The ECal in the SiD LOI

R. Frey (Oregon) for the ECal group

- Overview of status and progress
  - Silicon/tungsten concept
  - Technical options: Si sensors (baseline) and/or MAPS
  - baseline 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 ≈13 mm)

B) MAPS active CMOS pixels   (Terapixel option)

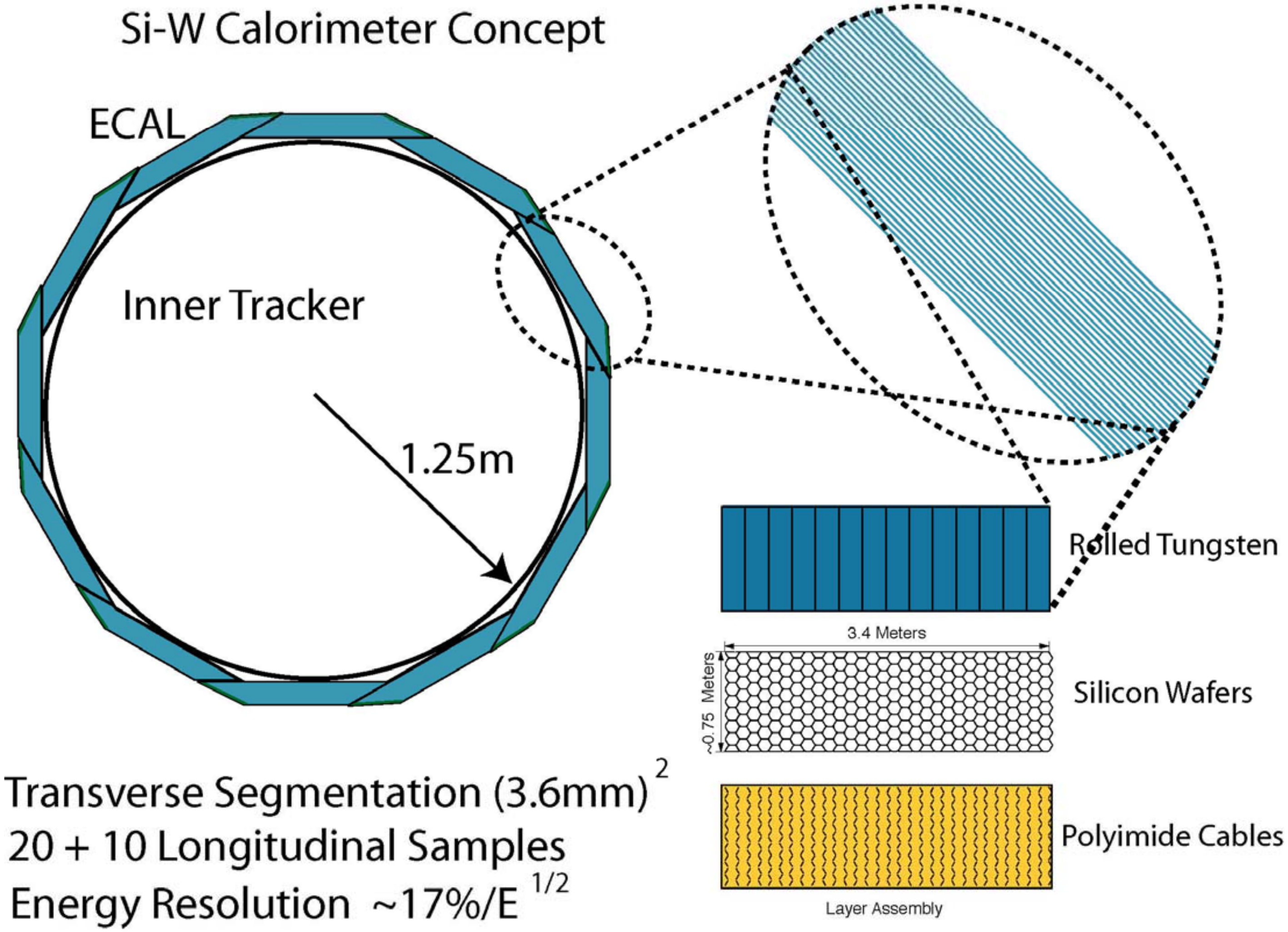
Transverse segmentation 0.05 mm   (Moliere radius ≈13 mm)

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

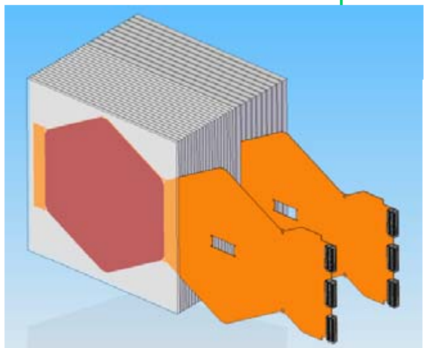


<u>SiD02 configuration:</u>

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

baseline Si/W 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.



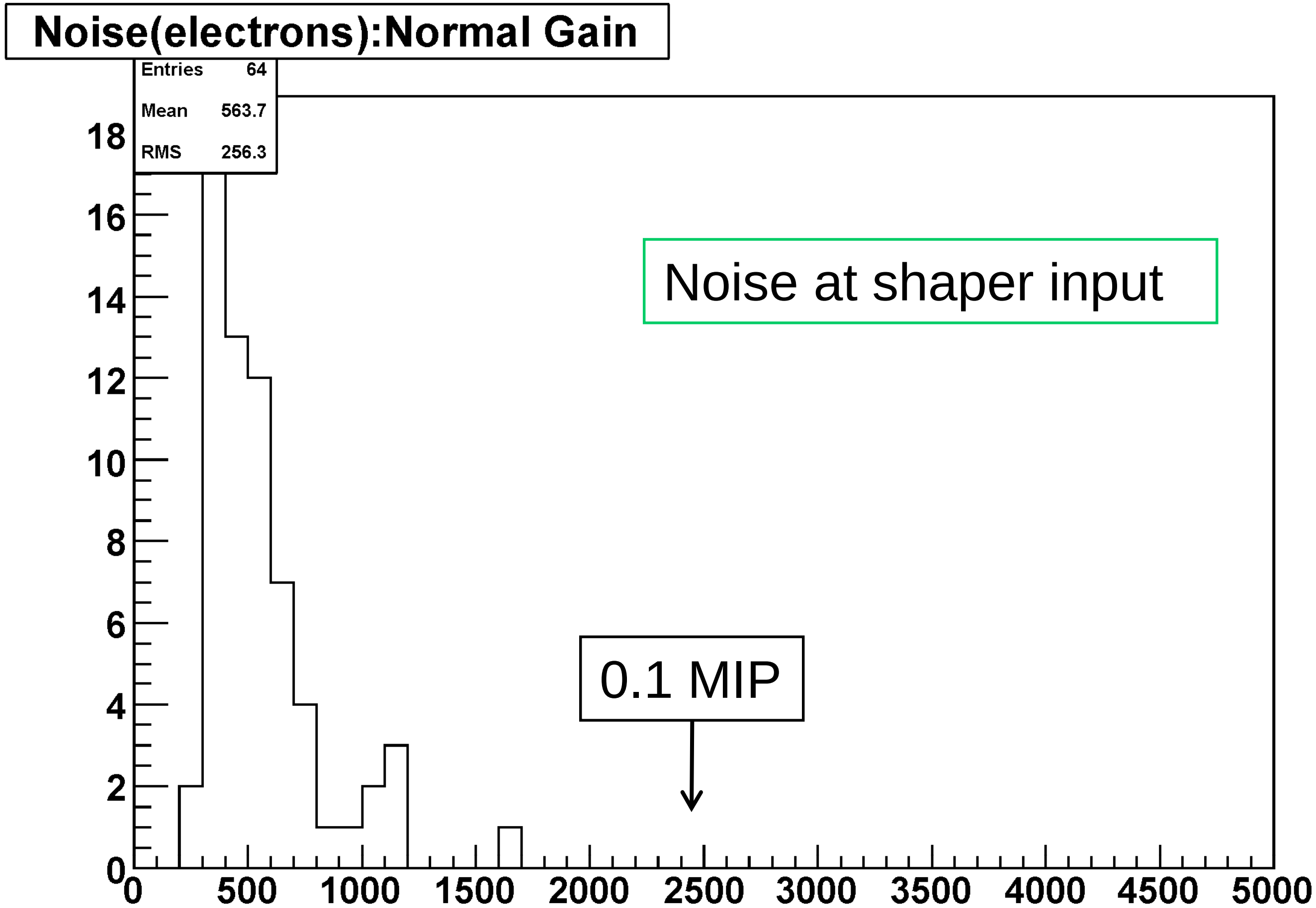
- Require 1024-channel KPiX ASIC chips
  - Latest 64-chan prototypes (KPiX-7) OK for Calor.
    - See Gunther Haller talk
- Silicon sensors
  - Procured 40 v2 sensors (+ 20 “NG” sensors) from Hamamatsu
- Bonding of KPiX to Si sensors
  - First trials completed (gold bump-bonds)
- Tungsten – in hand

SiD LOI: The above plus…

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

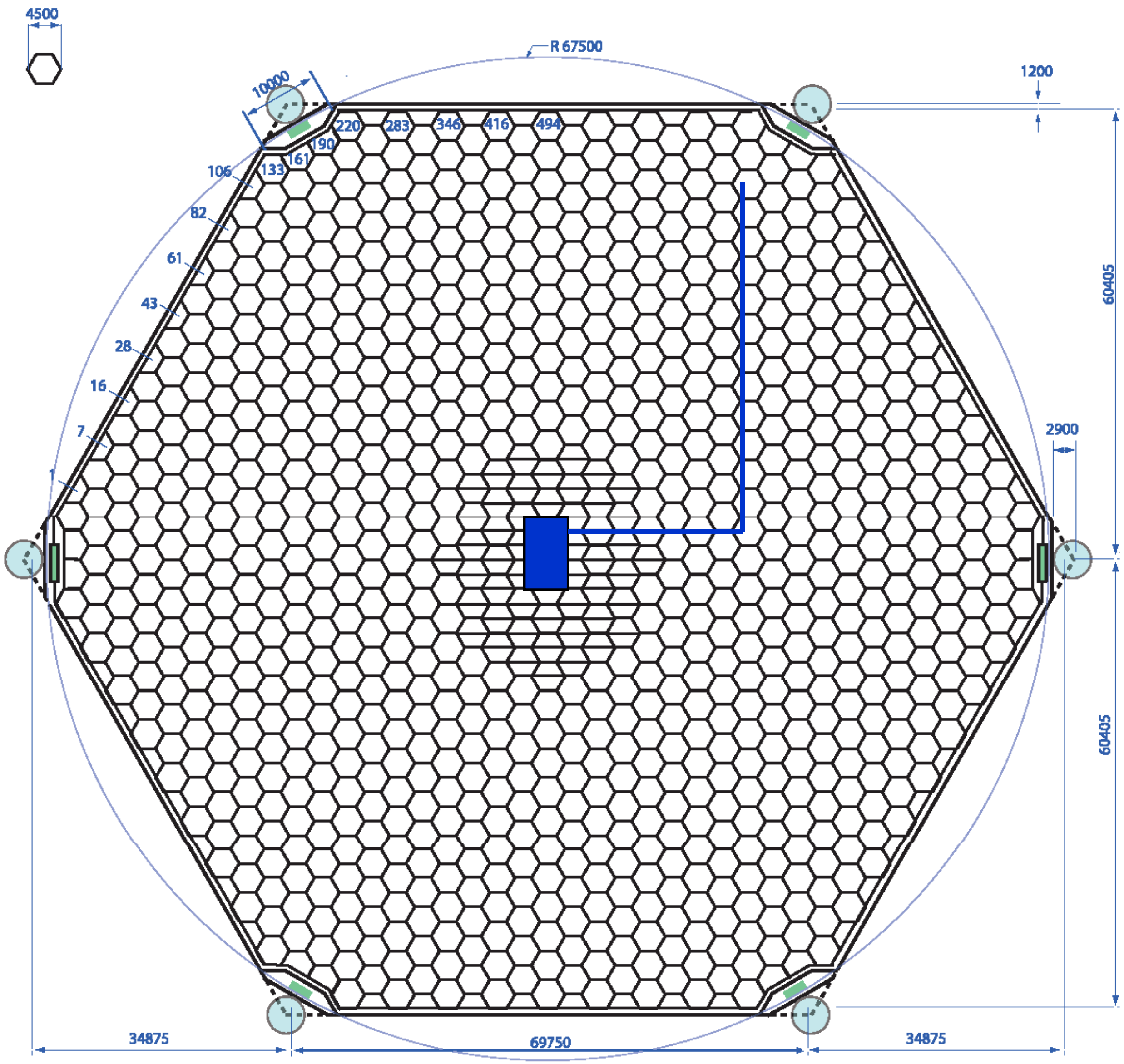
KPiX-7

The latest KPiX prototype’s performance deemed good enough for the ECal.



See Gunther’s talk…

v2 Si sensors

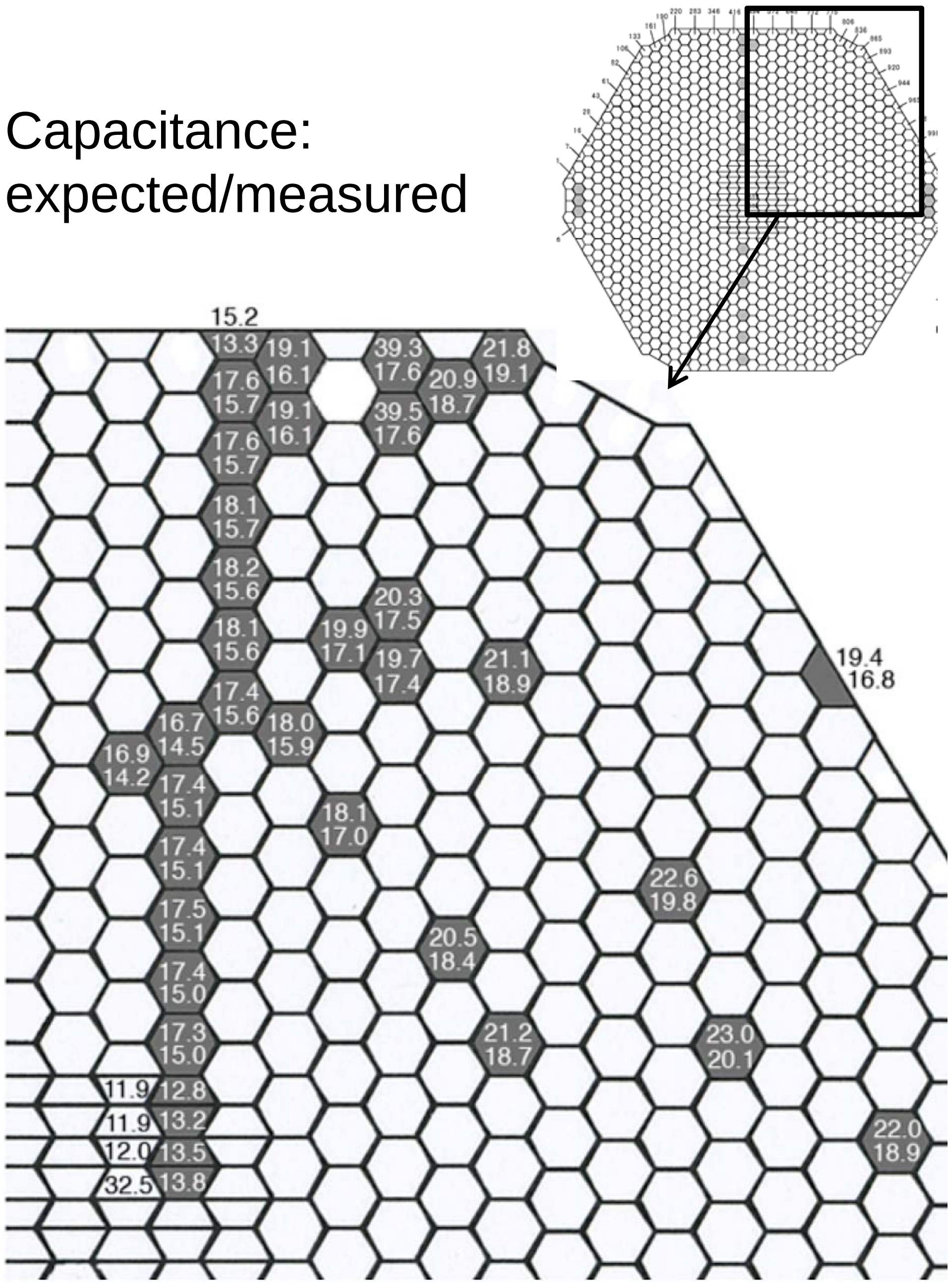


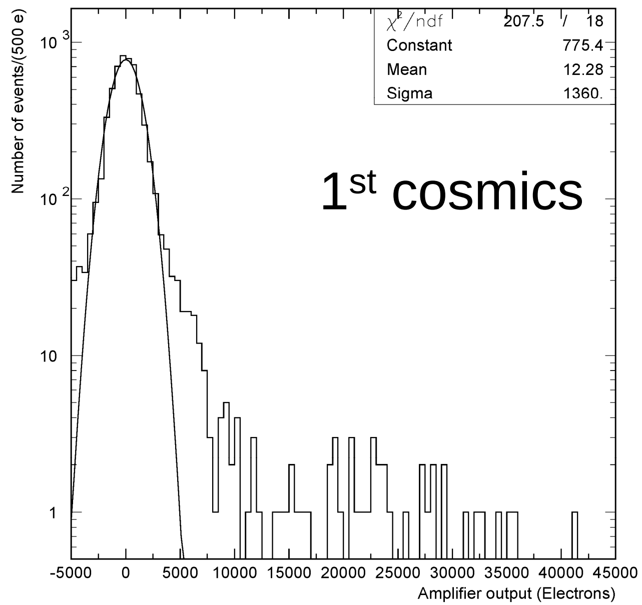
- 6 inch wafer
- 1024 13 mm^2 pixels
- improved trace layout and split pixels near KPiX to reduce capacitance
- 40 good + 20 NG sensors in hand, Hamamatsu

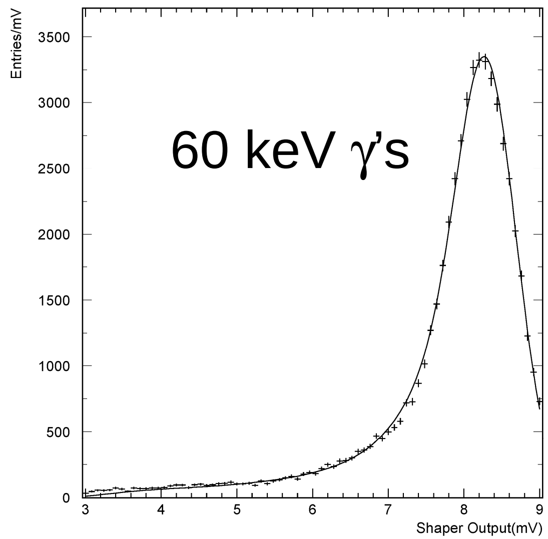
KPiX ASIC and sample trace

New sensors: initial studies

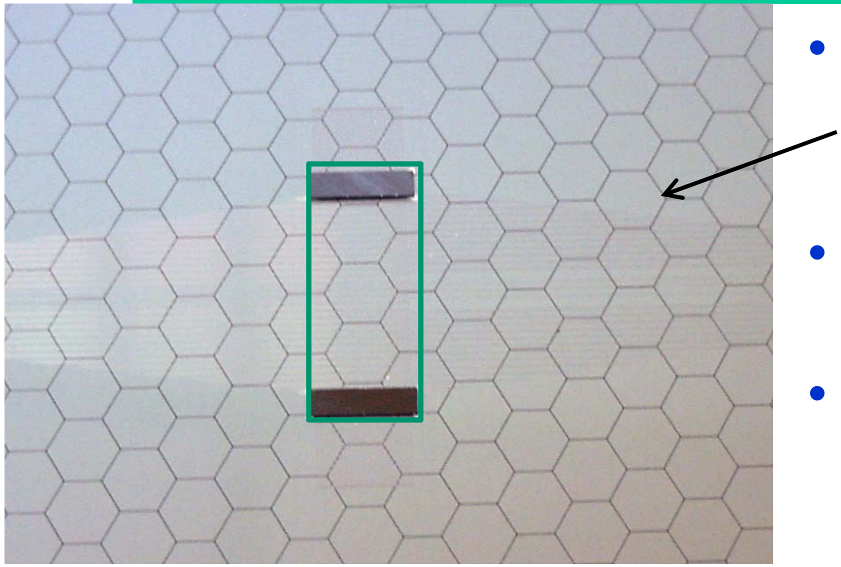
Capacitance:
expected/measured



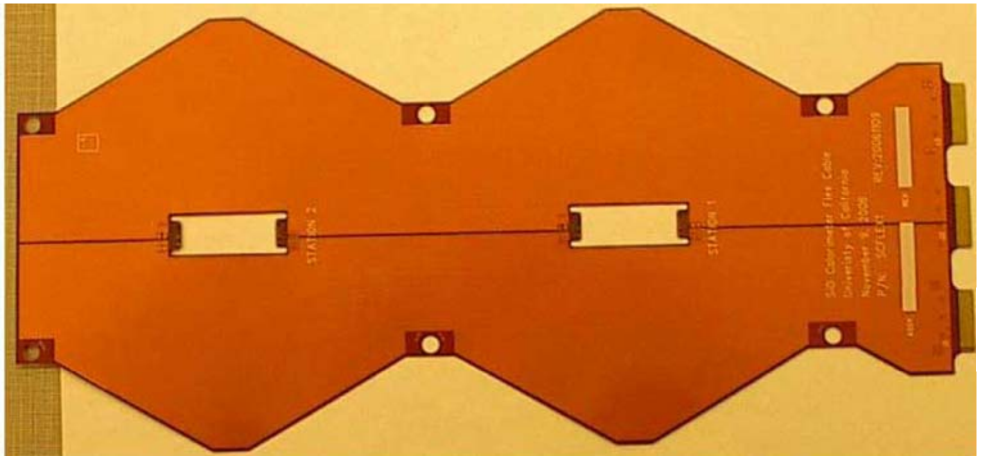




Interconnections (Davis)



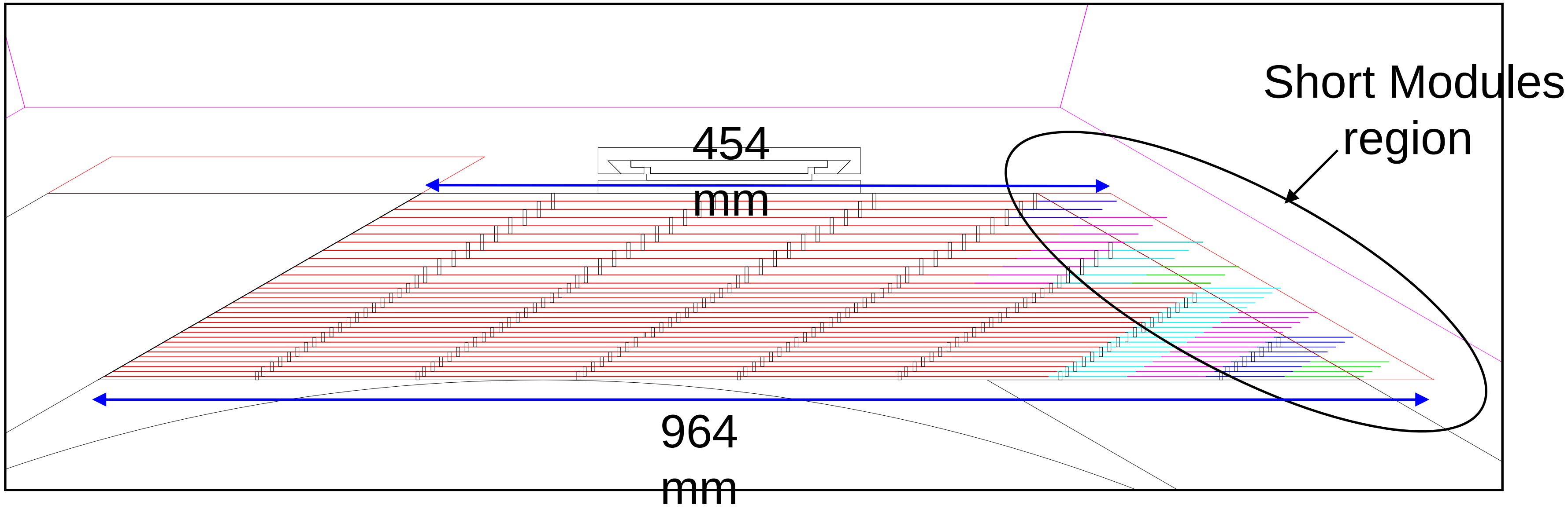
- Initial gold-stud bump-bonding trials had mixed results $\rightarrow$ consistent with surface oxidation
- Trials using titanium-tungsten treatment with dummies looks good
- Trials with KPiX-7 and Hama sensors with Ti-W to begin soon (Palomar Tech)

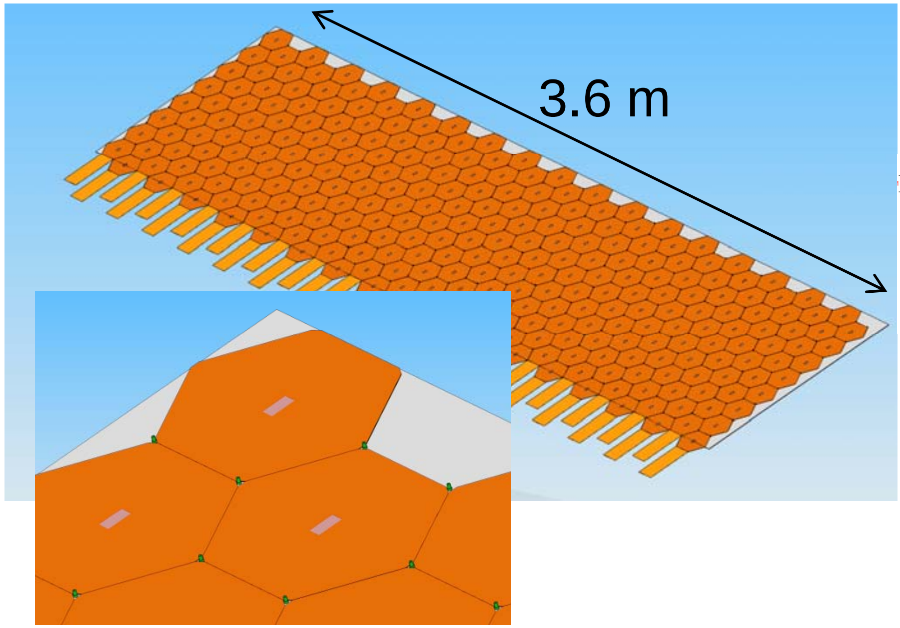


Flexcable – sensor connection technology (ACF) looks promising. Jig being built at Davis.

The flexcables will now need to be longer…

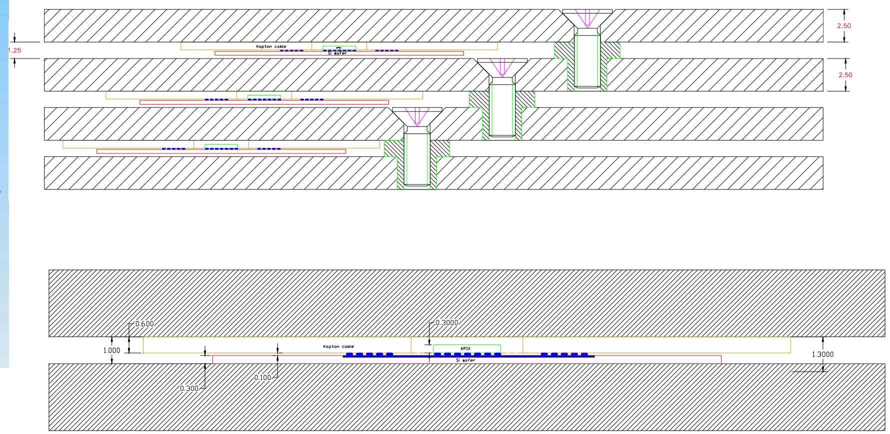
Emcal Barrel Mechanical design progress

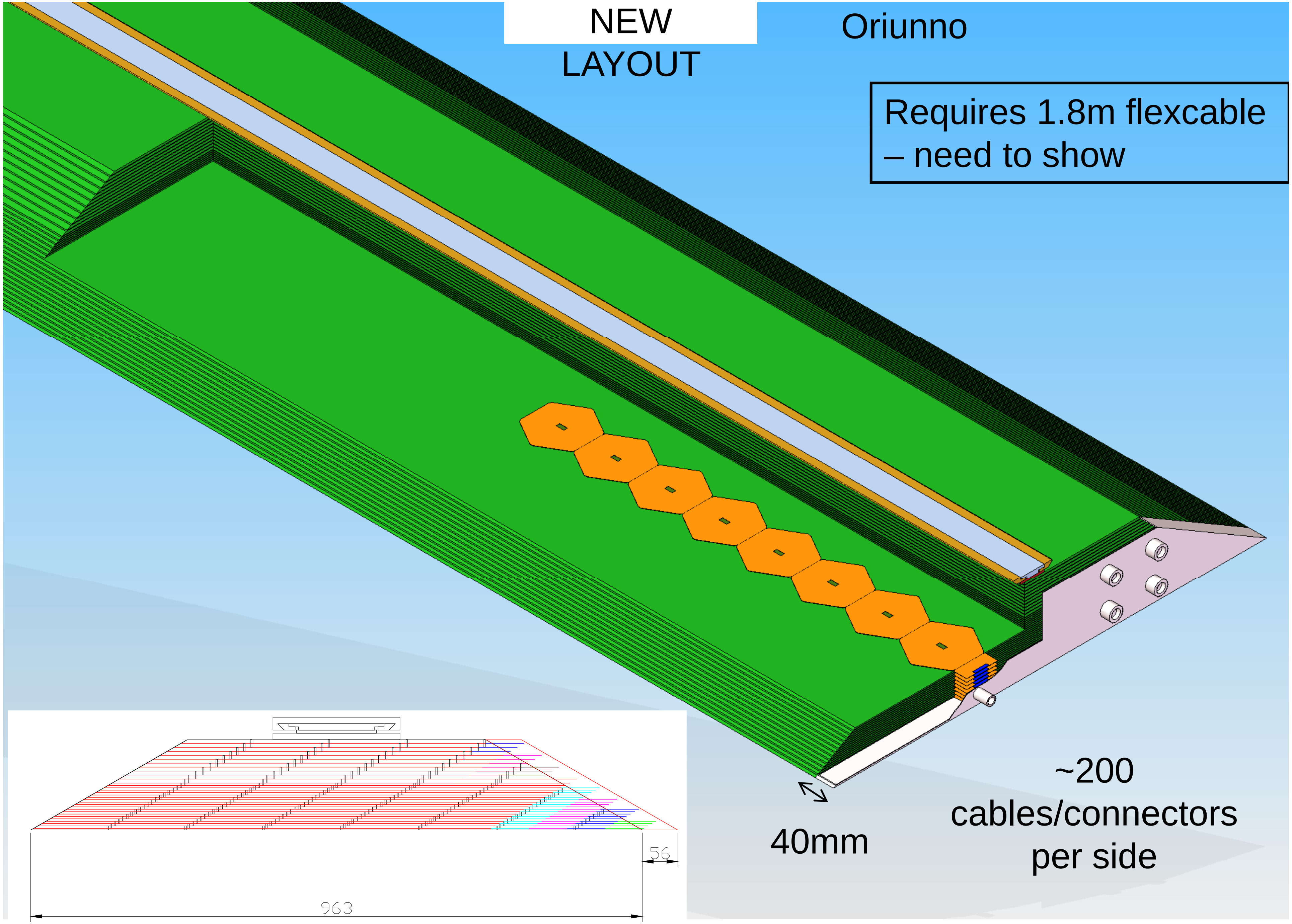




Staggered layout

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
56
963

Cooling

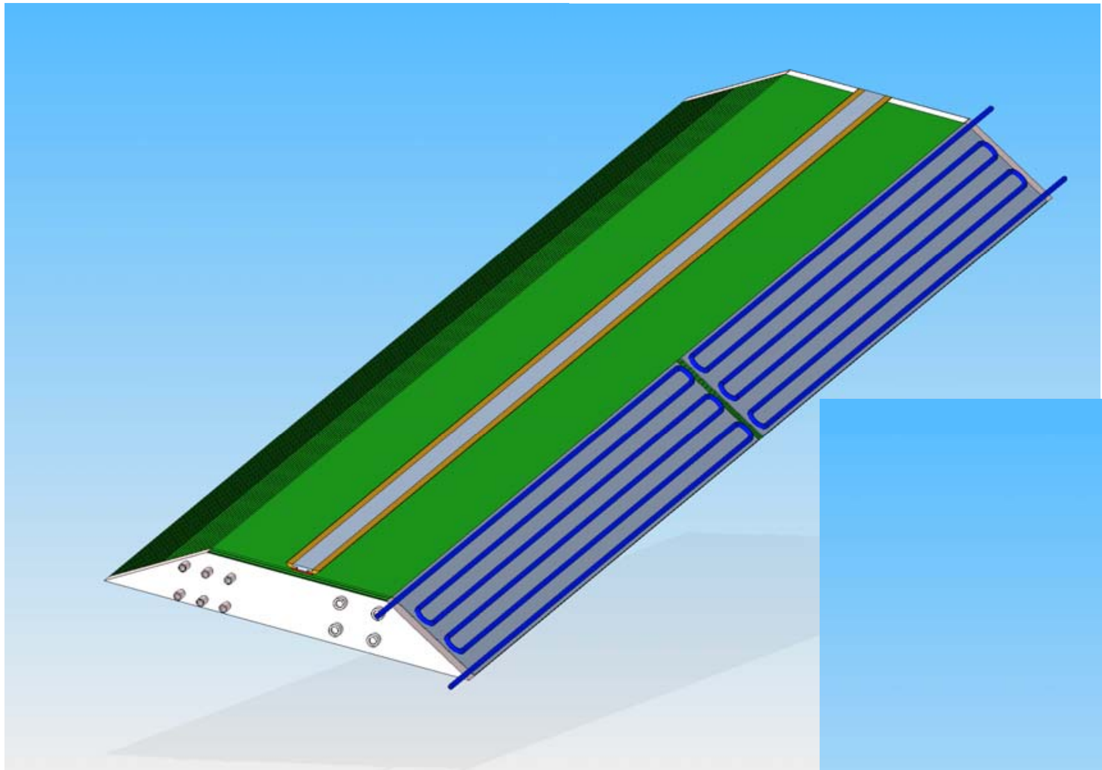
Cooling

Electronic operated in pulsed mode -> 20mW per chip

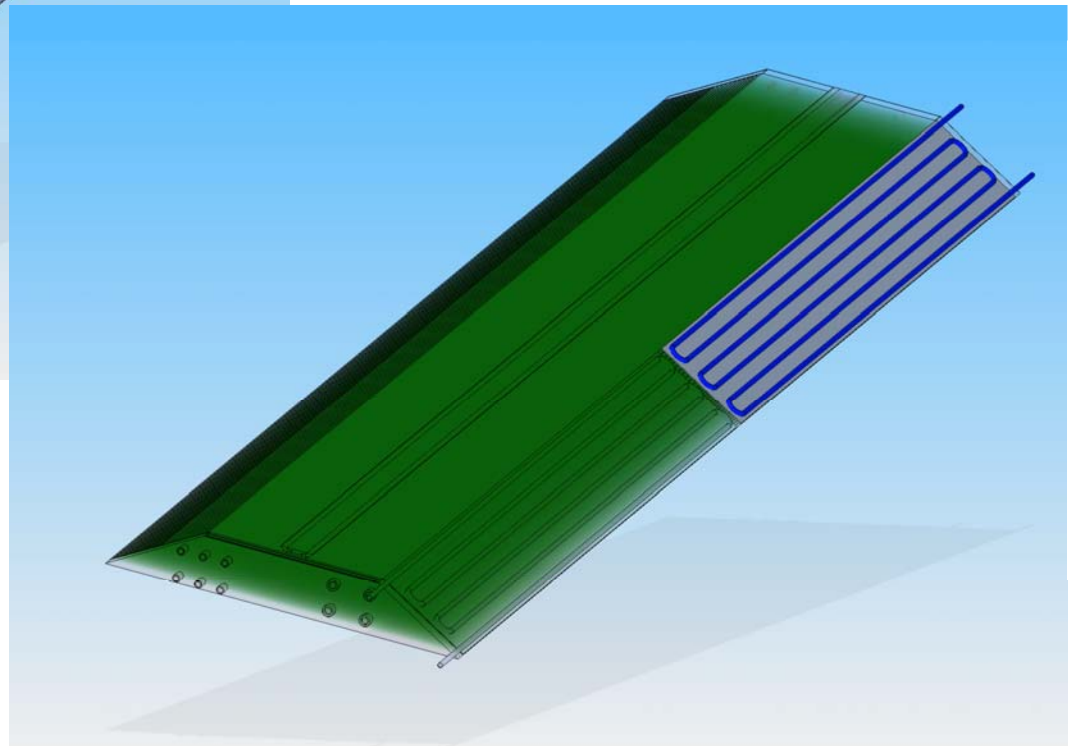
Total heat load per wedge module 115 Watt

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

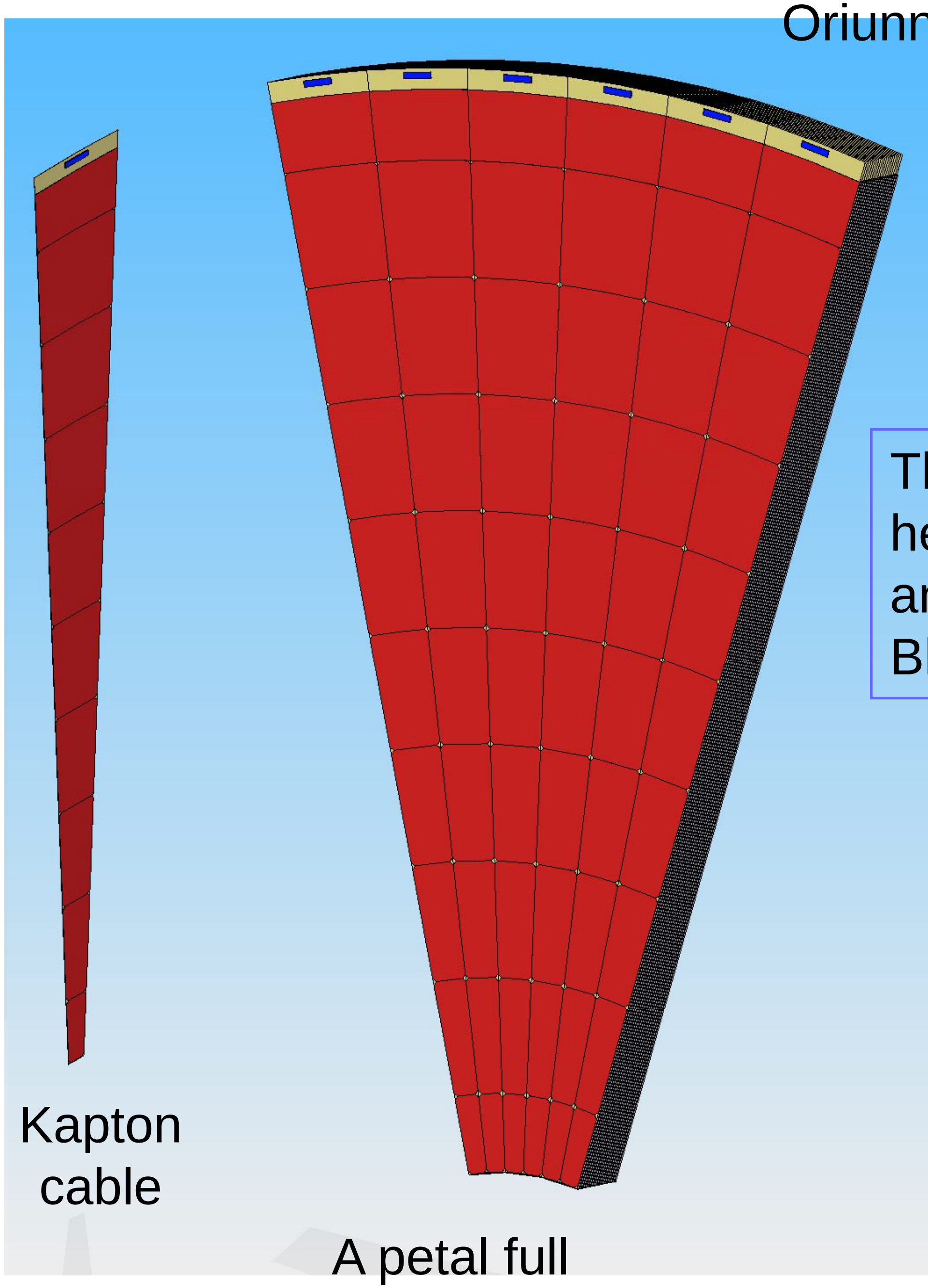
Cold plate with water pipes routed laterally of the wedge



Heat load (115 W) is OK and can be removed at an edge – studies in progress.



Oriunno --preliminary

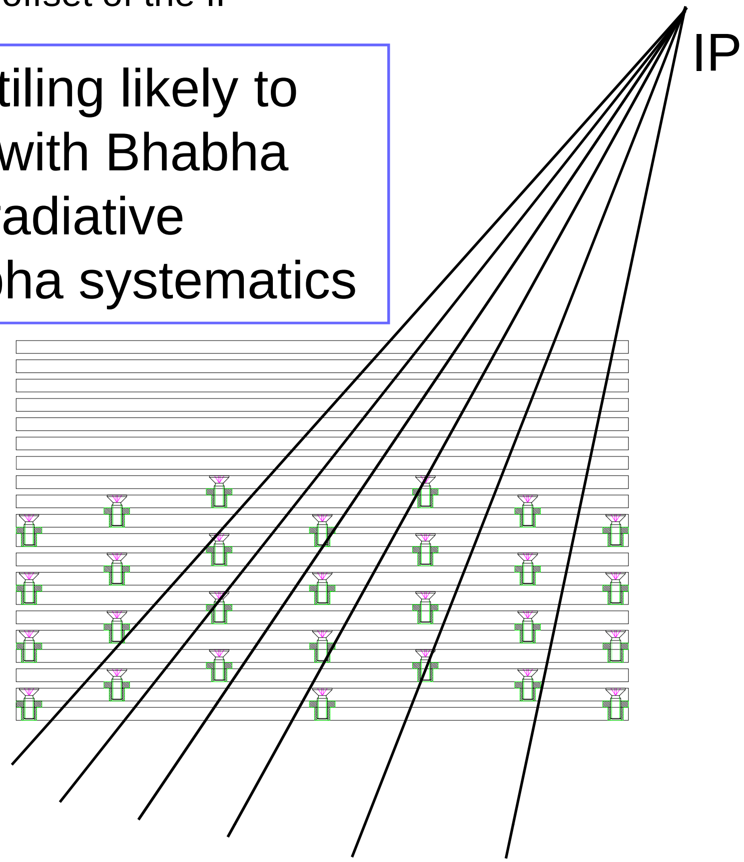


Mechanical connections between W plates as in the barrel wedges

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

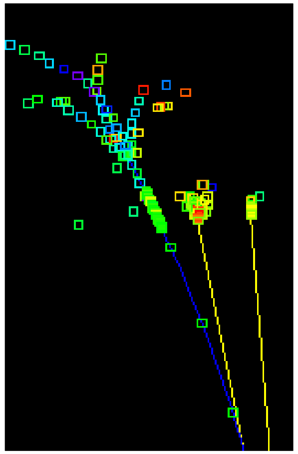
This tiling likely to help with Bhabha and radiative Bhabha systematics

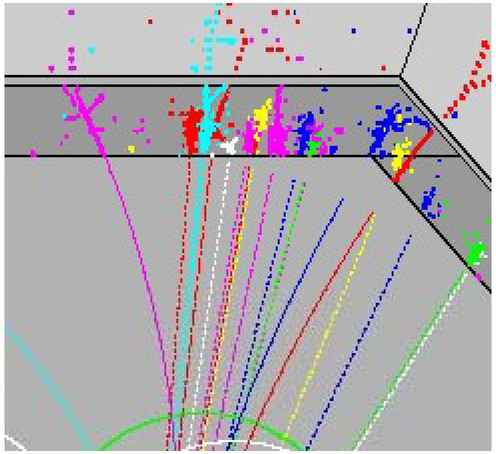


Physics, ECal, LOI

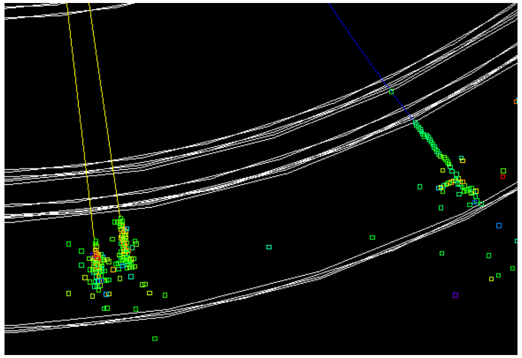
Guiding principles: Measure all final states and measure with precision

- 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 ($\sigma_b \sim 1$ cm), e.g. for GMSB
- Electron id
- Bhabhas and Bhabha acollinearity
- Hermiticity



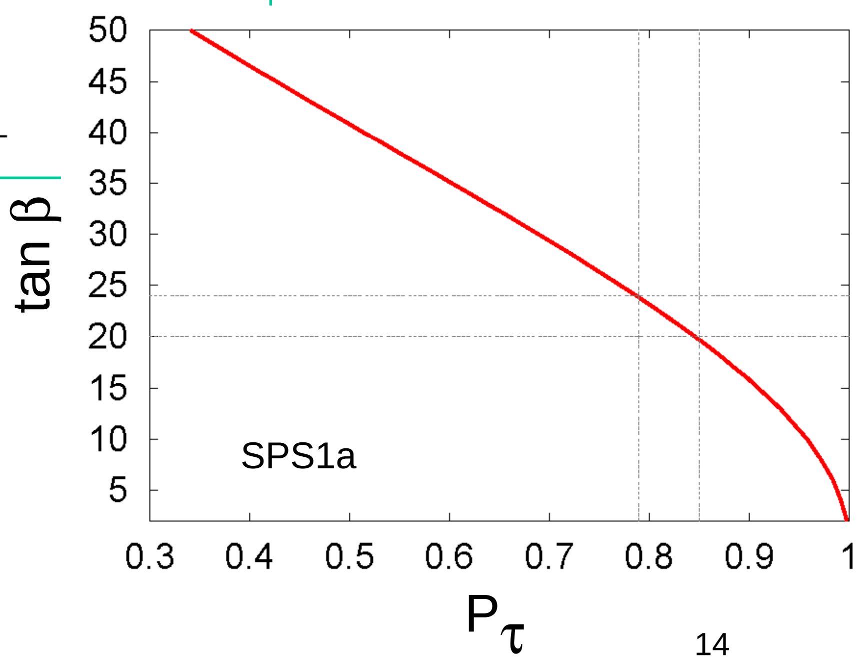
$\Rightarrow$ Imaging Ecalorimetry can do all this

tau id and polarization

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

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

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



References:

M. Nojiri, PRD 51 (1995)

E. Boos, et al, EPJC 30 (1993)

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

lessons from LEP

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

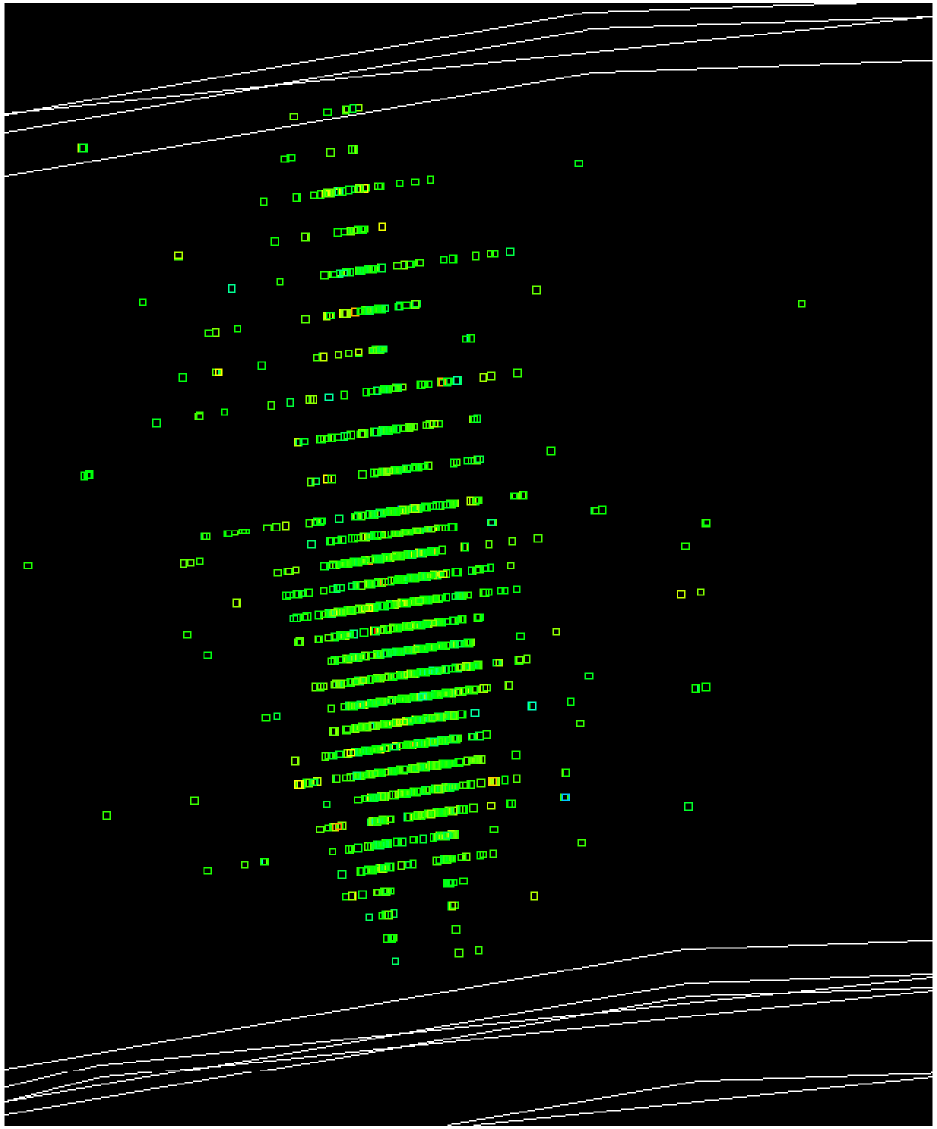
	$\tau \to \rho\nu$	$\tau \to \pi\nu$	$\tau \to e\nu\overline{\nu}$	$\tau \to \mu\nu\overline{\nu}$	$\tau \to a_1\nu$ $a_1 \to \pi^\pm\pi^+\pi^-$
Branching fraction	0.25	0.12	0.18	0.17	0.09
Maximum sensitivity:					
no 3D τ direction	0.49	0.58	0.22	0.22	0.45
with 3D τ direction	0.58	0.58	0.27	0.27	0.58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

- $\tau^+ \to \rho^+\nu$ $(\pi^+\pi^o\nu)$ [most powerful]
- $\tau^+ \to \pi^+\nu$ $(\pi^+\nu)$
- $\tau^+ \to a_1^{\ +}\nu$ $(\pi^+\pi^+\pi^-\nu,\ \pi^+\pi^o\pi^o\nu)$

MAPS: Do we need < few mm segmentation?



- EM showers are narrower than R_m for the first few radiation lengths.
- π° id and reconstruction are important, perhaps crucial:
  - Jet resolution
    - Graham Wilson algorithm
  - Tau id and analysis
  - Flavor tagging ??
- Few layers of MAPS is one option
- Improved energy resolution?

- Need to justify – can be part of a general need we have to develop our physics case for segmentation.

ECal performance plots/results for LOI (wish list)

- 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 (imho)
  - 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) ??
- pi0 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
  - Good benchmark for understanding impact of segmentation
- Benchmark #4 (see above)

LOI technology input: R&D now & post-LOI

Baseline:

- R&D needed to demonstrate readiness for “RDR” (2012)
  - 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
  - Mechanical prototype (including thermal demonstration)
- 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:

- Will provide list of milestones to demonstrate readiness to proceed post-2012

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 at the WWS calorimeter review at DESY (June 2007)
    - Needs to be reviewed, discussed, etc for LOI
  - Alignment not expected to be a huge issue

Summary

- The baseline silicon/tungsten ECal: steady technical progress
  - Getting very close to being able to fabricate a full test module.
- MAPS is a potentially attractive option (Dauncey talk)
  - Will be an option in the LOI
  - Technical progress going well; need to work on physics justification

- We need performance and physics studies to brag about our ECal !
  - Need to scramble to pull together a satisfactory offering for LOI.

Si/W (default option) R&D Collaboration

M. Breidenbach, D. Freytag, N. Graf,
R. Herbst, G. Haller, J. Jaros,
T. Nelson, M. Oriunno

Stanford Linear Accelerator Center

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

J. Brau, R. Frey, D. Strom,
B Hafner, A Reinsch, M von Hippel, B Fadness

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

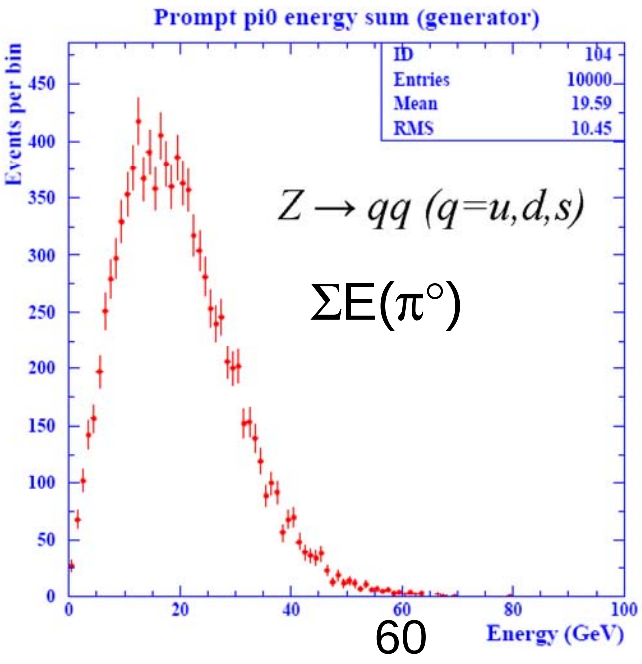
S. Adloff, F. Cadoux, J. Jacquemier,
Y. Karyotakis

LAPP Annecy

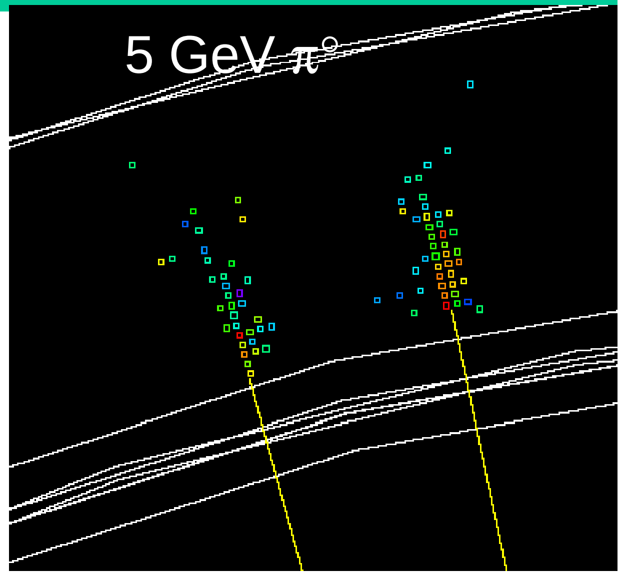
- mechanical design and integration

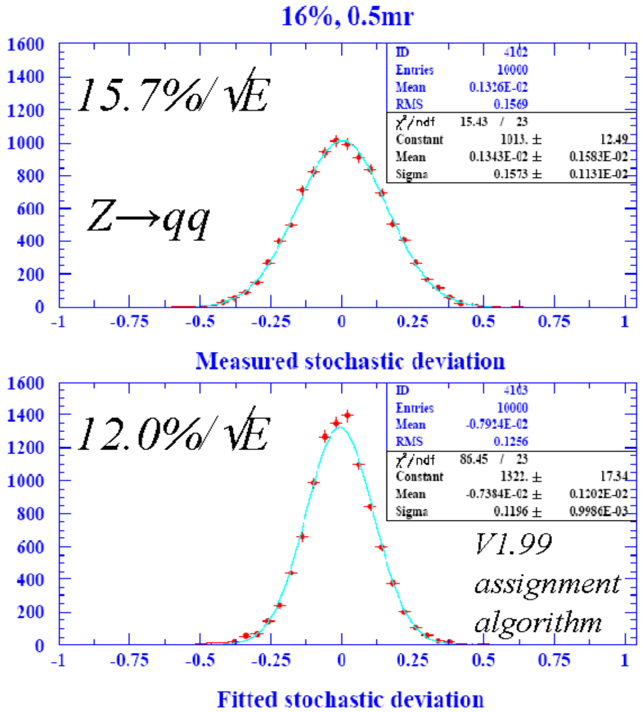
Improving jet resolution

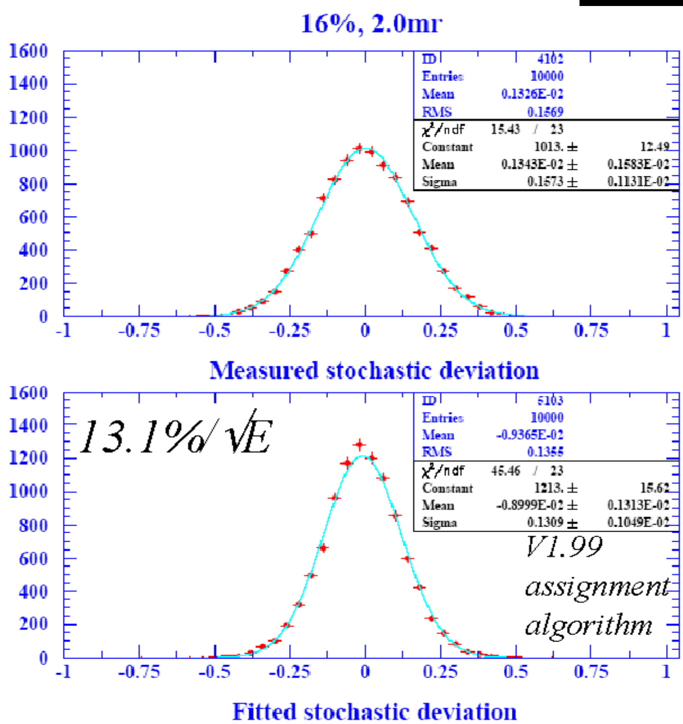
Graham Wilson



Use π° mass constraint to improve jet energy resolution







no constraint

with constraint