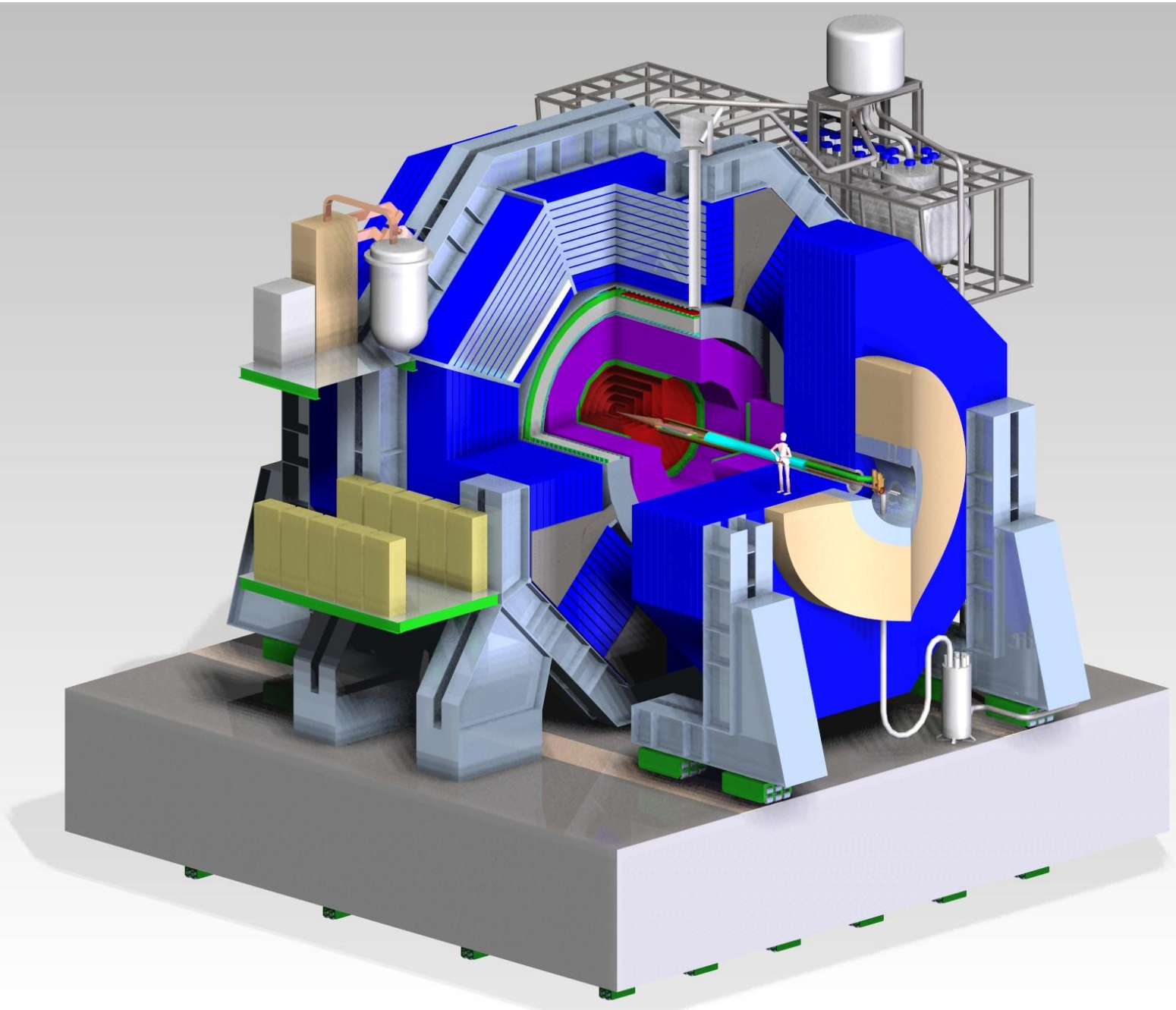
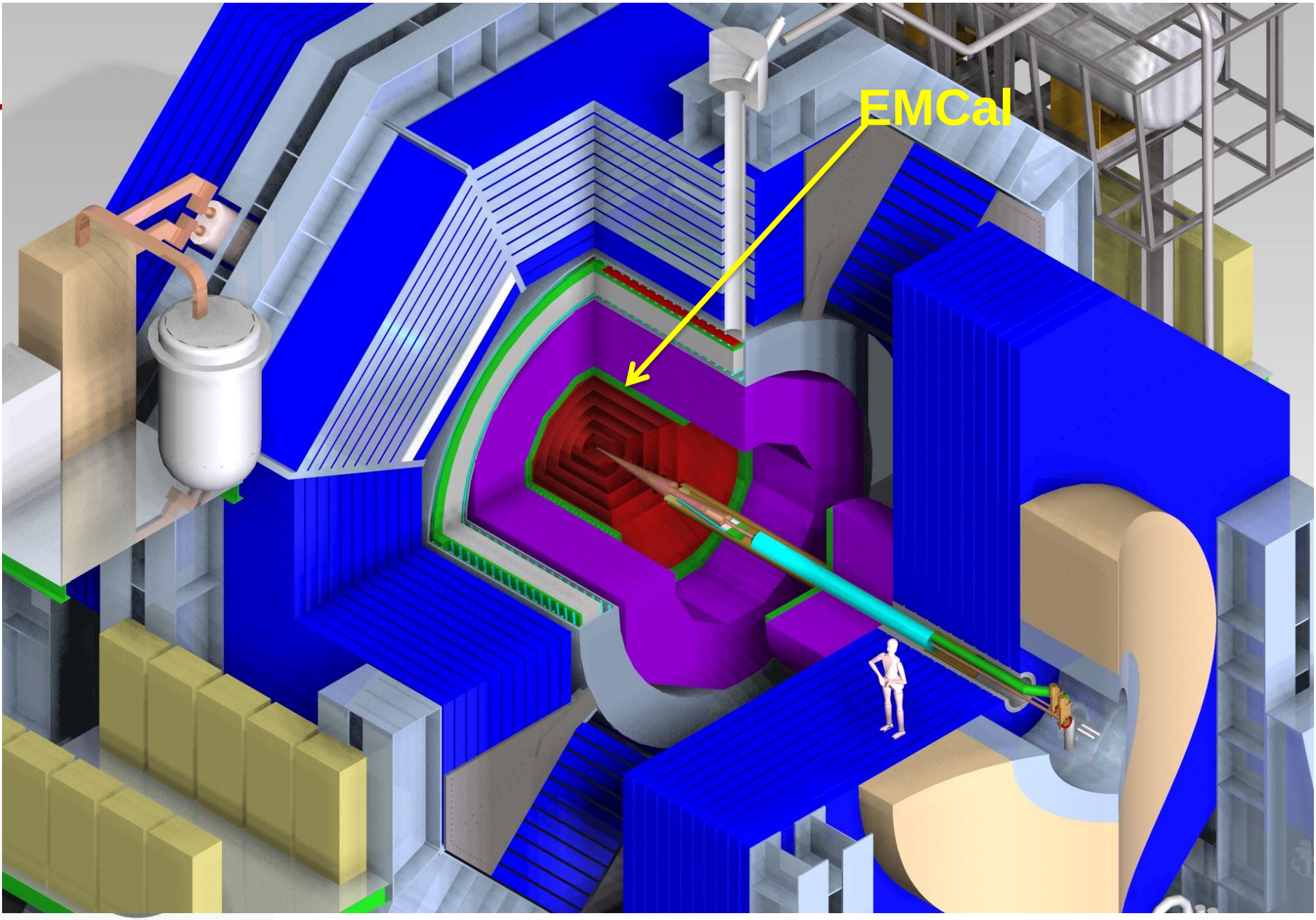
SiD EMCal Testbeam Prototype

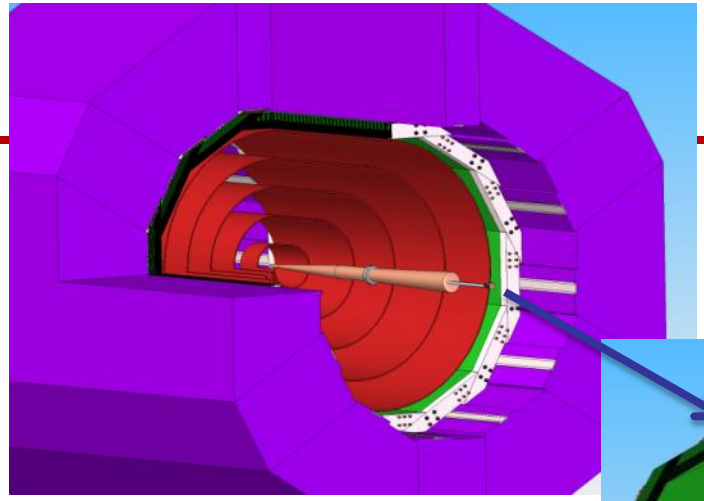
M. Breidenbach for the SiD EMCal and Electronics Subsystems

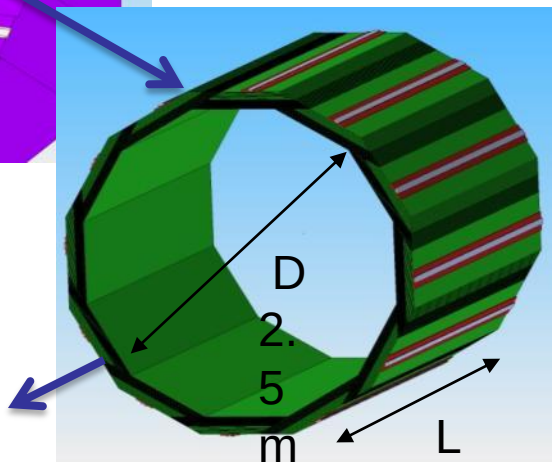



EMCal

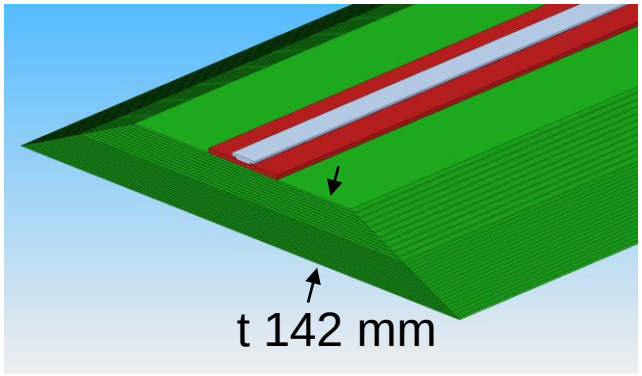
ECAL

Prototype Goals:
•Replicate full EMCal stack and test – 30 sensors.



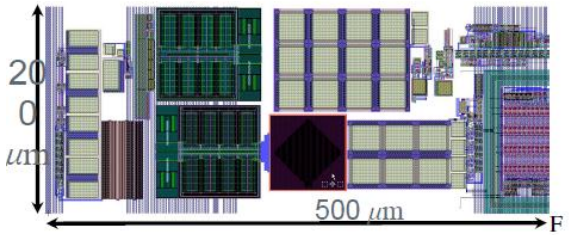


20 layers 2.5 mm W (5/7 X0)
10 layers 5 mm W (10/7 X0)
30 gaps 1.25 mm w Si pixels sensors
29 X_0; 1 λ
ΔE/E = 17%/√E;
Effective Moliere radius = 13 mm

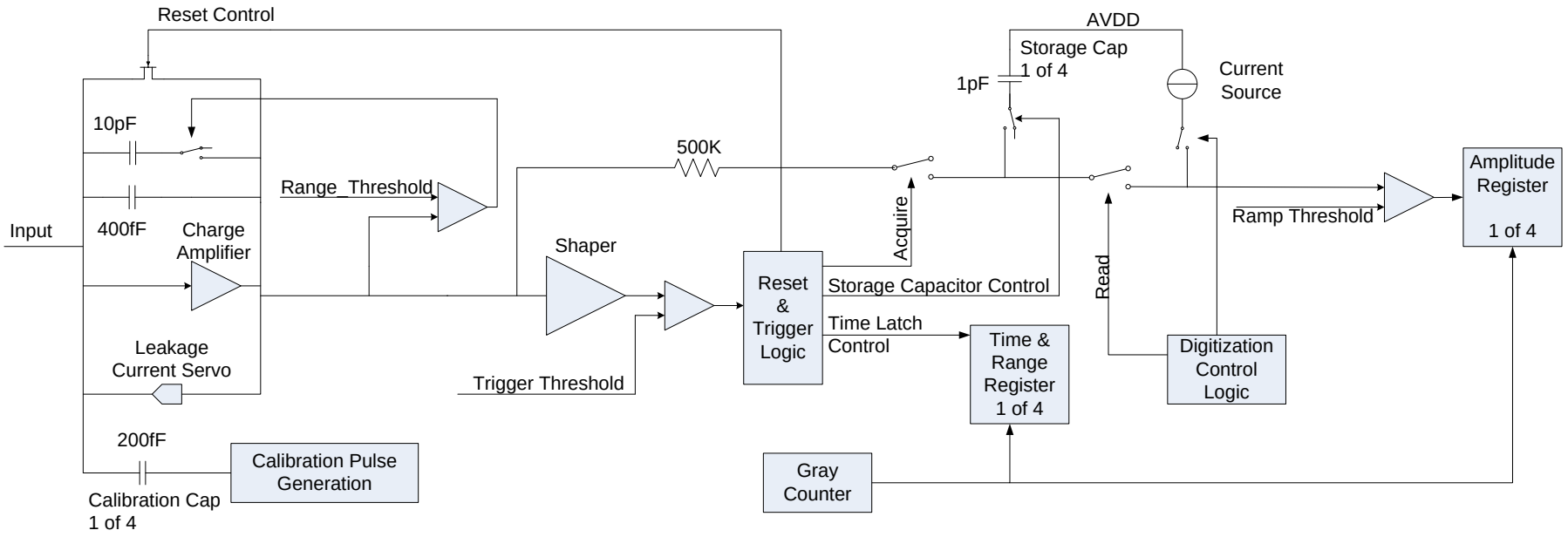


KPiX – System on a Chip

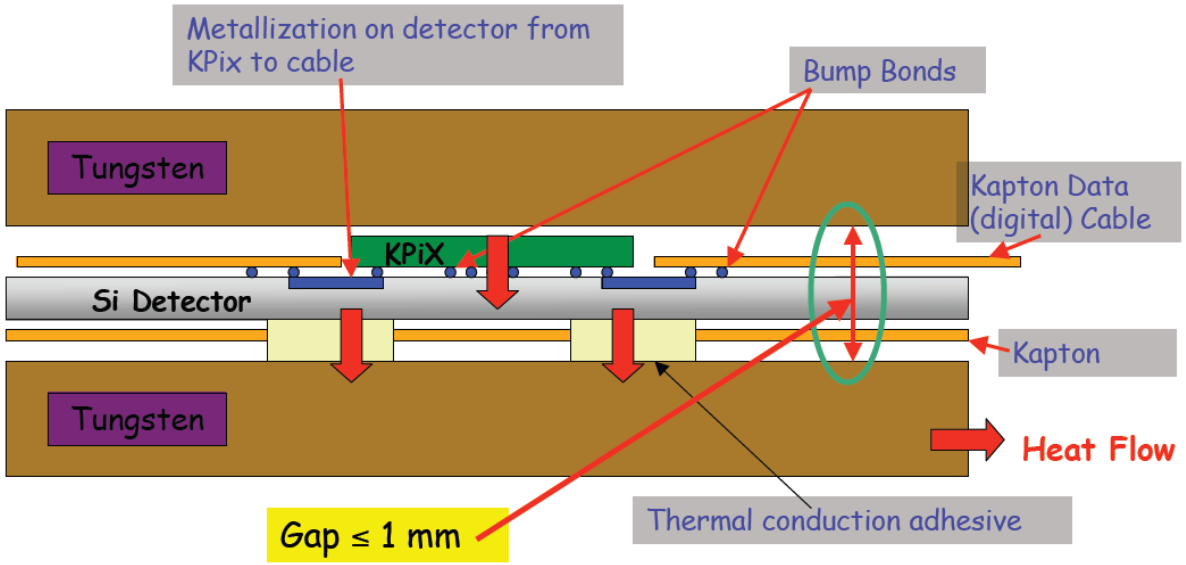
- KPiX is a 1024 channel intended to bump bond to Si detectors, optimized for the ILC (1 ms trains, 5 Hz rate):
  - Low noise dual range charge amplifier w 17 bit dynamic range.
  - Power modulation w average power <20 μW/channel (ILC mode).
  - Up to 4 measurements during ILC train; each measurement is amplitude and bunch number.
  - Digitization and readout during the inter-train period.
  - Internal calibration system
  - Noise Floor: 0.15 fC (1000 e^-)
  - Peak signal (Auto-ranging) 10 pC
  - Trigger Threshold Selectable (0.1 – 10 fC)



KPiX – Simplified bock diagram of single channel



Detail of Structure.



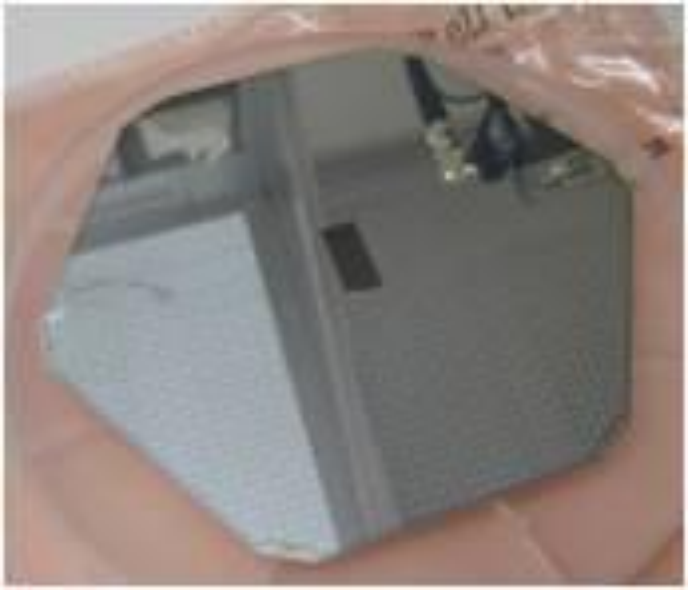
Boundary Conditions

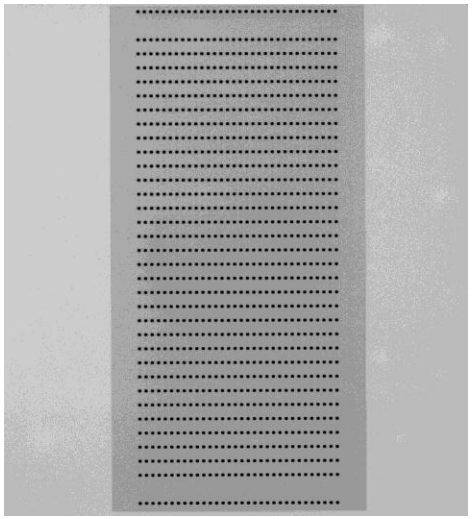
- We have 40 nominally good Hamamatsu sensors.
- We have ~20 nominally bad “mechanical prototype” sensors.
- The KPiXa’s come from TSMC with eutectic Sn-Pb bumps in place in wells on the chip.

- The Hamamatsu sensors (EMCal and Tracker) come with Al pads, so there is a layer of Al_2O_3 which must be removed…

Under Bump Metallization (UBM)

- UCD put a huge effort into UBM:
  - Used the mechanical prototype sensors
  - Zincate – chemistry to remove the Al_2O_3 and plate a stack ending with Au.
  - Sputtering – to directly implant Ti and then a stack ending with Au.
- With miserable results!
  - Possible explanation is that there is something else on the pads, but SEM sees only Al and O.
- We finally went to IZM in Germany who use a sputtering process.
  - They have bonded two KPiXa's to two mechanical prototype sensors.

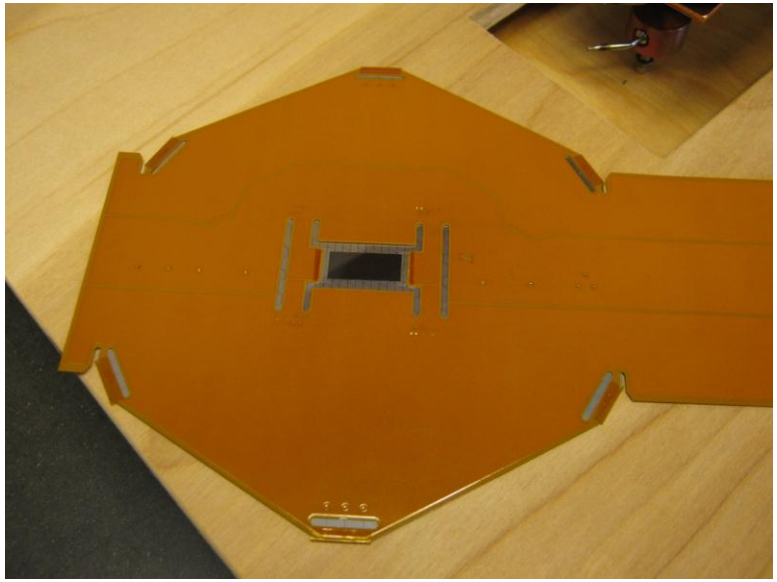


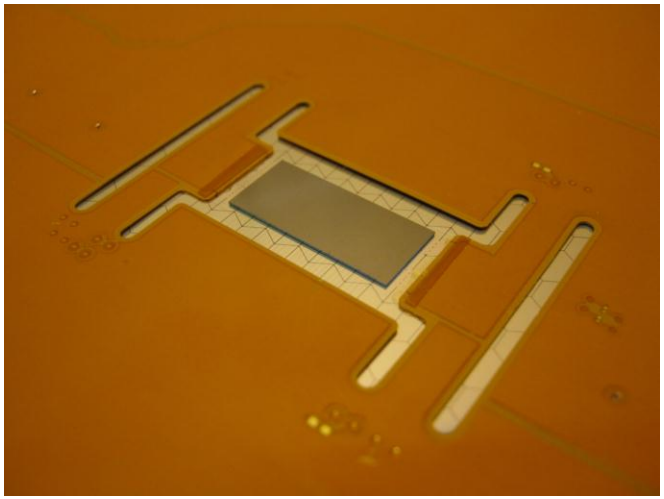


X-ray image of bumps - IZM

Bonded Sensor

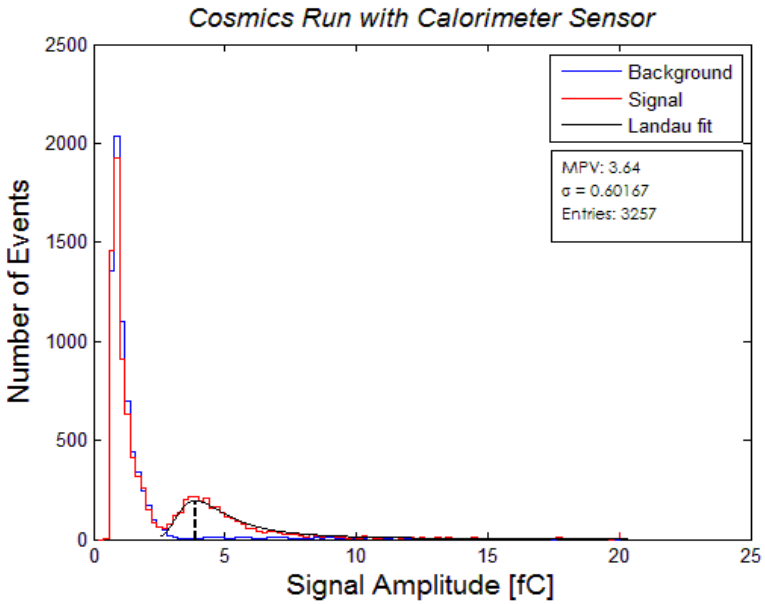
- UCD has bonded a cable to one; it is being tested at SLAC.
- UO is probe testing the other. First results will be shown.



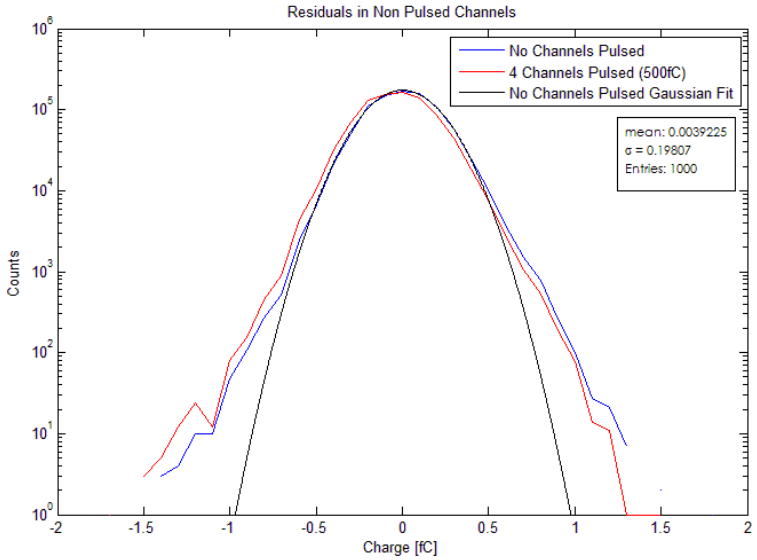


KPiX bump bonded to sensor
Cable bump bonded to sensor
Assembly 1 mm high

First Performance Studies

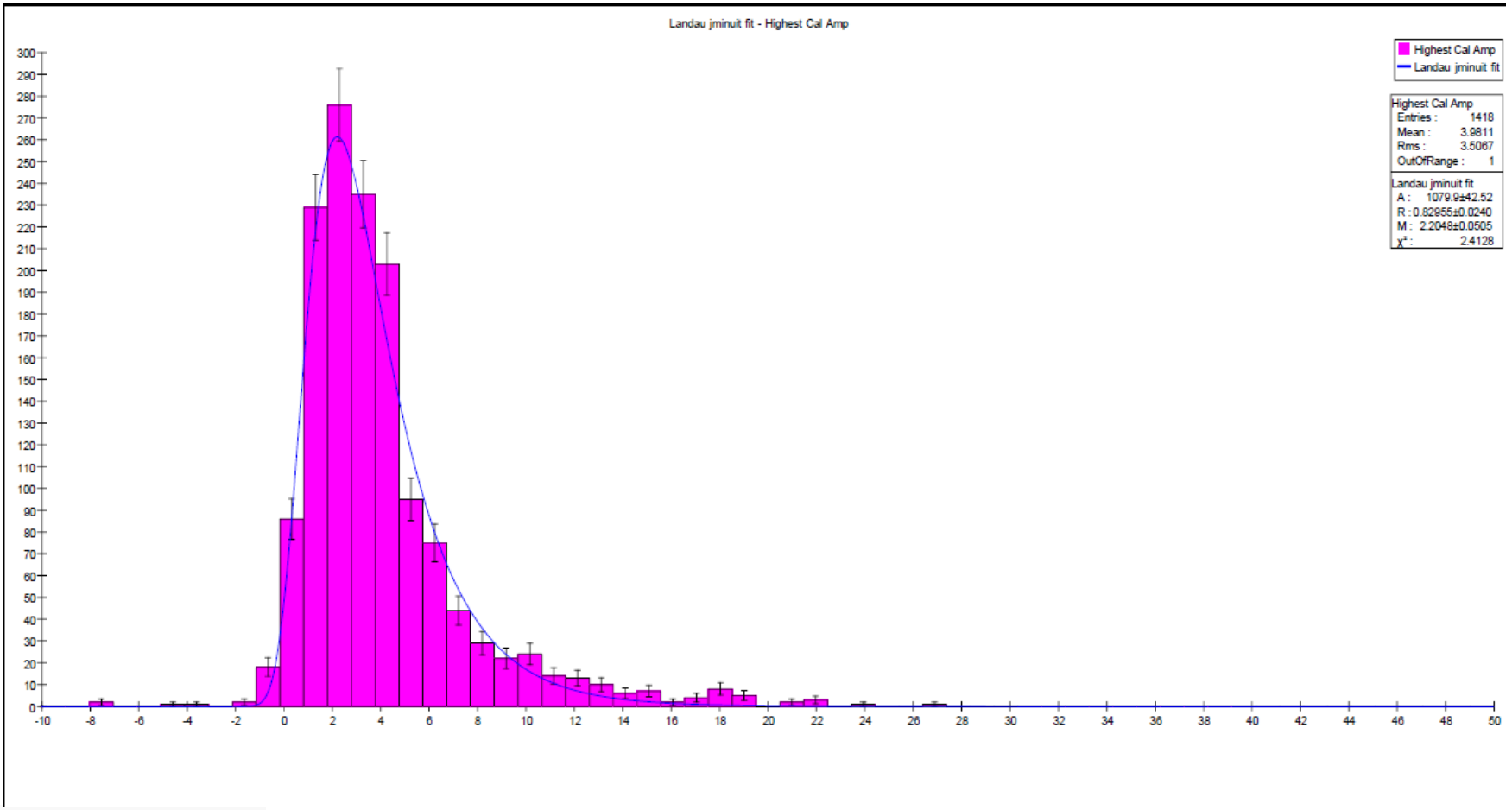


Cosmic telescope “forced” trigger



Cross talk Study: Red: 4 pixels pulsed at 500 fC,
All other channels shown. Blue: no pixels pulsed.

Cosmic Rays. KPiX Self Triggered (pixel by pixel)



Performance Comments

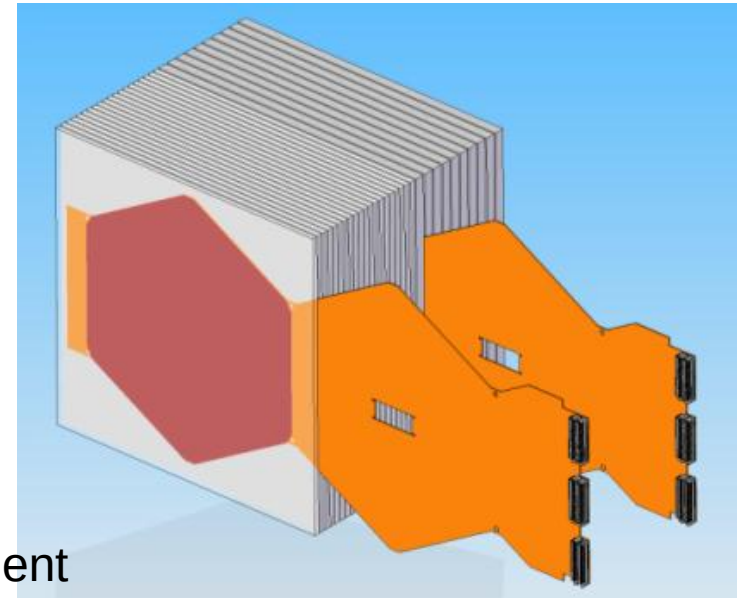
- The first version of the electronics reading out KPiX gave excellent “analog” performance – e.g. self triggered multiplicity was ~1, and there were no “everything lights up” events.
- This indicates that KPiX and its sensor, cable, and enclosure environment is satisfactory.
- IZM is now completing bumping 15 good sensors, and are due this week. If those seem satisfactory, we will complete the rest.

Prototype

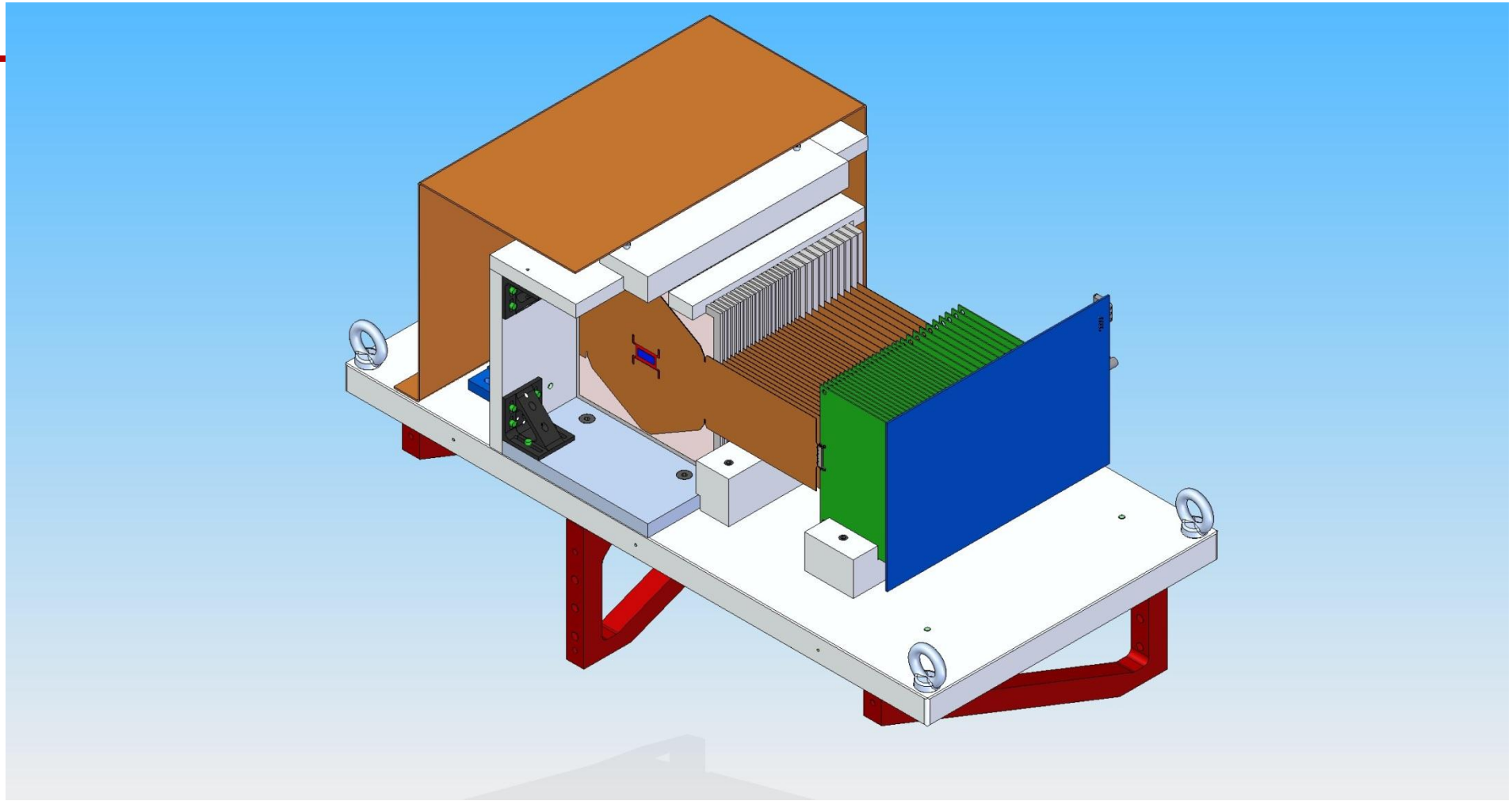
Silicon sensors: Meet specs. for SiD Ecal
- low leakage current; DC coupled
- sufficient number for prototype (30 layers)

KPiX: prototypes meet SiD specs.:
- low noise (10% of MIP)
- large dynamic range: ~10^4
- full digitization and multiplexed output
- passive cooling (power pulsing)

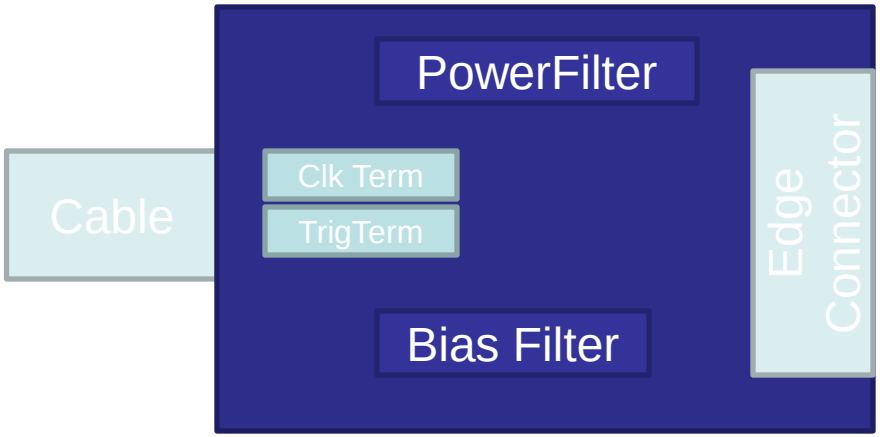
Interconnects:
- Flex cable R&D ok so far – successful attachment to dummy sensors and 1 mechanical prototype.
- Main focus of recent R&D is the KPIX – sensor interconnects … recently successful – we think…



Prototype module – circa LOI

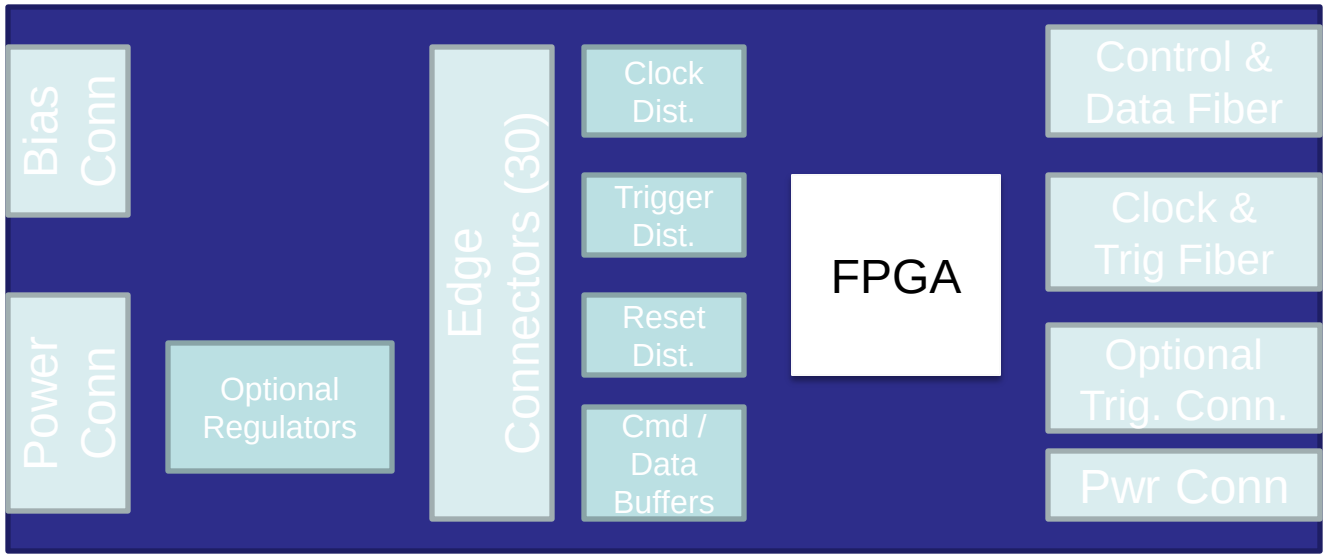


Cable Transition Board



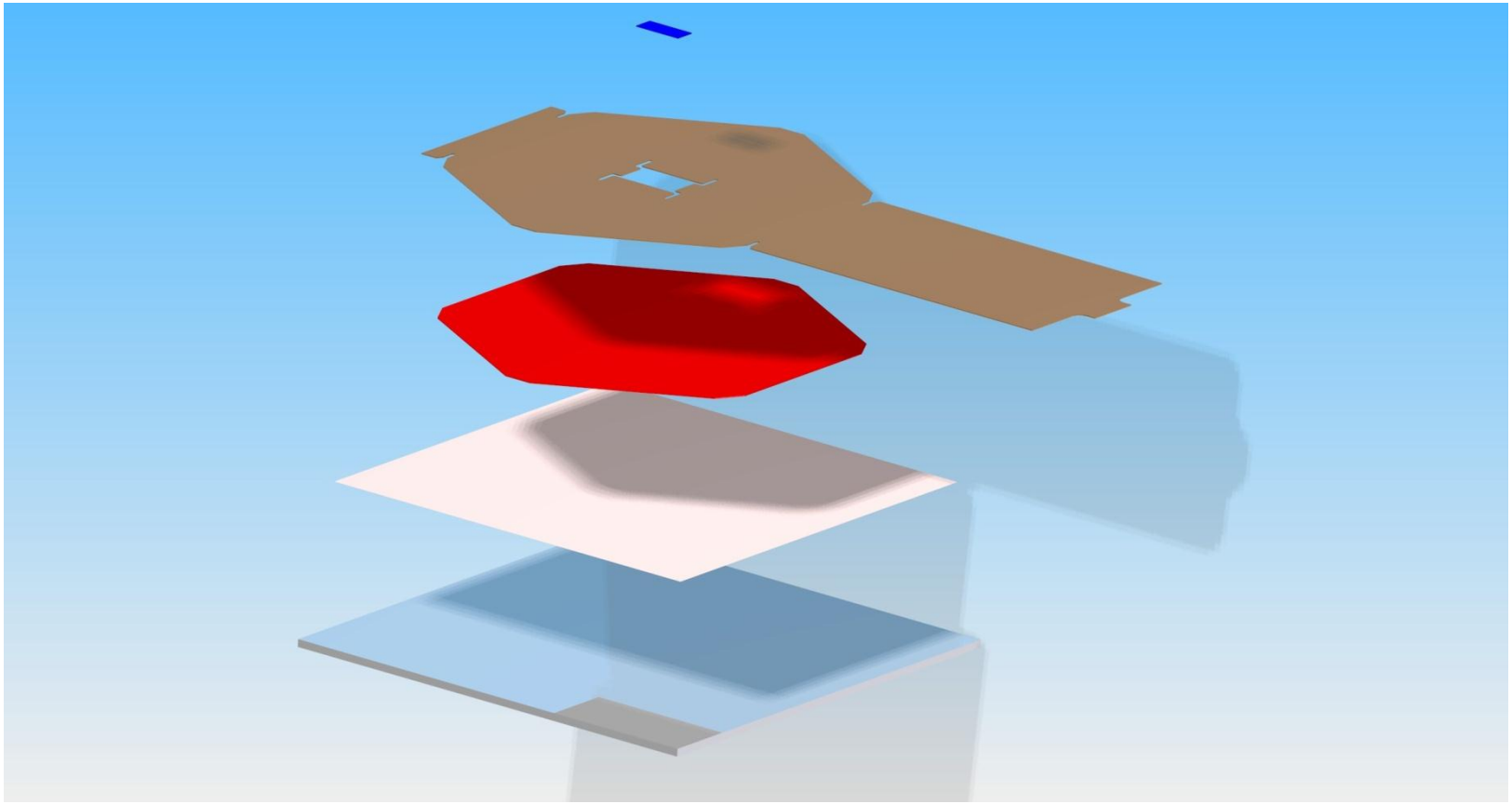
- Clock & trigger LVDS termination
- Power supply filtering
- Bias filtering

Cable Concentrator Board



- Clock, trigger & reset distribution
- Per sensor command & data connection
- Concentrator FPGA
- Optical control and data interface
  - 3.125gbps PGP
- Optical timing / trigger interface

Layer Assembly



Production

- All W plates are in hand.
- Complete design drawings for mechanics complete; mechanical assembly complete, waiting for sensors.
- Sensors and KPiX have been sent to IZM.
- IZM has produced 1 batch of 15 for evaluation.
- We hope to do a production run on more KPiX 1024 channel chips.
- Probe testing available at UO.
- UCD will manufacture and attach cables.
- Testing of cabled sensors at SLAC.
- Assembly and testing of system (pre-testbeam) at SLAC.

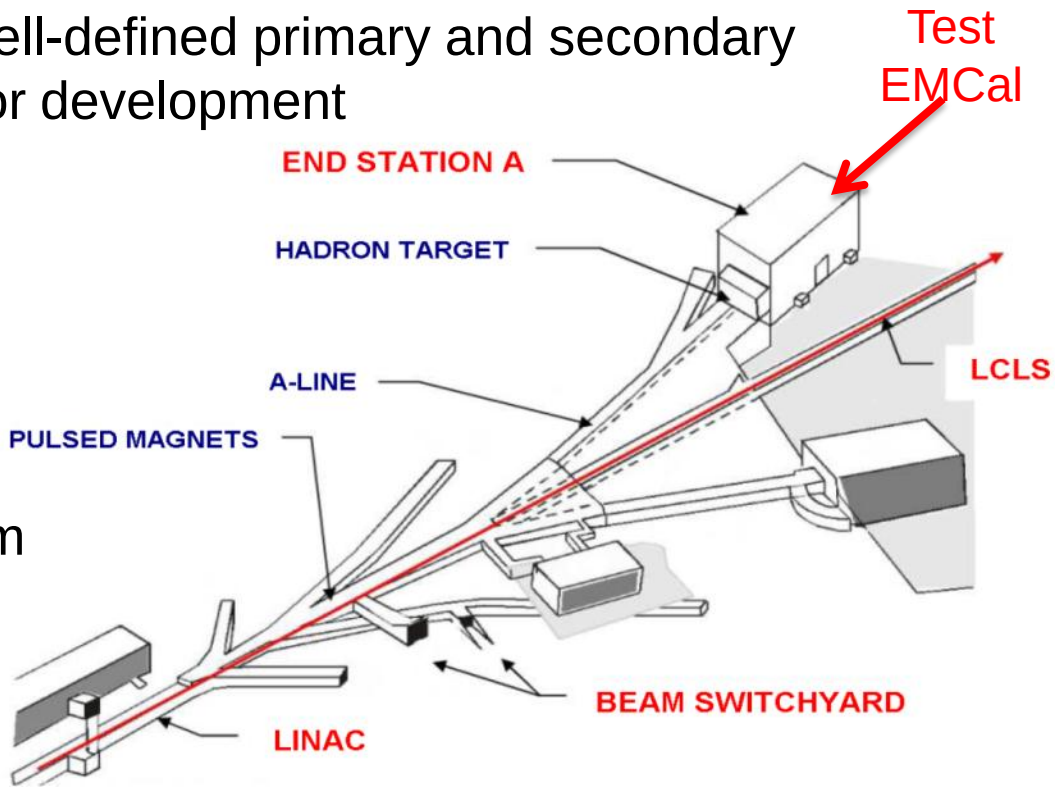
Software

- A new back end system that will handle 32 KPiX is being built, and data and calibration formats have been set.
- Data will be accessible with JAS3, and single KPiX testing is underway.
- UO has built a single event display.

SLAC End Station Test Beam (ESTB) Layout

- ESTB will be a unique HEP resource
  - » World's only high-energy primary electron beam for large scale Linear Collider MDI and beam instrumentation studies
  - » Exceptionally clean and well-defined primary and secondary electron beams for detector development

Pulsed magnets in beam switch yard to send LCLS beam to ESA



Test Expectations

- Expect to take data with a precisely synchronous bunch – what KPiX was designed for.
- Expect to take data at a range of energies and with mean e^+ multiplicity ~1.
- Measure energy and spatial resolution.
- Characterize KPiX in “synchronous” mode: noise, cross talk, channel uniformity, etc.

- Most important – look for problems with the basic approach.

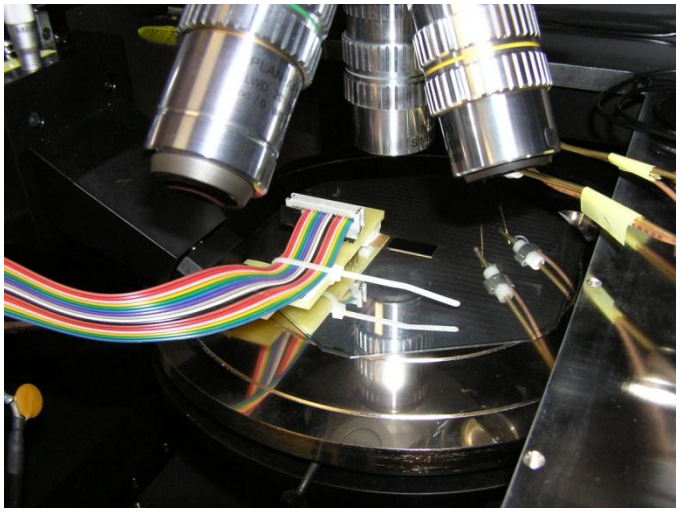
Backup

Results…

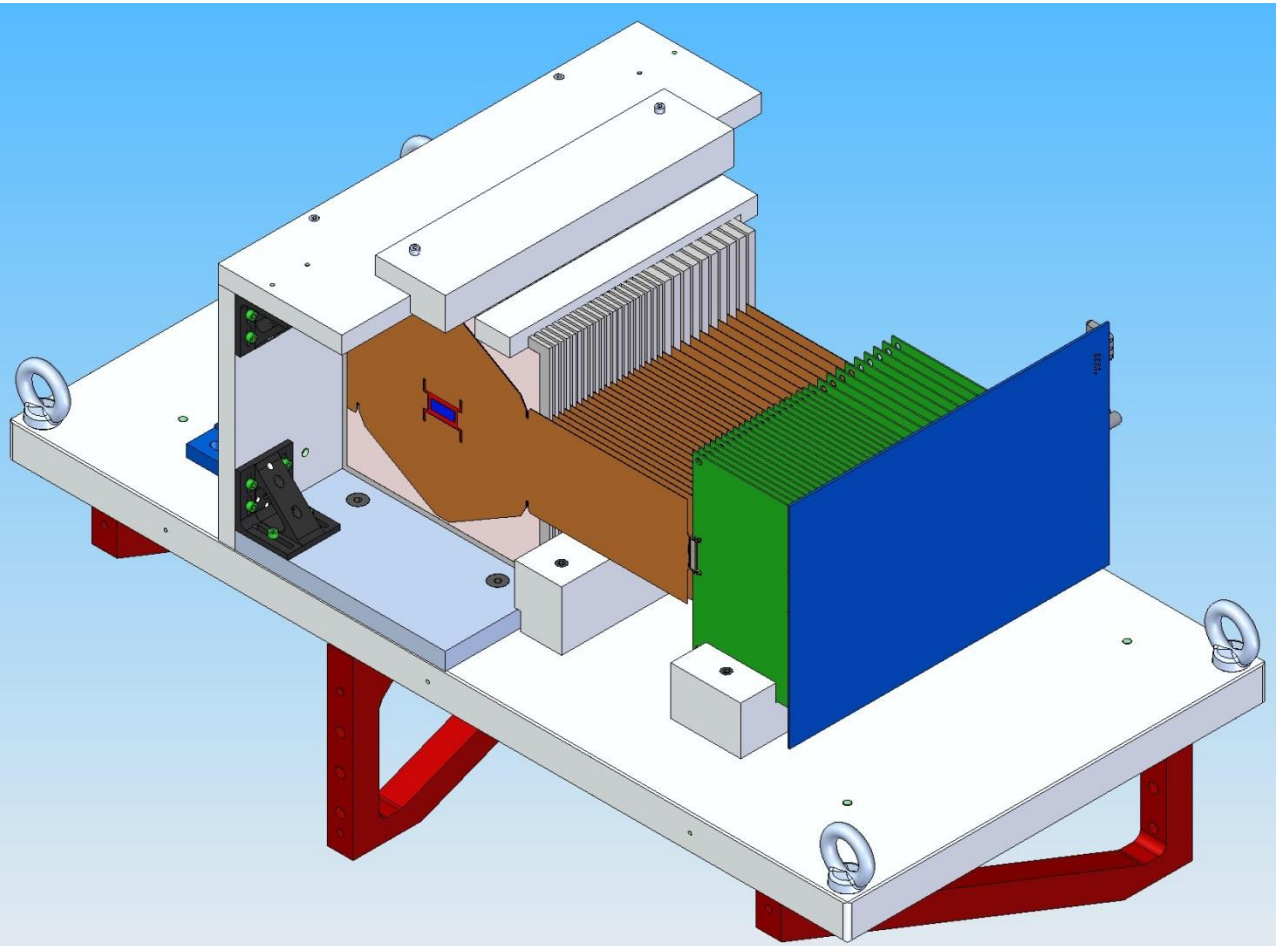
- 752 pixels seem ok.
- 114 pixels appear disconnected – no apparent increase in noise as expected from increased C.
- 158 pixels do not calibrate properly – leakage?

- *But this is a mechanical prototype!!!*

- UO has probed a few other prototype sensors, and sees ~3% opens.
- We do not yet have the corresponding good/open/bad pixel numbers for the UO sensor.



Prototype – Engineering Model



Layer