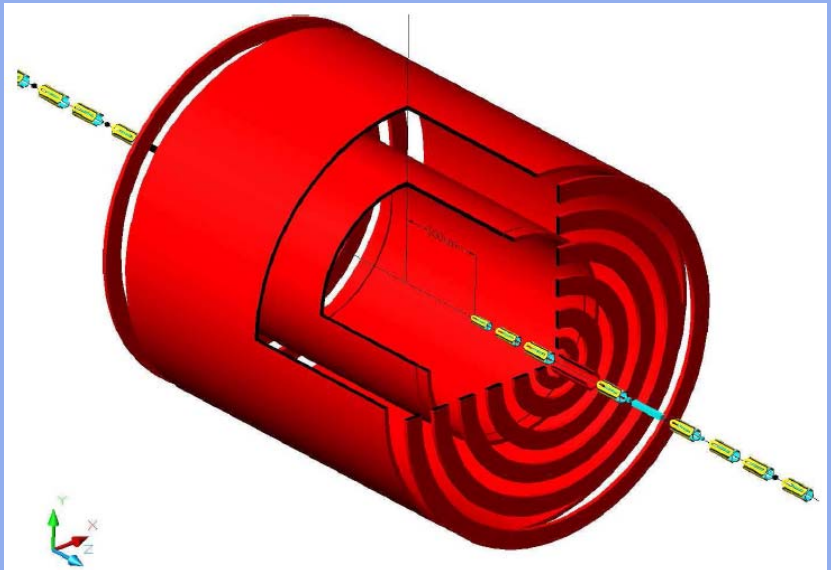
- Magnet
  - high field
  - but smaller volume

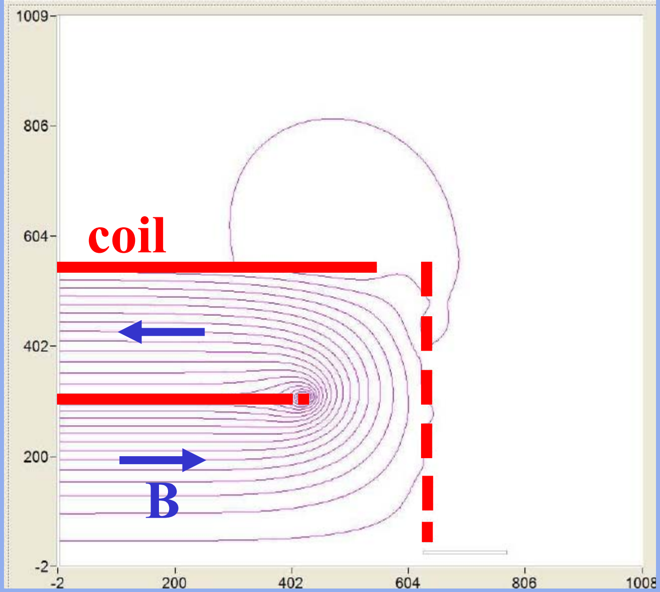


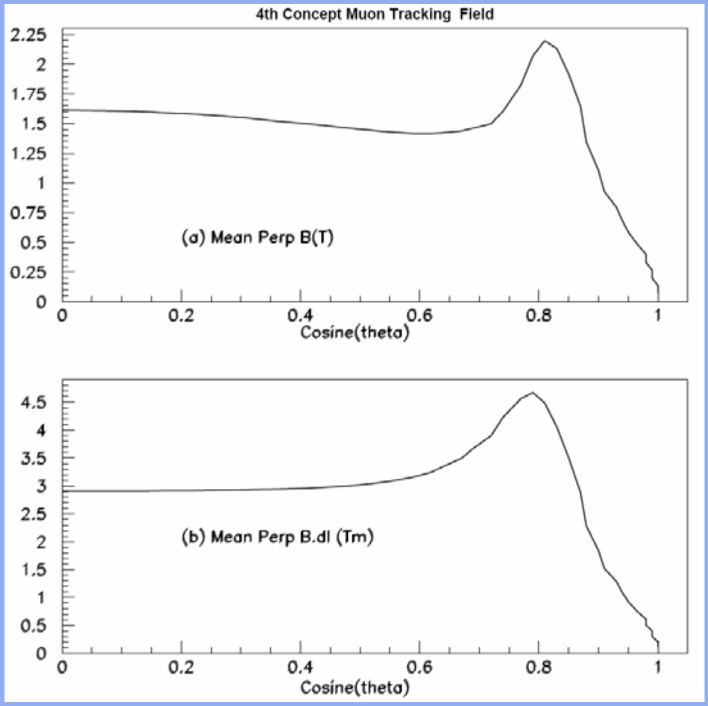
Detector Concepts

- 4th concept
  - TPC
  - multiple readout calorimeter
  - iron-free magnet, dual solenoid
  - muon spectrometer (drift tubes)

- Dual solenoid
  - iron return yoke replaced by second barrel coil and endcap coils







Average field seen by μ:

<B> ≈ 1.5 T

<Bl> ≈ 3 Tm

Detector Concept and R&D efforts

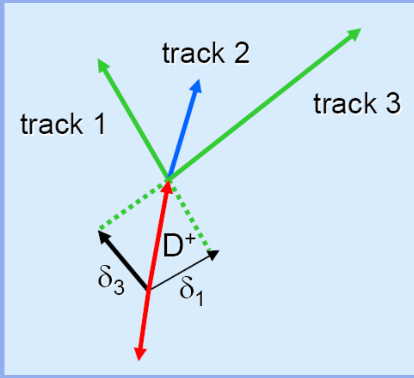
- R&D efforts for key detector elements
- Overlap with detector concepts:

	GLD	LDC	SID	4th concept	Detector R&D collaborations
Vertex	X	X	X	X	LCFI
Tracking					
- TPC	X	X		X	LCTPC
- Silicon	*	*	X	*	SILC
Calorimetry:					
- Particle Flow	X	X	X		CALICE
- Multiple Readout				X	
- Forward region	X	X	X	X	FCAL

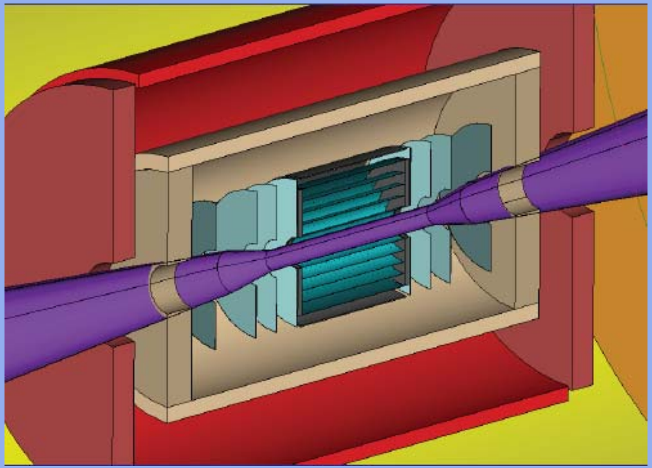
* silicon forward and auxiliary tracking also relevant for other concepts

Vertex Detector

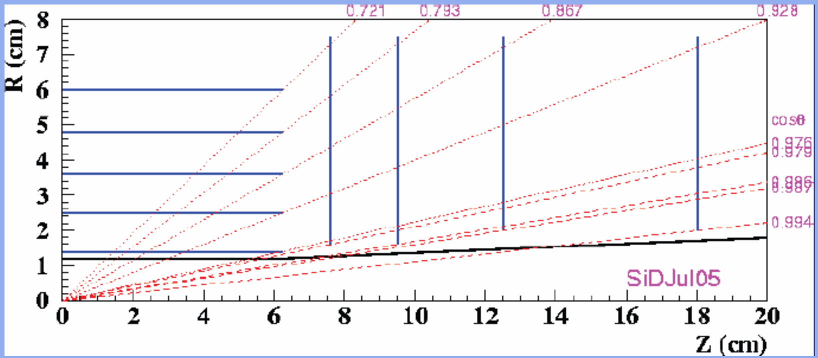
- Key issuses:
  - measure impact parameter for each track
  - space point resolution < 5 µm
  - smallest possible inner radius $r_i \approx 15$ mm
  - transparency: ≈ 0.1% X_0 per layer
    = 100 µm of silicon
  - stand alone tracking capability
  - full coverage |cos Θ| < 0.98
  - modest power consumption < 100 W



- Five layers of pixel detectors plus forward disks
  - pixel size O(20×20 µm²)
  - 10^9 channels



- Note: wrt. LHC pixel detectors
  - 1/5 r_i
  - 1/30 pixel size
  - 1/30 thickness



Vertex Detector

- Critical issue is readout speed:
- Inner layer can afford O(1) hit per mm^2 (pattern recognition)
  - once per bunch = 300 ns per frame too fast
  - once per train ≈ 100 hits/mm^2 too slow
  - 20 times per train ≈ 5 hits/mm^2 might work

    50 µs per frame of 10^9 pixels!

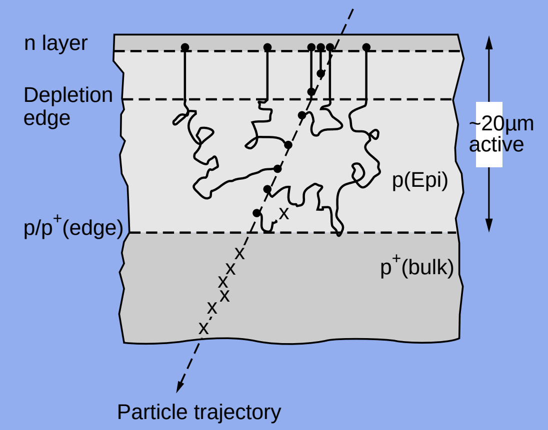
→ readout during bunch train (20 times)
or store data on chip and readout in between trains
e.g. ISIS: In-situ Storage Image Sensor

- Many different (sensor)-technologies under study
  CPCCD, MAPS, DEPFET, CAPS/FAPS, SOI/3-D,
  SCCD, FPCCD, Chronopixel, ISIS, …
  → Linear Collider Flavour Identification (LCFI) R&D collaboration
- Below a few examples

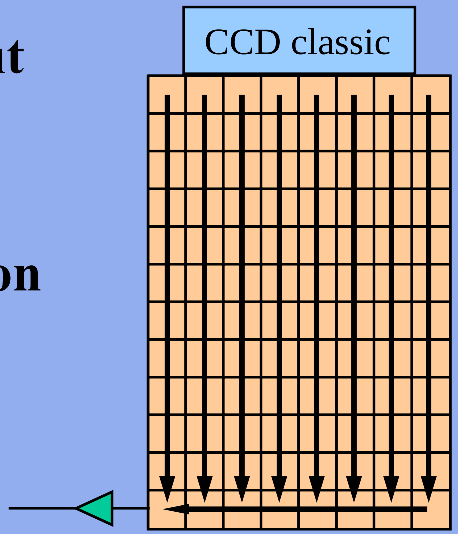
- Note: many R&D issues independent of Si-technology
  (mechanics, cooling, …)

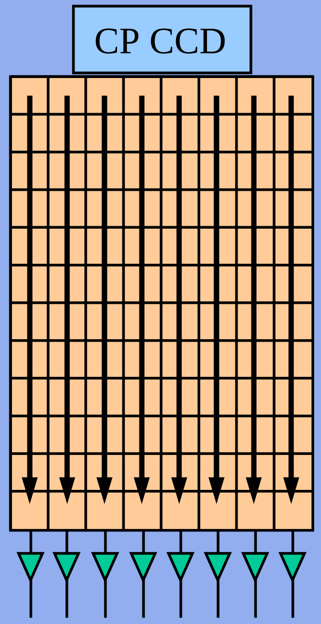
CP CCD

- **CCD**
  - **create signal in 20 µm active layer**
  - **etching of bulk material to keep total thickness ≤ 60 µm**
  - **low power consumption**
  - **but very slow**

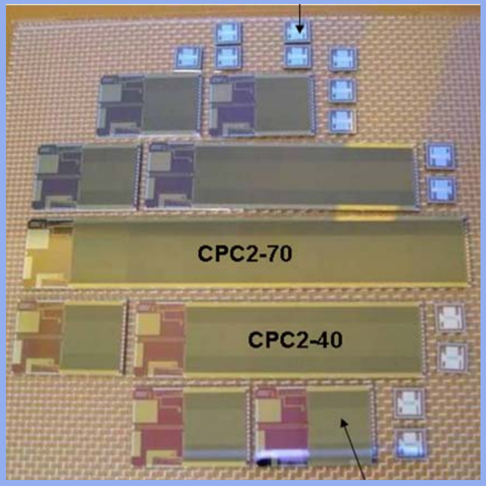


→ apply column parallel (CP) readout



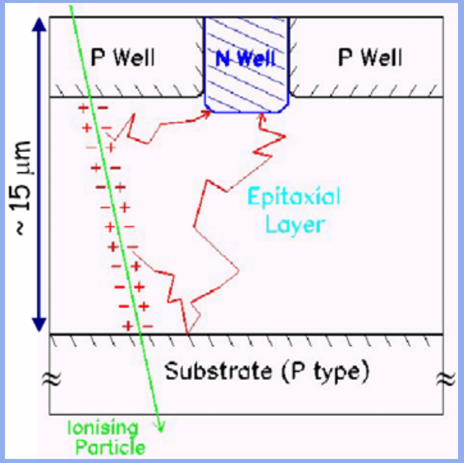


- **Second generation CP CCD designed to reach 50 MHz operation**

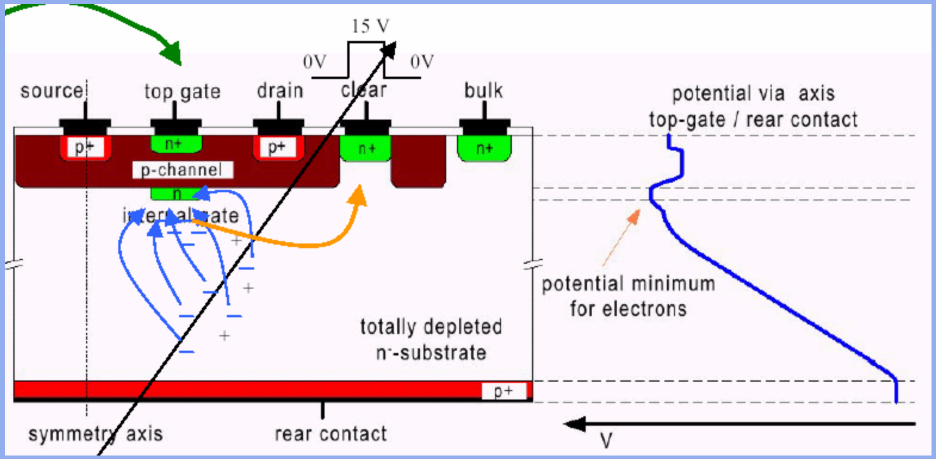


MAPS and DEPFET

- **CMOS Monolithic Active Pixel detectors**
  - **standard CMOS wafer integrating all functions**
  - **no bonding between sensor and electronics**
  - **e.g. Mimosa chip**



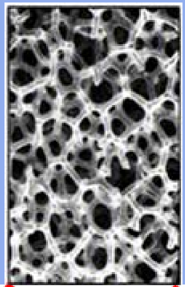
- **DEPFET: DEPleted Field Effect Transistor**
  - **fully depleted sensor with integrated pre-amplifier**
  - **low power and low noise**

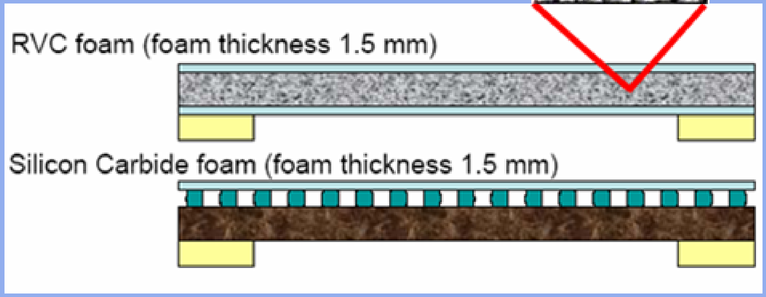


Vertex Detector Support

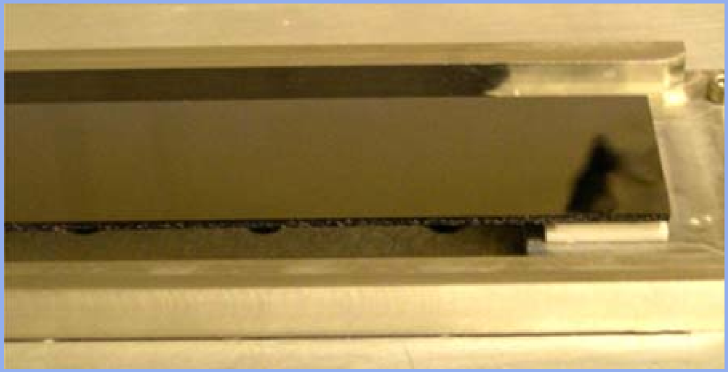
- Mechanical support structure goal 0.1% X_0 per layer

- Example:
  - Reticulated Vitreous Carbon (RVC)
  - or Silicon Carbid SiC foams
    both good thermal match to Si





1.5 mm RVC foam + 2×25 μm silicon
= 0.09% X_0
1.5 mm SiC foam + 25 μm silicon
= 0.16% X_0 (reducible, less dense foam)
achieved



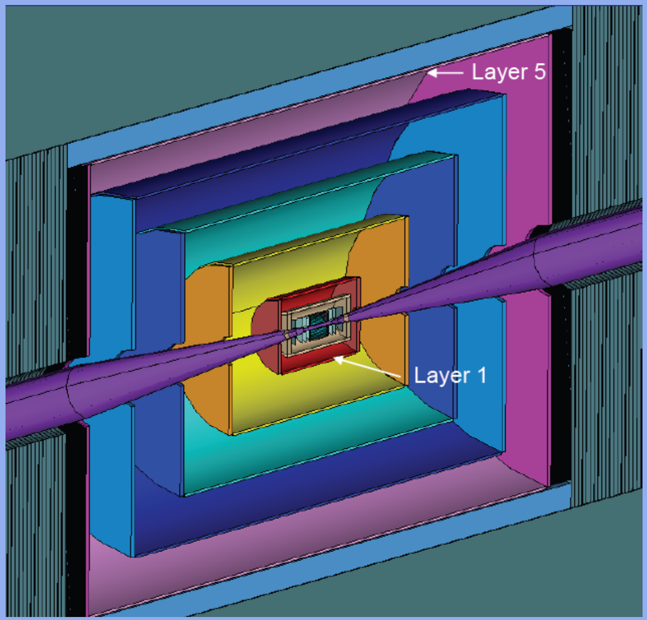
- can be adopted to all detector technologies

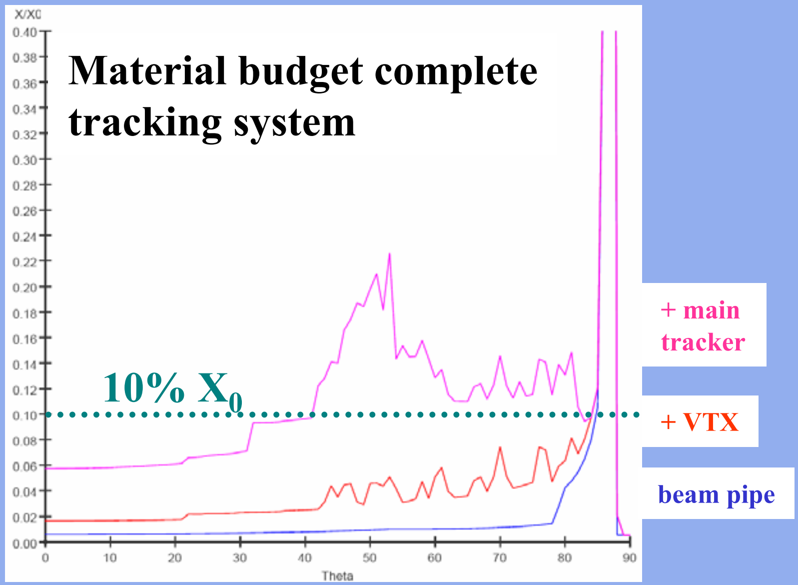
Silicon Tracking

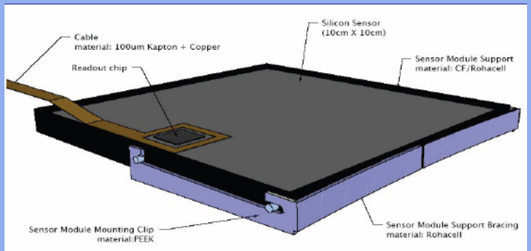
- The SiD tracker:
  - 5 barrel layers
    r_i = 20 cm
    r_o = 125 cm
  - 10 cm segmentation in z
    short sensors
  - measure phi only

- endcap disks
  - 5 double disk per side
  - measure r and phi

- critical issue:
  - material budget
    (support, cooling, readout)
  - goal: 0.8% X_0 per layer





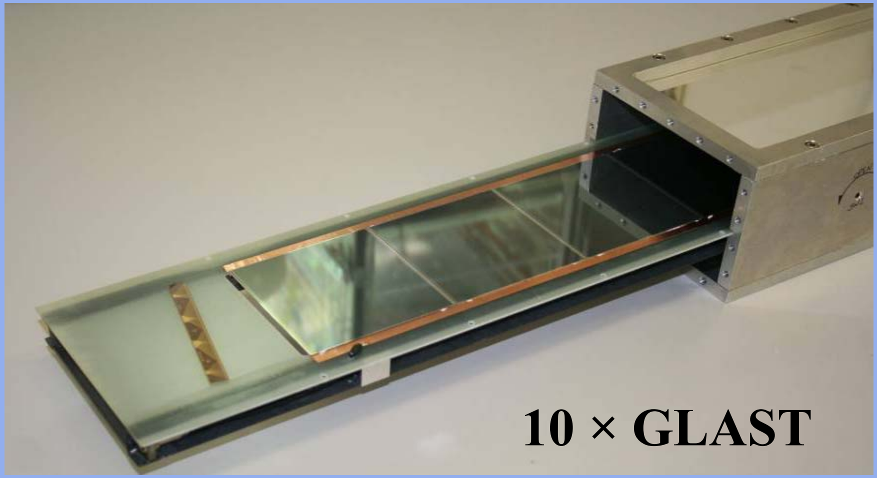


Silicon Tracking

- Alternative design: long ladder
  - Silicon tracking for the Linear Collider (SiLC) collaboration
  - for all-silicon tracker
    or silicon enveloppe (→TPC)

- Development of low noise electronics
  - amplification & pulse shaping
  - passive cooling
  - exploit low duty cycle

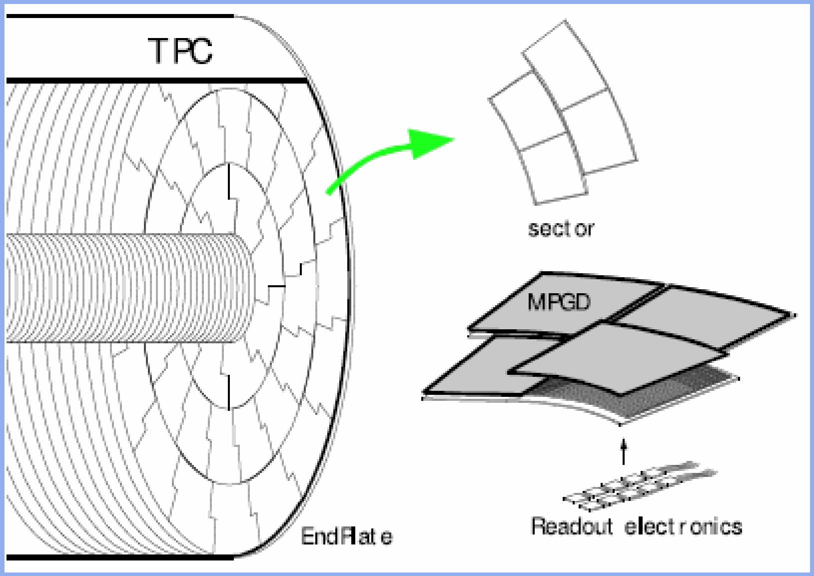
Prototype modules:



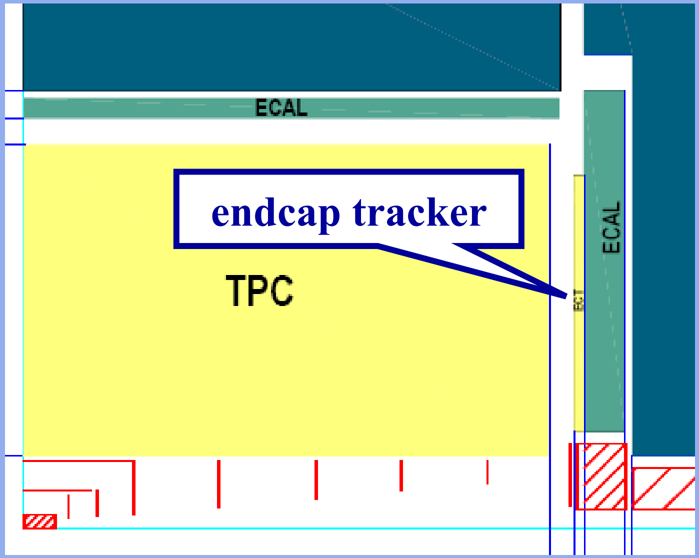
Time Projection Chamber

- GLD, LDC and 4th:
  high resolution TPC as main tracker
  - 3 – 4 m diameter
  - ≈ 4.5 m length
  - low mass field cage
    - $3\% X_0$ barrel
    - $< 30\% X_0$ endcap
  - ≈ 200 points/track
  - ≈ 100 µm single point res.

  $\rightarrow \Delta(1/p_T) = 10^{-4}$ /GeV
  (10 times better than LEP!)



- Complemented by Forward Tracking
  - endcap between TPC and ECAL
  - Si strip, straw tube, GEM-based, … are considered

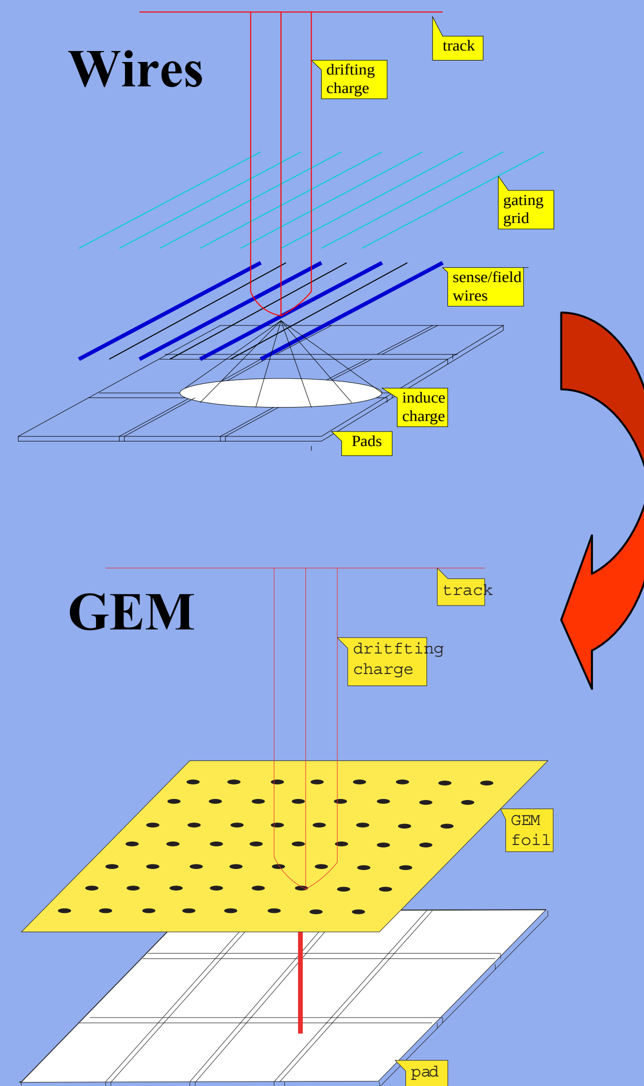


- TPC development performed in LCTPC collaboration

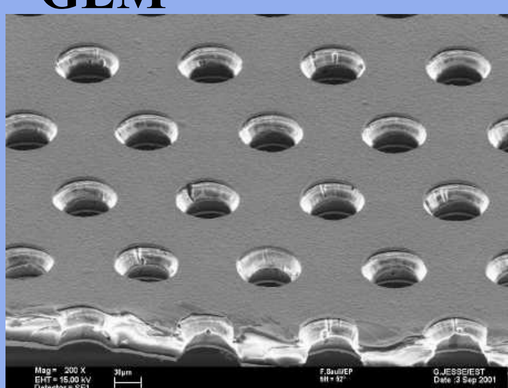
Time Projection Chamber

- New concept for gas amplication at end flanges: Replace proportional wires by Micro Pattern Gas Detectors (MPGD)

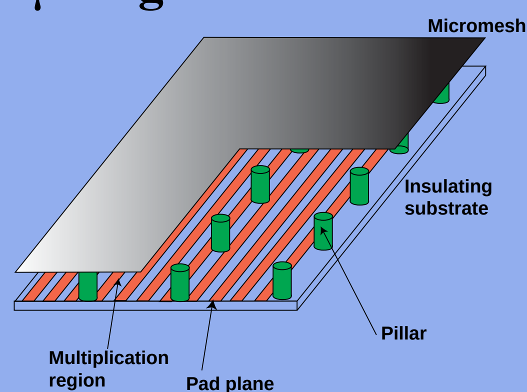
- GEM or MicroMegas
  - finer dimensions
  - two-dimensional symmetry → no E×B effects
  - only fast electron signal
  - intrinsic suppression of ion backdrift



GEM

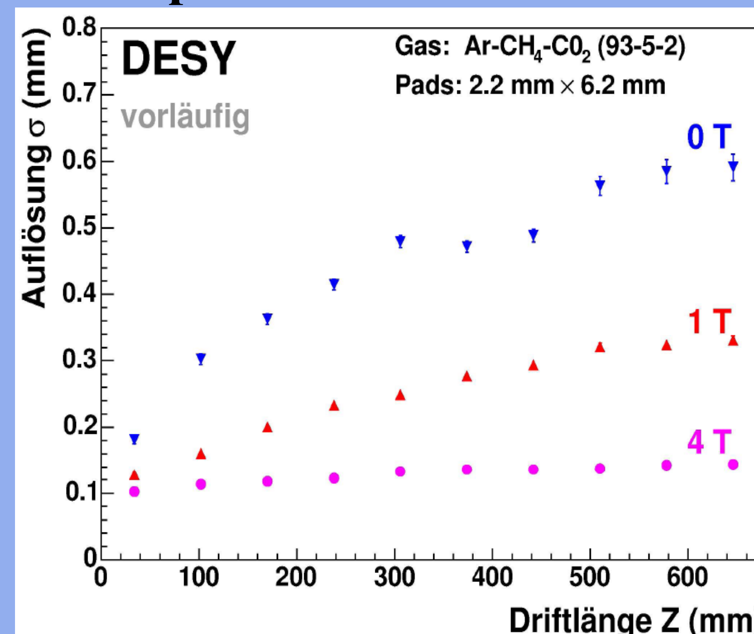


µMegas



- Principle of MPGD based TPC established
  many small scale prototype experiments over the last ≈ 5 years

Example:



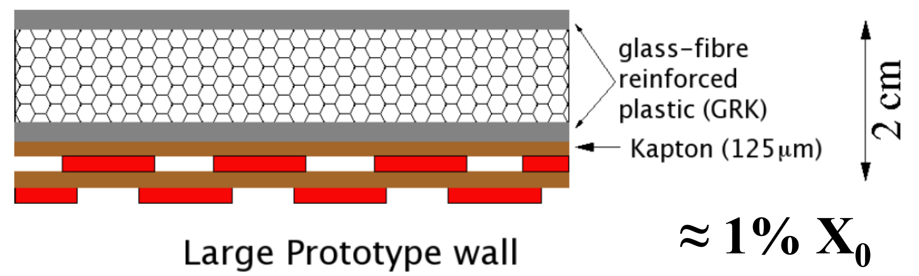
- cosmics, testbeam
- magnetic field

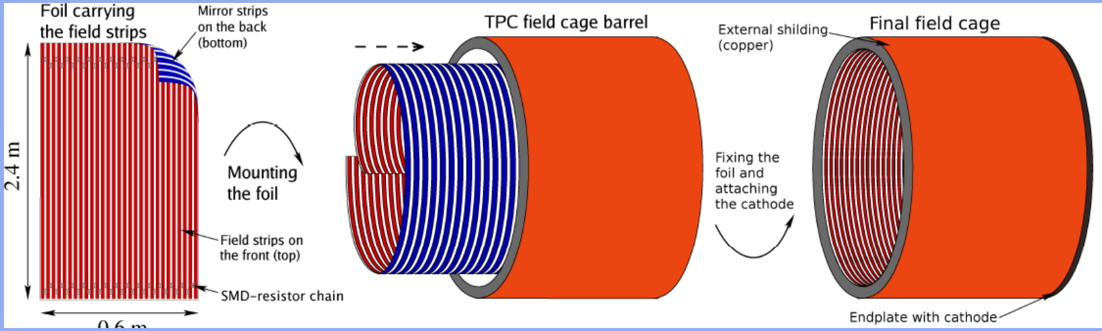
- under construction for experiments (MICE, T2K)

Single point resolution O(100 μm)
established in
- small scale prototypes
- high magnetic fields

Time Projection Chamber

- Low mass fieldcage
  - large prototype under construction
  - using composite material

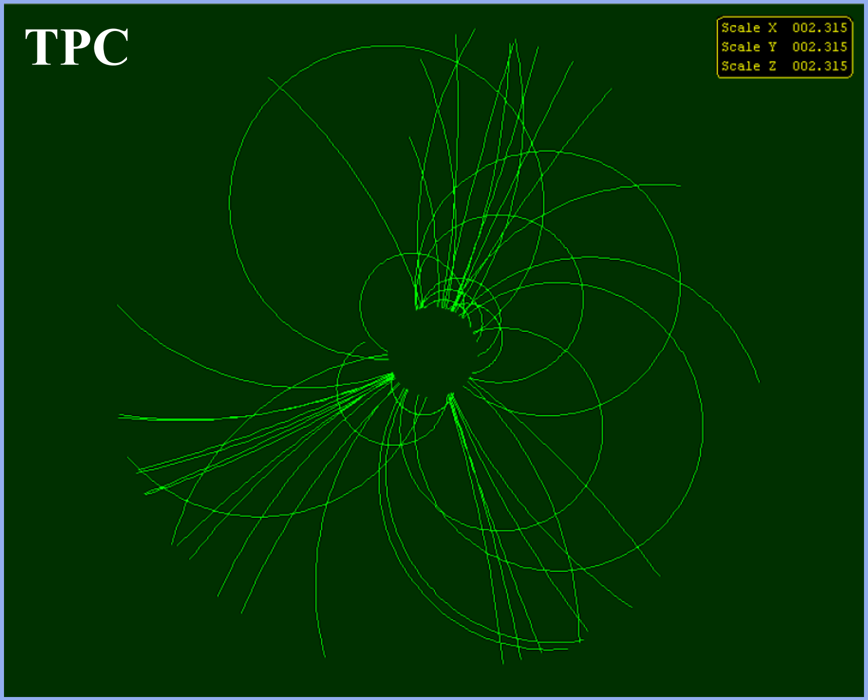


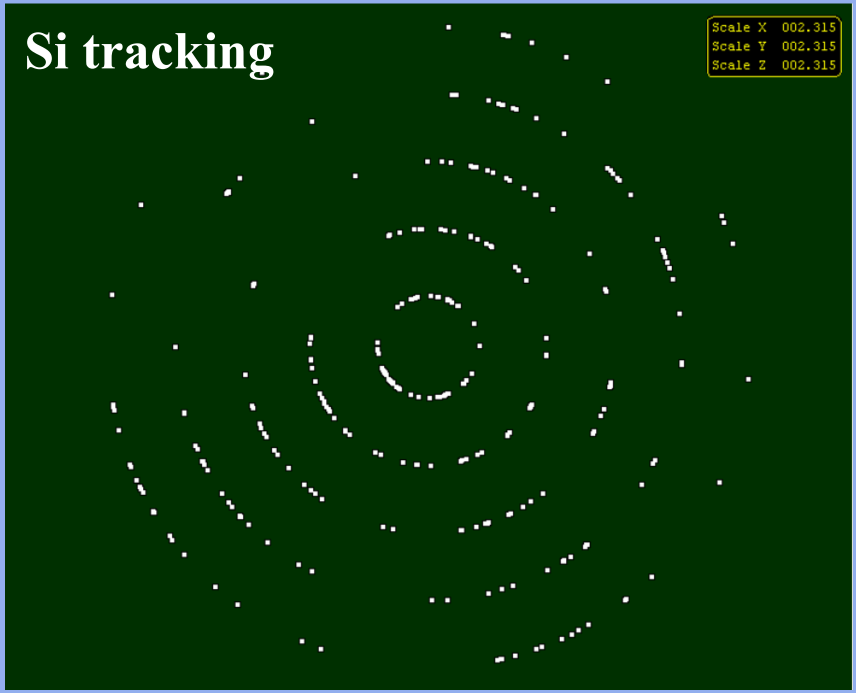


- Electronics
  - few 10^6 channels on endplate (ILD)
  - low power to avoid cooling
  - two development paths:
    - FADC based on ALICE ALTRO chip
    - and TDC chips

TPC versus Silicon Tracking

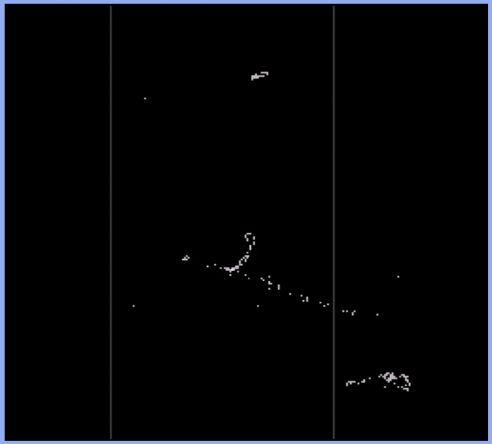
- TPC
  - 200 space points (3-dim) → continuous tracking, pattern recognition
  - low mass easy to achieve (barrel)
- Silicon tracking
  - better single point resolution
  - fast detector (bunch identification)



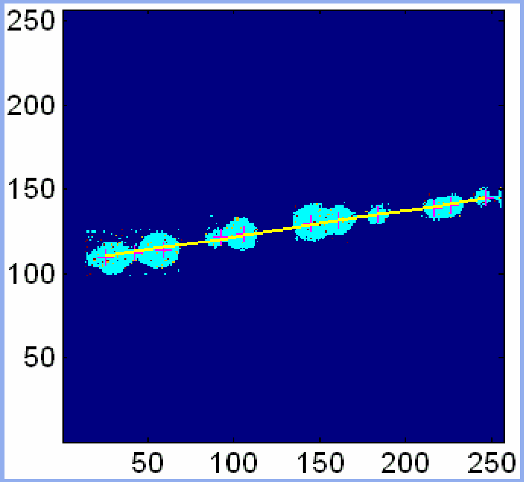


Silicon TPC Readout

- **Combine MPGD with pixel readout chips**
- **2-d readout with**
  - **- Medipix2 0.25 µm CMOS**
  - **- 256×256 pixel**
  - **- 55 ×55 µm²**



(Micromegas)

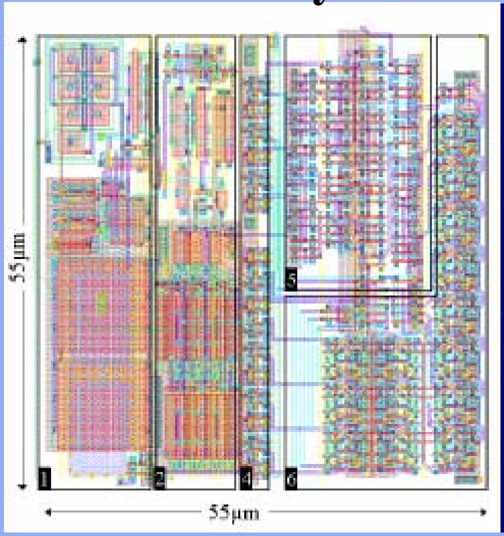


(GEM)

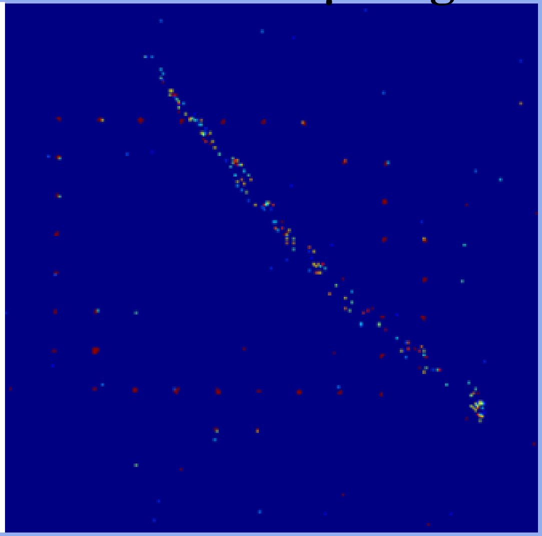
- **Medipix (2-d) → TimePix (3- d)**
- **50 - 150 MHz clock to all pixel**
- **1st version under test**

- **Will eventually lead to**
  - **TPC diagnostic module**
  - **cluster counting to improve dE/dx**

TimePix layout



TimePix + µMegas



Calorimetry

- **The paradigm of Particle Flow Algortihm (PFA) for optimum jet energy resolution:**
  - **try to reconstruct every particle**
  - **measure charged particles in tracker**
  - **measure photons in ECAL**
  - **measure neutral hadrons in ECAL+HCAL**
  - **use tracker + calorimeters to tell charged from neutral**

- **average visible energy in a jet**
  ≈ 60% charged particles
  ≈ 30% photons
  ≈ 10% neutral hadrons

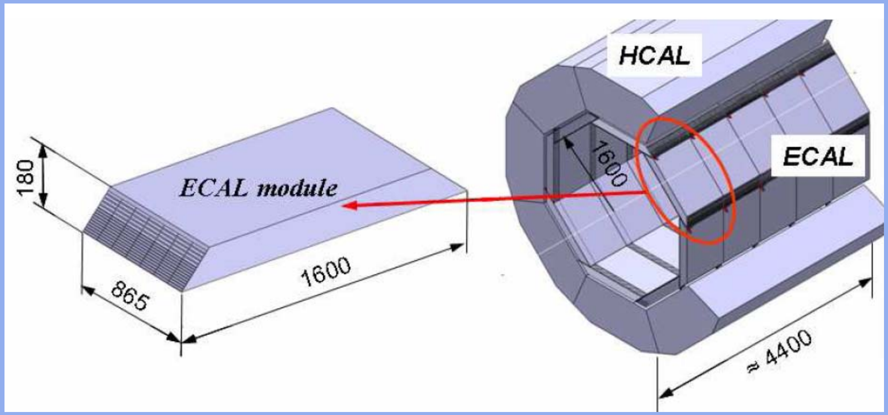
particles in jet	fraction of energy in jet	detector	single particle resolution	jet energy resolution
charged particles	60 %	tracker	$\frac{\sigma_{p_t}}{p_t} \sim 0.01\% \cdot p_t$	negligible
photons	30 %	ECAL	$\frac{\sigma_E}{E} \sim 15\%/\sqrt{E}$	$\sim 5\%/\sqrt{E_{jet}}$
neutral hadrons	10 %	HCAL+ECAL	$\frac{\sigma_E}{E} \sim 45\%/\sqrt{E}$	$\sim 15\%/\sqrt{E_{jet}}$

- **Jet resolution**
  $\sigma = \sigma_{charged} \oplus \sigma_{photons} \oplus \sigma_{neutral} \oplus \sigma_{confusion}$

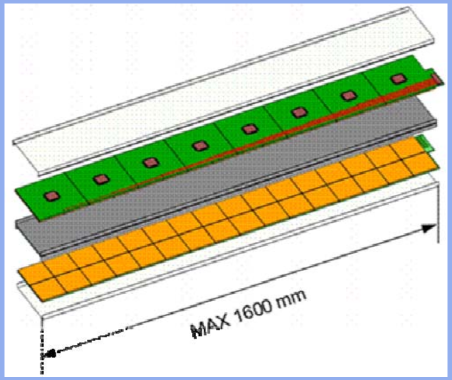
- **confusion term arises from misassignment, double counting, overlapping clusters, …**

- **minimizing confusion term requires highly granular calorimeter both ECAL and HCAL**

- CALICE collaboration (Calorimeter for the Linear Collider Experiment)
  > 30 institutes from > 10 countries
  - performs R&D effort to validate the concept and design calorimeters for ILC experiments



- GLD, LDC, SID concepts based on PFA calorimeters
- ECAL:
  - SiW calorimeter
  - 23 X_0 depth
  - 0.6 X_0 – 1.2 X_0 long. segmentation
  - 5×5 mm^2 cells
  - electronics integrated in detector
- Alternative:
  W + Scintillating strips (GLD)

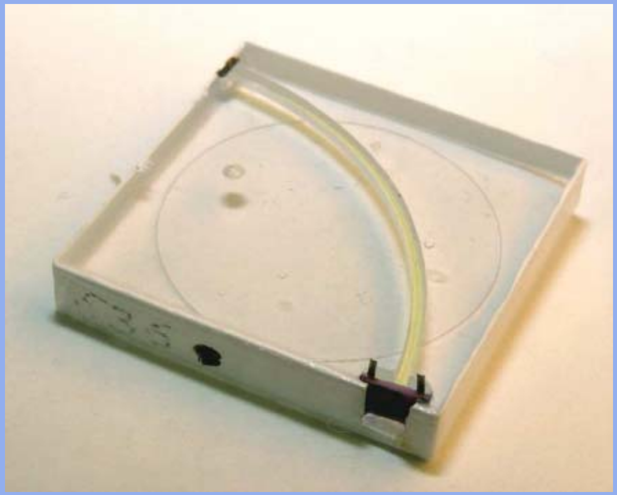


ECAL slab
- FE ASIC
- PCB board
- Si pads

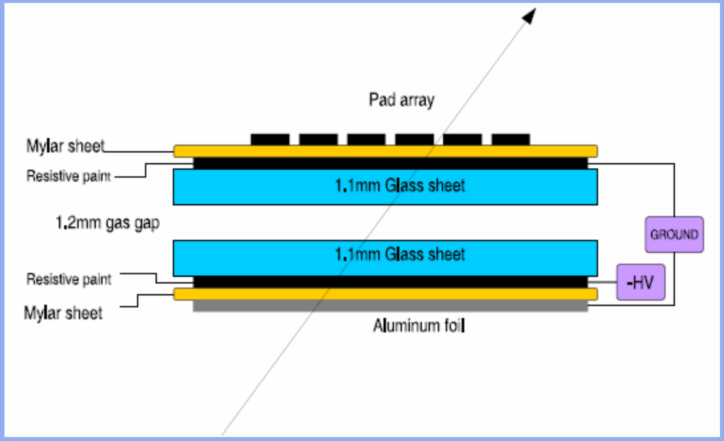
Calorimetry

- **HCAL:**
  2 options under consideration

- **Analogue Scintillator Tile calorimeter**
  - **moderately segmented 3×3 cm^2**
  - **use SiPM for photo detection**

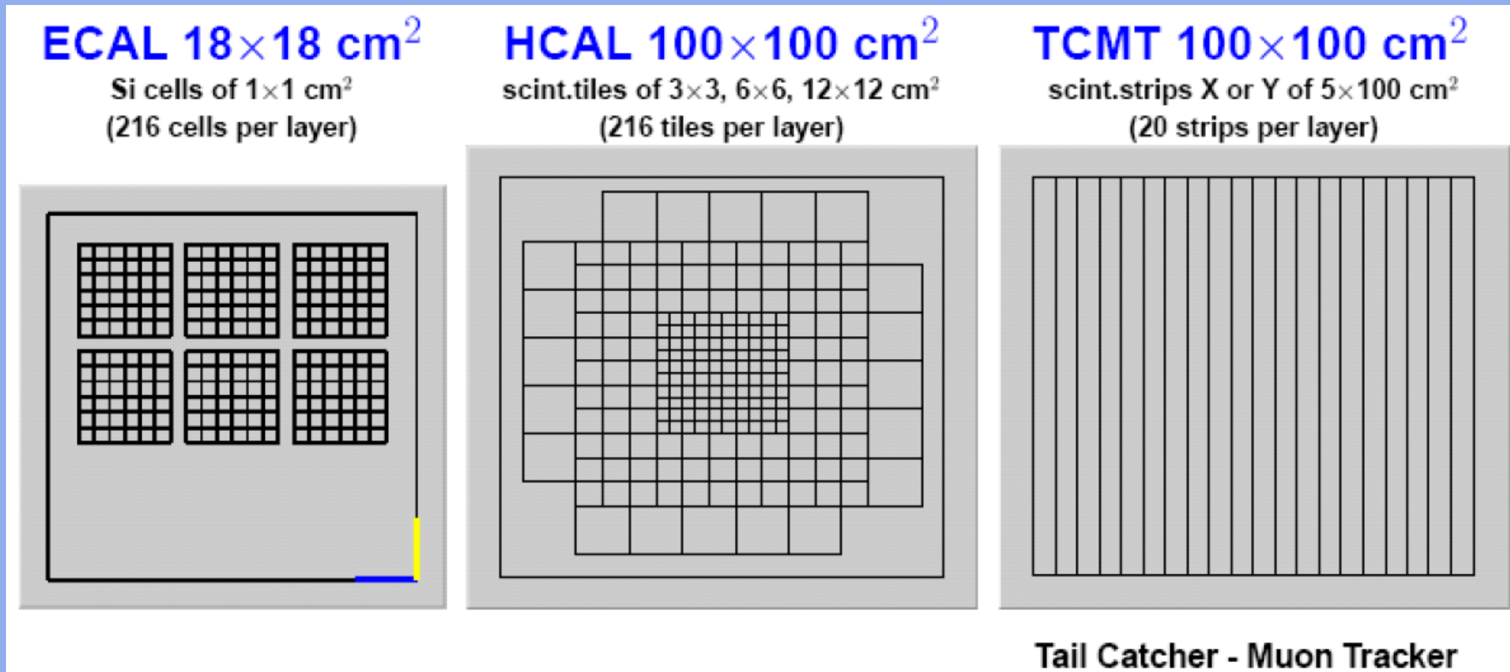


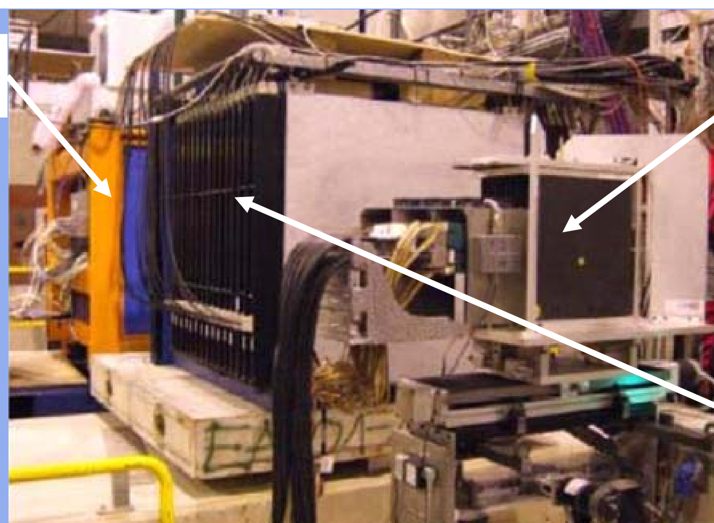
- **Gaseous Digital HCAL**
  - **finer segmentation 1×1 cm^2**
  - **binary cell readout**
  - **based on RPC, GEM or µMegas detectors**



Calorimeter

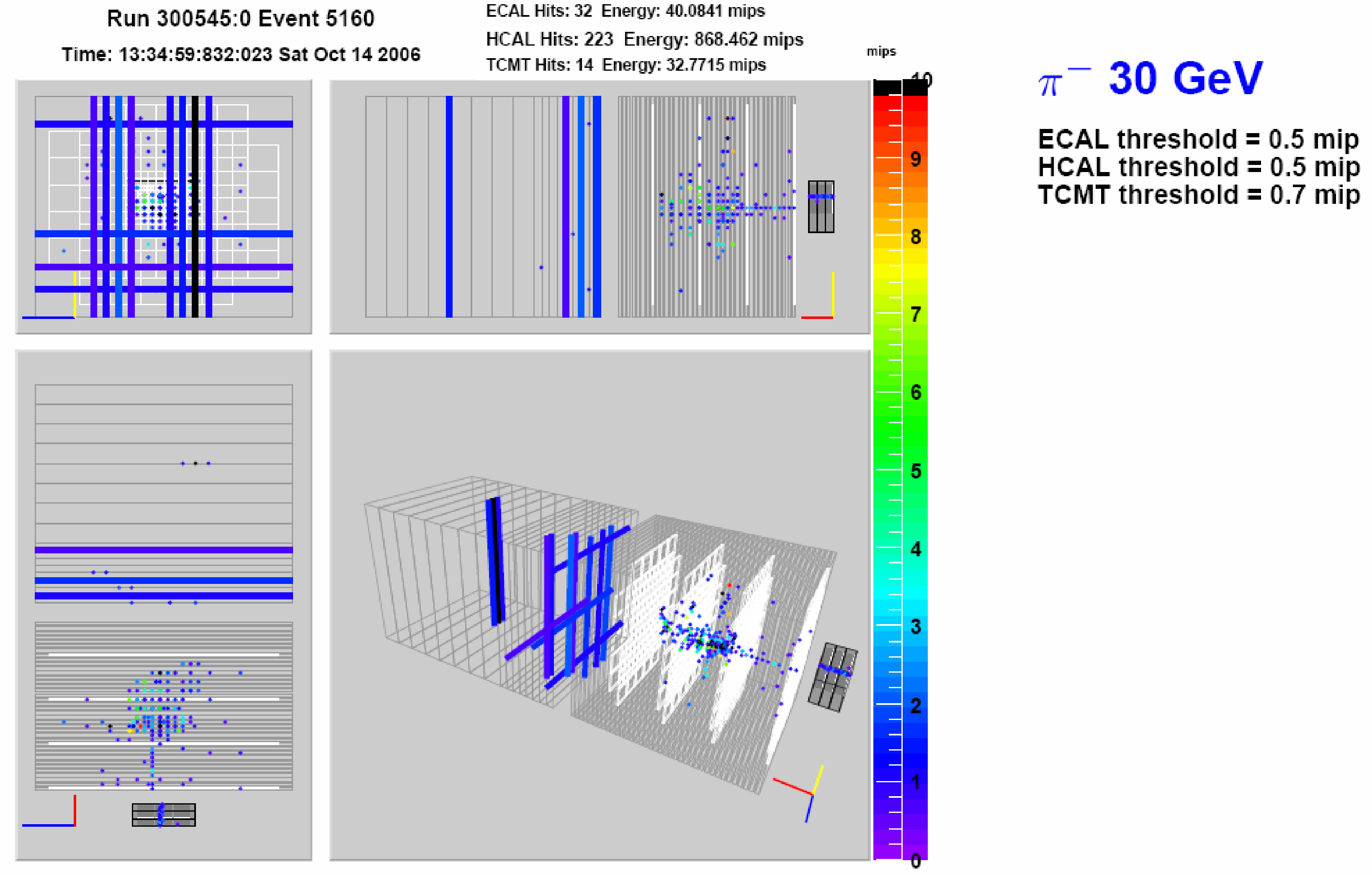
- **CALICE Testbeam at CERN (2006/07)**





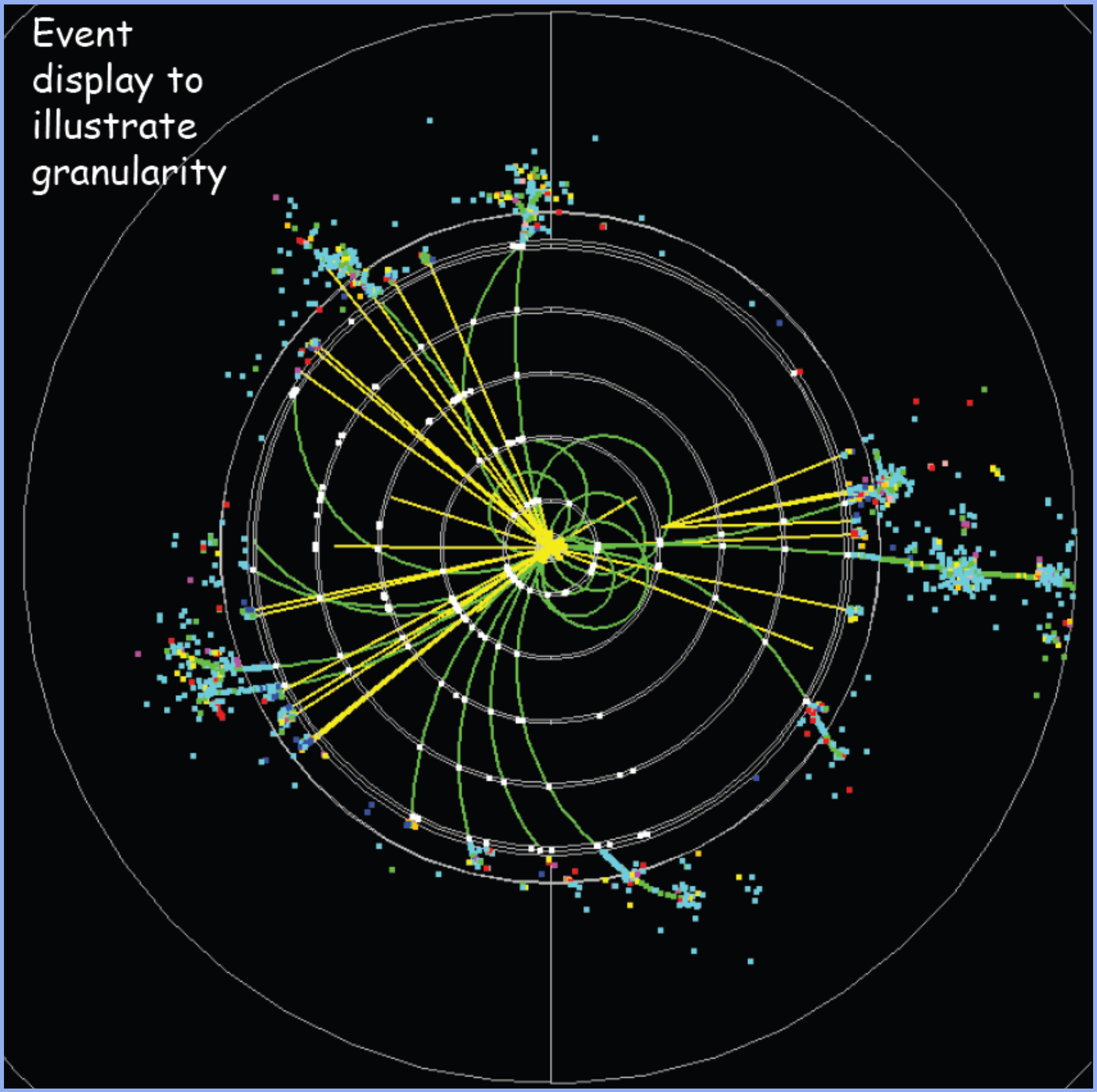
Calorimeter

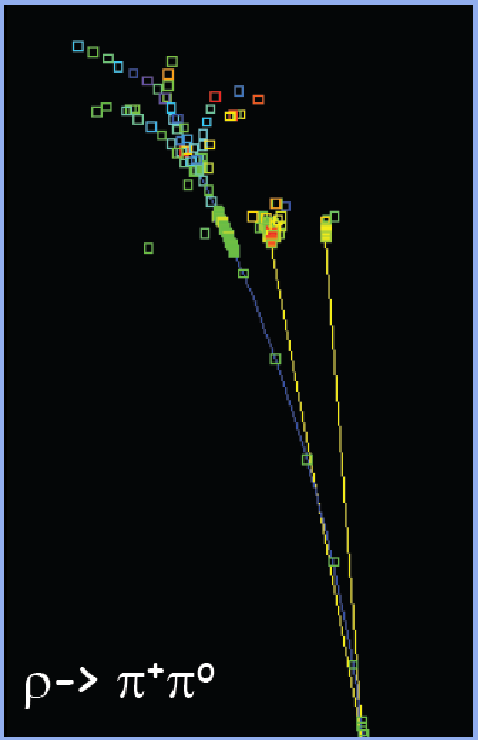
- CALICE Testbeam at CERN (2006/07)



- CALICE prototype now moving to FNAL, start test beam in summer 2008

- **Simulation of an ILC event**



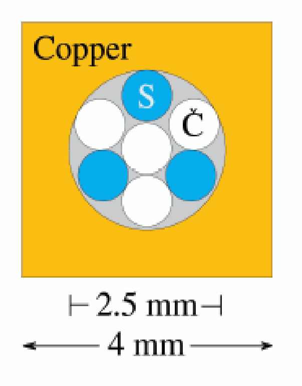


Dual Readout Calorimeter

- 4th concept
  - calorimetry based on dual/triple readout approach
  - complementary measurements of showers reduce fluctuations

- Fluctuations of local energy deposits → Fine spatial sampling with SciFi every 2 mm — like SPACAL (H1)

- Fluctuations in electromagnetic fraction of shower energy → clear fibres measure only EM component by Cerenkov light of electrons (E_{th} = 0.25 MeV) — like HF (CMS)



Dual Readout Module (DREAM) in testbeam at CERN

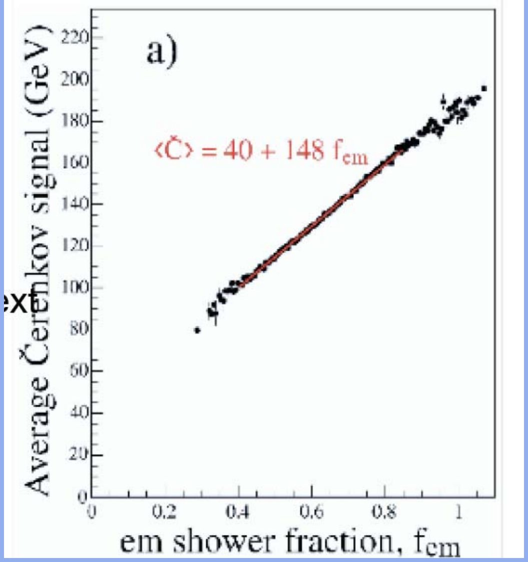
- Binding energy losses from nuclear break-up → try to measure MeV neutron component of shower (history or Li/B loaded fibres) — triple readout

- **DREAM testbeam:**
  - **measure each shower twice**

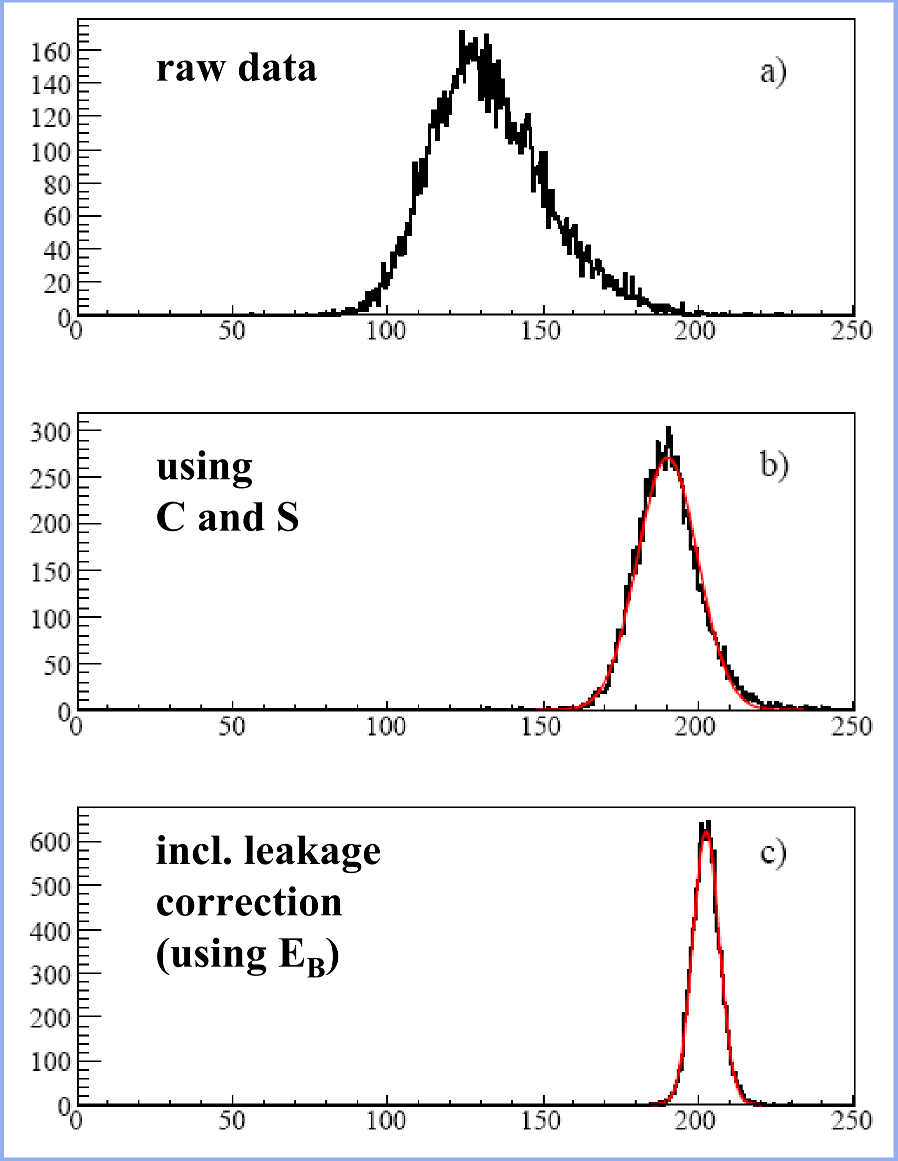
$$(e/h)_C = \eta_C \approx 5$$
$$(e/h)_S = \eta_S \approx 1.4$$

$$C = [f_{em} + (1 - f_{em})/\eta_C]E$$
$$S = [f_{em} + (1 - f_{em})/\eta_S]E$$

$$\rightarrow C/E = 1/\eta_C + f_{em}(1 - 1/\eta_C)$$



200 GeV π^- beam at CERN



Dual Readout Calorimeter

- **From DREAM to an ILC calorimeter:**

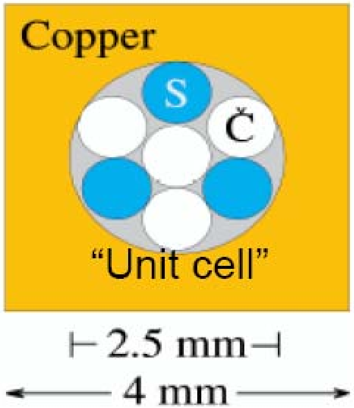
DREAM module

3 scintillating fibers
4 Cerenkov fibers

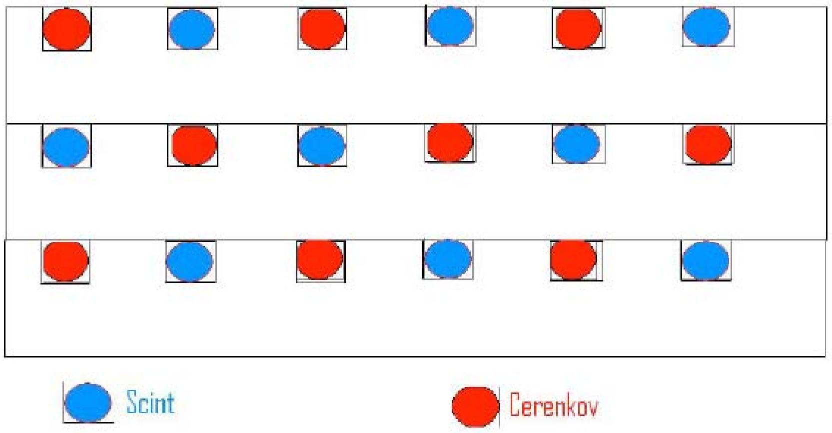
ILC-type module

2mm W, Pb, or brass plates;
fibers every ~2 mm

(Removes correlated fiber hits)



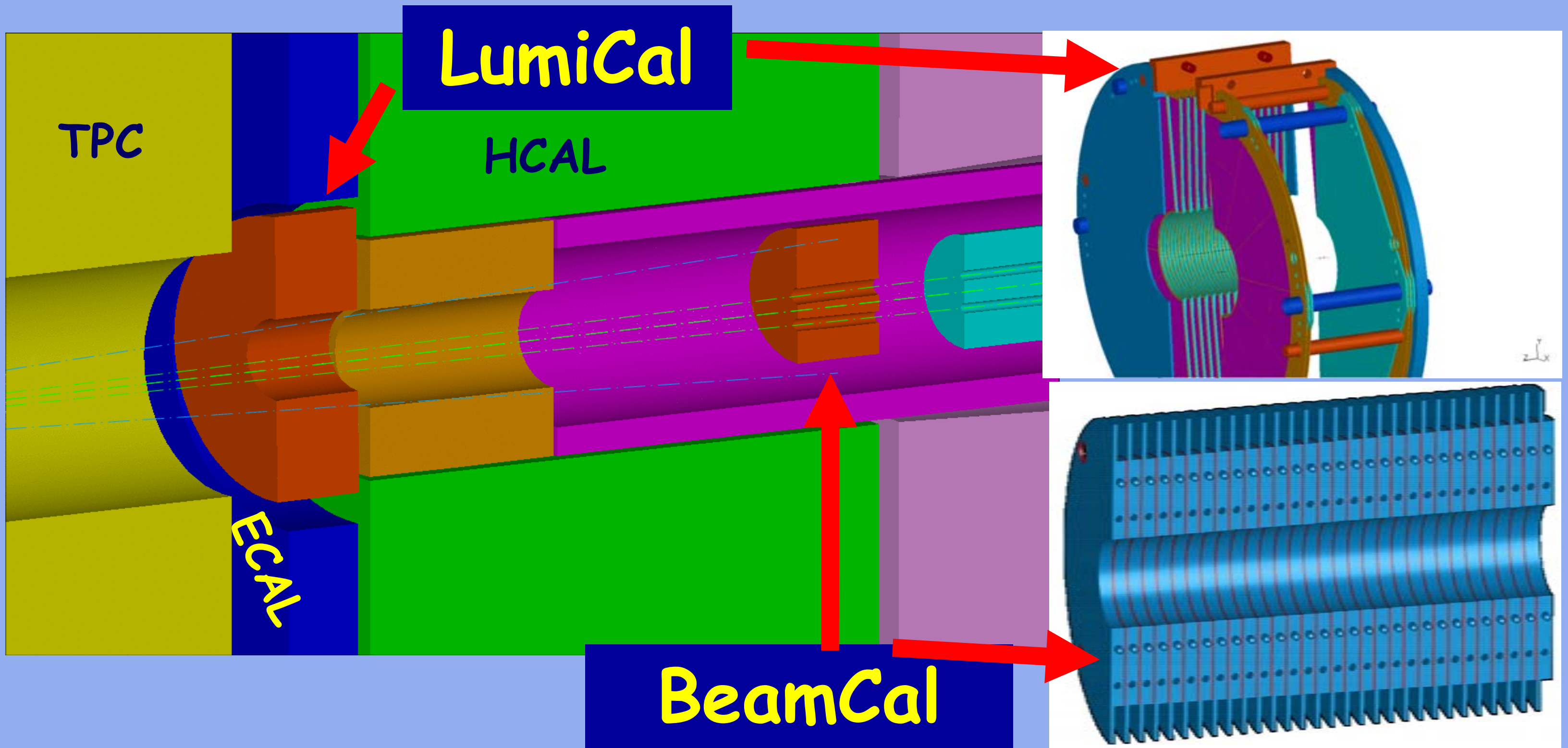
→



Forward Calorimetry

- Forward calorimeters needed
    - LumCal: precise luminosity measurement
      precision < 10^{-3}, i.e. comparable to LEP or better
    - BeamCal: beam diagnostics & luminosity optimisation

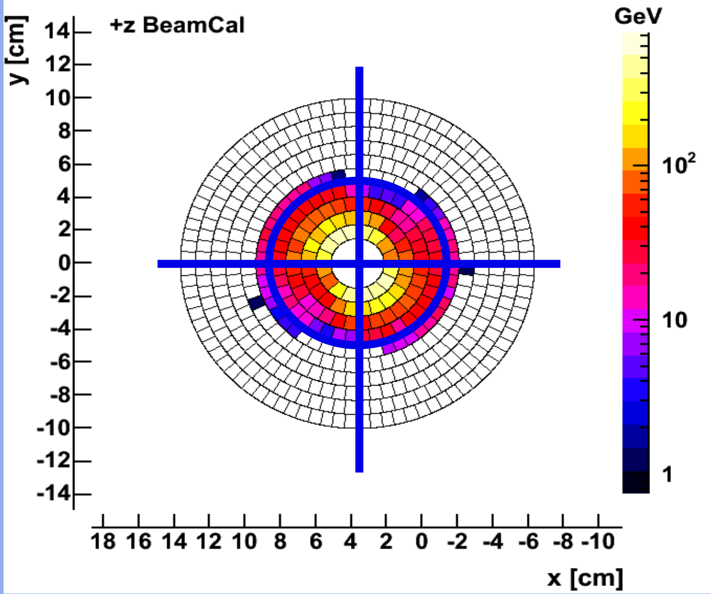
- Detector technology: tungsten/sensor sandwich
- Example: LDC design for zero cross angle
  to be adapted for 14 mrad ILC design



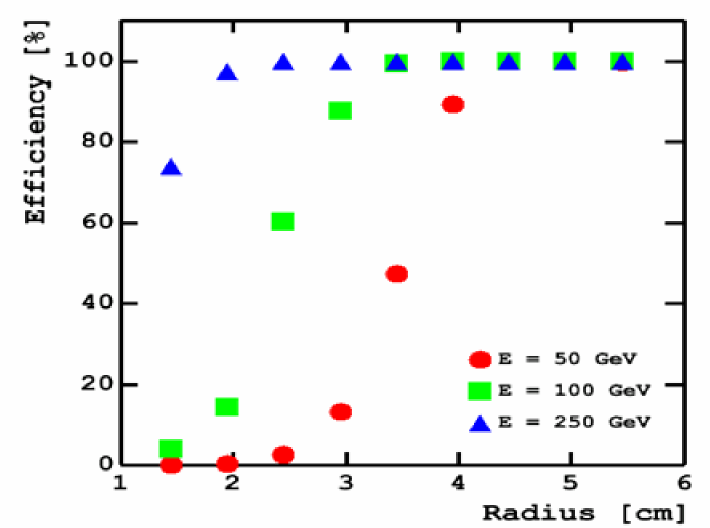
BeamCal

- Challenges:
  - ≈ 15000 e^+e^- pairs per BX in MeV range, extending to GeV
  - total deposit O(10 TeV)/BX
  - ≈ 10 MGy yearly rad. dose
  - identification of single high energy electrons to veto two-photon bkgd.
- Requires:
  - rad. hard sensors (diamond)
  - high linearity & dynamic range
  - fast readout (307 ns BX interval)
  - compactness and granularity

Energy deposit per BX:

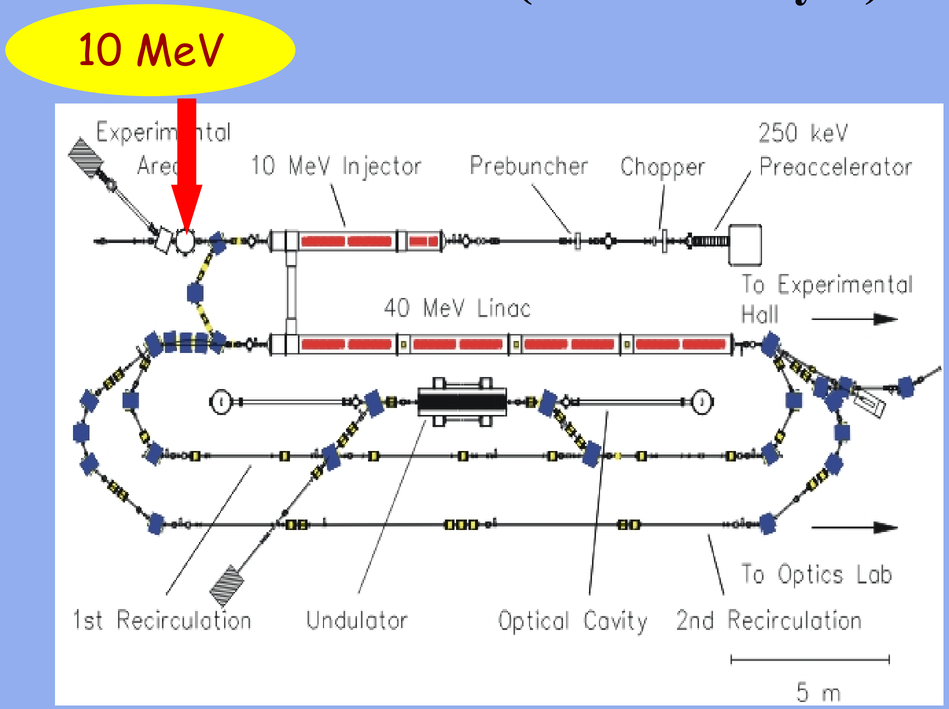


Electron ID efficiency:

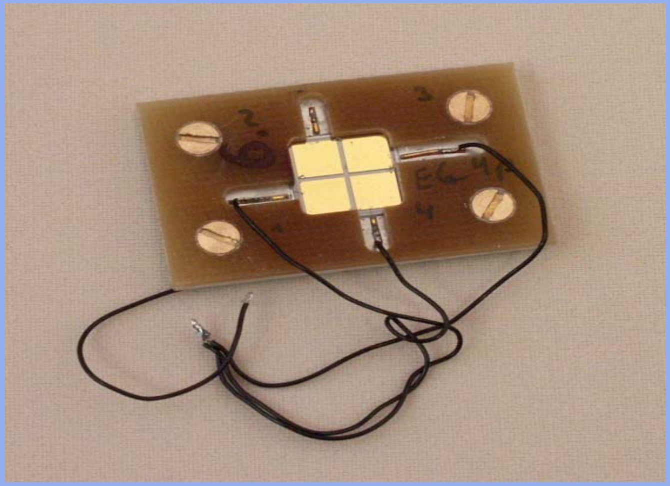


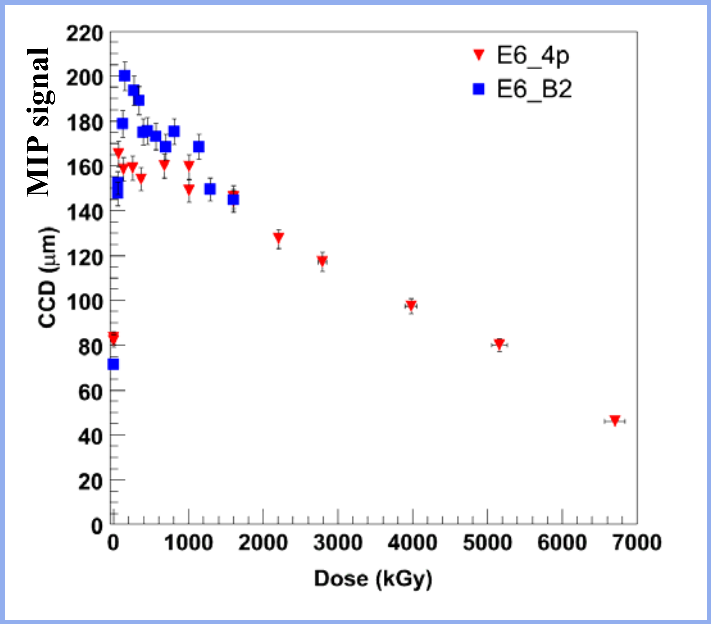
Forward Calorimetry

- Sensors tests at DALINAC (Darmstadt)
  current 1 – 100 nA (10 nA ≈ kGy/h)



Diamond sensor after ≈ 7 MGy

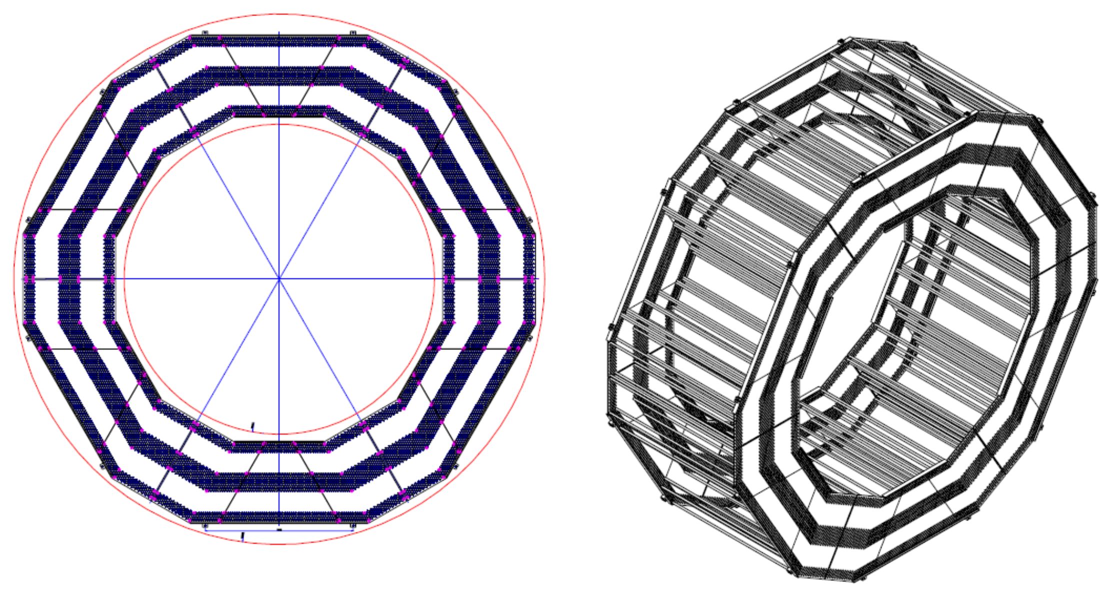


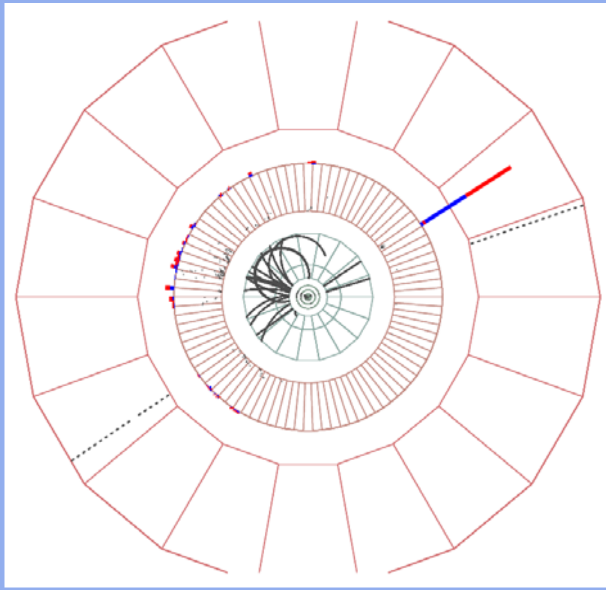


- Alternative sensor materials
  - GaAs
  - SiC
  - radiation hard silicon

Muon Detectors

- GLD, LDC & SiD have muon detection only: RPC, scint. fibre detector momentum in central tracker
- 4th concept:
  - muon spectrometer between coils
  - high precision drift tubes





$H^0Z^0 \rightarrow W^+W^-\mu^+\mu^- \rightarrow jje^-\bar{\nu}_e\mu^+\mu^-$

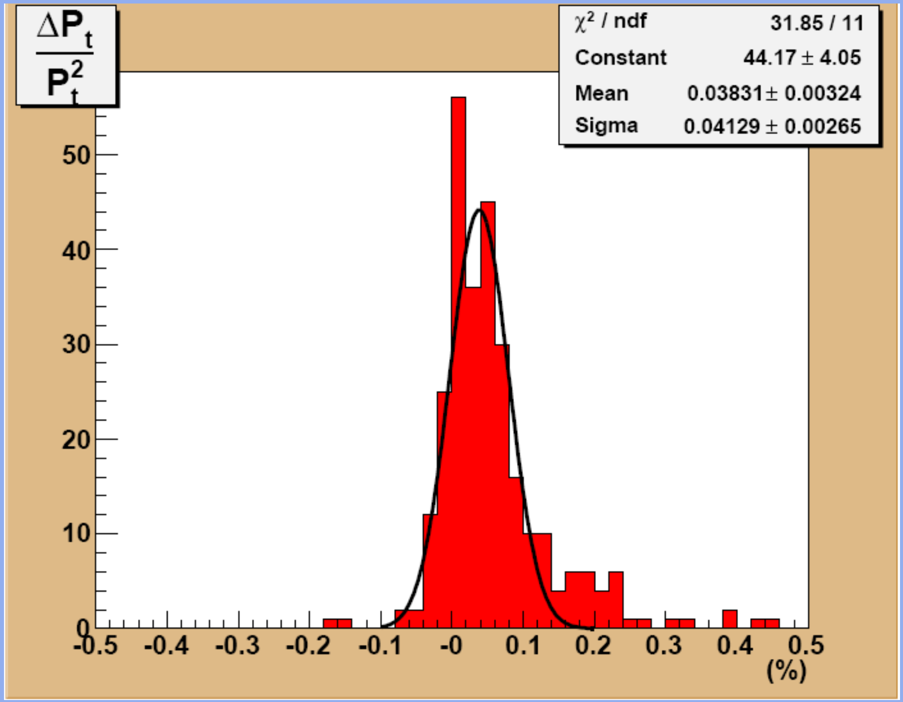
- low p_T-threshold for muons
- excellent π/μ separation
  also exploiting multiple readout calorimeter

Detector Performance

- Disclaimer:
  - all in early design phase
  - comparison difficult
  - assume that R&D is succesful and large scale detectors will keep performance

- A few DOD plots on performance from simulation studies

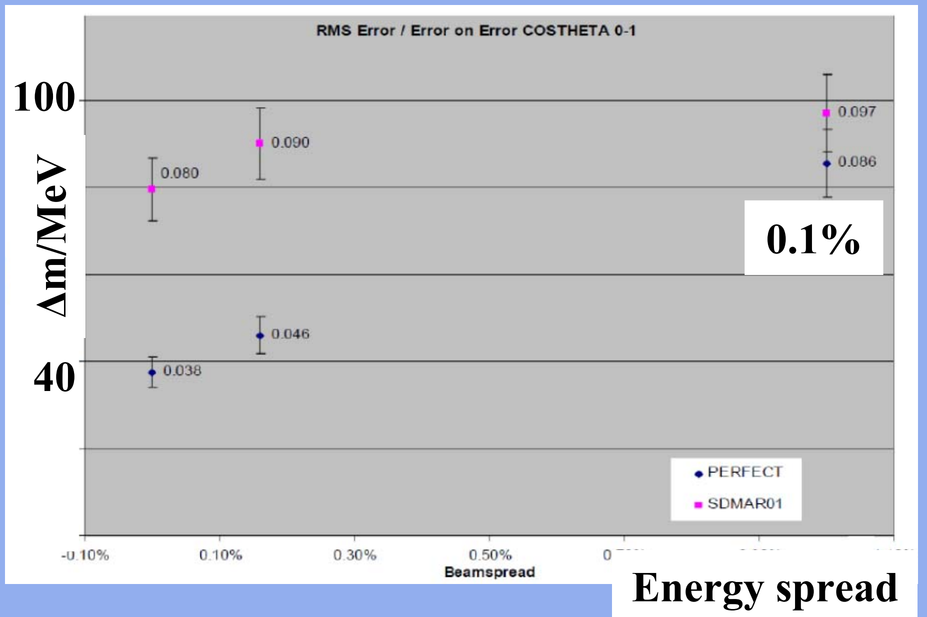
- 4th concept:
  - muon spectrometer
    $\sigma(1/p_T) \approx 4 \cdot 10^{-4}$ /GeV



Detector Performance

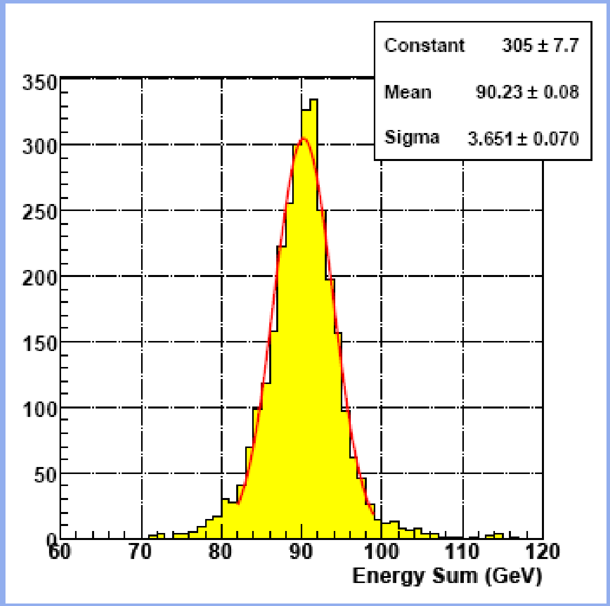
- **SiD Tracking:**

  143 GeV selectron at 1 TeV
  mass measurement from end point
  - 0.1% beam energy spread
  - 100 MeV error
  not limited by tracker



- **GLD calorimetry:**
  test of PFA with Z-pole events
  $Z \rightarrow$ hadrons

  38% mass resolution
  improvements are still possible



Detector R&D in Europe

- **Next step:**
  from small scale proof-of-principle experiments to larger scale prototypes

- **Example:**
  the EUDET programme in Europe
  - **improvements of infrastructures for larger scale detector prototypes (not only ILC)**
  - **devised in close cooperation with the international R&D collaborations**

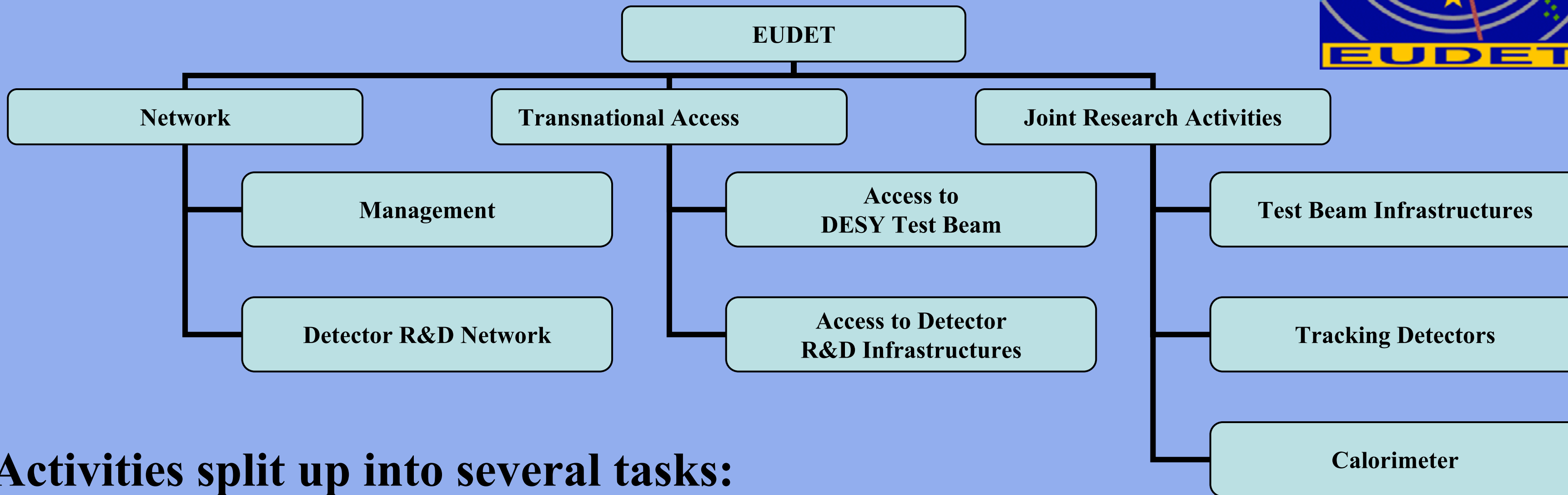
- **Project started in 2006 for 4 years duration**

- **Transnational Access:**
  - **support for (European) groups**
    - **DESY testbeam**
    - **usage of EUDET infrastructures**

- **More information at www.eudet.org**

Detector R&D in Europe

European infrastrucutre projects are based on three pilars:



Activities split up into several tasks:

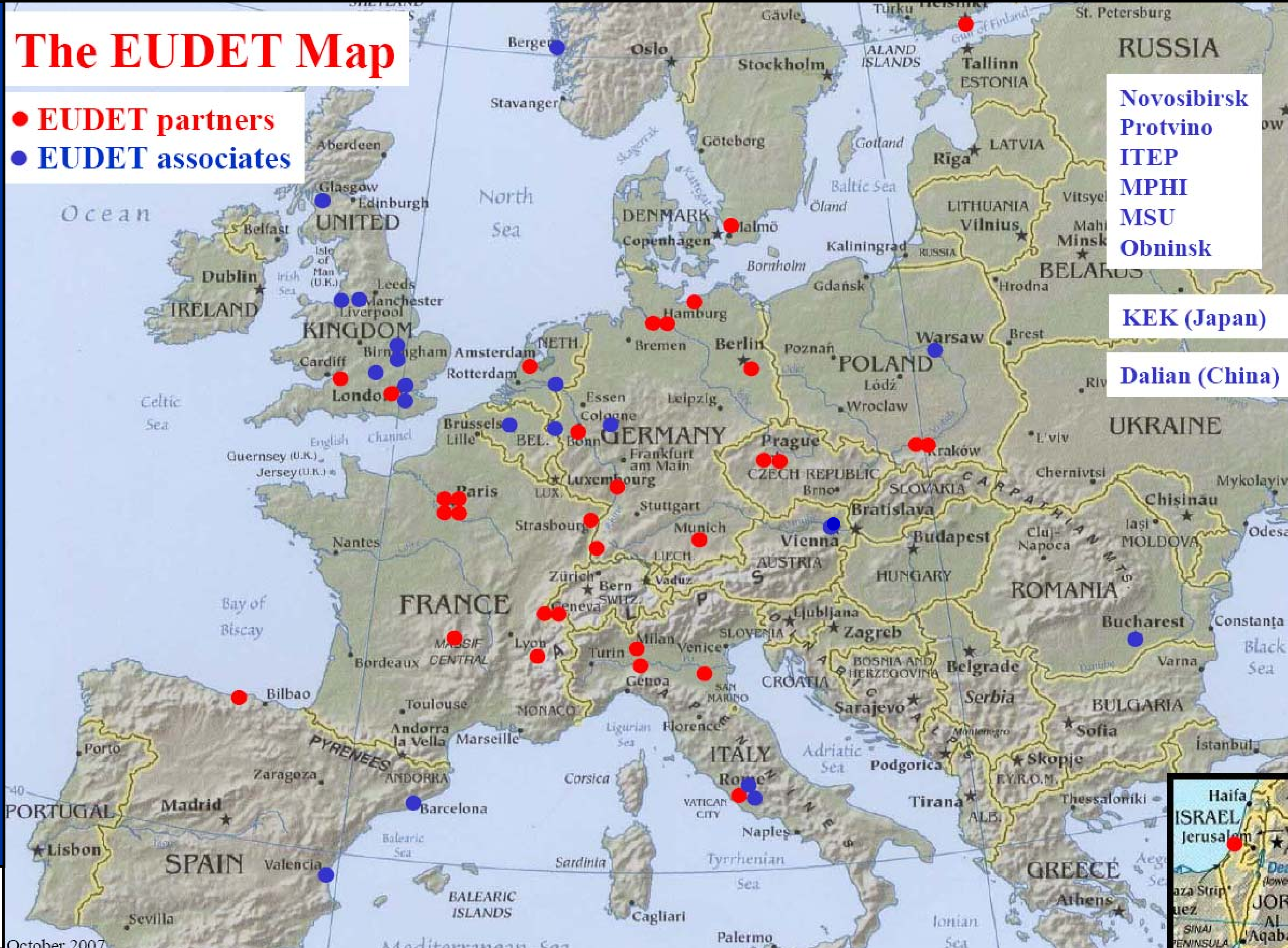
Detector R&D Network:
- Information exchange and intensified collaboration
- Common simulation and analysis framework
- Validation of simulation
- Deep submicron radiation-tolerant electronics

Test Beam Infrastructure:
- Large bore magnet
- Pixel beam telescope

Tracking Detectors:
- Large TPC prototype
- Silicon TPC readout
- Silicon tracking

Calorimeter:
- ECAL
- HCAL
- Very Forward Calorimeter
- FE Electronics and Data Acquistion System

EUDET


The EUDET Map
● EUDET partners
● EUDET associates
Novosibirsk
Protvino
ITEP
MPHI
MSU
Obninsk
KEK (Japan)
Dalian (China)
RUSSIA
St. Petersburg
Helsinki
Turku
Gävle
Oslo
Bergen
Stavanger
Stockholm
ALAND ISLANDS
Tallinn
ESTONIA
Göteborg
Gotland
Riga
LATVIA
LITHUANIA
Vilnius
Minsk
BELARUS
Hrodna
Brest
Aberdeen
Glasgow
Edinburgh
UNITED KINGDOM
Belfast
Dublin
IRELAND
Isle of Man (U.K.)
Irish Sea
Leeds
Manchester
Liverpool
Birmingham
Cardiff
London
Ocean
North Sea
Celtic Sea
English Channel
Guernsey (U.K.)
Jersey (U.K.)
DENMARK
Copenhagen
Malmö
Baltic Sea
Öland
Bornholm
Kaliningrad
Gdańsk
Hamburg
Bremen
Berlin
Poznań
POLAND
Warsaw
Łódź
Wrocław
Amsterdam
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Black Sea
Varna
Bordeaux
MASSIF CENTRAL
Lyon
Milan
Turin
Venice
Genoa
SAN MARINO
BOSNIA AND HERZEGOVINA
Sarajevo
Belgrade
Serbia
BULGARIA
Sofia
Bilbao
Toulouse
MONACO
Florence
Ligurian Sea
Andorra la Vella
ANDORRA
Marseille
PYRENEES
Porto
Zaragoza
ITALY
Adriatic Sea
Podgorica
Montenegro
Skopje
F.Y.R.O.M.
İstanbul
Madrid
PORTUGAL
Corsica
Rome
VATICAN CITY
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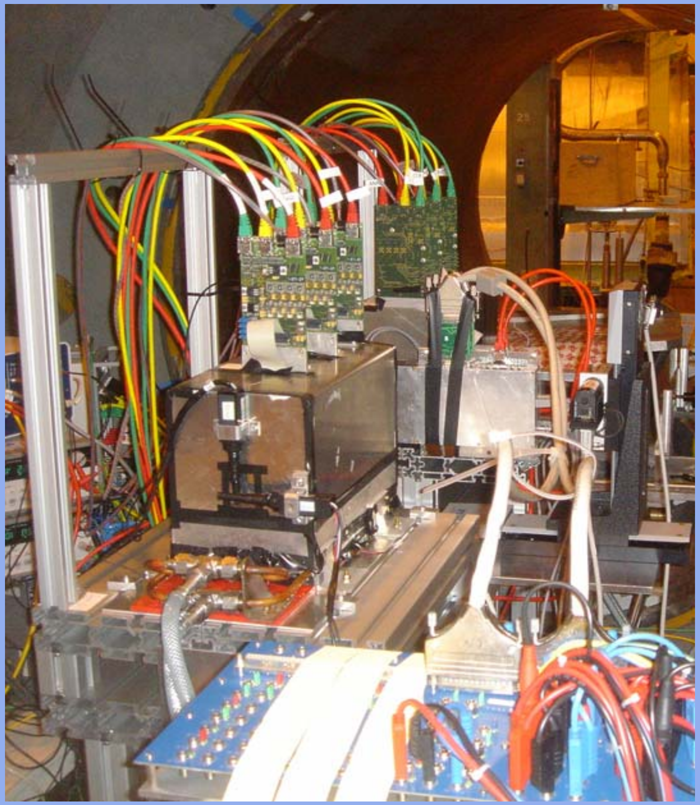
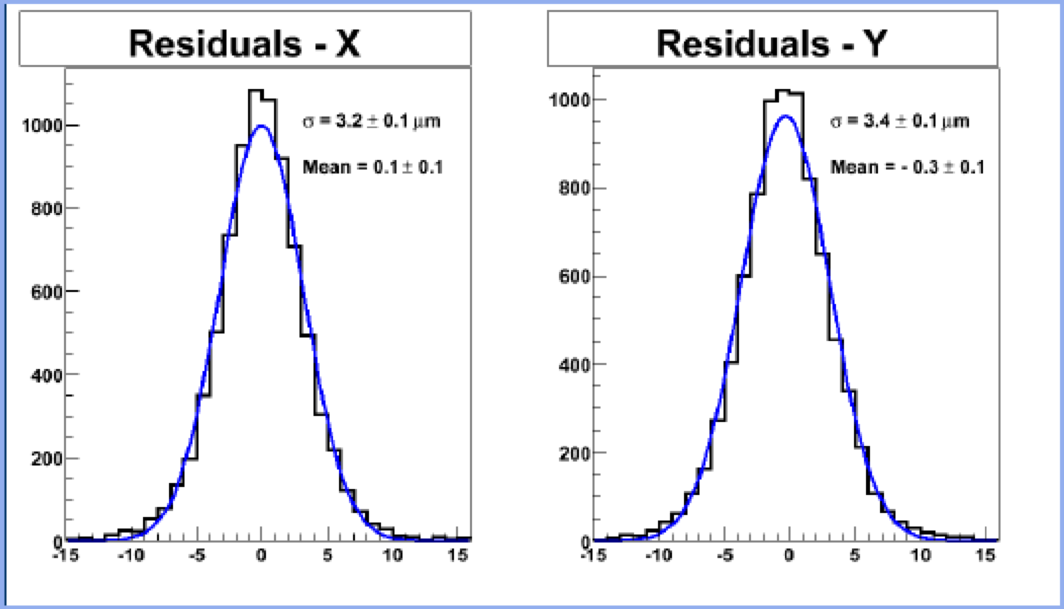
ALB.
Thessaloniki
Barcelona
Lisbon
SPAIN
Valencia
Balearic Sea
BALEARIC ISLANDS
Sardinia
Naples
Tyrrhenian Sea
GREECE
Athens
Aegean Sea
Sevilla
Cagliari
Palermo
Ionian Sea
Haifa
ISRAEL
Jerusalem
Gaza Strip
SINAI PENINSULA
Aqaba
October 2007

Beam Telescope

- 1^{st} version of pixel beam telescope:
  - analogue readout, reduced speed
  - tested & commissioned at DESY
  - now in CERN testbeam
- 2^{nd} version in preparation
  - digital readout

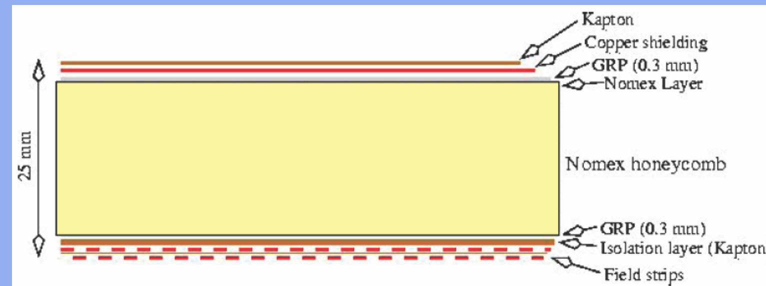


- Performance:
  - test with DEPFET detectors
  - 3.4 µm resolution (intrinsic + telescope)
  - in good agreement with expected DEPFET resolution (3 µm)



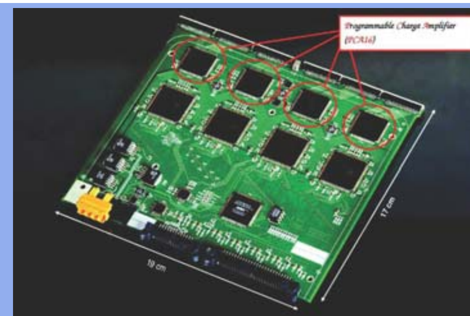
TPC

- **Fieldcage design**
  based on light small prototype TPC



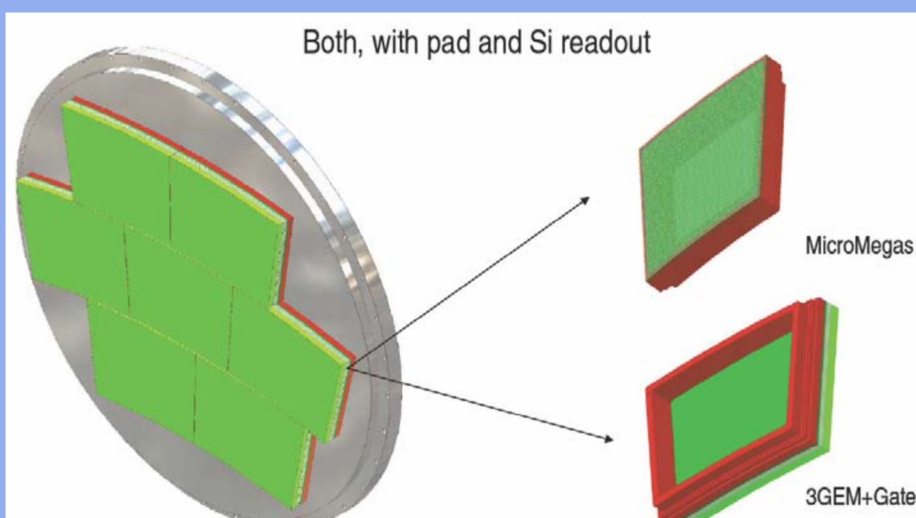
- **dimensions:**
  60 cm length
  80 cm diam.

- **Prototype electronics**
  - FADC based on ALTRO
  - TDC type readout

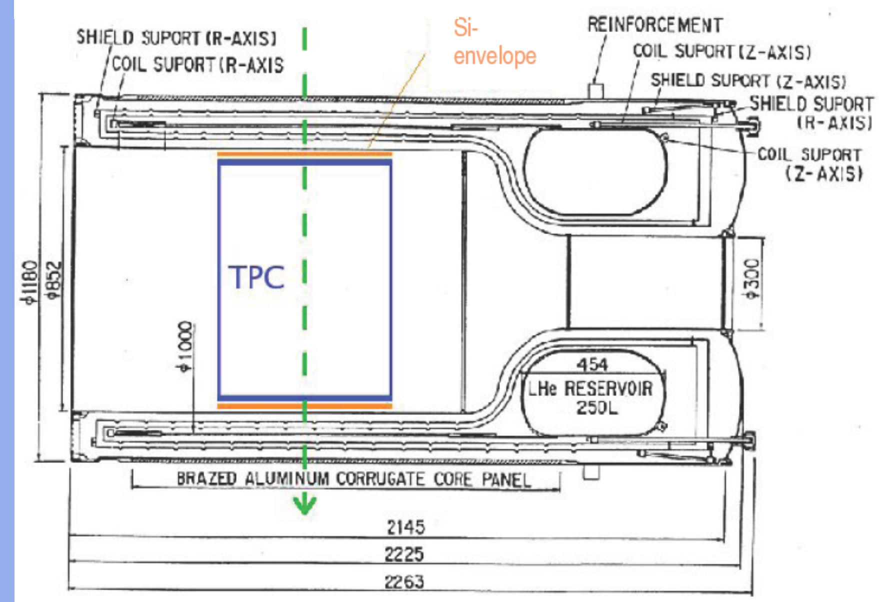


- **few 1000 channels under construction**

- **Well defined interfaces to readout plane**
  - mechanics
  - electronics

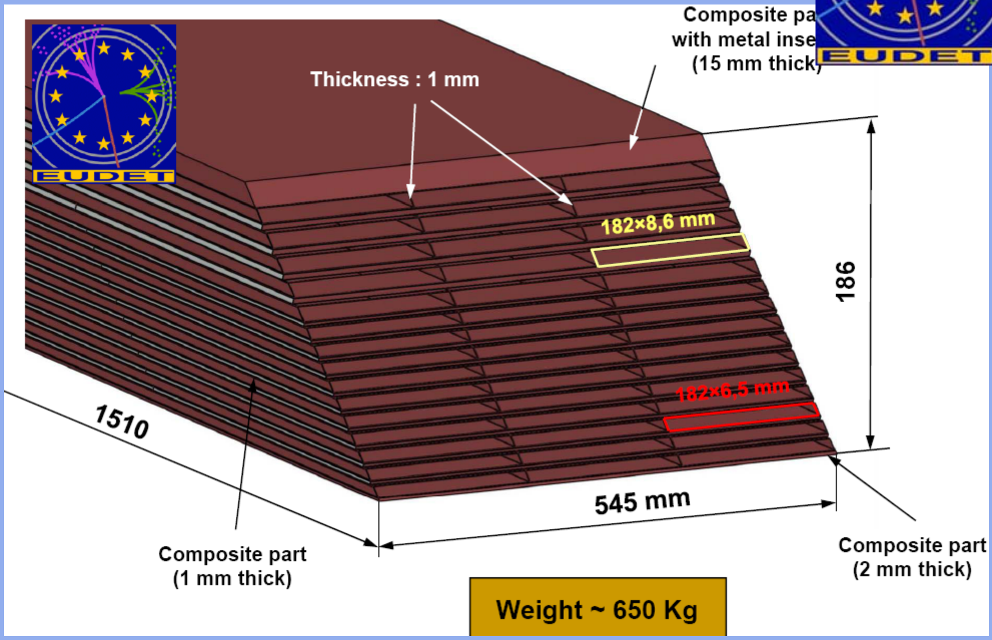


- **TPC in PCMAG**

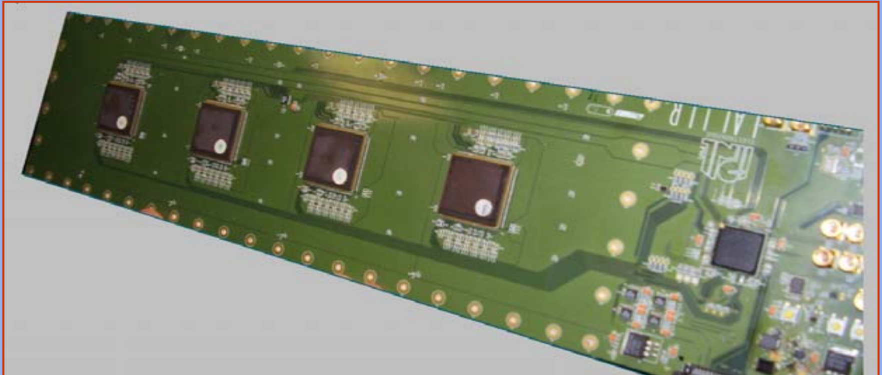


Calorimeter

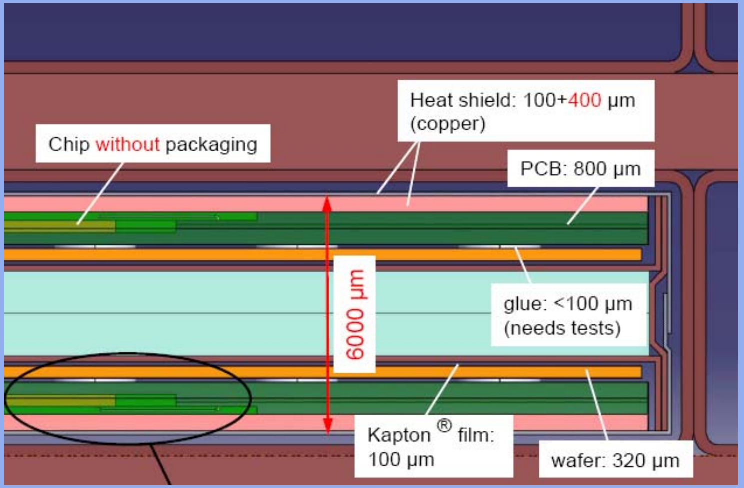
- Design of the EUDET module
  - ECAL (see right)
  - and HCAL



- Design and prototypes of readout ASICs
  - ECAL, DHCAL & AHCAL



DHCAL board



Transnational Access

- Call for applications
  - see advertisement in CERN courier
- EUDET can supply travel funds
  - for DESY testbeam
  - for use of EUDET infrastructures (beam telescope etc.)
- Conditions & requirements:
  - European institute
  - not from country of infrastructure
  - send short scientific proposal to Joachim.Mnich@desy.de
  - + some forms to fill …

CERN Courier May 2007:

EUDET Detector R&D towards the International Linear Collider

Transnational Access to Detector R&D Infrastructures

EUDET is a project supported by the European Union in the Sixth Framework Programme (FP6) structuring the European Research Area. This project aims at creating a coordinated European effort towards research and development for the next generation of large-scale particle detectors. EUDET comprises 23 European partner institutes and 24 associated institutes working in the field of High Energy Physics.

EUDET provides in the framework of the Transnational Access scheme travel support for groups from the EU and countries associated to FP6 using the following infrastructures:

TA1: Experiments at DESY testbeam (http://testbeam.desy.de)
TA2: Experiment using infrastructure developed in the EUDET project: high precision beam telescope; large, low mass TPC field cage; silicon based TPC readout system; infrastructure for development of SI-Stripdetectors; infrastructures for development of granular calorimeters.

TO APPLY FOR EC FUNDED ACCESS

visit our web site http://www.eudet.org to get more information about the modalities of application.

EUDET Summary

- EUDET is an EU funded infrastructure programme for detector R&D
  - well defined programme
  - embedded in international detector R&D collaborations such as CALICE, LCTPC etc.
- Provides additional funds for European institutes
  - to help in the next phase of ILC detector R&D from small to larger prototypes
- Even more important
  - EUDET fertilises collaboration between institutes („community building“)
  - EUDET can help to raise additional funds at national agencies
- Can provide some support for other European groups
  → Transnational Access
- EUDET is now at mid-term
  - project is on track with major milestones achieved
  - more exciting work ahead of us
  - still open for contributions from new interested groups

More information at www.eudet.org

Conclusion & Outlook

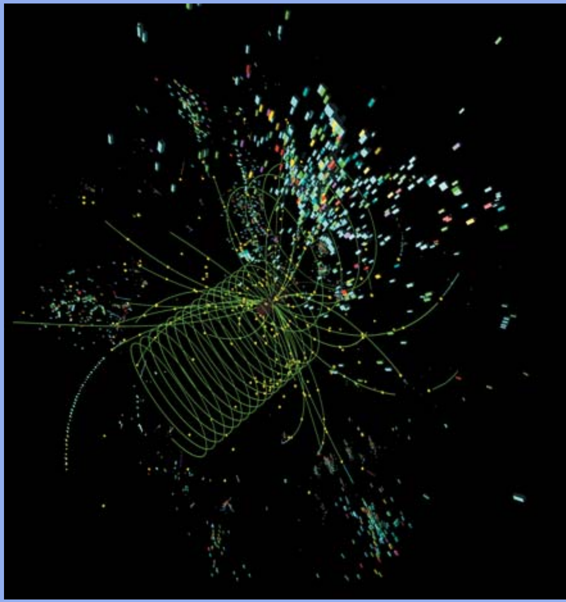
- ILC: 500 → 1000 GeV Linear Collider
  next large collider project

- Requires detectors with unprecedented performances
  - challenges different than at the LHC

- 4 (now 3) detector concepts under development
- R&D on detector technologies
  - candidate technologies
  - identified & verified in small scale experiments
- Many questions still to be answered

- Next steps:
  - engineering designs for machine and detectors
  - detector R&D move to larger scale prototypes
  - requires intensified international collaboration

- Need to increase efforts to have ILC and two detectors ready next decade


Simulated ee → ZZ