



# ILC Detector Activities in the UK

Mark Thomson, University of Cambridge



Past, Present and Future



# This Talk



## ★ Will cover UK:



**Past** ILC involvement



**Present** LC Activities



**Future:** what now?



- ★ Will not cover the different R&D topics in great depth
  - try to paint the general picture



# The Past

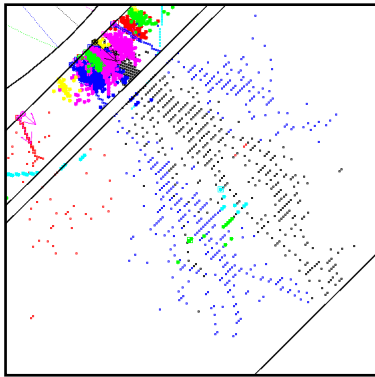


# Past UK Activities



- ★ Pre-2007 there was a very active UK LC community
- ★ Focussed on two areas of detector R&D:

## i: Calorimetry:



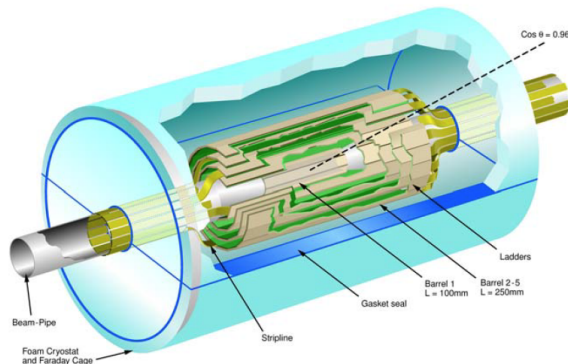
## CALICE-UK

Birmingham, Cambridge, Imperial, Manchester, RHUL, UCL

International R&D programme including:

- DAQ
- MAPS – digital ECAL concept
- Test beam data analysis
- Software: Particle Flow
- **Won't dwell on this area**

## ii: Vertex Detector:



## LCFI

Bristol, Edinburgh, Glasgow, Lancaster, Liverpool, Oxford, RAL

R&D programme including:

- CCD sensor development – ISIS
- MAPS development
- Mechanics and Support Structures
- Software: flavour tagging



# Past: LCFI

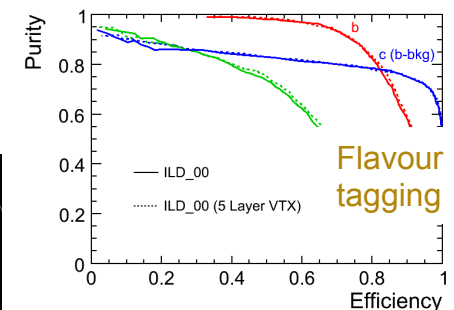
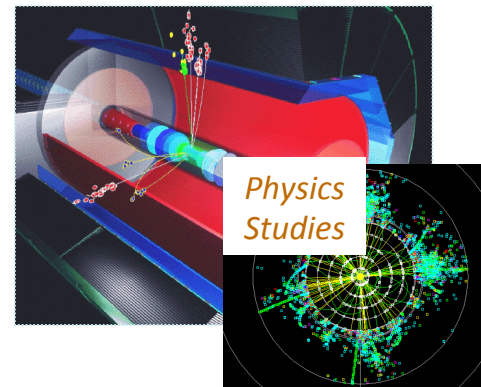
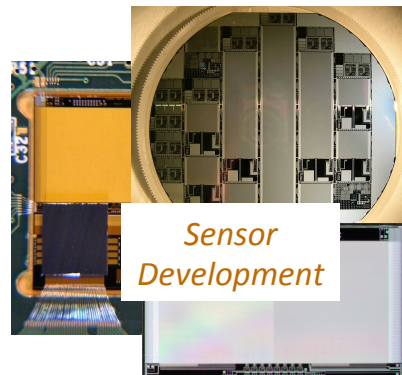
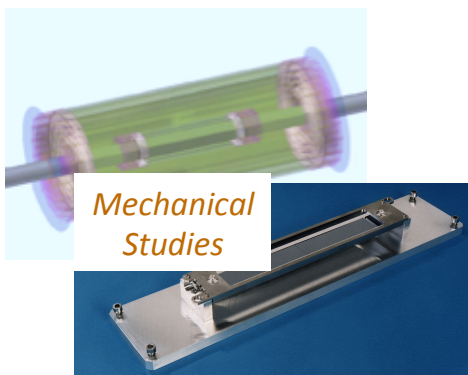


## ★ Linear Collider Flavour Identification: *LCFI*

- Born in the UK: grew to 9 institutes including international partners
- >£2M/year in grants
- Work packages developing all aspects of vertex detector
- Led international **pixel vertex detector development** for ILC

## ★ LCFI Accomplishments

- Several generations of fast CCDs, readout ASICs, bump bonding
- Ultra-light mechanics (foams)
- CMOS sensors
- State-of-art flavour-tagging software (**LCFIVertex**)





# Then... December 2007



- ★ UK built a vibrant LC Detector R&D community...
- ★ But then came, “Black December”:
  - STFC: due to lack of finance, STFC “**withdraws from ILC**”
  - USA budgetary crisis means large cuts to ILC (and other project funding) – impact beyond US

Somewhat negative effect  
on LC R&D in UK






# The Present



# Current Activities



- ★ 2007: more than a flesh wound...
- ★ But **some** generic R&D survived
- ★ Continuing  activities:
  - MAPS
  - Low mass structures
  - Particle Flow
  - Calorimeter Optimisation
  - Physics studies – not covered here, but a number of UK groups still active
  - **Also generic CMOS sensor development (LHC focussed, but applicable to ILC)**





# MAPS for LC

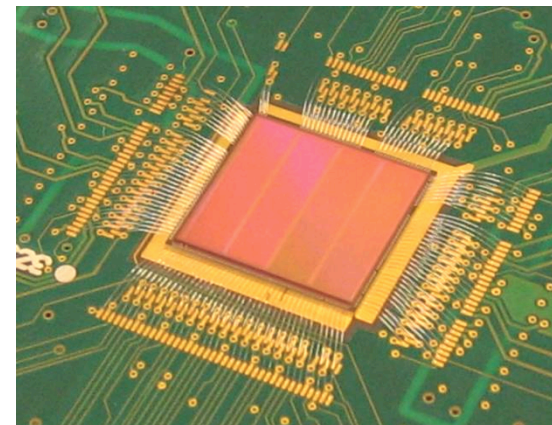


## Monolithic Active Pixel Sensors

### Some History

UK developed MAPS as technology with potential for vertexing, tracking and digital calorimetry

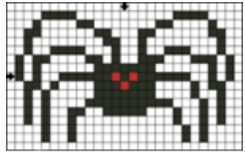
- CALICE-UK (ILC calorimetry, MAPS)
- SPiDer (adds **vertexing/tracking** at LC)
- Arachnid (generic detector + ALICE ITS)



See [Fergus Wilson's talk](#), ECFA LC 2013, DESY, for generic MAPS/silicon R&D in UK



# Arachnid



**Arachnid**



UNIVERSITY OF  
BIRMINGHAM



University of  
BRISTOL



Queen Mary  
University of London



Science & Technology Facilities Council  
Daresbury Laboratory

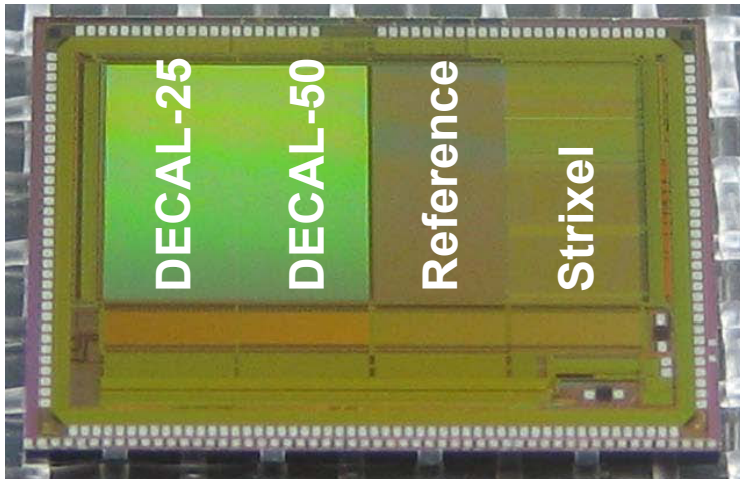


Science & Technology Facilities Council  
Rutherford Appleton Laboratory

## Arachnid CMOS MAPS programme:

- Cherwell chip has 4T pixels – validated strixel technology being used for ALICE prototype
- Enabled 4 MCHF programme between CERN and TowerJazz Foundary
- Performed numerous benchtests and test beam studies at CERN in 2012

## 4 main pixel types:



### Chip characteristics

- noise 8-12e<sup>-</sup> RMS
- Efficiency >99.7%
- S/N for a MIP ~150
- Hit resolution ~ 4µm



UK is a significant player in this area

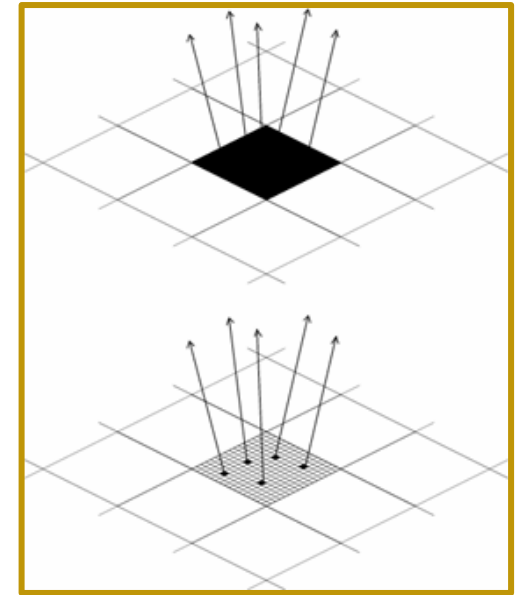


# MAPS Digital ECAL Concept



## ★ MAPS DECAL Concept

- UK idea with potential cost savings
- Swap “large”  $0.5 \times 0.5 \text{ cm}^2$  Si pads with **small** pixels
- With **small** enough pixels can count MIPs
- How small?
  - EM shower core density at 500GeV is  $\sim 100/\text{mm}^2$   
   ➔  $\sim 50 \times 50 \mu\text{m}^2$
  - Gives  $\sim 10^{12}$  pixels for ECAL – “Tera-pixel APS”
  - Mandatory to integrate electronics on sensor

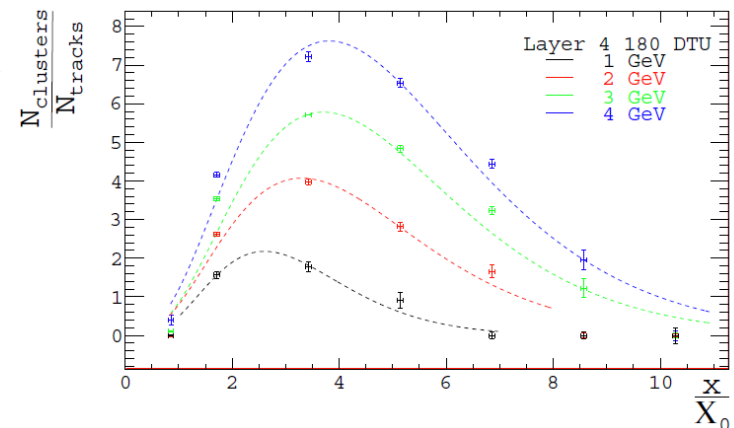


Studied TPAC sensors as “calorimeter” layer  
 Peak of sensor activity vs. depth of material

[see T. Price, PhD thesis, Aug. 2013, Univ. Birmingham]

## ★ Interesting concept

– but would requires serious R&D to raise TRL for ILC

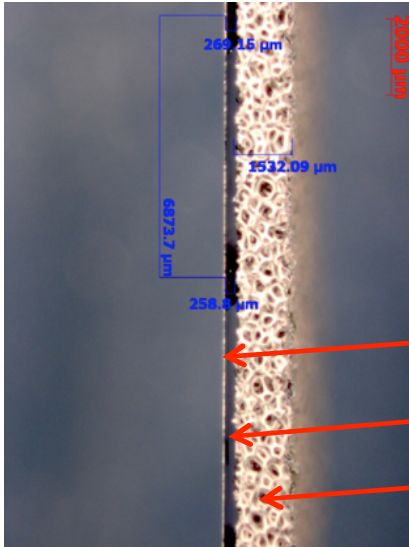




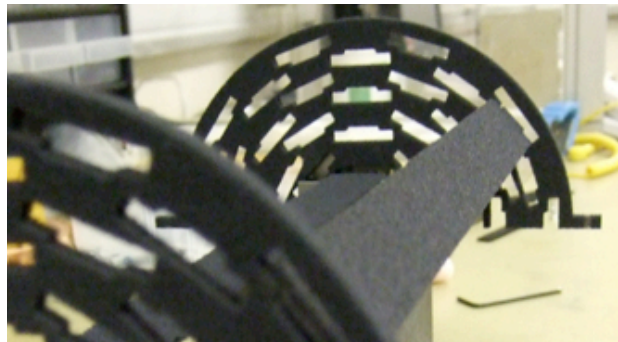
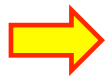
# Low Mass and PLUME



- ★ Ultra-high precision tracking → very low material budget
- ★ Low-mass (STFC funded) investigated SiC foam structures



- ★ Open-cell foam
- ★ Commercially available at 8%
  - Can get 2-3%
- ★ Baseline ladder:
  - 20μm silicon sensor
  - Silicone glue/gap
  - 1.5 mm foam



Prototype SiC vertex detector

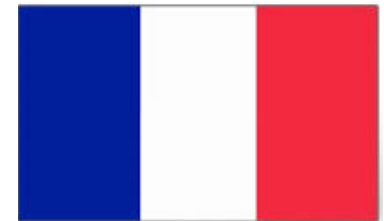
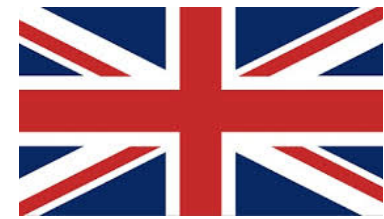
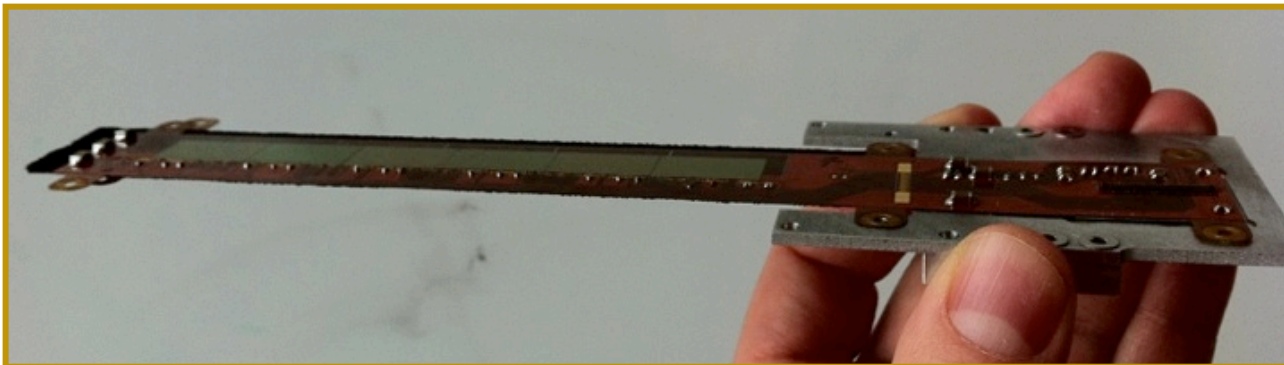


# Low Mass and PLUME



## PLUME = European R&D for ILC VXD ladders

- **Strasbourg, DESY, (Oxford), Bristol**
  - Double-sided with Mimosa (MAPS)
  - Kapton flex on SiC foam
- **Oxford were responsible for flex circuits**
- **Bristol responsible for foam and mechanics**






# Particle Flow Calorimetry

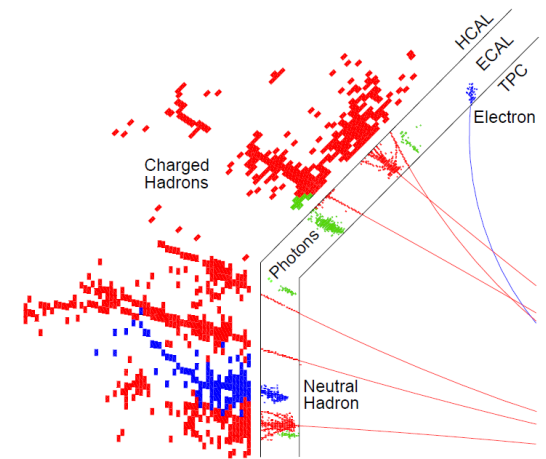


- ★ **Baseline calorimetry at LC = High granularity PFlow**  
➔ **Factor 2-3 better jet energy resolution**
- ★ **Lives or dies** on the quality of the reconstruction
- ★ **Requires high-performance software:**

## PandoraPFA



- ★ **Almost all ILC/CLIC studies based on Pandora C++ software development kit**
- ★ **Initial funding from STFC now EU**  **AIDA**
- ★ **Allowed/allows continued development**



- ★ **High-G Pflow is a new approach to calorimetry:**
  - **Drives ILC detector design**
  - **Will deliver unprecedented jet energy resolution**
  - **PandoraPFA used for many Calorimeter design studies**
    - e.g. see T.H. Tran's talk at this meeting
    - + UK pursuing many ECAL/HCAL optimisation





# ILC in the UK



## ★ Status of ILC in UK

- ILC is **not** currently part of UK roadmap
- Recent “Programmatic review” will define UK priorities for coming years
- The “Higgs Factory” aka ILC was in the mix
- Outcome not yet announced (due to delays in finalising the overall STFC budget)
- Vibes are reasonably positive
- But doesn’t imply that there will be money available...





# the Bottom-up View



- ⊙ **Currently a lot of renewed interest in the ILC in the UK**
  - ★ **1-day LCUK meeting in September**
    - **>50 people attended (mostly academics/lab staff)**
    - **all UK HEP groups represented**
    - **+ representatives from funding agency**
    - **very positive meeting**
  
- ⊙ **But...**
  - ★ **Recognise it is not an easy situation**
    - **money is still tight**
    - **any short-term ILC detector funding likely to have to compete with LHC upgrades for resources**



# The Cunning Plan



- ⊙ **If the ILC happens – we believe the UK must be there**
  - ★ **Need to start process now**
    - **Since September, held two smaller follow-up meetings**
    - **all UK HEP groups represented**
    - **discussed areas of interest**



- ⊙ **Next steps**
  - ★ **Early 2014: submit detector & accelerator “Sol” to funding agency (Phil Burrows & Mark Thomson)**
  - ★ **Followed by *detector R&D* proposal**
    - **initially scope will be (very) limited (travel + ε)**
    - **timing needs care....**
    - **clear and positive statement from Japan would help**



# UK Future directions



★ UK has interests in a number of areas

Calorimetry

Si

Mechanics

DAQ

Software



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R&D:

- ★ Testbeam/CALICE
- ★ DECAL

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CMOS sensors:  
★ hybrid readout  
★ INMAPS

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e.g. low mass

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A lot of expertise:  
★ Global design  
★ ILC readout

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R&D:  
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**Software**

PFA Development  
★ Calo optimisation  
★ DHCAL





# Collaboration



- ★ Previous page gives flavour of where people's interests lie
- ★ Need to develop this into real activities in coming years
- ★ Collaboration with international ILC partners essential

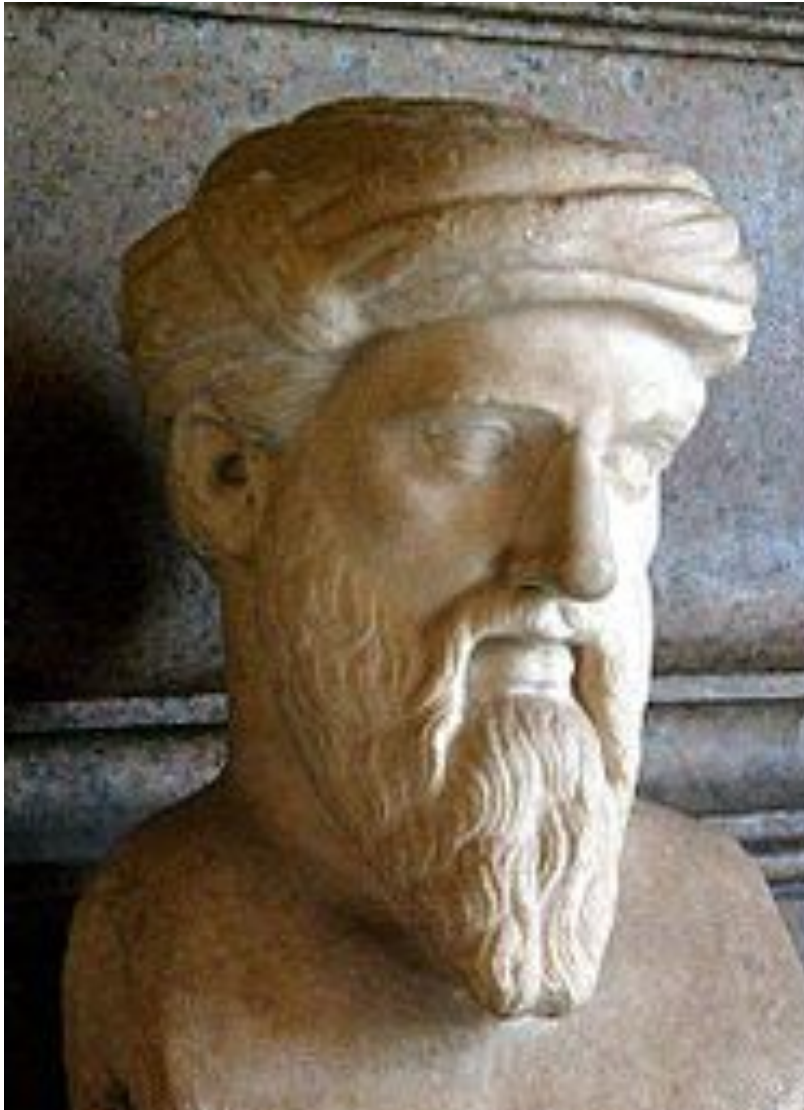
- ★ **Existing collaborative efforts:**

- CERN (through CLIC)
- CALICE
- DESY
- ...

- ★ **NOTE – real overlap between UK & French interests**
  - Calorimeter design/optimisation, Si sensors & mechanics
  - + DAQ
  - Potential for *effective* collaboration



# Concluding Thoughts



- ★ **The ILC will be a wonderful machine**
- ★ **Most in UK HEP believe the UK must be there**
- ★ **Need to reconnect with ILC - the interest exists**
- ★ **Starting formal process, but resources very limited**
- ★ **Desire to collaborate: think about UK-French interests**