TPC DD4HEP Detector Model

Validation and Updates before scheduled large scale MC production

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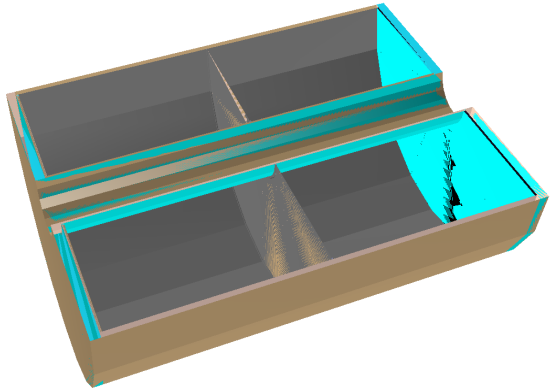
HELMHOLTZ ASSOCIATION

DESY

TPC dimensions

- Due to a change on the Ecal thickness, we had to find ~3.5 cm in the barrel region → TPC radius reduced to account for that
- We had to:
  - give up part (~half) of the uninstrumented gas region allocated to a laser alignment system
  - Reduce outer field wall to 5.5cm from 6cm
  - Remove 2 pad rows



- Current dimensions (~in agreement with DBD for large model)

large
- Inner radius: 329mm, Outer radius: 1770 mm, half length: 2350 mm
- Inner wall thickness: 25mm, Outer wall thickness: 55mm
- Inner and Outer radius of sensitive volume: 375-1697 mm (220 pad rows of 6mm height)

small
- Inner radius: 329mm, Outer radius: 1427 mm, half length: 2350 mm
- Inner wall thickness: 25mm, Outer wall thickness: 55mm
- Inner and Outer radius of sensitive volume: 375-1354 mm (163 pad rows of 6mm height)

Field Cage Material Budget

- DBD values: 1% X_0 inner wall, 1% X_0 gas, 3% X_0 outer wall
- Both the inner and outer field cage walls had the same material budget 0.9% X_0
- Fix: Increase all materials by x3 for outer wall to reach desired material budget
- Fix2: Change the order of Cu and Al. Now Cu is on the outside of the TPC → provides better shielding

Before

```
TPC10: Add Material to Outer Wall: dr =  0.07 mm. Material = G4_Cu X0 = 1.43516  0.00487749% X0
TPC10: Add Material to Outer Wall: dr =  0.05 mm. Material = G4_KAPTON X0 = 28.5903  0.000174884% X0
TPC10: Add Material to Outer Wall: dr =   0.3 mm. Material = g10 X0 = 16.1529  0.00185725% X0
TPC10: Add Material to Outer Wall: dr =  59.22 mm. Material = G4_AIR X0 = 30280.2  0.000195574% X0
TPC10: Add Material to Outer Wall: dr =   0.3 mm. Material = g10 X0 = 16.1529  0.00185725% X0
TPC10: Add Material to Outer Wall: dr =  0.05 mm. Material = G4_KAPTON X0 = 28.5903  0.000174884% X0
TPC10: Add Material to Outer Wall: dr =  0.01 mm. Material = G4_Al X0 = 8.8789  0.000112627% X0
TPC10: Outer wall material corresponds to 0.9% of a radiation length.
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Now

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TPC10: Add Material to Outer Wall: dr =  0.03 mm. Material = G4_Al X0 = 8.8789  0.00033788% X0
TPC10: Add Material to Outer Wall: dr =  0.15 mm. Material = G4_KAPTON X0 = 28.5903  0.000524653% X0
TPC10: Add Material to Outer Wall: dr =   0.9 mm. Material = g10 X0 = 16.1529  0.00557174% X0
TPC10: Add Material to Outer Wall: dr =  57.66 mm. Material = G4_AIR X0 = 30280.2  0.000190422% X0
TPC10: Add Material to Outer Wall: dr =   0.9 mm. Material = g10 X0 = 16.1529  0.00557174% X0
TPC10: Add Material to Outer Wall: dr =  0.15 mm. Material = G4_KAPTON X0 = 28.5903  0.000524653% X0
TPC10: Add Material to Outer Wall: dr =  0.21 mm. Material = G4_Cu X0 = 1.43516  0.0146325% X0
TPC10: Outer wall material corresponds to 2.7% of a radiation length.
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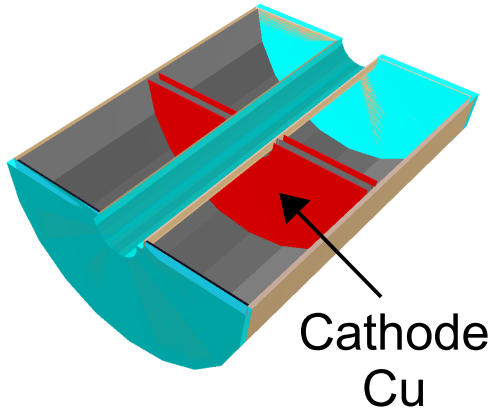
Air thickness slightly decreased to keep total dimensions unchanged

Cathode

- TPC cathode is positioned at z=0 held by rings from the field cage
- Some commands showed the cathode as “air” but in the reconstruction software it was properly taken into account → Fixed by placing the cathode volume as part of the TPC mother volume



- Fix2: Cathode made slightly thicker from 60µm to 100µm
  - 92 µm thick Kapton and on each side 4 µm Cu

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+-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------+
+ Material scan between: x_0 = ( 100.00, 100.00, -10.00) [cm] and x_1 = ( 100.00, 100.00,  10.00) [cm] :
+-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------+
|     \   Material          Atomic                    Radiation   Interaction                Path   Integrated  Integrated    Material
| Num. \  Name         Number/Z   Mass/A  Density     Length       Length    Thickness    Length       X0       Lambda      Endpoint
| Layer \                       [g/mole]  [g/cm3]     [cm]         [cm]         [cm]      [cm]       [cm]        [cm]     (     cm,     cm,     cm)
+-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------+
|     1 TDR_gas              17   38.746   0.0017  11539.6342   69059.7950      9.995     10.00   0.000866    0.000145  (   0.00,   0.00,  10.00)
|     2 G4_Cu                29   63.546   8.9600      1.4352      15.5141      0.000     10.00   0.001145    0.000171  (   0.00,   0.00,  10.00)
|     3 G4_KAPTON             6   12.701   1.4200     28.5903      24.8436      0.005     10.00   0.001306    0.000356  (   0.00,   0.00,  10.00)
|     4 G4_KAPTON             6   12.701   1.4200     28.5903      24.8436      0.005     10.00   0.001467    0.000541  (   0.00,   0.00,  10.00)
|     5 G4_Cu                29   63.546   8.9600      1.4352      15.5141      0.000     10.00   0.001745    0.000567  (   0.00,   0.00,  10.00)
|     6 TDR_gas              17   38.746   0.0017  11539.6342   69059.7950      9.995     20.00   0.002612    0.000711  (   0.00,   0.00,  20.00)
+-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------+
|     0 Average Material     12   26.954   0.0027   7658.4155   28115.8466     20.000     20.00   0.002612    0.000711  (   0.00,   0.00,  20.00)
+-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------+
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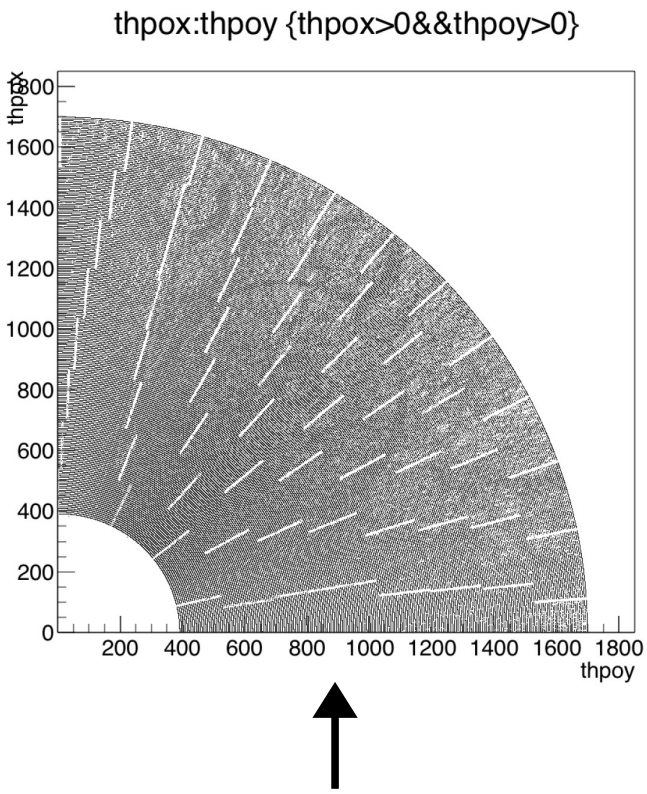
Gaps for module borders

- Previously, the anode was fully instrumented

- Now module gaps of 1mm width (dead region) have been introduced assuming 8 layers of modules for both the small and large models

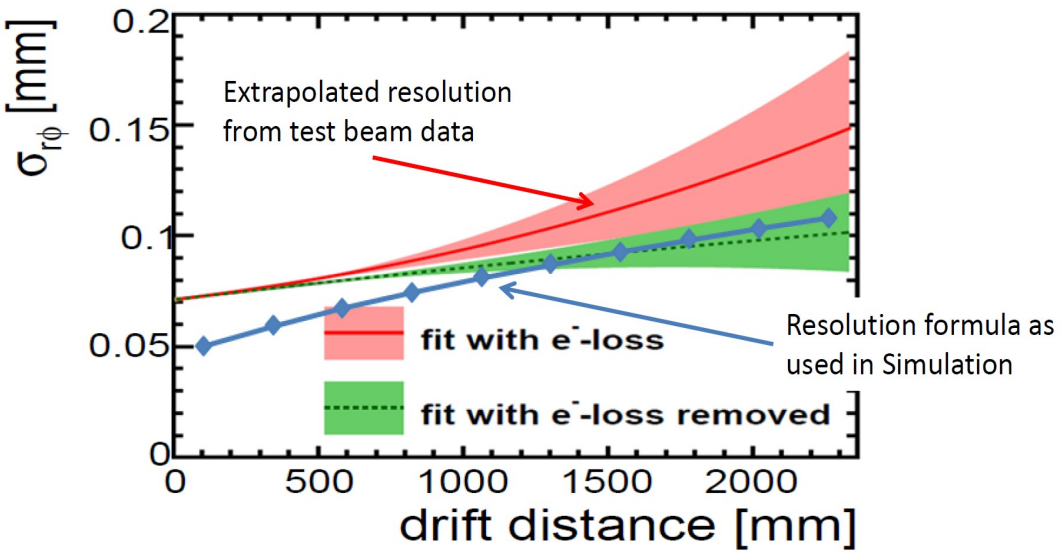
- We discussed with Frank the possibility of increasing the gaps by 1-2mm but this requires work to fix the pattern recognition



No consecutive gaps between modules. Gaps have been blown up here for illustration purposes

Point resolution formulae and values

- Some discrepancies between DD4HEP, DBD and current knowledge
- Formulae updated. Current situation shown below



- Even though we want to take a conservative approach, our simulation performs better than our current knowledge
- Agreed to update σ0 to 55μm instead of 50μm
- Requested this from Frank. Not sure if currently it has been updated → To check

Double hit resolution and dE/dx resolution

- Double hit resolution in DD4HEP model: 2mm (pad size: 1x6 mm2)
- Based on the double hit resolution studies by Oleksiy, this is possible to achieve but not with the default algorithms currently used for the prototype
- No change proposed

- dE/dx resolution is DD4HEP model is 5% for both large and small detectors
- Based on current studies by Aiko and Paul, this is ~4% and ~5% for large and small models respectively
- How to proceed? Different numbers for each model? (if changes are still accepted before the new MC production)
- If so, which input goes in? Current prototype studies are in 1T field. How does this extrapolate to 3.5-4T? How much do tracks <10GeV bend?
- Studies needed... Volunteers?

Summary

- TPC model updated and validated
- Additional changes → possible?
  - dE/dx different for large and small models?
- I will write a short document (notes) so that the general characteristics of the models are accessible without looking into the code
- New contact person?

Back-Up

dE/dx input for LCTPC DD4HEP model (Paul M.)

- How to parametrise dE/dx (resolution) in the DD4Hep model?
- Possible dependencies:
  - obvious: particle type & momentum
  - number of hits / fully contained or going through end plate
  - number of usable hits: overlapping tracks / tracks in jets (~50% usable hits)
  - polar angle / dip angle ($\lambda = \theta - 90°$): ~$1/\cos(\lambda)$
  - **local** azimuth angle $\alpha \rightarrow$ curvature of track (momentum): ~$1/\cos(\alpha)$
  - **global** azimuth angle / track reference angle φ: more complicated

Endcap Dimensions

Cathode
Sensitive
volume

Module
+
Endplate
12.5 cm

+ Material scan between: x_0 = (50.00, 0.00, 0.00) [cm] and x_1 = (50.00, 0.00, 300.00) [cm] :

Num. \ Layer \	Material Name	Atomic Number/Z	Mass/A [g/mole]	Density [g/cm3]	Radiation Length [cm]	Interaction Length [cm]	Thickness [cm]	Path Length [cm]	Integrated X0 [cm]	Integrated Lambda [cm]	Material Endpoint (cm, cm, cm)
1	G4_AIR	7	14.801	0.0012	30280.1689	66568.7074	0.003	0.00	0.000000	0.000000	(0.00, 0.00, 0.00)
2	TDR_gas	17	38.746	0.0017	11539.6342	69059.7950	222.497	222.50	0.019281	0.003222	(0.00, 0.00, 222.50)
3	G4_Cu	29	63.546	8.9600	1.4352	15.5141	0.000	222.50	0.019490	0.003241	(0.00, 0.00, 222.50)
4	G4_KAPTON	6	12.701	1.4200	28.5903	24.8436	0.003	222.50	0.019595	0.003362	(0.00, 0.00, 222.50)
5	G4_Cu	29	63.546	8.9600	1.4352	15.5141	0.000	222.50	0.019804	0.003381	(0.00, 0.00, 222.50)
6	TDR_gas	17	38.746	0.0017	11539.6342	69059.7950	0.445	222.95	0.019843	0.003388	(0.00, 0.00, 222.95)
7	G4_Cu	29	63.546	8.9600	1.4352	15.5141	0.000	222.95	0.020052	0.003407	(0.00, 0.00, 222.95)
8	G4_KAPTON	6	12.701	1.4200	28.5903	24.8436	0.003	222.95	0.020157	0.003528	(0.00, 0.00, 222.95)
9	G4_Cu	29	63.546	8.9600	1.4352	15.5141	0.000	222.95	0.020366	0.003547	(0.00, 0.00, 222.95)
10	TDR_gas	17	38.746	0.0017	11539.6342	69059.7950	0.445	223.40	0.020404	0.003554	(0.00, 0.00, 223.40)
11	G4_Cu	29	63.546	8.9600	1.4352	15.5141	0.000	223.40	0.020613	0.003573	(0.00, 0.00, 223.40)
12	G4_KAPTON	6	12.701	1.4200	28.5903	24.8436	0.003	223.40	0.020718	0.003694	(0.00, 0.00, 223.40)
13	G4_Cu	29	63.546	8.9600	1.4352	15.5141	0.000	223.40	0.020927	0.003713	(0.00, 0.00, 223.40)
14	TDR_gas	17	38.746	0.0017	11539.6342	69059.7950	0.445	223.84	0.020966	0.003719	(0.00, 0.00, 223.84)
15	G4_Cu	29	63.546	8.9600	1.4352	15.5141	0.005	223.85	0.024450	0.004042	(0.00, 0.00, 223.85)
16	g10	11	21.318	1.7000	16.1529	68.2164	0.200	224.05	0.036831	0.006974	(0.00, 0.00, 224.05)
17	G4_Si	14	28.085	2.3300	9.3496	45.7532	0.050	224.10	0.042179	0.008066	(0.00, 0.00, 224.10)
18	epoxy	6	11.888	1.3000	32.2936	27.1368	0.200	224.30	0.048372	0.015436	(0.00, 0.00, 224.30)
19	G4_KAPTON	6	12.701	1.4200	28.5903	24.8436	0.100	224.40	0.051870	0.019462	(0.00, 0.00, 224.40)
20	G4_Al	13	26.982	2.6990	8.8789	38.8766	0.200	224.60	0.074395	0.024606	(0.00, 0.00, 224.60)
21	G4_KAPTON	6	12.701	1.4200	28.5903	24.8436	0.100	224.70	0.077893	0.028631	(0.00, 0.00, 224.70)
22	CarbonFiber	6	11.956	1.4667	28.8192	54.6827	0.300	225.00	0.088303	0.034118	(0.00, 0.00, 225.00)
23	TDR_gas	17	38.746	0.0017	11539.6342	69059.7950	0.000	225.00	0.088303	0.034118	(0.00, 0.00, 225.00)
24	TPC_endplate_mix	9	17.288	0.5828	56.2236	137.6252	10.000	235.00	0.266164	0.106779	(0.00, 0.00, 235.00)
25	Air	7	14.801	0.0012	30280.1689	66568.7074	65.000	300.00	0.268311	0.107755	(0.00, 0.00, 300.00)
0	Average Material	9	17.556	0.0278	1118.1072	2784.0921	300.000	300.00	0.268311	0.107755	(0.00, 0.00, 300.00)

Expected
material budget