recent layout studies with *tkLayout*

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FNAL Workshop on CMS upgrade 2011

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- What is tkLayout
- Models studied
- Layout comparison
  - Properties
  - Tracking
  - Tracking trigger potential
- New feature
- Conclusions

tkLayout

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

assigns **material** to the volumes

can be used to **optimize a layout**

creates xml files for **CMSSW geometry**

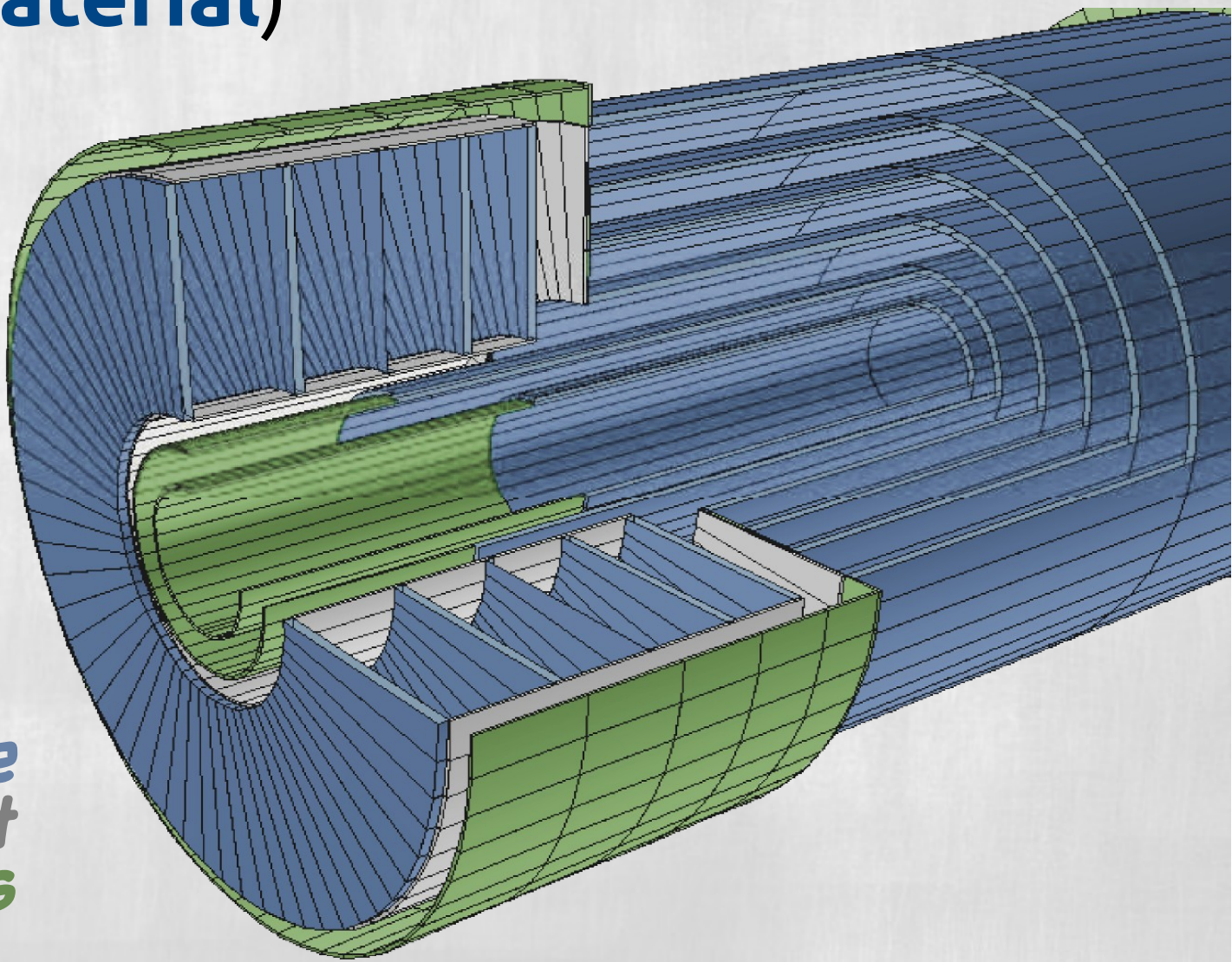
places **modules** in 3D space

makes an estimate of **tracking performance**

or to make a **quantitative comparison** between layouts

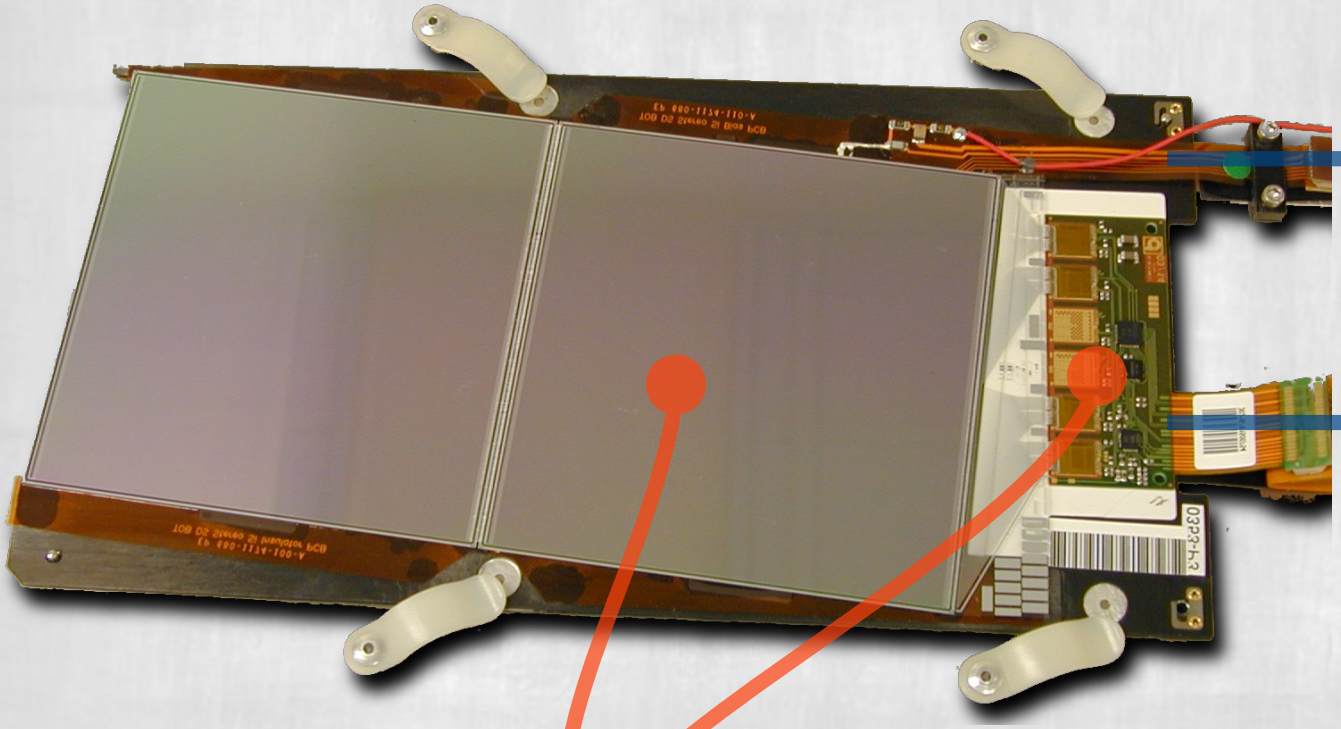
Developed by Nicoletta De Maio, Stefano Mersi

creates a 3D model of the layout (with **material**)



active
support
services

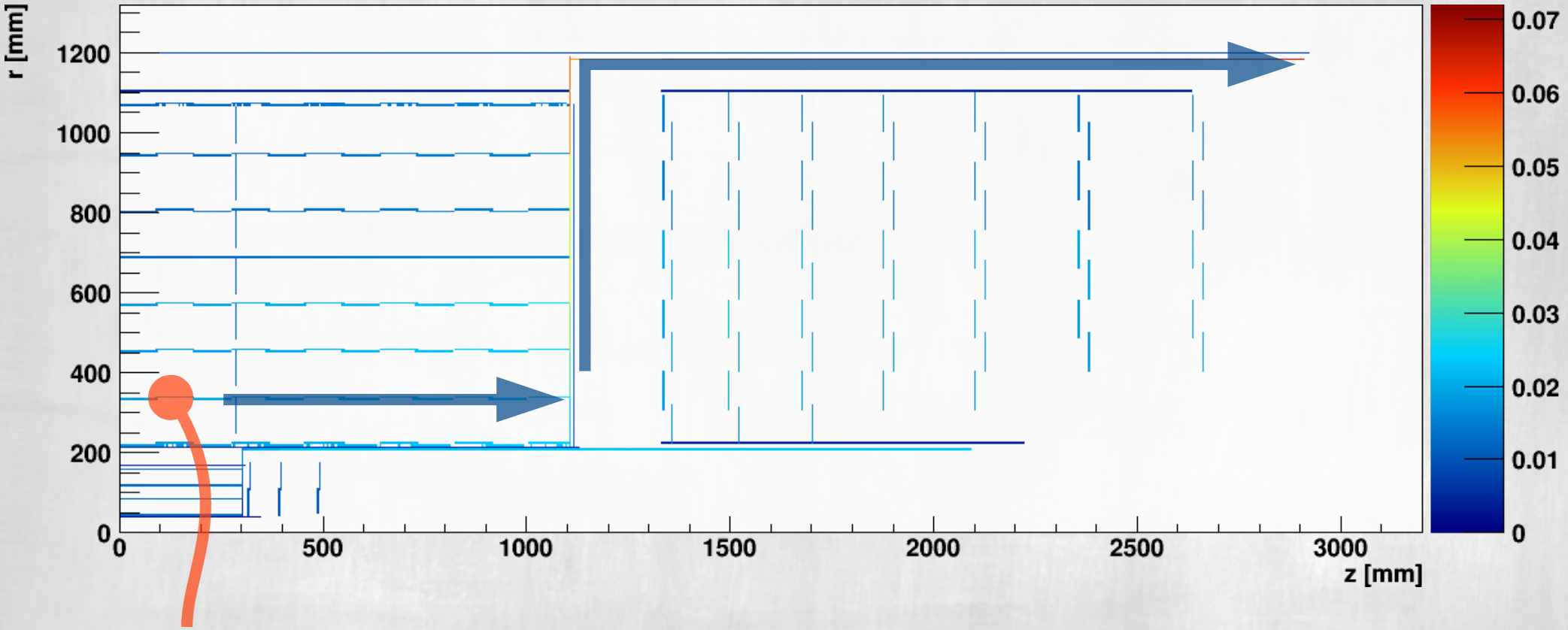
tkLayout material



services
cooling pipes
optical fibres
twisted pairs

on the module

tkLayout material



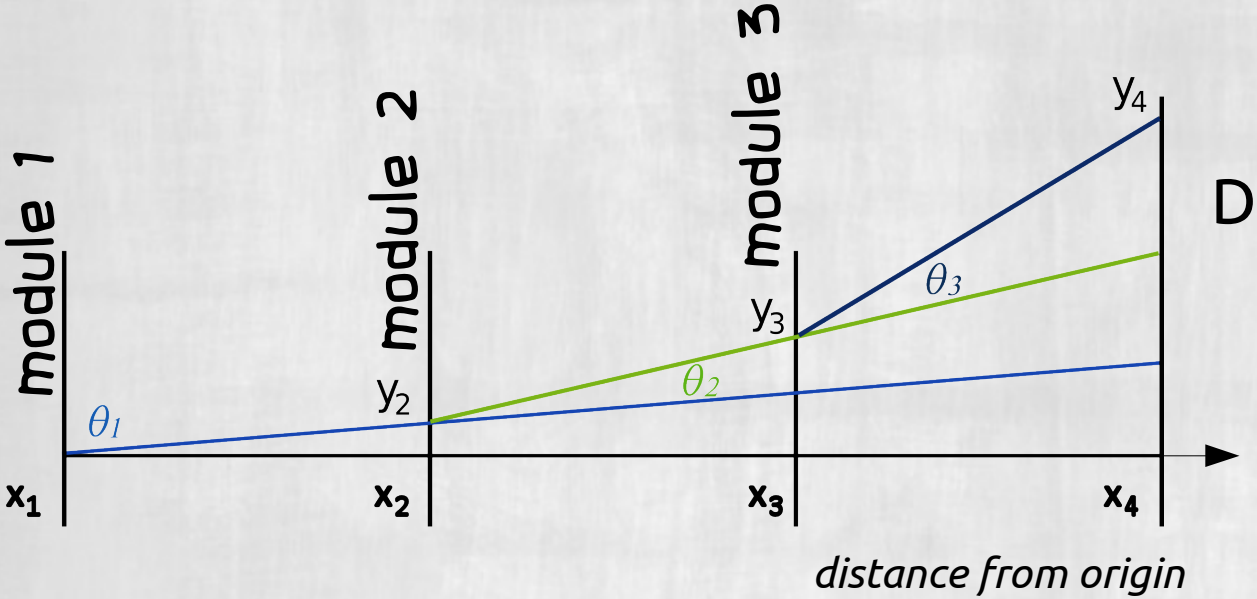
Material on active elements + Material for services automatically routed

Performance estimate

- **A priori error estimation**
  - **No Monte Carlo**
  - **No fit actually done**

- Ingredients:
  - Error propagation
  - **Sensor resolution** (measurement error)
  - **Multiple scattering** (treated as a correlated a measurement error)

Performance estimate



Deviation due to scattering:

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

Covariance matrix of the measured hit coordinates:

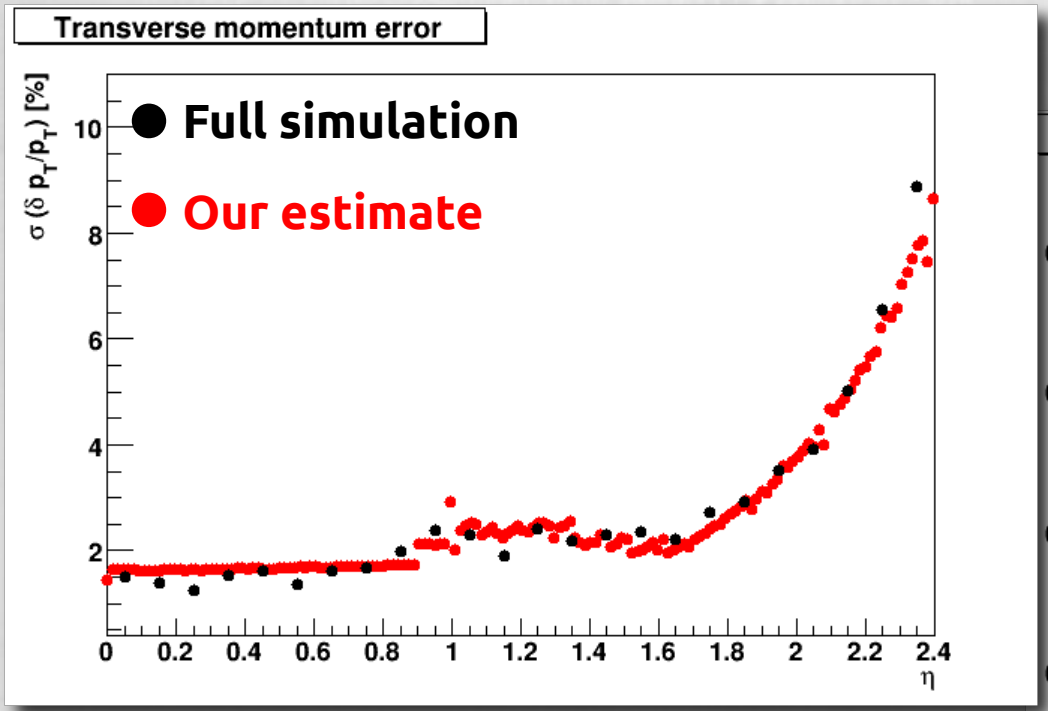
$$\sigma_n^2 = \frac{p^2}{12}$$

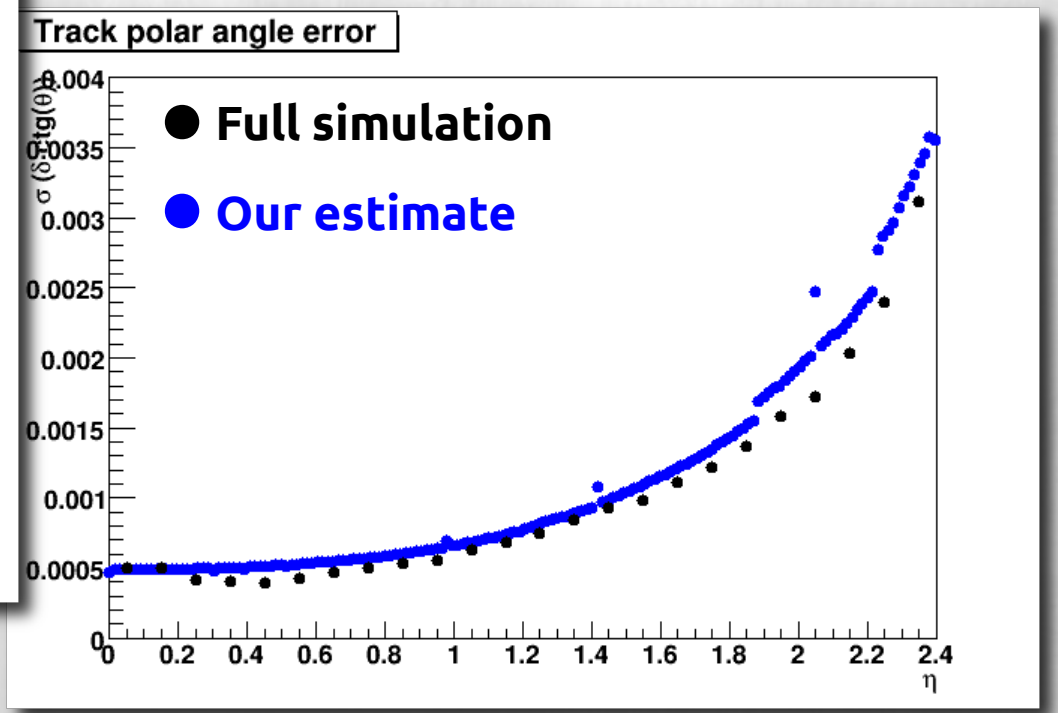
$$\sigma_{n,m} = \langle y_n y_m \rangle = \sum_{i=1}^{n-1} (x_m - x_i)\,(x_n - x_i)\,\langle \theta_i^2 \rangle$$

Method validated against the full CMSSW simulation

Performance estimate

this method was validated
modelling current CMS tracker
& comparing with full simulation





~~What is tkLayout~~

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The study performed

- To have a **quantitative estimation** of the impact of layout strategies on the detector performance
  - Traditional layout (Barrel + Endcap)
  - Long-barrel layout
  - Stacked layers
- Use a **consistent set of assumption**:
  - Material
  - Detector properties
  - Estimation method
- Modules used: Strip (2S) and Pixel+Strip (PS)
  - PS detectors was chosen because we have a reasonably detailed idea on **how to integrate** them in the system
  - Modules are quite “light”, so that the study is **not biased** (too much) **by the material** in PS layers
- All the layouts produced are reasonably lighter than the current one (in the central region)

~~What is tkLayout~~

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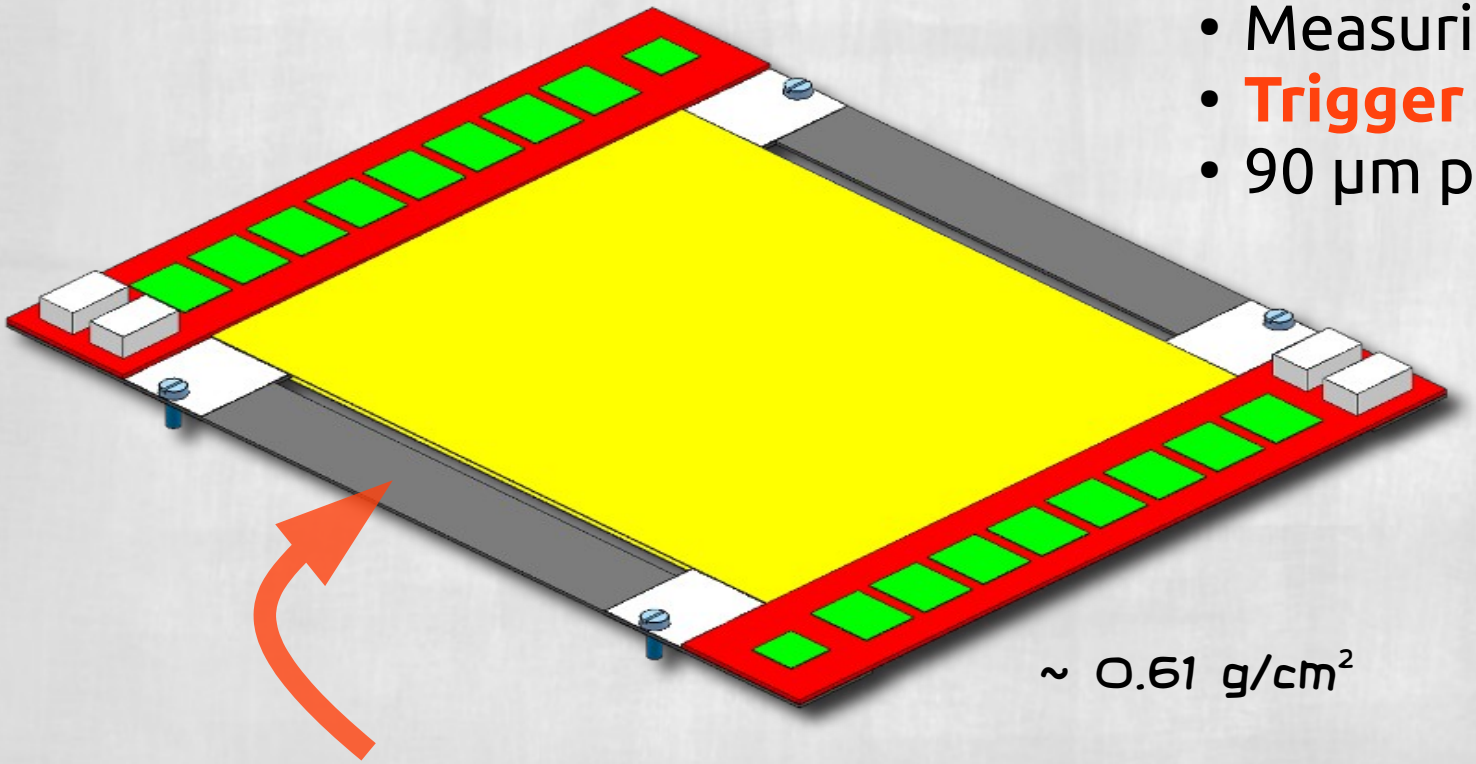
2 Strip pT module

2S: 2 paired strip sensors

- Works well in the outer part

- Sandwich of **strip sensors**
- 5 cm long strips
- Measuring pT locally
- **Trigger output**
- 90 μm pitch



~ 0.61 g/cm^2

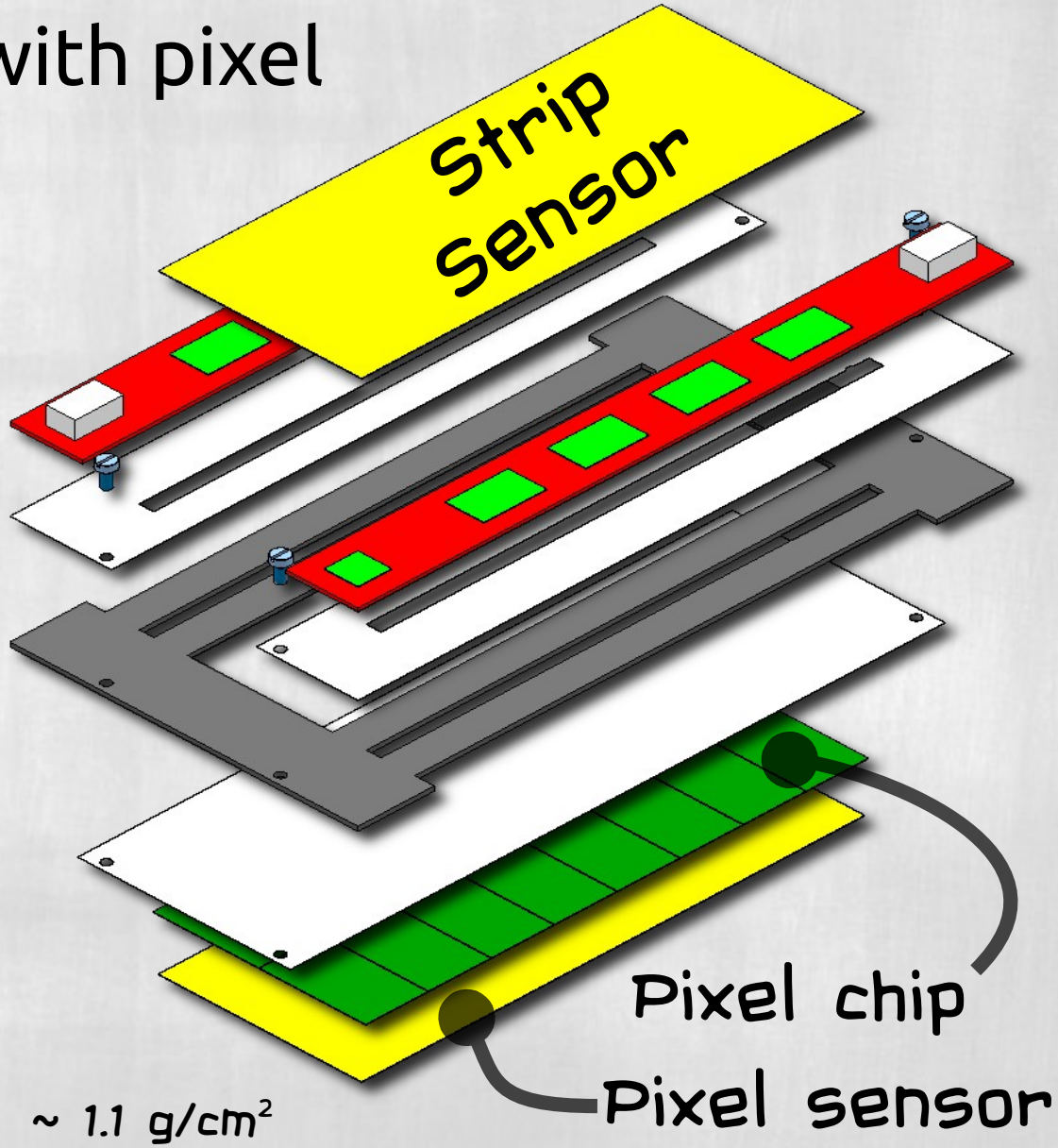
GBT + DC/DC for each module

Reasonably detailed model of material

Pixel + Strip pT module

PS: Strip sensor paired with pixel

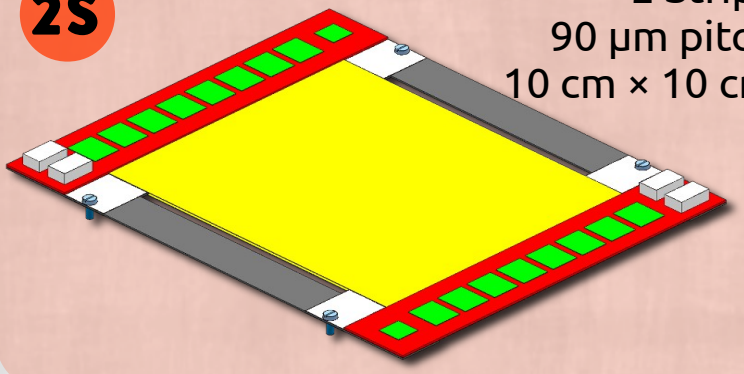
- Can work in the inner part
- Provides z information in the trigger
- Simple interconnection technology
- Relatively lower power & mass
- Tunable sensors spacing
- 100 μm pitch
- Less than 10 cm × 5 cm



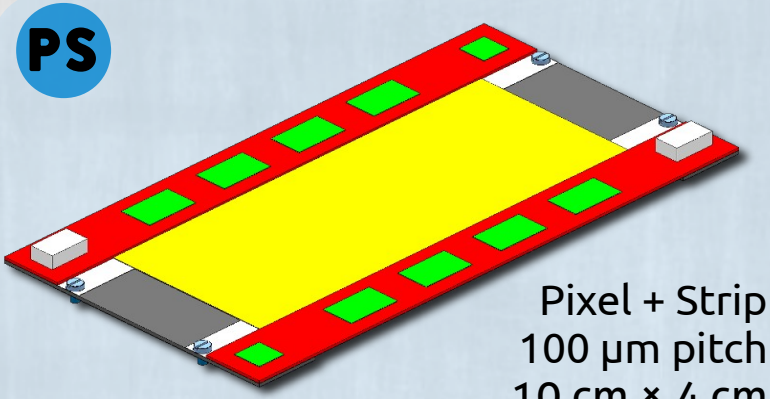
Barrel + End-cap layout

2S

2 Strips
90 µm pitch
10 cm × 10 cm



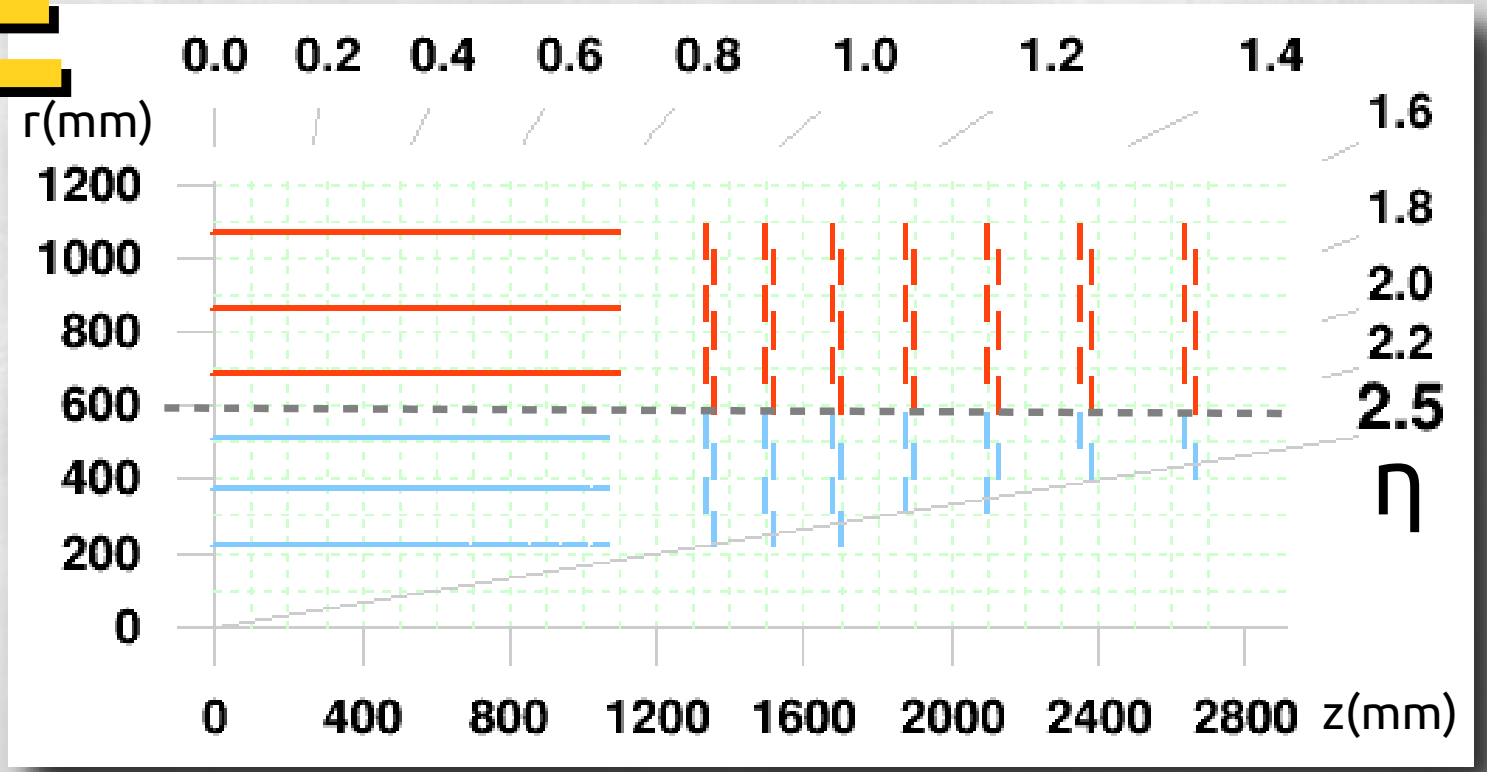
PS



Pixel + Strip
100 µm pitch
10 cm × 4 cm

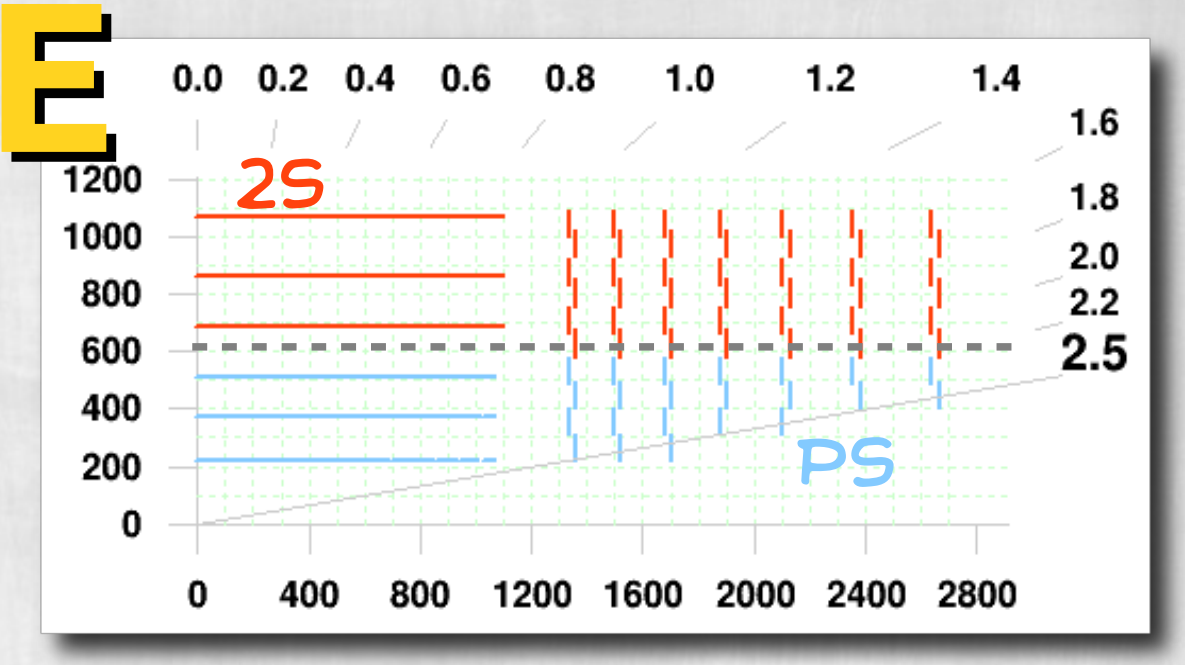
Lower density
2S modules
outside

z info in trigger
θ info in trigger
PS modules inside



Barrel + End-cap layout

A traditional barrel + **endcap** geometry used as reference in this study

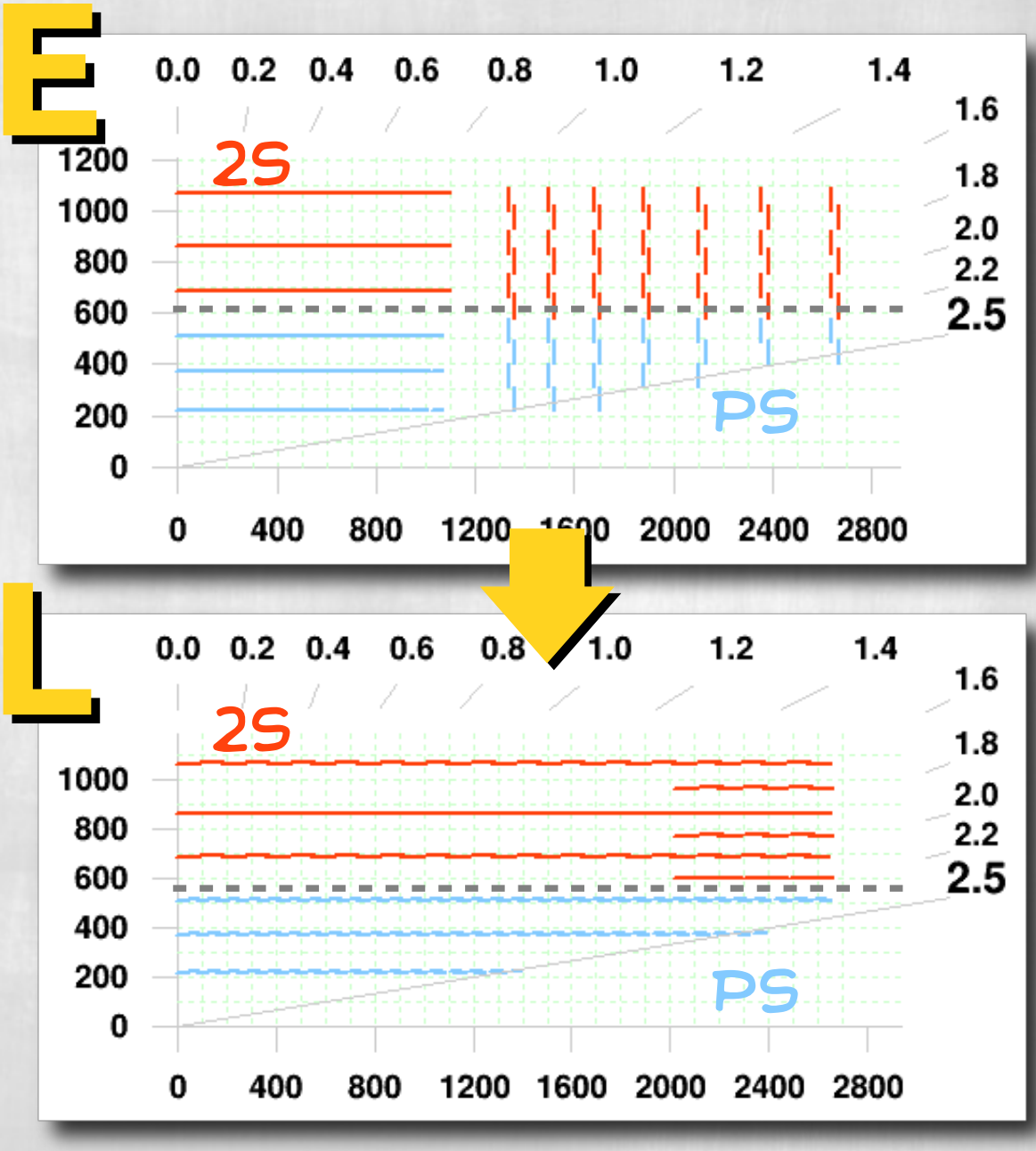


Long barrel layout

A **long barrel** example obtained extending the barrel into the end-cap region **with the same modules**

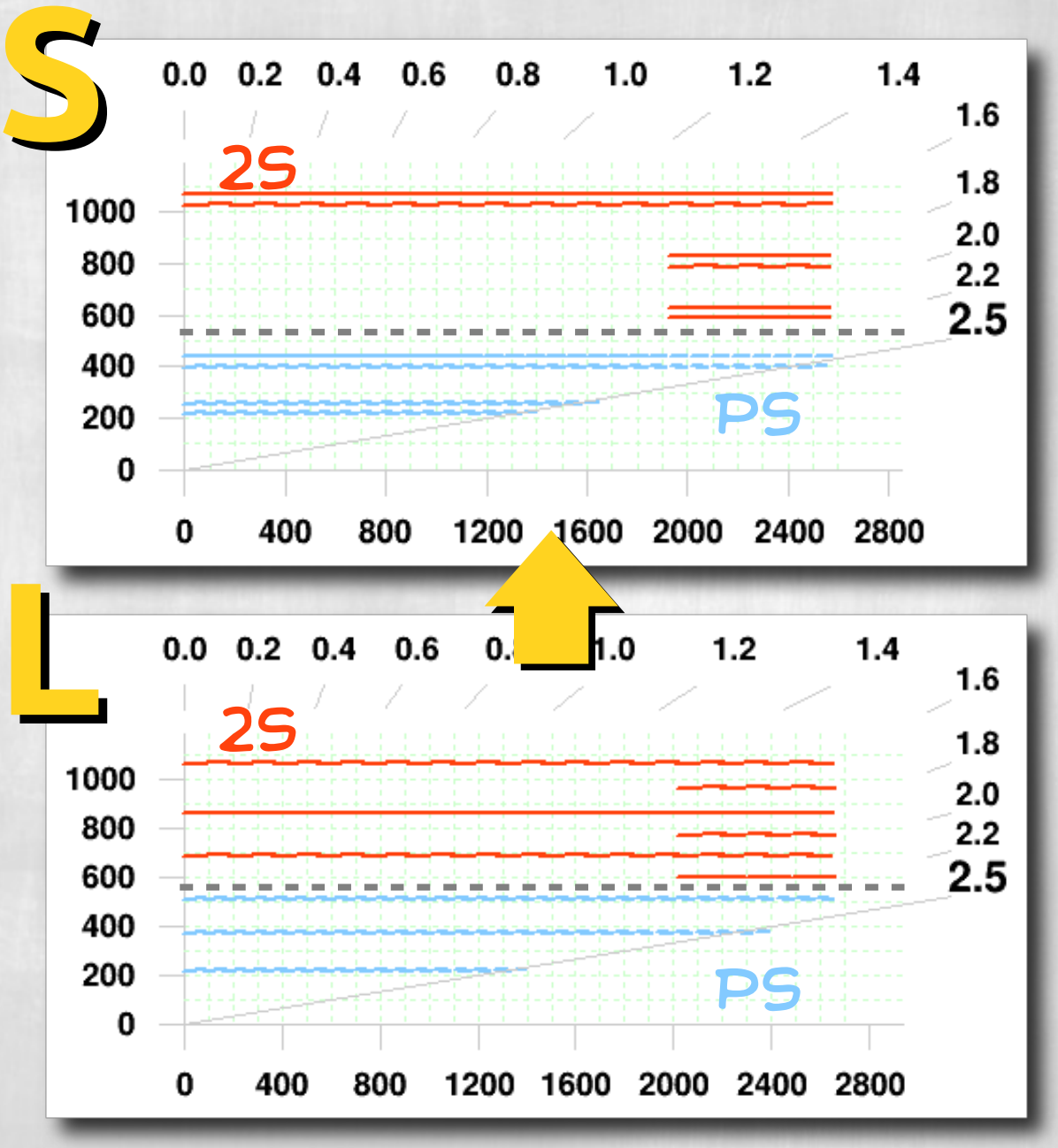
Same assumptions: no tuning of the material model

End-cap “hole” covered with mezzanine layers



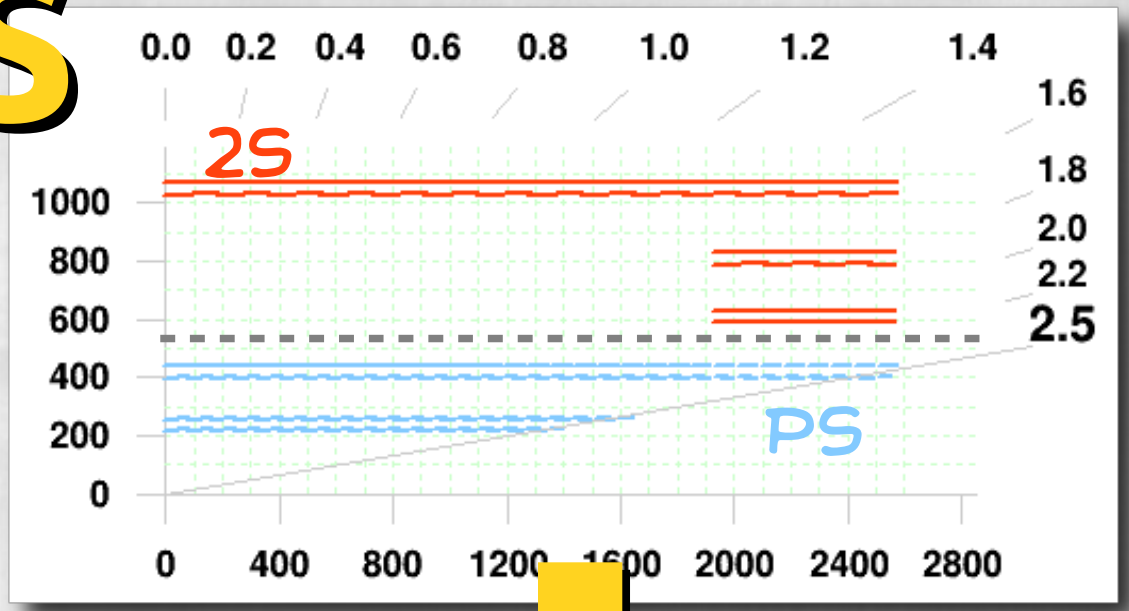
Stacked-layer layout

A **stacked** long barrel obtained again **with the same modules** and **material description**

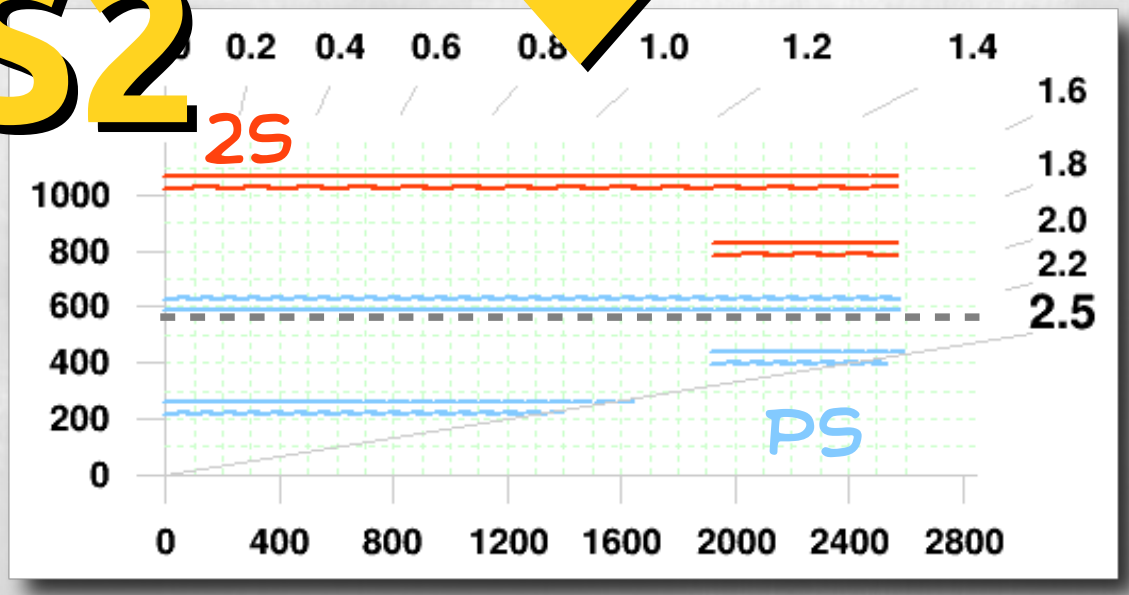


Stacked-layer layout (2)

S



S2



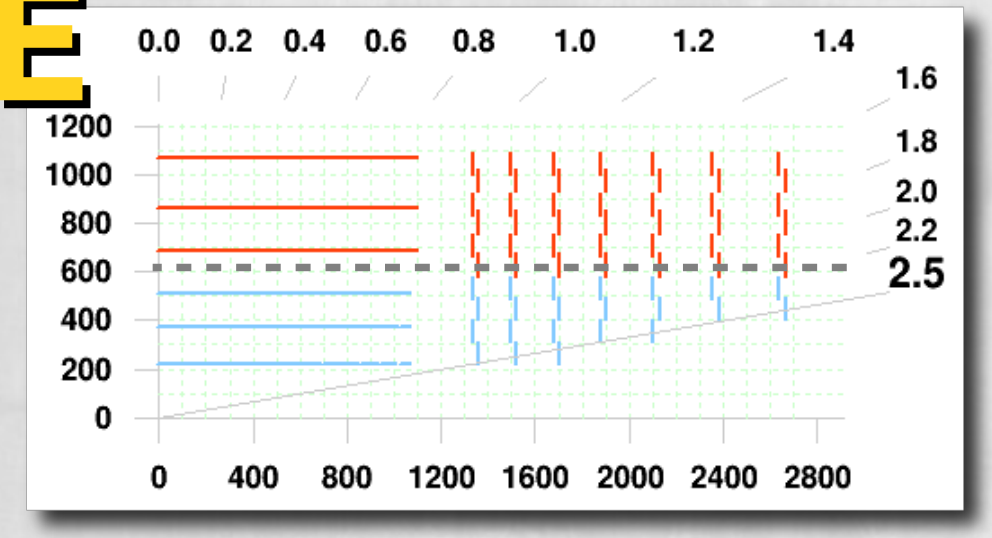
A variant of the **stacked** long barrel with a more balanced position of the second stack

Summary

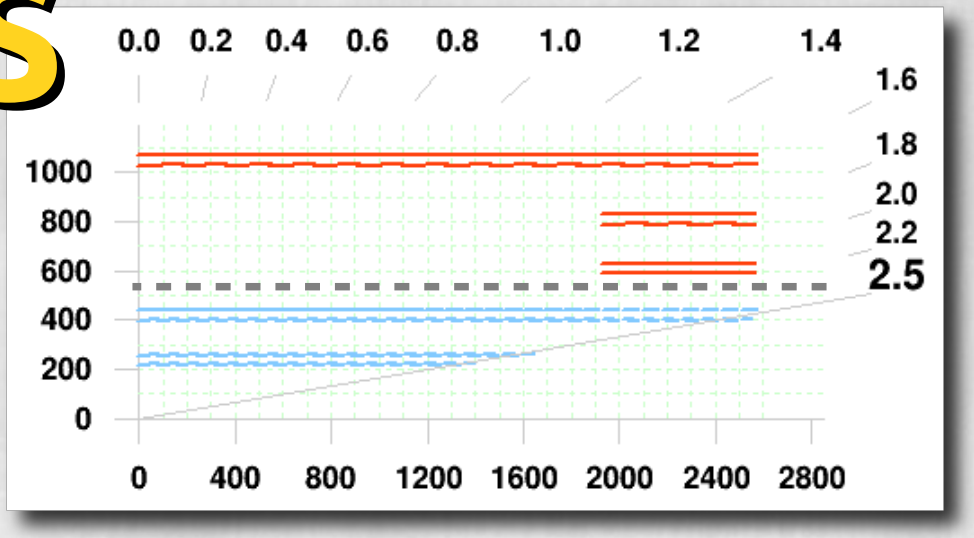
4 layouts with the **same approach** and **same modules**

2S outside
PS inside

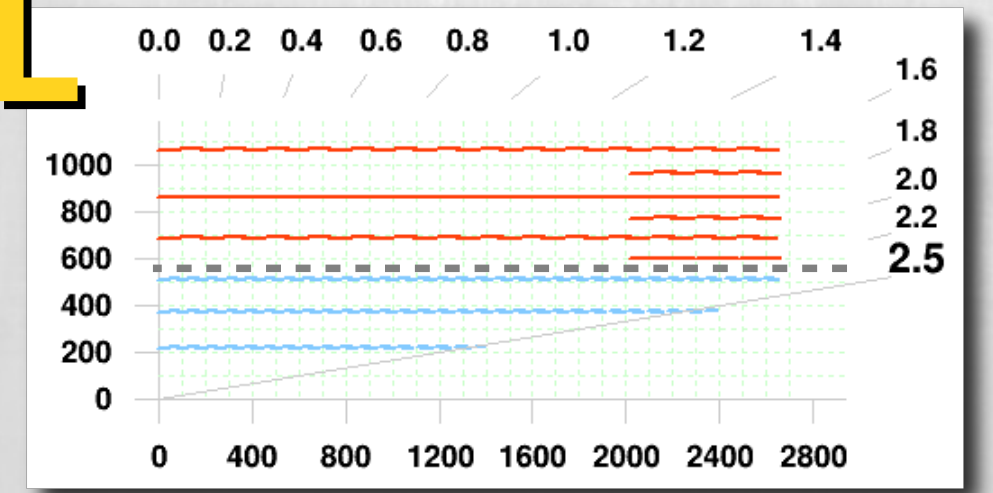
E



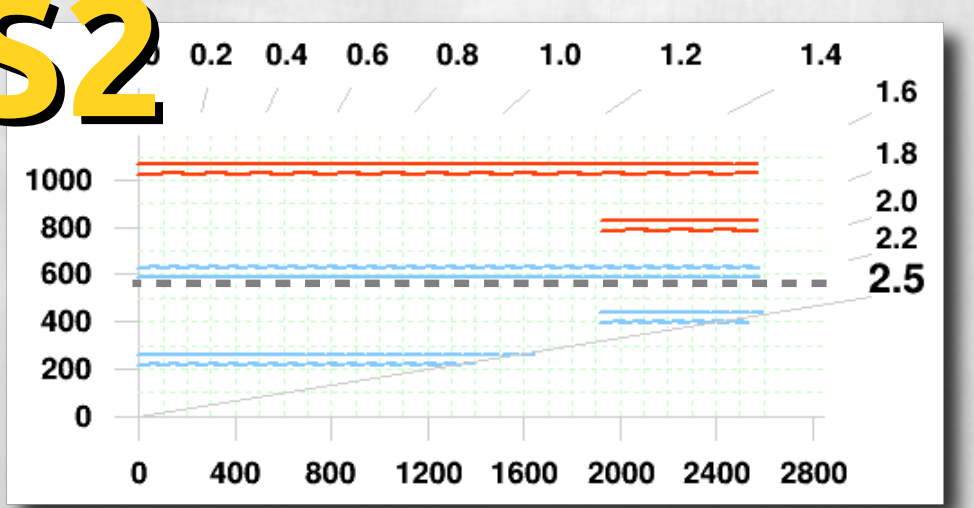
S



L



S2



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Layout comparison

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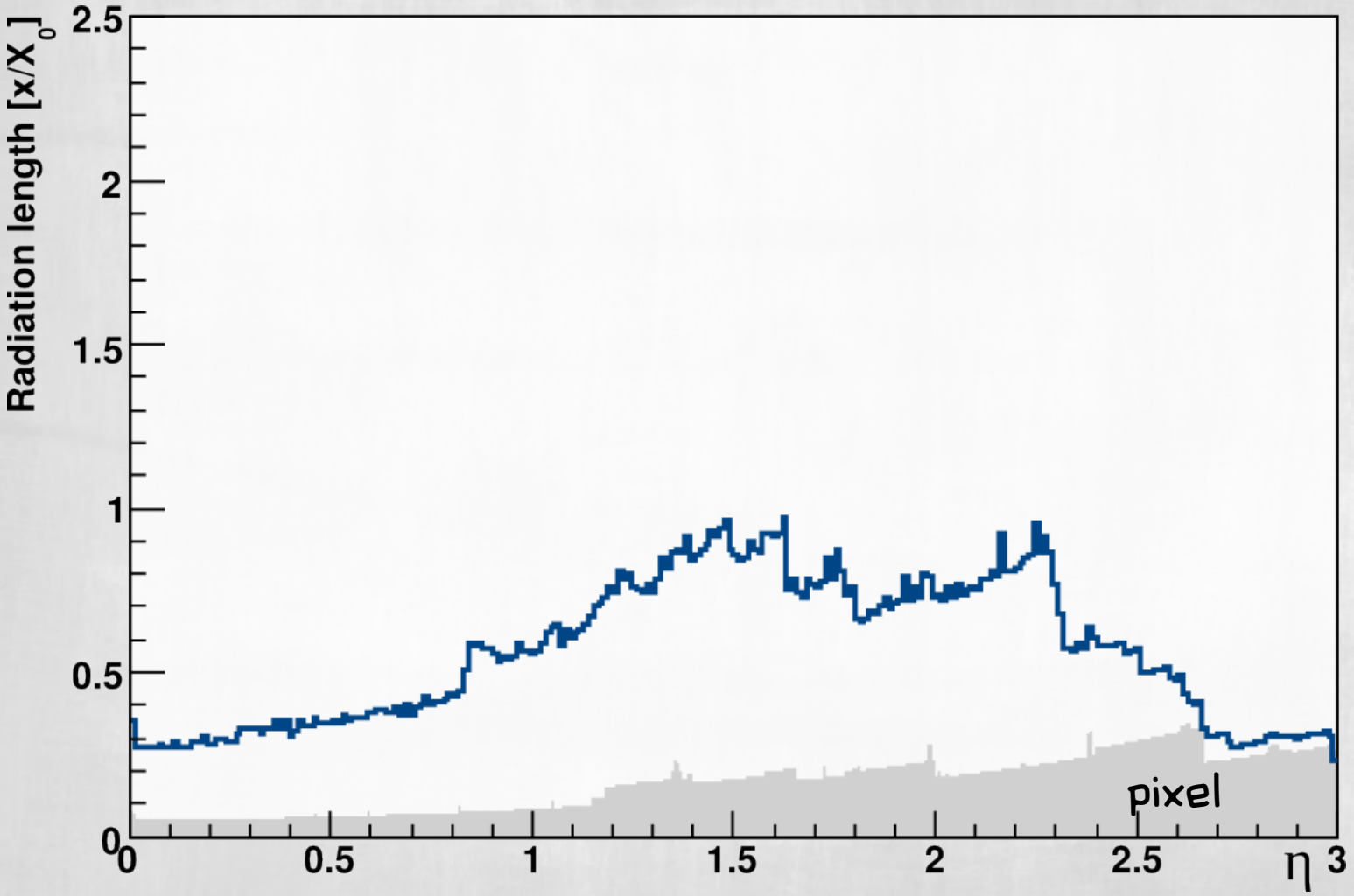
New feature

Conclusions

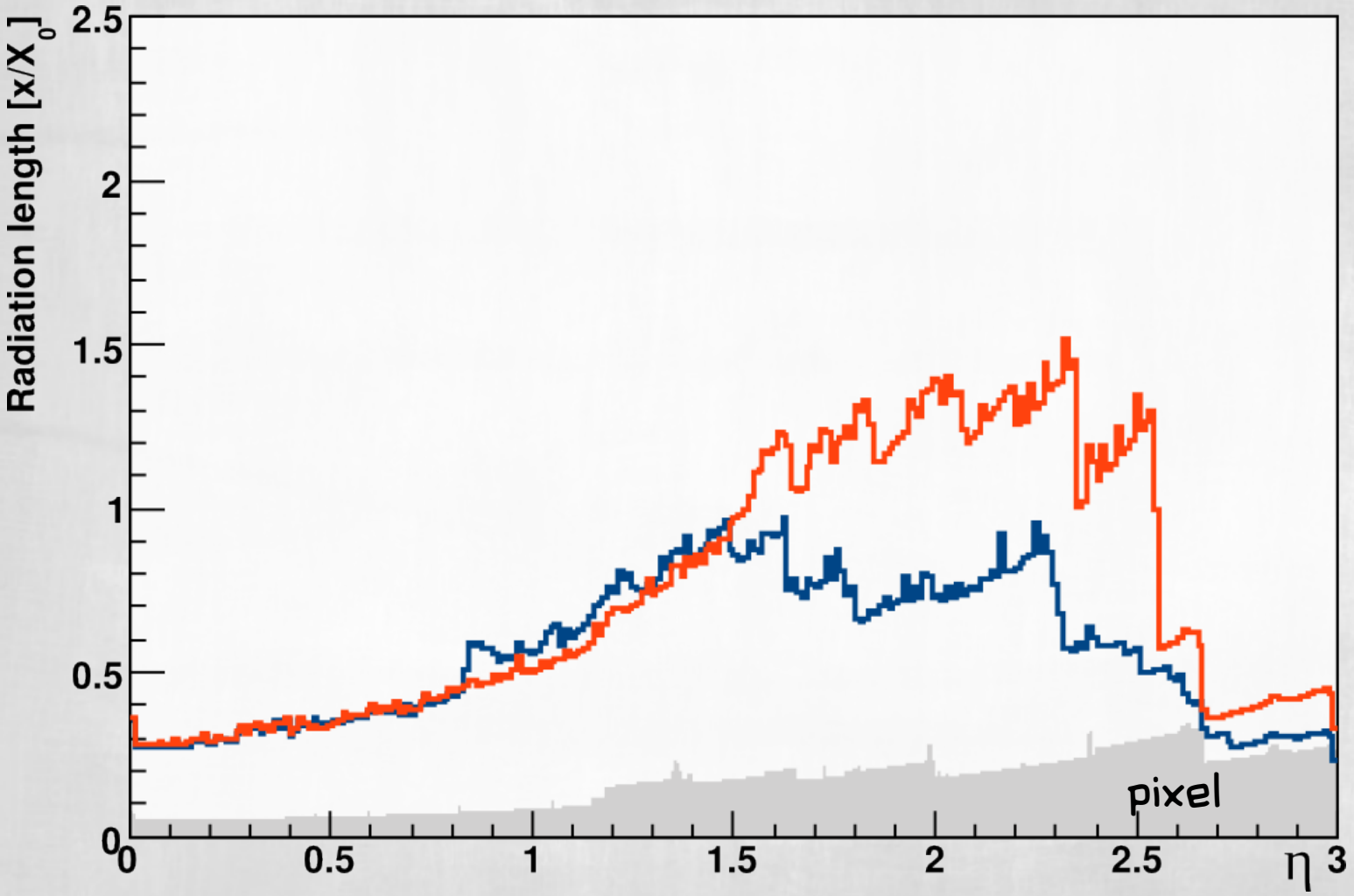
Material amount



E

pixel

Material amount

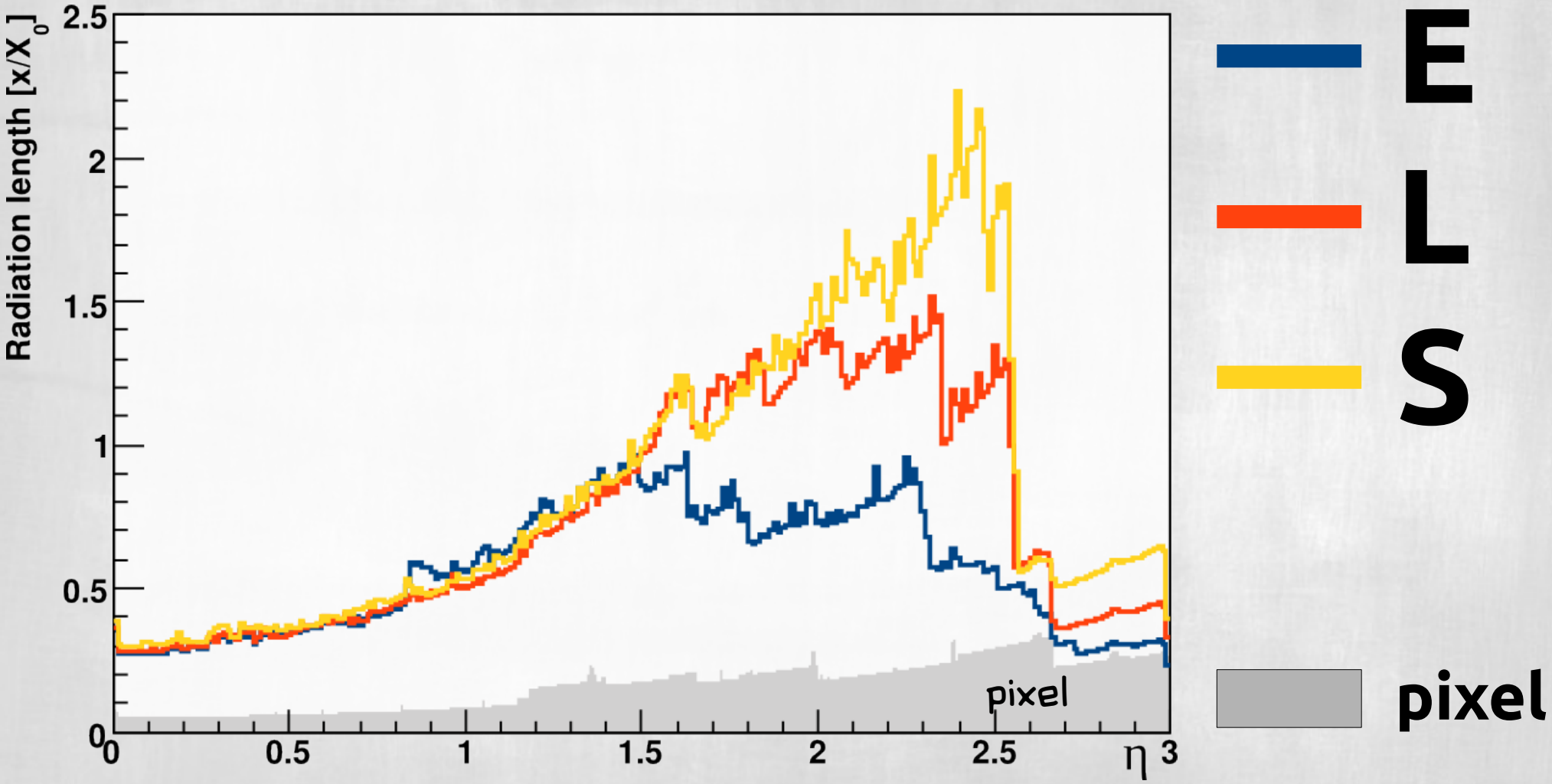


E

L

pixel

Material amount



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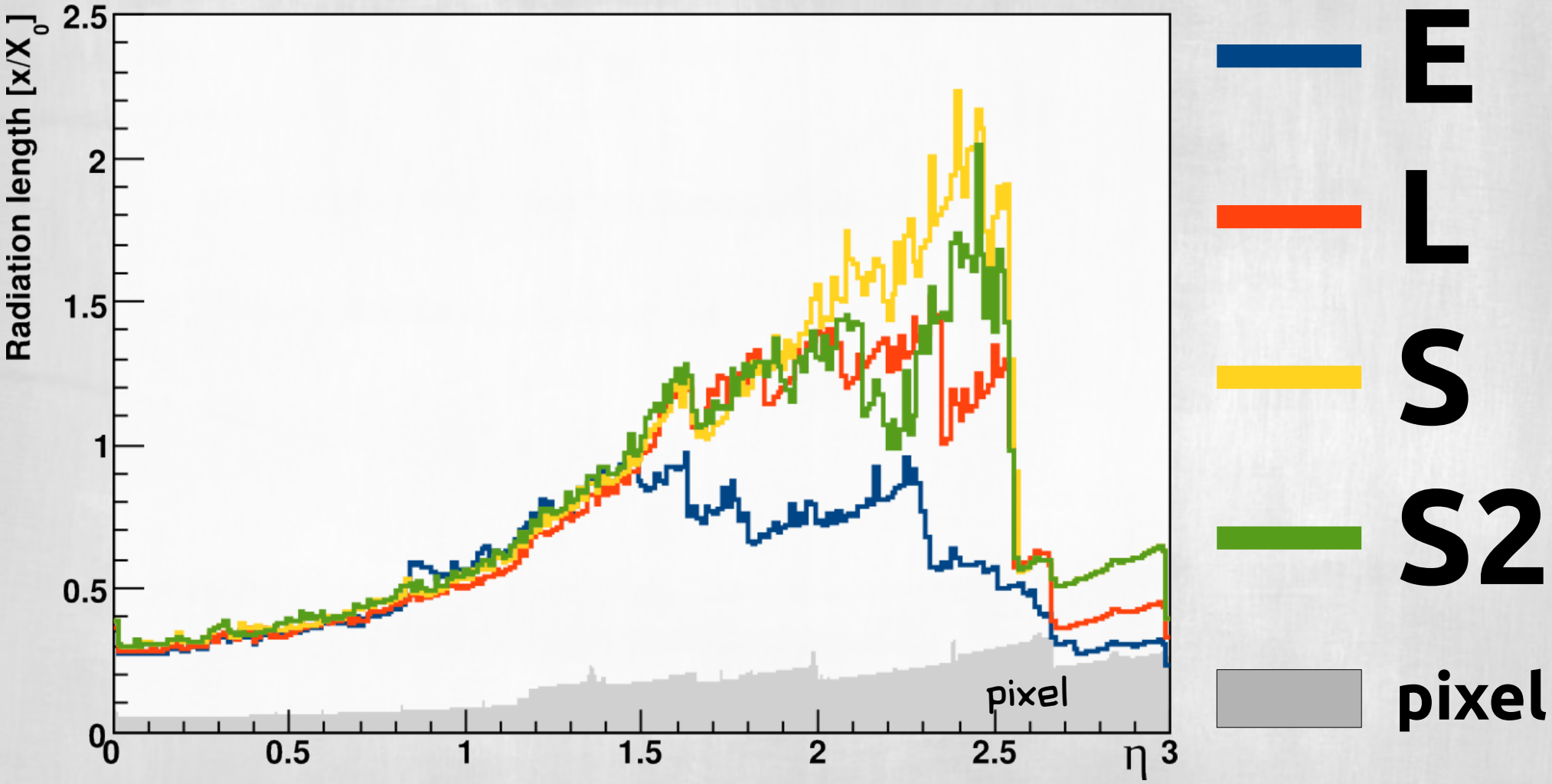
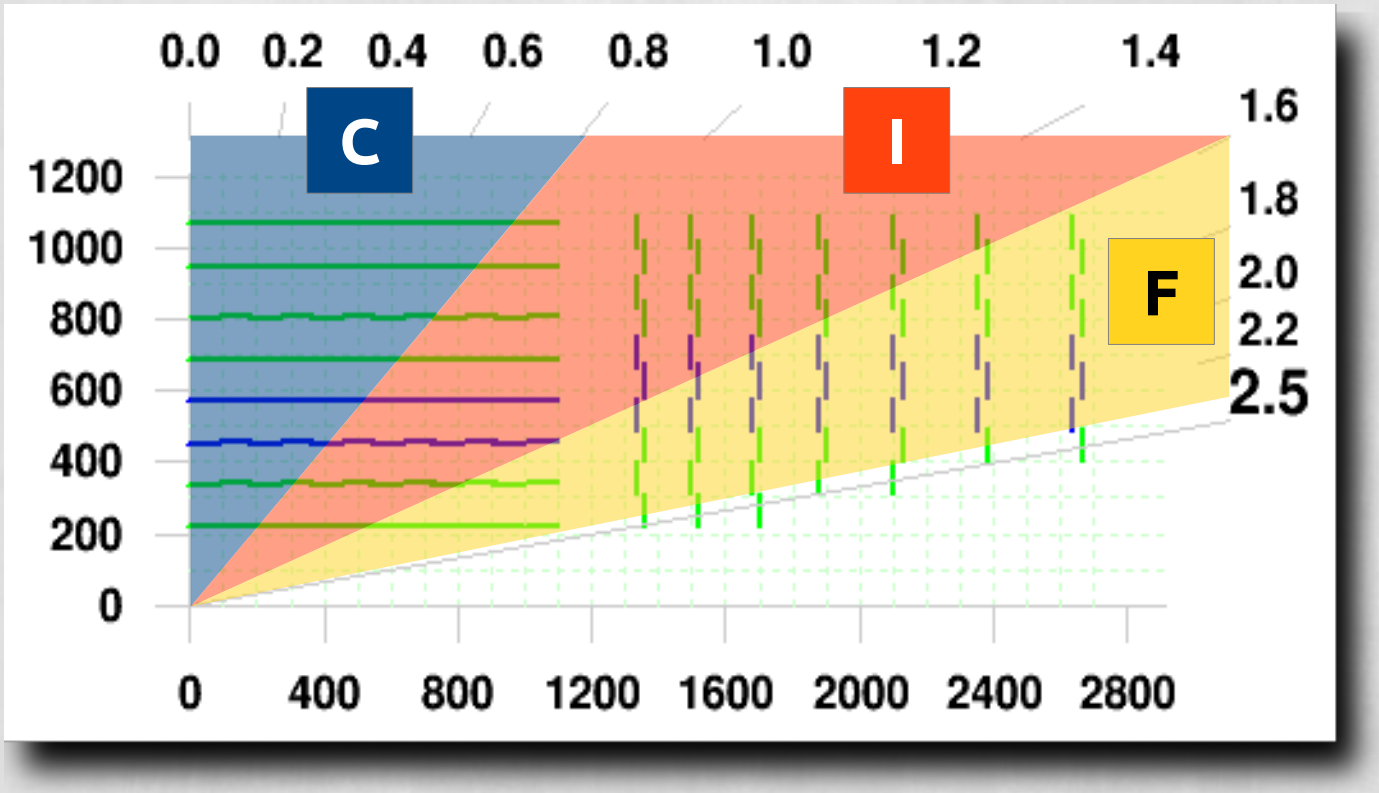


Region averaging



η

C	0 → 0.8
I	0.8 → 1.6
F	1.6 → 2.4

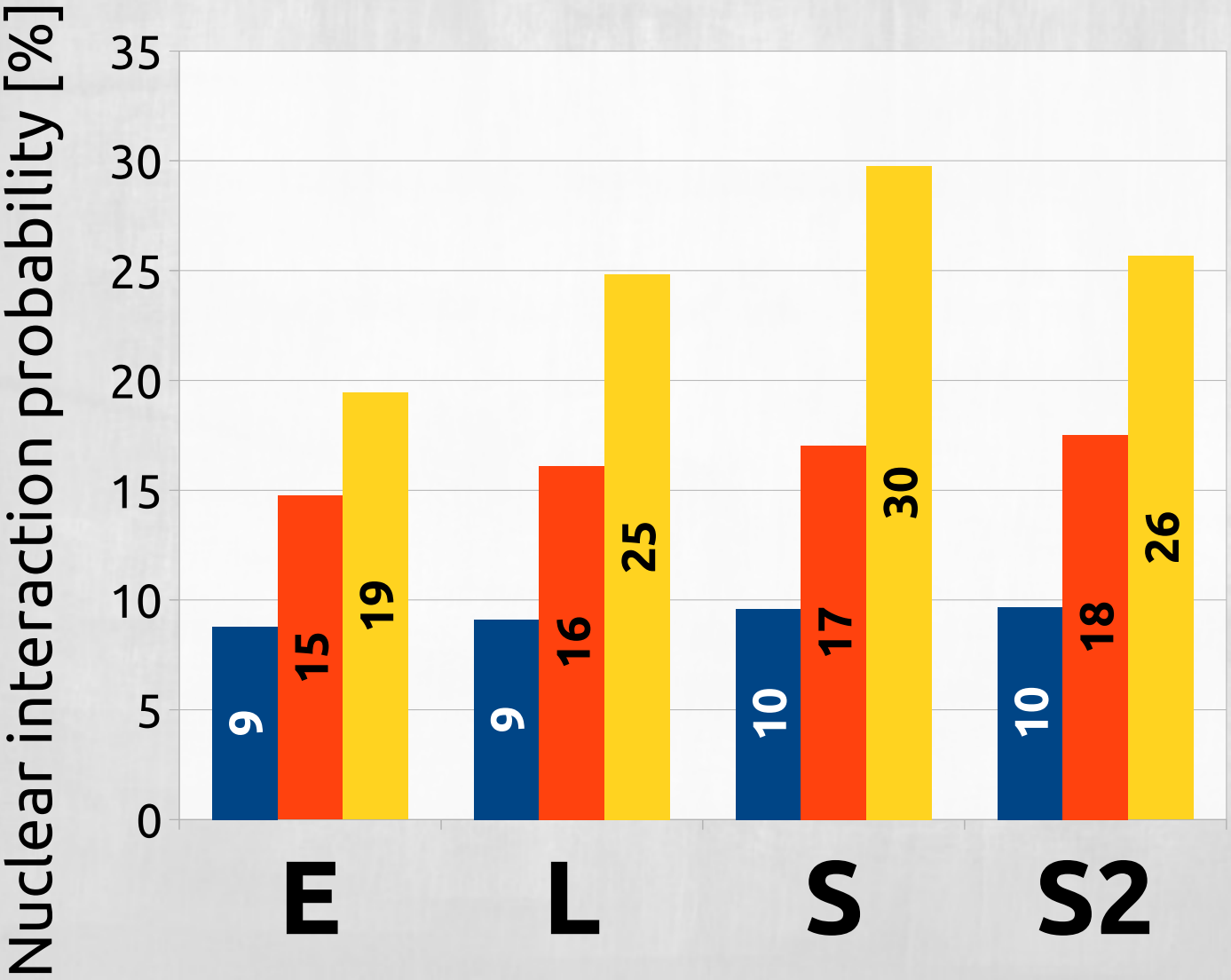
Δη= 0.8

Roughly same number of tracks expected

Δη= 0.7 for trigger used (0 → 2.1)

Material amount

Nuclear interactions



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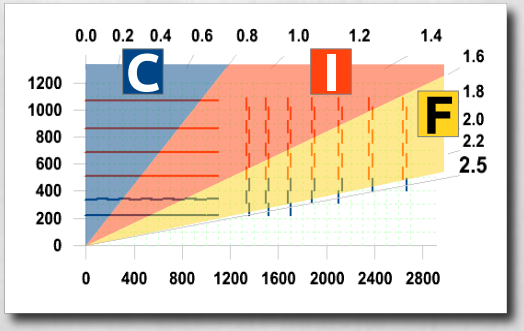
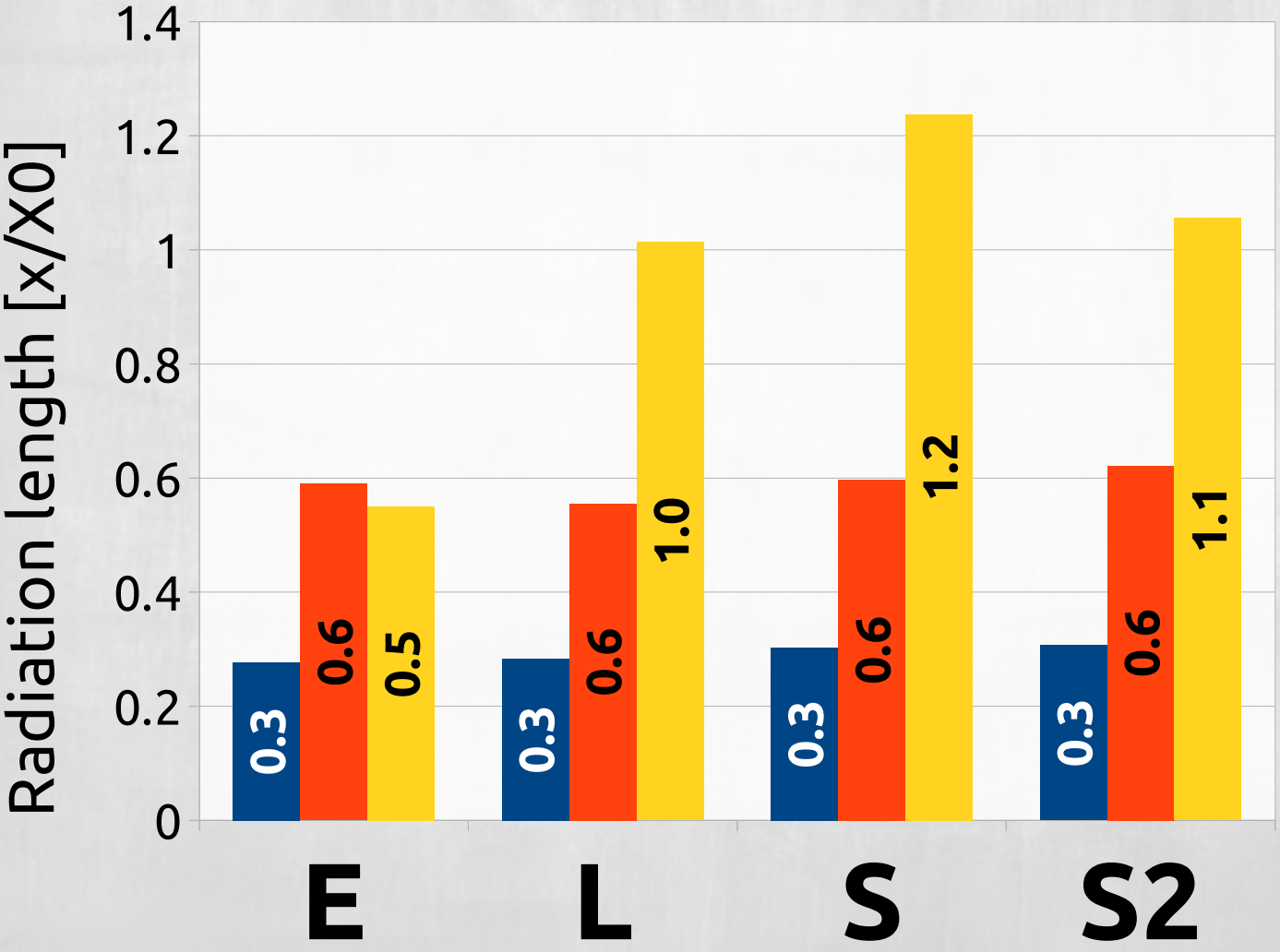


Material amount

Radiation length



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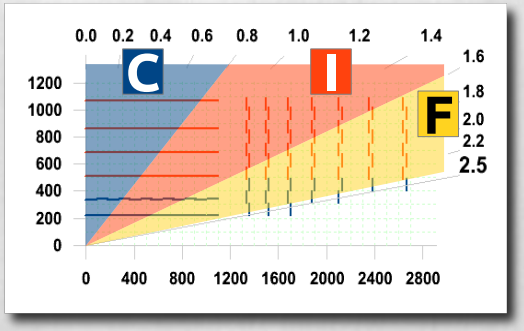

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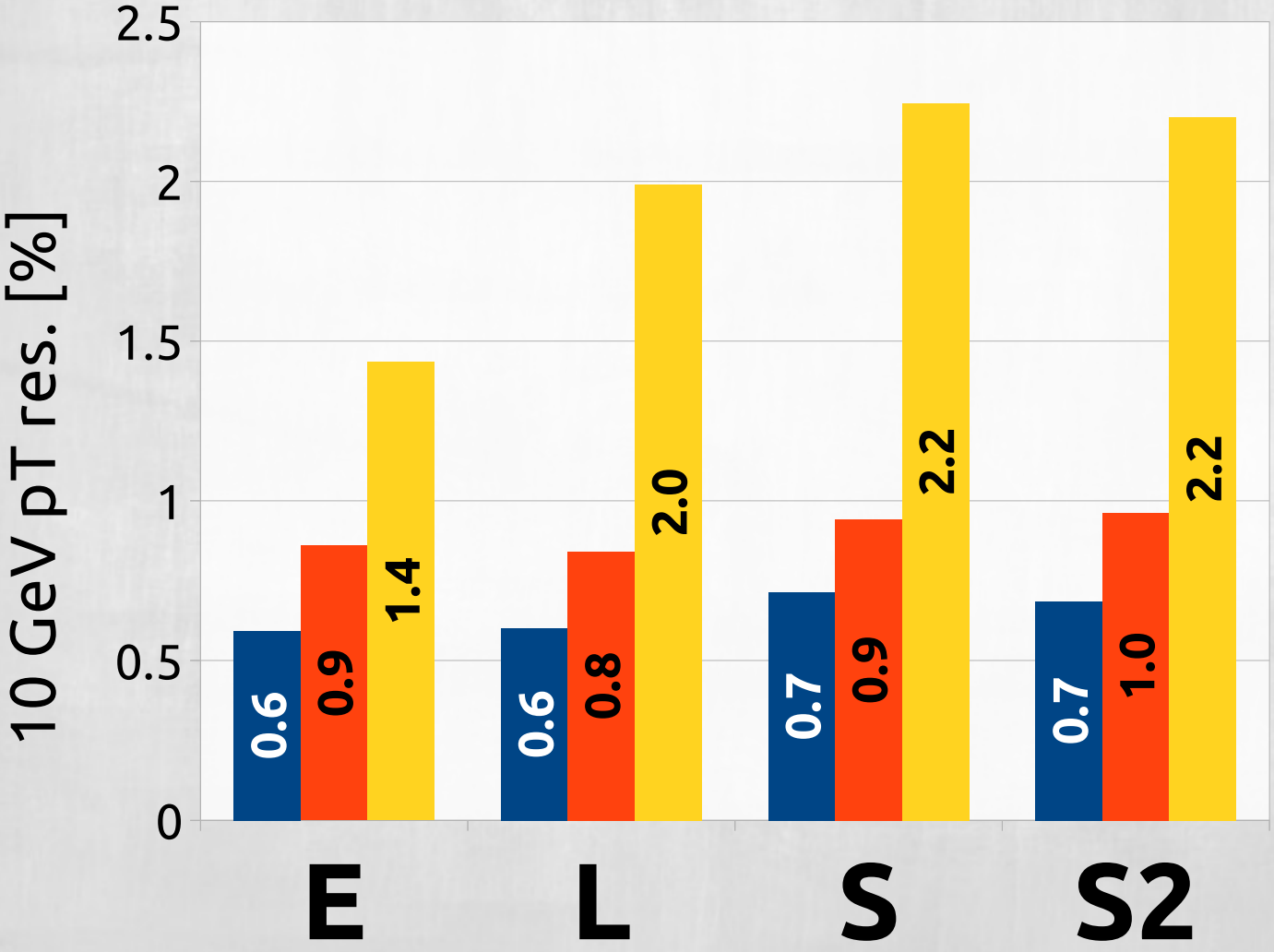
Tracking resolution

Transverse momentum (10 GeV)



η

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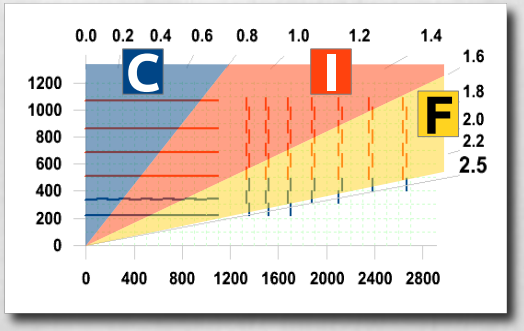
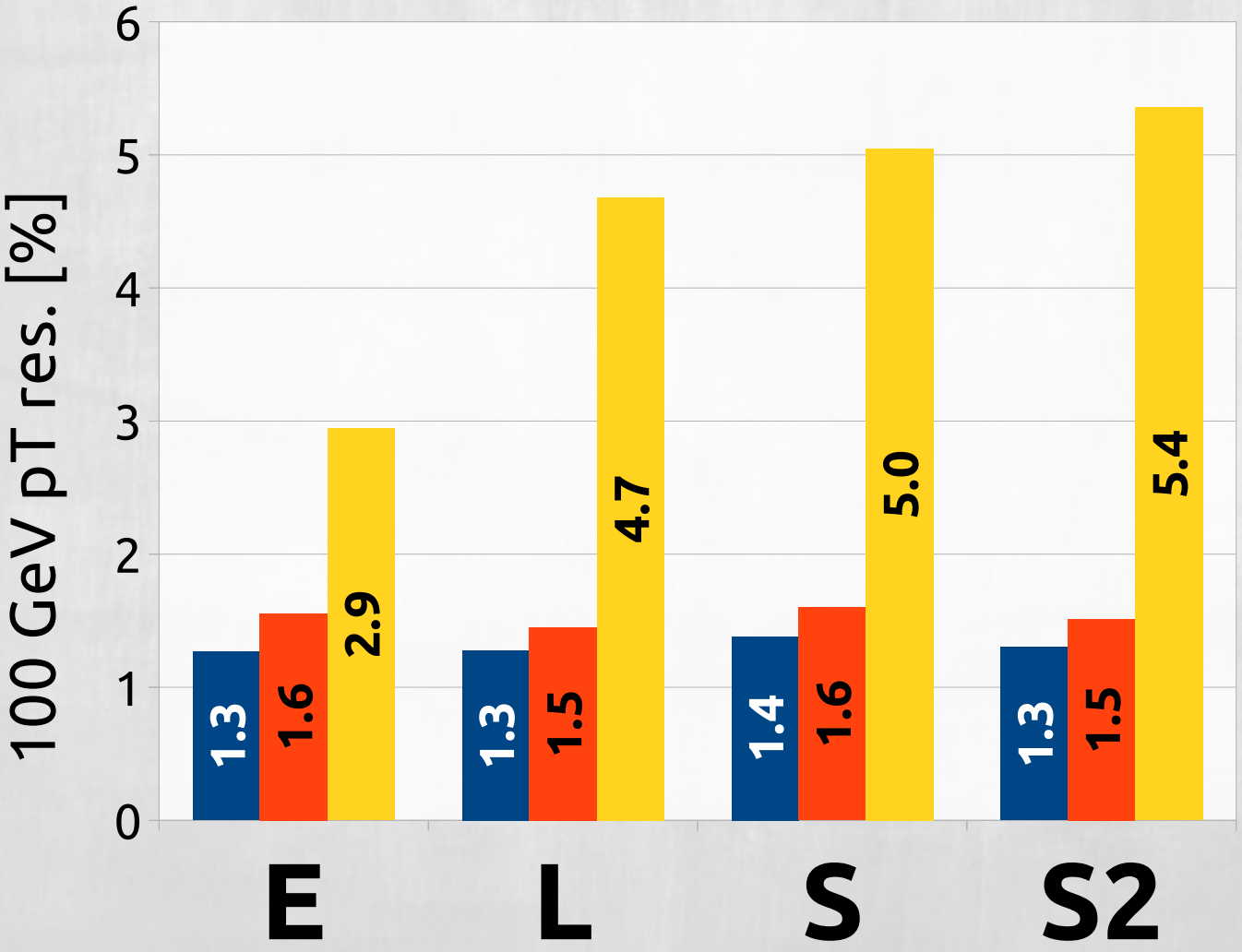
I 0.8 → 1.6

F 1.6 → 2.4



Tracking resolution

Transverse momentum (100 GeV)



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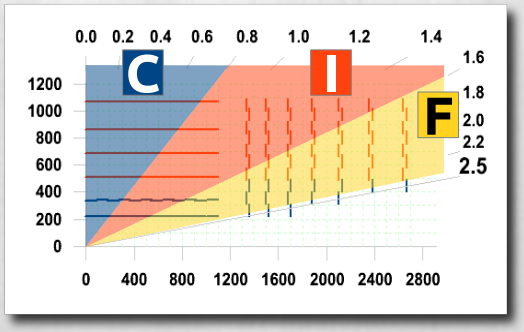

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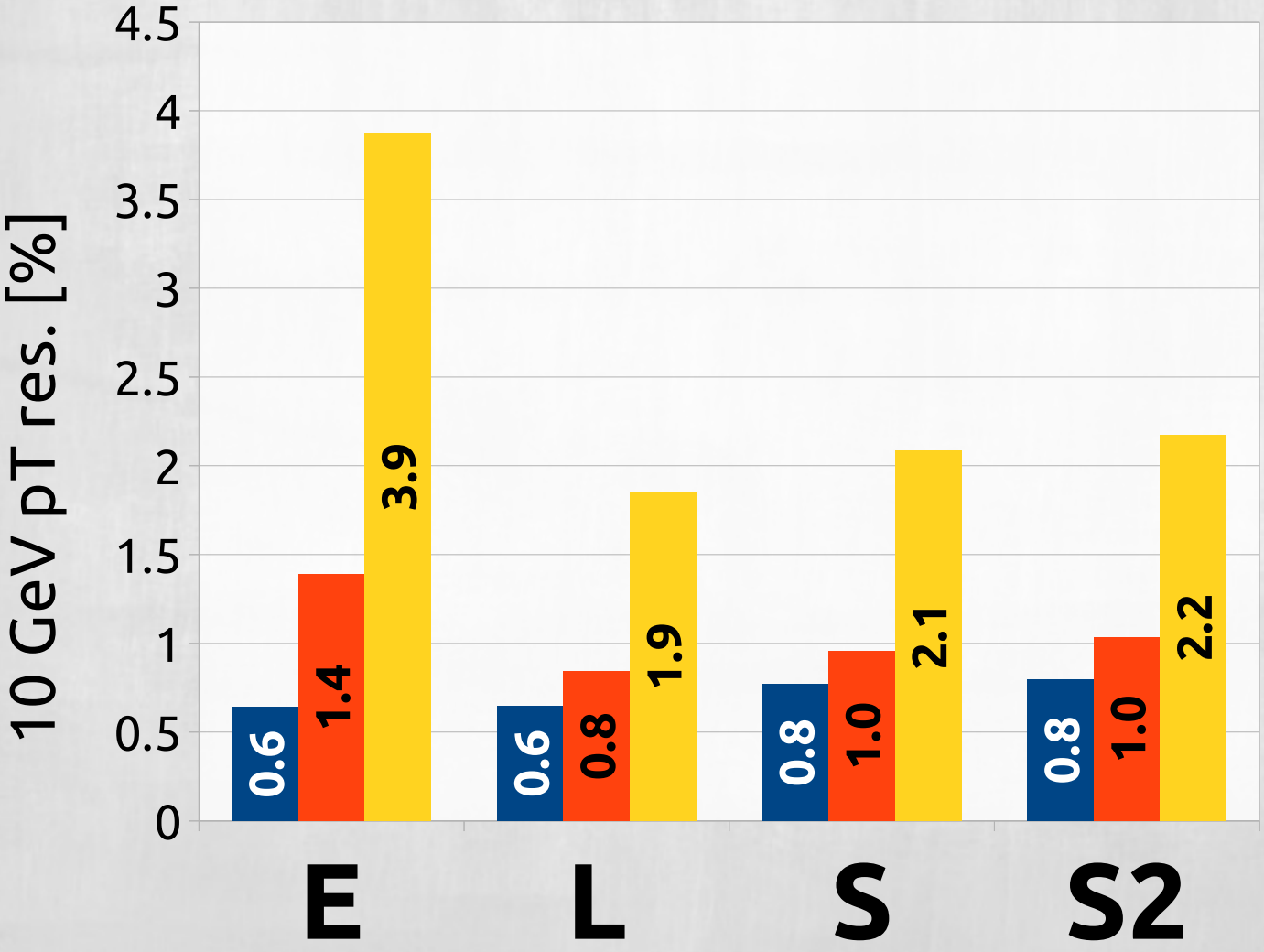
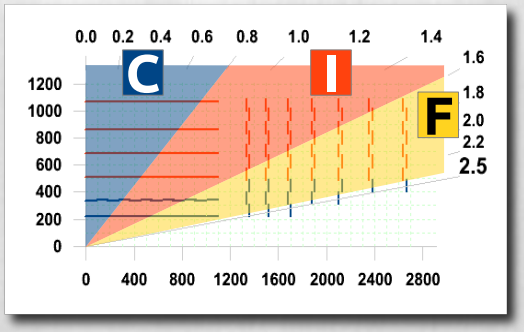
Trigger resolution potential

Transverse momentum (10 GeV)



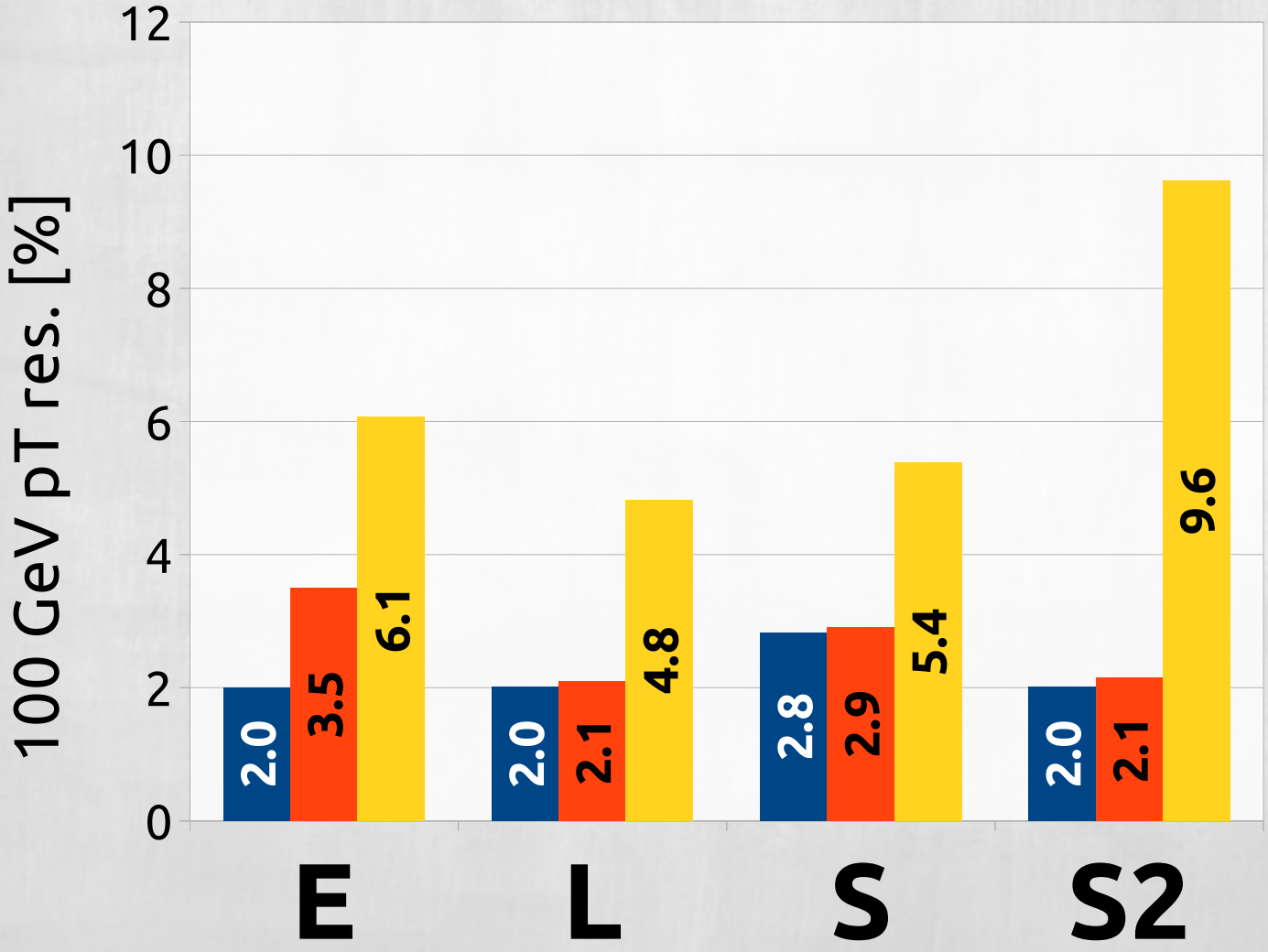
η

C	0 → 0.7
I	0.7 → 1.4
F	1.4 → 2.1



Trigger resolution potential

Transverse momentum (100 GeV)



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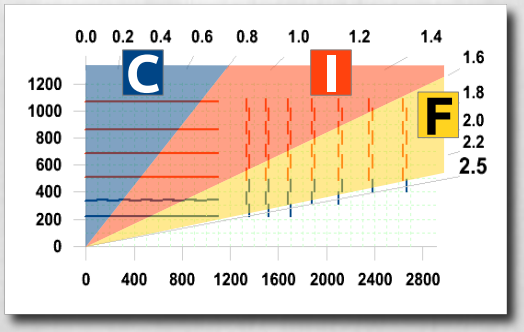
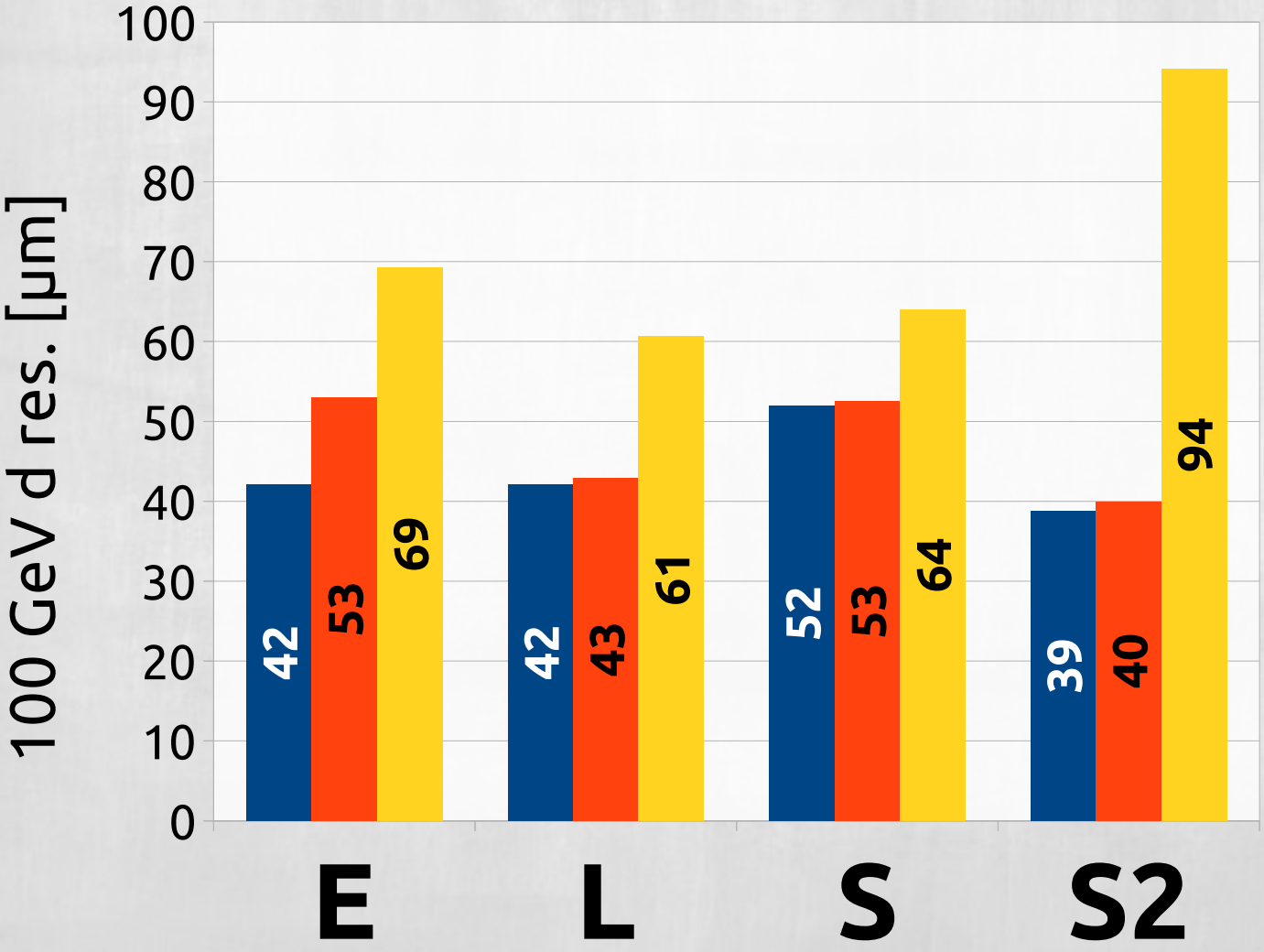


Trigger resolution potential

Transverse impact parameter



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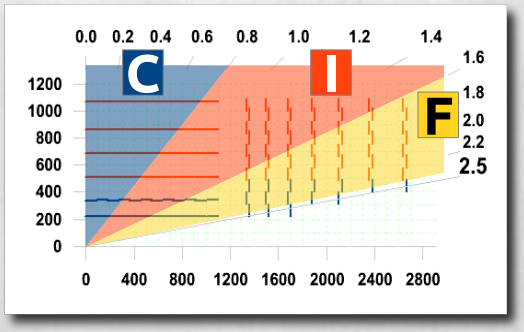
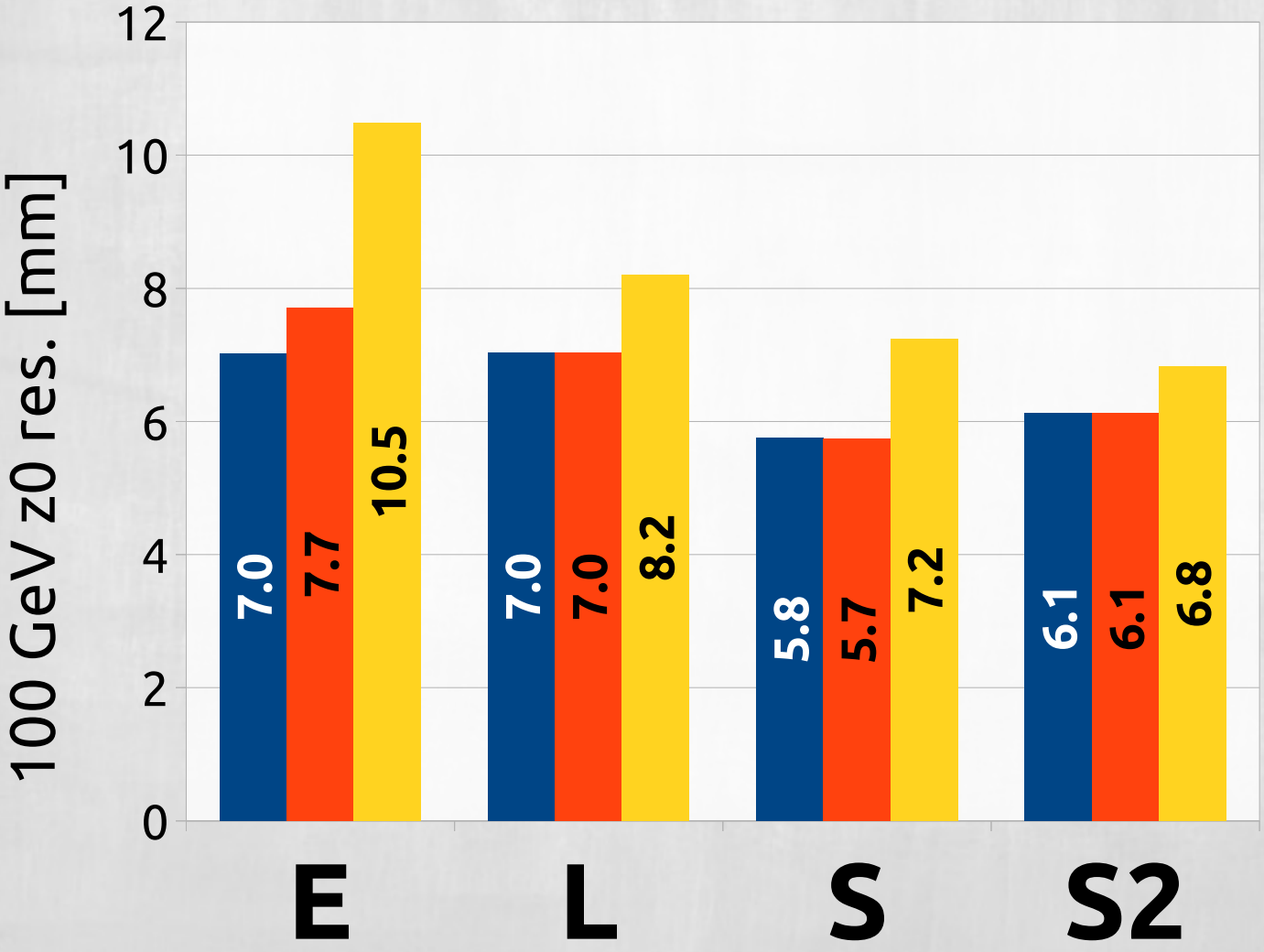


Trigger resolution potential

Longitudinal impact parameter

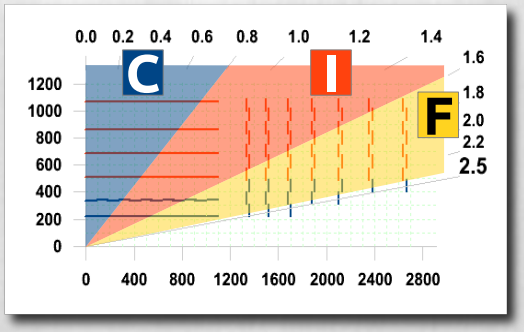


η

C 0 → 0.7

I 0.7 → 1.4

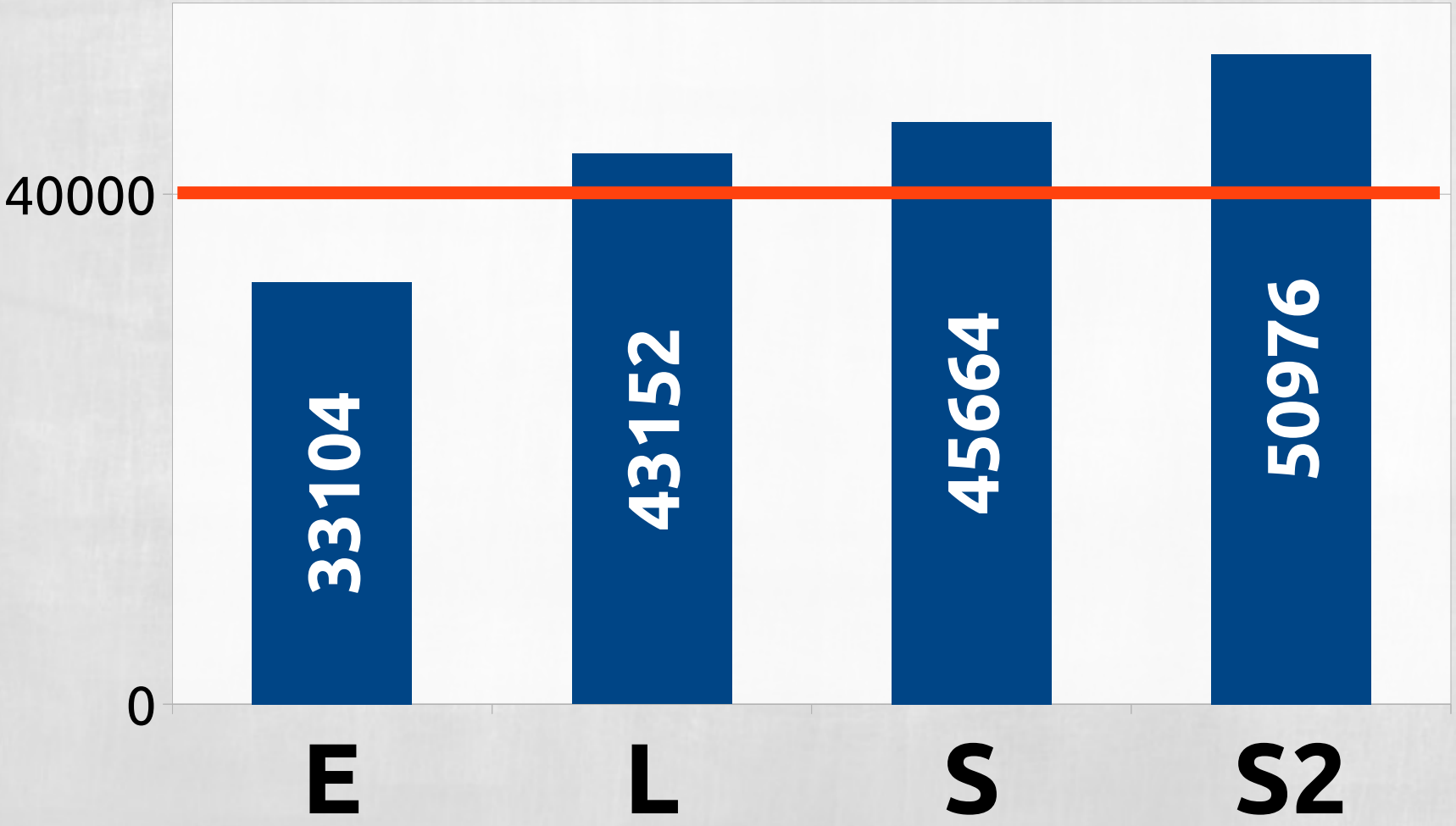
F 1.4 → 2.1



Number of fibres

Assuming 1 GBT/module

About **40000 installed fibres**



Partial conclusions (1/2)

- Trigger – pT
  - **Central** region is basically insensitive to the layout
  - **Intermediate** region favours the non-stacked barrel-only
  - **Forward** region clearly favours barrel-only layouts at low pT
    2% → 4% @ 10 GeV
    similar @ 100 GeV
- Trigger – longitudinal impact parameter
  - z resolution of around 7mm achievable in **central** and **intermediate** regions with all the studied layouts
  - **Forward** region prefers stacked, then barrel-only, then end-cap layouts
    (7 → 8 → 10 mm resolution)

Partial conclusions (2/2)

- Tracking
  - **Central** and **intermediate** regions (η = 1.6 → 2.4) have very similar performance
  - **Forward** region (η = 1.6 → 2.4) favours the end-cap layout
    1.4% → 2.1% @ 10 GeV
    3% → 5% @ 100 GeV
- Other major features
  - **Double amount** of material in the **forward** region for the barrel-only layouts (as seen by tracks)
  - Larger number of modules for the barrel-onlies
    +22% for Long-barrel
    +38% for Long-barrel stacked
    +54% for Long-barrel stacked 2
  - Multiplicity of fibres not compatible with the scheme of 1 link/module for barrel layouts with available fibres

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~~Layout comparison~~

- ~~Models studied~~
- ~~Properties~~
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- ~~Tracking trigger potential~~

New feature

Conclusions

pT module parameter tuning

- A new feature was added to tkLayout
- Computing the probability of a track to fire a high-pT hit on each module
- Depends on many parameters:
  - **Sensor separation**
  - High-pT **search window**
  - pT of the track
  - Position of the module
  - Strip pitch
  - Luck

tunable parameters

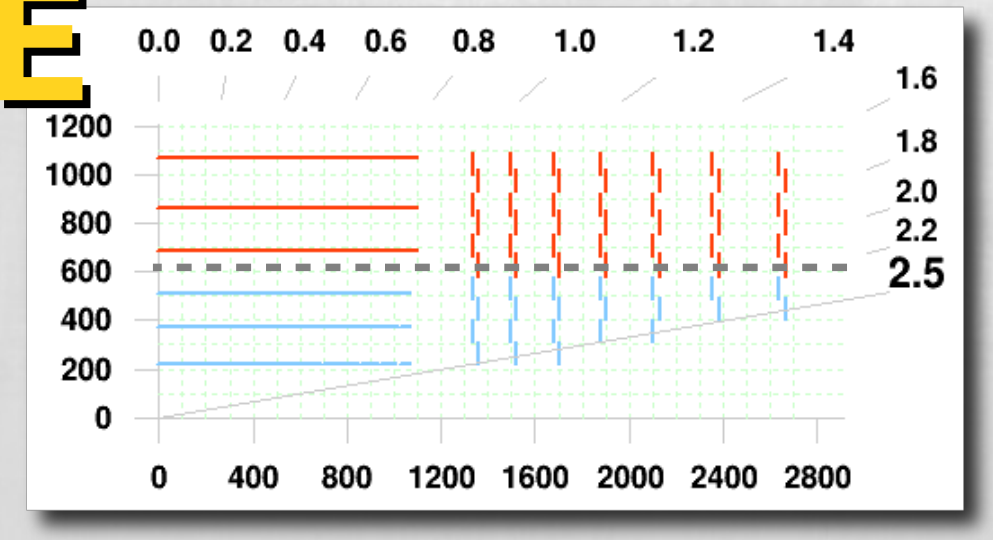
Configuration tuning

- With this feature it is possible to **tune the search window** and **sensor spacing** of a given layout
- Tuning procedure used:
  - Main goal: reject 1 GeV/c tracks (better than 100:1)
  - Secondary goal: maximise efficiency for 2 GeV/c tracks
- Exercise completed for two layouts

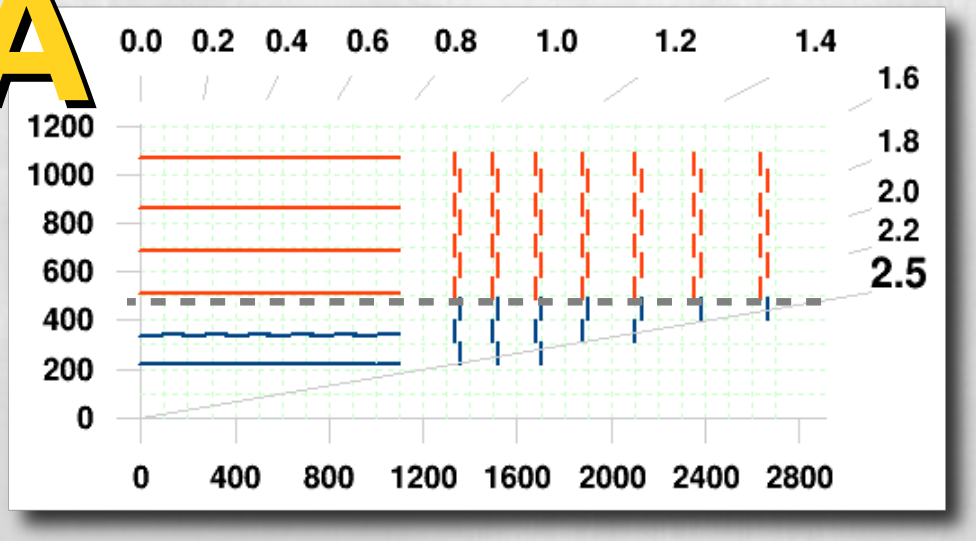
  End-cap layout (shown before)

  An all-strip layout (with non-pT **stereo modules** in the inner part)

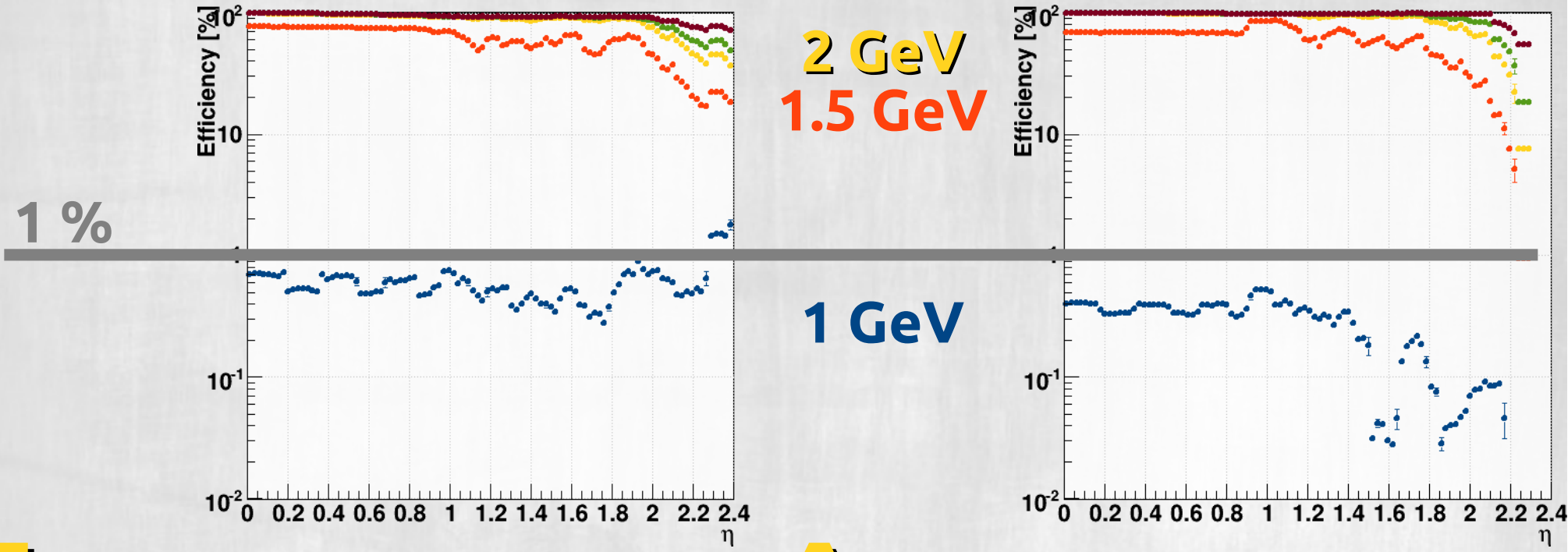
E

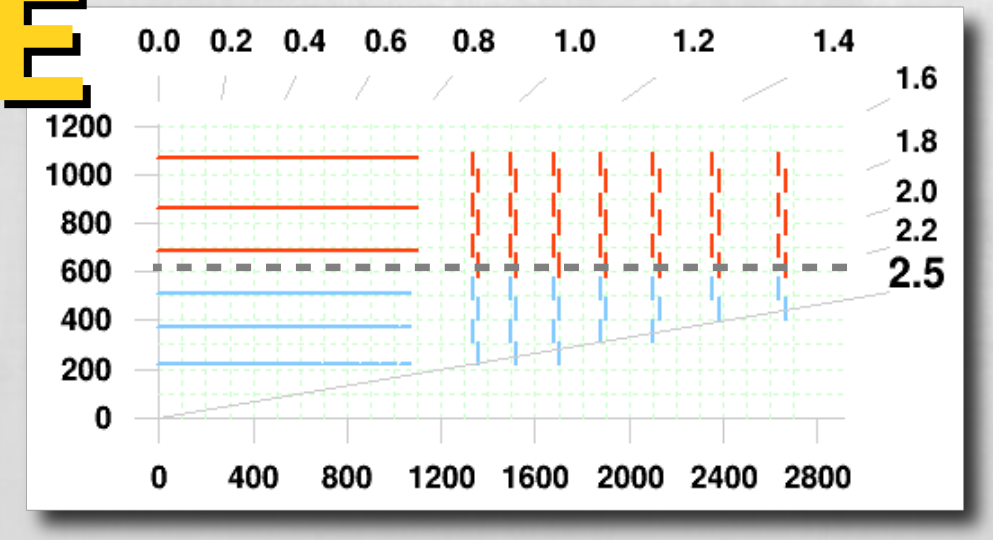


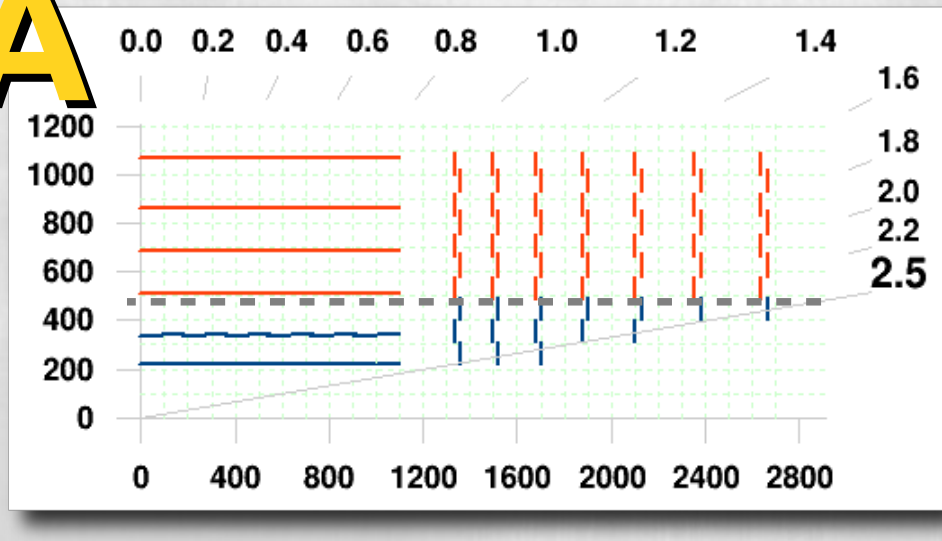
A



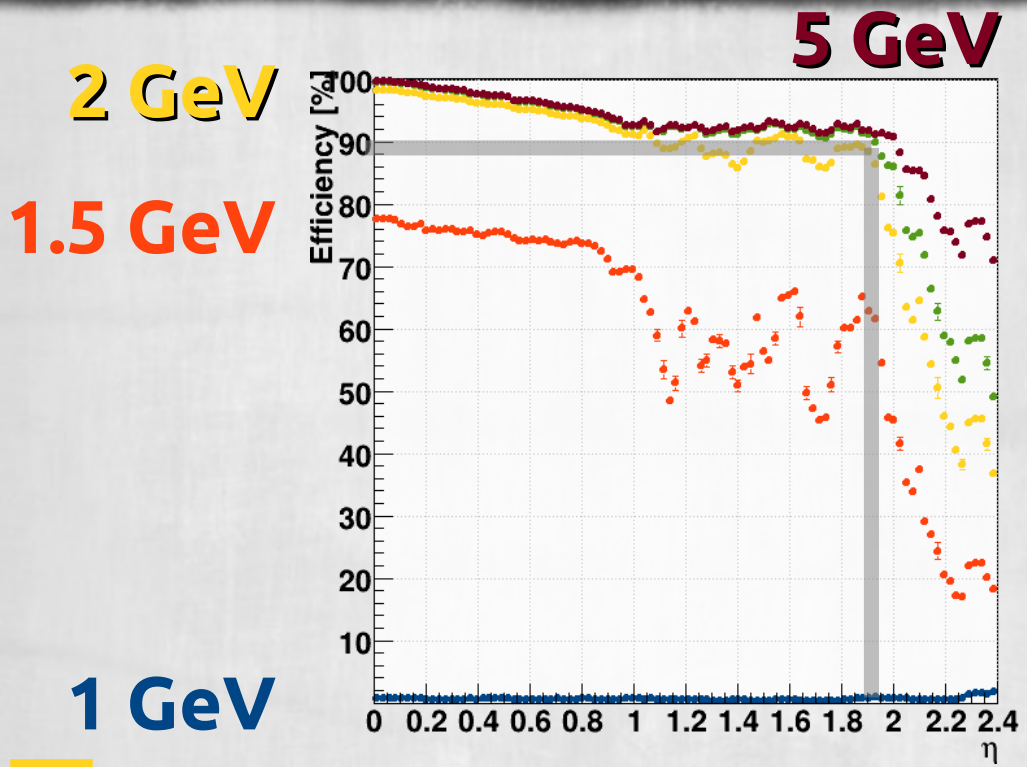
Configuration tuning

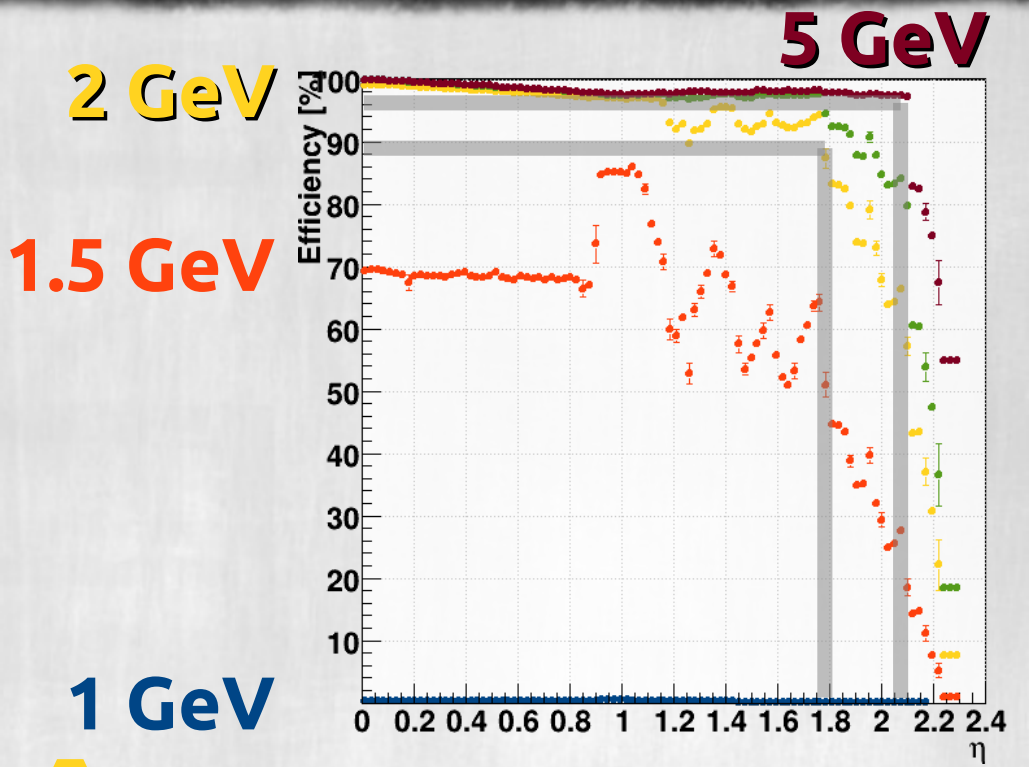




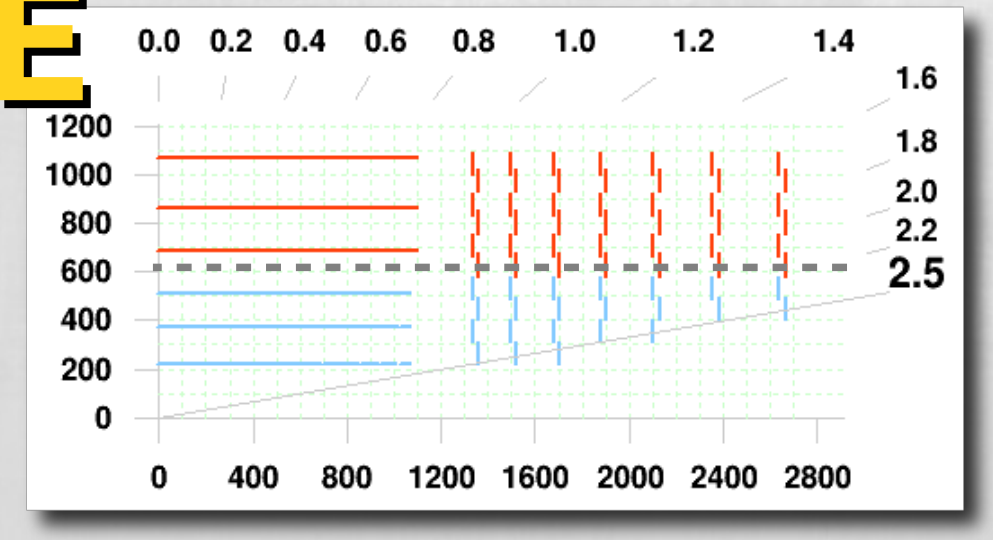


Configuration tuning





E



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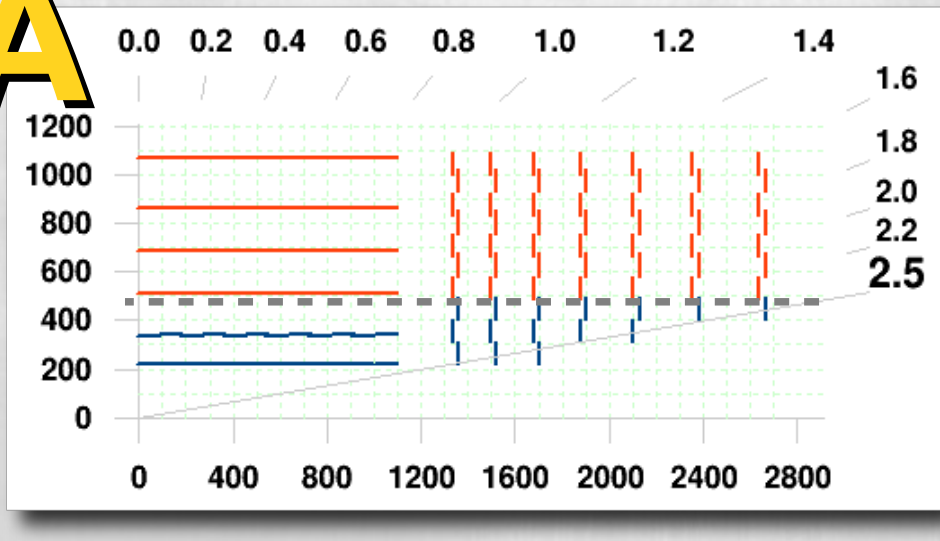

~~What is tkLayout~~

~~Layout comparison~~

- ~~Models studied~~
- ~~Properties~~
- ~~Tracking~~
- ~~Tracking trigger potential~~

~~New feature~~

Conclusions

Conclusions

- This is one input for the strategy choice, together with (e.g.):
  - Strategy for building a trigger, detector integration, ...
- When assumptions change, also the predicted performance is different, but the relation between choices is stable
- Outcome of this study:
  - **Trigger – pT**: favours the barrel-onlies in the **forward**, especially for low pT
  - **Trigger – z0**: ~ 7 mm achievable (slightly worse for non-stacked LB and end-cap in the **forward**)
  - **Tracking – pT**: **forward** region favours the end-cap layout
  - **Double amount** of material in the **forward** region for the barrel-onlies layouts (as seen by tracks)
  - **Larger number of modules** for the barrel-onlies (**+22%** to **+54%**, not compatible with 1 link/module)
- New feature: **pT-finding efficiency estimation**
  - Two layouts already tuned, more to come
  - Few module flavours (4 spacings) should allow a good rejection of 1 GeV/c tracks, with full efficiency already @ 2 GeV/c
  - Output fed back to CMSSW simulations

Thank you