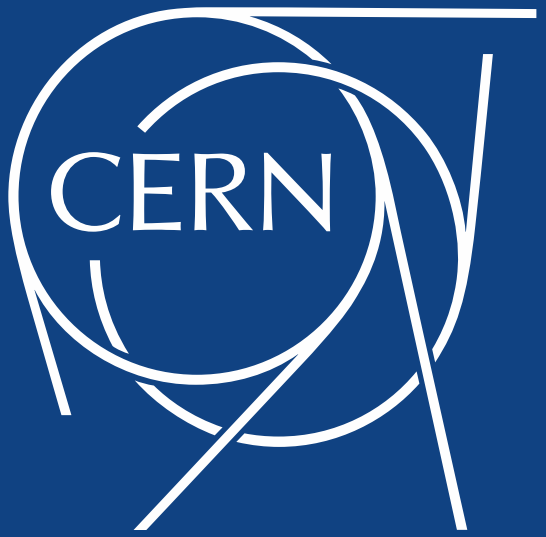

CERN

MQXFS Assembly Procedure

J.C Perez

HL-LHC/LARP International Review of the MQXF Design
December 10-12, 2014
CERN

N. Bourcey, B. Favrat, P. Ferracin, Ph. Grosclaude, M. Juchno, L. Lambert, P. Moyret,
J. Parrilla Leal, N. Peray, T. Sahner, A. Temporal and many others …

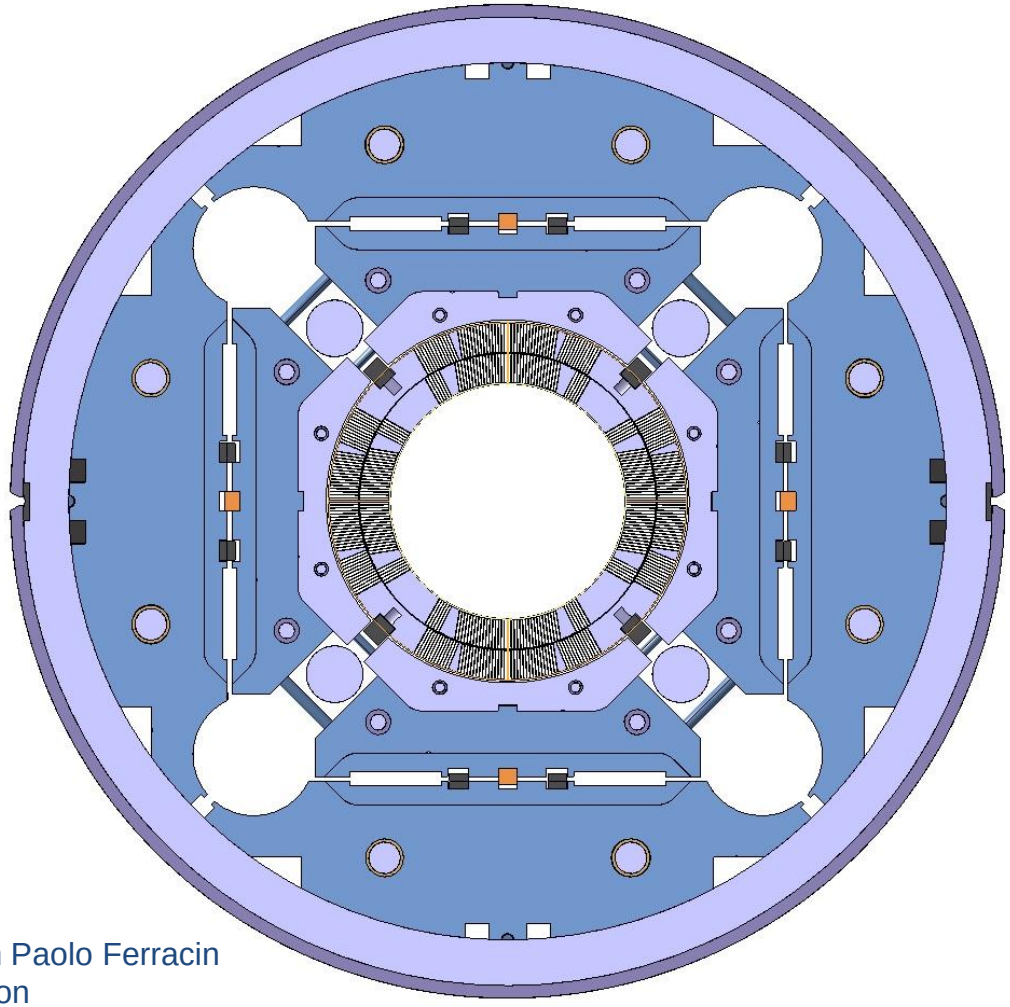
OUTLINE

- MQXFS model magnet assembly at CERN
  - Main assembly steps (Slide 5 to 19)
  - Status on components and tooling (Slide 20 to 24)
  - Possible MQXFB assembly procedure (7 meter long magnet)
  - 150 mm mechanical model assembly and cooling to 77K
  - First MQXFS mechanical assembly at CERN using aluminium dummy coils

- Conclusions

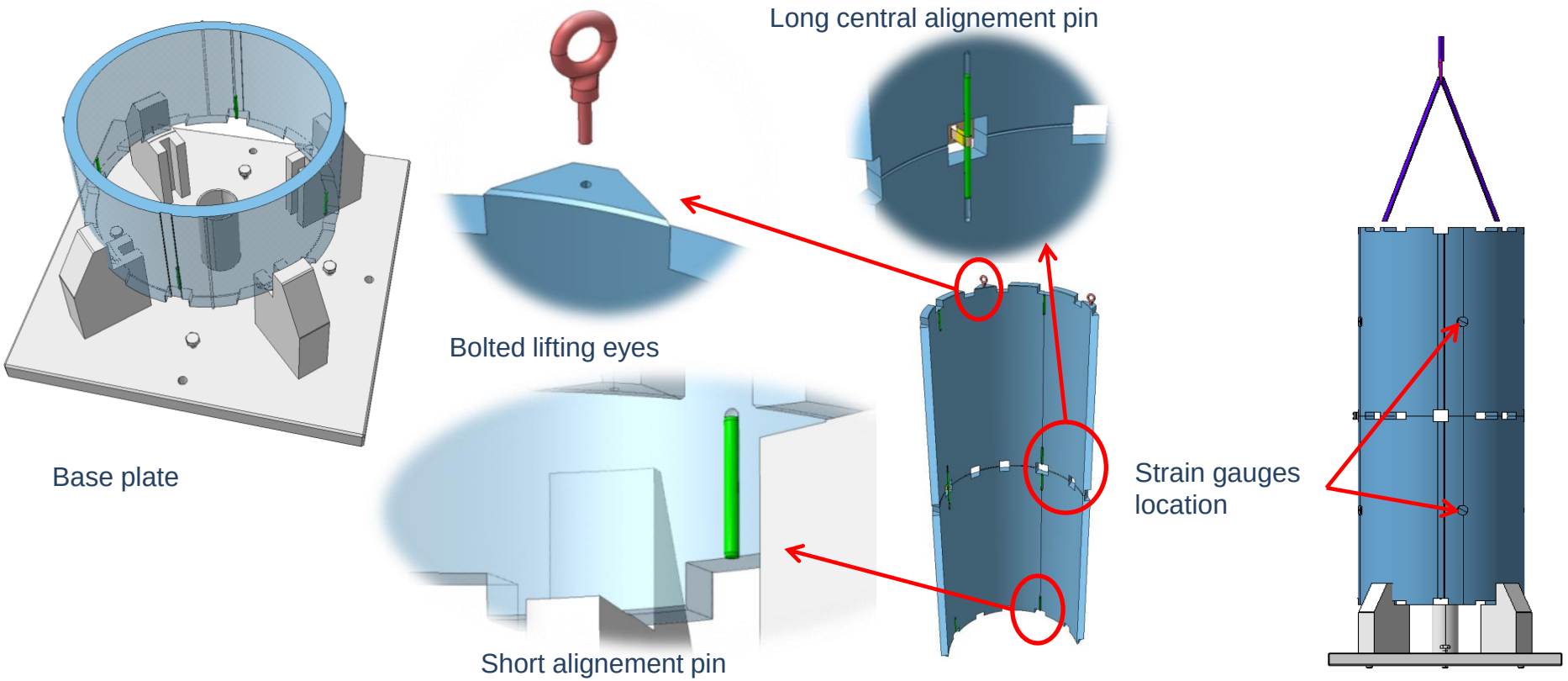
MQXFS cross section

- Coils
- Coils pole keys
- Aluminum collars
- Iron & stainless steel pads
- Iron masters, alignment and loading keys
- Iron yoke
- Aluminum shell
- Stainless steel shell and welding strip



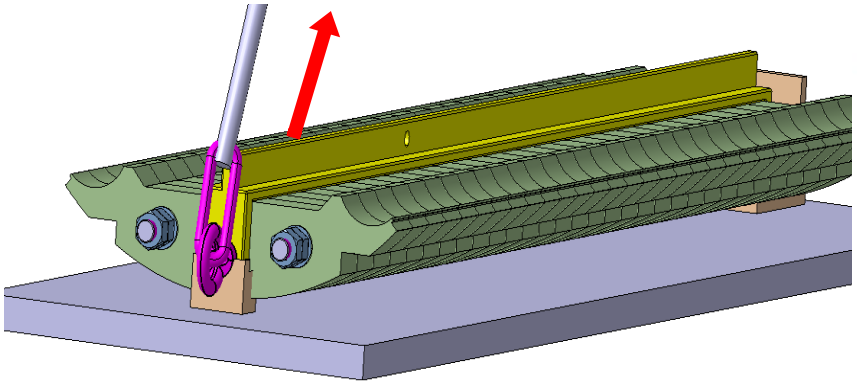
See detailed presentation on magnet components from Paolo Ferracin and shell welding operation from Herve Prin presentation

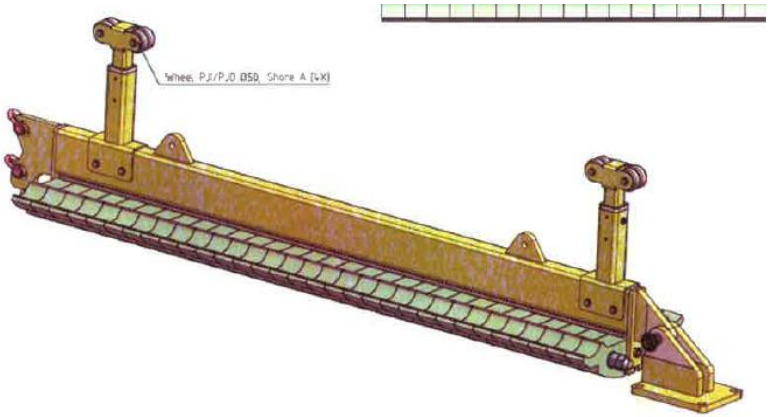
Shells preparation for vertical assembly

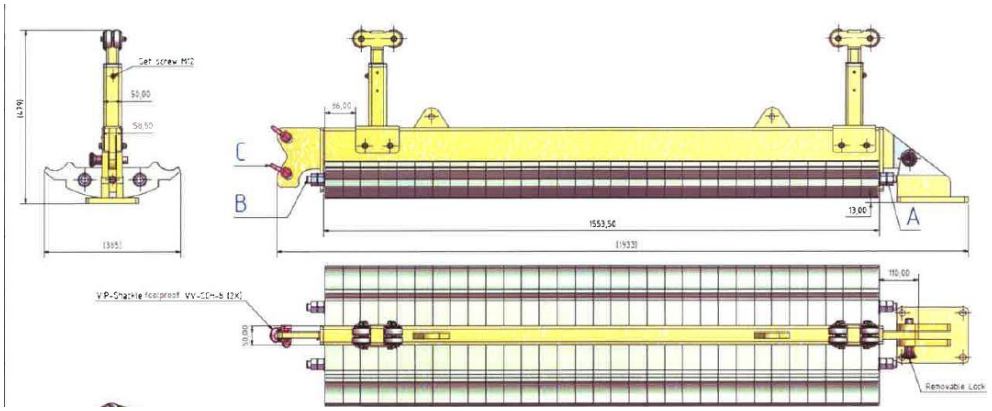


- The shells are instrumented with the strain gauges before starting the assembly sequence
- 4 short alignment pins are inserted and glued in the lower inner shell slots of the first shell to be installed on top of the assembly base plate
- The relative angular alignment between the 2 shells is guaranteed by the use of the 2 long pins

¼ yoke lifting and preparation for insertion

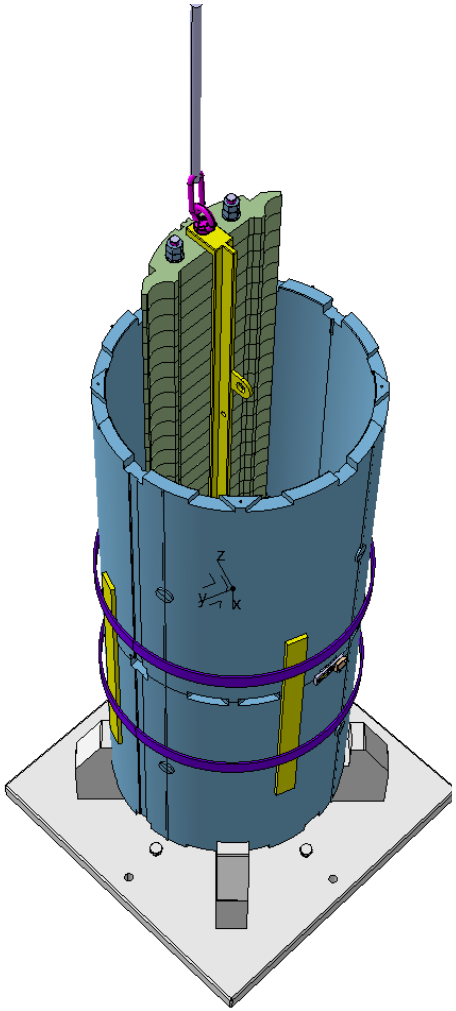


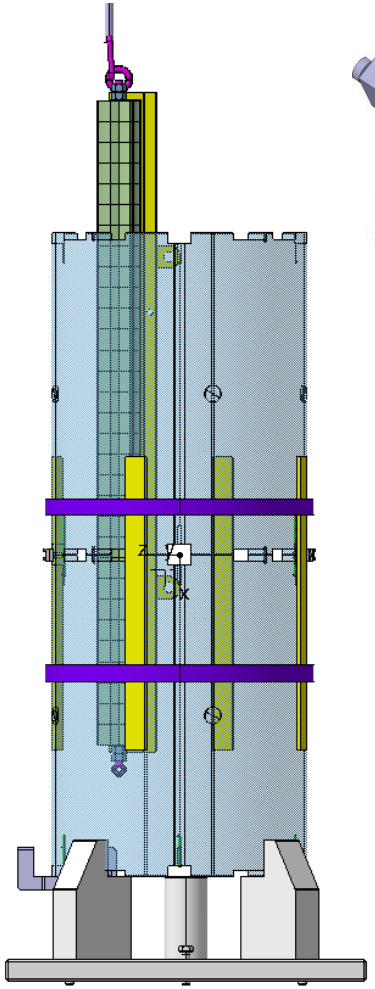


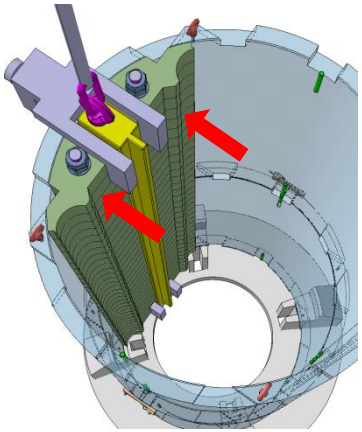


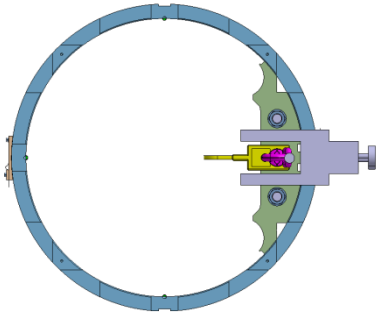
- The ¼ yokes are manipulated with a dedicated lifting and pivoting tool.
- The yokes are inserted on the shells in vertical position

¼ yoke insertion



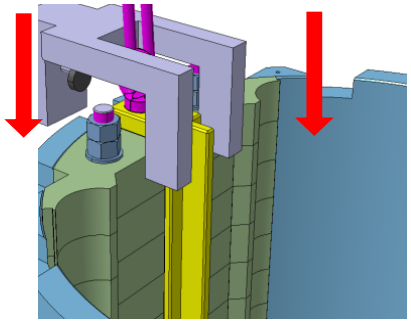




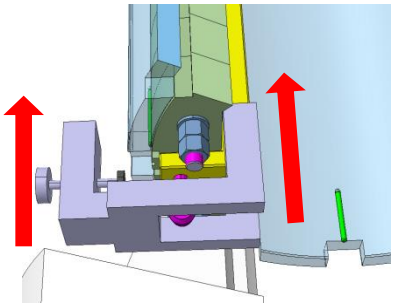


The angular alignment of the first ¼ yoke is defined by 1 long middle pin and 2 small pins located at the shell extremities

Upper radial clamp



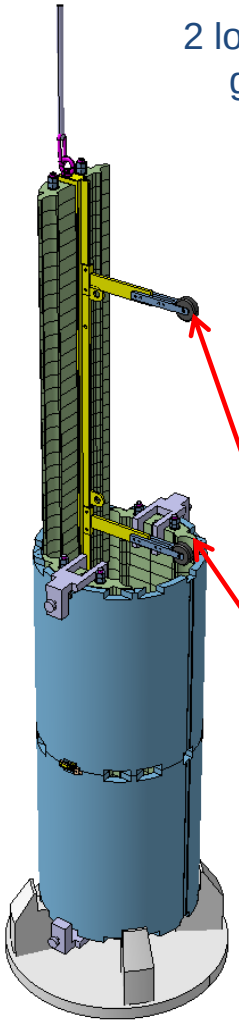
Lower radial clamp

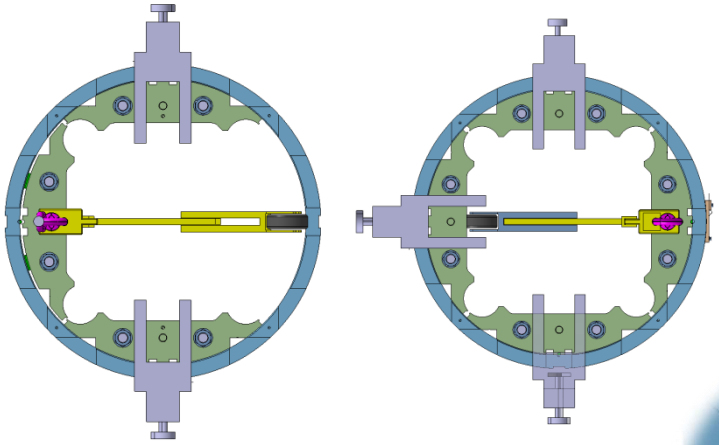


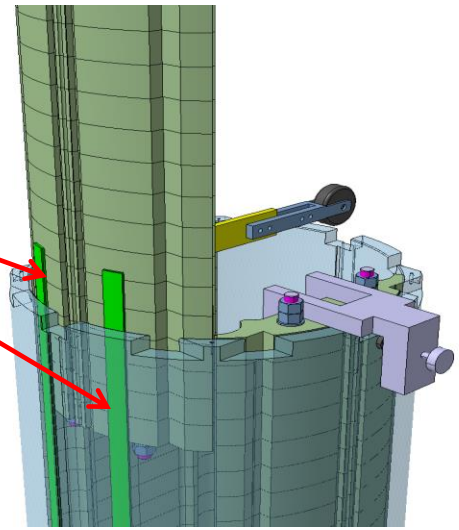
Dedicated clamping tools will be used to radially clamp the ¼ yoke in the shells

3rd and 4th ¼ insertion

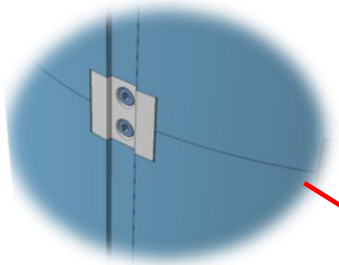
2 longitudinal plastic spacers will be used to guarantee a constant gap between yoke and shell preventing interference with the already inserted yokes

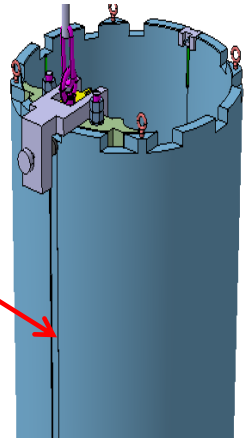






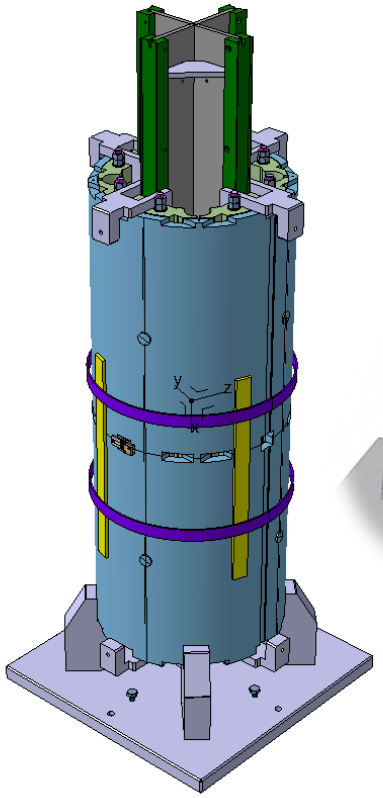
The Yoke lifting tool is equipped with 2 guiding wheels forcing the yoke against the plastic spacers

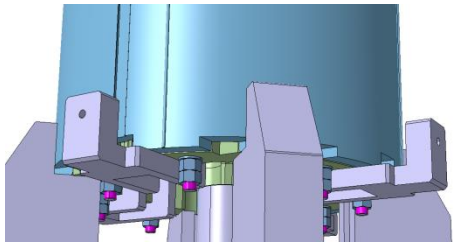


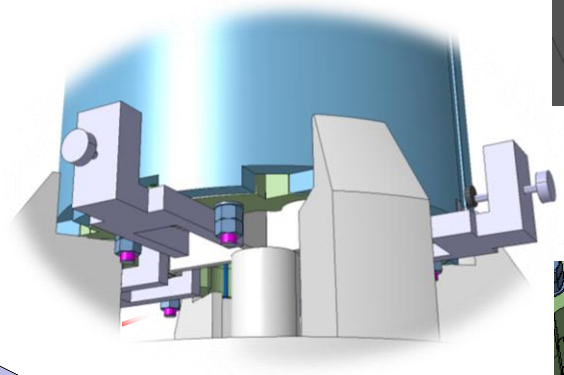


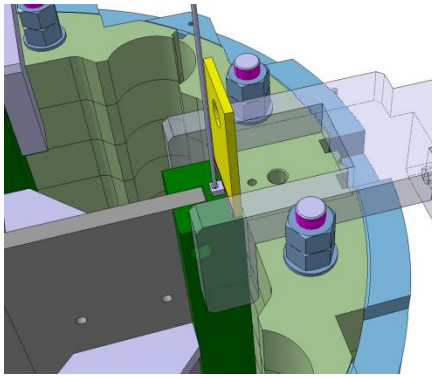
2 stainless steel blocks for welding key alignment and tack welding will be bolted to the yokes

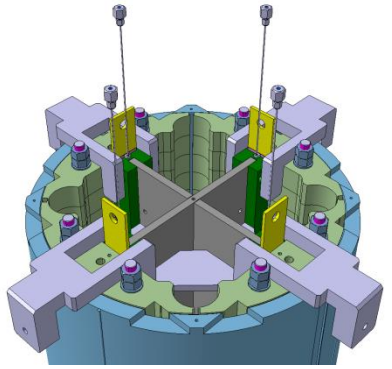
Bladders support structure for shell loading





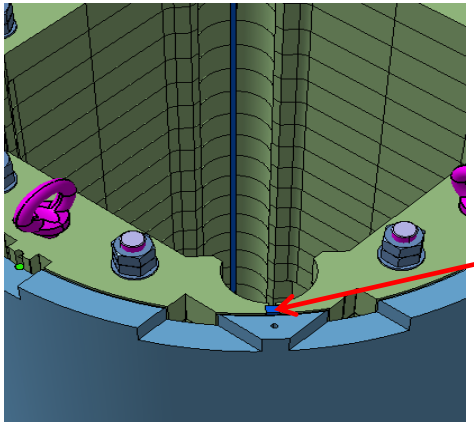






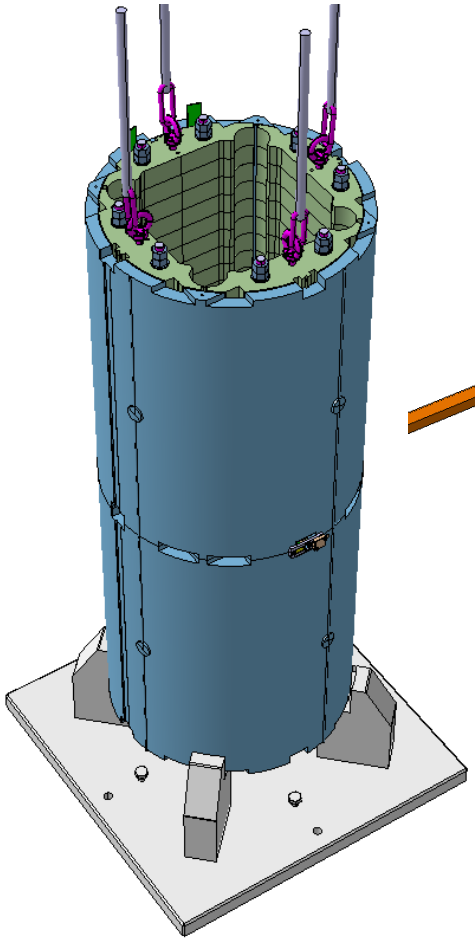
4 bladders 1549 mm * 57 mm will be used during shell pre-loading operation.

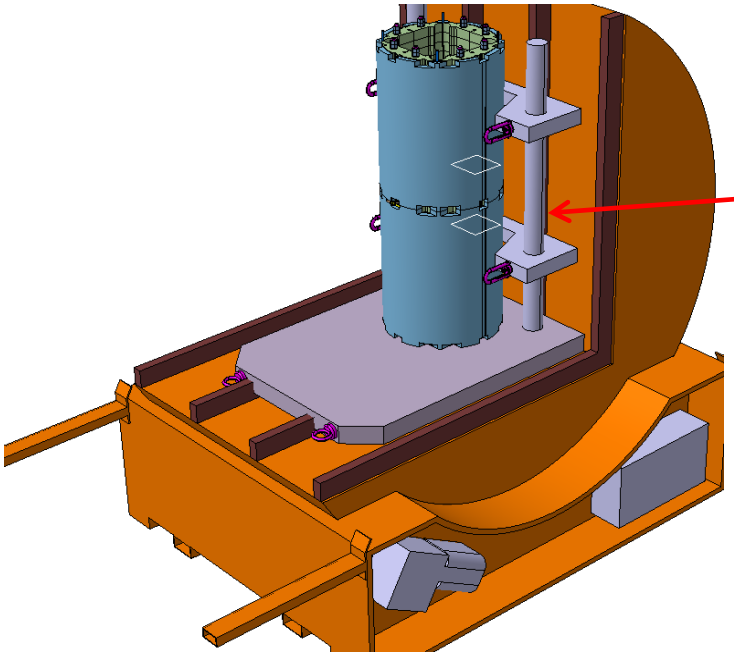
A cross-shape support inserted in the structure is used to support the bladders for shell pre-loading

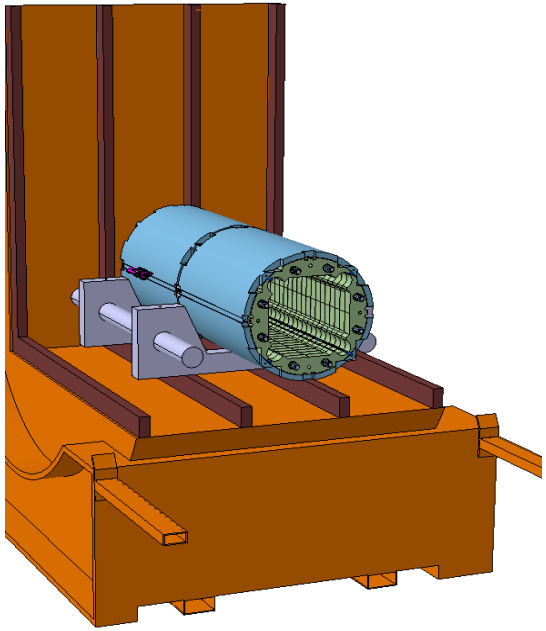


Temporary yoke keys are inserted in the yoke gaps

Lifting and rotating Yoke and Shell assembly

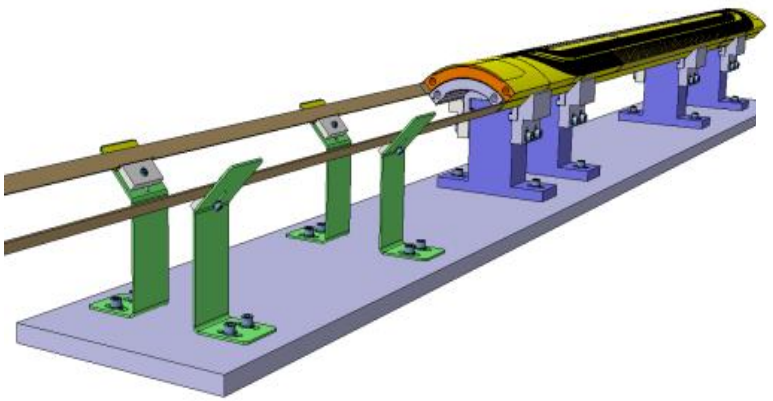


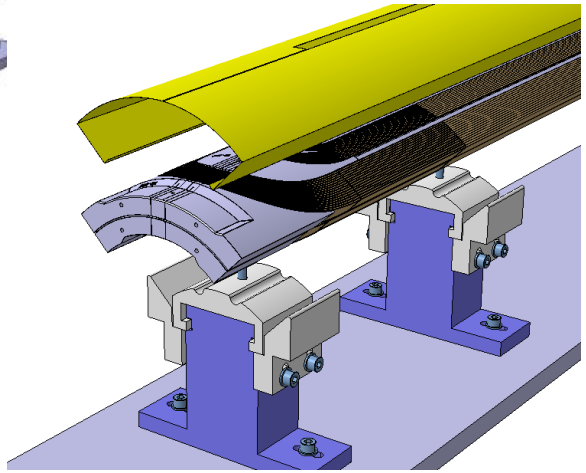


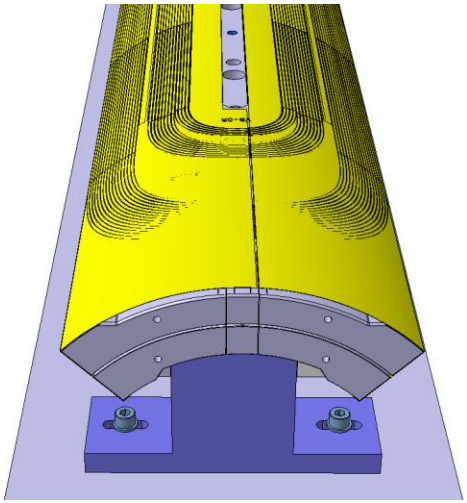


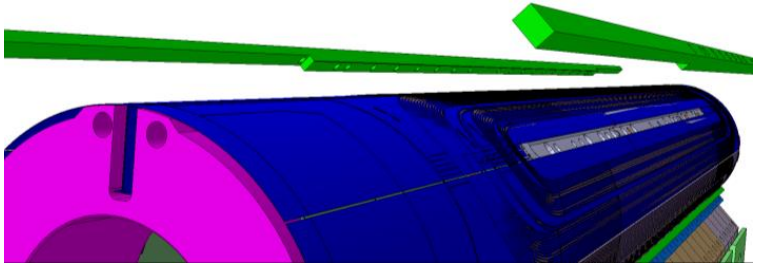
The yoke and shell assembly will be transported, using a 4 sling lifting tool and adjustable lifting eyes bolted on the yoke, to an existing rotating device. The yoke and shell assembly will be flipped from vertical to horizontal position.

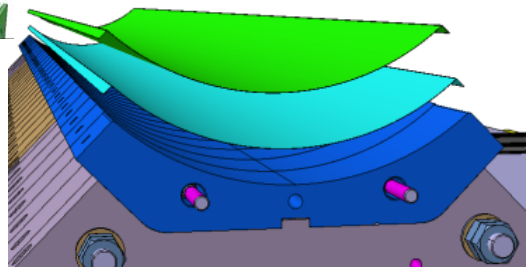
Coils and collars preparation





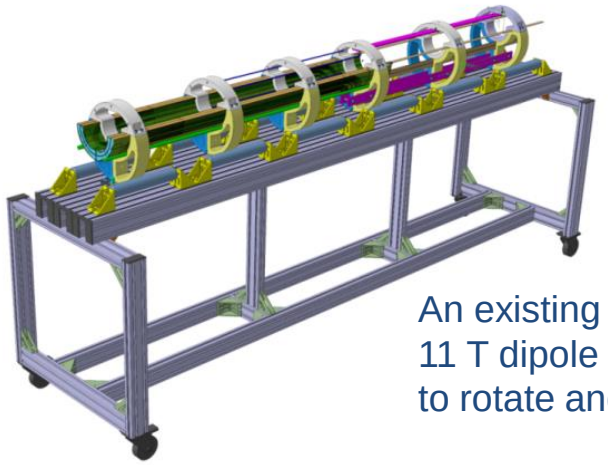




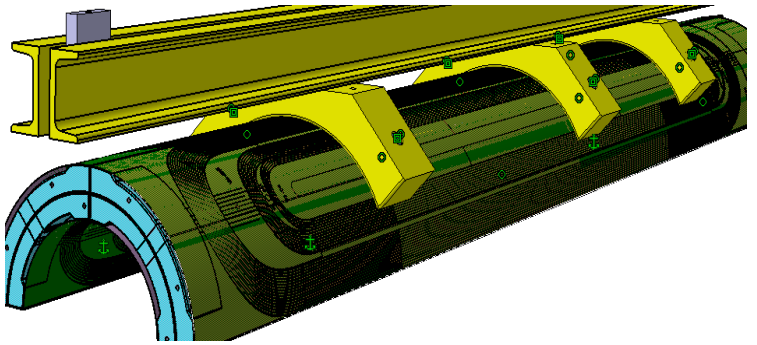


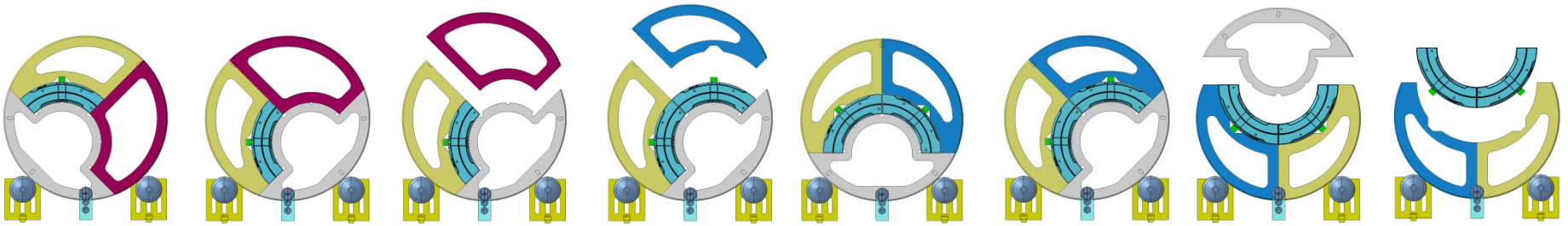
- Preformed Kapton sheets are mounted on the coil outer diameter for ground insulation.
- Fiber glass keys are inserted in the longitudinal pole slot.
- Ground insulation layers (G10 + Kapton) are glued to the aluminum collars inner radius

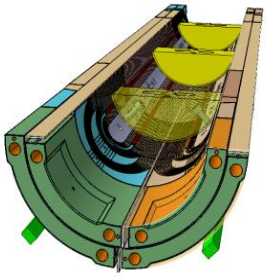
Coils rotation

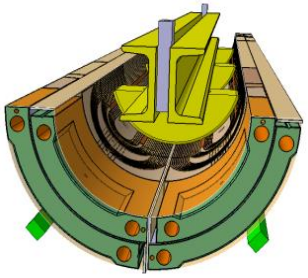


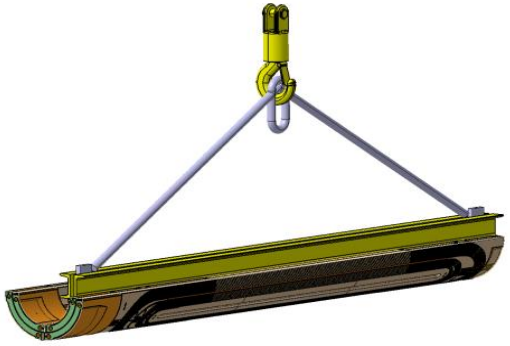
An existing assembly table used for the 11 T dipole project has been adapted to rotate and position MQXFS coils.







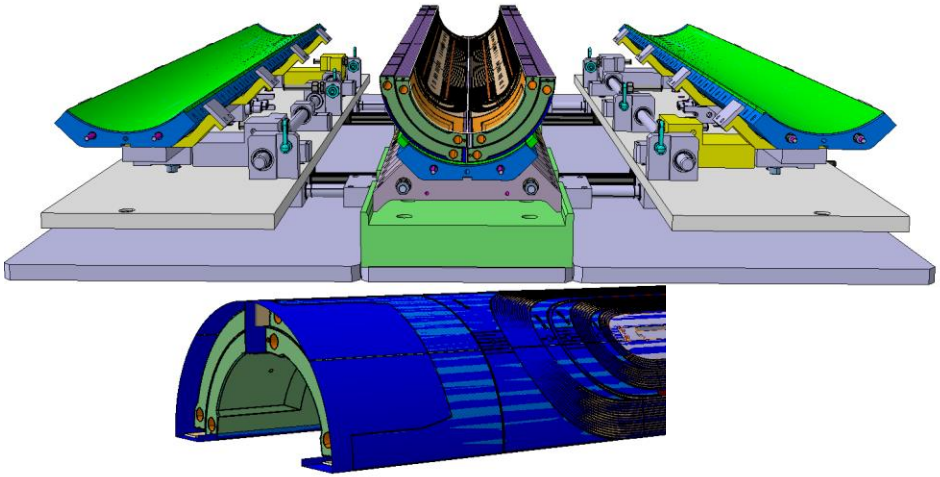


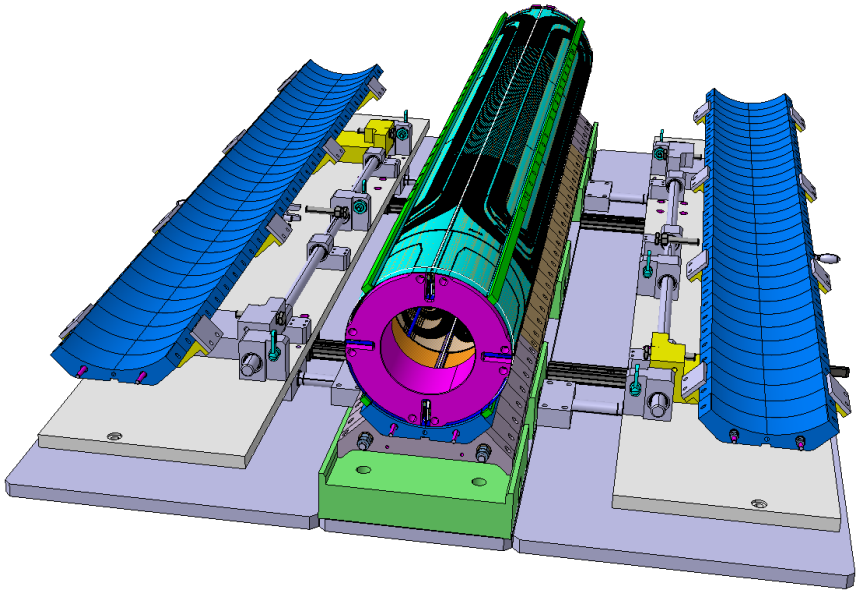


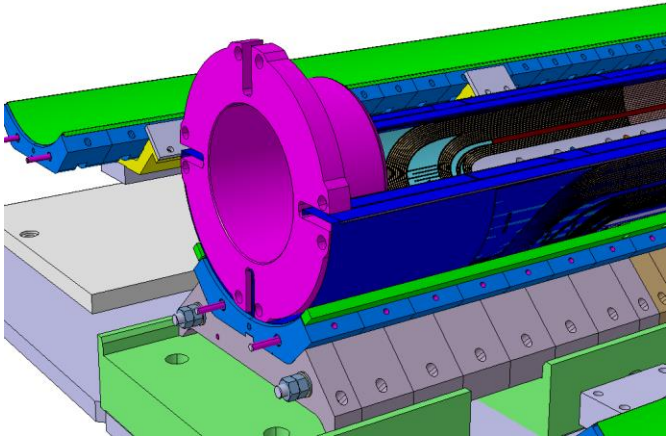
The first pair of coils to be assembled will be rotated up-side down and lifted from their inner face. The coil handling tooling is designed to manipulate the coils by pairs from inner and outer radius. The same tooling can be used to handle coils individually.

Coil pack assembly: mounting the coils

A dedicated table has been designed to precisely positior and assembly coils and coil-pack components



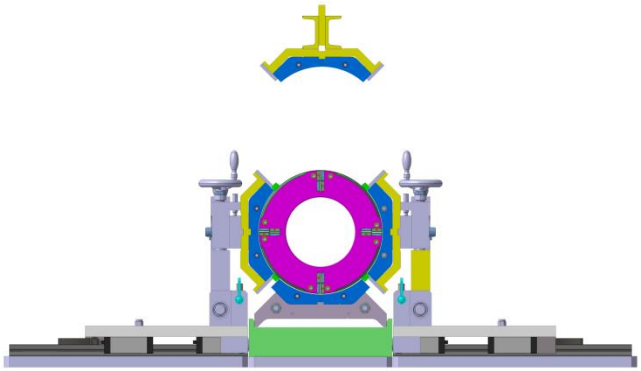


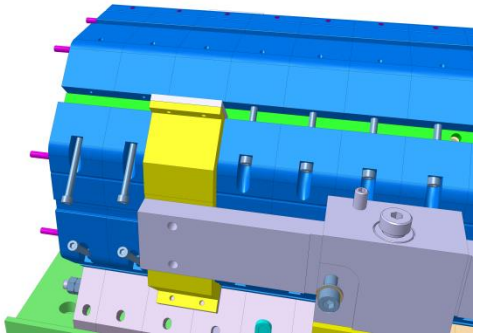


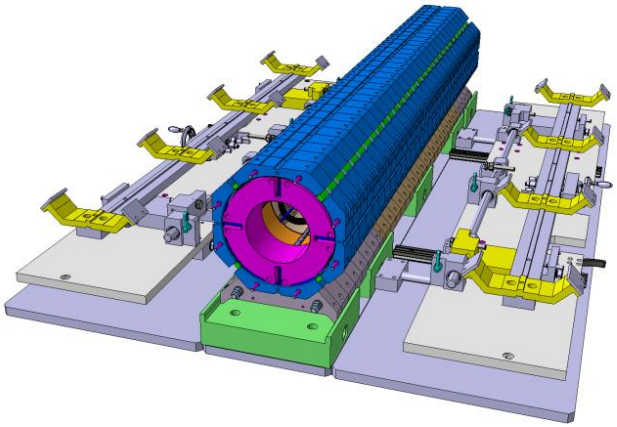
2 + 2 coils equipped with ground insulation and pole keys are positioned on top of the lower 1/4 pad and collar assembly

Even if such a tool may be not be 100% needed to perform the coil pack assembly on short model magnets, the concept will be tested and proven to be scalable in view of 7 m long magnets assembly.

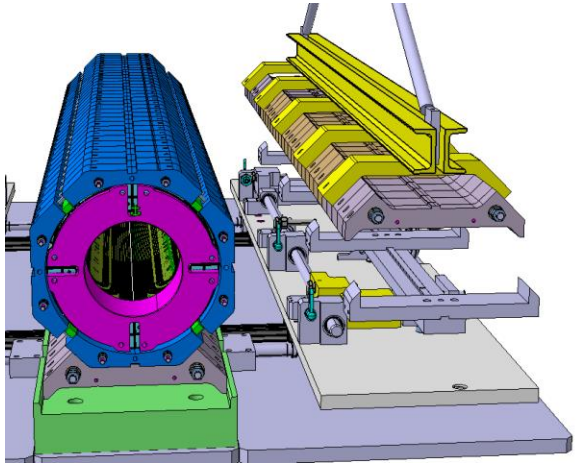
Collars and pads assembly

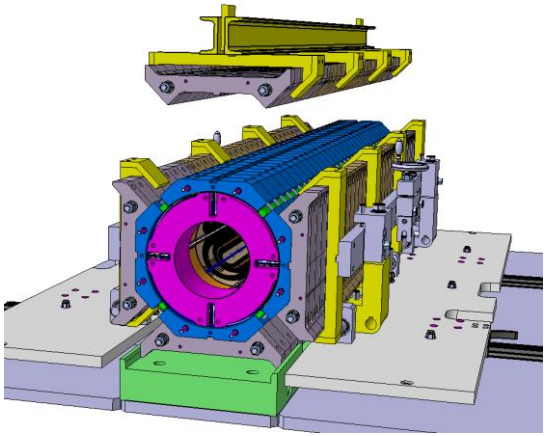


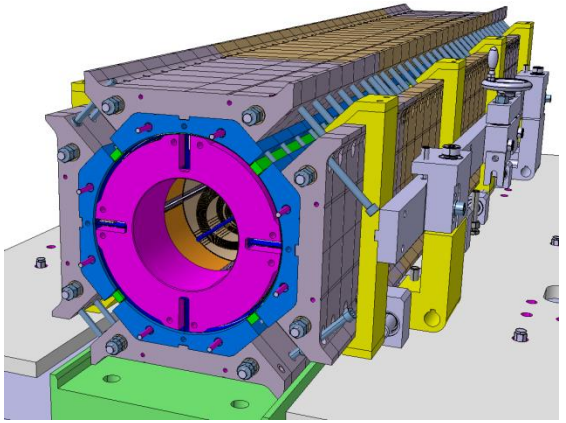




The aluminum collars are assembled and bolted around the coils

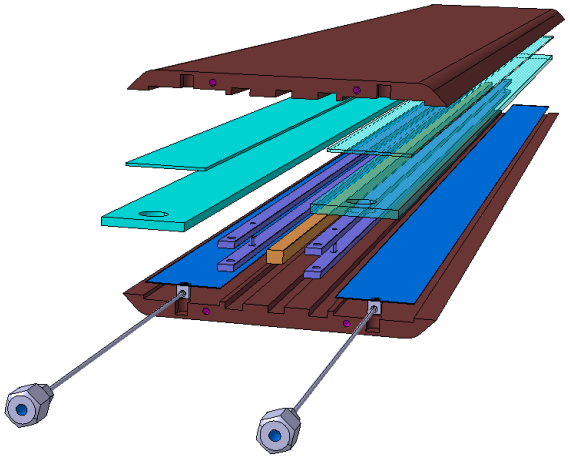




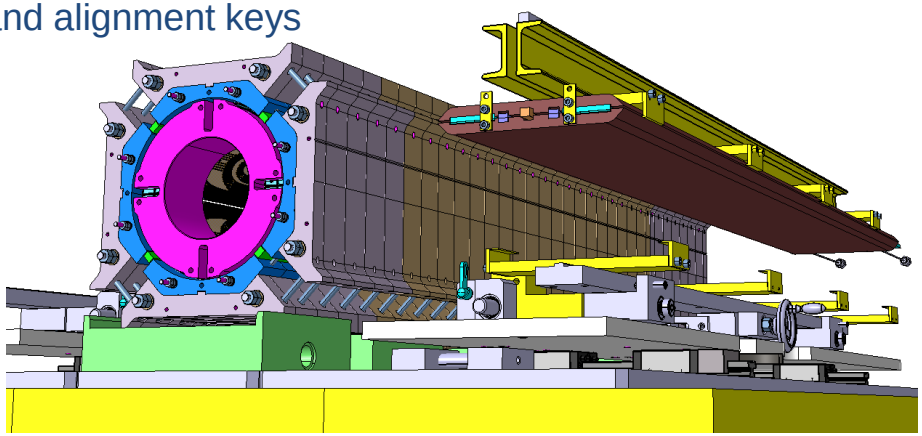


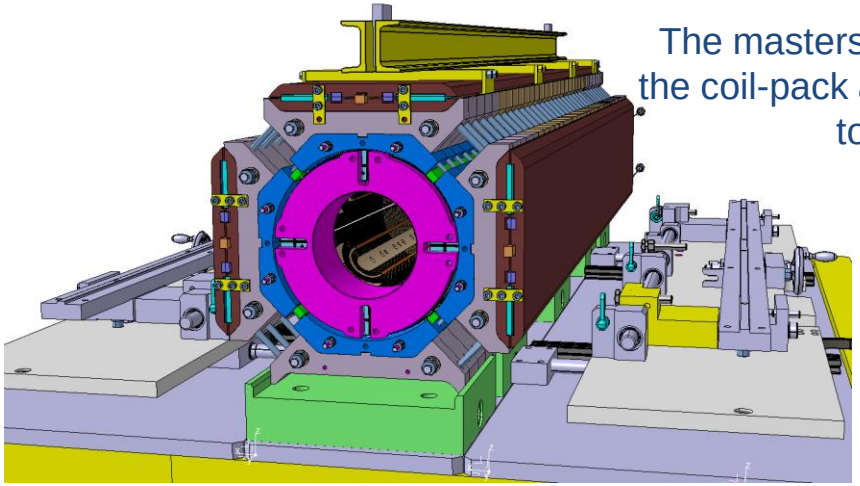
The same sequence is used to assemble and bolt the iron pads around the collars. The assembly tooling is designed to provide accurate alignment of all components during the assembly process.

Masters and coil pack preparation

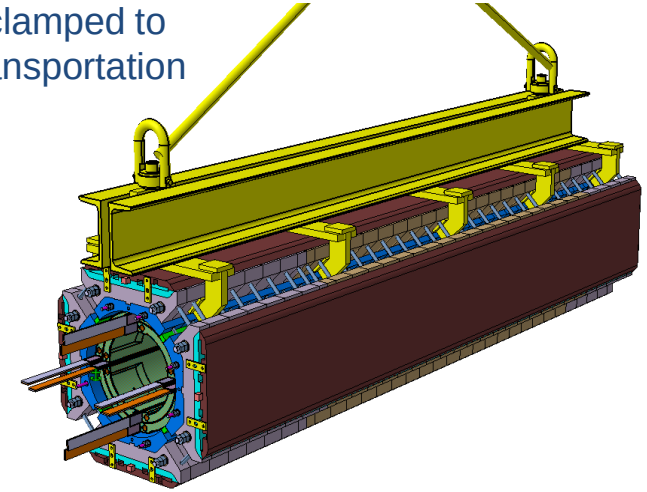


The four masters are equipped with bladders, shims and alignment keys

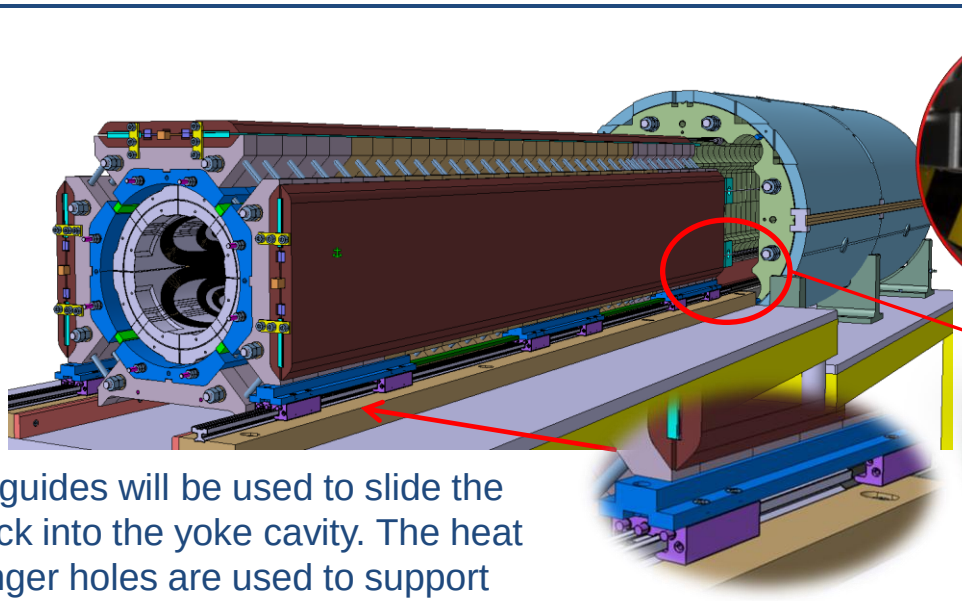


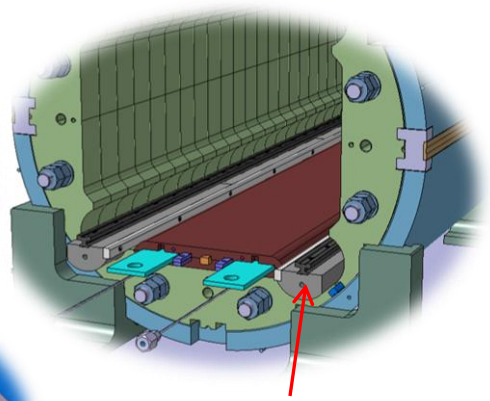


The masters are mounted and clamped to the coil-pack assembly before transportation to the insertion table



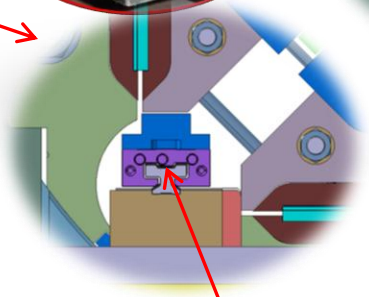
Coil-pack insertion concept



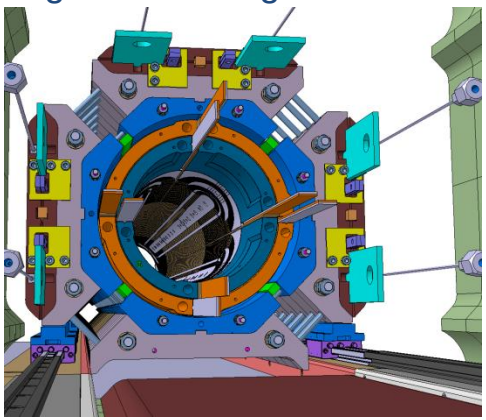


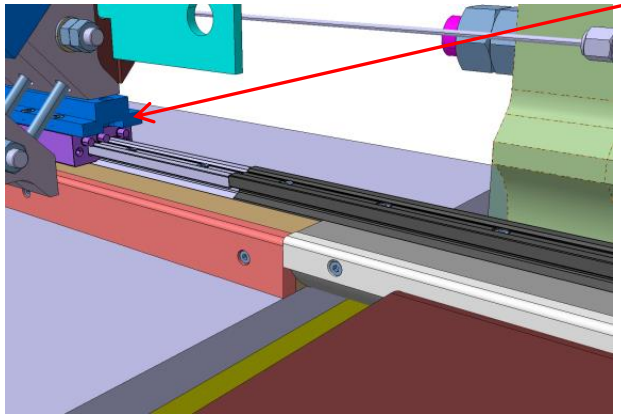
Aluminum profile interface to align the rail into the heat exchanger hole

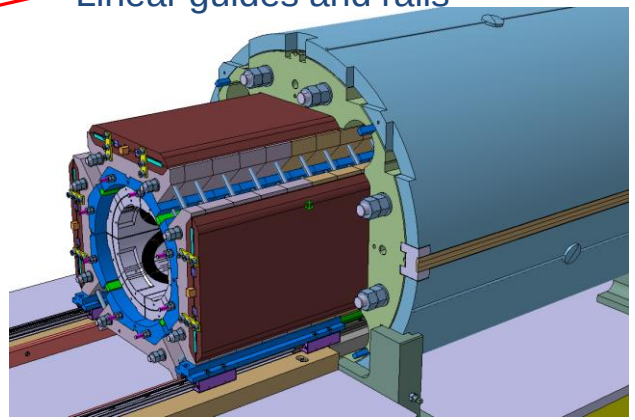
Linear guides will be used to slide the coil-pack into the yoke cavity. The heat exchanger holes are used to support and align the linear guides rails



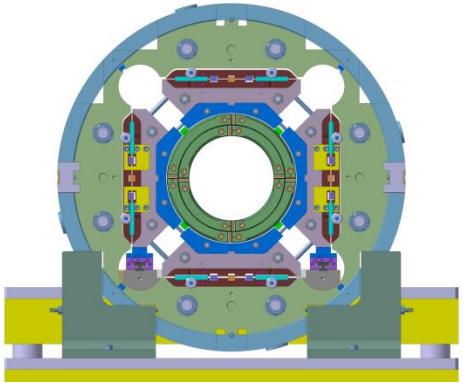
Linear guides and rails



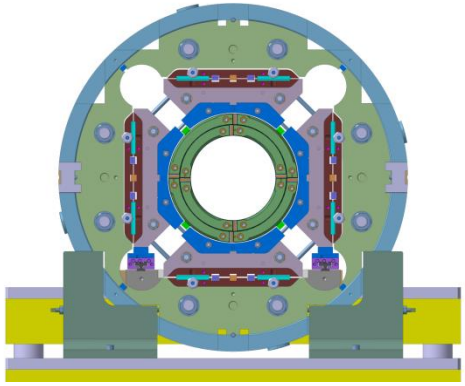




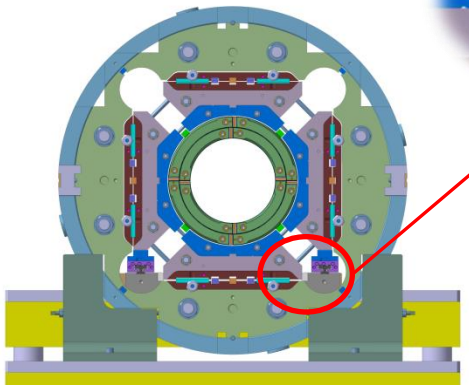
Bladders operation
CERN concept

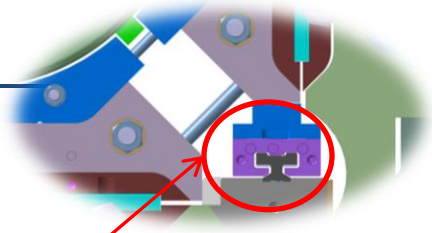


Coil pack inserted in the yoke



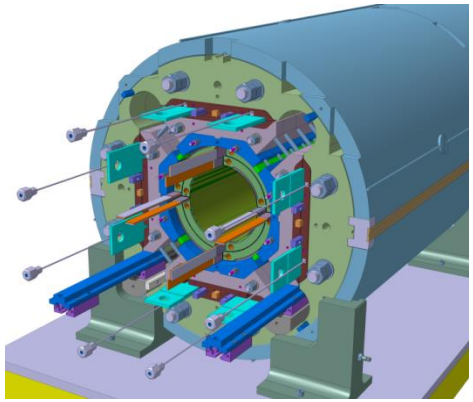
Master clamps are removed



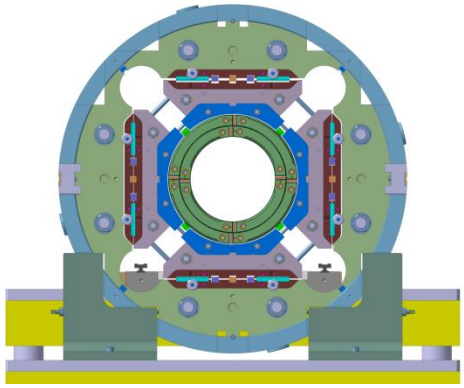


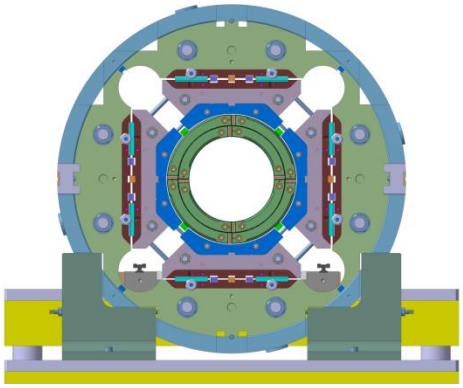
Lower bladder is pressurized. Top and bottom nominal keys are inserted.

2 lateral bladders are pressurized to insert the remaining nominal keys

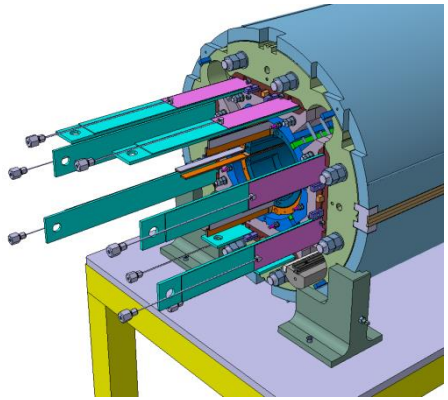


Insertion guiding rails are removed





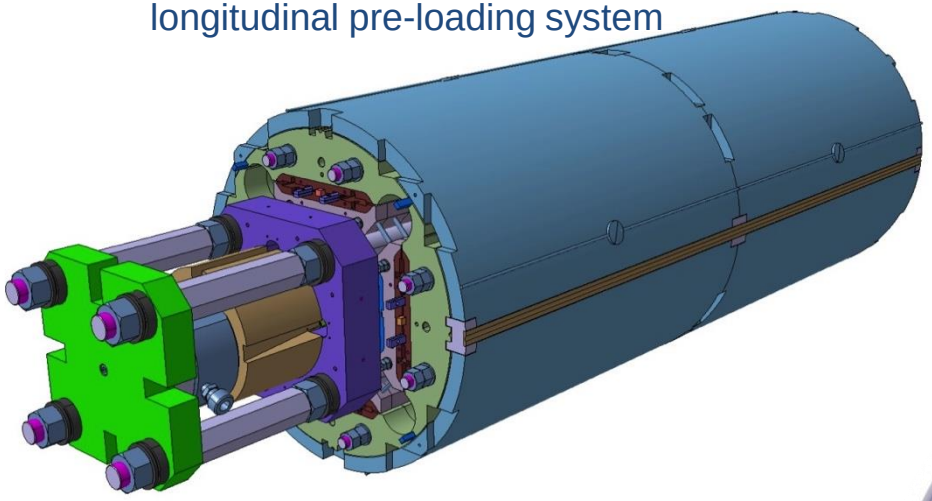
4 Bladders operation for final loading

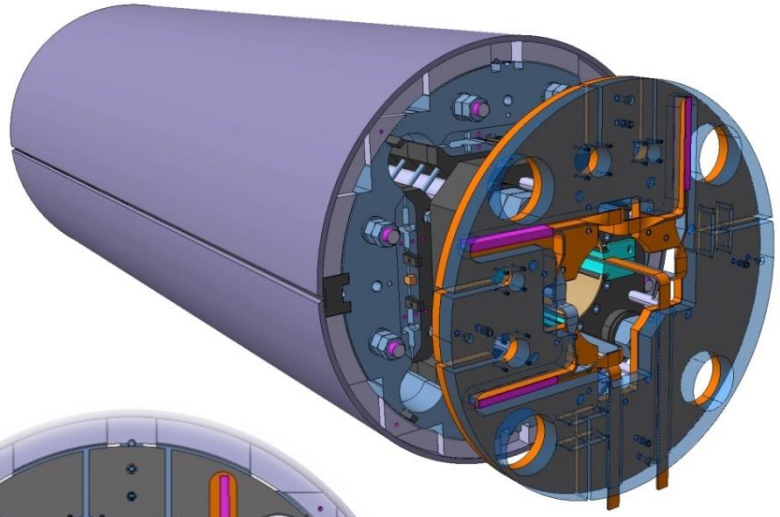


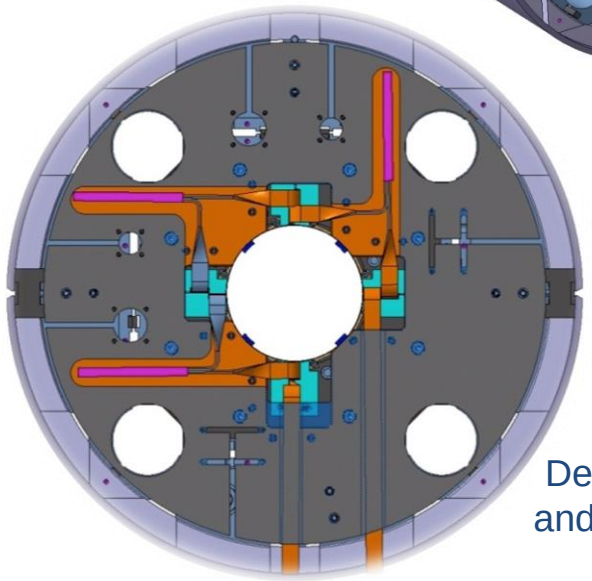
Bladders and slip shims are removed after full loading operation

Longitudinal loading & connexion box

View of the MQXFS Magnet equipped with the longitudinal pre-loading system





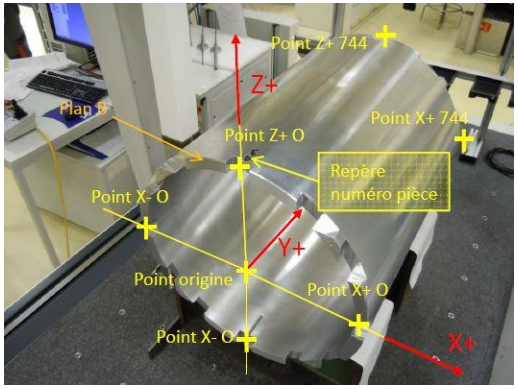


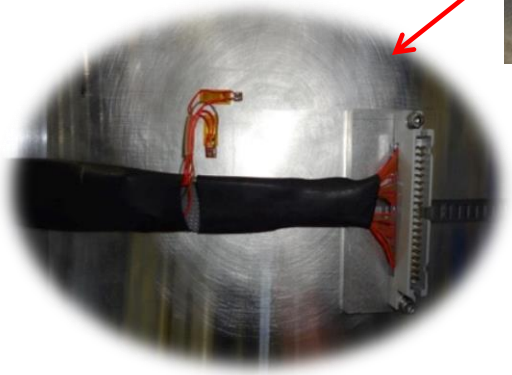
- The final assembly geometry will be checked using a Faro arm or/and with a Leica Laser tracker.
- Precise Ø6 H7 holes have been drilled on both magnet extremities (yoke, pads and collars)
- Existing holes in coil poles can be used to install Leica's reflectors

Design of the splice box and instrumentation plate in progress

- MQXFS model magnet assembly at CERN
  - Main assembly steps (Slide 5 to 19)
  - Status on components and tooling (Slide 20 to 24)
  - Possible MQXFB assembly procedure (7 meter long magnet)
  - 150 mm mechanical model assembly and cooling to 77K
  - First MQXFS mechanical assembly at CERN using aluminium dummy coils
- Conclusions

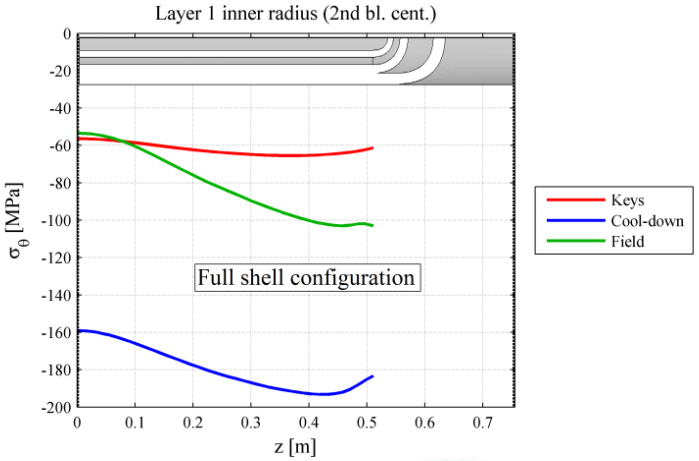
First batch of aluminium Shell

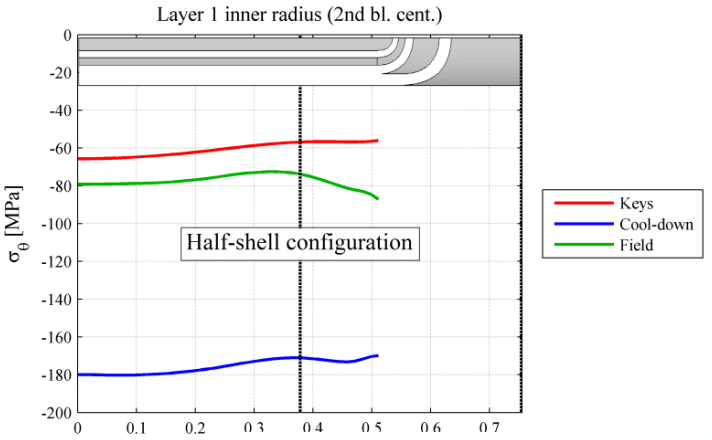


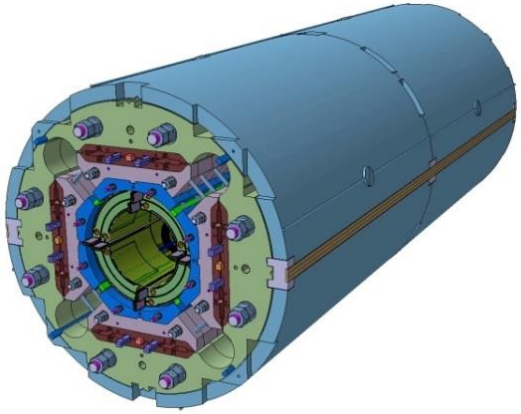


- 4 shells have been ordered and CMM controlled at CERN and LBNL (cylindricity and pins slots position out of tolerance)
- The shells have been instrumented with strain gauges

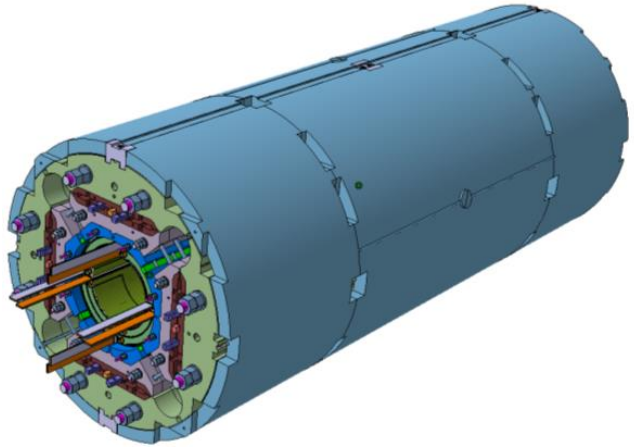
New outer aluminium shell configuration





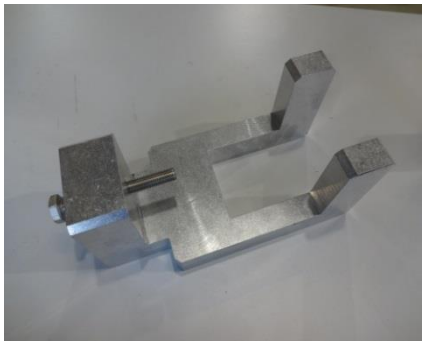


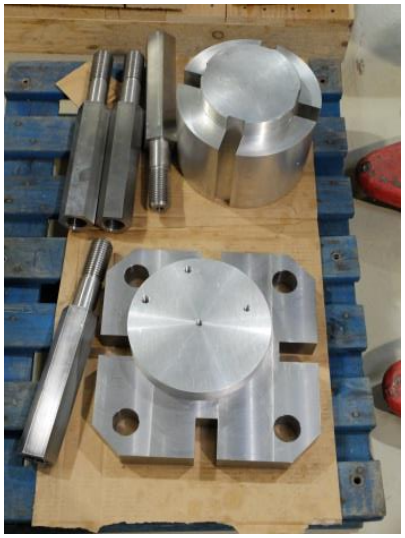
See presentation from Mariusz Juchno

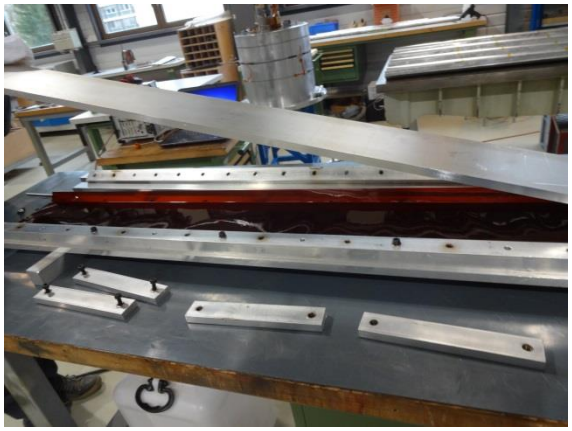


- 4 extra forged-rolled aluminum cylinders have been ordered ad are being machined
- One 774 mm shell and two 387 mm half shells will be used for MQXFS model assembly with real coils
- Using 3 shells instead of 2 for the 1.5 m model will not significantly impact the assembly procedure nor the schedule

Assembly tooling status







Ground insulation forming tool ready

2 Yoke and shell assembly supports and clamps ready for assembly operation

Longitudinal compression tooling ready

Bladders, shims and slip-shims ready

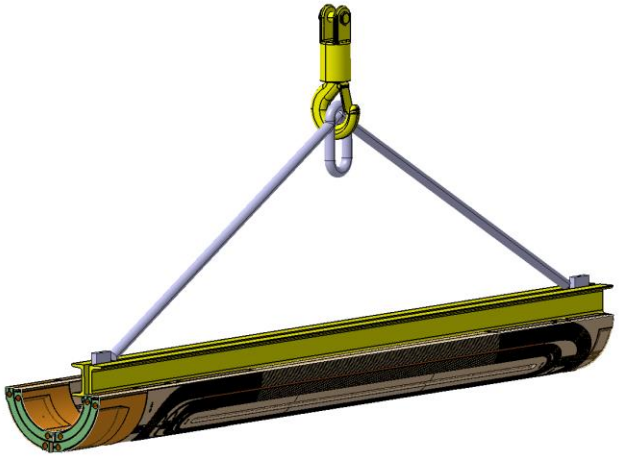
Ground insulation and instrumentation table ready

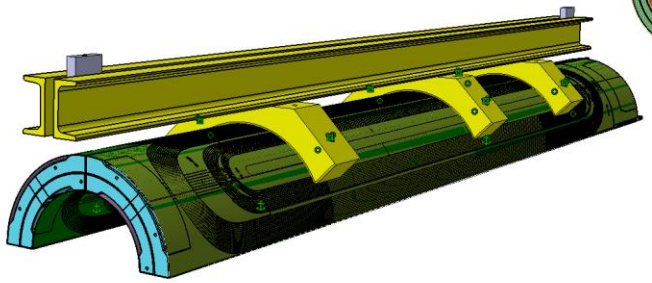
Yoke & shell support to flip from vertical to horizontal position ready.

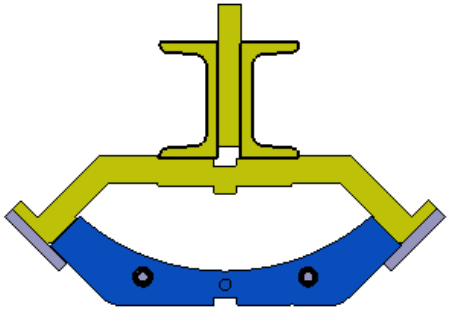
Lifting tooling status

Two yoke lifting tools CE certified have been delivered end of October

Pads and coil-pack lifting tooling delivered in December 2014





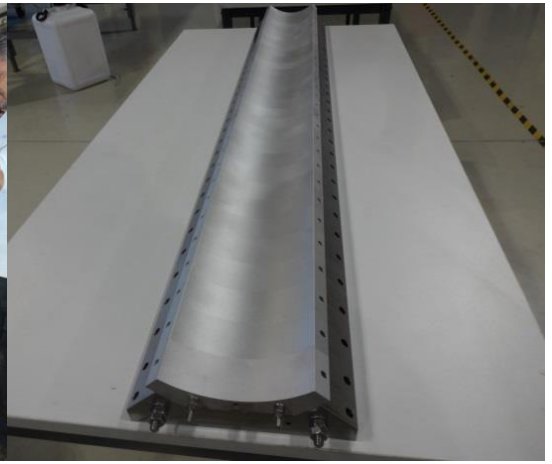


Coils lifting tooling ordered. Due for mid-December 2014

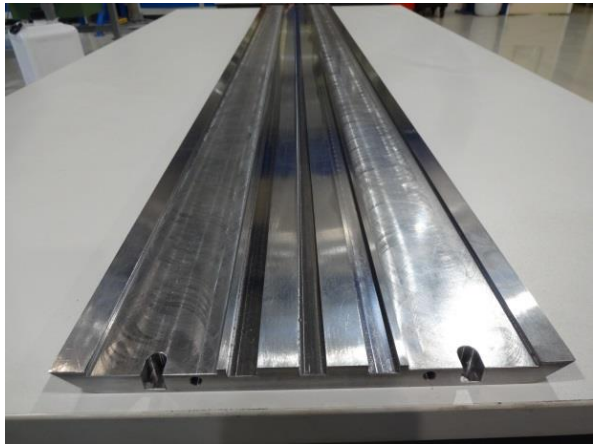
Components for first assembly using instrumented aluminum coils ready

Aluminum Shells

Iron yokes



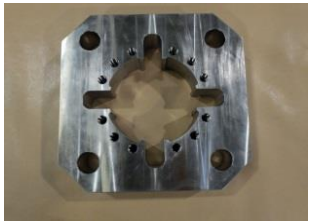
Collars and Pads

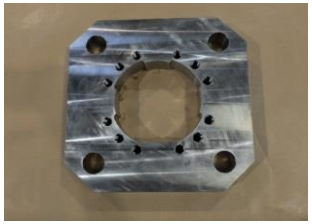


Masters

Instrumented dummy coils

Rods





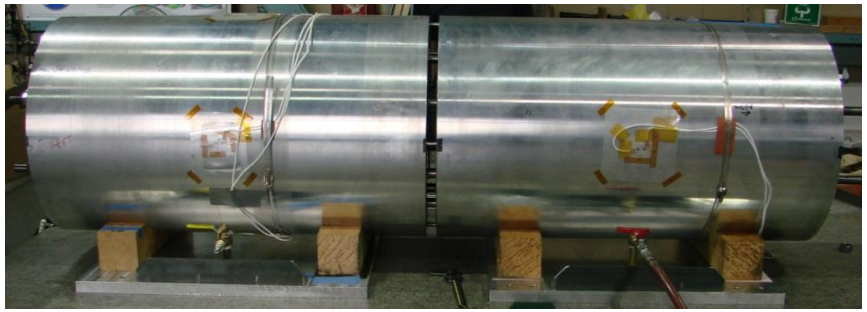
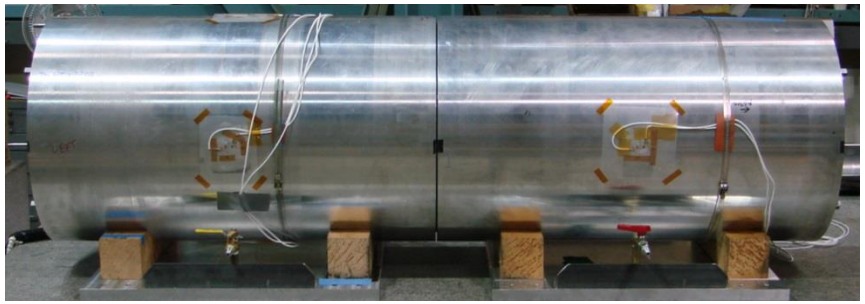
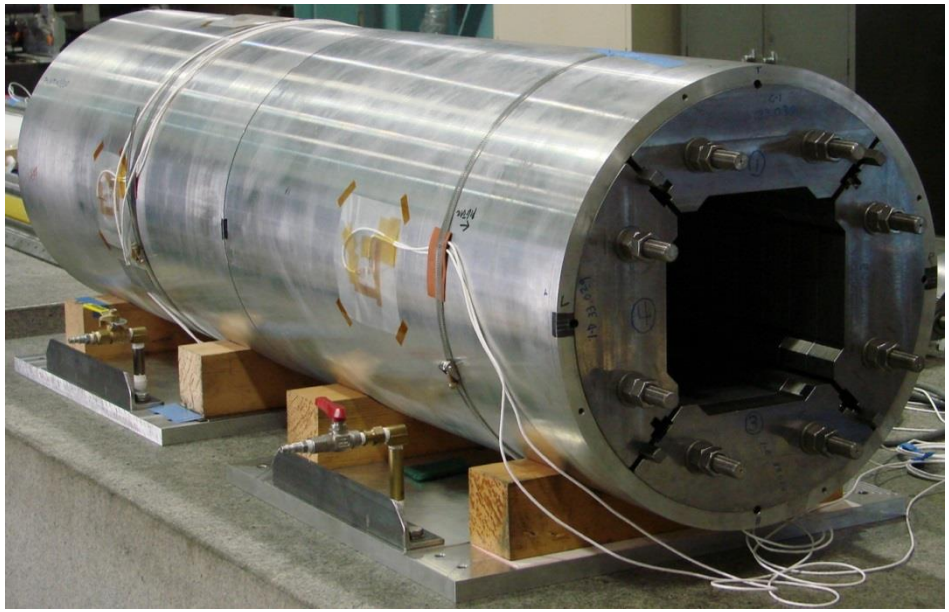
End-plates

- MQXFS model magnet assembly at CERN
  - Main assembly steps (Slide 5 to 19)
  - Status on components and tooling (Slide 20 to 24)
  - Possible MQXFB assembly procedure (7 meter long magnet)
  - 150 mm mechanical model assembly and cooling to 77K
  - First MQXFS mechanical assembly at CERN using aluminium dummy coils
- Conclusions

Assembly of LQ structure

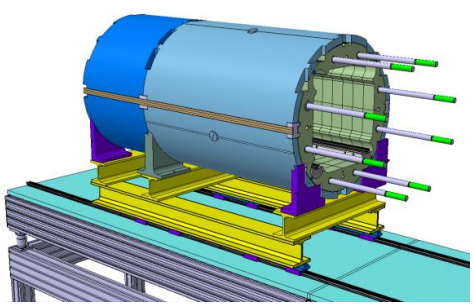


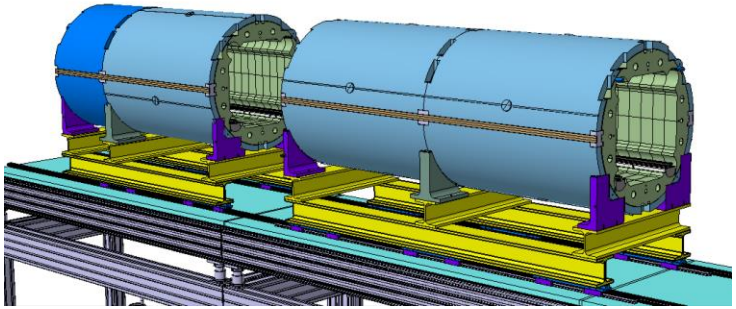


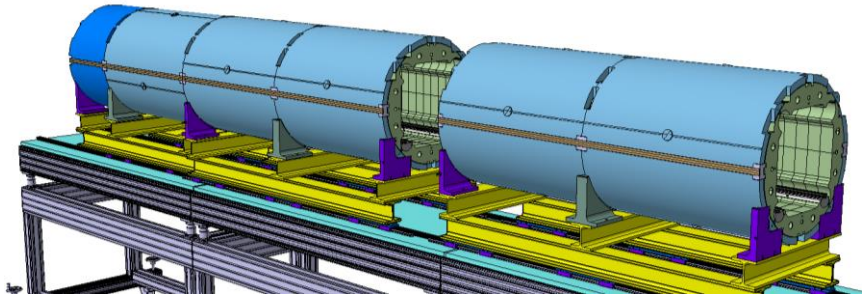
MQXFB yoke & shell assembly concept

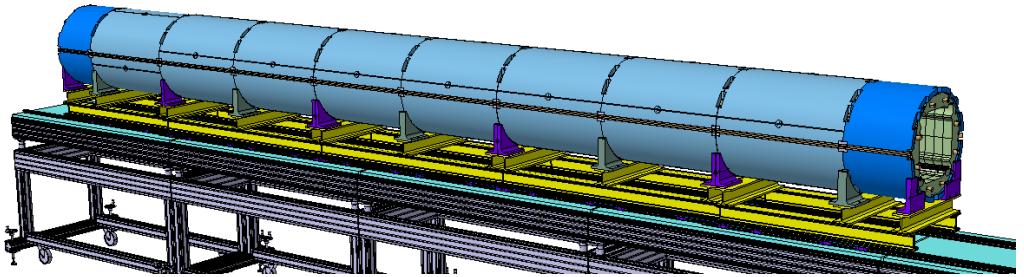
Modules composed by 2 aluminum cylinders (2 different module lengths) will be assembled on vertical position and then flipped to horizontal position





Each individual subassembly will be positioned on its support structure and assembled with the adjacent one using precision rails and linear guides.

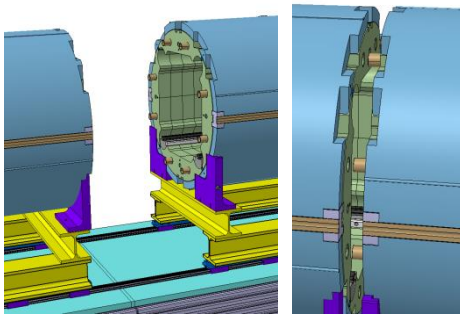


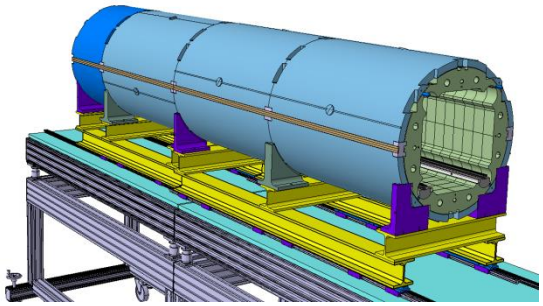


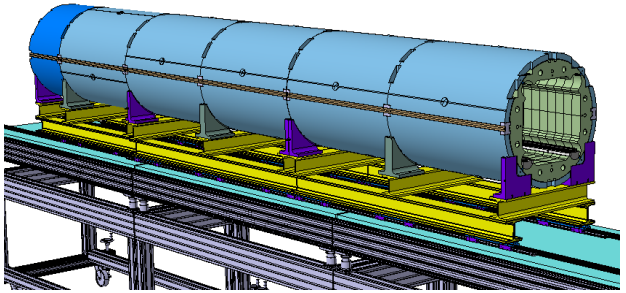
The subassembly rods will be replaced by longer ones using small hydraulic cylinders

See presentation from Dan Cheng

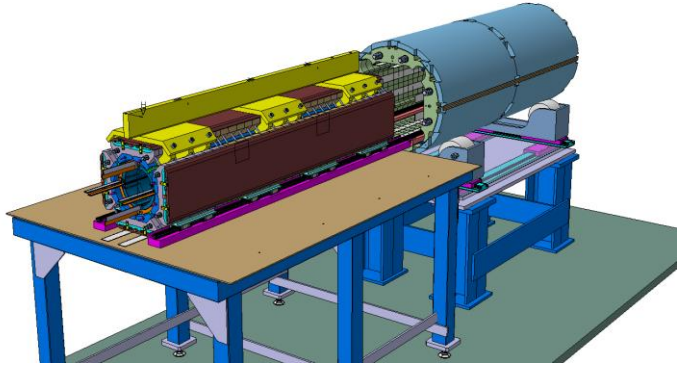
MQXFB assembly concept







- 3 different Bladders length will be required for magnet assembly
- The option to use 0.5 mm SS sheets for bladders production is being investigated and tested (cheaper)
- ≈ 0.8 m long shells seems to be the best compromise (raw material and machining cost, vertical assembly)
- 1.5 m long structure components subassemblies is our preferred solution (see presentation from P. Moyret)

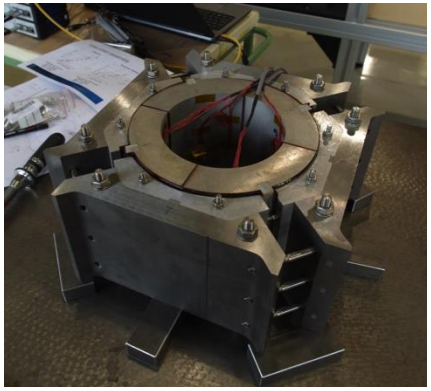


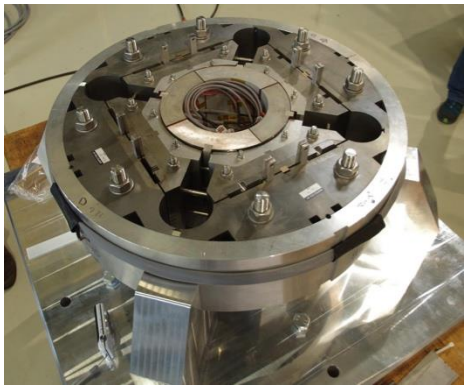
- 7 meters coil-pack assembly and insertion procedure will be scaled-up from model magnet assembly
- No show stoppers have been identified

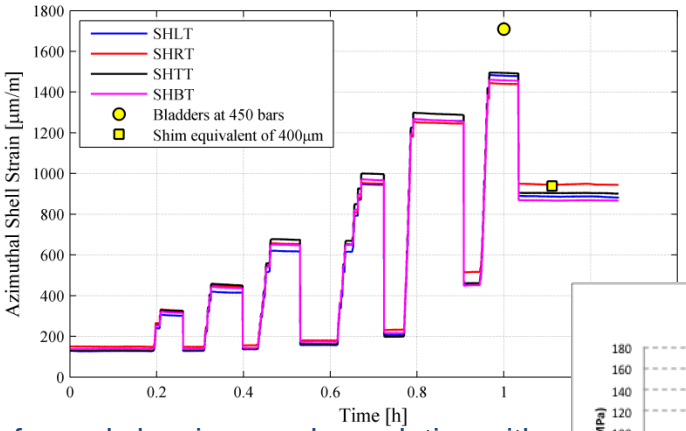
See presentation from Dan Cheng

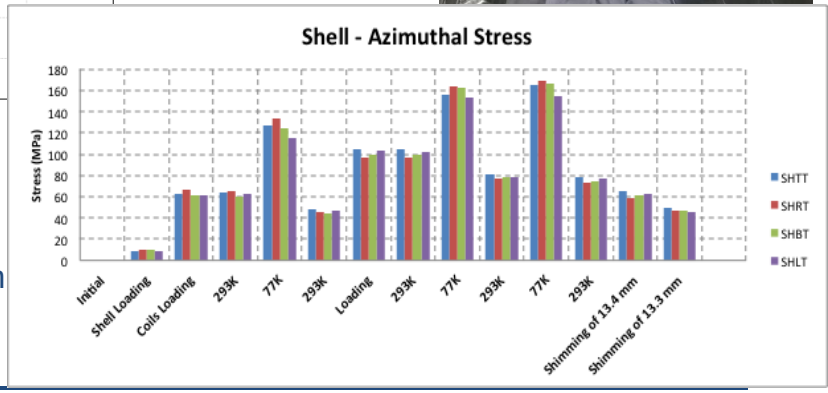
- MQXFS model magnet assembly at CERN
  - Main assembly steps (Slide 5 to 19)
  - Status on components and tooling (Slide 20 to 24)
  - Possible MQXFB assembly procedure (7 meter long magnet)
  - 150 mm mechanical model assembly and cooling to 77K
  - First MQXFS mechanical assembly at CERN using aluminium dummy coils
- Conclusions

Mechanical 150 mm mock-up









- 3 cool-down to 77K have been performed showing good correlation with FEM models
- Data analysis is in progress
- The force intercepted at cold by the G10 pole keys (see presentation from P. Ferracin & H. Felice) will be quantified with a dedicated test
- Low-grade coil #101 will be cut and used for further assembly trials

- MQXFS model magnet assembly at CERN
  - Main assembly steps (Slide 5 to 19)
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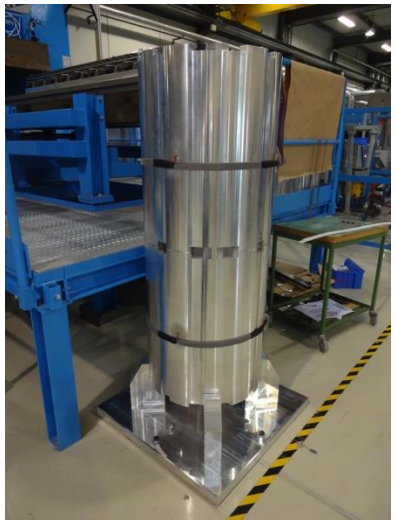
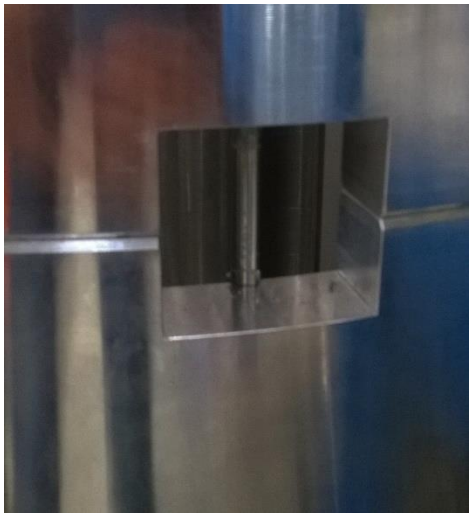
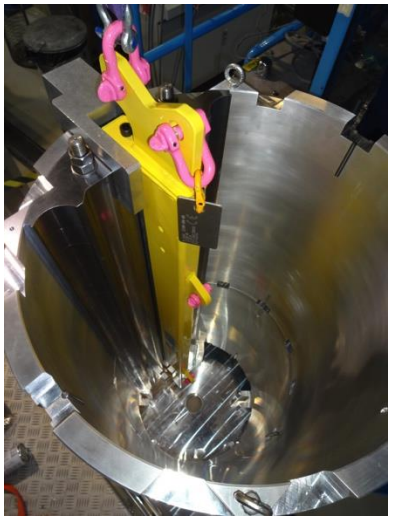
- Conclusions

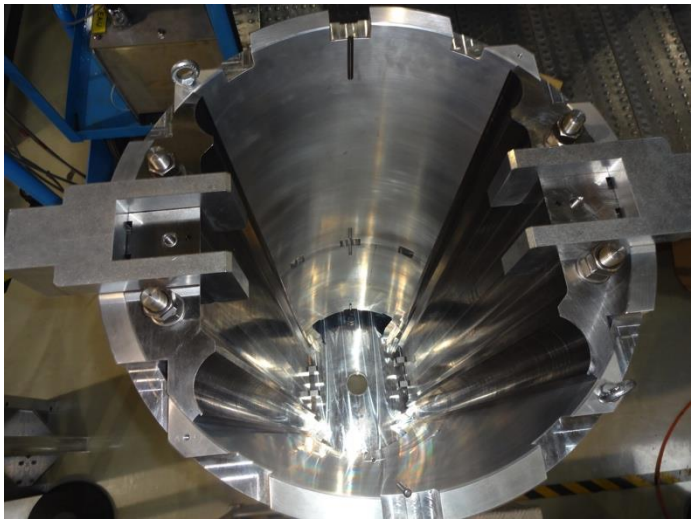
First yoke and shell assembly at CERN(1/2)

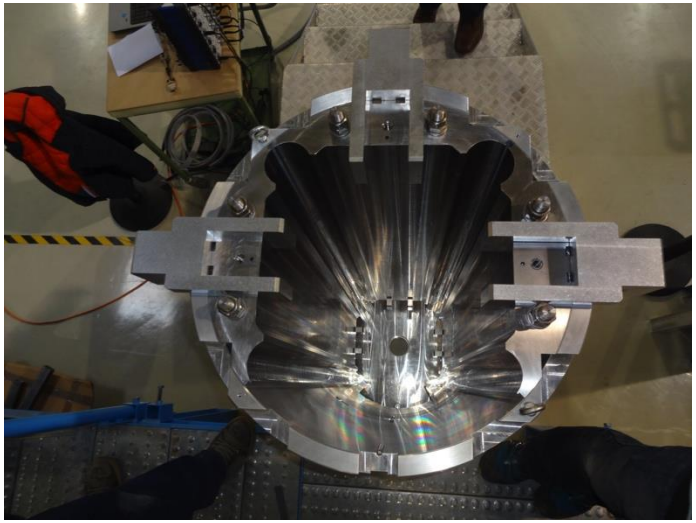
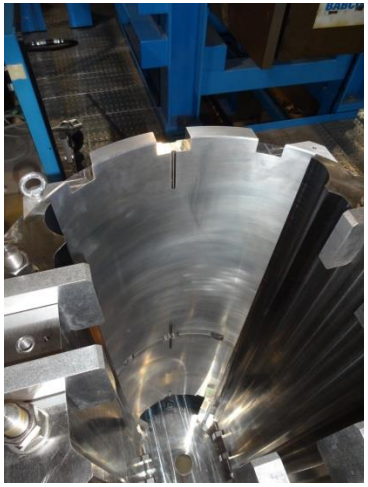
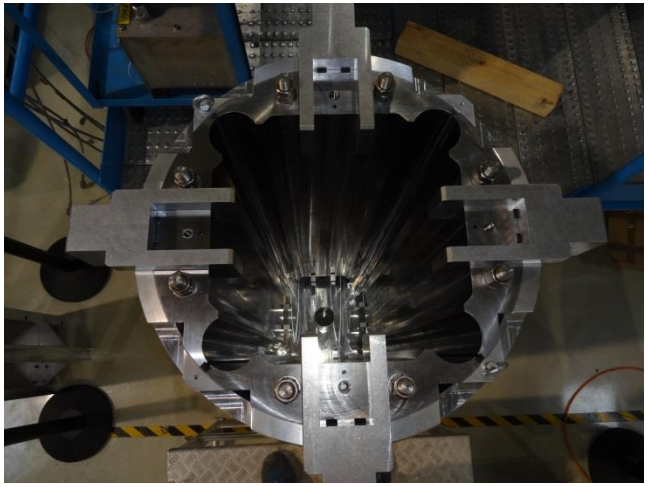






First yoke and shell assembly at CERN(2/2)



LN_2 tests in SM18

After Xmas brake, 3 cool-down to 77K,with different pre-stress applied to the aluminium dummy coils, are foreseen at CERN in SM18 LN_2 test station

Conclusions

- MQXFS assembly procedure has been defined and partially tested during the assembly of the 150 mm mock-up
- 2 identical structures and 2 sets of assembly tooling are operational (CERN & LBNL)
- CERN assembly tooling (except coil pack assembly & insertion table) has been delivered
- Coil-pack insertion table will be operational by mid December 2014
- Coil-pack assembly tooling is due for April 2015
- CERN team has started the mechanical assembly with instrumented aluminium dummy coils in December
- After Xmas brake, 3 cool-down to 77K, with different pre-stress applied to the dummy coils, are foreseen in CERN SM18 LN_2 test station
- The 150 mm mock-up equipped with segments of coil #101 will be used to better understand the structure behaviour and define shimming values
- Tooling design and assembly procedures are scalable for longer magnets

Thank you for your attention

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