status of main calorimeter simulations

A-HCAL SD-HCAL hybrid-HCAL

Si-ECAL Sc-ECAL

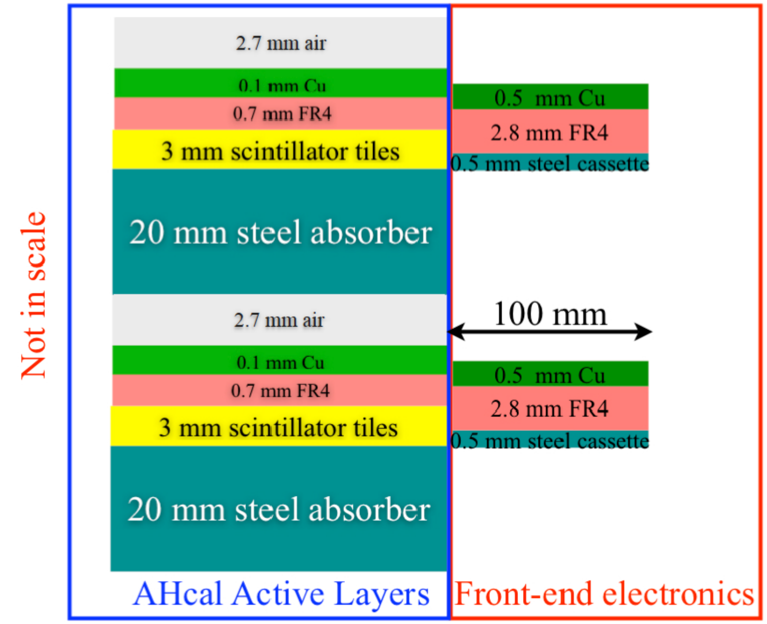
Daniel Jeans, IPNS/KEK
ILD soft/opt mtg
April 2017, Lyon

inputs from K. Krueger, T. Kurca

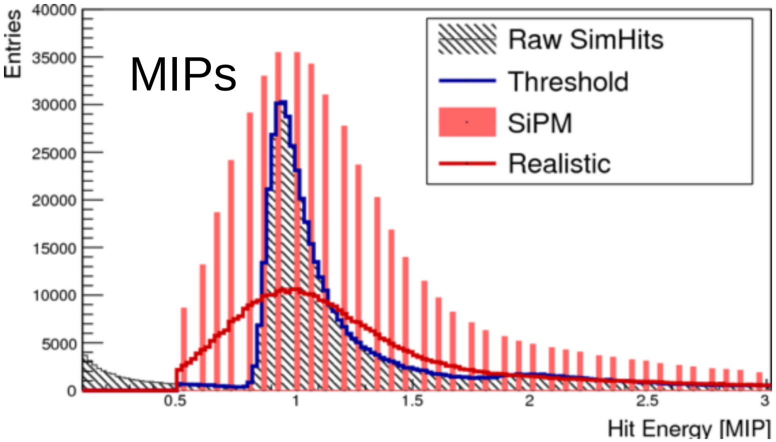
A-HCAL

AHCAL simulation in Mokka

- AHCAL model in Mokka very close to engineering design:
  - realistic layer thicknesses including tolerances
  - subdivision of scintillator layers into tiles
    - no gaps between tiles, but checked that the effect is negligible (https://arxiv.org/pdf/1006.3662.pdf)
  - space for readout electronics



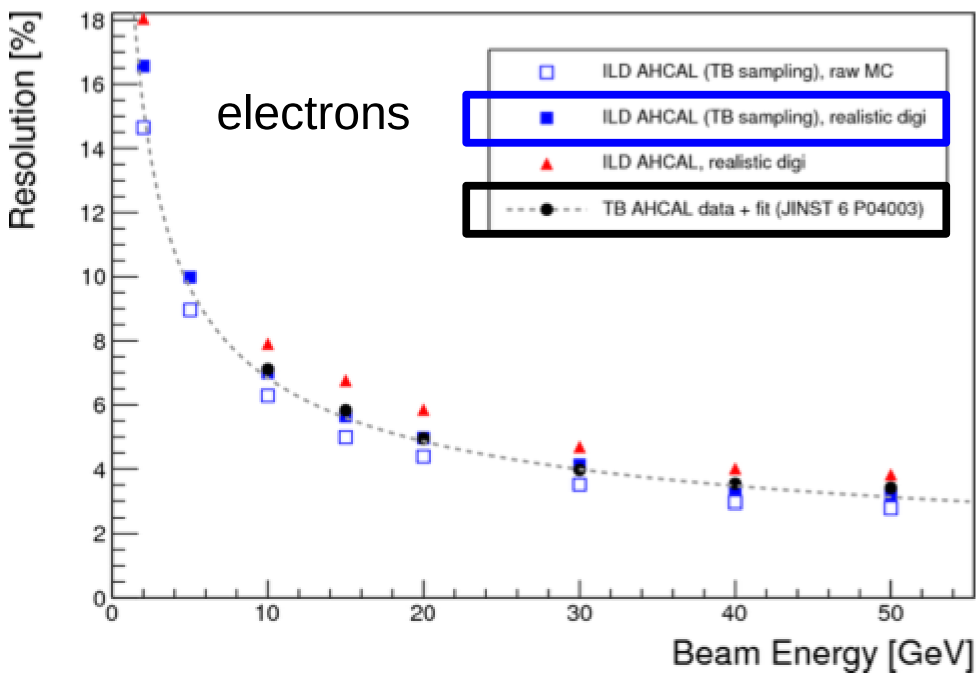
- detailed digitization taking into account
  - SiPM effects (pixel quantization, saturation)
  - timing cut (electronics shaping time)
  - threshold
  - electronics noise
  - pixel non-uniformity

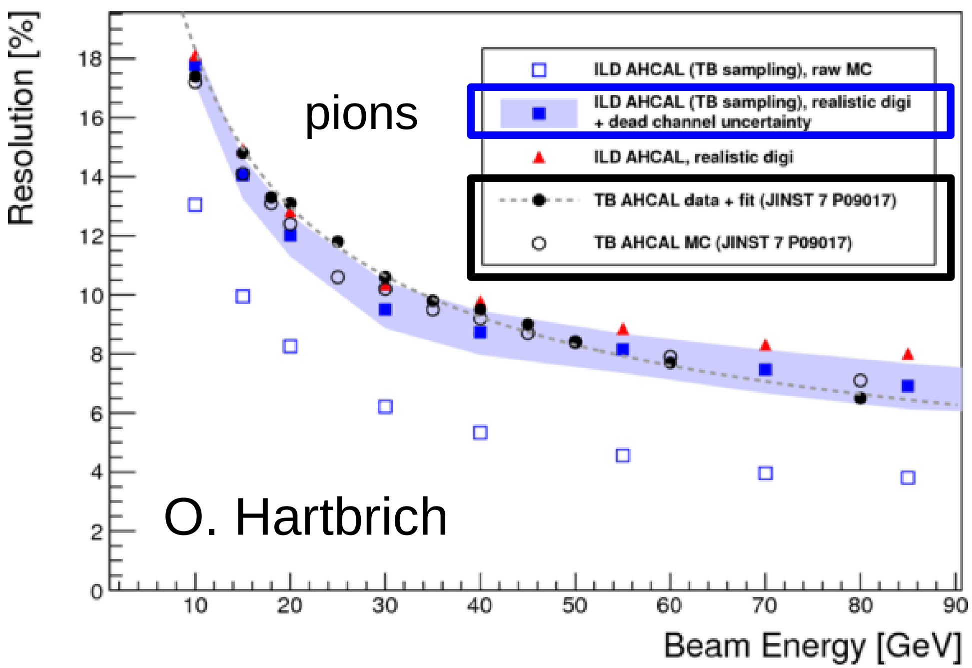


more details: https://agenda.linearcollider.org/event/6557/session/10/contribution/90/material/slides/0.pdf

AHCAL simulation in Mokka

- detailed study of digitization effects in Mokka simulation by Oskar Hartbrich
- when taking into account the difference in sampling between AHCAL technological prototype and ILD AHCAL: **ILD Mokka simulation agrees with data**
- Mokka simulation is ported to dd4hep

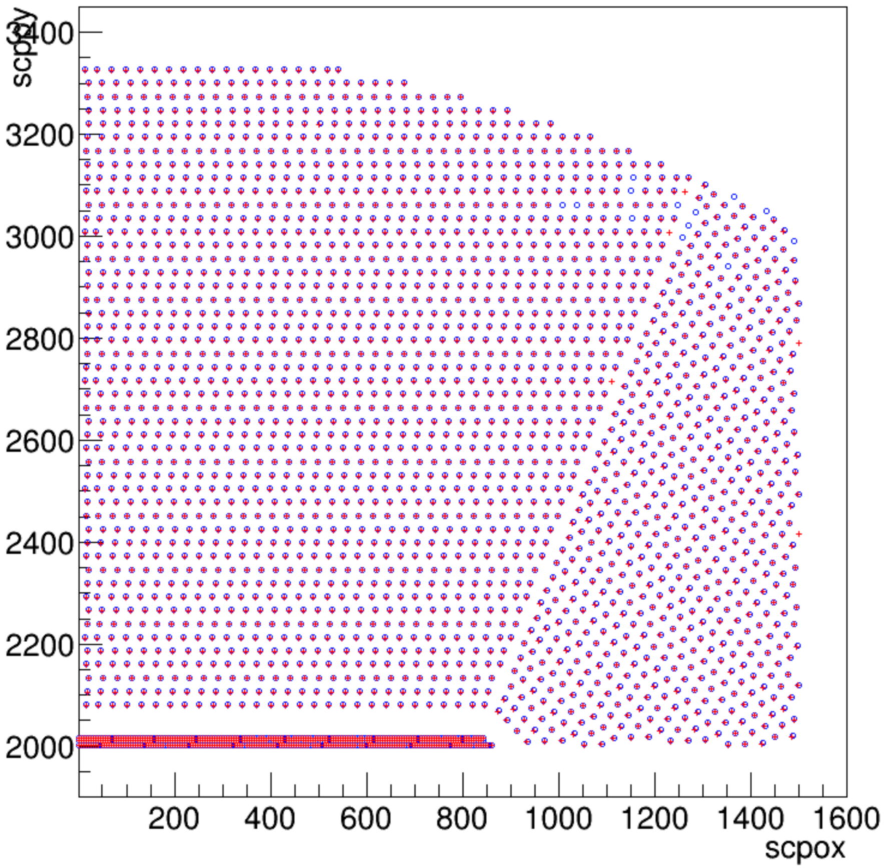


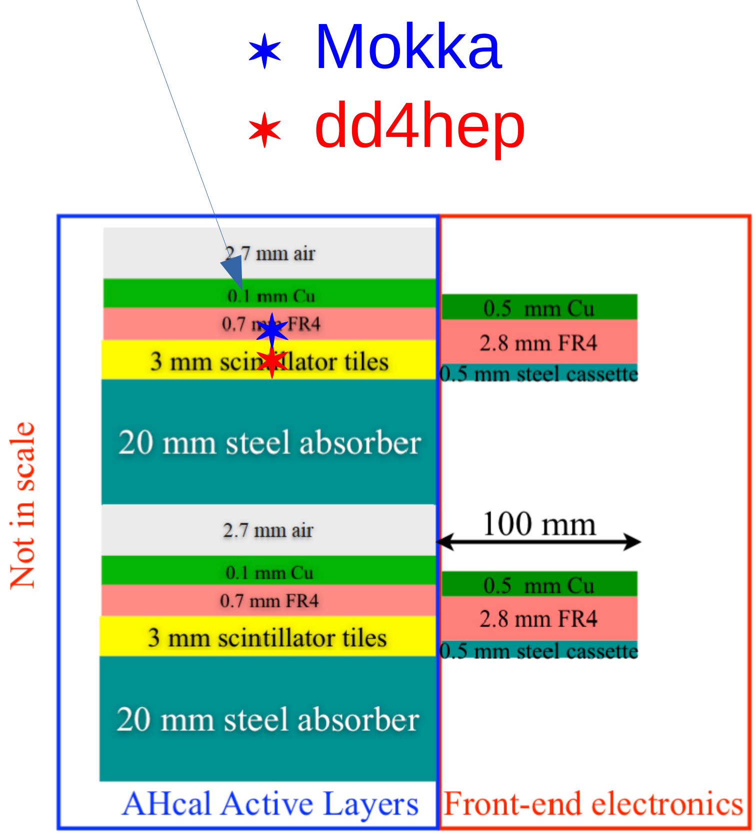


more details: https://agenda.linearcollider.org/event/6557/session/10/contribution/90/material/slides/0.pdf

Comparison Mokka/dd4hep: geometry

- **geometry and segmentation nearly identical** in Mokka and dd4hep simulation
- only difference: Mokka uses middle of "chamber" (includes electronics and air gap), while dd4hep uses middle of active layer for hit position
  - dd4hep "more correct"
  - expect very small influence





Comparison Mokka/dd4hep: material

- **material nearly identical** in Mokka and dd4hep simulation
- both rely on Geant4 materials, only tiny differences in rad. and int. lengths

dd4hep

```
+--------------------------------------------------------------------------------------
+ Material scan between: x_0 = (  10.00, 205.80,  10.00) [cm] and
| x_1 = (  10.00, 339.50,  10.00) [cm] :
+--------------------------------------------------------------------------------------
|     \   Material          Atomic                  Radiation   Interaction
| Num. \  Name            Number/Z   Mass/A  Density    Length       Length    Thickness
| Layer \                          [g/mole]  [g/cm3]     [cm]         [cm]        [cm]
+--------------------------------------------------------------------------------------
|     1 Steel235               26   55.758   7.8700      1.7609      16.9473      2.000
|     2 G4_POLYSTYRENE          6   11.159   1.0600     40.9316      68.8718      0.300
|     3 PCB                    10   20.338   1.7000     17.4091      48.4238      0.070
|     4 Copper                 29   63.546   8.9600      1.4352      15.5141      0.010
|     5 Air                     7   14.801   0.0012  30275.2374   71025.8371      0.270

Total thickness: 56.248440 X0    6.062787 lambda_I
```

Layer element	Thickness [mm]	Material	X_0 [mm]	λ_I [mm]
Absorber	20	Iron	17.57	169.59
Scintillator	3.0	polystyrene	413.12	688.72
PCB plate	0.7	FR4	175.05	484.24
Cu plate	0.1	Cu	14.36	155.14
Air gap	2.7	Air	303921	710261

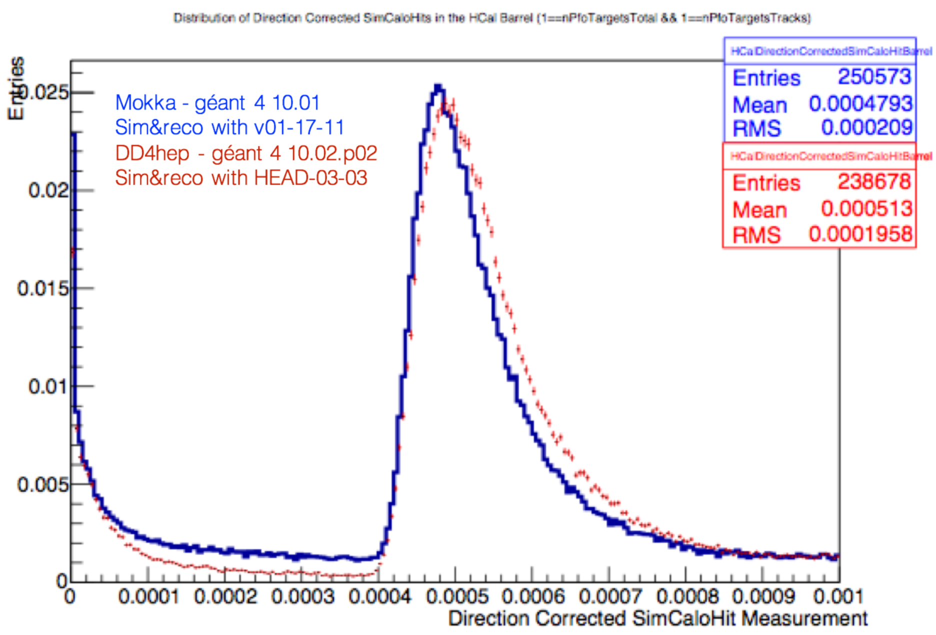
Mokka

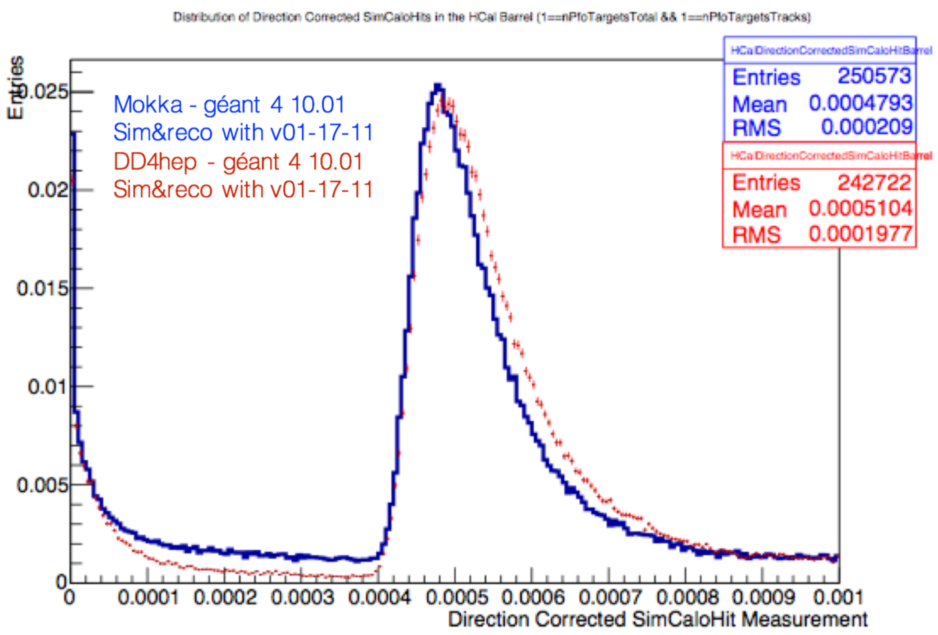
Depth in [X_0^e]	Depth in [λ_I^e]
56.3 X_0^e (50.9 - 57.1)	6.06 λ_I^e (5.48 - 6.14)

Comparison Mokka/dd4hep: response

disclaimer: the Mokka plots on the following slides were produced for ILD_o1_v06, while ILD_o1_v05 was ported to dd4hep → differences might be due to difference in ILD version or due to Mokka/dd4hep transition

- **simulated** response to MIPs (before digitization)
- similar, but not identical, even with identical Geant4 versions
- **difference** not understood
  - **expected to be negligible after digitization**
  - effect on larger hits/showers unclear





Comparison Mokka/dd4hep: response

> **K0L, in SiECAL+AHCAL**

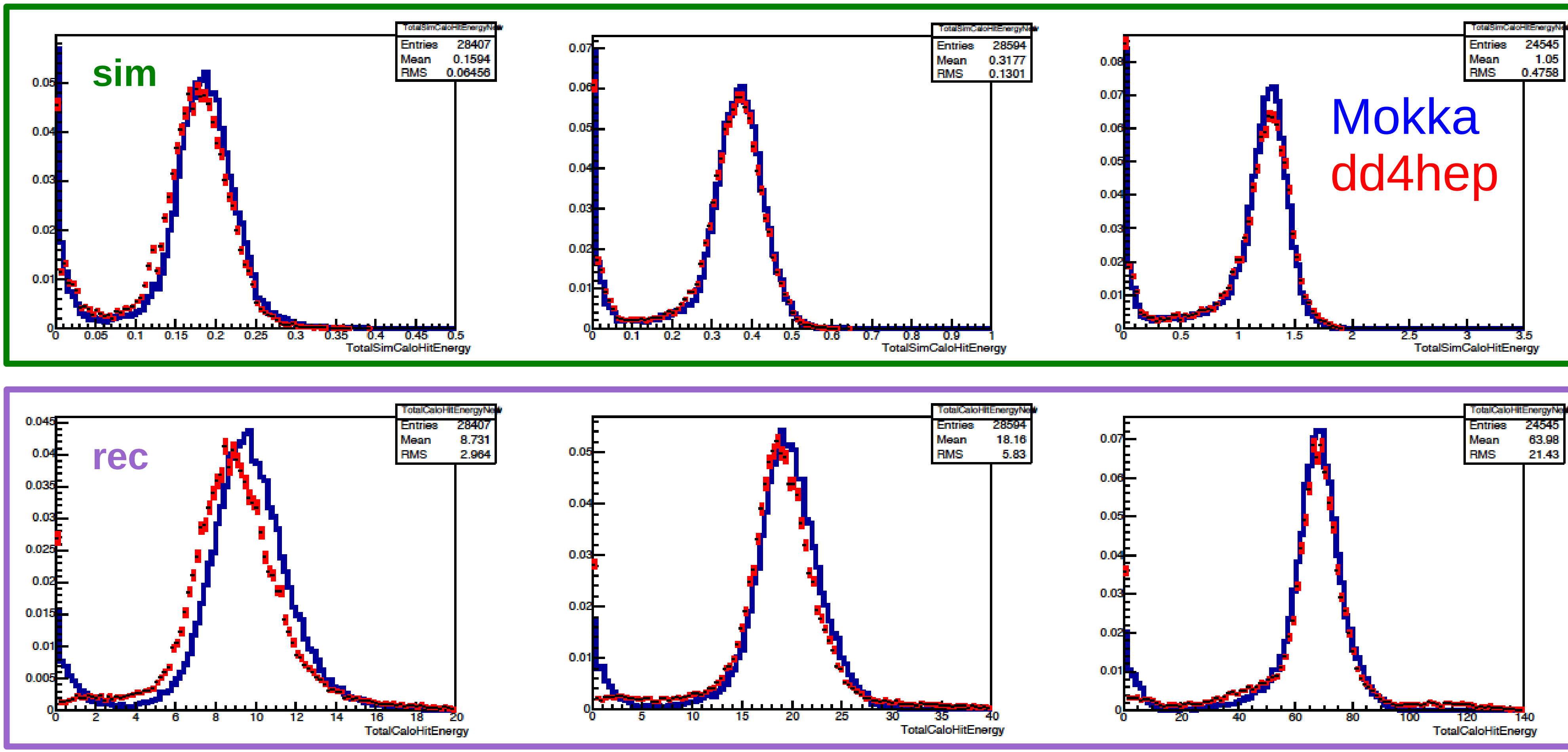
Mokka: ILD_o1_v06 in ILCsoft v01-17-11

dd4hep: ILD_o1_v05 in ILCsoft v01-17-11

10 GeV

20 GeV

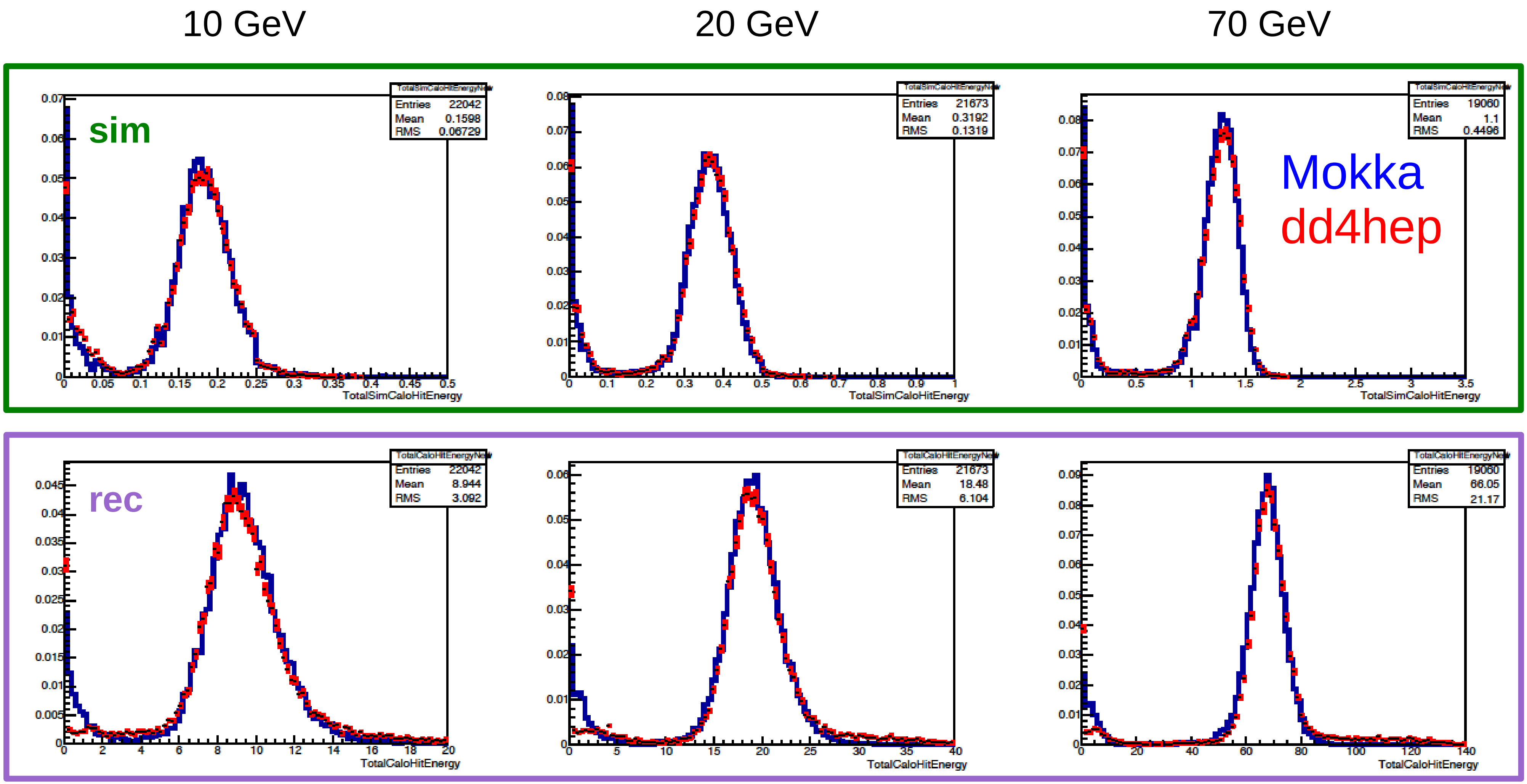
70 GeV



Comparison Mokka/dd4hep: response

> π-, in SiECAL+AHCAL

Mokka: ILD_o1_v06 in ILCsoft v01-17-11
dd4hep: ILD_o1_v05 in ILCsoft v01-17-11



Comparison Mokka/dd4hep: response

- differences observed in response to single hadrons:
  - good agreement for charged pions
  - dd4hep response for K0L lower at low hadron energy, good agreement at higher energies
- some effects already visible in simulated response (before digitization)
  - lower dd4hep response for K0L at lower energies
- unclear why effect is only visible for K0L, while charged pions look OK
- this is pure calorimetric response, not PandoraPFA reconstruction

- expected influence on particle flow reconstruction difficult to estimate

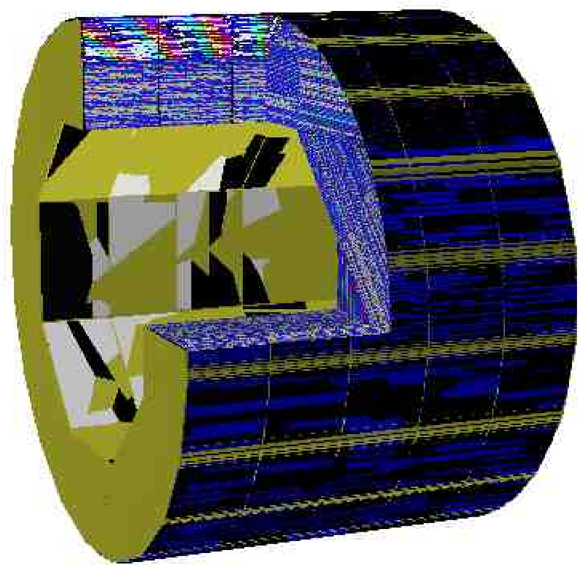
- difference in JER observed between Mokka and dd4hep (see talk in yesterday's “Software: tracking and PFA” session)

- investigating now what causes the observed differences:
  - different ILD models (ILD_o1_v06 vs. ILD_o1_v05) or
  - transition from Mokka to dd4hep

SD-HCAL

/

Hcal_Barrel_SD_v01



Detailed layer structure

Videau geometry : 8 staves (x,y) ,
5 modules (z)

→ corresponding to engineering design

Given dimensions (Barrel thickness 1272.3)

→ limit the number of layers,

→ number of readout pads in the layer

Work on new version with 3 modules

ILD_l2_v01 : layers 48/48, last one 3 pads

ILD_s2_v01 : downscaling

rInner 205.8 →171

rOuter 339.55→304.07

even if the barrel thicknes kept

→ less layers ,readout pads/layer

layers 47/48 , last one : 1 pad !!!

Geometry Test/Validation

Single muons: 60 GeV, full theta, phi random
- particle gun from the detector center
- DDSim and MarlinReco **v01-17-10**

SimDigital.cc : modifications to accommodate different geometry
→ different mapping of coordinates to channel indexes
- which is the best parameter to characterize different geometries?

Analysis:
- root tuples with calorimeter hits, Geant4 steps position, channel indices
- cell middle position of each step contributing to the hit is stored
- determine position zero corresponding to I,J,layer = 0
- calculate: (hit position-position zero)/I(J,layer)
→should peak at cell-, layer-size 10.406, 27.125 mm

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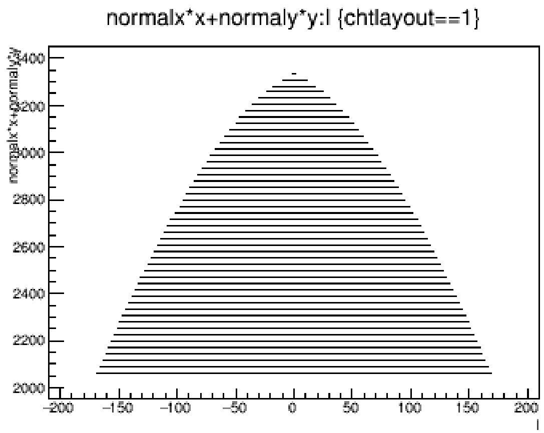
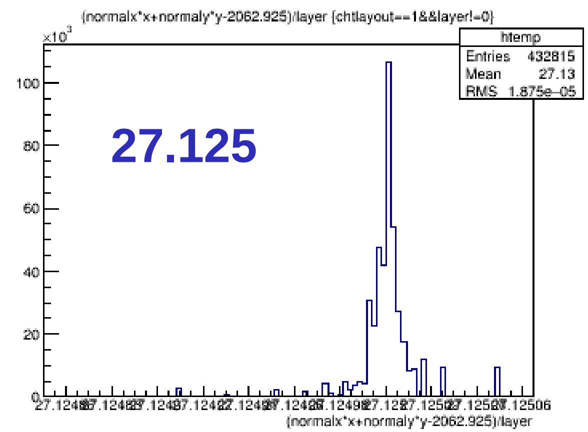
Hcal_Barrel_SD_v01
y-, x- resolutions

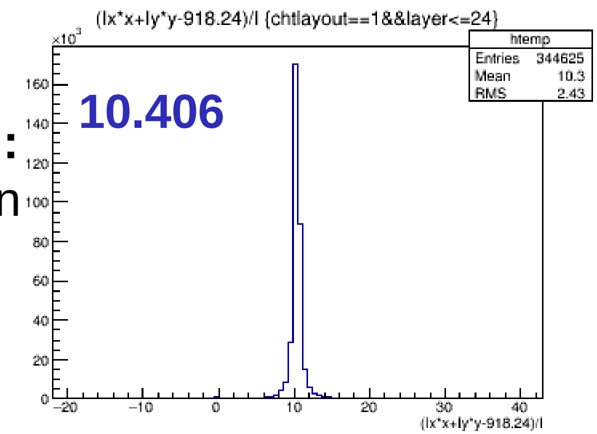
Y: index I

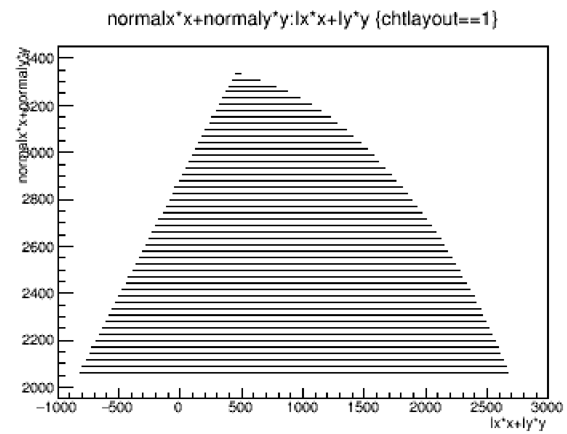




Y- resolution:
layers direction

X-resolution:
pads direction



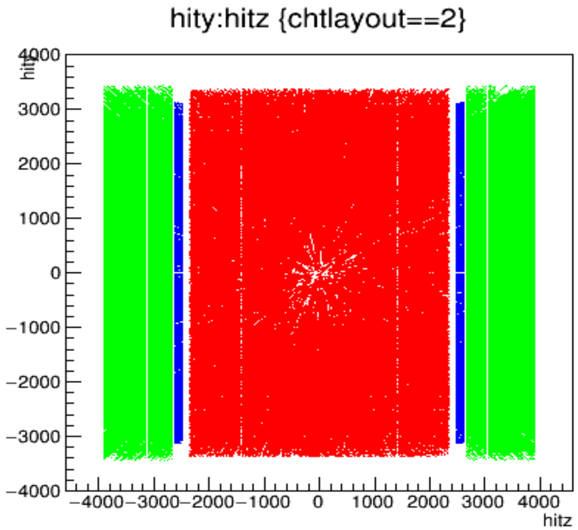


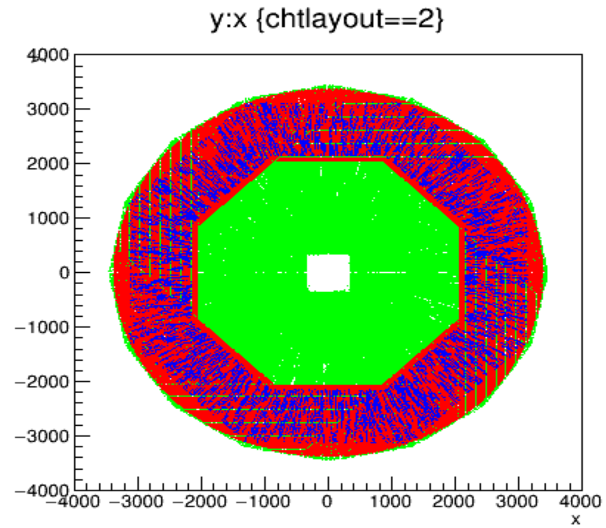
Y : X
staves projection

SDHCAL

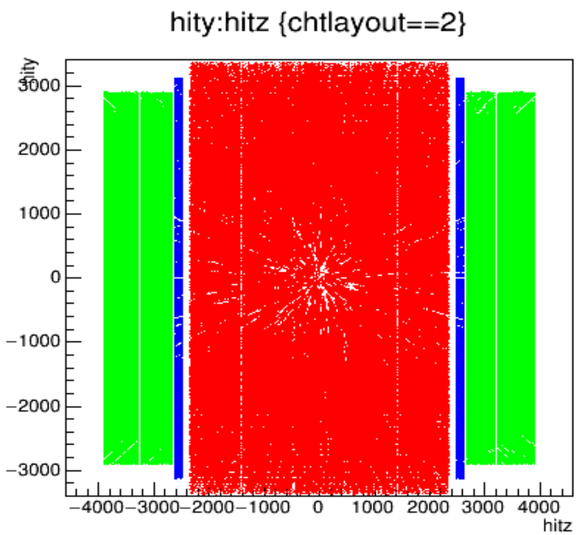
Y:Z

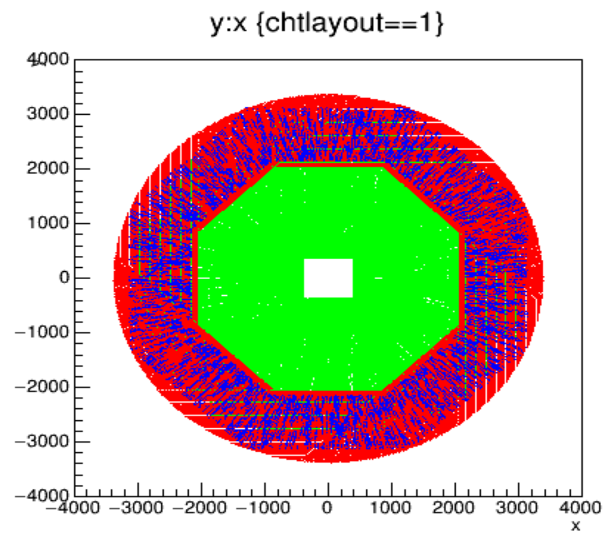
Y:X





Endcaps v01





Endcaps v02

Boxes(towers)

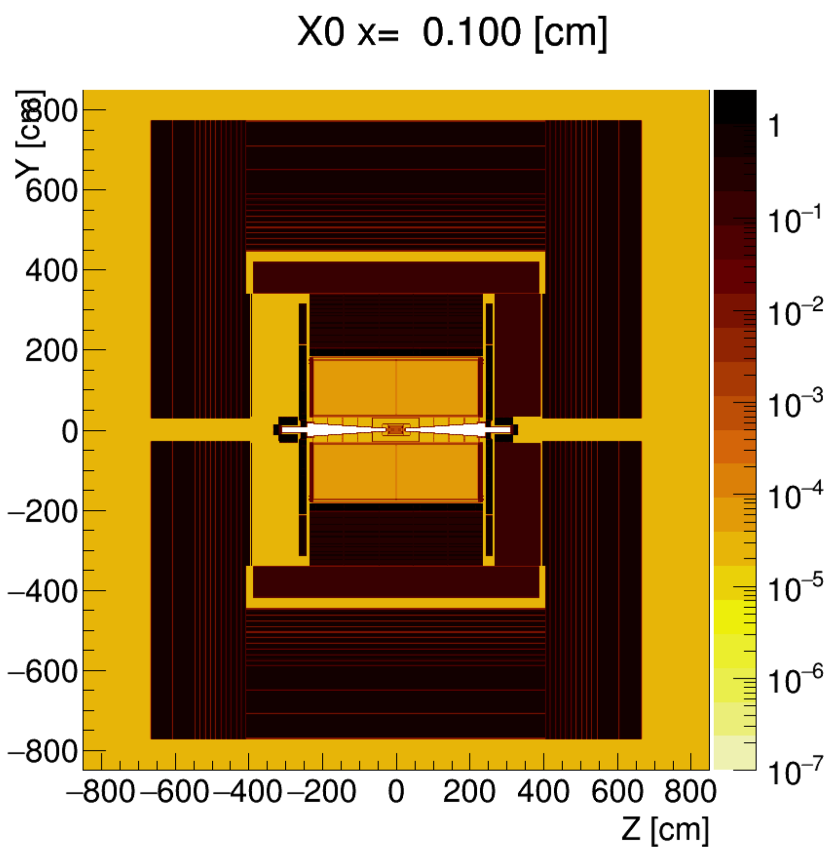
-to be optimized?

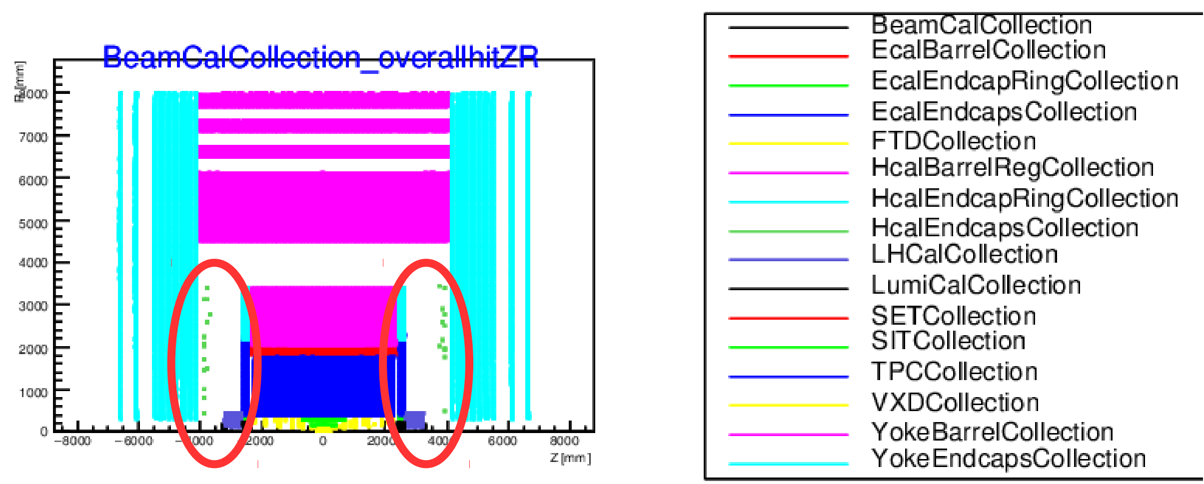
The previous SD-HCAL validation have been done using ilcsoft v01-17-10

we have discovered some issues when using
the same model in the latest v01-19-xx releases

Barrel: seems OK

Endcap: materials seem to (at least partially) disappear,
very few hits produced; problem understood, will be fixed

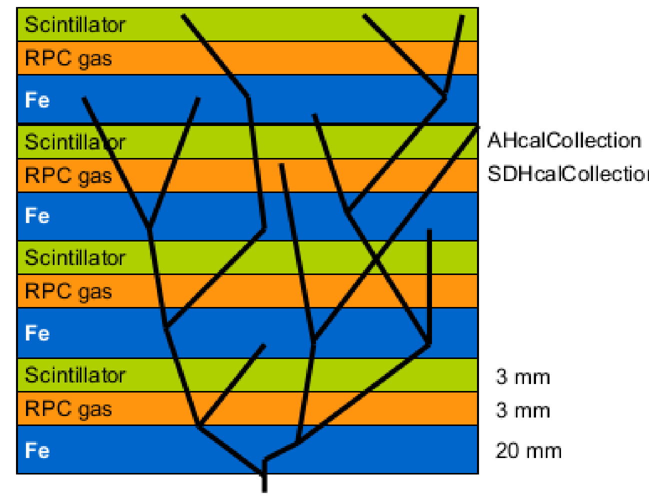


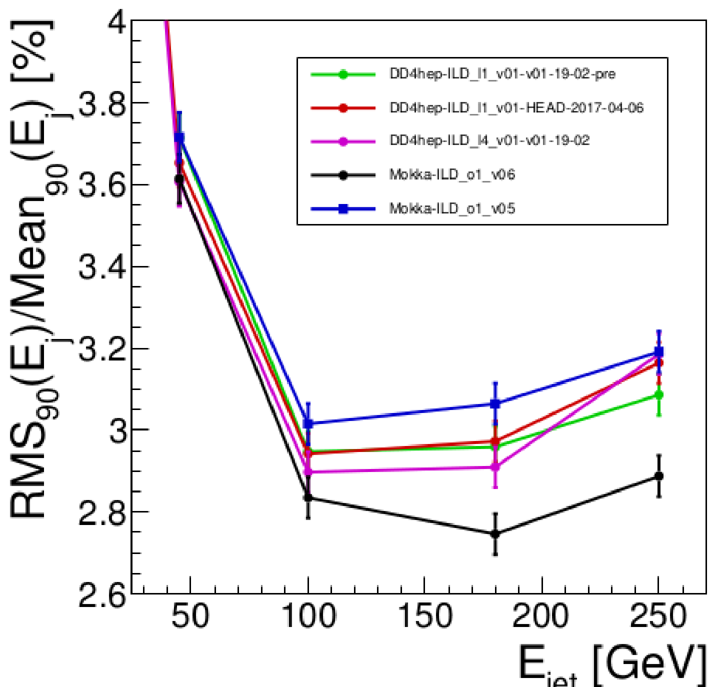


hybrid-HCAL

Introduction

- calorimeter shower development basically defined by absorber structure
- idea to create HCal (Ecal) model with two sensitive materials
- could use in large scale MC production with little overhead in disk space
- would provide possibility to **compare technologies** on full physics analysis using the **same events**





?

Frank Gaede's talk yesterday

Hybrid Calorimeter Simulation Model ILD SW Meeting, Lyon, Apr 24-28, 2017 3 / 16

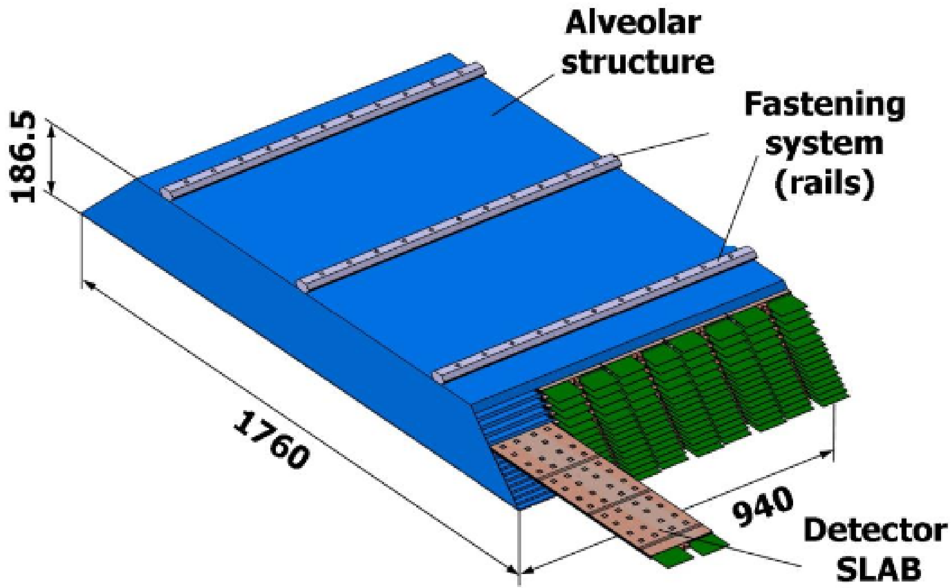
very fresh ; works technically
validation underway:
first results encouraging
(see also next talk)

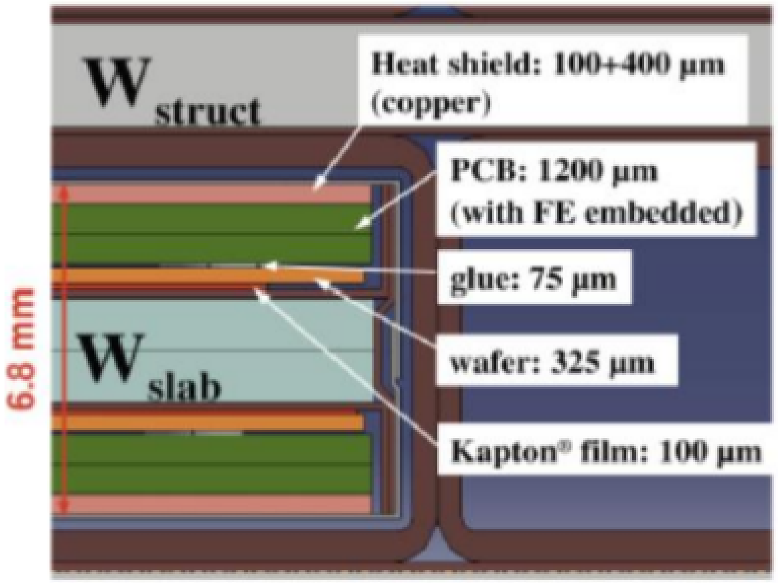
Si-ECAL

Si-ECAL

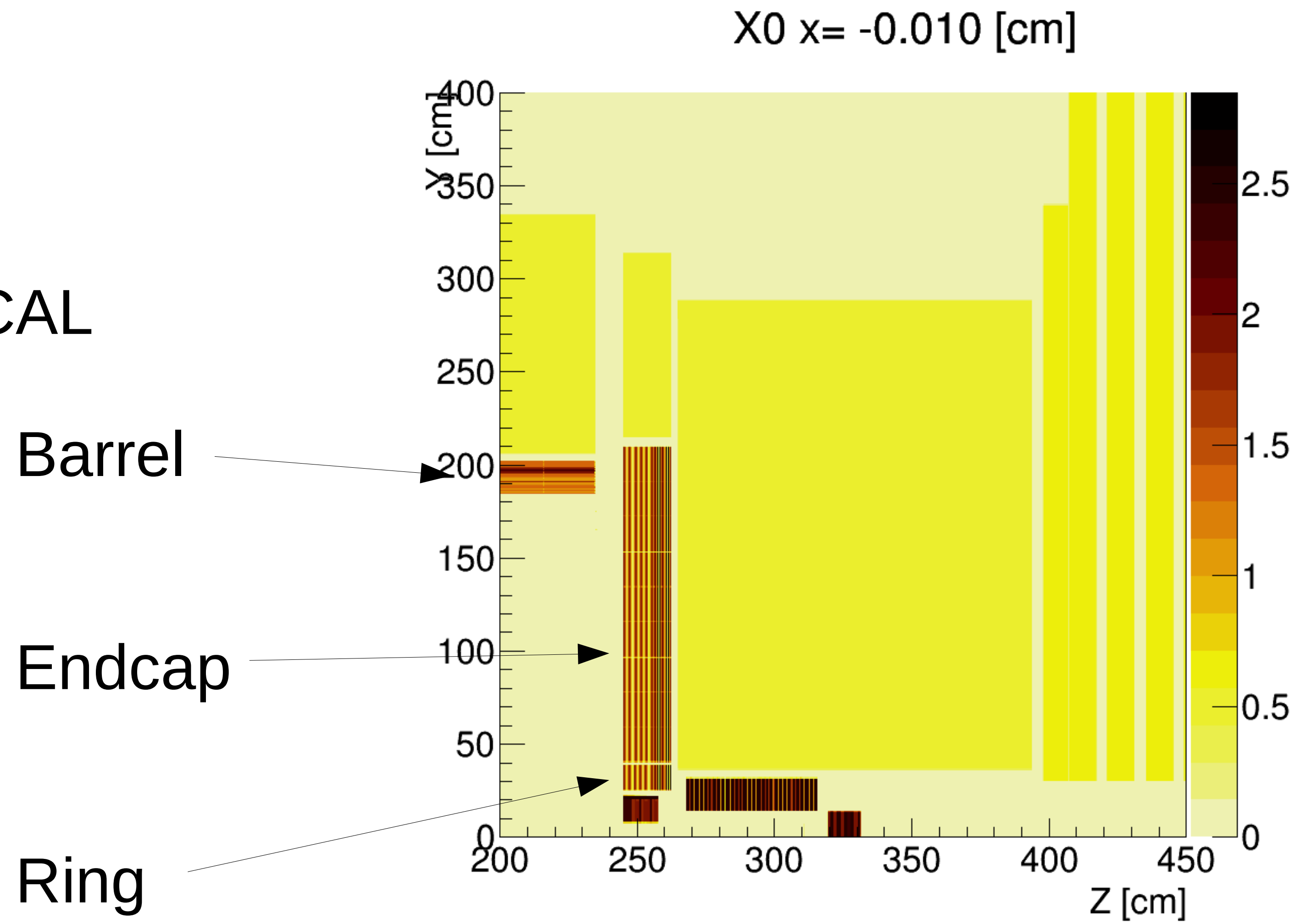
30-layer ECAL, 5x5 mm^2 pixels,
similar to DBD-era model
→ no more "preshower" layer,
absorber added before first layer
→ otherwise ~unchanged

rewritten / tidied-up driver





ECAL



Barrel and Endcap corresponds very closely to
“baseline” engineering model as defined by draft TDD
→ some aspects of this design
(in particular, thickness of PCB & electronics)
rather aggressive compared to today's prototypes

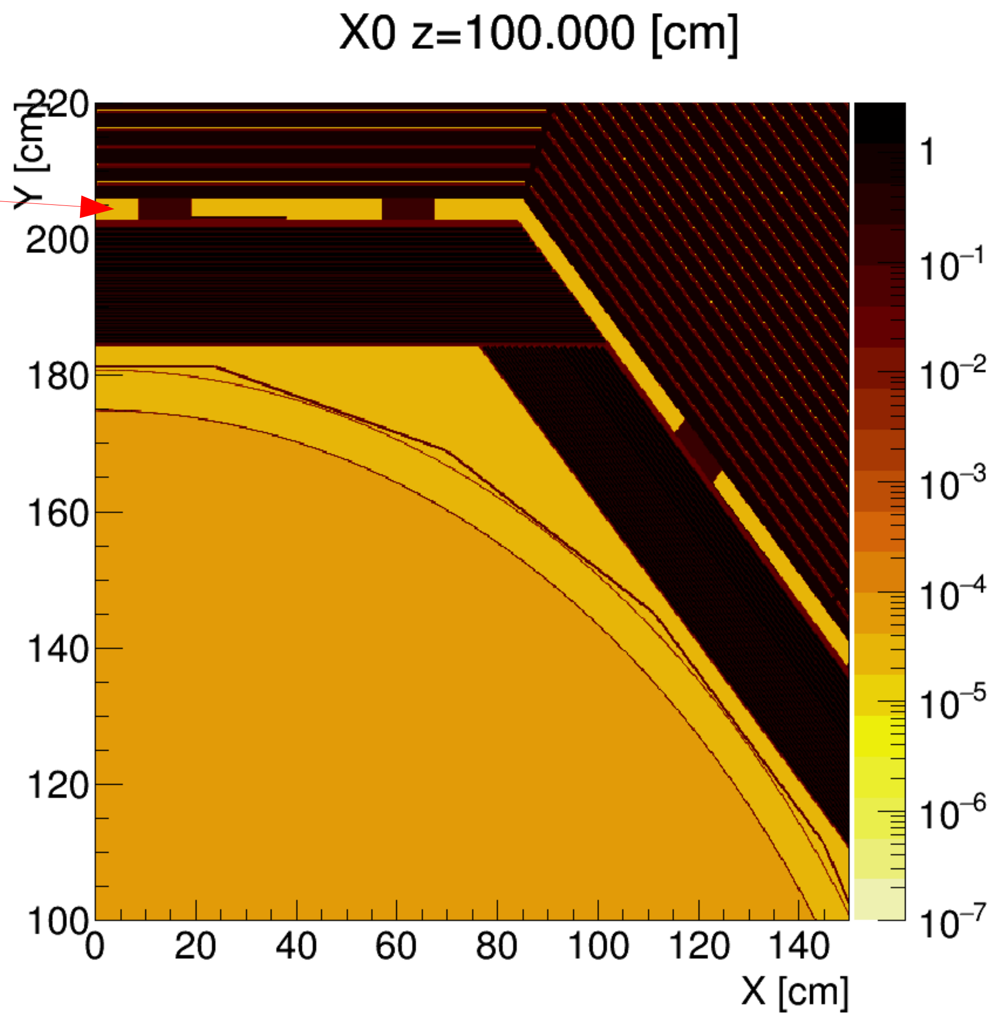
Ring is “generic”, naive design
(no serious engineering design exists)

supporting rails

cable & cooling materials

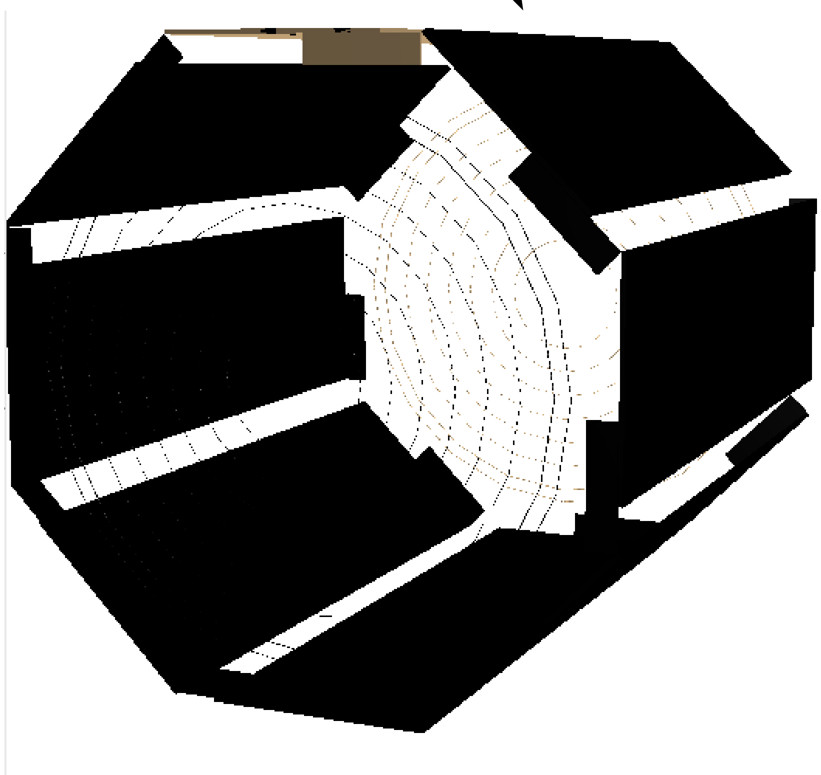
in the ECAL-HCAL gap

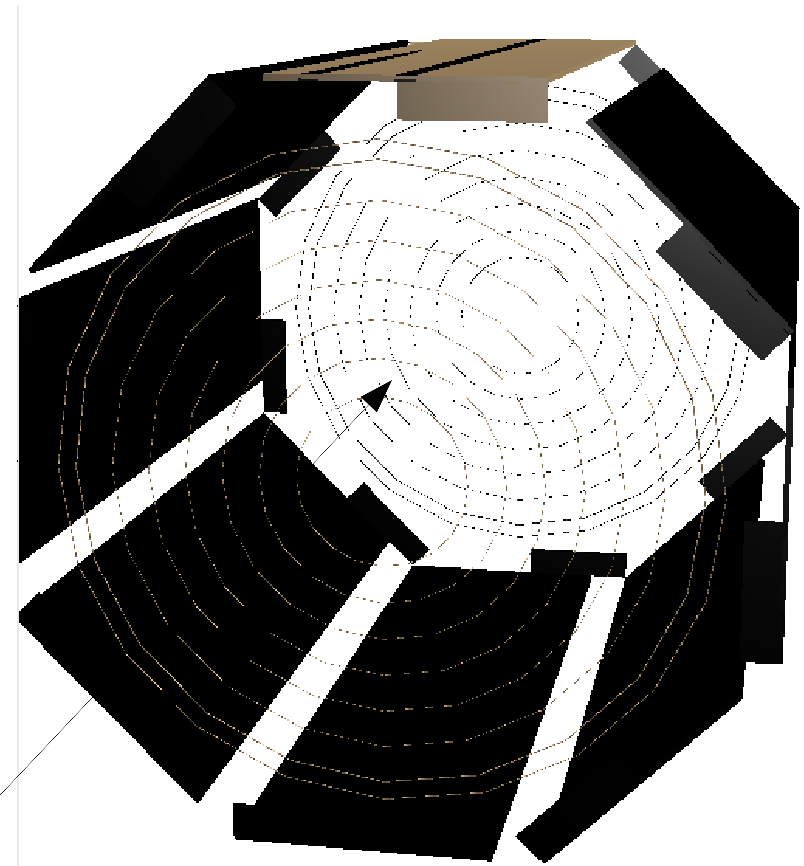
description somewhat out-of-date, (e.g. #rails / module should be reduced from 3 → 2) but probably good enough in this not-too-critical region



other views of the detector service volumes

material between ECAL & HCAL





TPC cooling

materials in the ECAL

Num. Layer	Material Name	Thickness [cm]	Path Length [cm]	Integrated X0 [cm]	Integrated Lambda [cm]
. . .					
4	CarbonFiber	0.030	0.33	0.001051	0.000553
5	G4_W	0.210	0.54	0.599843	0.020930
6	CarbonFiber	0.075	0.62	0.602445	0.022302
7	G4_AIR	0.025	0.64	0.602446	0.022302
8	siPCBMix	0.130	0.77	0.648748	0.027964
9	G4_AIR	0.010	0.78	0.648748	0.027964
10	Silicon	0.050	0.83	0.654096	0.029057
11	GroundOrHVMix	0.010	0.84	0.657773	0.030528
12	CarbonFiber	0.015	0.86	0.658294	0.030803
13	G4_W	0.210	1.07	1.257086	0.051180
14	CarbonFiber	0.015	1.08	1.257606	0.051454
15	GroundOrHVMix	0.010	1.09	1.261283	0.052926
16	Silicon	0.050	1.14	1.266631	0.054018
17	G4_AIR	0.010	1.15	1.266632	0.054019
18	siPCBMix	0.130	1.28	1.312933	0.059681
19	G4_AIR	0.025	1.31	1.312934	0.059681
20	CarbonFiber	0.075	1.38	1.315537	0.061052
21	G4_W	0.210	1.59	1.914329	0.081430
. . .					
0	Average Material	18.600	18.60	25.136259	1.106614

Structure

Slab

properties of simulated hits made by 50 GeV muons

produced semi-automatically by the ILDPerformance/validateSim processor

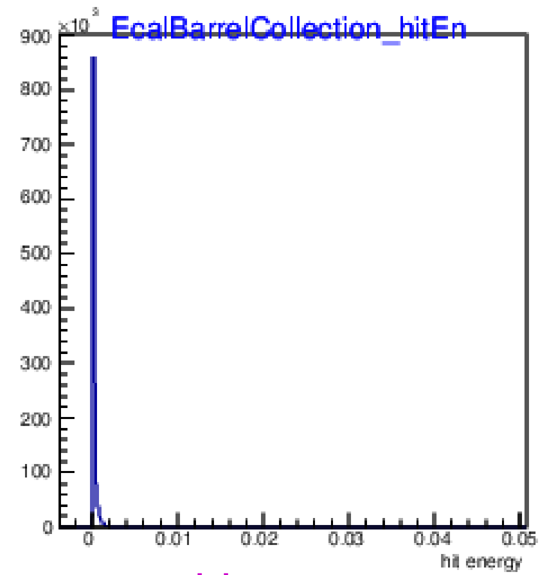
set of plots for all simulated hits.

I try to systematically run it for new releases, and publish plots on

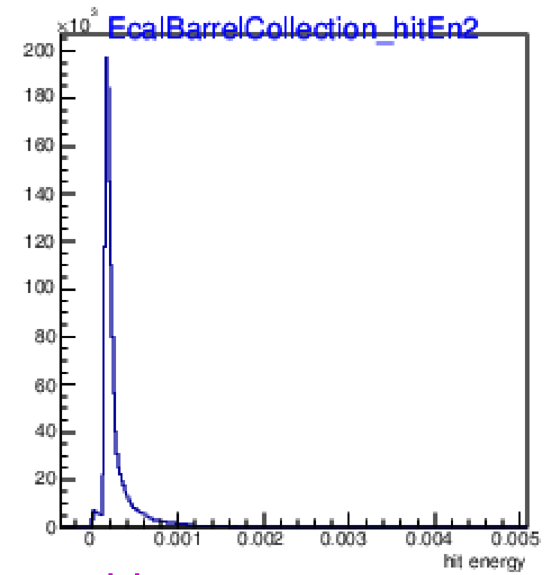
http://research.kek.jp/people/jeans/ctpics

linked from ILD confluence page: software – simulation – validation

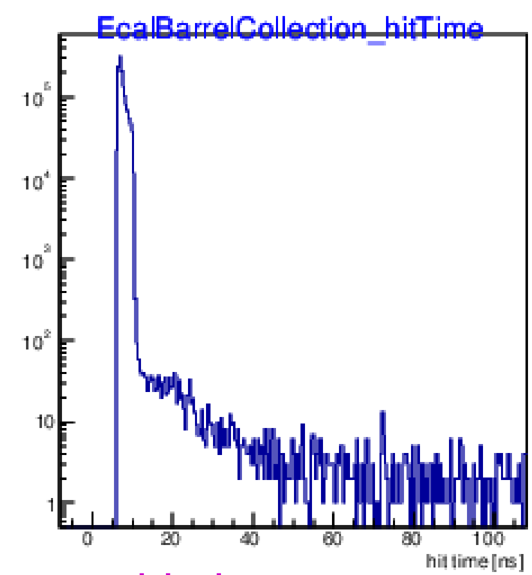
Idea is to check basic hit quantities



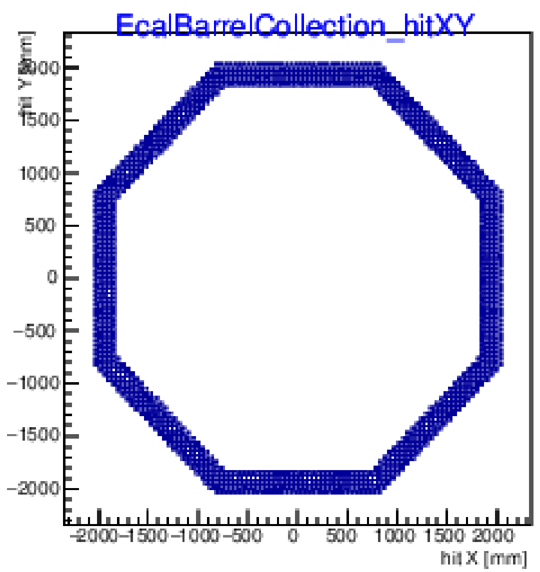
hit energy



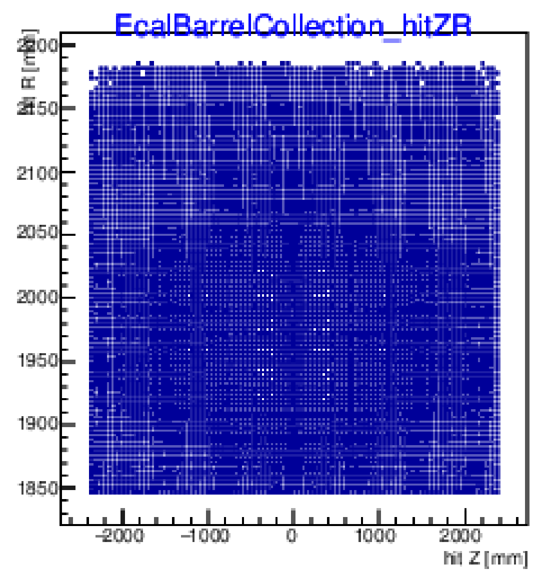
hit energy



hit time



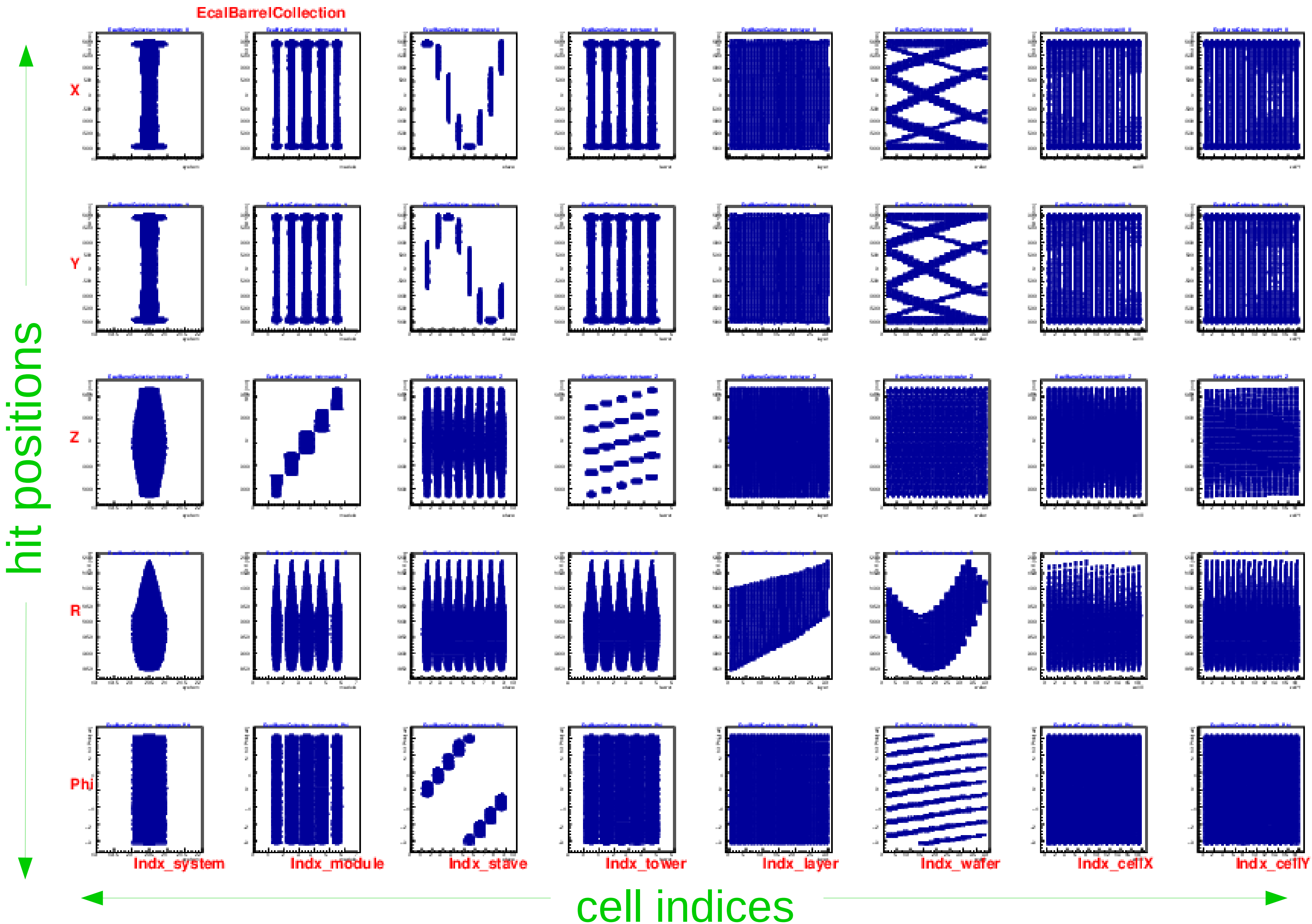
x-y map



r-z map

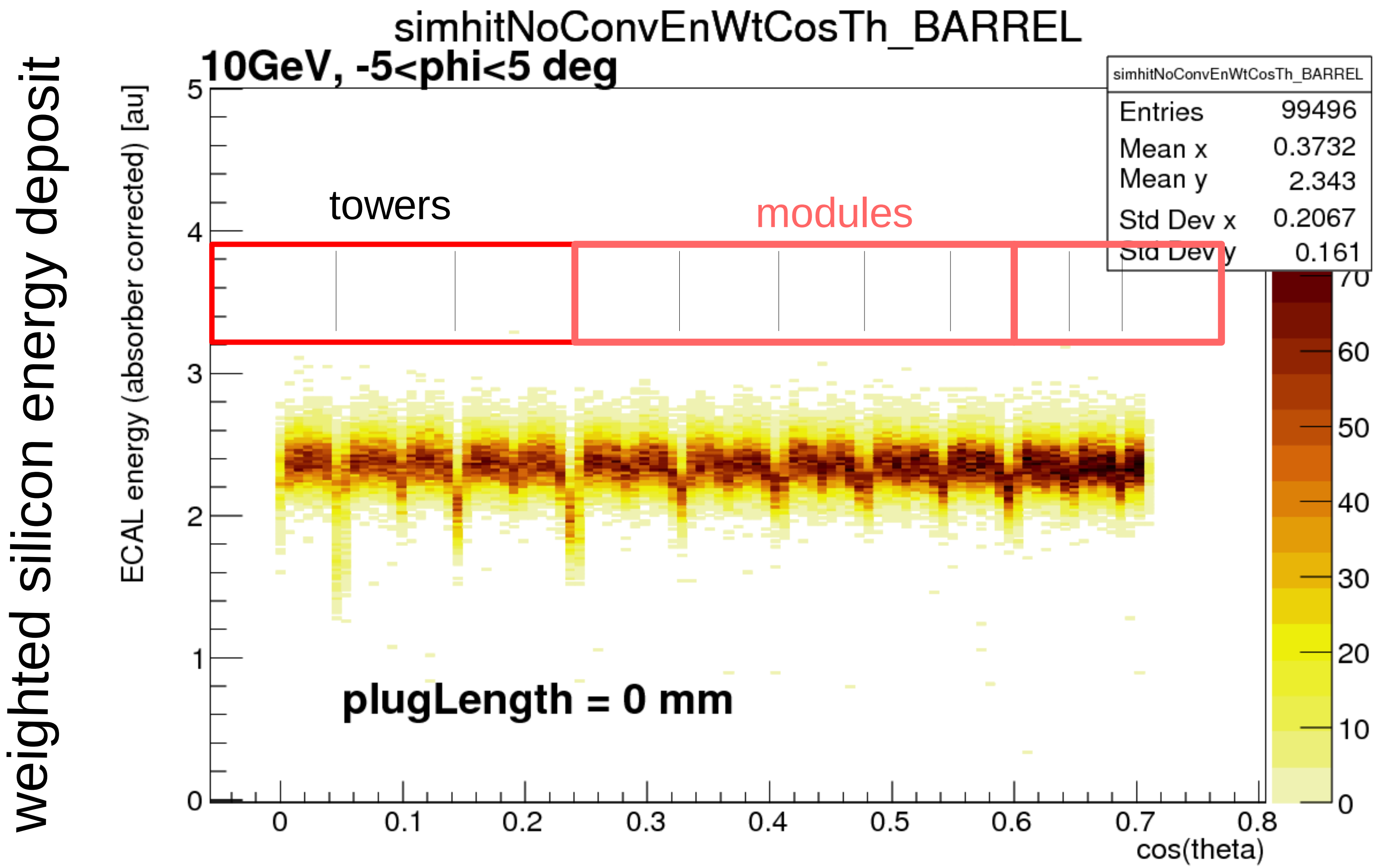
ECAL Barrel hits

check of cell indices: correlation with hit position: can help spot problems



single photon response sum of simhit energies

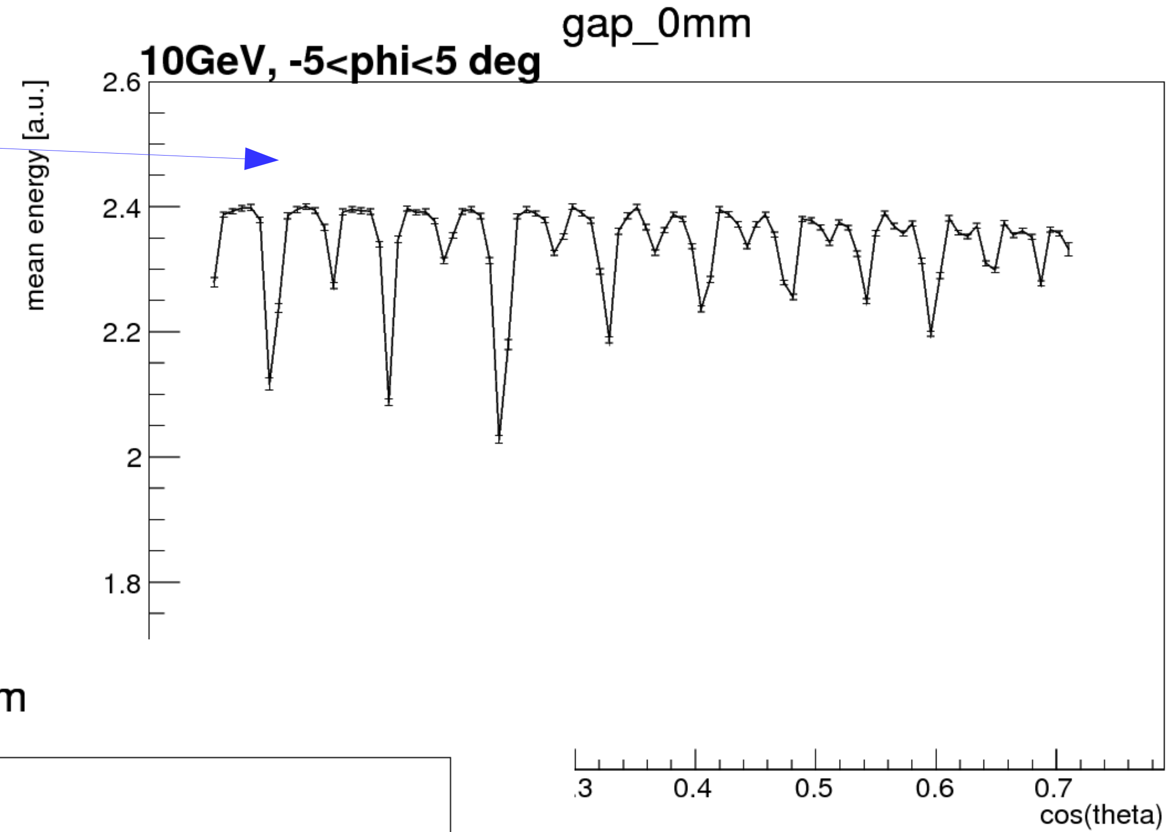
10 GeV photons from IP into barrel region
at -5 < phi < 5 degrees (far from phi cracks)

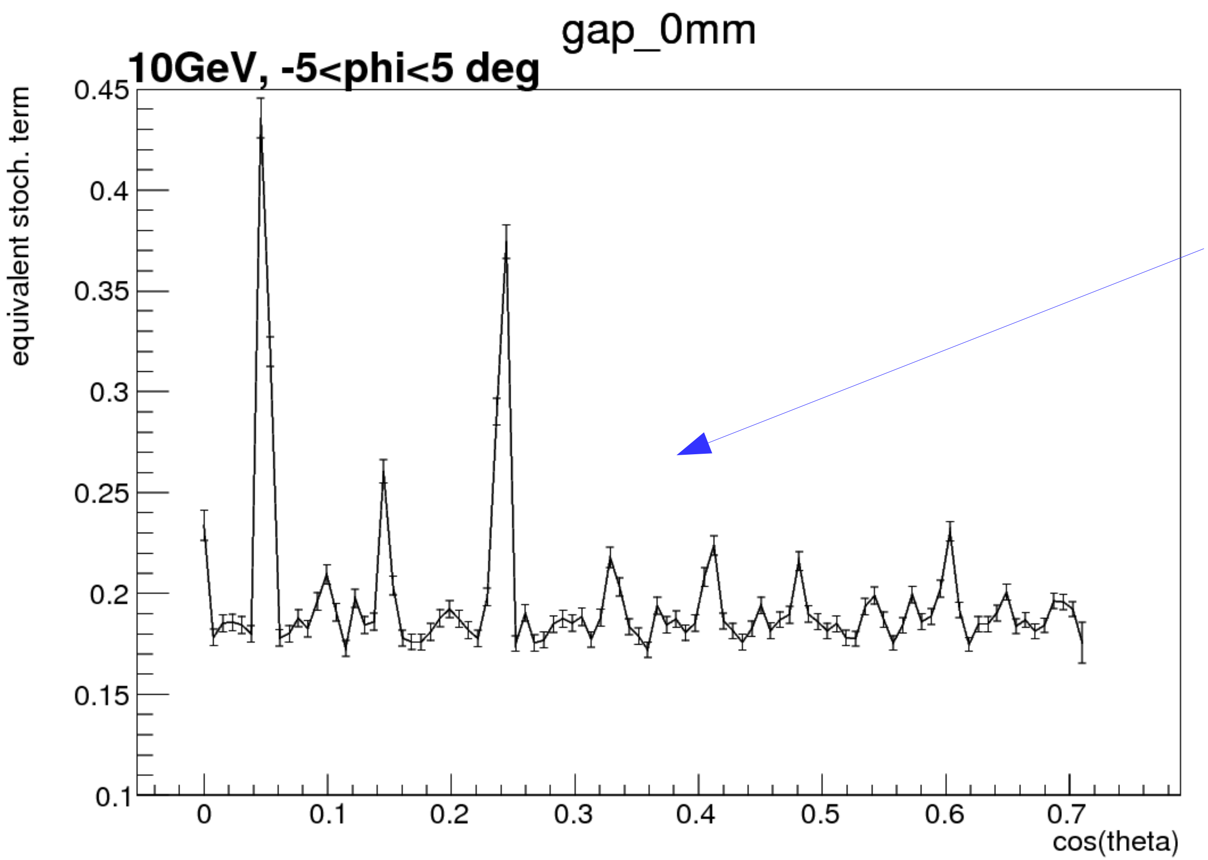


effect of "z" detector cracks clearly visible

Mean energy deposit

significant variations:
can be corrected if
position resolution is
sufficient





RMS of energy distribution
converted to “stochastic term”

RMS: do not ignore tails
“stoch. term”
~18% in best regions

consistent with expectations

Hit digitisation and reconstruction

digitisation rather simple: just an energy threshold

hit reconstruction: corrections are applied

- absorber thickness
- gaps in structure (“BruteForceEcalGapFiller”)

to-do list

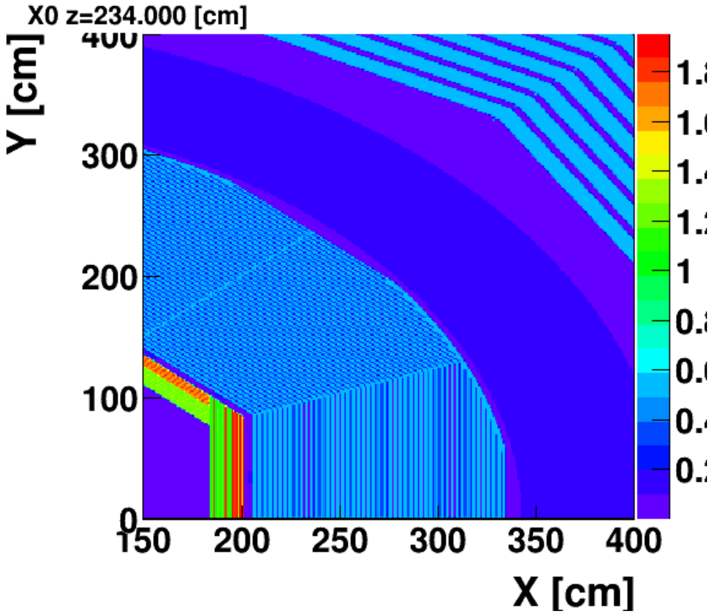
- validation of digi & reco processes
- single photon response at PFO level
- detailed comparisons to Mokka simulations

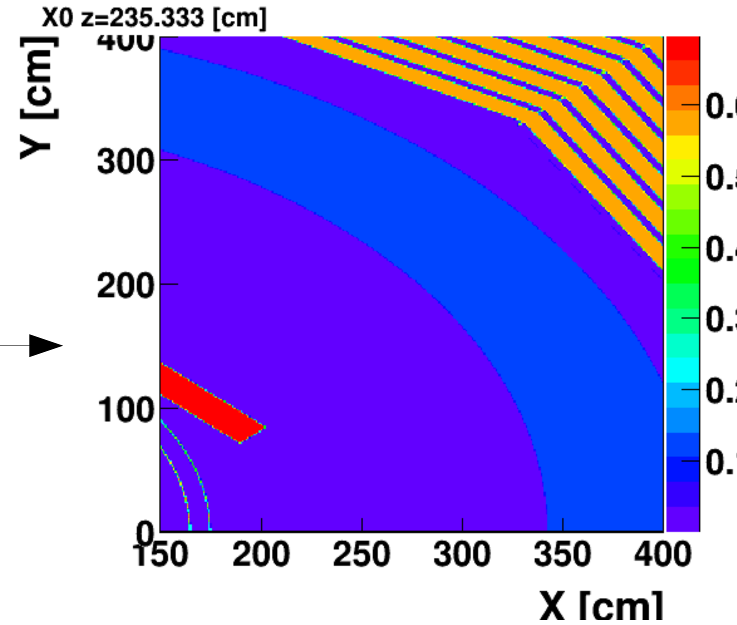
Sc-ECAL

no model implemented in lcgeo

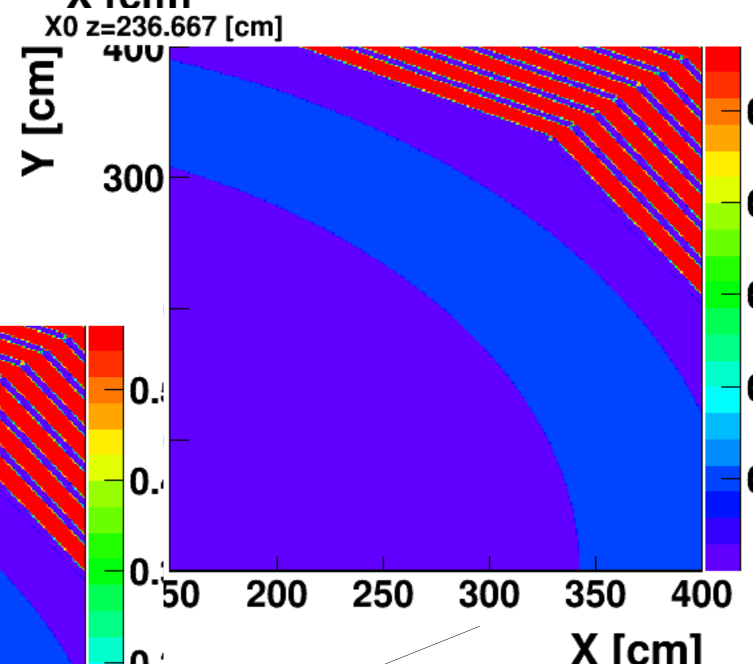
ECAL driver now used for Si-ECAL is designed to
 also deal with strip-based readout
 → in principle possible (even “easy”) to implement Sc-ECAL

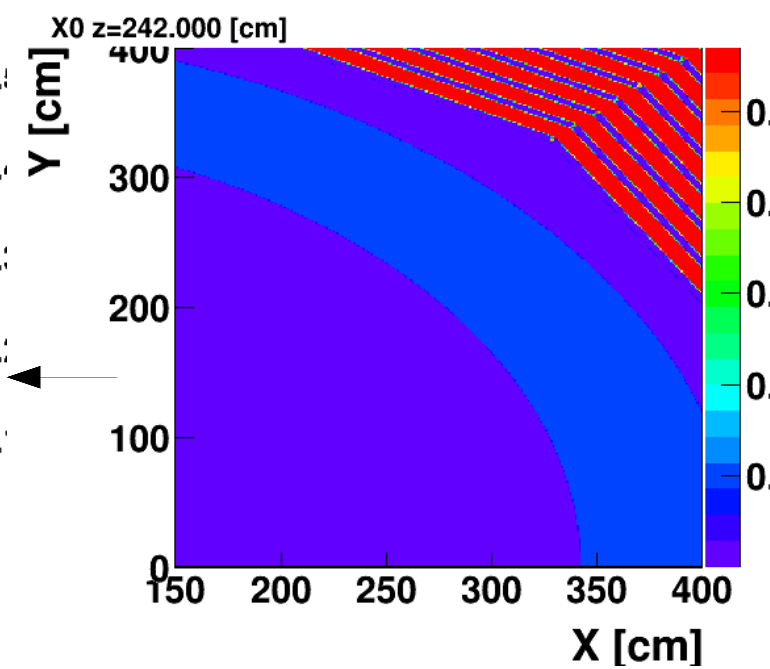
manpower limited

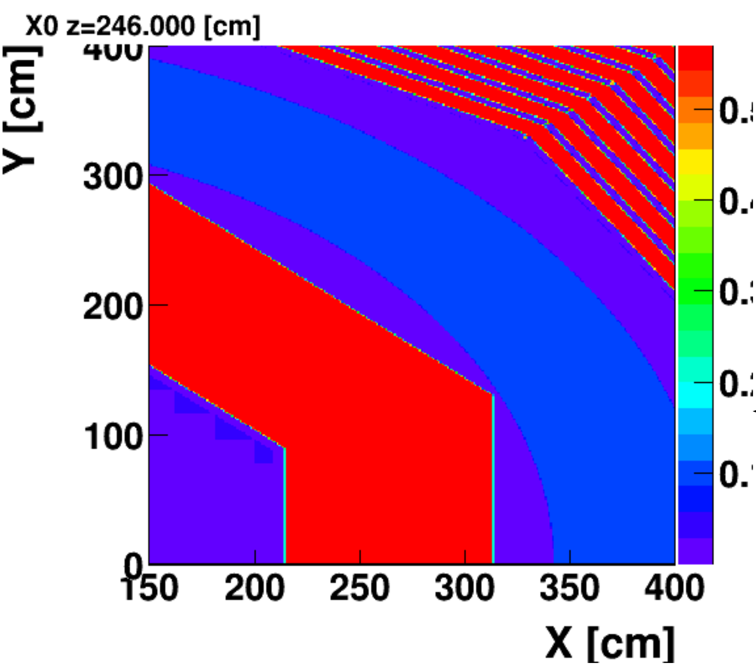




material in the barrel-endcap gap







summary (calorimeters)

detailed models of A-, SD-, hybrid-HCAL, Si-ECAL exist
  and have been integrated into ILD models

Sc-ECAL not yet implemented in dd4hep

sill a correspondence in HCAL between
  V-T geometry ↔ technology
    but this is easy to break (as it must be for hybrid model)

validation efforts are underway
  geometry and material descriptions quite well investigated
  more to do on digitisation, reconstruction levels
    several effects to be understood (e.g. see Katja's talk yesterday)
    almost certainly more effects to discover

progress determined by limited manpower

a few unexpected features (bugs)
I noticed from my general validation
studies of models in ilcsoft v01-19-02

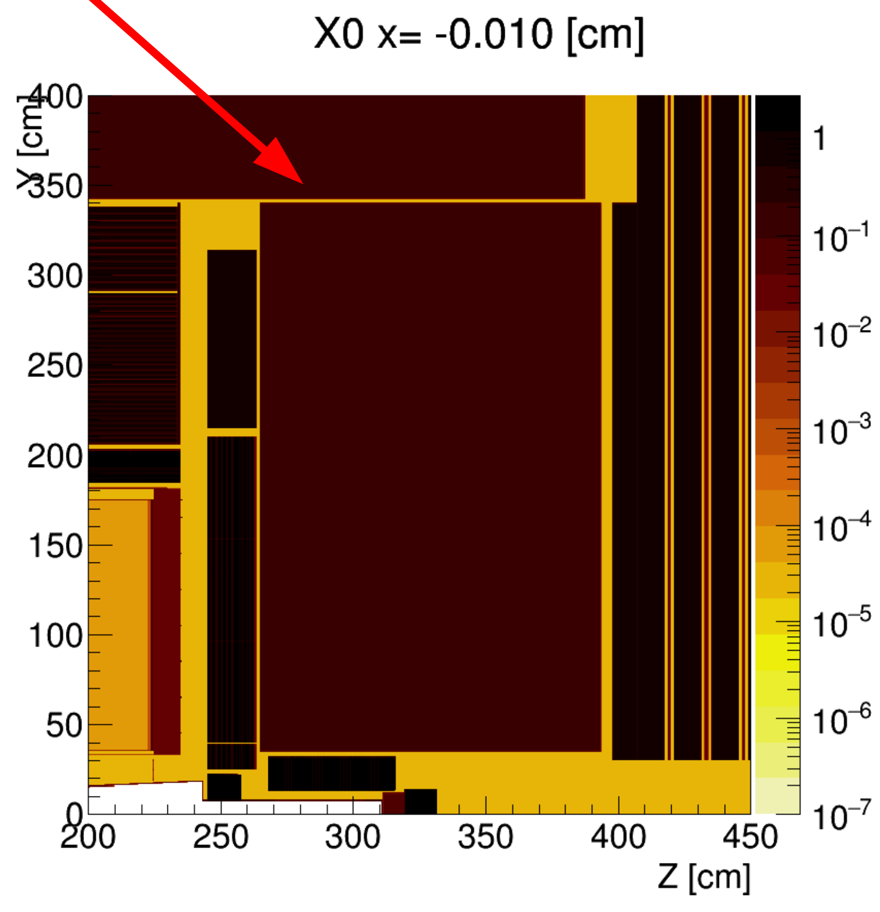
all pictures, and many more, can be found at

http://research.kek.jp/people/jeans/ctpics/

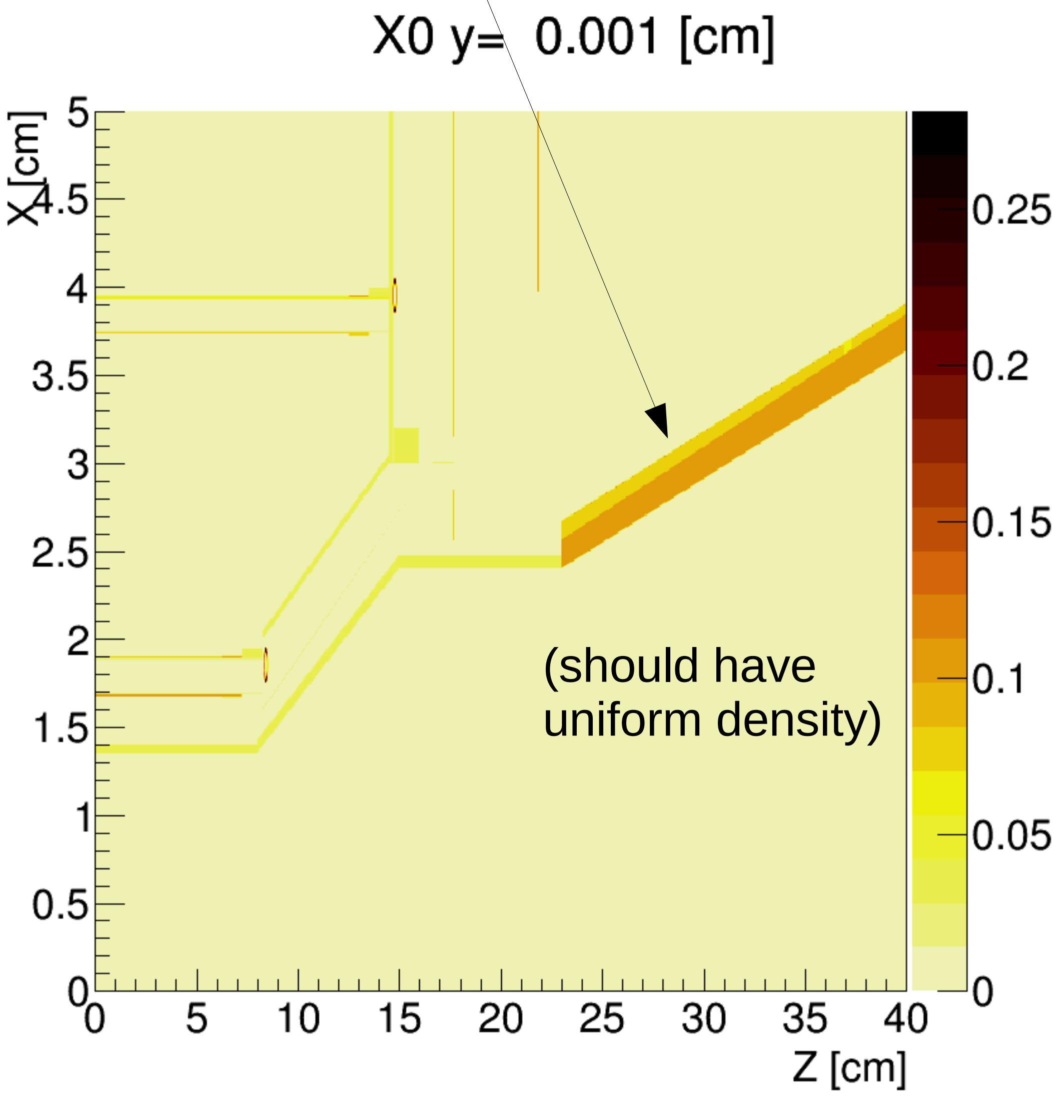
videau structure endcaps
fills space to solenoid

enough space for cables?

should reduce
HCAL envelope,
but by how much?



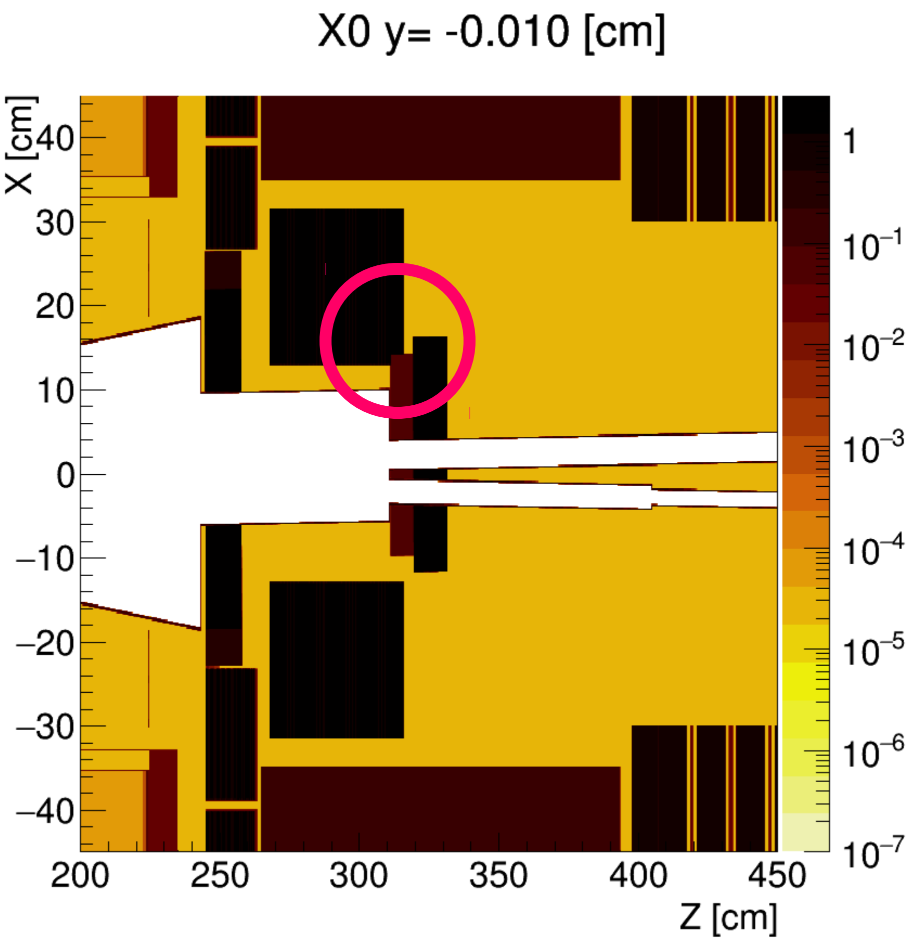
beamipipe second cone – ftd volume overlap ?



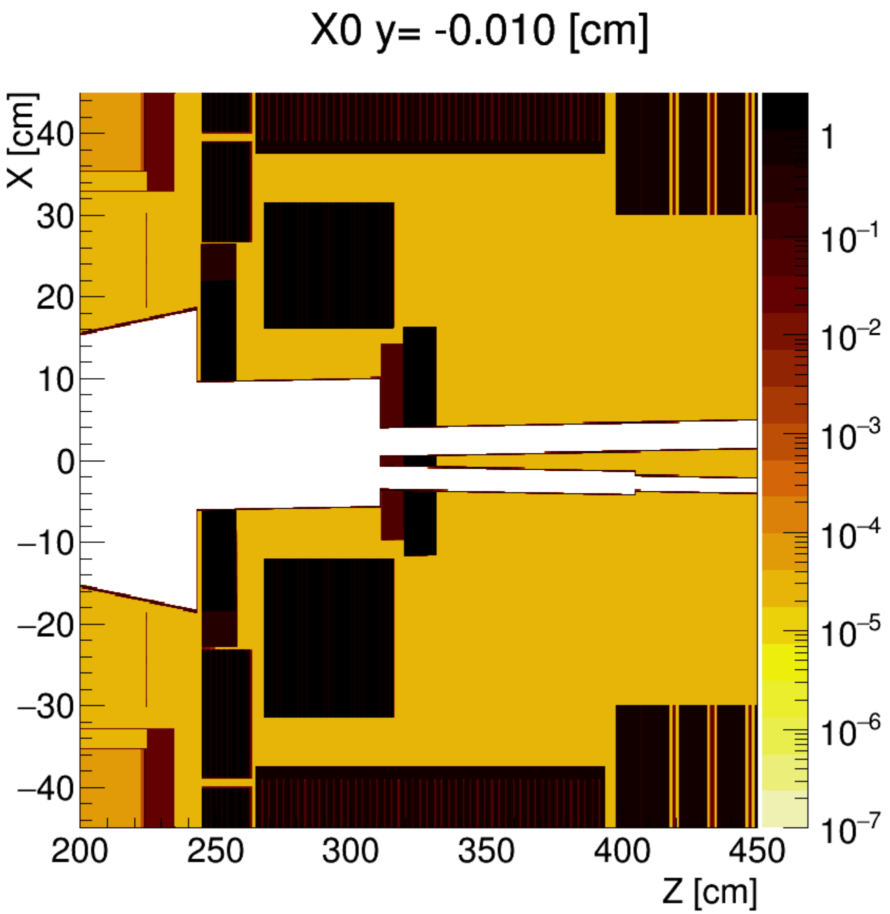
this is my bug

beamcal/lhcal collision in ILD_l2 model

ILD_l2

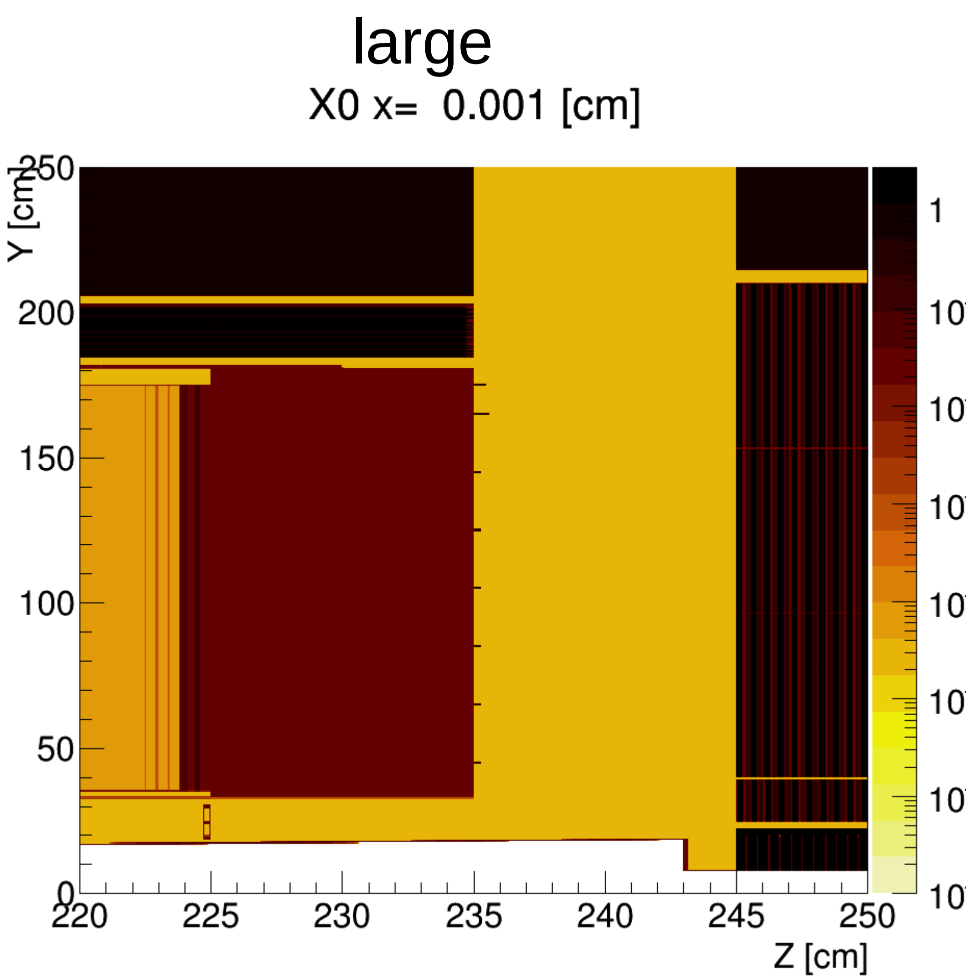


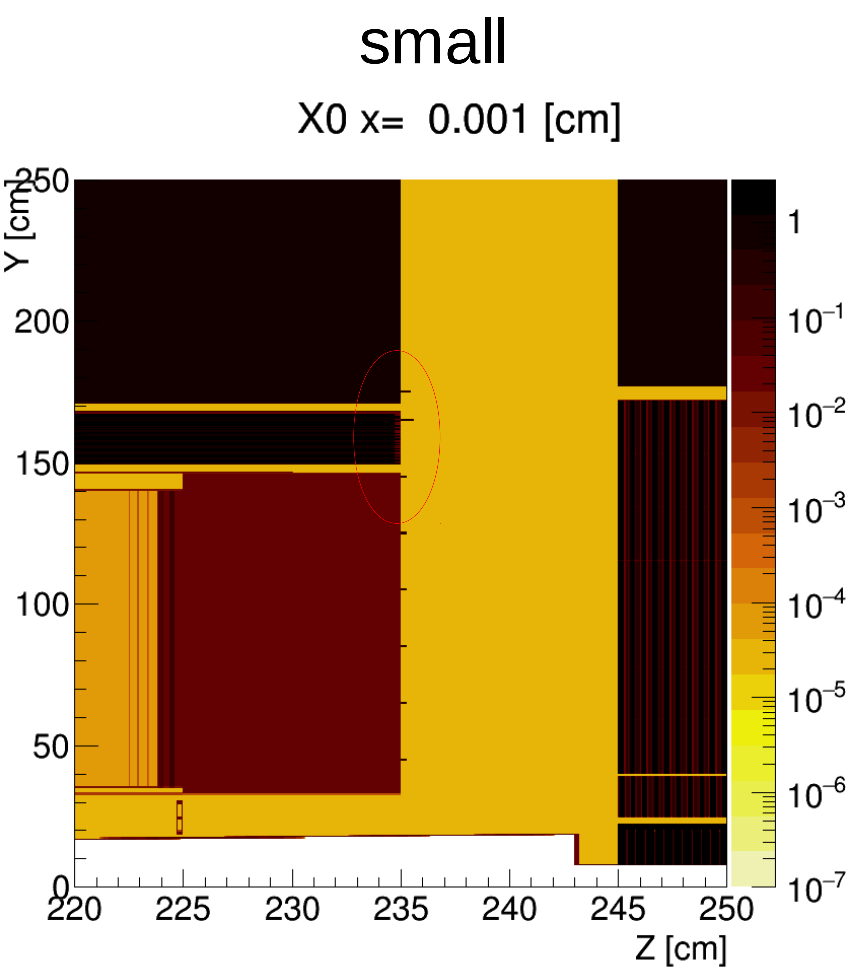
all other models OK



differences between common parts of models should be impossible...

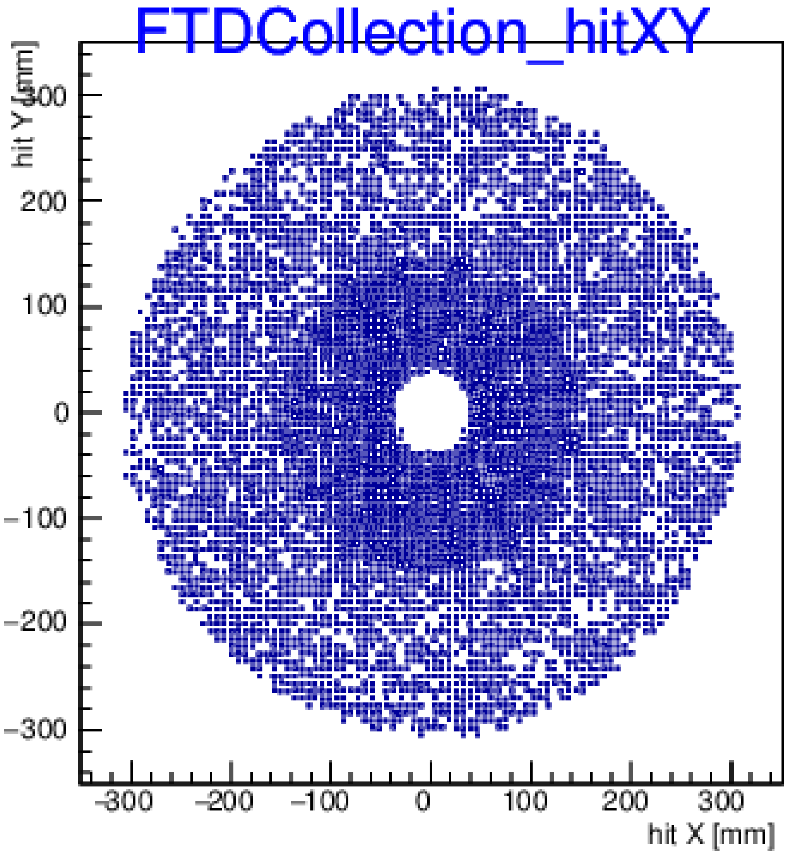
TPC services

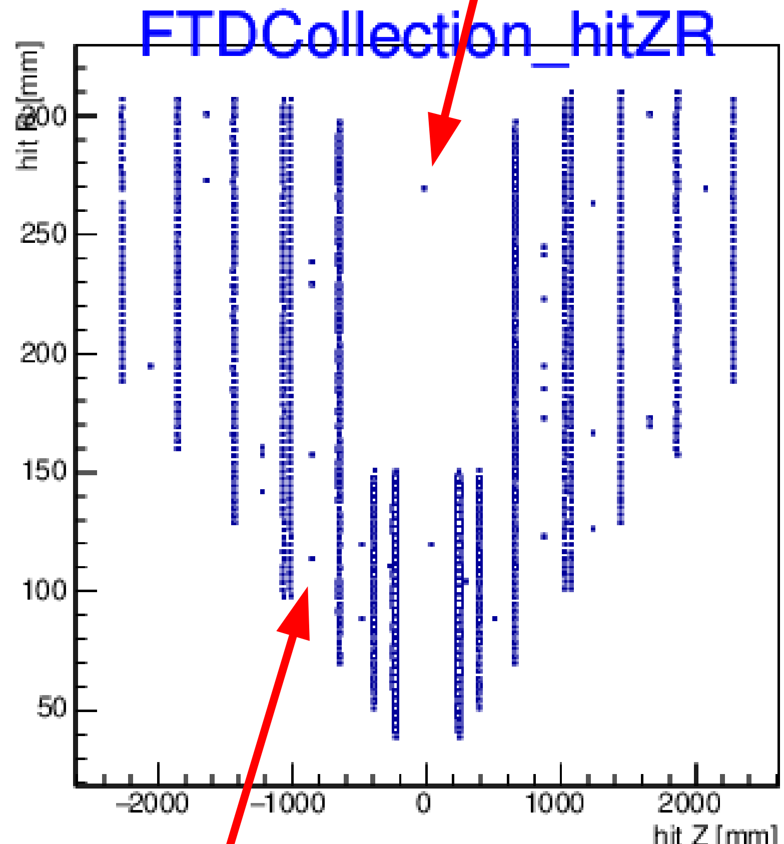




cooling pipes not scaled in small models

hit maps with problems: FTD

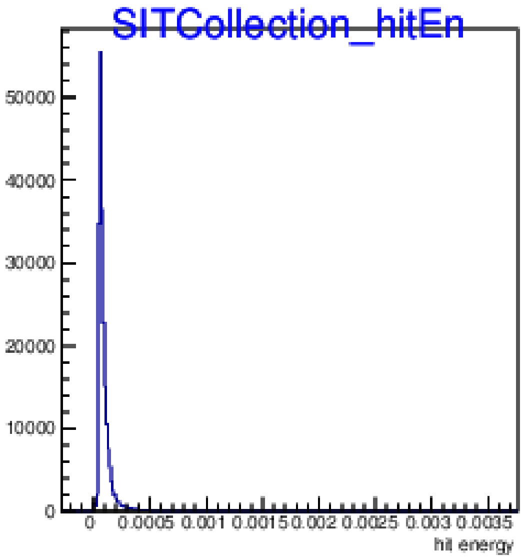


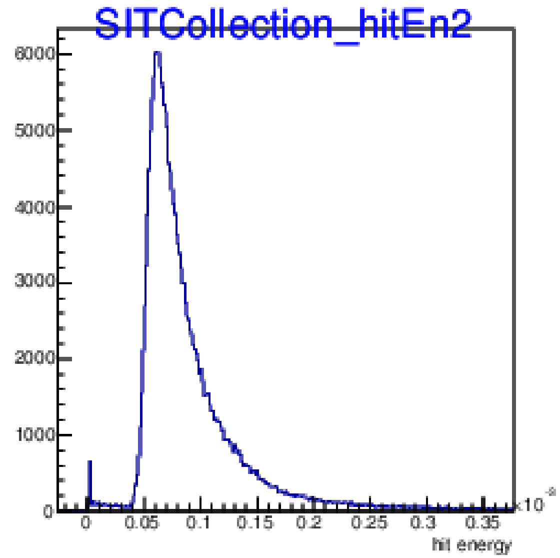


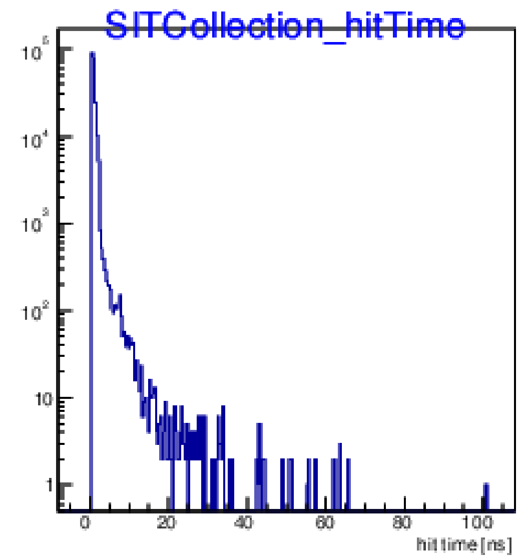
hits in impossible positions

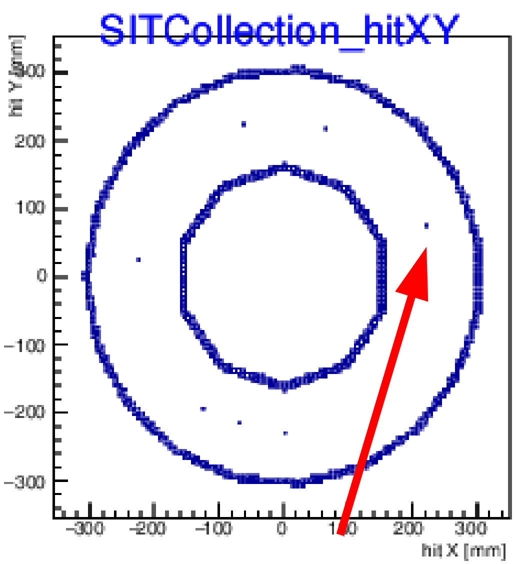
(50 GeV muons in v01-19-02 / ILD_l2_v01)

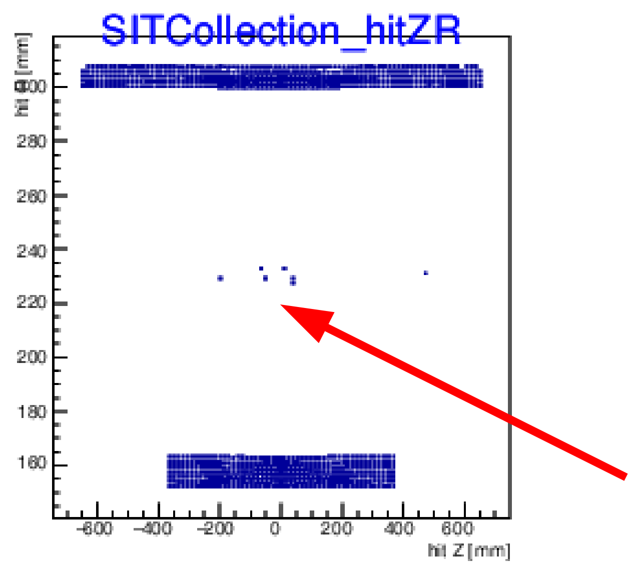
hit maps with problems: SIT





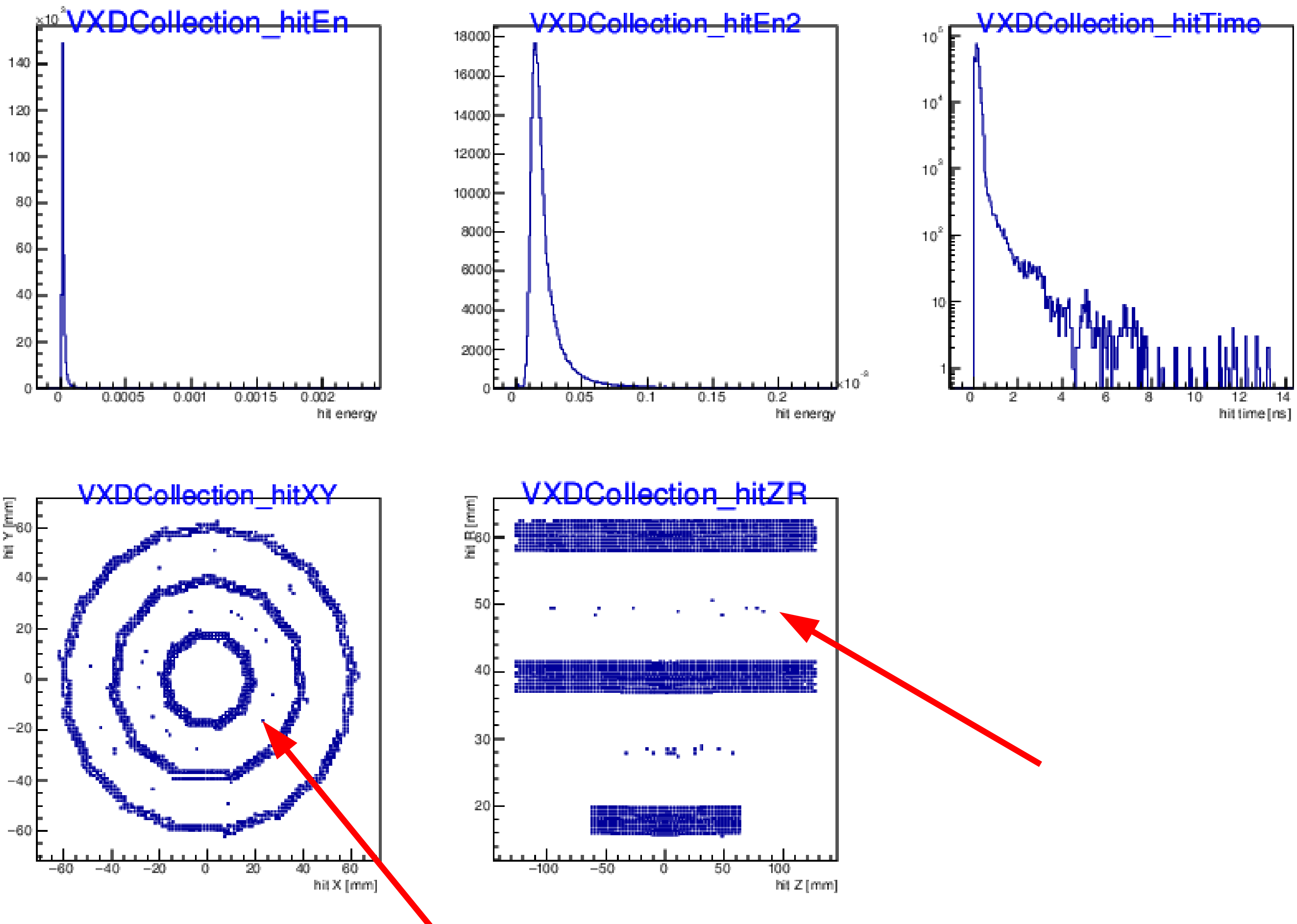






hits in impossible positions

hit maps with problems: VXD



hits in impossible positions