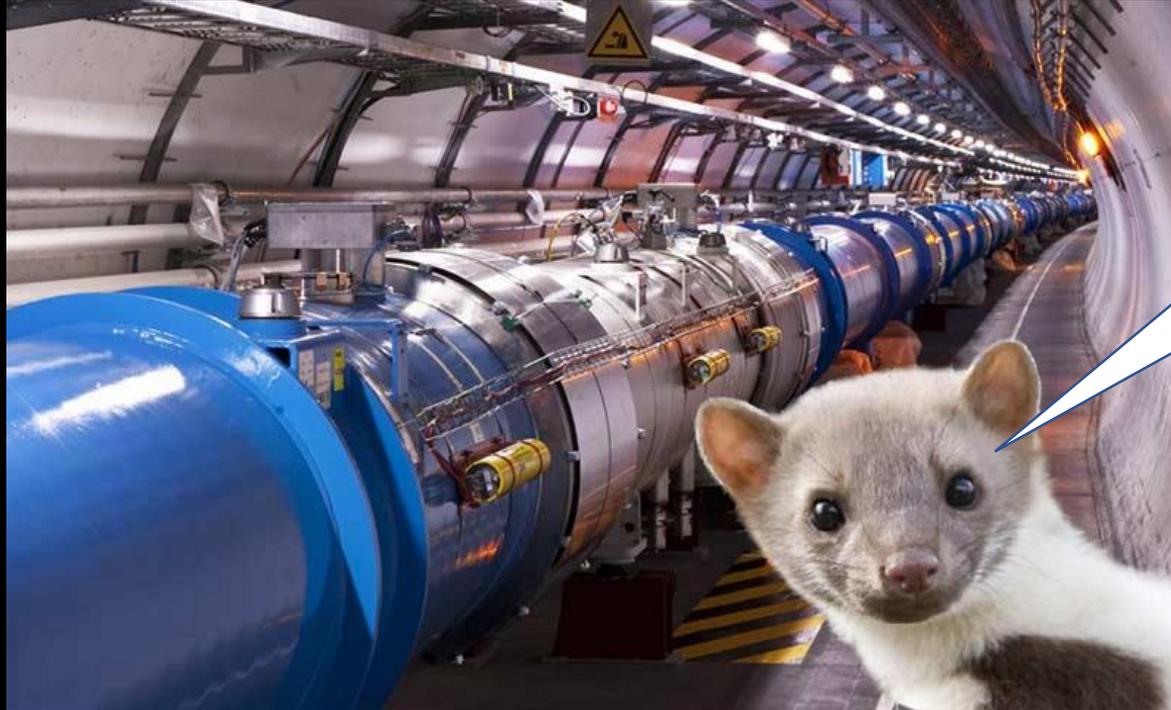




Basta che funzioni



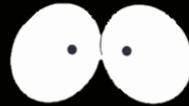
Ciao a tutti, sono Boris ma potete chiamarmi Murphy



LHC control room - 10 settembre 2008



LHC sector 3-4: 19 settembre 2008

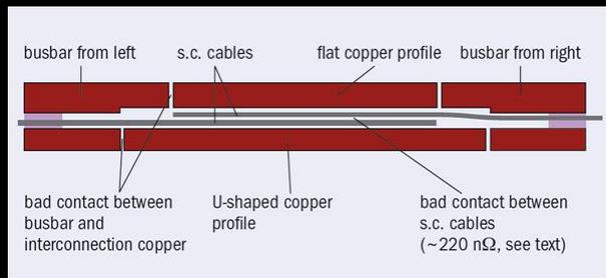
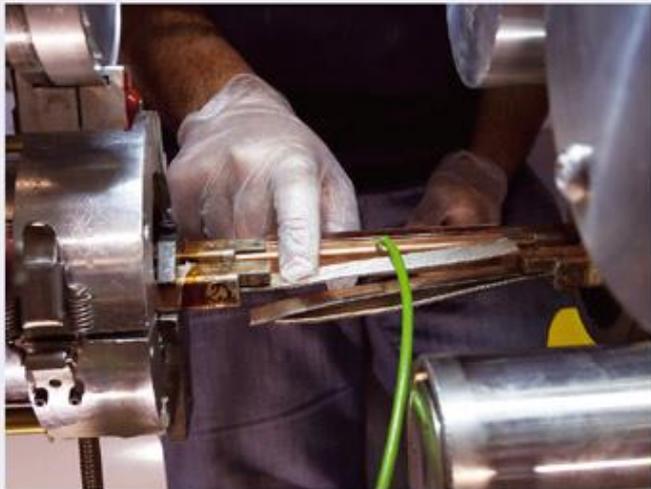
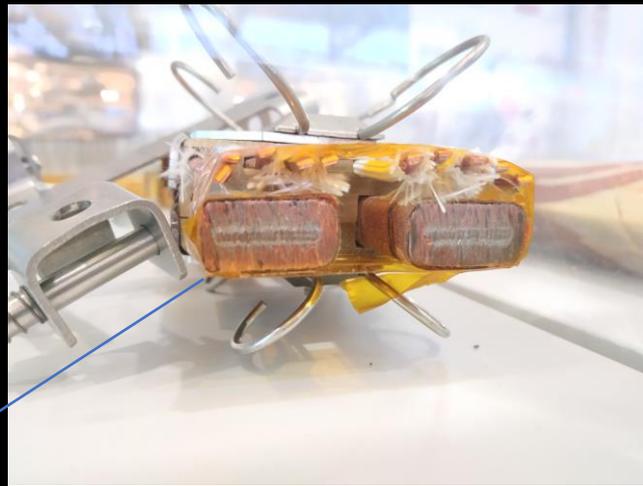
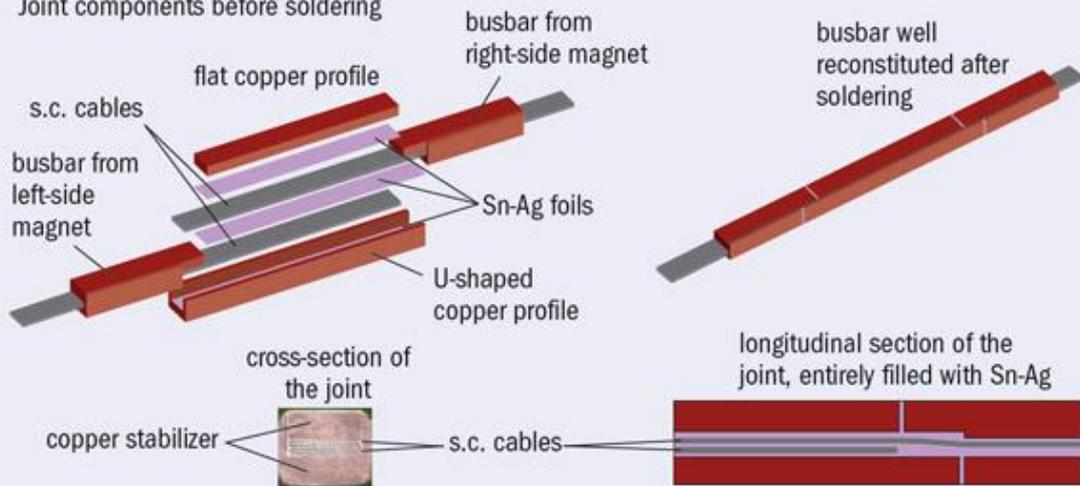


Corrente nei magneti: $\approx 9\text{kA}$



Arco elettrico da 5MW

Joint components before soldering



Giunzione non ottimale

Cosa abbiamo imparato

Il motivo dell'incidente non lo sapremo mai con certezza perché l'interconnessione (IC) dove è avvenuto l'incidente è sublimata

Analizzando altre IC si è notato che possibili fenomeni di capillarità dovuti a porosità del rame nelle barre, assorbendo parte del materiale di brasatura. 1500 circa le IC da rifare completamente su 10mila

Criticità

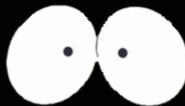
Non esisteva un piano di QA delle IC, non c'era il budget e tecnologicamente non ovvio

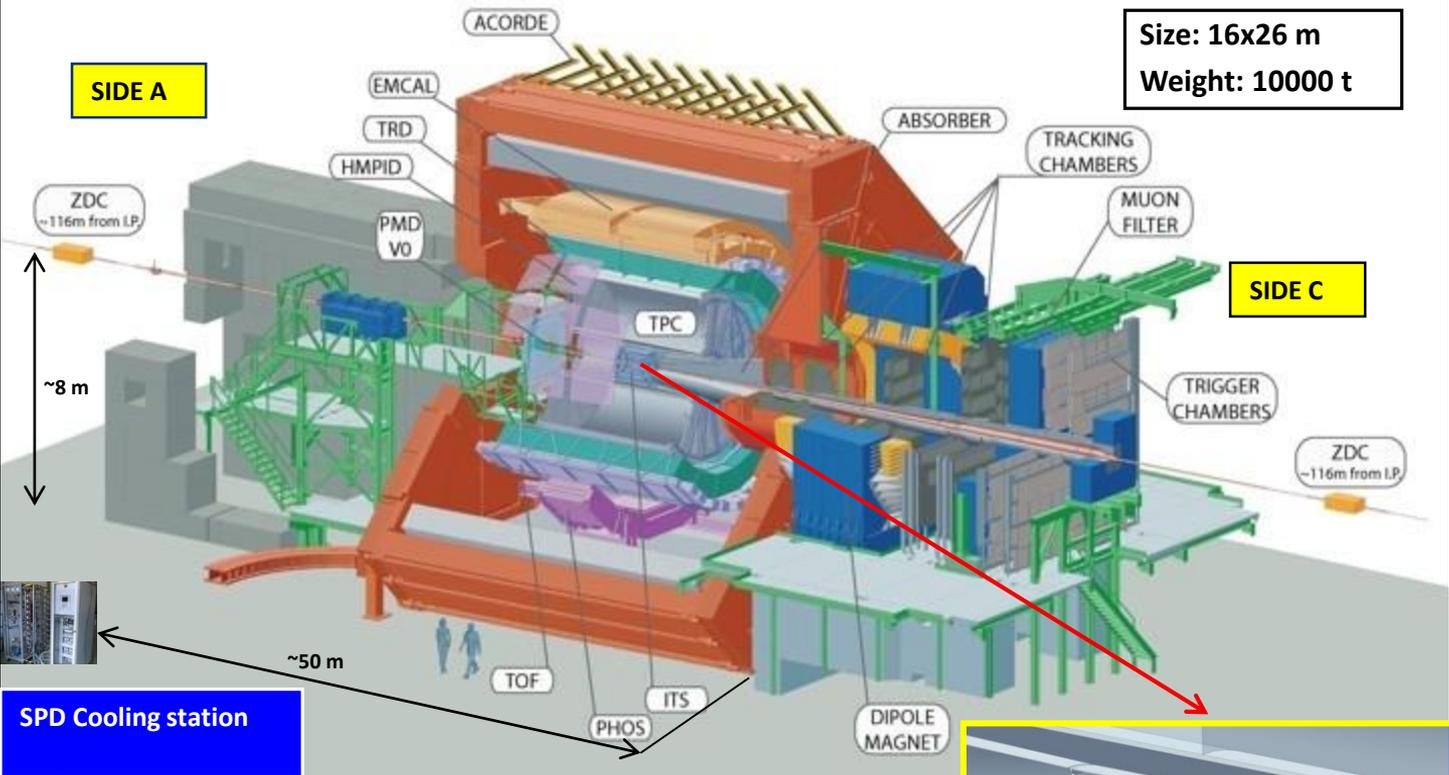
Il fattore tempo? L'incidente è avvenuto nell'ultimo assessore assemblato ...

Da non ovvio a realtà

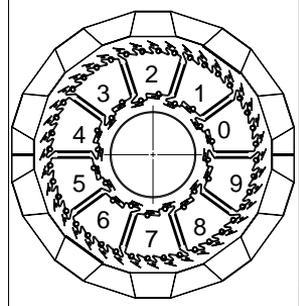
LS1: 200 persone coinvolte nella riparazione, 2 turni al giorno e 50 IC rifatte a settimana, procedura migliorata per maggiore controllo sulla resistenza delle IC.

ALICE pixel cooling: 2008-2011

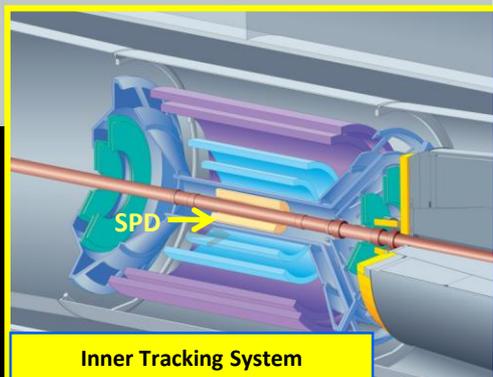




A Large Ion Collider Experiment (ALICE)



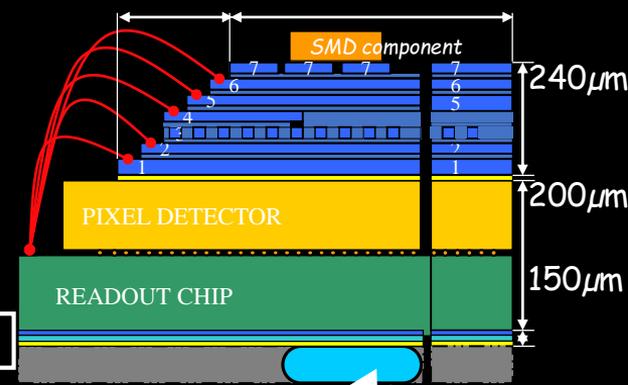
$R_{mi} = 39 \text{ mm}$
 $R_{mo} = 76 \text{ mm}$
 $L_{zs} = 282 \text{ mm}$



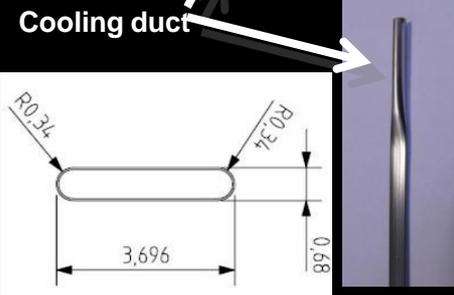
Raffreddamento evaporativo

Joule-Thomson cycle: Evaporazione a entalpia costante (dP capillari)

Fluido C_4F_{10} : dielettrico, Chimicamente stabile con radiazioni, non-tossico, bassa pressione.

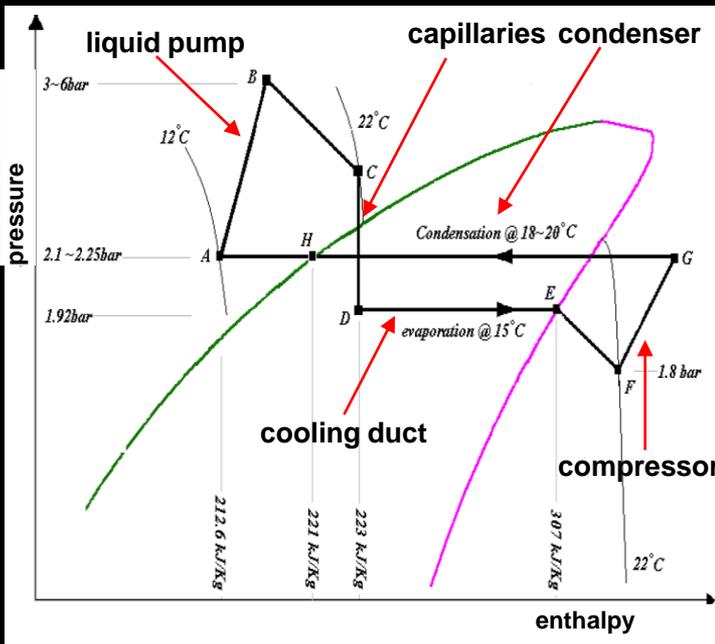
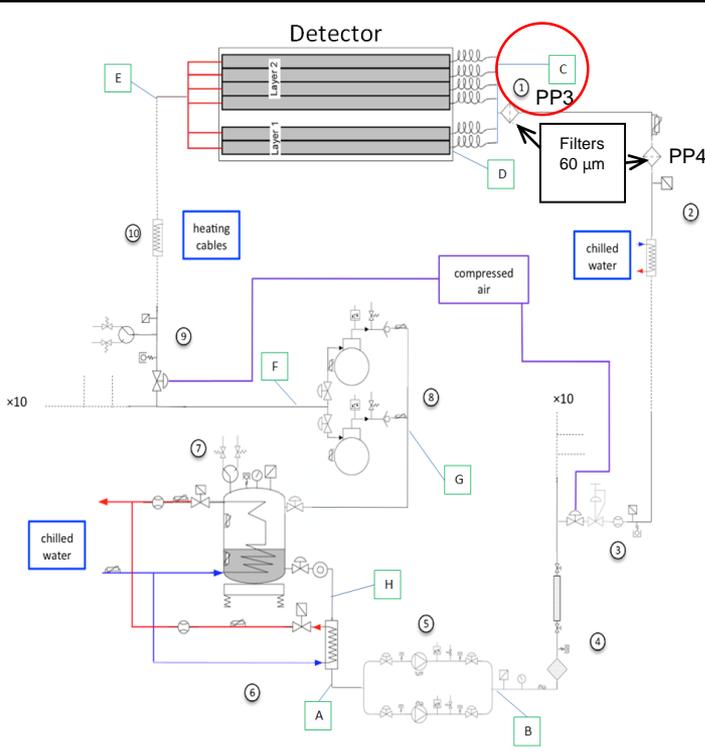


Stave cross section

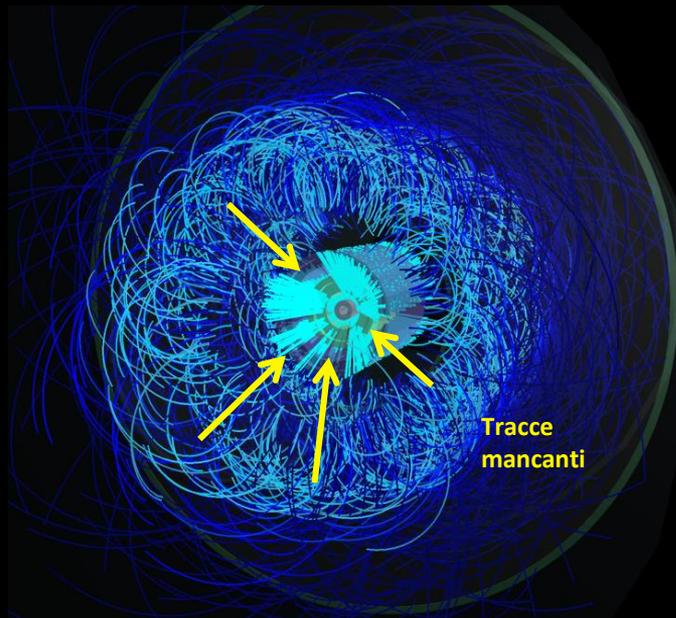


Critical components:

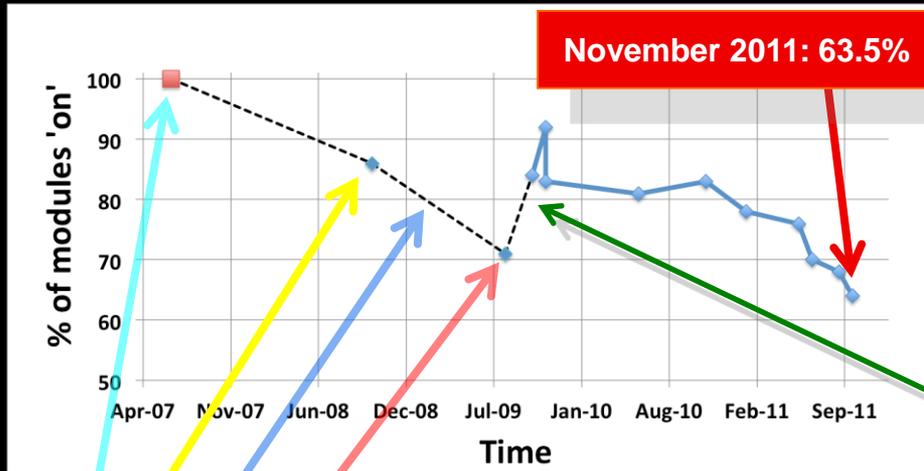
- 1) Tubi schiacciati: Phynox 40 μm wall thick
- 2) Capillari: CuNi 0.5 mm i.d. (L=550 mm)



ALICE heavy-ion run Nov. 2010



3 anni di tentativi



Clean room: 100%

First switching on: 87%

LHC incident: stop of 1 year

First restart after the long stop: 71%



Flow-meters



Pressure regulators



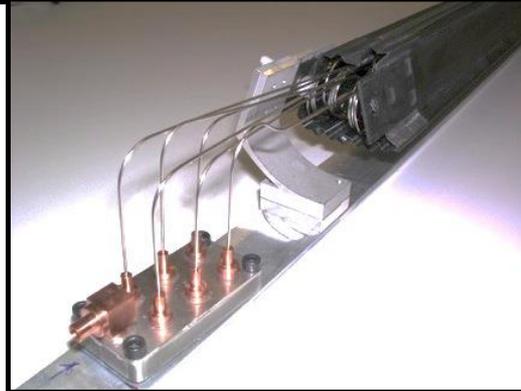
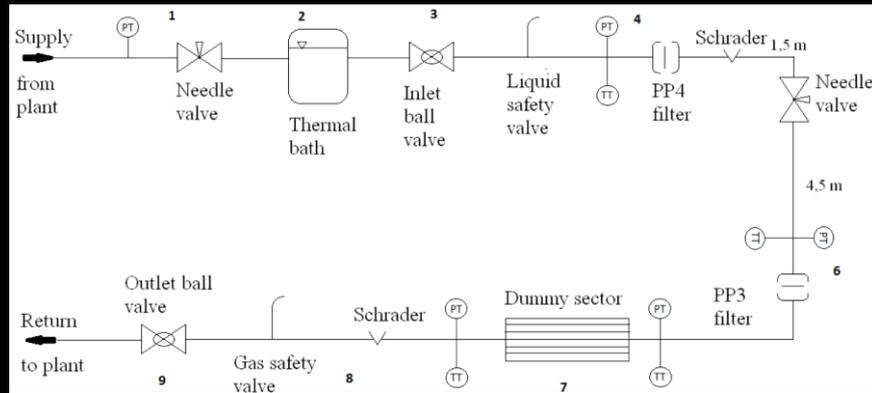
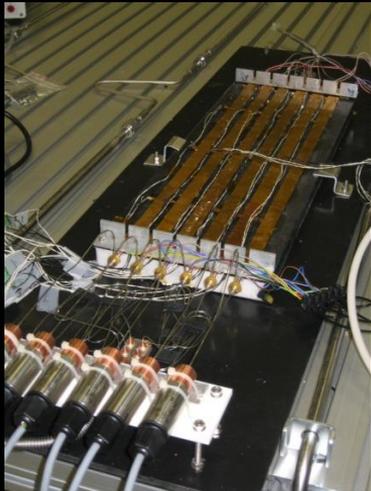
Heat exchangers
(sub-cooling)

Primavera 2011 - Test bench



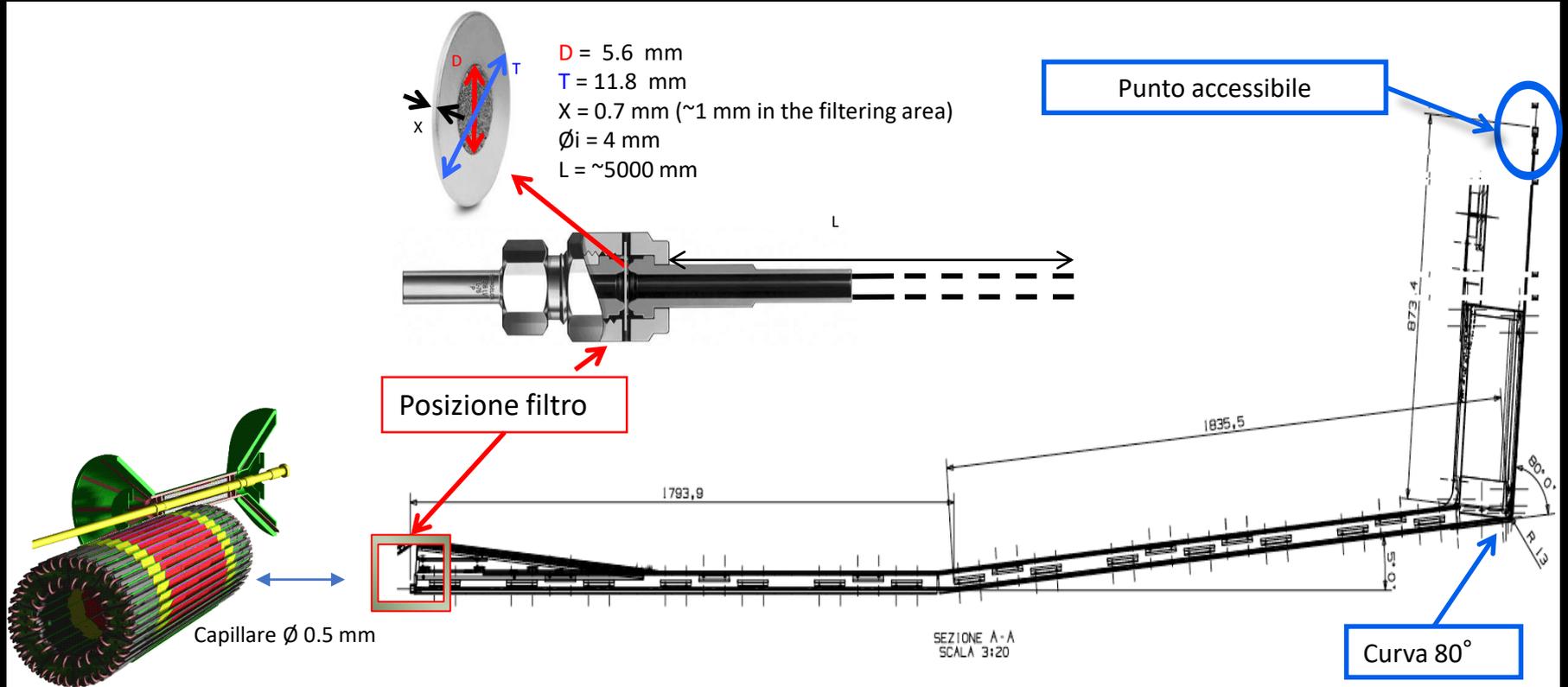
Test bench design: Collaborazione tra INFN-Padova (Italy) + CERN

- Stesse condizioni operative del rivelatore in caverna
- Una linea raffredda un settore completo dell'idraulica replica di quello in caverna (PP4, PP3, filtri, capillari, tubicini)
- Lunghezza dei tubi rappresentativa e bagno termico per verificare/testare le condizioni in ingresso nel rivelatore
- Decine di sensori tra T e p per descrivere il profilo del ciclo di raffreddamento e verificare alcuni comportamenti anomali del rivelatore



I tests: caratterizzazione dei filtri usando polvere metallica calibrata, sub-cooling tests, pGas tests

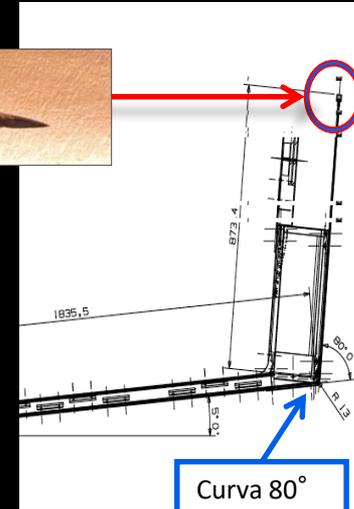
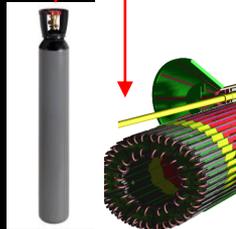
Rimuovere i filtri? Impossibile. Forarli? Forse ci giochiamo SPD



Una punta d'ingegno

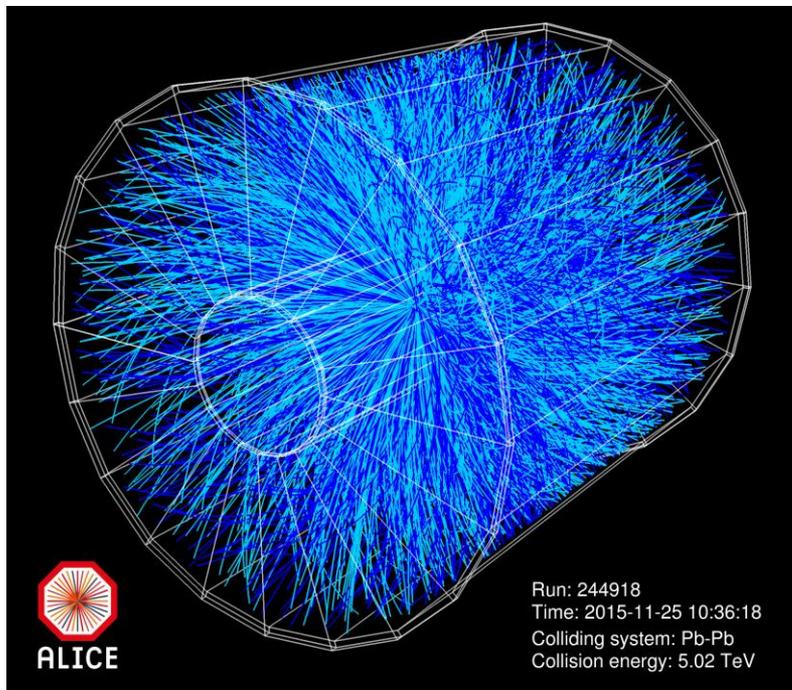


...nessun accesso visivo all'operazione



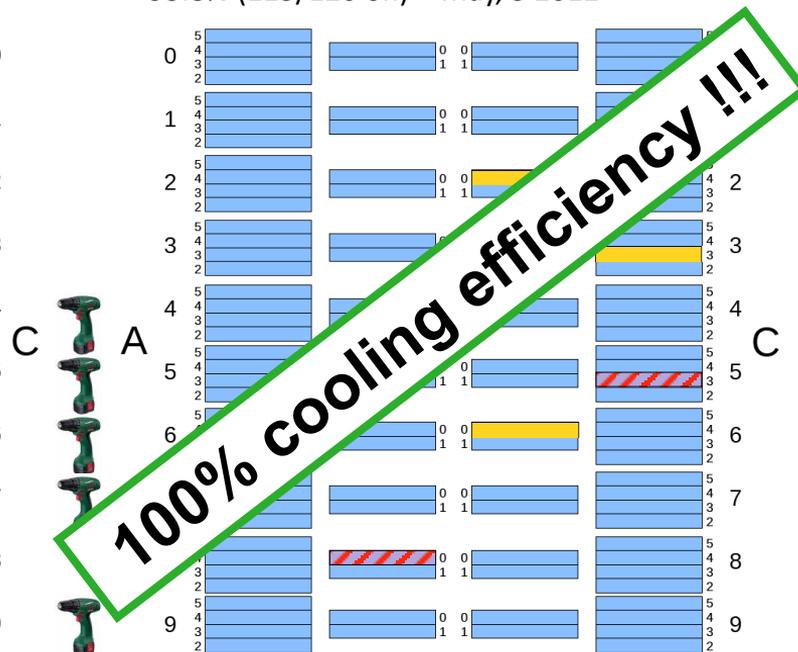
The detector performance

Acceptance changed from this...



...to this!

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

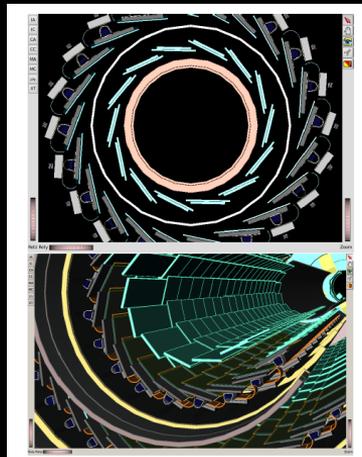
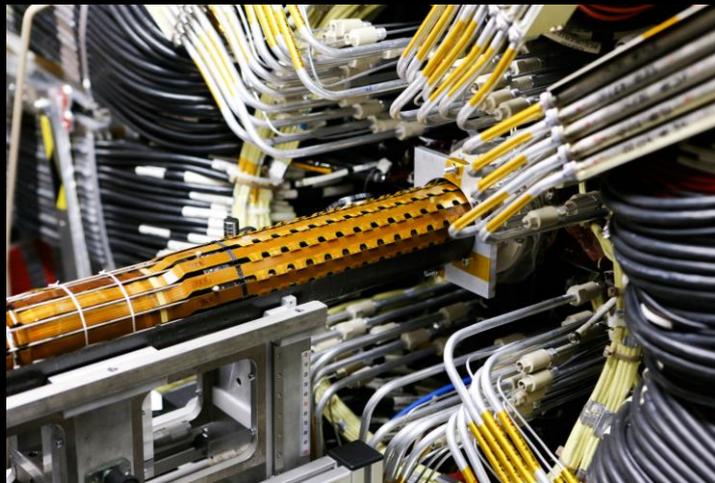


ATLAS Insertable B-Layer (IBL) 2014

Hey Houston, the flex lines are
too short!
Is Claudio there?

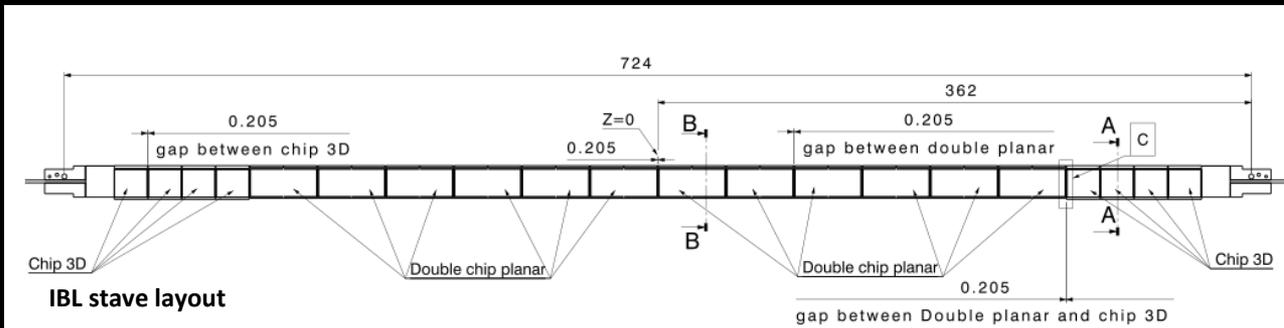


IBL il primo rivelatore montato sulla Beam pipe



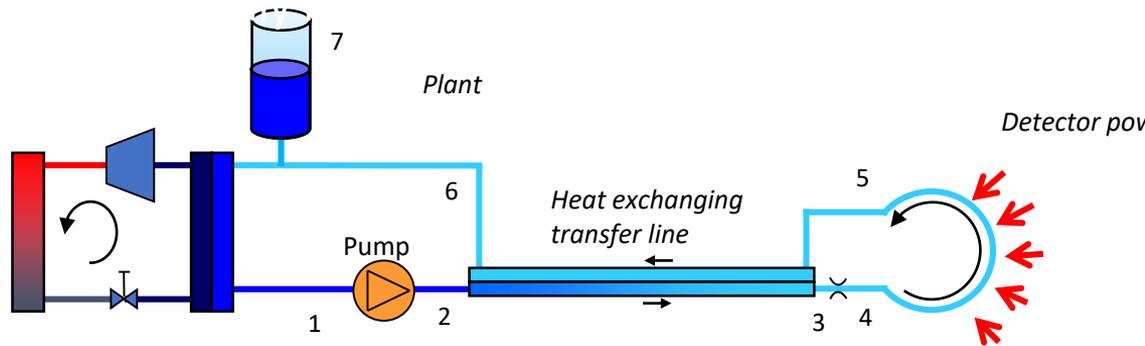
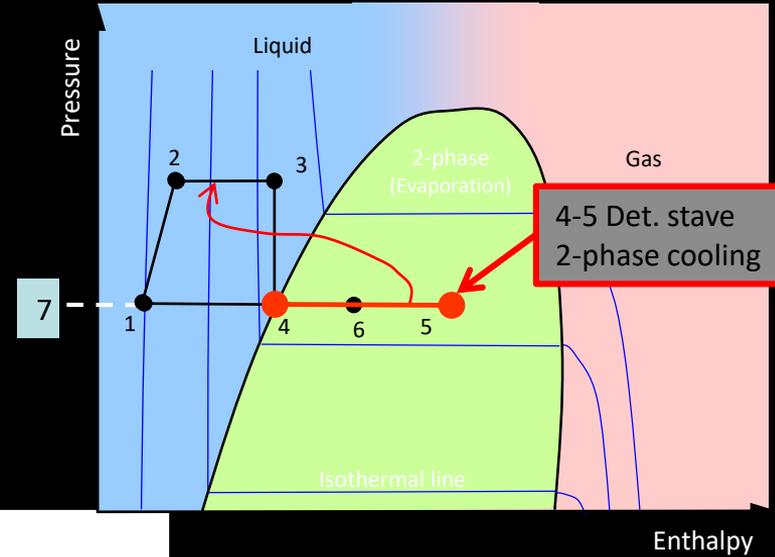
Detector characteristics:

- 14 staves ($r \approx 3.3$ cm)
- 1.9% X/X0 radiation length beam pipe included
- Pixel size (f; z) 50, 250 μ m
- 12Mpx
- Cooling T min= - 40°C
- Max Power dissipation: 1500W



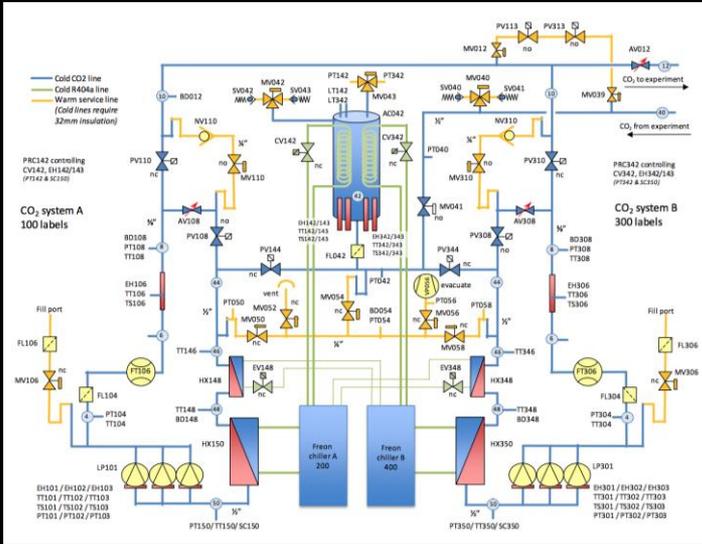
CO₂ cooling: 2-Phase Accumulator Controlled Loop

- Large latent heat of evaporation
- Low liquid viscosity
- High heat transfer coefficient
- High thermal stability due to the high pressure
- Operating Temperature: -40 to 25 C



IBL cooling system

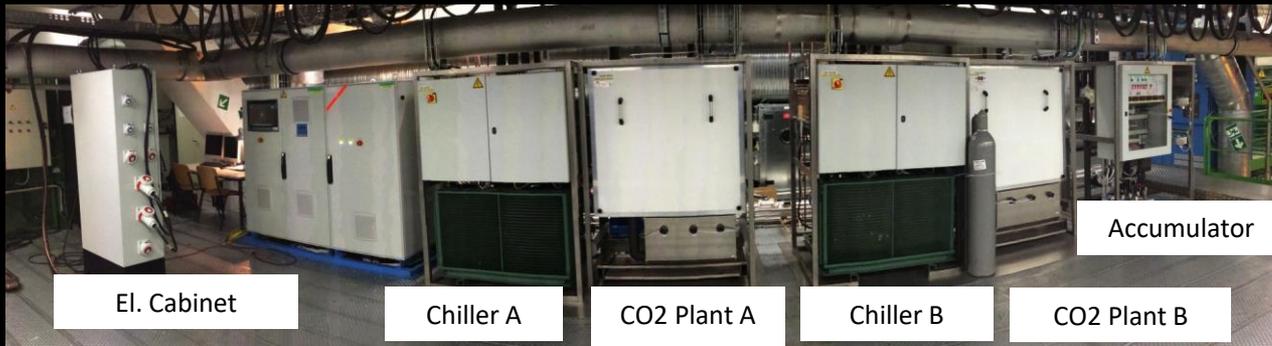
Manifold box



- 2 cooling plants (redundancy)
- 2 two stage chillers (redundancy)
- 1 accumulator with redundant control
- Common interconnection piping for maintenance operations
- Integrated internal by pass and small evaporator for stand-by operation



Junction box



El. Cabinet

Chiller A

CO2 Plant A

Chiller B

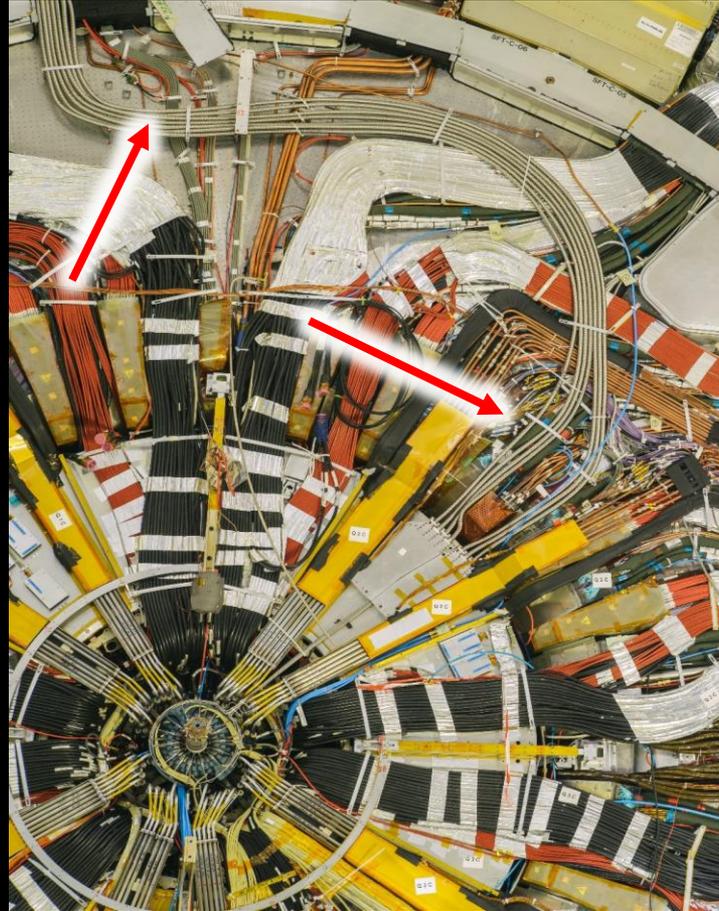
CO2 Plant B

Accumulator



Transfer line

Giugno 2014: ready to go

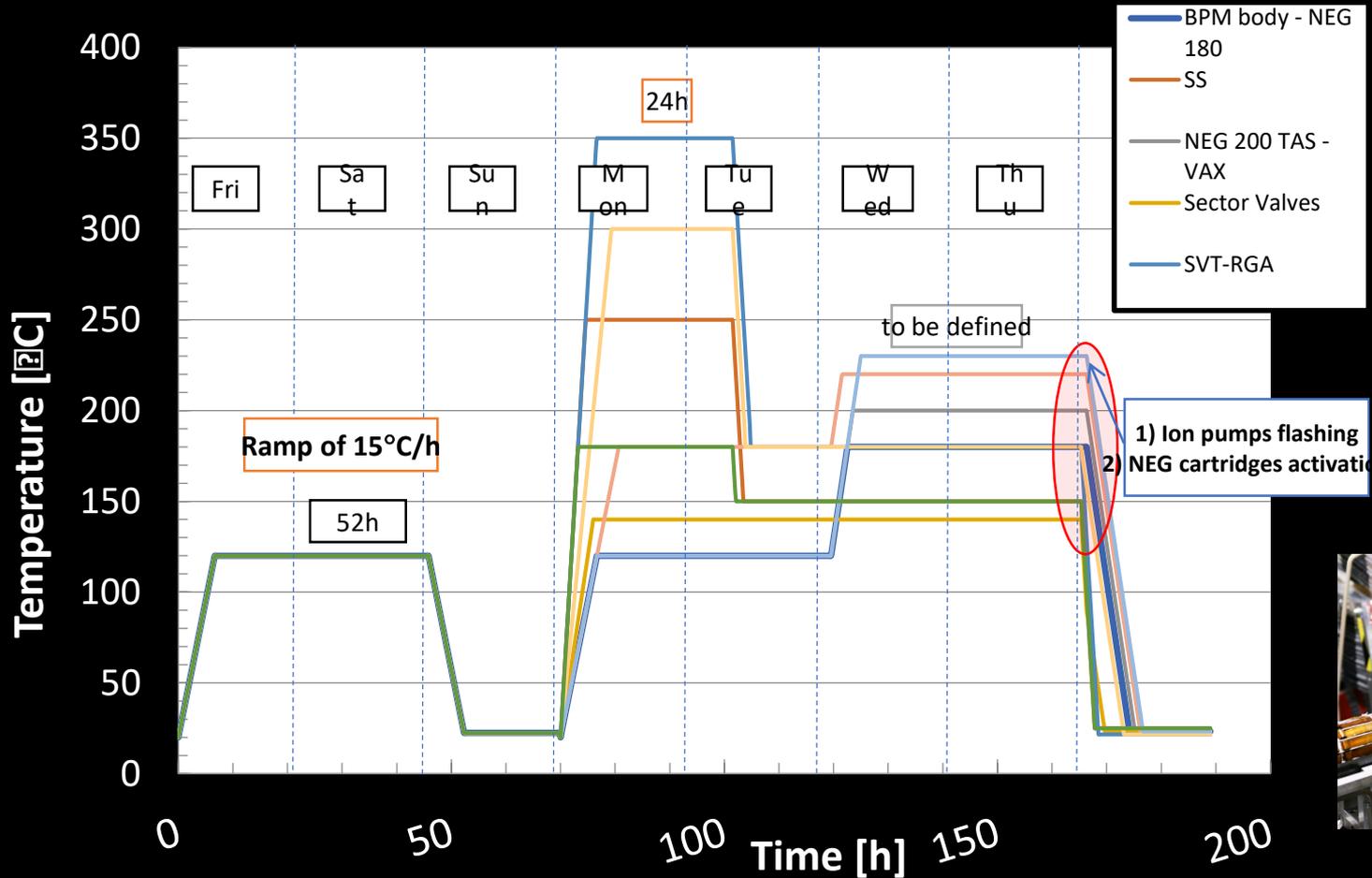


Luglio 2014

Ops....a metà ottobre abbiamo il bake-out

- As built bad bump fraction. The full sample of qualification modules should be subjected to a burn-in program involving of order 50 thermal cycles with power on between +40 °C and -35 °C. Live channel fraction should be determined with a radioactive source scan after burn-in. In addition, a group of 3 to 5 modules should be subjected to a more extreme program 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.**

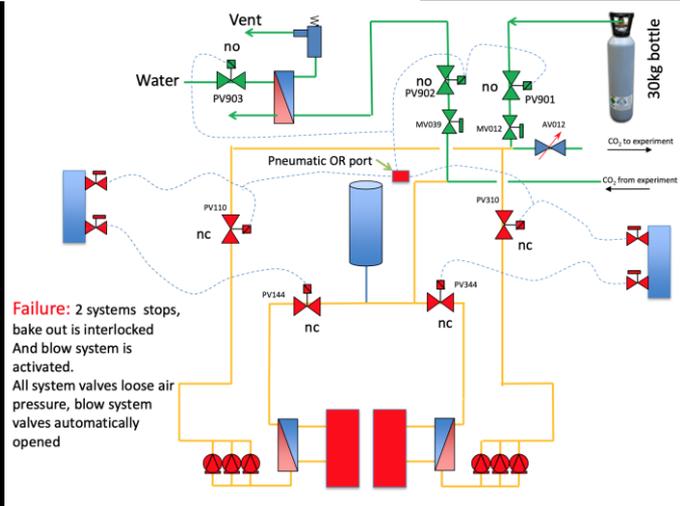
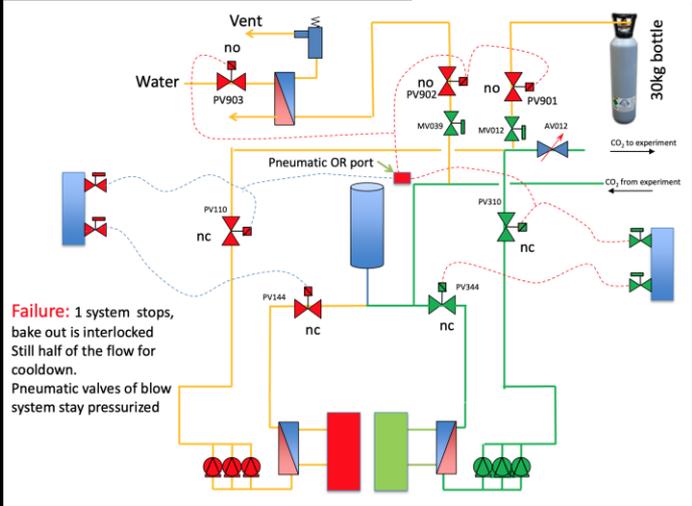
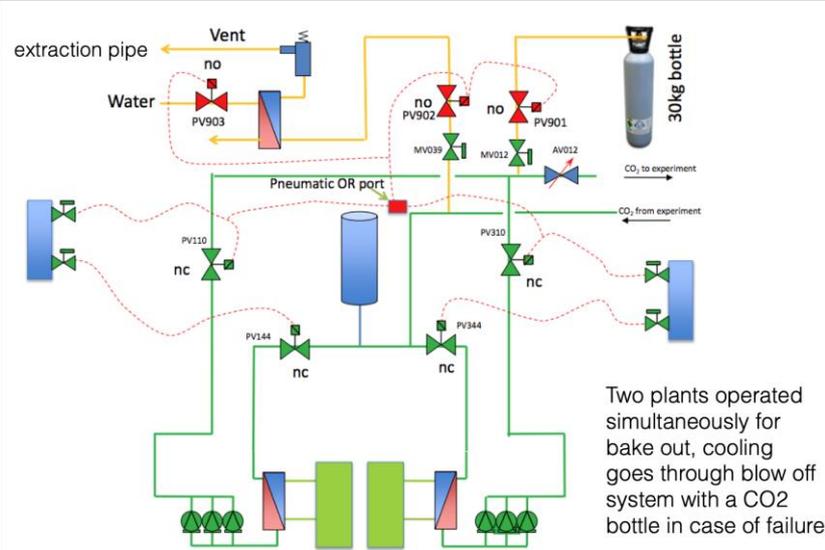
Temperatura Beam Pipe durante bake out



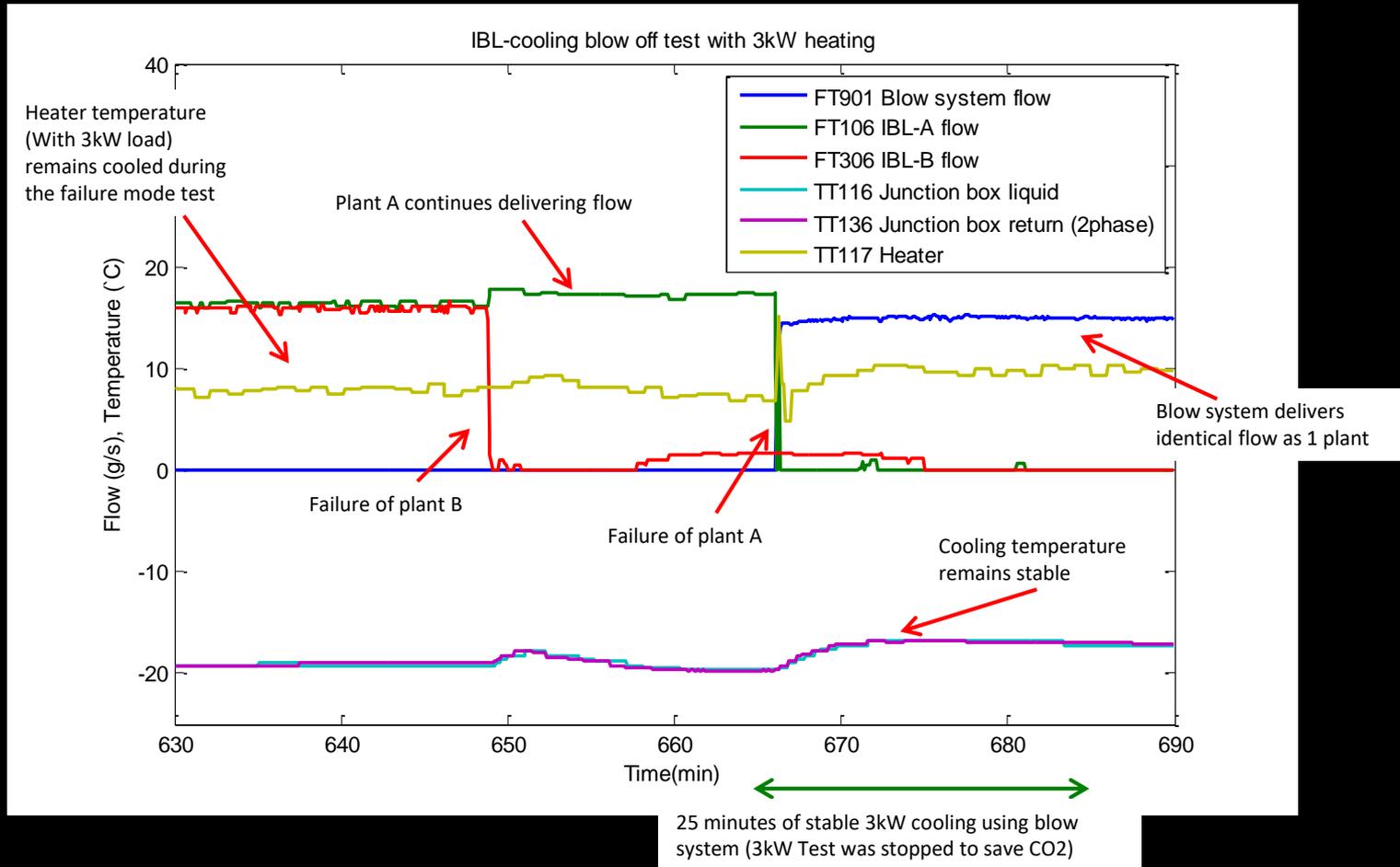
E lui?



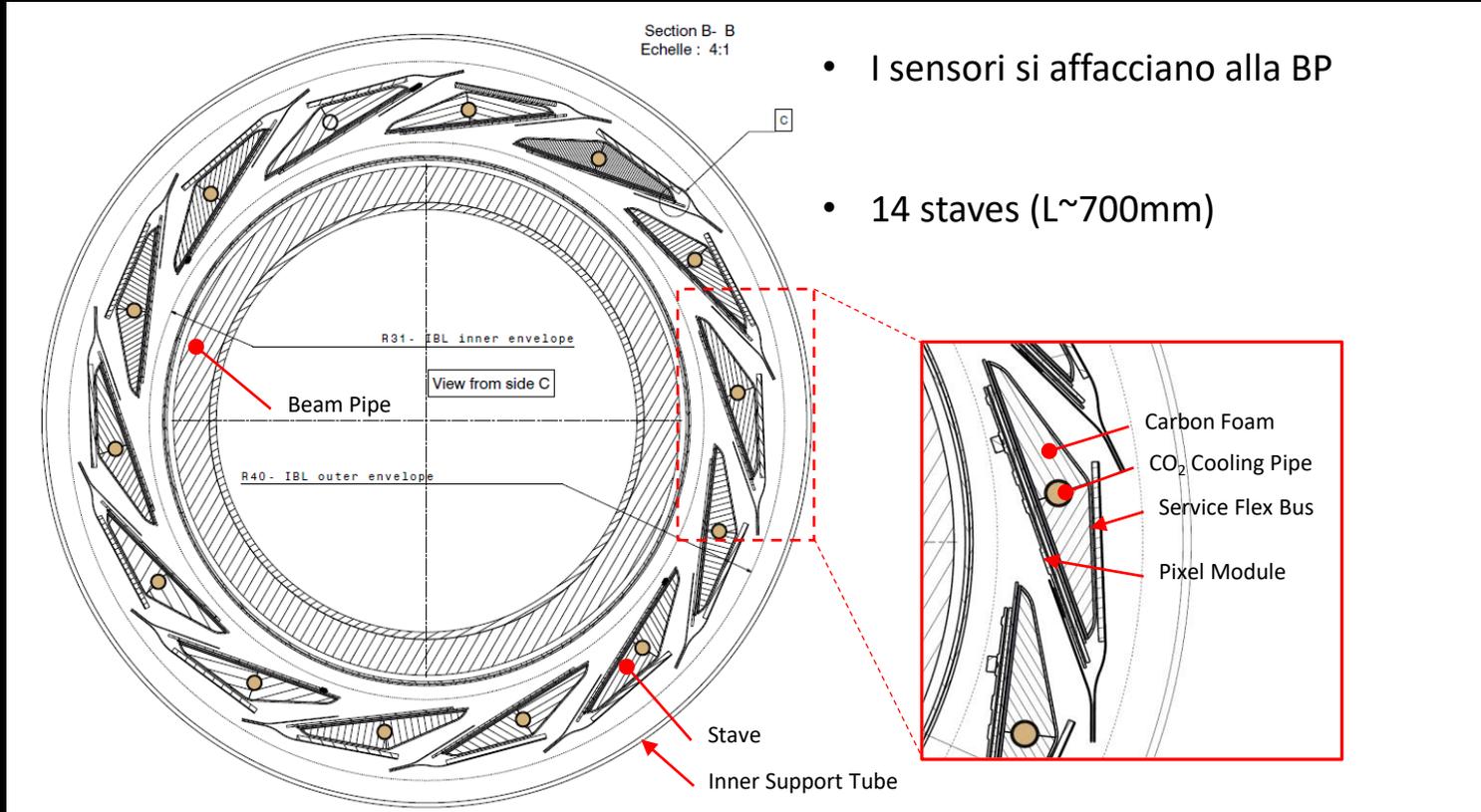
Failure modes and Blow-off system

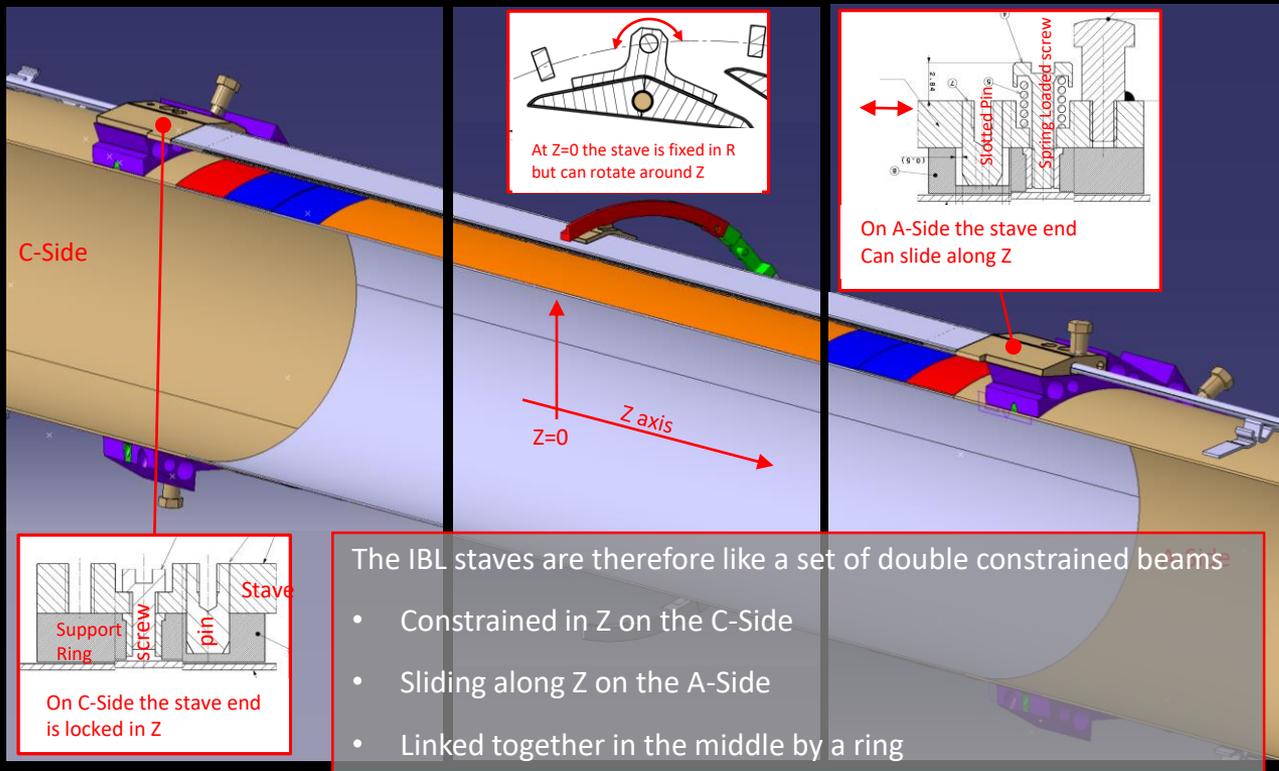


Failure modes tests



IBL twisting and bowing, magia?





Fantastico! Vorresti tracciare con una precisione del micron e il tracciatore si muove di decimi di mm....

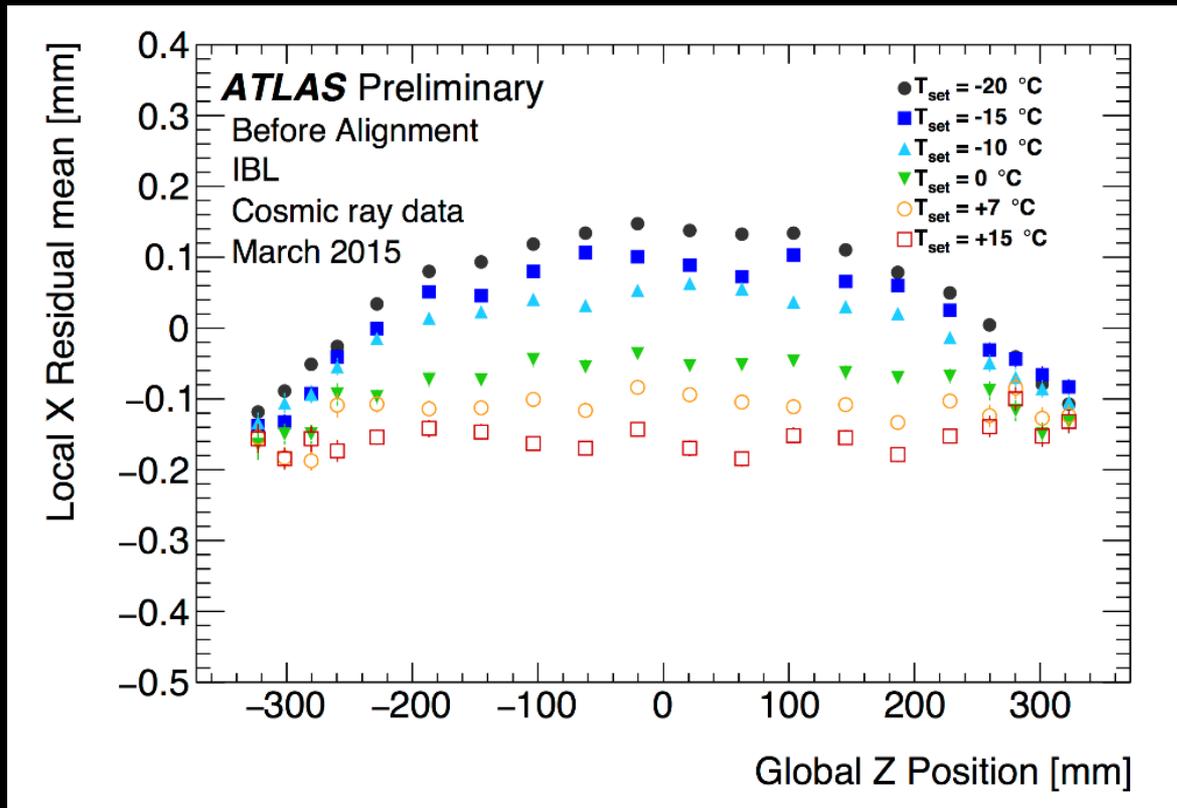
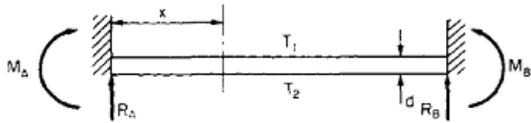


Figura by Danilo Giugni (ATLAS)



For bending $EI \frac{d^2y}{dx^2} = M_A + R_A x$.

For thermal effects $\frac{d^2y}{dx^2} = \frac{\alpha(T_2 - T_1)}{d}$

$EI \frac{d^2y}{dx^2} = EI \frac{\alpha(T_2 - T_1)}{d}$

∴ The combined differential equation is:

$EI \frac{d^2y}{dx^2} = M_A + R_A x + EI \frac{\alpha(T_2 - T_1)}{d}$

However, in the absence of applied loads and from symmetry of the beam:

$R_A = R_B = 0$
 $M_A = M_B = M$

$EI \frac{d^2y}{dx^2} = M + EI \frac{\alpha(T_2 - T_1)}{d}$

Integrating: $EI \frac{dy}{dx} = Mx + EI \frac{\alpha(T_2 - T_1)}{d} x + C_1$

Now at $x = 0, \frac{dy}{dx} = 0 \therefore C_1 = 0$

and at $x = L, \frac{dy}{dx} = 0 \therefore M = -EI \frac{\alpha(T_2 - T_1)}{d}$

Integrating again to find the deflection equation we have:

$EI y = M \frac{x^2}{2} + EI \frac{\alpha(T_2 - T_1)}{d} \frac{x^2}{2} + C_2$

When $x = 0, y = 0 \therefore C_2 = 0$

and, since $M = -EI \frac{\alpha(T_2 - T_1)}{d}$ then $y = 0$ for all values of x .

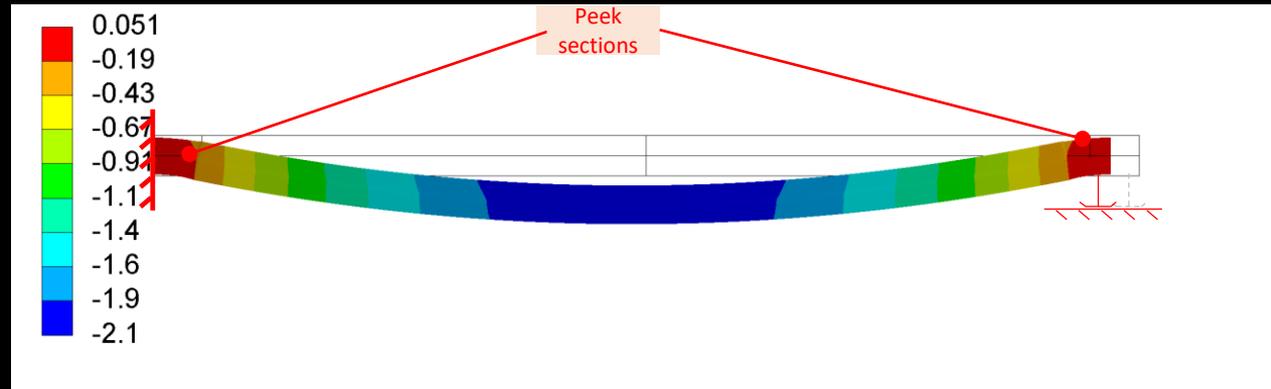
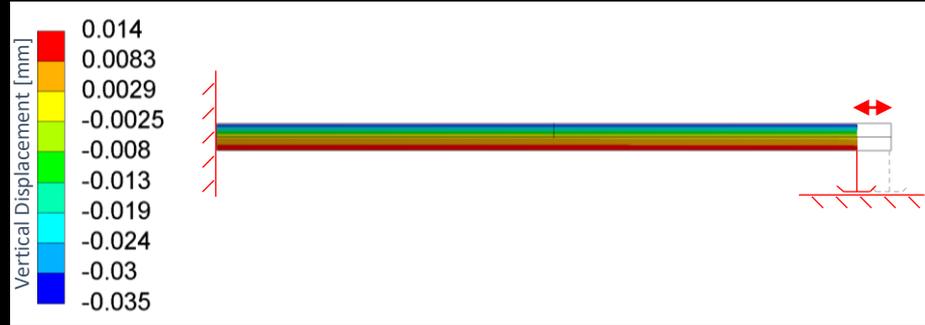


Figure by Danilo Giugni (ATLAS)

Ok, basta che il raffreddamento sia stabile con una precisione de 0.01K, che ci vuole?

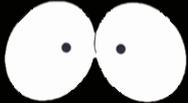
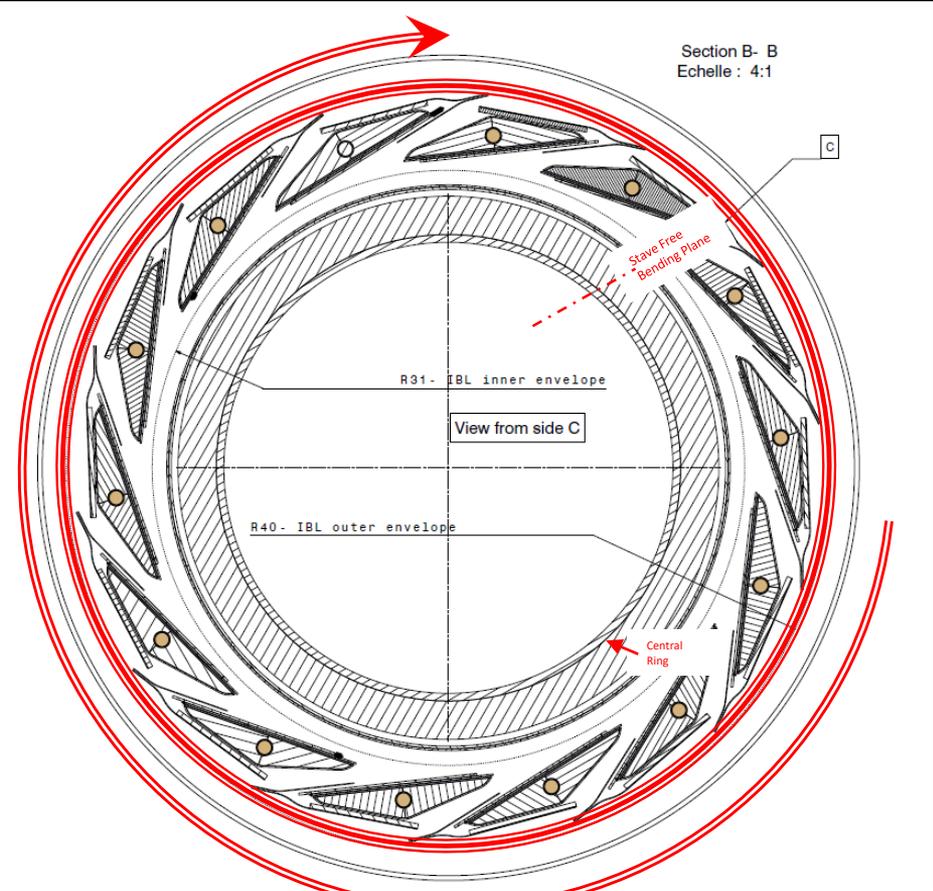
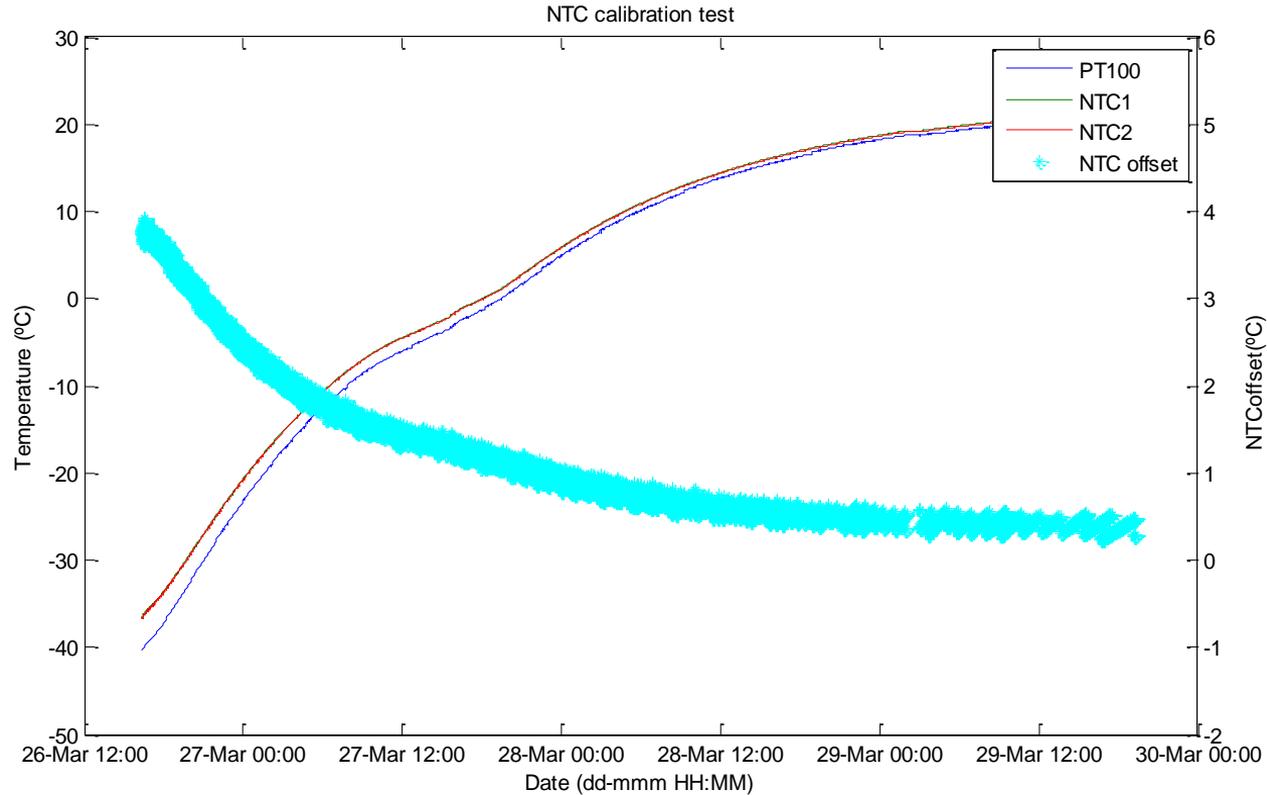
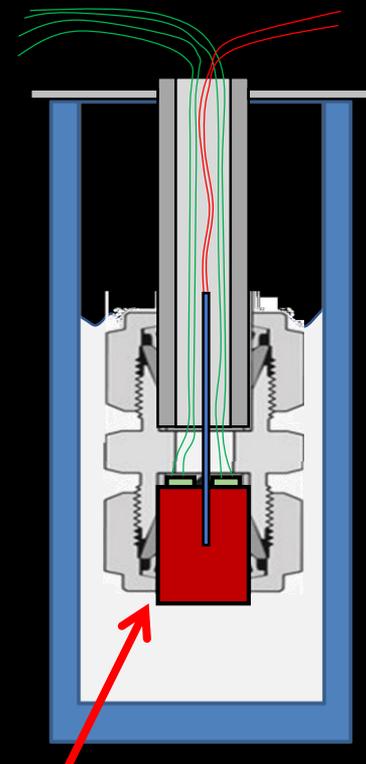
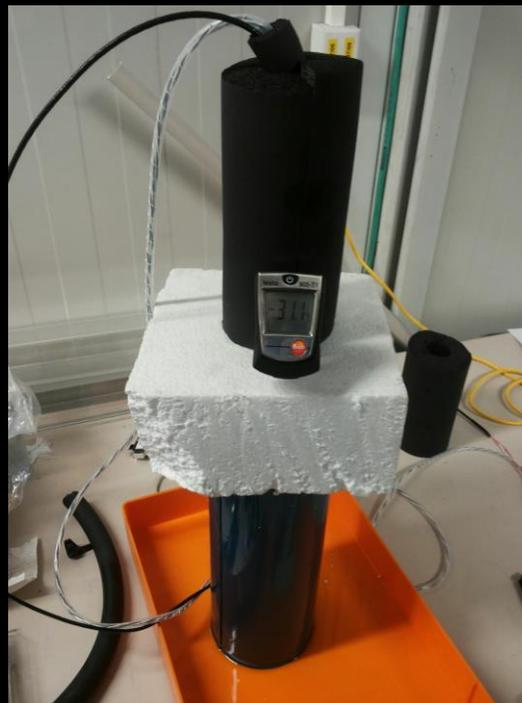


Figure by Danilo Giugni (ATLAS)

Un gioco da ragazzi se i sensori di T incollati sui tubicini di raffreddamento di IBL non sono stati mai calibrati



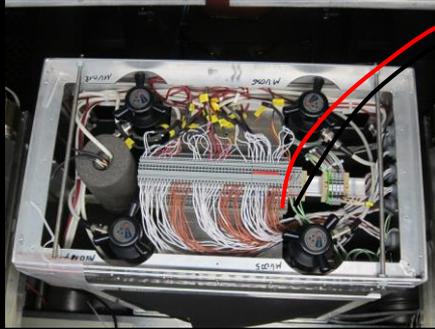
Come calibrare dei sensori che non puoi raggiungere



The glycol was cooled to -40°C and warmed up slowly over time to calibrate over the full range

Copper block with a PT100 and 2 NTC sensors dipped in cold glycol stored in a Dewar.

Calibration of cooling pipe NTC's in sector 5



Connect 1 PT100 to the junction box and archive the data using the cooling system



Cool the sensors all together in glycol bath



Connect 2 NTC 's to the patch panel near manifold box



Calibration set-up installation



1. Pre cooling in USA15



2. Cold transport to sector 5



3. Set-up installed in sector 5



4. And happy faces!

Slide by B. Verlaat

“Thanks to the great help of Piotr, Claudio, Lukasz and George! (And the delay in LHC....☺)”

2015

Tracciamento in Phase-II



Ricostruire le traiettorie delle particelle e' un processo ad alta difficolta' computazionale

- *a priori cresce esponenzialmente con il numero di punti rilevati nello spazio*

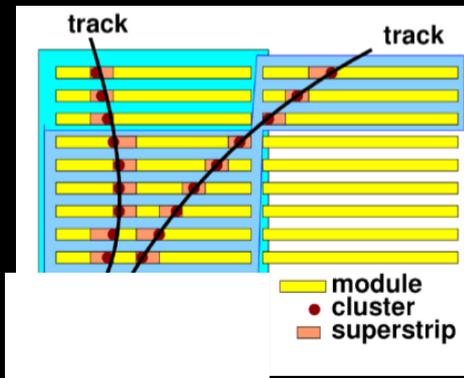
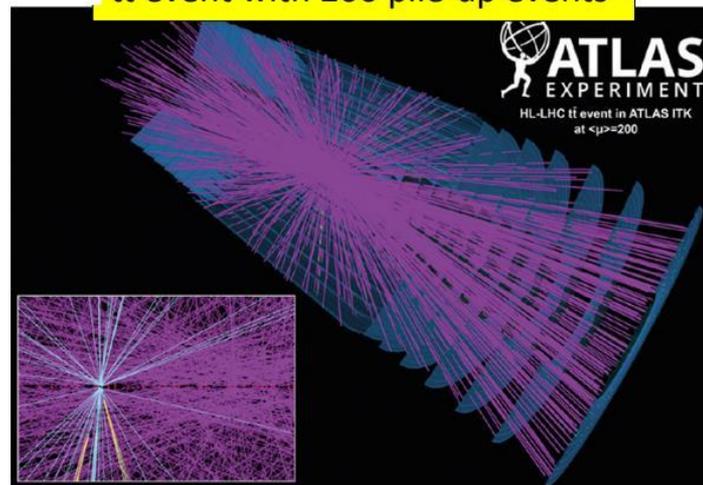
D'altra parte, conoscere le tracce e' fondamentale per una selezione efficace a livello di trigger

- *per esempio per separare getti di particelle da elettroni*

Stime con il software attuale indicano un centro di calcolo necessario per effettuare tracciamento a 1 MHz sarebbe incompatibile con l'infrastruttura esistente

- *miglioramenti negli algoritmi e nel software potrebbe cambiare questa prospettiva*

$t\bar{t}$ event with 200 pile-up events



Hardware Track Trigger

HTT (Hardware Track Trigger) e' un sistema altamente parallelo per effettuare tracciamento

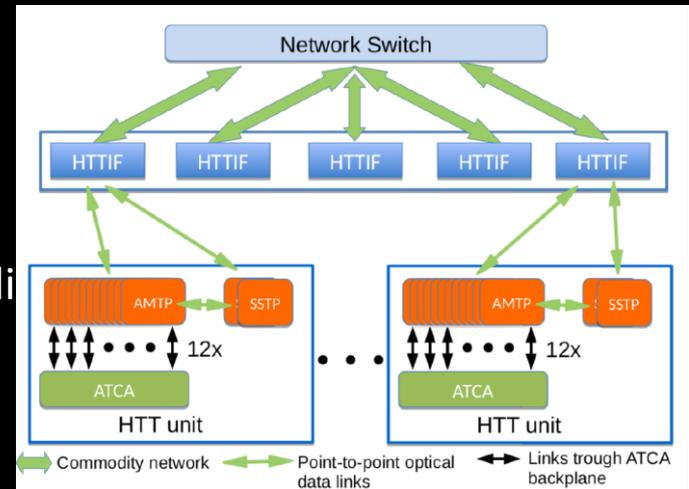
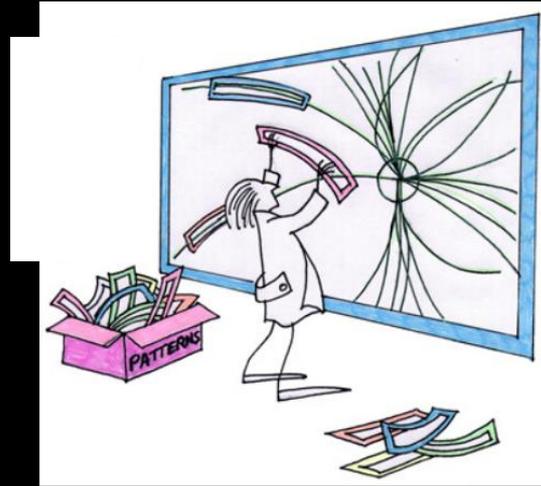
Elettronica dedicata

memorie CAM (ASIC) per contengono possibili modelli di tracce precalcolati

FPGA eseguono fit per raffinare il risultato

Approccio al tracciamento ampiamente sviluppato all'INFN (Frascati/Pisa)

con collaborazione di altri istituti internazionali



Tipica discussione con sviluppatori boards

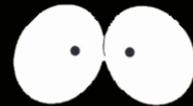
Io: Hey vecchio, ho fatto dei tests e puoi usare al massimo 400 W per ogni board altrimenti il rack si scioglie

Loro: ok nessuno problema, visto che volevo usarne 800 raddoppio il numero di racks

io: ah se ci stanno nella counting room underground che problema c'è?

Loro: devono però stare tutti nelle prime due file vicine al muro di separazione con la caverna sperimentale altrimenti i cavi sono troppo lunghi e il signal latency ci fotte

Io: spetta che chiedo il terreno del vicino...



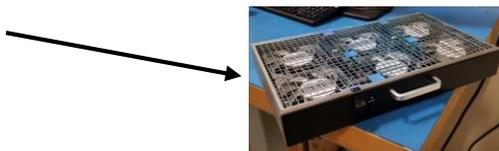
Perchè non aggiungere mezzo metro in altezza

“Cooling tower”

- 2x **CERN standard Schroff ATCA crate** – each equipped with 2 fan trays (1 top and 1 bottom)



- 1x **NOT** CERN standard ASIS ATCA crate – equipped with 3 fan trays on the top and one on the bottom



- Different LB sets => different cooling efficiency:

ASIS LB = a lot of heat sinks => higher air resistance => **better cooling efficiency**

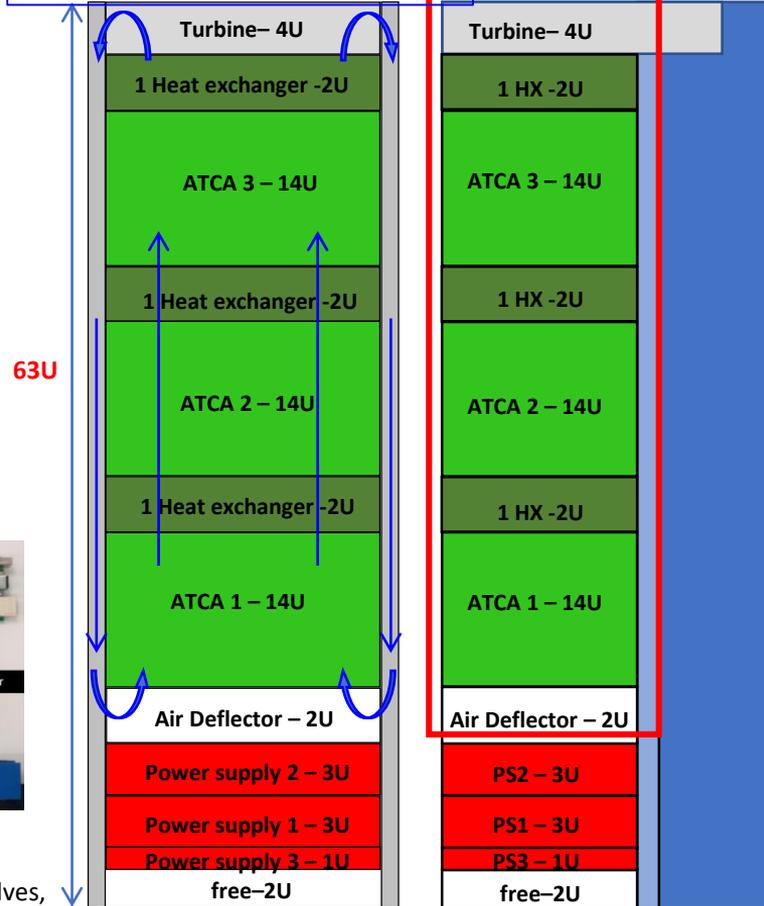
Old Comtel LB = no heat sinks => low air resistance => **high temperature peaks on axis of the fans**



New Comtel LB = not equipped with any sensors => **no readout**

Important note: To prolong the life time of the electrical equipment installed in the ATCA shelves, maximum target temperature on boards is **50C**.

Airflow indication in the rack =>



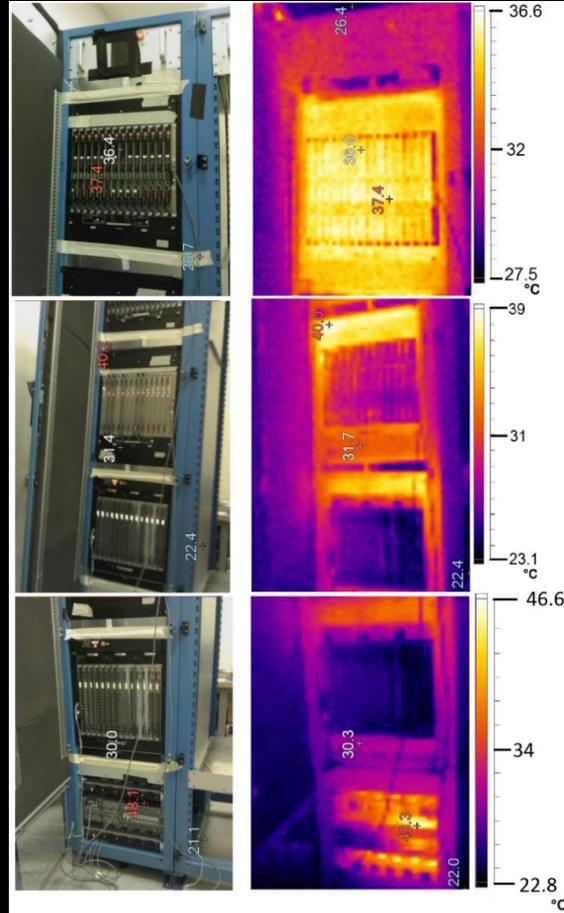
Test di performance per qualificare la scelta

3 anni di lavoro

6 studenti e 2 dei quali si sono innamorati

Una sala per racks aggiuntiva da costruire in superficie

Ma siamo riusciti a infilare il motore di una Ferrari nella Fiat 500



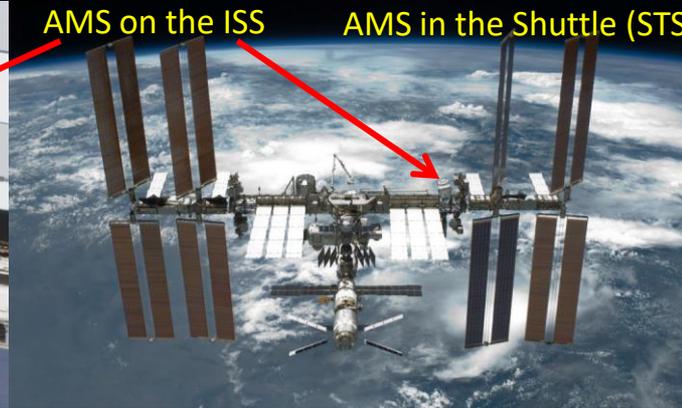
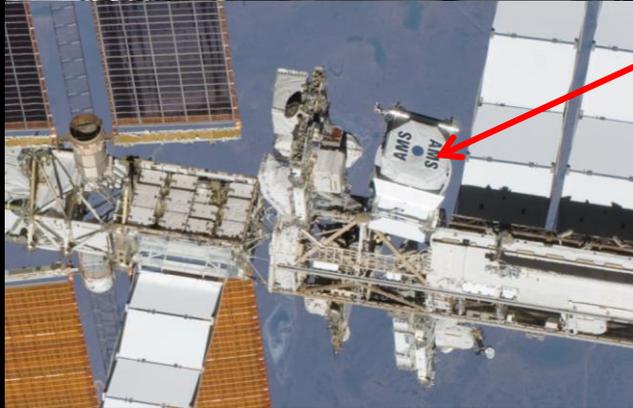
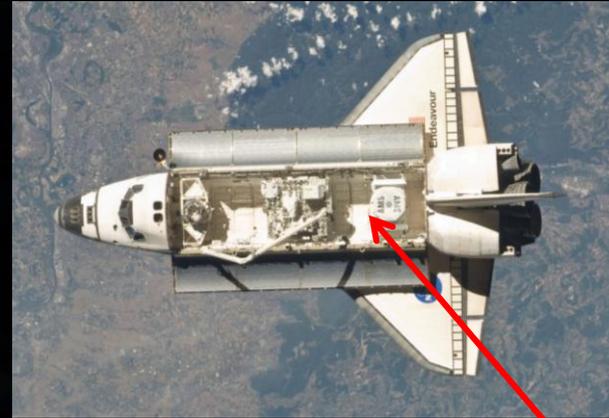
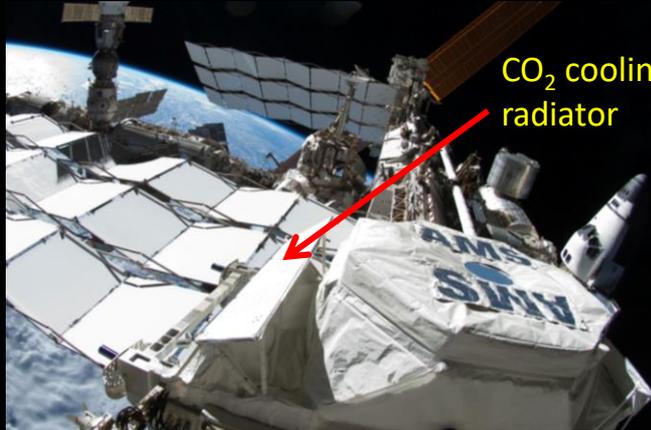
15/11/2019

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



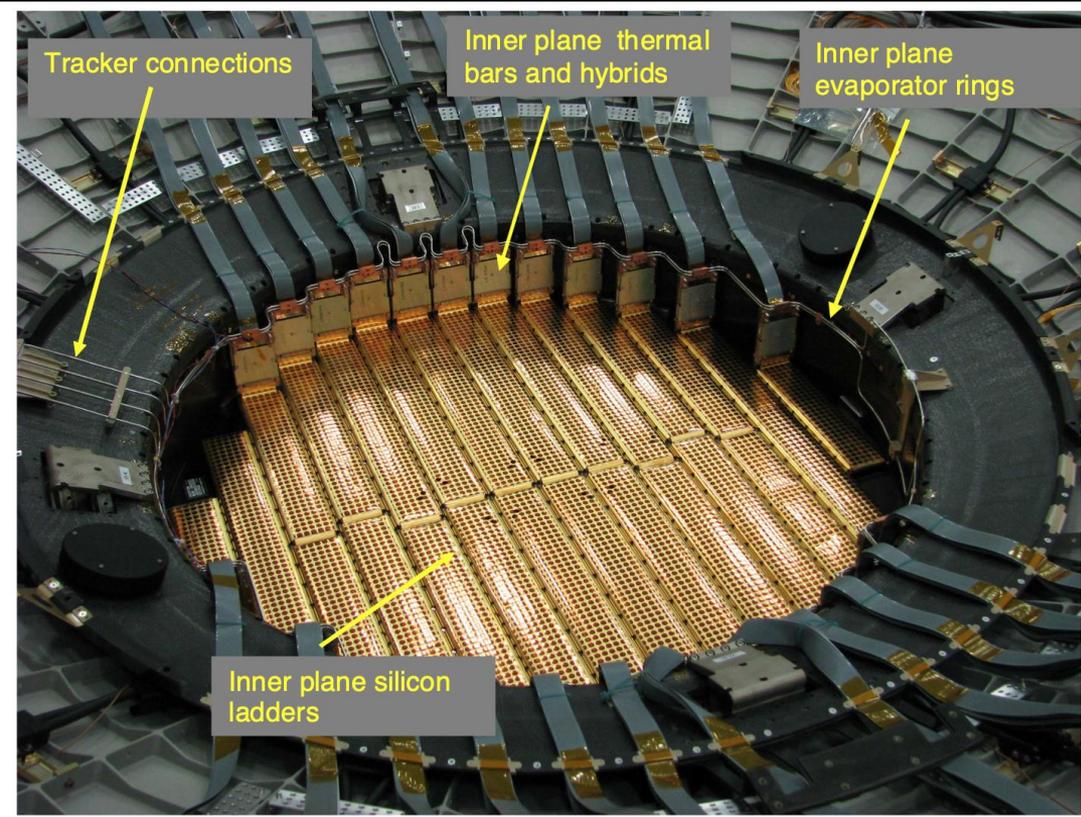
CO₂ cooling at CERN comincia con AMS

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

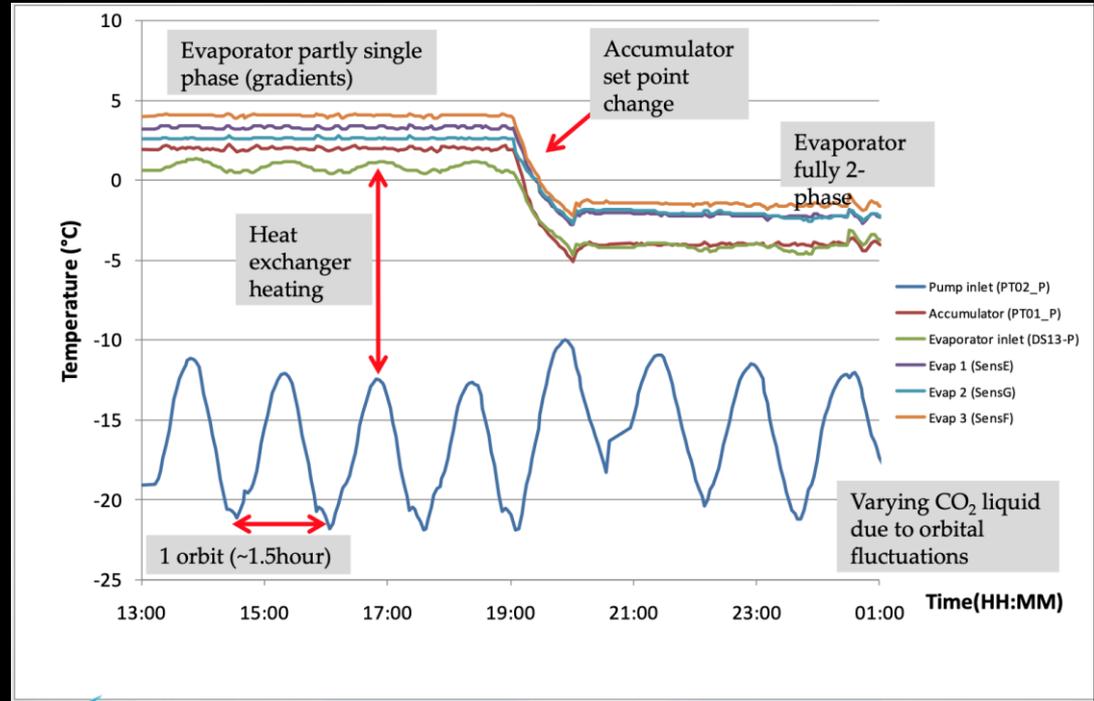
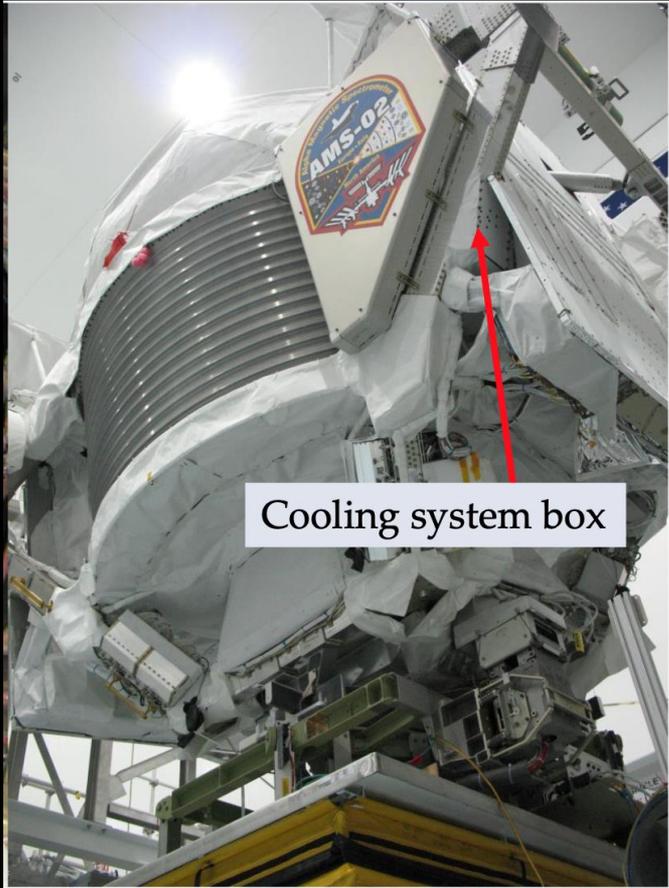


AMS in the Shuttle (STS-134, May 2011)

Il tracciatore di AMS-02

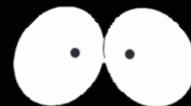


Il sistema funzionava in modo soddisfacente



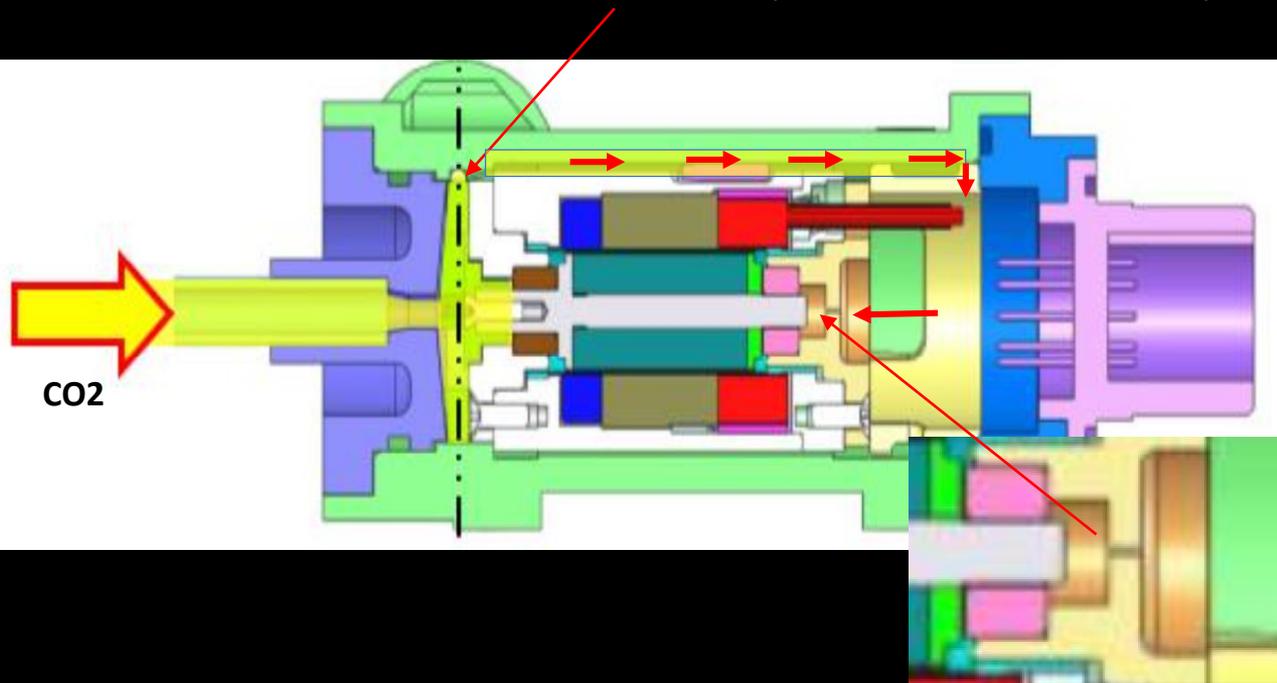
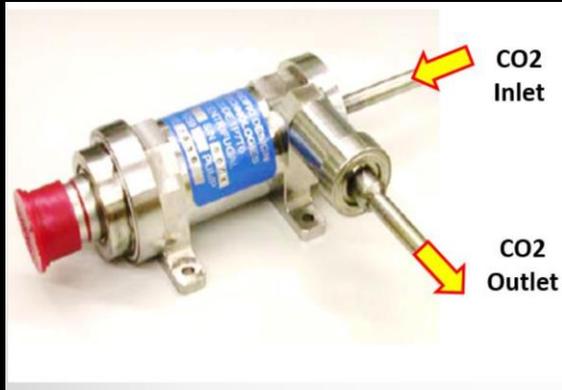
Maggio 2015, ricevo una telefonata...

...Houston abbiamo un problema.



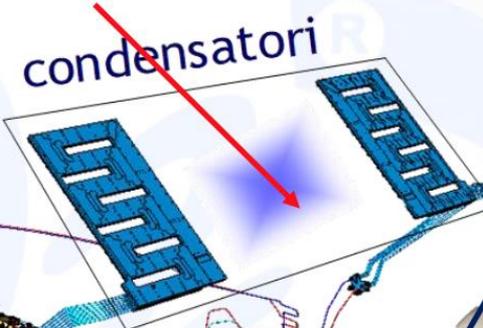
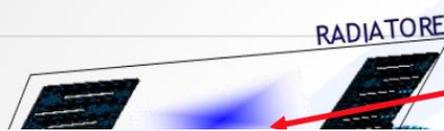
Perché Luca P. si è fatto queste 4 passeggiate

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

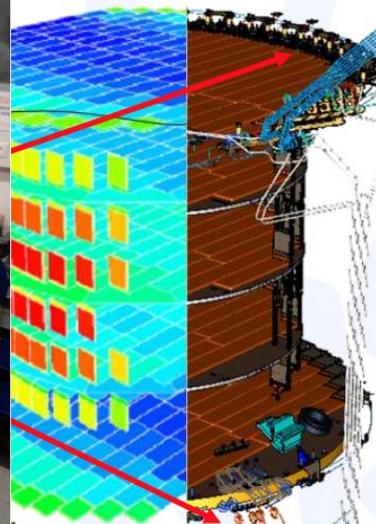


Il problema delle pompe di AMS sta qui...e su Mars Pathfinder non usavano CO2

Condensers reused

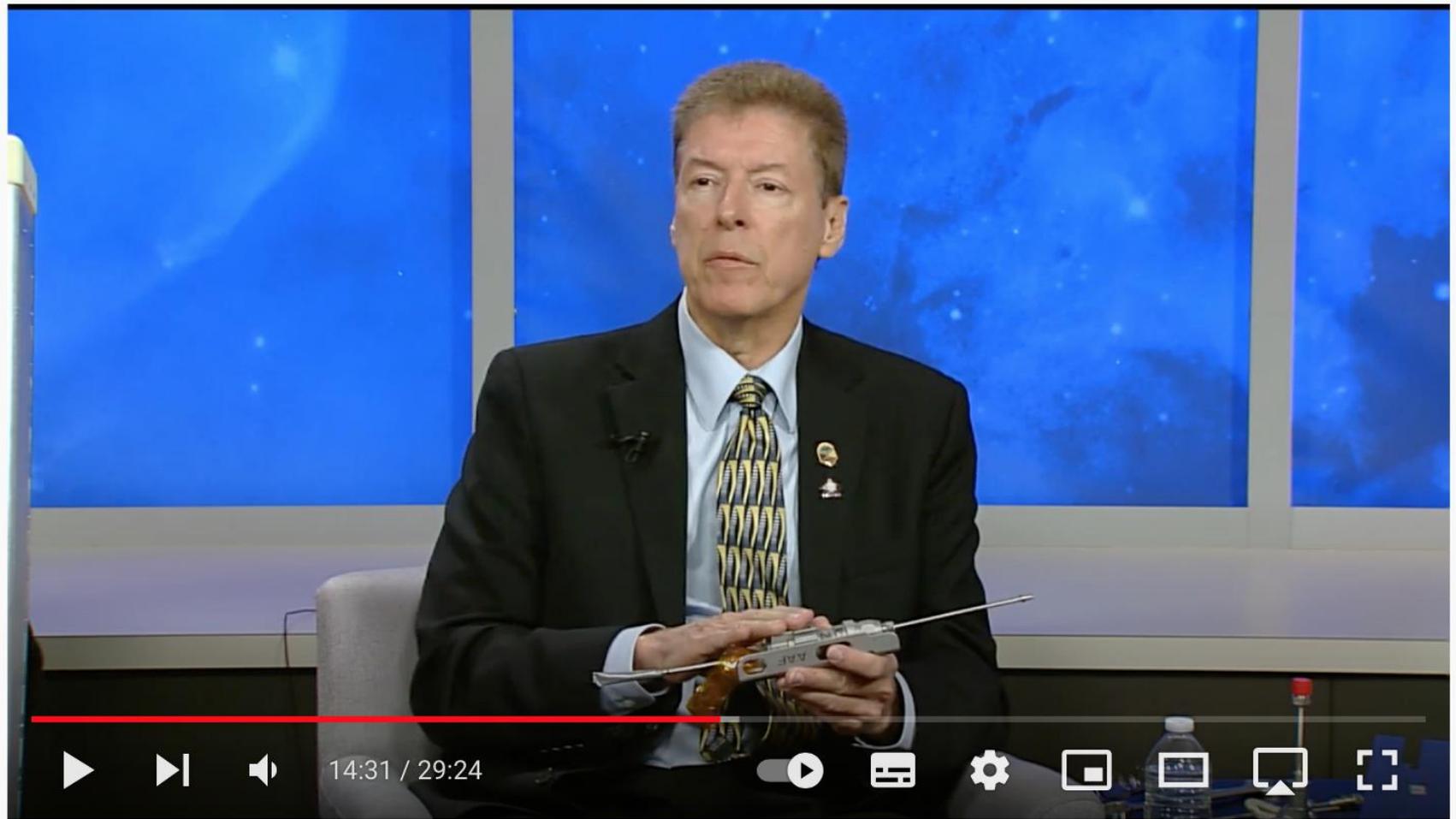


Cut the line, bend them outside and connect to new system



New system

Old system



Expedition 61 AMS Overview Briefing - November 12, 2019



My shop at home in Houston, Texas

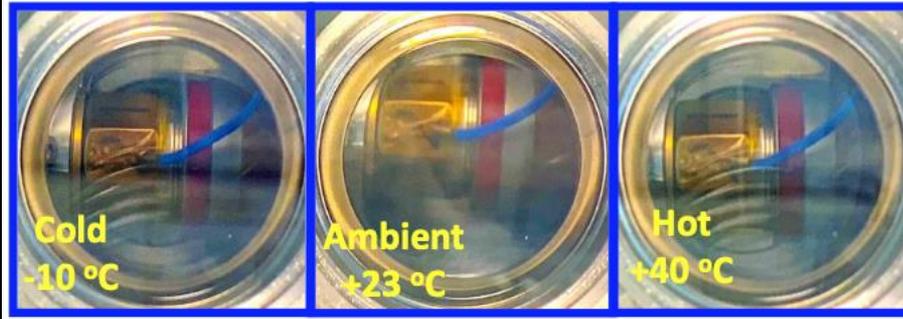


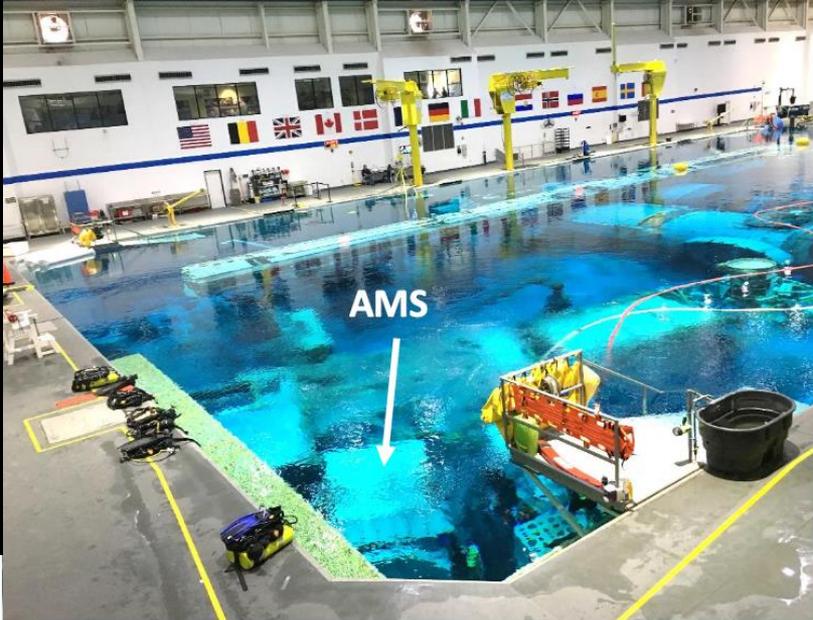
Photos by Ken Bollweg (NASA)

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



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





June 4, 2021
Ken Bollweg



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
Totals	27	34	34	95



June 4, 2021
Ken Bollweg

Il 2019 per AMS



Photos by Ken Bollweg (NASA)



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



SCIENCE



ENGINEERING

Grazie