AC-LGAD TOF for ATHENA

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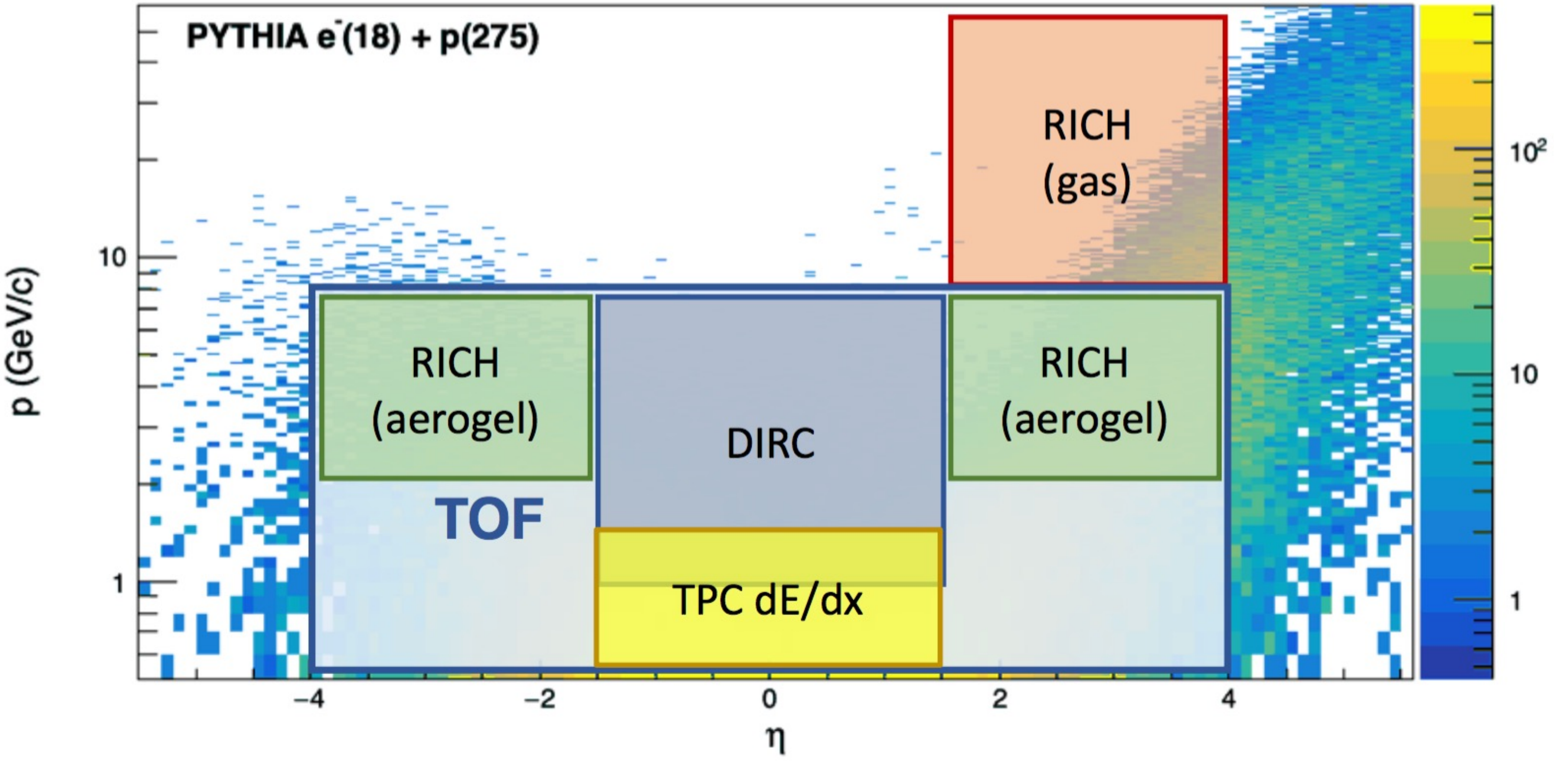
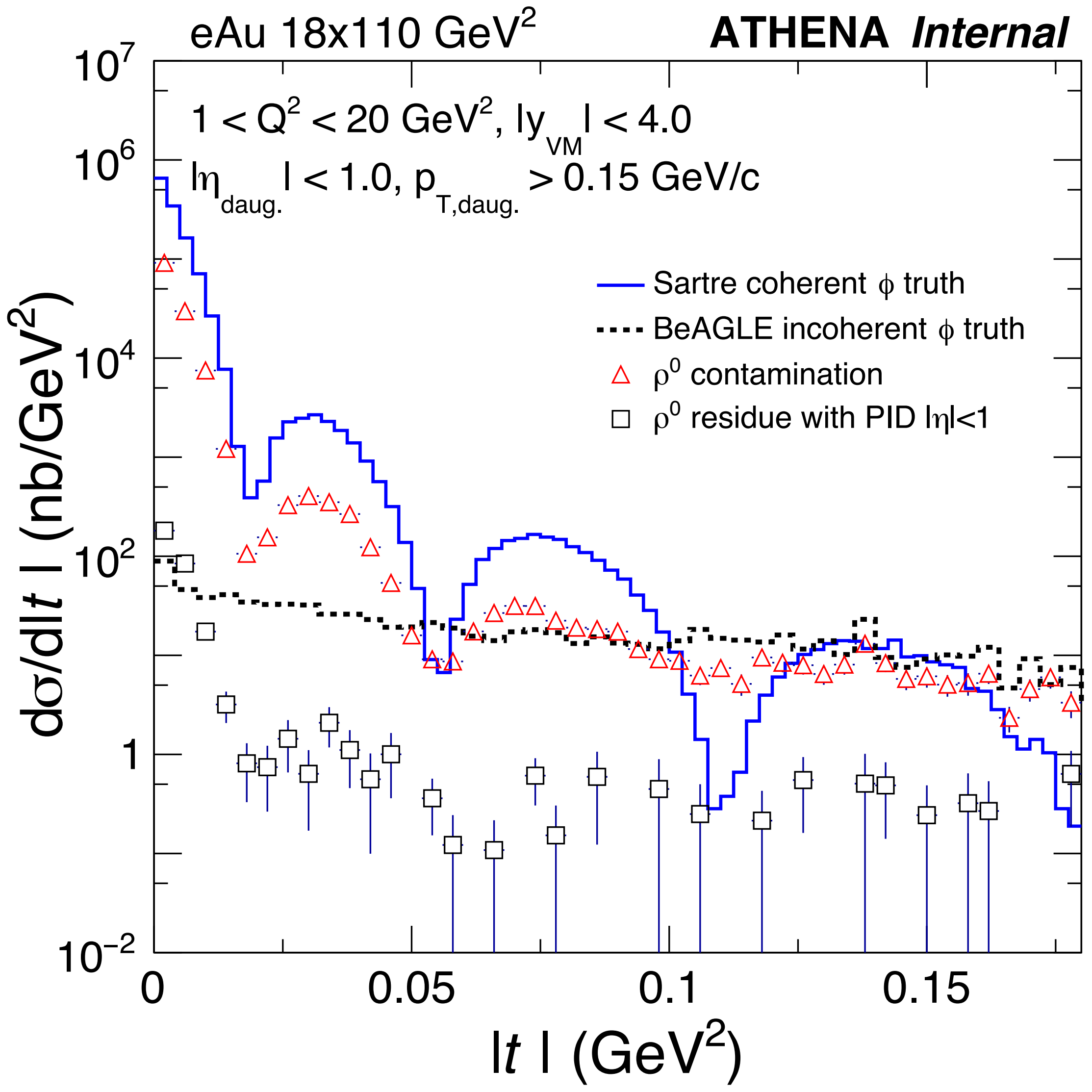
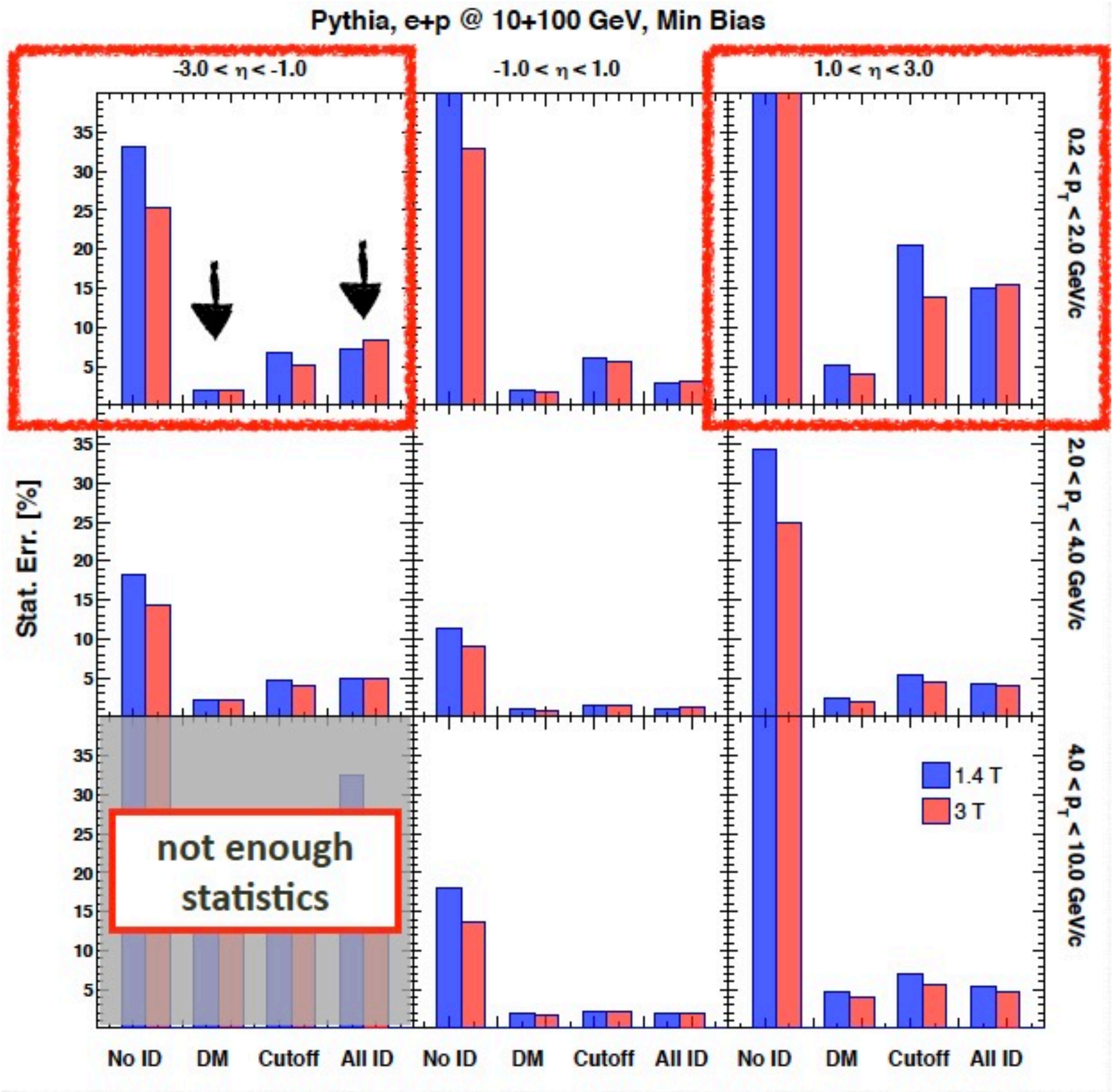


Low pT PID for Physics Measurements at EIC

Exclusive ϕ (Z. Tu)

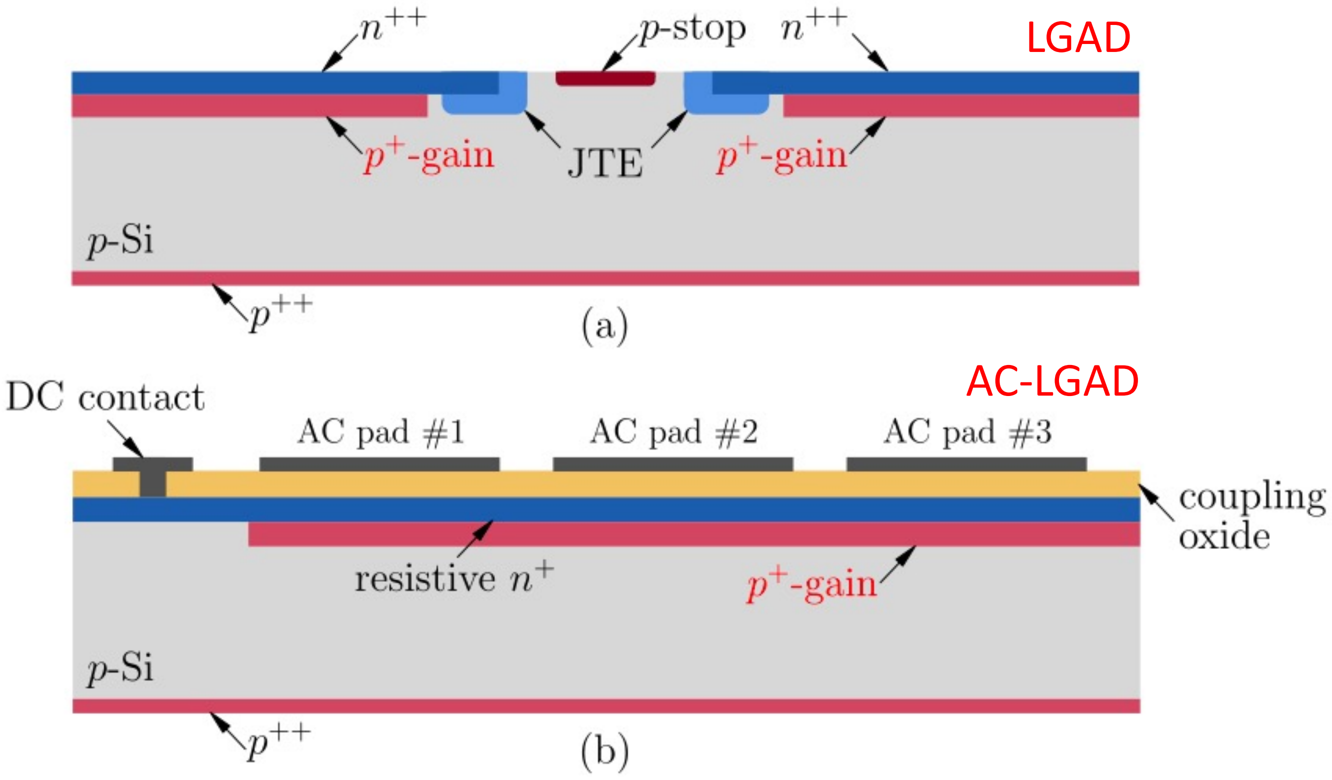


Λ_c (W. Fan)



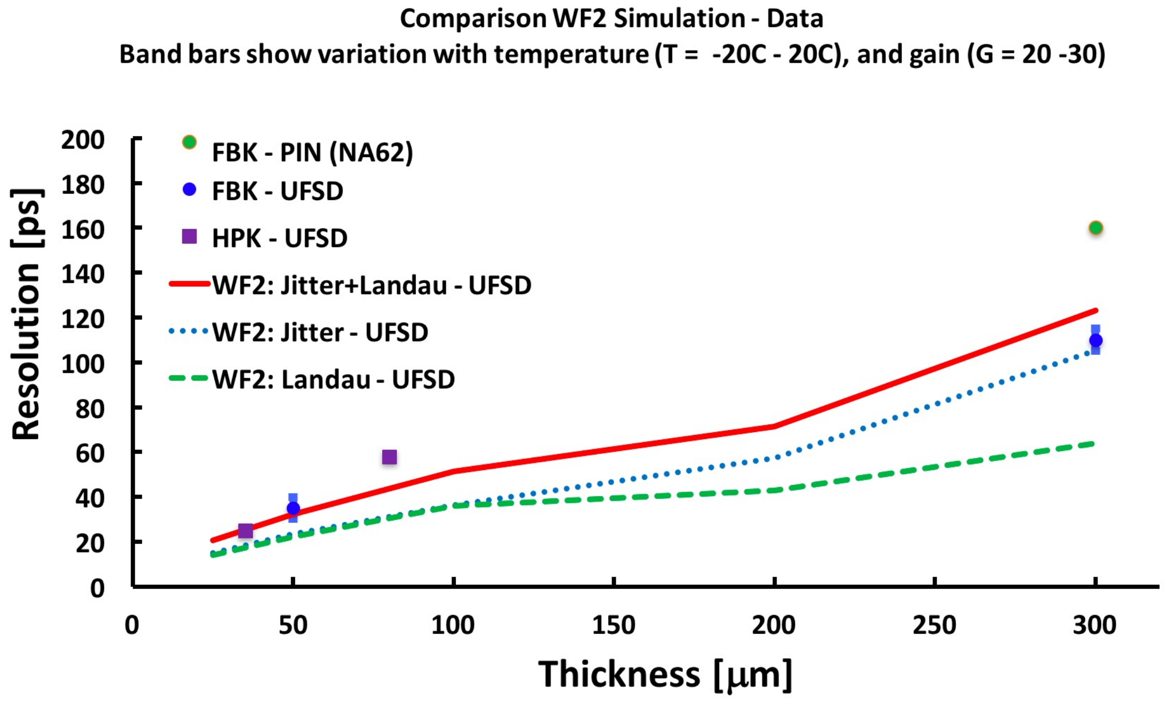
AC-LGAD for EIC

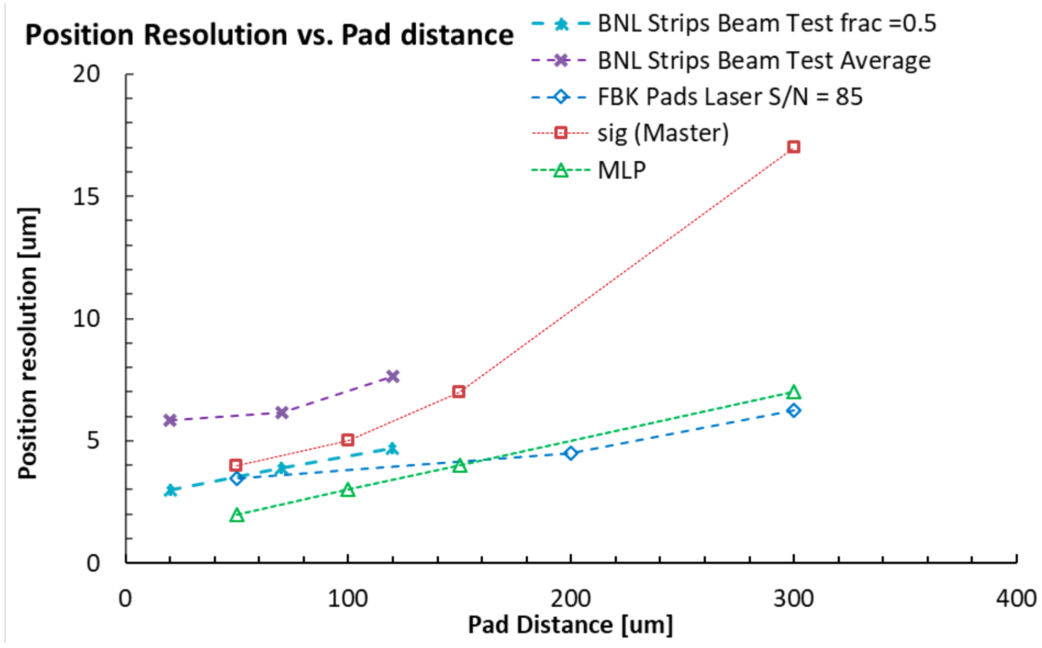
- Large area LGAD detectors are being built by ATLAS (6.4 m^2) and CMS (15.6 m^2) for data taking starting in 2026.
- AC LGAD detectors proposed for EIC
  - Roman Pots and B0
  - TOF for PID (and tracking)
- Have common designs in sensor, ASIC etc. when possible, combine R&D efforts



	Time resolution / hit	Position resolution / hit	Material budget / layer
Barrel ToF (Tracker)	<30 ps	(3-30 μm for Tracker)	$< 0.01\ X_0$
Endcap ToF (Tracker)	<25 ps	(30-50 μm for Tracker)	e-direction $< 0.05X_0$ h-direction $< 0.15X_0$
Roman Pots	<50 ps	$< 500/\sqrt{12}\ \mu m$	N/A
B0	<50 ps	$O(50)\ \mu m$	$< 0.01\ X_0$

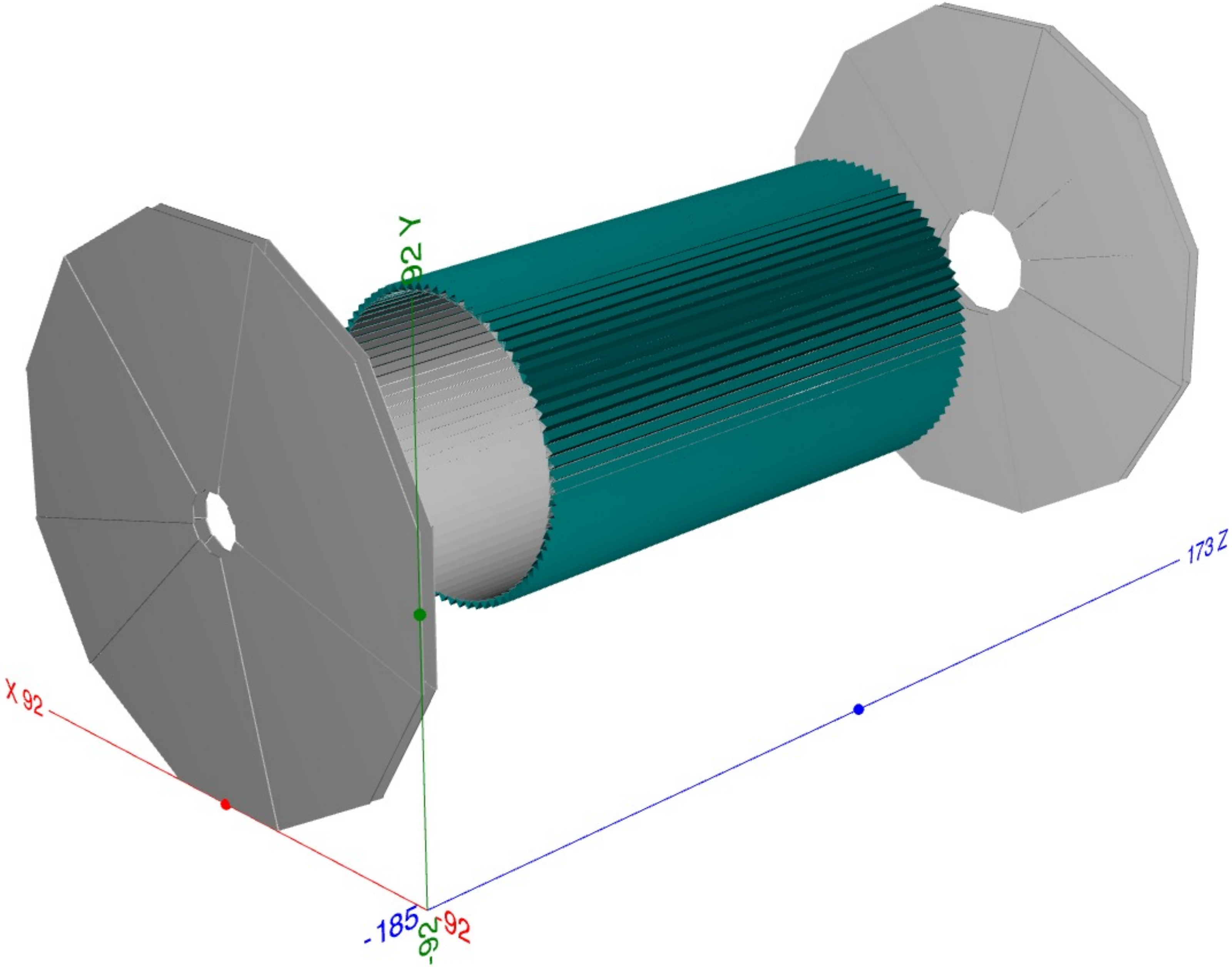
Sensor R&D





- **R&D Goals**
  - 15-20 ps timing resolution, O(3-50μm) position resolution where needed
  - Minimal readout channel density (long strip, rectangular pixel) for reduced power and thus material and cost
- **Plan**
  - Produce and test sensors with thinner active volume to achieve the desired timing resolution
  - Optimize implantation parameters and AC-pad segmentation through simulation and real device studies
  - Engage commercial vendors to improve fabrication process and yield

AC-LGAD TOF Detectors for EIC – eRD112



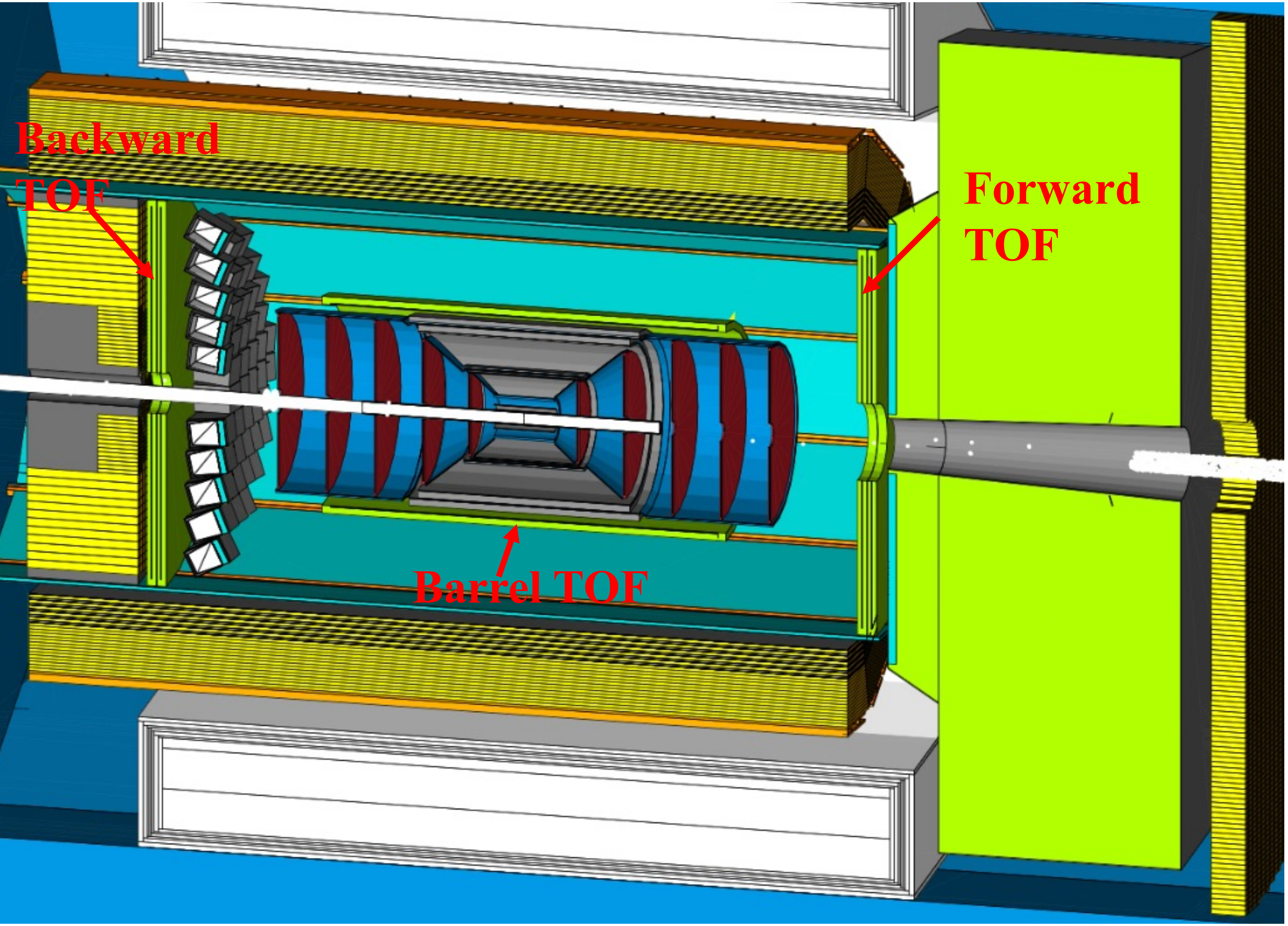
Barrel TOF
Single layer with 30 ps resolution and $2\%X_0$ material budget per layer

Forward TOF
Double layer with 25 ps resolution and $5\%X_0$ material budget per layer

Backward TOF
Double layer with 25 ps resolution and $5\%X_0$ material budget per layer

START Time
20 ps resolution

AC-LGAD TOF Detectors in ATHENA DD4HEP

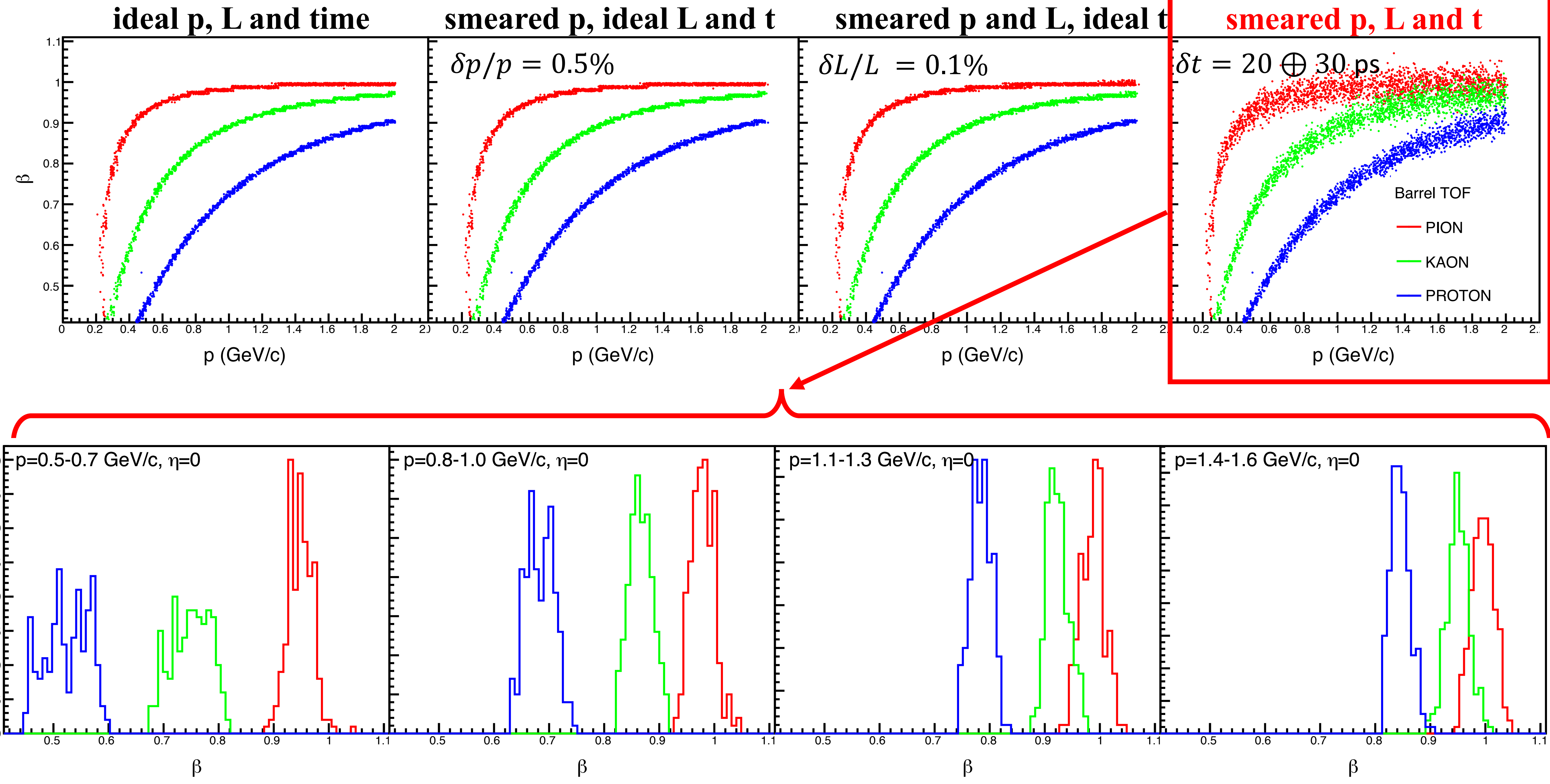


Barrel TOF (Area=6.28m^2)
Z=[-1m, 1m], R=0.5m,
Eta=[-1.44, 1.44]

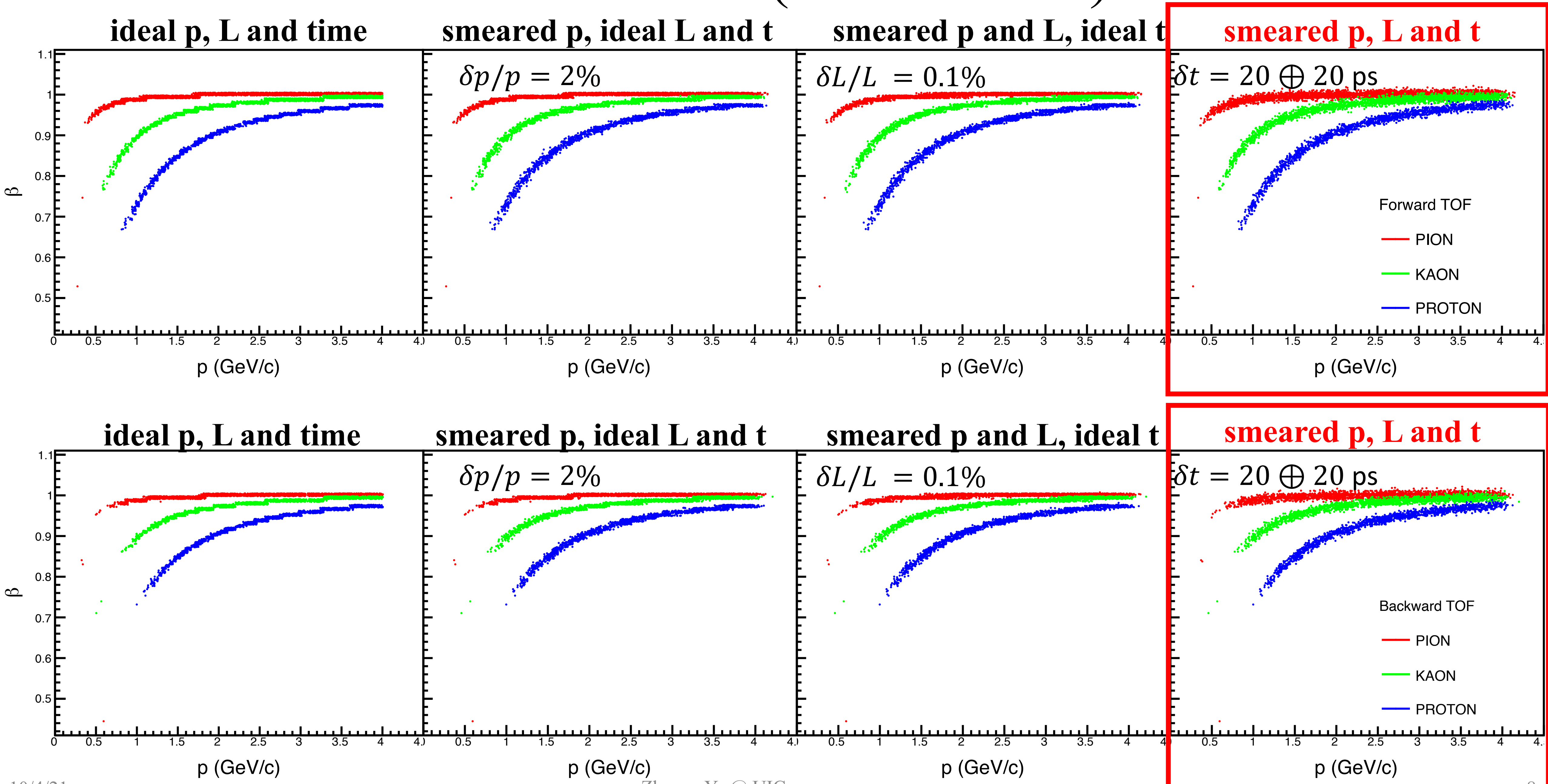
Forward TOF (Area=5.44m^2)
Z=1.73m, R_{in}=0.19m, R_{out}=0.95m
Eta=[1.36, 2.91]

Backward TOF (Area=5.44m^2)
Z=-1.85m, R_{in}=0.19cm, R_{out}=0.95m,
Eta=[-2.97,-1.42]

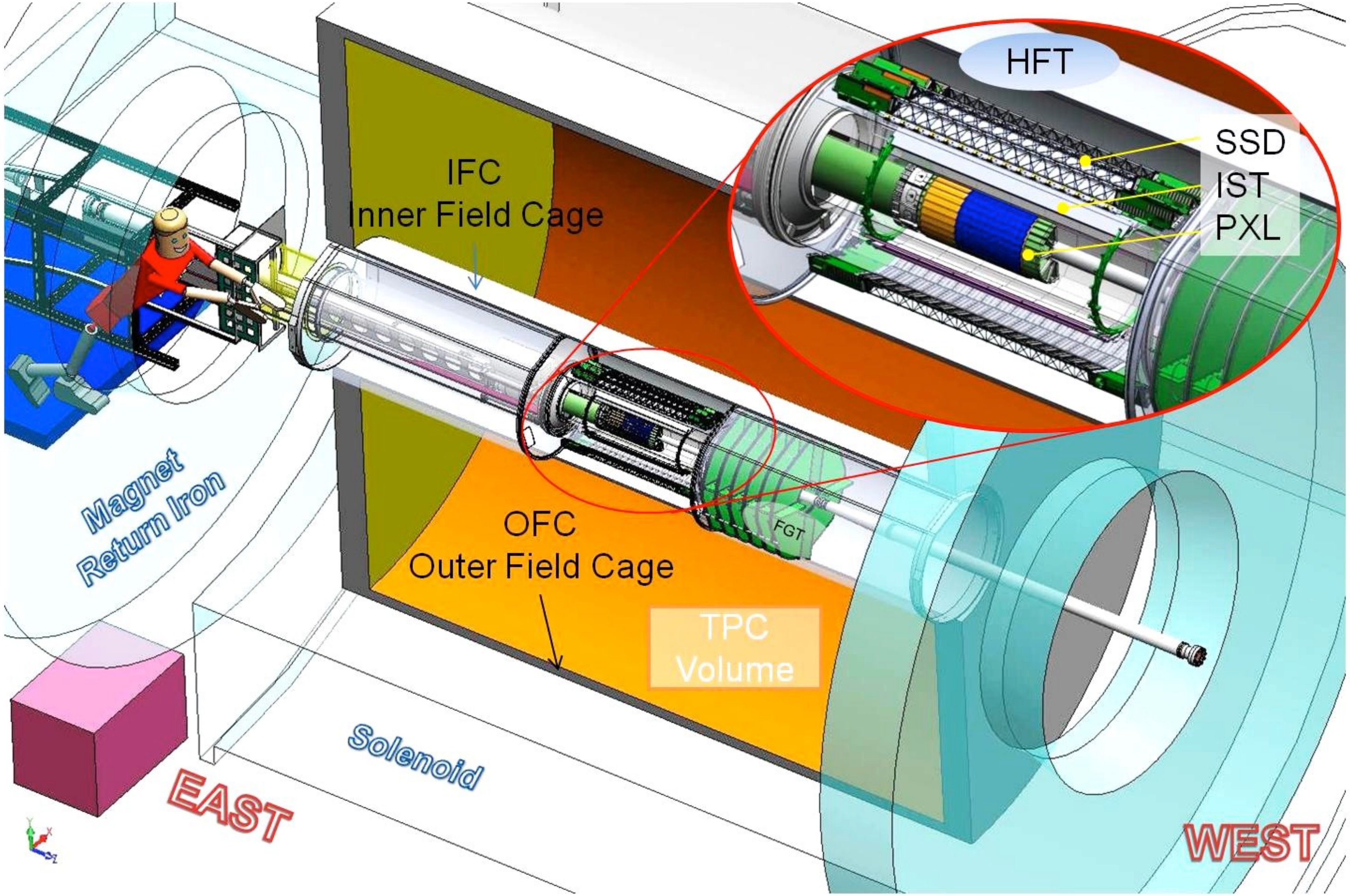
Barrel TOF (eta=0)



Forward and Backward TOF (eta=+/-2.25)



AC-LGAD Barrel TOF Detector for EIC – STAR IST



AC-LGAD Barrel TOF Detector for EIC – STAR IST

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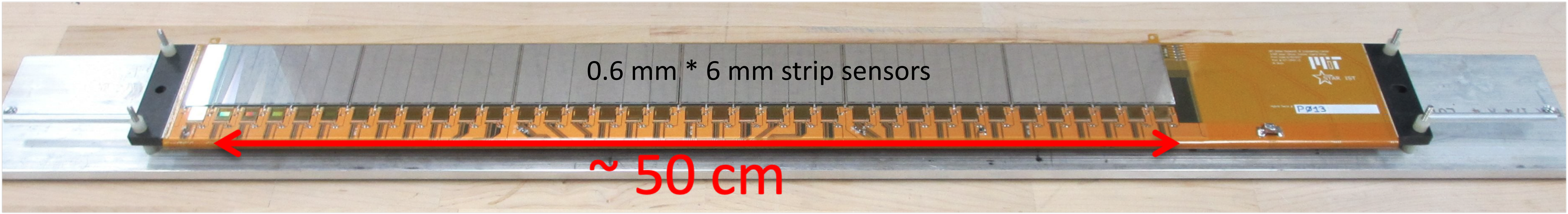
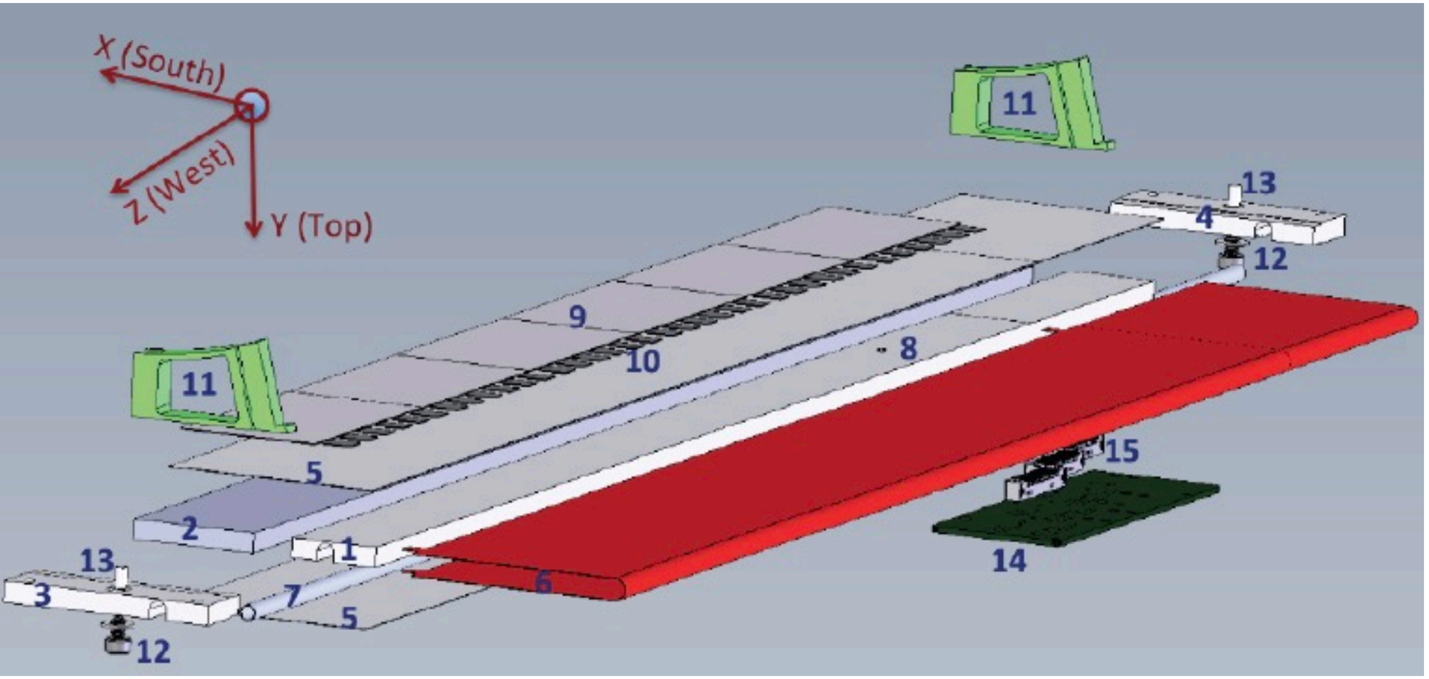
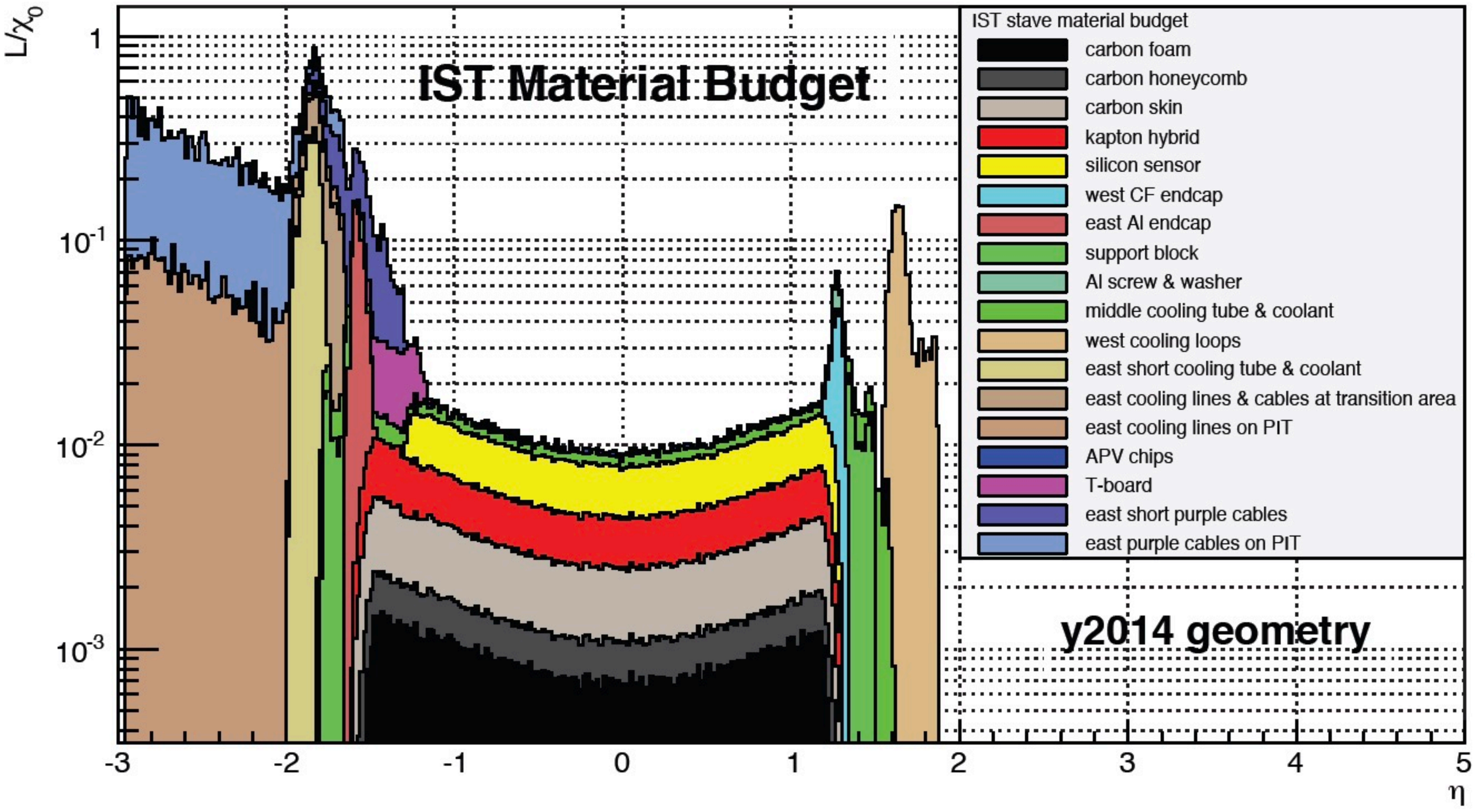


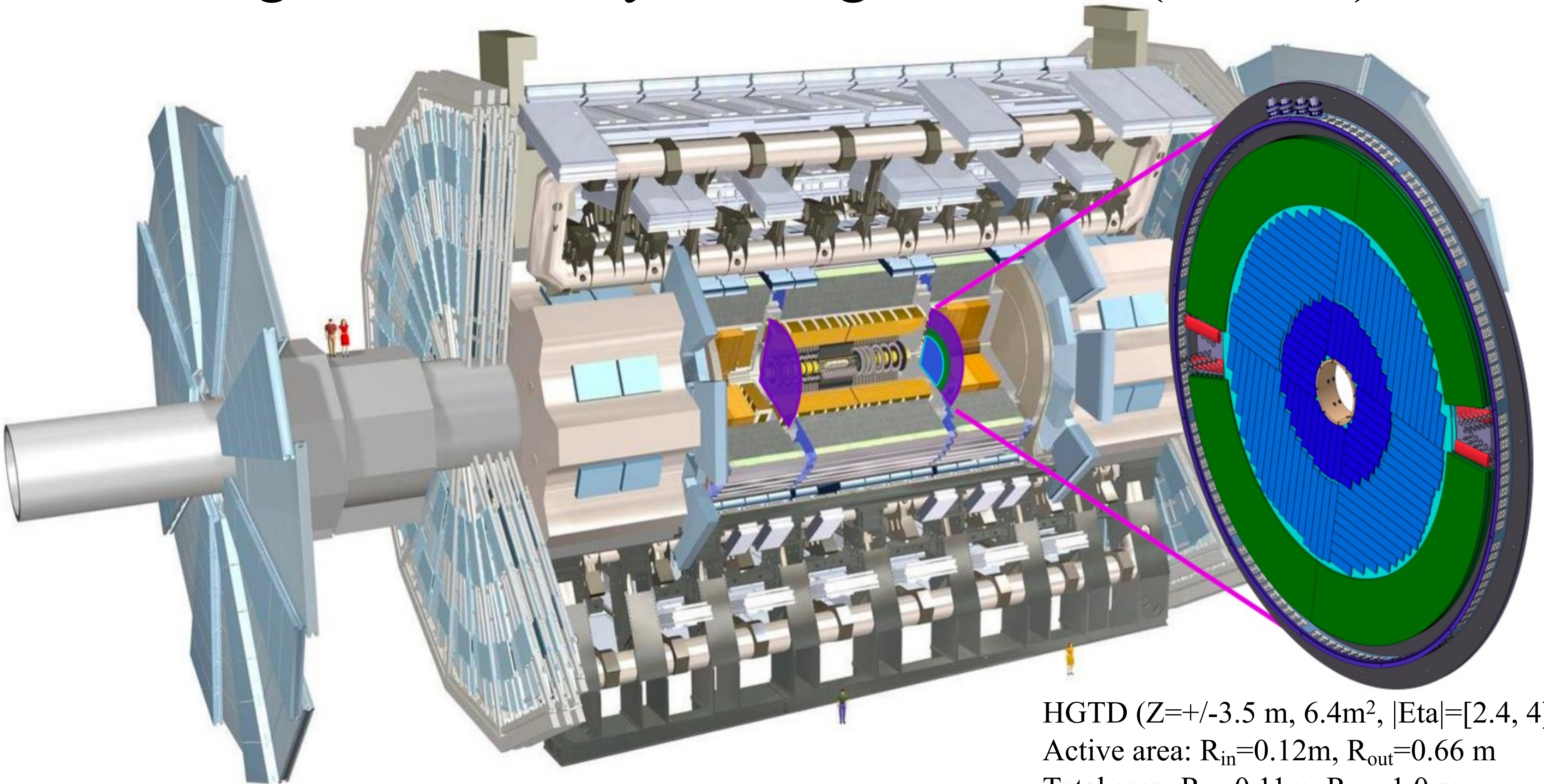


1) carbon foam 2) carbon honeycomb 3) west carbon end-cap 4) east Al end-cap 5) carbon fiber skins 6) Kapton hybrid 7) Al cooling tube with cooling liquid inside 8) thermal sensor 9) silicon sensors 10) APV chips 11) support blocks 12) screws with washers 13) spacers 14) transition board 15) readout connectors.

AC-LGAD Endcap TOF Detectors for EIC – STAR IST



ATLAS High Granularity Timing Detector (HGTD)



HGTD ($Z=+/-3.5$ m, $6.4m^2$, $|Eta|=[2.4, 4]$)
Active area: $R_{in}=0.12m$, $R_{out}=0.66$ m
Total area: $R_{in}=0.11m$, $R_{out}=1.0$ m
# of channels: 3.6M $1.3x1.3mm^2$

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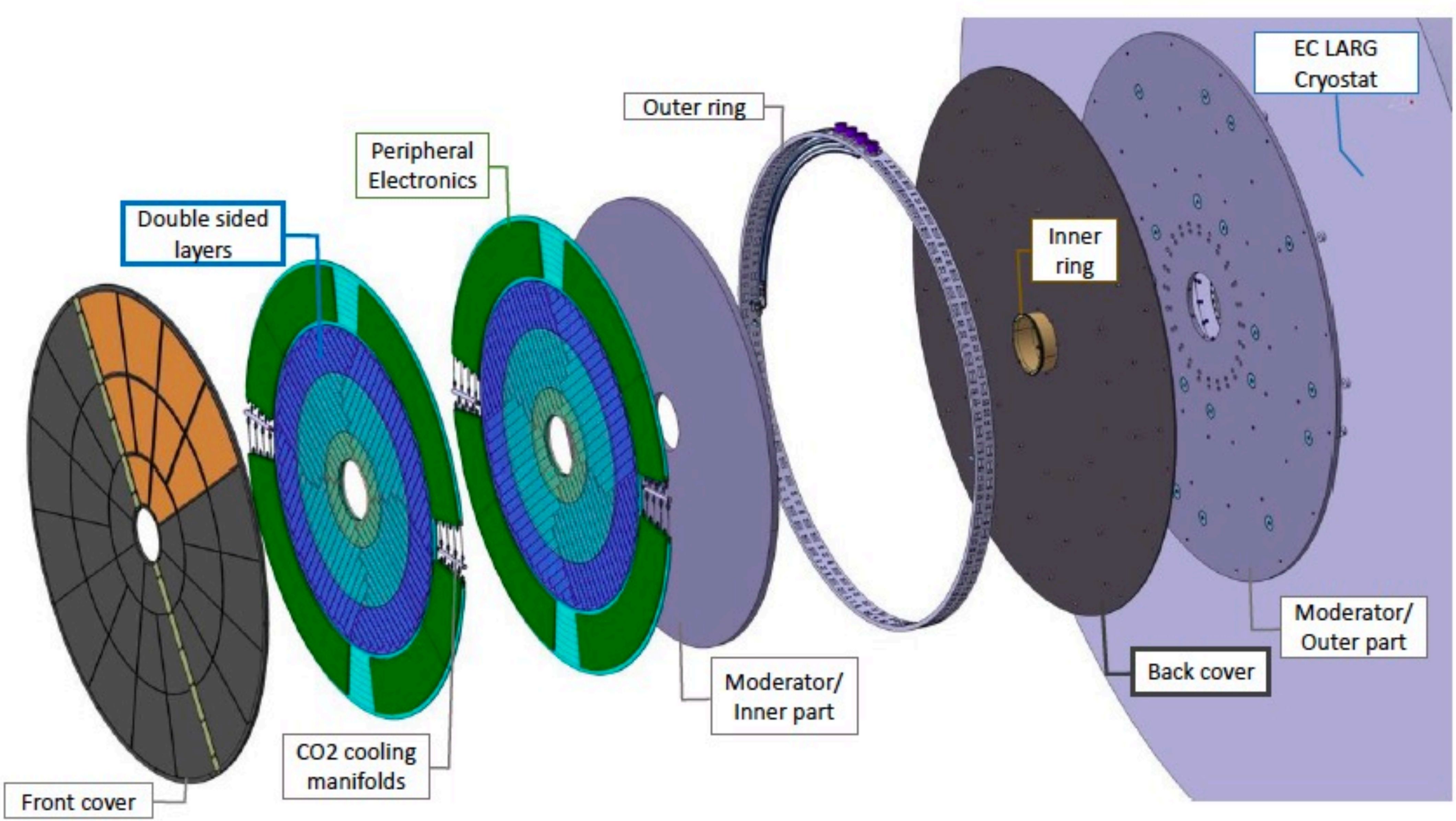


ATLAS High Granularity Timing Detector (HGTD)

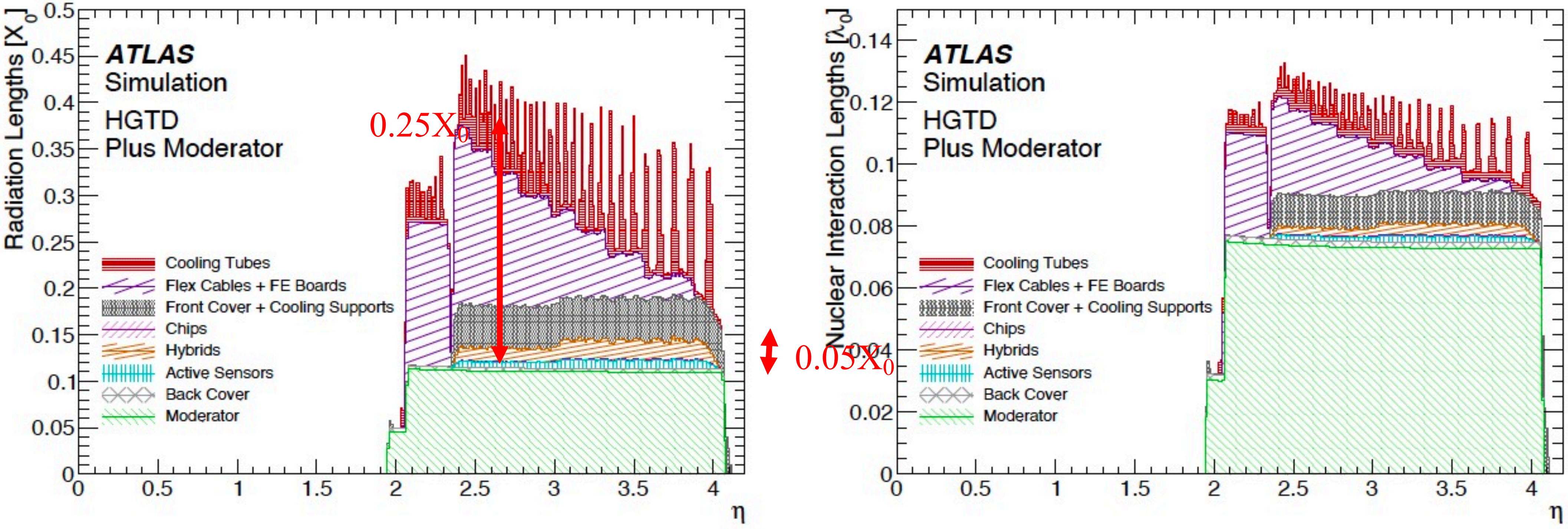
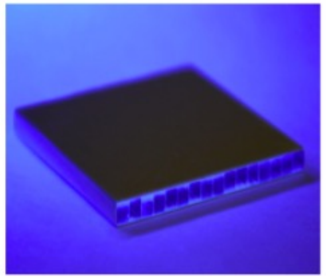


Figure 2.12: Radiation length X_0 (left) and nuclear interaction length λ_0 (right) as a function of pseudo-rapidity η, broken down by type of material for the HGTD, using the simulation of the two ring detector geometry described in Section 3.1.1. The moderator is included as it is within the hermetic vessel, although it is situated behind the active area of the HGTD. The baseline cooling pipes will be made with titanium instead of stainless steel as used in the simulation and material plots shown in this figure. The resulting radiation and nuclear interaction lengths will also be reduced with titanium cooling pipes.

CMS MIP Timing Detector (MTD) - Endcap Timing Layer

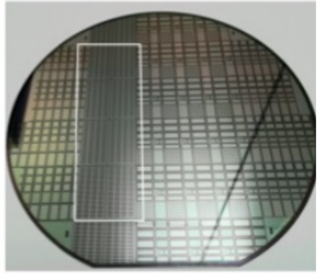
BTL: LYSO bars + SiPM readout:

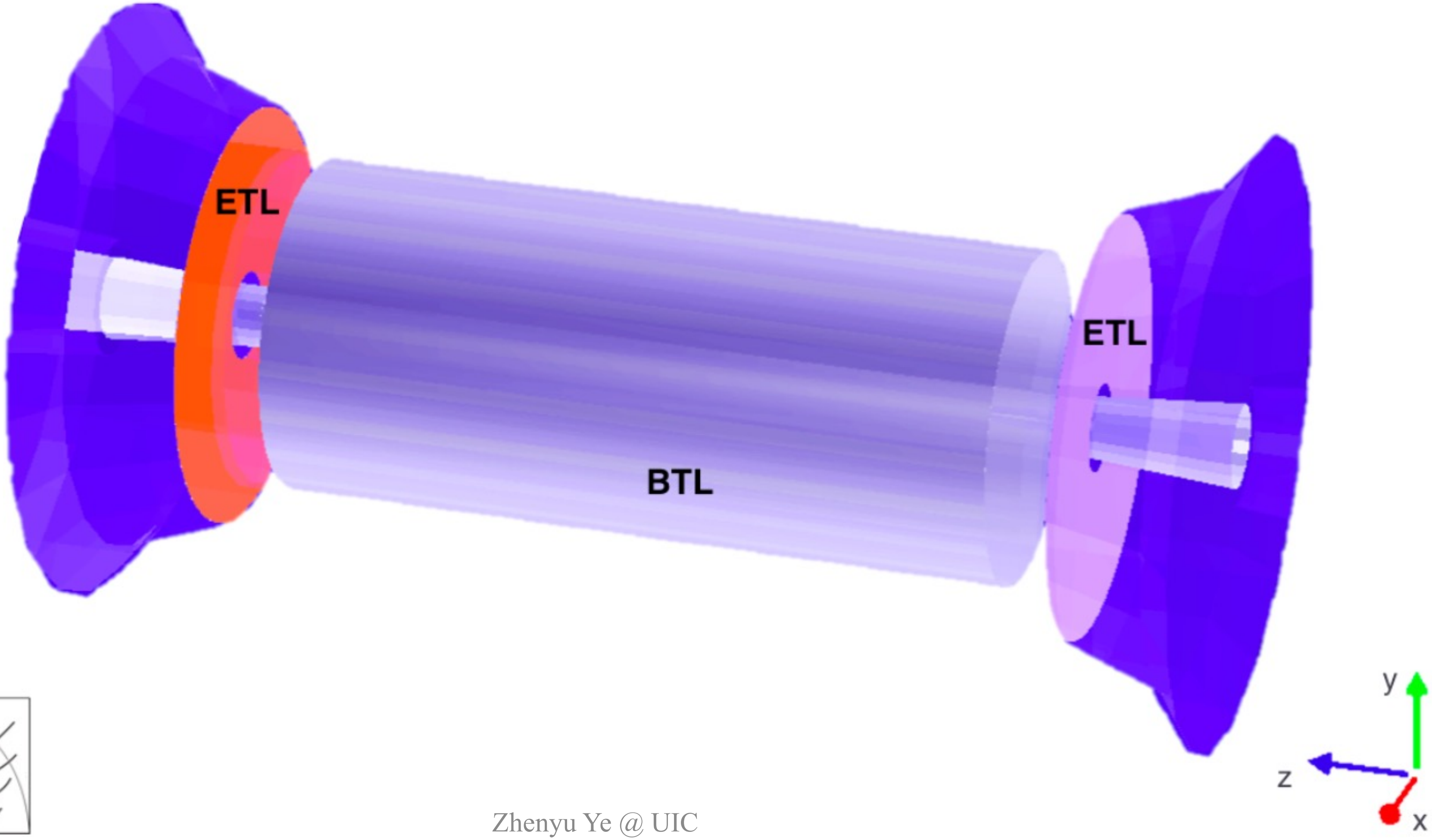
- TK / ECAL interface: |η| < 1.45
- Inner radius: 1148 mm (40 mm thick)
- Length: ±2.6 m along z
- Surface ~38 m^2; 332k channels
- Fluence at 4 ab^{-1}: 2x10^{14} n_{eq}/cm^2



ETL: Si with internal gain (LGAD):

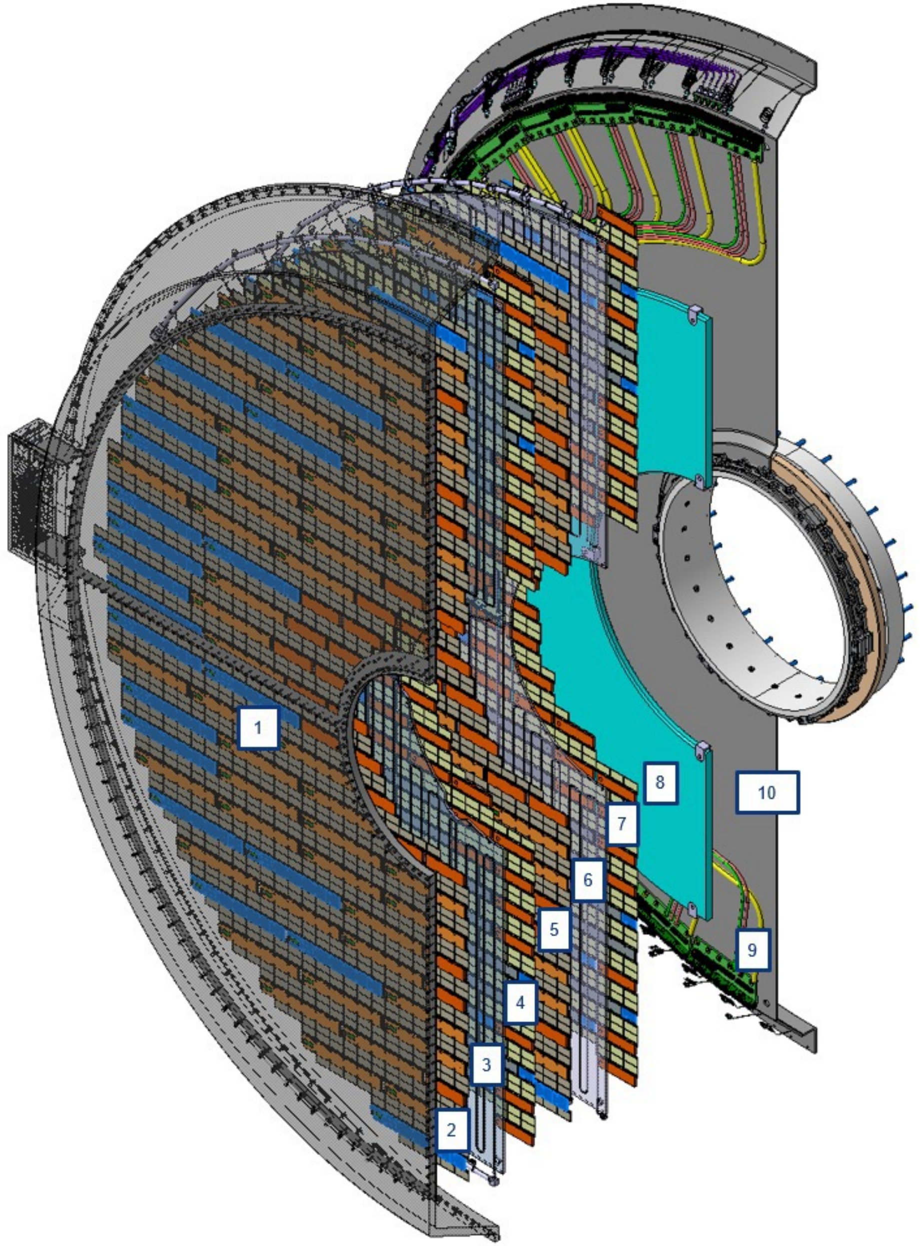
- On the CE nose: 1.6 < |η| < 3.0
- Radius: 315 < R < 1200 mm
- Position in z: ±3.0 m (45 mm thick)
- Surface ~14 m^2; ~8.5M channels
- Fluence at 4 ab^{-1}: up to 2x10^{15} n_{eq}/cm^2



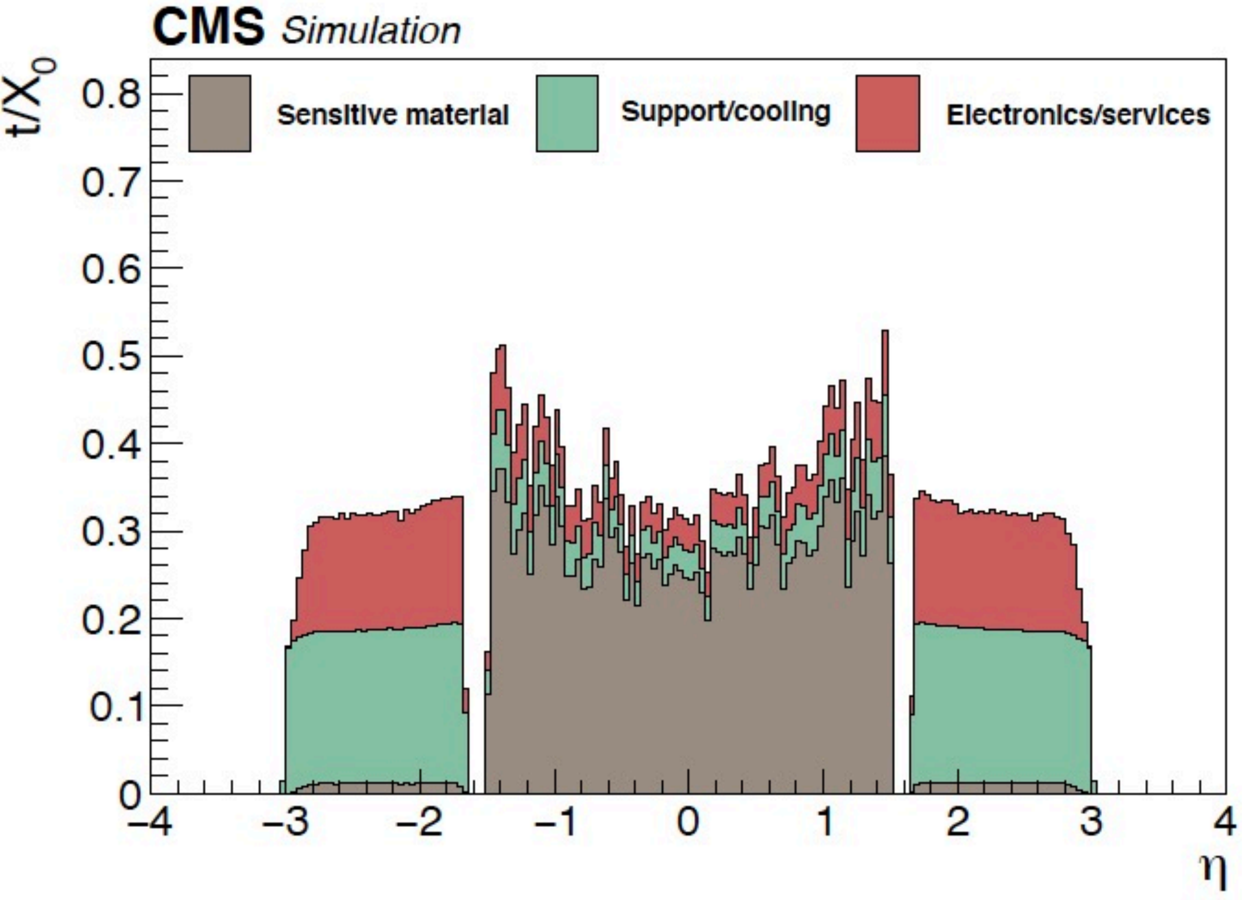


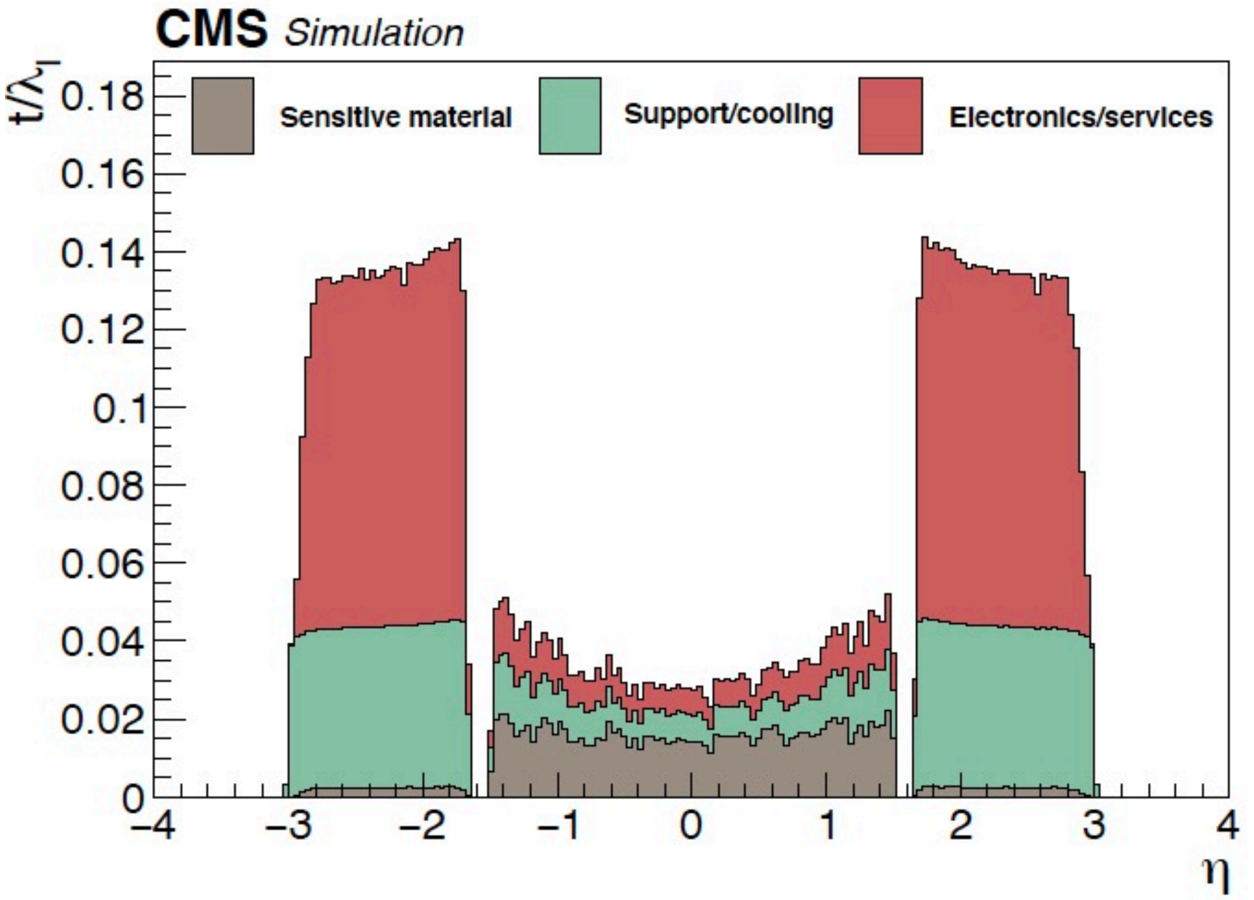
CMS MIP Timing Detector (MTD) - Endcap Timing Layer

Element	Elements in Z
1	Thermal screen
	Gap between thermal screen and front disc
2	Front face of electronics of the front DEE
3	Front disc
4	Rear face of electronics of the front DEE
	Gap between front and back discs
5	Front face of electronics of the back DEE
6	Back disc
7	Rear face of electronics of the back DEE
	Gap between cables and back disc
8 + 9	Patch panels 0 + cables [9] + moderator [8] at the innermost section
10	Back support plate
	Gap between ETL back support plate and HgCal thermal screen



CMS MIP Timing Detector (MTD) - Endcap Timing Layer





Relative contributions in radiation length
~5% from sensor+ASIC
~20% from module service
~30% from frontend electronics boards
~45% from support structure (Al) and cooling

AC-LGAD Endcap TOF Detectors for EIC – eRD112

	pixel/strip size (mm*mm)	# of channels per unit area (abs)	Power per channel (mW)
ATLAS/CMS pixels	1.3*1.3	1	4
Long strip – eRD112	0.5*25	1/7.5	1-2
Rectangle pixel – eRD112	0.5*2.6	4/3	1-2

1. **Much lower irradiation level at EIC than HL-LHC:** Operating AC-LGAD detectors at room temperature (no need for thermal separation from other detectors) without neutron moderator is possible.
2. **Much smaller multiplicity:** Using long strip sensors and reducing ASIC power consumption per channel. Power consumption density could be reduced by ~10. This will dramatically reduce the service materials (readout boards, cables, cooling, etc), and in turn the support structure due to the overall weight reduction.
3. **Using light weight materials for module and support structure.** Further reduce the material budget.