MAPS Project Status

CALICE-UK Meeting, Cambridge

Y. Mikami, O. Miller, V. Rajovic, N.K. Watson, J.A. Wilson
(University of Birmingham)
J.A. Ballin, P.D. Dauncey, A.-M. Magnan, M. Noy
(Imperial College London)
J.P. Crooks, M. Stanitzki, K.D. Stefanov,
R. Turchetta, M. Tyndel, E.G. Villani
(Rutherford Appleton Laboratory)

Presented by J. A. Ballin, HEP, Imperial College, London
j.ballin06@ic.ac.uk

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Outline

Calorimeter for ILC

The MAPS Project

A digital readout 50 $\times$50 μm pixel

Overview

- 50 $\times$50 μm pixel
- 0.18 μm CMOS process and digital readout
- 10^{12} pixels for a typical ILC detector – terapixel calorimetry
- Target noise rate of 10^{-6} per pixel
- Counting hits is the way to measure energy
- New INMAPS process improves charge collection efficiency (more in a moment)
- 8.7M transistors per sensor

Testing of first round sensor has just got underway!

The MAPS Project

Other points of note

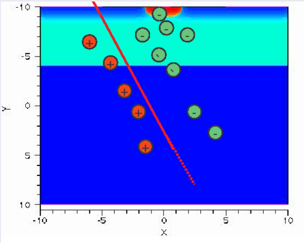
- Diode-pad and MAPS can share a common DAQ (EUDET project)
- Aims to preserve mechanical structure of ECAL
- Designed for the Silicon component of the ECAL, but we can be inventive in its deployment
- No ASIC $\Rightarrow$ even power dissipation
- Dissipates 40 μW mm^{-2} (Diode pad takes 1 μW mm^{-2}) but power consumption will be addressed in the 2nd design

Sensor design

Principle of operation

Charge collection

A charged particle passing through the epitaxial (currently 12 μm) layer creates free charges to be collected by n-well diodes, creating a signal.



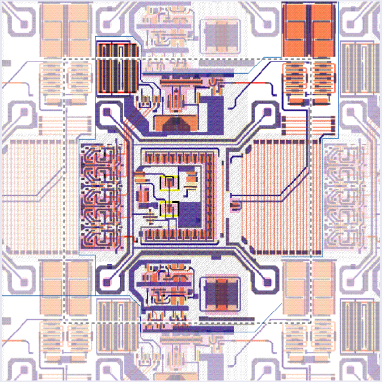
Sensor size

Size of sensor is chosen to minimise probability of more than one particle passing through, while not increasing pixel number in ECAL beyond an intractable number.

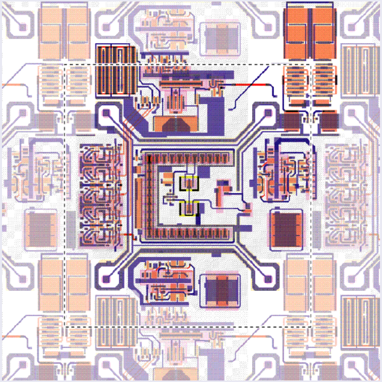
Sensor design

Two architectures

Pre–shaper design



Pre–sampler design

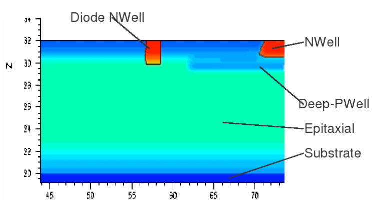


Manufacture

New INMAPS process . . . All n-wells attract charges: this includes diodes *and* other electronic components.

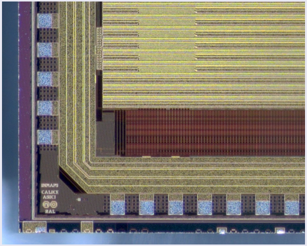
Charge collection

Charge collection efficiency increased by shielding electronics with a deep p-well layer: this is the INMAPS process.



First sensor complete!

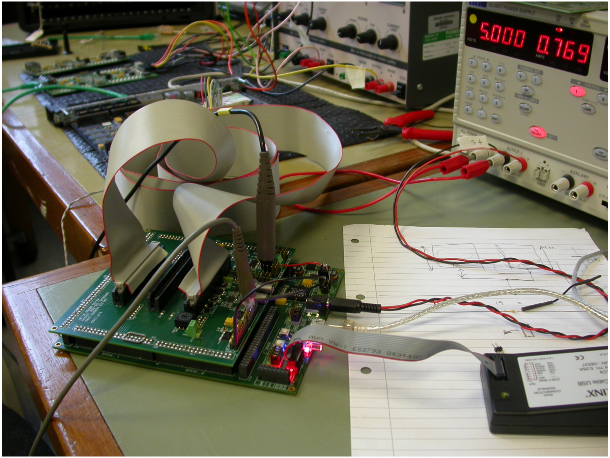
First round sensor design returned from manufacture in July.



Sensor design

Supporting system development

- Sensor has been wire bonded to a PCB
- DAQ hardware is working; firmware nearly complete
- DAQ software for PC data acquisition nearly complete
- A Front-end DAQ Gui also exists



Testing the sensor

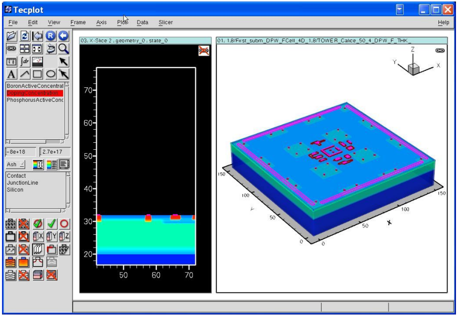
The first round sensor is operational

- Powered up, current's ok
- Test structures' functionality has been verified
- Can access complete configuration
- Can read/write data to pixels
- Two bugs found, both have workarounds (i.e non–blocking)
- Next tasks: check noise rates and global sensor operation. Move to laser in the next few days.

Sensor simulation

Physical simulation of charge diffusion and sharing between pixels is essential to understanding the binary nature of the system!

- Simulate pixel at 5 μm level
- Detailed simulation with complete pixel description takes weeks to complete
- Guides optimisation of issues such as diode size (0.8, 1.8, and 3.6 μm) and placement
- Use results in digitisation procedure post-Mokka

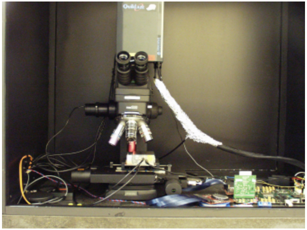


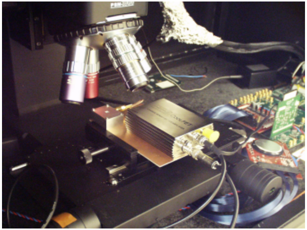
Testing the sensor

Laser setup at RAL

Use a laser to deposit charge in the pixel Allows us to validate and improve our sensor simulations

- Three wavelengths λ = 1064, 523 and 355 nm.
- 2 μm focussing allows us to study charge spread between pixels
- 4 ns pulse, 50 Hz repetition rate
- MIP-level calibration with a cooled Silicon reference detector

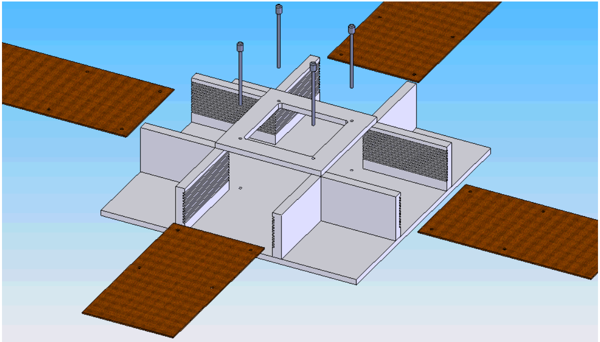




Testing the sensor

Cosmic test

MAPS sensors will be placed into an interleaving support structure making a mini-ECAL of about 4 layers. Testing will be done at Birmingham.



Testing the sensor

Source test

A Strontium β–source will be used at Imperial. Scintillators will provide a trigger source.

Beam test

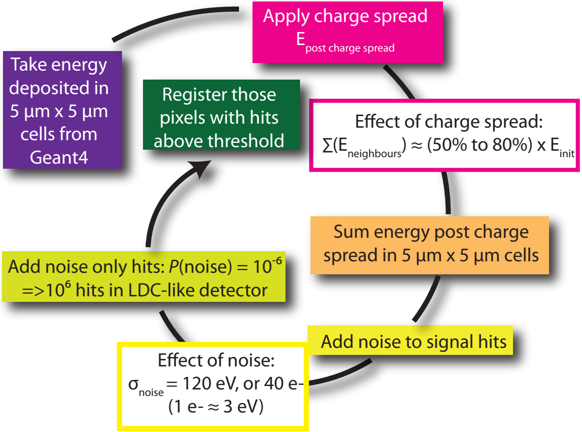
Possibility of taking the sensor in its interleaved support structure to DESY later this year (optimistic?), or Fermilab next year. Tungsten will be inserted between the layers.

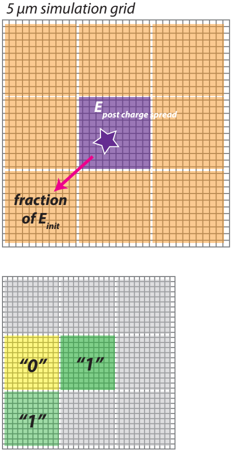
Charge sharing and digitisation

Simulation of MAPS' binary behaviour is not simple. . . One particle is not necessarily one hit

- Charge diffuses across pixel boundary, potentially causing neighbouring pixels to trigger if charge collected is above threshold
- Need to cluster hits to avoid double-counting the true energy deposition
- Requires a full simulation of pixel at the 5 μm level
- $P(\text{noise hit}) = 10^{-6}$ per pixel $\Rightarrow 10^6$ pixels fire per event in LDC01Sc (e.g. 3 noise hits expected in a 1.5 cm radius tower, compared with 1000 signal hits for 10 GeV photon).

Digitisation procedure





Charge sharing — effect on energy resolution

Ideal case

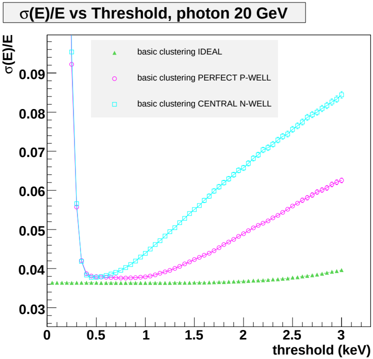
No detector effects: All charge collected by one pixel, with no charge sharing

Optimistic scenario

Perfect p-well: (All charge collected by diodes) Long plateau implies a large choice for the threshold

Pessimistic scenario

Central n-well: (Ineffective deep p-well layer) Minimum of energy resolution still occurs in the same place as optimistic case



⇒ Not constrained by a single working point

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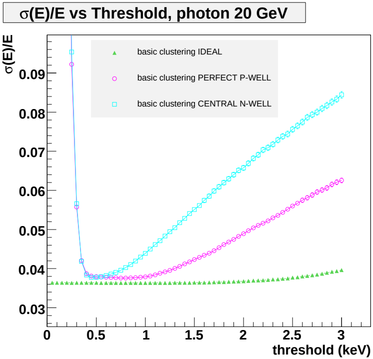

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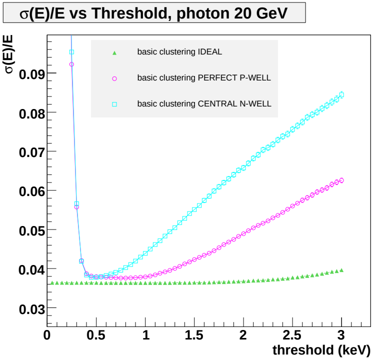

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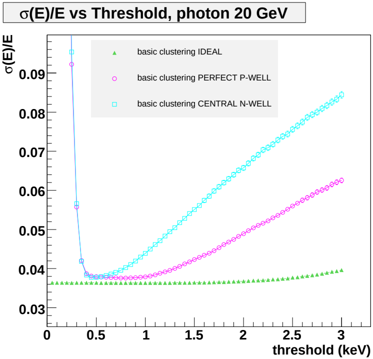

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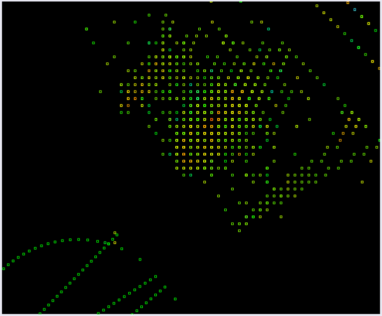
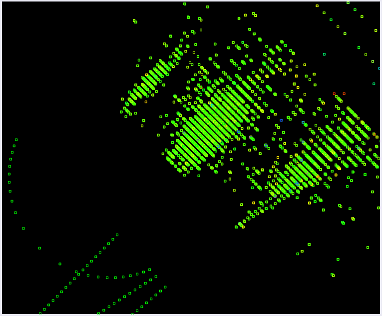
Overview of software workflow

Physics studies getting underway — e.g. $e^+e^- \rightarrow Z + H$ Really want to push calorimeter as hard as possible!

Standard ECAL



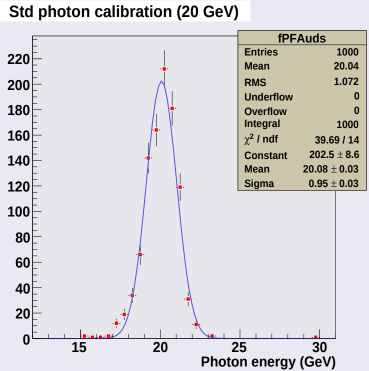
MAPS ECAL



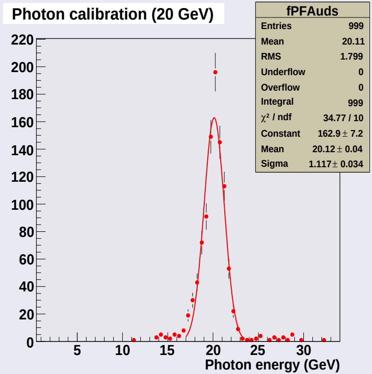
Using PandoraPFA and MAPS

A first look... Following MT's recommendations, calibrations have been made by hand for Pandora and MAPS[1]. Results are promising! (LDC01Sc used)

20 GeV photon, Standard ECAL



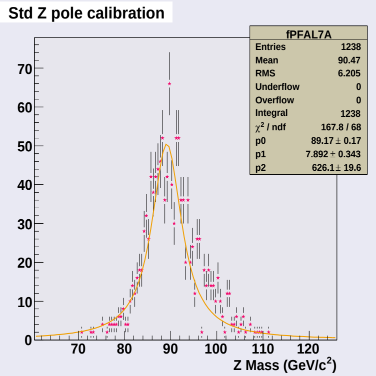
20 GeV photon, MAPS ECAL



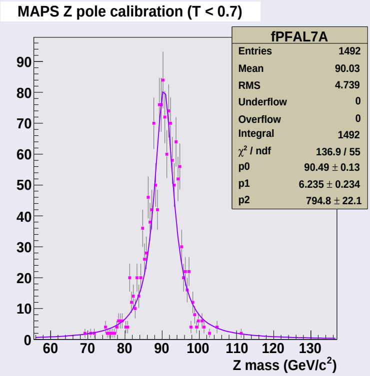
[1] Without complete digitisation applied!

$Z \rightarrow uds$ pole

Standard ECAL



MAPS ECAL



Using PandoraPFA and MAPS

Towards an optimised algorithm?

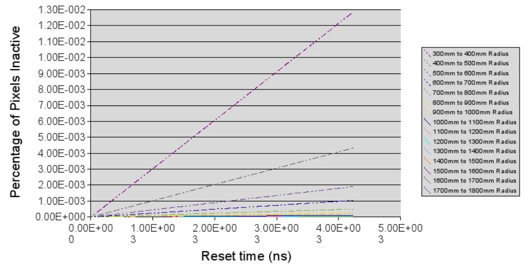
- Missidentification of photons as neutral hadrons.
- Results are very preliminary: calibration is subjective; have not yet included full charge sharing model.
- Pandora's performance with MAPS vs. Std concept = open question

So, once again, performance = detector + software

Studies on beam background

How does MAPS perform in the very forward regions?

1 TeV, 50 layers



- Studies performed using Guinea Pig (machine simulation)
- Consider occupancy as a function of pixel size, reset time and distance from beam pipe ⇒ MAPS's reset time is satisfactory, at a few hundred ns.

Calorimeter for ILC

Project status

CALICE MAPS exists!

- First round sensor is operational
- Testing has started, expect results soon
  - Physics (simulation) studies underway: have demonstrated that, to zeroeth order at least, MAPS is competitive
  - open questions: pixel size; pixel shape; dead area; epitaxial layer thickness
  - has the INMAPS significantly improved the charge collection efficiency?
  - what ECAL energy and position resolution do we *need* to analyse the physics channels of interest?
- Test data will guide our characterisation of its behaviour. . .
  - better understanding
  - $\Rightarrow$ optimised reconstruction
- . . . guiding design of a 2nd sensor for Spring 2008

Fin.