UK Opportunities in SiD Calorimetry

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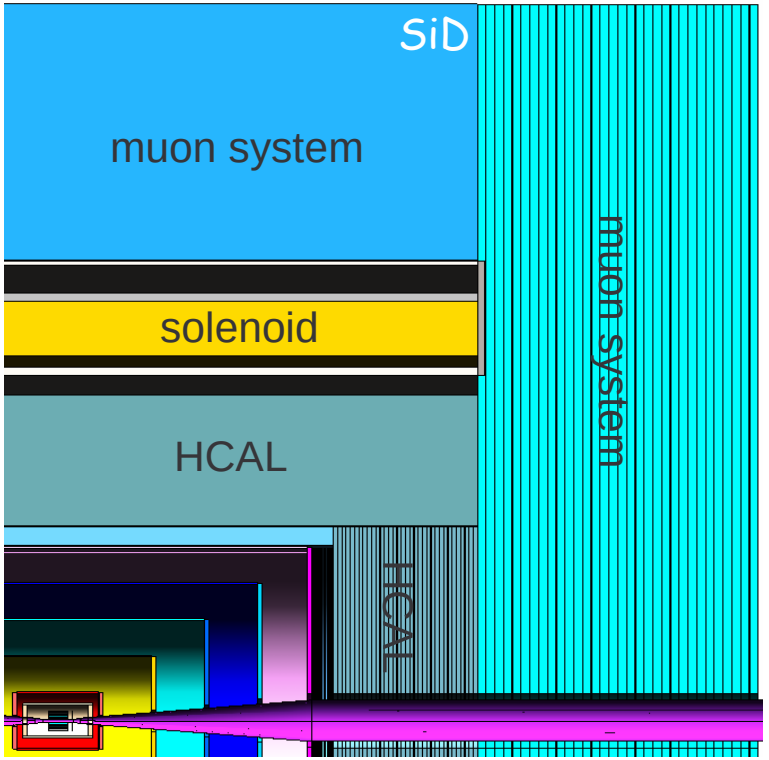
Overview

- SiD is designed for particle flow
  - Calorimeters will be optimised using particle flow algorithms (PFA)
  - Requires ability to distinguish individual particles in jets
  - Needs fine-grained calorimeters with minimal dead space

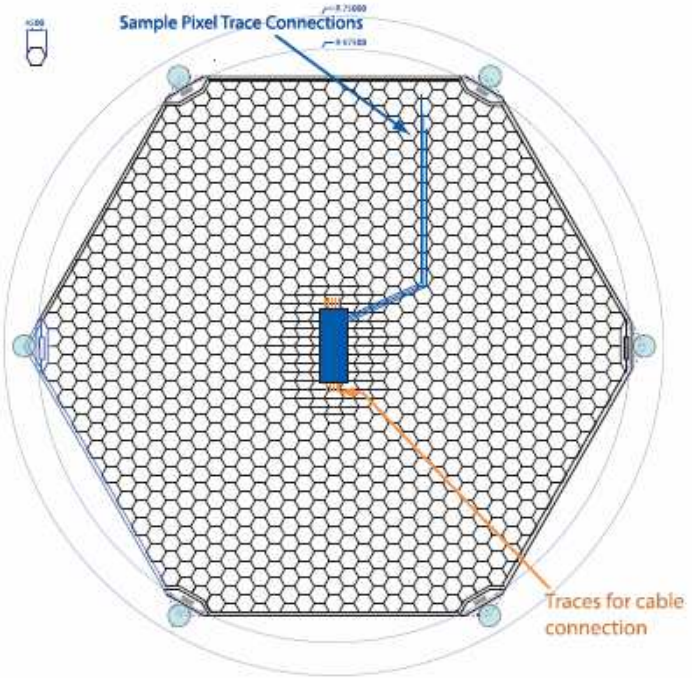


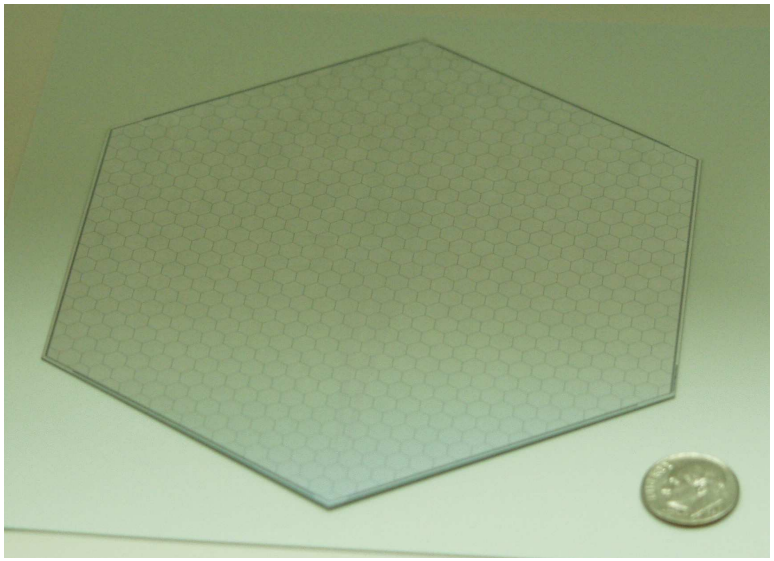
- This forces the electromagnetic calorimeter (ECAL) and hadronic calorimeter (HCAL) to be inside the solenoid
  - Calorimeters and solenoid are easily the biggest cost of the whole detector
  - Calorimeter design will be heavily constrained by money
- Radiation hardness is not a real issue
  - Rates at calorimeters are very small compared with the LHC

- ECAL
- HCAL
- Forward calorimeters
- Calorimeter DAQ
- Physics studies

ECAL

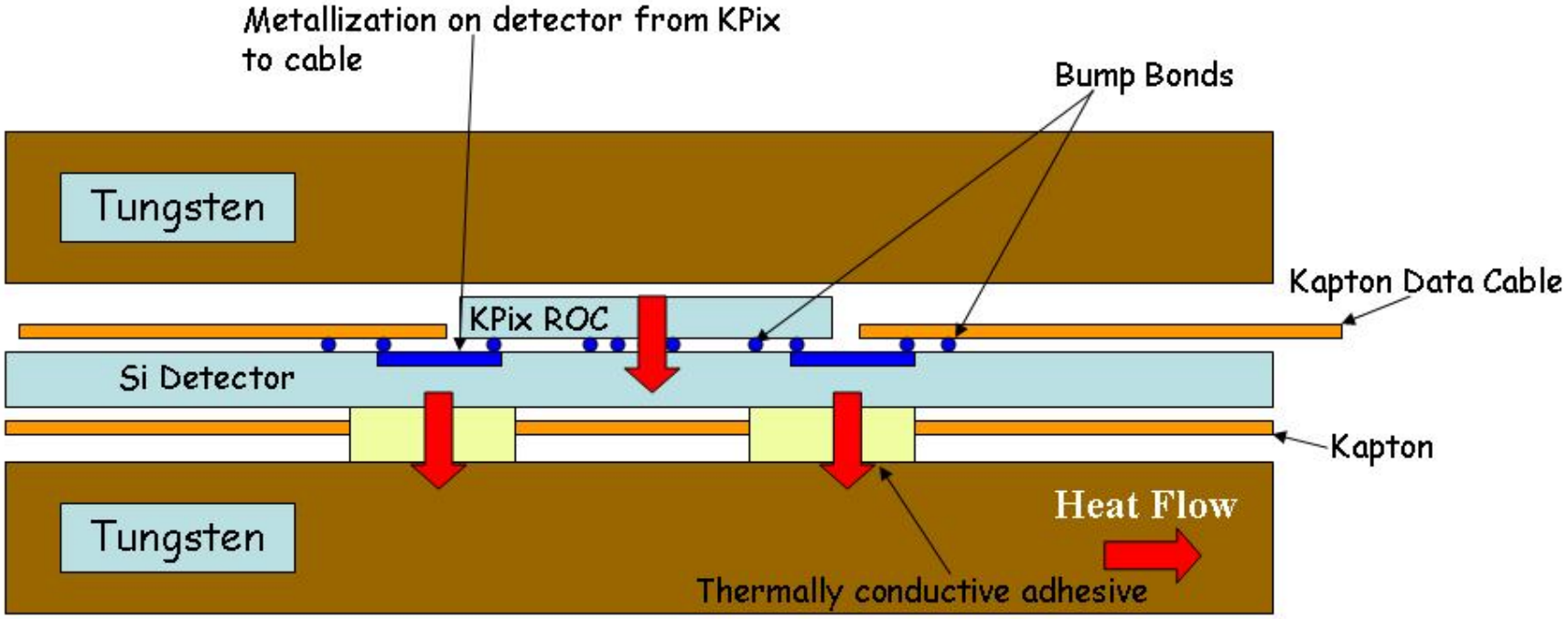
- General agreement that silicon-tungsten (Si-W) sampling calorimeter would be best for PFA
  - Silicon sensitive layers are compact and can have high granularity
  - Tungsten has a small Molière radius (9mm) to help in particle separation and a small radiation length (3.5mm) to keep calorimeter compact
  - But it is still very expensive…
- SiD has a Si-W ECAL design
  - Based on hexagonal diode pad silicon detectors, ~1300m^2 total area needed
  - Cell size around 5×5mm^2, ~50M cells
  - Readout chip ("KPIX") mounted in centre of wafer





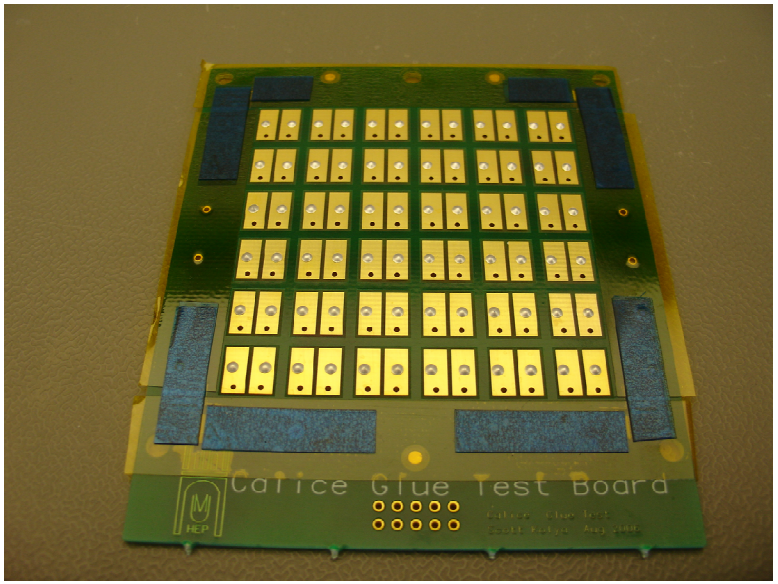
ECAL mechanics

- Mechanics to support ECAL is non-trivial
  - Want minimal gap (<1mm) between tungsten sheets to keep "effective" Molière radius small
  - Preferably no cooling pipes inside bulk so only passive (conductive) cooling
  - Requires very low power readout electronics and pulsed power operation during ILC bunch trains



ECAL mechanics (cont)

- Clear indication from SiD they would welcome help in this area
  - In particular, engineering effort is at a premium
  - Shortage is more general than just ECAL; see talk by Andy

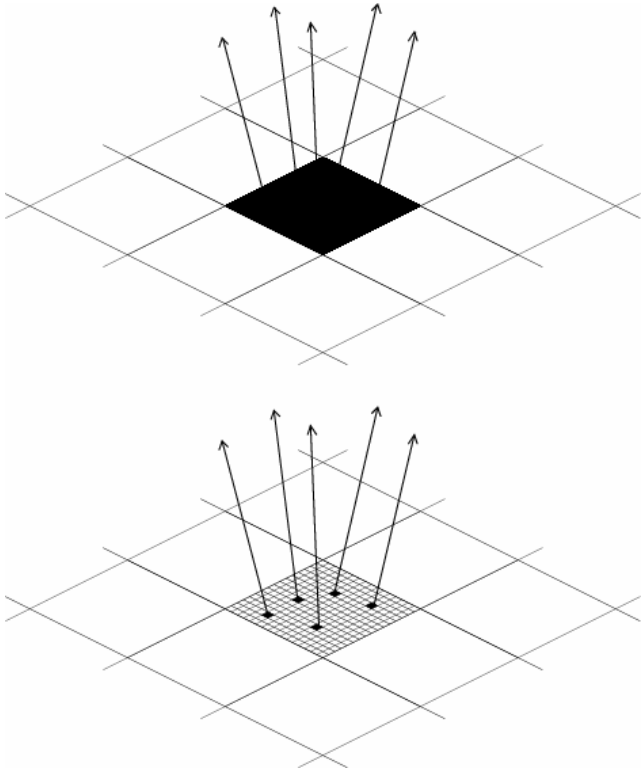


- Some UK work within CALICE, currently focussed on GLDC
  - Investigation of glue aging, conductivity, etc.
  - Using expertise in thermal modelling from Atlas
  - Also considering assembly methods for industrial scale production

- This could expand if effort and interest exists in UK
  - Mechanical structure for holding tungsten
  - Cooling around outside of structure
  - Active cooling with small pipework within ECAL

MAPS ECAL

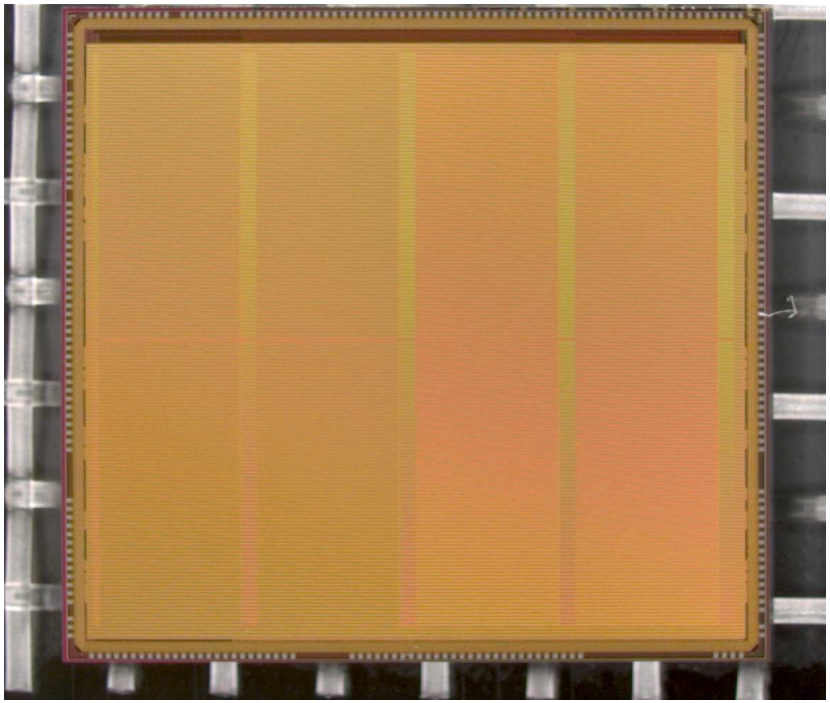
- Replace silicon diode pad sensors with CMOS active pixels sensors
  - Readout electronics integrated onto sensor wafer
  - Pixels very small, $50\times50\mu m^2$
  - Number of pixels large, $\sim5\times10^{11}$!
  - Low probability of two or more particles in one pixel
  - Binary readout; “digital ECAL”



- Sensors made in CMOS, doesn’t require high resistivity silicon
  - Advantages in terms of silicon process availability, so multiple vendors
- Other potential advantages
  - Granularity (for PFA) and possibly EM energy resolution
- Main disadvantage may be power consumption

MAPS ECAL (cont)

- Purely UK development
  - "Proof of concept" sensor fabricated this summer, ~30k pixels
  - Under test for only three weeks so far; will continue for ~6 months
  - Funding for second round of fabrication in 2008
  - Will try for more "ILC-realistic" sensor in next round



- If adopted by SiD, would be a major UK contribution to the detector
- Possible options if they don't buy the whole concept
  - MAPS as a very high granularity "presampler"; help in PFA separation in first few layers before shower spreads too much
  - MAPS in endcaps; higher boost at lower angles may make high granularity more valuable there

Other ECAL opportunities

- Comparison of KPIX and FLC_PHY readout chips
  - LDC readout chip is very similar (in concept) to KPIX
  - R&D review this summer said they should try to work together
  - Experience in CALICE of LDC ASIC which could be applied
- Apply CALICE beam test data to verification of SiD ECAL simulation
  - Huge dataset (300M events so far) to all verification of electron and hadron showers in simulation
- Get involved with ECAL beam tests in 2008/9
  - SiD plan ECAL beam test with 30-layer stack
- Take on endcap design
  - Very little work in this area; almost all studies for the barrel

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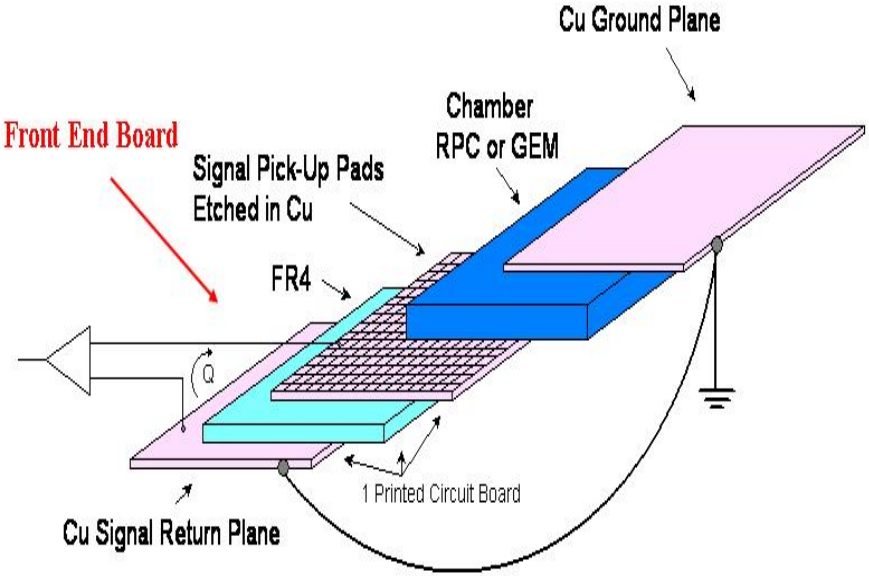
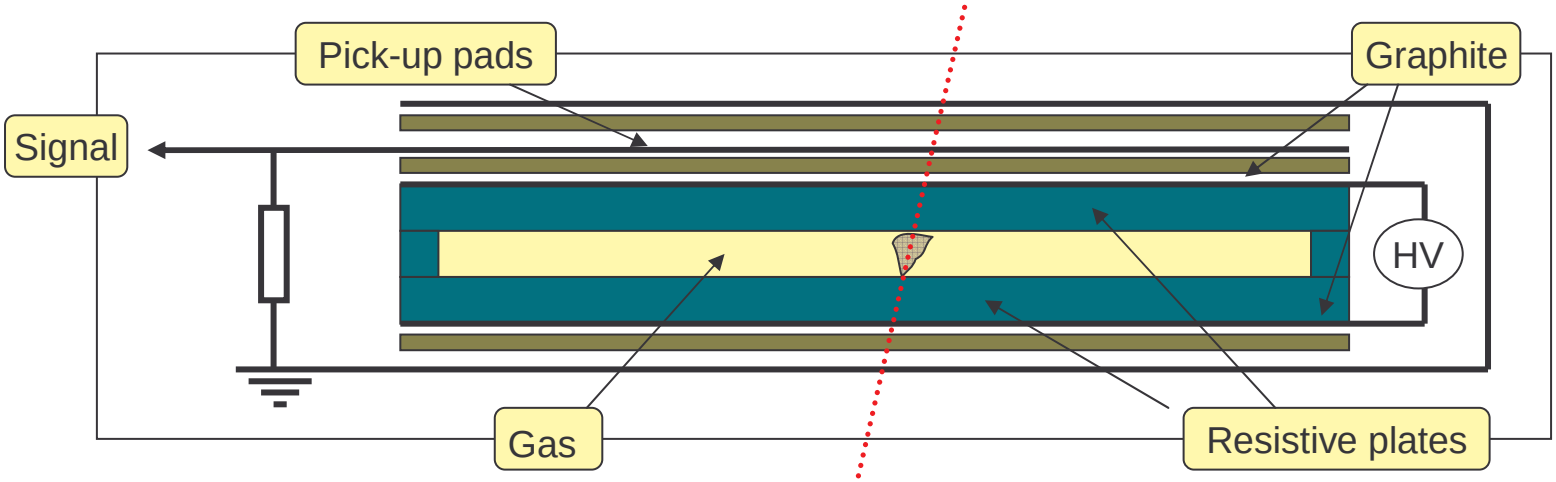
HCAL

- Two general concepts being considered; analogue and digital sampling calorimeters, both with steel converter
  - Both projects are being done within the CALICE framework
  - Digital is small pads (~1×1cm^2) with binary readout, either RPCs or GEMs
  - Analogue is larger scintillating tiles (~3×3cm^2) with SiPM and ADC readout
- UK has no involvement in either HCAL in CALICE
  - Would need to start a new activity from scratch
  - UK has recent experience in SiPMs through T2K and long history in RPCs (but not GEMs)
  - First step could be analysis of CALICE beam test data, both existing (2006/7, analogue HCAL) and future (2008, digital HCAL)

Digital HCAL

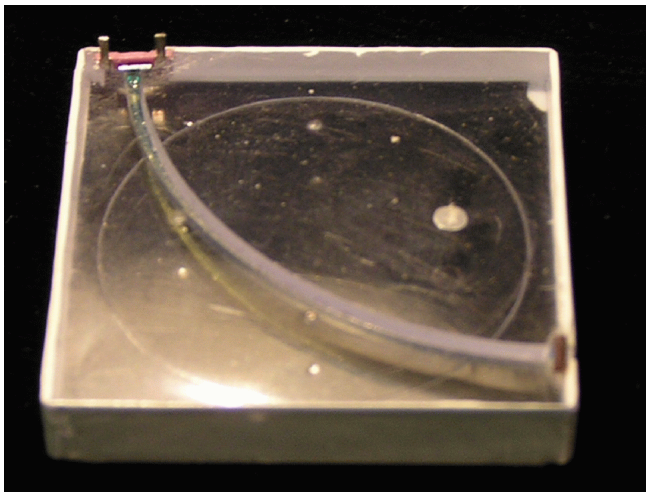
- Mainly driven by US groups so far
  - Although European group starting up in CALICE
- RPC mini-stack put in FNAL beam this summer
  - No public results yet
- GEMs are further behind
  - No existence proof yet of shower performance

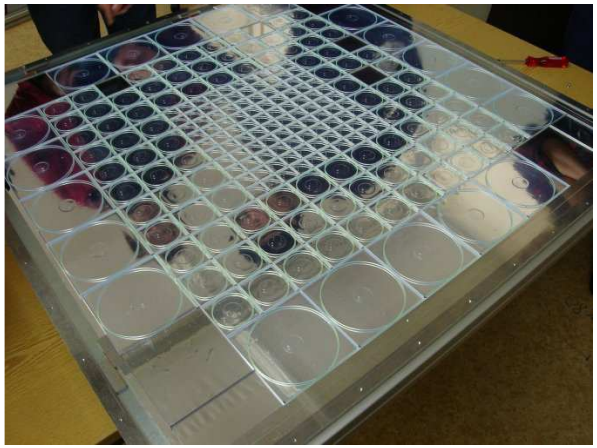




Analogue HCAL

- Analogue HCAL is mainly a DESY and Russian collaboration
  - Really nothing to do with SiD as the work is very much focussed on GLDC
- CALICE SiPMs are Russian design
  - Although now available from Hamamatsu
  - Overall calorimeter design is DESY





- Huge amount of beam test data with 38 layer device within CALICE
- Experience is that SiPMs are not trivial to use
  - Sensitive to temperature
  - Calibration tricky due to non-linear behaviour
- Clear area in which work is needed

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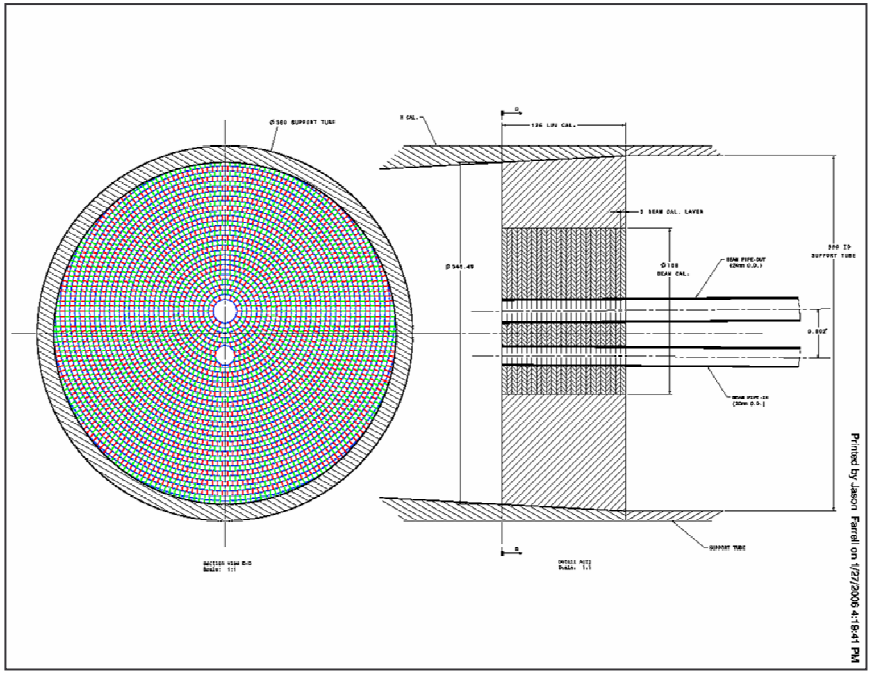
Forward calorimeters

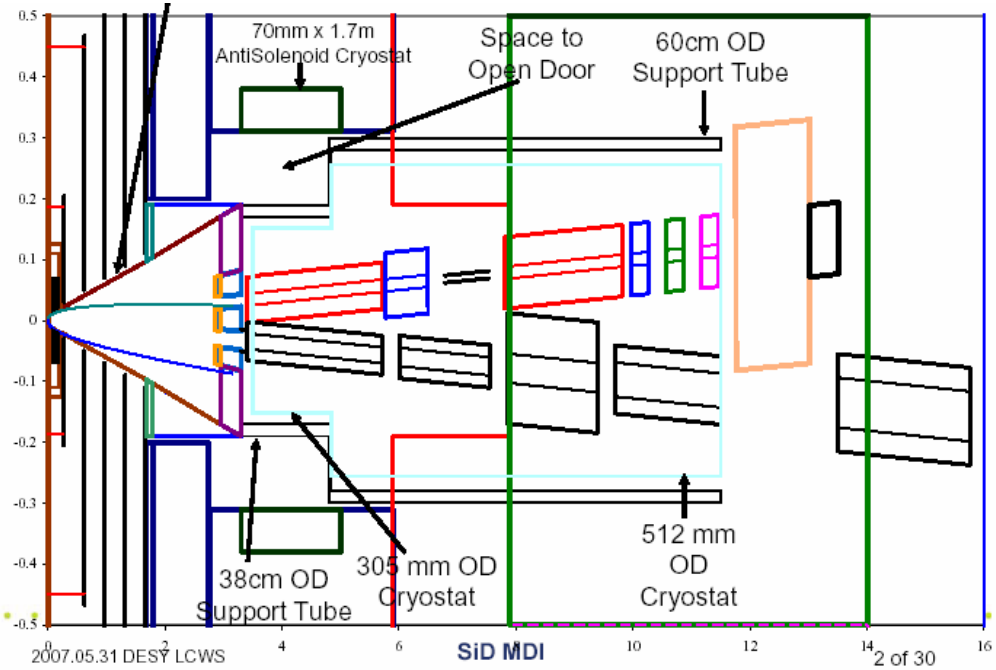
- Not endcaps but low angle "luminosity monitor"-type calorimetry
  - Small solid angle detectors but essential for hermiticity
  - Small means cheap so could afford exotic solutions (diamond, etc)
  - Needs to fit around beam pipe



- Main issues are backgrounds, backgrounds, backgrounds
  - Bhabha scattering and showering in FF magnets
  - Result in 100's GeV going into each forward calorimeter cell each bunch crossing
  - Detectors need to be radiation hard
  - Significant UK experience in these areas from LHC

Forward region and MDI

- Would need significant integration with accelerator design
  - ILC jargon “MDI” = Machine-Detector Interface
- UK already has expertise and effort here through LC-ABD
  - Phil Burrows is leader of MDI task force within SiD



- Forward detectors themselves are not studied within CALICE
  - Separate FCAL collaboration
  - No UK involvement so far

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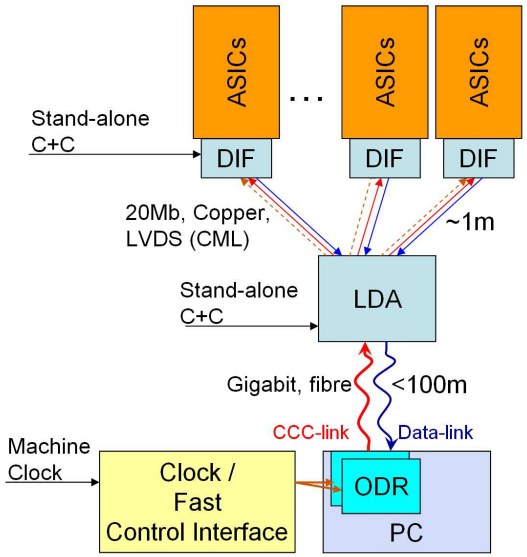
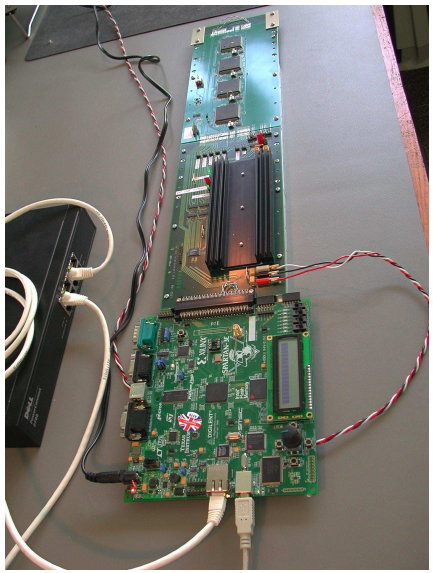
Calorimetry DAQ

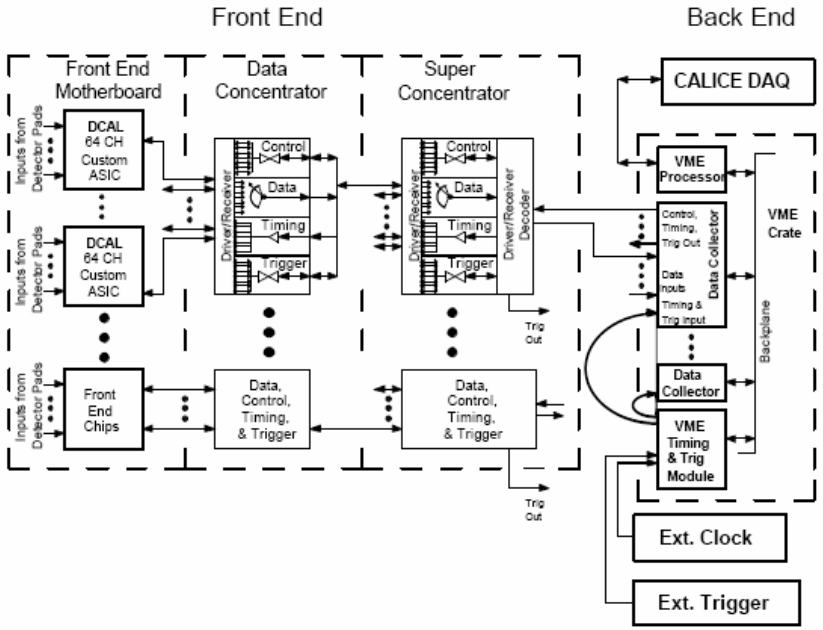
- Area of real, active UK expertise within CALICE
  - Provided DAQ for CALICE beam tests
  - Major project on developing realistic DAQ for ILC conditions
- CALICE and EUDET funded
  - Includes both ILC design and hardware tests of ideas
  - UK is leading DAQ work within Europe
  - UK is probably leading the whole ILC community worldwide





SiD DAQ

- SiD has done little work here
  - ECAL has only benchtop FPGA board readout
  - Digital HCAL: US system exists, European work will use UK design
  - Analogue HCAL is CALICE-only so will use UK design as well



- SiD ECAL beam tests could be good way to get involved
  - First application of UK DAQ within SiD
- Long term could define calorimeter DAQ system for EDR
  - Much of DAQ is generic so may even be possible to design DAQ of whole experiment
  - Big opportunity for the UK if there is someone to take it up

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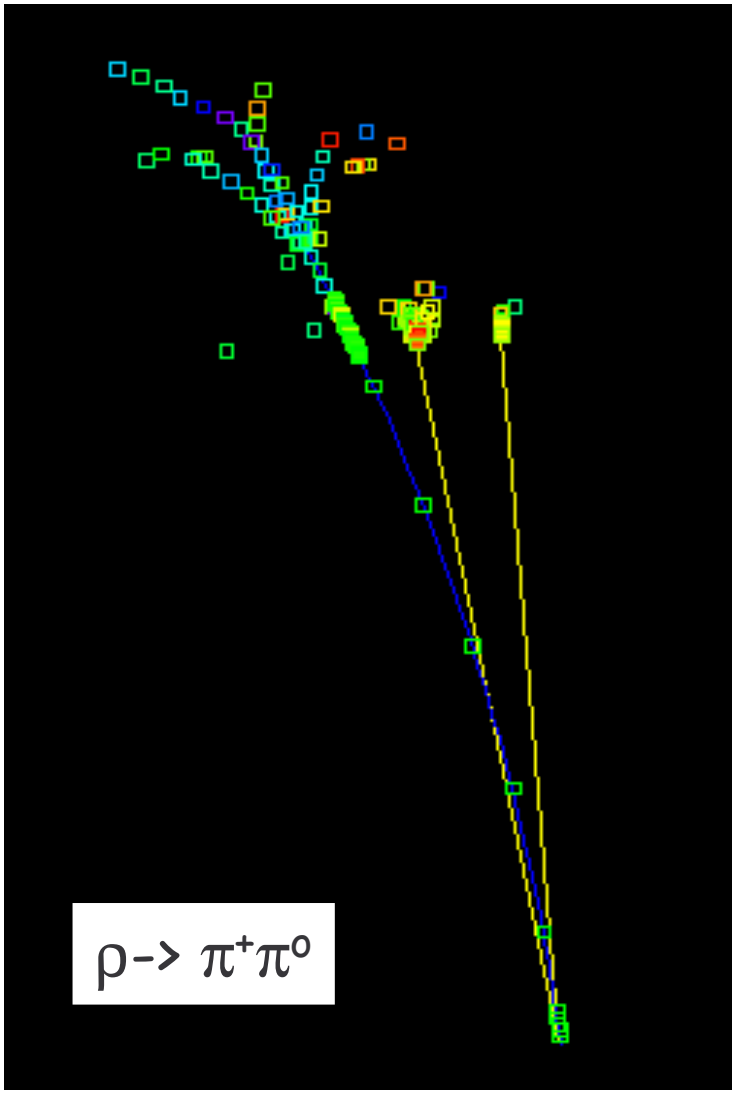
Physics studies: ECAL resolution

- Main driver for calorimeter designs will be PFA for jet resolution
  - See talks by Andrei and Tomas
- But there are other physics issues which need to be considered at the same time
  - Consider two ECAL examples here
  - Relative weighting of these and PFA is an open question
- ECAL resolution
  - Ongoing argument about the main driver for requirement here
  - Probably defined by $H \rightarrow \gamma\gamma$ (assuming this is seen at LHC soon)
  - Important for ILC to then confirm the decay and measure the BF
- Signal is “easy”; two ~60GeV photons together with a Z
  - But Higgs BF is tiny so backgrounds are the issue (radiative Z, ZZ,…)
  - This needs a serious study to see how much resolution can help

Physics studies: ECAL granularity

- ECAL granularity
  - Especially important in the context of MAPS
- Usually assumed that requirement will be set by PFA needs for separation of nearby particles
  - But $H \rightarrow \tau\tau$ may have tighter requirement
  - Physics is BF and CP of Higgs
- For CP measurement in particular, need to distinguish
  - $\tau \rightarrow \rho\nu \rightarrow \pi^{\pm}\pi^{0}\nu$ from $\tau \rightarrow e\nu$.
  - Due to boost, π^0 photons can be very close to the $\pi^{\pm}$
  - High granularity would clearly be a factor here; again needs study



Conclusions

- There are several places in SiD calorimetry where the existing CALICE UK work can be exploited
- There are several other places where more effort would be very welcome within SiD although it may require new projects (and probably new funding) within the UK to get started
- CALICE is covering many aspects of the calorimetry studies needed and this might be the way to get involved easily
- If you are interested in this, please let us know!