

Some Previous ECAL studies

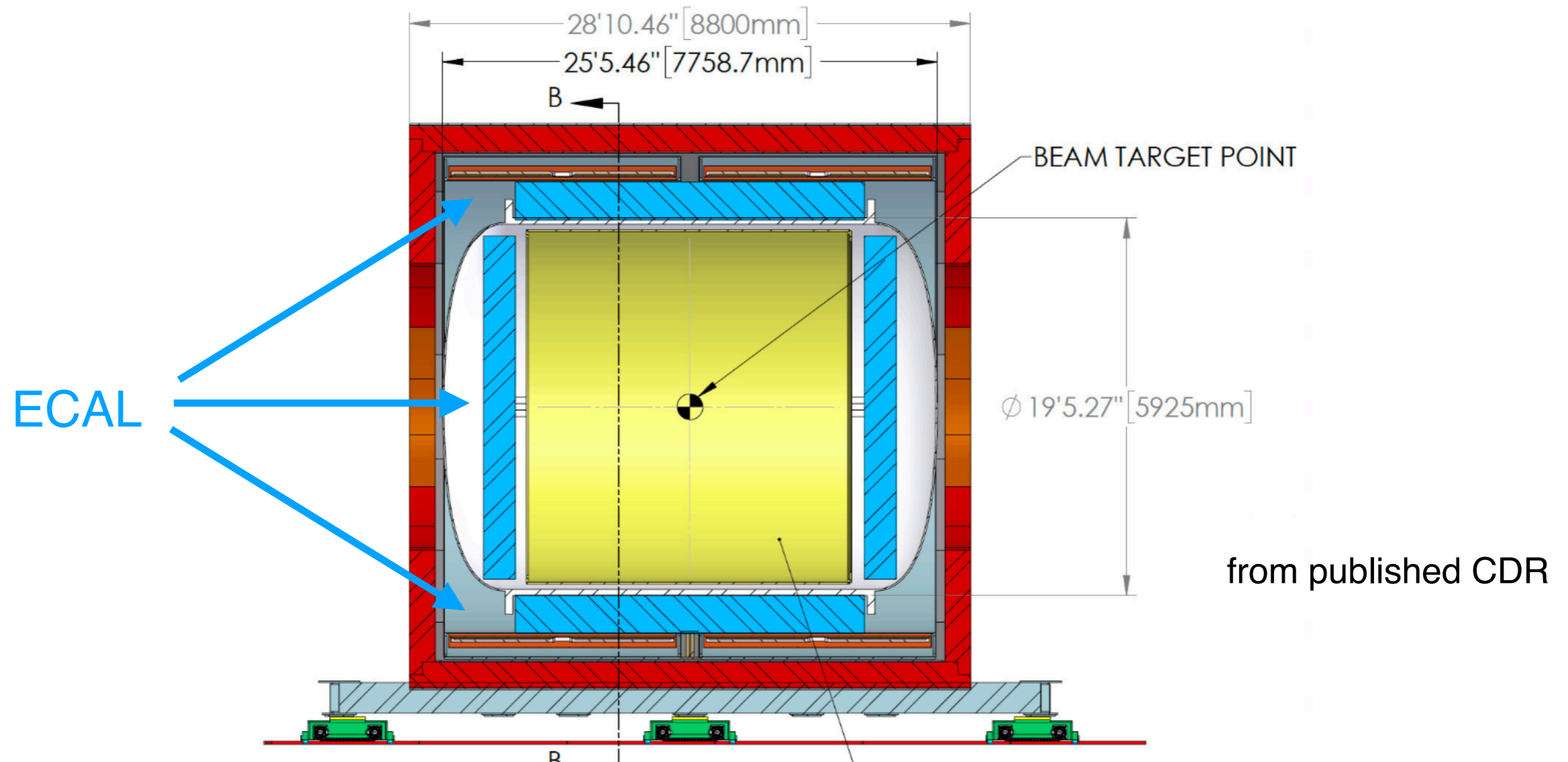
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ECAL studies

- Not reporting on any of my own work here!
- Since it can be hard to find things in Indico, trying to collect some of the previous ECAL studies
- Lots of previous work on ECAL optimization done from 2018 through early 2022 by Eldwan Brianne, Frank Simon, Lorenz Emberger, and Sebastian Ritter
- Studies for CDR
 - Energy and angular resolution for photons, including impact of varying number of layers of tiles vs strips
 - pi-zero reconstruction
 - studies of neutron detection (which I won't really cover here)
- Studies after CDR
 - mu/pi separation
 - Re-optimized for SPY magnet
 - Asymmetric ECAL

DUNE Near Detector CDR



- Published in [Instruments 2021, 5, 31](#), Nearly identical to [DUNE-doc-21267](#)
- Barrel ECAL **outside** pressure vessel ($\sim 0.5 X_0$), Endcaps inside

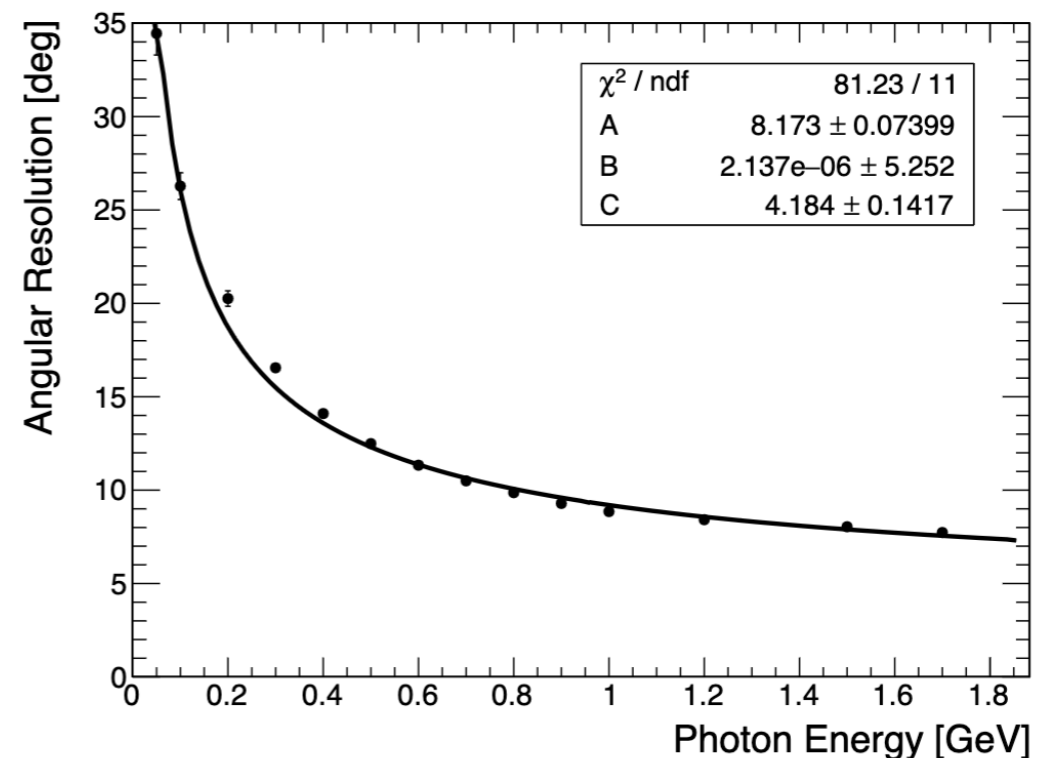
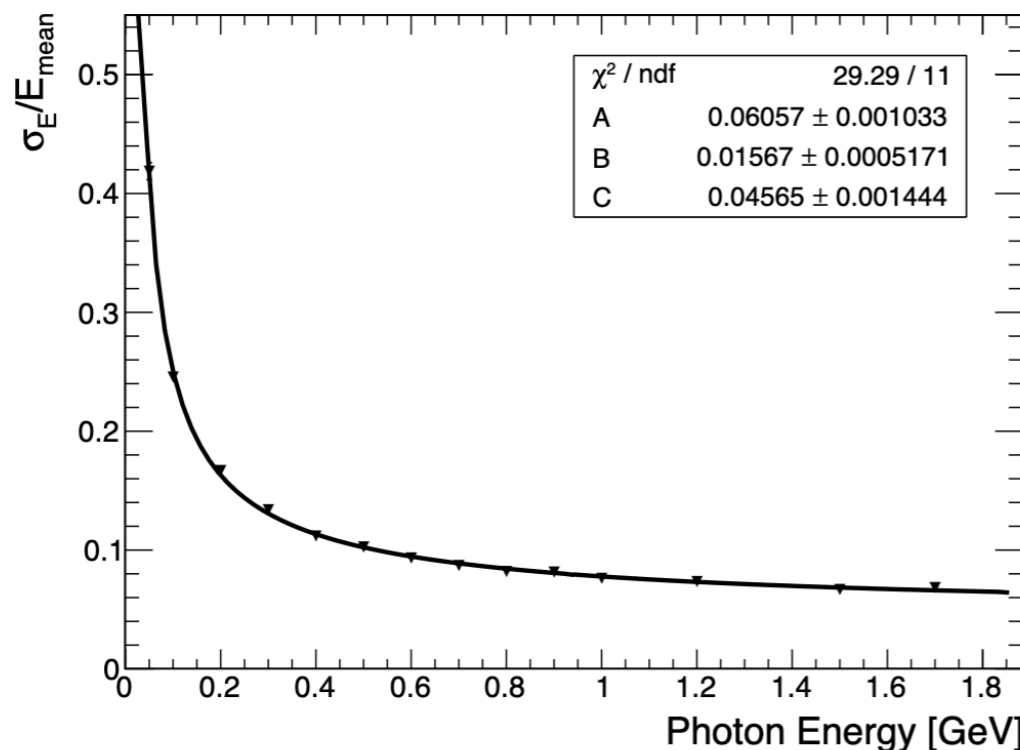
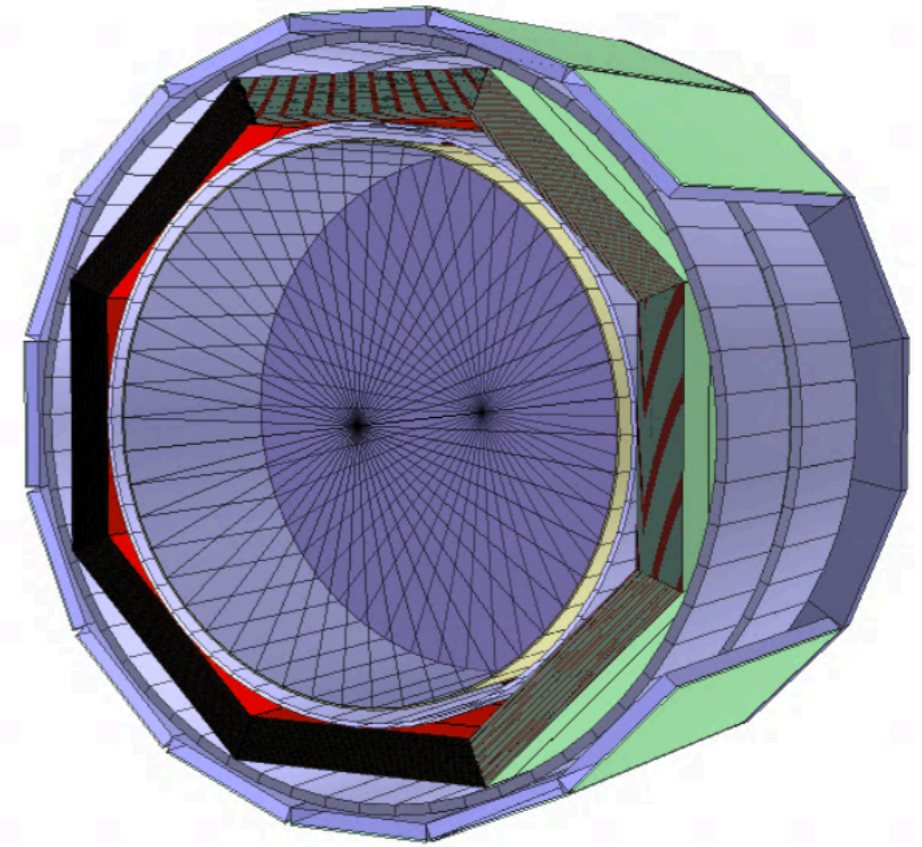
Some pre-CDR presentations

- “A highly granular calorimeter concept for long baseline near detectors,” Lorenz Emberger and Frank Simon, CALOR2018
- “ECAL Status”, Eldwan Brianne at the May 2019 DUNE collab meeting (includes studies of scintillator and absorber thickness)
- “DUNE ND ECAL: Status Update,” Eldwan Brianne at the Sept 2019 DUNE collab meeting (include studies of 60 vs 80 layers, and octagon by dodecagon)
- “The MPD ECAL”, Frank Simon, Jan 2020 DUNE collab meeting (nice overall summary of CDR baseline design)
- “ECAL CDR update”, Eldwan Brianne, Oct 12, 2020 ND-GAr meeting (more on CDR baseline)
- “ECAL CDR update Part 2”, Eldwan Brianne, Nov 16, 2020 ND-GAr meeting (more on CDR baseline)

CDR ECAL

from published CDR

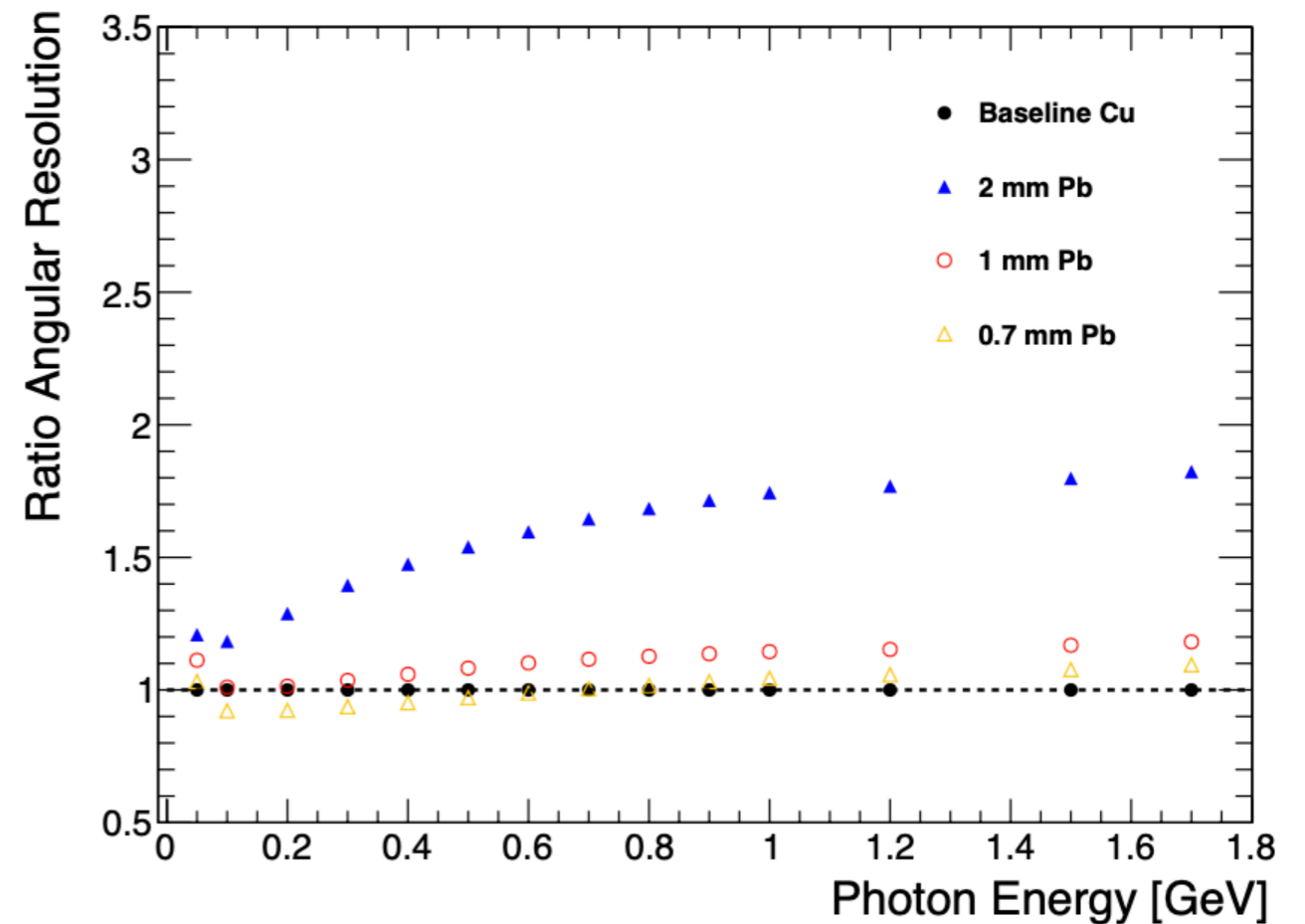
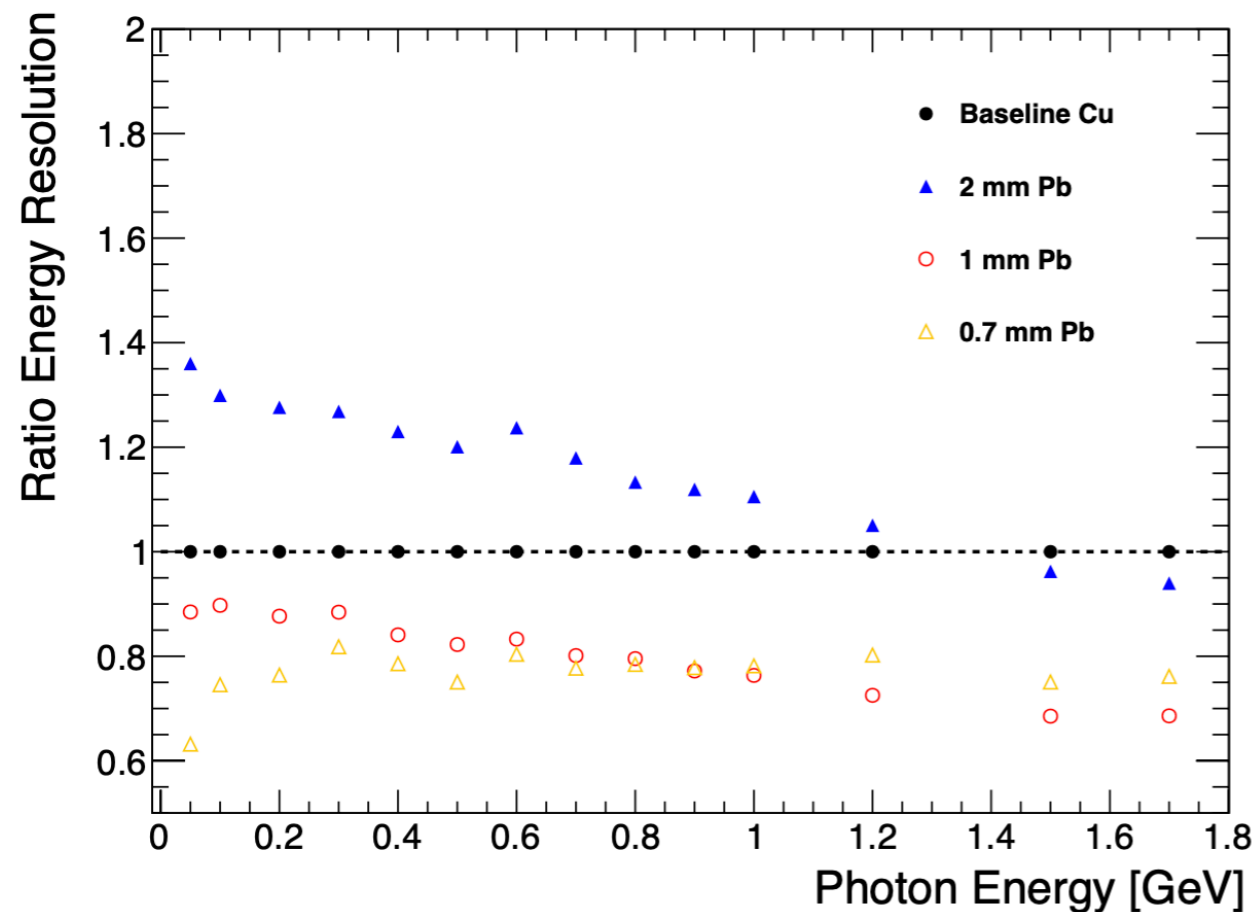
- Baseline ECAL design in CDR
 - Octagonal barrel geometry, 60 layers. 8 layers of 2mm copper + 5mm of 2.5x2.5 cm² tiles + 1mm FR4
 - 52 layers of 2 mm copper + 5 mm of cross-strips 4 cm wide



baseline design, from published CDR

Absorber Thickness

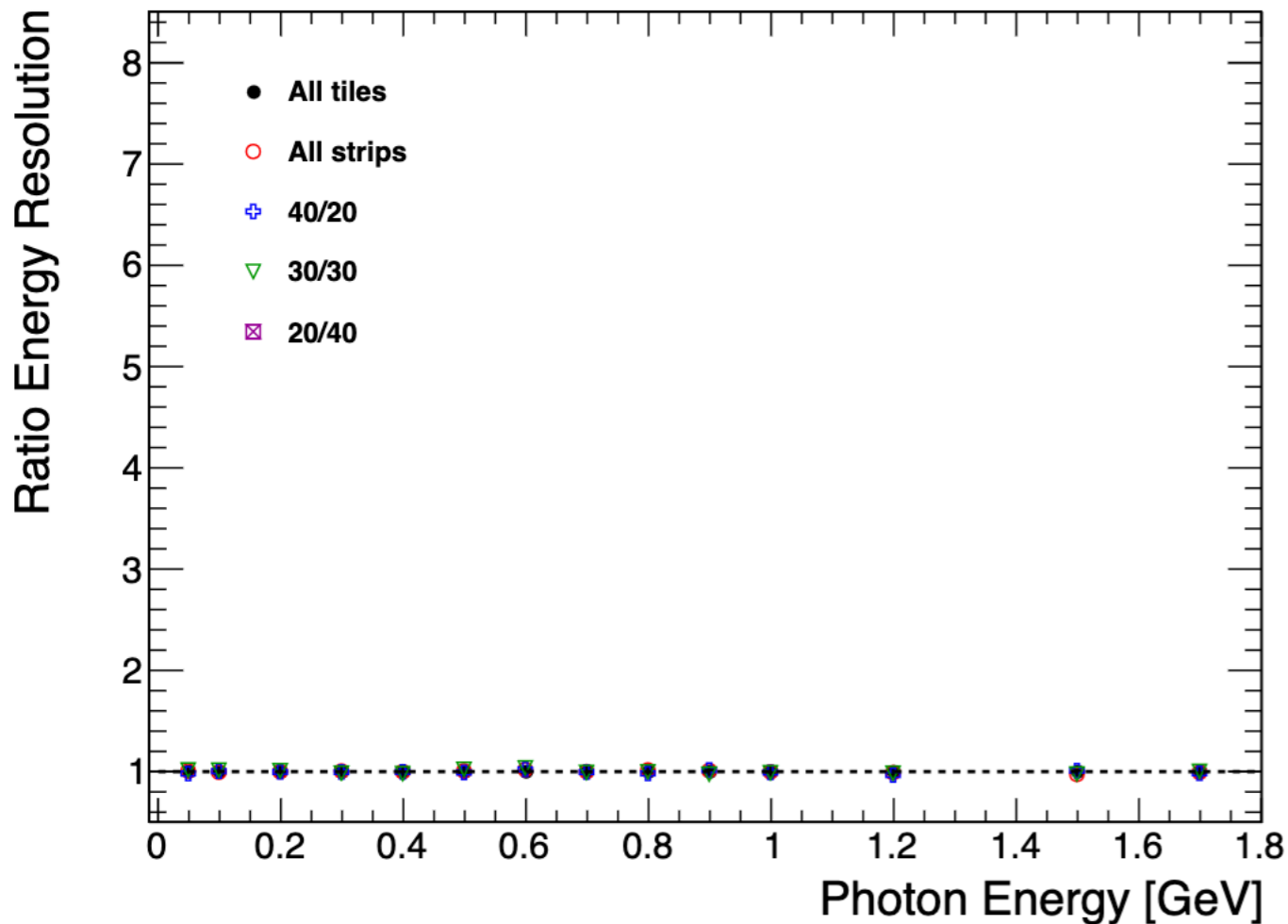
from published CDR



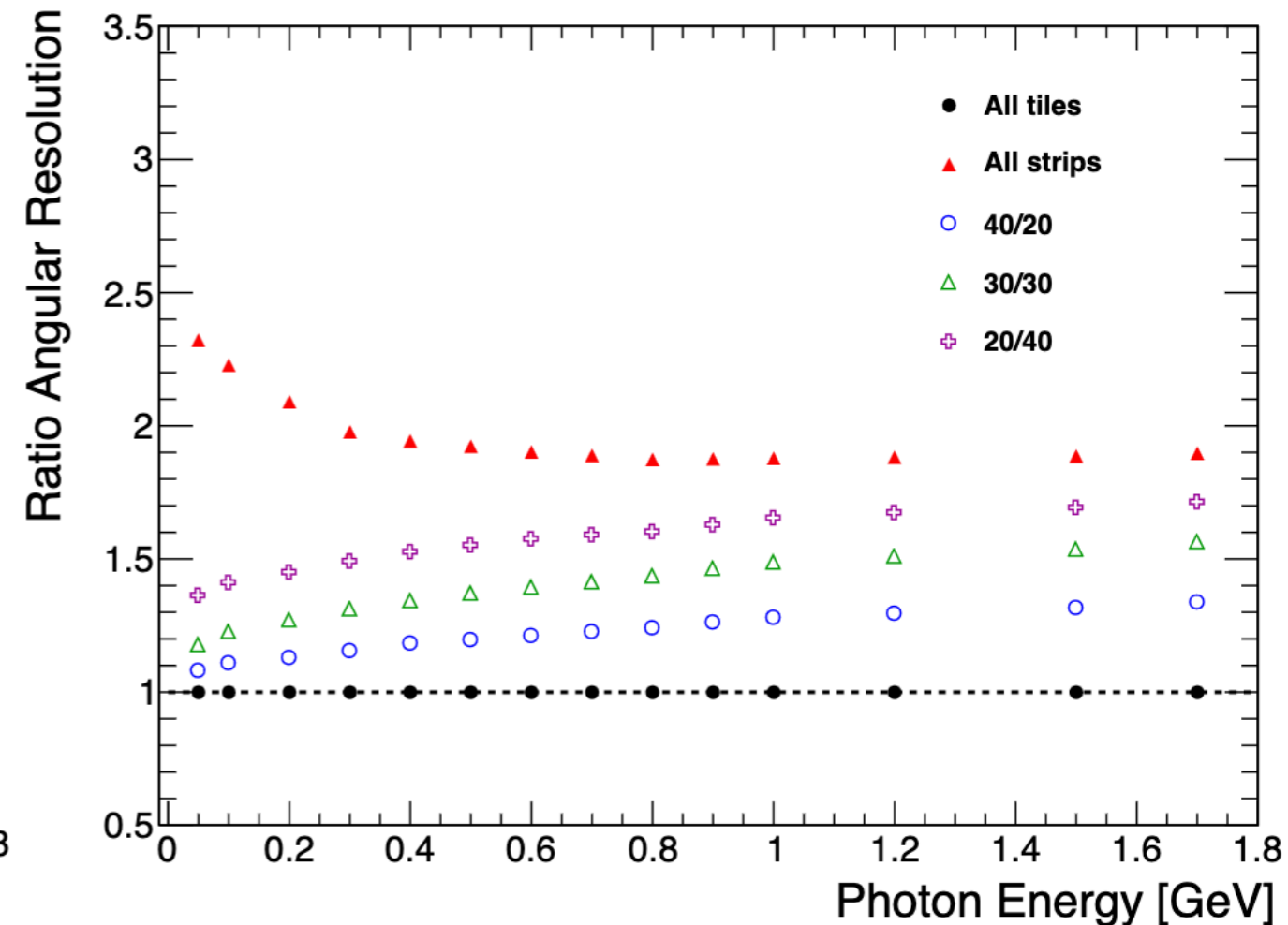
- Earlier additional studies on the absorber and scintillator thickness are discussed in Eldwan's May 2019 talk
- Pb absorber tends to have worse angular resolution since showers are more compact and less "pointy"

Tiles vs Strips

from Eldwan's Oct 12th 2020 talk



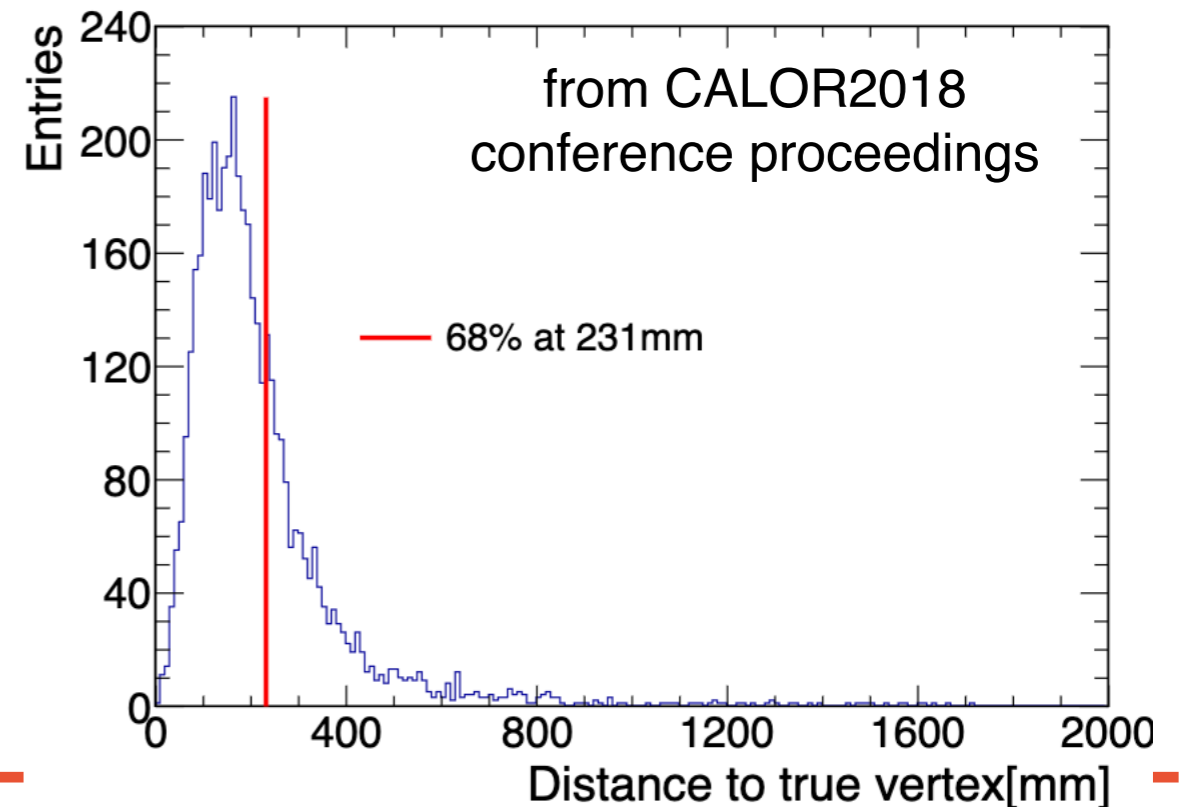
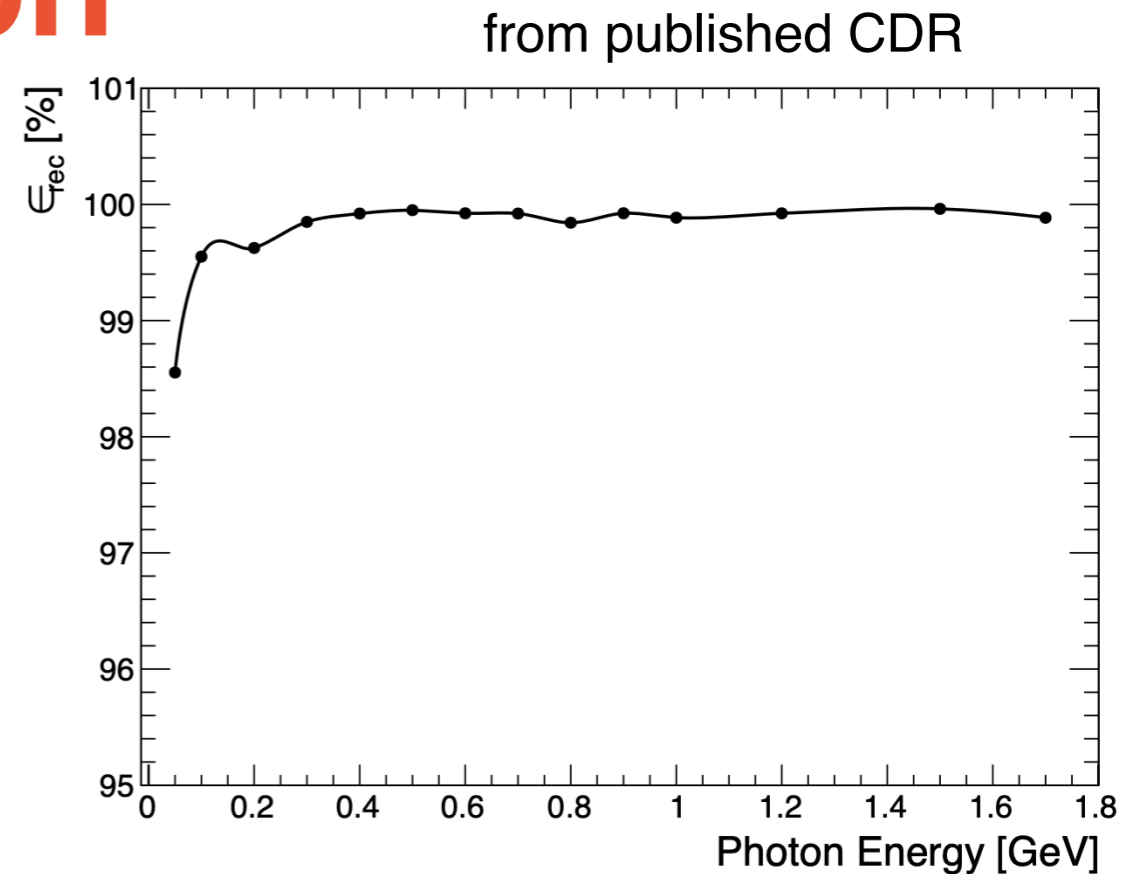
from published CDR



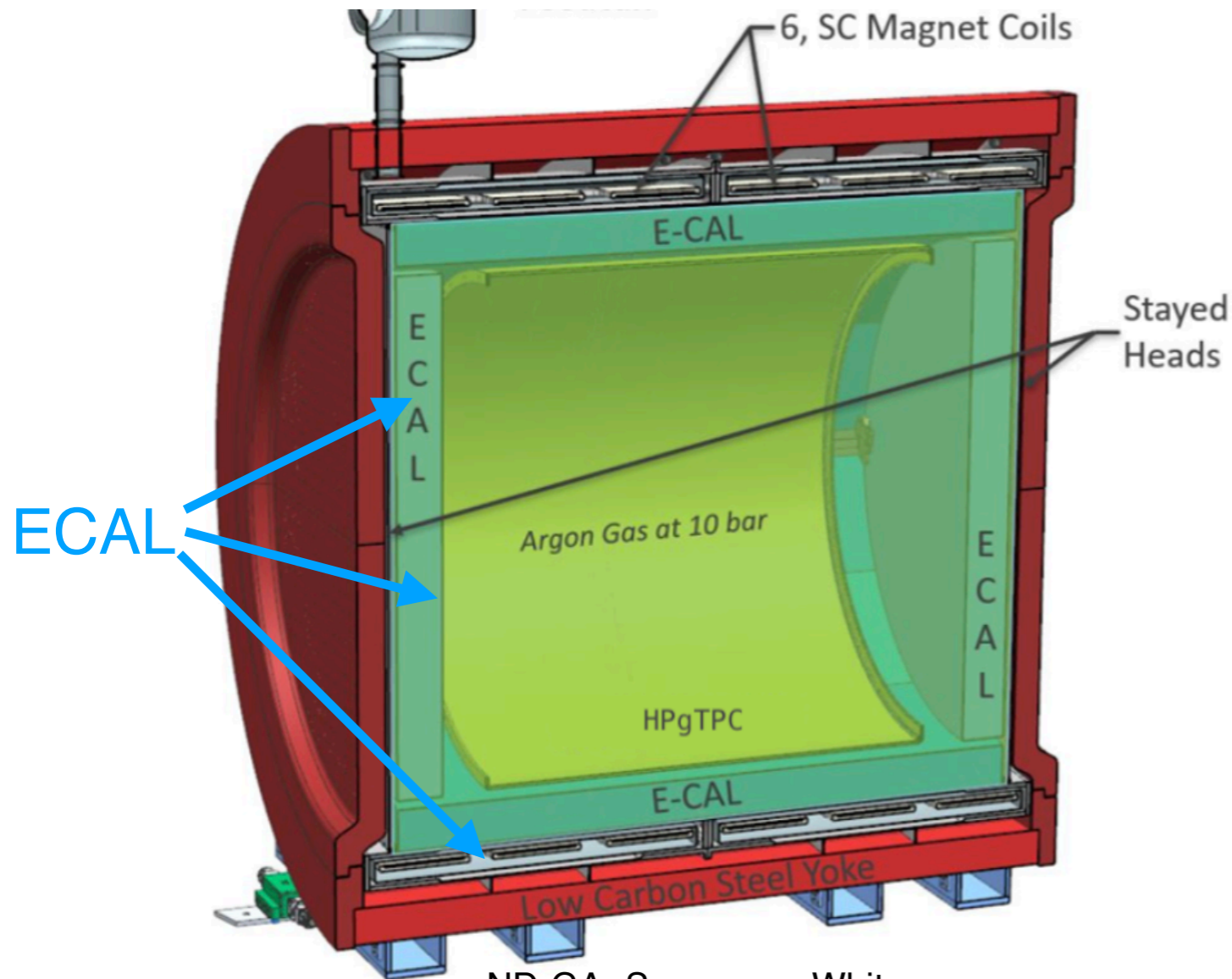
- As expected, having no tiles has a big impact on angular resolution

Pi-zero reconstruction

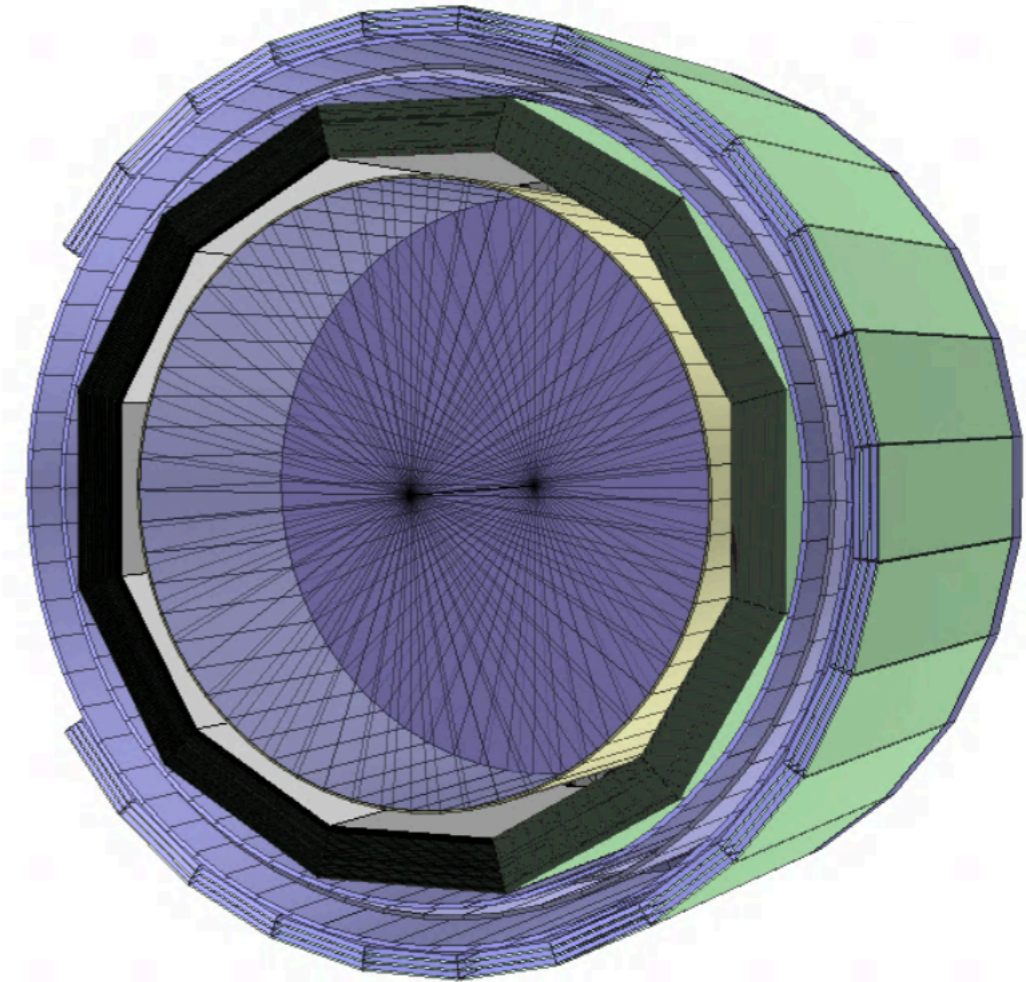
- Top right is photon efficiency (not including photons that convert in gas)
- Decay vertex accuracy 10-40 cm from CALOR2018 proceedings
- Lorenz Emberger looked into adding timing in into the reconstruction in early 2020, but don't think any of his work ended up in CDR



Post-CDR Design with SPY



ND-GAr Snowmass Whitepaper
<https://arxiv.org/pdf/2203.06281.pdf>



Eldwan Brianne, 2nd ND-GAr workshop

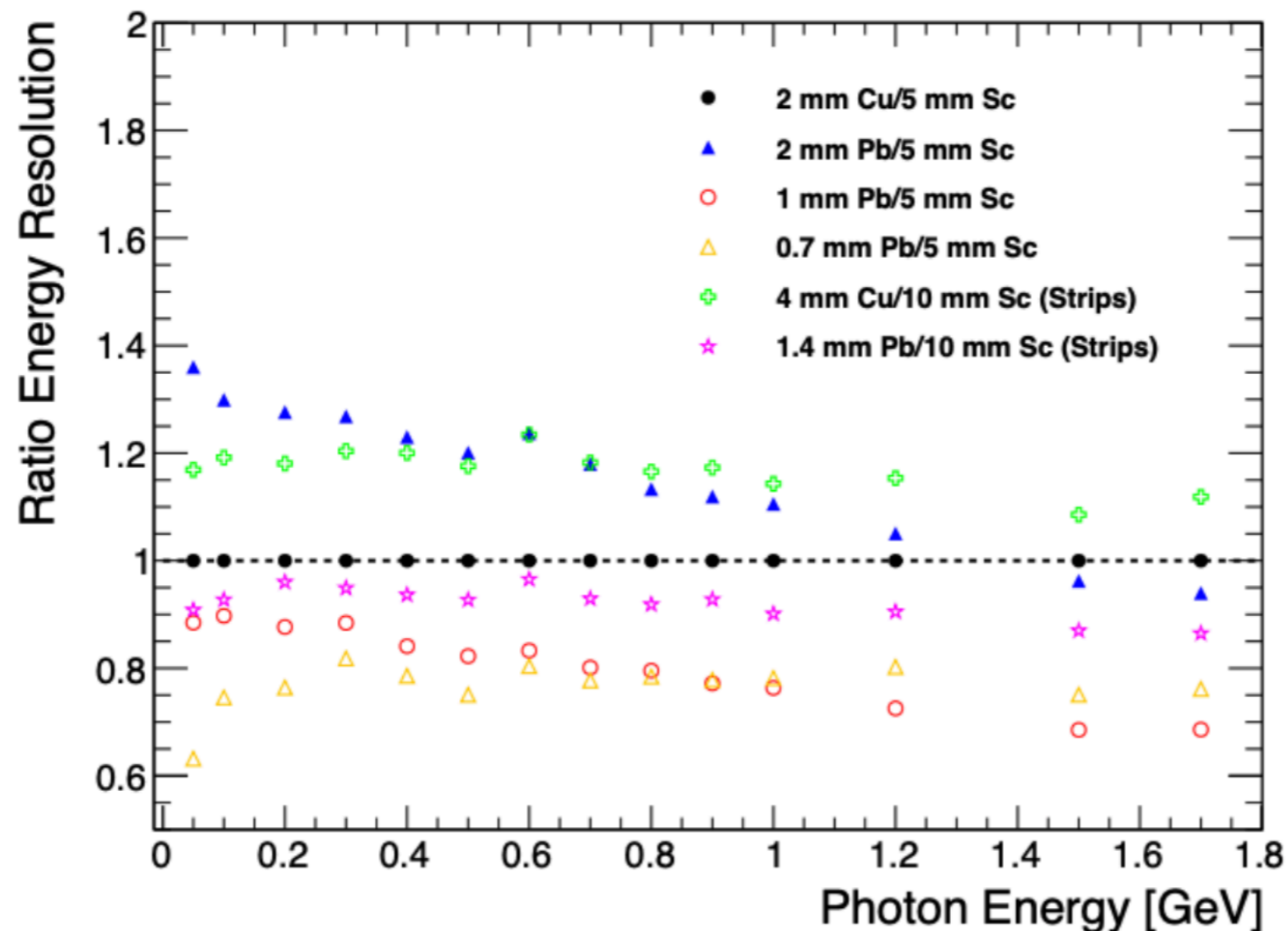
- Magnet changed to Solenoid with Partial Yoke
- ECAL entirely inside pressure vessel, 12-sided

Some post-CDR presentations

- “Muon/Pion separation with the ECAL and MuonID,” Lorenz Emberger, DUNE Jan 2021 collab meeting (studies using a BDT)
- “ND-GAr: ECAL Design Status”, Eldwan Brianne, Jan 2021 Collab meeting
- “ND-GAr: ECAL Design Status”, Eldwan Brianne, Jan 2021 ND-GAr Workshop
- “ND-GAr: ECAL Status and Future”, Eldwan Brianne, Jun 2021 Second ND-GAr Workshop
- “DUNE ND-GAr ECAL Concepts,” Sebastian Ritter, Oct 25, 2021, ND-GAr meeting
- “DUNE ND-GAr ECAL Concepts,” Sebastian Ritter, DUNE Jan 22 Collab meeting

Reoptimization for SPY

- Once magnet design changed to SPY, this limited some of the space for the ECAL
- Absorber changed to Pb (for better containment), scintillator thickness changed, total number of strips reduced



from Eldwan's Jan 2021
collab meeting talk

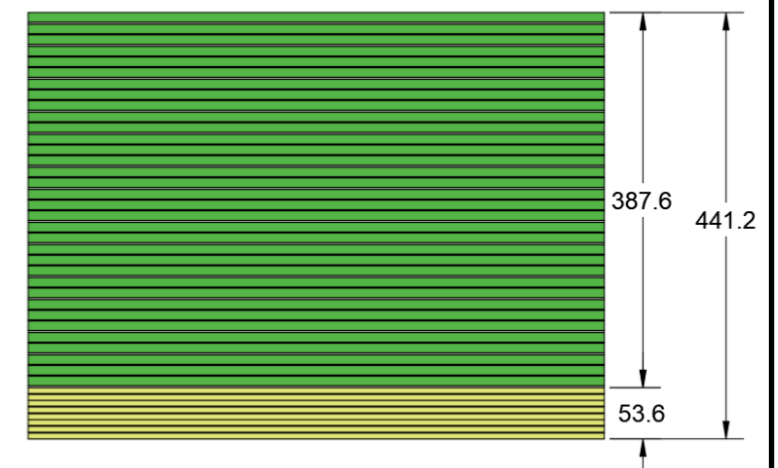
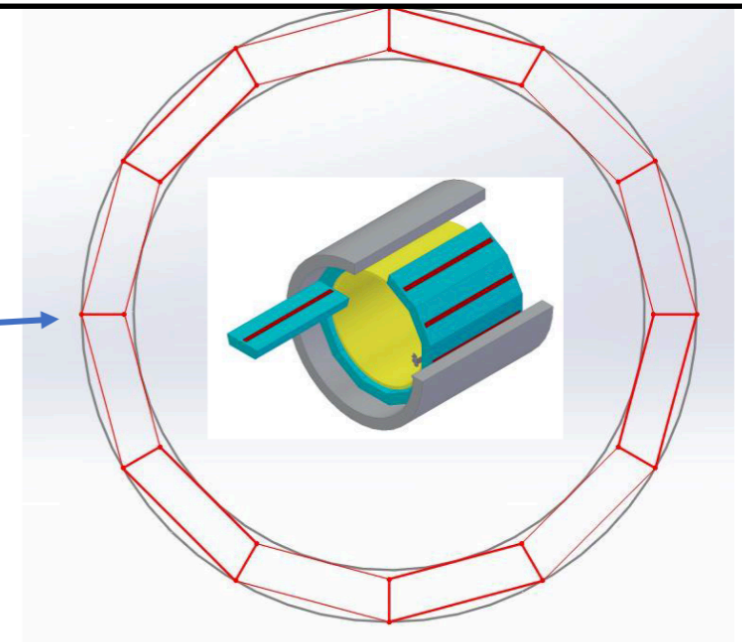
SPY Baseline Design

- From S. Ritter, Oct 25, 2021

Possible typo?
GARsoft code has 5cm

BASELINE DESIGN

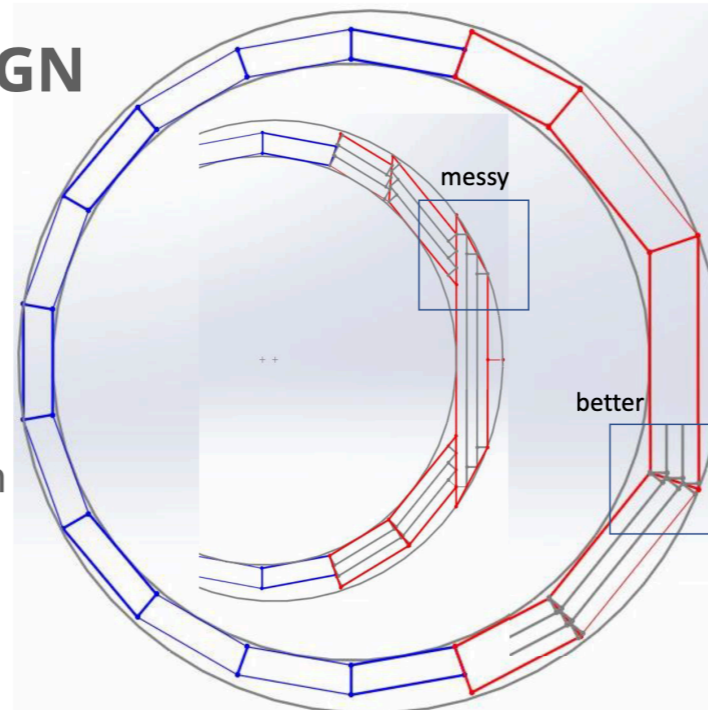
- 12 sided barrel design
- TPC outer radius $R=2780\text{mm}$
- Cryostat inner radius $R=3360\text{mm}$
- Total ECAL thickness around 450mm
- 8 tile layer = 0.7mm lead + 6mm scintillator
- 34 strip layer = 1.4mm lead + 10mm scintillator
- Correction: $z=\pm 2730\text{mm}$ \rightarrow $z=\pm 3750\text{mm}$



Asymmetric ECAL

HYBRID REWORK DESIGN

- Super module size decreased
 - Center facing edge possible
 - More homogeneity in instrumentation
- Still maximal diameter reduction of Asymmetric Barrel design



- See Sebastian's talks
- Proposed making modules more than 70 degrees off horizontal axis thinner
- But this was never simulated in detail

		3 layers (%)	2+ layers (%)	1+ layer (%)	0+ layer (%)	Mean number of layers (percentage weighted) 70/90
Hybrid centered	-up stream	71.8	22.9	5.2	0	2.79/2.63
	-center	84.4	13.4	0	2.1	
	-down stream 70°	90	10.1	0	0	
	-down stream 90°	71.2	10.7	8.2	9.9	
Hybrid perpendicular	-up stream	65.6	31.7	2.6	0	2.76/2.61
	-center	77.7	21.6	0	7.1	
	-down stream 70°	90	10.1	0	0	
	-down stream 90°	71.2	10.7	8.2	9.9	
Asymmetric Barrel	-up stream	89.4	5.9	1.9	2.9	2.80/2.79
	-center	94.7	0	0	5.3	
	-down stream 70°	73.3	26.7	0	0	
	-down stream 90°	70.3	29.7	0	0	
Hybrid Rework	-up stream	86.9	4.3	4.5	4.3	2.80/2.76
	-center	94.6	0	0	5.4	
	-down stream 70°	88.1	7.9	4	0	
	-down stream 90°	77.4	14.7	7.9	0	

more is better ← → less is better

- Hybrid rework most superior design under current considerations

Summary

- Lots of previous studies to evaluate performance of ECAL as a function of various ECAL design parameters
 - But was based on an earlier magnet/pressure vessel design where barrel ECAL was outside pressure vessel
- Some reoptimization done in 2021 for the more space-constrained SPY magnet
 - Perhaps revisit some of this, also looking at strip vs tile percentage?
 - Also how strong is radial constraint if we don't reuse ALICE chambers?
- Sebastian Ritter suggested some possible layouts for asymmetric ECAL, but not simulated in detail
 - Perhaps do optimization studies for a cylindrical ECAL and then afterwards remove some of the upstream layers and check that degradation is not significant?