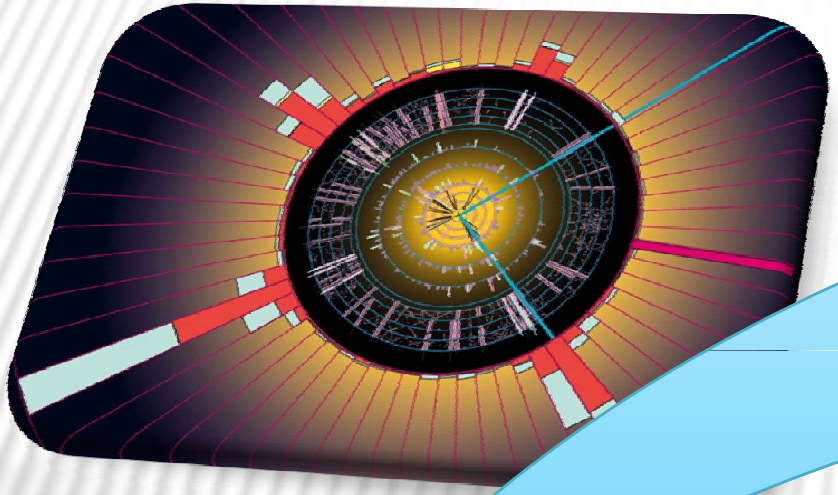
David Bailey

University of Manchester – For the CALICE Collaboration

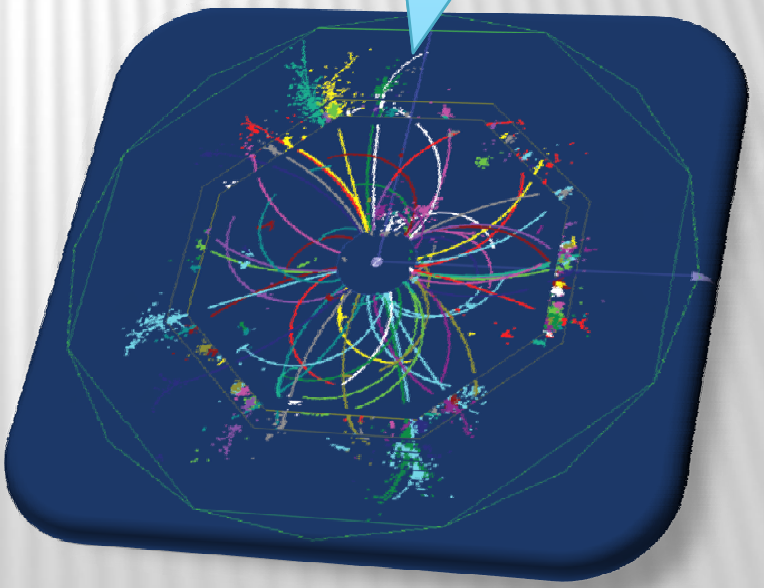
CALORIMETERS FOR THE ILC

PROJECT GOALS



From this...

To this...



THE PHYSICS WE WANT TO DO

Need Boson Tagging

Multi bosons	Multifermions + Boson(s)
ZH	e^+e^- H , e+e− Z
WW	νν H , νν Z
ZZ	ttH
ZHH	e ν W
ZZZ	νν WW, νν ZZ
ZWW	ttbar in bbar WW

etc... but also tau decay reconstruction for SUSY, CP...

Best use of the luminosity … use decays into jets

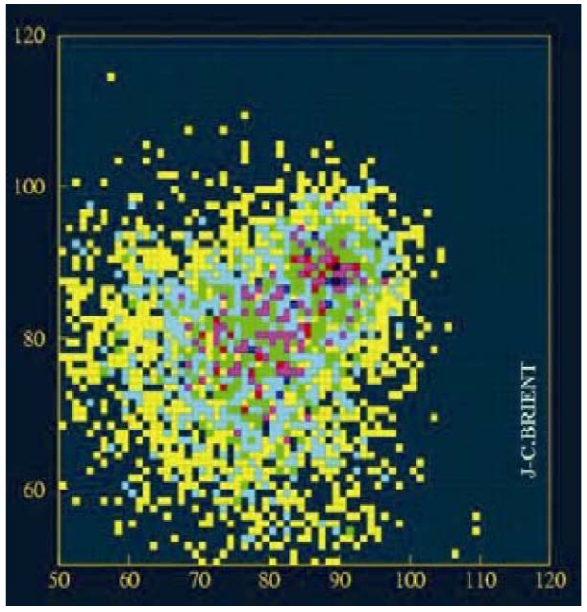
Z to	BR
$\ell^+ \ell^-$	10%
qq (jets)	70%

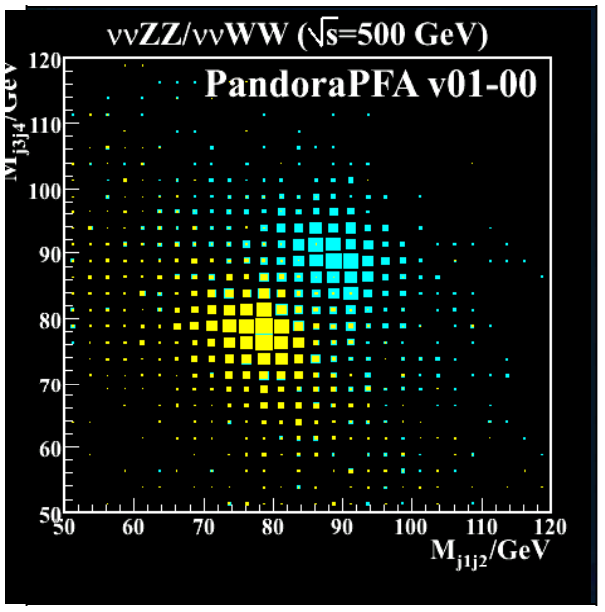
W to	BR
$\ell^\pm \nu$	32%
qq' (jets)	68%

H(120,SM) to	BR
$\ell^+ \ell^-$	<15%
qq(jets) ,WW,ZZ	>85%

JET ENERGY RESOLUTION

- Boson ID improves if $\sigma_{\text{Dijet Mass}} < \Gamma^{\text{Tot}}_{\text{Boson}}$
  - Translates to jet energy resolution of $\approx 30\%/\sqrt{E}$ at the Z mass





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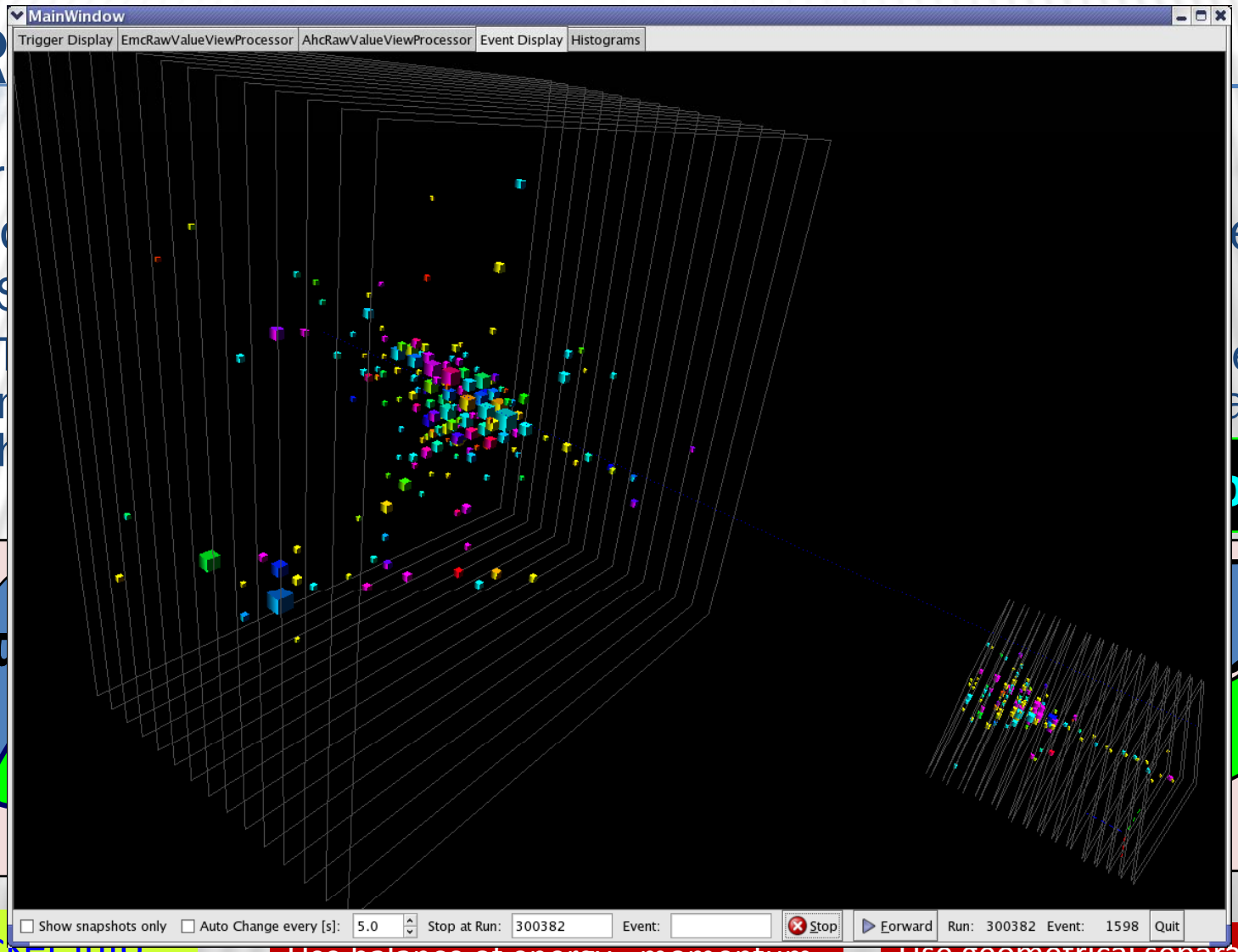


Tracker info.

Use balance of energy - momentum

Use geometrical separation

TECHNOLOGY

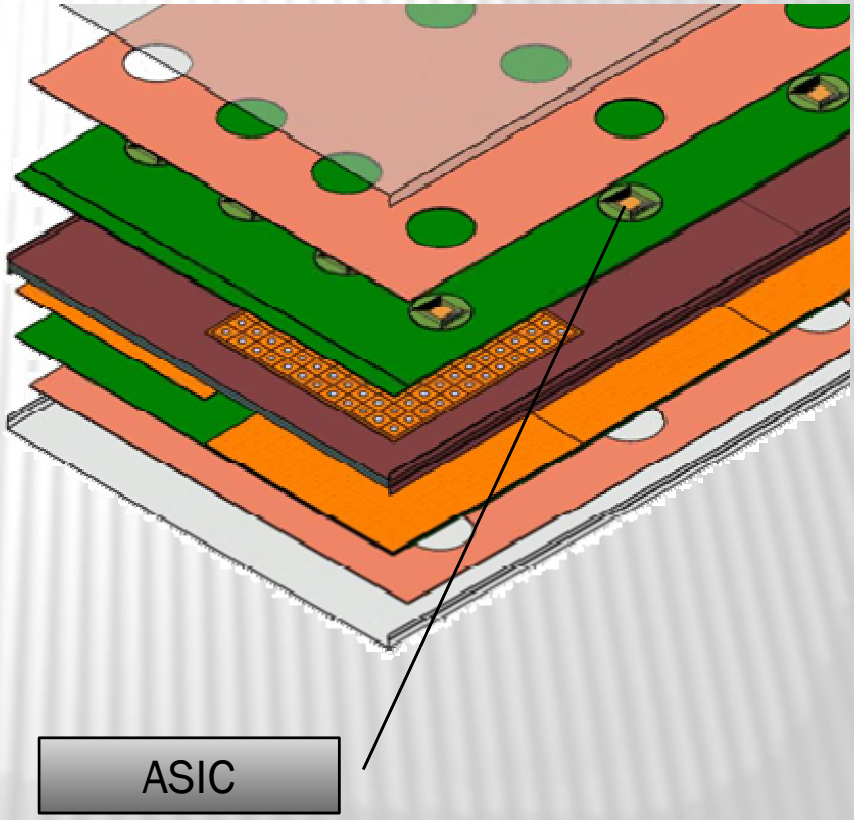
- All calorimeters designed for particle flow
  - High spatial granularity
  - Integrated electronics on detector wherever possible
    - ASICs mounted on active material
    - Silicon PMs/MPPCs mounted on scintillators
  - Different technologies being prototyped
    - Analogue/Digital devices
    - All optimised for excellent position resolution

CALORIMETER PROTOTYPES

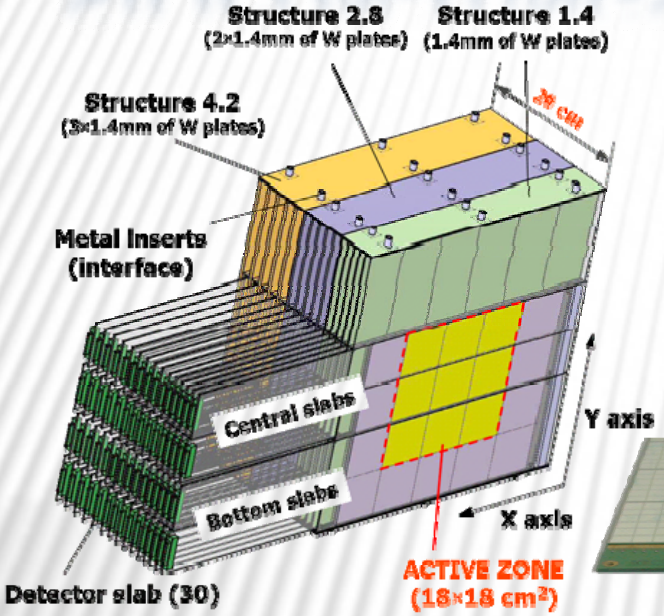
- Electromagnetic Calorimeter
  - Silicon-Tungsten
    - MAPS Option
  - Scintillator-Tungsten
- Hadronic Calorimeter
  - Scintillator with Analogue Readout
  - RPC and MICROMEGAS – Digital HCAL Concept
- Coordinated test beam programme to combine different technologies at the same time and extract meaningful physics

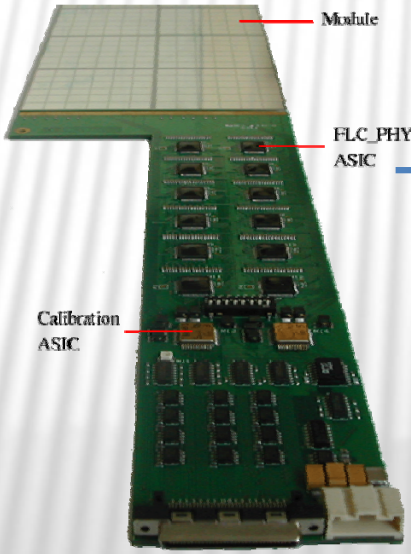
ELECTRONICS

- Requirements for electronics
  - + Large dynamic range
  - + Auto-trigger on ½ MIP
  - + On-chip zero suppress
  - + Front-end embedded in detector
  - + Ultra-low power
    - × « 25μW/ch
    - × Power Pulsing



SILICON-TUNGSTEN ECAL

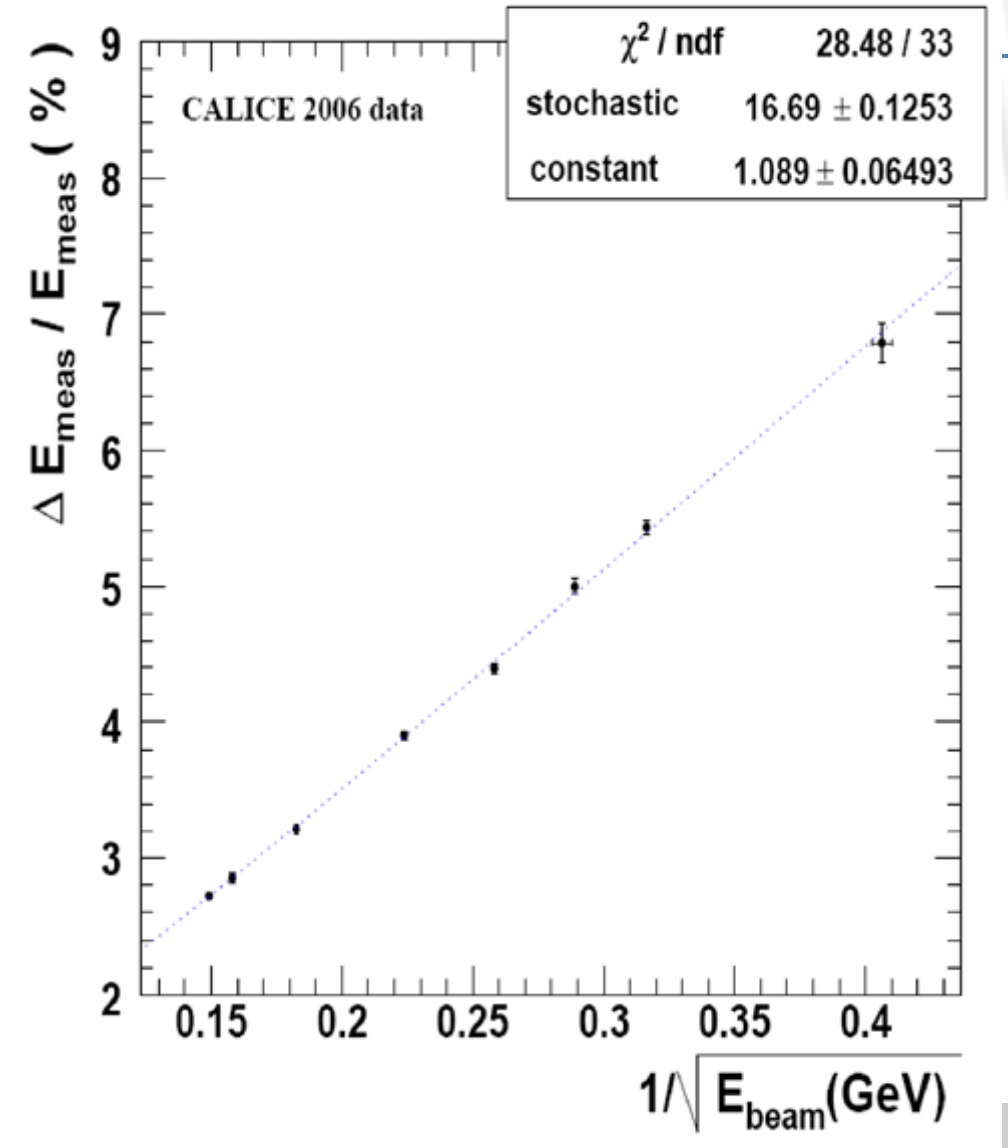




- Highly granular calorimeter
  - + Absorber
    - × 30 layers of tungsten
      - * 1.4,2.8 and 4.2mm thick
  - + Active Element
    - × 30 layers of Si diode pads
      - * 1cm^2
      - * 9720 channels

SILICON-T

- Respons
- Test Bea
  - + Sampli
  - + Consta
  - + Linearit
- Calorime
  pattern r
  separati



SILICON-TUNGSTEN ECAL

- Longitudin
  - reasonably
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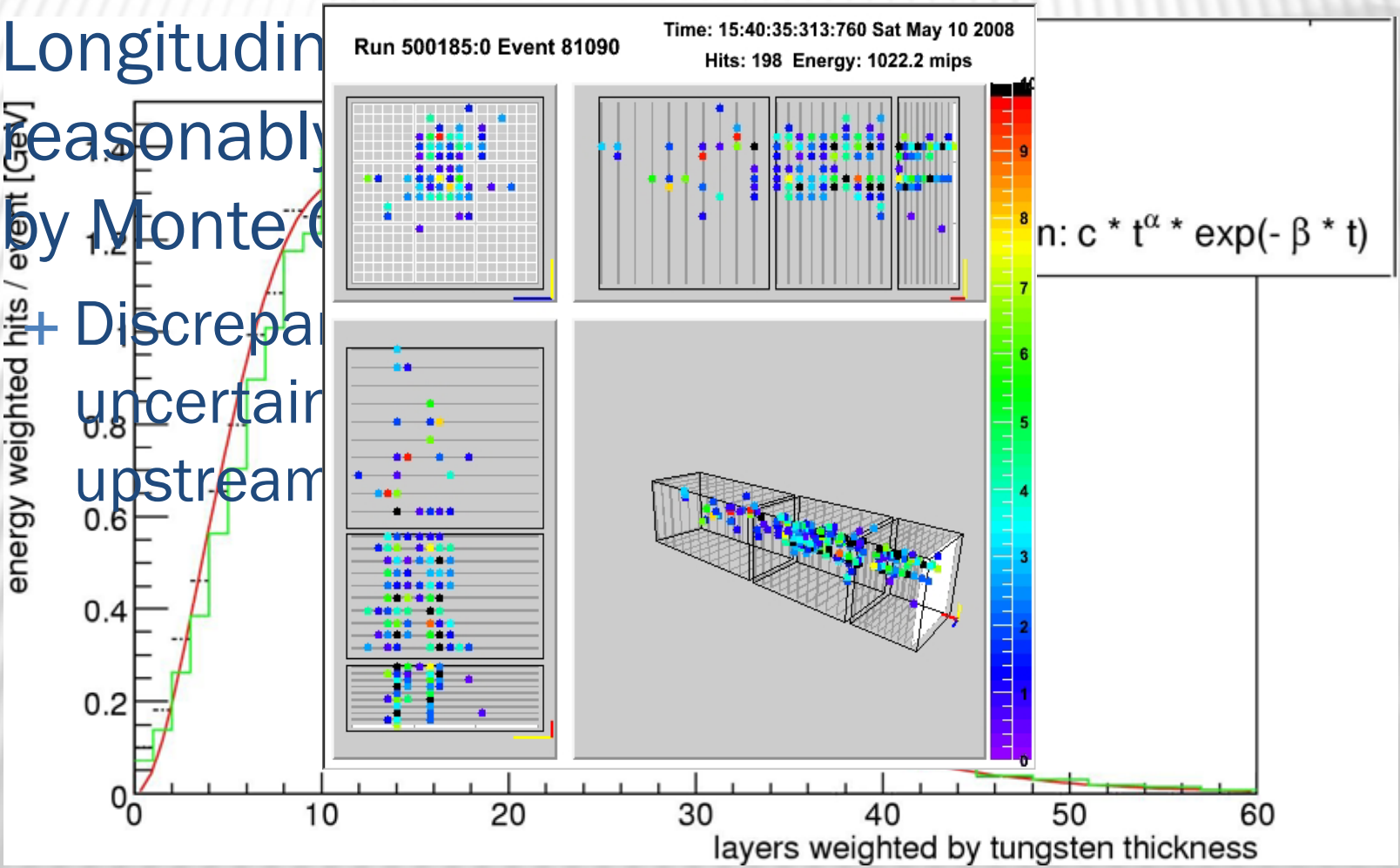
  - + Discrepa
    - uncertair
    - upstream



MAPS OPTION

- Determine energy by counting
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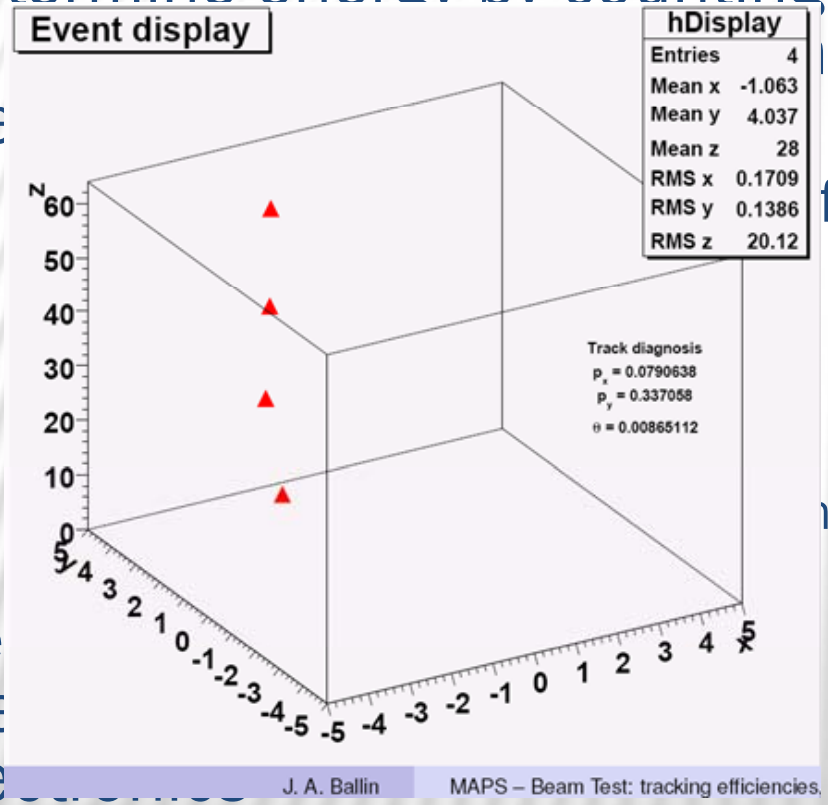
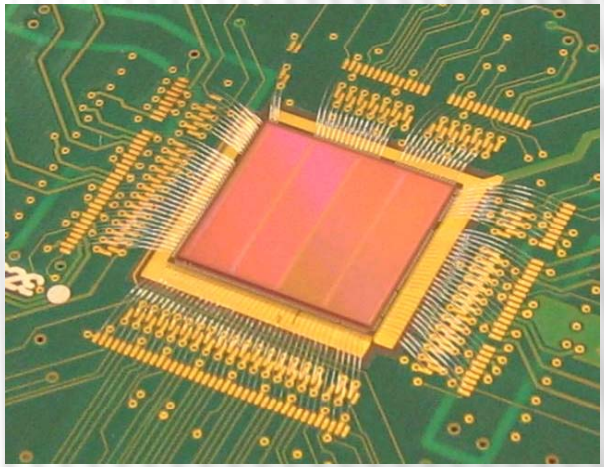
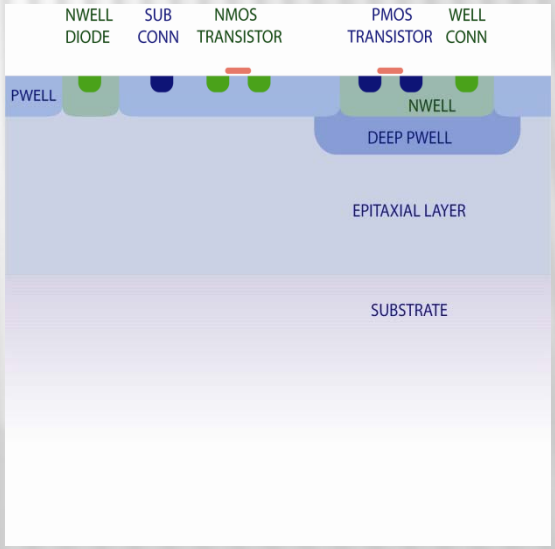
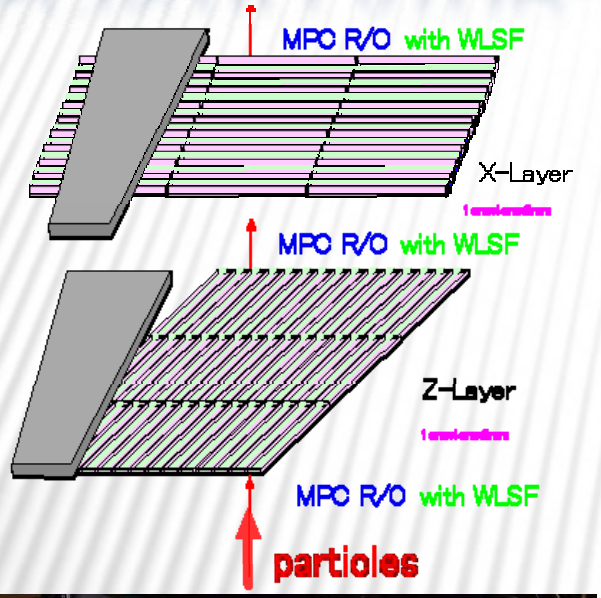
- De
  pre
  ele

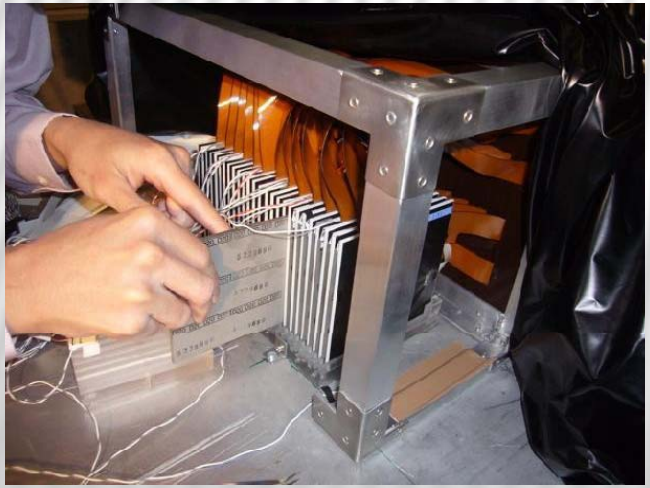






SCINTILLATOR-TUNGSTEN ECAL



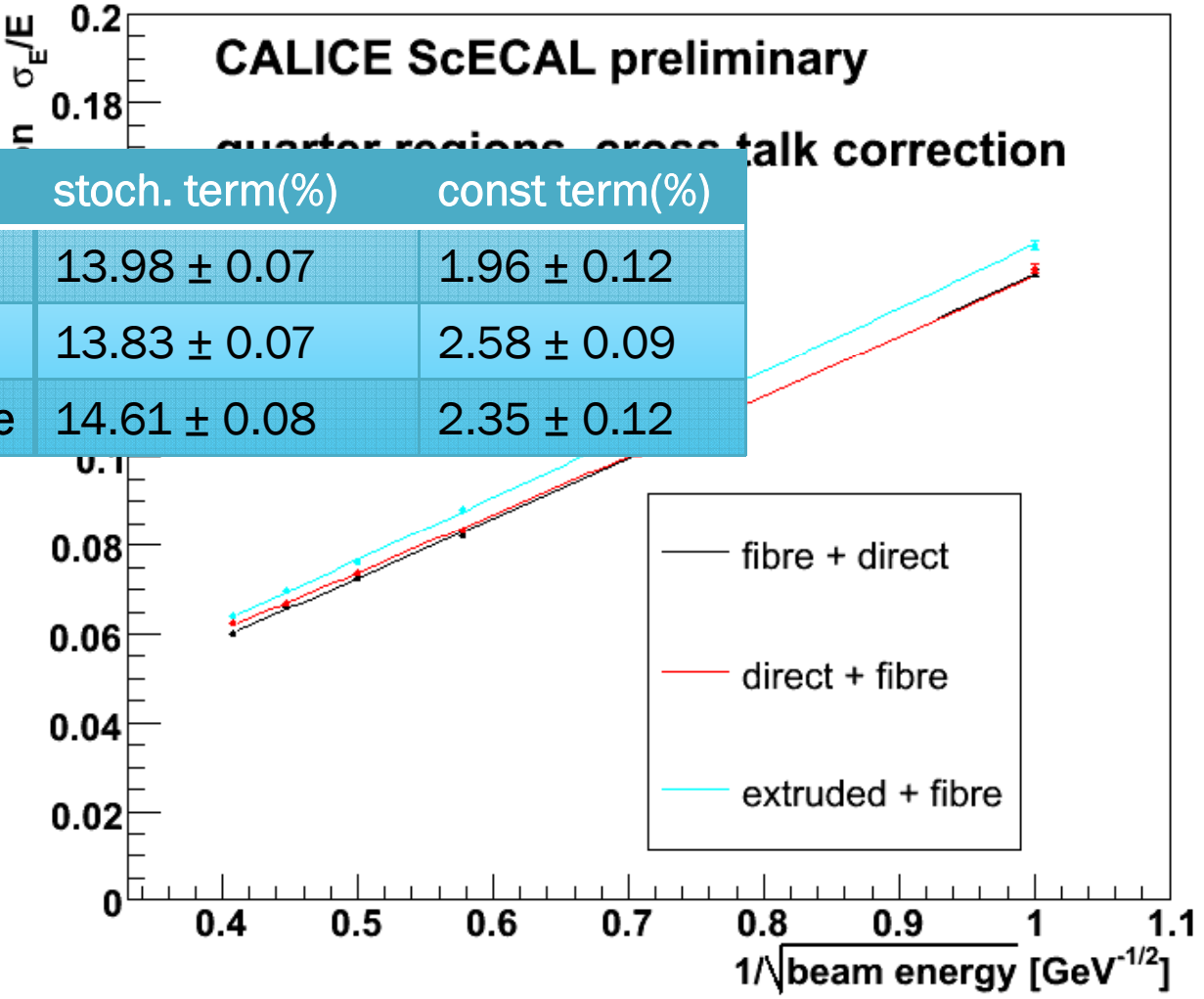


- Sampling Calorimeter
  - Tungsten Absorber
  - Scintillator Active Material
    - Strips 1cm wide, 3.5mm thick
      - 3 different configurations
      - WLSF readout
    - Each strip read out by MPPC
- Put into DESY Test-Beam in 2007
  - 26 Layer device

SCINTILLATOR-TUNGSTEN ECAL

- Respor

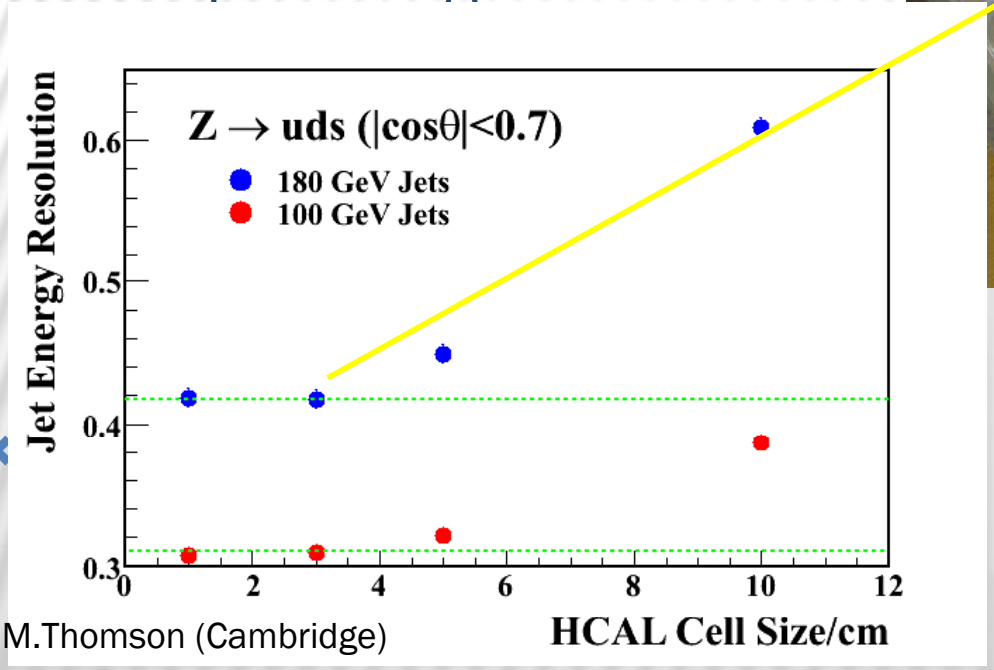
	stoch. term(%)	const term(%)
fibre+direct	13.98 ± 0.07	1.96 ± 0.12
direct+fibre	13.83 ± 0.07	2.58 ± 0.09
extruded+fibre	14.61 ± 0.08	2.35 ± 0.12



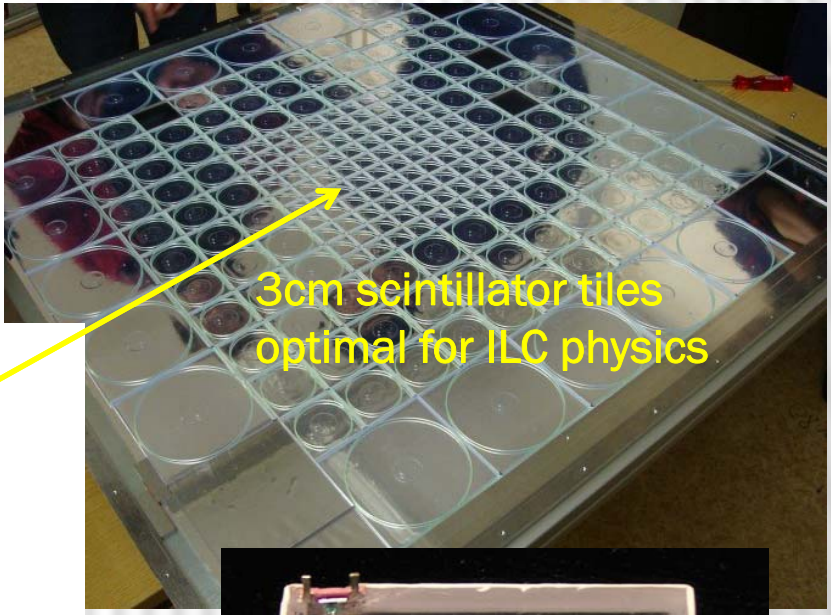
- Resolu
  ILC req
  - + Now
    proto
  - + Beam

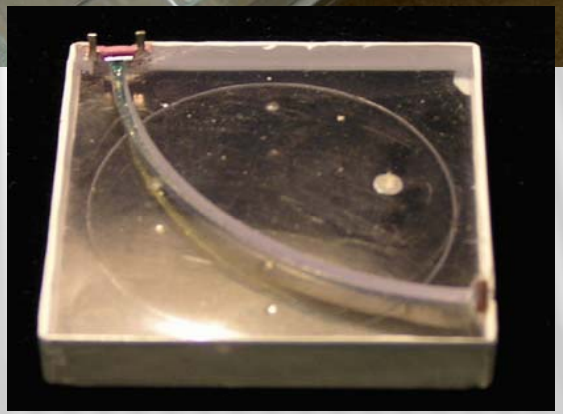
ANALOGUE HCAL

- Scintillator tiles with embedded wavelength shifting fibres
- Multi-pixel Geiger mode



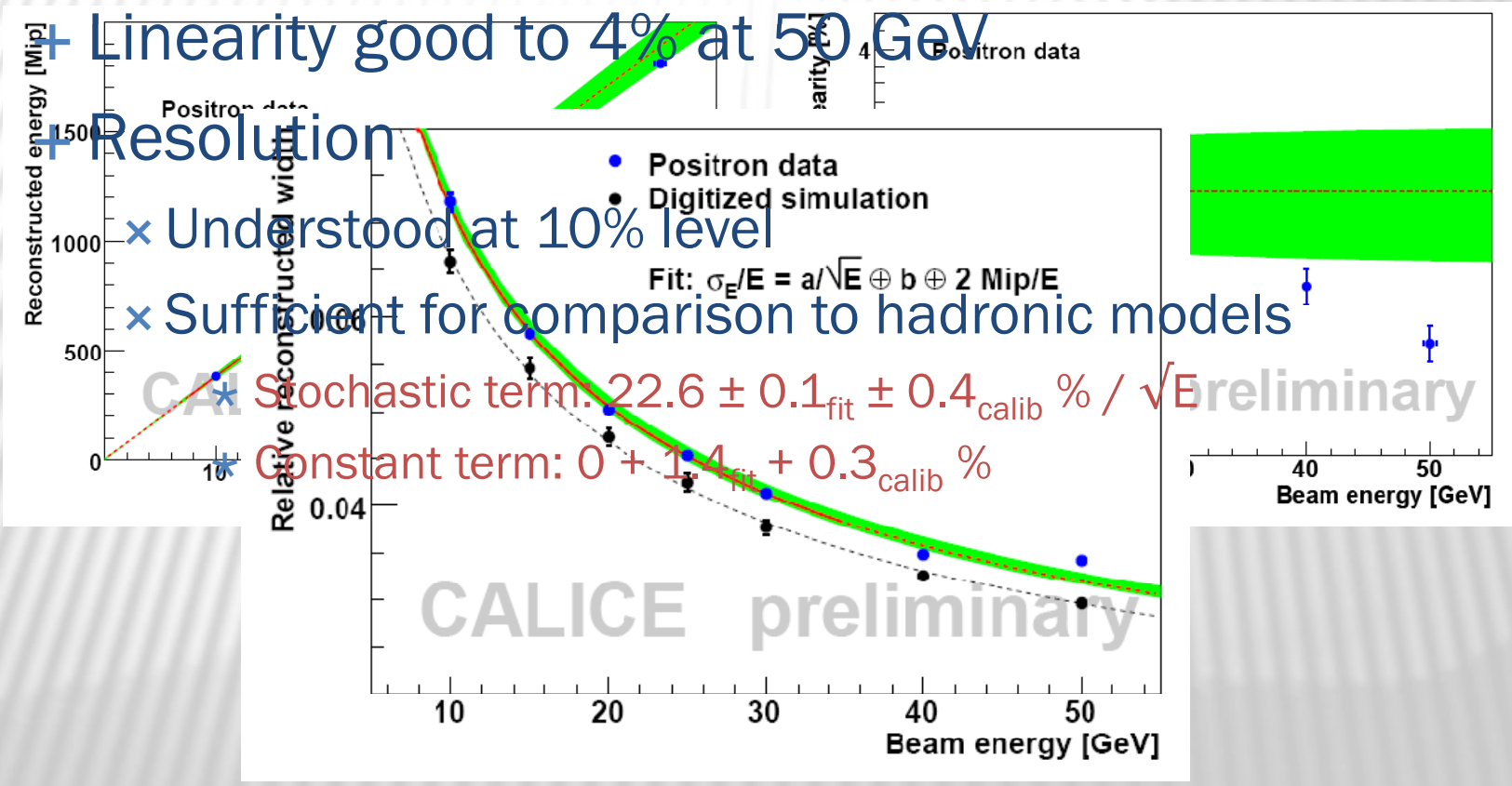
M.Thomson (Cambridge)





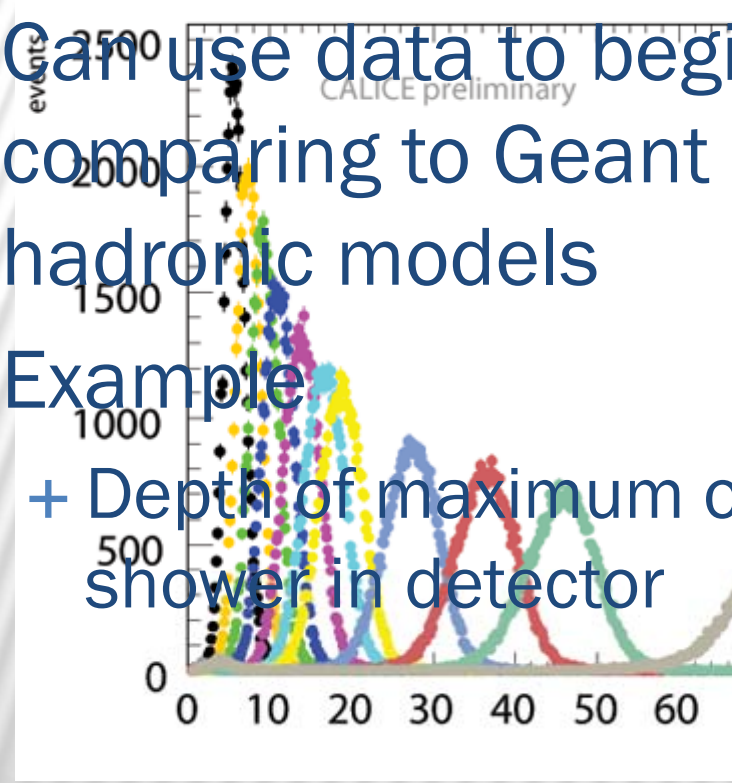
ANALOGUE HCAL

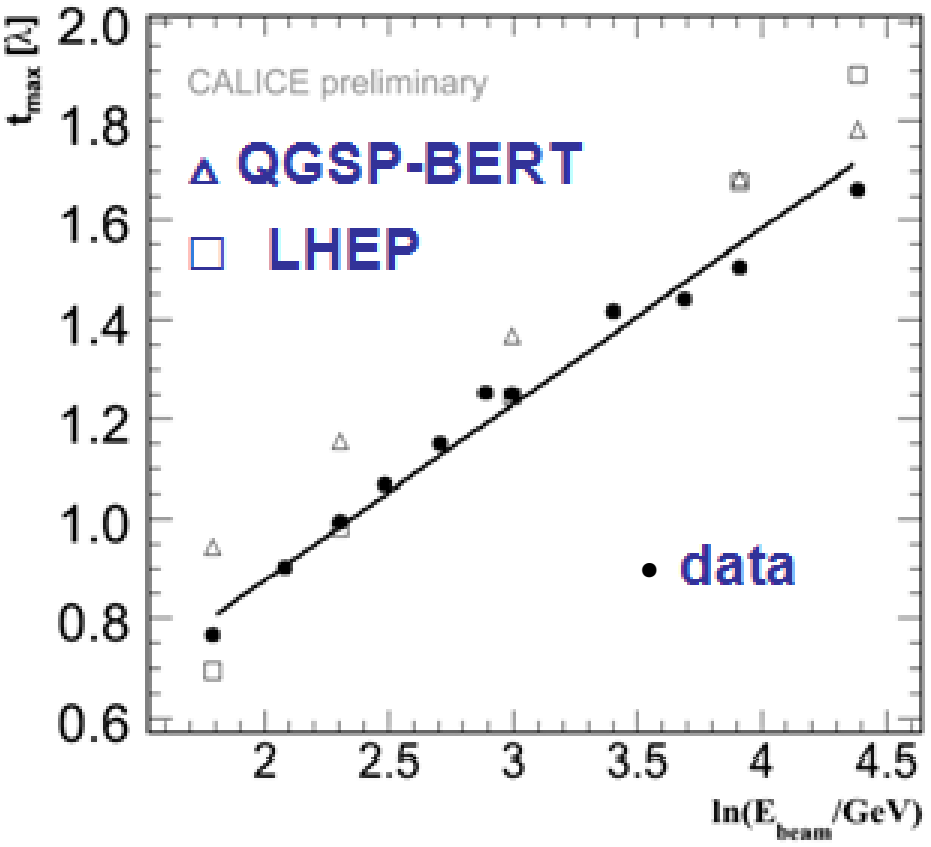
- Operation verified using positron beam
  - Linearity good to 4% at 50 GeV
  - Resolution
    - Understood at 10% level
    - Sufficient for comparison to hadronic models
      - Stochastic term: $22.6 \pm 0.1_{fit} \pm 0.4_{calib}$ % / √E
      - Constant term: $0 + 1.4_{fit} + 0.3_{calib}$ %



ANALOGUE HCAL

- Response to Hadron
- Can use data to begi
  comparing to Geant
  hadronic models
- Example
  - Depth of maximum c
    shower in detector





DIGITAL HCAL

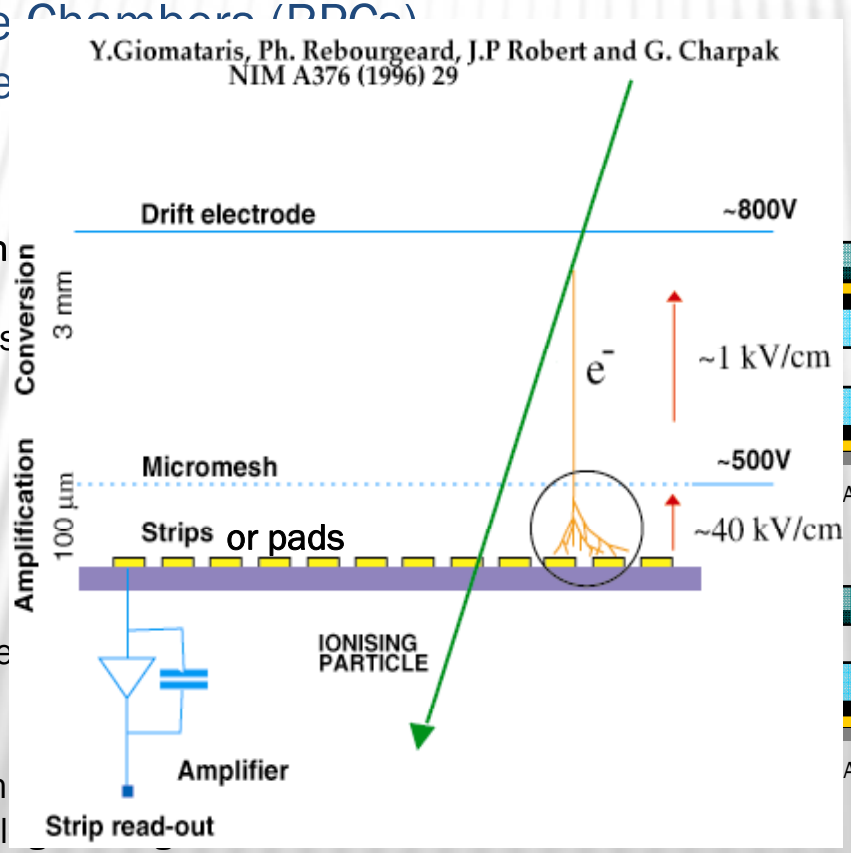
- Trades resolution on a small number of cells (towers) in traditional calorimeters with low (one-bit) resolution on a large number (~10^7 – 10^8) of cells. Not using scintillator (neutron sensitivity) allows smaller pad sizes.
- Resistive Plate Chambers (RPCs)
  - + 1 x 1 cm^2 re
- MicroMegas

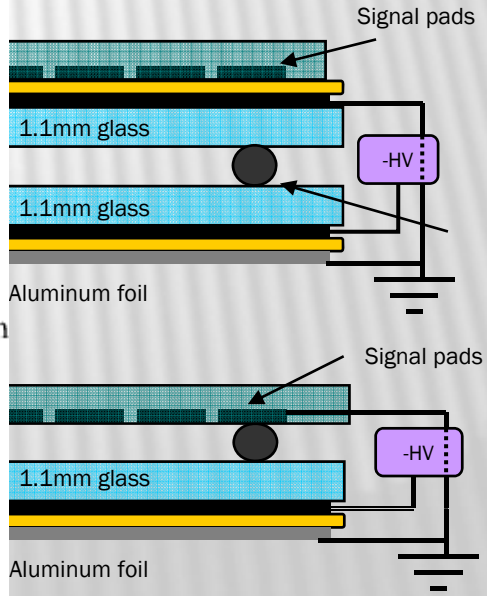
Pursued two design

Two-glass des

One-glass de

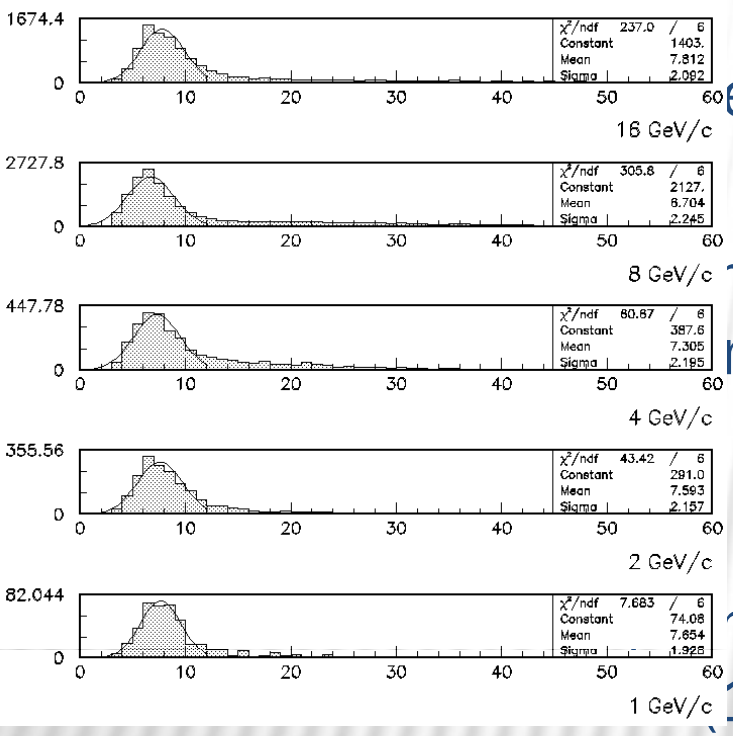
Extensive tests with
multiple pads, anal





DIGITAL HCAL

- RPCs



esigns

Nice MIP peaks

mm

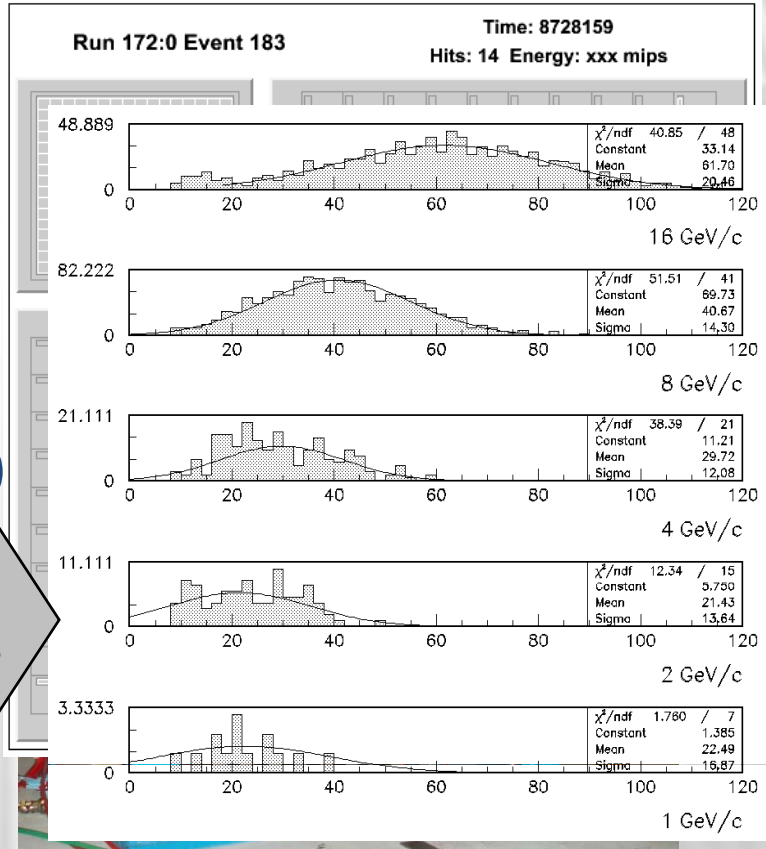
mm (readout)

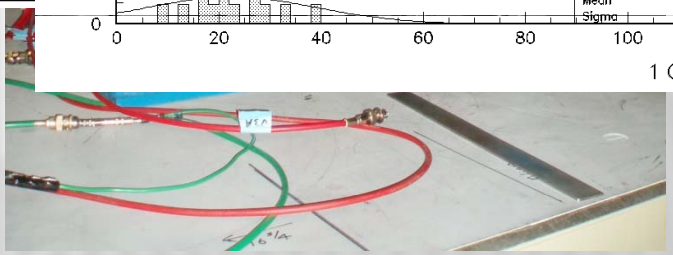
Gaussian distributions

muon, pions,

16 mm) +

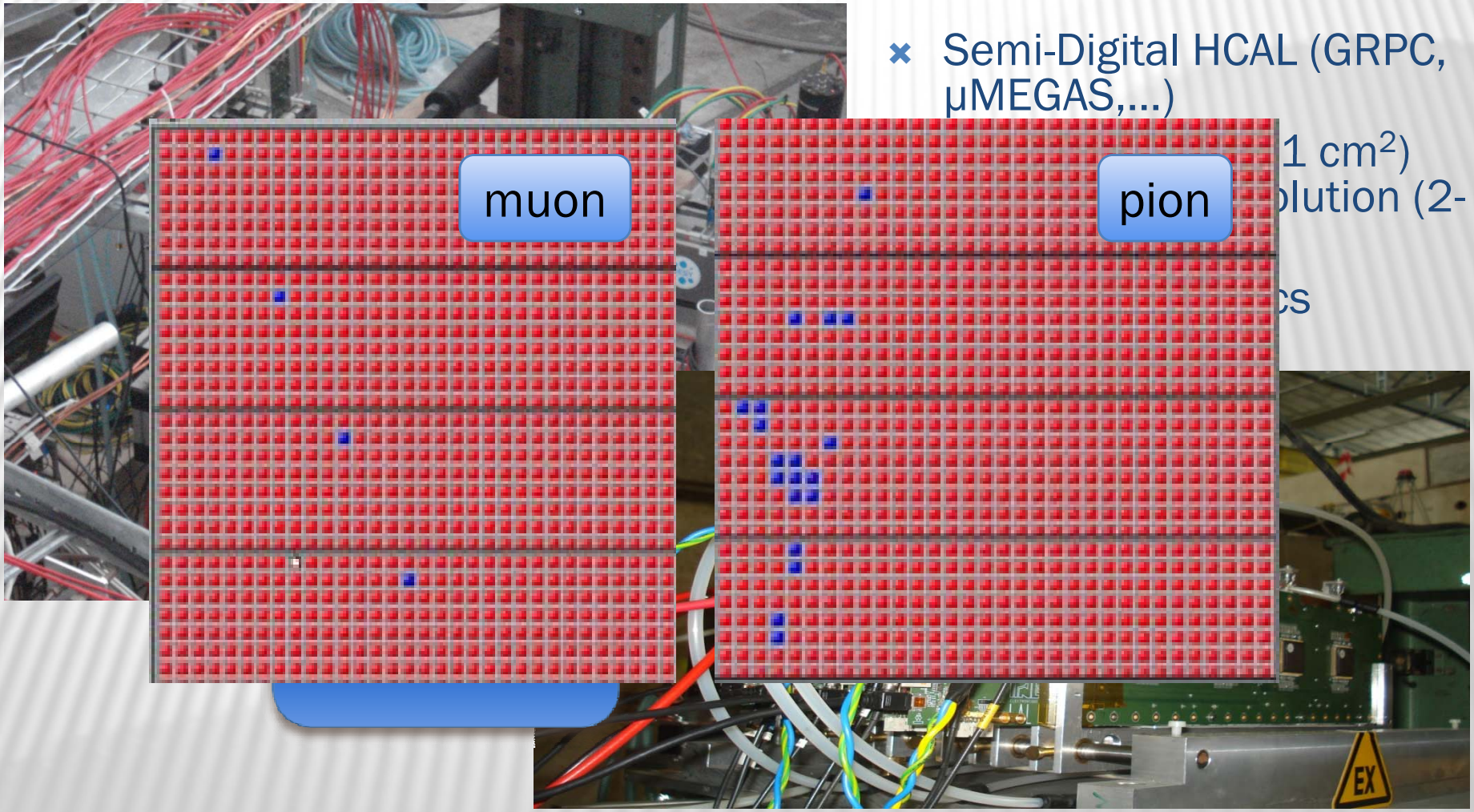
Copper (4 mm)





DIGITAL HCAL

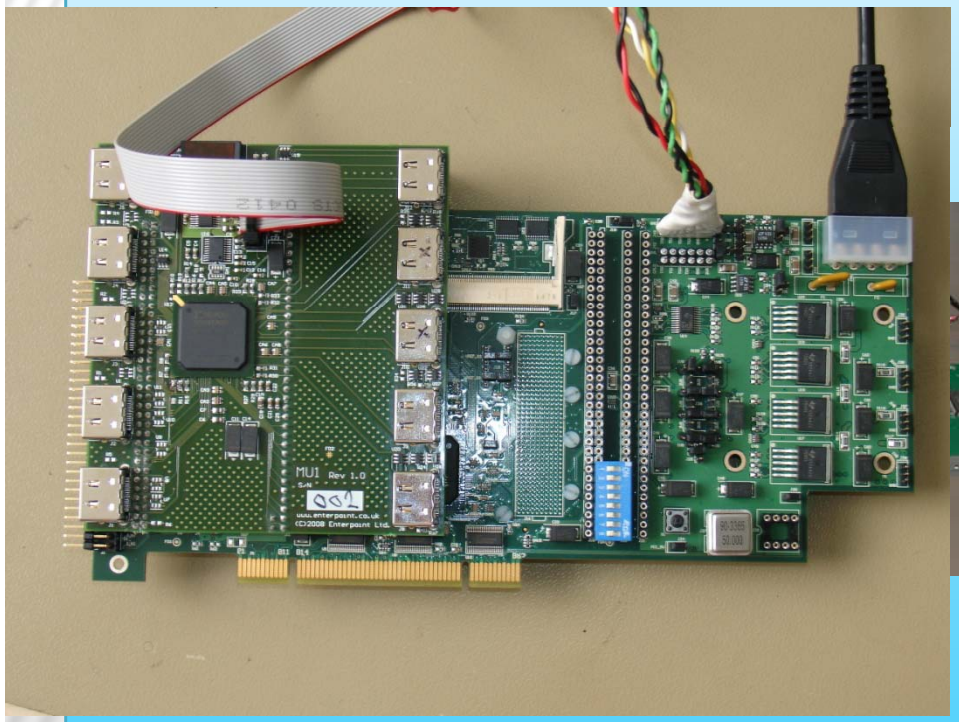
- Semi-Digital HCAL (GRPC, μMEGAS,…)
- 1 cm^2)
- olution (2-
- cs

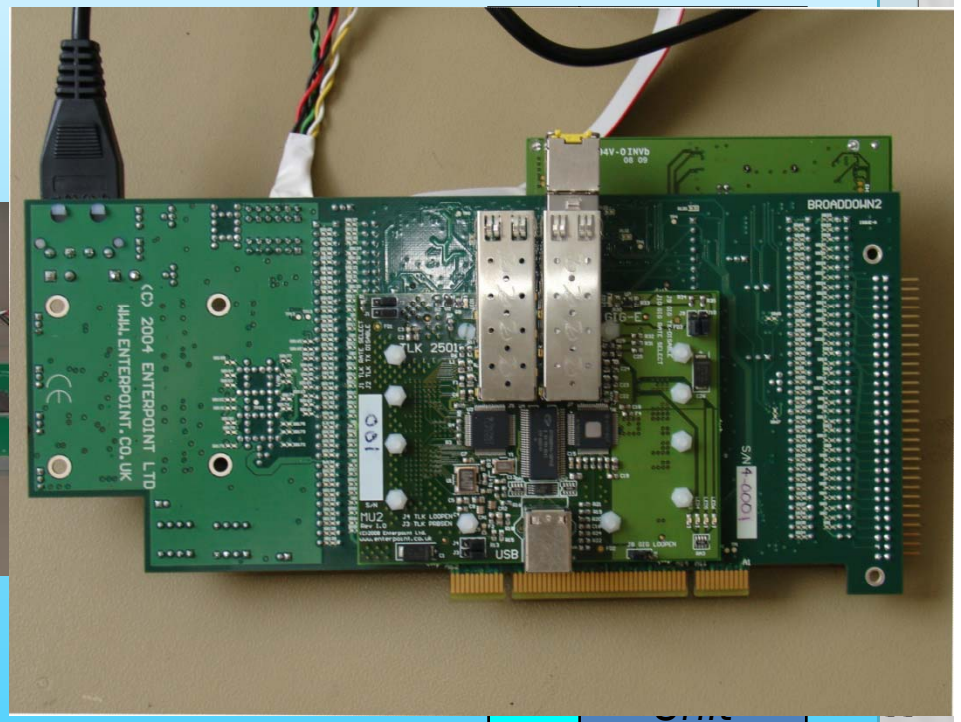


FUTURE PROGRAMME

- EUDET
  - European framework 6 project
    - Development of physics technological prototypes
    - Large-scale detectors
    - Associated next-generation readout systems
- HCAL 1m^3 prototypes

NEXT GENERATION DAQ





- Prototypes using FPGA developments boards with some custom daughter boards

SUMMARY

- Lots going on
  - Very active test beam programme
    - 2008 running at Fermilab underway now
  - Many different technologies
    - Analogue/Digital devices
    - Embedded electronics
    - All have potential to deliver a working particle flow calorimeter for an ILC experiment
- Expect the results of new test-beam analyses soon