Impact of pixel size and material budget on resolution(s)

A reminder

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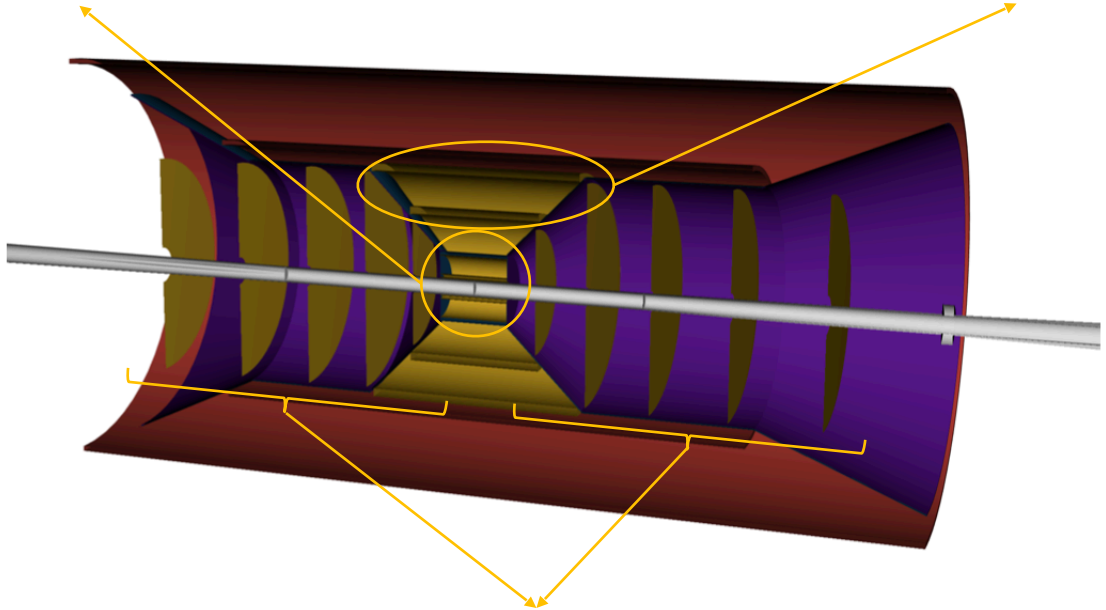
SVT

Inner Barrel (IB)
- 2 curved silicon vertex layers
- 1 curved dual-purpose layer

Outer Barrel (OB)
- 1 stave-based sagitta layer
- 1 stave-based outer layer



Electron/Hadron Endcaps (EE, HE)
- 5 disks on either side of the IP

Total (active) area ~ 8.5 m^2

c.f. https://wiki.bnl.gov/EPIC/index.php?title=Si_Vertex_Tracker

SVT — single track impact resolution

Consider single charged pion tracks at mid-rapidity in fast simulations*,

Recall the default barrel geometry:

Region	Layer	radius [mm]	length [mm]	X/X0
IB	L0	36	270	0.05 %
	L1	48	270	0.05 %
	L2	120	270	0.05 %
OB	L3	270	540	0.25 %
	L4	420	840	0.55 %

The beam-pipe is considered to be at a radius of 31 mm, be made of Beryllium, and have a thickness of 800 μm so that X/X_0 ~ 0.23%. It is coated internally with a Gold layer of 5 μm thickness, corresponding to X/X_0 ~ 0.14%.

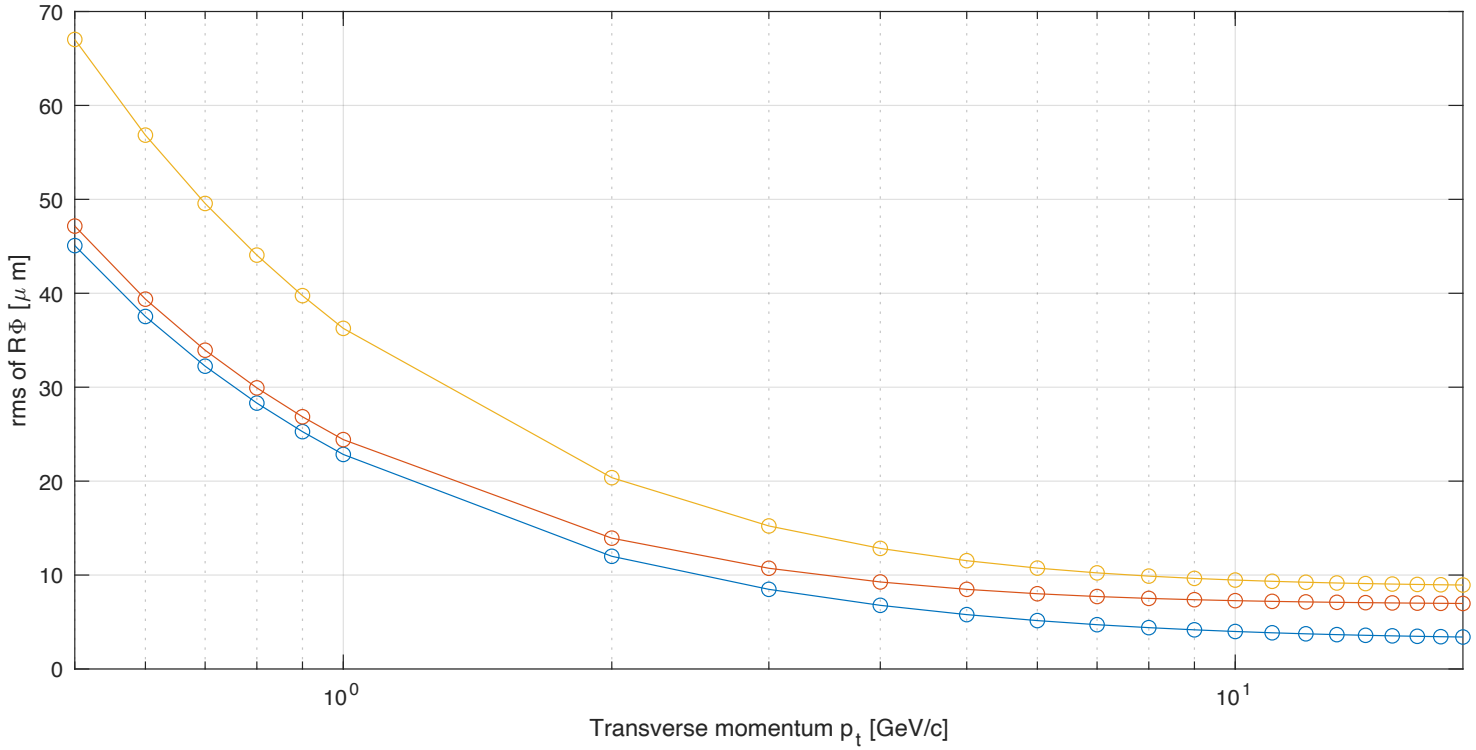
Consider effects of increased pixel pitch (point resolution) and material in L0—L3 (L4).

The outer (non-MAPS) tracker is not considered in any of the simulations that follow.

* LDT — includes e.g. effect of multiple scattering on angle, though not energy loss

SVT — single track impact resolution

Consider single charged pion tracks at mid-rapidity in fast simulations* and consider effects of increased pixel pitch (point resolution) and material in L0—L3 (L4),



Blue: 10 μm pitch, X/X_0 ~ 0.05%

Red: 22 μm pitch, X/X_0 ~ 0.05%

Yellow: 28 μm pitch, X/X_0 ~ 0.3%

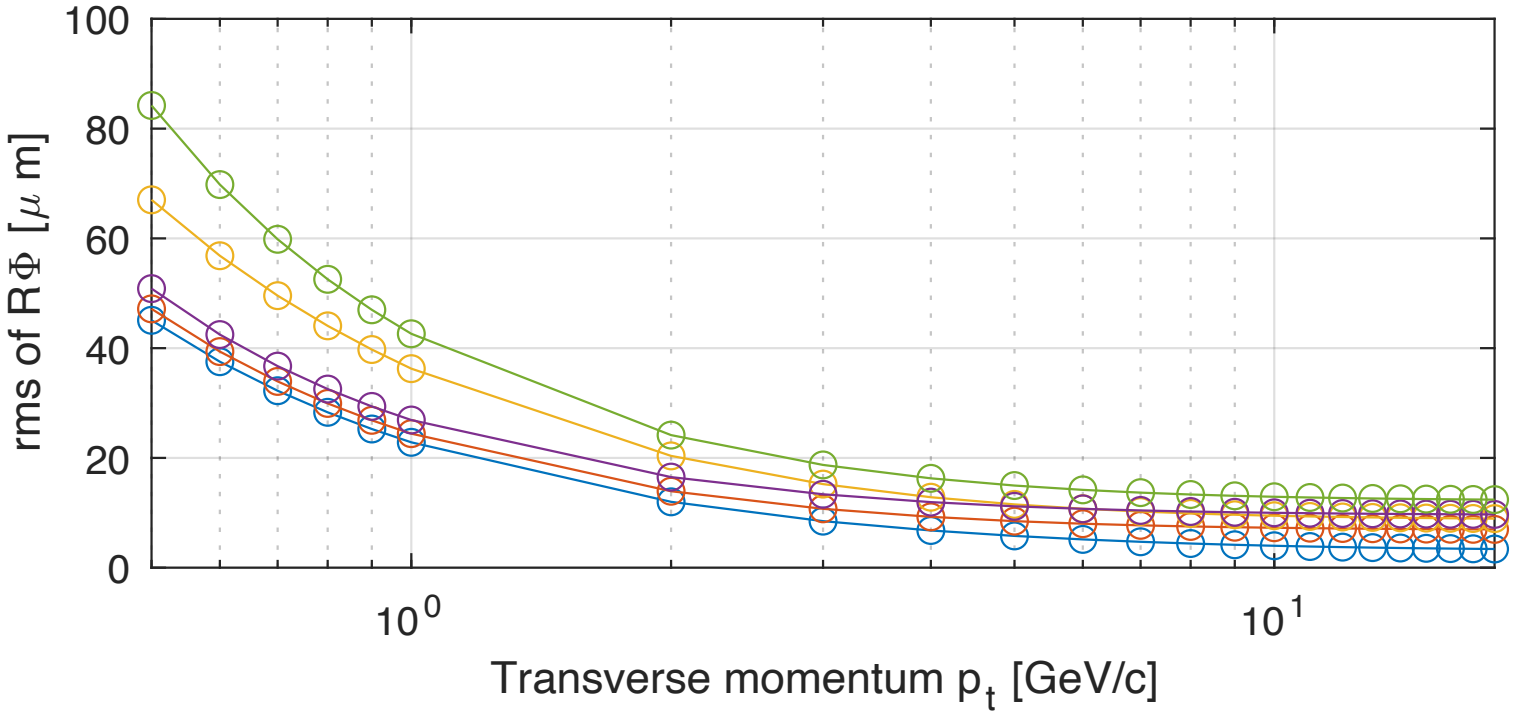
Point resolution and pixel pitch are proportional in these simulations; the usual factor of √12.

Pitch is a ~10% and material a ~50% effect at 1 GeV/c in this parameter range.

* LDT — includes e.g. effect of multiple scattering on angle, though not energy loss

SVT — single track impact resolution

L0 and L1 are closely spaced in radius and thereby provide a form of redundancy for the track's anchor point near the beam-pipe; it is illustrative to consider the "what if" L0 were inefficient.



Blue: 10 μm pitch, X/X_0 ~ 0.05%

Red: 22 μm pitch, X/X_0 ~ 0.05%

Yellow: 28 μm pitch, X/X_0 ~ 0.3%

Purple: like red, L0 inefficient

Green: like yellow, L0 inefficient

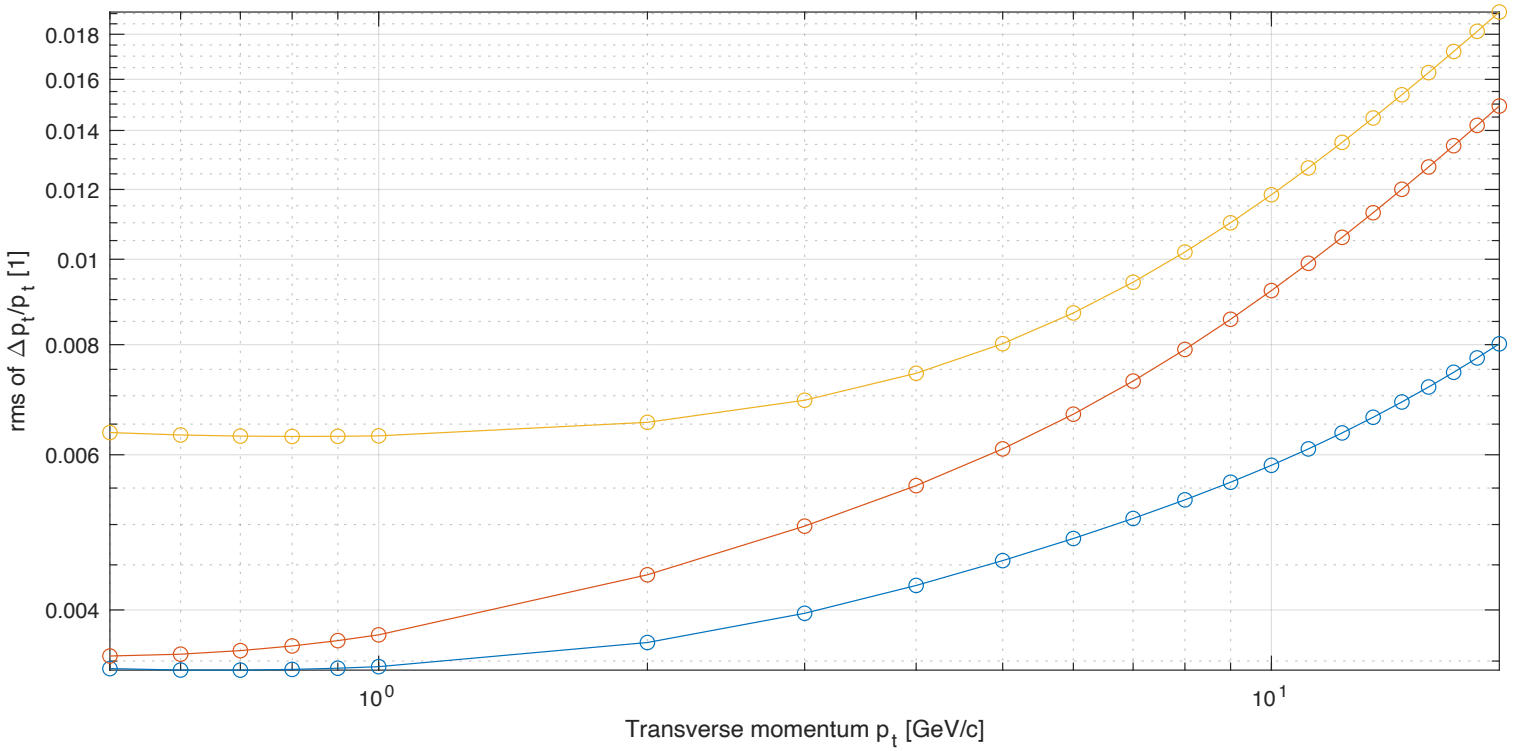
Point resolution and pixel pitch are proportional in these simulations; the usual factor of √12.

L0 inefficiency is a ~10% effect for X/X_0 ~ 0.05% and a ~20% effect for X/X_0 ~ 0.3% at 1 GeV/c.

* LDT — includes e.g. effect of multiple scattering on angle, though not energy loss

SVT — single track momentum resolution

Consider single charged pion tracks at mid-rapidity in fast simulations* and consider effects of increased pixel pitch (point resolution) and material in L0—L3 (L4),



Blue: 10 μm pitch, X/X_0 ~ 0.05%

Red: 22 μm pitch, X/X_0 ~ 0.05%

Yellow: 28 μm pitch, X/X_0 ~ 0.3%

Point resolution and pixel pitch are proportional in these simulations; the usual factor of √12.

Pitch is a ~10% (60%) and material a ~85% (25%) effect at 1 GeV/c (10 GeV/c) in this parameter range.

* LDT — includes e.g. effect of multiple scattering on angle, though not energy loss

SVT — single track momentum resolution

Consider single charged pion tracks at **backward angles** — here, 174.3° or η~3 — in the EE disk array in fast simulations, and consider the effects of the shrunk lever arm and pixel pitch,

Recall the (slightly revised) backward geometry:

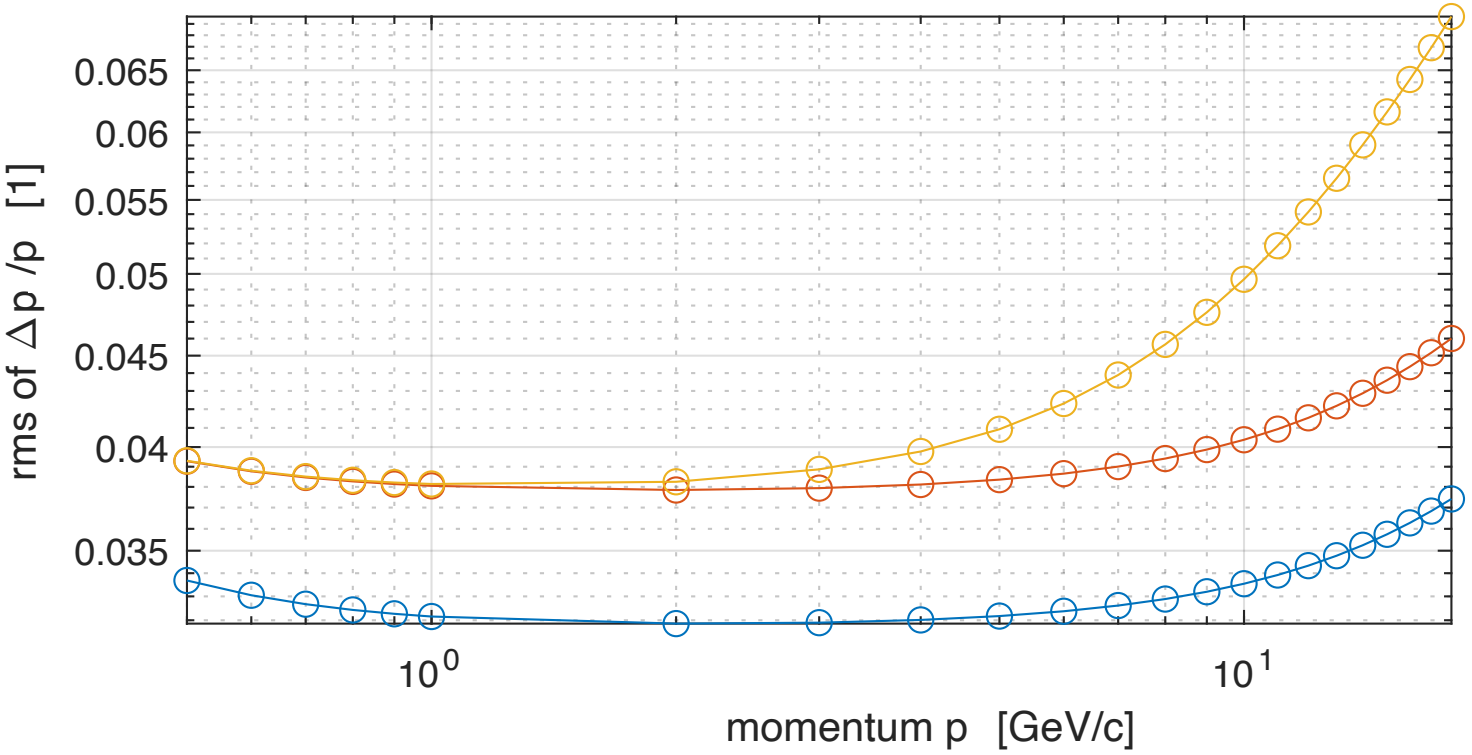
Region	Disk	z [mm]	inner radius [mm]	outer radius [mm]	X/X0
EE	ED0	-250	36.76	240	0.24 %
	ED1	-450	36.76	415	0.24 %
	ED2	-650	36.76	421.4	0.24 %
	ED3	-850	40	421.4	0.24 %
	ED4	-1050	46.35	421.4	0.24 %

Note that the disks are (now) equidistant; previously ED3 was at -900 mm and ED4 at -1150mm,

The shrunk lever arm serves to accommodate two MPGD disks (in combination with the pfRICH).

SVT — single track momentum resolution

Consider single charged pion tracks at **backward angles** — here, 174.3° or η~-3 — in the EE disk array in fast simulations, and consider the effects of the shrunk lever arm and pixel pitch,



Blue: 10 μm pitch, ED4 at -115cm

Red: 10 μm pitch, ED4 at -105cm

Yellow: like red, 22 μm pitch

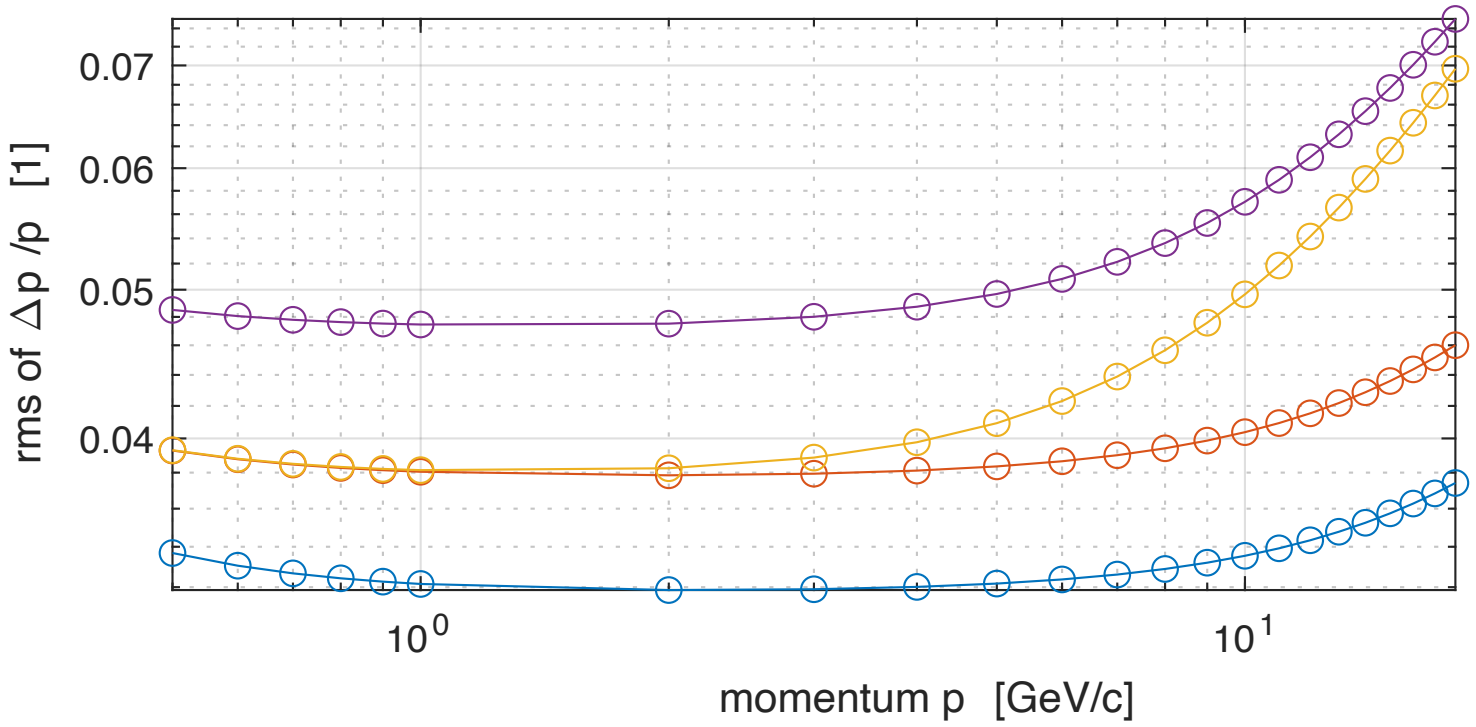
Note, disk ED0 is outside of the acceptance at this angle so that L ~ 60 cm with ED4 at -105 cm,

Effect of lever arm is ~19% for 1 — 10 GeV/c and less than the ratio of L^2 ~ 35%,

Effect of pixel pitch is ~25% at 10 GeV/c for a change in pitch from 10 to 22 μm.

SVT — single track momentum resolution

The disks are estimated to each have X/X_0 ~ 0.24%; it is illustrative to consider "what if" this were to increase.



Blue: 10 μm pitch, ED4 at -115cm

Red: 10 μm pitch, ED4 at -105cm

Yellow: like red, 22 μm pitch

Purple: like yellow, X/X_0 ~ 0.36%

A ~25% effect from a ~50% increase in X/X_0 at 1 GeV/c (indeed; expect √-scaling all else being equal),

(Aside, the "floor" in dp/p also scales as B^{-1})

Closing comments

Considered mid-rapidity and backward charged pion tracks:

- 10% effect on mid-rapidity impact parameter from pixel pitch (10 to 22 μm) at 1 GeV/c,
- 50% effect on mid-rapidity impact parameter if material increases (X/X_0 ~ 0.05% to ~0.30%) at 1 GeV/c,
- ~25 μm default mid-rapidity impact parameter at 1 GeV/c, decreasing to less than 10 μm at 10 GeV/c,
- ($c\tau$ ~123 μm for D^0, ~60 μm for Λ_c),

- 10% effect on mid-rapidity dp/p from pixel pitch (10 to 22 μm) at 1 GeV/c,
- 85% effect on mid-rapidity dp/p if material increases (X/X_0 ~ 0.05% to ~0.30%) at 1 GeV/c,
- ~0.35% default dp/p at mid-rapidity at 1 GeV/c,
- Relative impact changes (reverses) with increasing p; 60% from pitch and 25% from material at 10 GeV/c,

- Anticipate backward dp/p to worsen by ~19% from reduced lever arm (does *not* scale as L^2; slower),
- dp/p essentially unaffected by an increase of pixel pitch from 10 to 22 μm* up to p ~ 3 GeV/c; 25% effect at 10 GeV/c,
- 25% effect on dp/p from 50% increase in X/X_0 (as expected from $\sqrt{}$-scaling),
- dp/p ~ 4% for $1 < p < 5$ GeV/c at η ~ -3

- Will prepare a short writeup, time-permitting.

* yes, this is specific to this particular range; it does *not* hold for, say, a 100 μm pitch let alone MPGD resolutions.