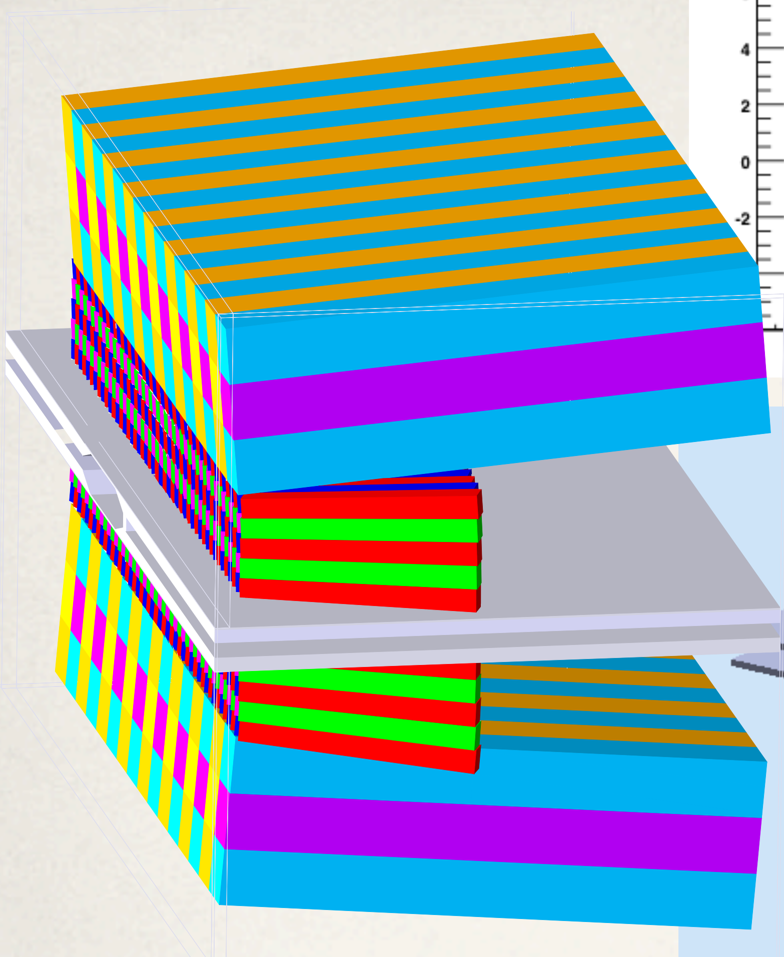
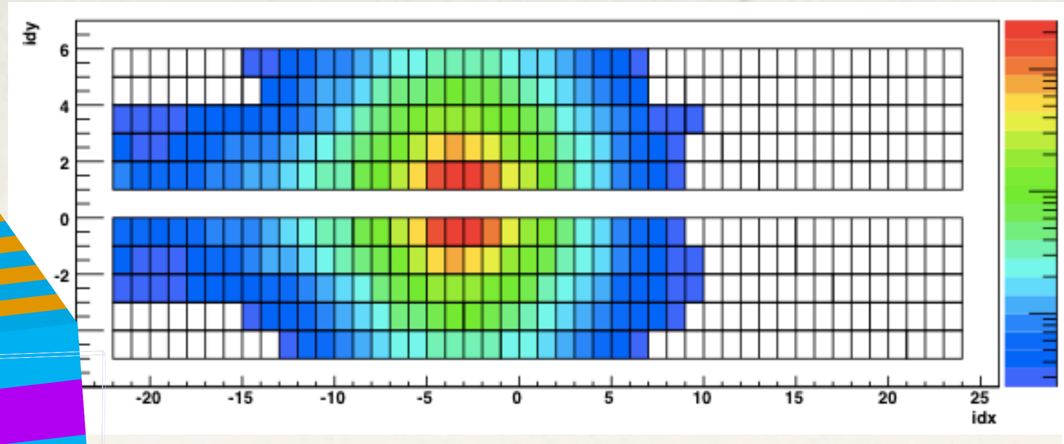
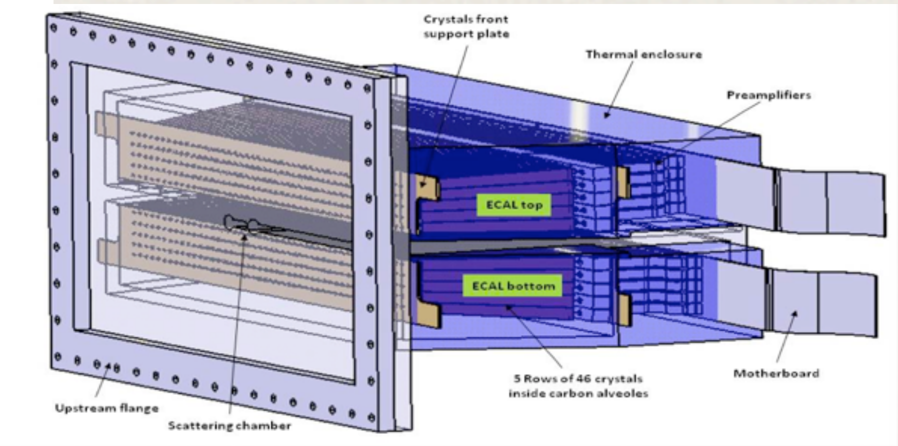
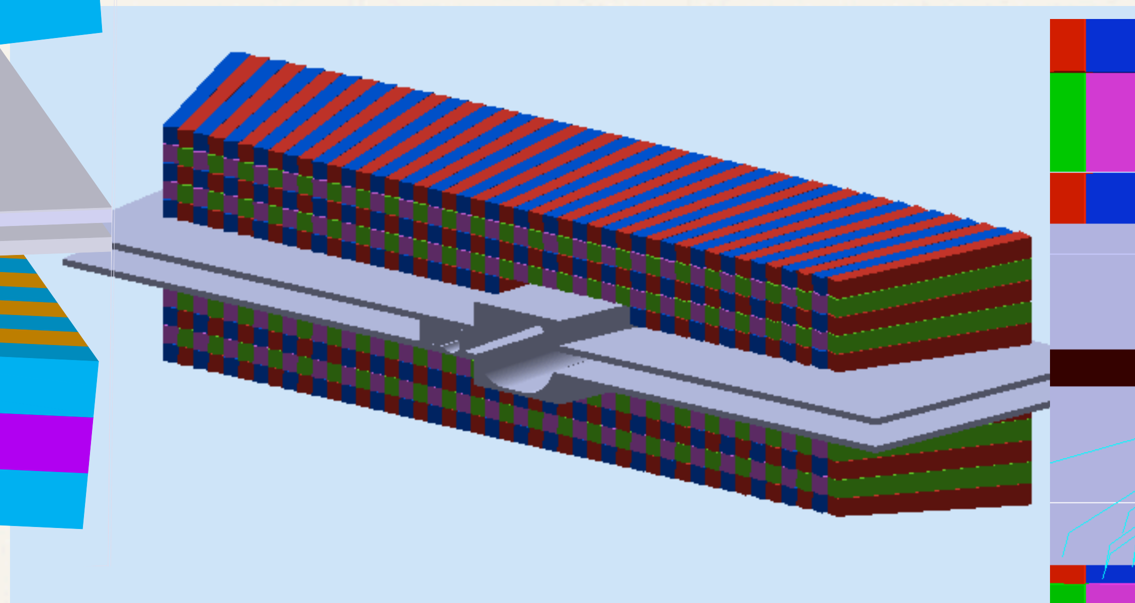
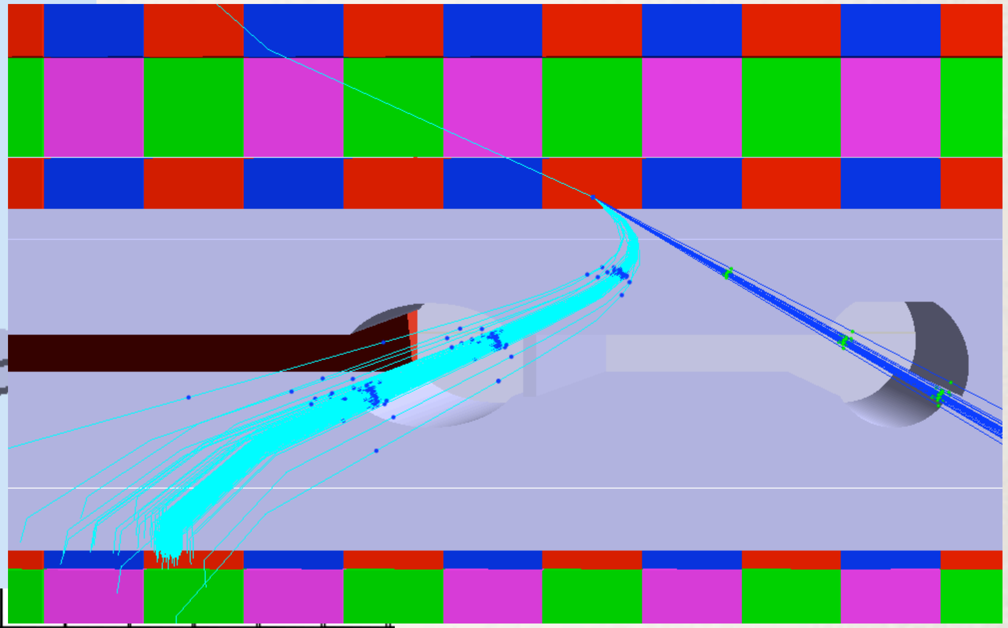
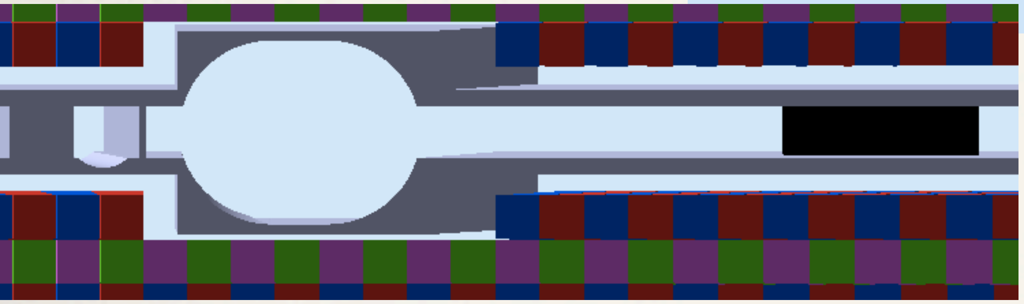


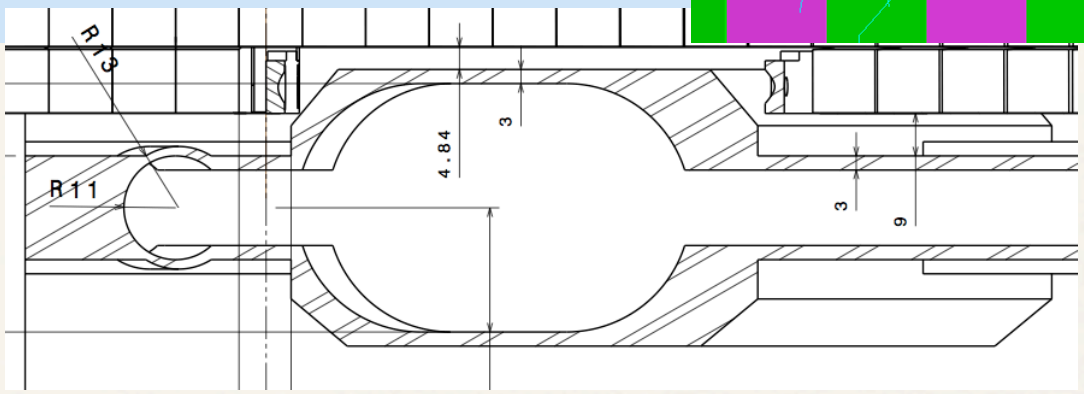












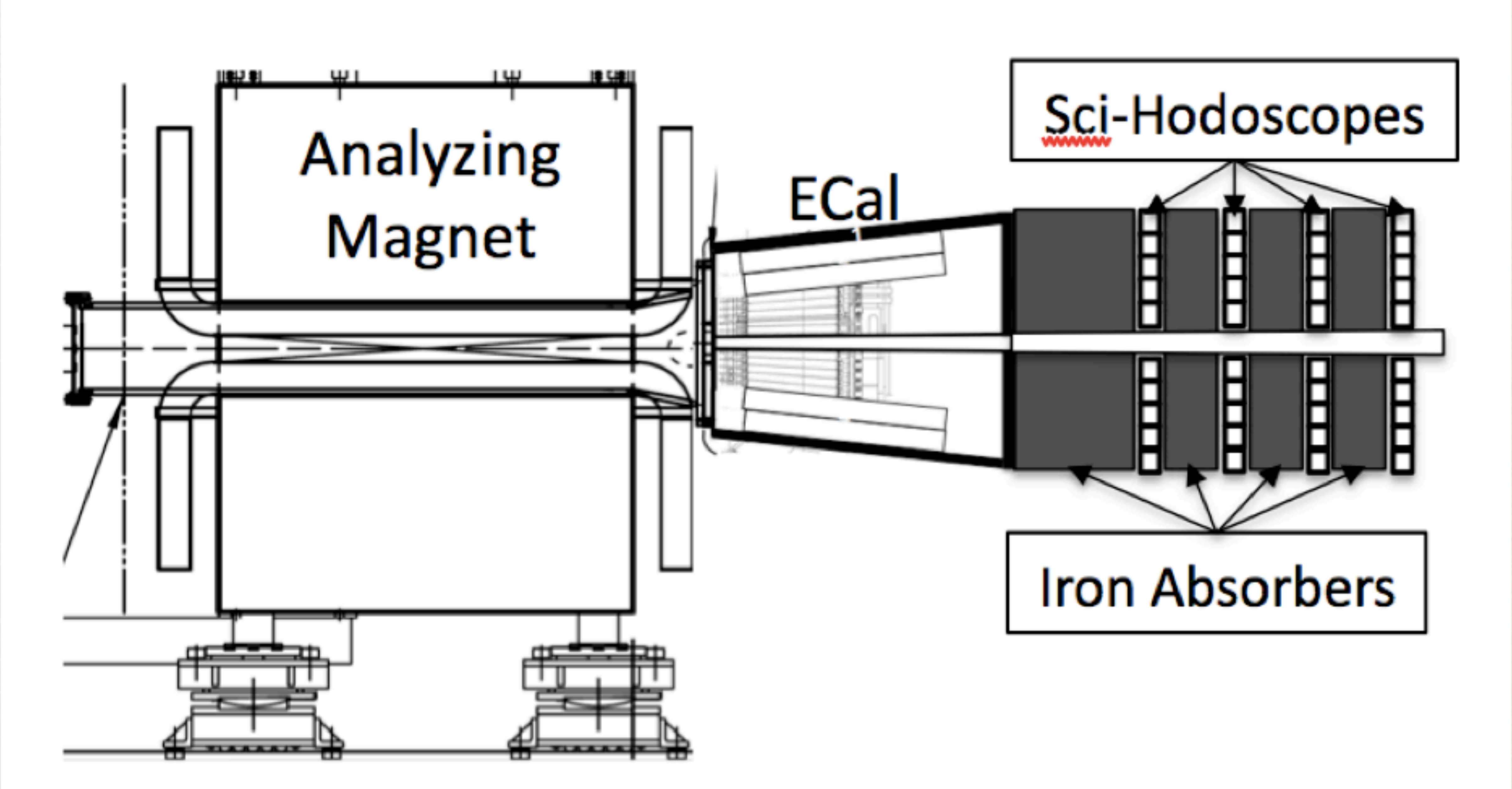
HPS ECal & Trigger Simulation

HPS Collaboration Meeting.

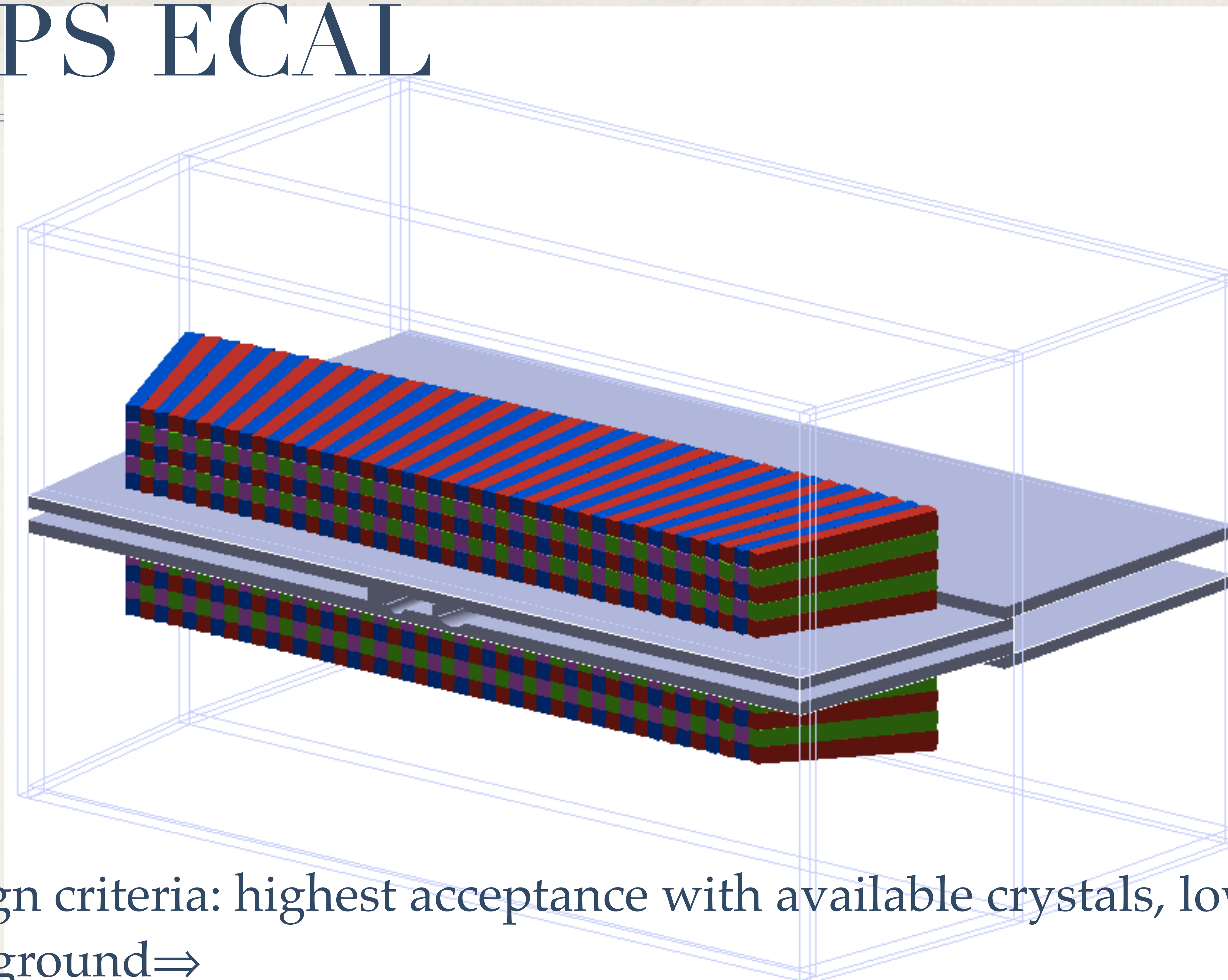
May 27, 2011

HPS Electromagnetic Calorimeter

- HPS Experiment needs the calorimeter to identify the electron/positron pair and to construct the trigger.
- High rates requires a highly segmented design and fast readout system.



HPS ECAL

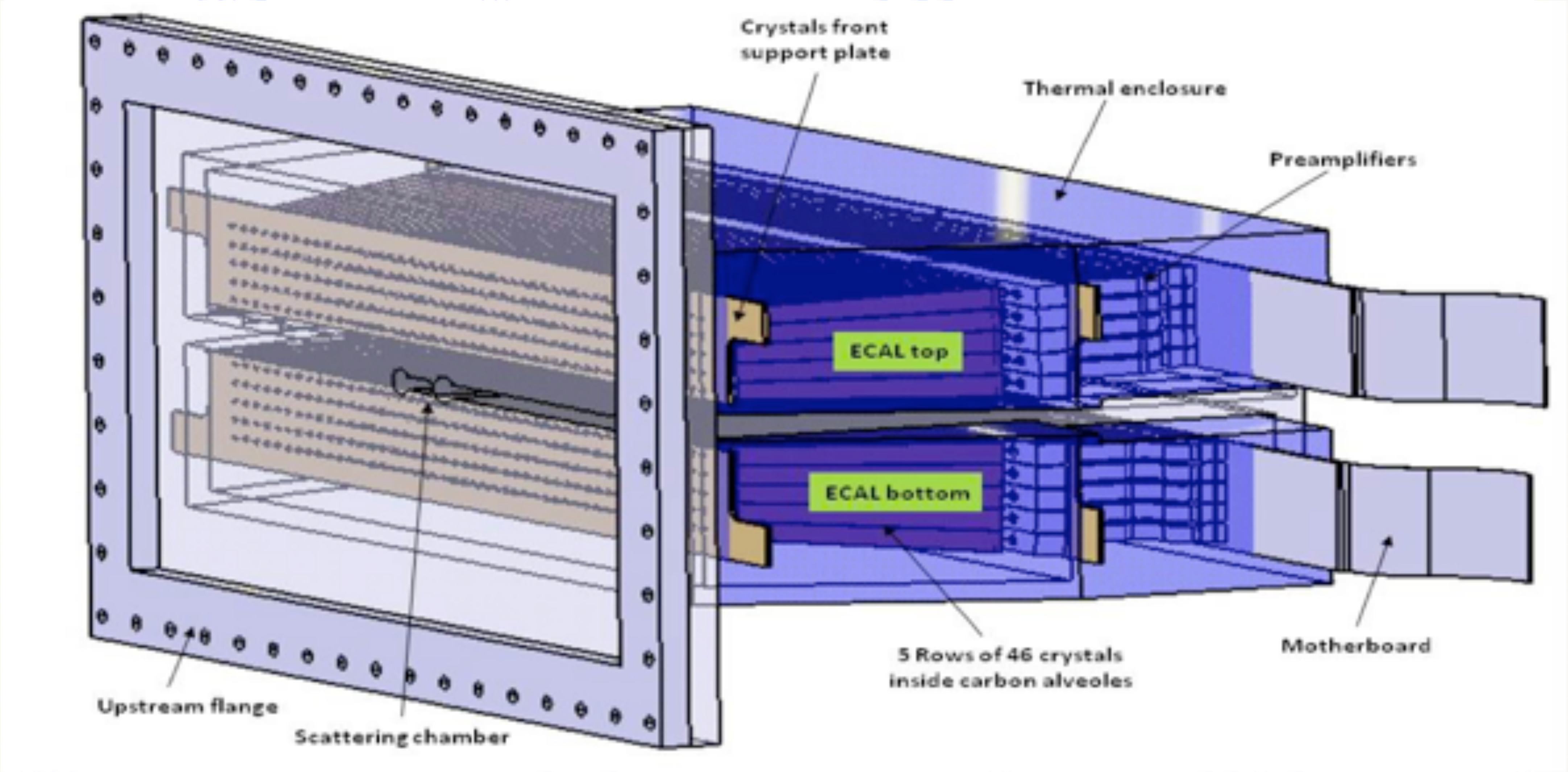


Design criteria: highest acceptance with available crystals, low background⇒

460 PbWO4 Crystals (2 segments, 5 rows of 46 crystals)

Vacuum box with cutout region for beam

HPS ECAL

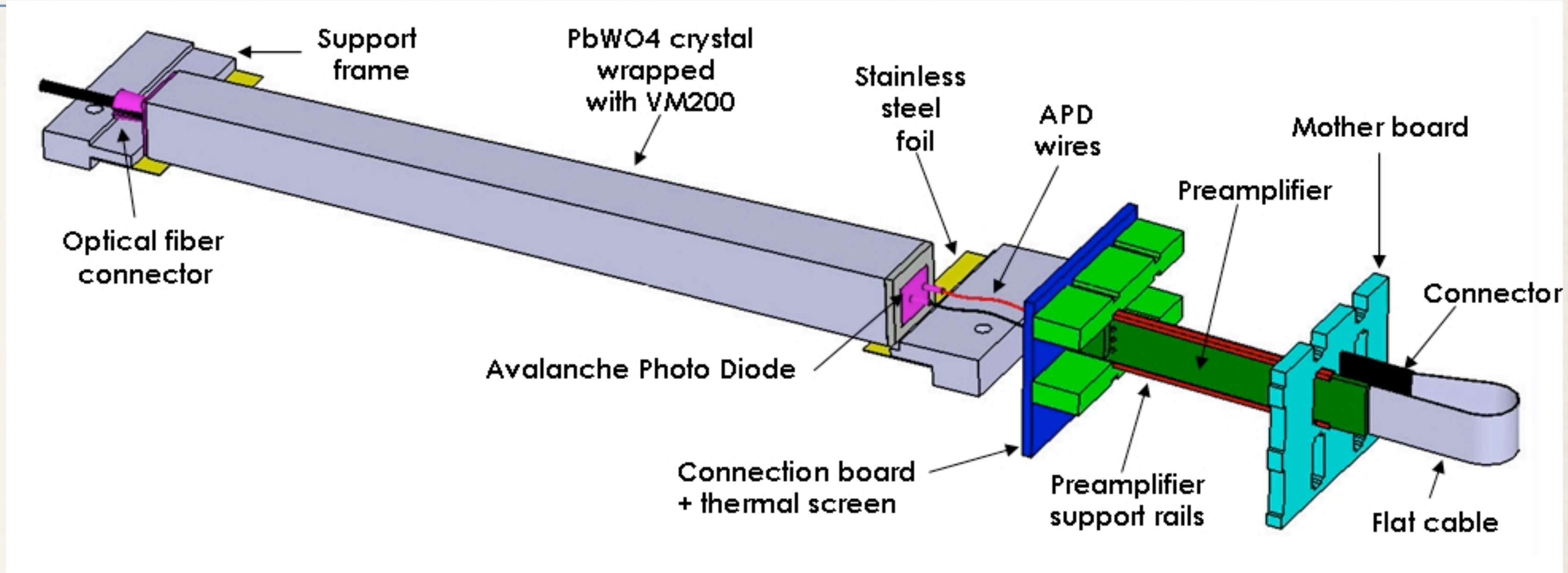


Design criteria: highest acceptance with available crystals, low background⇒

460 PbWO4 Crystals (2 segments, 5 rows of 46 crystals)

Vacuum box with cutout region for beam

Available Crystals: PbWO4

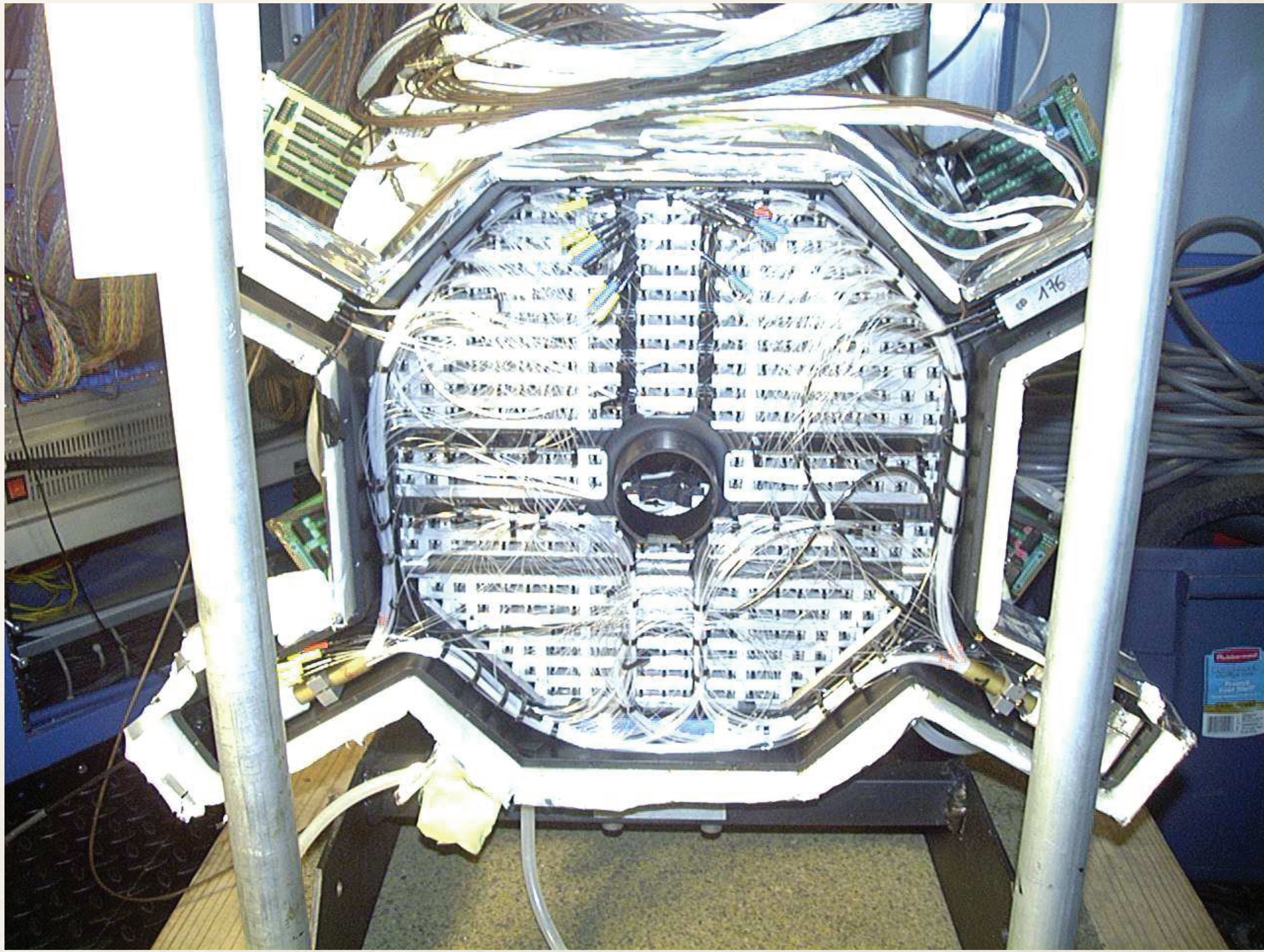


Lead-Tungstate crystals available from inner calorimeter of CLAS.

Energy resolution: $\sigma/E \sim 4.5\%/\sqrt{E}$ (GeV)

460 crystals available

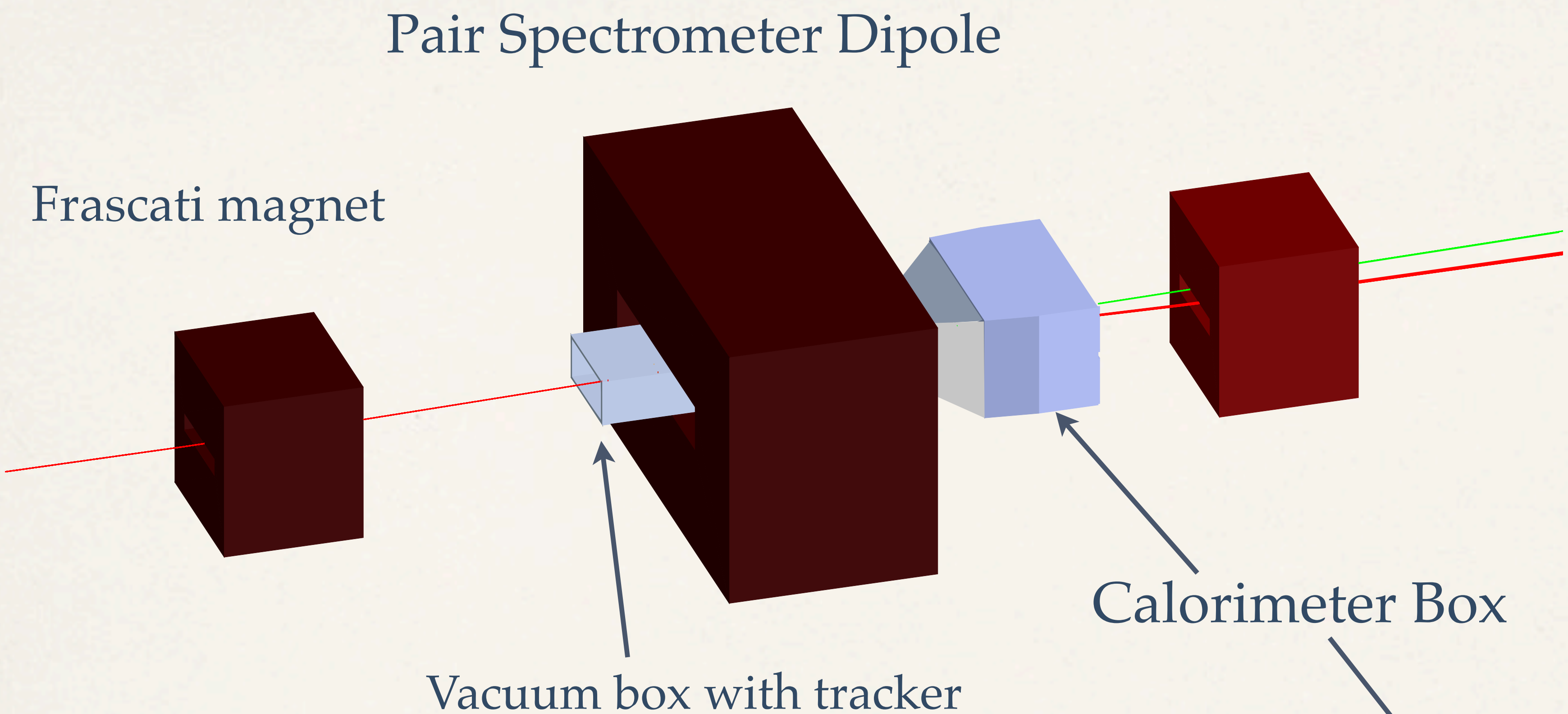
See: CLAS-Note 2005-007

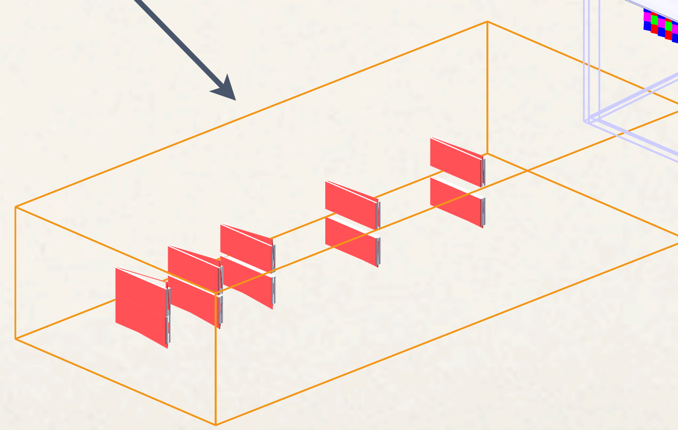


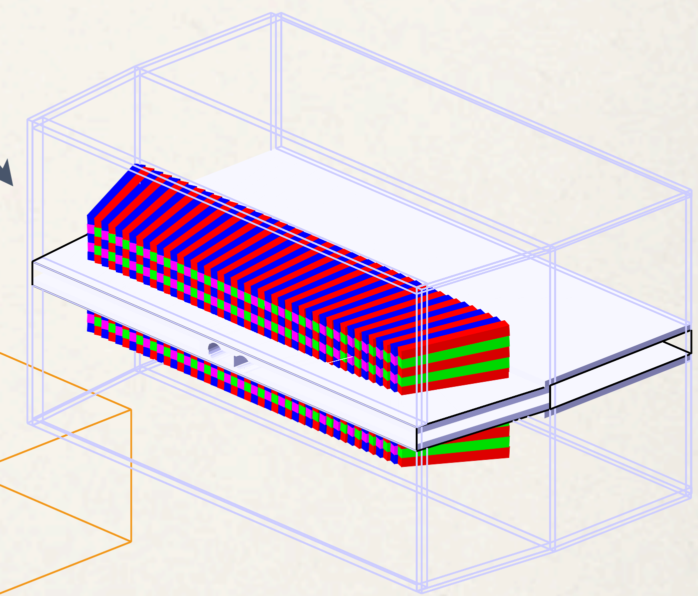
ECal Signal

- Full length of the signal (APD+pre-amplifiler) is ~60 ns
- For triggering purposes signal will be integrated in 32 ns (8 FADC samples) time window after passing the threshold
- Every 16 ns integrated pulses will be sent to trigger board (8 bits)
- The full pulse, 64 ns (16 FADC samples, 2 before threshold crossing) will be read out for analysis

Test Run Simulation



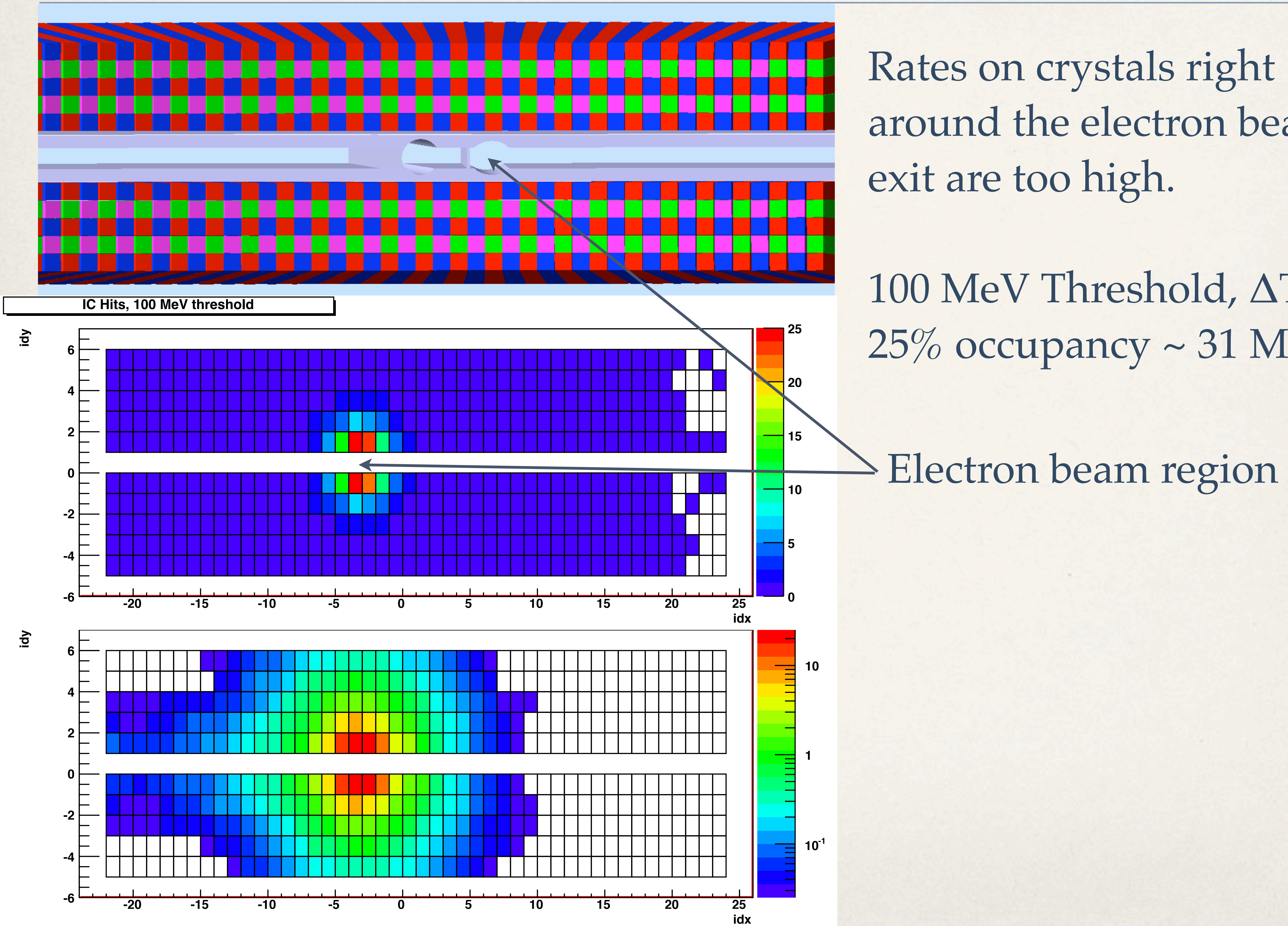




Full simulation of the experiment implemented in GEANT4:

- Based on CLAS12 simulation (gemc)
- Flexible geometry from database allows for rapid prototyping.
- Full GEANT4 physics model.
- Field maps for magnetic fields.
- A′ events from generator (MadEvent)
- Background from electrons through target.

Simulated ECAL Performance

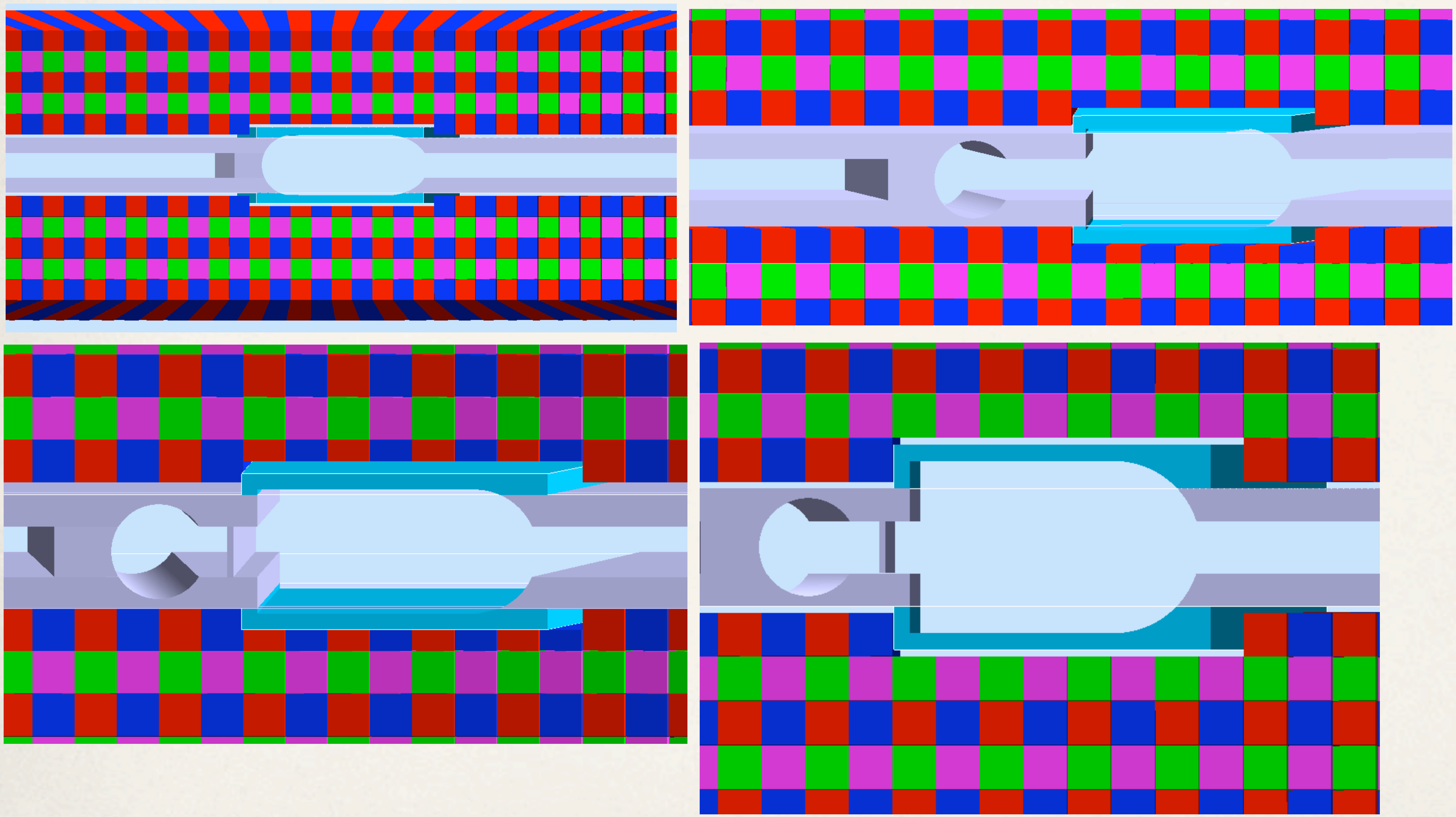


Rates on crystals right around the electron beam exit are too high.

100 MeV Threshold, $\Delta T = 8$ ns
25% occupancy ~ 31 MHz

Multiple Configurations Tried

Either cutting the crystals around the electron beam exit, or eliminating them all together and/or opening up the gap between the plates.



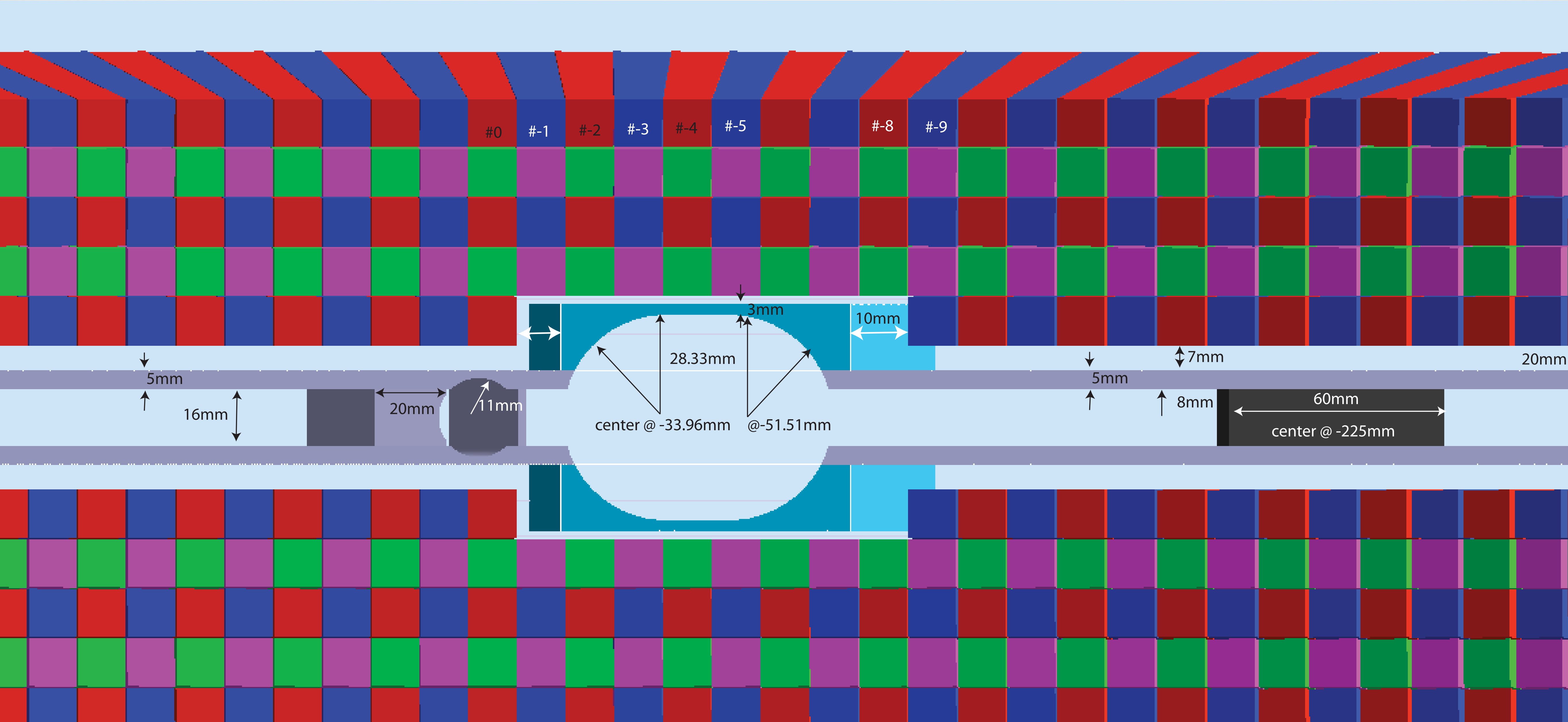
Details, run 26 configuration

Crystals -1 through -8 eliminated.

10mm space next to crystals

Hole rounded on both sides

Plates reduced thickness (5 mm)

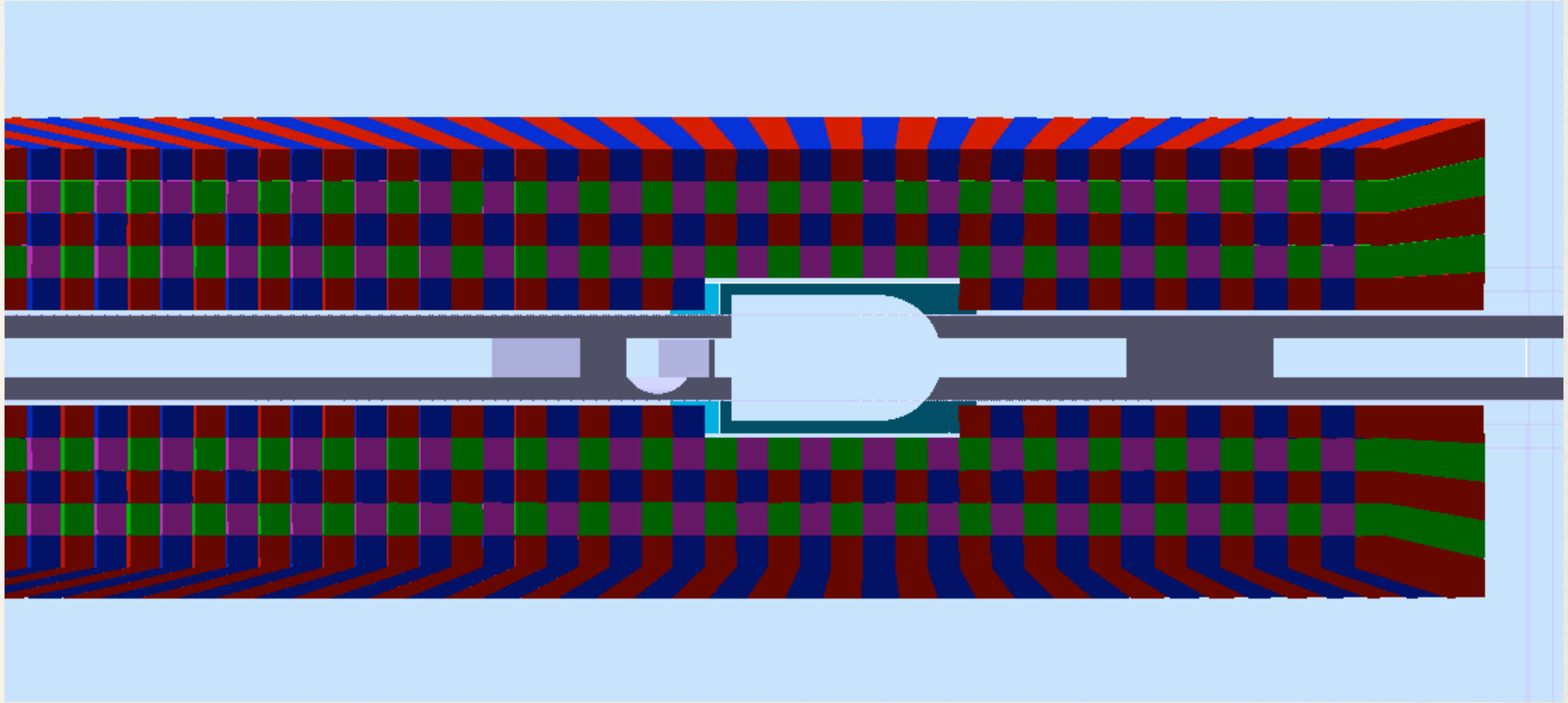


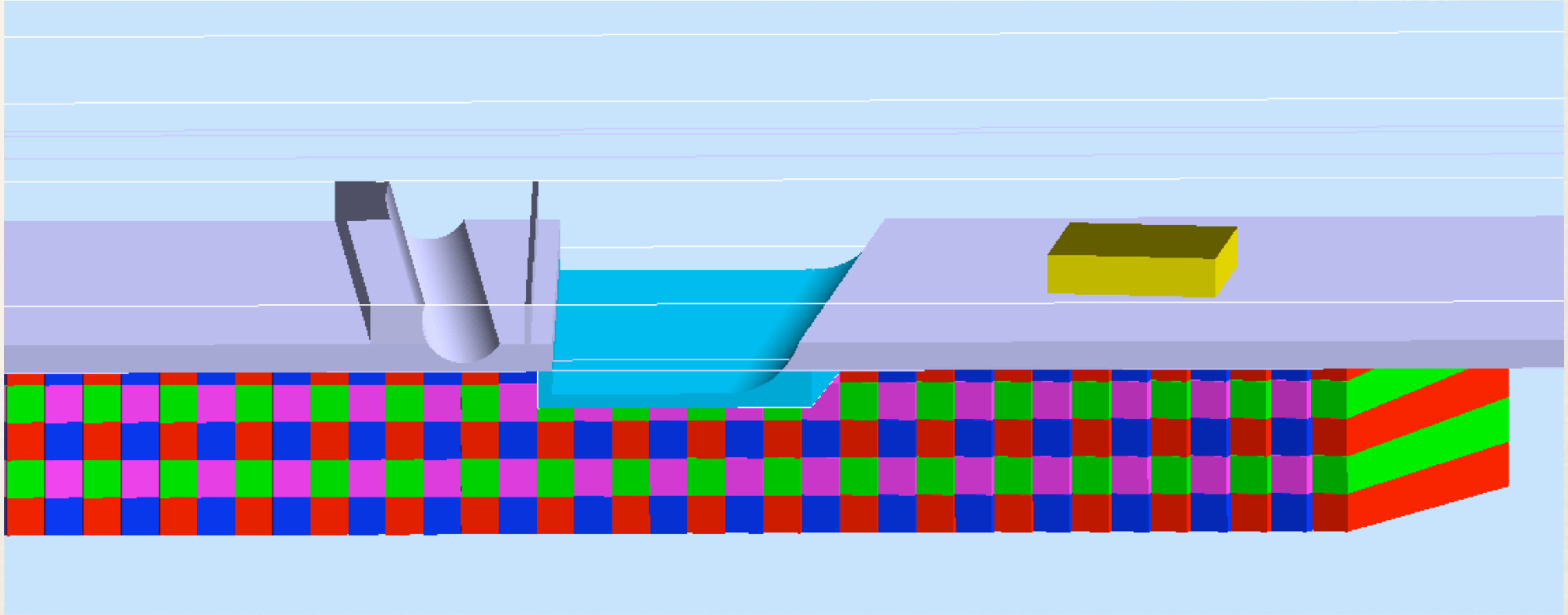
Added Support Pillar

Support pillar is 1/2 way between electron gap and end of vacuum system.

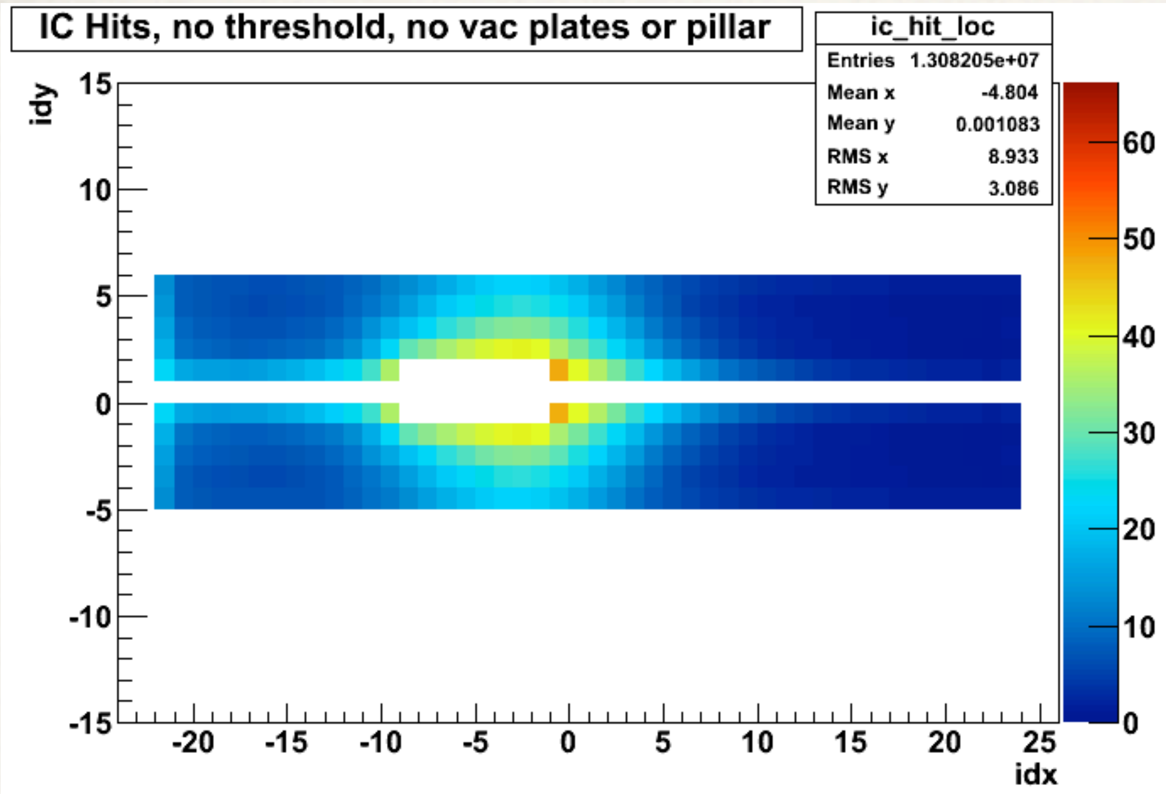
3 Runs:

1) Solid Aluminum
2) Honeycomb Alum
3) Vacuum (check)





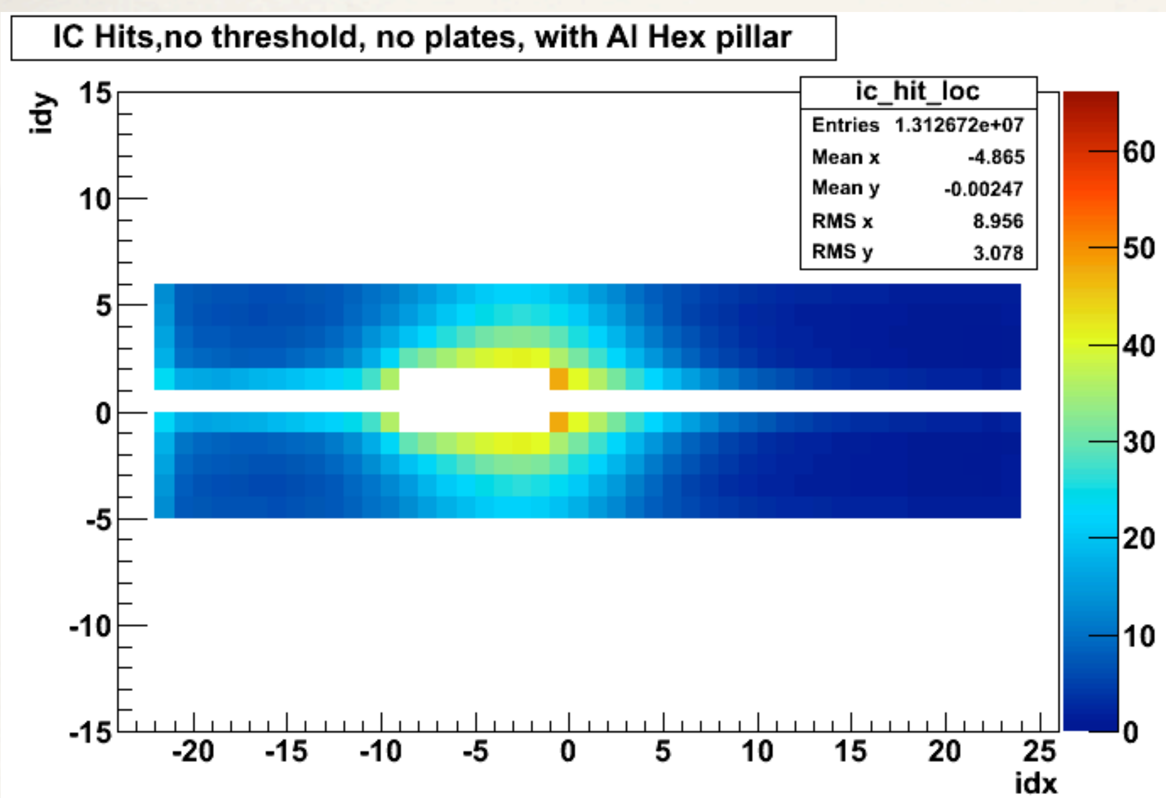
Effects of the Support Pillar

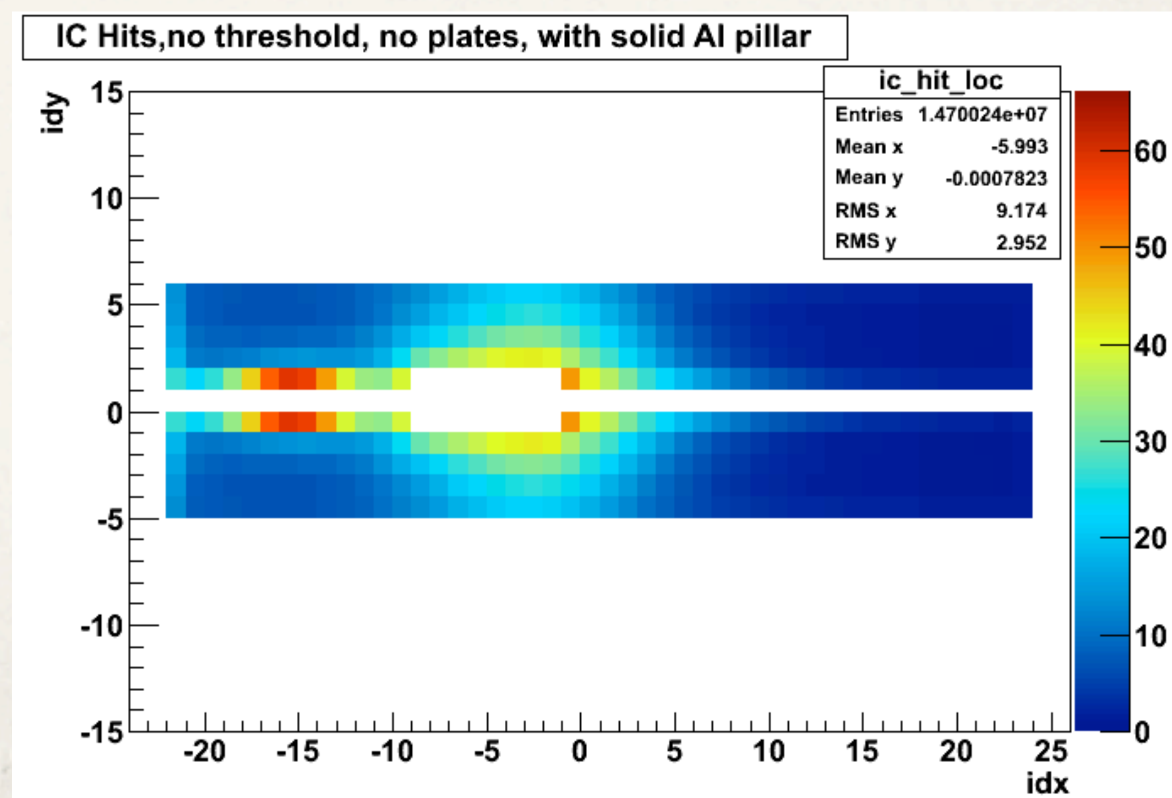


Study by Sarah Phillips

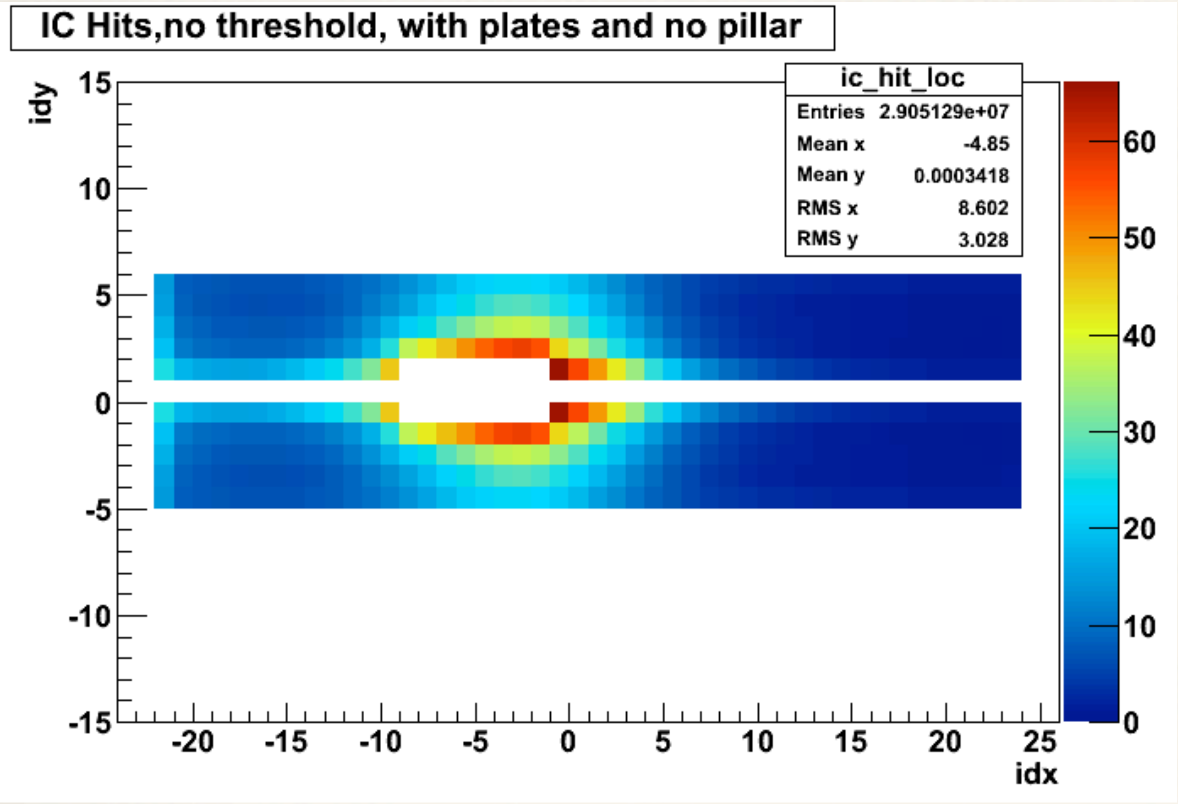
The effect of the support pillar is insignificant, if using “honeycomb” material.

Assumption that “honeycomb” can be correctly approximated with “airy aluminum” will be checked.





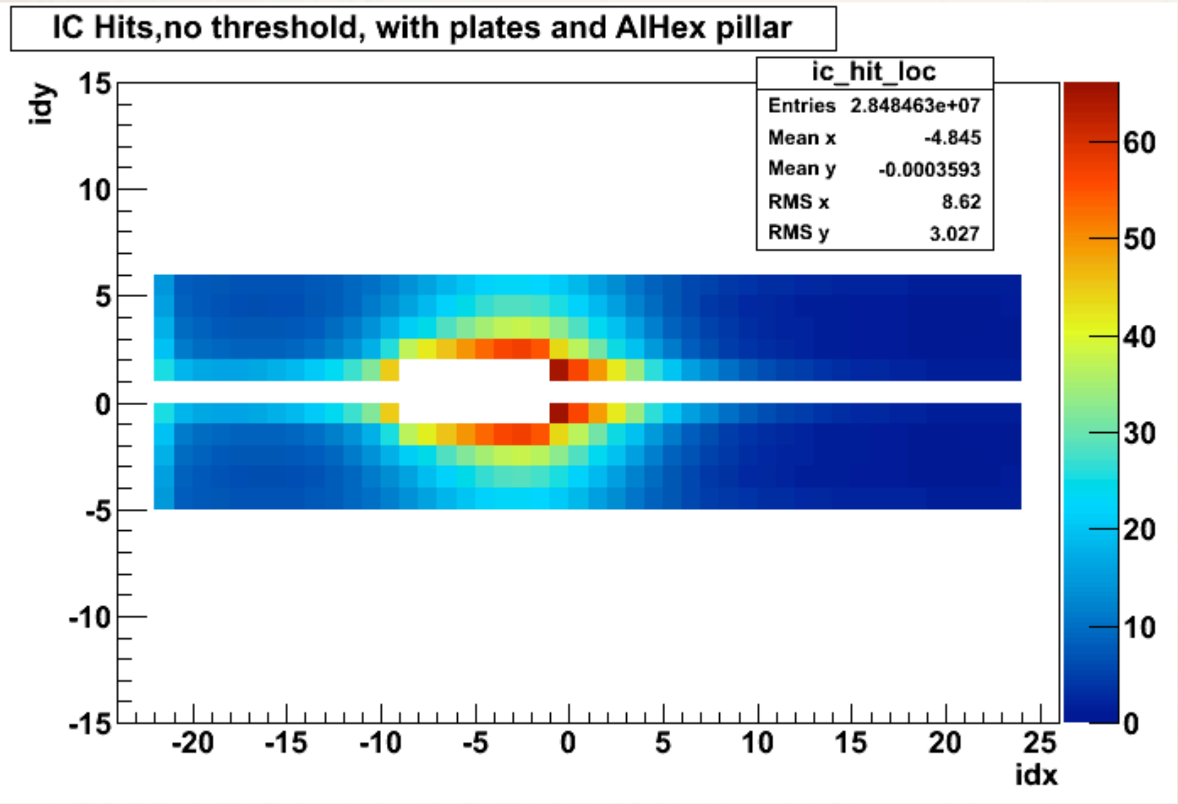
Effects of the Support Pillar

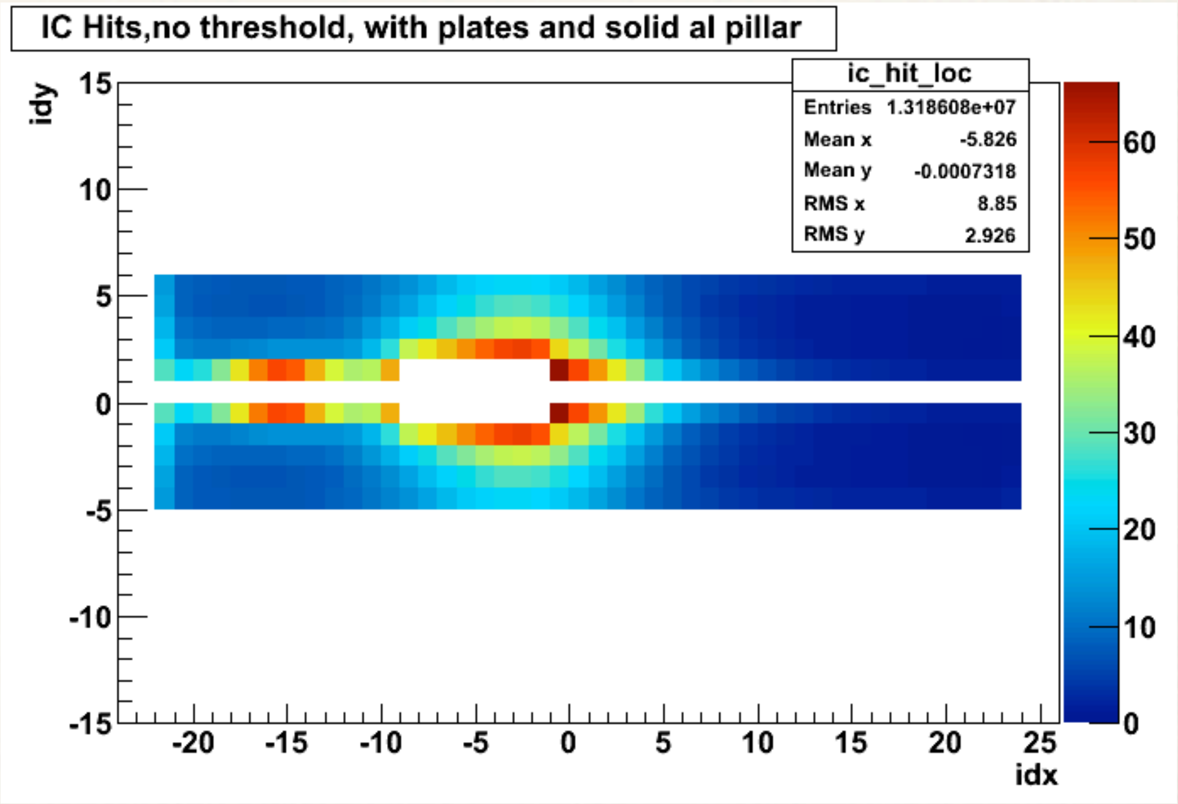


Adding the vacuum enclosure plates increases the noise in the detector overall.

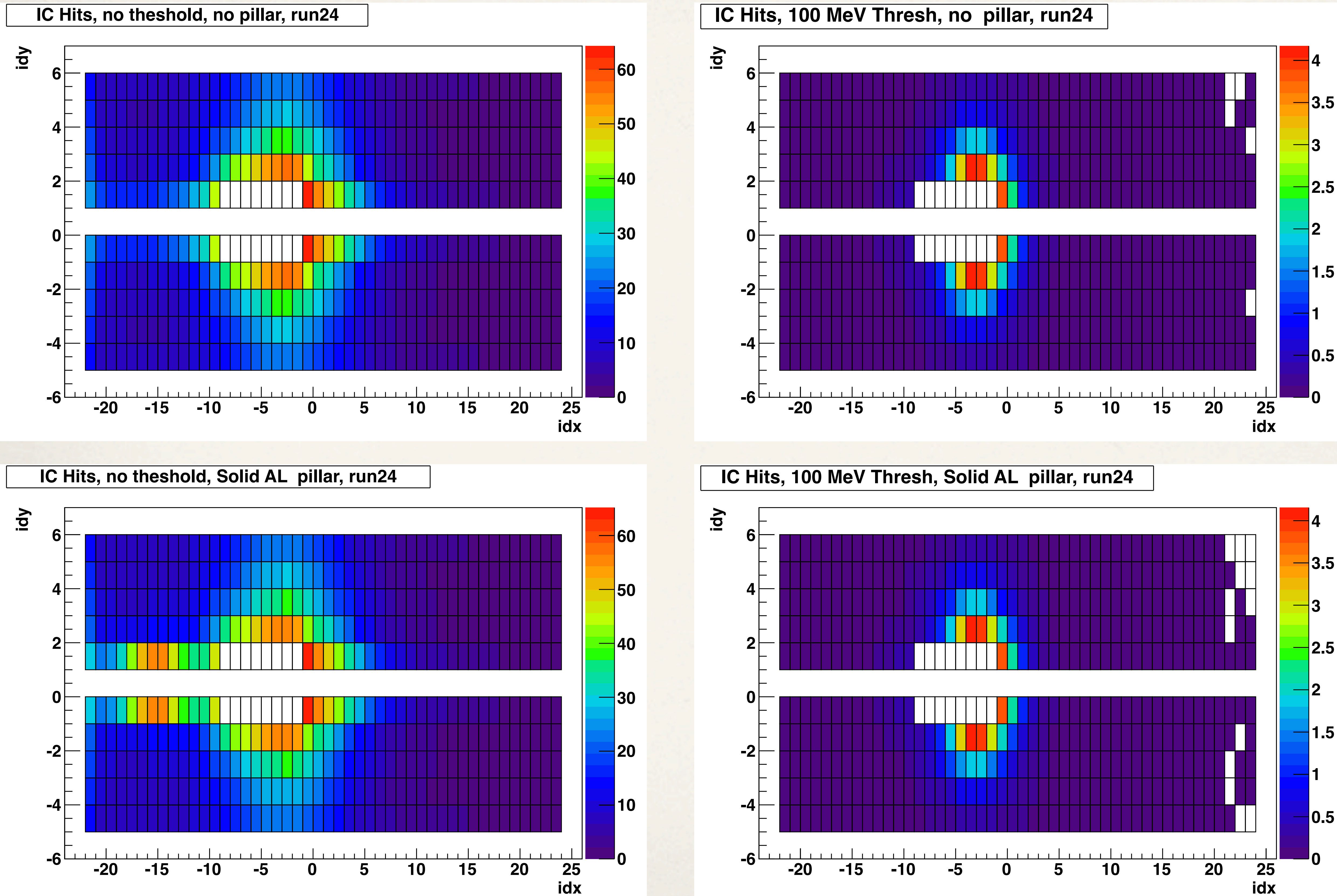
It slightly *decreases* the noise due to the pillar (solid aluminum).

Details of Sarah's results at:
http://nuclear.unh.edu/~sarahp/HPS/Ecal_Studies/Comparison1/Ecal_AlBlockStudiesComparison.html

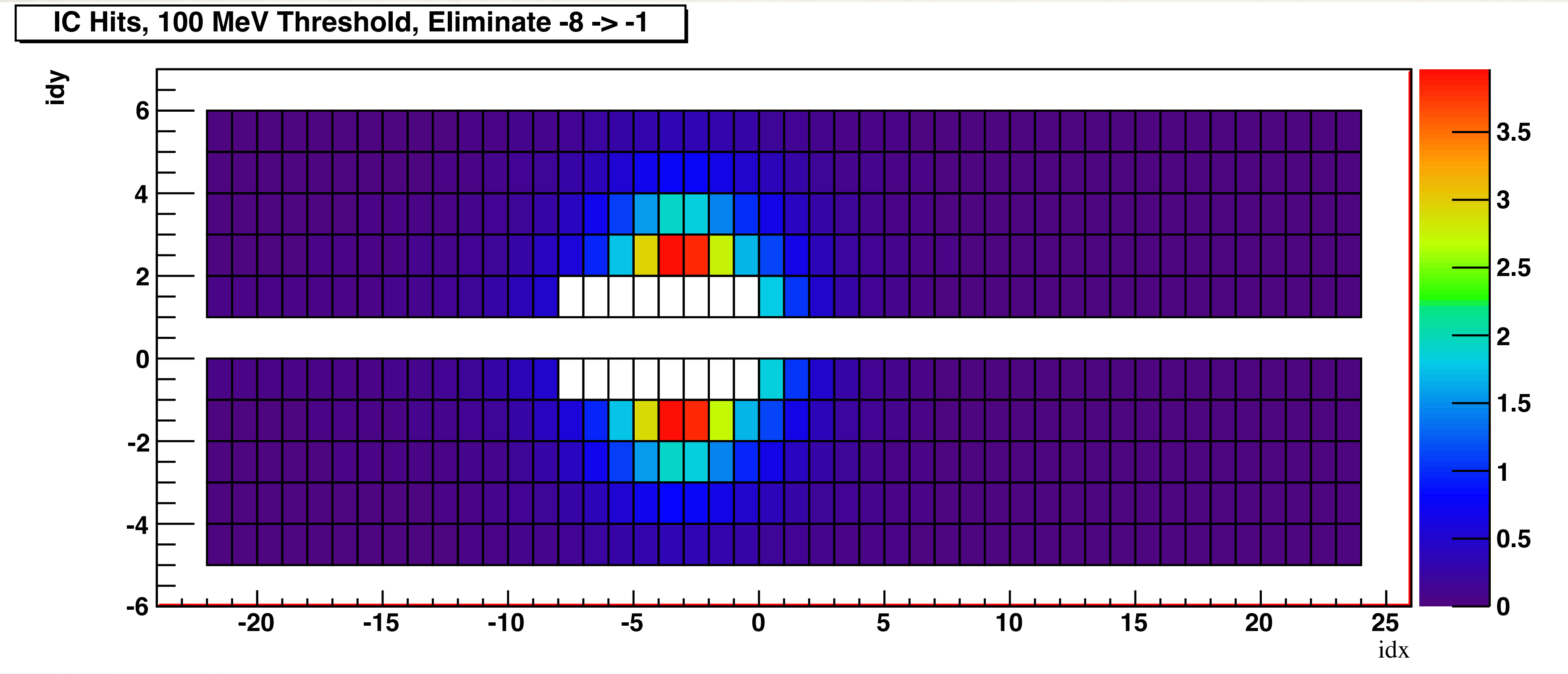


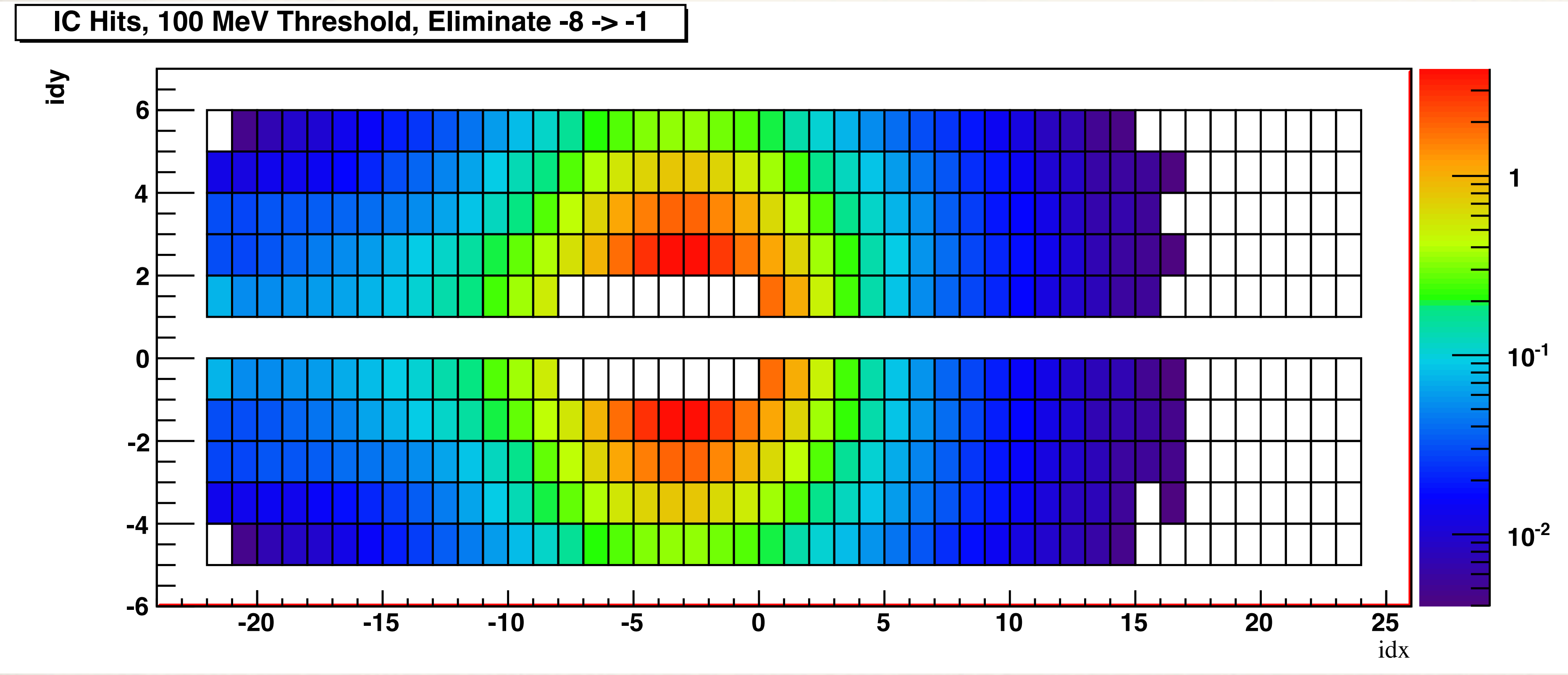


Pillar - No Pillar, run24



ECAL Performance ("Run26")



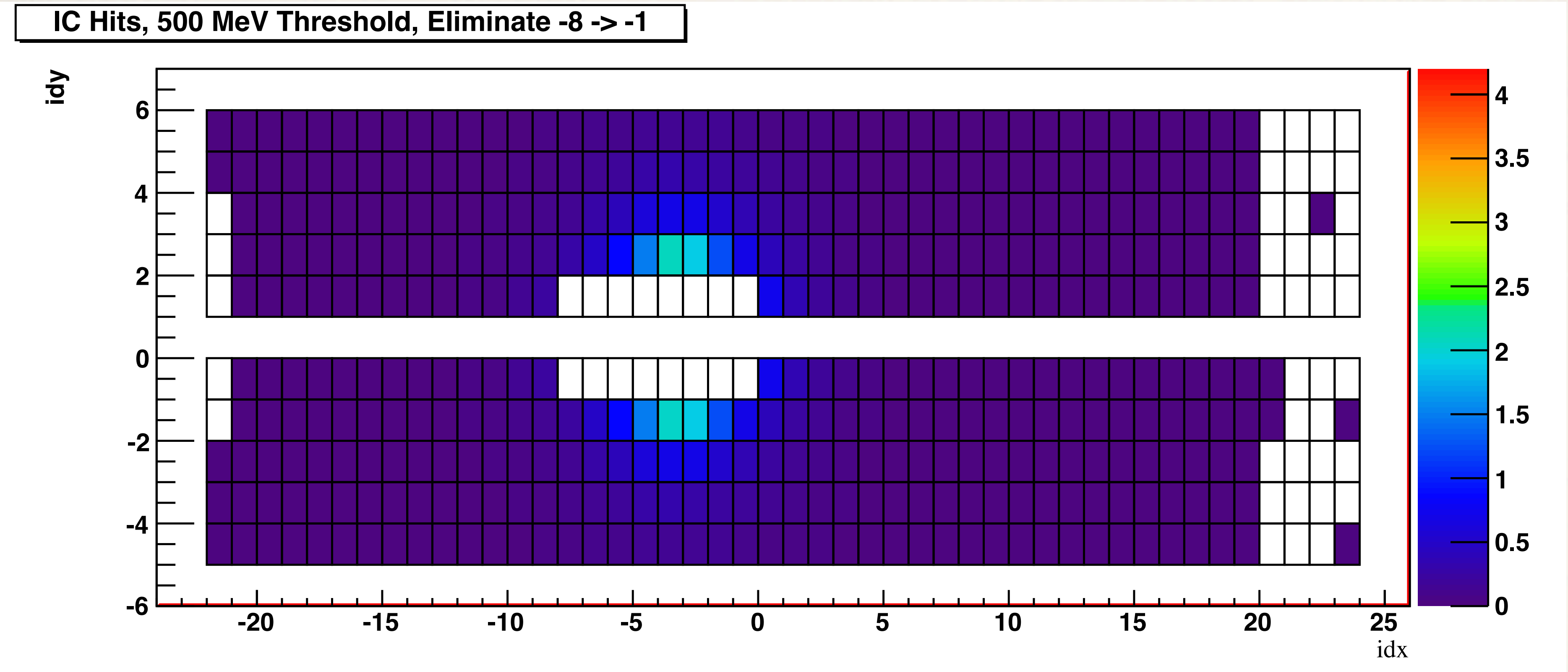


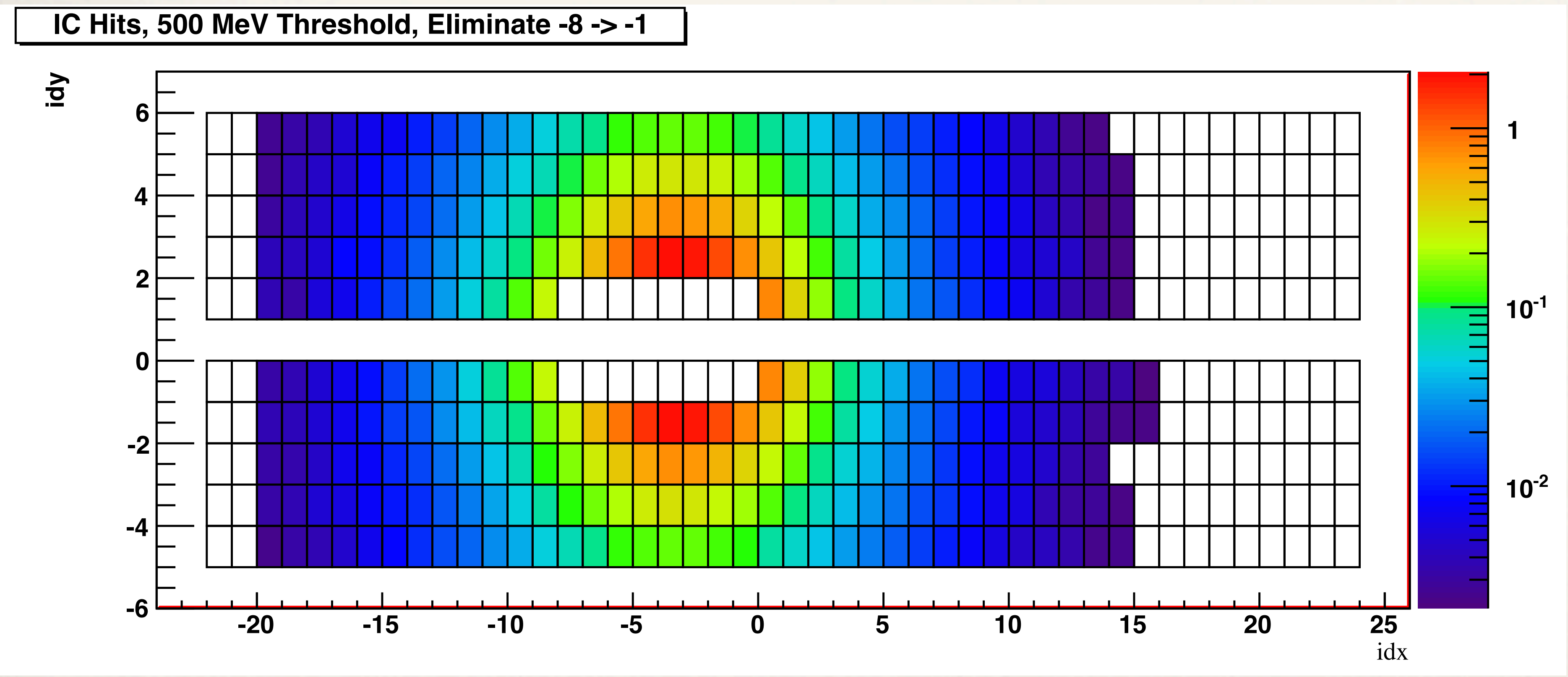
100 MeV Threshold

Occupancy now <4%

Rate ~ 5 MHz max.

ECAL Performance ("Run26")





500 MeV Threshold
Occupancy now <2%
Rate ~ 2.5 MHz max.

Threshold can be raised on only a few "hot" crystals.

Level 1 Trigger Algorithm

Trigger algorithm will be implemented in FPGA units.

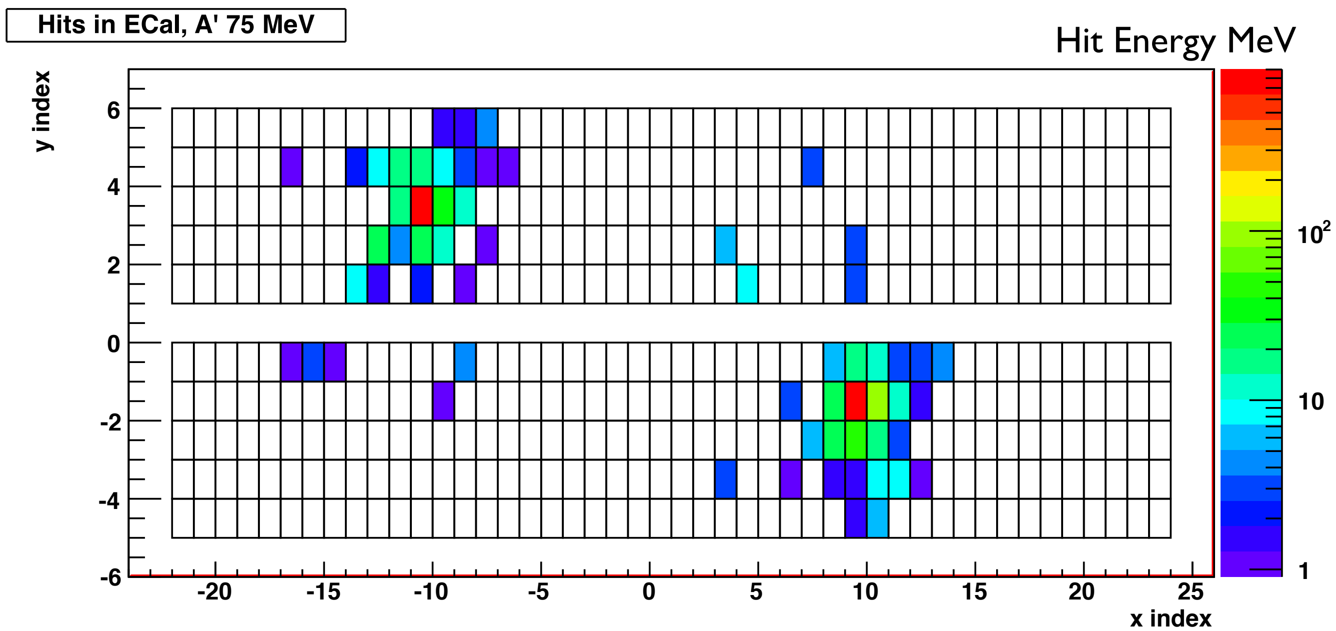
- Fast parallel processing of information.
- Fairly sophisticated operations possible.
- 4 ns clock cycle, allows for trigger coincidence down to $\Delta T = 8$ ns.

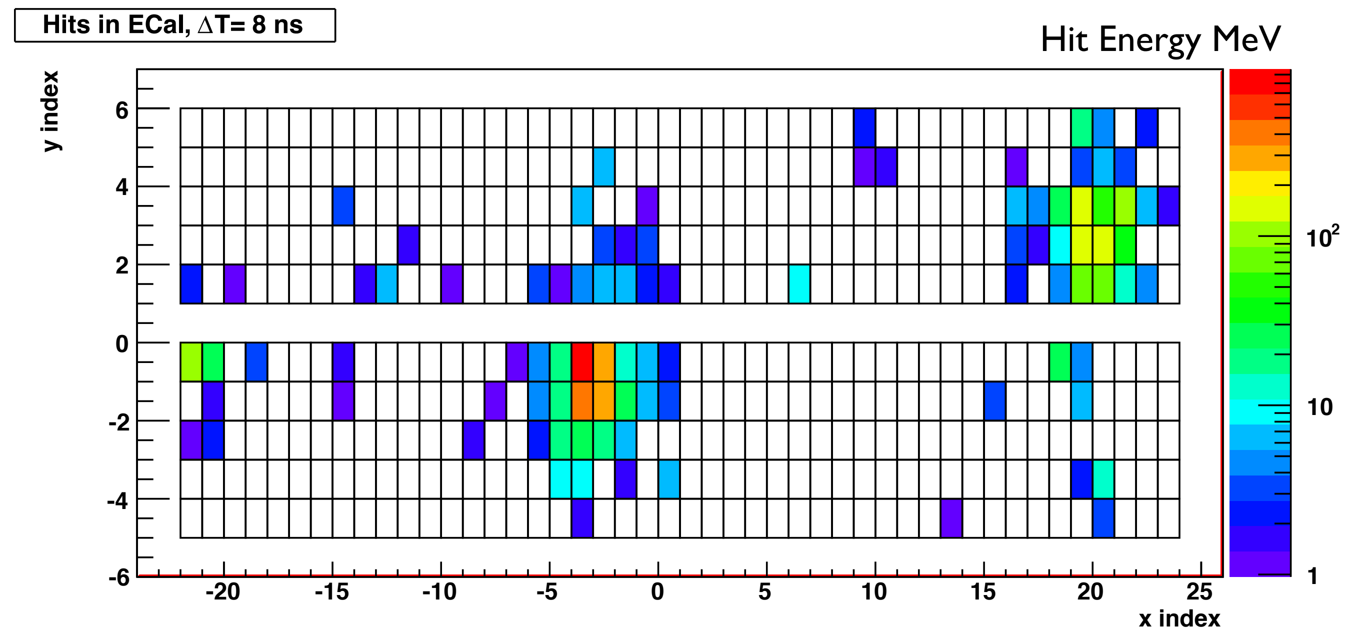
Simulation of trigger in two steps:

- Simple cluster finding algorithm.
- Strict trigger selection criteria

Trigger: Cluster Finding

Two “interesting” events in the calorimeter.





Set loose criteria to find many clusters:

1. For each hit with E > 50 MeV.
2. Search 3x3 square for other hits.
3. If no hit has more energy → Store hit
4. Else → move to next hit.

Store hit: Add energies of 3x3 square if within 8 ns of center hit.

Trigger Selection

Find additional criteria to reduce background rates.

Objective:

- Reduce the background rate to < 25 kHz (50 kHz HW limit)
- Keep acceptance of A' particles close to maximum

Simulated Data sample:

3 M background events representing 4 ns of beam each.

200 nA ≈ 5,000 e- per 4 ns event @ 2.2 GeV.

0.125% X_0 Tungsten target.

Two 4 ns events are combined to simulate 8 ns trigger time.

Simulated A' masses:

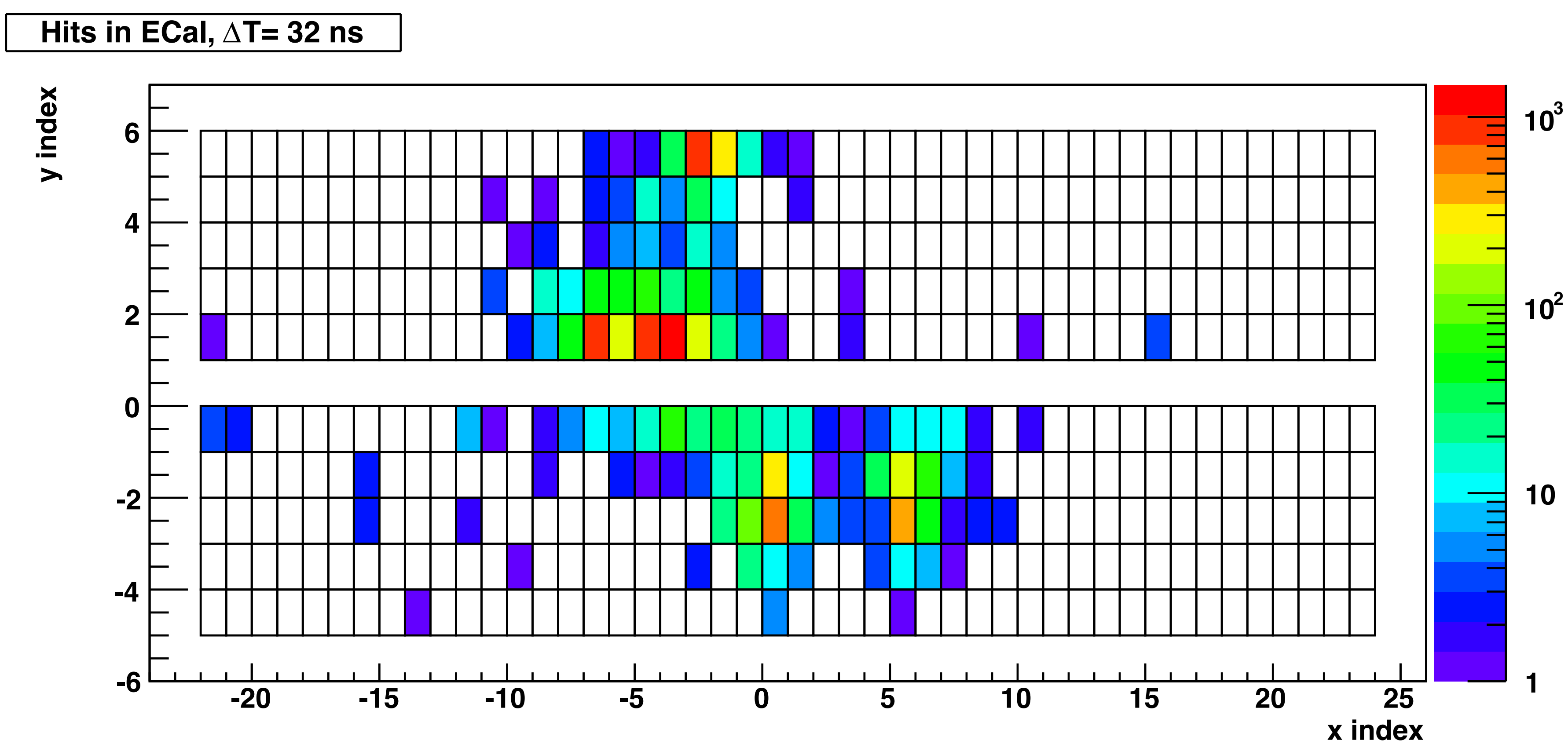
25, 75, 100, 150, 200, 250 MeV.

Trigger Selection

Trigger Cut.	75 MeV/c² A'	Background	Background rate
2+ Clusters, Opposite sect.	38.9%	1.16%	1.5 MHz

Starting point:

Two clusters, one e- one e+: Opposite quadrants of detector ⇒ Background trigger rate ≈ 1.5 MHz



Trigger Selection

Trigger Cut.	75 MeV/c^2 A’	Background	Background rate
2+ Clusters, Opposite sect.	38.9%	1.16%	1.5 MHz
100MeV< $E_{cluster}$ <1.85 GeV	53.9%	0.80%	1.0 MHz
Σ E <= 2 GeV (E_{beam}*sampling fraction)	51.7%	0.27%	337 KHz
E_{hi} - E_{lo}< 1.5 GeV	51.6%	0.22%	275 kHz

1-st level cuts:

Both clusters have 0.1 < E <1.85 GeV ⇒ Bkg rate ≈ 1.0 MHz

Sum of cluster E <= 2 GeV

Diff of cluster E < 1.5 GeV ⇒ Bkg rate ≈ 275 kHz

(Details of cut depend on actual sampling fraction)

Caveat: Double counting! Three clusters can now account for 2 triggers, both of which are counted!

Trigger Selection

Trigger Cut.	75 MeV/c² A’	Background	Background rate
2+ Clusters, Opposite sect.	38.9%	1.16%	1.5 MHz
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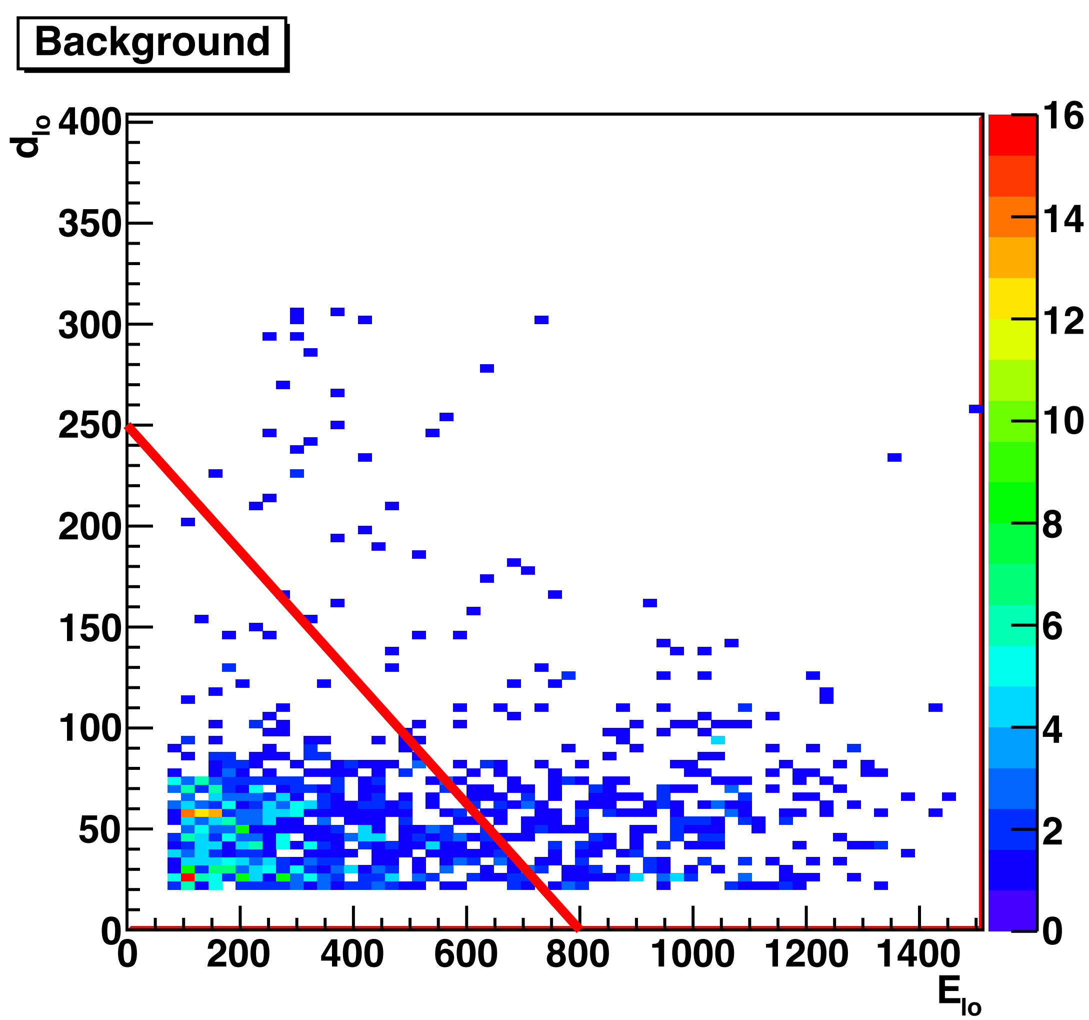
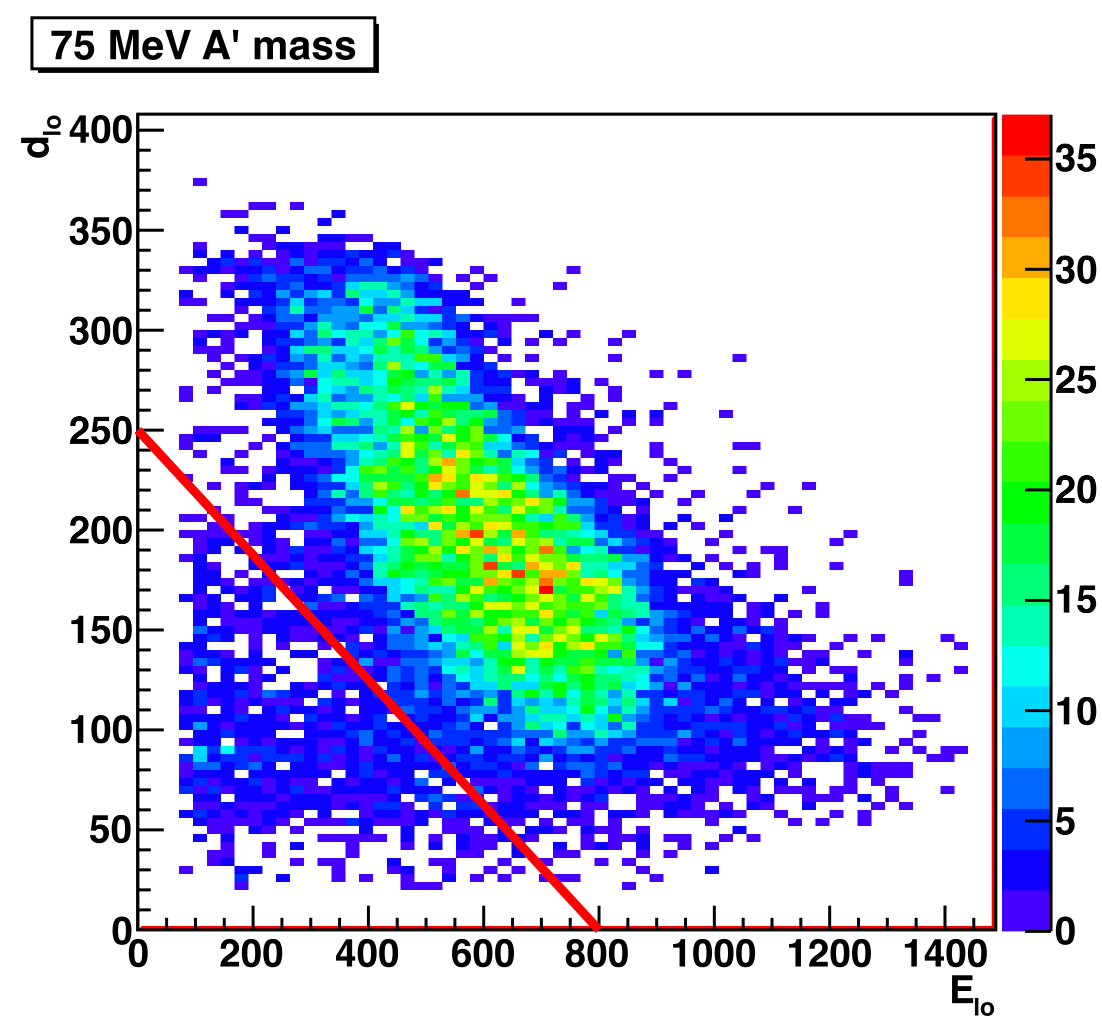
E_{hi} - E_{lo}< 1.5 GeV	51.6%	0.22%	275 kHz
Distance vs Energy slope cut	45.7%	0.05%	**63 kHz**





Trigger Selection

Trigger Cut.	**75 MeV/c^2 A'**	**Background**	**Background rate**
2+ Clusters, Opposite sect.	38.9%	1.16%	1.5 MHz
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Σ E <= 2 GeV	51.7%	0.27%	337 KHz
E_{hi} - E_{lo}< 1.5 GeV	51.6%	0.22%	275 kHz
Distance vs Energy slope cut	45.7%	0.05%	63 kHz
Clusters coplanar to 35°	44.8%	0.022%	**27 kHz**
Not counting double triggers	33.6%	0.020%	**25 kHz**
Eliminate crystals 1,2	33.6%	0.016%	20 kHz

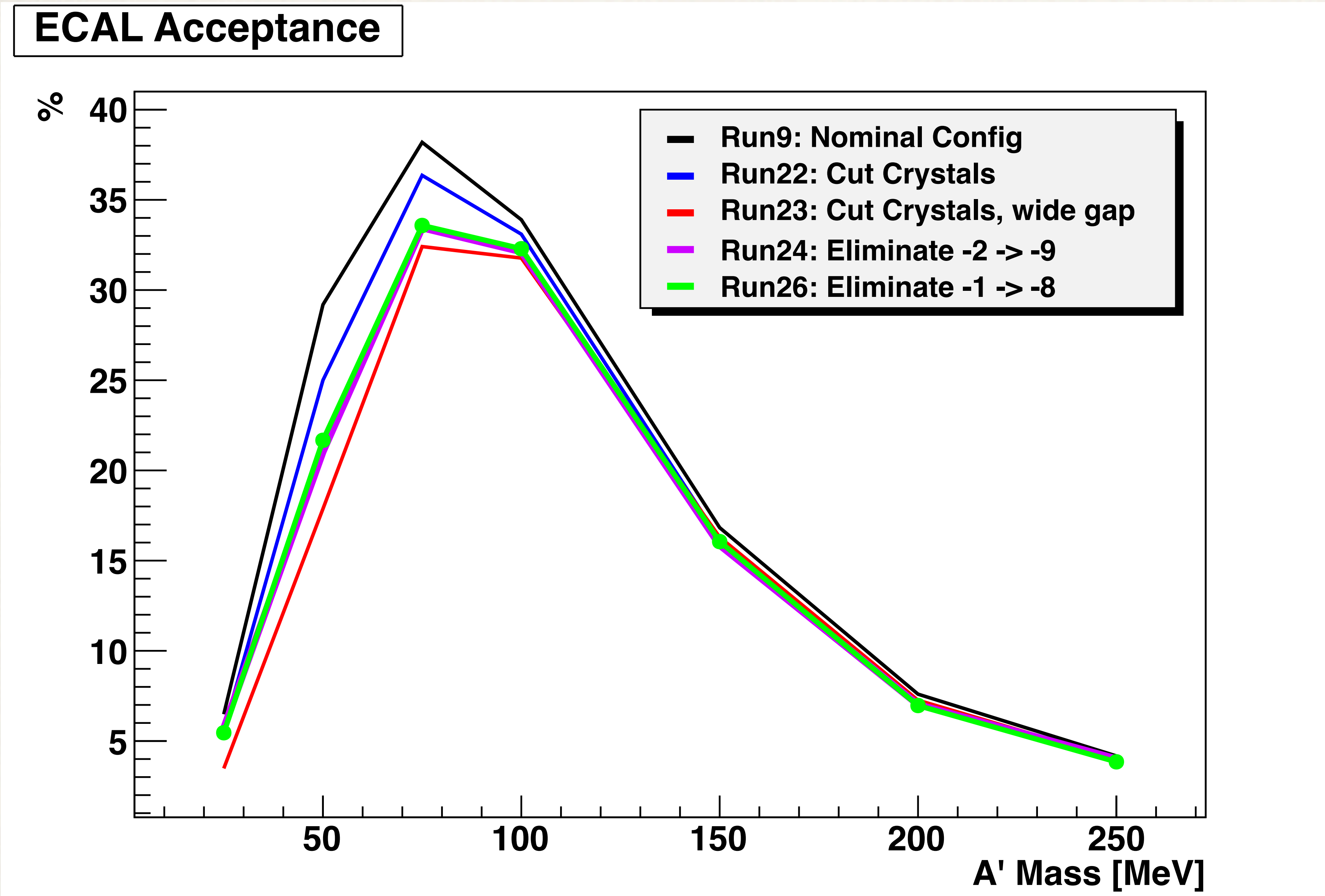
Background rate = 25. ±1. kHz.

3 M events simulated, 607 triggers.

A' Mass Simulation

- A′ events are simulated by theorist.
- Events are rotated to align with the photon beam in apparatus.
- Events are processed by MC
- Result is analyzed with identical algorithm and cuts as before.
- Tracking is NOT included:
  - No background is overlaid on A′ events. This would artificially falsely the trigger efficiently.
  - True experimental acceptance is less than shown here.

Effect on Acceptance



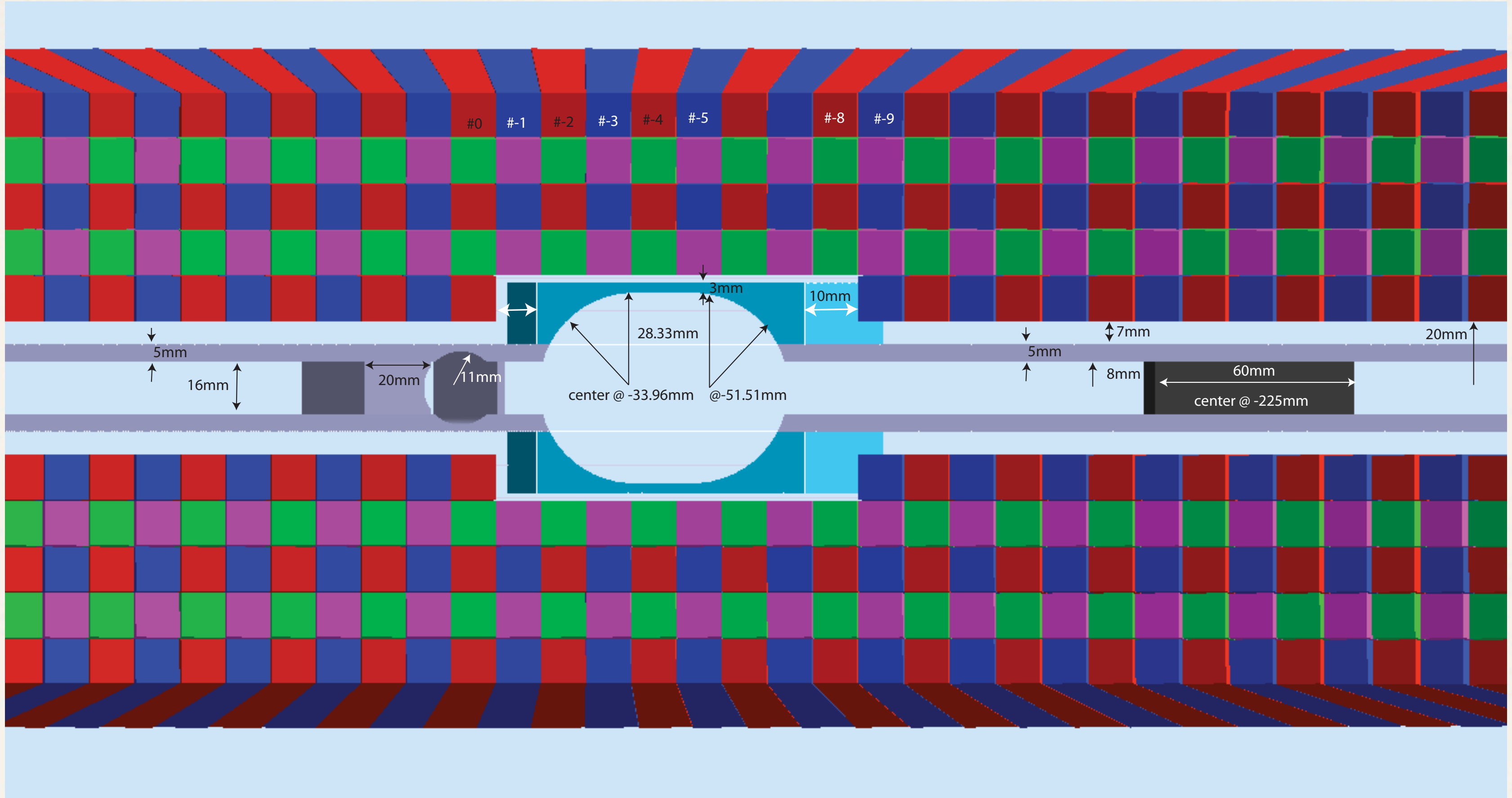
New design has only small effect on acceptance while significantly reducing the background rates.

	25 MeV	50 MeV	75 MeV	100 MeV	150 MeV	200 MeV	250 MeV
Nominal	6.5%	29%	38%	34%	16.8%	7.6%	4.2%
-8 to -1 Eliminated	5.46%	21.6%	33.6%	32%	16%	7.0%	3.8%

TO DO List:

- Final tweaks of geometry to correspond to engineering designs (see Emmanuel Rindel's talk)
- Move simulation of ECal & Trigger to SLIC/lcsim framework.
- Combine ECal performance with Tracker performance for overall experiment acceptances.
- Incorporate measured signal shape & study pileup + possible FADC algorithms.
- ...

Conclusions



- To bring the rates on all individual crystals down to below 4% for 8 ns time slices (< 5 MHz), eliminate crystals -8 through -1.
  - Complicated vacuum enclosure will be needed.
  - Relatively small effect on acceptance.
  - Improves background trigger rate as well.
- Trigger rates are well under control.
- Still a big “to do” list.