The Engineering of the Mu2e Calorimeter

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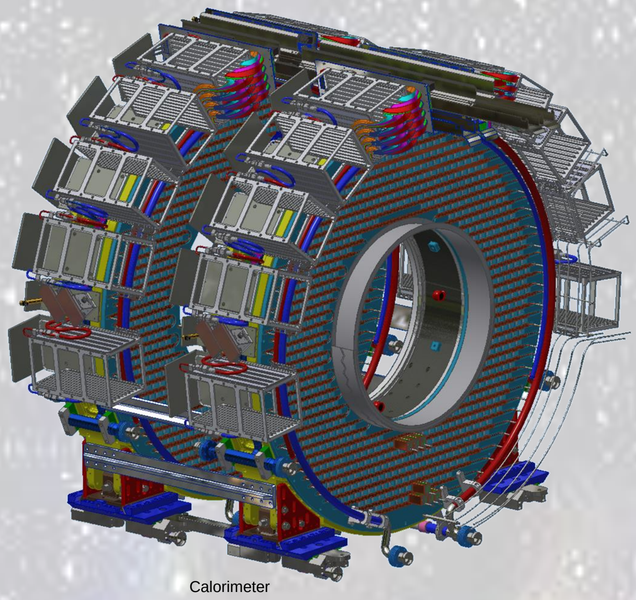
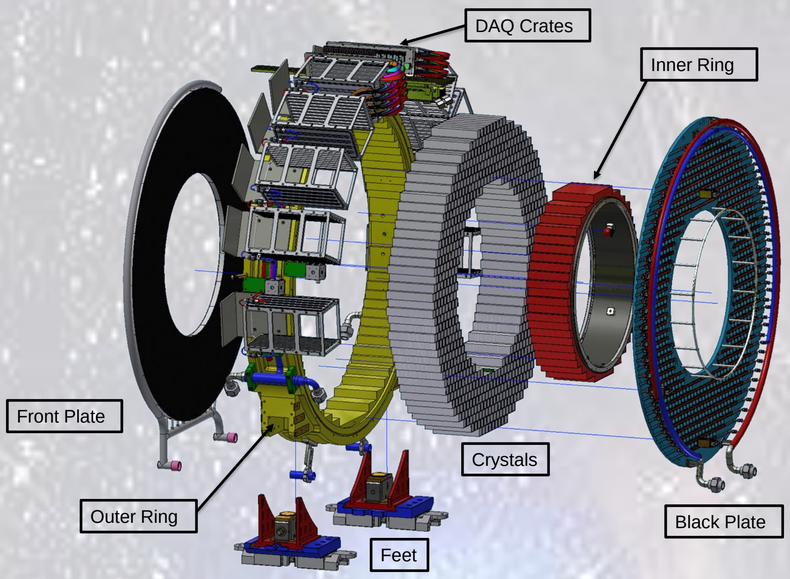
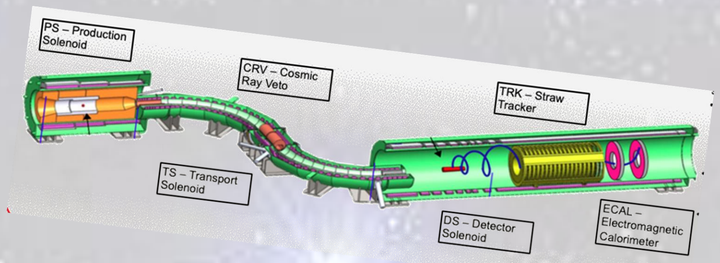
Mu2e Electromagnetic Calorimeter

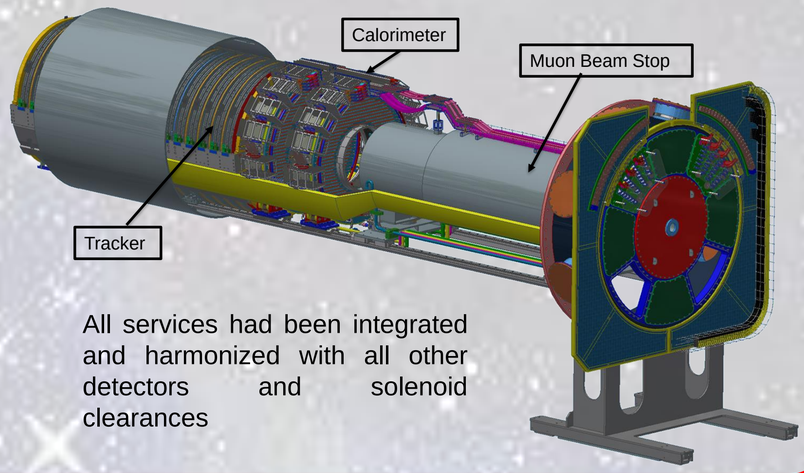
The Mu2e calorimeter is composed of two annular disks, each one filled with 674 pure CsI crystals. Each crystal is coupled to two custom 2x3 arrays of 6x6 mm^2 SiPMs.
The calorimeter requirements are to provide a large acceptance for 100 MeV electrons and resist to the 1 T magnetic field and to a harsh radiation environment.


Calorimeter





Mu2e is composed of a system of three superconducting solenoids:
- The Production Solenoid: the 8 GeV proton beam hits the tungsten target producing mostly pions
- The Transport Solenoid: filter the beam and select low momentum (40 MeV/C) μ- beam
- The Detector Solenoid: muons are stopped in the Al Target, the Straw-tube tracker and the calorimeter optimized to detect conversion electron. The entire region is surrounded by a cosmic ray veto (CRV)



Layout
- 2 Calorimeter Disks
- Total calorimeter length: 1300 mm
- Outer Diameter: 1820 mm
- Total weight: 3600 kg

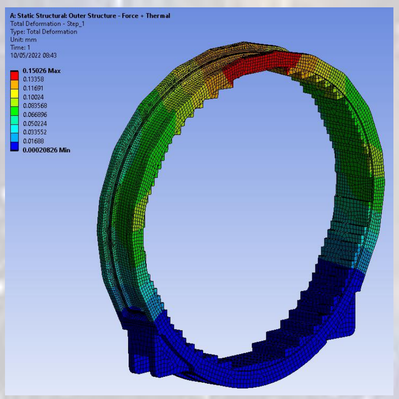
Requirements
- a time resolution better than 0.5 ns @ 100 MeV;
- an energy resolution *O*(10%) @ 100 MeV;
- a position resolution of 1 cm.

Mu2e Calorimeter numbers
- 674 CSI crystals (each disk)
- 6066 cm2 active area (each disk)
- 1340 SiPM channels (each disk)
- 50 cooling lines

All services had been integrated and harmonized with all other detectors and solenoid clearances

Outer Ring

The Outer Ring is the main support structure of the calorimeter. It supports the crystals from outside.



FEM Analysis

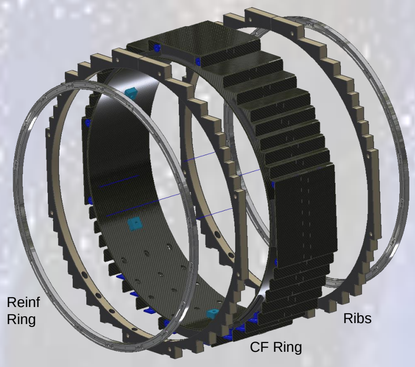

Outer Ring

The Outer Ring is a monolithic C-profiled ring and it is machined from a block of aluminum EN AW 6082 T6 to achieve maximum stiffness (max def. 200 microns). FEM analysis shows that the maximum deformation is 150 microns.

Inner Ring

The crystals are supported by a ring from inside. It is made of a carbon fiber cylinder (to minimize the particle energy loss) stiffened by 2 aluminium rings and 3 supporting ribs. It provides also the reference of the crystals matrix.


Inner Ring



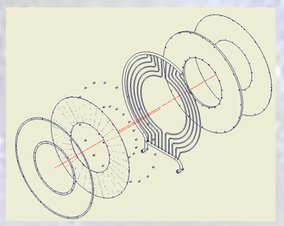
Inner Ring Exploded view

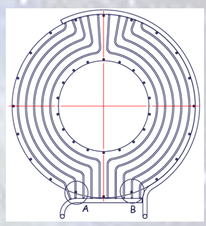
The Inner Ring is supported by both Front Plate and Back Plate and provides the internal reference of the Crystal Matrix.

Front & Back Plates

The Front Plate, made of carbon fiber honeycomb sandwich, hosts the calibration source (aluminum pipes). The source calibration system provides an absolute crystal-by-crystal calorimeter calibration on demand.

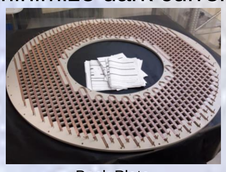

FP under construction

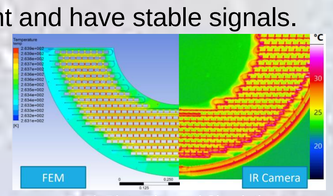

FP Exploded view



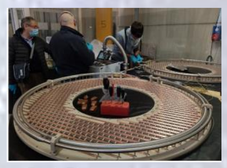
FP pipes layout

The Back Plate, made of peek, hosts the readout electronics and the SiPM cooling system. SiPMs are thermalized down to -15 ° C to minimize dark current and have stable signals.

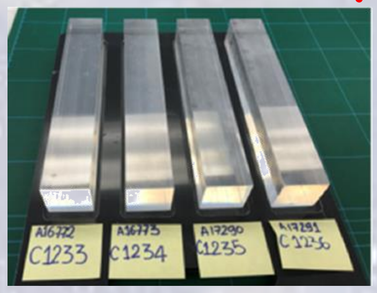

Back Plate

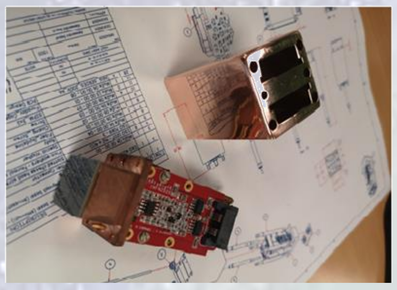


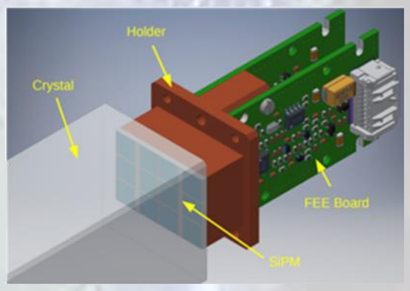
Back Plate Thermal Simulation


Back Plate under leak test

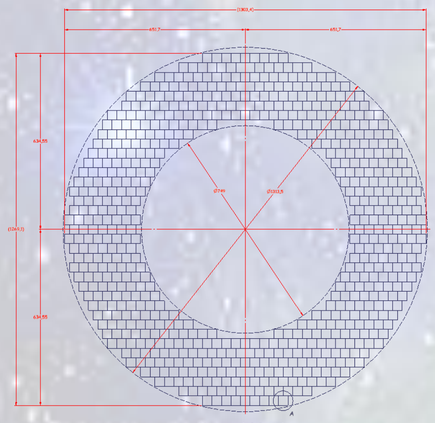
The eyes of the calorimeter

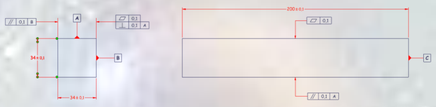


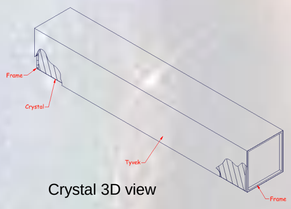




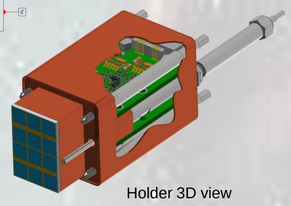
The 674 crystals are arranged in a staggered geometry.
Each crystal is wrapped in Tyvek foil (150 um) to improve the light reflection and separated with Tedlar foil (50 um) to minimize the cross-talk.

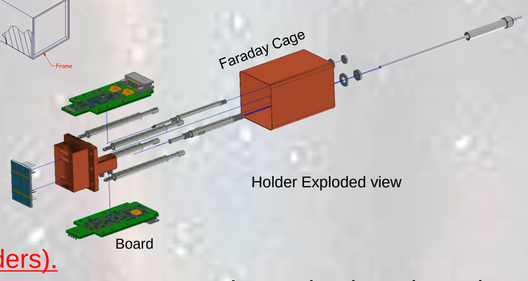

Crystal Matrix


Crystal Dimensions



Crystal 3D view

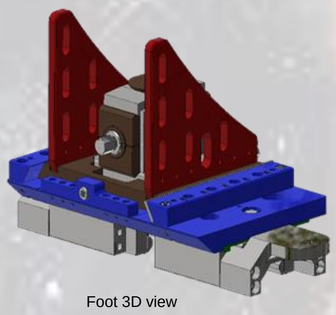

Holder 3D view

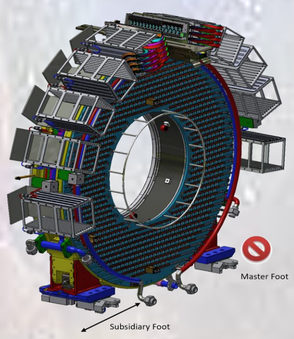


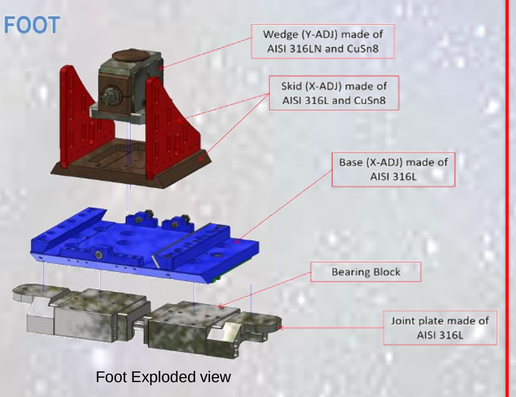
Holder Exploded view

Each dsik is equipped with 674 FEE modules (named holders).
The holders are composed by two SiPMs glued on a copper support, two electronics boards and a Faraday cage made of copper.
The holders are bolted to the Back Plate Cooling lines to remove the heat from the SiPM.

Feet


Foot 3D view





Foot Exploded view

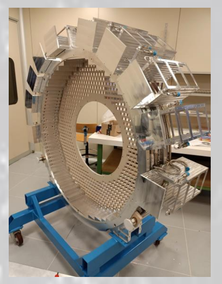
Each calorimeter disk is mounted on two feet that allow it to be aligned and slide on rails.
The Master Foot can slide only in the rail direction, whereas the Subsidiary Foot can slide also in the direction orthogonal to the rail. This degree of freedom allows to compensate any straightness error of the rails and also the displacement due to the thermal contraction/expansion of the Outer Structure. The component named “Wedge” allows to adjust, with the accuracy of 0.1 mm, the position of the calorimeter along the vertical direction.

Now in progress .....

- Design and integration of the components within the envelope ✓
- Outer ring construction ✓ → one disk is installed in FNAL clean room and one at LNF clean room for mechanics dry runs
- Back FEE plate construction ✓
- Front CF plate with source incorporated under assembly □
- Inner CF ring construction ✓
- 1340 holders have been assembled ✓
- Assembly at FNAL will start in June □


Calorimeter Feet ready to be installed


FEE fully assembled


OR, BP and Crates ass.bly