The Commissioning Plan for CSNS Accelerators

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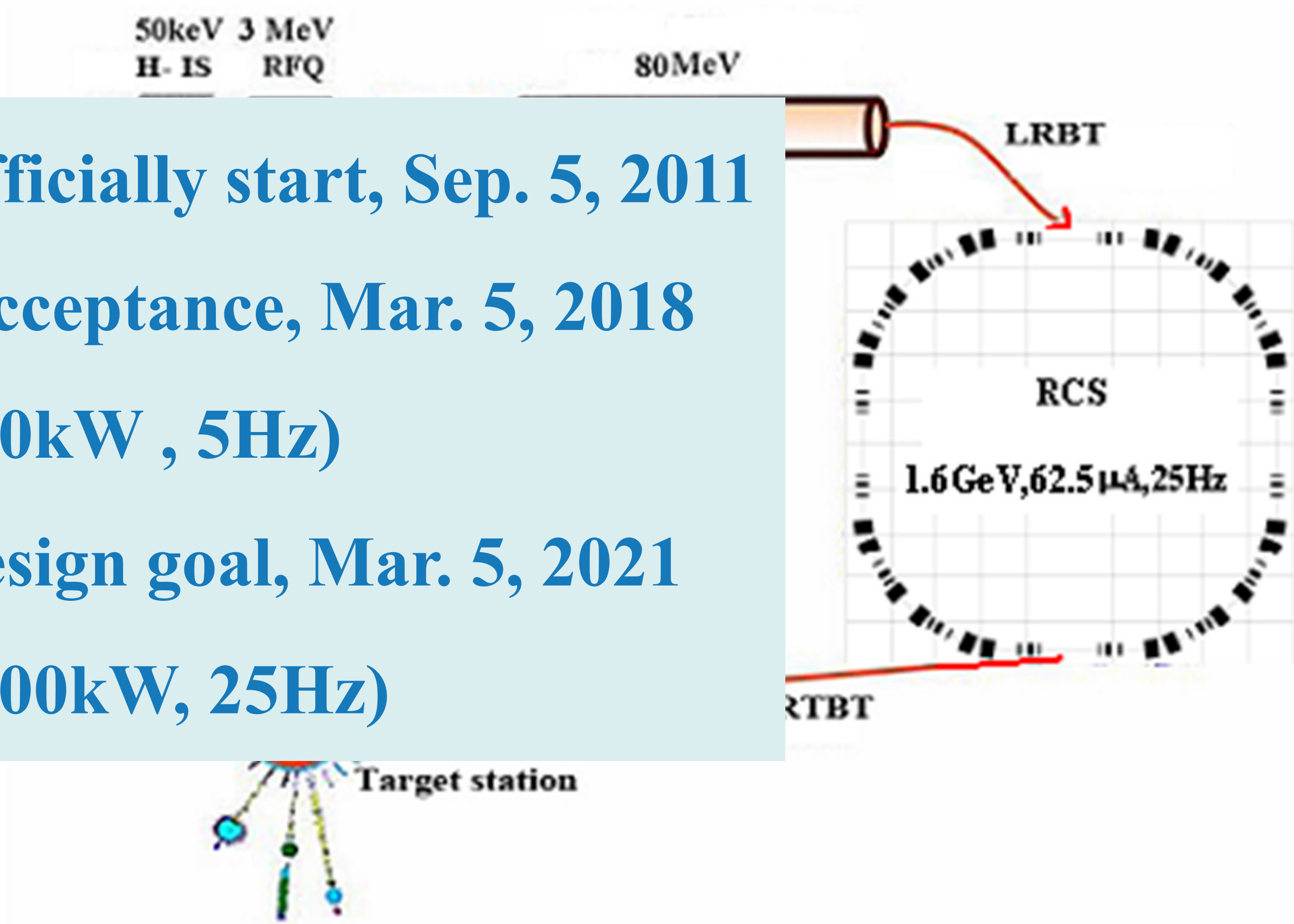
CSNS
CHINESE ACADEMY OF SCIENCES

Outline

- A brief introduction to CSNS
- The commissioning schedule and the goal at each stage
- The linac commissioning plan
- The RCS commissioning plan
- Summary

A brief introduction to CSNS

- Officially start, Sep. 5, 2011
- Acceptance, Mar. 5, 2018 (10kW , 5Hz)
- Design goal, Mar. 5, 2021 (100kW, 25Hz)



3-stage beam commissioning goal

- **First stage: Oct. 2013 to Aug. 2017**

  low intensity beam on the target

- **Second stage: 2017.03-2018.03**

  10kW beam for acceptance

- **Third stage: 2018.03-2021.03**

  beam power to the design goal of 100kW

Planned commissioning Schedule

Front end	Oct.18,2013-Apr.10, 2014	125 days
RFQ,MEBT,DTL1	Jun.5,2014-Aug.27, 2014	60 days
DTL2-4	Jun.30, 2015-Nov.3, 2015	90 days
LRBT+Linac	Nov.4,2015-Jan.6, 2016	46 days
RCS	May13,2016-Mar.2, 2017	210 days
RTBT	Mar.3,2017-May 25, 2017	60 days
First beam on target	Aug.24, 2017	
Beam power to 10kW	Aug.25,2017-Mar.3,2018	6 months
Beam power to 100kW	Mar.3,2018-Mar.3,2021	3 years

Commissioning goal of first stage

- Bring the Linac, LRBT, RCS, and RTBT (up to the Extraction Dump/target) into beam operation
- Characterize the primary beam parameters with low beam intensity
- Establish and validate the whole commissioning procedures which will used for the high intensity normal operations
- Study the dependence of beam performance on various tuning parameters
- Study various error effects on the beam
- Study the beam loss, and measure the beam losses to determine the threshold of beam loss for MPS

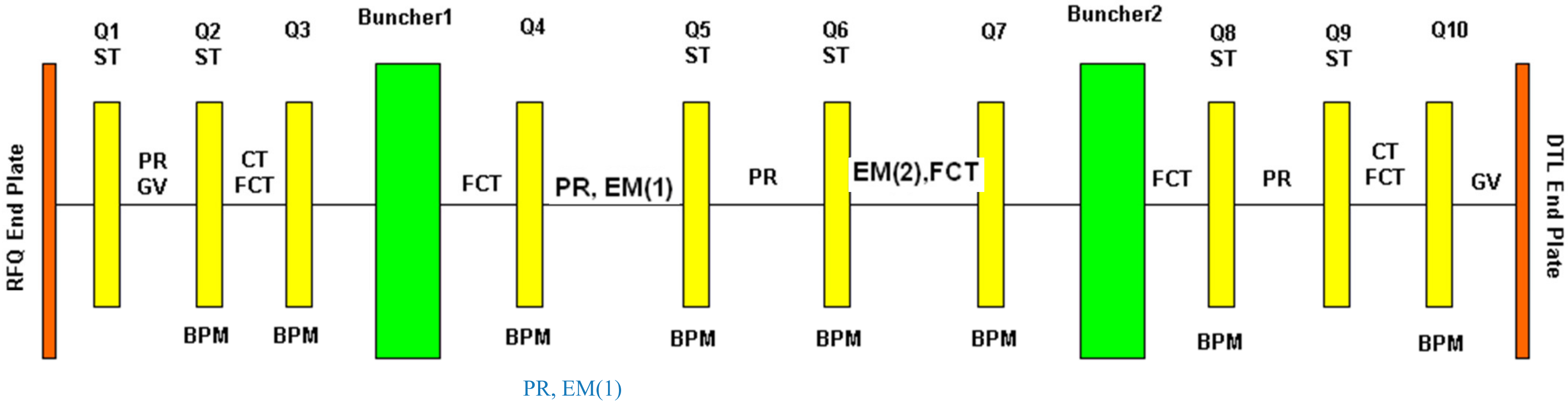
Beam dumps

Beam dumps	Beam energy	Power limit
Linac-dump1	250MeV	4kW
Linac-dump2	250MeV	0.2kW
Temp-dump	30MeV	0.16kW
Inj-dump	250MeV	2kW
RCS-dump	1.6GeV	7.5kW

Beam parameters for linac commissioning

	Peak current	Pulse width	Repetition
Short-current	5mA	50μs	1Hz
Commissioning goal for acceptance	15mA	420μs	5Hz
Design	15mA	420μs	25Hz
Single shot	5mA	150ns~420μs	Sporadic

MEBT commissioning



BPM=beam position monitor
PR=profile monitor

FCT=fast current monitor
CT=current monitor

Q=quadrupole magnet
EM=emittance monitor

GV=gate vale
ST=steering magnet

DR=drift space

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

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

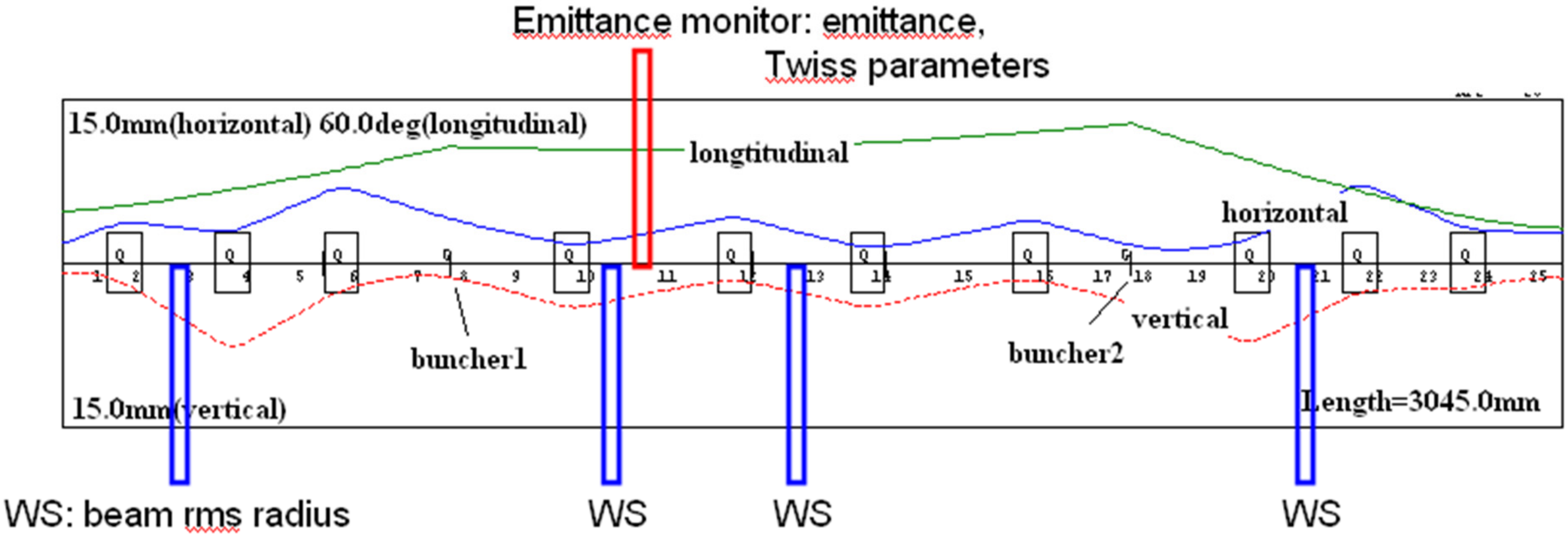
Longitudinal tuning

Find the RF set point of buncher cavities with a phase scan method.

The amplitudes of two bunchers are determined finally by the beam transmission rate at the exit of DTL-1.

Transverse tuning

Beased on the values of measured beam parameters, calculate the emittance and Twiss parameters at the exit of RFQ, and then the quadrupole strength is determined based on the calculated emittance and Twiss parameters



DTL commissioning

Temporal Beam Diagnostic system:
1BPM,1CT,2FCT,1 QEM,1 x-y steering magnet,1EM,1WS
1 Energy degrader /Faraday cup,1 Beam dump(0.163kW)

Tank number	1	2	3	4	total
Output energy (MeV)	21.67	41.41	61.07	80.09	80.09
Number of cell	64	37	30	26	157
RF driving power (MW)	1.35	1.32	1.32	1.34	5.33
Total RF power (MW) (I=15mA)	1.62	1.62	1.62	1.63	6.49
Accelerating field (MV/m)	2.86	2.96	2.96	3.0	
Synchronous phase (degree)	-35 to -25	-25	-25	-25	

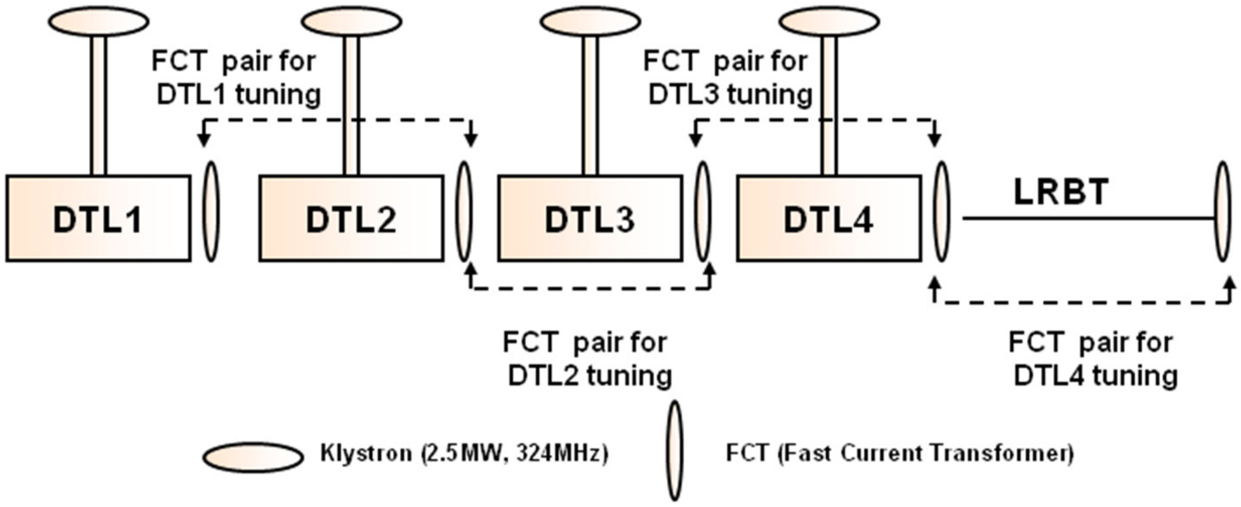
DTL-1 commissioning

- **Measuring the transmission rate**

  The RF of DTL-1 is turned off and the quadrupole setting is 3MeV beam transport line mode.

- **Longitudinal tuning**

  Find the RF set point of DTL1 with a phase scan method**.** The tuning goal of the RF set point is **1deg** in phase and **1%** in amplitude.



Phase scanning

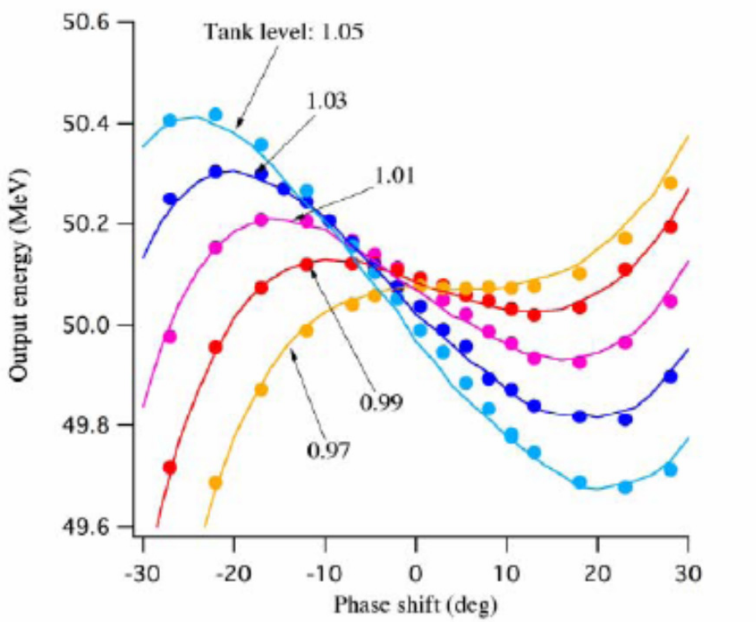


Figure 4: Phase scan curves for the DTL-1. Circles show measured beam energies and curves show results from the modelling.

By courtesy of K. Hasegawa, "Commissioning of the J-PARC Linac"

- The phase scan curve obtained with a numerical model for the design RF set-point is adopted as the reference curve;
- The reference curves is shifted to fit the measured phase scan curves under various RF amplitude settings;
- Calculating the deviation between the measured phase scan curve and the fitted phase scan curve ;
- The deviation between the measured phase scan curve and the fitted phase scan curve is fitted using a 2nd order polynomial function with respect to the tank amplitude so as to find the optimum tank level.

DTL-1 commissioning

➢ **Transverse tuning**

The quadrpole setting for DTL-1 is based on the beam dynamic design

➢ **An alternative transverse matching method of the MEBT to the DTL-1**

By tuning the four matching quadrupoles of the MEBT, minimize the rms emittances measuered from emittance scanners in D-plate

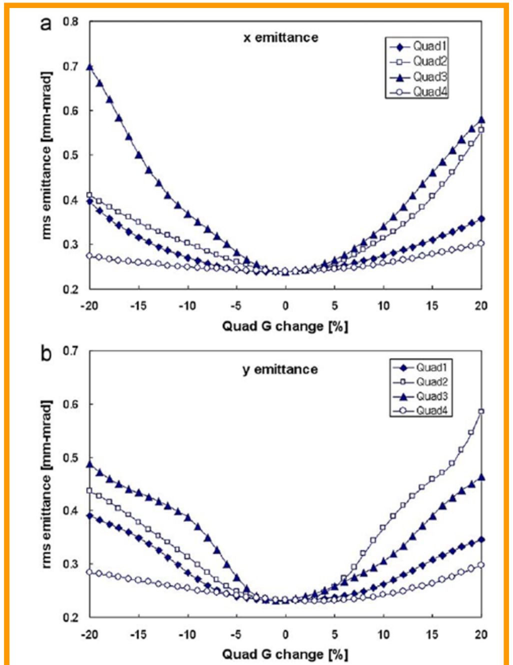
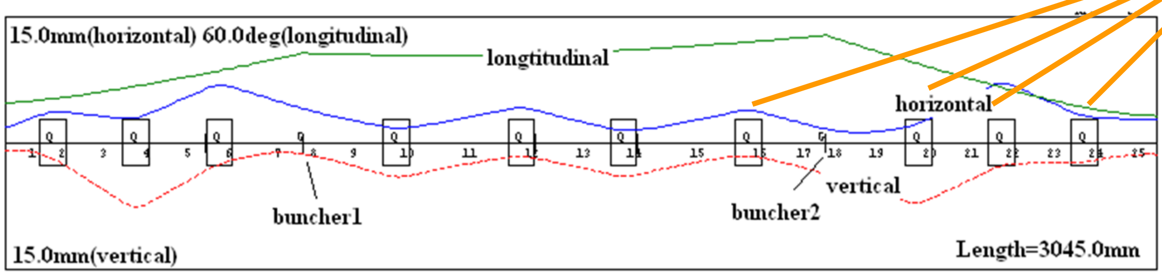


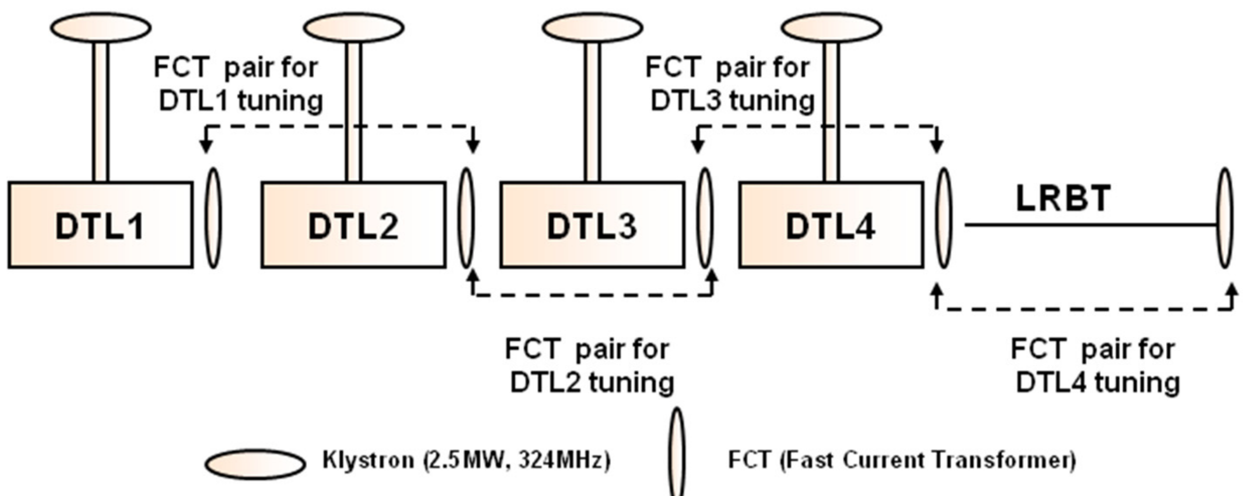
Fig. 2. Plots of the transverse rms emittance values vs. individual gradient changes of the MEBT matching quadrupoles, expressed as percent deviations from their design values, with all other gradients held at their design values.

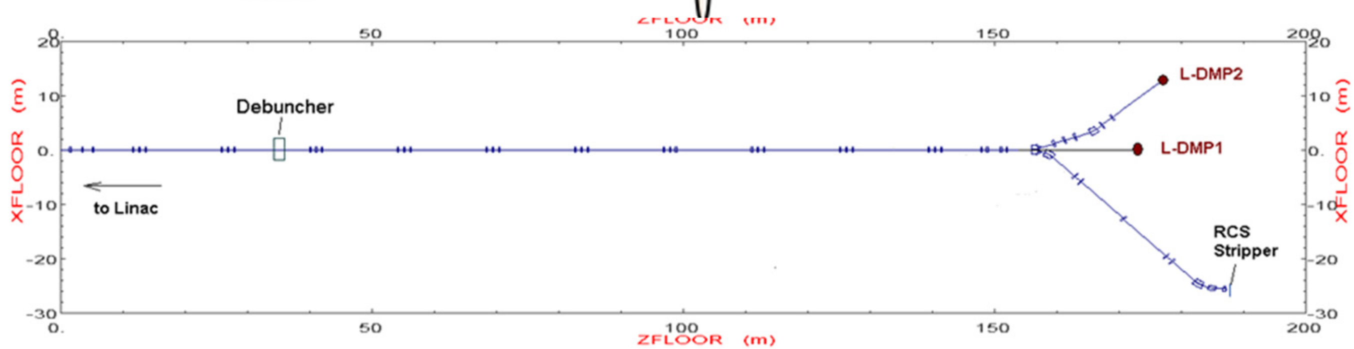


By courtesy of D.Jeon et al,
"Parctical transverse matching of the high-intensity SNS Linac"

DTL-2 ,3,4 commissioning

- The three tanks will be commissioned one by one
- The tuning procedure for each tank is similar to the DTL-1.





DTL-1,2,3,4 commissioning

- Beam current **5mA->15mA**, step length 5mA, marco-pulse length 50μs, repetition rate 1Hz

Repeat RF tuning of bunchers and transvers matching

- Beam current 5mA, marco-pulse length **50μs->420μs**, repetition rate 1Hz

Monitoring the transmission rate

- Beam current 5mA, marco-pulse length 50μs, repetition rate **1Hz->5Hz**

Monitoring the transmission rate

- Beam current **15mA**, marco-pulse length **50μs->420μs**, repetition rate **1Hz->5Hz**

Monitoring the transmission rate

RCS , LRBT and RTBT Commissioning

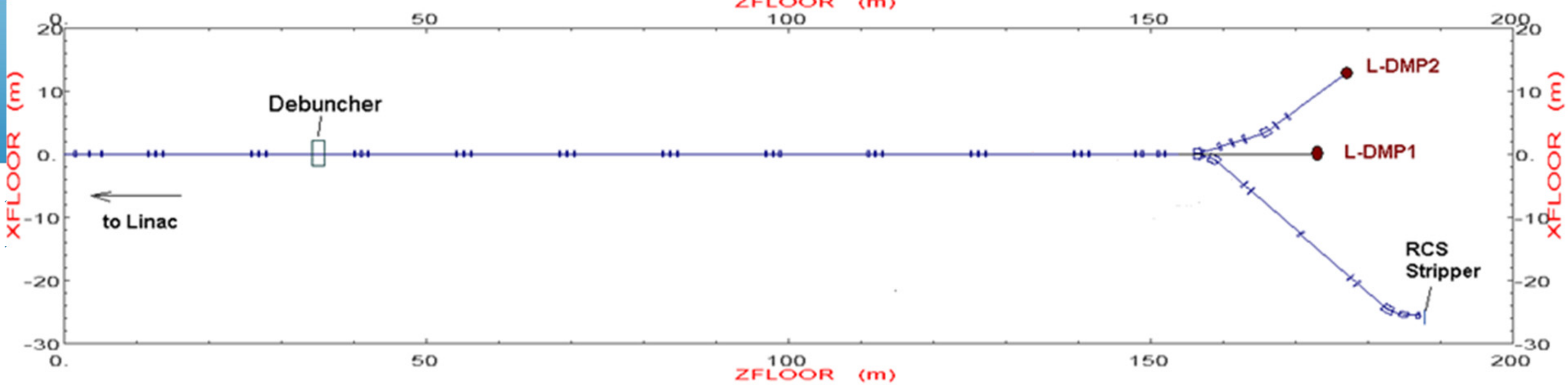
Diagnostics for RCS and Beam line commissioning

Section	CT	FCT	BPM	BLM	FBLM	WS	WCM	MWPM
LRBT	2	3	20	28		7	3	5
RTBT	4		33	50	2	8		2
Inj. Dump	1		2	3	1			1
R-Dump	1		2	6	1			1

	SCT	MCT	DCCT	FCT	WCM	BPM	BLM	FBLM	tune
RCS	1	1	1	3	2	32+3	72	9	2

Beam power limit to diagnostic system

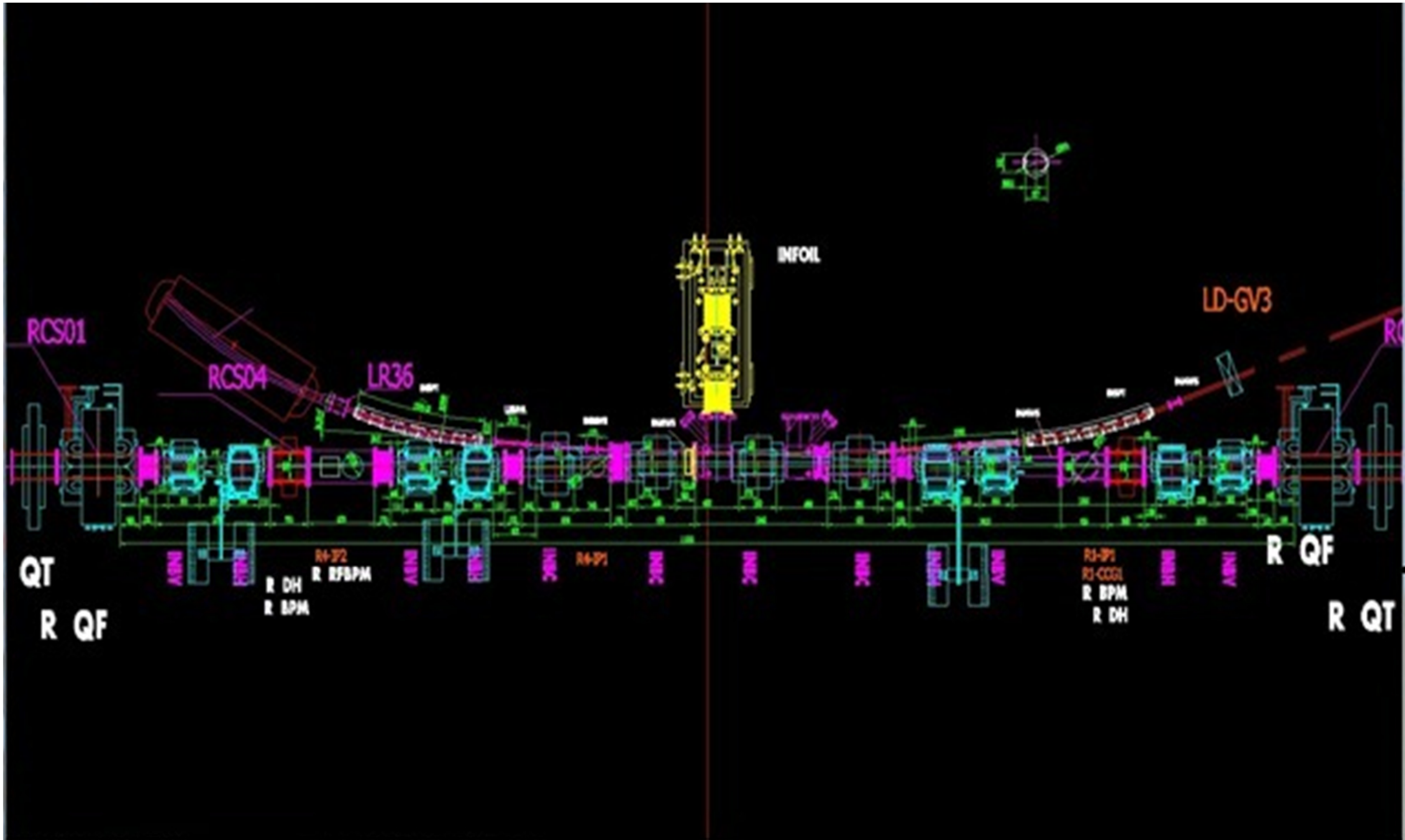
	Peak current	Pulse length	Repetition rate
LRBT BPM	>5mA	/	/
LRBT WS	≤15mA	≤ 100μs	<1Hz
RCS BPM	≥5mA	>500ns	/
RTBT BPM	≥ 5mA	/	/
RTBT WS	/	/	/



- Transporting a beam through the LRBT line (including linac dump line), the RCS injection region, the injection dump line and to the injection dump;
- Commissioning the diagnostic devices, BPMs, BCMs, WSs, then measure the beam energy, emittance, trajectory and optics;
- The dispersion in LRBT can be measured by adjusting the linac energy via the accelerating phase of the last cavity;
- In the beginning, the beam can be tracked by both BPM and BLMs;
- The transport efficiency will be measured by using BCMs;
- The beam orbit can be corrected by correctors to minimize the beam loss;
- The optics model can be re-calculated and calibrated based on the measured emittance , twiss parameters and the beam profiles as constraints;
- Linac beam ready to inject into RCS…

Preparing for injection

Firstly, directed beam to injection dump



RCS commissioning – injection

- In day 1 commissioning, large stripping foil will be used
- Firstly, multi-turn injection with fixed injection point
- After the beam has been stored, the injection bump orbit need to be precisely tuned. By using one turn by turn BPM, with a single short mini-pulse injection beam (less than 150ns), the relative injection orbit height can be precisely measured. The precise measurement of relative injection orbit height is one of the most important issue in the injection commissioning.

RCS commissioning – painting

- The phase space painting will be performed first in one plane, and then in both plane
- The painting beam will be extracted immediately after painting, and the painting beam distribution can be measured by using MWPM in the RTBT beam line
- With the RF off, the injected beam momentum spread can be estimated by using WCM, or by WS at the dispersion region of LRBT
- Debuncher parameters will be optimized according to the estimation of momentum spread and beam loss

RCS commissioning –DC mode

- The RCS will be commissioned with DC mode and mini-pulse
- The transverse secondary collimators can be used as beam dump
- By using turn by turn BPM and BLM to track the beam, perform the storage of the first beam
- WCM can be used to measure the beam current
- Chicane and COD correction
- Measure and restore the nominal tunes and linear optics, measure the transverse coupling
- Beam loss and collimation study
- Application software commissioned with beam

RCS commissioning – extraction and RTBT

- Extracting beam from RCS and transport the beam to the RCS dump;
- The diagnostics will be commissioned in the RTBT line up to dump.
- The kicker should be checked independently with small amplitude, and the timing of kicker should be adjusted
- In the beginning, BLMs in RCS and RTBT will be the tool to track the extraction procedure, and the extraction condition will be established by tuning the timing and amplitude of kickers
- The emittance of extraction will be measured.
- The optics of RTBT line up to dump will be corrected based on beam measurement

RCS commissioning – AC mode

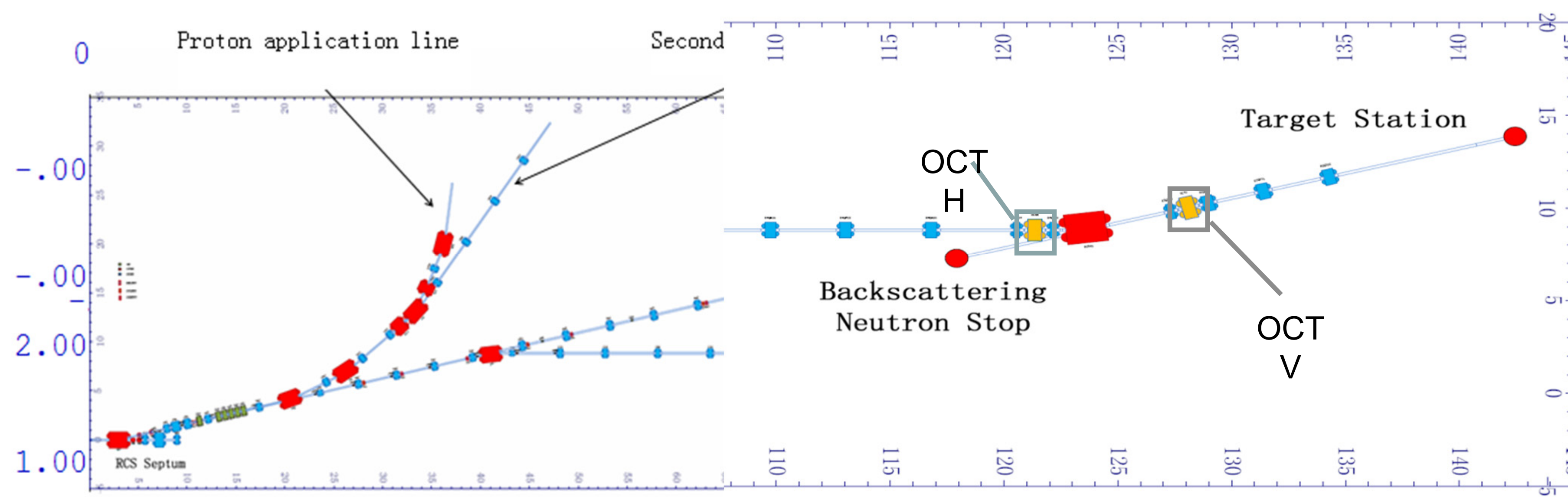
- Based on the optimized DC mode with RF cavities
- Start with the minimum injection pulse
- Check the tracking among 5 families Q power supply and 1 family dipole power supply based on the beam
- Measure the COD and optics parameters during the different stage of a RCS cycle by ICA method using turn by turn BPMs
- Optimizing the extraction parameters under AC mode
- ……

RF cavity commissioning with beam

- Commissioning for both DC mode and AC mode
- Commissioning with both low beam density and high beam density
- The lowest frequency will be set according to the measured energy of injection beam
- Interlock with LEBT chopper and extraction kickers will be checked
- 8 cavities will be firstly independently commissioned with beam, and then commissioned together
- For AC mode, the voltage curve should be optimized based on the beam

RTBT commissioning

- The remain part of RTBT will be commissioned upon target condition
- The orbit and optics will be corrected based on beam
- The effect of octupoles will studied with low intensity beam
- The beam loss on the 3-collimators in front of the target will be measured to determine the local optics



Thank you for your attention!