A TRACKER LAYOUT MODELLING TOOL

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ACES

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What is tkLayout?

Evaluation of tracking performance

Validation on a full simulation

Layout comparison

Layout optimization

Conclusions

TkLayout

is a **lightweight** tool to evaluate tracker layouts

uses a **simple** description of design parameters

places **modules** in 3D space

assigns **material** to the volumes

makes an *a priori* estimate on **tracking performance**

Developed by Nicoletta De Maio, Stefano Mersi

A lightweight tool

BEFORE simulation

- Meant to compare different layouts
- To narrow down the parameter space
- Help the simulation to focus on:
  - fewer options
  - pre-optimized designs

INSTEAD OF simulation

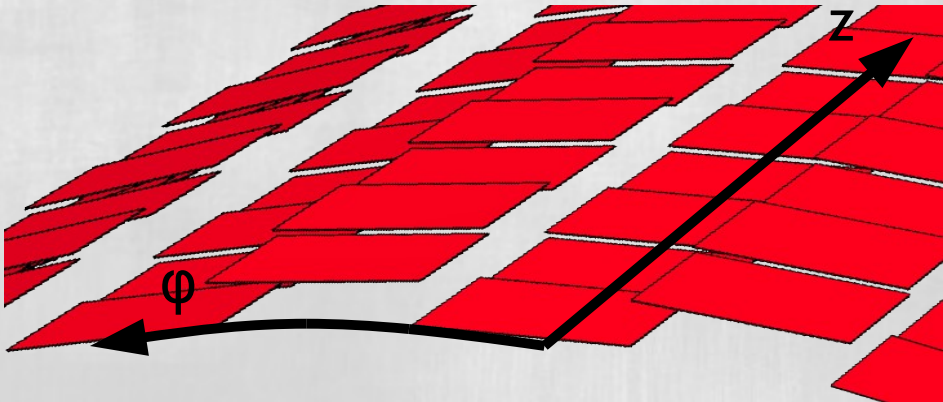
- Fair comparison of layouts with *a priori* estimate of performance
- Does not depend on (supposedly) optimized reco algos

- Does not replace simulation to estimate impact on trigger, physics channels, occupancy, efficiency, ...

Simul. NEEDED

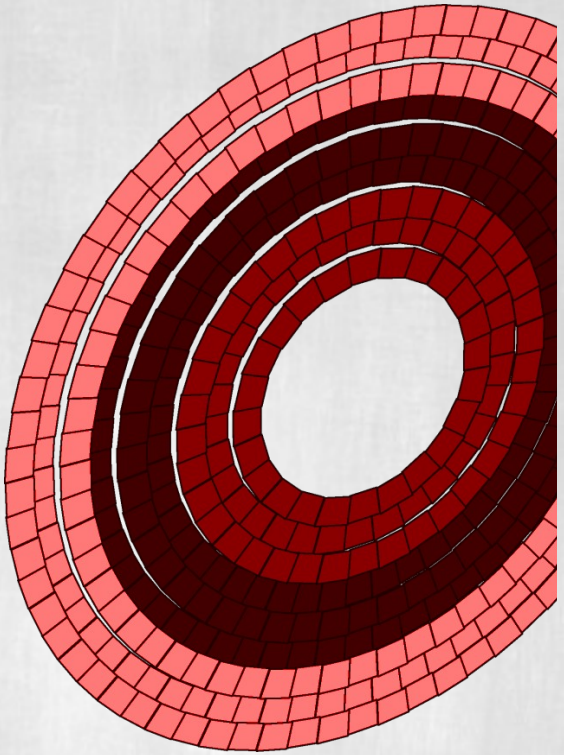
3D placement

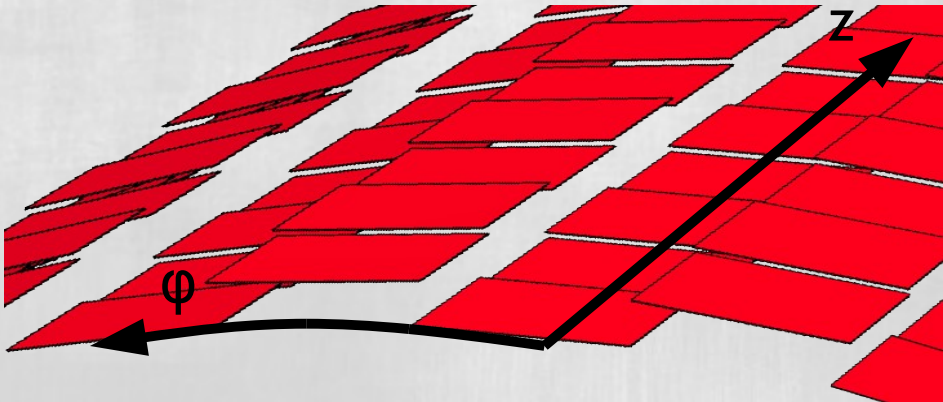
- Small set of parameters
  - Barrel layers



3D placement

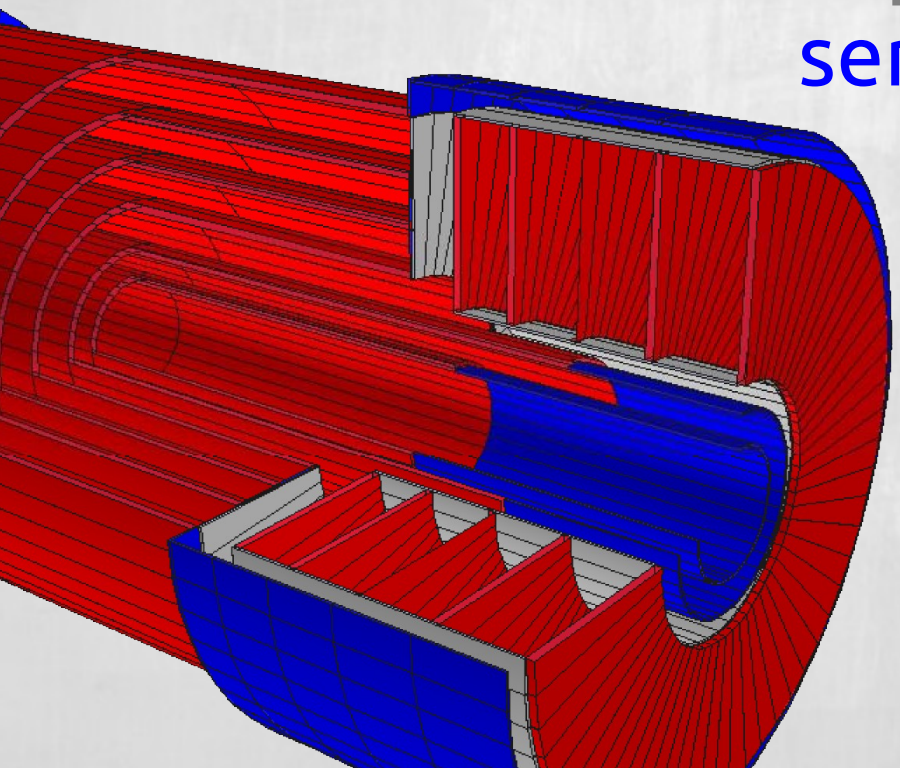
- Small set of parameters
  - Barrel layers
  - End-cap disks

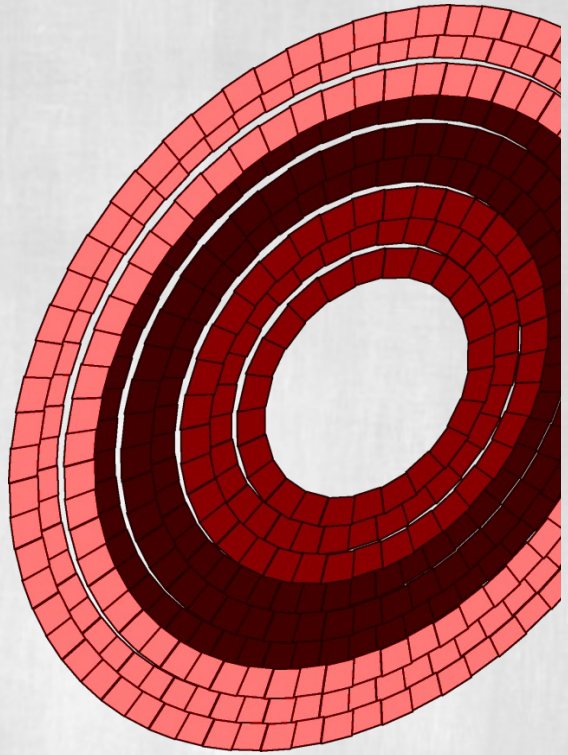


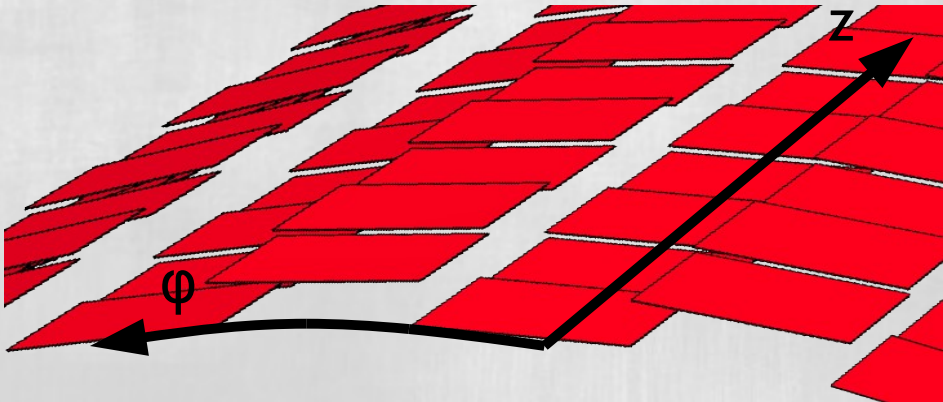


3D placement

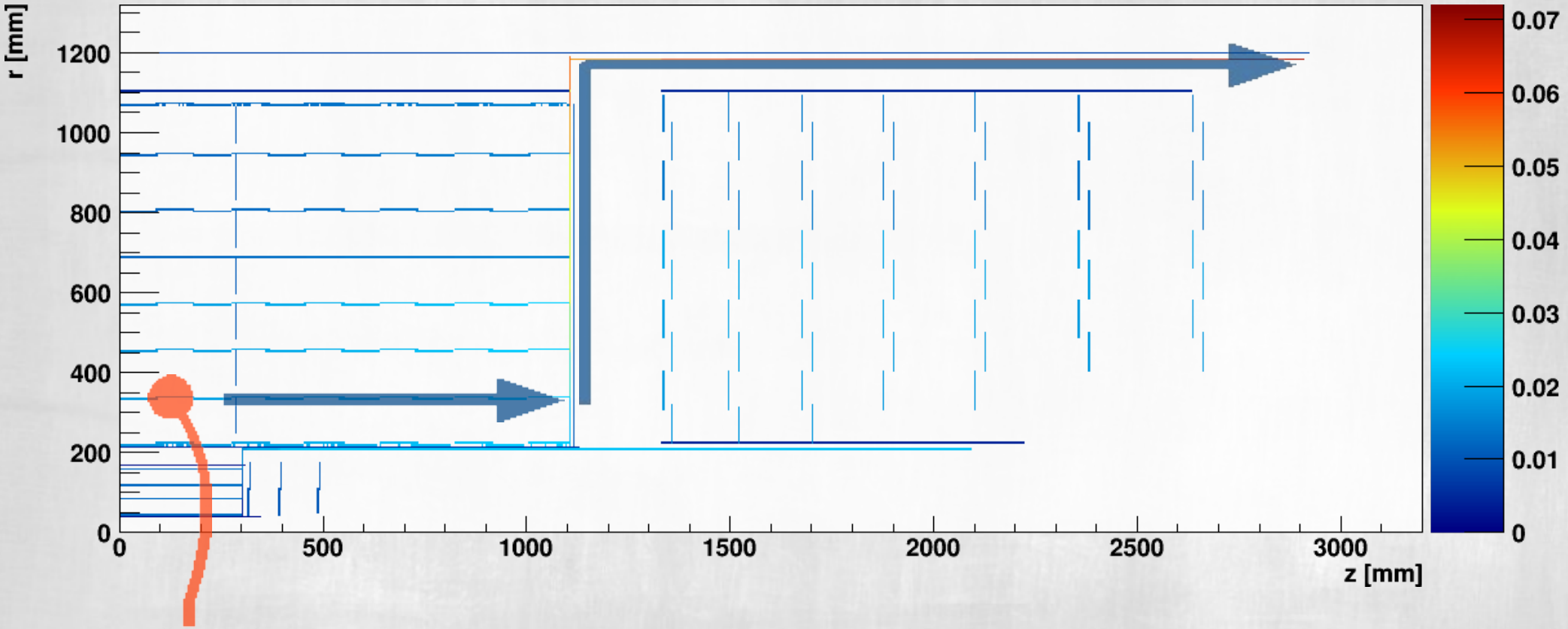
- Small set of parameters
  - Barrel layers
  - End-cap disks
- Material assign: active
  support
  services







Material



Material on active elements

+

Material for Services automatically routed

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Resolution estimate

- Error estimation, following
  - Baseline: Karimäki [1]
  - Multiple scattering introduced by G. Hall [2]
  - With variable geometry [3]
- **A priori error estimation**
  - **No Monte Carlo**
  - **No fit actually done**

[1] V. Karimäki – CMS Note 1997/064 [NIM A410 (1998) 284]
NIM A305 (1991) 187

[2] G. Hall – Calculating parameters for the Pixel and Tracker upgrade performance studies (Tracker Week) http://bit.ly/eXvi8L

[3] S. Mersi – Progress on layout tools (TUPO) http://tinyurl.com/2u7dbbv

Error correlation matrix

- Use measurement errors to estimate the errors in track fit parameters
- **Multiple scattering** treated as (correlated) a measurement error

deviation from the ideal (straight) path

Error correlation matrix

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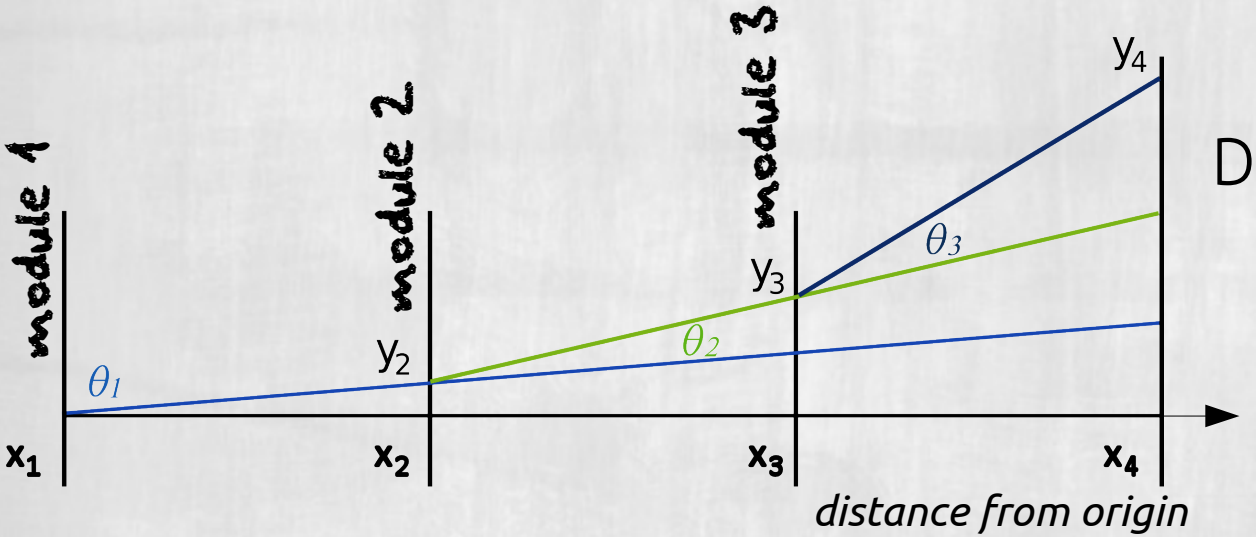
- **Multiple scattering** treated as (correlated) a measurement error



Deviation due to scattering:

$$y_n = \sum_{i=1}^{n-1} (x_n - x_i)\,\theta_i$$

Correlation matrix:

$$\sigma_{n,m} = \langle y_n y_m \rangle = \sum_{i=1}^{n-1} (x_m - x_i)\,(x_n - x_i)\,\langle \theta_i^2 \rangle$$

$$\sigma_n^2 = \frac{p^2}{12}$$

Measurement correlation

- Measurement error is:
  - **Intrinsic resolution** of the module
  - Deviation of the track from the ideal path due to **multiple scattering**

diagonal elements of C (uncorrelated)

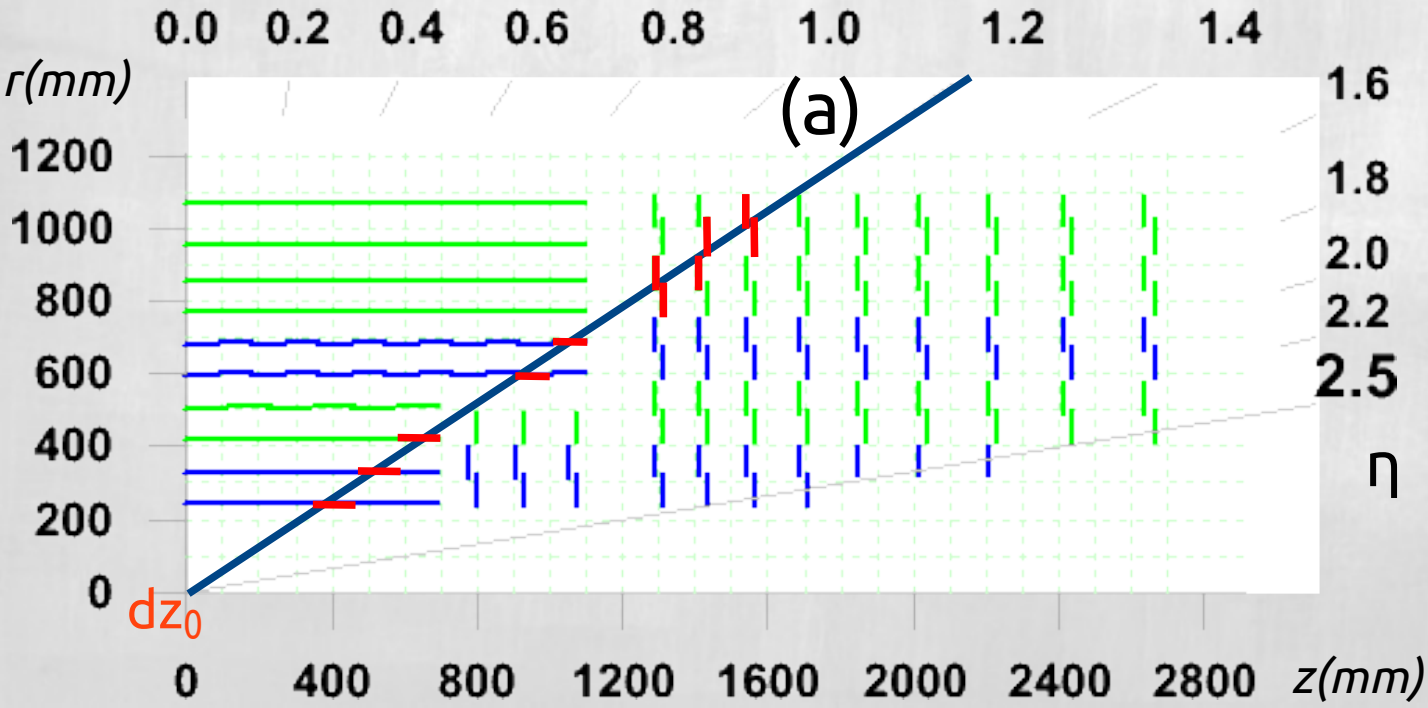
diagonal and off-diagonal elements of C

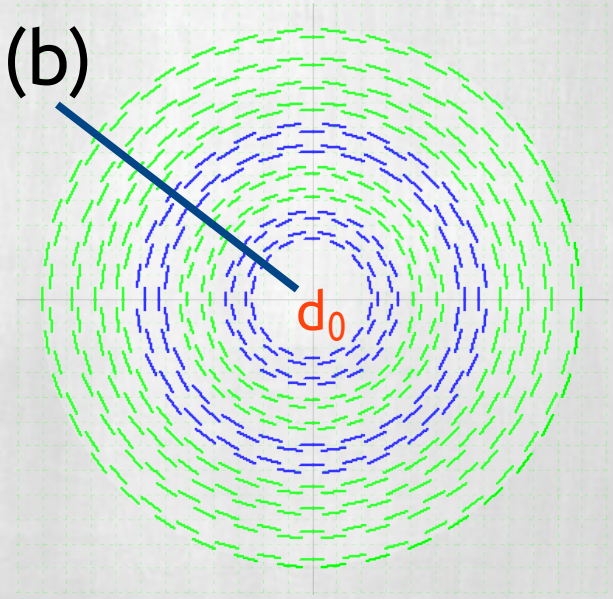
$$\begin{pmatrix} \sigma_{nn}+\sigma^2_{mod} & \sigma_{nm} \\ \sigma_{nm} & \ddots \end{pmatrix}$$

Error estimation procedure

- For each η value:
  Find volumes met **by straight lines**
  Compute average **multiple scattering**
- Error correlation matrix
- **Expected error** in track fitting

Two independent fits evaluated
5 parameters
(a) r,z plane: straight ctg(θ), dz_0
(b) rφ plane: circle d_0, φ, p_T





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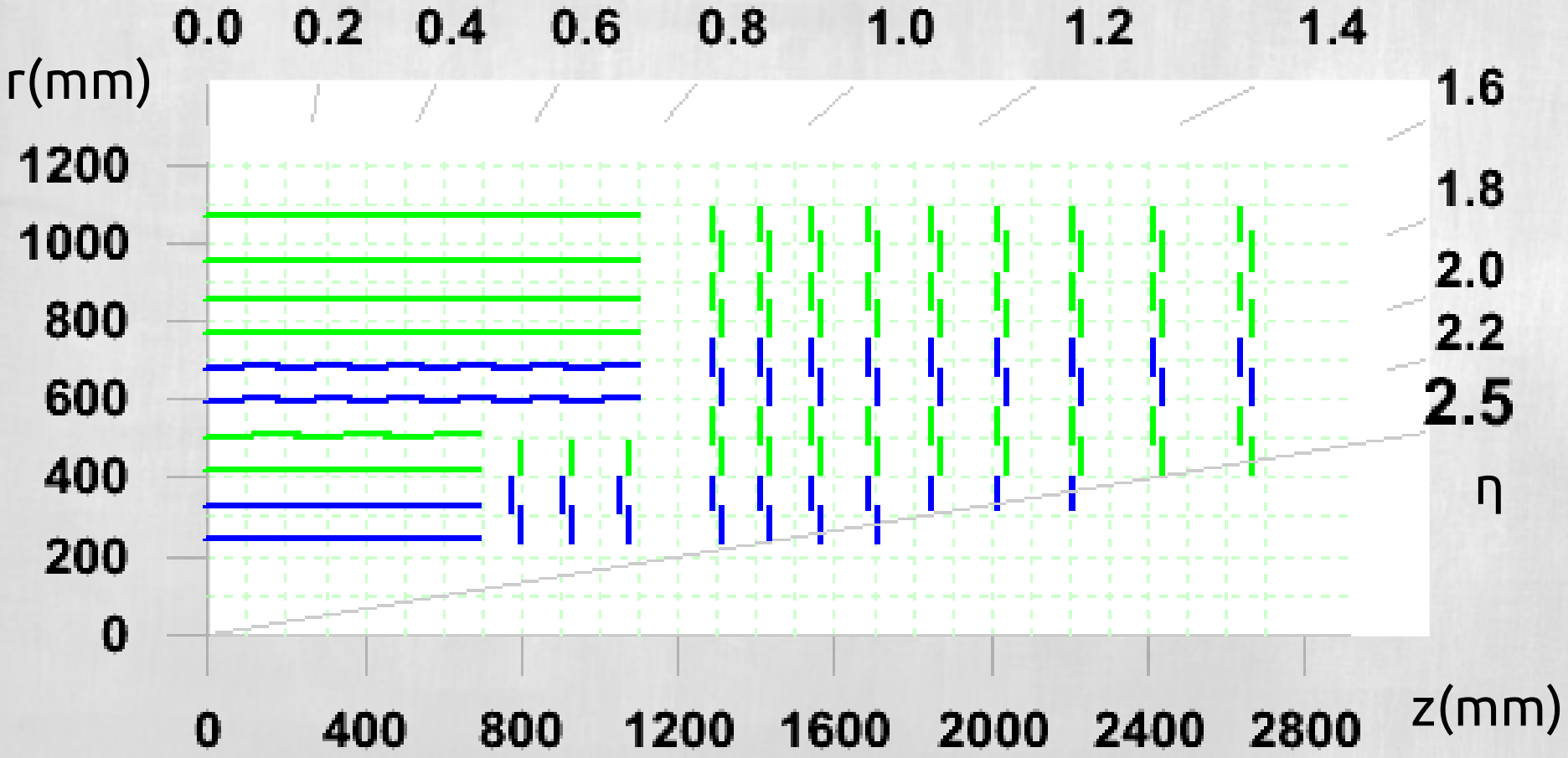
Conclusions

A benchmark layout

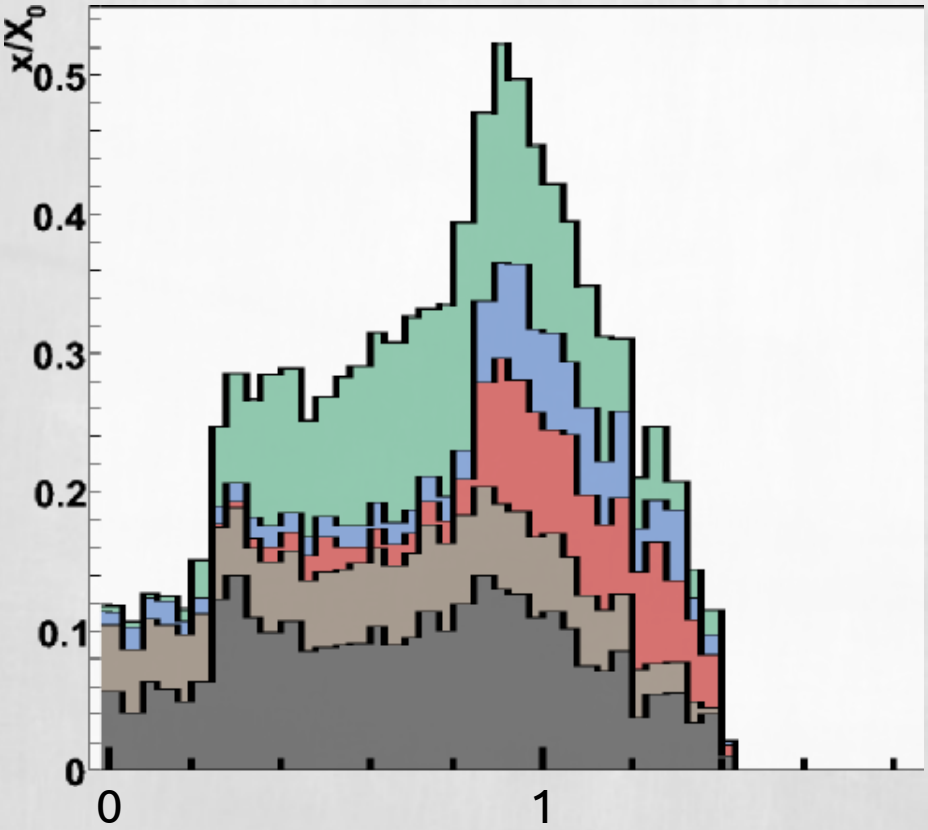
- Benchmark simulation to reproduce CMS tracker
- Pixel is modelled as another small tracker inside



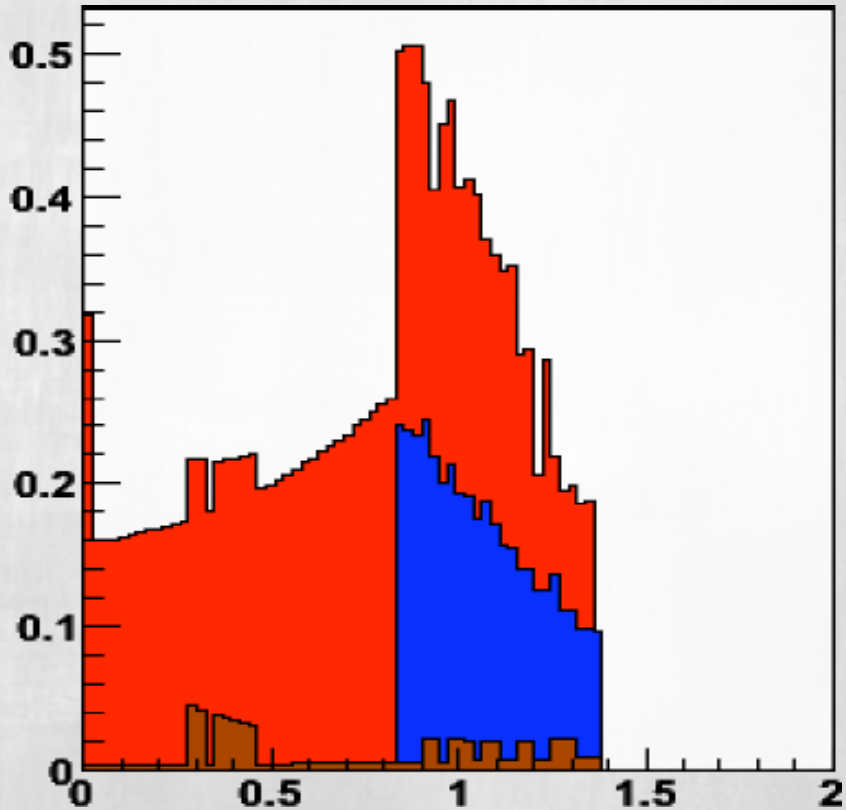
Material - outer barrel

- Distribution of material inside the tracking volume

CMS simulation



Our estimate

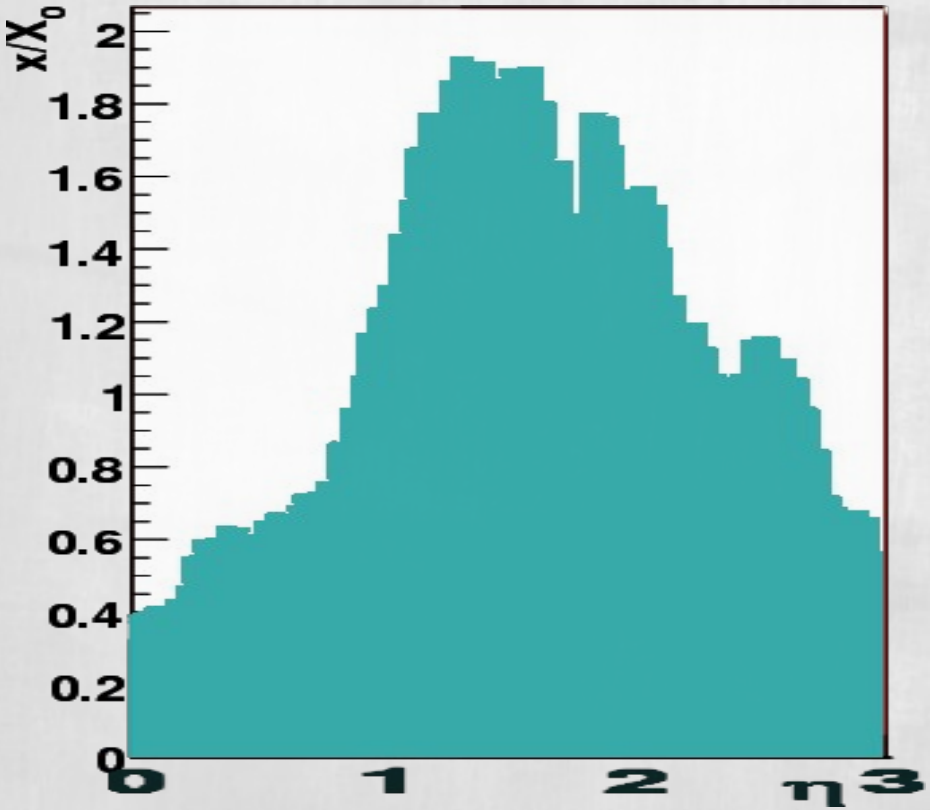


Differences are expected and understood

Material - everything

- Distribution of material inside the tracking volume

CMS simulation



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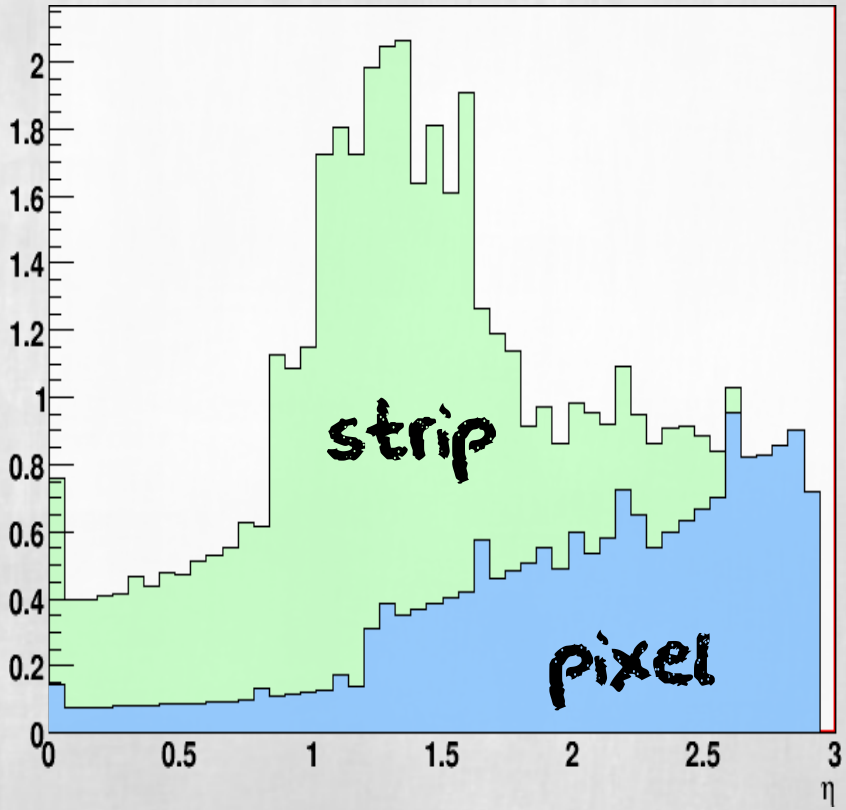
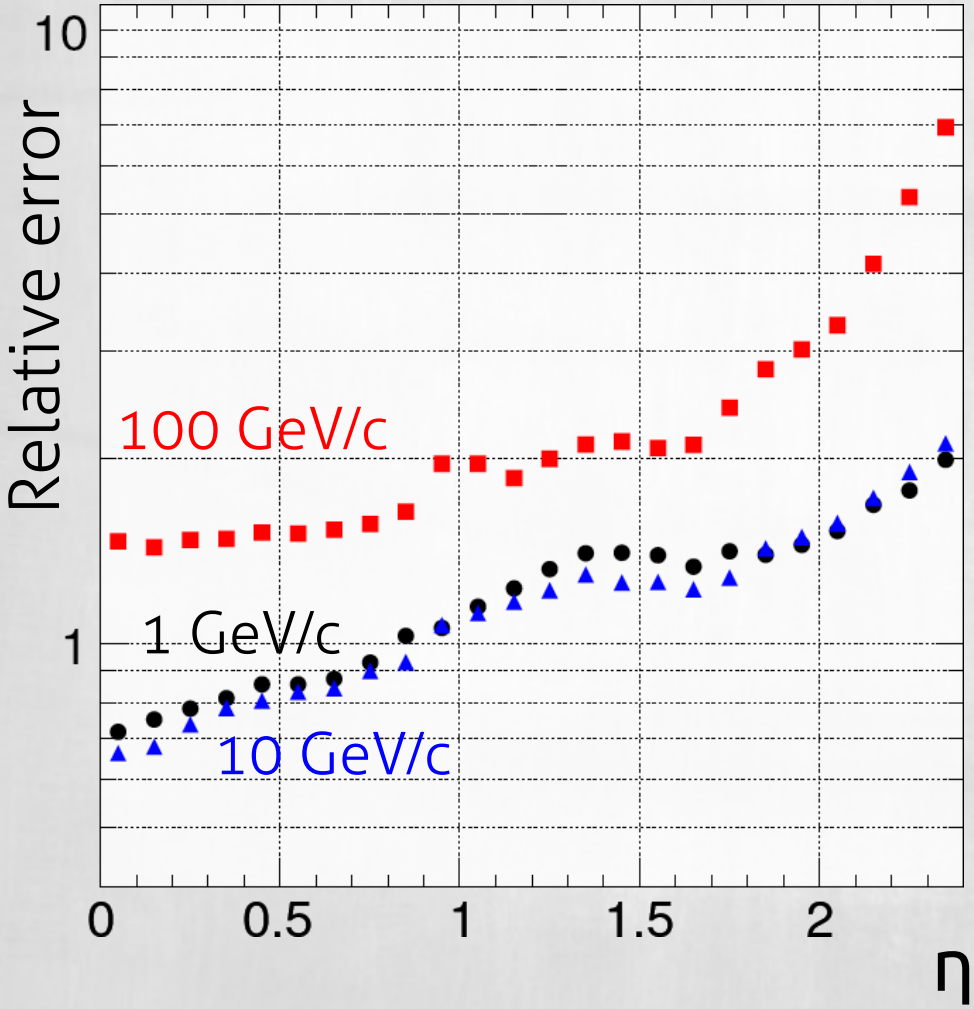
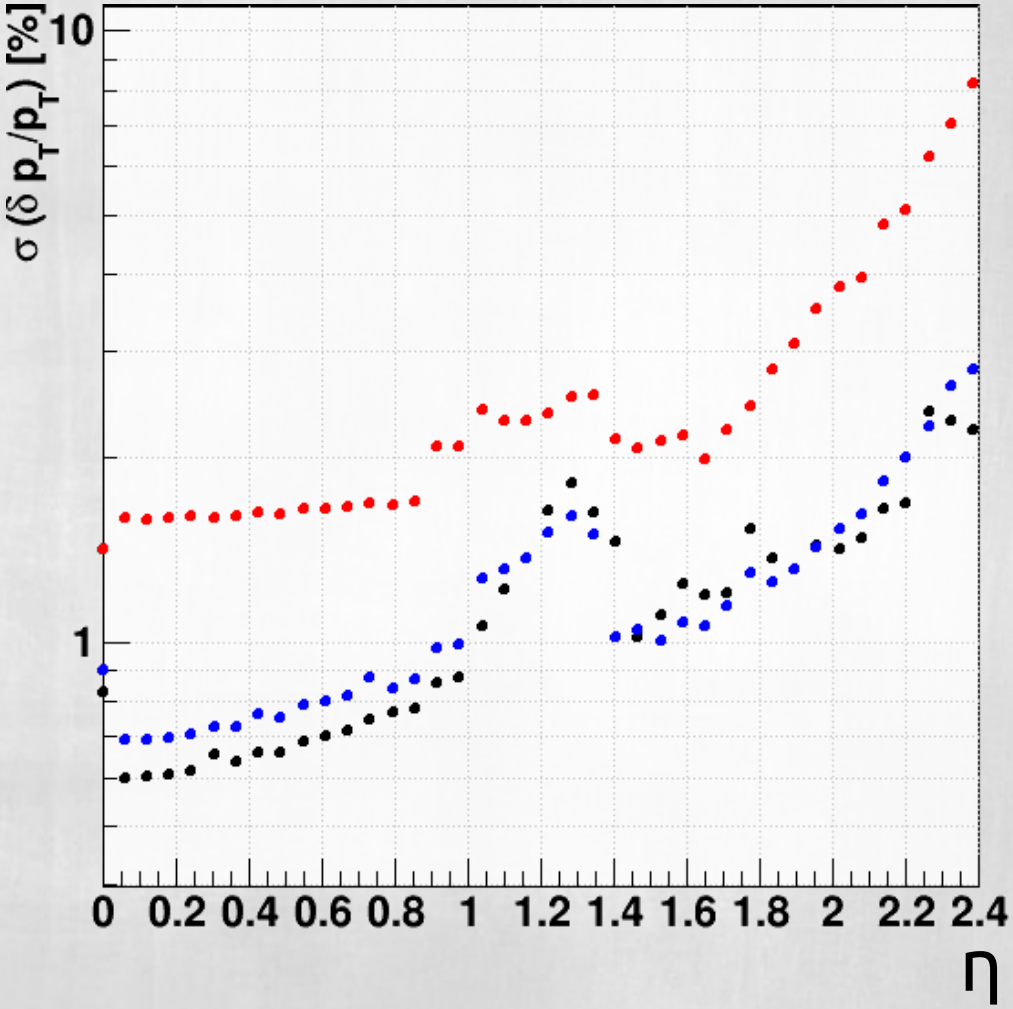


Differences are expected and understood

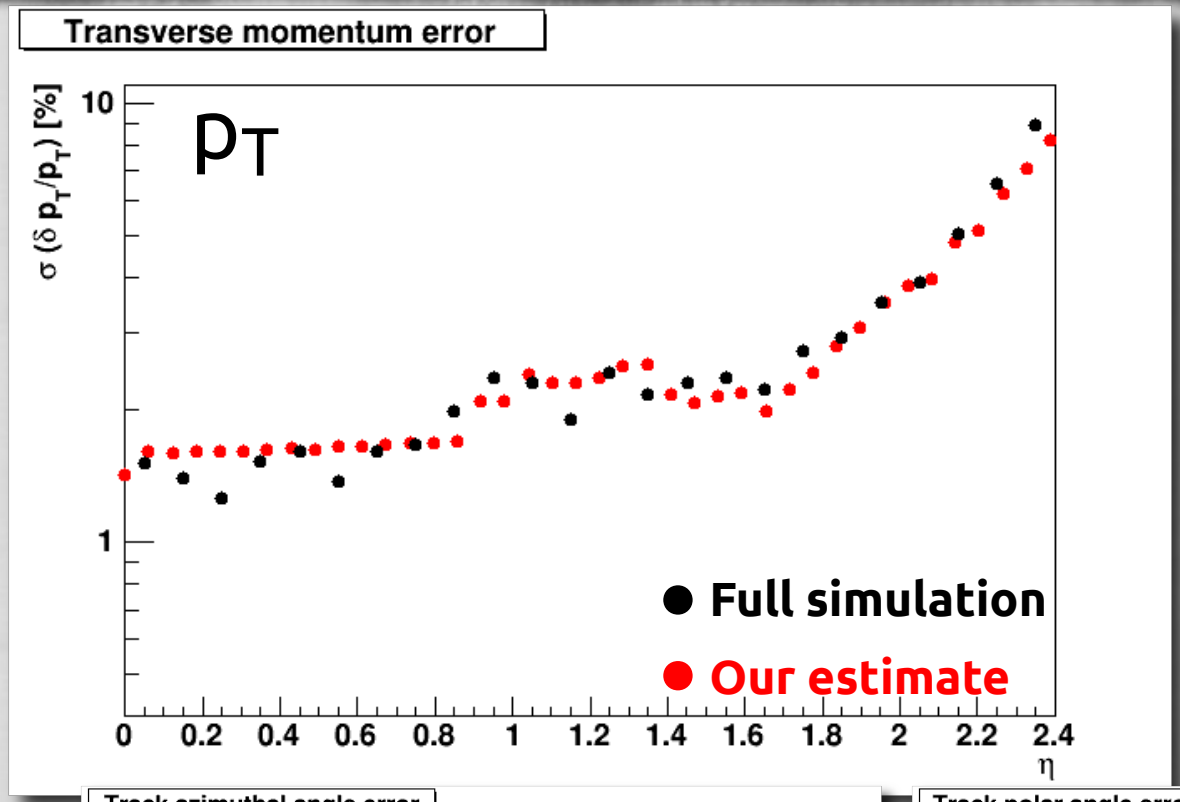
Pt resolution

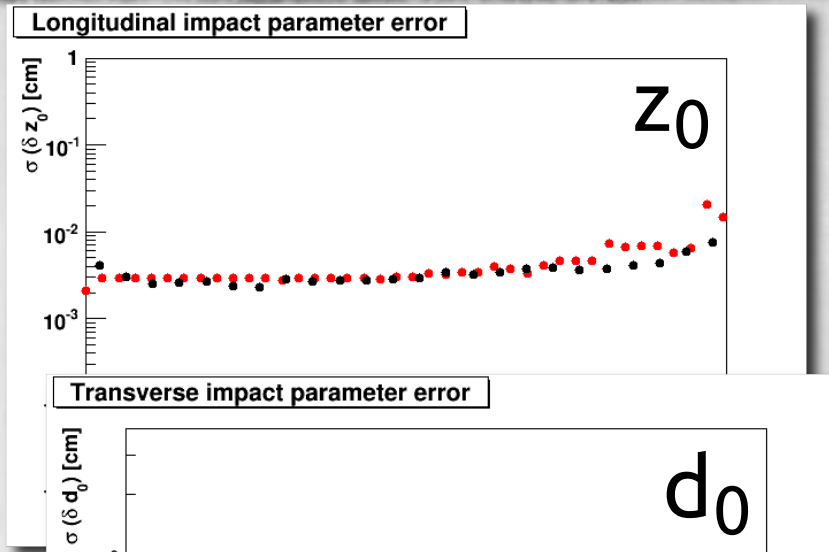
- Error estimate vs. full simulation (muon)

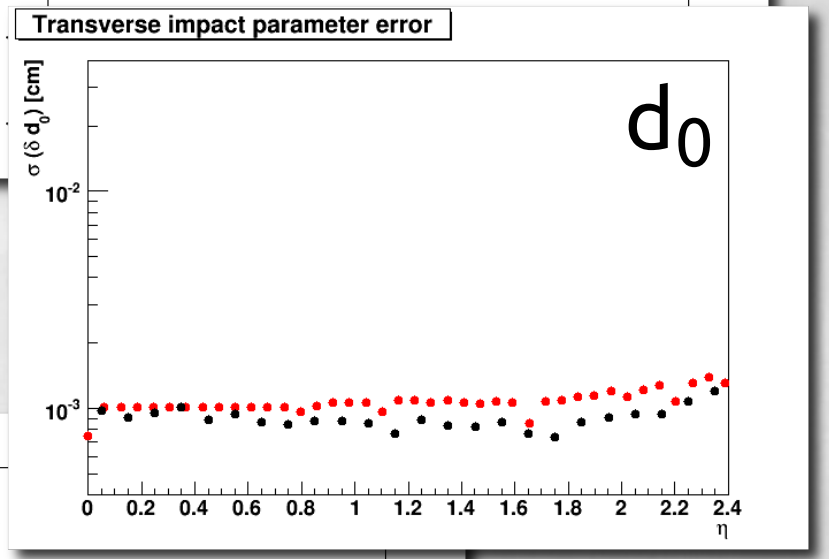


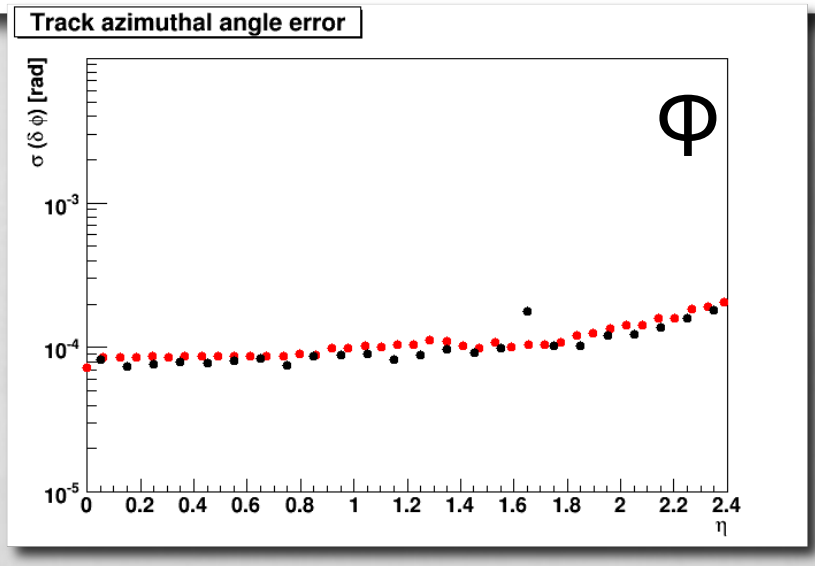


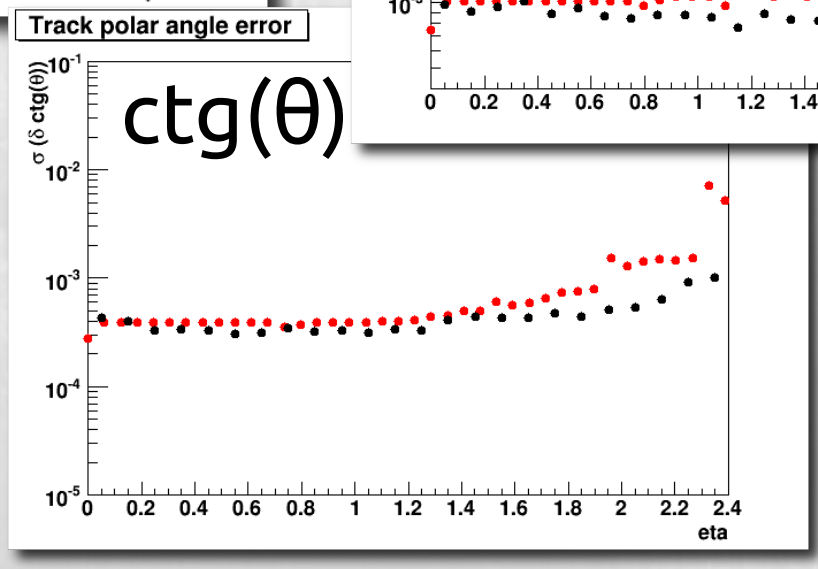
Performance @ 100 GeV/c



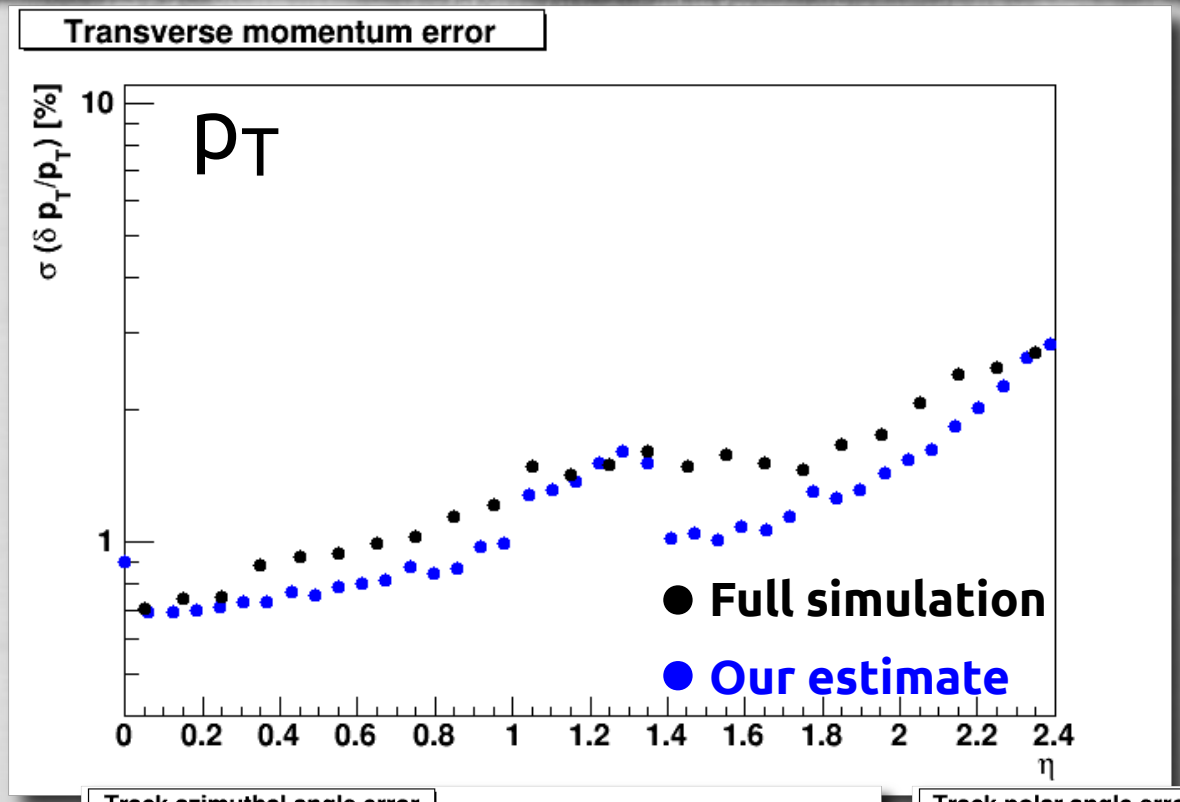


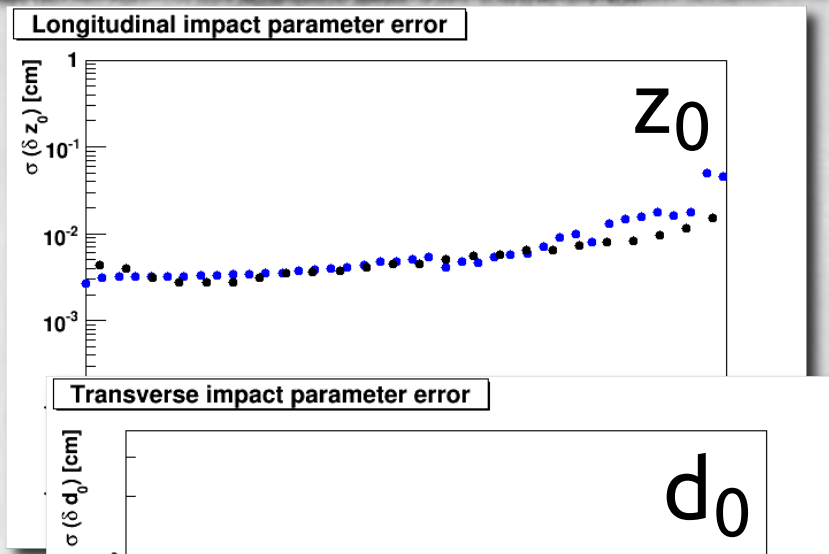


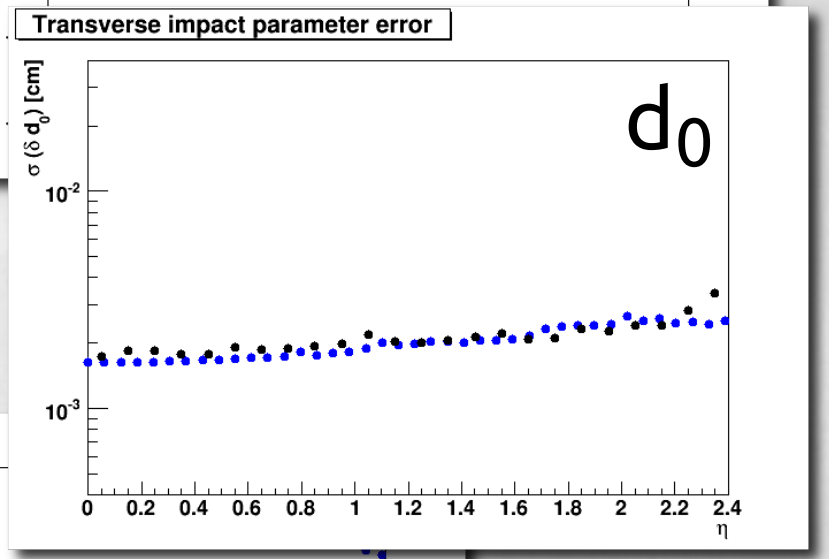


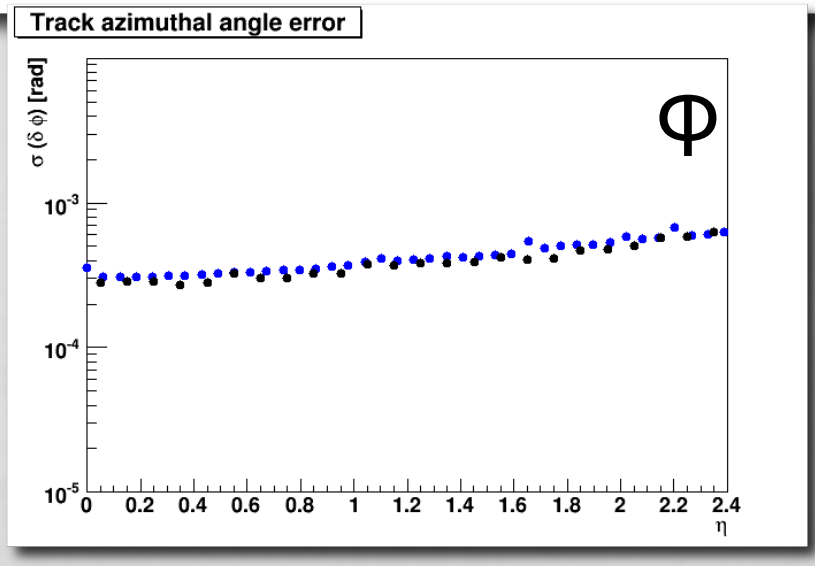


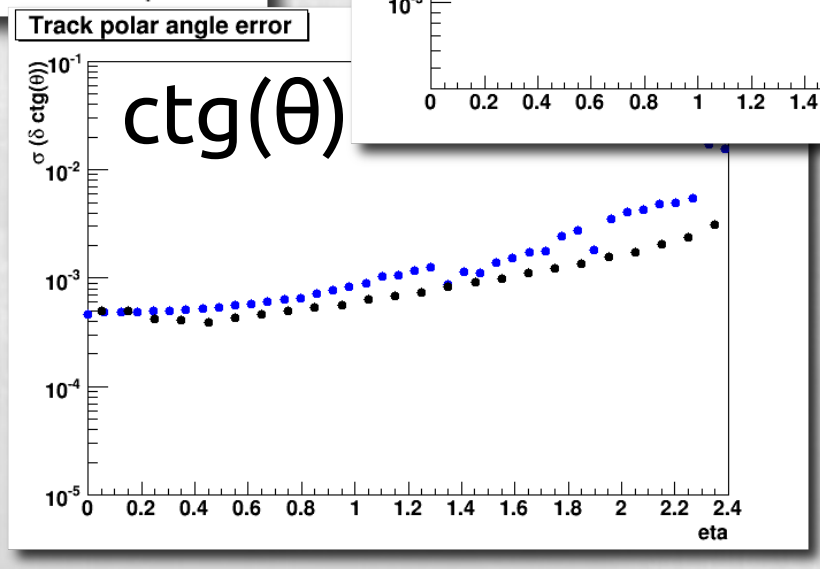
Performance @ 10 GeV/c









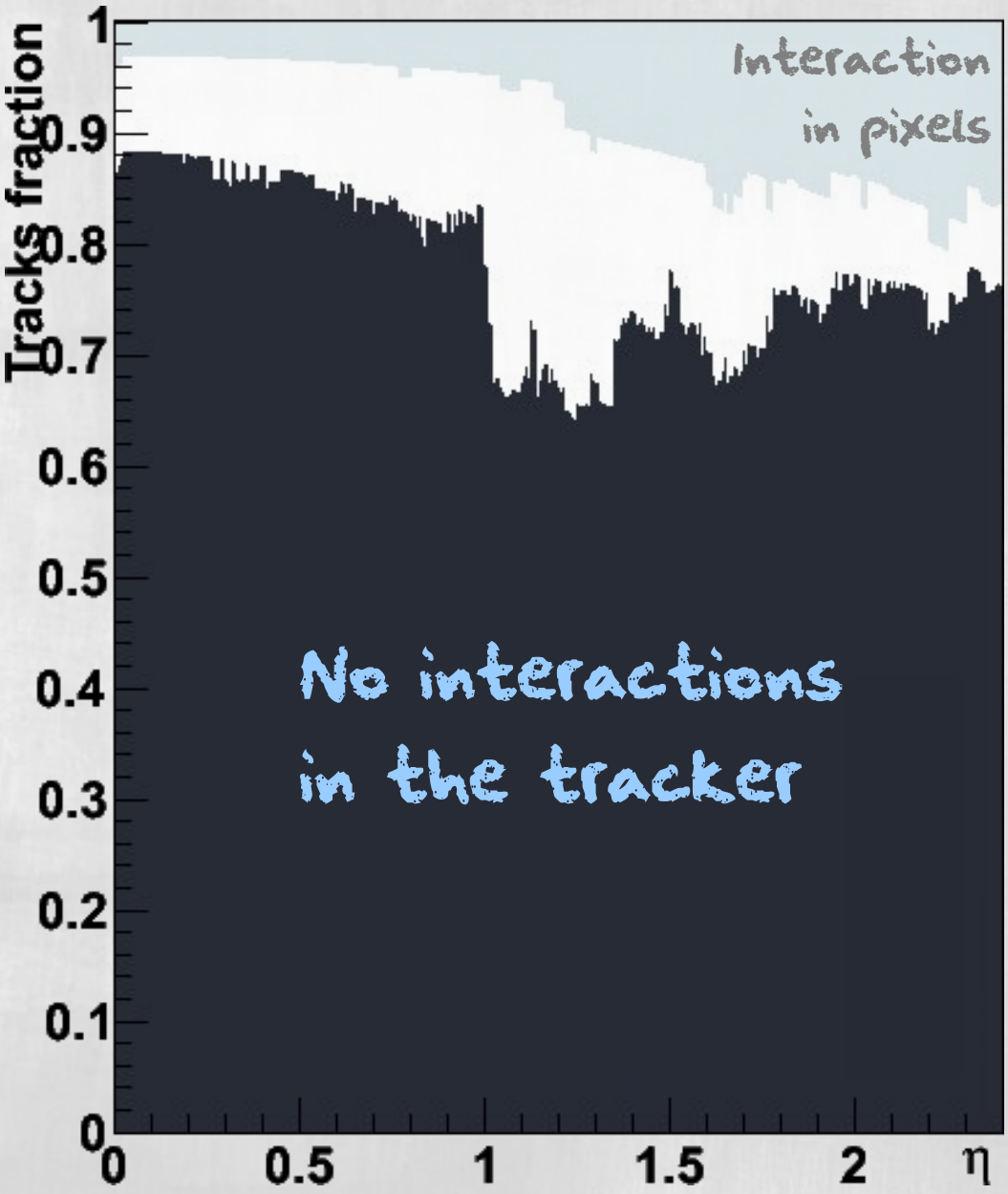


Nuclear interactions

- Most particles are pions
- Interact with the nuclei

$$p_n = \exp\left[-\sum_{i=1}^{n-1} \frac{l_i}{\lambda_i}\right]$$

an indicator of how many "good" pion tracks we should expect



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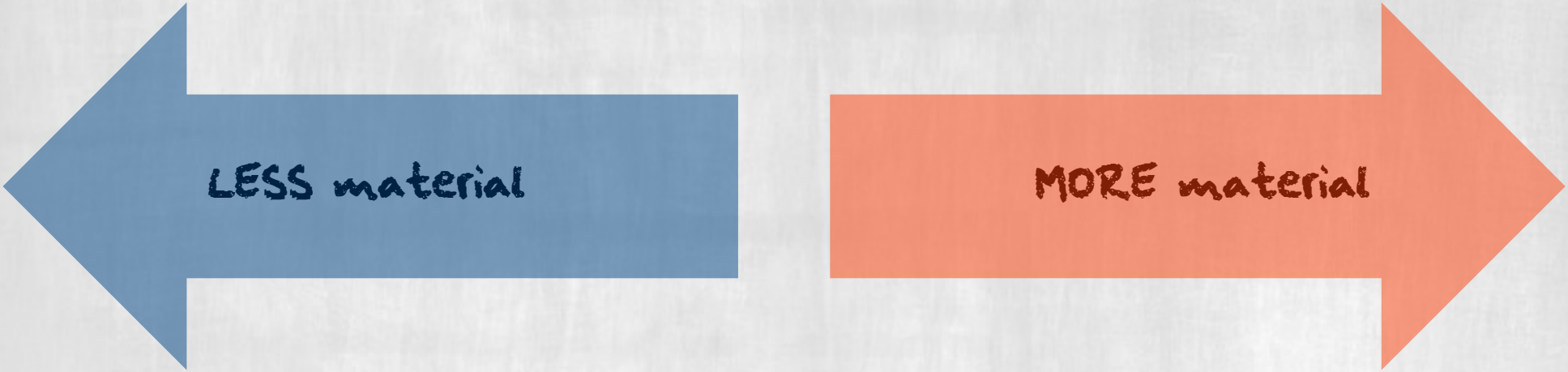
"Simple" upgrade

Higher granularity

"Simple" upgrade



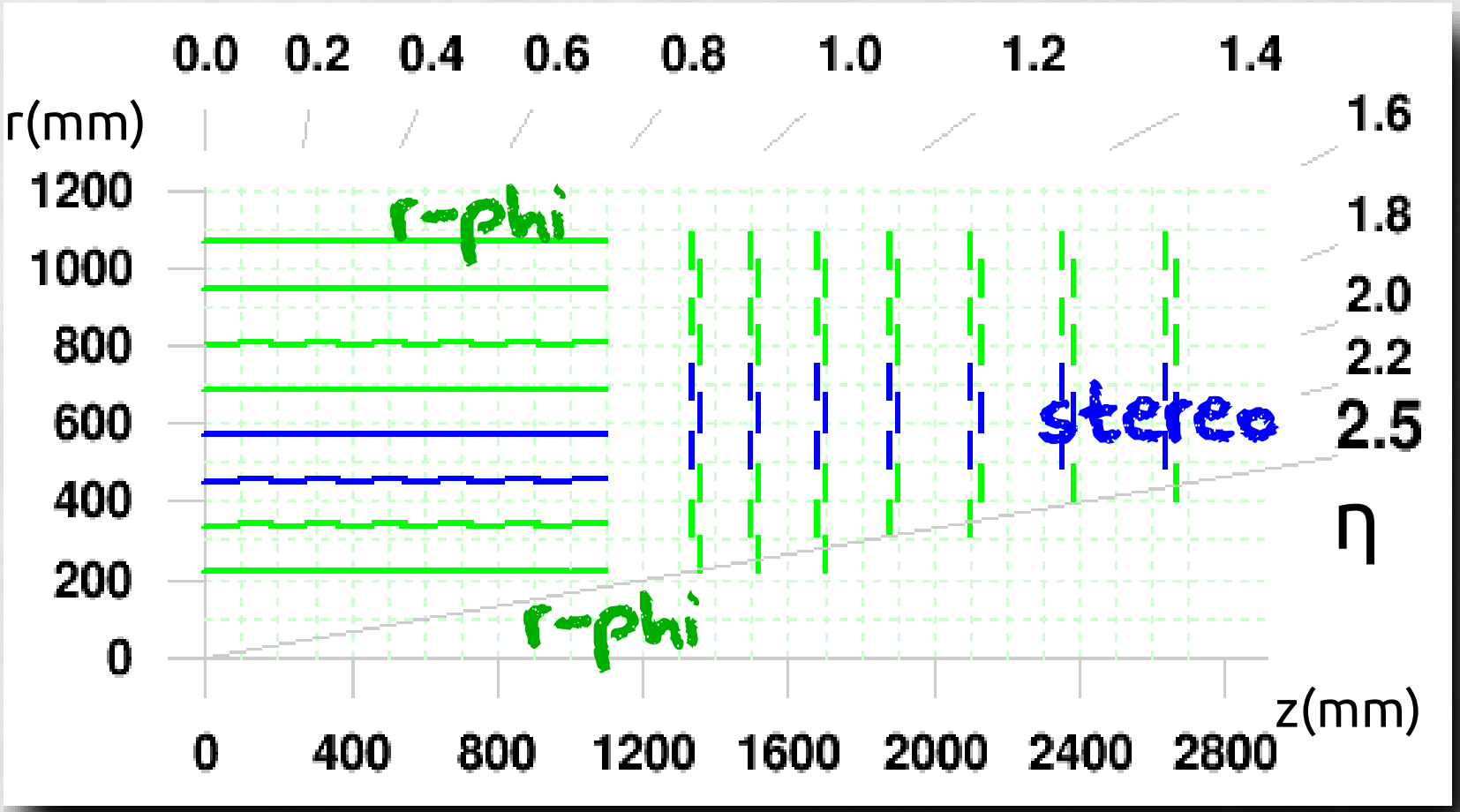
New technologies

- DC-DC converters
- CO_2 cooling
- GBT
- CBC

Less layers

Higher granularity

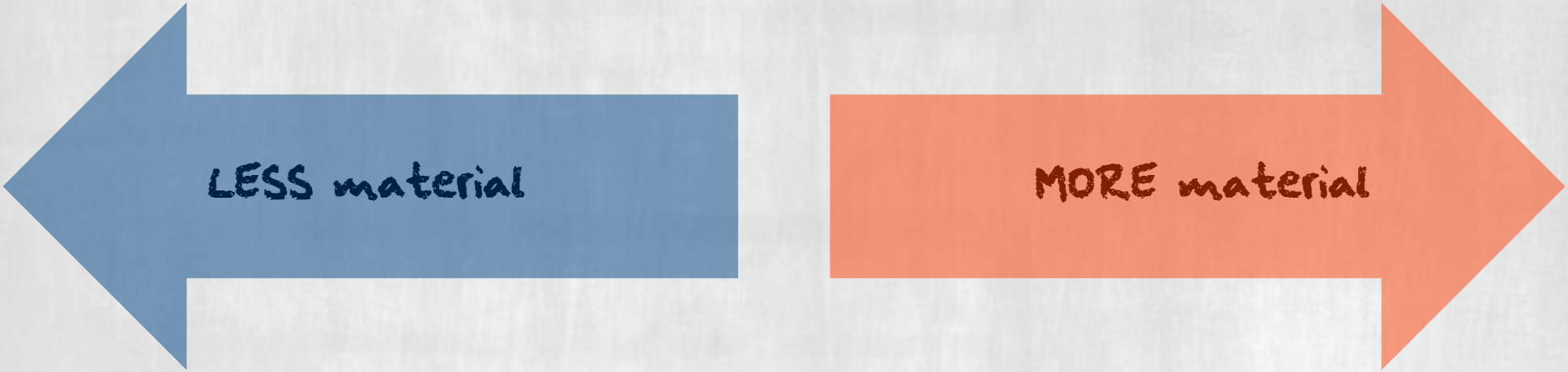
"Simple" upgrade example



- 10 x 10 cm^2
- 90 μm pitch
- Square end-cap

Expected reduction of material amount (even with conservative assumptions)

Further challenge



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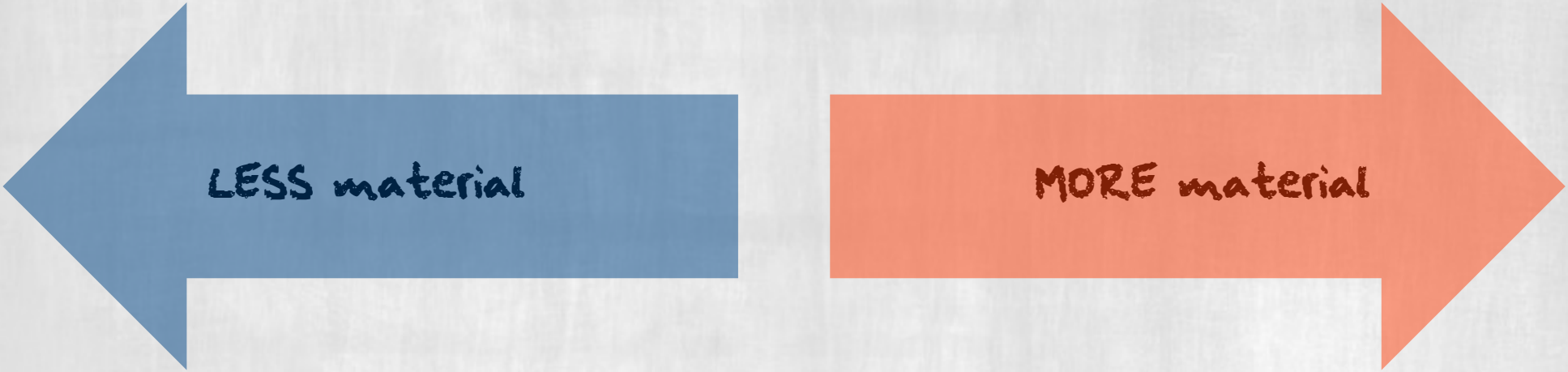

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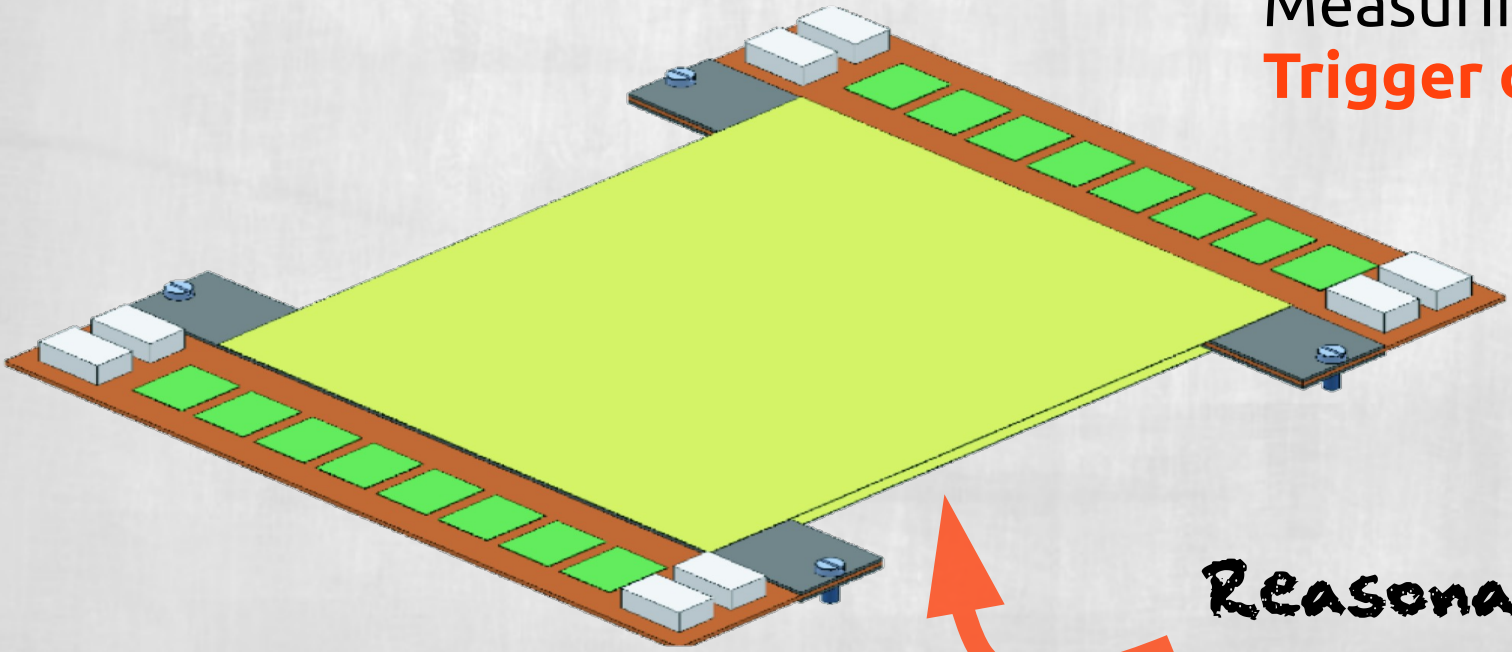
Higher granularity

Trigger capabilities!

Triggering pT module

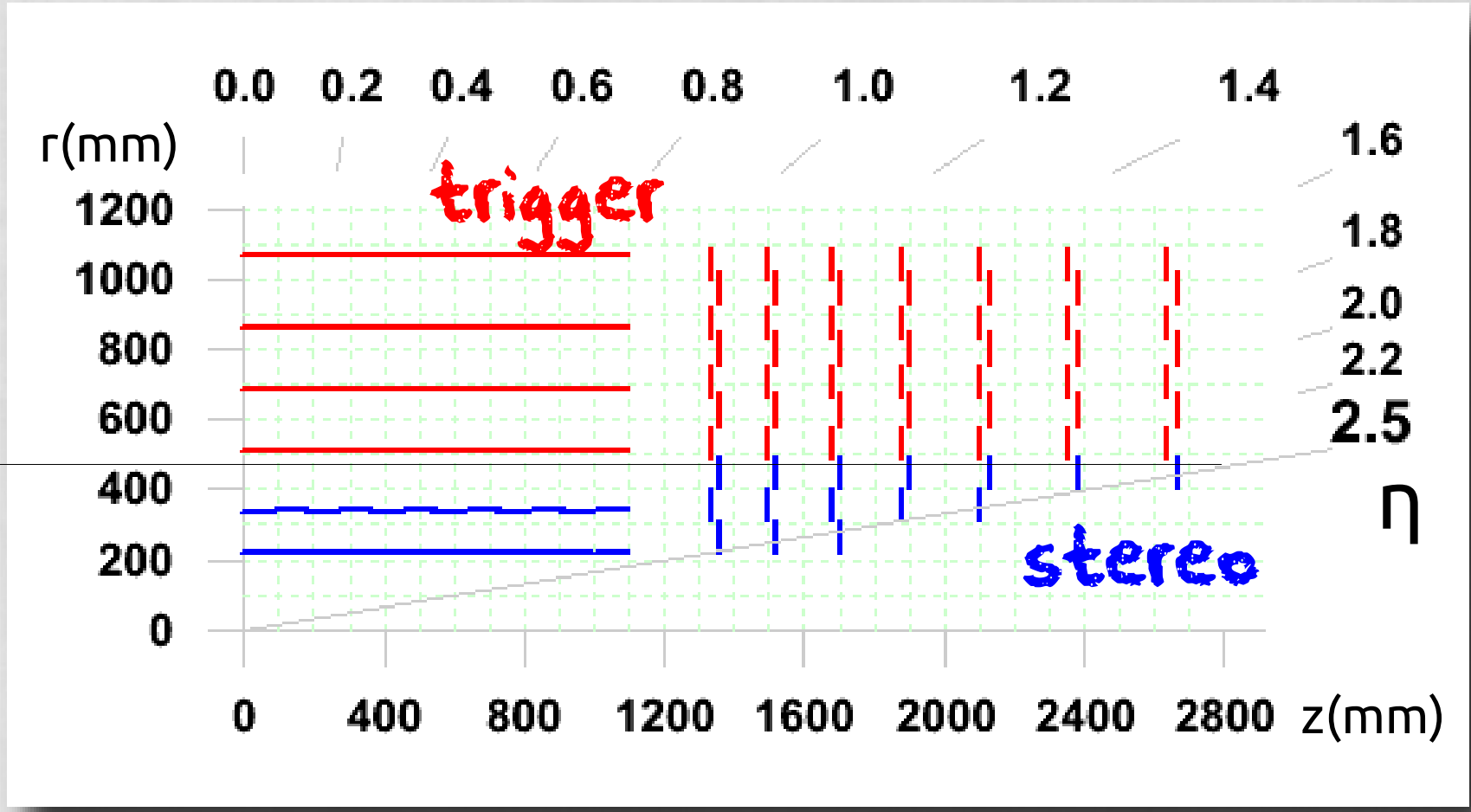
- Several options under study
- One concept sufficiently developed
  - Can work in the outer part
  - See later talk by D. Abbaneo

Sandwich of **strip sensors**
5 cm long strips
Measuring pT locally
Trigger output



Reasonably **detailed** model of material

Other example - trigger in outer layers



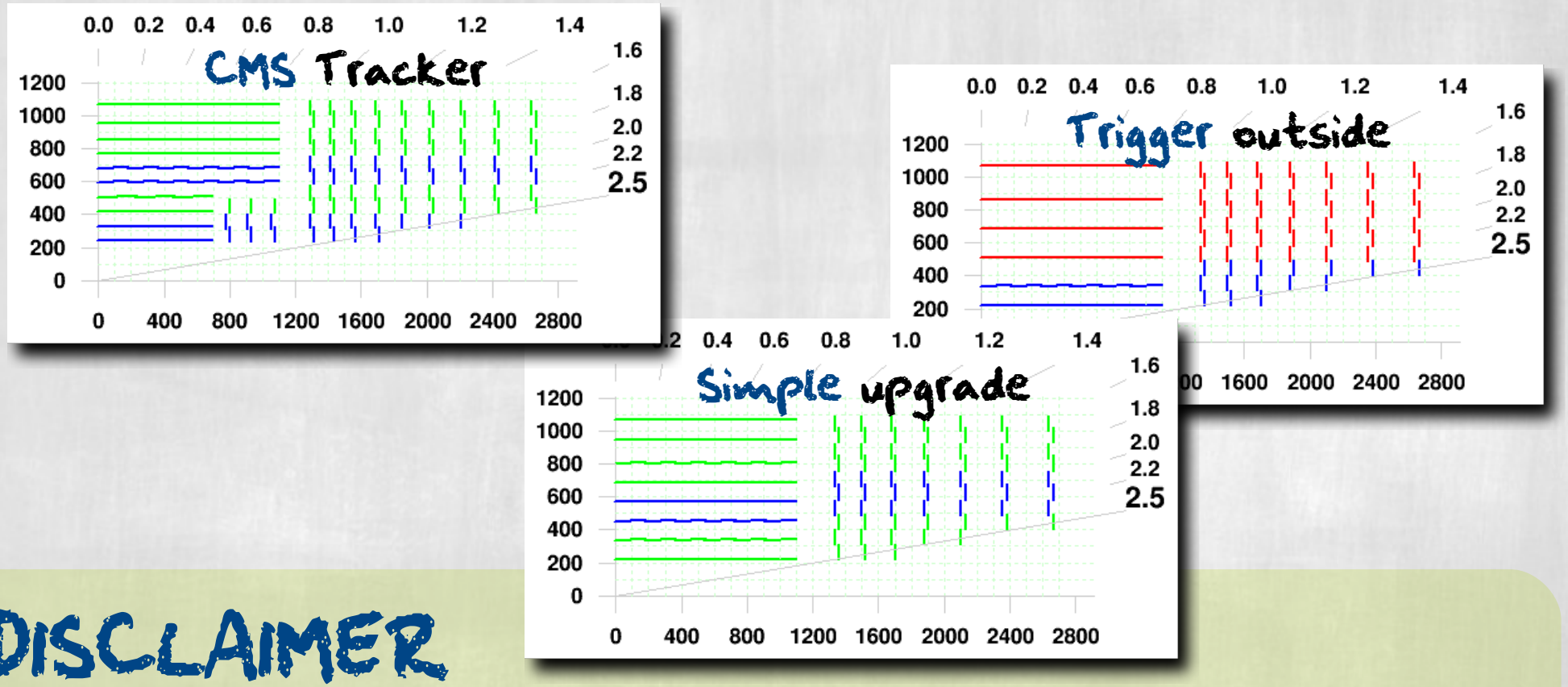
500 mm

- 10 x 10 cm^2
- 90 µm pitch
- Square end-cap

High particle density inside => “simple” modules
Lower density outside => trigger modules

3 example layouts

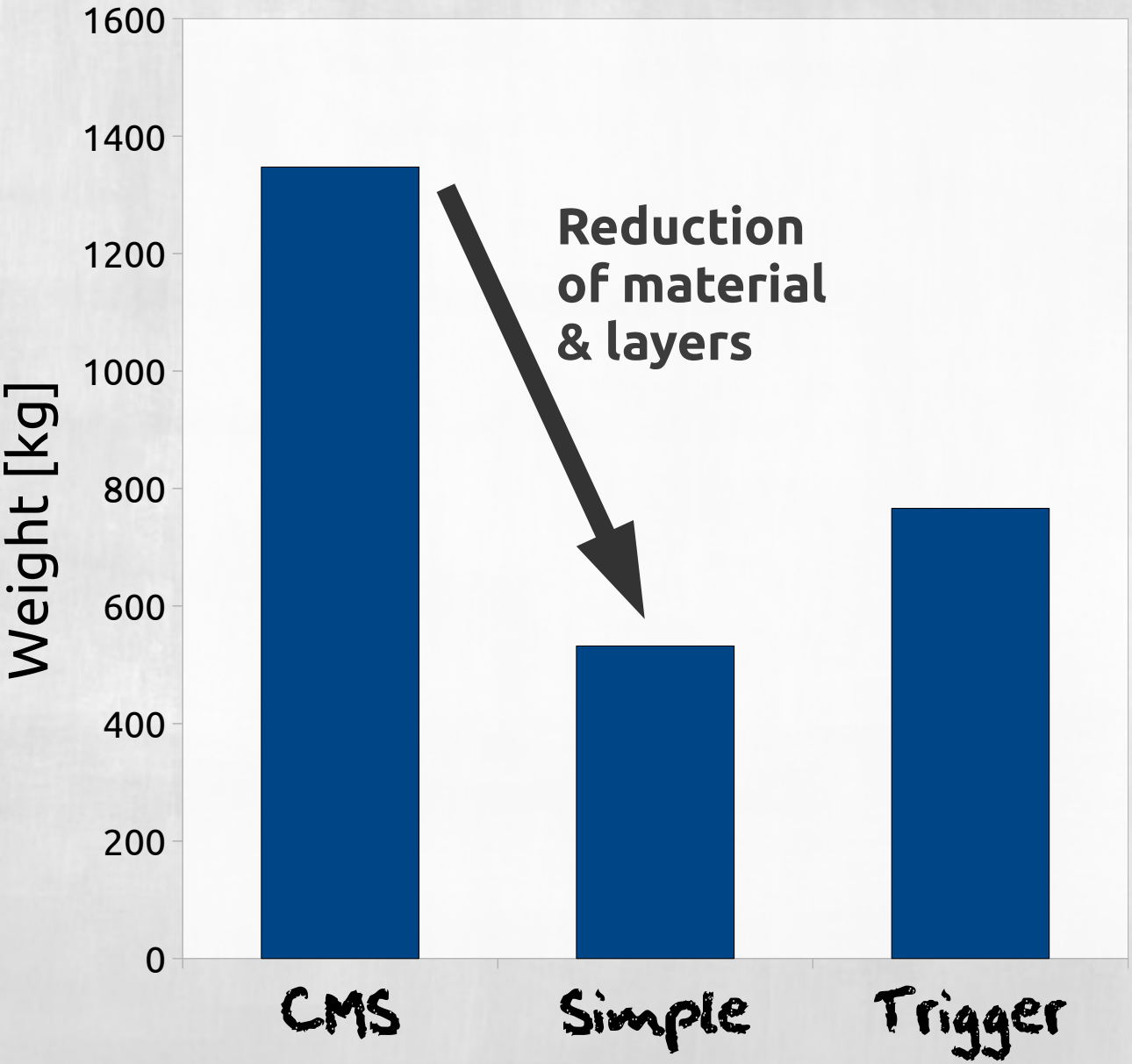
Some comparisons of these layouts



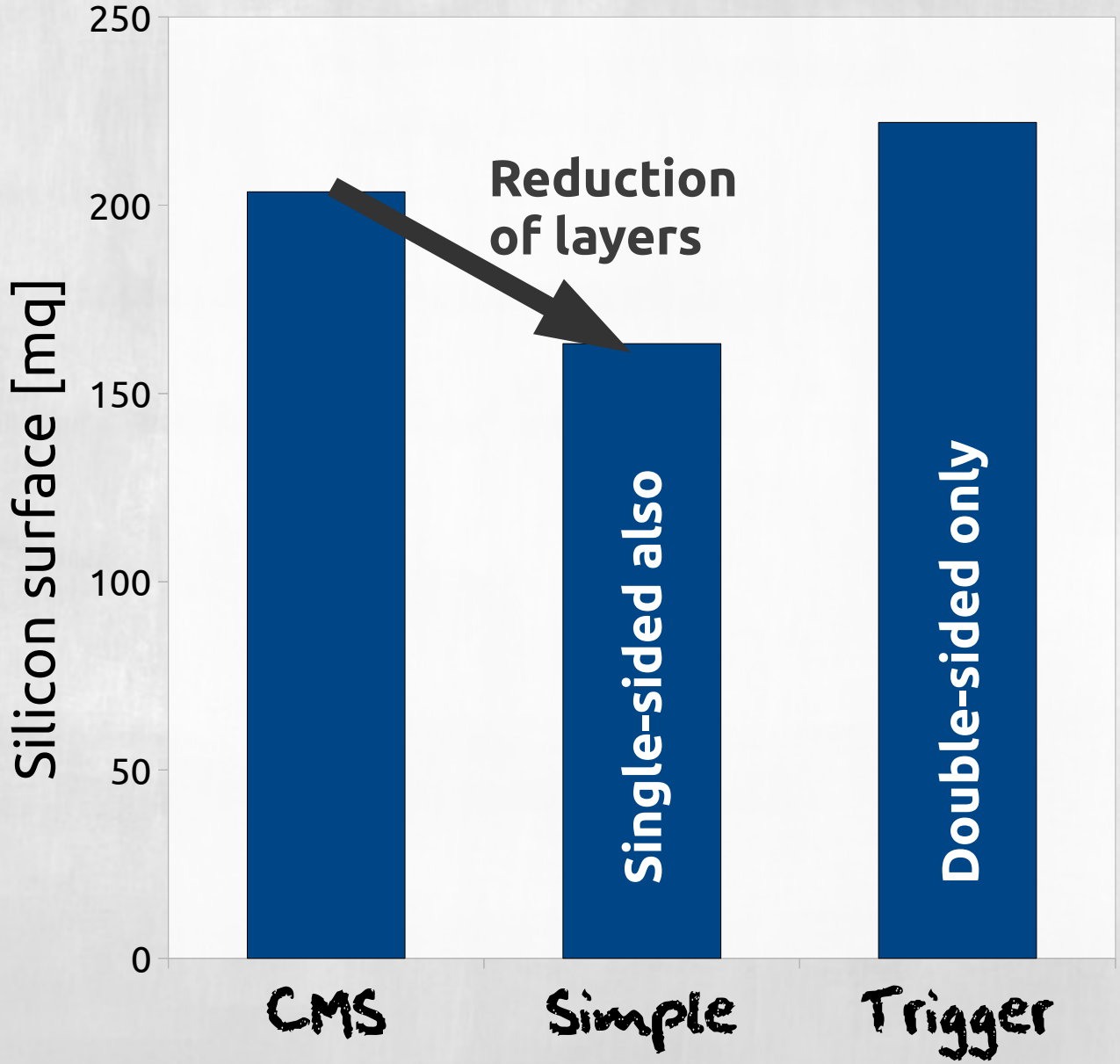
DISCLAIMER

These examples were selected to show the functionalities of tkLayout, but they are not the only, nor the most significant options under study

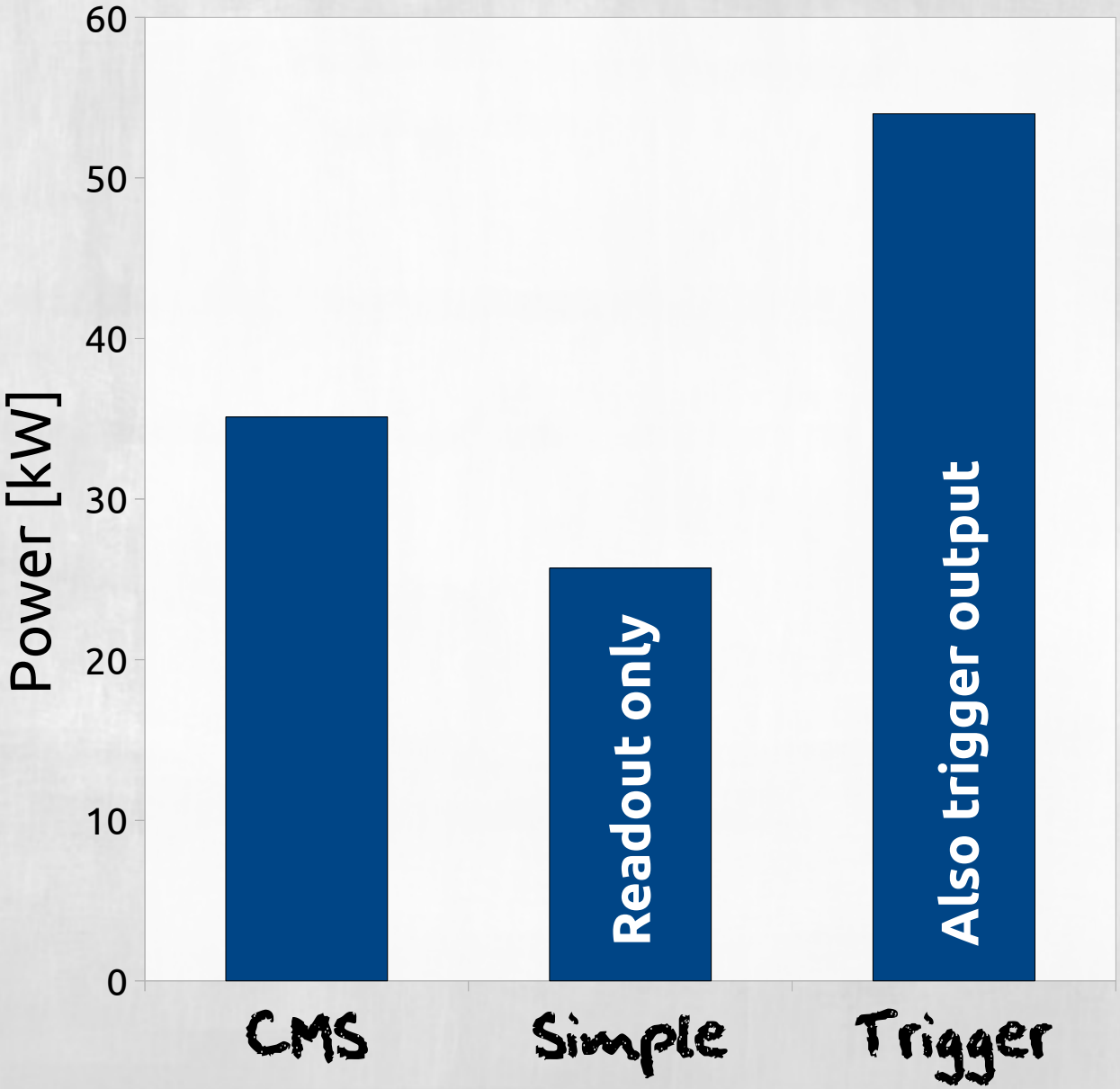
Summary - weight



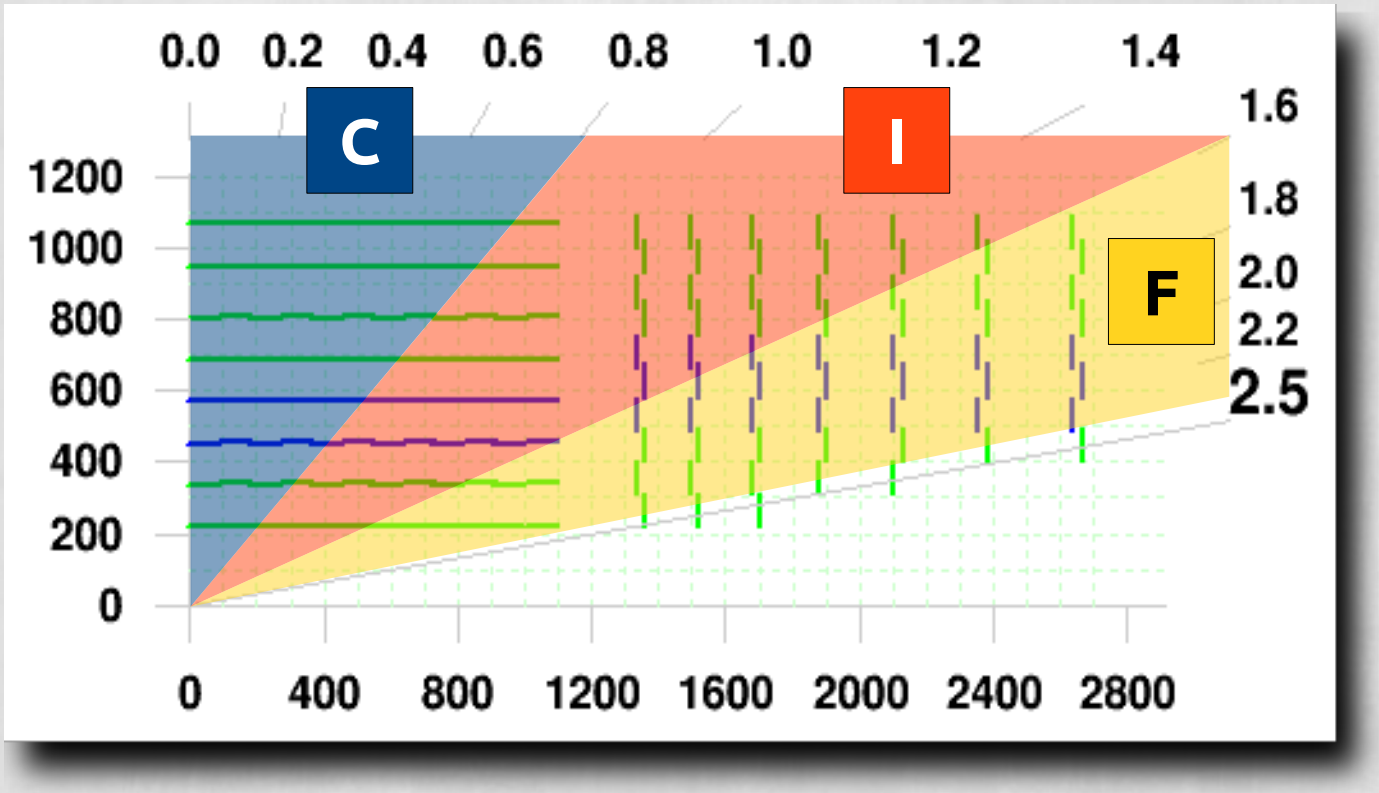
Summary - surface



Summary - power dissipation



Tracking regions



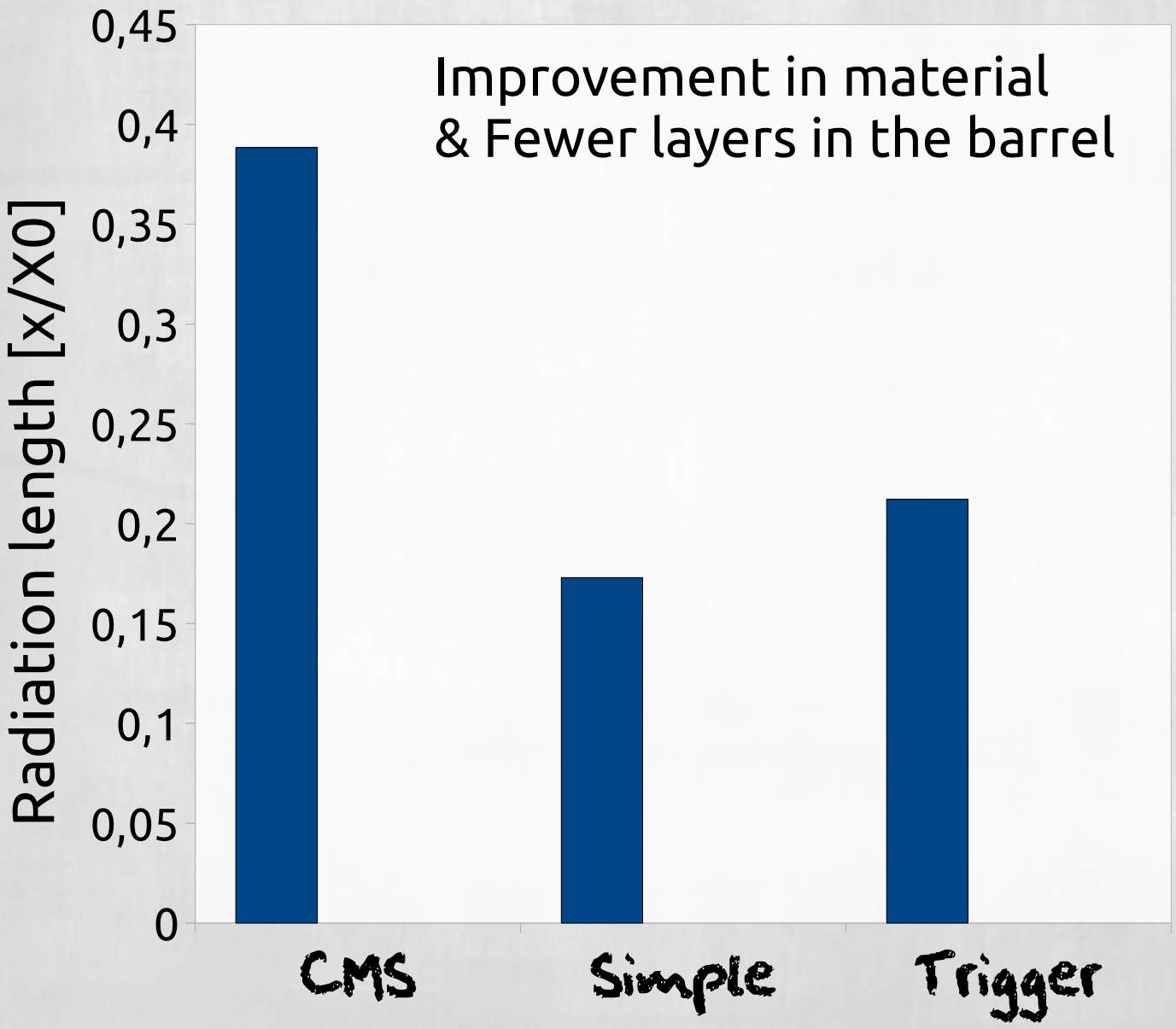
η

C	0 → 0.8
I	0.8 → 1.6
F	1.6 → 2.4

Δη= 0.8

Roughly same number of tracks expected

Material



η

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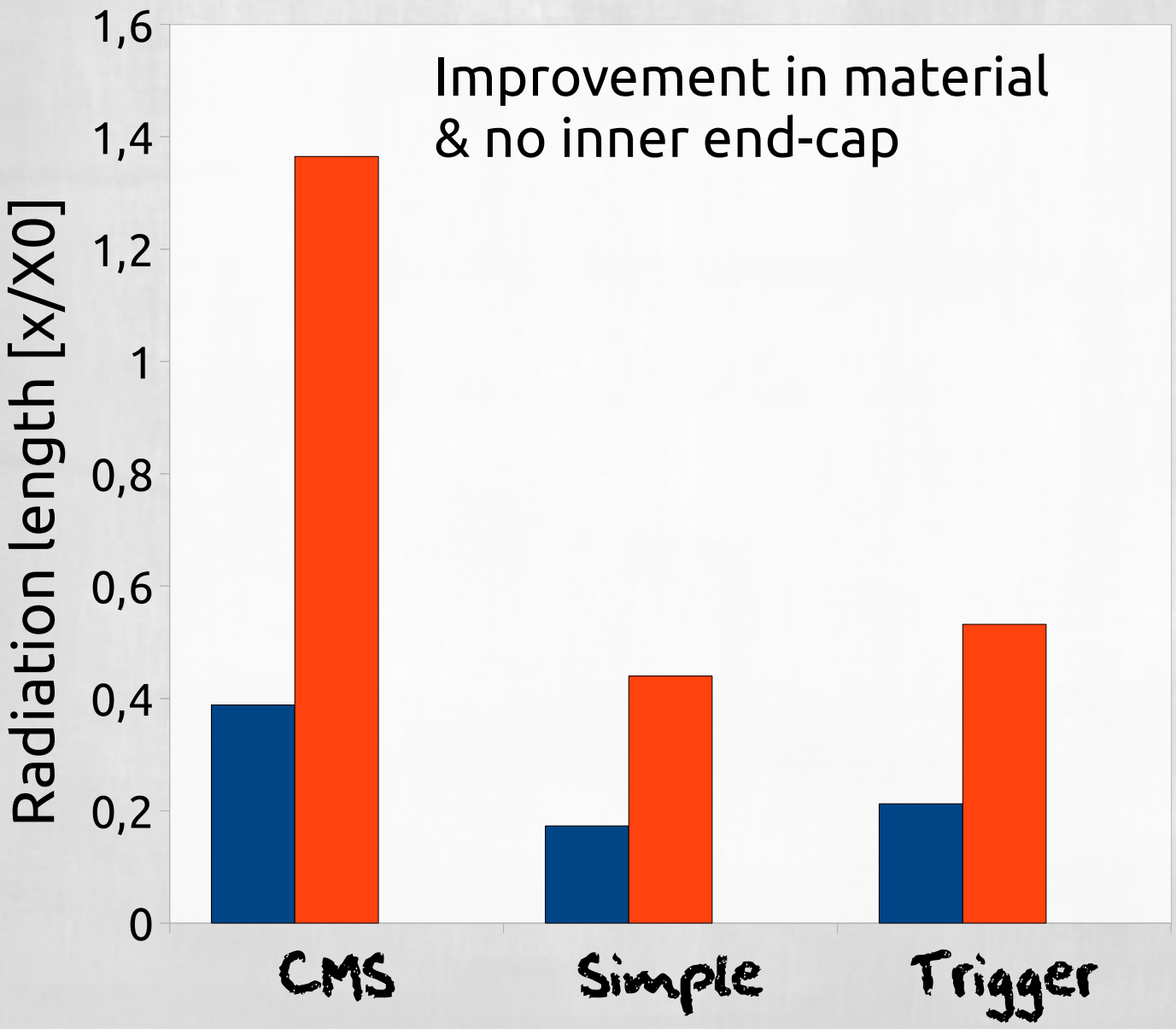
Material



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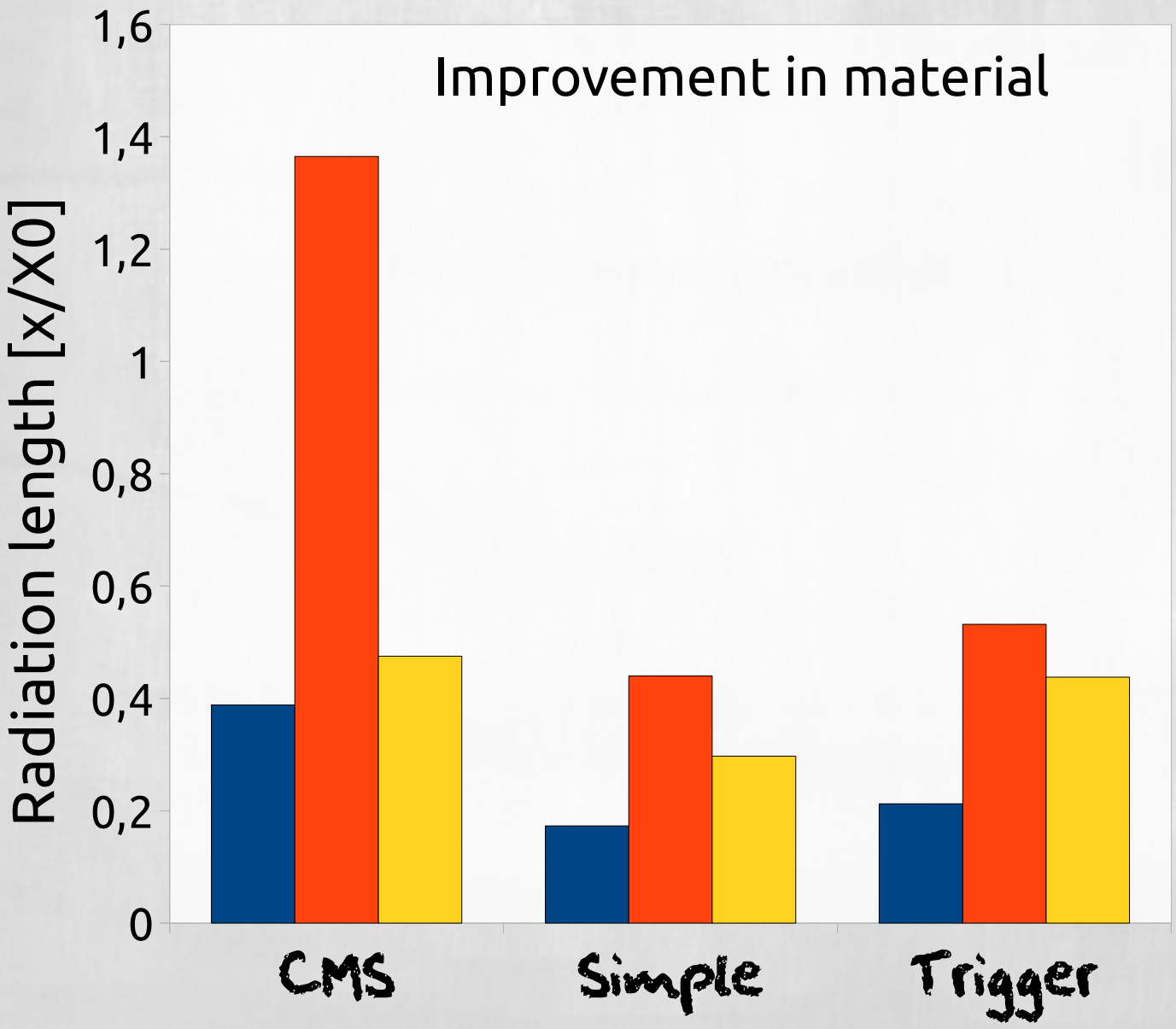

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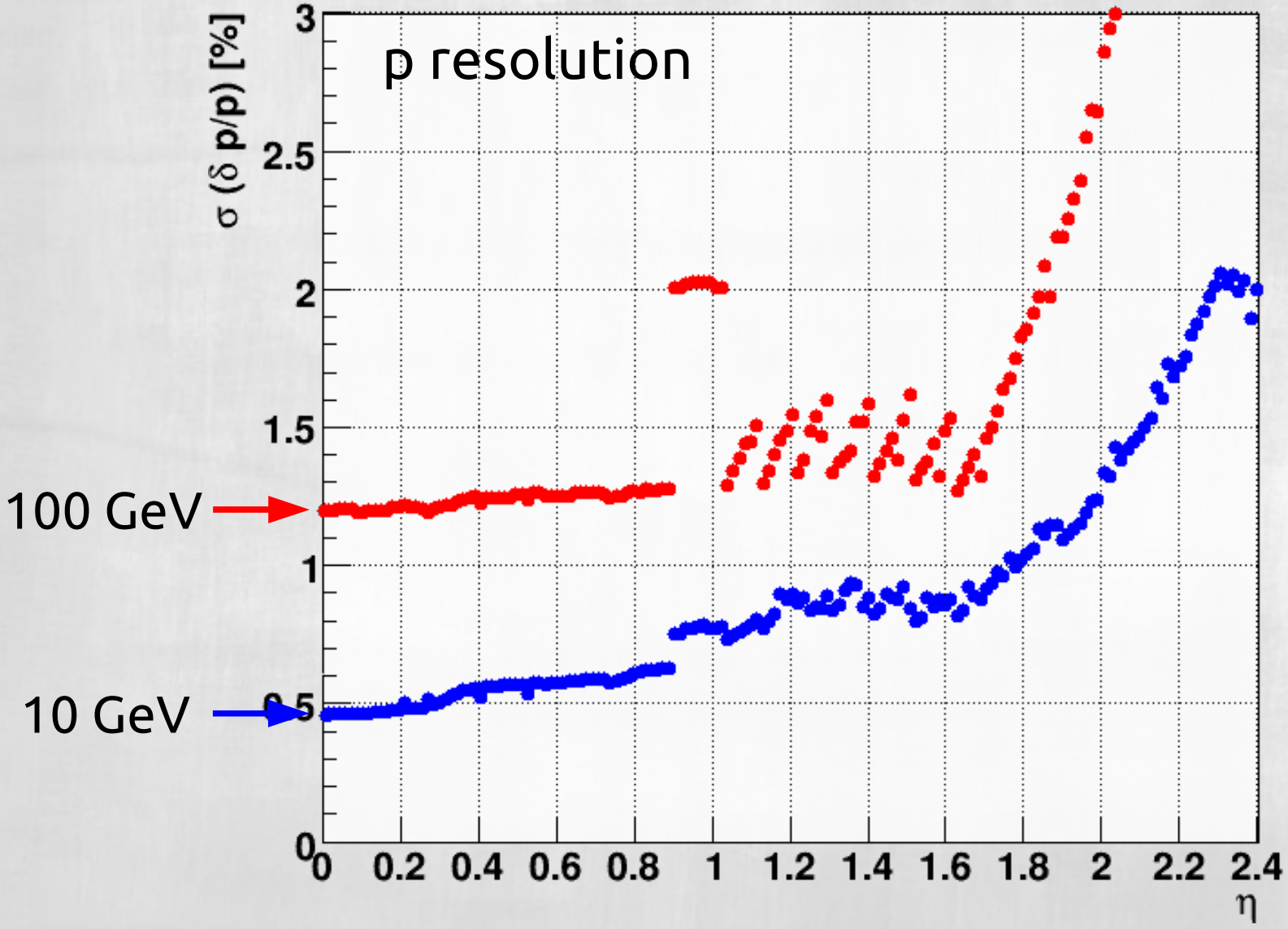
Comparing p resolution



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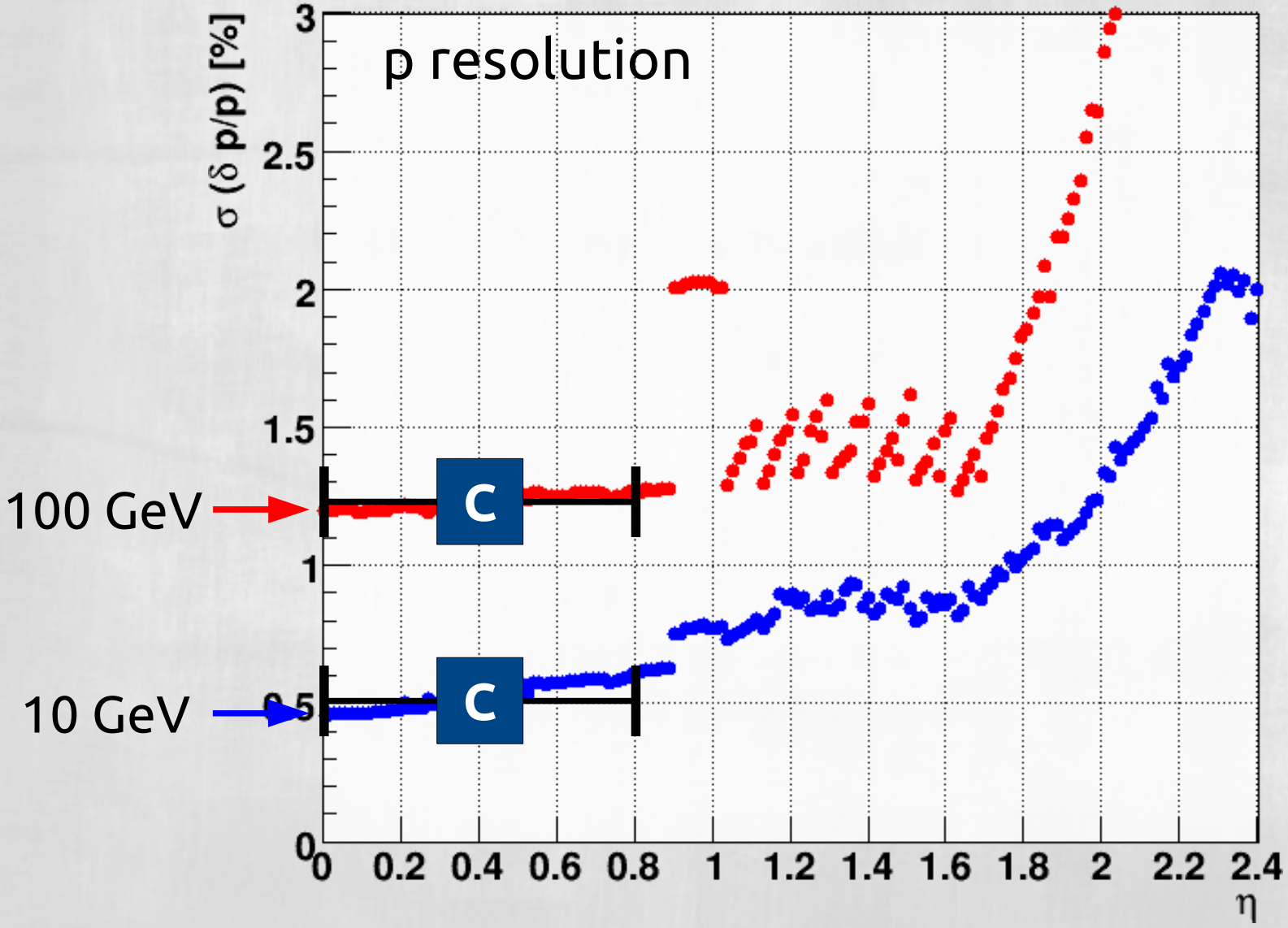

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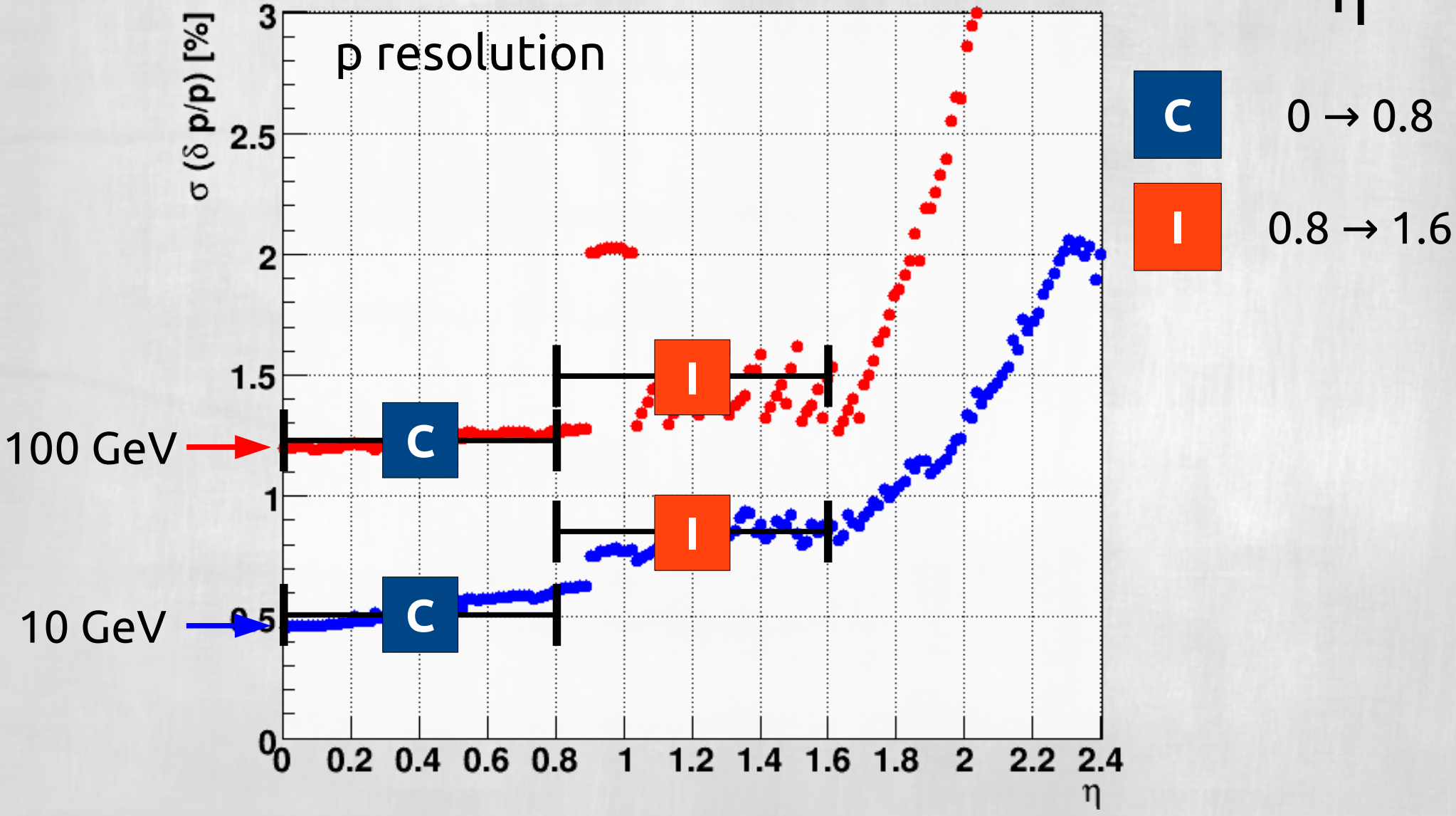

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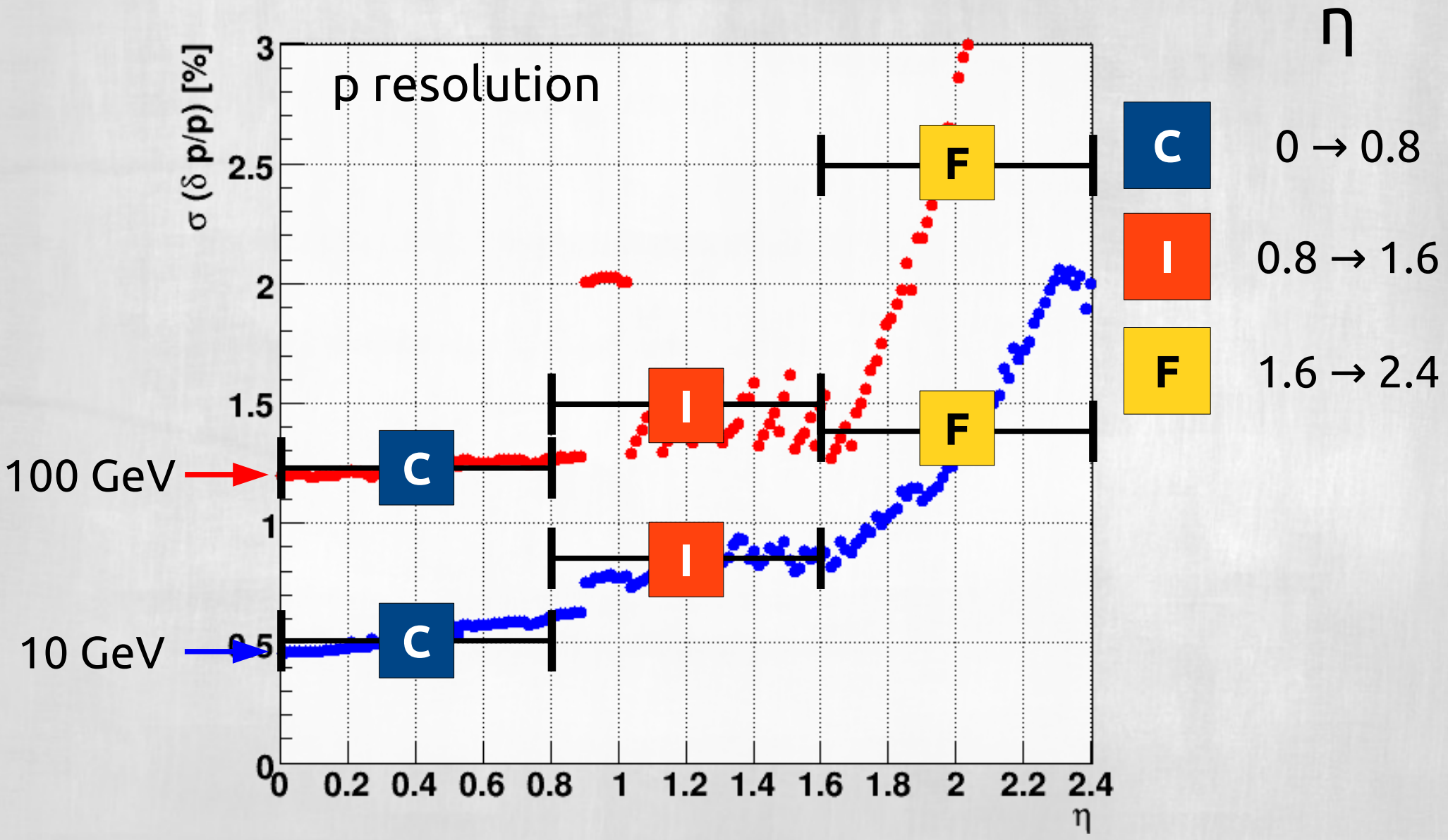

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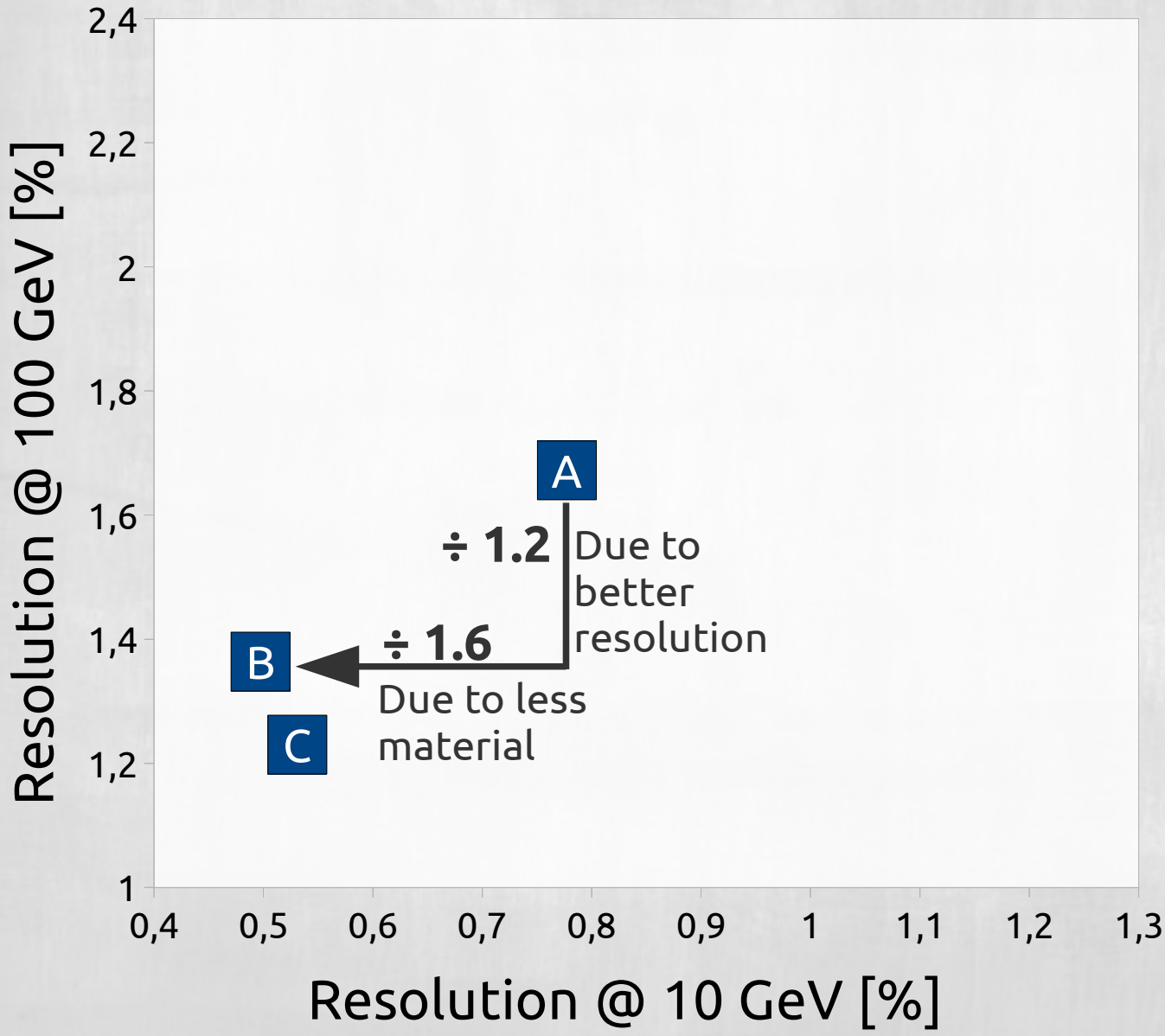


η

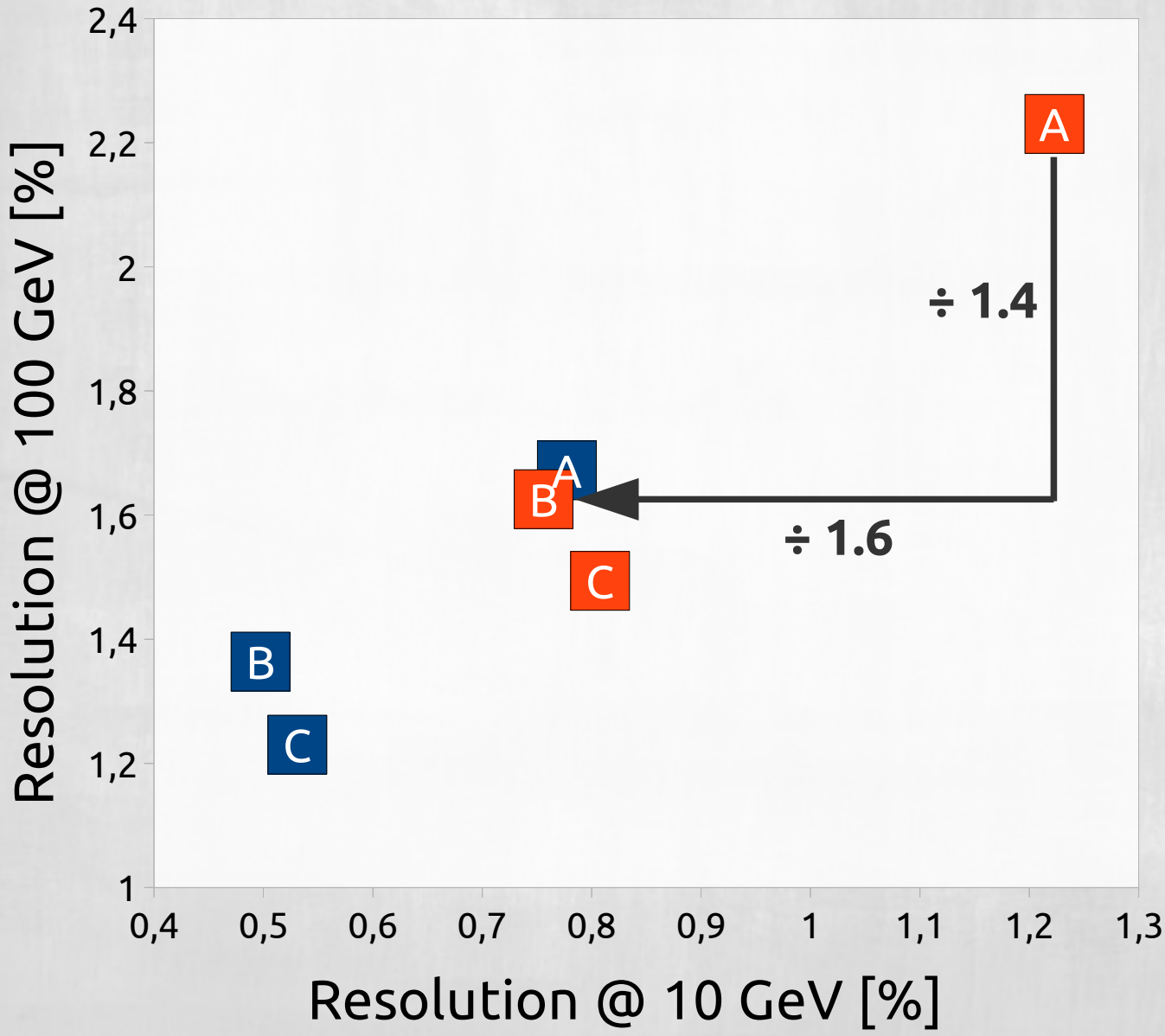
C 0 → 0.8

A CMS Tracker

B Simple upgrade

C Trigger

Comparing p resolution



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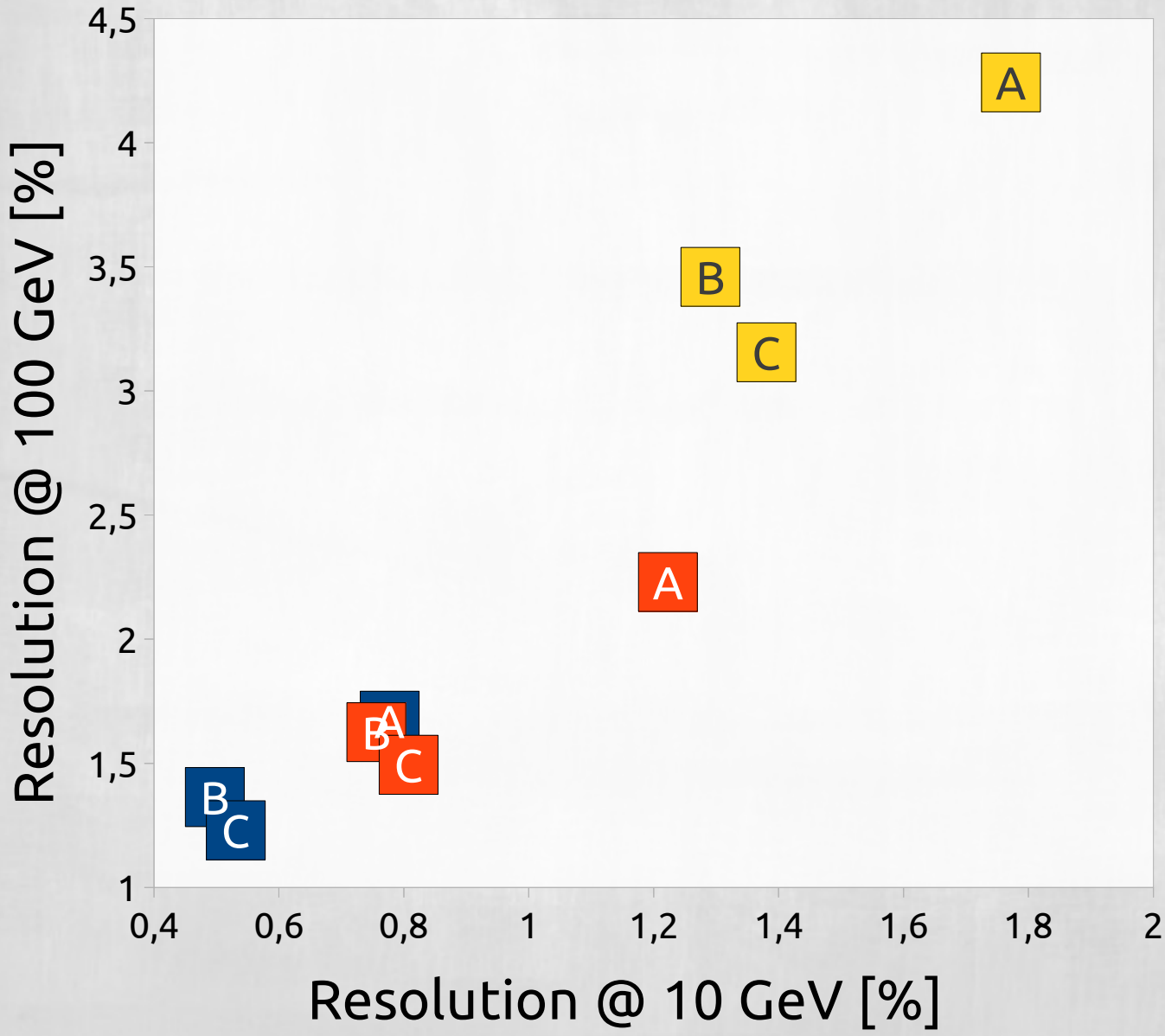
B Simple upgrade

C Trigger

Comparing p resolution

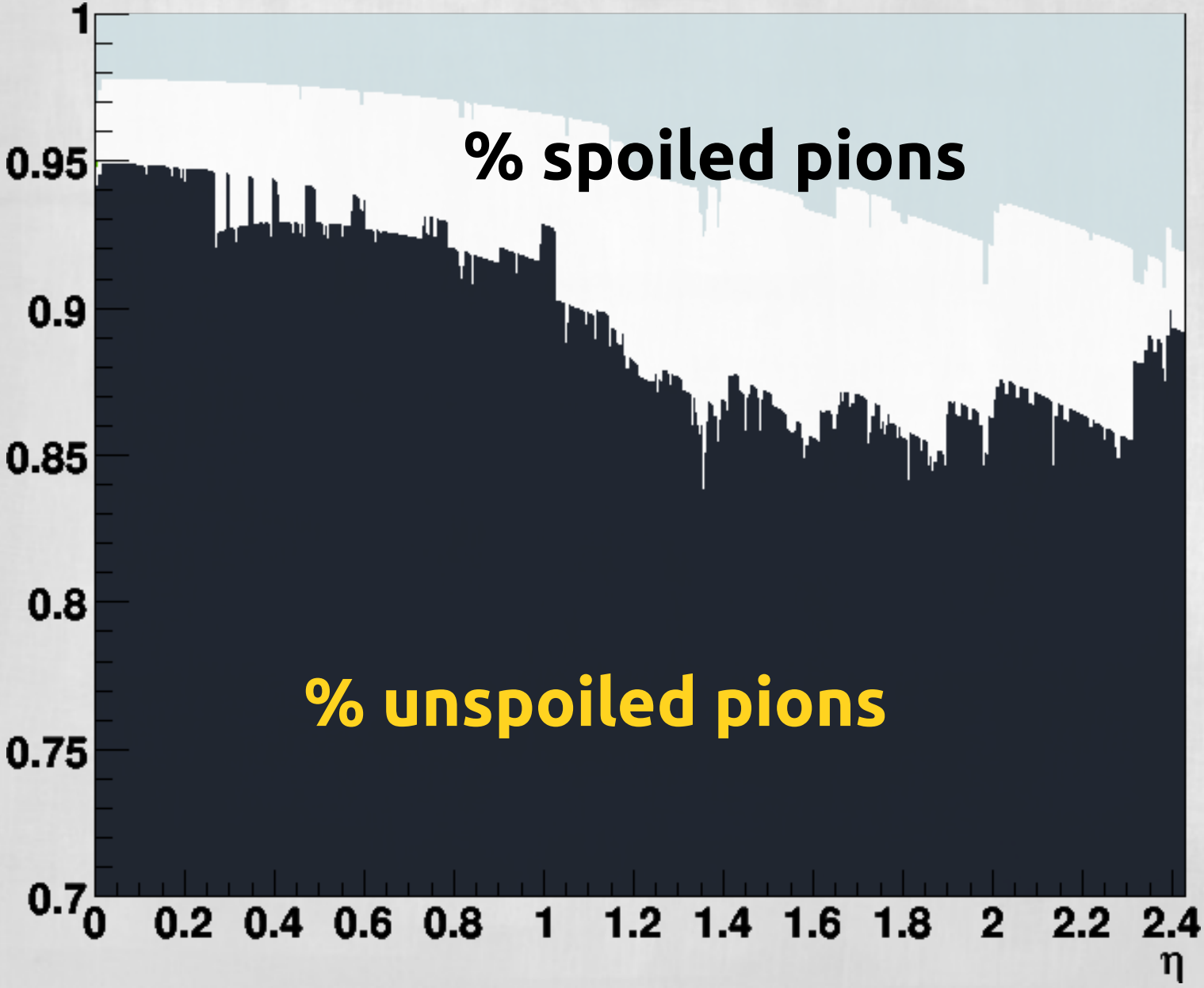


η

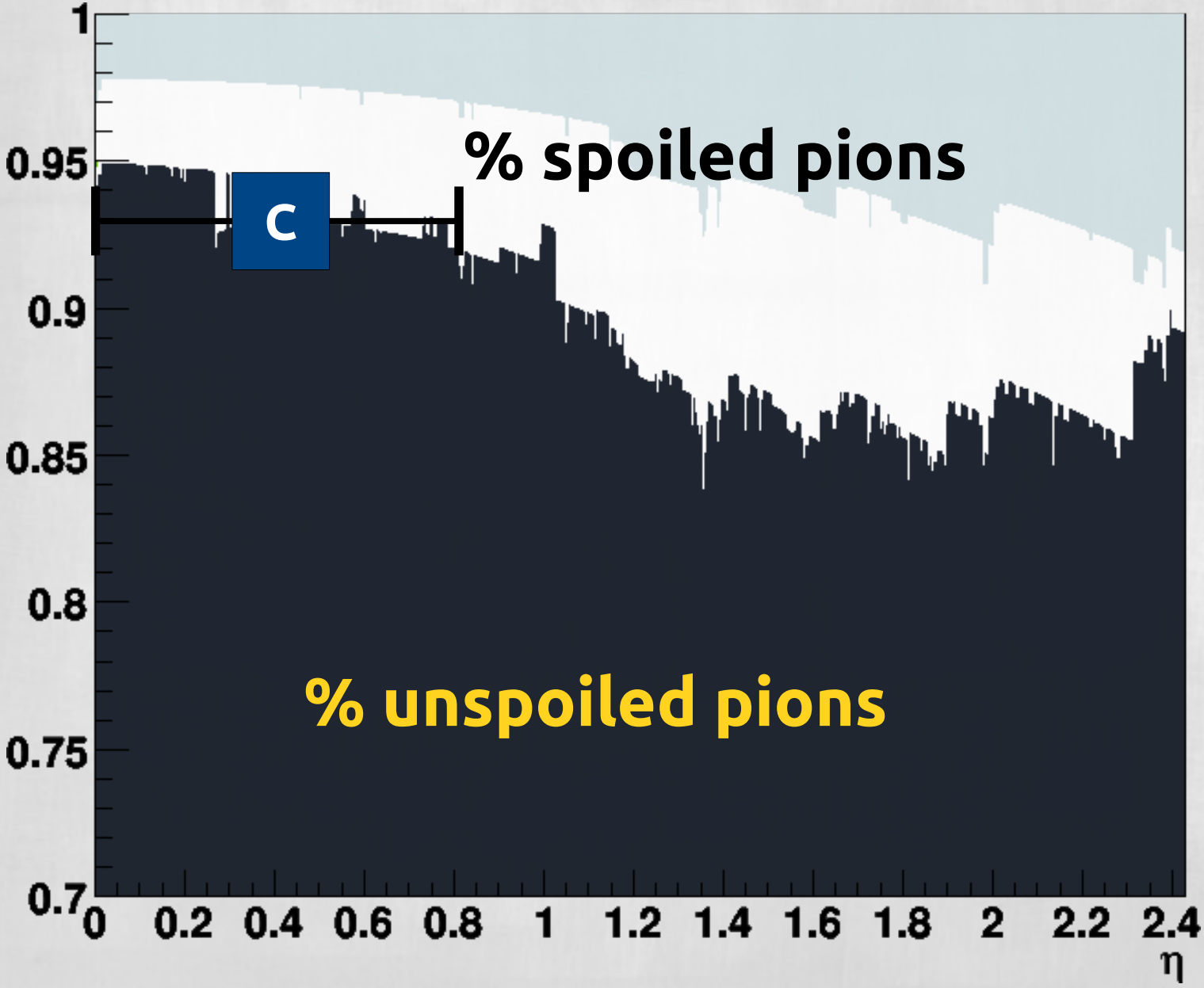
C	0 → 0.8
I	0.8 → 1.6
F	1.6 → 2.4

A	CMS Tracker
B	Simple upgrade
C	Trigger

Comparing nucl. interactions



Comparing nucl. interactions

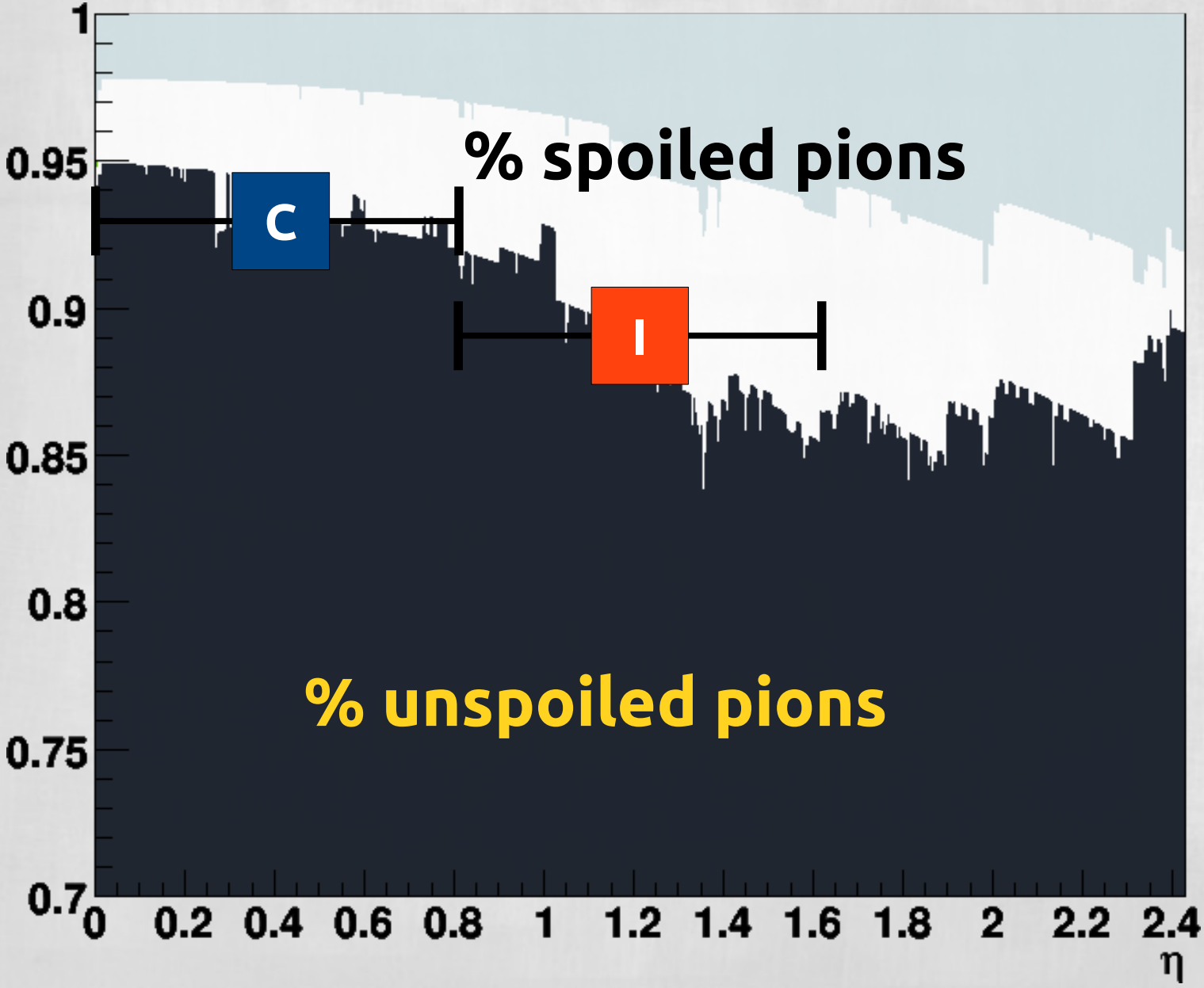


η

c

0 → 0.8

Comparing nucl. interactions

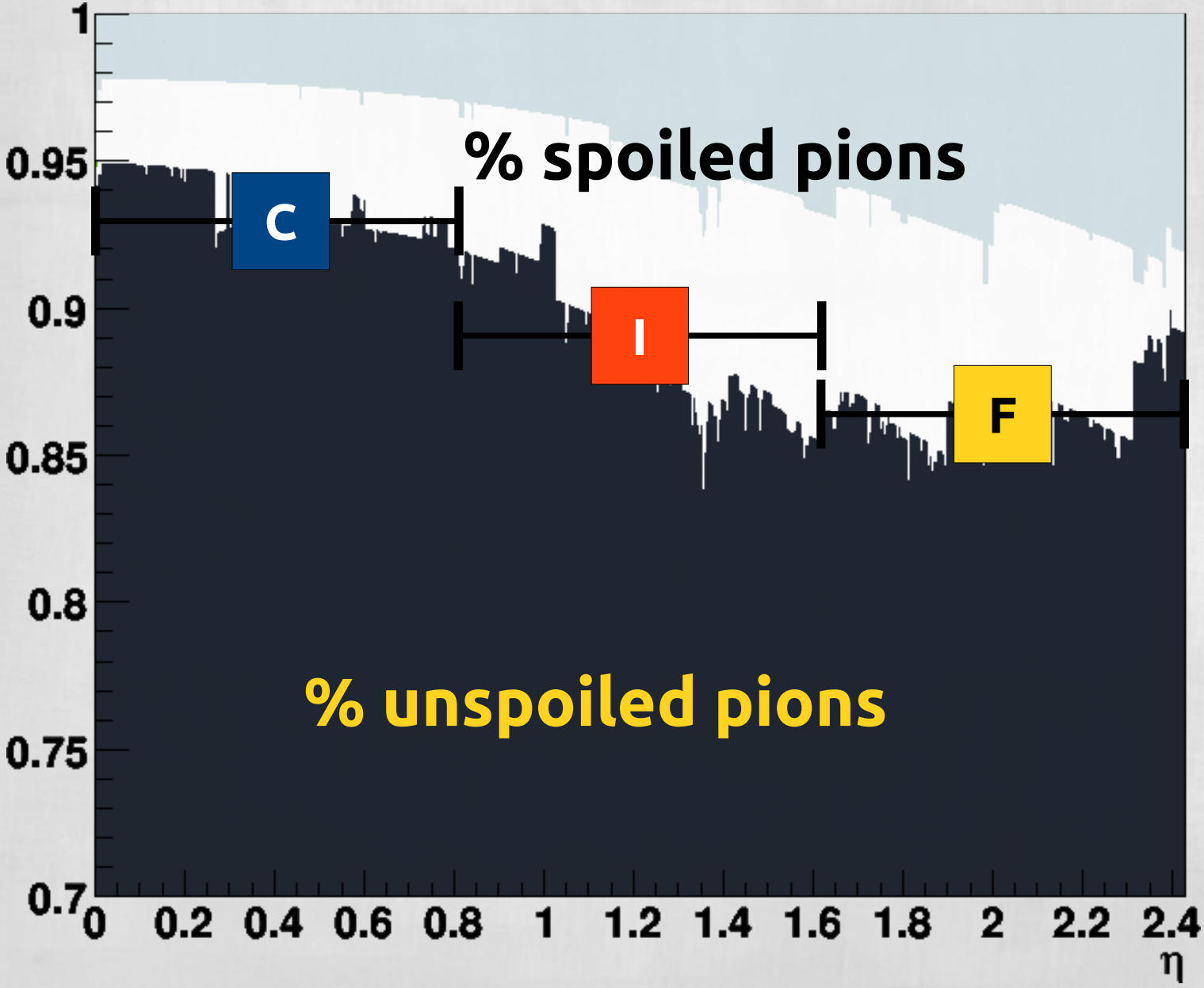


η

C 0 → 0.8

I 0.8 → 1.6

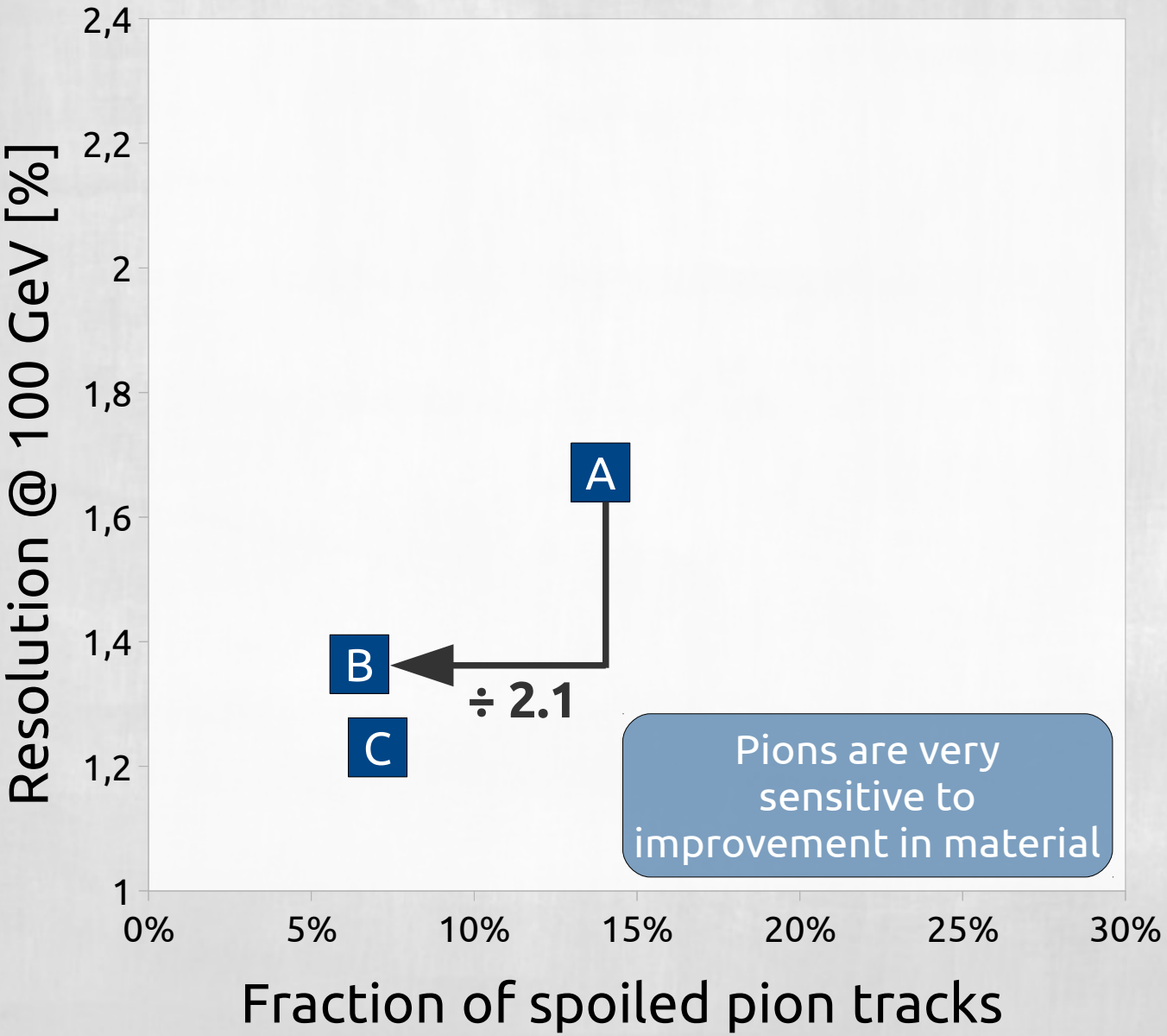
Comparing nucl. interactions



η

C	0 → 0.8
I	0.8 → 1.6
F	1.6 → 2.4

Nuclear interactions



η

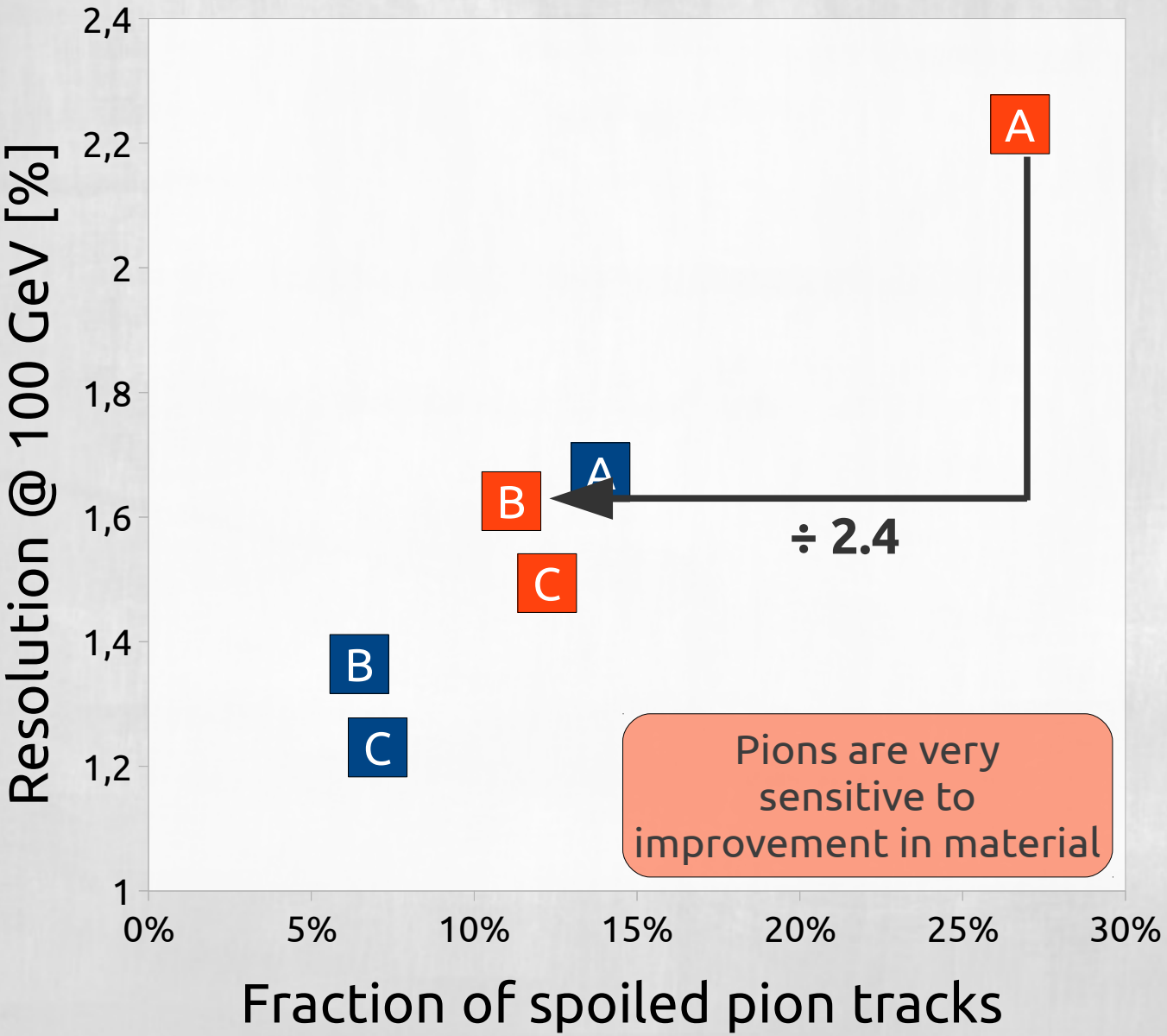
C 0 → 0.8

A CMS Tracker

B Simple upgrade

C Trigger

Nuclear interactions



η

C 0 → 0.8

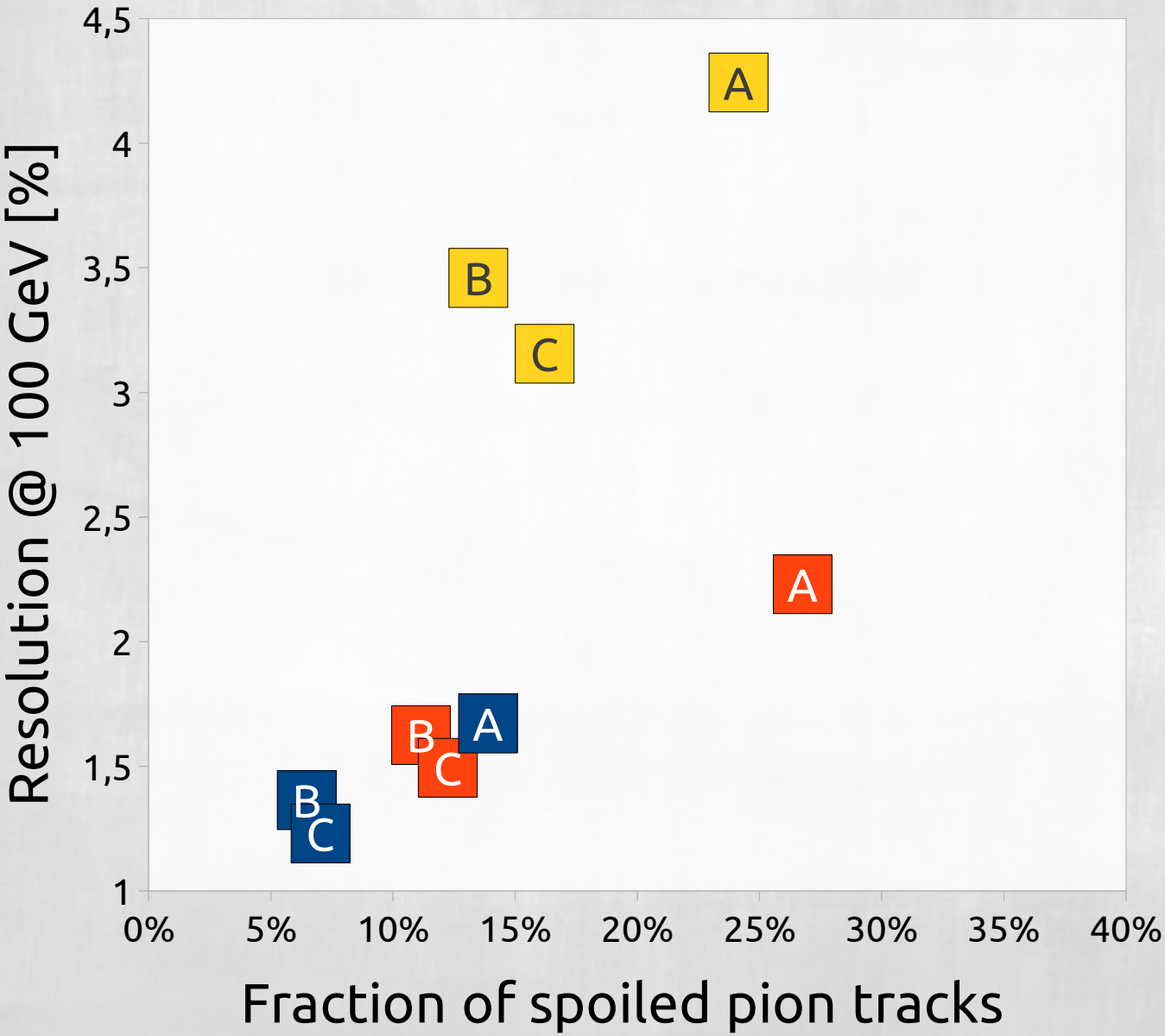
I 0.8 → 1.6

A CMS Tracker

B Simple upgrade

C Trigger

Nuclear interactions

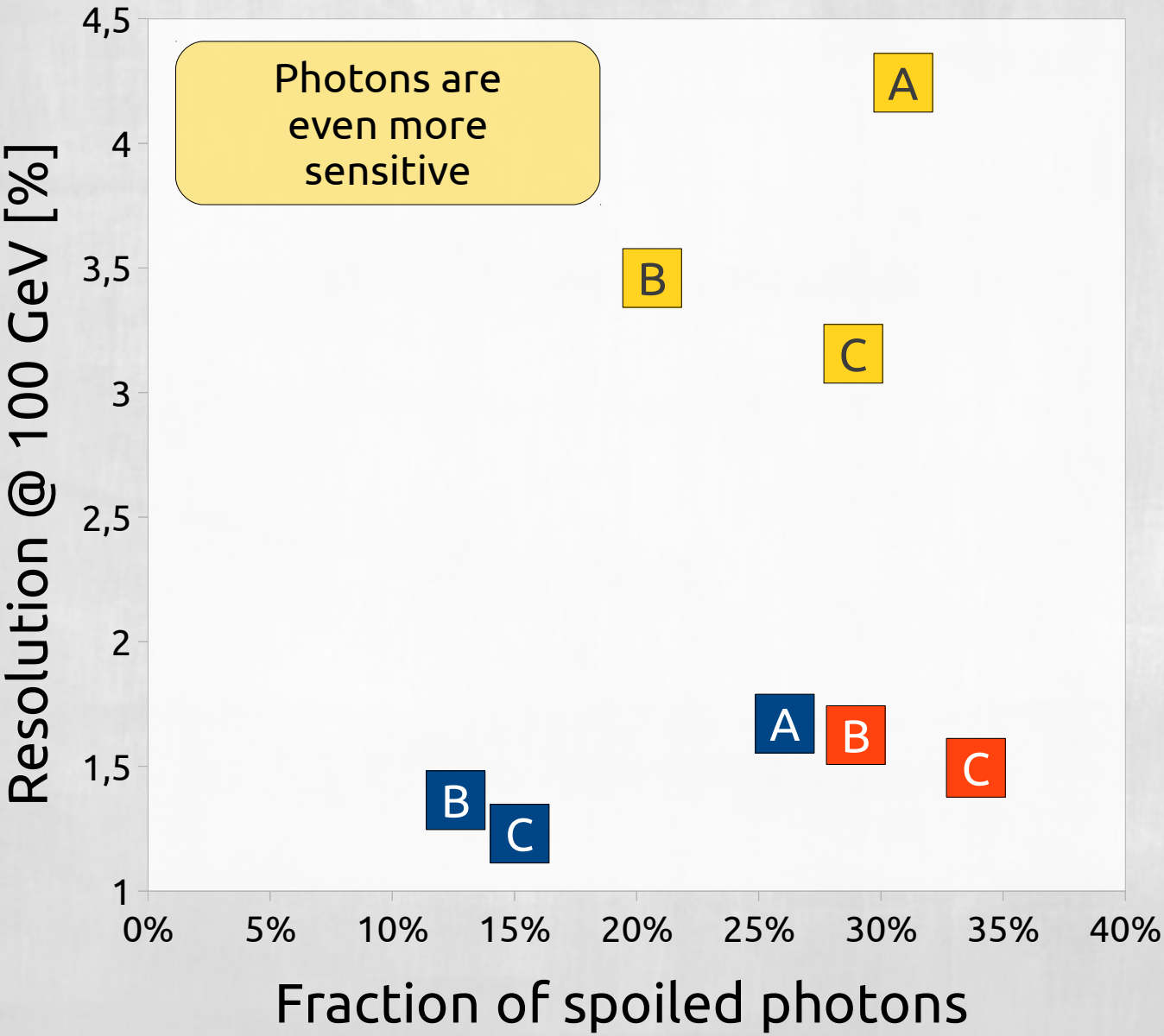


η

C	0 → 0.8
I	0.8 → 1.6
F	1.6 → 2.4

A	CMS Tracker
B	Simple upgrade
C	Trigger

Photon conversion



η

C	0 → 0.8
I	0.8 → 1.6
F	1.6 → 2.4

A

A	CMS Tracker
B	Simple upgrade
C	Trigger

~~What is tkLayout?~~

~~Evaluation of tracking performance~~

~~Validation on a full simulation~~

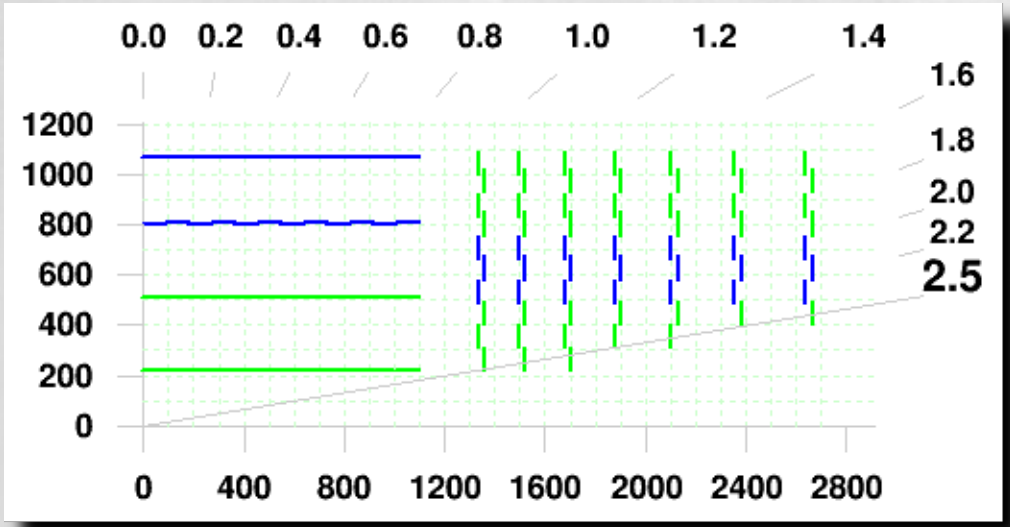
~~Layout comparison~~

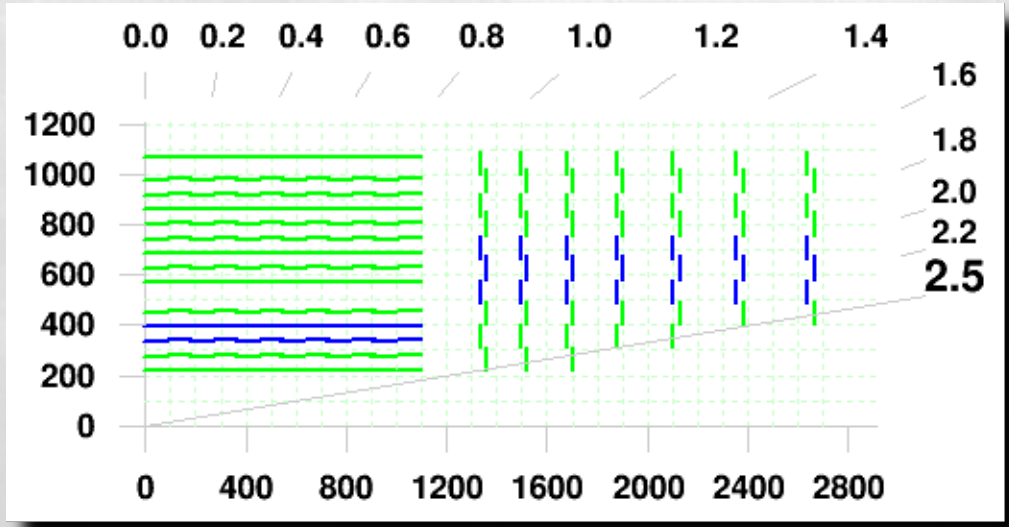
Layout optimization

Conclusions

Trade-off in number of layers

- More layers
  - More measurement points
  - Better 100 GeV p resolution
- Less layers
  - Less multiple scattering
  - Better 10 GeV p resolution



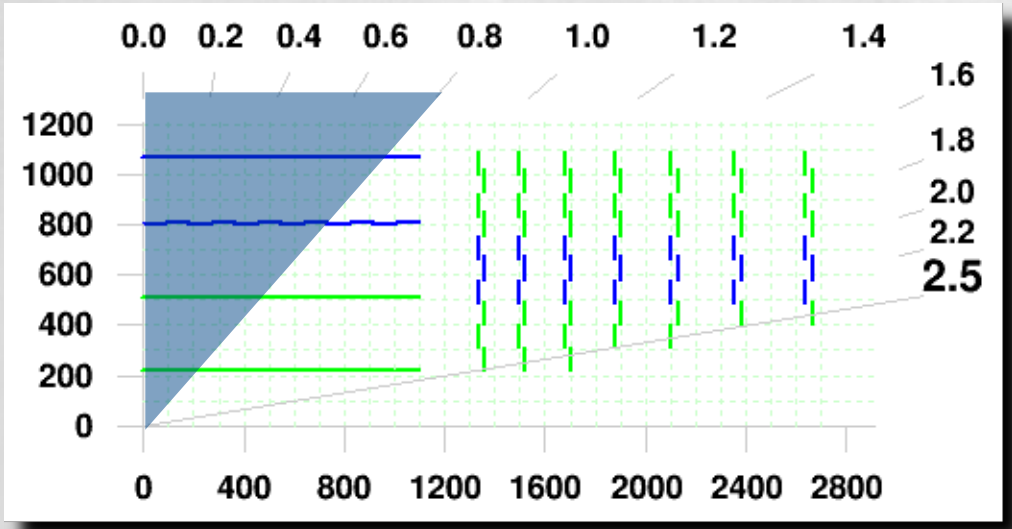


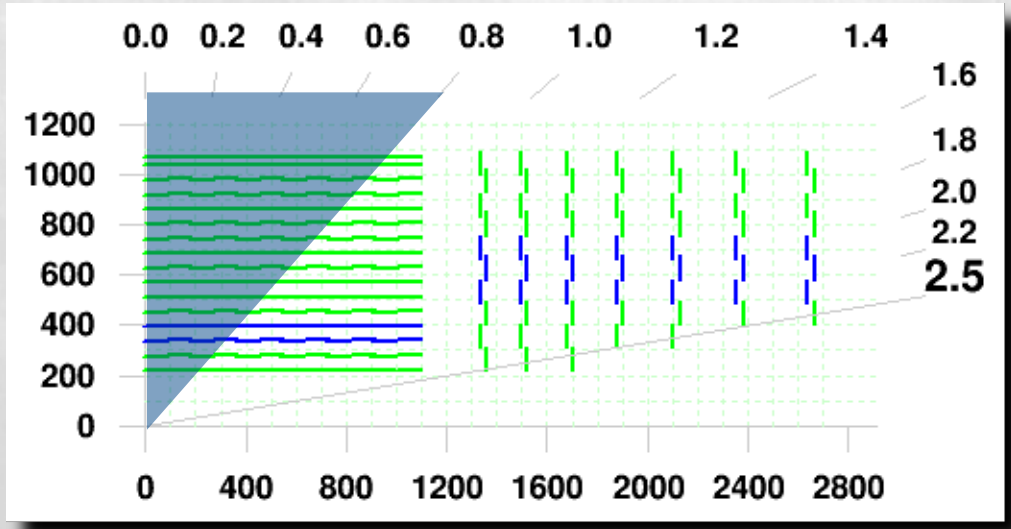
Trade-off in number of layers

- More layers
  - More measurement points
  - Better 100 GeV p resolution
- Less layers
  - Less multiple scattering
  - Better 10 GeV p resolution

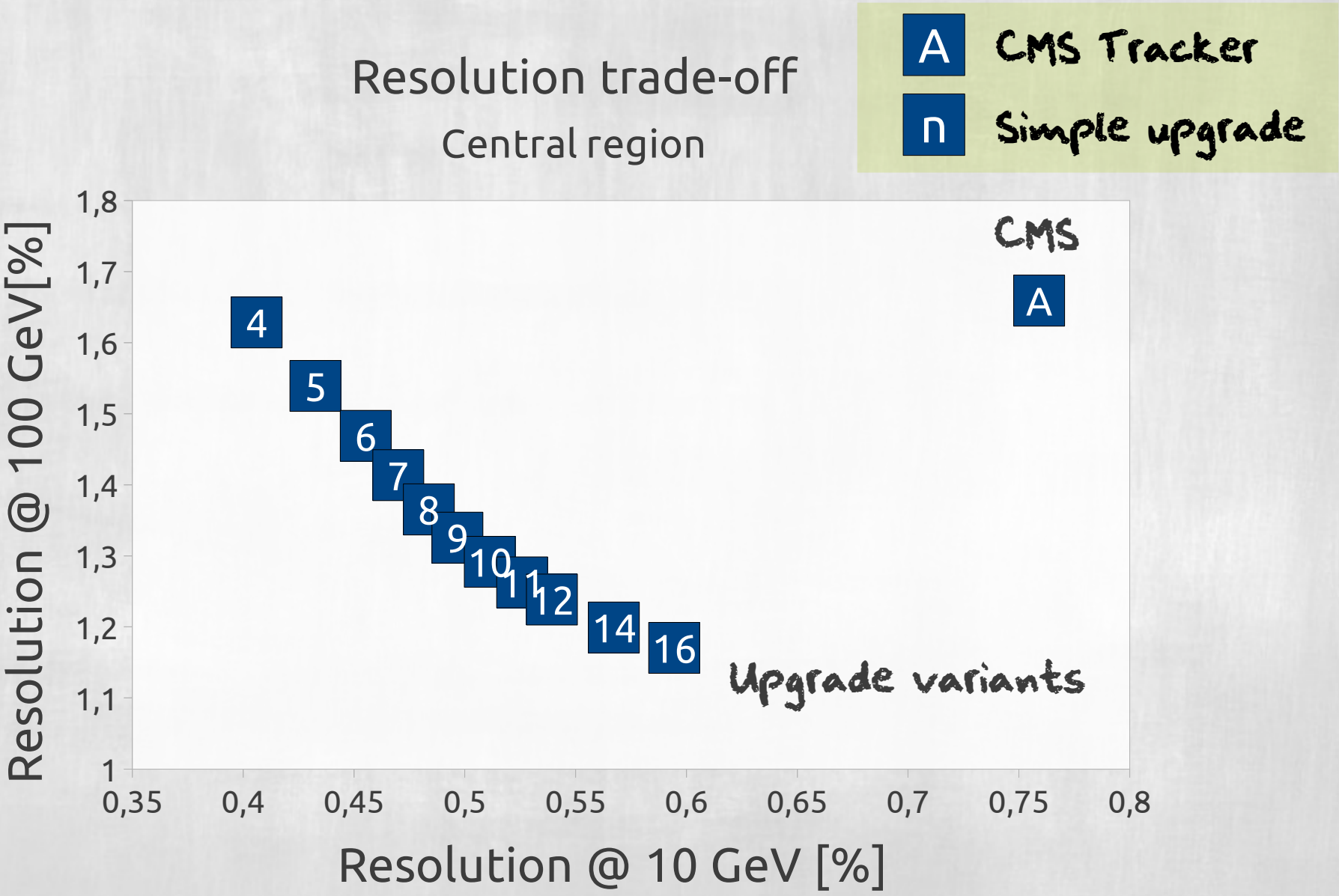
Let's measure Δ(p10) and Δ(p100)
in the central region on a series of barrels

4 barrel layers → 16 barrel layers





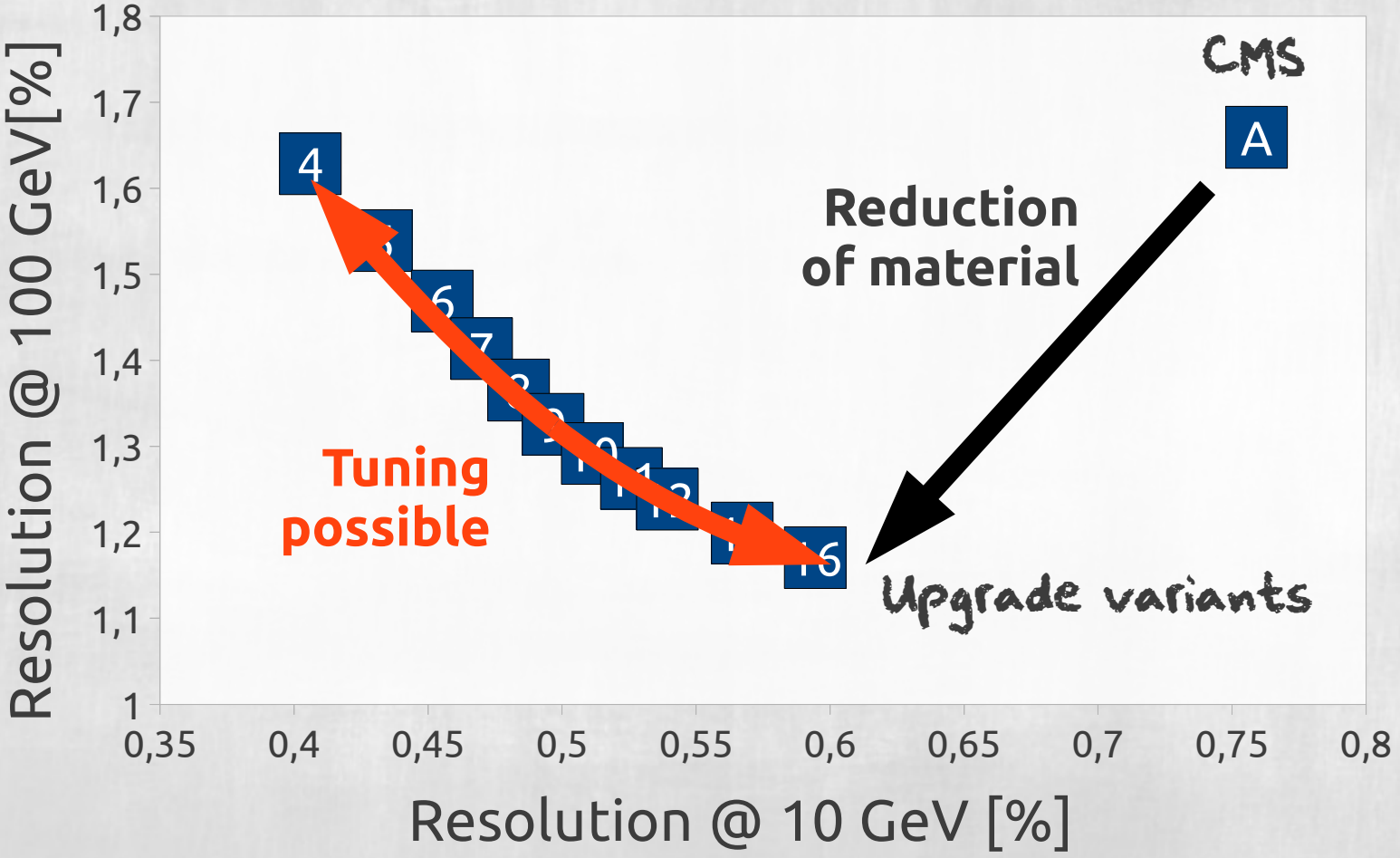
Trade-off in number of layers



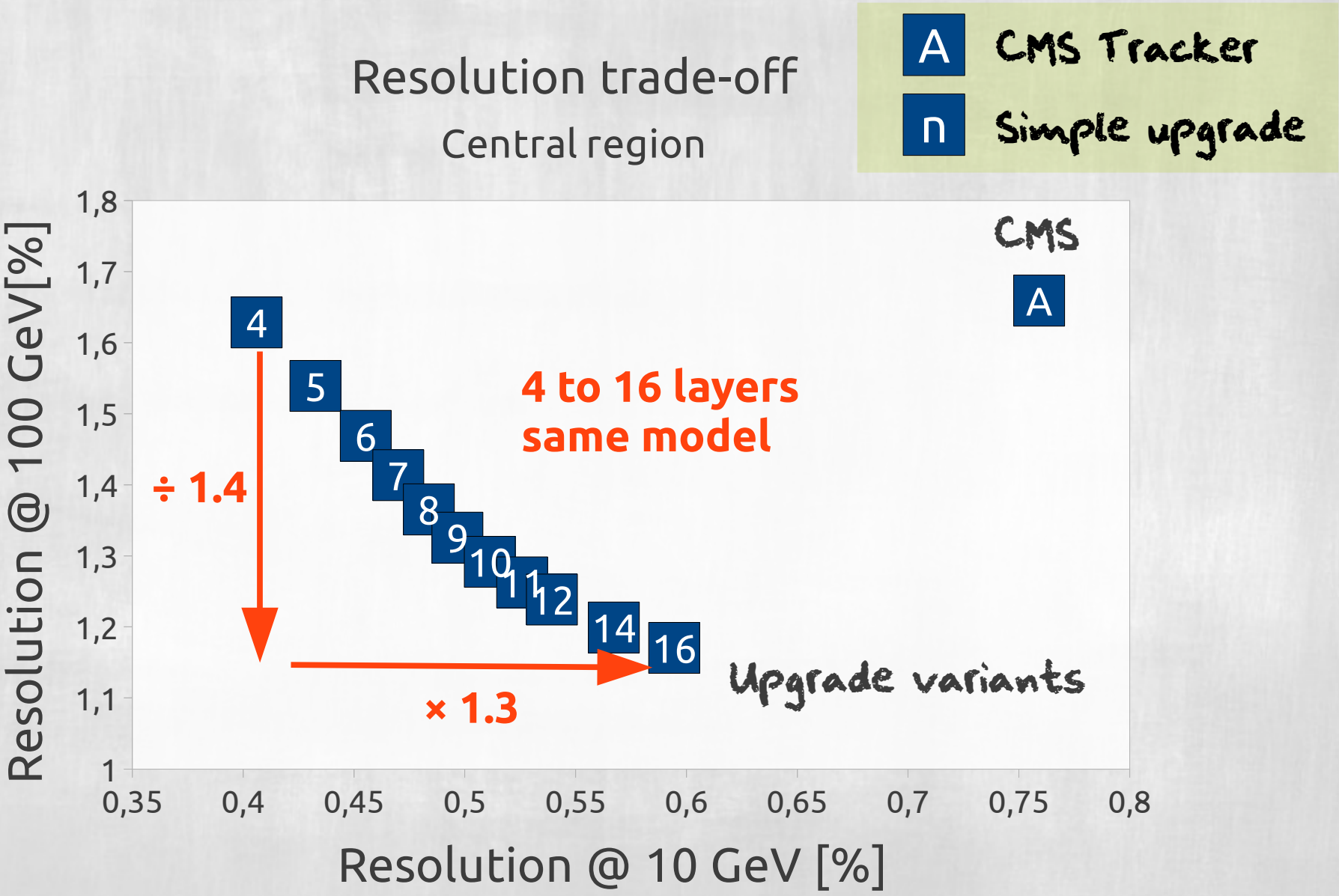
Trade-off in number of layers

A CMS Tracker

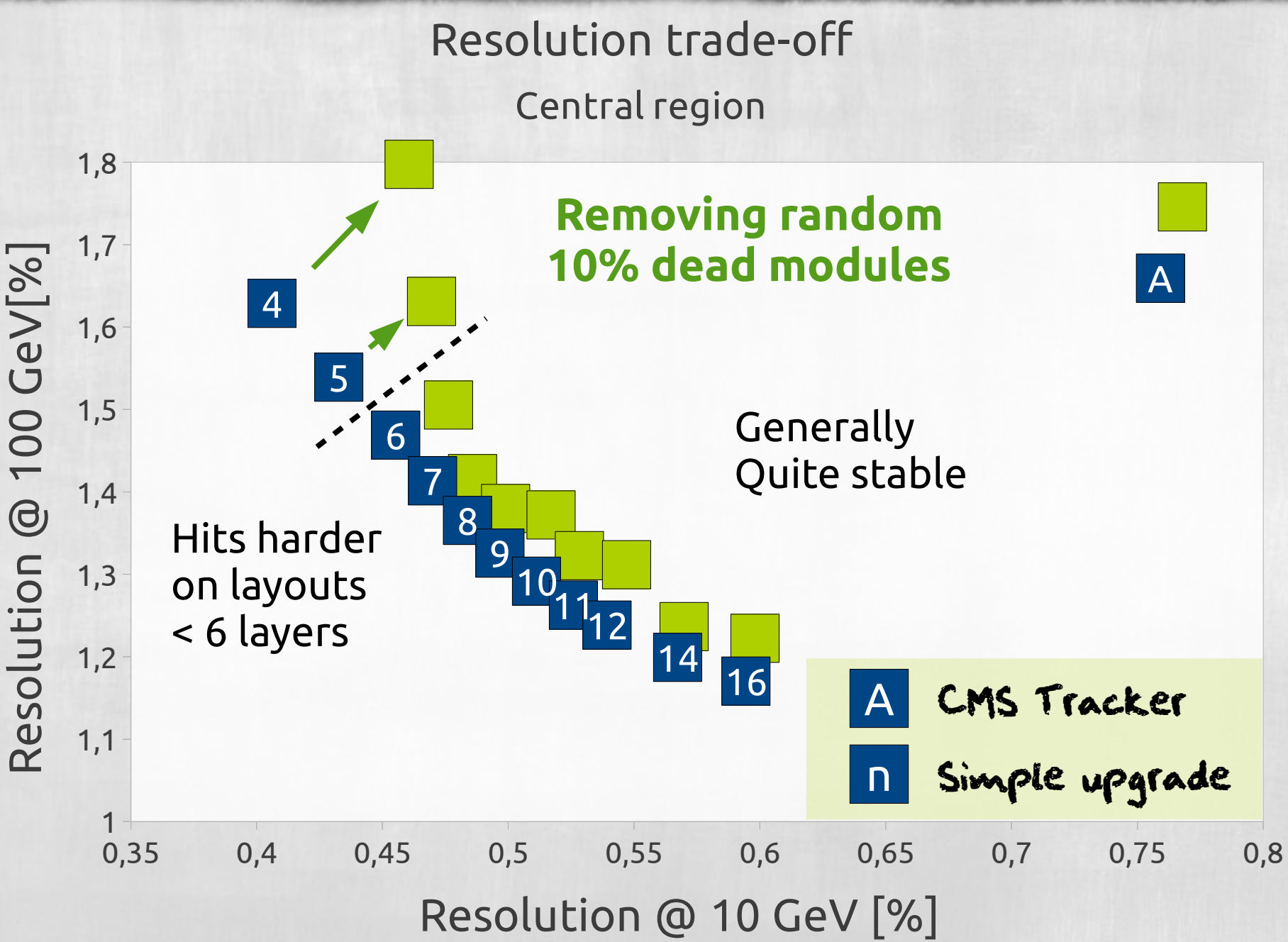
n Simple upgrade



Trade-off in number of layers



Trade-off in number of layers

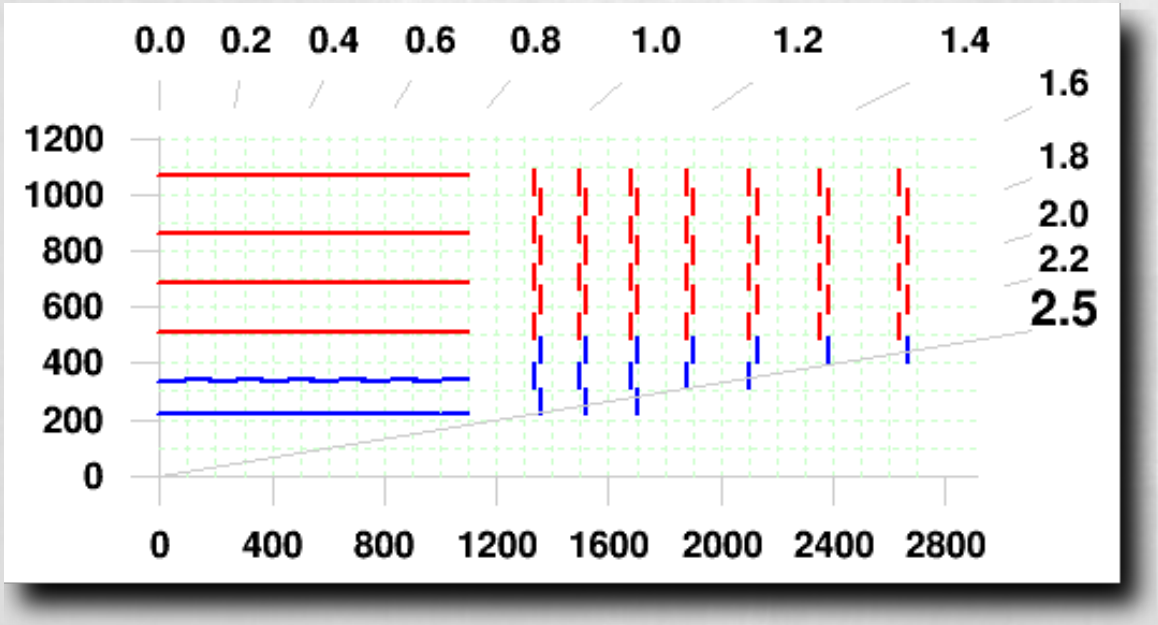


Strip pitch optimization

Prejudice: (Originated from current tracker)

The resolution would improve if we reduce the number of channels (material dominates)

Is this true?



Simple test

90 µm pitch

↓

120 µm pitch

Strip pitch optimization

η

C 0 → 0.8

I 0.8 → 1.6

A	CMS Tracker
B	Simple upgrade
90/120	Trigger

~~What is tkLayout?~~

~~Evaluation of tracking performance~~

~~Validation on a full simulation~~

~~Layout comparison~~

~~Layout optimization~~

Conclusions

tkLayout

is **totally generic**

CMS
ATLAS
ILC
...

fast running **simple** and **usable** tool

needs **well understood** model of **materials** to give a **solid output**

quantification of **performance**

fair comparison between models

no dependence on algorithm tuning

drive the **selection** of a small number of **optimized options** for study with full simulation

and...

...it's **free**

http://code.google.com/p/tkgeometry

THANK YOU