Spoke Cavity Development and Beam Commissioning of 10 MeV Spoke-Based Proton Linac

Feisi He

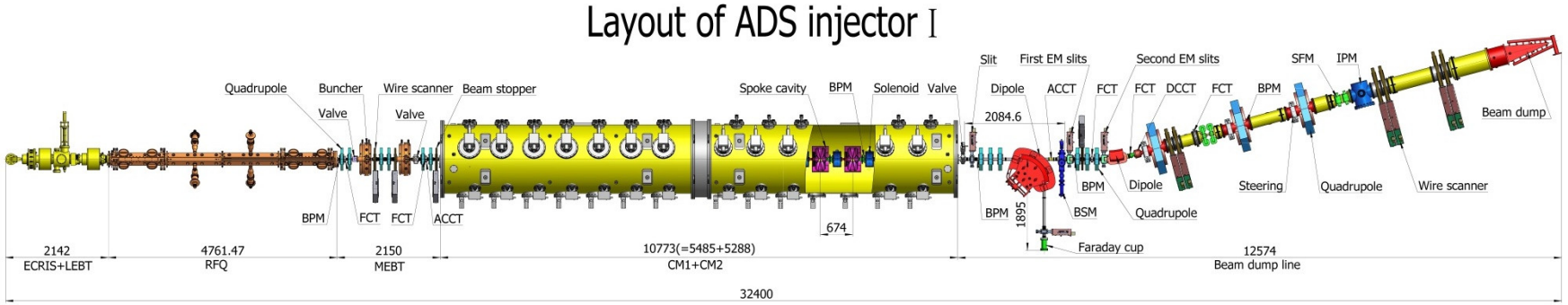
On behalf of colleagues in IHEP SRF group

Institute of High Energy Physics (IHEP)

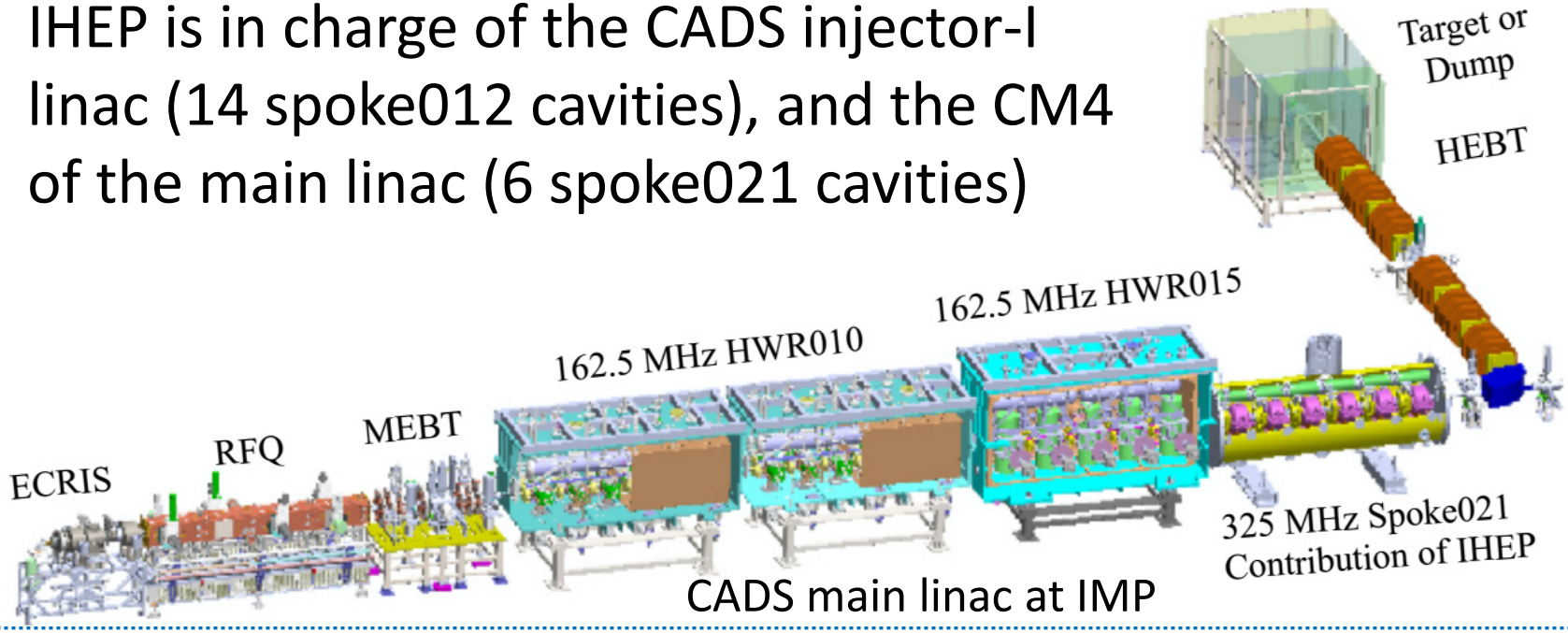
Outline

- Background
- Fabrication and quality control
- Post processing
- Vertical test statistics
- String and cold-mass assembly
- Cryomodule commissioning
- Operation with beam

Spoke cavities for CADS linac

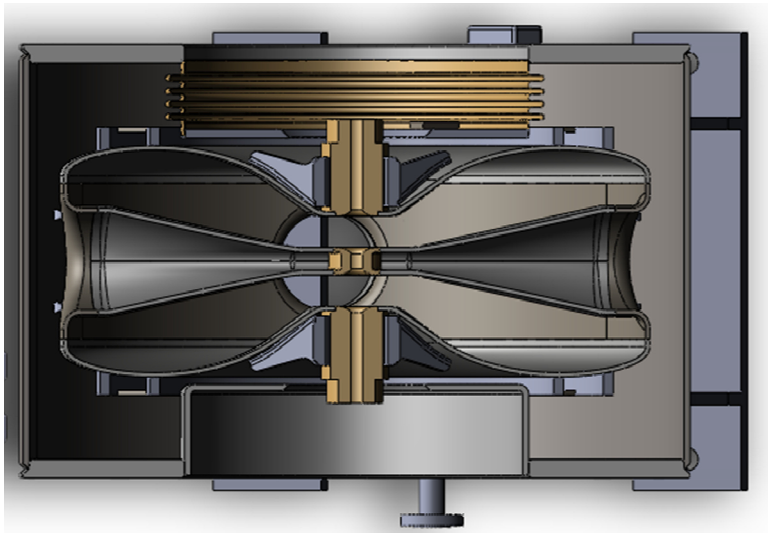


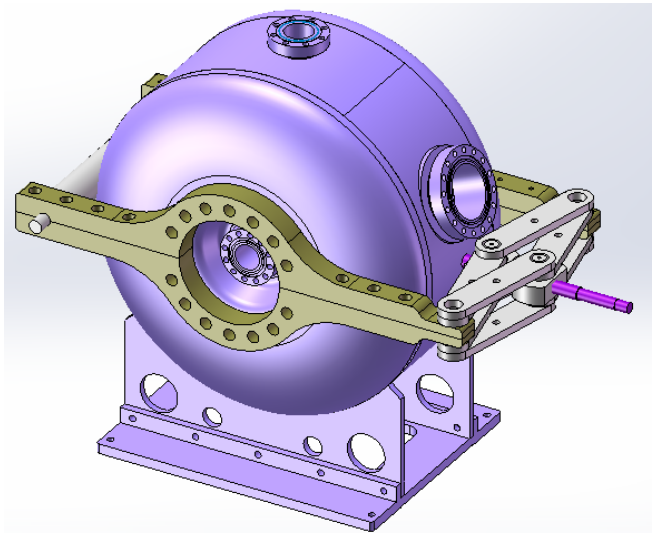
- IHEP is in charge of the CADS injector-I linac (14 spoke012 cavities), and the CM4 of the main linac (6 spoke021 cavities)

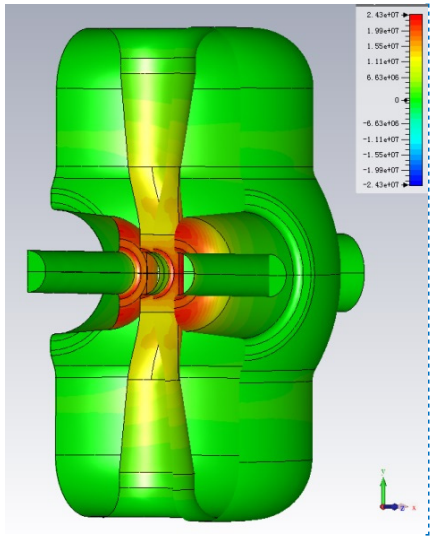


CADS main linac at IMP

Spoke cavities for CADS linac (2)



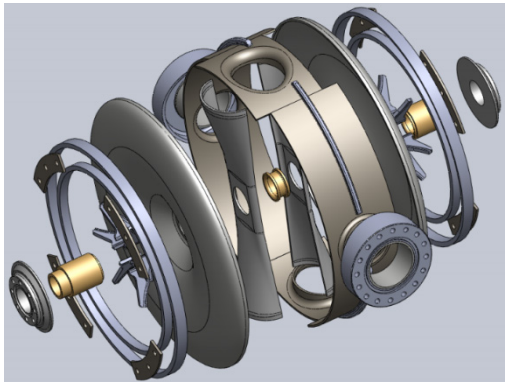




	Spoke 012	Spoke 021	Spoke 040	Spoke 024	HWR 325
β_0	0.14	0.24	0.46	0.24	0.14
Ep/Eacc	5.0	4.4	3.9	4.0	4.6
Bp/Eacc-mT/(MV/m)^2	6.9	9.4	9.2	6.4	4.8
G-Ω	60	71	104	81	73
R/Q-Ω	150	191	265	206	197

Note: Eacc normalized with $\beta_0\lambda$;

Fabrication of IHEP ADS spoke cavities



LHe vessel ← Single cavity test

Design → Fabrication → Post processing → Assembly

Certification from vendor
Eye inspection

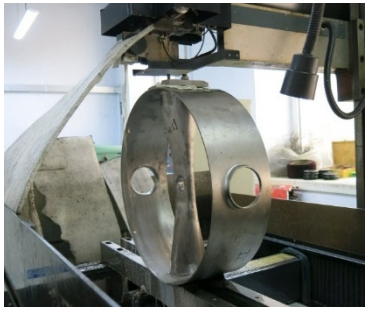
Material

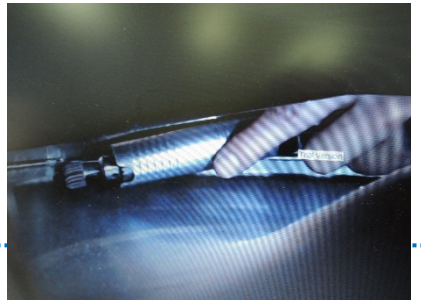
Technology

Quality control

Defect inspection and grinding before final EBW, size control, frequency control

Deep drawing, annealing, machining, frequency control, grinding, EBW



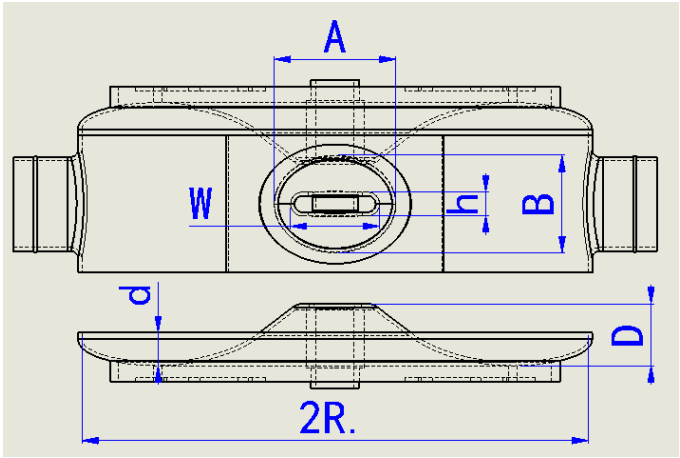


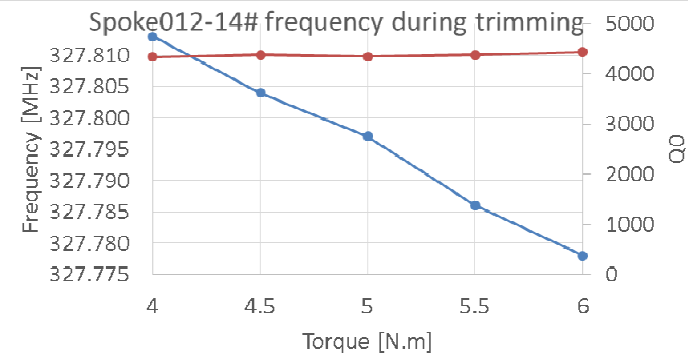
Surface quality control

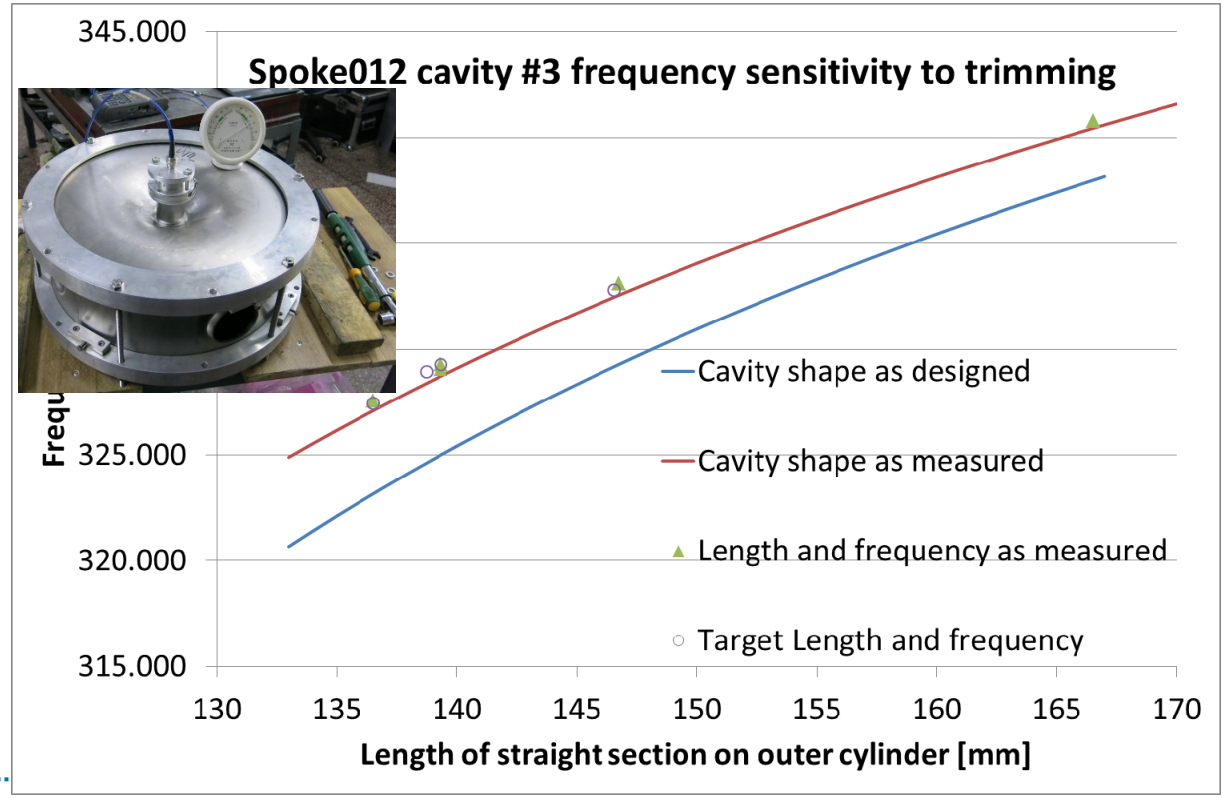
- Before final EBW it is the last chance to get easy access to the cavity inner surface
- Defect, e.g. pits in diameter 0.1mm, could be addressed by eye inspection. Sometimes magnifier or very light BCP helps to find defects.

Frequency control

- Frequency tuning is typically done by stacking parts together before EBW, and trim the cylindrical part after frequency measurement.



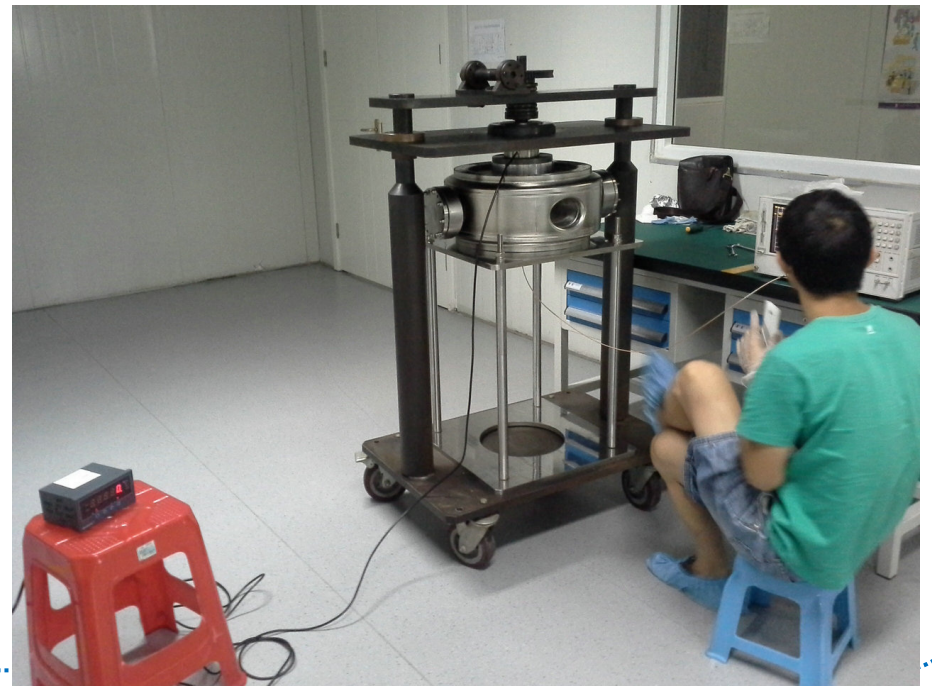




Reference [18]

Pre-tuning of the cavities

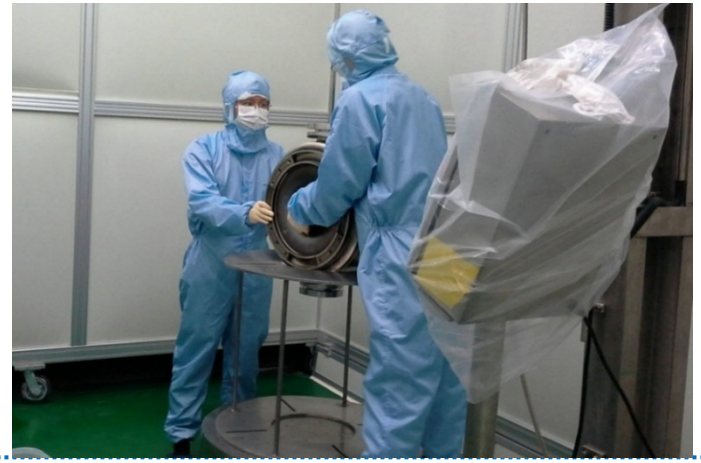
- Pre-tuning is typically done after the bulk BCP
- A specific tooling was used to press the cavity to reduce frequency;
- High pressure gas in the cavity was applies to increase frequency



Reference [18]

Post processing of Spoke cavities

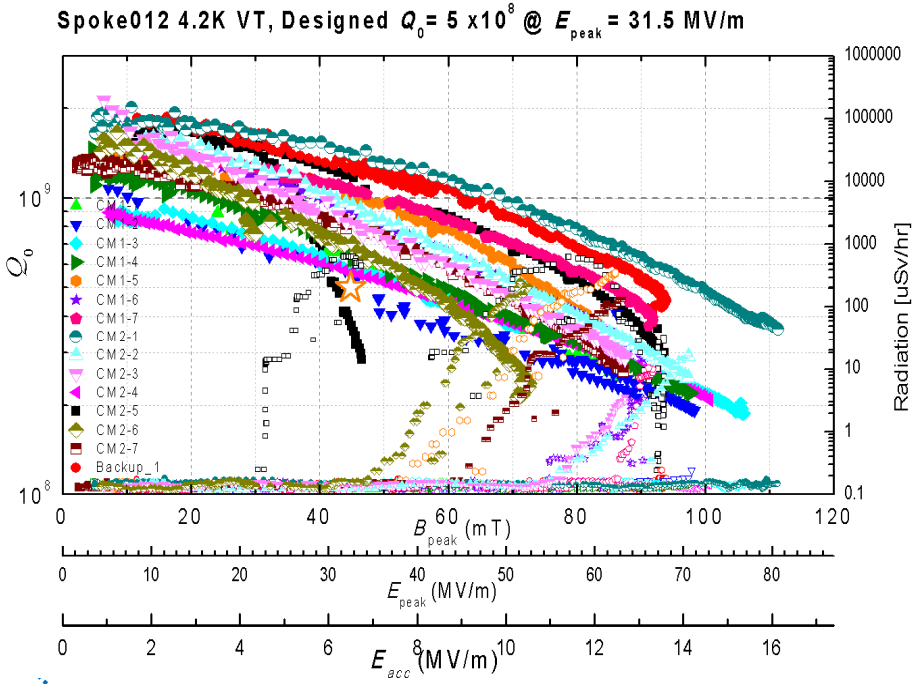
- BCP in Ningxia OTIC; re-HPR and clean assembly in IHEP

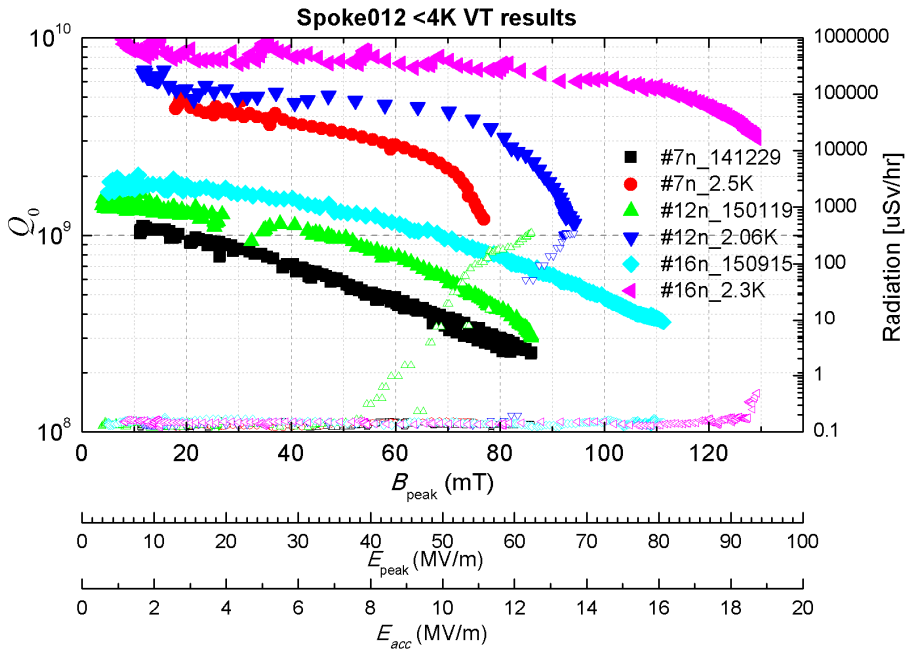


Ultrasonic
↓
BCP120 um
↓
800C 2hr
↓
BCP30 um
↓
HPR
↓
120C 48hr
↓
Vertical test
↓
Vessel weld
↓
650C 3hr
↓
BCP30 um
↓
HPR
↓
String assembly

VT results of the spoke012 cavities

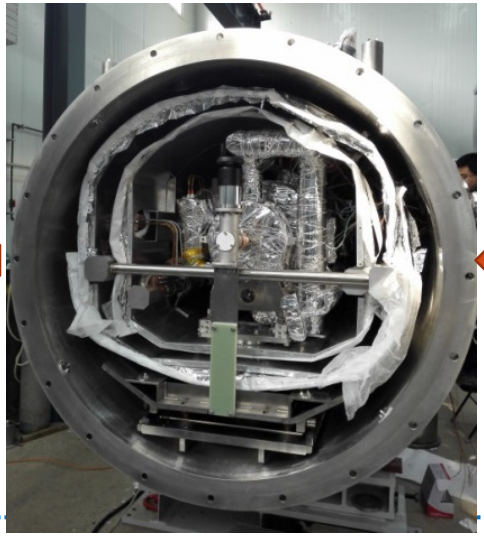
- MP conditioned in 1 hour with variable coupler
- Eacc increased by 2 MV/m with better cooling
- 120C baking increases Q_0 by about 50-100%
- At 2K, Q0 is 6 times higher, Bp~125mT achieved.

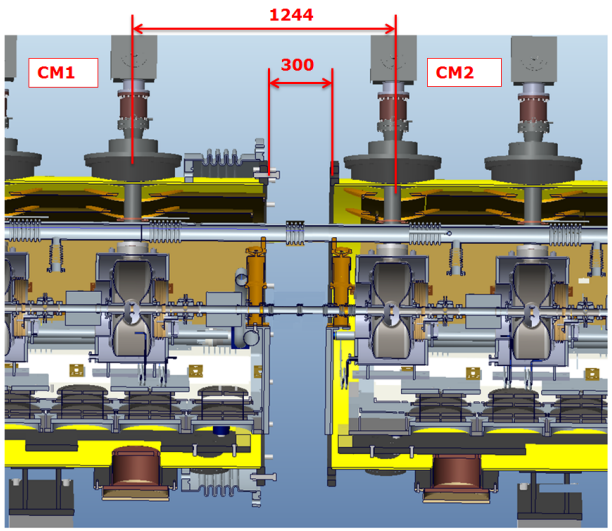




String and cold-mass assembly

- String assembly in cleanroom
- 120C Low baking
- String attach to assembly tool
- Allignment
- Cryomodule assembly
- Leak check and cold shock
- Shipment to tunnel and allignment

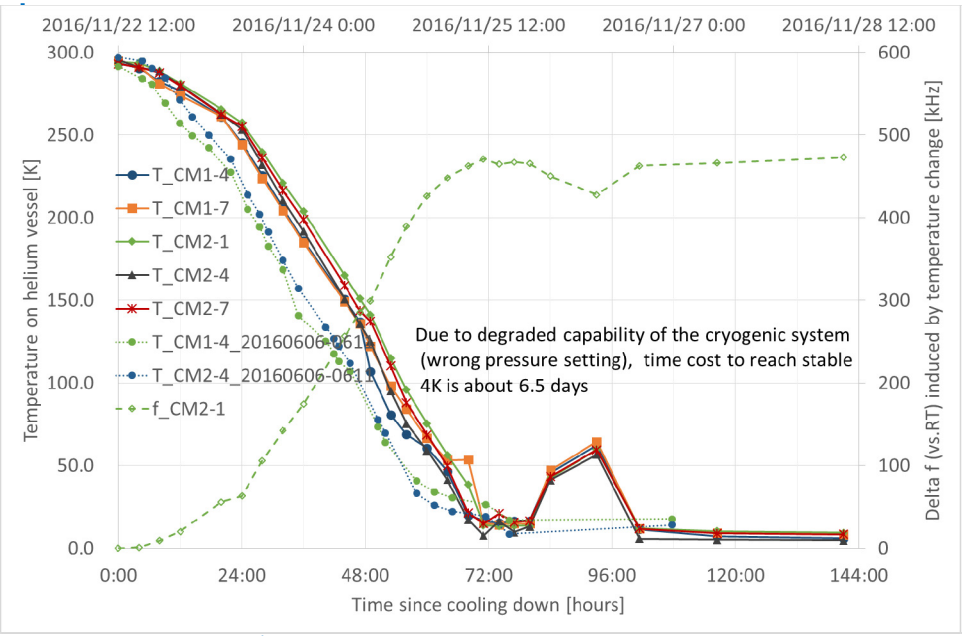


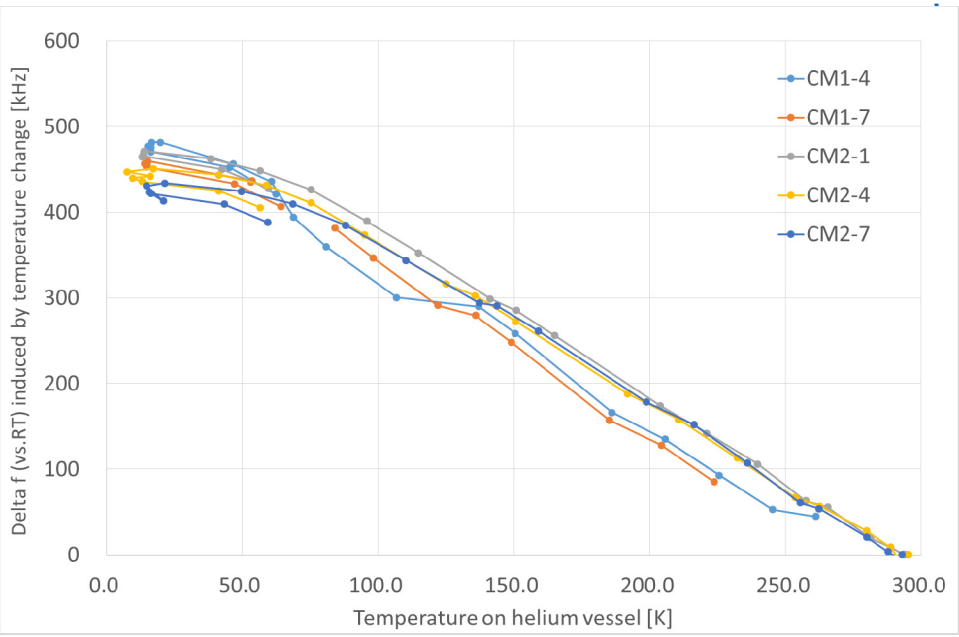


CM1&CM2 cooling down

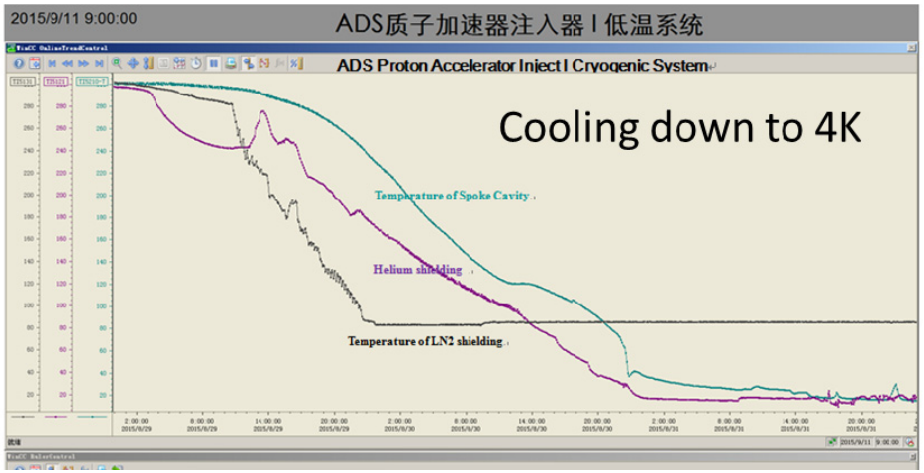
- It takes about 5-6.5 days to reach 4K stable operation
- Measured df/dp is about -130Hz/mbar for CM1 cavities, and -83Hz/mbar for CM2 cavities; LFD is about -13Hz/(MV/m)2; Q0 is not measured yet.

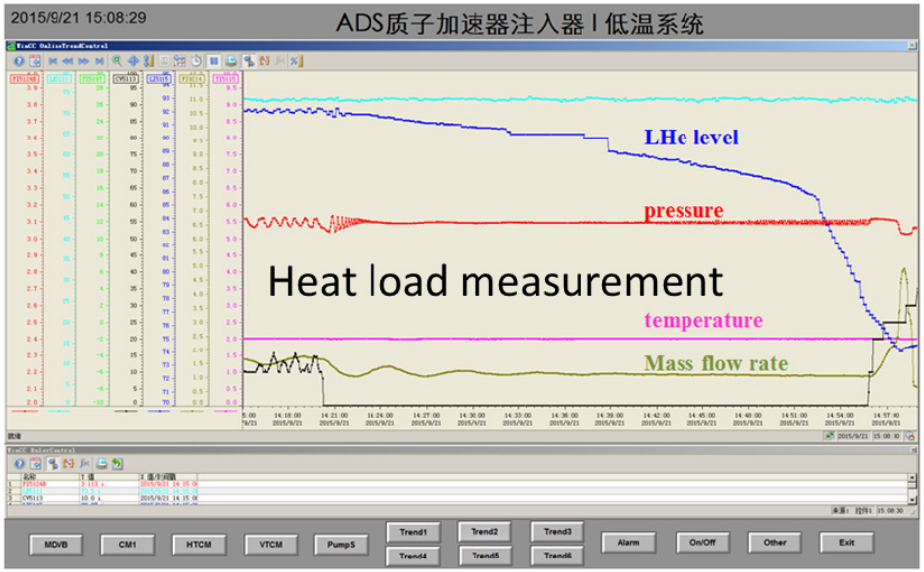
Cavity_ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14
df_4KvsRT [kHz]	546	523	540	462	509	557	496	408	428	511	323	572	519	553
df/dp [Hz/mbar]	-157	-129	-134	-150	-131	-119	-91	-66	-47	-96	-82	-75	-97	-119
LFD [kHz]	-14	-12	-11	-13	-12	-10		-13	-13	-9	-10	-12	-9	-16



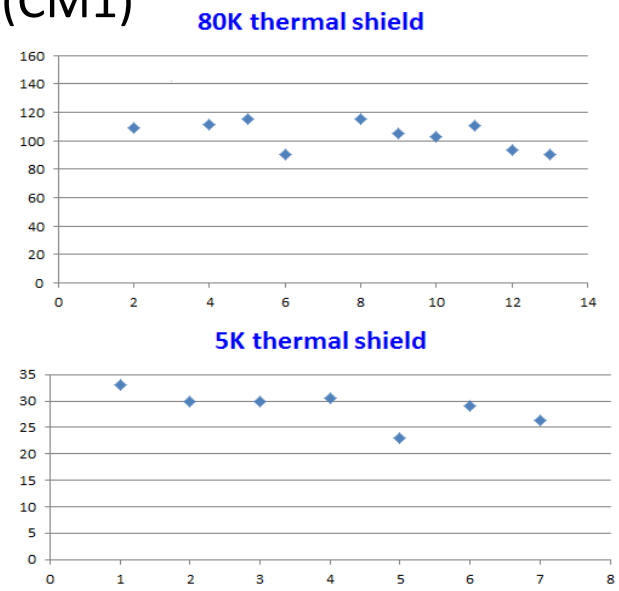


Static heat load of the CM1



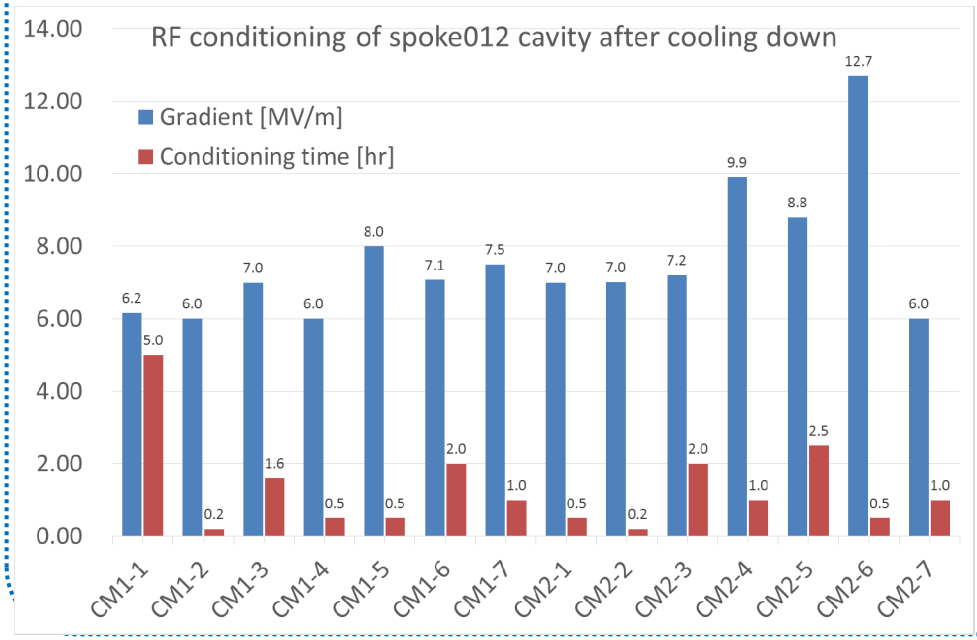


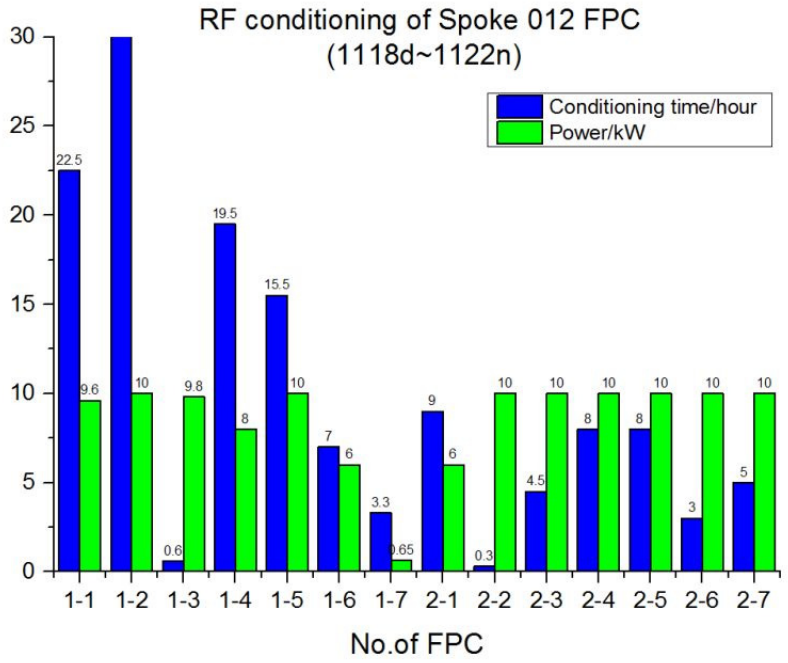
- The maximum temperature difference on thermal shields were less than 40K during cooling down
- Heat load of 30W measured by liquid level and mass flow rate agree in 7%
- LHe pressure stability was improved from ±0.6 mbar (TCM) to ±0.05 mbar (CM1)



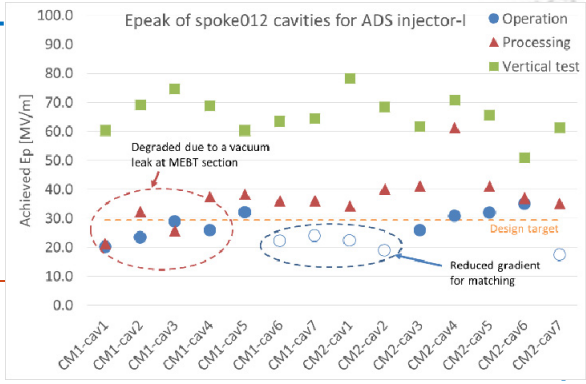
Spoke cavity conditioning

- Cavity conditioning at 4K typically takes 1-2 days
- Cavity was conditioned to 8MV/m before beam operation (FE for cav 1-4#, administrative for Cav5-14#)
- On CW beam operation of 2mA@10MeV mode, average cavity gradient is 6MV/m, i.e. Ep~27MV/m

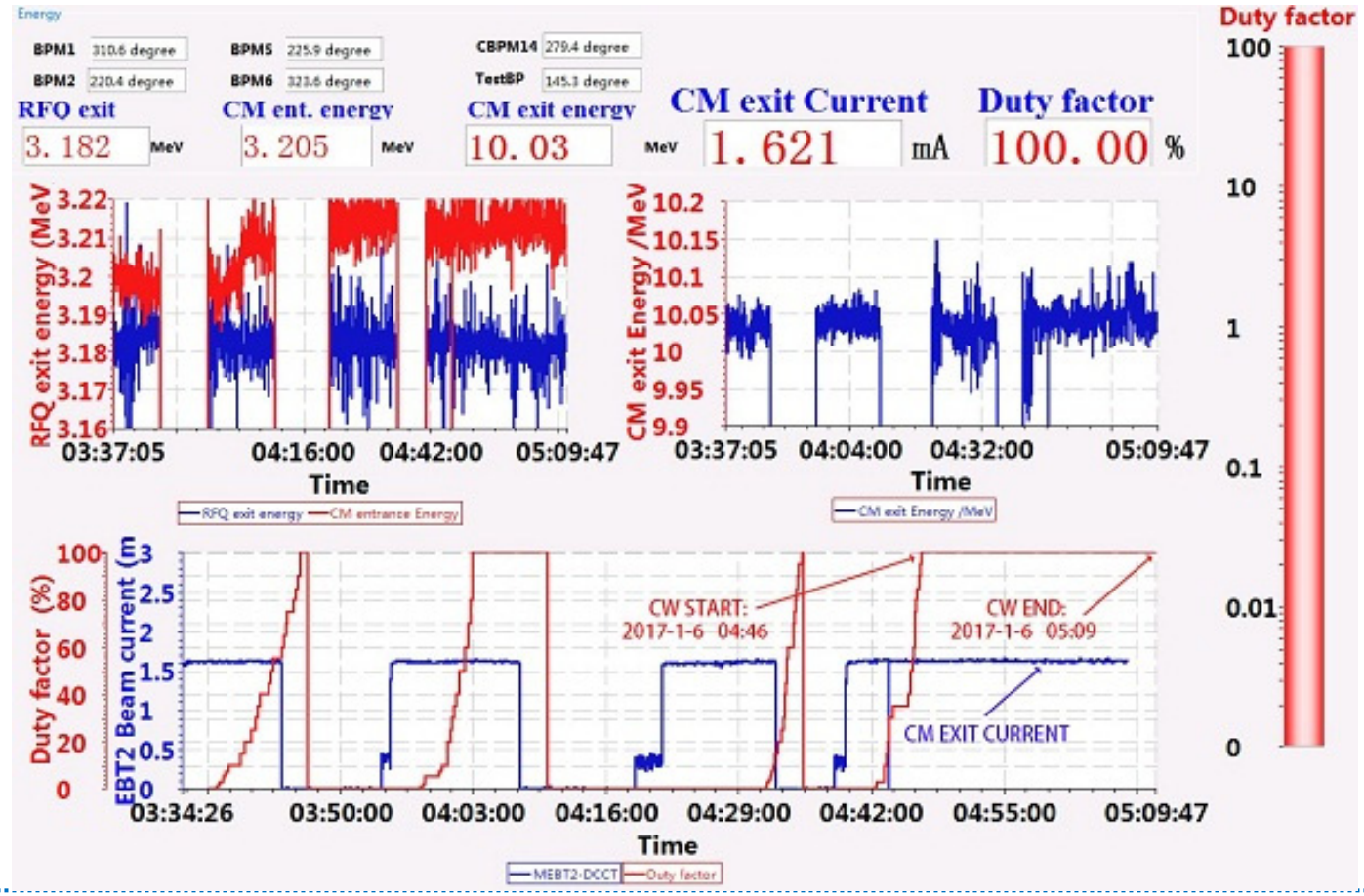




Operation with beam



- Pulsed operation of 23 hours without trip
- CW proton beam of 1.6mA at 10MeV for 23 minutes



Thanks for your attention!