SiD ECal overview

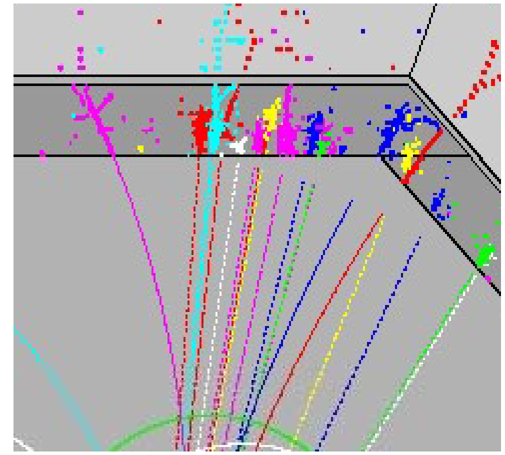
From R.Frey's talk given by Y.Karyotakis

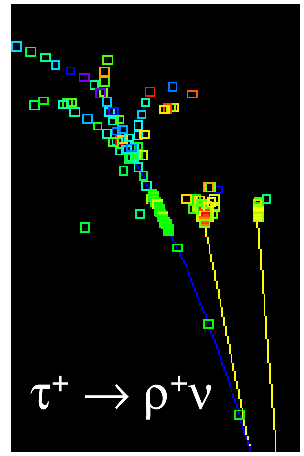
- Physics (brief)
- Proposed technical solutions: silicon/tungsten
  - "traditional" Si sensors
  - MAPS
- Progress and Status
- Opportunities for Research

Physics and ECal

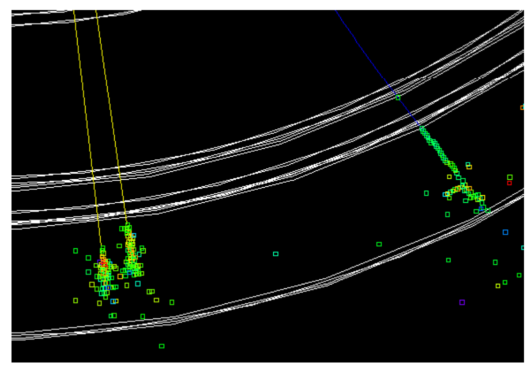
<u>Guiding principles</u>: Measure all final states and measure with precision

- Multi-jet final states
  - π° measurement should not limit jet resolution
  - id and measure h° and $h^\pm$ showers
  - track charged particles
- Tau id and analysis





- Photons
  - Energy resolution, e.g. $h \rightarrow \gamma\gamma$
  - Vertexing of photons (σ_b~1 cm), e.g. for GMSB
- Electron id
- Bhabhas and Bhabha acollinearity
- Hermiticity

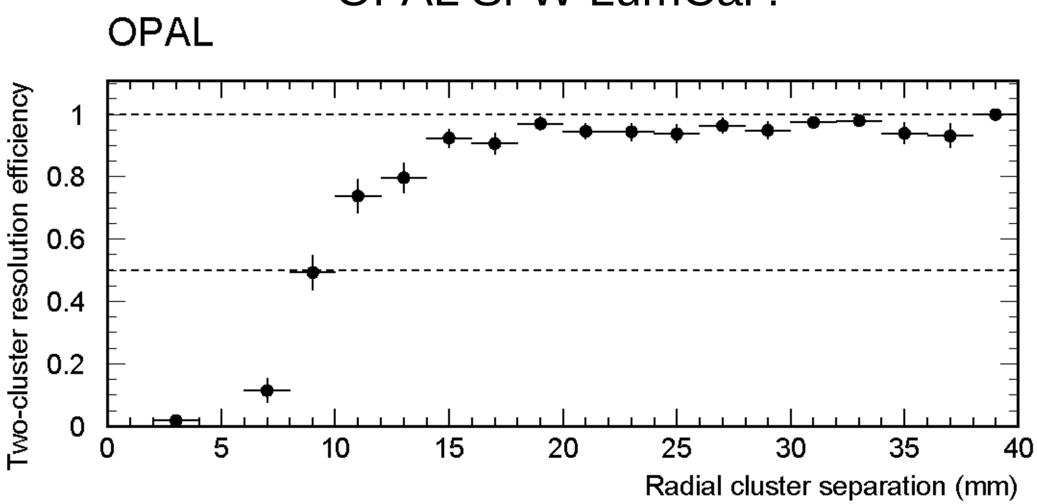


$\Rightarrow$ Imaging Ecalorimetry can do all this

Segmentation requirement

- The above benefit from a highly segmented (in 3d) ECal
- In general, we wish to resolve photons in jets, tau decays, etc.
- The resolving power depends on Moliere radius and segmentation.
- We want segmentation significantly smaller than R_m – how *much* smaller is an open question

Two EM-shower separability in LEP data with the OPAL Si-W LumCal :



$$d = 2.5\text{mm} \ , \ R_M \sim 17\text{mm}$$

$$f_E \simeq \frac{R_{cal}}{\sqrt{R_M^2 + (4d_{pad})^2}}$$

Proposed technical solutions in SiD

A.) silicon/tungsten B.) silicon/tungsten

A) "traditional" silicon diodes with integrated readout

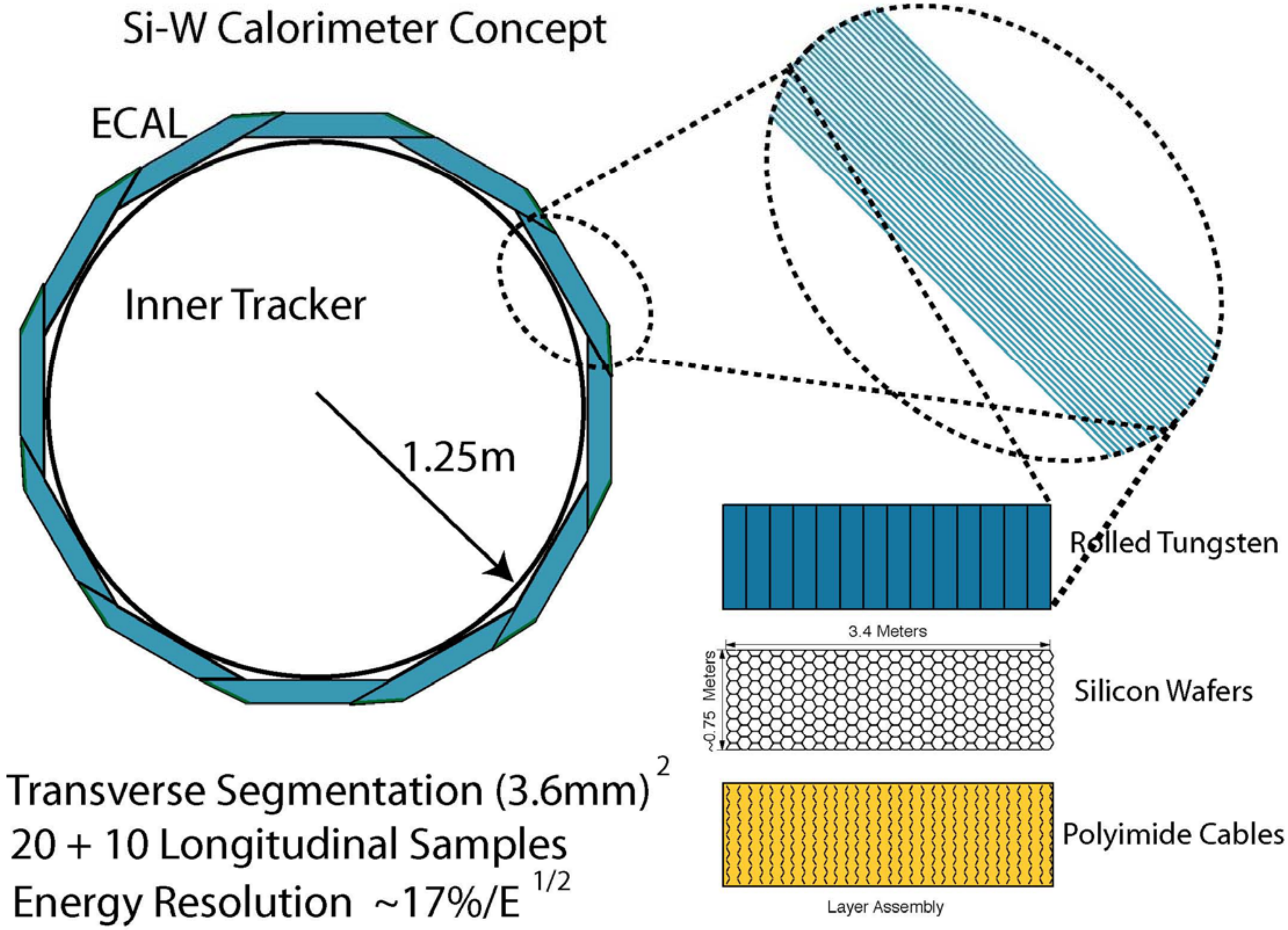
Transverse segmentation 3.5 mm (Moliere radius $\approx$13 mm)

B) MAPS active CMOS pixels (Terapixel option)

Transverse segmentation 0.05 mm (Moliere radius $\approx$13 mm)

Goal: The same mechanical design should accommodate either option

SiD Silicon-Tungsten ECal



<u>Baseline configuration:</u>

- longitudinal: $(20 \times 5/7\ X_0)$ $+ (10 \times 10/7\ X_0)$ $\Rightarrow$ 17%/sqrt(E)
- 1 mm readout gaps $\Rightarrow$ 13 mm effective Moliere radius

Generic technical considerations

- Small readout gap
  - Maintains small Moliere radius, hence performance
  - Big impact on cost
  - ≈1 mm still looks feasible

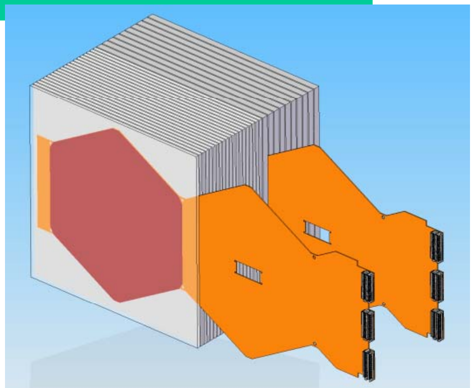
Config.	Radiation length	Molière Radius
100% W	3.5mm	9mm
92.5% W	3.9mm	10mm
+1mm gap	5.5mm	14mm

- Power cycling
  - Turn off power between beam trains

  ⇒ Passive cooling (highly desirable!)

  - for (A), passive conduction of 20 mW to module end (≈75 cm) via the tungsten radiator results in a few °C temperature increase ⇒ OK !
  - for (B), this is an open question

Si/W (A) R&D status overview



Goal: Produce full-depth (30 layers = 30 sensors) module for evaluation in a test beam using technology which would be viable in a real ILC detector.

- Require 1024-channel KPiX ASIC chips (Strom talk)
  - Evaluating 64-chan prototypes (KPiX-6 is latest)
    - Noise is OK for Ecal, but not understood to our satisfaction
  - Has been the critical-path item
- Silicon sensors
  - v1 evaluated successfully
  - v2 on order – expect to have 40 ~ Mar 08
- Bonding of KPiX to Si sensors
  - First trials completed (gold bump-bonds)
- Tungsten – in hand
- Readout cables – short kapton cables OK
- Module mechanics and electromechanical - serious work starting
- DAQ

Si/W (A) R&D Collaboration

M. Breidenbach, D. Freytag, N. Graf, R. Herbst, G. Haller, J. Jaros
Stanford Linear Accelerator Center

- KPiX readout chip
- downstream readout
- mechanical design and integration

J. Brau, R. Frey, D. Strom, Barrett Hafner (ug), Andreas Reinsch (g)
U. Oregon

- detector development
- readout electronics

V. Radeka
Brookhaven National Lab

- readout electronics

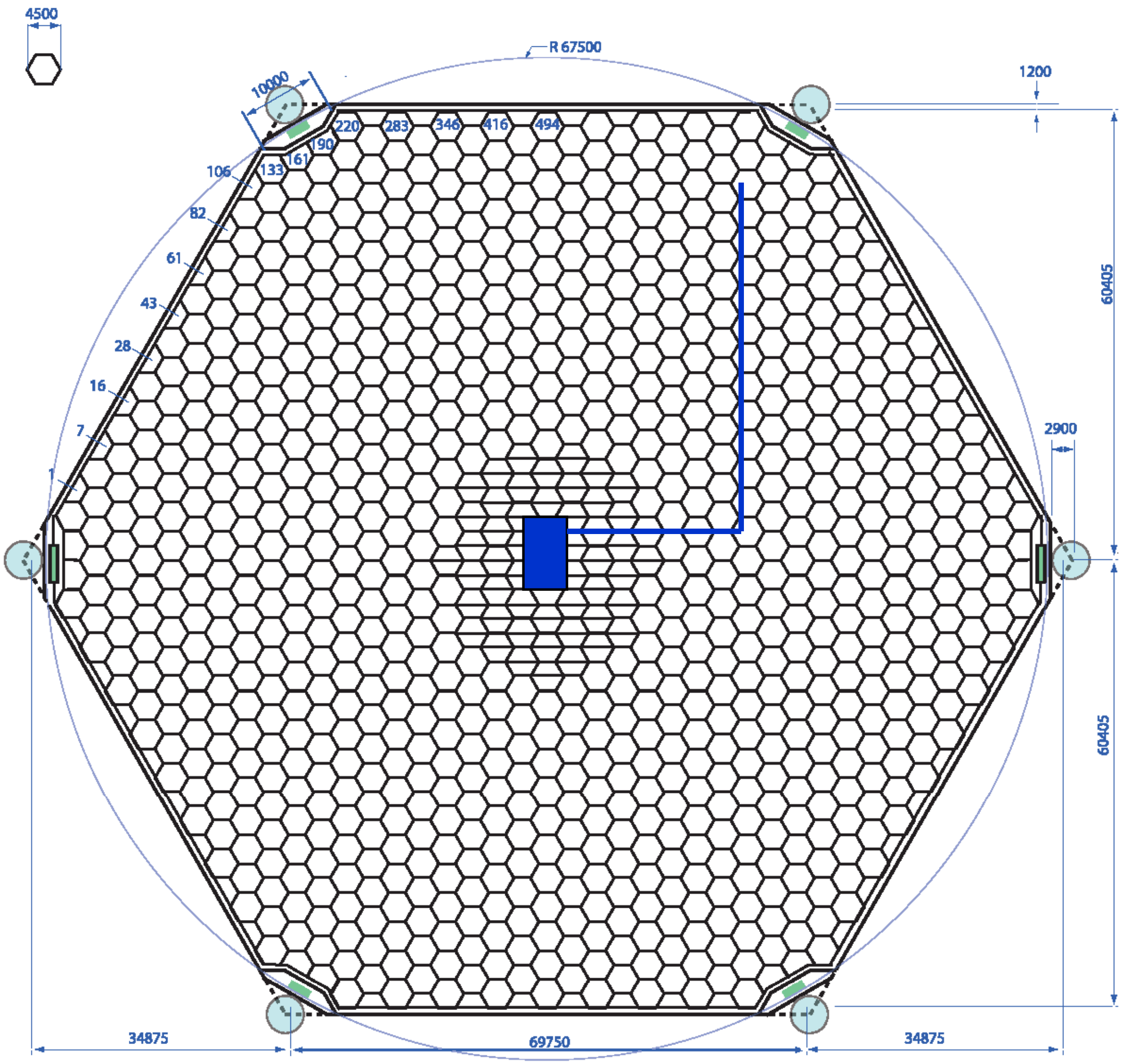
B. Holbrook, R. Lander, M. Tripathi
UC Davis

- cable development
- bump bonding

S. Adloff, F. Cadoux, J. Jacquemier, Y. Karyotakis
LAPP Annecy

- mechanical design and integration

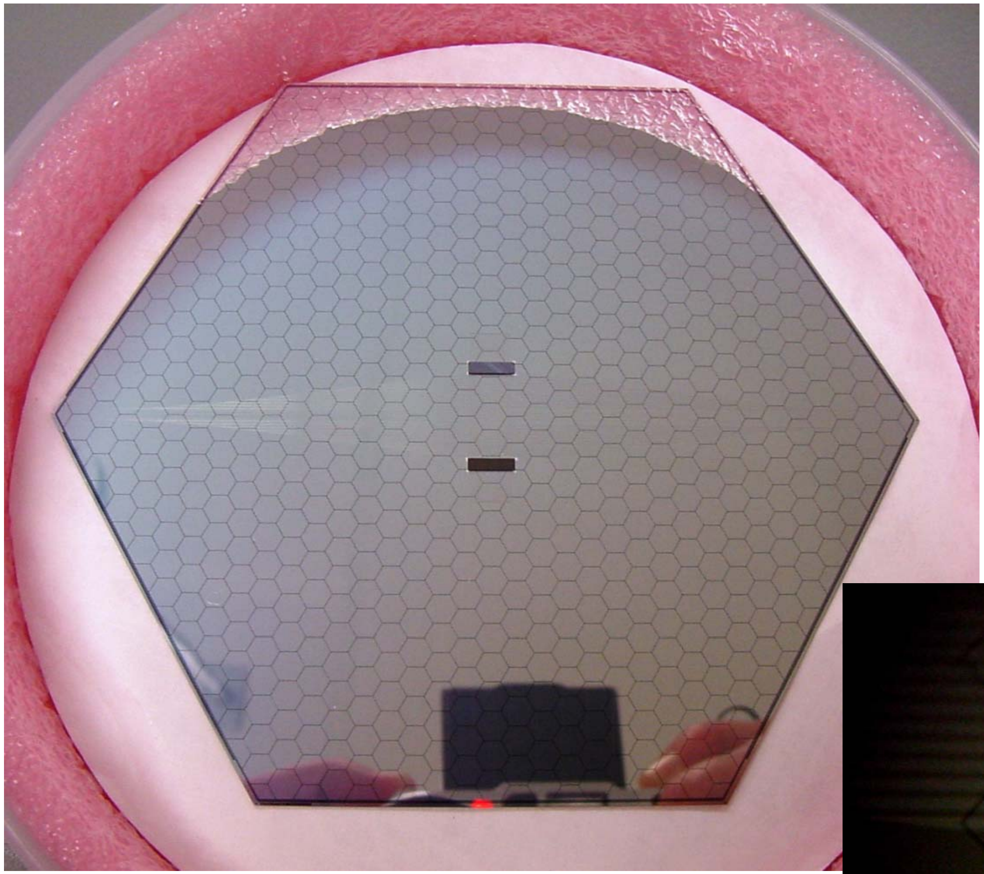
v2 Si sensor – for test beam module



- 6 inch wafer
- 1024 13 mm^2 pixels
- improved trace layout near KPiX to reduce capacitance
- procurement in progress, 40 sensors, Hamamatsu

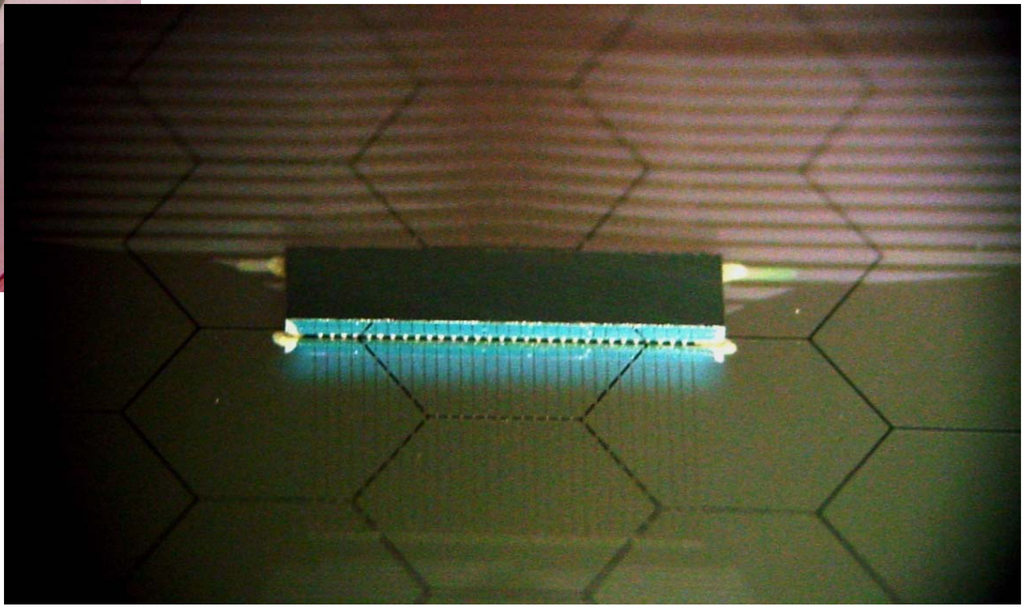
KPiX ASIC and sample trace

KPiX-v6 gold-stud bonded to v1 sensors
UC Davis group, Jan 08

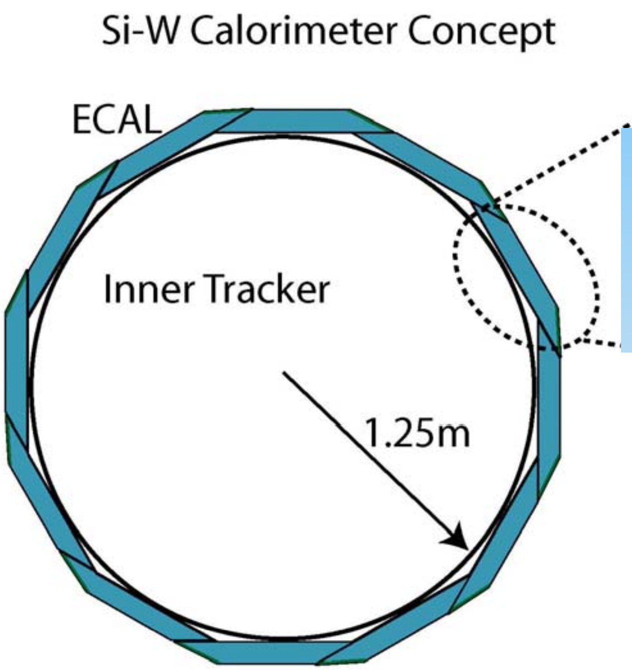


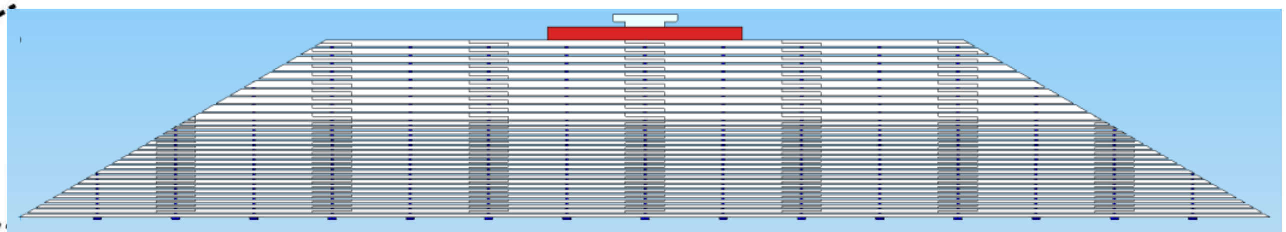
Initial test results (1/25/08, UO) of first attempt (Palomar Tech.):

one open / 24 connections tested

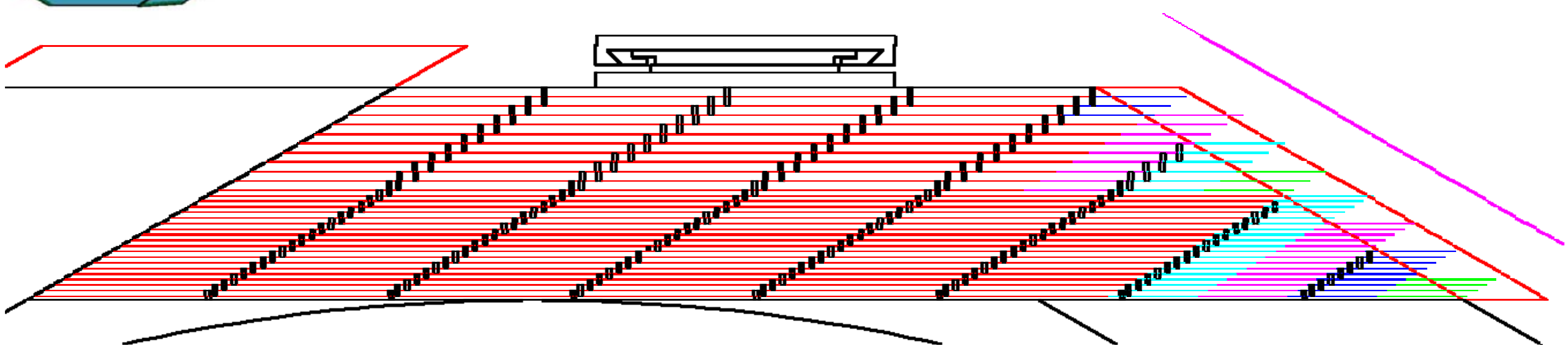


Towards a mechanical design…





Marco Oriunno, SLAC



Only 2 Si sensor mask-sets required

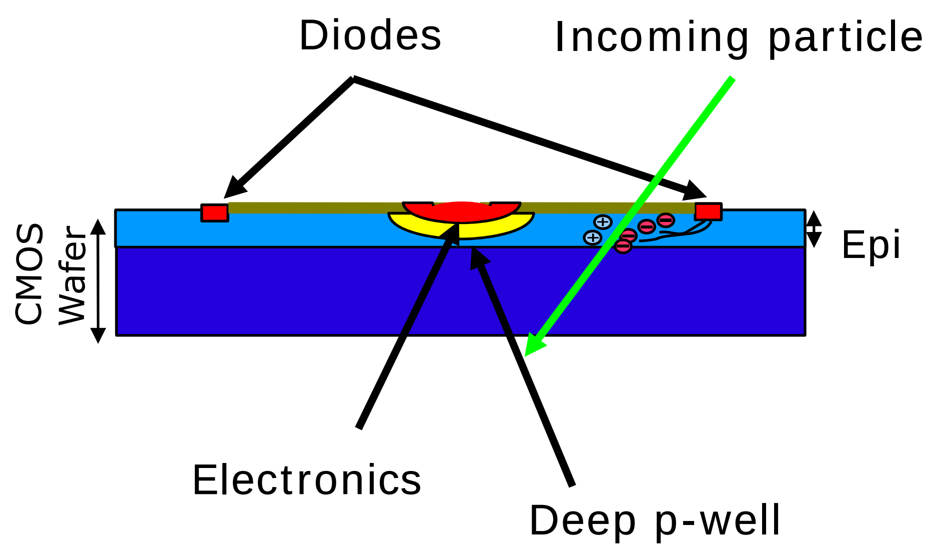
B.) MAPS (Terapixel) Si/W

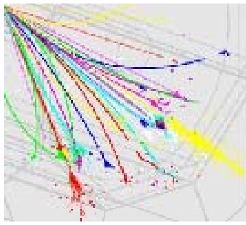
The MAPS ECAL

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

What are MAPS ?

- **M**onolithic **A**ctive **P**ixel **S**ensor
- Integration of Sensor and Readout Electronics
- Manufactured in Standard CMOS process
- Collects charge mainly by diffusion
- Development started in the mid-nineties, now a mature technology

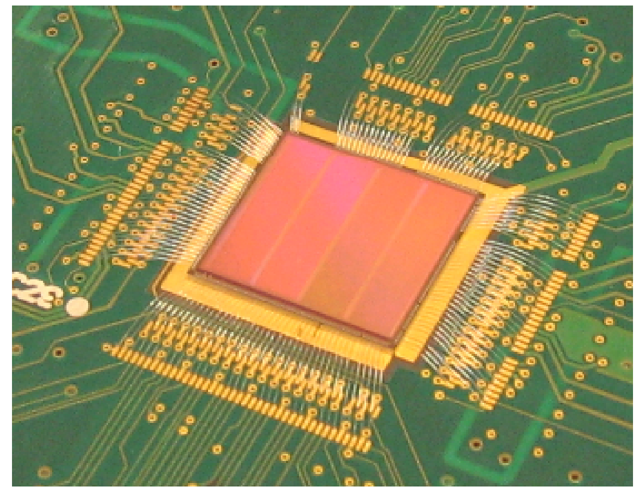




The Chip - Specifications

- 50x50 micron cell size
- Binary Readout (1 bit ADC)
- 4 Diodes for Charge Collection
- Time Stamping with 13 bits (8192 bunches)
- Hit buffering for entire bunch train
- Capability to mask individual pixels
- Threshold adjustment for each pixel

⇒ Usage of INMAPS (deep-p well) process

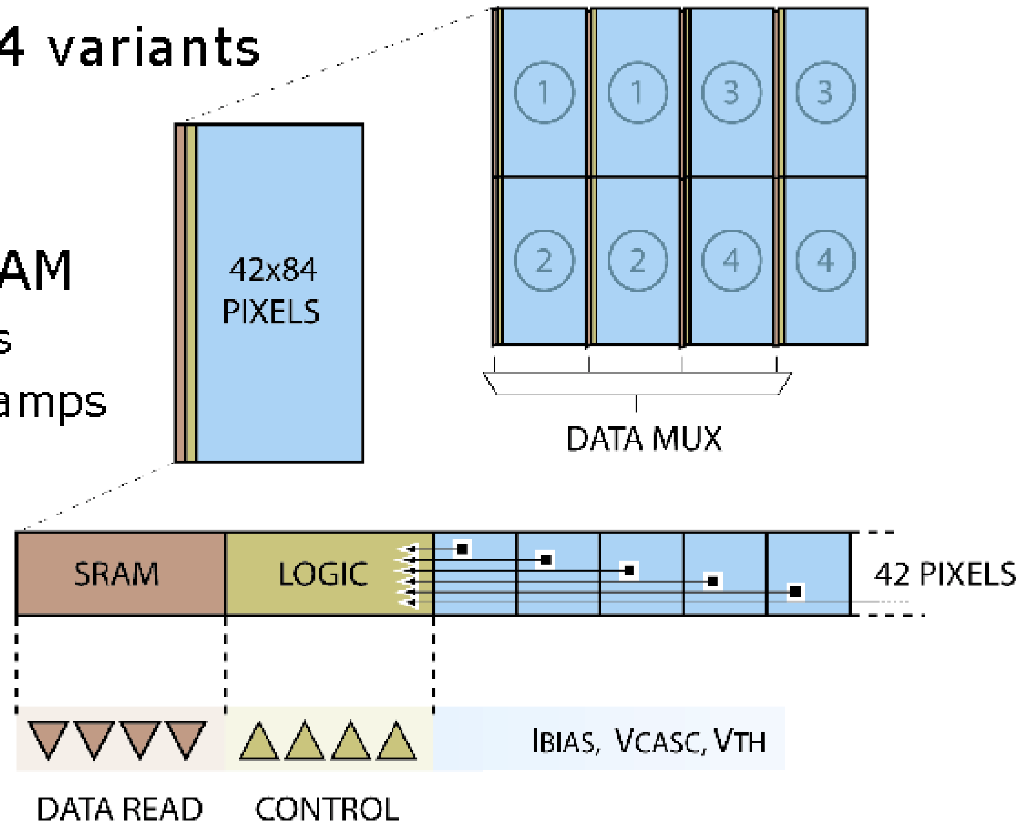


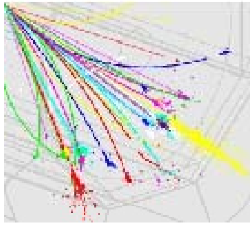
The Chip : TPAC1 (ASIC1)

- 8.2 million transistors
- 28224 pixels; 50 microns; 4 variants
- Sensitive area 79.4mm^2

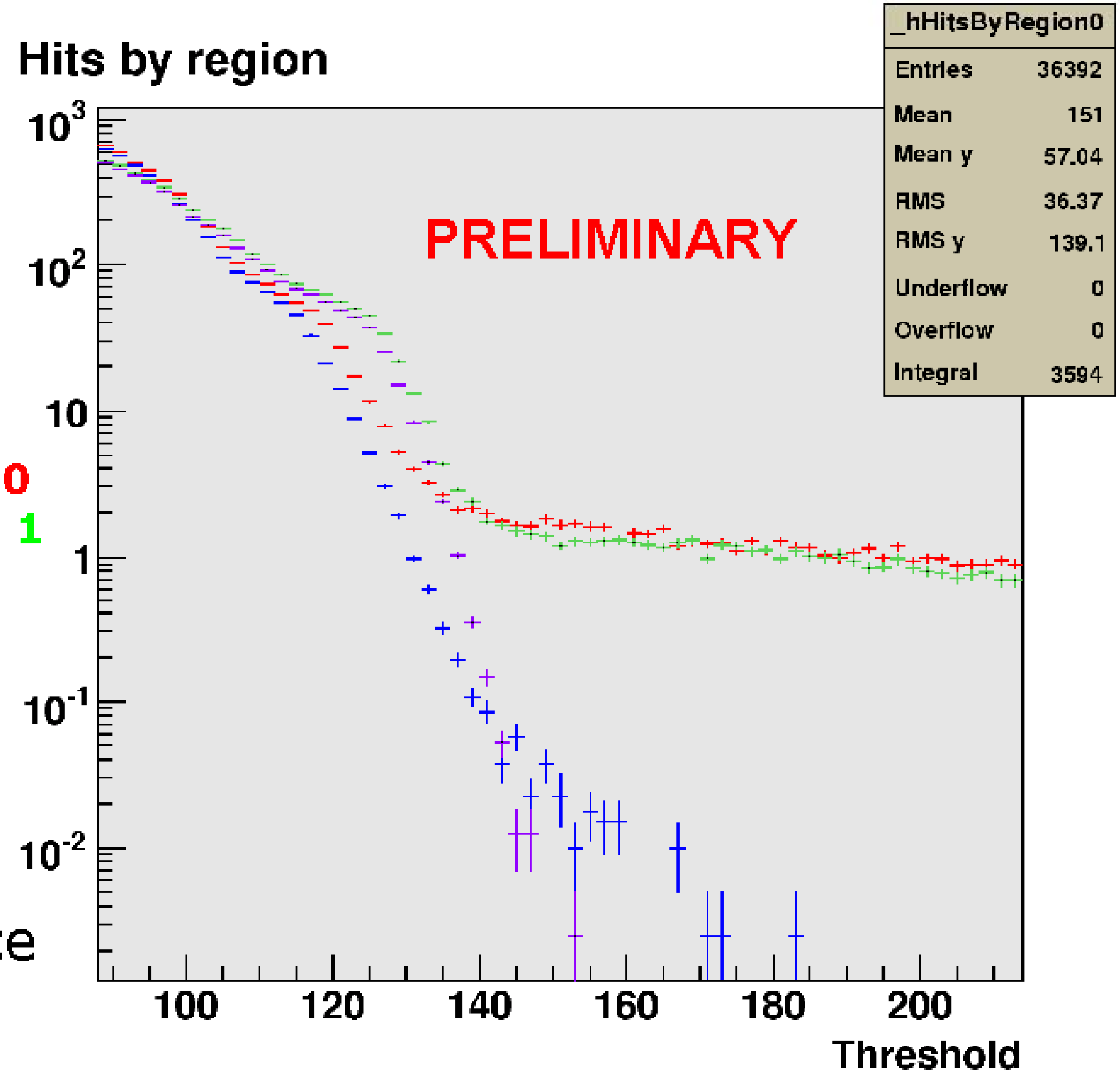
- Four columns of logic + SRAM
  - Logic columns serve 42 pixels
  - Record hit locations & timestamps
  - Local SRAM

- Data readout
  - Slow (<5 MHz)
  - Current sense amplifiers
  - Column multiplex
  - 30 bit parallel data output



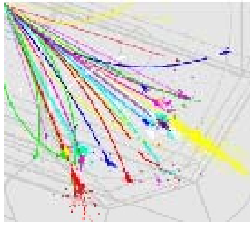


Threshold scan



red - with source, region 0
green - with source, region 1
blue - no source, region 0
purple - no source, region 1

Made using a β source



Plans

(from Nov 07)

- Calibrations / Gain measurements
- Test beam at DESY (10 days)
  - All effort focusing on this right now
- Power measurements
  - Also try power pulsing
  - The chip is up for it
- Detailed charge collection studies
  - Deep p-well
  - Epi-thickness
- Design a second chip !

This happened !
No results yet.

uncertain?!

The path to the LOI

- Technology choice
  - MAPS terapixel still needs to be proven as a viable ECal technology
  - Si diode/W ECal technology is well established for relatively small calorimeters. But the integrated electronics needs to come together.
  - What does the physics say? Is there a physics case for segmentation<< R_m ? Perhaps. The case needs to be made and weighed against the risks.

  - Agreement: Make Si diodes the default, but continue the R&D and studies for terapixel. Attempt to make an ECal mechanical structure which can accommodate either without important compromise.

- We need to do a lot of work to solidify and amplify the physics case for the LOI -- simulation studies at all levels.
- Fallout from Dec 2007 funding problems in UK and US: Still evaluating the status. Bottom line: Continue R&D as best possible.

There is a lot to do...

- Si diode technical
  - Current focus on KPiX development
  - Starting serious look at mechanical issues
    - For SiD structure
    - For the test beam module
  - What goes on the other end of the cable from KPiX?
  - Procurement, layout, testing of a large number of sensors.
  - Test beam(s) !
    - e.g. DAQ and data analysis
- Terapixel technical
  - Reconstruction within org.lcsim framework

General needs:

- Sensor and electronics configuration for the inner endcap
- Simulation studies are badly needed
  - Especially to elucidate physics $\Leftrightarrow$ segmentation

Some needed studies

- Longitudinal structure (baseline is a motivated guess)
  - What EM resolution is *required* ?
    - Particle flow (photon E res. shouldn't contribute on average)
    - Other indications? $h \rightarrow \gamma\gamma$?
  - Depth (containment) and numbers of layers (money, E resolution, pattern recognition of EM)
    - How much can the HCal help with EM resolution?
- Segmentation
  - gamma-gamma and $h^{\pm}$ –gamma separability; π° reconstruction
  - EM shower id
    - There has been progress. But we are still at an unsophisticated level relative to what has been accomplished, for example, at LEP.
- Physics/detector studies
  - jet/pflow processes [pushes seg. issue]
    - Without beam constraint (eg invisible decays)
    - Jet combinatorics in complicated finals states
  - Tau id and final-state reconstruction (polarization) [pushes seg. issue]
  - Photon tracking
  - Heavy quark id: electrons in jets, neutrino recon; exclusive B/D tags?

Summary

- The silicon/tungsten approach for the SiD ECal still looks good.
- We think it can meet the LC physics and technical challenges.
- Two technical approaches:
  - Baseline: Si diode sensors with integrated (KPiX) electronics
  - MAPS (terapixel) – completely integrated
- There has been good, steady progress.
- There is a lot to do for the LOI.

- The recent political choices in the U.S. and U.K. have thrown a monkey wrench in the works.
- We are “taking stock” of the situation, but vow to press on to the extent possible.