Construction and Beam Commissioning of CSNS Accelerators

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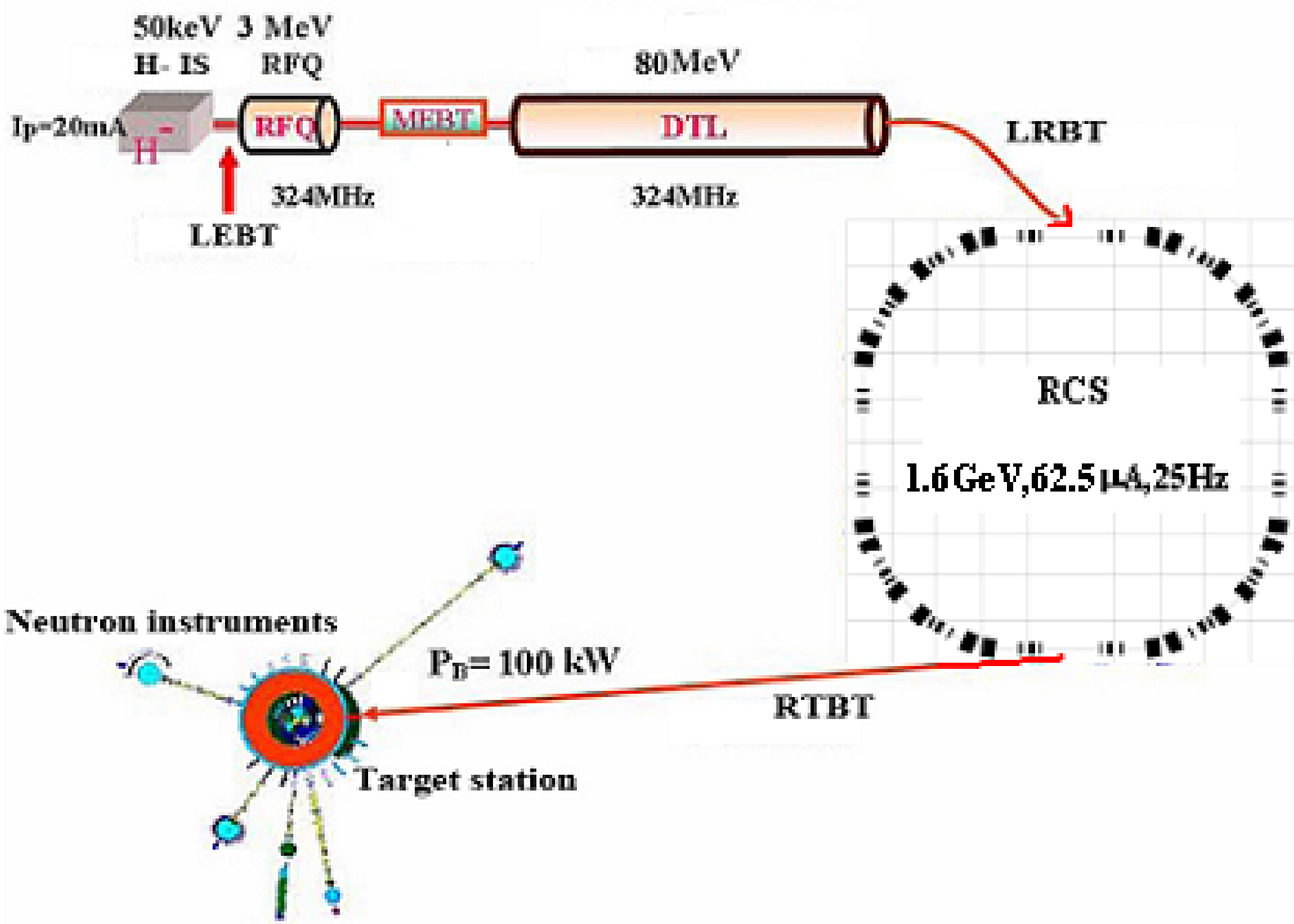
CSNS
CHINESE ACADEMY OF SCIENCES

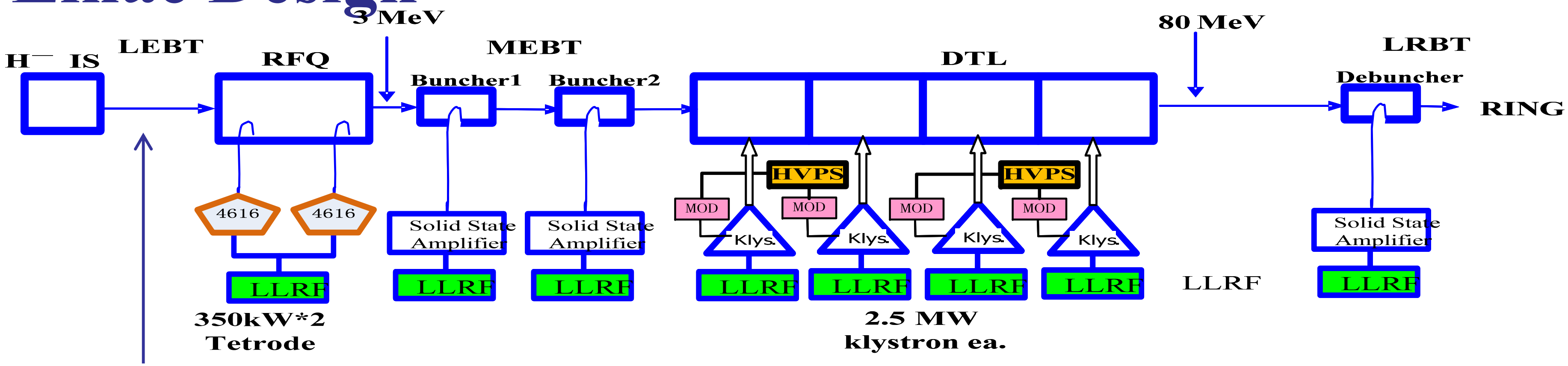
Outline

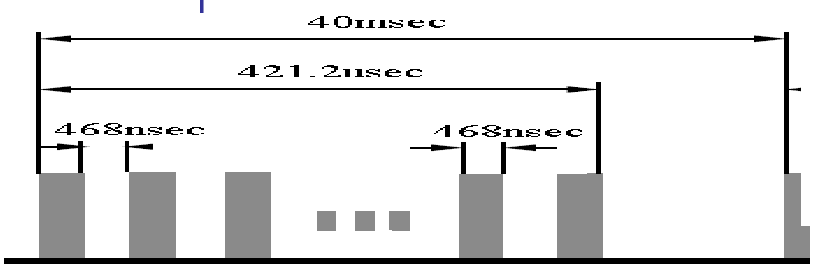
- A brief review to CSNS accelerator
- Linac construction and commissioning
- RCS construction and commissioning preparation
- Commissioning plan
- Summary

A Brief introduction to CSNS



Linac Design





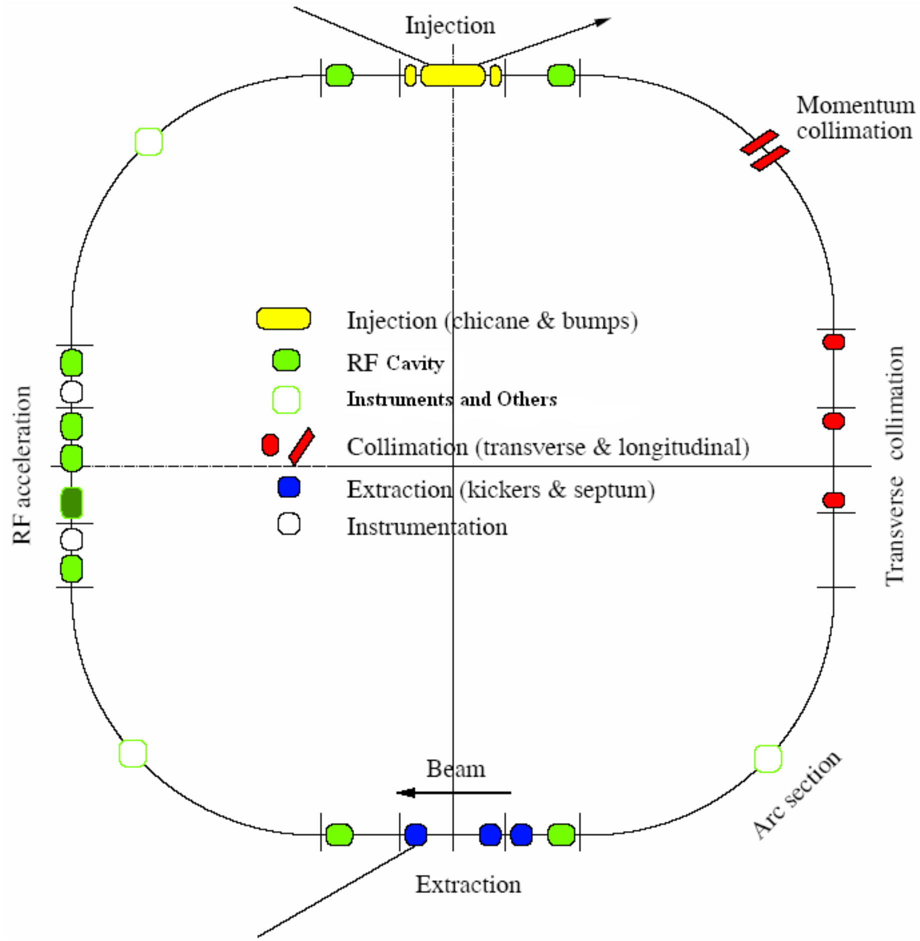
EMQ operation in FFDD lattice

Electrostatic chopper in LEBT

	Ion Source	RFQ	DTL
Input Energy（MeV)		0.05	3.0
Output Energy(MeV)	0.05	3.0	80
Pulse Current (mA)	20/40	20/30	15/30
RF frequency (MHz)		324	324
Chop rate (%)		50	50
Duty factor (%)	1.3	1.05	1.05
Repetition rate (Hz)	25	25	25

RCS Design

- Lattice of 4-fold symmetry, triplet.
- 227.92m circumference.
- Four long straight sections for injection, acceleration, collimation and extraction.
- 24 main dipoles with one power supply.
- 48 main quadrupoles with 5 power supplies.
- Ceramic vacuum chambers for the AC&pulsed magnets.
- 8 RF ferrite loaded cavities to provide 165 kV.



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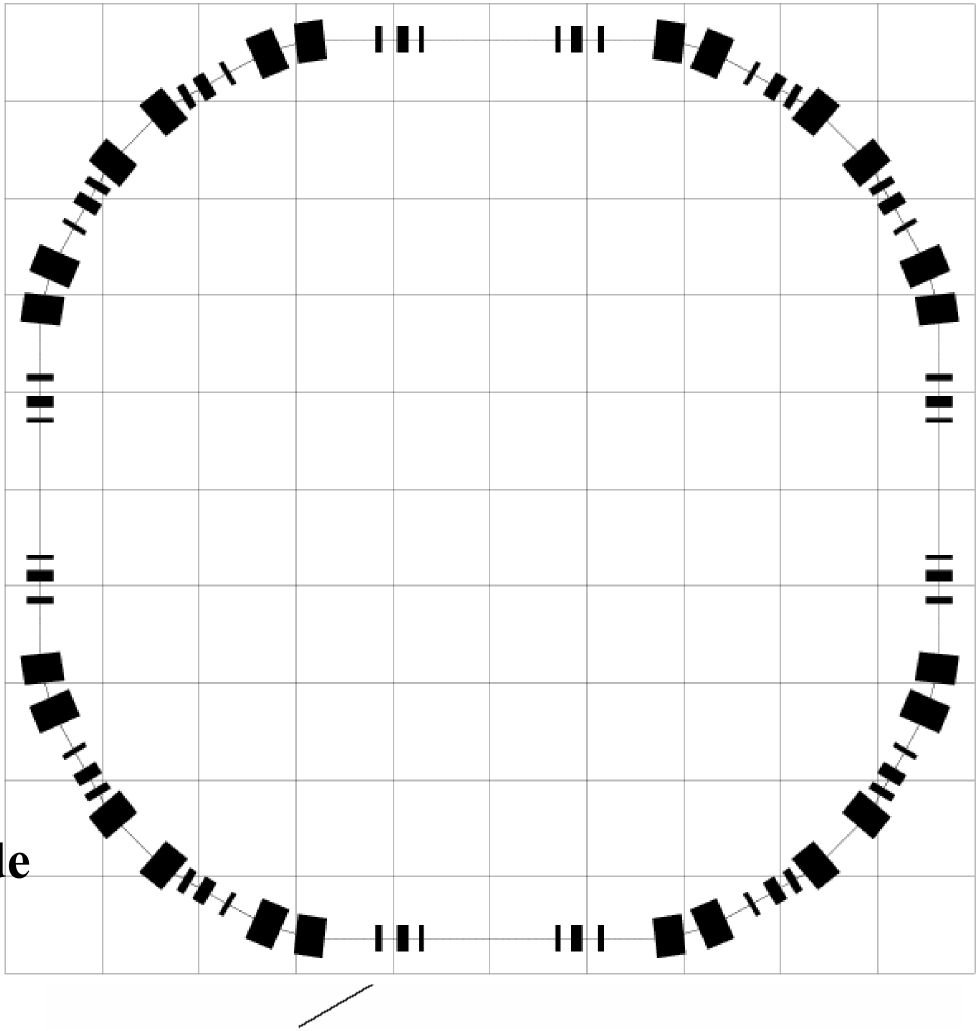
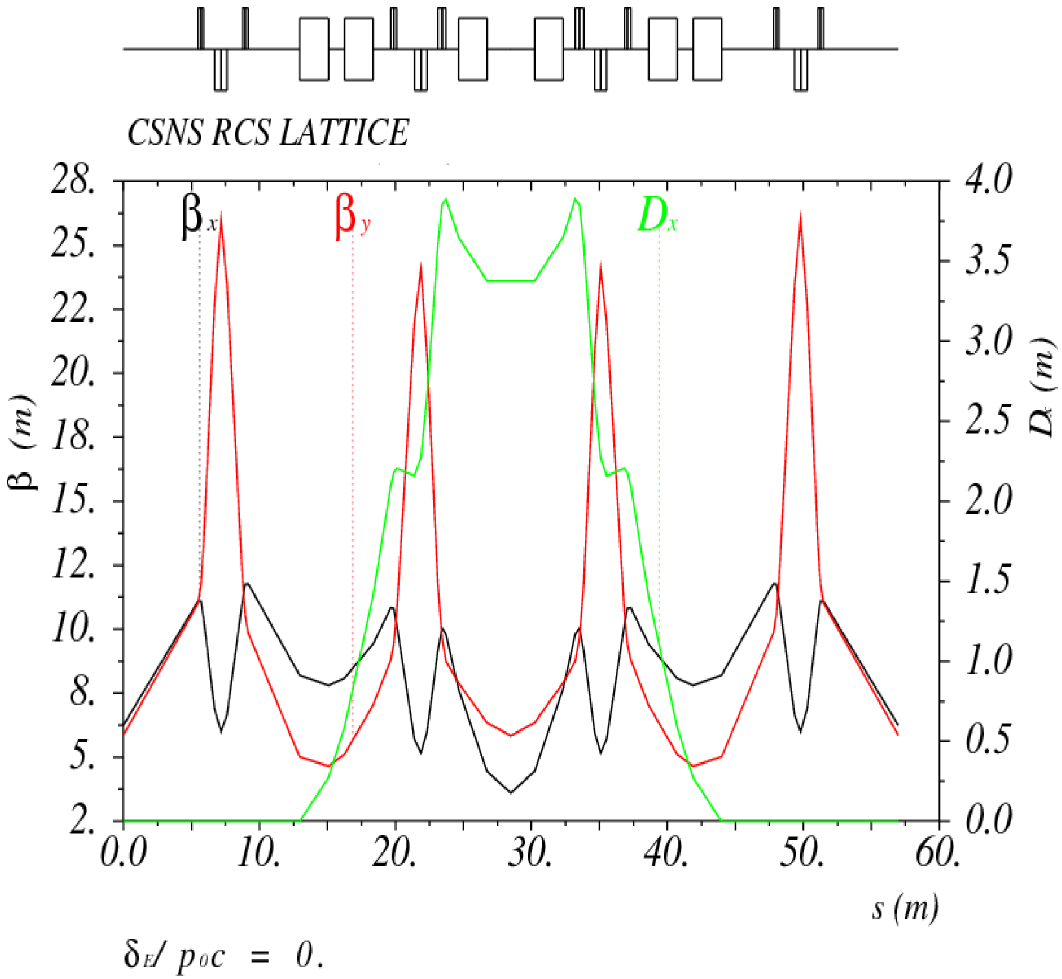
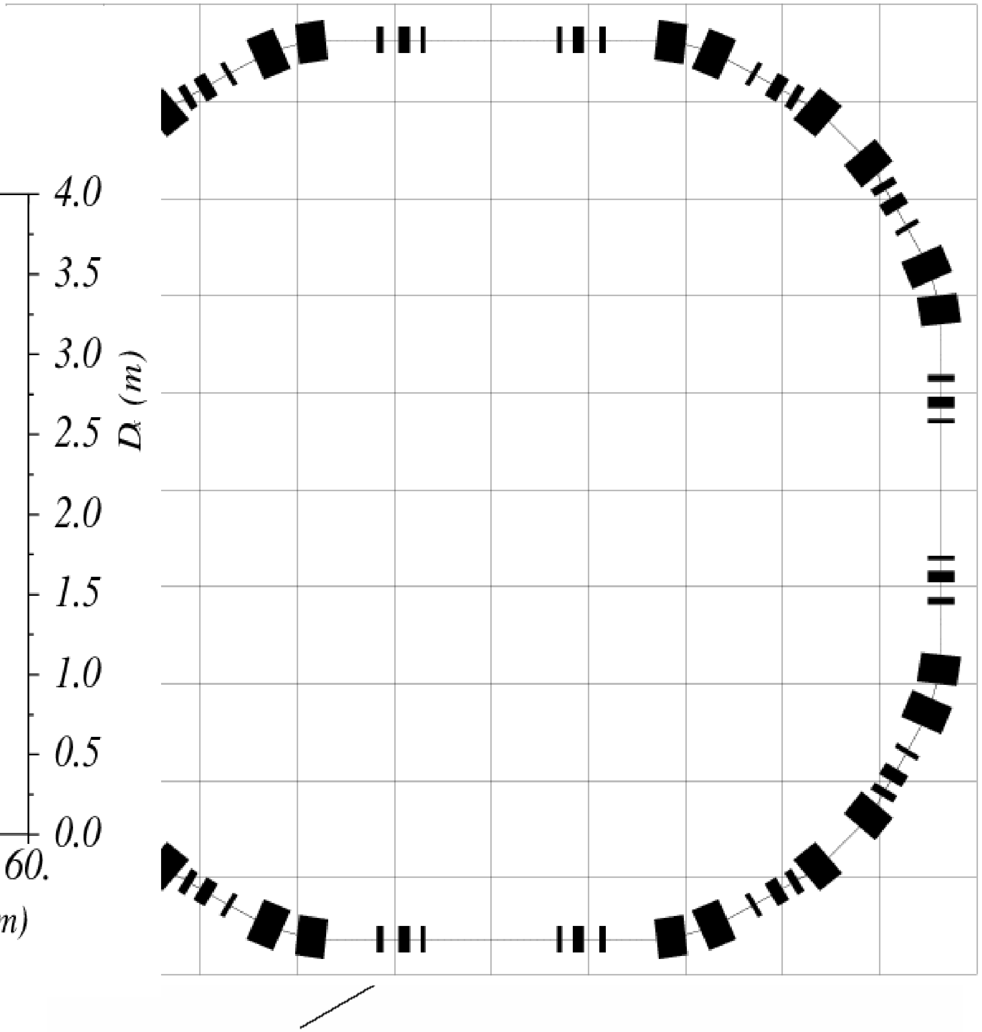


RCS Design


CSNS RCS LATTICE
β (m)
28.
25.
22.
20.
18.
15.
12.
10.
8.
5.
2.
βx
βy
Dx
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Dx (m)
0.0
10.
20.
30.
40.
50.
60.
s (m)
δE/ p0c = 0.



The Site of CSNS

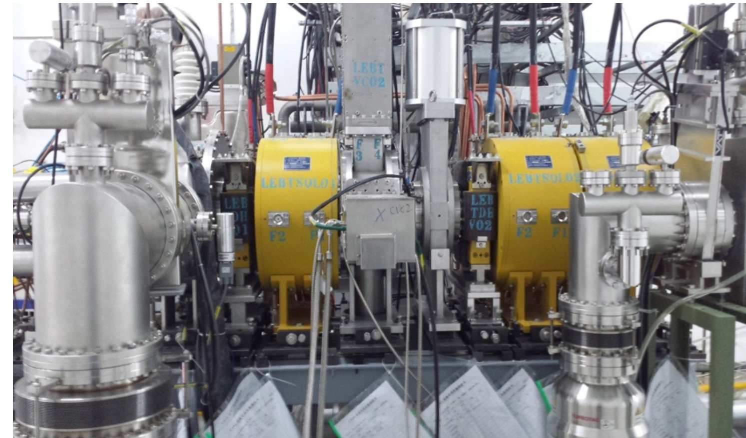
May 2009: before land breaking

Aug 2011: land is prepared

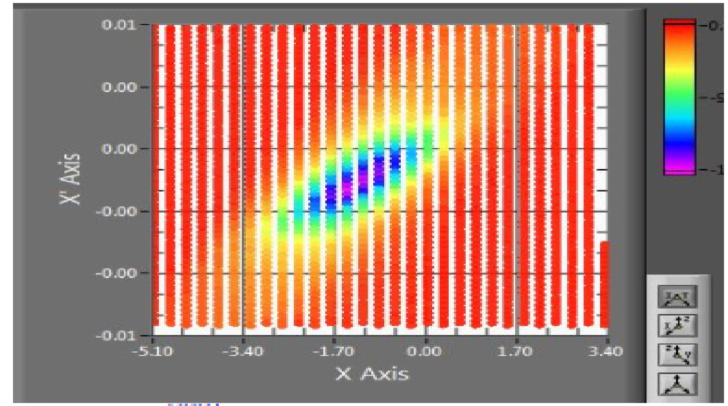
CSNS site (2015/11)

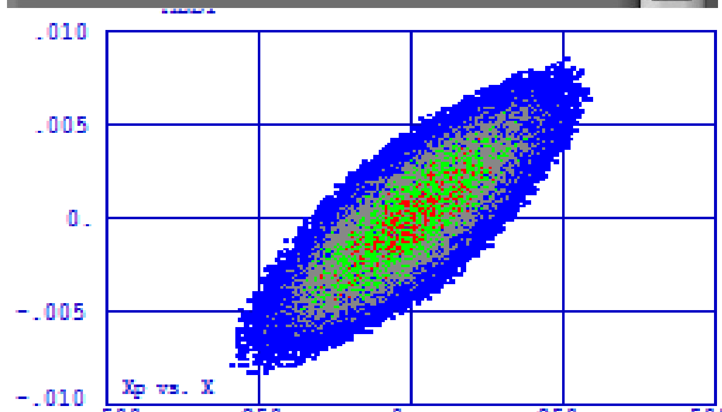
Linac Construction and Beam Commissioning

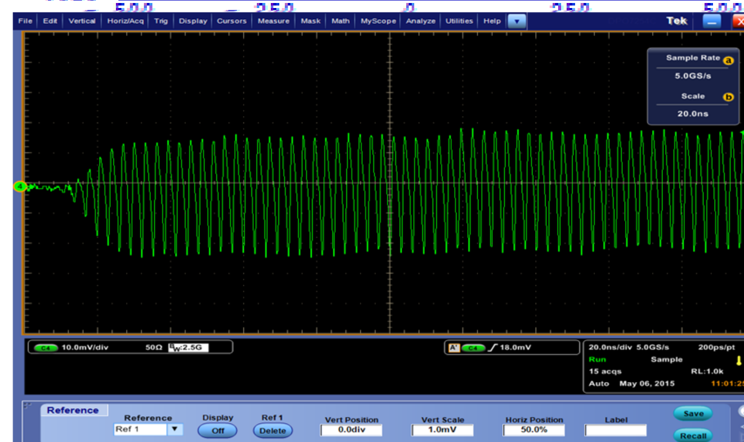
- Installation of ion source and LEBT in tunnel was started On Oct. 15, 2014. On Dec. 1st, 2014, beam commissioning of ion source and LEBT was started. a collimator at LEBT to scrape the beam beyond the acceptance of RFQ was installed.
- High power RF conditioning for RFQ has been done before installing into the tunnel, with a duty of 700us and 25Hz, input RF power 450kW. In total, 240 hours RF conditioning have been done, and finally the spark number was reduced to 1~2 times per day.
- April 6, 2015, RFQ installation completed
- April 21, 2015, First beam of RFQ



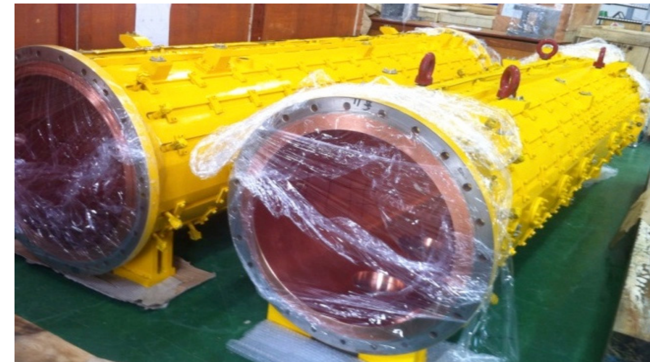
- The beam commissioning of RFQ was done together with MEBT. Many measurements have been done.
- RFQ highest transmission rate reached 88%.
- 90 hours continuous test operation at the design specification has been done (17mA, 500 µs, 25 Hz, chopping rate 50 %).
- The rise time of LEBT electrostatic chopper is about 15ns(5 RF periods)
- RFQ tetrode power source worked stably with field amplitude and phase < ±0.5% / ±0.5 º respectively.



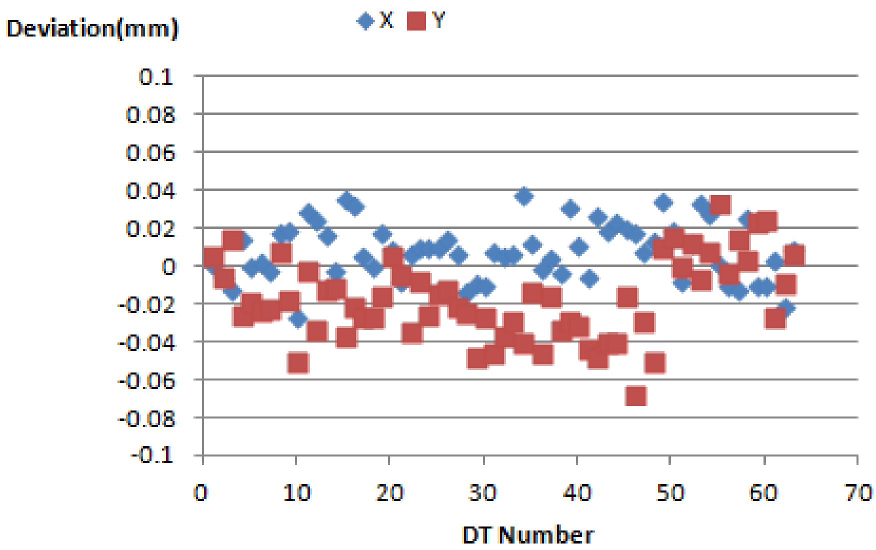


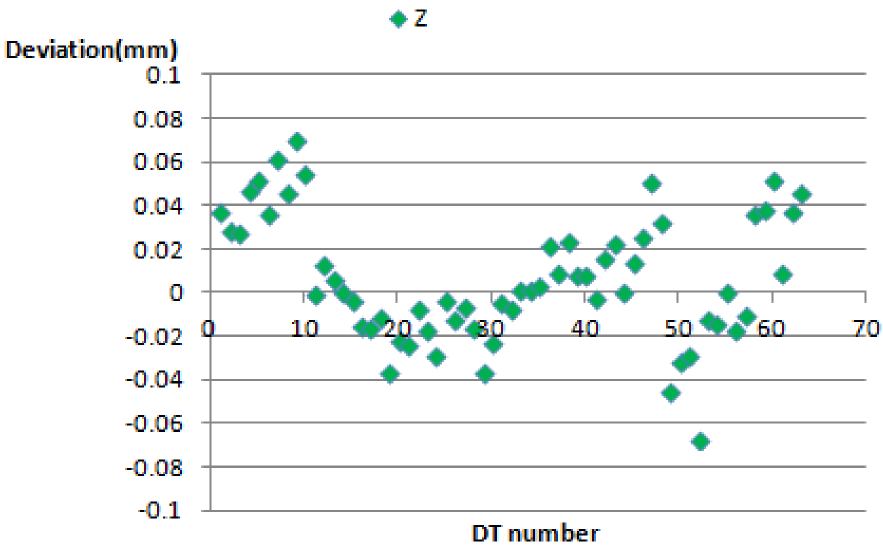


- **The mass production of all 12 DTL unit tanks and 156 drift tubes have been completed.**
- **The assembly of all drift tubes will be completed soon.**
- **1 set of CPI klystron have been tested in the commissioning of the first tank, and the other 3 klystron will delivered to CSNS site successively.**
- **Two set of resonant high voltage power supplies, crowbar and modulator have past high voltage test.**



Drift tube alignment of DTL1





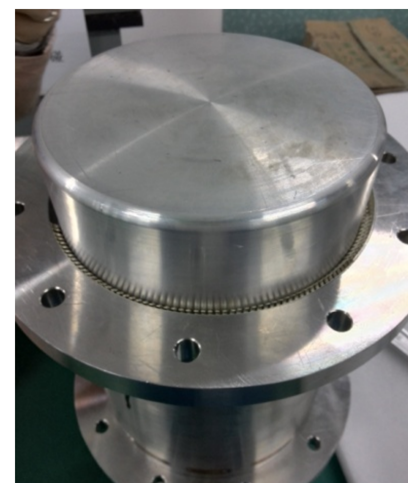
- Tolerable alignment error of the DTs is 0.05mm in the transverse (x-y) plane, 0.1mm along the beam line, take into account the effect of thermal expansion and contraction
- DT alignment of DTL1 has been finished, the required accuracy for the alignment of the DTs has been achieved.

Low power RF tuning

The DTL1 has 63 full drift tubes and 2 half drift tubes to provide longitudinal acceleration, 31 post-couplers to stabilize the accelerating field, 12 fixed tuners and 2 movable tuners to adjust the resonant frequency

Movable tuner

Post-coupler



slug tuner

Low power RF tuning

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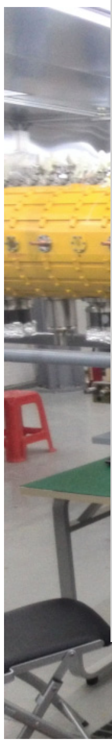
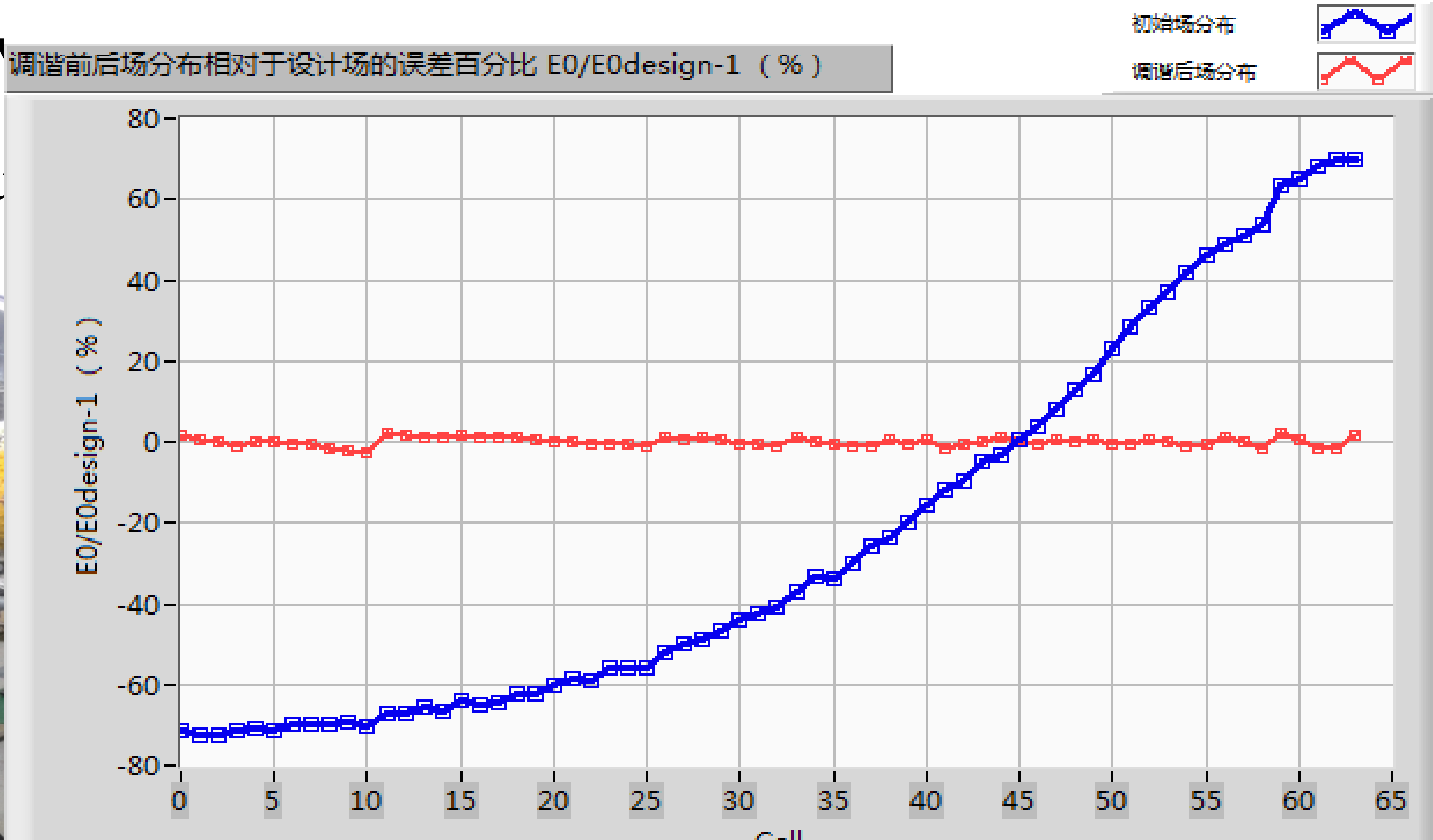
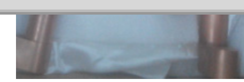
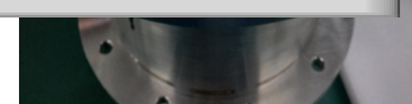








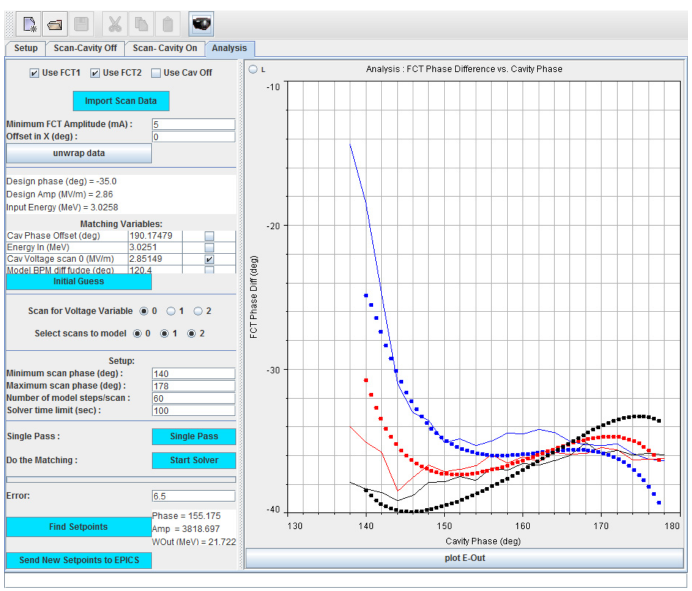
Post-coupler　　slug tuner

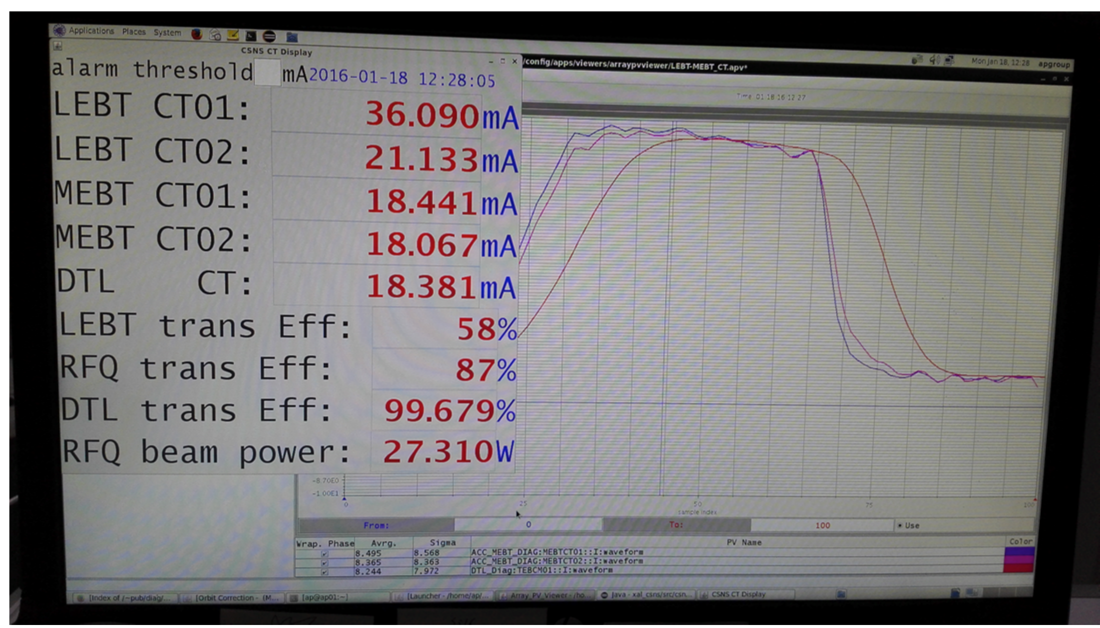
DTL-1 Beam Commissioning

- The beam commissioning for DTL-1 was done before the installation of other three DTL tanks, with a D-plate, including a temporary beam dump.
- After the commissioning of DTL-1, the D-plate was removed, and DTL2-4 has been installing together. The beam instruments in the LRBT will be used for the commissioning of the other three DTL tanks.

DTL-1 Beam Commissioning

- The RF set point of DTL-1 was searched with phase scan method.
- In Jan. 9, 2016, the beam reached the end of DTL-1 without acceleration.
- In Jan. 11, the first beam is accelerated to the end of DTL-1, with 4mA at 21.6MeV.
- In Jan. 18, 2016, 18mA/21.67MeV/50us/1Hz beam was obtained, which exceeds the design goal of beam current of 15mA. the beam reached the end of the first DTL tank with peak current of 18mA at 21.67 MeV, with transmission rate of 100% within the error of Current Transformer.





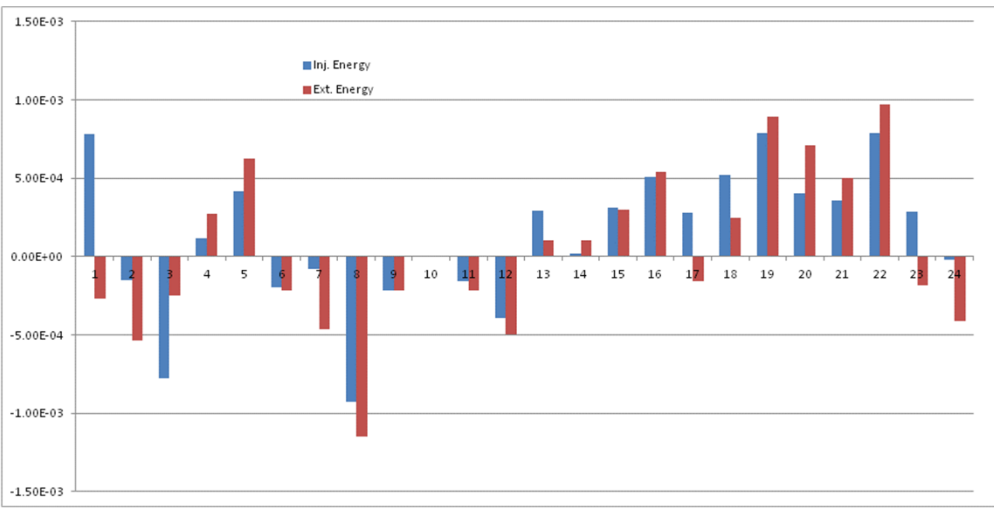
The RCS Construction

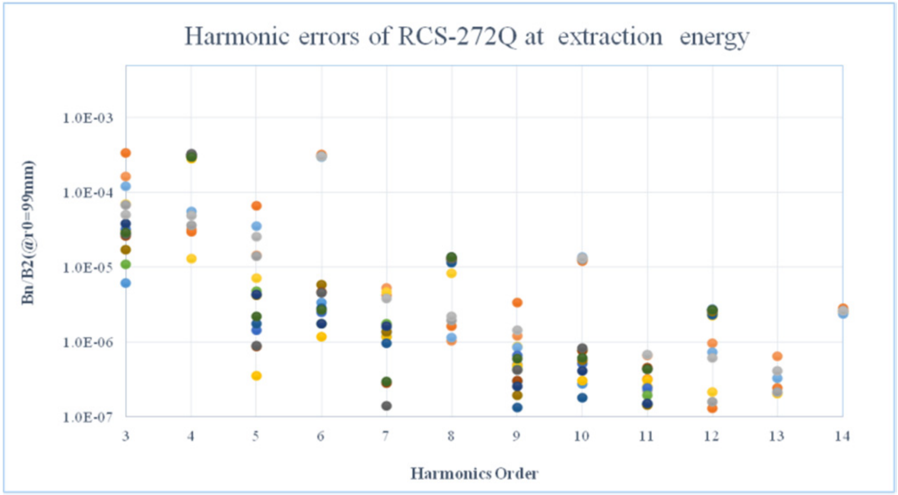
Mass Production and Installation

Almost all the RCS components have been fabricated and tested. Now these components have been installing in to the RCS tunnel or local station. The cable and vacuum chamber connecting and alignment have been doing.

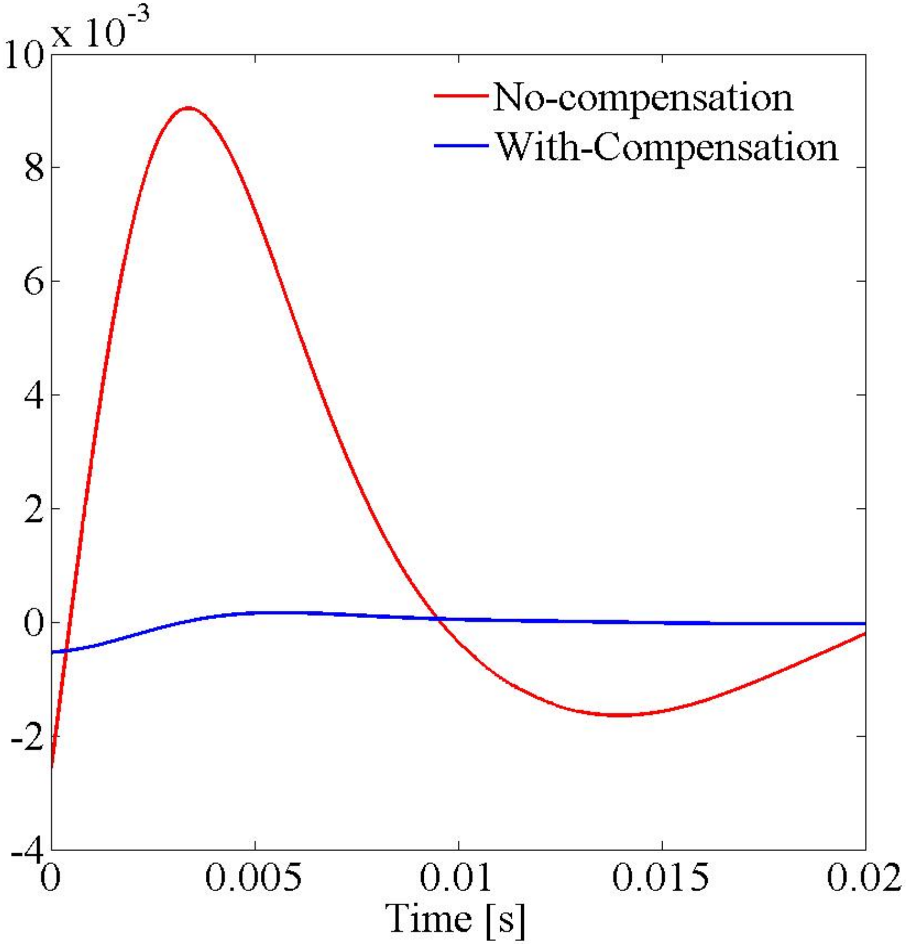
Dipoles and Quadrupoles Field measurement

- 24 ring dipole magnets are all measured with a field quality better than requirement. The uniformity is nice with integral field difference among them less than ±0.1%. Sorting has then been determined. With harmonic injection the time-harmonic error is reduced to <0.01%.
- 48 quadrupoles have been measured in both DC and AC mode. Family uniformity is better than ±0.2%. Space-harmonic error is less than 0.06% and time-harmonic error is suppressed to less than 0.1% for single quadrupole.

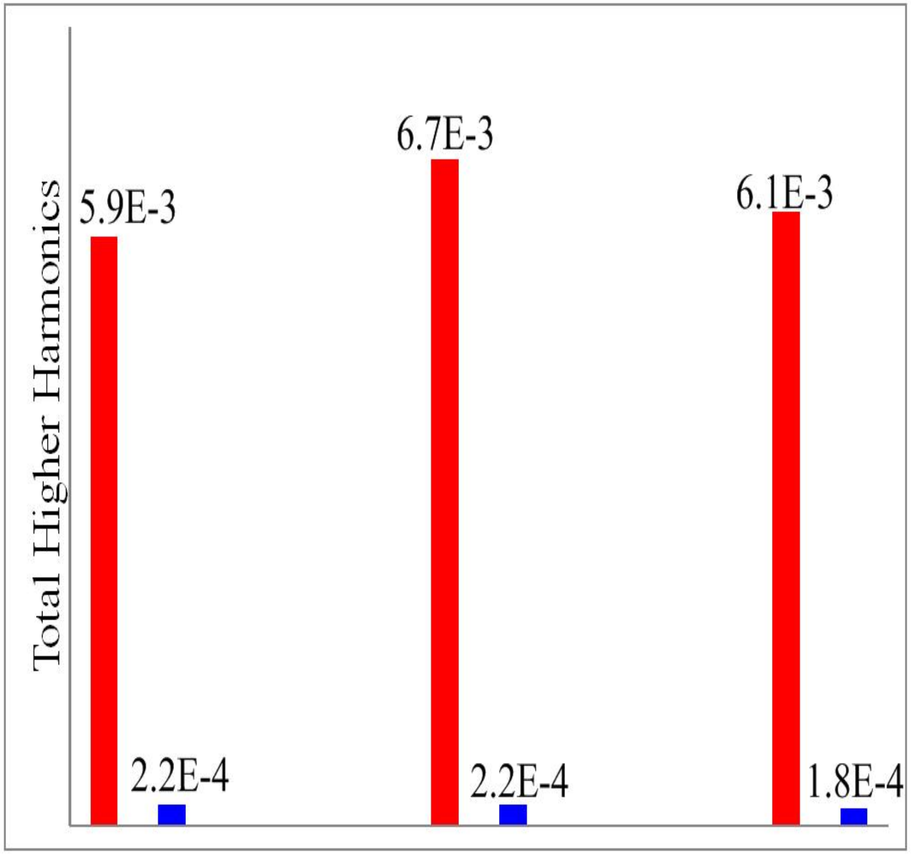




The Field Compensation by Harmonic Injection



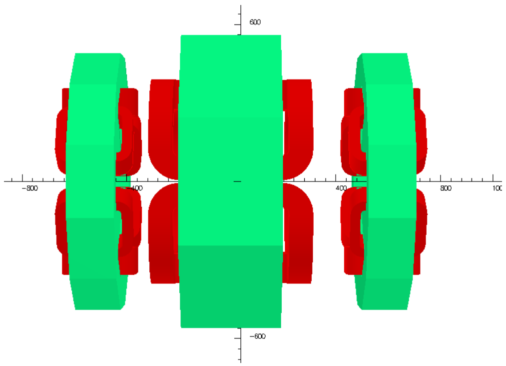
The field deviation from pure 25Hz sinusoidal curve, before and after harmonic injection.

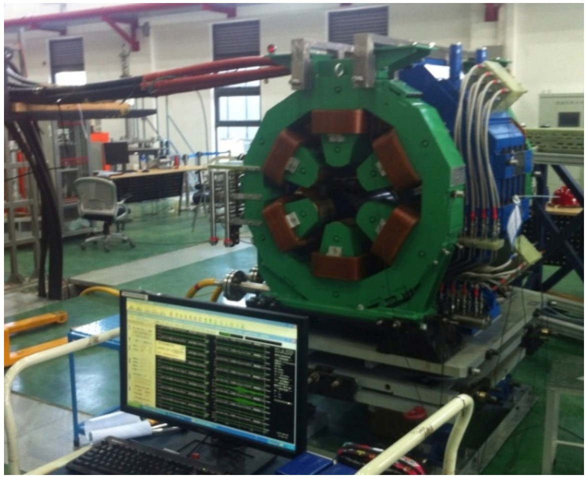


The effect of harmonic injection. The harmonic injection is based on the individual measurement.

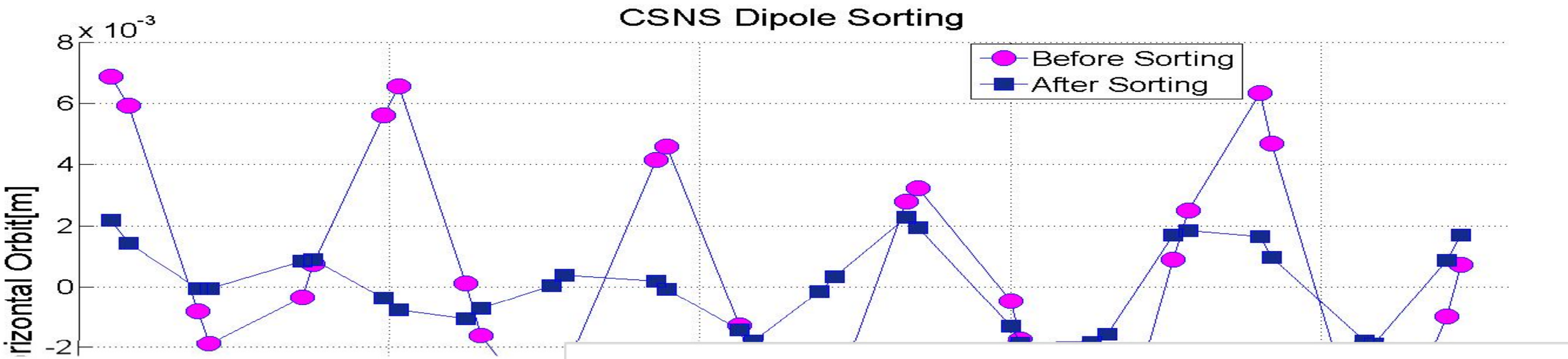
Interference Between Neighbor Magnets

- The fringe field interference and interaction between quadrupole and nearby sextupole/corrector was studied by both measurement and simulation.
- The study shows that the interference effect is not negligible, the Max. effect to quadrupole field is 1.4%.
- It is considered in the I-B curve and magnet sorting.
- The vibration of sextupoles was found also a problem, due to the AC operation mode of quadruople.





Magnet sorting

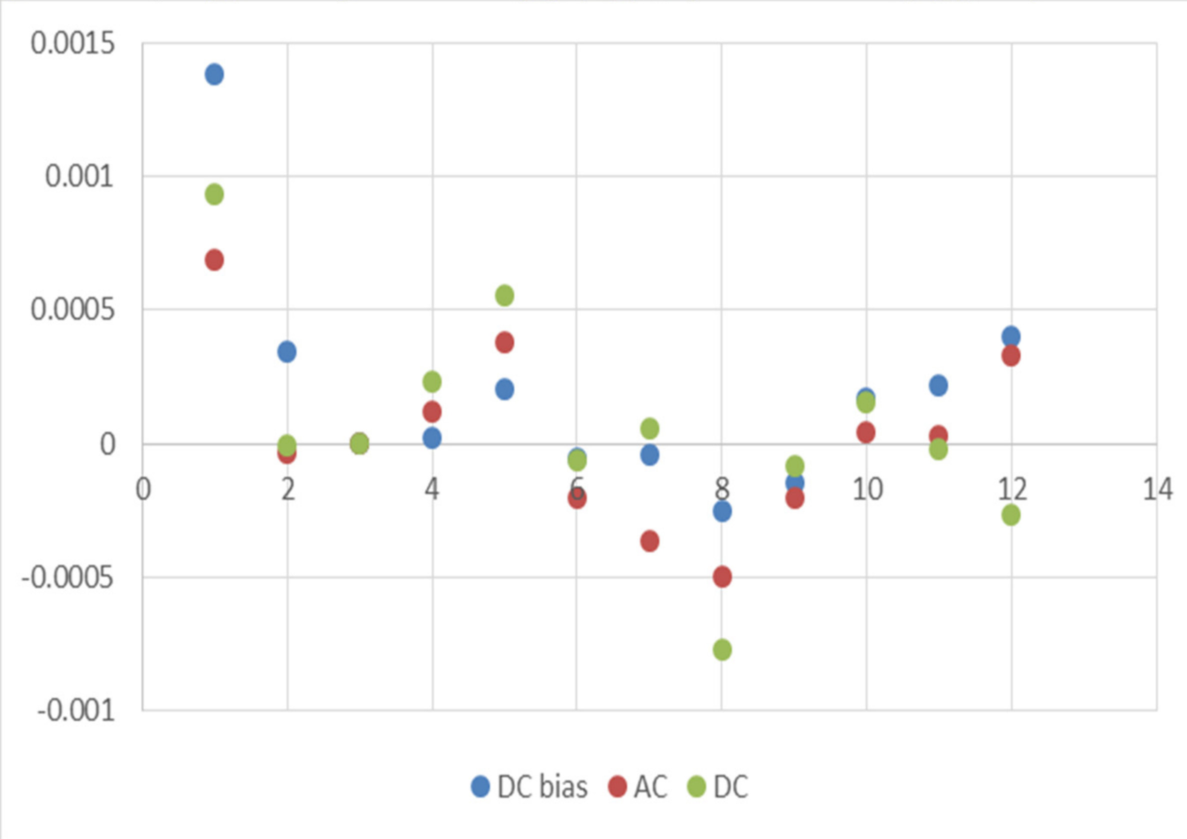


Three kind of field

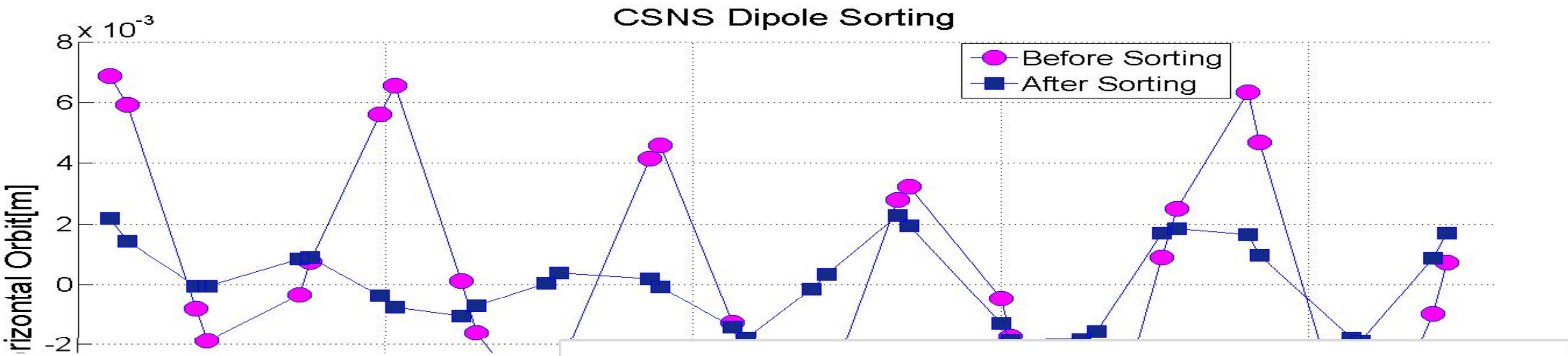
- **DC field**
- **AC field (25Hz)**
- **DC bias field**

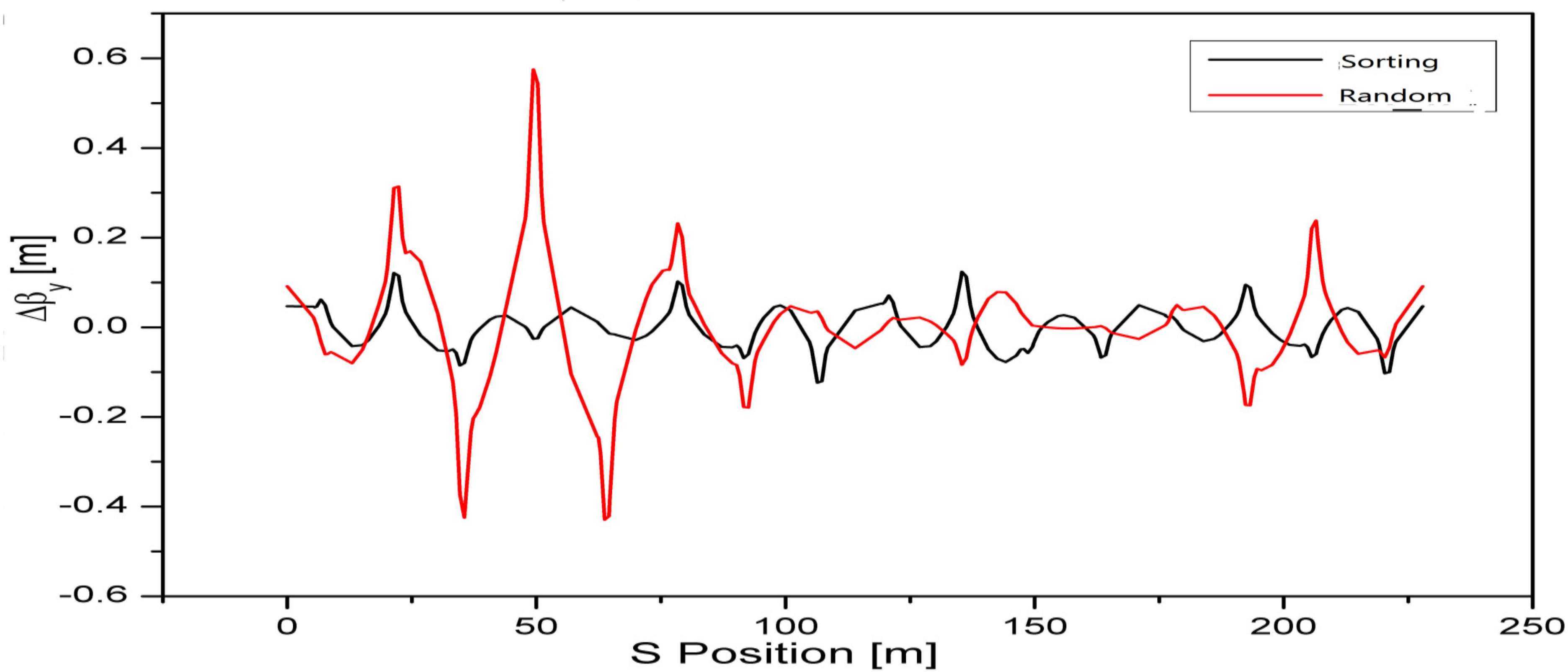
Sorting

- **Based on DC field**
- **Based on AC field**

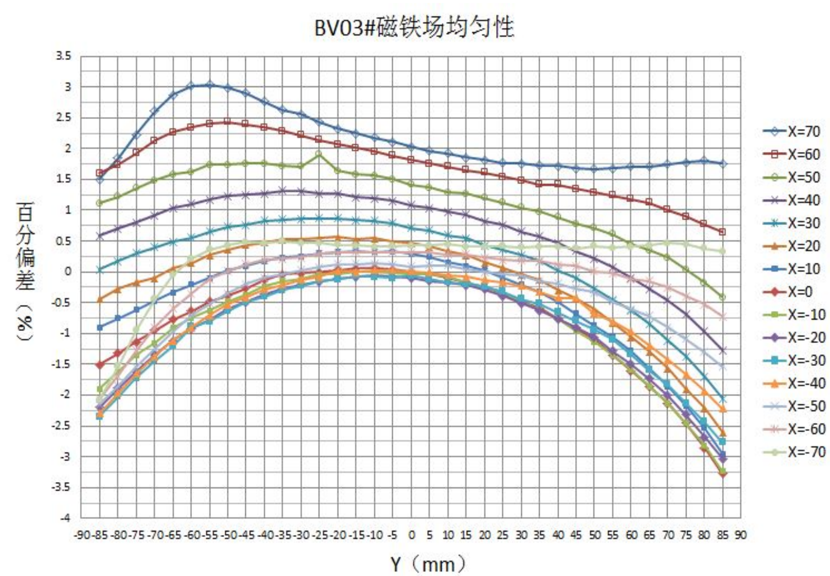


Magnet sorting





- 8 Injection painting magnets were measured with short and long coils. Their field and vibration meet the requirement.
- 4 injection bumping magnets and 2 septum magnets were measured with Hall probe and the field quality is satisfactory.



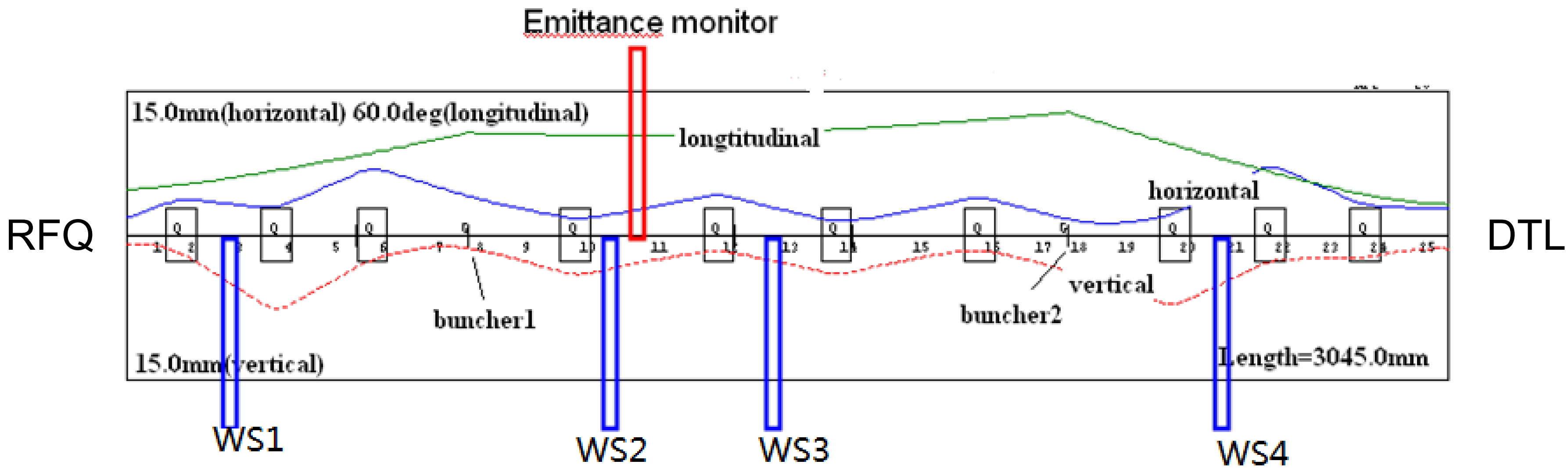
- All 8 ferrite-loaded RF cavities and their tetrode RF power sources with biased power supplies have been delivered to CSNS site, and the cavity assembly have been completed.
- The system integral test have been done. 7 of 8 cavities have been done the 7 days high power test. The amplitude error is better than ±0.5%, and the phase error is better than ±0.5° during the long time high power test.

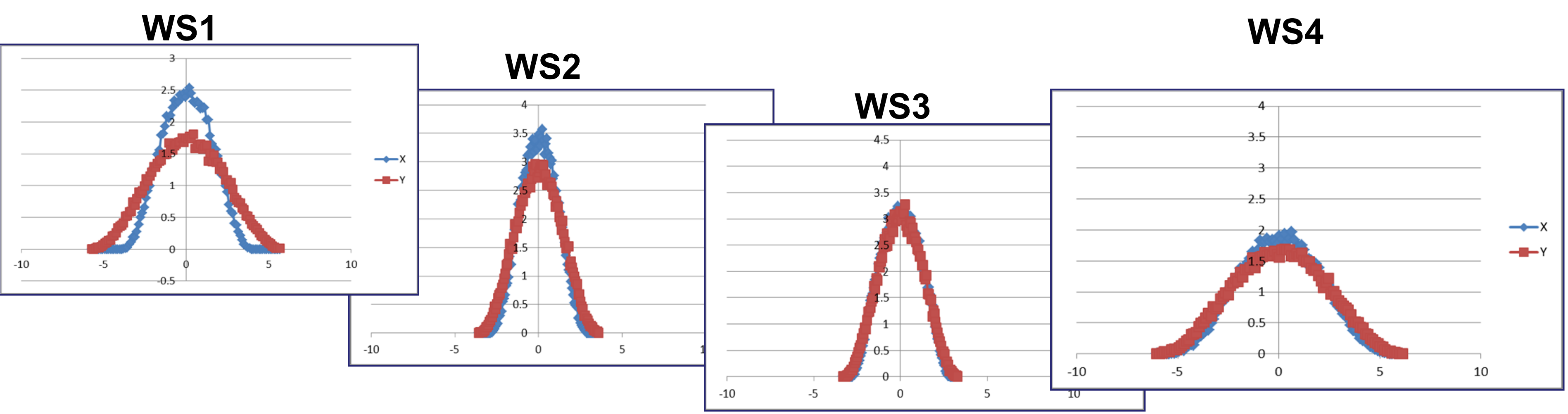
- Totally 86 pieces ceramic chamber have been delivered to CSNS site. The TiN coating have been doing in the test hall, and all the RF shielding wrapping have been done.
- 8 Extraction kickers and their pulsed power supplies, a Lambertson magnet, have been tested;
- 1 primary collimator and 4 secondary collimators have been put into the tunnel;
- Most of the beam diagnostics are now available for installation;
- Most of the control system have been installing.

Application software development

- Based on the XAL, application software for the beam commissioning of CSNS accelerators have been developed.
- The lattice model database and PV logger database has been developed.
- Part of application software and database have been successfully put into use in the front end and first DTL tank beam commissioning.

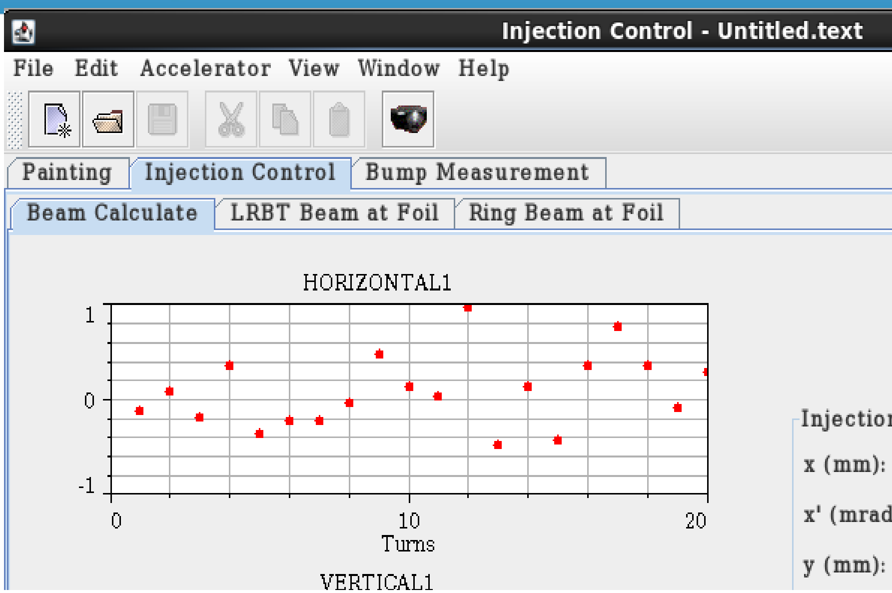
Calculating the emittance parameter at the exit of RFQ

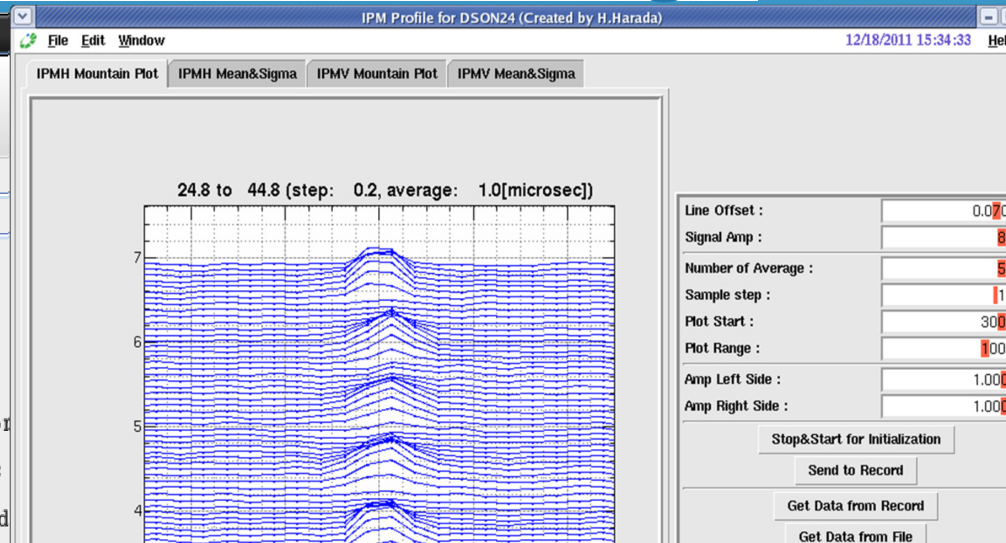




Simulation by using PARMILA, I=15mA

The study on the injection orbit matching

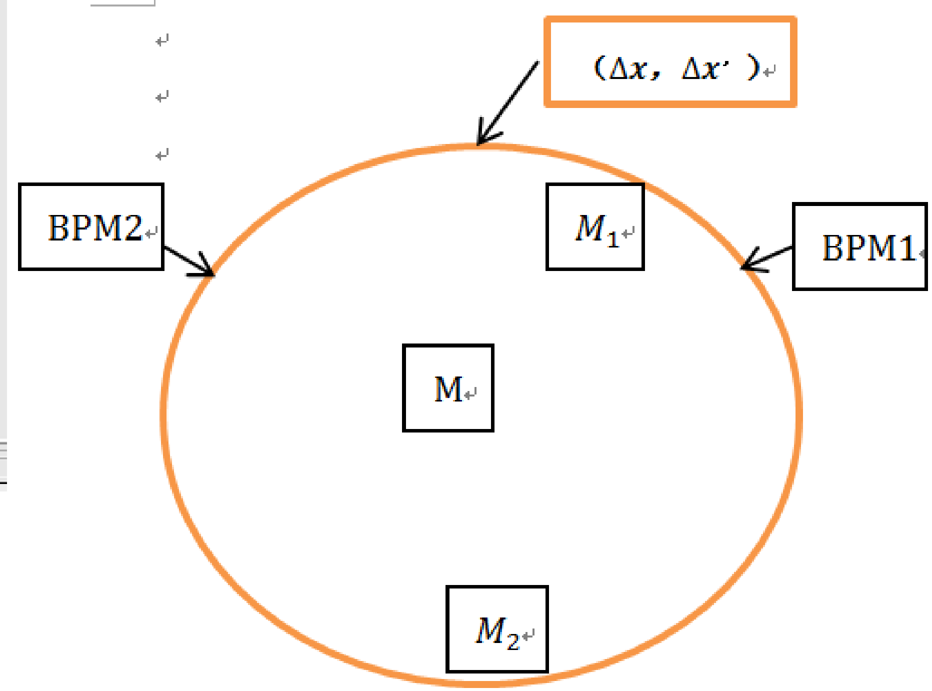




$$n*\begin{pmatrix}\Delta z_1\\ \Delta z_1'\end{pmatrix} = M_1(M^{n-1}+M^{n-2}+\cdots M+I)\begin{pmatrix}\Delta x\\ \Delta x'\end{pmatrix}$$

$$n*\begin{pmatrix}\Delta z_2\\ \Delta z_2'\end{pmatrix} = M_2(M^{n-1}+M^{n-2}+\cdots M+I)\begin{pmatrix}\Delta x\\ \Delta x'\end{pmatrix}$$

$$\begin{pmatrix}\Delta z_1\\ \Delta z_2\end{pmatrix}=\begin{pmatrix}M_{11}^1 & M_{12}^1\\ M_{11}^2 & M_{12}^2\end{pmatrix}\begin{pmatrix}\Delta x\\ \Delta x'\end{pmatrix}$$



Planned commissioning Schedule

IS+LEBT	**2015.4.14-2015.4.14**
RFQ+MEBT	**2015.4.15-2015.7.8**
DTL1	**2016.1.8-2016.1.18**
DTL2-4+LRBT	2016.9.1-2016.12.31
RCS	2017.1.1- 2017.6.15
RTBT	2017.6.15 - 2017.6.30
First beam on target	2017.6.30
Beam power to 10kW	2017.7.1-2017.12.31
CSNS to acceptance goal	2017.12.31
Official acceptance	2018.3
Beam power to 100kW	2018.3.1-2021.3.1

Summary

- The construction of CSNS is in good progress. Almost all the components have been tested and installed into the accelerator tunnel.
- The beam commissioning of the front end and first DTL tank have been successfully performed.
- It is planned the first beam will bombard the neutron target in the June of 2017.

Thank you for your attention!