Porting the fully-projective Hidra-like dual-readout calorimeter to k4geo

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Introduction

- A DD4hep full-simulation of the IDEA dual-readout calorimeter using the capillary tubes technology has been developed in recent times by myself and Andreas Centeno (Sussex University)
- I am currently working on porting this geometry to the FCC framework (specifically k4geo)
- This change in the IDEA full simulation is part of a major upgrade to combine a dual-readout crystal section with the Hidra-like dual-readout calorimeter → the result will be named IDEA_o(ption)2
- In the following I will describe the new tubes-based dual-readout calorimeter, the subdetector of IDEA and the work plan towards IDEA_o2

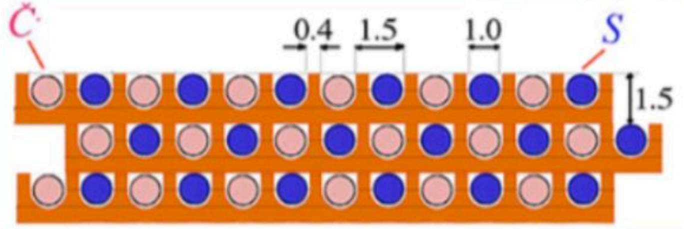
The capillary tubes technology

- The capillary tubes technology is the baseline choice of INFN and its European Partners to design and build a fully projective optical fiber dual-readout calorimeter

- The problem: to insert optical fibers inside the calorimeter module/towers, one would have to drill ~1-mm-thick holes over 2/2.5 m long metal absorbers (copper, brass, …) → impossible

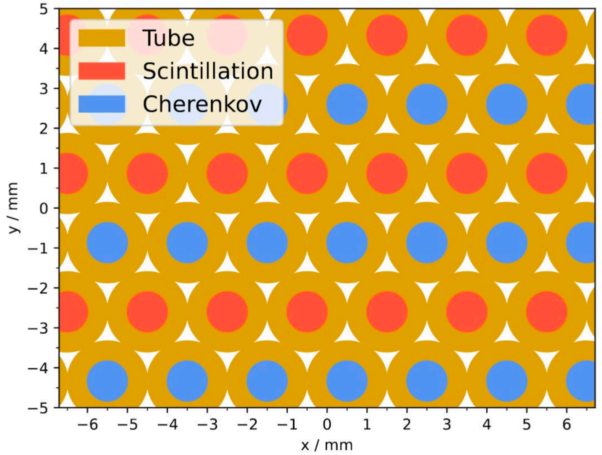
  - The RD52 Collaboration used the stacking technique. Copper plates were extruded with U-shaped incisions to house optical fibers and stacked vertically to form a "module"

    → technically possible but time consuming and very imprecise



- The solution: instead of machining the absorber buy metal capillary tubes industrially produced, position optical fibers inside, and glue them to form a calorimeter module/tower

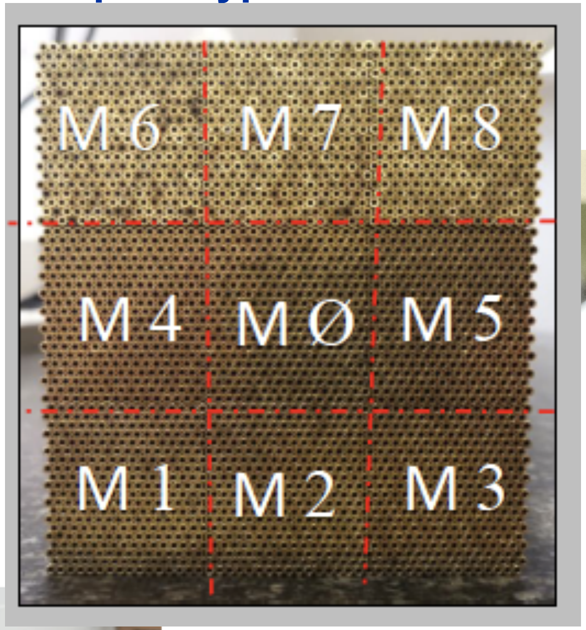
  - Cheaper, faster and more precise solution w.r.t. the RD52 choice



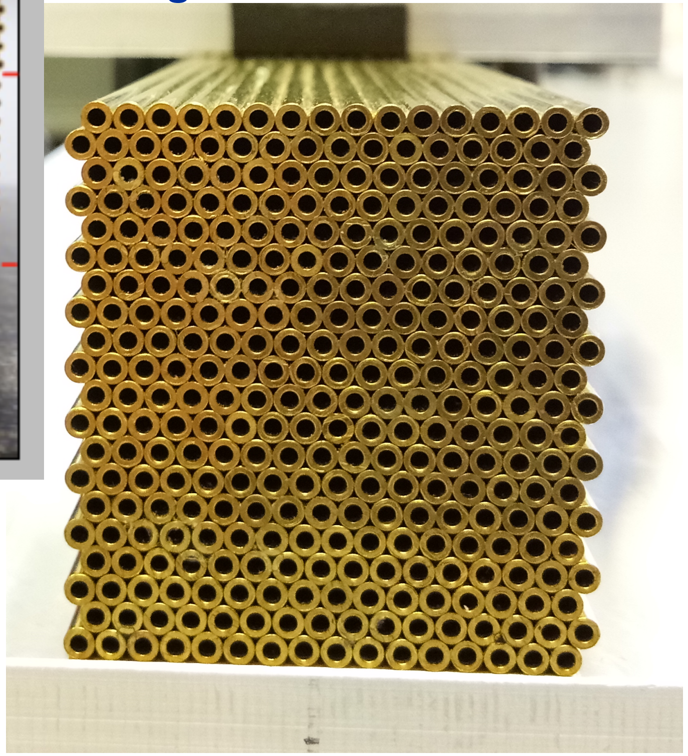
The first capillary tubes prototype

- In 2020/2021 the first prototype exploring this technology was built and beam tested at CERN
  - EM dimensions of $10 \times 10 \times 100$ cm^3
  - Brass capillary tube outer diameter of 2 mm and inner diameter of 1.1 mm. 1-mm-thick fibers.
  - Simulation validated for electromagnetic showers [Article]

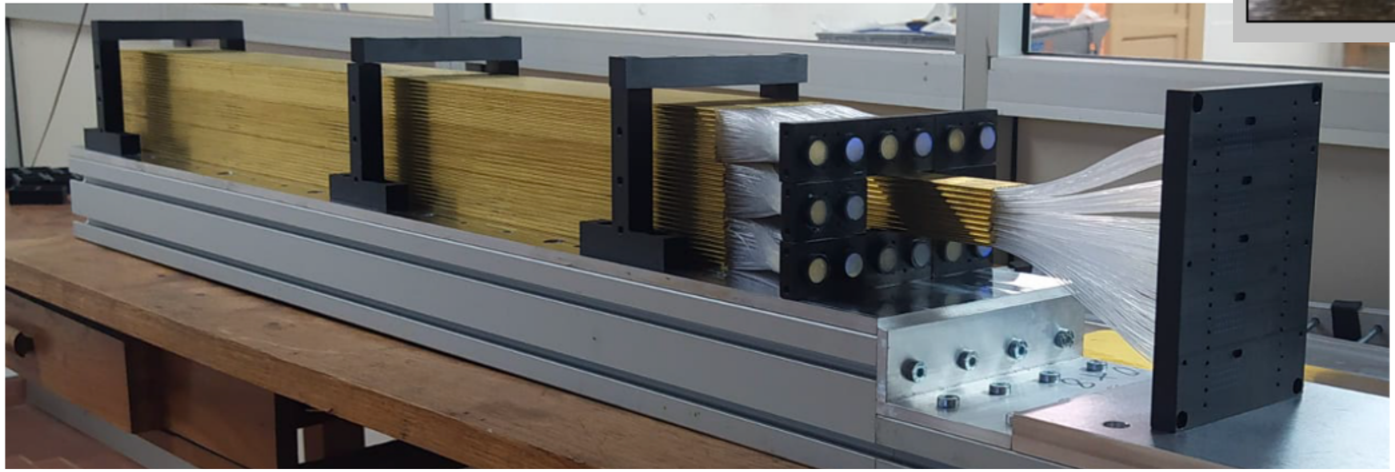
Full prototype - 9 towers



A single tower

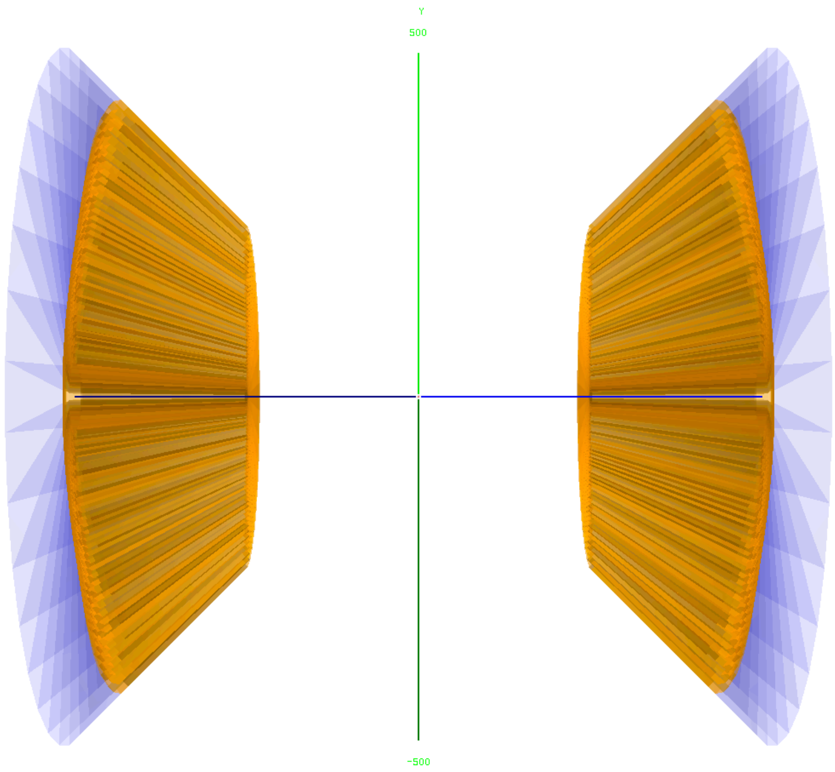


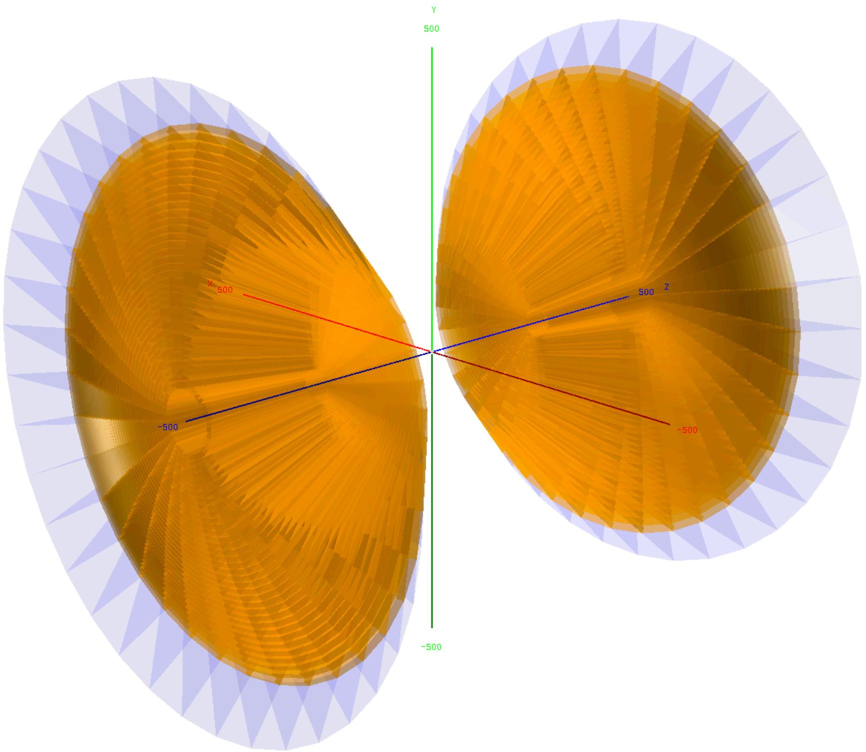
Prototype rear end



DD4hep endcap geometry implementation

- The Hidra-like projective endcap geometry was created over this summer
- For a detailed description see presentation1, presentation2

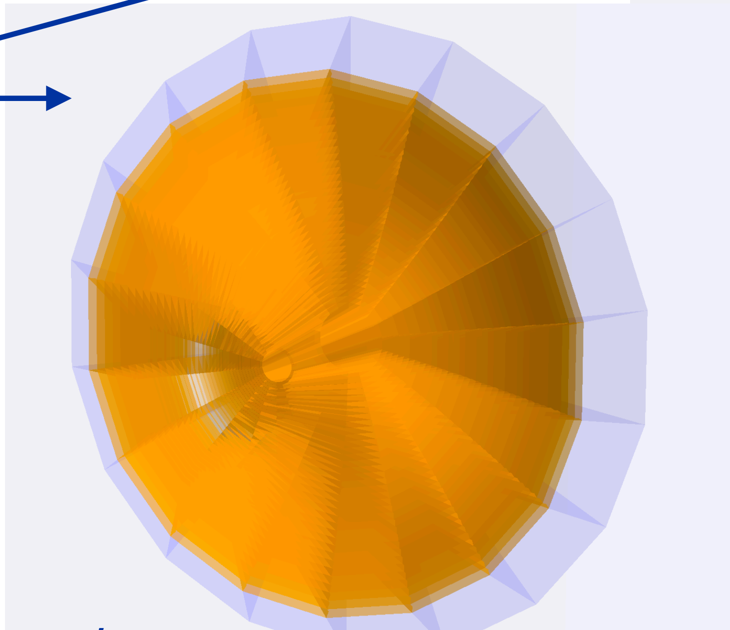




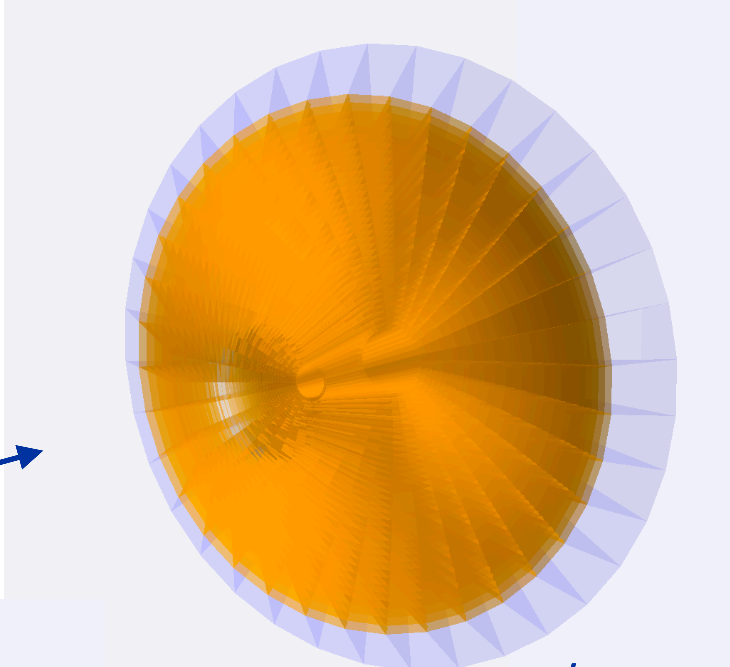
Modularity

- All the geometry custom parameters are encapsulated in the XML description file

```xml
<define>
  <constant name="world_side"  value="6*m"/>
  <constant name="world_x"     value="world_side/2"/>
  <constant name="world_y"     value="world_side/2"/>
  <constant name="world_z"     value="world_side/2"/>
  <constant name="innerRadius"value="2.5*m"/>
  <constant name="towerHeight"value="2.5*m"/>
  <constant name="NbOfZRot"    value="36"/>
  <constant name="TubeRadius" value="1.0*mm"/>
  <constant name="CladRadius" value="0.5*mm"/>
  <constant name="CoreRadius" value="0.45*mm"/>
</define>
```



18 ϕ-slices



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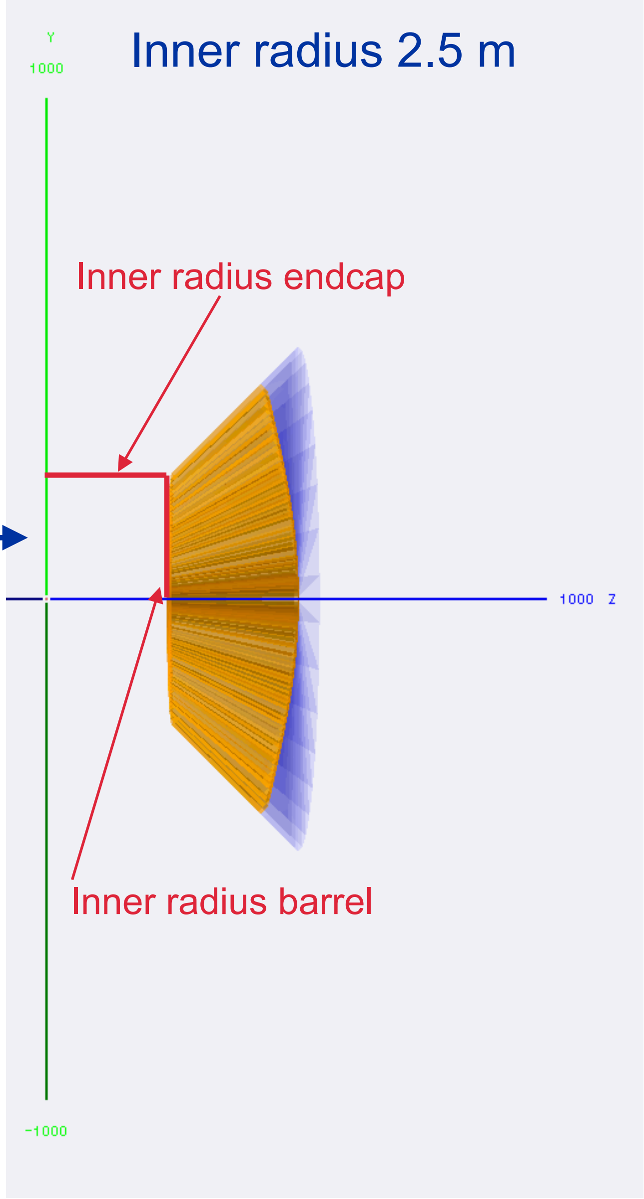
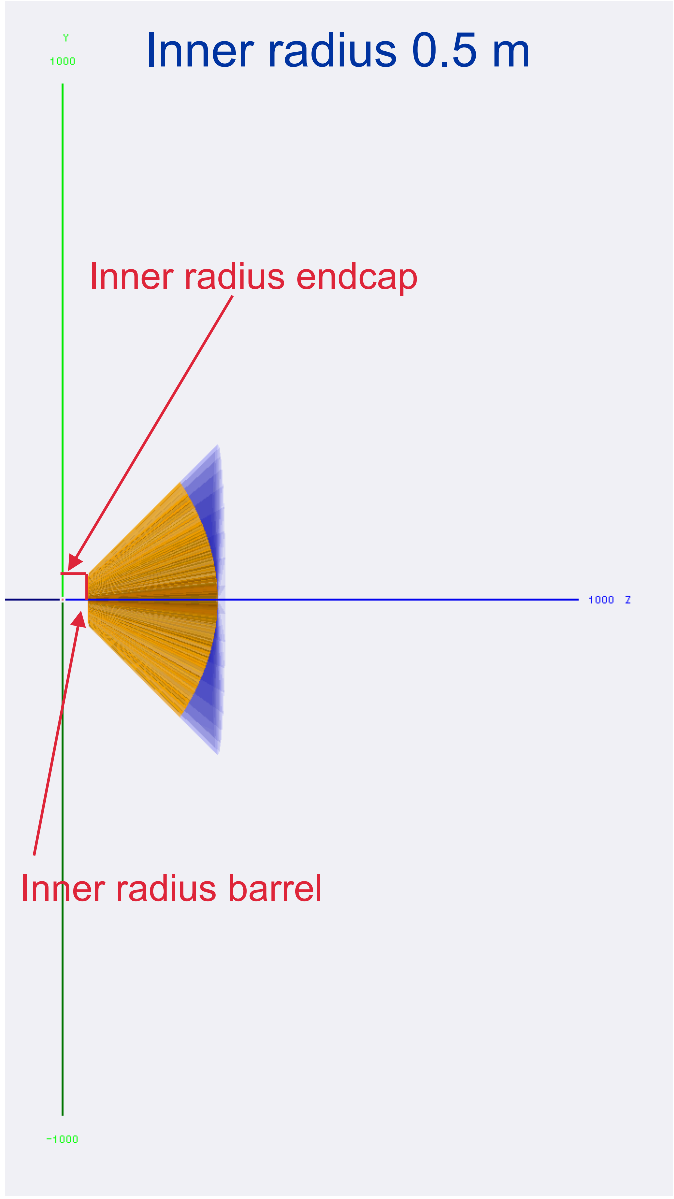
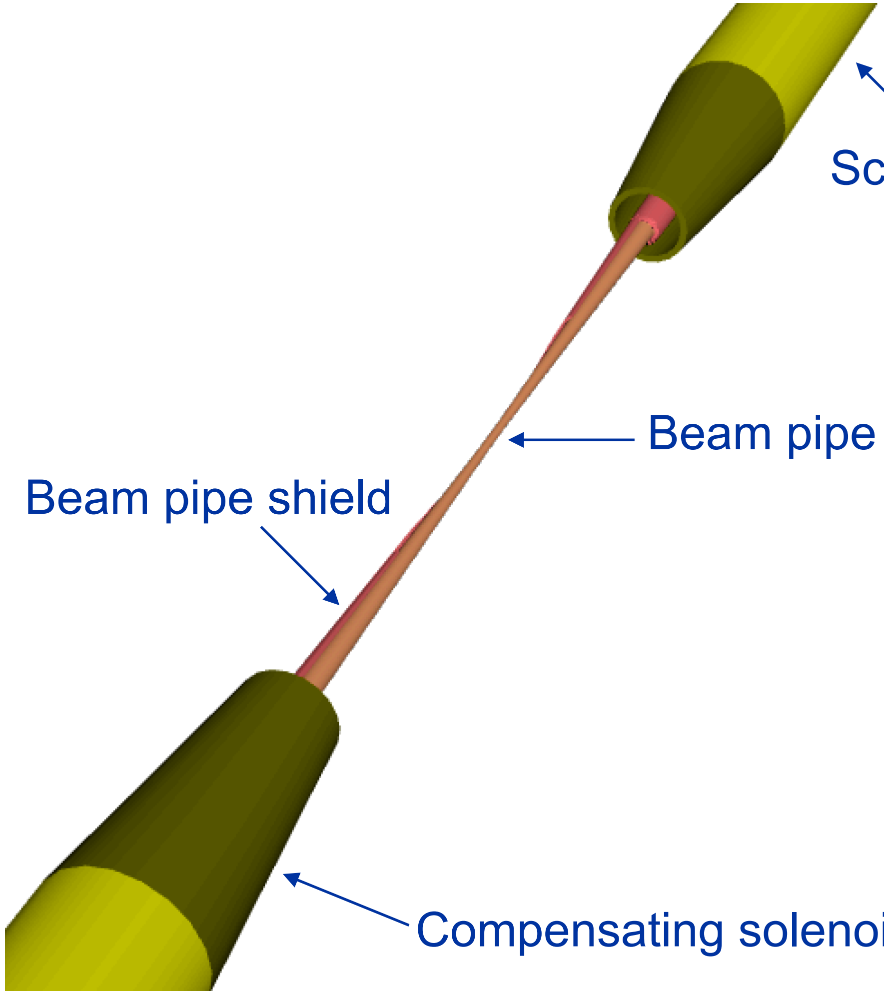
```

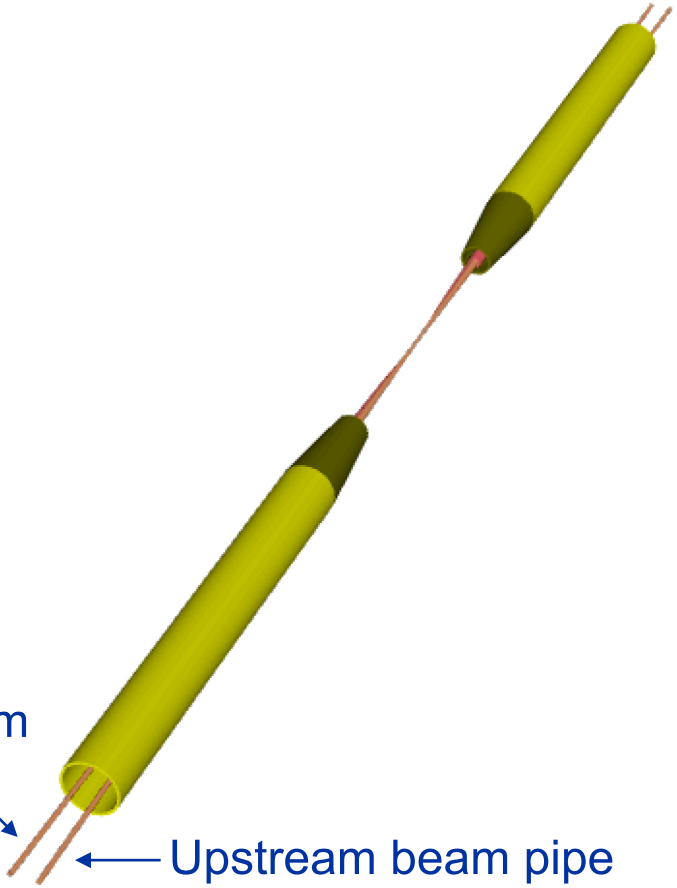
- The only geometry constrain: the barrel inner radius and the endcap inner radius are identical or, equivalently, the endcap starts at $\theta = \pi/4$





IDEA_option2 geometry (PRELIMINARY)





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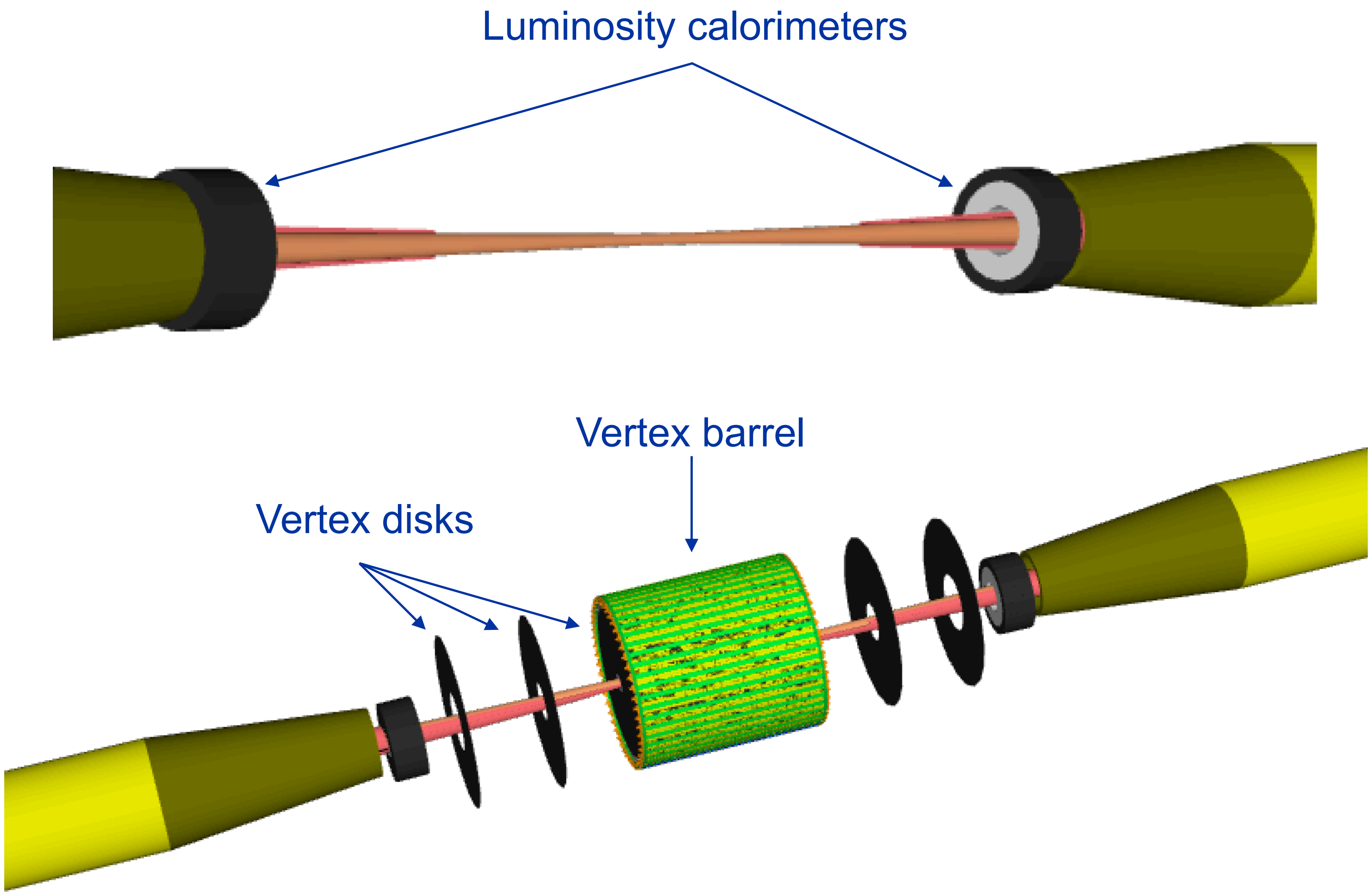

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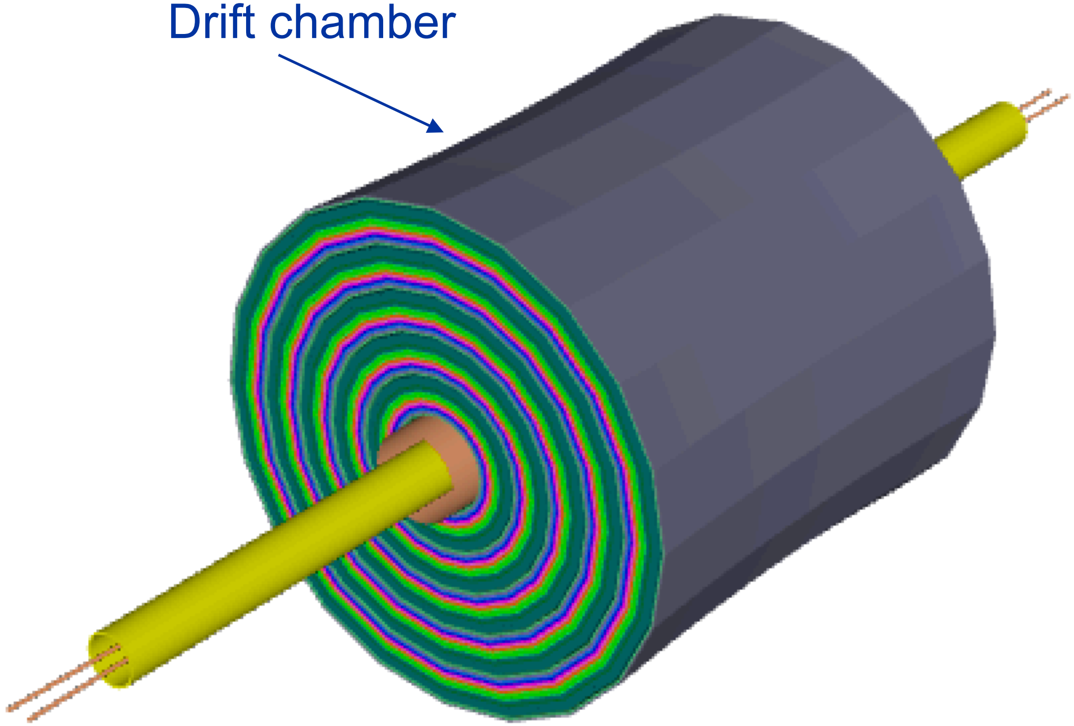

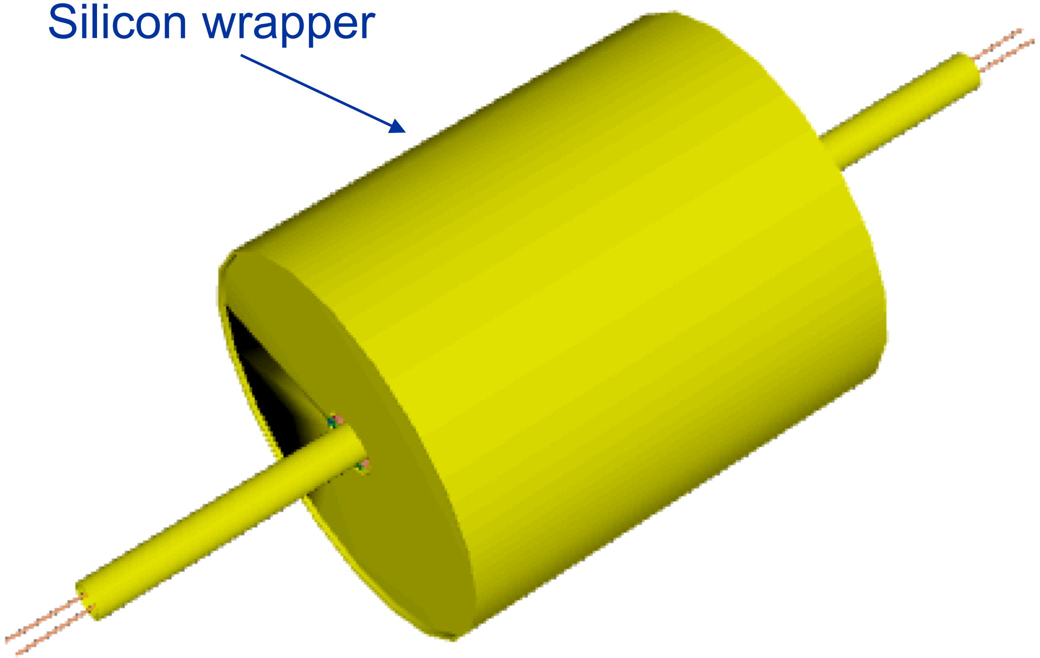

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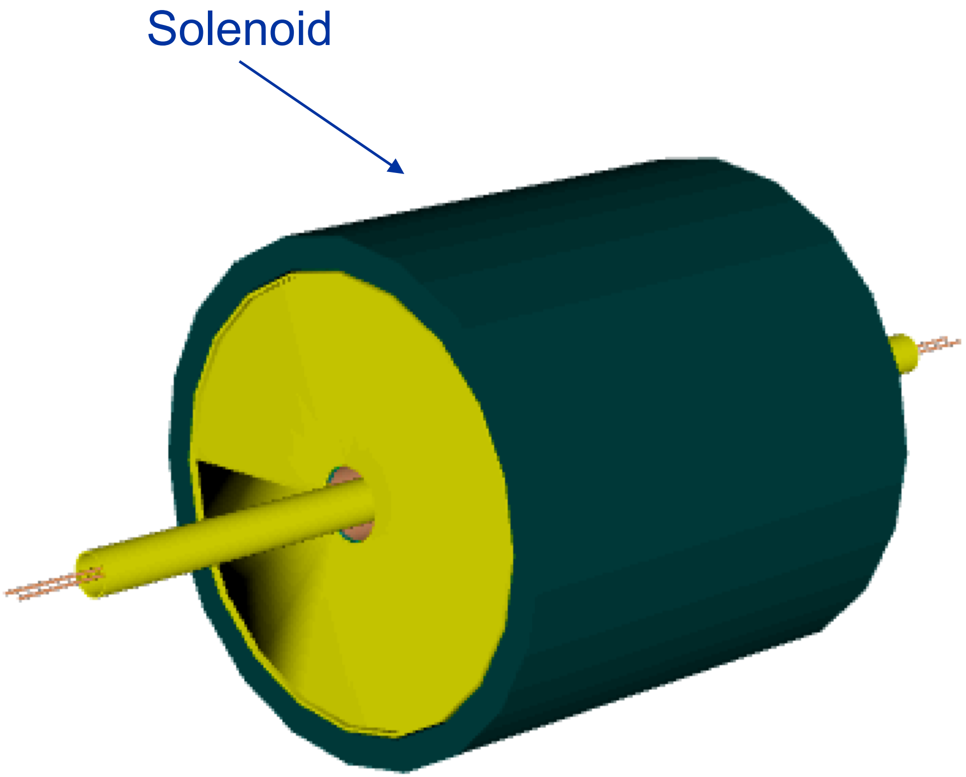

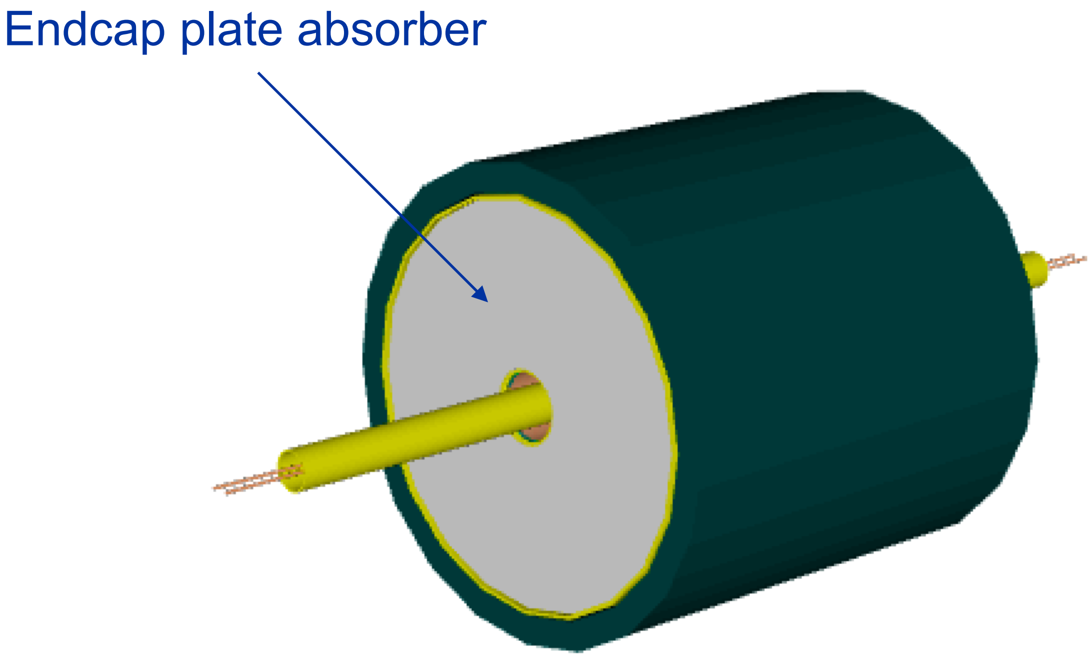

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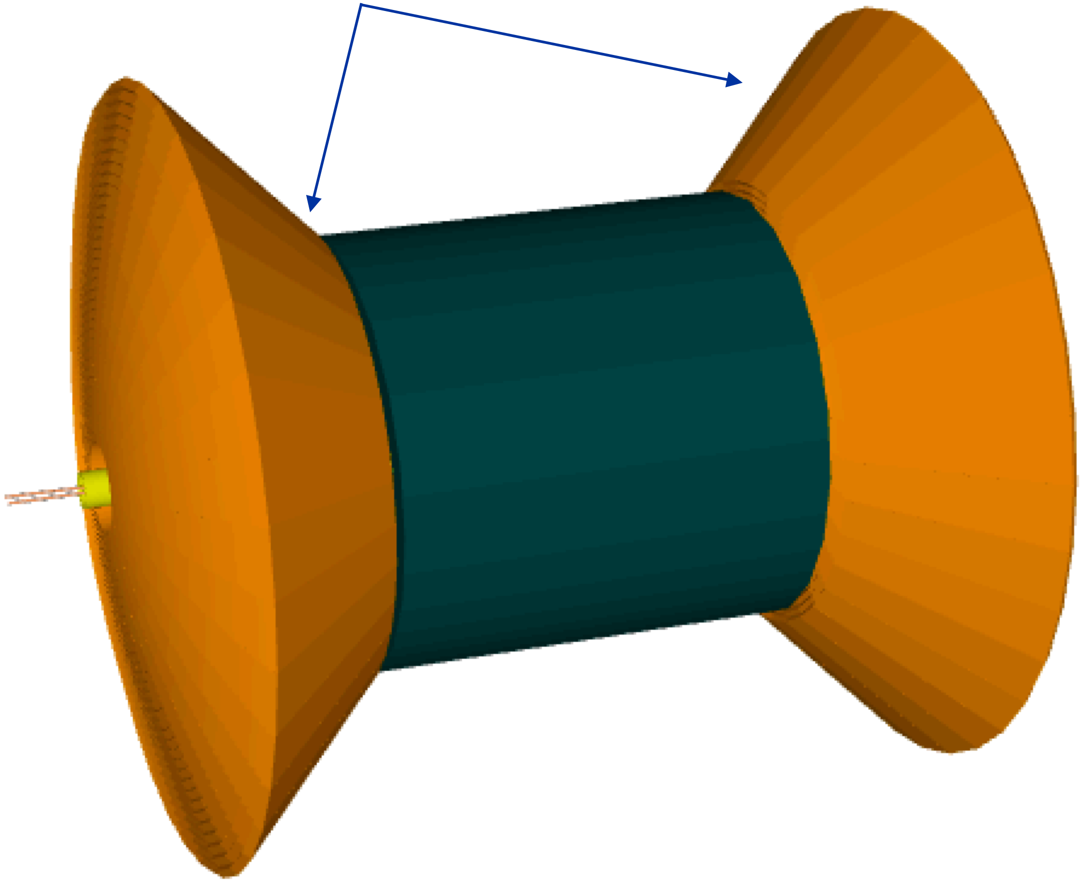

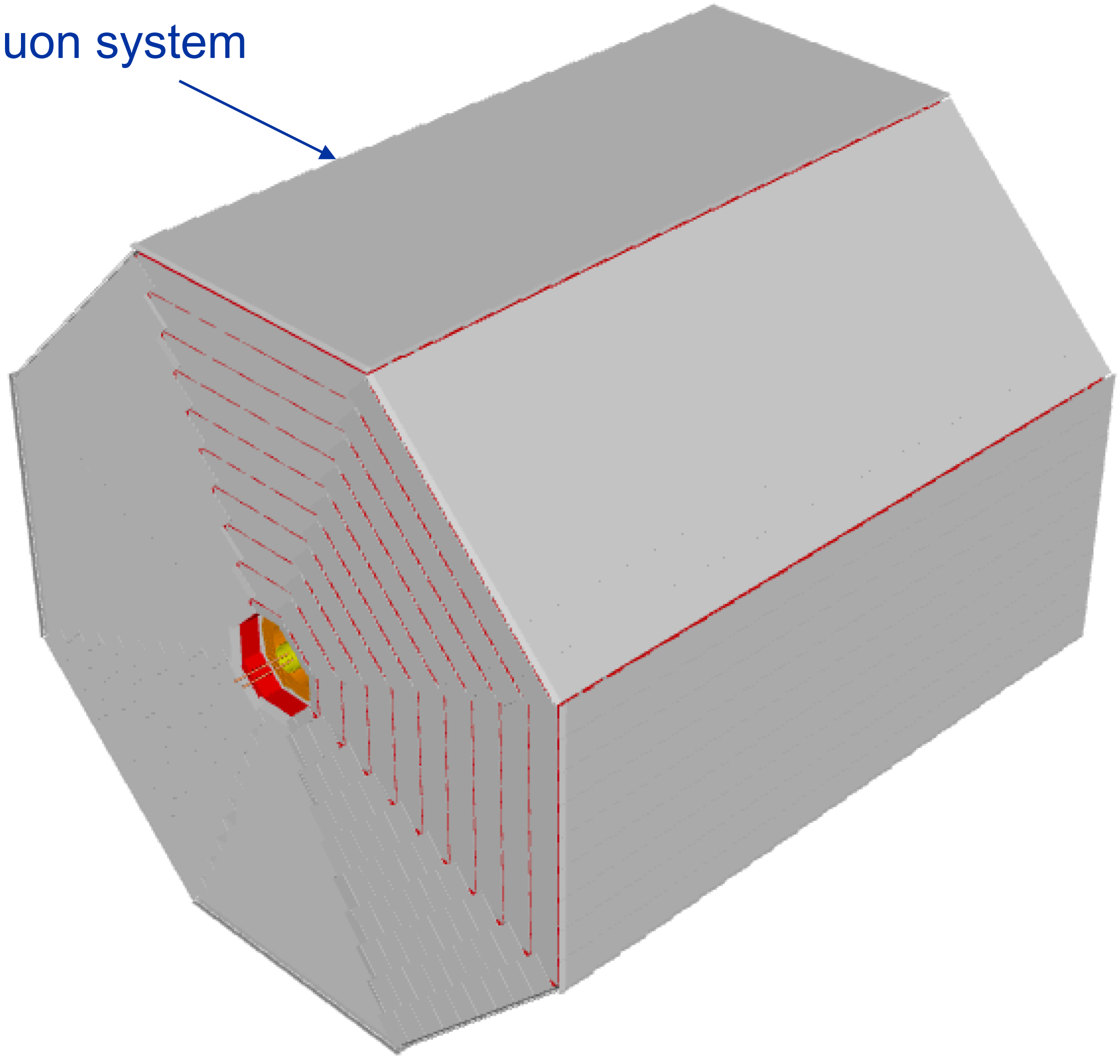

Conclusion

- The dual-readout Hidra-like endcap calorimeter is being ported to k4geo
- This new subdetector is part of a major change in the IDEA full-simulation leading to IDEA_o(ption)2
- Additional work towards IDEA_o2 full simulation:
  - Add the Sensitive Detector Action in order to create an edm4hep file with hit collections for the endcap calo (code exists already, just have to port it to k4geo)
  - Add the Hidra-like barrel calorimeter
  - Extend the Sensitive Detector Action to create the hit collections from the barrel calo
  - Include the dual-readout crystal em-section
  - Do a major revision of the IDEA geometry parameters:
    the pre-shower will likely be removed, the solenoid must include the crystal em-section, the tubes-based calorimeter must have a larger inner radius, and the muon-system must be adapted accordingly