Commissioning results for the CSNS MEBT and DTL1

Jun Peng

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On behalf of CSNS physics group

CSNS
CHINESE ACADEMY OF SCIENCES

Outline

- Introduction
- Chopping experiments(LEBT)
- MEBT commissioning
- DTL1 commissioning
- Summary

Introduction: the CSNS Project

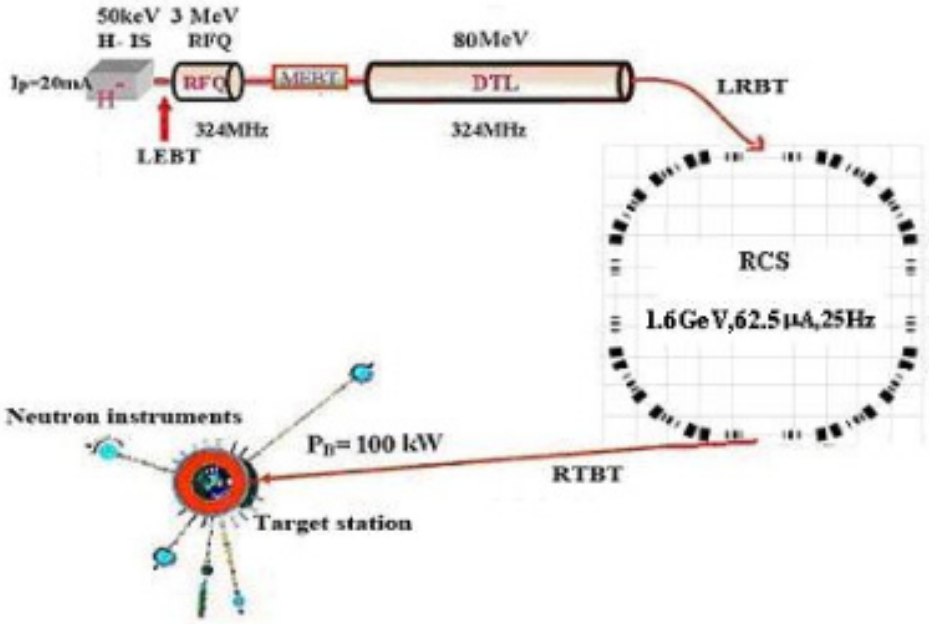


Figure 1.2-1 Layout of CSNS accelerators

Parameters:

Project phase	I	II
Beam ave.power,kW	100	500
Proton energy, GeV	1.6	
Linac energy, MeV	80	300
Repitition rate,Hz	25	
Macro duty factor,%	1.1	1.7
Macro ave.I,mA	15	40

Commissioning runs

- **Run #1**

  Front end

  705hours(24/7)

- **Run #2**

  DTL tank1

  153hours(12/7)

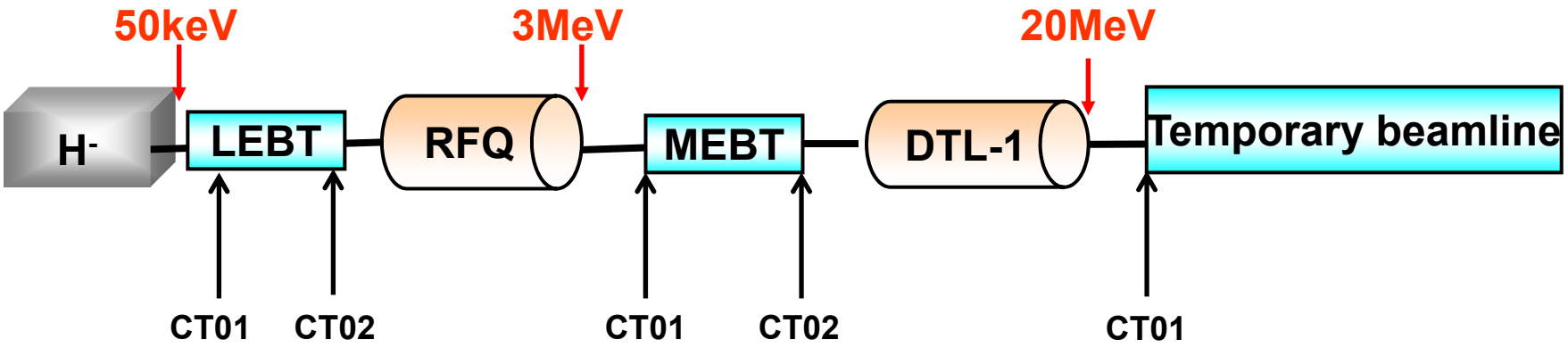
  for reduced beam power

  (200μs,5Hz)

Table 2. CSNS design vs. achieved beam parameters

	Baseline Design or Goal	**Achieved**
MEBT beam pulse length [μs]	420	500
MEBT pulse repetition rate [Hz]	25	25
Chopping rate [%]	50	50
LEBT peak current [mA]	20	31
MEBT peak current [mA]	15	18
DTL1 peak current [mA]	15	18
MEBT horiz emittance [π mm mrad (rms, norm)]	0.22	0.21
MEBT vertical emittance [π mm mrad (rms, norm)]	0.22	0.21
MEBT Beam Energy[MeV]	3.0258	3.02±0.015
DTL1 output energy[MeV]	21.67	21.7±0.022

Beam transmission

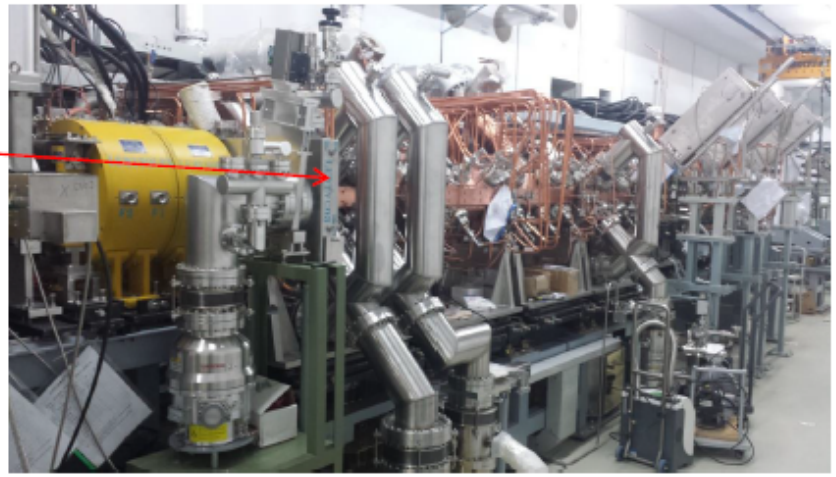


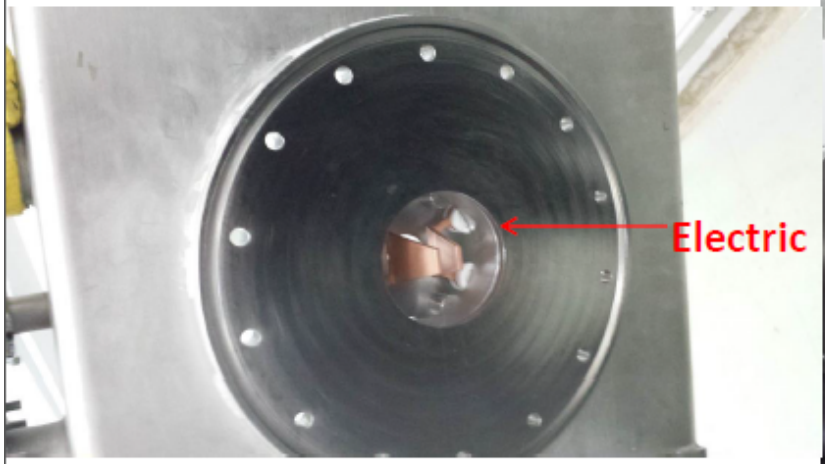
Chopping experiments

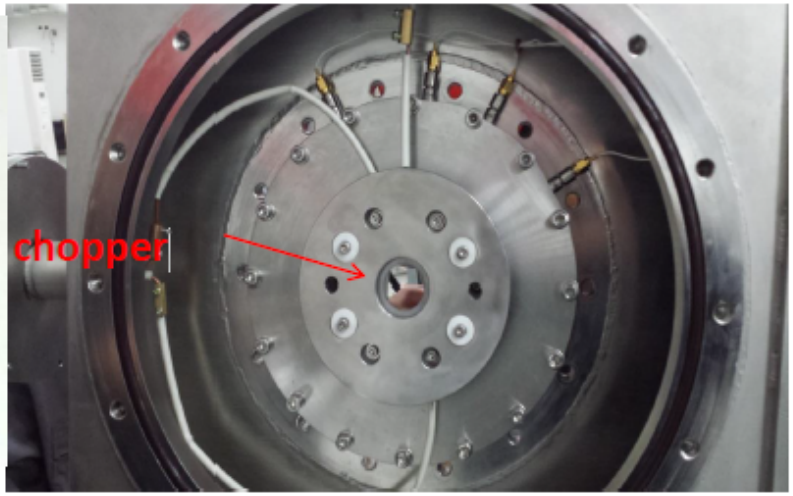
Chopping experiments

--from H.F. Ouyang, FE group, CSNS

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

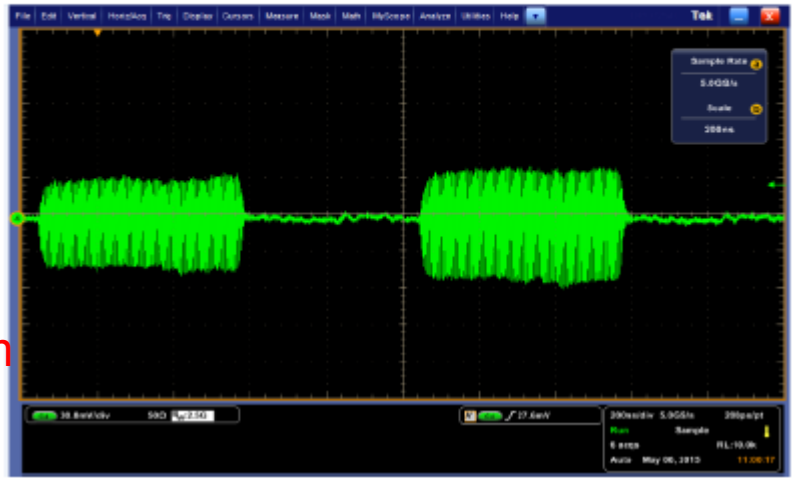






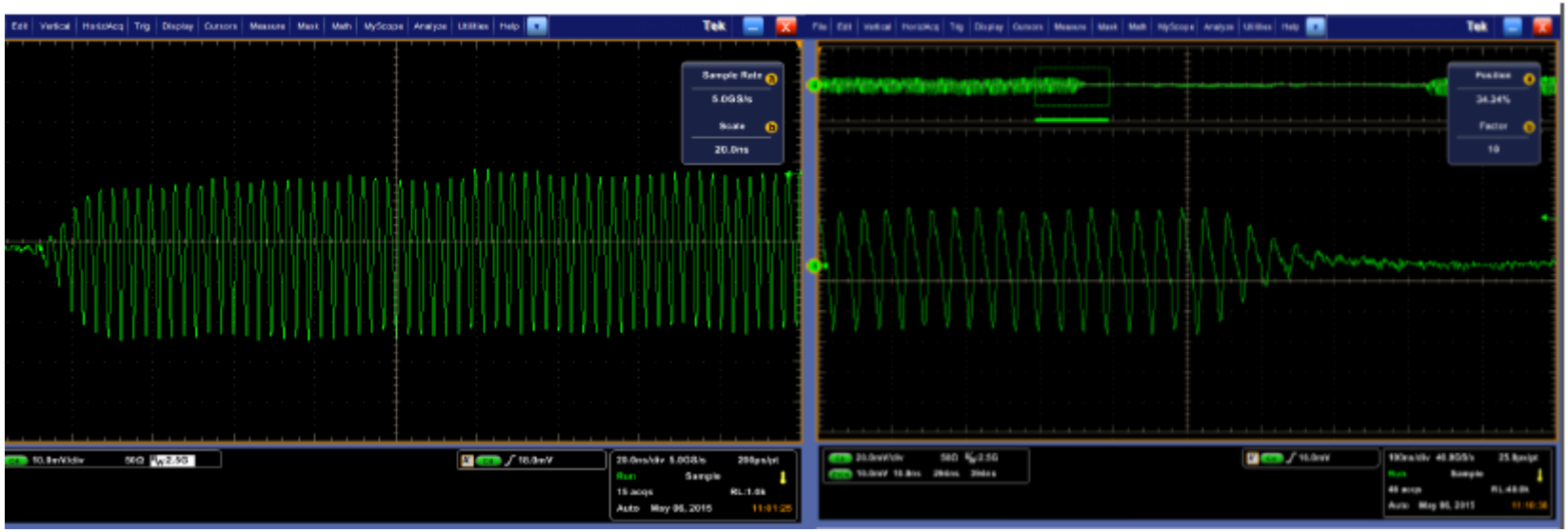
Chopping experiments

Beam structure: 100us, 1Hz (37mA)
Chopping structure: 500ns, 1MHz
Applied chopping voltage: 3.8kV
Theoretical chopping voltage: 3.7kV



1MHz, 500ns signal after chopping

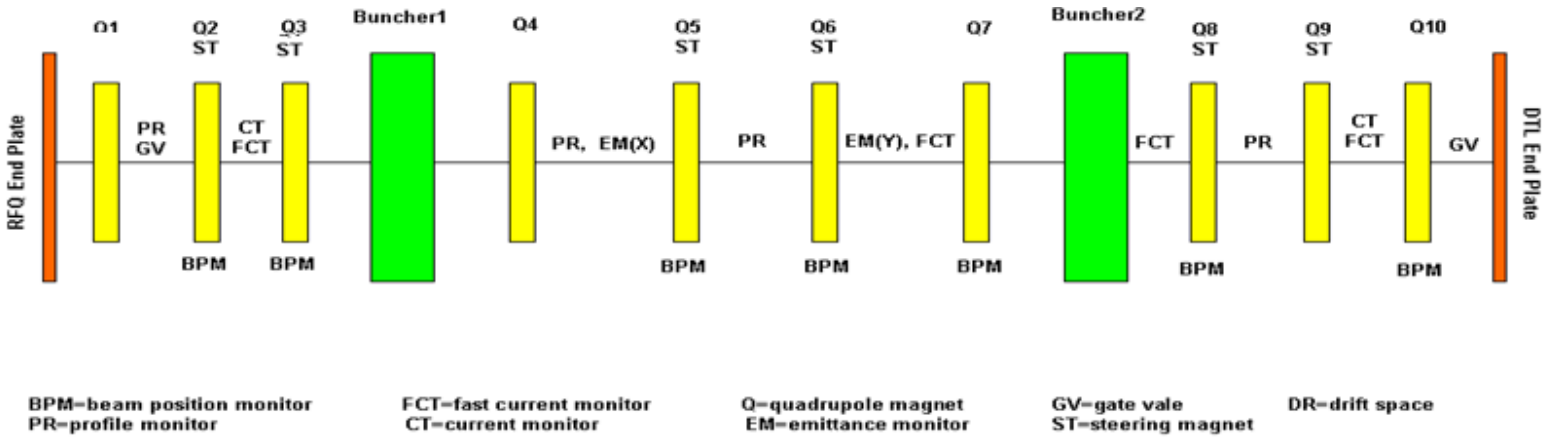
Both the rise/fall time for the chopped beam is about 4-5 periods of the working RF (1 period T=3.086ns)



Measured effect of chopper on the beam

MEBT commissioning

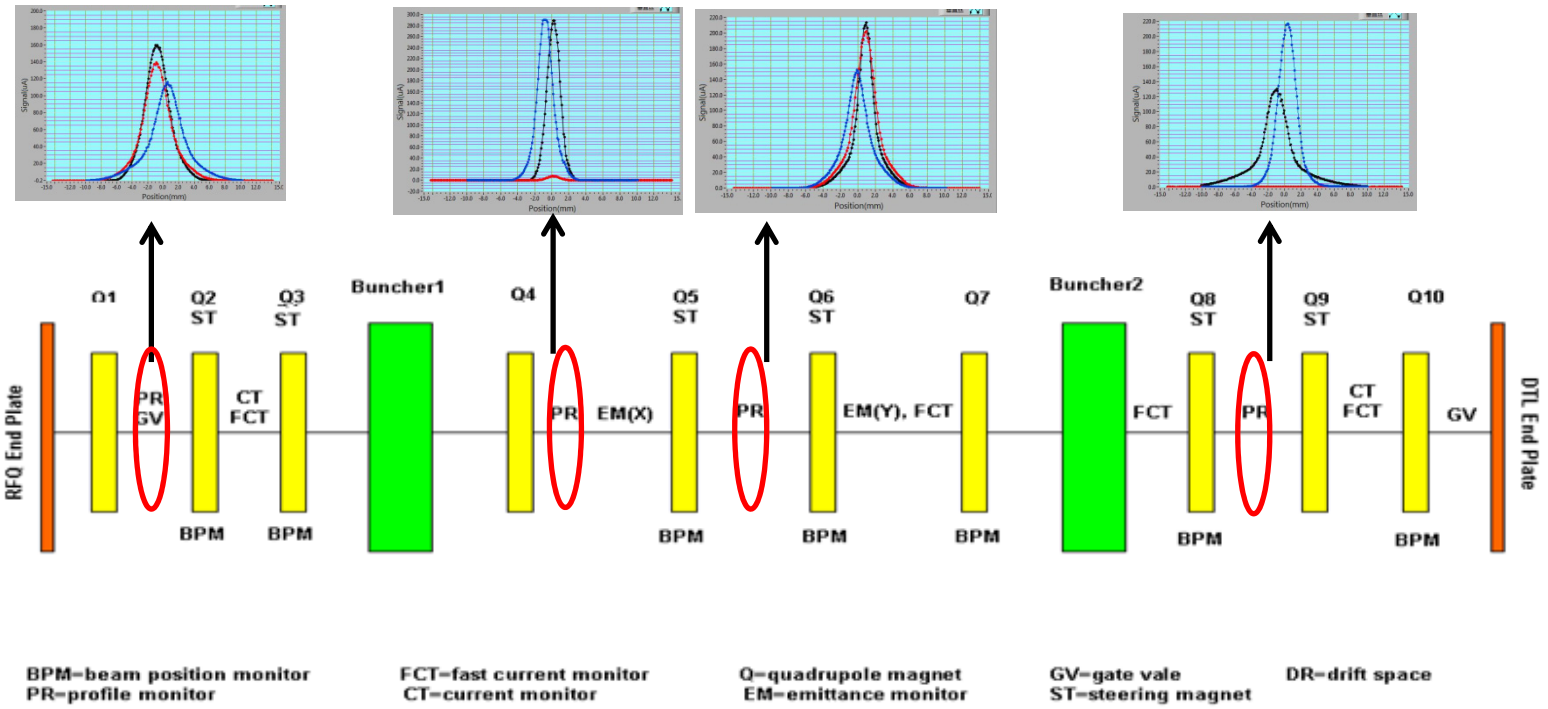
MEBT layout



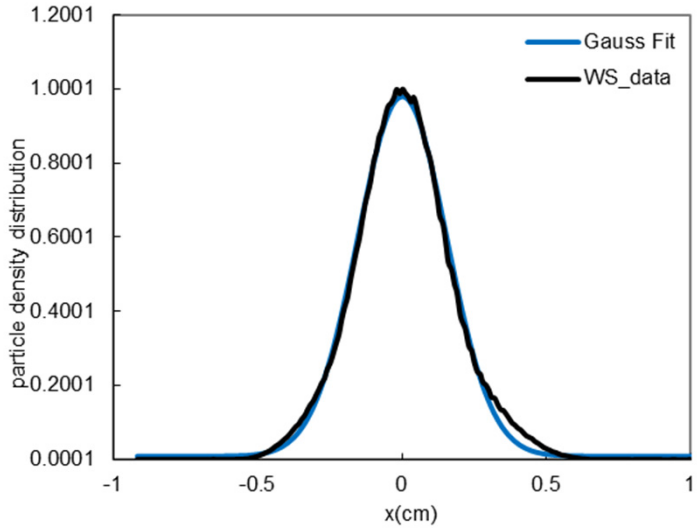
MEBT is comprised of:
10 electrical megnets
6 Steering magnets
2 Bunchers

Beam diagnostics including:
7 BPMs
2 CTs
5 FCTs
4 Wire Scanners
1 Emittance Monitor

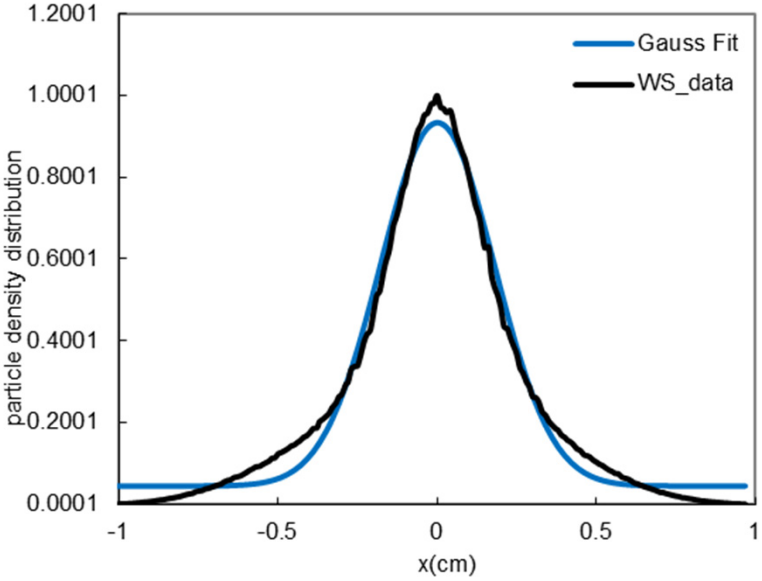
Transverse emittance measurement



4 wire scanners are used



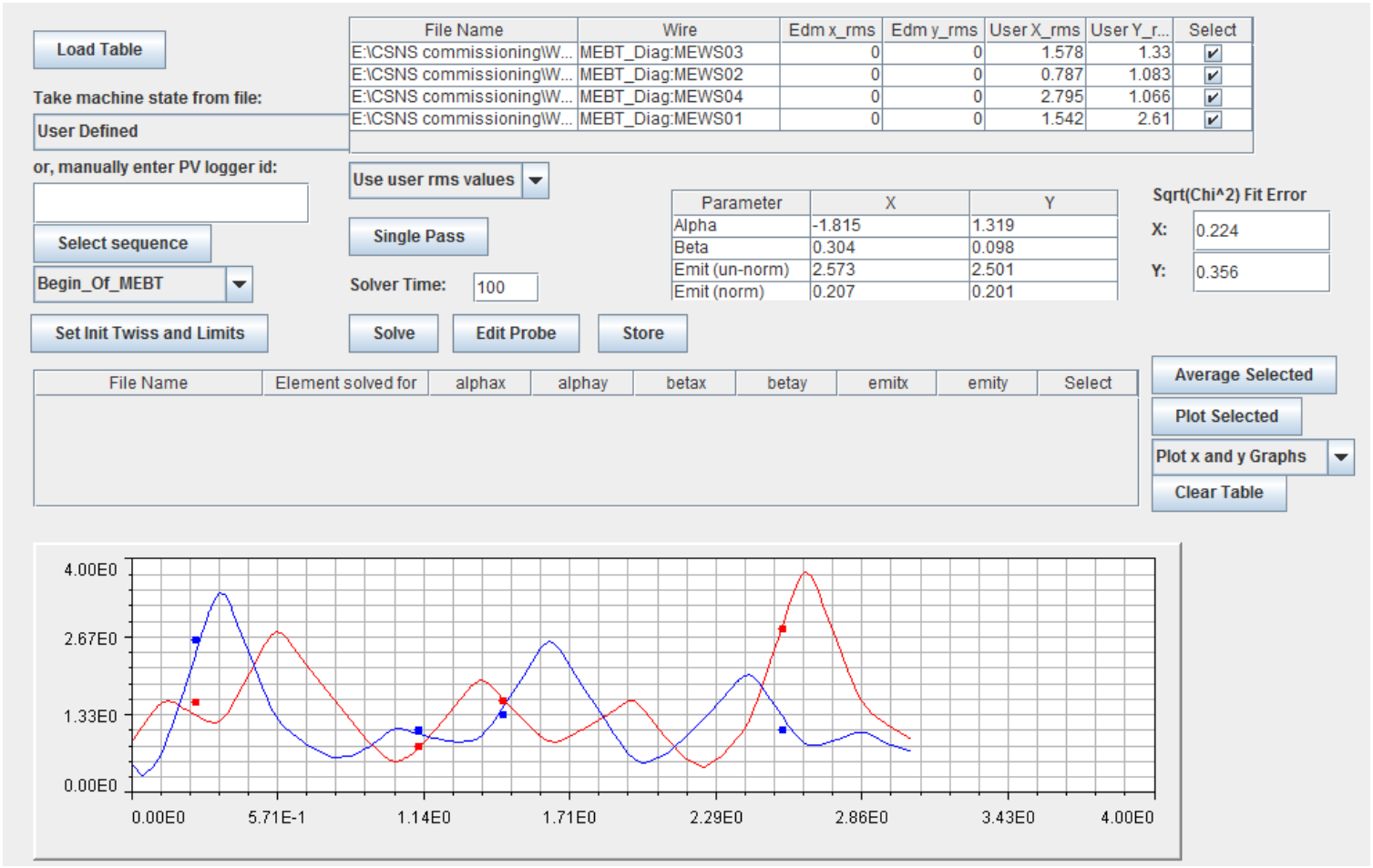
WS01, X direction



WS01, Y direction

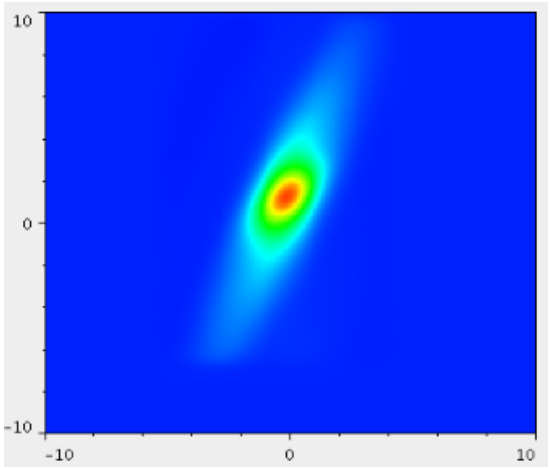
Beam profile measured with WS01

Wireanalysis, XAL，SNS

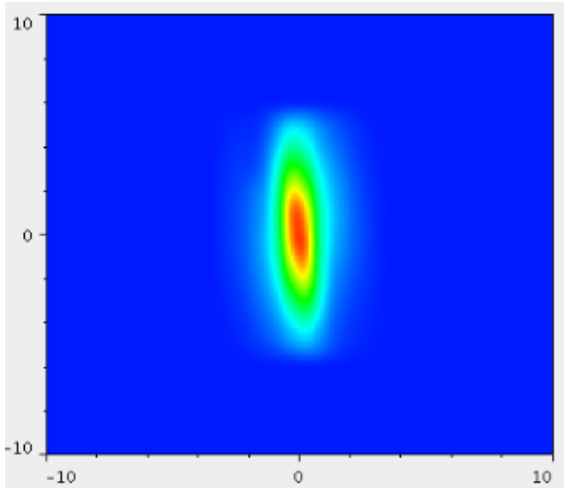


Twiss parameters at the entrance of the MEBT (rms, norm)

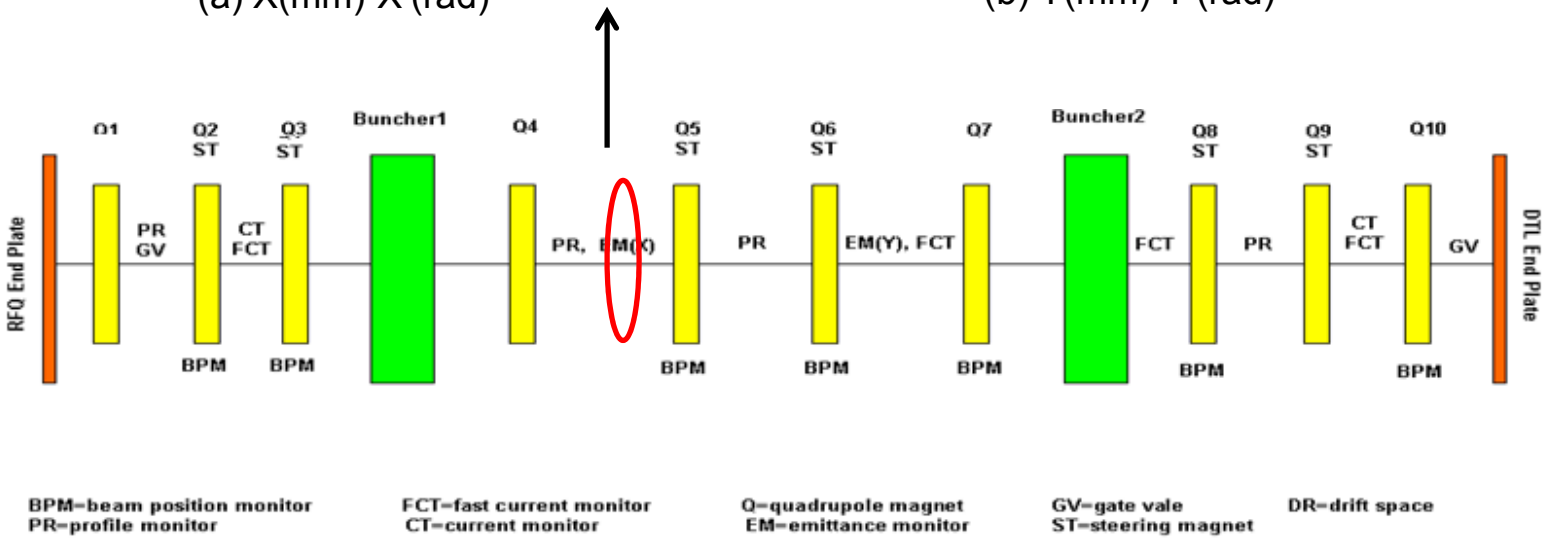
	α_x	β_x mm/mrad	α_y	β_y mm/mrad	ε_x mm mrad	ε_y mm mrad
Measured emittance with four wire scanners (I=15mA)	-1.815	0.304	1.319	0.098	0.207	0.201



(a) X(mm)-X'(rad)



(b) Y(mm)-Y'(rad)



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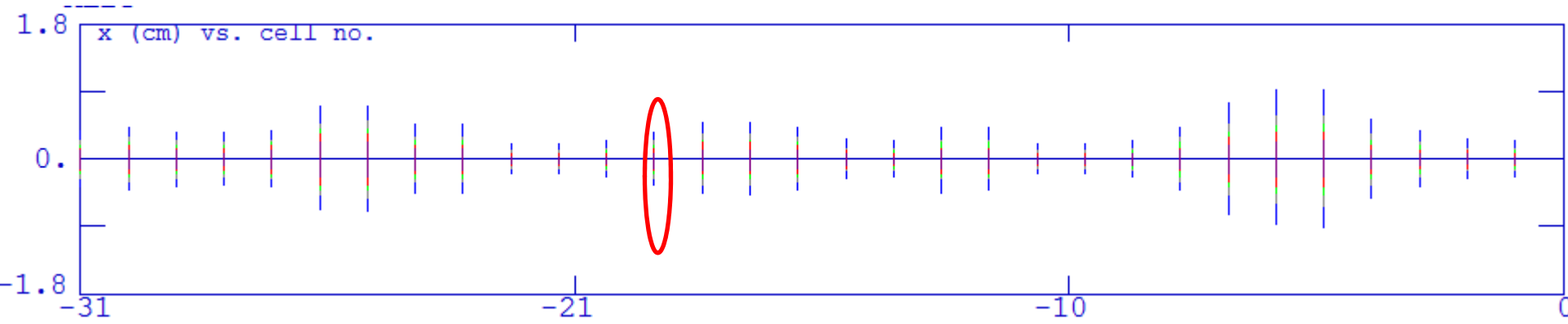
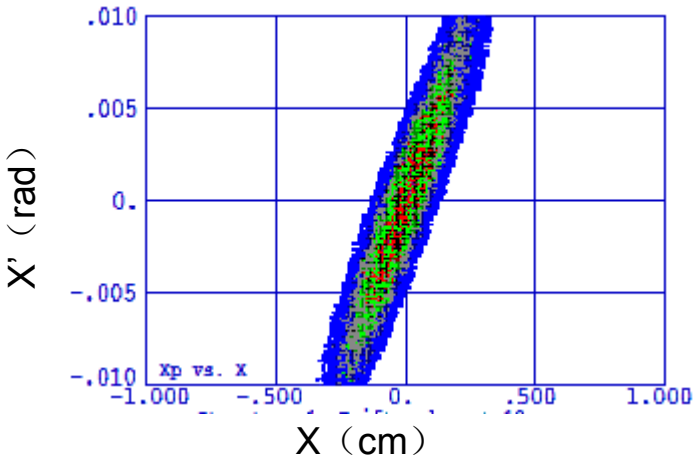
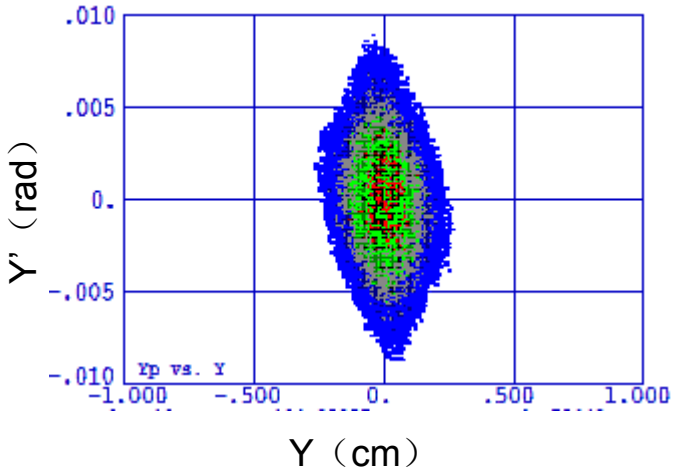


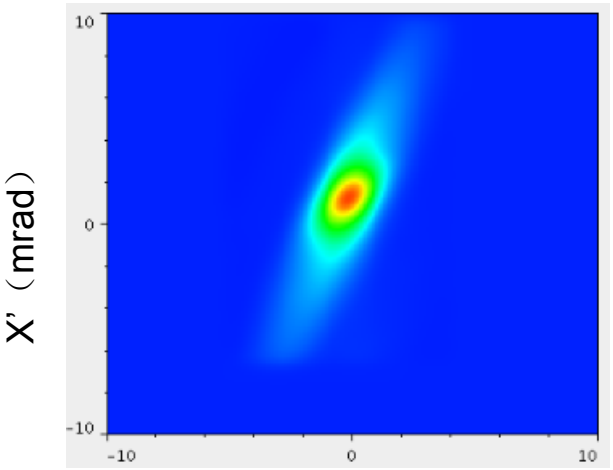
Beam envelope along the MEBT from PARMILA

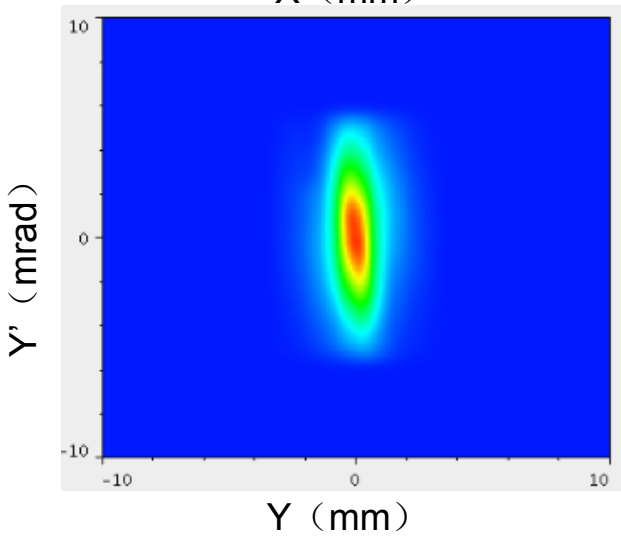
Simulated beam distribution from PARMILA





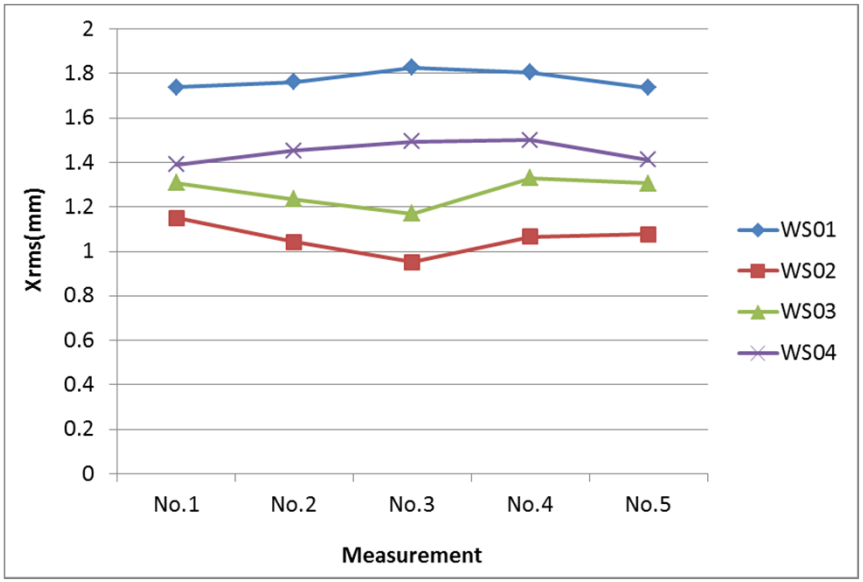
Measured beam distribution from the EM



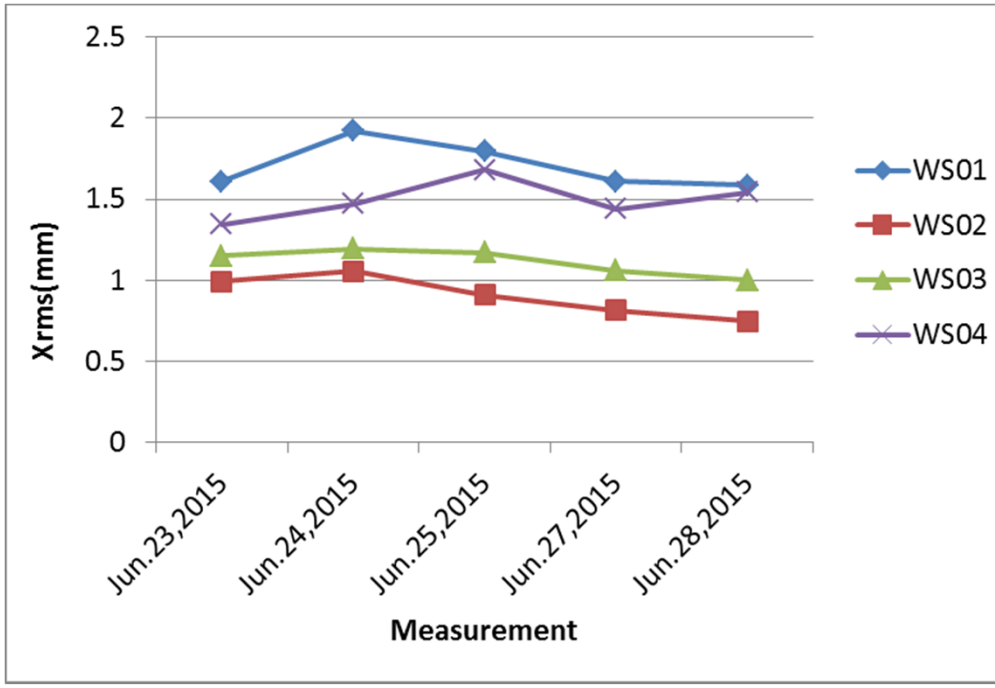


Twiss parameters at the EM (rms, norm)

	α_x	β_x mm/mrad	α_y	β_y mm/mrad	ε_x mm mrad	ε_y mm mrad
Simulated (I=15mA)	**-2.455**	**0.692**	**0.163**	**0.303**	**0.208**	**0.203**
Measured (I=15mA)	-1.14	0.624	0.017	0.374	0.211	0.184



Data from the same day



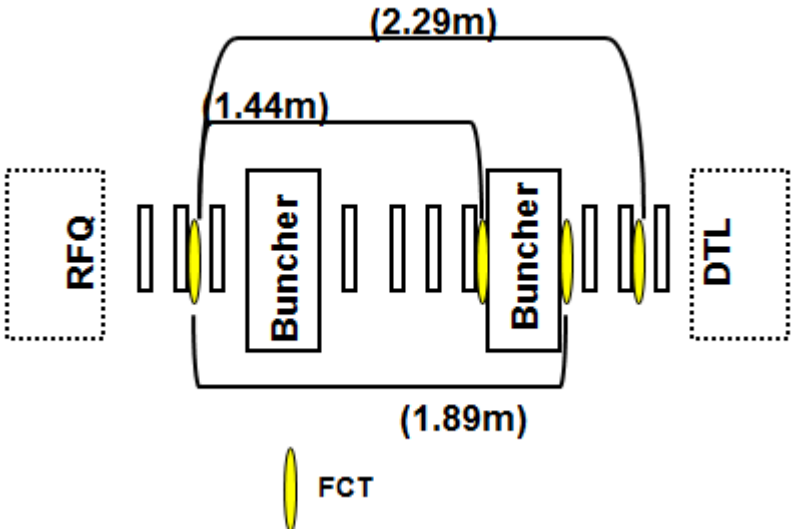
Data from different days

The measurement error is about 20%.

Energy measurement

The design energy of beam output from the RFQ is **3.0258**MeV

Monitoring the beam energy with TOF (Time Of Flight) method： 3.02±0.015MeV



Distance~30 βλ

$$W = m_0 c^2 \left(\frac{1}{\sqrt{1 - v^2/c^2}} - 1 \right)$$

$$v = \frac{L}{nT + \Delta t}$$

→ From oscilloscope

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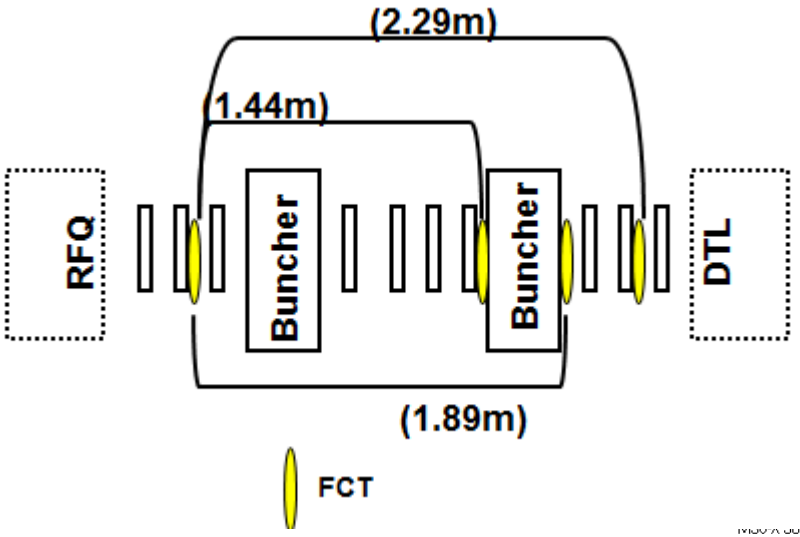

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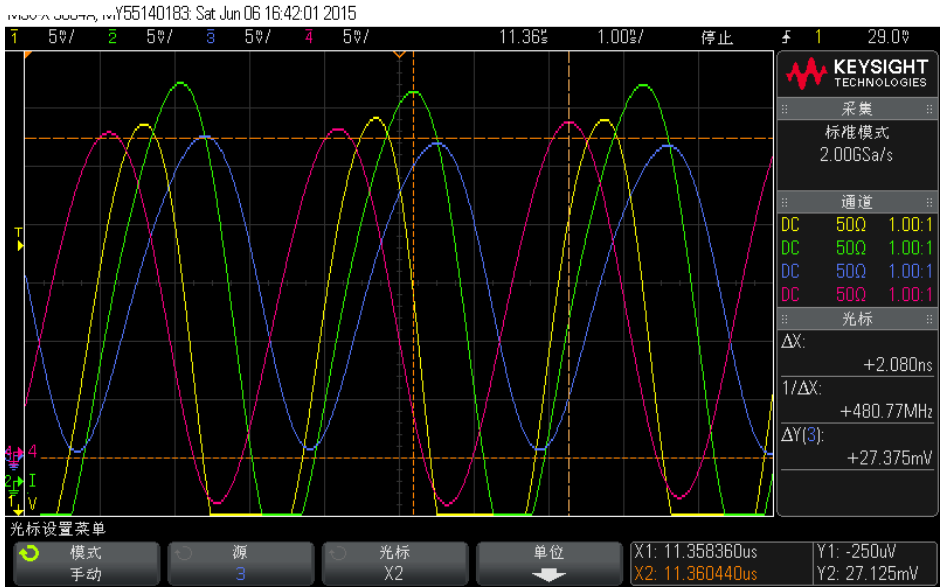
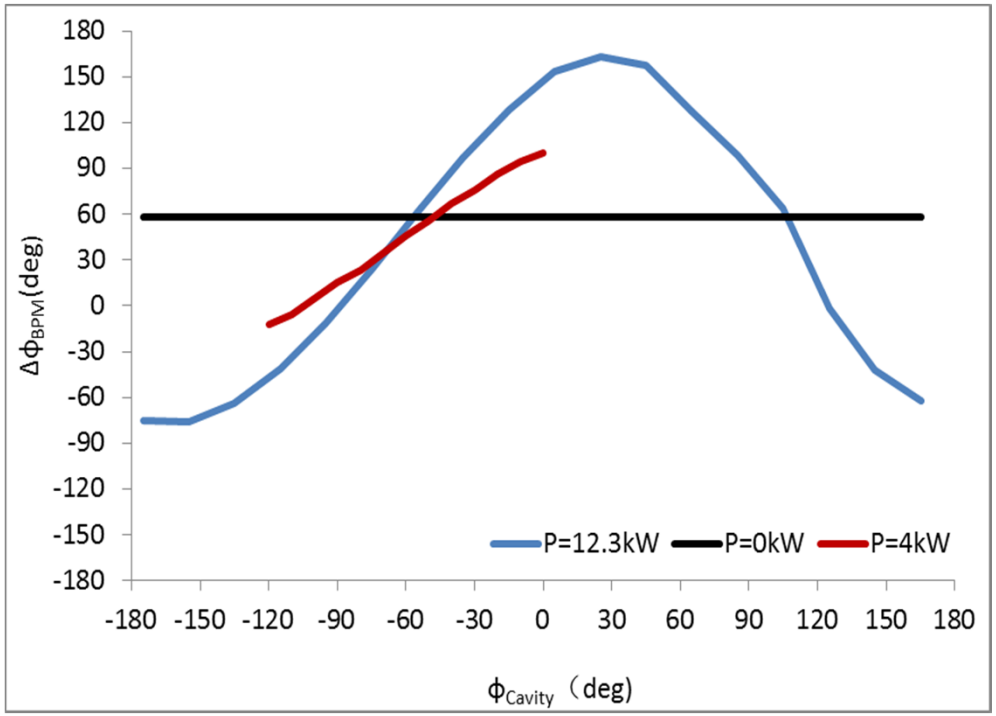


Buncher01

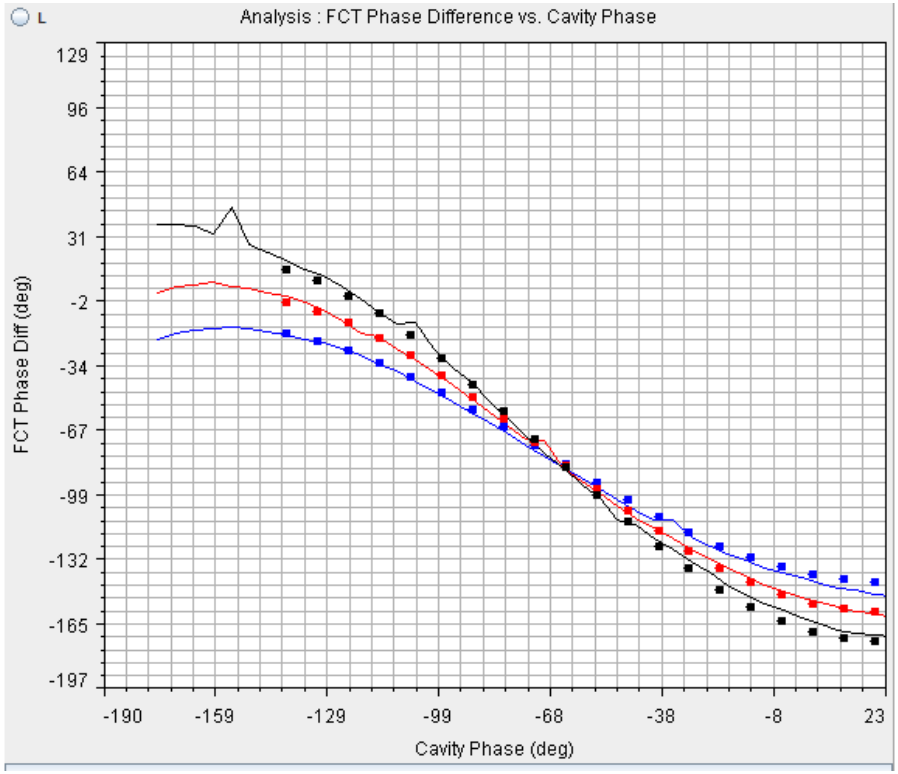


Measured phase differences with two BPMs

Φ_{cavity}=-55^{o}

Buncher01

XAL, Pasta (an RF phase scan and tuning application)

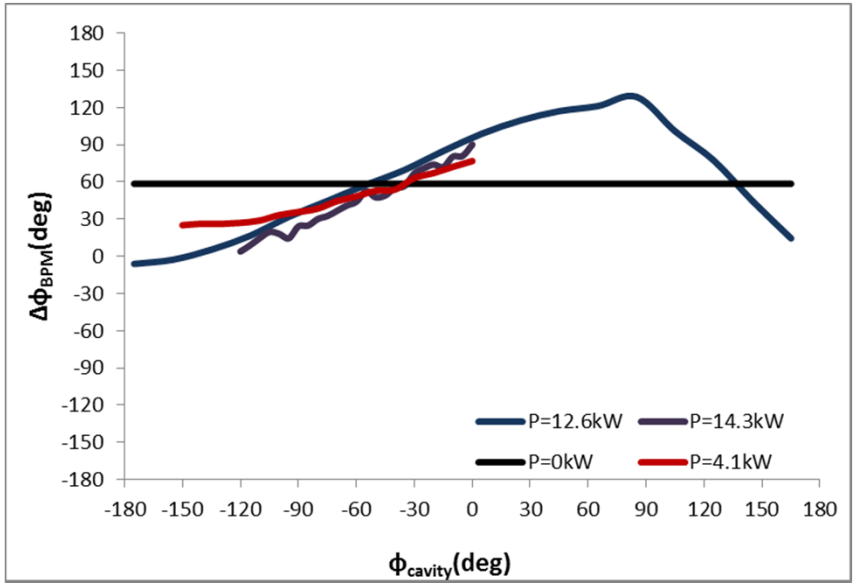


Input energy
Cavity amplitude
Phase offset between beam and cavity
Phase offset of a FCT's measured phase

Measured phase differences with two FCTs

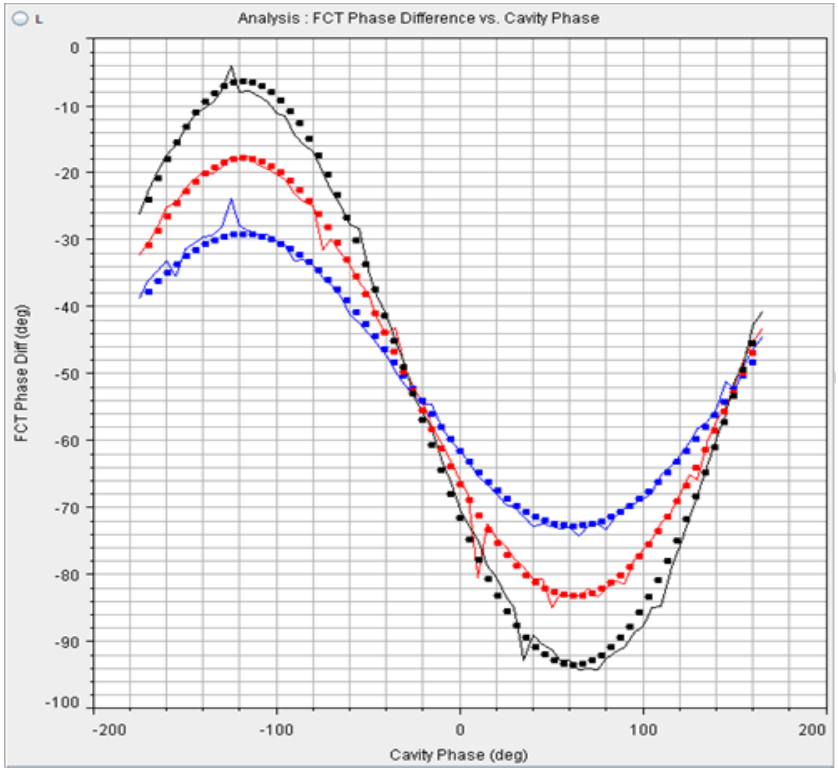
Φ_{cavity} =-60.097^{o}

Buncher02



With oscilloscope

Φ_{cavity}=-30°



With Pasta,XAL

Φ_{cavity} =-27.857°

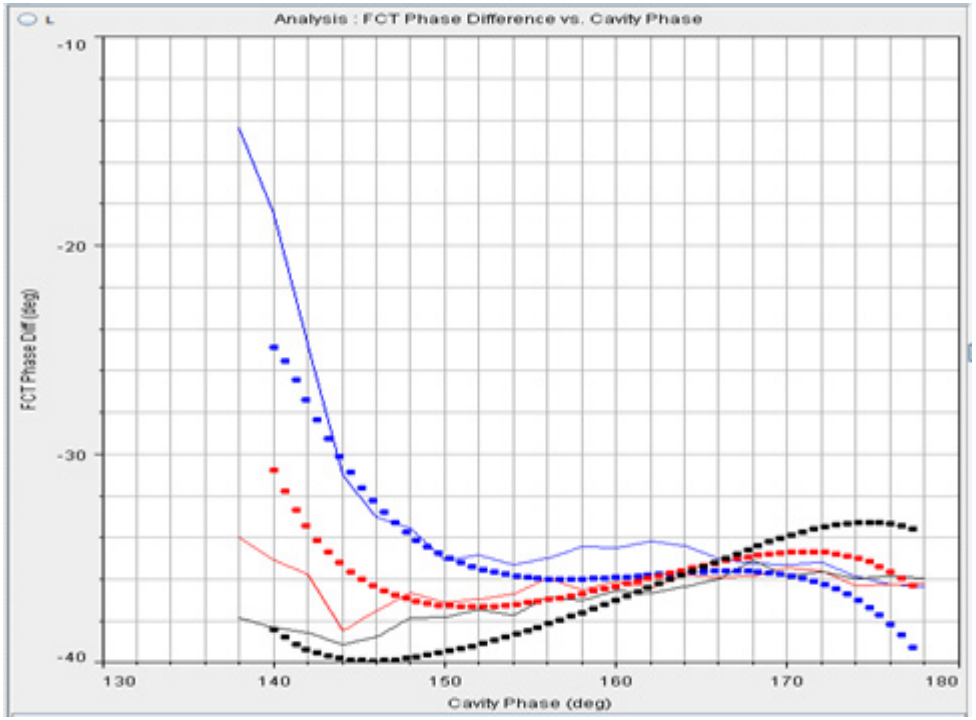
RFQ output energy

	Time Of Flight	Buncher1 Scan (Jan. 13th)	Buncher2 Scan (Jan. 13th)	Design
W_{RFQ}(MeV)	3.02±0.015	3.015	3.026	3.0258

DTL 1 commissioning

Setting DTL phase and amplitude

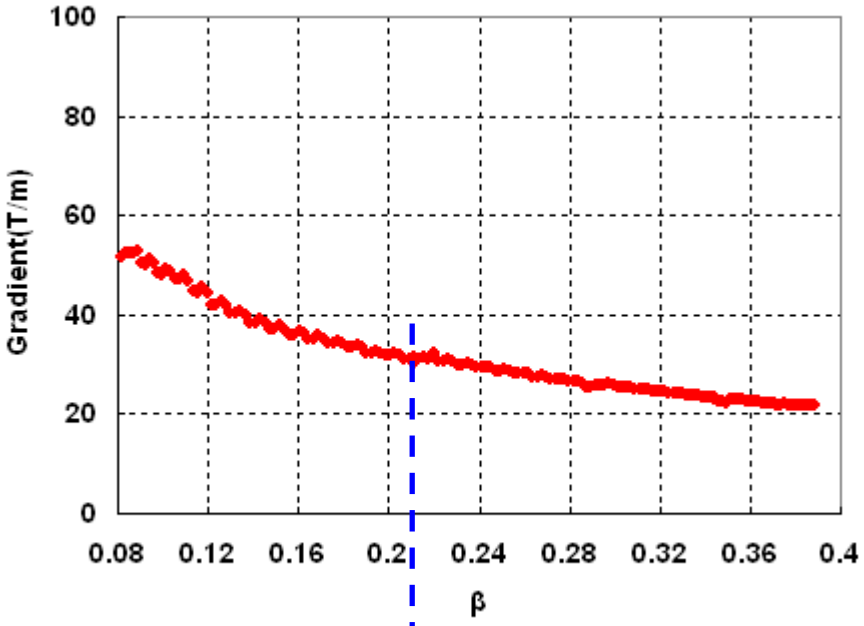
XAL, Pasta (an RF phase scan and tuning application)



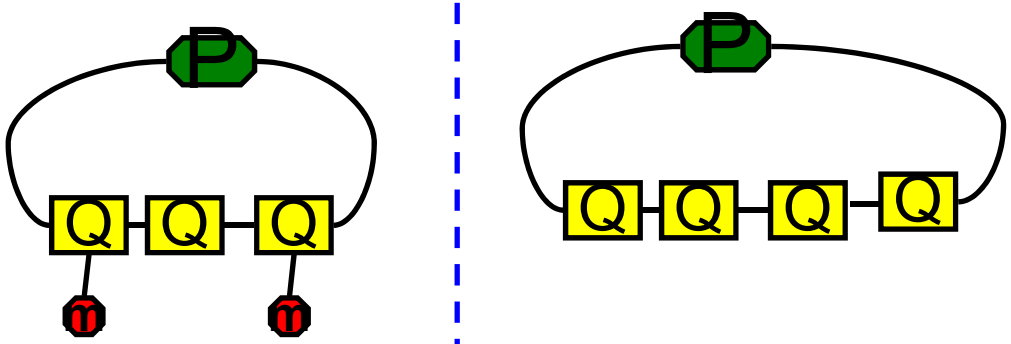
	DTL1 Scan1 (Mar. 1st)	Design
Φ_{cavity}（degree）	155.175	-30
Amp	3818	2.86MV/m
W_{RFQ}(MeV)	3.025	3.0258
W_{DTL1}(MeV)	21.722	21.67

Signature matching

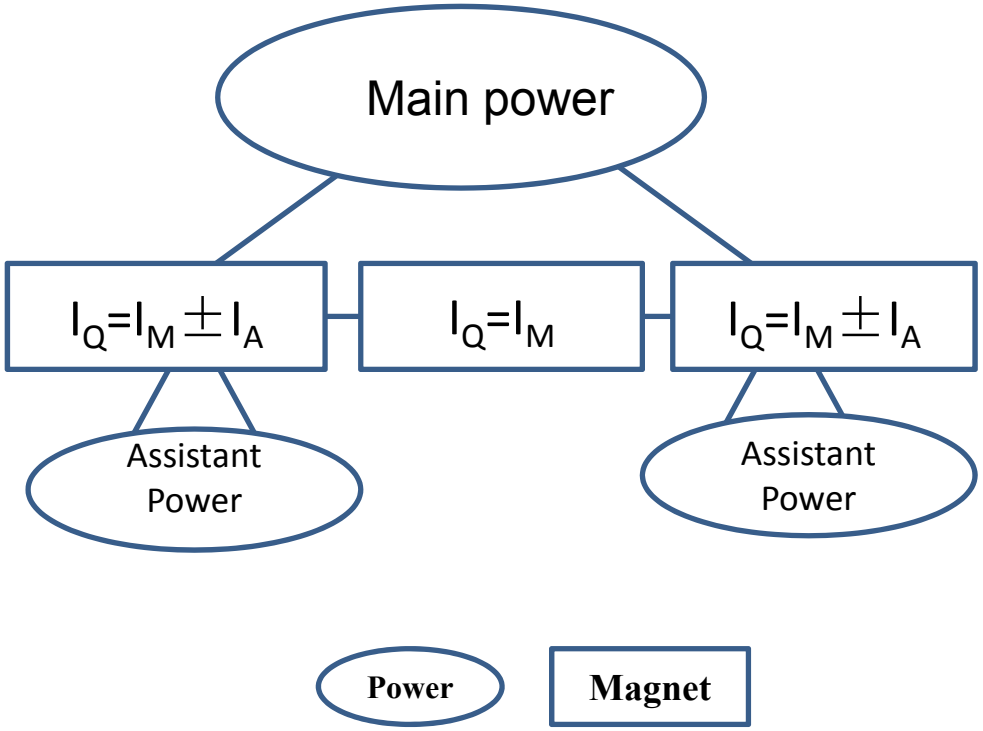
DTL Quadrupole power supply



DTL-1 DTL-2,3,4



DTL1, 65EMQs, FFDD



Assistant power: ~10% of the main power

Summary

- The Front-end and DTL1 have been fully commissioned, the primary design goals of peak current, transverse emittance and beam energy have been achieved.
- The RFQ output energy, measured by phase scan method, agrees well with that measured by time-of-flight method.
- Because the presence of beam halo, we need to do more work on transverse matching.

Thank you!