MAPS Project Status

CALICE-UK Meeting, Cambridge

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20th September 2007

Outline

The MAPS Project
A digital readout 50 $\times$50 μm pixel

Overview

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

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
- Aims to preserve mechanical structure of ECAL
- A technology designed for the Silicon component of the ECAL, but we can be iventive in its deployment

Possible further benefits

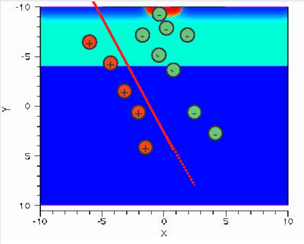
- Reduced PCB thickness: a slightly thinner ECAL; less shower spread between layers
- No ASIC: even power dissipation
- Spread out logic: fewer SEUs

Sensor design

Principle of operation

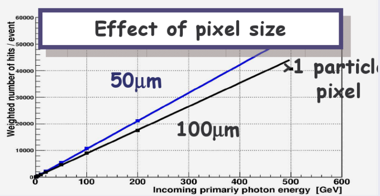
Charge collection

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



Sensor size

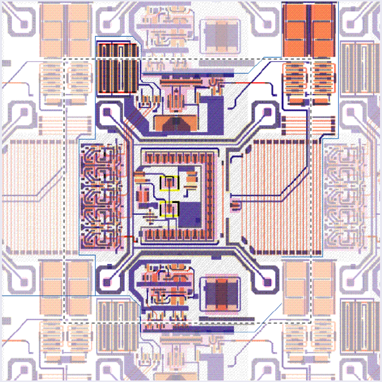
Size of sensor is chosen to minimise probability of more than one particle passing through, while not increasing pixel number in ECAL beyond an intractable number.



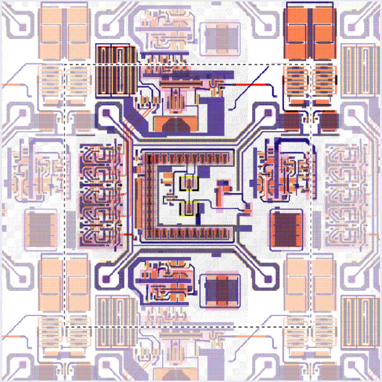
Sensor design

Two architectures

Pre–shaper design



Pre–sampler design

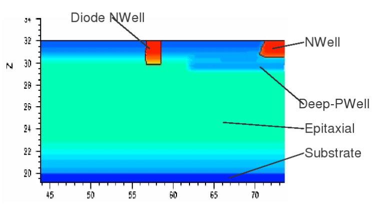


Manufacture

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

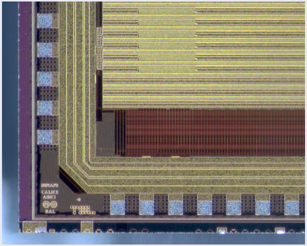
Charge collection

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



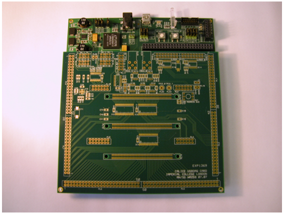
First sensor complete!

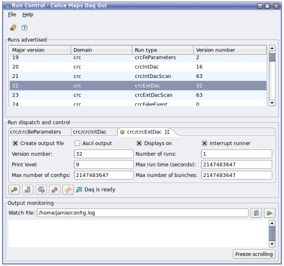
First round sensor design returned from manufacture in July.



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

Inital tests show sensor is alive

Since the sensor returned from testing

- It has performed exactly as expected. Ahem.
- No one has lost any sleep over it.
- Jamie and Matt are the pictures of Zen.

Add Jamie's table here

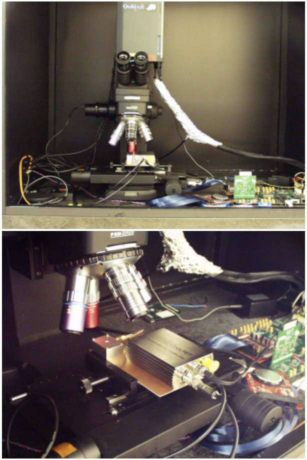
Sensor simulation

To be done.

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

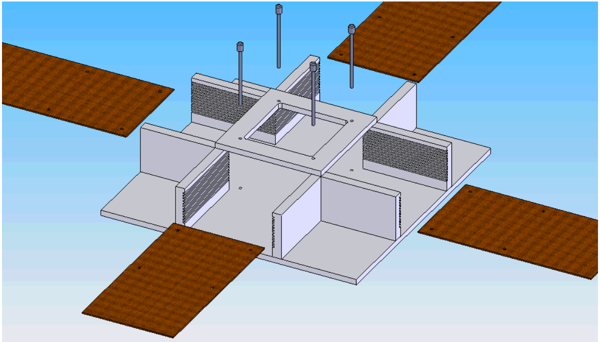
- Three wavelengths λ = 1064, 523 and 355 nm.
- 2 μm focussing allows us to study charge spread between pixels
- 4 ns pulse, 50 Hz repetition rate
- Sub-MIP calibration with a cooled Silicon reference detector



Testing the sensor

Cosmic test

MAPS sensors will be placed into an interleaving support structure (with Tungsten) 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.

Charge sharing and digitisation

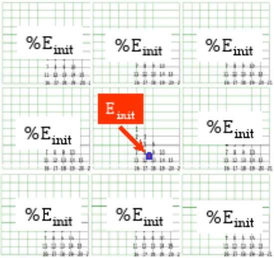
MAPS is not just an “on/off” pixel system!

- 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(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

Geant4 E_{init} in 5x5 μm² cells

Apply charge spread $E_{after\ charge\ spread}$



Importance of the charge spread :

$$\sum E_{neighbours} \sim (50\% - 80\%) \times E_{init}$$

Sum energy in 50x50 μm² cells E_{sum}

Add noise to signal hits with σ = 120 eV (1 e- ~ 3 eV → 40e- noise)

+ noise only hits (pessimistic scenario): proba 10^{-5} → ~ 10^{7} hits in the whole detector BUT in a 1.5*1.5 cm² tower : ~30 hits.

Register the position and the number of hits above threshold

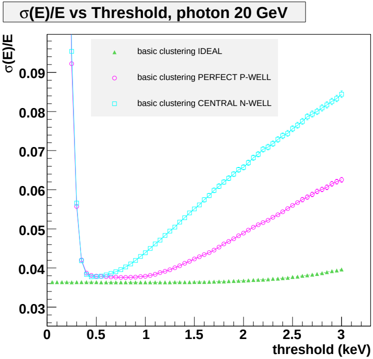
Charge sharing — effect on energy resolution

Optimistic scenario

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

Pessimisitic scenario

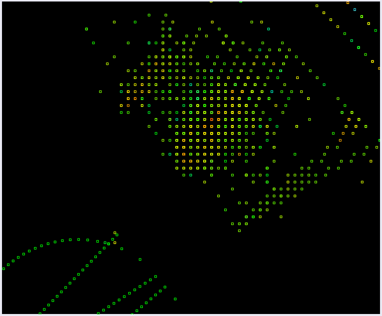
Central n-well: (Ineffective deep p-well layer) Minimum of energy resolution still ocurrs in the same place as optimistic case.



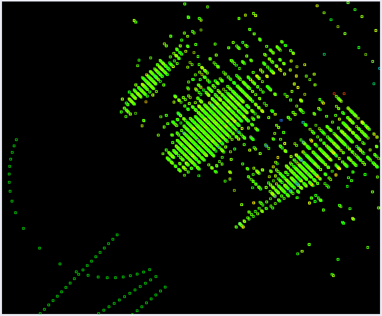
Overview of software workflow

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

Standard ECAL



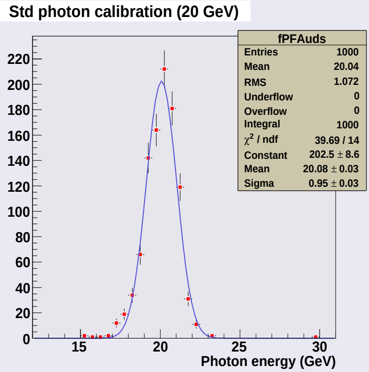
MAPS ECAL



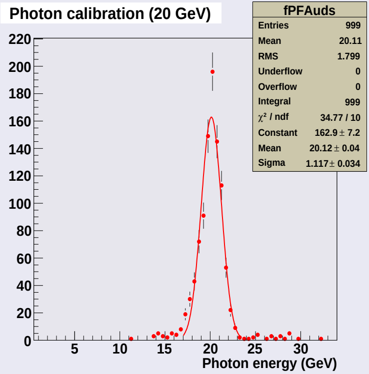
Using PandoraPFA and MAPS

A first look. . . 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

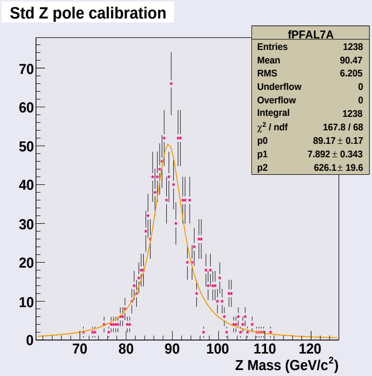


[1] Without complete digitisation applied!

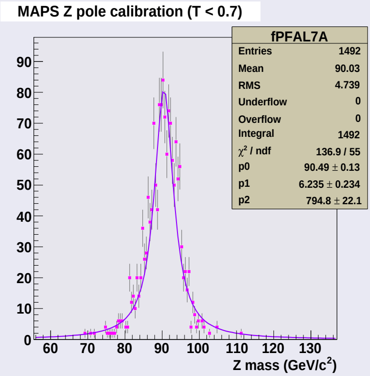
Calorimeter for ILC

$Z \rightarrow uds$ pole

Standard ECAL



MAPS ECAL

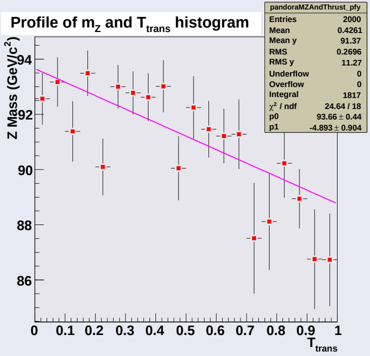


Using PandoraPFA and MAPS

Towards an optimised algorithm?

- Pandora's performance $= f$(transverse thrust)?
- 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

Standard ECAL Z mass and T_{trans}



So, once again, performance = detector + software

Studies on beam background

Summary of concepts

Project status

MAPS exists!

- Testing has started, expect results soon
- Physics studies underway
    - have demonstrated that, to zeroeth order at least, MAPS is competitive
    - open questions: pixel size; pixel shape; dead area; epitaxial layer thickness; INMAPS performance?
    - what ECAL 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
    - $\Rightarrow$ optimised second round design

Fin.