Injection/Extraction optics of CEPC with considerations of Kickers and septa

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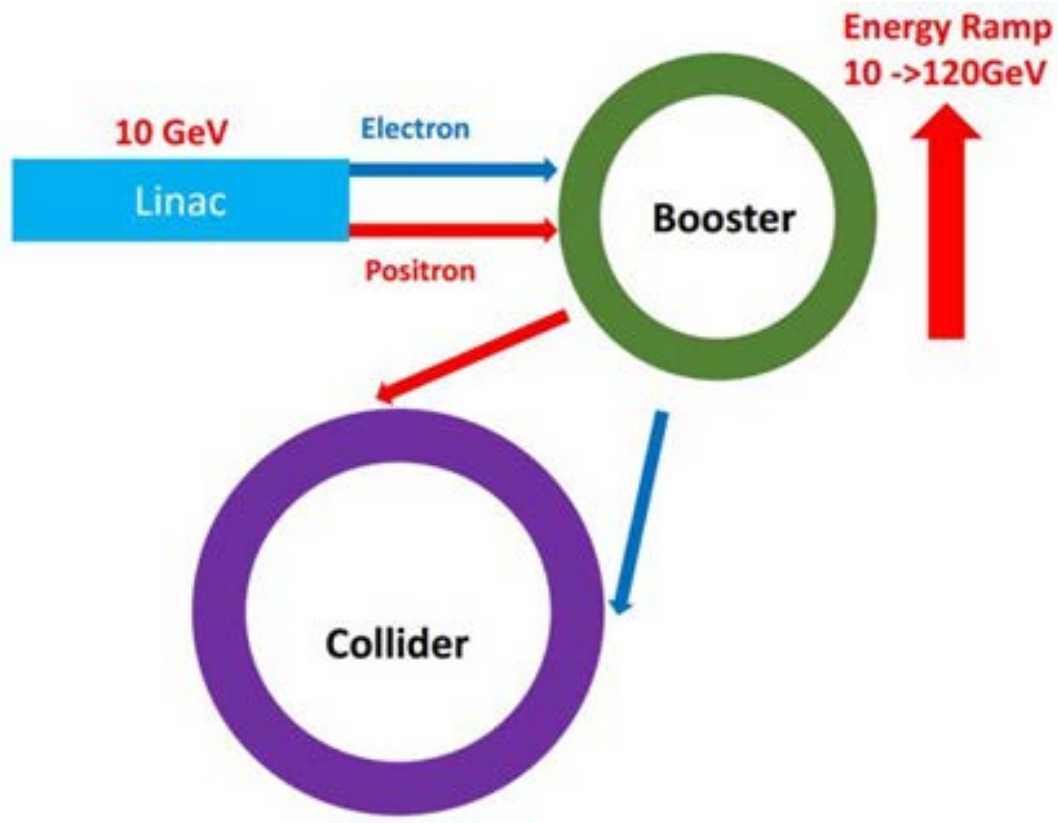
IAS Program, High Energy Physics, January 2019

Contents:

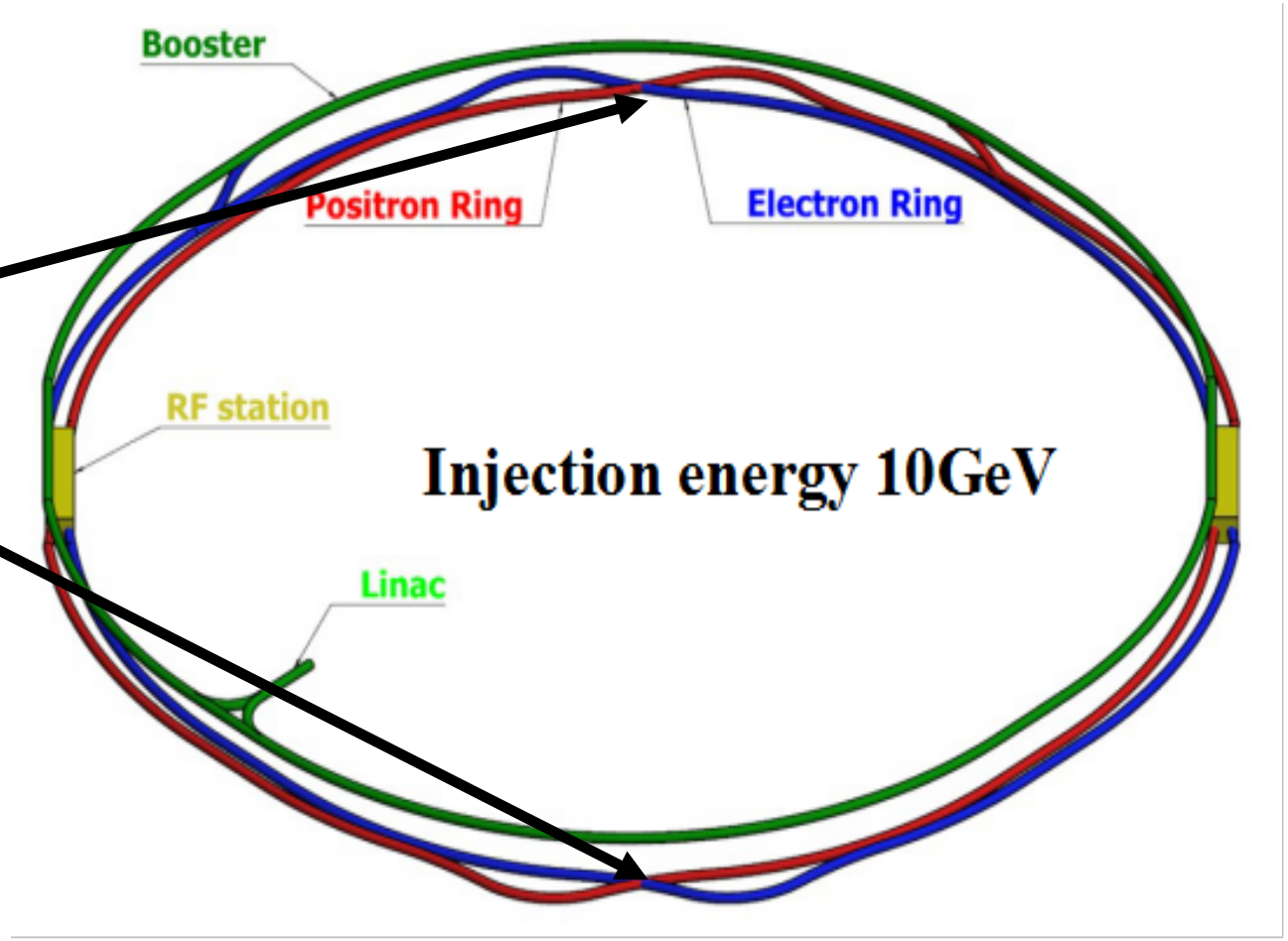
1. Introduction to CEPC

- The CEPC is a circular e+e- collider with a 100-km circumference.
- The collider will operate as a Higgs factor (240 GeV center-of-mass energy), and a W factory(160 GeV center-of-mass energy), and Z factory(91 GeV).
- It consists of a double-ring collider, a booster, and a linac.
- The Linac accelerate electrons and positrons to 10 GeV.
- The booster has the same circumference with the collider, and will be in the same tunnel.



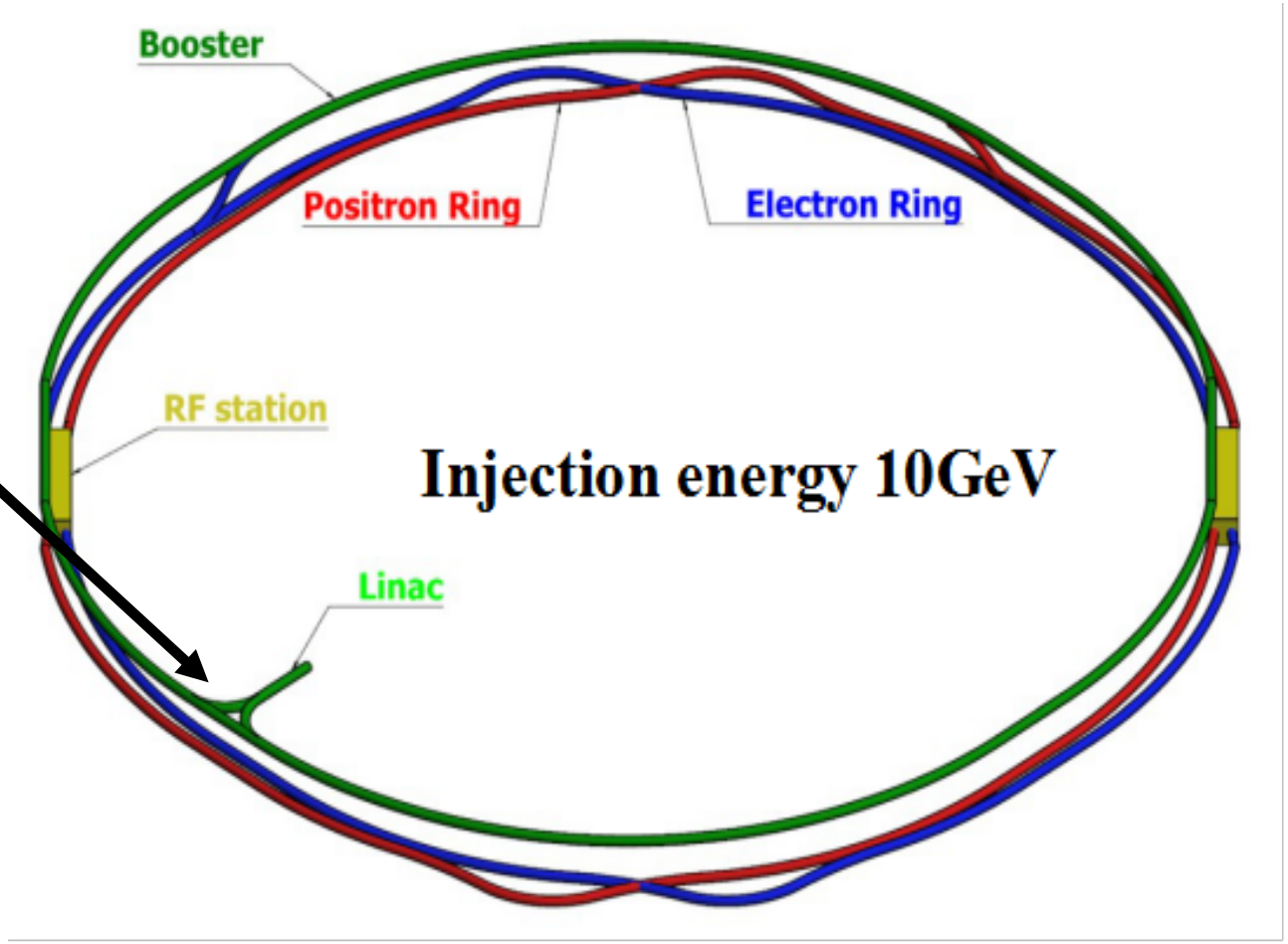
The Geometry:

The interaction point



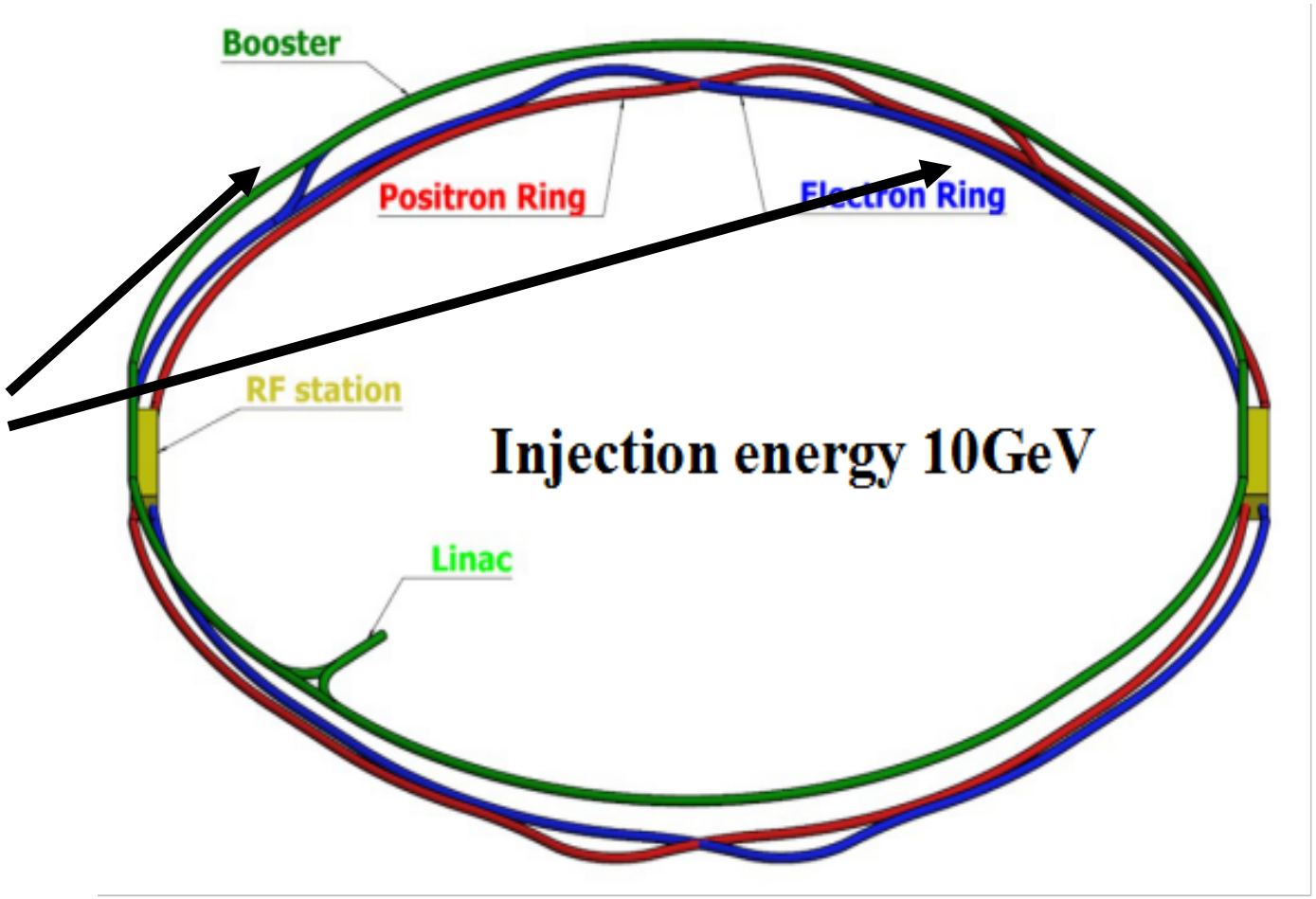
The Geometry:

Linac to booster

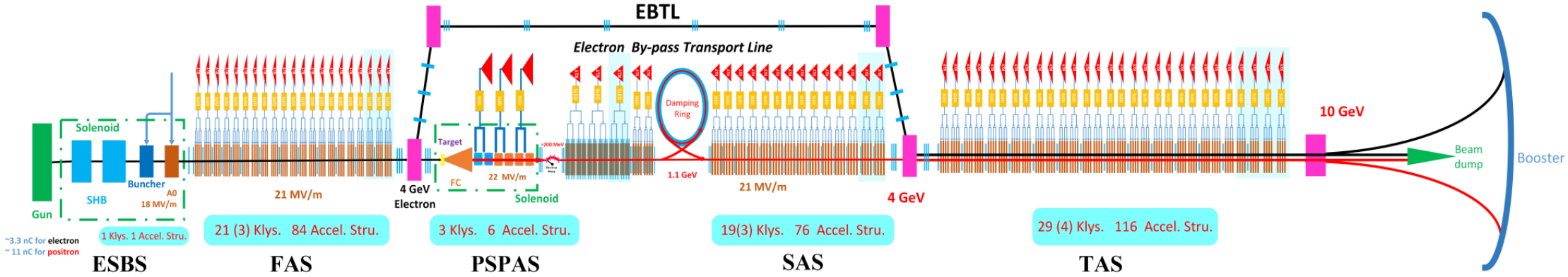


The Geometry:

Booster to collider



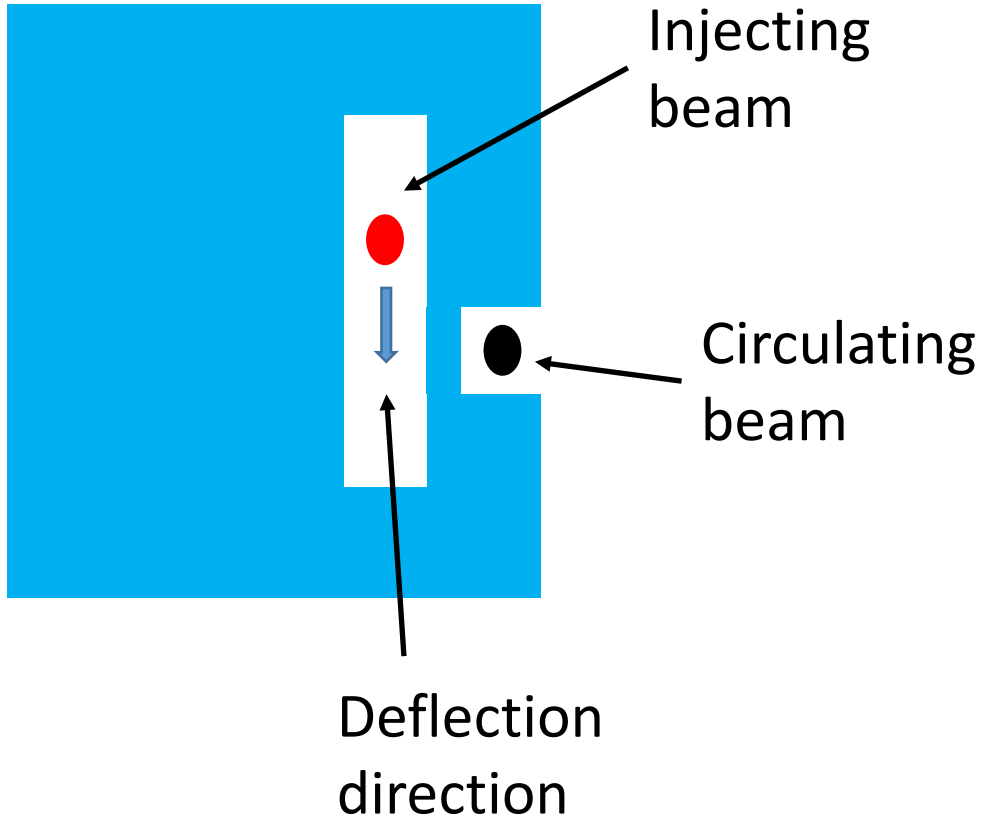
Damping ring:



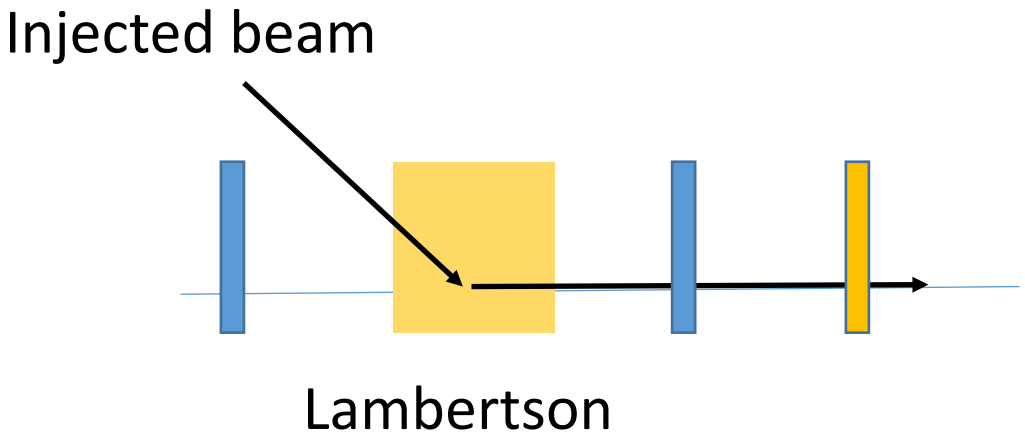
- To reduce the emittance of the positron beam, a damping ring is added.
- Injection and extraction from the damping ring should be considered.

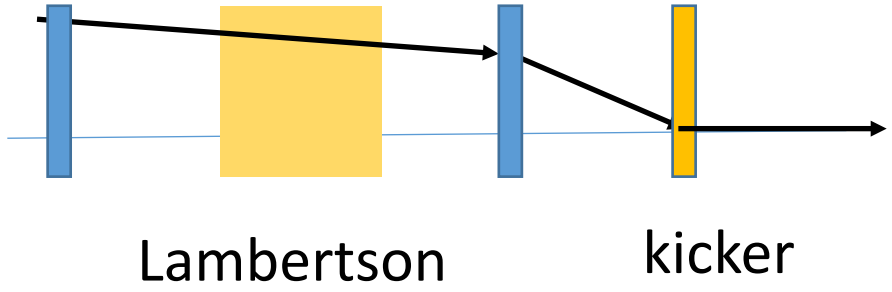
Lambertson Septum:

- Lambertson septum can produce higher magnetic fields and is more reliable in long term operation.
- The deflection direction of a lambertson magnet is parallel with the septum foil.
- Kickers deflects beam orthogonal to Lambertson deflection: a two plane deflection.



Lambertson Septum:





Lambertson septum deflects beam horizontally

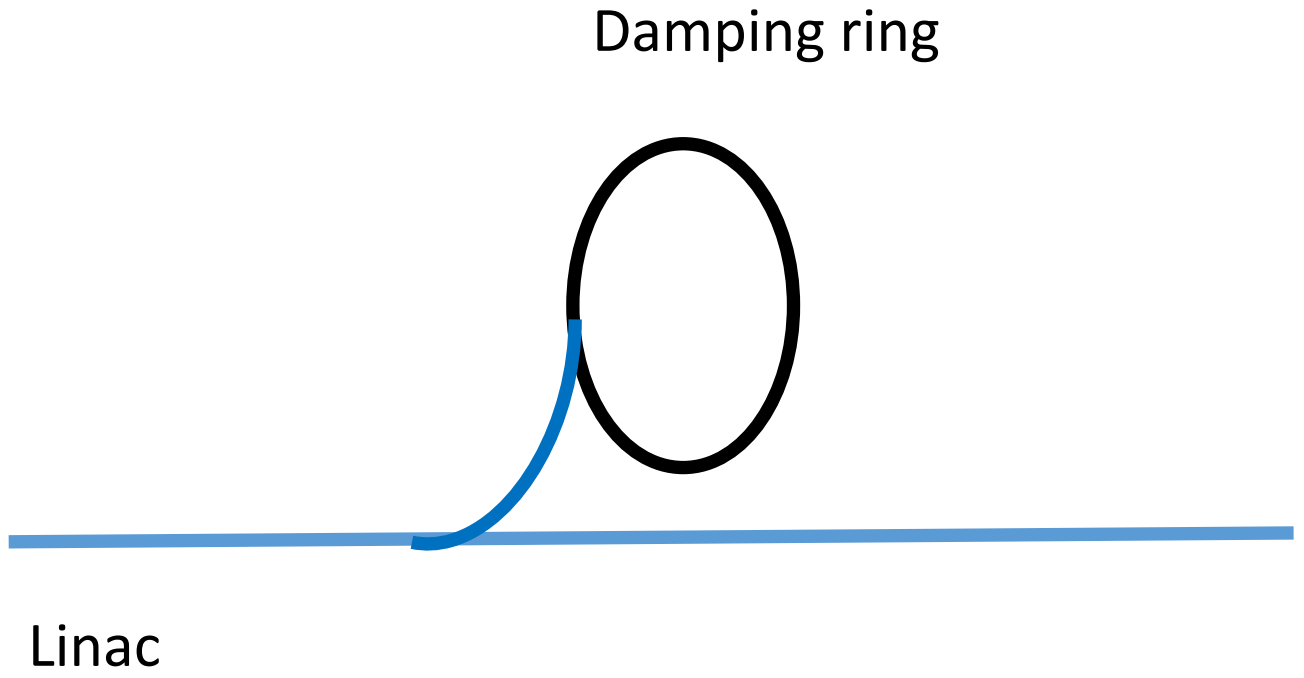
Kicker deflects beam vertically

Some key parameters of the collider ring:

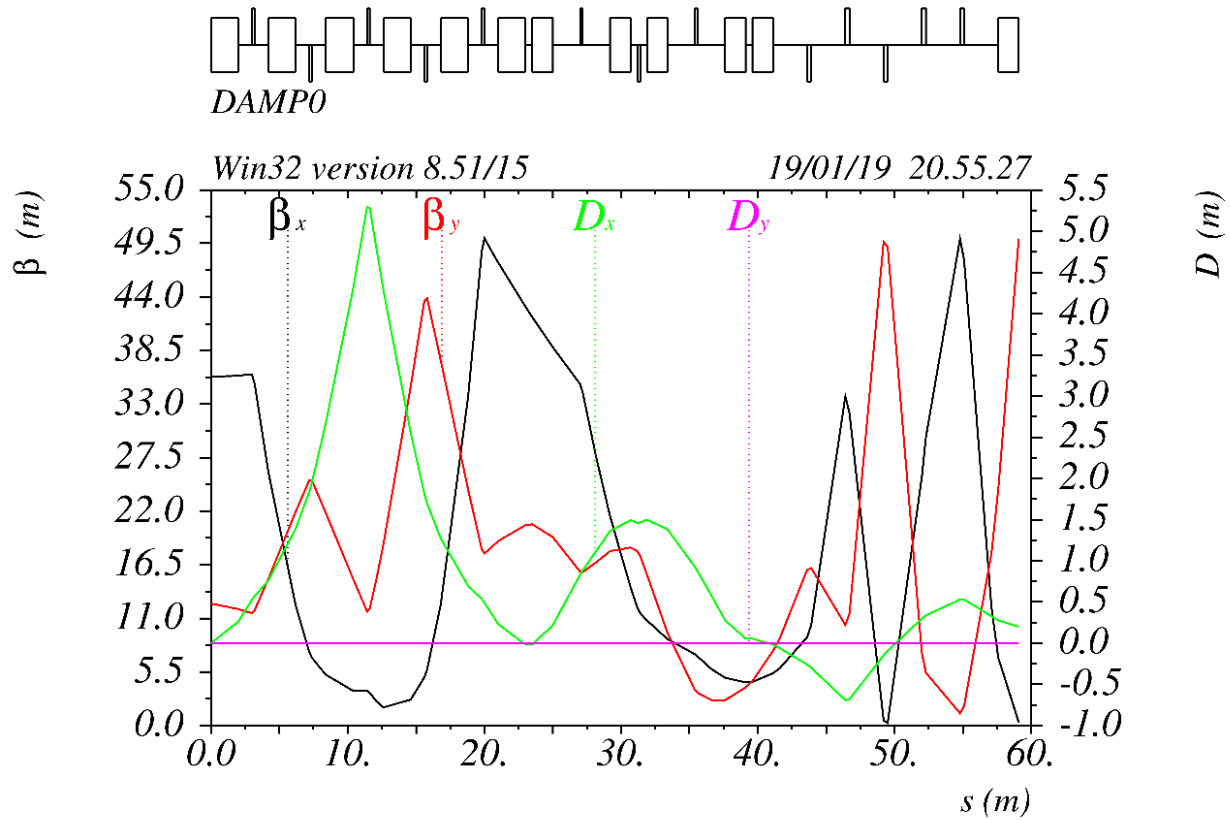
	Higgs	W	Z
Energy (GeV)	120	80	45.5
Bunch number	242	1524	12000
Bunch Charge (nC)	24	19.2	12.8
Bunch Current (mA)	17.4	87.9	461
Revolution Period (ms)	0.3336	0.3336	0.3336
Emittance x/y (nm)	1.21/0.0031	0.54/0.0016	0.17/0.004
Life time (Hour)	0.67	1.4	4

2. Injection to the damping ring

- A small ring with about 70 m circumference, energy 1.1 GeV.
- There will be two bunches in the damping ring.
- Energy compression and bunch length compression should be considered in the transport line.



Twiss of the transport line:

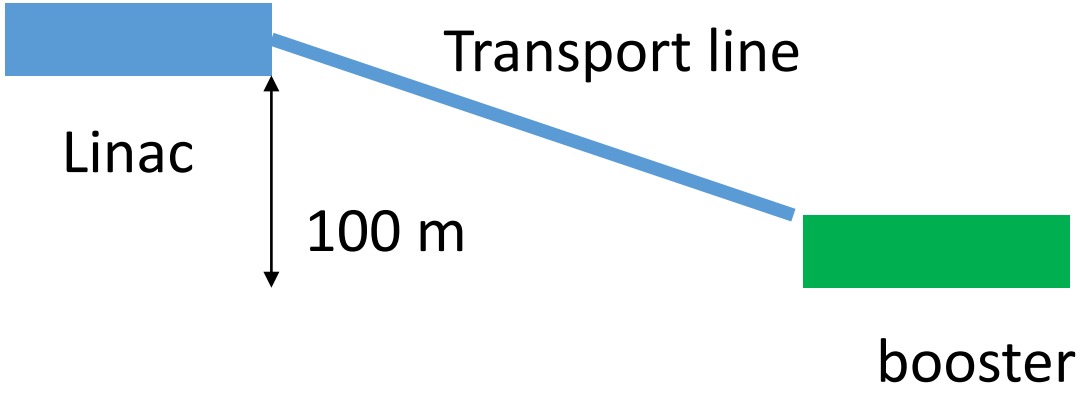


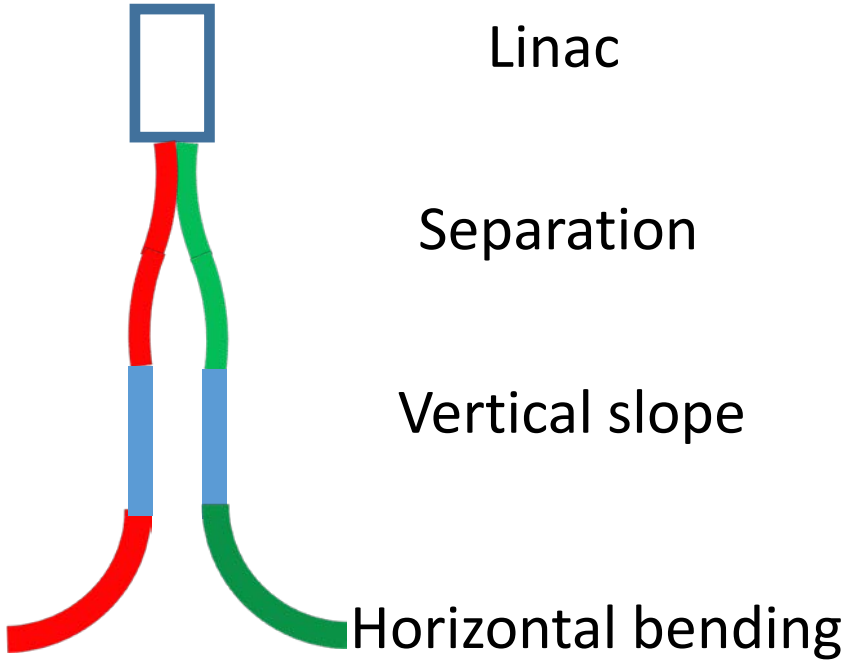
Kickers and Septa:

- Since there are two bunches in the ring, the rise time and fall time of the kickers should be less than the bunch spacing 100 ns.

Component	Number	Septum width	Length (m)	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
						H(mm)	V(mm)
Septum	2	10mm	2	100	0.18	60	60
Kicker	2		0.5	1.5	0.01	60	60

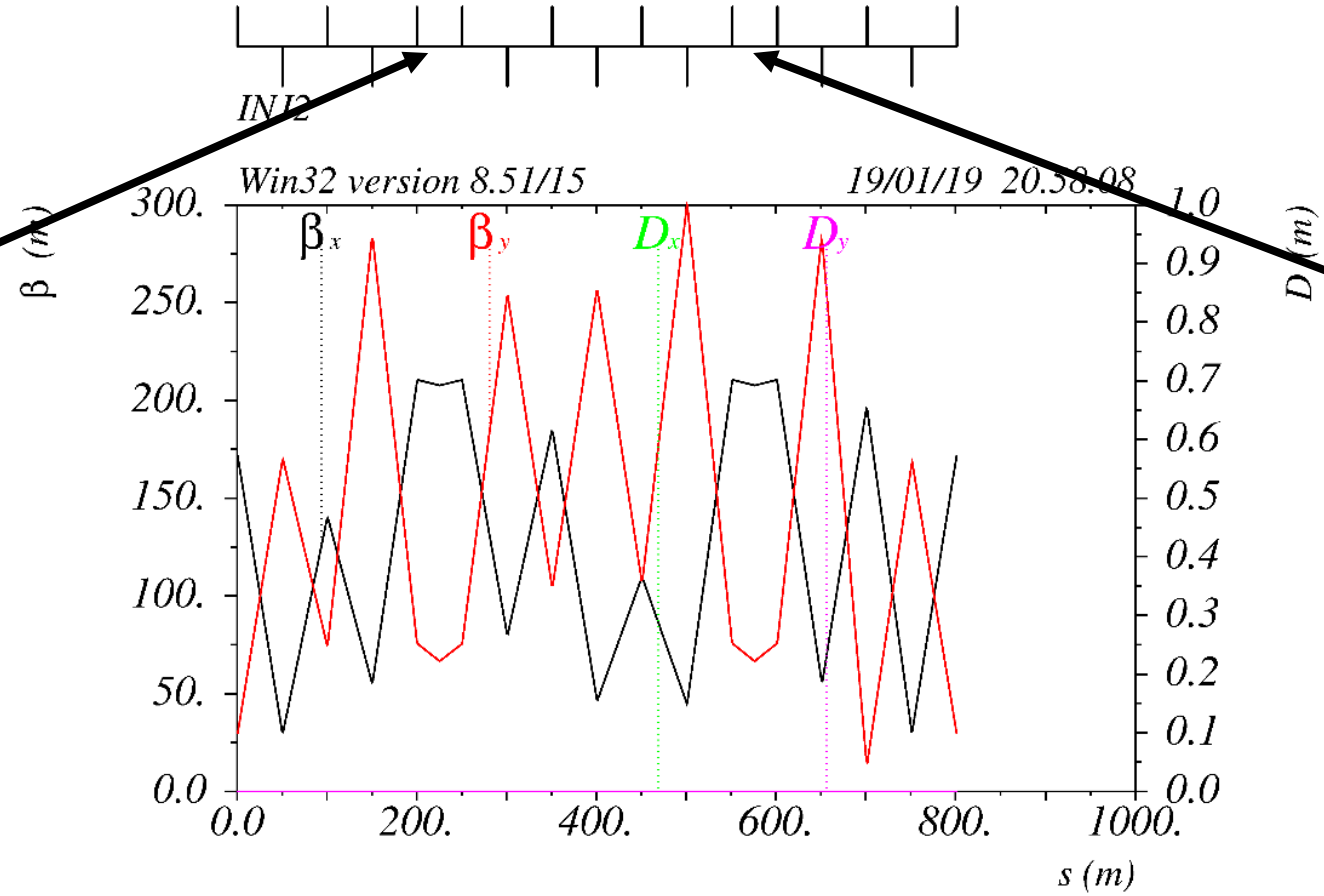
3. Injection to the booster





- Guiding the beam from Linac to the booster
- Beam Energy: 10 GeV
- horizontal bending section and one vertical bending section
- Vertical bending section matches the 100m height

Booster injection point:



Positron injection

Electron injection

Kickers and Septa:

- One-turn on-axis injection due to the long damping time of the booster.
- The septum gives a horizontal deflection while the kickers give a vertical bending.
-

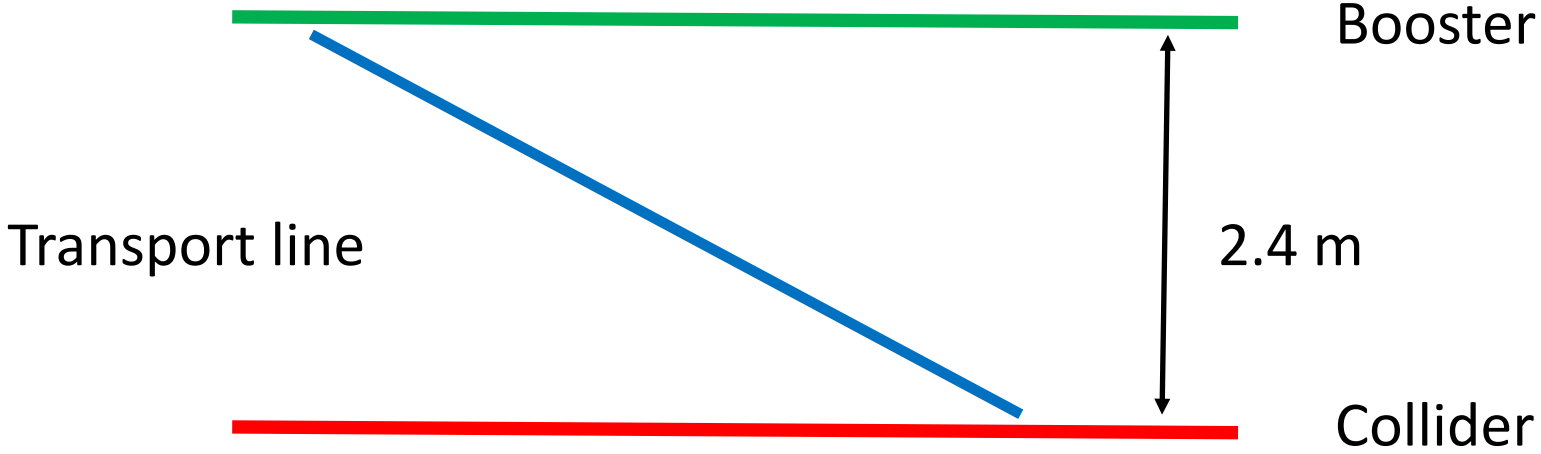
Component	Number	Septum width	Length (m)	Type	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
							H(mm)	V(mm)
Septum	2	10 mm	2	Lambertson	22	0.366	63	63
Kicker	2		0.5		1	0.066	63	63

Rise time of the kickers:

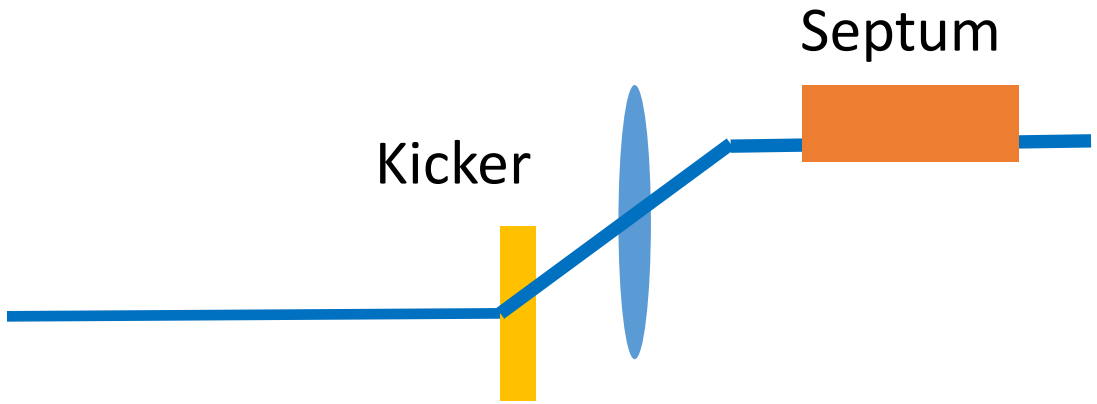
- The bunch number in the booster are the same with that in the collider at Higgs and W mode.
- The bunch number in the booster are 1/2 of the number in the collider at Z mode.
- We’d like the same pattern structure in all these running modes.
- To control the injection pattern, the rise time of the kickers should be less than the spacing between two bunches, that’s 30 ns for Z mode.

4. Extraction from the booster & Injection to the collider

- The booster and collider are in the same tunnel.
- The booster is 2.4 m higher than the collider.
- Considering the DA requirement in the collider, it's better to kick the beam horizontally, and so the septa give a deflection in the vertical plane.
- Consider the case of 120 GeV.



Extraction:

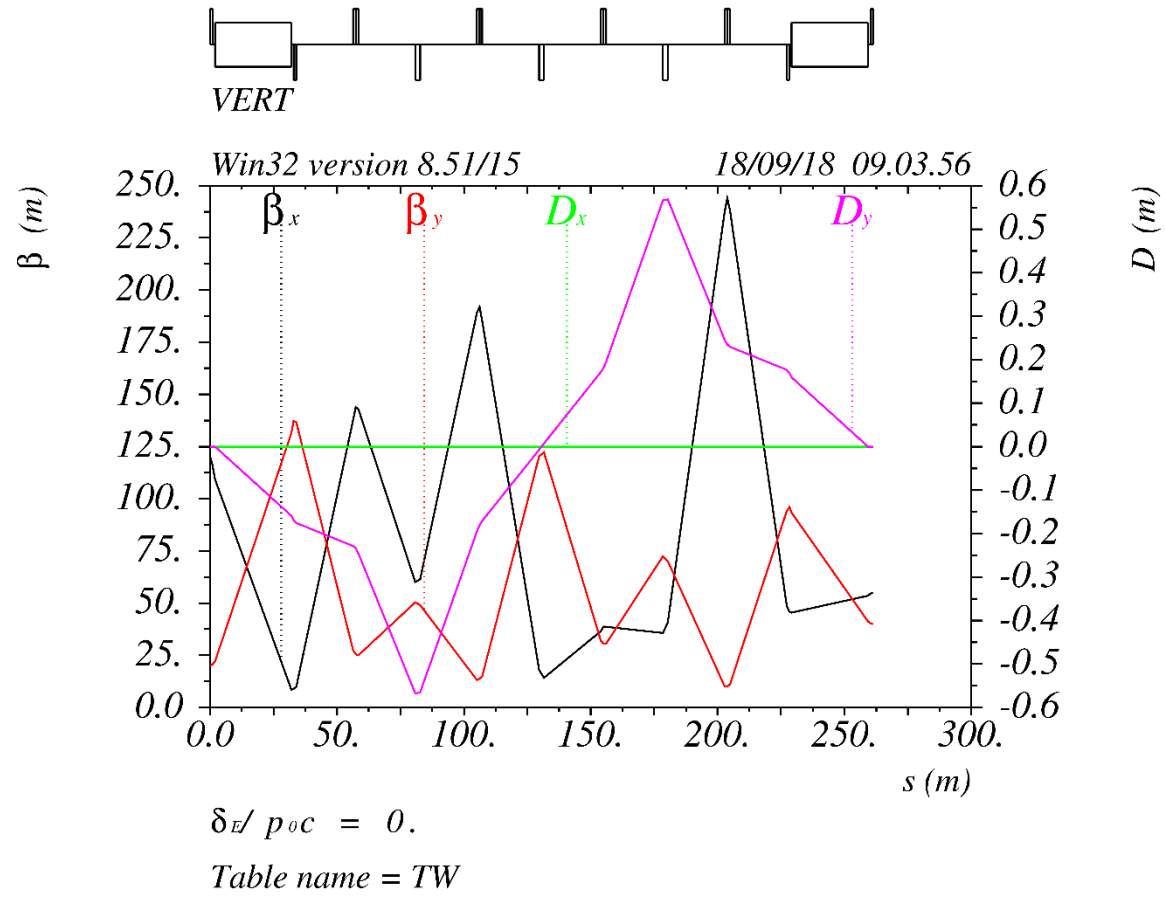


Component	Number	Septum width	Length (m)	Type	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
							H(mm)	V(mm)
Septum	2	10 mm	15	Lambertson	26	0.69	20	20
Kicker	2		2		0.2	0.04	20	20

Extraction Kicker:

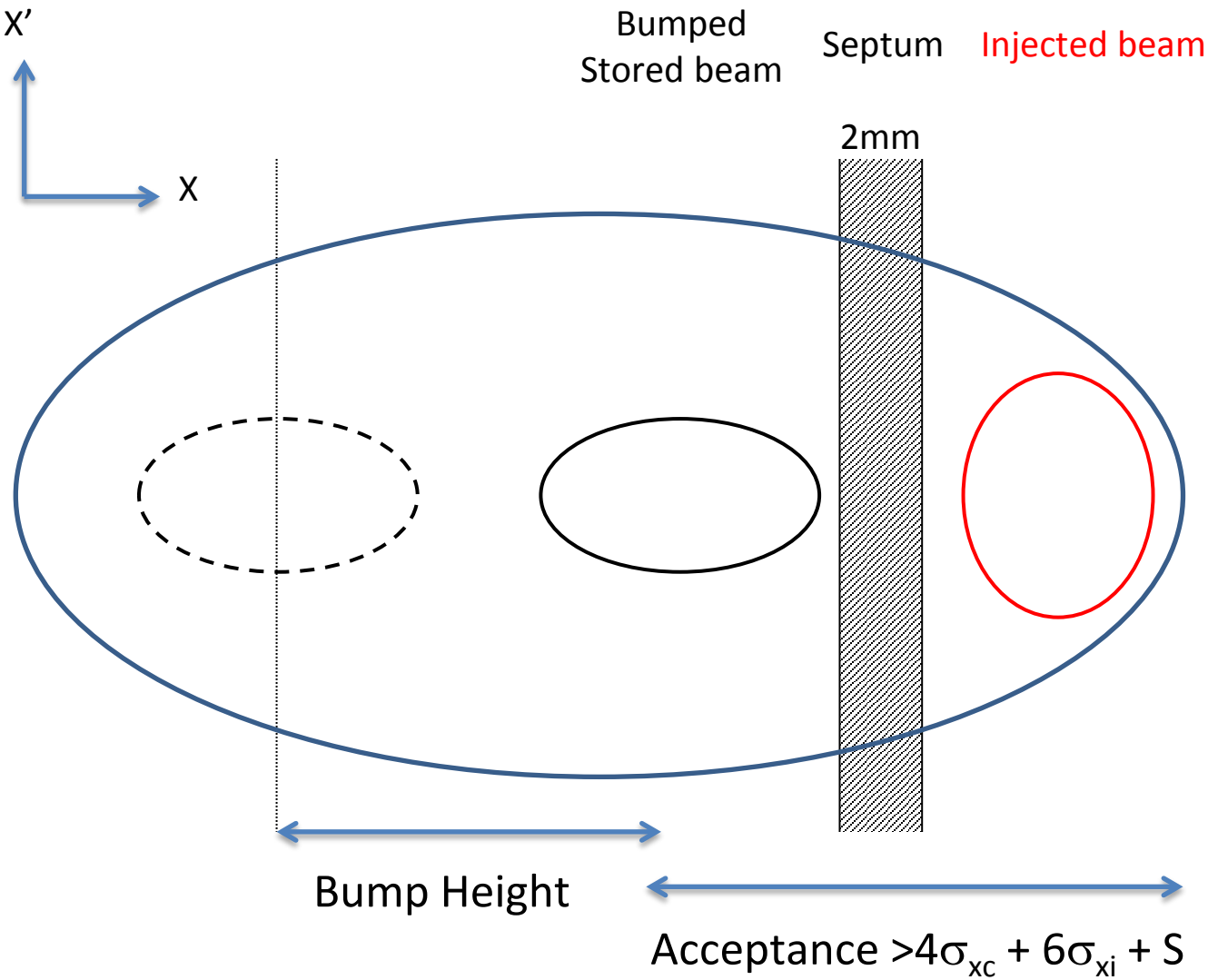
- All the bunches in the booster are injected into the booster once, to reduce the complexity of the injection.
- So the extraction kicker should stay a long time of 300 μs at its top.
- The rise time should be less than the bunch spacing at W mode, that is about 200 ns.
- Only half of the ring is filled at Z mode.

Twiss function of the transport line:



Injection into the collider:

- A standard off-axis injection in the horizontal plane.
- It's important to reduce requirement on the DA in collider.



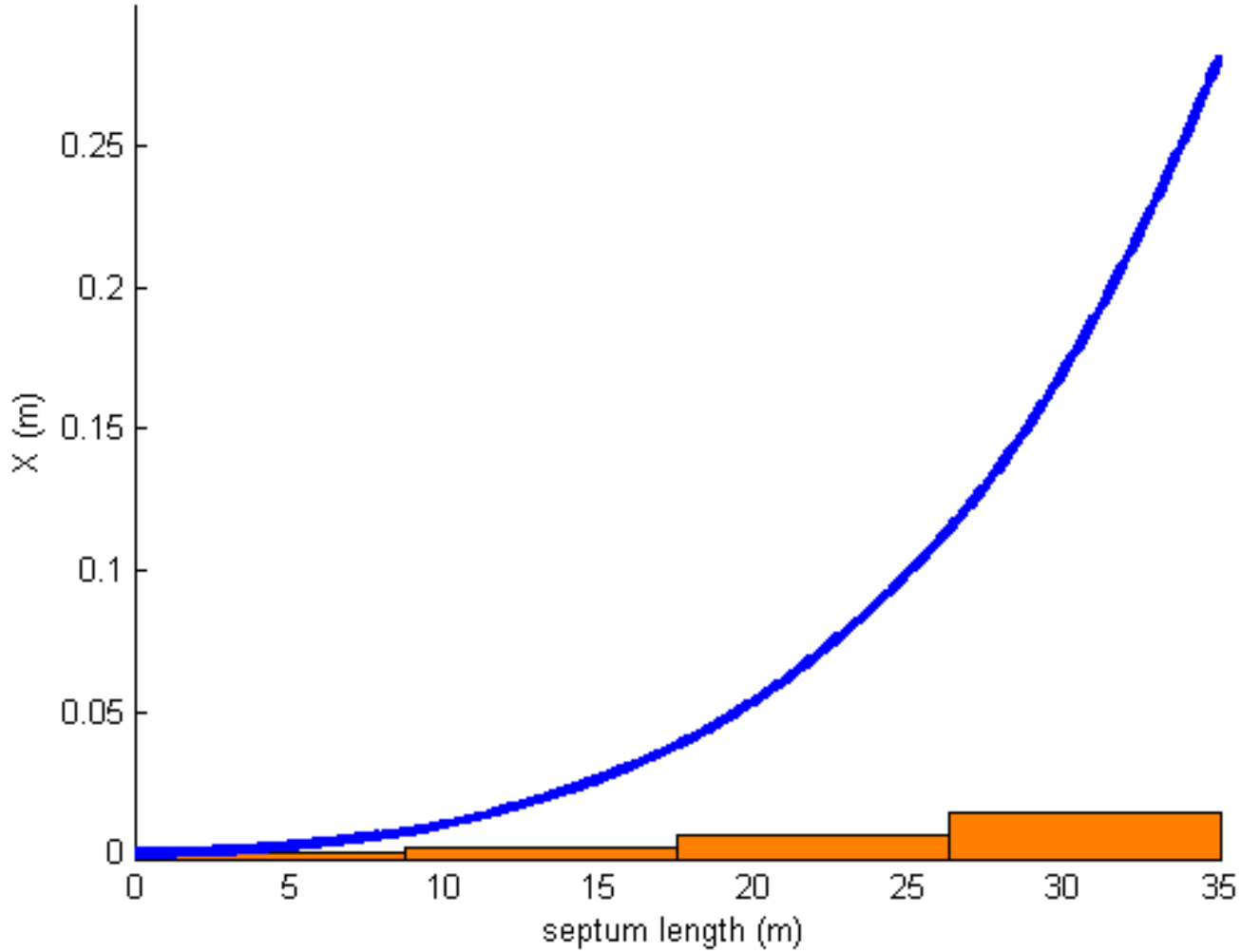
Kickers and Septa:

Component	Number	Septum width	Length (m)	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
						H(mm)	V(mm)
Septum	2	16mm	8.75	14	0.64	20	20
Septum	2	8mm	8.75	7	0.32	20	20
Septum	2	4mm	8.75	3.5	0.16	20	20
Septum	2	2mm	8.75	1.75	0.08	20	20
Kicker	8		2	0.1	0.02	20	20

Injection Kickers:

- Similar with the extraction kicker, the injection kickers should stay a long time of 300 μs at its top.
- The rise and fall time should be less than the bunch spacing at W mode, that is about 200 ns.

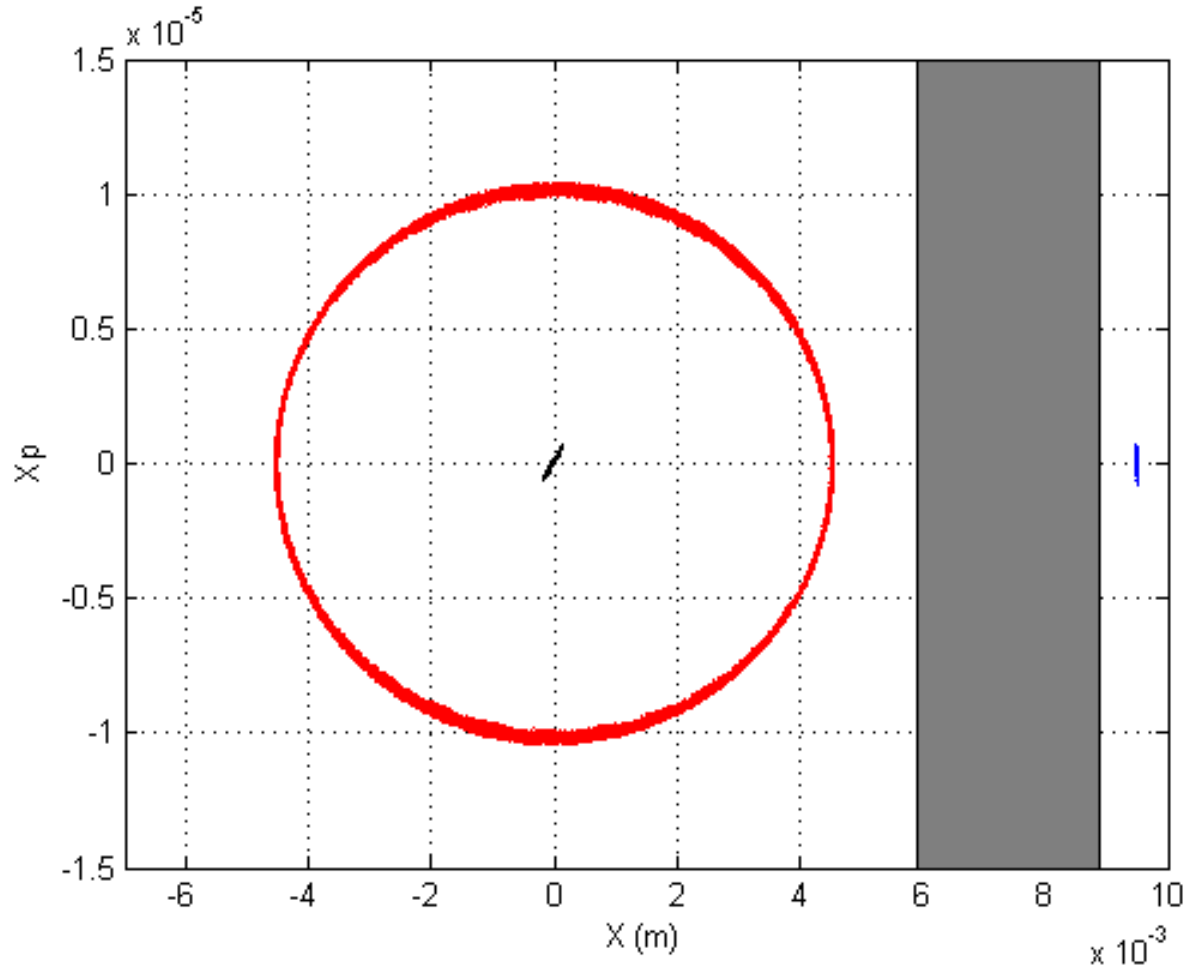
Width of the septa:



The beam in the septum

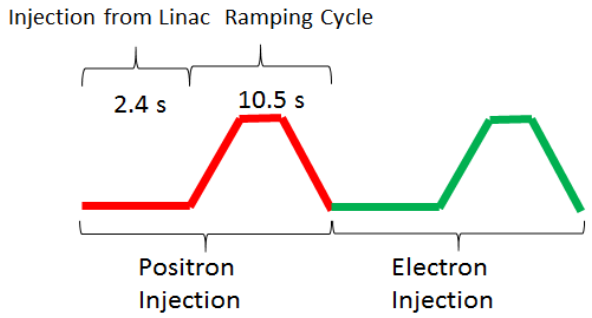
Septum foil

Beam in phase space:

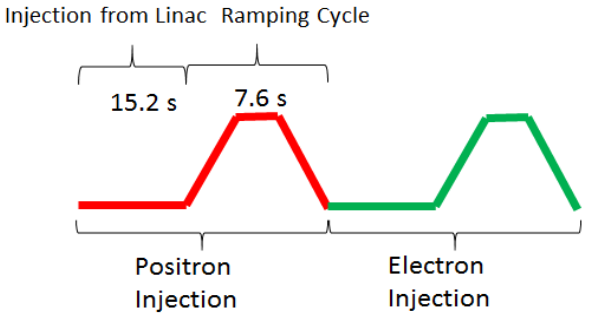


5. Injection process

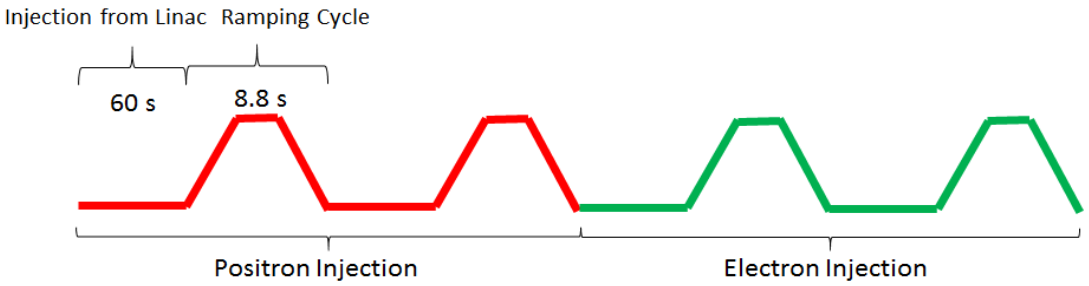
Higgs:



W:



Z:



Injection parameters:

Mode	**Higgs**		**W**		**Z**	
Injection Mode	Top-up	Full	Top-up	Full	Top-up	Full
Bunch number in booster	242		1524		6000	
Beam Current (mA)	0.5227	0.726	2.63	3.67	6.91	10
Number of Cycles	1		1		2	
Ramping Cycle (sec) (Up + Down）	10		6.6		3.8	
Filling time (sec) （e+，e-)	25.84		39.6		275.2	
Injection period (sec)	47		131		438	

6. Summary

- The optics of transport lines and some basic considerations of injection magnets are discussed.
- More optimization is needed to increase the injection efficiency and reliability.
- Towards CEPC TDR, more detailed discussions with the hardware people is needed.

Thank You