

# The ECal in the SiD LOI

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- Overview of status and progress
  - Silicon/tungsten concept
  - Technical options: Si sensors (default) and/or MAPS
  - “default” option progress
    - Mechanical design
    - Sensors
    - KPiX readout
    - Interconnects
  - MAPS progress (see Paul Dauncey talk)
- LOI plan
  - Description – ok; some issues to refine/resolve
  - Technology choice – ok
  - Needed: improved reconstruction and performance plots
  - Needed: justify choices in terms of physics

# 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)

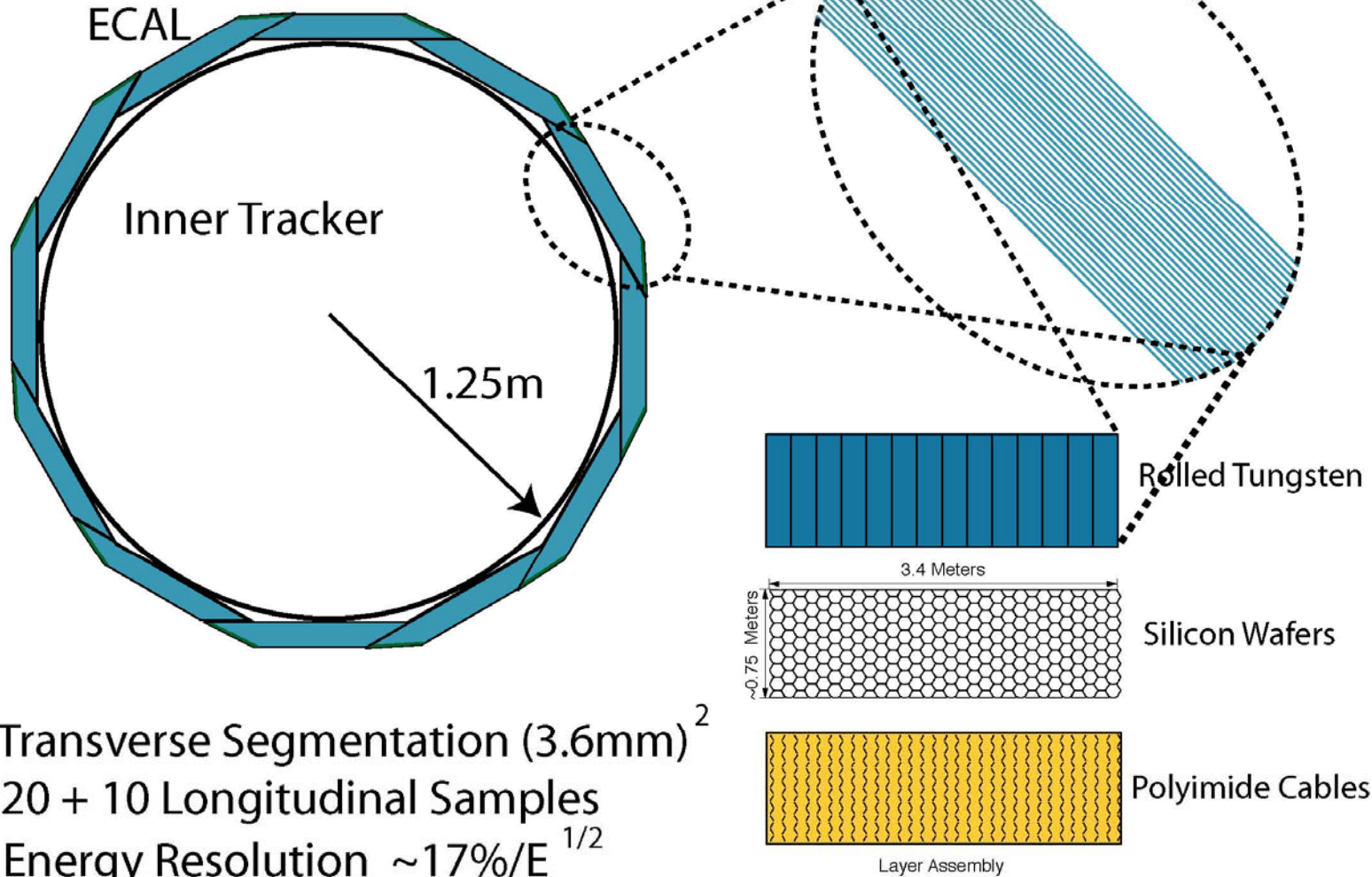
Goal: The same mechanical structure should accommodate either option

C) A+B: Some number of MAPS layers before shower max.

On LOI timescale: A is the baseline;  
B (or C) is an option to keep open for the future

# SiD Silicon-Tungsten ECal

## Si-W Calorimeter Concept



## SiD02 configuration:

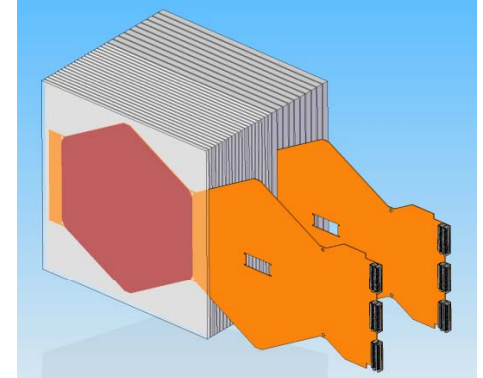
- longitudinal:  
(20 x 5/7  $X_0$ )  
+ (10 x 10/7  $X_0$ )  
 $\Rightarrow 17\%/\text{sqrt}(E)$
- 1 mm readout gaps  $\Rightarrow$  13 mm effective Moliere radius

Transverse Segmentation  $(3.6\text{mm})^2$   
20 + 10 Longitudinal Samples  
Energy Resolution  $\sim 17\%/E^{1/2}$

# Si/W (A) technology status

R&D project goal (still !): Produce full-depth (30 layers) module for evaluation in a test beam using technology which would be viable in a real LC detector.

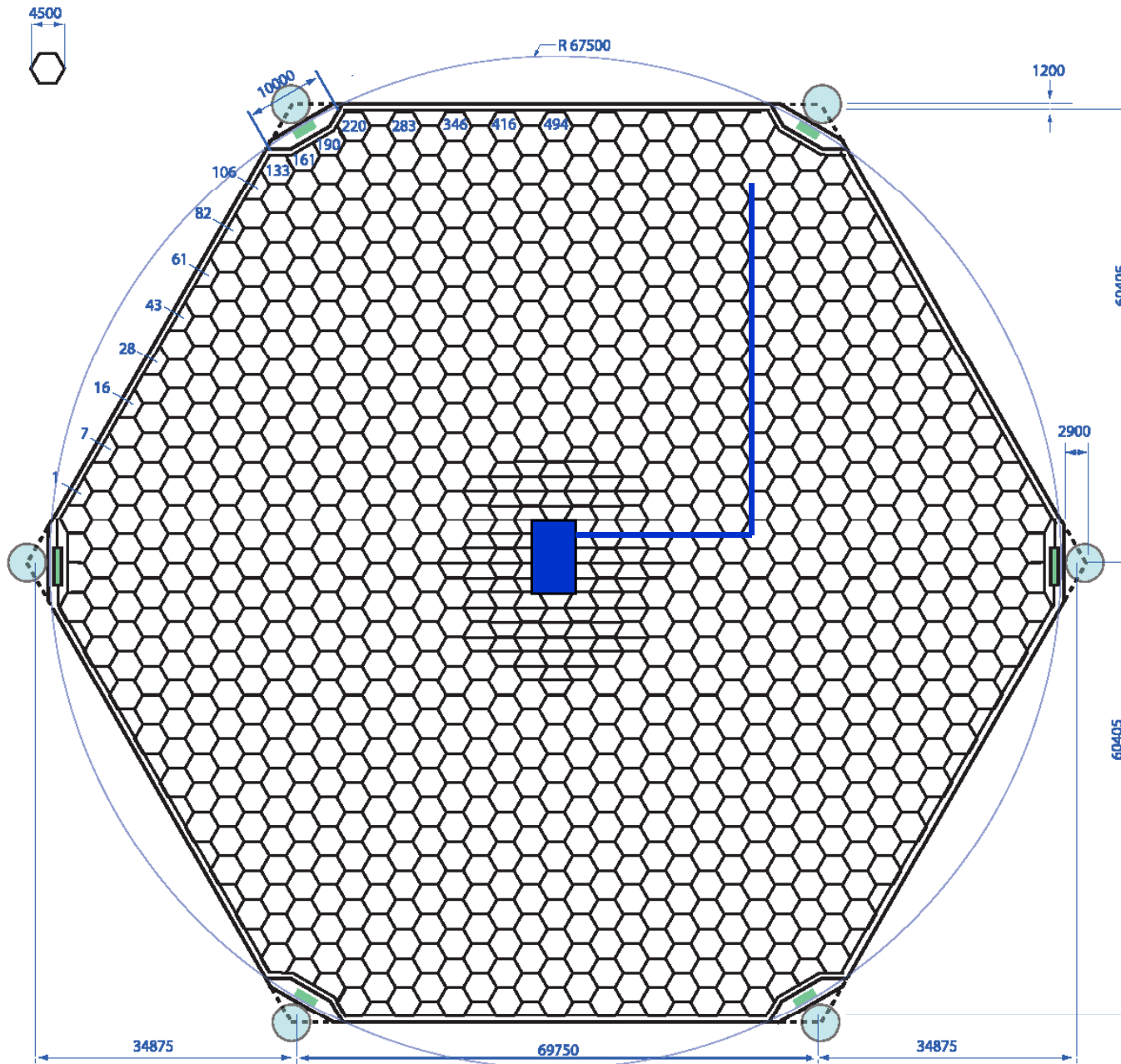
- Require 1024-channel KPiX ASIC chips
  - Latest 64-chan prototypes (KPiX-7) OK for Calor.
    - See Tim Nelson talk
- Silicon sensors
  - Procured 40 v2 sensors (+ 20 “NG” sensors) from Hamamatsu
- Bonding of KPiX to Si sensors
  - First trials completed (gold bump-bonds)
- Tungsten – in hand



SiD LOI: The above plus...

- Mechanical structure design
- Long flex cables
- Thermal design, etc

# v2 Si sensors

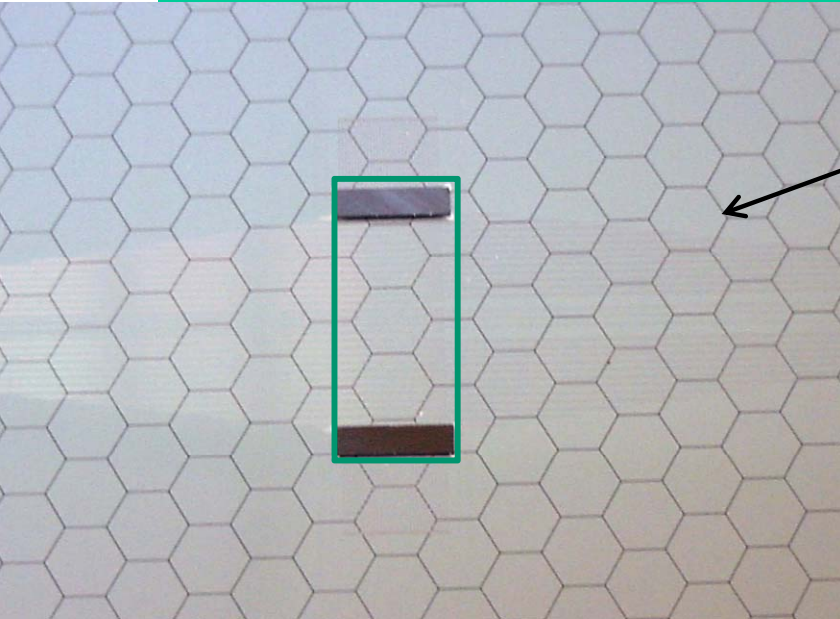


- 6 inch wafer
- 1024 13 mm<sup>2</sup> pixels
- improved trace layout and split pixels near KPiX to reduce capacitance
- 40 good + 20 NG sensors in hand, Hamamatsu

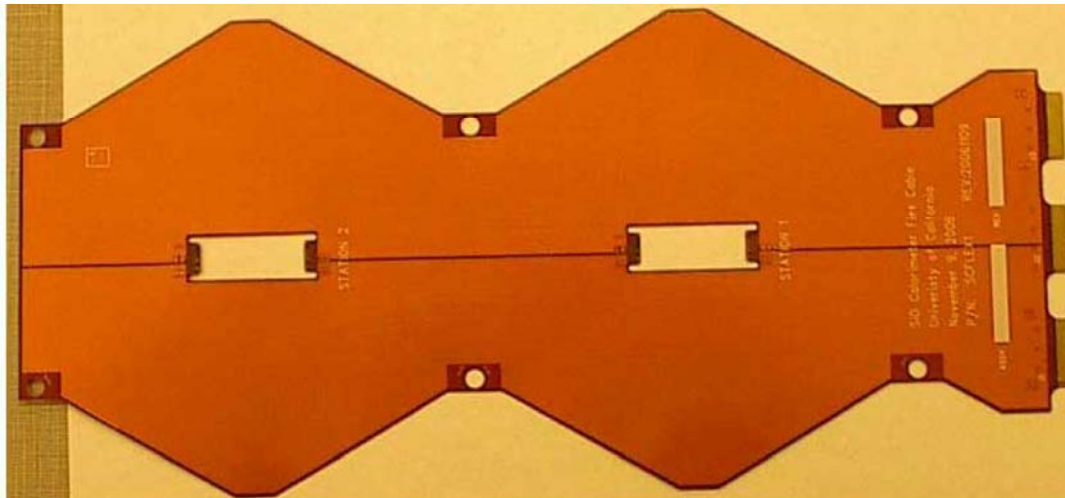
KPiX ASIC and sample trace



# interconnections



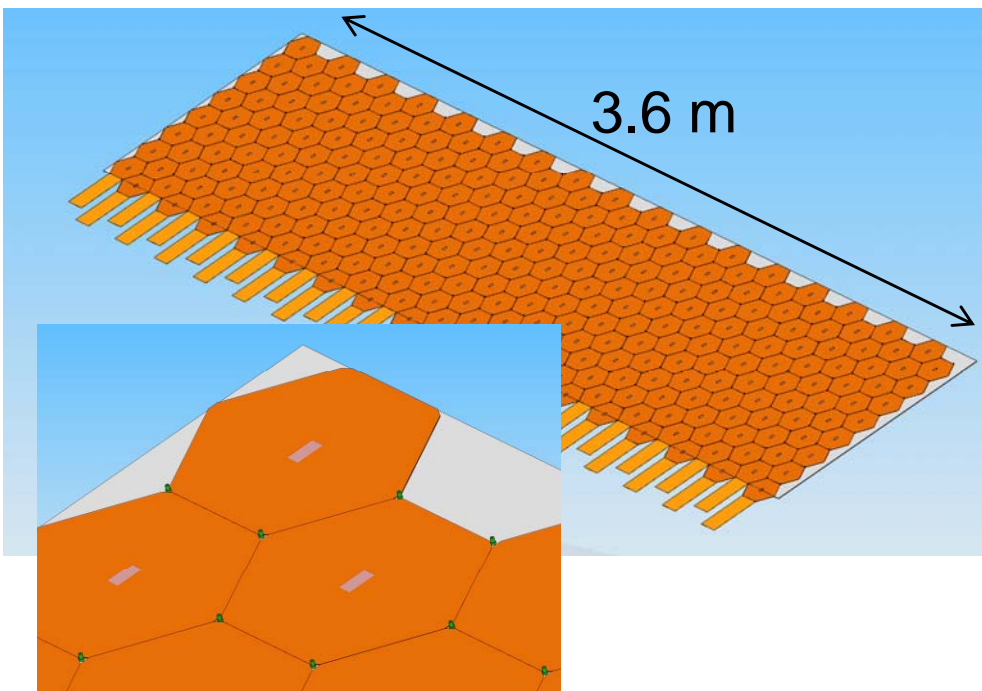
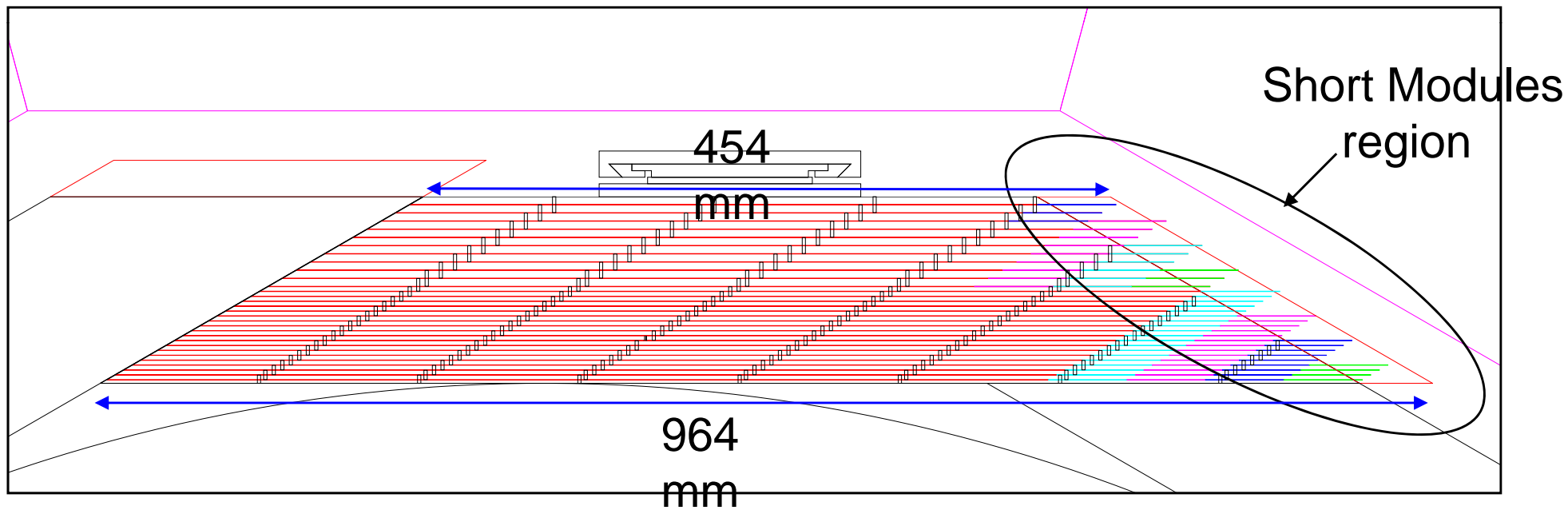
- Initial gold-stud bump-bonding trials had mixed results → consistent with surface oxidation
- Trials using titanium-tungsten treatment with dummies looks good
- Trials with KPiX-7 and Hama sensors with Ti-W to begin soon (Palomar Tech)



Flexcable – sensor connection technology (ACF) looks promising. Jig being built at Davis.

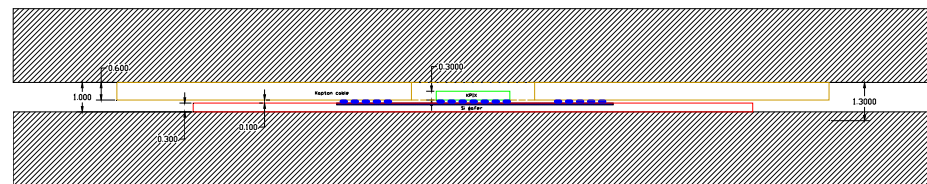
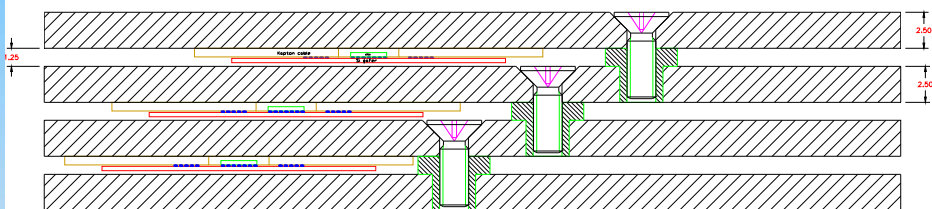
The flexcables will now need to be longer...

# Emcal Barrel Mechanical design progress



Staggered layout

Only 2 masks for the wafer and 8 for the kapton

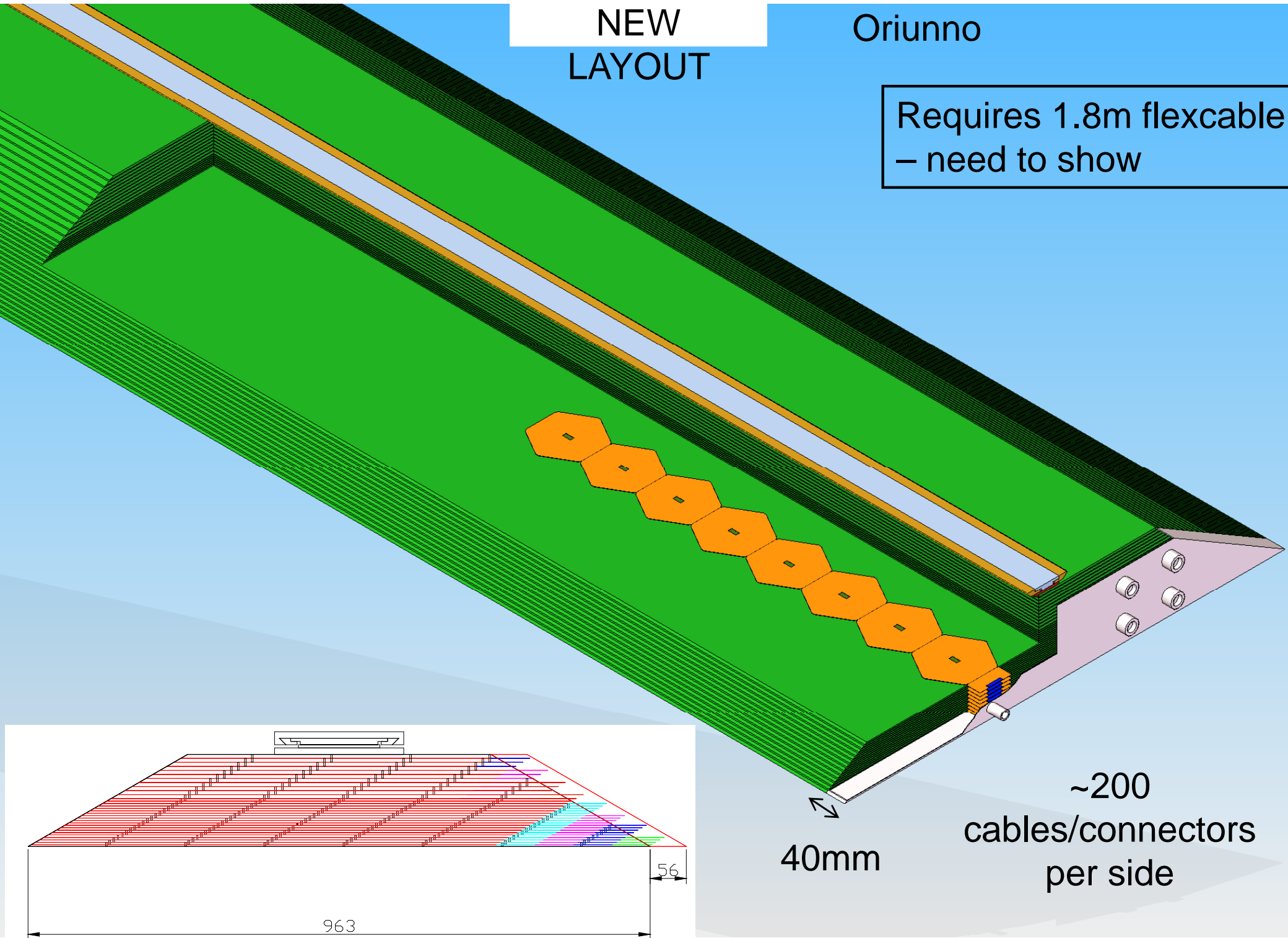




NEW  
LAYOUT

Oriunno

Requires 1.8m flexcable  
– need to show



40mm

~200  
cables/connectors  
per side

963

56

# Cooling

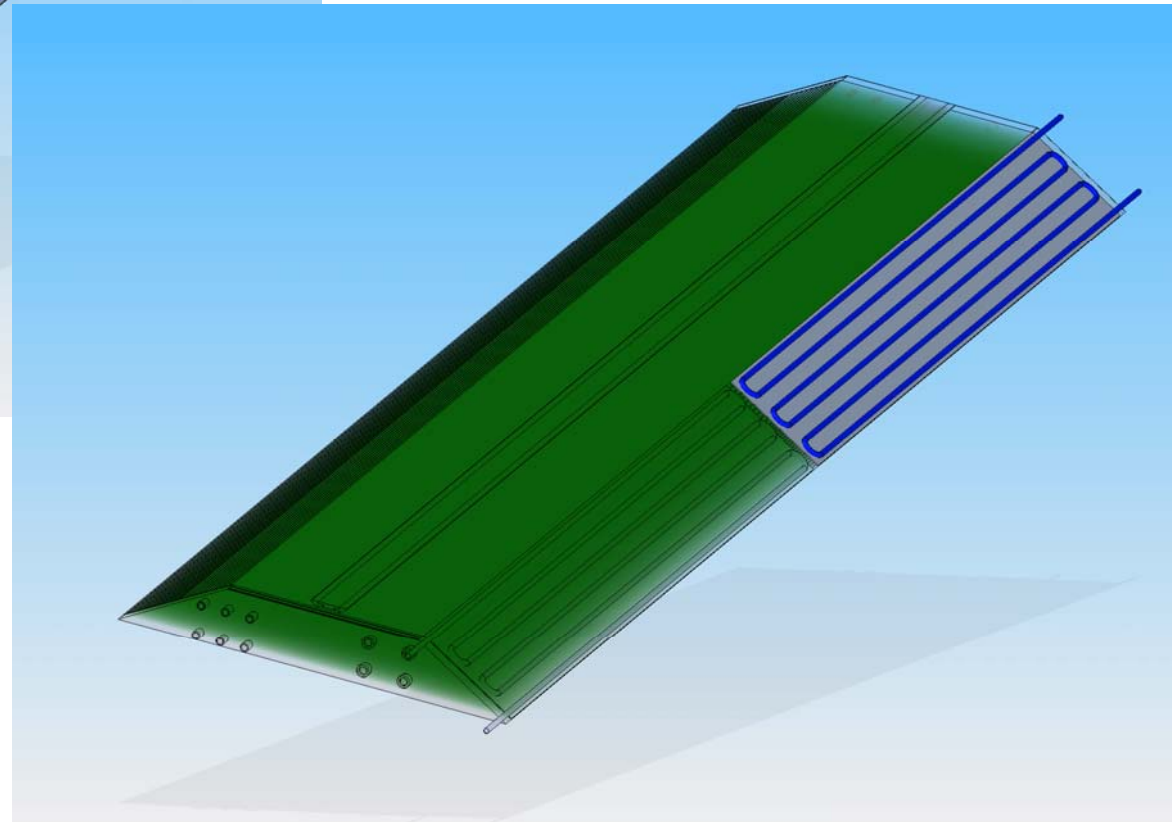
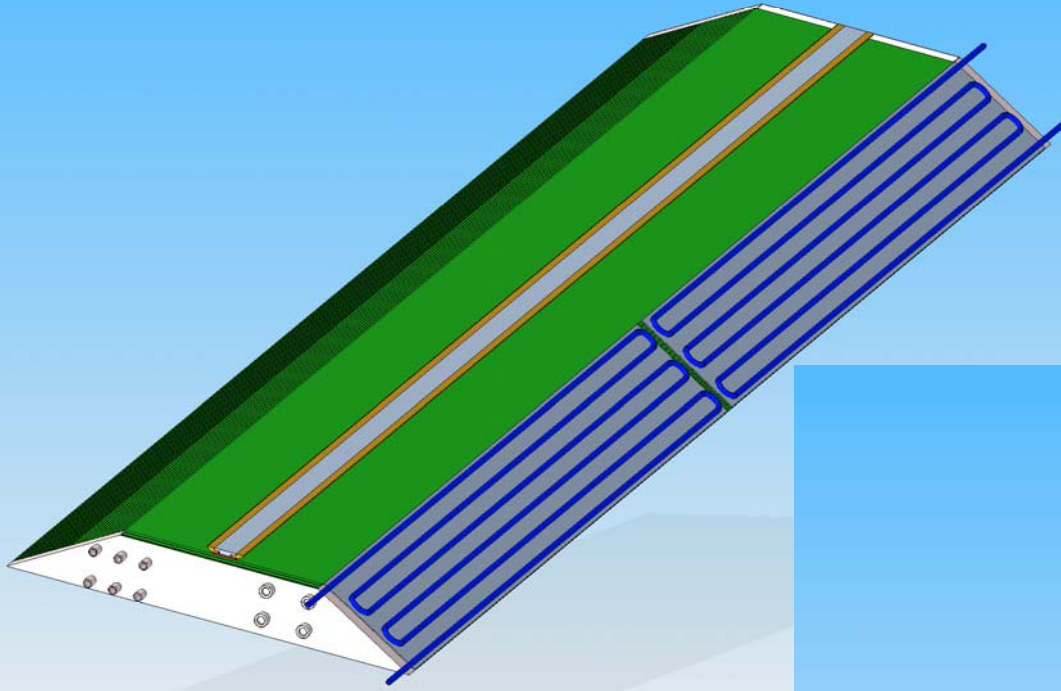
## Cooling

Electronic operated in pulsed mode -> 20mW per chip

Total heat load per wedge module 115 Watt

Active cooling required (each sub detector must remove the heat produced)

Cold plate with water pipes routed laterally of the wedge



Heat load is OK and can be removed at an edge – studies in progress.

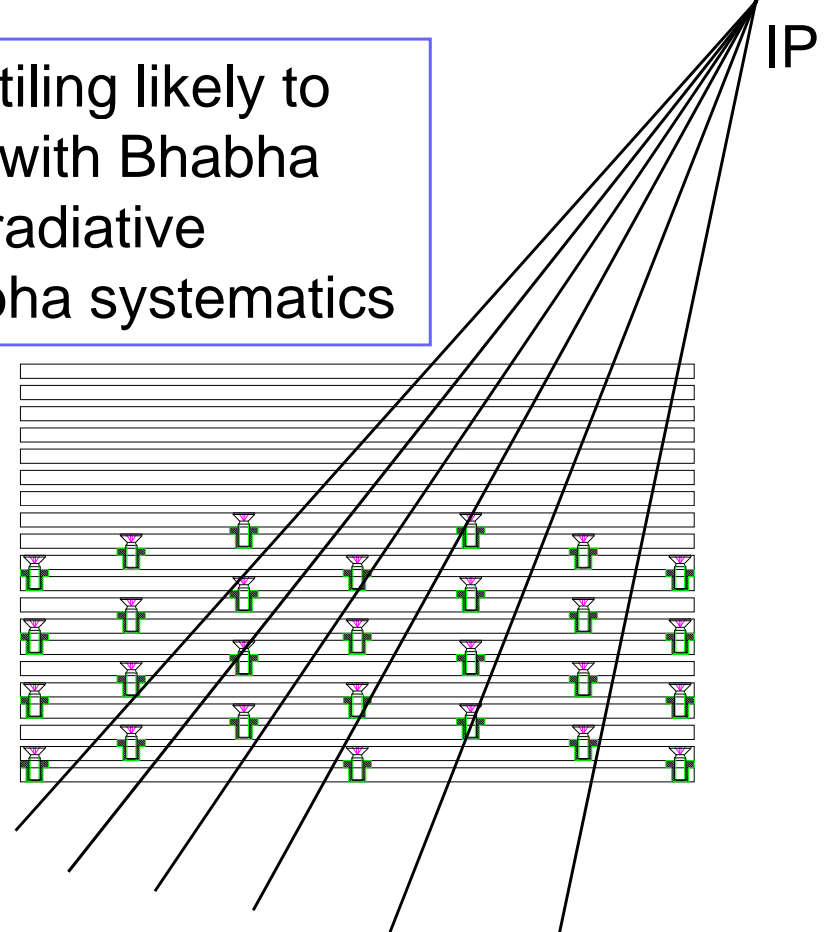
# Oriunno --preliminary

Mechanical connections between W plates as in the barrel wedges

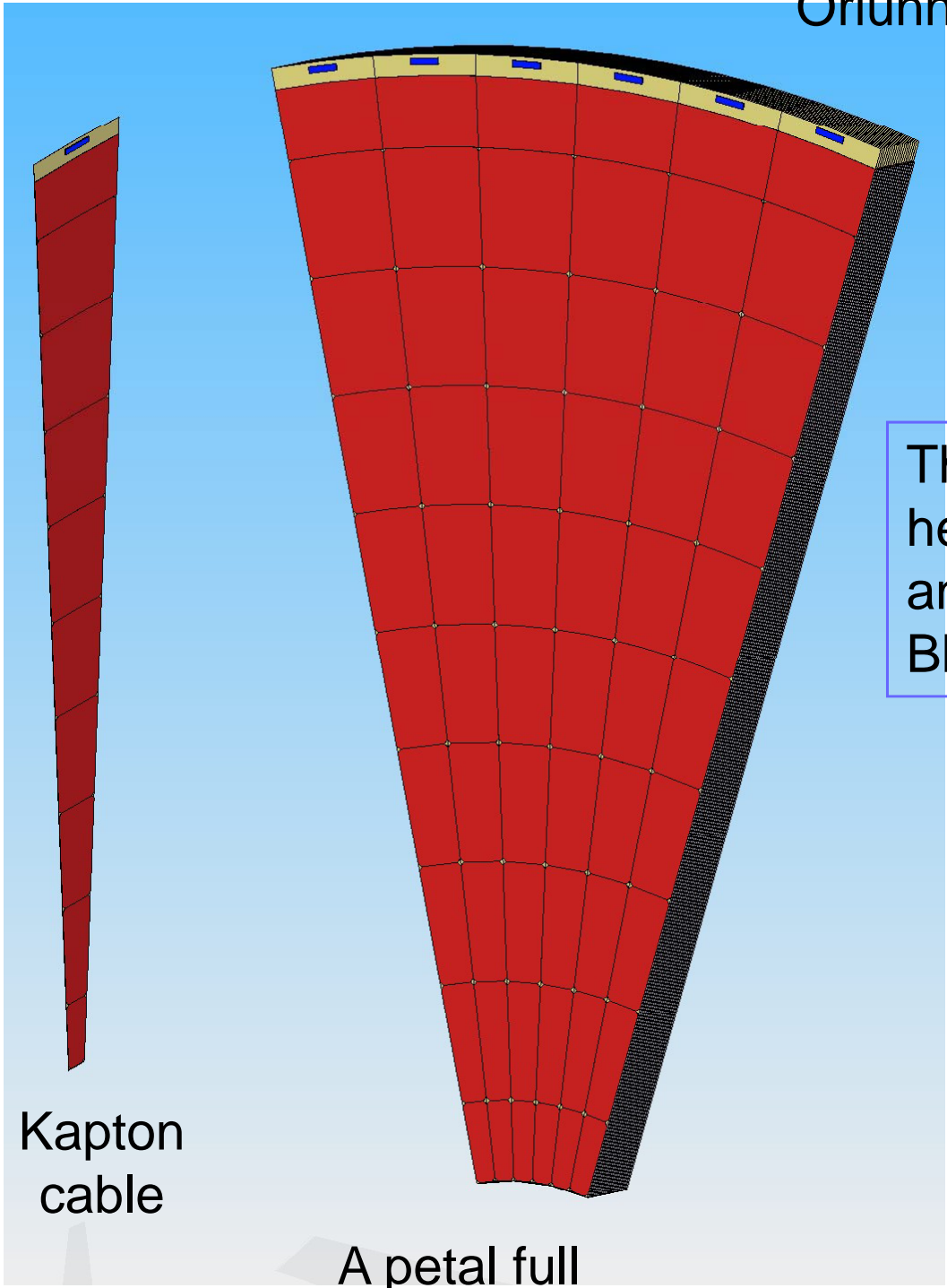
Not all the screws in the name planes need to be used

Some projectivity on the dead space, mitigated by the coiling due to B and the offset of the IP

This tiling likely to help with Bhabha and radiative Bhabha systematics



particles



Kapton cable

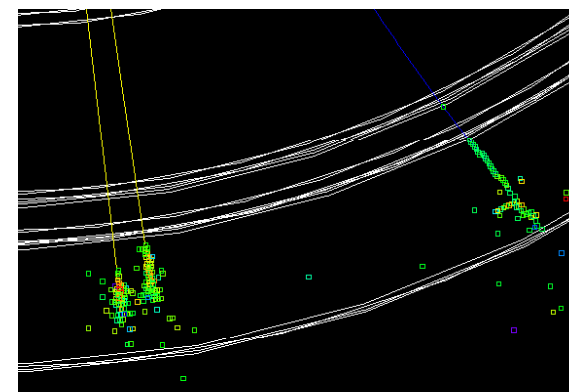
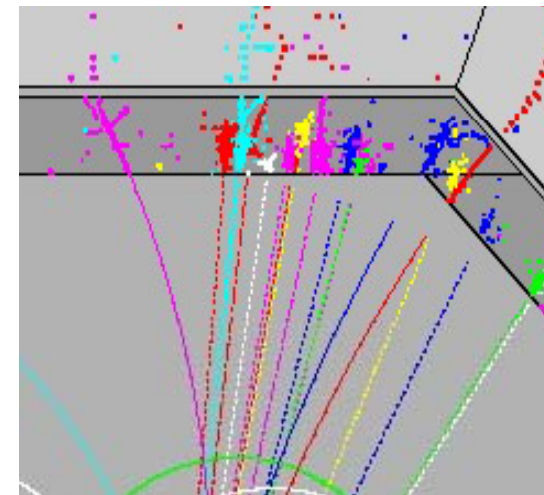
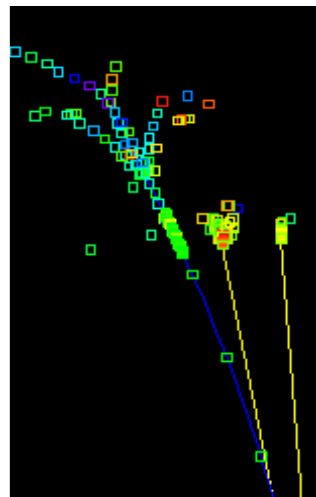
A petal full assembled

# Physics, ECal, LOI

Guiding principles: Measure all final states and measure with precision

- Multi-jet final states
  - $\pi^0$  measurement should not limit jet resolution
  - id and measure  $h^0$  and  $h^\pm$  showers
  - track charged particles
- Tau id and analysis
- Photons
  - Energy resolution, e.g.  $h \rightarrow \gamma\gamma$
  - Vertexing of photons ( $\sigma_b \sim 1$  cm), e.g. for GMSB
- Electron id
- Bhabhas and Bhabha acollinearity
- Hermiticity

⇒ Imaging Ecalorimetry can do all this



# tau id and polarization

- Analysis of tau final states can provide crucial information on new physics
- Important & broad example:  $e^+e^- \rightarrow \tilde{\tau}_1^+ \tilde{\tau}_1^-$  ,  $\tilde{\tau}_1^\pm \rightarrow \tilde{\chi}_1^0 \tau^\pm$
- The SUSY model leaves fingerprint on tau polarization:

$$\tilde{\chi}_1 = N_{11}\tilde{B} + N_{12}\tilde{W} + N_{13}\tilde{H}_1 + N_{14}\tilde{H}_2$$

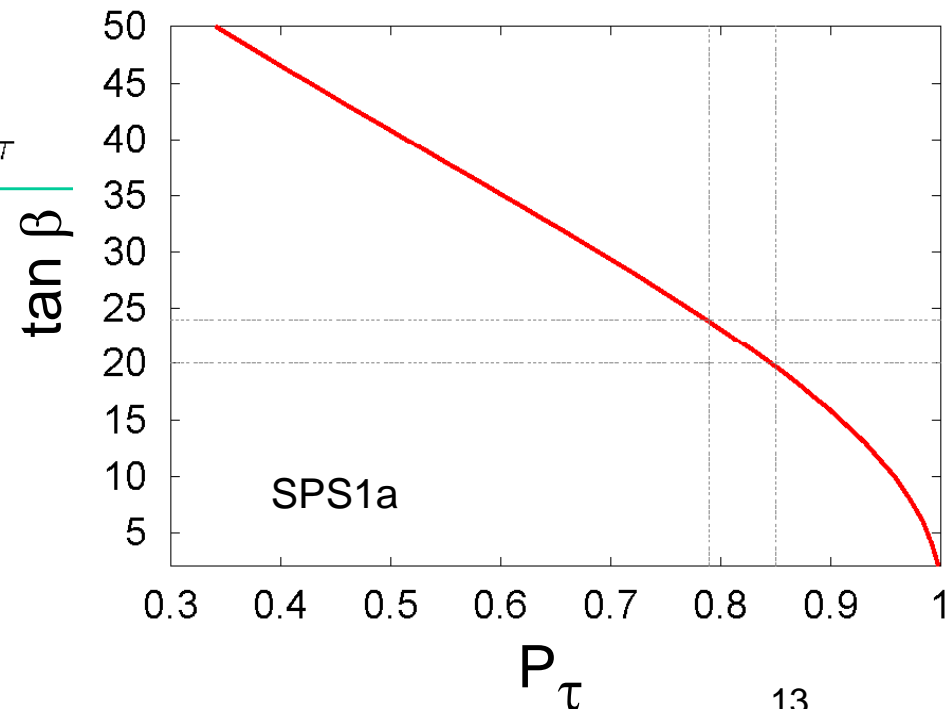
- mSUGRA:  $\tilde{\chi}_1 \sim \tilde{B} \Rightarrow P_\tau \approx +1$
- non-universal SUGRA:  $\tilde{\chi}_1 \sim \tilde{H} \Rightarrow P_\tau \approx \cos^2 \theta_\tau - \sin^2 \theta_\tau$
- AMSB:  $\tilde{\chi}_1 \sim \tilde{W} \Rightarrow P_\tau \approx -1$
- GMSB:  $\tilde{\tau}_1^\pm \rightarrow \tilde{G}_\tau^\pm \Rightarrow P_\tau \approx \sin^2 \theta_\tau - \cos^2 \theta_\tau$

## References:

M. Nojiri, PRD 51 (1995)

E. Boos, et al, EPJC 30 (1993)  $\longrightarrow$

Godbole, Guchait, Roy, Phys Lett B (2005)



# lessons from LEP

**Precision electroweak measurements on the Z resonance.**  
**Phys.Rept.427:257,2006.**

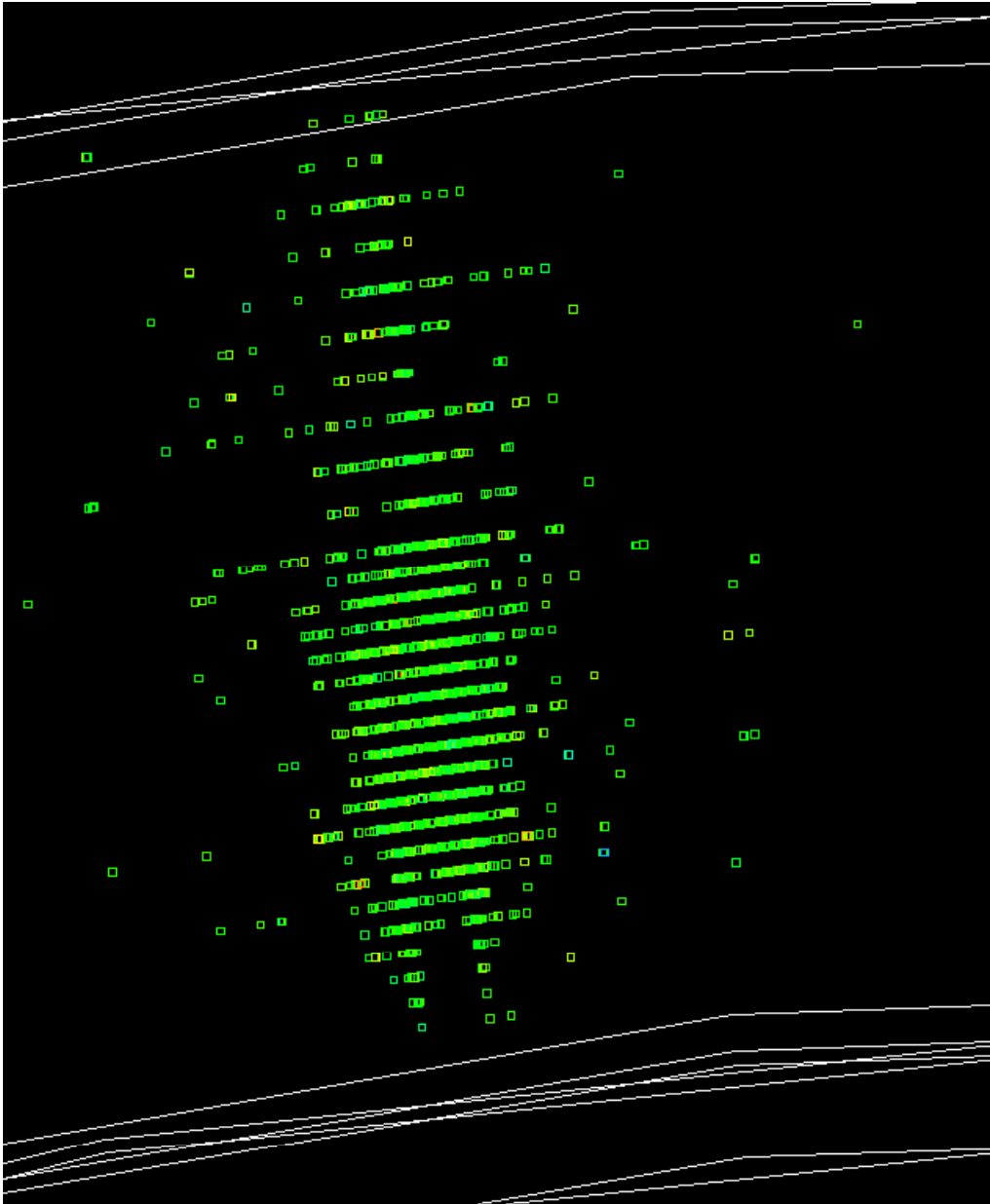
	$\tau \rightarrow \rho\nu$	$\tau \rightarrow \pi\nu$	$\tau \rightarrow e\nu\bar{\nu}$	$\tau \rightarrow \mu\nu\bar{\nu}$	$\tau \rightarrow a_1\nu$ $a_1 \rightarrow \pi^\pm\pi^+\pi^-$
Branching fraction	0.25	0.12	0.18	0.17	0.09
Maximum sensitivity:					
no 3D $\tau$ direction	0.49	0.58	0.22	0.22	0.45
with 3D $\tau$ direction	0.58	0.58	0.27	0.27	0.58
Normalised ideal weight:					
no 3D $\tau$ direction	0.44	0.30	0.06	0.06	0.13
with 3D $\tau$ direction	0.47	0.22	0.07	0.07	0.17

Note that this is LOI  
 physics benchmark #4  
 (at 500 GeV instead of 91)

Need to separate:

- $\tau^+ \rightarrow \rho^+\nu$  ( $\pi^+\pi^0\nu$ ) [most powerful]
- $\tau^+ \rightarrow \pi^+\nu$  ( $\pi^+\nu$ )
- $\tau^+ \rightarrow a_1^+\nu$  ( $\pi^+\pi^+\pi^-\nu$ ,  $\pi^+\pi^0\pi^0\nu$ )

# Do we need < few mm segmentation?



- EM showers are narrower than  $R_m$  for the first few radiation lengths.
- $\pi^0$  id and reconstruction are important, perhaps crucial:
  - Jet resolution
    - Graham Wilson algorithm
  - Tau id and analysis
  - Flavor tagging ??
- Future option: few layers of MAPS ?
  - This avoids saturating the MAPS pixels at shower max.

# FNAL 10/07: 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;  $\pi^0$  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?



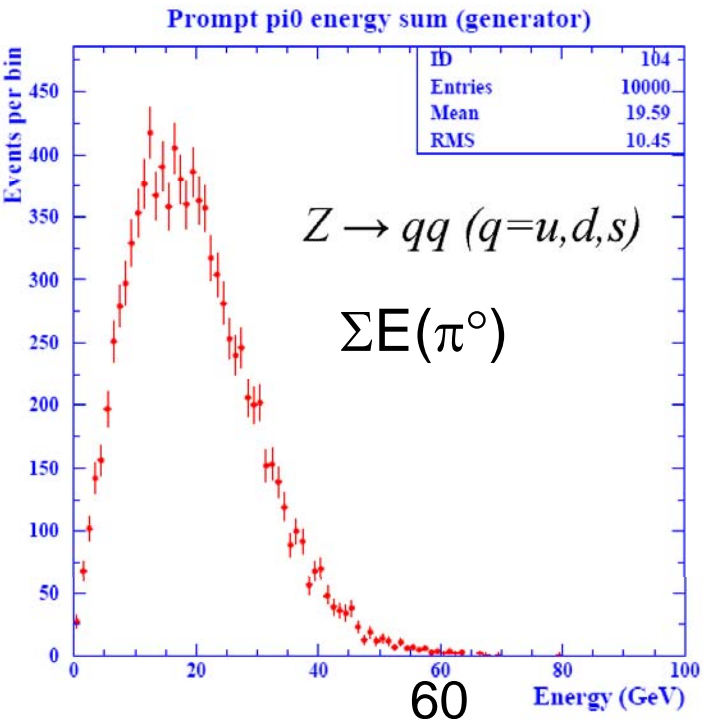
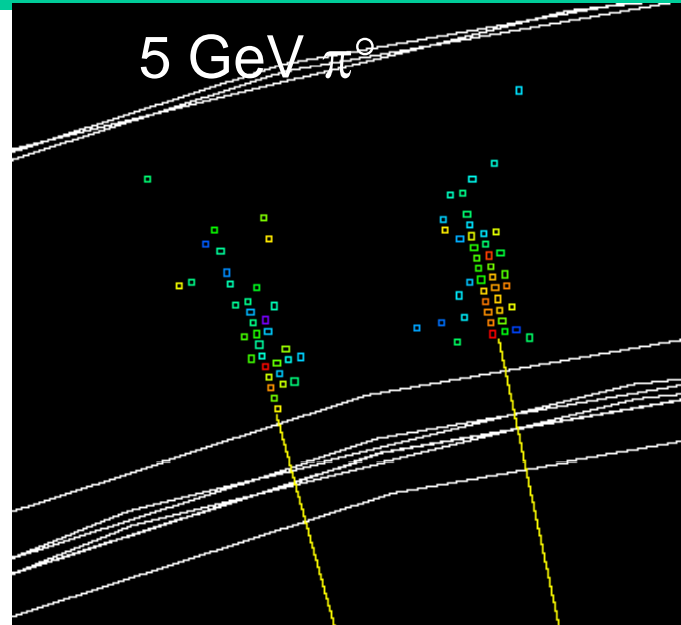
# ECal performance plots/results for LOI

- Energy resolution for isolated photons/electrons
  - This ~exists in DOD – needs to be checked, updated, improved (RF)
- Photon finding efficiency (in jets – need to define process)
  - This ~exists from PFA algorithms
  - But SiD versions not so good
  - What can we do for the LOI ?
- Radiative Bhabha measurement and/or Bhabha acollinearity ??
- Track finding seeded by Ecal (eg K0s) – in tracking section??
- Vertexing of photons (eg GM Susy) ??
- $\pi^0$  reconstruction efficiency
  - in jets (allows improvement of jet energy measurement)
  - in tau's – this is the key for tau decay mode reconstruction (bench #4)
  - This is untouched in SiD (maybe also in ILD?)
  - Good benchmark for understanding impact of segmentation
- Benchmark #4 (see above)

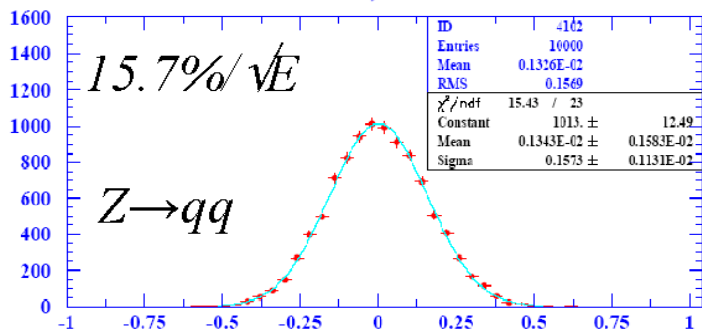
# Improving jet resolution

Graham Wilson

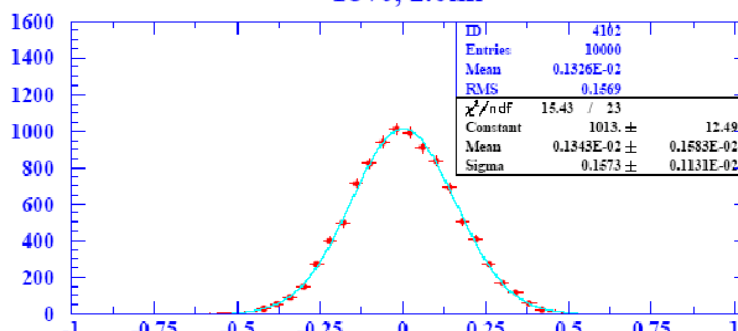
Use  $\pi^0$  mass constraint to improve jet energy resolution



16%, 0.5mr

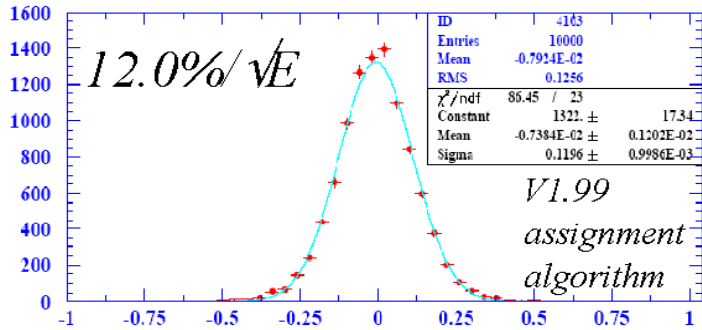


16%, 2.0mr



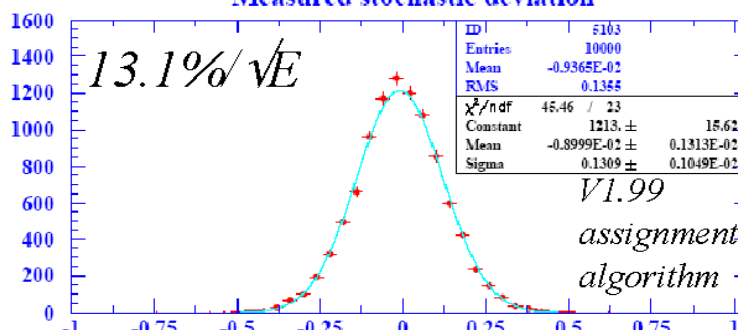
no constraint

Measured stochastic deviation



Fitted stochastic deviation

Measured stochastic deviation



Fitted stochastic deviation

with constraint

# What R&D needs to be done now? post-LOI ?

- baseline option – what is needed to demonstrate readiness for “RDR”
  - Fabricate a functional test module with the real elements
    - KPiX-1024 bump-bonded to sensors
    - Test in a beam with good noise performance
  - Long flexcables
  - Thermal management with mechanical prototype and correct time structure
- Baseline: What could/should be done for LOI
  - Demonstrate good bump-bonding (KPiX prototypes)
  - Long flexcables proof of principle
  - Clear measure of acceptable KPiX noise performance
- MAPS....

# Other LOI items

- IDAG (1): “sensitivity to machine backgrounds as characterized in the MDI panel”
  - Takashi: help!
- IDAG(2): calibration and alignment schemes
  - Calibration was discussed some at the WWS calorimeter review at DESY (June 2007)
  - Needs to be reviewed, discussed, etc

# Summary

- Two technical approaches:
  - Baseline: Si diode sensors with integrated (KPiX) electronics
  - MAPS (terapixel) – completely integrated
- There has been good, steady progress.
- 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.

# Generic technical considerations

- Small readout gap
  - Maintains small Moliere radius, hence performance
  - Big impact on cost
  - $\approx 1$  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 ( $\approx 75$  cm) via the tungsten radiator results in a few  $^{\circ}\text{C}$  temperature increase ⇒ OK !
  - for (B), this is an open question

# Si/W (default option) R&D Collaboration

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Y. Karyotakis  
*LAPP Annecy*

- KPiX readout chip
- downstream readout
- mechanical design and integration
- detector development
- readout electronics
- readout electronics
- cable development
- bump bonding
- mechanical design and integration