

Design and Beam Commissioning of Dual Harmonic RF System in CSNS RCS

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Main Content

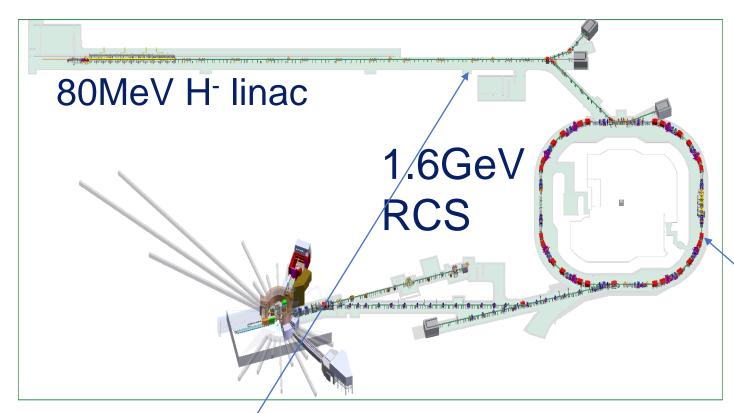


- ➤ The dual harmonic RF system
- > Beam measurement
- ➤ Next step



CSNS Layout





The RCS main parameters.

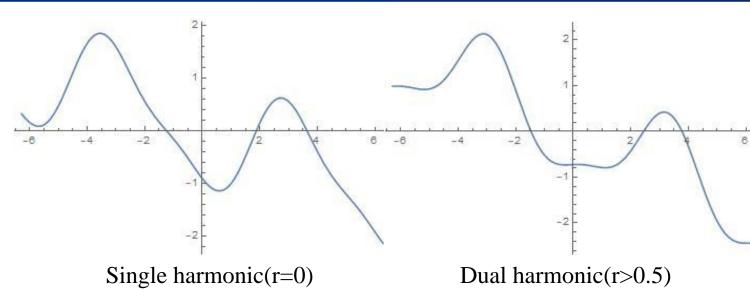
Parameter (unit)	Value
Circumference (m)	227.92
Protons	1.56e13
Inj./ext. kinetic energy (GeV)	0.08/1.6
Inj./ext. revolution time (µ s)	2/0.8
Inj./ext. RF frequency (MHz)	$1.022 \sim 2.444$
Harmonic number	2
Repetition rate (Hz)	25
Transition gamma	4.9
Inj. energy spread (%)	0.05-0.5
Momentum filling factor	0.81
Inj./ext. bunch length/ns	600/110

For CSNS-II, super conductive cavities will be added to increase the Linac energy from 80MeV to 300MeV

Three magnet alloy cavities will be added to RCS (2 already)

The Dual Harmonic RF System





Reduce the longitudinal peak current intensity, and thus reduce the beam loss caused by space charge effect.



140kW has achieved

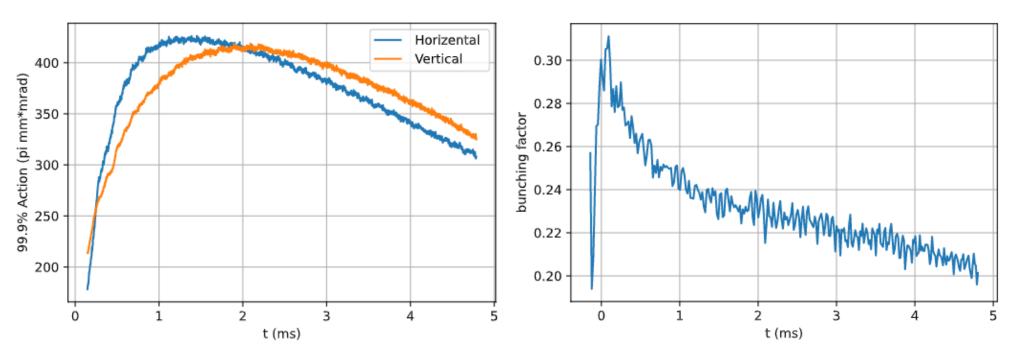


170kW (Three MA cavities added) (Three MA cavities added, 100kV) (300MeV Linac energy)



backgrounds about beam upgraded

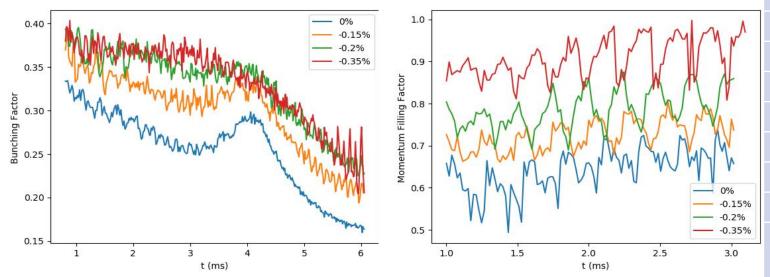
- Due to the edge focusing of injection magnets, the acceptance is decreased from 540π mm·mrad to 480π mm·mrad.
- After the trim quadrupoles adopted, the acceptance can be recovered (RCS trans over 99%)



Maximum (99.9%) transverse emittance and bunching factor on 130kW



Optimization of bunching factor



Since the upgrade project of 200kW doesn't include the momentum collimator at the first place, the momentum spread should be controlled under 1% to avoid that large beam loss occur in arc section, and the corresponding momentum filling factor is 0.8.

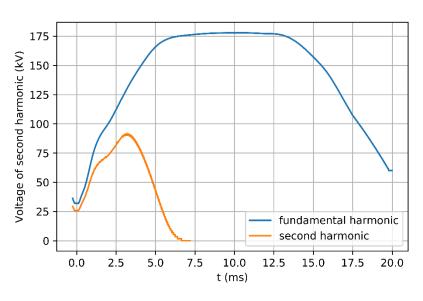
As a condition, r=0.8 and momentum offset is -0.2% during injection

Circumference (m)	227.92
Energy range(GeV)	0.08-1.6
Harmonic Number	2/4
Inj/Ext rf frequency (MHz)	1.022~2.444
Inj/Ext rigidity (T·m)	1.320~7.867
RMS Energy spread (Inj) (%)	0.05
Repetition (Hz)	25
Transition energy - γ	4.89
RCS work tune (H/V)	4.80/4.87
Transverse painting range(mm)	30/20
β function of inject point (m)	6.72/5.58
99.9% emittance after painting	170/155
without SC (π mm mrad)	
Inject period (ms)	0.5
Chopper duty (%)	50
Total Injected particle number at 130	2.028×10^{13}
kW N_p	
Total Injected particle number at 200	3.12×10^{13}
kW N_p	h

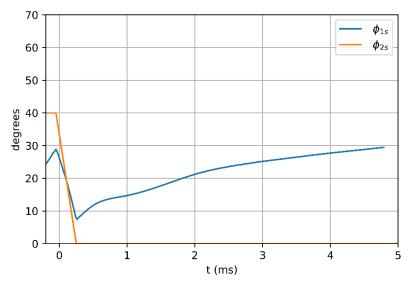
b



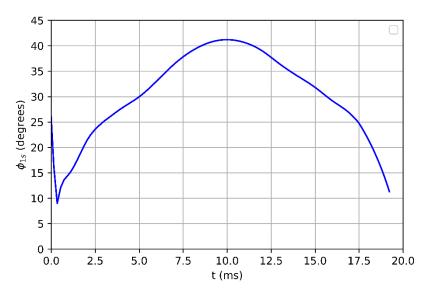
Optimized rf curves



rf voltage curve in RCS



rf phase curve in the first 5ms



the design value of φ_{1s}



Only a few

exceed the

lower than

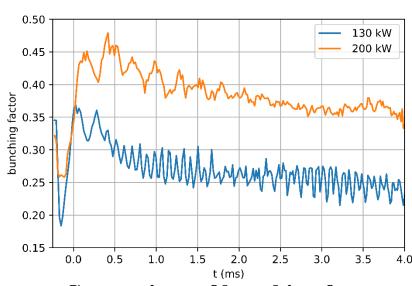
0.006% in

simulation

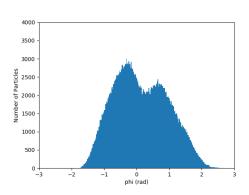
particle

bucket,

130kW vs 200kW



Comparison of bunching factor

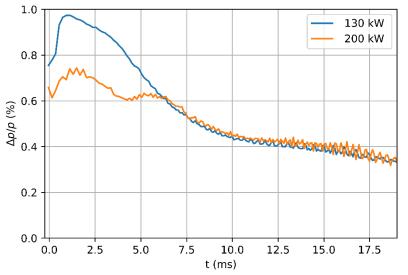


1500

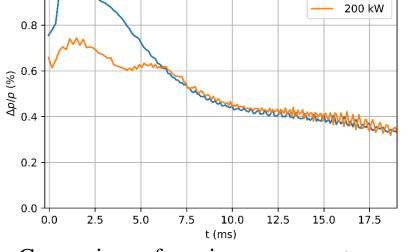
Comparison of beam profile

Bunch length and momentum spread remain same after injection (even smaller), and the peak value of particle number has been decreased.

Bunching factor increases because of the flatten longitudinal profile.



Comparison of maximum momentum spread

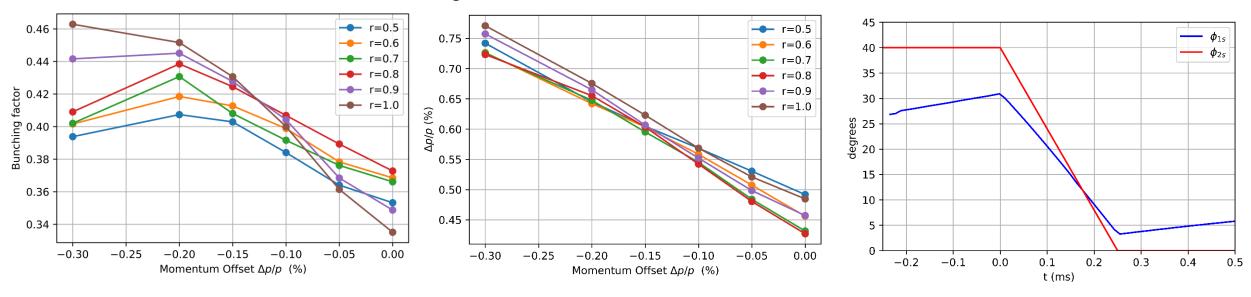


Comparison of phase space at the 5 ms



Optimization of longitudinal parameters during injection

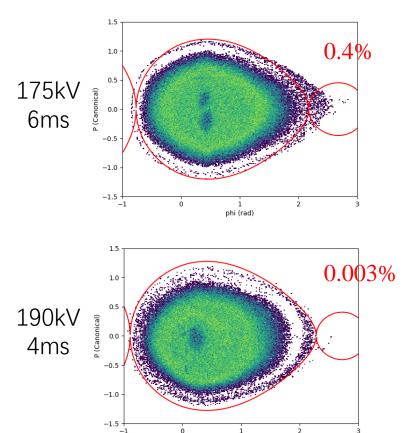
The inject energy of RCS is 300MeV, the longitudinal distribution of the injected beam is uniform, the momentum is Gaussian distributed, the rms momentum spread is 0.1%, and the slice rate is 50%. The simulation includes a multi-turn injection process, and the injection pulse width is 500 µs, which is equivalent to 430 turns. In order to ensure that there is enough bucket height after the energy increases, the initial cavity pressure is increased from 32 kV in the first stage to 60 kV.



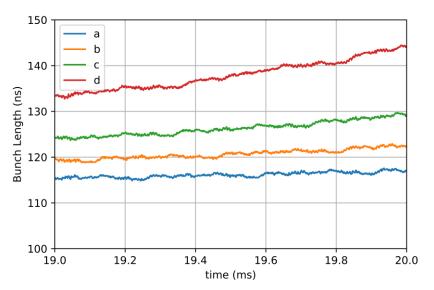
A combination of r=0.8 and momentum offset of -0.15% was used, that is, the longitudinal emittance after injection was 1.78 eVs. Second harmonic phase sweep was used during injection



Other optimizations



180 160 (2) 140 120 80 60 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 time (ms)



Optimization of rf voltage at extraction stage

After optimization, the particles exceed bucket are relatively reduced. When the cavity voltage at the extraction stage is increased to above 90 kV, the bunch length can be compressed to below 130 ns

Optimization of longitudinal phase space distribution in the middle of acceleration period



Optimized rf curves and main parameters

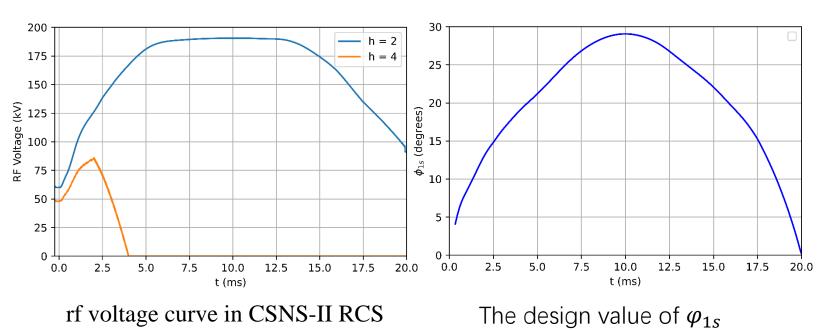


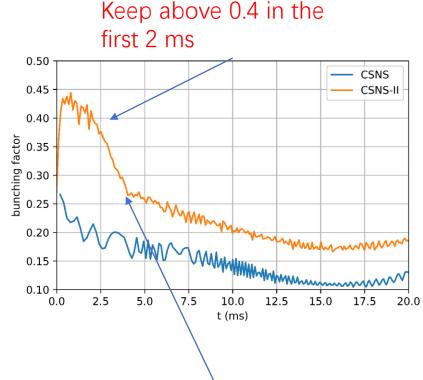
 Table 3
 RCS main simulation parameters

Parameters	CSNS	CSNS-II
RCS betatron tunes (H/V)	4.80/4.87	4.86/4.80
Transverse painting range (mm)	30/15	30/30
The beta function of injection point (m)	6.72/5.58	6.72/5.58
transition γ	4.89	4.89
Inj./ext. magnetic rigidity (T.m)	1.320-7.867	2.695-7.867
Chopper duty (%)	50%	50%
Injection period (μ s)	400	500
Number of circulating particles (N_p)	1.56×10^{13}	7.8×10^{13}
Inj./Ext. Energy (GeV)	0.08/1.6	0.3/1.6
Inj. Energy Spread (%)	0.05-0.5	0.05 - 0.5
Fundamental harmonic RF Voltage (kV)	45–175	60–190

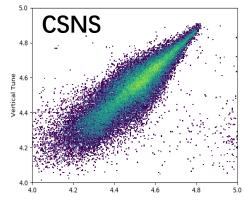
The results of CSNS and CSNS-II in the simulation will be compared in next slide.

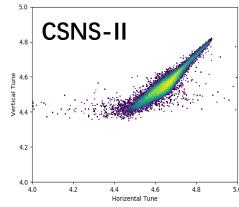


CSNS vs CSNS-II

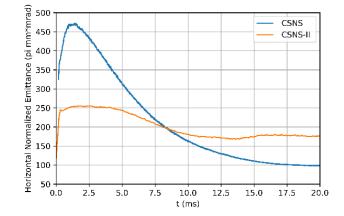


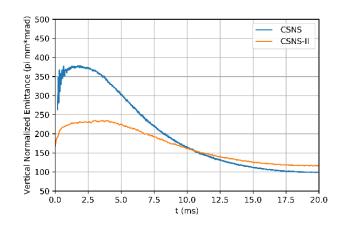
Since the energy increased ,space charge becomes weaker. Lower bunching factor is acceptable.





The tune spread at 500 kW is much smaller than at 100 kW.





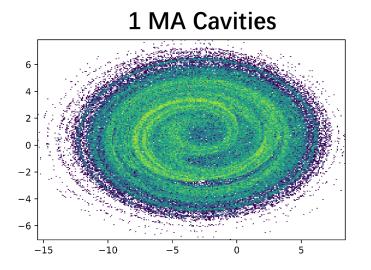
Transverse emittance

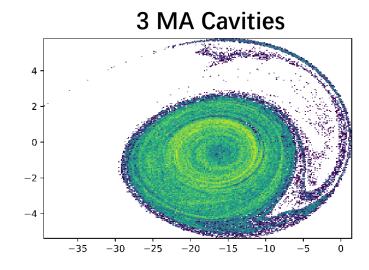
- The transverse emittance at 500 kW is much lower.
- Because of the energy ramp range shrined, the emittance decreases with increasing energy is correspondingly reduced
- However, it is still much smaller than the acceptance of the extraction transport line.

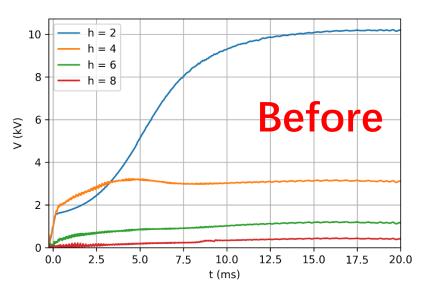
Beam Loading Effect-Compensation

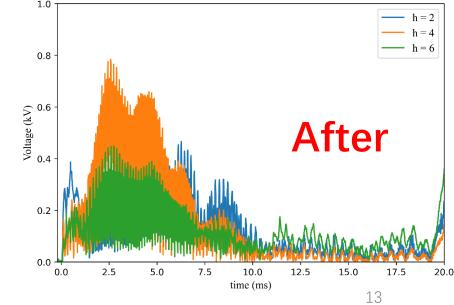


- The MA cavity has a higher accelerating voltage gradient compared to the ferrite cavity and also a wider bandwidth.
- The beam loading effect of MA cavities is very serious and should be considered carefully in high-intensity proton synchrotrons.
- To reduce the beam loading effects, a feedback system is used in the MA cavity for compensating the induced voltage.



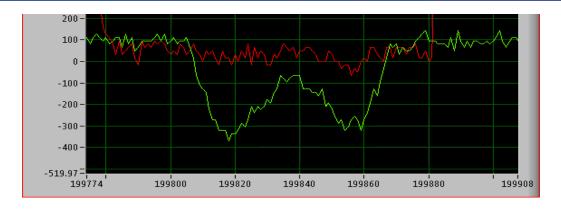






Beam measurement

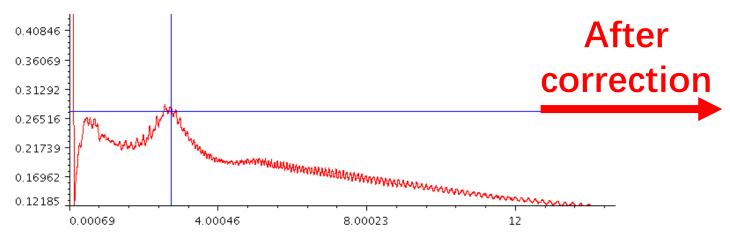


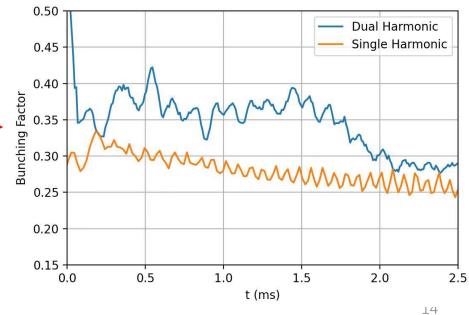




Add magnetic alloy cavity, r=0.8, adjust the second harmonic phase, ensure the peak height of both sides same(phase calibration)

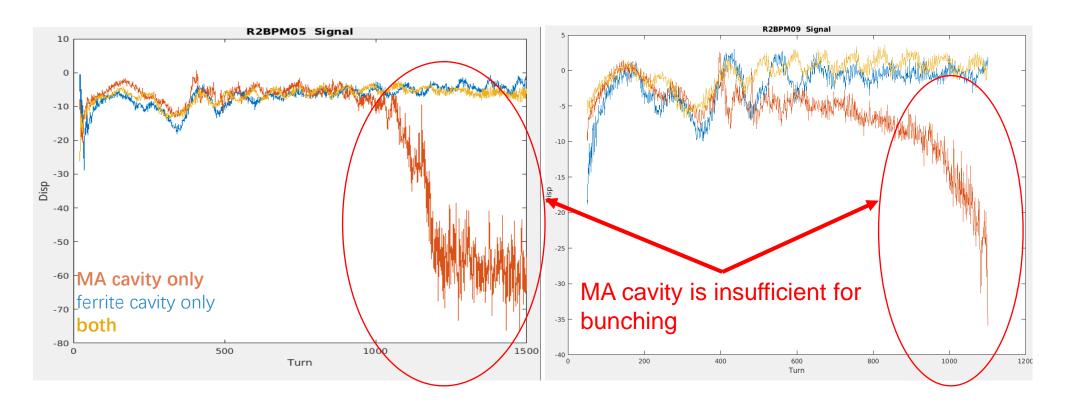
The nominal cavity RF is 16.6kV, the cavity pressure of ferrite is 32kV, r=0.5, which is consistent with the theoretical results (voltage calibration).





Beam measurement

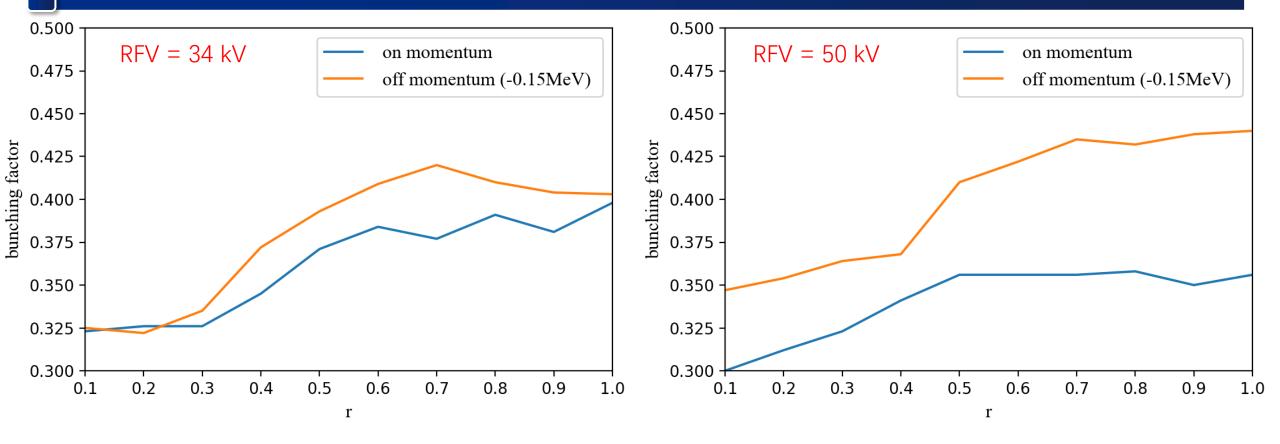




The orbit in the arc section is consistent, which ensures the timing and frequency are consistent to a certain extent

Beam measurement-Optimizations

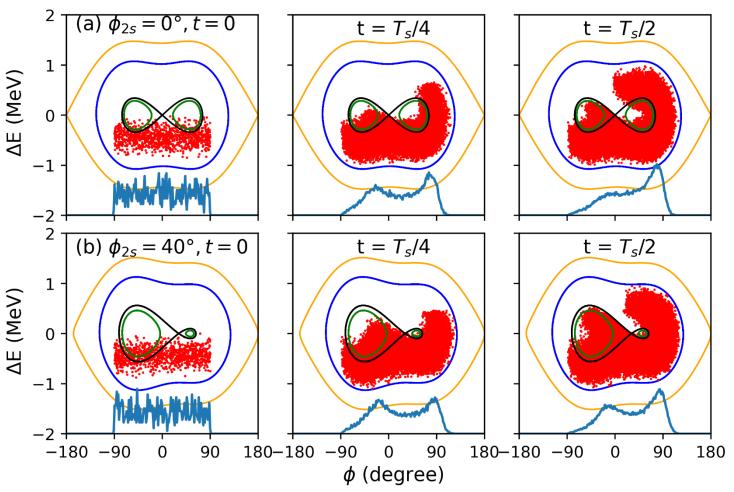




Combining injection momentum offset with a large second harmonic cavity voltage can better increase the bunching factor.

The purpose of phase sweep

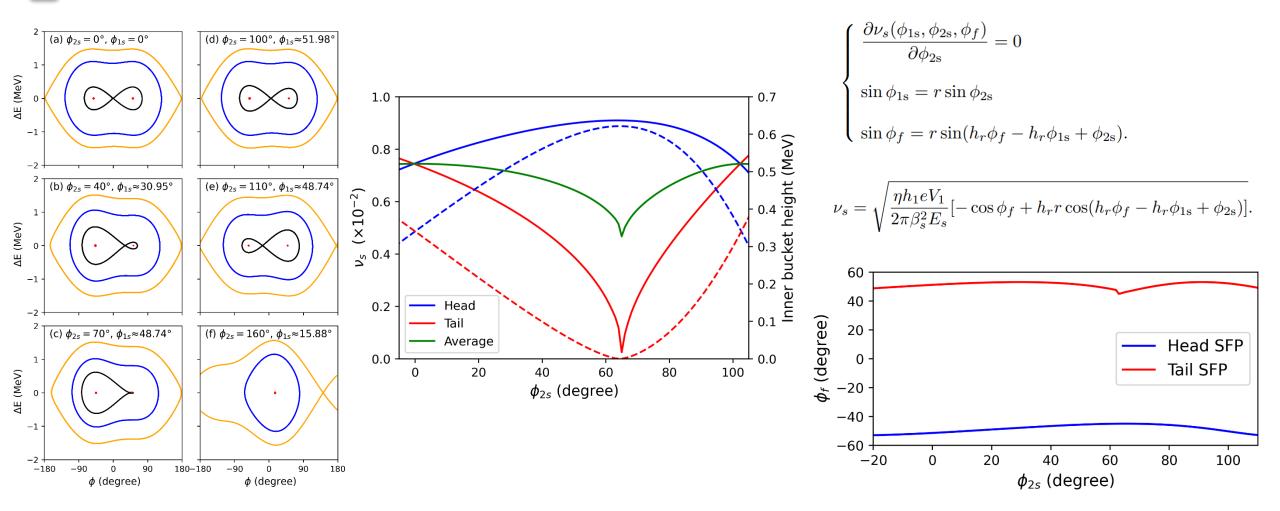




- In the presence of non-zero momentum
 offset the bunching factor decreases in the
 first one quarter of the synchrotron
 oscillation period during beam injection.
- More particles are accumulated in one end
 of the rf bucket, increase the local peak
 beam current and the (transverse) space
 charge strength, consequently deteriorate
 beam quality.
- To address this issue, a phase sweep scheme was proposed by Yamamoto from J-PARC

Calculation of phase sweep





The fixed point position is almost unchanged, but the longitudinal tune nearby fixed points changes dramatically.

Beam measurement-Optimizations



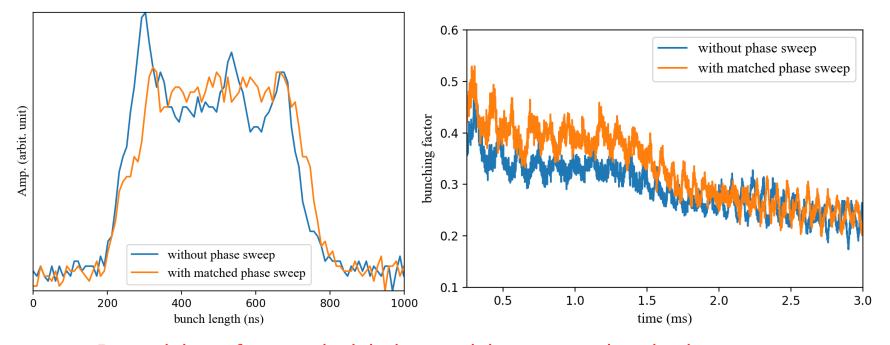
Two goals of "matched phase sweep":

- 1. Increase the bunching factor during the injection
- 2. Match the Injected beam with the bucket

$$n_0 \nu_{\text{s2,max}} + \int_{n_0}^{n_{\text{inj}}} \frac{1}{2} [\nu_{\text{s1}}(n) + \nu_{\text{s2}}(n)] dn = m$$

The maximum synchrotron oscillation frequency of the head fixed point remains unchanged at the early stage of injection,

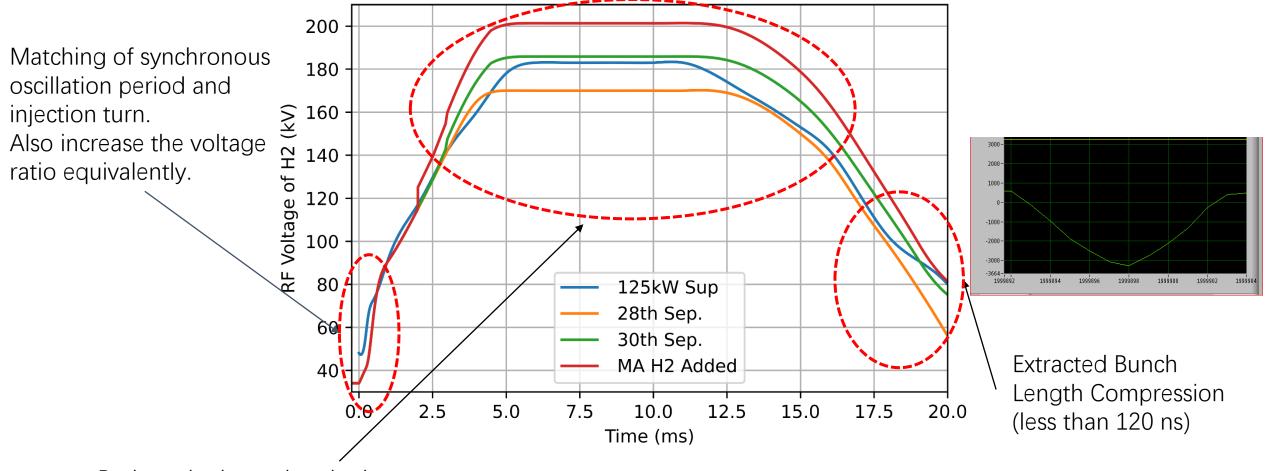
and the second harmonic RF phase is slowly shifted to 0 before the end of injection (make the m be a integer)



Bunching factor is higher with a matched phase sweep method. Additionally, the beam loss can also increase by approximately 3% with this method.

Beam measurement-Optimizations





Reduce the beam loss in the arc section

Beam measurement-Beam Status

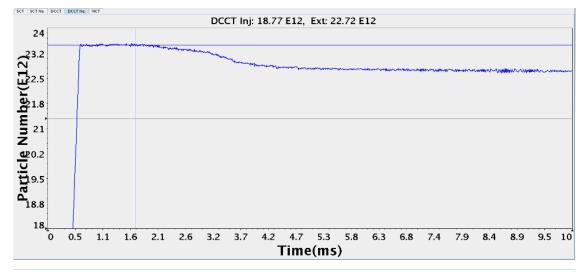


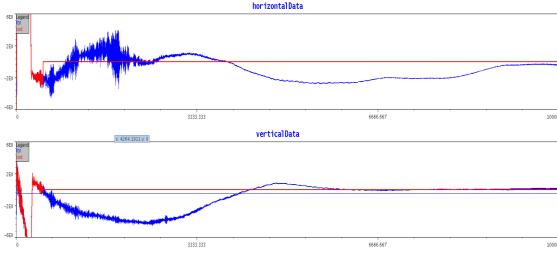
351.33

			5	 	2022-10-03 16	5:51:26	R4BLM01 351.6 R4BLM02 351.6 R4BLM03 411.64	束流损失	R1BLM01 R1BLM02 R1BLM03 R1BLM04 R1BLM05
	LEBT CT01	41.32	mA	RTBT CT03	-0.04	E12	R4BLM05 447.31 R4BLM06 168.8	••••••	R1BLM06 R1BLM07 R1BLM08
	LEBT CT02	3.14	mA	RDBT CT01	21.59	E12	R4BLM07 120.6 R4BLM08 1293.00 R4BLM09 1909.06	R2BLM15	R1BLM09 R1BLM10
	MEBT CT01	7.11	mA	LEBT Trans	7.6	%	R4BLM10 131.93 R4BLM11 964.31	122962	R1MB03IN R1MB03OUT R1BLM11
	MEBT CT02	7.13	mA	RFQ Trans	226.1	%	R4BLM12 33.14 R4BLM13 107.75	-10	R1BLM12 R1BLM13 R1BLM14
	LRBT CT01	7.20	mA	MEBT Trans	100.33	%	R4BLM14 204.85 R4BLM15 138.03 R4BLM16 288.23	-10	R1BLM15 R1BLM16 R1BLM17
	LRBT CT02	7.18	mA	DTL Trans	100.93	%	R4BLM17 393.65 R4BLM18 523.62	-43	R1DH12BLM R1BLM18 R1BLM19
	LRBT CT03	7.16	mA	LRBT Trans1	99.7	%	R48LM19 275.3 R3BLM17 1426.25	-583	R2BLM17 R2BLM16
	LDBT CT01	-0.00	mA	LRBT Trans2	99.8	%	R3BLM16 3266.92 R3BLM15 790.83 R3BLM14 \$22.78	-463 -763	R2DH12BLM R2QF12OUT
	DCCT-INJ	1921.51	mA	LDBT Trans	-	%	R3BLM13 1216.8 R3BLM12 1421.28	-463	R2BLM15 R2QF10NBLN R2BLM14
	DCCT-EXT	4499.05	mA	EXT Trans	101.9	%	R3BLM11 1291.53 R3BLM10 651.6.63	• 49	R2BLM13 R2BLM12 R2QF07IN
	DCCT-INJ No	23.39	E12	RCS Trans	98.3	%	R3BLM09 886.34 R3BLM08 1051.2	-1.027864 0 50 100 100 200 200 100 800 400 400 500 500 600 600 700 750 800 800 900 900 1000 1000 1100 1149	R2BLM11 R2QF07OUT
	DCCT-EXT No	23.00	E12	RTBT Trans		%	R3MB03IN 1074,724 R3BLM07 1779,18	•	R2BLM10 R2BLM09 R2BLM08
	RTBT CT01	23.43	E12	RDBT Trans	92.1	%	R3BLM06 3367-67 R3BLM05 3056.09		R2BLM07 R2BLM06 R2BLM05
	RTBT CT02	-0.13	E12	Beam Power	(150.148)	kW	R3BLM03 1108.8 R3BLM02 57.68.519	• • • • • • • • • • •	R2BLM04 R2BLM03 R2BLM02
							R3BLM01 10274.38	LRBT RTBT MM	R2BLM01
}			束	流状态	2022-10-06 05:3	2:34	RABLMO1 337.15	RCS BLM 2022-10-06 05:33:28	R18LM01
Ì	LEBT CT01	41.83	束 mA	流状态 RTBT CT03	2022-10-06 05:33 -0.05	2:34 E12	R4BLM02 506.62 R4BLM03 663.88		R1BLM02 R1BLM03 R1BLM04
Å	LEBT CT01 LEBT CT02	41.83 3.10					R4BLM02 506.62 R4ELM03 663.88 R4BLM04 239.38 R4ELM05 236.77 R4ELM06 196.63	RCS_BLM 2022-10-06 05:33:28	R1BLM02 R1BLM03 R1BLM04 R1BLM05 R1BLM06 R1BLM07
Å			mA	RTBT CT03	-0.05	E12	R4BLM02 506.62 R4BLM04 239.38 R4BLM05 236.77 R4BLM05 156.63 R4BLM07 371.81 R4BLM07 104.01	RCS BLM 2022-10-06 05:33:28	R1BLM02 R1BLM03 R1BLM04 R1BLM05 R1BLM06
A	LEBT CT02	3.10	mA mA	RTBT CT03 RDBT CT01	-0.05 22.47	E12 E12	R4BLM02 506.62 R4BLM04 299.38 R4BLM05 196.63 R4BLM07 371.81 R4BLM07 371.81 R4BLM09 102.81	RCS_BLM 2022-10-06 05:33:28	R18LM02 R18LM03 R18LM04 R18LM05 R18LM06 R18LM07 R18LM08 R18LM09
de la companya de la	LEBT CT02 MEBT CT01	3.10 6.75	mA mA	RTBT CT03 RDBT CT01 LEBT Trans	-0.05 22.47 7.4	E12 E12 %	RABLIMO2 506.62 RABLIMO3 653.88 RABLIMO4 239.38 RABLIMO5 236.77 RABLIMO6 196.63 RABLIMO6 104.01 RABLIMO6 104.01	RCS BLM 2022-10-06 05:33:28	RIBLMO2 RIBLMO4 RIBLMO6 RIBLMO6 RIBLMO6 RIBLMO6 RIBLMO9 RIBLMO9 RIBLMO9 RIBLM10 RIBLM11 RIBLM12 RIBLM12 RIBLM13 RIBLM13 RIBLM14 RIBLM14 RIBLM14 RIBLM14 RIBLM15
4	LEBT CT02 MEBT CT01 MEBT CT02	3.10 6.75 6.77	mA mA mA	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans	-0.05 22.47 7.4 218.1	E12 E12 % %	R4BLM02 506.62 RAELM03 663.88 R4BLM04 239.38 R4BLM06 236.77 R4BLM06 371.81 R4BLM07 371.81 R4BLM00 104.01 R4BLM00 102.81 R4BLM00 113.74 R4BLM01 113.74 R4BLM12 21.88 R4BLM12 20.85 R4BLM14 220.15 R4BLM14 530.57	RCS BLM 2022-10-06 05:33:28	RISLIMO2 RISLIMO4 RISLIMO6 RISLIMO6 RISLIMO6 RISLIMO6 RISLIMO6 RISLIMO6 RISLIMO1
As	LEBT CT02 MEBT CT01 MEBT CT02 LRBT CT01	3.10 6.75 6.77 6.82	mA mA mA mA	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans MEBT Trans	-0.05 22.47 7.4 218.1 100.28	E12 E12 % %	R4BLM02 506.62 R4BLM04 239.38 R4BLM06 239.38 R4BLM06 196.63 R4BLM07 371.81 R4BLM09 102.81 R4BLM09 102.81 R4BLM09 113.74 R4BLM09 122.81 R4BLM11 113.74 R4BLM12 21.88 R4BLM13 20.65 R4BLM14 120.15 R4BLM14 120.15 R4BLM16 112.73 R4BLM16 112.73 R4BLM16 241.19	RCS BLM 2022-10-06 05:33:28 R3BLM08	RIBLINGS
À	LEBT CT02 MEBT CT01 MEBT CT02 LRBT CT01 LRBT CT02	3.10 6.75 6.77 6.82 6.80	mA mA mA mA mA	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans MEBT Trans DTL Trans	-0.05 22.47 7.4 218.1 100.28 100.64	E12 E12 % % %	RABLING2 RELINGS RELING4 RELING4 RELING5 RELING5 RELING5 RELING5 RELING6 RELING6 RELING7 RELING6 RELING7 RELING8 RELING9 RELING9 RELING8 RELING9 RELIN	RCS BLM 2022-10-06 05:33:28 R3BLM08	RIBLINGS RIB
As .	LEBT CT02 MEBT CT01 MEBT CT02 LRBT CT01 LRBT CT02 LRBT CT03	3.10 6.75 6.77 6.82 6.80 6.80	mA mA mA mA mA mA	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans MEBT Trans DTL Trans LRBT Trans1	-0.05 22.47 7.4 218.1 100.28 100.64 99.7	E12 E12 % % % %	R4BLM02 506.62 R4BLM04 239.38 R4BLM06 239.38 R4BLM06 239.38 R4BLM06 376.63 R4BLM07 371.81 R4BLM00 104.01 R4BLM00 102.81 R4BLM00 102.81 R4BLM00 122.82 R4BLM11 113.74 R4BLM12 21.89 R4BLM14 220.15 R4BLM14 220.15 R4BLM15 112.73 R4BLM16 112.73 R4BLM16 212.18 R4BLM17 241.19 R4BLM18 150.68 R4BLM18 150.68 R4BLM19 753.16	RCS BLM 2022-10-06 05:33:28 R3BLM08	RISLINGS RIS
As .	LEBT CT02 MEBT CT01 MEBT CT02 LRBT CT01 LRBT CT02 LRBT CT03 LDBT CT01	3.10 6.75 6.77 6.82 6.80 6.80 0.00	mA mA mA mA mA mA	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans MEBT Trans DTL Trans LRBT Trans1 LRBT Trans2	-0.05 22.47 7.4 218.1 100.28 100.64 99.7 100.0	E12 E12 % % % % %	R4BLM02 506.62 RELM03 663.88 RELM04 239.38 RELM04 239.38 RELM06 236.77 RELM06 196.63 RELM06 196.63 RELM07 371.81 RELM06 104.01 RELM07 102.81 SELM07 102.81 SELM09 RELM01 113.74 RELM02 20.8 RELM01 20.8 RELM01 20.8 RELM01 15.00.57 RELM01 15.00.57 RELM01 15.00.65 RELM01 15.	RCS BLM 2022-10-06 05:33:28 R3BLM08	RILLMOZ RILLMOS RILLMO
è	LEBT CT02 MEBT CT01 MEBT CT02 LRBT CT01 LRBT CT02 LRBT CT03 LDBT CT01 DCCT-INJ	3.10 6.75 6.77 6.82 6.80 6.80 0.00 1806.60	mA mA mA mA mA mA mA	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans MEBT Trans DTL Trans LRBT Trans1 LRBT Trans2 LDBT Trans	-0.05 22.47 7.4 218.1 100.28 100.64 99.7 100.0	E12 E12 % % % % % %	R4BLM02 506.62 864.88 R4BLM03 661.88 R4BLM04 239.38 R4BLM05 136.63 R4BLM07 371.81 R4BLM09 102.81 R4BLM09 102.81 R4BLM09 102.81 R4BLM00 102.81 R4BLM00 102.81 R4BLM00 102.81 R4BLM01 215.99 R4BLM11 21.88 R4BLM12 21.88 R4BLM13 208 R4BLM14 200.15 R4BLM15 112.73 R4BLM15 112.73 R4BLM17 241.19 R4BLM18 112.73 R4BLM17 735.16 R4BLM17 735.16 R4BLM17 735.16 R4BLM17 735.16 R4BLM17 735.16 R4BLM17 R4BLM18 R4BLM19 215.3 R	RCS BLM 2022-10-06 05:33:28 R3BLM08	RIBLIMOZ RIBLIMOS RIB
÷	LEBT CT02 MEBT CT01 MEBT CT02 LRBT CT01 LRBT CT02 LRBT CT03 LDBT CT01 DCCT-INJ	3.10 6.75 6.77 6.82 6.80 6.80 0.00 1806.60 4223.55	mA mA mA mA mA mA mA mA	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans MEBT Trans DTL Trans LRBT Trans1 LRBT Trans2 LDBT Trans EXT Trans	-0.05 22.47 7.4 218.1 100.28 100.64 99.7 100.0	E12 E12 % % % % % % % % %	R-SELMO2 RABLMO2 RABLMO3 RABLMO5 RABLMO5 RABLMO6 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLM	RCS BLM 2022-10-06 05:33:28 R3BLM08	RIBLIMOZ RIBLIMOS RIB
è	LEBT CT02 MEBT CT01 MEBT CT02 LRBT CT01 LRBT CT02 LRBT CT03 LDBT CT01 DCCT-INJ DCCT-EXT DCCT-INJ No	3.10 6.75 6.77 6.82 6.80 6.80 0.00 1806.60 4223.55 22.00	mA mA mA mA mA mA mA mA mA	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans MEBT Trans DTL Trans LRBT Trans1 LRBT Trans2 LDBT Trans EXT Trans RCS Trans	-0.05 22.47 7.4 218.1 100.28 100.64 99.7 100.0	E12 E12 % % % % % % % % % %	R-SELMO2 RABLMO2 RABLMO3 RABLMO5 RABLMO6 RABLMO6 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLMO7 RABLMO6 RABLMO6 RABLMO6 RABLMO6 RABLMO6 RABLMO6 RABLMO6 RABLMO7 RABLM	RCS BLM 2022-10-06 05:33:28 R3BLM08	RIBLMO2 RIBLMO6 RIBLMO6 RIBLMO6 RIBLMO6 RIBLMO6 RIBLMO6 RIBLMO6 RIBLMO10 RIBLMO11 RIBLMO11 RIBLMO12 RIBLMO12 RIBLMO12 RIBLMO12 RIBLMO13 RI
ř	LEBT CT02 MEBT CT01 MEBT CT02 LRBT CT01 LRBT CT02 LRBT CT03 LDBT CT01 DCCT-INJ DCCT-EXT DCCT-INJ No	3.10 6.75 6.77 6.82 6.80 6.80 0.00 1806.60 4223.55 22.00 21.59	mA mA mA mA mA mA mA mA mA E12 E12	RTBT CT03 RDBT CT01 LEBT Trans RFQ Trans MEBT Trans DTL Trans LRBT Trans1 LRBT Trans2 LDBT Trans EXT Trans RCS Trans RTBT Trans	-0.05 22.47 7.4 218.1 100.28 100.64 99.7 100.0 - 102.2 98.2	E12 E12 % % % % % % % % % % %	R4BLM02 506.62 R4BLM04 239.38 R4BLM05 156.63 R4BLM05 156.63 R4BLM07 371.81 R4BLM00 104.01 R4BLM00 102.81 R4BLM00 102.81 R4BLM00 125.99 R4BLM11 113.74 R4BLM02 21.88 R4BLM12 21.88 R4BLM13 208 R4BLM13 208 R4BLM14 120.15 R4BLM15 112.73 R4BLM16 112.73 R4BLM16 112.73 R4BLM17 241.19 R4BLM18 150.68 R4BLM18 150.68 R4BLM18 150.68 R4BLM19 215.3 R4BLM19 215.3 R4BLM19 215.3 R4BLM19 215.3 R4BLM19 215.3 R4BLM19 215.3 R4BLM10 215.3 R4BLM10 150.68 R4BLM10 150.68 R4BLM11 227.44 R4BLM10 237.07 R4BLM10 370.97 R4BLM00 370.97	RCS BLM 2022-10-06 05:33:28 R3BLM08	RIBLIMOZ RIBLIMOS RIB

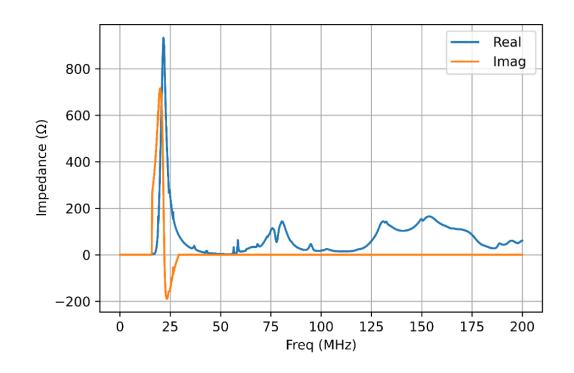
Next Step-Instability







transverse instability



longitudinal impedance of MA Cavity (from power supply)

Summary & Outlook



- 1. The beam commissioning with the first MA cavity in CSNS RCS has been completed, and the beam power has achieved to 140 kW, which is 40% higher than the design.
- 2. One more MA cavity has been installed in this summer of 2023;
- 3. Momentum collimator has been designed (2024);
- 4. Octupoles have been installed to increase Landau damping;
- 5. Increase the beam power to 200kW with the linac energy of 80MeV



Thanks for your attention!