LGADs-based TOF for ECCE

- status of simulations in Fun4All

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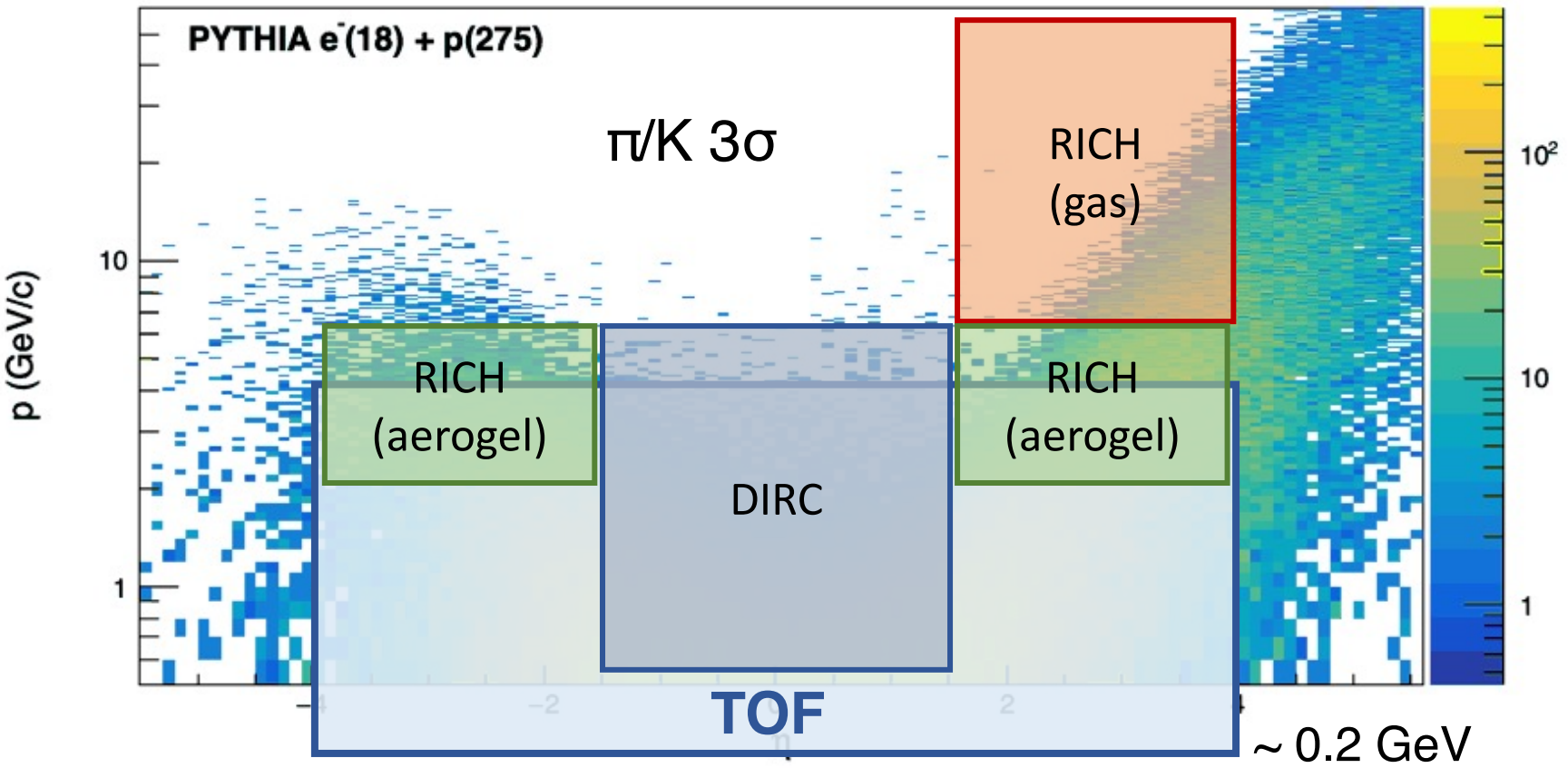
ECCE PID WG meeting
May 20, 2021

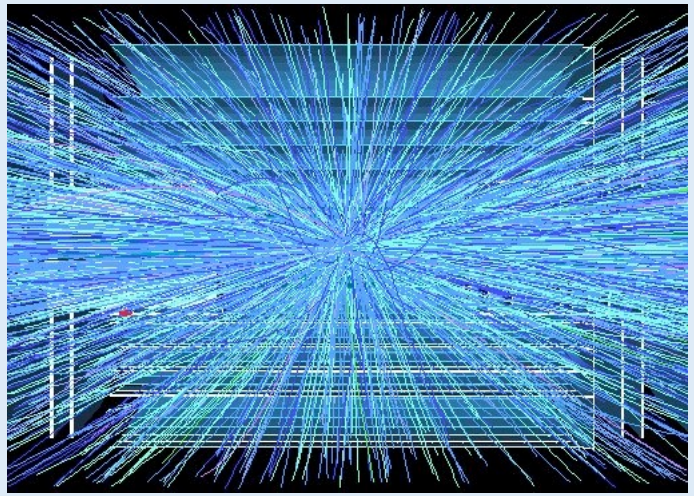
My view on PID@ECCE



η	π/K/p PID	
	p-Range (GeV/c)	Separation
-3.5 — -3.0	YR Table 8.20	
-3.0 — -2.5		
-2.5 — -2.0		
-2.0 — -1.5	≤ 7 GeV/c	
-1.5 — -1.0		
-1.0 — -0.5		
-0.5 — 0.0		
0.0 — 0.5	≤ 10 GeV/c	≥ 3σ
0.5 — 1.0	≤ 15 GeV/c	
1.0 — 1.5	≤ 30 GeV/c	
1.5 — 2.0		
2.0 — 2.5	≤ 50 GeV/c	
2.5 — 3.0	≤ 30 GeV/c	
3.0 — 3.5	≤ 45 GeV/c	

Concept of LGADs sensors

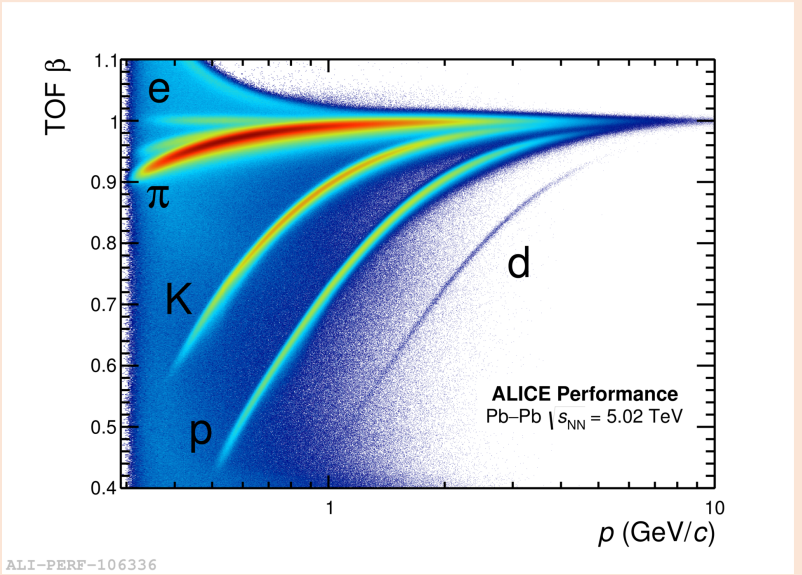
Precision position detectors:



e.g., silicon:

Thin & Light
Segmented
B tolerant
Rad-hard

Precision timing detector:

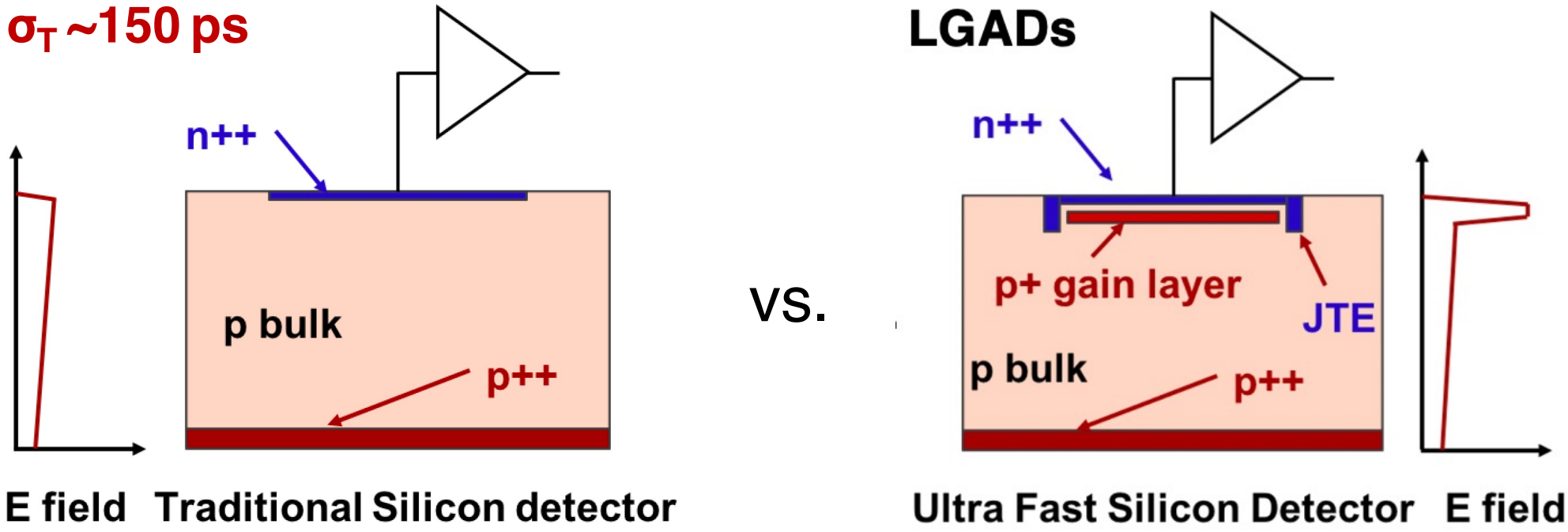


Scintillation
Ionization
+
High gain

LGADs sensors:
precision **position** and **timing**

Low Gain Avalanche Diodes (LGADs)

High E field → larger, faster signal → better timing resolution

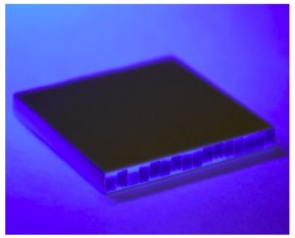


Adding an extra doping layer

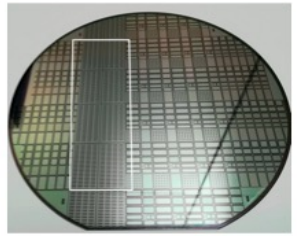
- E ~ 300 kV/cm, close to breakdown

LGADs at the HL-LHC (2028)

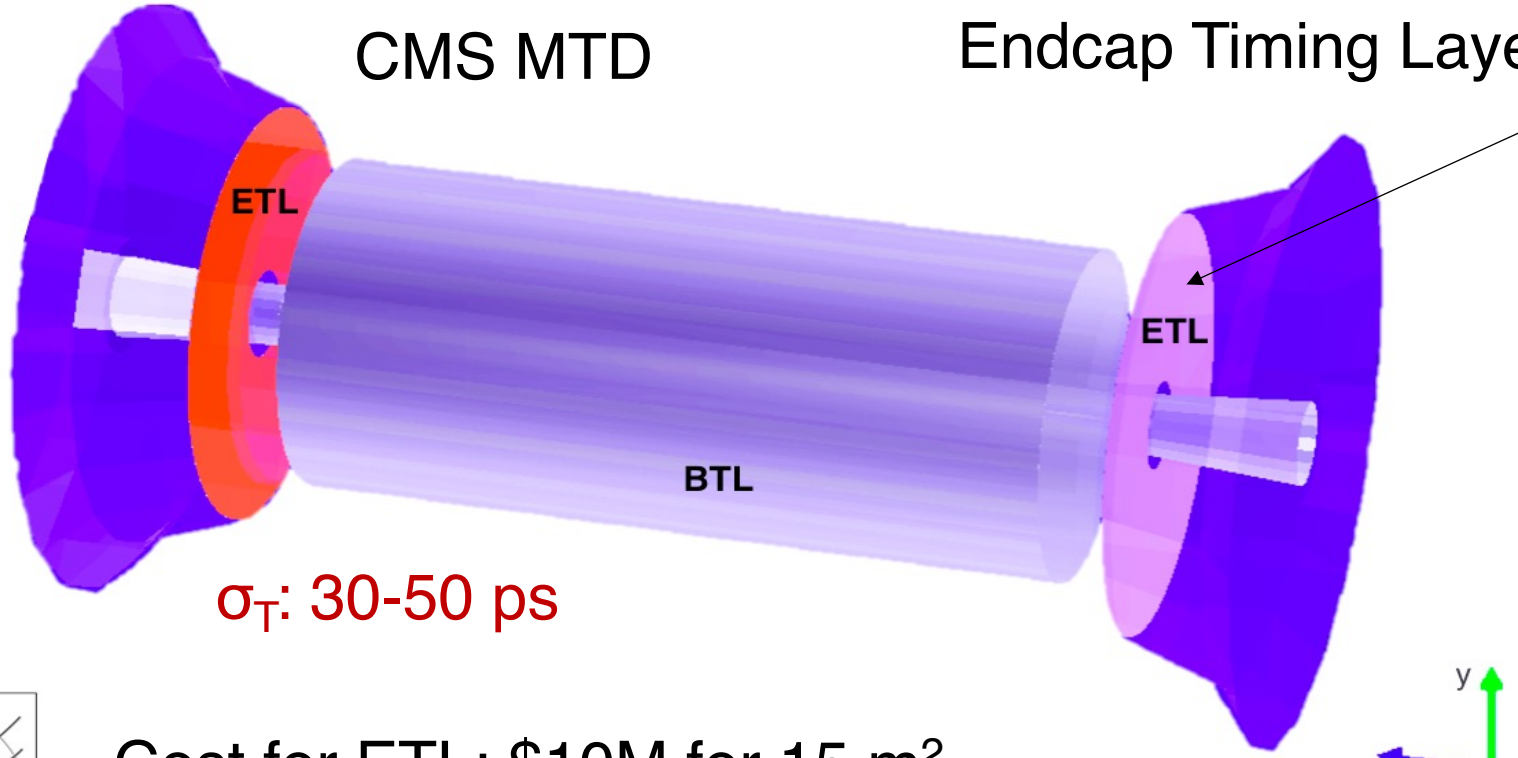
BTL: LYSO bars + SiPM readout:
- TK / ECAL interface: $|\eta| < 1.45$
- Inner radius: 1148 mm (40 mm thick)
- Length: ±2.6 m along z
- Surface ~38 m^2; 332k channels
- Fluence at 4 ab^{-1}: $2x10^{14}$ n_{eq}/cm^2



ETL: Si with internal gain (LGAD):
- On the CE nose: $1.6 < |\eta| < 3.0$
- 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

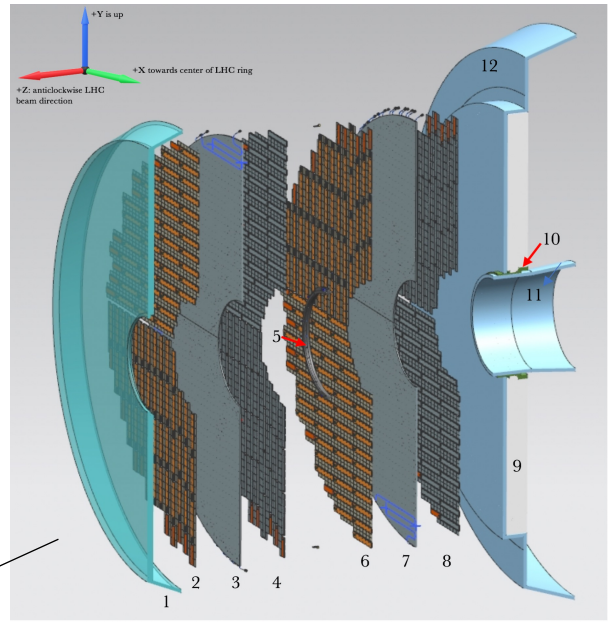


CMS MTD

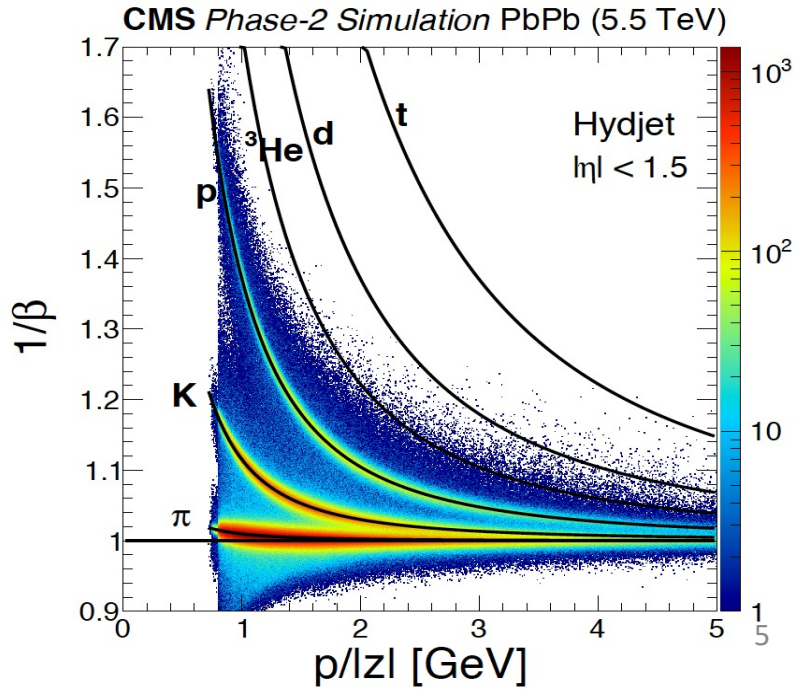


σ_T: 30-50 ps

Endcap Timing Layer

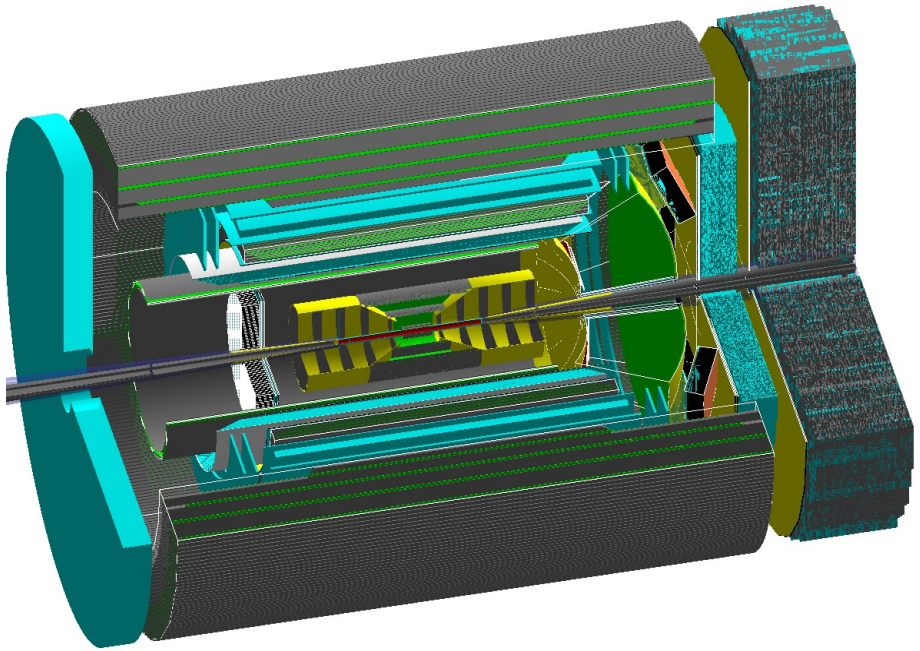


Particle ID in HI



Cost for ETL: $10M for 15 m^2
(possible to optimize for low radiation)

LGADs TOF simulation in Fun4All



- Silicon layers with timing and position smeared to expected resolution
- Timing and path length of each track stored for calculating the velocity
- Material budget is dummy for now. Expect $< 0.2\%\ X_0$ per two layers based on CMS ETL

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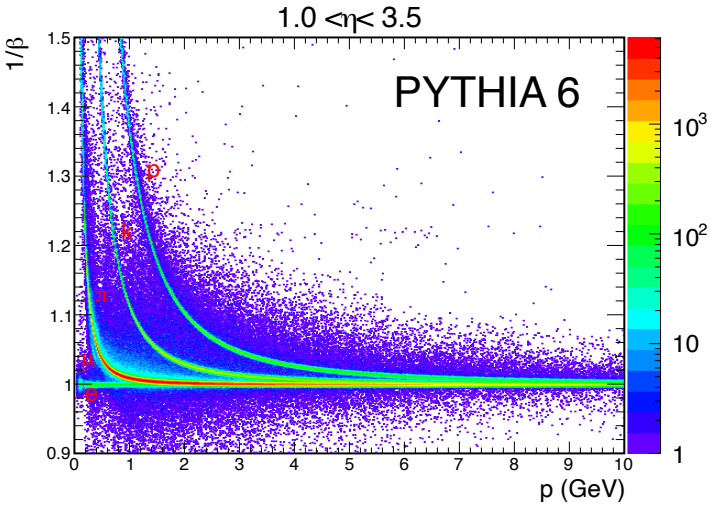
https://github.com/eic/fun4all_eicmacros/blob/master/common/G4_TTL_EIC.C

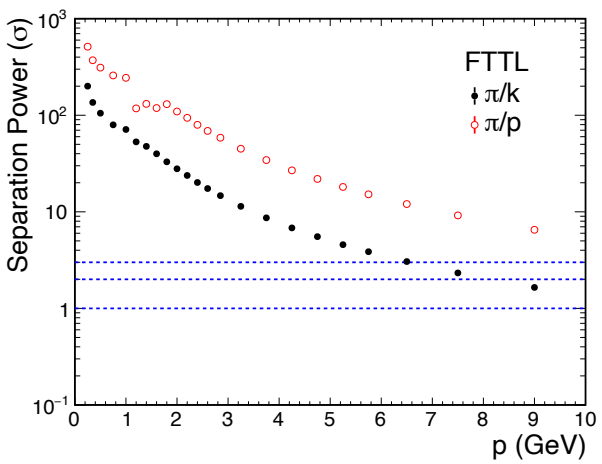
	Default	R_{barrel}	Length	z location	$R_{endcap,in}$	$R_{endcap,out}$	η coverage	Area (m^2)
Backward	$ETTL_0$			-1.555	0.077	0.632	[-3.7,-1.6]	1.23
	$ETTL_1$			-1.585	0.078	0.62	[-3.7,-1.6]	1.19
Central	$CTTL_0$	0.92	3.6				[-1.34,1.34]	20.8
	$CTTL_1$	1.147	3.6				[-1.11,1.11]	25.9
Forward	$FTTL_0$			2.87	0.116	1.527	[1.3,3.9]	7.28
	$FTTL_1$			2.89	0.117	1.538	[1.3,3.9]	7.39
	$FTTL_2$			3.4	0.138	2.185	[1.1,3.9]	14.94

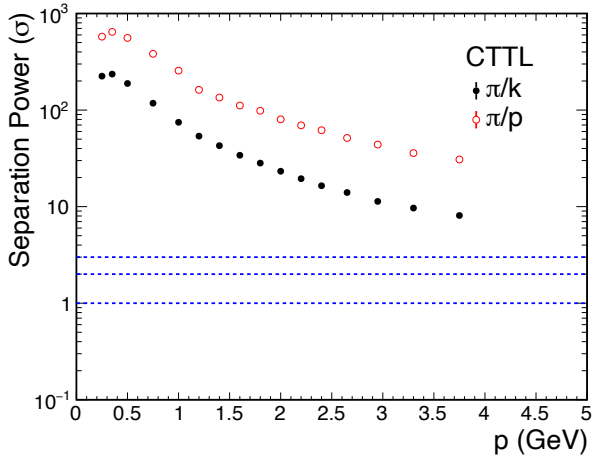


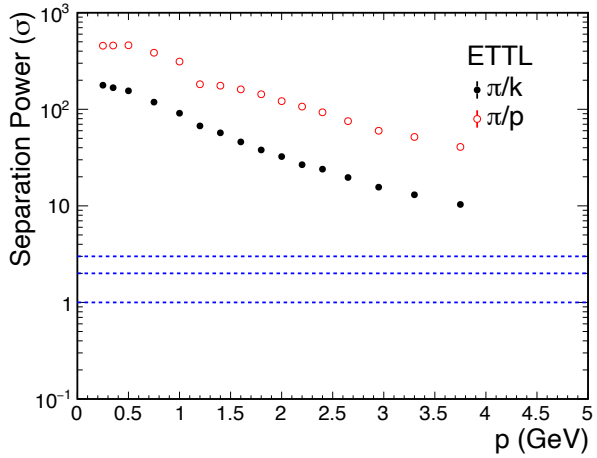
PID performance

Forward (1<η<3.5): Central (|η|<1): Backward (-3.5<η<-1):

σ_t = 0 ps

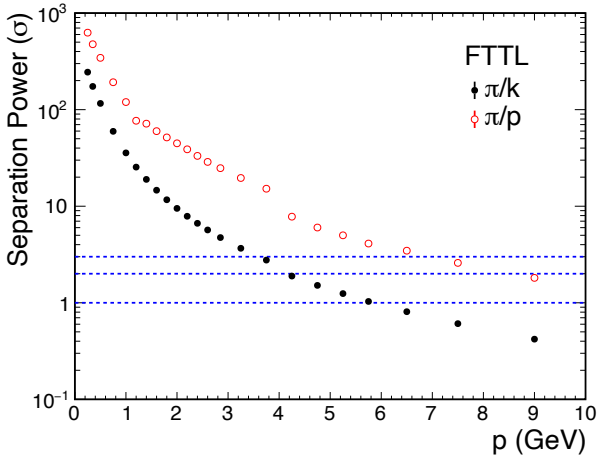


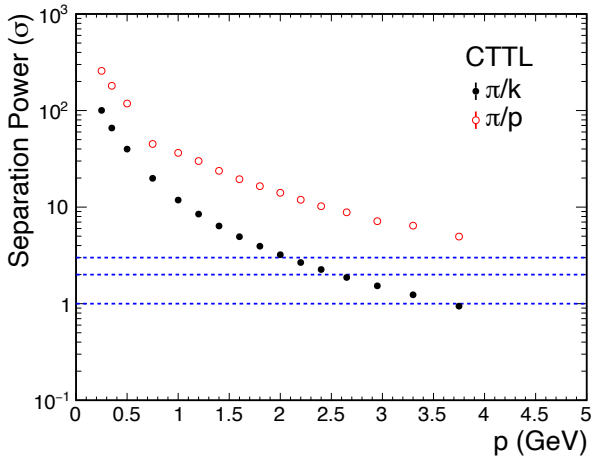


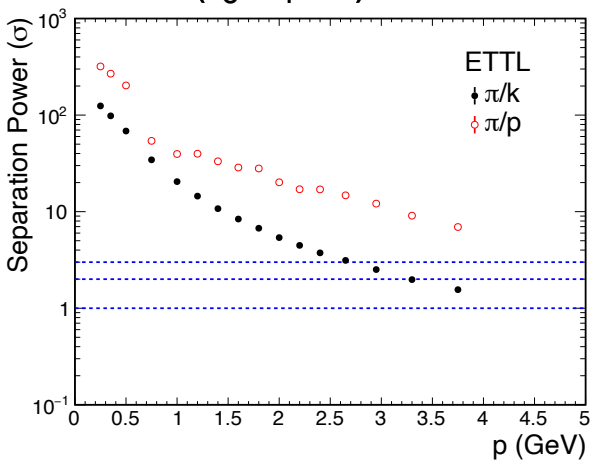


all uncertainties (t_0, t_f, L) included

σ_t = 20 ps

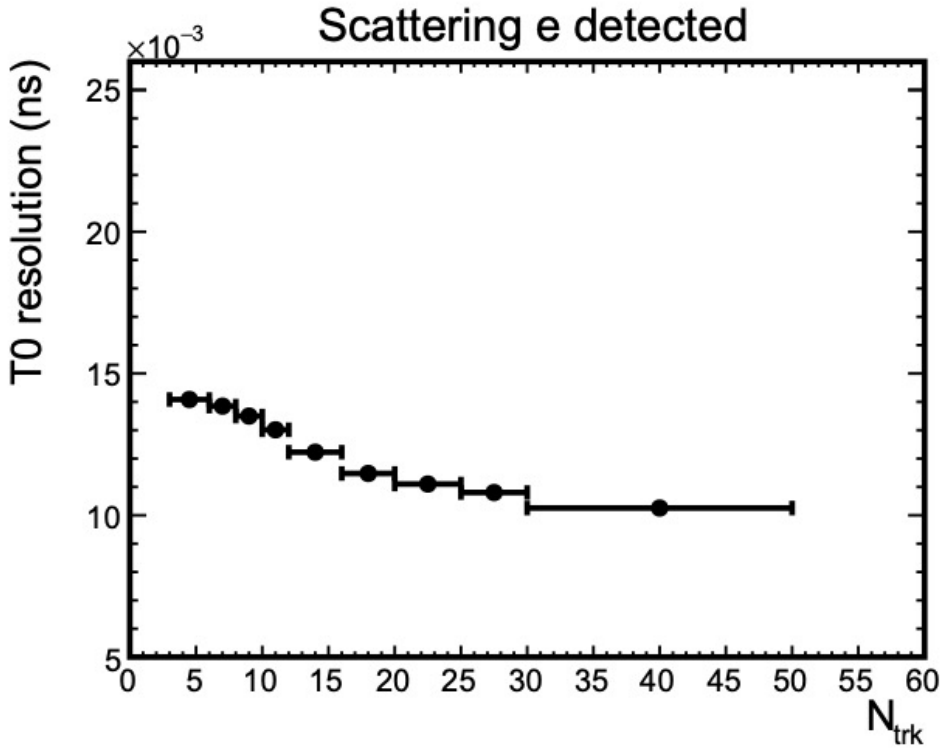






0.2-4 GeV 0.2-2.5 GeV 0.2-3 GeV

PID performance



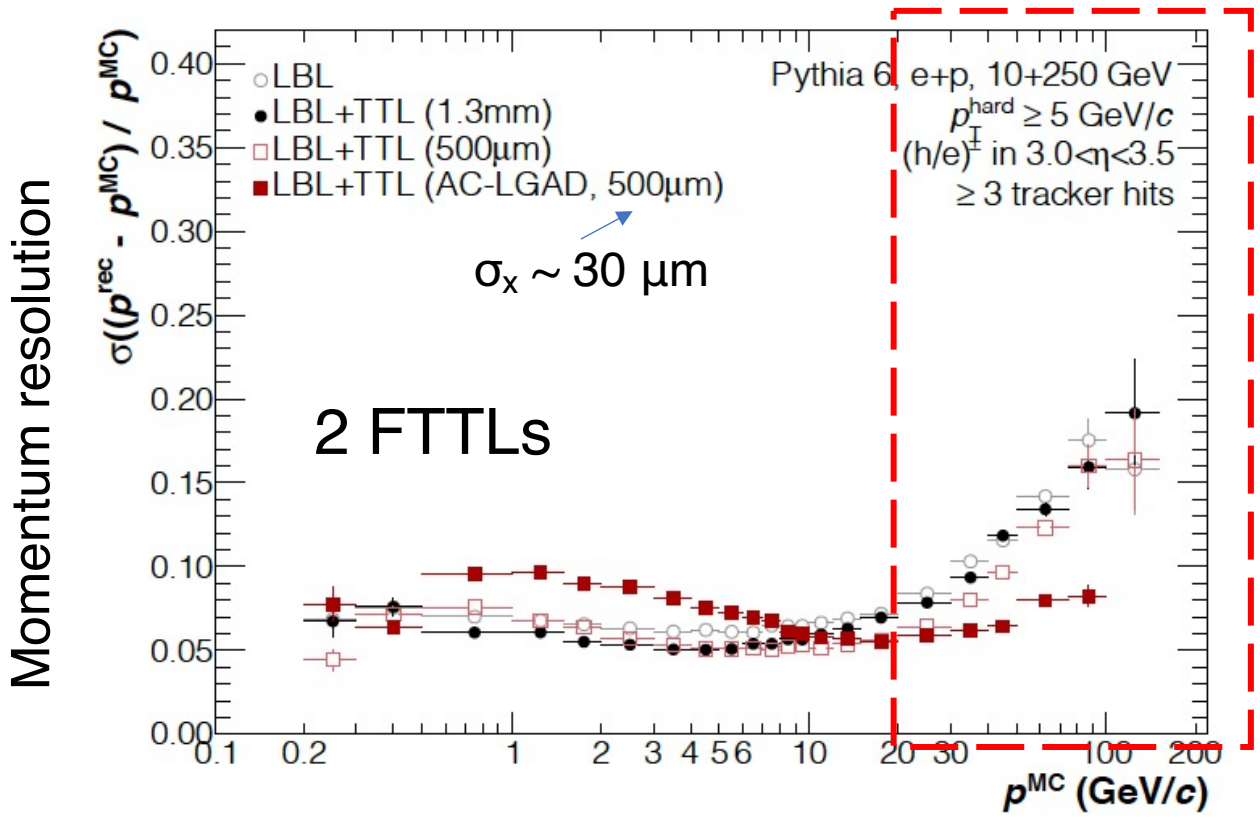
Iterative procedure to determine T_0:

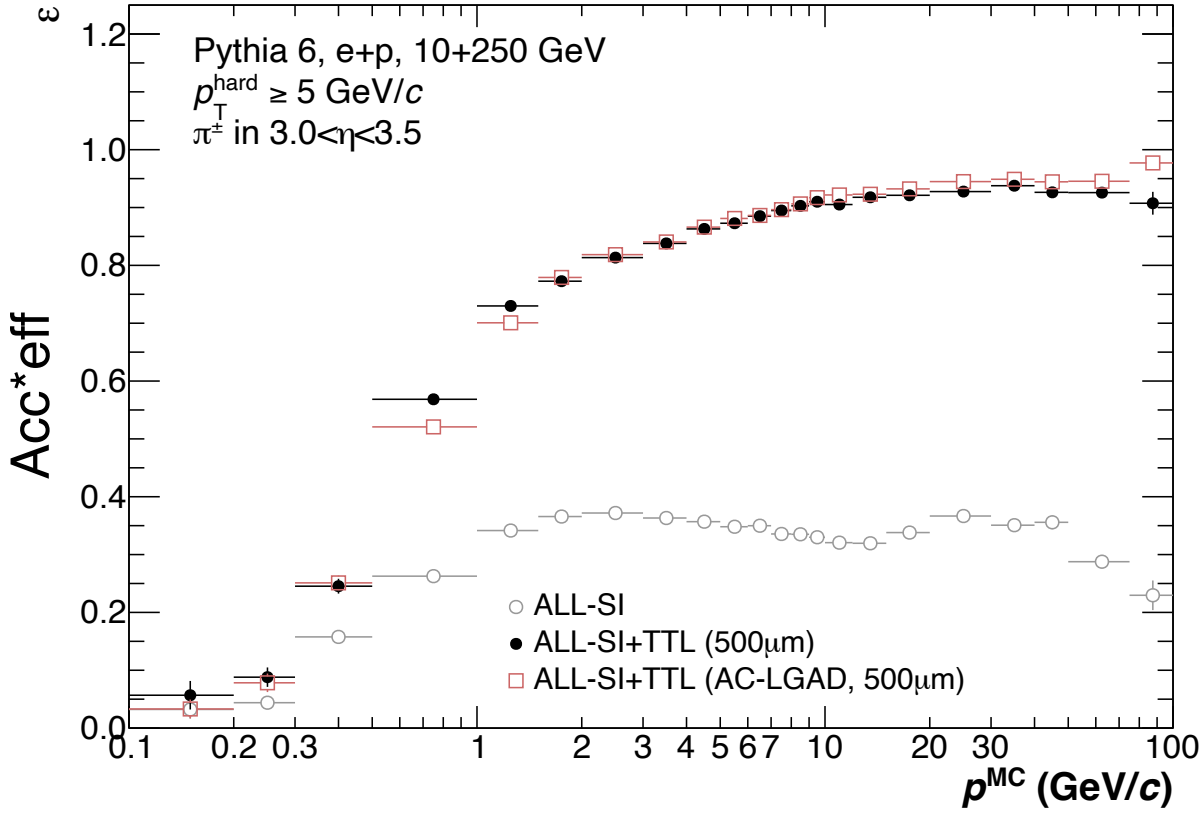
- Assume scattered e is detected by TOF
- Start with pion assuming for all other particles to fit T_0
- Update mass assumption for outliers in next iterations

Details described in https://wiki.bnl.gov/conferences/images/0/01/ERD29_progress_report_March2021.pdf
(still optimizing)

Forward tracking with LGADs

Tracking w/o vs. w/ LGADs layers

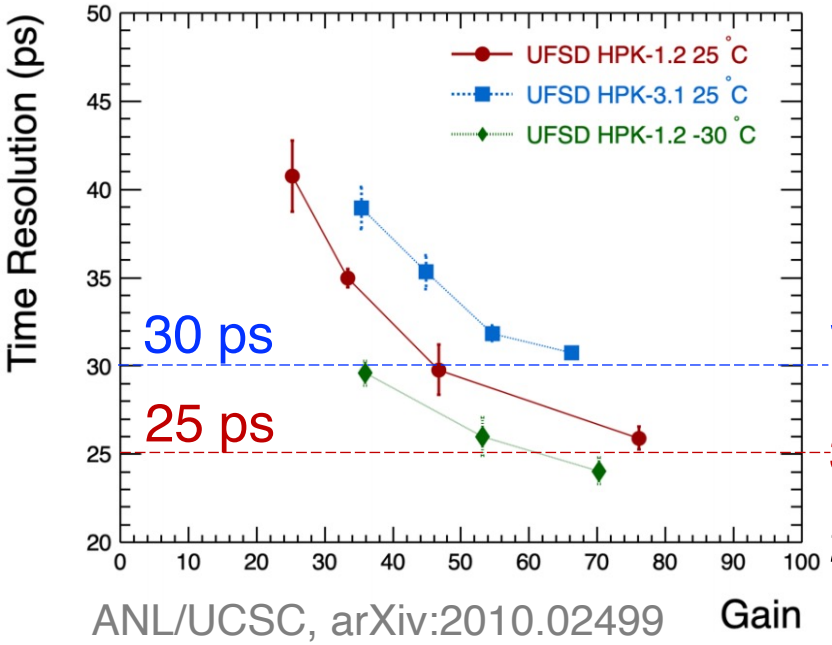




LGADs layers will serve as outer tracker to improve *p* resolution by up to 50% at 100 GeV/c and efficiency at forward y

Status of various R&Ds

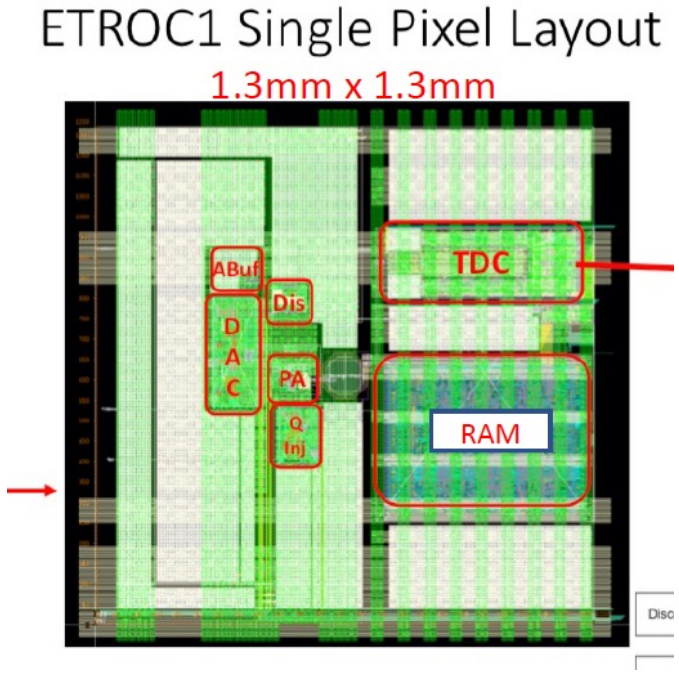
LGADs sensor timing performance



ANL/UCSC, arXiv:2010.02499

$\sigma_T \sim 20$ ps with 20-25 µm sensors well within the reach

Pitch size: 1.3 mm – 700 (500) µm (mainly limited by ASICs)

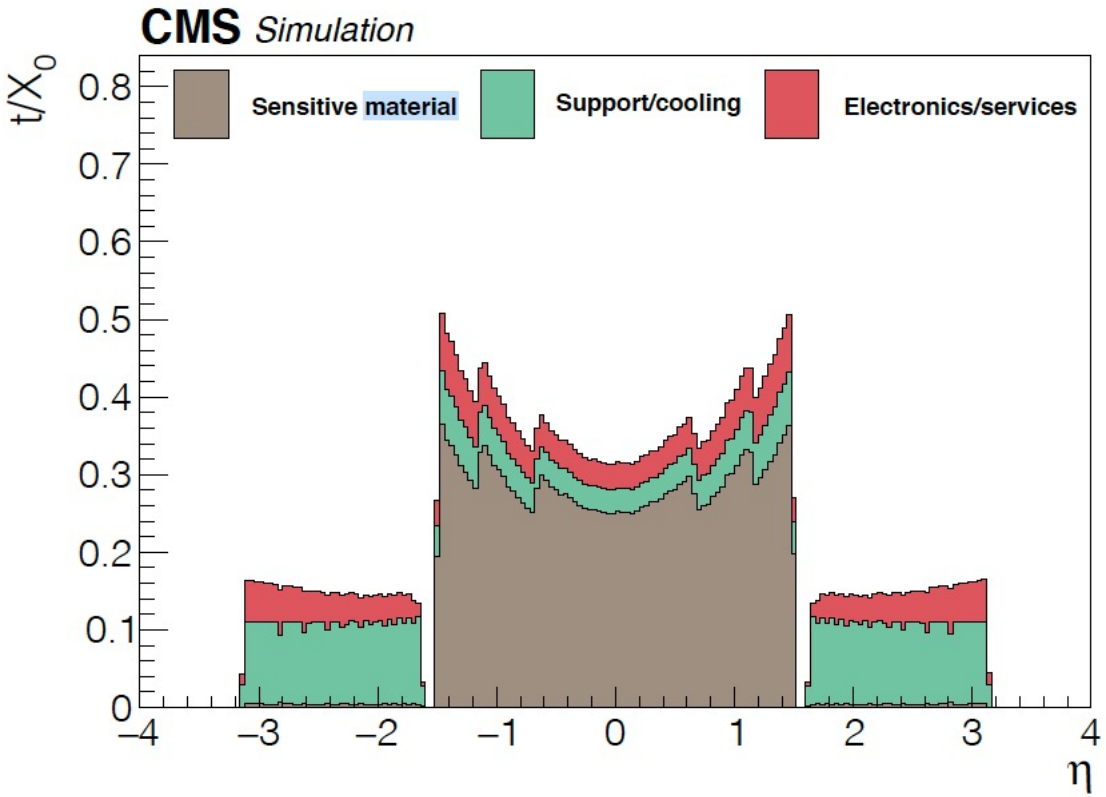


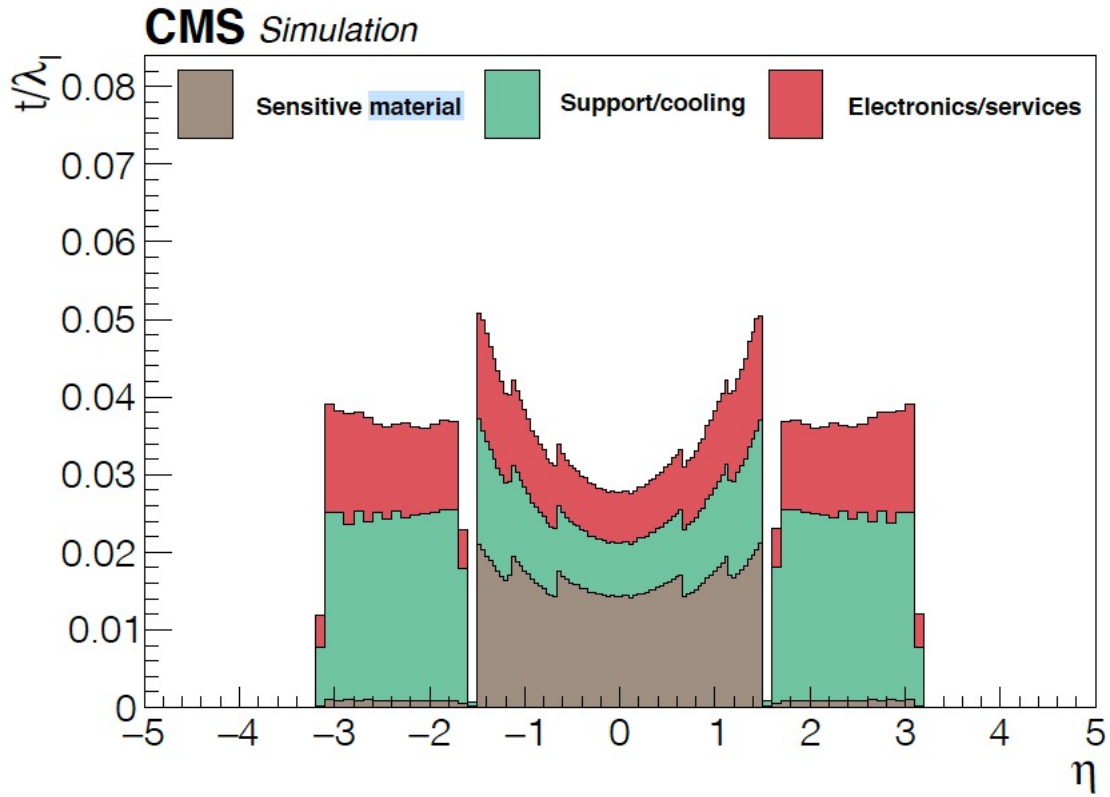
Small pitch → more channels → more power consumption (~ 2 mW/ch)

LGADs consortium meeting on electronics:
https://indico.bnl.gov/event/11717/

What is the realistic cool capability?

Backups


CMS Simulation
t/X0
Sensitive material
Support/cooling
Electronics/services
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−4
−3
−2
−1
0
1
2
3
4
η


CMS Simulation
t/λI
Sensitive material
Support/cooling
Electronics/services
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
−5
−4
−3
−2
−1
0
1
2
3
4
5
η