Calorimetry at a future e^+e^- collider

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- Requirements on detector from jet physics
- Practical realization in R&D in CALICE Coll.

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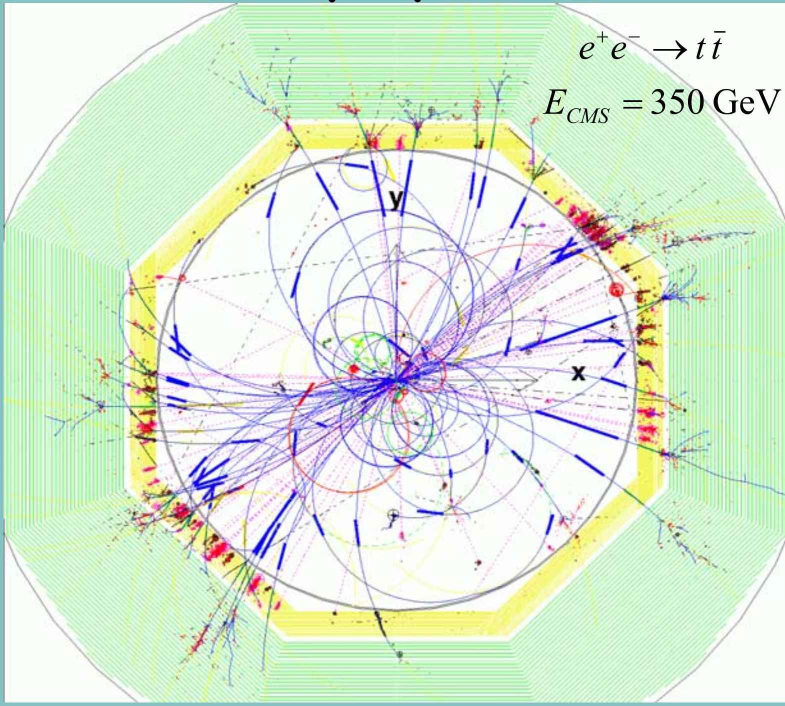
Physics at the future LC

Complementarity between LHC <-> LC physics.

LC: precision, polarization …



$e^+ e^-$ -> H,W, Z, t, …

- many jets
- W/Z separation by mass
- heavy q's and tau tags

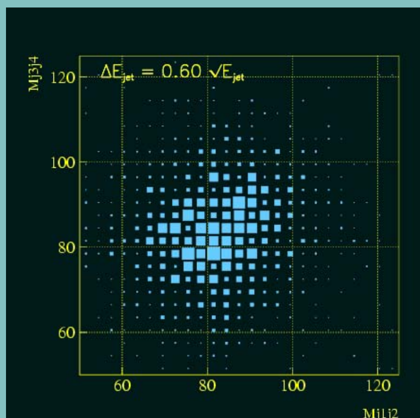
dijet or multijet events with the best resolution, lepton flavour identification, shower full containment

LC advantage: clean events -> low event overlapping

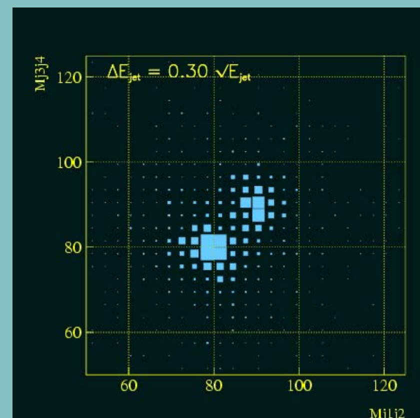
Detector performance

Goal: to reach resolution $\sigma_E / E \approx 30\% / \sqrt{E}$ for jets

$\frac{60\%}{\sqrt{E}}$



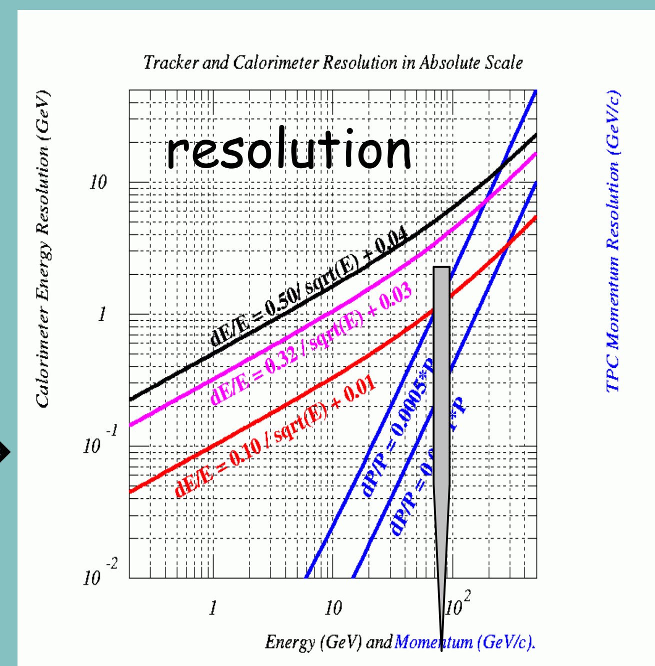
$\frac{30\%}{\sqrt{E}}$



W/Z identification
by mass reconstruction
← in 4 jets

Typical multijet event:
60 % charged energy
30 % from photons
10 % neutral hadrons (K^0_L,n)

Calo →



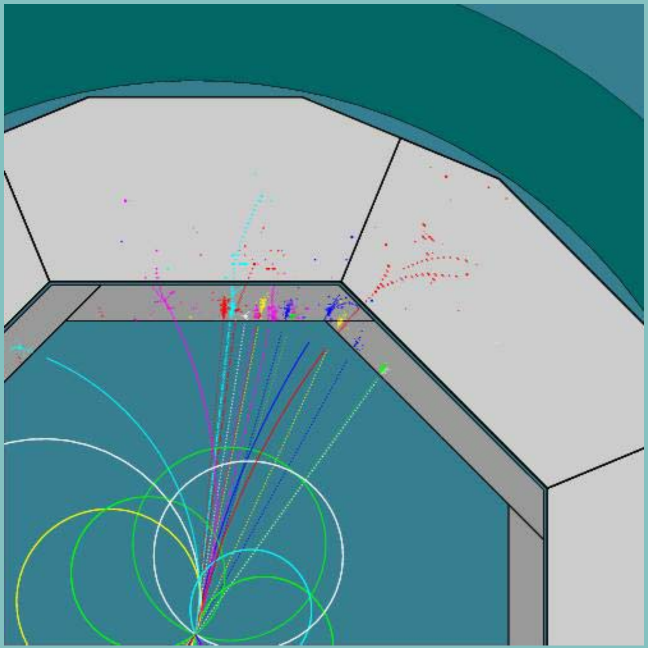
Tracker better <= 70 GeV/c

Ideas on event reconstruction

To get the best energy resolution for jets ->

measure every particle:

- charged particles in the tracker
- photons in electromagnetic calo
- neutral hadrons in hadron calo
- good lepton ID



→ tracker in strong magnetic field

→ fine granularity of both em + hadron calorimeters

From 'old' energy flow to

Individual Particle Reconstruction

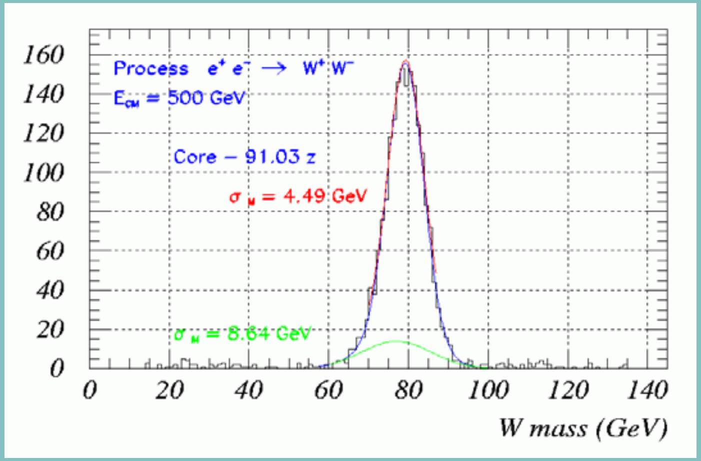
Proper tools needed!

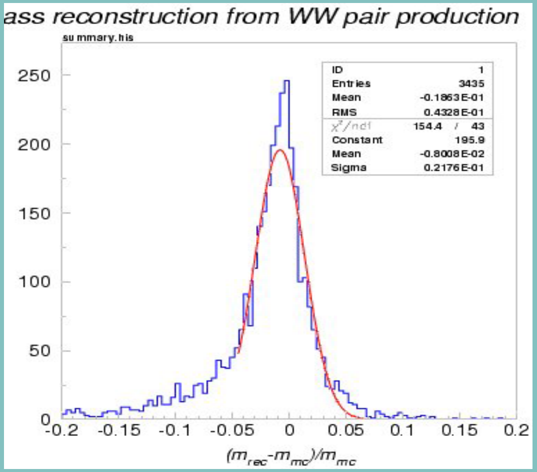
Complete event simulation & reconstruction packages:

- MOKKA (Ge4) + Replic (E. Polytech.+ IHEP Protvino)
- BRAHMS(Geant3) + Snark (DESY)
- MOKKA + analytic Eflow (UPC Clermont)

  + Northern Illinois, ANL, …

W mass reconstruction





Snark $$\frac{\sigma_m}{m} \approx \frac{40\%}{\sqrt{m}}$$ analytic Eflow

Calorimeter R&D effort

The aim:

Choice of adequate technology for calorimeters ECAL & HCAL in hardware & software fulfilling requirements of a LC experiment.

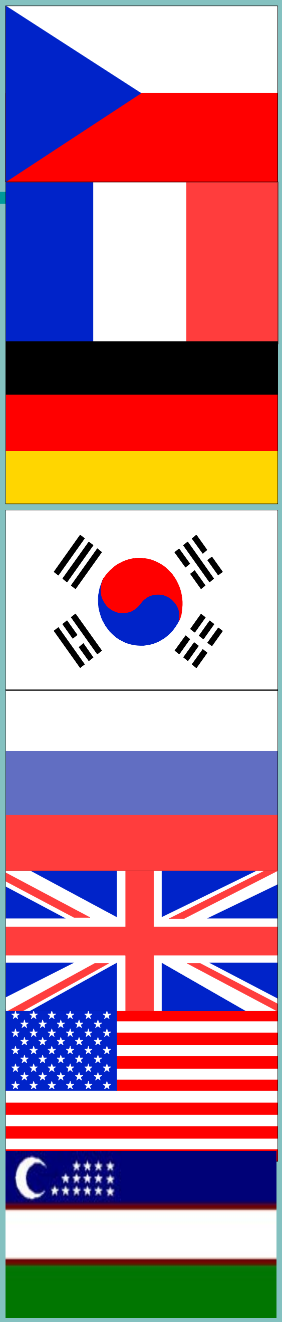
Find solutions suitable for industrial production (several 10^7 channels)

To build a prototype of the complete calorimeter.

Be ready to build the calorimeters!

ECAL + HCAL R&D proposal accepted for 2002-4

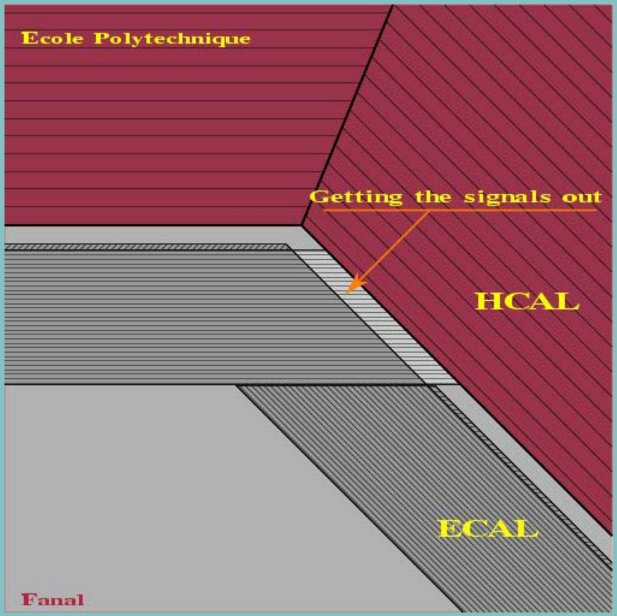
CALICE collaboration – about 130 physicists, 23 labs, 8 countries



Calorimeter - highly granular

ECAL:

- identify particles even at low energy
- longitudinal segmentation ~ X_0
- X_0 / λ small
- transversal ~ r_M, no cracks
  Si/W is a natural possibility
- r_M=9 mm, easily segmented, cost?



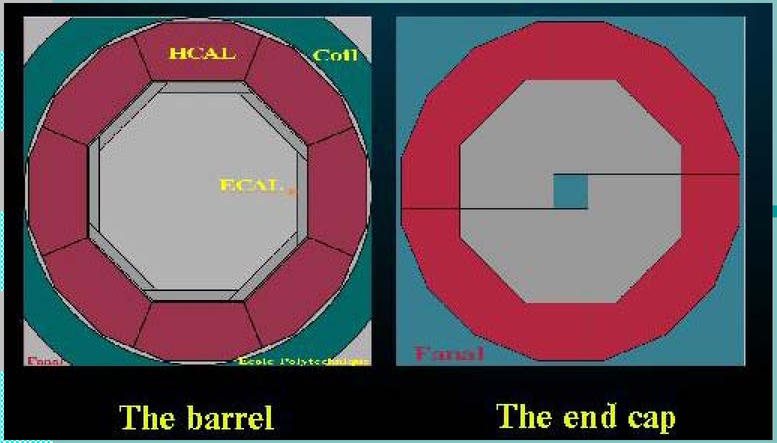
1/8 of TESLA calorimeter

HCAL:

- cell size close to X_0 : 18 (4) mm in Fe (W)
  (shower core made by em part of cascade, H1 energy weighting)
- good cluster separation
- good energy resolution

ECAL, HCAL with different absorbers and sampling → non compensating

The ECAL Design



<u>W/Si EM Cal</u>.

W thickness: 1.4, 4.2 mm;

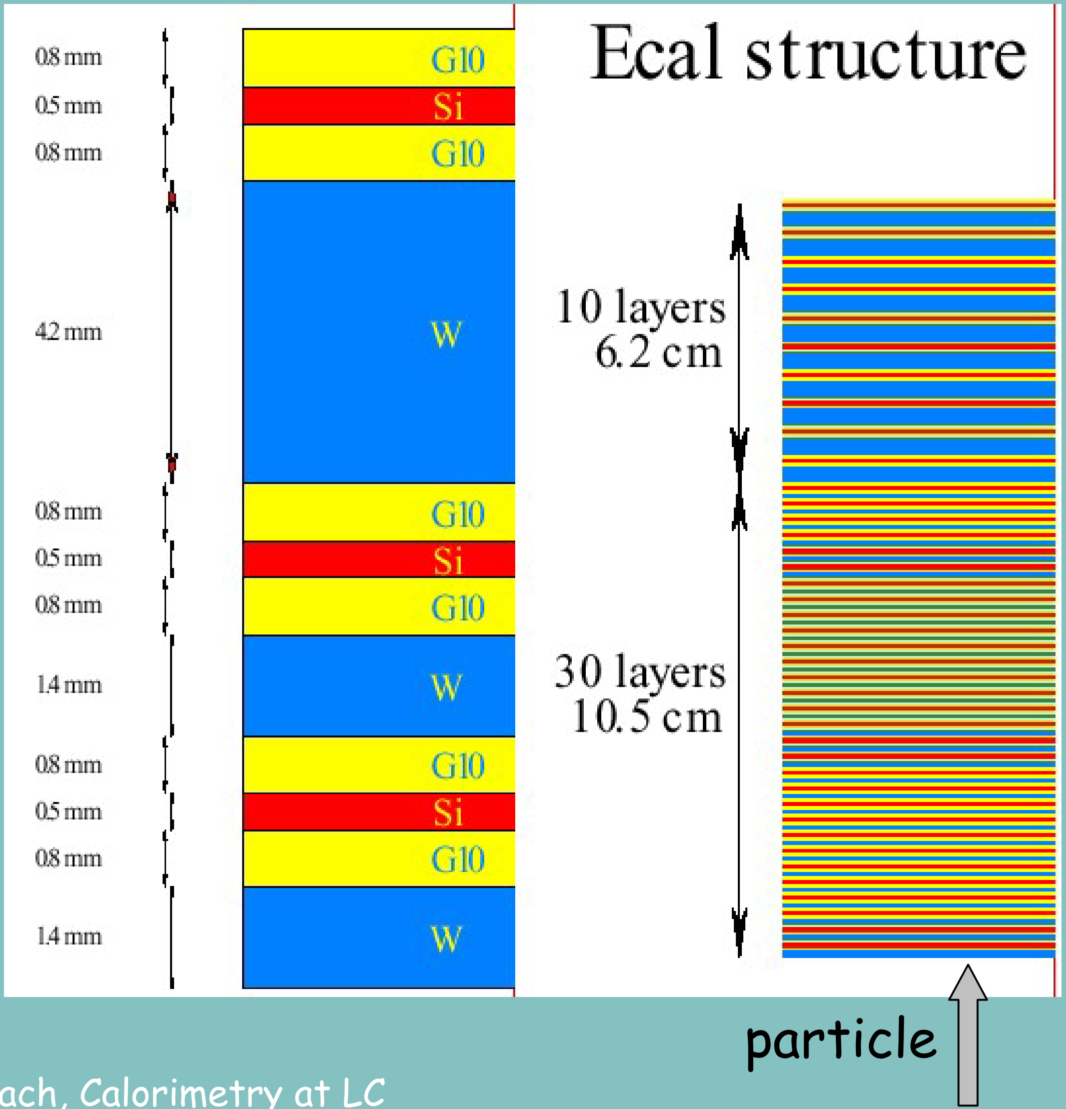
40 layers; 1700 m^2 total;

24 X_0, 19 cm depth- compact

10x10 mm^2 segmentation;

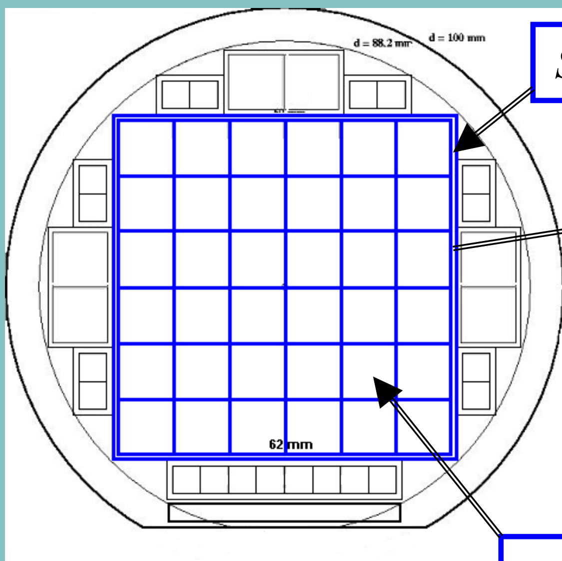
0.5 mm thick Si of

5-10 kOhm cm resistivity;



Technological prototype of ECAL – a slab

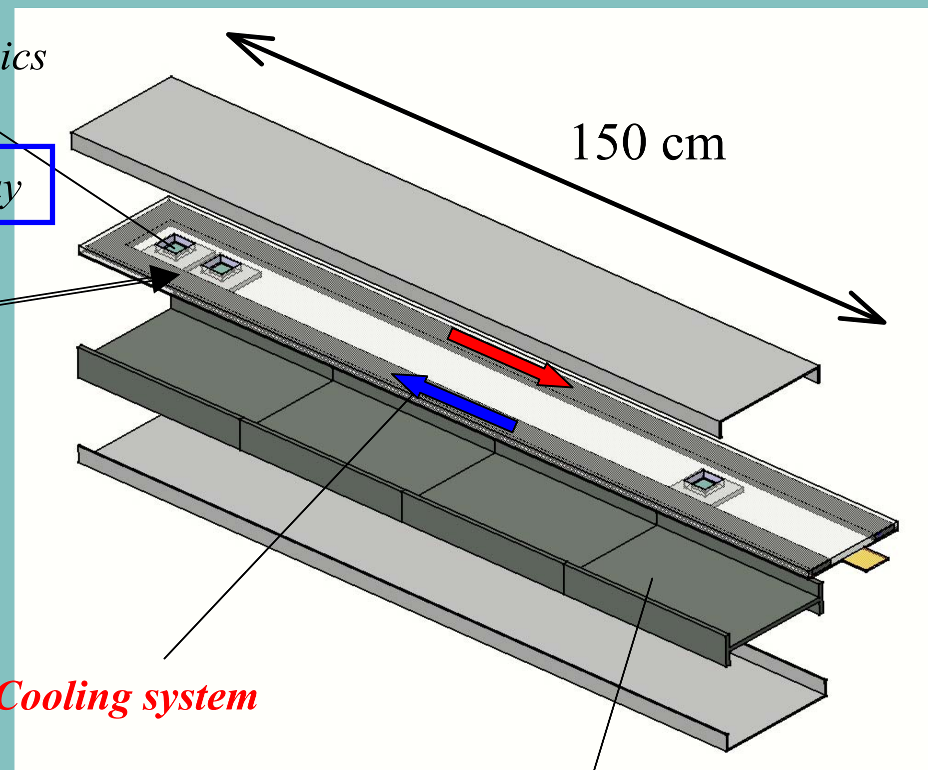
4" Si wafer with one guard ring



Front-end chip based on Opera design

Front End electronics

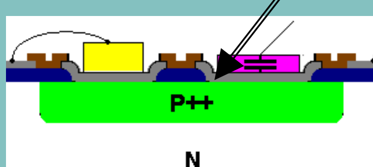
Silicon sensor array



sensor pad
10 x 10 mm²

Cooling system

Vertical cross section



AC coupling, deposition of R and C on Si

(C / W) structure H profile
W and C/epoxy moulding

Two HCAL concepts

Tile

- moderate segmentation
- analog readout
- Active medium: scintillator, WLS fibre readout
- pad: ~ 5x5x0.5 cm^3

Digital

- highly segmented
- binary readout per pad
- Resistive Plate Chamber (RPC), Short Drift Cham.
- ~1x1x0.1 cm^3

Advantages:

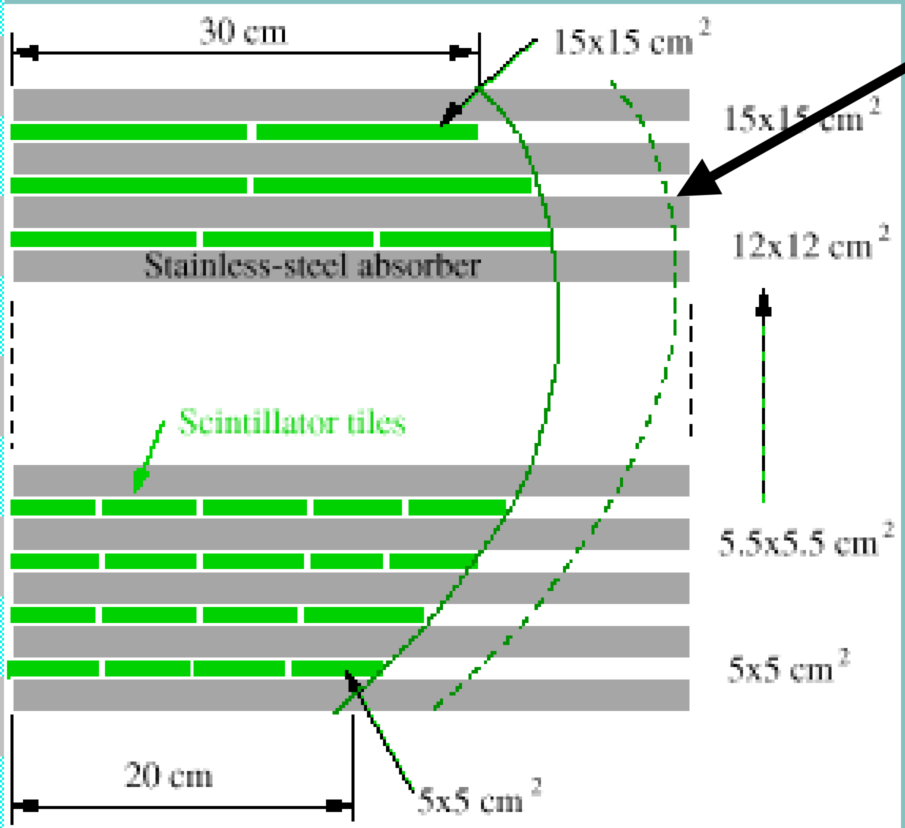
Tile

- resolution: energy
- stable (LED monitoring)
- proven technology

Digital

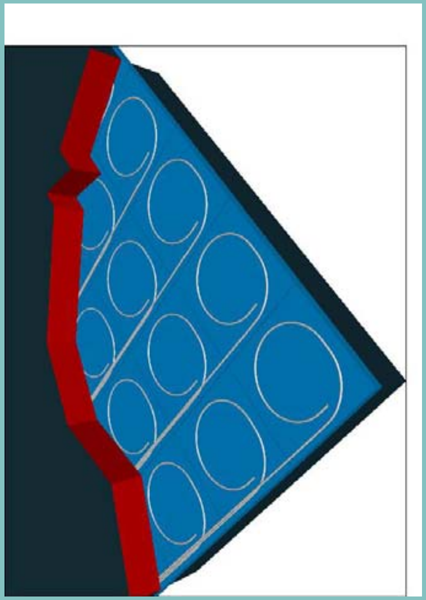
- spatial - shower topology
- simple front-end electronics, chip close to the cell

Layer structure of tilecal



Sandwich layer:

- 5 mm scintillator
- 1.5 mm gap for fibre RO and reflector foil
- 20mm stainless steel absorber
- 1 sampling layer 1.15 X_0, 0.12 λ

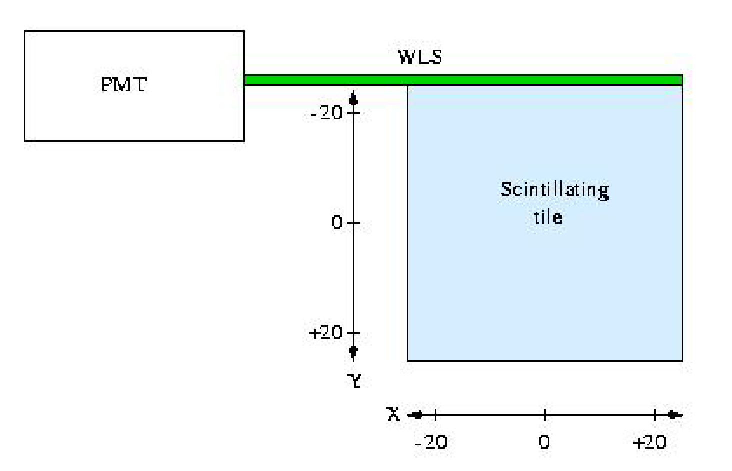


32 pixel APD array HAMAMATSU S8550

tile sizes: 5x5 – 15x15 cm^2

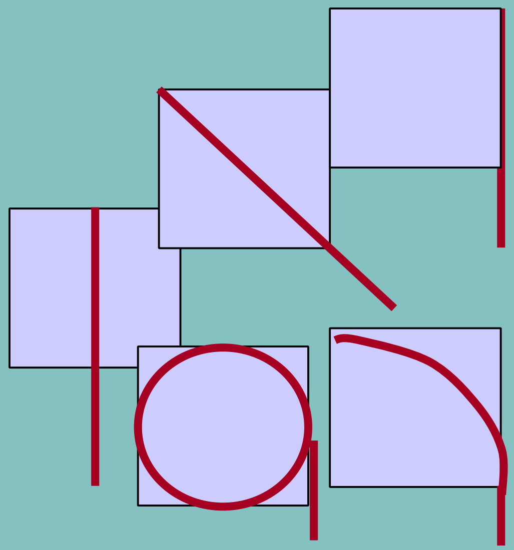
future detector: Si-PMs (MEPHI) ?

Measurement of tile/WLS fibre coupling



Fibre end polished, open Tyvek coating of tile 5x5, air gap contact tile/WLS

WLS \ Tile	Protvino	Bicron 408
Bicron 92M Ø 0.8 mm	3.0 ph.e.	4.9 ph.e.
Bicron 91A MC Ø 0.8 mm	4.6 ph.e	6.5 ph.e.
Kuraray Y-11(200)M Ø 0.6 mm	2.8 ph.e.	4.5 ph.e.
Kuraray Y-11(200)M Ø 0.8 mm	4.6 ph.e.	6.6 ph.e.
Kuraray Y-11(200)M Ø 1.0 mm	5.2 ph.e.	7.5 ph.e.



Search for optimal tile/WLS arrangement

← LY > 4 ph.e. satisfactory

straight fibre on side

+ tiles from Bicron 416, Kuraray, Vladimir

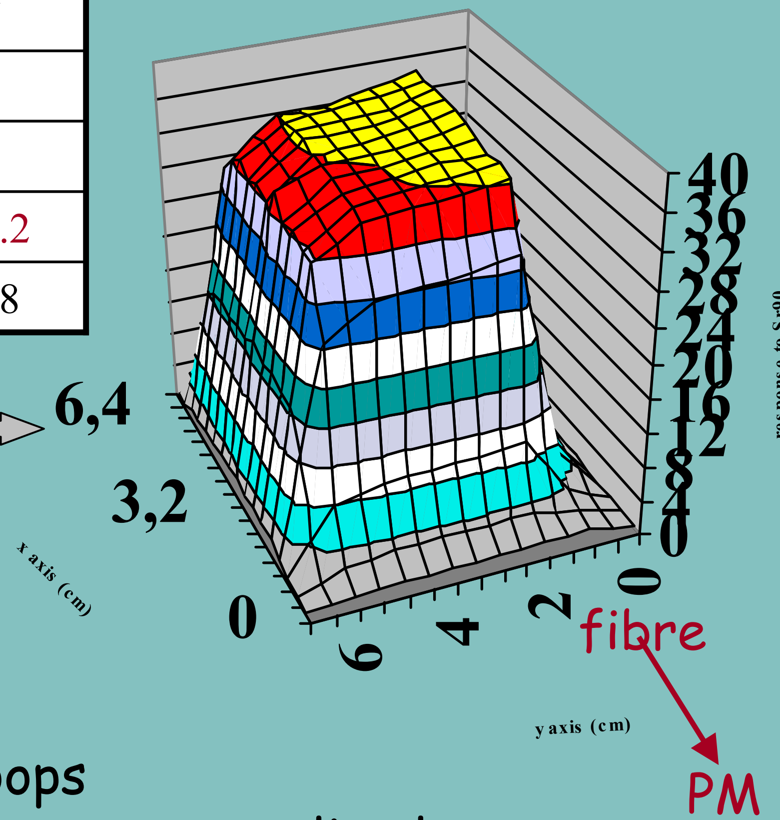
Light yield and uniformity for tiles

Tile a x a (cm^2)	5 x 5	10 x 10	15 x 15
LY (nA) - source	105 +- 6	60 +- 4	39 +- 6
Relative LY	2.4 +- 0.4	1.5 +- 0.3	1
Photo e^- - cosmics	6.5+-0.4	4 +- 0.2	2.5 +- 0.2
LY / photo e^- (nA)	16 +- 1.7	15 +- 1.4	16 +- 2.8

⇧ Light Yield

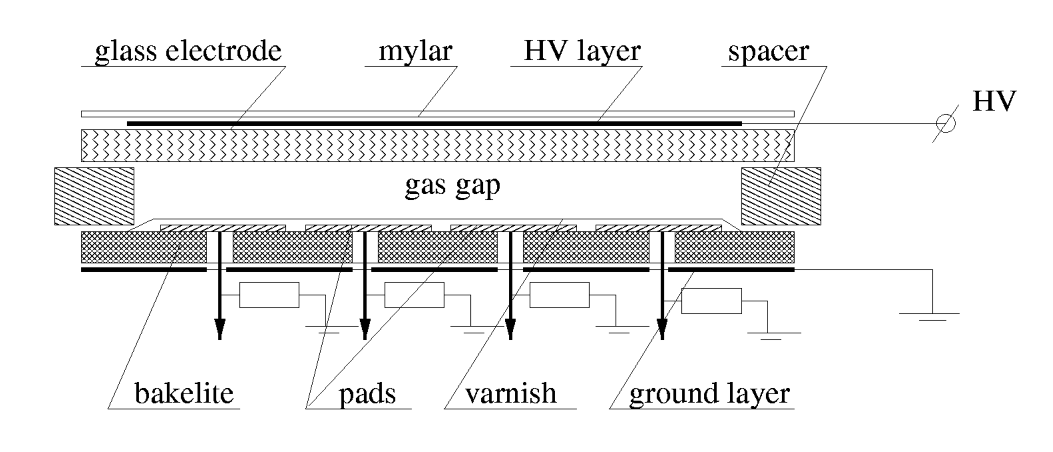
Uniformity

Tile (cm^2)	5 x 5	10 x 10	15 x 15
Uniformity (%)	4.0 – 6.0	5.0 – 6.5	4.0 – 5.5



- improve LY for large tiles with WLS loops
- signal of large cells will be increased by more sampling layers
- actual established LY is ~20 ph.e./cell/MIP, cell >= 3 layers
- uniformity is ok, needs confirmation by simulation studies.

Gaseous detectors for digital HCAL

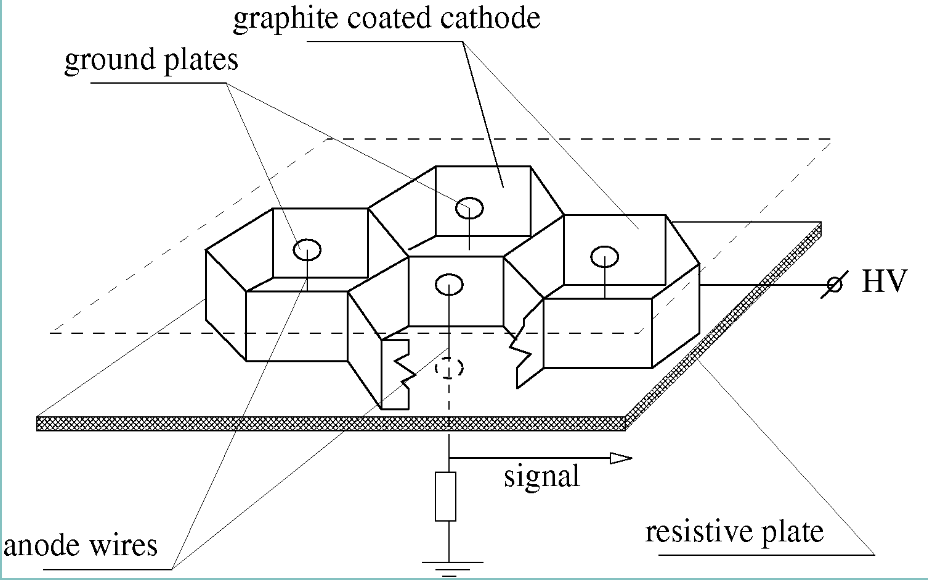


1. Resistive Plate Chamber
- gap 1.3 mm
- glass plates 1.7 mm
- TFE/N2/IB 80/10/10
- signal on 50 Ω : 3 V

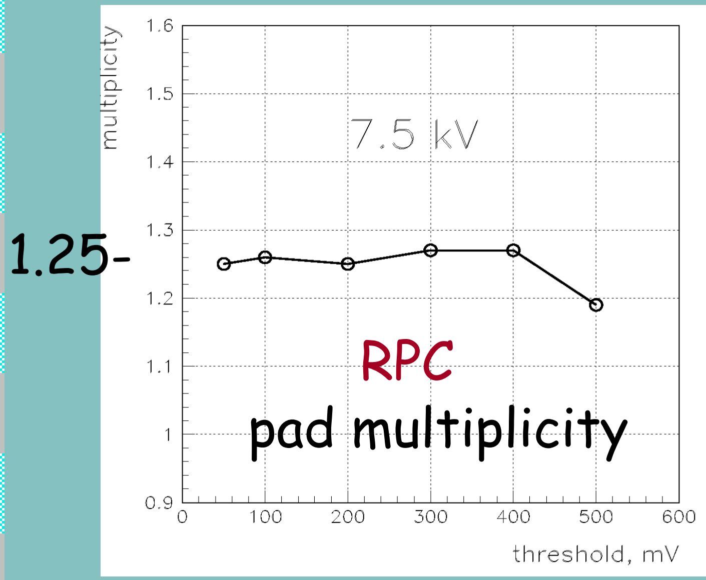
Cell size ~ 1x1 cm^2

2. Short Drift Tubes
- 3 mm tube length
- Ar/TFE/IB 10/10/80
- beam rate 1-10^3 Hz/cm^3

RPC: IHEP, ANL
SDT: IHEP



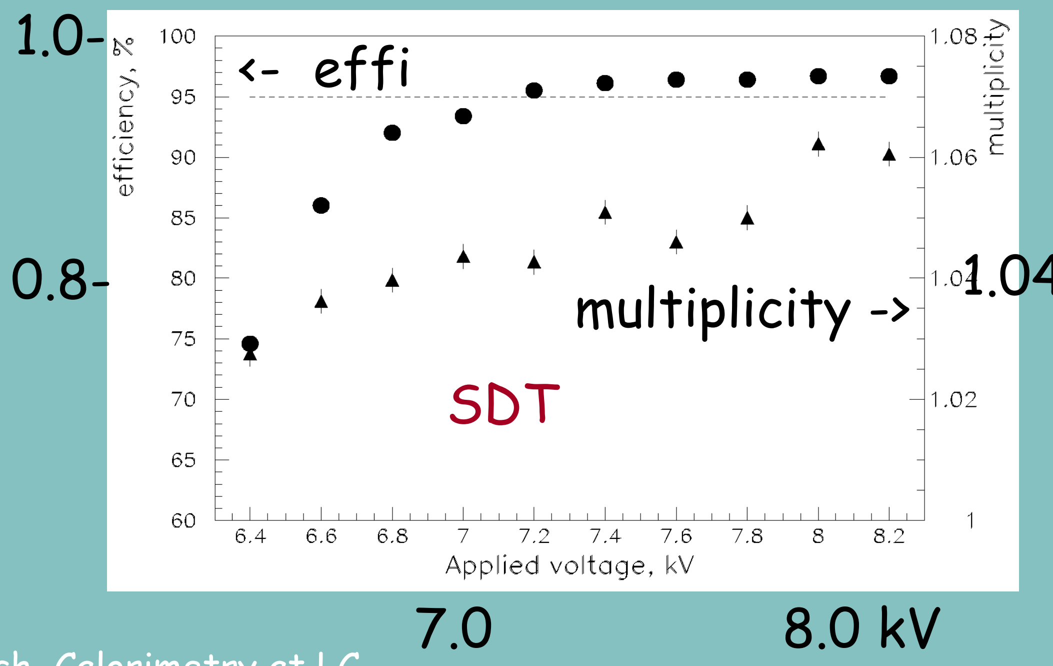
Beam, cosmics tests (IHEP Protvino)



streamer mode operation

Investigation of efficiency, hit multiplicity on

- gas mixture
- HV
- charge distribution
- resistivity of cathode, walls



RPC: low rate (< 10 Hz/cm^2)
cell/cell signal overlap <20%
SDT: efficiency ~ 95 %
gas mixture

by courtesy of Vladimir Ammosov

Conclusions

- Physics requirements need highly granular calorimeters + new concept of energy flow
- The CALICE Coll. proposes to build ~ 1 m^3 calorimeter prototype in 2004
- Significant effort in hardware technology and software development is needed
- Interested people are invited to join CALICE Coll. in a world wide effort

http://polywww.in2p3.fr/tesla/calice.html