Mu2e Calorimeter: Mechanics

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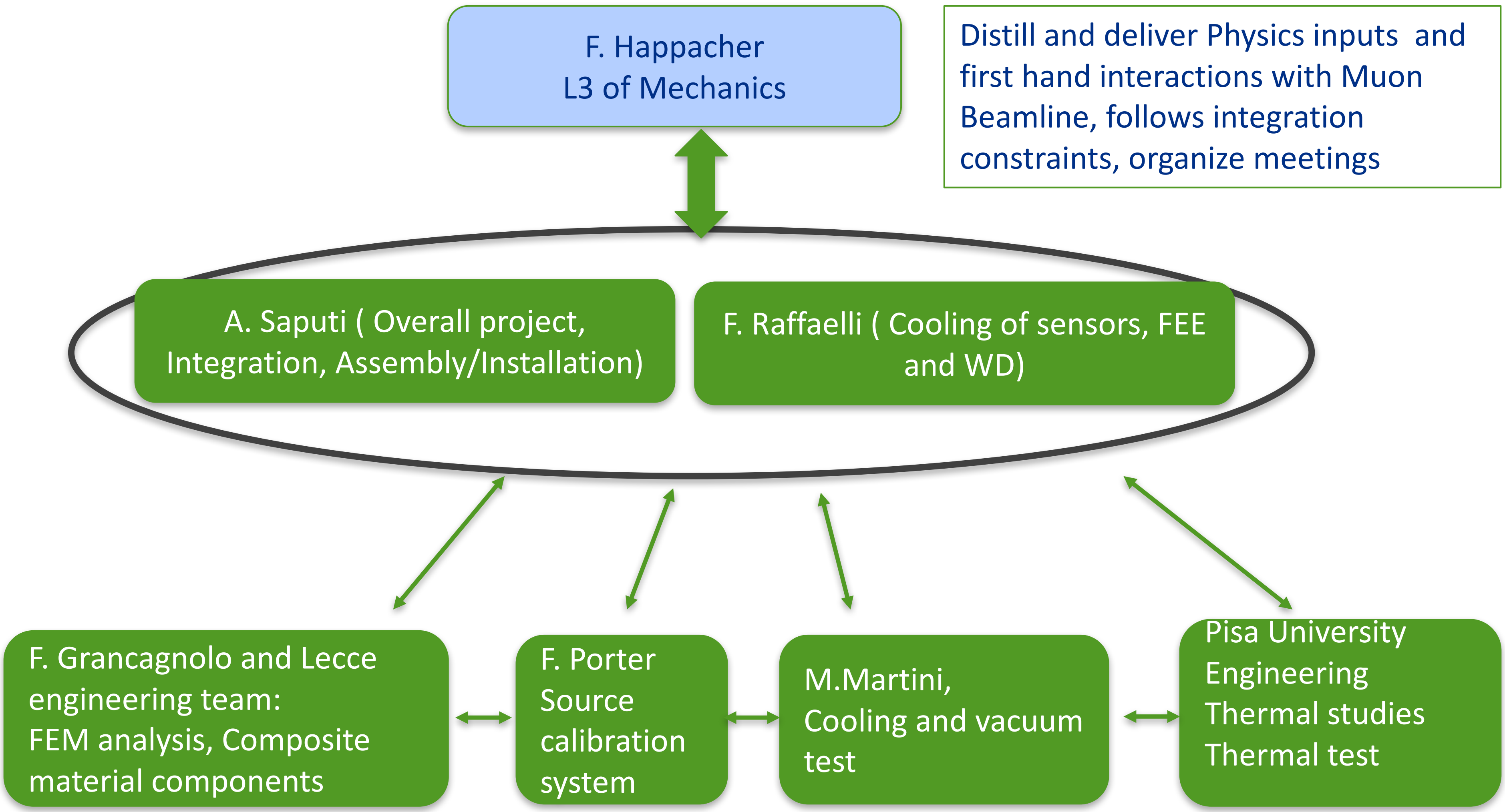
Fermilab – Muse Meeting

Layout

- Scope of Mechanics
- Calorimeter mechanics Requirements
- Calorimeter Mechanics design
- Prototyping
- Procurement status and plans

Mechanics team



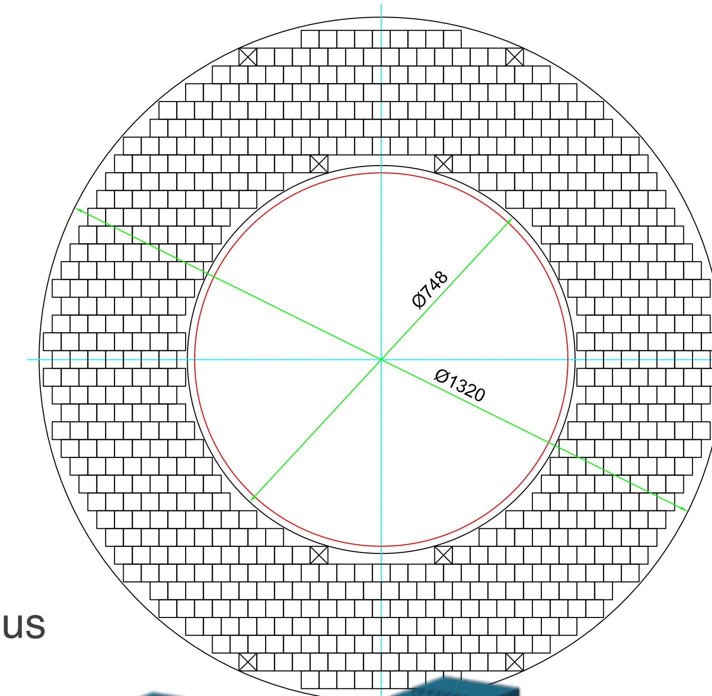
Requirements for the mechanics of the calorimeter

The Mechanics of the calorimeter needs to fulfill the following requirements:

- be a support structure for the crystals, for the read-out silicon photosensors (SiPM), the Front End electronics, the HV/LV controller Mezzanine boards and the WF Digitizer boards
- minimize stresses on crystals
- minimize the passive material where conversion electron could pass by
- respect the clearances of the muon beamline geometry
- respect the interferences with the Tracker and other components of the detector solenoid
- provide a cooling system to thermalize the SiPM and extract the heat dissipated by the electronics
- host the source and laser calibration systems
- operate in vacuum and in Magnetic field
- define the assembly procedure and install it on the detector rails

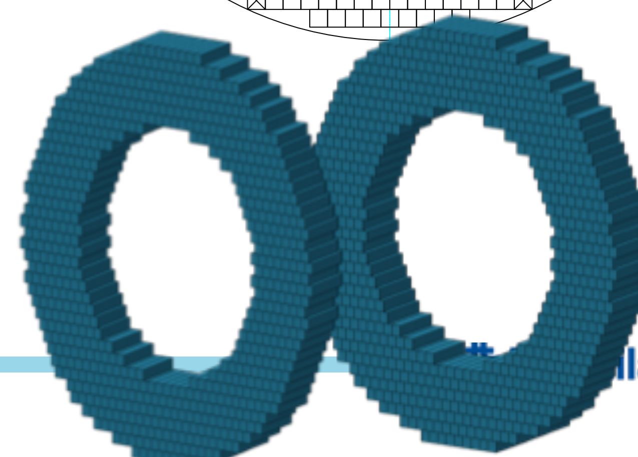
Calorimeter active area

- The core of the calorimeter is the array of pure CsI crystals. The single crystal dimensions and the 2 annuli geometry have been chosen to achieve:
  - Max Acceptance for conversion electrons
  - Good Spatial resolution
  - > 10 radiation length for shower containment
  - Perfect symmetry for e+ and e-
  - Photosensor FEE shielding
  - Respect constraints of the detector solenoid



The 2 arrays are shifted by 70 cm, 1/2 wave length, along *z* to detect signal electron escaping the first annulus

The active area of the Mu2e calorimeter consists of two annuli, with an Inner radius of 374 mm and an Outer radius of 660 mm, made up by 674 staggered scintillating crystals with a parallelepiped shape (34 x 34 x 200 mm^2), each wrapped with 150 μm thick reflective Tyvek sheet



Calorimeter Design Choice

We tailored the calorimeter structure around the best ideal layout for the crystals obtained by acceptance maximization simulations. Given the chosen pattern, the best solution is to pile up the individual crystals in a self standing array building two annular structures.

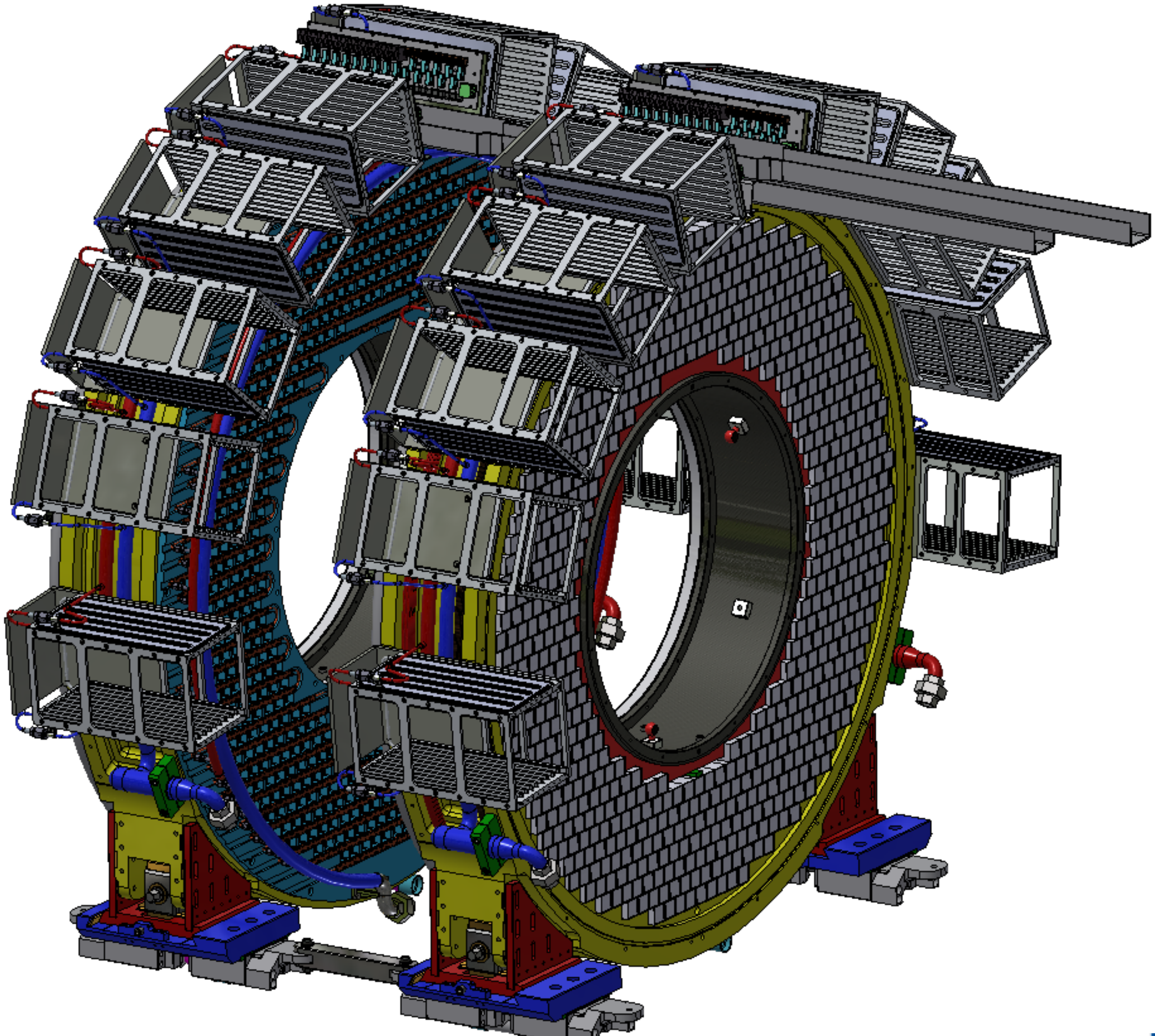
The supporting structure of each annulus needs to guarantee that :

- the crystals don't undergo any static or dynamic stress
- it is made by low radiation length material where high flux of low momentum electrons is present and minimize energy degradation for signal electrons

Each annulus is composed of the following components:

- Outer monolithic Al supporting cylinder with integrated cradle and stands
- Inner carbon fiber cylinder
- PEEK material back plate, housing SiPM and FEE electronics
    - Embedded cooling system
- Carbon fiber front plate integrating the source calibration system
- Array of 674 wrapped crystals
- 10 Read out/service electronics crates (8 boards each)

CAD: ensemble of calorimeter system



Presentations details

We will show the detailed design of the mechanical system along with all the prototyping activities:

- Supporting structure
- Feet with X-Y adjustment mechanisms
- CF components geometry
- Photosensors +FEE housing
- FEE back plate + Crate design
- Thermal studies for FEE and Digitizer crates
- Assembly procedures
- Hoisting procedure

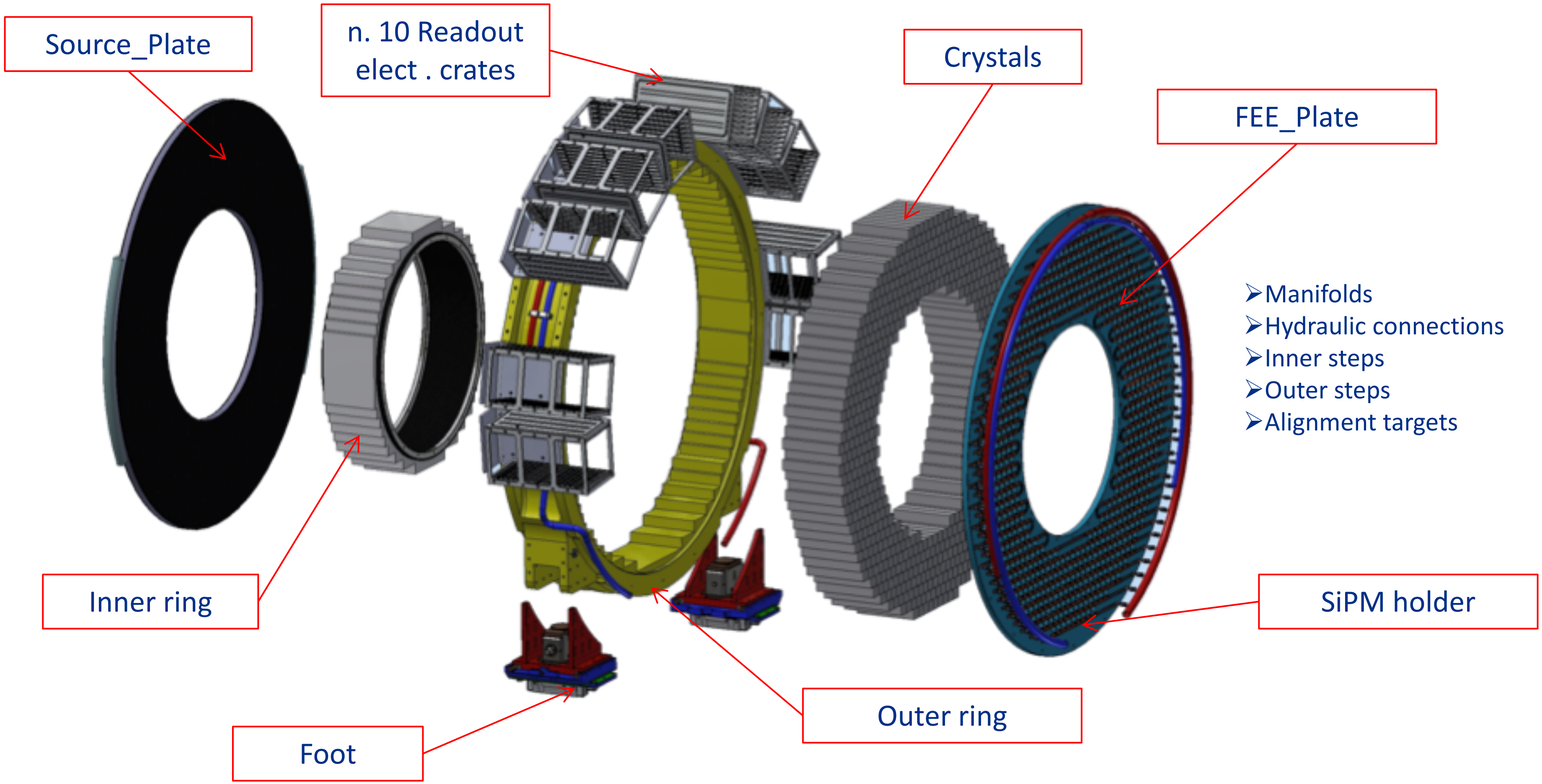
Prototypes

We have prototyped most of the mechanical parts of the calorimeter:

- The feet
- The outer cylinder
- The inner CF cylinder
- The crates and theyr cooling
- The CF source plate
- The FEE plate (module 0)
- The FEE cooling circuit
- The FEE holder

Main components

The calorimeter consists of two disks each one composed of:

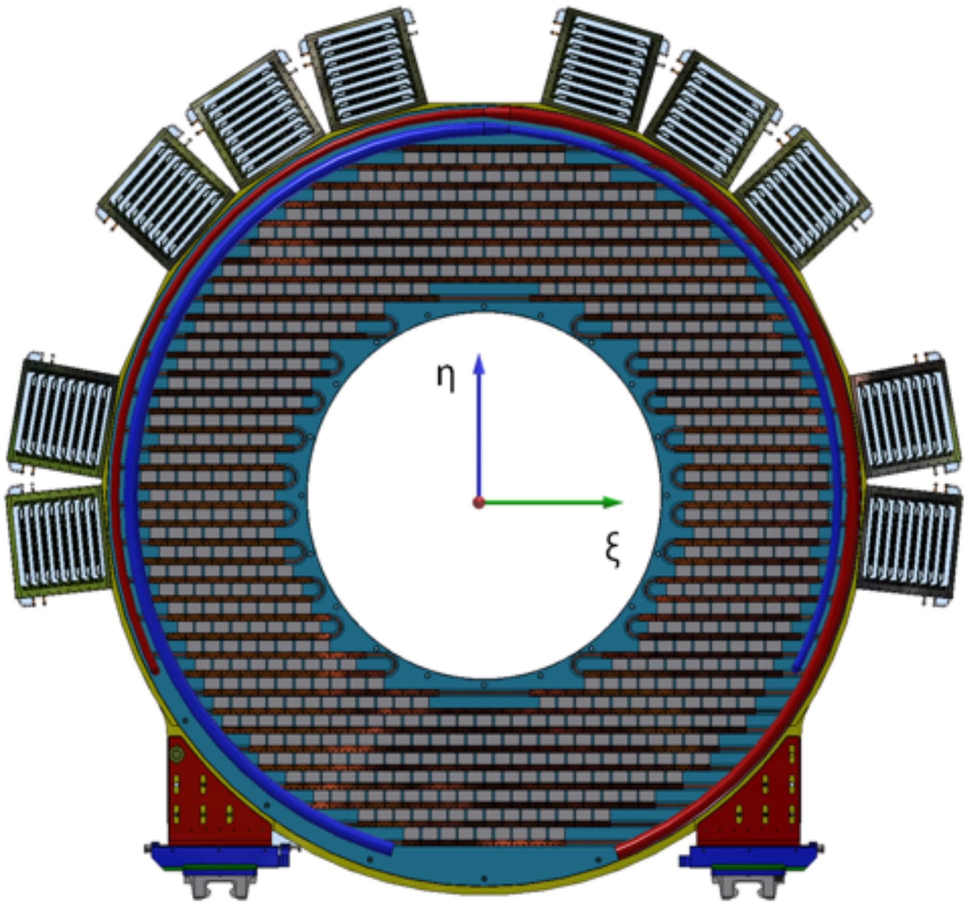


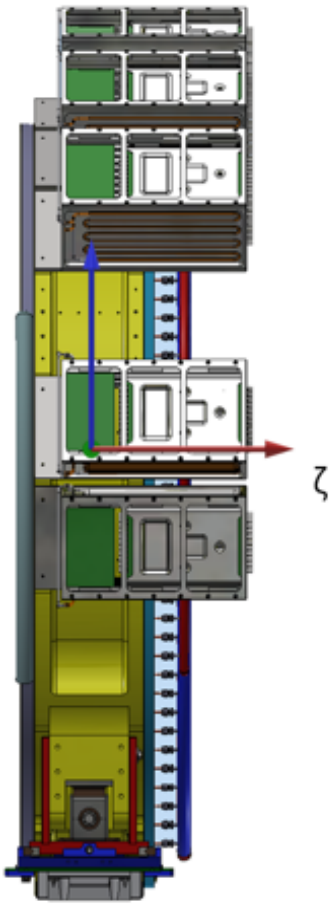
- Manifolds
- Hydraulic connections
- Inner steps
- Outer steps
- Alignment targets

Main components

Total weight: ~1400 kg

Overall sizes:
R_{in}= 336 mm
R_{out} = 910 mm
Width= 350 mm





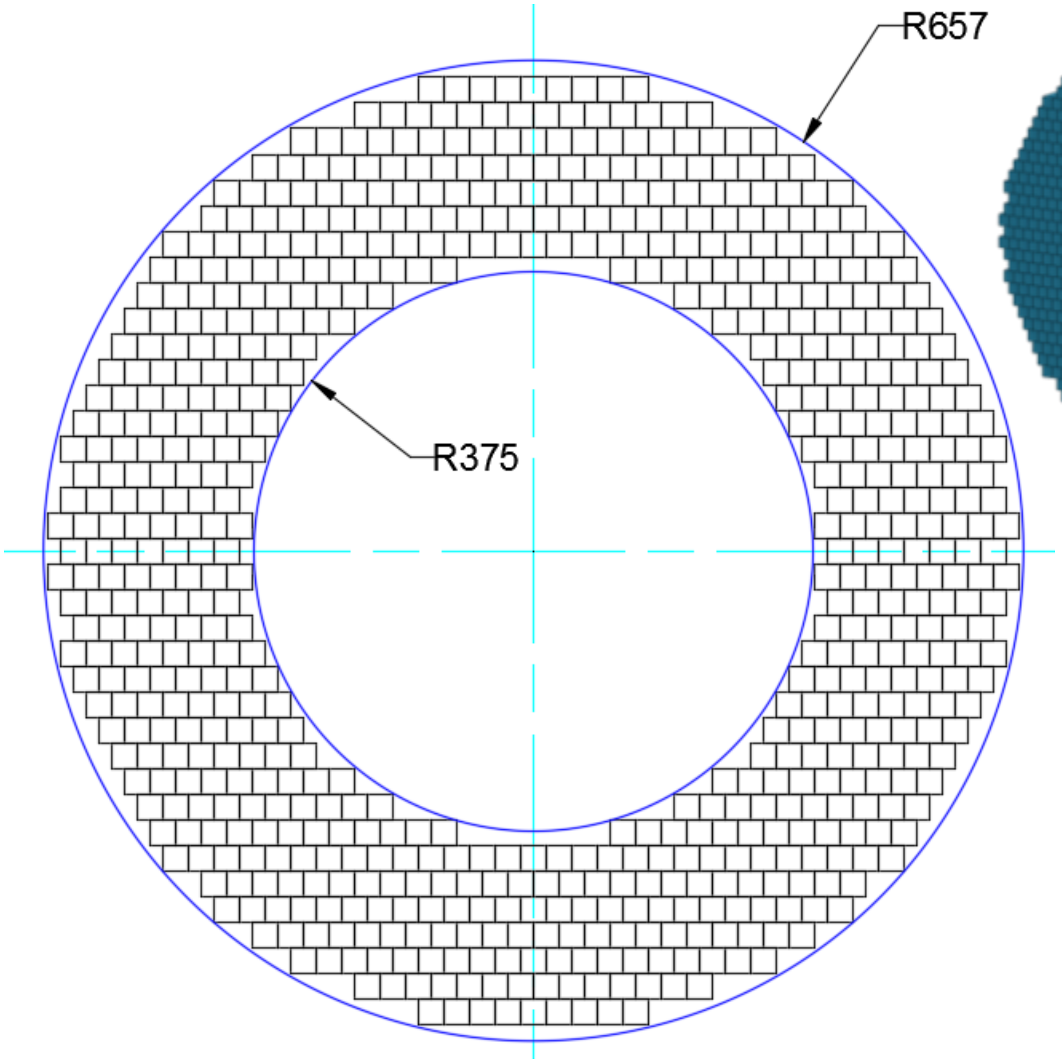
Crystals matrix

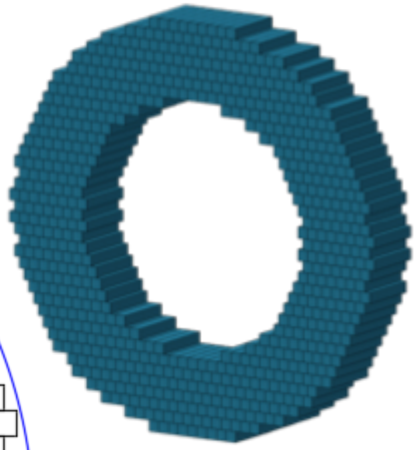
n. of crystals: 674

Fill Factor: ~85%

Total weight: ~700 kg

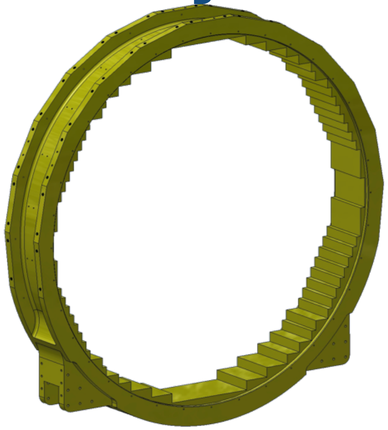
Overall sizes:
R_{in}= 375 mm
R_{out} = 657 mm





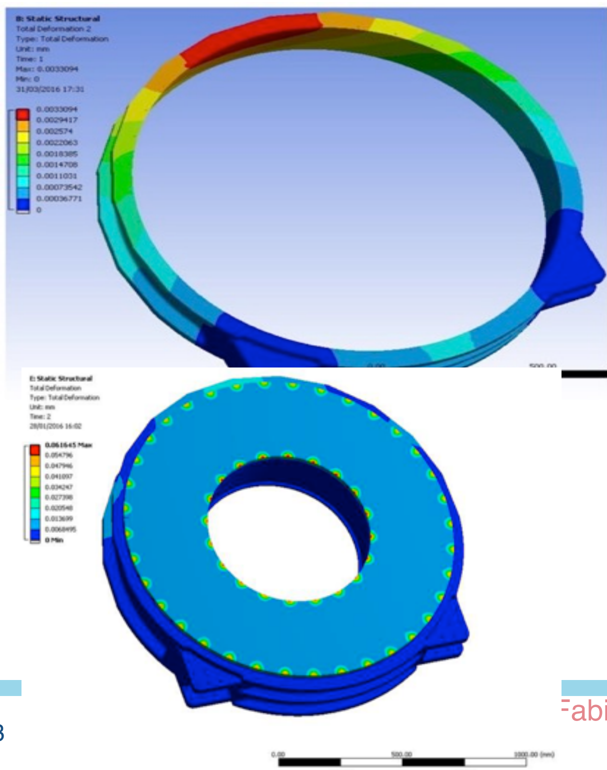
To prevent contacts between two adjacent sharp edges, “staggered layout” has been chosen

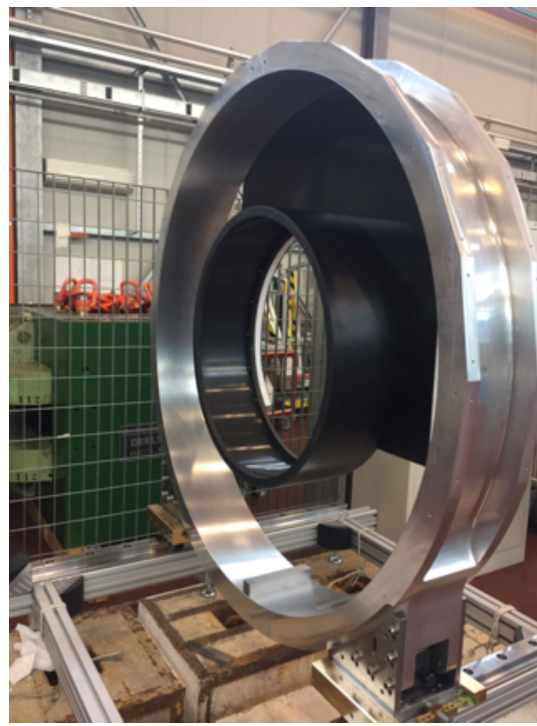
Outer cylinder



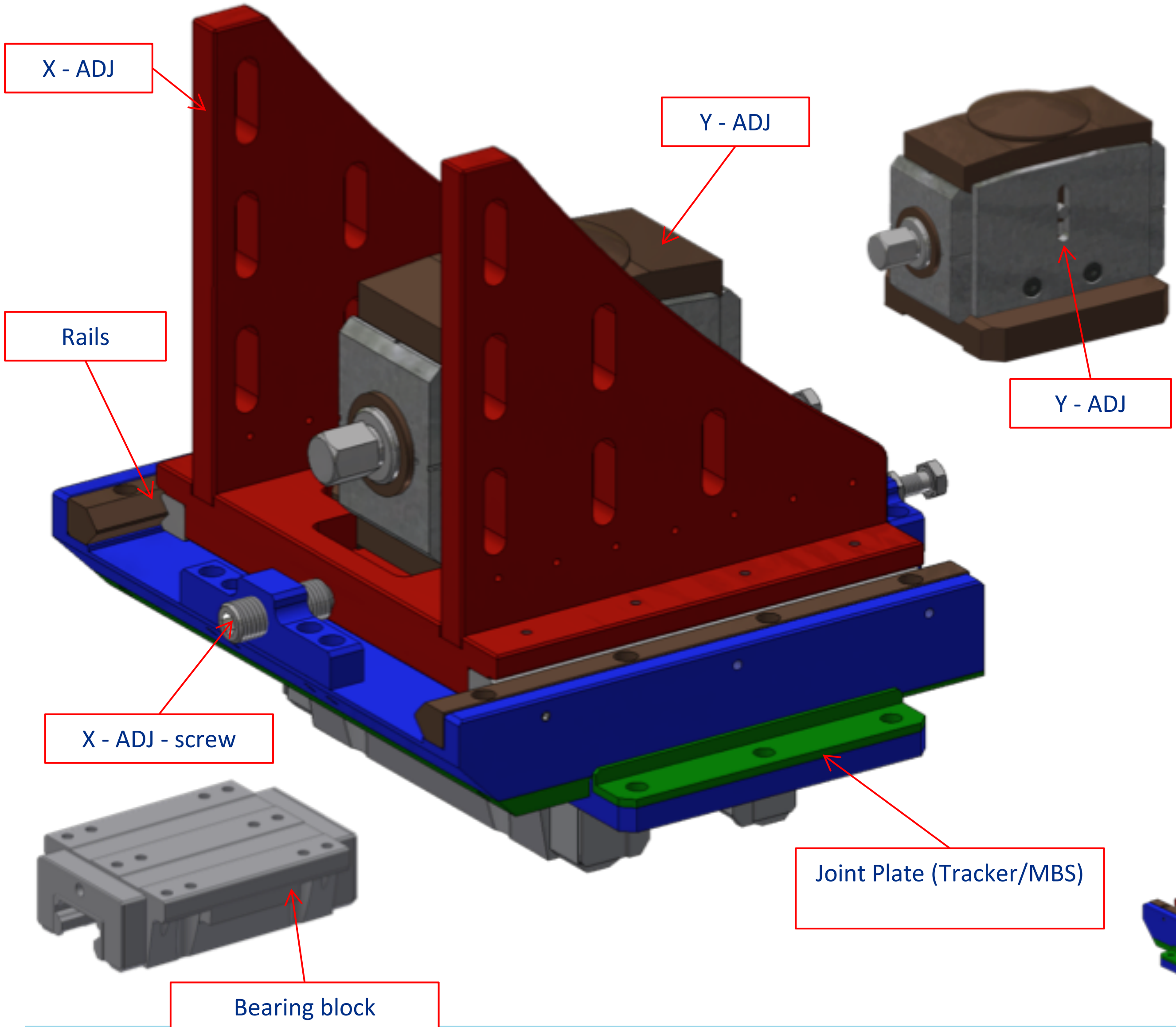
Outer monolithic C-profiled ring is machined from a block of Al 6082 to achieve maximum stiffness (max def. 4 microns).

- ➢The supporting structure of each annulus needs to guarantee that the crystals don't undergo any static or dynamic stress.
- ➢The inner surface has a "stairway" shape for the purpose of housing the crystals.





Feet & X-Y adjustment

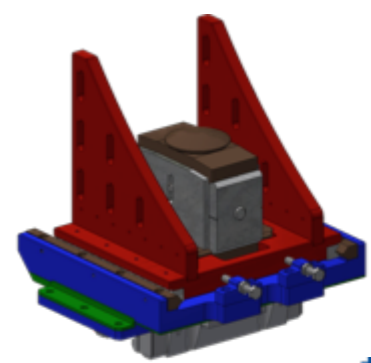


Each foot consists of:
- a bearing block
- a skid (runner)
- Two rails
- a wedge mechanism

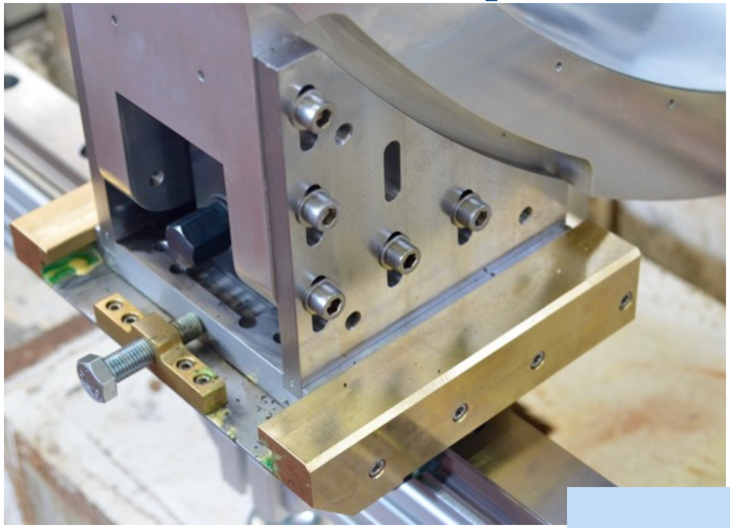
It allows an adjustment of:
- Y = +/- 20 mm
- X = +/- 10 mm

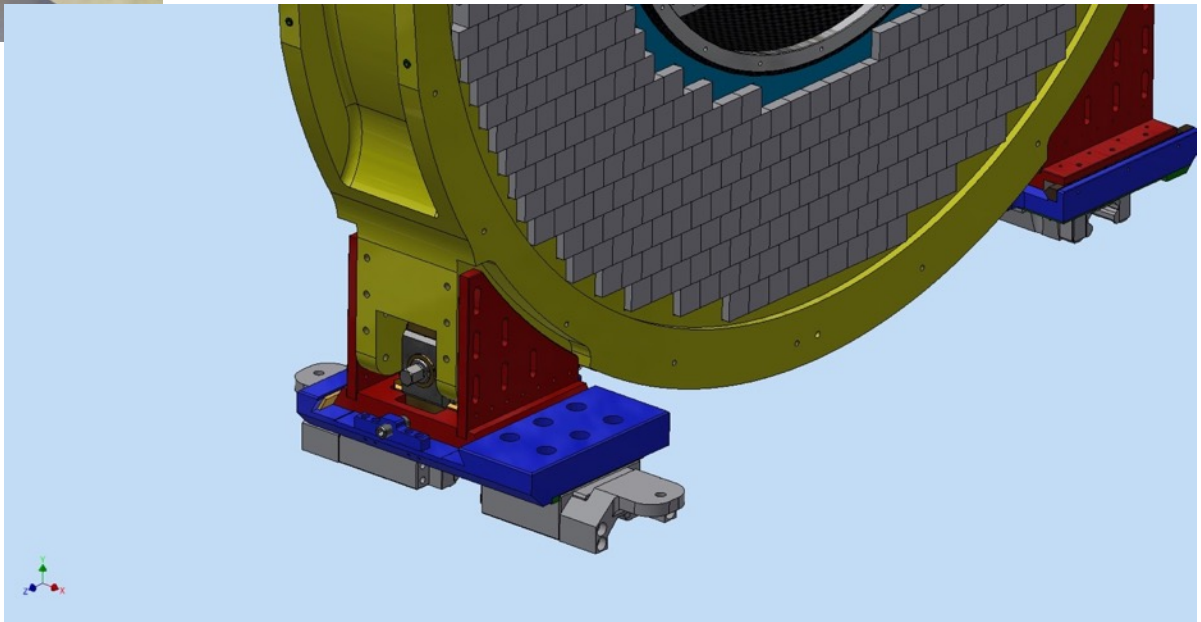
It is made from:
- Aluminium
- AISI 316L
- Bronze
- FR4

All holes are designed to provide complete evacuation of trapped volumes of air during pump-down and eliminate "virtual leaks" (through-holes).

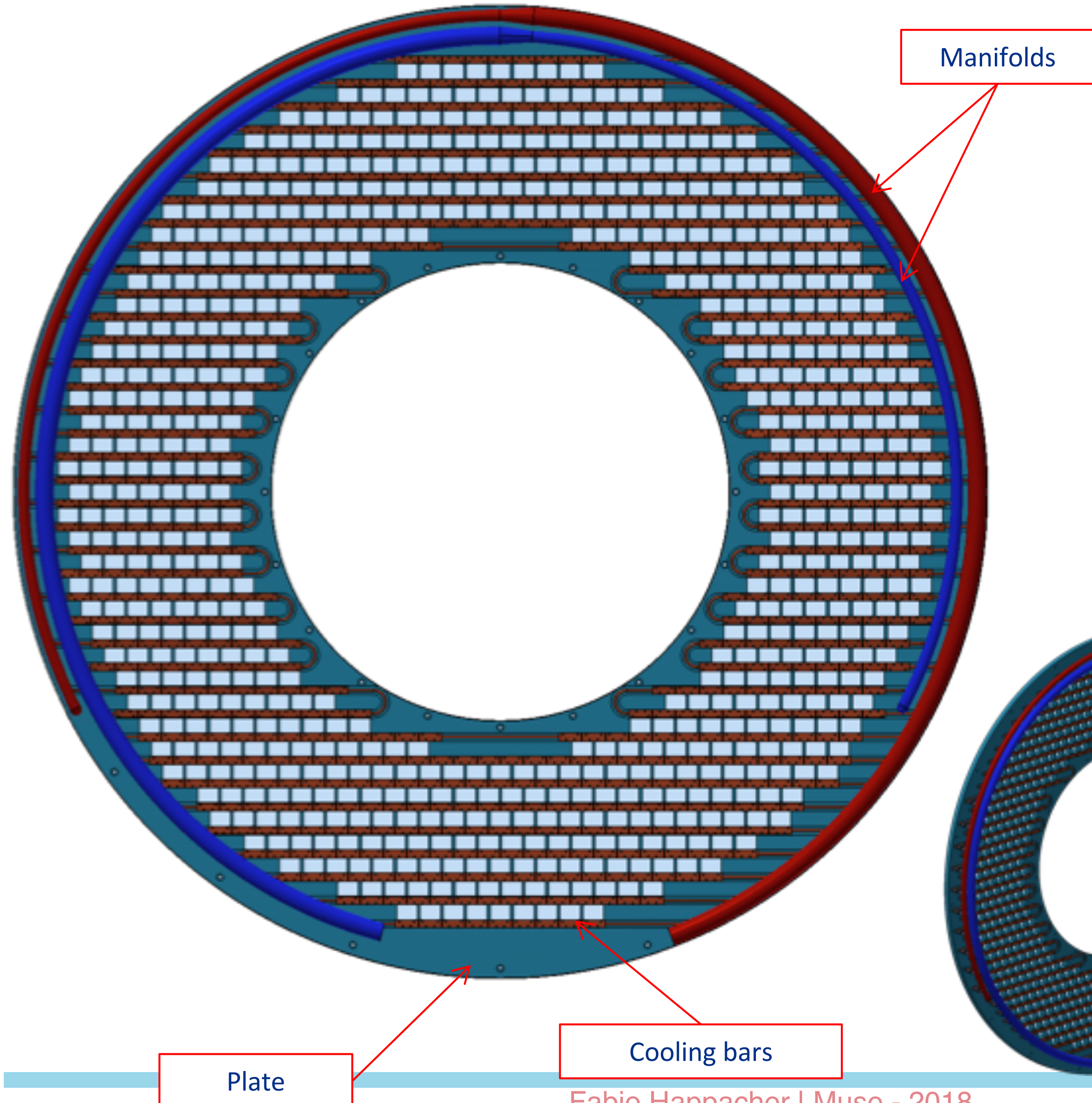


Feet mock up





Front End Electronics plate



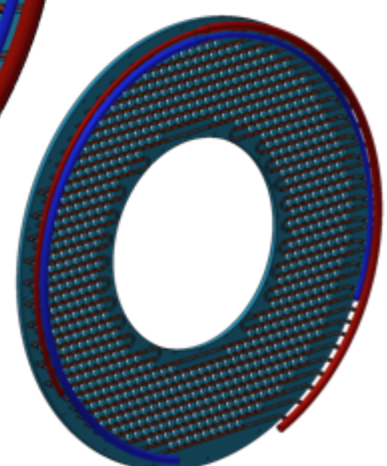
The FEE plate consists of:

- a machined plastic plate (one whole piece)
- cooling channels made from copper
- two manifolds (inlet/outlet) made from AISI 316L

It is machined from a plate of Peek to achieve the thermal/electric insulation and a good stiffness.

The manifolds are electrically insulated from the supply line by means dielectric fittings.

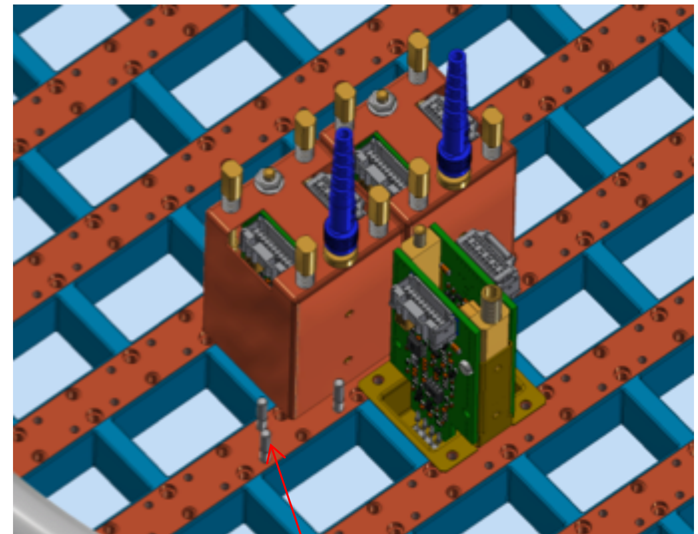
All holes are designed to provide complete evacuation of trapped volumes of air during pump-down and eliminate "virtual leaks."

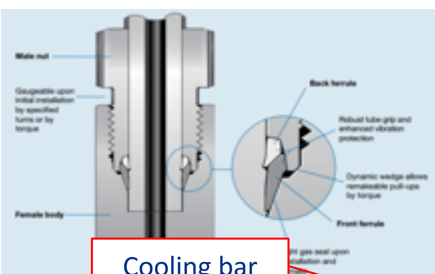


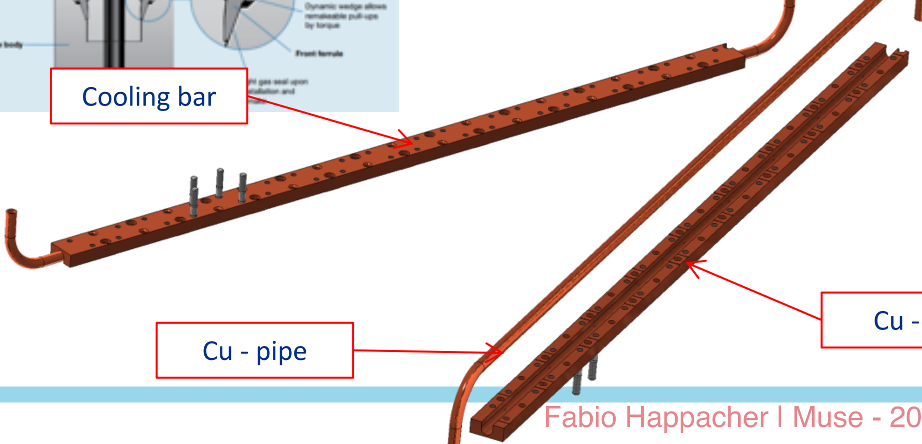
Overall sizes:
D_{in}= 672 mm
D_{out} = 1430 mm
Thickness= 15 mm

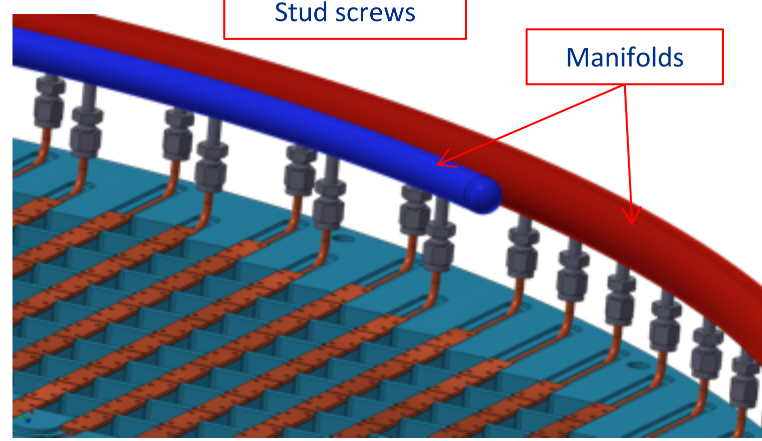
FEE plate

- The FEE plate houses the Front End electronics and photosensors holders and provides cooling.
- The coolant runs inside the cooling channels, at ~ -10ºC.
- The manifolds are jointed to the cooling channels by means of tube fittings (Swagelok type).
- The SiPM holders are bolted to the cooling channels by means four stud screws. It is in thermal contact with the cooling channels.
- The plate is thermally isolated from the outer ring and from the crystals.







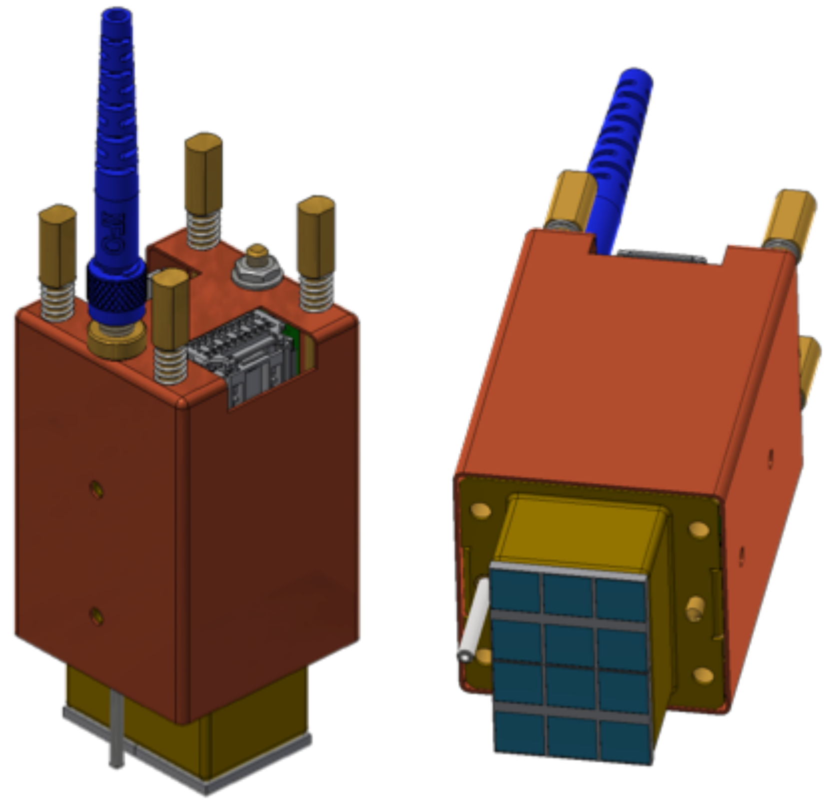


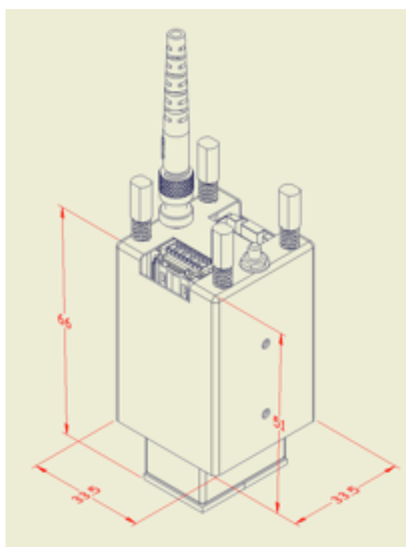
SiPM & FEE holders

- The holder houses the SiPMs, the EL boards and fiber connectors.
- It is made of golden copper to achieve a good thermal conductivity and facilitate the gluing of the SiPMs.

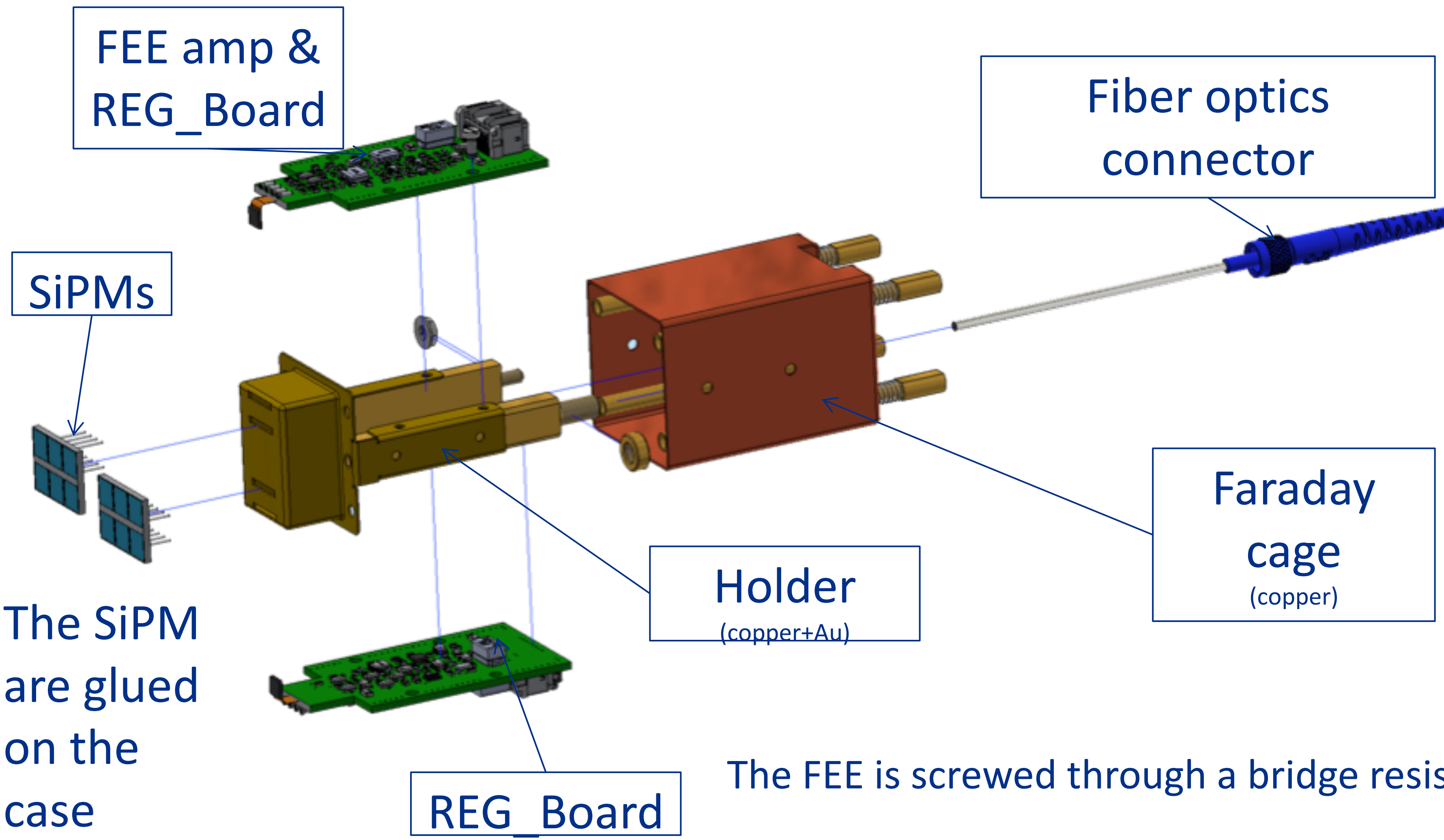
It provides:

- mechanical support for SiPM & EL board;
- heat exchange between SiPM and cooling circuit;
- light-tightness;
- faraday cage.





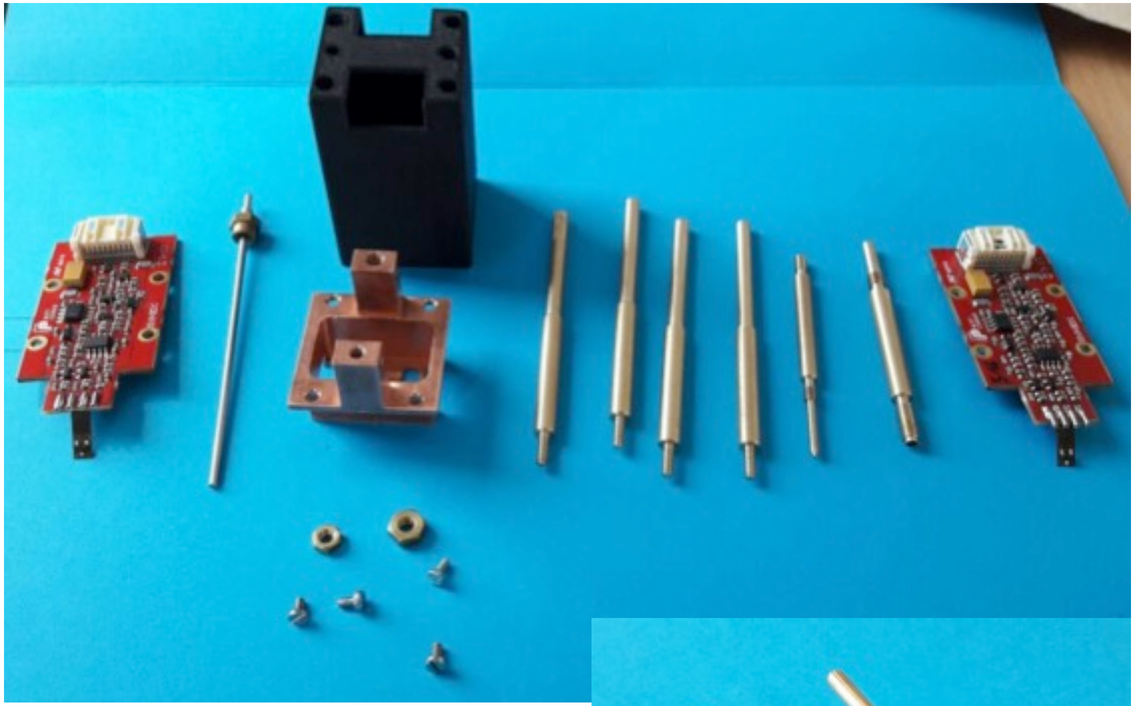
SiPM & FEE holders: components

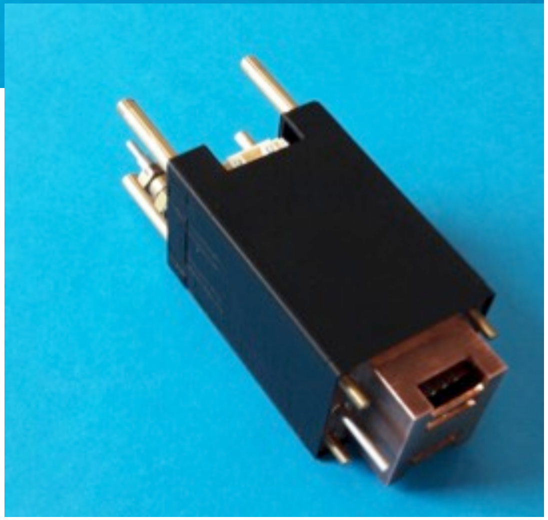


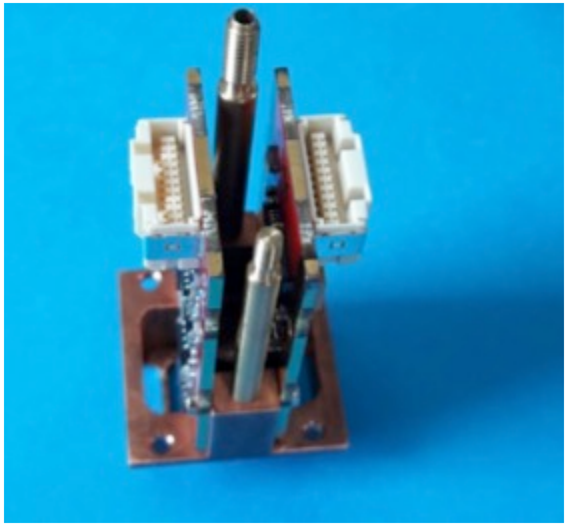
The SiPM are glued on the case

The FEE is screwed through a bridge resistor

Sipm holder





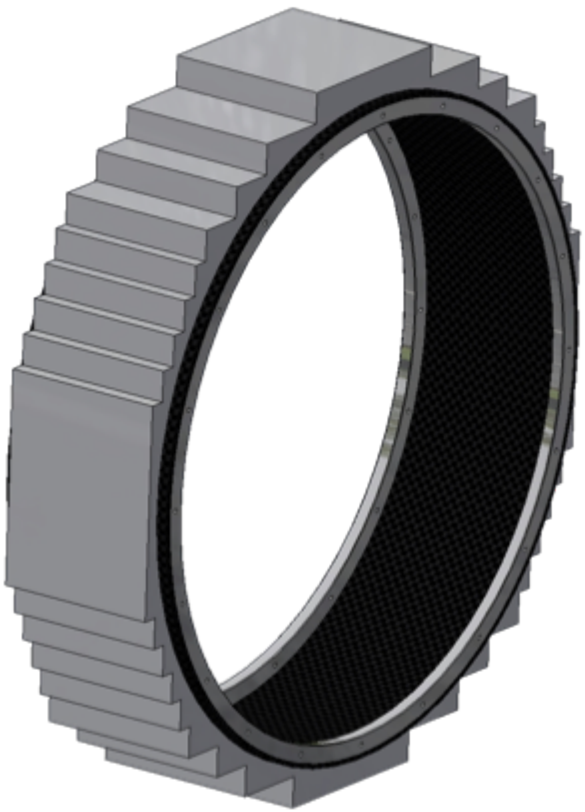


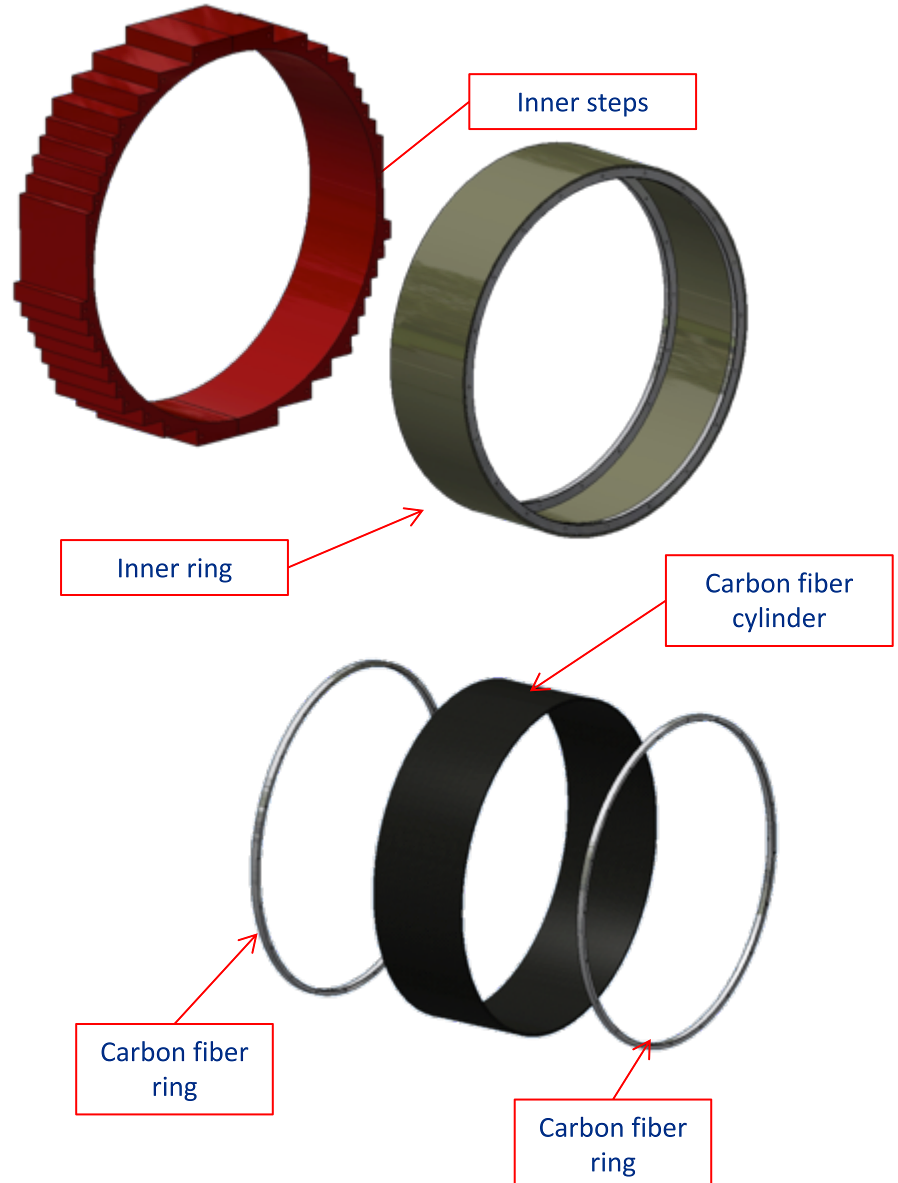
Inner cylinder

The Inner Ring consists of:

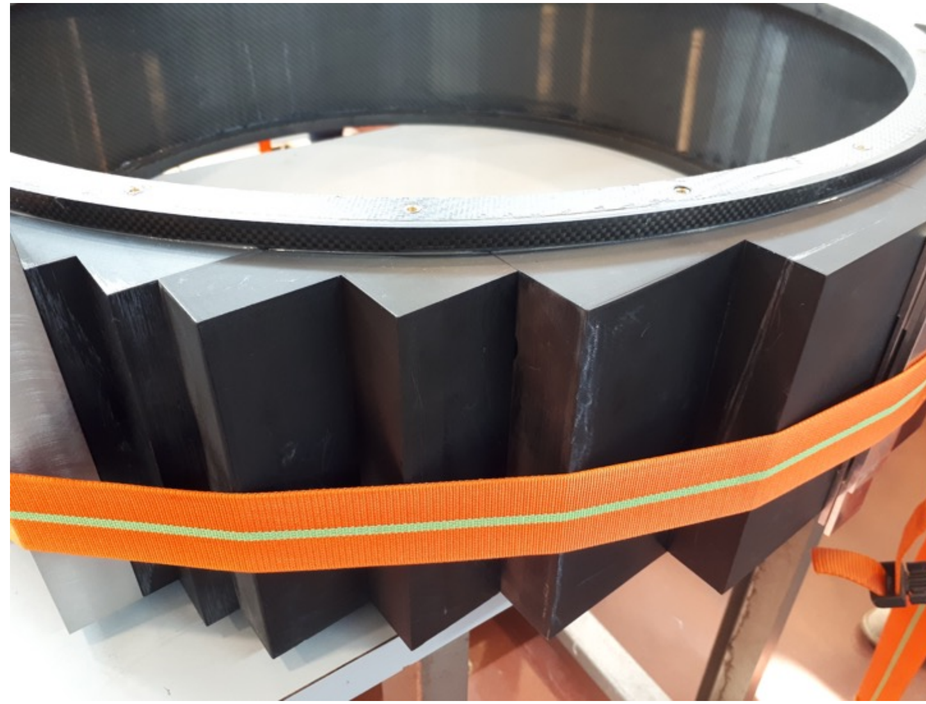
- a cylinder made of low density CF
- two rings made of CF
- steps made of CF and Al honeycomb

The rings and the inner steps are glued on the cylinder – Or printed together

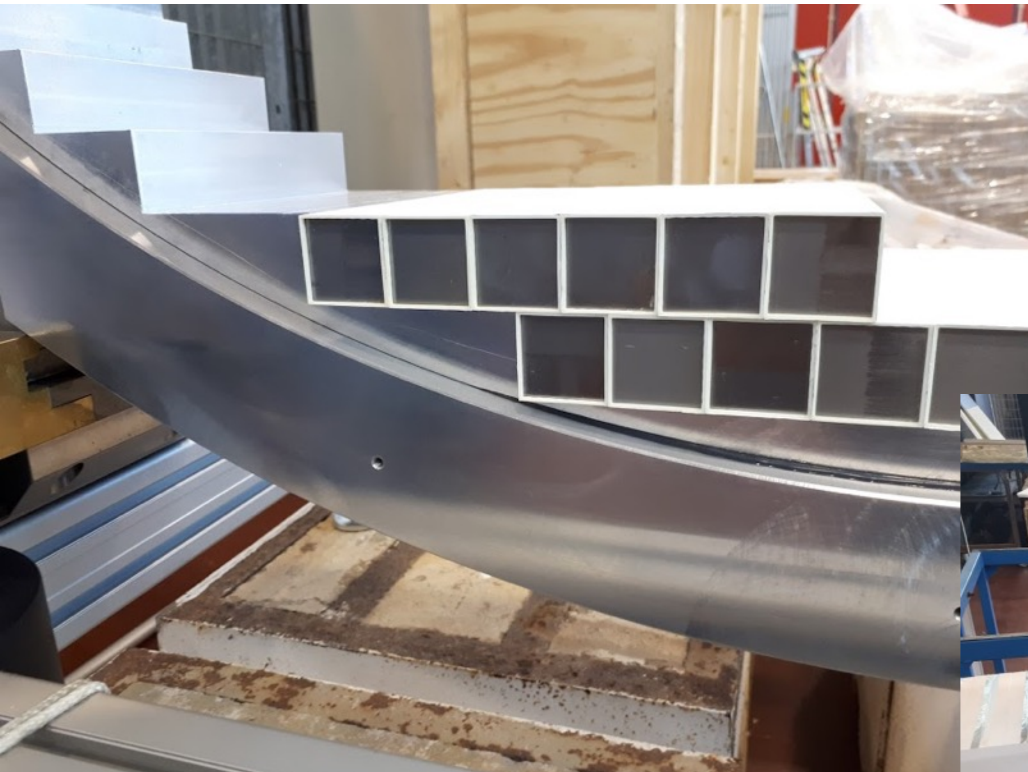




Inner steps mockup

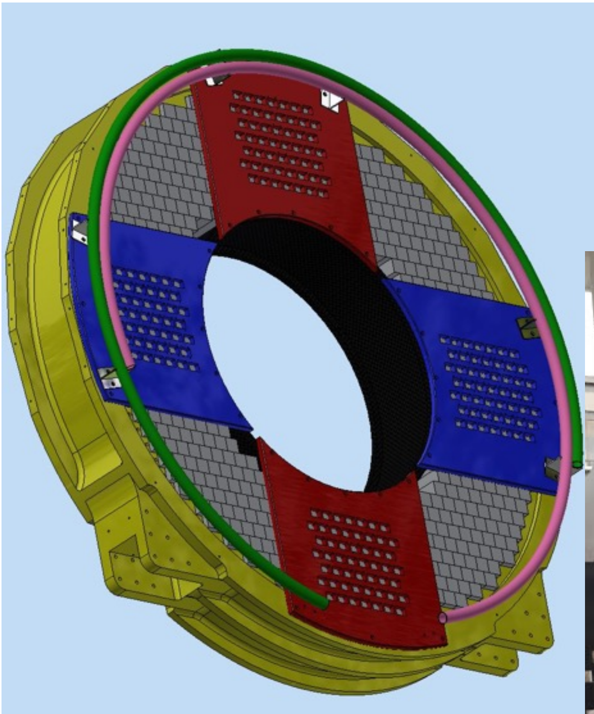


Crystal assembly procedure



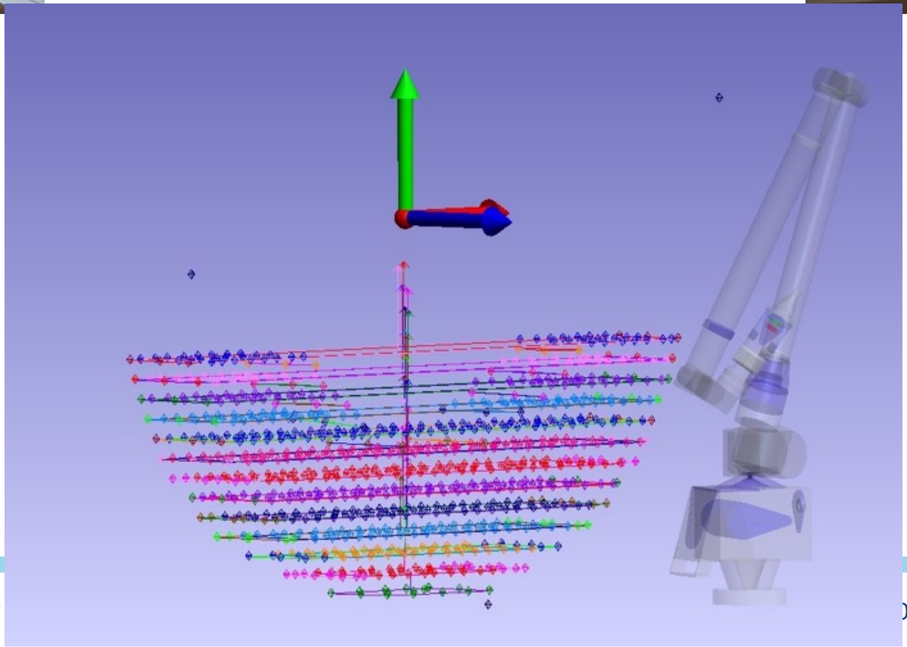
Mock up

Assembly procedure



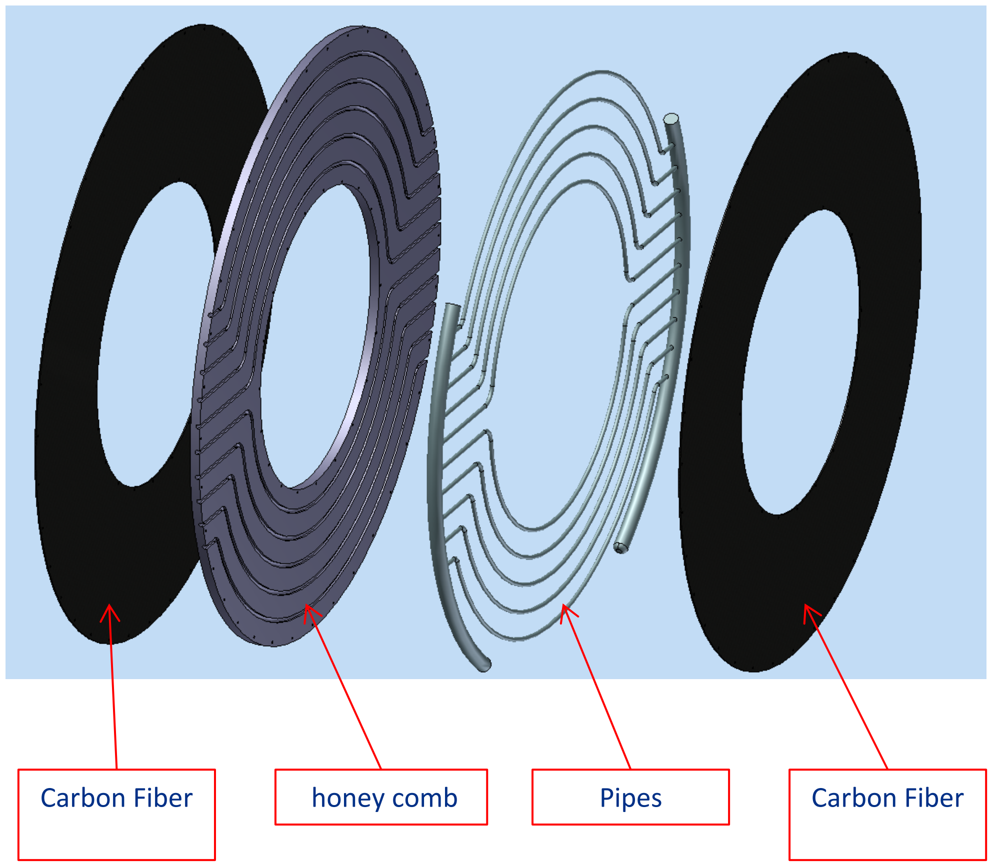
PVC FEE plate sections

Piling up and measuring wrapped iron crystals



Calibration source plate

The calibration source consists of two CF sheets placed on both sides of a honeycomb core.
The sandwich contains the source pipes embedded in Al honeycomb.

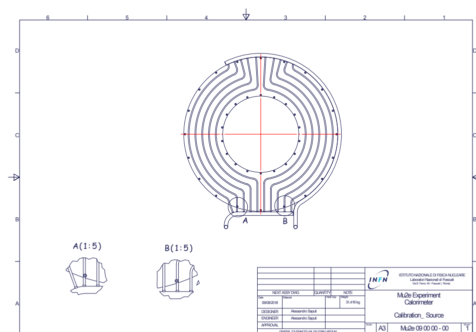


Materials:

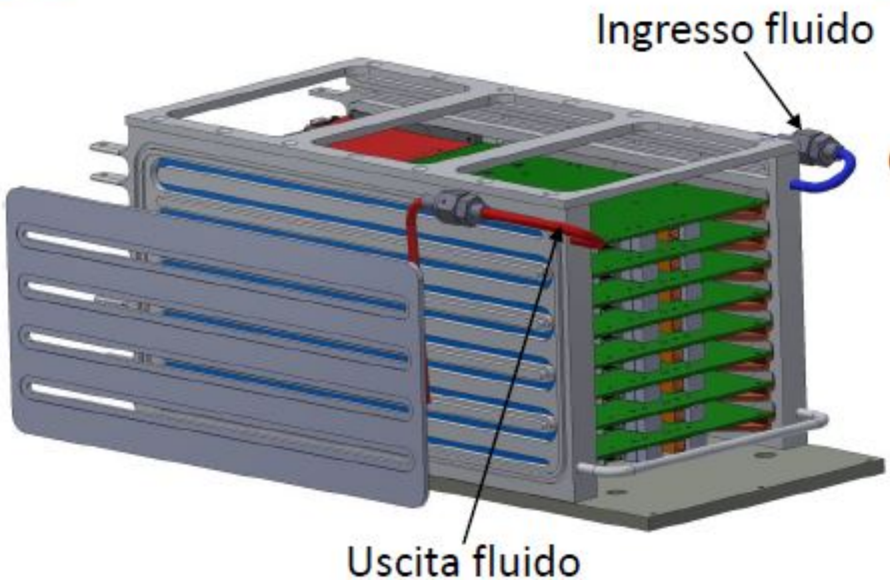
- Carbon fiber
- Al honeycomb

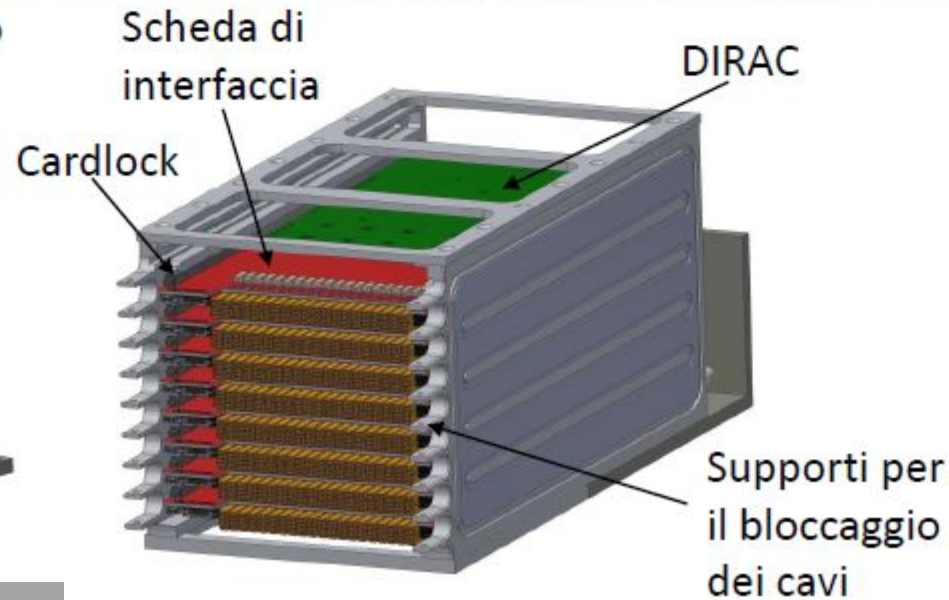
Overall sizes (envelope):

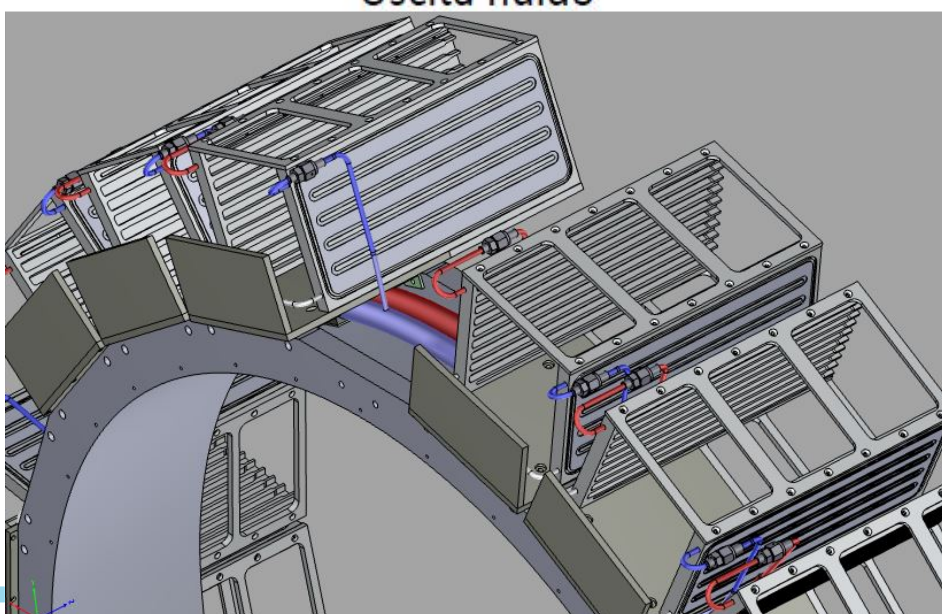
- D_{in}= 672 mm
- Max D_{out} = 1430 mm
- Max tickness= 50 mm



Crates with cooling







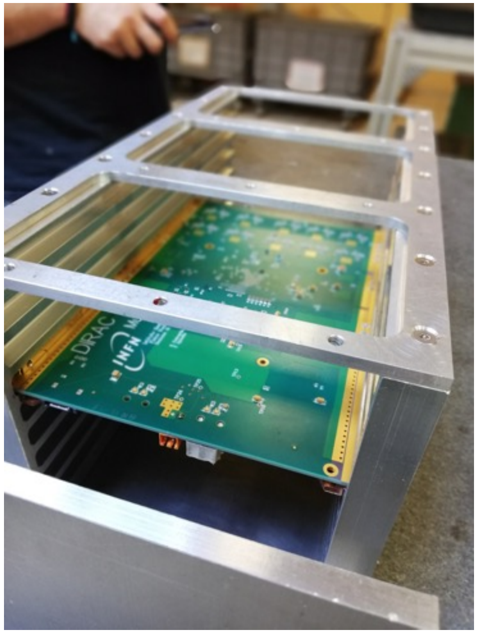
Overall sizes (envelope)

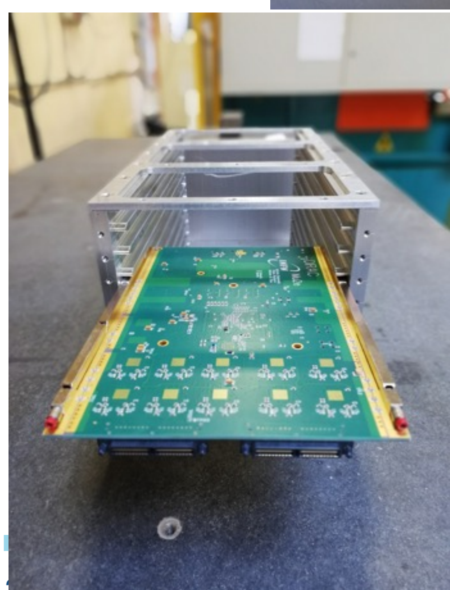
- width = 190 mm
- height = 183 mm
- depth = 350 mm

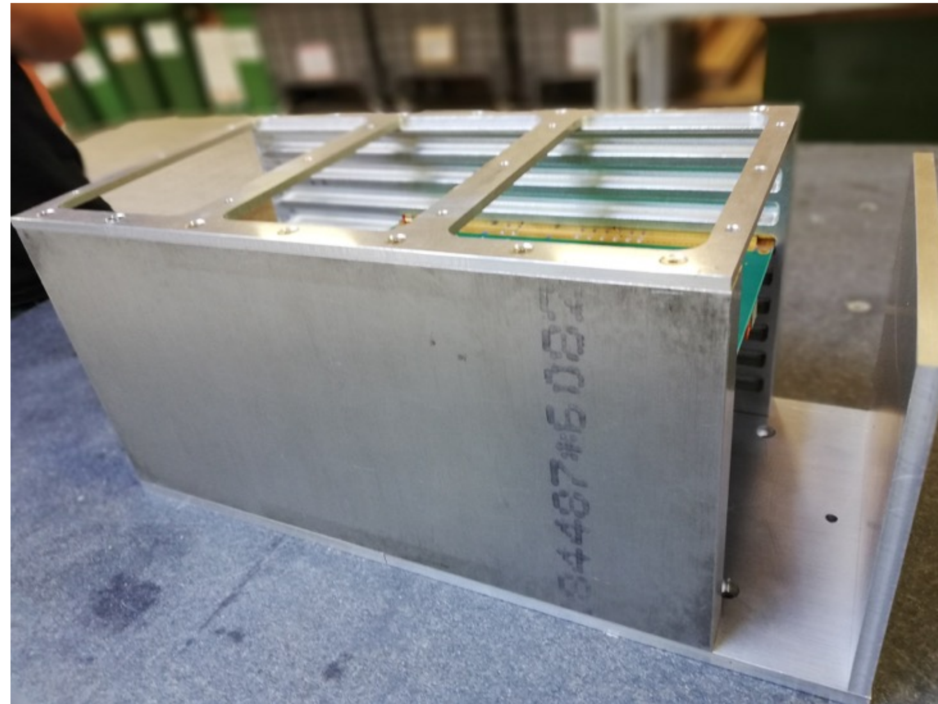
- Each crate contains 9 slots
- Each slot houses one Digi+HV/LV boards

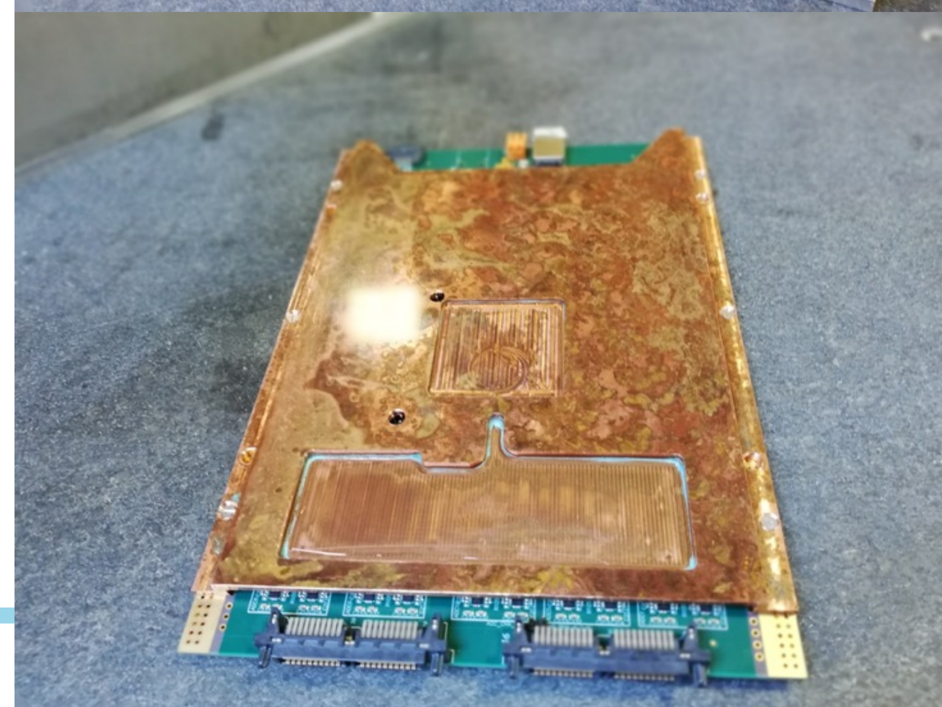
- Total weight = ~11 kg

Crate prototypes







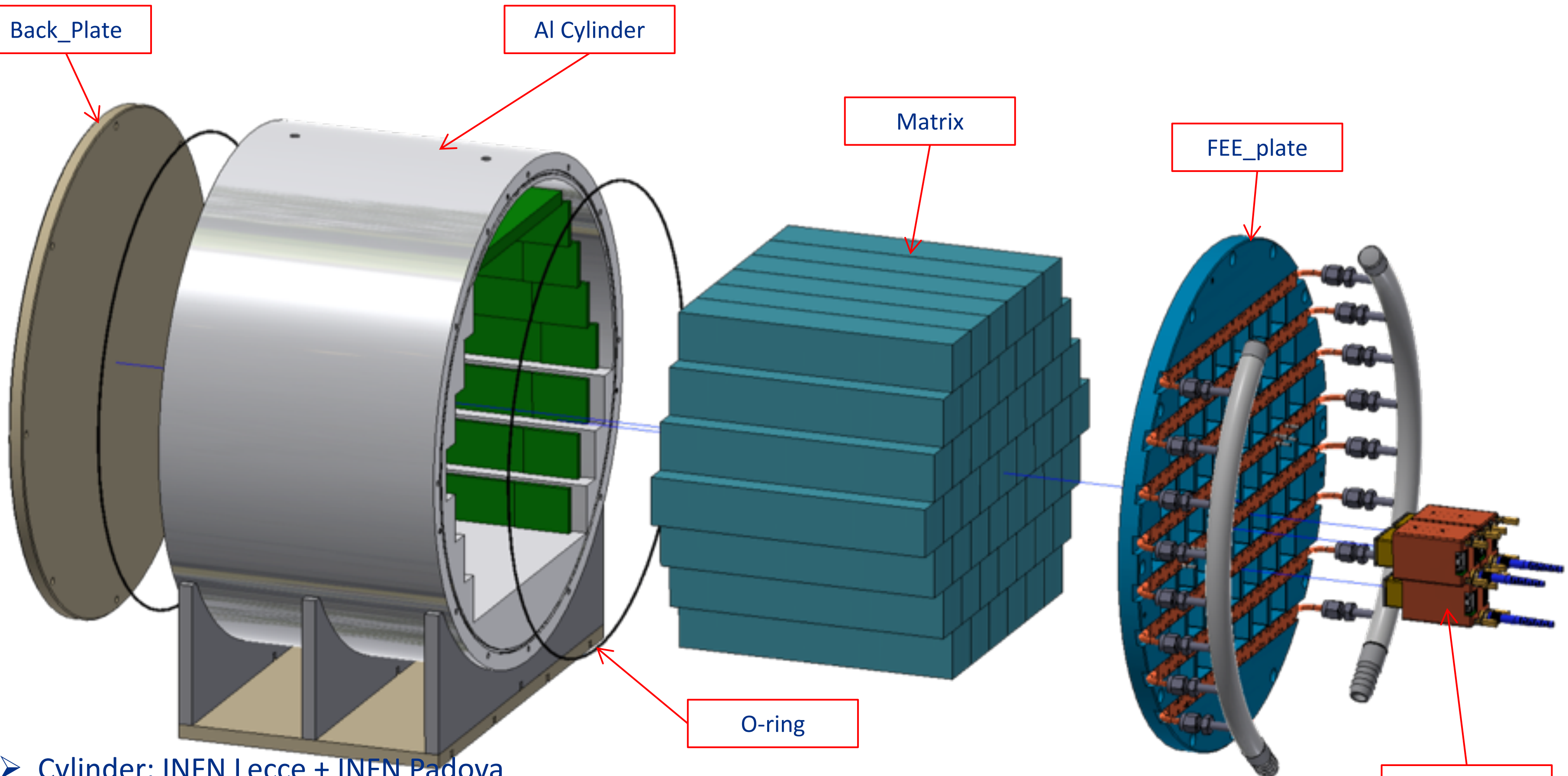


Prototyping: Full scale mock-up and Module-0

All the design technology is being tested building:

- a full scale mock-up to test:
  - Arrangement of crystals precision
  - Structure stiffness
  - Handling
  - Crate positioning
  - Cables routing
- a module 0 that implements all the technological choices of the actual calorimeter:
  - Arrangement of crystals
  - Cooling system
  - FEE+Sipm housing
  - Crystal wrapping

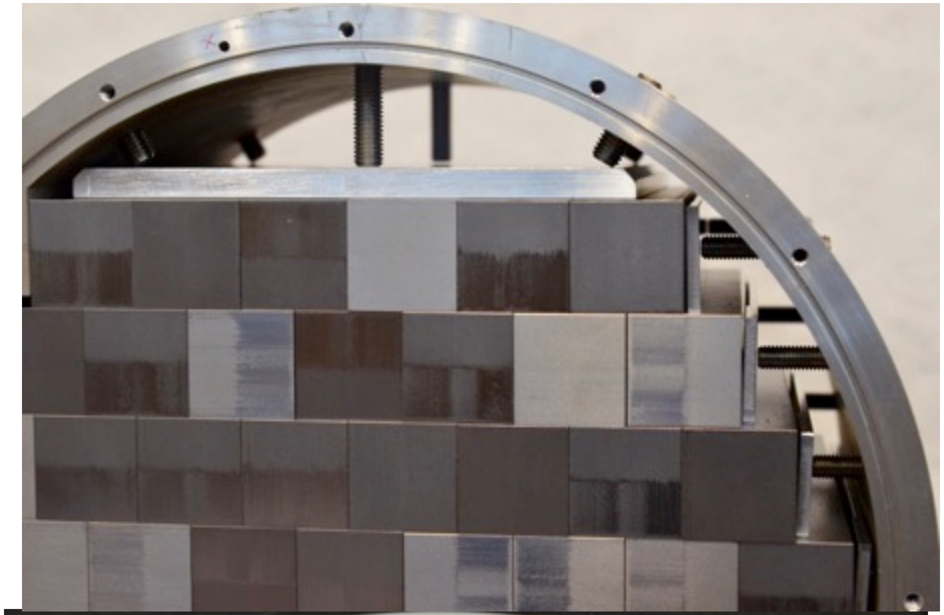
Module - 0

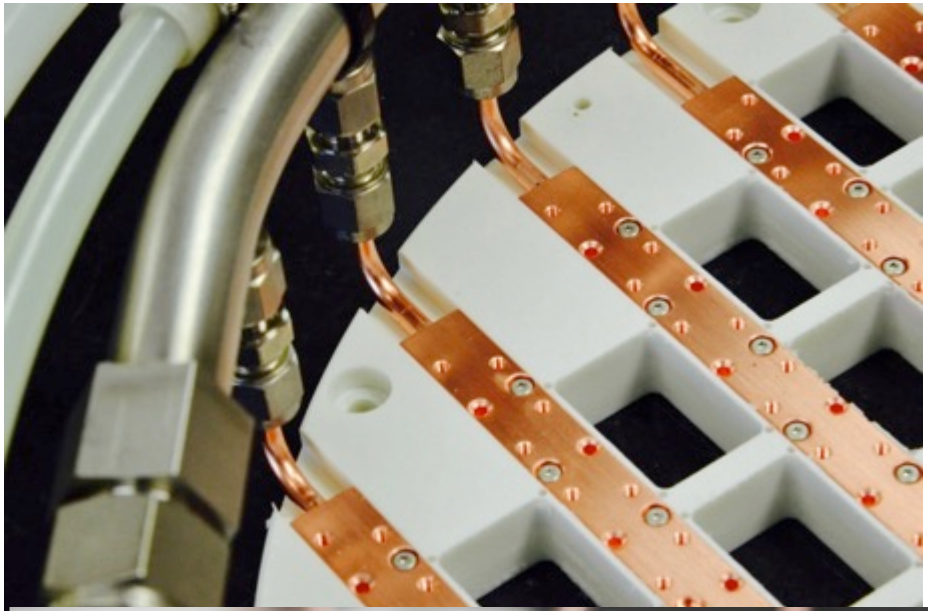


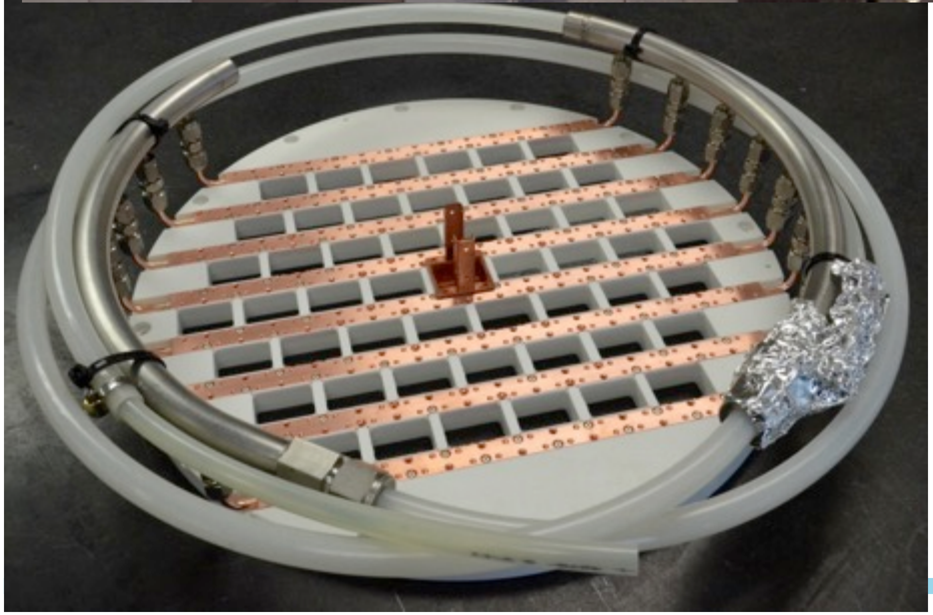
- Cylinder: INFN Lecce + INFN Padova
- Back plate + base: INFN Lecce
- FEE_plate: INFN Pisa
- SiPM holders: INFN/LNF
- Crystals wrapping: INFN/LNF

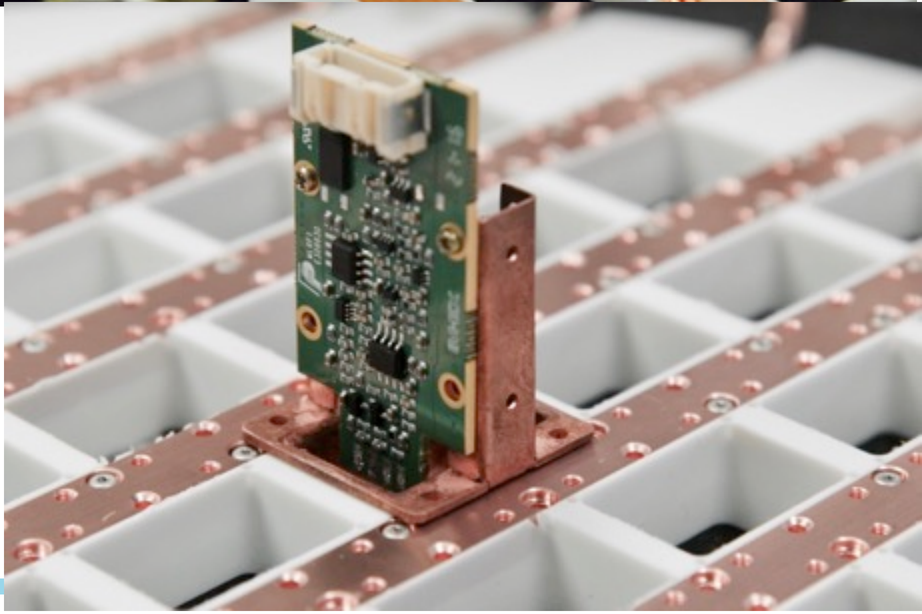
Assembly = ALL

Module 0 shell and FEE plate

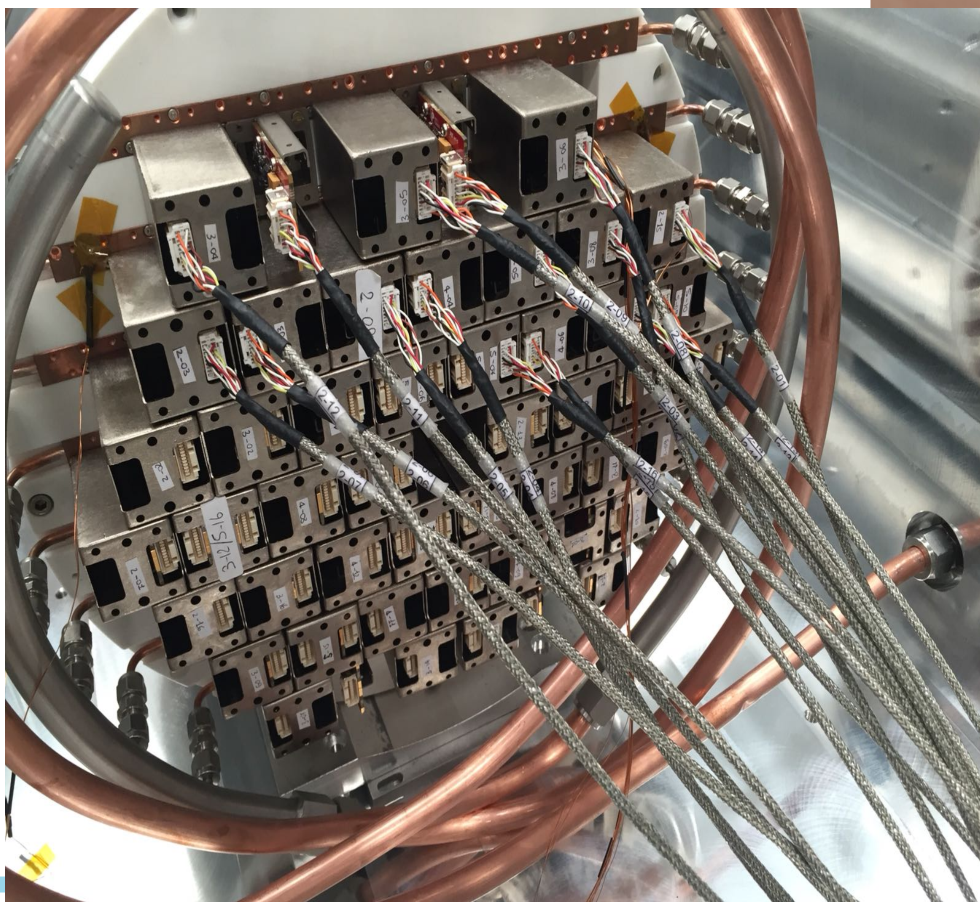




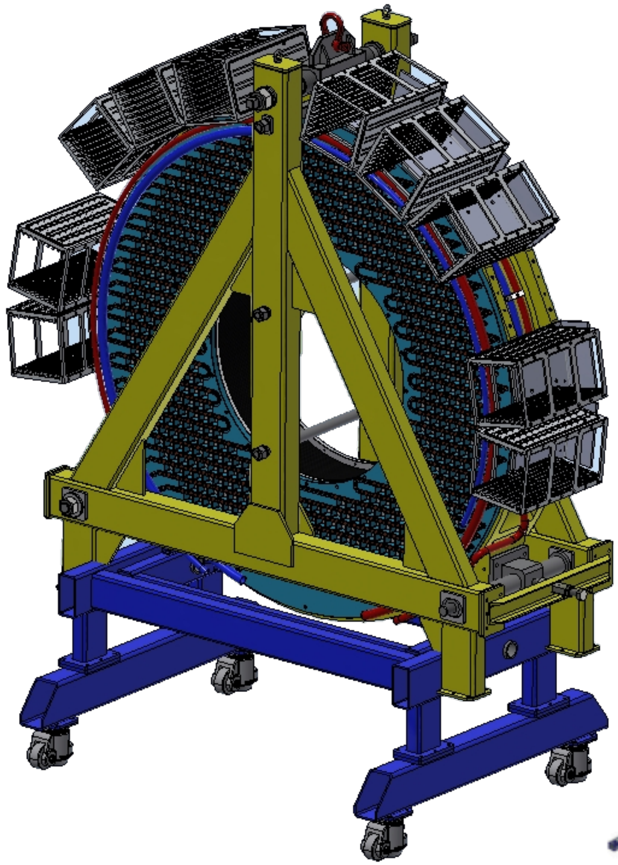


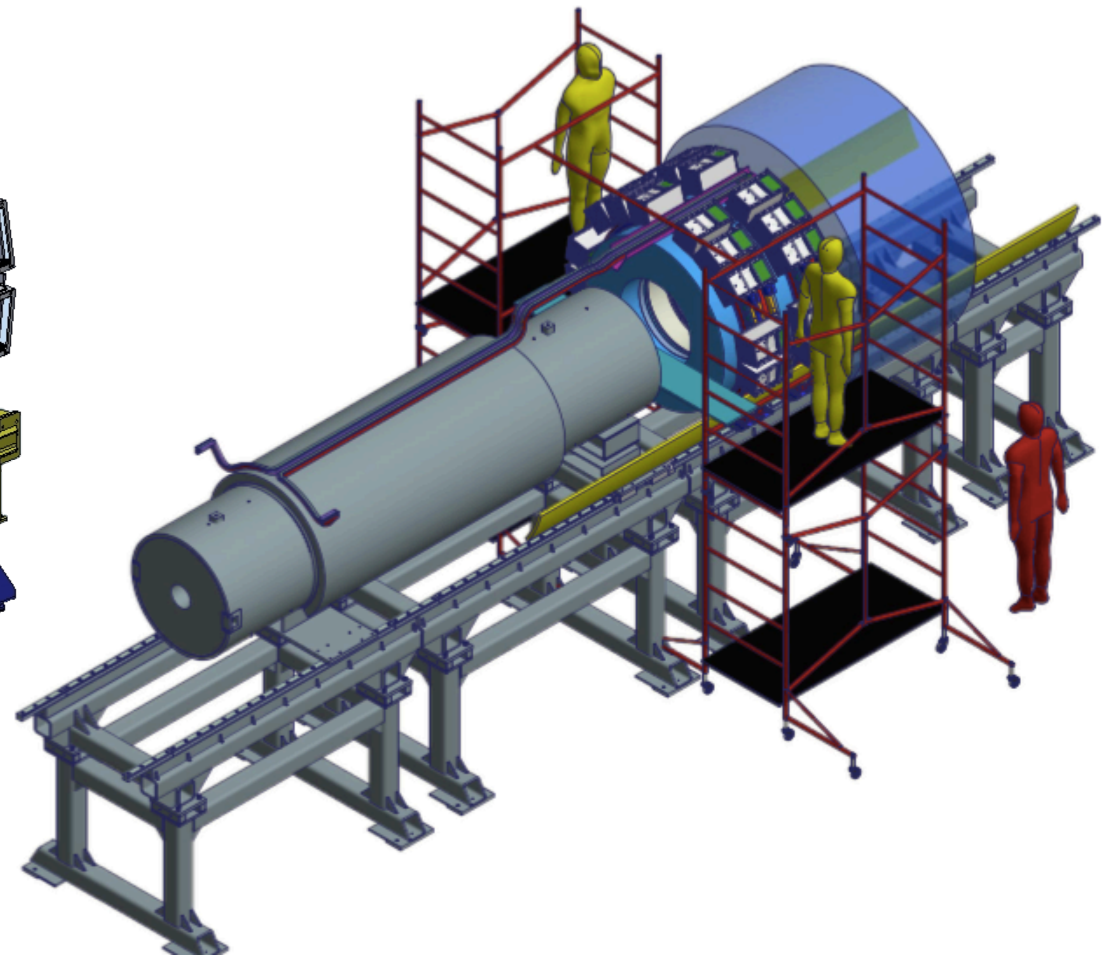


Assembling the Module – 0, Crystals and FEE



Assembling, moving and servicing





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Summary

- The mechanics of the calorimeter is going to be reviewed at the next Construction Readiness Review – Dec 2018

- We are addressing final recommendations
- Finalizing the Executable Drawings
- Started bids for non critical components – Construction waiting for green light from the review:
  - Outer Al Support cylinders
  - Inner CF cylinders
  - Front plate
  - SiPM+FEE holders
  - Feet and Adjustment

Calo Mechanics team activities

- Frascati
  - F. Happacher (L3), A. Saputi(L3), M. Martini, M.Ricci
    - overall design and integration
    - Photosensors and FEE integration
    - cooling station
- Lecce/Caltech
  - F. Grancagnolo, F. Porter + Eng. Support from UniSalento
    - Composite material components
    - FEM analysis of support structure
    - source integration
- Pisa
- F. Raffaelli (L3), S. Donati, S. Di Falco + Eng. students
  - Crate design and cooling
  - FEE cooling plate design and tests