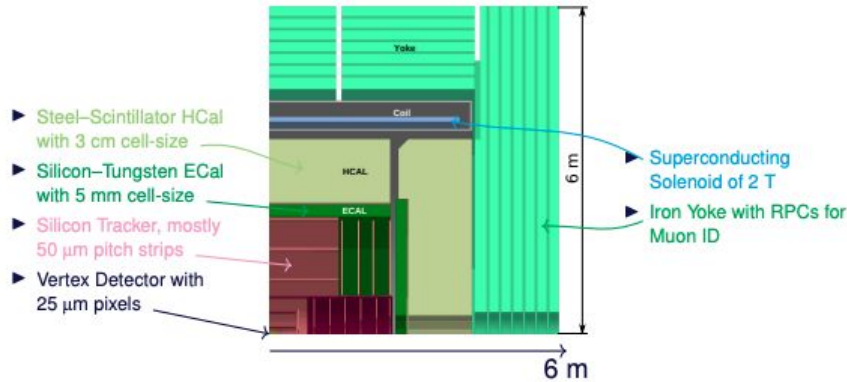


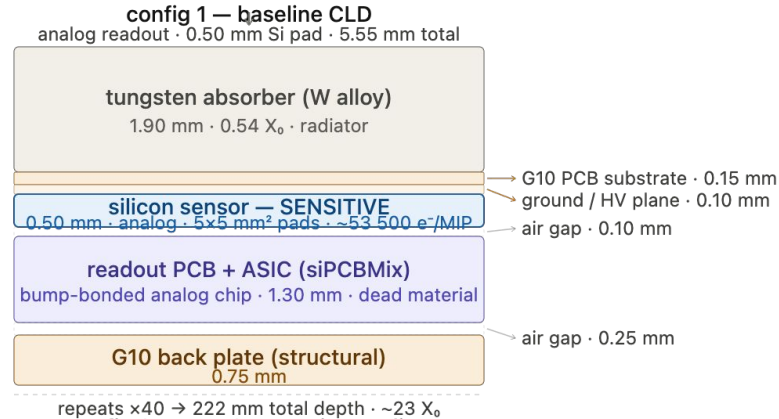
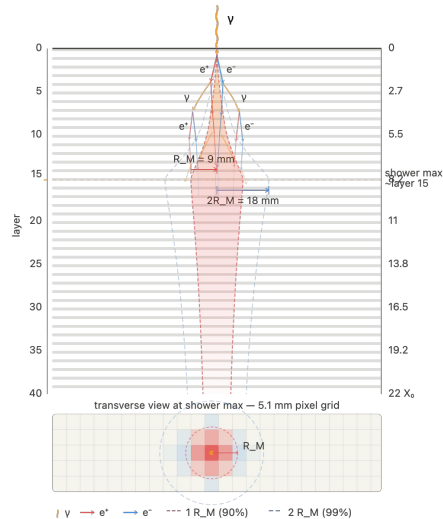
MAPS Calorimetry for FCC: Cooling Follow Up

Prajita Bhattarai
06/04/2026

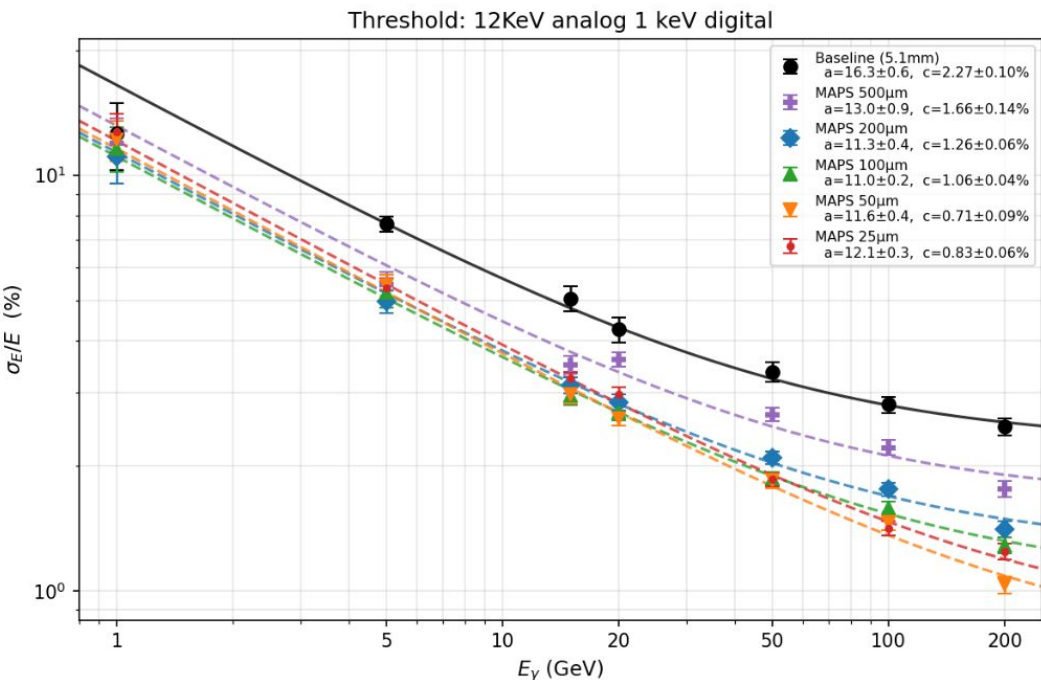
Introduction



- Si/W detector
- 5x5 mm sensor pad
- Can we improve pflow by going to ultra high granularity?
- Possible with MAPS sensor that operates at room temperature and already being considered for vertex detector

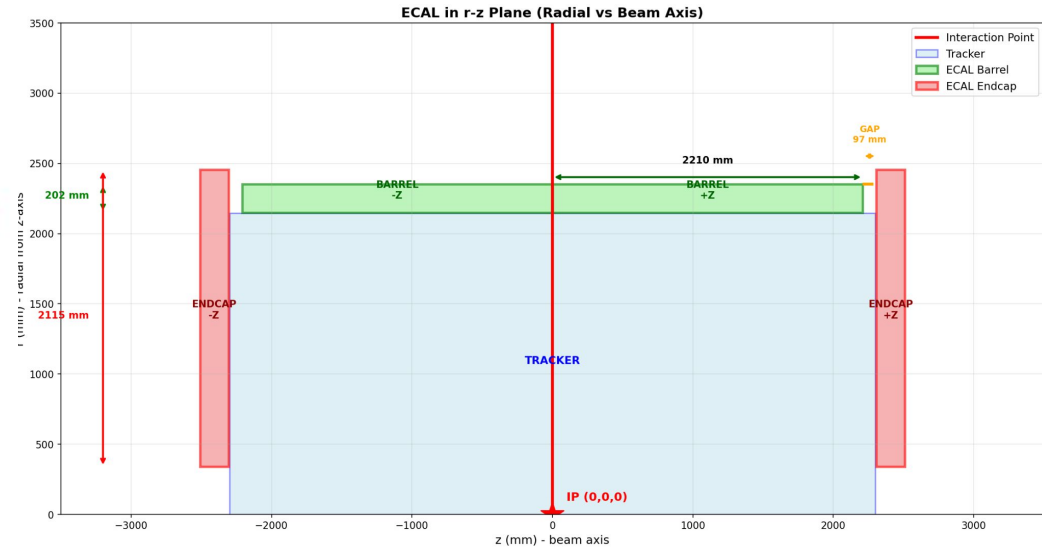
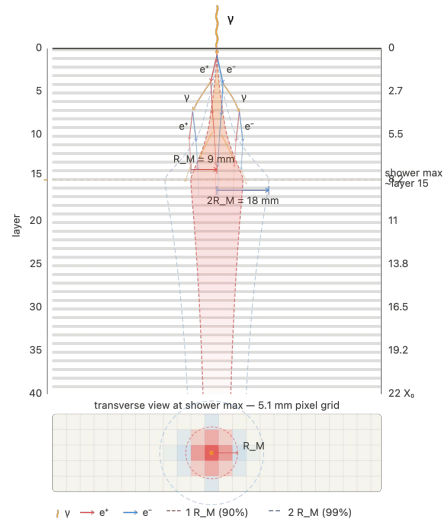
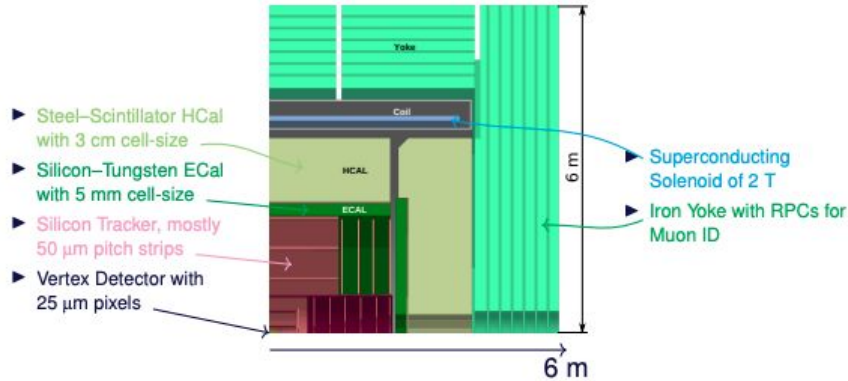


Recap



- Replacing CLD ECAL with higher granularity MAPS sensors
- Studied impact on photon & pi0 gun with varying pixel sizes from 25-500 um
- Digital readout (hits vs no hit), no clustering
- See very similar performances across 25-100 um pixel sizes
- Picked 100 um pixel pitch as alternative to baseline
- [Link](#) to the last presentation
- This presentation shows some update thinking about adding active cooling to calorimeter

CLD Geometry & ECAL



- Study shown today tries to keep the volume of the detector as close as to the original design
- But varies radiation length of the calorimeter to accommodate cooling material

Some Inspiration for Active Cooling in Calorimeter

CMS HGICAL

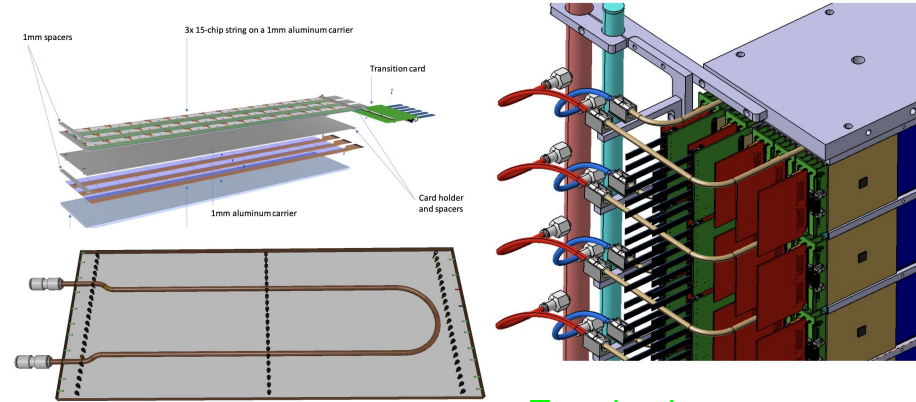


Fig. 6. CE-E copper cooling plate prototype

- Regular Si sensor of pad size 0.5-1.2 cm²; power 35-85 mW/cm²
- Operates at -30C
- Cooling pipes embedded in copper, dual phase CO₂ cooling

Too complex

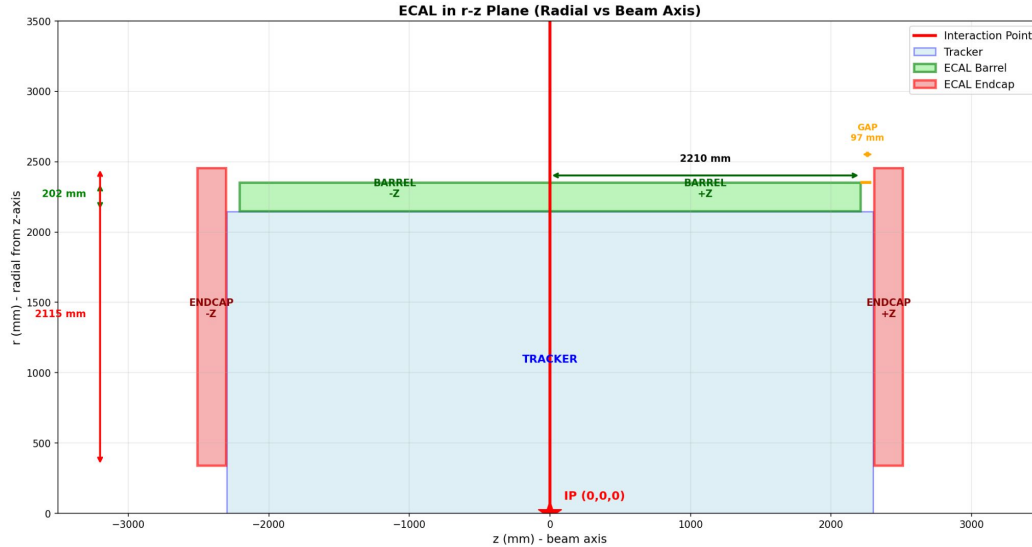
ALICE FoCAL



Too simple

- MAPS Alpid sensor operational at room temperature
- Cooling plates on top & bottom of the FOCAL, cooled with water
- Area per layer ~1m²
- CLD detector much bigger

Cooling Needed for CLD MAPS ECAL



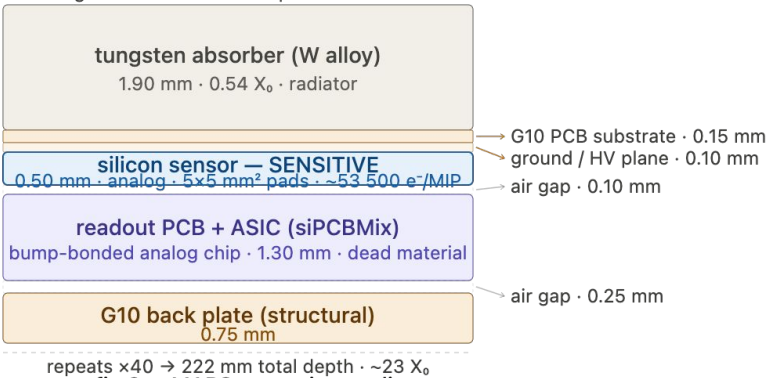
- After chatting with Lorenzo, MAPS power consumption = 40 mW/cm^2
- Area per layer of = $2 * \pi * L * R$
~55-65 m^2 depending on barrel layer (barrel == cylinder)
- Power consumption in last (largest) layer
 $P = 40 \text{ mW/cm}^2 * 65 \text{ m}^2 = 26 \text{ kW}$
- Typically cooling lines split in barrel halves so we need to cool ~13kW in last layer
→ **This is what I use as baseline need**

- As sensors operate at room temperature dual phase cooling like CMS probably an overkill and adds too much complexity
 - As detector volume is much larger than ALICE FoCAL we probably need per layer cooling

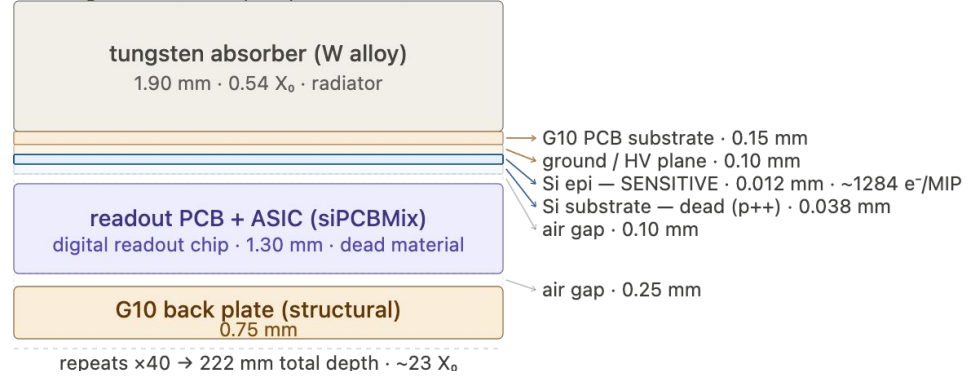
Adding Active Cooling

■ W / Ti
 ■ Si sensitive
 ■ Si dead
 ■ G10 / Cu
 ■ siPCBMix
 ■ CO₂ cooling
 ■ Al (config 3)

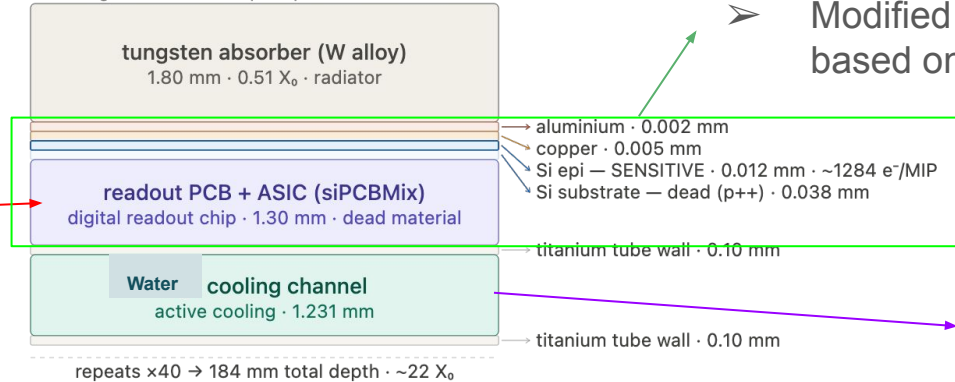
config 1 — baseline CLD
analog readout · 0.50 mm Si pad · 5.55 mm total



config 2 — MAPS_μ no active cooling
digital readout · 12 μm epi · 5.55 mm total



config 3 — MAPS_μ active CO₂ cooling
digital readout · 12 μm epi · 4.60 mm total



➤ Modified MAPS layer to be realistic based on chat with Lorenzo

Probably too large might be able to make this smaller & add an airgap before sensor

➤ Added water based cooling size 1.2mm

■ W / Ti
 ■ Si sensitive
 ■ Si dead
 ■ G10 / Cu
 ■ siPCBMix
 ■ CO₂ cooling
 ■ Al (config 3)

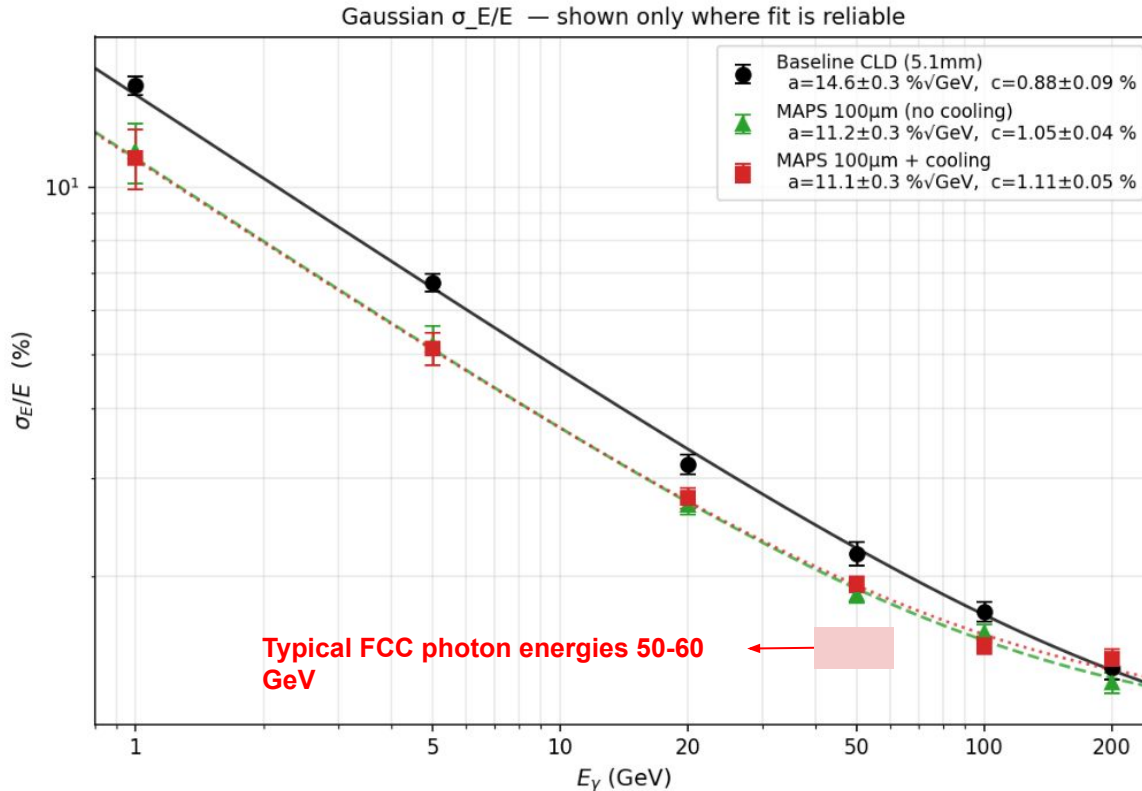
Is this cooling realistic first order implementation?

- Typically cooling lines split in barrel halves so we need to cool ~13kW in last layer
- Two separate implementation water layer 1.2mm
- Assuming $\Delta T=20$ C (water+anti freeze)

$$flow = \frac{Power}{water\ specific\ heat \times \Delta T} = \frac{1300}{2800 \times 20} = 0.16kg/s = 10L/min$$

- Tungsten a big thermal mass, a good conductor of heat, so depending on lateral heat transfer could have pipes spread out
- I think this could be feasible with parallel cooling circuits

Adding Active Cooling



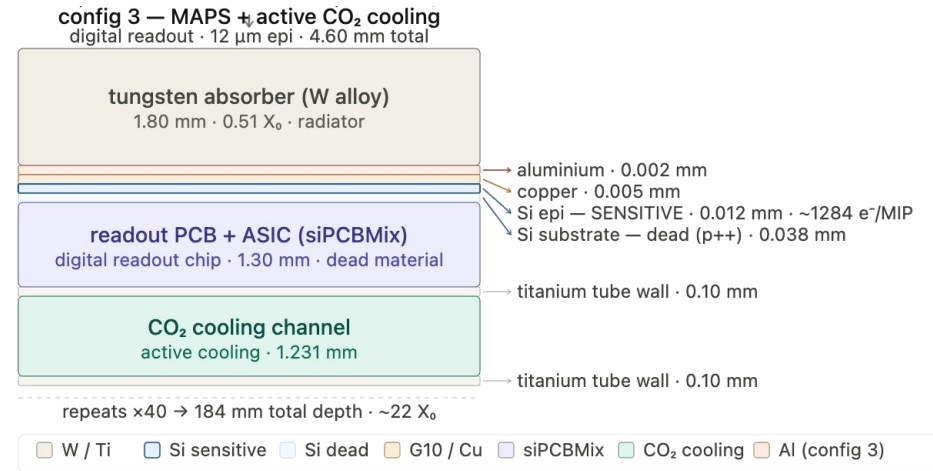
- No significant change below 100 GeV energy
- For FCC e+e- Z/H pole most photon energy below 100 GeV so change doesn't w.r.t baseline
- >100 GeV worse than baseline, because of reduction by $1X_0$

Limitation of this cooling design

- This is a very naive first order implementation to understand **when we add material to cool, do we lose improvement from increased granularity?**
- Two very critical design pieces are missing, what holds the cooling tubes and sensor in place? Currently everything is flat uniform plane
 - Could design a plate that hold cooling on one end & sensors on another?
- How will the shower change with non-uniformity in the detector?
- Can we optimize the heat transfer by placing cooling layer right next to the sensor before PCB?

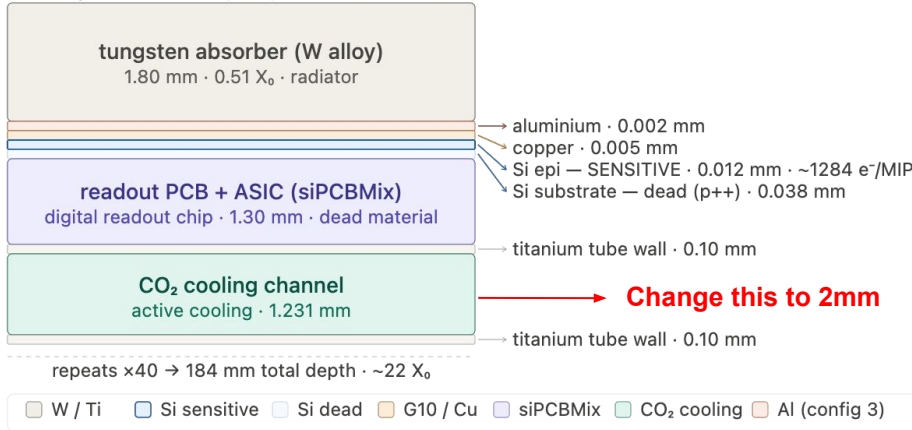


Cooling design implemented



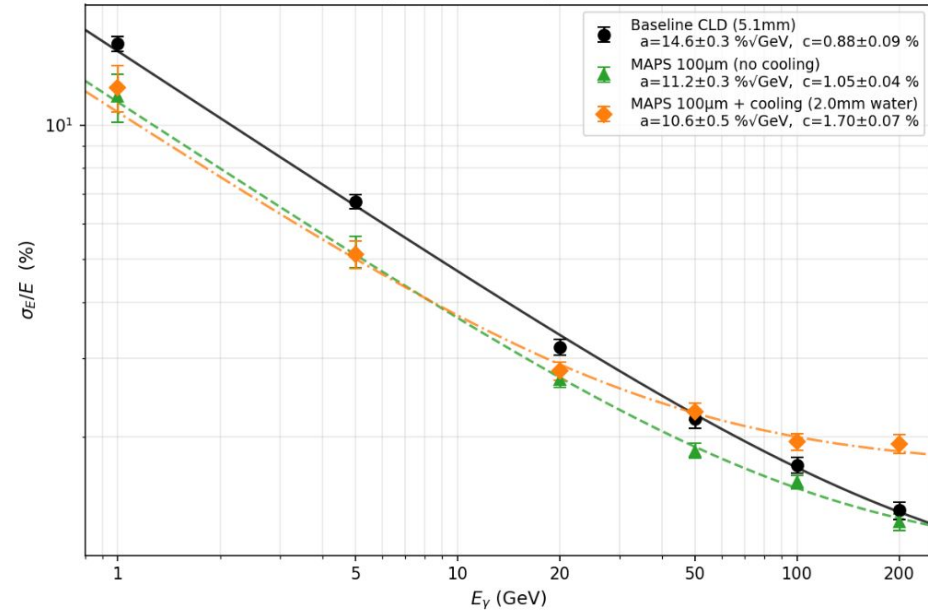
Can we afford more non-W material?

config 3 — MAPS + active CO₂ cooling
digital readout · 12 μm epi · 4.60 mm total



- Volume kept the same
- Number of layers 35 & 18 X_0
- We could also increase the number of layers & make the overall size larger if needed
- Could also increase W thickness per layer and decrease number of layers

Gaussian $\sigma_{E/E}$ — shown only where fit is reliable



Summary

- A first order attempt to add active cooling material inside the calorimeter volume
 - Changes radiation length to 22 (18) from 23 when adding 1.2 mm (2 mm) of water layer
 - Many important second order details not considered
- Based on naive design and just looking at photon energy, ultra high granular detector might be realistic
 - Many details yet to be optimized, could use AI agents for optimization
- Full FEA thermal analysis needed, outside of scope of my study or expertise
- But if this is good enough first order approximation, planning to look at jet resolution next