CLIC Workshop 2015

Engineering aspects of the CLIC detector

F. Duarte Ramos, H. Gerwig

January 28, 2015

Outline

- Current detector layout
- Tracker design
- HCAL design
- Forward region and opening scenario
- Yoke endcap thickness
- Other open questions

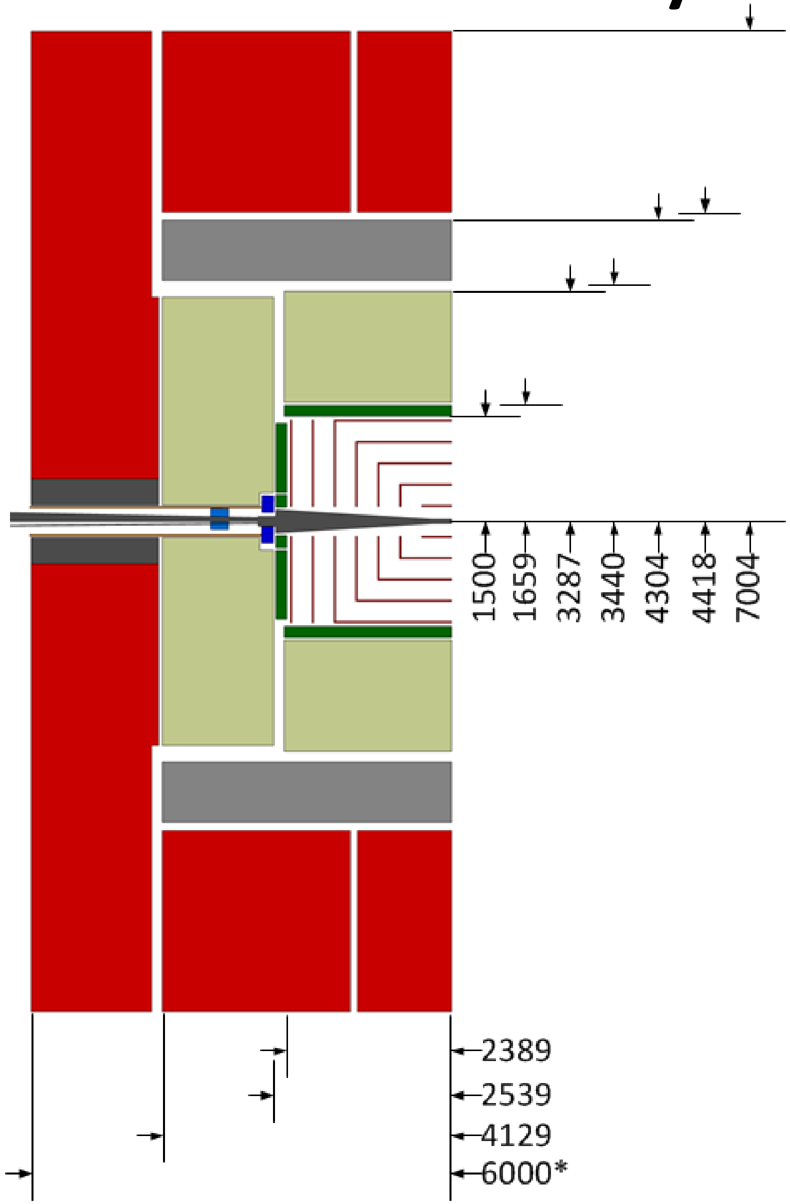
Current detector layout

- Decisions taken so far:
  - Single detector (no push-pull)
  - Si tracker
  - ECAL inner radius: 1500 mm
  - ECAL endcap z-start: 2350 mm
  - ECAL layers: 17x2.4mm + 8x4.8mm
  - Steel HCAL (7.5 interaction lengths)
  - 4T B-field
  - Vertex detector layout from CLIC_ILD
- Working assumptions:
  - HCAL layers: 60x19mm (+1mm of steel in the cassette)
  - QD0 outside the detector volume

Current detector layout

Top View

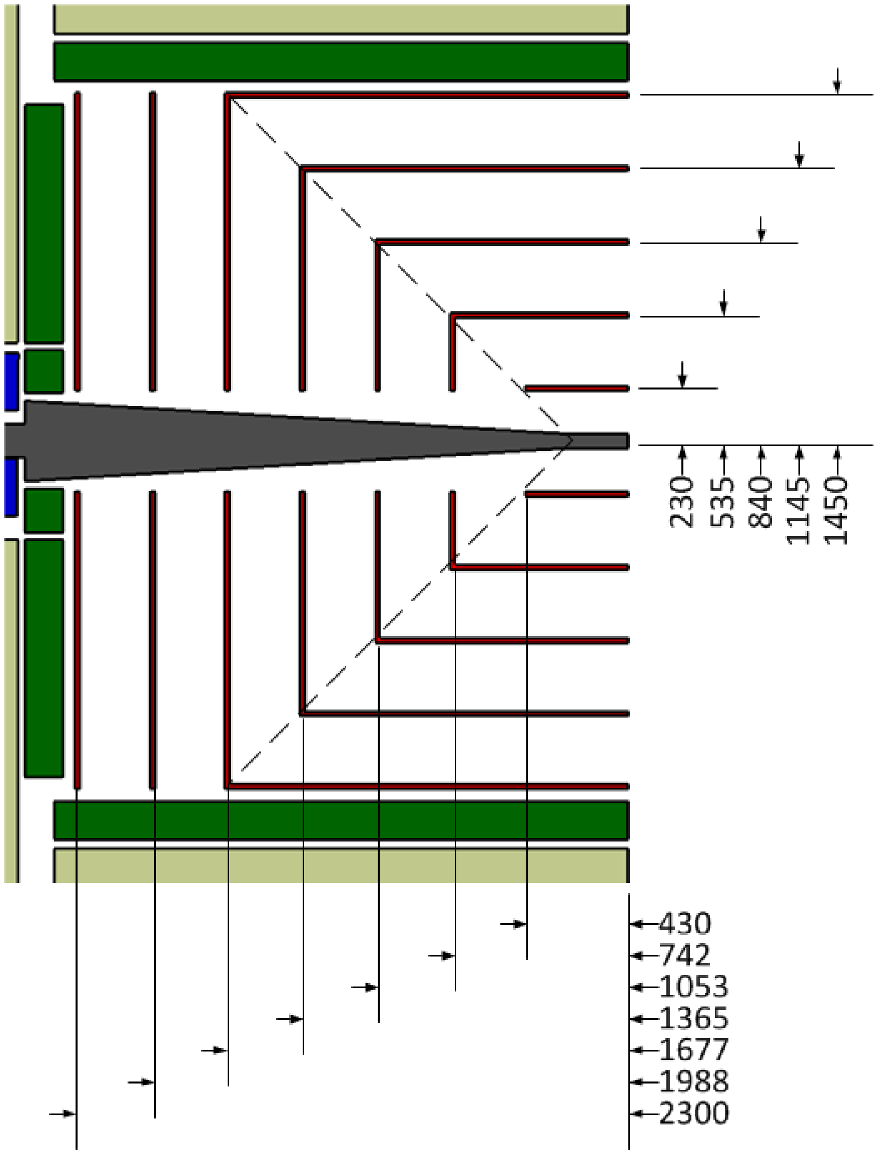
- ECAL
- HCAL
- Vactank
- Yoke
- Anti-solenoid
- Lumical
- Beamcal



*Assuming yoke endcap ring coils

Tracker design

- Shown dimensions are based on (my!) assumption of 5 equidistant barrel layers and 6 endcaps;
- Feedback on optimal number and location of layers is needed;
- Feedback on power dissipation is needed;
- Total material budget ≈ 1% X_0 per layer;
- Feedback on budget available for support and cooling is needed;

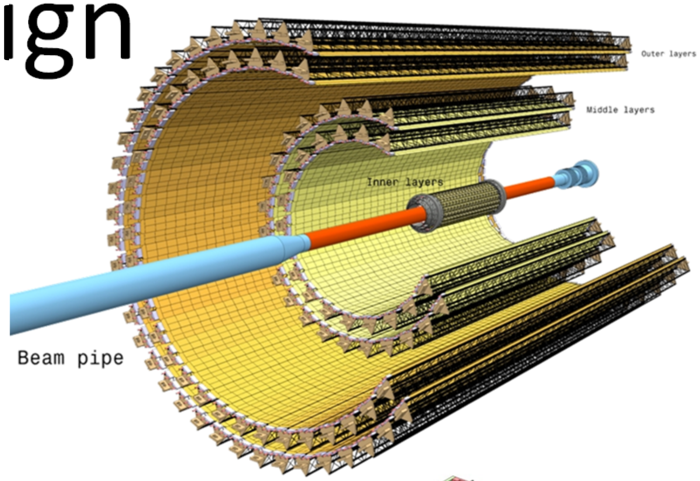


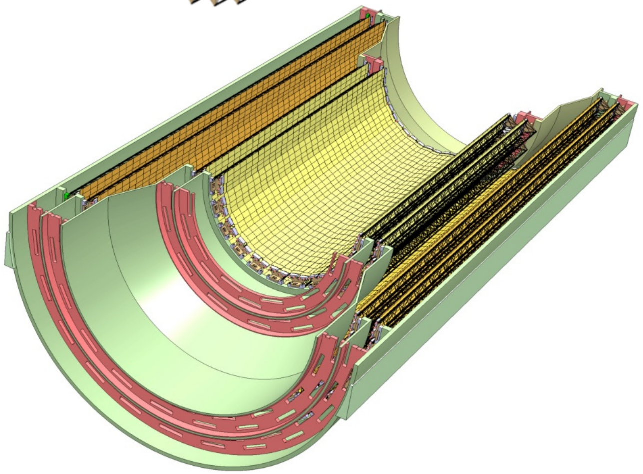
Tracker design

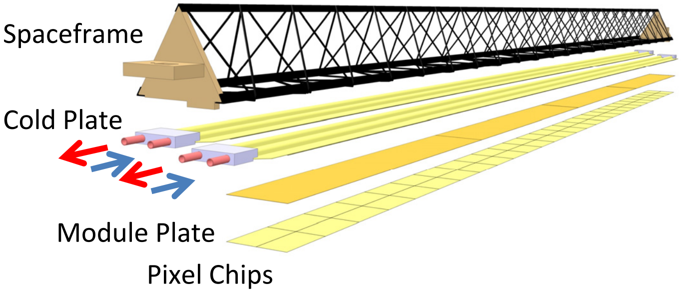
- Option 1 – Stave design (e.g. ALICE):
  - 2 innermost barrel layers within ALICE ITS OB dimensions;
  - Outermost barrel layer is 2.3 times longer than longest ALICE stave;
  - I think it will be hard to achieve the material budget goals with this option (stiffness goes with $1/L^4$…).

ALICE ITS upgrade data:

- Outer radius: 405 mm;
- Max. Length: 1475 mm;
- Power dissipation: 100 mW/cm^2;
- Total material budget per layer: 0.8% X_0;
- Leakless water based cooling (0.2% X_0 per layer).

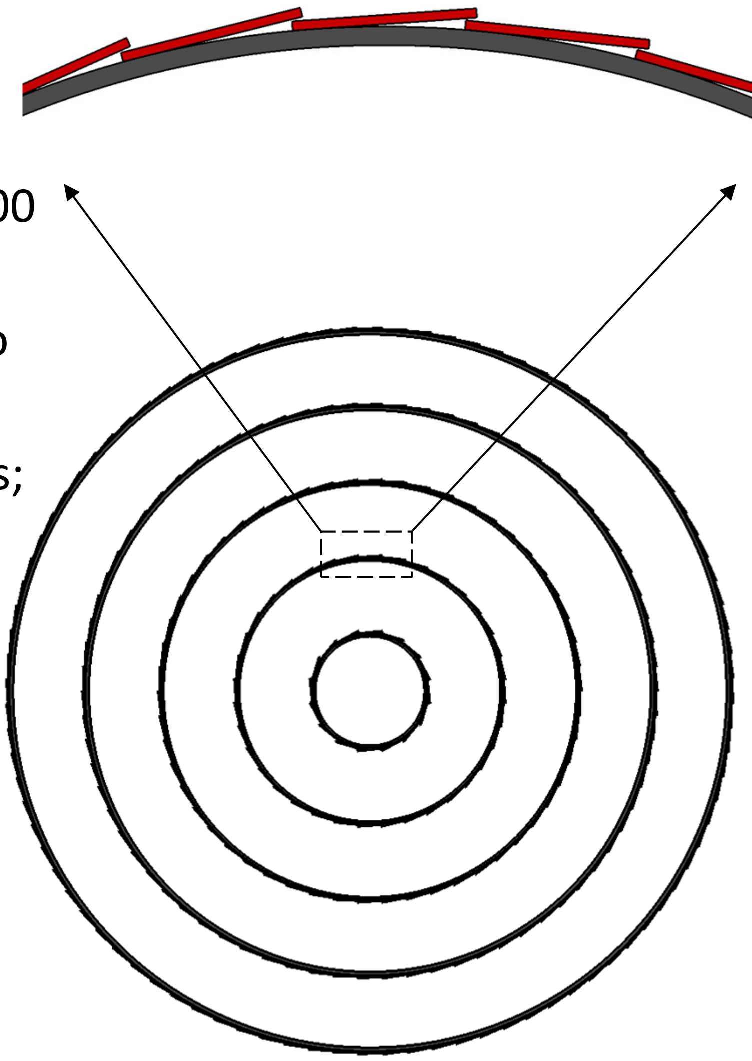


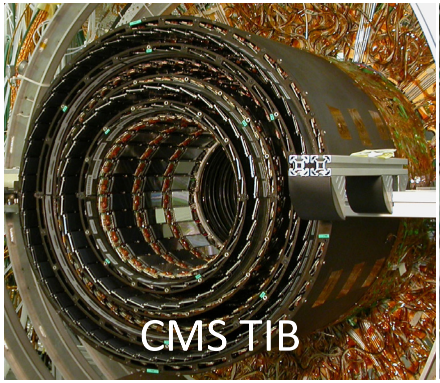


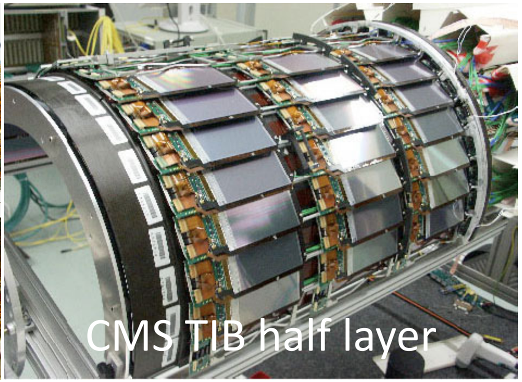


Tracker design

- Option 2 – Cylindrical support structures (e.g. CMS):
  - E.g. 2x500 µm CFRP + 15 mm Rohacell 51 + 2x100 µm adhesive = 0.63% X_0;
  - Maybe one can reduce the Rohacell thickness to e.g. 10 mm in the inner layers (i.e. 0.57% X_0);
  - Simulations are needed to calculate exact values;
  - Modules can be placed alternately on the outer/inner radius of the cylinder to guarantee overlap in z.





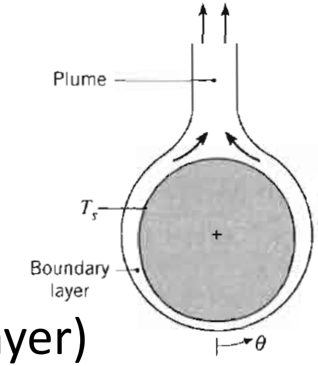


Tracker cooling

Air cooling has been mentioned in the past but…

- Assuming natural convection:

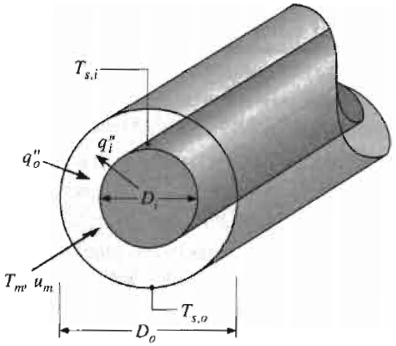
T_{sensor}<40 °C → q < 6 mW/cm^2



Already <u>very</u> optimistic calculation (e.g. nothing around the detector layer)

- Assuming forced convection

q = 30 mW/cm^2 & T_{sensor}<40 °C → V_{avg} > 7 m/s



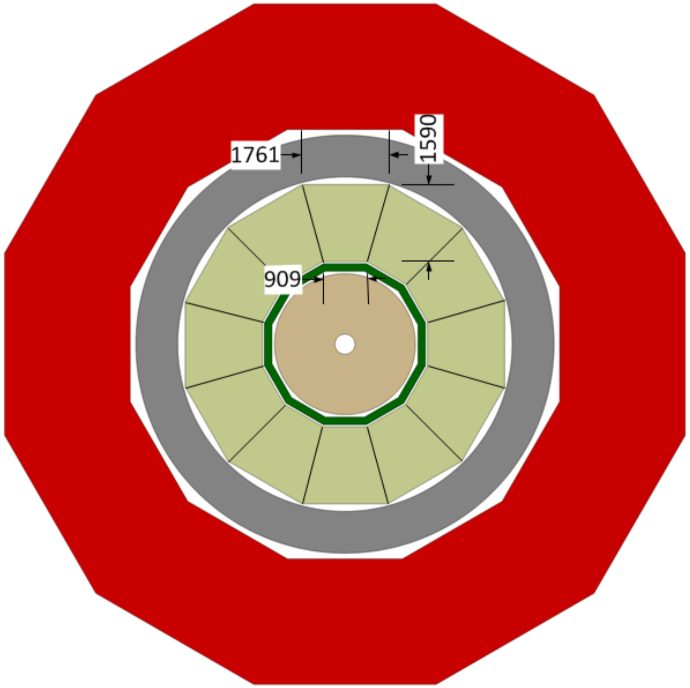
In other words, 46 m^3/s for the whole barrel (not mentioning the 13 °C of temperature gradient along the barrel length)!

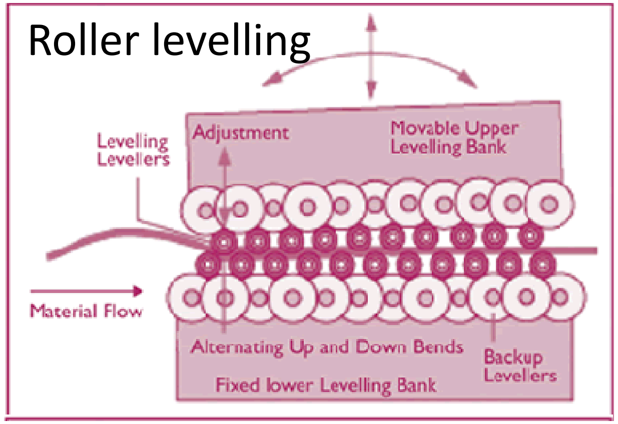
I believe liquid/2-phase cooling is the only solution

<u>Disclaimer</u>: these are results from first order hand calculations (i.e. with many approximations). Nevertheless I don't consider the results promising enough to pursue more detailed studies.

HCAL barrel design

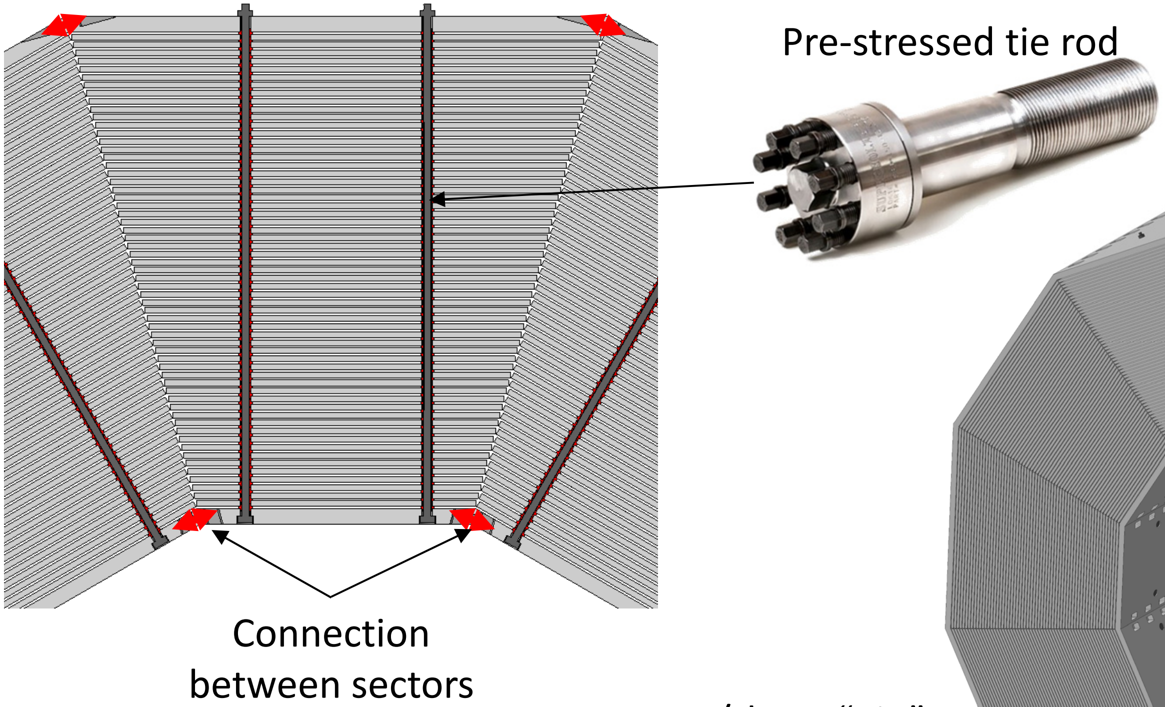
- Assuming 60x19 mm thick steel layers;
- Max. plate size: 1761x2389x19 mm^3;
- Plates can be machined to very tight tolerances (but expensive and time consuming);
- A more economical solution would be roller levelling (as for the AHCAL);
- A gap of 20-30 mm is recommended between the barrel and the vactank (i.e., assuming a 12-sided HCAL, with current HCAL dimensions, the solenoid free bore is 3440 mm).

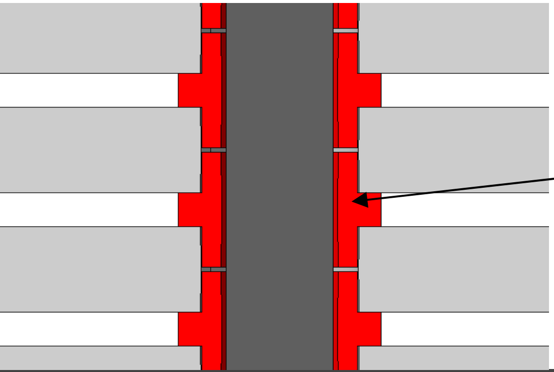


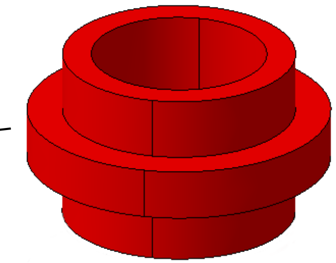


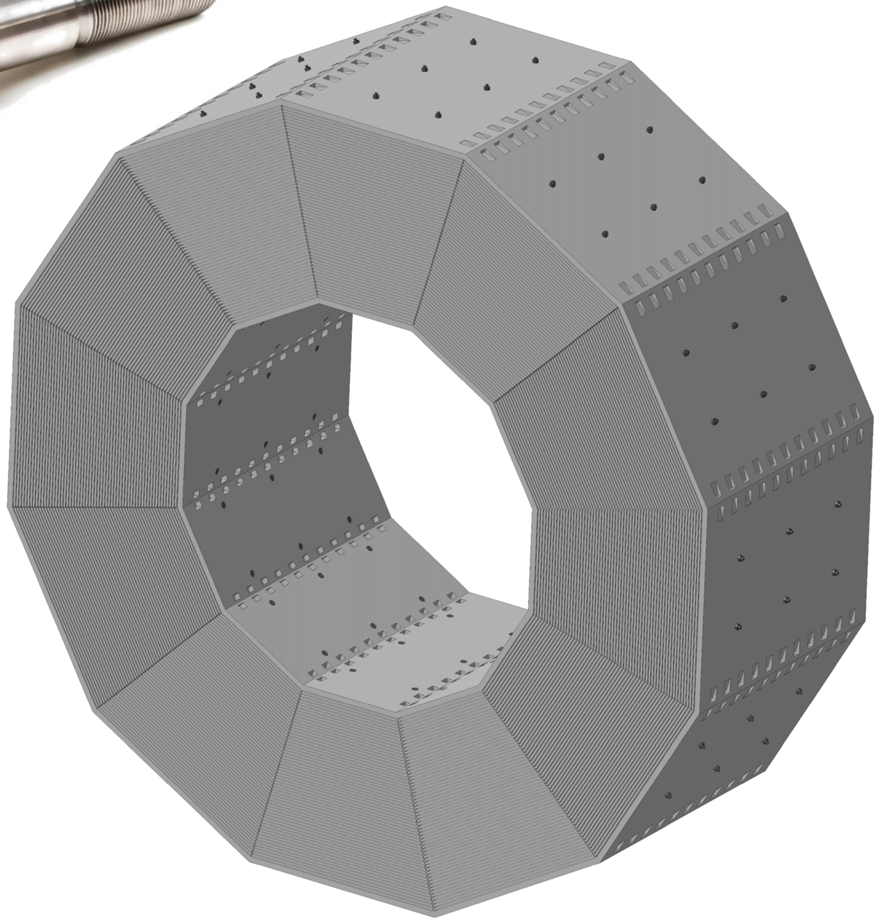
HCAL barrel design

Just a first idea! (to be verified with FEA)



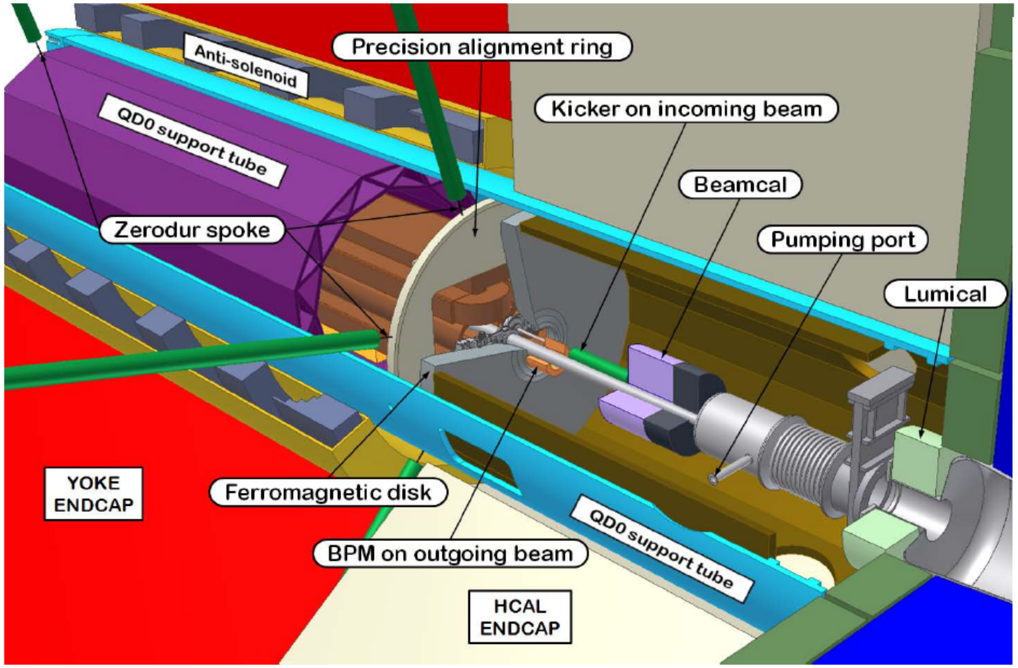


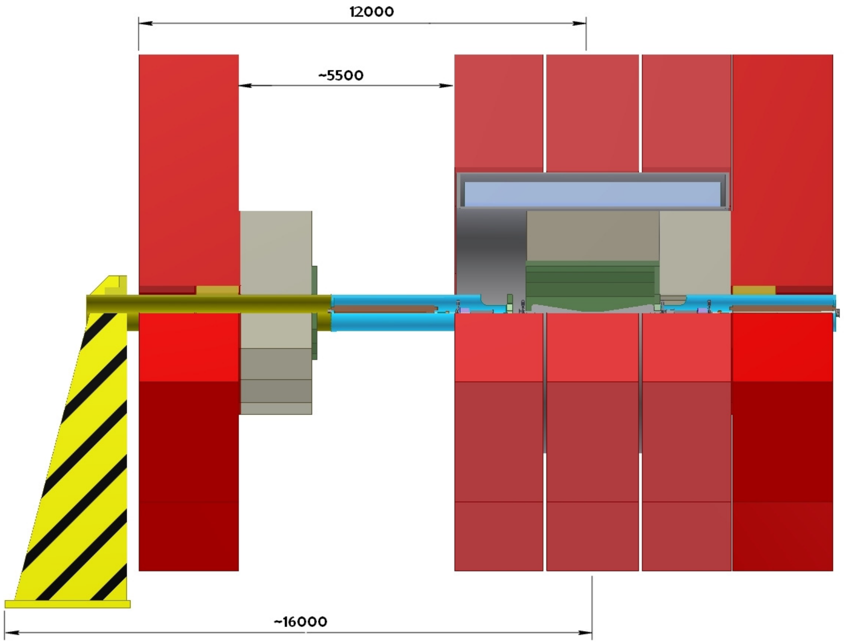




Forward region and opening scenario

CDR design with QD0 inside the detector volume

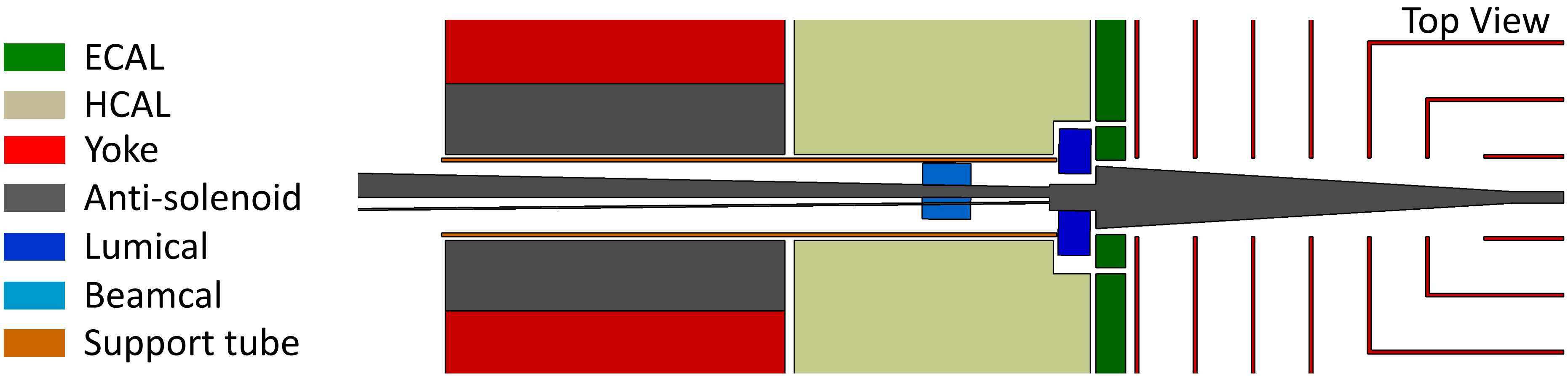




Forward region and opening scenario

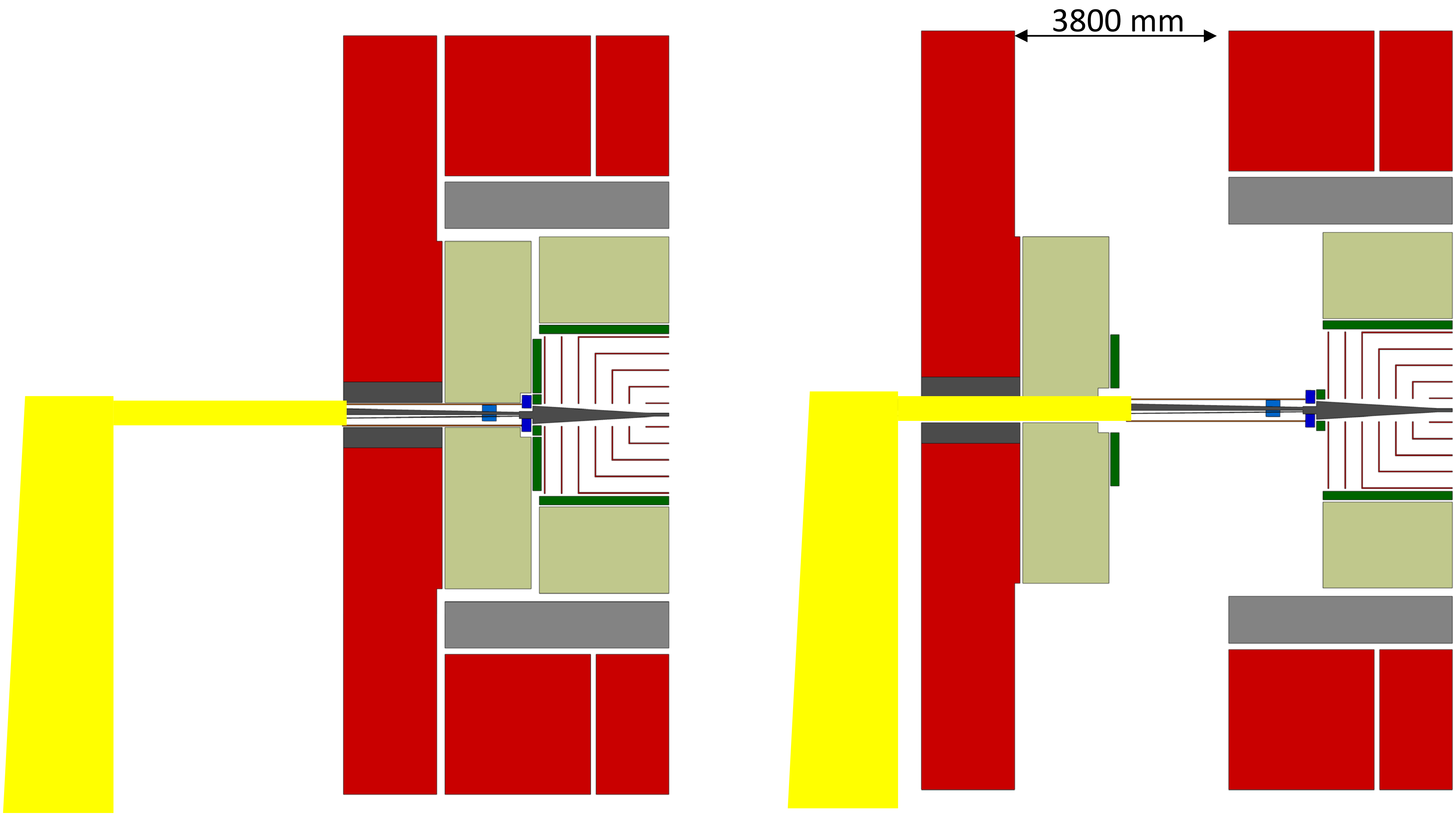
Options with QD0 outside the detector volume

1. Maintain support tube solution:
   - Supports Lumical, Beamcal, BPM & kicker, ECAL plug & beampipe sector;
   - Assuming a supported mass of 2 tonne, a 20 mm thick tube should suffice (for L=3300 mm);
   - Minimum free bore of the endcaps: R=250 mm (to be checked).



Forward region and opening scenario

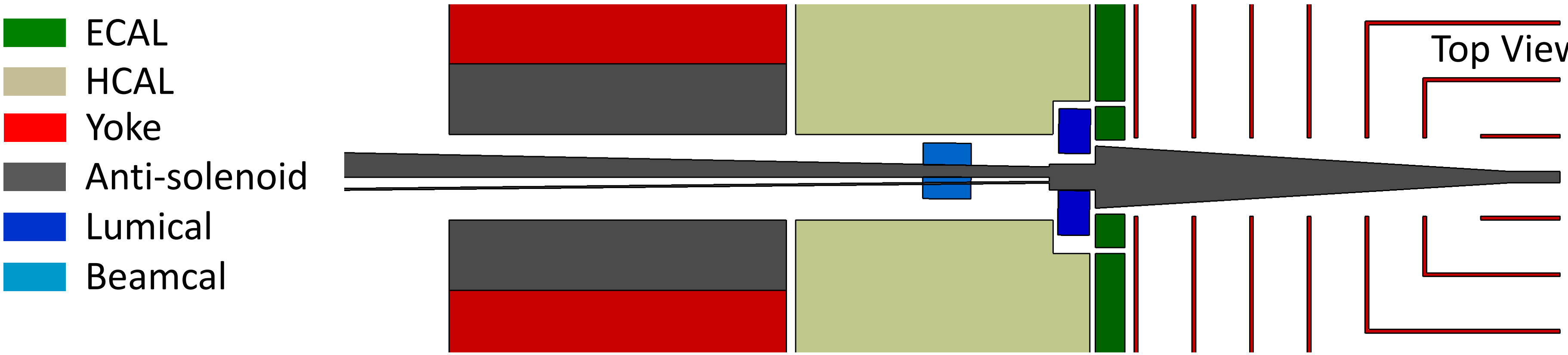
Option 1 – Keep support tube



Forward region and opening scenario

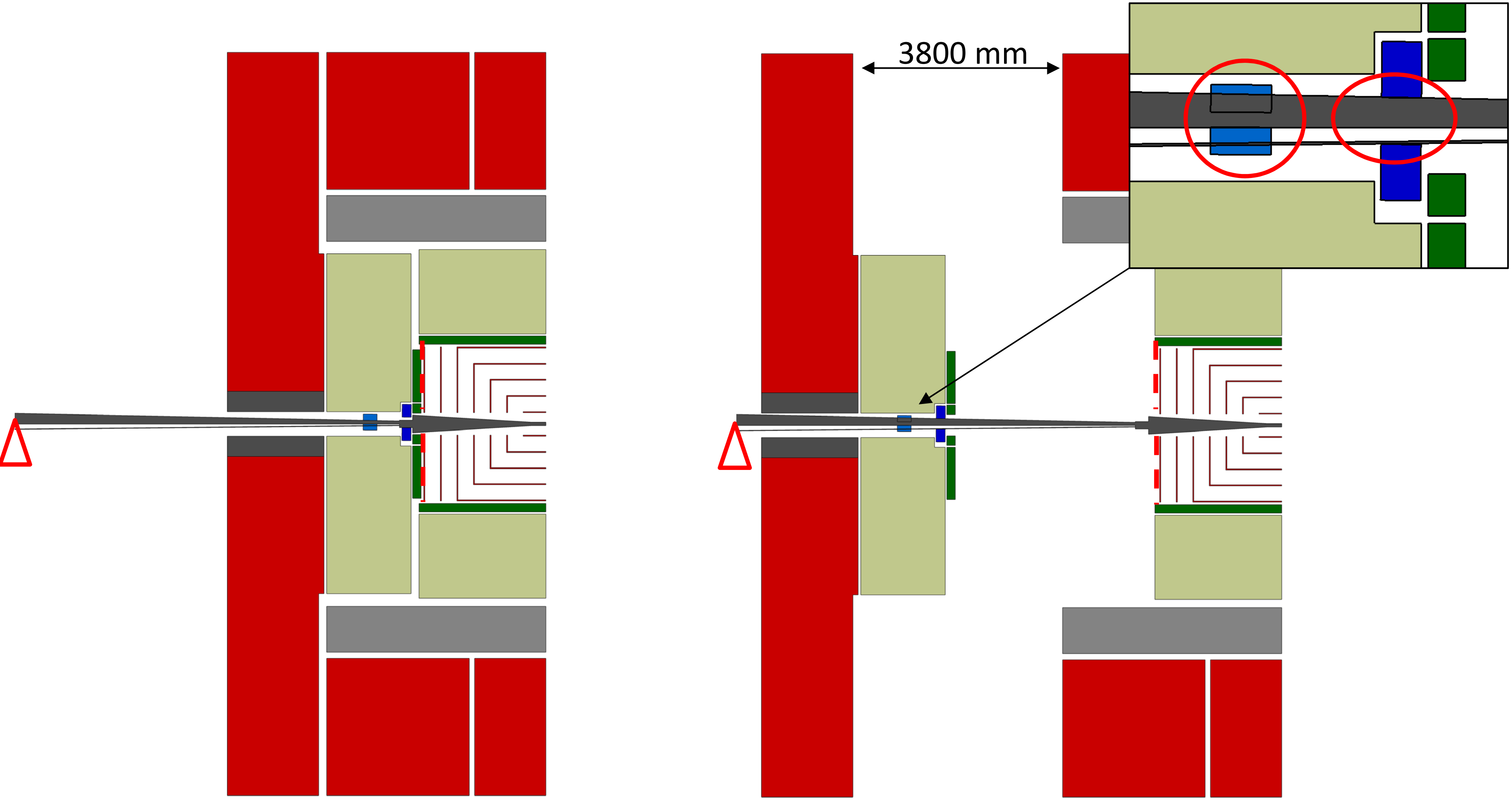
Options with QD0 outside the detector volume

2. No support tube:
   - Lumical, Beamcal and ECAL plug supported from the endcaps (beampipe supported from ECAL barrel & tunnel? BPM & kicker?);
   - Due to crossing angle (20 mrad) and outgoing beampipe, the Beamcal (and likely Lumical) need to pull away from the beampipe in order to open the detector;
   - Minimum free bore of the endcaps: R≈300 mm (to be checked).



Forward region and opening scenario

Option 2 – No support tube

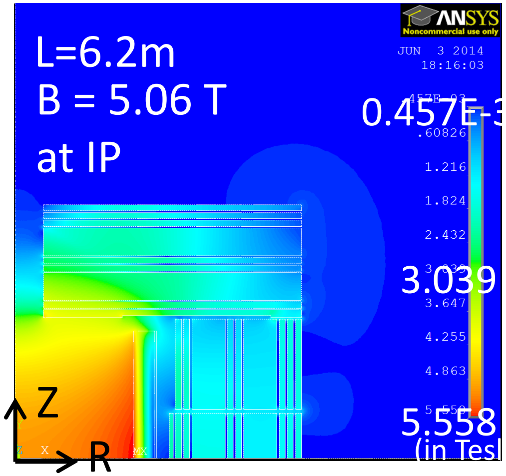


Forward region and opening scenario

- These are just 2 possible scenarios;
- A detailed study of the new forward region requires a 3D model;
- Choice of solution depends also on layout of the cavern (i.e. open detector in IP or garage position);
- Impact on L* needs to be assessed.

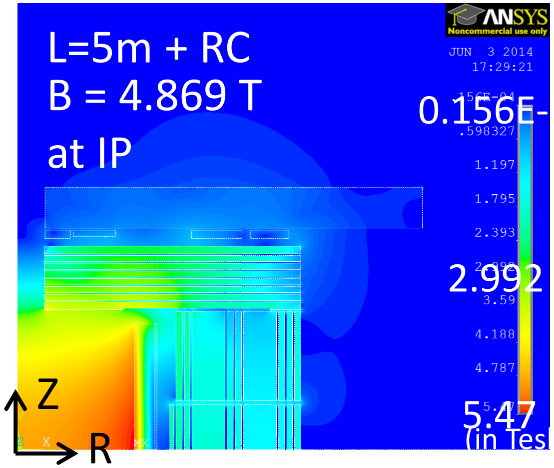
Yoke endcap thickness (B. Curé)

- For CLIC_SiD (5T B-field), with an external radius of 7 m and a half length of 6.2 m, the required thickness for the yoke endcaps has been found to be 2445 mm;
- B. Curé has investigated the possibility of reducing the CLIC_SiD endcap thickness (by removing 1160 mm of steel) using ring coils.



Axial force on coil: -164MN
Axial force on end cap: -170 MN

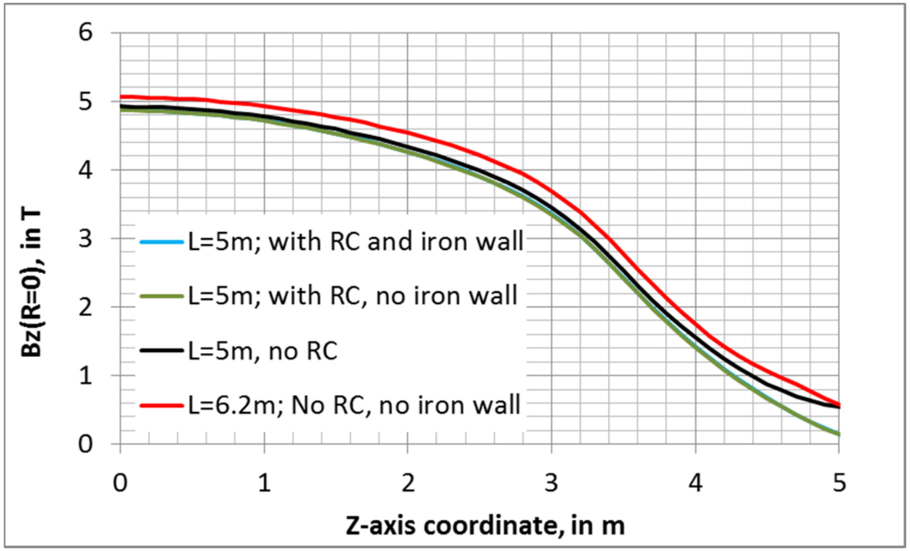
4 RCs with resistive copper conductor (water cooled, Jrc=3A/mm^2)



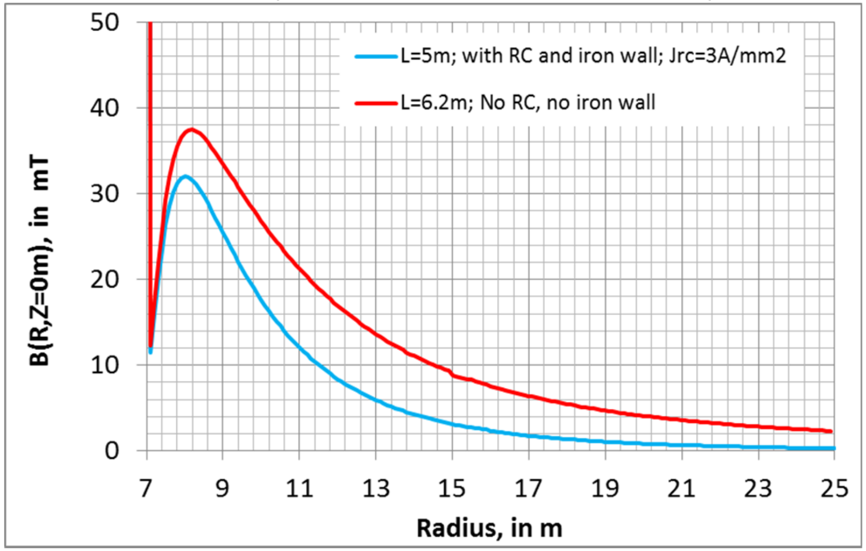
Axial force on coil: -207 MN → **Still acceptable**.
Axial force on end cap: -100 MN

Yoke endcap thickness (B. Curé)

- With respect to original design (L=6.2 m):
  - Uniform field reduction on the Z-axis of the detector (field at IP is 3.8% lower)
  - Stray field inside and outside the endcap is much lower – e.g. 150 mT vs. 600 mT on detector axis at Z=5 m;
  - Stray field around the yoke with RC is below 3.2 mT at R=15 m (9 mT in the original design);



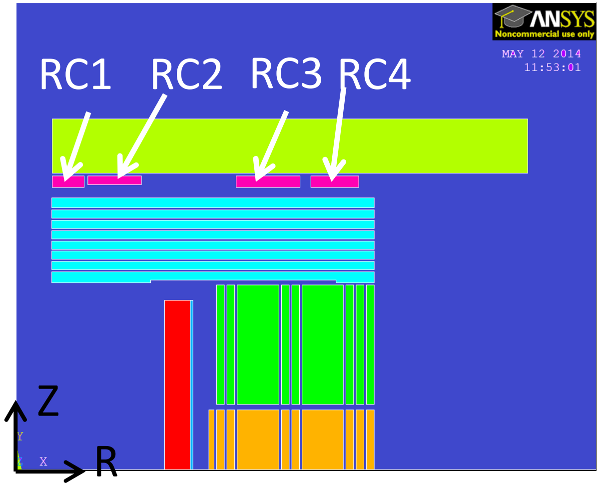
Transverse plane Z=0m, outside the yoke



Yoke endcap thickness (B. Curé)

- Same copper conductor for all RCs;
- Total electrical power of RCs (2 end caps): **2 x 2.26 MW**;
- Total copper weight : **250 tons** (for 2 end caps);
- Suppressed steel mass w.r.t. CLIC_SiD (L=6.2m) ≈ **2800 tons** for 2 end caps;
- Space available for radiation chicane on the end cap faces.

Coil	Nb. turns	Copper mass (ton)	Resistance (1e-3 ohm)	Voltage drop (V)	Power (kW)
RC1	4x12	5.6	2.7	16.5	101
RC2	3x20	13.3	6.4	39.1	240
RC3	4x24	54.4	26.2	**160.4**	**984**
RC4	4x18	51.7	24.8	**152.2**	**934**



Water cooling system characteristics:

- Total water flow (2 end caps): **2 x 57 m^3/hour**;
- Estimated temperature increase ≈ **45°C**.

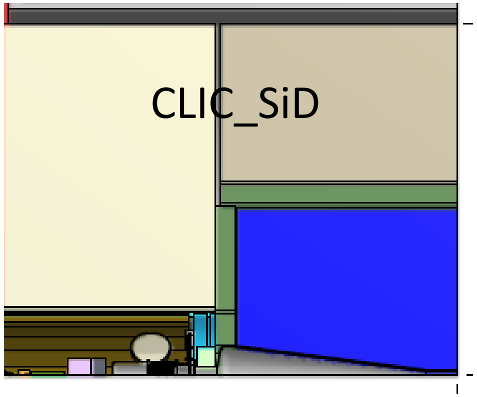
Similar parameters to those of the LHCb dipoles

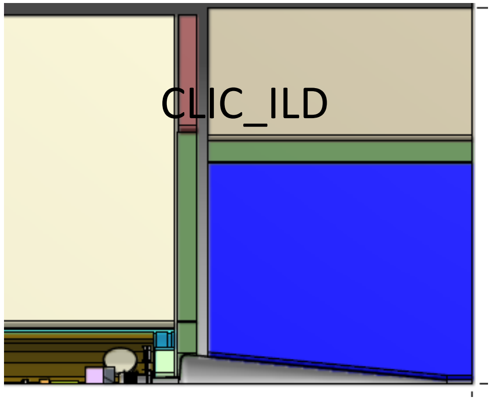
Yoke endcap thickness (B. Curé)

- The option whether or not to use a shorter endcap with ring coils should be considered at this early stage:
  - Is the field homogeneity in the central volume acceptable for the physics?
  - If we have QD0 outside the detector, a reduction in the endcap thickness is beneficial for the L*;
  - Cost of manufacturing, infrastructure and operation of the ring coils should be compared to the savings on the yoke cost.
- If there is only one detector in the cavern, the yoke barrel could also be reduced in diameter (no access to cavern during a physics run means less concerns about radiation levels due to accidental beam loss).

Other open questions

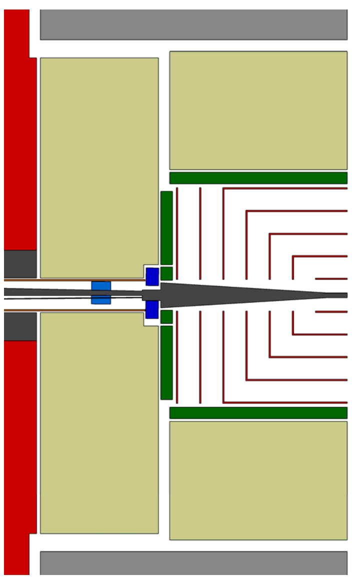
- ECAL barrel-endcap transition – CLIC_SiD or CLIC_ILD like?
  - CLIC_SiD flavour makes for a simpler design (no HCAL plug);
  - CLIC_ILD flavour can be more hermetic and easier to close.

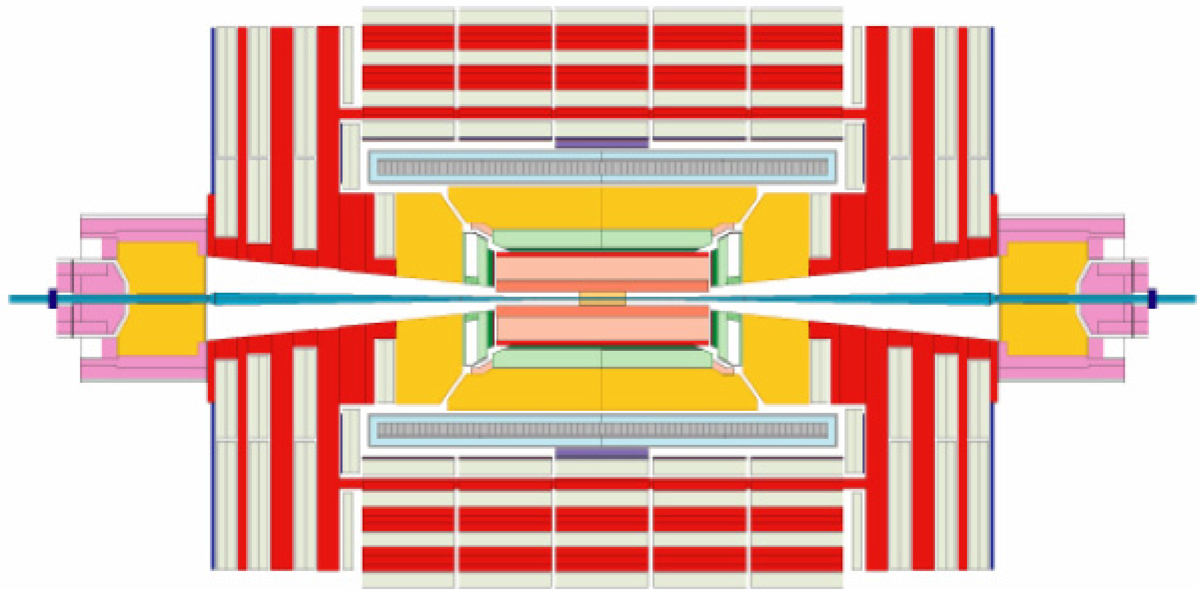




Other open questions

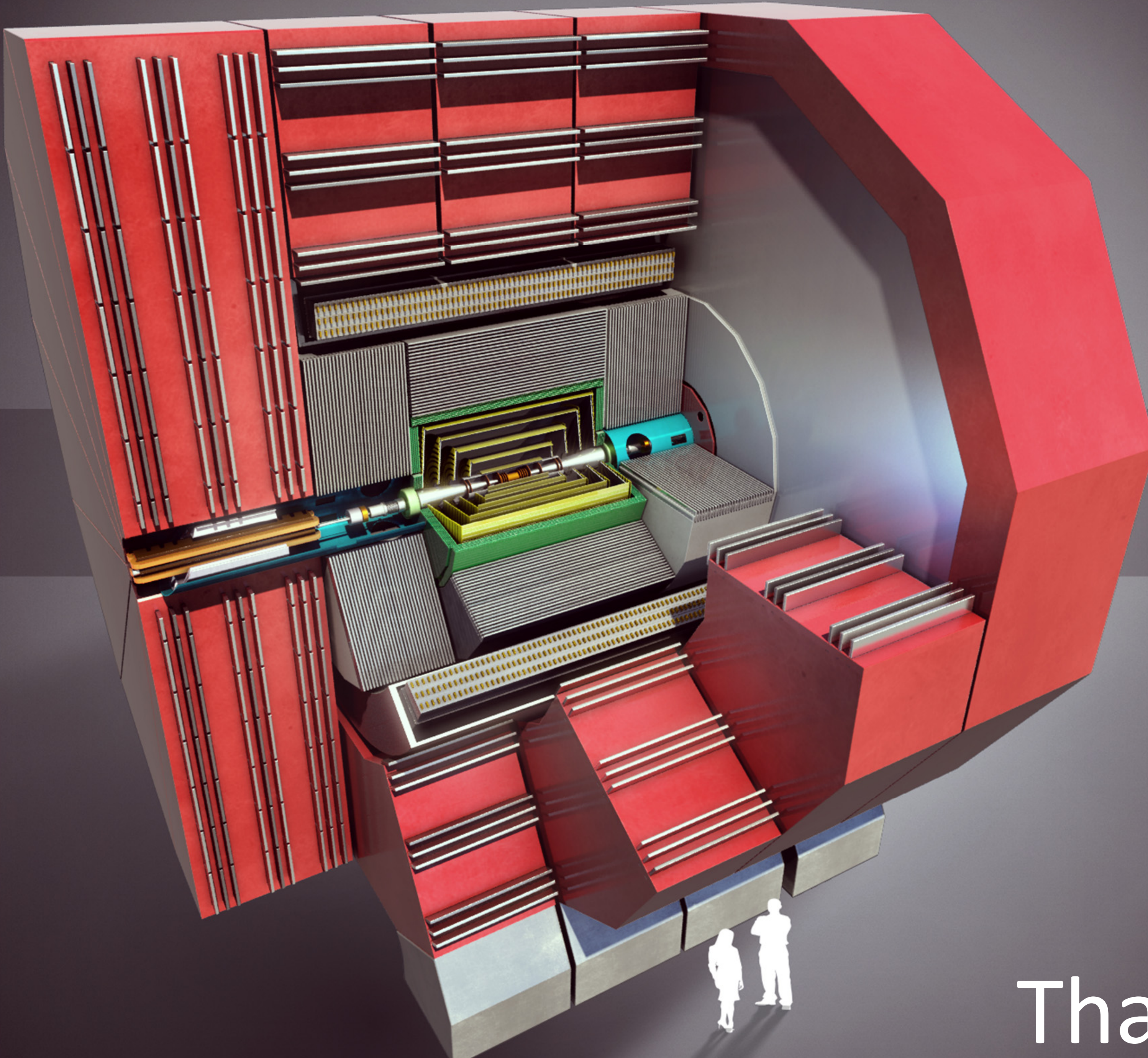
- HCAL barrel-endcap transition – CMS style nose?
  - Smaller (although "projecting") gaps for cables due to softer bends;
  - But higher number of individual detector units & overlay between readout cards locations.





Summary

- The decisions taken so far have allowed us to establish a preliminary layout for the new CLIC detector;
- However many things are borrowed from the old detector layouts (CLIC_ILD & CLIC_SiD) and others are just pure assumptions;
- Feedback is still missing on some areas (especially the tracker);
- Air cooling of the tracker seems highly unlikely (even more if we consider how difficult it was to implement it in the vertex detector);
- A steel HCAL will be easier to manufacture and feedback from other groups may prove useful (e.g. AHCAL);
- As with the old detectors, the design of the forward region, opening scenario and experimental cavern layout will require some iterations;
- A lot of work is ahead of us.



CLIC Detector

Thank you