A New Geometry for the Crystal Calorimeter (eEMCAL)

Update: 6/30/15

Josh LaBounty

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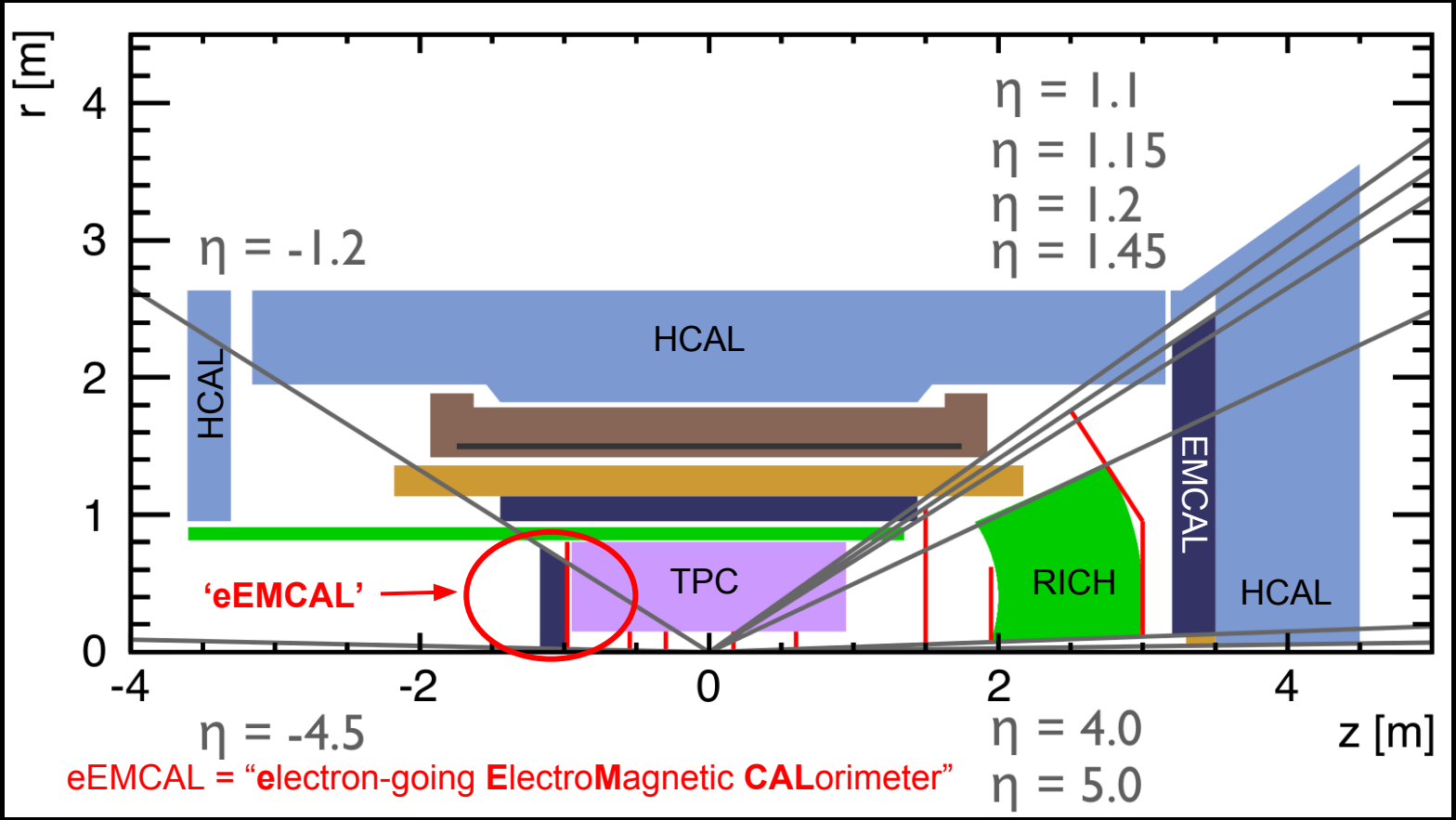
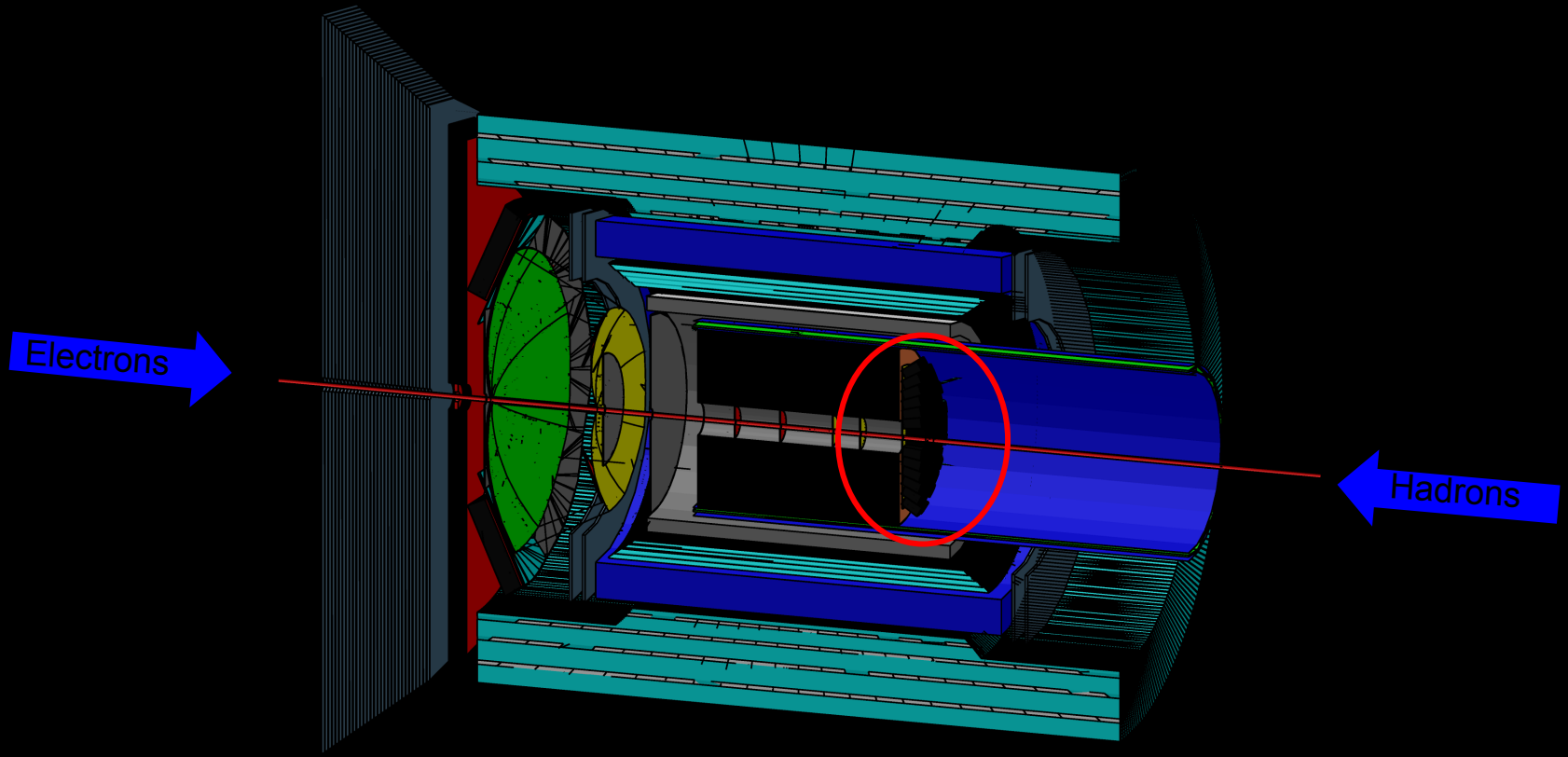
Location

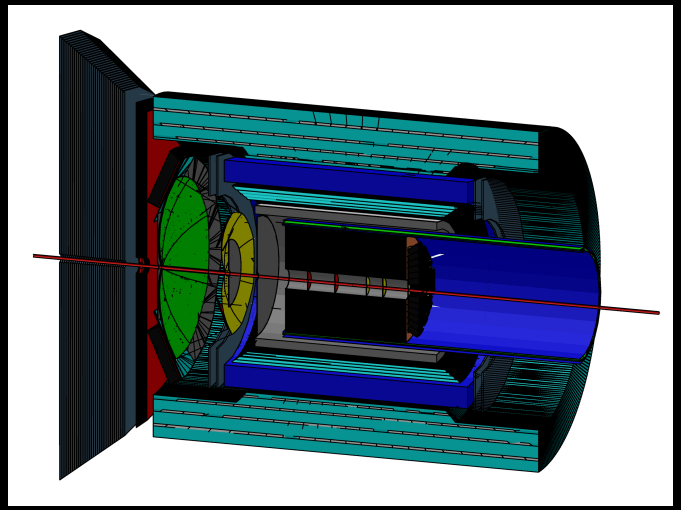


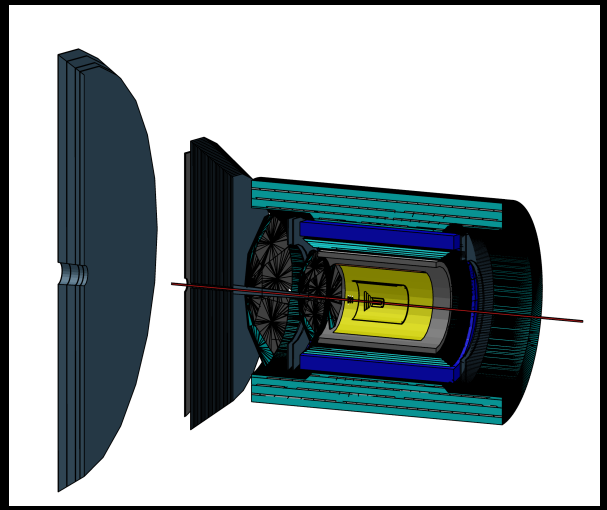
eEMCAL = "**e**lectron-going **E**lectro**M**agnetic **CAL**orimeter"

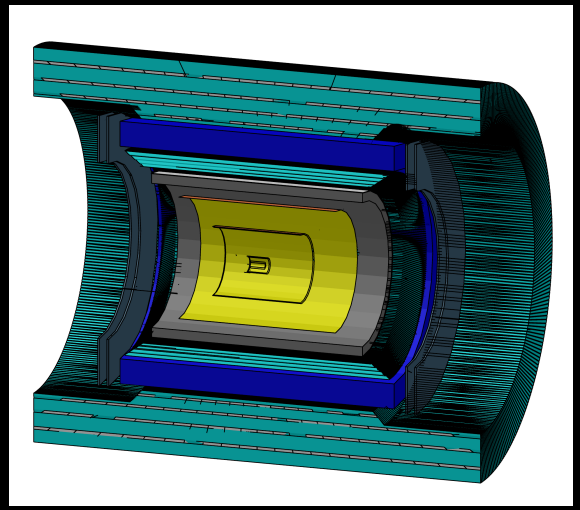
Location



Quick Aside







Over the course of the week, I generated these prim/eps files for ePHENIX, fsPHENIX, and sPHENIX detectors

Can be downloaded from here: https://github.com/jlabounty/wip/tree/master/PRIM_files

DAWN Viewer needed to view PRIM Files:

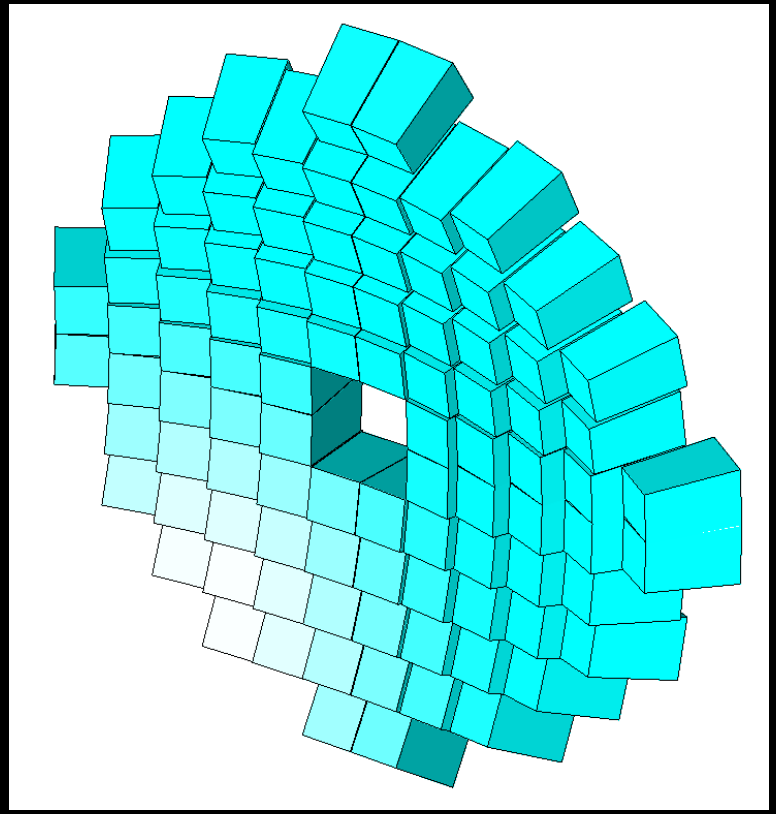
http://geant4.slac.stanford.edu/Presentations/vis/G4DAWNTutorial/G4DAWNTutorial.html

DAWNCUT can be used to create cuts (as in images above):

http://geant4.kek.jp/~tanaka/DAWN/About_DAWNCUT.html

Previous Implementation

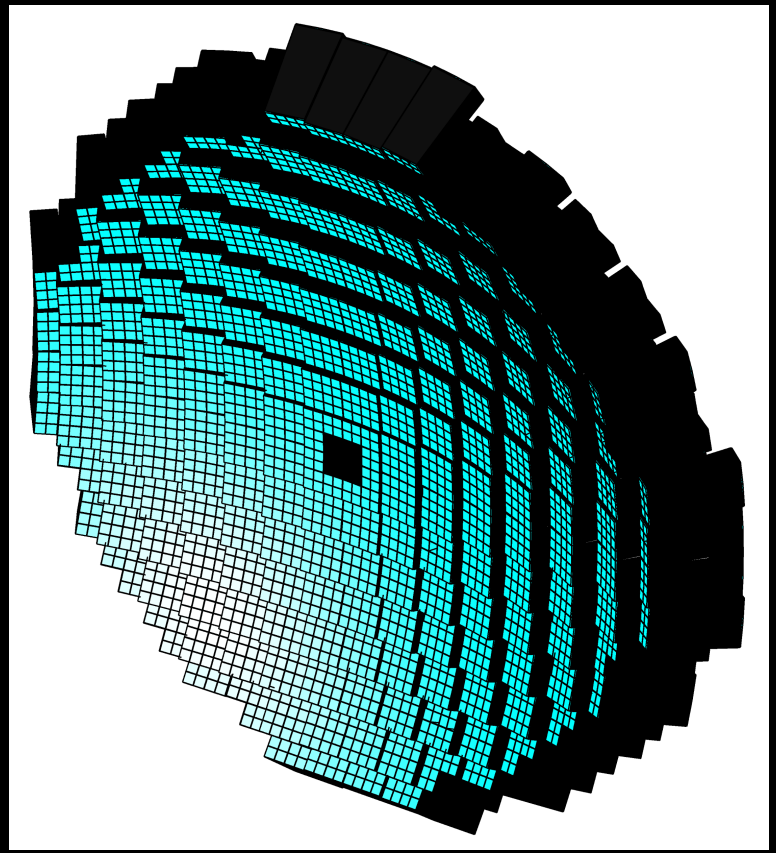
- 92 $PbWO_4$ units arranged in an off-pointing geometry
  - Front face: 100.38 mm x 100.38 mm
  - Back face: 118.63 mm x 118.63 mm
  - Length: 180.00 mm
- Each unit represents a 4x4 block of $PbWO_4$ crystals



https://github.com/jlabounty/coresoftware
commit: `2f4ab1754c9131a127d66d7ab1e20eb7a005f4f5`

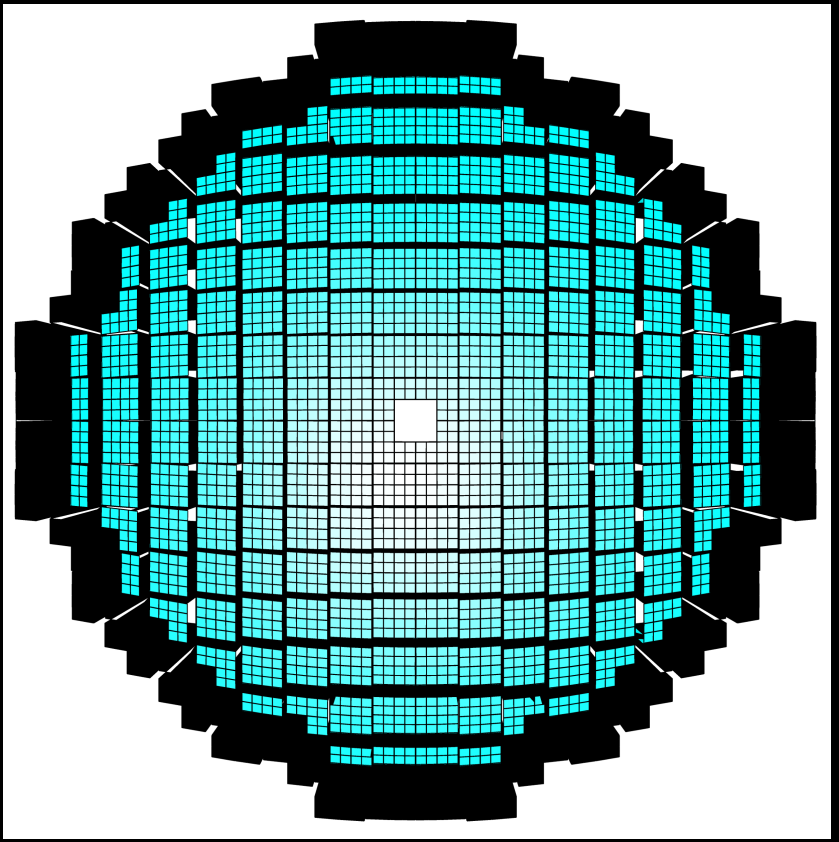
Current Implementation

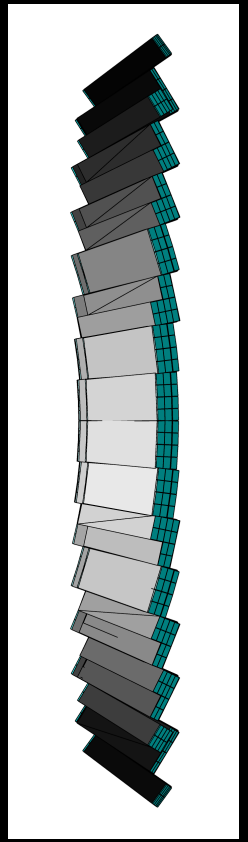
- 2736 $PbWO_4$ crystals arranged in an off-pointing geometry
  - Each Crystal: 2.0 cm x 2.0 cm
- Multiple subunits consisting of between 4 and 16 Crystals
  - Carbon fiber surrounding each subunit

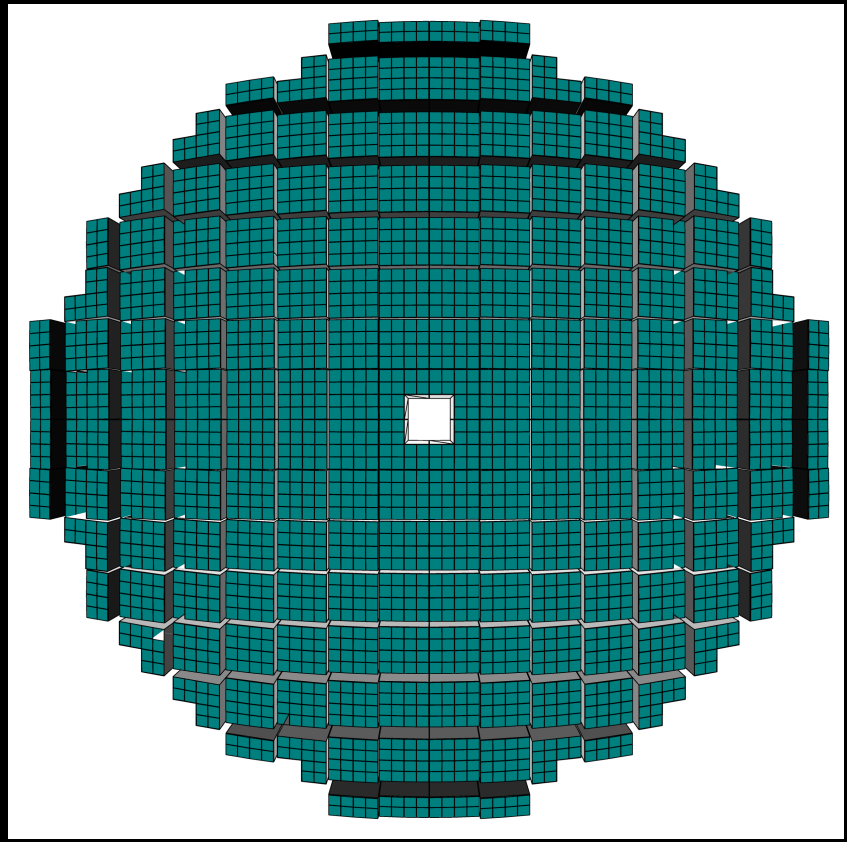


https://github.com/sPHENIX-Collaboration/coresoftware
commit: `c7a7318c0b2fc8fe9e933117adff6c98cc21d3c1`

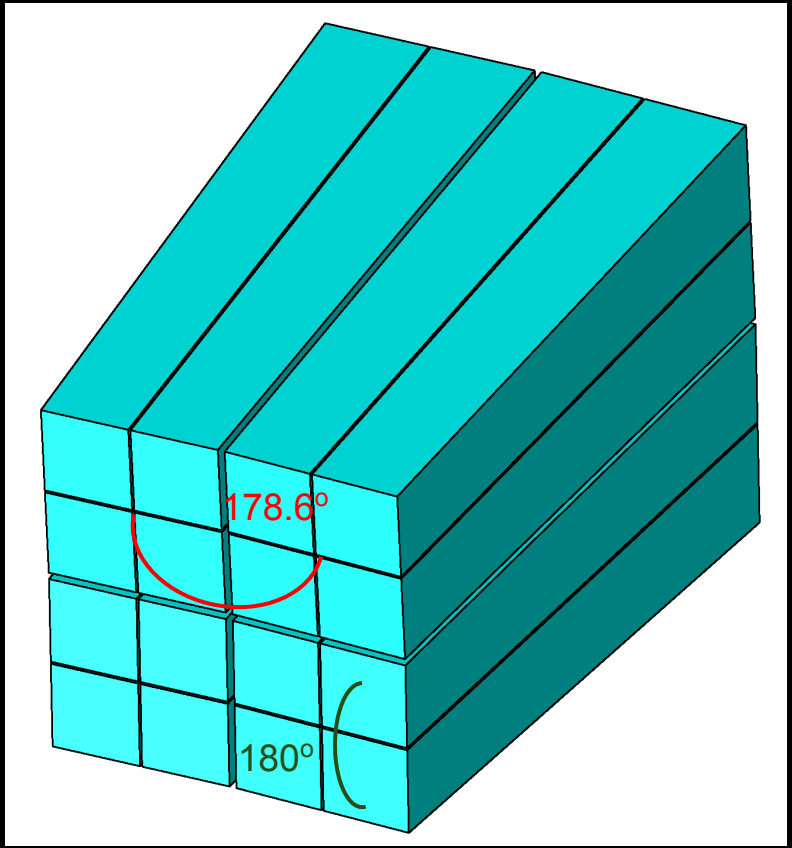
Current Implementation



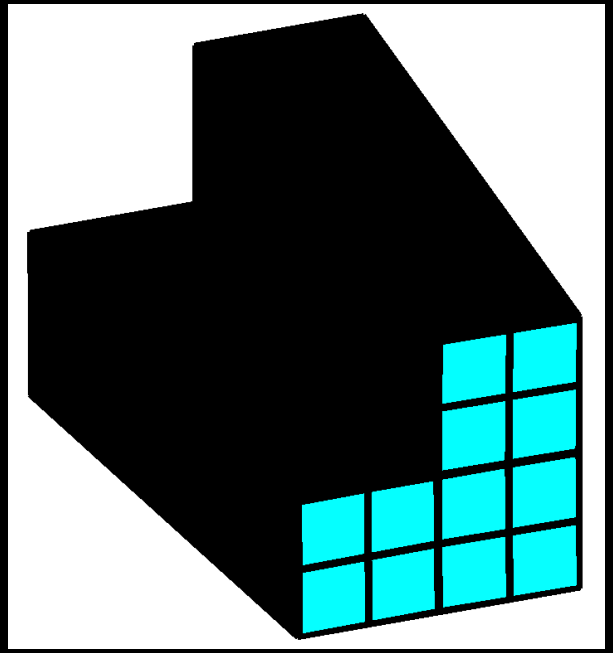




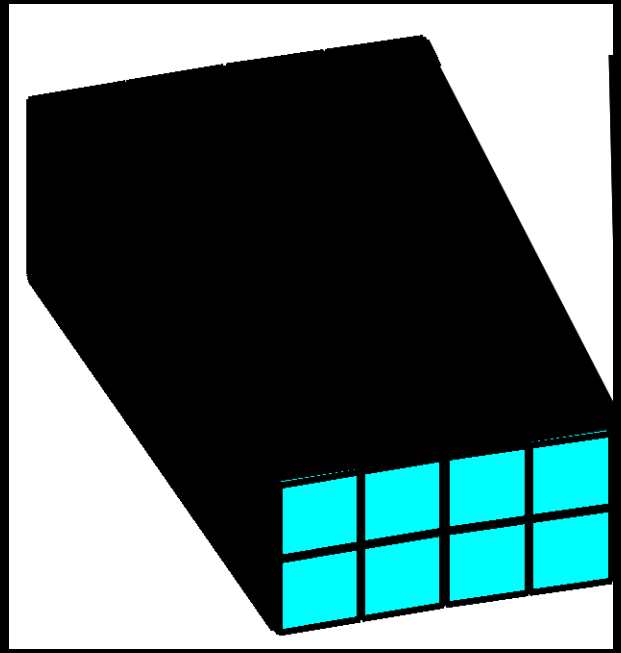
Current Implementation



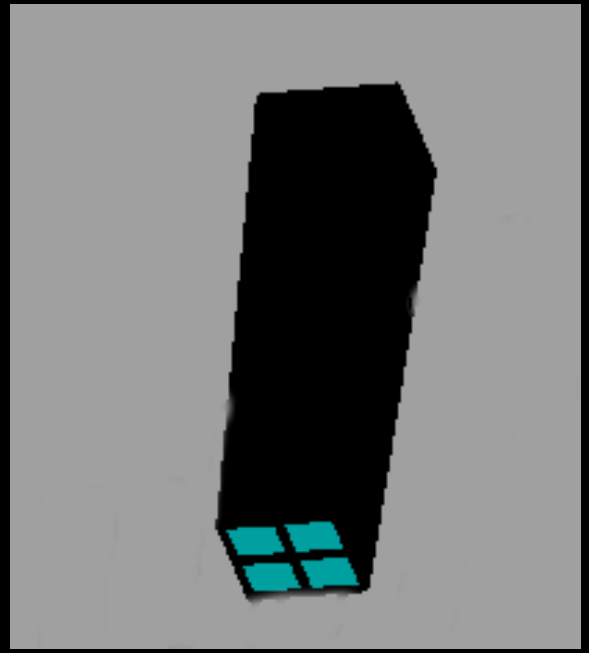
Current Implementation



12 Crystal Subunit



8 Crystal Subunit

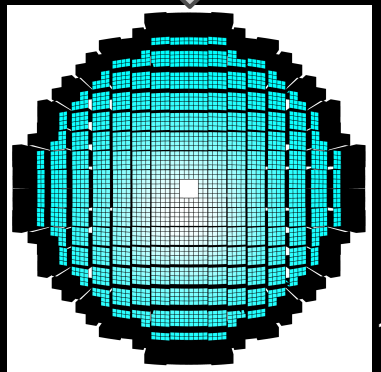


4 Crystal Subunit
(Implemented but not used)

Current Implementation: Mapping

- Geometry read in at runtime from data file
  - 1 quadrant sufficient to define whole geometry
- Can be altered without recompiling

0	0	-0.3	-0.3	0	0	0	3.141592654	1
1	0	0.3	-0.3	0	0	0	1.570796327	1
0	1	-0.3	0.3	0	0	0	-1.570796327	1
1	1	0.3	0.3	0	0	0	0	1
1	0	-22.01130644	-22.01130644	0	-0.025346976	0.025346976	0	4
0	0	22.01130644	-22.01130644	0	-0.025346976	-0.025346976	0	4
1	1	-22.01130644	22.01130644	0	0.025346976	0.025346976	0	4
0	1	22.01130644	22.01130644	0	0.025346976	-0.025346976	0	4



$$[\ \underbrace{j,\ k,}_{\text{Indices}}\ \underbrace{x,\ y,\ z,}_{\text{Coordinates of center in mother volume}}\ \underbrace{\alpha,\ \beta,\ \gamma,}_{\text{Rotation about center}}\ \underbrace{\aleph}_{\text{Line type}}\ ]$$

Mapping: 2 Separate Files

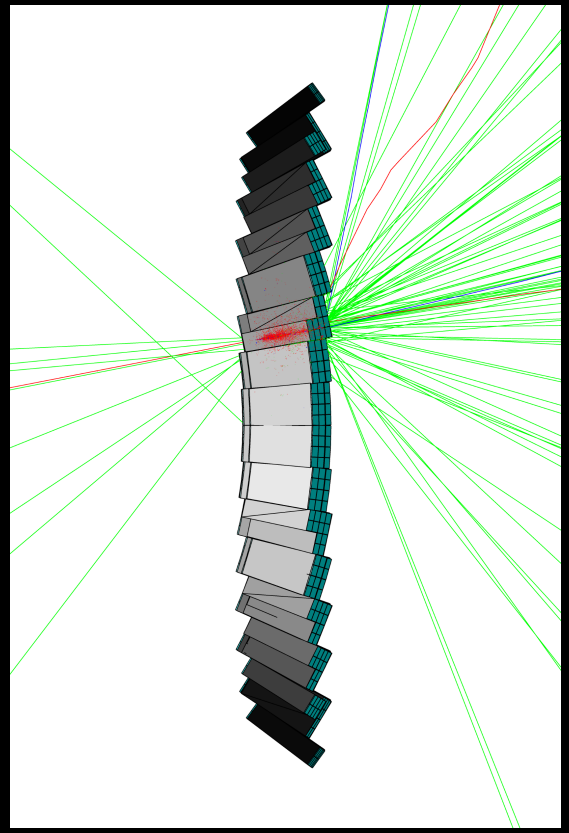
0	0	-0.3	-0.3	0	0	0	3.141592654	1
1	0	0.3	-0.3	0	0	0	1.570796327	1
0	1	-0.3	0.3	0	0	0	-1.570796327	1
1	1	0.3	0.3	0	0	0	0	1
1	0	-22.60363636	-22.60363636	0	-0.020928529	0.020928529	0	4
0	0	22.60363636	-22.60363636	0	-0.020928529	-0.020928529	0	4
1	1	-22.60363636	22.60363636	0	0.020928529	0.020928529	0	4
0	1	22.60363636	22.60363636	0	0.020928529	-0.020928529	0	4
1	0	0	22.60363636	0	0.020928529	-0.020928529	0	22
1	1	0	-22.60363636	0	-0.020928529	-0.020928529	0	22
1	0	-22.60363636	-22.60363636	0	-0.020928529	0.020928529	0	32
0	0	22.60363636	-22.60363636	0	-0.020928529	-0.020928529	0	32
1	1	-22.60363636	22.60363636	0	0.020928529	0.020928529	0	32

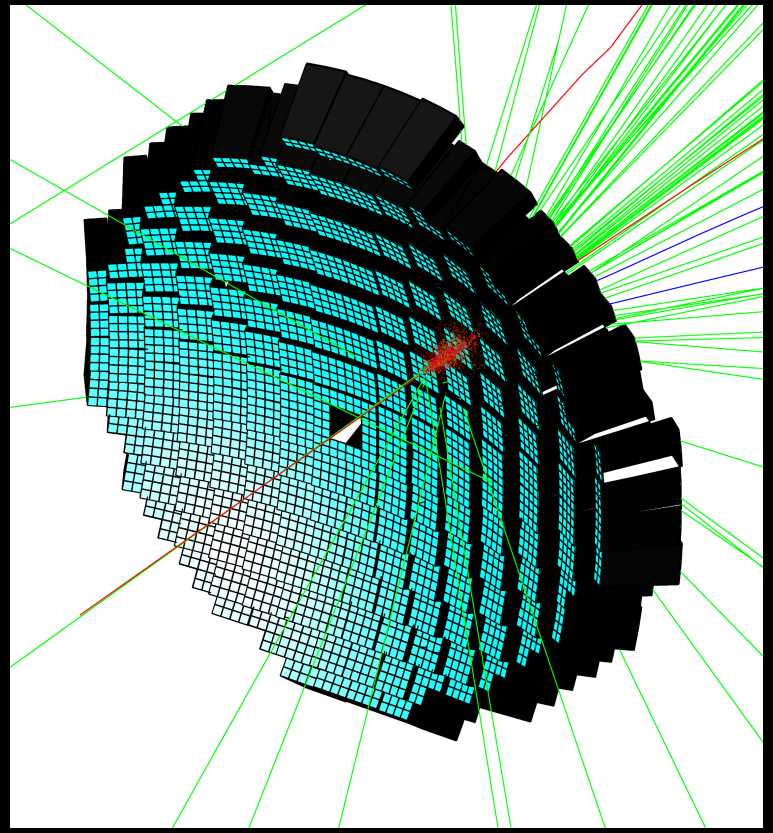
Construction of Subunits

Construction of Calorimeter

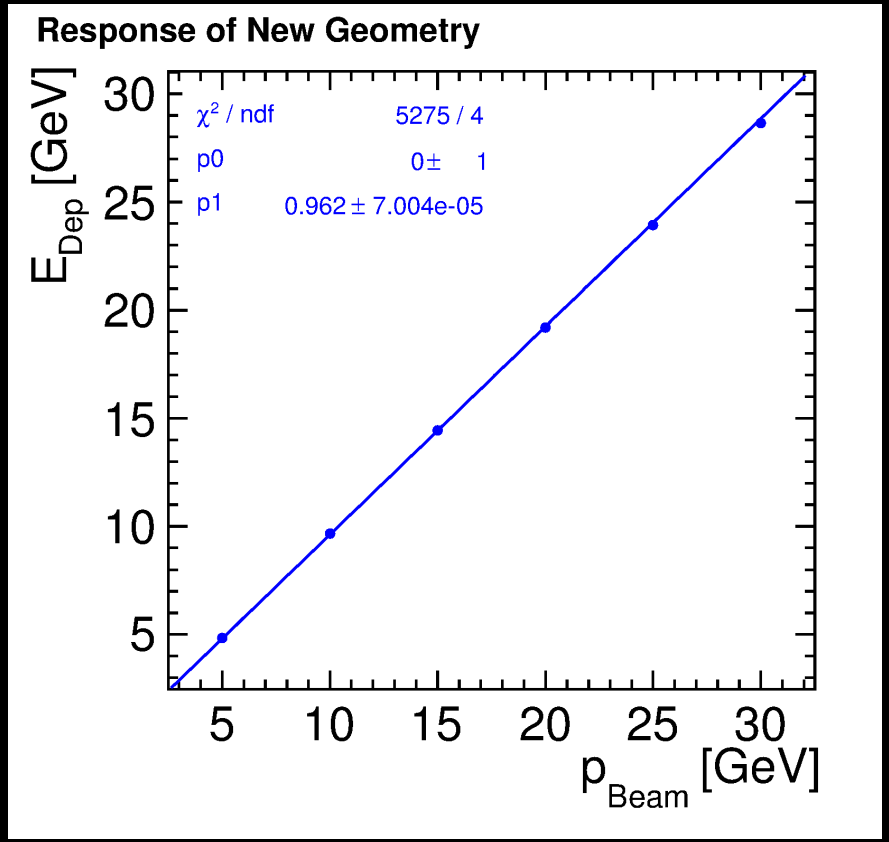
5	7	136.73138	45.3011518	-1086.1207	-0.1255025	0.04183416	0	16
4	7	229.301146	45.3011518	-1088.2616	-0.2091708	0.04183416	0	16
3	7	323.57377	45.3011518	-1089.715	-0.2928391	0.04183416	0	16
2	7	420.10781	45.3011518	-1090.4708	-0.3765075	0.04183416	0	16
1	7	519.557801	45.3011518	-1090.5237	-0.4601758	0.04183416	0	16
0	7	622.715933	45.3011518	-1089.8733	-0.5438441	0.04183416	0	16
6	8	45.4884858	136.524298	-1086.1298	-0.0418342	0.12550249	0	16
5	8	137.08499	136.524298	-1088.9234	-0.1255025	0.12550249	0	16
4	8	229.887746	136.524298	-1091.025	-0.2091708	0.12550249	0	16
3	8	324.389256	136.524298	-1092.4197	-0.2928391	0.12550249	0	16
2	8	421.146478	136.524298	-1093.0979	-0.3765075	0.12550249	0	16
1	8	520.812383	136.524298	-1093.0548	-0.4601758	0.12550249	0	16
0	8	624.177651	136.524298	-1092.2907	-0.5438441	0.12550249	0	16
6	9	45.5789867	228.95762	-1088.2918	-0.0418342	0.20917082	0	16
5	9	137.355859	228.95762	-1091.0703	-0.1255025	0.20917082	0	16
4	9	230.337089	228.95762	-1093.1418	-0.2091708	0.20917082	0	16
3	9	325.013929	228.95762	-1094.4915	-0.2928391	0.20917082	0	16
2	9	421.94211	228.95762	-1095.1103	-0.3765075	0.20917082	0	16
1	9	521.773408	228.95762	-1094.9936	-0.4601758	0.20917082	0	16
6	10	45.6412098	323.096203	-1089.7783	-0.0418342	0.29283915	0	16
5	10	137.542093	323.096203	-1092.5465	-0.1255025	0.29283915	0	16
4	10	230.646031	323.096203	-1094.5971	-0.2091708	0.29283915	0	16
3	10	325.443417	323.096203	-1095.916	-0.2928391	0.29283915	0	16
2	10	422.48914	323.096203	-1096.4939	-0.3765075	0.29283915	0	16
1	10	522.434153	323.096203	-1096.3267	-0.4601758	0.29283915	0	16
6	11	45.6747199	419.499544	-1090.5789	-0.0418342	0.37650748	0	16
5	11	137.642389	419.499544	-1093.3414	-0.1255025	0.37650748	0	16
4	11	230.812411	419.499544	-1095.3809	-0.2091708	0.37650748	0	16
3	11	325.674717	419.499544	-1096.6832	-0.2928391	0.37650748	0	16
2	11	422.783742	419.499544	-1097.239	-0.3765075	0.37650748	0	16
6	12	45.6792824	518.823091	-1090.6879	-0.0418342	0.46017581	0	16
5	12	137.656044	518.823091	-1093.4496	-0.1255025	0.46017581	0	16
4	12	230.835064	518.823091	-1095.4876	-0.2091708	0.46017581	0	16
3	12	325.706209	518.823091	-1096.7876	-0.2928391	0.46017581	0	16
6	13	45.6548655	621.859919	-1090.1046	-0.0418342	0.54384413	0	16
5	13	137.582965	621.859919	-1092.8704	-0.1255025	0.54384413	0	16
0	0	45.3703403	45.3011518	-1083.3073	-0.0418342	0.04183416	6.28318531	32
7	0	707.96625	45.3011518	-1088.5241	-0.6275125	0.04183416	6.28318531	22
7	1	709.624878	136.524298	-1090.8109	-0.6275125	0.12550249	6.28318531	22
6	2	625.297346	228.95762	-1094.1424	-0.5438441	0.20917082	6.28318531	32
6	3	603.463546	323.096203	-1095.4156	-0.5438441	0.29283915	6.28318531	22
5	4	522.789994	419.499544	-1097.0446	-0.4601758	0.37650748	6.28318531	32
4	5	422.823853	518.823091	-1097.3405	-0.3765075	0.46017581	6.28318531	32
5	5	522.838444	518.823091	-1097.1423	-0.4601758	0.46017581	3.14159265	12
2	6	230.713833	621.859919	-1094.9165	-0.2091708	0.54384413	6.28318531	32
3	6	325.537674	621.859919	-1096.2286	-0.2928391	0.54384413	3.14159265	12
0	7	45.6016399	706.994921	-1088.833	-0.0418342	0.62751246	1.57079633	22
1	7	137.42366	706.994921	-1091.6077	-0.1255025	0.62751246	1.57079633	22

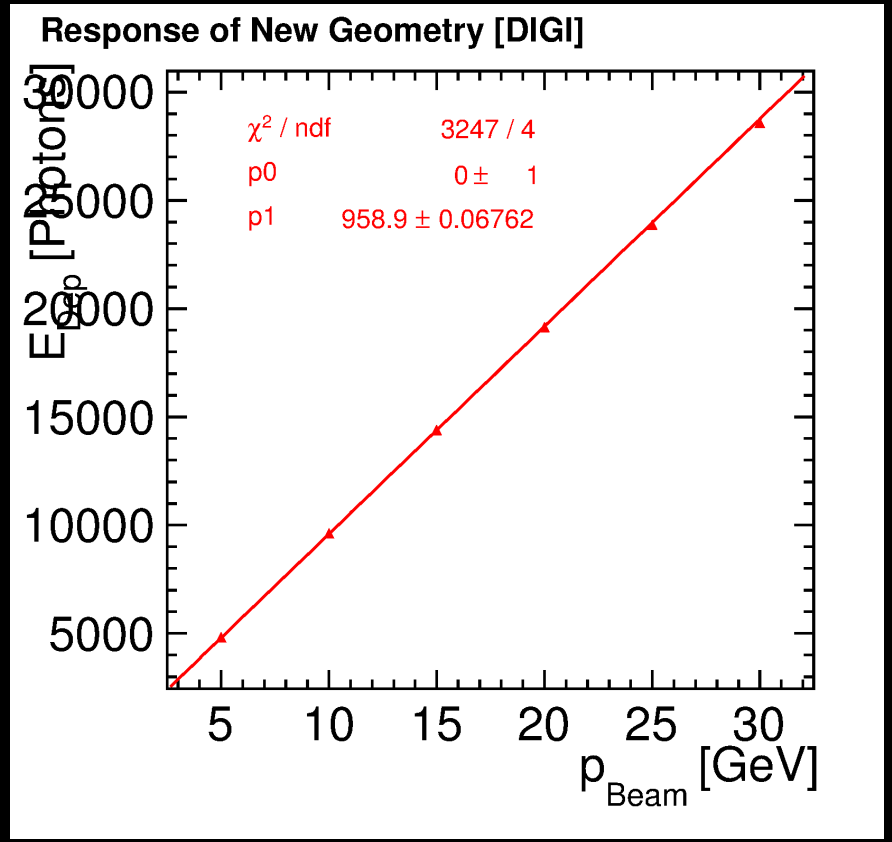
Current Implementation



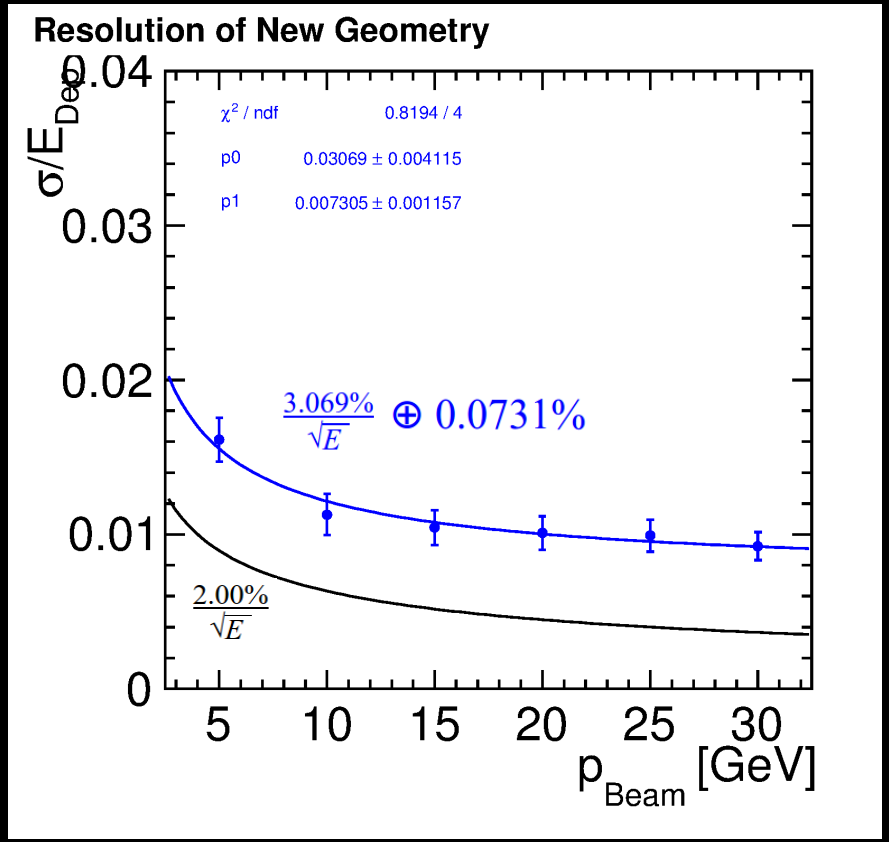


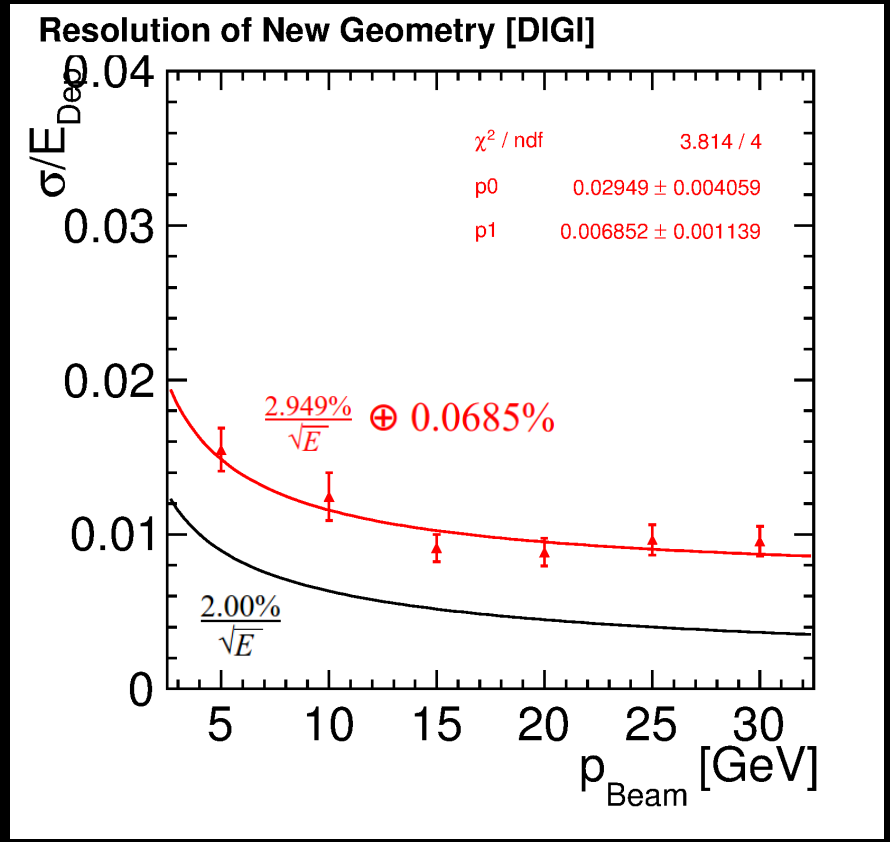
Linearity — New Geometry



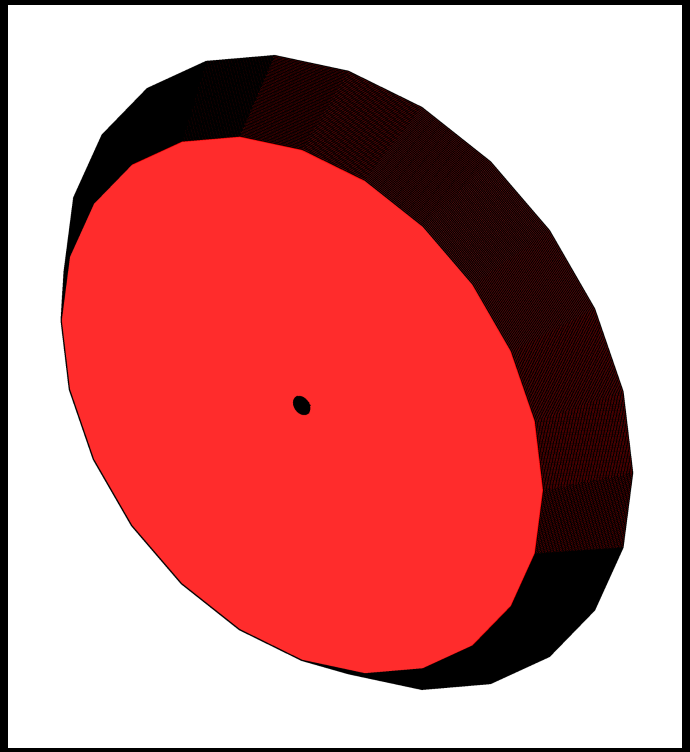


Resolution — New Geometry



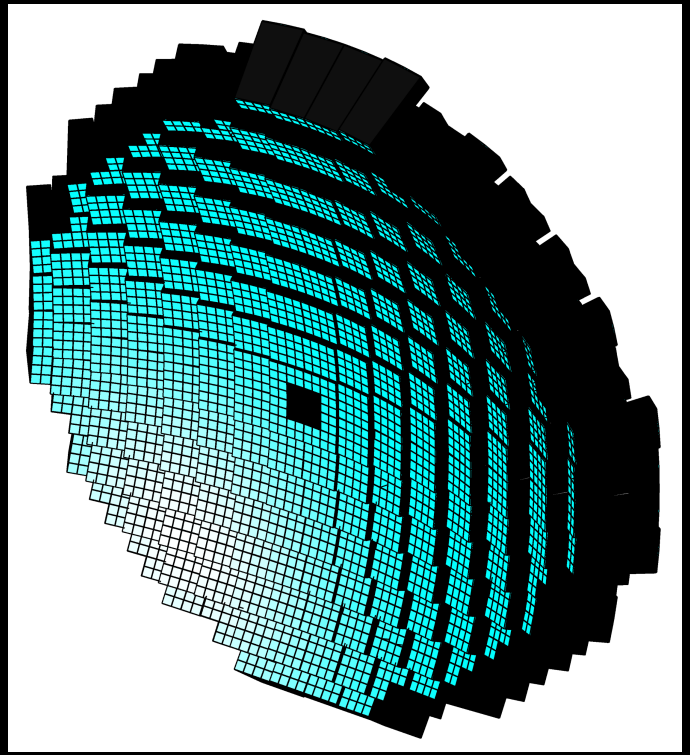


Linearity and Resolution Plots



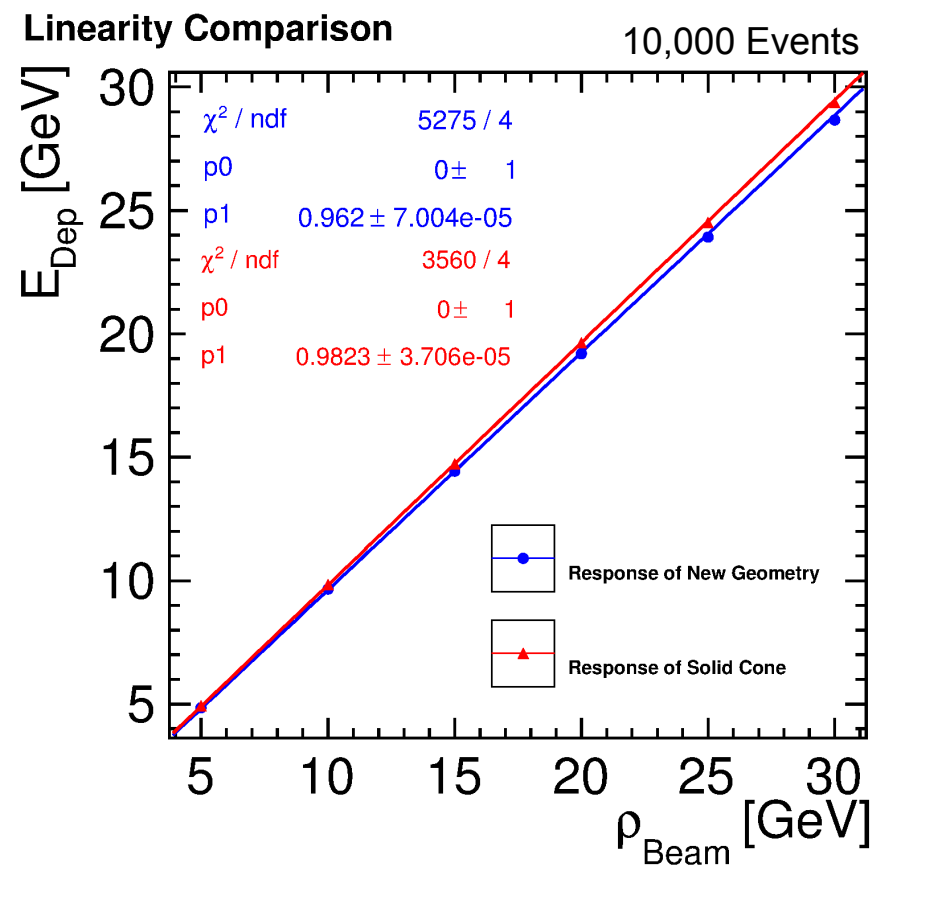
Solid Cone of $PbWO_4$
$-1.2 \leq \eta \leq -4.5$

vs.

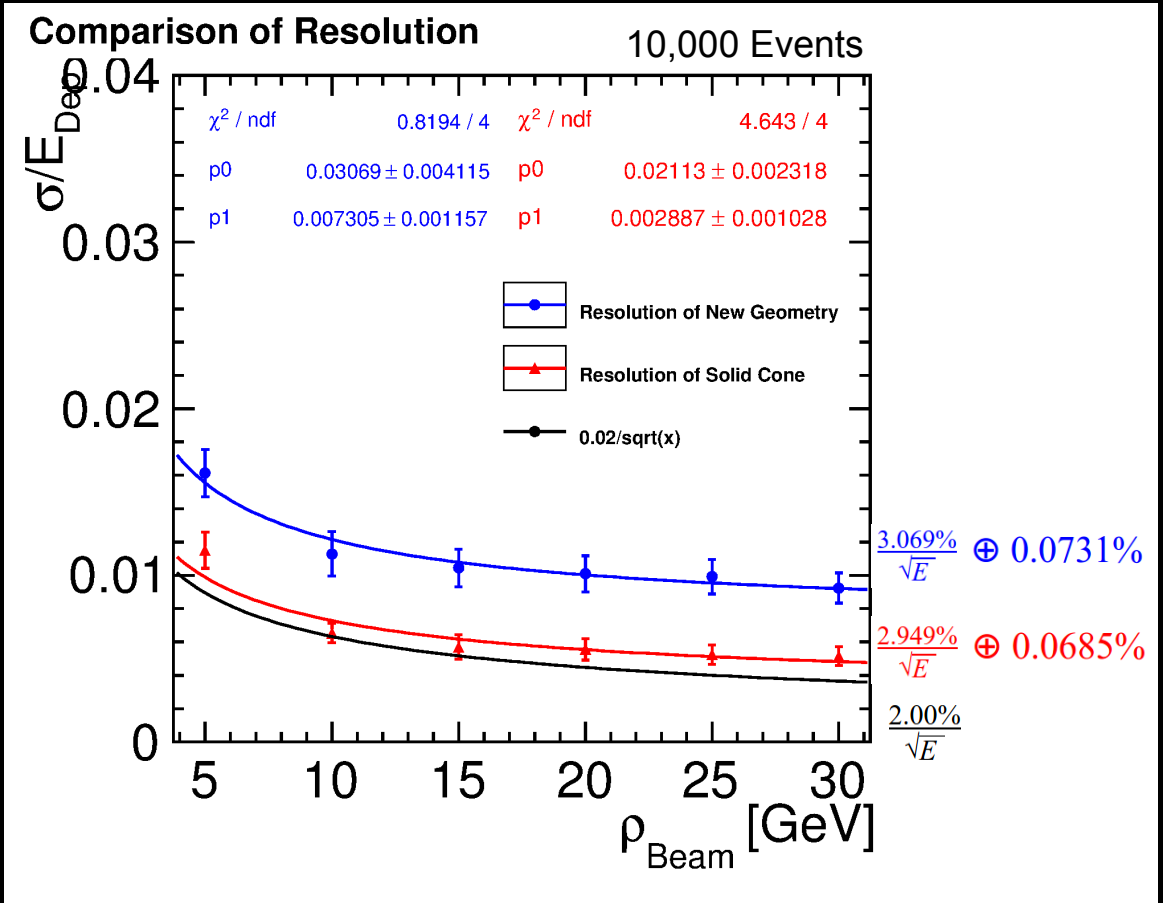


New Geometry

Linearity — Compared

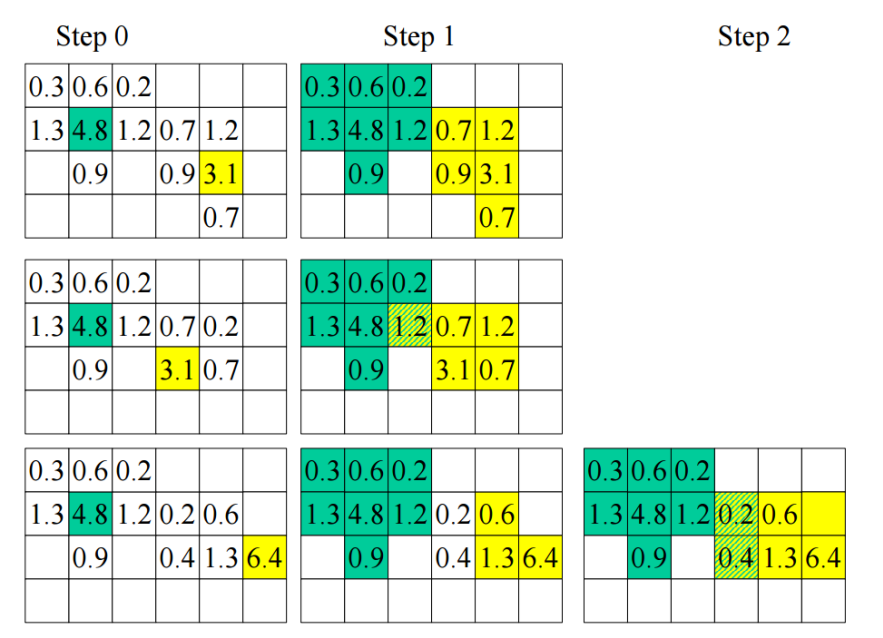


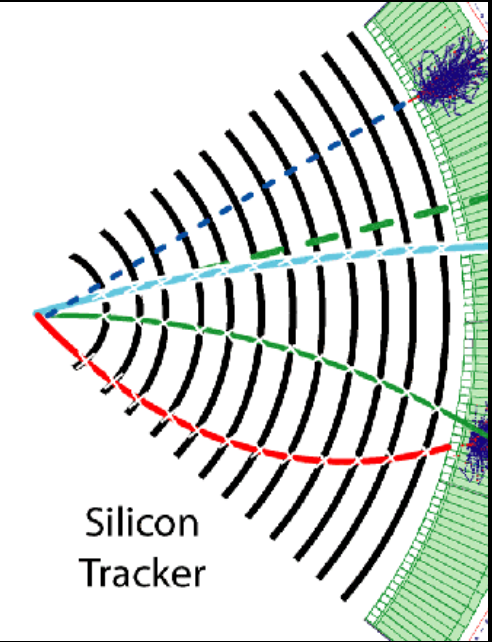
Resolution — Compared



Next Steps

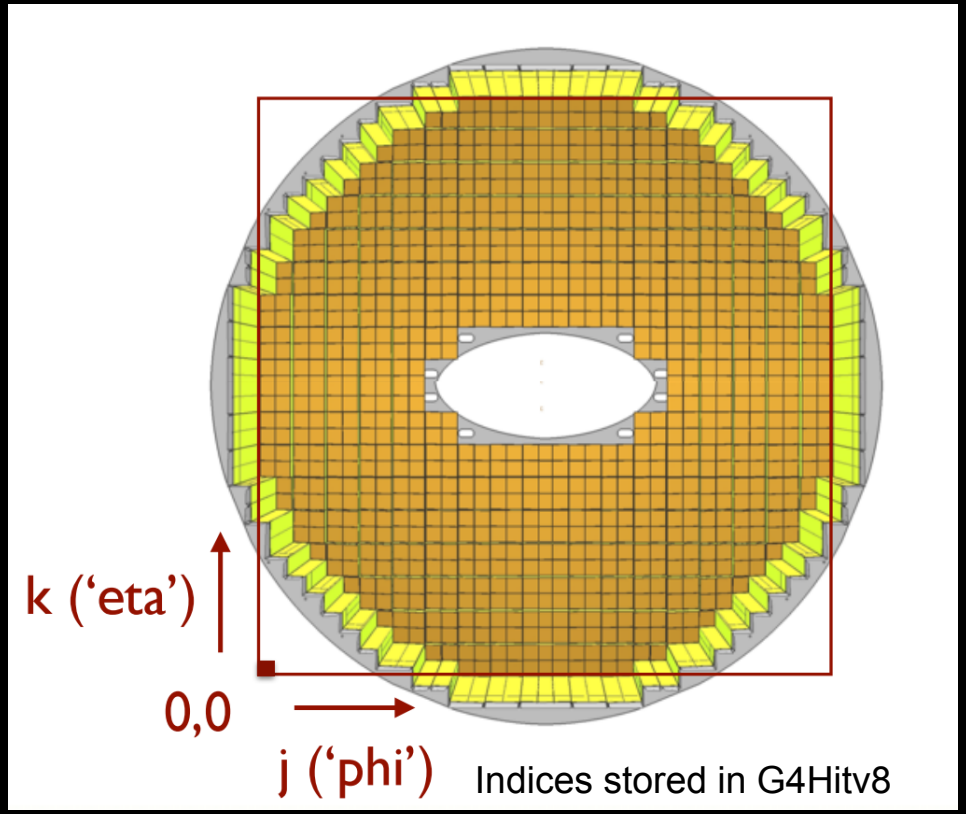
- Implement tower clustering algorithms and tracking for electron/pion identification

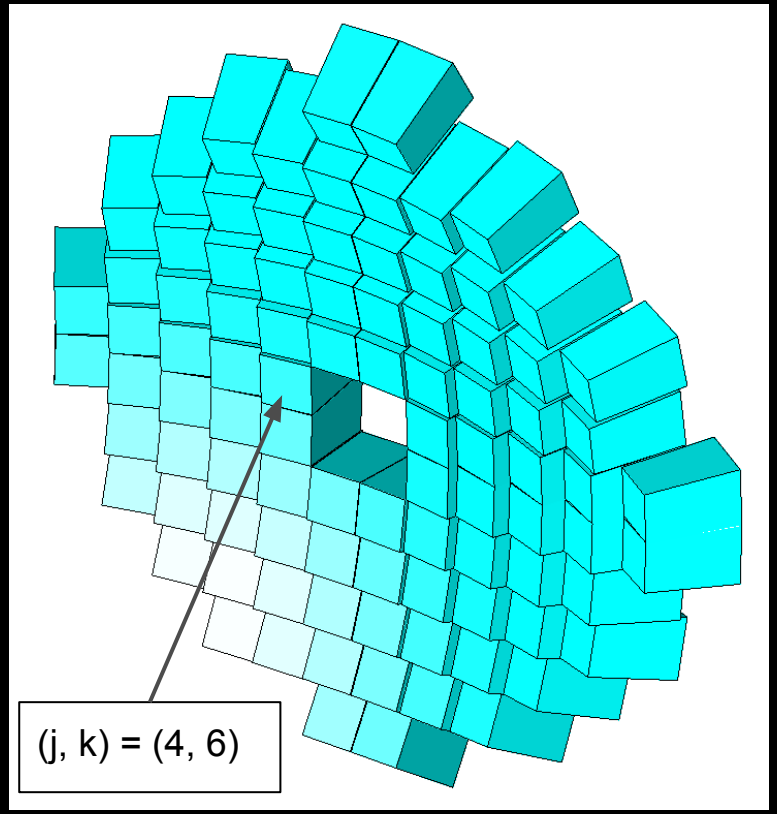




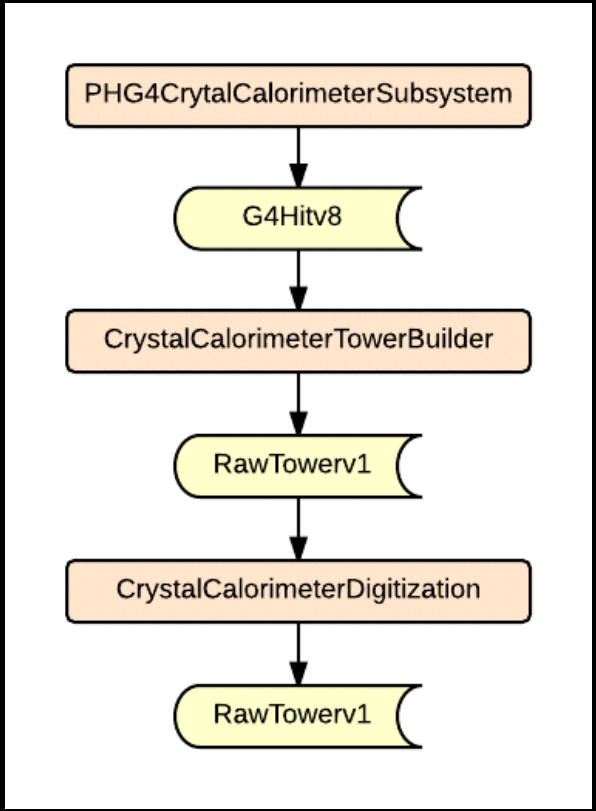
Additional Slides

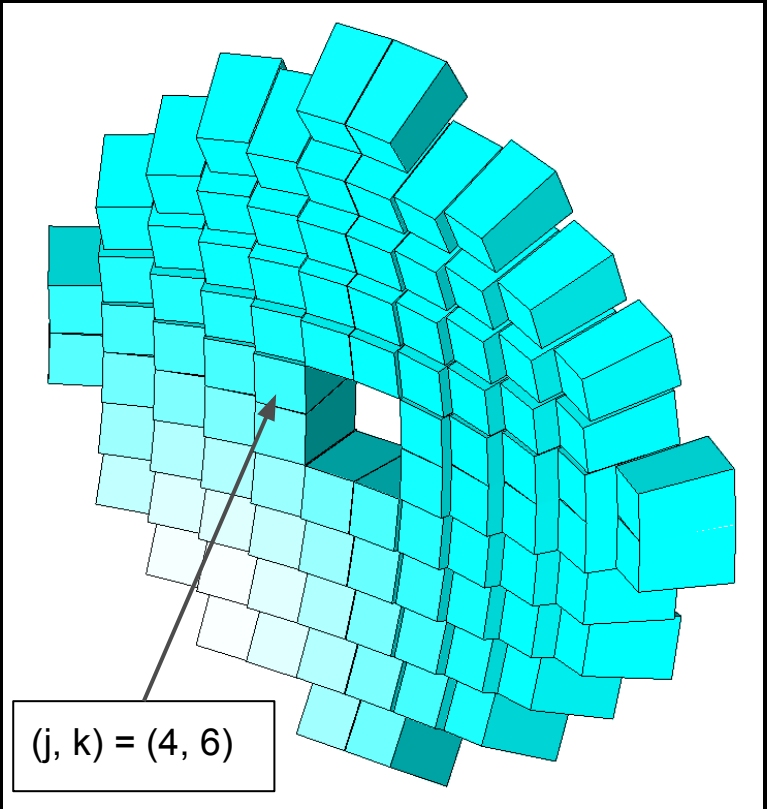
Current Implementation



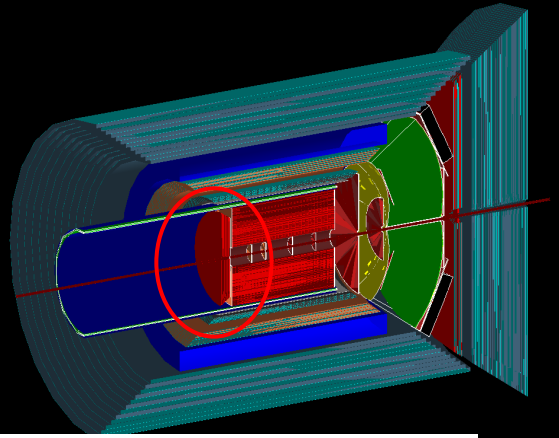


Current Implementation: Software

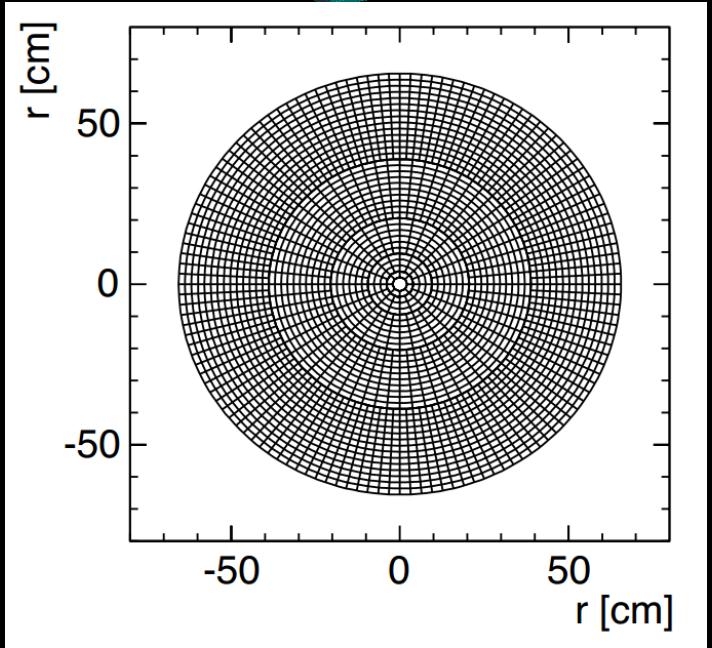




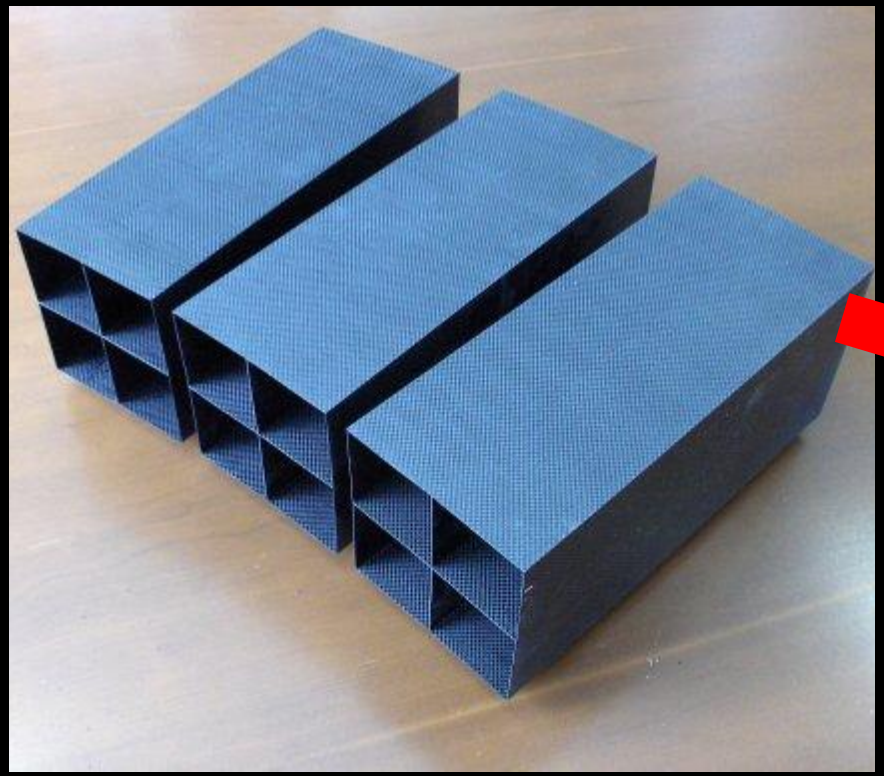
(Much) Previous Design

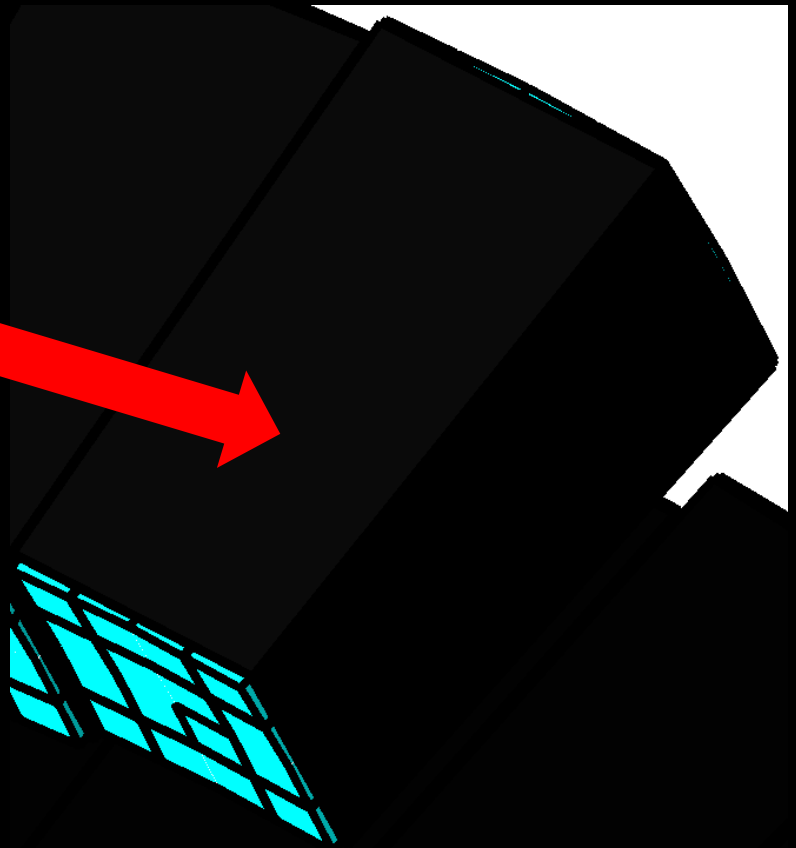


- Previous implementation was simplified
  - Starting z-position: -99.0 cm
  - Thickness: 18 cm
  - Material: $PbWO_4$
- Split into 5 sections via RawTowerBuilderCone() depending on ‘η’
  - $-1.2 \leq \eta \leq -4.5$



Carbon Fiber Shell





arXiv:0810.1216v1 -- Figure 7.26

Fit Data for Resolution Plots

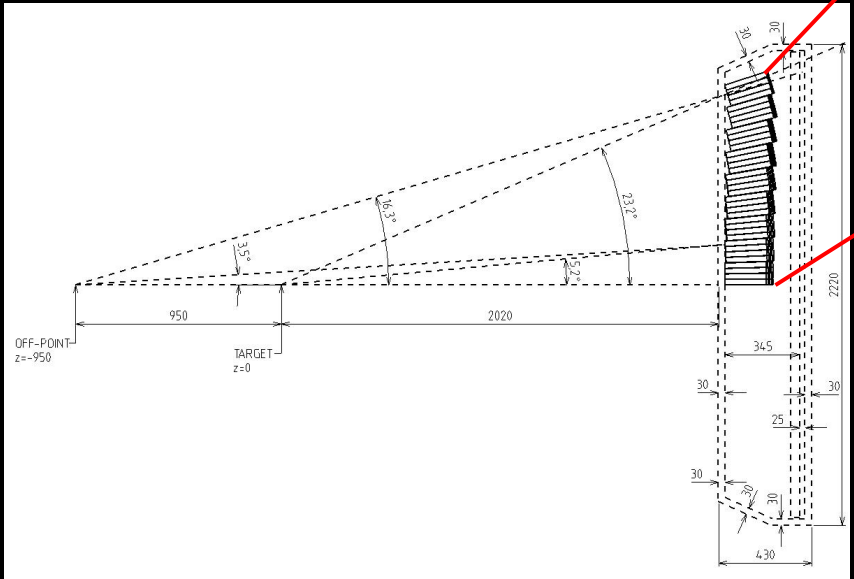
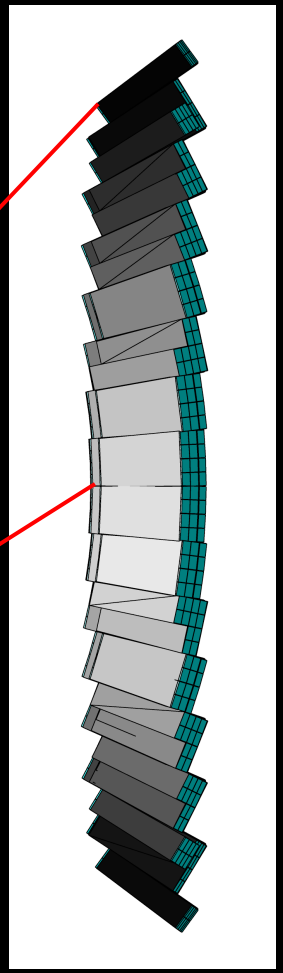
$$\sqrt{A^2 + B^2} = A \oplus B$$

Table 28.8: Resolution of typical electromagnetic calorimeters. E is in GeV.

Technology (Experiment)	Depth	Energy resolution	Date
NaI(Tl) (Crystal Ball)	$20X_0$	$2.7\%/E^{1/4}$	1983
$Bi_4Ge_3O_{12}$ (BGO) (L3)	$22X_0$	$2\%/\sqrt{E} \oplus 0.7\%$	1993
CsI (KTeV)	$27X_0$	$2\%/\sqrt{E} \oplus 0.45\%$	1996
CsI(Tl) (BaBar)	$16\text{–}18X_0$	$2.3\%/E^{1/4} \oplus 1.4\%$	1999
CsI(Tl) (BELLE)	$16X_0$	1.7% for $E_\gamma > 3.5$ GeV	1998
$PbWO_4$ (PWO) (CMS)	$25X_0$	$3\%/\sqrt{E} \oplus 0.5\% \oplus 0.2/E$	1997
Lead glass (OPAL)	$20.5X_0$	$5\%/\sqrt{E}$	1990
Liquid Kr (NA48)	$27X_0$	$3.2\%/\sqrt{E} \oplus 0.42\% \oplus 0.09/E$	1998
Scintillator/depleted U (ZEUS)	$20\text{–}30X_0$	$18\%/\sqrt{E}$	1988
Scintillator/Pb (CDF)	$18X_0$	$13.5\%/\sqrt{E}$	1988
Scintillator fiber/Pb spaghetti (KLOE)	$15X_0$	$5.7\%/\sqrt{E} \oplus 0.6\%$	1995
Liquid Ar/Pb (NA31)	$27X_0$	$7.5\%/\sqrt{E} \oplus 0.5\% \oplus 0.1/E$	1988
Liquid Ar/Pb (SLD)	$21X_0$	$8\%/\sqrt{E}$	1993
Liquid Ar/Pb (H1)	$20\text{–}30X_0$	$12\%/\sqrt{E} \oplus 1\%$	1998
Liquid Ar/depl. U (DØ)	$20.5X_0$	$16\%/\sqrt{E} \oplus 0.3\% \oplus 0.3/E$	1993
Liquid Ar/Pb accordion (ATLAS)	$25X_0$	$10\%/\sqrt{E} \oplus 0.4\% \oplus 0.3/E$	1996

Quantum fluctuations	$\sim 1/\sqrt{E}$
Electronic noise	$\sim 1/E$
Shower leakage*	$\approx$ const

Source: http://pdg.lbl.gov/2011/reviews/rpp2011-rev-particle-detectors-accel.pdf

Future Plans

- Optimise off point geometry to minimize leakage through gaps using Linearity/Resolution plots