TKLAYOUT, A TOOL FOR CMS TRACKER DESIGN

Coffee seminar

Stefano MARTINA

stefano.martina@cern.ch

European Organization for Nuclear Research

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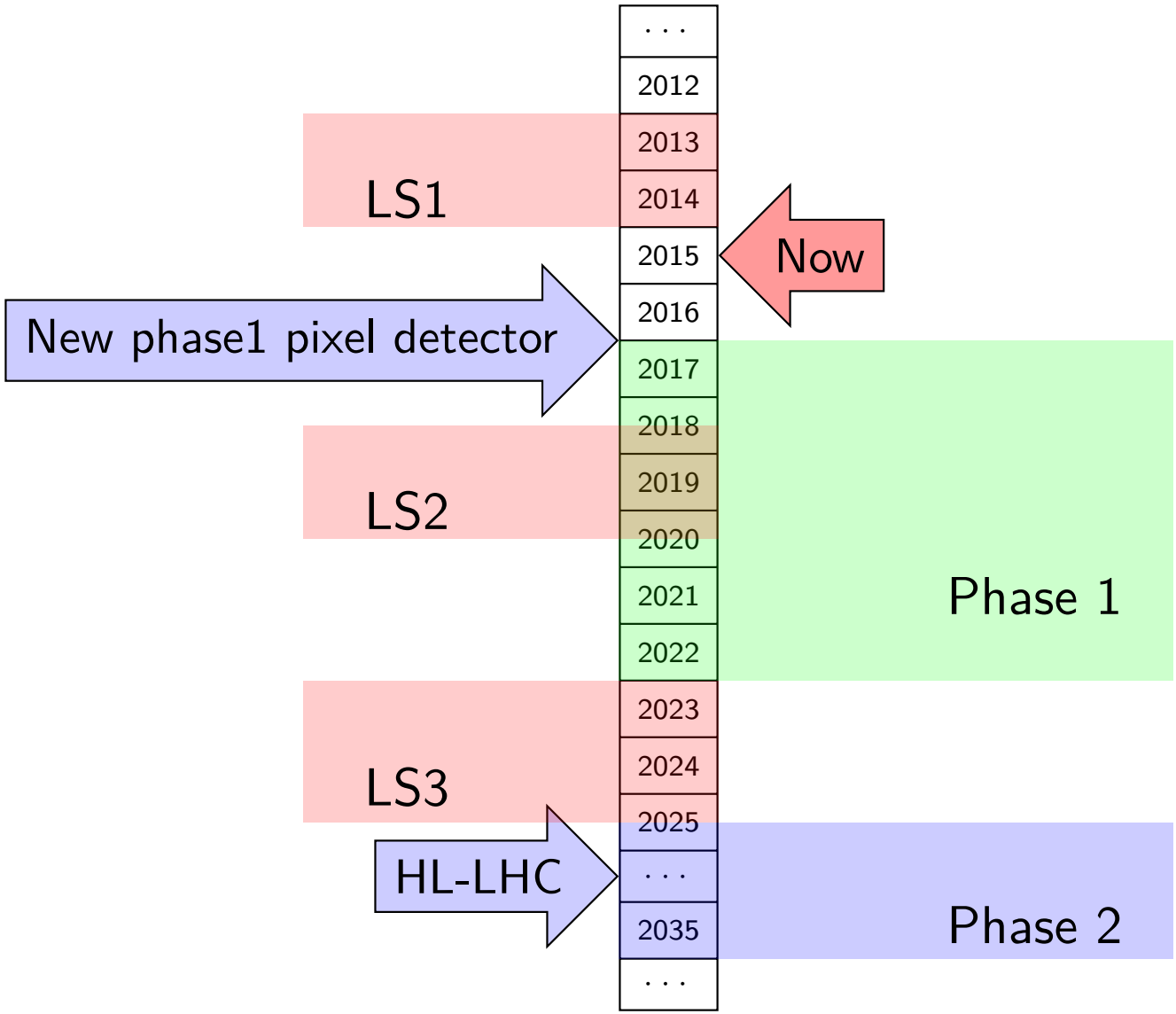
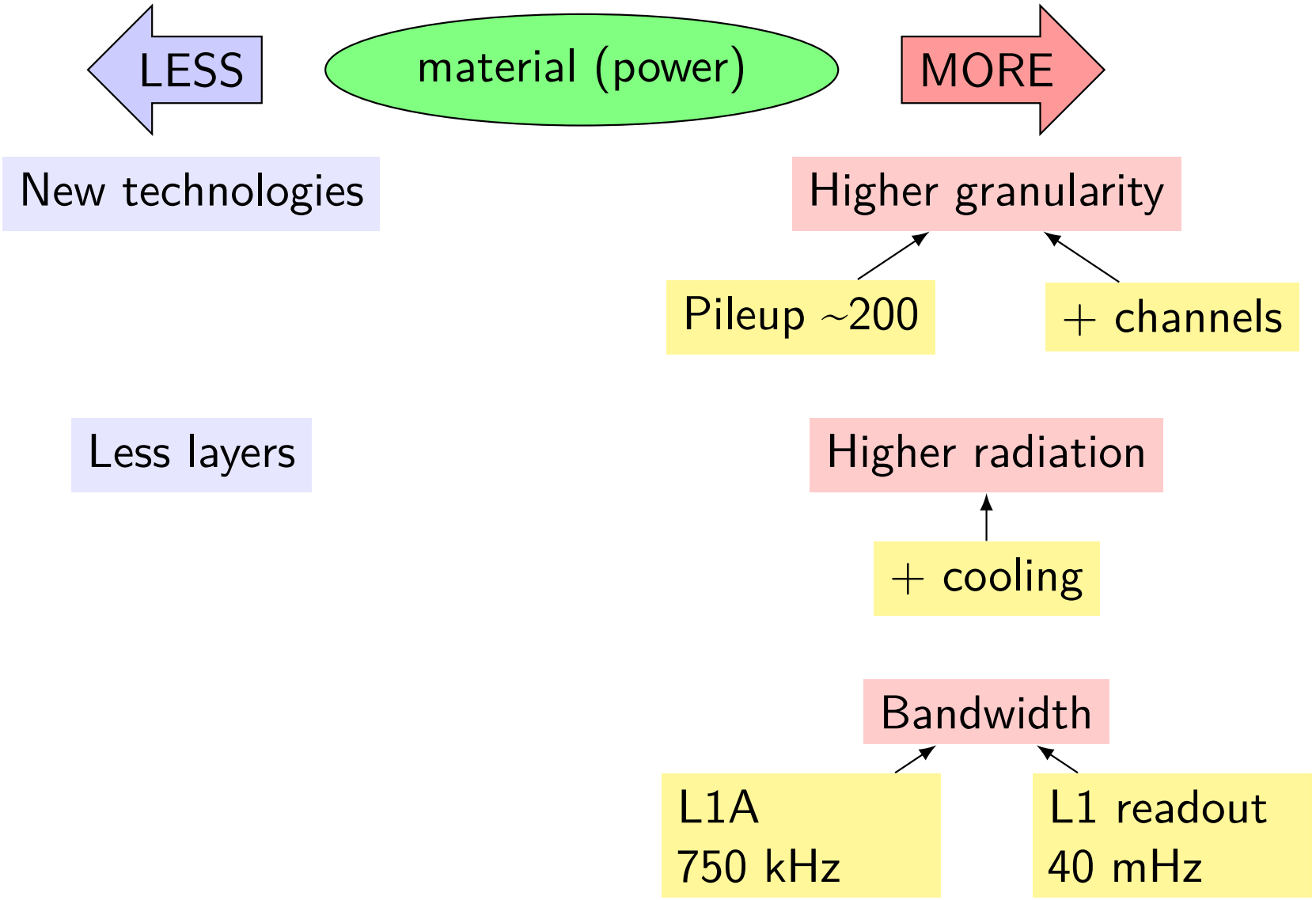
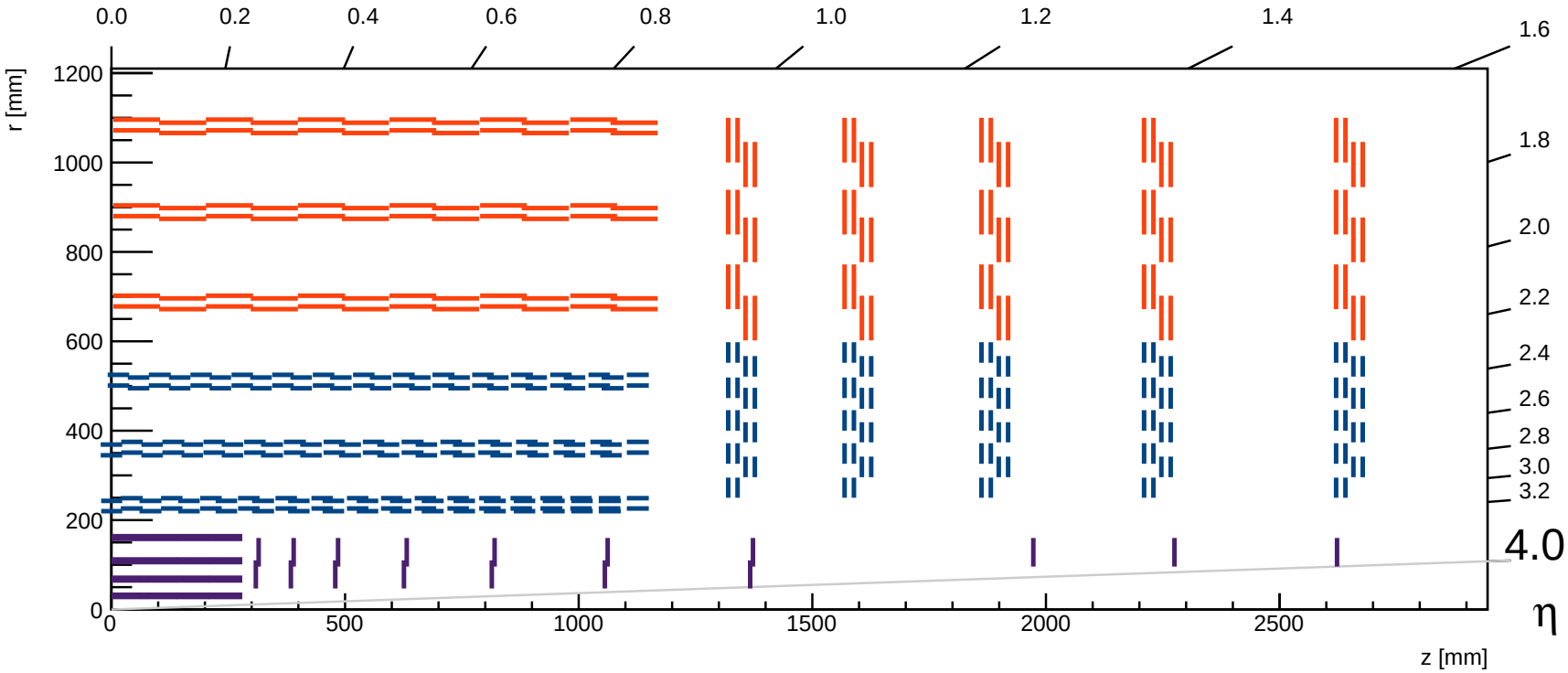
Timeline


. . .
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
. . .
2035
. . .
LS1
Now
New phase1 pixel detector
LS2
Phase 1
LS3
HL-LHC
Phase 2

Trade off


LESS
material (power)
MORE
New technologies
Higher granularity
Pileup ~200
+ channels
Less layers
Higher radiation
+ cooling
Bandwidth
L1A
750 kHz
L1 readout
40 mHz

Tracker layout



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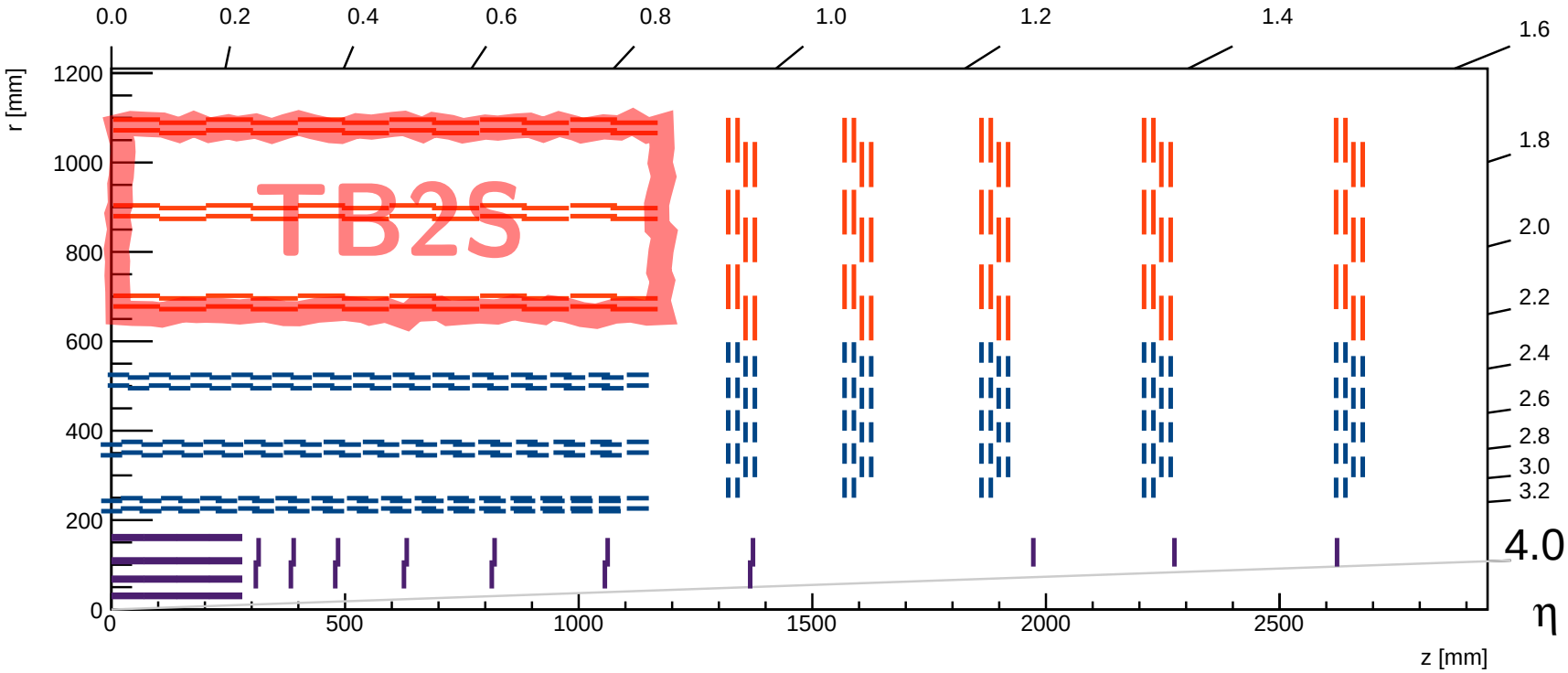

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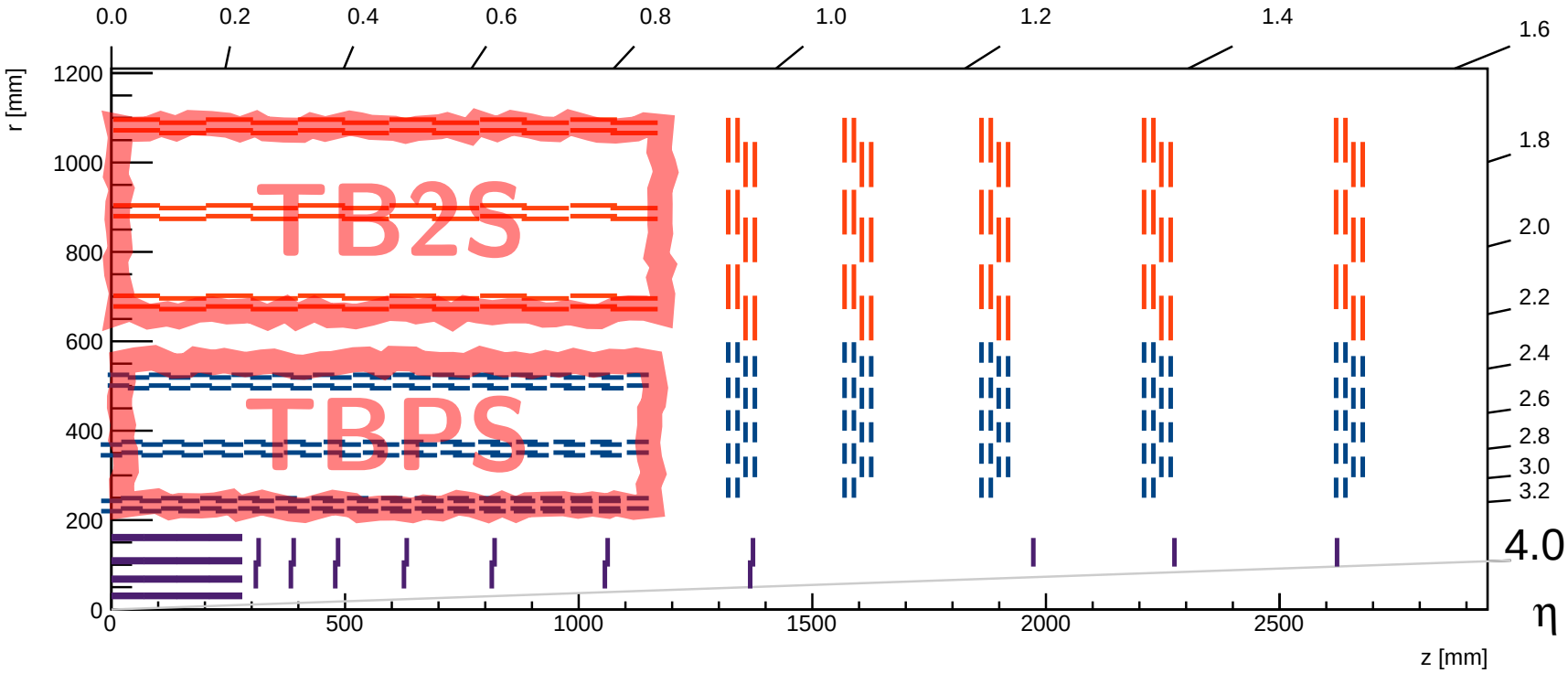

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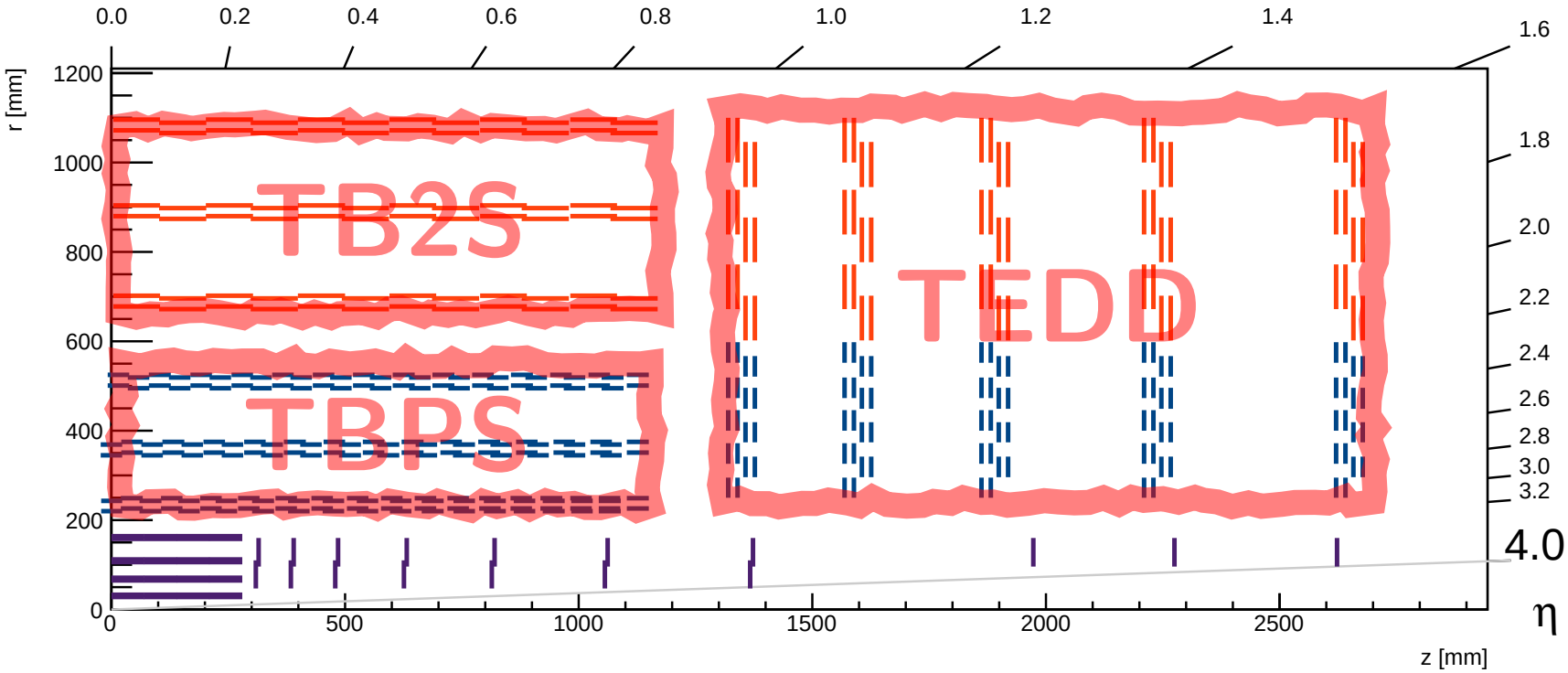

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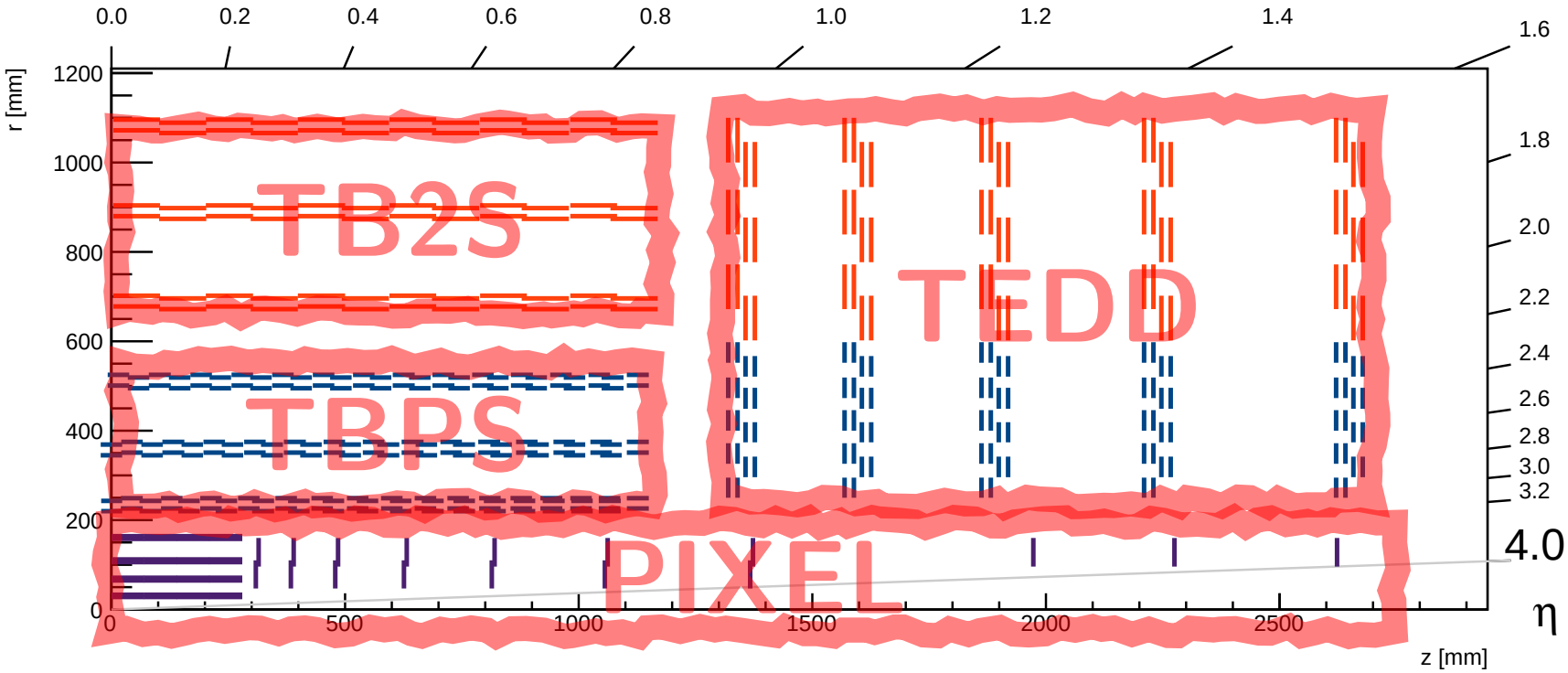
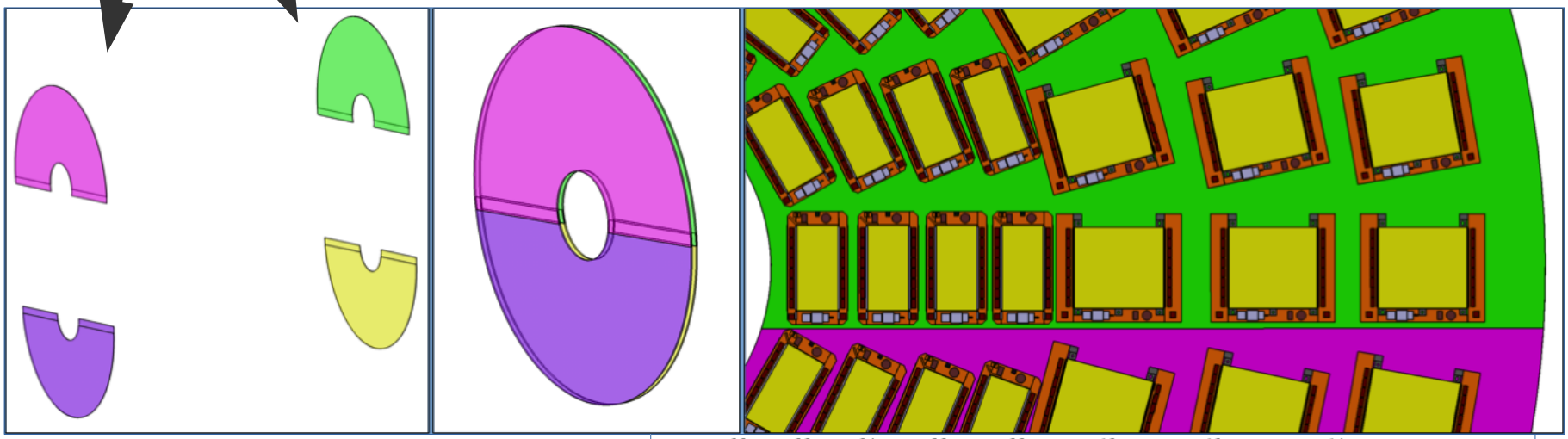
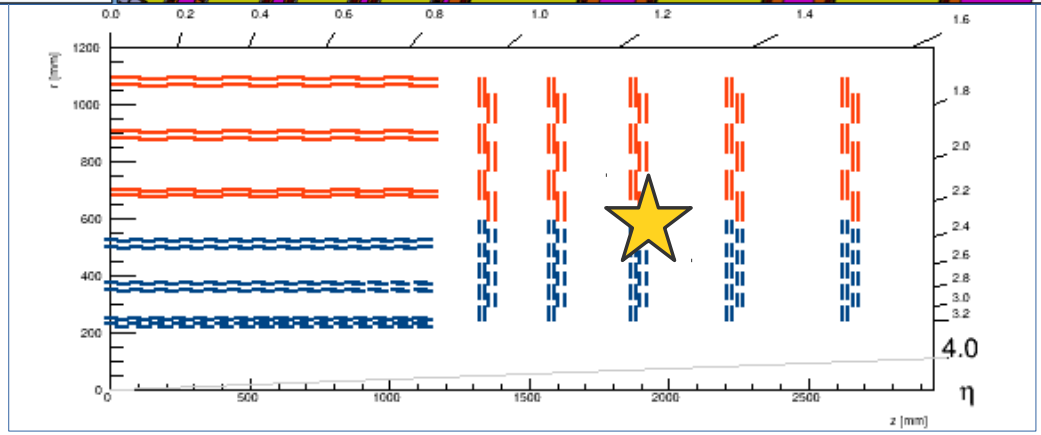


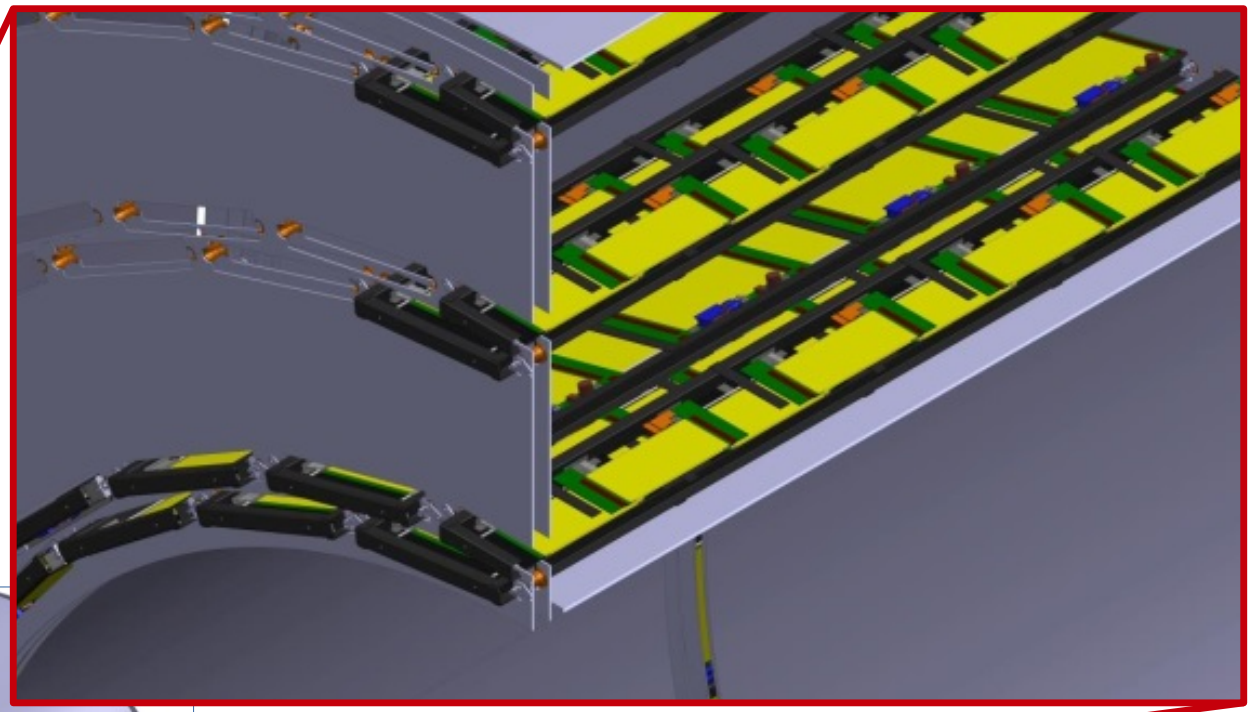
Endcaps mechanics (2S & PS)

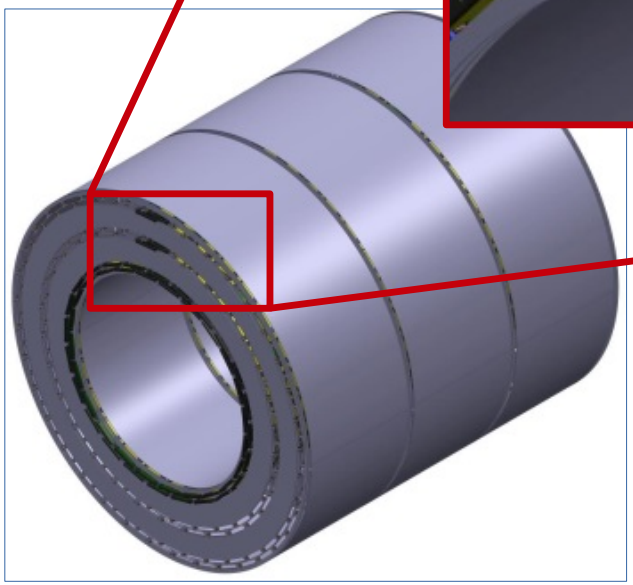
Double disks

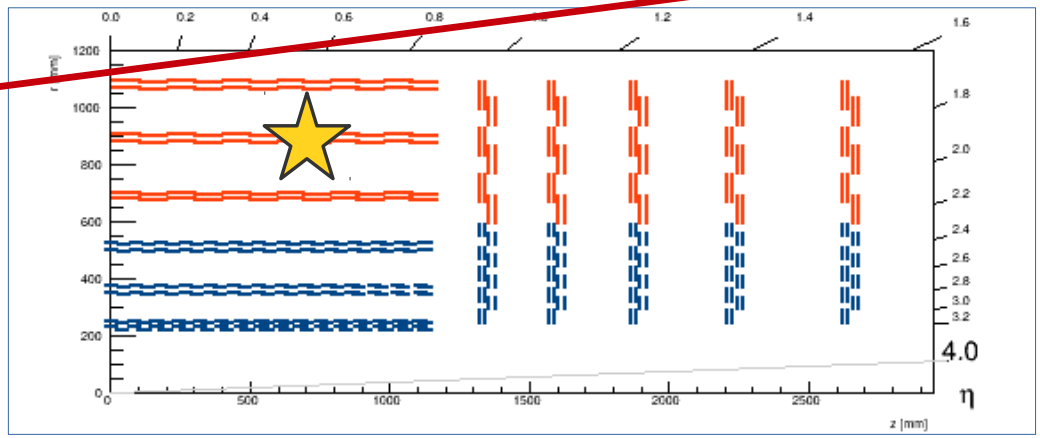




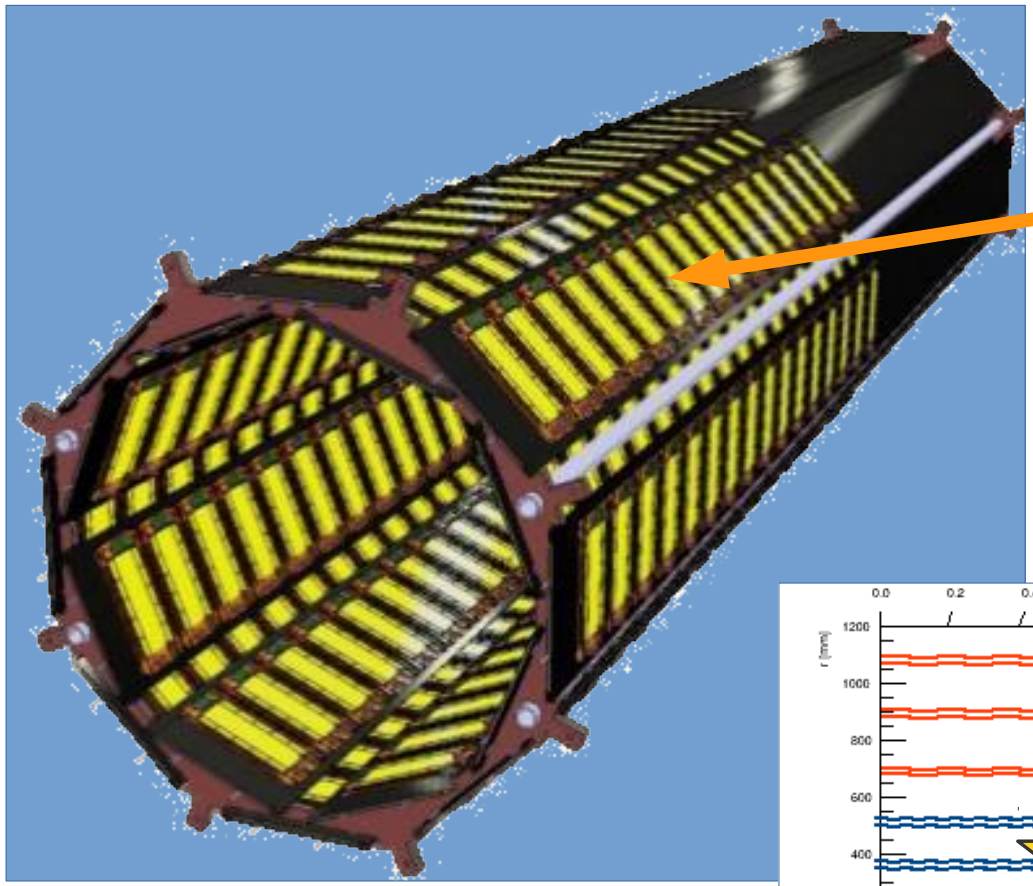
Barrel mechanics (2S)

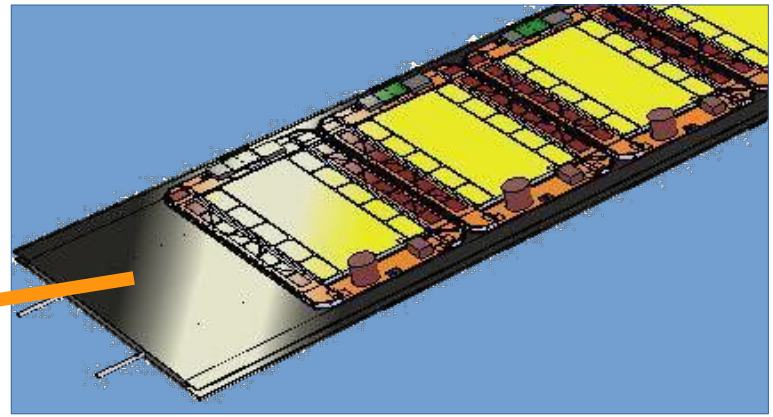


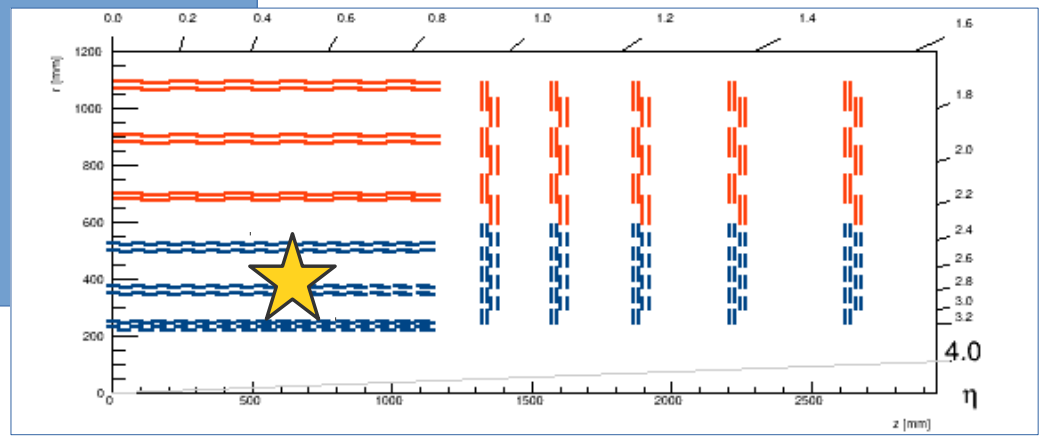




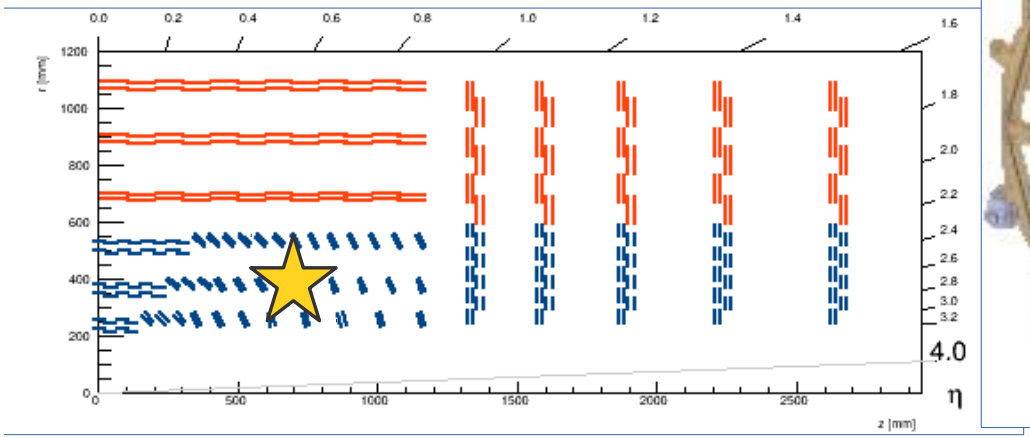
Barrel mechanics (PS)

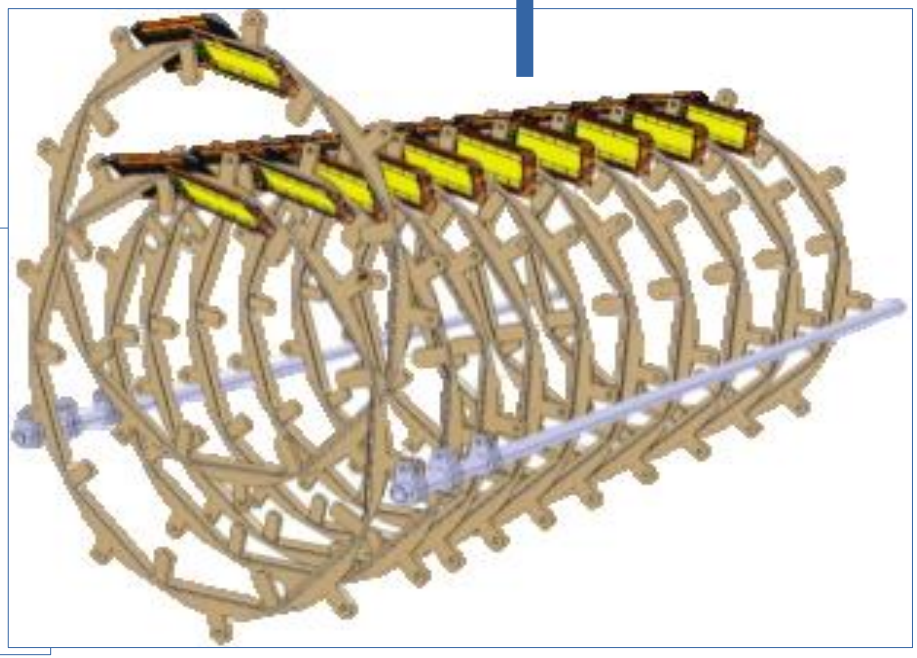






Barrel mechanics (PS alternative)





Target

- ✓ Evaluate material amount (aim to a lighter tracker with respect to the current one)
- ✓ Evaluate tracking performance

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- ✓ not yet for pixel
- ✓ we have a fairly stable design for the TB2S and TEDD
- ✓ we have two competing concepts for the TBPS
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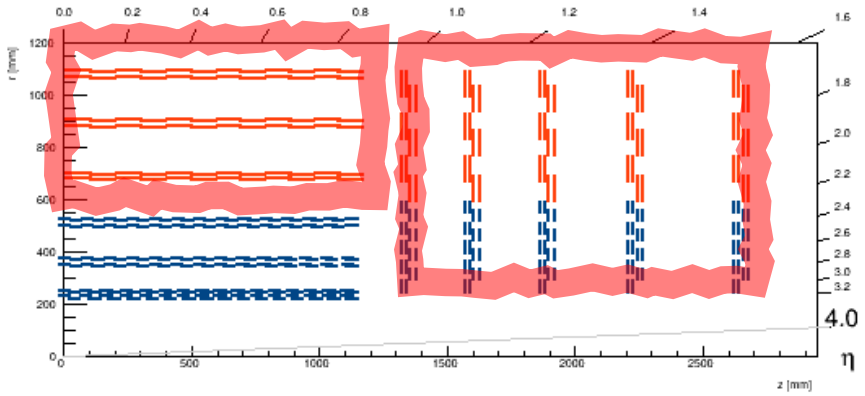

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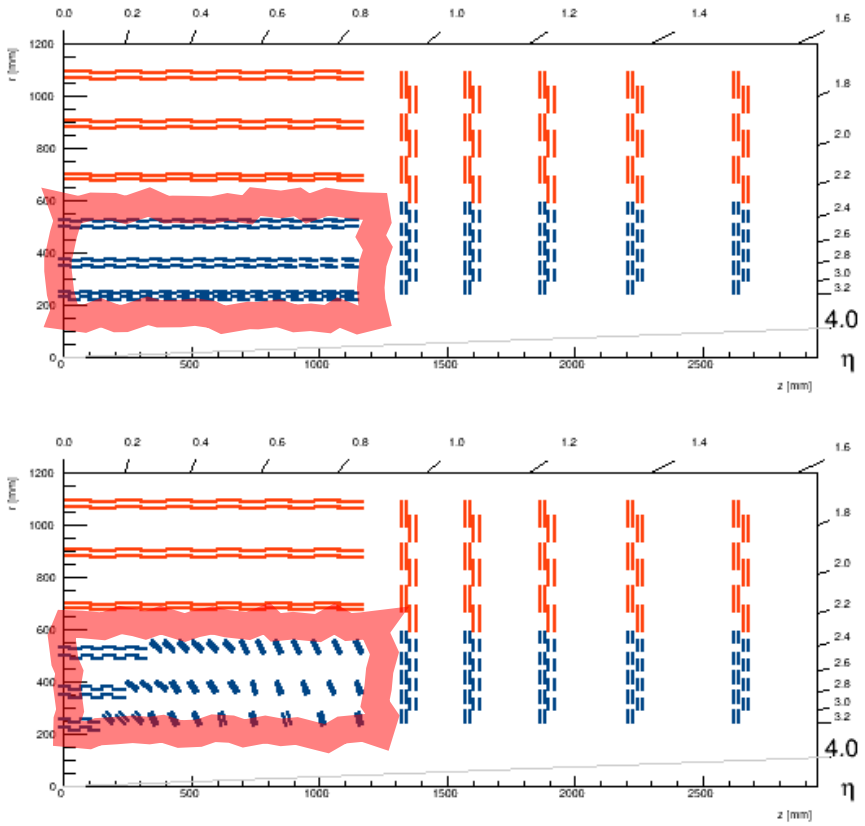

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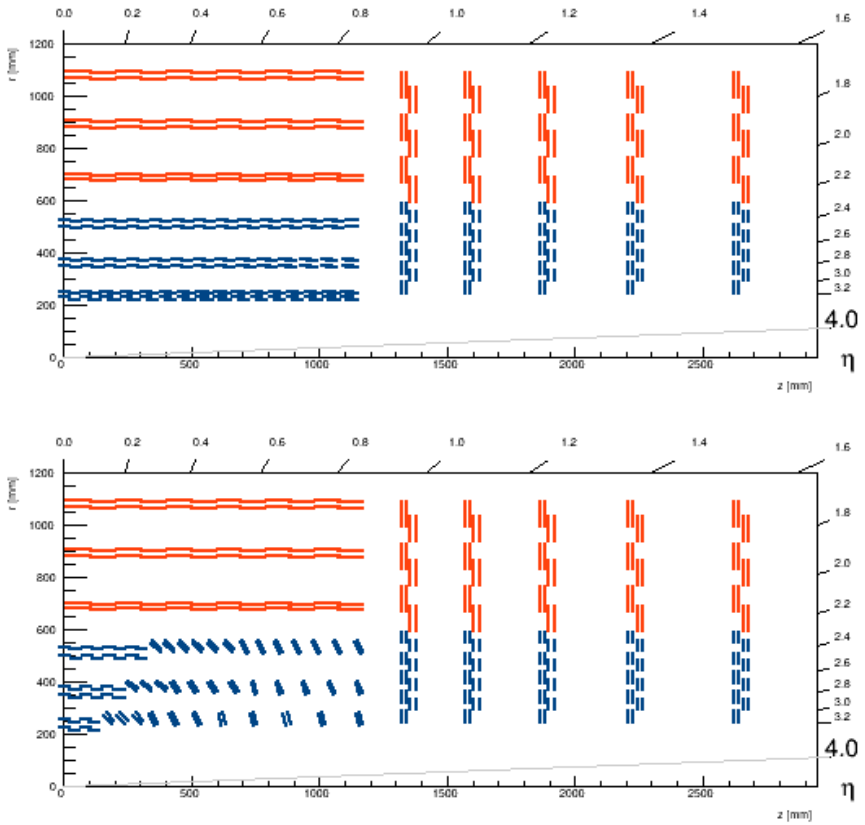

1. in order to study the pixel detector a more detailed radiation map of the inner region was needed, along with a coarser, but wider radiation map for the outer tracker
2. the tilted barrel option offers an attractive reduction of number of modules needed (less material and lower cost), at the potential expense of z0 resolution in the trigger readout (comparative study needed)
3. material from pixel detector effect on tracking resolution is to be quantified

Solution

1 $\rightarrow$ more flexible input of FLUKA radiation maps into tkLayout

2,3 $\rightarrow$ completely rework the model of material (see later)

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TkLayout main features

- ✓ predict material distribution and effects
- ✓ predict resolution
- ✓ generate CMSSW input files for simulation (XML with geometry)
- ✓ evaluate tilted barrel and pixel

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- ✓ error propagation
- ✓ not use simulations
  - → fast analysis

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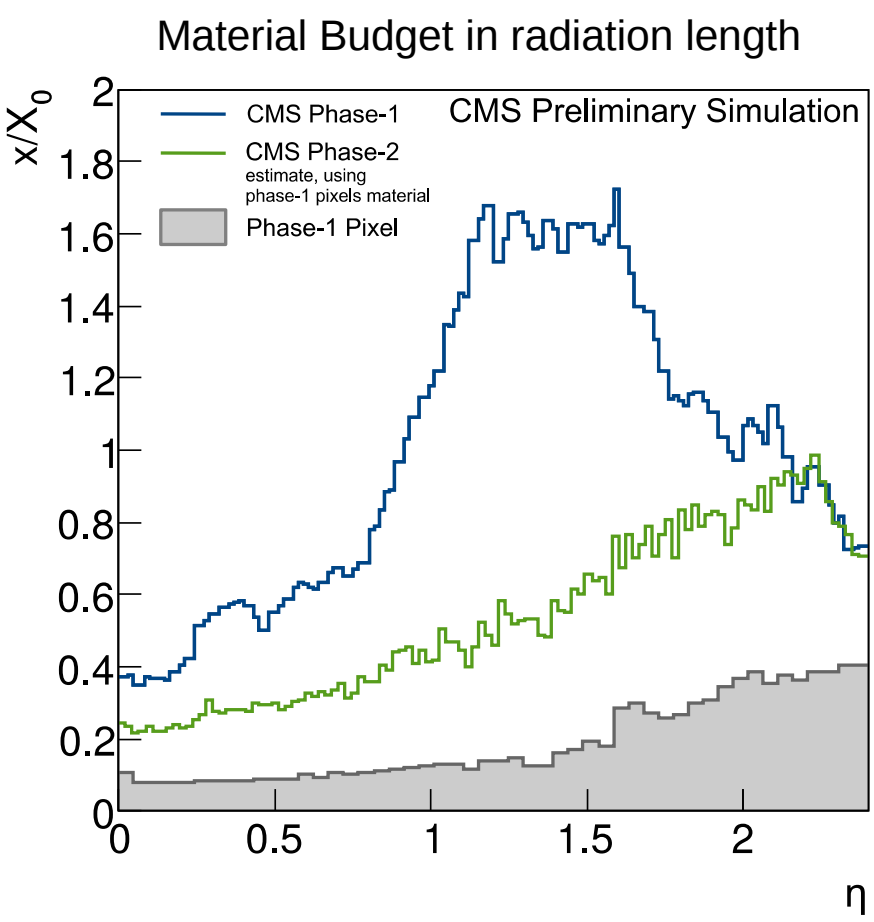
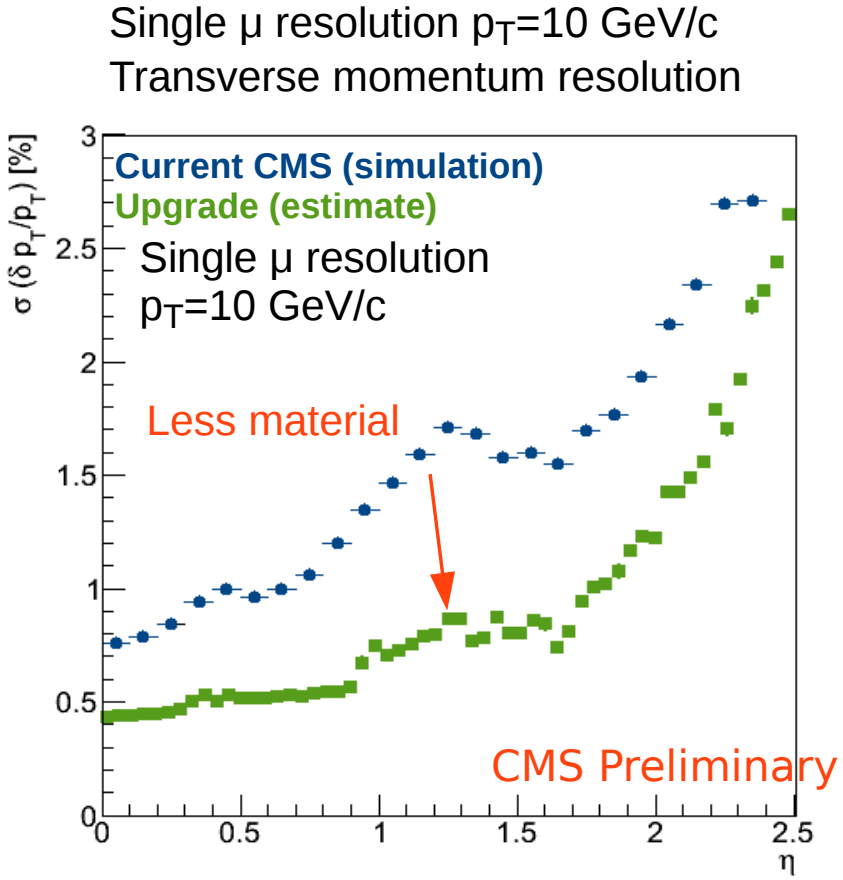
Importance of material

✓ material is important for determine the resolution of phase2 tracker





.../geometries/Baseline2015

```
Tracker Outer {
    @include Baseline2015_SupportsTracker.cfg

    // Layout construction parameters
    zError 70
    bigDelta 12
    zOverlap 1
    phiOverlap 1
    etaCut 10
    barrelRotation 1.57079632679
    smallParity 1

    trackingTags trigger,tracker

    Barrel TBPS {
      @include Baseline2015_SupportsBarrelTBPS.cfg
      Layer 1   { smallDelta 3.65 }
      Layer 2,3 { smallDelta 3.15 }
      numLayers 3
      maxZ 1150
      startZMode modulecenter
      innerRadius 230
      outerRadius 508 // 509 or 540
      width 96
      length 46.26
      physicalLength 71
      phiSegments 2
    }
...
```

Geometry

layers and disks

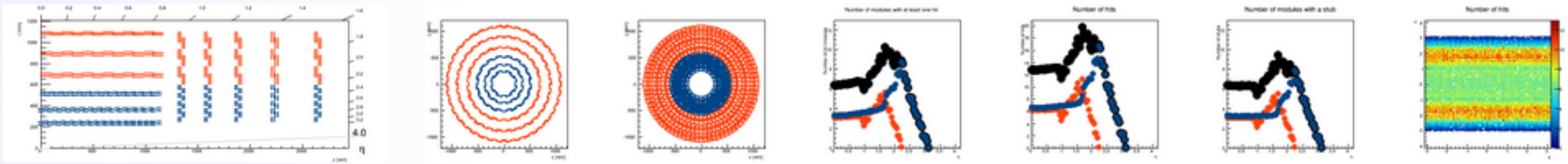
Layer	1	2	3	1	2	3	Total
r	686.000	887.901	1080.000	230.000	357.368	508.000	
z_max	1169.445	1169.445	1169.445	1150.000	1150.000	1150.000	
# mod	1152	1488	1824	1008	1320	1836	8628
# rods	48	62	76	16	24	34	

Disk	1	2	3	4	5	Total
z	1349.445	1597.452	1891.039	2238.583	2650.000	
# mod	680	680	680	680	680	6800

Ring	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
r_{min}	245.559	292.723	323.197	370.867	397.703	447.368	470.641	519.273	550.565	600.567	670.515	775.849	838.158	944.543	999.500
r_{max}	291.819	338.983	369.457	417.127	443.963	493.628	516.901	565.533	596.825	701.067	771.015	876.349	938.658	1045.043	1100.000

modules

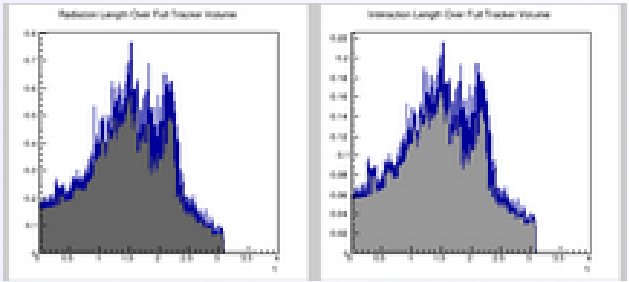
plots



Material distribution 1D

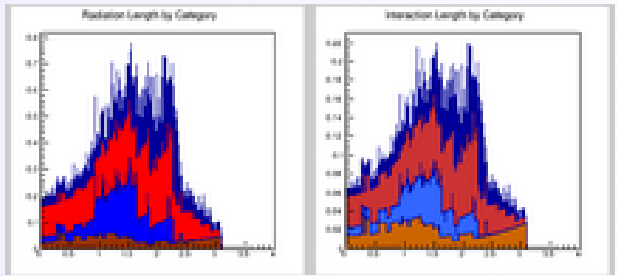
1d overview

Average radiation length in full volume (eta = [0, 4.0]) 0.24597
Average interaction length in full volume (eta = [0, 4.0]) 0.07726



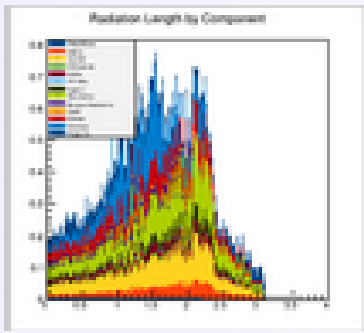
detailed

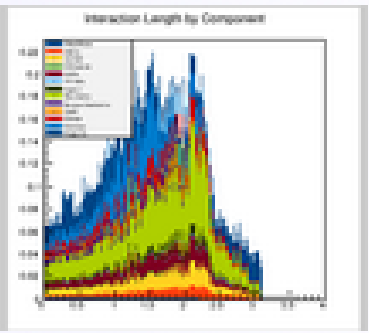
Average (eta = [0, 4.0])	Radiation length	Interaction length
modules	0.16252	0.04678
services	0.05477	0.01454
supports	0.02868	0.01594



module components detail

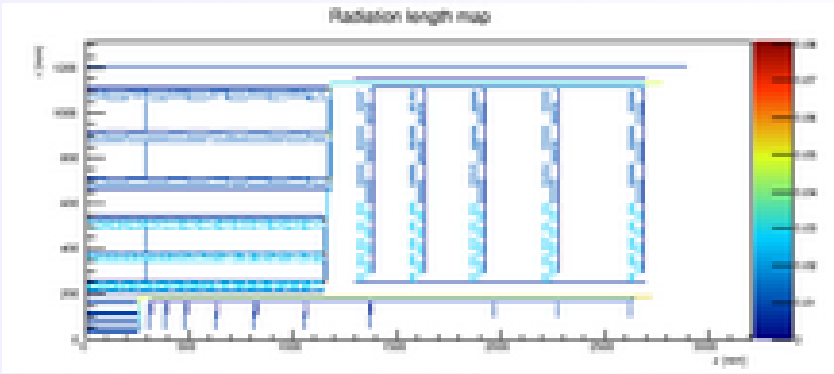
Average (eta = [0, 4.0	Radiation length	Interaction length
2NalSPairs	0.00060	0.00013
ASICs	0.01356	0.00273
DC/DC	0.03593	0.00531
FEHybrids	0.00264	0.00056
GBTs	0.01014	0.00556
HV tails	0.00057	0.00027
Hybrid	0.01119	0.00238
Mechanics	0.04599	0.01959
Module Mechanics	0.00836	0.00343
NalS	0.00293	0.00065
Sensor	0.03061	0.00616
Services	0.05477	0.01454
Supports	0.02868	0.01594

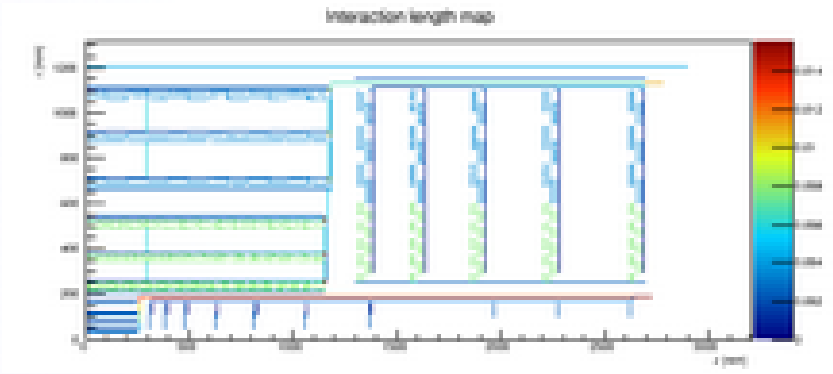




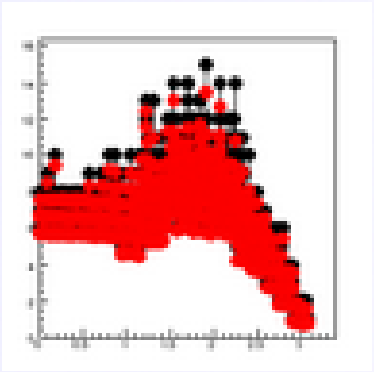
Material distribution 2D

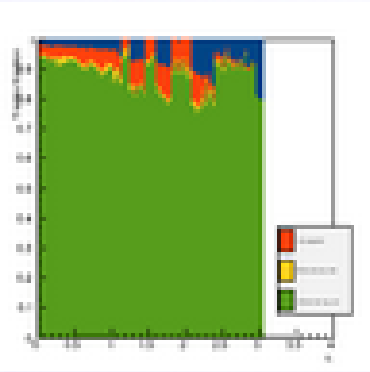
material distribution





nuclear interactions





My contribution to the project

- ✓ radiation maps
  - multiple maps possible
  - more detail
  - useful for pixel study
- ✓ new material model
  - configuration files definition
  - internal representation
  - routing algorithm
  - useful for tilted barrel and pixel study
- ✓ small bug-fix and improvements

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  - Presence of an header with map properties
  - Presence of multiple maps with different resolutions and size
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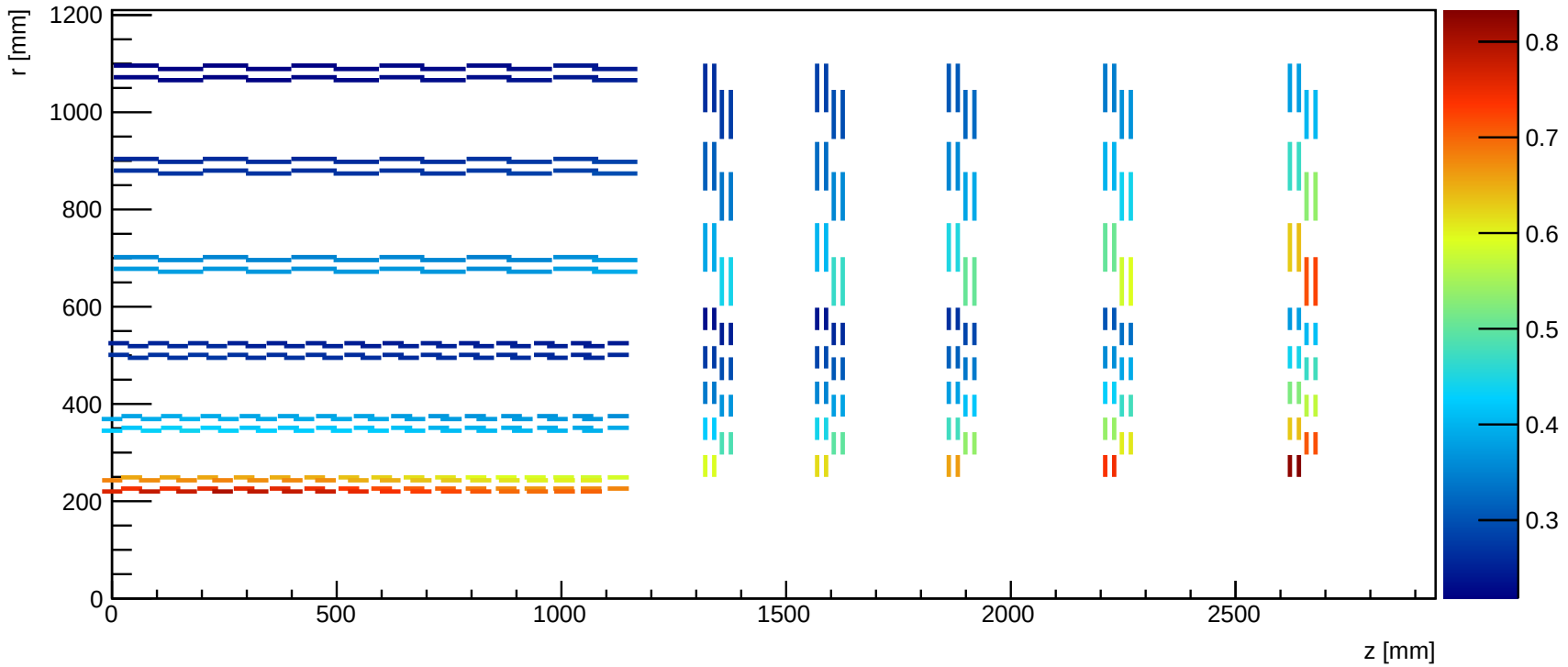
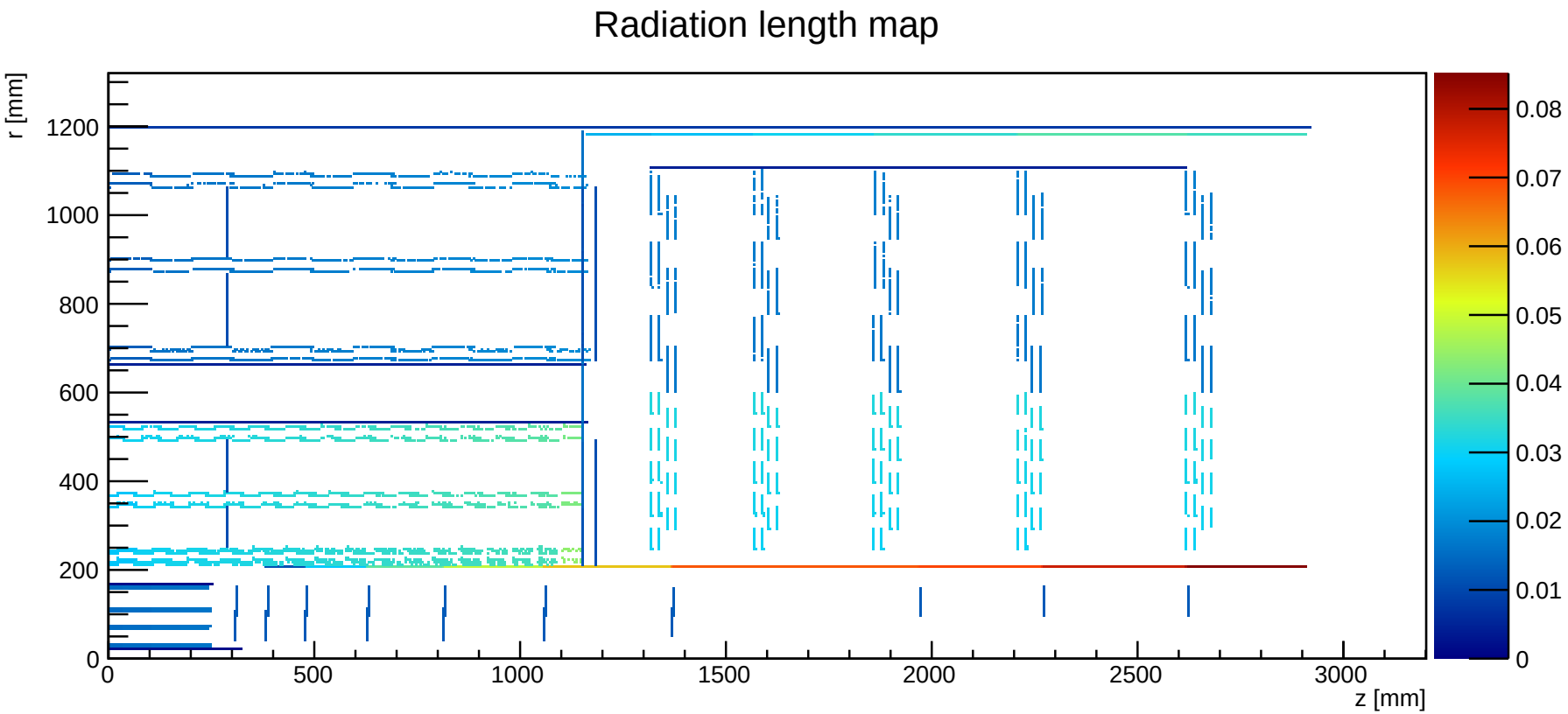


Old material model



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- ✓ Possible to model cooling pipe along rods, manifold in the flange and bigger cooling pipe out of the barrel

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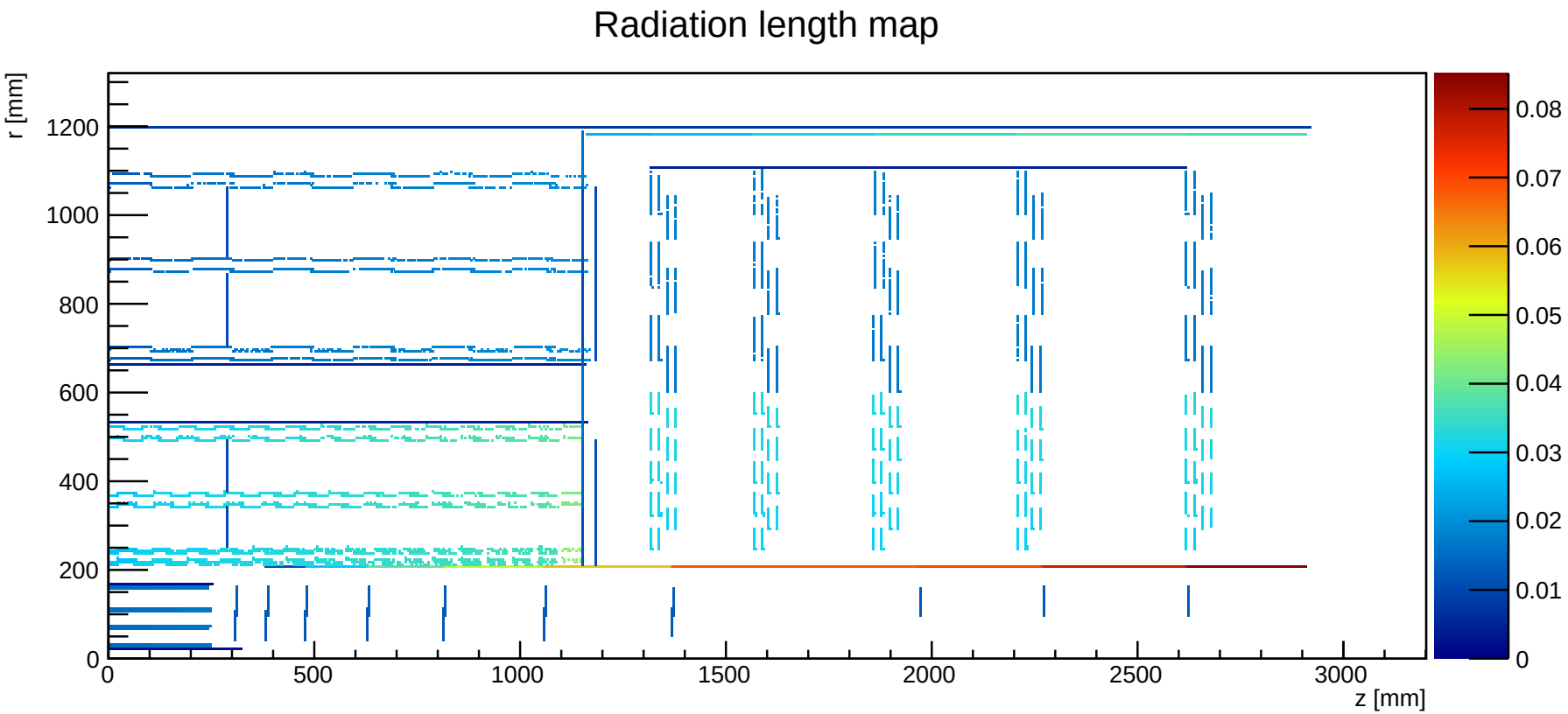

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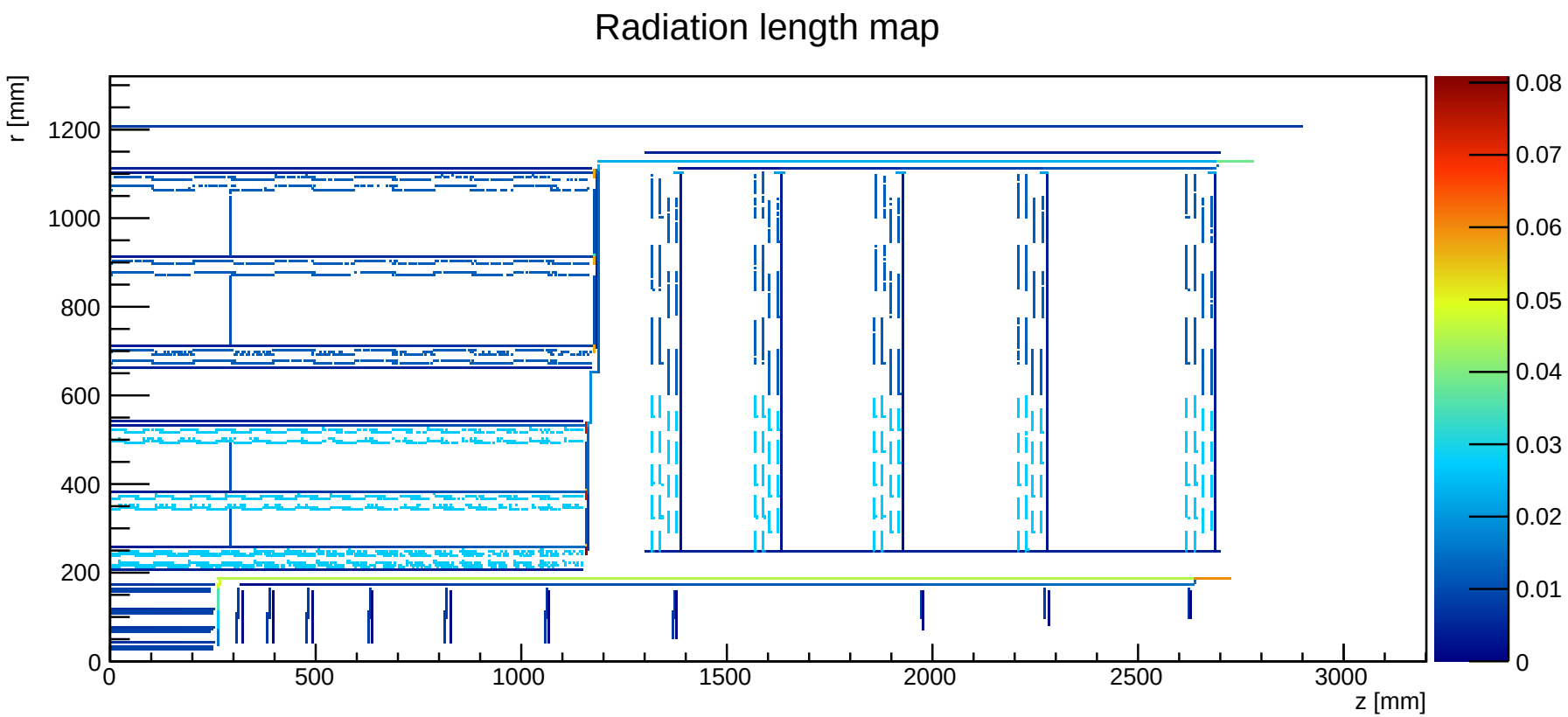

- ✓ Cables material in dedicated volumes
- ✓ More detailed
- ✓ Better routing algorithm
  - automatically decide where cables go
  - avoid collisions
- ✓ More functionality

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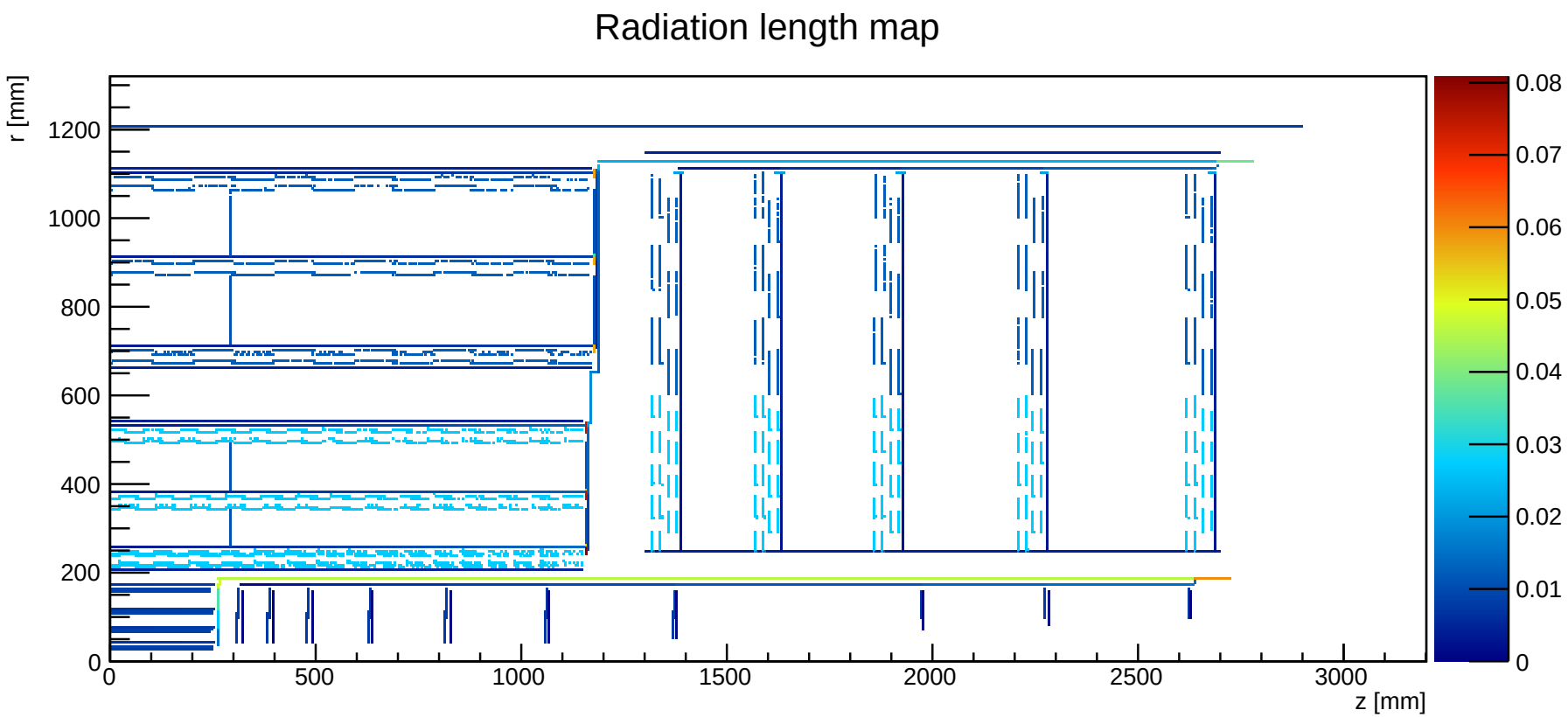

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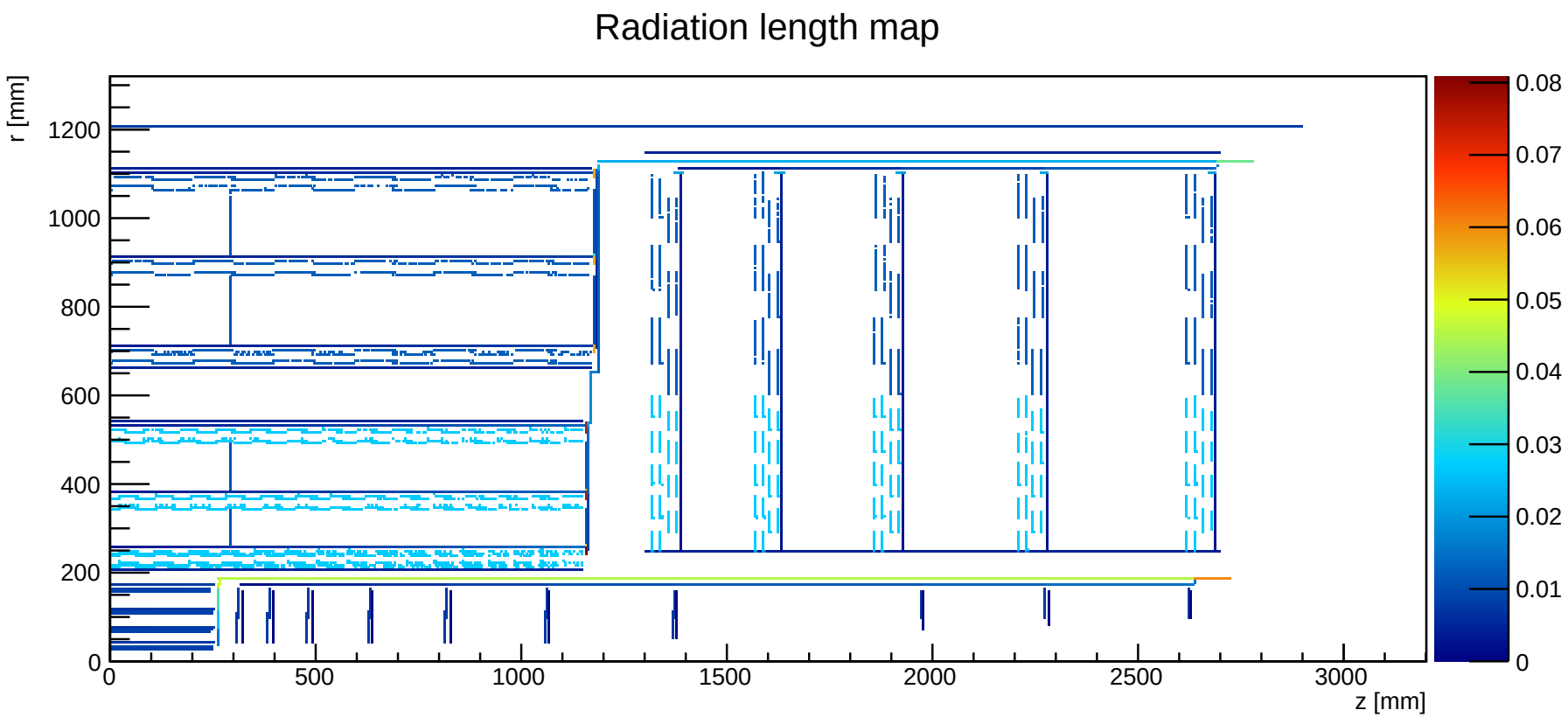

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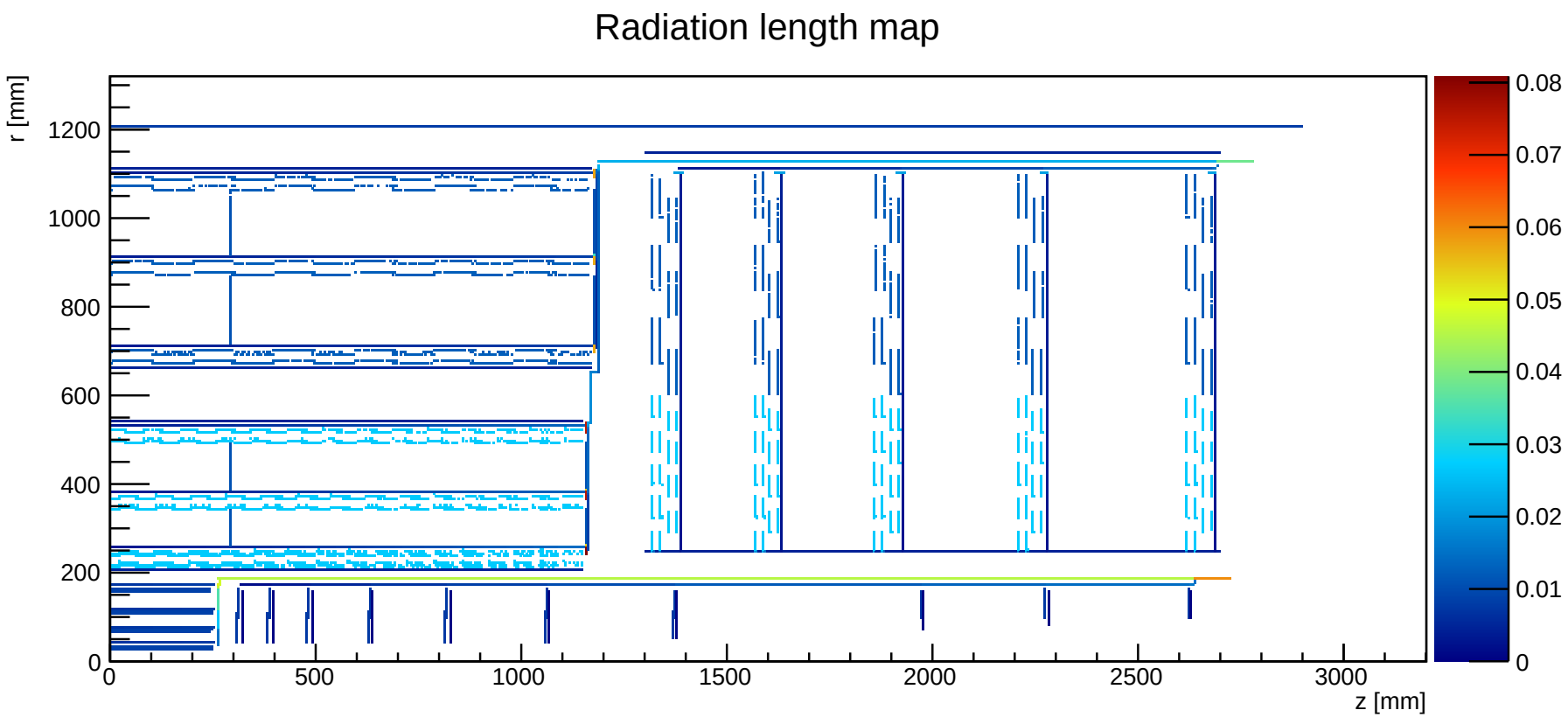

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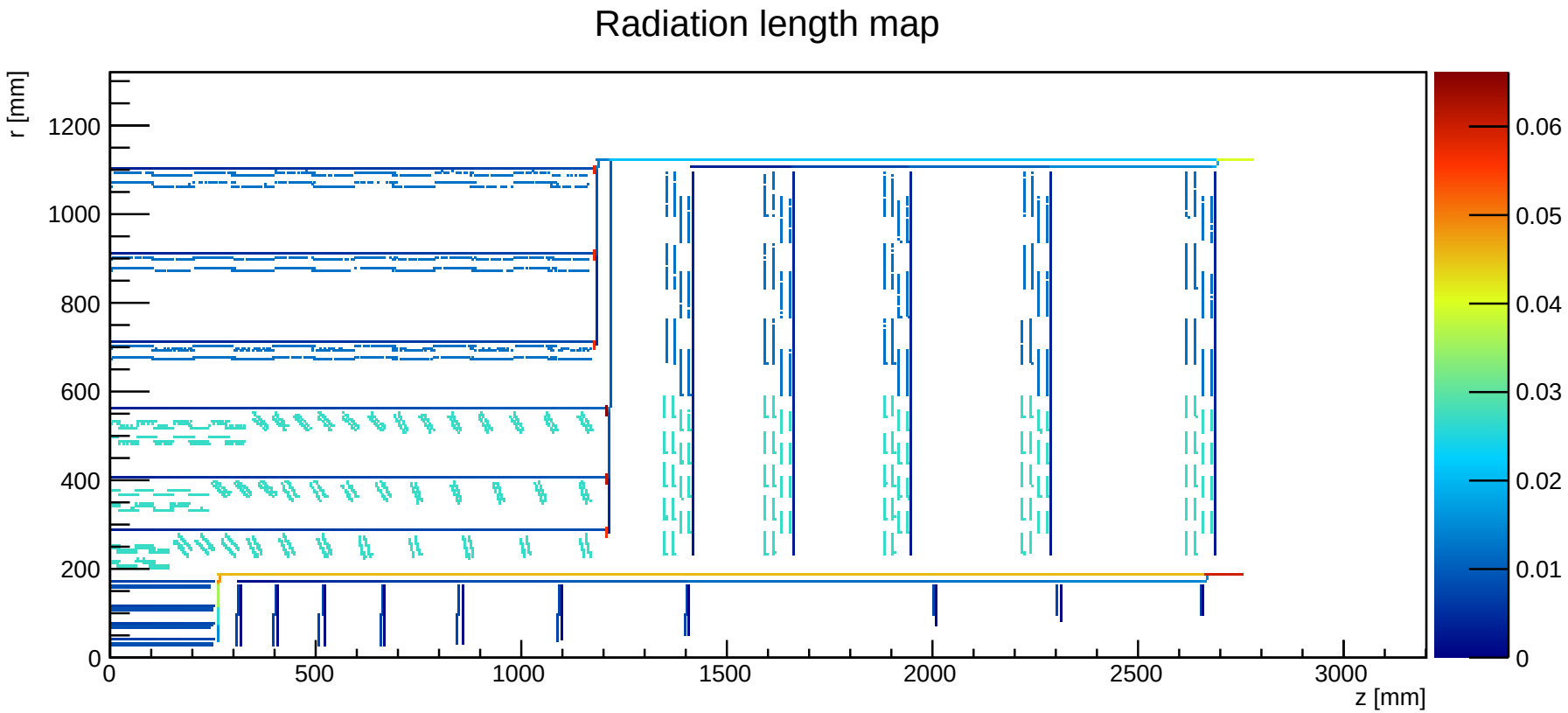
Correct description for tilted modules

- ✓ In old model the cables were distributed inside the modules
  - wrong result in case of tilted modules
- ✓ Now is possible to model this design



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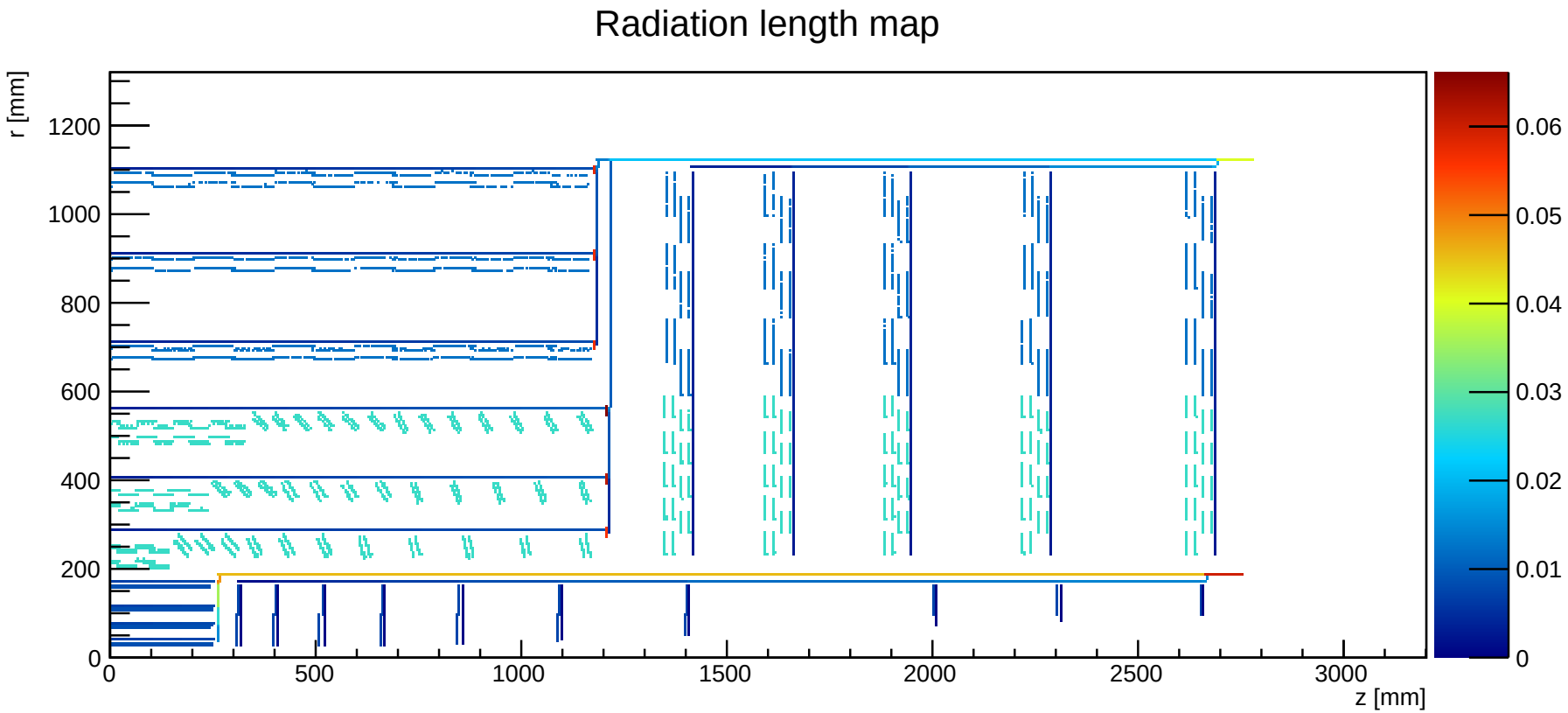
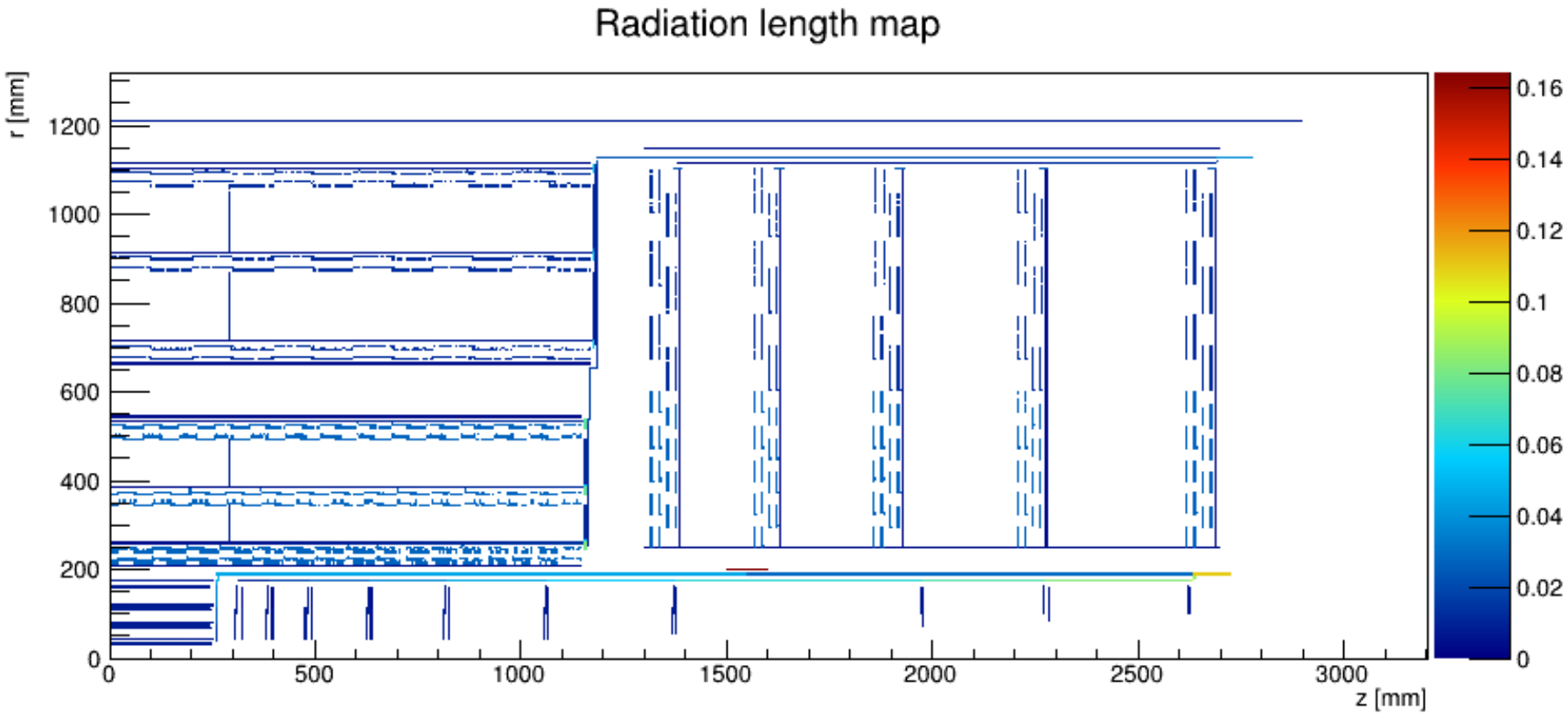


New feature

Model for pixel-like materials

- ✓ All the situations where material conversion are far from the modules
- ✓ For instance twisted pair from modules, electrical optical transducer, and optic fibres after it



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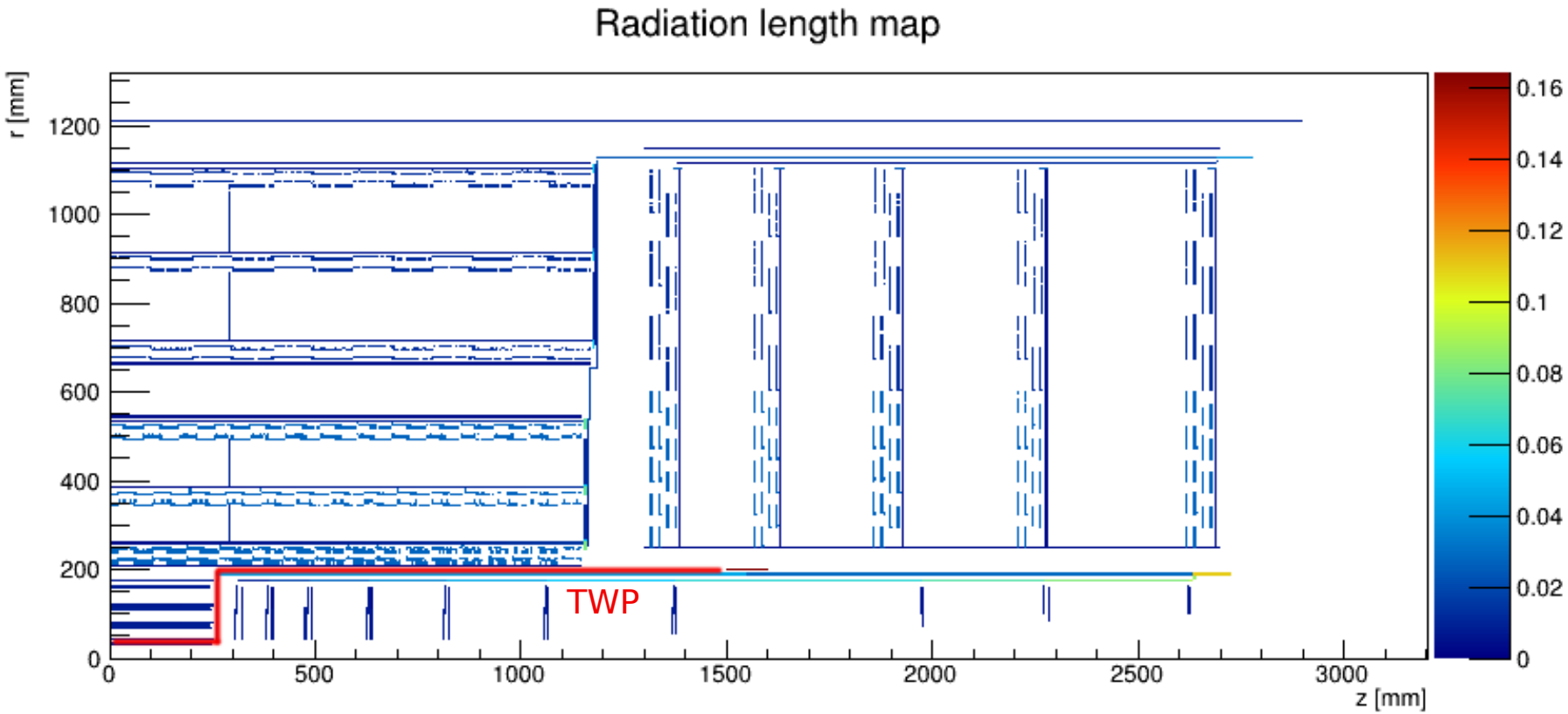

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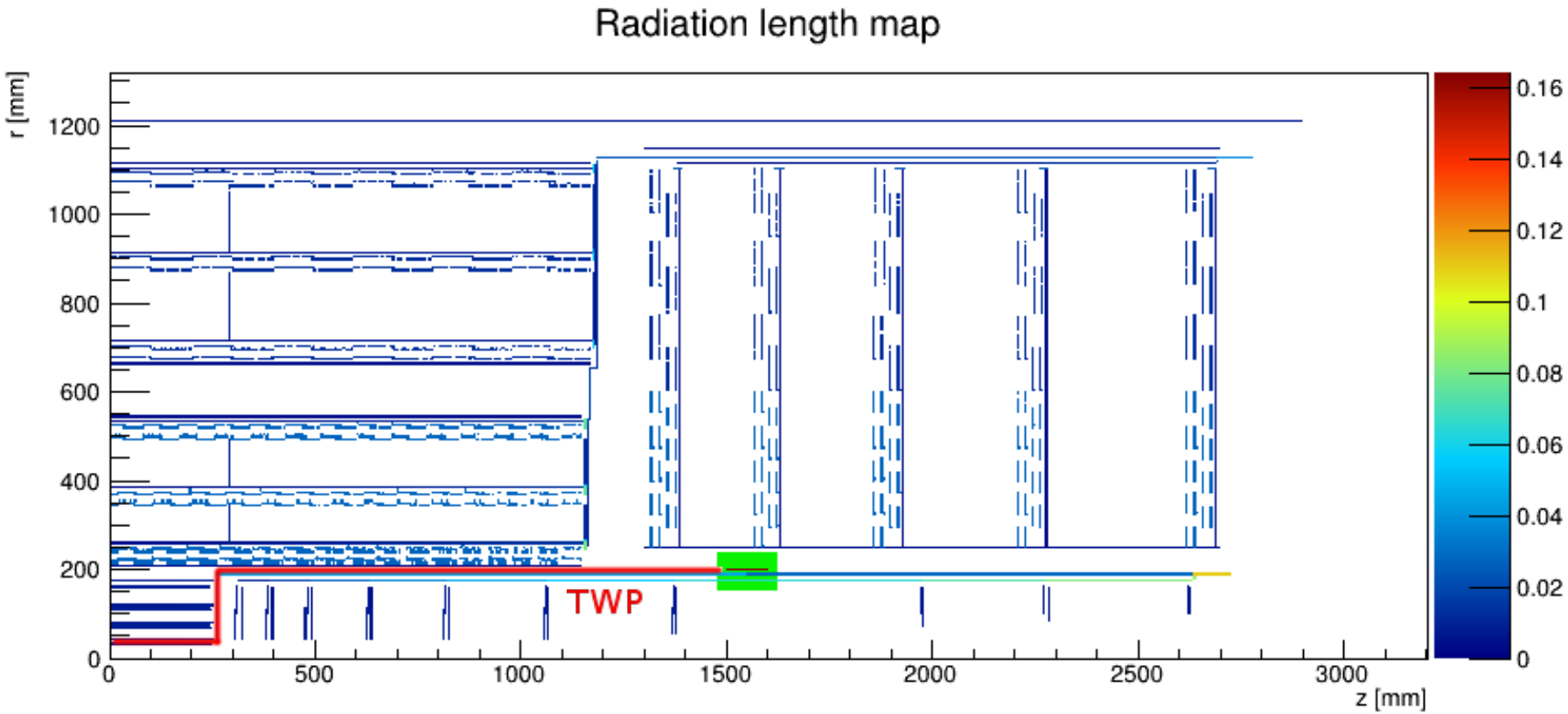

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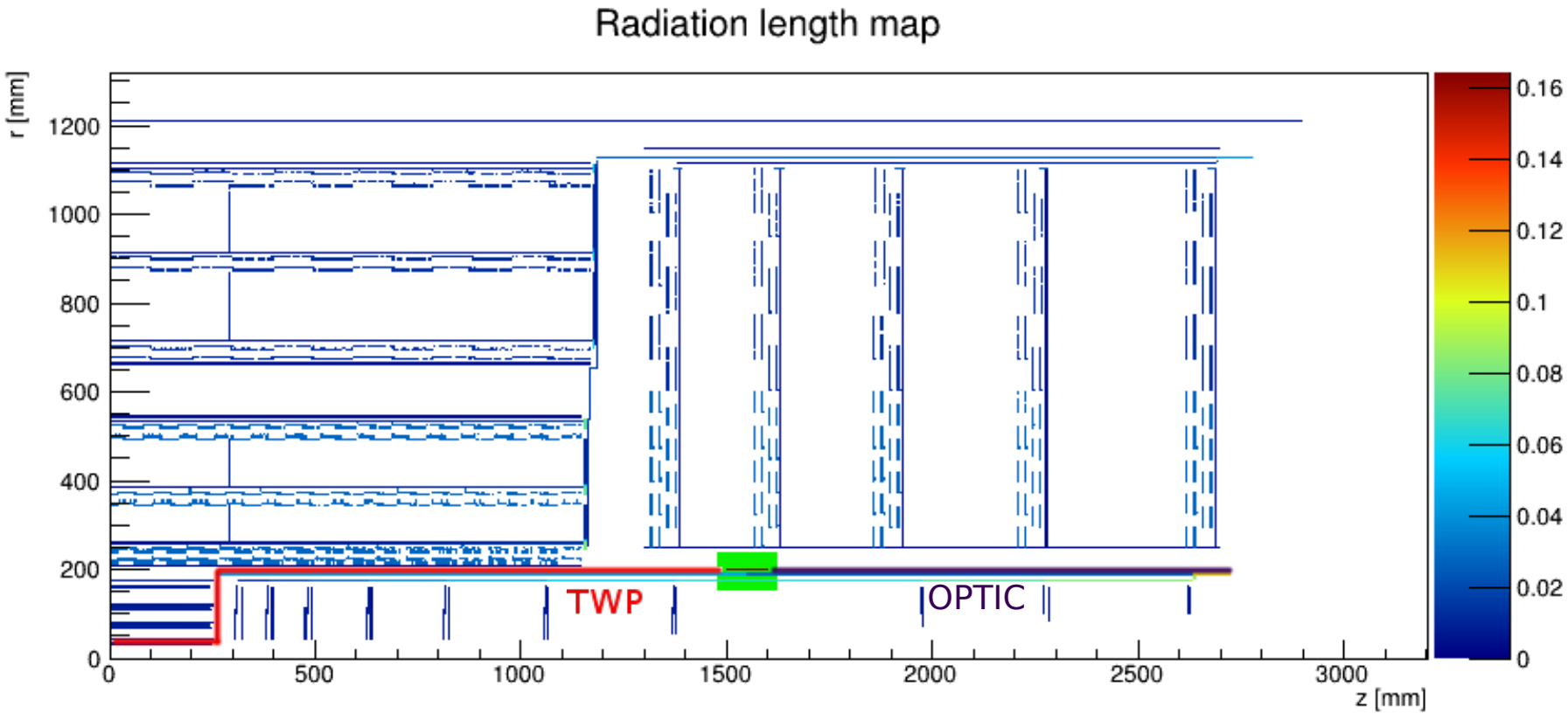

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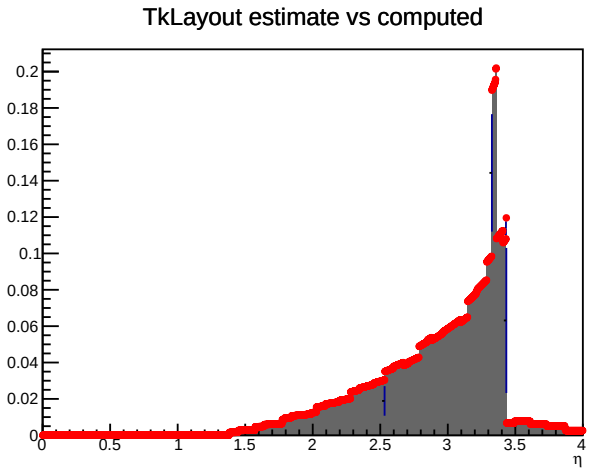
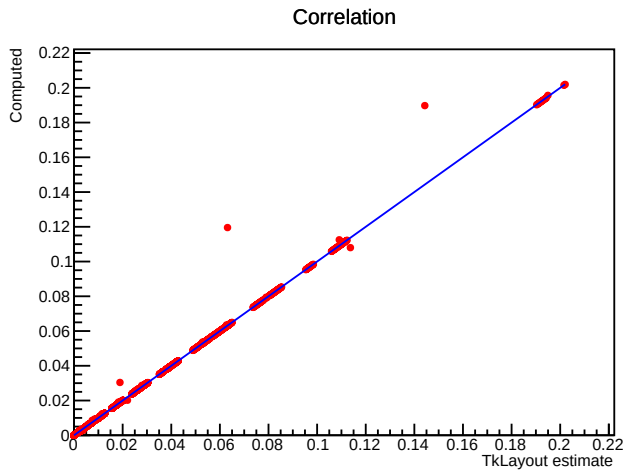
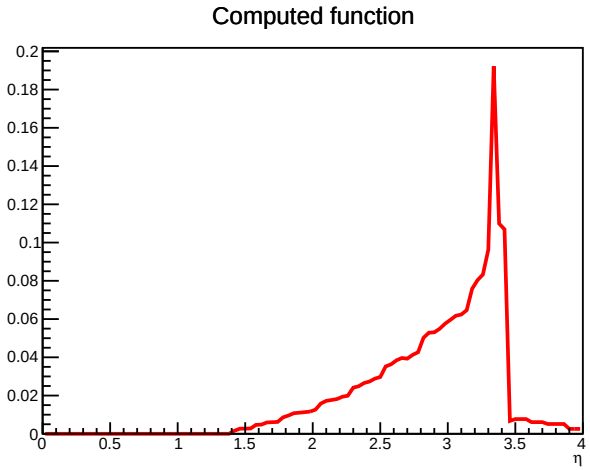
Test15 → tested in all possible inputs

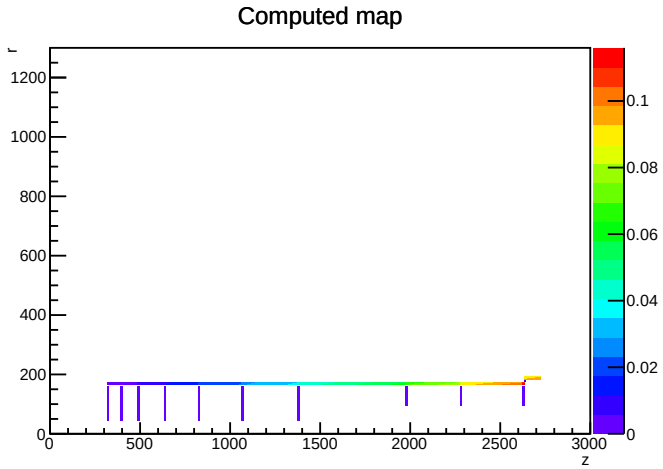
$100g/m$ of Cu in the disk of endcap

- ✓ service true

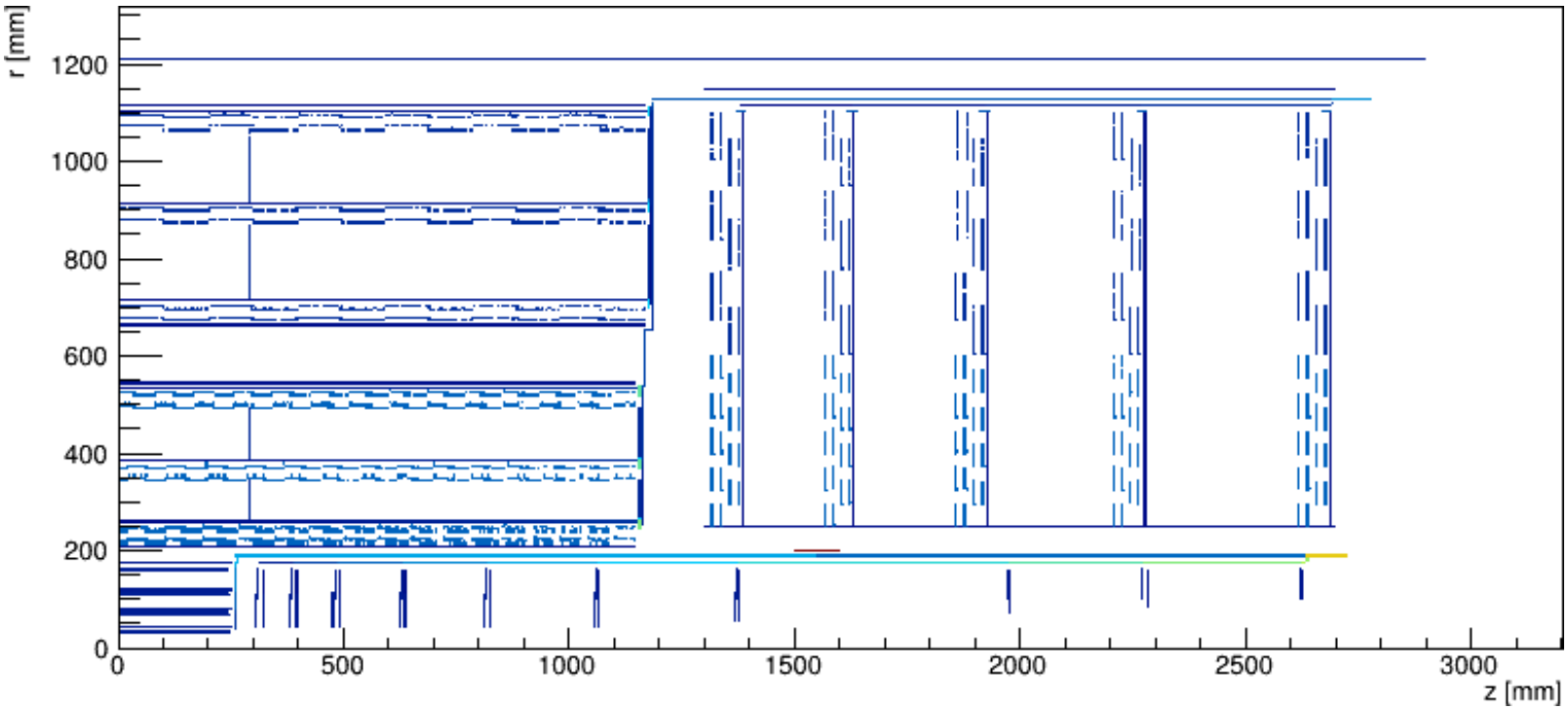








Material destination, with different unit (g, g/m, mm)



Destination

- ✓ In module
- ✓ In rods, a series of modules of barrel with same ϕ
- ✓ In layers/disks

Behavior

- ✓ Locally (also volumes inside module)
- ✓ as a service
  - can be converted in flange or custom position

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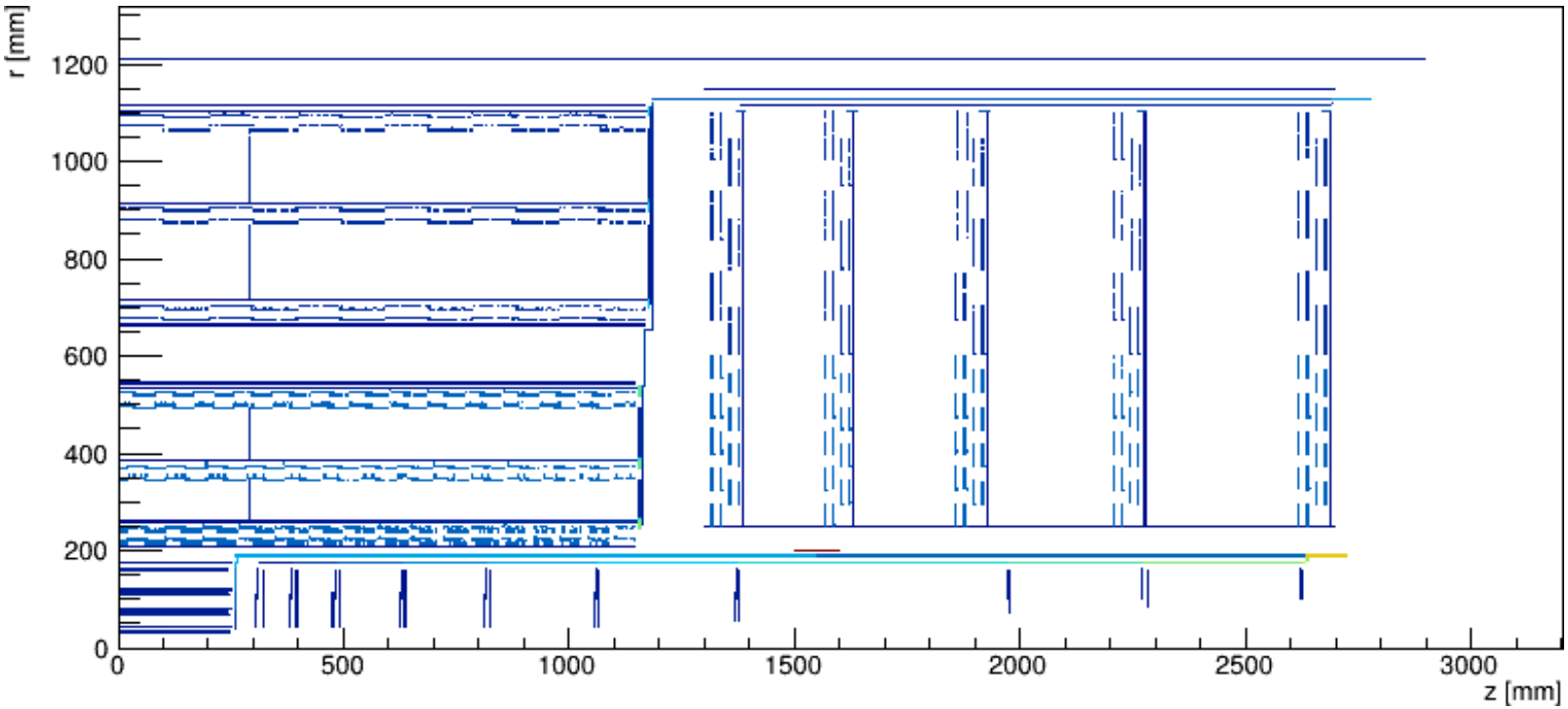

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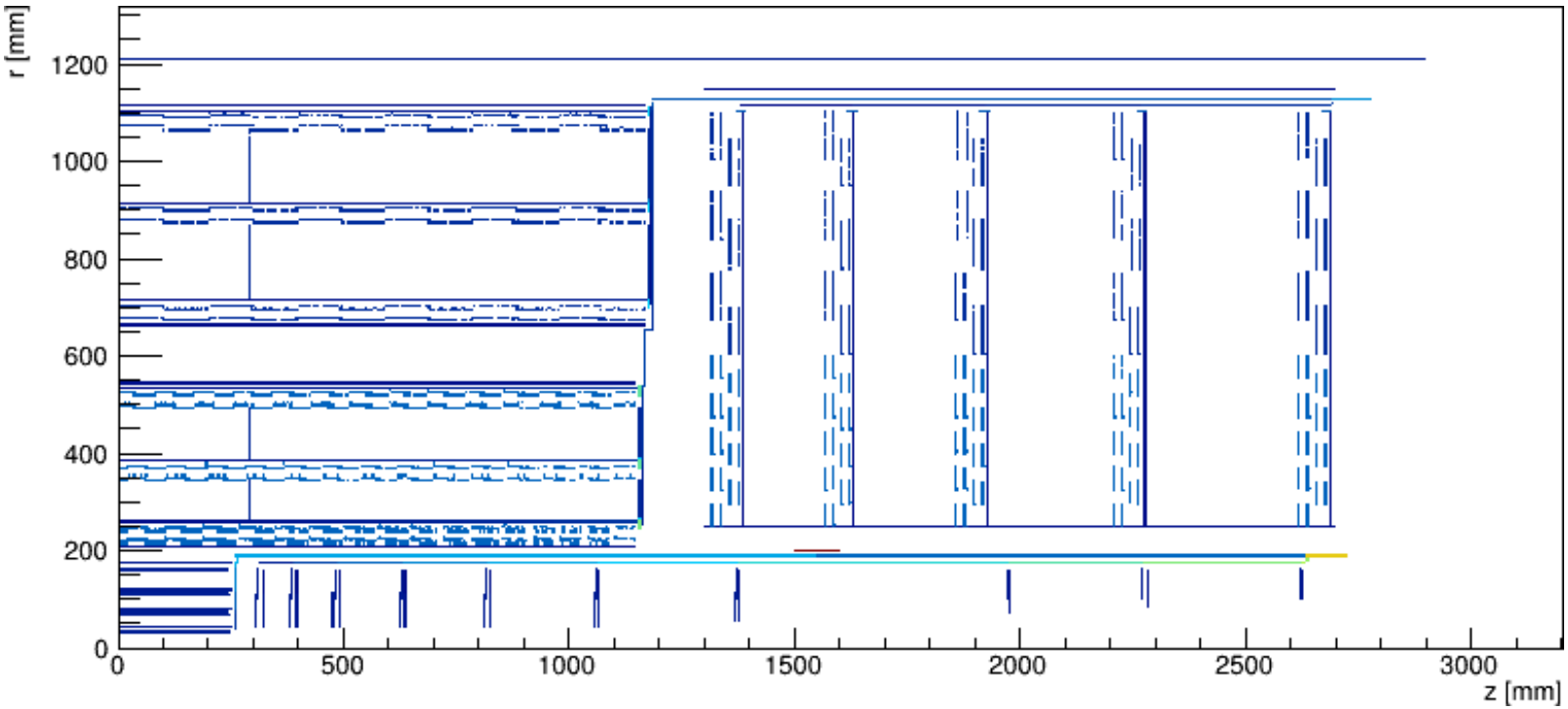

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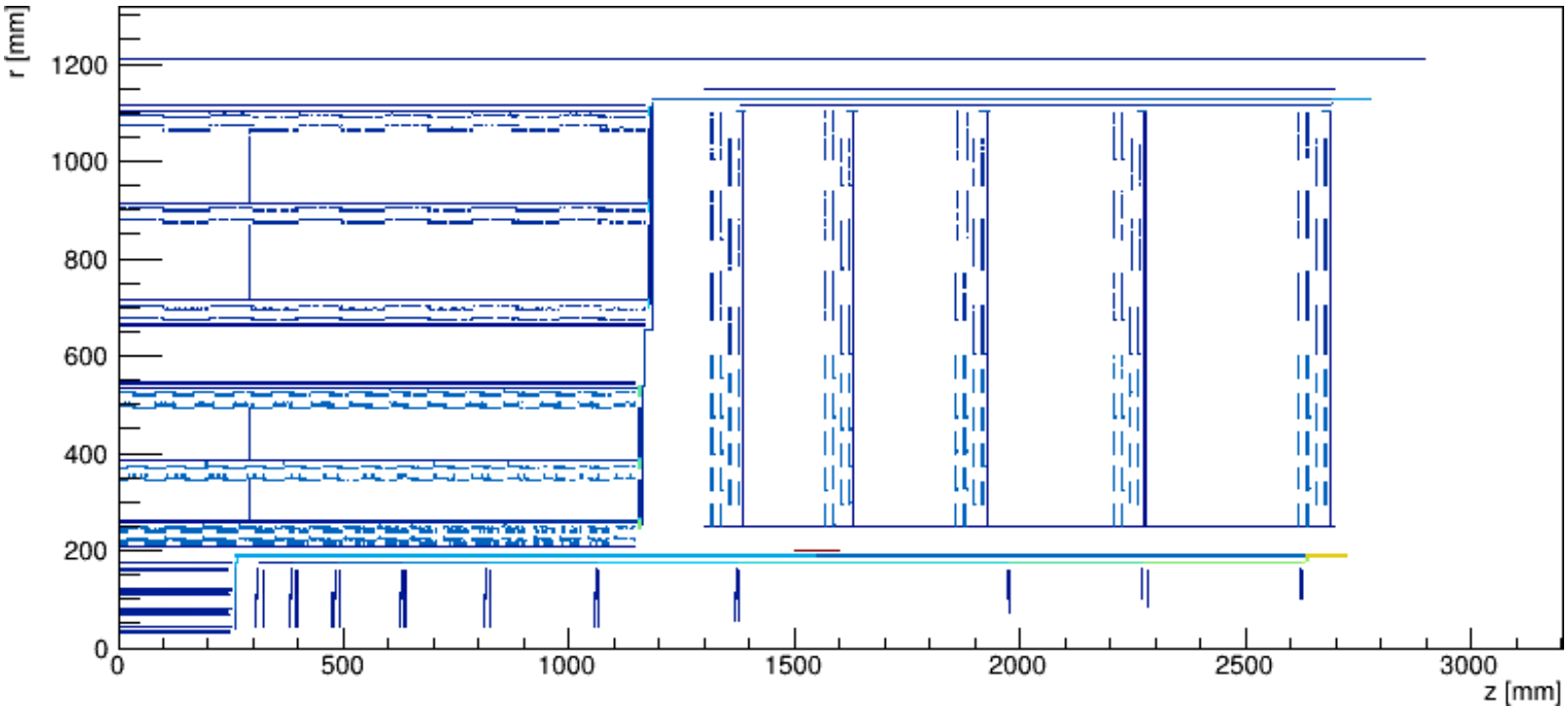

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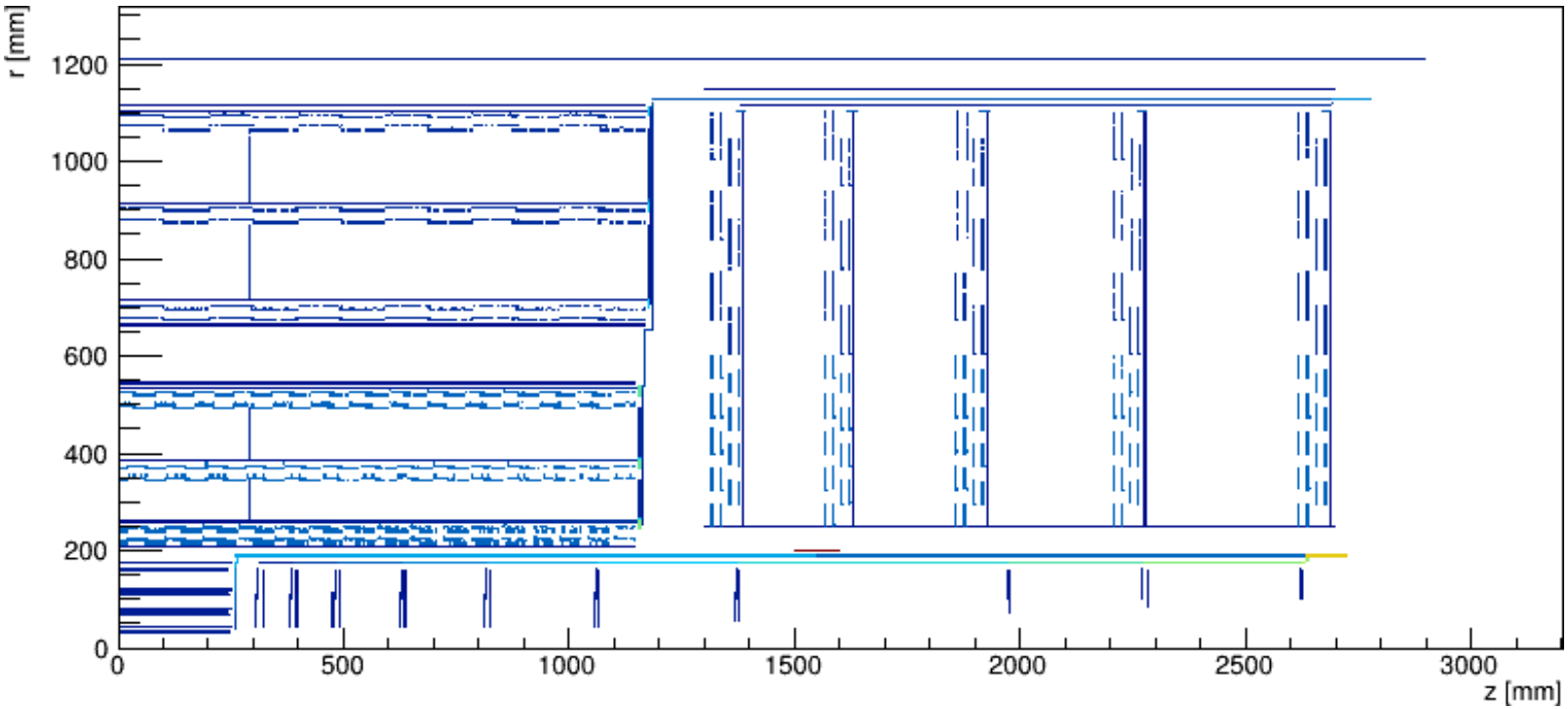

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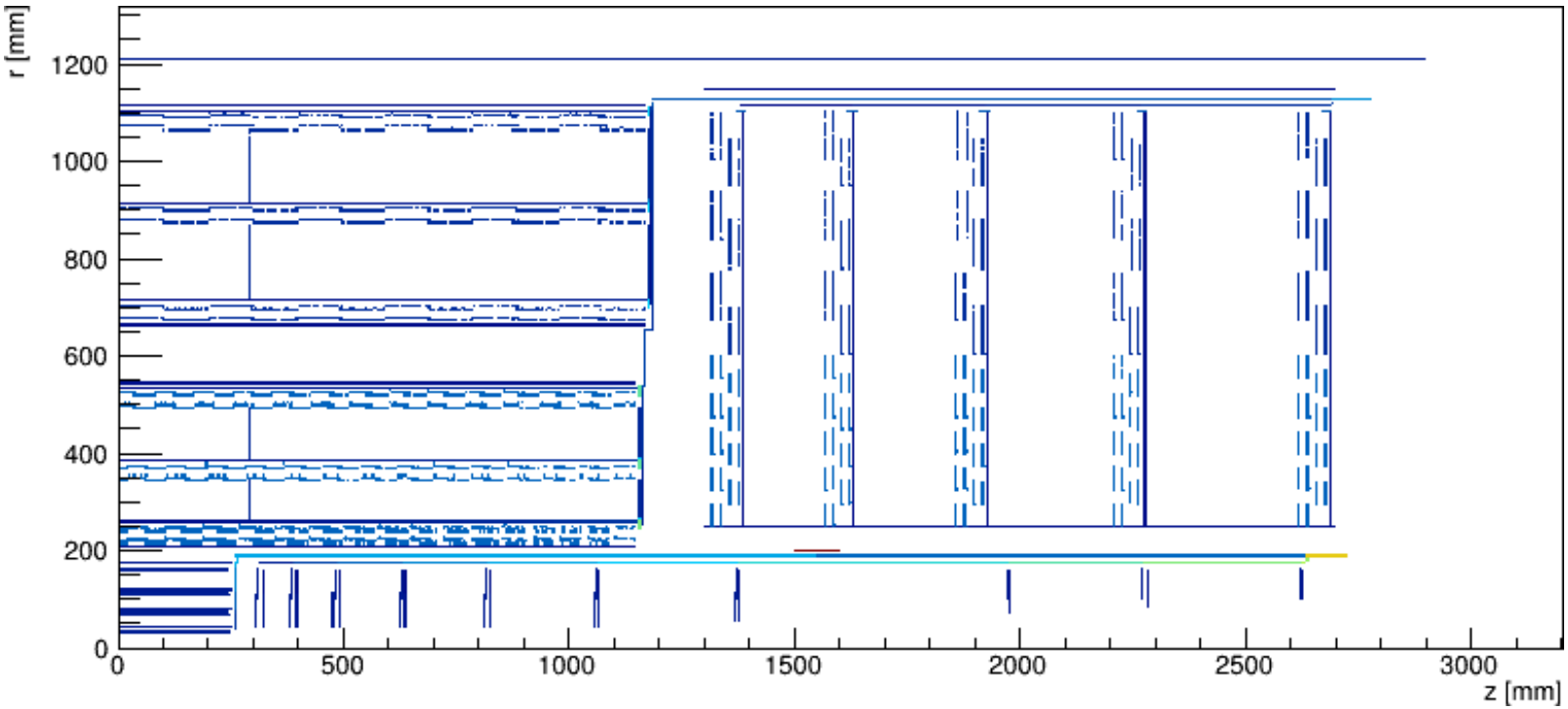

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	Unit=g/m	Unit=mm	Unit=g
Module Service=false	Module $\times$ *moduleLength* No accumulation No conversion Scaling possible	Module $\times$ *moduleSurface* $\times$ ρ (sensor surface) No accumulation No conversion Scaling possible	Module $\times 1$ No accumulation No conversion Scaling possible
Module ring R of N Service=true	Following supports $S_{R+1} \ldots S_i \ldots S_N$ $\times$ *numModules*$_R$ $\times$ *supportLength*$_i$ Accumulation Conversion(1:1 by default, with warning) Scaling possible	Following supports $S_{R+1} \ldots S_i \ldots S_N$ $\times$ *numModules*$_R$ $\times$ *supportSurface*$_i$ $\times$ ρ Accumulation Conversion(1:1 by default, with warning) Scaling possible Deprecated warning	Error
Rod(barrel) Service=false	All supports $S_1 \ldots S_i \ldots S_N$ $\times$ *numModules*$_1$ $\times$ *supportLength*$_i$ No accumulation No conversion Scaling not possible	All supports $S_1 \ldots S_i \ldots S_N$ $\times$ *supportSurface*$_i$ $\times$ ρ No accumulation No conversion Scaling not possible	All supports $S_1 \ldots S_i \ldots S_N$ $\times$ *numModules*$_1$ $\times \frac{\text{supportLength}_i}{\sum_{j=1}^{N} \text{supportLength}_j}$ No accumulation No conversion Scaling not possible
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Example configuration

.../Materials/ptPS

```
Materials module-ptPS {
  type module

  // Default sensor:
  ReferenceSensor 1 {
    numStripsAcross 960
    numSegments 32
  }
  ReferenceSensor 2 {
    numStripsAcross 960
    numSegments 2
  }

  // Sensor
  Component {
    componentName Sensor
    service false
    scaleOnSensor 0
    targetVolume 1
    Element {
      elementName SenSi
      quantity 0.2
      unit mm
    }
  }


...
```

.../Materials/rodPtPS

```
Materials rodPtPS {
  type rod

  Component {
    componentName Cooling
    service true
    scaleOnSensor 0
    Element {
      elementName Steel
      quantity 7.860696517
      unit g/m
    }
    Element {
      elementName CO2
      quantity 1.791044776
      unit g/m
    }
  }


...
```

Example configuration

.../Conversions/flange

```
Station {
  stationName flange
  type flange
...
  Conversion {
    Input {
      Element {
        elementName Cu_MV
        quantity 10
        unit g/m
      }
    }
    Output {
      Element {
        elementName Cu
        quantity 10
        unit g/m
        service true
      }
      Element {
        elementName Cu
        quantity 0.423
        unit g
        service false
      }


...
```

.../Conversions/endcap1

```
Station {
  stationName endcap1
  type second

  minZ 1500
  maxZ 1600

  Conversion {


...
```

Conclusions

- ✓ new material model finished
- ✓ model validated
- ✓ detailed radiation maps

Next steps

- ✓ develop configuration files for pixel and inspect possibilities
- ✓ tracking & track-trigger performance with tilted barrel (within tkLayout)
- ✓ study of pixel (vertex resolution & impact of material on tracking in general)
- ✓ export of tilted barrel to CMSSW (allows studies in full simulation)

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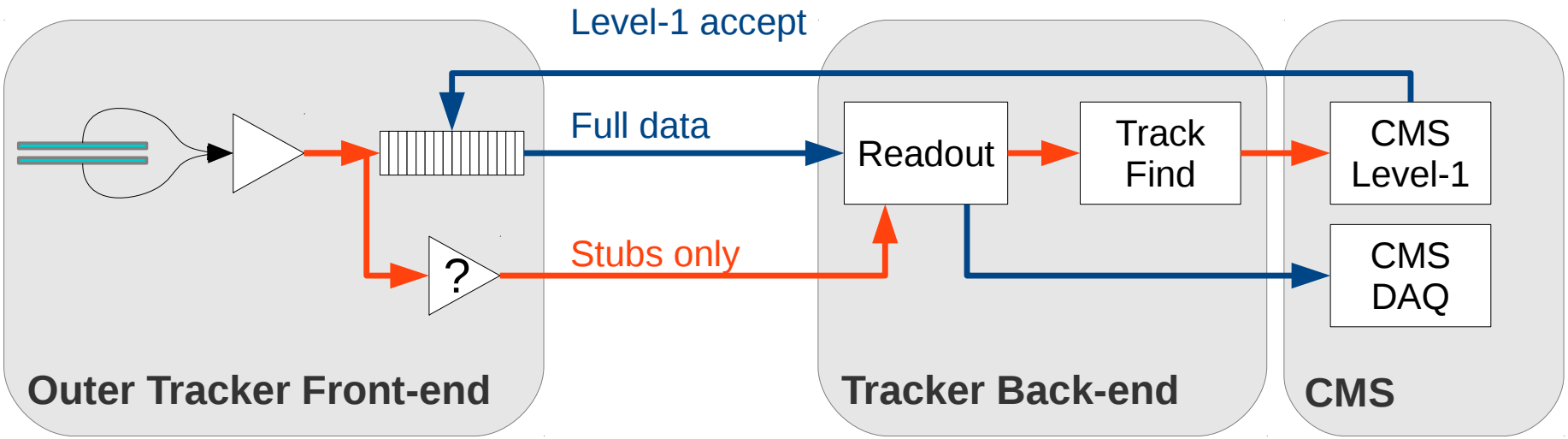
SO LONG,

AND THANKS FOR ALL THE FISH.

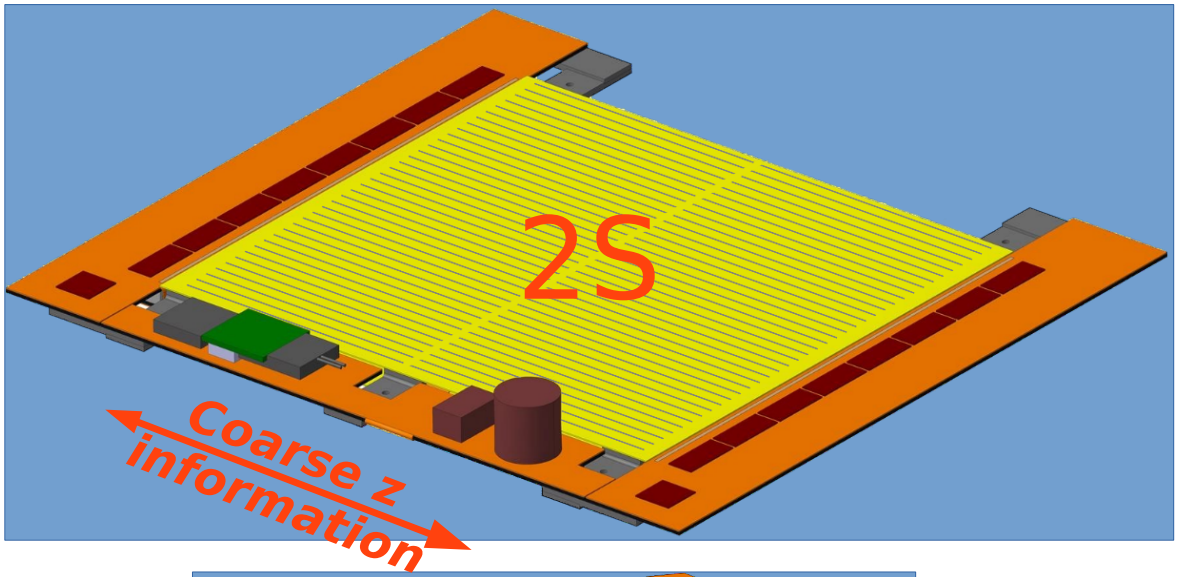
Outer tracker Bandwidth



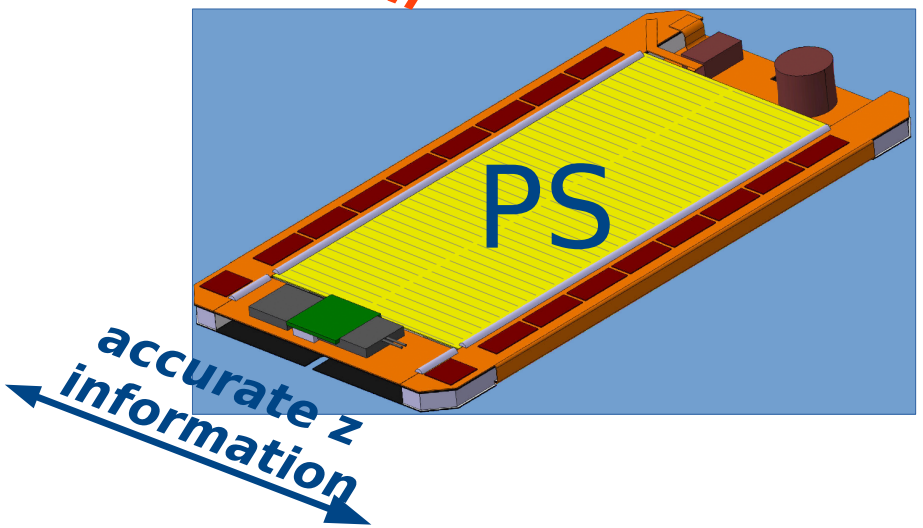
@ **40 MHz** – Bunch crossing
@ **750 kHz** – CMS Level-1 trigger

Modules

2 Strip sensors
Strips: 5 cm × 90 µm
Strips: 5 cm × 90 µm
P = 2.7 W
~ 92 cm^2 active area
For r > 40 cm



Pixel + **S**trip sensors
Strips: 2.5 cm × 100 µm
Pixels: 1.5 mm × 100 µm
P = 5.0 W
~ 44 cm^2 active area
For r > 20 cm



Pixel Bandwidth

Bandwidth

Phase-1

Rate → **400 MHz/cm²**

L1 rate **100 kHz**

x 25~50

x 5

x 5~10

HL-LHC

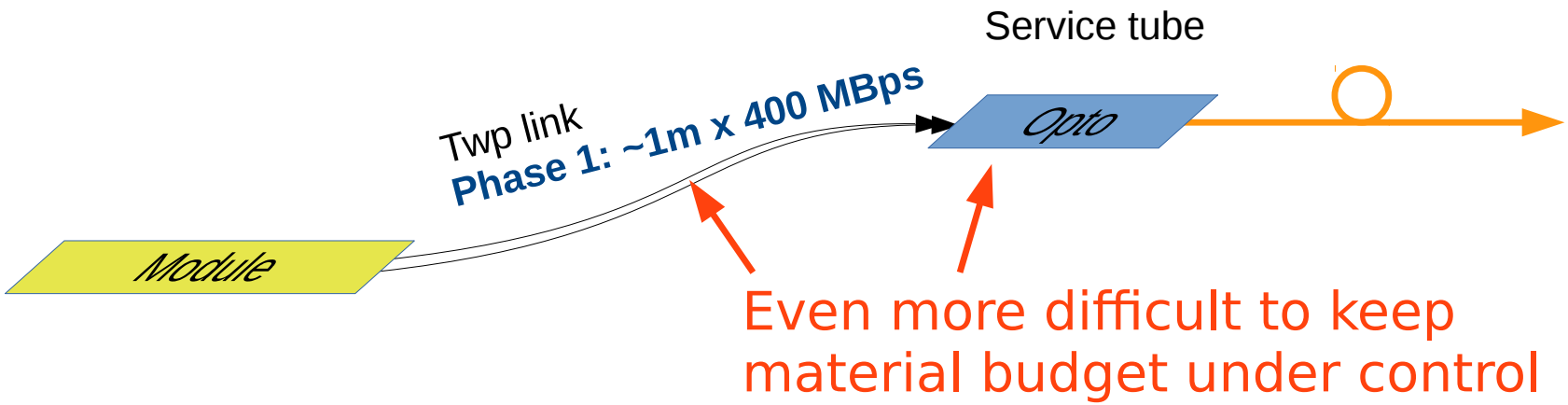
Rate → **2 GHz/cm²**

L1 rate **750 kHz**

Optical on-board readout not possible:

- Rad-hardness
- Material/space

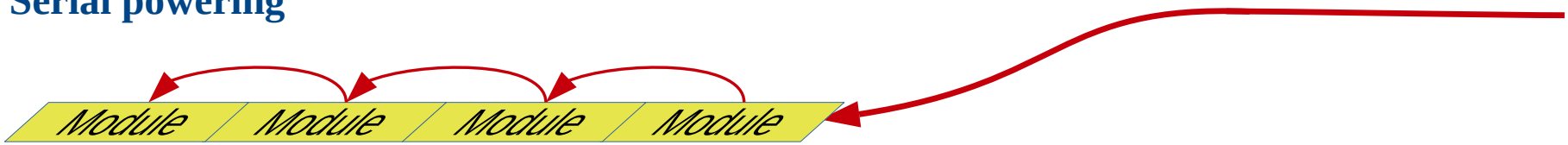
=> Electrical links to opto links



Pixel Powering

Target: O(0.5) W/cm^2
Traditional inductor-based on-board DC/DC not possible:
Possible options:

Serial powering



More complex schemes