Future R&D from UK groups in CALICE

Matthew Wing - UCL
(on behalf of the CALICE-UK groups)

Birmingham, Cambridge, Imperial, Manchester, RAL, RHUL, UCL

- **Completion of current program - test-beam running and analysis.**
- **Data acquisition system**
- **Simulation**
- **Mechanical and thermal aspects**
- **Use of MAPS technology**

Test-beam programme

The UK have built the read-out for the CALICE ECAL to be installed in test beam here in January.

The UK have contributed to simulation efforts for a calorimeter and a full detector in general.

Want to get the test system running, take data, process, analyse and compare with Monte Carlo simulations to verify concept of tracking calorimetry.

- **Validation of different shower simulation models.**
- **Test of particle (track) separation.**
- **Estimate of energy resolution of electrons and hadrons.**

Data acquisition system - general concept

In ECAL, 24 million channels and TESLA design of 4886 bunch crossings every 176 ns.

Assuming 2 bytes per pad per sample: raw data is $24 \cdot 10^6 \times 4886 \times 2 = 250$ GB

For ASICs with $32 - 256$ channels, have $0.3 - 2.5$ MB per ASIC and within a bunch train, $0.4 - 3$ GB/s to be transported. Take as 1 GB/s

- **Data transportation from ASICs to front-end electronics.**
- **Shipping data off detector to receiver.**
- **Structure of off-detector receiver.**

Data acquisition system - Related to VFE

Expect zeroth VFE chip design in 1-2 years - provide DAQ

Readout MAPS design

Final DAQ should be able to readout ECAL and HCAL - coordinate convergence of ideas.

Do not expect full 1.5 m prototype on this timescale:

- Build 1.5 m slab with FPGAs connected to test data transfer.
- Use of copper or optical data transfer lines.
- Noise, interference, power issues, space between layers.

Data acquisition system - Connection on to off detector

Assume off-detector receiver is (some largish numer of) PCI cards in PCs.

Connection off detector and receiver itself are commercial components.

Two scenarios:

- **Threshold suppression done in FE, data rate $\sim$ 5 MBytes/s, data transported via network switch.**
- **No FE, data directly from VFE (data rate $\sim$ 1 GBytes/s) using optical fibre, via optical (“layer-1”) switch.**

First will work, but tests can be done. Second would need to be studied now.

FE inaccessible for long periods - need “failsafe” - able to reboot, reconfigure.

Understand clock and control and configuration of different commercial components to accelerator clock.

Data acquisition system - Off-detector receiver

Receiver is system of PCI card housed in PCs. Local clustering performed on PCI cards.

PCs can be unreliable, one may be busy - how good is switching between PCs?

How much data (i.e. how much of calorimeter) can be sent to one PC?

How much data needs to be sent to PC for local clustering to be effective?

Simulation - R&D programme

Understanding test-beam data and improving base simulation.

Energy flow algorithms. Review, optimisation, different detector configurations.

Participation in global detector design studies.

Integration with worldwide activities.

Support of hardware-related tasks. Changes to detector, influence of data acquisition systems.

Physics studies supporting the above.

Mechanical and Thermal - R&D programme

Studies of gluing of the silicon (conductivity and ageing).

Plan to build assembly robot for gluing hundreds of thousands of silicon detectors, with repeatable accuracy.

Many thermal issues: power from VFEs, optical fibres. General temperature profiles in various scenarios and possible cooling techniques.

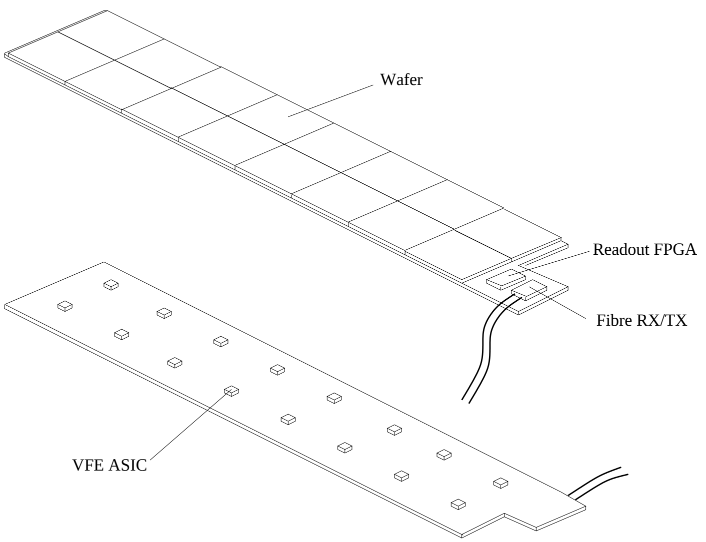
Design of the endcap calorimeters.

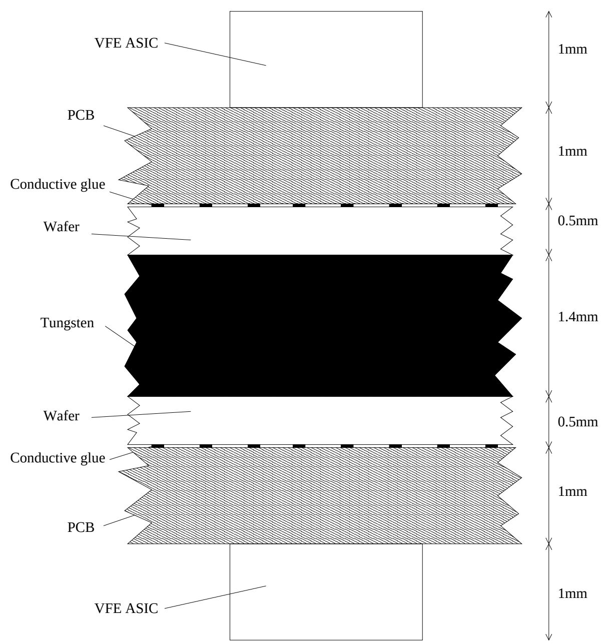
MAPS - a new design

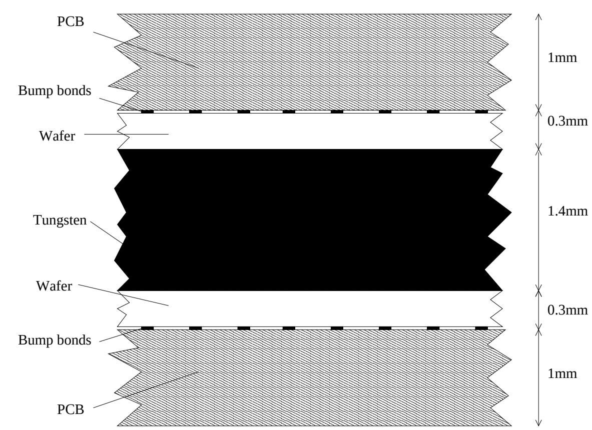
Considering alternative technology which may be cheaper.

Instead of using conventional silicon diodes, use Monolithic Active Pixel Sensors (MAPS).

Readout integrated into the MAPS - no need for separate chip.







Pixel size 50 $\times$ 50 μm^2. Binary decision - effective digital ECAL.

MAPS - advantages

Due to finer granularity, improved two cluster separation - endcaps?

No VFE chip on silicon, so reduced spacing between layers:

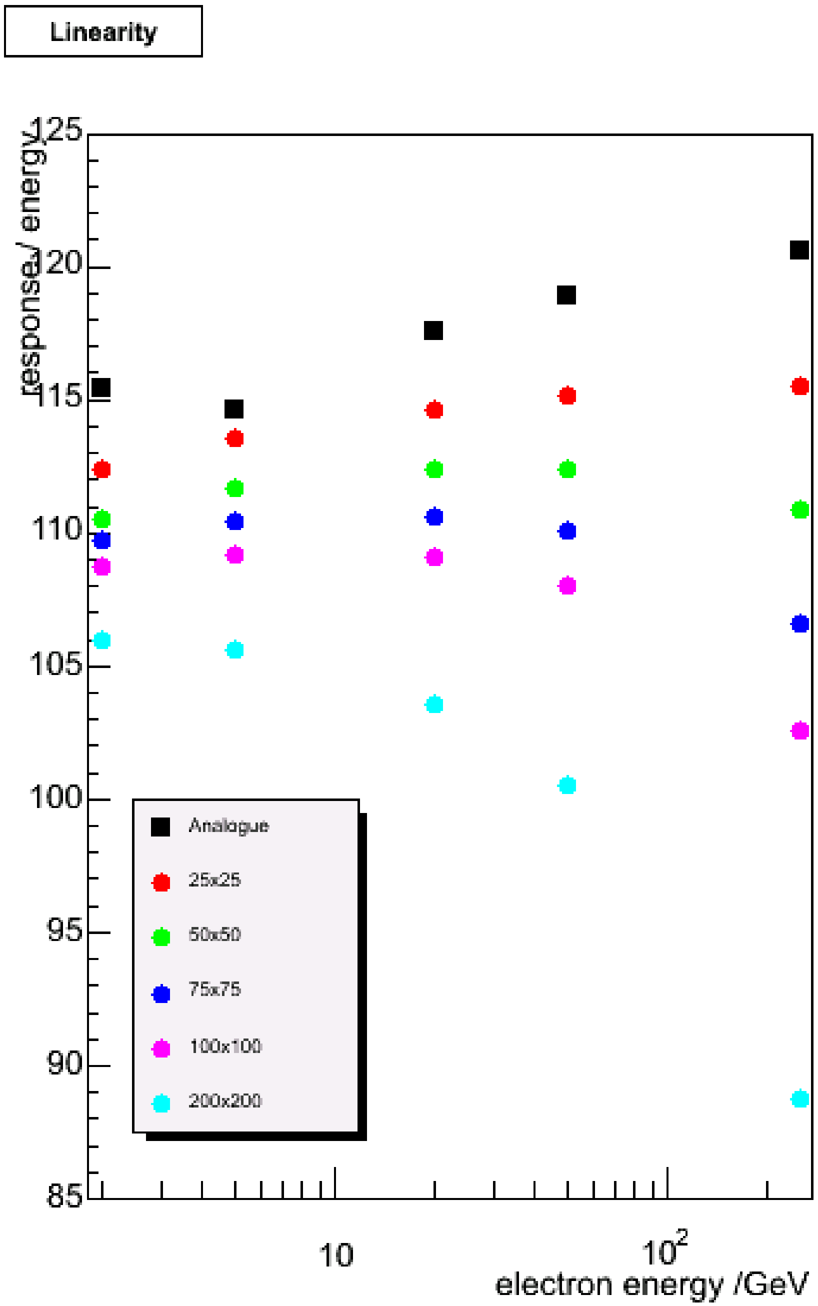
- **Reduced Molière radius, i.e. better shower containment.**
- **Smaller (radius) ECAL, i.e. smaller (radius) solenoid, which leads to a big saving.**

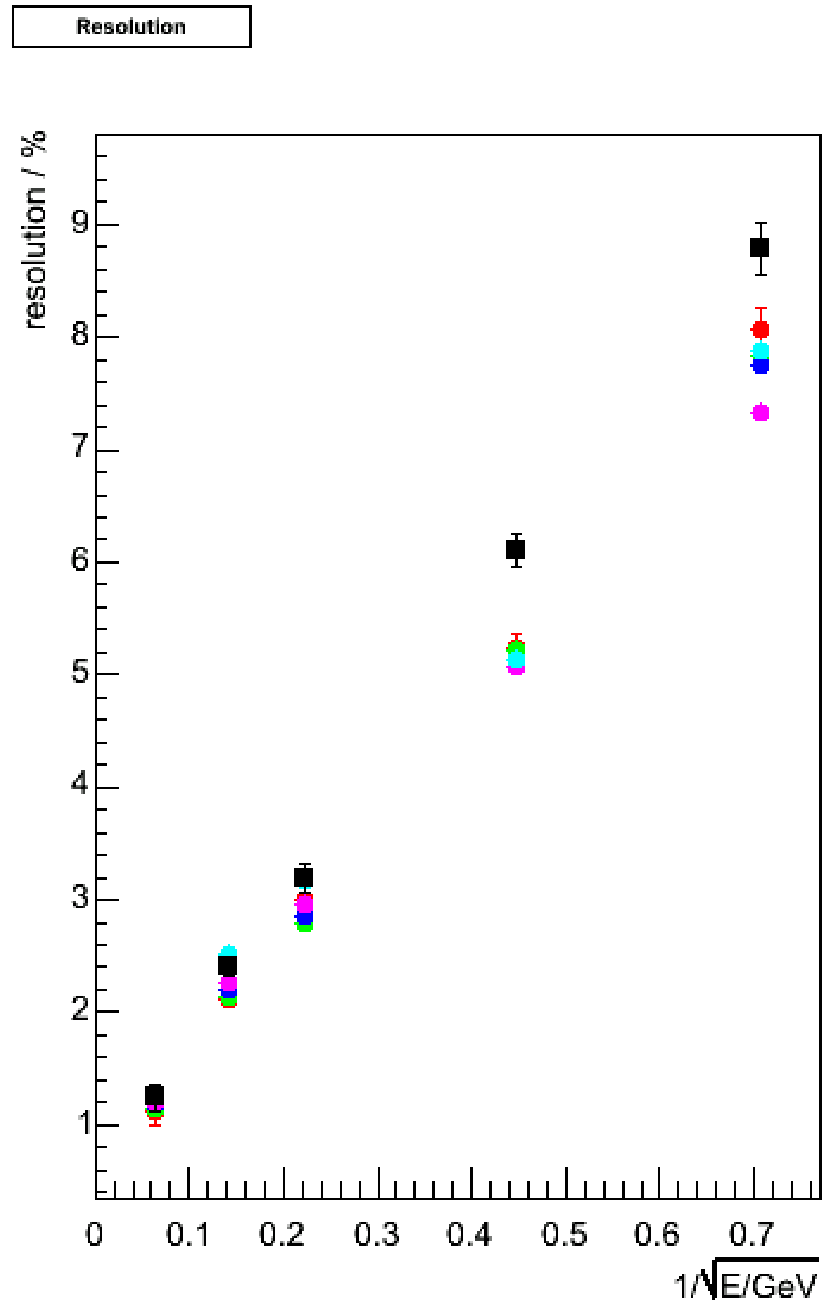
Heat production more evenly spread over surface of sensor.

Relative to conventional silicon diodes, MAPS are roughly half the price: \$ 4/cm^2 compared to \$ 10/cm^2.

Indications of improved energy resolution for EM showers of 20% for single electrons.

MAPS - improvements





MAPS - R&D programme

Signal/noise for binary readout. No pulse height information; physical particles and noise harder to distinguish. Reset or not.

Crosstalk. Inefficient charge collection in epitaxial layer leads to charge being collected by neighbouring pixels. Balance layer thickness and signal size.

Uniformity and stability. A threshold cannot be set per pixel, so uniformity needed per sensor. And stability needed with temperature changes.

Power dissipation has so be the same (or less) as for the diode-pad option.

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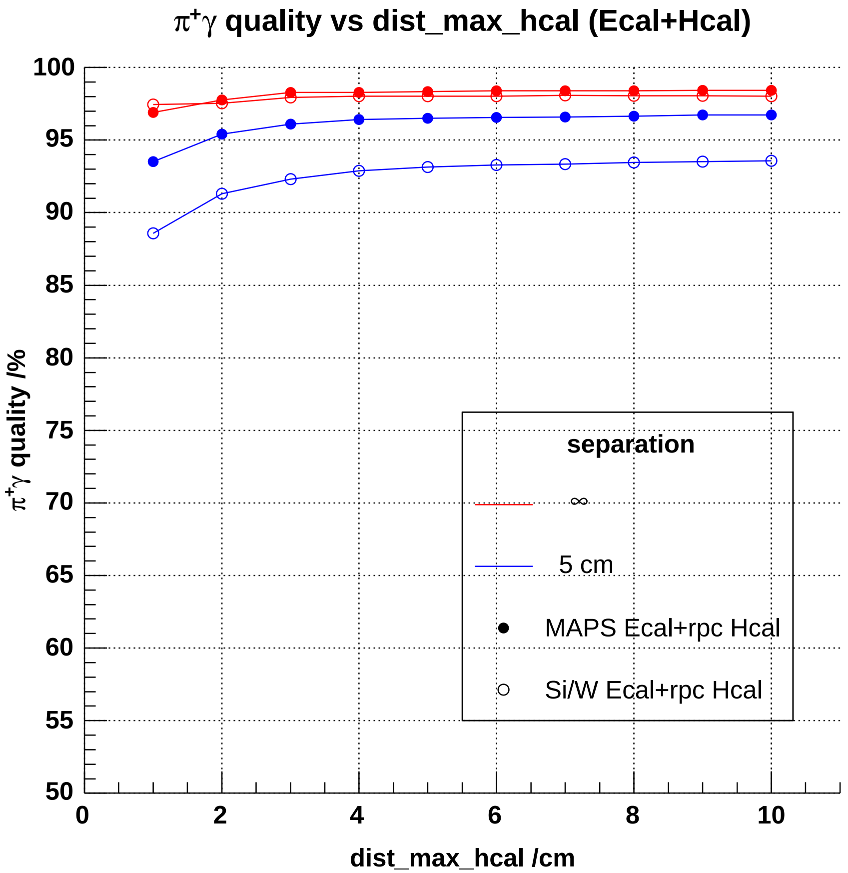
Final word

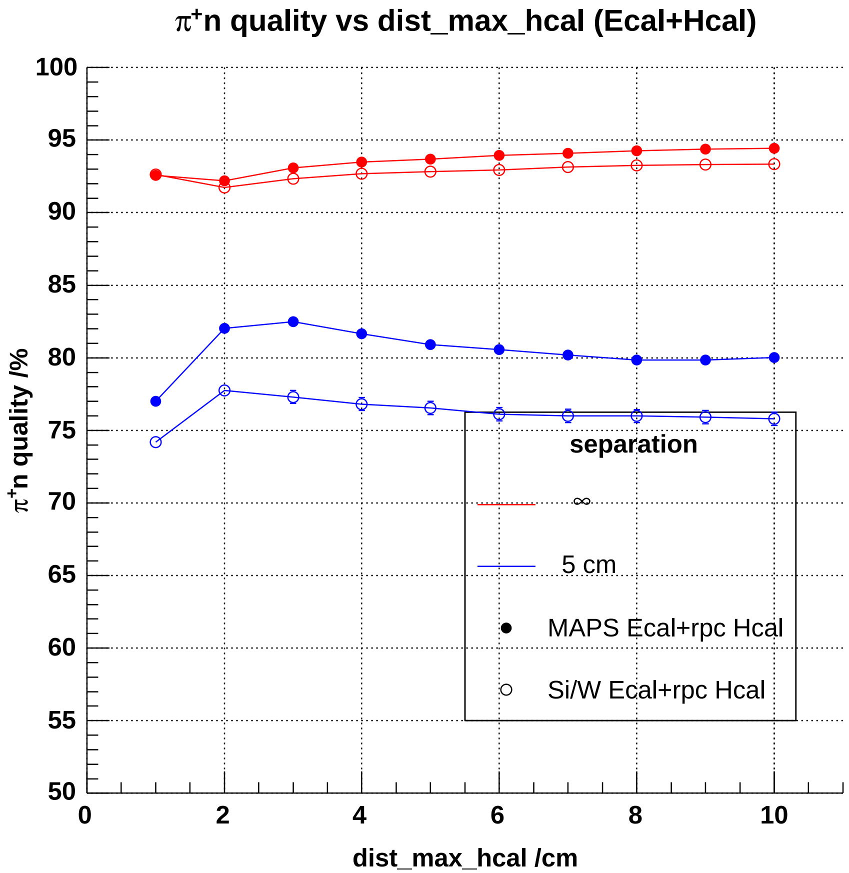
UK has a proposal for future work within CALICE.

Any comments are welcome to strengthen our plan.

MAPS - backup



π+γ quality vs dist_max_hcal (Ecal+Hcal)
π+γ quality /%
dist_max_hcal /cm
separation
∞
5 cm
MAPS Ecal+rpc Hcal
Si/W Ecal+rpc Hcal



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