

Beam Commissioning of CSNS Front End

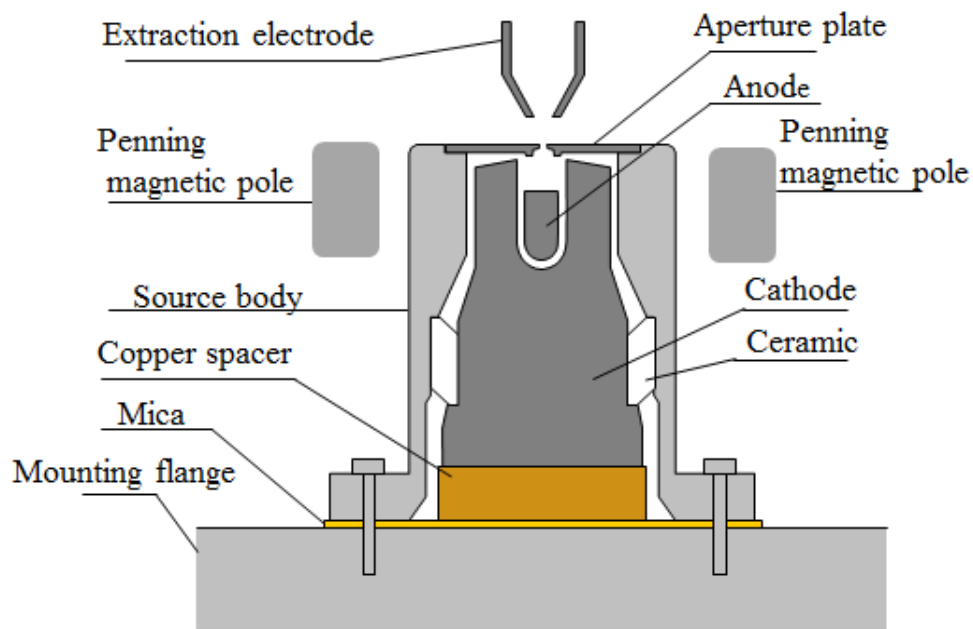
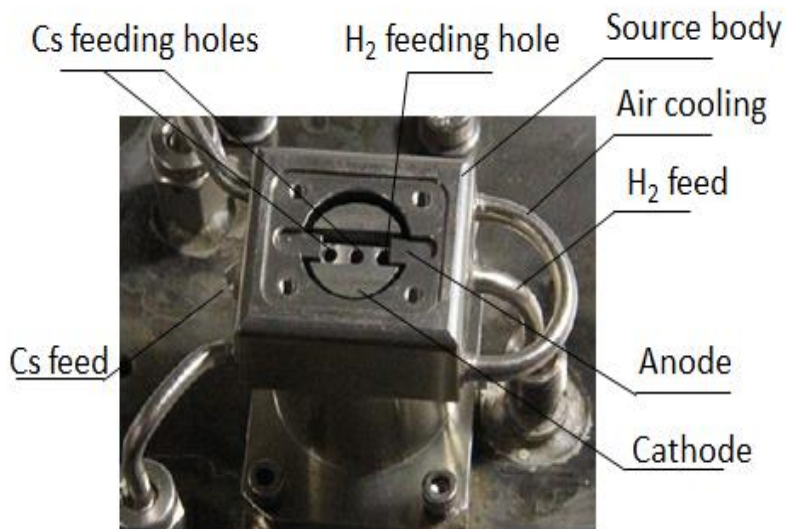
Huafu Ouyang
8 June, 2015

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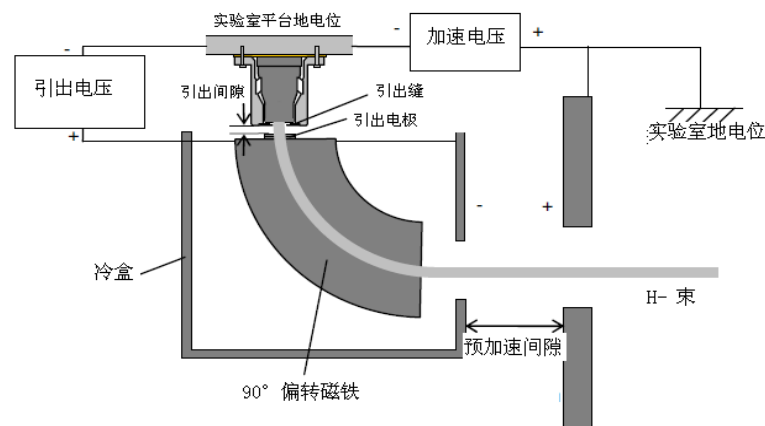
1. Ion source commissioning
2. LEBT
3. RFQ RF conditioning
4. MEBT buncher RF conditioning
5. Front end beam commissioning

1. Ion source commissioning

Ion source type: Penning surface negative hydrogen source (with cesium)



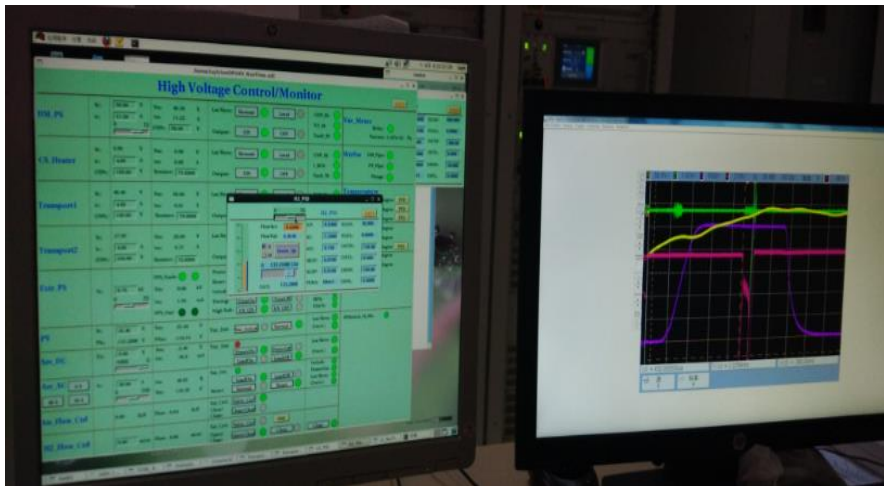
The components of the discharge chamber.



Ion source overview in tunnel

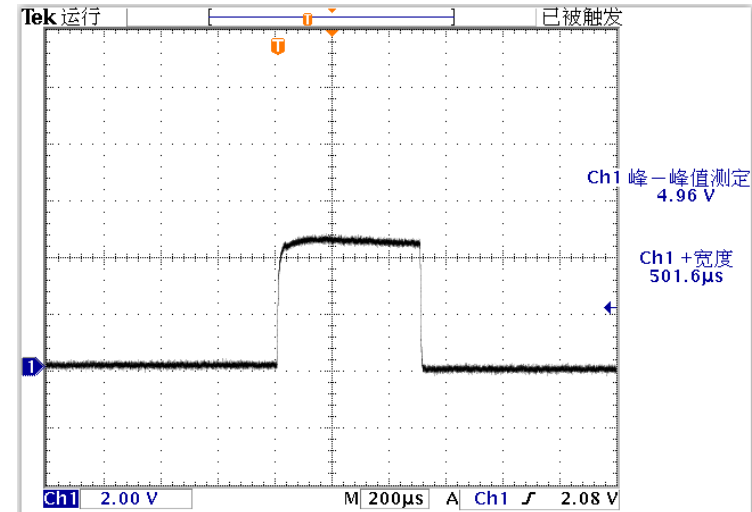
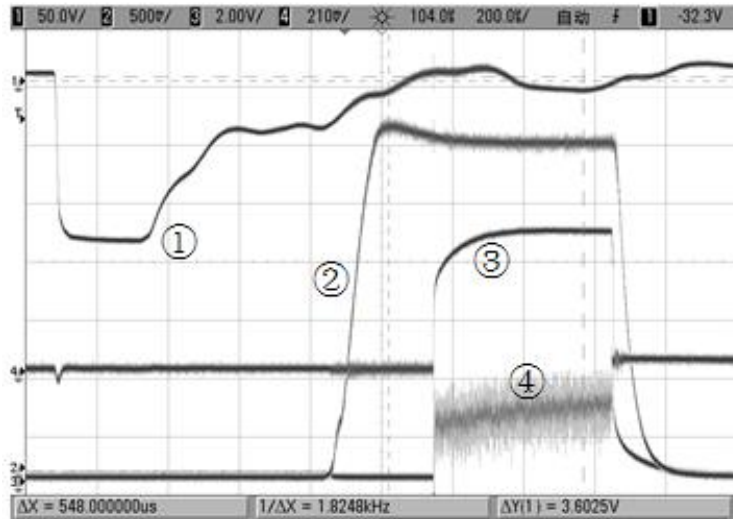


Local control platform



Remote control panel

Ion source commissioning



Typical running parameters:

Output energy	50 keV	Temperature of Cs oven	150~170 °C
Repetition rate	25 Hz	Temperature of Cs transport line	~300 °C
Pulse H ⁻ beam width	500 ms	Extraction voltage	17 kV
Pulse H ⁻ beam current	50 mA	Current of Analyzing magnet	10.7A
Flux of H ₂	~10SCCM	Pulse arc current	50A
Pulse arc width	800 ms	Chamber vacuum	~3.0×10 ⁻³ Pa

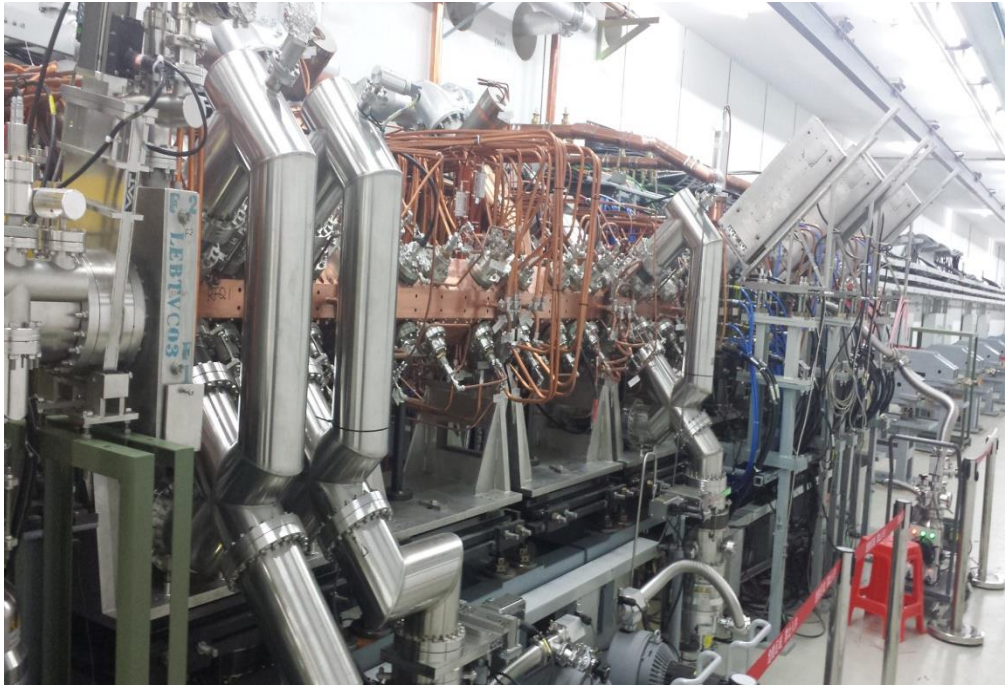
2. LEBT

- Overview (length 1.6m)

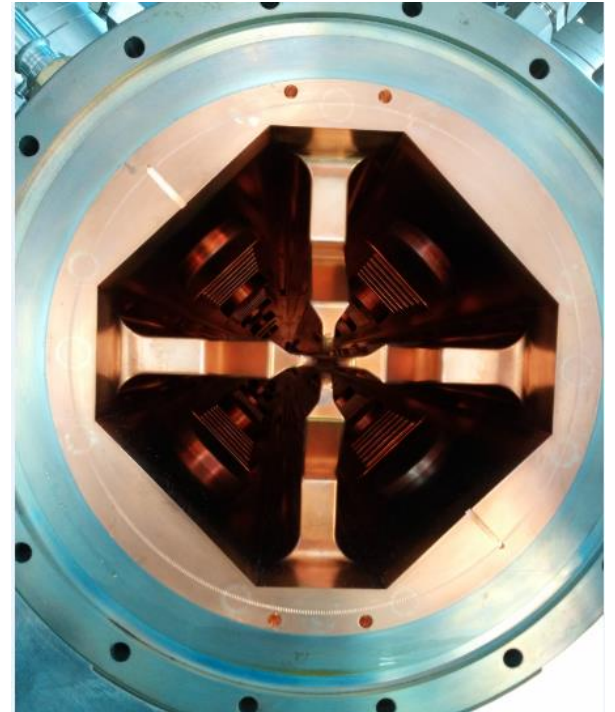


3 solenoids, 2 steering magnets, 2 ACCT, 1 chopper, 1 GV, 1 EM

3. RFQ



Overview

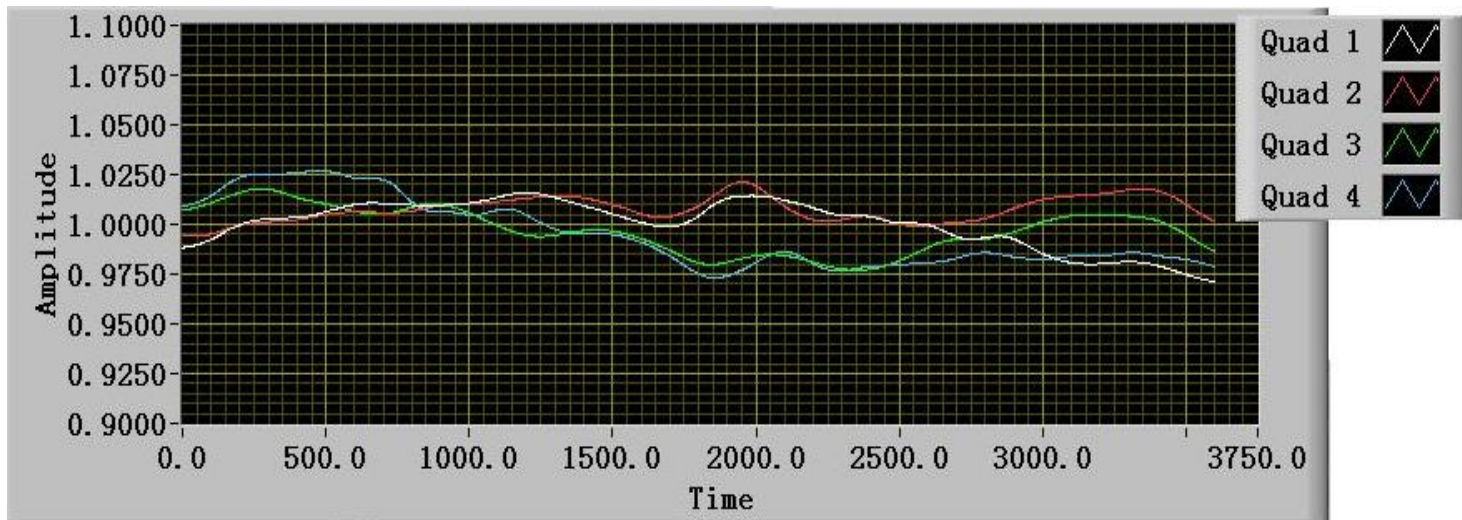


inside

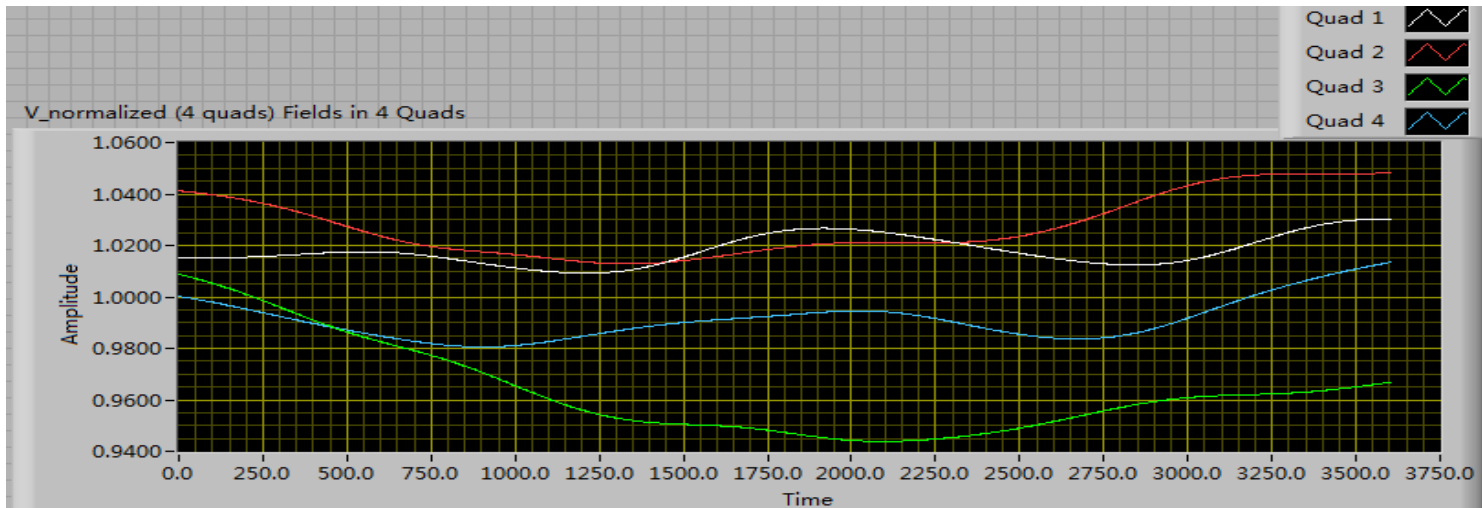
Main design parameters

Parameters	Value
Frequency (MHz)	324
Injection energy (keV)	50
Output energy (MeV)	3.0
Pulsed beam current (mA)	40
Beam duty factor (%)	1.05
Vane length (cm)	3.6
Norm. rms input emittance (π . mm. mrad)	0.2
Inter-vane voltage (kV)	80
Maximum surface field (MV/m)	31.68
Average bore radius (mm)	3.565
Vane tip curvature (mm)	3.173
Cavity power dissipation (kW)	390
RFQ Length (cm)	362

RFQ cold measurement in tunnel



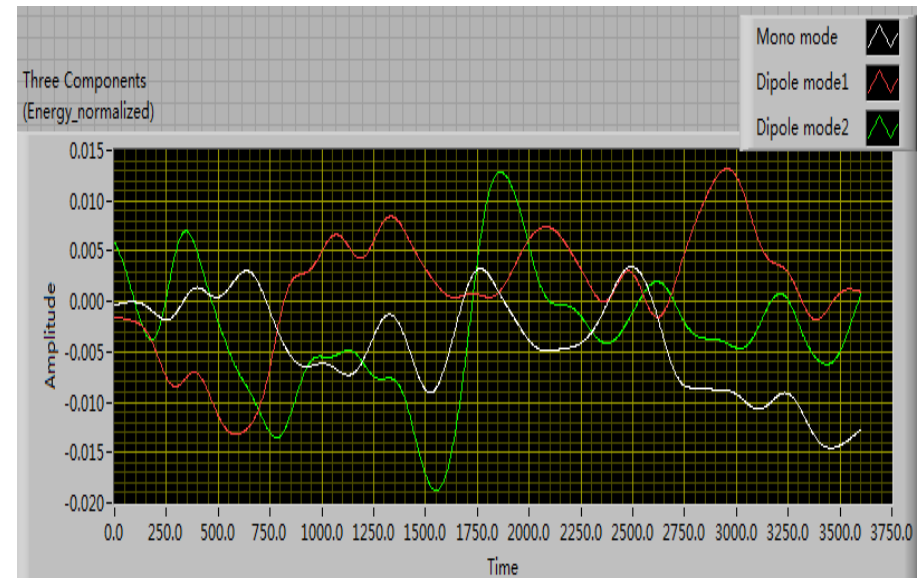
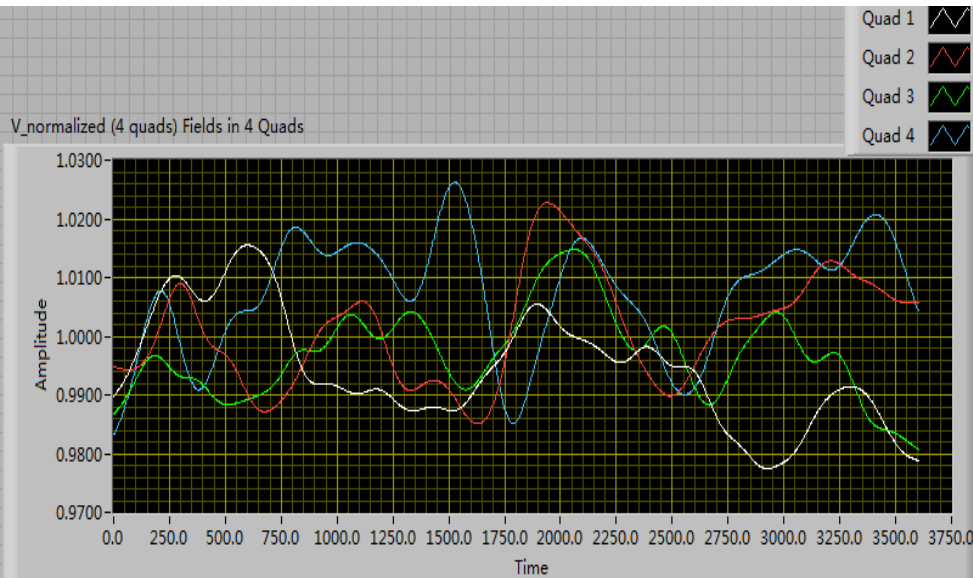
The electric field distribution in lab.



Initial electric field distribution in tunnel after RFQ transported from Lab. to tunnel

RFQ cold measurement in tunnel

**Final result: Field flatness in 4 quads $\sim 2\%$.
Dipole mode components: $\sim 1.5\%$**



Final electric field distribution of RFQ in tunnel after tuning

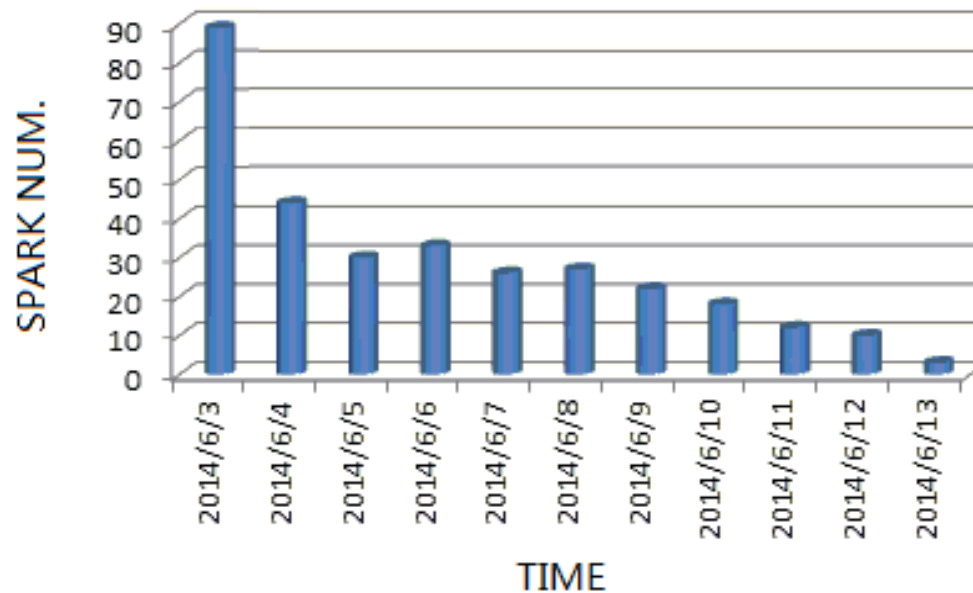
High power RF conditioning in lab.

A duty of 700us and 25Hz

Input power RF power 450kW > 390kW (required)

The reflected RF power is about 60kW

In total , 10days, 24 hours a day

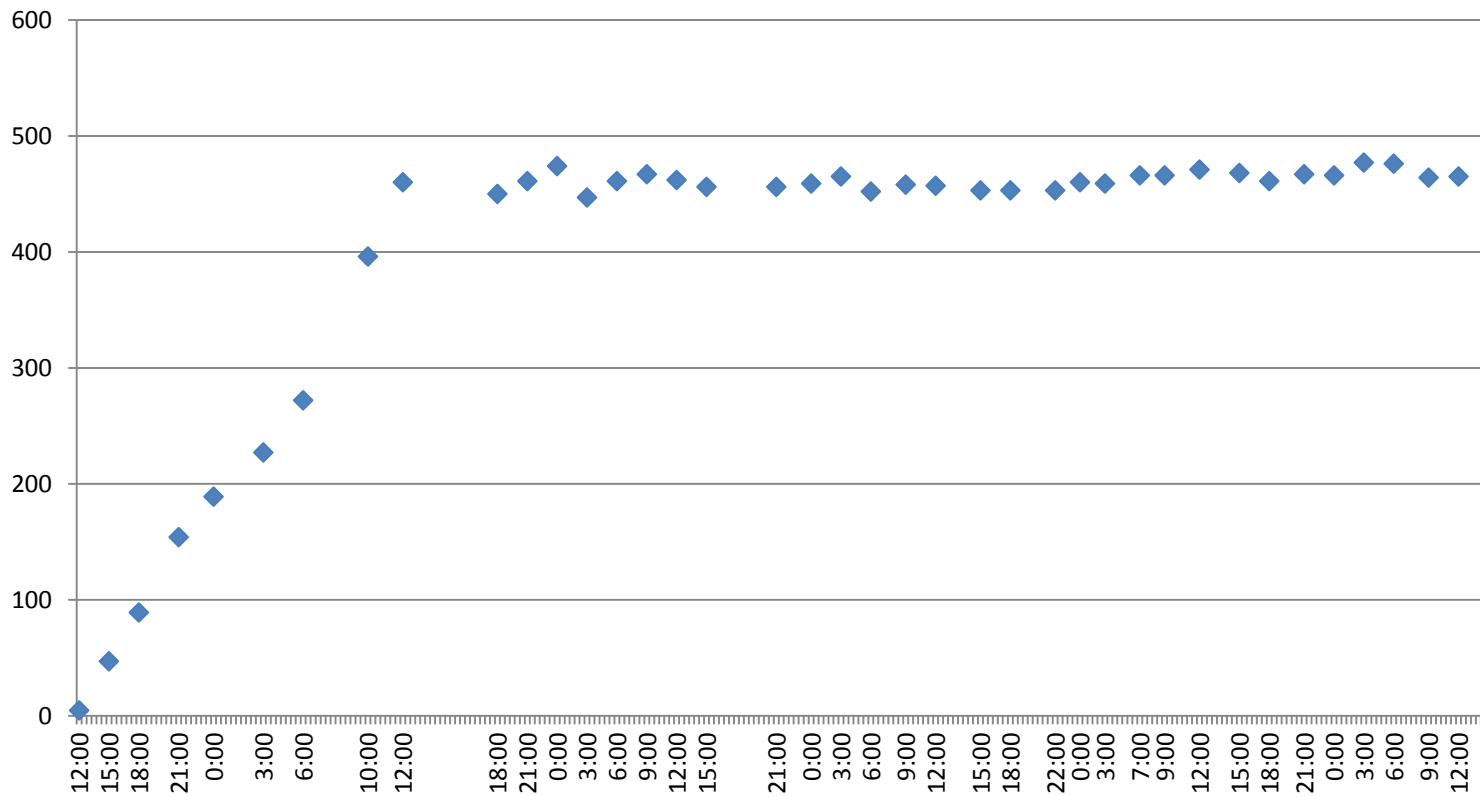


Spark number of RFQ conditioning in lab.

High power RF conditioning in tunnel

Input RF power 450-460kW, in total 5days

RFQ input power

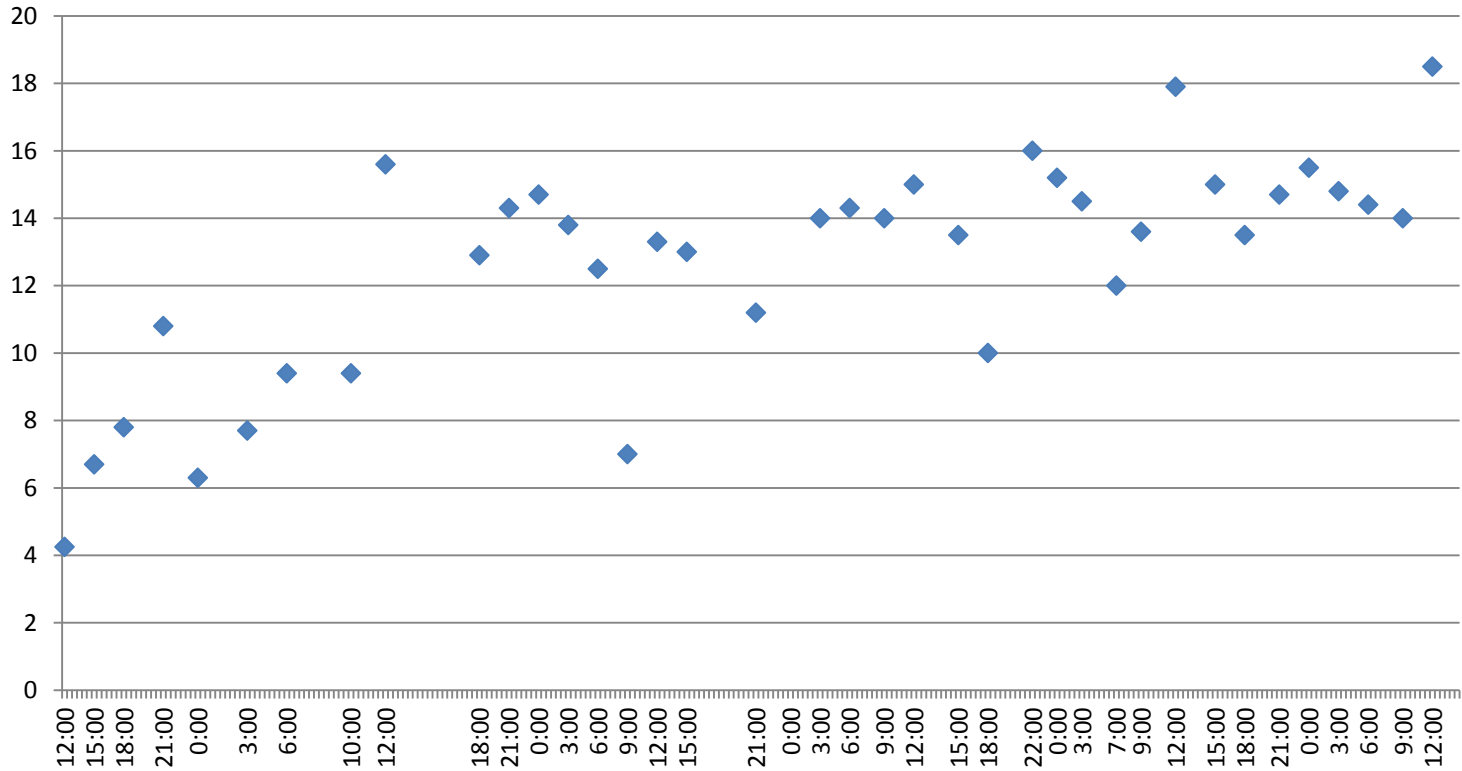


From 2015.2.5 09:00 to 2015.2.10 12:00

High power RF conditioning in tunnel

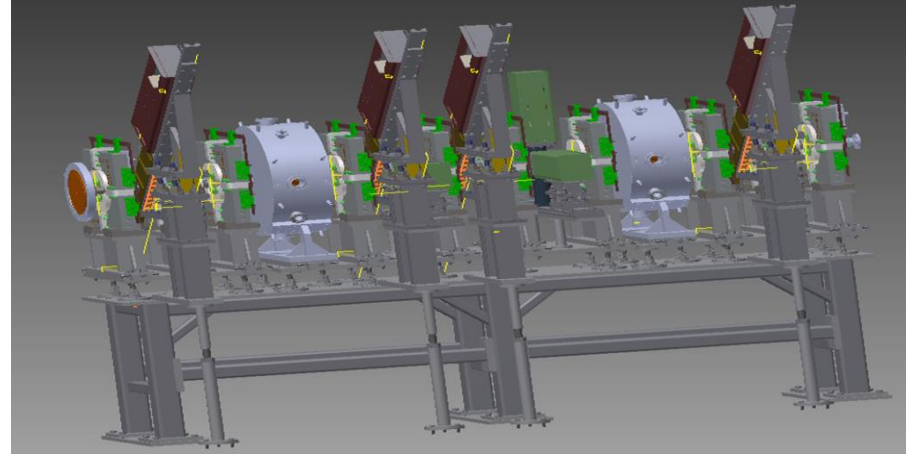
The reflected RF power is about 16kW

RFQ reflected power



From 2015.2.5 09:00 to 2015.2.10 12:00

4.MEBT

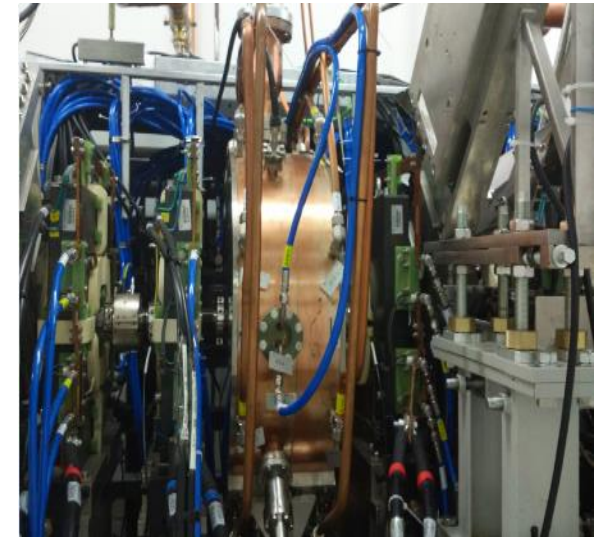


MEBT

- 10Q magnets, of which 6Q magnets have the x and y steering function
- 2 bunchers
- 8BPM, 4PR, 5FCT, 2CT, 1EM

Main design parameters of bunchers

•Beam Kinetic Energy	3.026	MeV
•RF Frequency	323.5	MHz
•Beam chamber aperture diameter	32	mm
•Reserved longitudinal space (L)	162	mm
•Inner cavity diameter	569	mm
•Nose-cones separation	15	mm
•Q value (computed)	27915.2	
•Transit time factor	0.596	
•Shunt impedance (linac convention)	2.26	M Ω
•R/Q	40.964	Ω
•Nominal voltage	156	kV
•Peak dissipated power	11.53	kW
•Duty cycle	1 %	
•Peak electric field on nose cones	26.107	MV/m
•Ratio peak field to Kilpatrick limit	1.47	
•Cone angle	20	
•F	0	
•L	162	mm
•S	2	mm



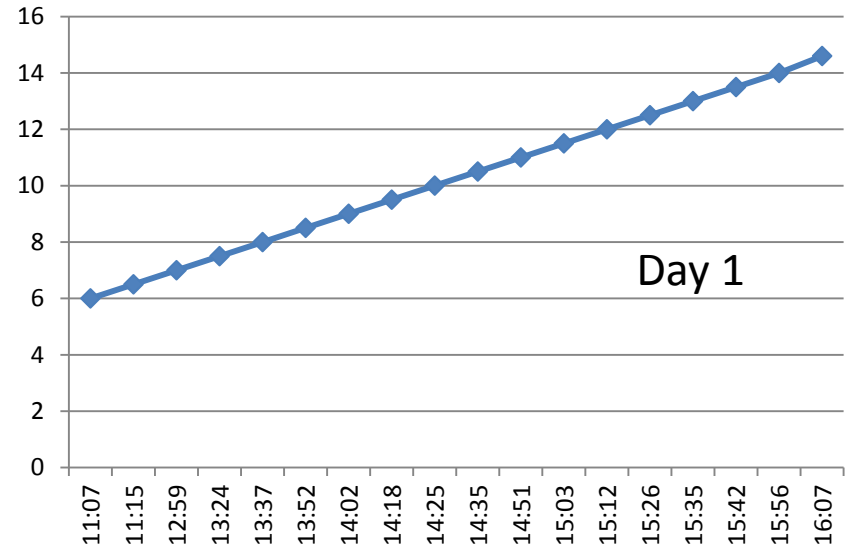
Buncher

➤ The measured Q0 value is high up to 26000, about 93% got by SUPERFISH.

High power RF conditioning of bunchers

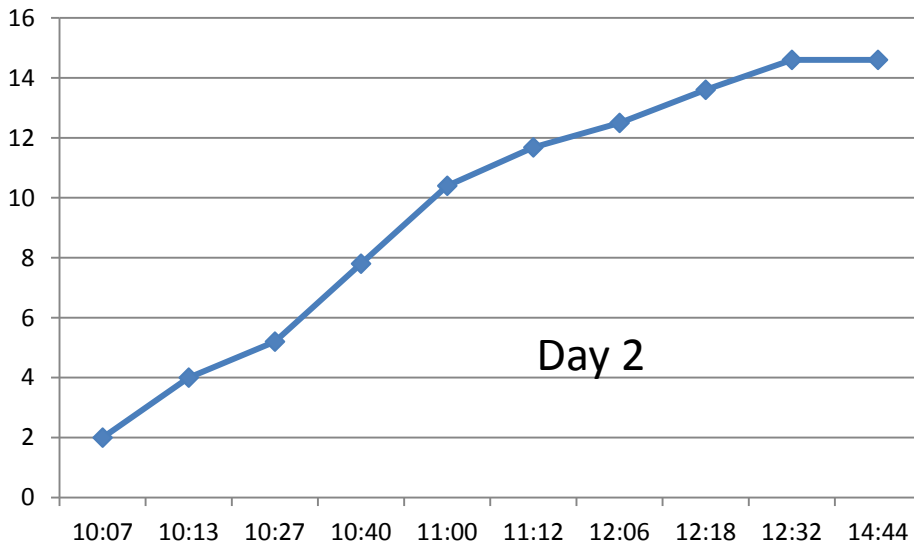
- Day1,2 duty 650 μ s 25Hz
- Day3 duty 7000 μ s 25Hz
- The largest input power:
15kW > 12.4kW (required)
- No spark

Input power



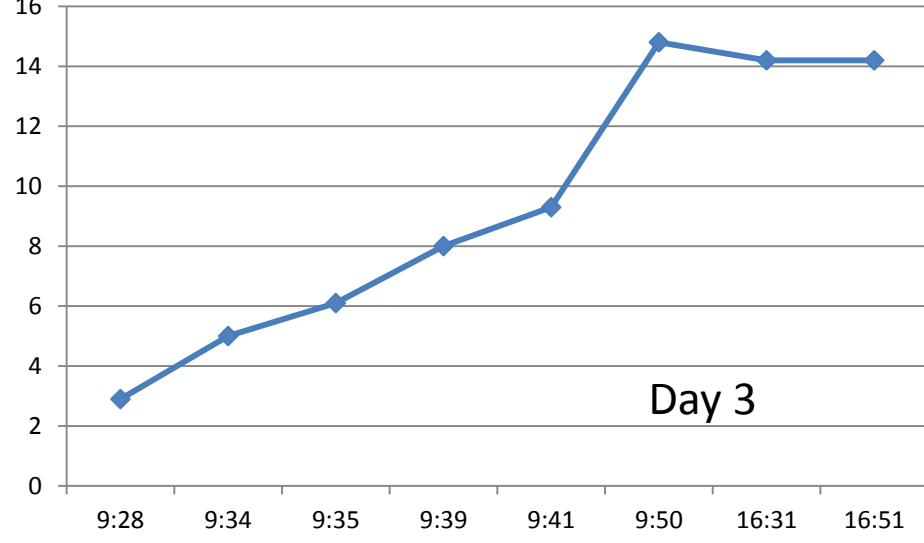
Day 1

Input power



Day 2

Input power

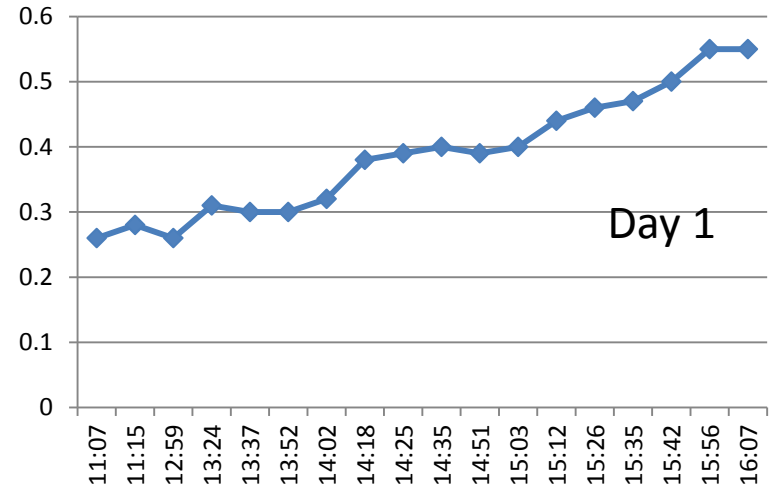


Day 3

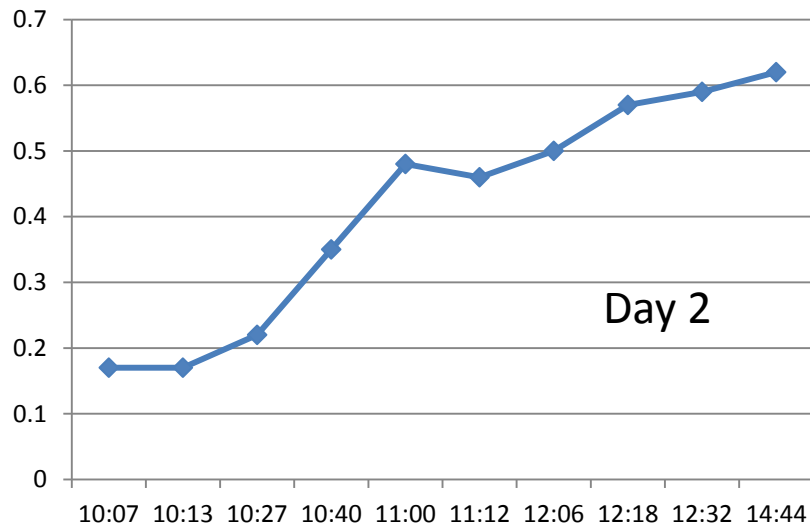
High power RF conditioning of bunchers

Reflected power:
At 15kW, reflected power is around 0.5kW

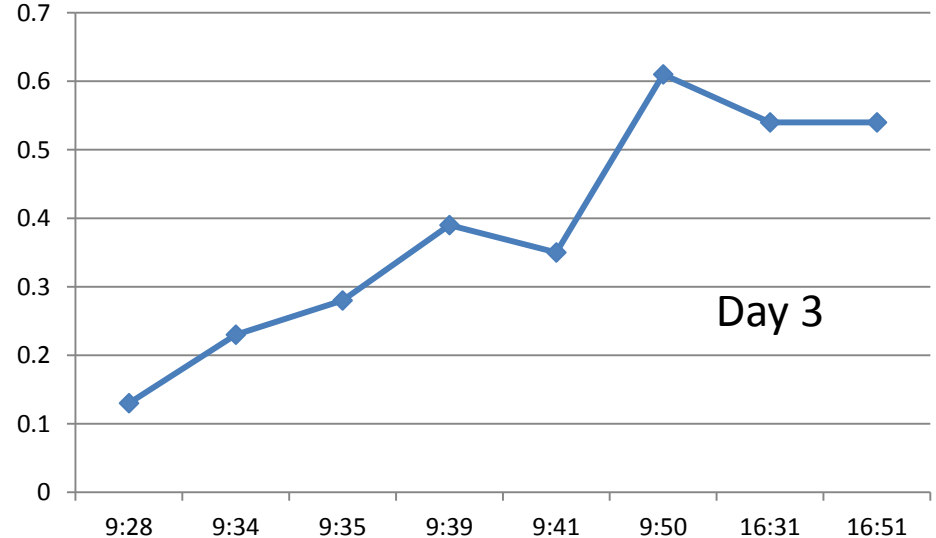
Reflected power



Reflected power



Reflected power



5. Beam commissioning



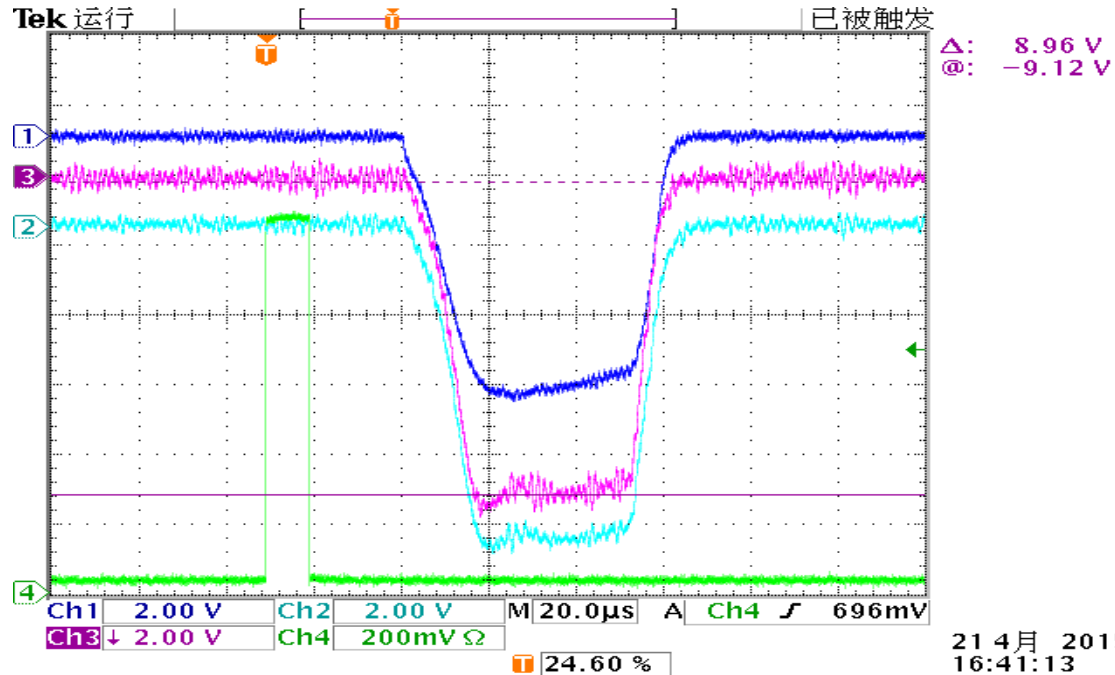
➤ LEBT parameter set :

	SOL 1	SOL 2	SOL3	DH1	DH2	DV1	DV2
Theo.(A)	96	71	137	0	0	0	0
Exp.(A)	105	49	145	0	0.3	4	-1.6

➤ MEBT parameters are set to the theo. value.

➤ No input power for the two bunchers

5. Beam commissioning



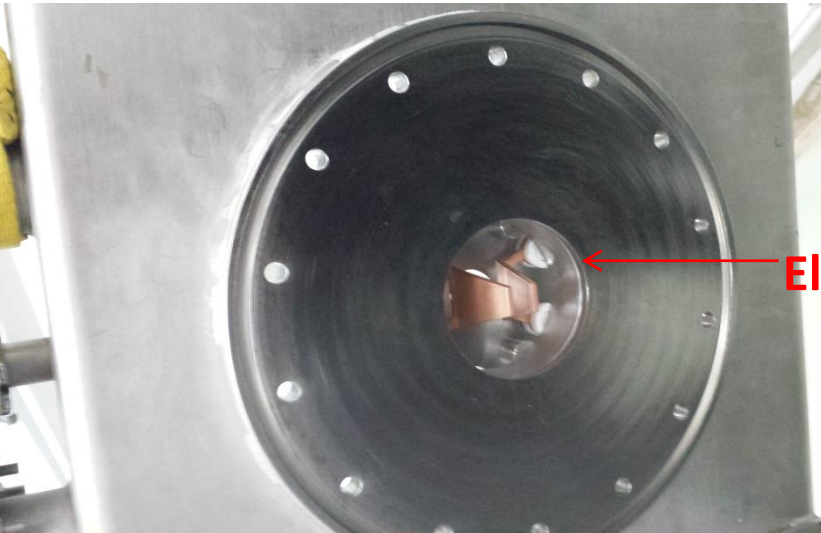
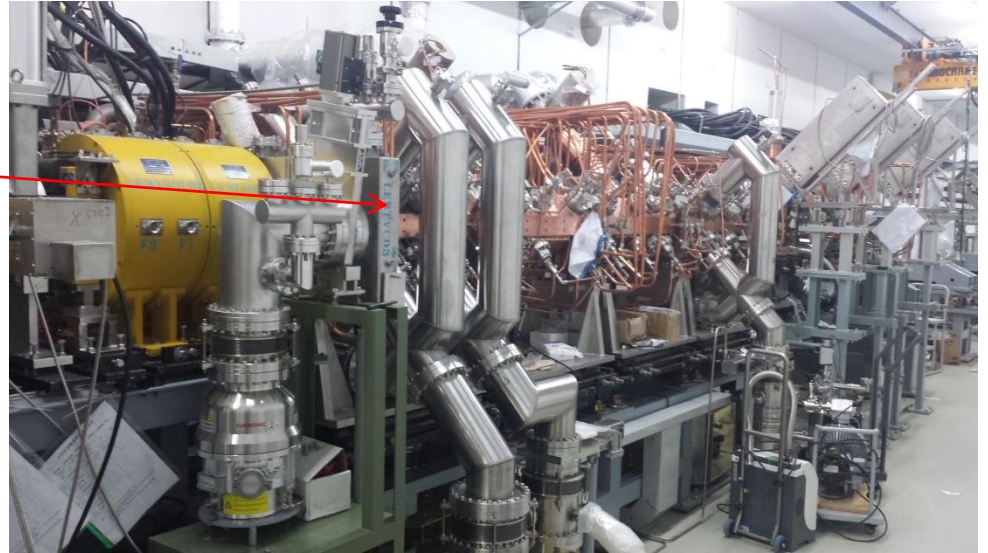
CT signals

CT1	CT2	CT3	CT4
45mA	37mA	28mA	28mA

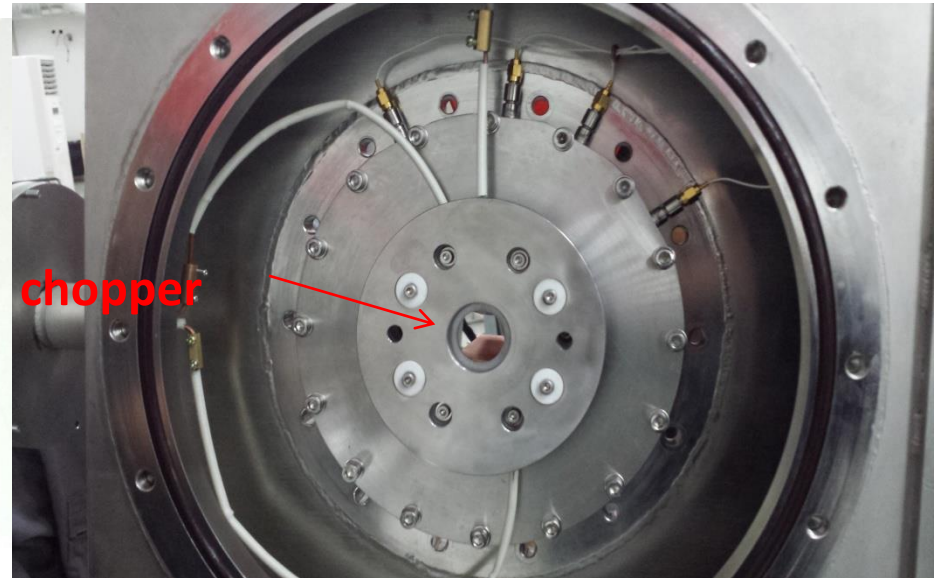
CT value

Chopping experiments

A electric chopper located **in the third chamber** of LEBT just before the entrance of RFQ to chop beam to the required structure for RCS



Electric chopper



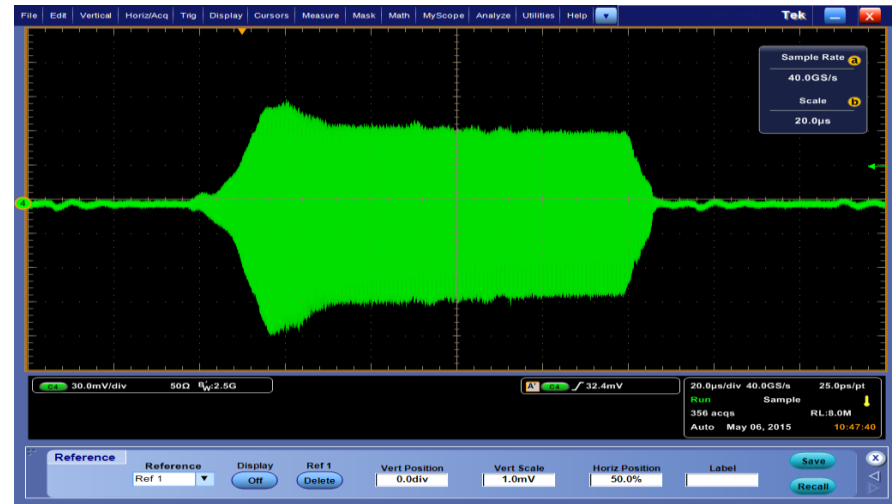
Chopping experiments

Beam structure: 100us, 1Hz (37mA)

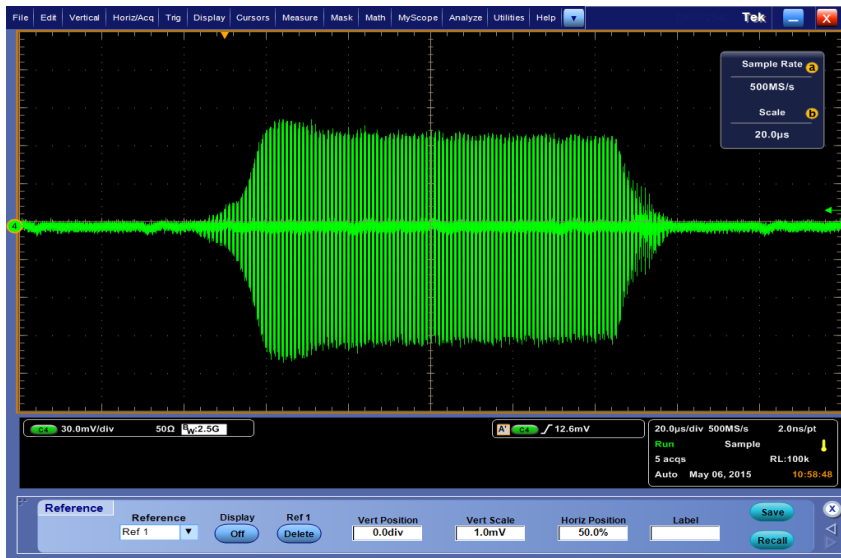
Chopping structure: 500ns, 1MHz

Applied chopping voltage: 3.8kV

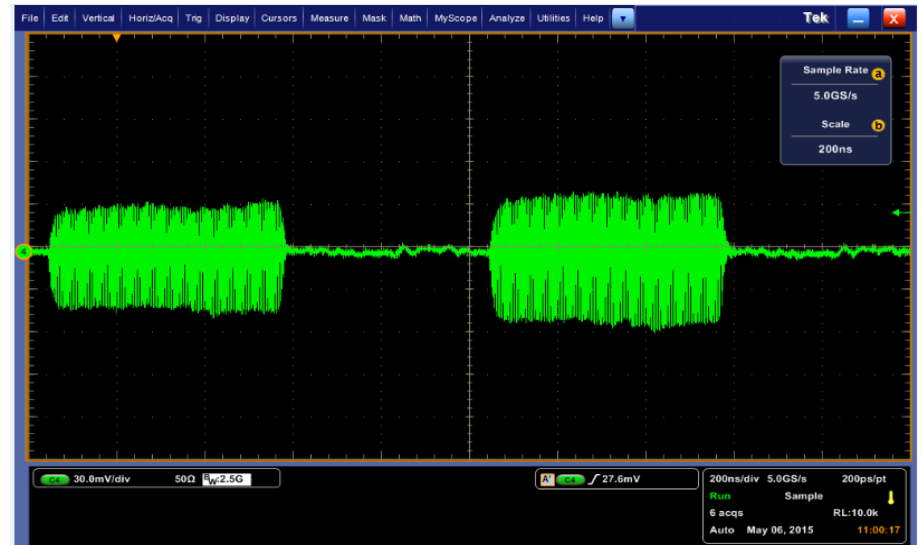
Theoretical chopping voltage: 3.7kV



BPM signal before chopping at the exit of RFQ



BPM signal after chopping at the exit of RFQ



1MHz, 500ns signal after chopping

Chopping experiments

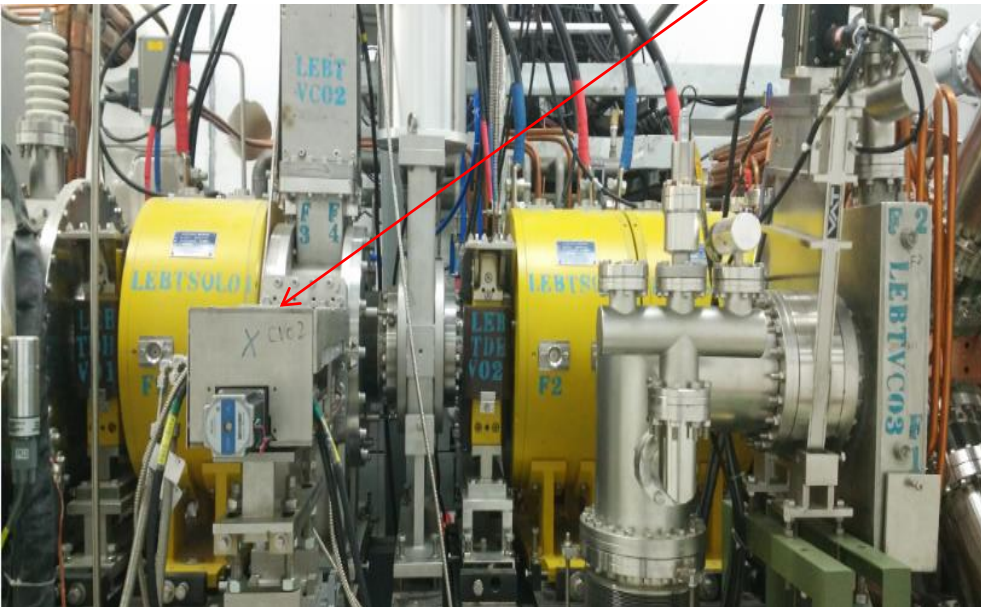
Both the rise/fall time for the chopped beam is about 4-5 periods of the working RF (1 period $T=3.086\text{ns}$).



Beam emittance measurement

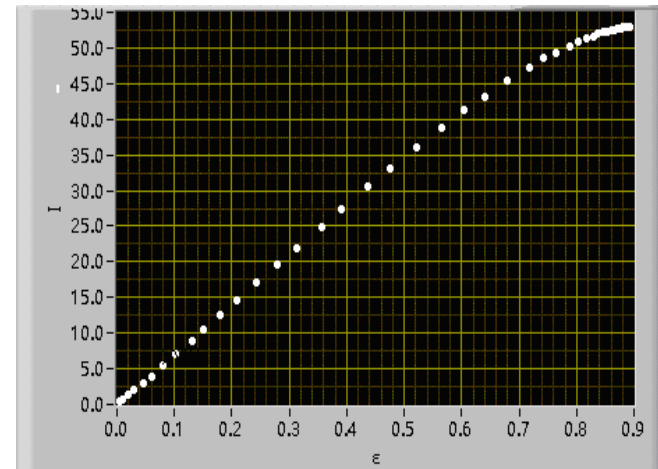
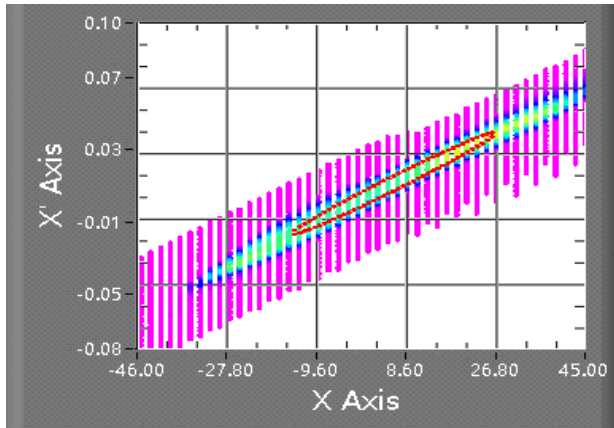
Both in the LEBT and MEBT, A double slit type EM is installed on line to measure the beam emittance.

EM



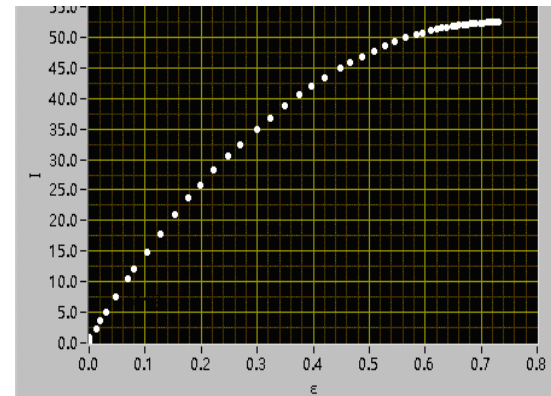
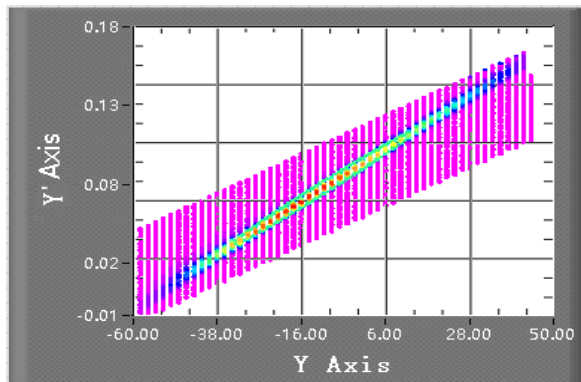
Beam emittance measurement

LEBT emittance measured in lab.



Beam current 53mA X-plane: $0.892\pi\text{mmrad}$ 15mA at $0.2\pi\text{mm.mrad}$ (norm. rms).

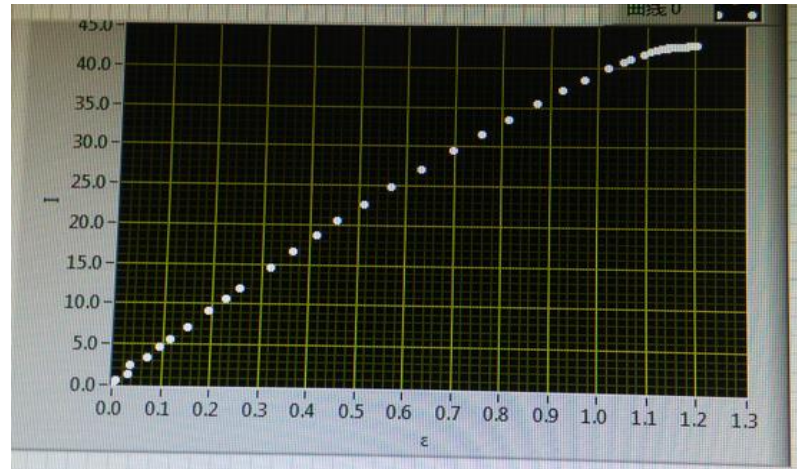
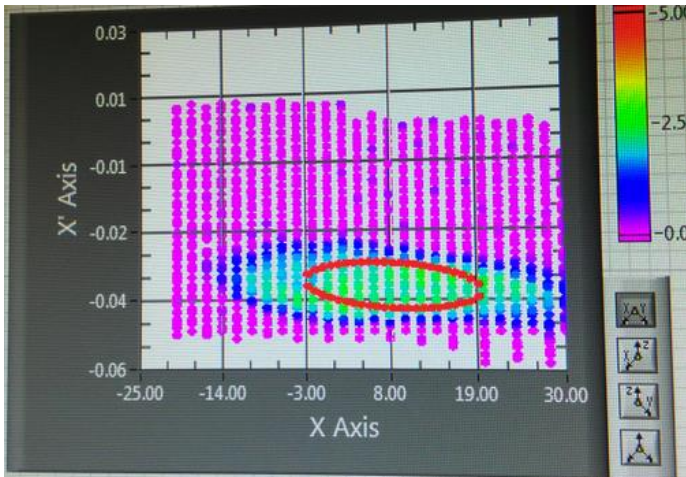
The relation between beam current and emittance



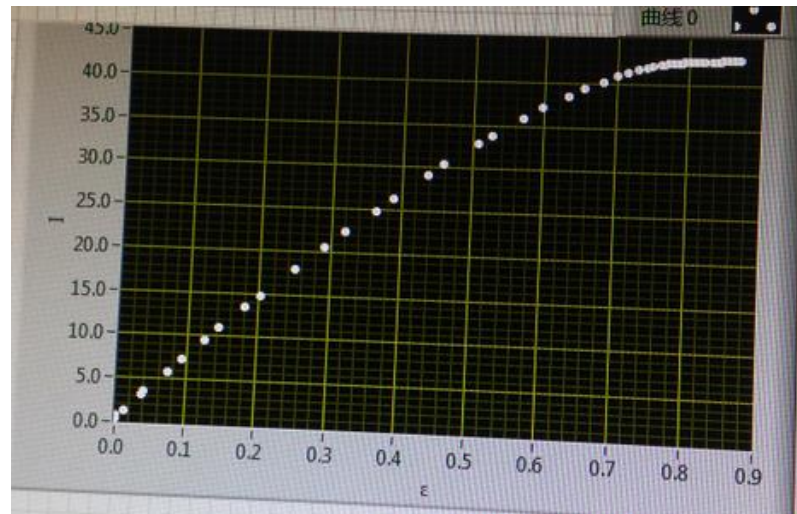
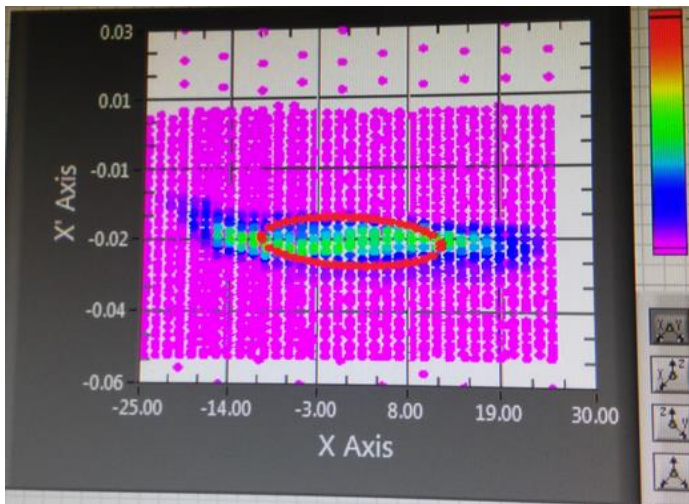
Beam current 53mA Y plane: Y-plane: $0.742\pi\text{mmrad}$ 25mA at $0.2\pi\text{mmrad}$

Beam emittance measurement

LEBT emittance measured in tunnel



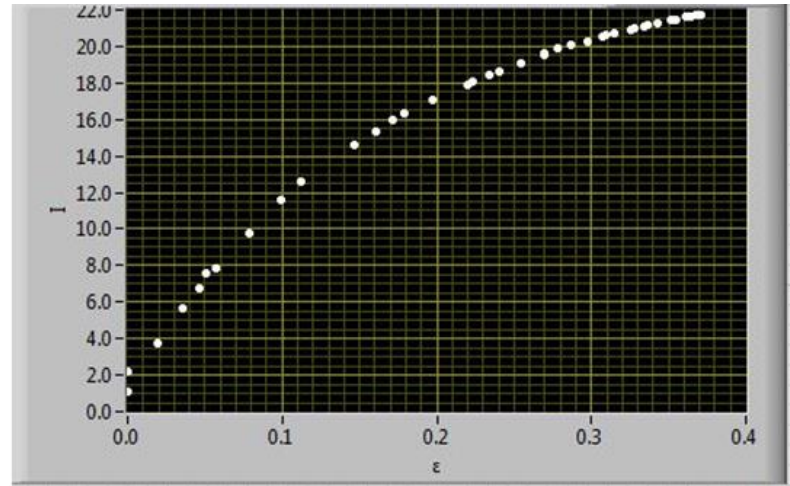
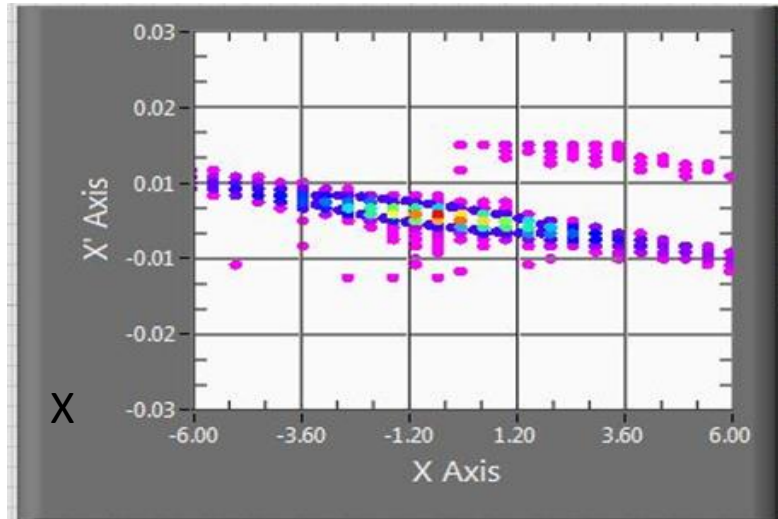
Beam current: 43mA, X: $0.2\pi\text{mm.mrad}$ (norm. rms) with 10mA



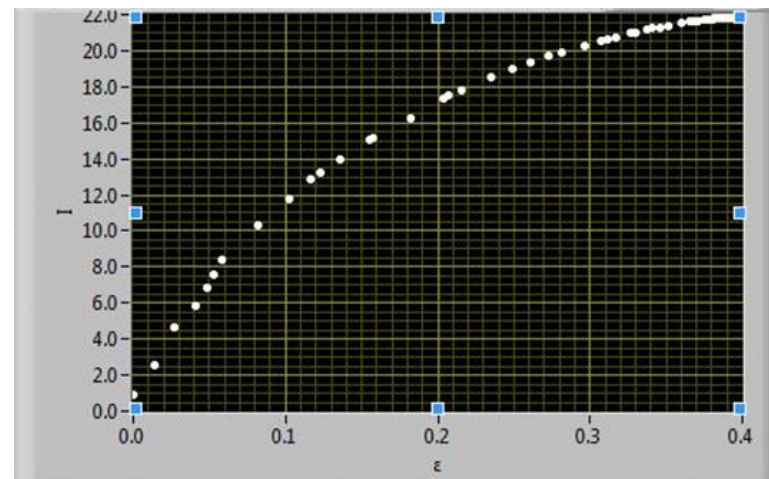
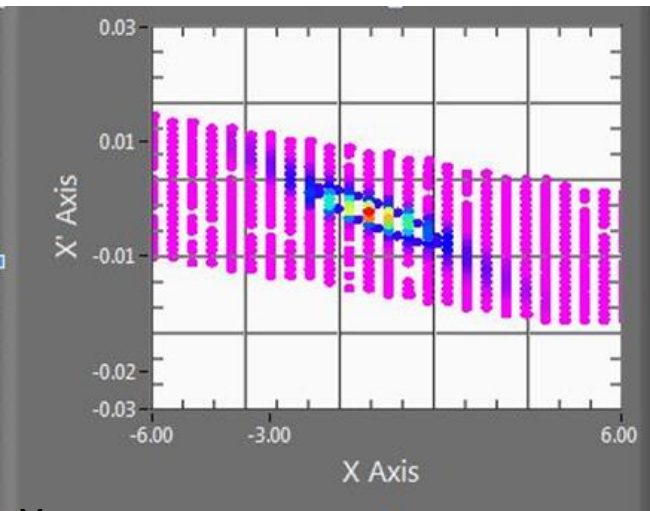
Beam current: 43mA, Y: $0.2\pi\text{mm.mrad}$ (norm. rms) with 15mA

Beam emittance measurement

MEBT emittance measured in tunnel

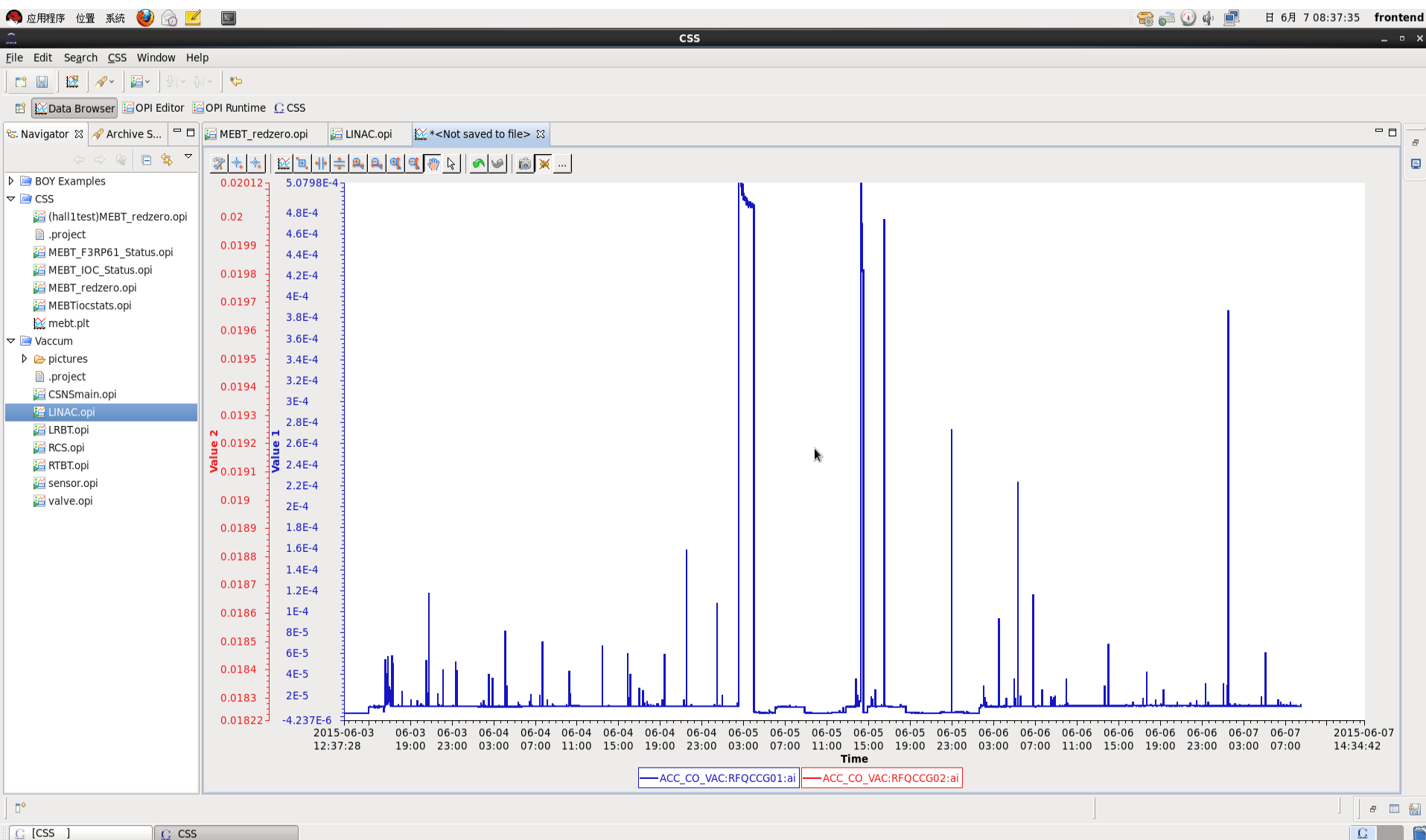


Beam intensity: 22mA, X: $0.2\pi\text{mm.mrad}$ (norm. rms) with 17mA



Beam intensity: 22mA, Y: $0.2\pi\text{mm.mrad}$ (norm. rms) with 17.5mA

RFQ vacuum pressure



➤ MEBT BPM test also finished

Thank you !