# TTL detector performance studies
# - follow-up -

**EPIC Tracking Meeting**
**August 4, 2022**

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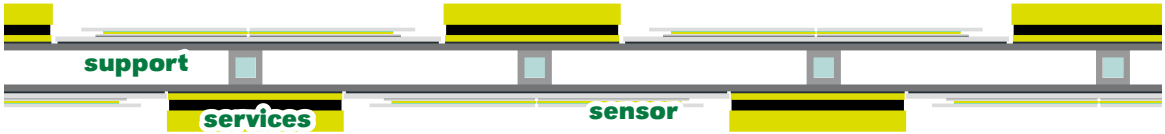
Electron Proton and Ion Collider
EXPERIMENT

OAK RIDGE
National Laboratory

# Reminder: ECCE-style TTL Layers in Geant4




## Support:

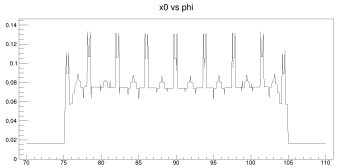
| Layer | material | thickness |
|---|---|---|
| Top plate | aluminum | 1mm |
| air gap | air | 5mm |
| bottom plate | aluminum | 1mm |
| cooling | aluminum | 5mm diam. tube<br>1mm wall |

## Services:

| Layer | material | thickness |
|---|---|---|
| Thermal pad | graphite | 0.25mm |
| High Speed Board | polystyrene | 1mm |
| Power board | polystyrene | 3.1 mm |

## Sensor:

| Layer | material | thickness |
|---|---|---|
| Thermal pad | graphite | 0.25mm |
| AlN | AlN | 0.79mm |
| Laird Film | graphite | 0.08mm |
| ROC | plastic | 0.25mm |
| Solder (Tin) | tin | 0.03mm |
| Sensor | silicium | 0.3mm |
| Epoxy | epoxy | 0.08mm |
| AlN | AlN | 0.51mm |

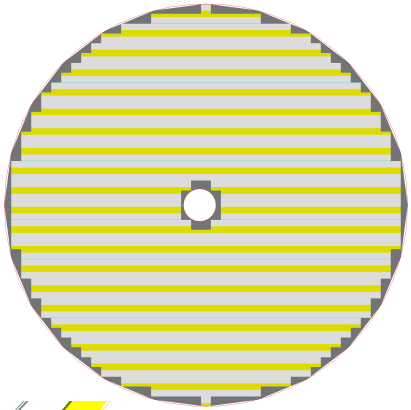


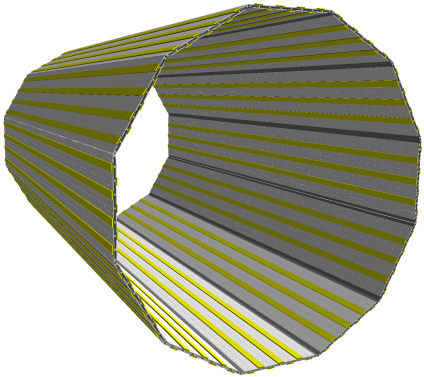

- Material budget $\sim 8\% X/X_0$ dominated by Al plates
  $\rightarrow$ cooling pipes with substantial material

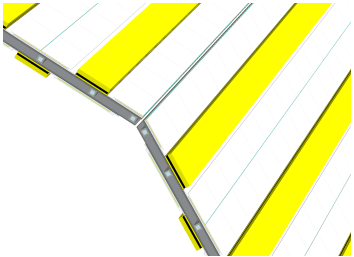
**More infos in CMS ETL TDR [[Link]]**

# Reminder: ECCE-style TTL Laye

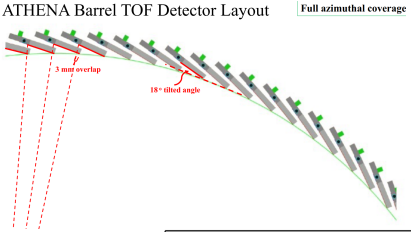
- Barrel made of 12 modules in azimuth and multiple modules along $z$-axis
- Forward layers mounted on both sides of large disk
- AC-LGAD pixel sensors with 500$\mu$m pitch
  $\rightarrow$ 30$\mu$m position resolution

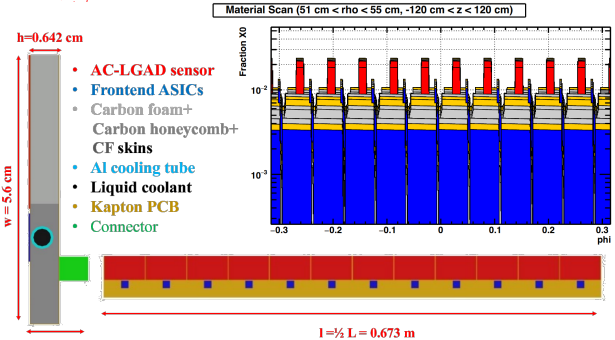






# Reminder: ATHENA-style barrel TOF (DD4hep)

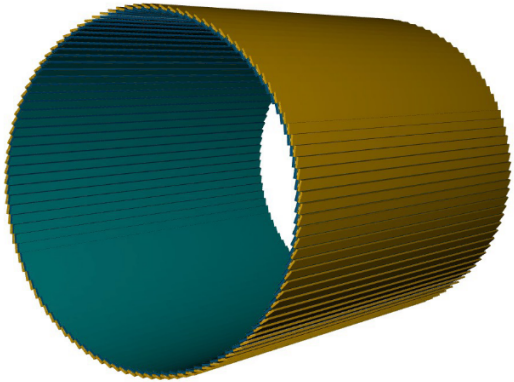


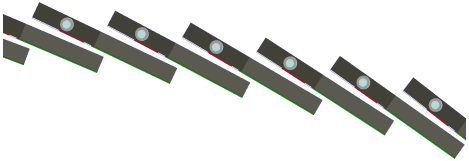




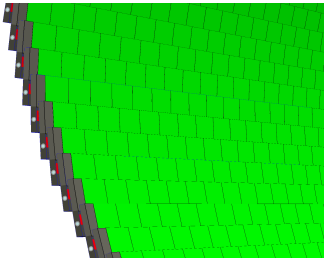
- Material budget $\sim 1\%X/X_0$
- ATHENA design placed at $R \sim 52.5$cm
- Strip AC-LGAD with $0.5 \times 10$mm pitch
- Full coverage in $\varphi$, 98% coverage in $z$

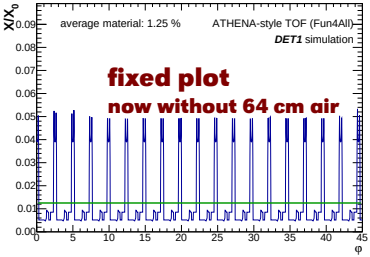


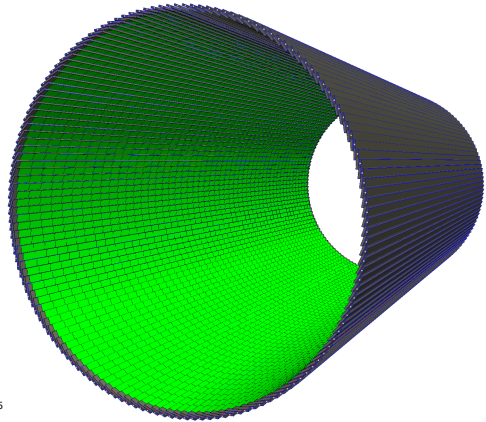
# NEW: ATHENA-style barrel TOF (Fun4All)



- **Material budget** $\sim 1.2\% X/X_0$
  $\rightarrow$ C-foam (honeycomb) density 0.09(0.03) g/cm$^3$
  $\rightarrow$ cooling with significant material
- Detector placed at $R \sim 64$cm
- Detector length $\sim 2.8$m $\rightarrow \approx 11$m$^2$ of sensors

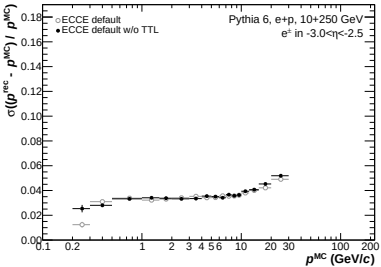


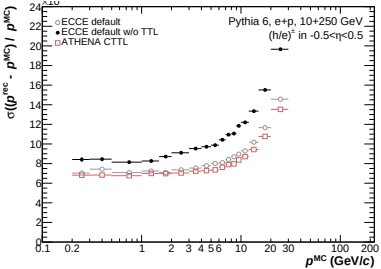


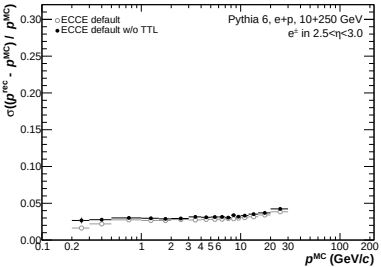



# Momentum resolution - Different Detectors

**now with lower $|\eta|$ bins!**

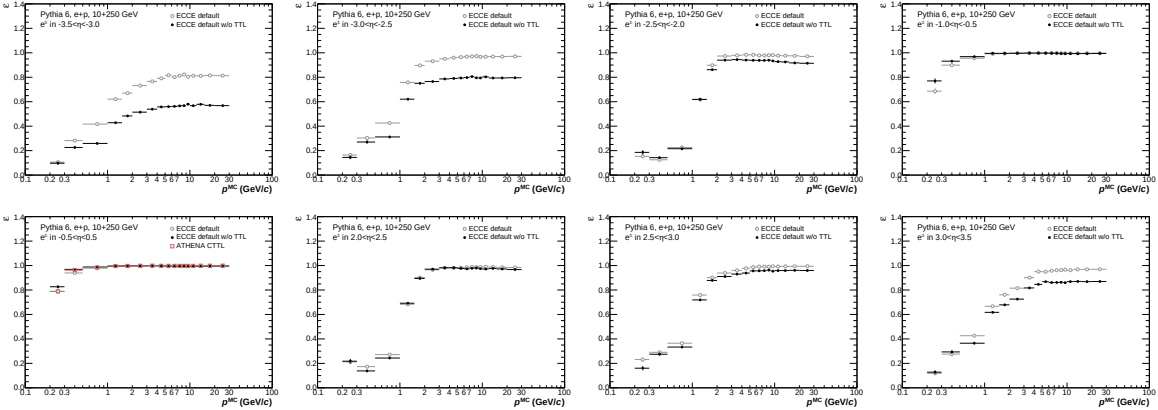



- Comparison between CTTL and ATHENA TOF detector design
  → slight improvement of tracking performance
  → possibly due to all sensors being in front of support material
- Comparison to TTL layers being excluded from Kalman filter
  → important tracking constraints in barrel and forward
  → surprisingly low impact in backward direction

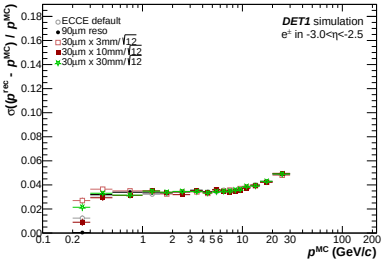
# Tracking efficiency - Different Detectors

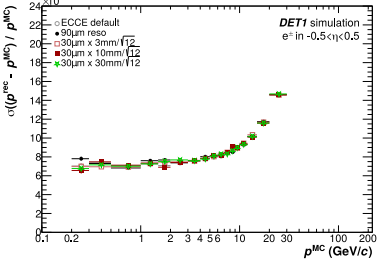


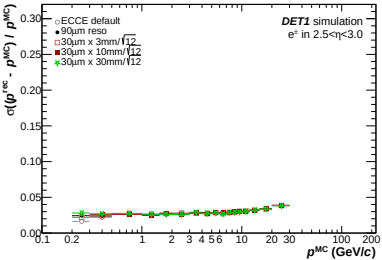

- Clear improvement of tracking efficiency with TTL, especially at high $|\eta|$
- Overall low efficiency for $p < 1$GeV in fwd/bwd

# Momentum resolution - Different Sensors

**now with lower $|\eta|$ bins!**



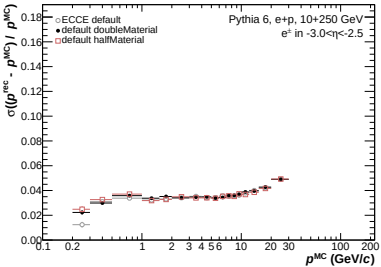



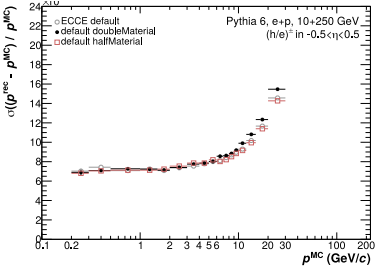



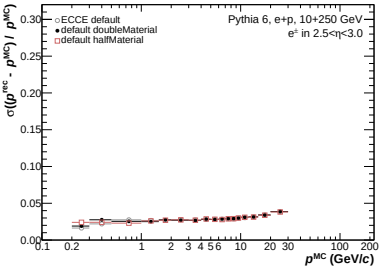

- Studies performed via Kalman filter adjustments
  → Forward/backward sensor resolution changed in $\varphi$ and $R$
  → Barrel sensor resolution changed in $\varphi$ and $z$
- Momentum resolution appears unaffected by AC-LGAD pitch
  → strip sensors (also with larger pitch in $\varphi$) can be used

# Momentum resolution - Different Material

**now with lower $|\eta|$ bins!**

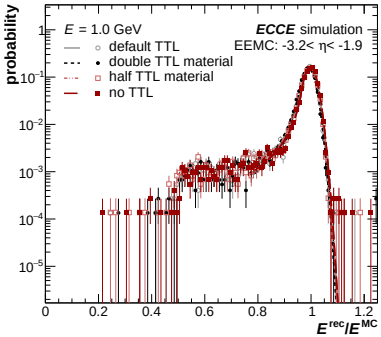


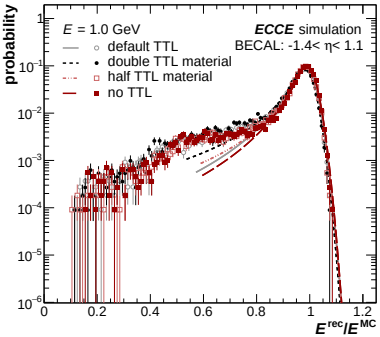



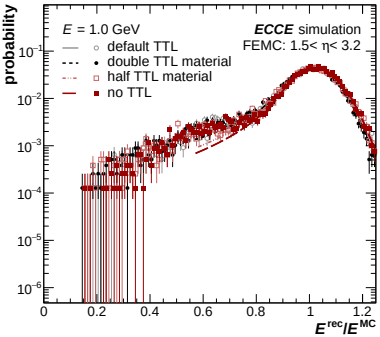




- Material of TTL layer with small/negliglible impact on tracking resolution
  → however, ECal performance might depend on low material budget

# Calorimeter resolution - TTL Material




- Negligible impact of TTL material to calorimeter resolution in all directions
  → allows for more freedom with supports and cooling as tracking performance is similarly unaffected by material

# Conclusions



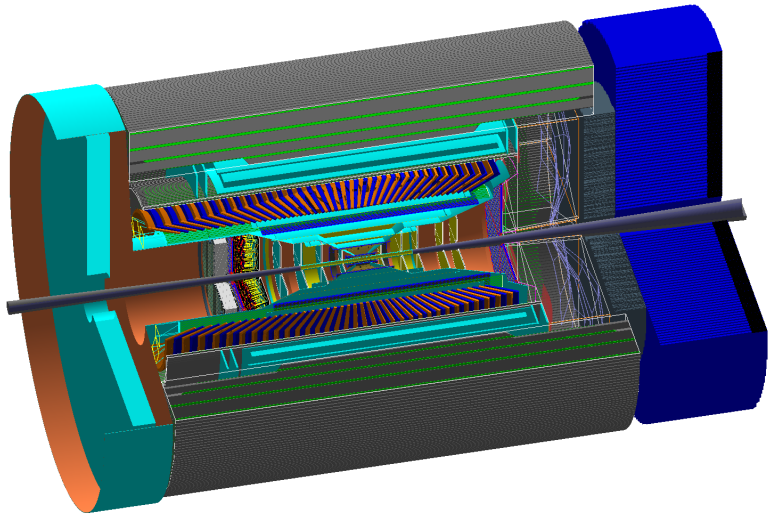
- ATHENA-style barrel design implemented in Fun4All
  $\rightarrow$ material, cooling and support to be further evaluated
- TTL layers have significant impact on momentum resolution in barrel and forward
  $\rightarrow$ not that sensitive to sensor pitch in $\varphi$ direction
- Small effect from TTL layer material variations on tracking performance
  $\rightarrow$ but calorimeters would benefit from less material
- TTL layers provide crucial information for Cherenkov detectors
  $\rightarrow$ position and angle constraints at entrance of detector
  $\rightarrow$ significantly worse position resolution without TTL hits

Backup

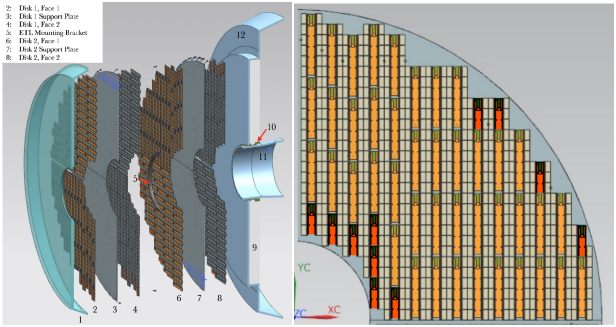
# Performance studies in today's meeting

- **spatial resolution of sensors**
  1) Ideal 30*30 $\mu$m
  2) Barrel: 30$\mu$m along r*phi, while 3 mm/$\sqrt{12}$, 1cm/$\sqrt{12}$, or 3 cm/$\sqrt{12}$ in Z
  3) Endcap: 30$\mu$m along phi, while 3 mm/$\sqrt{12}$, 1cm/$\sqrt{12}$, or 3 cm/$\sqrt{12}$ in R
- **timing resolution of sensors (see presentation by Friederike next week)**
  1) 25 ps (Default ECCE design)
  2) variations: 30 ps, 35 ps, 40 ps, 50 ps
- **material budget**
  1.a) Default ($\sim$7.5%$X_0$ based on ECCE)
  1.b) $\sim$3.75%$X_0$ (half thickness of ECCE design)
  1.c) $\sim$15%$X_0$ (twice thickness of ECCE design)
  ~~2.a) $\sim$1%$X_0$ based on ATHENA design~~
  2.b) $\sim$2%$X_0$ (twice of ATHENA design)

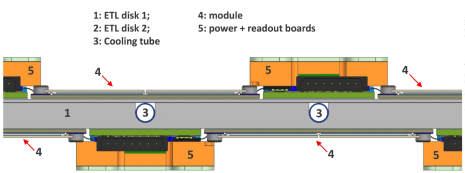
# ATHENA-style barrel TOF in Det1 (Fun4All)

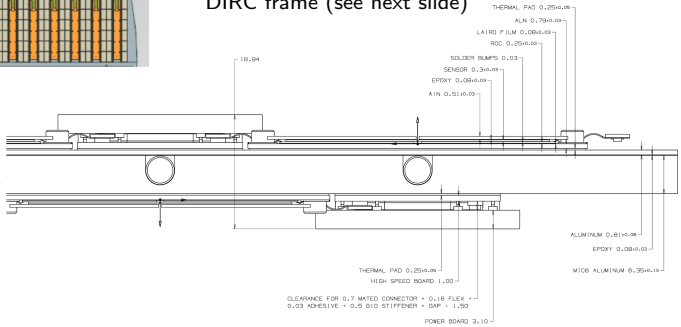


# TTL disk design

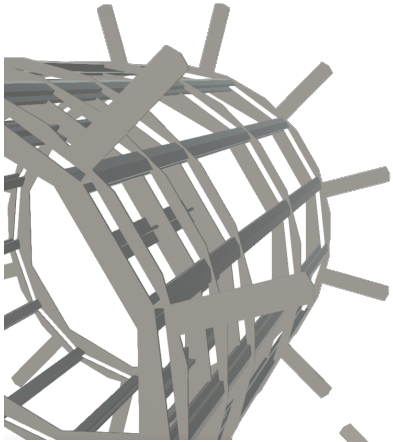



- Design based on the CMS forward upgrade [link]
- Basic elements: ladders of 3 or 6 LGAD sensors with service hybrid (for readout and power)
- Sensors mounted on aluminum plate (currently 6mm thick) and contains cooling
- Sensors on back side of plate shifted to cover service hybrid dead area (see bottom figure)
- Barrel layer to be mounted on inner or outer part of DIRC frame (see next slide)

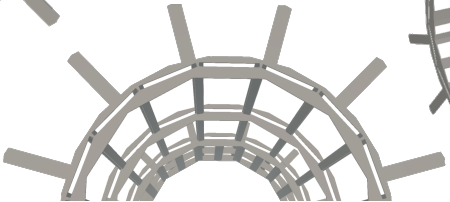


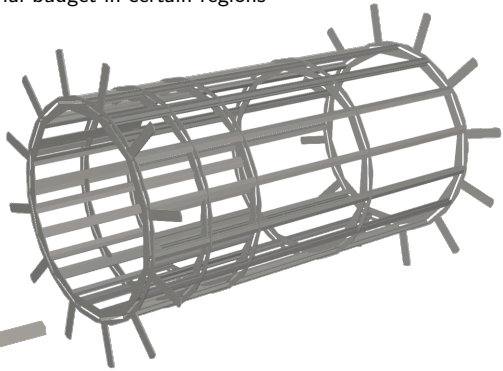



# DIRC frame in barrel



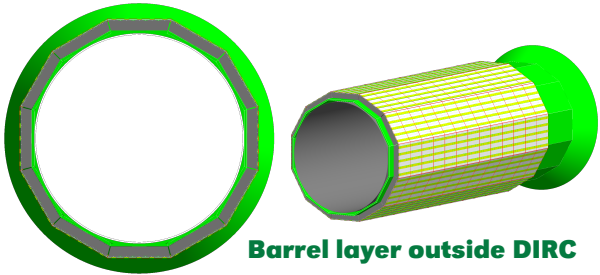
- Currently only stepping files of this frame exist (sent around by Tanja)
  → porting to Fun4All needed
- Frame allows to mount modules on various radial positions
- Considered material is steel at the moment
  → significant material budget in certain regions



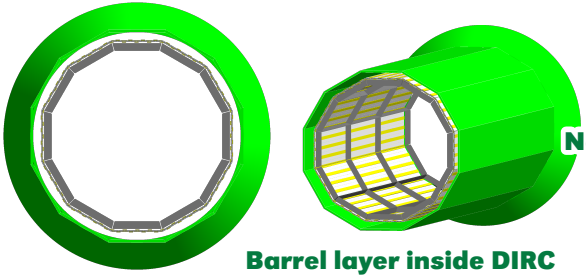


# New Layers in Geant4 - 3



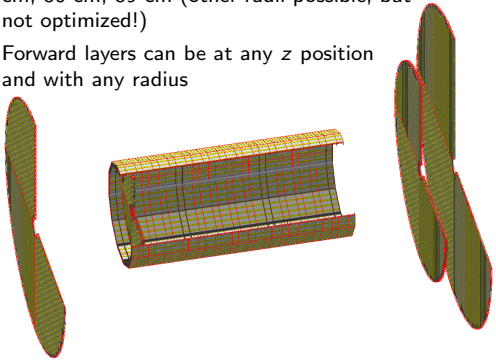


Barrel layer outside DIRC



Barrel layer inside DIRC

- Implemented barrel radial positions: 50 cm, 80 cm, 89 cm (other radii possible, but not optimized!)
- Forward layers can be at any $z$ position and with any radius



New TTL layers in default ECCE configuration