Update on the Rectilinear Cooling Channel Design

Ruihu Zhu (瑞虎 朱)
Institute of Modern Physics, Chinese Academy of Sciences
University of Chinese Academy of Sciences

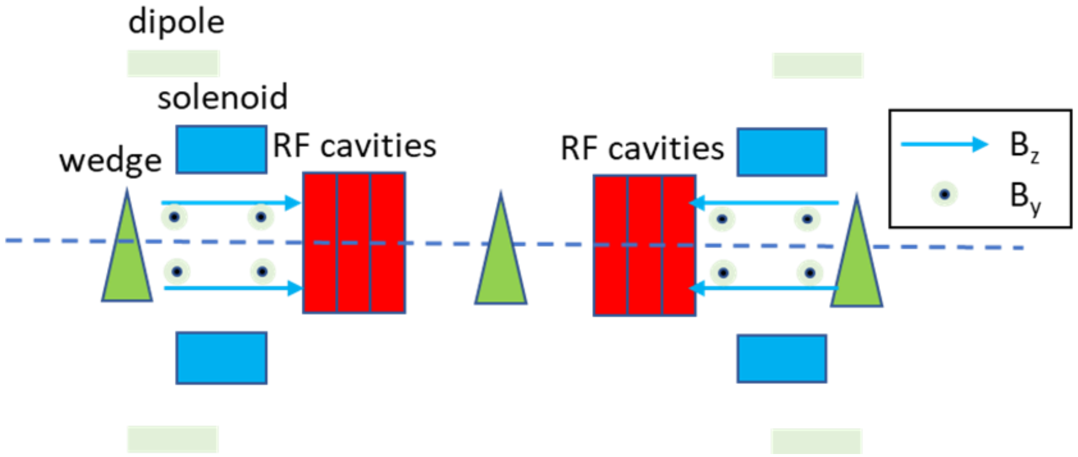
Supervisor: Jiancheng Yang (建成 杨)

Special thanks to Chris Rogers (RAL)

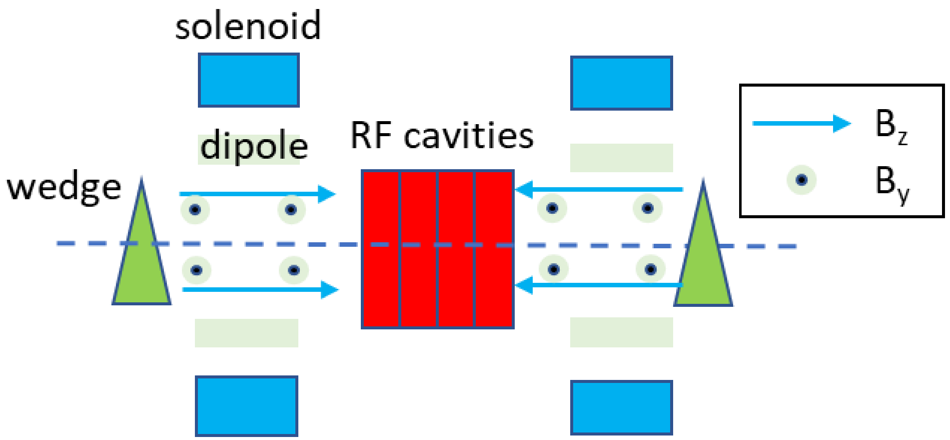
2024.02.21

zhuruihu@impcas.ac.cn

Cooling cell configuration



LH2 + normal RF
LiH + normal RF
LiH + π RF
(number of RF cavities must be even)



LH2 + π RF

Large dispersion (stage 1 before bunch merging)

- D=10 cm, β=70 cm

	LH2 + normal RF	LiH + normal RF	LH2 + π RF	LiH + π RF
Stage length	101 m	137 m	104 m	142 m
Dipole strength	0.0653 T	0.0653 T	0.0653 T	0.0653 T
On-axis wedge length	14.5 cm	2.7 cm	26 cm	2.7 cm
Wedge apex angle	40°	7.8°	66°	7.8°
RF #	6	6	3	4
RF length	19 cm	19 cm	39.3 cm	39.3 cm
RF gradient	25.96 MV/m	25.73 MV/m	25.94 MV/m	25.95 MV/m
RF phase	19.16°	19.76°	23.11°	19.68°
Transverse ε	6.43 mm	6.88 mm	6.58 mm	6.87 mm
Longitudinal ε	13.2 mm	11.8 mm	1.27 mm	11.8 mm
Transmission	71.6%	64.5%	60%	64.5%

Small dispersion (stage 1 before bunch merging)

- D=6 cm , β=70 cm

	LH2 + normal RF	LiH + normal RF	LH2 + π RF	LiH + π RF
Stage length	104 m	122 m	113 m	137 m
Dipole strength	0.6*0.0653 T	0.6*0.0653 T	0.6*0.0653 T	0.6*0.0653 T
On-axis wedge length	14.5 cm	3.1 cm	26 cm	3.1 cm
Wedge apex angle	45°	10°	73°	10°
RF #	6	6	3	4
RF length	19 cm	19 cm	39.3 cm	39.3 cm
RF gradient	25.83 MV/m	25.91 MV/m	25.75 MV/m	25.68 MV/m
RF phase	18.53°	21.36°	22.05°	22.74°
Transverse ε	5.49 mm	5.86 mm	5.49 mm	6.07 mm
Longitudinal ε	19 mm	16.5 mm	18.4 mm	15.4 mm
Transmission	77.4%	69.8%	68.1%	69.2%

Stage 2 and 3 (before bunch merging)

	Stage 2	Stage 3
Stage length	107 m	66.4 m
Dipole strength	0.067 T	0.11 T
Dispersion	5.7 cm	4 cm
β	45 cm	30 cm
On-axis wedge length	10.5 cm	15 cm
Wedge apex angle	60°	100°
RF #	4	5
RF length	19 cm	9.5 cm
RF gradient	25.84 MV/m	31.74 MV/m
RF phase	23.18°	23.84°
Transverse ε	2.66 mm	1.66 mm
Longitudinal ε	7.28 mm	3.91 mm
Transmission	85.7%	86.9%

Stage	Cell length [m]	Total length [m]	rf frequency [MHz]	rf gradient [MV/m]	rf #	rf length [cm]	Coil tilt [deg]	Pipe radius [cm]	Dispersion [cm]	Wedge angle [deg]
A1	2.000	132.00	325	22.0	6	25.50	3.1	30.0	10.7	39
A2	1.320	171.60	325	22.0	4	25.00	1.8	25.0	6.8	44
A3	1.000	107.00	650	28.0	5	13.49	1.6	19.0	4.2	100
A4	0.800	70.40	650	28.0	4	13.49	0.7	13.2	1.9	110

Stage	ε_T^{sim} [mm]	ε_L^{sim} [mm]	P_z^{sim} [MeV/c]	T [%]
Begin	17.00	46.00	255	
A1	6.28	14.48	238	70.6
A2	3.40	4.64	229	87.5
A3	2.07	2.60	220	88.8
A4	1.48	2.35	215	94.6

Until the end of stage 3:

✓ The stage length is reduced by 132.6m (32%).

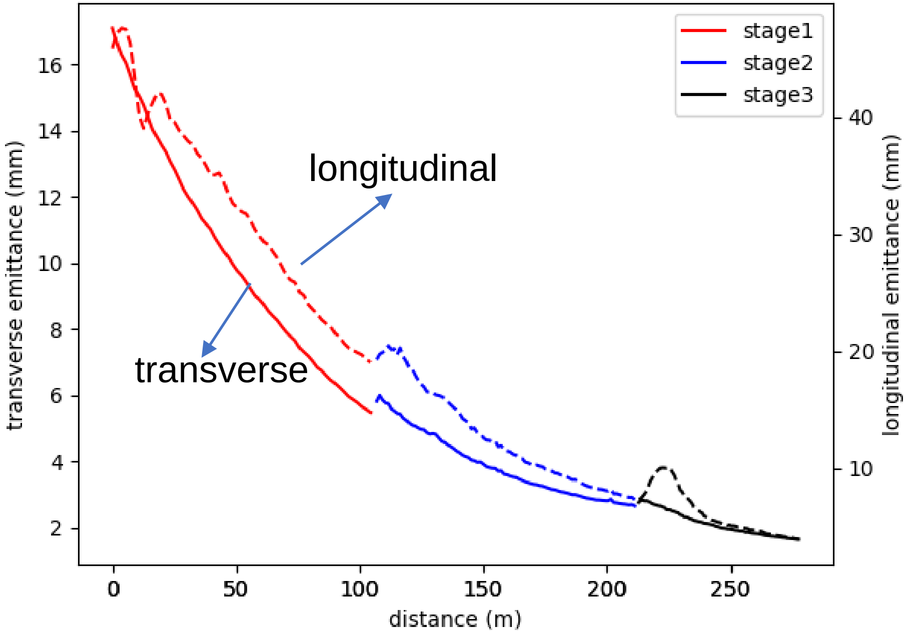
Cell length: stage 1, 1.8 m stage 2, 1.2 m stage 3, 0.8m

✓ Transverse emittance is 19.8% smaller and longitudinal emittance is 50.4% larger. (same 6D emittance)

✓ Transmission in stage 1 is 7% higher but in stage 2 and stage 3 is 2% lower.

End of stage 3 (before bunch merging)

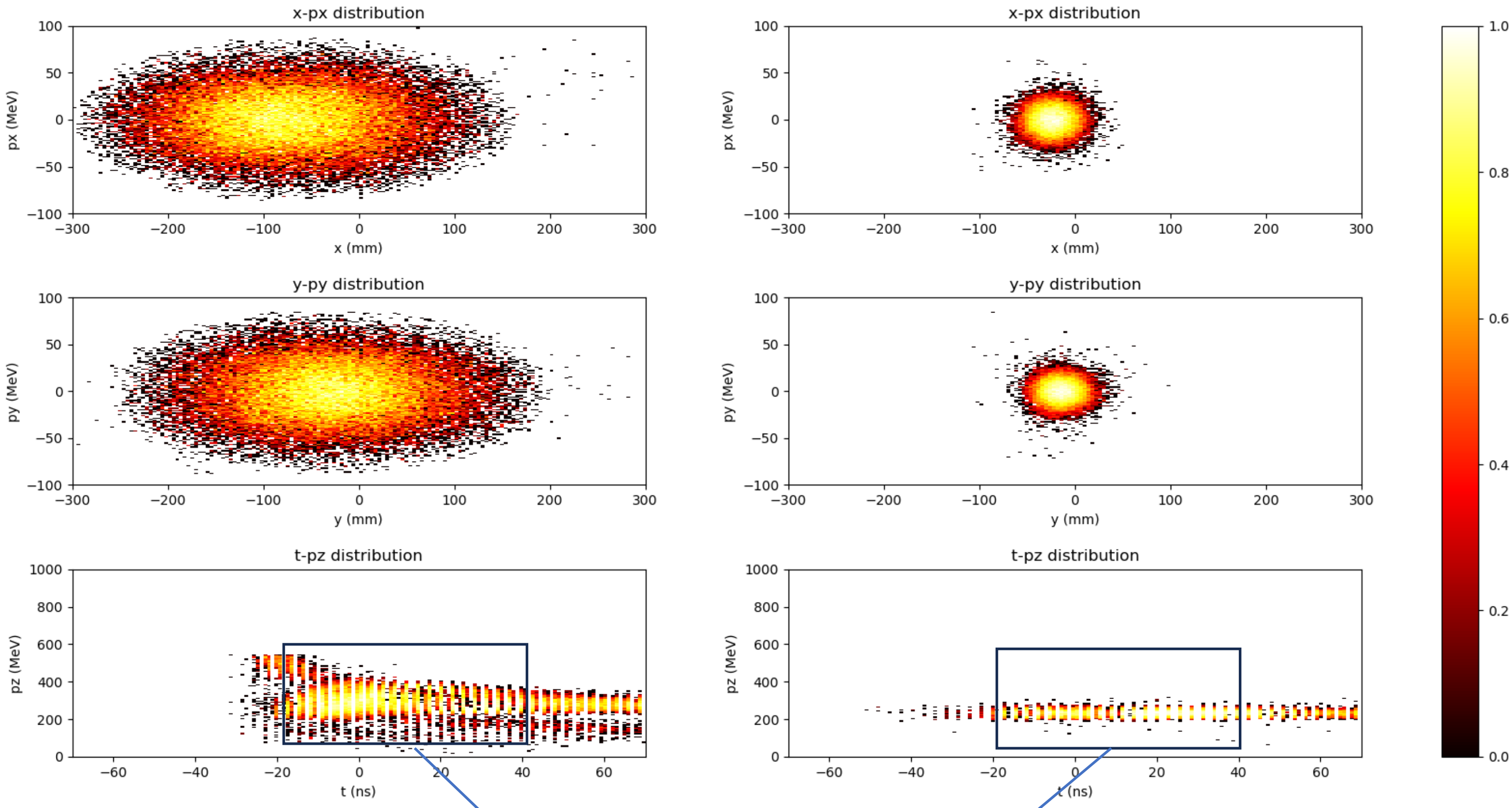
Emittance reduction



Particles distribution in phase space

Start of stage 1

End of stage 3



Should calculate the emittance of these 21 bunches.

Next steps

- Re-calculate the emittance of the 21 bunches within -20 ~ 40 ns.
- Try to increase the dispersion to reduce the longitudinal emittance without making the transmission worse.
- Add one more stage for smaller emittance. ($\varepsilon_{\perp}$=1.3 mm, $\varepsilon_{\parallel}$=1.7 mm in bunch merging paper)
- Sort out the problems in the previous design for the cooling section after the bunch merging. (e.g., using the physical dipole fringe field…)