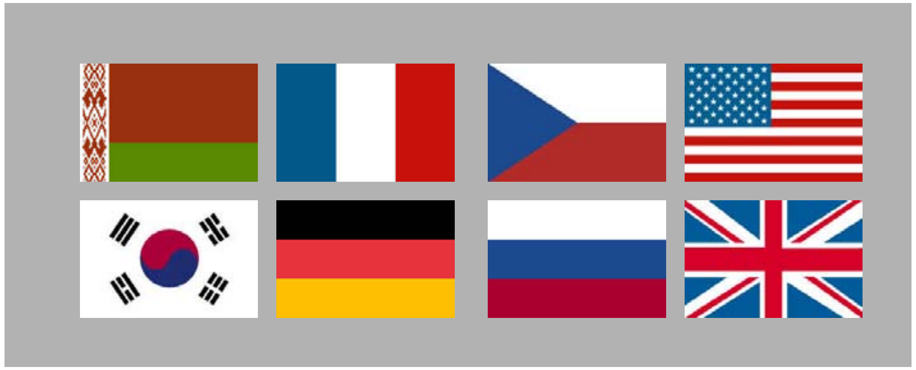
CALICE
Calorimetry for LC

- Physics motivation
- Calorimetry
  - Design Considerations
  - CALICE
  - Status
- Future
- Summary



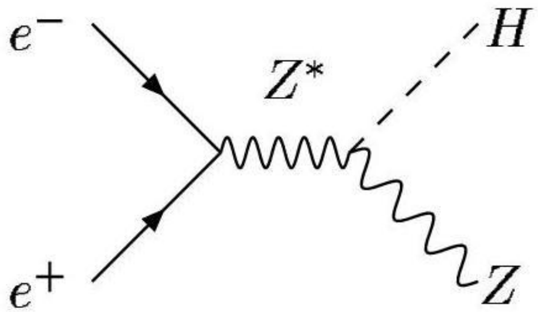
168 physicists
28 institutes
8 countries

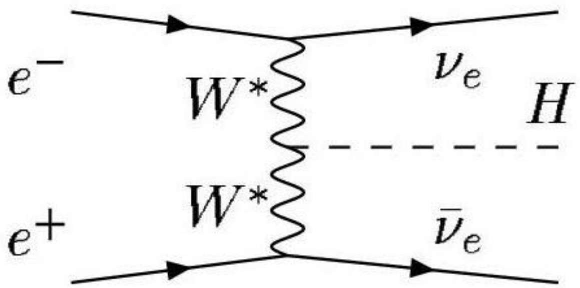
UK: Bham, Cambridge, Imperial
Manchester, RAL, UCL

Nigel Watson / CCLRC-RAL PPD

RAL, 25-Jan-2005

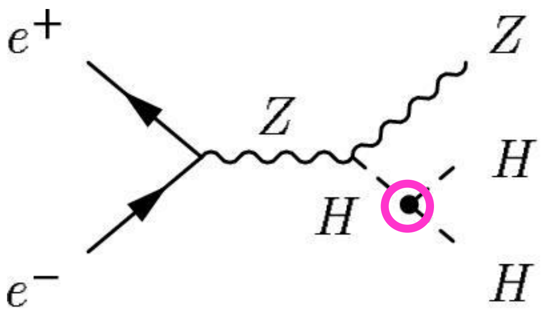
Physics

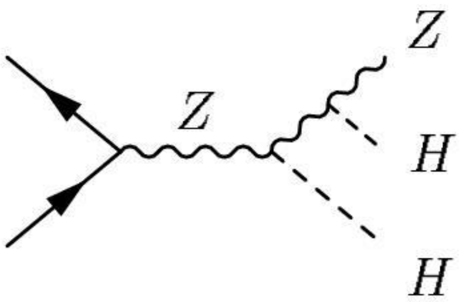


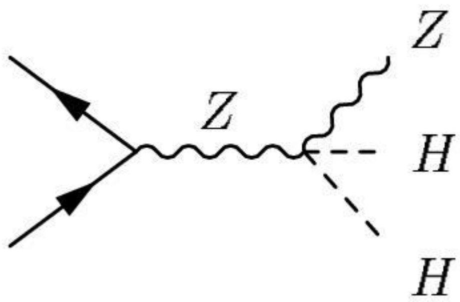


- Higgs (or equivalent) will be discovered at LHC
- Detailed properties
  - Mass, coupling, J^{PC}, ... of model
  - Only accessible w...
- H self-coupling, impli... known m_H and <ϕ>, test consistency

New: see LHC-LC Study Group,
Georg Weiglein et al.,
hep-ph/0410364 (485 pages)

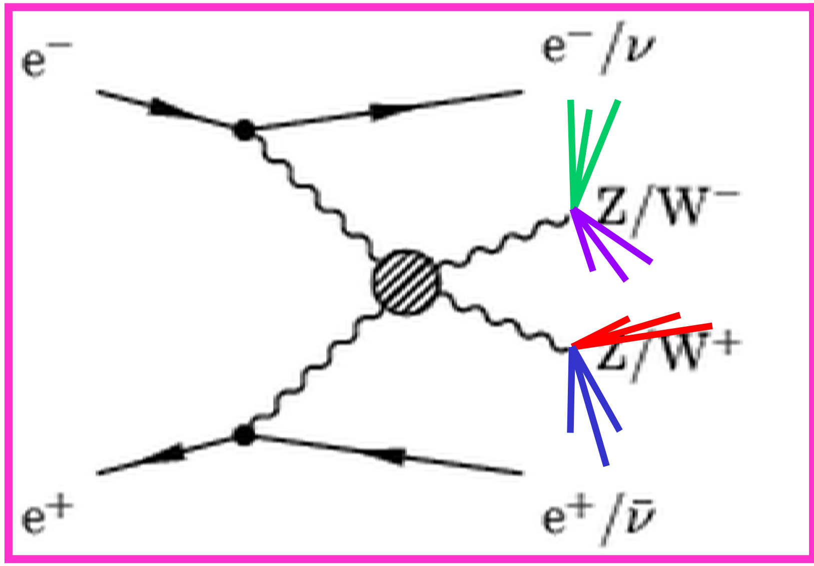


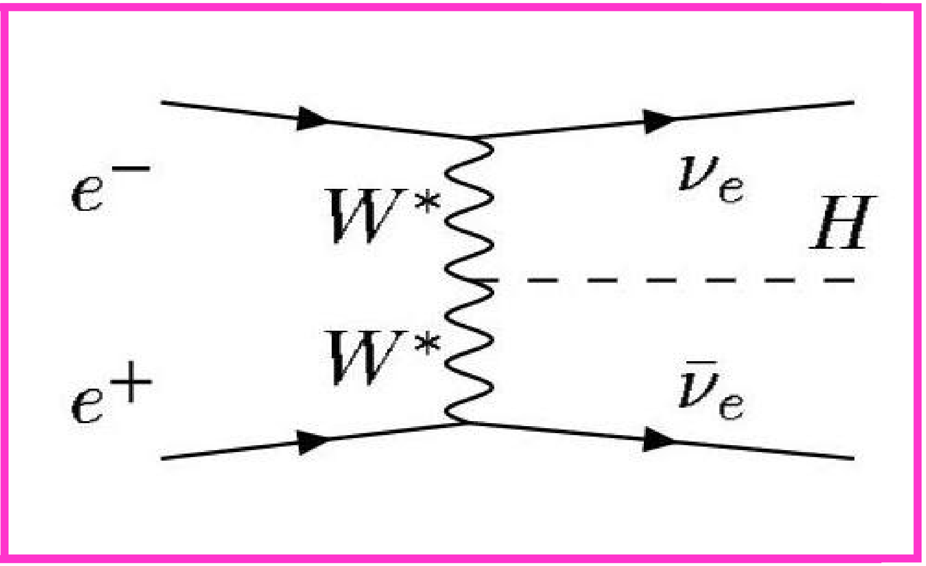




High Performance Calorimetry

- Essential to reconstruct jet-jet invariant masses in hadronic final states, e.g. separation of $\nu\nu W^+W^-$, $\nu\nu Z^0Z^0$, tth, Zhh

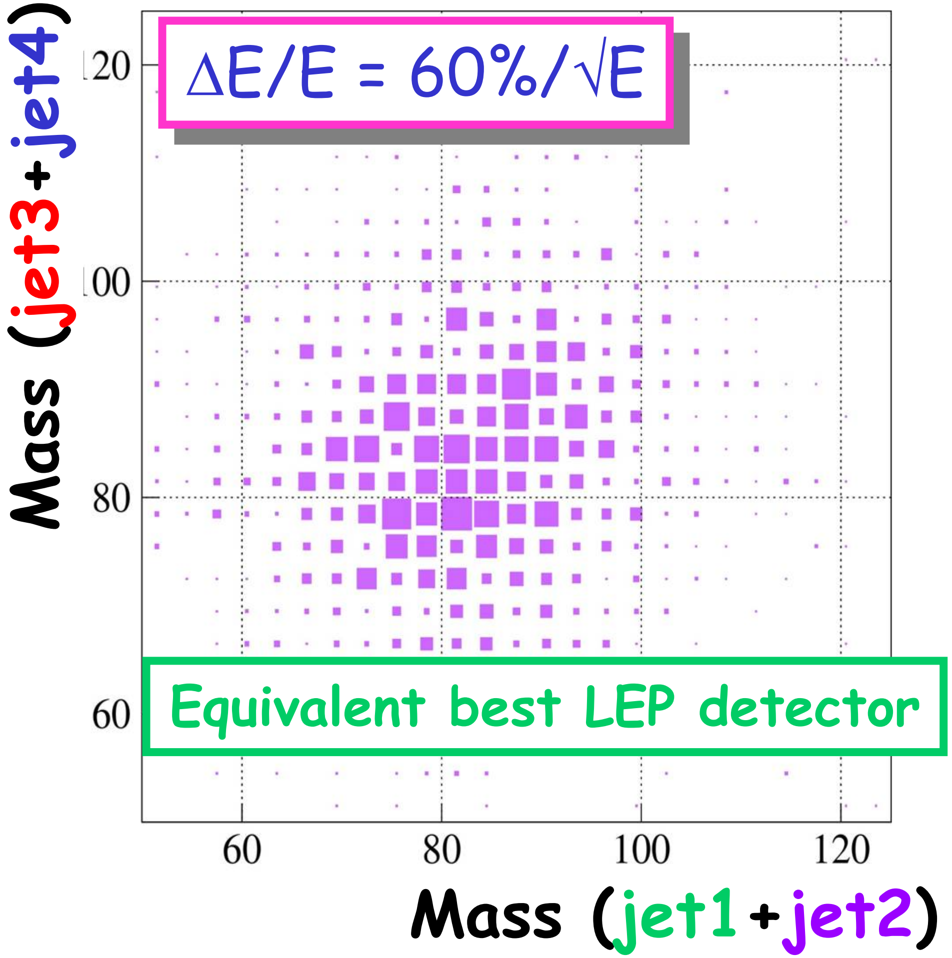


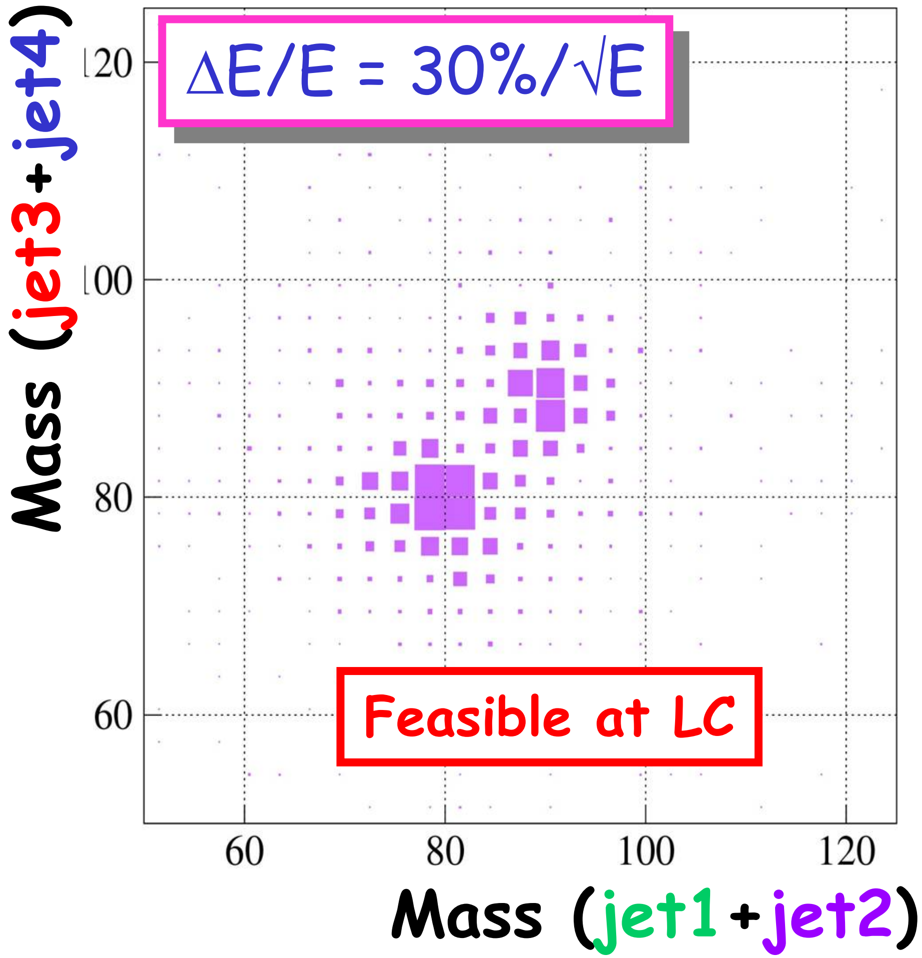


Little benefit from beam energy constraint, cf. LEP

High Performance Calorimetry

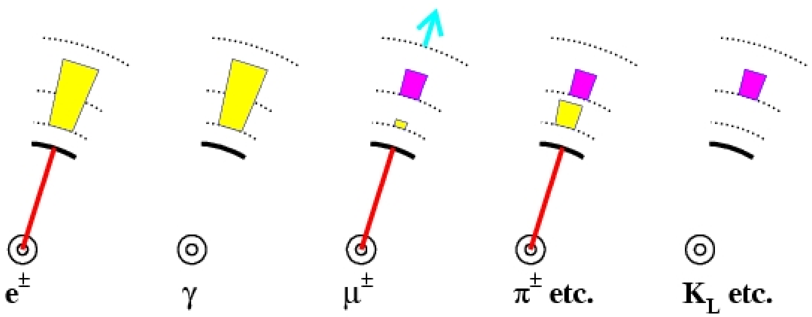
- Essential to reconstruct jet-jet invariant masses in hadronic final states, e.g. separation of $\nu\nu W^+W^-$, $\nu\nu Z^0Z^0$, tth, Zhh





High Performance Calorimetry

- Essential to reconstruct jet-jet invariant masses in hadronic final states, e.g. separation of $\nu\nu W^{+}W^{-}$, $\nu\nu Z^{0}Z^{0}$, tth, Zhh
  - LEP/SLD: optimal jet reconstruction by energy flow
    - Explicit association of tracks/clusters
    - Replace poor calorimeter measurements with tracker measurements – no "double counting"



- Charged particles (62%): measured in tracker
- Photons (27%): ECAL separates γ's from hadronic debris
- Neutral hadrons (10%): ECAL & HCAL

ECAL Design Principles

- Measure 100% EM energy
  - shower containment in ECAL, ΣX_0 large
- Resolve energy deposited by individual particles
  - small $R_{moliere}$ and X_0 – compact and narrow showers
- Separation of hadronic/EM showers
  - λ_{int}/X_0 large, $\therefore$ EM showers early, hadronic showers late
- Minimal material in front of calorimeters
- Strong magnetic field
  - lateral separation of neutral/charged particles
  - keeps a lot of background inside beampipe

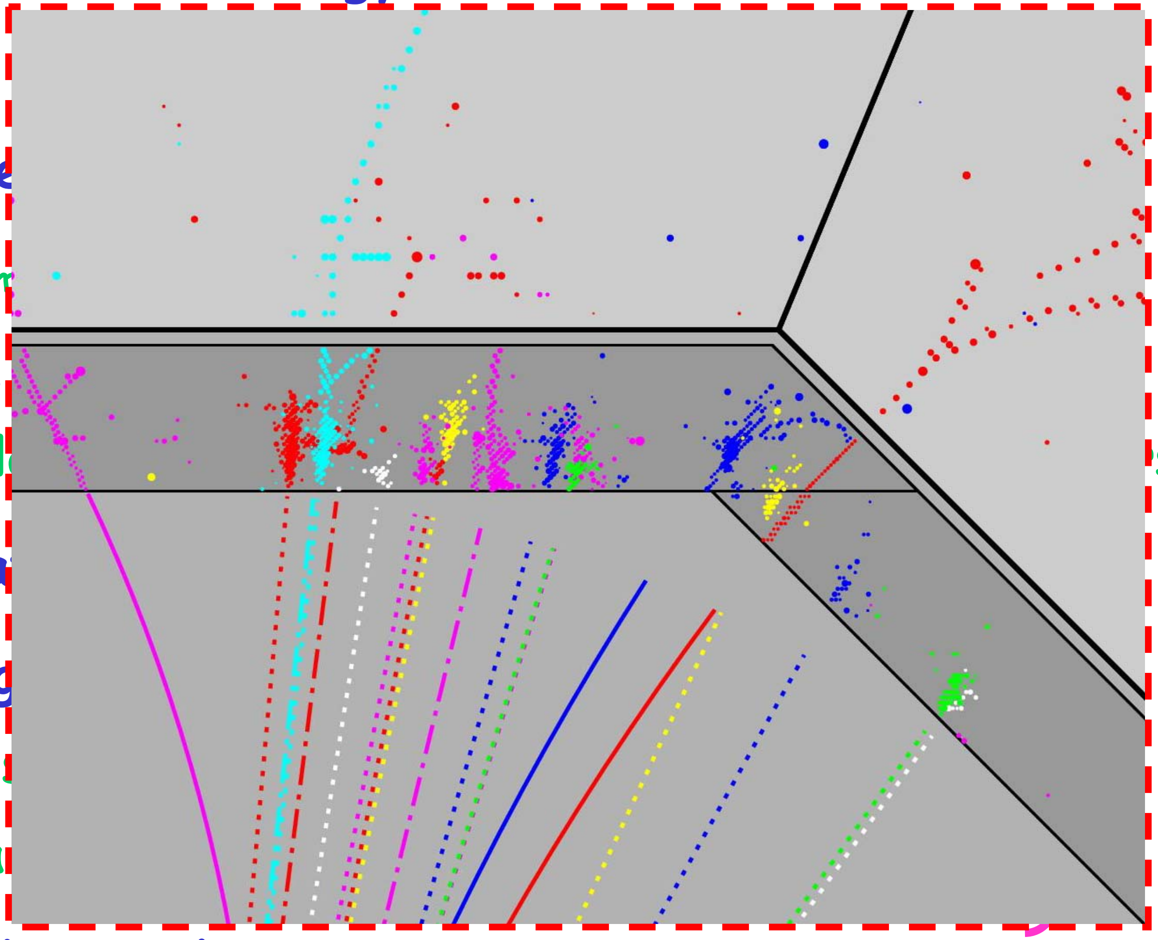
} ECAL, HCAL inside coil (cost!)

- Active medium: Silicon

$\Rightarrow$ Pixel readout, minimal interlayer gaps, stability

ECAL Design Principles

- Measure 100% EM energy
  - shower
- Resolve ene
  - small R_m
- Separation
  - λ_{int}/X_0 l… s late
- Minimal ma
- Strong mag
  - lateral s
  - keeps a

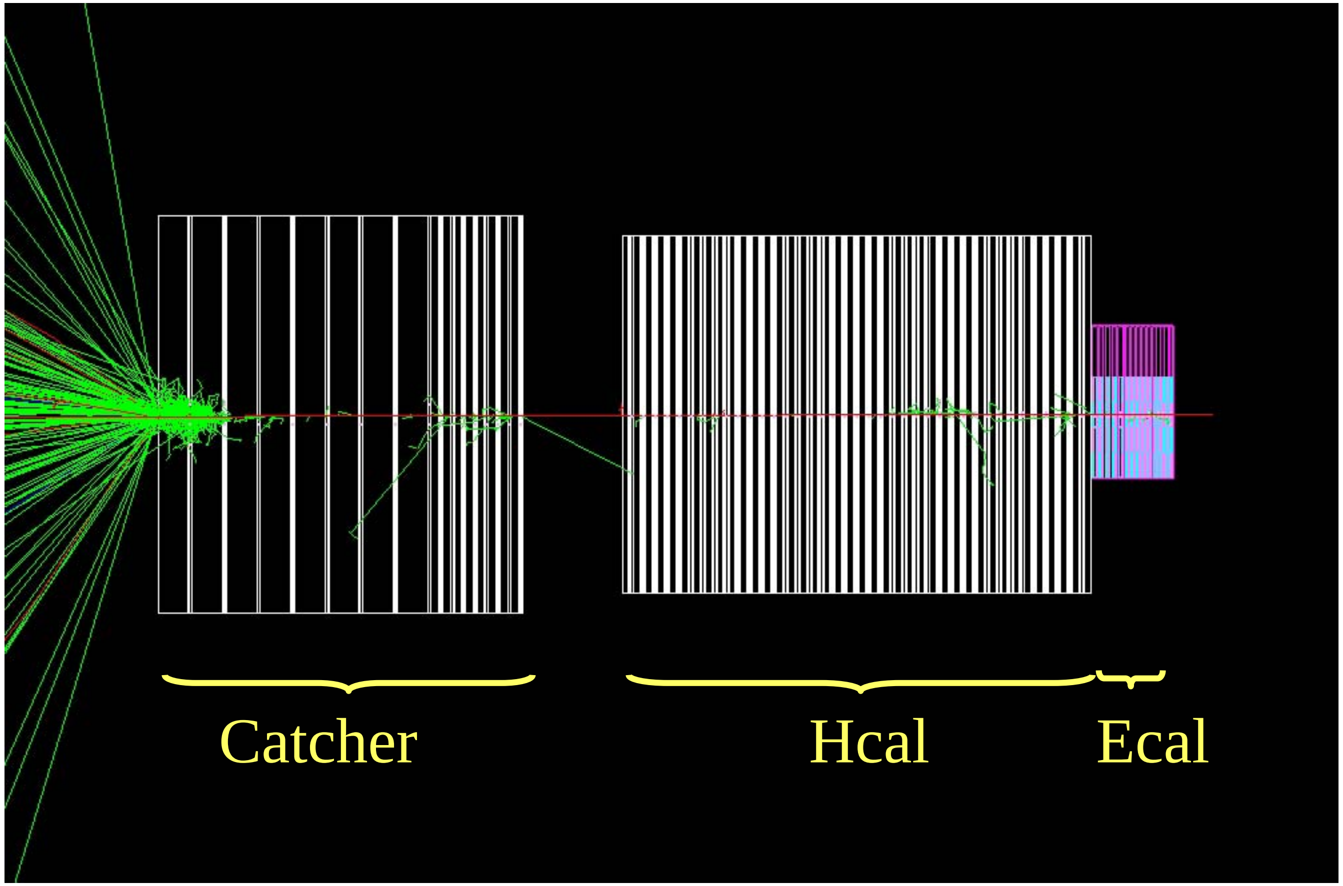


ECAL, HCAL inside coil (cost!)

- Active medium: Silicon

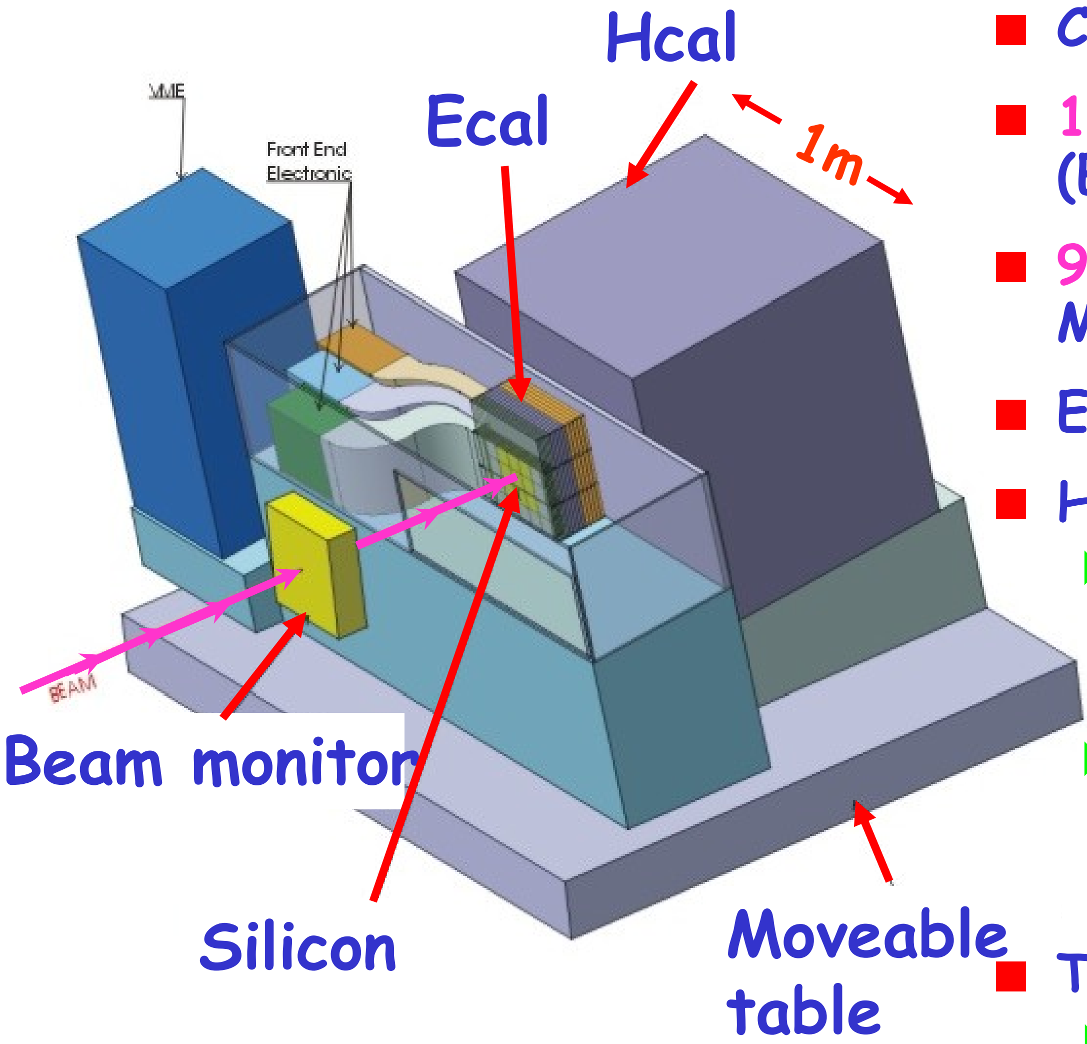
$\Rightarrow$ Pixel readout, minimal interlayer gaps, stability

CALICE Programme



- Fine granularity calorimetry for energy/particle flow
- Integrated ECAL/HCAL R&D, both h/w and s/w
- Technology demonstration
- Validate simulation, allow design optimisation

Test Beam Prototypes

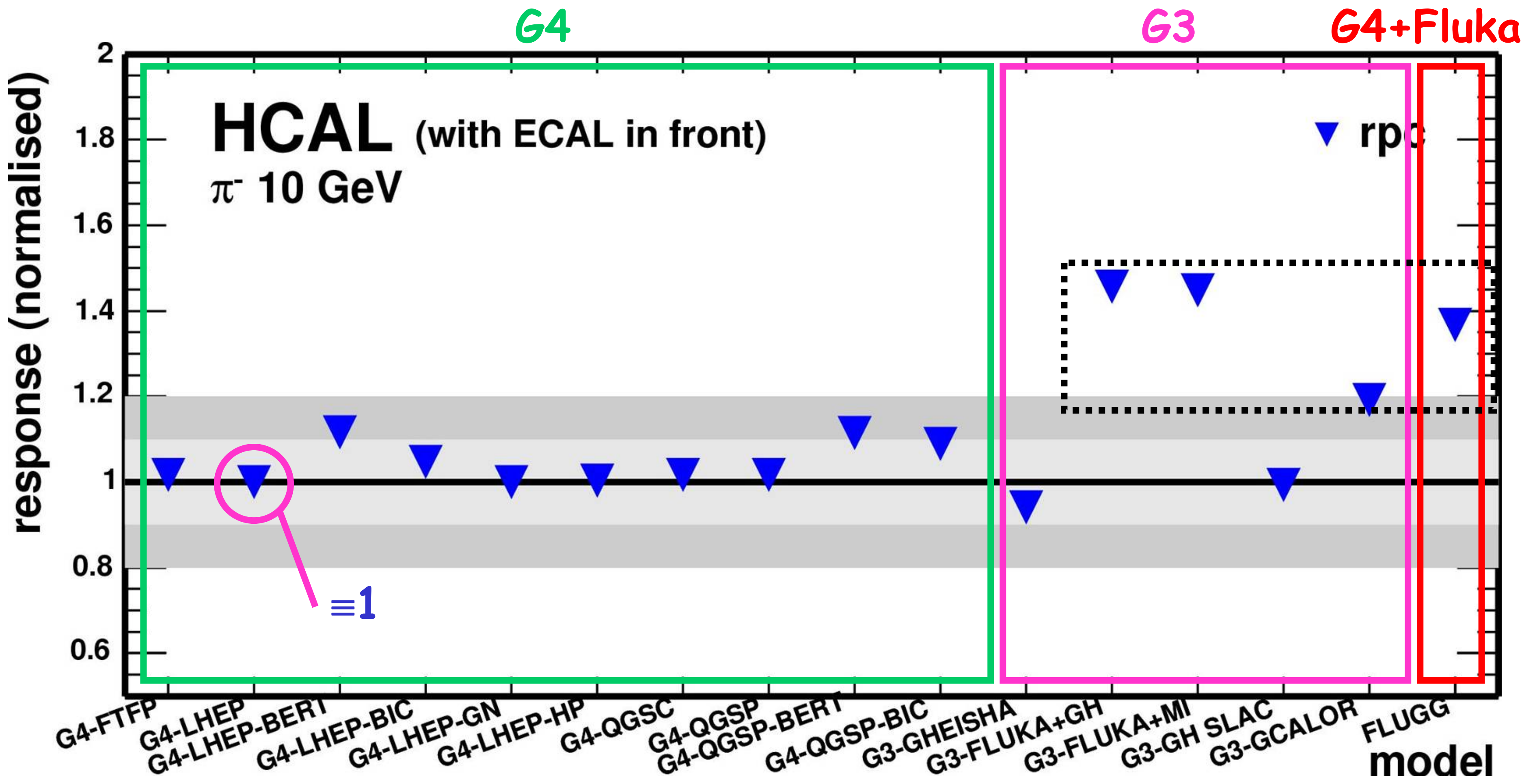


- Combined ECAL & HCAL
- 1/2005: DESY, 6 GeV e^-, (ECAL only)
- 9/2005+: physics run at FNAL MTBF p/π^+ beam
- ECAL: 30 layers
- HCAL: 40 layers Fe +
  - "digital" pads
    - ⇒ GEM, RPC
    - ⇒ 350k, $1\times1cm^2$
  - "analogue" tiles
    - ⇒ scintillator tiles
    - ⇒ (8k, $5\times5cm^2$)
- Tail catcher/muon tracker steel
  - 8 x 2cm layers, 8 x 10cm
  - 5cm scintillator strips

UK Effort

- Simulation studies
  - ECAL cost/performance optimisation
  - Impact of hadronic/electromagnetic modelling on design.
  - Comparisons of Geant4/Geant3/Fluka
- Provide readout electronics for the ECAL (+HCAL)
  - DAQ for entire system
  - Readout and DAQ for test beam prototype
- Reconstruction/Energy Flow
  - Started work towards ECAL/HCAL reconstruction
  - Ultimate goal – Generic energy flow algorithm

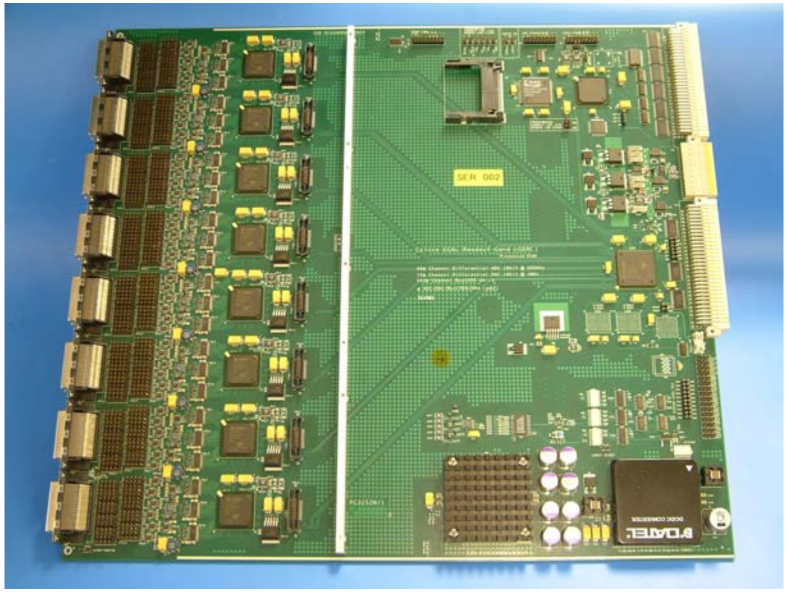
<No. HCAL cells hit/event>, 10 GeV π^-



- RPC HCAL more stable vs. model than scint.
- Models incorporating FLUKA >20% above G4-LHEP

ECAL Electronics

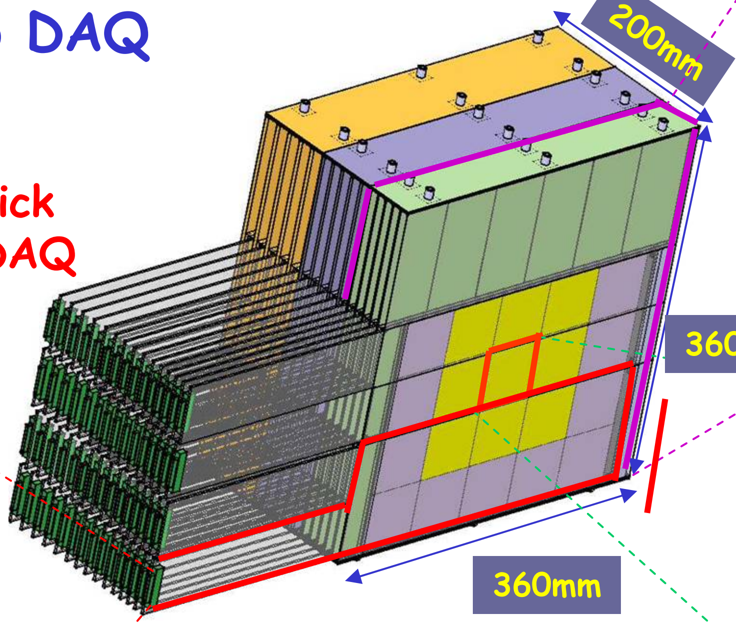
- 30 layer prototype = 9720 channels
- 6 x 9U VME boards
  - 18 fold multiplexed analogue from 96 VFE chips
  - On board buffering for 2k events
- Based on CMS FED
  - Saved time
- Designed/built Imperial, RAL ID, UCL
- Prototypes 11/2003, pre-prod^{n}. 5/2004
- Board fab. 10/2004
- AHCAL/TC now to use these also
  - 7 more boards ordered from RAL

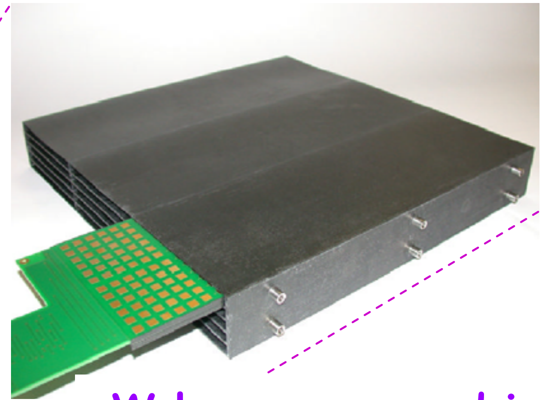


ECAL Prototype Overview

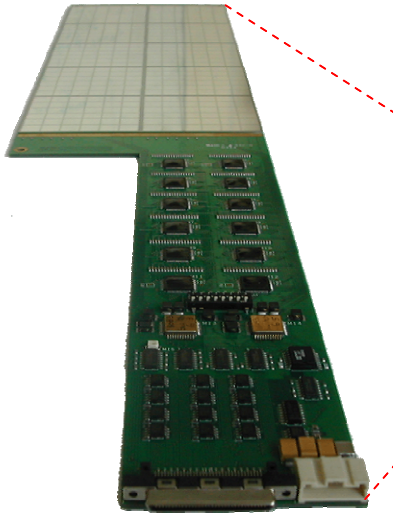
- 30 layers of variable thickness Tungsten
- Active silicon layers interleved
- Front end chip and readout on PCB board
- Signals sent to DAQ

- PCB, with VFE
- 14 layers, 2.1mm thick
- Analogue signals → DAQ

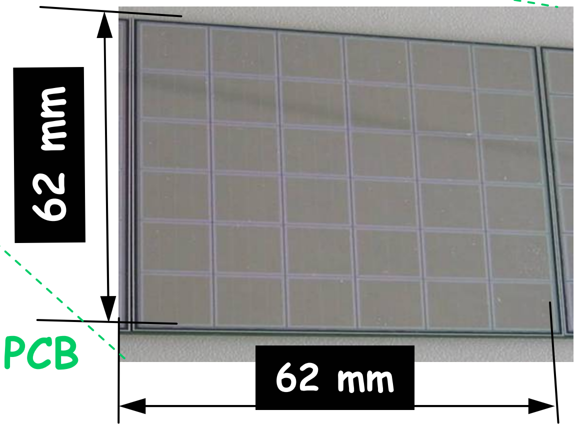




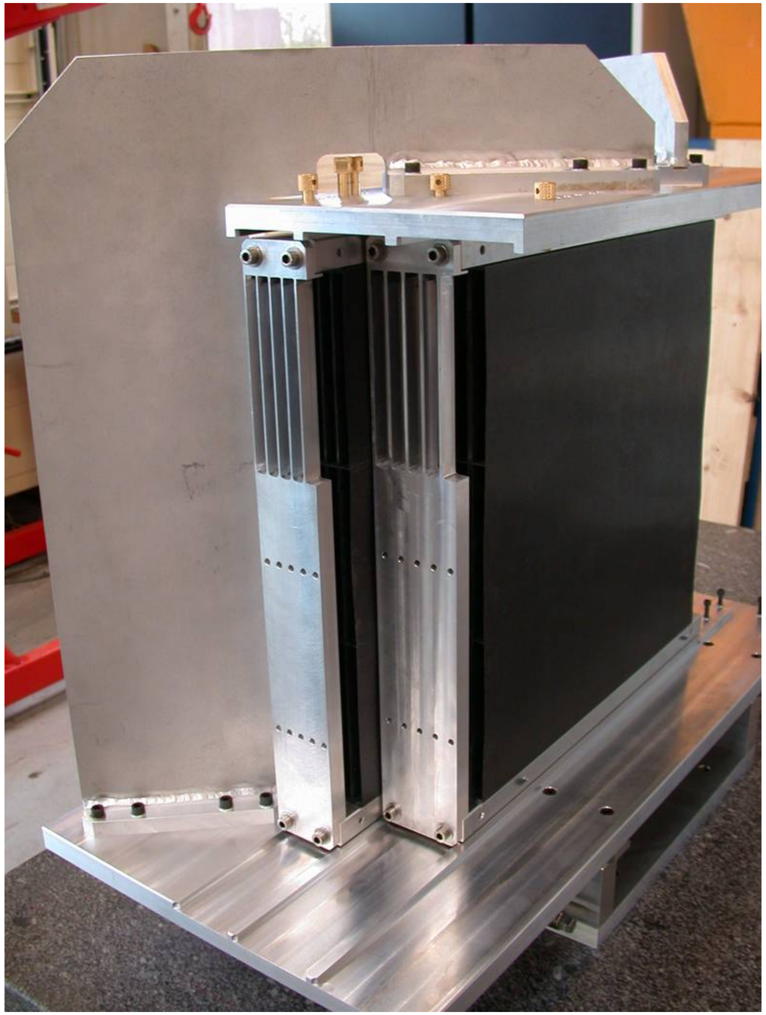
- W layers wrapped in carbon fibre
- PCB+Si layers:8.5 mm



- 6x6 1x1cm^2 Si pads
- Conductively glued to PCB

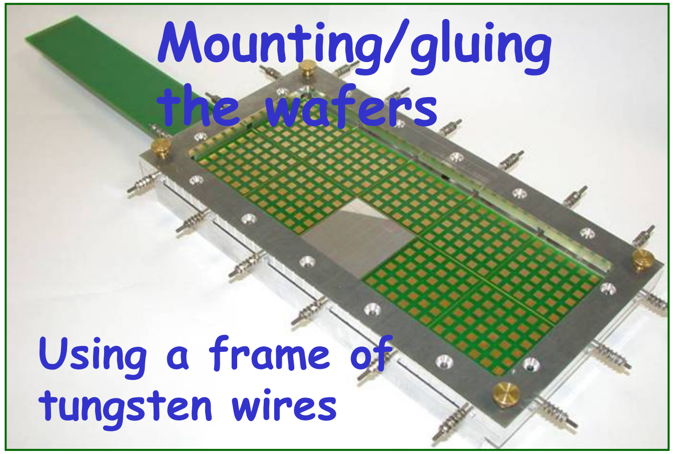


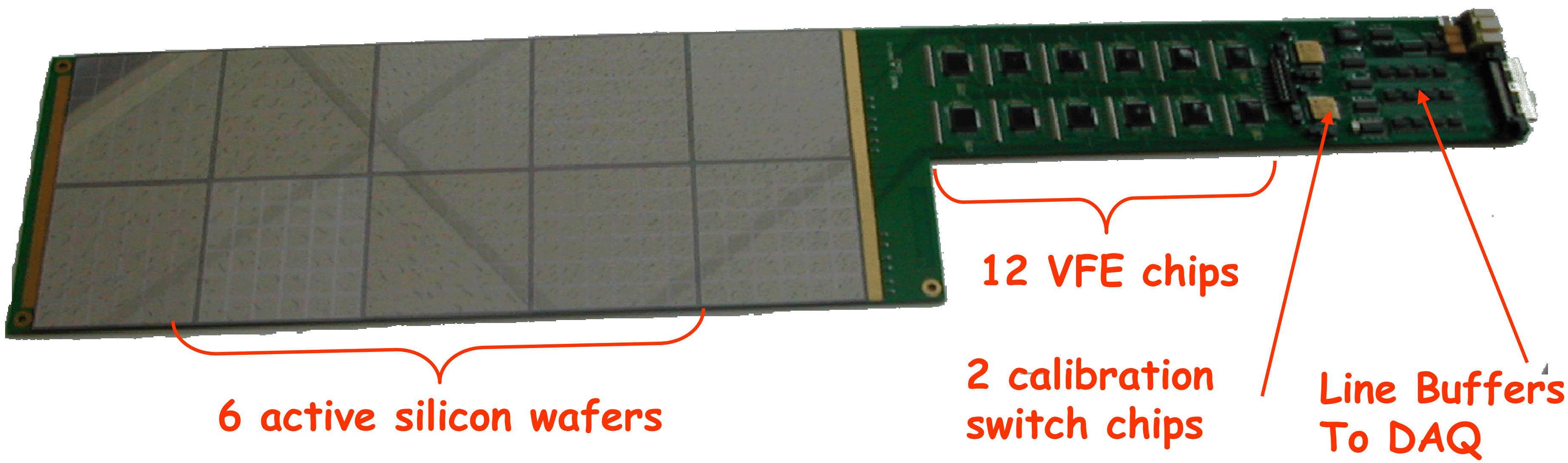
Mechanical structure for TestBeam



Production & Testing

- PCB designed in LAL-Orsay, made in Korea (KNU)
- 60 Required for Prototype
- Automation, glue : EPO-TEK® EE129-4
- Glue/place (± 0.1 mm) of 270 wafers with 6×6 pads
- ~ 10k points of glue.
- Production line set up at LLR

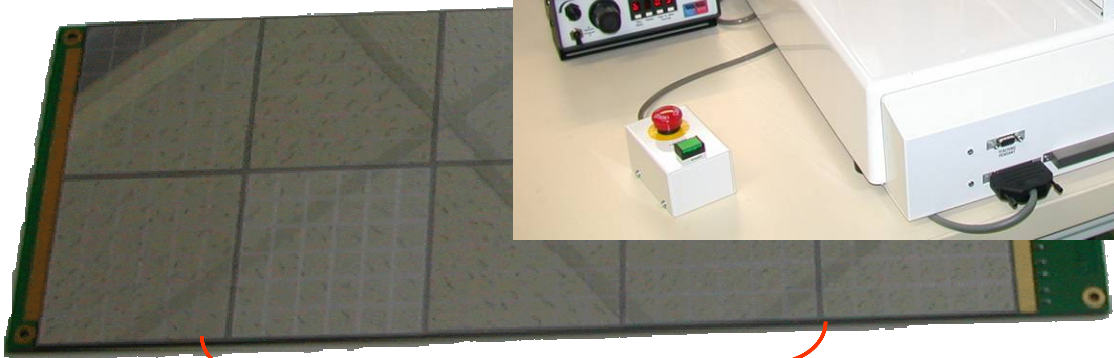


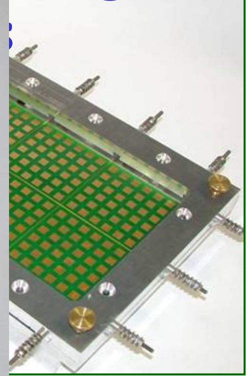


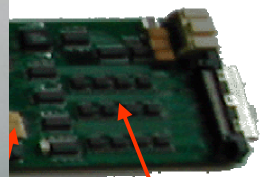
Production & Testing

- PCB designed in LAL-O
(KNU)
- 60 Required for Prot
- Automation, glue : E
- Glue/place (± 0.1 mm
pads
- ~ 10k points of glue.
- Production line set u

luing







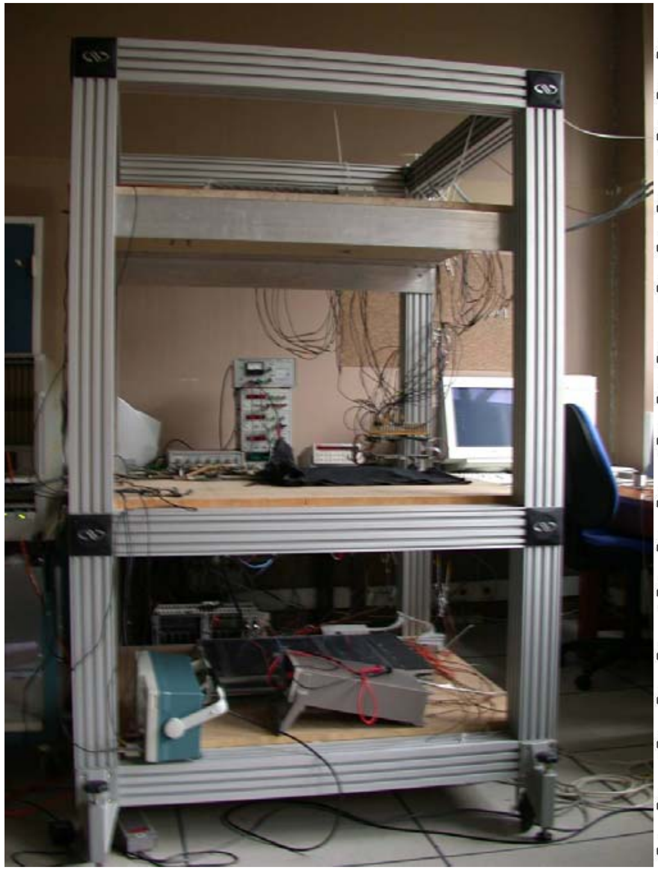
12 VFE chips

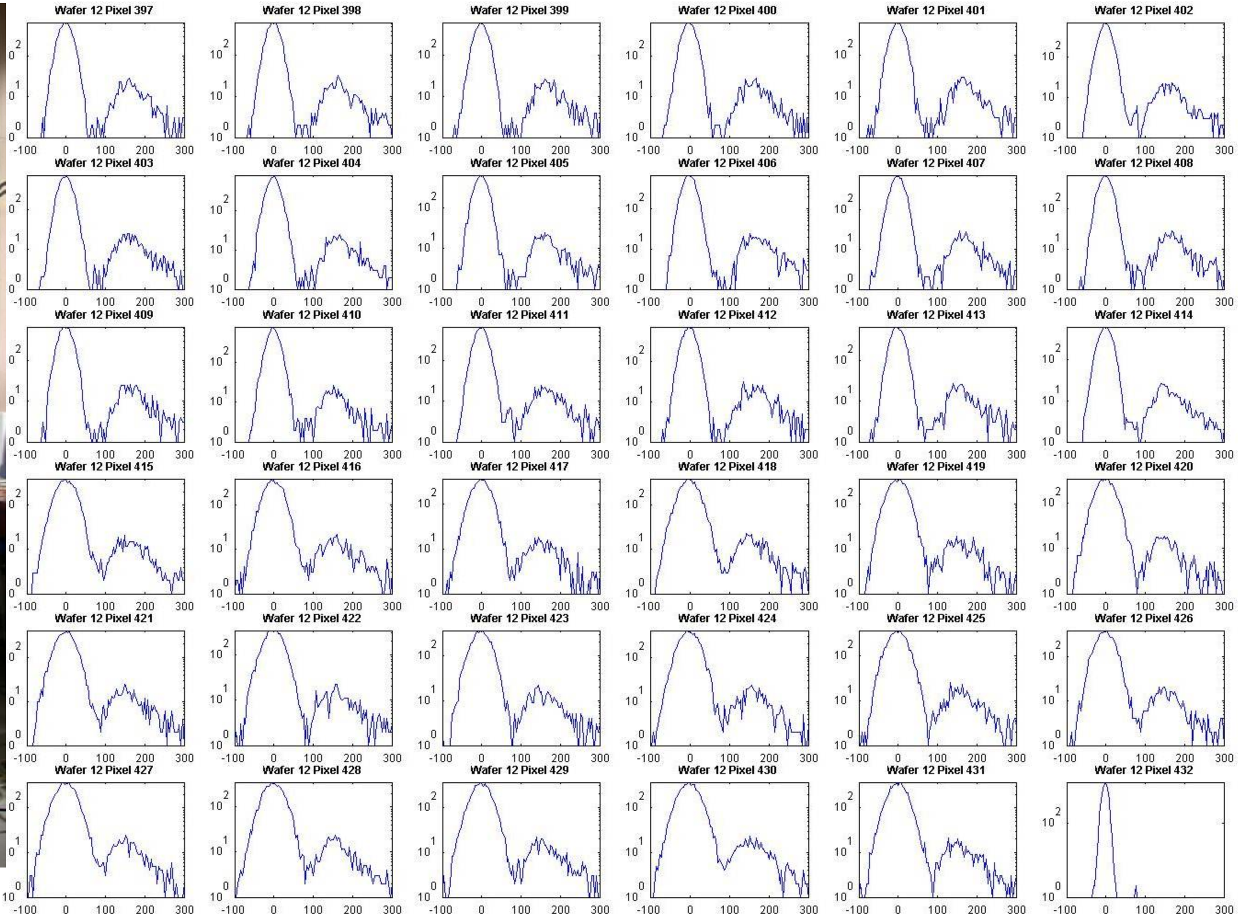
2 calibration switch chips

Line Buffers To DAQ

6 active silicon wafers

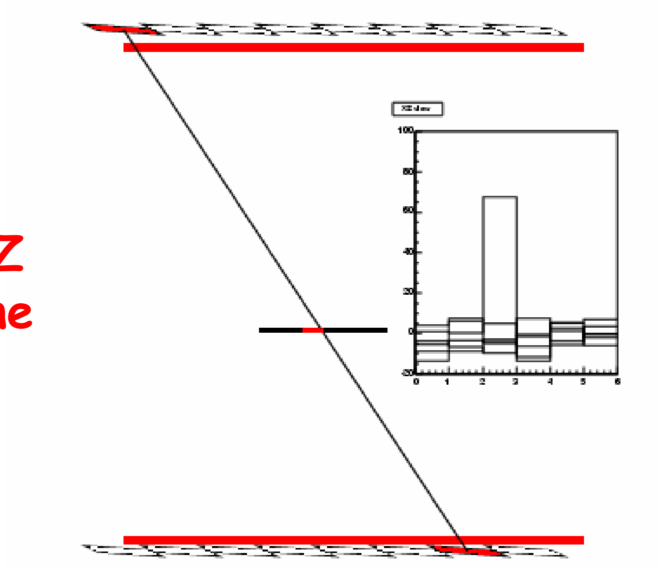
Cosmics Tests





Cosmics Tests: Single Layer

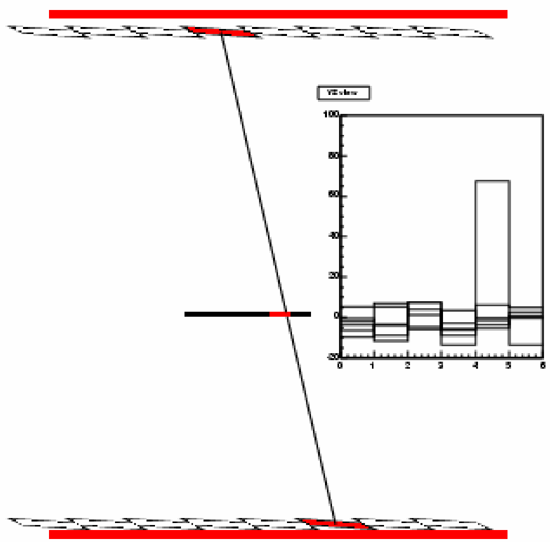
X-Z plane



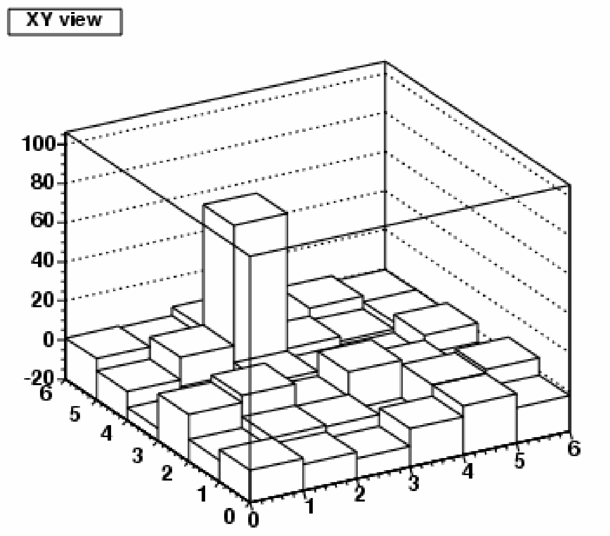
Scintillator

Wafer

Scintillator

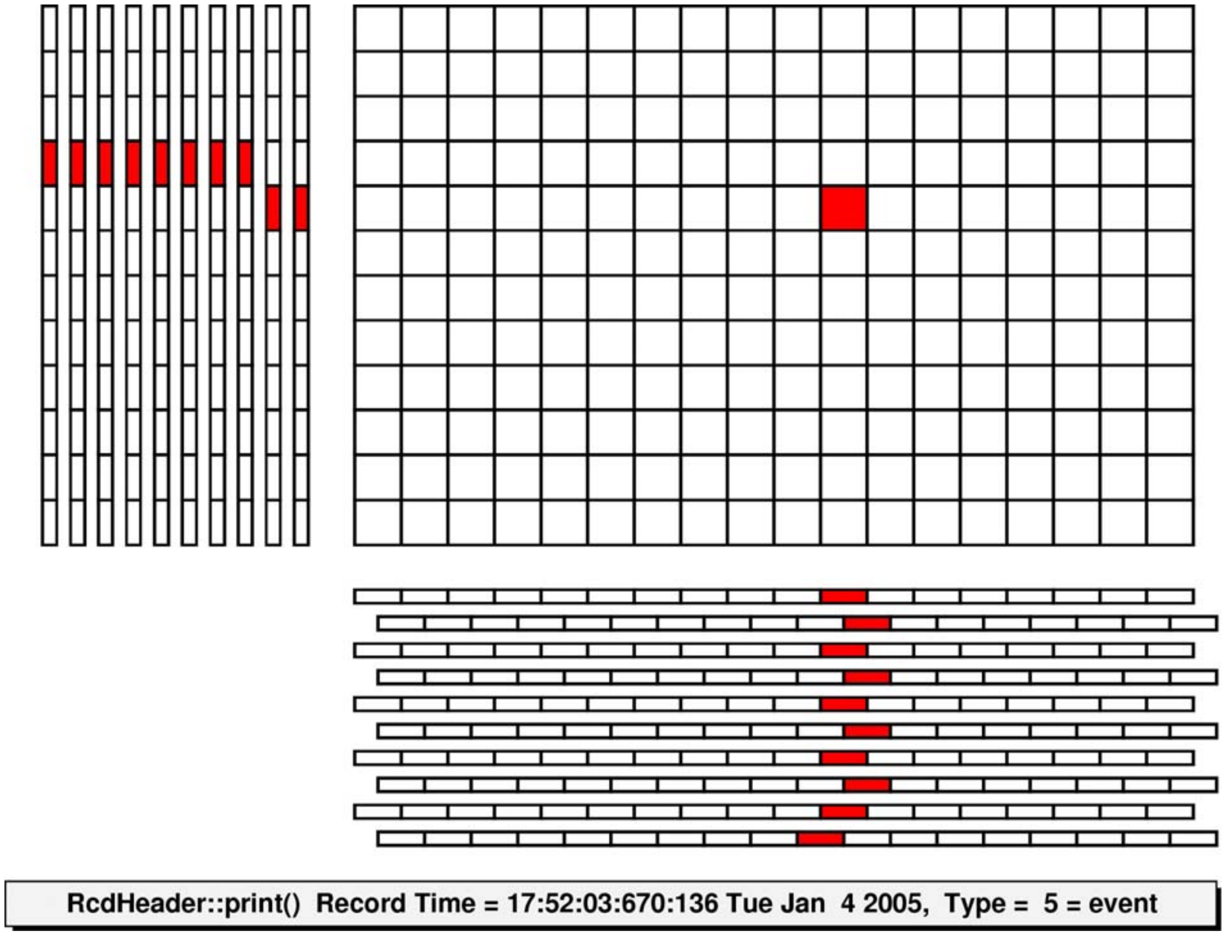


Y-Z plane



- Example of Cosmic Event
- Passes through scintillators
- Extrapolated through silicon
- Clear signal above background
- Full readout chain used

Cosmics Tests, 10 layers



Dec. 2004

10 layers assembled LLR

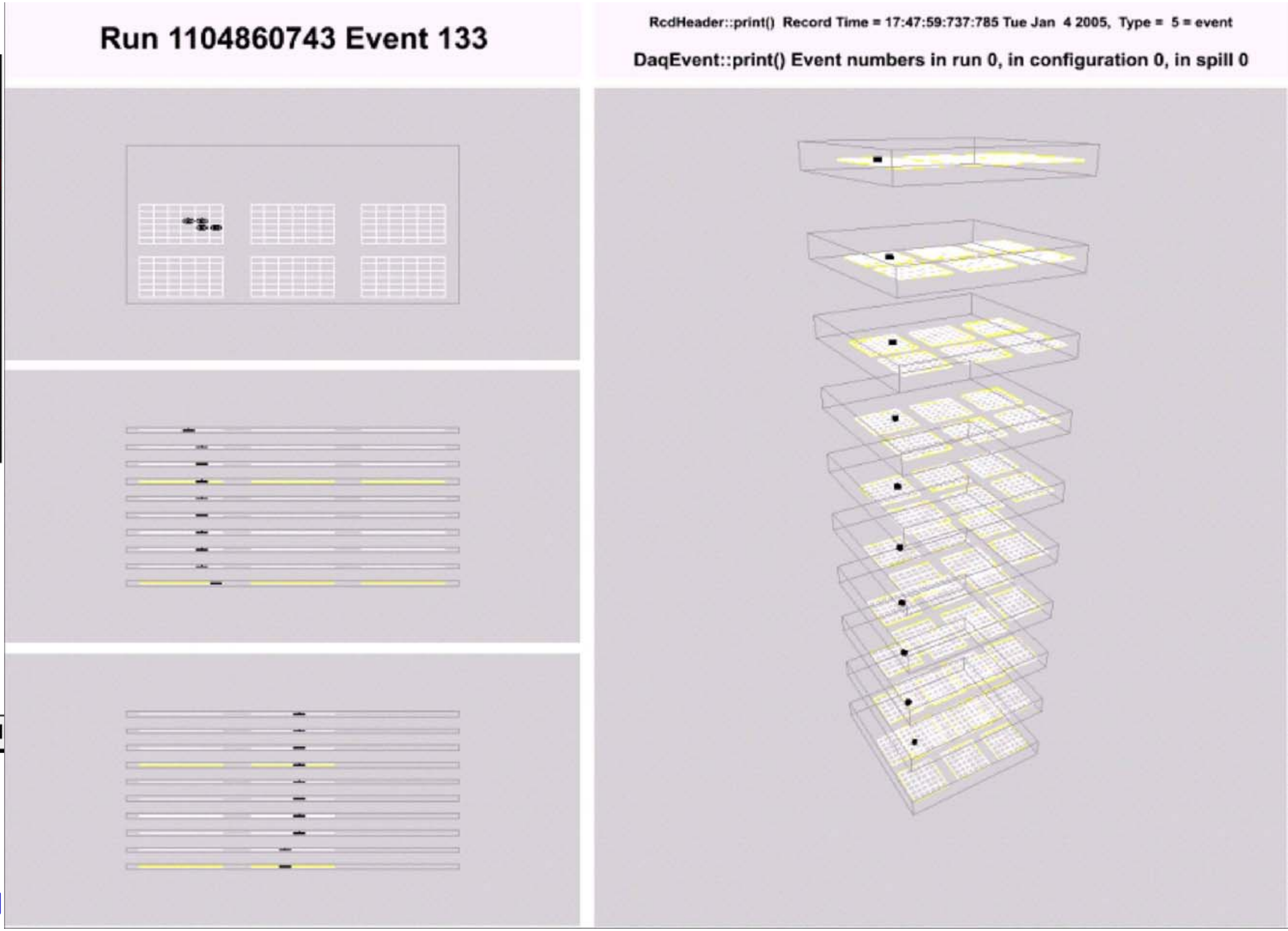
2 production CRC boards

>10^6 events over Christmas

S/N ~ 9

This event, Jan. 4

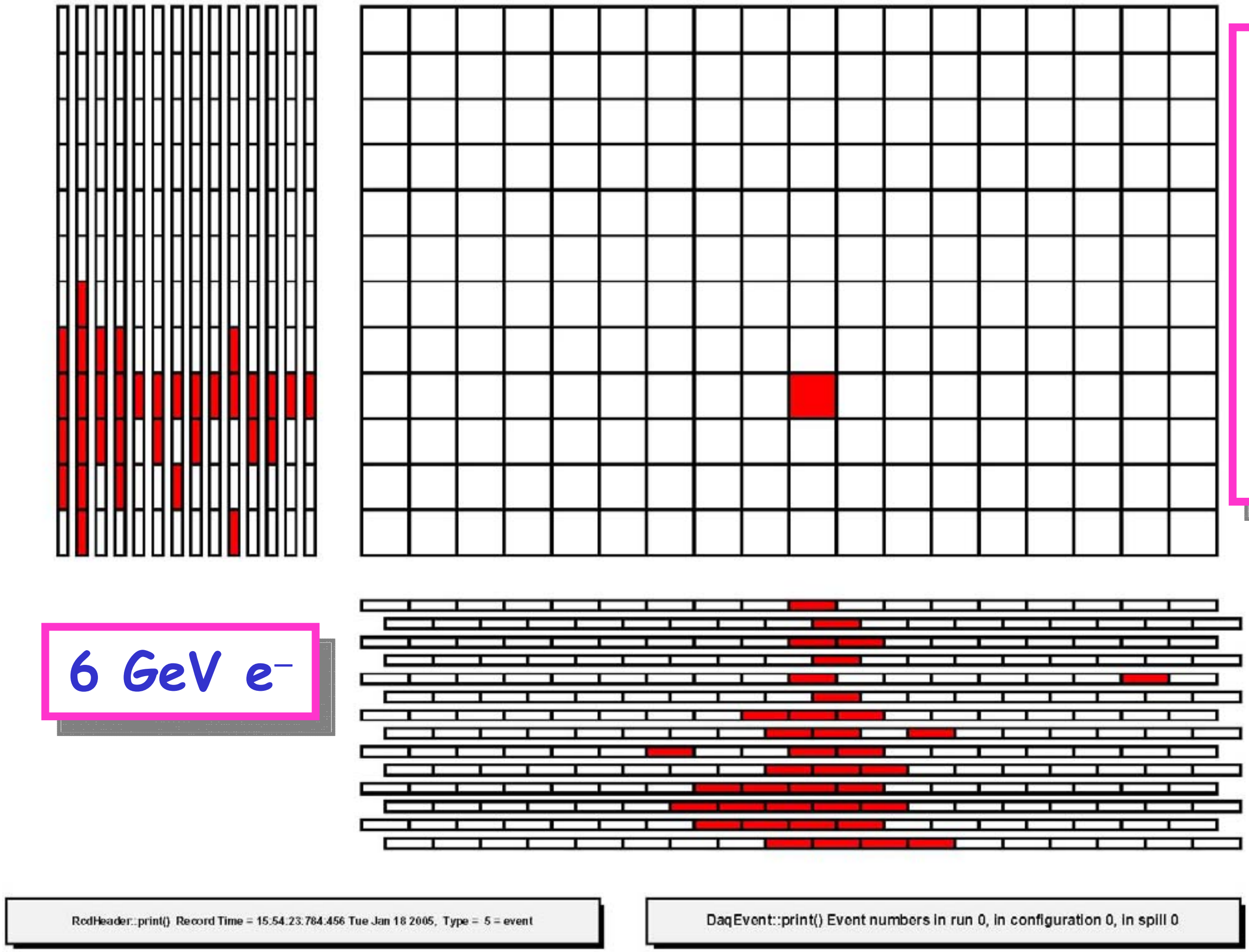
Cosmics Tests, 10 layers



Rcd

Nigel

1st Beam Data From DESY



6 GeV e^-

Jan. 2005

12th, H/W arrived DESY

13-4th, assembled

17th, 1st beam recorded

This event, Jan. 18

Calice UK Future Plans

- 3 y
  -
- To
  -
  -
  -
  -
  -
- RH ... fla
- CA
- La ... ps?)
- In... ahead.

Case for Support - CALICE
Calorimetry for the International Linear Collider

C.G.Ainsley[2], R.J.Barlow[4], G.Boorman[5], D.Bowerman[3], J.Crooks[6], P.D.Dauncey[3]*, M.J.Goodrick[2], B.J.Green[5], M.G.Green[5], C.M.Hawkes[1], R.Hughes-Jones[4], S.Kolya[4], M.Lancaster[7], G.Mavromanolakis[2], N.Pezzi[7], M.Postranecky[7], D.R.Price[3], F.Salvatore[5], S.Snow[4], R.J.Staley[1], R.J.Thompson[4], M.A.Thomson[2], R.Turchetta[6], M.Tyndel[6], E.G.Villani[6], D.R.Ward[2], M.Warren[7], N.K.Watson[1], J.A.Wilson[1], M.Wing[7], O.Zorba[3]

[1]University of Birmingham, [2]University of Cambridge, [3]Imperial College London, [4]Manchester University, [5]Royal Holloway, University of London, [6]Rutherford Appleton Laboratory, [7]University College London

January 14, 2005

Executive Summary

The International Linear Collider (ILC) is seen by high energy physicists in all regions of the world as the most important new project in the subject. Its physics program has been shown to complement that of the LHC; in particular the ILC will be able to perform many high precision measurements. The CALICE collaboration brings together physicists from all parts of the world who have an interest in calorimetry for an ILC detector. The immediate focus for CALICE is the construction and testing of prototypes of highly granular calorimeters, using technologies suitable for the ILC, in test beams during 2005-6. Five UK groups were approved by the PPRP at the end of 2002 to join CALICE.

The UK contribution was to provide readout electronics and DAQ software for the CALICE electromagnetic calorimeter, and also to contribute strongly to software and analysis efforts. During the past two years, the electronics has been successfully constructed and the prototype is about to move into a test beam. We have also made a leading contribution to the software work in CALICE.

See this & other docs at http://www.hep.ph.ic.ac.uk/~calice/

London,

Calice UK Future Plans

- 3 year programme, 2005-08
  - Fits well with schedule for C/TDR
- Topics
  - Existing test beam programme
  - DAQ
  - MAPS – digital ECAL
  - Mechanical/Thermal
  - Simulation
- RHUL recently joined, interest from 1 other group flagged to PPRP
- CALICE already a global enterprise, all regions
- Large scope for expansion ($$ MAPS, DAQ, endcaps?)
- Interesting times ahead!

Come to PPRP review, 1 Feb. 2005, 10am, Senate House, London,