Summary

-Stato delle gare in corso.
-Fondi da sbloccare nel 2019
-Spese previste nel 2020.
-Aggiornamento sul raffreddamento del calorimetro.
-Aggiornamento sul cilindro interno di carbonio.

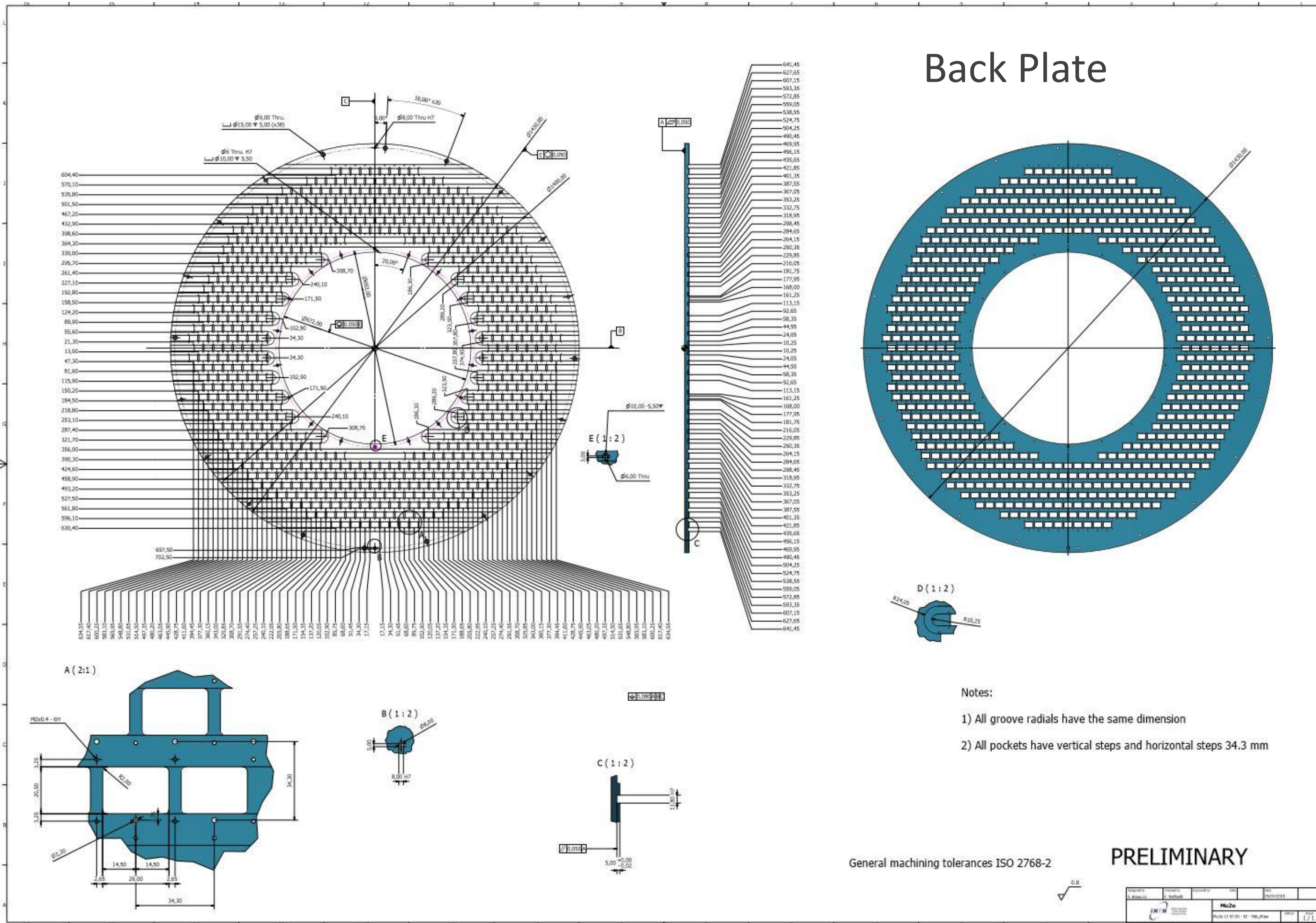
Stato delle gare

-Tre gare sono state completate;

- I due piani in peek di back end.
- linee di raffreddamento in rame compreso di collettori e l'integrazione di esse sul piano di back end.
- La gara dei crate e dei collettori

La situazione e' la seguente I risultati delle gare sono state approvate dalla giunta in Luglio. L'amministrazione centrale deve stipulare I contratti. Ho delegato Bruno Quarta per la verifica dei requisiti delle ditte il 26 Agosto 2019.
Sono previste 6 mesi per le consegne dal momento della stipula del contratto e dal rilascio dei disegni eseguivi.

Back Plate



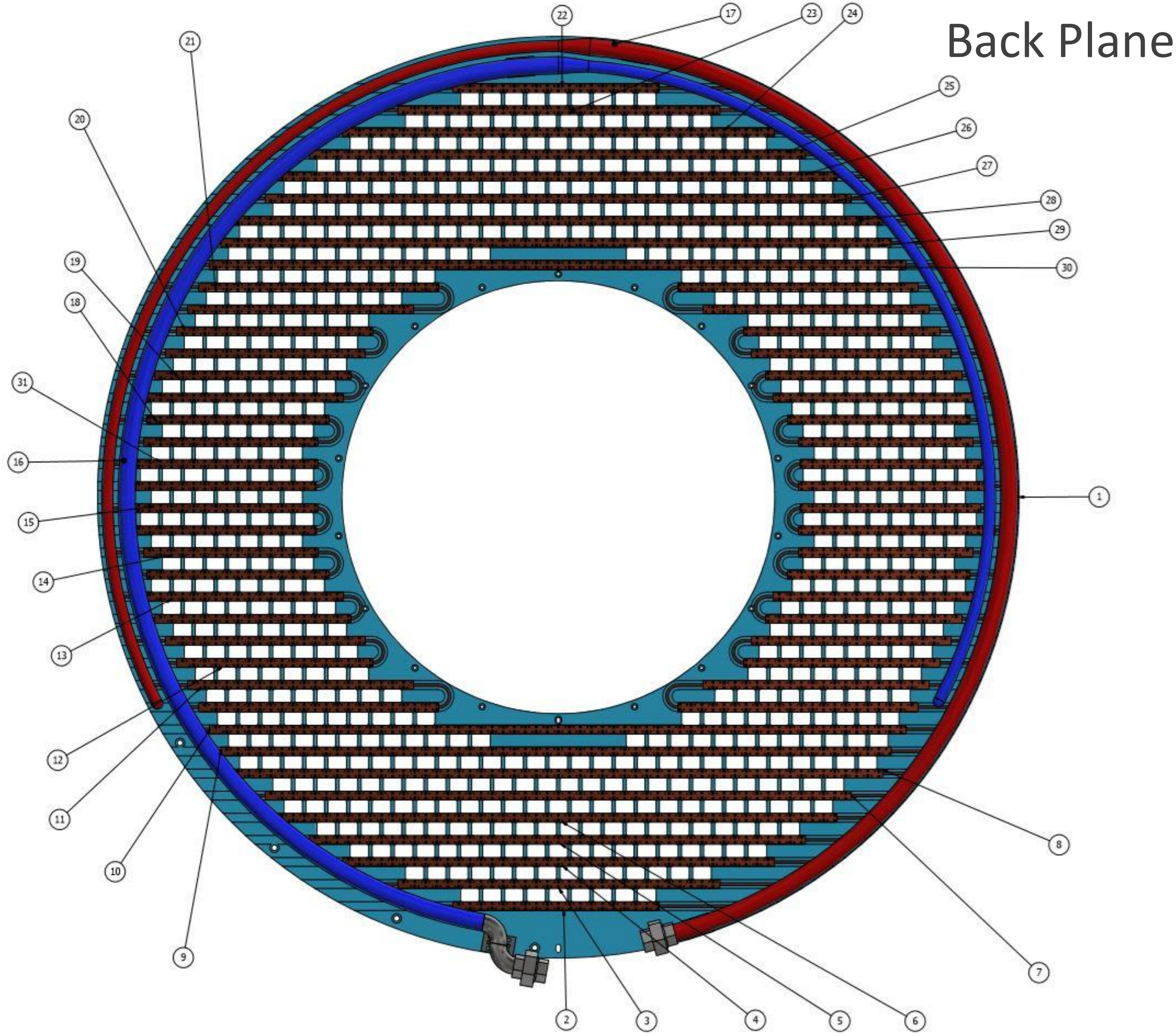
Notes:

1) All groove radials have the same dimension

2) All pockets have vertical steps and horizontal steps 34.3 mm

General machining tolerances ISO 2768-2

Back Plane



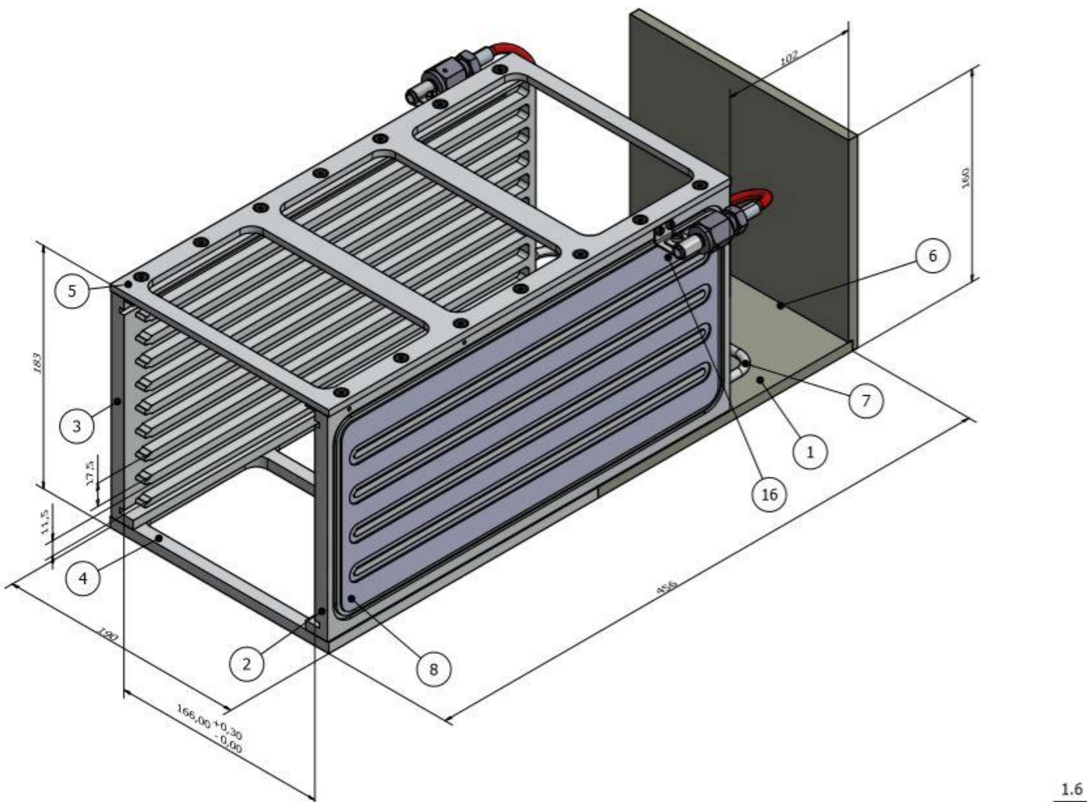
ELENCO PARTI			
ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	1	Mu2e 11 00 00 - 02 - Plate_PROVA_01	
2	1	Mu2e_MZ-0200 - Canale_01	
3	1	Mu2e 11 04 00 - 00 - Cooling_Channel_02	
4	1	Mu2e 11 05 00 - 00 - Cooling_Channel_03	
5	1	Mu2e 11 06 00 - 00 - Cooling_Channel_04	
6	1	Mu2e 11 07 00 - 00 - Cooling_Channel_05	
7	1	Mu2e 11 08 00 - 00 - Cooling_Channel_06	
8	1	Mu2e 11 09 00 - 00 - Cooling_Channel_07	
9	1	Mu2e 11 10 00 - 00 - Cooling_Channel_08	
10	1	Mu2e 11 11 00 - 00 - Cooling_Channel_09	
11	2	Mu2e 11 12 00 - 00 - Cooling_Channel_10	
12	2	Mu2e 11 13 00 - 00 - Cooling_Channel_11	
13	2	Mu2e 11 14 00 - 00 - Cooling_Channel_12	
14	2	Mu2e 11 15 00 - 00 - Cooling_Channel_13	
15	2	Mu2e 11 16 00 - 00 - Cooling_Channel_14	
16	1	Mu2e 11 01 00 - 00 - FEE_Manifold	
17	1	Mu2e 11 02 00 - 00 - FEE_Manifold	
18	2	Mu2e 11 15 00 - 00 - Cooling_Channel_13_MIR	
19	2	Mu2e 11 14 00 - 00 - Cooling_Channel_12_MIR	
20	2	Mu2e 11 13 00 - 00 - Cooling_Channel_11_MIR	
21	2	Mu2e 11 12 00 - 00 - Cooling_Channel_10_MIR	
22	1	Mu2e 11 03 00 - 00 - Cooling_Channel_01_MIR	
23	1	Mu2e 11 04 00 - 00 - Cooling_Channel_02_MIR	
24	1	Mu2e 11 05 00 - 00 - Cooling_Channel_03_MIR	
25	1	Mu2e 11 06 00 - 00 - Cooling_Channel_04_MIR	
26	1	Mu2e 11 07 00 - 00 - Cooling_Channel_05_MIR	
27	1	Mu2e 11 08 00 - 00 - Cooling_Channel_06_MIR	
28	1	Mu2e 11 09 00 - 00 - Cooling_Channel_07_MIR	
29	1	Mu2e 11 10 00 - 00 - Cooling_Channel_08_MIR	
30	1	Mu2e 11 11 00 - 00 - Cooling_Channel_09_MIR	
31	2	Mu2e 11 16 00 - 00 - Cooling_Channel_14_MIR	

Designed by F. Raffaelli	Checked by	Approved by	Date	Date 05/07/2018

Mu2e

Mu2e 11 00 00 - 00 - FEE_Cooling_Plate | Edition | Sheet 1 / 1

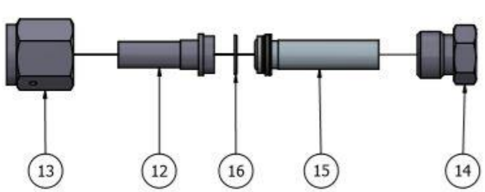
Scale (1:2)



ELENCO PARTI				
ITEM	QTY	PART NUMBER	MATERIAL	MASS
1	1	Pavimento	Aluminium 6061-T6	6,46 kg
2	1	Left_wall	Aluminum 5083-H111	1,66 kg
3	1	Right_wall	Aluminum 5083-H111	1,66 kg
4	1	Parte_sotto_Al	Aluminum 6061-T6	0,25 kg
5	1	Crate_Plate_connect_top_new	Aluminum 6061-T6	0,27 kg
6	1	Parete	Aluminun 6061-T6	4,60 kg
7	1	Pipe_collegamento_pareti_laterali_crate	Aluminum 6061	0,01 kg
8	2	Cover	Aluminum 6061	0,40 kg
11	2	Tube sustain 8	Aluminum 6061	0,00 kg
12	2	BN 640 1242490 hexagon self clinching nut M4_INOX A1	Stainless Steel, Austenitic	0,00 kg
13	2	ISO 1207 - M4 x 10	Stainless Steel, 440C	0,00 kg
14	2	ISO 1207 - M3 x 6	Stainless Steel, 440C	0,00 kg
15	2	Gland 6LV-4-VCR-3S-8MTB7-SwagelokCompany	Stainless Steel, Austenitic	0,01 kg
16	2	Femal nut SS-4-VCR-1-SwagelokCompany		0,03 kg
17	2	Male nut SS-4-VCR-4-SwagelokCompany	Stainless Steel, Austenitic	0,02 kg
18	2	ATCRBI-BW5010-AtlasUHV	Stainless Steel, Austenitic	0,02 kg
19	2	Metal Gasket SS-4-VCR-2-SwagelokCompany	Generico	0,00 kg
23	14	ISO 4762 - M4 x 6	Stainless Steel, 440C	0,00 kg
25	14	ISO 10642 - M4 x 8	Steel	0,00 kg
27	1	Crate_manifold_warm_MIR	Aluminum 6061	0,00 kg
28	1	Tube sustain 8_MIR	Aluminum 6061	0,00 kg
29	1	BN 640 1242490 hexagon self clinching nut M4_INOX A1_MIR	Stainless Steel, Austenitic	0,00 kg
30	1	ISO 1207 - M4 x 10_MIR	Stainless Steel, 440C	0,00 kg
31	2	ISO 1207 - M3 x 6_MIR	Stainless Steel, 440C	0,00 kg
32	1	Gland 6LV-4-VCR-3S-8MTB7-SwagelokCompany-07-06-2018_MIR	Stainless Steel, Austenitic	0,01 kg
33	1	Male nut SS-4-VCR-4-SwagelokCompany-07-06-2018_MIR	Stainless Steel, Austenitic	0,02 kg
34	1	ATCRBI-BW5010_MIR	Stainless Steel, Austenitic	0,02 kg
35	1	Metal Gasket SS-4-VCR-2-SwagelokCompany-07-06-2018_MIR	Generico	0,00 kg
36	1	Crate_manifold_warm_MIR_MIR	Aluminum 6061	0,00 kg

Nota: Per tutte le pareti interne 1.6

Swagelok VCR Assembly (1:1)



Preliminary

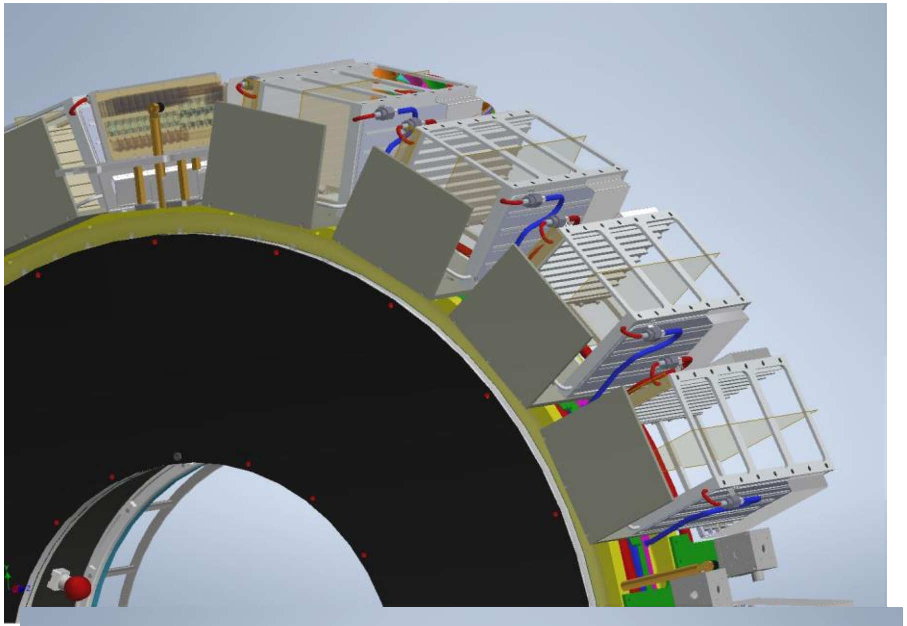
ISTITUTO NAZIONALE DI FISICA NUCLEARE
Sezione di Pisa

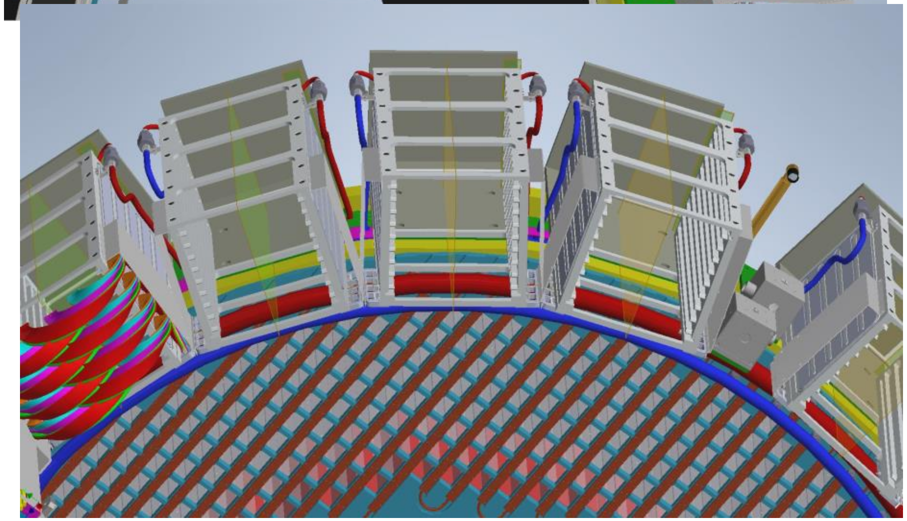
Checked by: F. Raffaelli
Date: 20/09/2018
Drawing N°: Crate_telaio_2.0_TOP
Sheet N°: 1 di 1
Size: A2

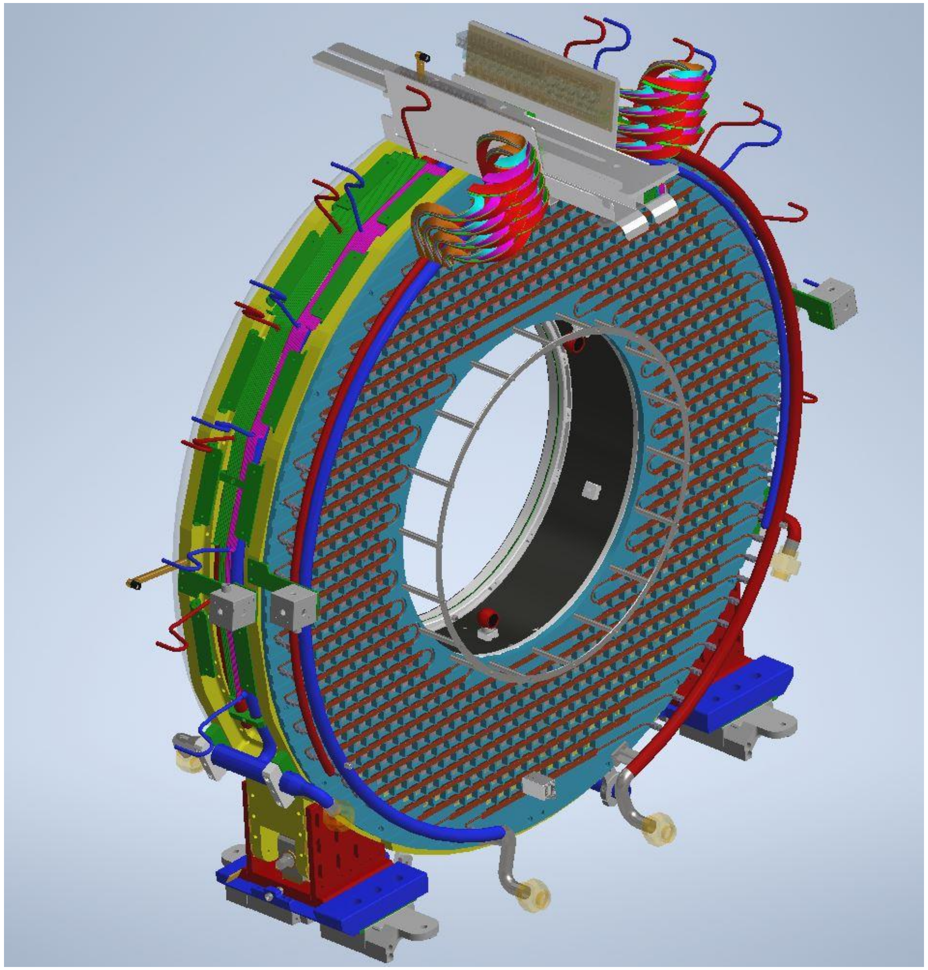
Fondi da sbloccare nel 2019

- Mock-up per la costruzione dei manifolds 4 Keuro
- Alette e support crate in G10 7 Keuro.
- Atrezzatura di trasporto del back plane 2 Keuro

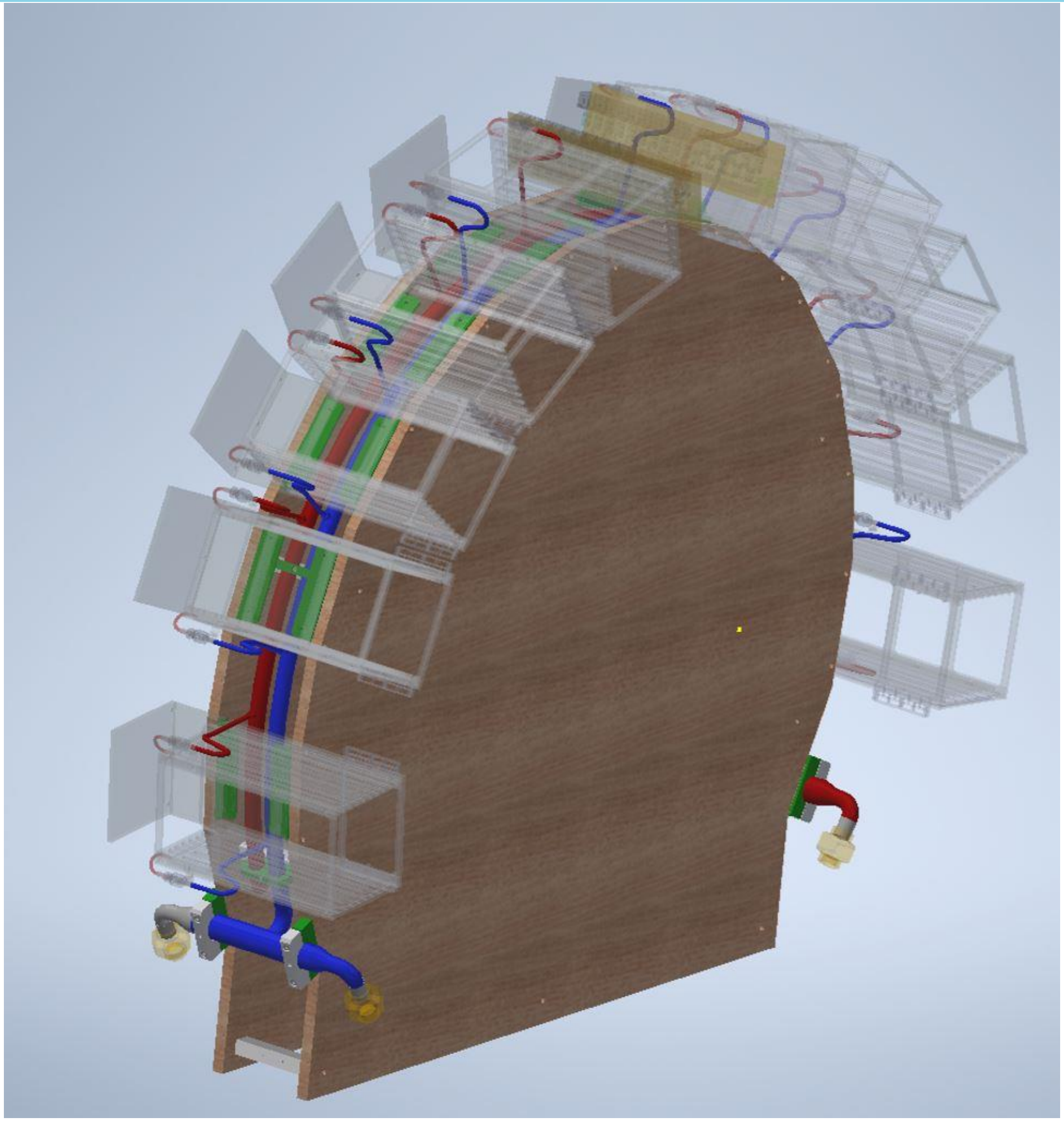
Mockup collettori e alette di supporto



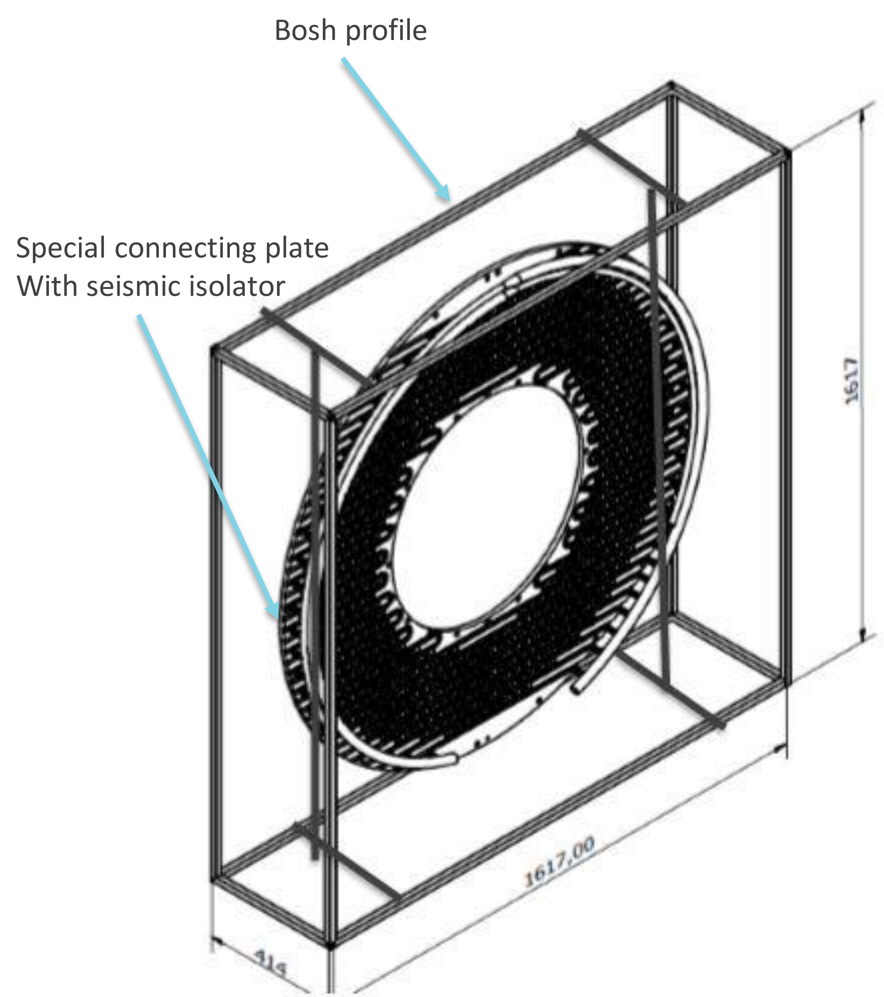




Mockup collettori e alette di supporto



Attrezzatura di trasporto del back plane.



Mass 100 kg
Dimensions need to be compatible with air transportation.
The external bag can be dismount leaving the back plane on his support with the internal bag. This will be removed at the time of installation on the ring.
Sufficient space need to store and perform the handling operations.

Spese previste 2020

1) Attrezzature leak test back plane e crates 15 Keuro.

1) Sistema di raffreddamento per test a Fermilab per il front end. (chiller pompa ausiliaria valvole di controllo e di isolamento, flow meter Filtri, sensori di pressione etc.) 15Keuro.

Aggiornamento sul raffreddamento del calorimetro.

- Mechanical Review at Fermilab 21-05-2019

The mu2e calorimeter group has proposed to improve the calorimeter SIPM reliability in the final period of operation, reducing the SIPM max operating temperature.

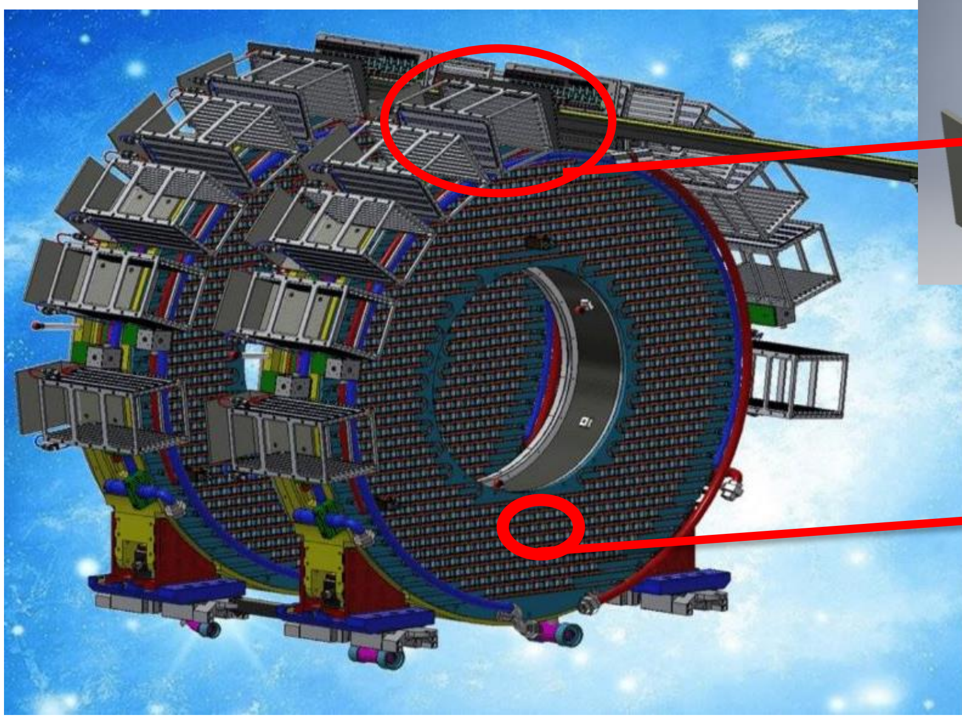
•The max allowed temperature has been set to 0-degree C for a long period of time. Now knowing better the SIPM behavior under radiation and considering the uncertainties on the effective dose absorbed, we consider prudent to have the possibility to operate the SIPM at -10 degree C.

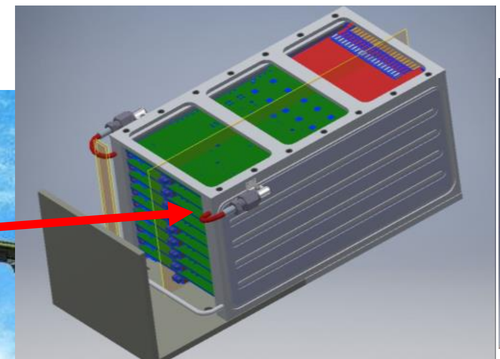
•The implications of lowering the temperature has been preliminary analyzed thermally and mechanically. The first thing to do, is to reconsidered the secondary fluid. Etc,Etc, Etc.

Thanks Fabrizio Raffaelli

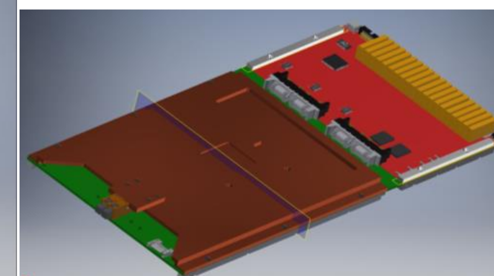
Cooling system overview

- The power dissipated are in two main areas:
- on the Back plate (SIPMs and pre-amplifiers)
- on the outside perimeter of the calorimeter ring (10 DAQ crates).

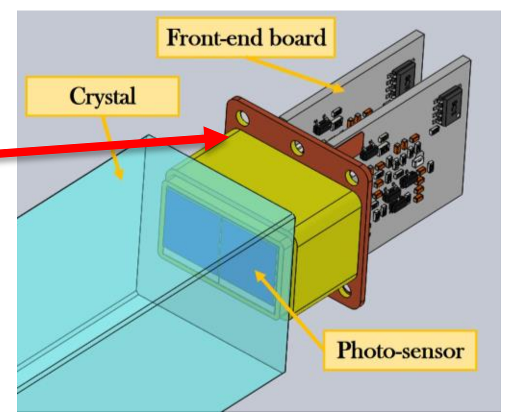




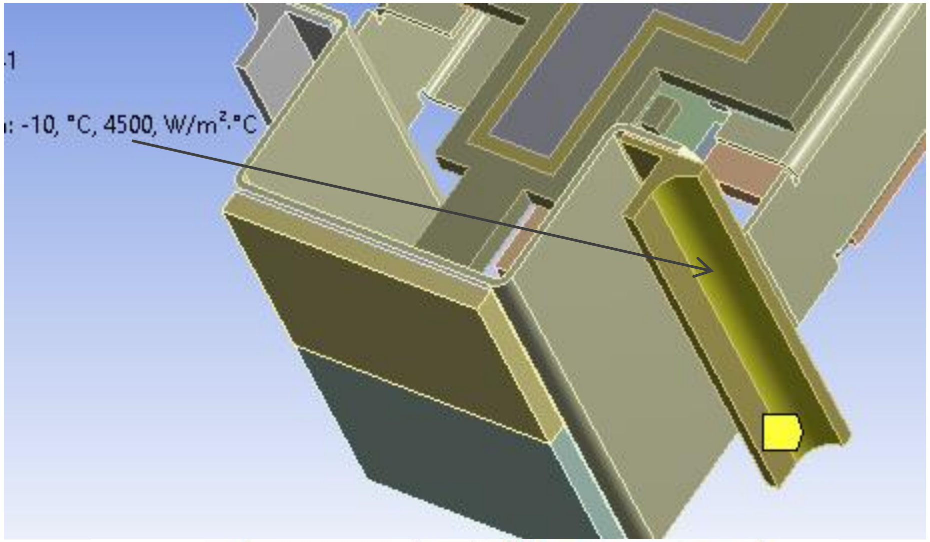
Dirac and mezzanine

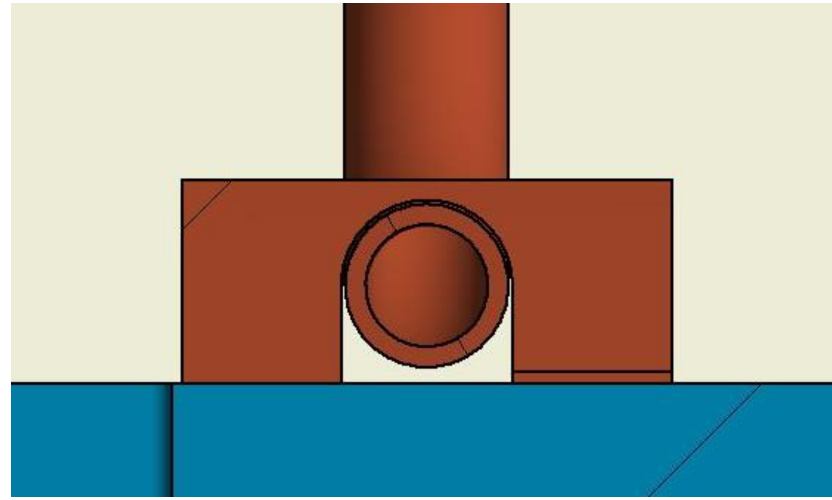


Front-end

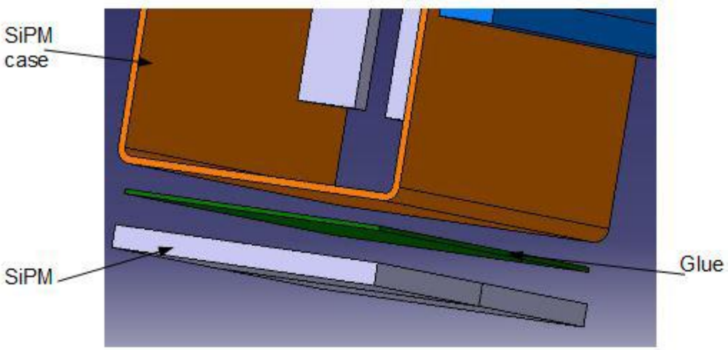


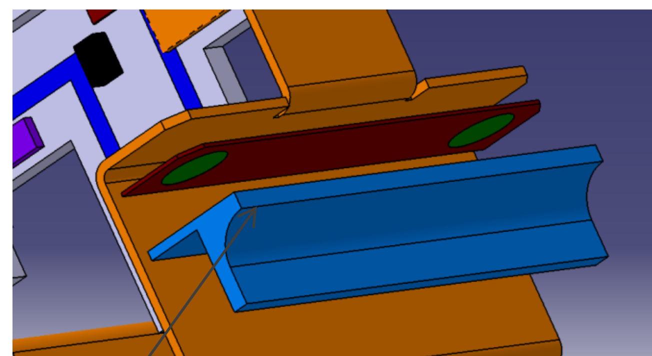
Mu2e SIPM FEM details





Realist model respected the adopted solution



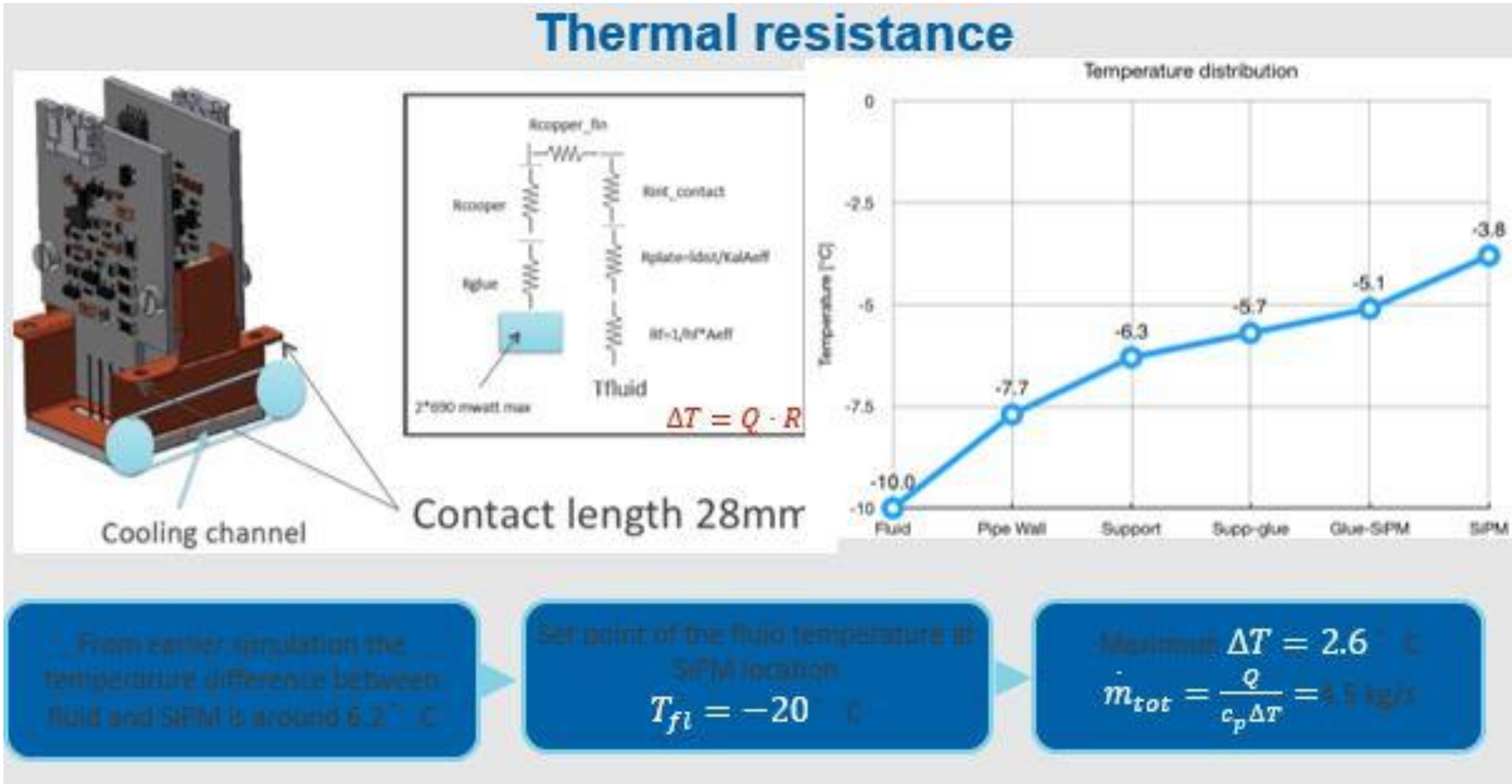


The pressure is assure by M2.5 property class 70 that can be preload at 250 Newton considering that the thread is on cooper. So an average pressure di 25 Mpa

Rint=0.01 m^2 k/kwatt

Gasket to simulate the thermal contact

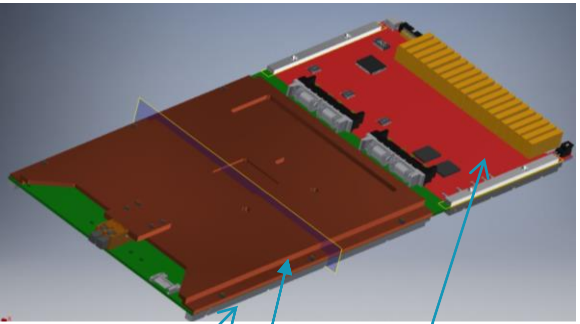
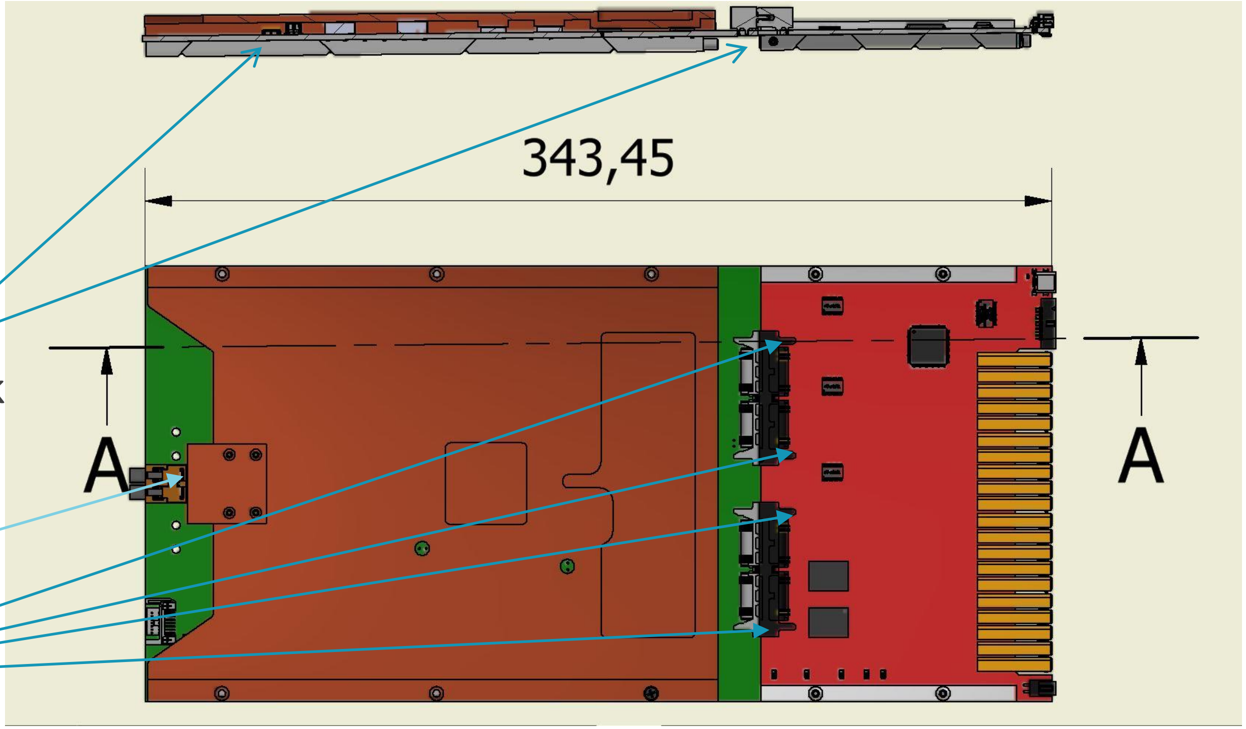
Aggiornamento sul raffreddamento del calorimetro.



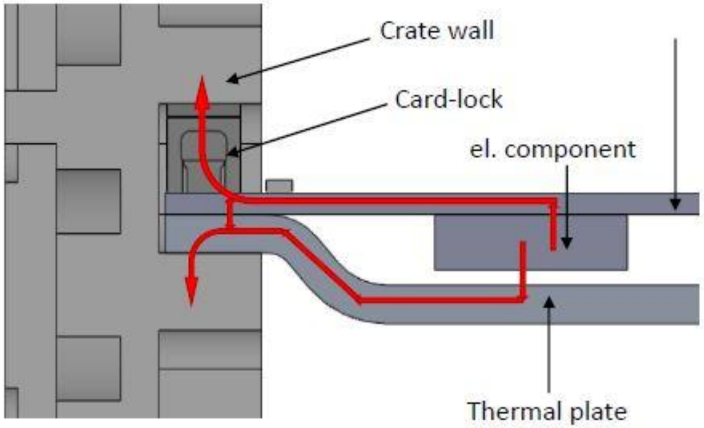
FEM analysis qualify with experimental data

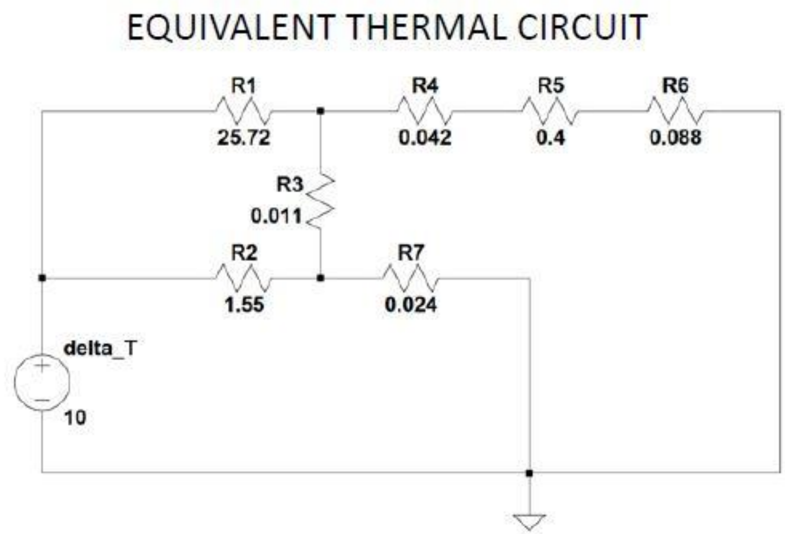
A compact crate with 9 board slots

- The crates house the electronic boards and provide their cooling.
- Mechanical issues:
  - The available space is quite limited.
  - The space for the insertion and extraction of the cards does not allow to have a single card.

Board cooling





R1: thermal resistance between the junction and the edge of thermal plate
R2: thermal resistance between the junction and the edge of the board
R3: thermal resistance due to the contact (Cu-Cu) between the board and the thermal plate
R4: thermal resistance due to the contact (Cu-Al) between the board and the card-lock
R5: Internal thermal resistance of the card-lock
R6: thermal resistance due to the contact (Al-Al) between the card-lock and the crate wall
R7: thermal resistance due to the contact (Cu-Al) between the thermal plate and the crate wall

Crate cooling.

The first prototype of DIRAC has been available. We were able to do a realist thermal test on it.

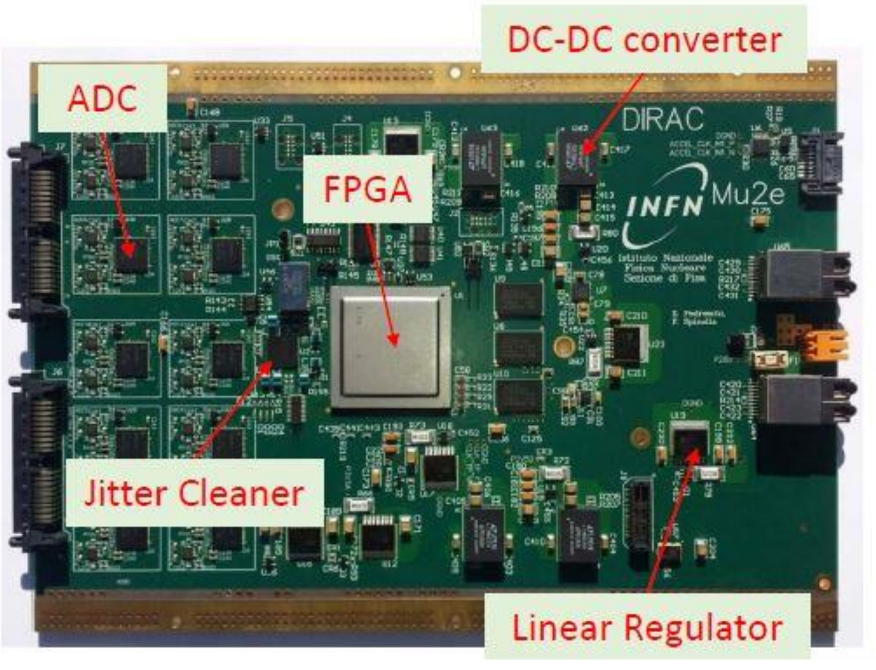
Componenti elettronici	Potenza dissipata [W]
➢ 10 ADC	5
➢ 1 FPGA	4
➢ 1 Jitter cleaner	0.8
➢ 4 DC-DC converters	7
➢ 6 Linear Regulator	20

The powers reported are the maximum reported on the components datasheet.

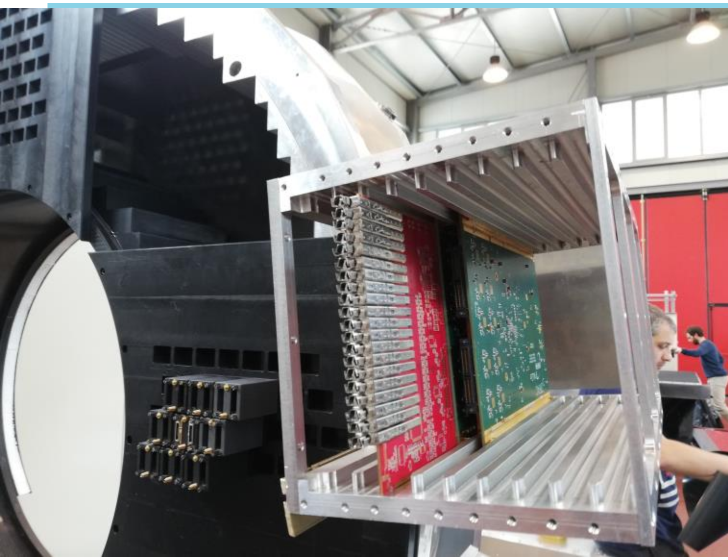
$$P_{diss}^{DIRAC} \approx 37W$$

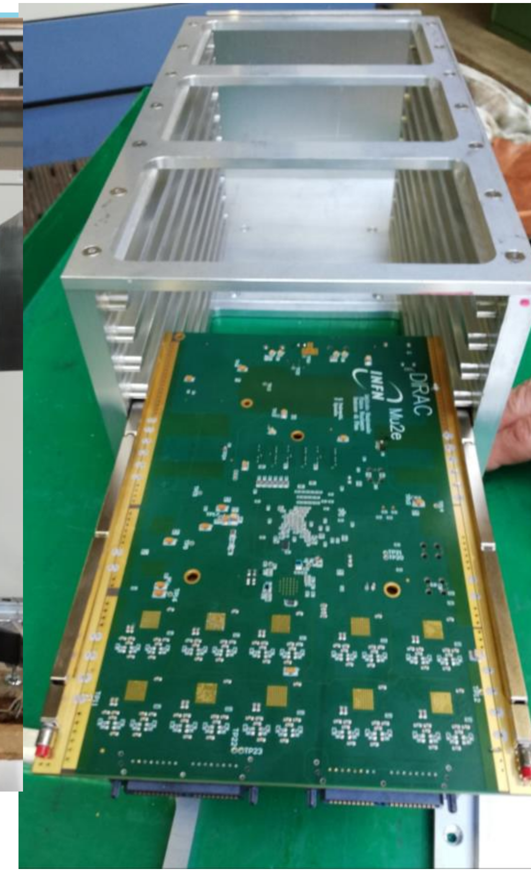
$$P_{diss}^{INTERF} \approx 10W$$

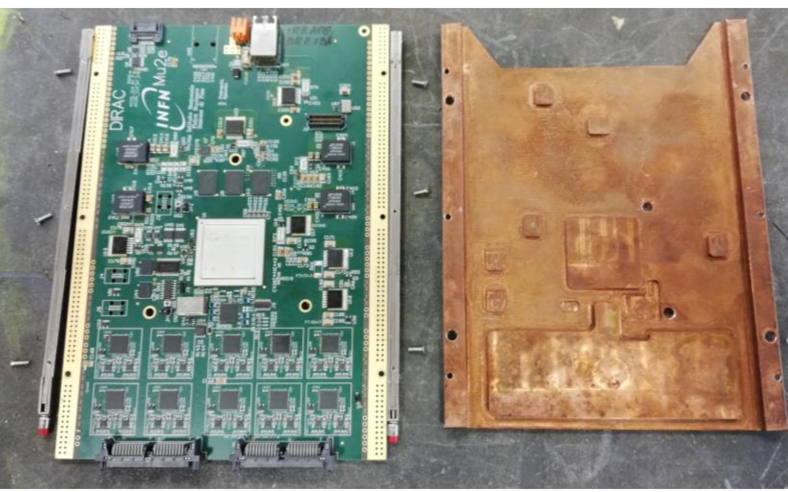
$$P_{diss}^{Crate} \approx 423\,W$$

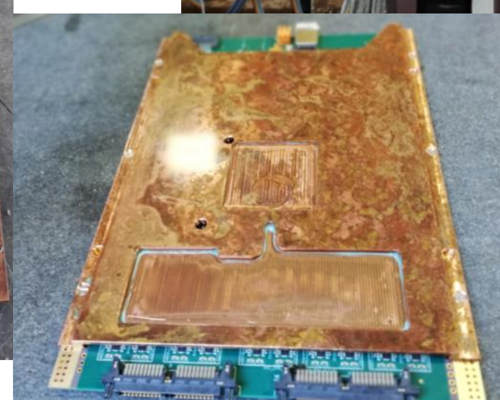


Dirac board assembly and test.



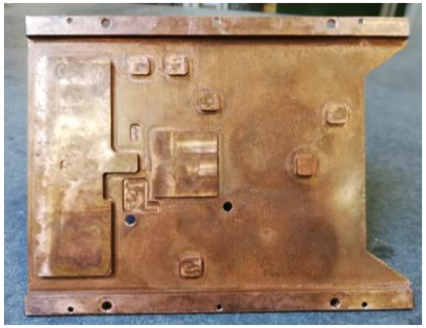




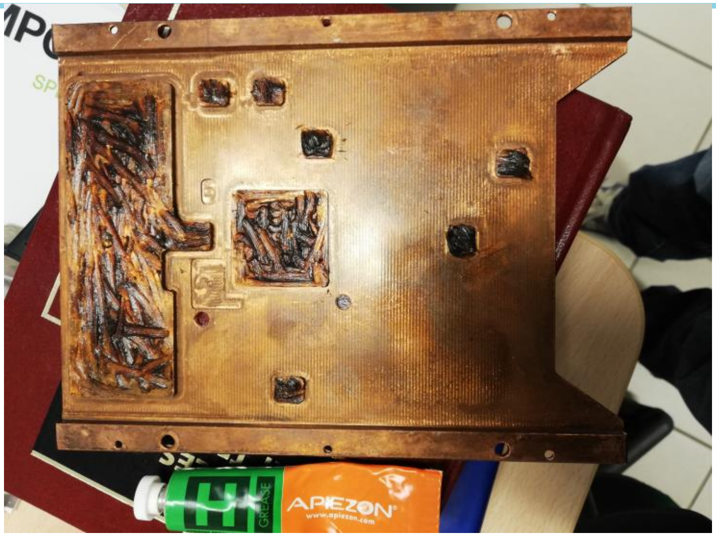


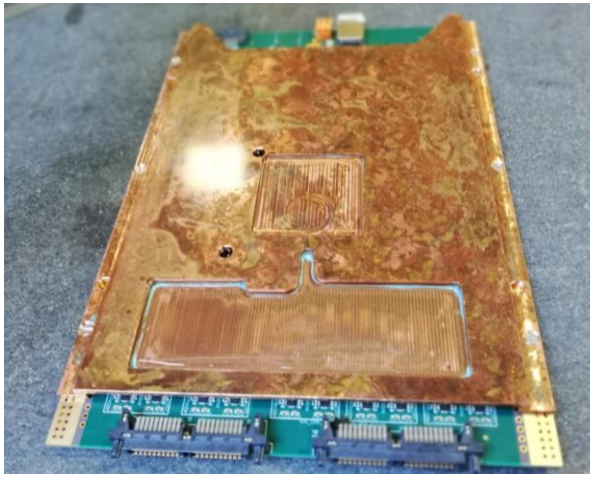
Crate design.

Copper Plate



We prototype three copper plate in our machine shop. We are testing under vacuum with different TIM materials.





Crate cooling test.

Temperatures test

Test sequence.

- Vacuum vessel sealed.
- Vacuum level Ok.
- Chiller start flowing.
- Equilibrium reached.
- Data are taken.

25 temperature point has been measured

Crate cooling test.

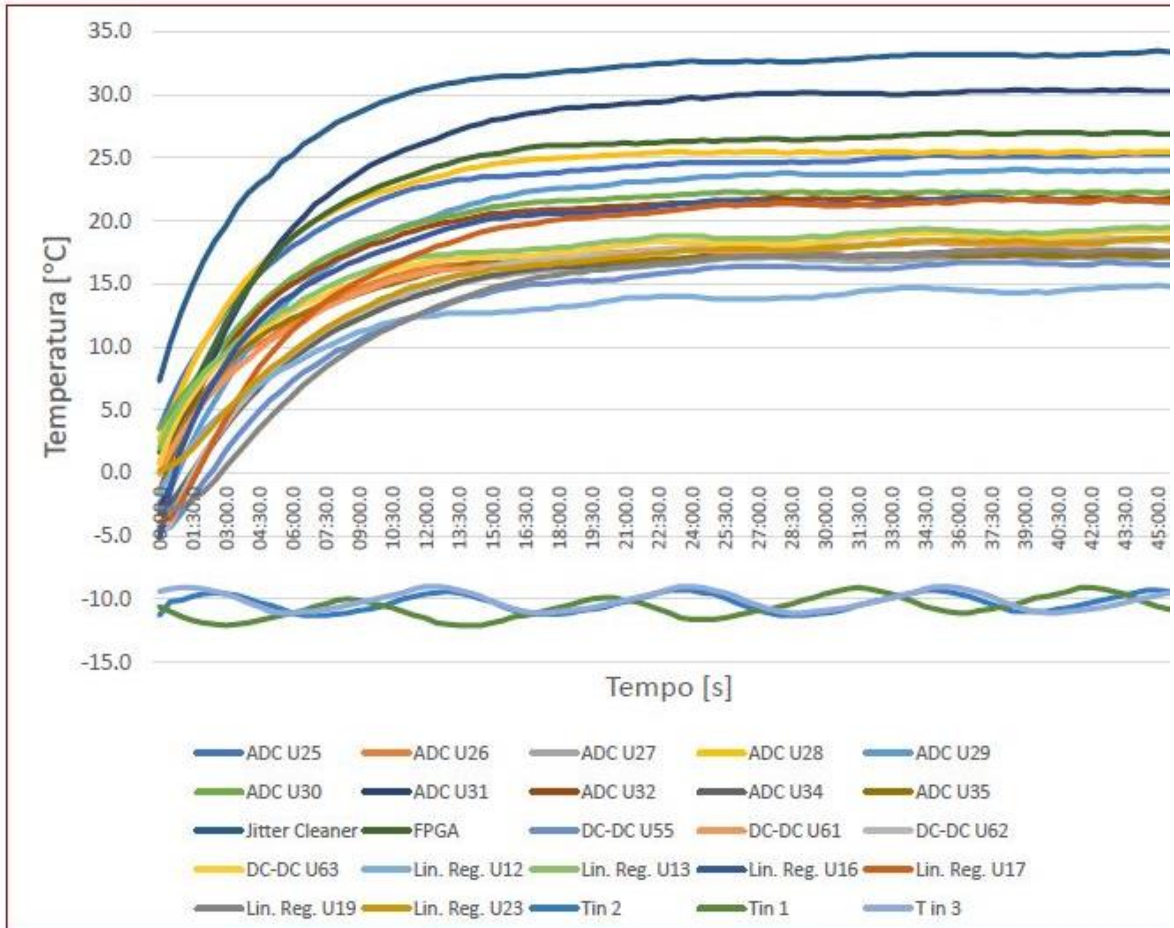
Temperature test

INFN Fermilab

UNIVERSITÀ DI PI

Results:

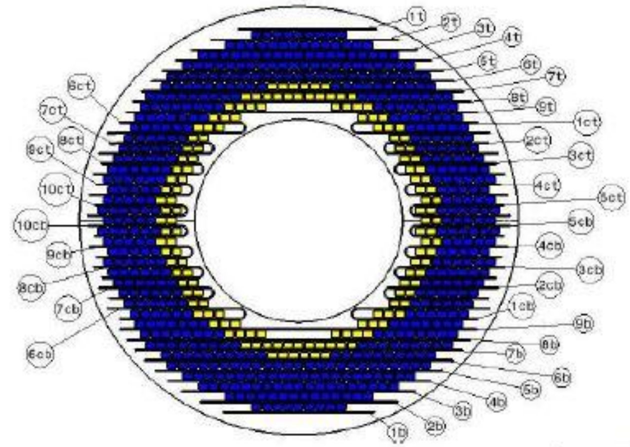
- Total measurement time 45 minutes
- State status reached in 20 minutes



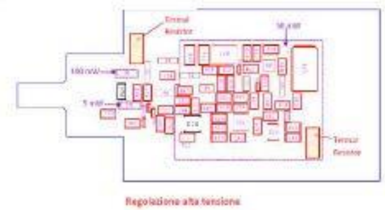
Summary of cooling.

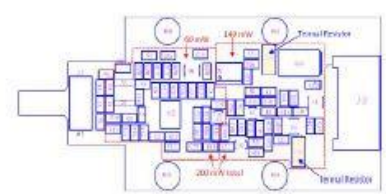
Heat to remove

Item	Contribute	Number	Total
Internal SiPMs (yellow)	0.69W for each SiPM	284 for each disk	196W for each disk
External SiPMs (blue)	0.23W for each SiPM	1064 for each disk	245W for each disk
FEE boards	0.355W for each board	1348 for each disk	479W for each disk
Digitizer	46.9W for each board	9 for each crate	422W for each crate
TOTAL for both disks			**10300W**



Exp. less





Item	Mass flow
Front end	1.1kg/s for one disk
Digitizer	0.8kg/s for one disk
Total for one disk	1.9kg/s
TOTAL for 2 disks	**3.8kg/s**

Aggiornamento sul raffreddamento del calorimetro.

Cooling fluid: perfluoro-hexane: C_6F_{14} as alternative to 35% glycol

Advantages

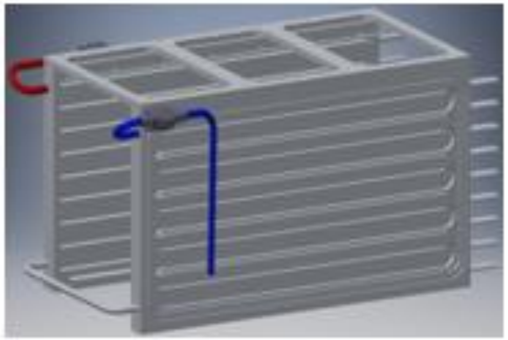
- Lower viscosity ($1.37 \cdot 10^{-3}$ Pa•s)
- Higher density (1792 kg/m^3)
- Evaporate immediately and cleanly
- Non toxic

Drawbacks

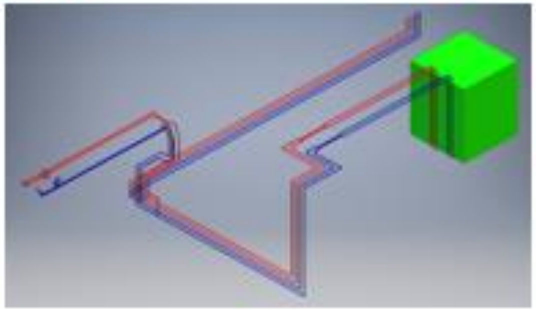
- Lower specific heat (982 J/kgK)
- Lower thermal conductivity ($6.62 \cdot 10^{-2}$ W/Km)
- Higher cost (65 $/kg)
- More probable leaks

Aggiornamento sul raffreddamento del calorimetro.

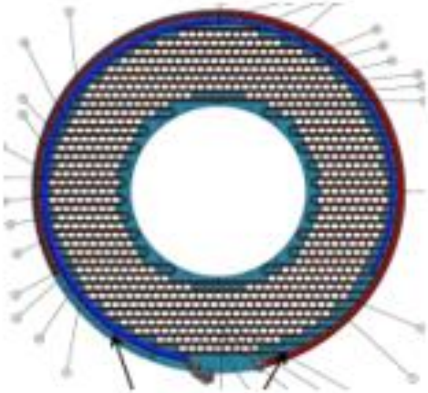
Hydraulic volumes



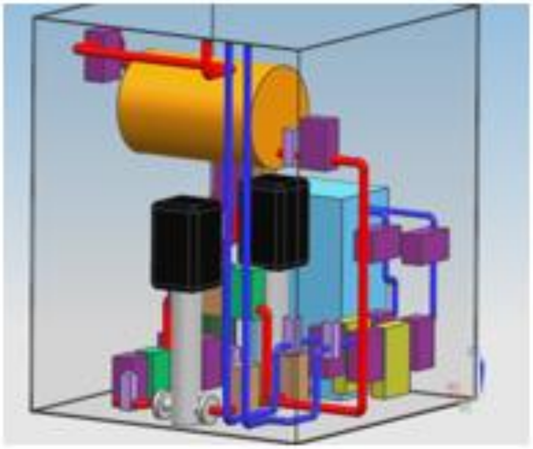
DAQ line:
$8 \cdot 10^{-3}\ m^3$



Routing lines:
$3.6 \cdot 10^{-2}\ m^3$



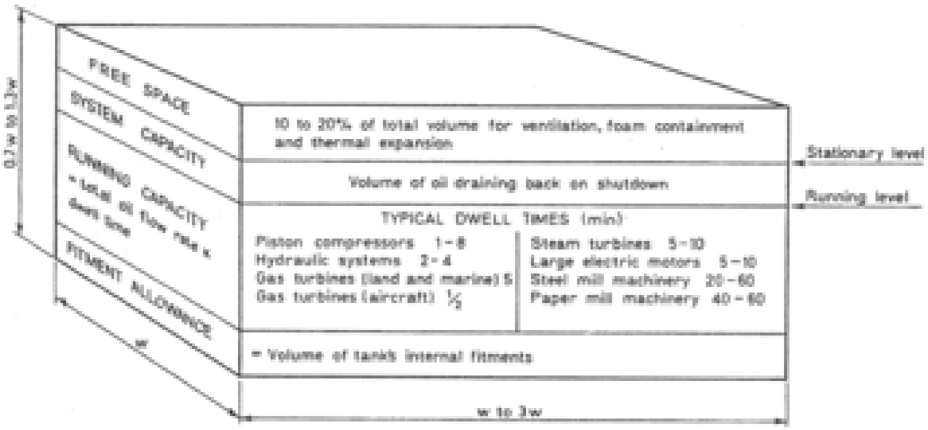
FEE line:
$3.27 \cdot 10^{-3}\ m^3$



Alcove:
$1.22 \cdot 10^{-1}\ m^3$

Aggiornamento sul raffreddamento del calorimetro.

Tank size

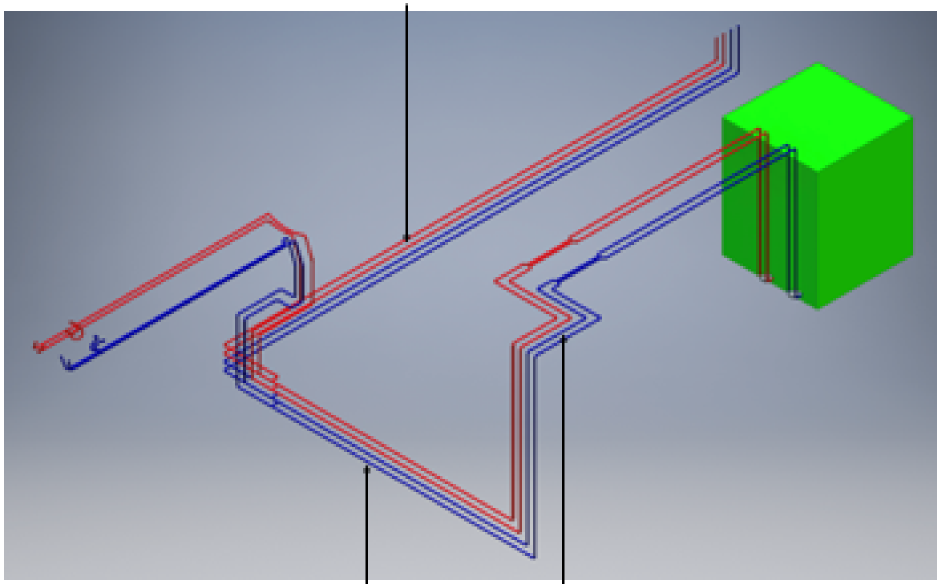


TANK VOLUME AND PROPORTIONS

DWELL TIME	30 sec
FLOW RATE	4.5 kg/s
RUNNING CAPACITY	0.075 m^3
SYSTEM CAPACITY	0.3 m^3
TANK VOLUME	0.413 m^3
MASS OF THE FLUID	740 kg
INITIAL FLUID COST	48.9 k$

Aggiornamento sul raffreddamento del calorimetro.

Routing lines pressure losses

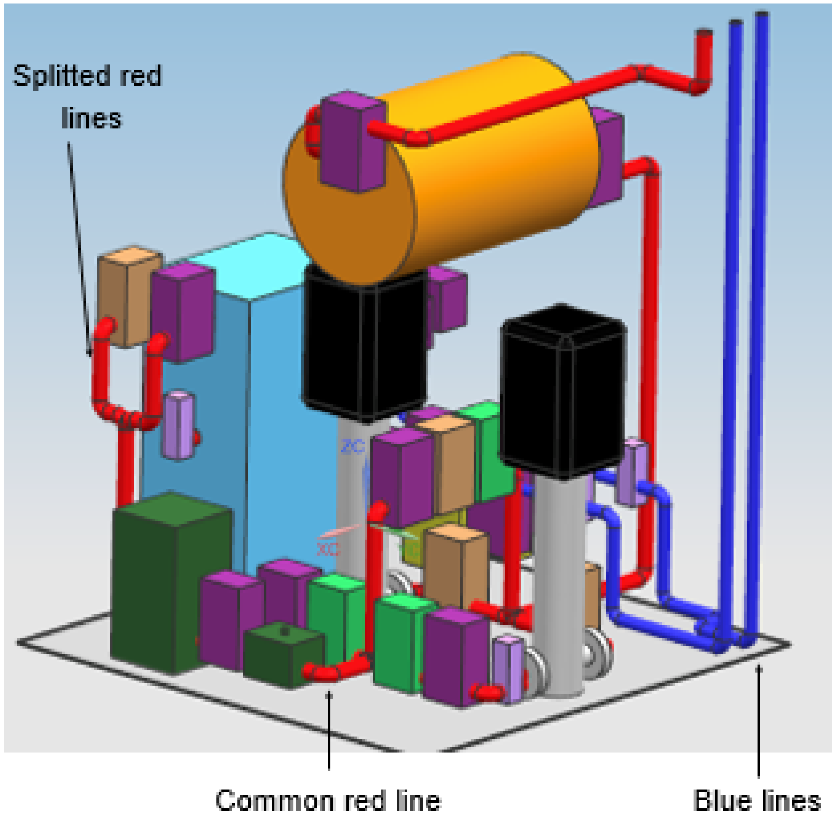


	Flow rate	Pressure loss
Inlet FEE line (1")	2.5 kg/s	1.56 bar
Inlet Digitizer line (1")	2 kg/s	0.98 bar
Outlet common line (1 1/2")	4.5 kg/s	0.34 bar
Total pressure loss		**1.9 bar**

The drawing needs to be updated.
At least the outlet common line

Aggiornamento sul raffreddamento del calorimetro.

Mechanical alcove pressure losses

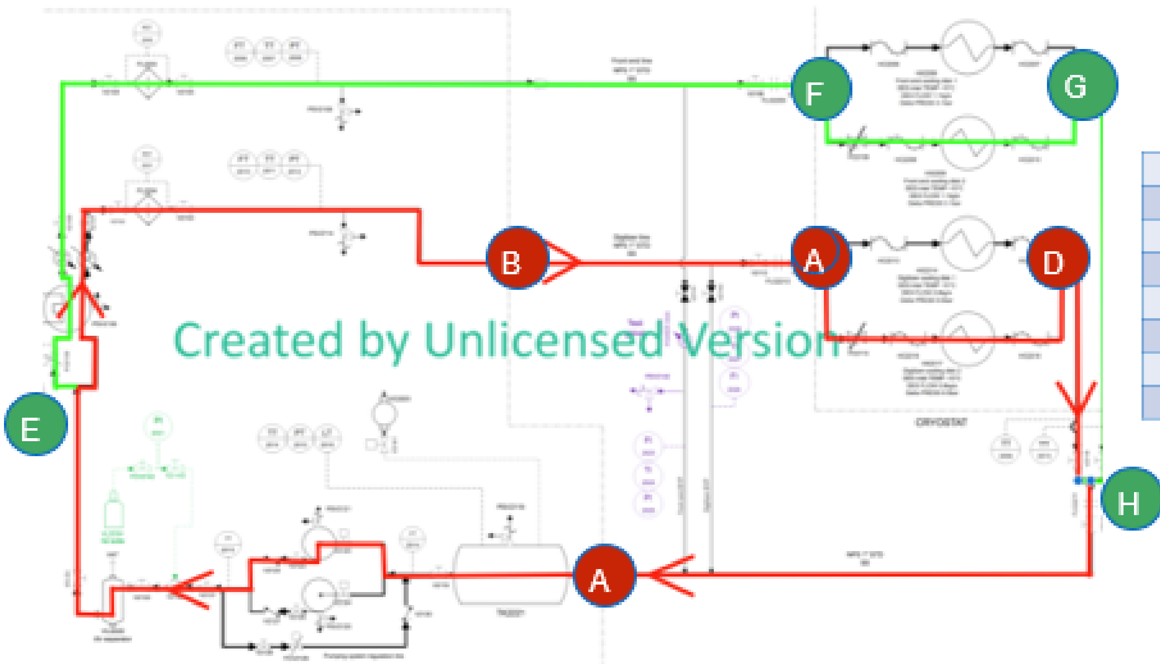


	Flow rate	Pressure loss
COMMON RED LINE (2")	4.5 kg/s	0.18 bar
SPLITTED RED LINES (1 1/2")	2 and 2.5 kg/s	0.01 bar
BLUE LINES (1 1/2")	2 and 2.5 kg/s	0.04 bar
Total pressure loss		0.23 bar

As soon as the lines get out of the chiller envelope, they match the routing pipes dimensions

Aggiornamento sul raffreddamento del calorimetro.

Pressure losses summary

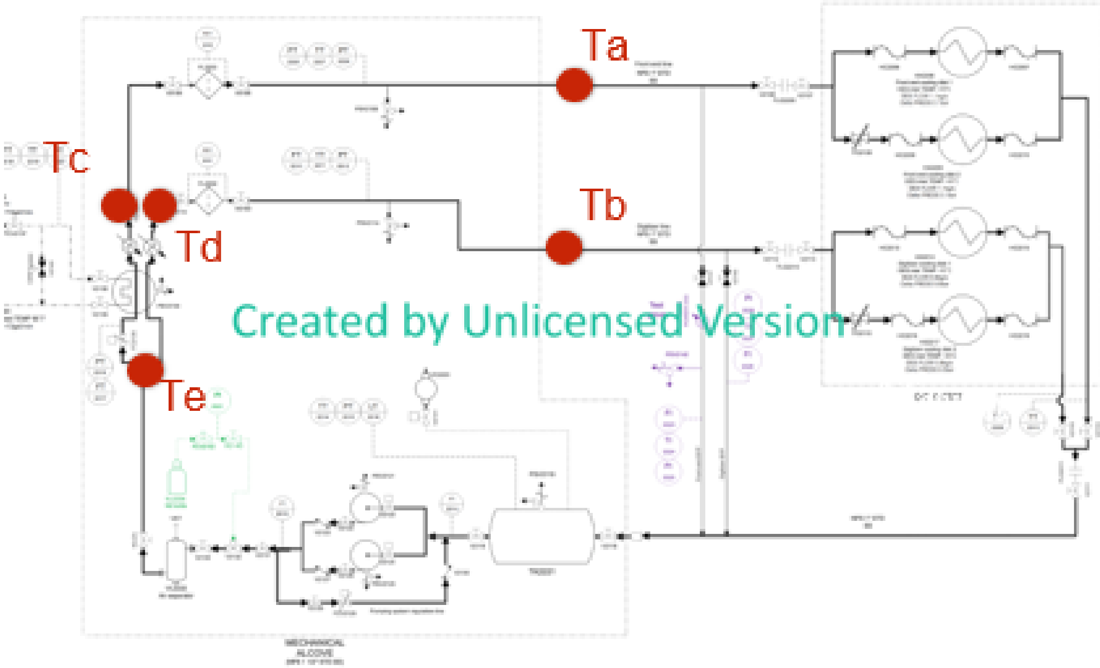


PATH	PRESSURE LOSS
MECHANICAL ALCOVE A-B	0.23 bar
ROUTING DIGITIZER B-C	0.99 bar
CRATES COOLING LINE C-D	4.45 bar (9.1*)
COMMON OUTLET LINE D-A	0.34 bar
VALVES & EQUIPMENT	1.04 bar
MARGIN OF SAFETY	10%
TOTAL	7.5 bar (13.8*)

Balancing pressure E-B-C-D & E-F-G-H: 3.07 bar

Aggiornamento sul raffreddamento del calorimetro.

Fluid temperatures

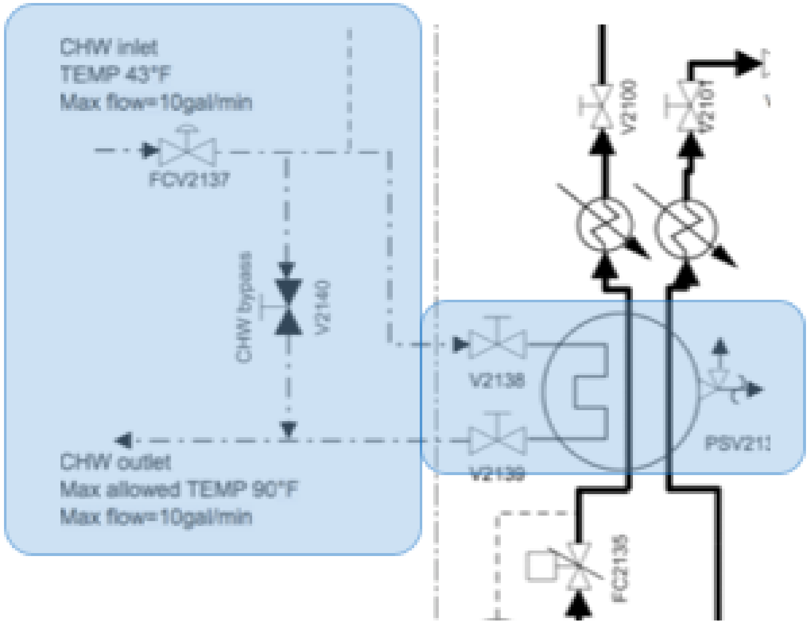


LOCATION	TEMPERATURE
Ta	-20.9 °C
Tb	-21.1 °C
Tc	-21 °C
Td	-21.2 °C
Averaged Tc/Td	-21.1 °C
Te	-18.5 °C
DeltaT chiller:	2.6 °C

The chiller must provide fluid at -21.1 °C of 4.5 kg/s perfluorohexane

Aggiornamento sul raffreddamento del calorimetro.

Chiller requirements



- Chemically compatible with perfluorohexane
- 2 inlet and 2 outlet ports
- One channel crossed by 2 kg/s, and the other by 2.5 kg/s
- T entrance -21.1 °C, and outlet T -18.5 °C
- Able to absorb 10.8 kW
- Water cooled (preferably)
- Able to withstand a fluid pressure of 9 bar

Aggiornamento sul raffreddamento del calorimetro.

Open problems:

1) Max power available 25 Kwatt. Power needs to remove 10.8 Kwatt. Considering 2 Kwatt for pumping. We have 12 Kwatt that are marginal for the chiller efficiency and for the temperature control.

May be we need to have a very efficient chiller (more expensive)

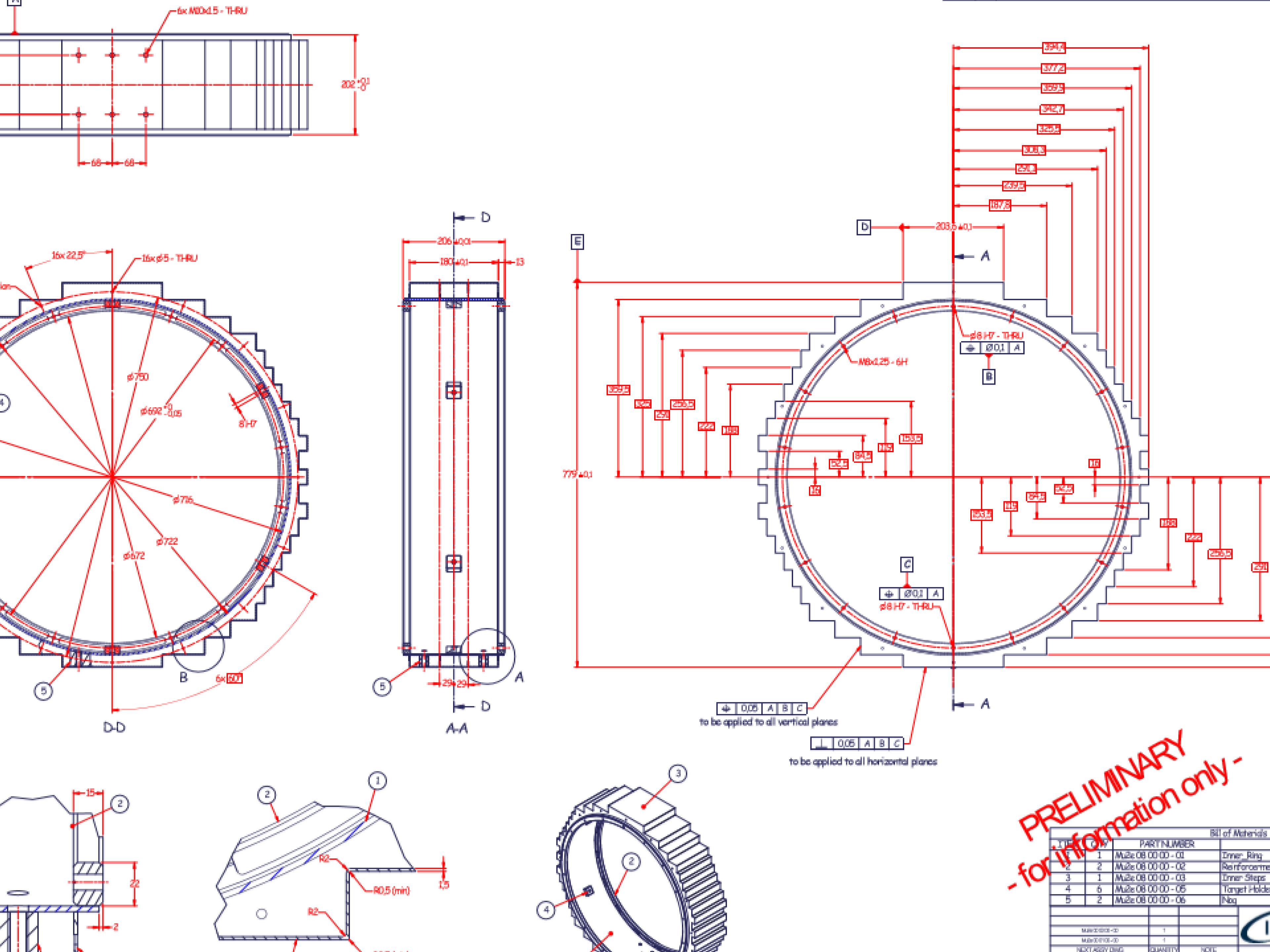
We need to have to line at different temperature -26 degree C and -10 degree C.

2) Calorimeter temperatures control:

Equilibrium temperatures it is very difficult to estimate with a good level of confidence. All cold part are thermally isolate for the calorimeter structure and from crystals, but small thermal flow are unavoidable. (like the cold SIPM toward the crystal). On the other end cables and outer surface are warm and irradiated toward the calorimeter. In this situation we need to have an active temperature control system.

Aggiornamento sul cilindro interno di carbonio.

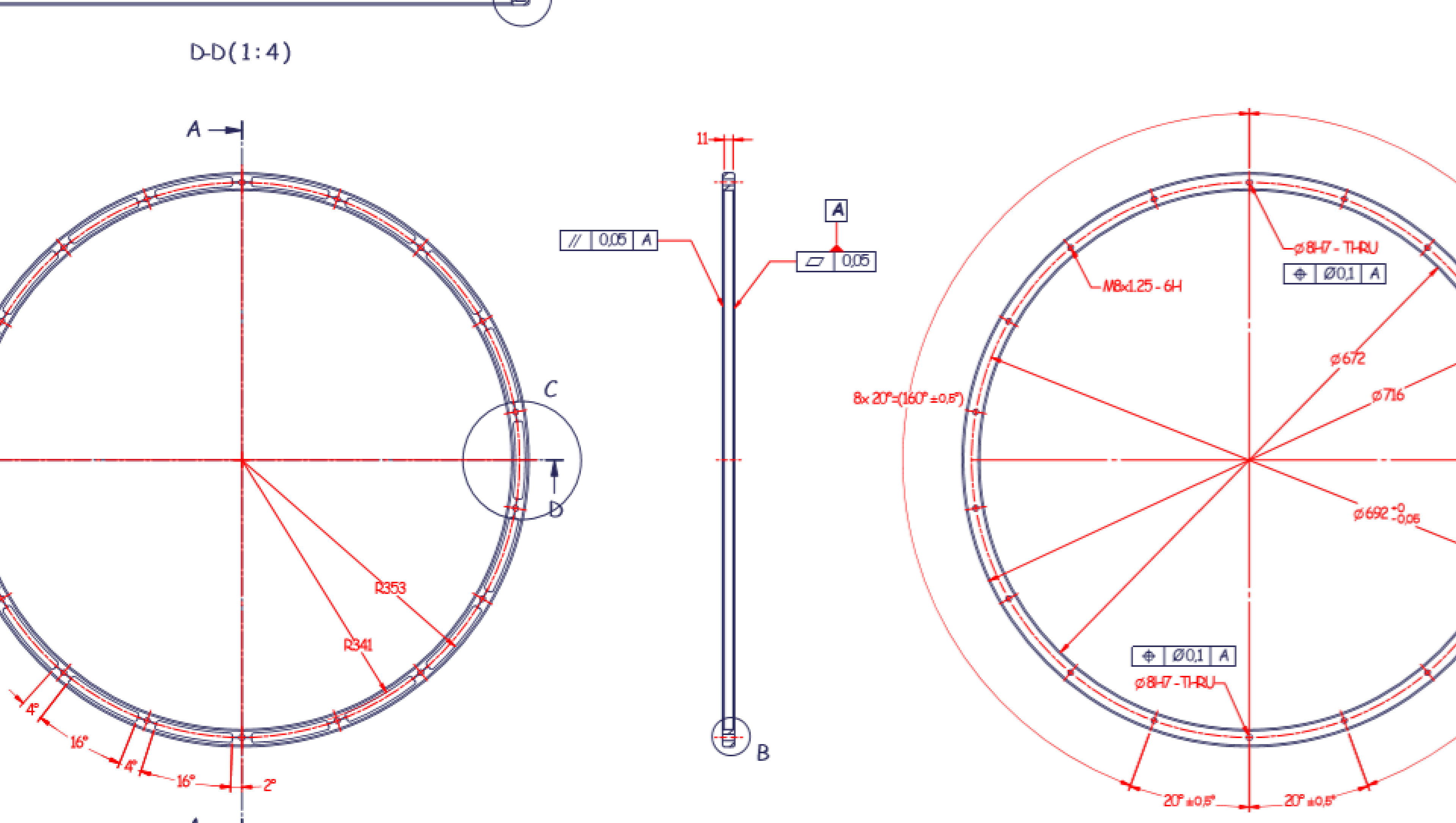
Base solution: end rings aluminum CF inner cylinder, aluminum open cell foam, CF steps.
During the mechanical review was pointed on the problem to cut or machine the Aluminum foam without close the cell and contaminated the material. So we are searching a solution full carbon with no aluminum foam.
The company that has to manufacturing the carbon fiber component is CETMA at Brindisi.
He has the carbon fiber pre-preg in house one mold to make the inner tube, It is placing the order for the two ends rings. They need to produced the mold for the steps and the assembly gluing tooling. A preliminary manufacturing and control steps has been made by us and revised by Cetma.

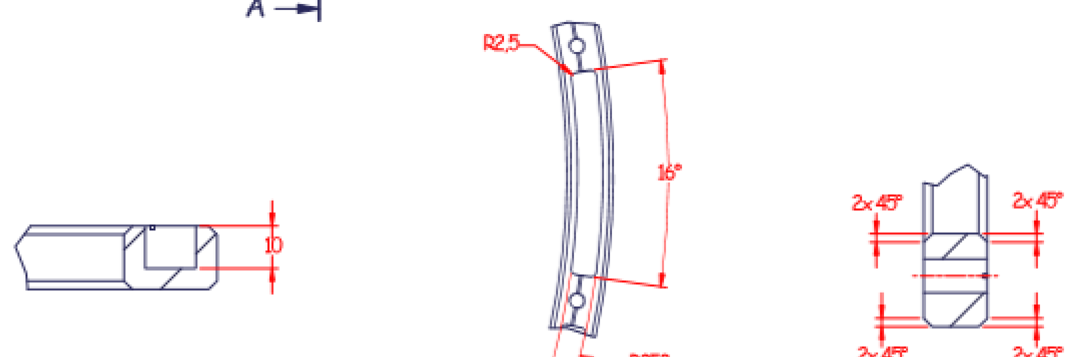


Bill of Materials

ITEM	QTY	PART NUMBER	
1	1	Mu2e 08 00 00 - 01	Inner_Ring
2	2	Mu2e 08 00 00 - 02	Reinforceme
3	1	Mu2e 08 00 00 - 03	Inner Steps
4	6	Mu2e 08 00 00 - 05	Target Holde
5	2	Mu2e 08 00 00 - 06	Nog

NEXT ASSY DWG	QUANTITY	NOTE
Mu2e 08 00 00 - 00	1	
Mu2e 08 00 00 - 00	1	





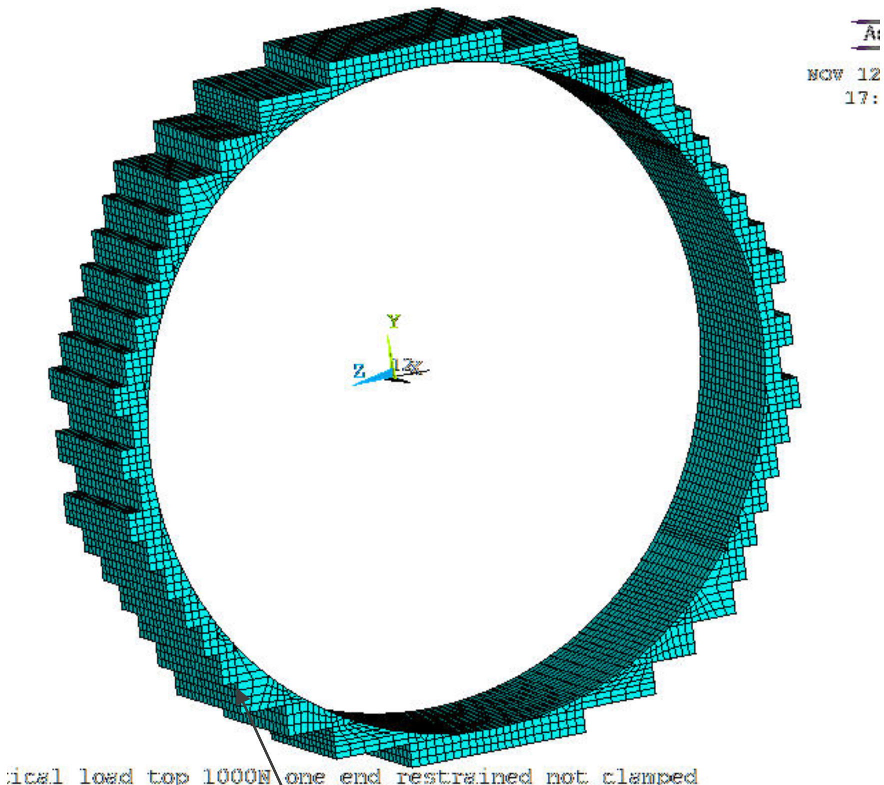
- Part to be free of burrs and shar
- All material to be clean, degreas
- Any change must be authorized
- If in doubt, ask

PRELIMINARY
information only

ASSY DWG	QUANTITY	NOTE

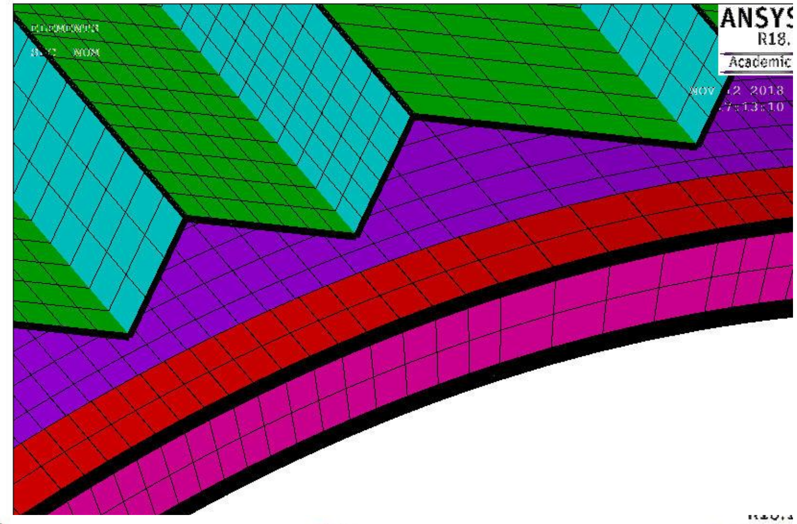
INFN

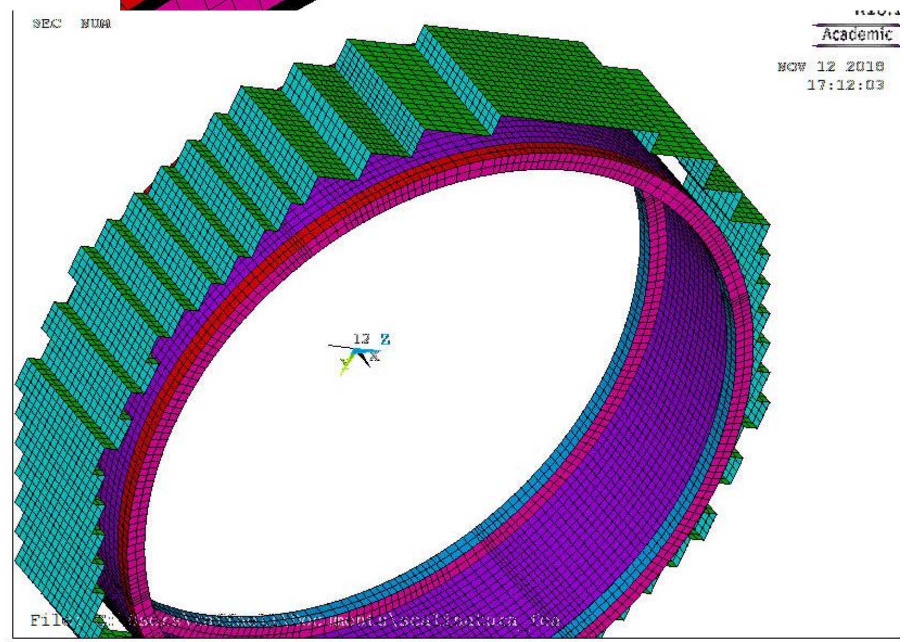
Model with CF steps and Aluminum foam



EX	1E+008	GXY	1.99E+008
EY	1E+008	GYZ	1.99E+008
EZ	1E+008	GXZ	1.99E+008

Unit SI (Pa)





Aluminum open cell Foam properties

Physical Characteristics of Duocel® Aluminum Foam* (8% Nominal Density 6101-T6)

Compression Strength	367 psi	(2.53 MPa)
Tensile Strength*	180 psi	(1.24 MPa)
Shear Strength*	190 psi	(1.31 MPa)
Modulus of Elasticity (Compression)*	15×10^3 psi	(103.08 MPa)
Modulus of Elasticity (Tension)*	14.6×10^3 psi	(101.84 MPa)
Shear Modulus	2.9×10^4 psi	(199.95 MPa)
Vickers Pyramid Number	35 HV	
Specific Heat	.214 $^{\text{BTU/lb-°F}}$	(.895 $^{\text{J/g-C}}$)
Bulk Thermal Conductivity	3.4 $^{\text{BTU/ft-hr-F}}$	(5.8 $^{\text{W/m-C}}$)
Coefficient of Thermal Expansion (0-100°C)	13.1×10^{-6} $^{\text{in/in--F}}$	(23.58×10^{-6} $^{\text{m/m--C}}$)
Bulk Resistivity	2.84×10^{-5} ohm - in	(7.2×10^{-5} ohm - cm)
Melting Point	1220°F	(660°C)

Aluminum Foam Thermal conductivity
Kfoam=167*0.08*0.33=4.49 W/m C

Ctotal = Csolid ligaments + Cgas + Cgas convection + Cradiant

Where

Csolid ligaments =the conductivity of the three-dimensional array of solid ligaments or struts that form the foam structure. This term is also often referred to as the "bulk thermal conductivity" of the foam. In most applications, particularly for metal foams used as heat exchangers, this is the quantitatively largest and most thermally dominant of the four components and has the following simplified equation form:

Csolid ligaments = Csolid × relative density × .33

Where

Csolid ligaments = direct thermal conductivity or bulk conductivity of the ligament array

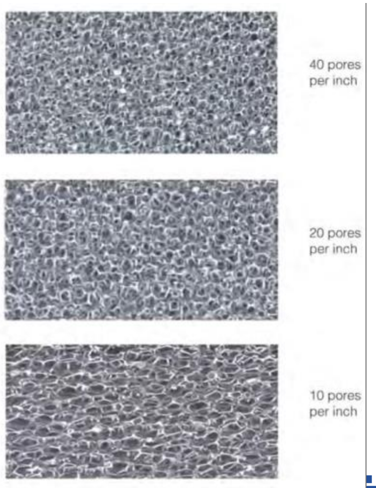
Csolid = conductivity of the solid material of the struts

Relative Density = % relative density in decimal form, i.e. 10% = .1

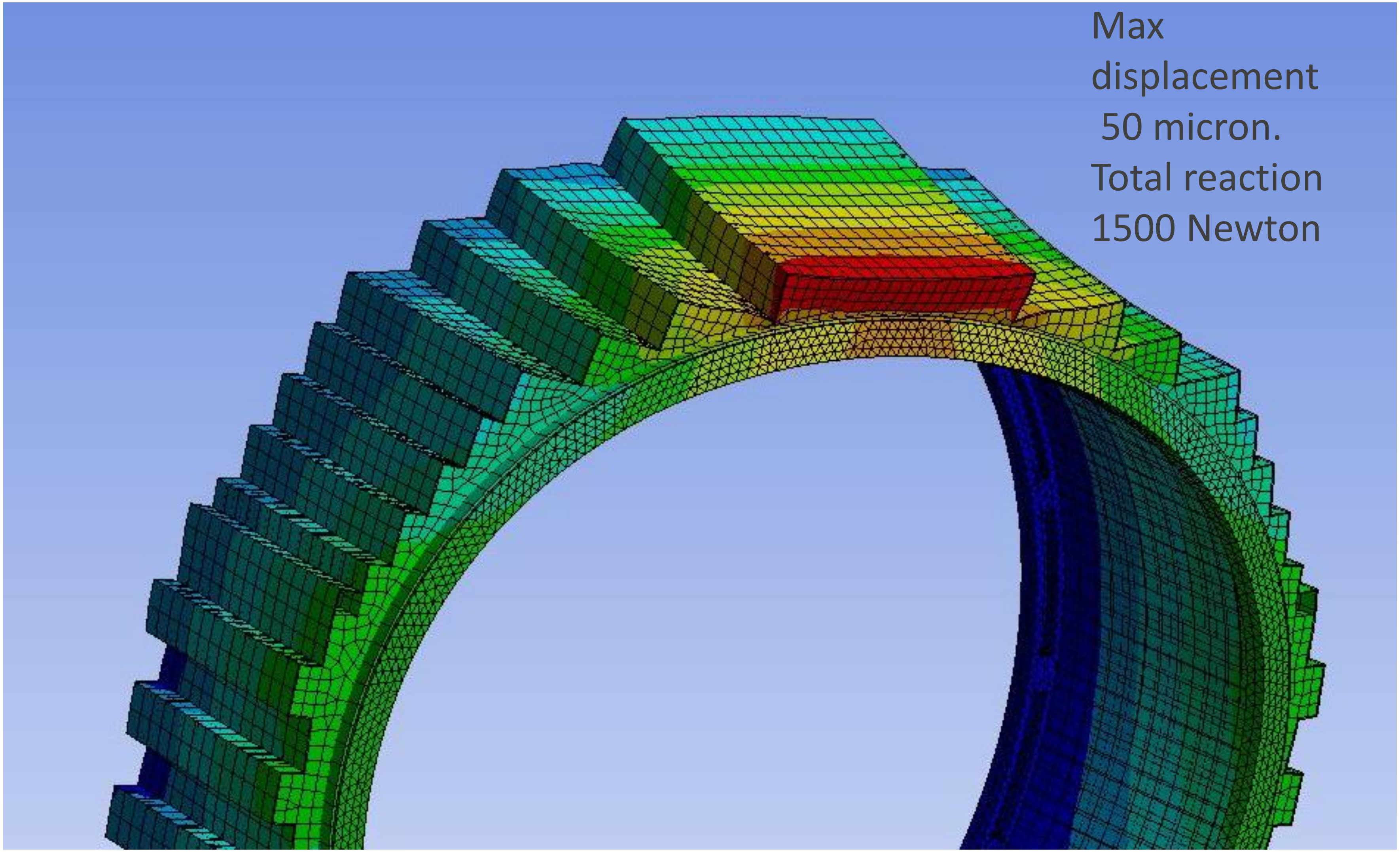
.33 = coefficient representing the foam structure geometric or "tortuosity" factor.

It should be noted that the .33 coefficient is derived both from conductivity tests and conceptual analysis wherein the foam can be analogized to a three-dimensional orthogonal pin fin array. In this case is it obvious that one third of the pins or pin mass are oriented in each of the orthogonal x, y, and z directions.

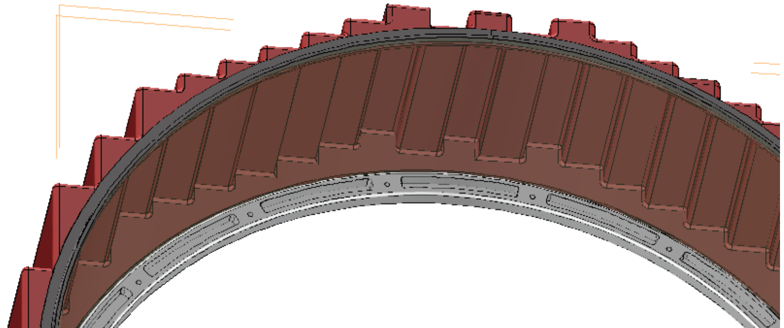
It should also be noted that this equation is somewhat simplified, but is reasonably accurate, slightly conservative, and is more easily understood from a conceptual standpoint than some of the empirical equations that have been developed from various tests.

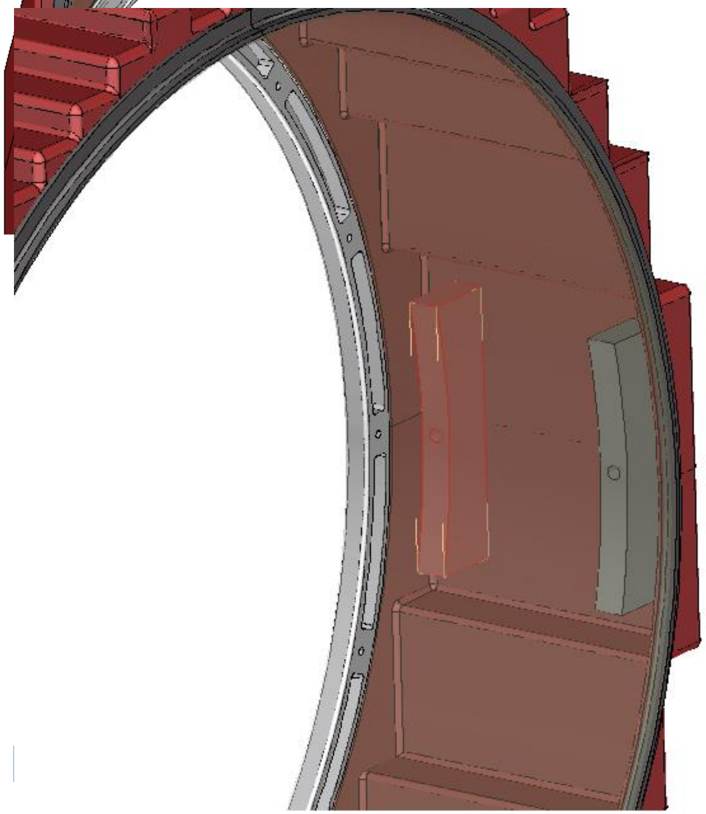


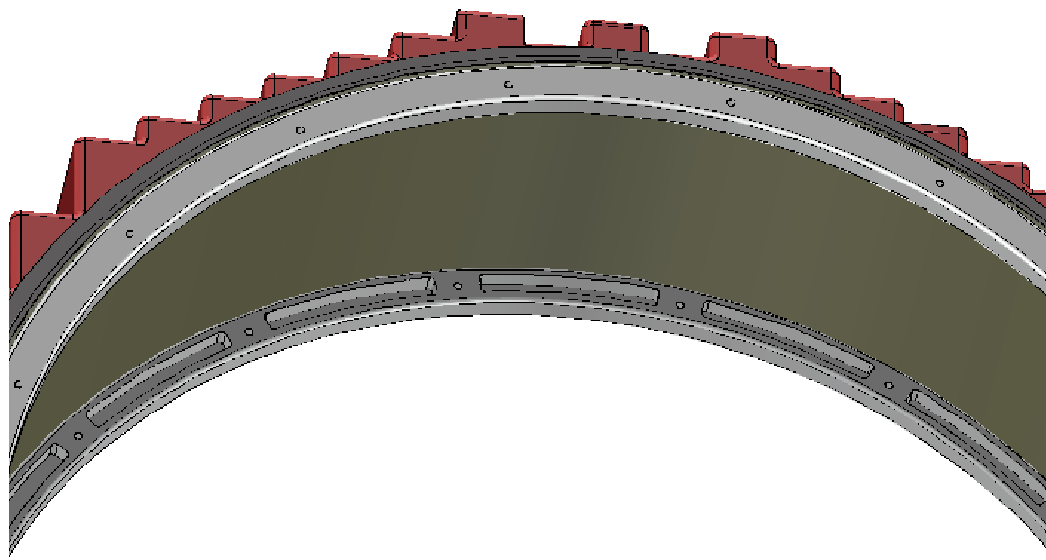
Aluminum ends ring



Aluminum ends ring full carbon







Conclusion

- Cooling:
- we need to have some iterations with the integration Fermilab group to verify that the new cooling specification are implemented on their own environmental.
- We need to qualify components during the production to verify their cooling performances.
- Carbon fiber components:
- We are not yet converging on mechanical solution for the inner cylinder that it is accepted by Cetma for the moment.