EIC Tracking and PID studies beyond the Yellow Report

arXiv:2102.08337

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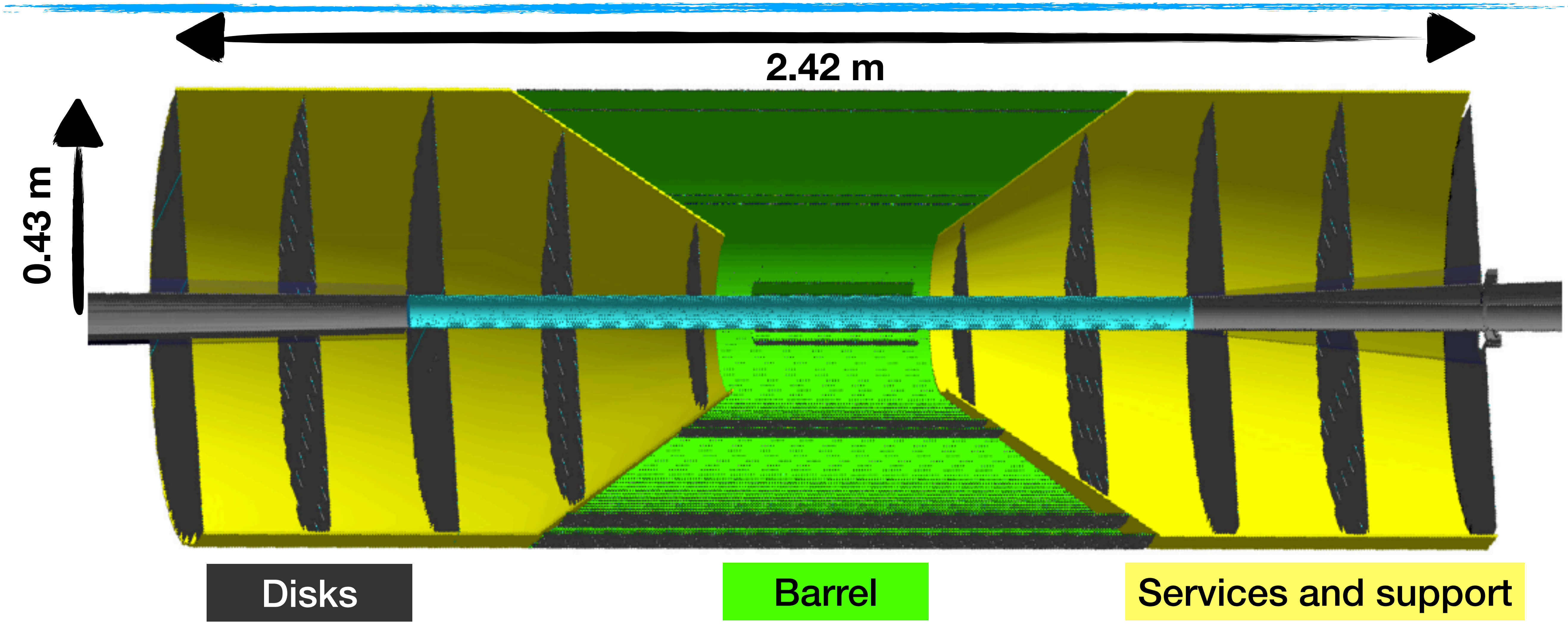
ECCE Detector Meeting
05/11/2021

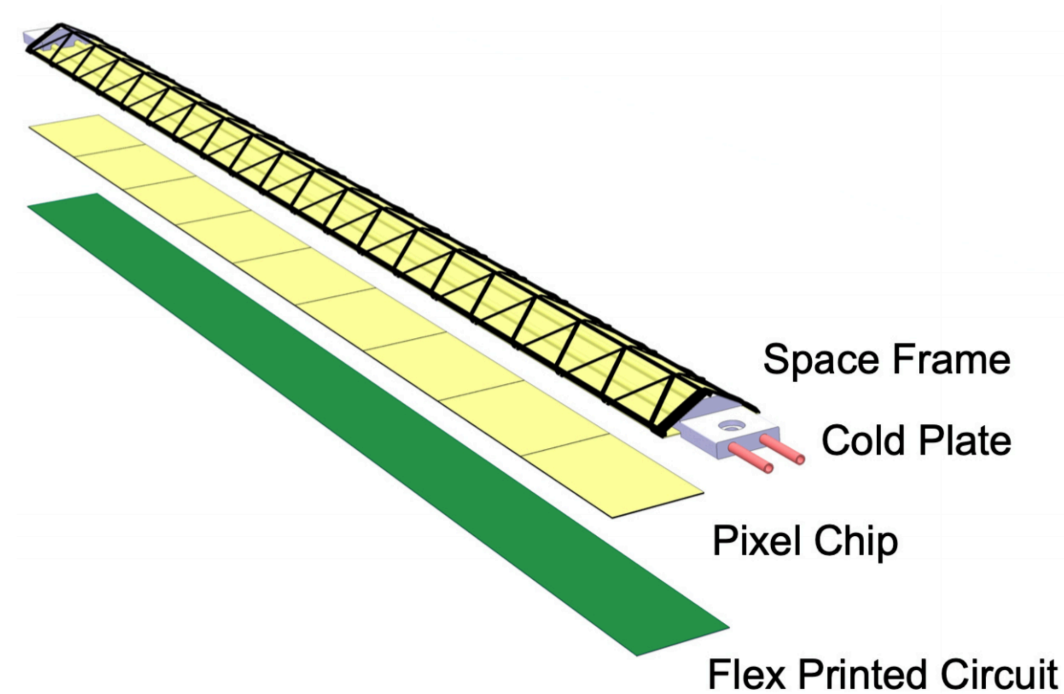
Integrated (Barrel+Disks) All-Silicon Tracker Concept



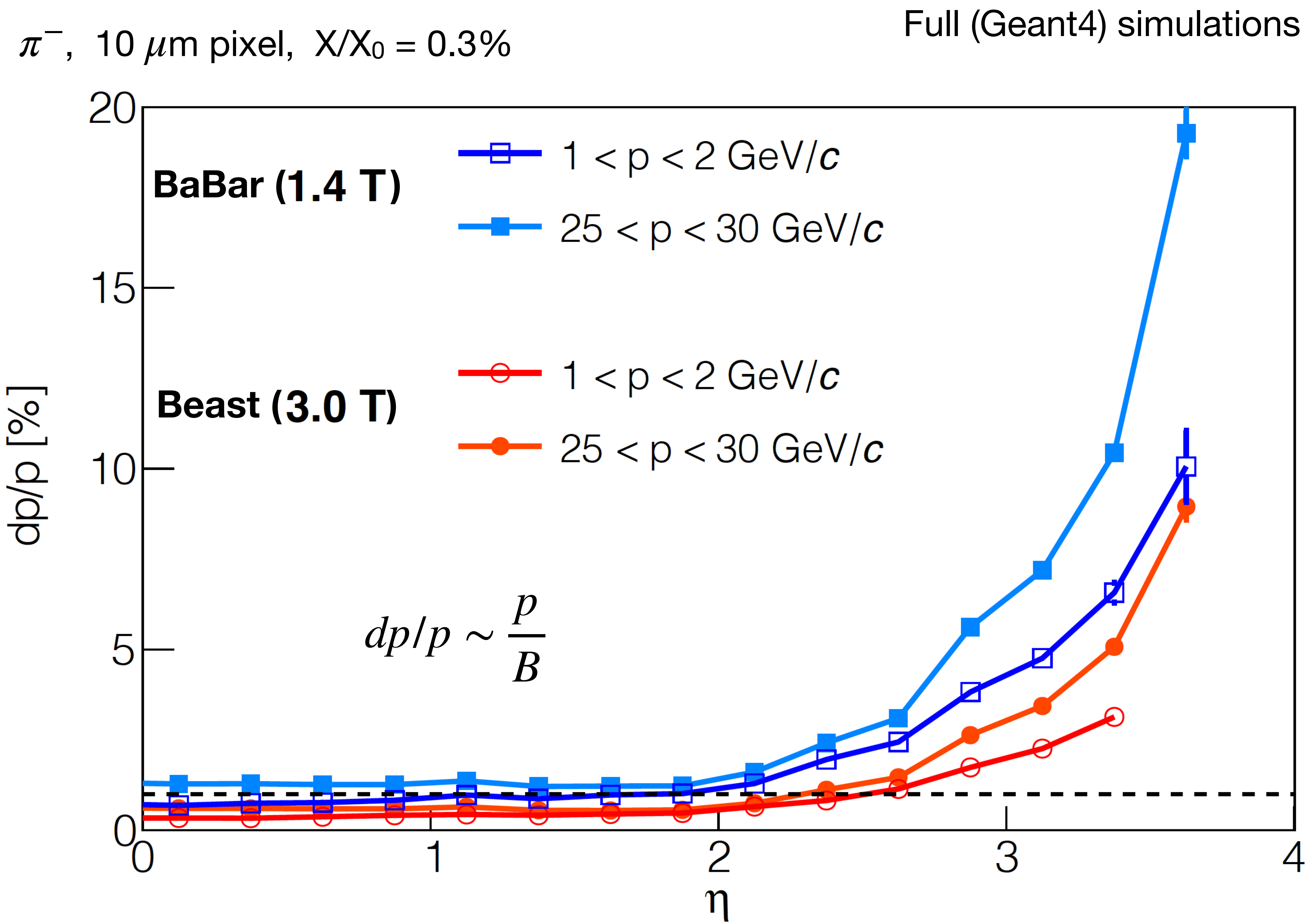
- Geometry made out of Alice ITS2-like staves (material budget X/X0 = 0.3%)

- silicon pixel of 10 μm pitch based on Monolithic Active Pixel Sensor

- Simulations carried out in the Fun4All full-simulation framework

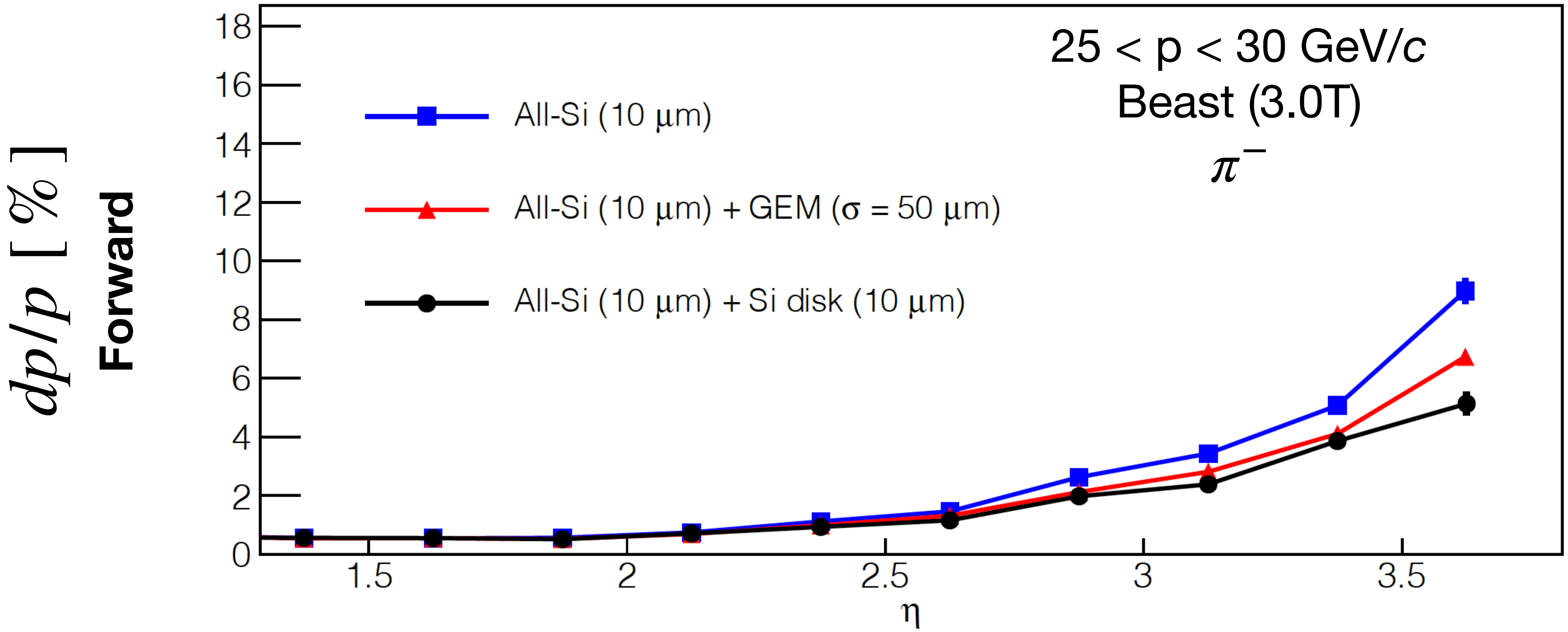


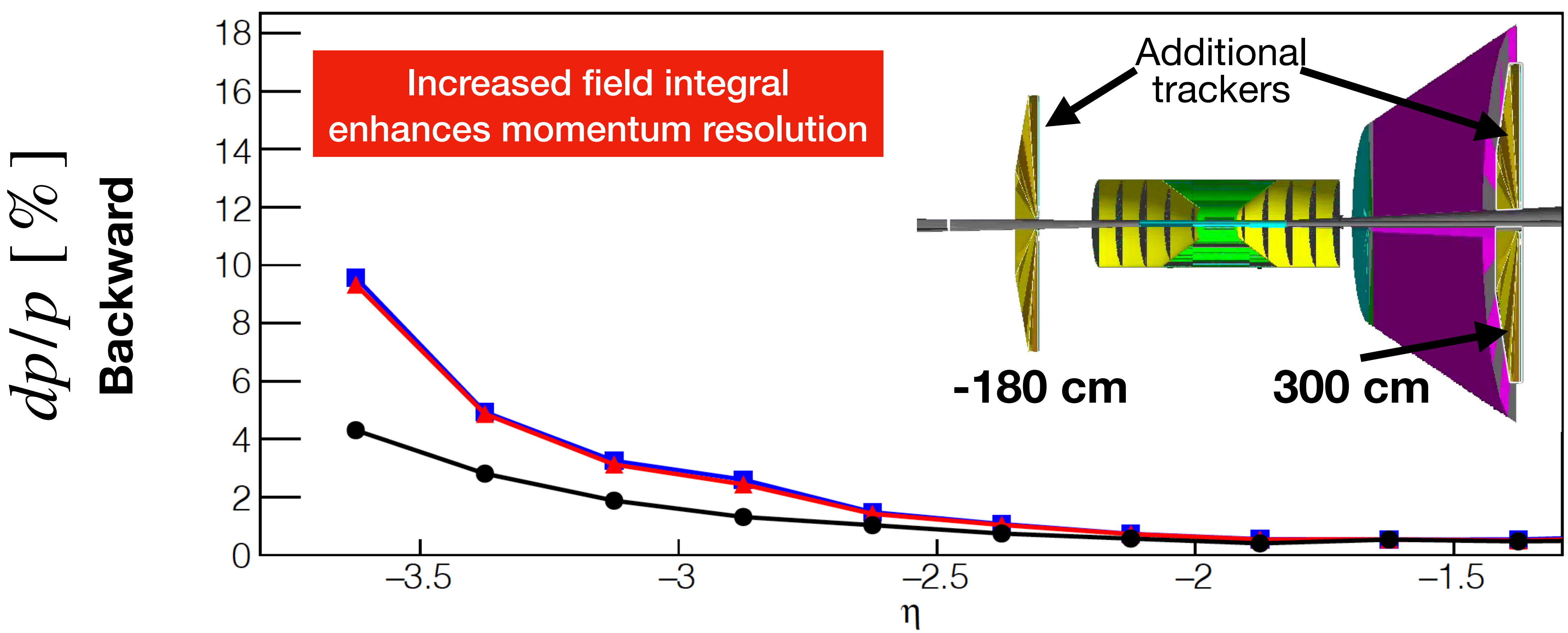
Momentum resolution vs. pseudorapidity



η	0	0.5	1	1.5	2	3	4	5
θ [deg]	90	62	40	25	15	5.7	2.1	0.8

Complementing All-Si tracker with other detectors

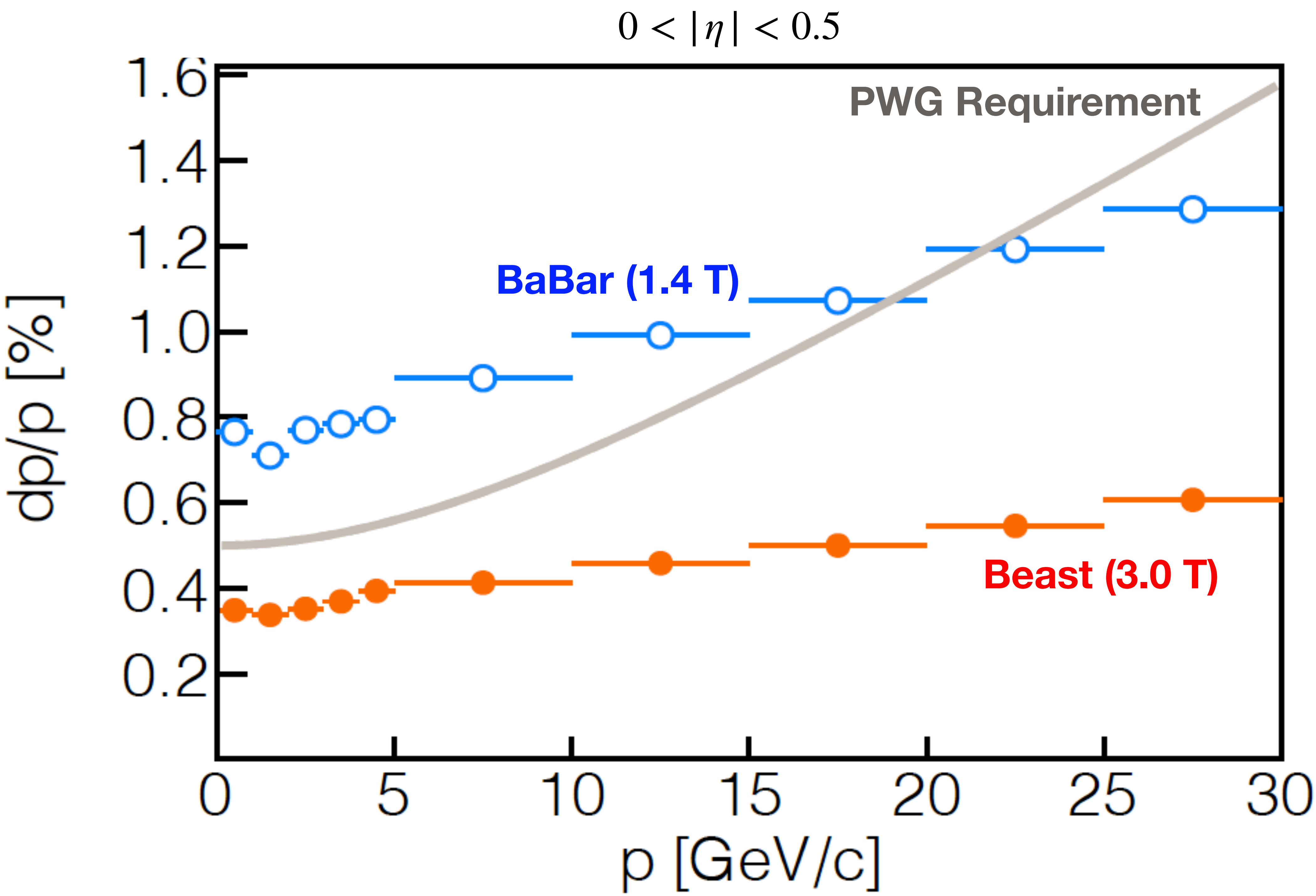




Momentum resolution vs. momentum

π^-, 10 μm pixel, $X/X_0 = 0.3\%$

Full (Geant4) simulations



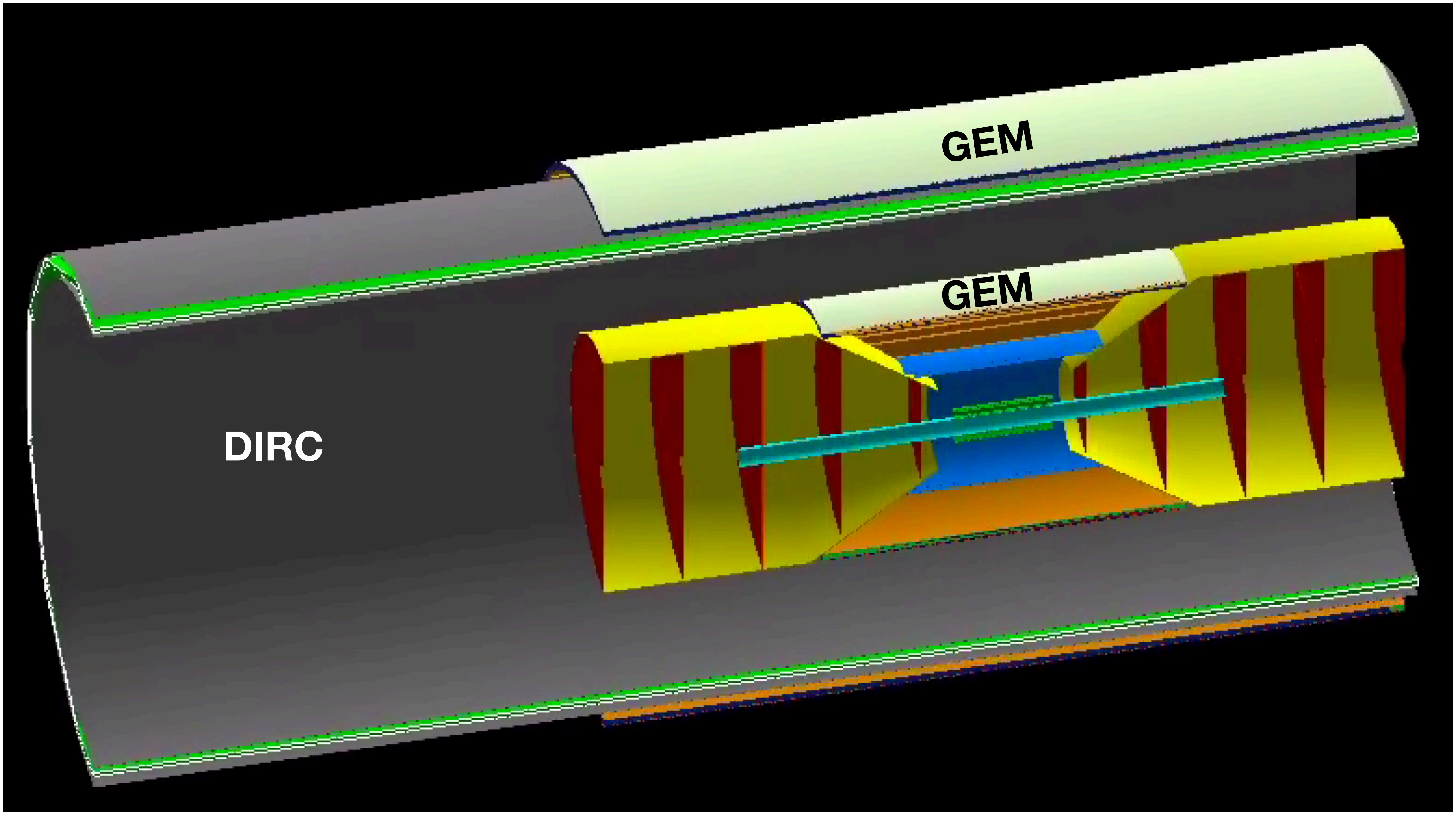
Can we get better performance at mid rapidity?

Complementing the all-si tracker in the barrel region

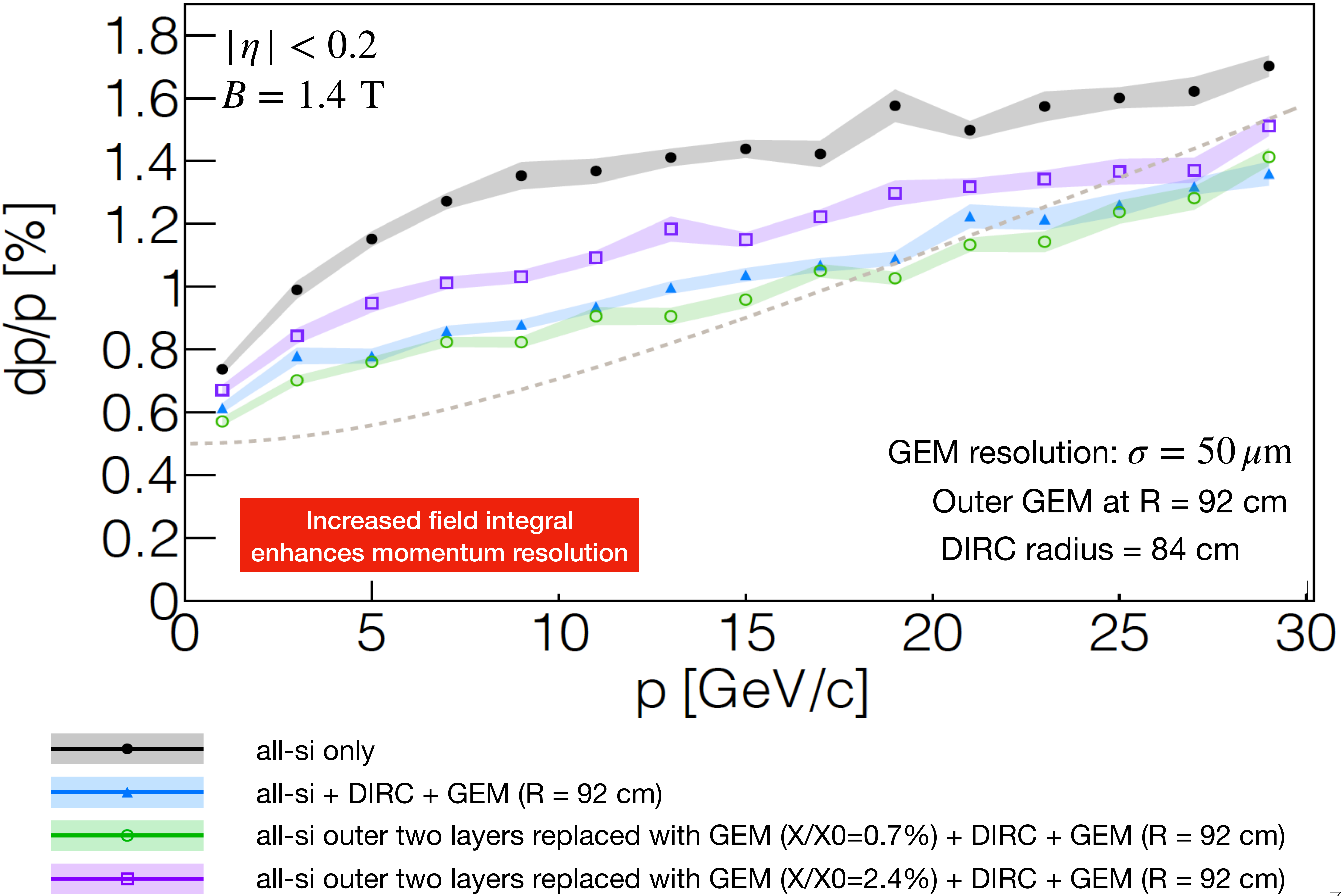
Variant #1:
All-silicon tracker + GEM outside the DIRC

Variant #2:
Outermost two barrel layers replaced with a GEM, and a second GEM added outside the DIRC

All-si tracker material budget (X/X0):
- Vertexing layers: 0.05%
- Barrel Layers: 0.55%
- Disks: 0.24%



GEM Material Budget Effect



DIRC radius effect

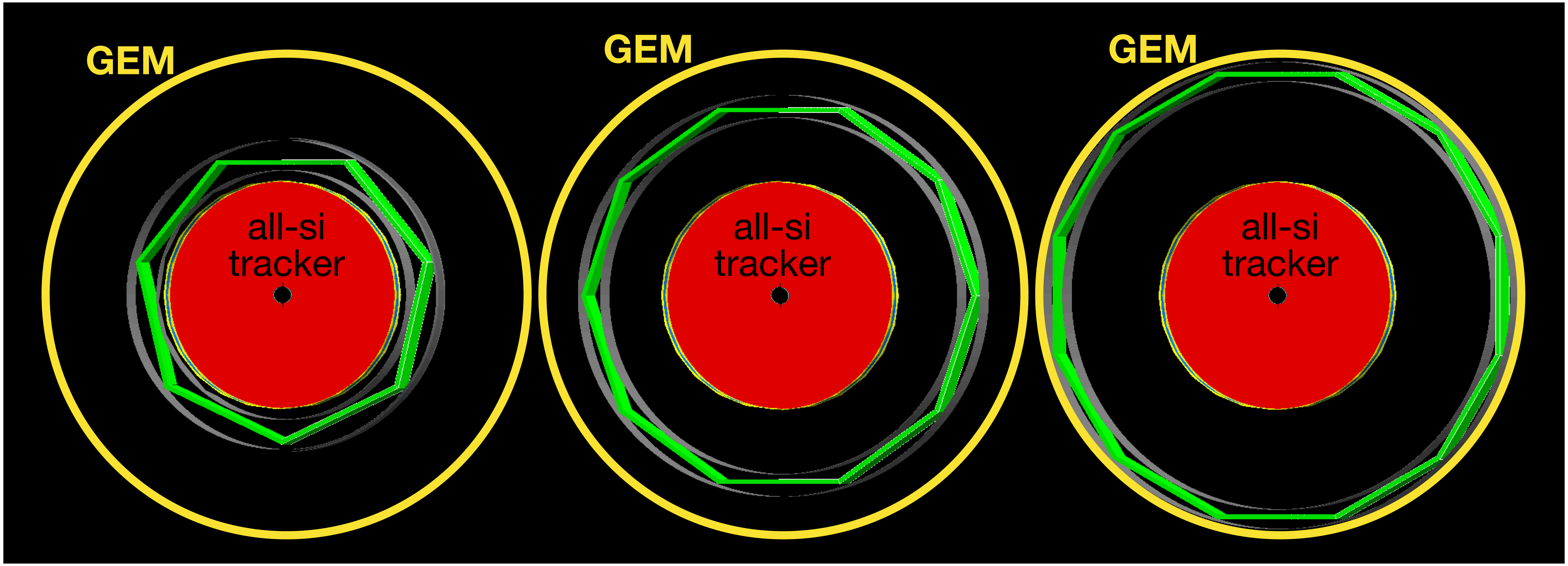
Previous study assumes outer GEM is very close to DIRC (and there is no additional material between DIRC and all-si tracker)

The distance between scattering centers and tracking layers affects the momentum resolution

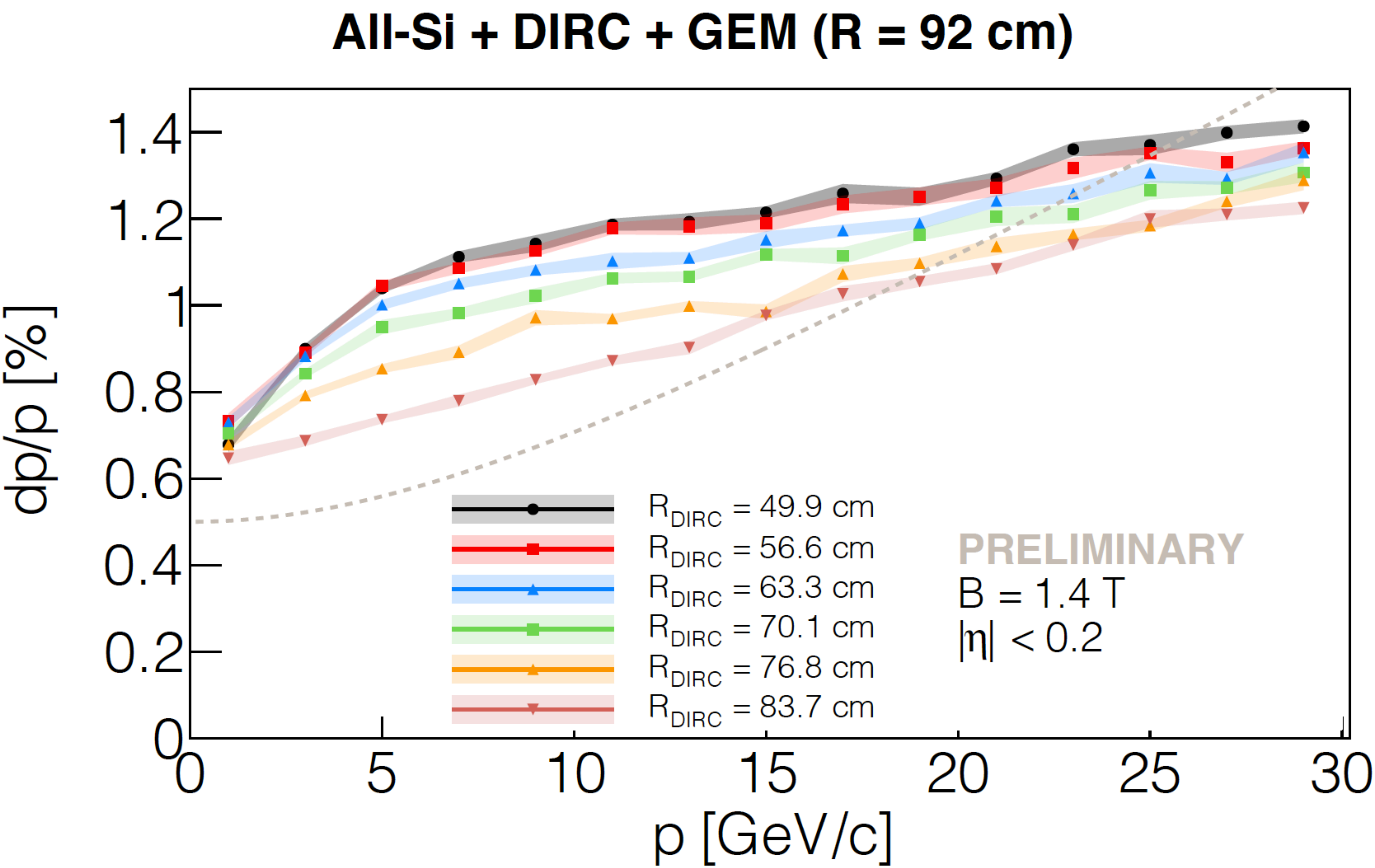
Study effect of changing DIRC radius

DIRC modules exist (BaBar), so DIRC radius is quantized

n	R_n [cm]
6	43.30
7	49.90
8	56.57
9	63.30
10	70.06
11	76.85
12	83.65



DIRC-radius effect



Interim Summary

- Studied All-Silicon tracker prototype for the EIC in full simulations
- Current concept uses Alice ITS2 staves and 10 μm pitch MAPS sensor
- Tracker does not supply the YR PWG requirements in the entire kinematical region considered
- Momentum resolutions can be enhanced by complementing detectors with additional tracking stations
- Amount of material and placement inside active tracking region may have a significant impact on tracking performance

This requires close coordination with PID efforts

Low p threshold for RICH detectors

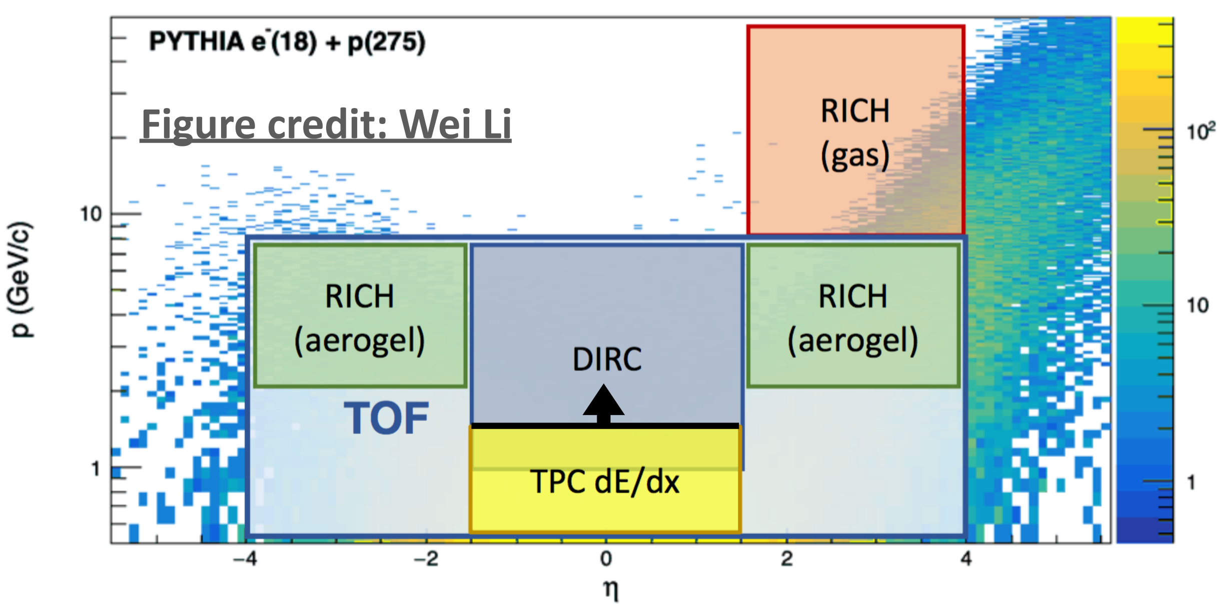
EICUG YR

Physics requirements:

Rapidity	π/K/p and π0/γ	e/h	Min pT (E)
-3.5 – -1.0	7 GeV/c	18 GeV/c	100 MeV/c
-1.0 – 1.0	8-10 GeV/c	8 GeV/c	100 MeV/c
1.0 – 3.5	50 GeV/c	20 GeV/c	100 MeV/c

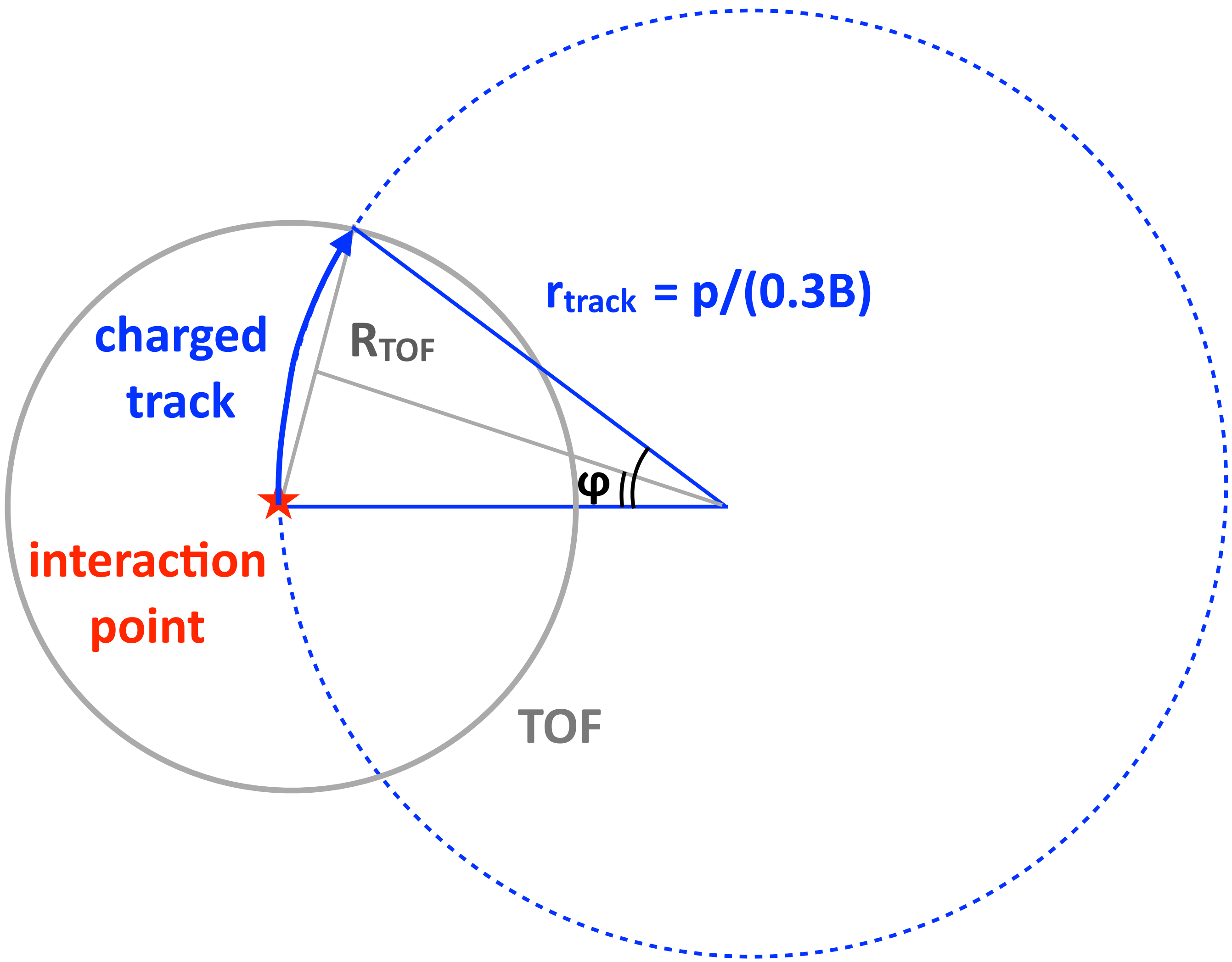
radiator	index	Threshold (GeV/c) e	π	K	p
quartz (DIRC)	1.473	0.00048	0.13	0.47	0.88
aerogel (mRICH)	1.03	0.00207	0.57	2.00	3.80
aerogel (dRICH)	1.02	0.00245	0.69	2.46	4.67
C_2F_6 (dRICH)	1.0008	0.01277	3.49	12.34	23.45
CF_4 (gRICH)	1.00056	0.01527	4.17	14.75	28.03

Table 11.23: Table of Cherenkov thresholds for various media.



Magnetic field can affect the low p_T range

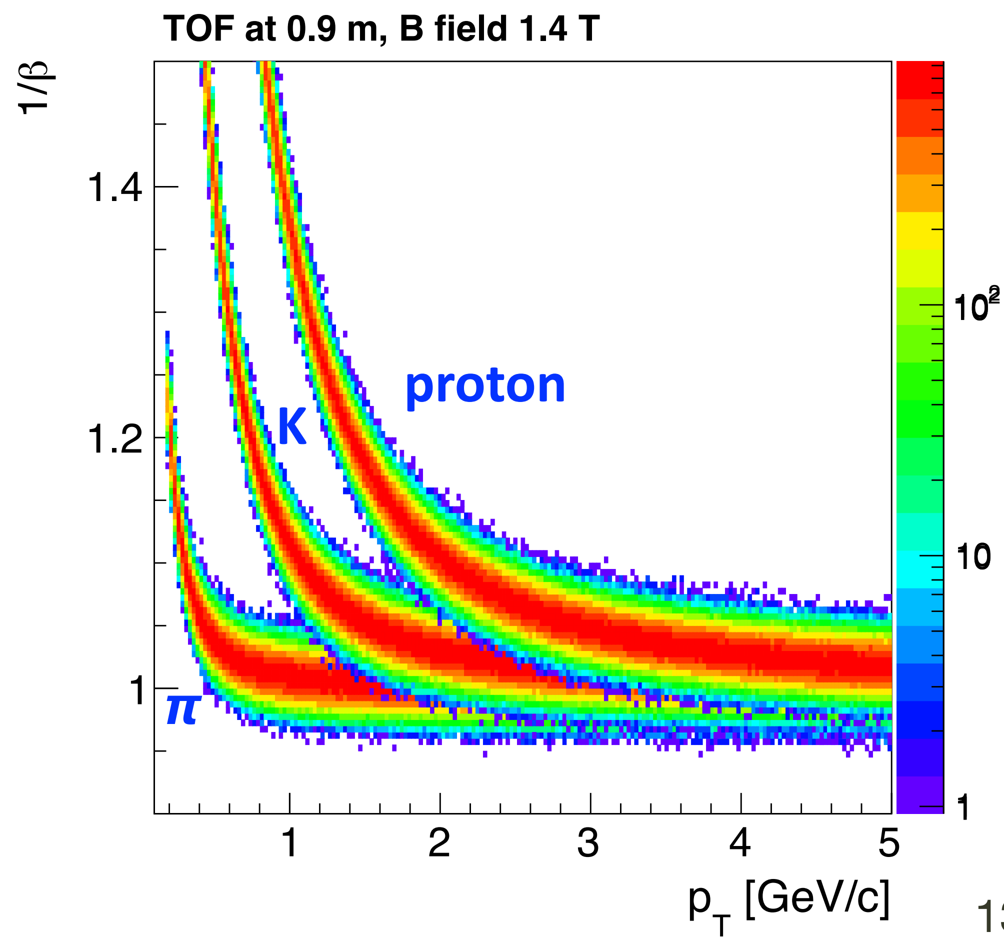
Path length calculation for η=0



path length $L = 2r_{track} \operatorname{asin}(0.5R_{TOF}/r_{track})$ → function of p

Toy MC simulation

- Throw particles (**π**, K, proton) of different p at η=0
  - Calculate path length L ➞ time of flight t_{flight} = L/velocity
  - Truth: $t_0 = 0$, $t_f = t_0 + t_{flight}$ = L/velocity
  - $\beta = L^{reco} / [(t_f^{reco} - t_0^{reco})\cdot c]$
    - t_f^{reco} : smear t_f by 20 ps
    - t_0^{reco} : smear t_0 by 20 ps
    - L^{reco} : smear L by 1%
- Extract the high p limit of 3σ separation



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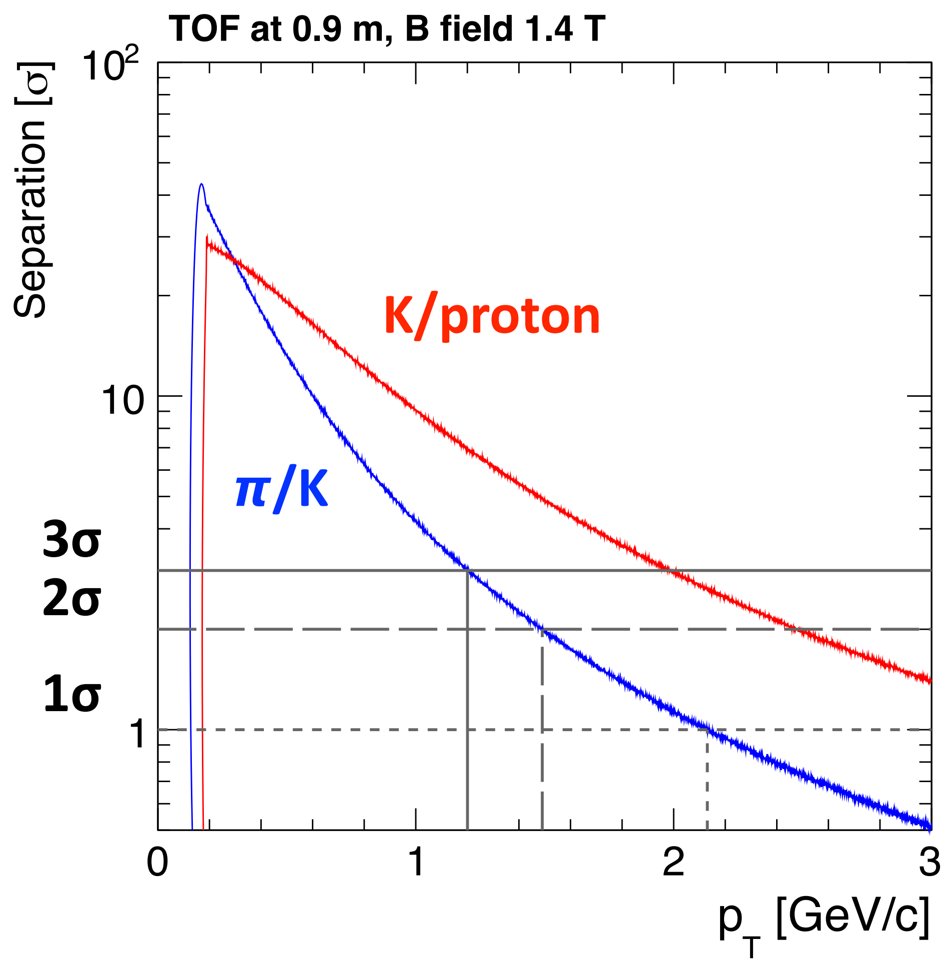
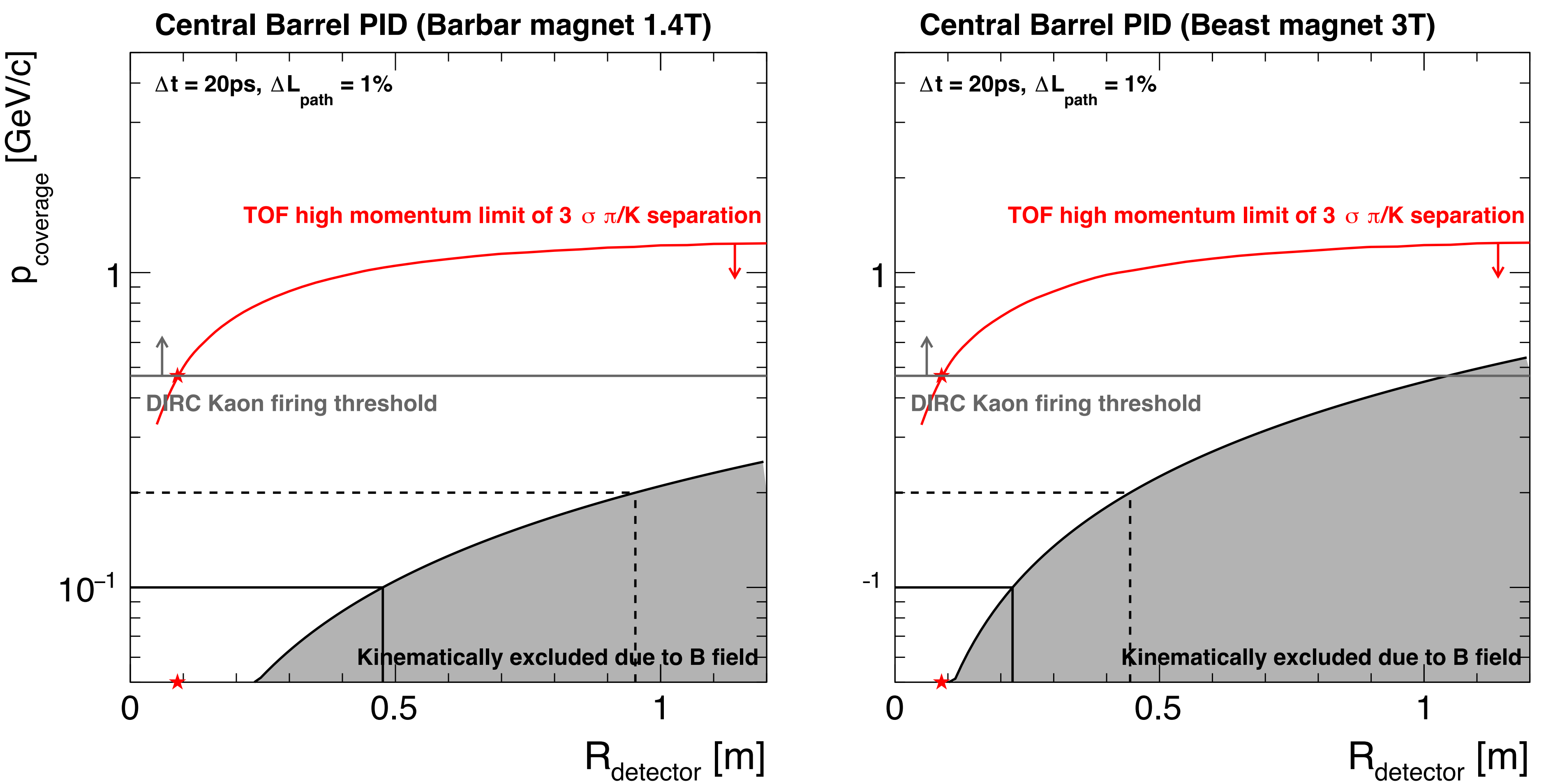
- Run for different R (5, 10, …120cm) location



Effect of B field

- One needs to be very careful with the low momentum cutoff due to the strong B field (espicially 3T)

$$p_T\,[\mathrm{GeV}/c] \;=\; 0.3 \cdot B\,[\mathrm{T}] \cdot r/2\,[\mathrm{m}]$$



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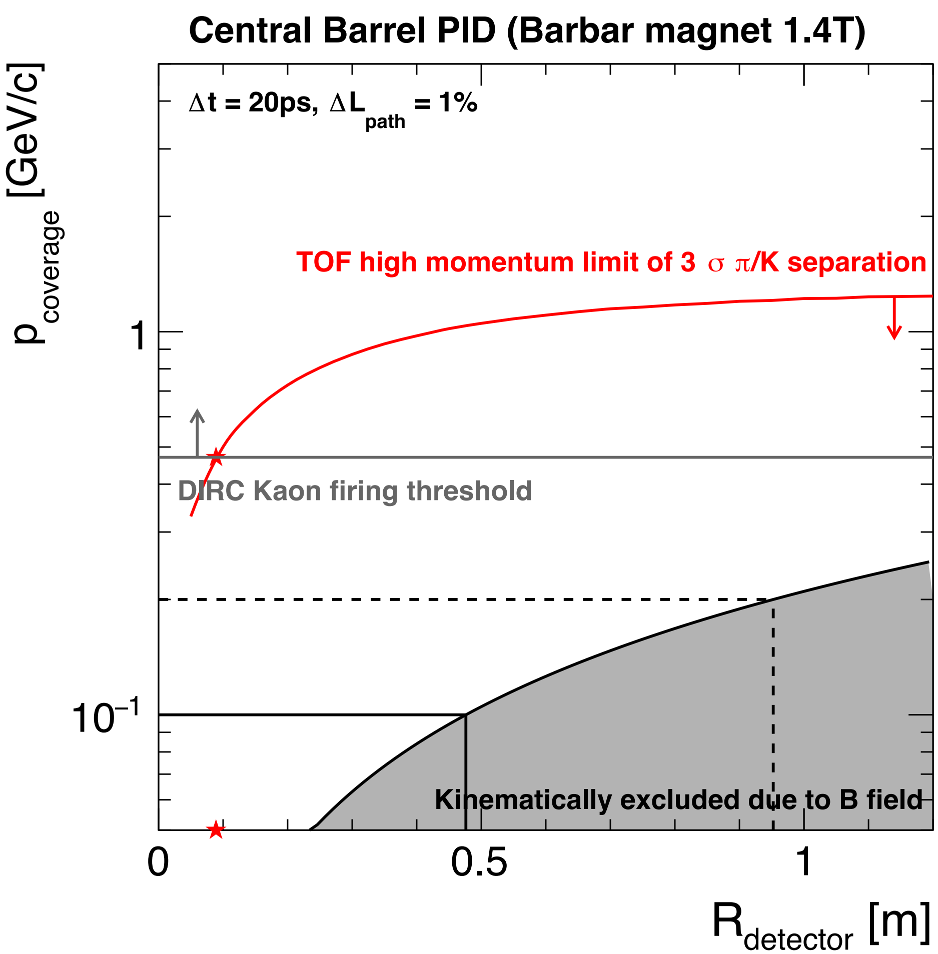


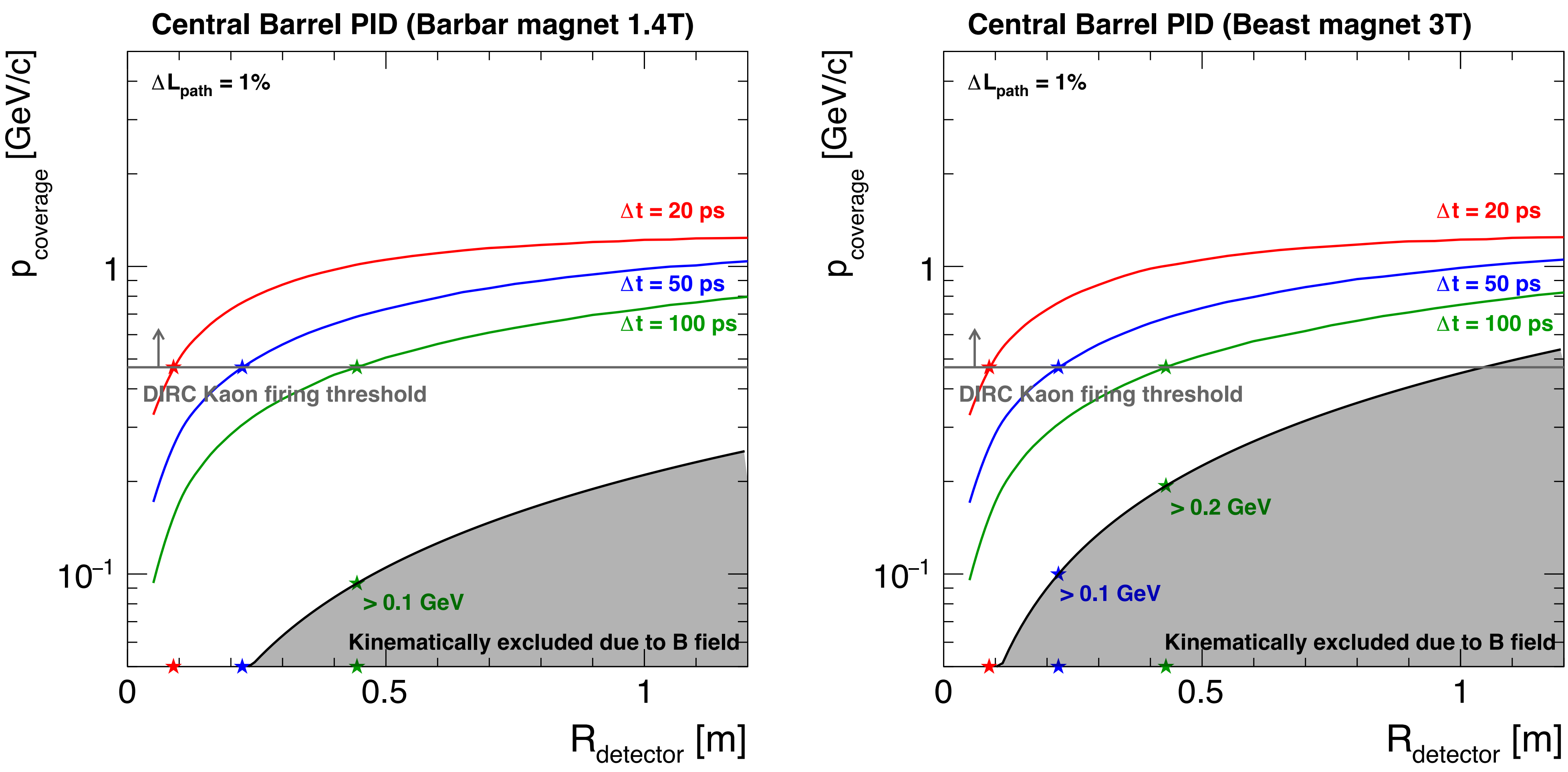
Easier to perform low p PID (DIRC, TOF, dE/dx): 0.2 GeV paricles can reach detector ~1m

For LGAD TOF have 3σ π/K separation, it needs to be placed >10cm

If one want to use dE/dx (cluster counting) or TOF to cover low p, it needs to sits at a moderate R (<50cm if one want PID ~0.1 GeV, <100cm if one want PID ~0.2 GeV)

Effect of timing resolution

- TOF with better intrinsic resolution can be put closer to the interaction point → smaller area



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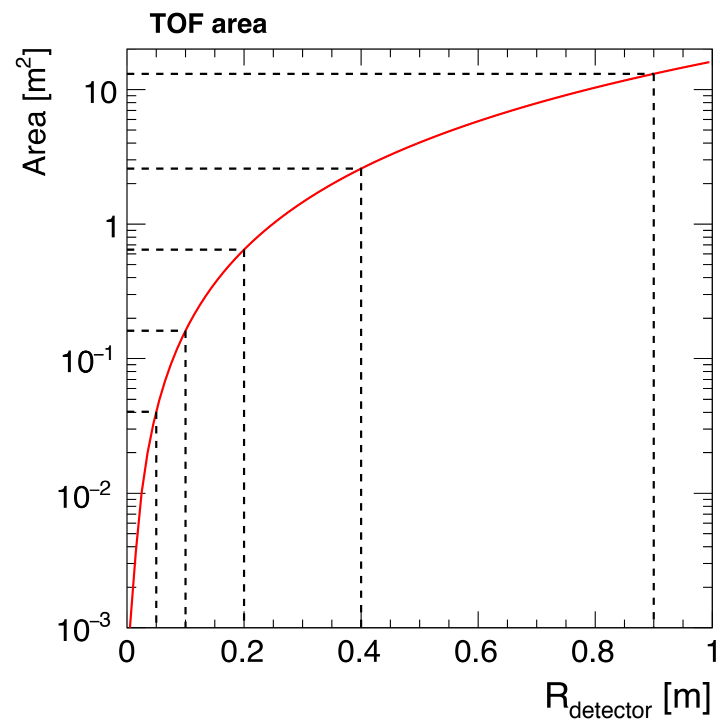
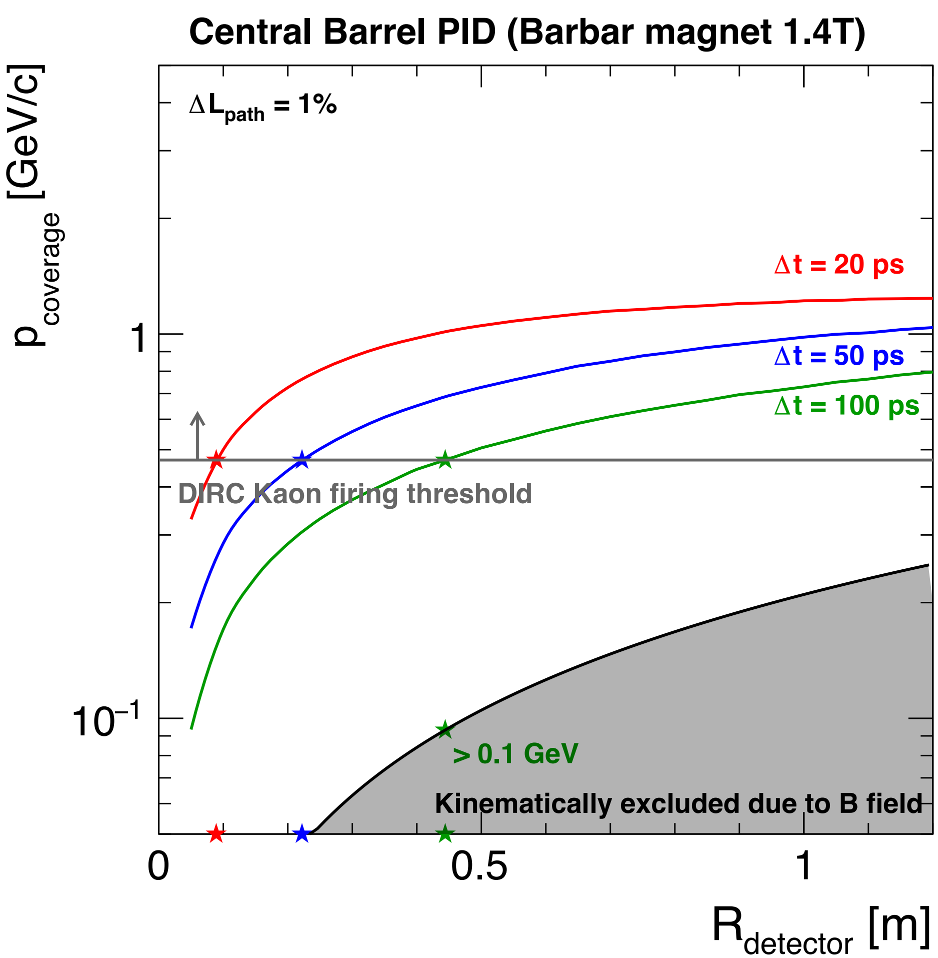




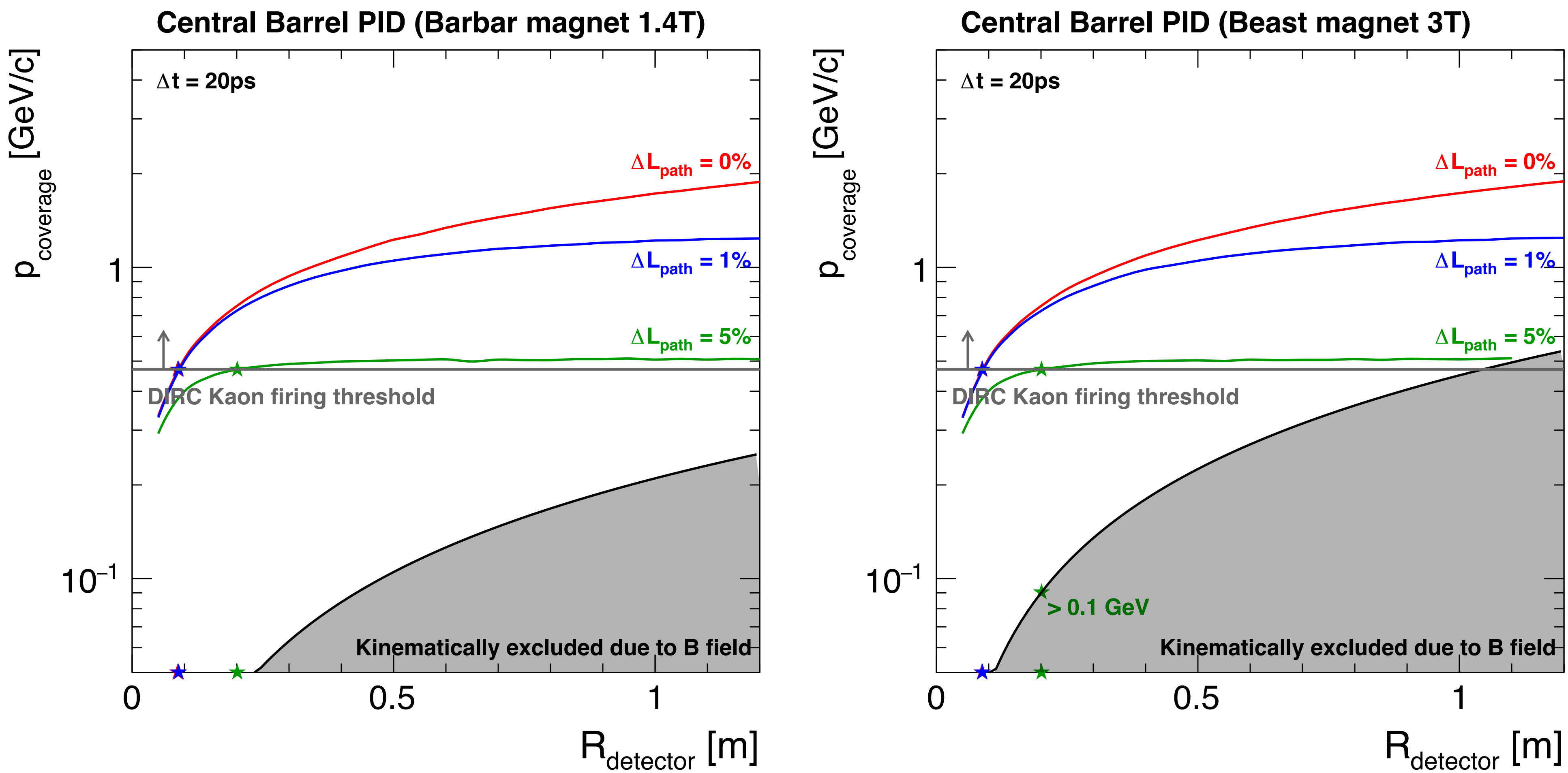
20ps: 5-50cm (100cm) to reach down to 0.1GeV (0.2GeV)

50ps: 10-50cm (100cm) to reach down to 0.1GeV (0.2GeV)

100ps: 45-50cm (100cm) to reach down to 0.1GeV (0.2GeV)

Effect of path length resolution

- Momentum coverage by LGAD TOF is sensitive path length uncertainty



Summary

- DIRC cannot identify particles below firing threshold or particles which can not reach it
- Complementry PID detector should be put close enough so low momentum particles can reach it
- TOF: further → higher momentum reach; closer → smaller area
- Results sensitive to the path length uncertainties
- Nest step: put LGAD at different radial locations and study its impact on the momentum and projecting resolution