All-Silicon Tracker Performance Studies

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ATHENA Tracking Meeting

09/14/2021

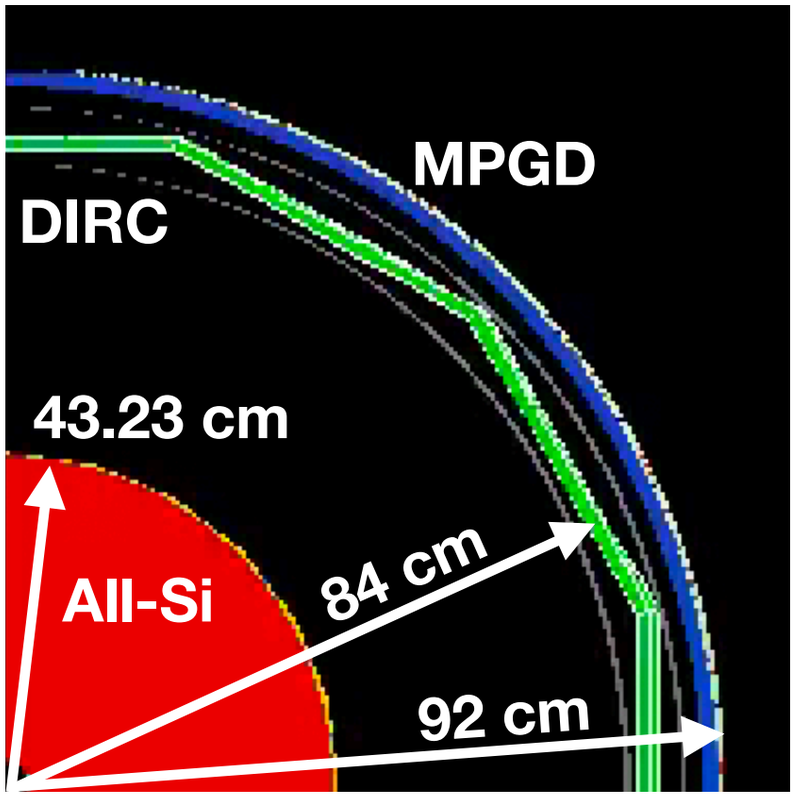
Outline

- MPGDs in the barrel region

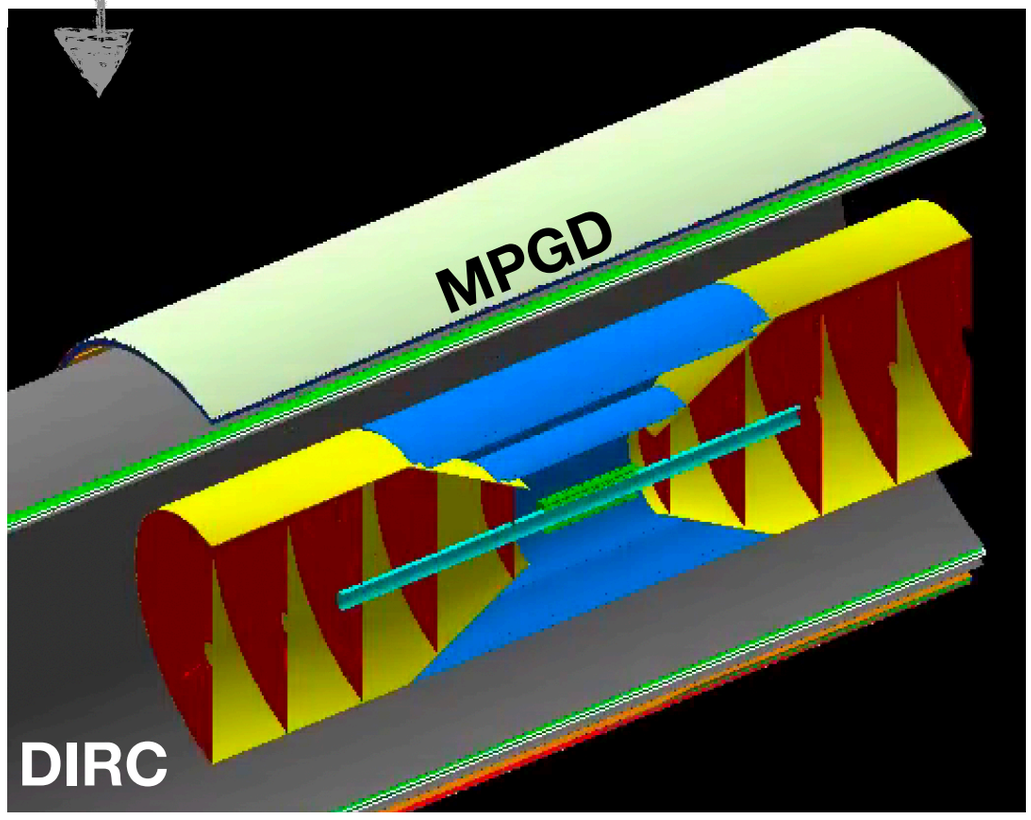
- MPGDs behind the mRICH

Complementing the all-si tracker in the barrel region

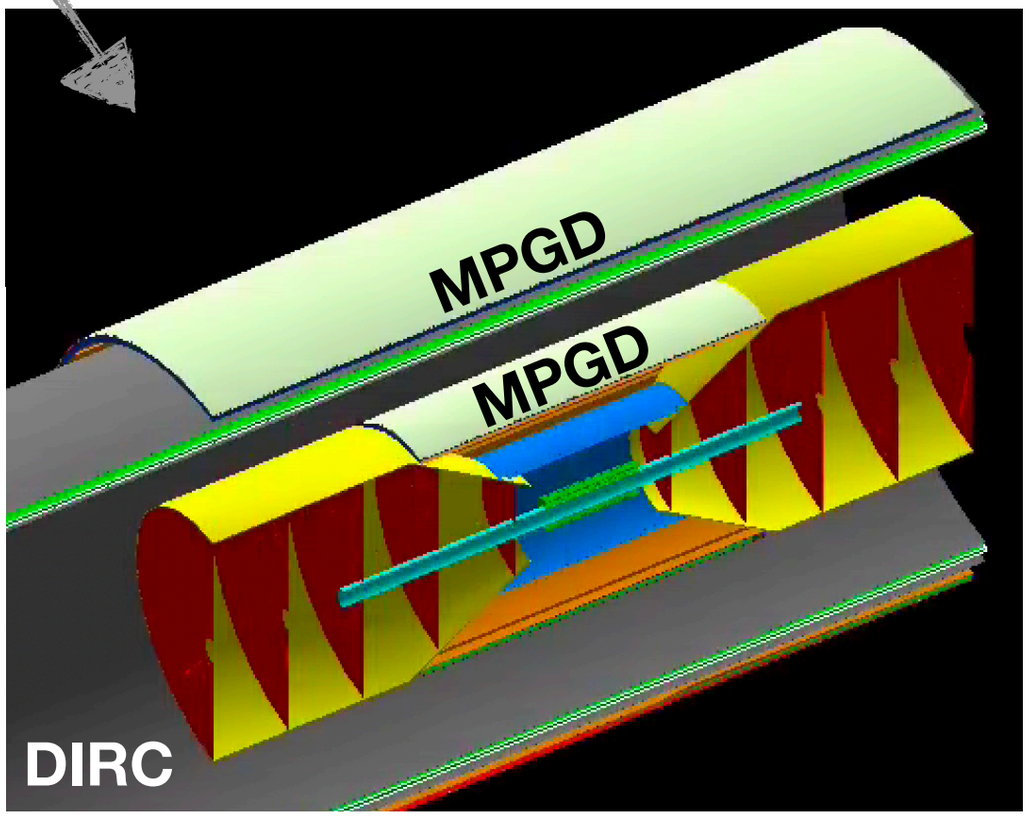
All-si tracker material budget (X/X0):
- Vertexing layers: 0.05%
- Barrel Layers: 0.55%
- Disks: 0.24%



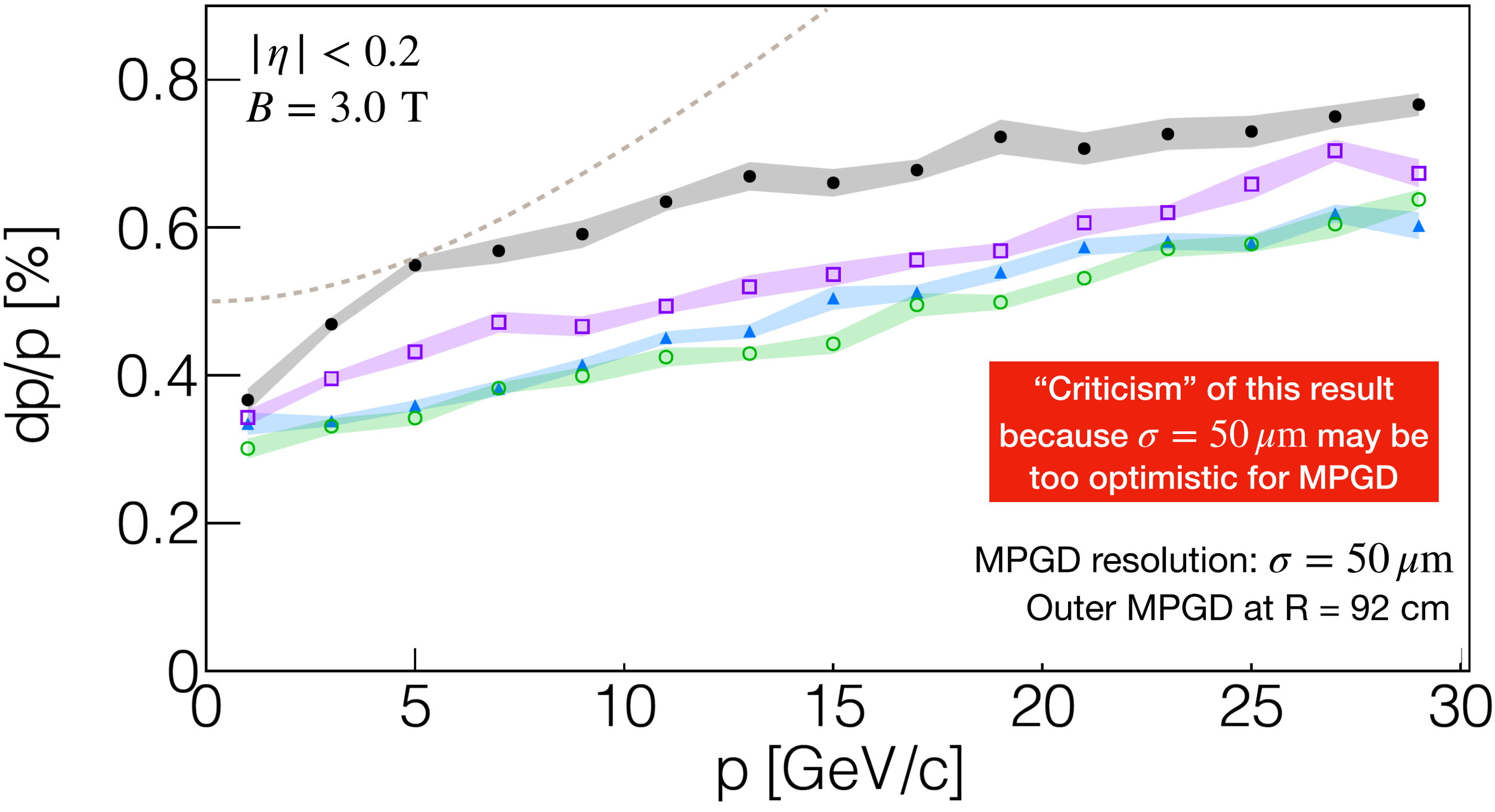
Variant #1:
All-silicon tracker
+ MPGD outside
DIRC



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



MPGD Material Budget Effect



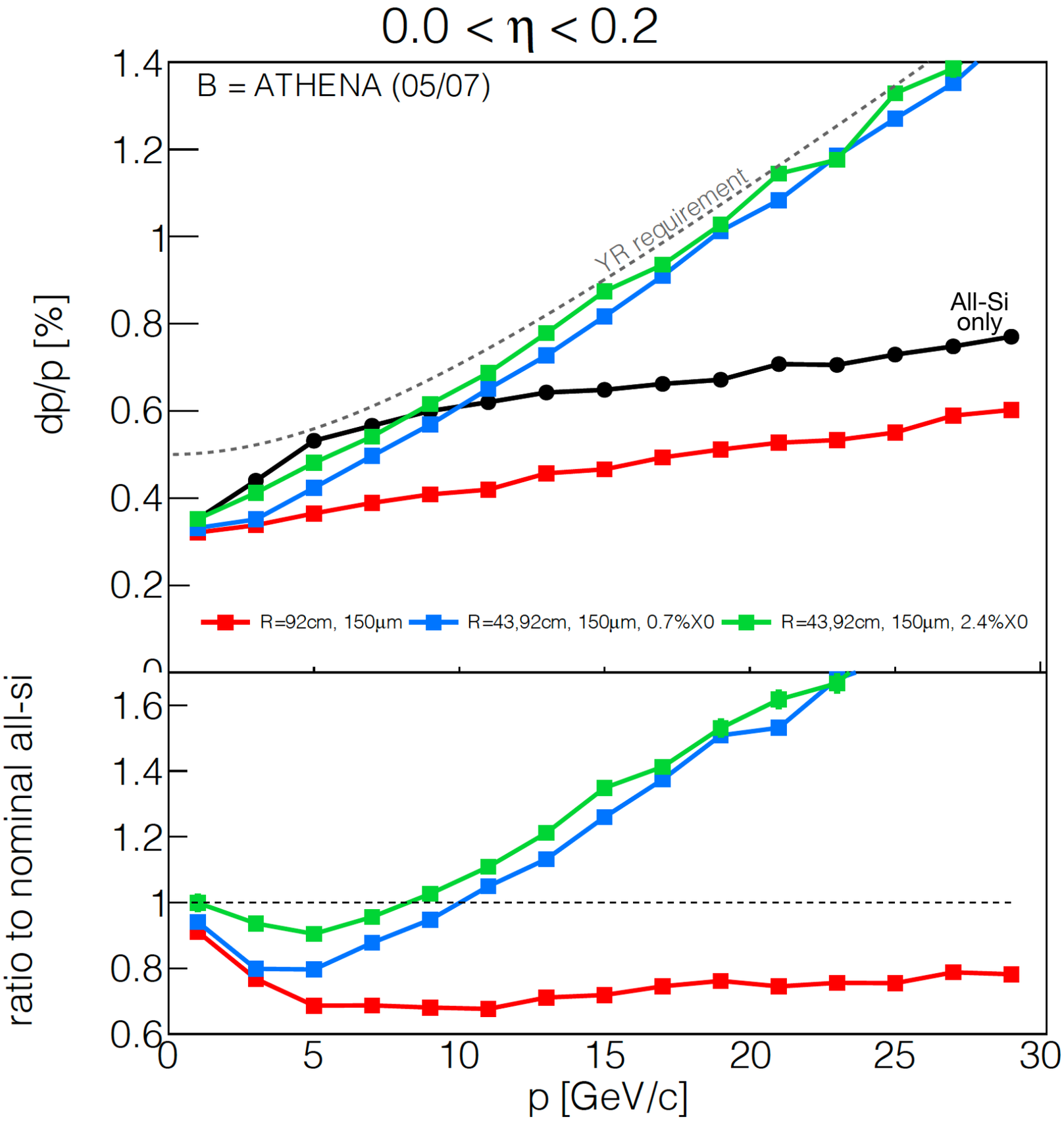
all-si only

all-si + DIRC + MPGD (R = 92 cm)

all-si outer two layers replaced with MPGD (X/X0=0.7%) + DIRC + MPGD (R = 92 cm)

all-si outer two layers replaced with MPGD (X/X0=2.4%) + DIRC + MPGD (R = 92 cm)

MPGDs in the barrel region



All-silicon (6 layers)

All-silicon (6 layers) + DIRC + MPGD (R=92 cm)

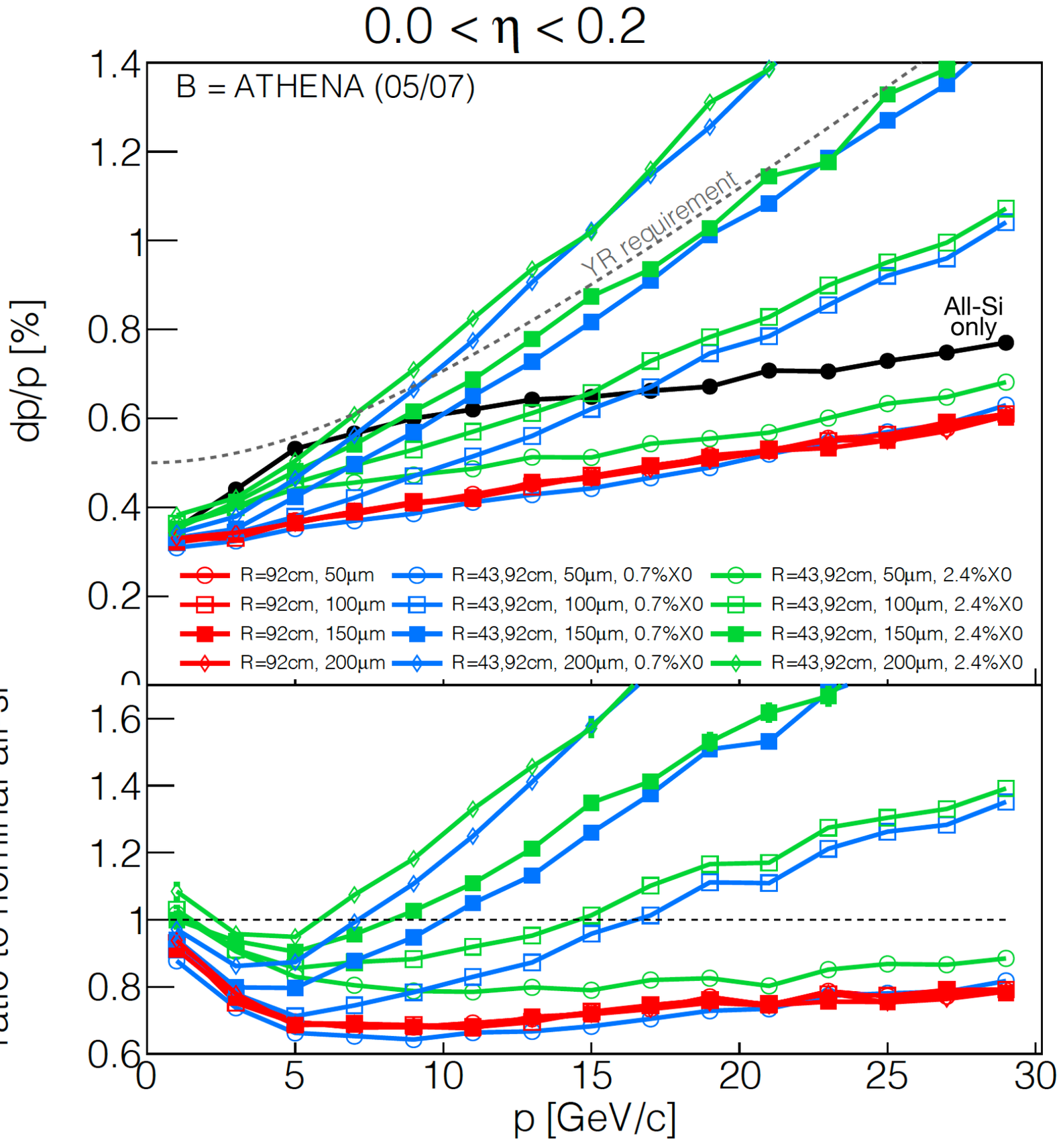
All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=0.7%X0)

All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=2.4%X0)

MPGD Resolution

150 μm

MPGDs in the barrel region



All-silicon (6 layers)

All-silicon (6 layers) + DIRC + MPGD (R=92 cm)

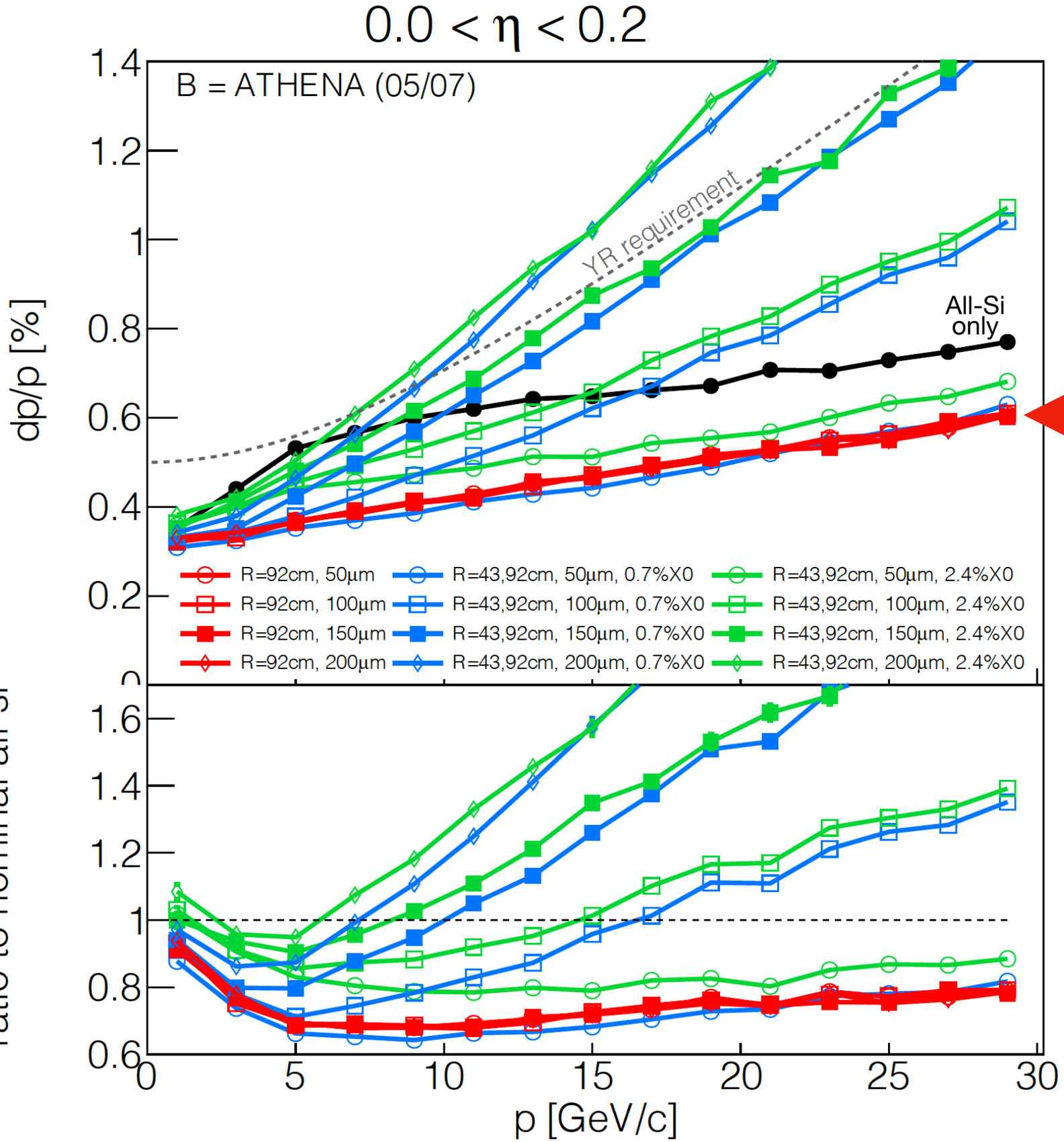
All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=0.7%X0)

All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=2.4%X0)

MPGD Resolution

- **50 μm**
- **100 μm**
- **150 μm**
- **200 μm**

Summary



All-silicon (6 layers)

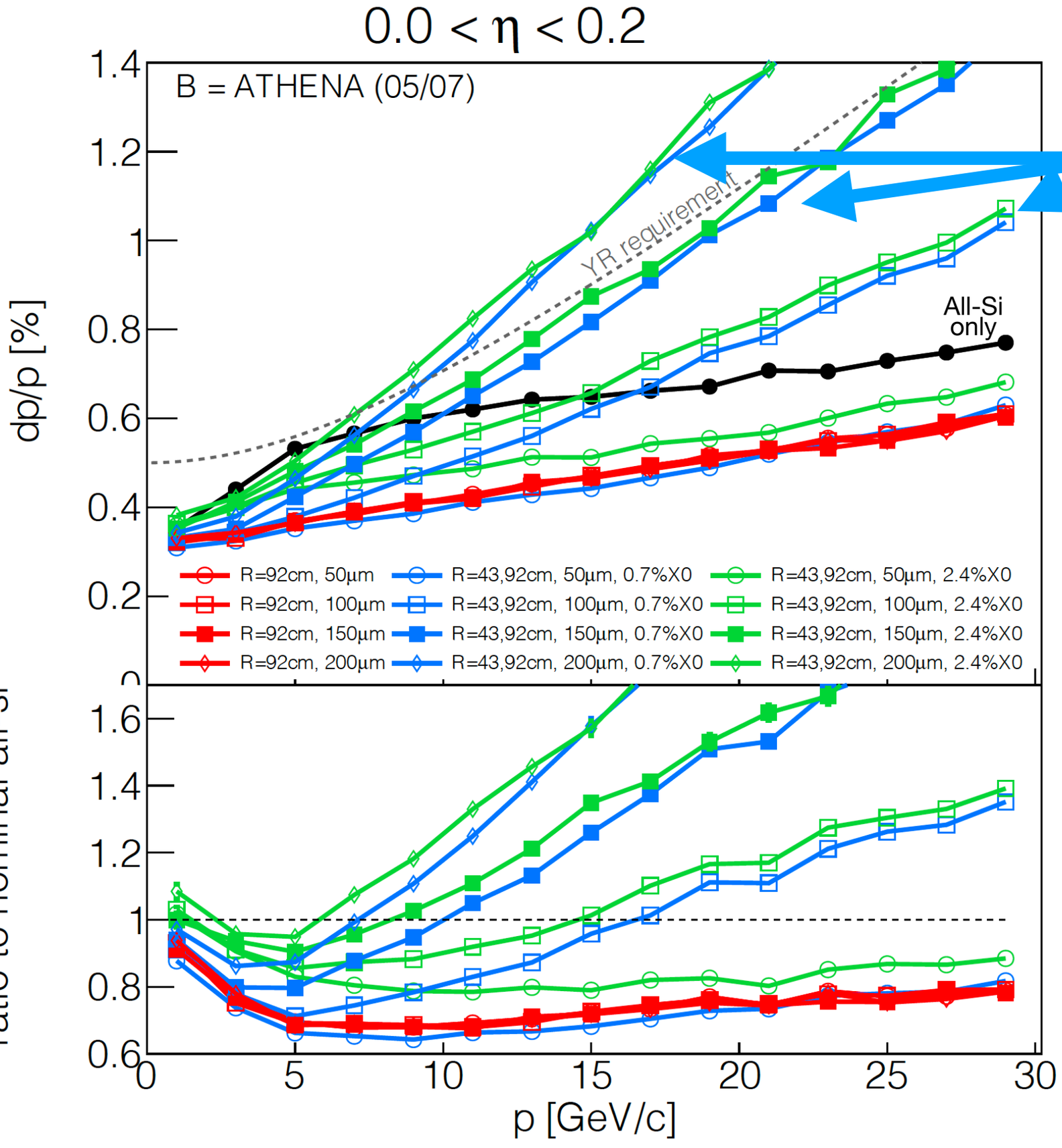
All-silicon (6 layers) + DIRC + MPGD (R=92 cm)

All red curves are bundled together (in this configuration the GEM resolution [between 50 and 200 μm) does not play a significant role)

MPGD Resolution

- 50 μm
- 100 μm
- 150 μm
- 200 μm

Summary



For a given MPGD resolution, the differences between the two material budgets considered (0.7 vs 2.4%) is small

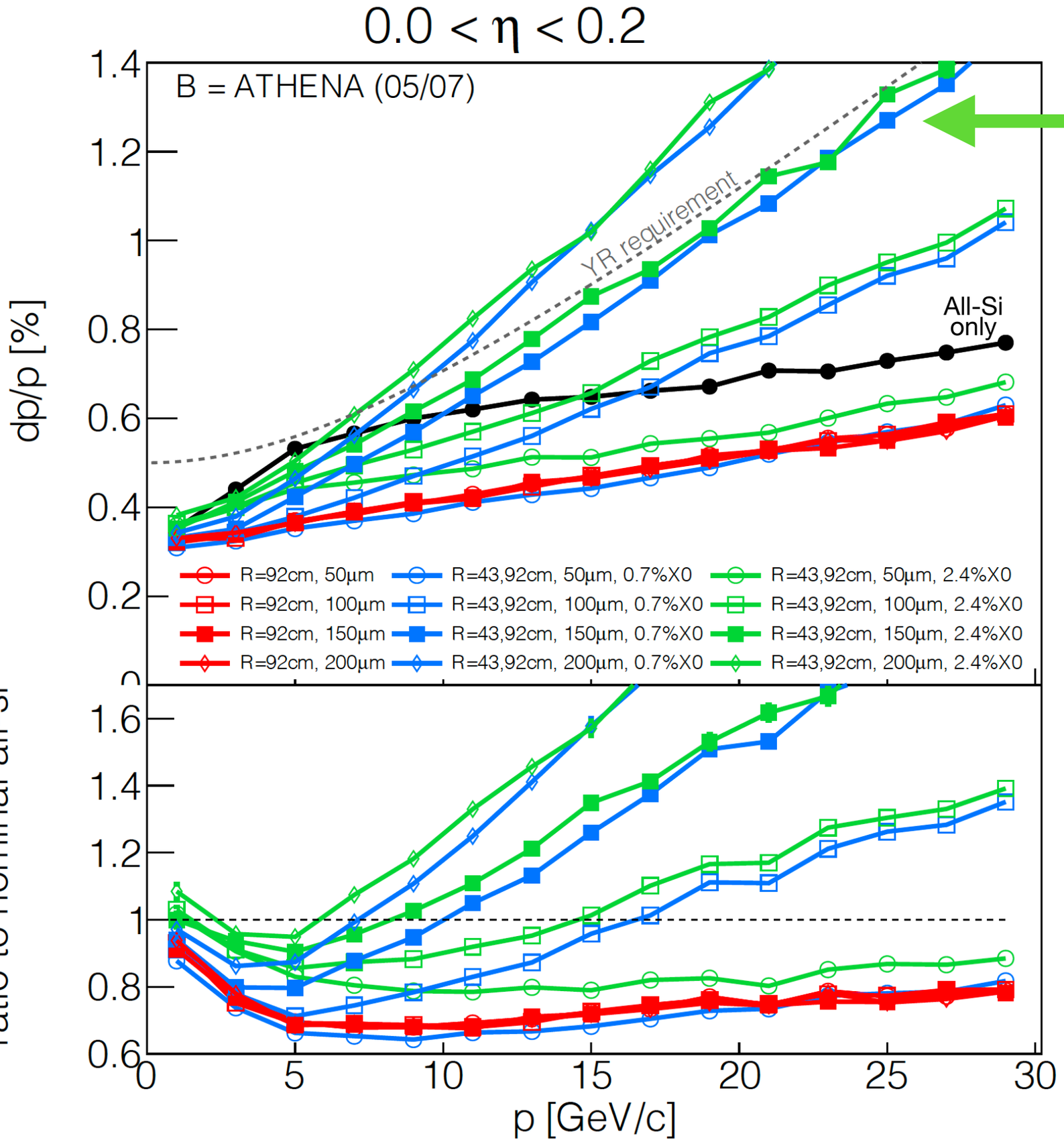
All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=0.7%X0)

All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=2.4%X0)

MPGD Resolution

- 50 μm
- 100 μm
- 150 μm
- 200 μm

Summary



The YR requirements are fulfilled with MPGDs of 150 μm resolution

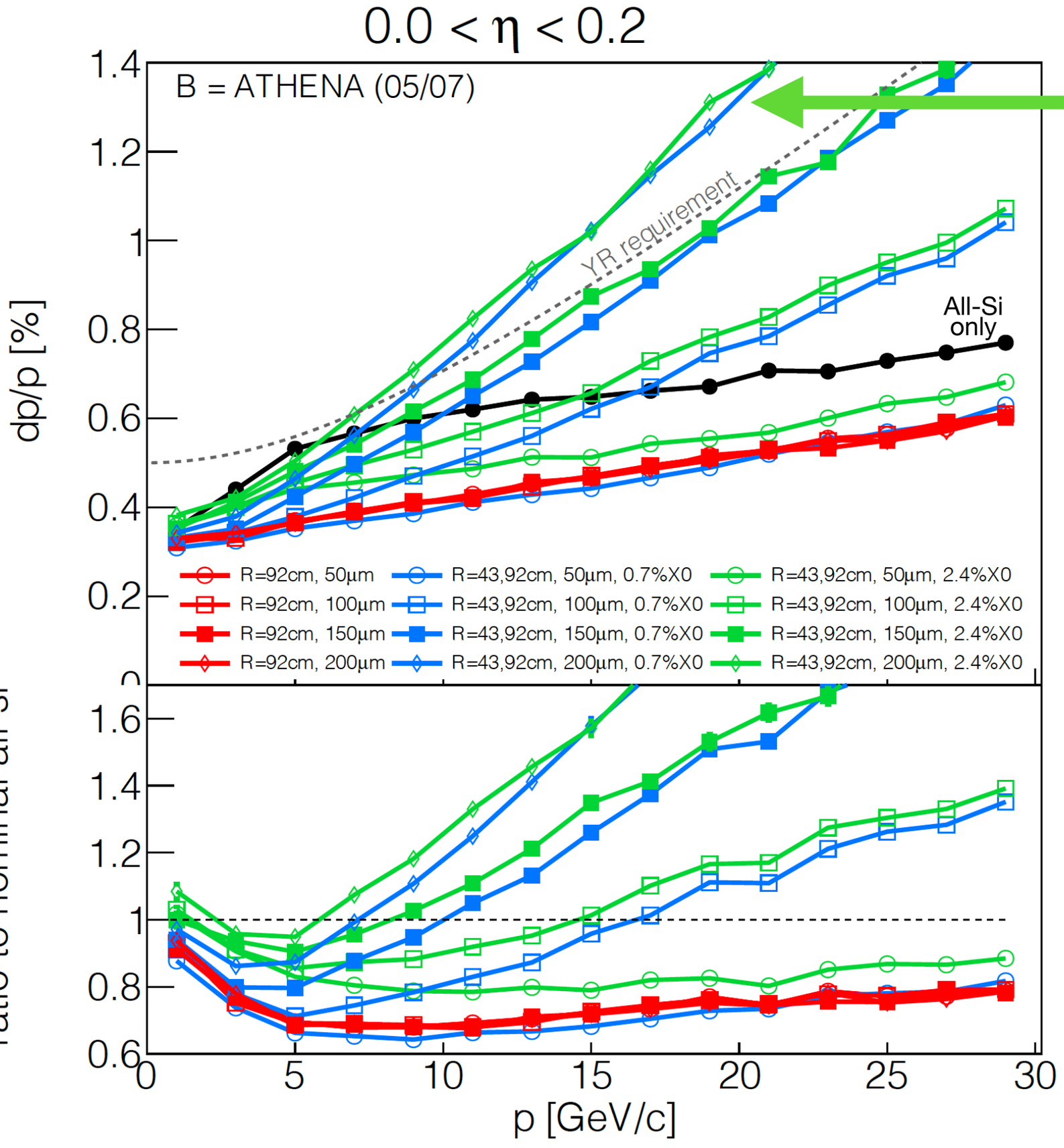
All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=0.7%X0)

All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=2.4%X0)

MPGD Resolution

- **50 μm**
- **100 μm**
- **150 μm**
- **200 μm**

Summary



The YR requirements are NOT fulfilled with MPGDs of 200 μm resolution

All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=0.7%X0)

All-silicon (4 layers) + MPGD (r=43 cm) + DIRC + MPGD (R=92 cm) (MPGD X=2.4%X0)

MPGD Resolution

- **50 μm**
- **100 μm**
- **150 μm**
- **200 μm**

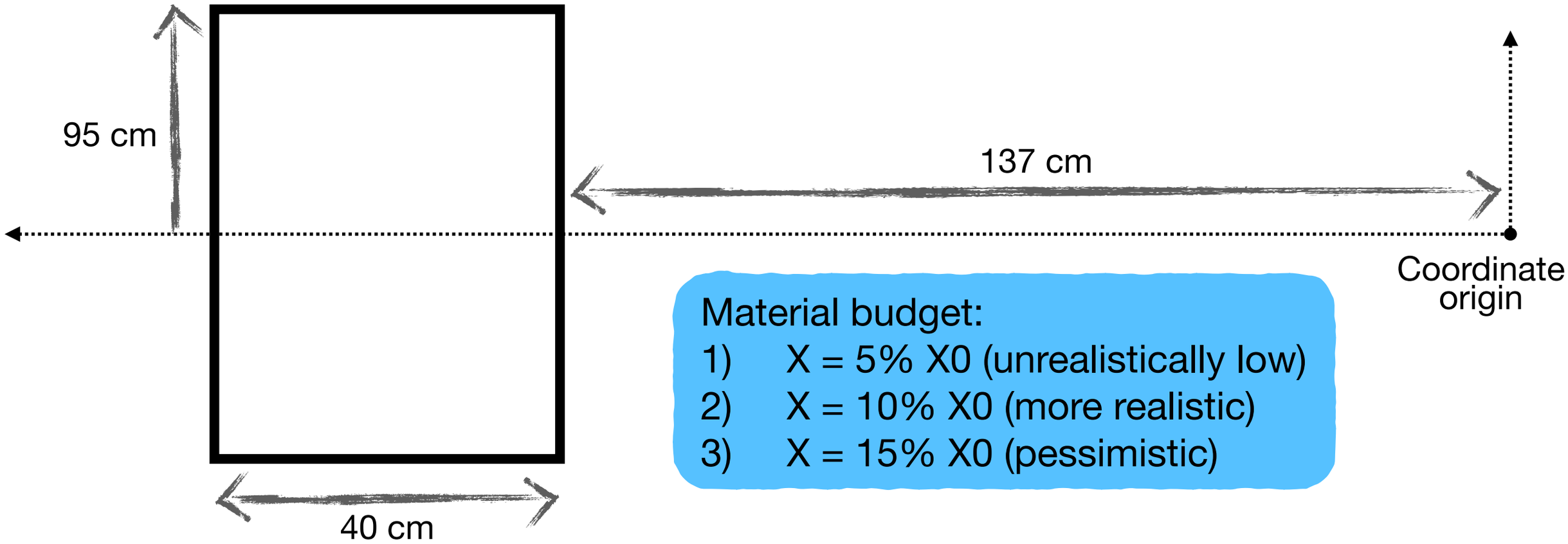
Outline

- MPGDs in the barrel region

- MPGDs behind the mRICH

mRICH Parametrization

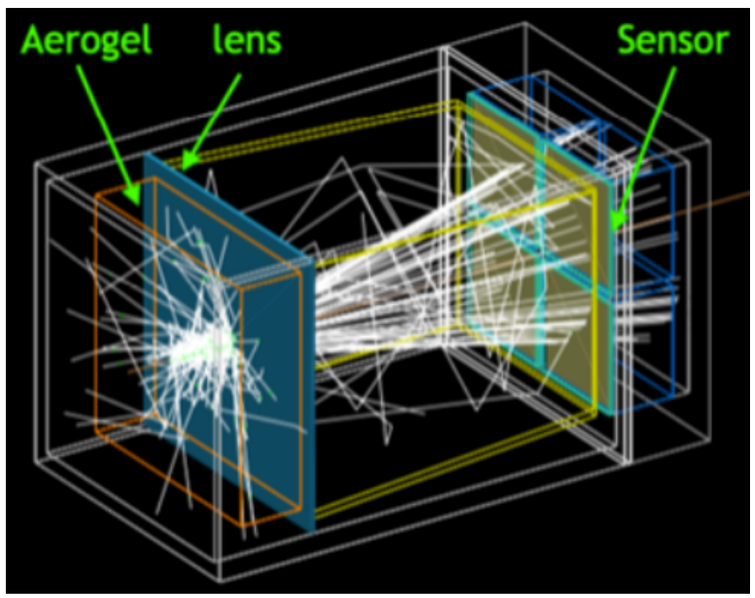
Information from private communication with S. Joosten (09/08/2021)



Material budget:

1) X = 5% X0 (unrealistically low)
2) X = 10% X0 (more realistic)
3) X = 15% X0 (pessimistic)

Parametrize as air with support in the back adding up to the right material budget



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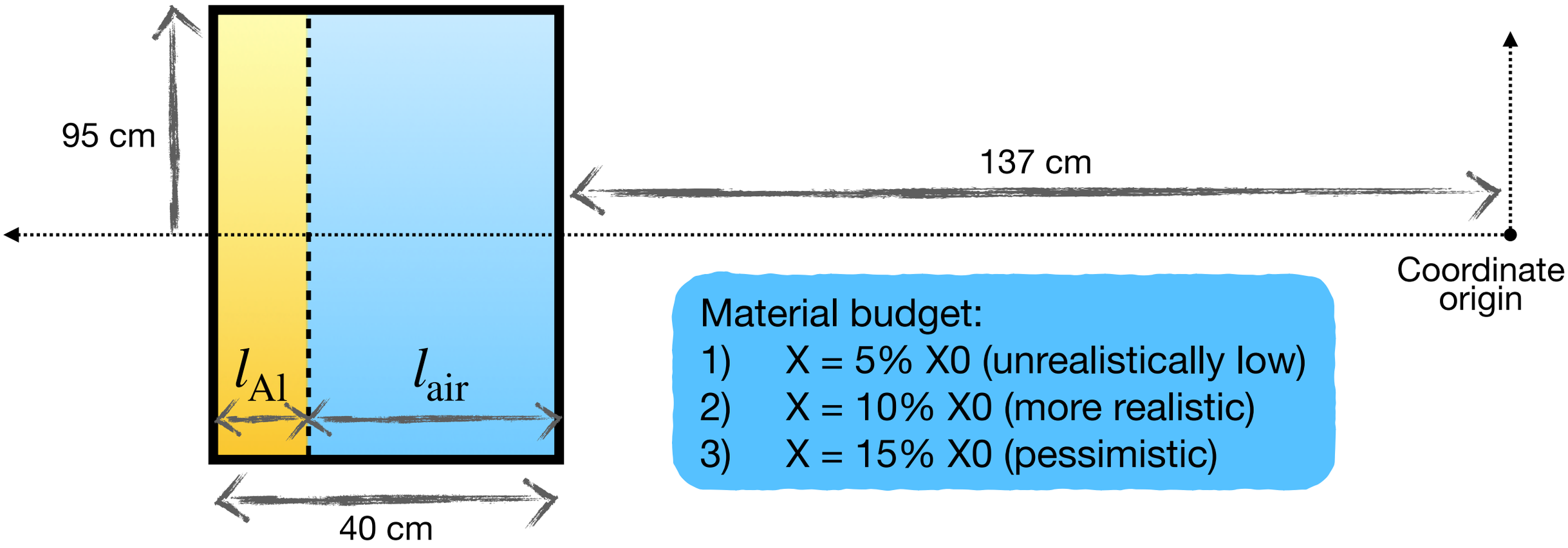

Material budget:
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$$l_{\mathrm{Al}} + l_{\mathrm{air}} = 40\,\mathrm{cm}$$

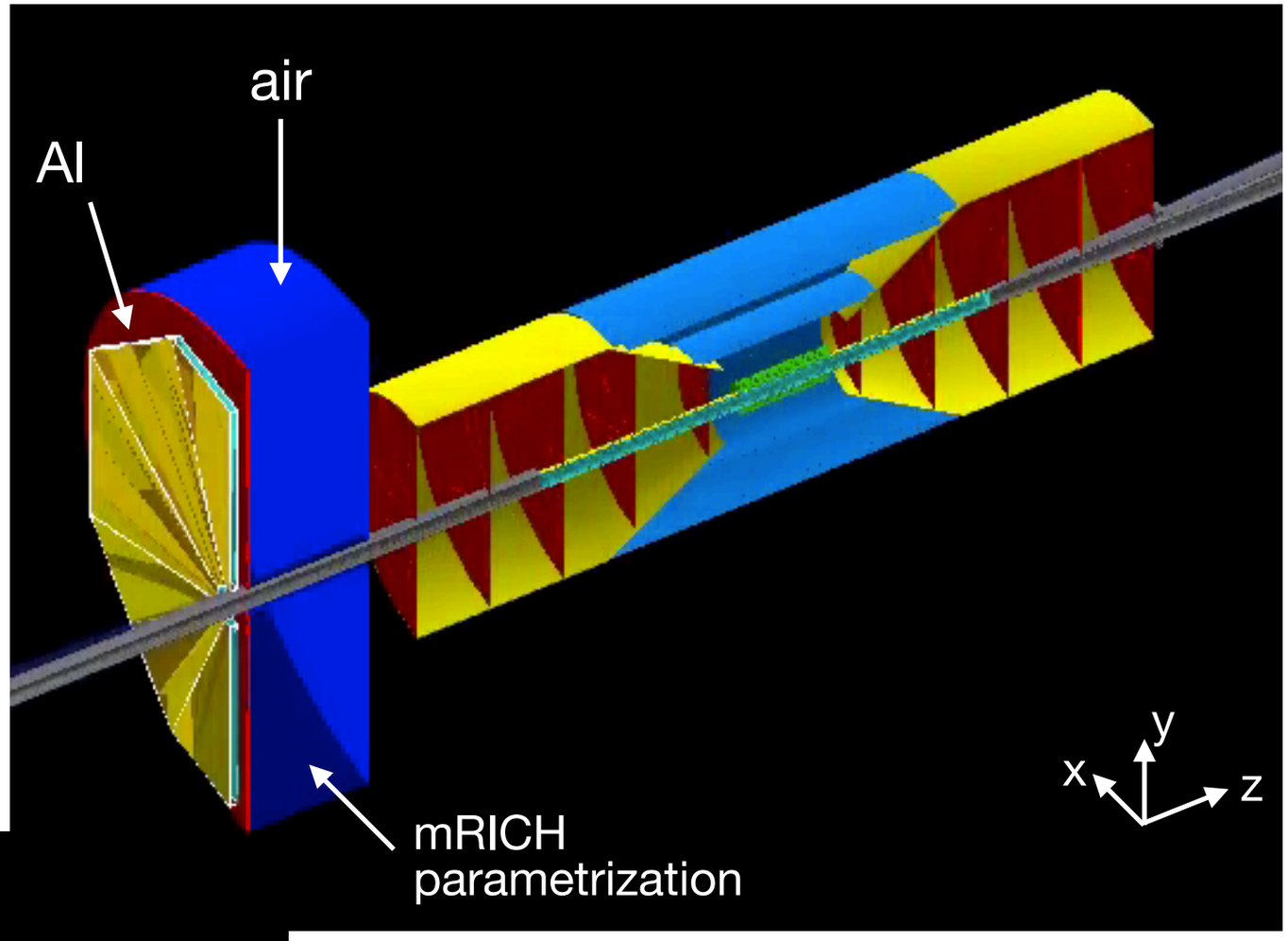
$$\frac{l_{\mathrm{Al}}}{X_0^{\mathrm{Al}}} + \frac{l_{\mathrm{air}}}{X_0^{\mathrm{air}}} = \frac{X}{100}$$

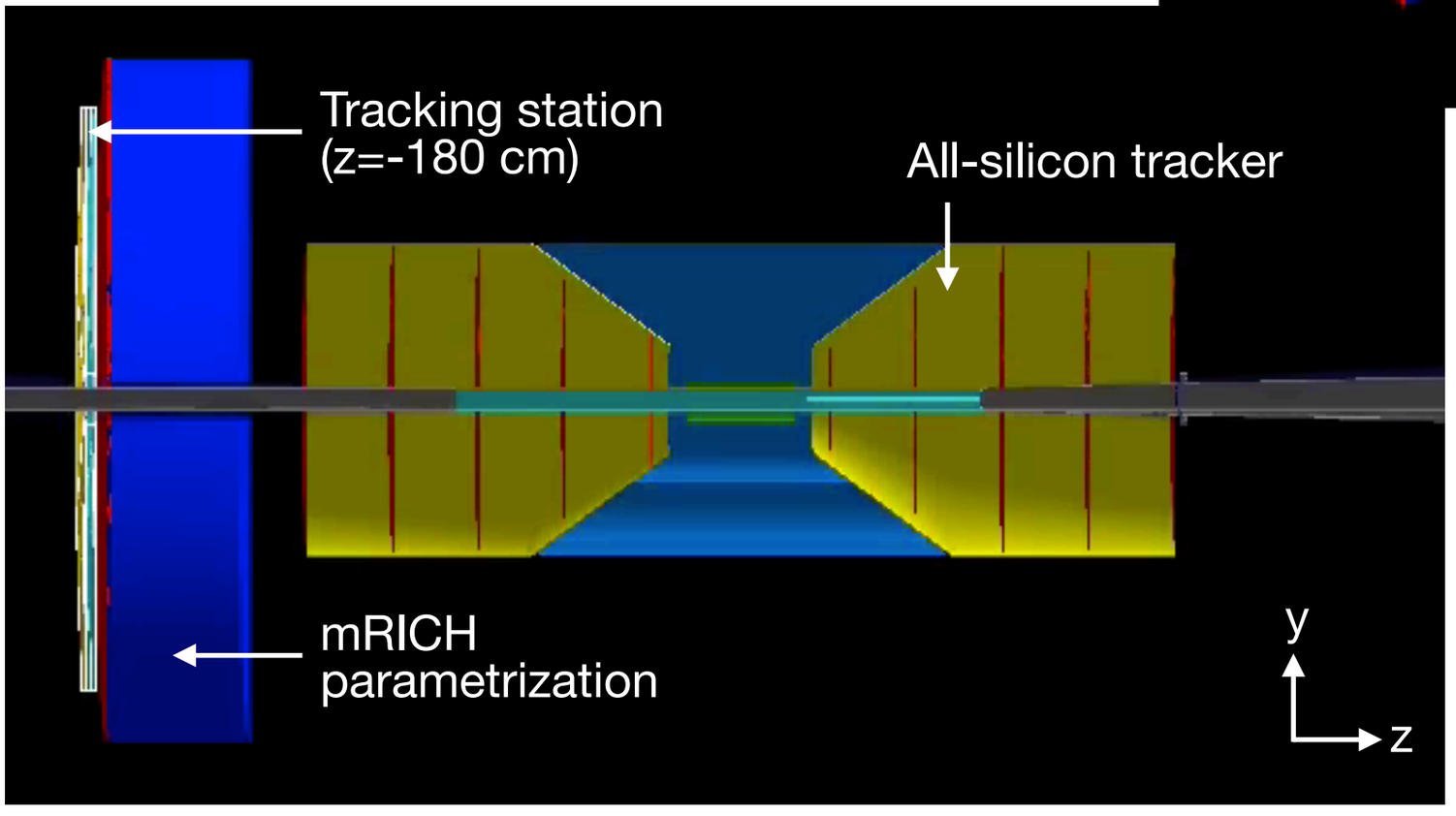
$$X_0^{\mathrm{Al}} = 8.897\,\mathrm{cm}$$

$$X_0^{\mathrm{air}} = 3.039 \times 10^4\,\mathrm{cm}$$

mRICH Parametrization

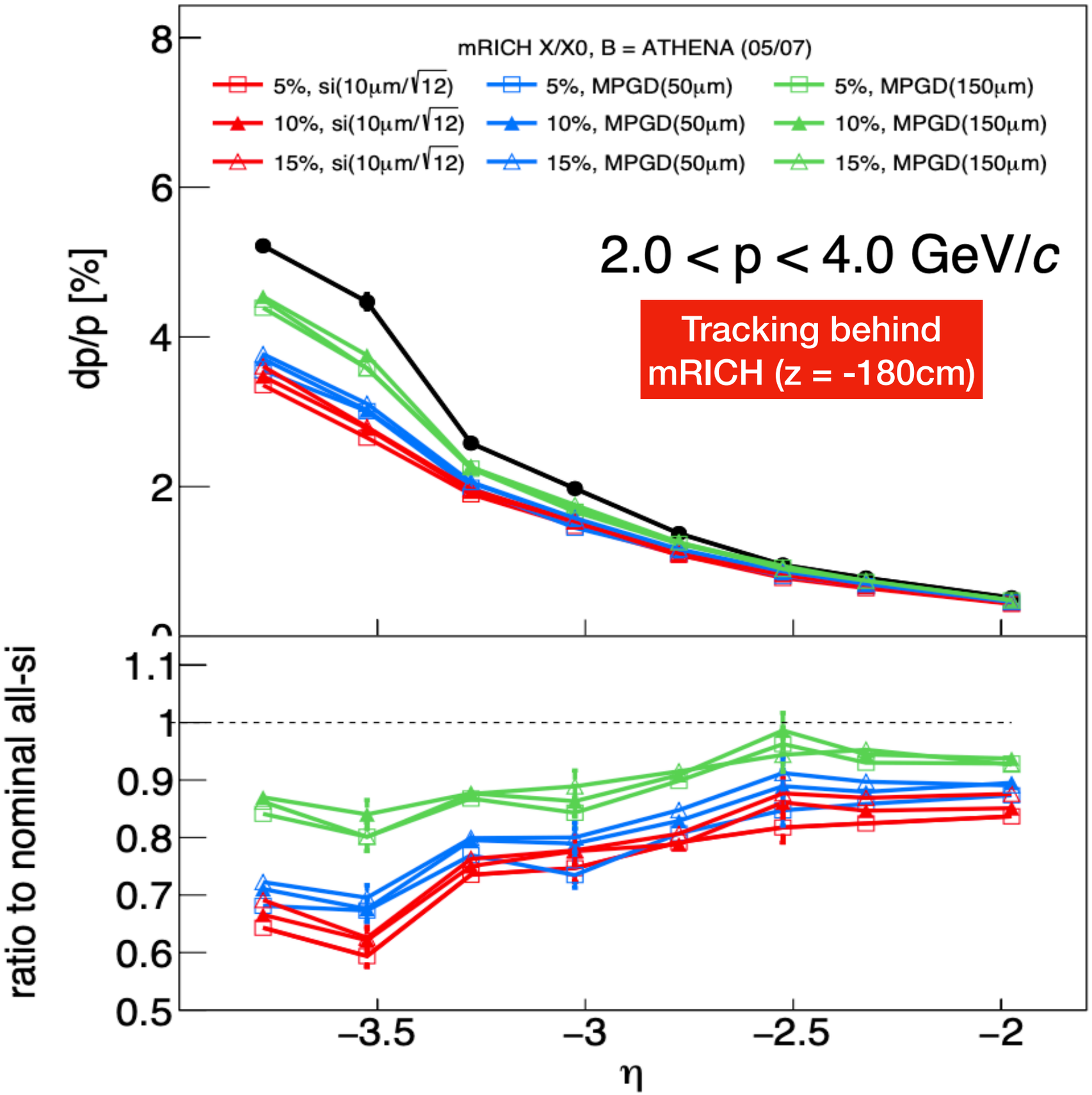
X [% X0]	l_{air} [cm]	l_{Al} [cm]
5	39.567	0.433
10	39.122	0.878
15	38.677	1.323





Measured the mockup mRICH material budget with a geantino scan

Performance vs. pseudorapidity



All-Si tracker only

All-Si tracker + si disk

All-Si tracker + MPGD ($\sigma = 50\,\mu$m)

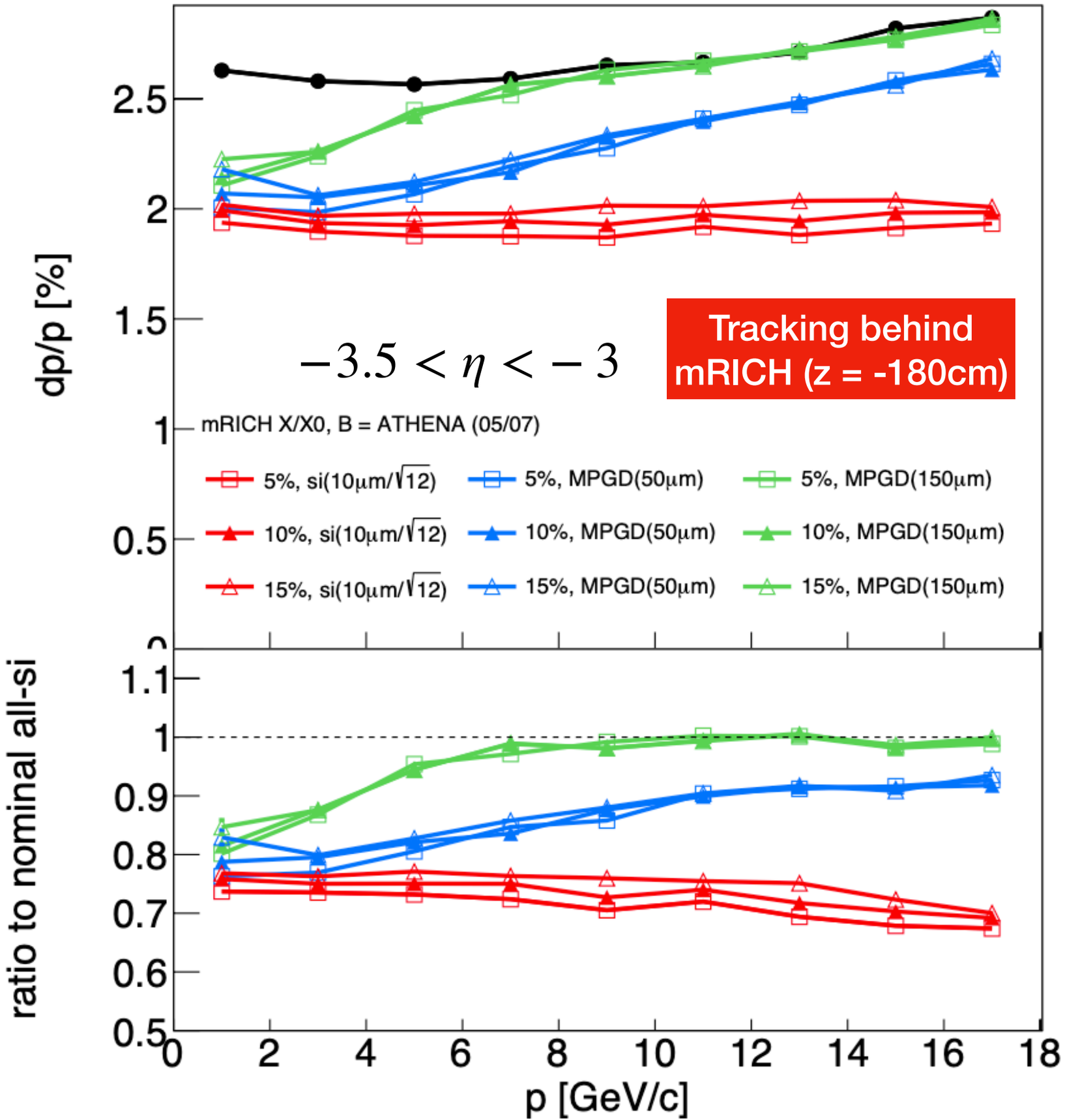
All-Si tracker + MPGD ($\sigma = 150\,\mu$m)

mRICH X = 5% X0

mRICH X = 10% X0

mRICH X = 15% X0

Performance vs. momentum



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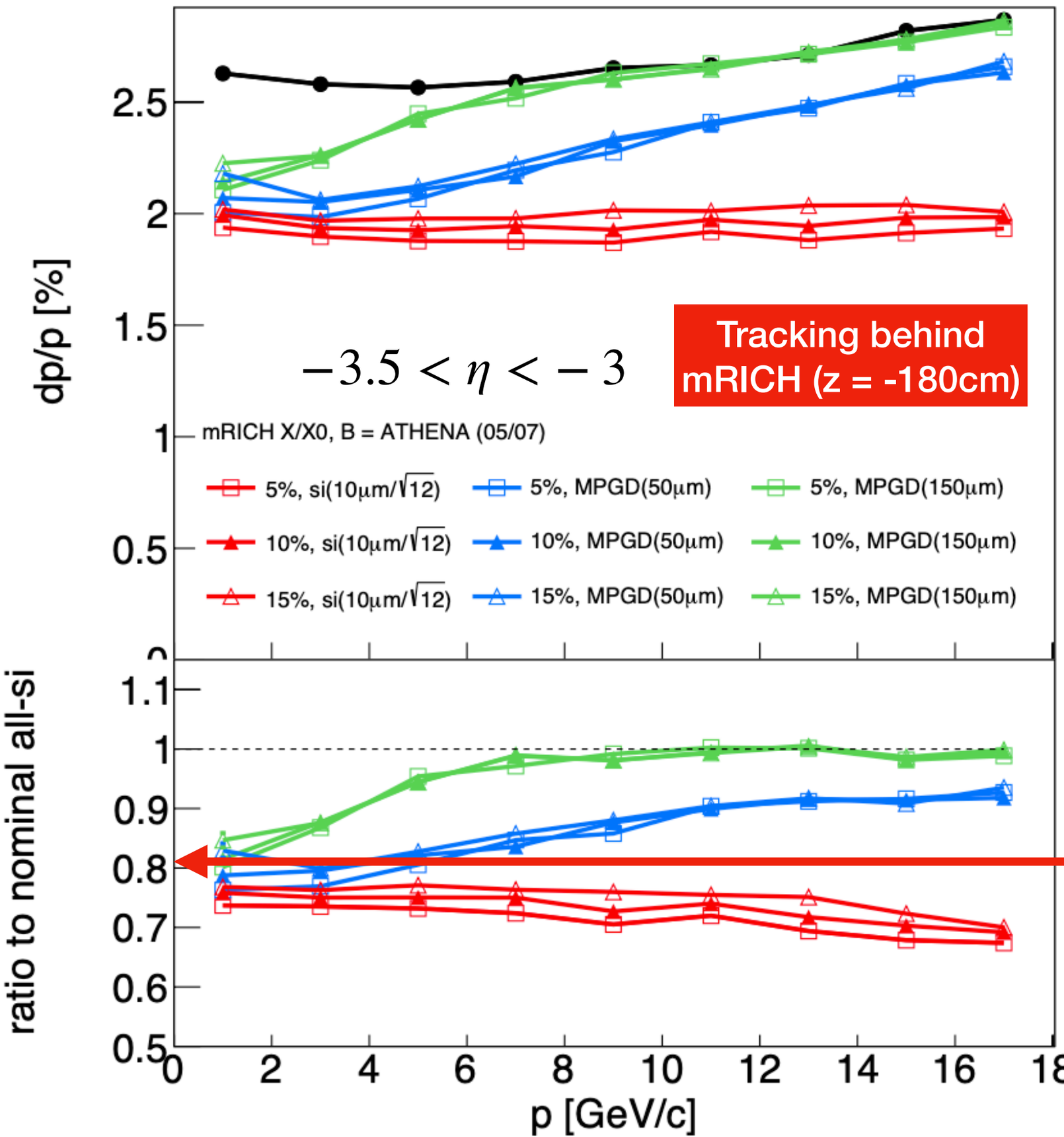
Summary



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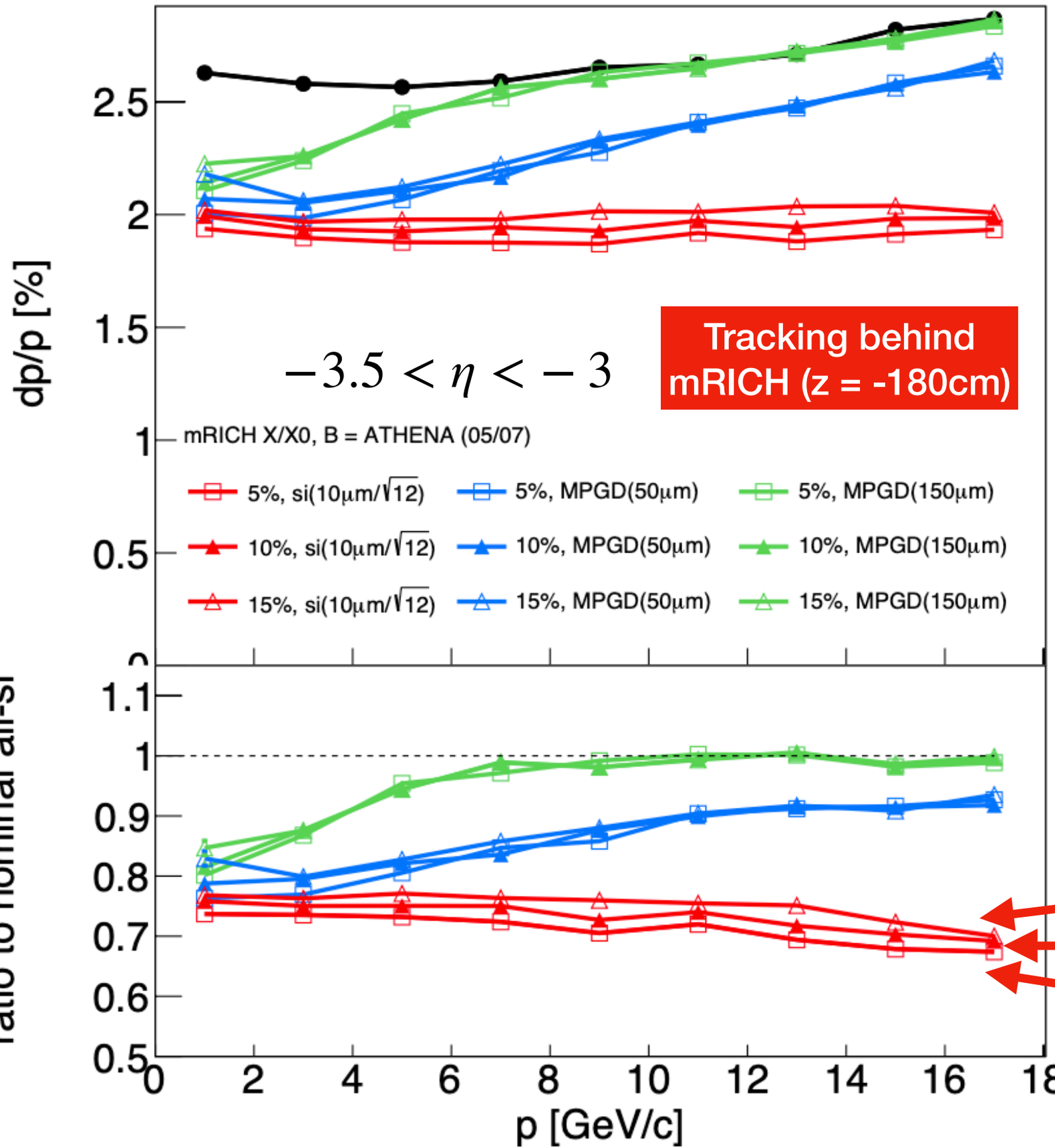
At high η and low p both GEMs and silicon disks enhance the momentum-resolution performance up to $\approx 20\,\%$

Summary



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mRICH X = 5% X0

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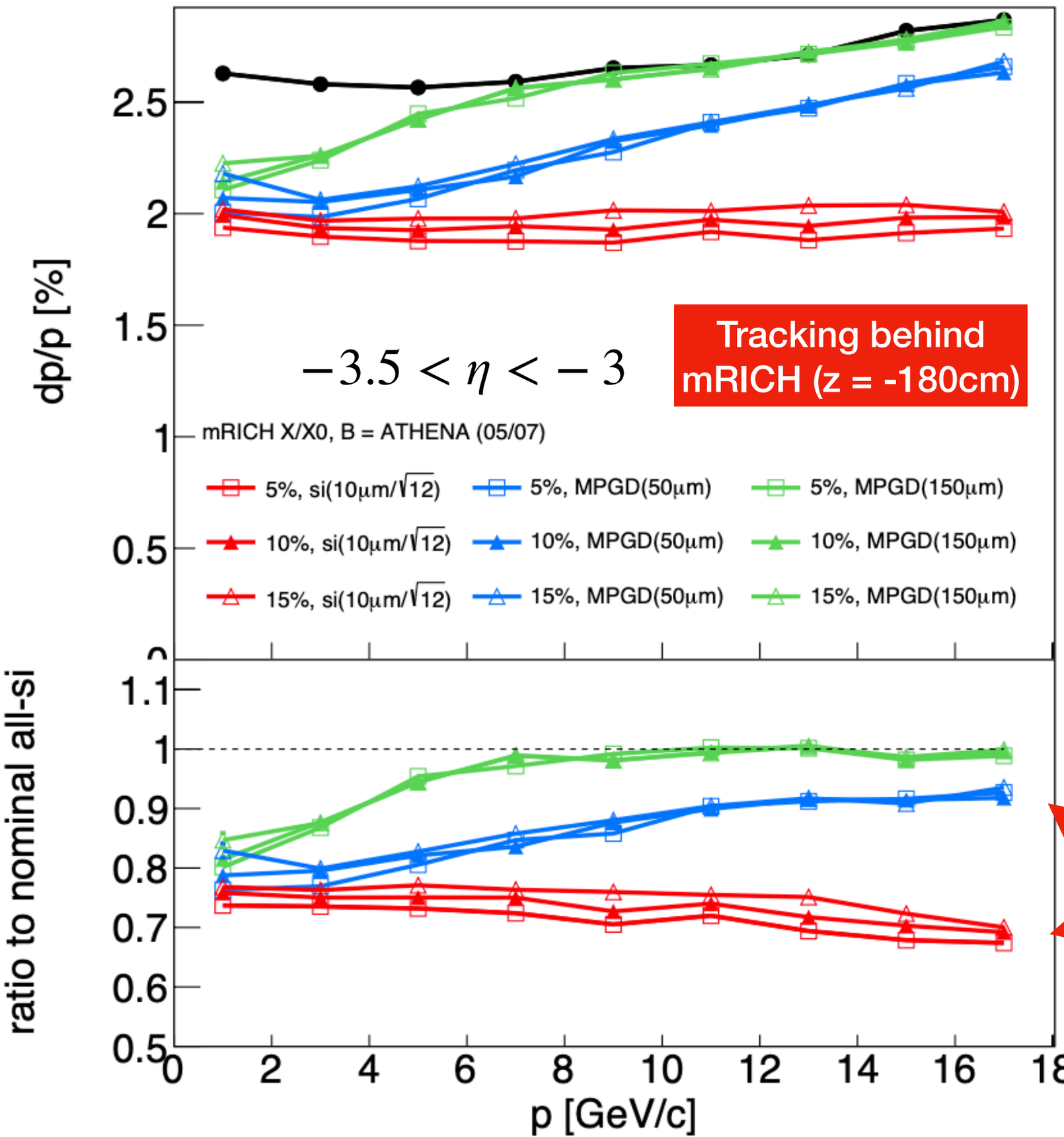
The performance does not change significantly for the different mRICH material budgets (even in the pessimistic case)

Summary



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mRICH X = 5% X0

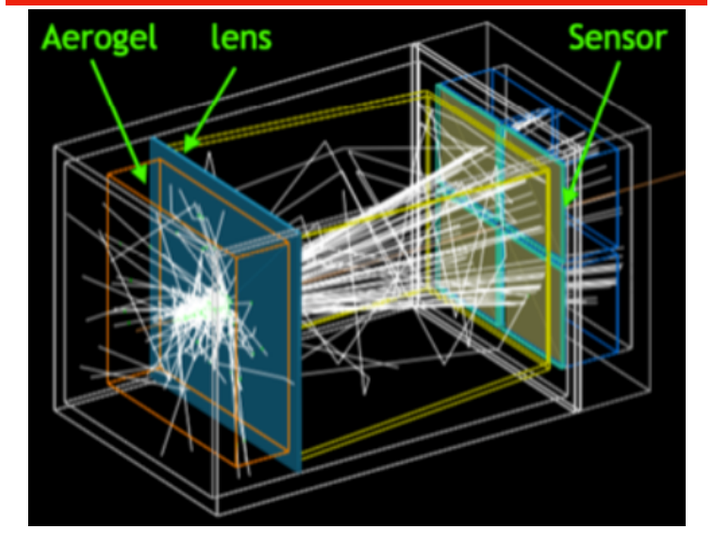
mRICH X = 10% X0

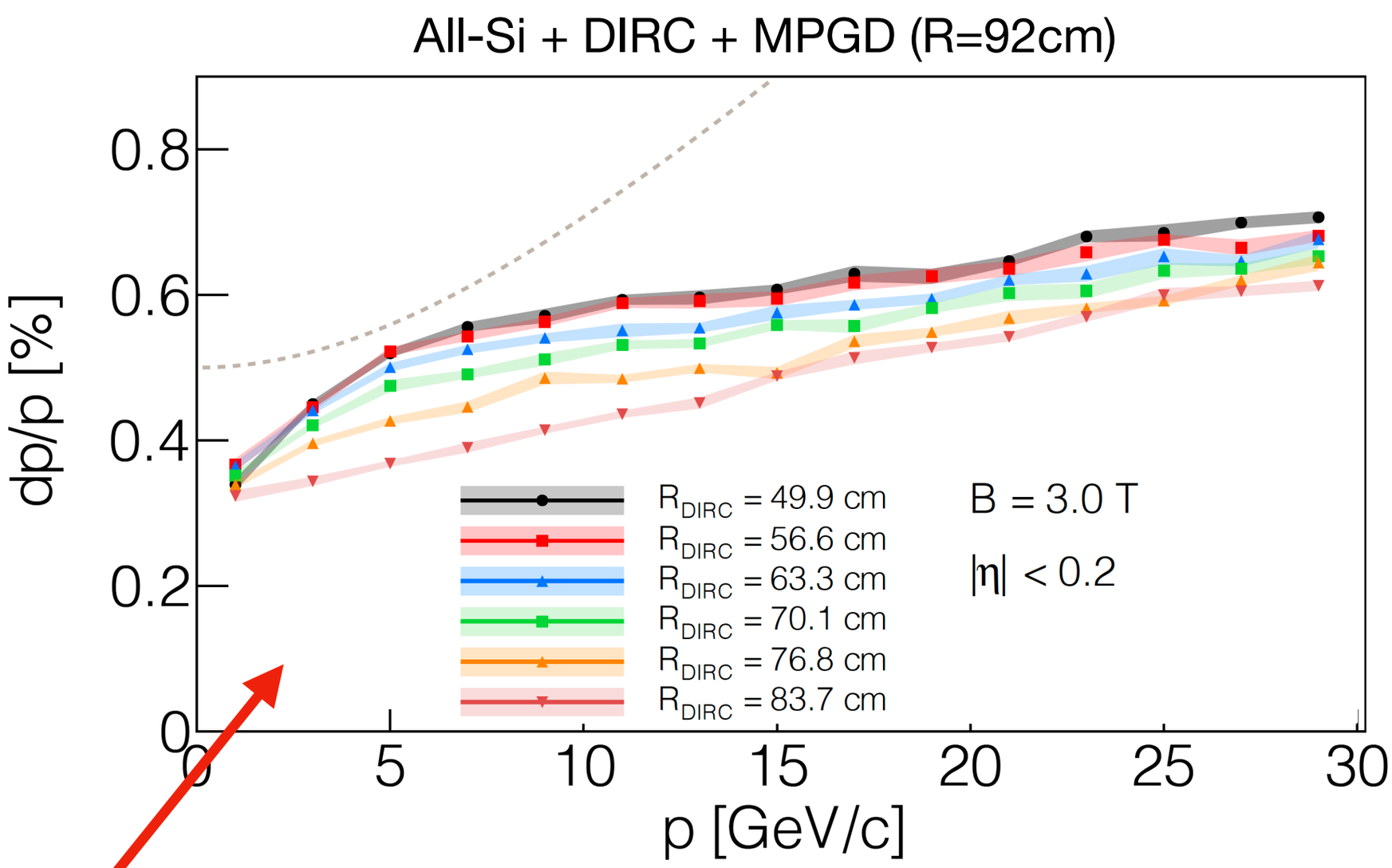
mRICH X = 15% X0

With a silicon disk or a $\sigma = 50\,\mu$m GEM, the performance is better than with the nominal all-silicon tracker in the entire range (at higher η)

Caveat!

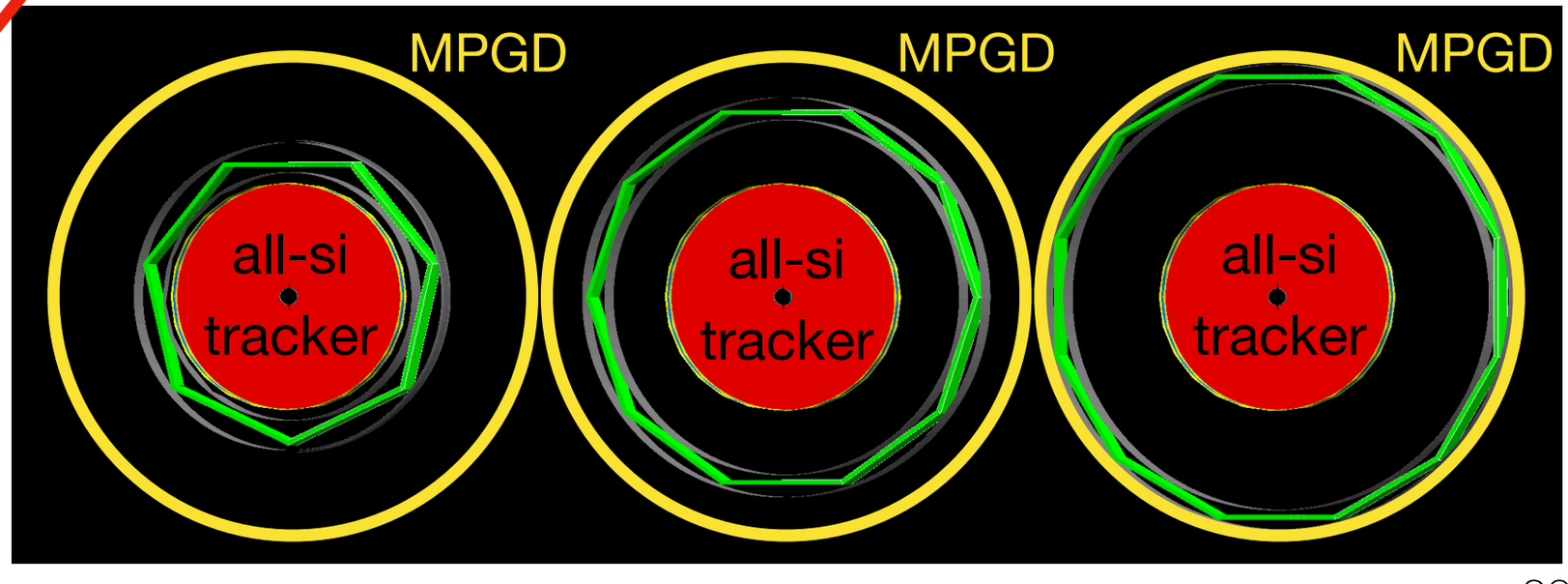
In these simulations the mRICH was modeled with all the material concentrated towards the back (higher |z|)



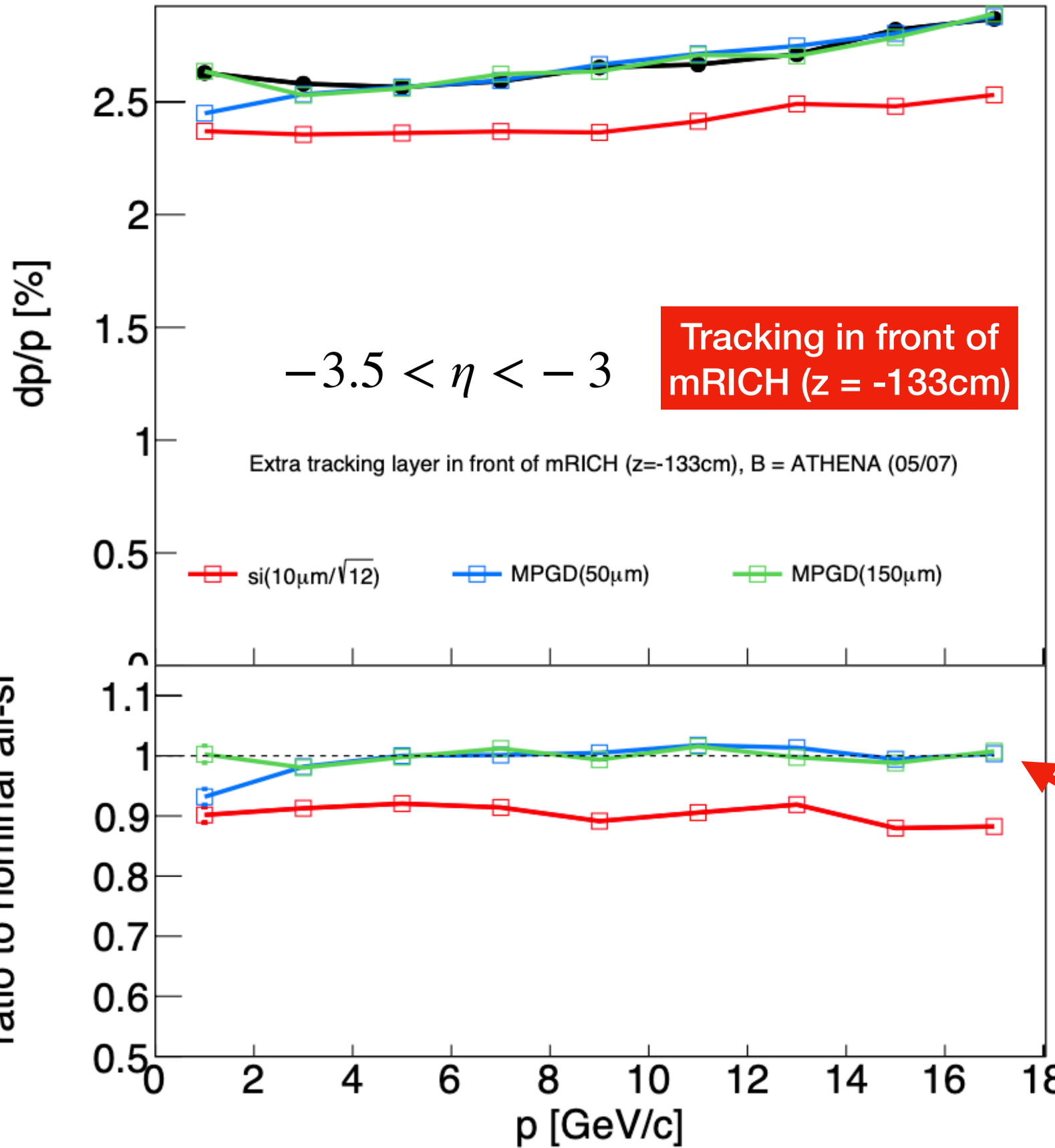


This study should be repeated with a more realistic mRICH geometry and placement

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



Tracking (MPGD or Si disk) in front of mRICH



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All-Si tracker + si disk

All-Si tracker + MPGD ($\sigma = 50\,\mu$m)

All-Si tracker + MPGD ($\sigma = 150\,\mu$m)

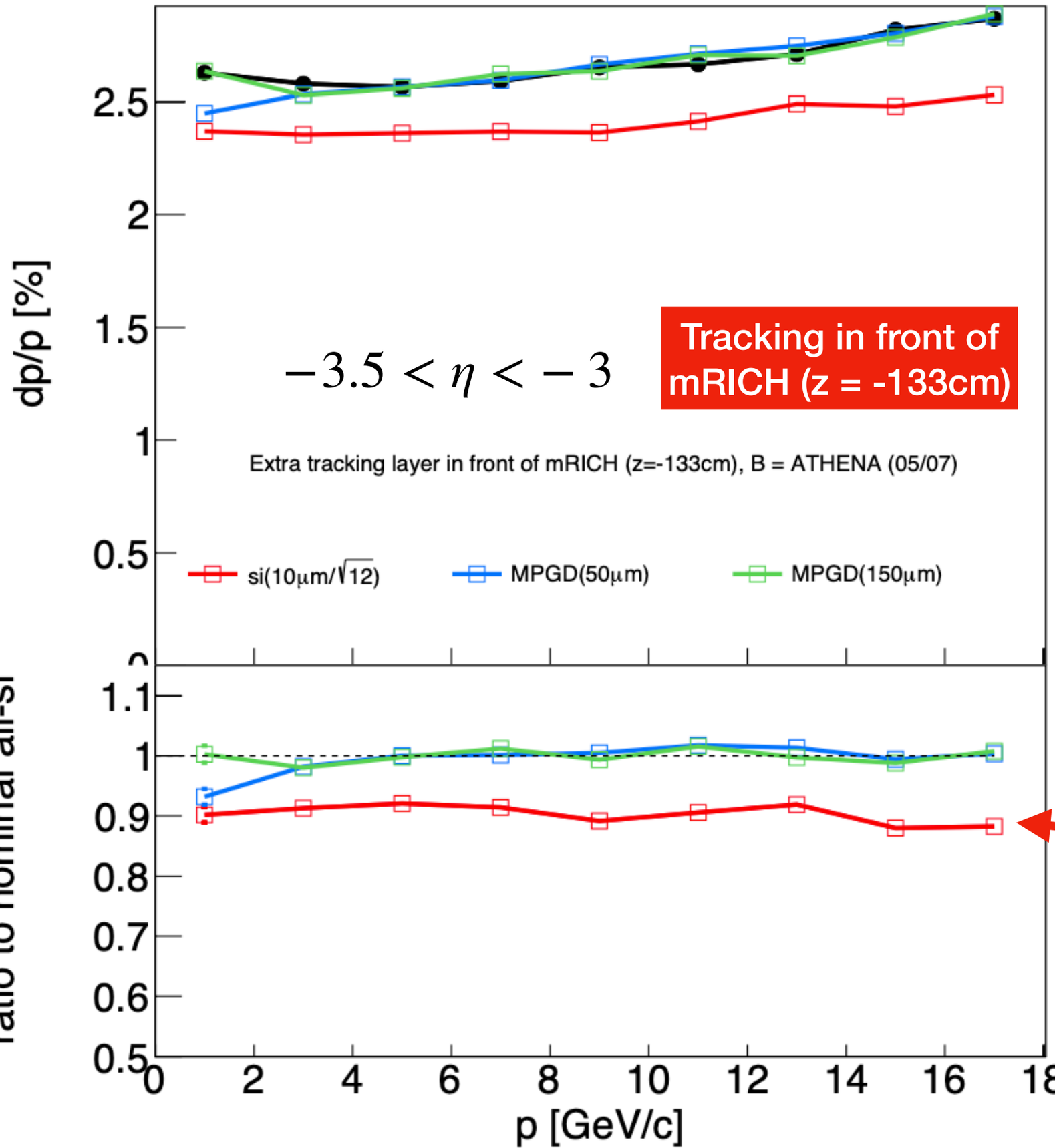
mRICH X = 5% X0

mRICH X = 10% X0

mRICH X = 15% X0

No momentum-resolution improvement over standalone all-silicon tracker when moving MPGD in front of mRICH

Tracking (MPGD or Si disk) in front of mRICH



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All-Si tracker + MPGD ($\sigma = 150\,\mu$m)

mRICH X = 5% X0

mRICH X = 10% X0

mRICH X = 15% X0

~10% momentum-resolution improvement over standalone all-silicon tracker when moving silicon disk in front of mRICH

Thanks