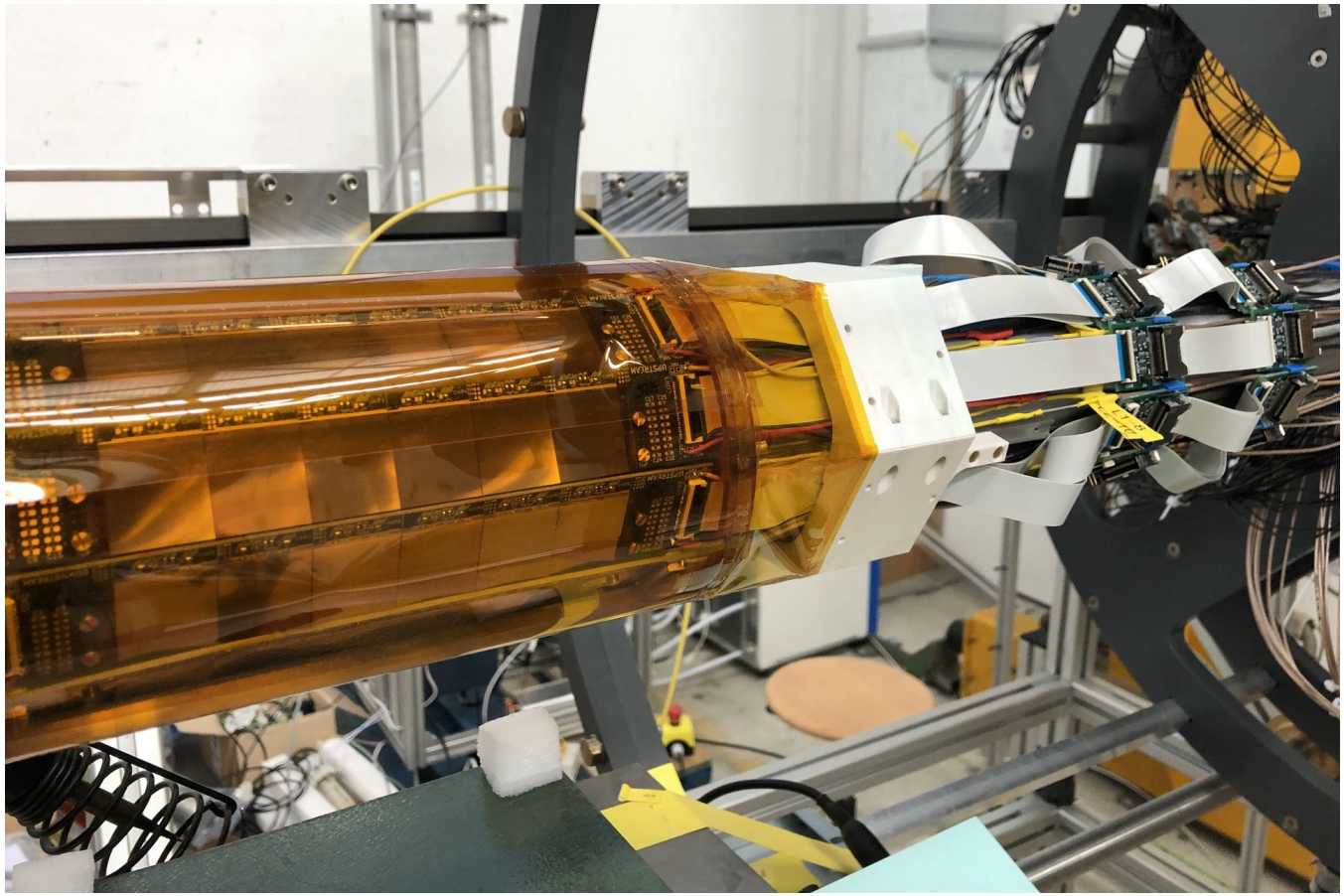
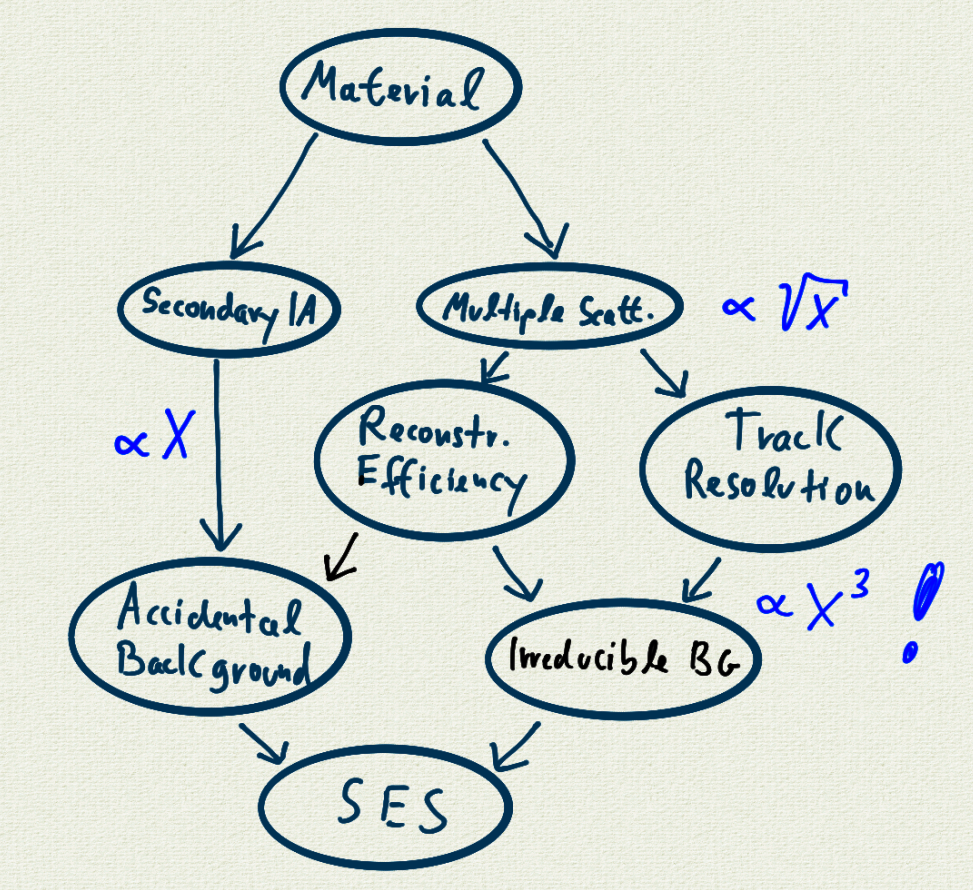
# Copper and the 1 per mil goal

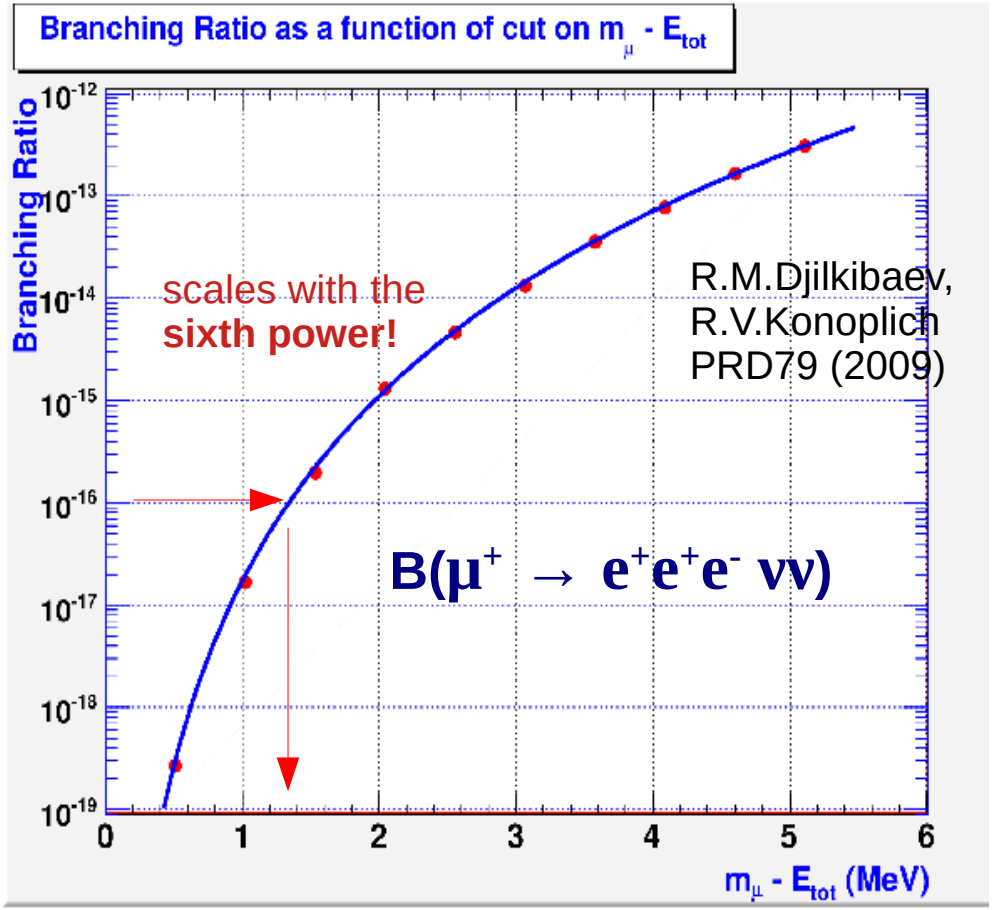
## Mu3e Pixel Flexprint Meeting

## 30.03.2022



# What defines(d) the 1 per mil per layer?




- The **1 per mil** material goal is motivated by phase II SES of **$10^{-16}$** assuming that the irreducible BG dominates (BTW: it was never demonstrated in a full simulation)
- A SES of **$10^{-15}$** corresponds to about **2 per mil** radiation length per layer
- Mu3e decided to stick to the 1 per mil goal in phase I to **demonstrate** the technology for phase II

# Aluminium or Copper for Phase I?

| | $X_0$ /cm) | ρ *(g/cm³)* | σ (A/V µm) |
|---|---|---|---|
| Al | 8.896 | 2.699 | 37 |
| Cu | 1.435 | 8.96 | 85 |

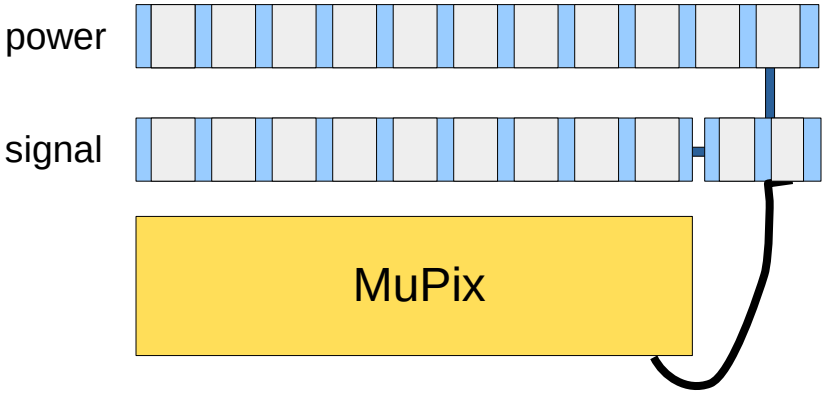
| Radiation length: | const. mass | const. thickness | const. resistance |
|---|---|---|---|
| $\frac{x}{X_0}$ | $\propto \frac{m}{\rho X_0}$ | $\propto \frac{d}{X_0}$ | $\propto \frac{R\,\sigma}{X_0}$ |
| $\left(\frac{x}{X_0}\right)_{Cu} / \left(\frac{x}{X_0}\right)_{Al}$ | **1.87** | **6.20** | **2.70** |

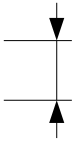
- The copper solution increases the material wrt 2 x 12.5 µm aluminium by
  - 0.3 · $10^{-3}$ $X_0$ (Al fraction) x (2.7-1) (**same electrical properties**) = **+0.5 · $10^{-3}$ $X_0$**
  - the corresponding copper thickness is about 10 µm (2 x 5 µm) **in average!**

**Copper-only is a viable option for phase I assuming that the amount of other material is the same and that acc. BG and track efficiency are not heavily affected (to be demonstrated)**

# Copper HDI Variants

Variant 1 (compatible to LTU baseline)

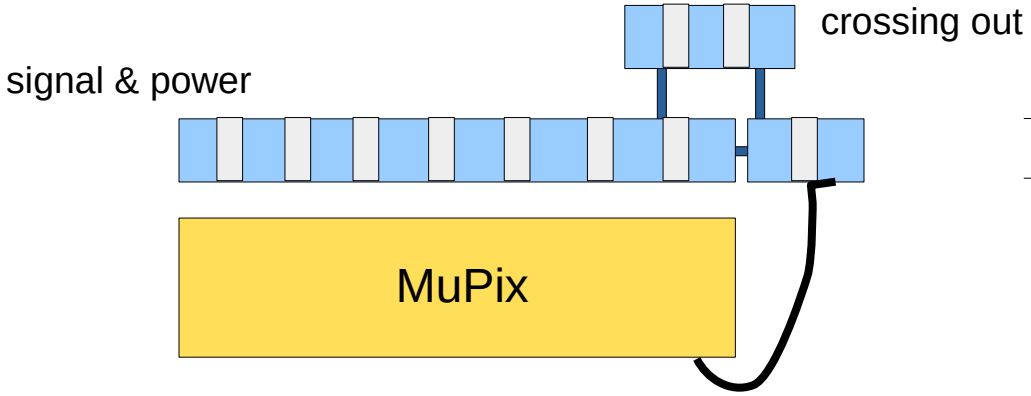


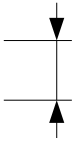



5 µm (average)

→ preferred solution

Variant 2

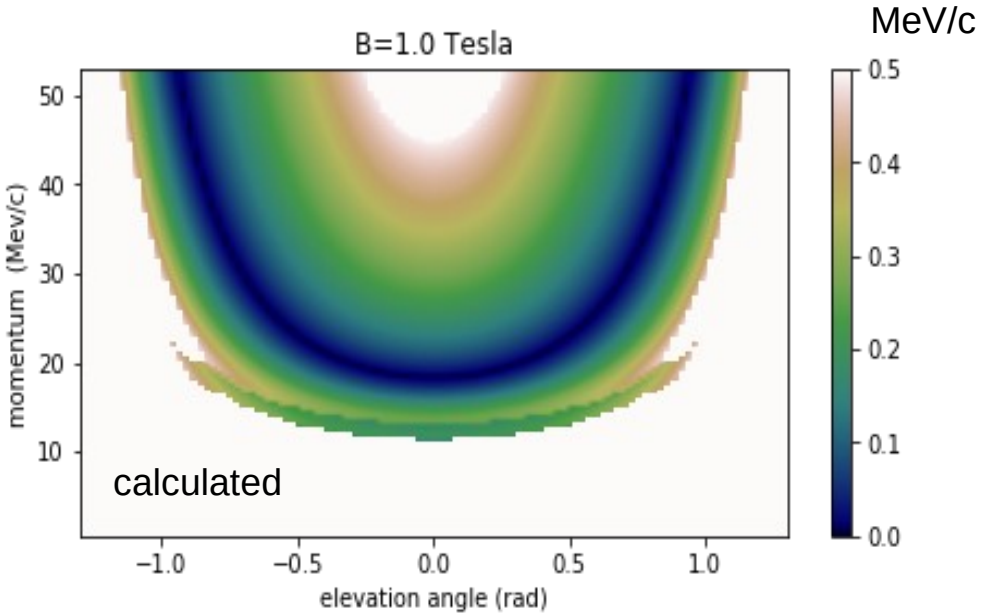


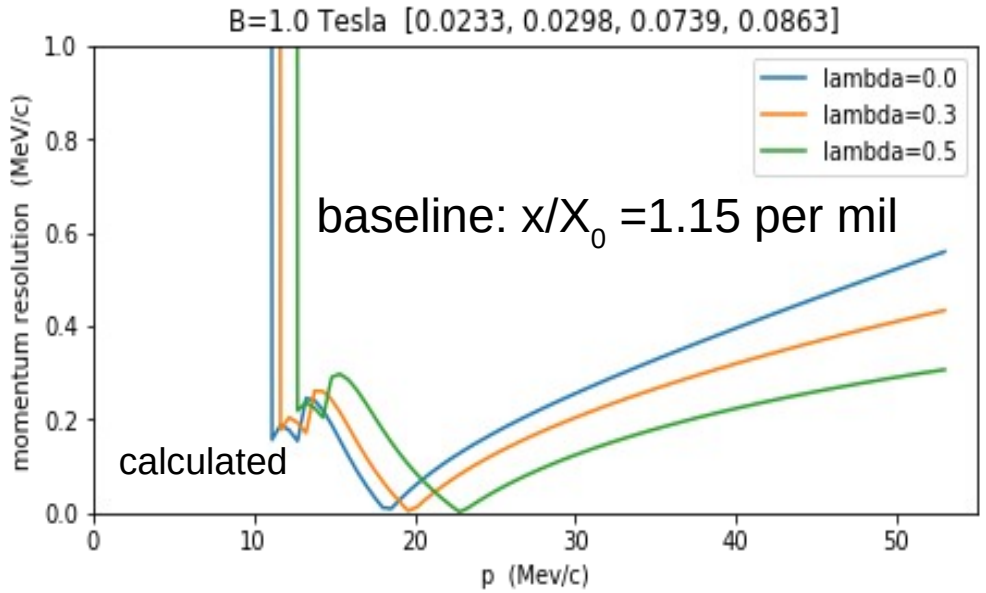



10 µm (average)

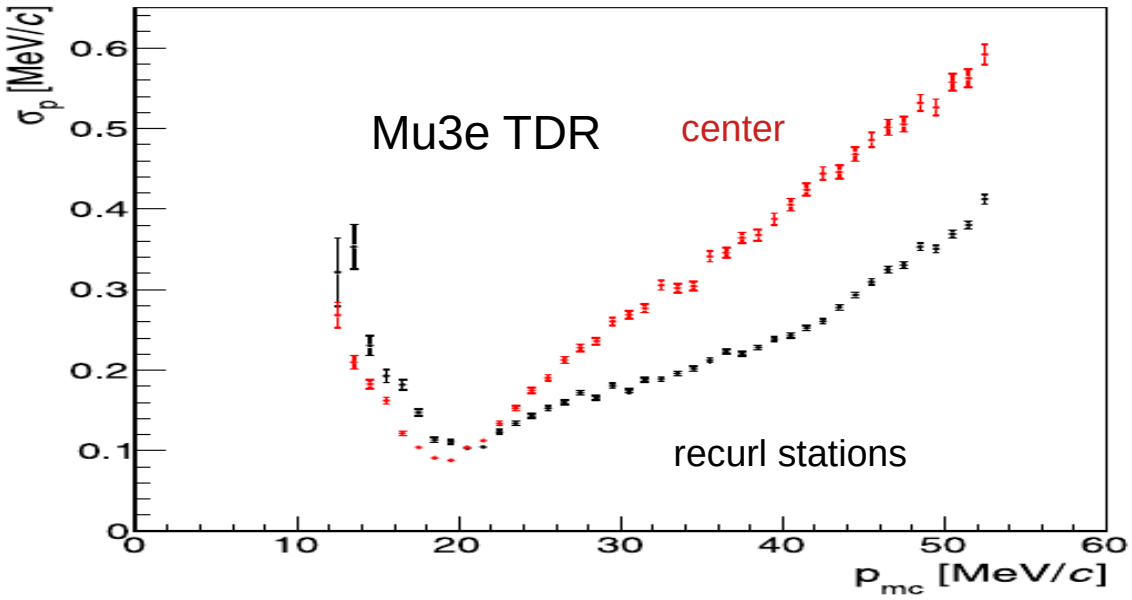
Note, standard copper thickness in industry is **18 µm**!

# Momentum Resolution Baseline

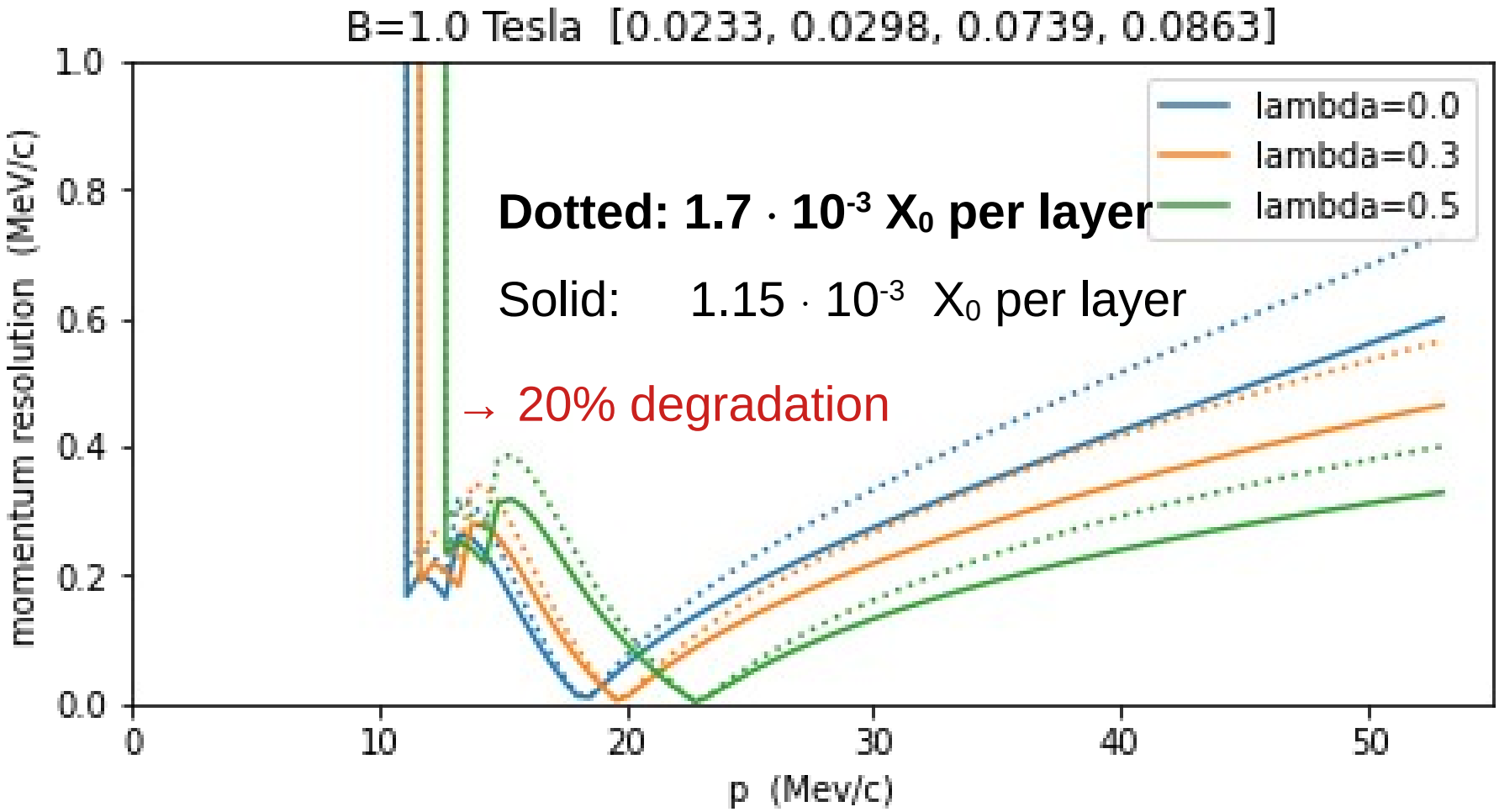



comparison with
simulation and reconstruction:



# Momentum Resolution +50% radiation length



# Alternative Designs

- In case of production (yield) problems or delays (e.g. LTU starts production in late 2023) one can also consider a mix of copper HDI and aluminium HDI designs
- For **vertexing** the most inner layer is most important → smallest $x/X_0$
- For **momentum resolution** the most outer layer is crucial → smallest $x/X_0$

# Momentum Resolution
# Mix of 1.0 and 1.5 per mil layers