Overview and progress from CALICE

Calorimeter for ILC

MANCHESTER 1824
The University of Manchester

CCLRC

UNIVERSITY OF CAMBRIDGE

UNIVERSITY OF BIRMINGHAM

On behalf of the Calice-UK collaboration

Imperial College London

UCL

Royal Holloway University of London

Valeria Bartsch, University College London
presenting the work of my colleagues

Content:

- Introduction
- UK activities
  - test beams - analysis and data taking
  - DAQ - on the way to a technical prototype
  - MAPS - an interesting detector concept
  - PFA and physics analysis - Higgs self coupling and WW scattering
  - mechanical and thermal studies

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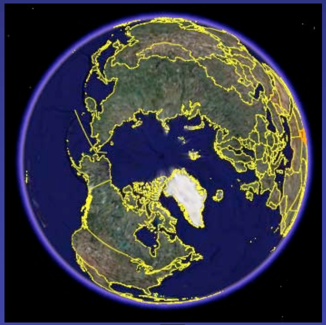
Members of the CALICE Collaboration

Calorimeter for ILC



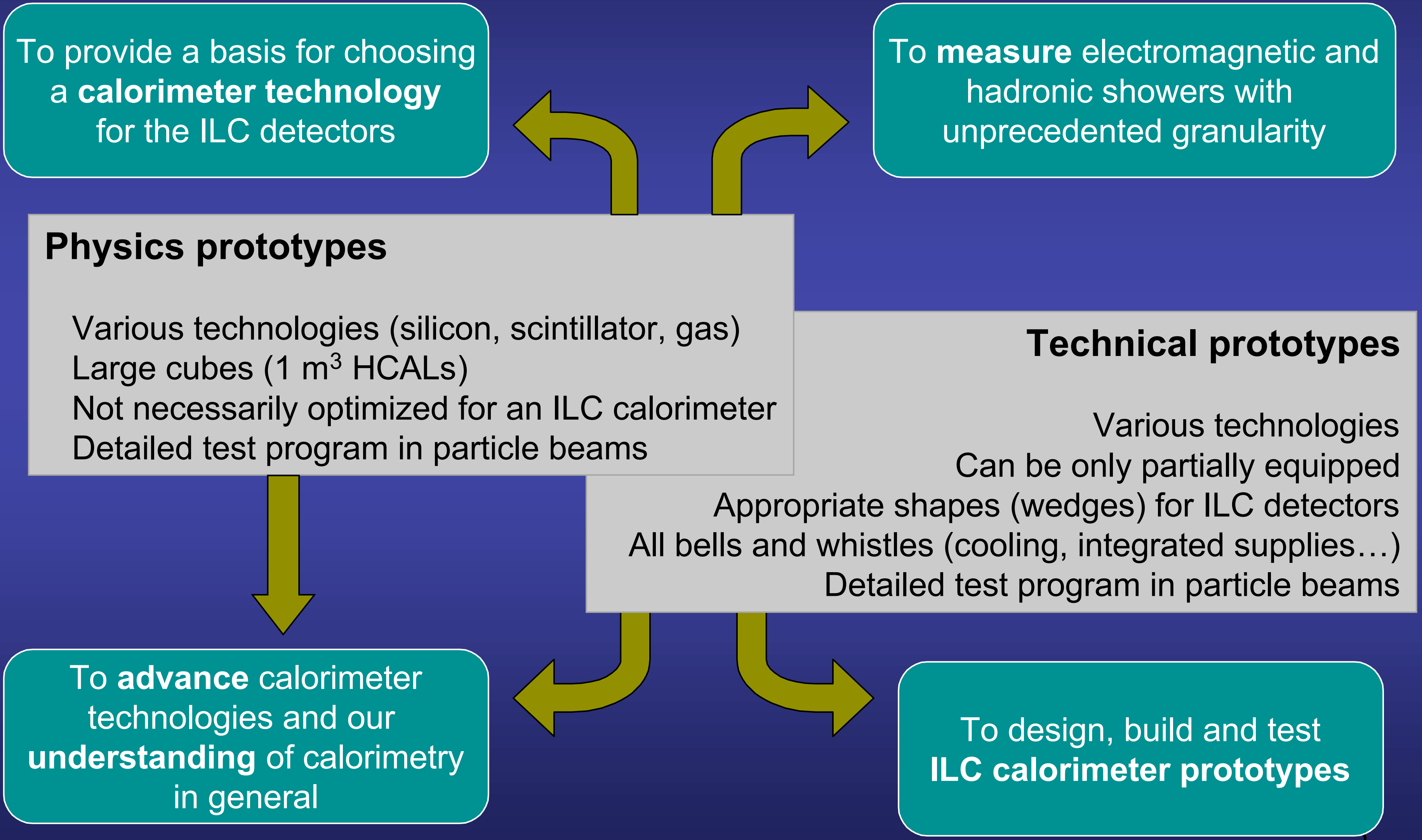
3 regions

12 countries

41 institutes

> 200 physicists

Goals of the Collaboration



To provide a basis for choosing a **calorimeter technology** for the ILC detectors

To **measure** electromagnetic and hadronic showers with unprecedented granularity

Physics prototypes

Various technologies (silicon, scintillator, gas)
Large cubes (1 m^3 HCALs)
Not necessarily optimized for an ILC calorimeter
Detailed test program in particle beams

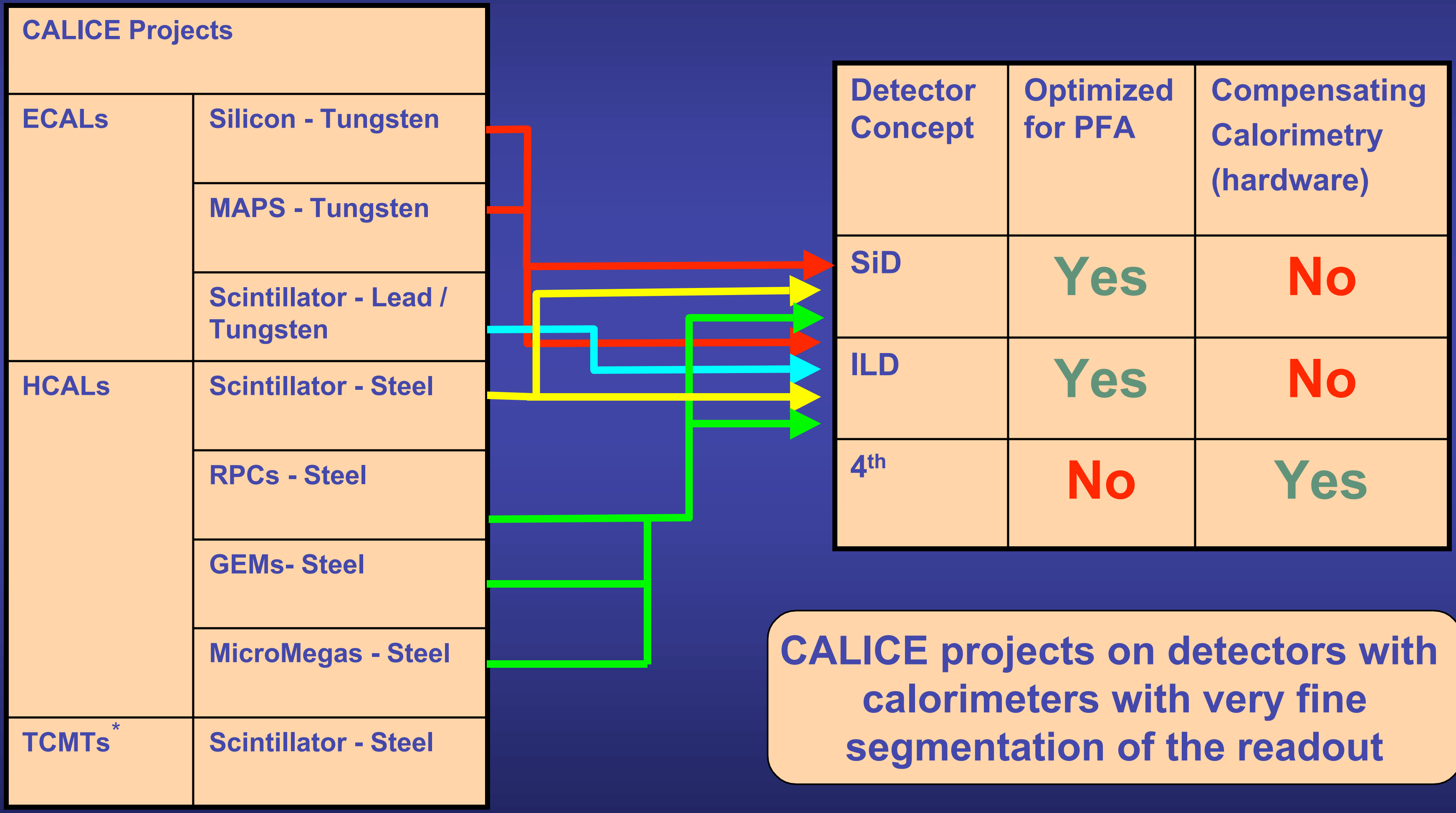
Technical prototypes

Various technologies
Can be only partially equipped
Appropriate shapes (wedges) for ILC detectors
All bells and whistles (cooling, integrated supplies…)
Detailed test program in particle beams

To **advance** calorimeter technologies and our **understanding** of calorimetry in general

To design, build and test **ILC calorimeter prototypes**

CALICE Projects and the Concepts



CALICE Projects	
ECALs	Silicon - Tungsten
	MAPS - Tungsten
	Scintillator - Lead / Tungsten
HCALs	Scintillator - Steel
	RPCs - Steel
	GEMs- Steel
	MicroMegas - Steel
TCMTs*	Scintillator - Steel

Detector Concept	Optimized for PFA	Compensating Calorimetry (hardware)
SiD	Yes	No
ILD	Yes	No
4th	No	Yes

CALICE projects on detectors with calorimeters with very fine segmentation of the readout

* Tail catcher and Muon Tracker

PFAs and Calorimetry

Fact

Particle Flow Algorithms improve energy resolution compared to calorimeter measurement alone (see ALEPH, CDF, ZEUS…)

How do they work?

Particles in jets	**Fraction of energy**	**Measured with**	**Resolution** $[\sigma^2]$
Charged	65 %	Tracker	Negligible
Photons	25 %	ECAL with $15\%/\sqrt{E}$	$0.07^2\ E_{jet}$
Neutral Hadrons	10 %	ECAL + HCAL with $50\%/\sqrt{E}$	$0.16^2\ E_{jet}$
Confusion	The real challenge		$\leq \mathbf{0.04^2}$ (goal)

$18\%/\sqrt{E}$

Minimize confusion term

Maximize segmentation of the calorimeter readout

High segmentation

O(<1 cm^2) in the ECAL
O(~1 cm^2) in the HCAL
~O(10^7 – 10^8) channels for entire ILC calorimeter

Can PFAs achieve the ILC goal?

YES!

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CALICE Test Beam Activities

DESY electrons 1 – 6 GeV 2006

Silicon-ECAL
Scintillator HCAL

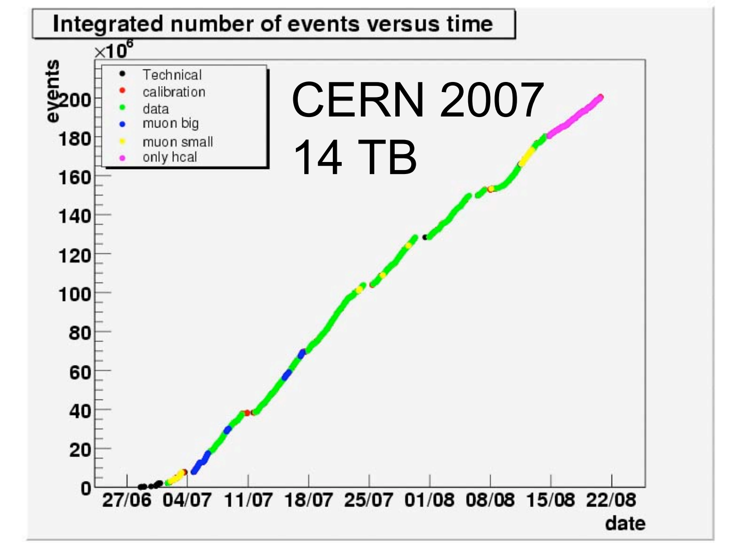
Scintillator ECAL
TCMT

CERN electrons and pions 6 – 120 GeV 2006 and 2007

Silicon-ECAL
TCMT (complete)

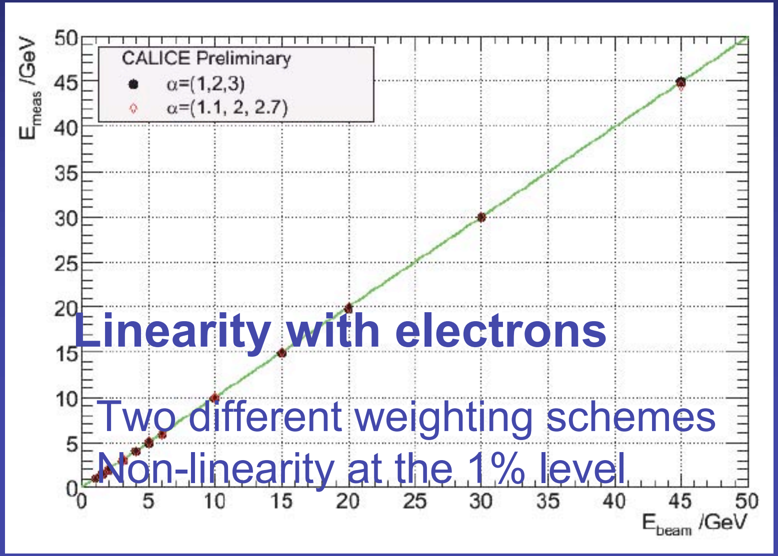
Scintillator HCAL

UK activities concentrate on test beam operation and ECAL analysis



CERN 2007
14 TB

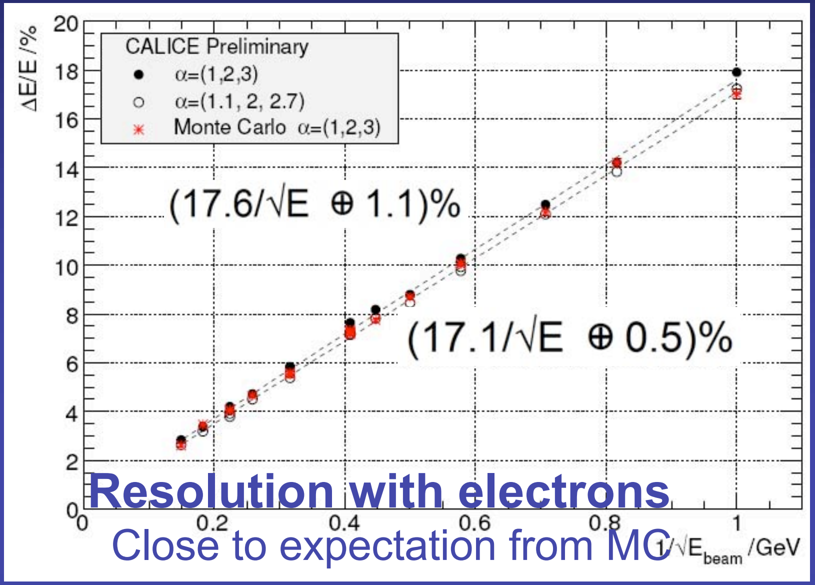
CALICE Test Beam Activities - data analysis 2006: Special emphasis on UK contributions



Linearity with electrons

Two different weighting schemes

Non-linearity at the 1% level

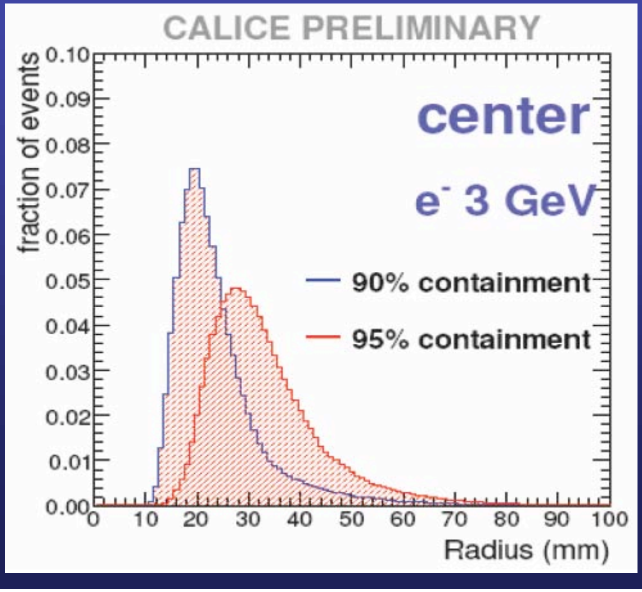


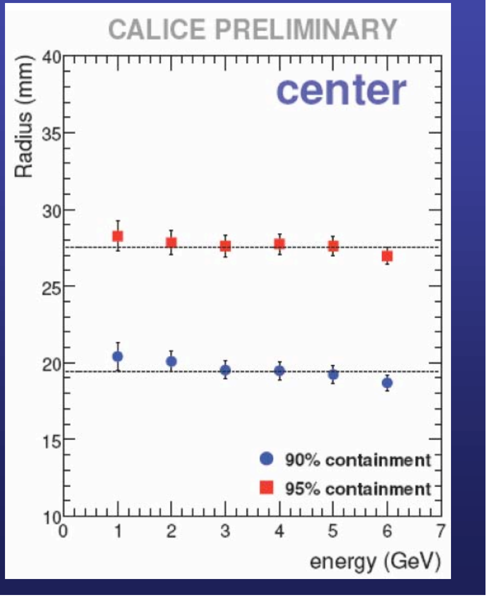
Resolution with electrons

Close to expectation from MC

Transverse shower profile

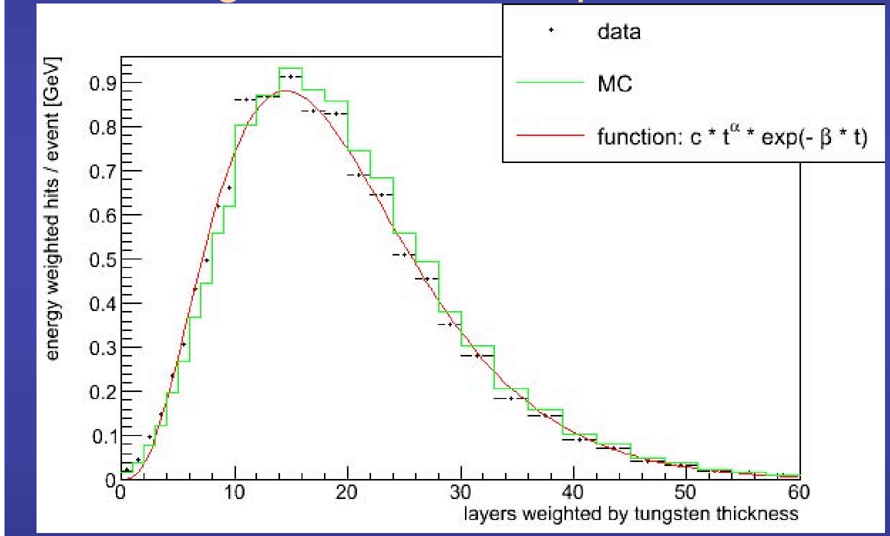
Moliere radius R_M contains
 90% of EM shower energy
 independently of energy
R_M (W) = 9 mm
Gap will increase R_M(W) _ R_M^{eff}





CALICE Test Beam Activities - analysis of 2006 data: detailed look

Example:
longitudinal shower profile



- data suggest that more preshowering happens than MC
- leakage energy is not consistent with estimates from beam energy

discrepancy between MC and data:

- low pulse height hits
- inter-wafer gaps
- shower depth
- number of hits
- transverse shower shape
- mismatch of energy scale between CERN and DESY

Ideas to investigate:

- understand beam line better
- optimise alignment and rotation of detector
- understand passive material in front of calo better
- optimise calibration

CALICE Test Beam Activities - 2007

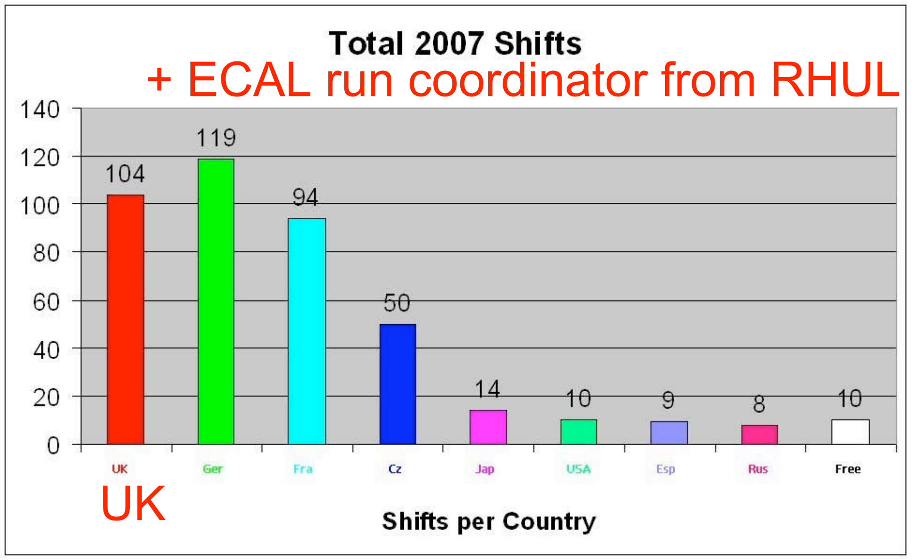
Physics prototype

3 structures with different W thicknesses

30 layers; 1 x 1 cm^2 pads

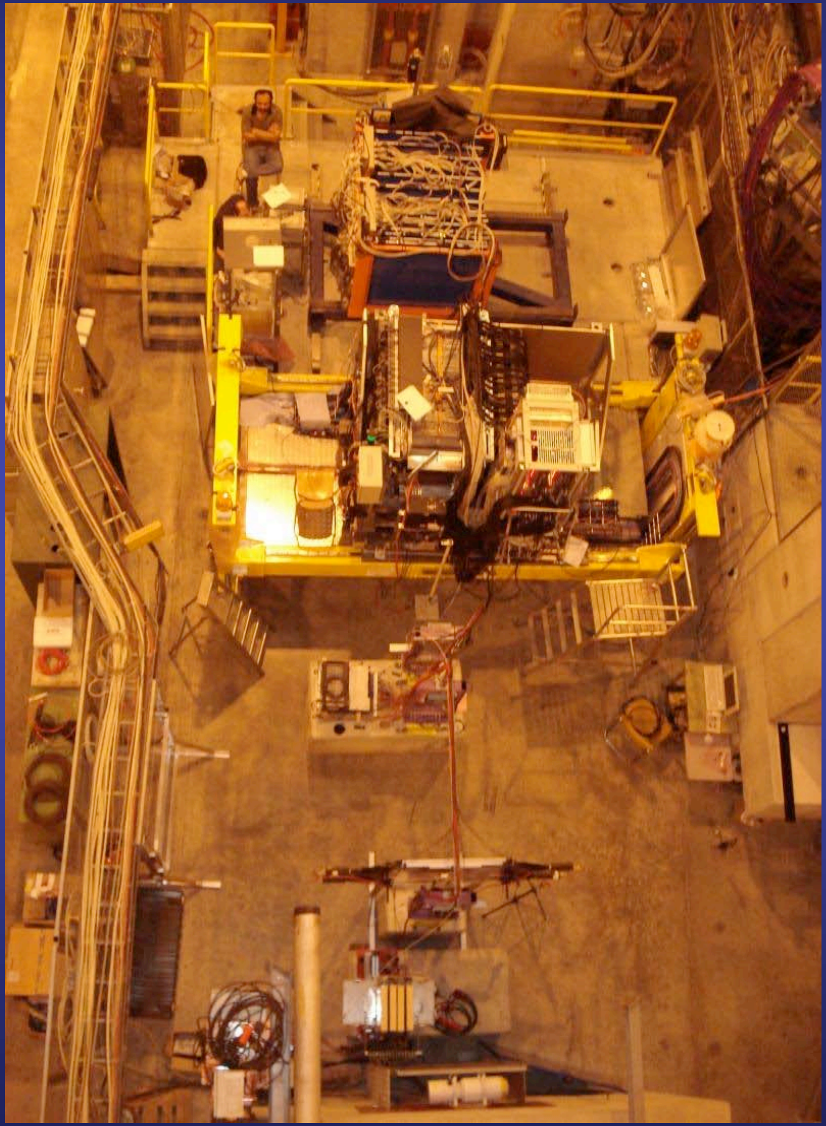
12 x 18 cm^2 instrumented in 2006 CERN tests

about 6480 readout channels



+ ECAL run coordinator from RHUL

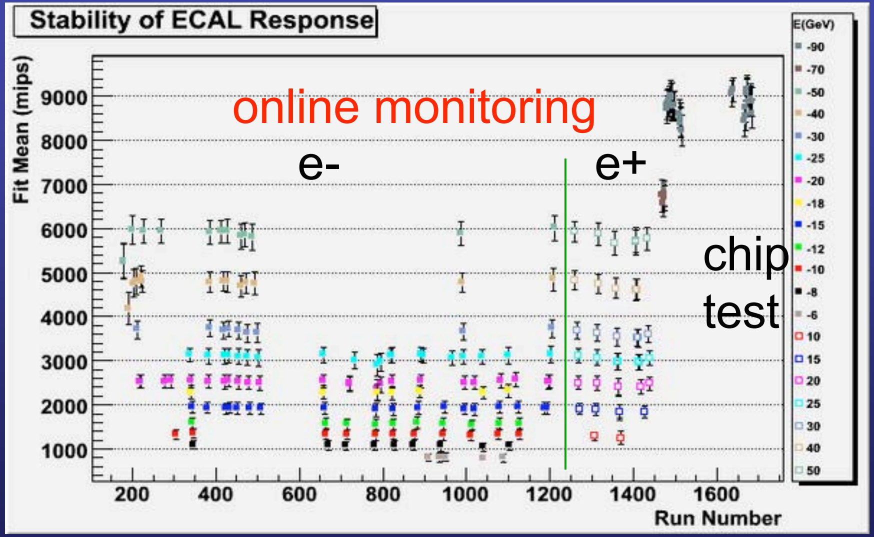
UK

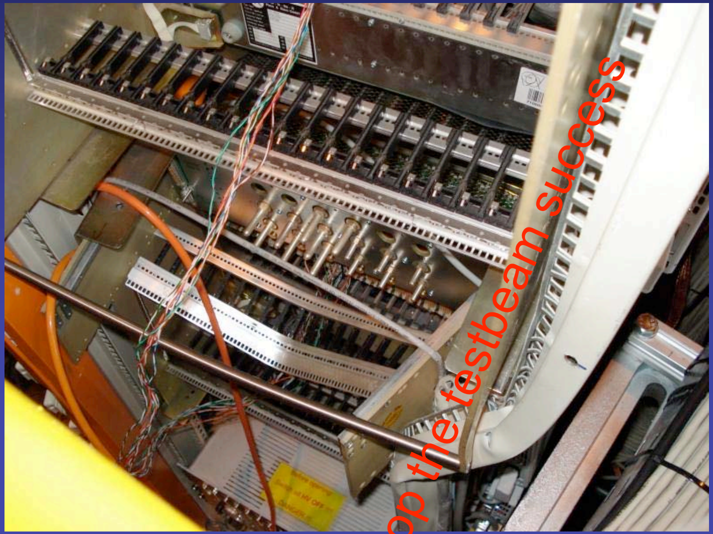


CALICE Test Beam Activities - 2007

summary of data taking:

- π^+, π^-, e^+, e^-, p:
- 6-180 GeV
- with position scans
- angles from 0^0 - 30^0





even accidents could not stop the testbeam success

Test beam activities with physics prototypes

	Project	**2007b**	**2008a**	**2008b**	**2009a**	**2009b**
ECAL	**Si-W**	CERN test beam	FNAL test beam			
	MAPS	1st prototype chip and test beam		2nd prototype chip	DESY test beam	
	Scintillator			FNAL test beam		
HCAL	**Scintillator**	CERN test beam	FNAL test beam			
	RPC	Vertical slice test in FNAL test beam	Physics prototype construction	FNAL test beam		
	GEM	Vertical slice test In FNAL test beam	Further R&D on GEMs		Physics prototype construction	FNAL test beam
	MicroMegas		1 plane			
TCMT	**Scintllator**	CERN test beam	FNAL test beam			

+ further R&D, technical prototype designs, construction & testing…

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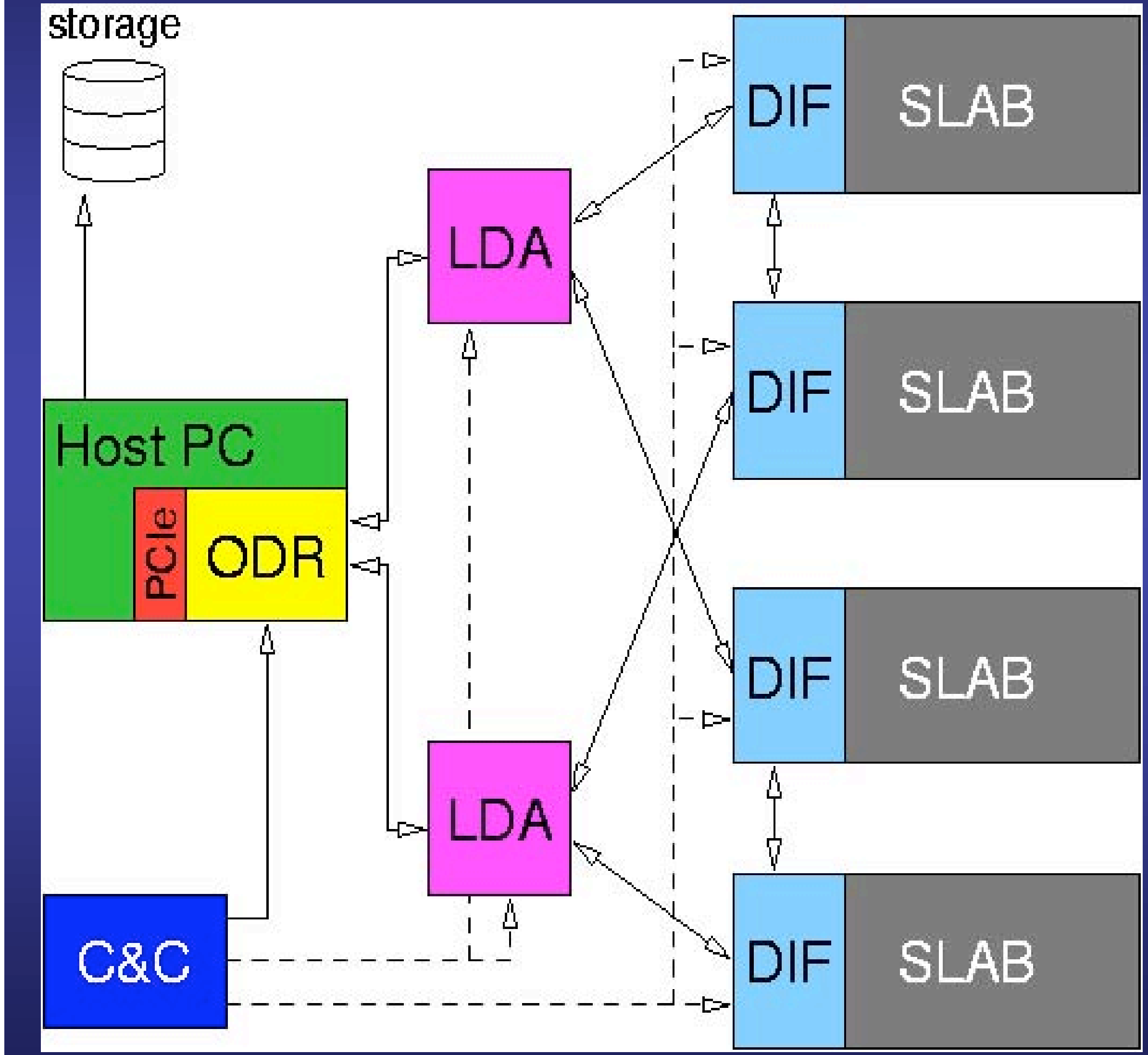
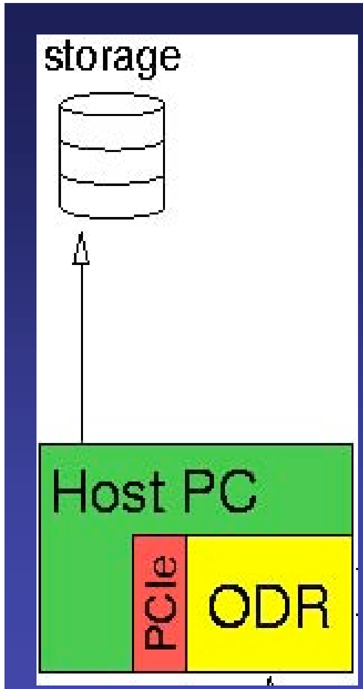
DAQ architecture



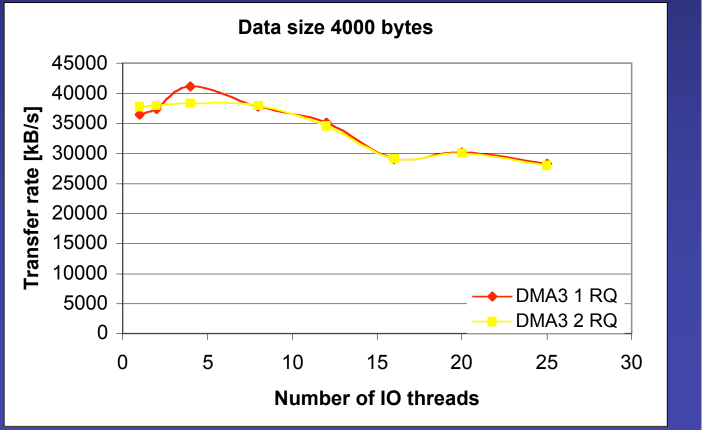
- Slab hosts VFE chips
- DIF connected to Slab
- LDA servicing DIFs
- LDAs read out by ODR
- PC hosts ODR, through PCIexpress
- C&C routes clock, controls

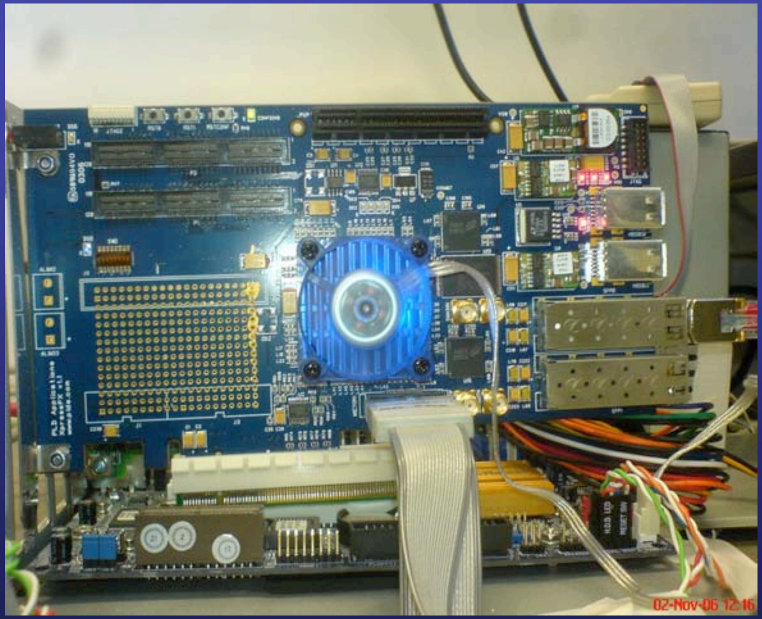


ODR and Data Rates

Off Detector Receiver:
Gets data into a usable form for processing

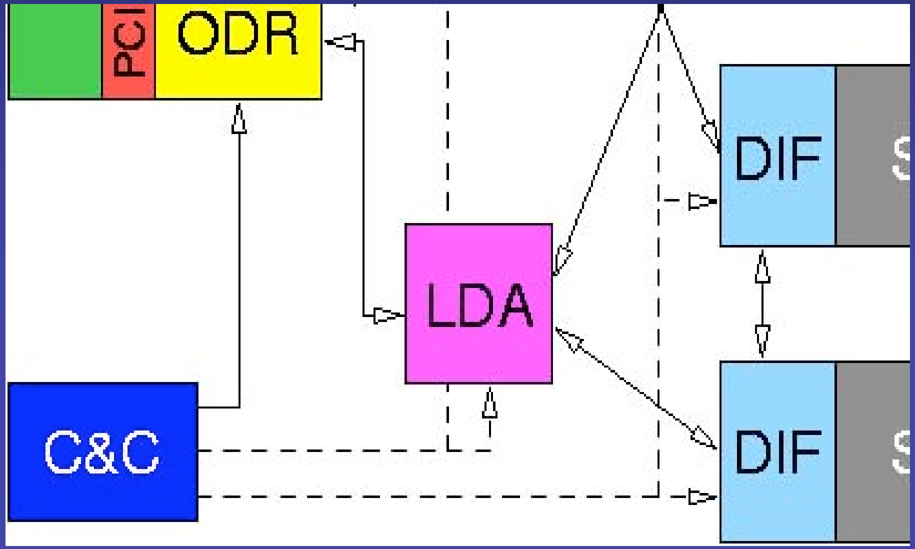
3 logical tasks:
- Receive
- Process
- Store





- ODR is a commercial FPGA board with PCIe interface
- Custom firm- and software
- Performance studies & optimisation

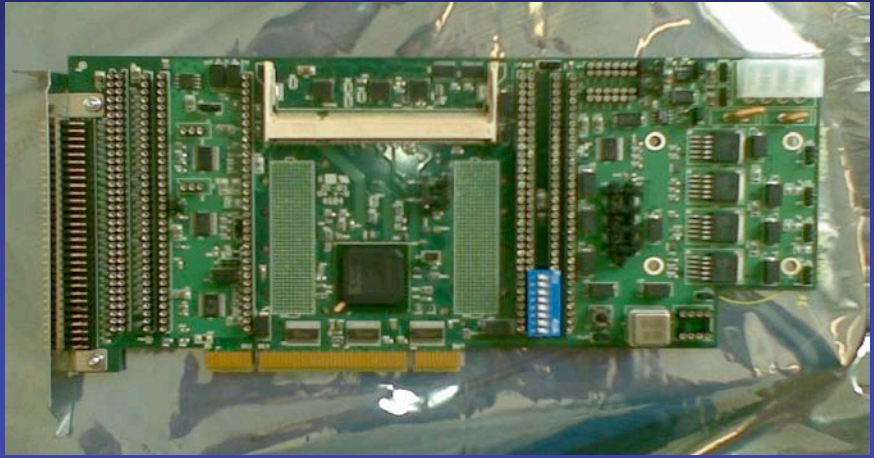
Clock & Controls Distribution



- C&C unit provides machine clock and fast signals to ODR, LDA (and DIF?)
- Clock jitter requirement seems not outrageous

  (at the moment)
- Low-latency fast signal

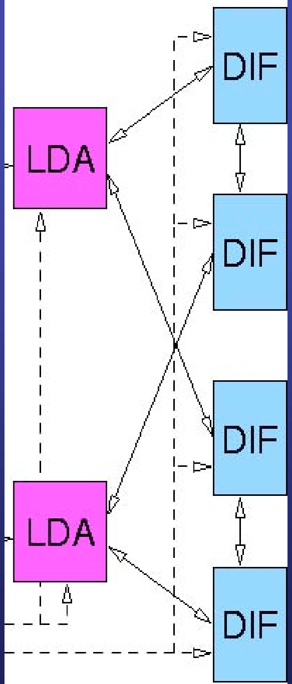
LDA; LDA-DIF and DIF-DIF link



LDA

1st Prototype is again a commercial FPGA board with custom firmware and hardware add-ons:

- Gbit ethernet and Glink Rx/Tx for ODR link -probably optical
- Many links towards DIFs



LDA-DIF link:

- Serial link running at multiple of machine clock
- LDAs serve even/odd DIFs for redundancy

DIF-DIF link:

- Redundancy against loss of LDA link
- Provides differential signals:
  - Clock in both directions
  - Data and Control connections
  - Two spares: one each direction

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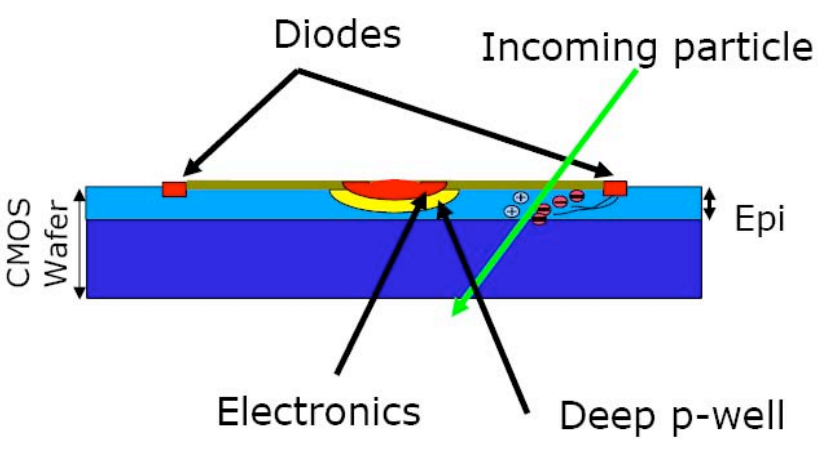
MAPS ECAL

Monolithic Active Pixel Detectors

In-pixel comparator and logic
50 x 50 μm^2 pixels
10^{12} pixels for the ECAL

} Digital (single-bit) readout



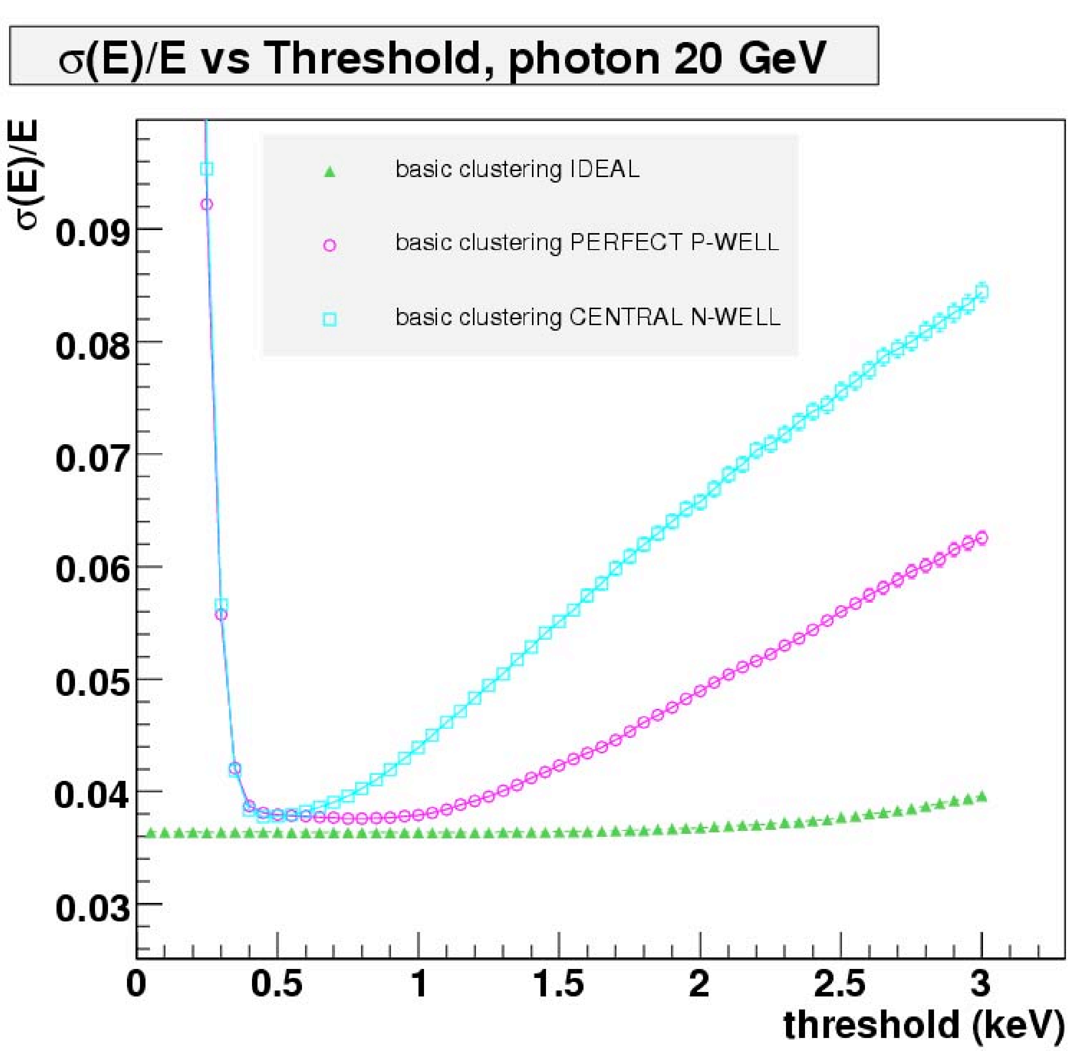
Test Sensor
Area of 1 x 1 cm^2 ~ 28,000 pixels
Testing different architectures n-well or p-well

Extensive simulation studies
Charge collection effects
Resolution versus threshold
….

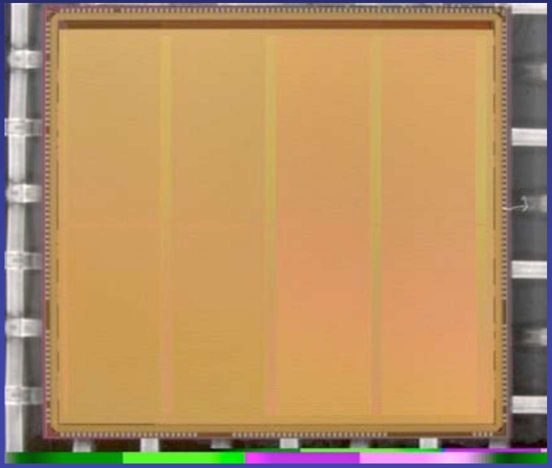
Effect of charge spread model

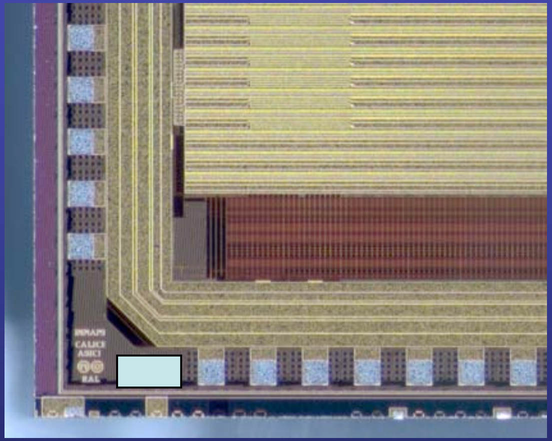
Optimistic scenario:
Perfect P-well after clustering: large minimum plateau ➔ large choice for the threshold !!

Pessimistic scenario:
Central N-well absorbs half of the charge, but minimum is still in the region where noise only hits are negligible + same resolution !!!



Plans for the autumn





- Sensors delivered this summer, tests can go forward
- Charge diffusion studies with a powerful laser setup at RAL :
    - 1064, 532 and 355 nm wavelength,
    - focusing < 2 μm,
    - pulse 4ns, 50 Hz repetition rate,
    - fully automated
- Cosmics and source setup to provide by Birmingham and Imperial respectively

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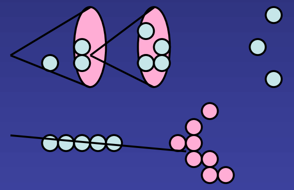
News from the Pandora particle flow algorithm

Eight Main Stages:

- Preparation (MIP hit ID, isolation, tracking)
- Loose clustering in ECAL and HCAL
- Topological linking of clearly associated clusters
- Courser grouping of clusters
- Iterative reclustering (e.g. according to jet energy)
- Photon recovery (new)
- Fragment removal (new)
- Formation of final particle flow objects



E_{jet}	$\sigma_E/E = \alpha/\sqrt{(E/GeV)}$	σ_E/E
45 GeV	0.227	3.4%
100 GeV	0.287	2.9%
180 GeV	0.395	2.9%
250 GeV	0.532	3.4%

Mark Thomson's comment:
Now convinced that PFA can deliver the required ILC jet energy performance

News from the Pandora particle flow algorithm

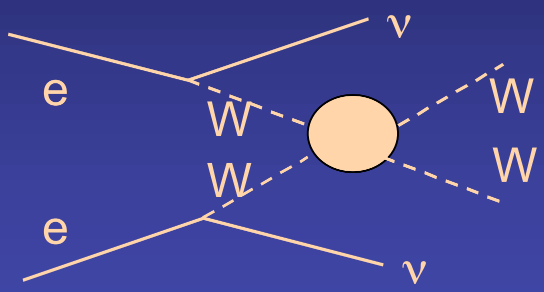
Perfect Pandora added to Pandora which relies on MC information to create the ProtoClusters.

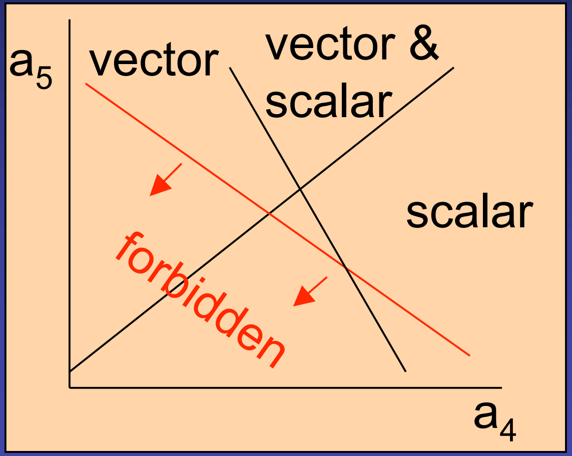
	$\sigma_E/E = \alpha/\sqrt{(E/GeV)}$	
E_{jet}	PerfectPandora	Pandora
100 GeV	0.220	0.305
180 GeV	0.305	0.418

⇒ the current code is not perfect, things will get better

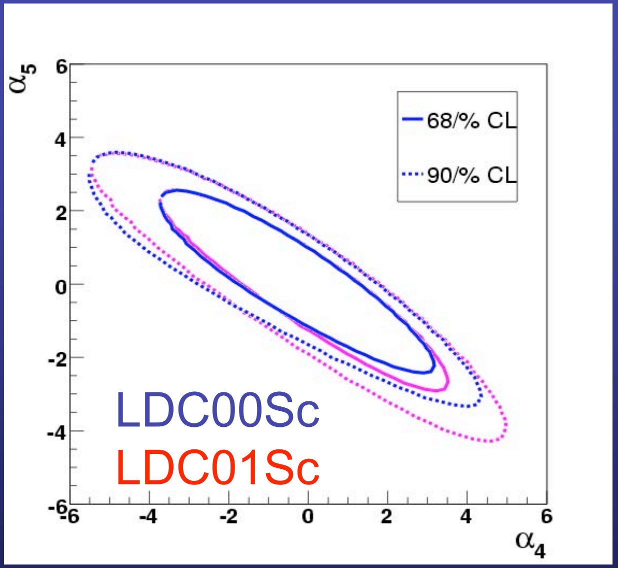
Future developments:
- moving to LDCTracking is highest priorities
- optimisations of newly introduced features

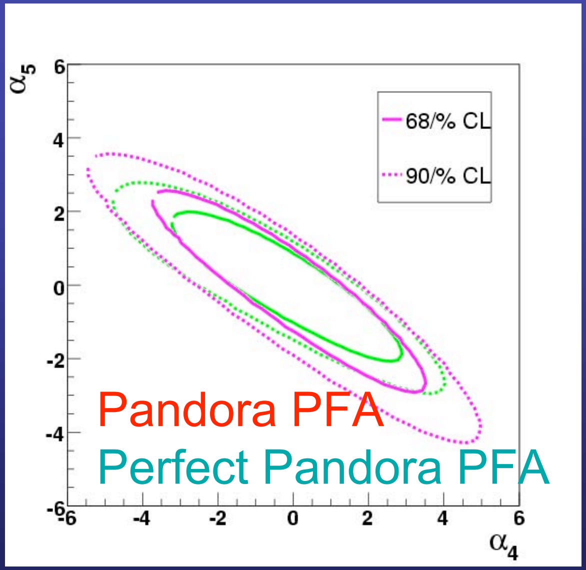
WW scattering





WW scattering model independent way of checking the unitarity breakdown of the standard model



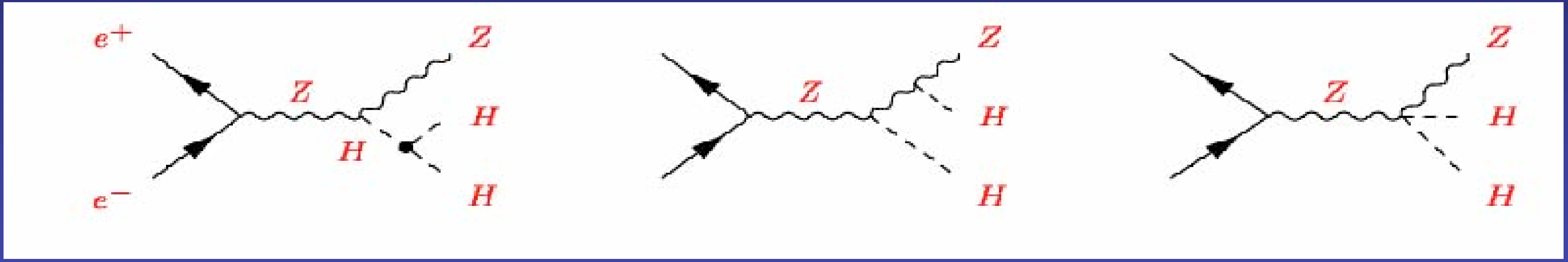


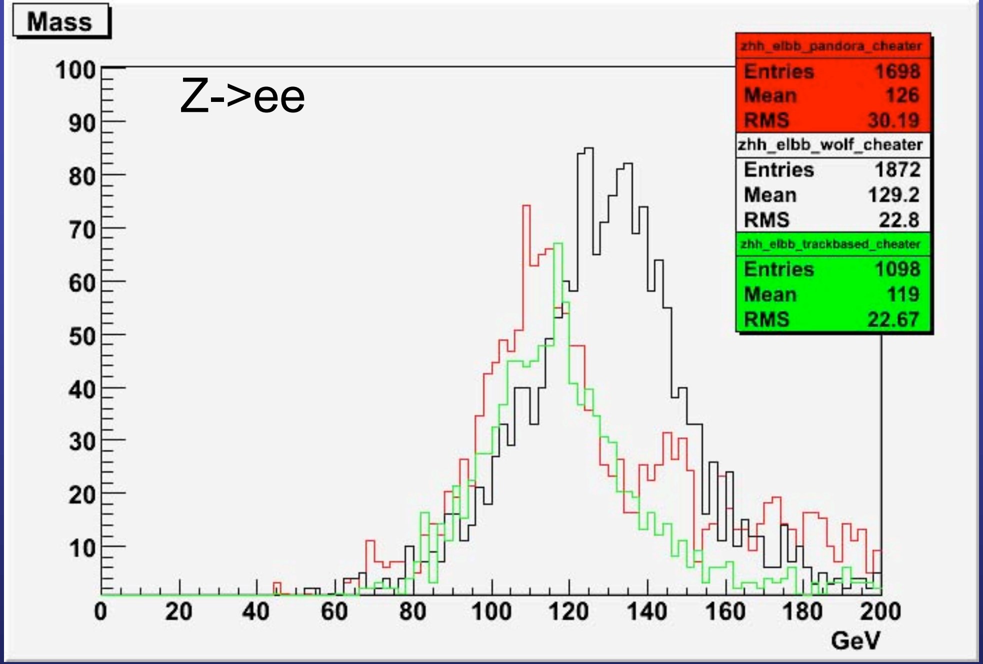
⇒ detector optimisation with this study possible

⇒ shows room for improvement within Pandora

Higgs Self Coupling

study of the Higgs self coupling constant





- Pandora has very good RMS
- Wolf reconstructs too high mass
- Track based PFA works, but problems with muons

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Mechanical and Thermal Studies

- Sensor attached to PCBs with conductive glue
  - about 100,000 glue joints
  - all have to work in a reasonably high radiation environment and stay stuck for 10 years -> long-term tests underway

- Assembly and Integration studies
  - Sensor attachments to PCBs and associated testing
  - Integration of cooling and services on the EUDET module
  - Coordinating task with French groups

Conclusion:

- **test beams:**

  2006 analysis needs to be finalised,
  2007 analysis not yet started,
  challenging program for 2008/2009

- **DAQ:**

  at the moment only components ready,
  need to be integrated to a whole system by 2008
  test beam in 2009

- **MAPS:**

  making good progress,
  in the phase of prototype testing

- **PFA:**

  success story of the UK,
  WW scattering a good testing analysis,
  probably need a few more physics analyses