

TOF in ATHENA Proposal

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Content

- Requirements and Design Consideration
- Detector Layout and Module Design
- Material Budget and Integration
- Cost and Performance in Simulation

ATHENA Detector Proposal

Magnetic field: **3 T**

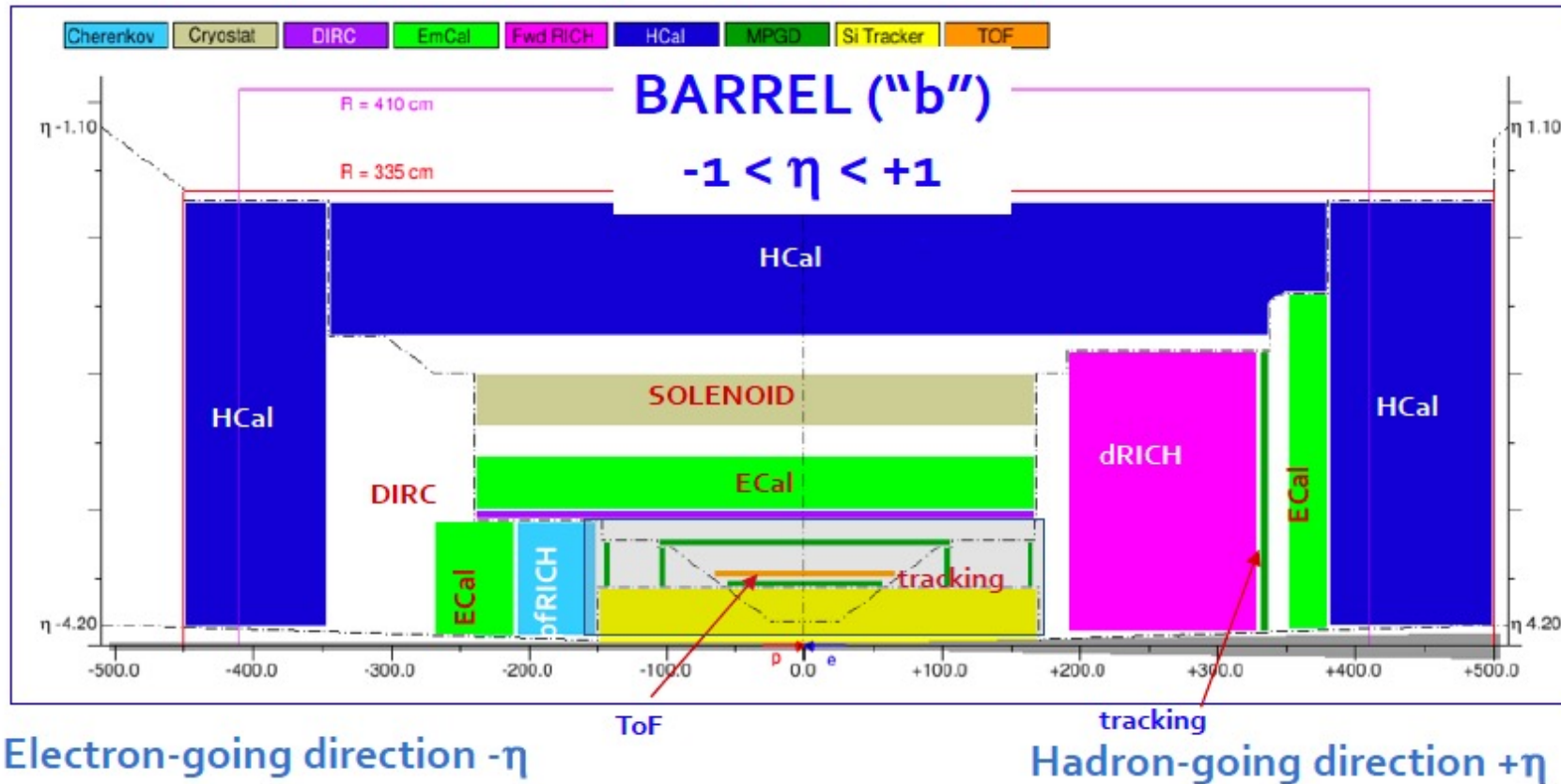
Vertexing and Tracking: **MAPS, MPGD**

PID: **barrel TOF, DIRC, RICHs**

Calorimeters: **ECals, HCal**

Hadron beam (41-275 GeV)

Electron beam (5-18 GeV)



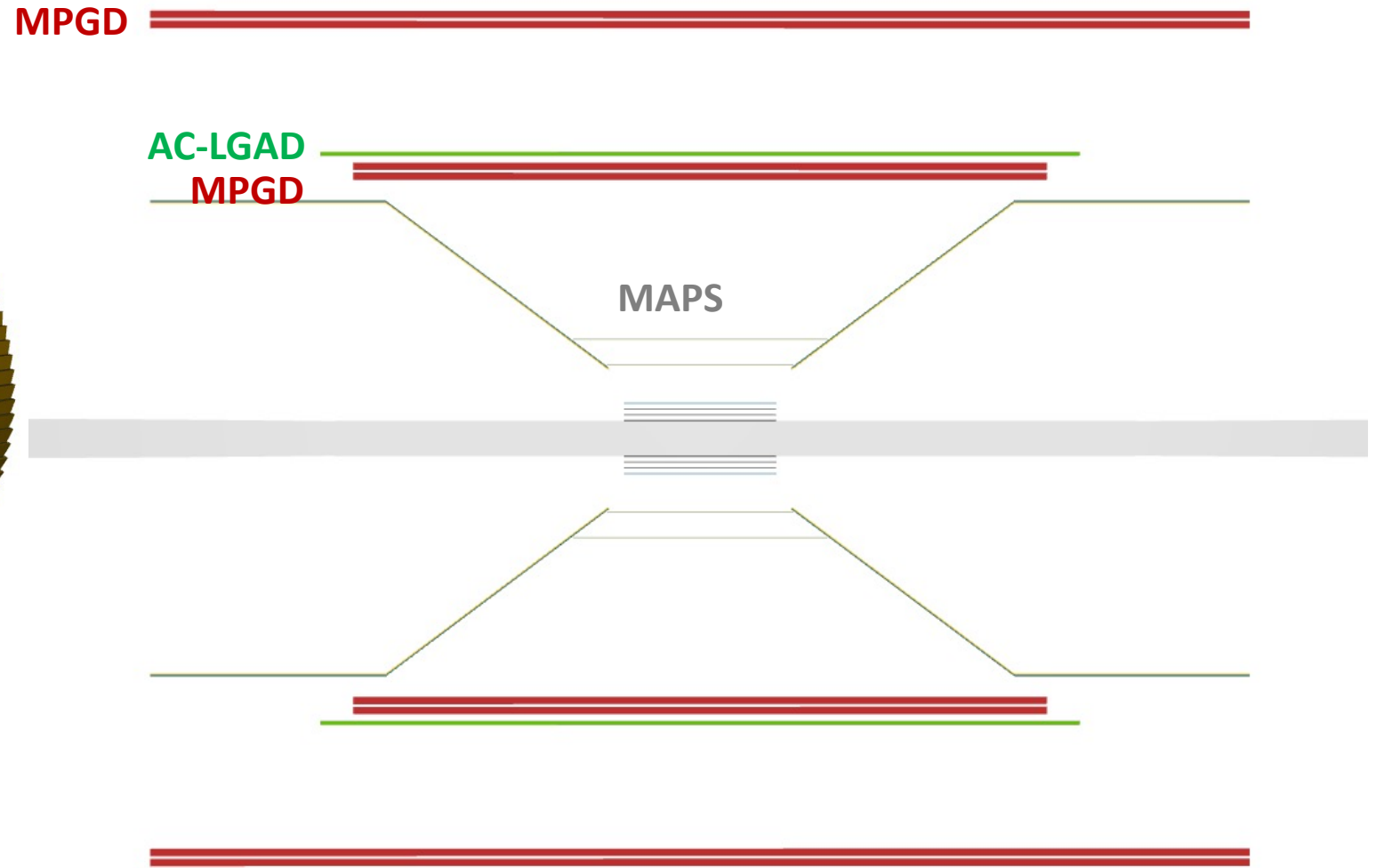
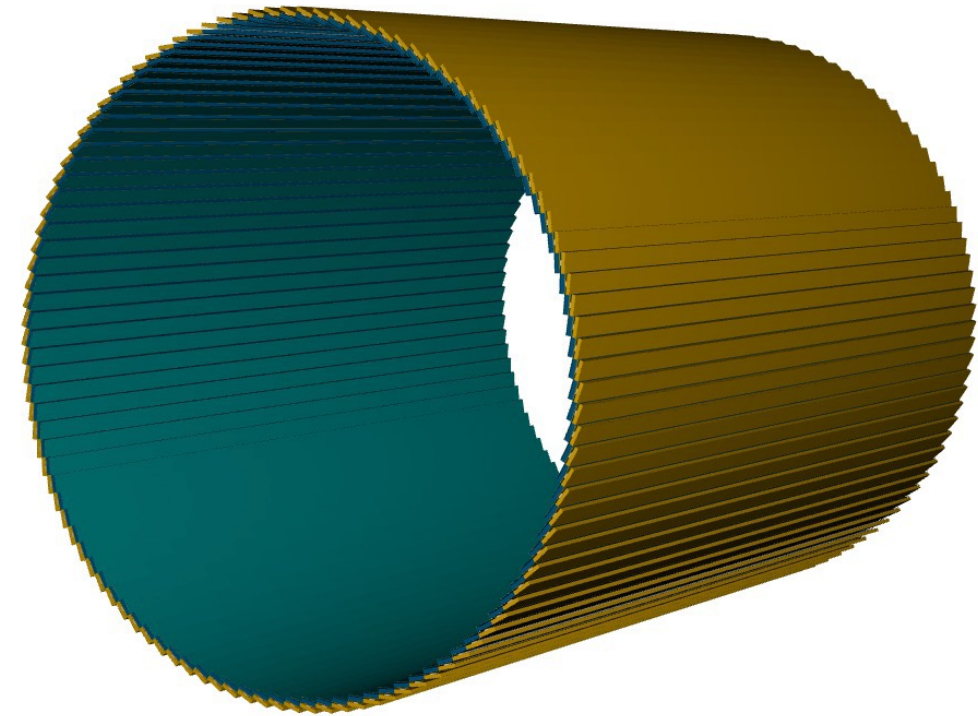
Backward
Endcap ("n")
 $\eta < -1$

Forward
Endcap ("p")
 $\eta > +1$

Barrel TOF in ATHENA Detector Proposal

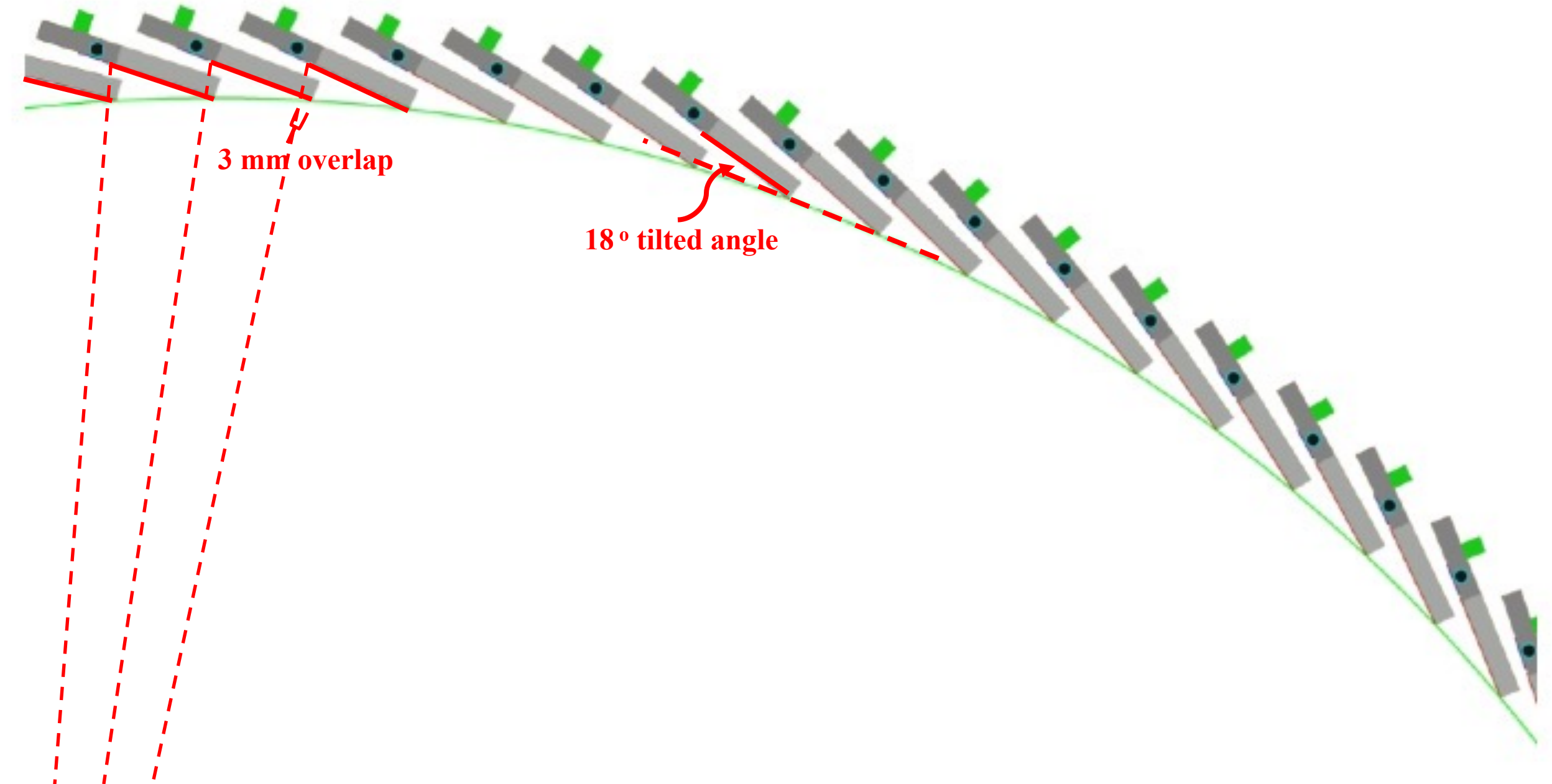
- **Single layer of AC-LGAD**
 - ~100% fill factor, excellent timing for PID below DIRC threshold, and possibly good spatial measurements for tracking as well
- **Placement: $R \sim 52.5$ cm**
 - not too close to the beam to have a reasonable $1/\beta$ resolution for PID, but also not too far from the beam to detect very low momentum particles in the 3 Tesla magnetic field
- **Strip readout electrodes, with $500 \mu\text{m}$ pitch in $r\phi$ and $O(1 \text{ cm})$ length in z**
 - Minimize material budget by reducing the readout channel density, and thus impact on tracking and Ecal
 - Space point with precise $r\phi$ measurement for improved momentum reconstruction

Barrel TOF in ATHENA Detector Proposal



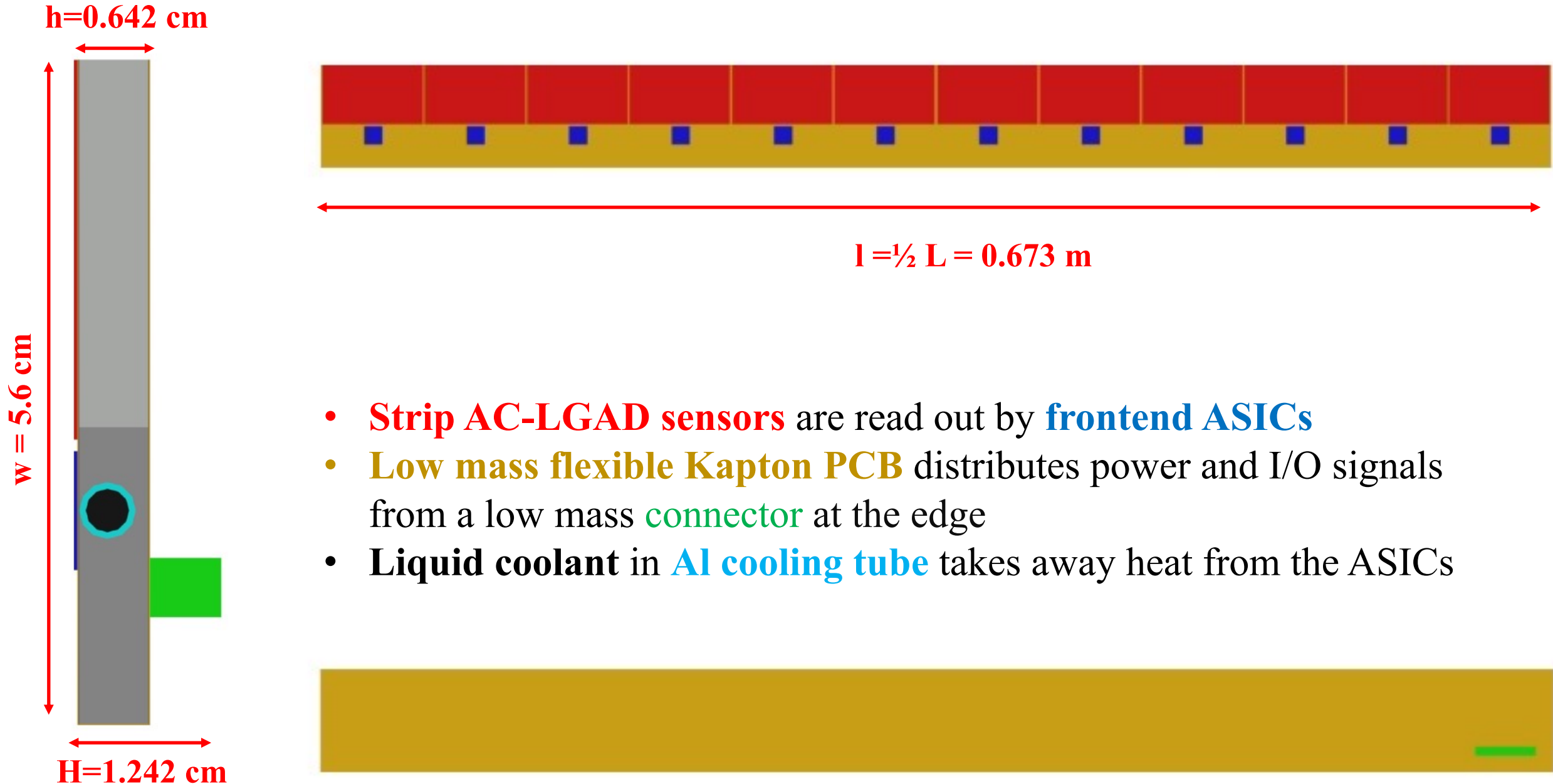
ATHENA Barrel TOF Detector Layout

Full azimuthal coverage



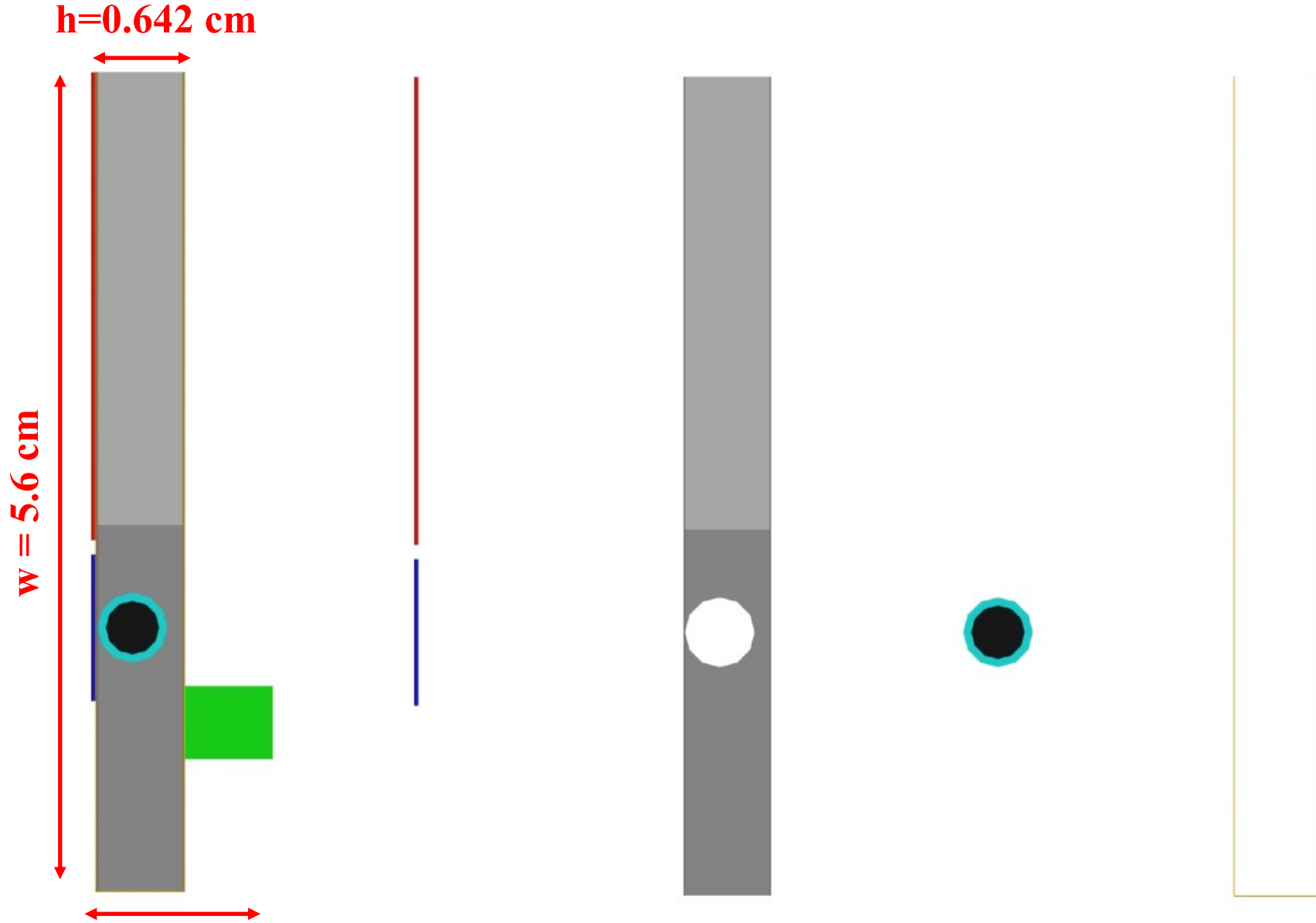
ATHENA Barrel TOF Module

98 % coverage in Z



- **Strip AC-LGAD sensors** are read out by **frontend ASICs**
- **Low mass flexible Kapton PCB** distributes power and I/O signals from a low mass **connector** at the edge
- **Liquid coolant** in **Al cooling tube** takes away heat from the ASICs

ATHENA Barrel TOF Module

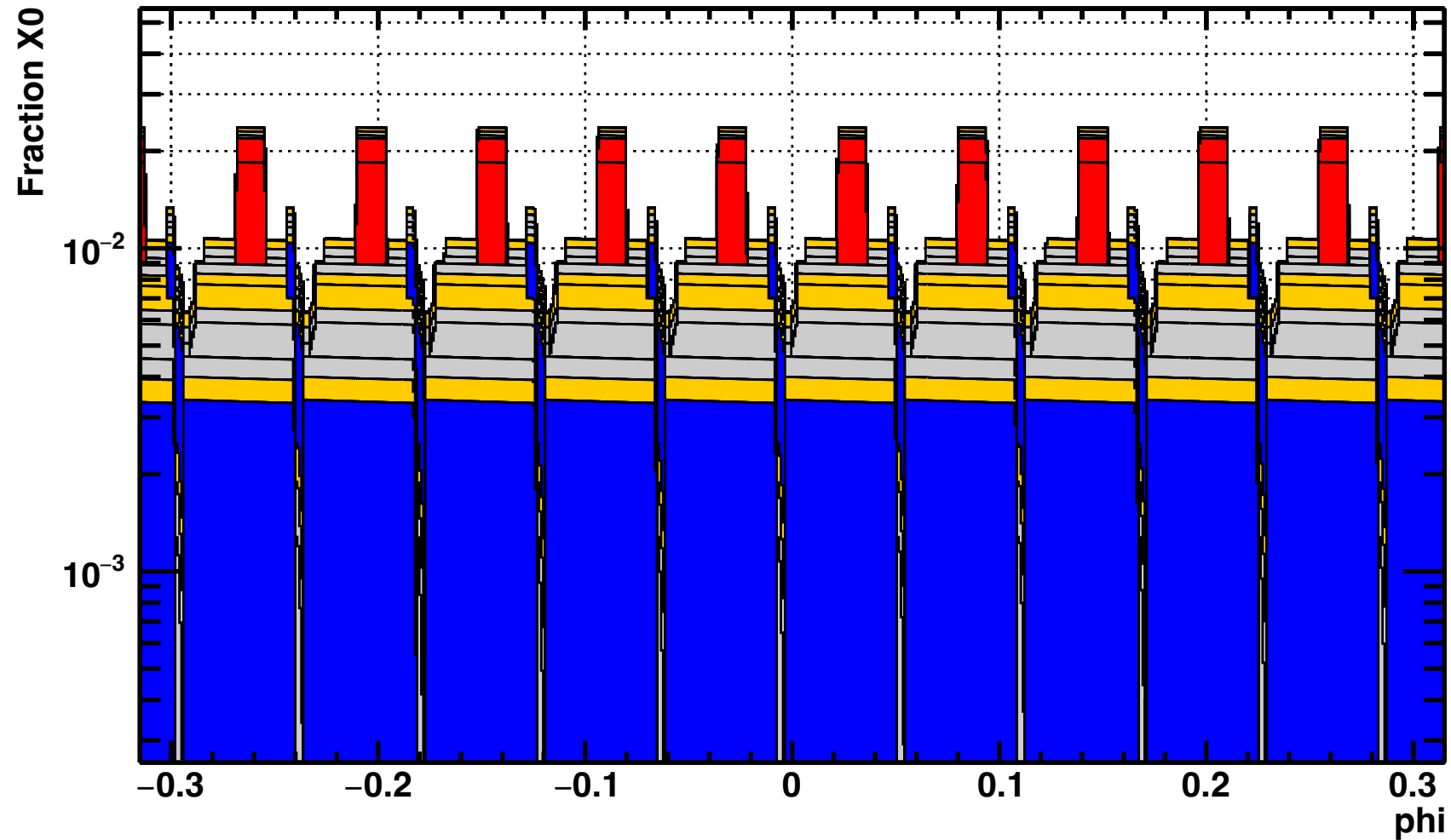


- **AC-LGAD sensor**
- **Frontend ASICs**
- Carbon foam+
Carbon honeycomb+
CF skins
- **Al cooling tube**
- **Liquid coolant**
- **Kapton PCB**
- **Connector**



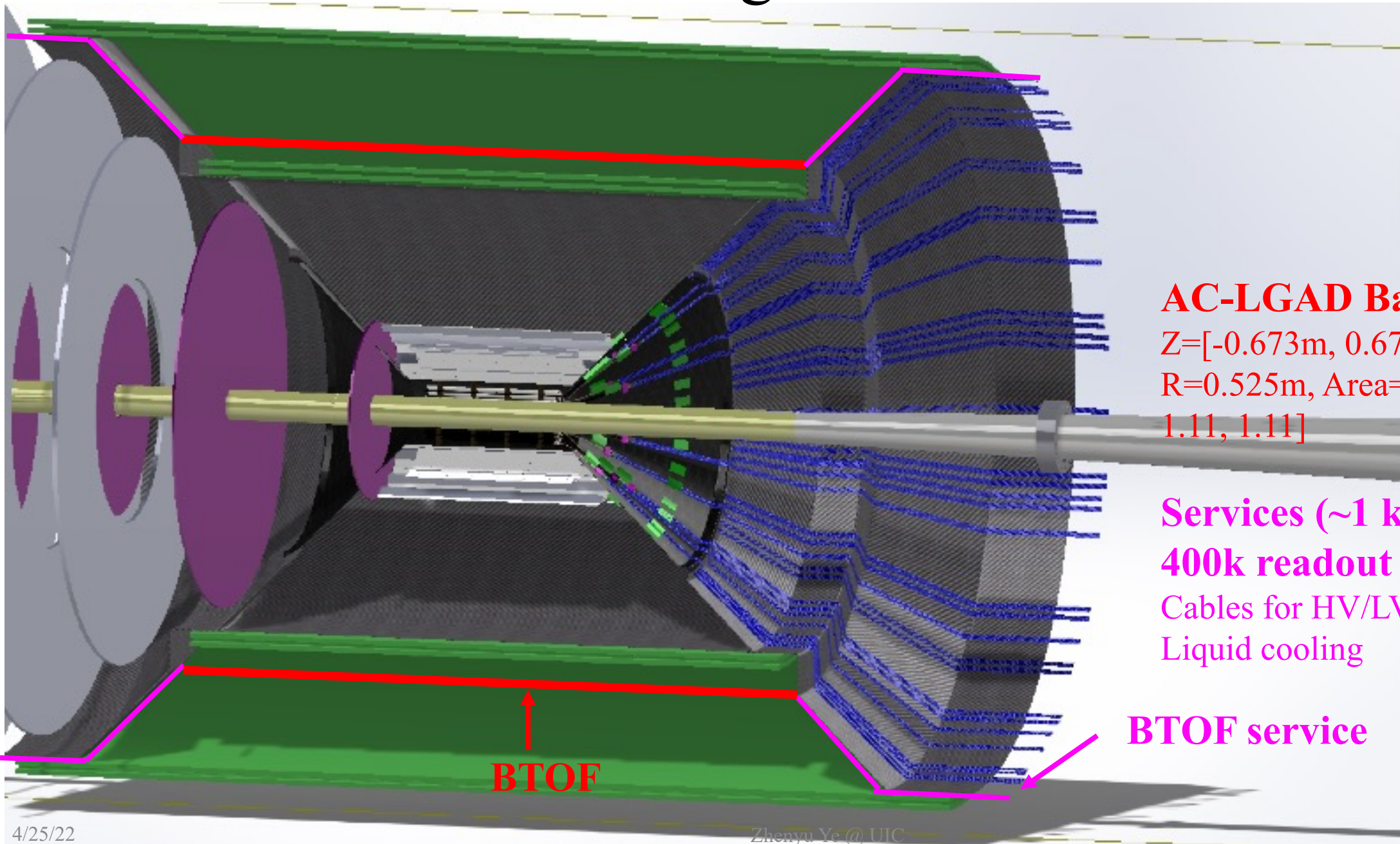
ATHENA Barrel TOF Material Budget

Material Scan ($51 \text{ cm} < \rho < 55 \text{ cm}$, $-120 \text{ cm} < z < 120 \text{ cm}$)



Average material budget $\sim 1\% X_0$

ATHENA Barrel TOF Integration



AC-LGAD Barrel TOF
 $Z=[-0.673\text{m}, 0.673\text{m}]$,
 $R=0.525\text{m}$, Area= 4.9 m^2 , Eta= $[-1.11, 1.11]$

Services (~1 kW with 400k readout channels)
Cables for HV/LV, I/O signals
Liquid cooling

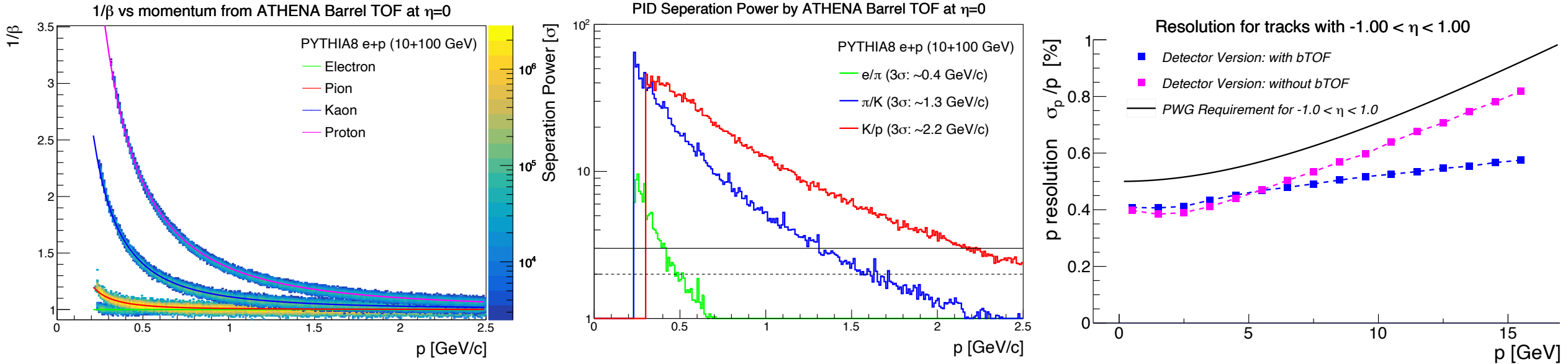
BTOF service

ATHENA Barrel TOF Cost Estimate

- Total cost on project: **\$8.2M = \$5.1M M&S + \$3.1M Labor**
 - includes \$3.4M for R&D, prototyping and final design optimization that will be shared with B0, RPs, and other EIC experiments with AC-LGAD
- Total in-kind cost: **\$0.85M = \$50k M&S + \$0.80M Labor**
 - All the cost is for R&D, prototyping and final design optimization that will be shared with B0, RPs, and other EIC experiments with AC-LGAD

Total construction cost ~ \$6M

ATHENA TOF Performance in Simulation



- ToF provides low momentum PID, covering the gap below the DIRC threshold
 - TOF: pion/kaon 0.2-1.3 GeV/c vs DIRC > 0.47 GeV/c
- The spatial hit from ToF improves tracking performance at higher momenta.