SiD EMCal Progress

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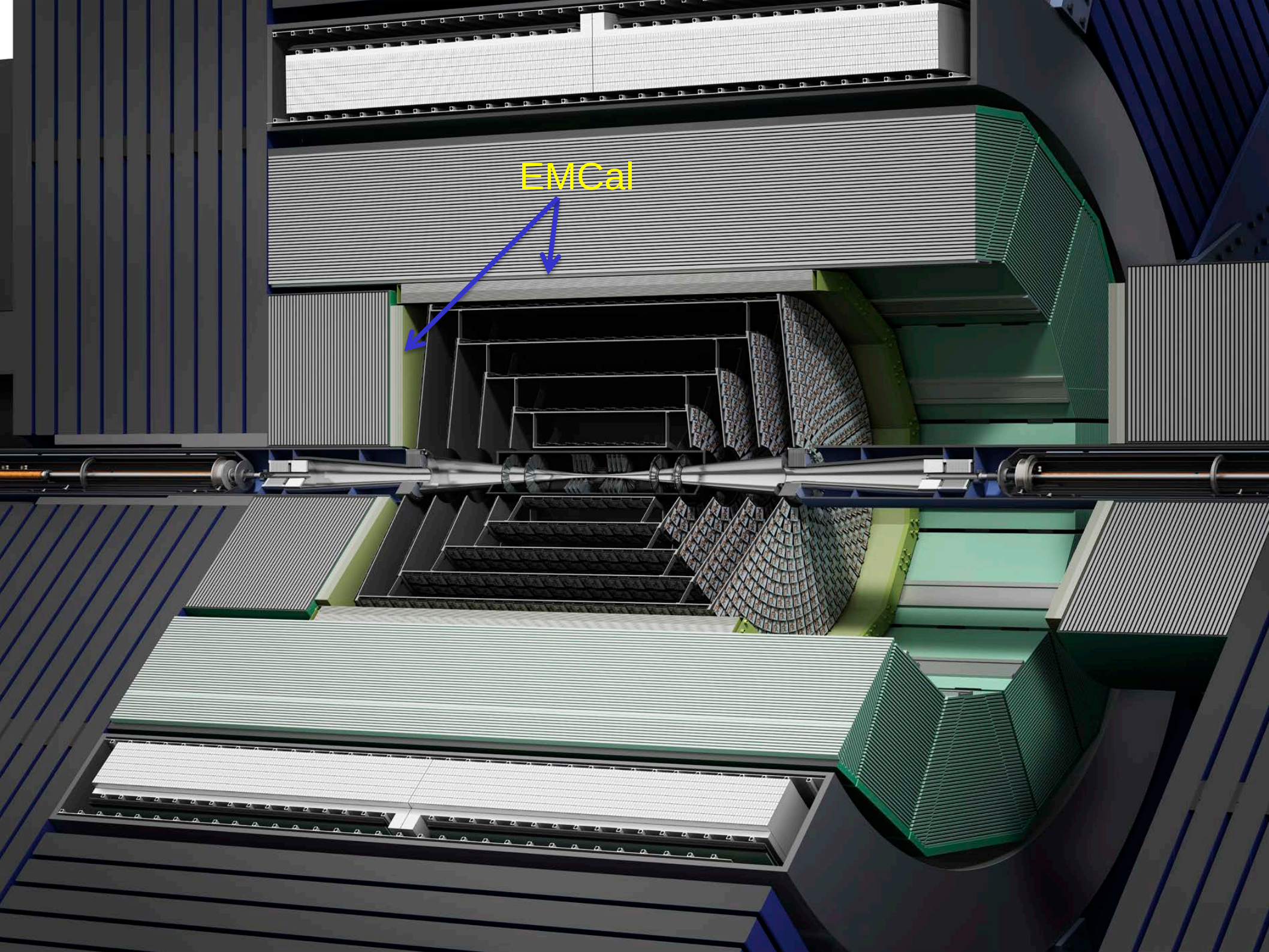
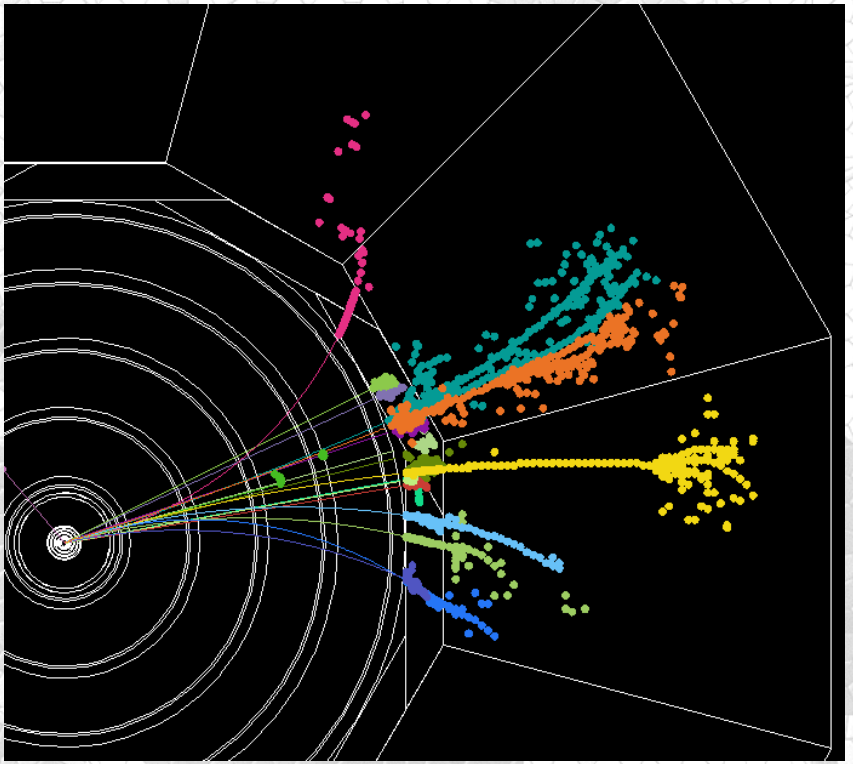
Outline

- Some context and history
- Mechanical Progress
- Beam test & major implications
- Possible new sensor design
- Multiplicity studies
- KPiX modifications


EMCal

Calorimetry- Optimized for Particle Flow

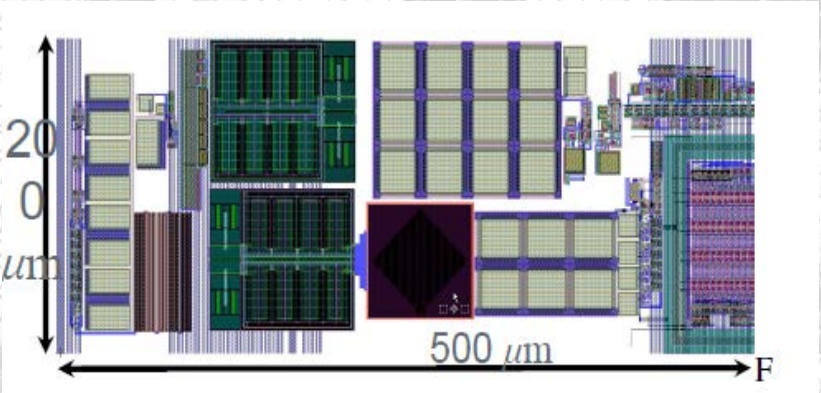
- SiD ECAL
  - Tungsten absorber
  - 20+10 layers
  - 20 x 0.64 + 10 x 1.30 X_0
- Baseline Readout using
  - 5x5 mm^2 silicon pads
- SiD HCAL
  - Steel Absorber
  - 40 layers
  - 4.5 Λ_i
- Baseline readout
  - 1x1 cm^2 RPCs
- Contender:
  - 3x3 cm scintillator w SiPM's

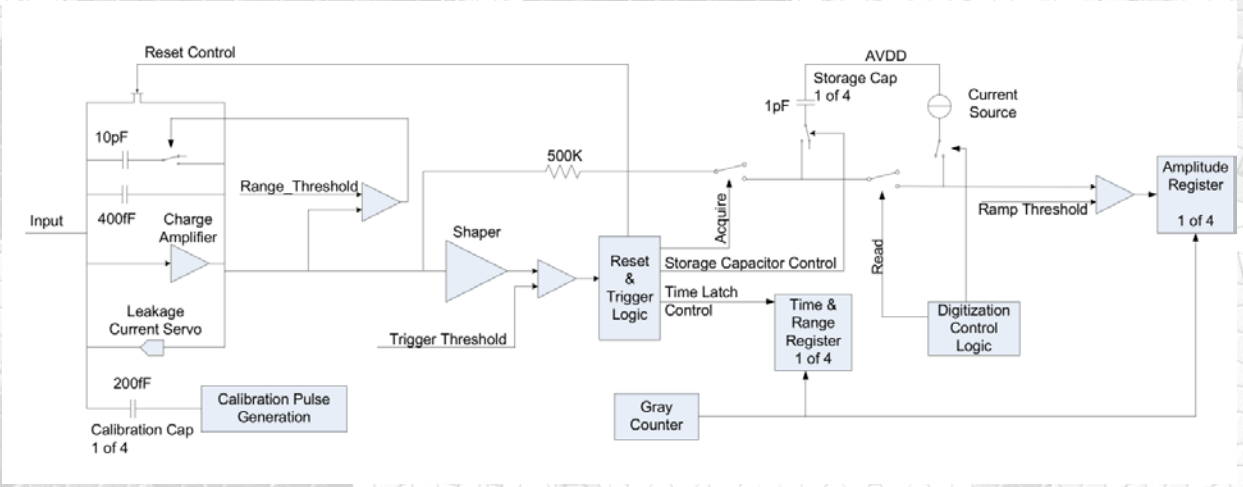


Particle flow significantly improves jets resolution by reducing contribution of hadron calorimeter resolution.

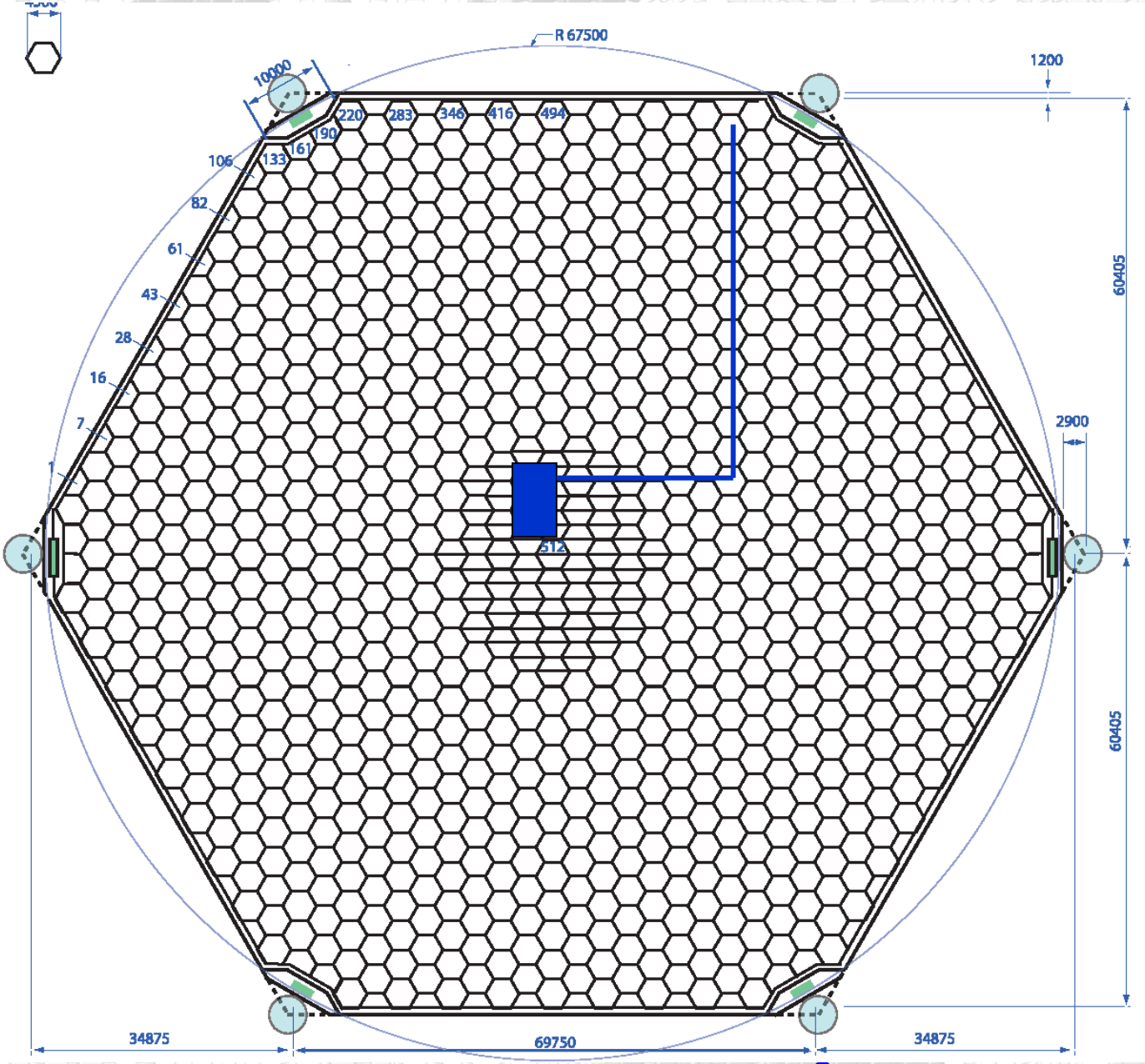
KPiX – a readout system on a chip

- A 1024 channel system to be bump bonded directly to large Si Sensors – enabling the Si Tracker and EMCal.
- Optimized for the ILC, with multi-hit recording during the train, and digitization and readout during the inter-train gap (199 ms).
- Front-end power down during inter-train gap. Mean power/channel <20 μW.
- Large dynamic range (for calorimetry) by dynamically switching the charge amp feedback cap.
- Pixel level trigger; trigger bunch number recorded.
- 0.15 fC noise floor
- Options for RPC readout





Si sensors



- 6 inch wafers
- 1024 13 mm^2 pixels
- KPiX readout is bump-bonded directly to sensor

KPiX ASIC and sample trace

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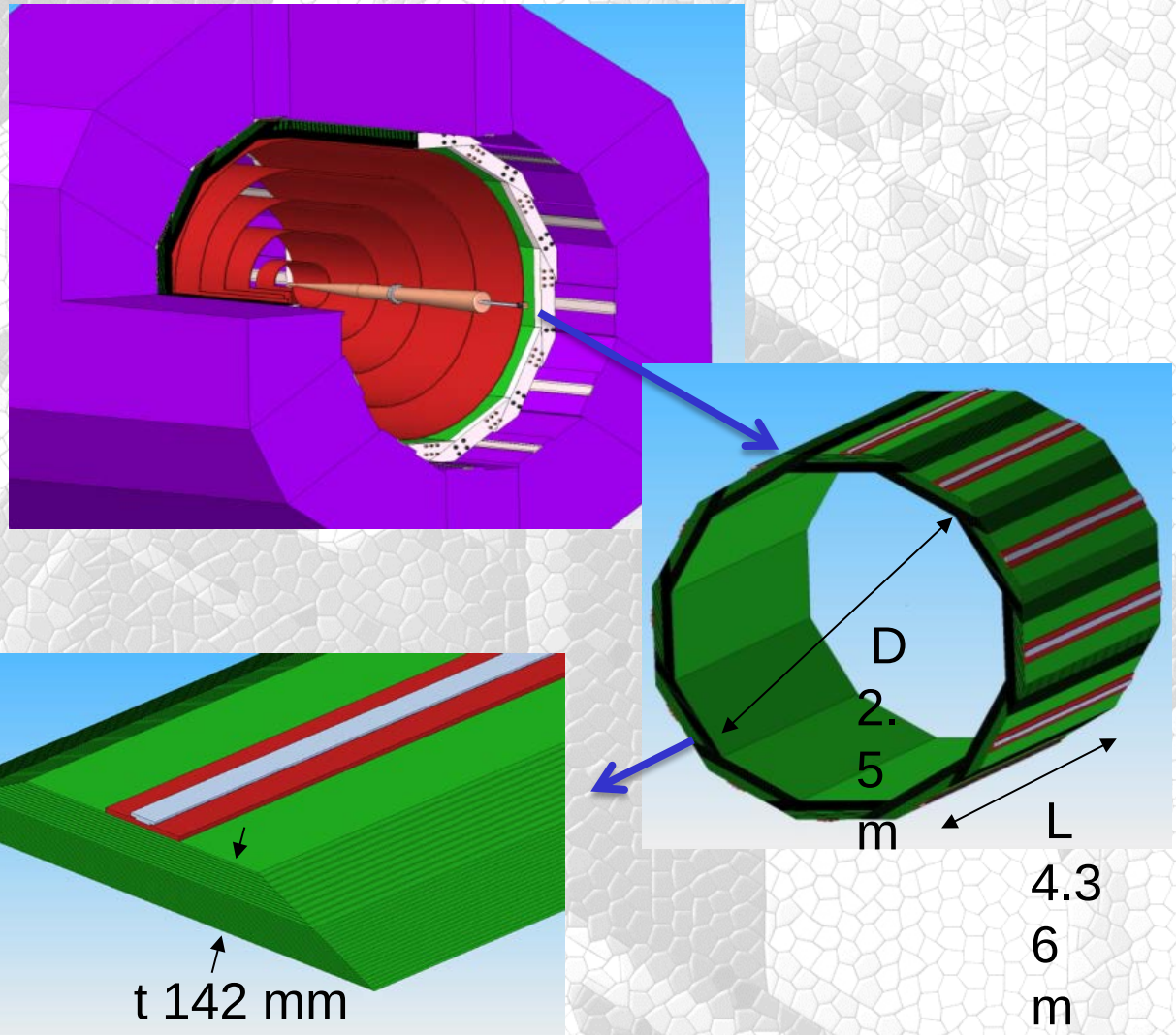
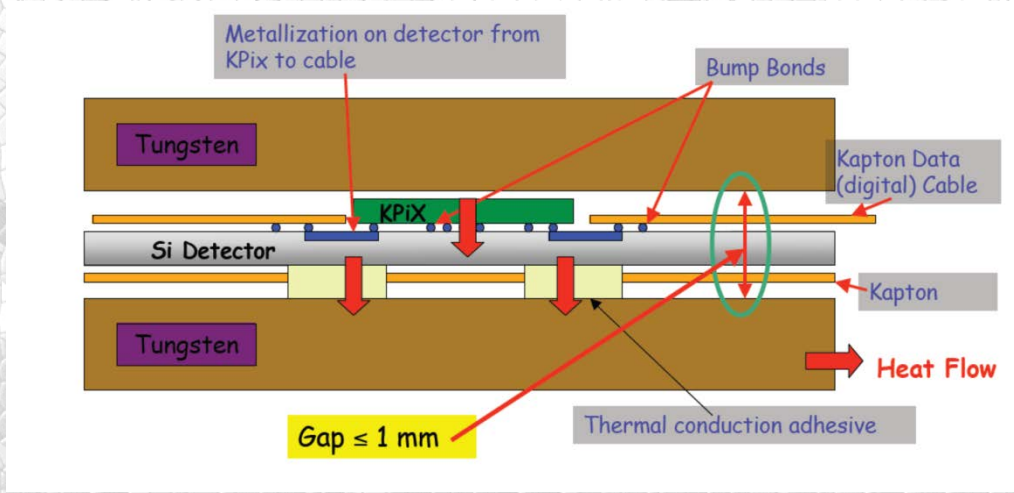
Compact Electromagnetic Calorimeter w 13 mm Moliere Radius

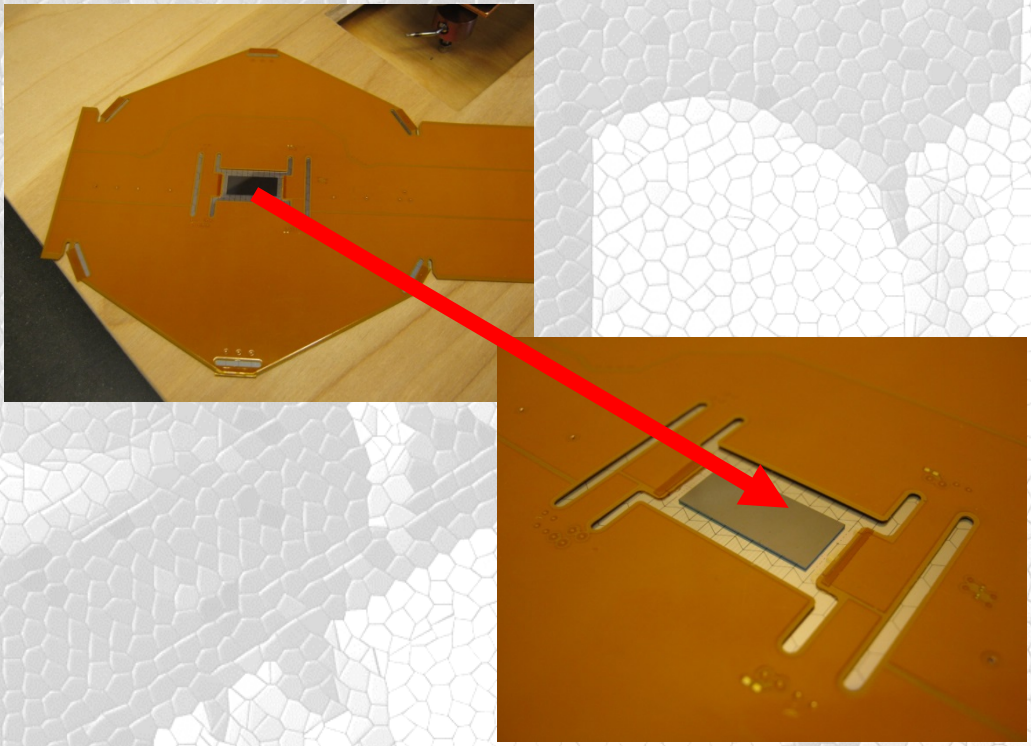


DBD version - very much pre-conceptual…

Gap Structure

- One ECAL Si sensor
- KPiX and cable bump-bonded to the sensor
- ~1 mm gap: minimize Moliere radius, keep calorimeter compact
- Tungsten plates thermal bridge to cooling on edge

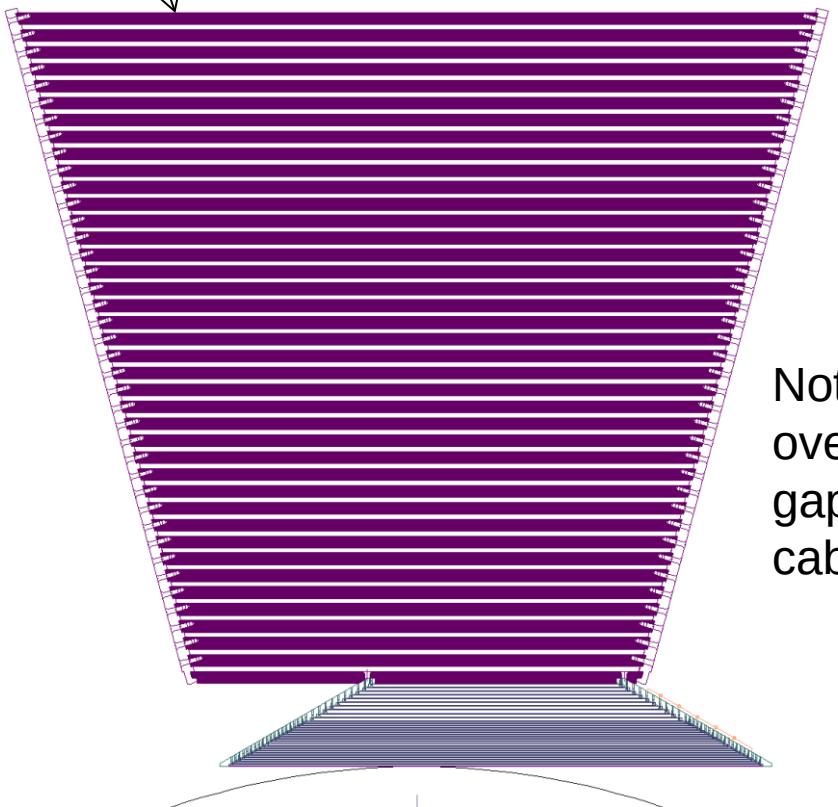




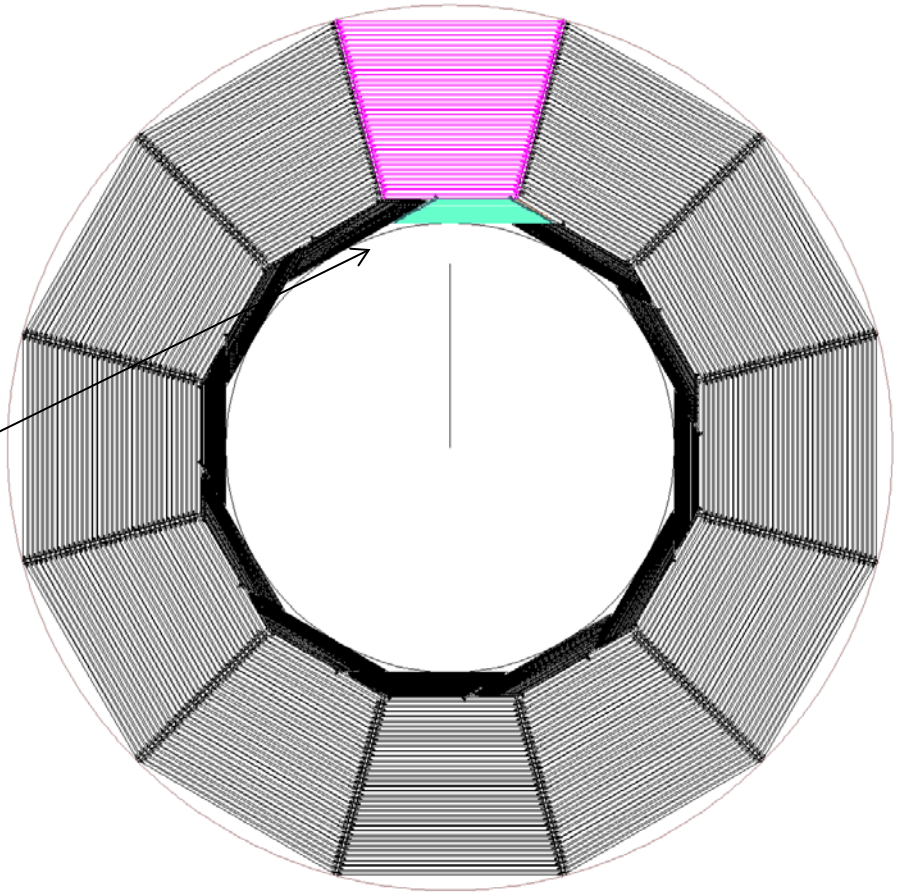
Mechanical Progress

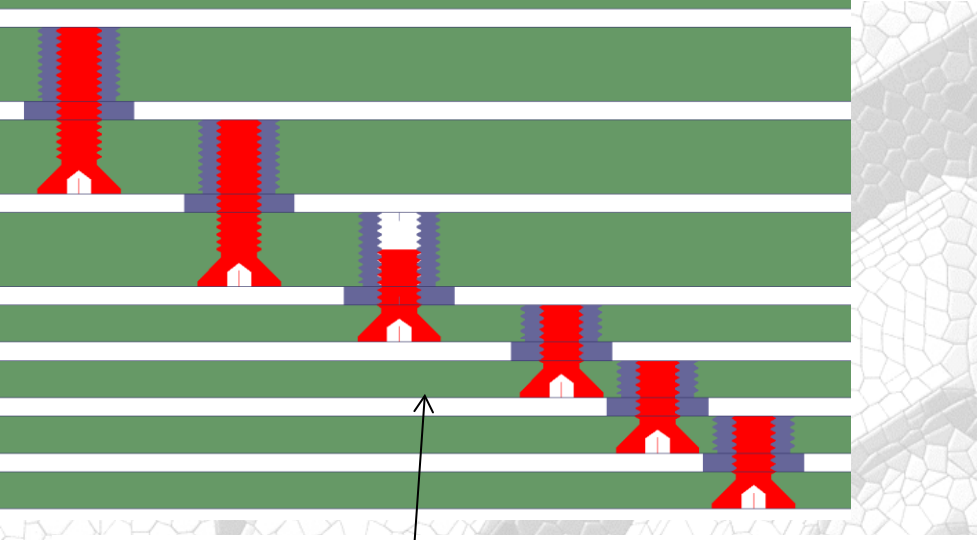
ECAL module is built on first layer of HCal

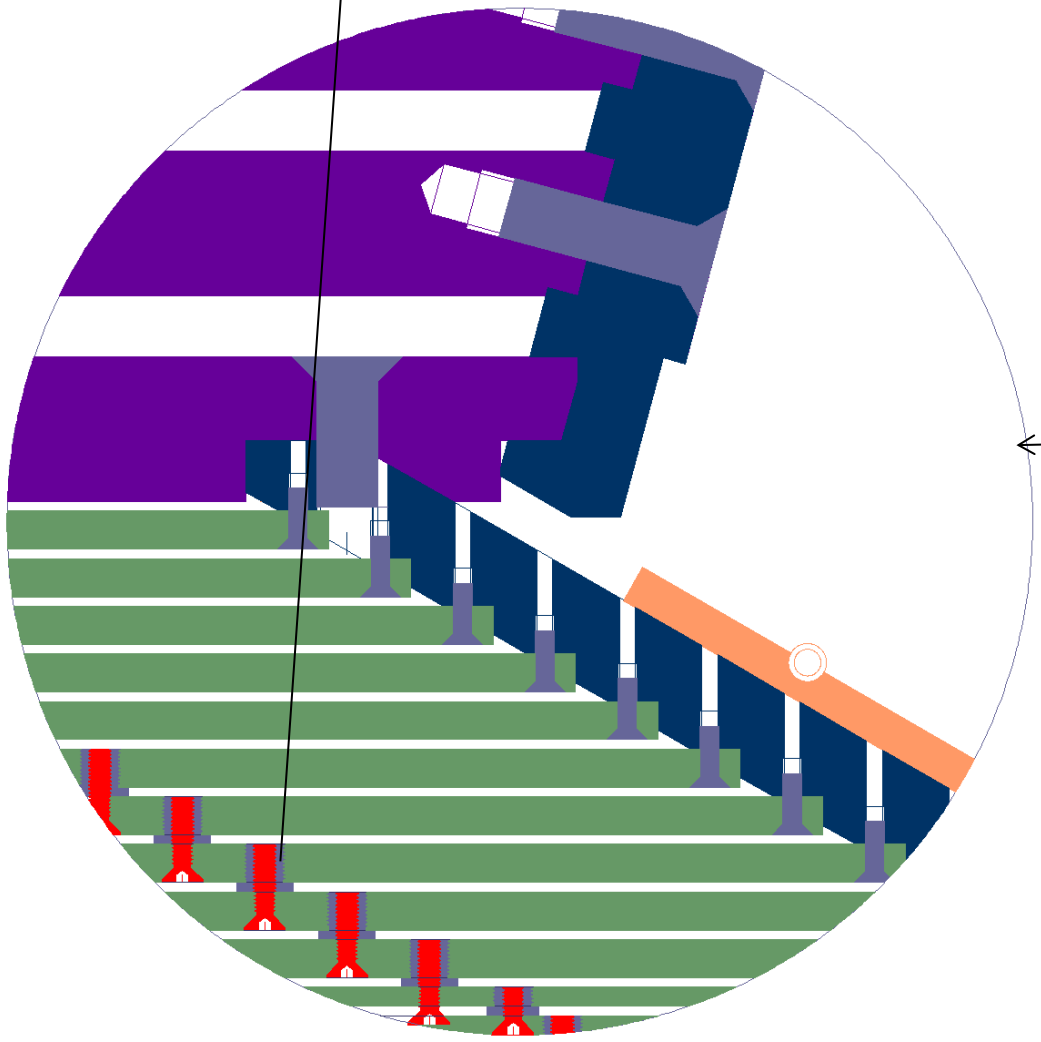
HCAL module supports ECAL module

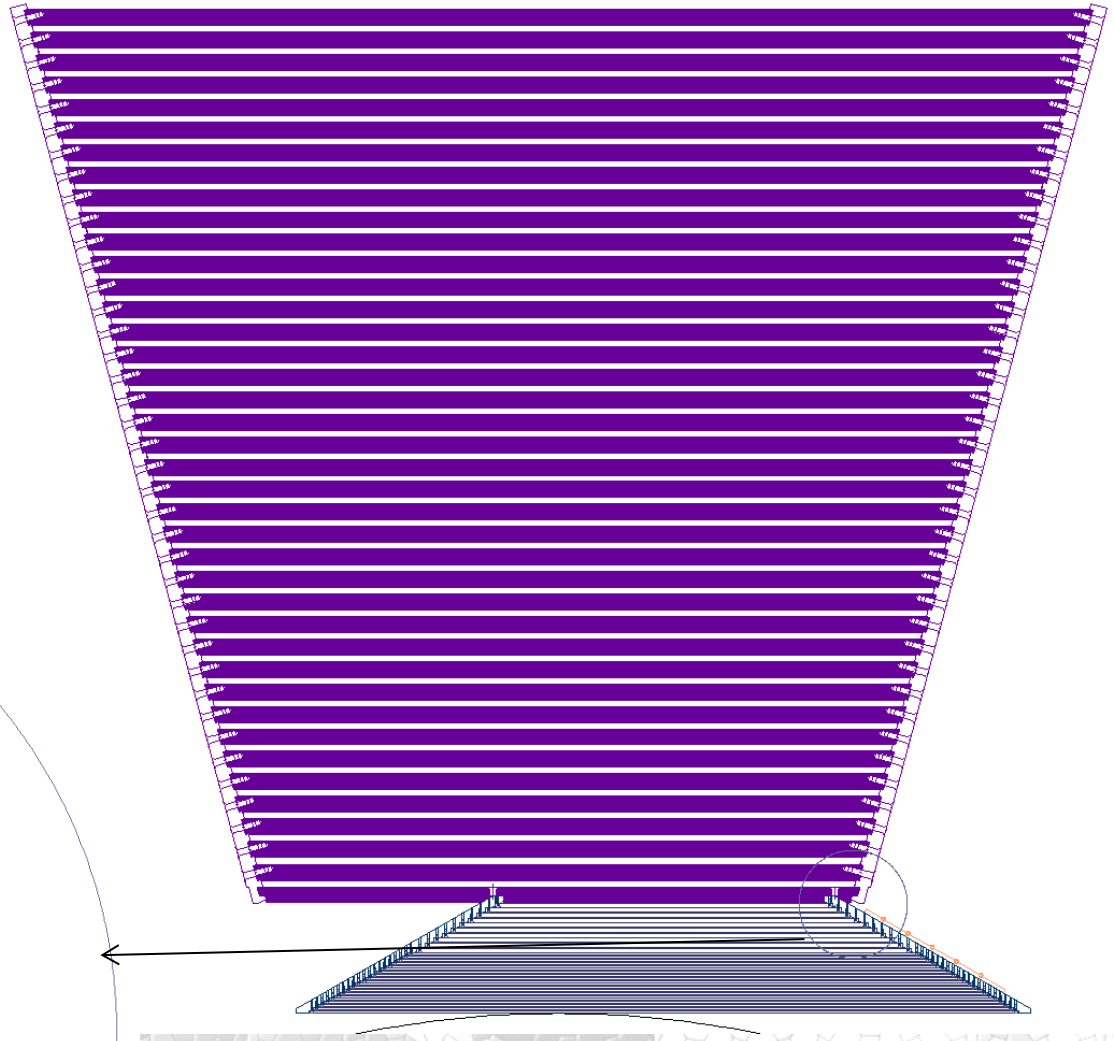


Note module overlap: No gaps; service cables at ends.



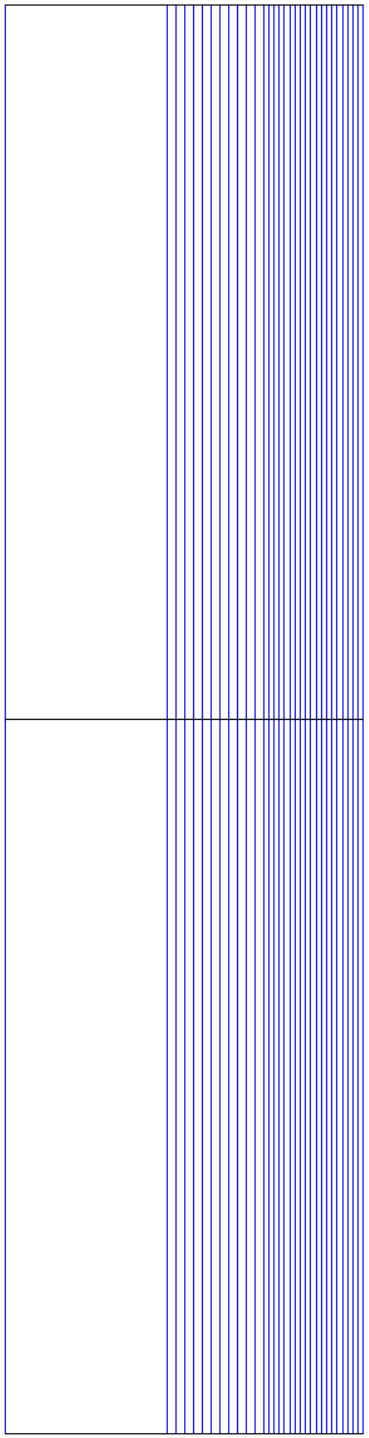






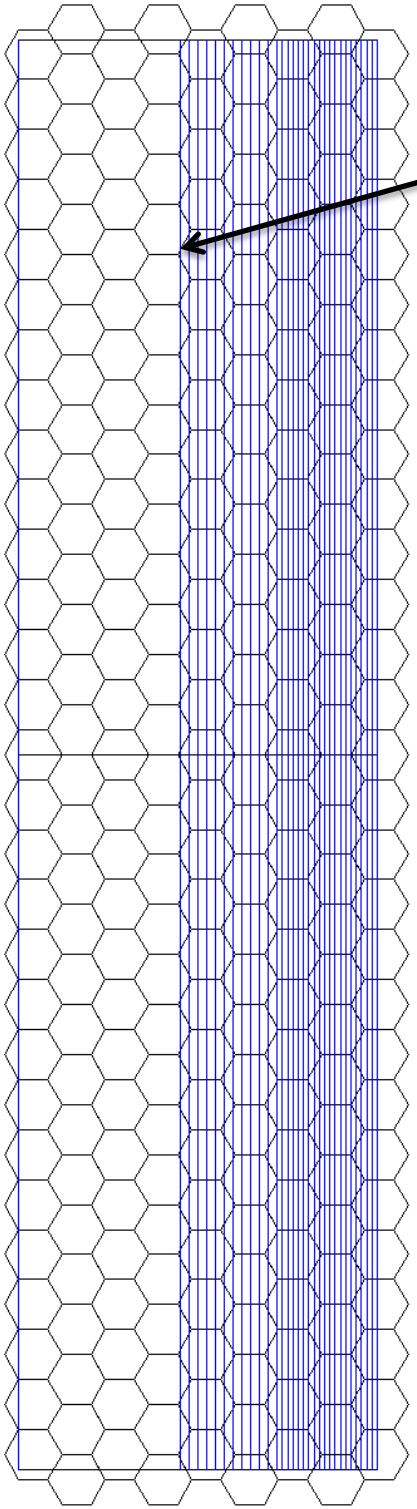
- HCal plates supported by interlaced grooved straps
- EmCal plates screwed to support plates tied to inner Hcal plate. Inner Hcal plate “belongs” to EMCal module.
- Tungsten plates tied to each other with plausible screws and spacers

Tiling Issues



Top view of stack of W plates
Left edge aligned
Note range of widths.

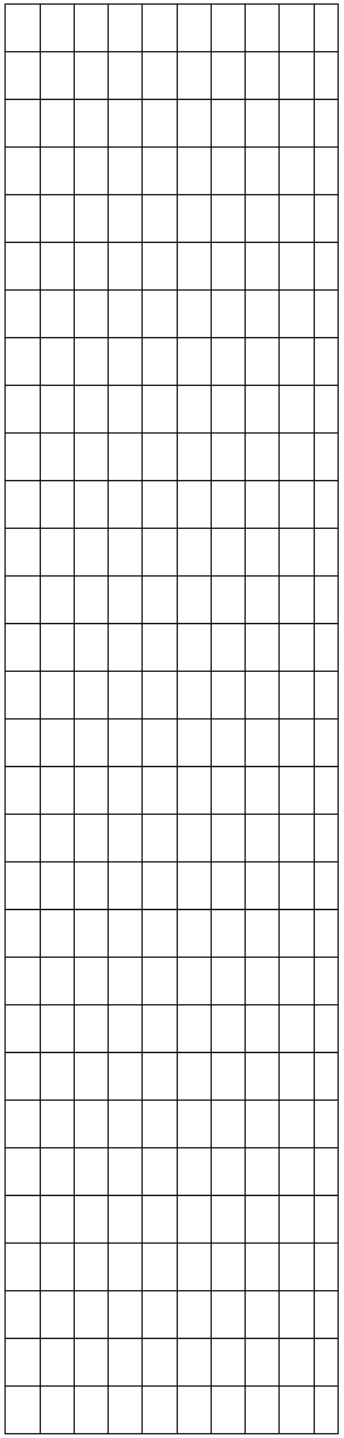
This makes efficient tiling challenging.



Pre-conceptual design:

Worry about tiling later!

(Hexagons make efficient use of the wafer though…)



Next iteration:

Efficient tiling is possible with two different sized rectangles.

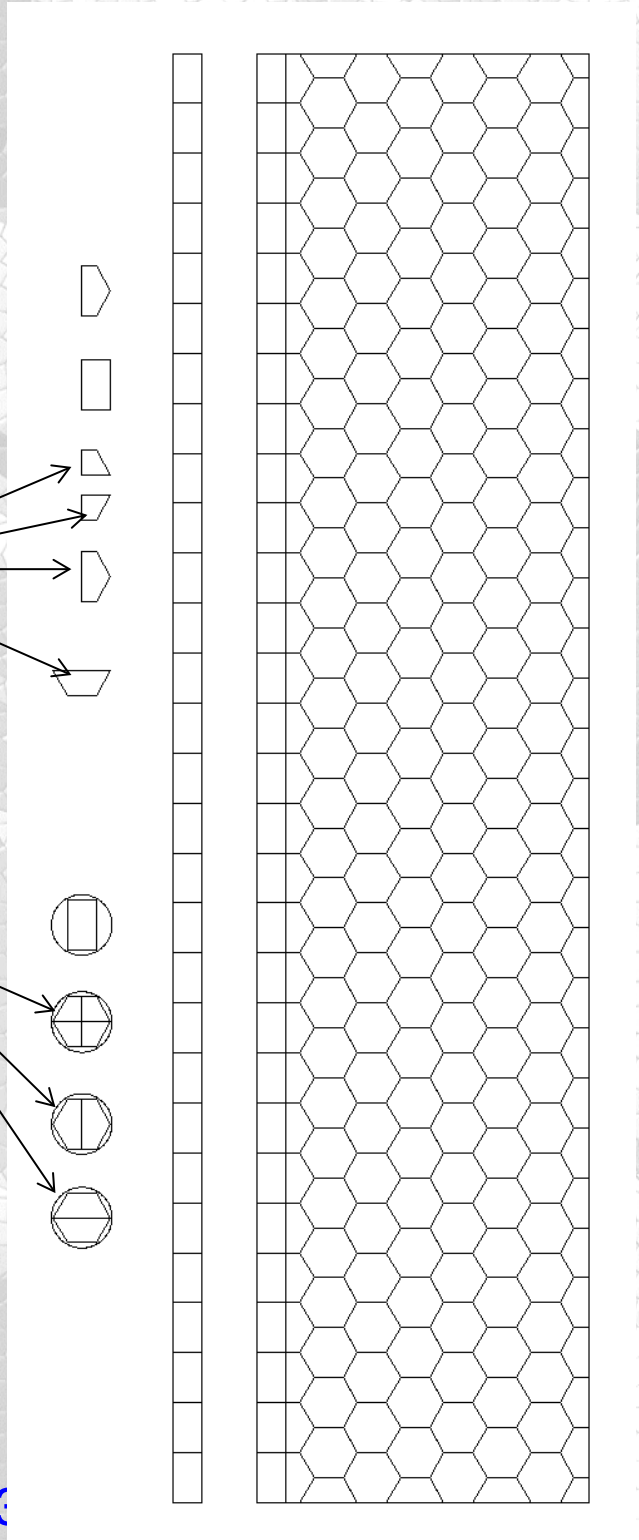
Penalty is ~30% more wafers.

Beginning study of hybrid tiling:

Hexagons for the field, with standard elements to fill the hexagon tiling to a large rectangle.

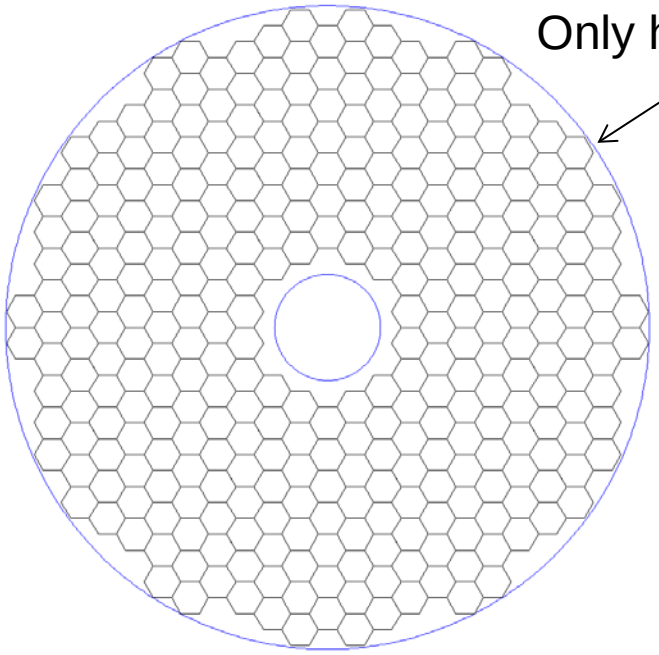
These elements efficiently fill a wafer.

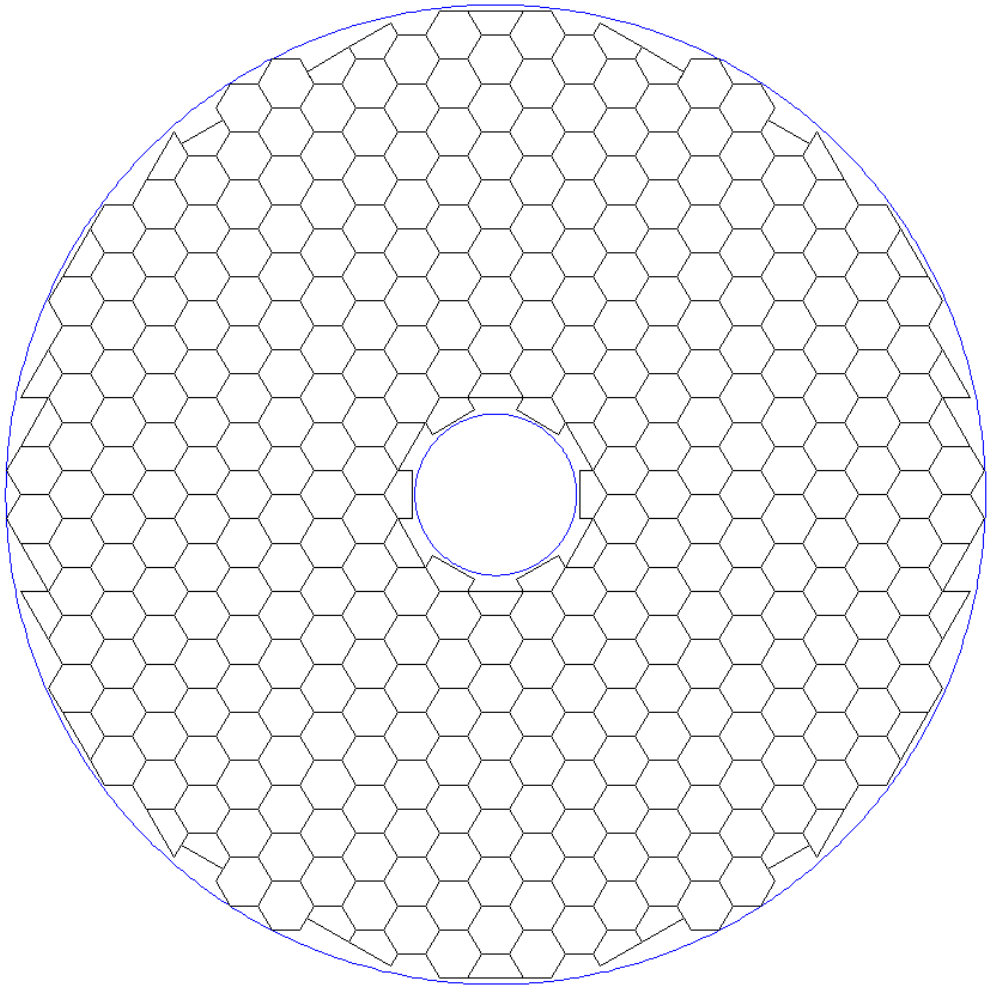
Then fill to layer edge with rectangles.

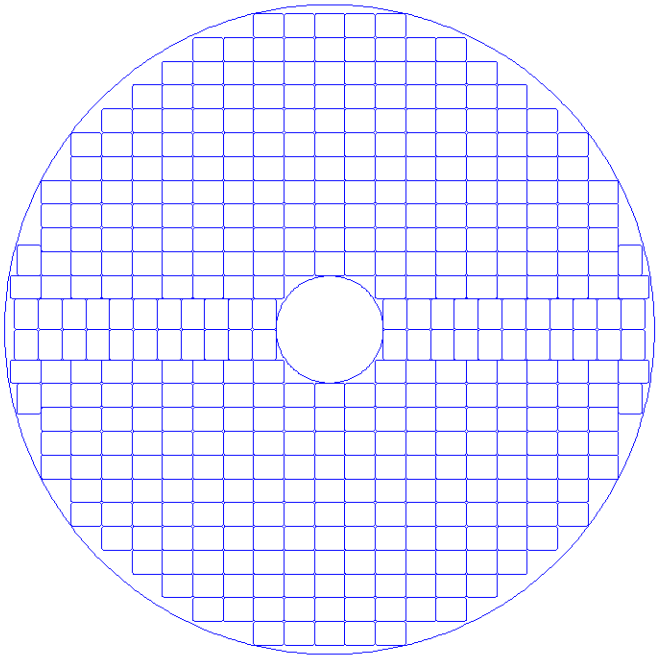


Endcap Tiling – first tries

Only hexagons



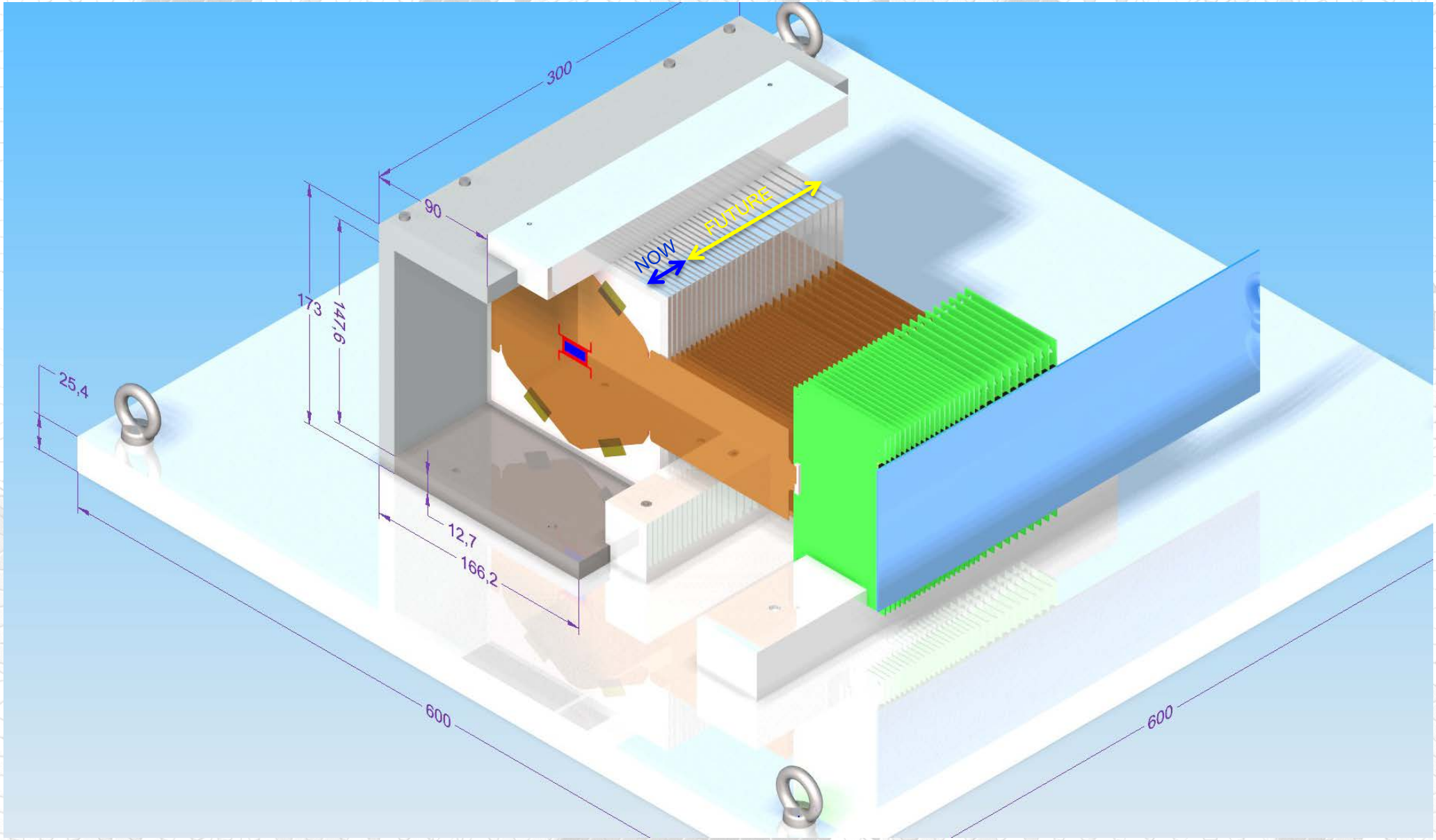




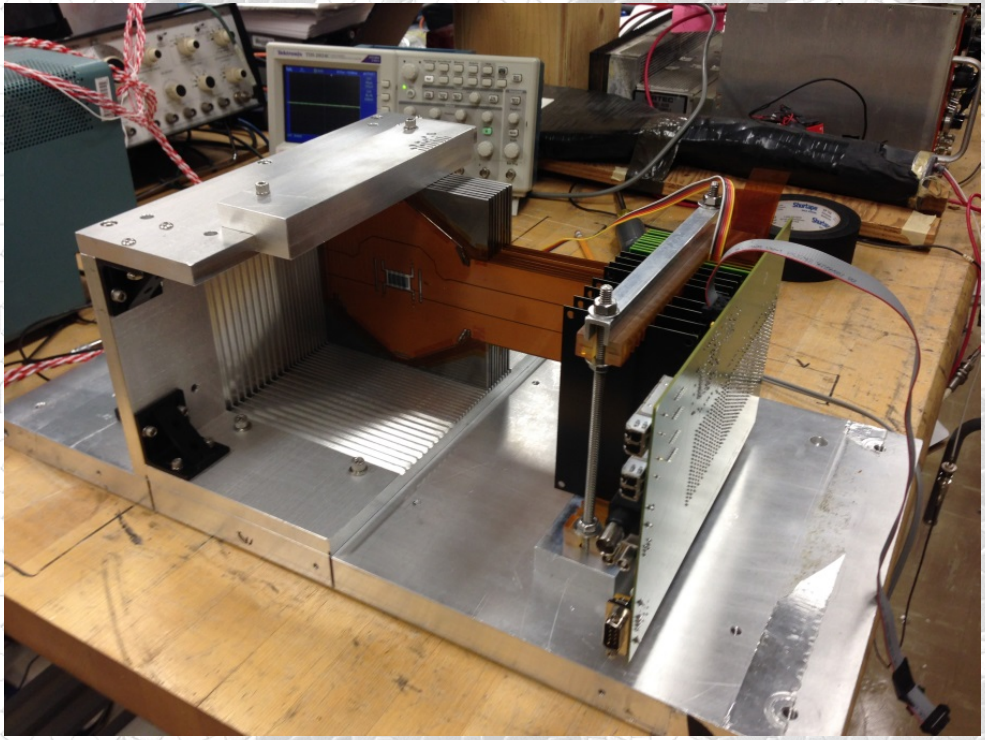
"Barrel" rectangles

Hexagons + Barrel hybrid elements

Initial test beam module for T-511
only 9 Si + 8 W layers (~ 6 X_0)

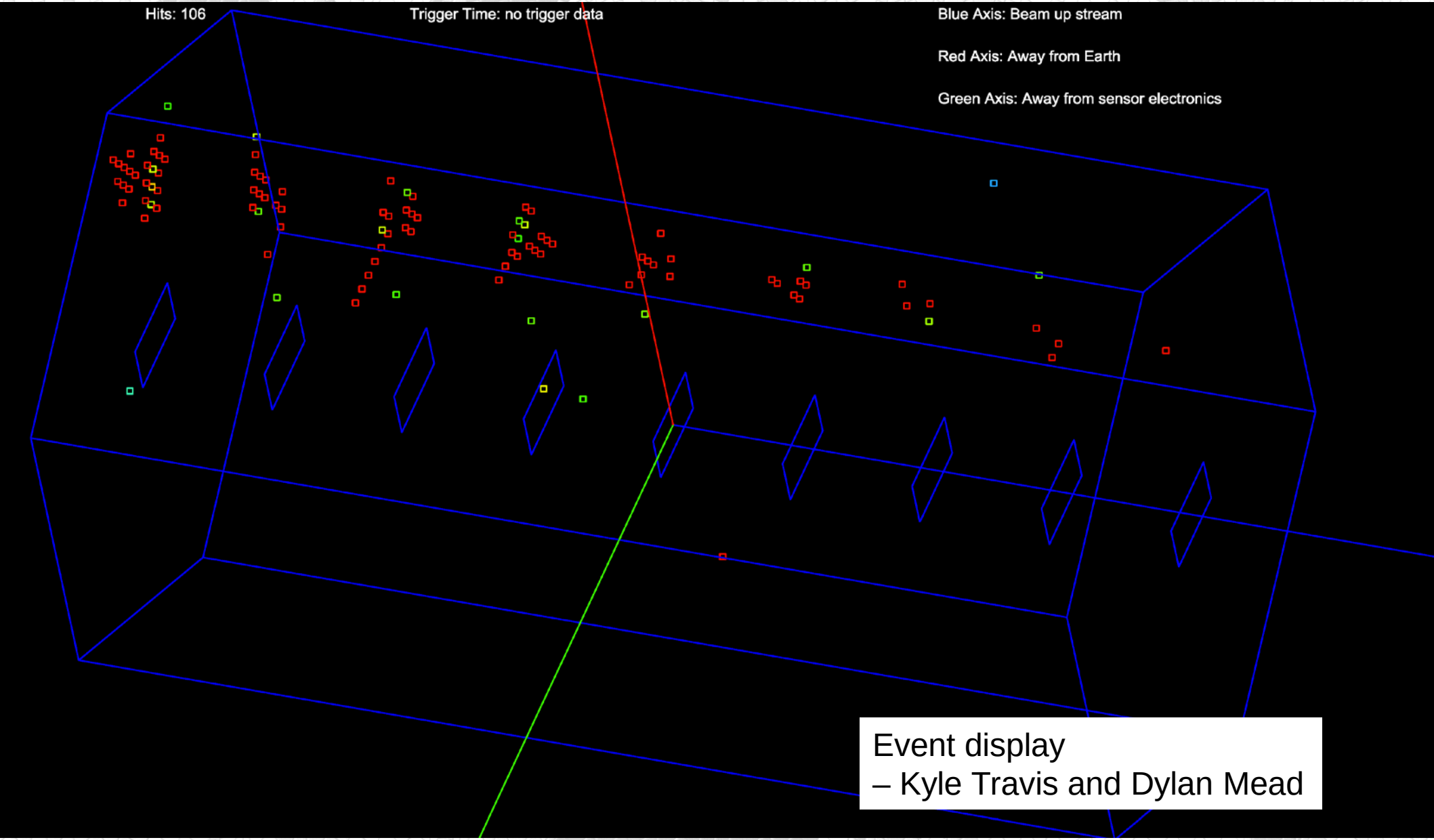


Test beam Ecal prototype design – with SiD longitudinal profile



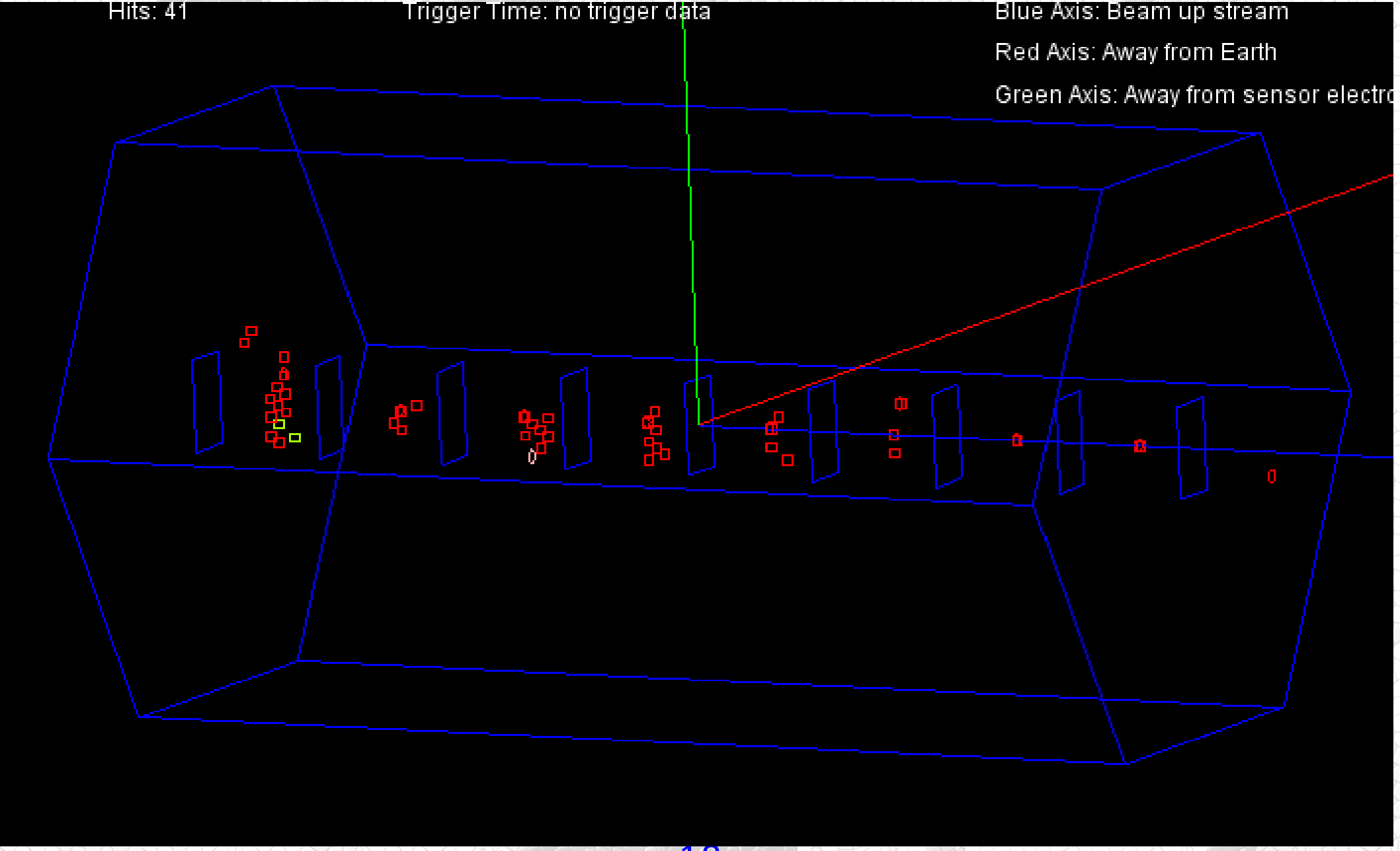
- First system test EMCal sensors in SLAC End Station A beam.
- Utilized (finally!) successfully bump bonded KPiX to sensor and sensor to cable.
- Uncovered issues related to many pixels triggered simultaneously. One part of solution may be on sensor:

single-electron showers



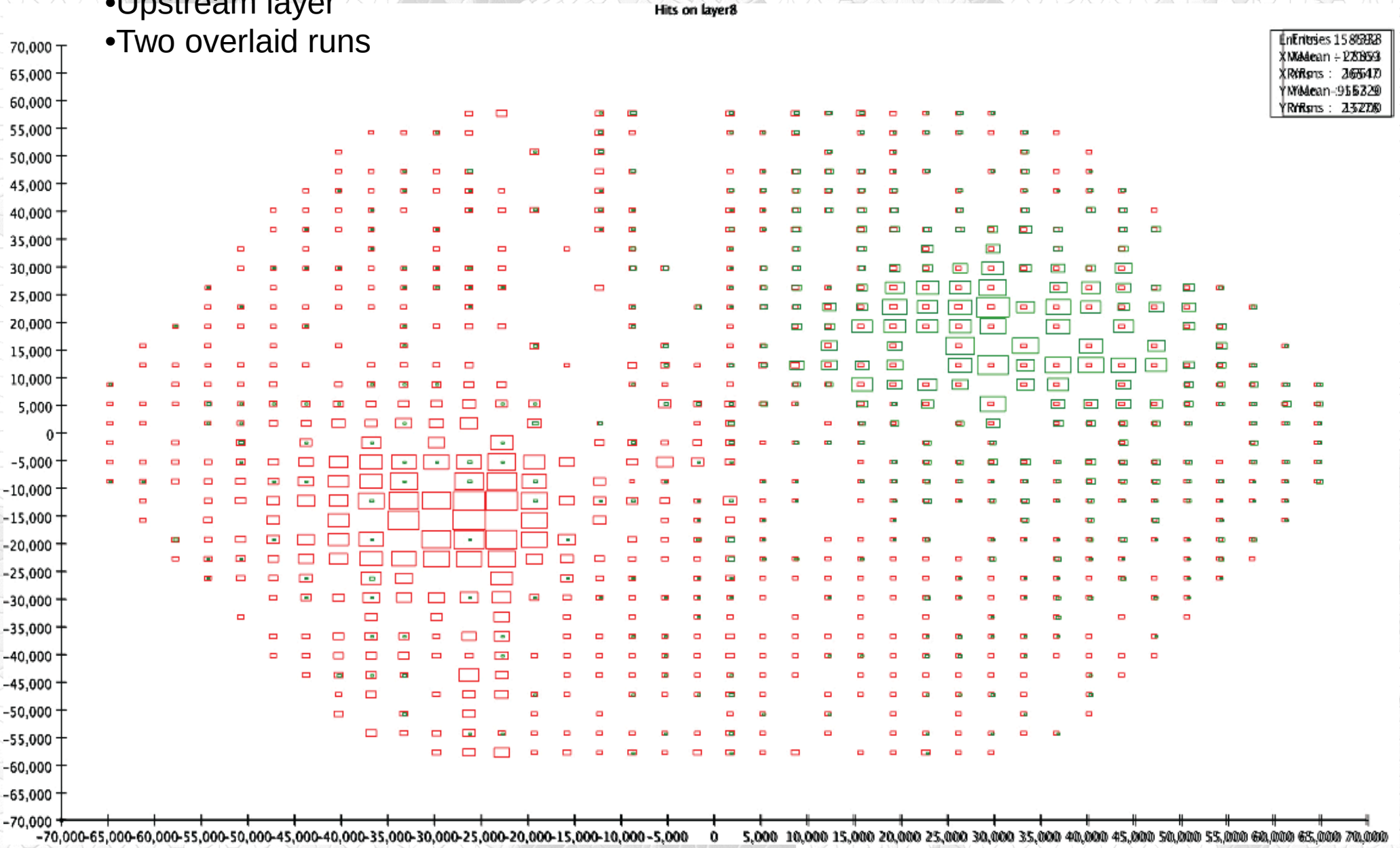
Event display
– Kyle Travis and Dylan Mead

another one-electron event

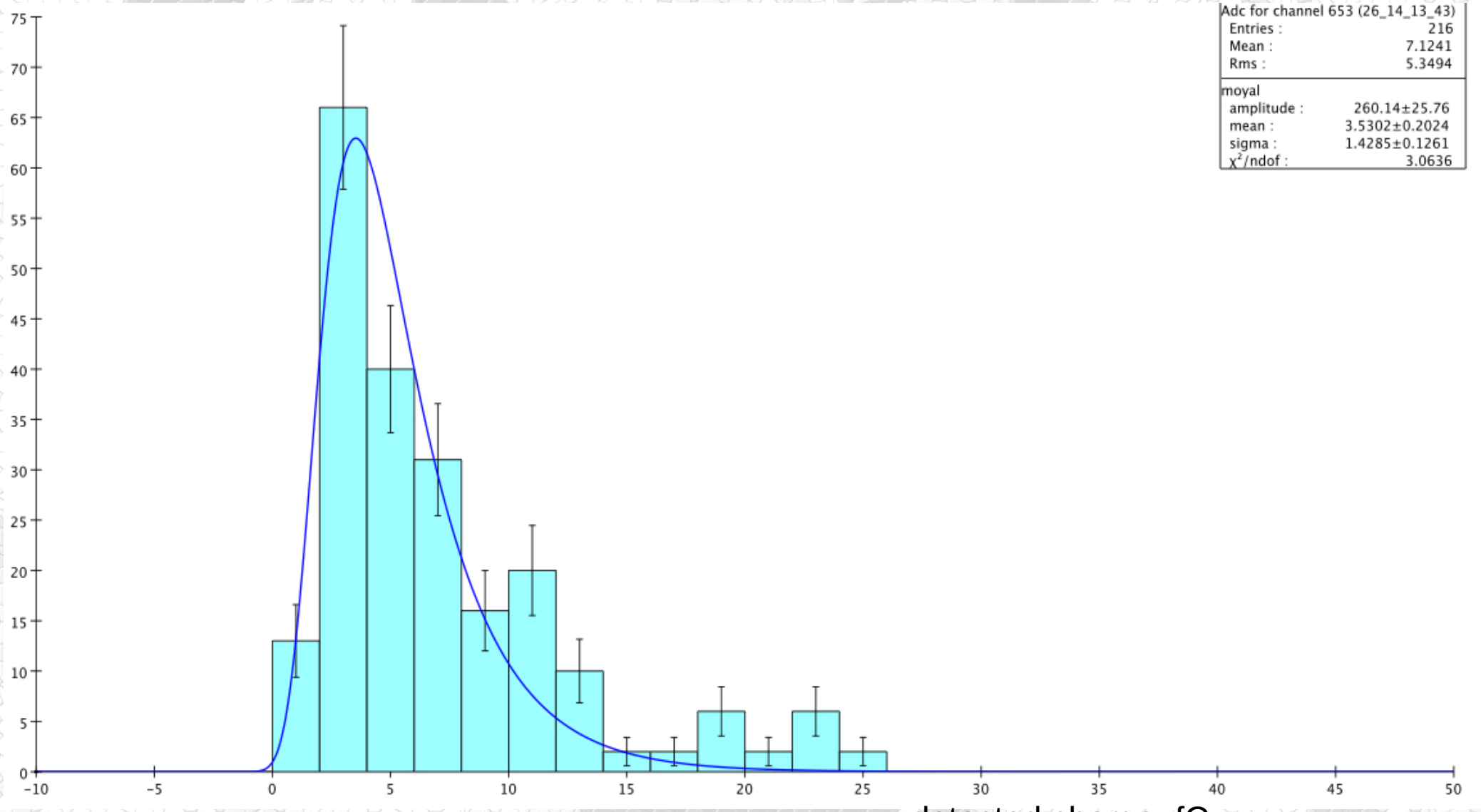


beam size

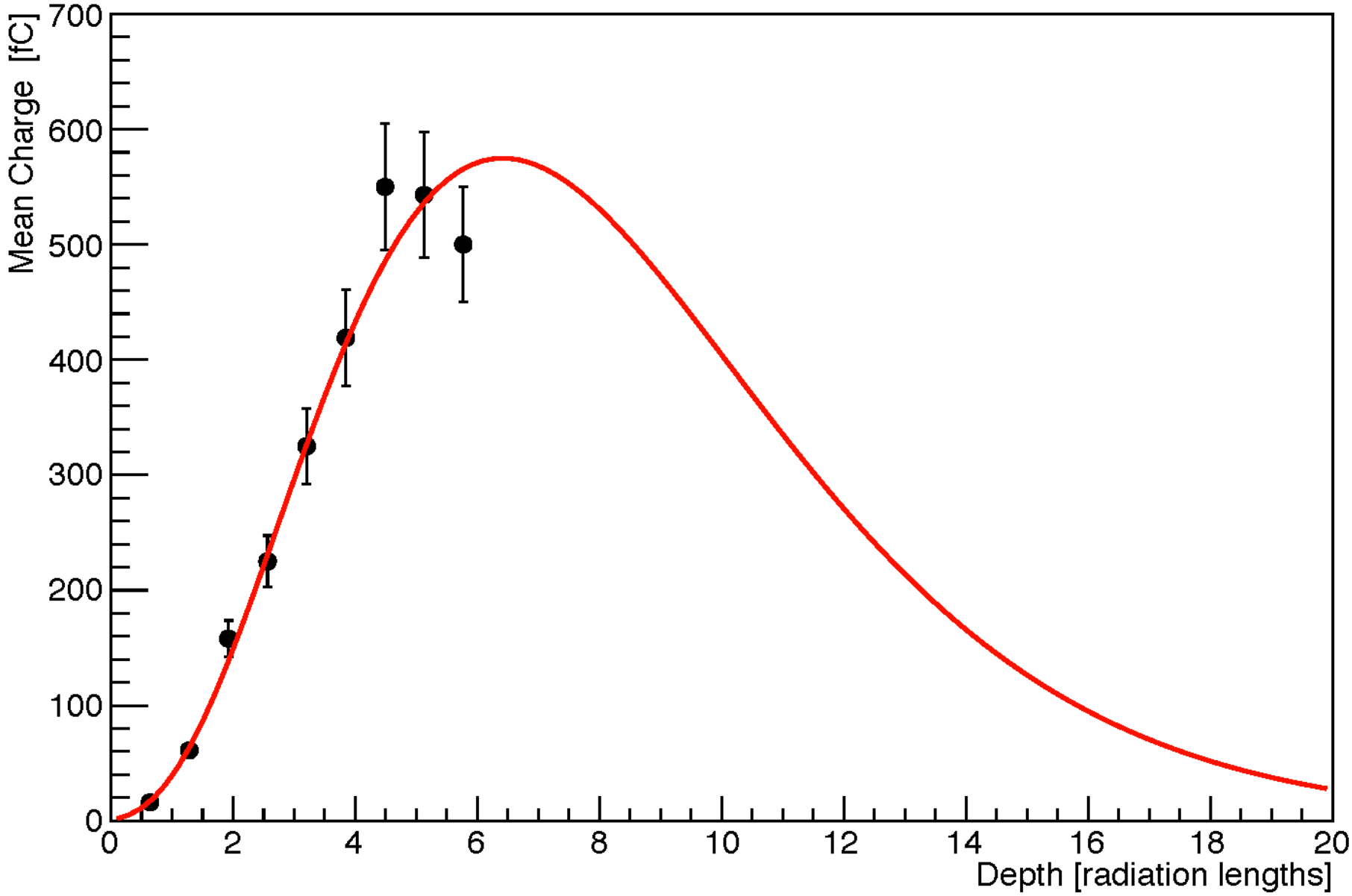
- Upstream layer
- Two overlaid runs



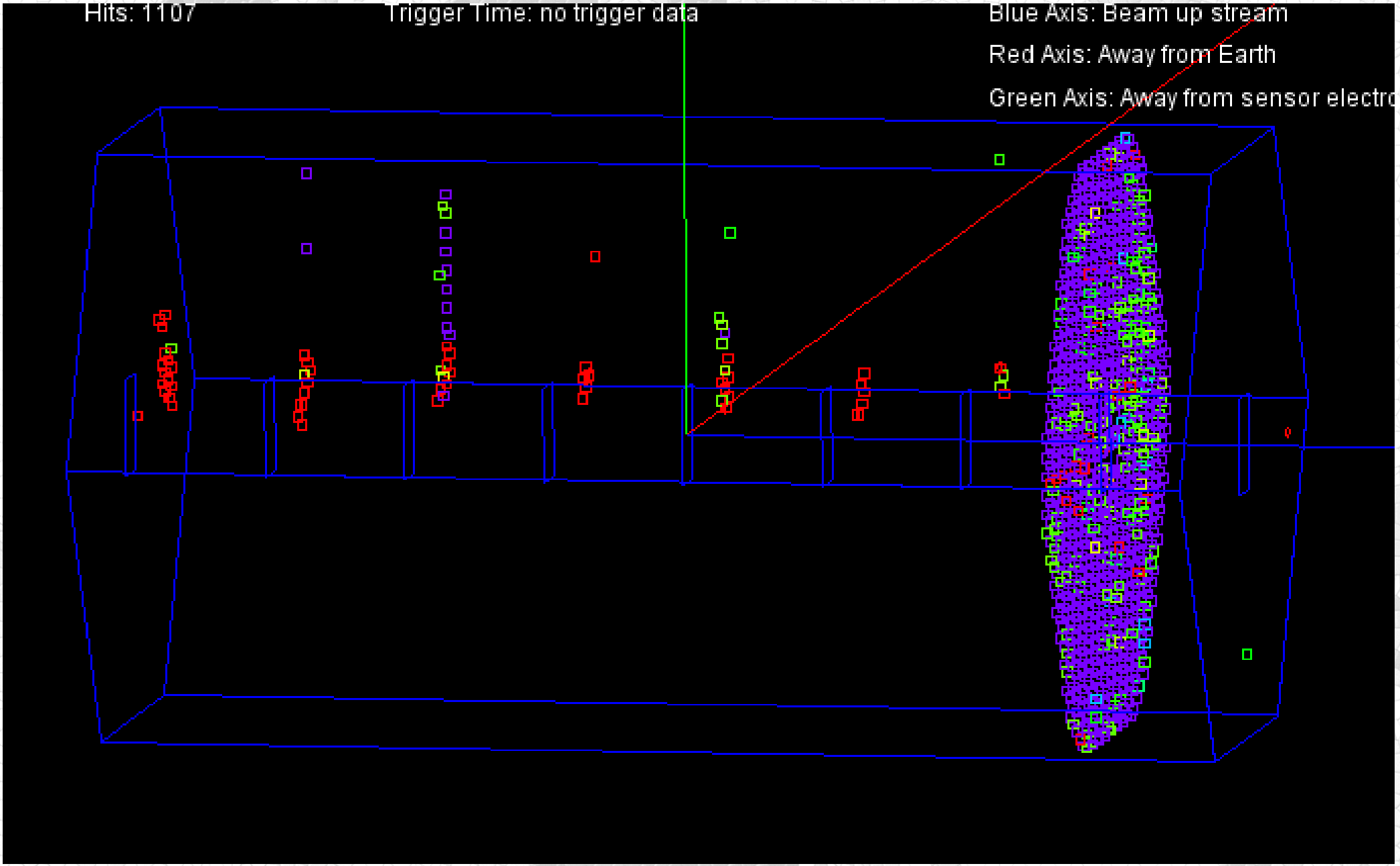
Upstream layer - MIPs



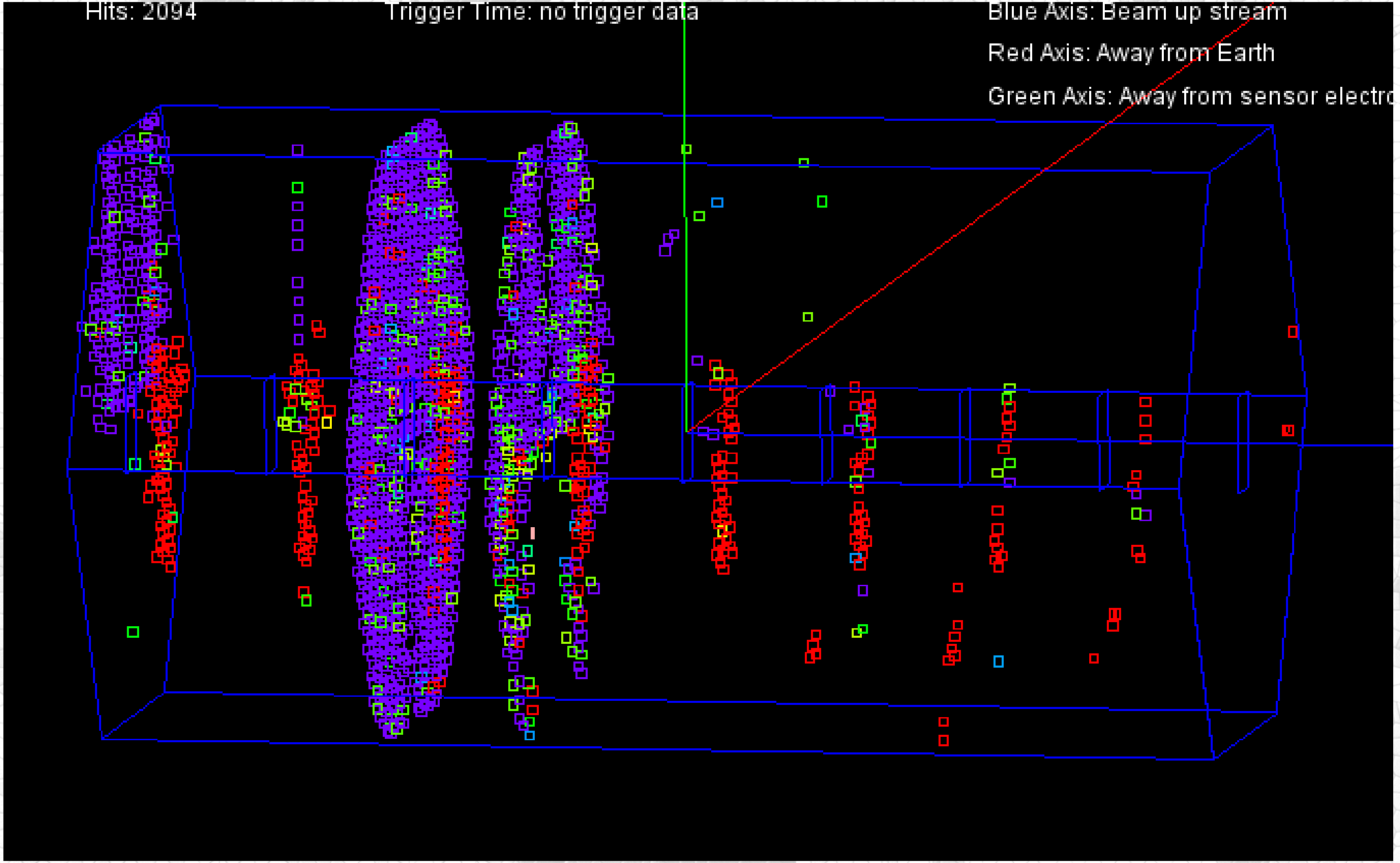
profile in depth



“monster events” with many negative amplitude and out of time hits

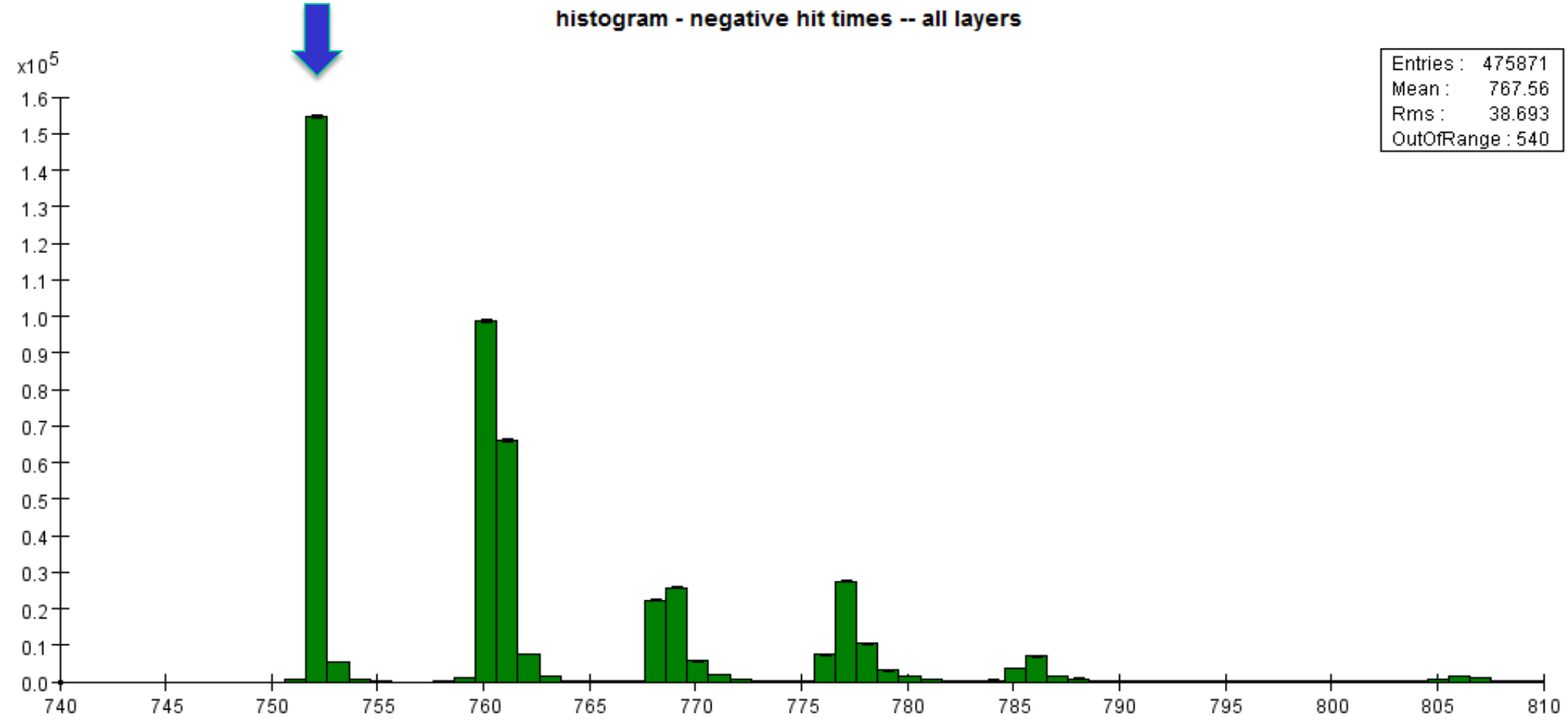


monster behavior increases with more hit pixels (multi-electrons)



times of negative-amplitude hits

beam time

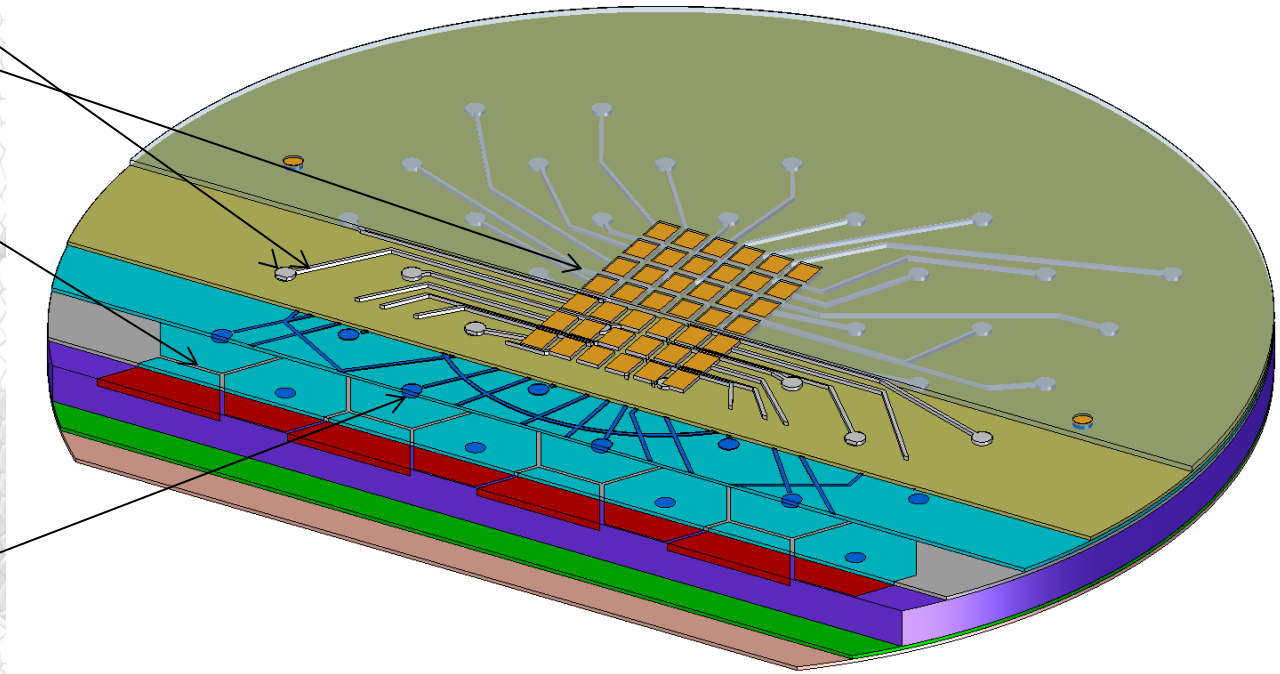


Major Lessons (so far)

- Bump bonding to sensors with Al pads can be very difficult…
  - Consider sensor foundry build final pad stack.
  - Don’t dice the sensors until bonding issues are fully controlled.
- EMCal can have huge number of pixels hit simultaneously, causing synchronous disturbances as pixels reset…Problem understood, small changes in KPiX design.
- Sensors with ROC’s can have issues with parasitic couplings…

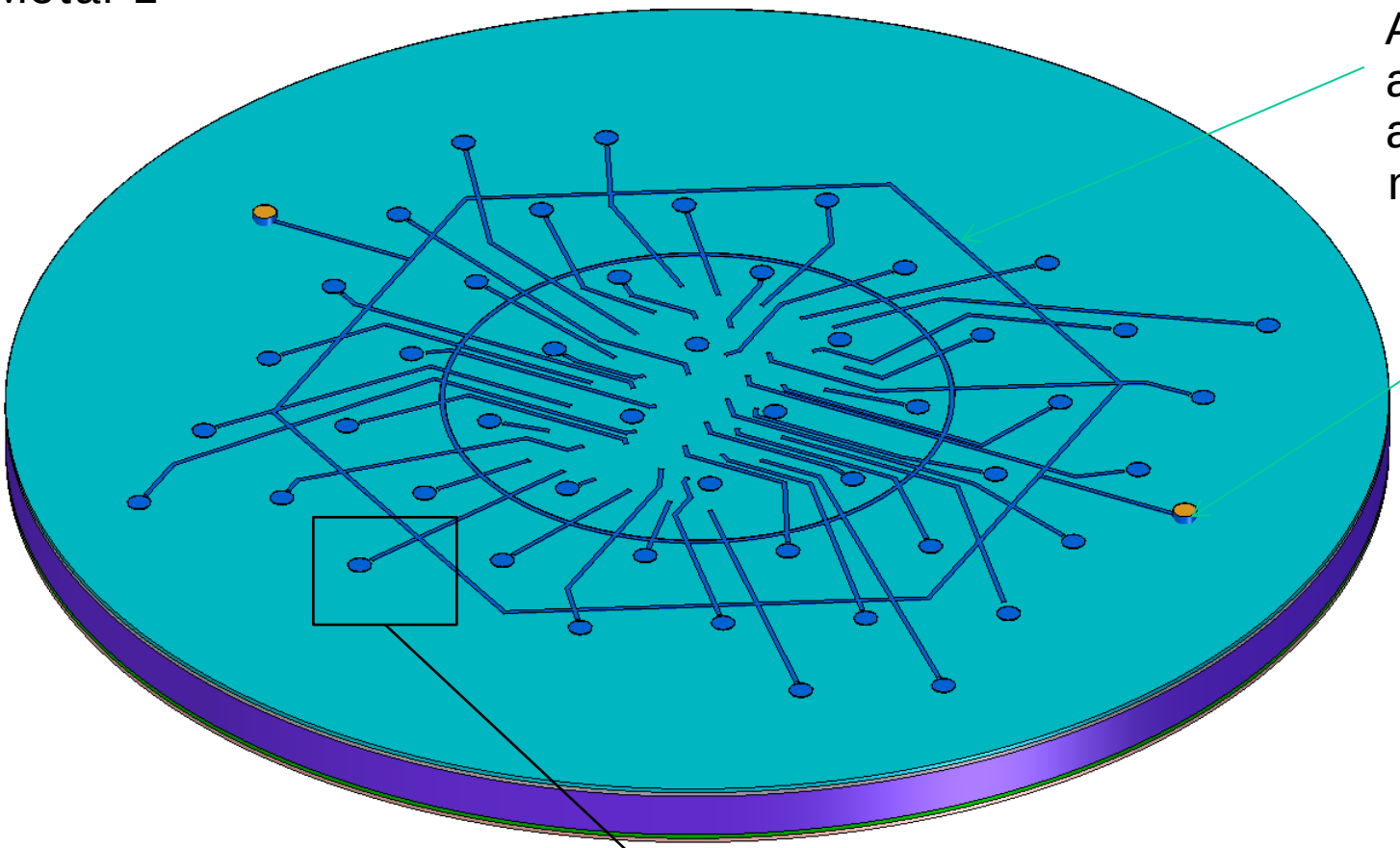
Sensor Traces

In present design, metal 2 traces from pixels to pad array run over other pixels: parasitic capacitances cause crosstalk.



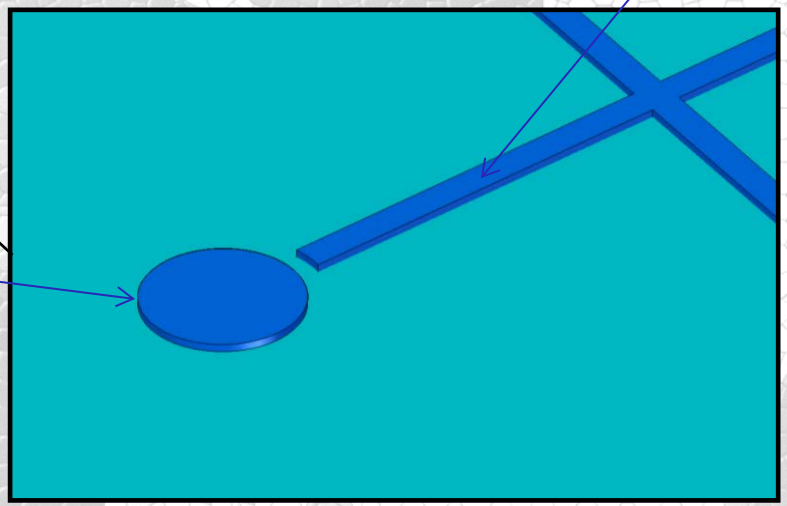
New scheme has “same” metal 2 traces, but a fixed potential metal 1 trace shields the signal traces from the pixels.

Metal 1



All shield traces are tied together, and brought to a metal 2 pad.

Shield trace running under Metal 2 signal trace.



connection of implant to metal 2 trace to pad.

Probably will be tested in next sensor prototype.

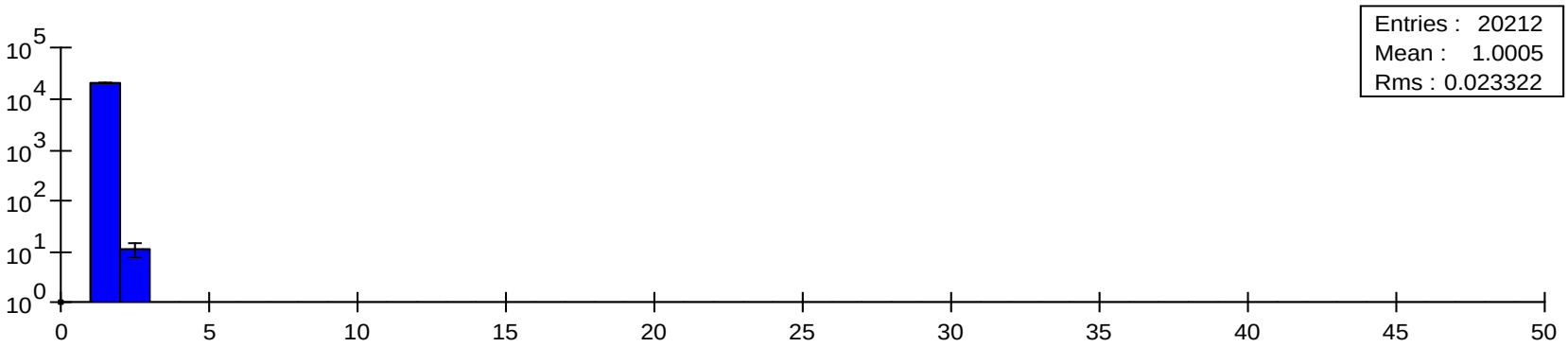
Multiplicity

- There have been indications that forward multiplicity might be more than 4 buffer KPiX could handle.
  - Long known that BeamCal required BEAN chip, which digitizes every pulse.
- Study only has Guinea Pig pairs so far;
- Bhabhas must be added before concluding anything!

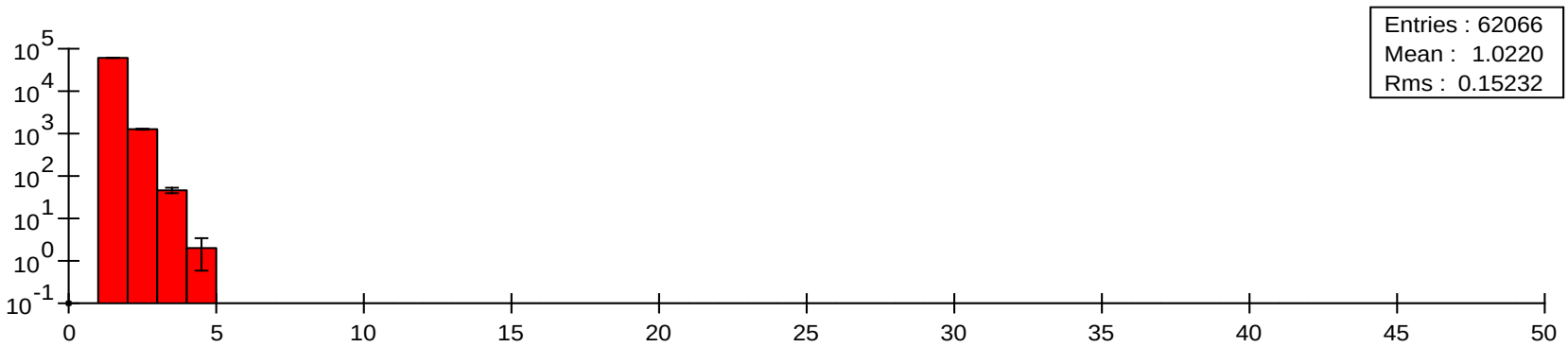
Have generated one train's worth of pairs resulting from beam-beam interactions at 500GeV - 1325 bunches

Represent nominal ILC luminosity, "high-luminosity" running would be x2

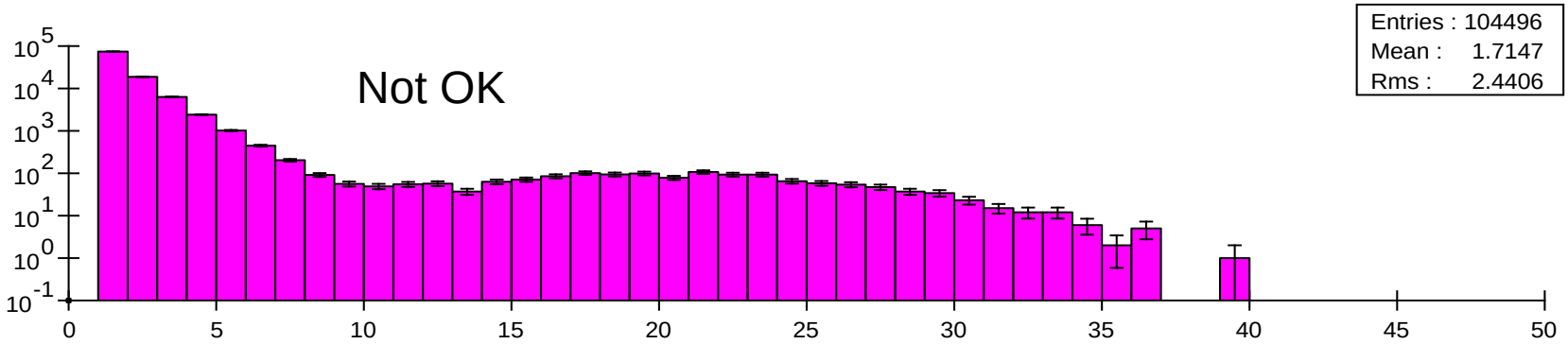
EcalBarrelHitsoccupancy rates



EcalEndcapHitsoccupancy rates



LumiCalHitsoccupancy rates



Multiplicity

- Bhabhas must be added
- Lumical must be studied to see if high multiplicity is only first layers, which might not need to be instrumented.
- Study KPiX to see if more buffers might be added, preserving architecture.
- Study somewhat different architecture – preconceptual ideas only…

Summary

- There is progress towards a mechanical conceptual design of the EMCal!
- The beamtest demonstrated expected behavior of the prototype but showed different crosstalk issues in the sensor and KPiX.
- There is a shielding concept for the next sensor iteration.
- Achieving bump bondable pads on the sensors is extremely difficult. A different approach is needed.
- Evaluation of expected forward multiplicities is ongoing. This will influence KPiX evolution.