Mechanical Concept of the TESLA Detector

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Snowmass

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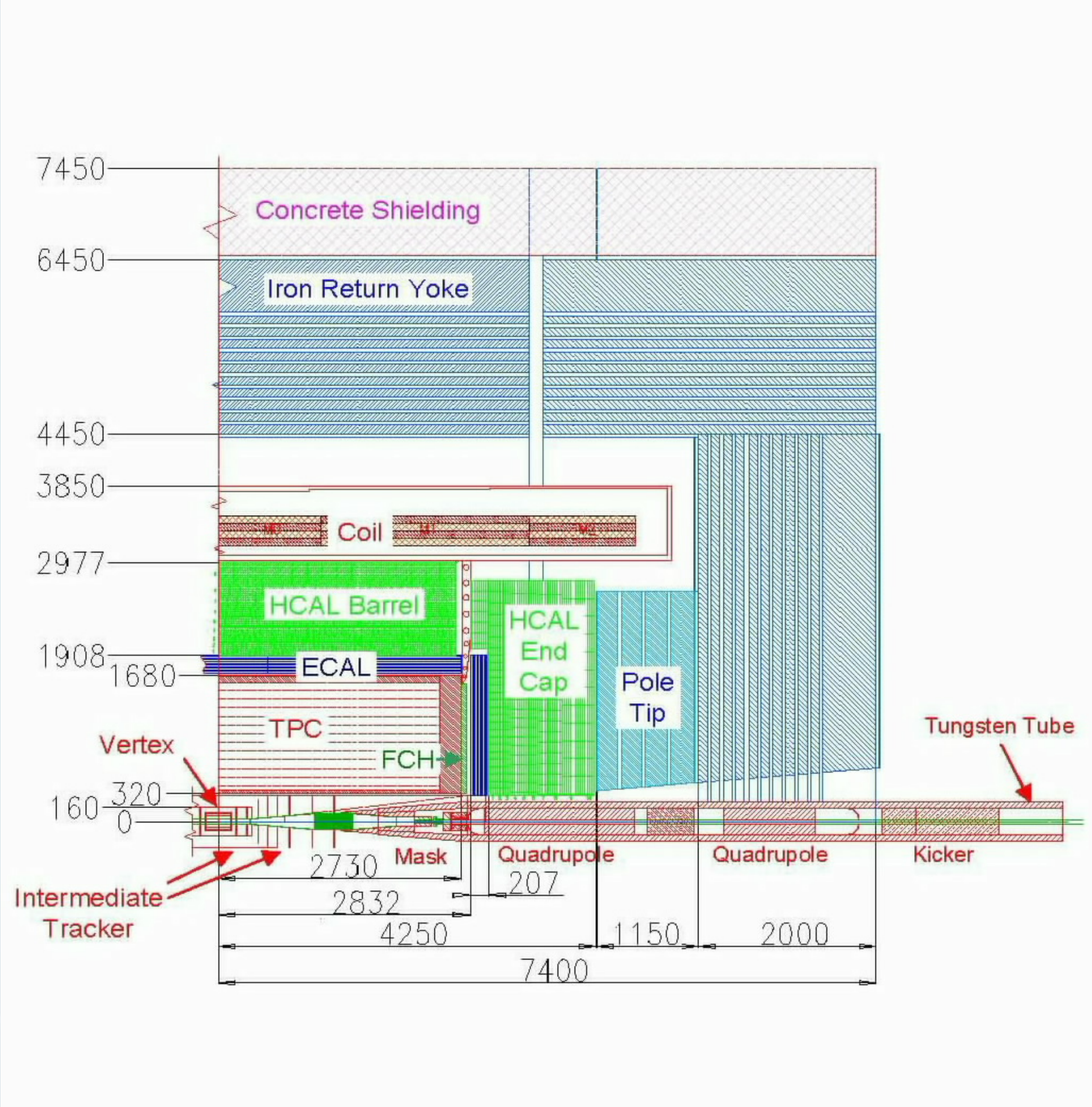
Detector parameters of one detector quadrant. Shown dimensions are in mm

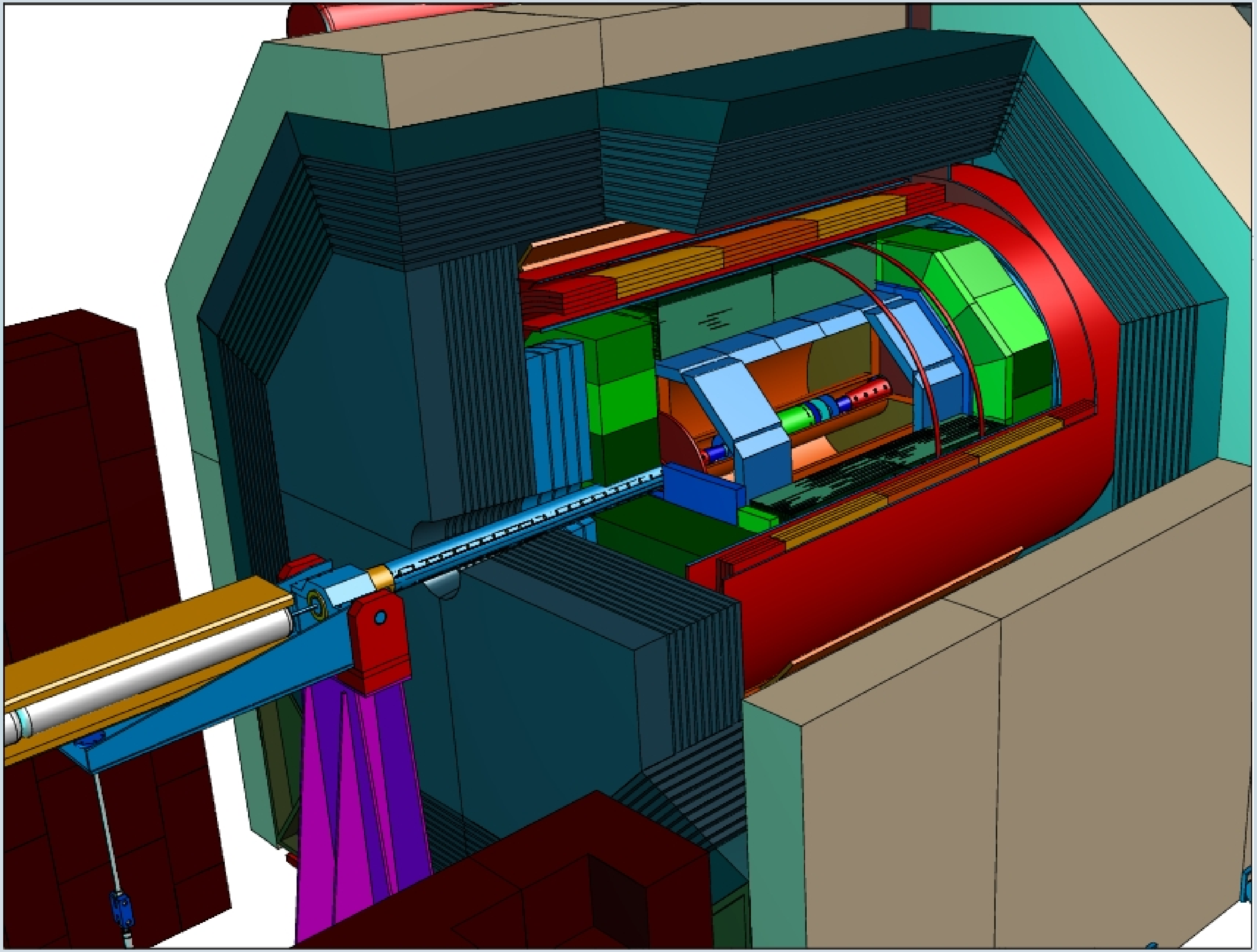


Design criteria

- The design of the TESLA Detector has been driven by the requirements of modular assembly and easy access for maintenance of the sub-detectors. Particular emphasis has been given to the development of a concept which allows the access to the inner part of the detector, without removing the detector from the beamline. It allows the access to the inner parts of the detector on a moderate time scale and permits maintenance of the vertex and inner tracking systems while the central detector beam pipe remains connected to the linac vacuum system.

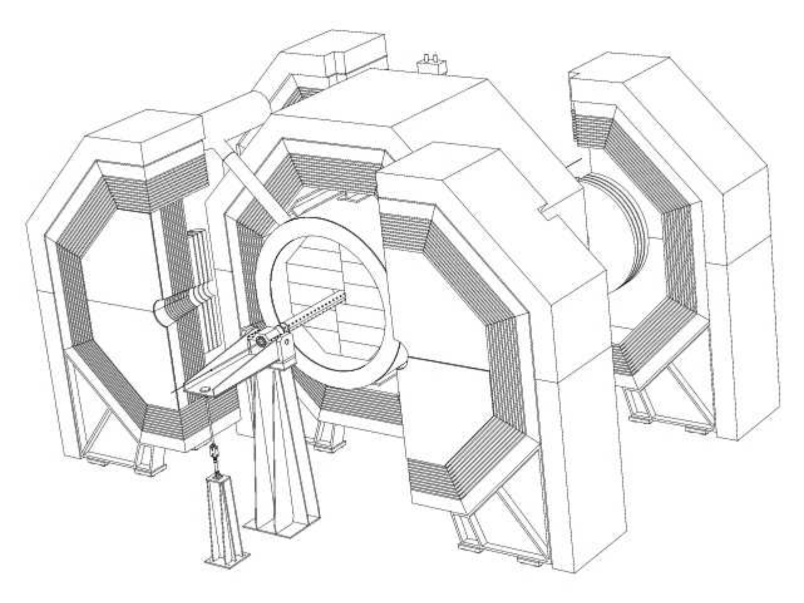
- Commissioning of the linac and machine studies should be completely independent from the detector status in the parking position during detector assembly or maintenance work.

View of the detector in the beam position

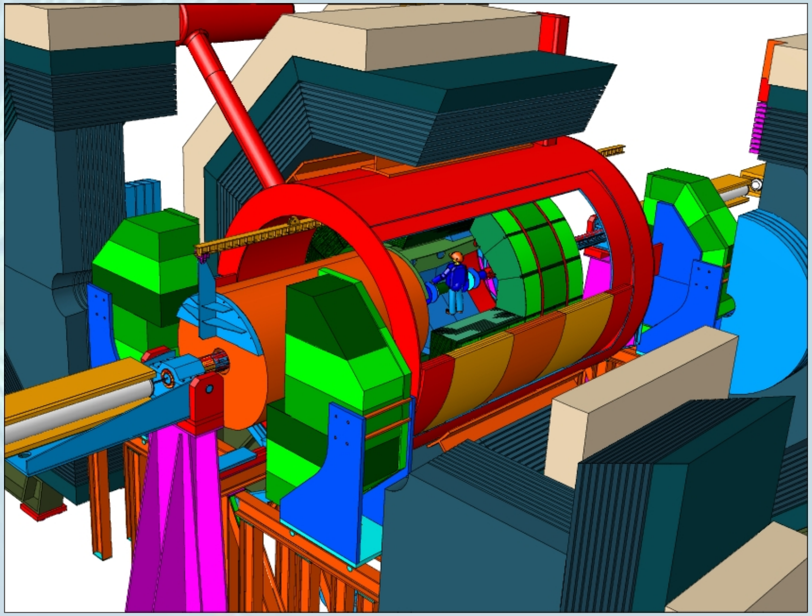


Isometric view of the open detector

- The detector has been divided into five parts. The central yoke ring supports the coil cryostat with the calorimeter and the central tracking chamber inside. The four corner half shells complete the iron return yoke. They can be moved independently on air pads along and perpendicular to the beam line. The vertex detector and inner tracker are fixed to the central beam pipe. Together with the tungsten shielding tubes they form an inner part that can be mechanically decoupled from the rest of the detector.



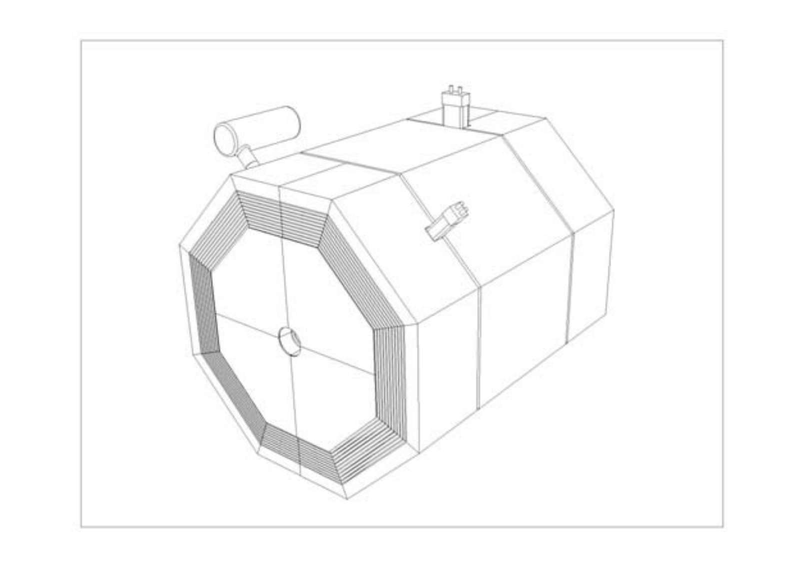
- Once the magnet yoke has been opened and the calorimeter end caps have been removed, the TPC can be moved in beam direction, sliding over the tungsten tube. This allows access from the opposite end of the detector to the Si-tracking detectors, the mask system and the beam pipe.

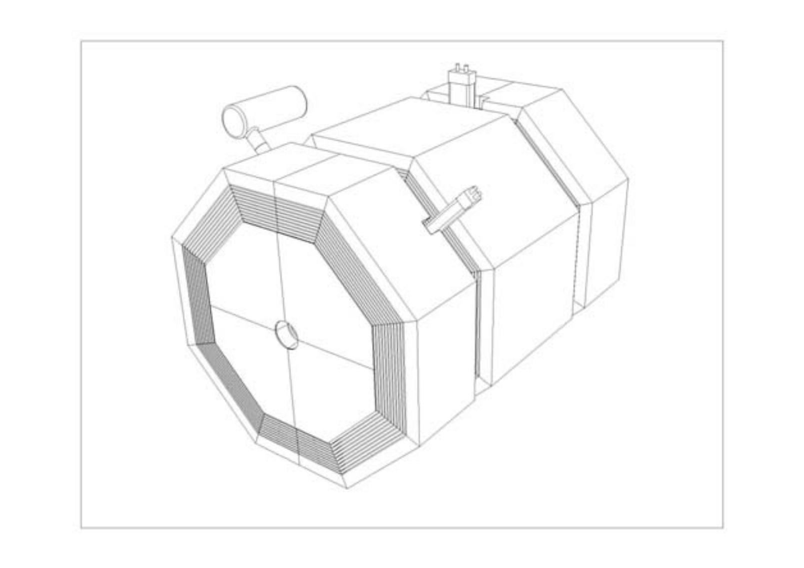


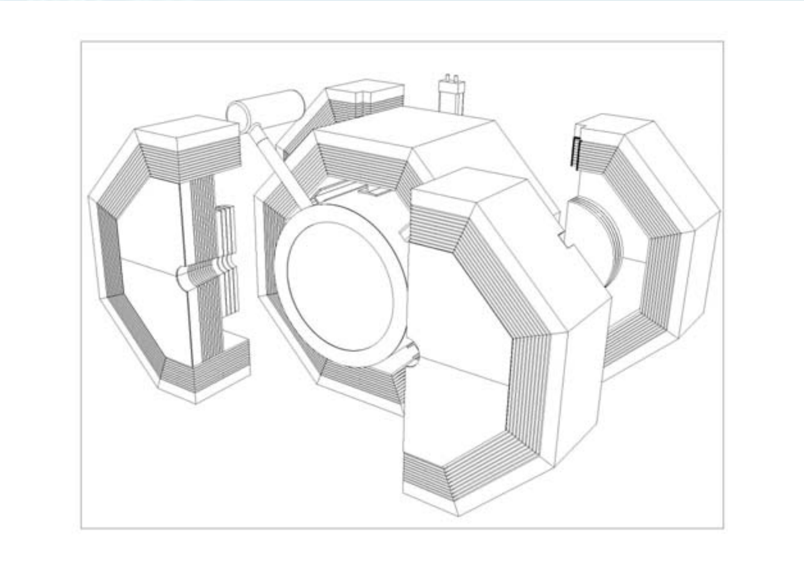
Magnet

- The main parts of the magnet are the superconducting solenoid and the iron flux return yoke instrumented with a muon detection system. Designed as an 8-sided structure the yoke is divided into a central barrel ring centered on the interaction point and two end caps . Additional iron cylinders (pole tips) fixed to the yoke end caps protrude into the cryostat volume to achieve the required field homogeneity. This led to the concept of splitting the two yoke end caps into four corner half shells. The detector yoke is opened by moving the corner half shells longitudinal to the beam to pull the fieldshaping pole tips out of the cryostat and than perpendicular to the beam to get access to the detector components of the central barrel part.
- The cutouts for the cryostat chimneys are in the corner half shells to facilitate the access to the current leads, helium transfer line and vacuum pumping line of the superconducting solenoid when the yoke is in the open position.

Opening scheme of the iron yoke

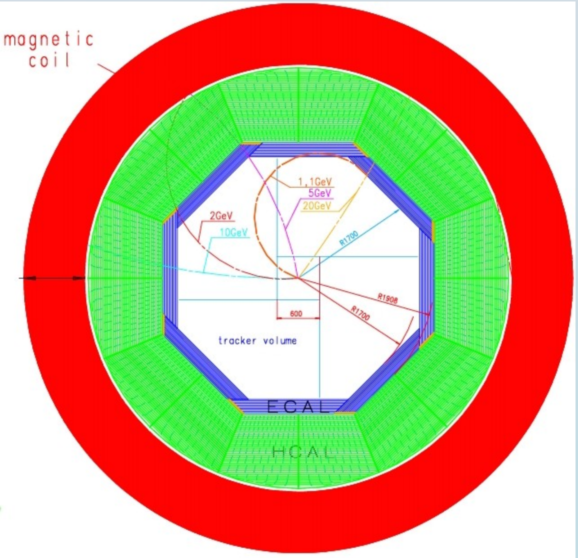


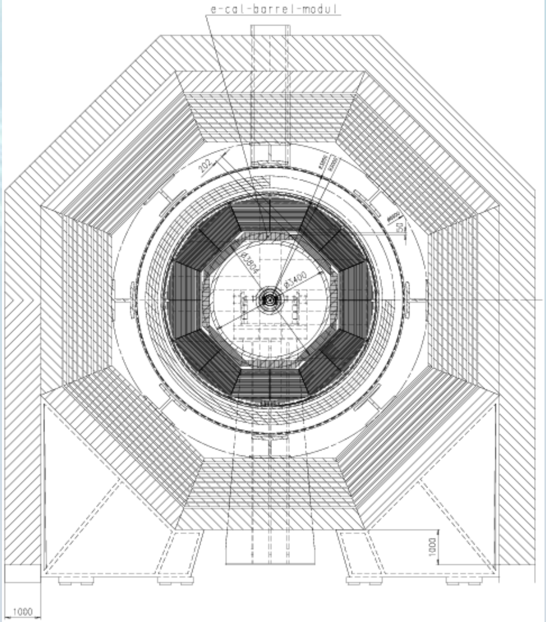




Barrel Calorimeter

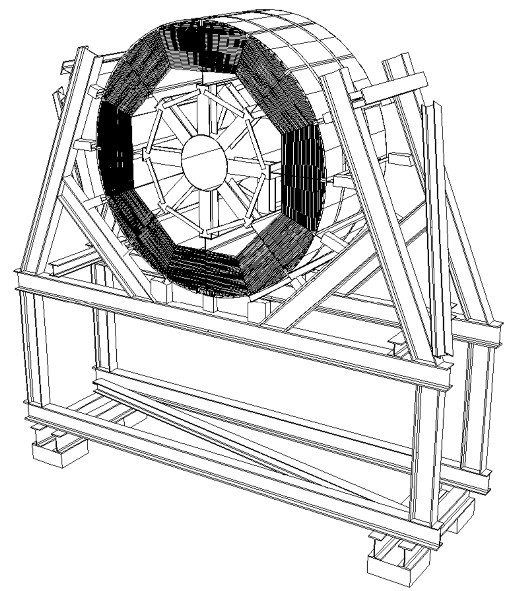
- Since the coil in its cryostat is the most rigid part of the detector, it is used to support the tracking system, the electromagnetic (ECAL) and the hadronic (HCAL) calorimeter. They are fixed to the inner shell of the vacuum tank of the coil. The calorimeter rest on a rail at the bottom and are held sideways by rollers against the tank walls. The coil itself is supported by the central ring of the barrel yoke.

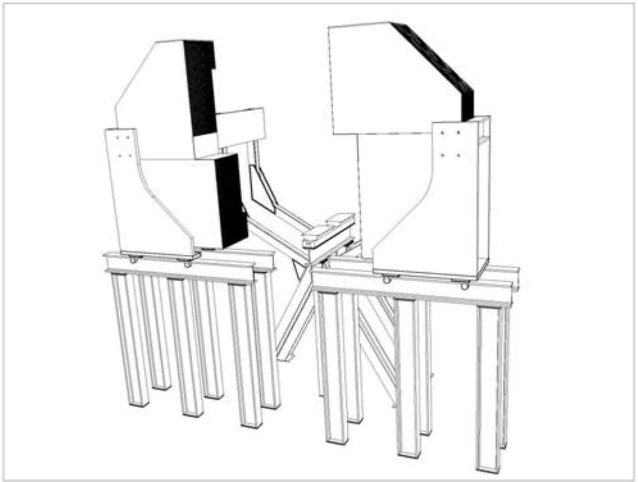




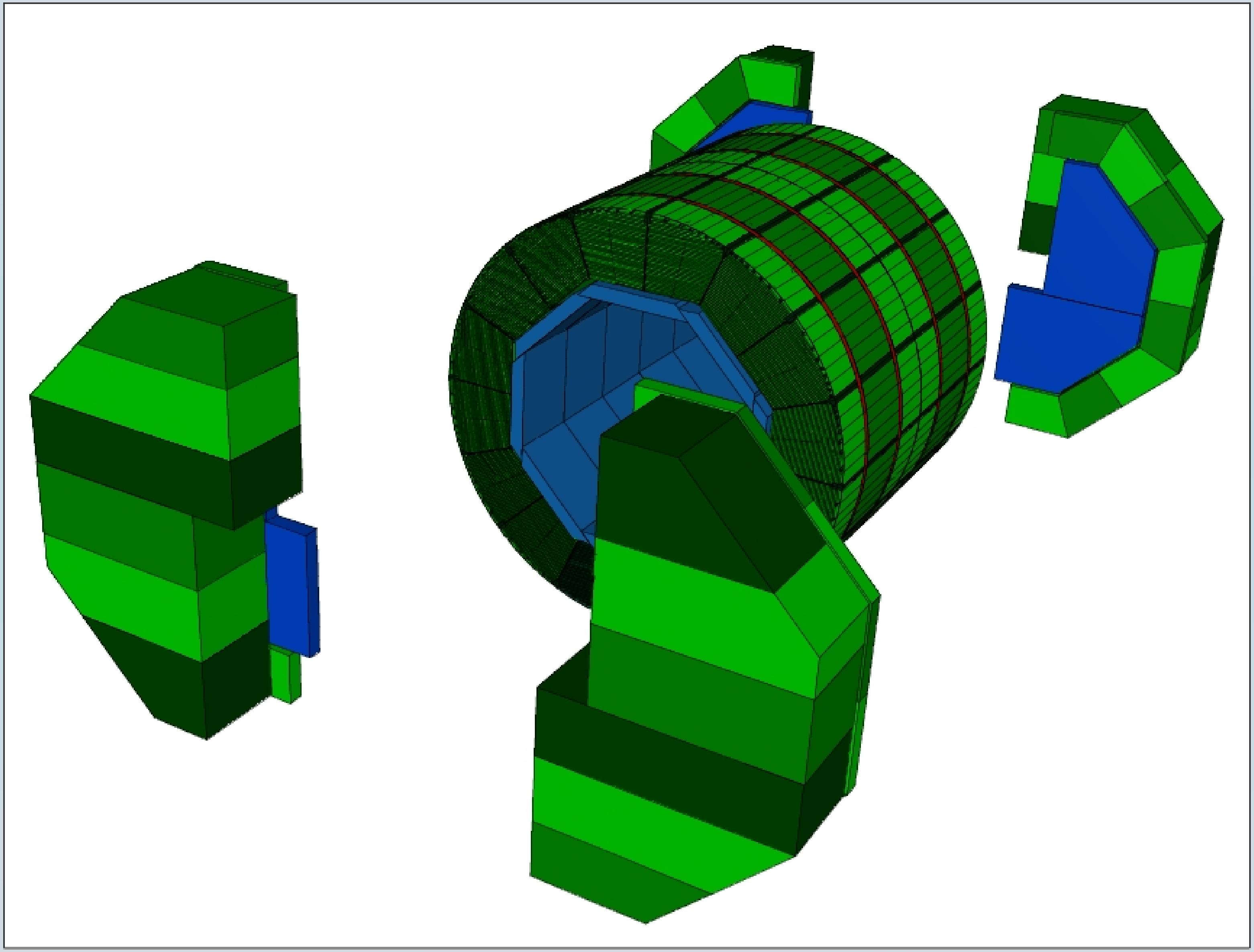
Barrel and end cap calorimeter

- The complete hadronic barrel calorimeter is made of two half-barrels with 16 modules in each half. The cylindrical half-barrel will be assembled on a cradle before they slide on a set of rollers along a rail extension into the cryostat. The eight ECAL supermodules are connected via small rails to the front plates of the corresponding HCAL barrel modules.Both calorimeter end caps are made of four quadrants. The end cap calorimeter disk moves longitudinal on rollers running on the extended rail out of the cryostat and once outside the load of each half disk is taken by movable supports. It is now possible to disconnect the two halves and open them in lateral direction.



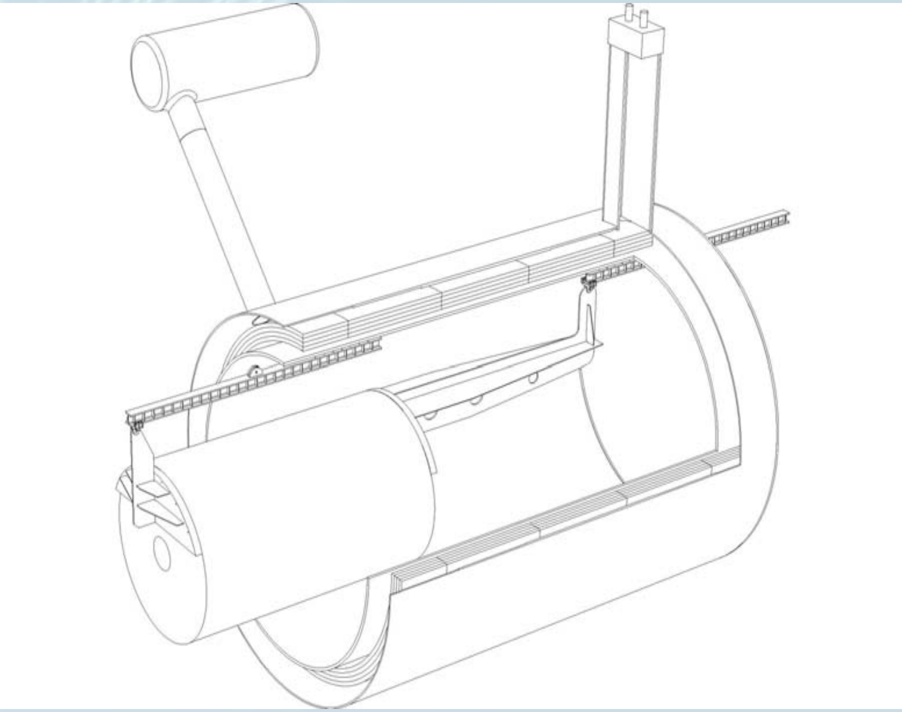


Calorimeter system with open end cap calorimeters

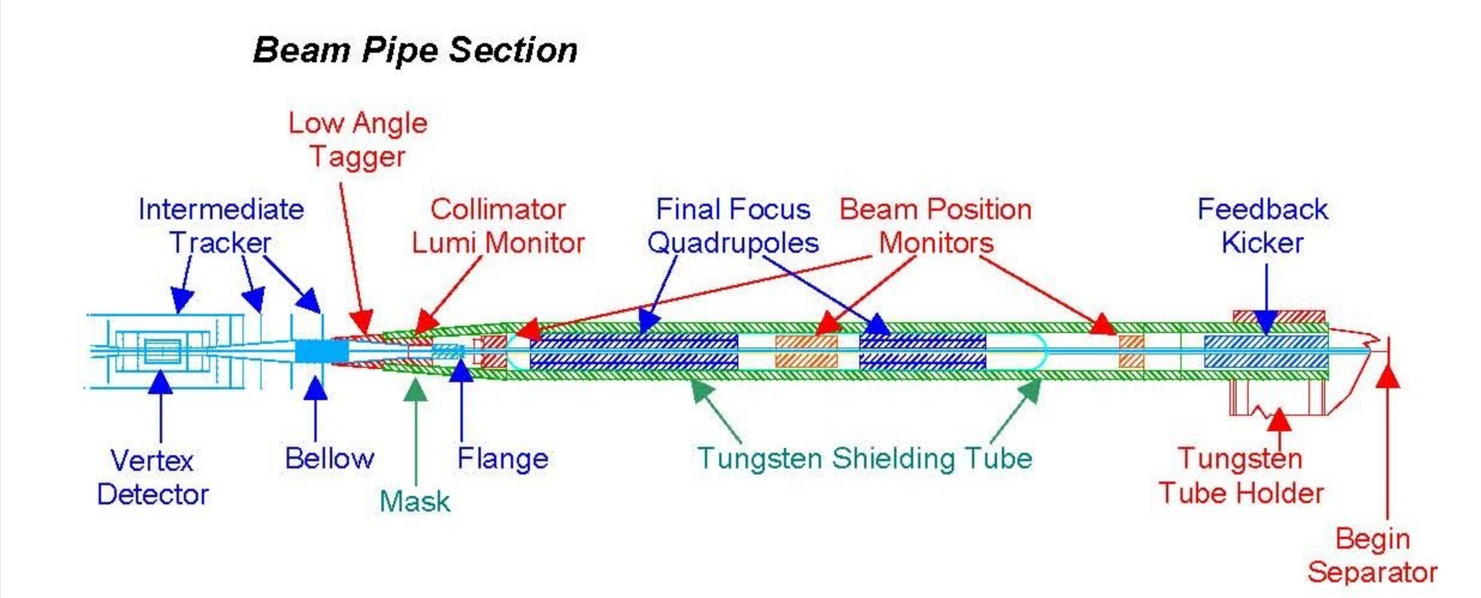


Time Projection Chamber

- The time projection chamber (TPC) is inserted into the electromagnetic barrel calorimeter. The chamber is fixed to the inner wall of the magnet cryostat at both ends with spokes located in the gap between barrel and end cap calorimeter.
- For installation and removal the TPC can be connected to a temporary support mechanism and decoupled from the spokes. The removal is necessary to allow access to the inner subdetectors. Auxiliary girders are mounted to the inner wall of the magnet cryostat tank on both sides of the cryostat. The TPC support frame move on rollers running on the girders.



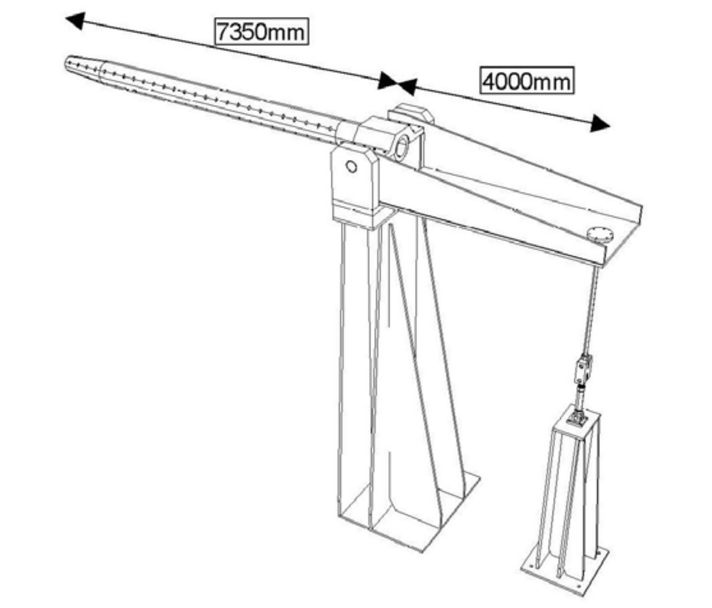
Beam pipe



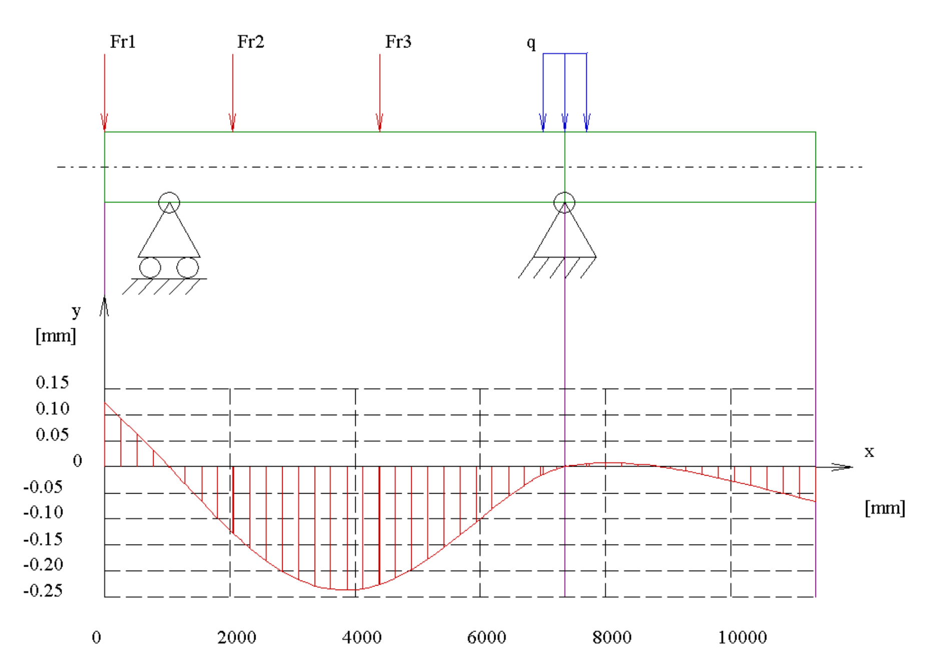
- The vertex detector and the intermediate tracker are directly attached to the central beam pipe made of beryllium alloy. Two bellows before the low angle tagger are foreseen to remove stress and torsion from this fragile structure. Flanges to disconnect the central pipe are located between the collimators and the beam position monitor within the conical mask.
- The tungsten shielding tubes are needed to reduce the background induced by the final focus quadrupoles. The tubes support the instrumented masks, the collimators, the beam monitors, the final focus quadrupoles and the feedback kickers.

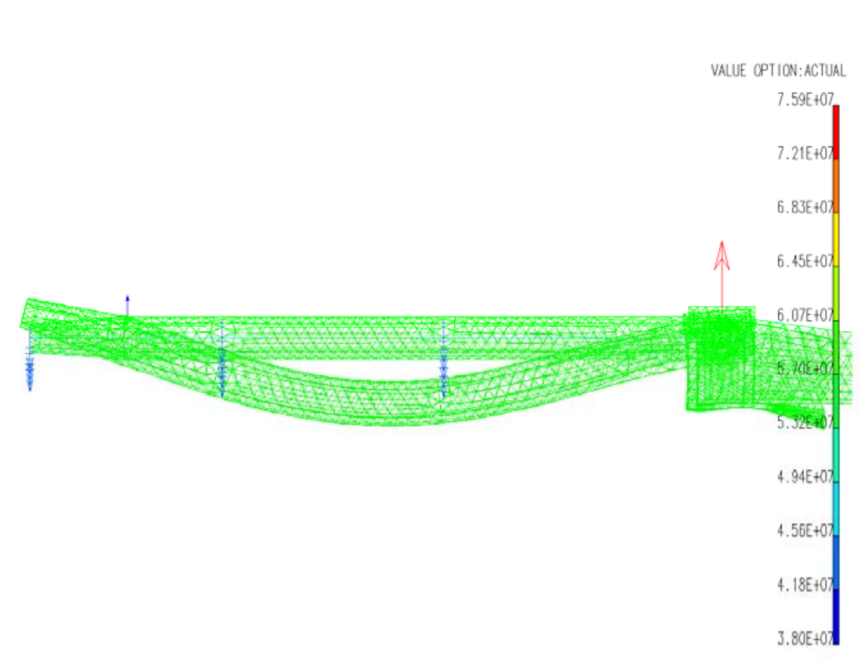
Tungsten tube support and cantilever system

- A particular difficult part of the mechanical design is the support and control of the tungsten tube loaded with the detector and machine elements. During normal operation the tube is supported at its two ends, outside the detector through the cantilever system shown below and inside the detector through a system of spokes to the cryostat of the coil.



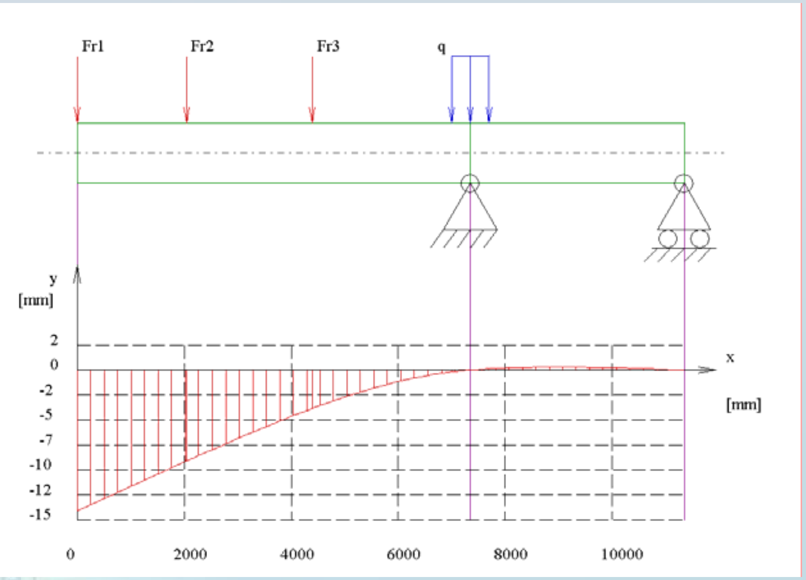
Finite element calculation of the tungsten tube supported at both ends.

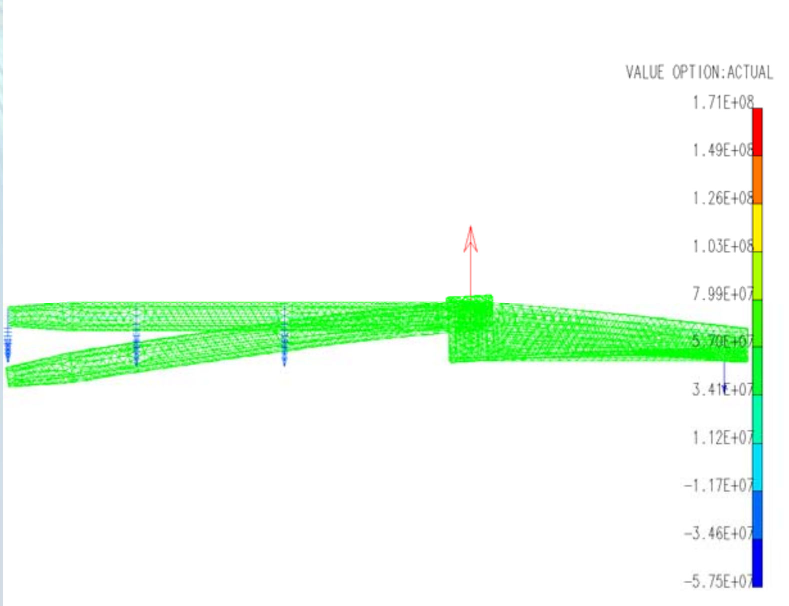




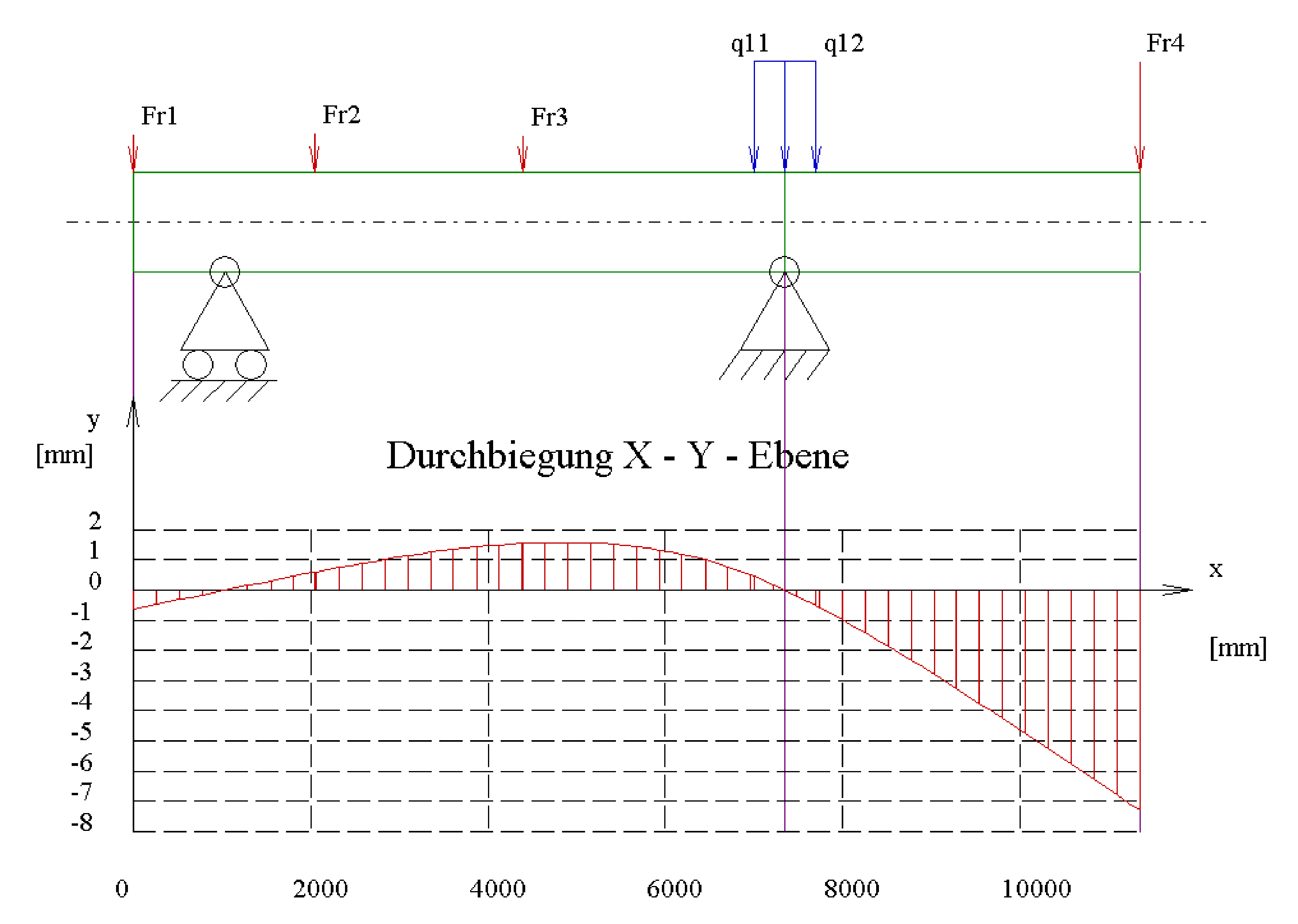
Finite element calculation of the tungsten tube with the support at the tip of the mask released

- The situation is very different during the opening of the detector. The support at the tip of the mask has to be released to allow the TPC to move out of the central detector region. As a result the tip of the mask will sag by around 20 mm.This is counteracted by the cantilever system. By applying a opposite force to the cantilever structure the tube support inside the detector is relieved and can be removed. The position of the tip of the mask remains stable within 0.6 mm. During movements of detector parts an active position control system has to ensure that the tip of the mask does not move.



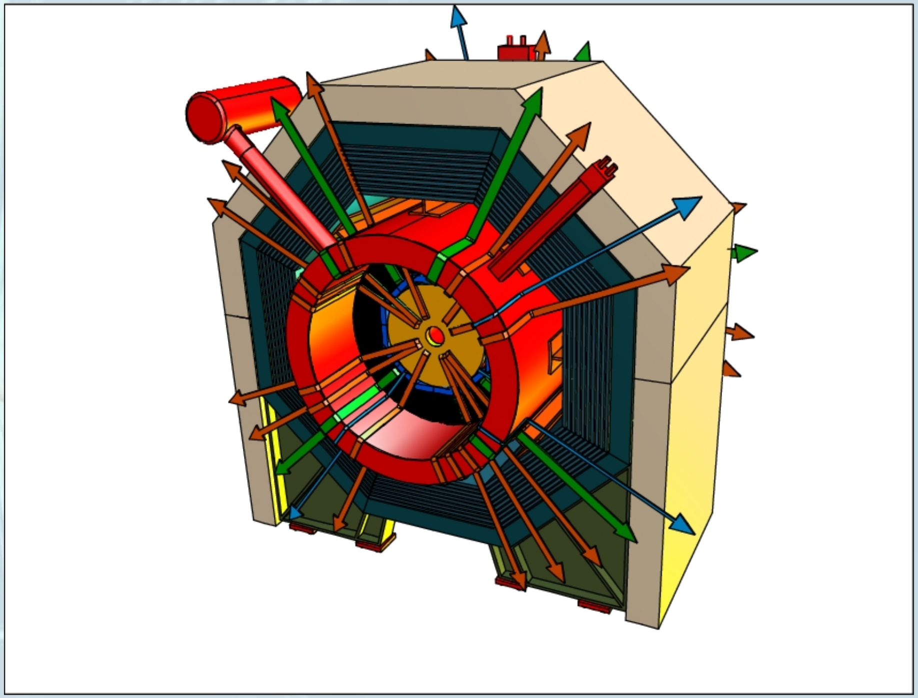


Bending calculation of the tungsten tube held only by the cantilever system with an opposite force Fr4 applied with the cantilever system, Fr1 is the load of the maqsk, Fr2 and Fr3 are the loads of the quadrupoles



Cable Routing

- The cables and pipes from the TPC, Forward Chamber and Calorimeter will be guided through the gap between the barrel and end cap calorimeter. They are routed along the walls of the vacuum tank to the gap between central yoke ring and end cap yokes where they leave the detector.



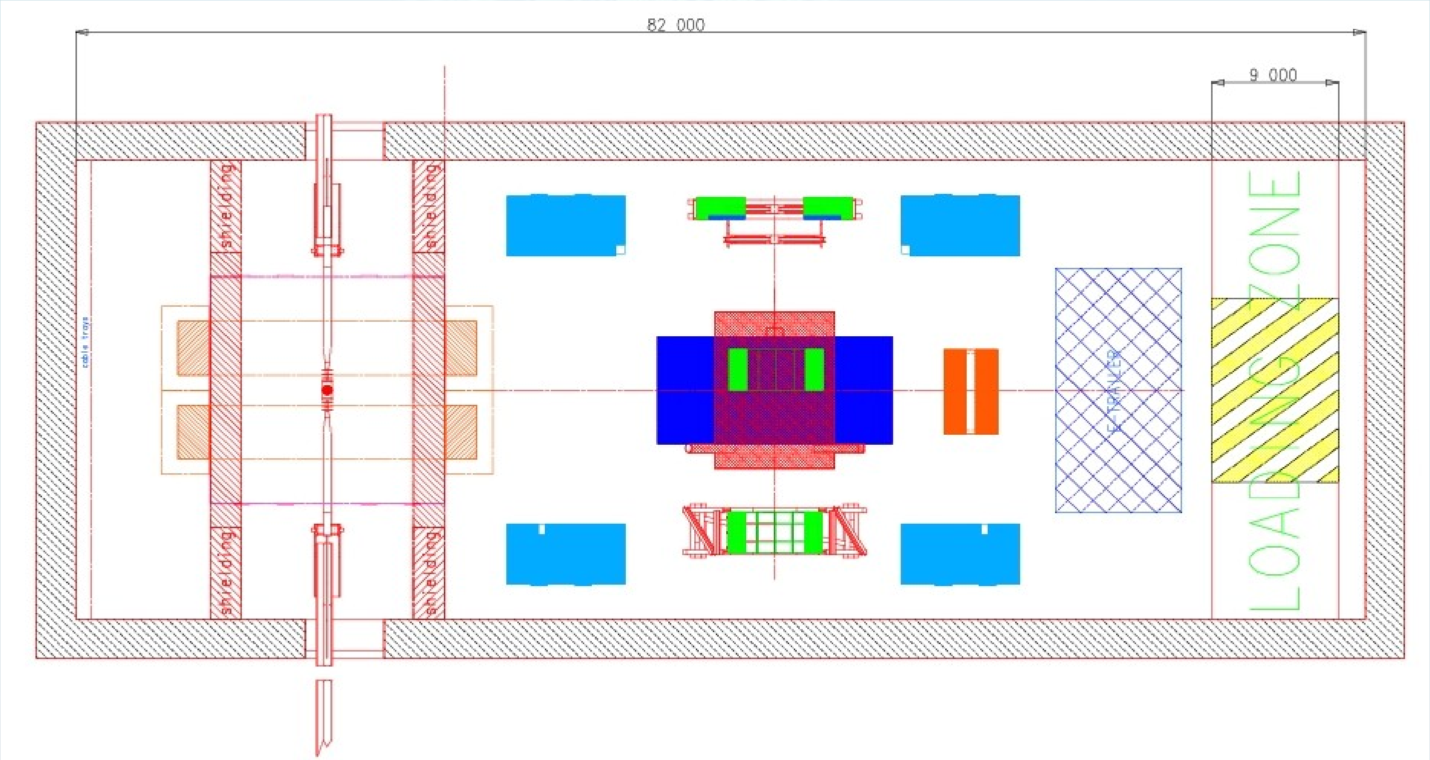
- The cables and pipes from the inner detectors have to be guided along the tungsten pipes to the outside of the detector.

Underground Experimental Hall

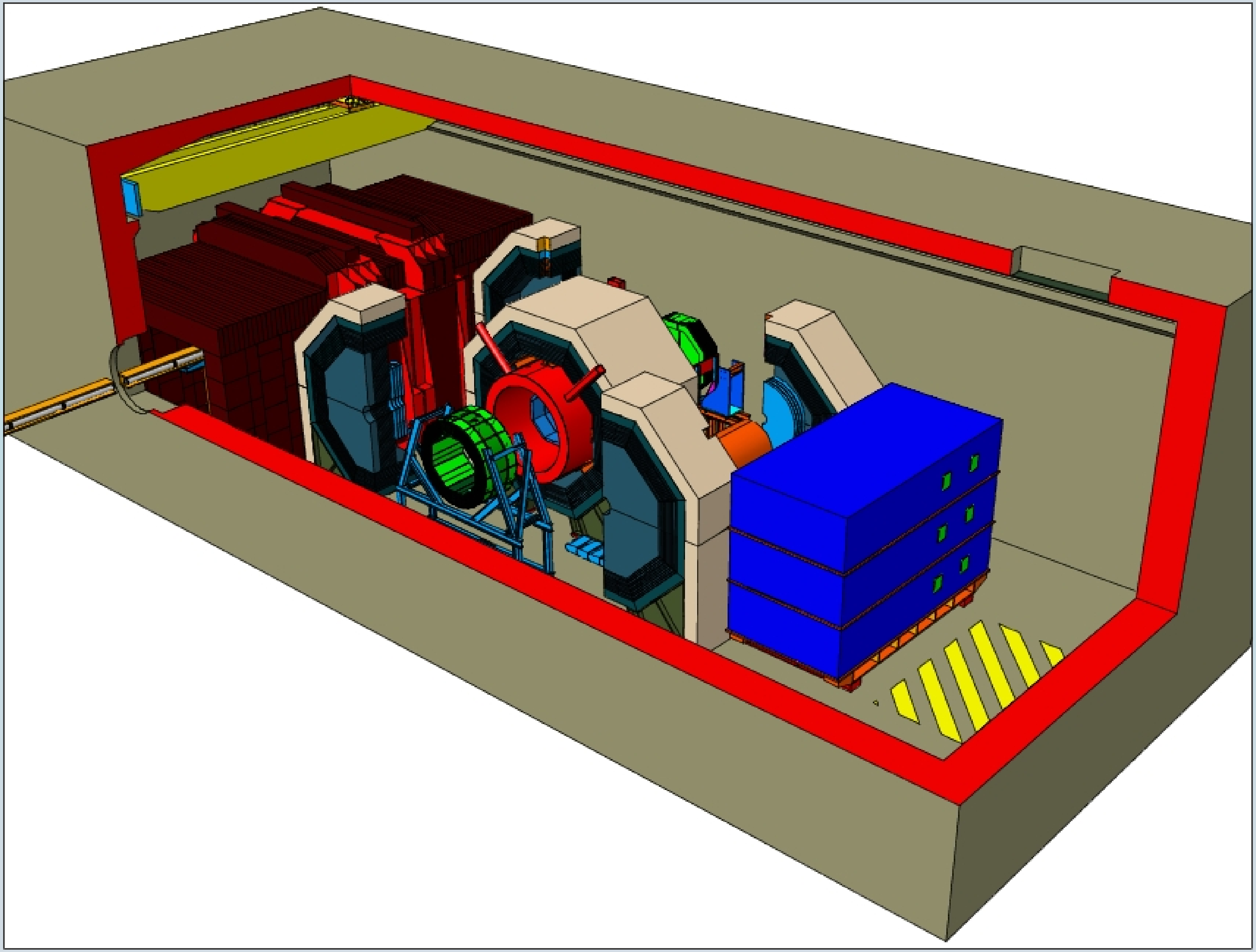
- The underground experimental hall is divided by the beamline into a short and a long section.
- The short section is defined by the open position of the detector when the detector is in the interaction region.
- The long section allows detector assembly, detector maintenance and detector upgrade.
- The beamline inside the hall is shielded by a system of movable concrete blocks. Therefore commissioning of the linac and machine studies are possible independant of the detector status in the long assembly and parking section of the hall.

Assembly in the long hall section

- The modular concept of the detector allows simultaneous installation work on different detector parts. Work on the central yoke ring and work on the four corner half shells can proceed in parallel.
- The picture shows the installation scenario of the detector in an advanced stage. The linac beam line is shielded with concrete blocks and two movable shielding portals. One half-barrel calorimeter and one end cap calorimeter are in preparation on maintenance supports.

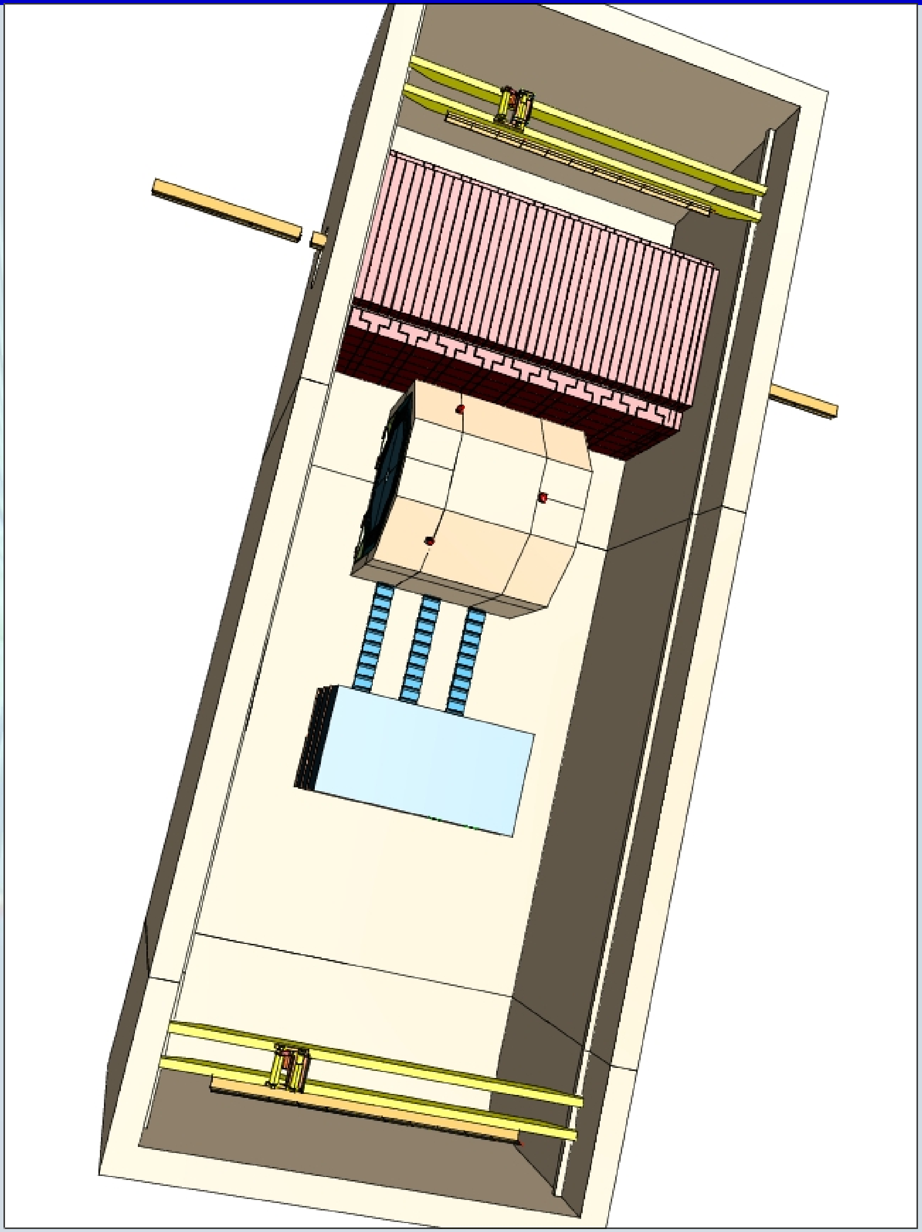


Assembly in the long hall section

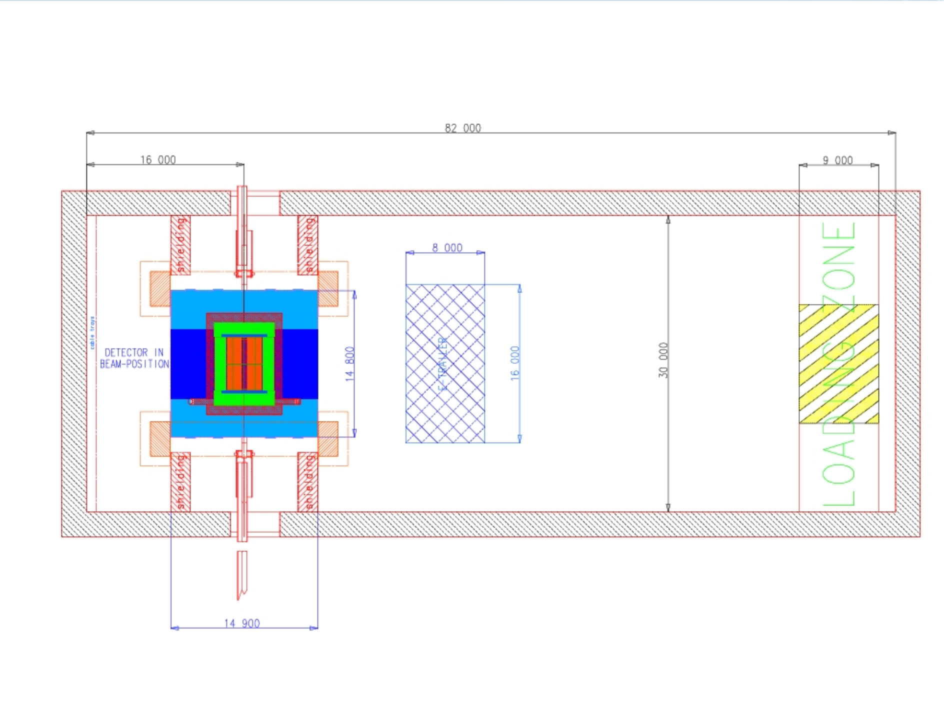


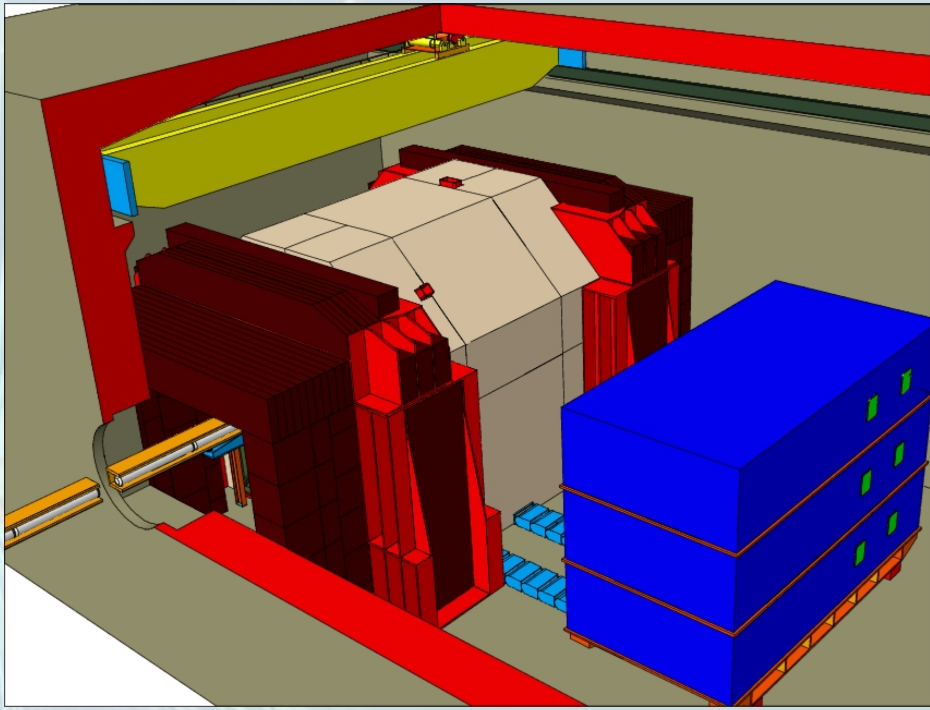
Closed detector in parking position

- When the five detector elements, central barrel part and four corner half shells are equipped with all the subdetectors, the cabling is completed and all subdetector systems are tested, the detector can be closed for a cosmic run before the transfer to the interaction region.



Closed detector in beam position



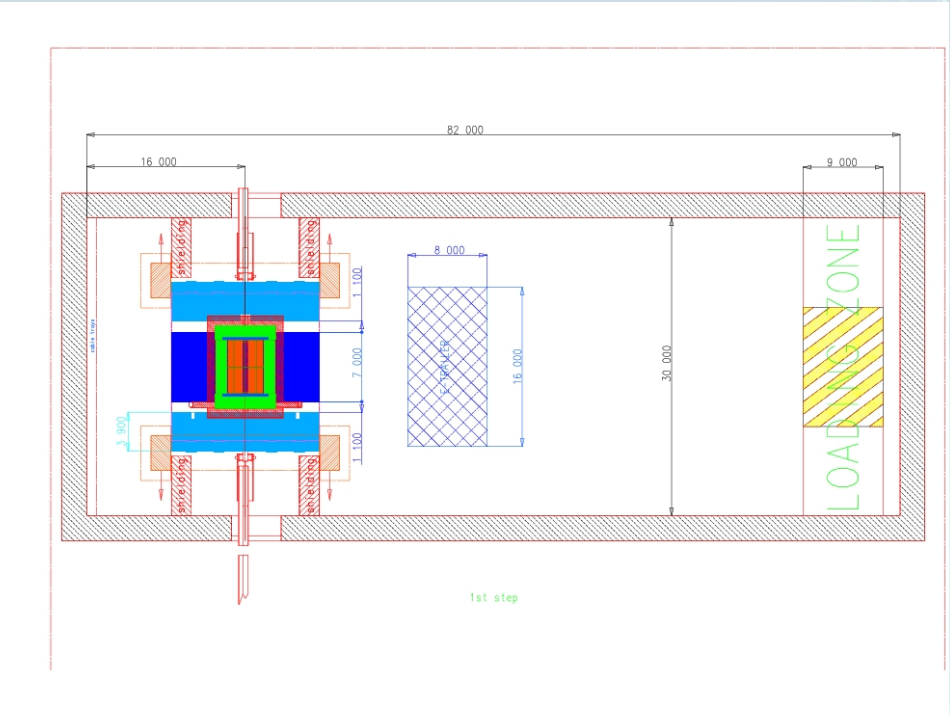


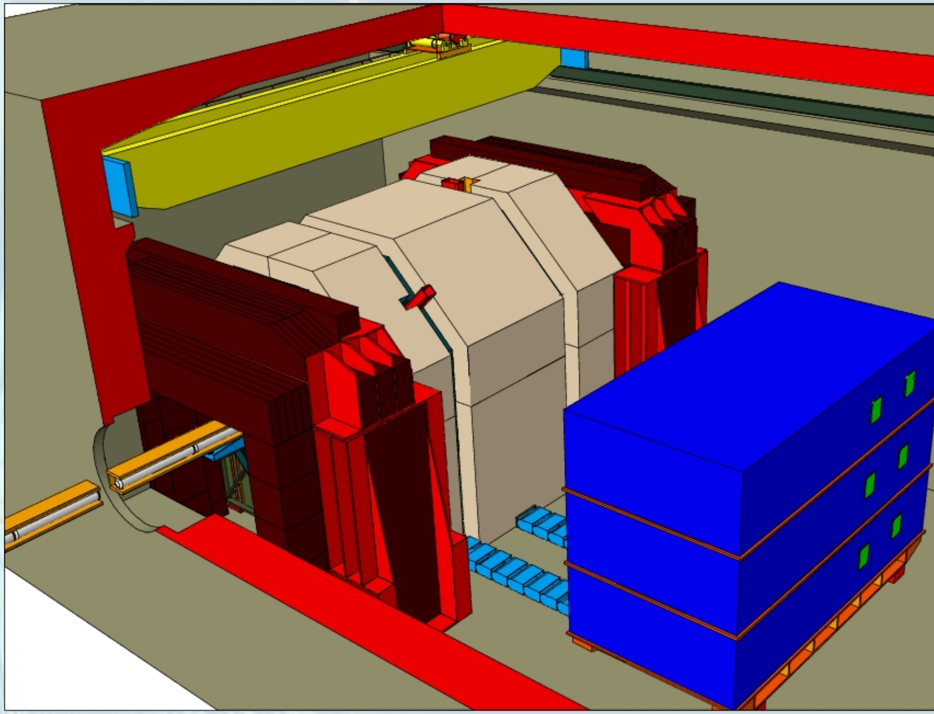
- Detector closed in the interaction region with the movable shielding portals in place

Maintenance in the beam position

- To obtain access to the central detector region from the closed position of the detector in the beam position the opening of the four corner half shell pieces and the installation of temporary support structures for the removal of several detector elements is required.
- In a first step the two shielding portals covering the slits between the selfshielding detector and the linac shielding will be moved along the beam direction to allow the four corner half shells to be moved away from the central yoke to retract the field shaping pole tips from the cryostat and clear the corner half shells for a lateral movement.

Maintenance in beam position (opening sequence)

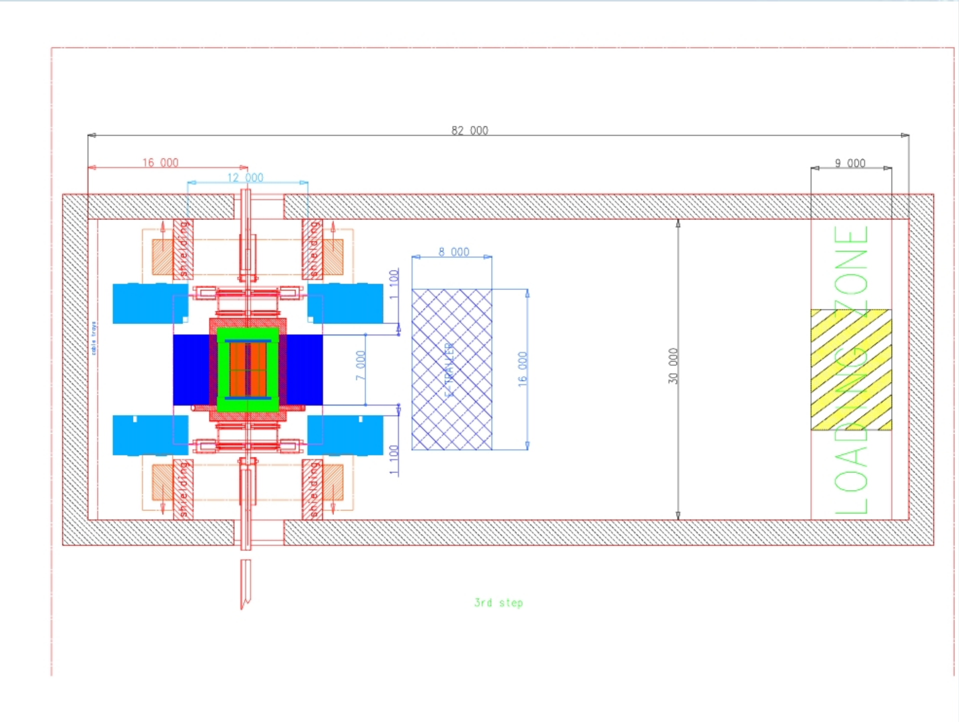


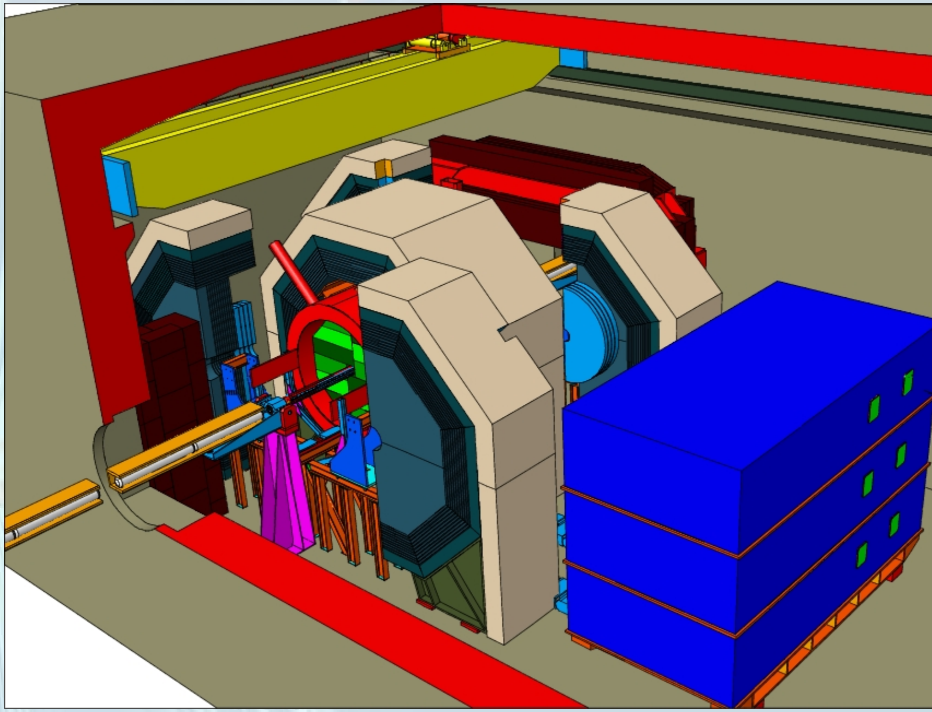


- **Step 1:** Both shielding portals retracted and corner half shells opened on both sides along the beam direction

Maintenance in the beam position

- The second step is the lateral opening of the corner half shells and the transfer of the auxiliary support frames for the endcap calorimeters from their park position within the shielding walls to a position adjacent to the cryostat tank

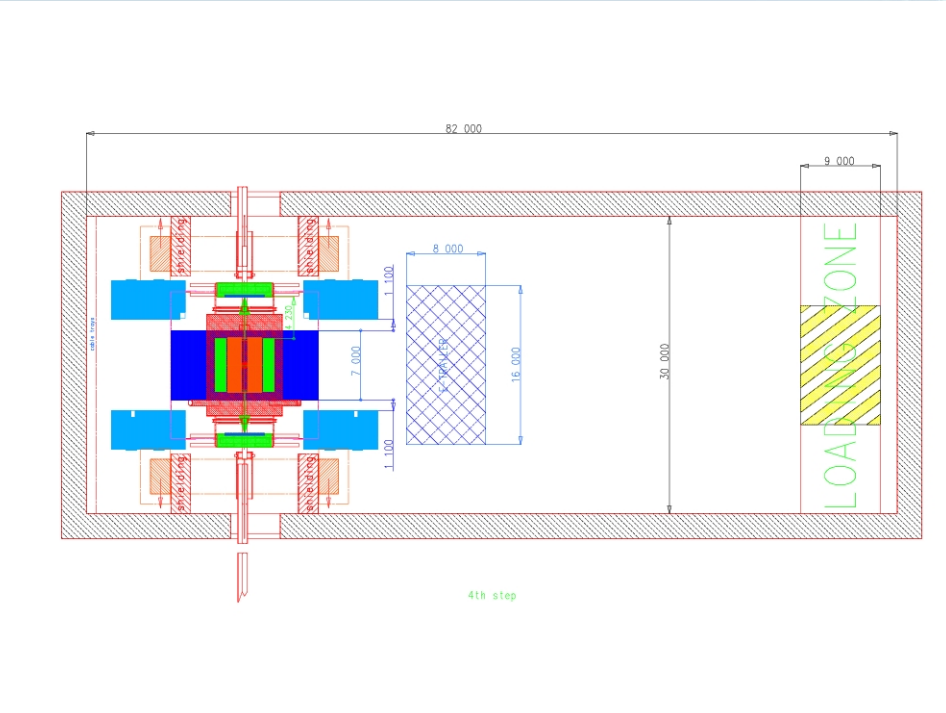


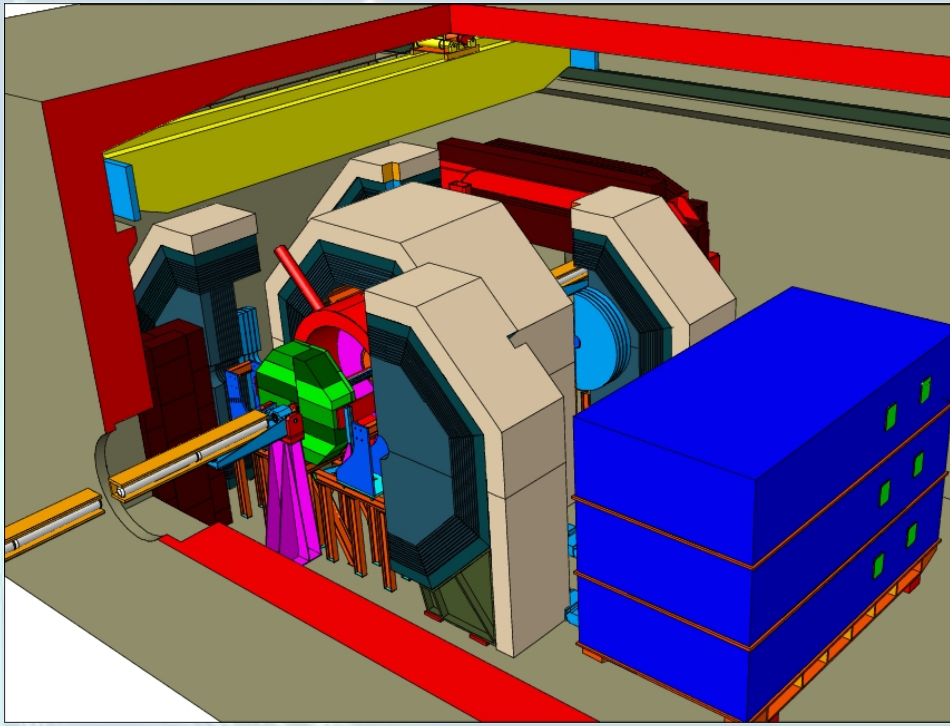


- **Step 2:** Corner half shells laterally opened, auxiliary support for calorimeter end cap installed

- The endcap calorimeter diks will be rolled out in step three.

Maintenance in beam position (opening sequence)

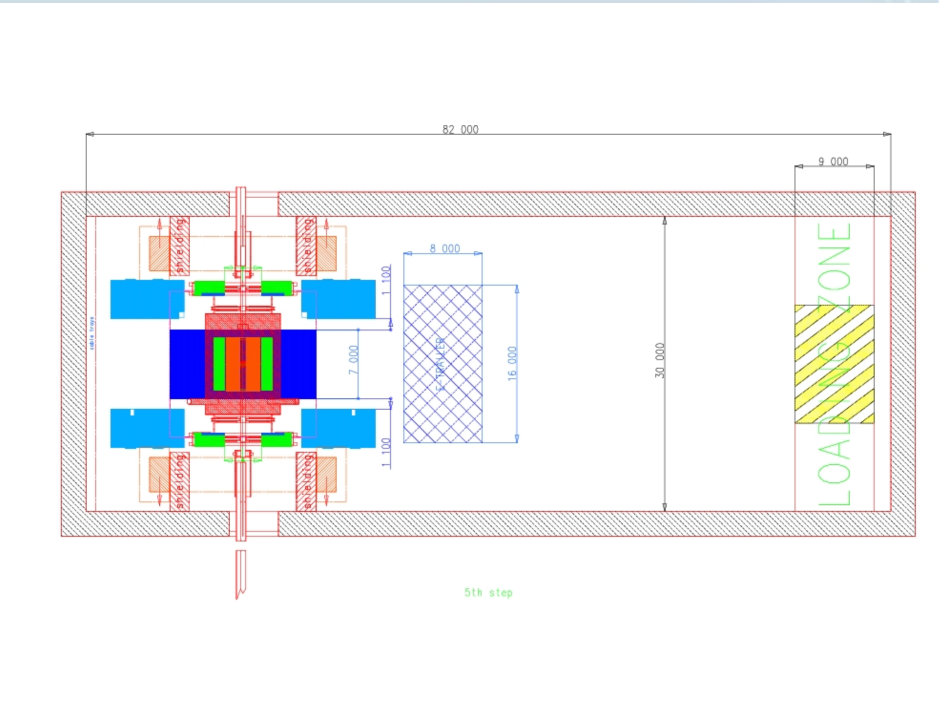


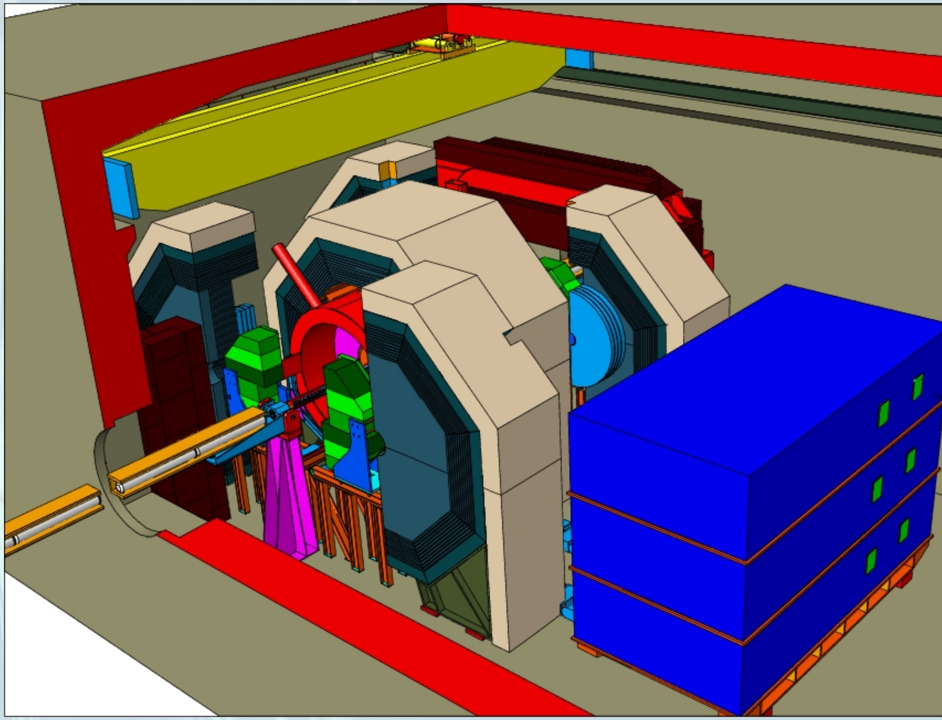


- **Step 3:** End cap disks rolled out onto support frame

- The endcap calorimeter disks are seperated into two halves and opened in step four. This clears the area in front of the mask support and allows the installation of the auxiliary girders for the temporary TPC sliding support structure to the inner wall of the cryostat tank.
- The support of the tungsten tube at the tip of the mask within the cryostat will be released and deinstalled to allow the movement of the TPC along the beam direction.

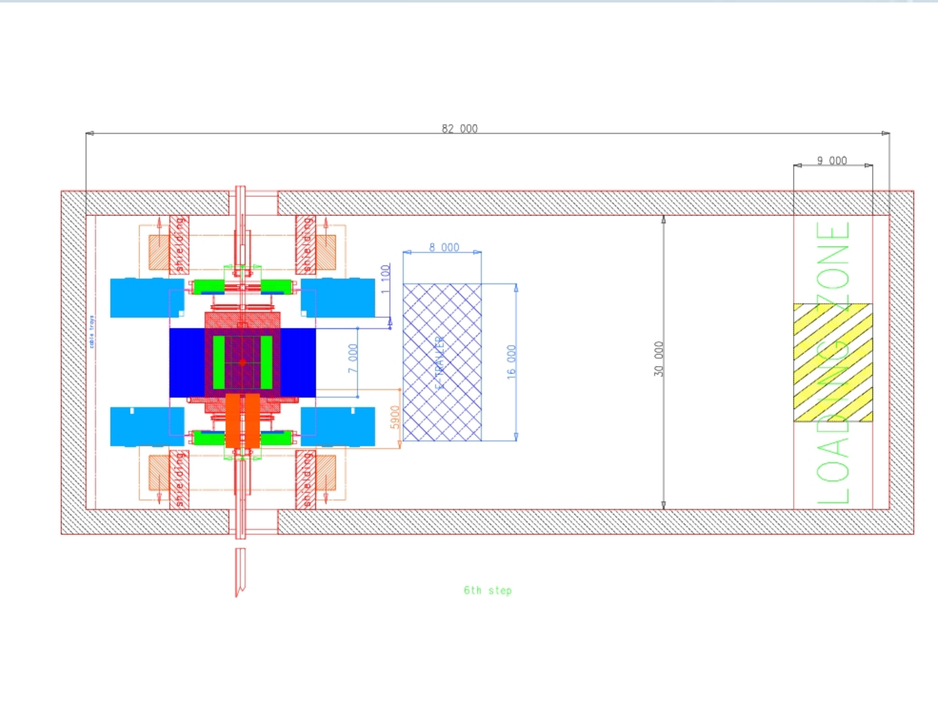
Maintenance in beam position (opening sequence)

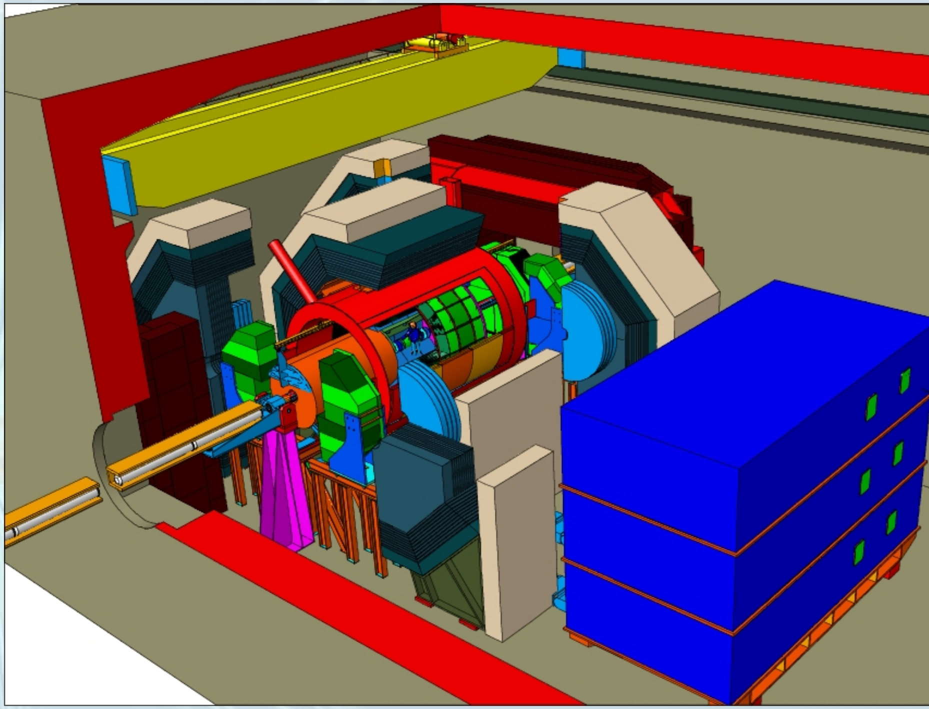




Step 4: End cap calorimeter disks opened on the support frame

- In step five the TPC is fixed to the temporary rolling mechanism and removed from the inner detector region.

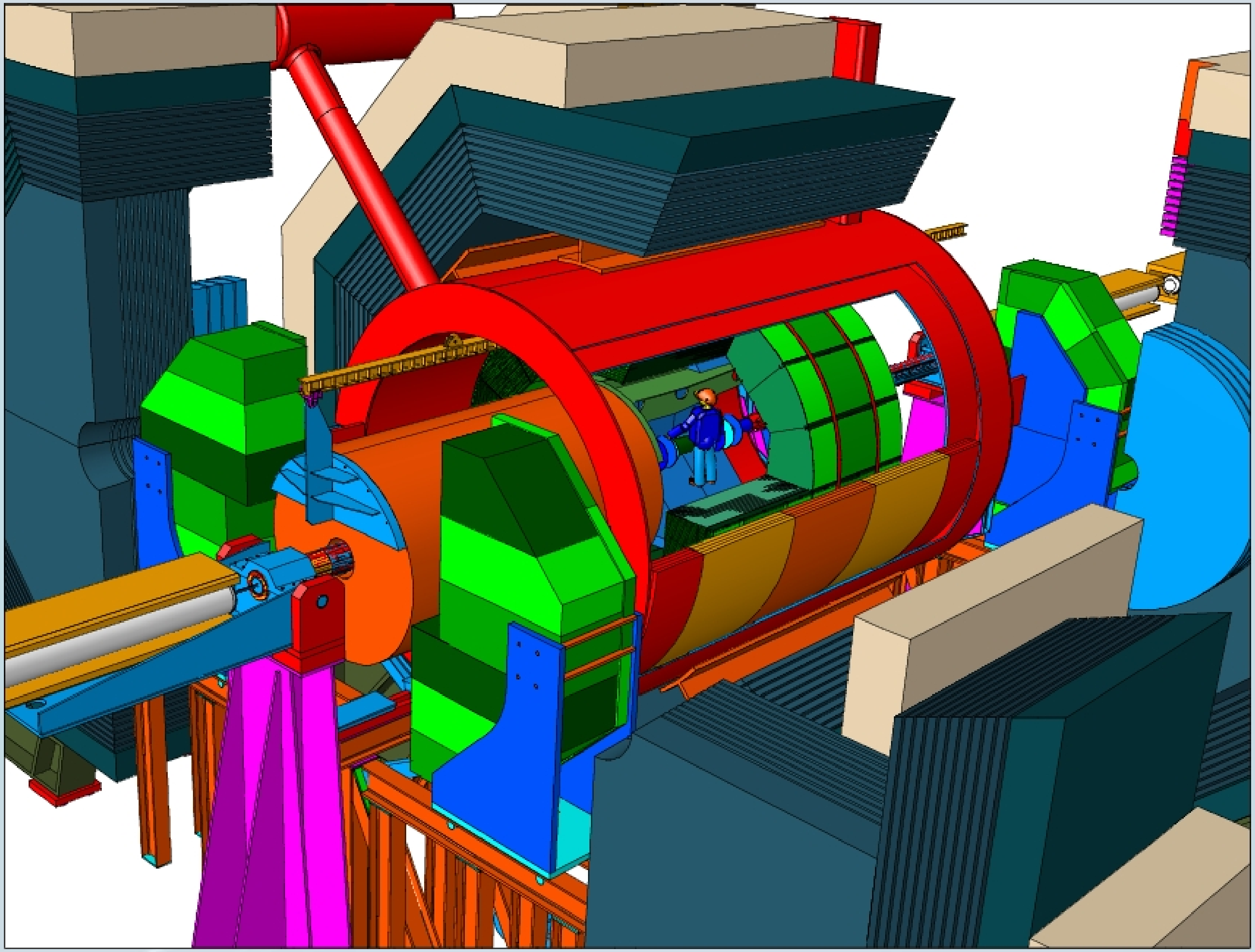




- **Step 5:**Time projektion chamber moved out of the inner detector region

- With the TPC in this position a temporary platform can be installed in step six below the beam pipe from the opposite end of the central yoke and personnel can enter the inner detector region for vertex detector maintenance.
- The vacuum flanges of the central detector beam pipe are now accessible and an exchange of the central pipe section is possible.

Maintenance in beam position (opening sequence)

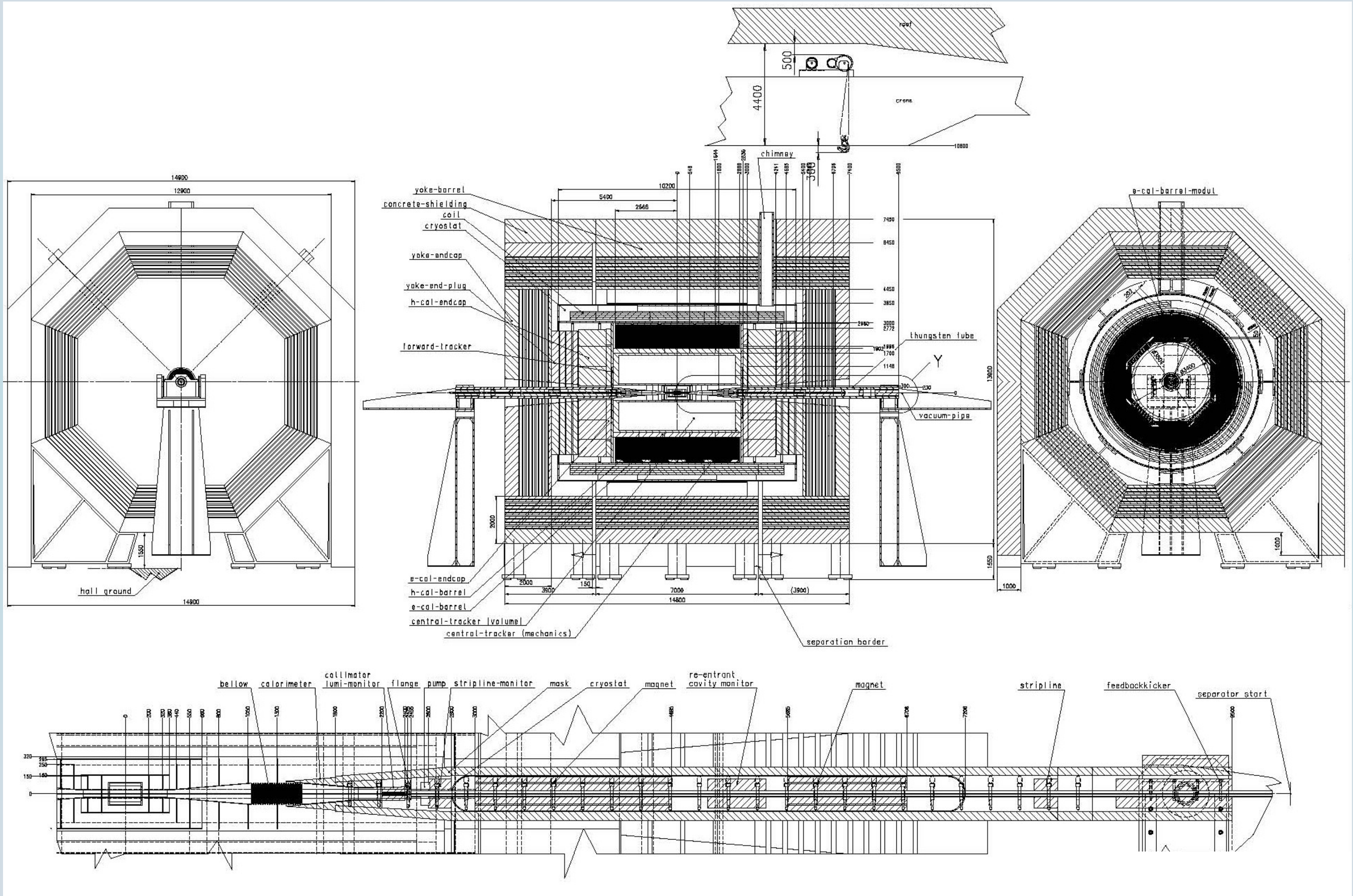


- **Step 6:** Vertex detector maintenance (For illustration several detector parts are cut out)

Detector weight

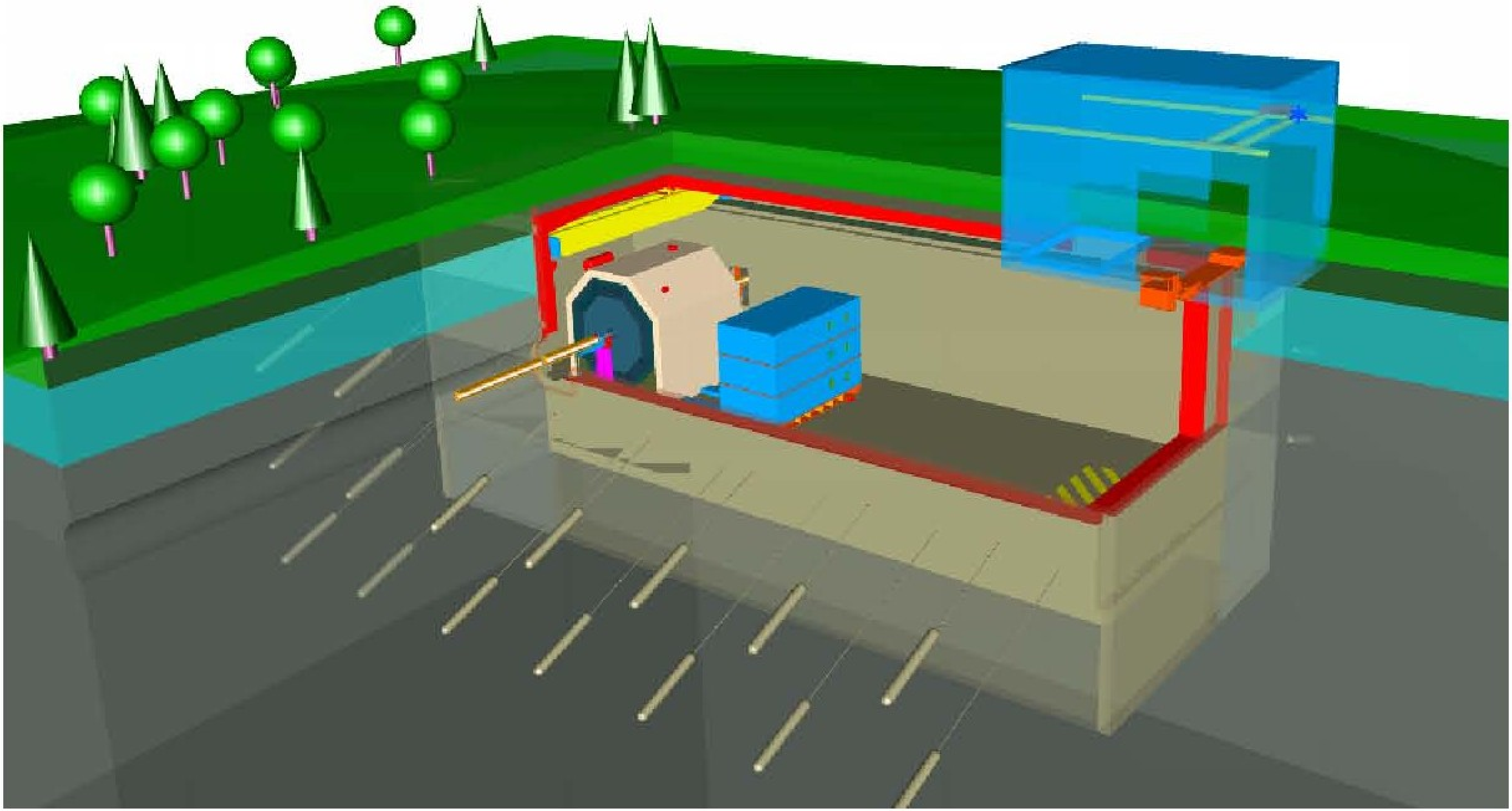
Weight of Detector Components

Component	Weight per Module	Number of Modules	Total Weight
Central Yoke Ring	-	1	~4000t
Cold Mass (Coil with Vacuum Tank and Cryostat)	-	1	~200t
HCAL Barrel	15.3t	2 x 16	~490t
HCAL End Caps	49t	2 x 4	~392t
ECAL Barrel	~2.83t	8 x 5	~113t
ECAL End Caps	5.18t	2 x 4	~42t
TPC and FCH	~5t	1	~5t
Sum Central Part			~5240t
Corner Half Shells	~1600t	4	~6400t

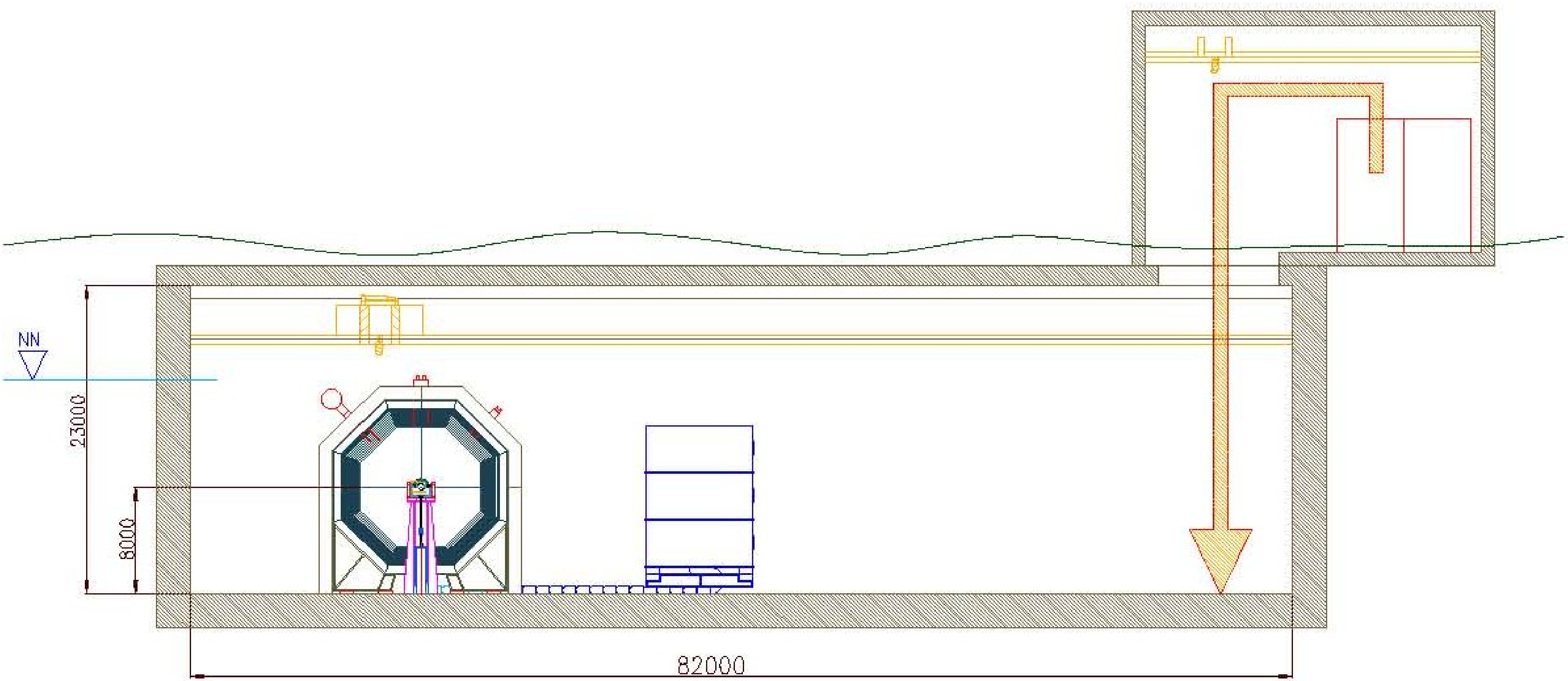


roof
crane
chimney
yoke-barrel
concrete-shielding
coil
cryostat
yoke-endcap
yoke-end-plug
h-cal-endcap
forward-tracker
thungsten tube
vacuum-pipe
e-cal-barrel-modul
e-cal-endcap
h-cal-barrel
e-cal-barrel
central-tracker (volume)
central-tracker (mechanics)
separation border
hall ground
14900
12900
14900
10200
5400
2666
2000
3900
150
7000
(3900)
14800
bellow
calorimeter
collimator
lumi-monitor
flange
pump
stripline-monitor
mask
cryostat
magnet
re-entrant
cavity monitor
magnet
stripline
feedbackkicker
separator start

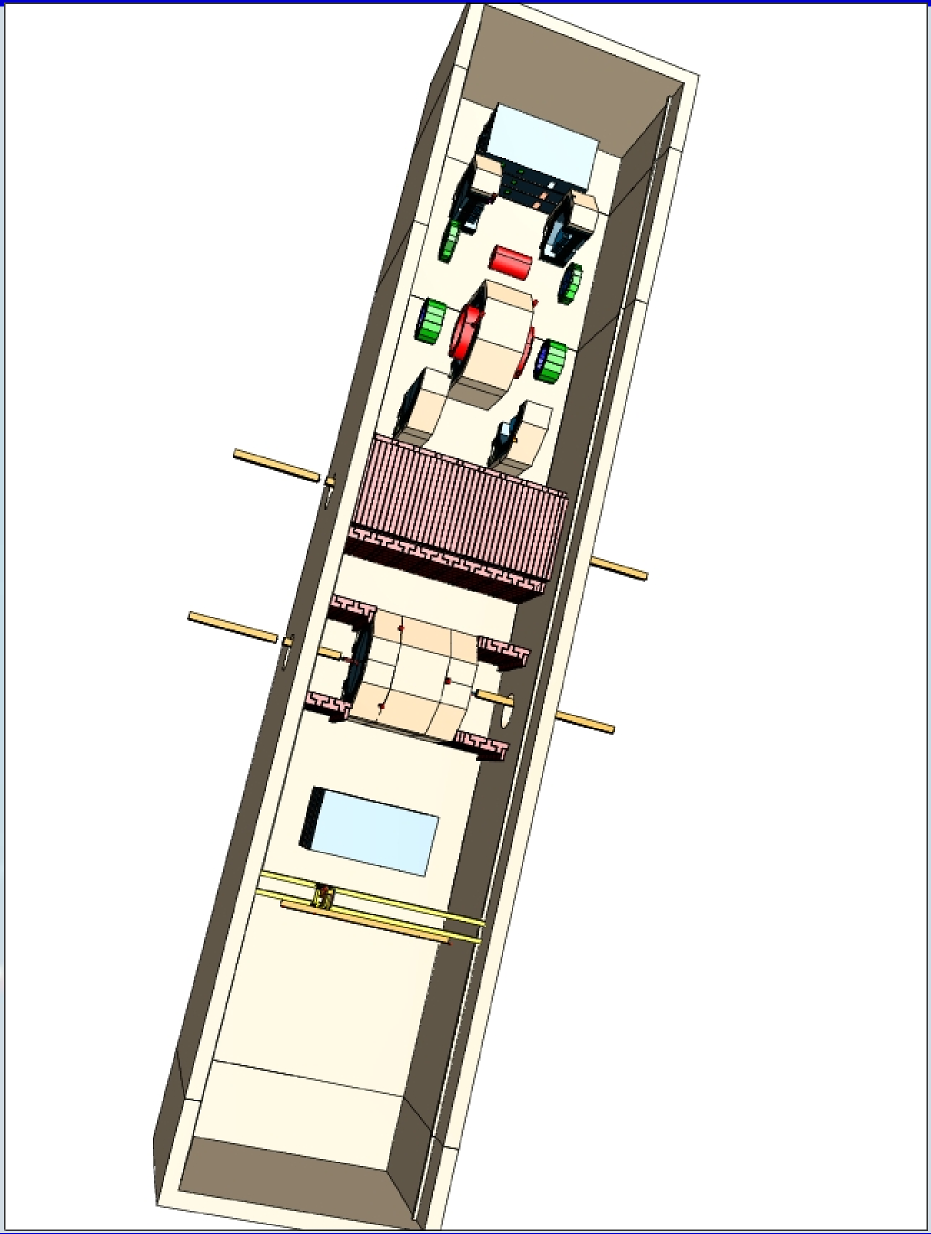
Principle experimental hall arrangement



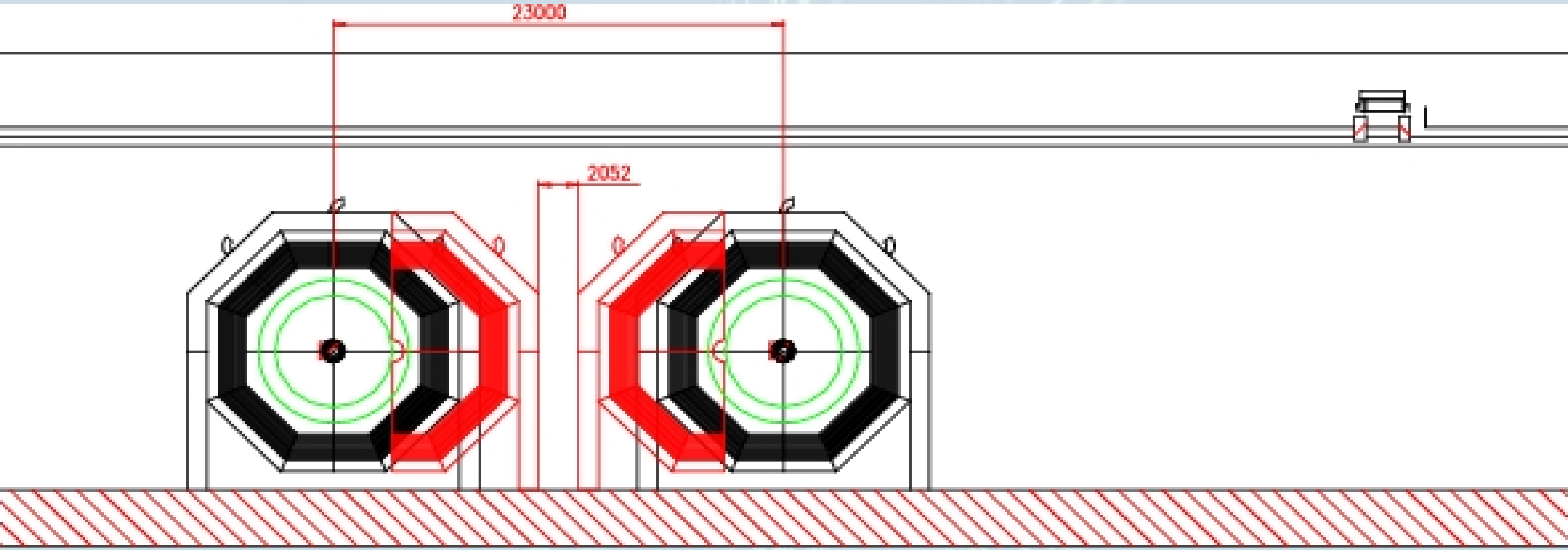
Principle cross section of the hall arrangement



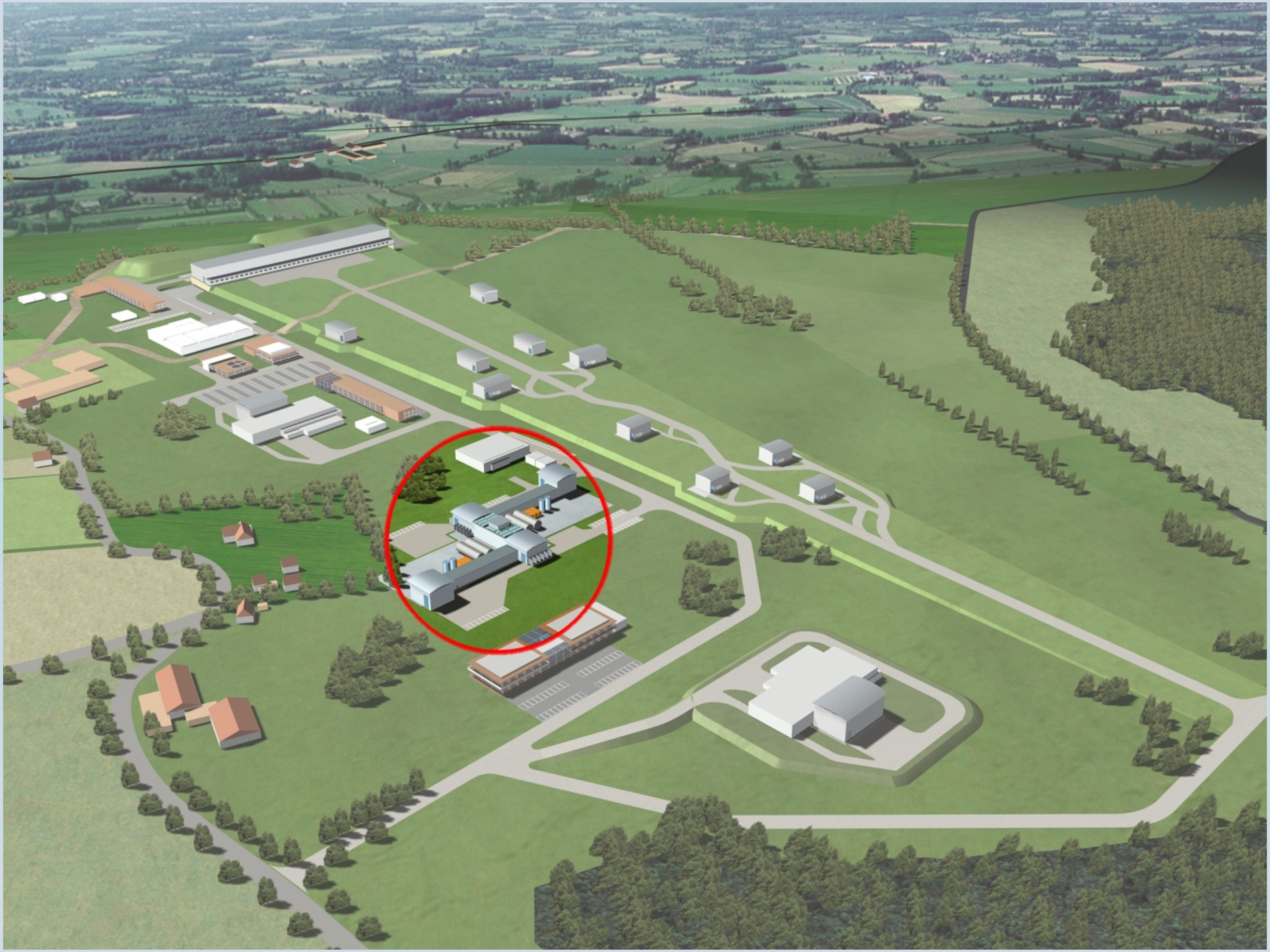
Experimental hall with two interaction regions



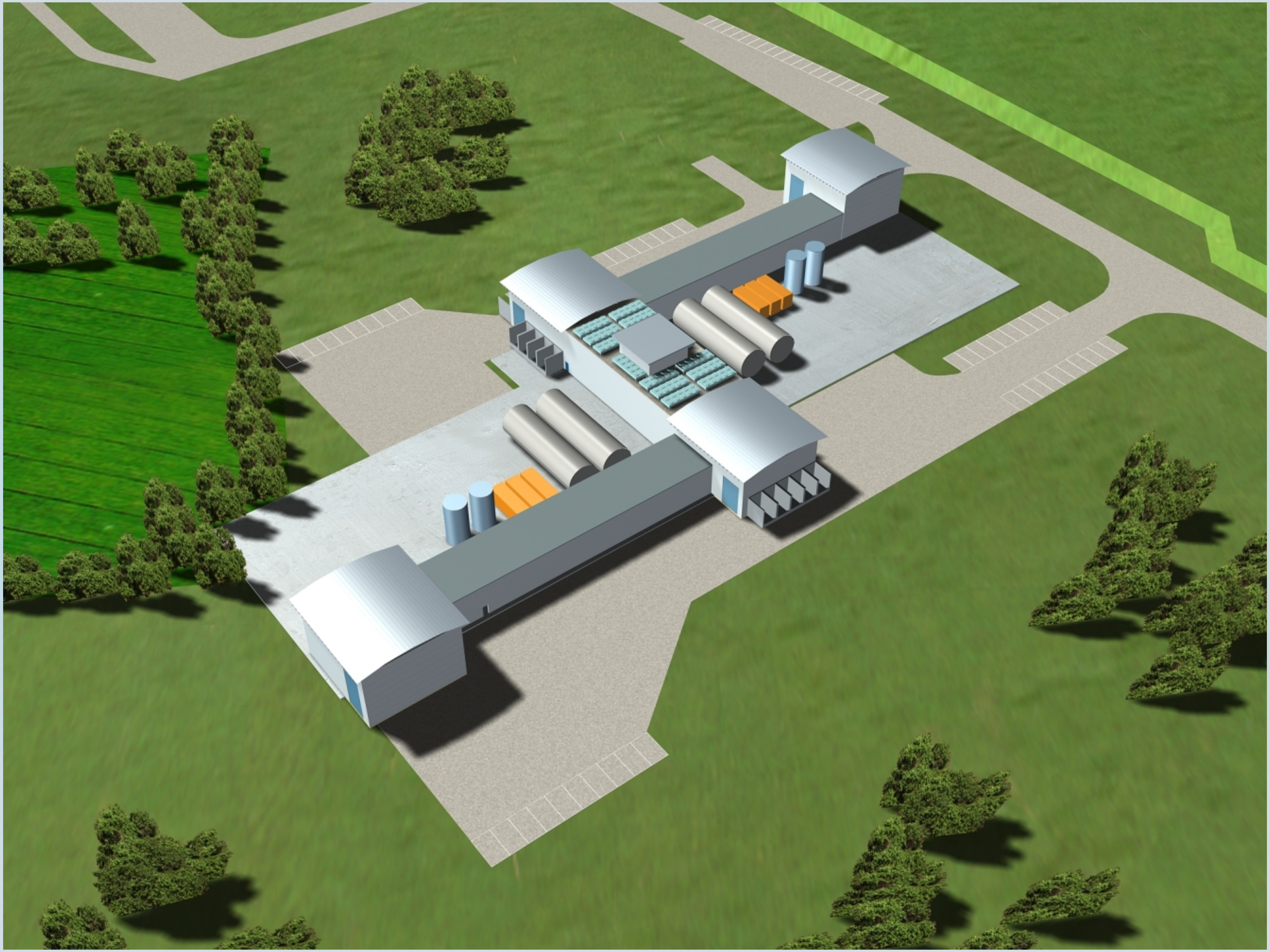
Minimum distance between 2 detectors



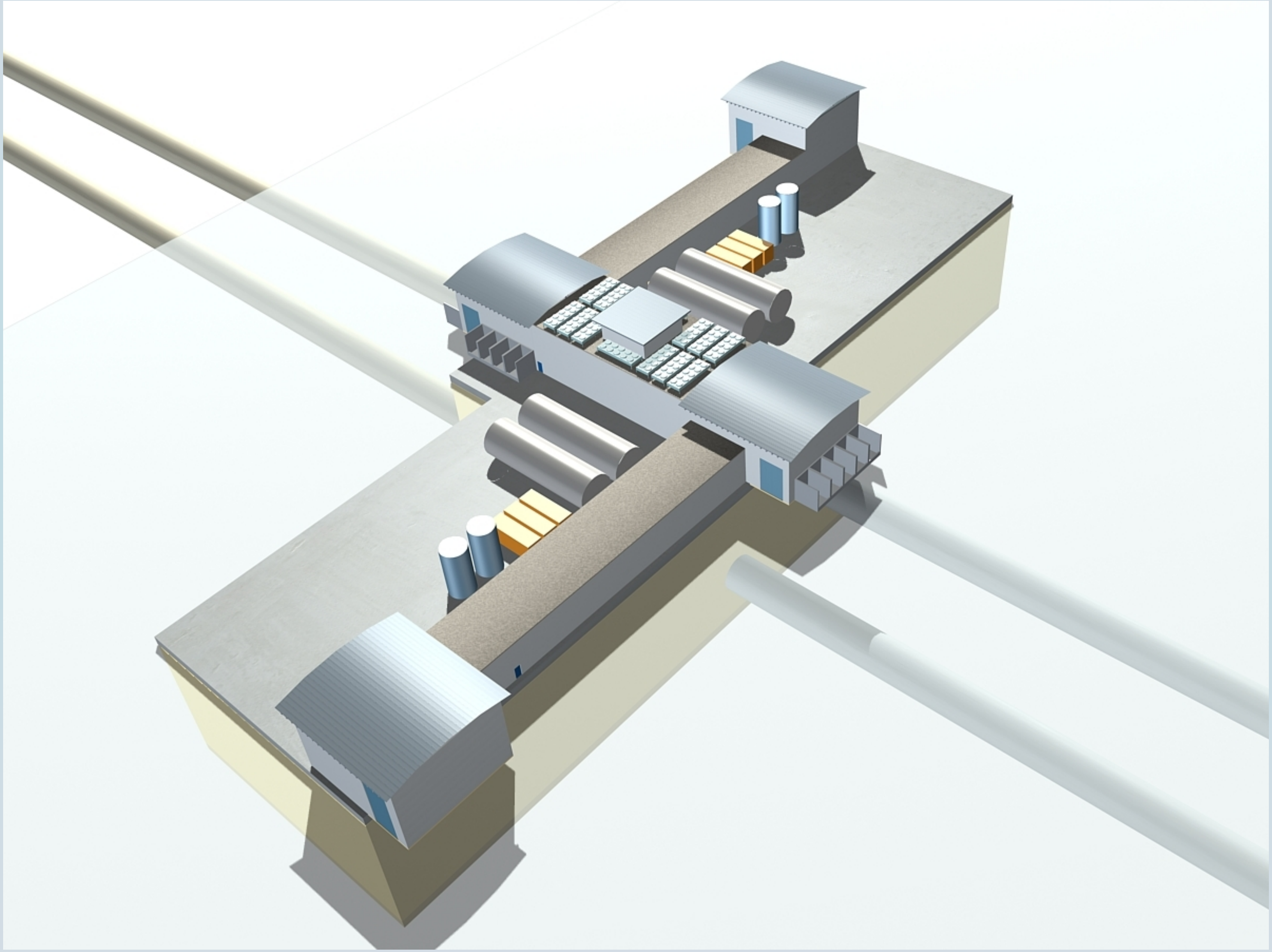
Ellerhoop site



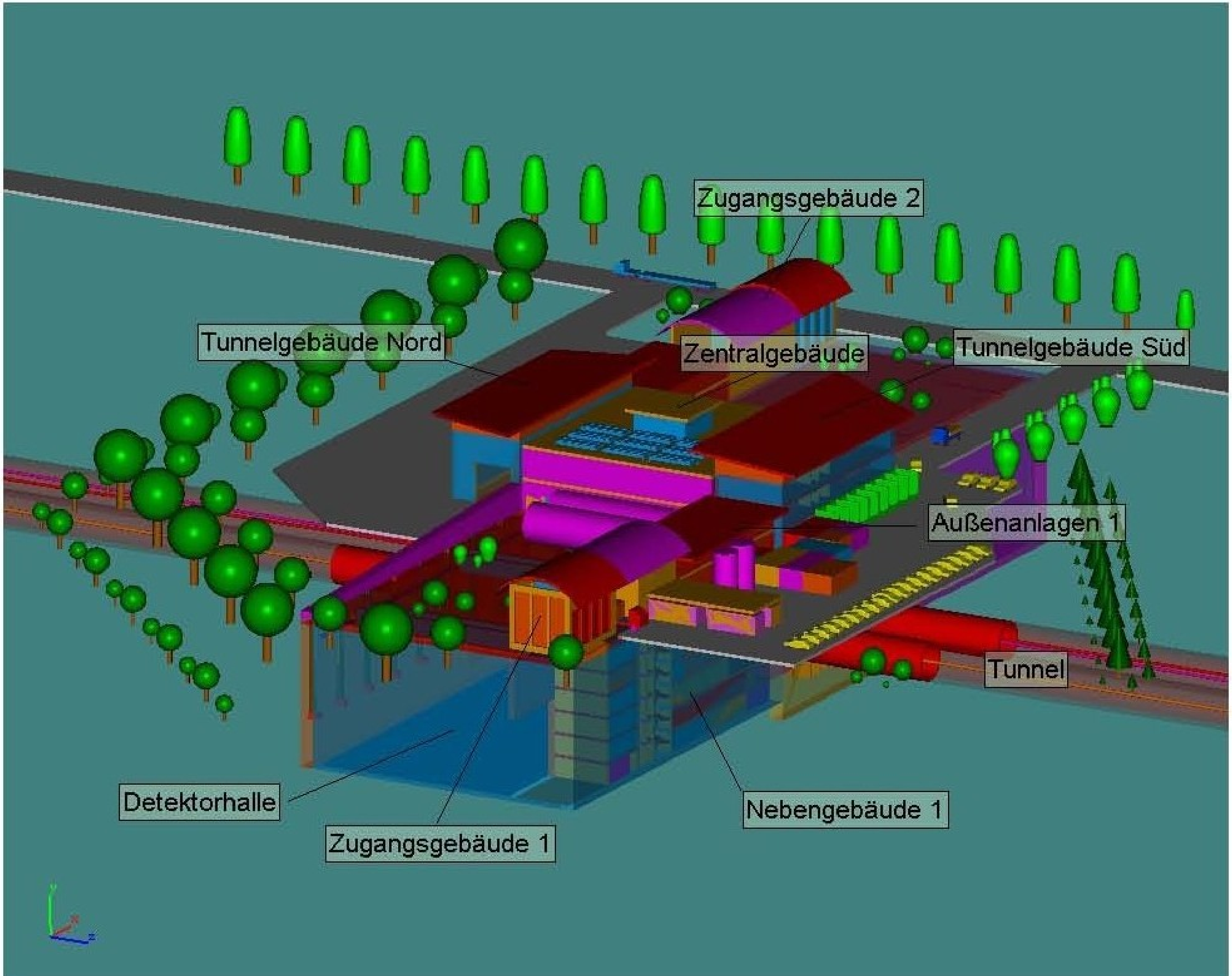
Experimental Hall Ellerhoop



Experimental Hall Ellerhoop



HEP Experimental hall at Ellerhoop



Detector 1 during installation in the experimental hall