

Progress and CW Beam Commissioning of China ADS

Yuan He

On behalf of ADS Linac Team

Institute of Modern Physics, CAS



Outlines



- **Introduction of ADS Project of China**
- Commissioning Progress of 162.5MHz injector in IMP
- Brief introduction of Commissioning Progress of 325MHz injector in IHEP
- Summary



Motivation (NPP in China)



● To July 2013 (<http://www.iaea.org/NuclearPower/Systems-and-Databases/index.html>)

- 18 reactors in operation, 13.860GW_e ; (6th in the world)
- 28 reactors under construction, 27.790GW_e ; (1st in the world)

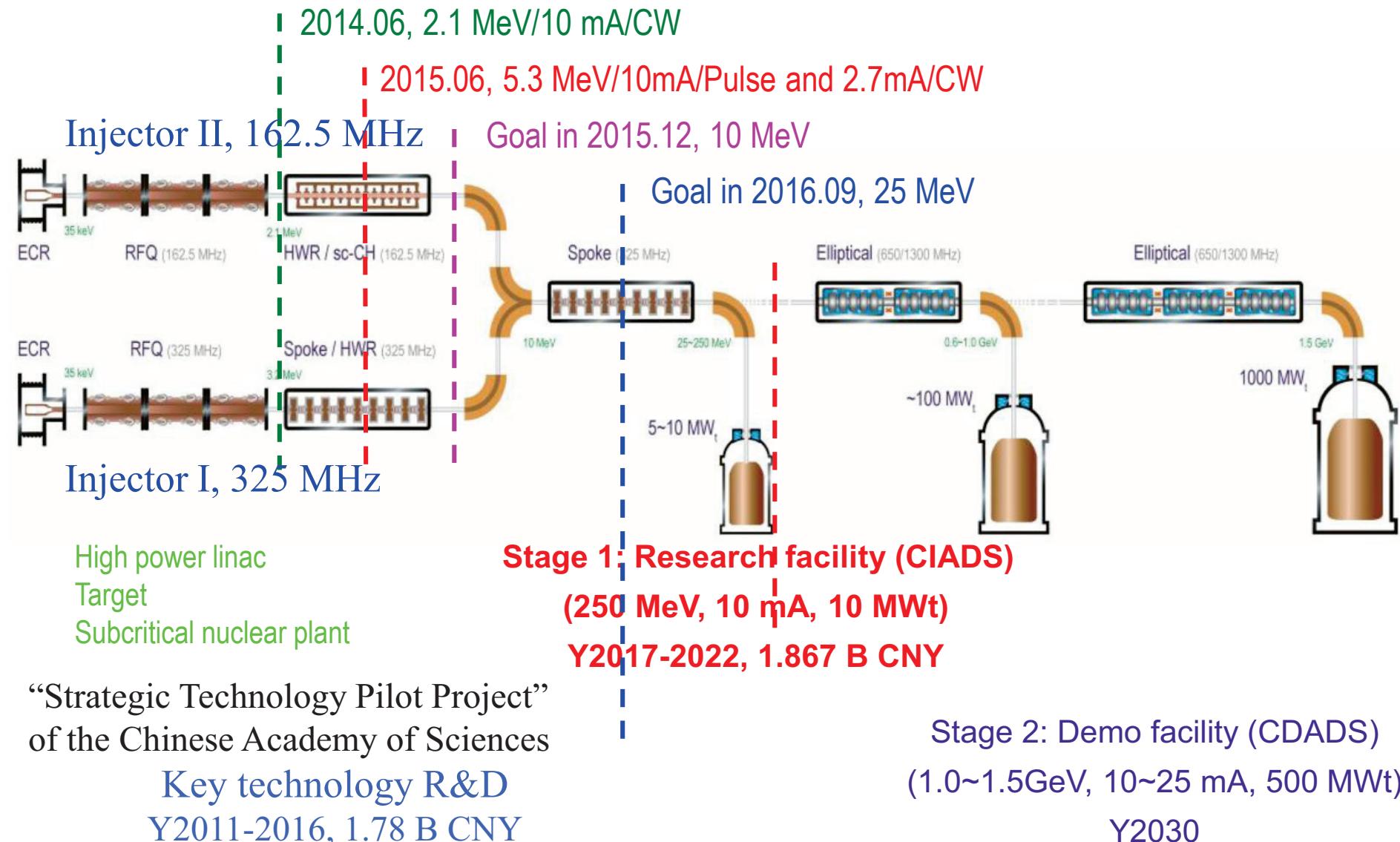
● Estimation for the future (slow down after 2011.3)

- **2020**: $\sim 58\text{ GW}_e$ NPP in operation
- **2030**: $\sim 10\%$ of NP to total power capacity
- **2050**: $350\text{--}400\text{ GW}_e$, $\sim 20\%$ of NP to total power capacity
→ almost same as the scale of the total in the world today!

Nuclear Waste Management is a serious Issues for Sustainable NP Development



Roadmap of ADS project in China

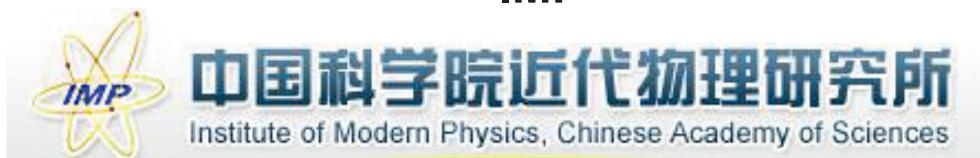


The CAS ADS Program (2011-2016)



- The program of “**Advanced Nuclear Fission Energy --- the Accelerator Driven Sub-critical System**” was initiated by CAS under the frame of “**Strategic Technology Pilot Project**” in 2011
- The budget is ¥1.78 billion for a five-years period
- **IMP is the leading institute** to carry out the research in cooperation with a number of participants.

IMP



IHEP

The CAS ADS Program

HIPS



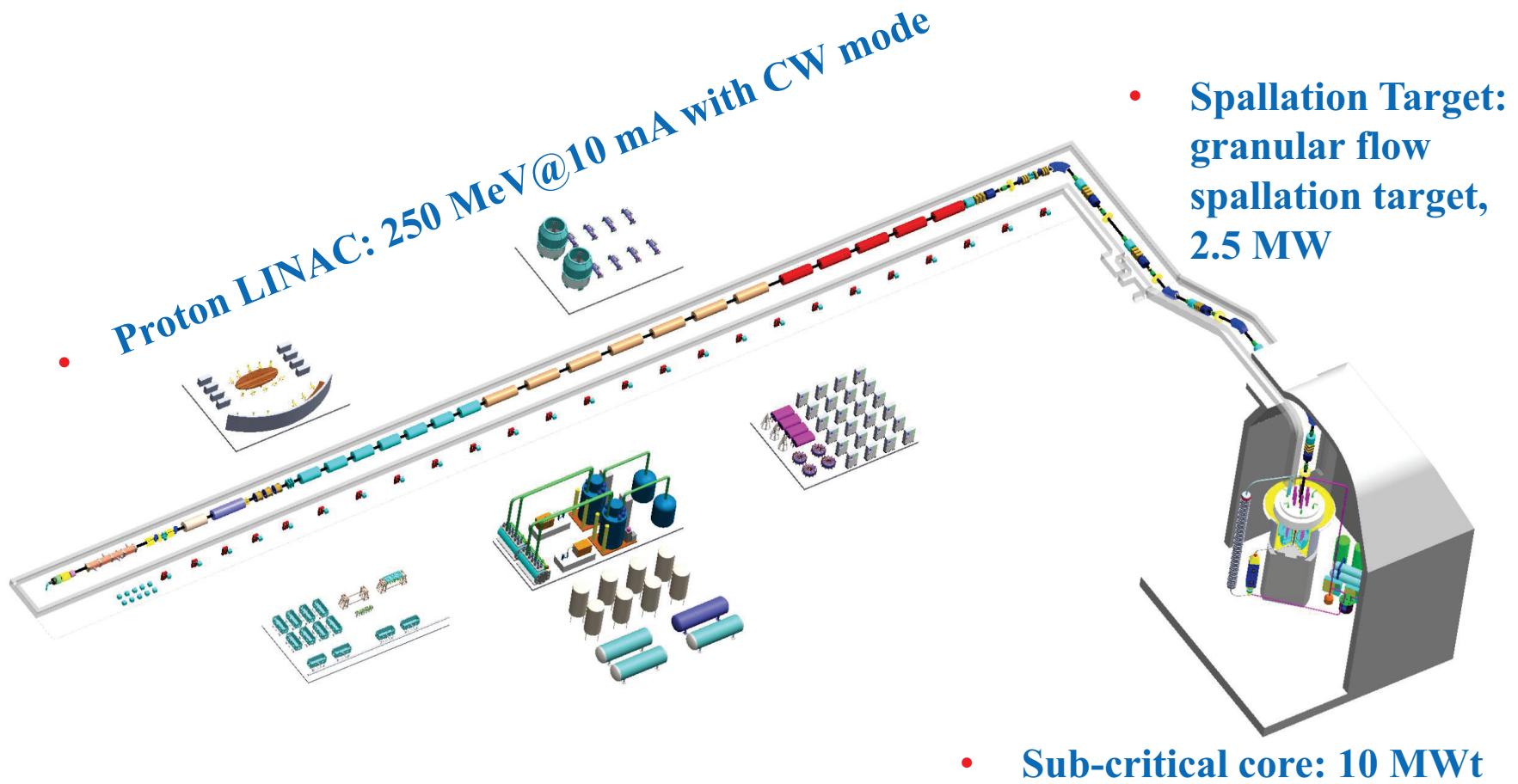
中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences



Hefei Institutes of Physical Science
Chinese Academy of Sciences

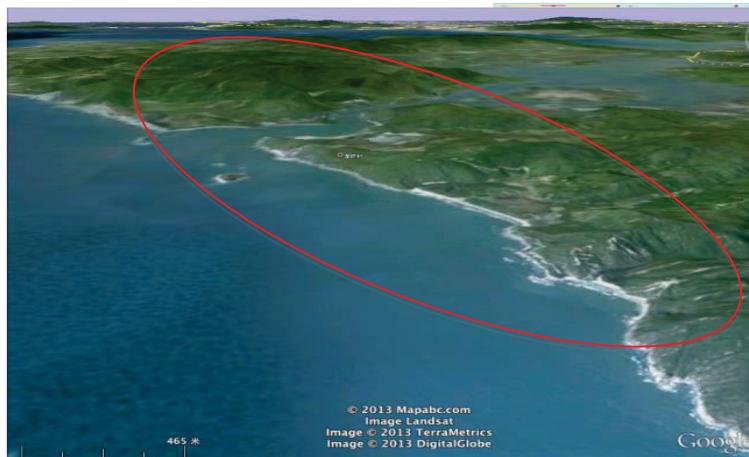
China Initiative Accelerator Driven System

- Budget: ~2.25 B CNY
- Location: Huizhou, Guangdong Prov.



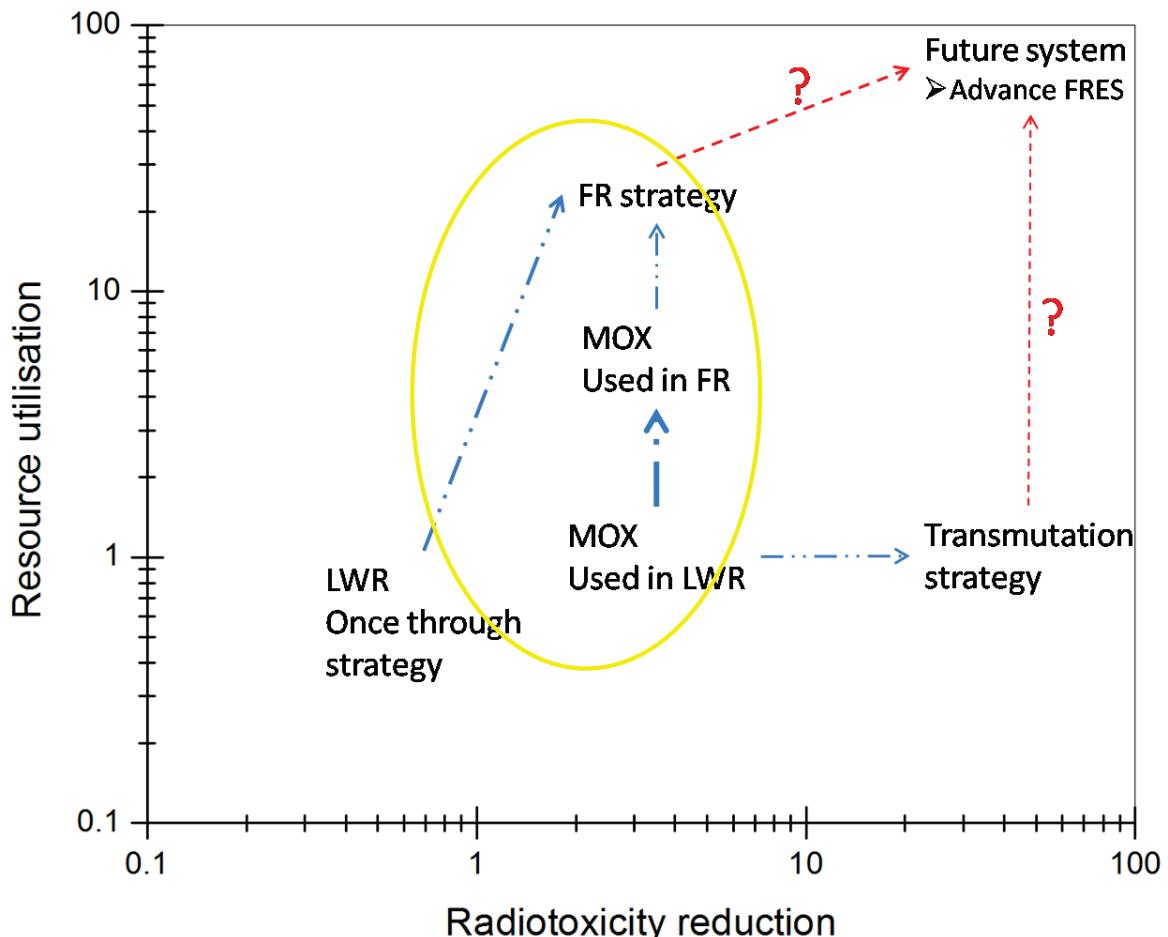


Location of CIADS



- A new site, which locates in Huizhou, Guangdong, was selected
- This new site is nearby the planed Huizhou nuclear power plant

Paths to the future for nuclear fission energy



We proposed

ADANES:
Accelerator
Driven Advanced
Nuclear Energy
System

Fuel supply: $>10^3$ yr
Radiotoxicity: < 500 yr
Volume of NW: $< 4\%$

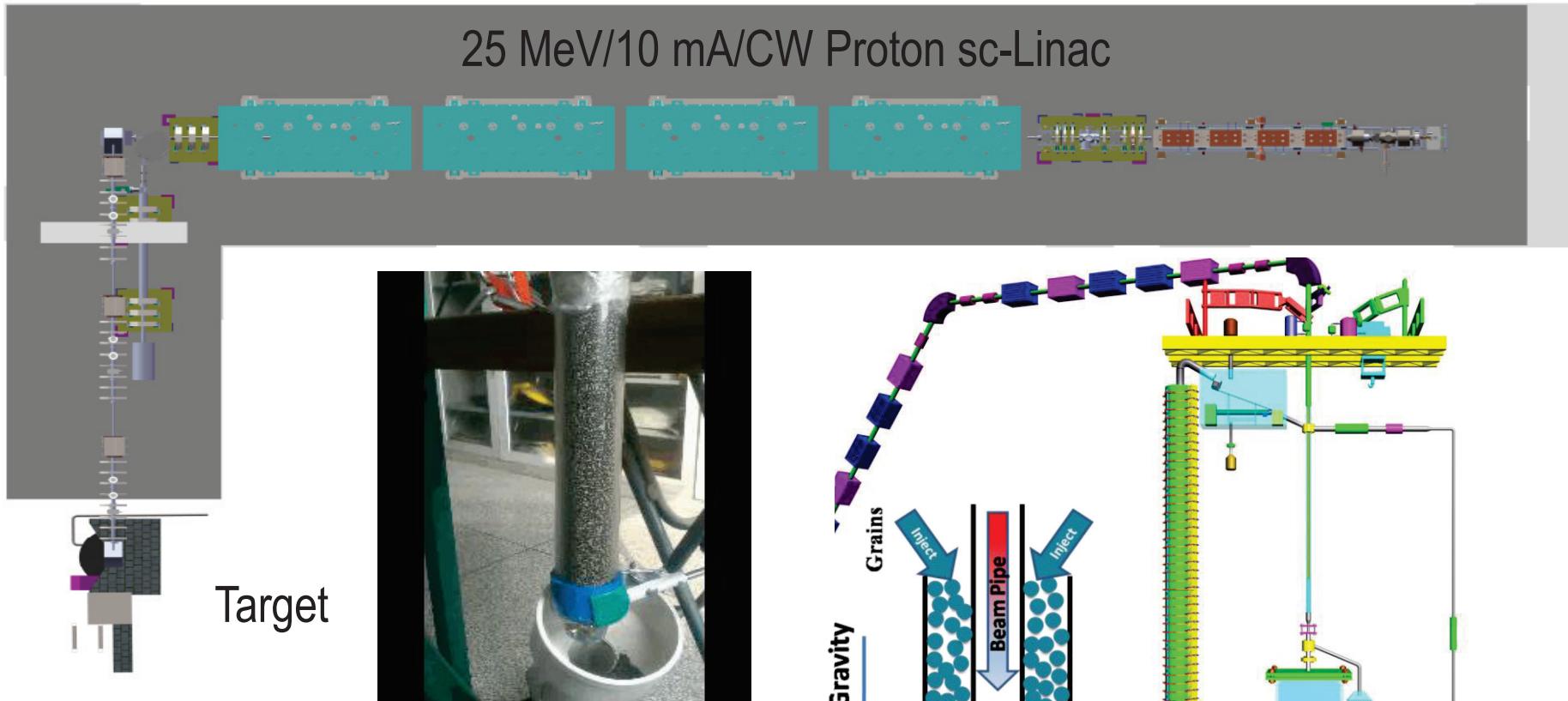


Outlines



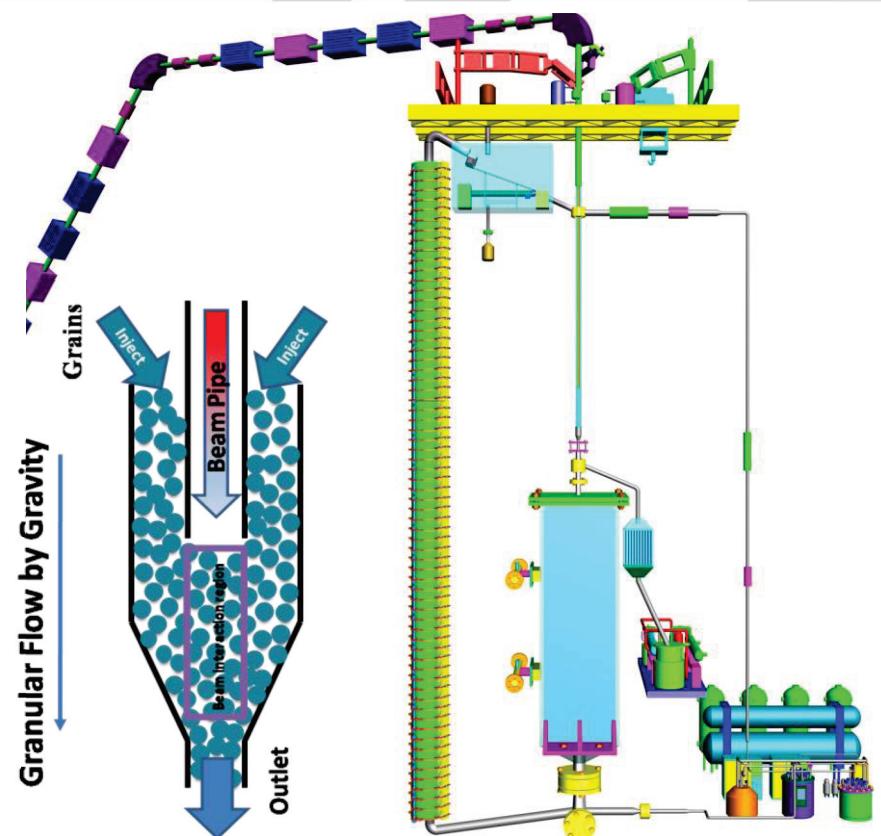
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25 MeV/10 mA/CW Proton sc-Linac



Target

Beam: 25 MeV, 10 mA, 250 kW
Target: tungsten granular,
windowless, vacuum differential
Lifter: mechanical



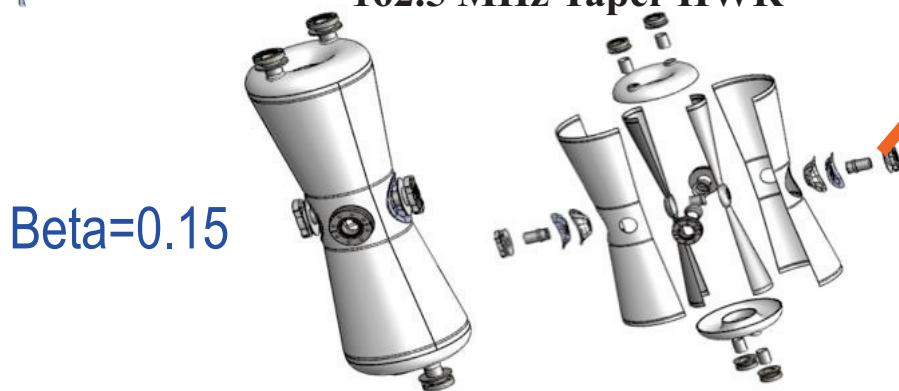
SRF cavities in the Linac



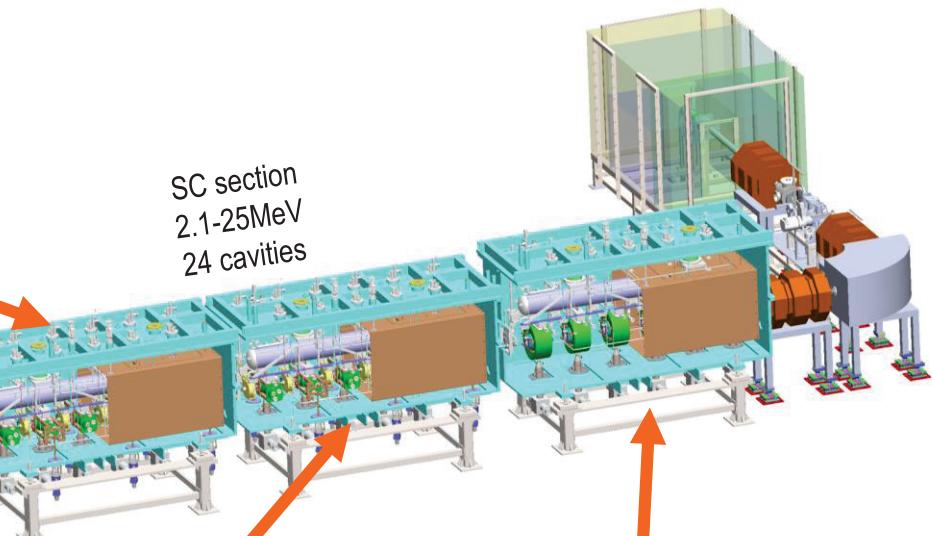
162.5 MHz Half-wave Cavity



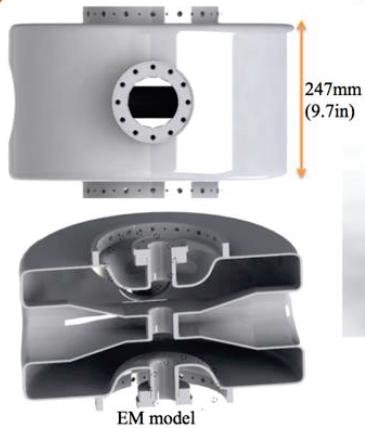
162.5 MHz Taper HWR



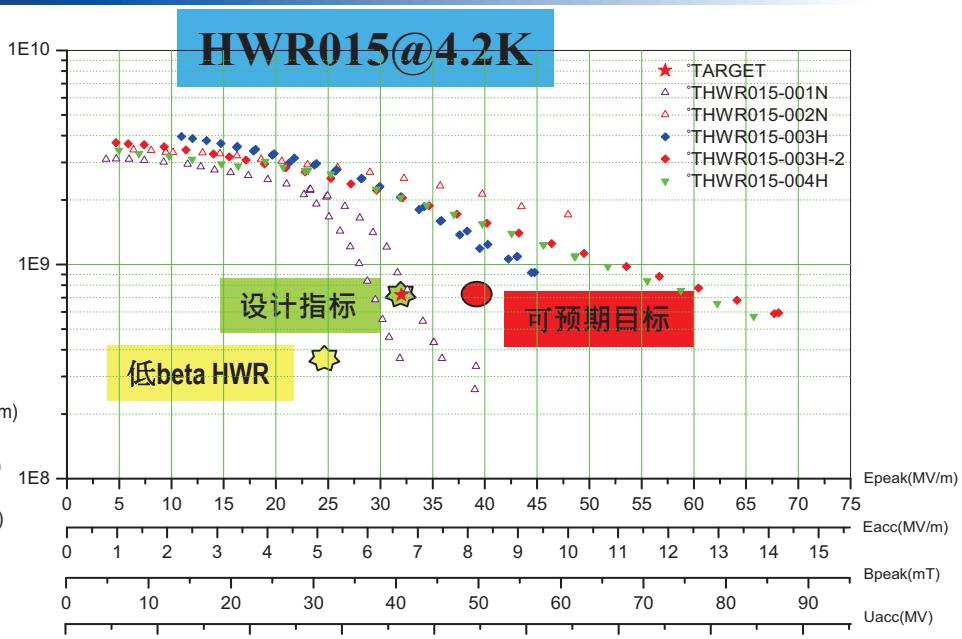
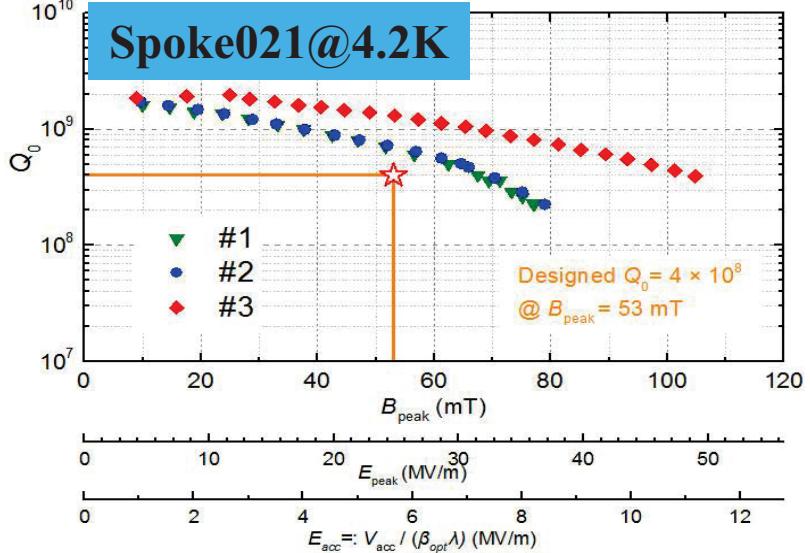
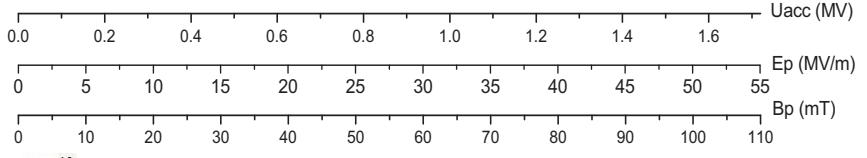
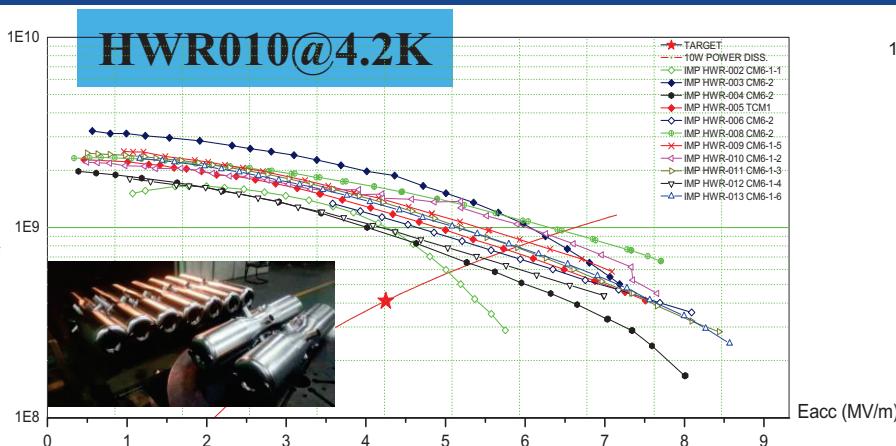
SC section
2.1-25MeV
24 cavities



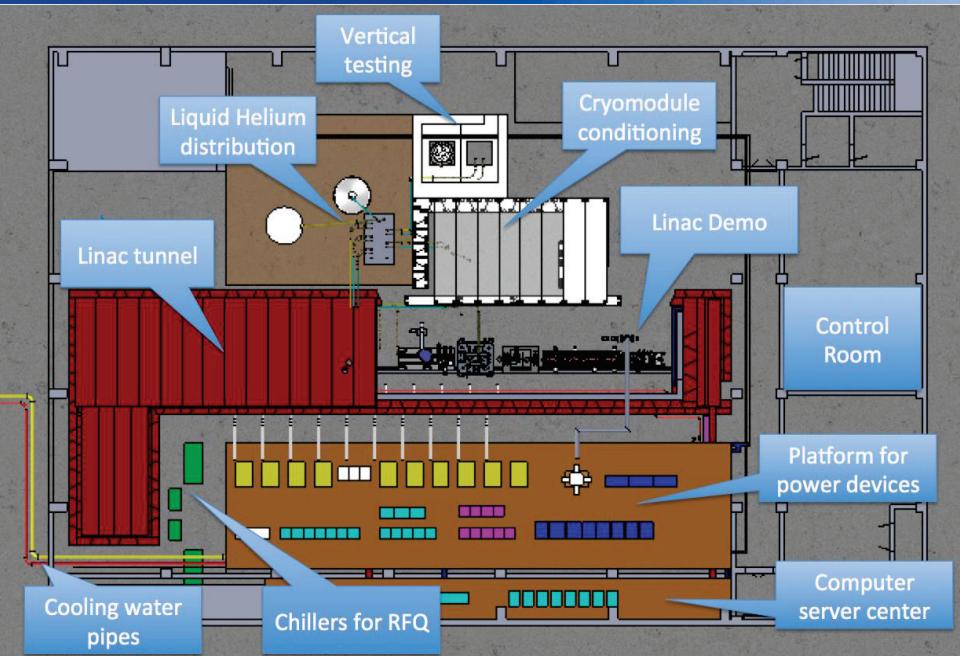
325 MHz Spoke cavity



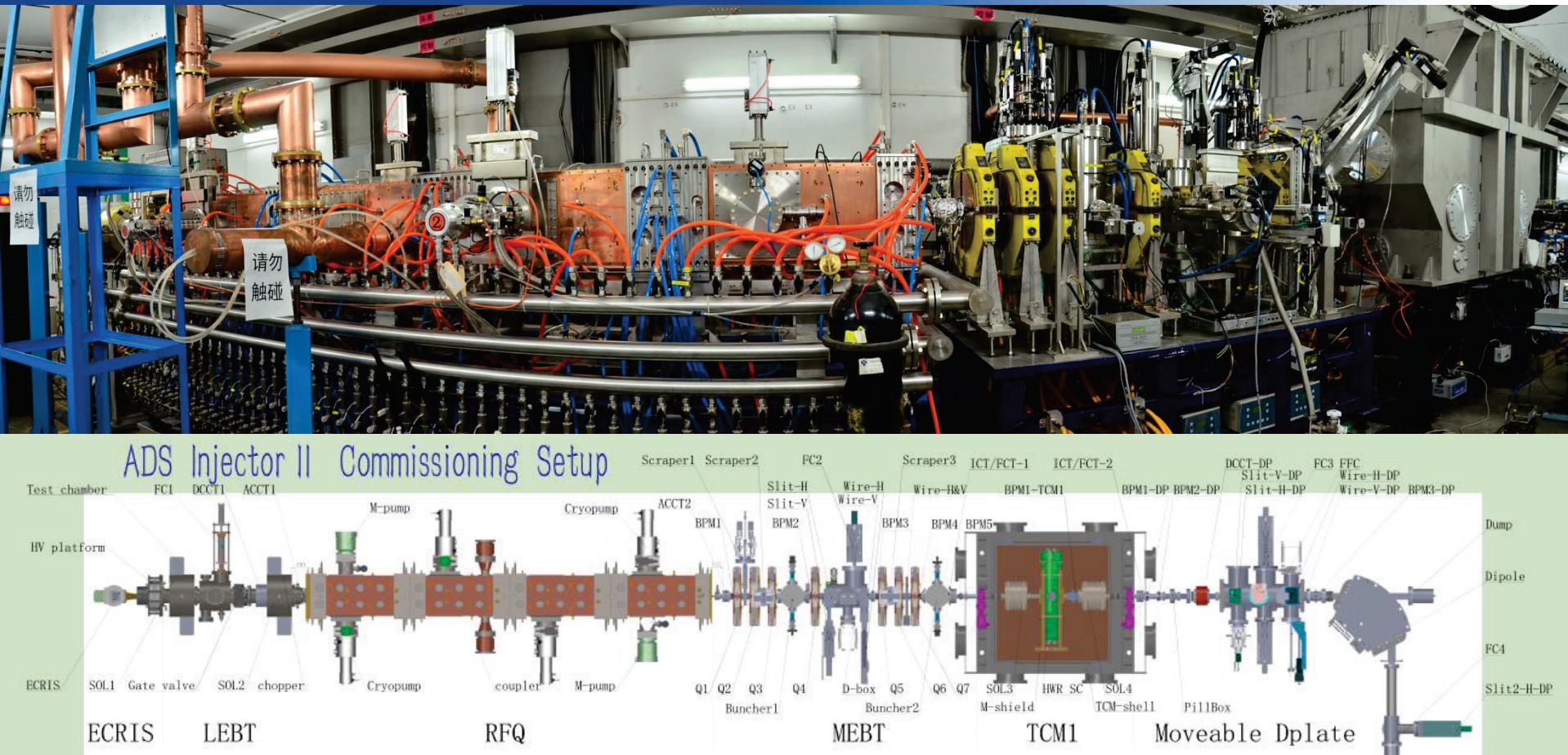
Status of SRF Resonators



Commissioning hall for demo facility

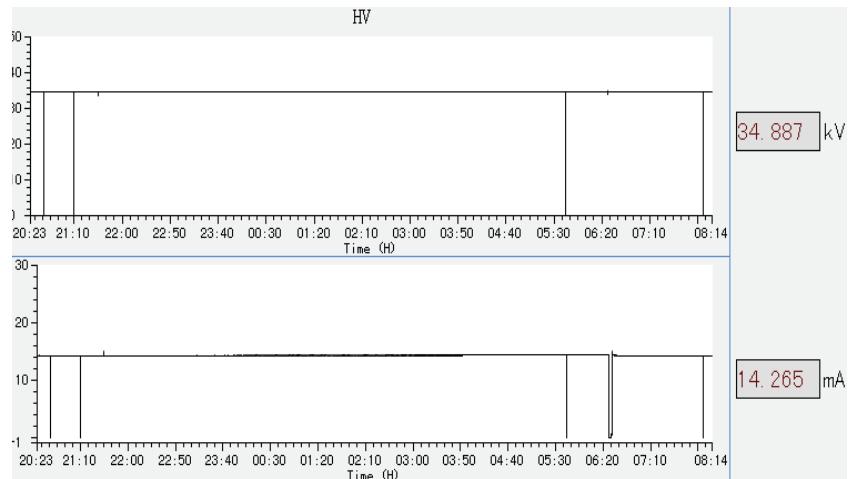
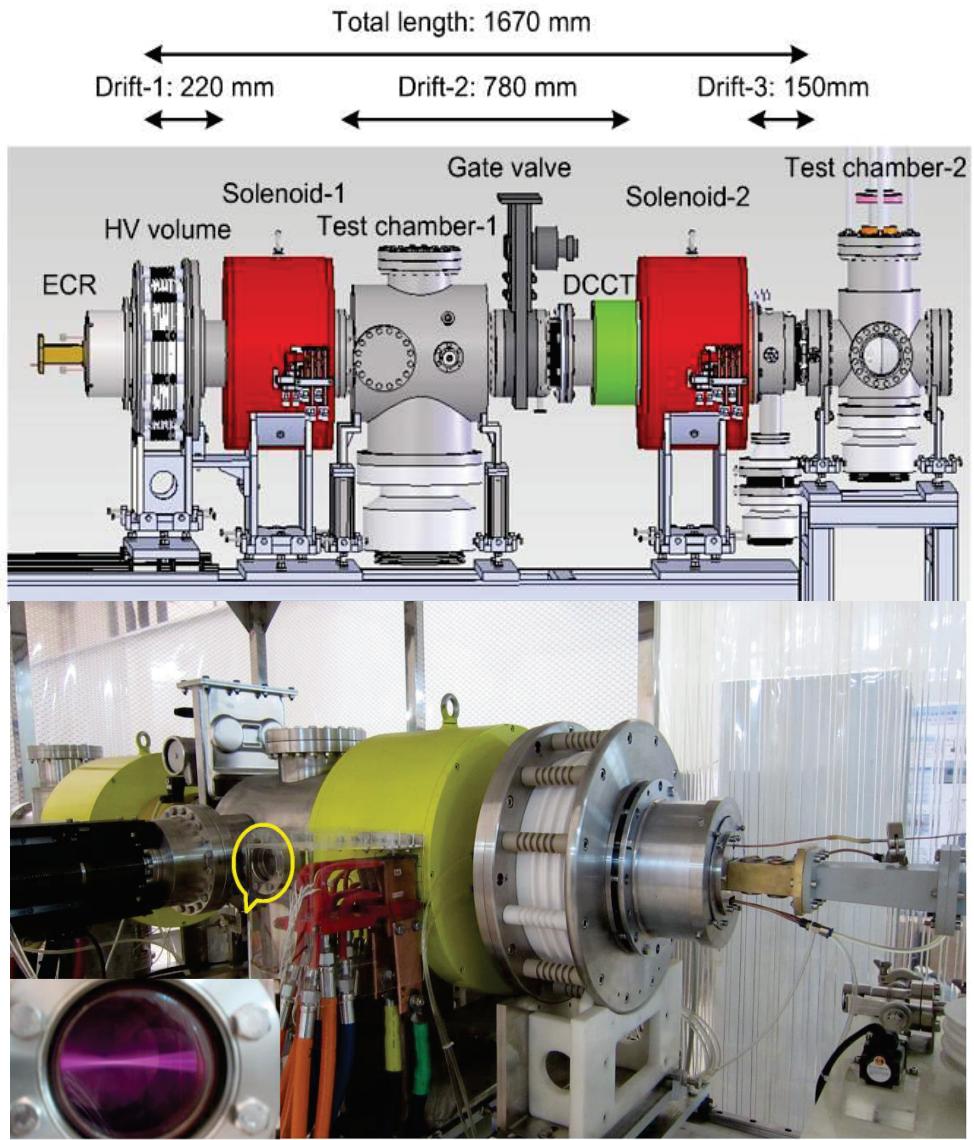


Commissioning diagnostics

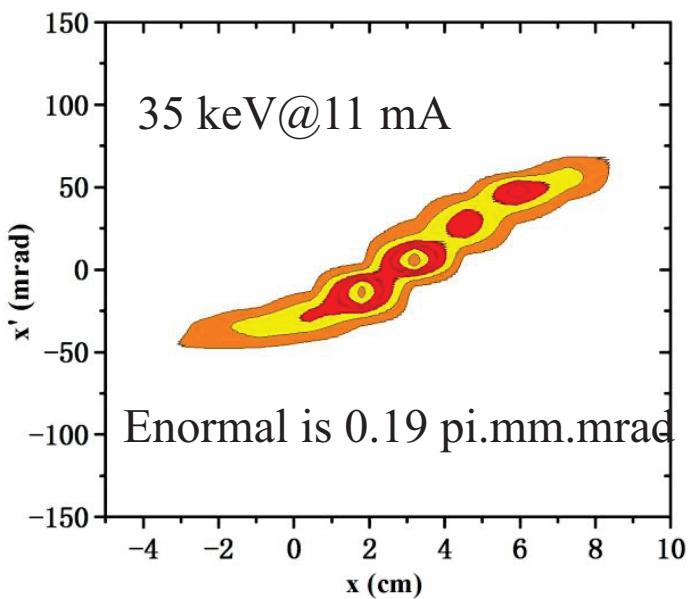


Energy measurement : BPM1-DP, BPM3-DP, Time of flight
 Energy measurement: Slit2, deflection dipole, FC4
 Beam current measurement: DCCT-DP, ACCT2
 Transmission efficiency measurement: DCCT-DP, ACCT2

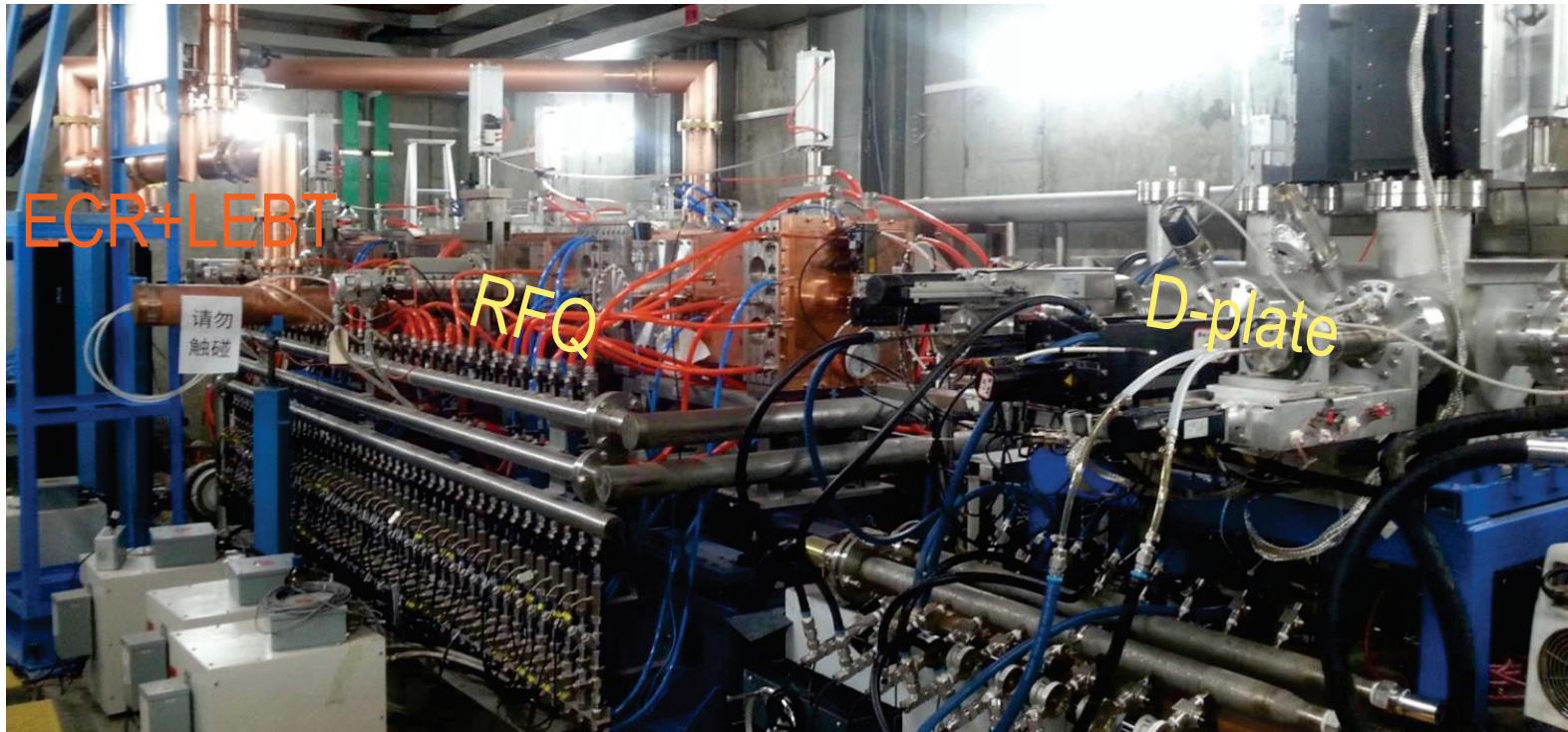
ECRIS and LEBT



14mA (12 hrs)

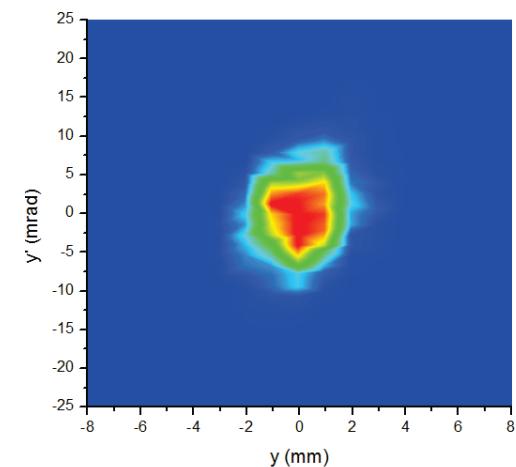
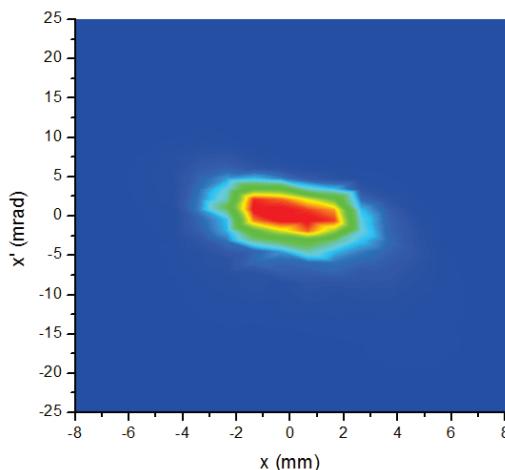
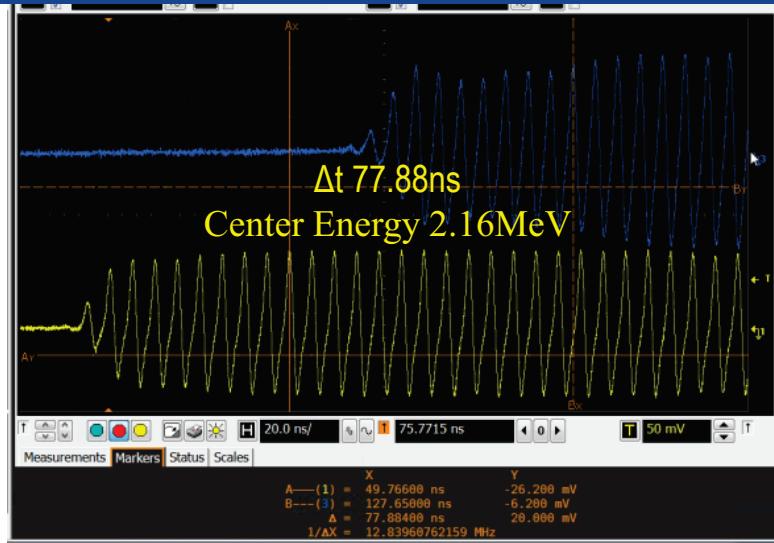


Commissioning of 162.5-MHz CW RFQ

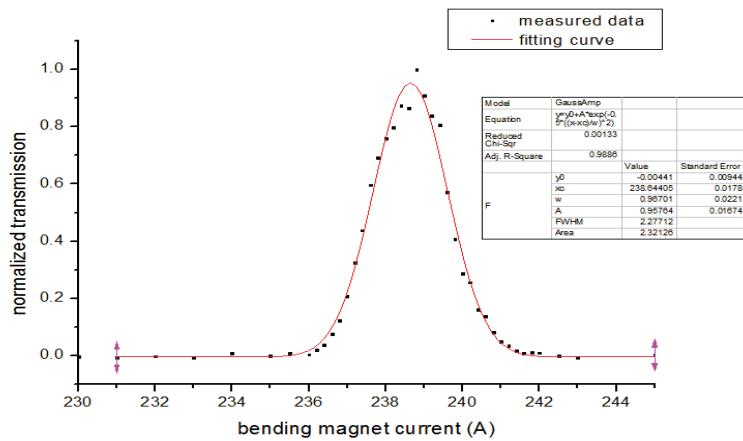


- June 6th, the first beam, energy is 2.15 MeV
- June 30th, 10 mA, CW beam, 4.5 hours, beam power 21.6 kW
- July 18th-19th, tested and peer reviewed by CAS
- July 24th, 18 mA, pulse beam, 37.8 kW, transmission 87%
- Total operation time is ~1000 hours including CW@10mA around 10 hours
- Record of non-trip operation is ~220 hours

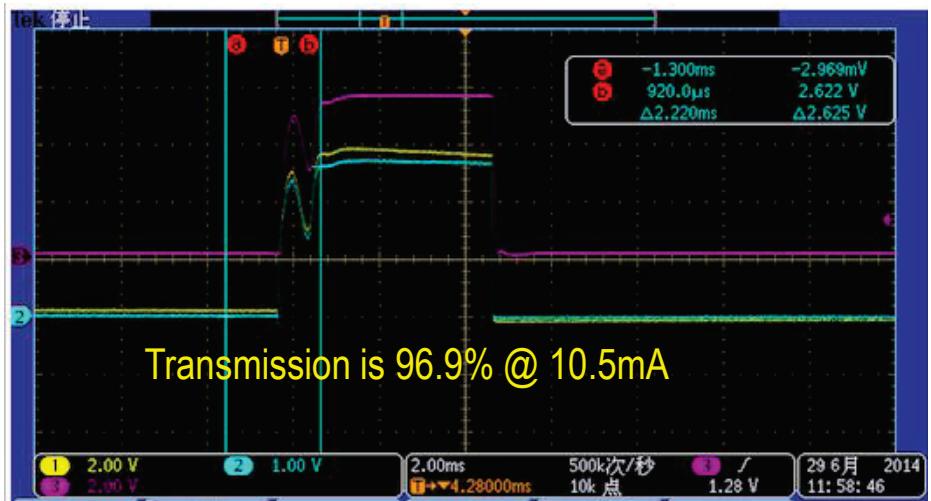
Beam quality from RFQ



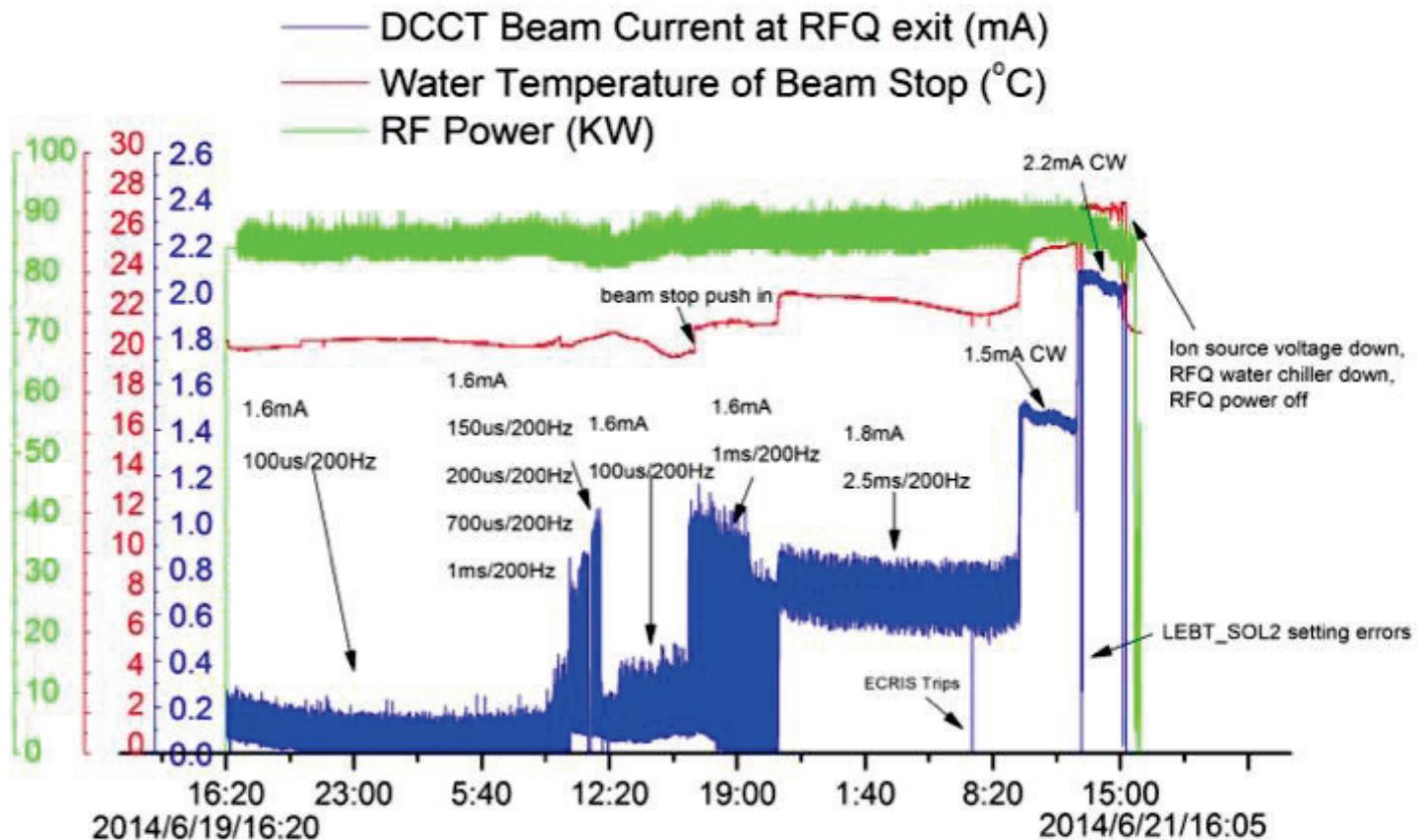
$$e_x = 0.271 \pi \text{ mm mrad}, e_y = 0.291 \pi \text{ mm mrad}$$



Momentum spread 0.95% (FWHM)



First attempt to CW beam

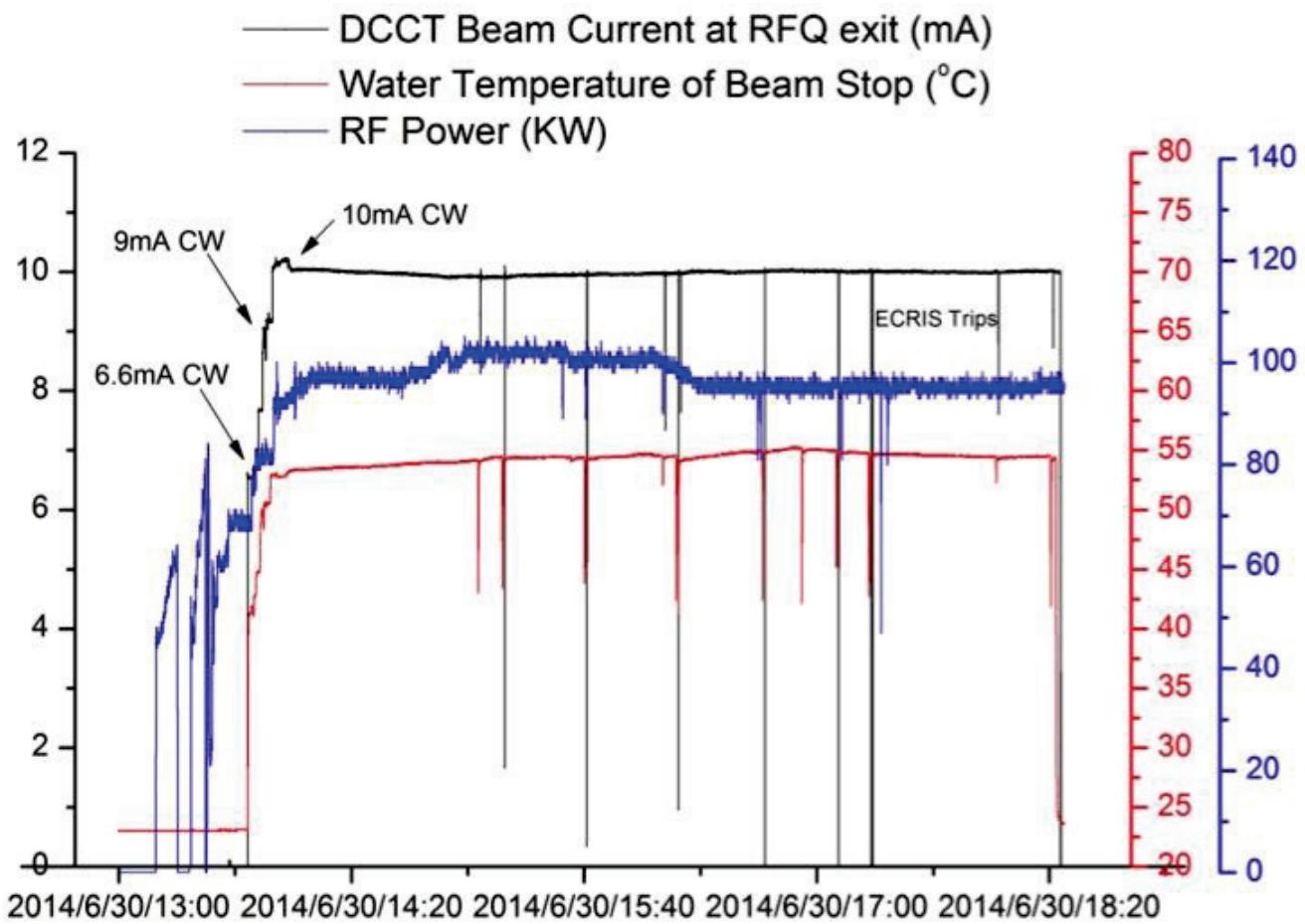


*The DCCT waveform signal is acquired by PLC with sampling rate 2Hz.

*The DCCT beam current number is measured by Oscilloscope.

June 21st, 2014, ~47 hours non-stop commission, conditioning RFQ with pulsed beam ~2 mA, extend pulse length from 0.1ms to CW @ 200Hz

First attempt to full power beam of RFQ



June 30th, 2014, Beam is CW. The current jumped from ~5 mA to ~10 mA, kept for 4.5 hours. Ion source spark is the mean trips and caused the AMP shutdown finally.



Commissioning of MEBT and TCM1



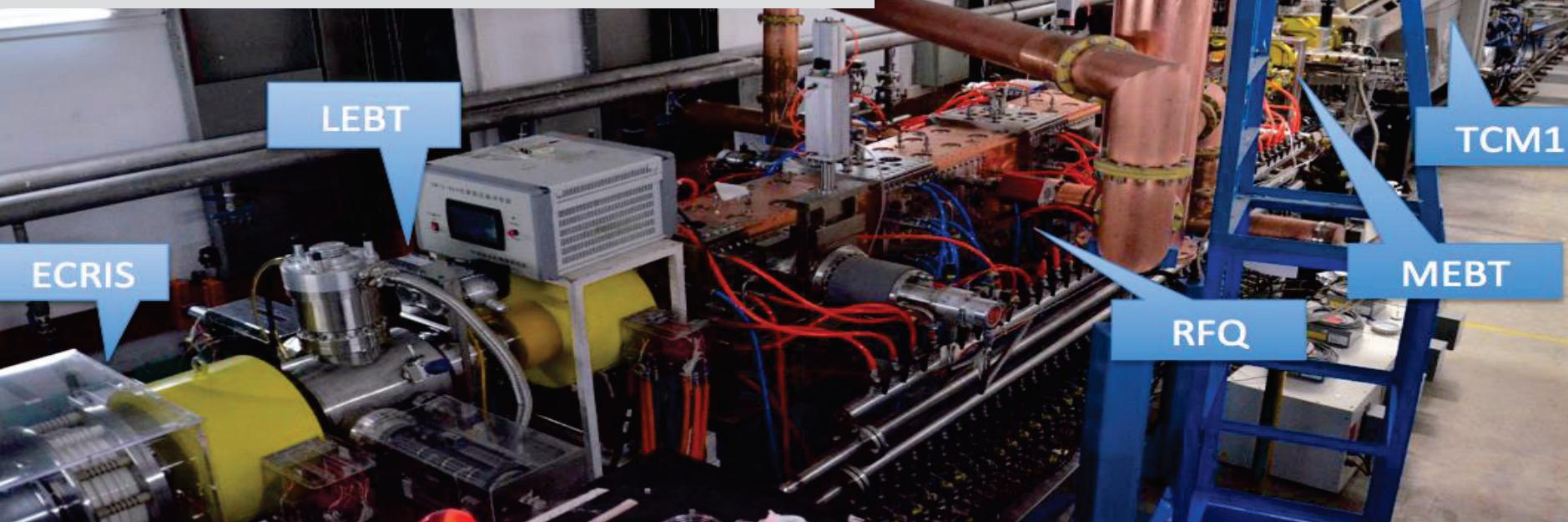
ECRIS+LEBT+RFQ+MEBT+TCM1+D-Plate ~2.5 MeV at 10 mA

Energy measurement : BPM1-DP, BPM3-DP, Time of flight

Energy measurement: Slit2, deflection dipole, FC4

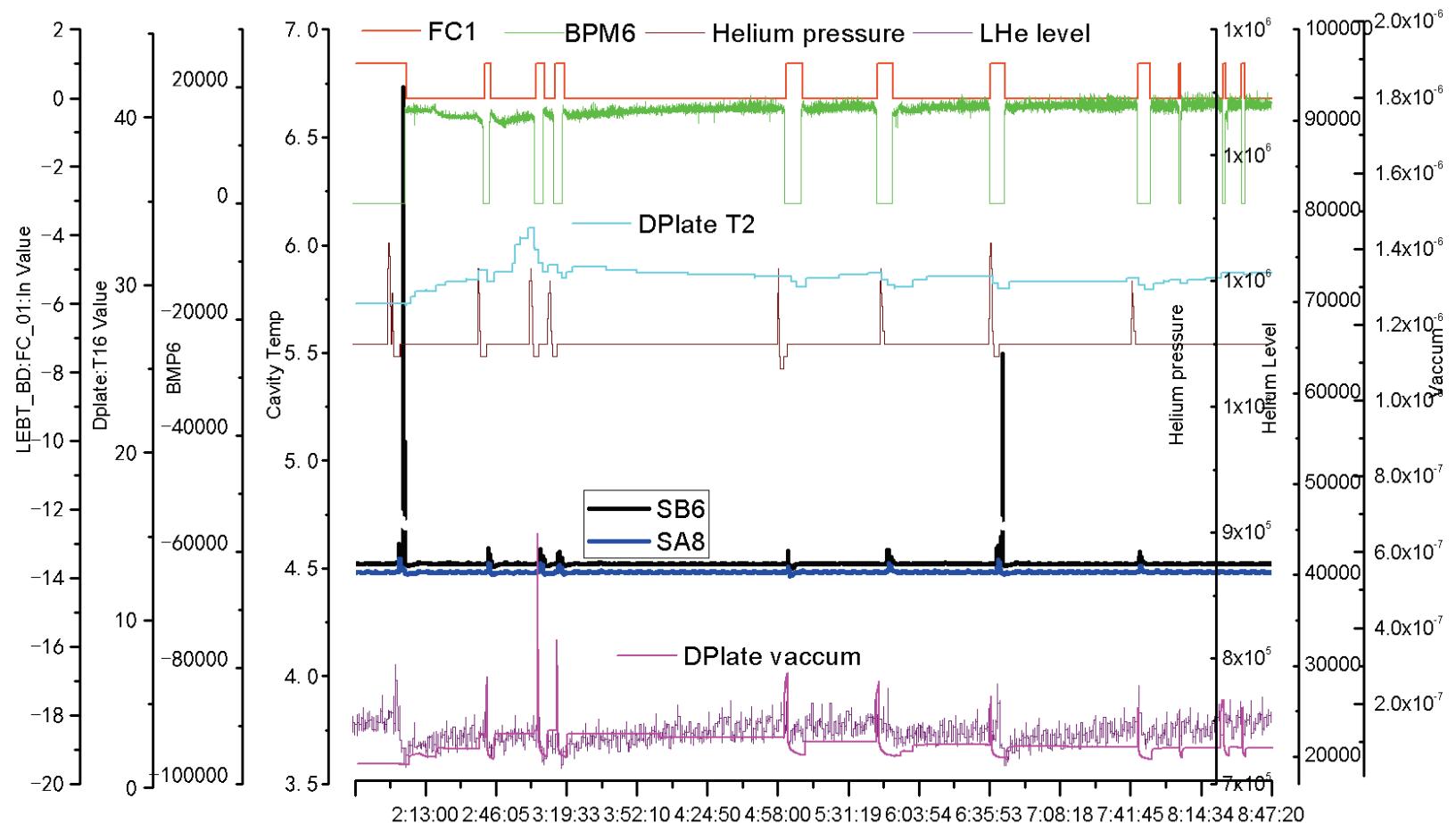
Beam current measurement: DCCT-DP, ACCT2

Transmission efficiency measurement: DCCT-DP, ACCT2



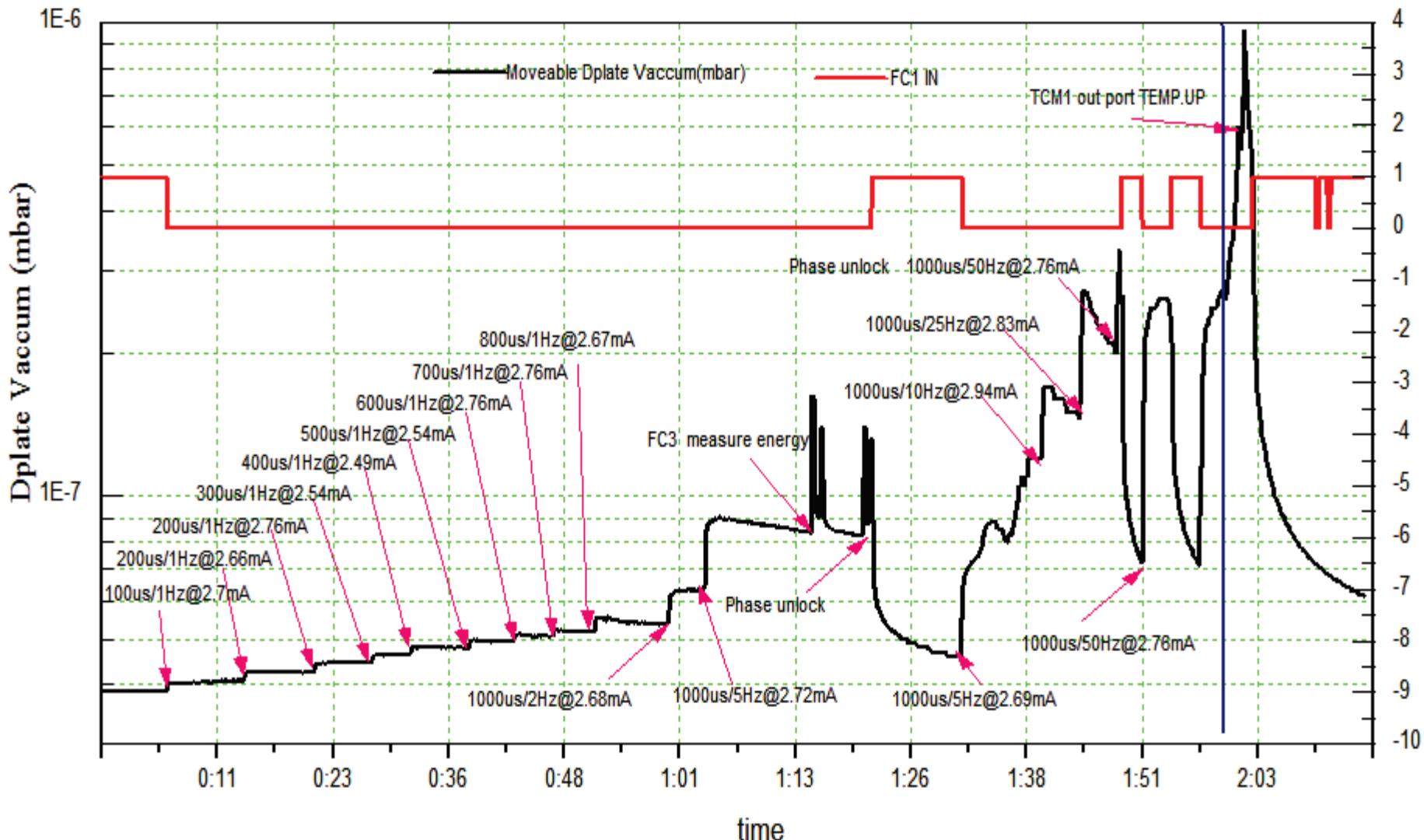
- Oct. 1st, 2014, first beam from TCM1, 2.6 MeV, 2.3 mA, Transmission ~100%
 - Nov.25th, MEBT and TCM (HWR010) operated at 2.67MeV@CW mode around 6 hours. The max current was 3.6 mA and beam power >9.6 kW.
 - Feb. 5th, 2015, 2.51MeV/4.2-10.83mA/72m, Feb. 23rd, 2.55MeV/~11mA/60m.
 - Hours on Nov. 27th. Total operation time was ~ 200 hours.

First commissioning with pulsed beam

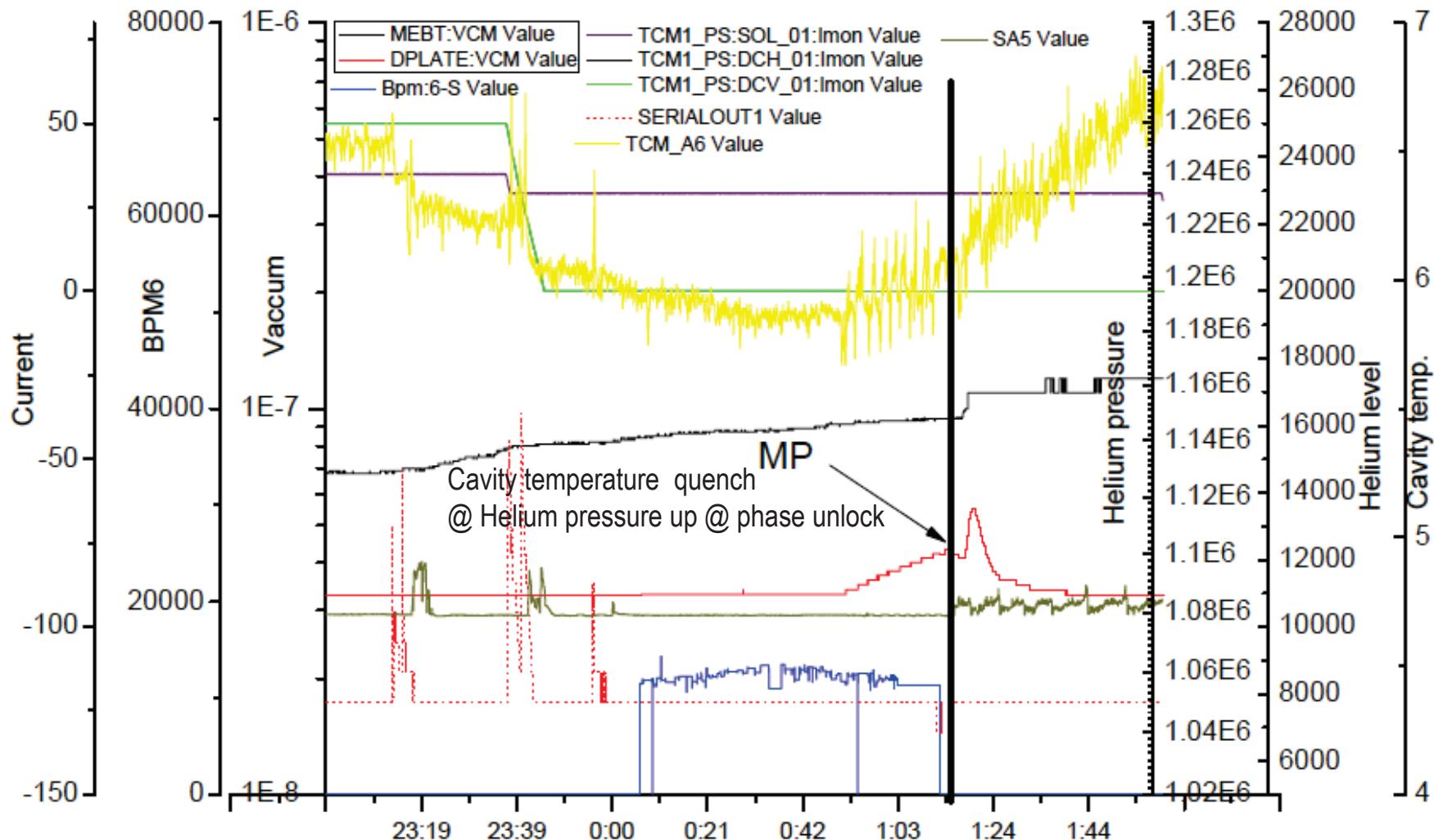


Oct. 3rd, 2014, 2.3 mA, 2.6 MeV, Pulse 5% @50 Hz, 407min;

Dynamic vacuum with beam at C-ADS

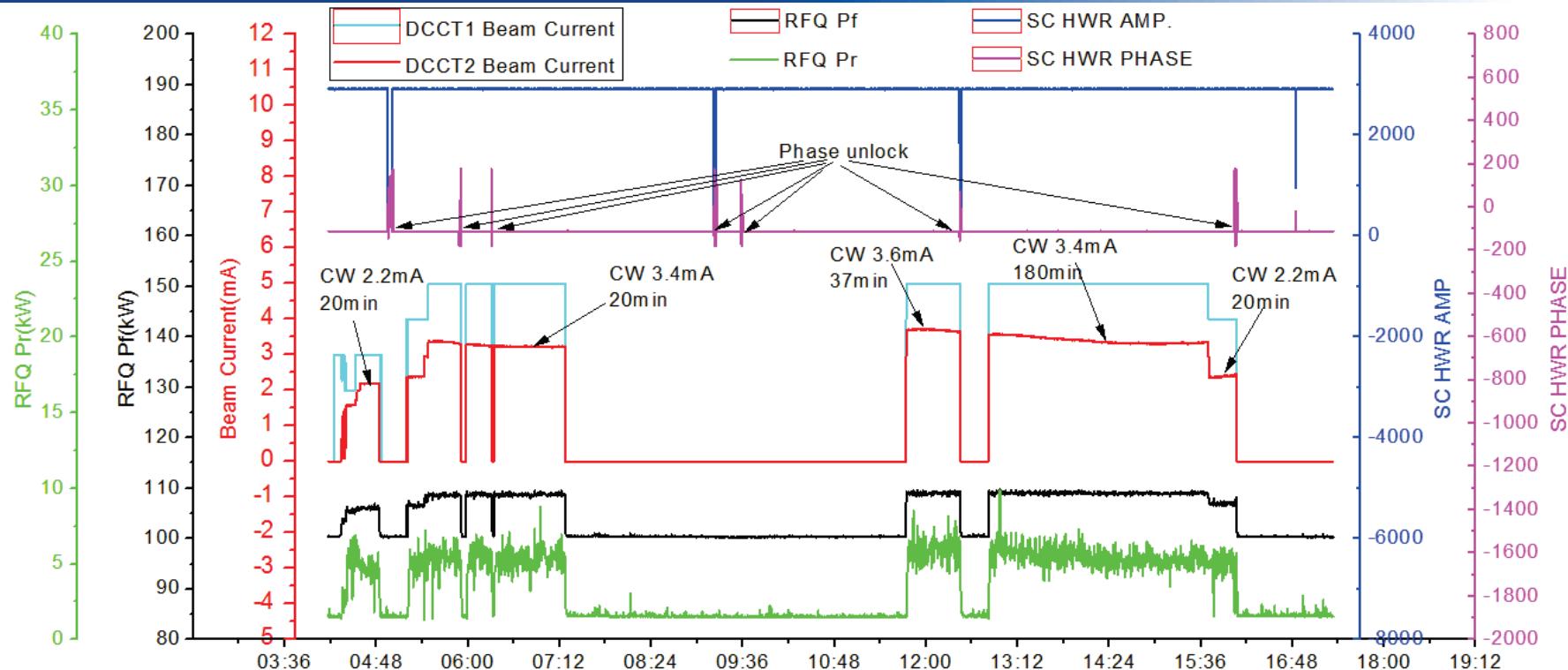


Superconducting Cavity quench



Warm up TCM to room temperature and bake coupler and sc-cavity to recover.

First CW beam

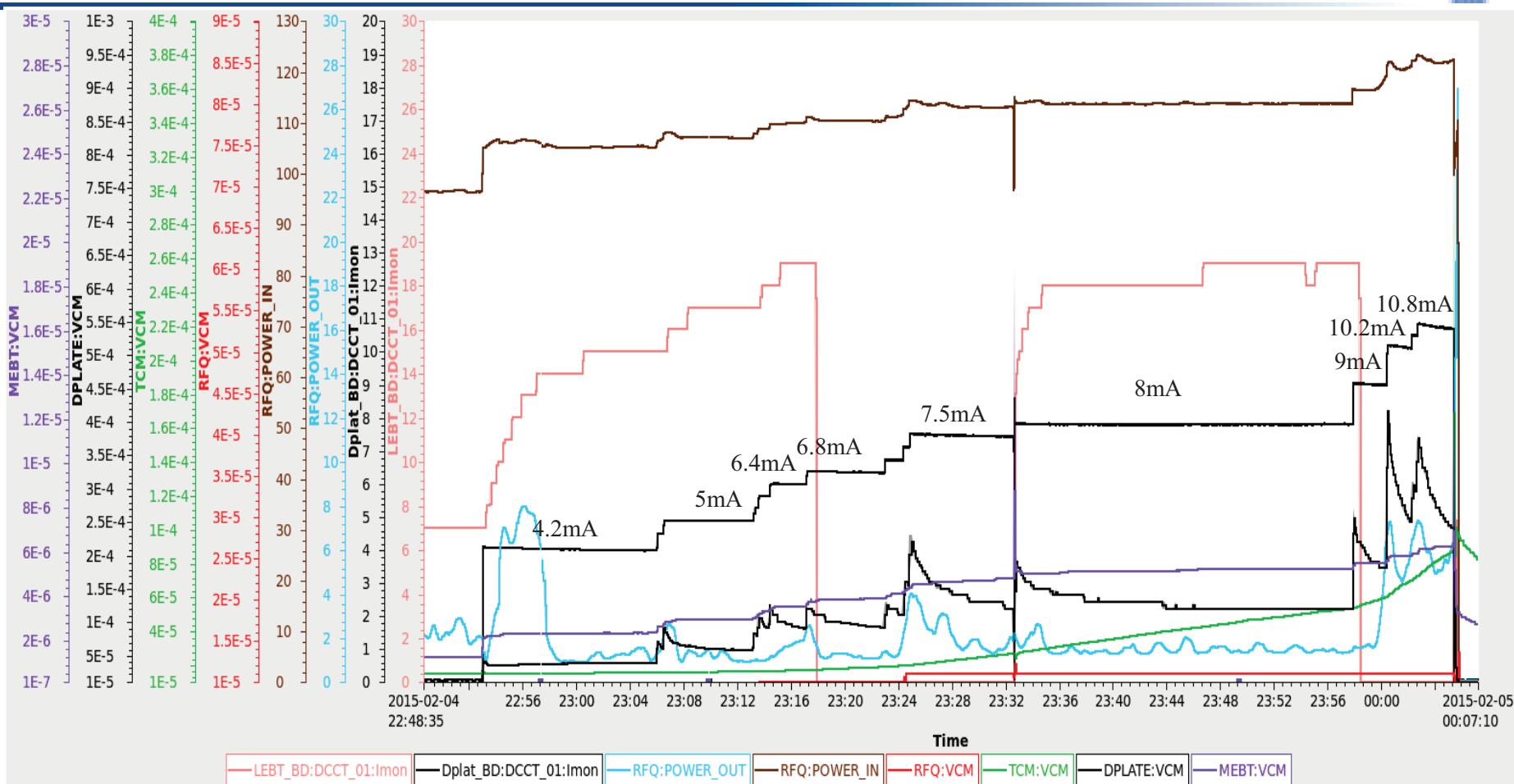


Nov. 25th, 2014, 2.67MeV/~3mA, Energy gain of single cavity is 0.52MeV.

CW beam kept 6 hours. Max beam power 9.6kW.

- The beam match from RFQ to SC
- MPS
- LLRF
- Cooling for normal conducting beam pipe

Attempt to 10 mA/CW

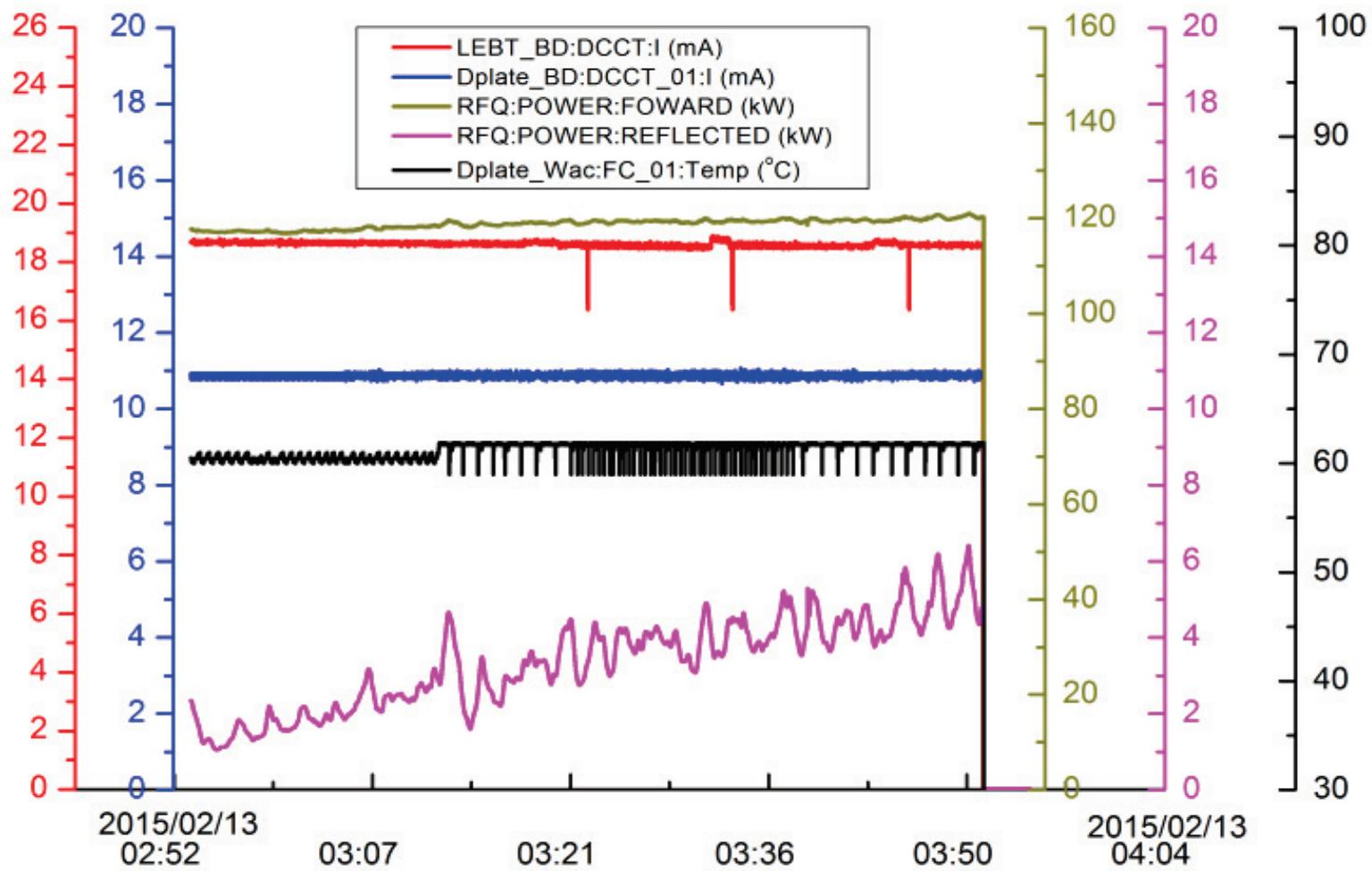


Feb. 4th, 2015, 4.2 mA – 10.83 mA, 2.51 MeV, CW. No circulator.

Power reflection caused by beam loading made the AMP shutdown.
Overcoming of reflection will be introduced in the next talk.

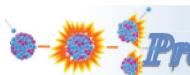


First long-term run of 10mA/CW



Feb. 13th, 2015, ~ 11 mA, 2.55 MeV, CW, 60min; beam power 28kW.

Beam stop due to ion source trip. No circulator caused high reflection.





Commissioning of 5 MeV



ECRIS+LEBT+RFQ+MEBT+HCM6-1+D-Plate ~5 MeV at 10 mA

Energy: BPMs, Time of flight
Current: DCCT-DP, ACCT2
Transmission: DCCT-DP, ACCT2

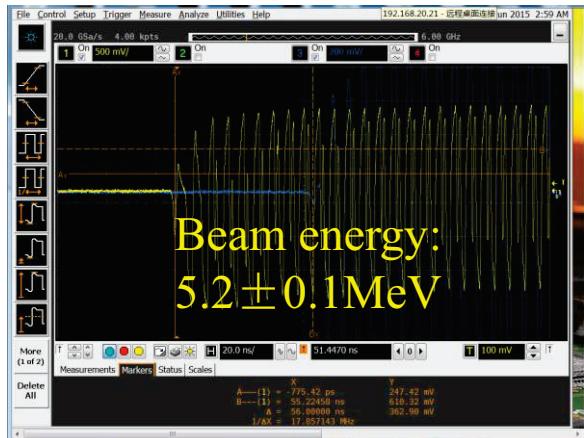
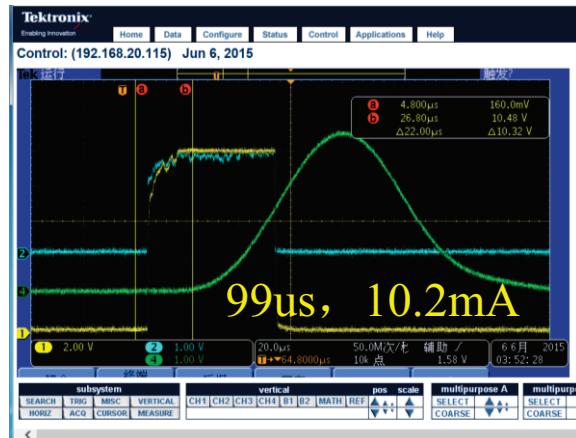


June 6th, 2015, pulse beam 99us@1Hz, 5.2MeV, 10.2mA

June 24th, 2015, 5.3MeV/2.7mA/CW/14kW

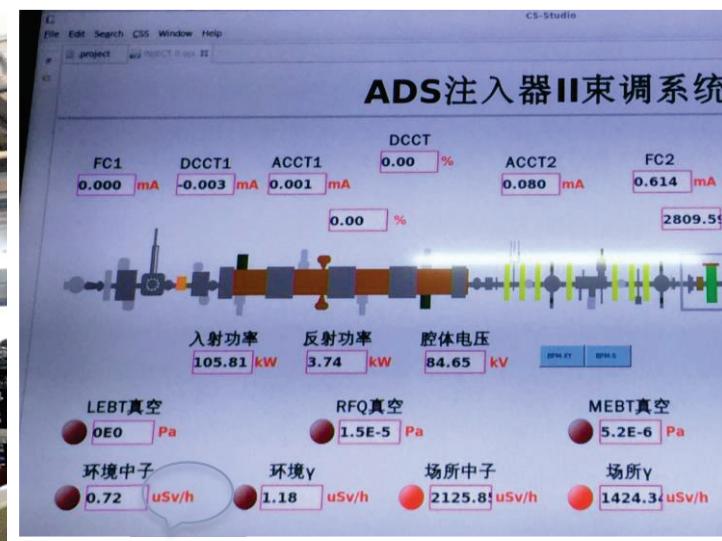


Commissioning with Pulsed beam



June 6th, 2015, 5.2MeV, 10.2mA, 99us@1Hz;

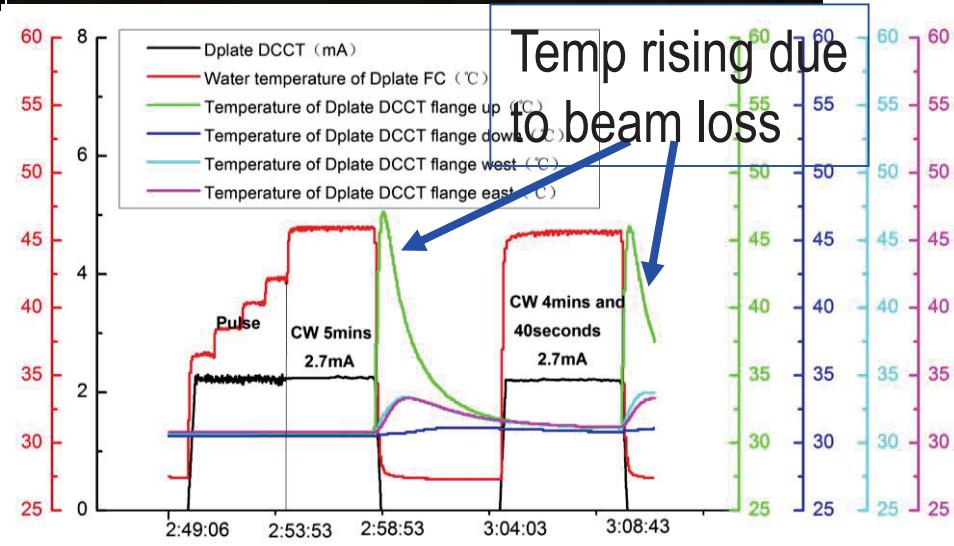
June 12th, 2015, 5.1MeV, 2.7mA, 100ms@1Hz ; stop due to radiation



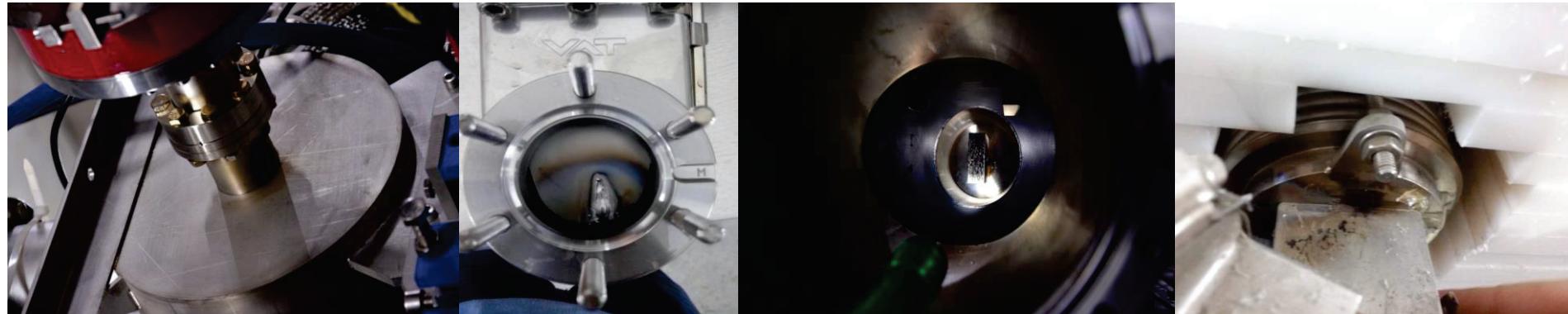
The beam commissioning of RFQ+CM6



- June 6th, the first beam, **5.2MeV, 10.2mA, 99us@1Hz , 0.01%**
- June 12th, **5.1MeV, 2.7mA, 100ms@1Hz , 10%, power 1.4kW**
- July 24th, **6.24, CW, 2.7mA**



Risks of high power beam



2014/07/06
100us/10 Hz 2.4mA
the pump chamber

2015/06/29
CW 2mA
the valve

The slit in the pump
chamber

the front flange of
dipole

Machine Protect——unpredictable beam loss

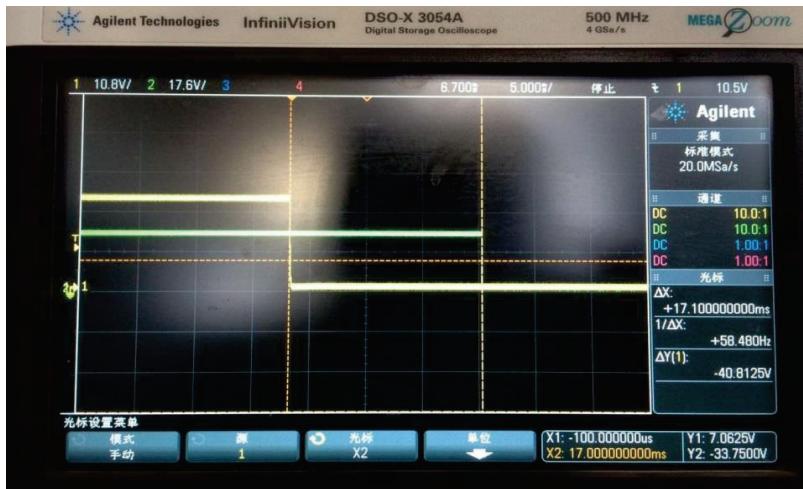
- July 2014, 1 kW beam, ~5 min, a hole in vacuum chamber
- July 2015, 7 kW beam, side particles, ~1 min, leakage

Machine Stability——uncontrolled beam loss

- ~30 kW beam, 99.99% transmission, ~3 W heat, quench

Fast Beam loss online detection is the key of MPS and commissioning!

Fast protection base on BPM



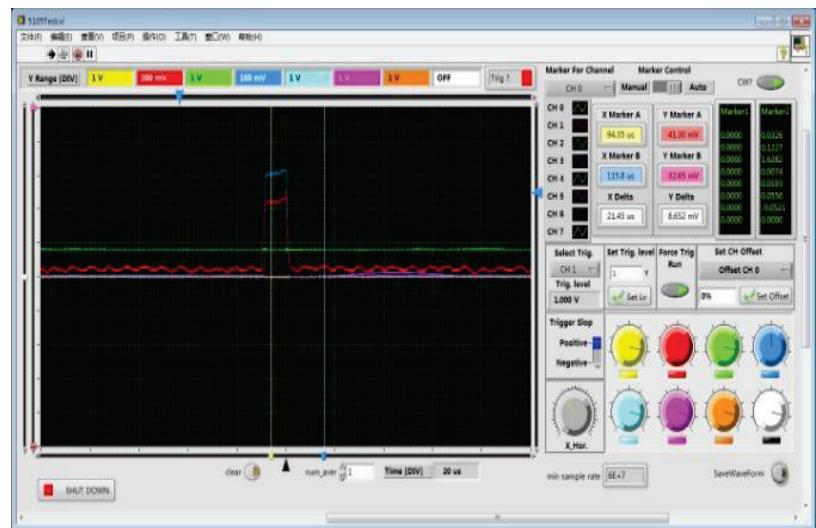
response time of PLC on the east platform: 17.1ms



response time of PLC out of the tunnel: 20.4ms



time of Ion Source's High Voltage shutting off :3.5us



total time of cutting off beam by chopper: 10us

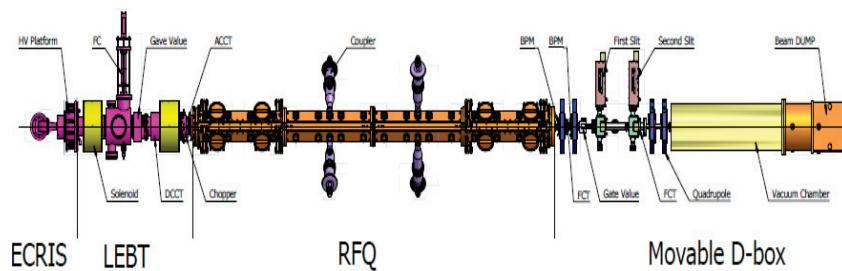


Outlines



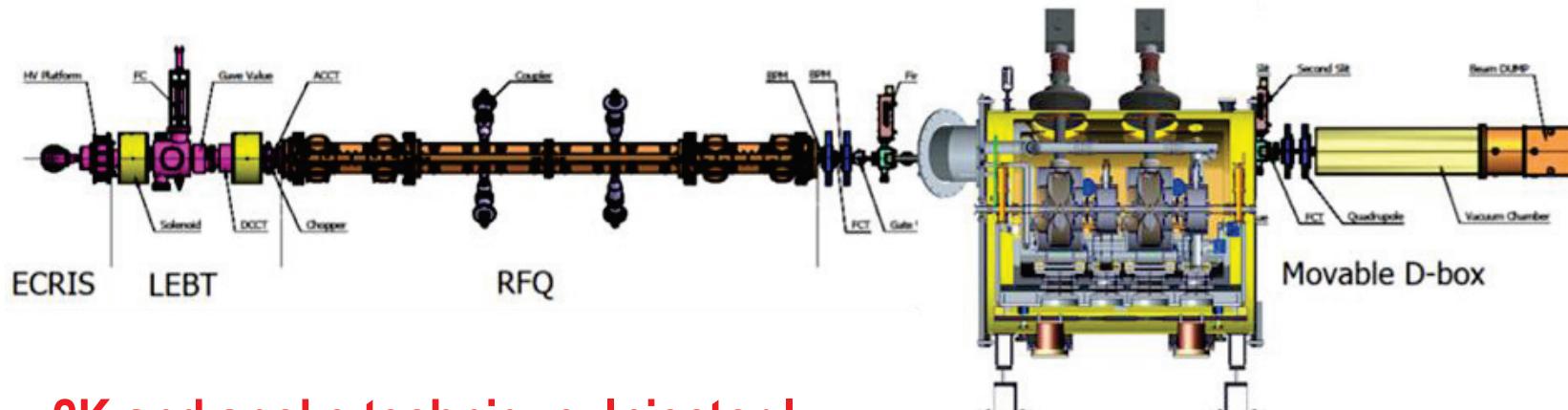
- Introduction of ADS Project of China
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Commissioning of 325-MHz Linac



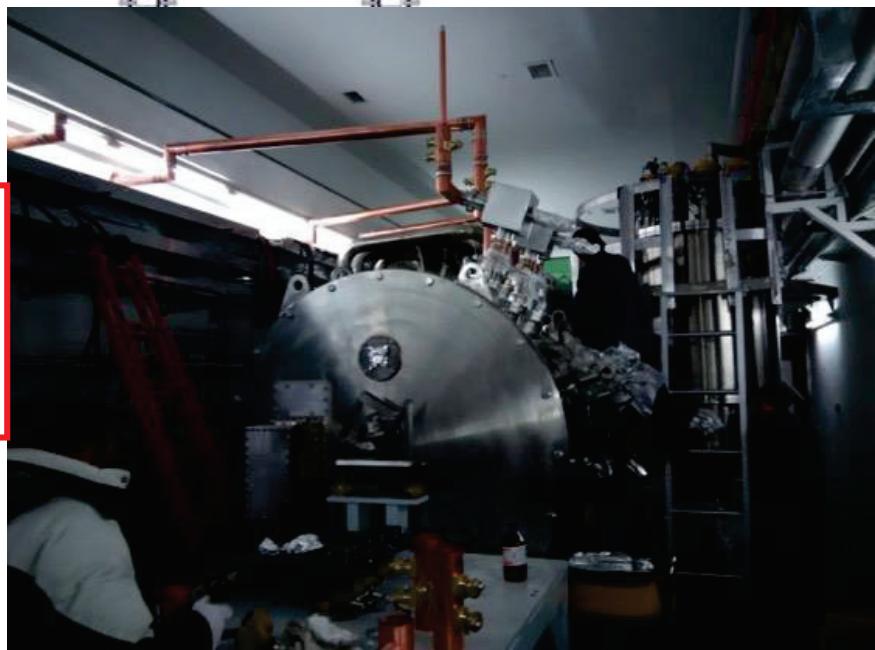
- **Pulses: 11 mA, 50 Hz, duty factor >90%**
- **Efficiency > 97% (duty factor 70%)**
- **Energy 3.2 MeV, average power > 31 kW**

Commissioning of 325-MHz Linac



2K and spoke technique, Injector I

- Two spokes
- Pulses: 10 mA, 30~130 us, 1 Hz
- Efficiency > 99.7%
- Energy 3.61MeV





Summary



- ▶ Chinese Initiative ADS project (CIADS) will be approved. 250 MeV SRF proton linac, Granular target and 10 MWt subcritical LBE FR are chosen.
- ▶ A demo SRF linac with 25 MeV/10 mA/CW will be build in 2016 and coupled with granular target.
- ▶ The prototype of 2.5 MeV/10 mA/CW SRF linac is in operation around 200 hours, 11 mA/CW/1 hr was achieved.
- ▶ The demo facility of 5 MeV is commissioning. 10 mA was achieved. The first attempt to 5 MeV/CW was done. 2.7mA/CW beam lasted 5 min. The LLRF need to be upgraded to keep the stability.



Acknowledgements



Thanks for your attention

&

Team of China ADS Linac

Thanks for the helps

from LBNL, J-Lab, TRIUMF, RIKEN, ANL, MSU/FRIB, FNAL,
ORNL, CEA/Saclay, IPN/Orsay, IAP, KEK,

HIT, PKU, SINAP,.....

Welcome Collaboration!