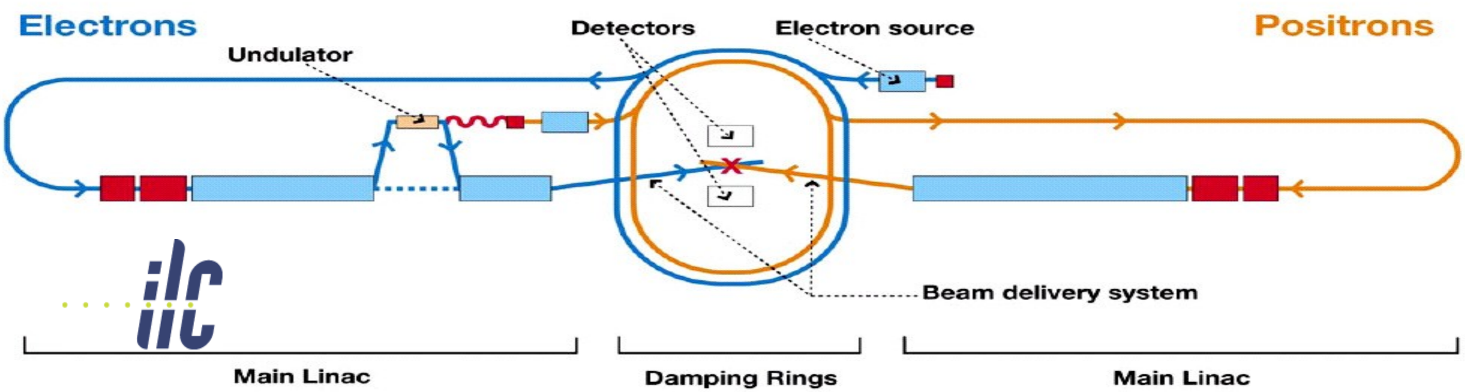
CALICE status and plans

Roman Pöschl
on behalf
CALICE Collaboration

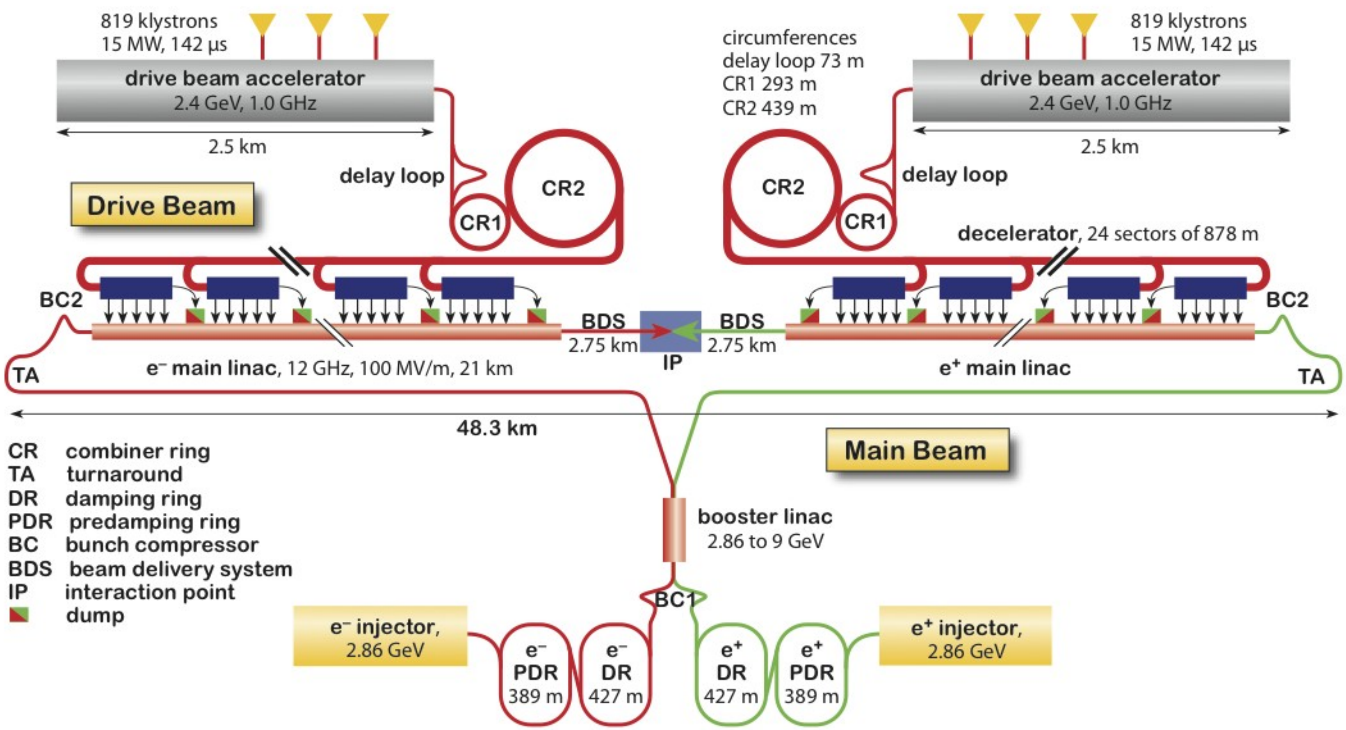
ILC Tokosui Workshop, KEK 20/12/12

(Future) Linear electron-positron colliders



Energy: 0.1 - 1 TeV

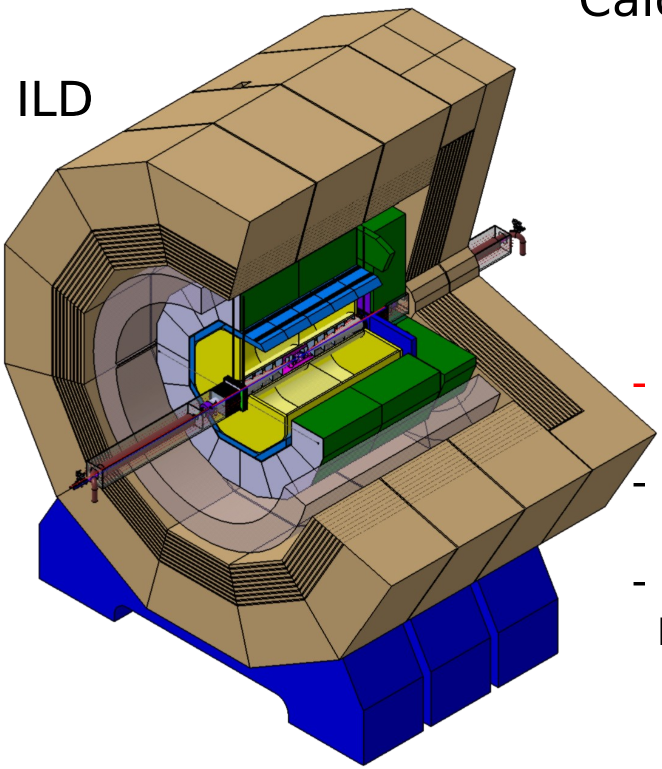
TDR in 2012
+ DBD for detectors



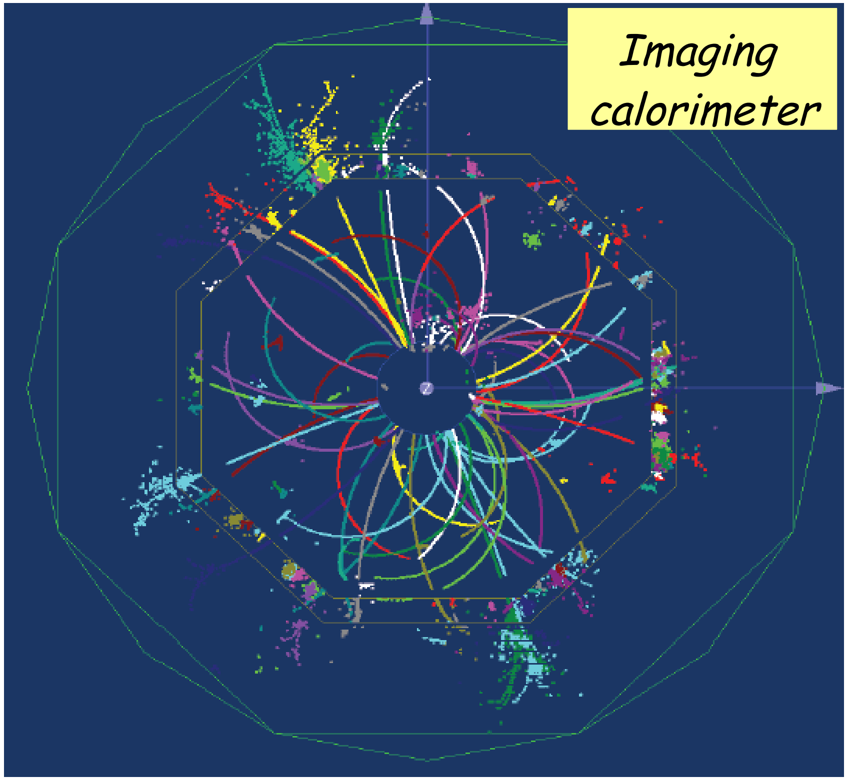
Energy: 0.5 - 3 TeV

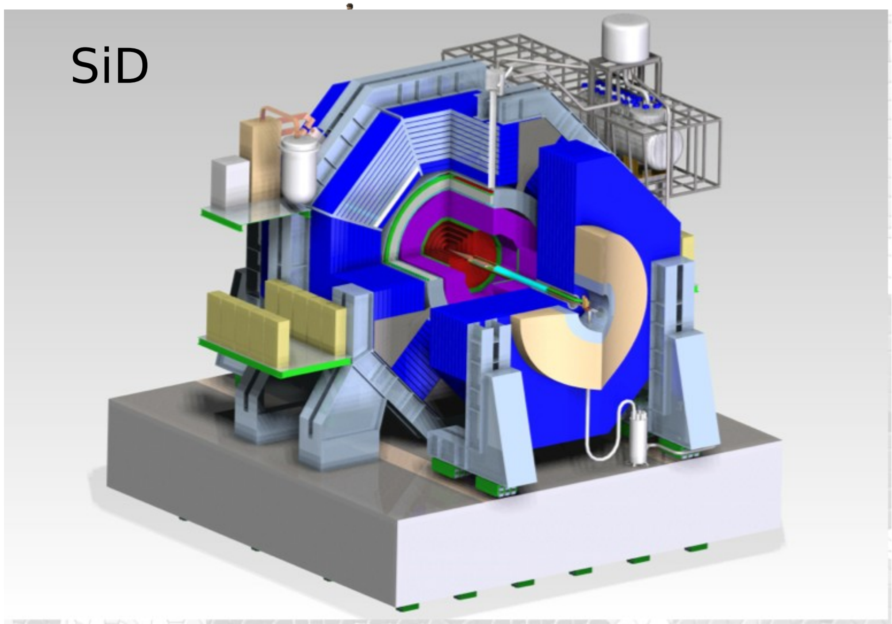
CDR in 2012

Calorimeter – Design requirements



- Extreme high granularity
- Hermetic
- Compact
  Inside the coil of the solenoid





Calorimeter design optimised
for Particle Flow detectors

The CALICE Collaboration

Calorimeter for ILC

Calorimeter R&D for future linear colliders

~330 physicists/engineers from 57 institutes
and 17 countries from 4 continents

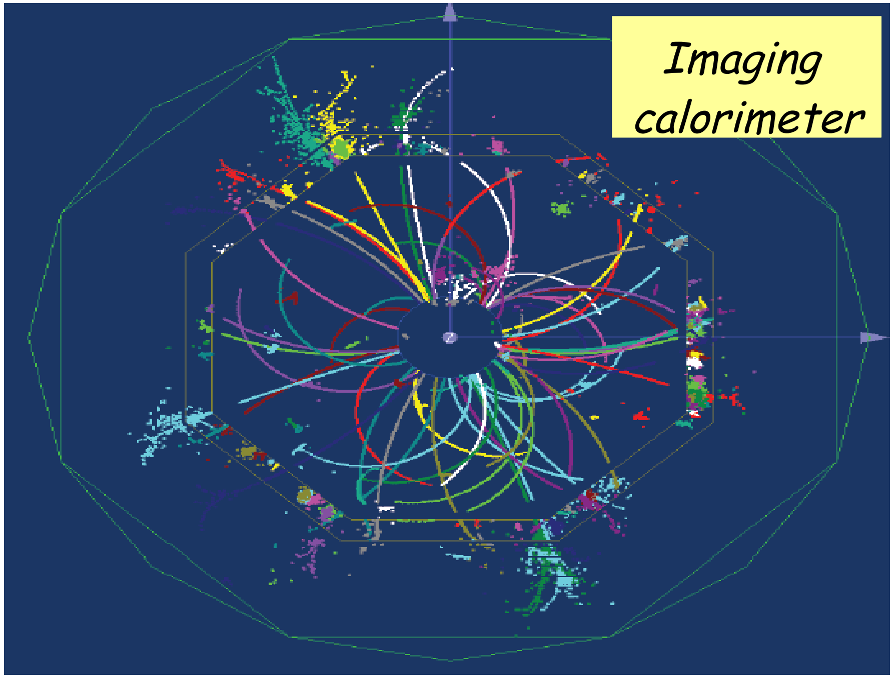
- Integrated R&D effort

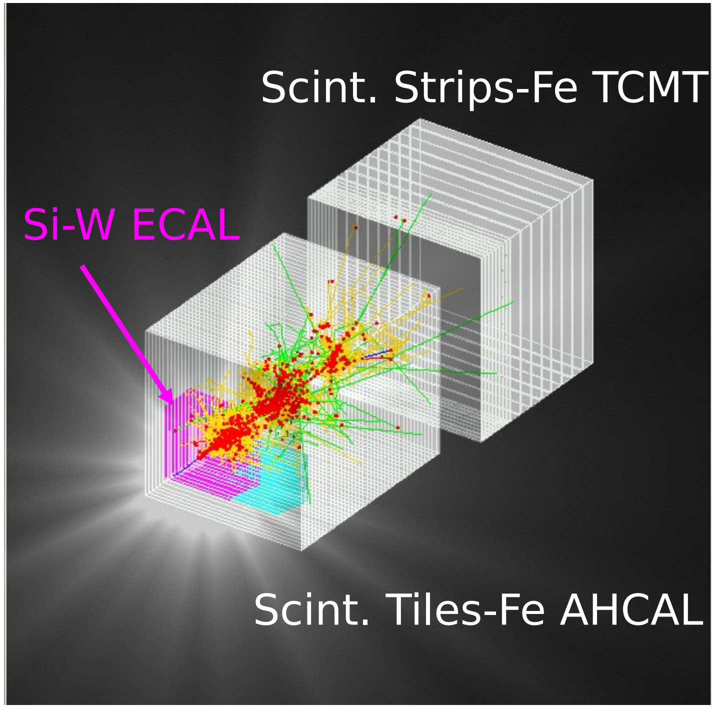
- Benefit/Accelerate detector development due to *common* approach

The Calice mission

Final goal:

A highly granular calorimeter
optimised for the Particle Flow
measurement
of multi-jets final state at
future linear colliders

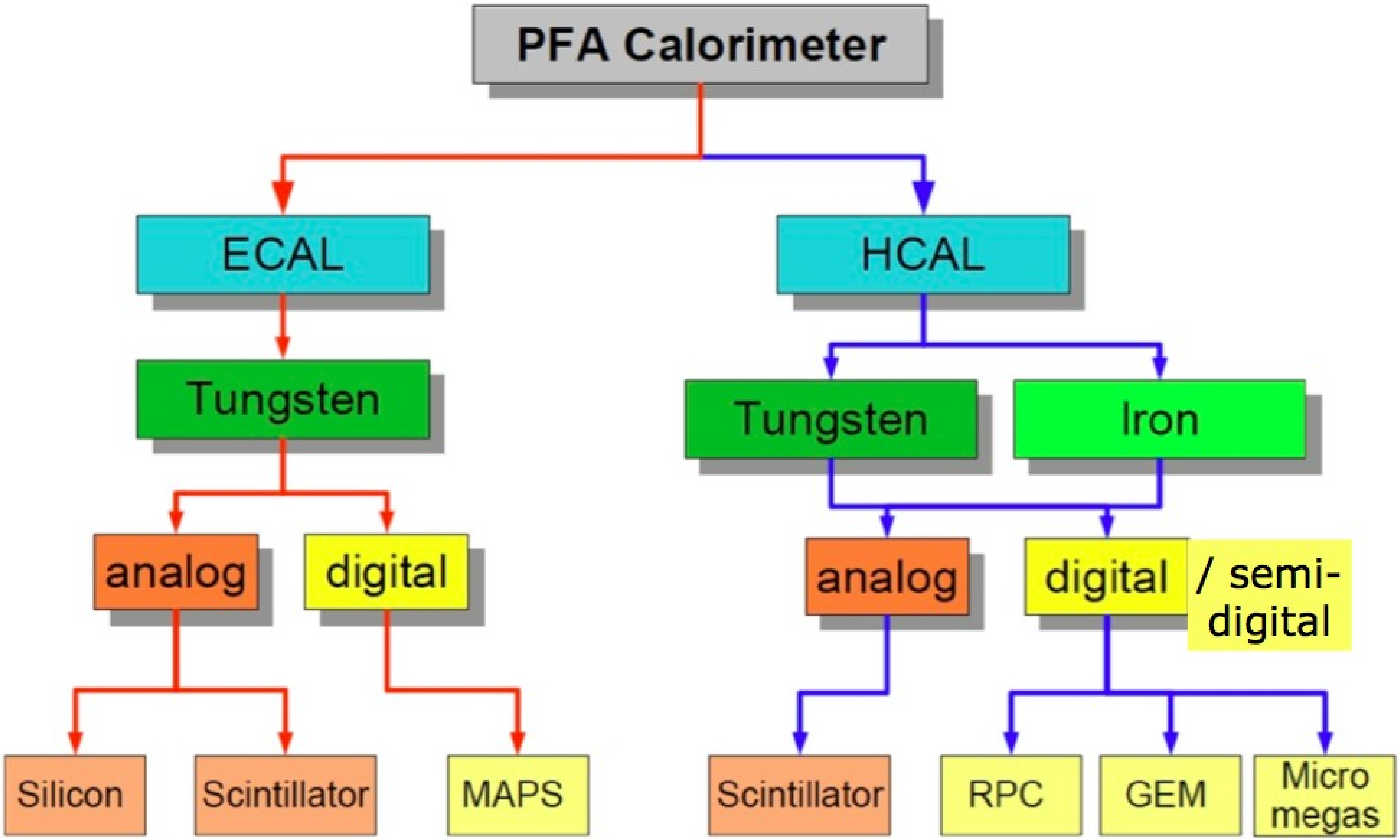




Intermediate task:

Build prototype calorimeters to
 Establish the technology
 Collect hadronic showers
data with unprecedented granularity to
 - tune clustering algorithms
 - validate existing MC models

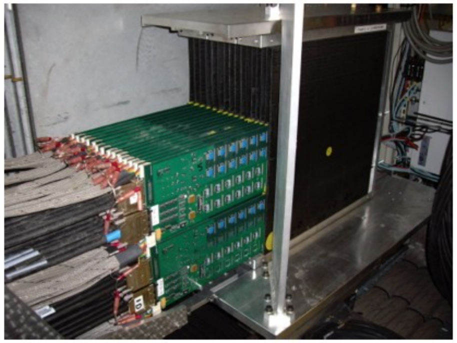
Everything under one roof



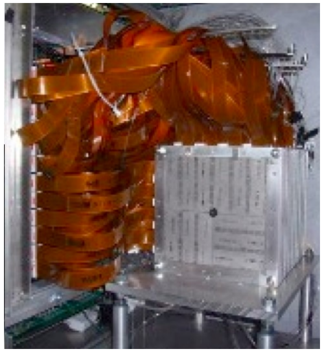
“History” of CALICE

2002 Foundation of CALICE

2002 – 2010 Construction of physics prototypes SiW Ecal, ScintW Ecal, analogue Hcal



SiW Ecal



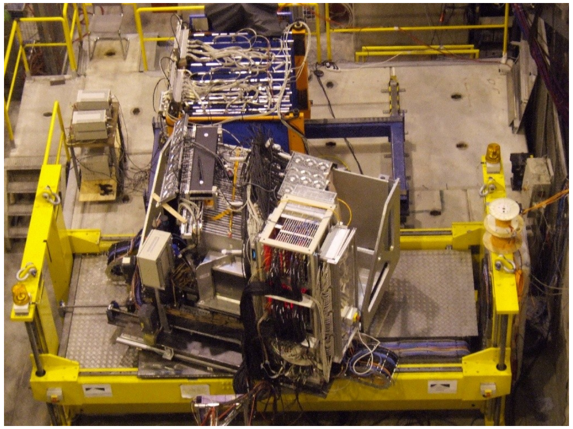
ScintW Ecal

Analogue Hcal

Digital Hcal

TCMT

2005 – 2012 Large scale beam tests with physics prototypes (DESY, CERN, FNAL)



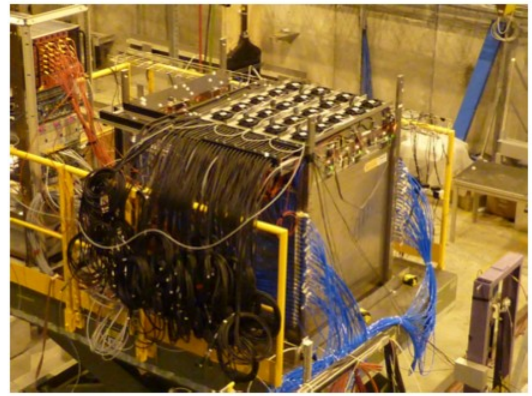
Beam test setup at CERN

Beam test setup at FNAL

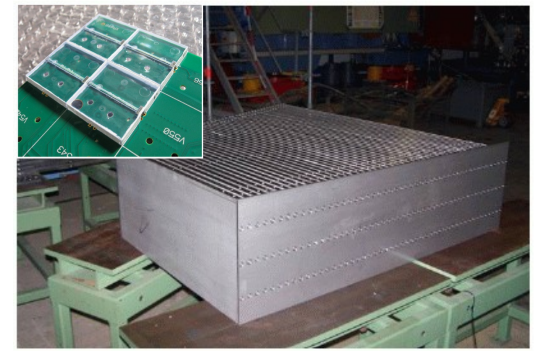
"History" of CALICE cont'd

Since ~ 2007 Conception, construction, operation of second generation prototypes and small systems with special set-ups or alternative technologies

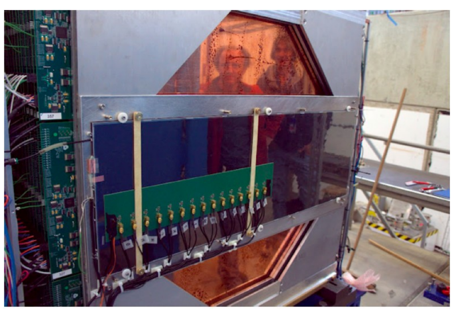
Si W-Ecal Scint



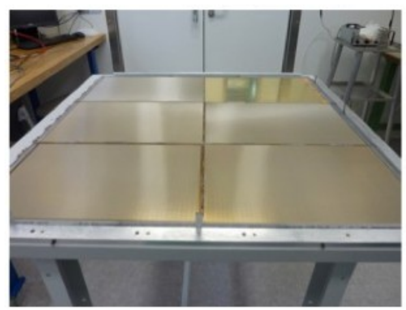
GRPC-SDHCAL



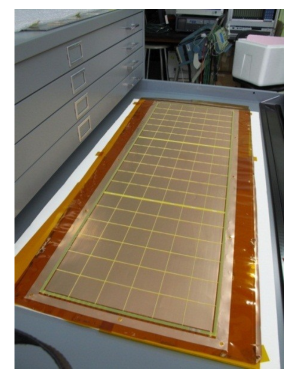
Analogue Hcal



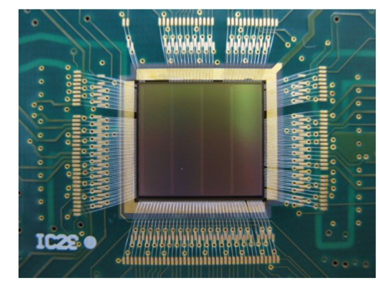
T3B



Micromegas



GEM



DECAL

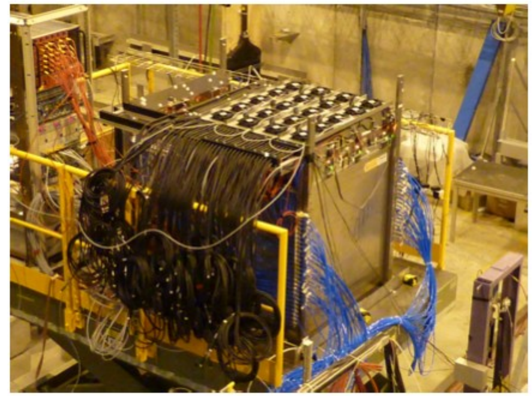
> 2011 Tests with new prototypes and (now) **orientation towards questions for large systems**

Got ilc ?

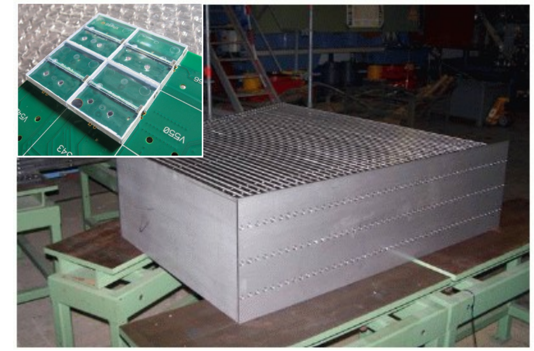
"History" of CALICE cont'd

Since ~ 2007 Conception, construction, operation of second generation prototypes and small systems with special set-ups or alternative technologies

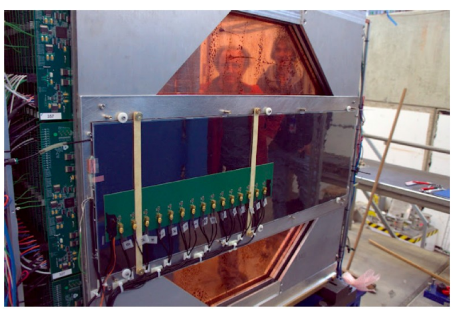
Si W-Ecal Scint



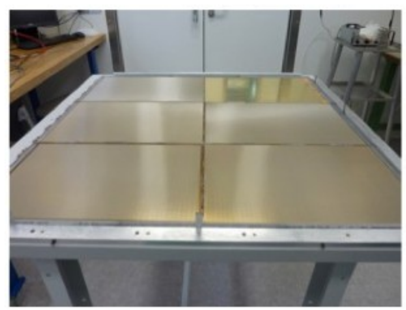
GRPC-SDHCAL



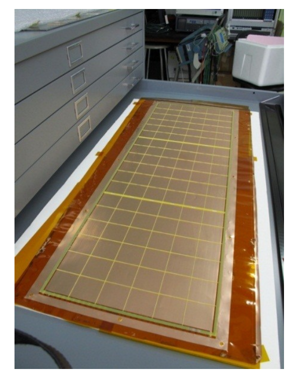
Analogue Hcal



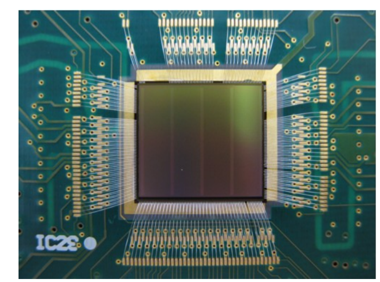
T3B



Micromegas



GEM

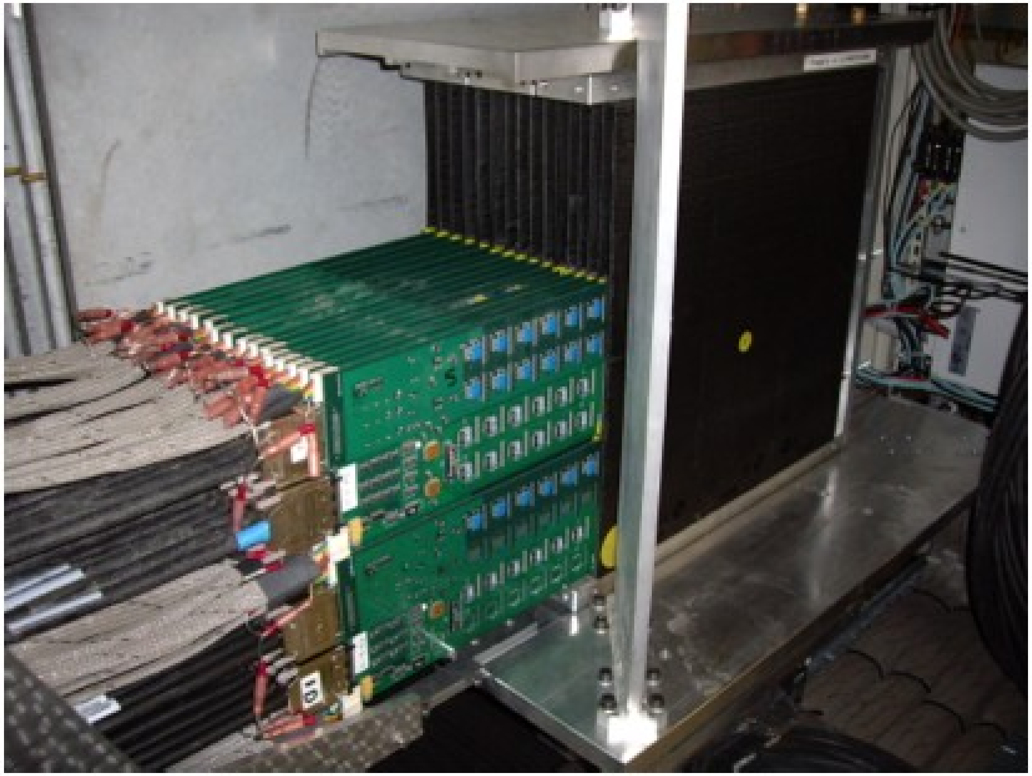


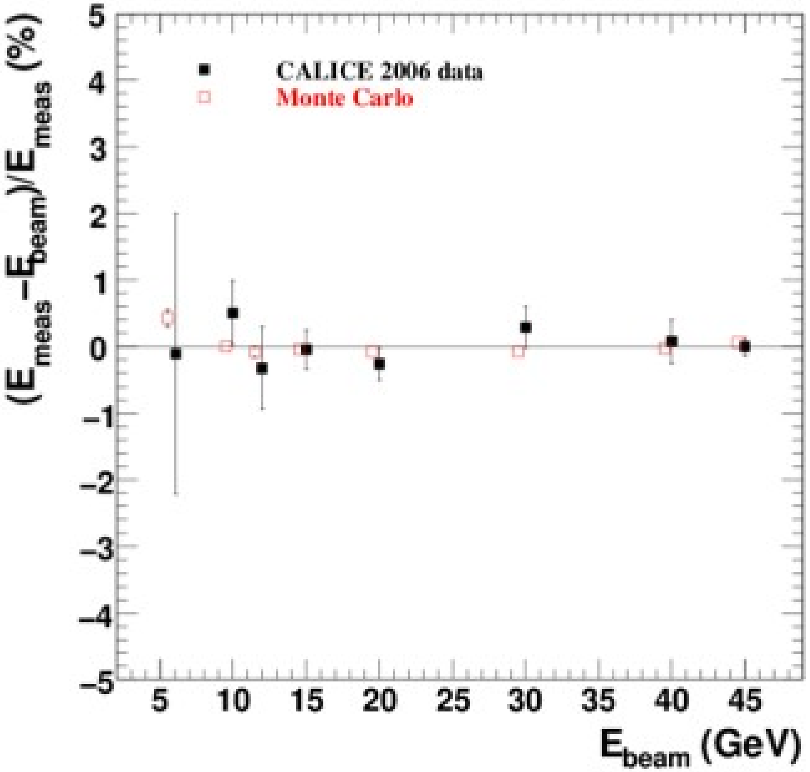
DECAL

> 2011 Tests with new prototypes and (now) **orientation towards questions for large systems**

Got ?

SiW Ecal – Physics prototype



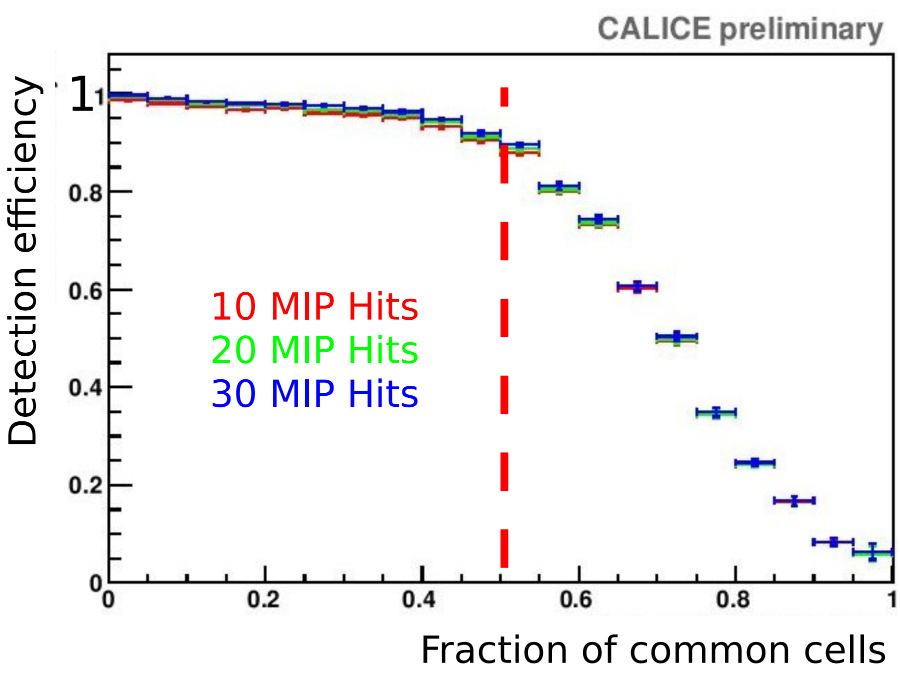


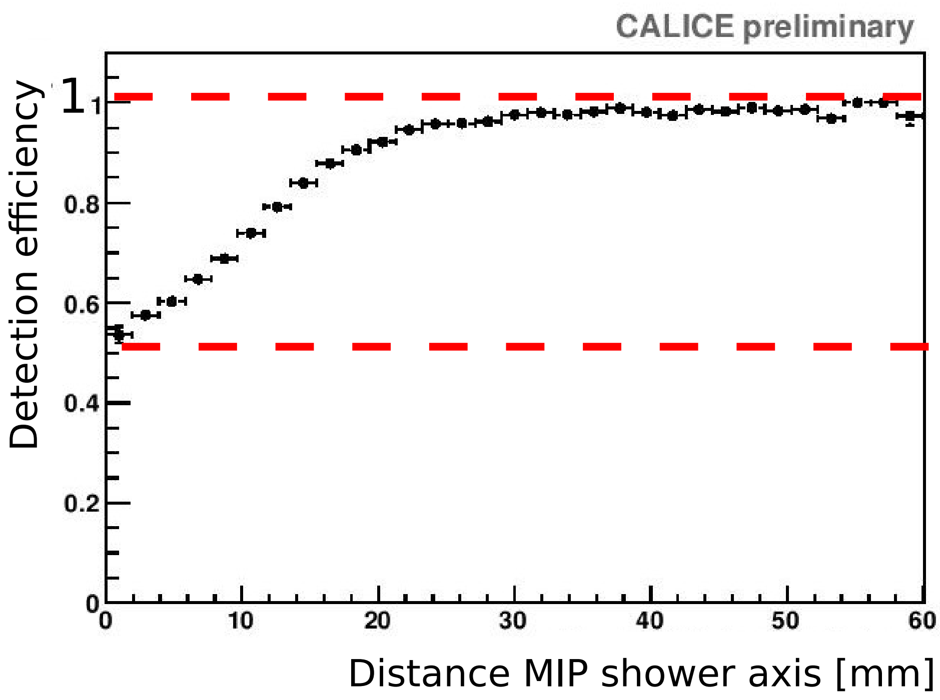
- Carbon-fibre mechanical structure
- 30 layers of tungsten: 24 X_0, 1 λ_I
- S/N ~ 8
- σ_E / E = 16.5/√E(GeV) + 1.1 %
- 10k channels
- Studied in various test beam facilities

2006-2011: DESY, CERN, FNAL, e-, π, μ, p (1 → 180 GeV)

Efficiency of particle separation

Separation MIP <-> Electron

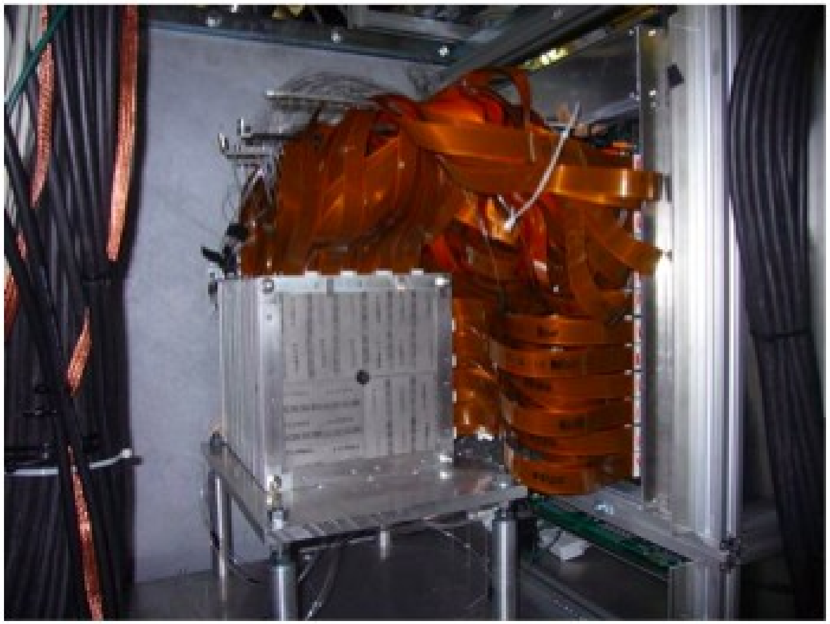




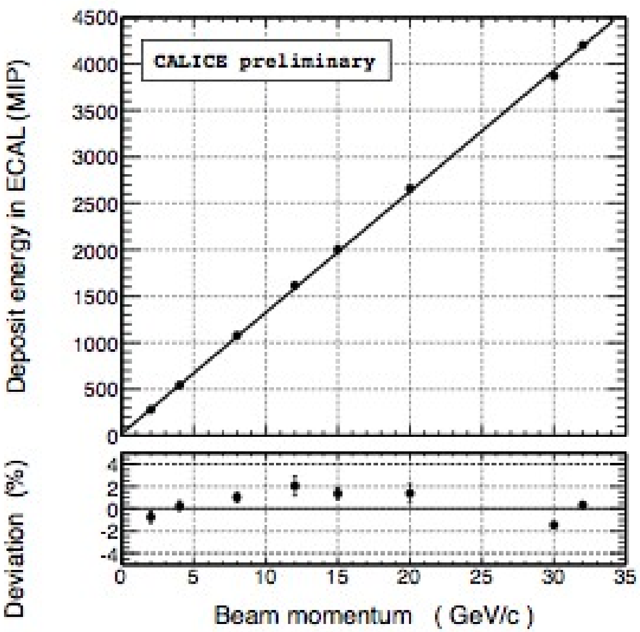
E -> 100% for up to 50% shared hits

Independent of hits generated by MIP

Full separation for distances > 2.5 cm



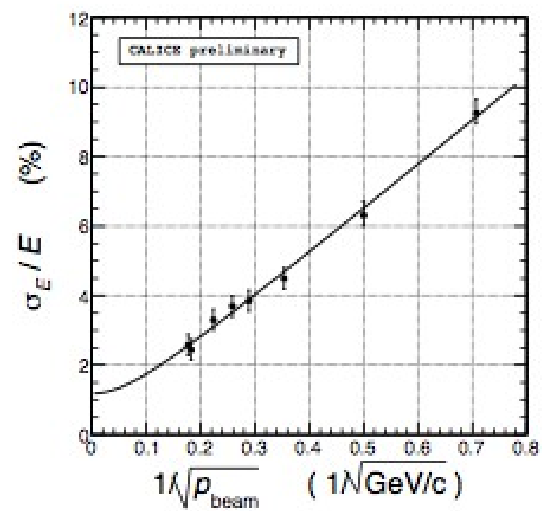
ScECAL physics prototype in front of the AHCAL at FNAL



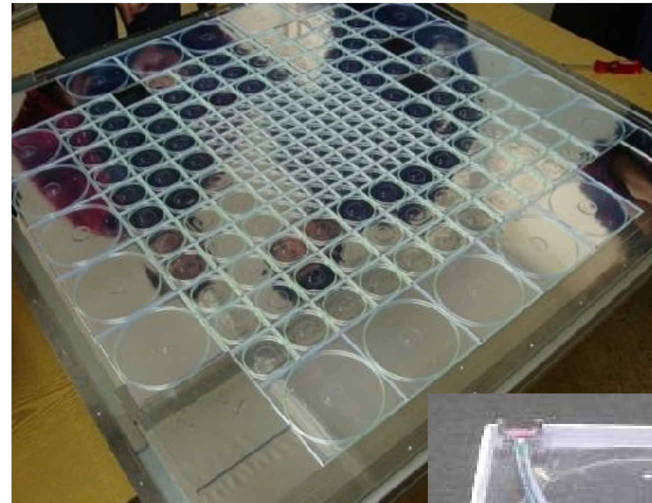
Linearity:
deviation < 2%

Resolution:
Stochastic 12.9±0.4%
Constant 1.2 $^{+0.4}_{-1.2}$ %

Nice performance of Physics prototype

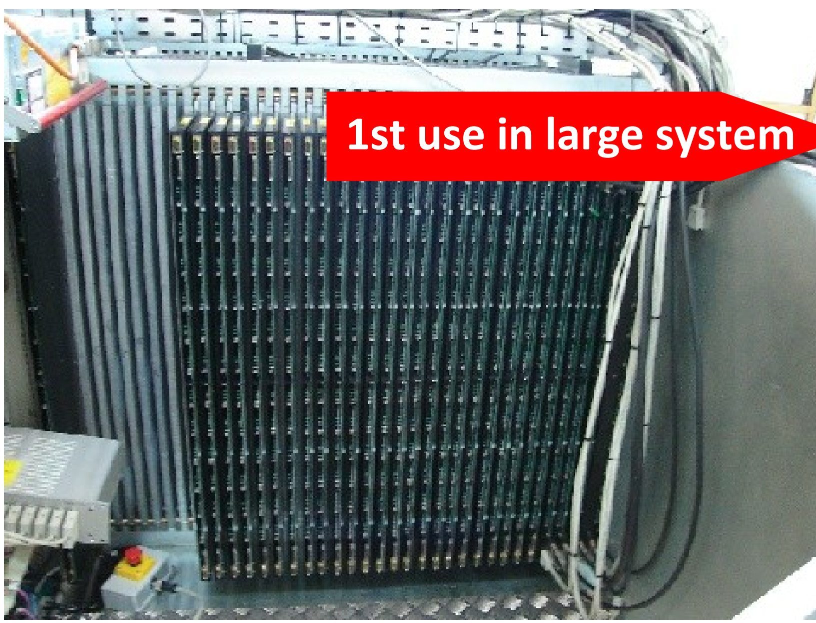


Large Prototype I
Scintillator – AHCAL



Description

38 active layers
Scintillator pads of 3 x 3 → 12 x 12 cm2
→ ~8,000 readout channels
Complemented by a Scintillator strip tail-catcher (TCMT)



1st use in large system

Electronic readout

Silicon Photomultipliers (SiPMs)
Digitization with VME-based system (off detector)

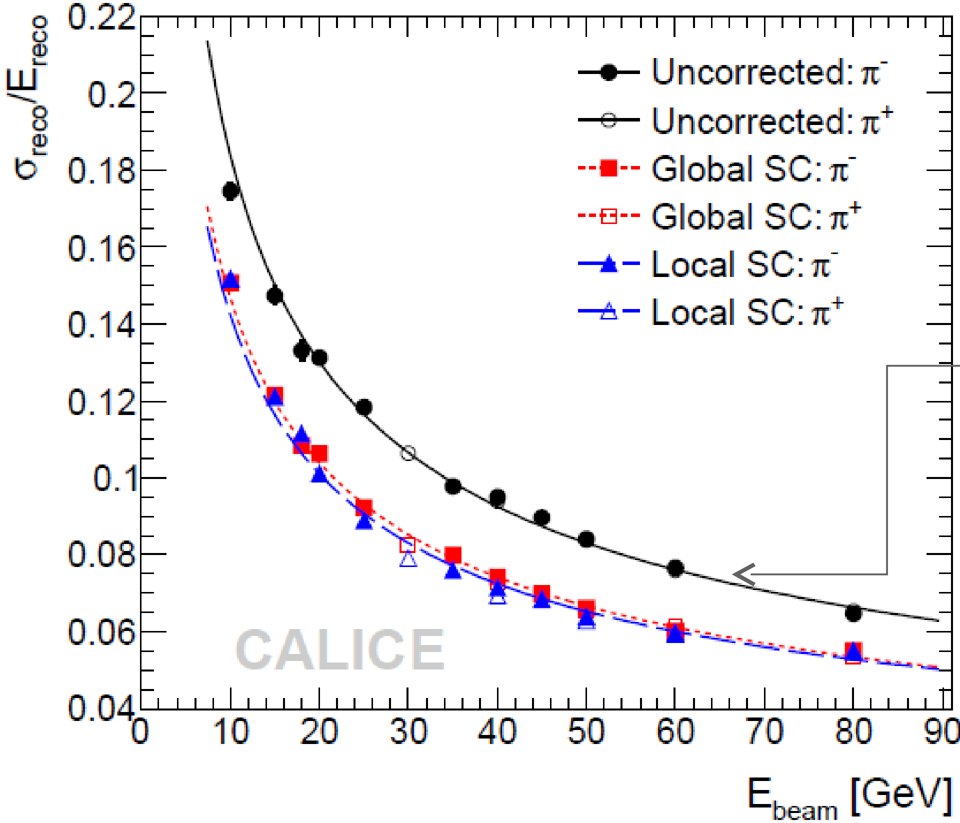
Tests at DESY/CERN/FNAL
with Iron absorber in 2006 - 2009

Tests at CERN
with Tungsten absorber 2010-2011

Software compensation – Scintillator AHCAL

Apply different weights to 'hadronic' or 'electromagnetic' sub-showers

based on energy density



Large improvement (~20%)

Stochastic term 58%/√E → 45%/√E

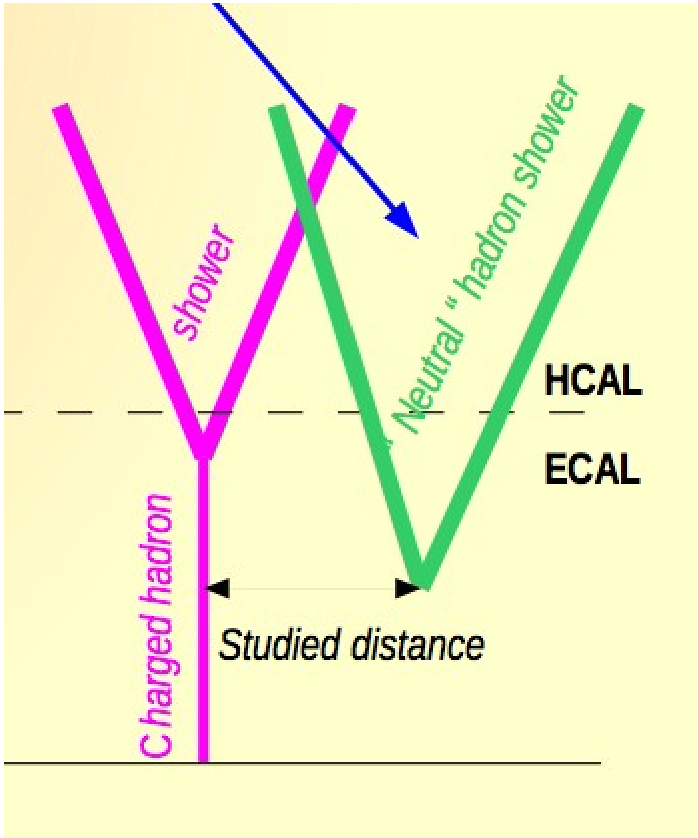
Similar stochastic terms of Steel – DHCAL and 'raw' AHCAL

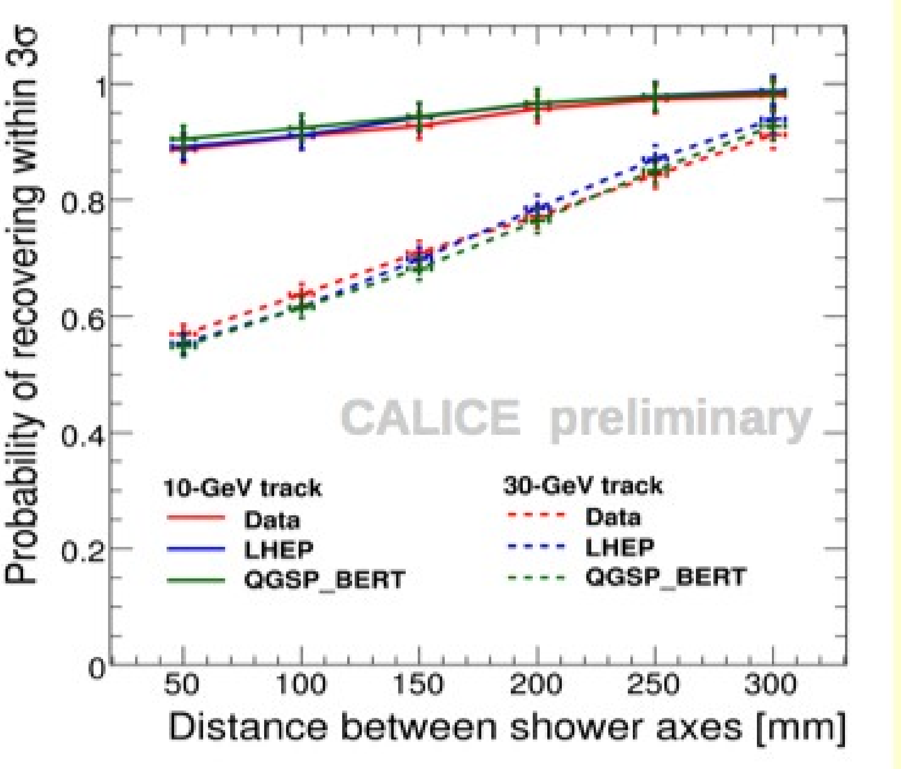
→ Resolution dominated by sampling

Software compensation should also work for the DHCAL: how well?

PFA on beam test data

CALICE **Data** mapped onto ILD detector to test PFA

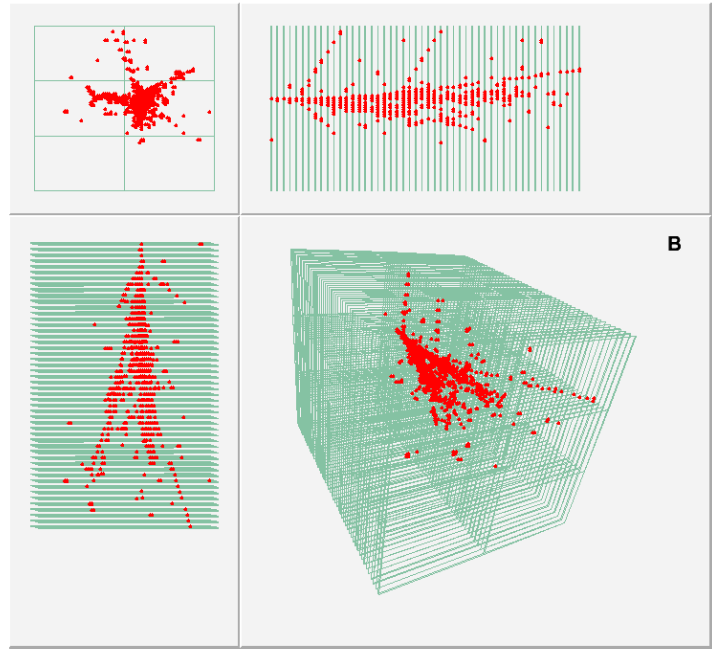




Transport of beam test data into physics studies

Successful Application of PFA to real data with highly granular calorimeters

Large Prototype II
RPC – HCAL (DHCAL)



Description

54 active layers
Resistive Plate Chambers with 1 x 1 cm2 pads
→ ~500,000 readout channels
Main stack and tail catcher (TCMT)

Electronic readout

1 – bit (digital)
Digitization embedded into calorimeter

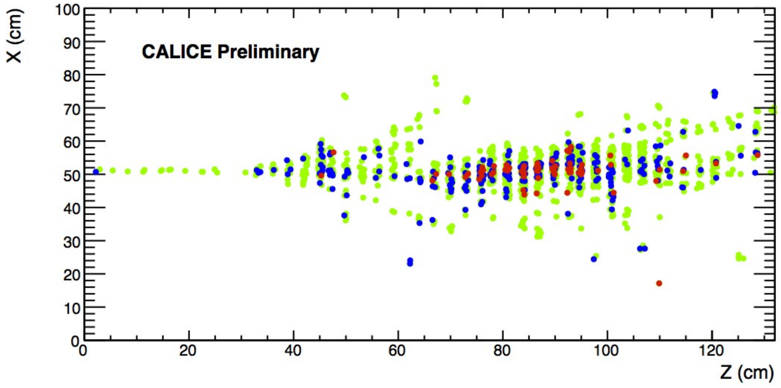
Tests at FNAL
with Iron absorber in 2010 - 2011

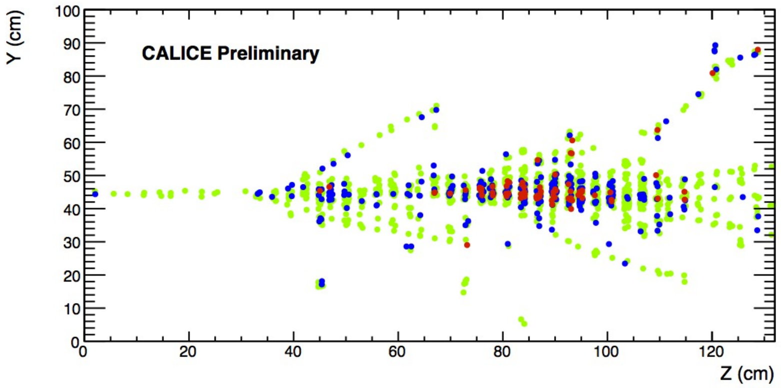
Tests at CERN
with Tungsten absorber 2012

Large Prototype III
RPC – HCAL (SDHCAL)

Description

48 active layers
Resistive Plate Chambers with 1 x 1 cm2 pads
→ ~430,000 readout channels





Electronic readout

2 – bit (semi-digital) → 3 thresholds
Digitization embedded into calorimeter
Power pulsing

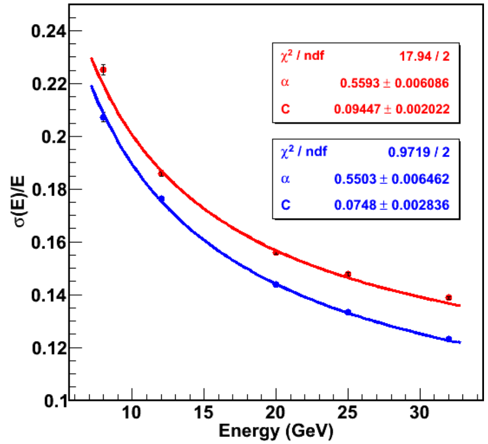
Tests at CERN
with Steel absorbers 2012

J. Repond - Hadron Calorimetry

Resolutions

For PFAs this is only part of the story…

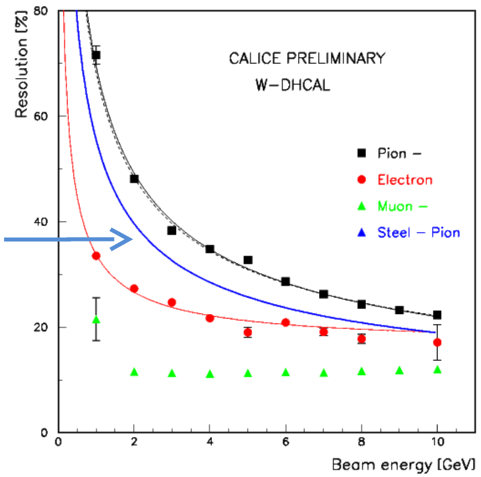
Steel – DHCAL



Without containment cut
With containment cut

Not corrected for
non-linearity
(expected to be a +(3±2)% correction)

Tungsten – DHCAL



Resolution
~ 25% worse
than with steel

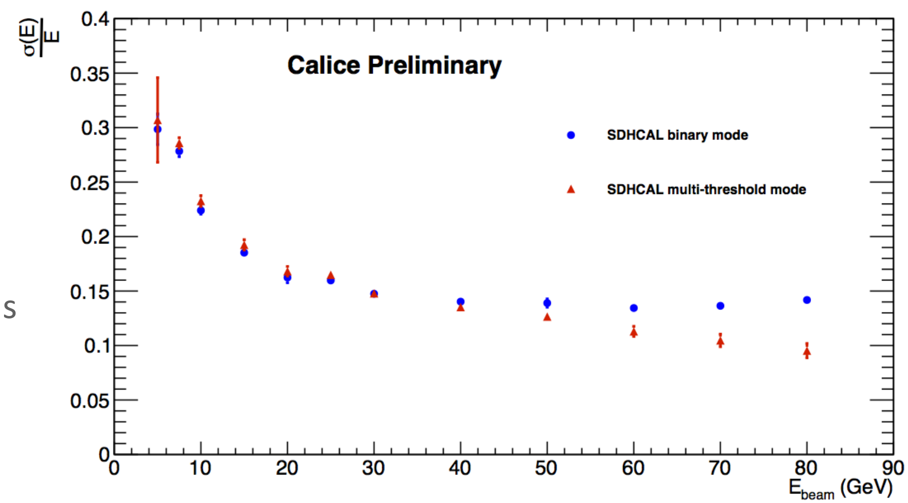
Corrected for
non-linearity

Steel – SDHCAL

Correction for non-linearity applied

Measurements using either **1 or 3 thresholds**

Improvement at higher energies with 3 thresholds



J. Repond - Hadron Calorimetry

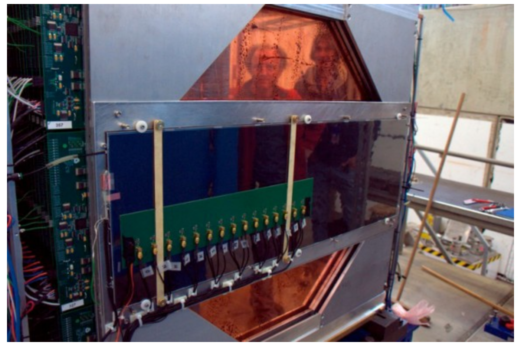
Timing measurements

Measurement of **shower timings** using

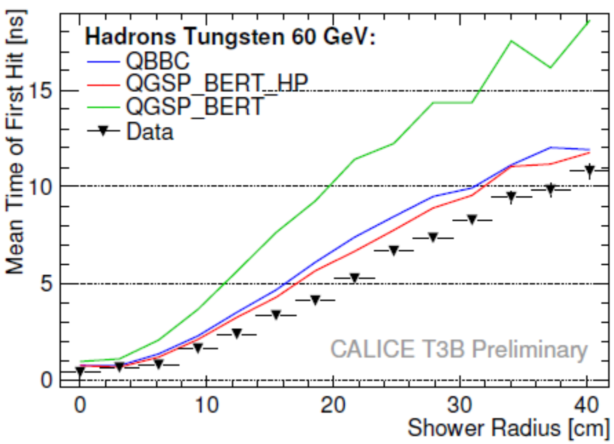
Scintillator pads or
RPC with pads

Positioned downstream of

Steel stack or
Tungsten stack

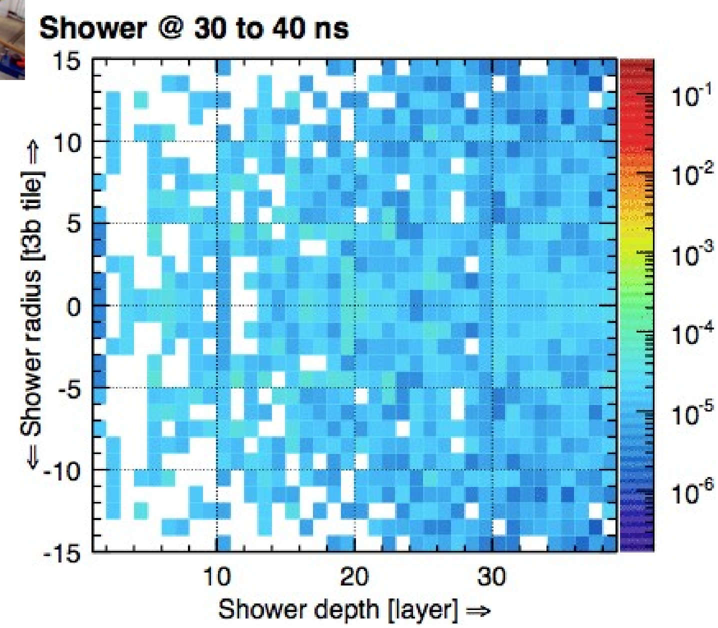


Comparison with hadron shower models



Average 60 GeV shower in 4D

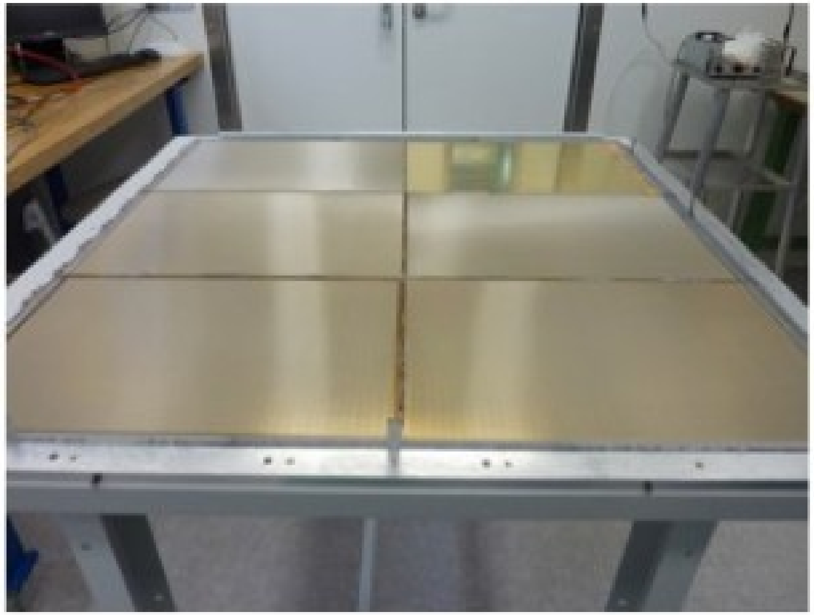
Use reconstructed interaction point in Tungsten - AHCAL



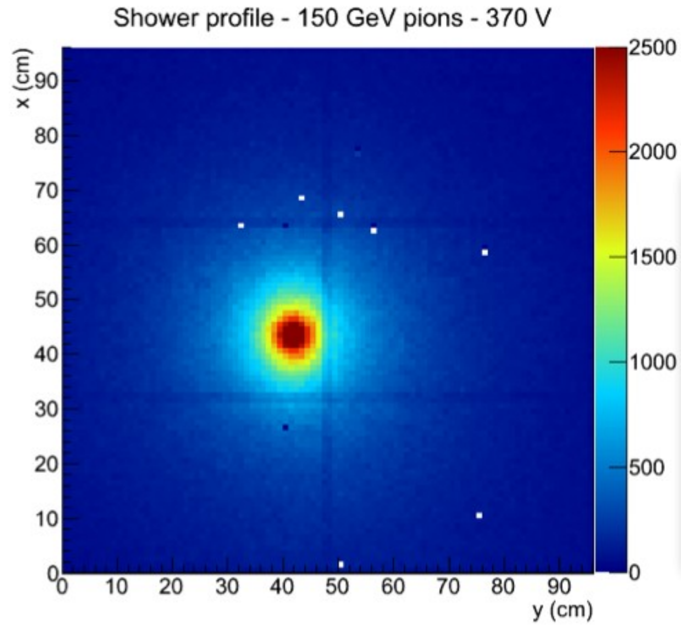
J. Repond - Hadron Calorimetry

The power of imaging calorimeters

Micromegas



Up to four chambers tests in 2012



Beam spot

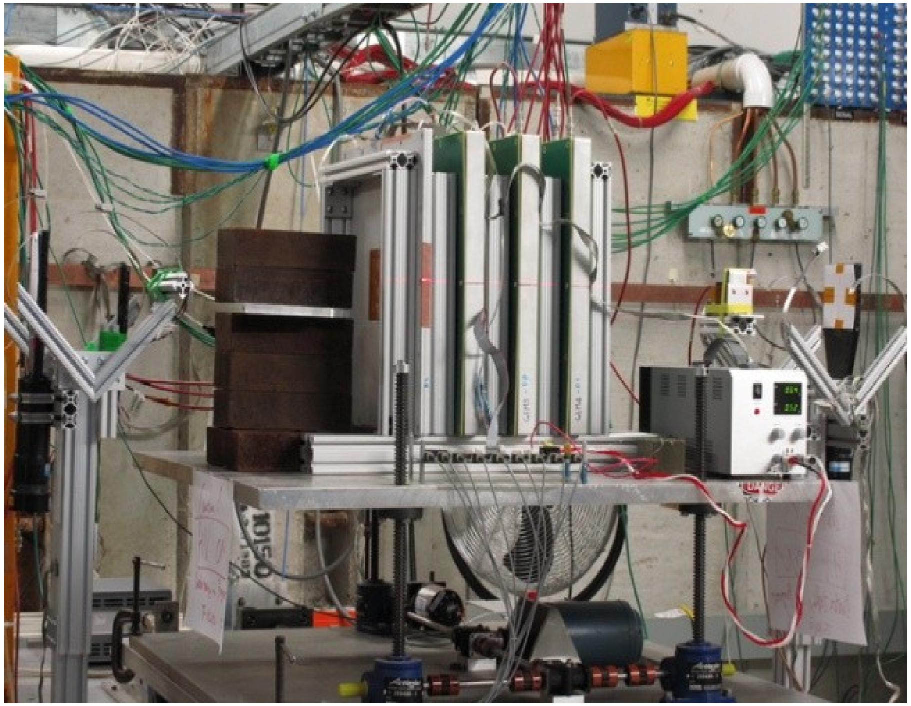
Questions to answer:

- How to fix semi digital thresholds
- Values for high and medium
- Stability, rates sparks

Promising results presented to CALICE TB

I feel that I should not be the first one to present them in public

GEM beam test at FTBF in August 2011

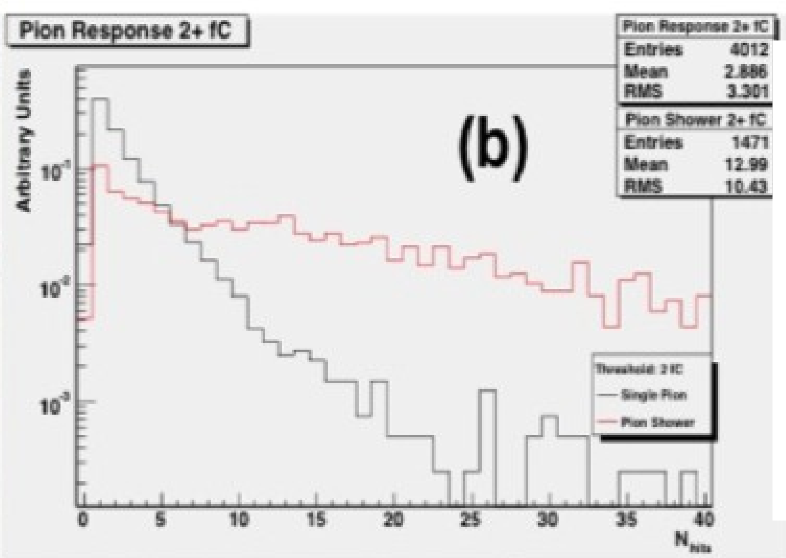


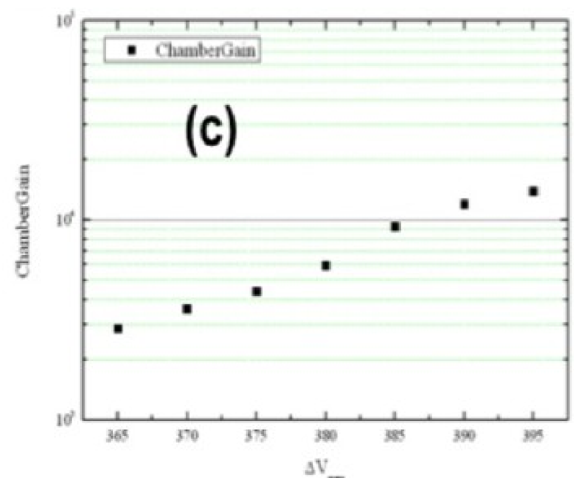
Test of different r/o electronics

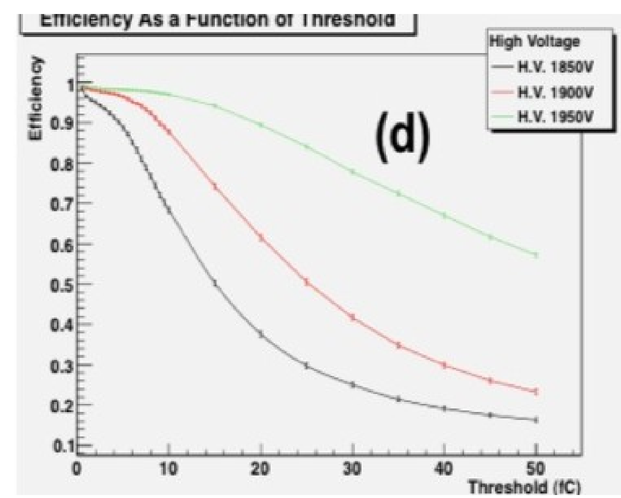
GEM6: Read out by 13bit KPiX

GEM7, GEM5, GEM4: Read out by 1bit DCAL chip

GIA: Medical image intensifier prototype with 12 bit ADC

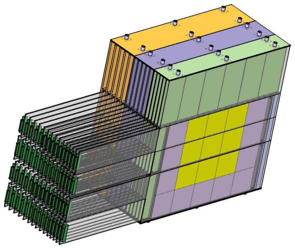


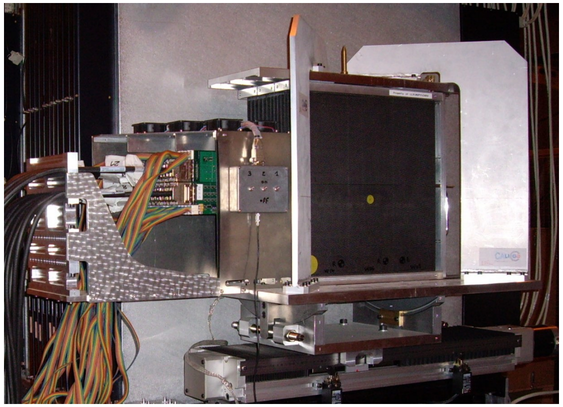


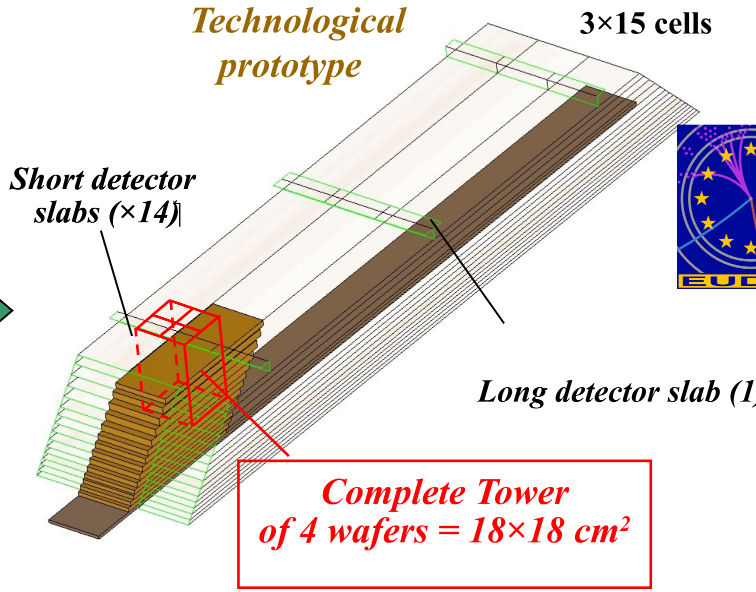


Technological Prototypes

Technical solutions for the/a final detector – Example Ecal







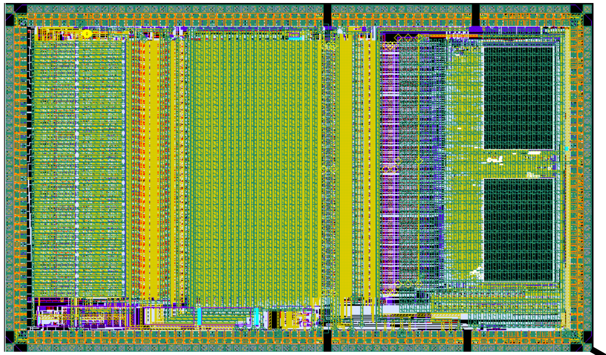
- Realistic dimensions

- Integrated front end electronics

- Small power consumption

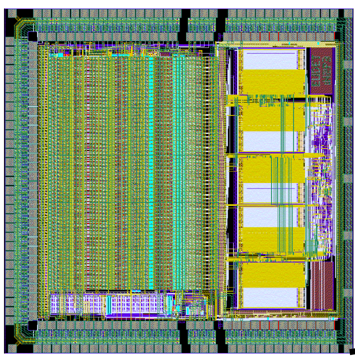
  Power pulsed electronics

Front end ASICs: The 'ROC' chips

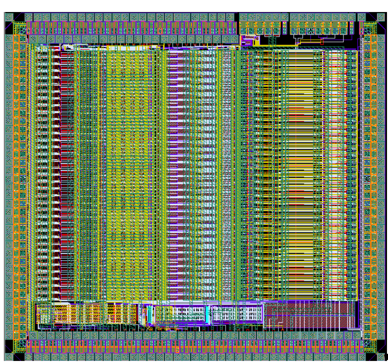


SPIROC
Analog HCAL
(SiPM)
36 ch. 32mm²

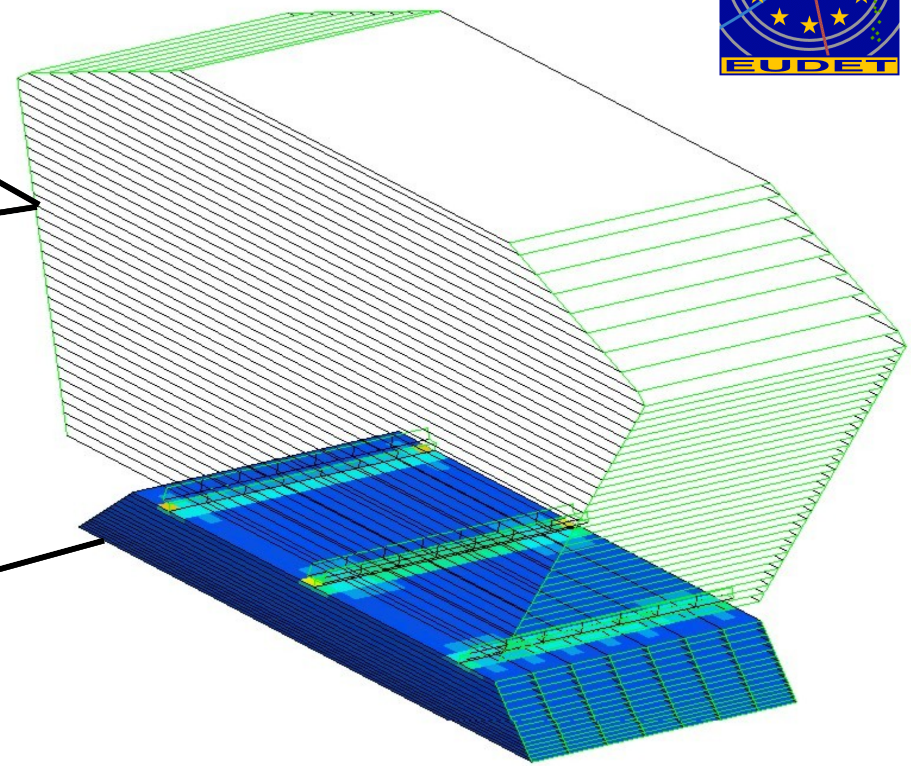
- CALICE Prototypes: large scale modules (~2m)
- Partially funded by EU (06-09)
  AIDA 2011-...
- ECAL, AHCAL, SDHCAL



HARDROC
Digital HCAL
(RPC, µmegas or GEMs)
64 ch. 16mm²



SKIROC
ECAL
(Si PIN diode)
64 ch. 20mm²

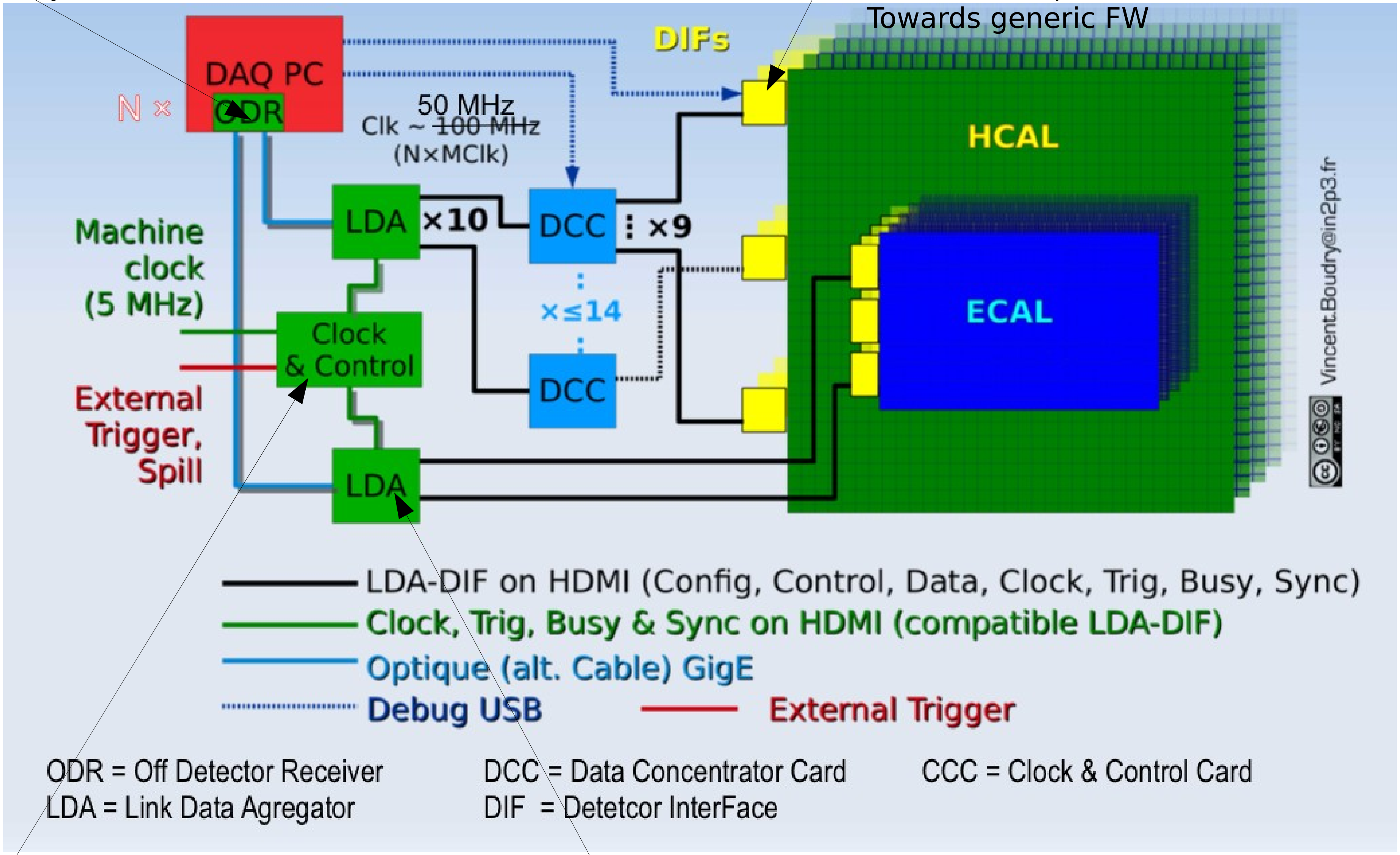


DAQ systems – Common system for tech. prototypes

Example: DAQ2 for systems >~ 2011

ODR:
Stability of data transfer in network

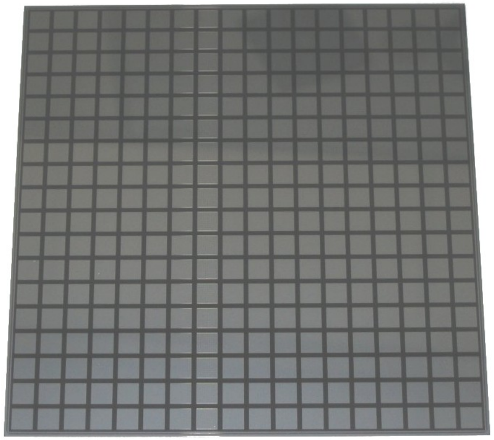
DIF:
Continous improvement of FW
Towards generic FW

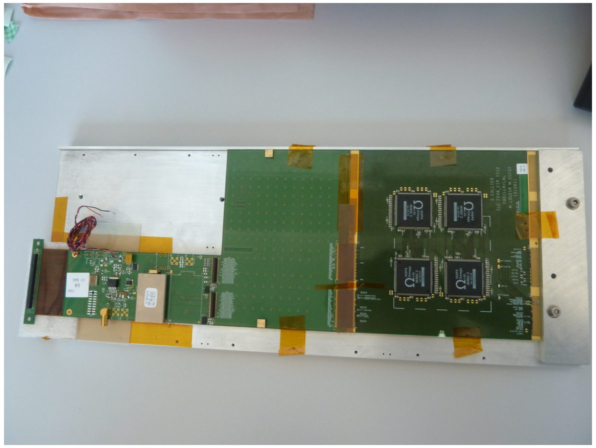


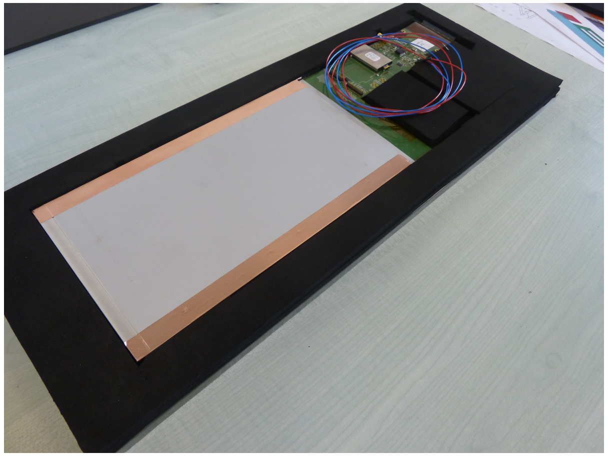
CCC:
Revision of system level features
Firmware

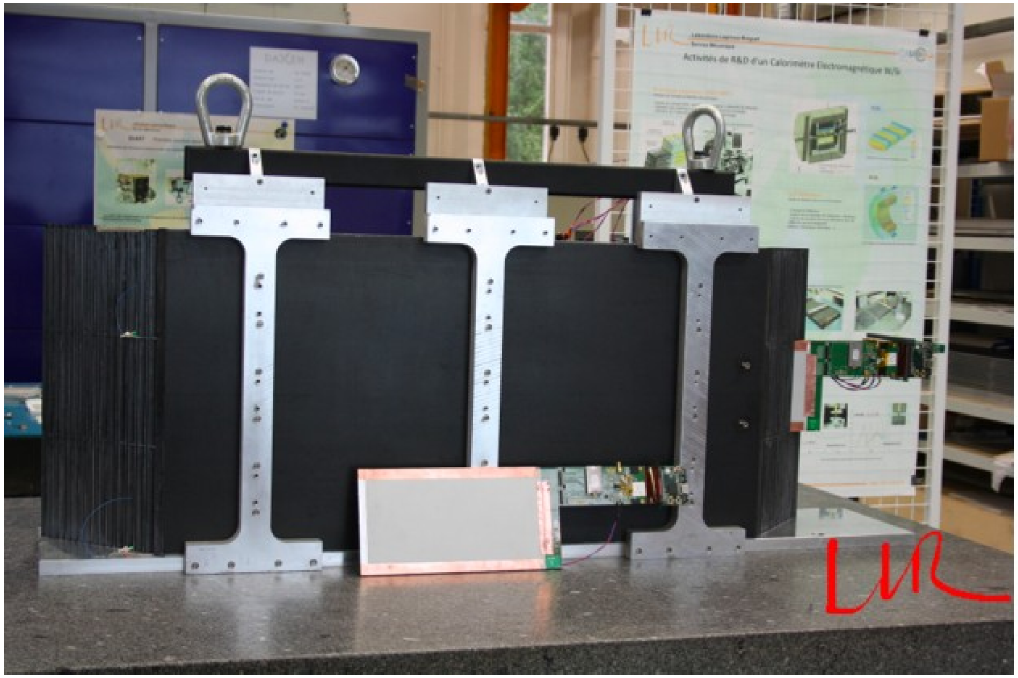
LDA:
To be replaced by **GigaDCC**

SiW Ecal elements of tech. prototype









Beam test DESY – April and July 2012

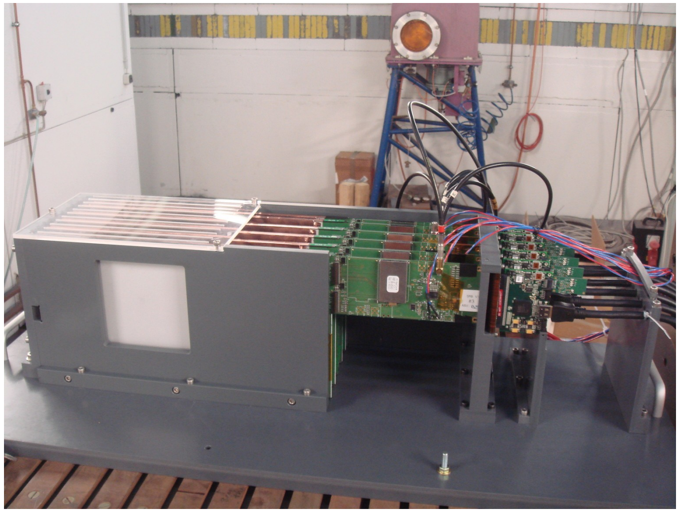
e- (1 - 5 GeV)

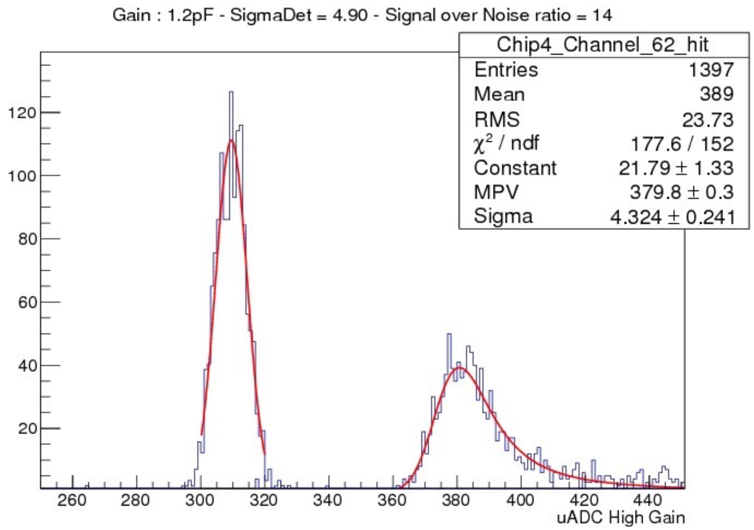
- 6 layers (FEV8)
  - Internal trigger

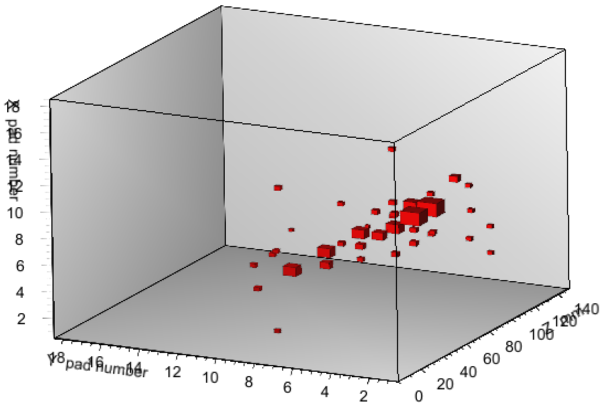
Total = 1536 channels

PreAmplifiers of noisy channels are switched off

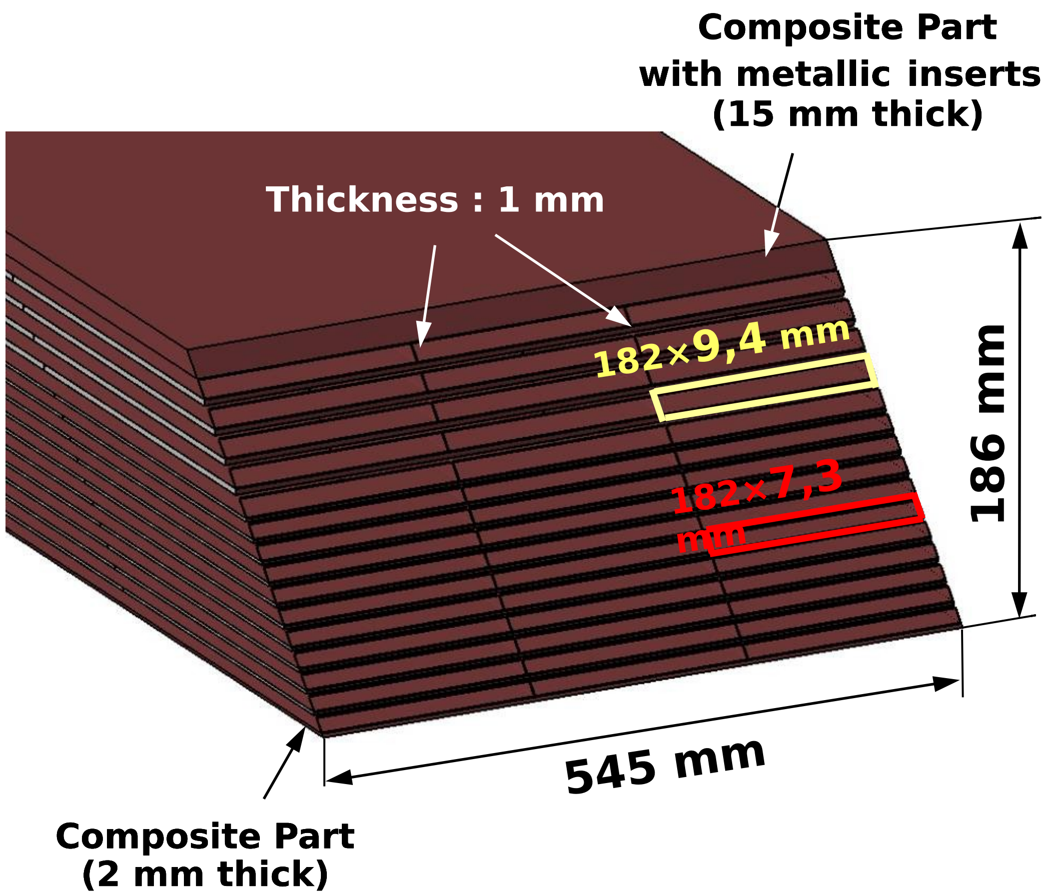
total active channels = 1278

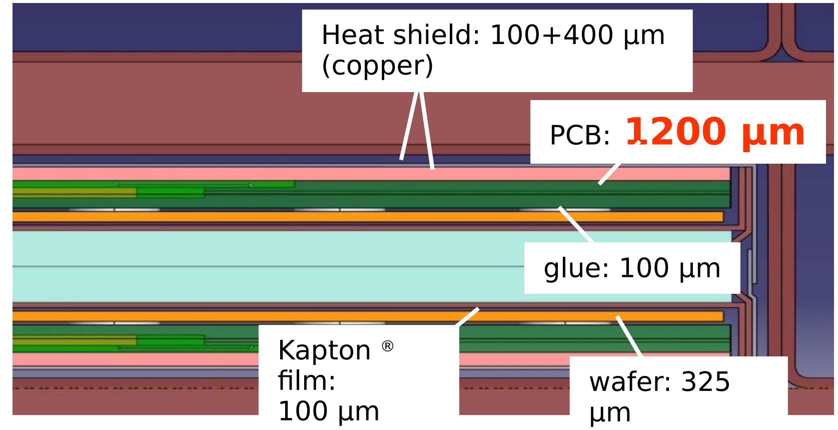


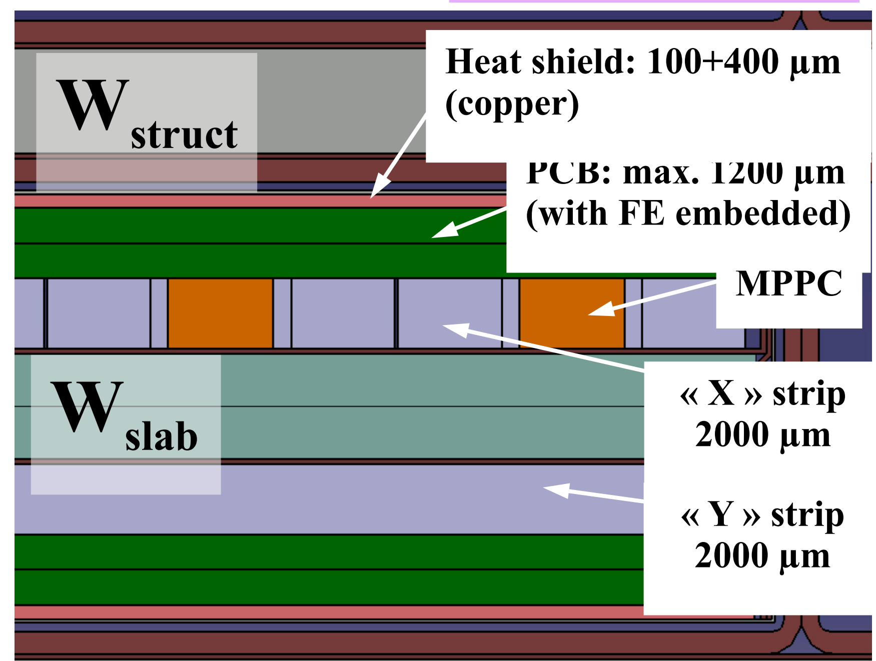




Collaboration SiW-Scint Ecal



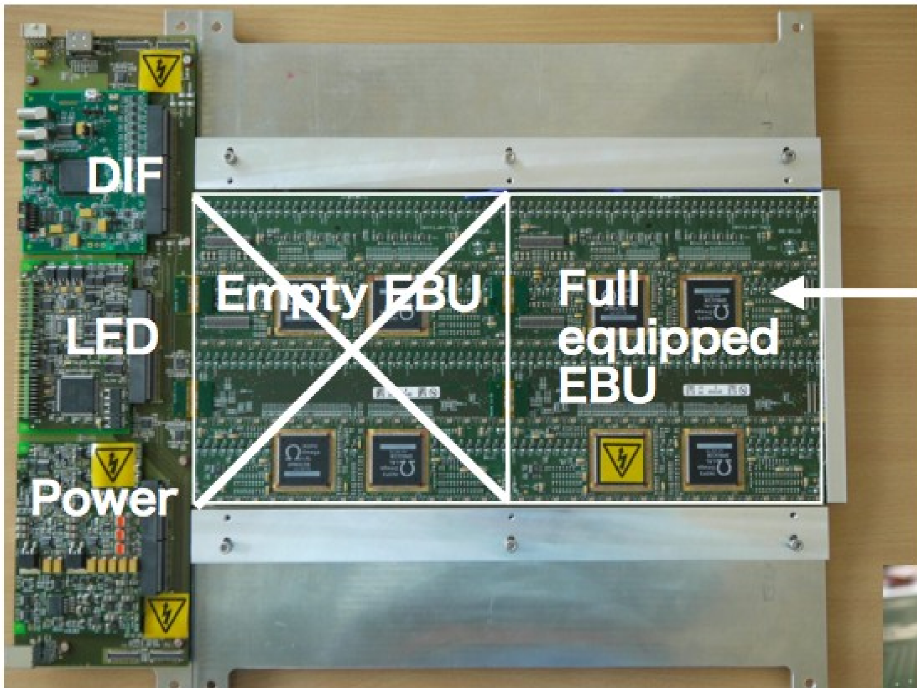




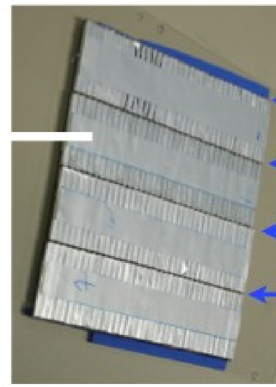
- Alveolar structure applicable for both Ecal proposals
- Details on integration are currently worked out.
  Communication SiW Ecal-ScintEcal-DESY
- Schedule to be precised in coming months
- Common CALICE DAQ would be crucial for success of integration

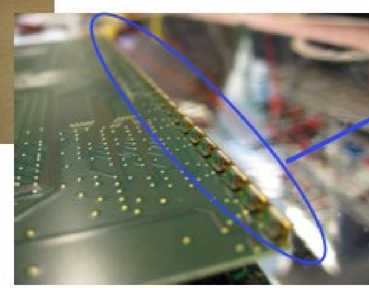
Towards ScEcal prototype

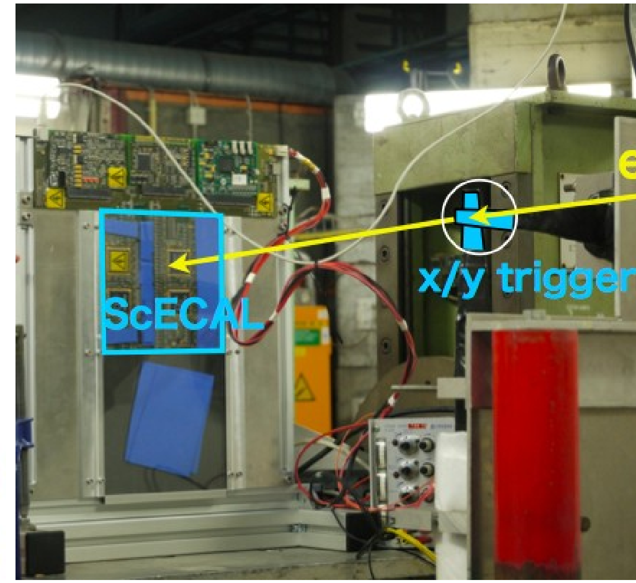
- One layer one base board (EBU) prototype so far.
- Four SPIROC2b on an EBU controls 144 MPPCs.

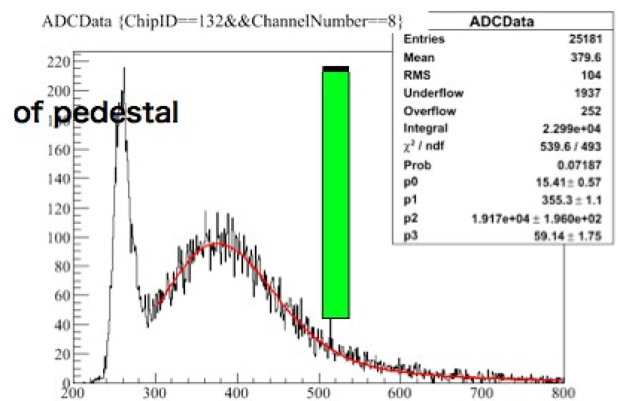


The other side.





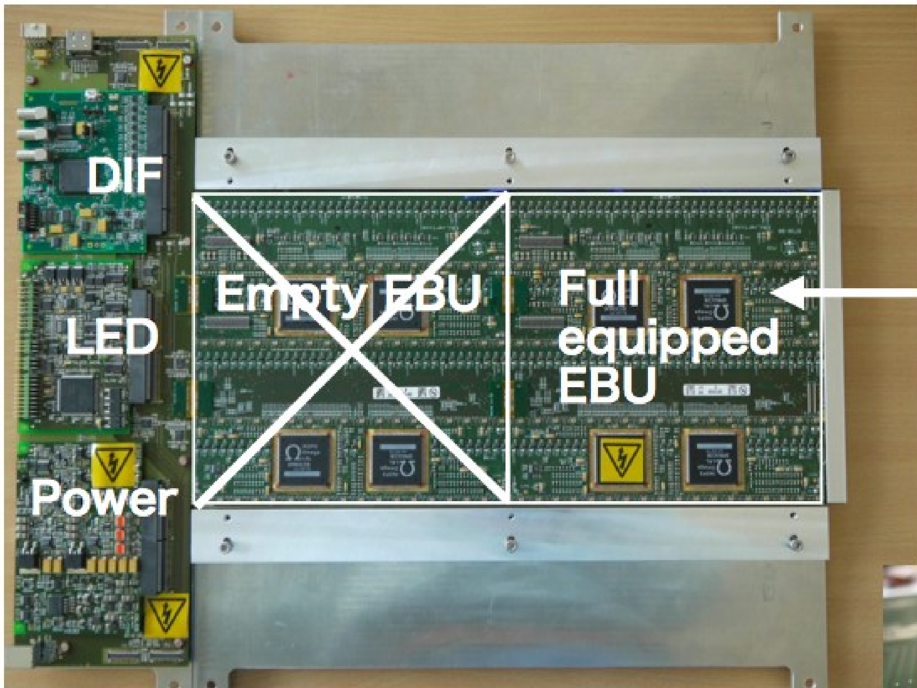




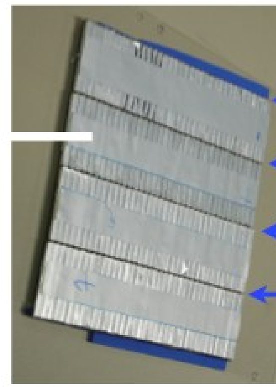
TB version DIF does not work with two EBU. We gave up to use two EBU.

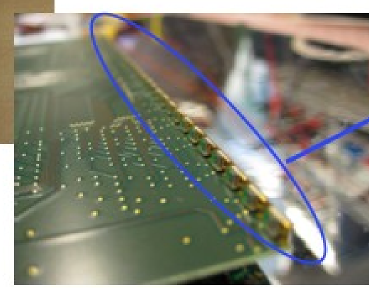
Towards ScEcal prototype

- One layer one base board (EBU) prototype so far.
- Four SPIROC2b on an EBU controls 144 MPPCs.



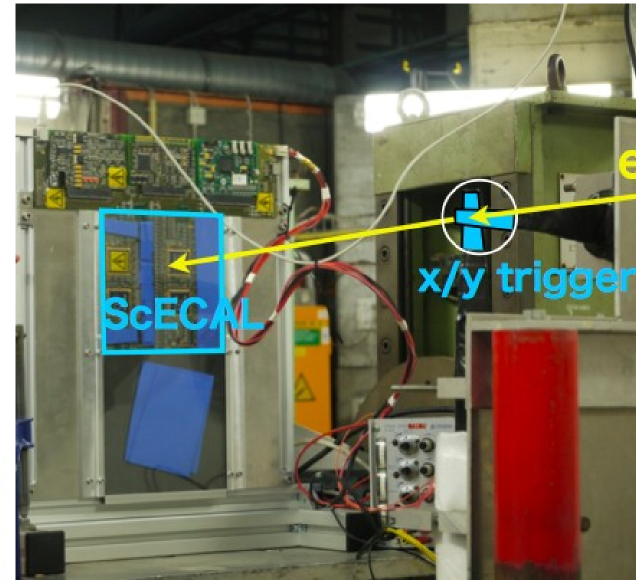
The other side.

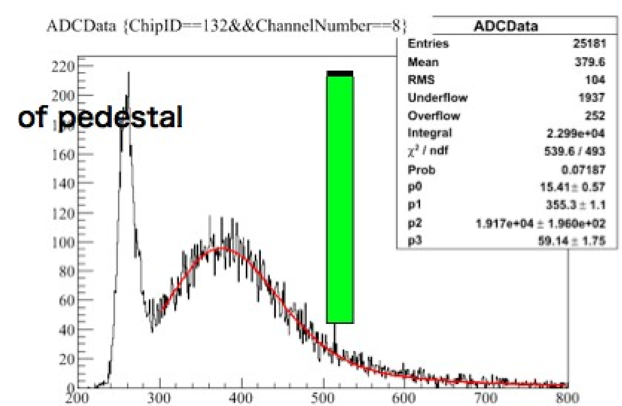




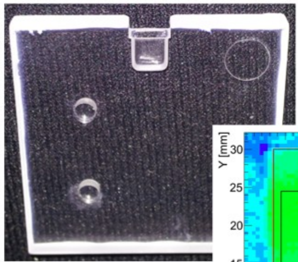
MPPCs

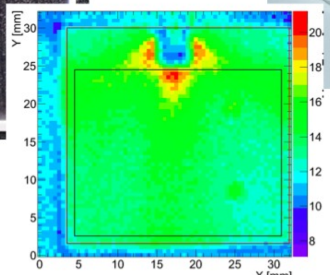
TB version DIF does not work with two EBU. We gave up to use two EBU.



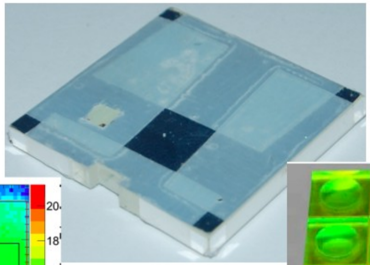


Towards AHCAL tech. prototype



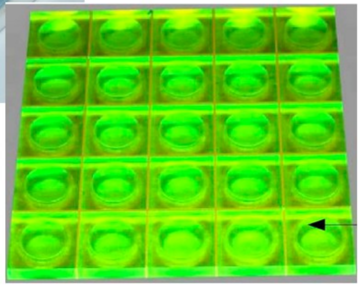


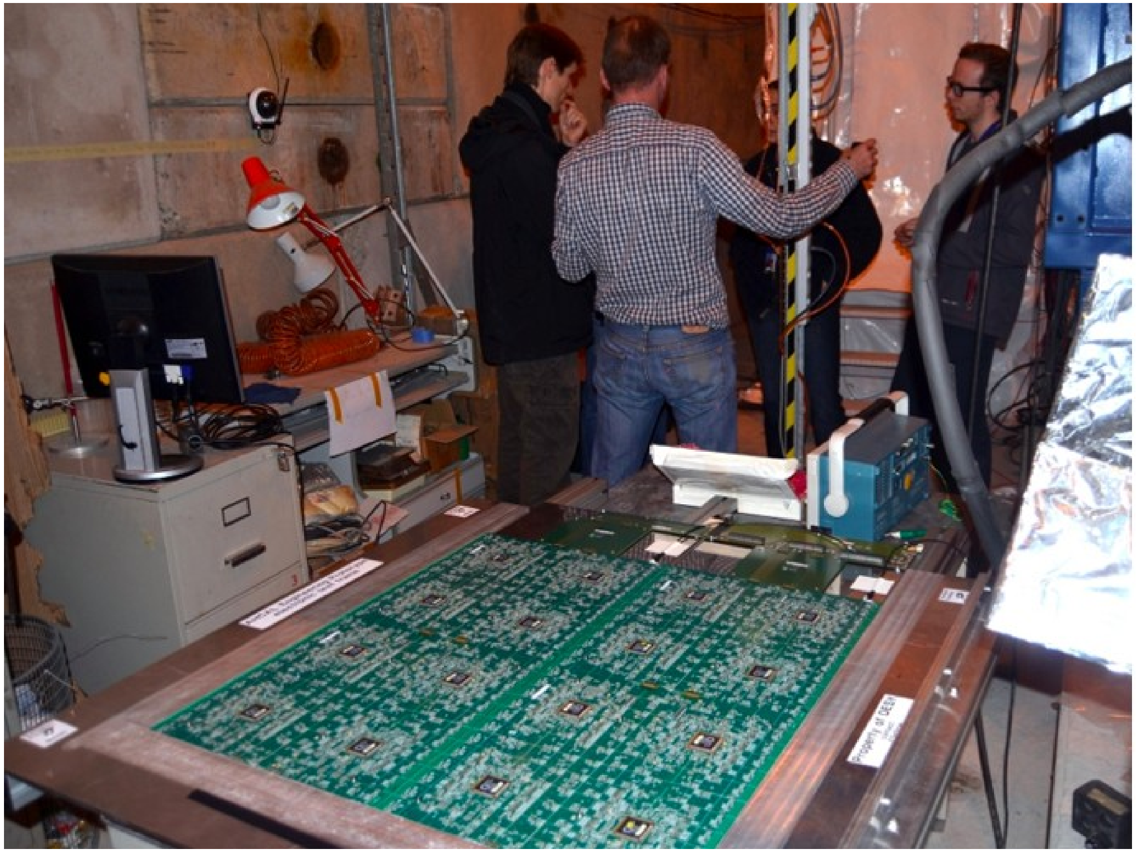
fiberless tile
MPI Munich
and ITEP

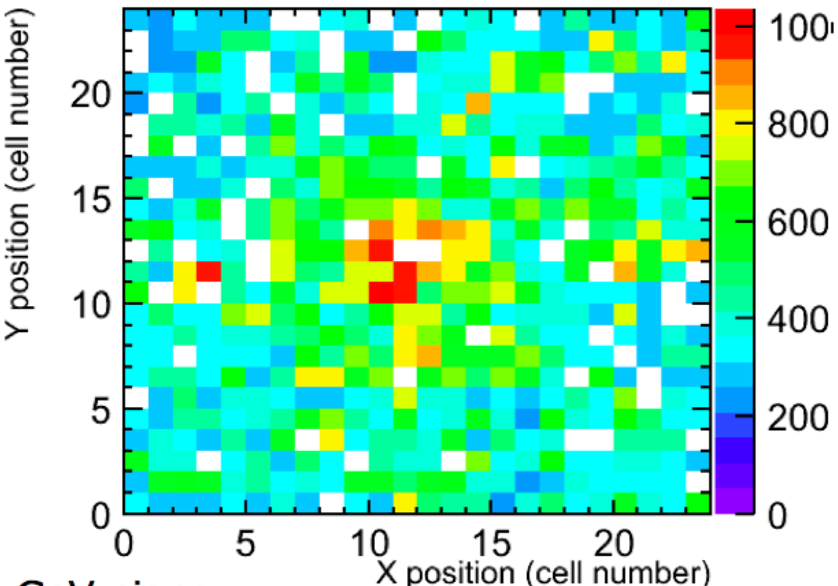


fully wrapped
Uni. Hamburg

Megatile SiPM on
top side (NIU)



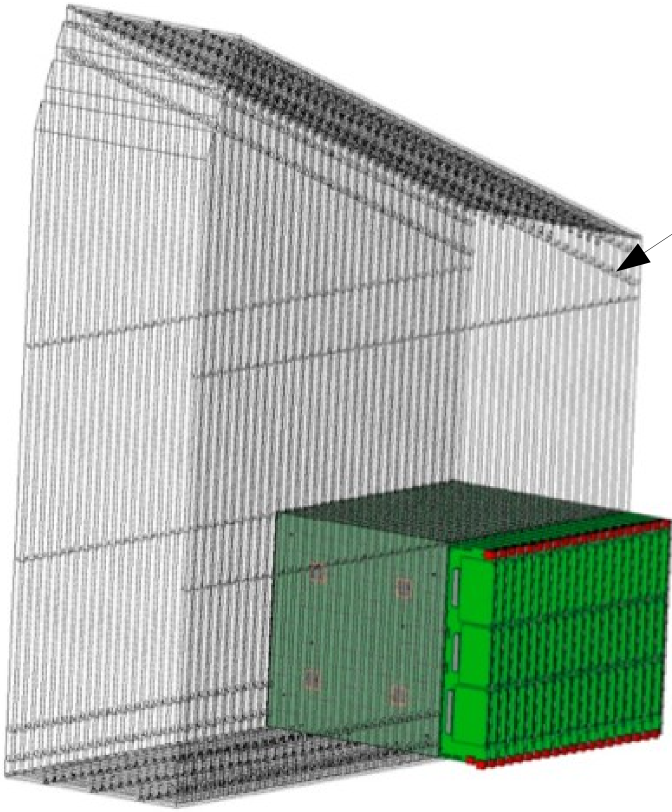


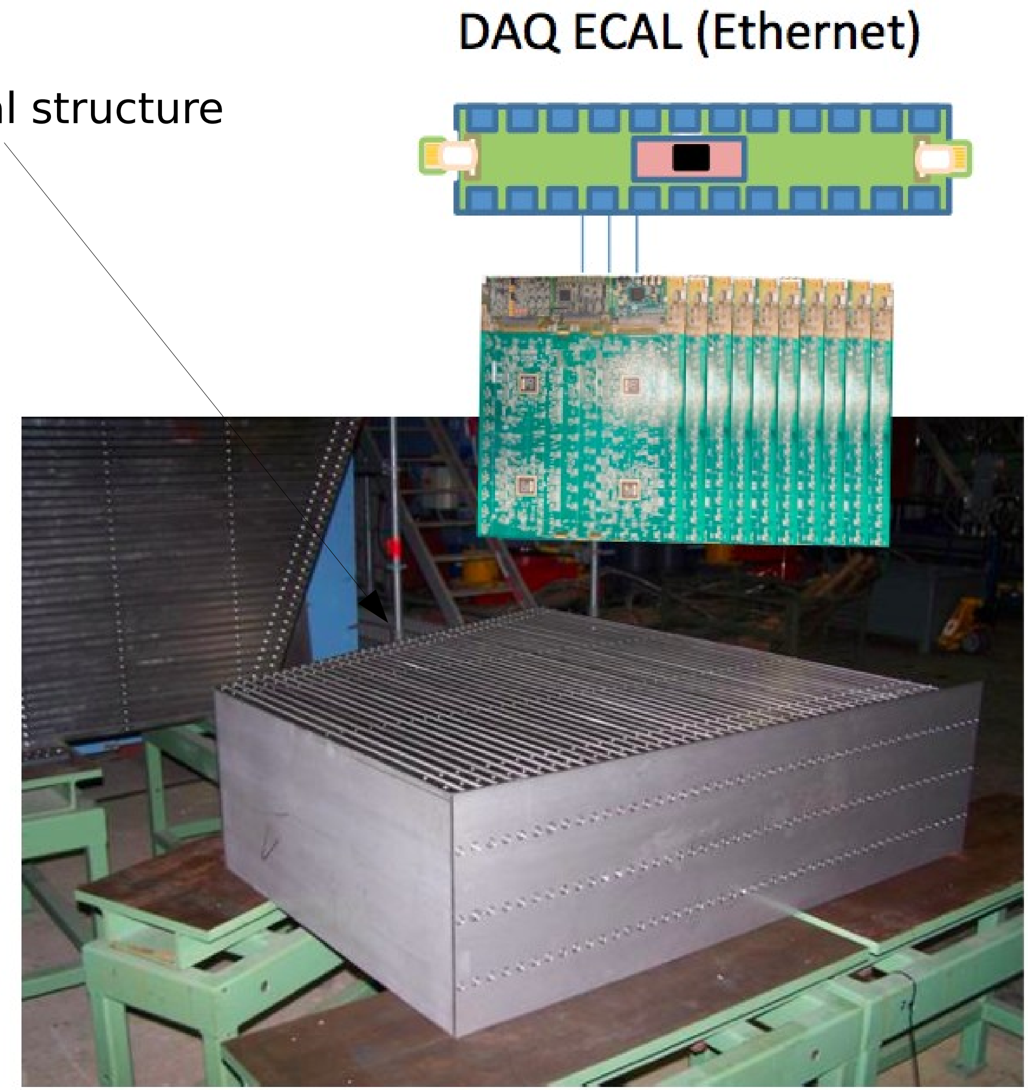


30 GeV pions

Towards AHCAL tech. Prototype – cont'd

Mechanical structure





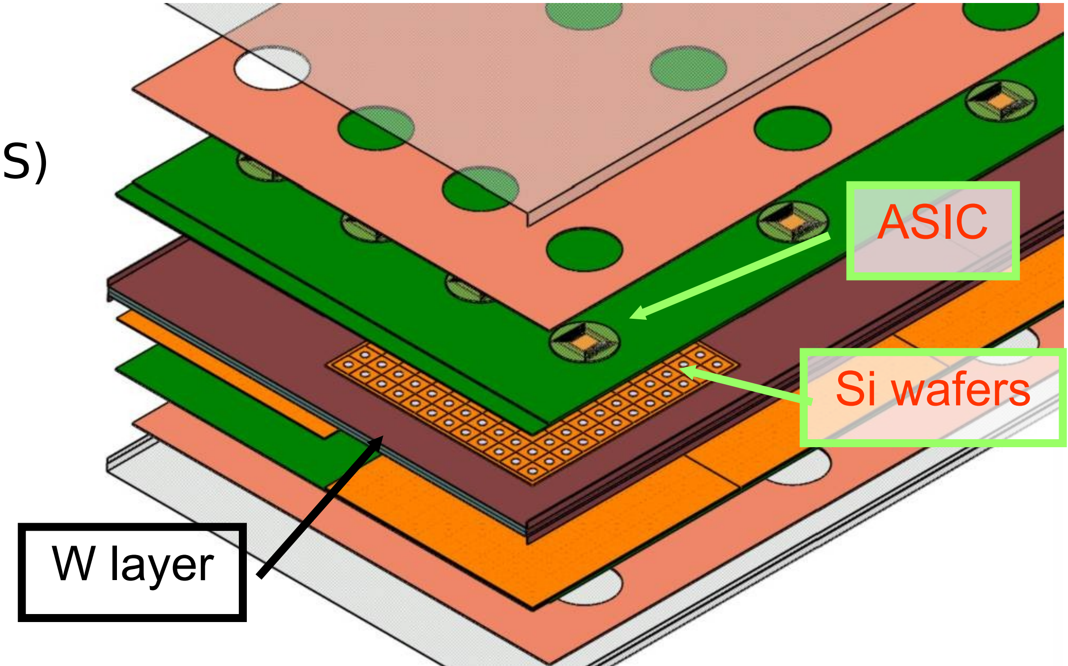
HCAL layers
Arranged as elm. Calortimeter

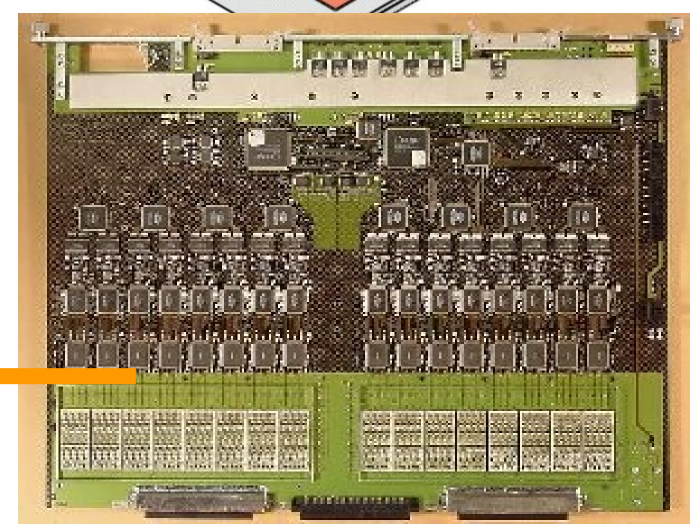
Test May 2013 with
Common CALICE DAQ planned

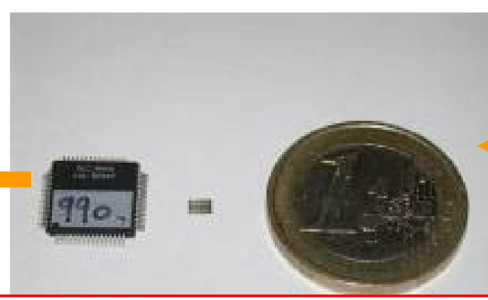
Front end electronics

- Requirements to electronics
  - Large dynamic range (~3000 MIPS)
  - Front end electronics embedded
  - Autotrigger at ½ MIP
  - On chip zero suppression

  - **Ultra low power: («25µW/ch)**
  - 10^8 Channels
  - Compactness





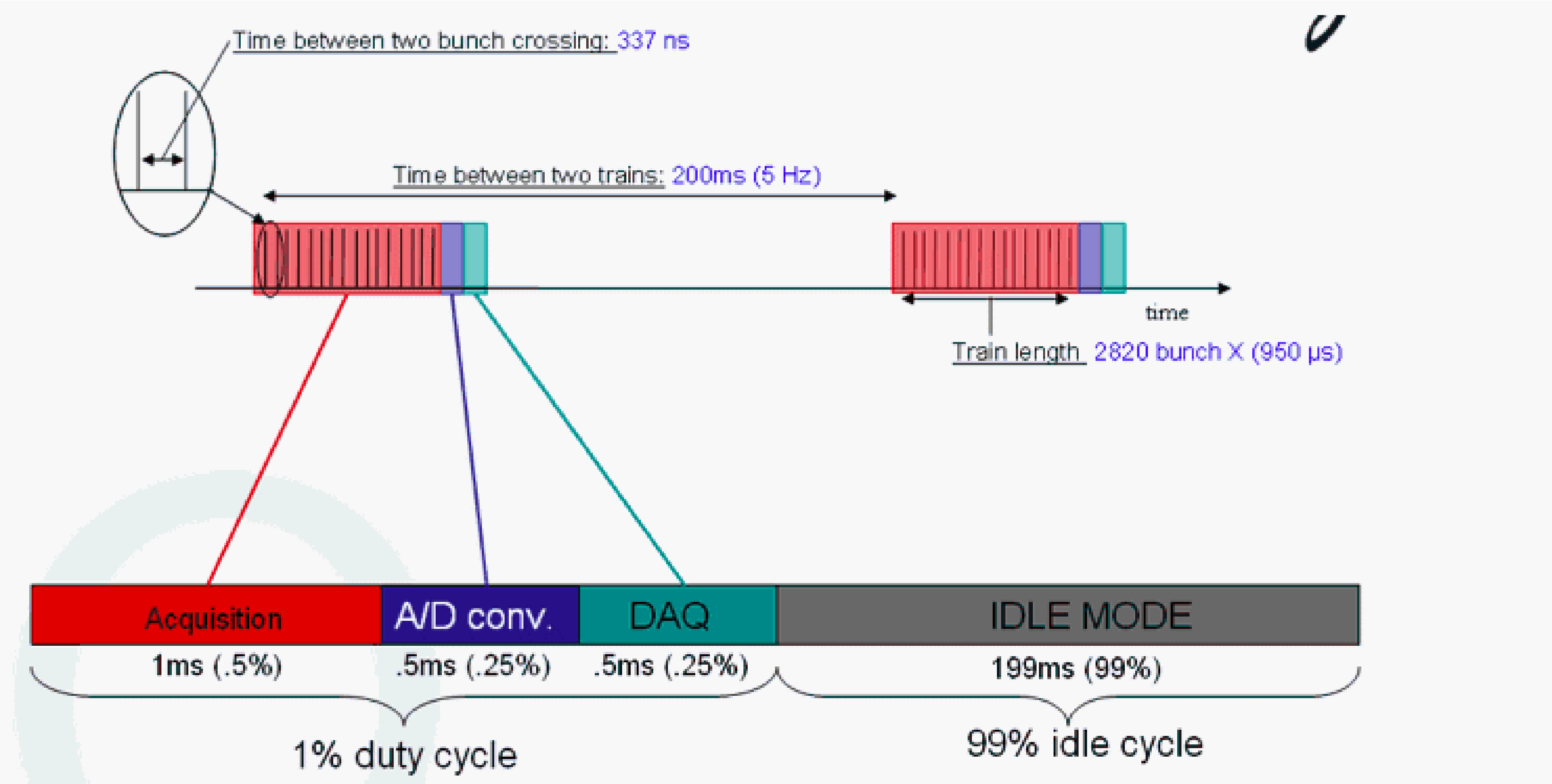


ILC : **25µW/ch**

FLC_PHY3 18ch 10*10mm **5mW/ch**

ATLAS LAr FEB 128ch 400*500mm **1 W/ch**

One approach: Power gating



- Electronics on during 1ms of ILC bunch train and immediate data acquisition

- Bias currents shut down between bunch trains

- Mastering of technology is essential for operation of (I)LC detectors Proof is Priority in 2013

Beam test plans until ~2015

Project	2013/1	2013/2	2014/1	2014/2	2015/1	2015/2
SiW ECAL	x	x	xx	xx	xx	?
SiW ECAL/SDHCAL	-	-	?	?	?	?
Si-W ECAL/AHCAL	-	-	?	?	?	?
ScECAL	x	x	x	x	?	?
AHCAL	x	x	xx	xx	xx	?
DHCAL RPC	x	x	x	?	?	?
GRPC SDHCAL	x	x	xx	xx	?	?
Mmegas SDHCAL	x	x	?	?	?	?
DHCAL GEM	-	x	x	x	x	x

Summary and outlook

- Need for highly granular calorimeters for a LC triggered a vast R&D program for this new kind of detector

  -> Qualitative step in detection capabilities

- Since 2002 structured R&D approach under the roof of the CALICE collaboration

  From proof of principle to the eve of full detector systems

- Collaborative effort saved (a lot of) resources

- Collaborative approach facilitated access to beam test facilities
  Increased impact/visibility of R&D program

- CALICE contributes to the development and understanding of calorimetry

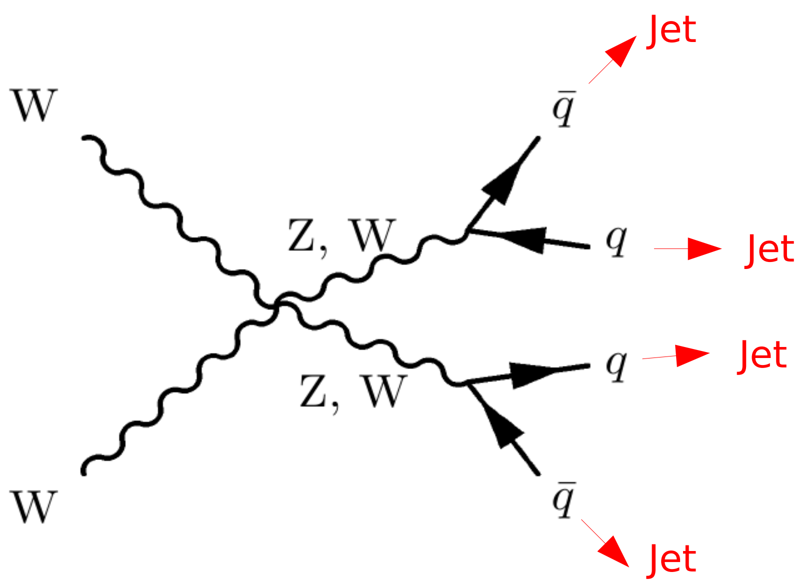
- CALICE offers an excellent forum for discussing issues/challenges/results of imaging calorimetry

Backup Slides

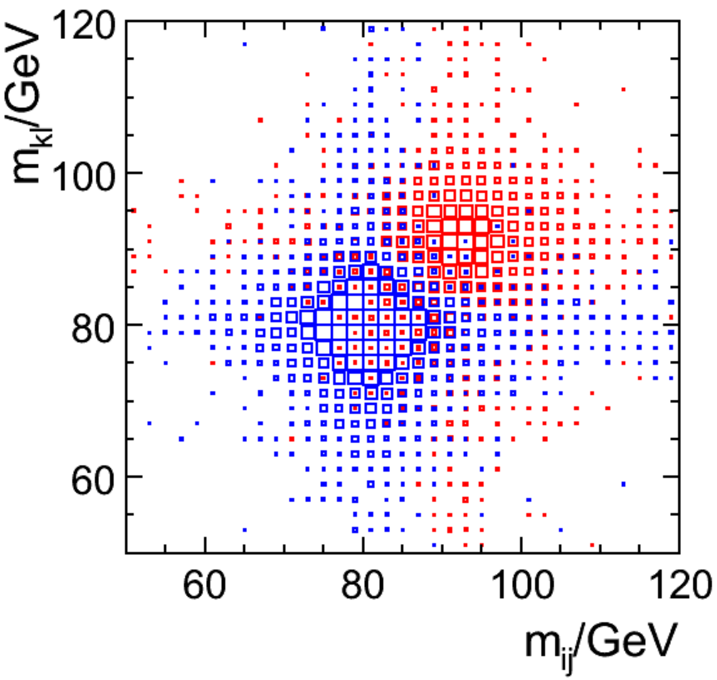
Hadronic decays of W and Z bosons

Boson Boson scattering

Manifestation of new physics
Strong Electroweak Symmetry Breaking



W, Z separation in the ILD Concept

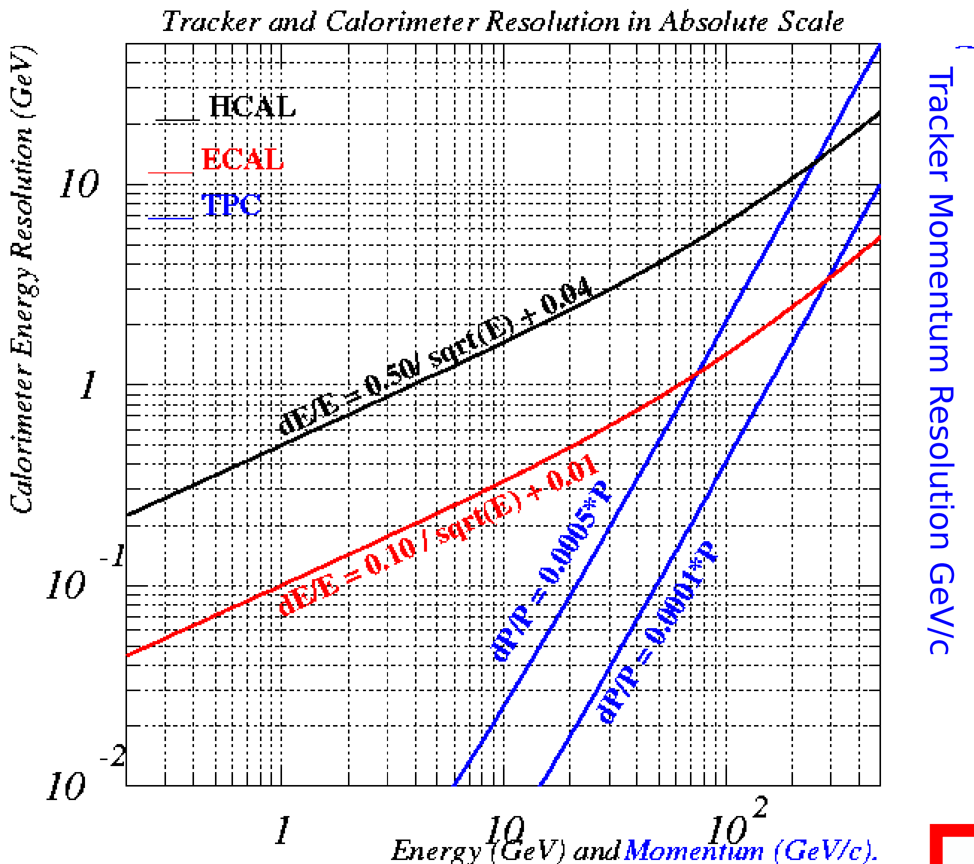


Remember: $M_Z - m_W \approx 10$ GeV

- Need excellent jet energy and dijet mass resolution to separate W and Z bosons in their hadronic decays
  $3\%/E_{jet}$-$4\%/E_{jet}$
- Basic mean: Highly granular calorimeters optimised for Particle Flow

Jet energy resolution

Final state contains high energetic jets from e.g. Z,W decays
Need to reconstruct the jet energy to the utmost precision !



Jet energy carried by …

- Charged particles ($e^{\pm}$, $h^{\pm}$,$\mu^{\pm}$)): 65%
  Most precise measurement by Tracker
  Up to 100 GeV

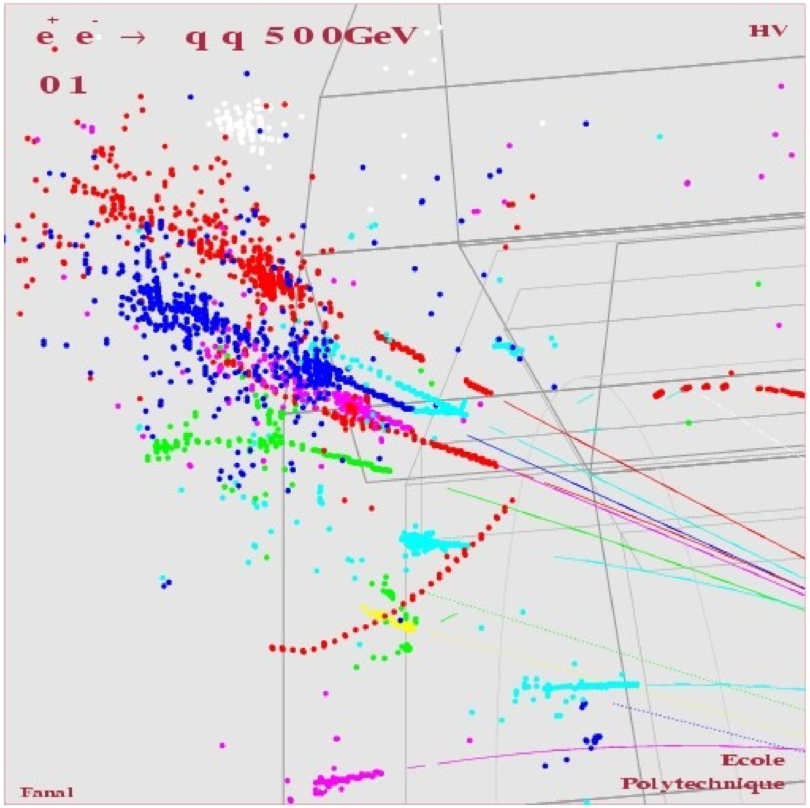
- Photons: 25%
  Measurement by Electromagnetic Calorimeter (ECAL)

- Neutral Hadrons: 10%
  Measurement by Hadronic Calorimeter (HCAL) and ECAL

$$\sigma_{Jet} = \sqrt{\sigma^2_{Track} + \sigma^2_{Had.} + \sigma^2_{elm.} + \sigma^2_{Confusion}}$$

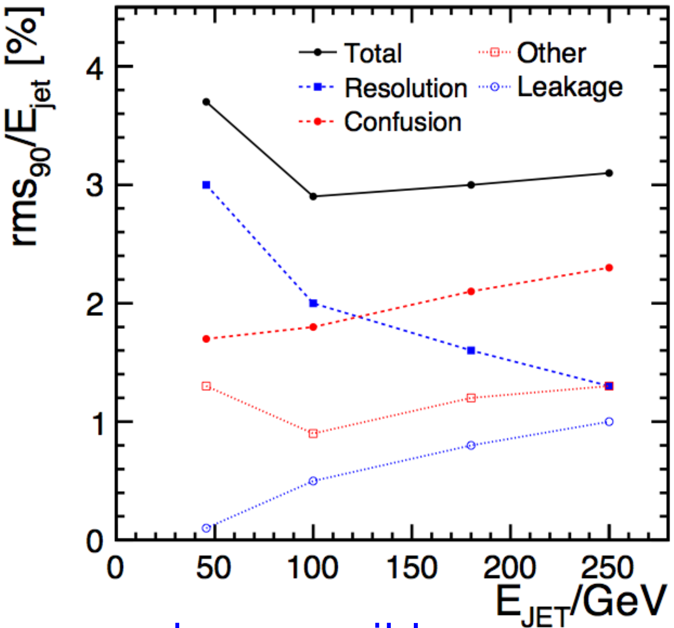
Confusion term

- Base measurement as much as possible on measurement of charged particles in tracking devices
- Identify energy deposits in calorimeter as belonging to incident charged or neutral particles



- Complicated topology by (hadronic) showers
- Correct assignment of energy nearly impossible

⇒ Confusion Term

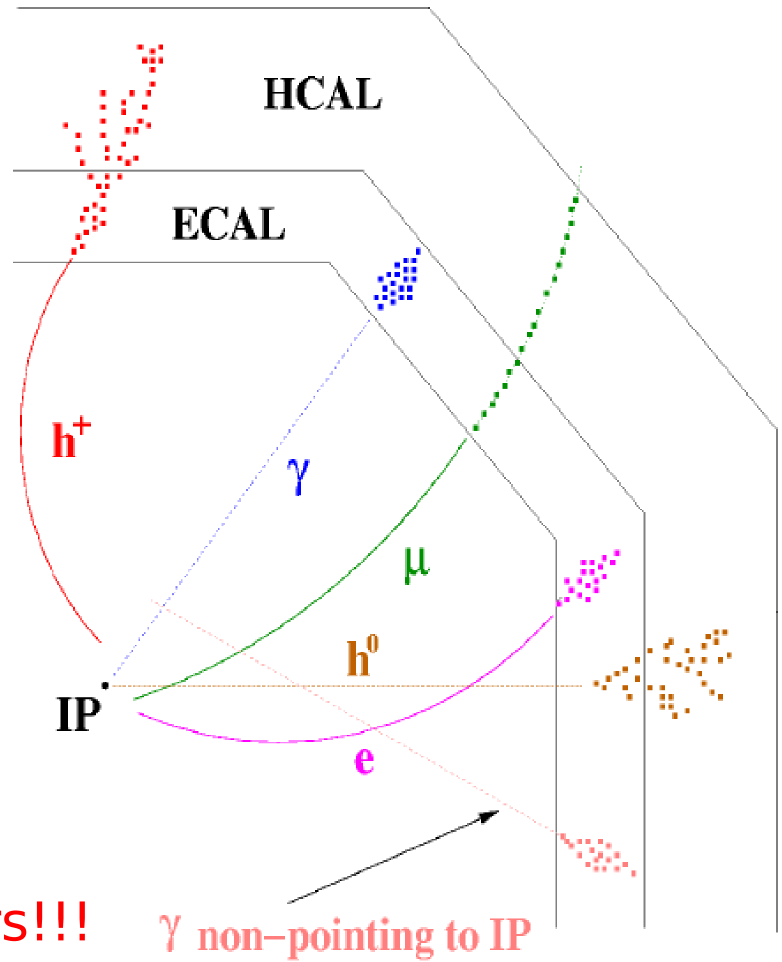


Need to minimise confusion term as much as possible

Detector and calorimeter concept – Particle Flow

Jet energy measurement by measurement of **individual particles**
Maximal exploitation of precise tracking measurement

- large radius and length
  - ➔ to separate the particles
- large magnetic field
  - ➔ to sweep out charged tracks
- “no” material in front of calorimeters
  - ➔ stay inside coil
- small Molière radius of calorimeters
  - ➔ to minimize shower overlap
- **high granularity of calorimeters**
  - ➔ to separate overlapping showers



Physics goals at the ILC demand the
Construction of highly granular calorimeters!!!

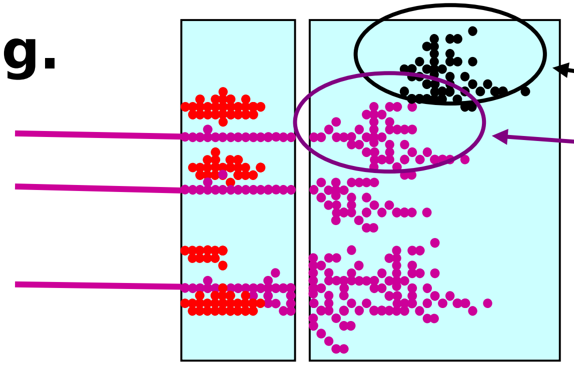
Emphasis on tracking capabilities of calorimeters
Energy resolution important for successful track cluster matching
and neutral particles

Event reconstruction with particle flow algorithm

Reconstruction of a Particle Flow Calorimeter:

- ★ **Avoid double counting of energy from same particle**
- ★ **Separate energy deposits from different particles**

e.g.

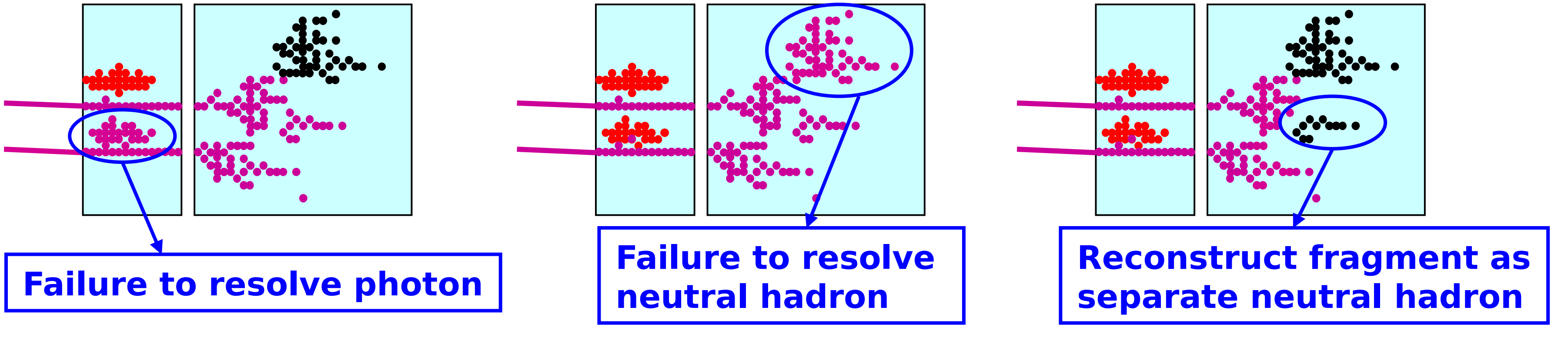


If these hits are clustered together with these, lose energy deposit from this neutral hadron (now part of track particle) and ruin energy measurement for this jet.

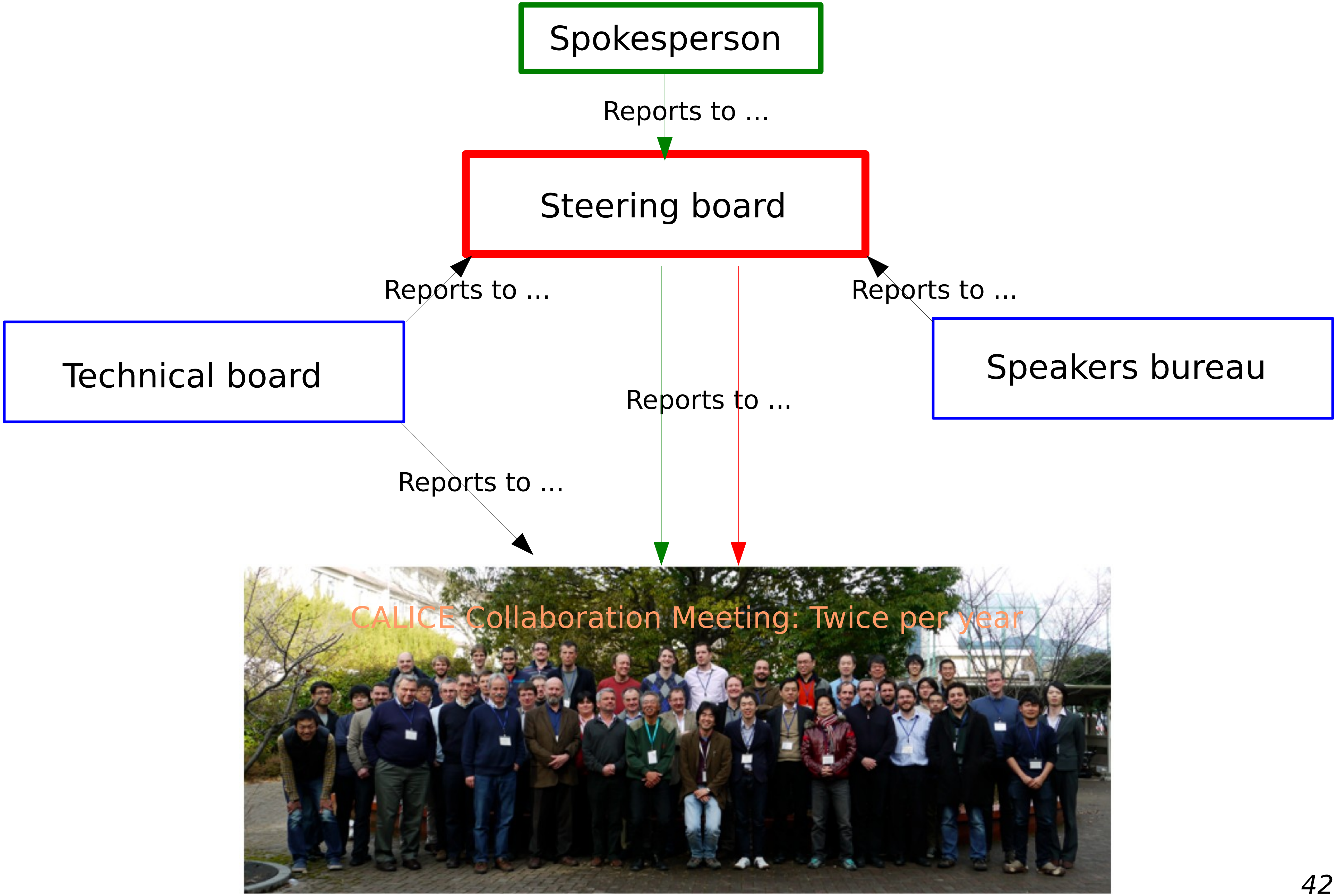
Level of mistakes, "confusion", determines jet energy resolution not the intrinsic calorimetric performance of ECAL/HCAL

Three types of confusion:

i) Photons **ii) Neutral Hadrons** **iii) Fragments**



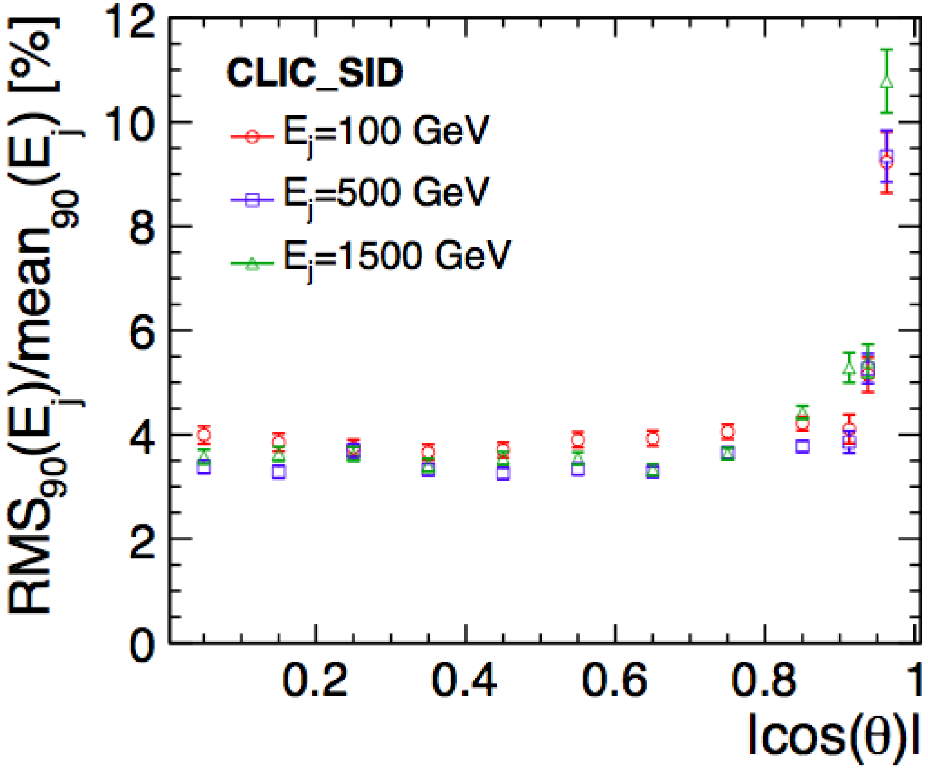
CALICE organigram



PFA @ high energies

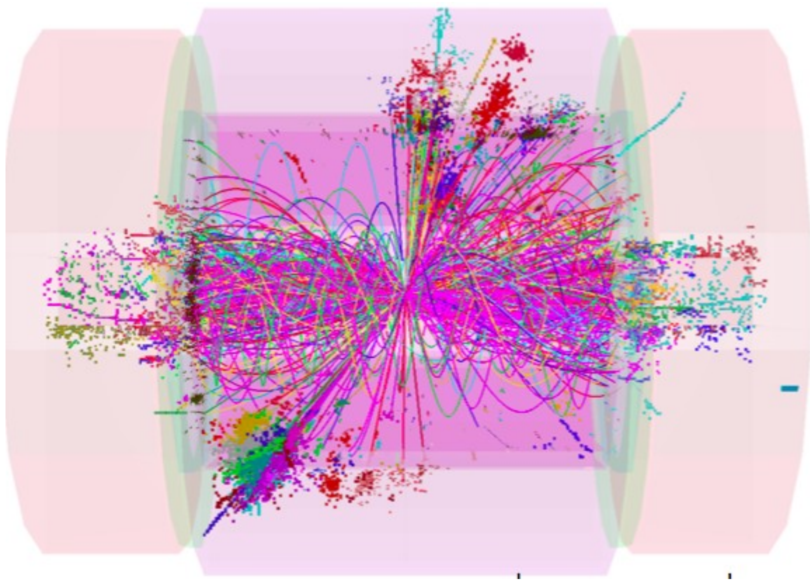
Works also for CLIC energies

Hcal with W as absorber

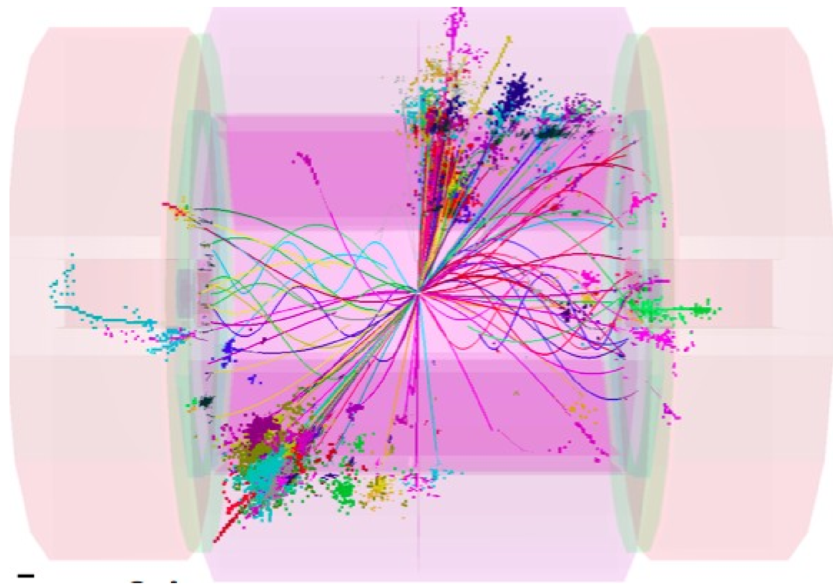


CLIC would need
high granularity in 4 dimensions

Need time stamping



No cut



Cut on 1ns

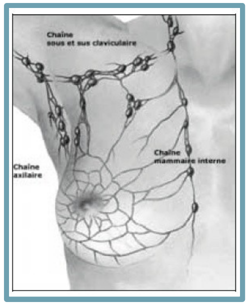
Spin offs outside particle physics

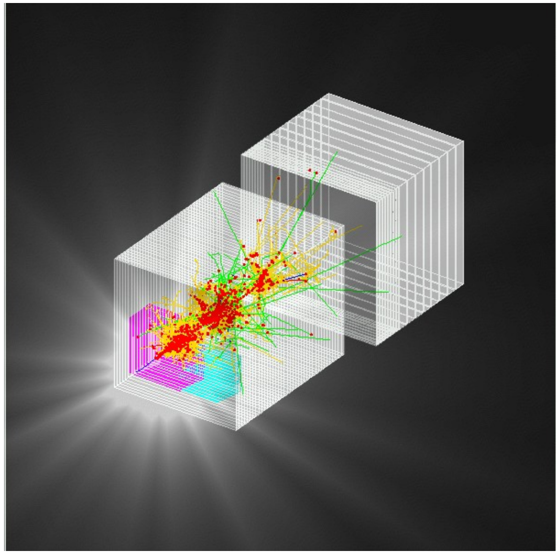
Earth sciences

Medical R&D

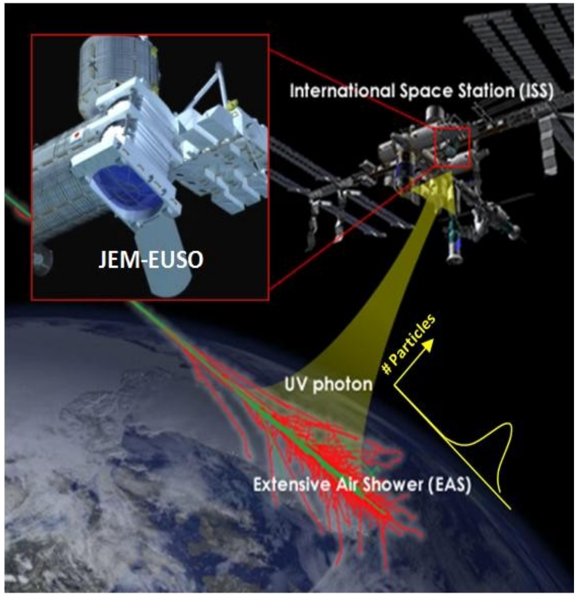
THE PICOSEC MC-NET PROJECT
Pico-second Siliconphotomultiplier Electronics & Crystal research

ENDO TOFPET US
Endoscopic TOFPET & Ultrasound

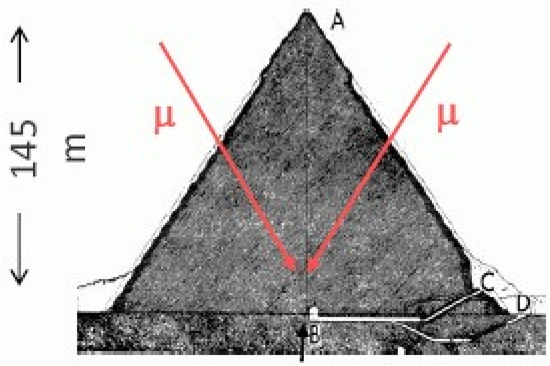




Space research



History/Archeology



Telescope in Belzoni chamber