

# Il diavolo è nei dettagli...



...ma a volte gli diamo una mano

## Thermodynamics

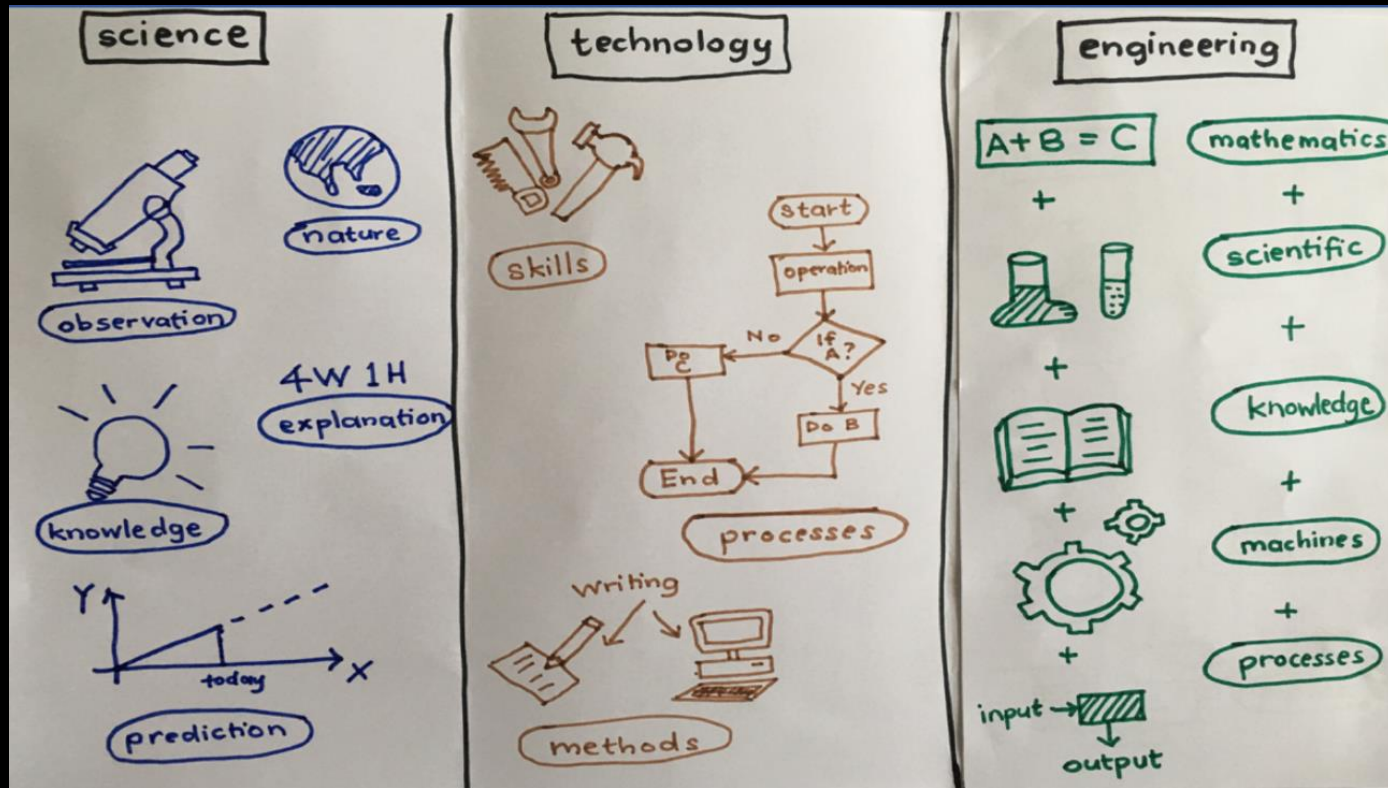
- There are four laws
- The third of them, the *Second Law*, was recognized first
- The first, the *Zeroth Law*, was formulated last
- The *First Law* was second
- The *Third Law* might not even be a law in the same sense as the others

# 7 Gennaio 1610

“Ho visto cose mai viste prima” G. Galilei



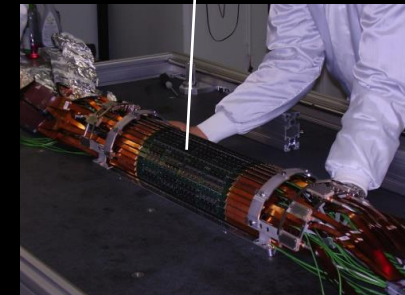
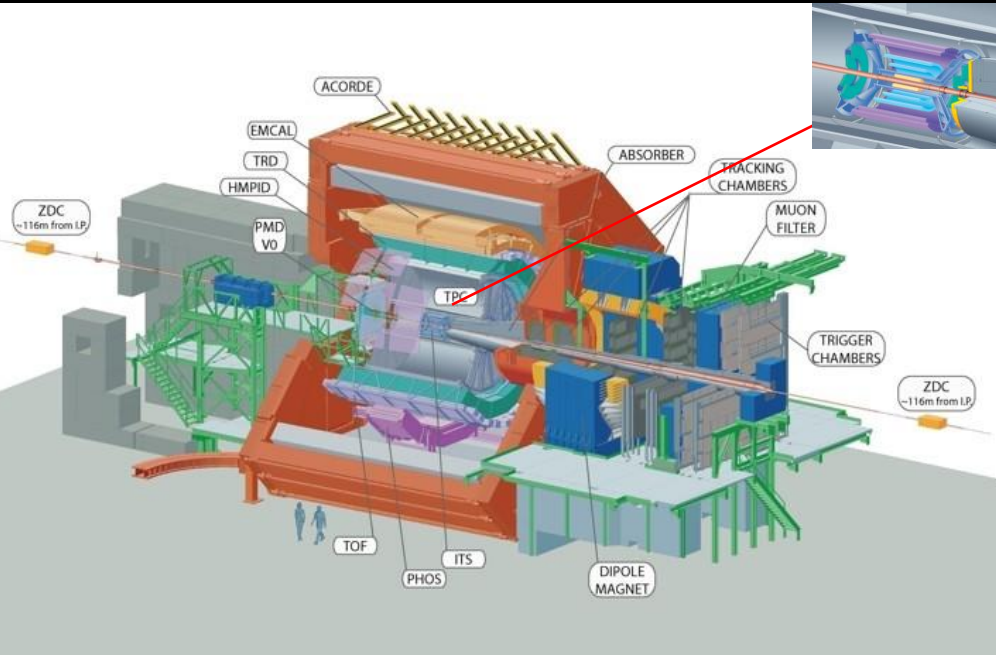
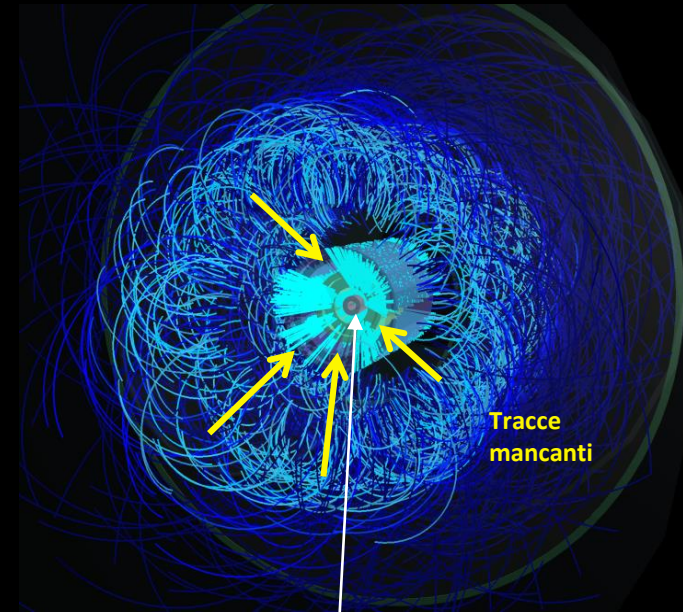
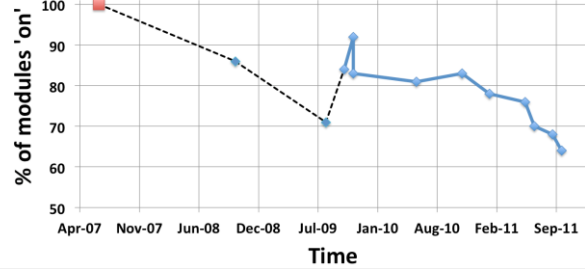
# Superare ai limiti tecnologici



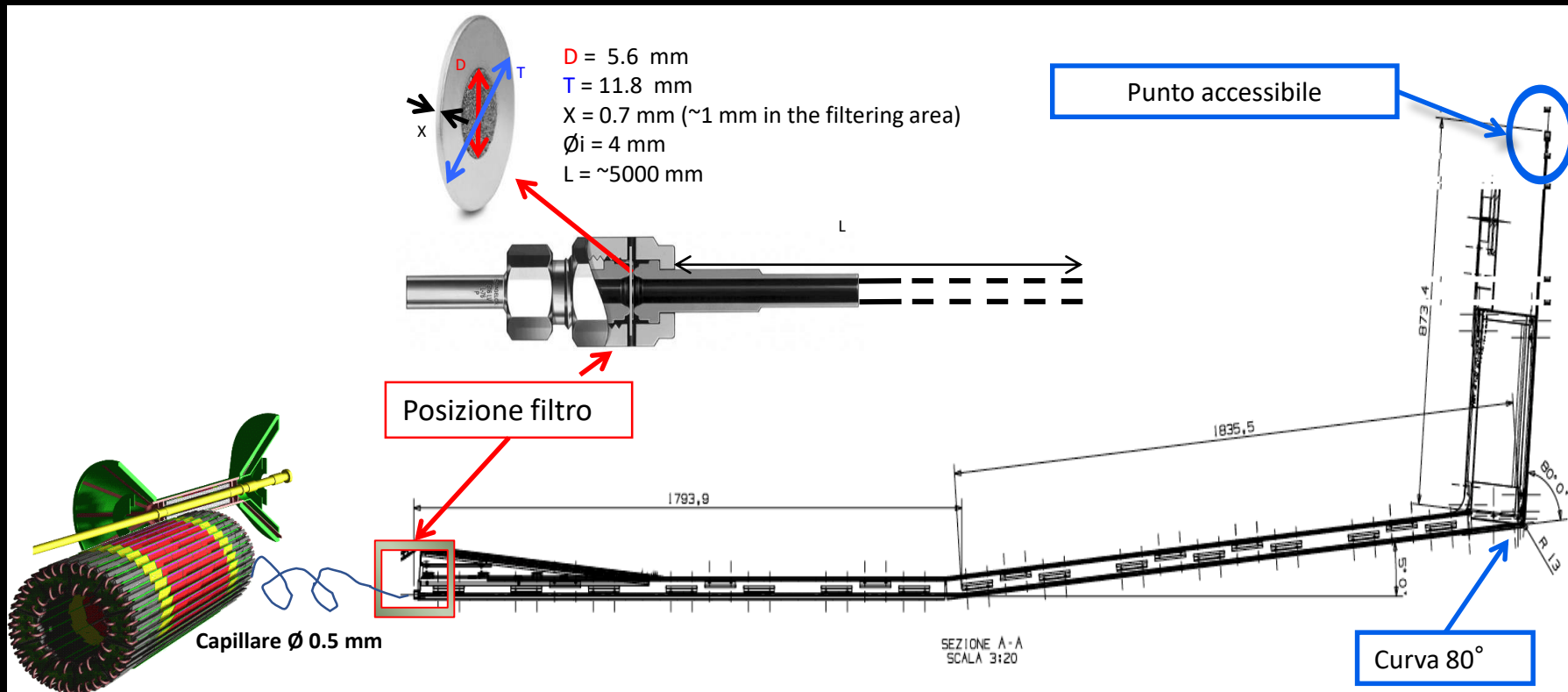
Superare i limiti dell'osservazione

# ALICE heavy-ion run Nov. 2010

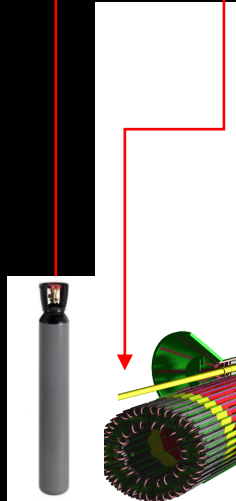
## SPD cooling efficiency



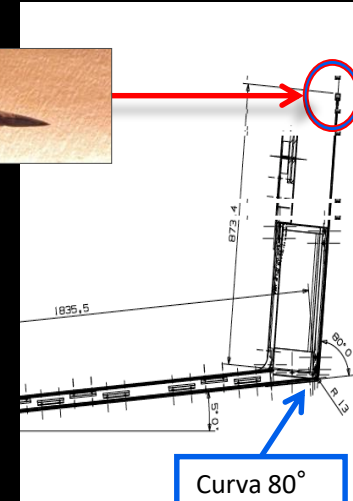
# Dopo 2 anni di tentativi ecco dove sta il problema



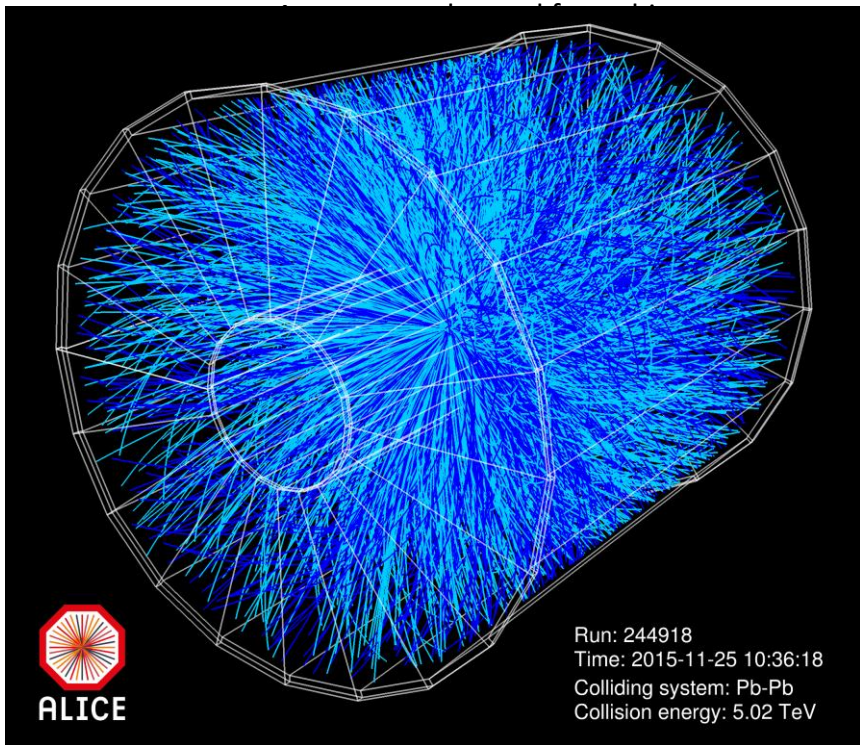
# Una punta d'ingegno



...nessun accesso visivo all'operazione

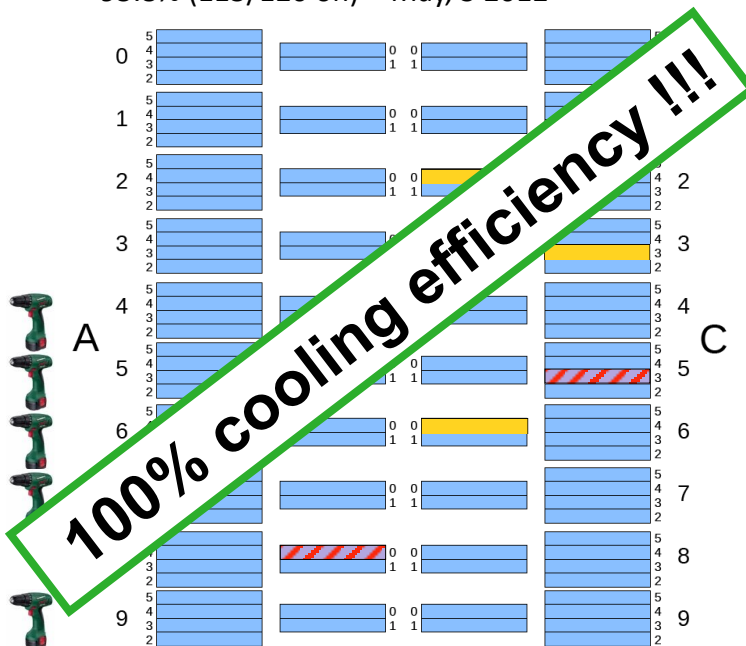





# The detector performance



...to this!

95.8% (115/120 on) - May, 3 2012

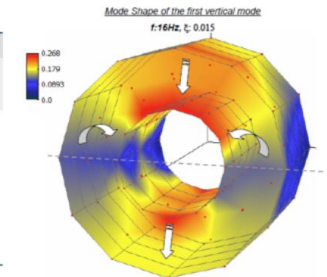
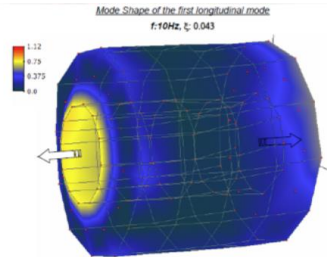
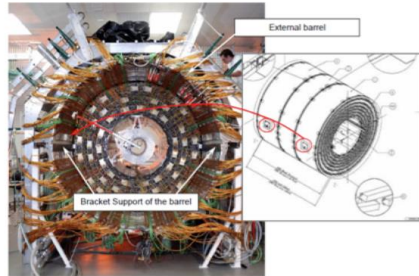


-  cannot be recovered
-  could be recovered
-  hot

# Mechanics and materials

Dal design al prodotto finale

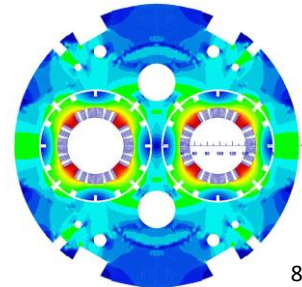
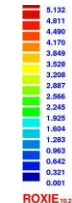
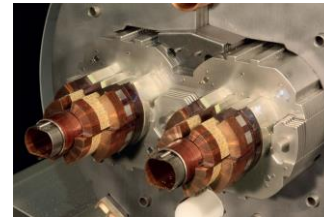
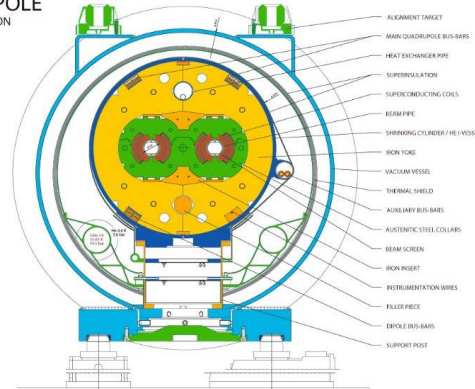
## Rivelatori



ATLAS SCT Barrel		
Frequency (Hz)	Damping (%)	Mode shapes
10	4.3	First longitudinal mode
16	1.5	First vertical mode
18	1.5	First breathing mode
26	2.4	Second longitudinal mode
32	2.1	Second breathing mode
43	1.5	Third breathing mode

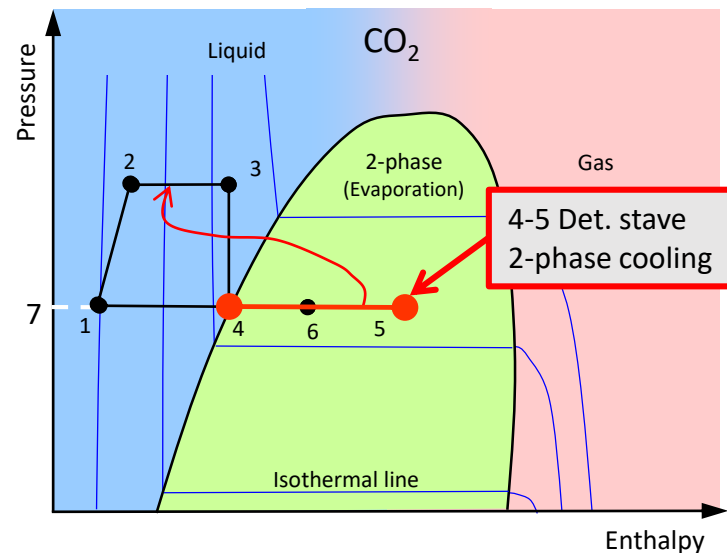
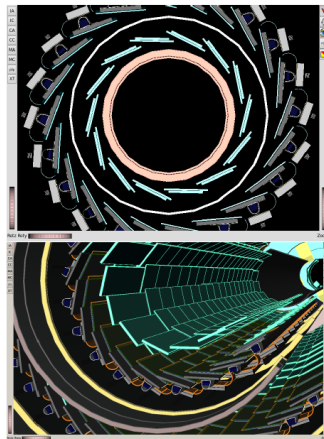
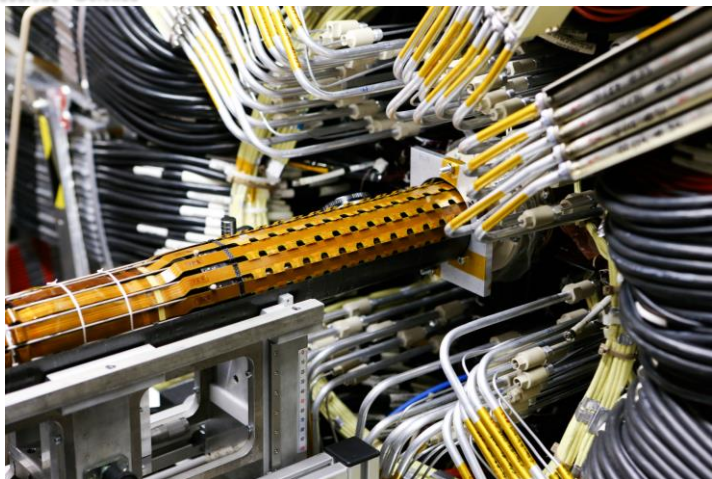
## Acceleratori

LHC DIPOLE CROSS SECTION

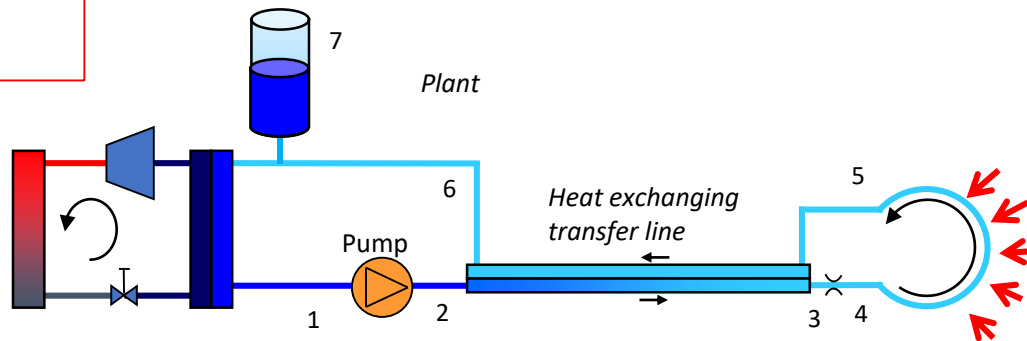




# IBL il primo rivelatore montato sulla Beam pipe



CO<sub>2</sub> Cooling T min= - 40°C  
 Max Power dissipation: 1500W  
 Operation T=-40 to -25C (+/-0.5K)



The IBL staves are therefore like a set of double constrained beams

- Constrained in Z on the C-Side
- Sliding along Z on the A-Side
- Linked together in the middle by a ring

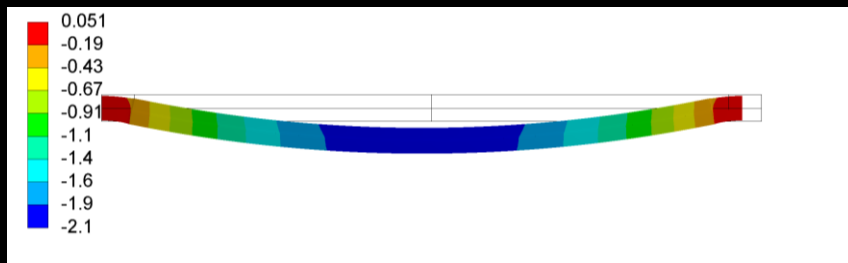
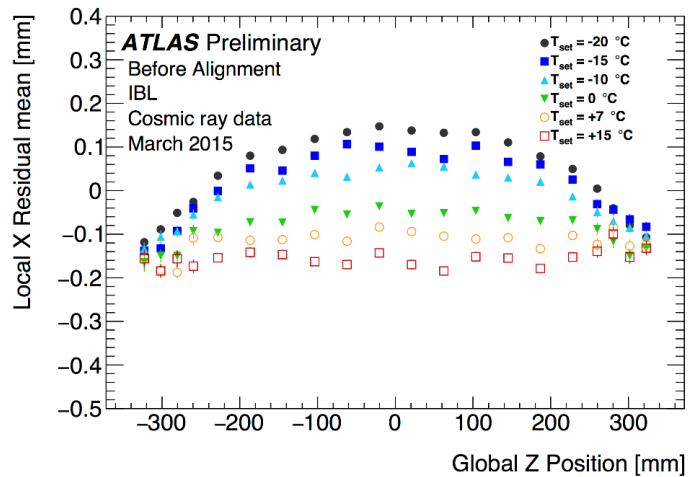
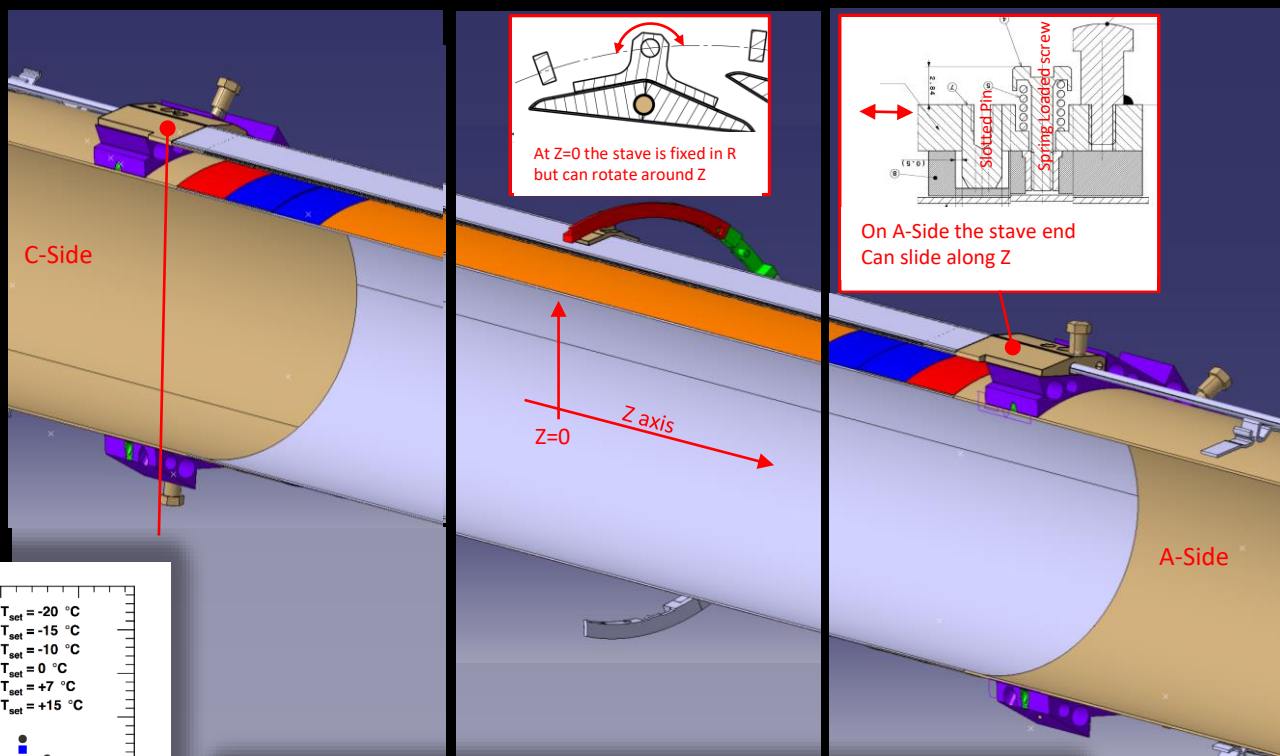


Figure by Danilo Giugni (ATLAS)

# Cryogenics & Superconductivity

## Mechanical and welding operation

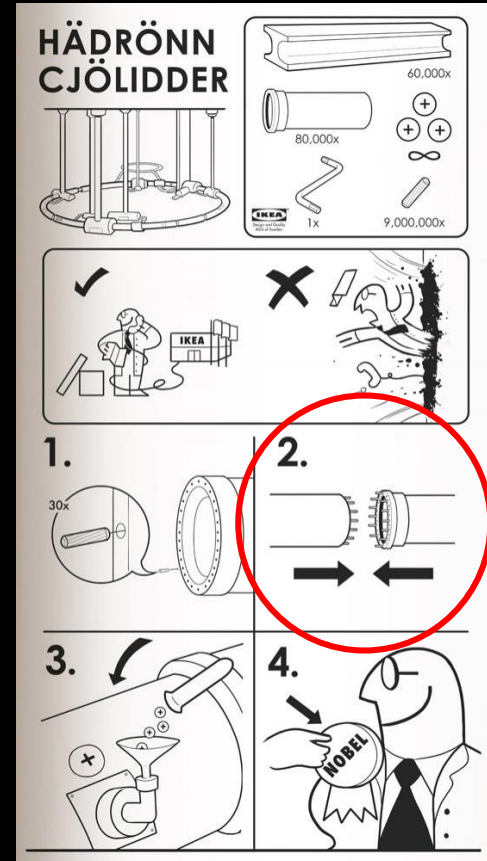
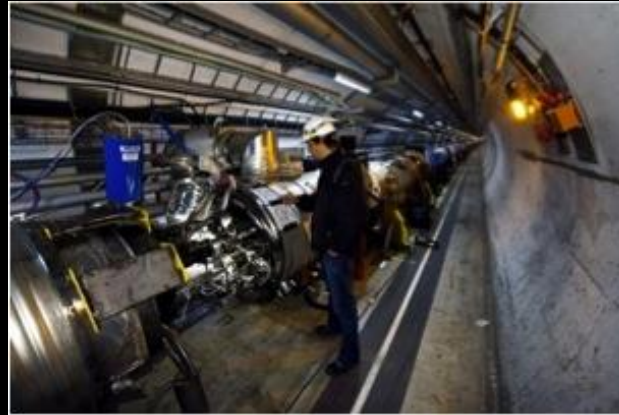


- 23 km superconducting magnets
- 1232 dipoles, 474 quadrupoles, 7612 corrector magnets



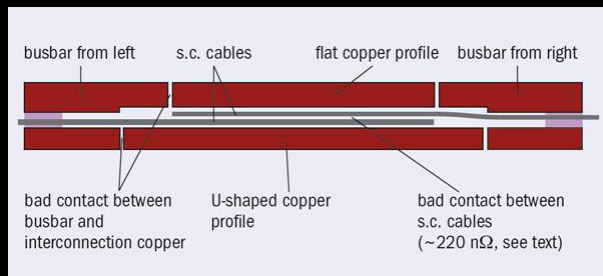
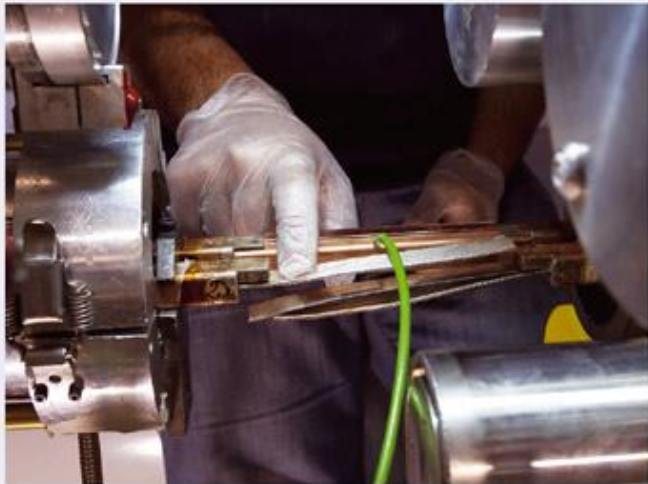
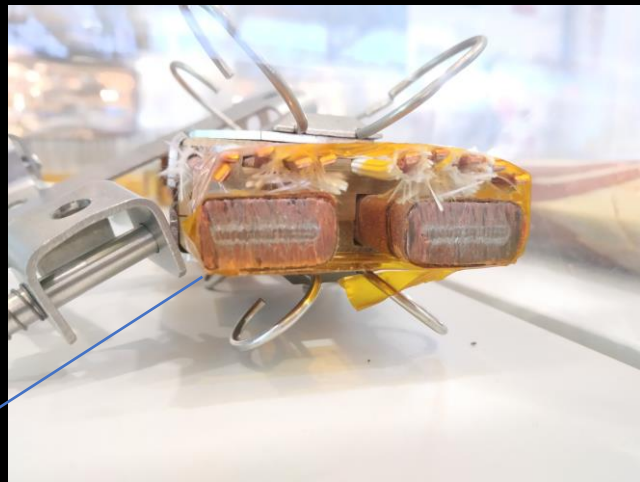
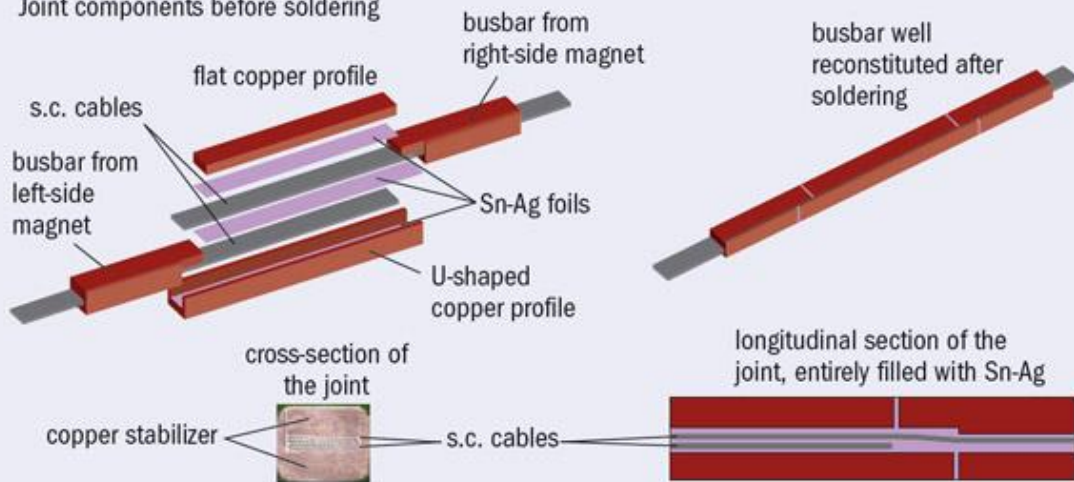
	Résistif	Supraconducteur (LHC)
<b>Induction magnétique</b>	1.8 T (saturation du fer)	8.3 T (surface critique NbTi)
<b>Géométrie du champ</b>	Définie par le circuit magnétique	Définie par les bobines
<b>Densité de courant dans les bobines</b>	10 A/mm <sup>2</sup>	400 A/mm <sup>2</sup>
<b>Force électromagnétique</b>	20 kN/m	3400 kN/m
<b>Consommation électrique</b>	10 kW/m	2 kW/m

# 19/9/2008 Corrente nei magneti: $\approx 9\text{kA}$



Arco elettrico da 5MW

Joint components before soldering



Giunzione non ottimale

# Vacuum, surfaces and coatings

Source: Paolo Chigiato (TE-VSC)

Il vuoto è necessario per evitare scariche elettriche negli elementi ad alta tensione (decine di MV/m)... e per isolare termicamente i fluidi criogenici.

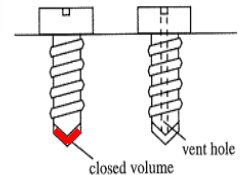
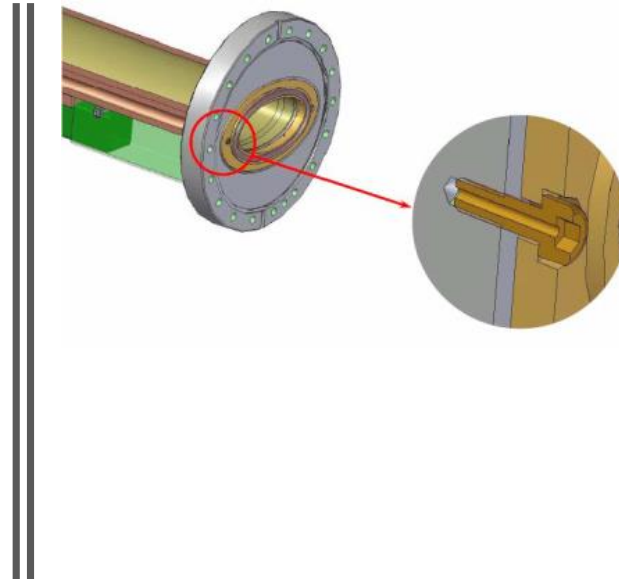
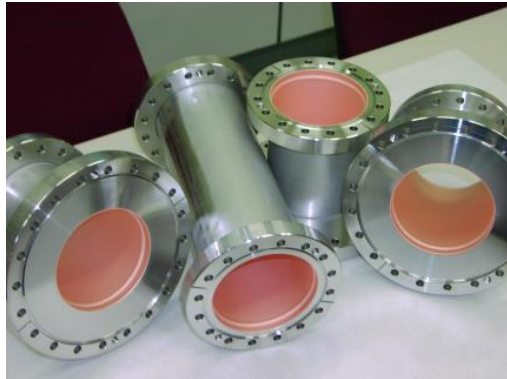


Fig 1 The screw to the right has a bored through ventilation hole to prevent virtual leaks and slow pump-down

LHC vacuum  $< 10^{-8}$  Pa

# Vacuum, surfaces and coatings

Source: Paolo Chiggiato (TE-VSC)

Neoprene (10 h di pompaggio):

$$q_{\text{H}_2\text{O}} = 10^{14} - 10^{15} \text{ molecule cm}^{-2}$$

Unbaked stainless steel (10 h pumping):

$$q_{\text{H}_2\text{O}} = 5 \times 10^9 \text{ molecules cm}^{-2}$$

Baked stainless steel (150° C x 24 h):

$$q_{\text{H}_2} = 10^7 - 10^8 \text{ molecules s}^{-1} \text{ cm}^{-2}$$

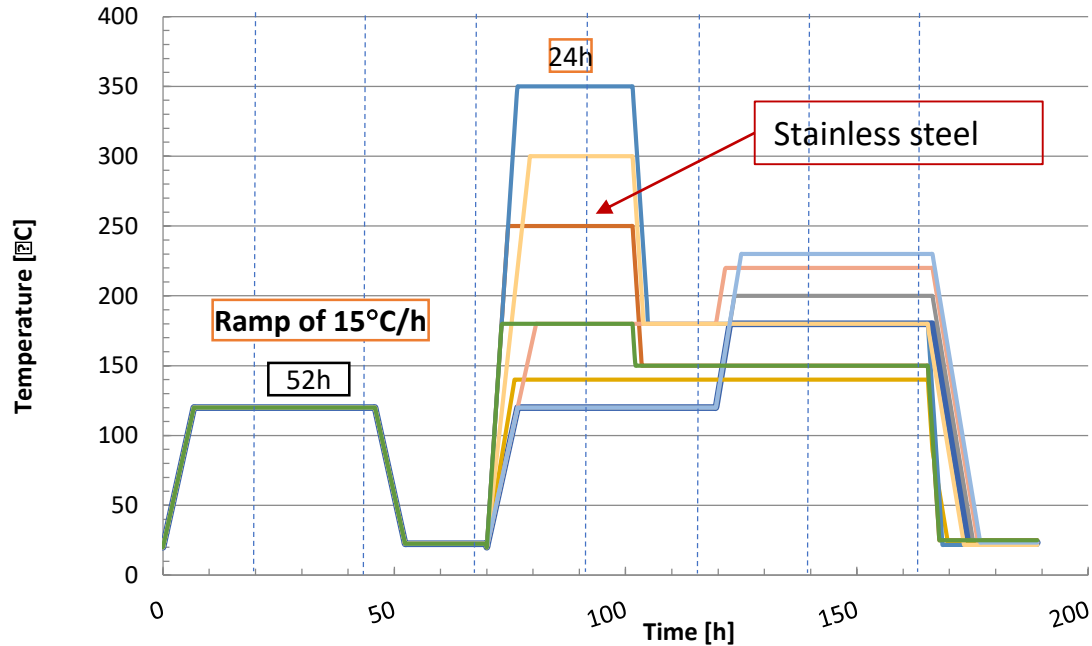
Baked OFS Copper (200° C x 24 h):

$$q_{\text{H}_2} = 10^5 - 10^6 \text{ molecules s}^{-1} \text{ cm}^{-2}$$

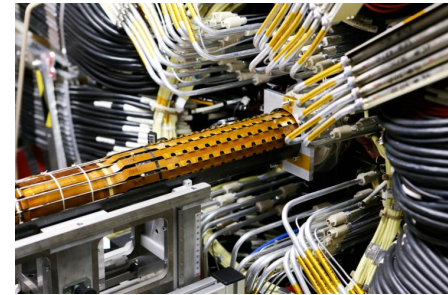
*Un errore nella scelta dei materiali non può essere recuperato con un aumento della capacità di pompaggio.*



# Temp Beam Pipe durante bakeout

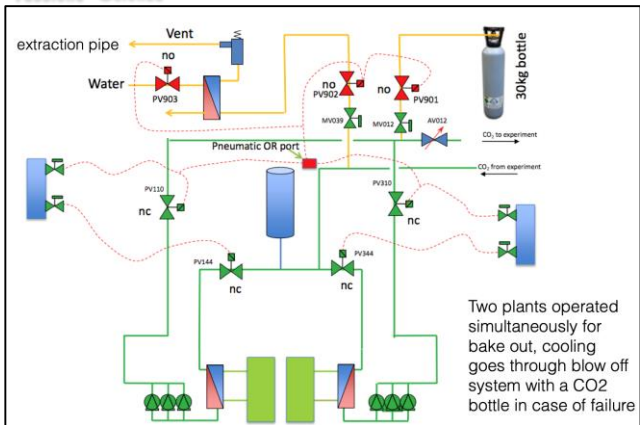


E lui?

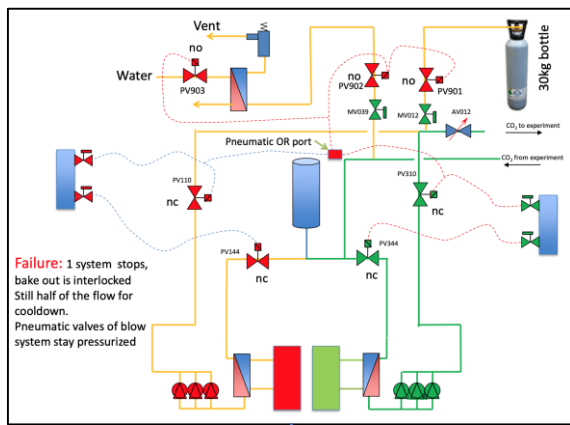


involving thermal shock and power-off cycling between +80 °C and -40 °C, with mechanical attachment to dummy stave substrates using the baseline adhesive. If any damage is seen in these modules, the mechanism should be understood, including cycling more modules as needed. The survival of +80 °C with power off is not a baseline requirement, but could be adopted as production test to guarantee that beam pipe bake out is a safe operation even without cooling.

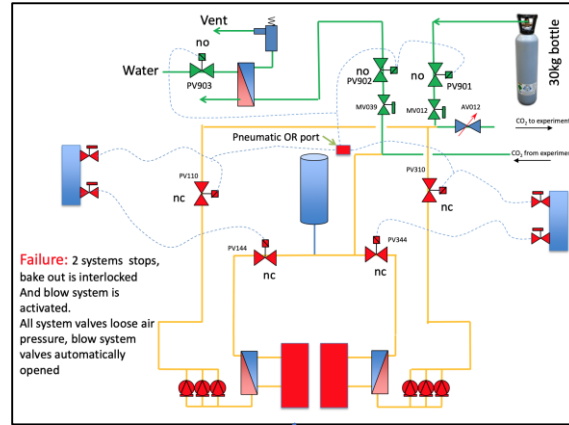
# Blow-off system



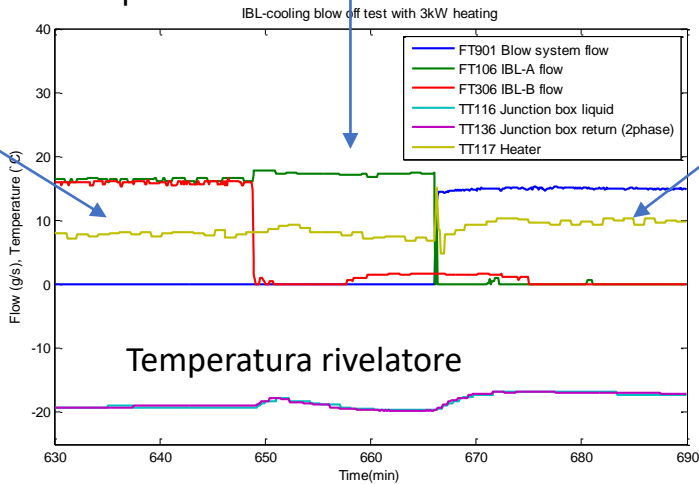
2 impianti ON



1 impianto ON



Impianti OFF  
Blow-off ON



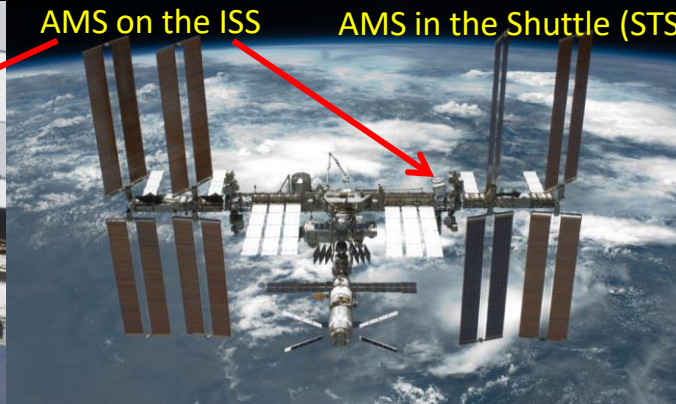
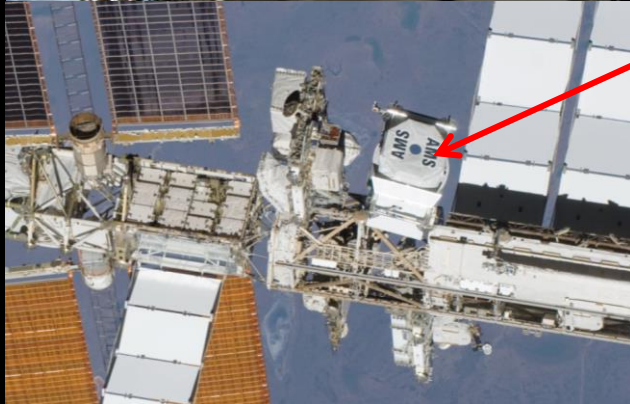
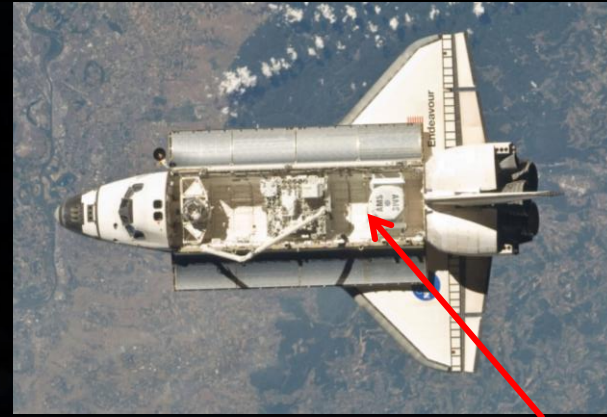
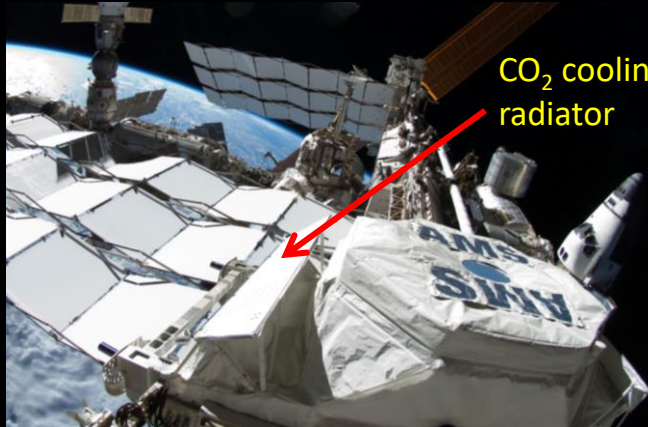
# Cooling and Ventilation

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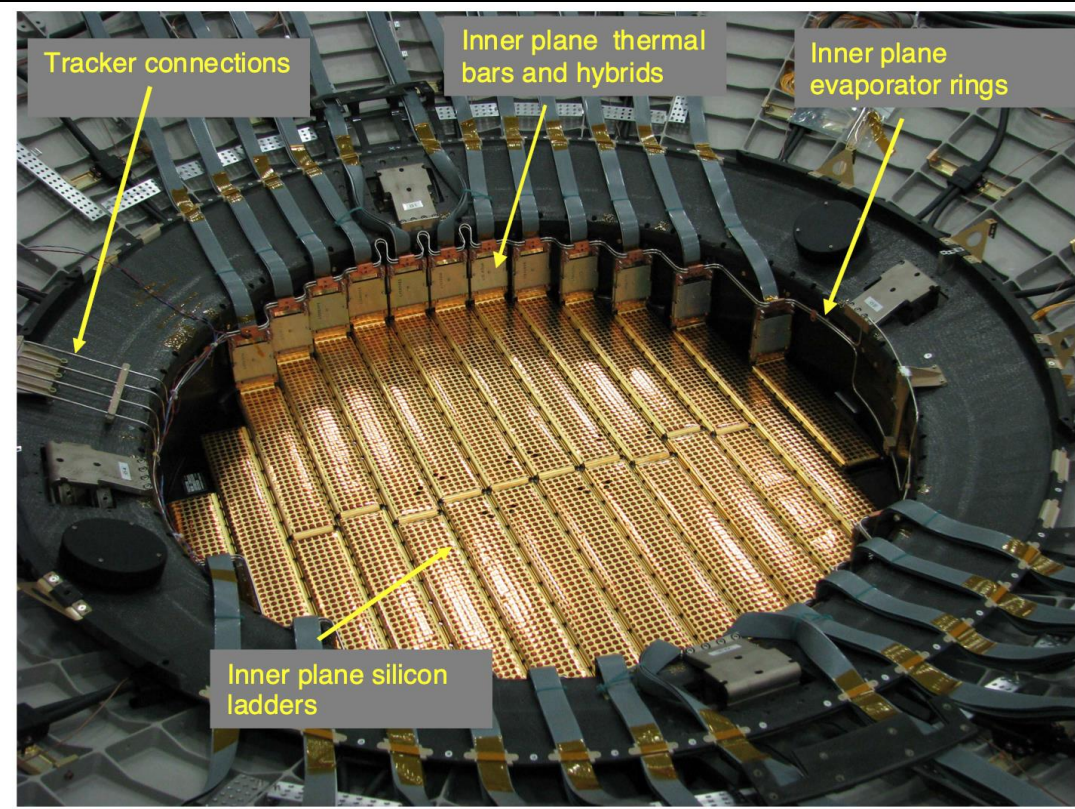


# *CO<sub>2</sub> cooling al CERN comincia con AMS*

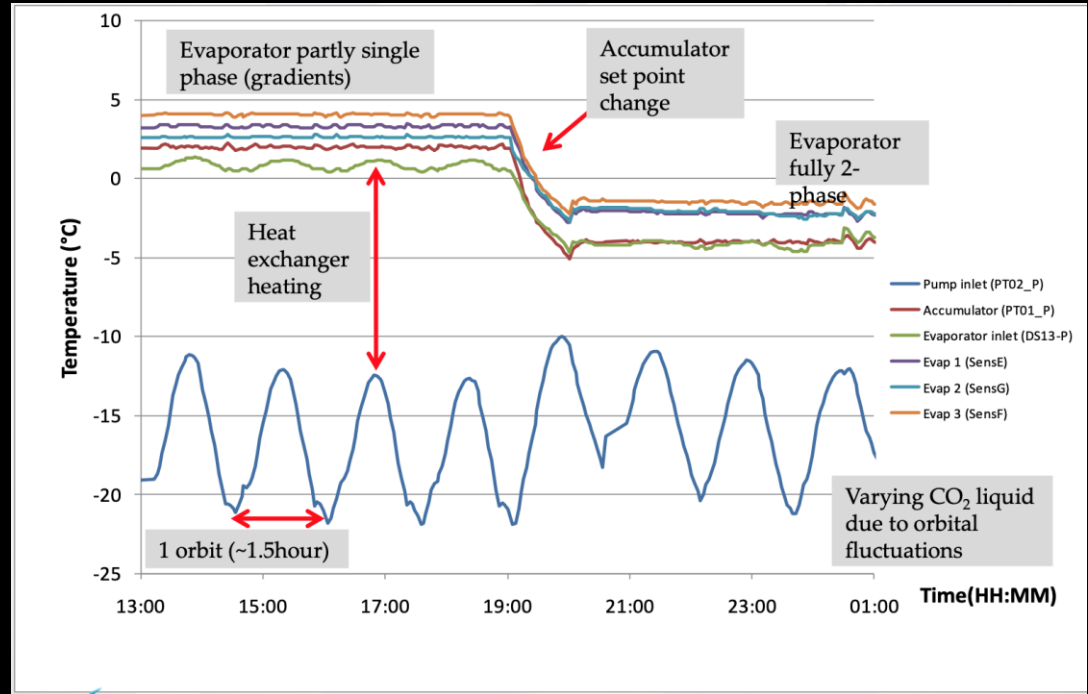
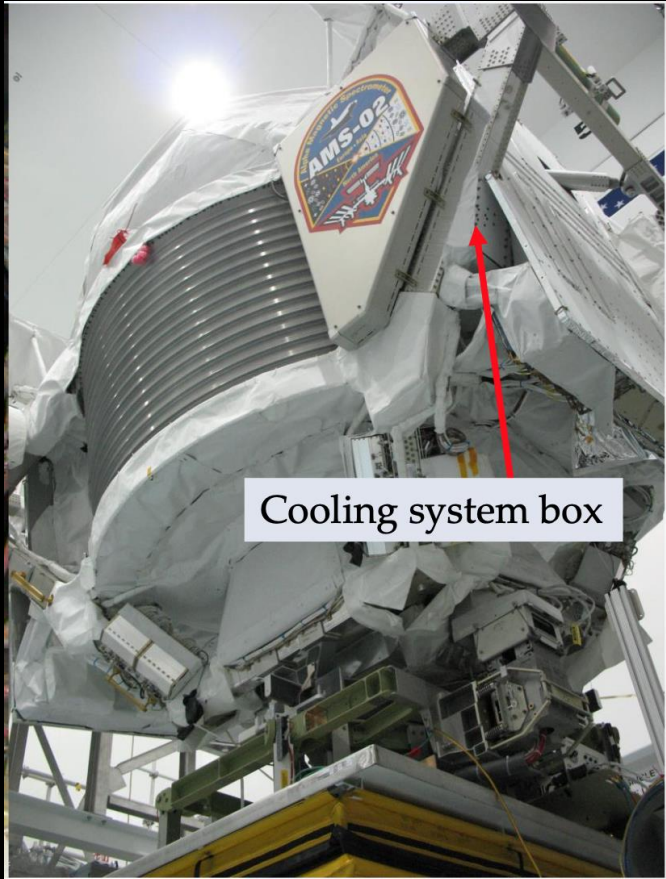
Alpha Magnetic Spectrometer (AMS) Tracker Detector on the International Space station (ISS)



# Il tracciatore di AMS-02



# Il sistema funzionava in modo soddisfacente

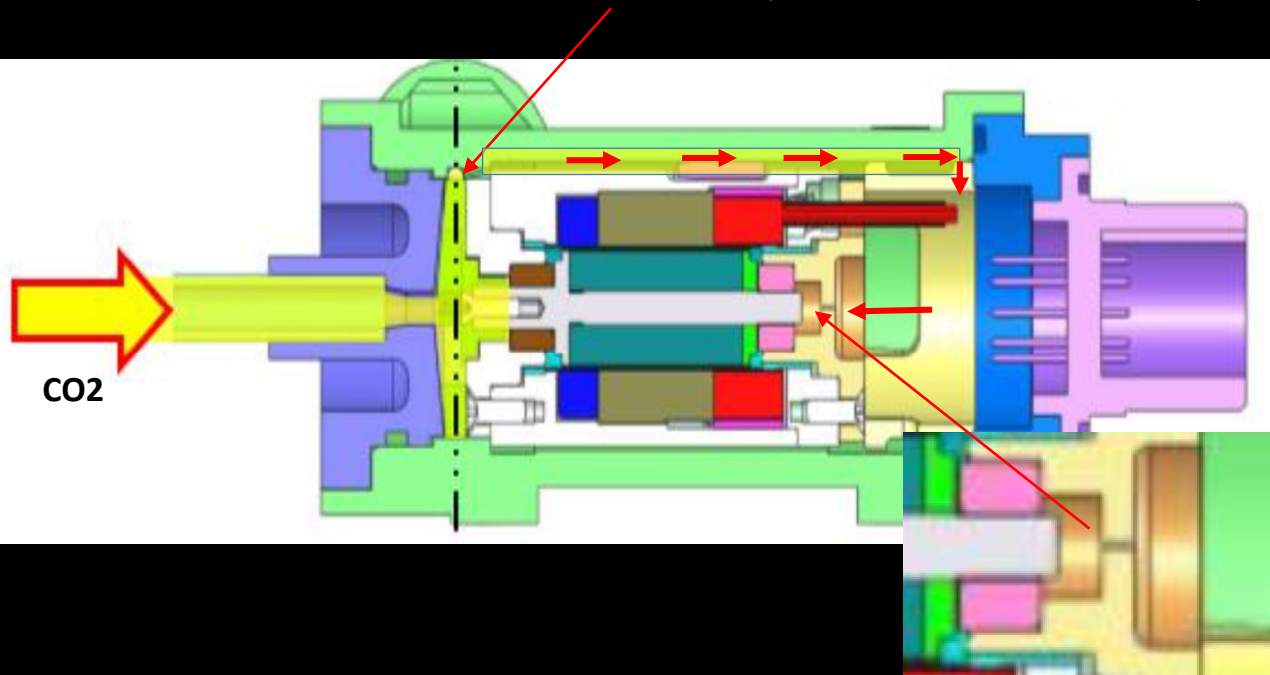


Maggio 2015, ricevo una telefonata...

...Houston abbiamo un problema.

# Perché Luca Parmitano si è fatto queste 4 passeggiate

Foro di ricircolo, serve ad usare una piccola parte del fluido come lubrificante delle parti in rotazione (1-5% del flusso totale)



Il problema delle pompe di AMS sta qui...e su Mars Pathfinder non usavano CO2





Samuel Ting



Expedition 61 AMS Overview Briefing - November 12, 2019



**My shop at home in Houston, Texas**

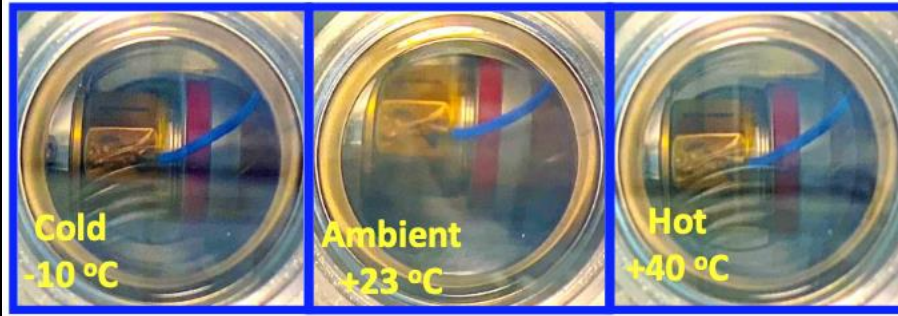


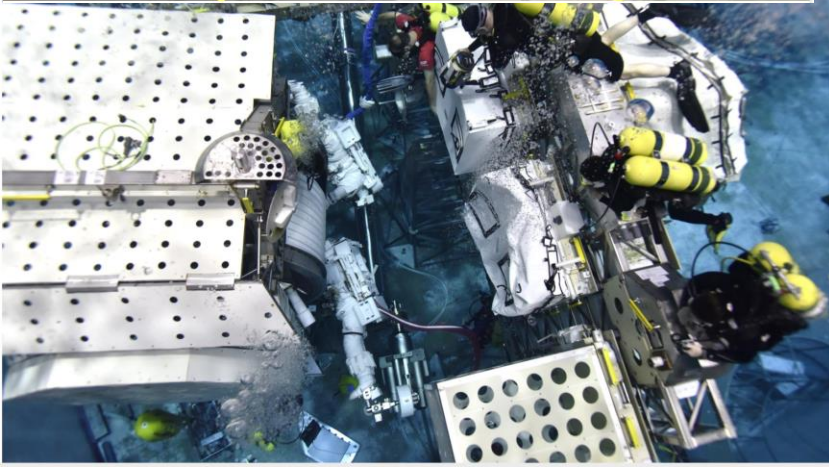
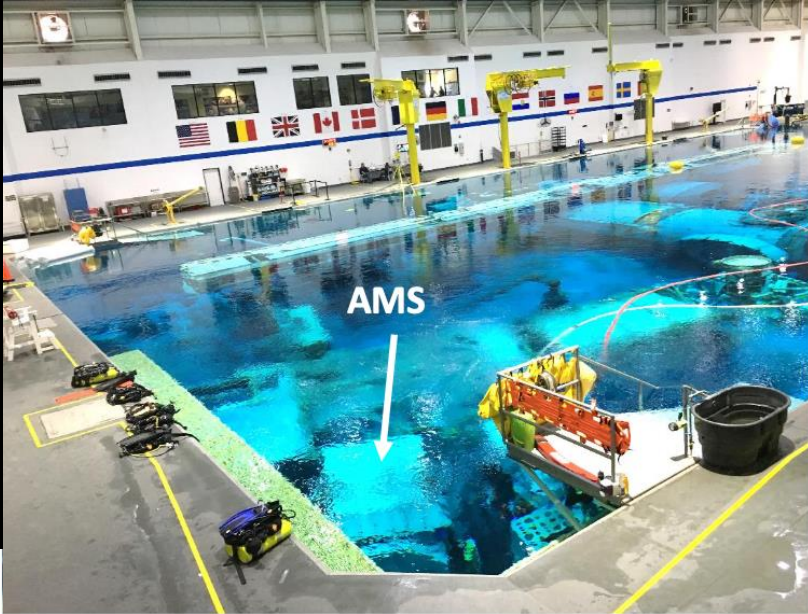
Photos by Ken Bollweg (NASA)

**Pressure Actuation tests in Climate Chamber at RWTH Aachen  
(All VLIs actuated)**



**CO2 Accumulation in Thermal Vacuum at RWTH Aachen (VLIs actuated @ all temps)**





**AMS EVA Repair: ARGOS & NBL Runs**  
**Thru November 1, 2019**

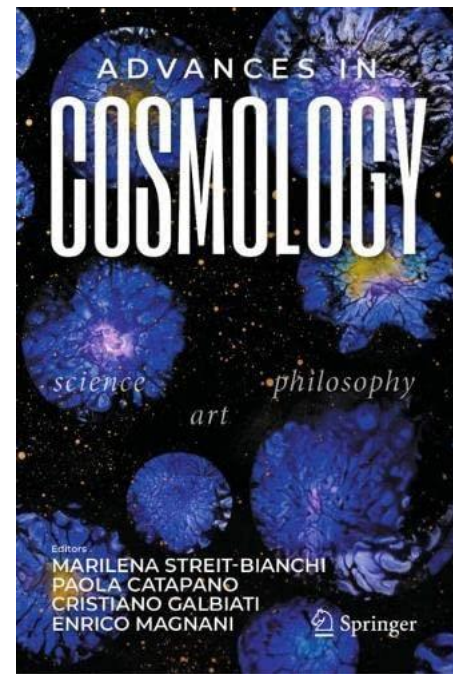
AMS EVA Repair Crewmember	ARGOS	NBL		Totals
	EV1	EV1	EV2	
Parmitano (EV1)	2	10	2	14
Morgan (EV2)	0	0	8	8
Cassidy (Ground IV)	15	13	1	29
Hansen (Ground IV)	2	1	8	11
Hopkins	4	2	6	12
Rubins	2	1	1	4
McClain	1	0	1	2
Others (1 Run Each)	1	7	7	15
<b>Totals</b>	<b>27</b>	<b>34</b>	<b>34</b>	<b>95</b>



15/11/2019

*Vediamo...il cacciavite c'è..  
Brugole prese...  
Giratubi...ecchecazz...  
..è rimasta soprà il tavolo in cucina  
Houston...ehehem...avrei un  
problemino...*





Uscita a Novembre 2022

Photo by Drew Morgan (NASA)

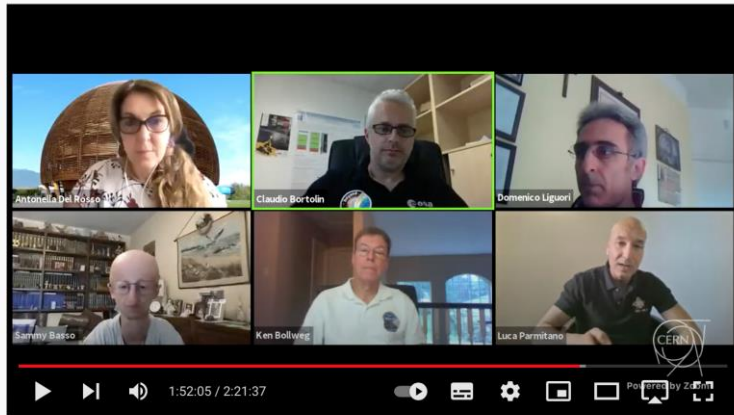


Luca Parmitano 

@astro\_luca

My favourite picture of last Saturday's EVA, so symbolic: that wrench saved the day – and AMS!

La mia foto preferita dell'EVA di sabato scorso, così simbolica: quella chiave ha salvato la giornata – e AMS! [#SpacewalkForAMS](#)



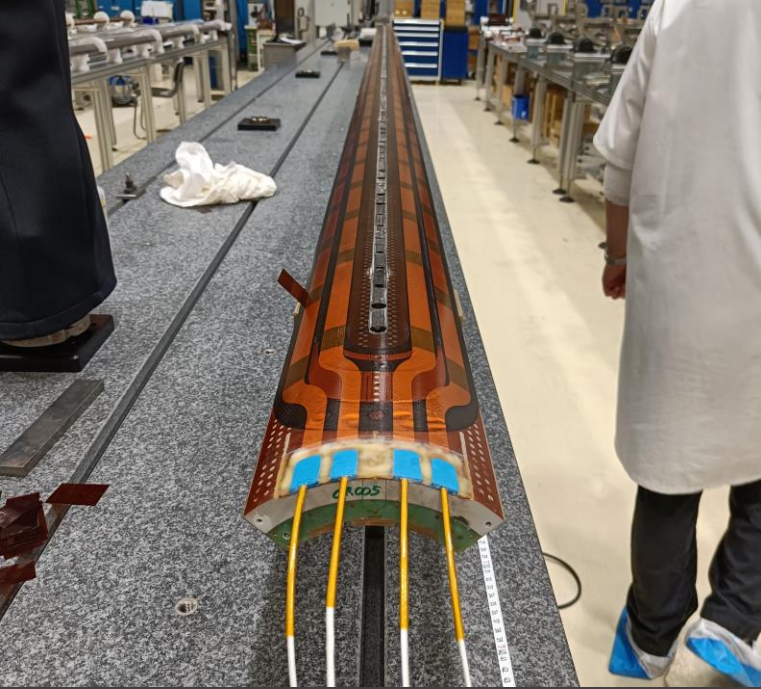
Convegno ITP CERN e evento PassioneScienza "La Chiave Giusta"

Disponibile sul canale youtube di PassioneScienza



Photo by Drew Morgan (NASA)





HI-LUMI LHC

*Grazie*



[www.passionescienza.com](http://www.passionescienza.com)