

# The Conditioning and Operation of HWR Cryomodules for C-ADS

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Cryogenic Department / IMP, CAS

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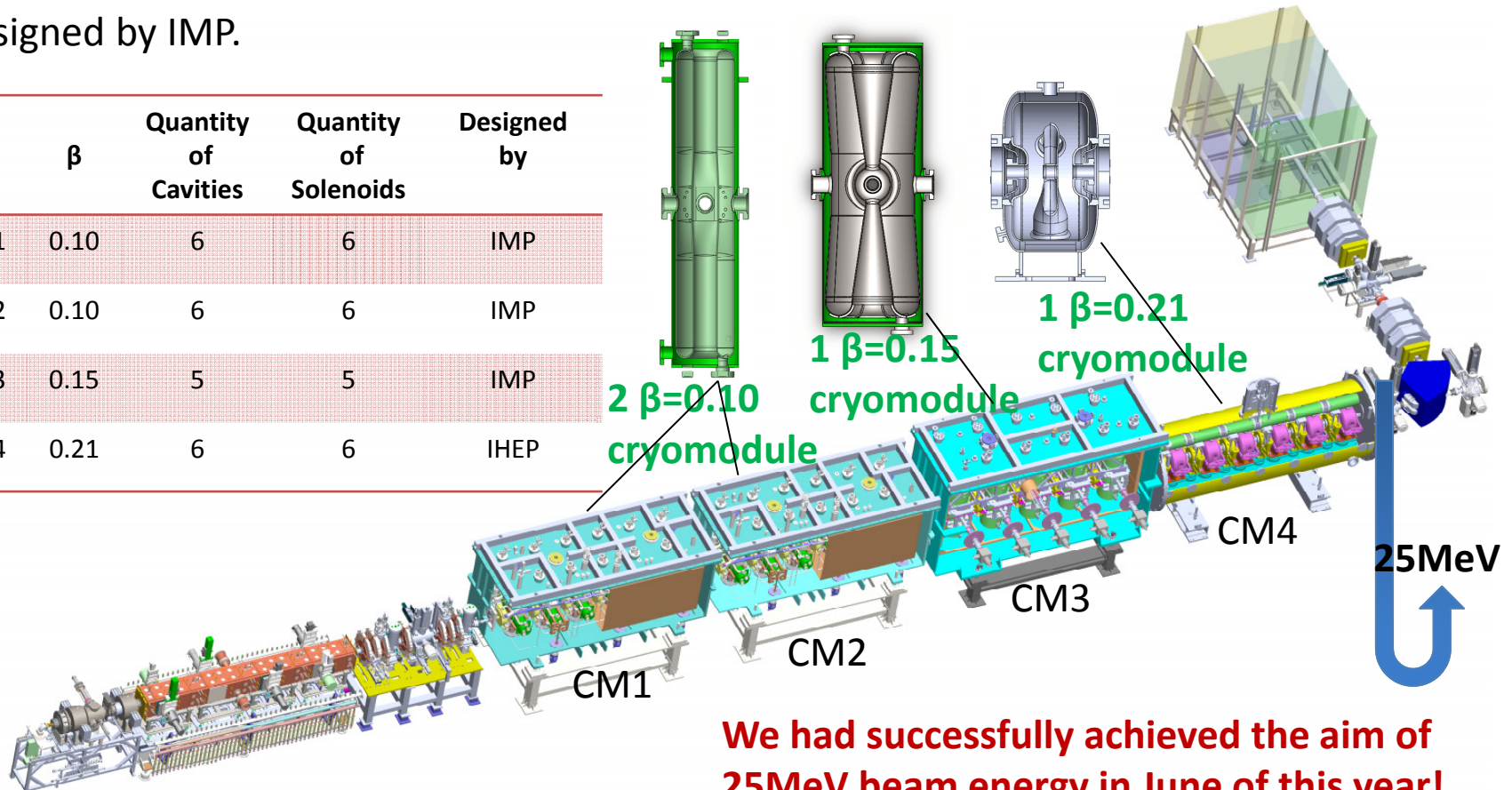
2017.07.20

# Overview



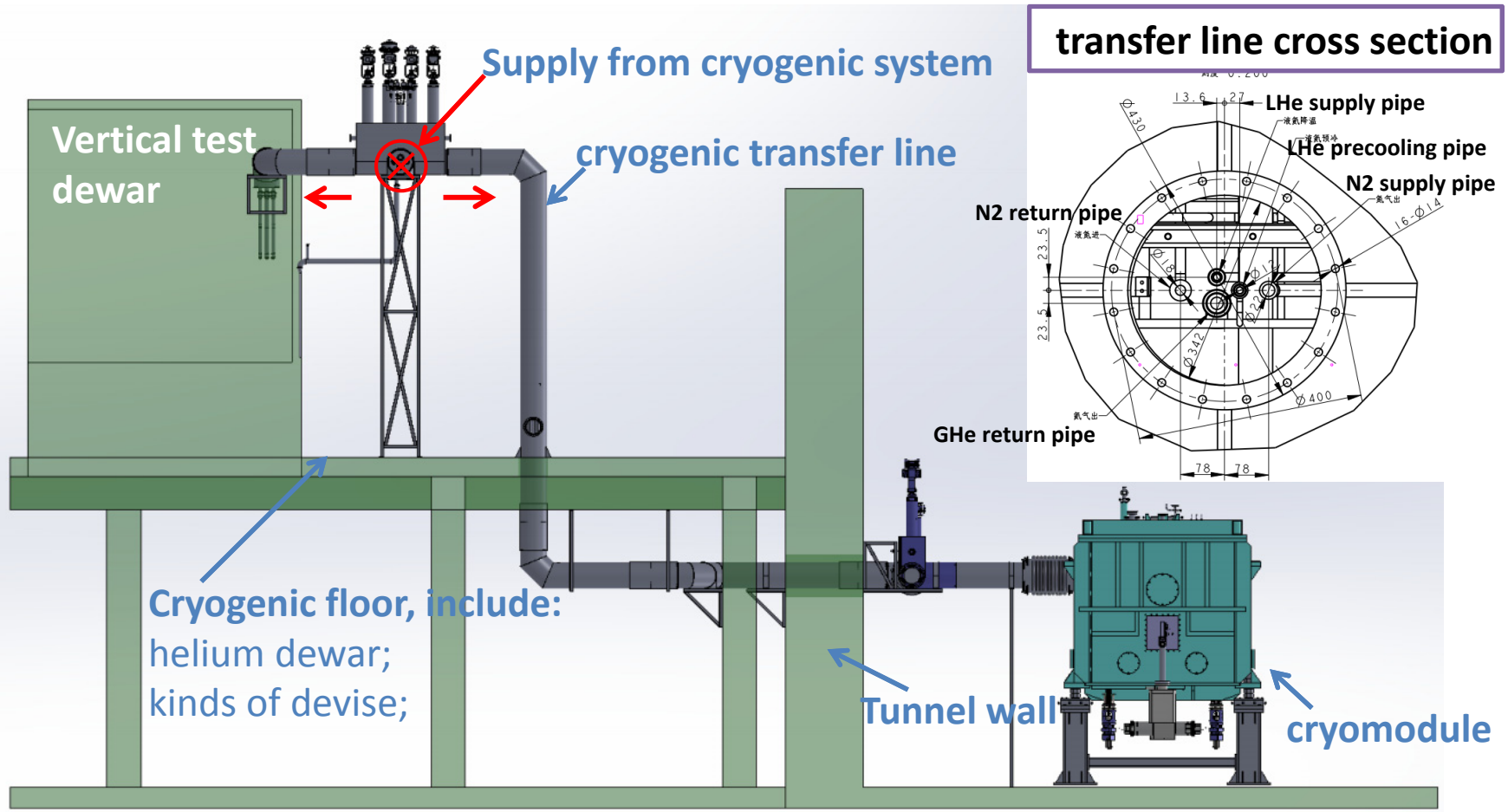
C-ADS Injector II Linac includes four cryomodules for three types of cavities which can accelerate proton energy to 25MeV. CM4 was designed by IHEP, the others was designed by IMP.

|     | $\beta$ | Quantity of Cavities | Quantity of Solenoids | Designed by |
|-----|---------|----------------------|-----------------------|-------------|
| CM1 | 0.10    | 6                    | 6                     | IMP         |
| CM2 | 0.10    | 6                    | 6                     | IMP         |
| CM3 | 0.15    | 5                    | 5                     | IMP         |
| CM4 | 0.21    | 6                    | 6                     | IHEP        |



**We had successfully achieved the aim of 25MeV beam energy in June of this year!**

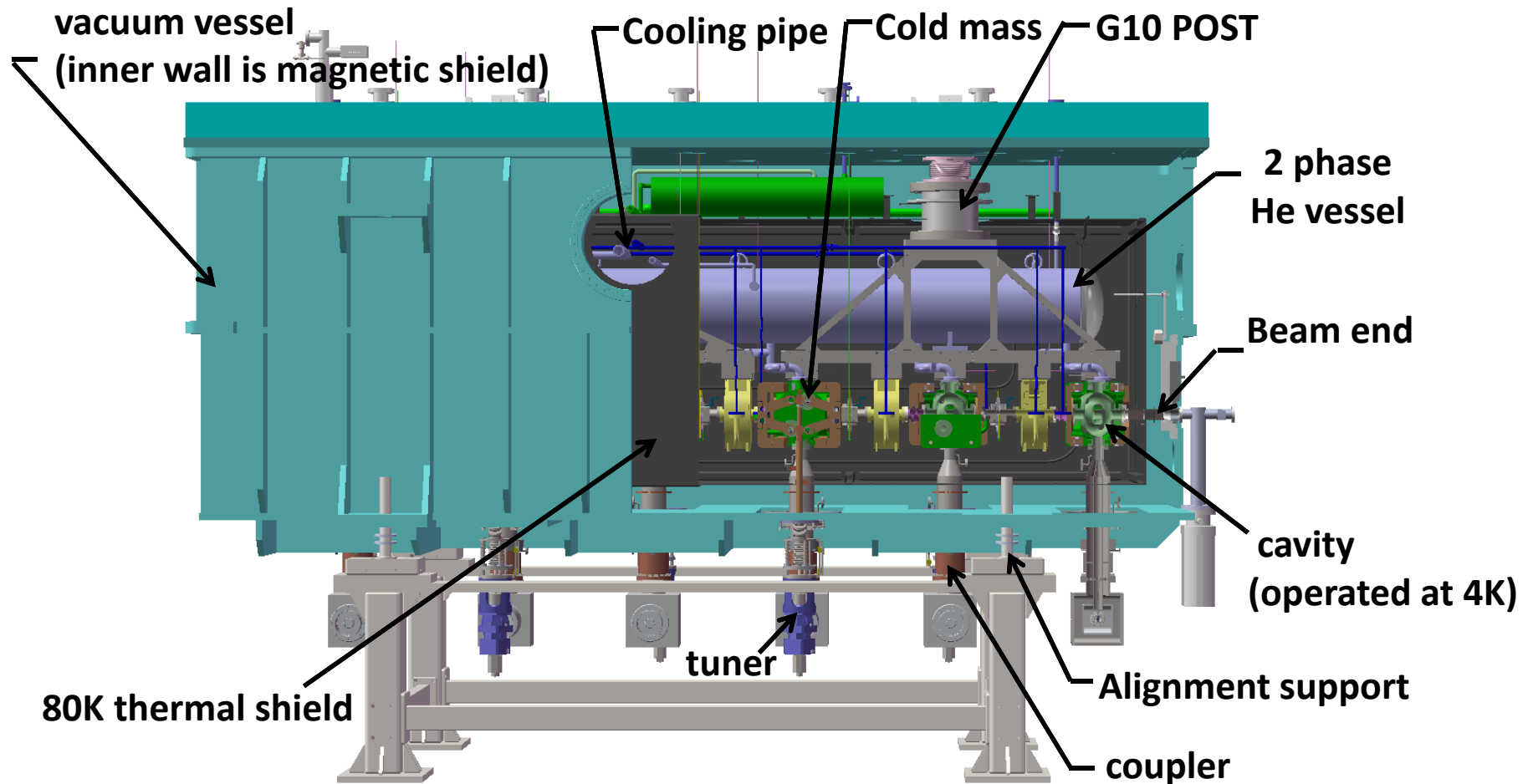
# 4K cryogenic transfer line



Total length  
40m

The heat load  
0.2W/m

# Cryomodule design

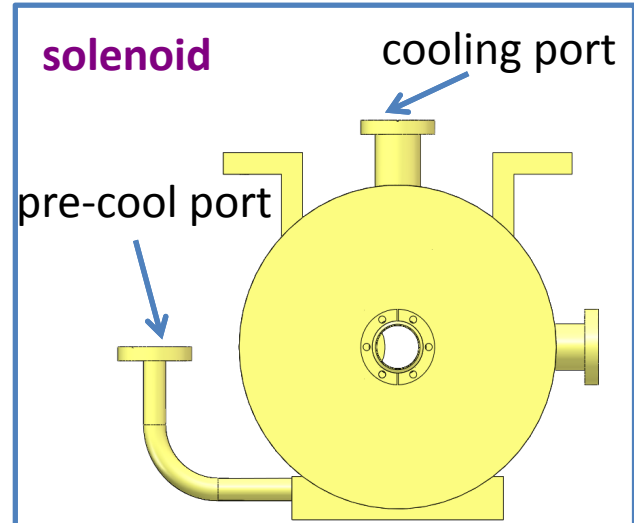
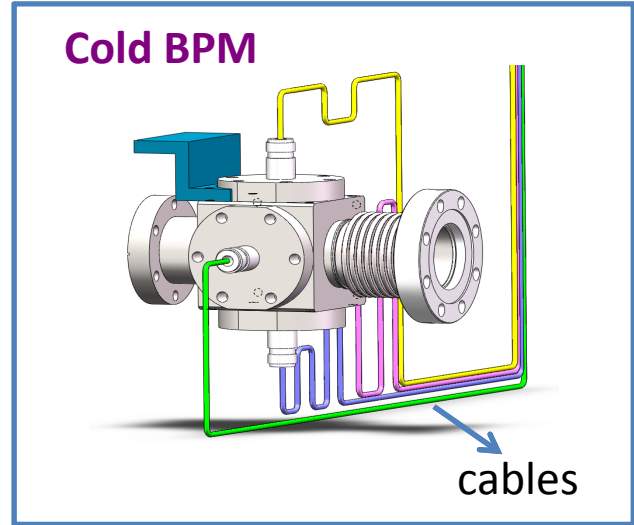
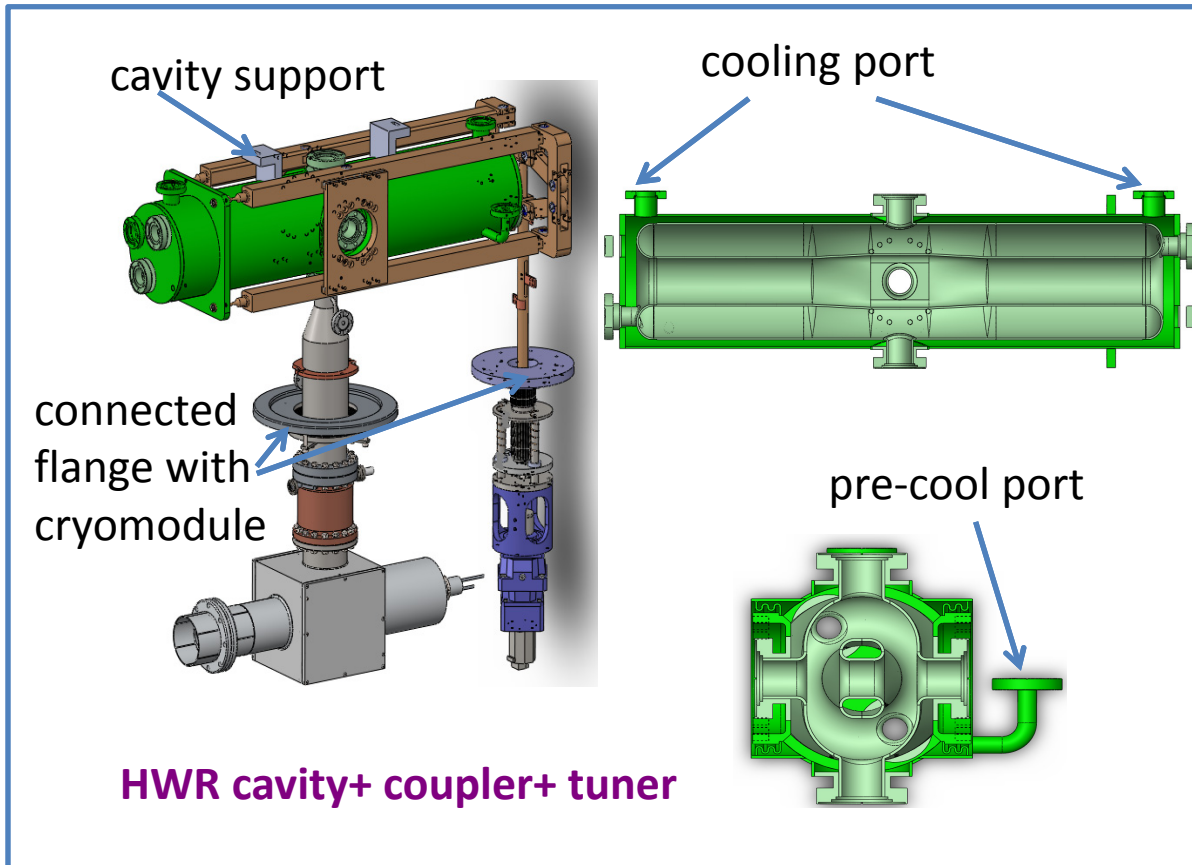


Cryomodule1 and 2 have the same design, each one contains 162.5MHz,  $\beta = 0.10$  dressed HWR cavities and tuner, coupler, SC solenoids, Cold BPM.

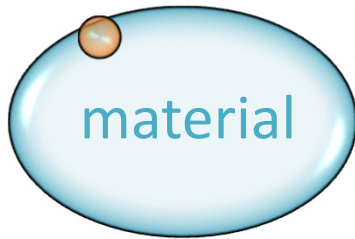
# Cryomodule design



- an interface with cold mass



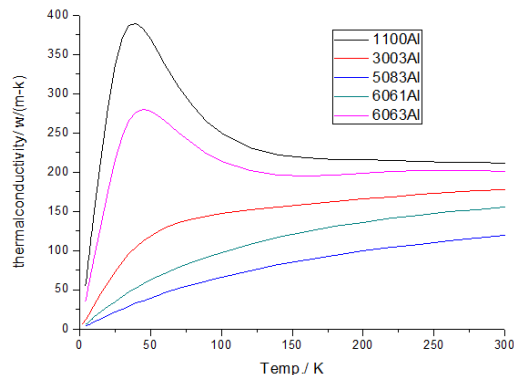
# Cryomodule design



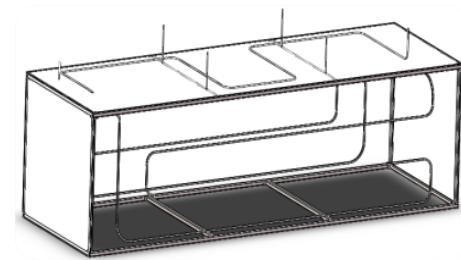
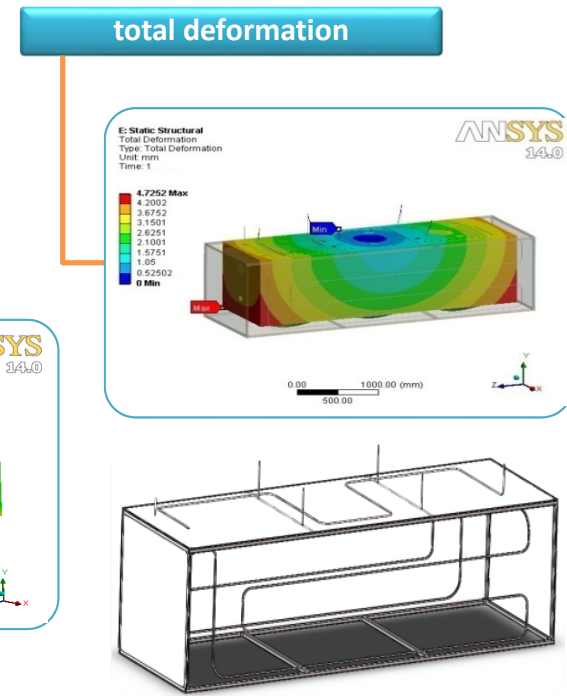
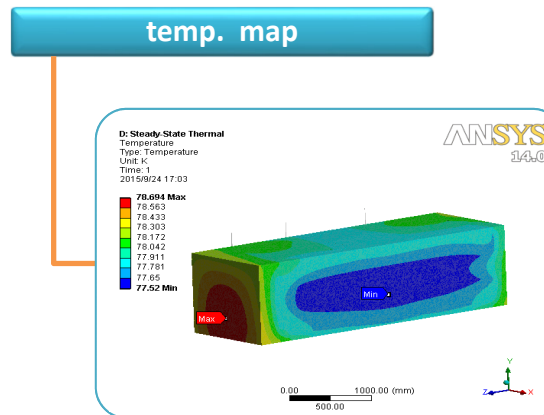
| material   | Thermal Contraction        |                          | Thermal Conductivity |            |
|------------|----------------------------|--------------------------|----------------------|------------|
|            | $\Delta L / L (300 - 100)$ | $\Delta L / L (100 - 4)$ | $q_{300-77}$         | $q_{77-4}$ |
| 316L       | $296 \times 10^{-5}$       | $35 \times 10^{-5}$      | 2705                 | 326        |
| AL         | $415 \times 10^{-5}$       | $47 \times 10^{-5}$      | 20830                | 2322       |
| G10-warp   | $279 \times 10^{-5}$       | $47 \times 10^{-5}$      | 143                  | 19         |
| G10-normal | $602 \times 10^{-5}$       | $115 \times 10^{-5}$     | 97                   | 15         |

## ◆ Thermal radiation shield

- 1100 Aluminum plate, 3mm
- weight: 240 kg



thermal conductivity of AL



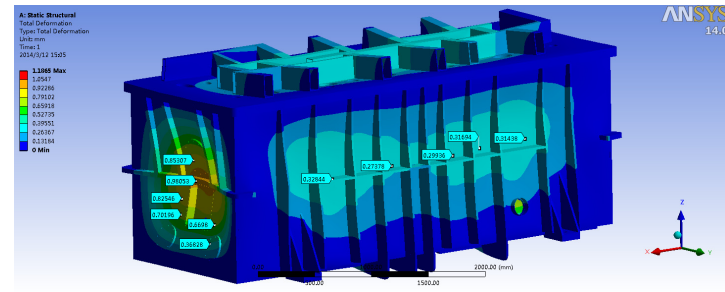


# Cryomodule design



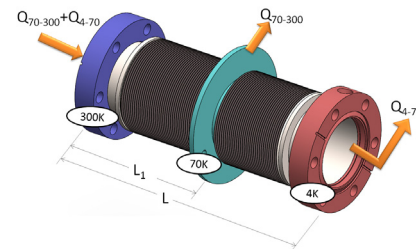
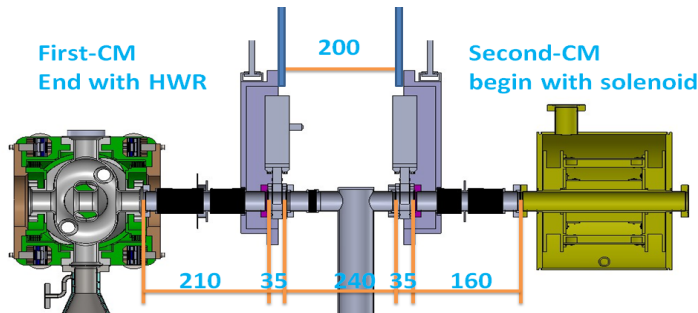
## Vacuum vessel

- Outer dimension: 4.2m × 1.5m × 1.6m
- Material: 316L SUS
- insulating vacuum: 10<sup>-4</sup>Pa
- beam vacuum: 10<sup>-7</sup>Pa



## Cold-to-warm transition

- end bellows design
- low heat load of helium and nitrogen
- narrow assemble space



$$Q_{70-300} + Q_{4-70} = \frac{A}{L_1} \int_{70}^{300} k(T) dT$$

$$Q_{4-70} = \frac{A}{L-L_1} \int_4^{70} k(T) dT \quad (4)$$



# Cryomodule design

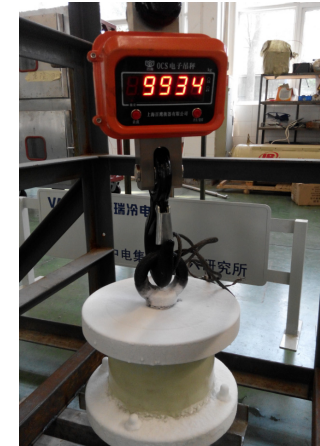


## ◆ G10 POST

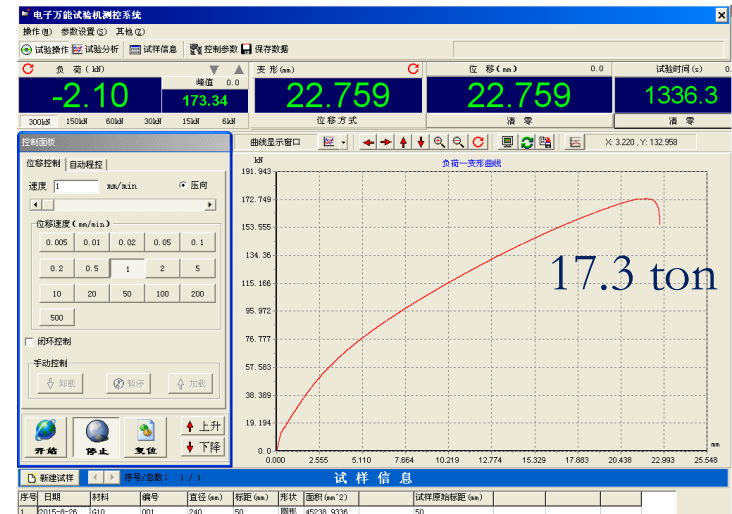
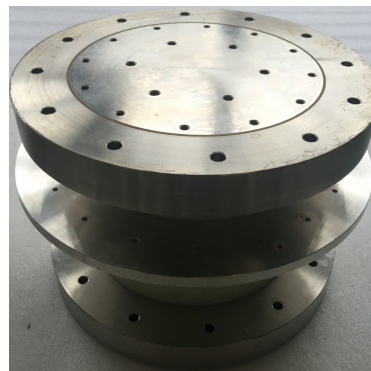
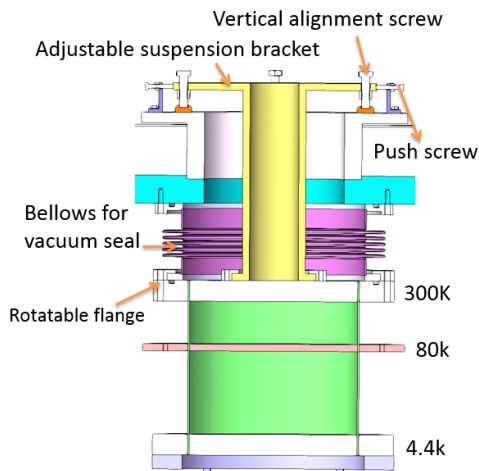
- decrease thermal conduction from 4K to room temp. .
- 80K thermal intercept
- design weight: 5 ton
- test weight: 9.9ton



pull test



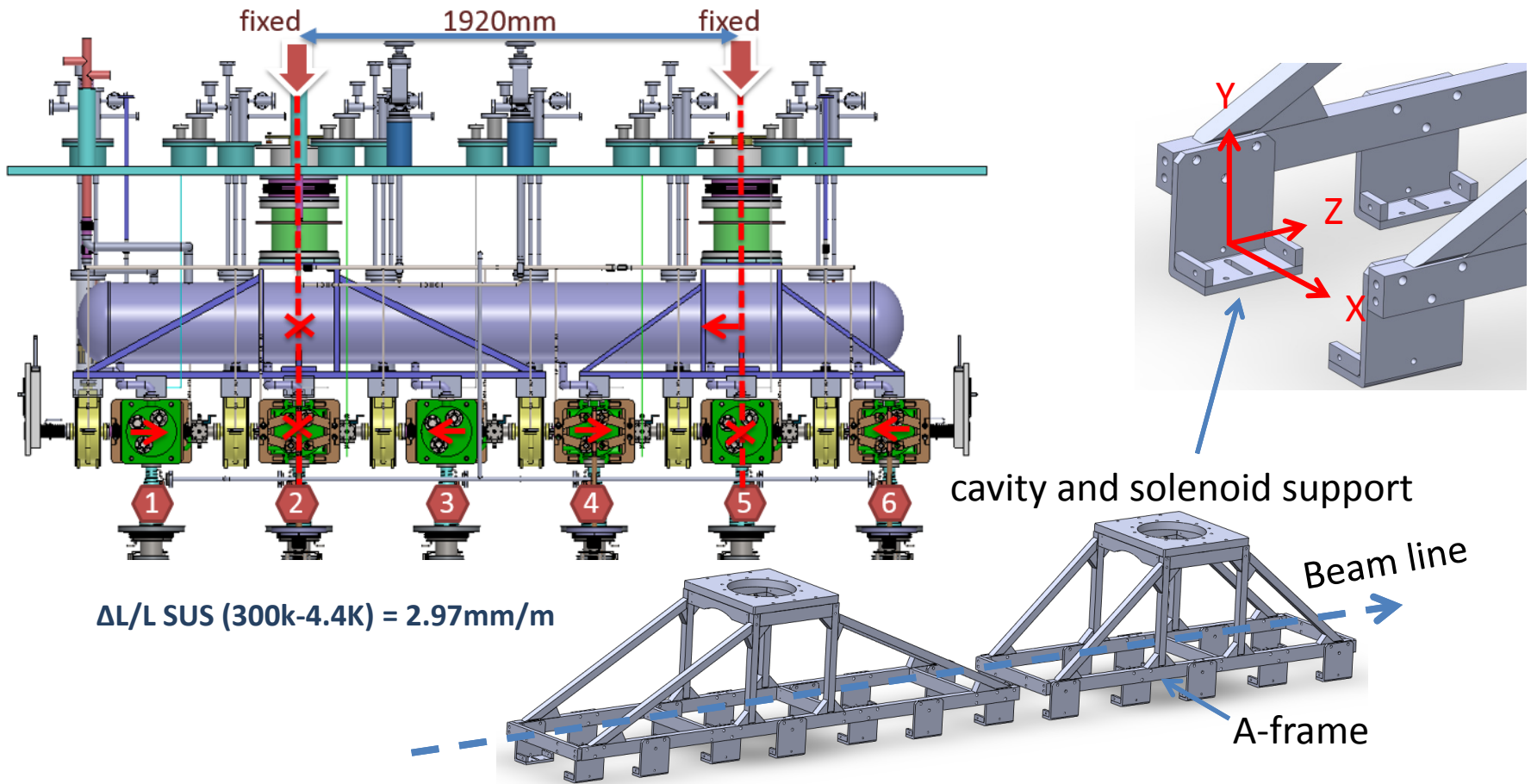
cold test



destructive test



# Cryomodule alignment

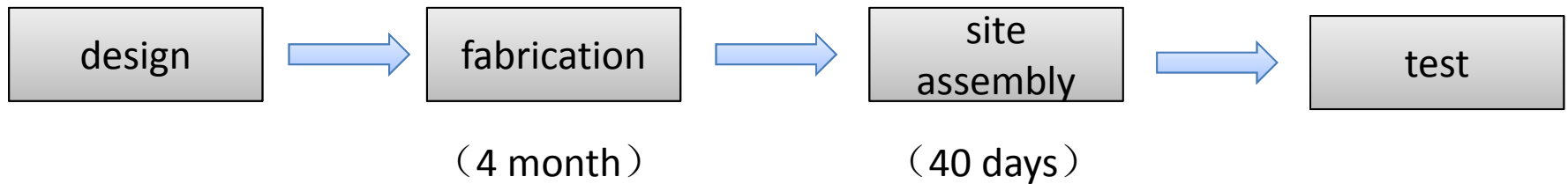


- The distance between two POST is 1920mm, the thermal contraction is 5.7mm.
- Helium vessel have 2 support point with A-frame: left is fixed, right can slide.
- NO.2 and 5 cavities are also fixed on A-frame
- The other cavities can move 1.9mm along the beam line during cool-down and warm-up.

# Cryomodule fabrication



Since last month, we had made 6 HWR cryomodules.  $\left\{ \begin{array}{l} 4, \beta=0.10 \\ 2, \beta=0.15 \end{array} \right.$



helium vessel



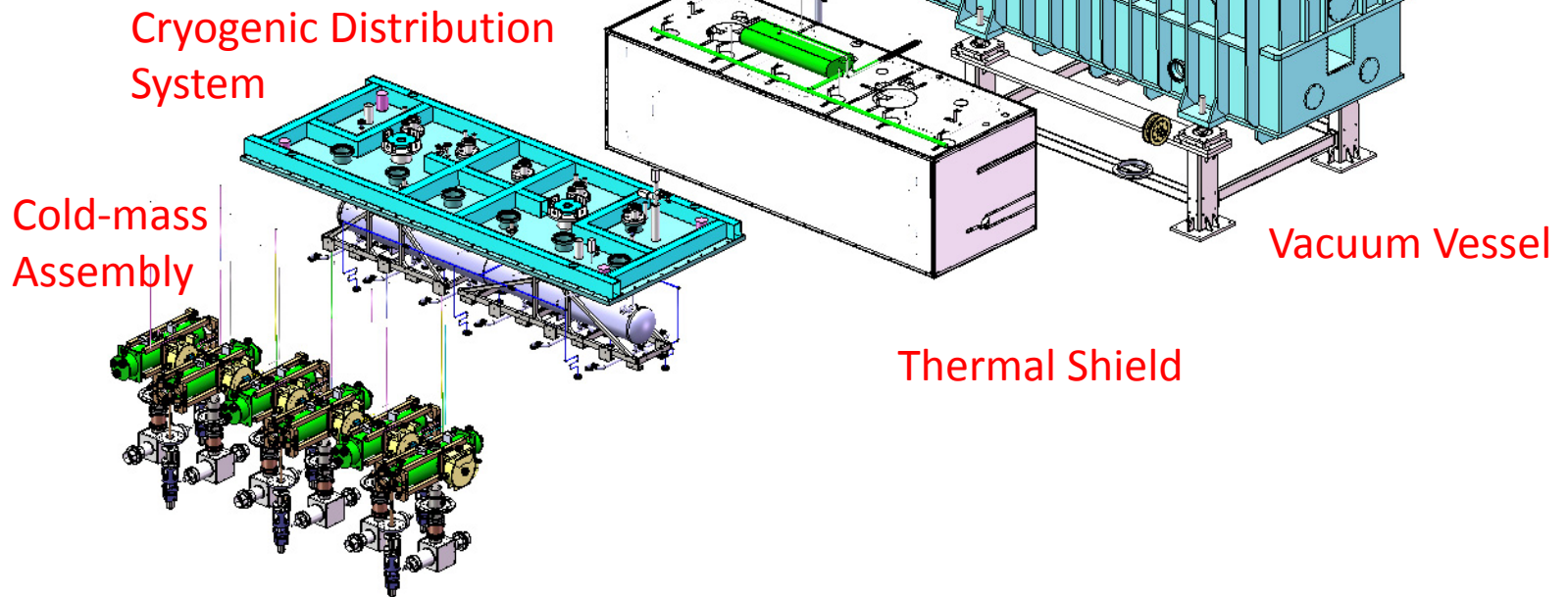
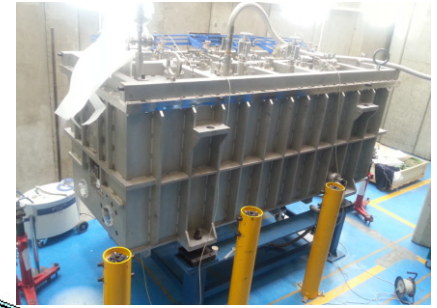
thermal shield



vacuum vessel

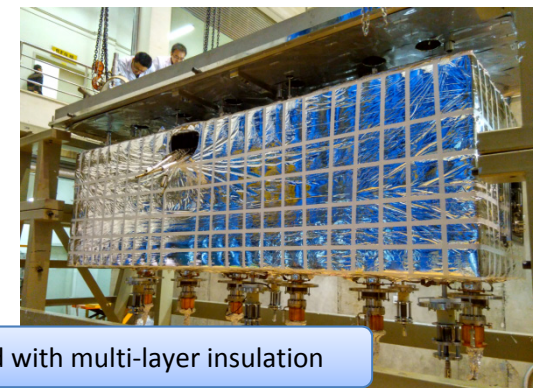
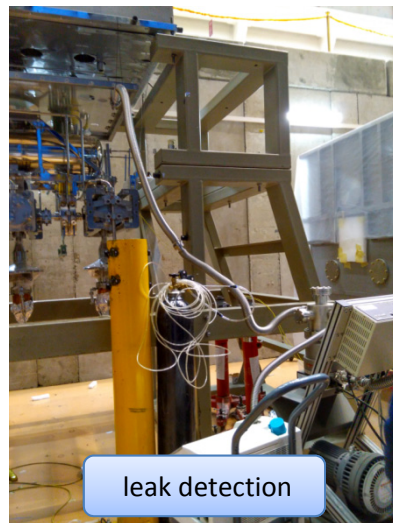
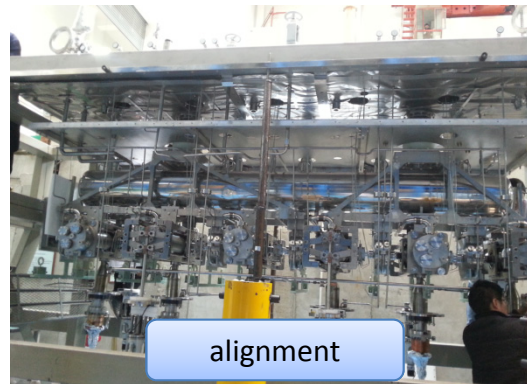


# Cryomodule assembly

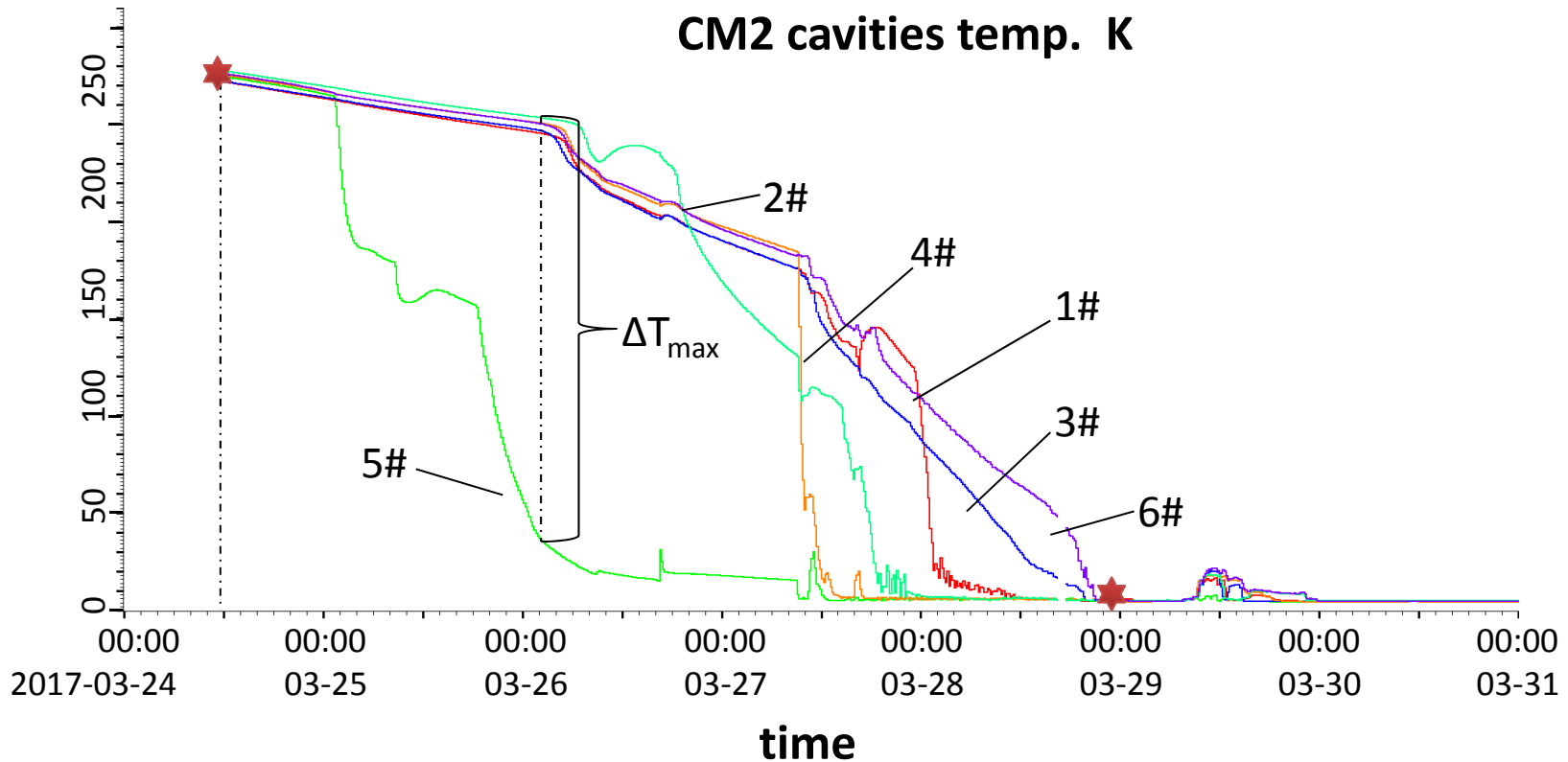




# Cryomodule site assembly



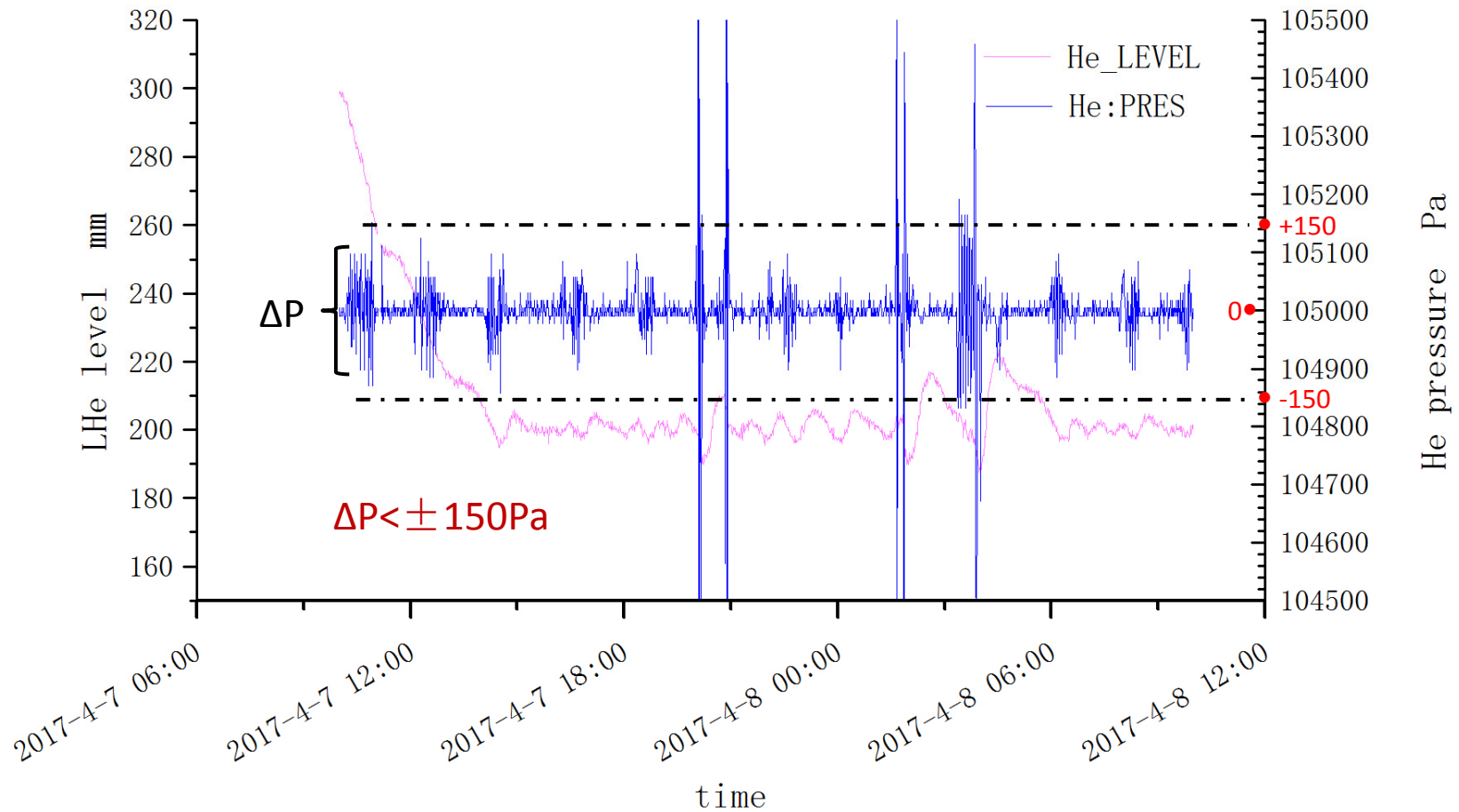
# Cryomodule test on line



- Cavity cooling down from 290K to 4K: 03/24 12:00 – 03/29 00:00, 108h (4.5 days) ;
- Average cooling rate : 2.65K/h;
- Max temperature difference: 220K (260K-40K) ;
- 5# cavity is cooled so fast, because it is so closer to the main pipe of helium when precooling down.
- Then we will optimize the design later.



# Cryomodule test on line



Cryomodule work pressure is 1.05 bar.

Helium pressure fluctuation can be controlled within  $\pm 150$  Pa.

# summary



## three important tests of ADS injector II

5MeV

- 2015.06
- 10mA @PW

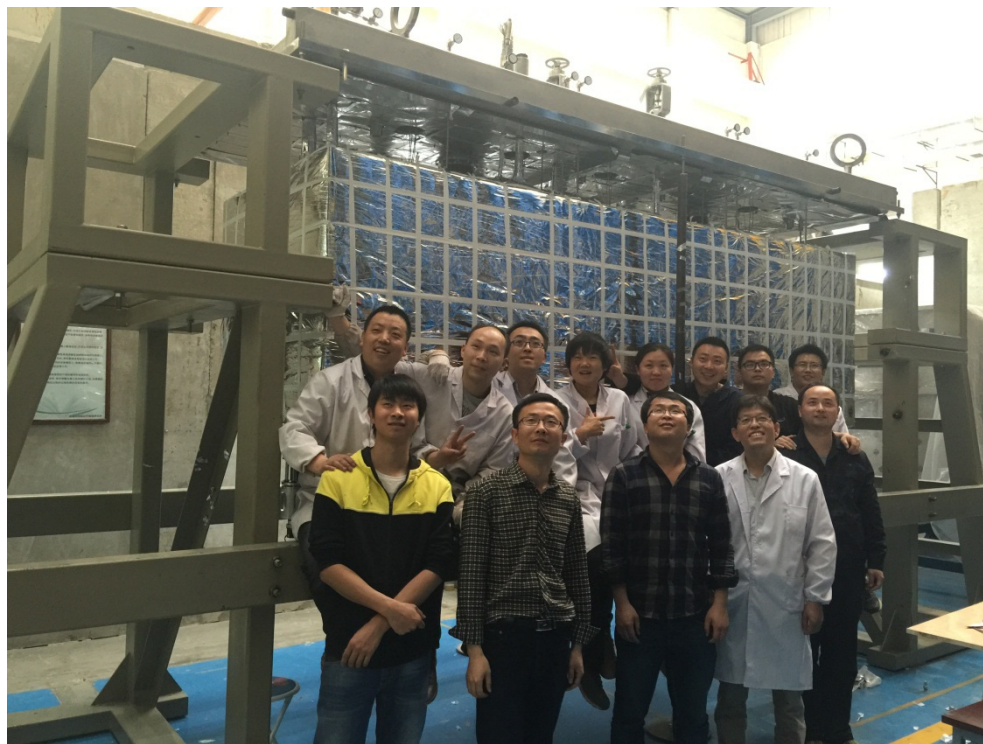
10MeV

- 2016.12
- 11.7mA @PW
- 1.16mA @CW

25MeV

- 2017.06
- 12.6mA @PW
- 150 $\mu$ A @CW

In the past three years, we had achieved the target step by step, learn lots of technology and experience, which can make later project more efficiency .



**Thank You !**