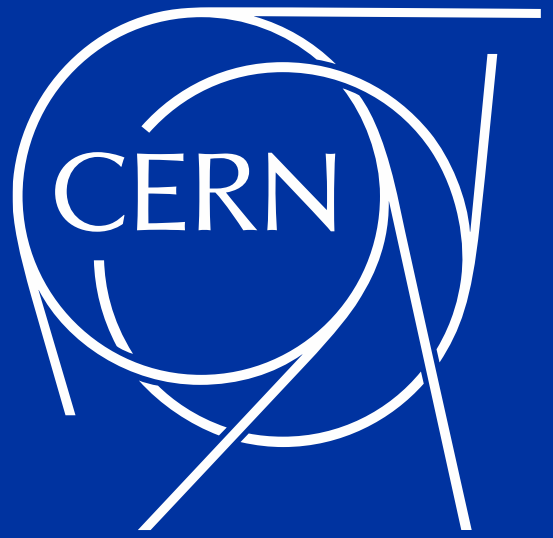

CERN

Injection/extraction systems across the complex

S. Yue, on behalf of SY-ABT
CERN, Geneva, Switzerland

Outline

- Injection/extraction of Damping ring
- Booster Injection
- Integration at PB
- Dump & Booster Extraction
- Conclusion

Damping ring: Mid-term review

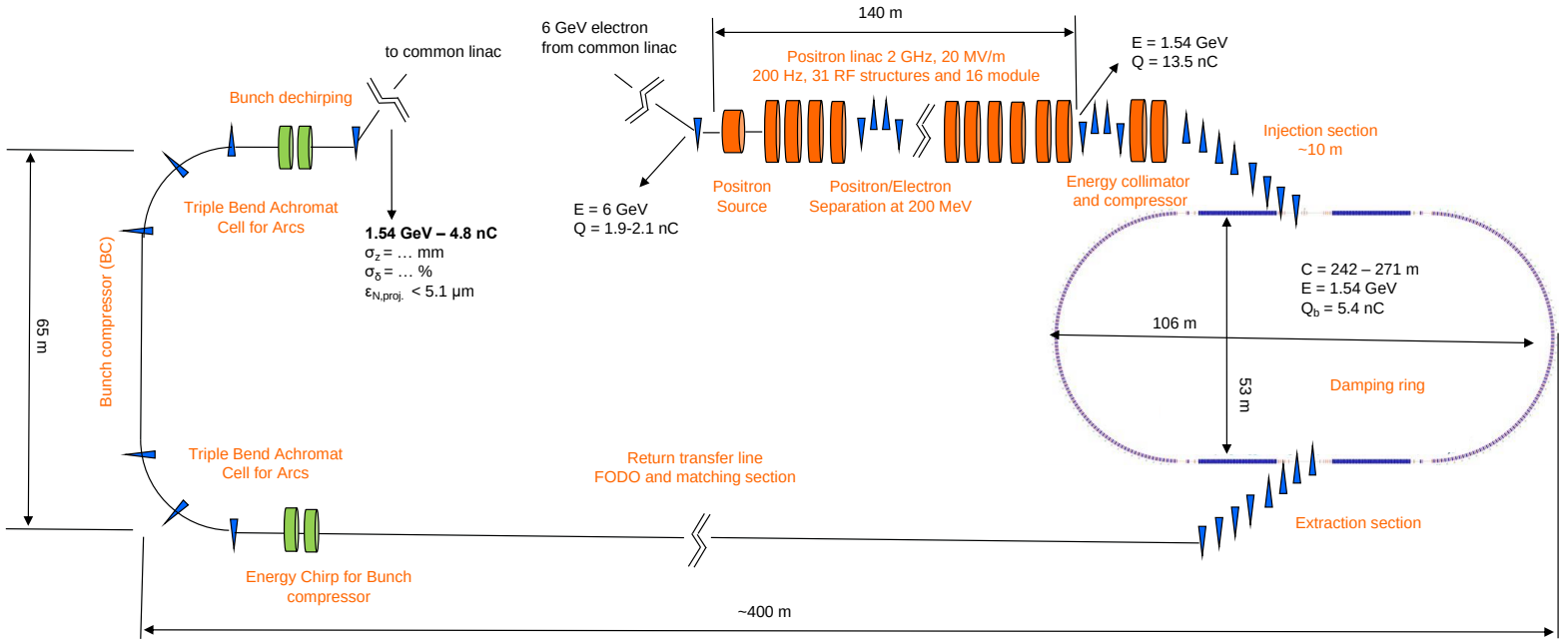
Repetition rate: 200 Hz / 2-bunch per pulse

- Bunch separation: 25 ns
- Beam energy: 1.54 GeV

Concept developed by ABT

- Stripline kicker is used
  - injection / extraction is mirrored
- Rise & Fall time: 50 ns
- Deflection angle: 3 mrad

[1]



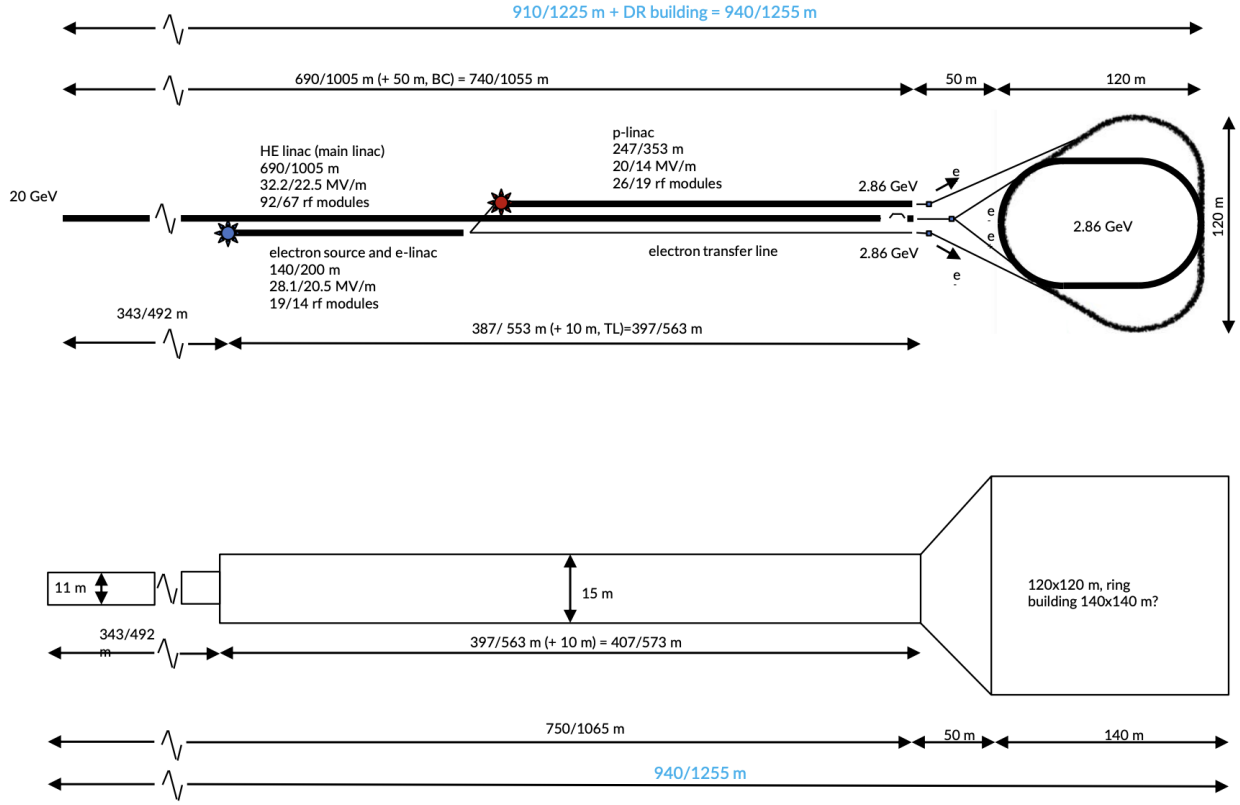
[1] FCC-ee Injector Design (CHART proposal) Coordination meeting

Damping ring : High energy concept

Status under development[1]:

See talk of P. Craievich [1]

- **Repetition rate: 100 Hz / 4-bunch per pulse**
- Beam energy: 2.86 GeV
- Also working for **e- beam**
- Kicker gap: 82 ns
- ABT already developed a inj /extr concept for the PRD and DR of CLIC[2]



Next steps:

- Need a frozen baseline
  - Also close collaboration to establish the inj / extr systems concepts with the ring design teams

[1] FCC-ee Injector Design (CHART proposal) Coordination meeting [2] CLIC Pre-Damping and Damping Ring Kickers

Booster Injection

See talk of W. Bartmann, Thursday

Follows siting of transfer lines

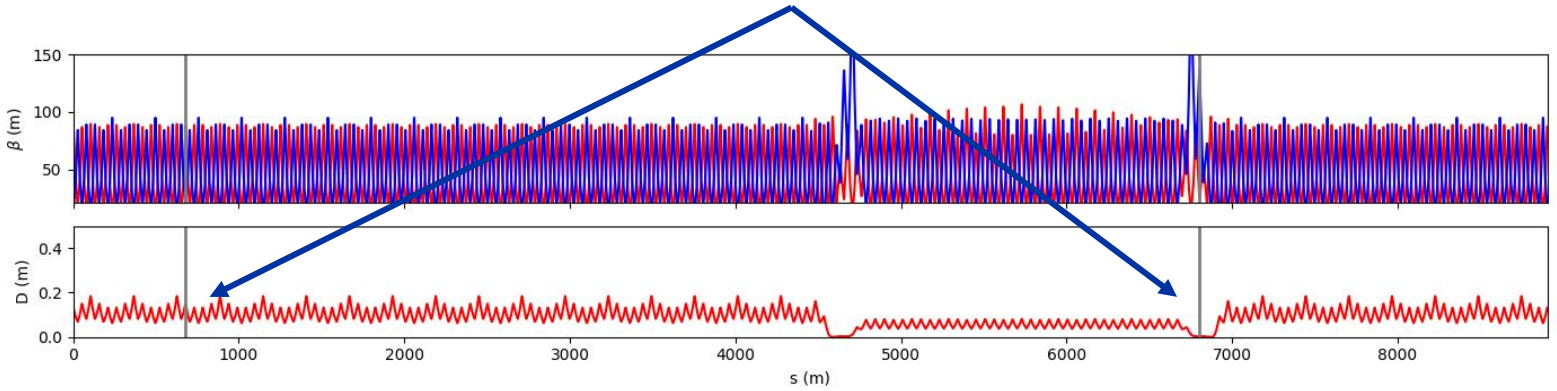
- Trajectories bypass the SPS tunnel

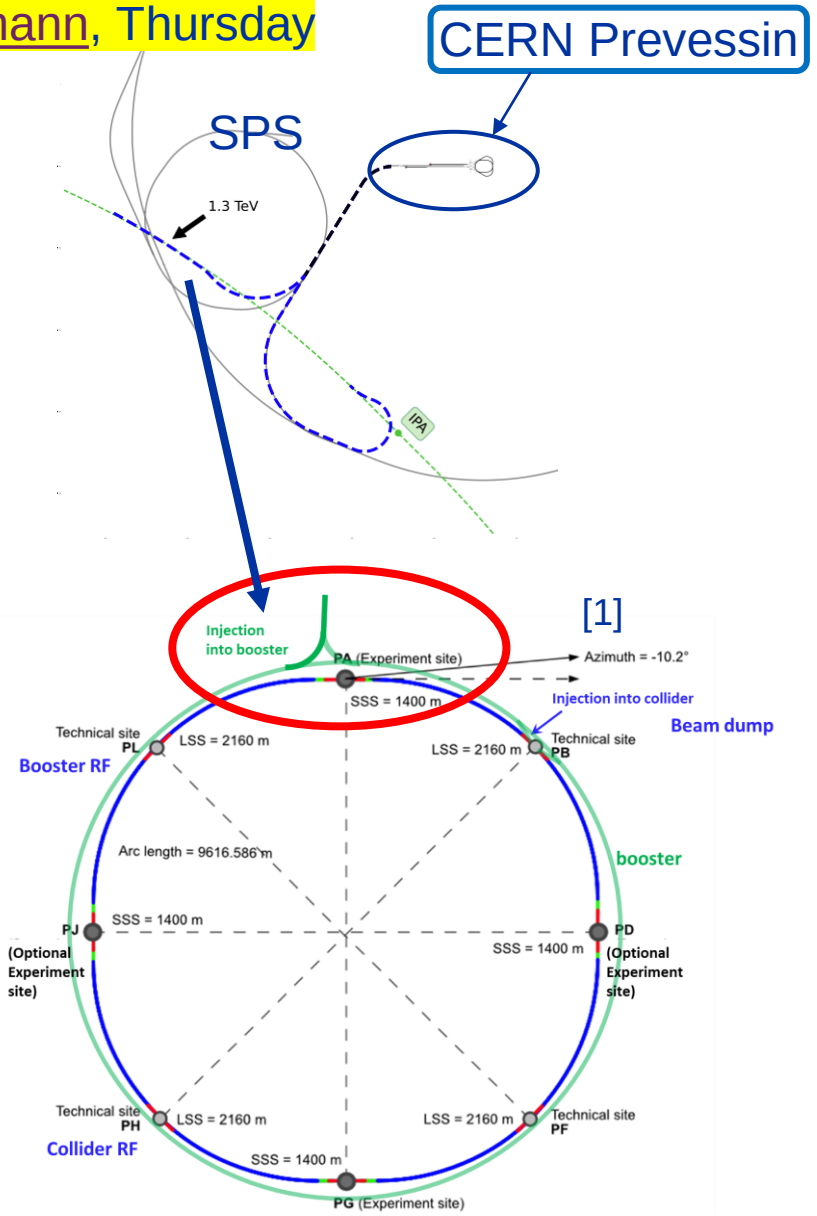
CW injection of positron in the arc towards PA

CCW injection of electrons in the arc towards PL

- Baseline scheme of 4 bunches separated by 25 ns, injected at 100 Hz
- Only 4 bunches at 20GeV per injection ➡ not considering local machine protection system presently

Vertical Injection at the arc section

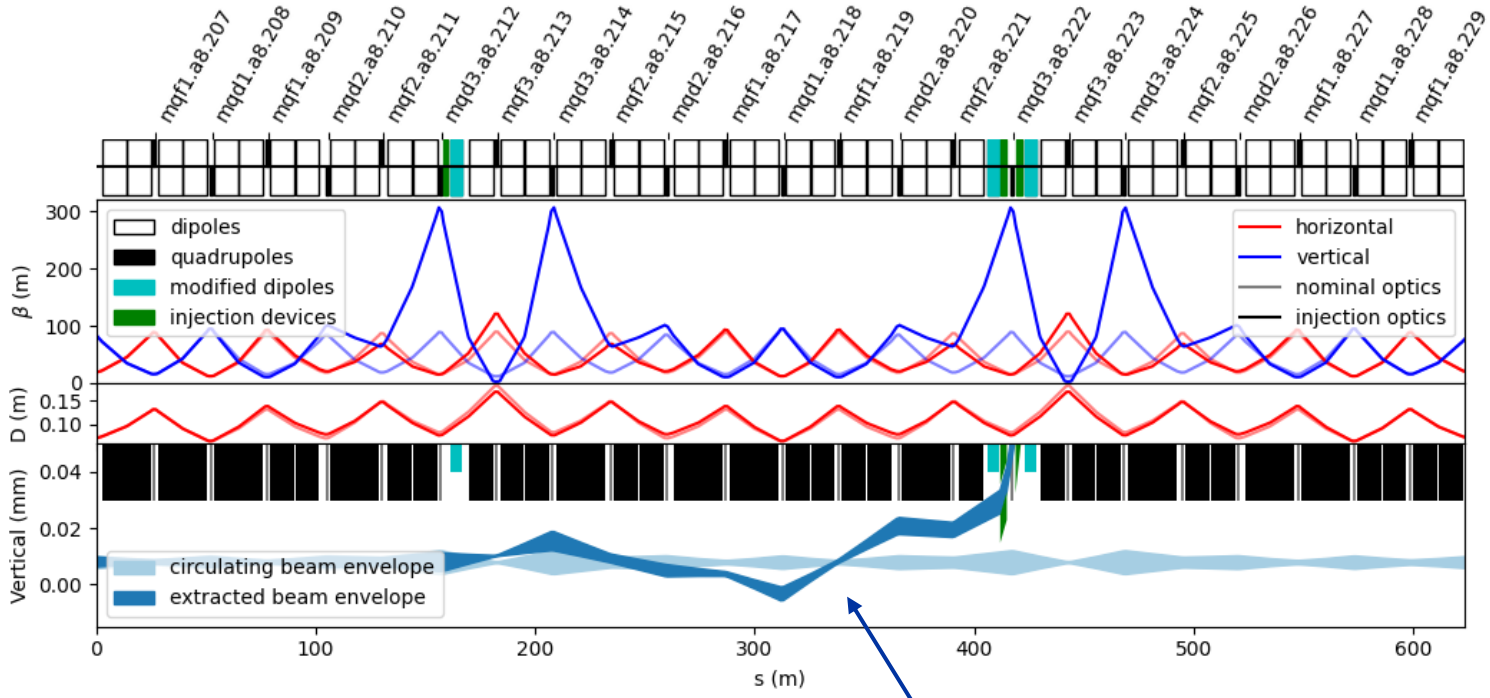




Booster Injection

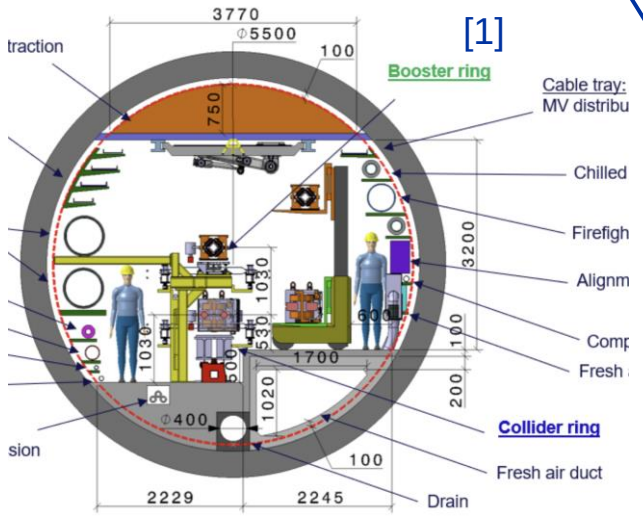
Status:

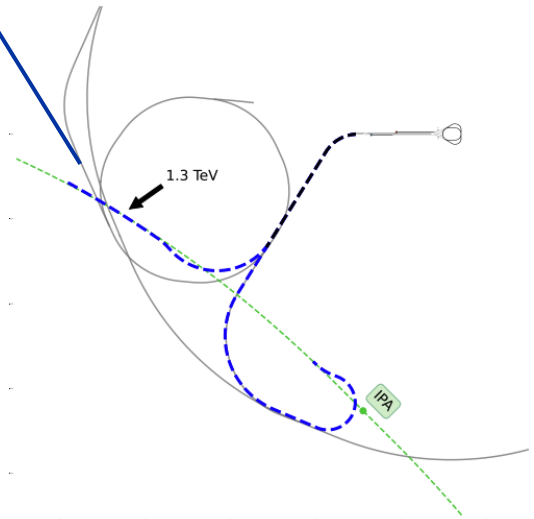
- 3 special dipoles with shorter length
- Preliminary discussion with magnet group did not highlight strong show-stopper
- Booster injection lattice and layout can be found in Gitlab



Challenges:

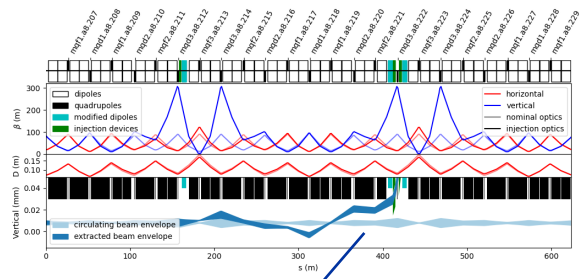
- Raises integration concerns for vertical transfer line
- Rise time (<25 ns) constrains the cable length
  - Minimize the distance between kicker and alcove
  - Back-up: let the beam oscillate and have a kicker at the next long straight section





[1]FCC Underground Civil Engineering, FCCweek2023

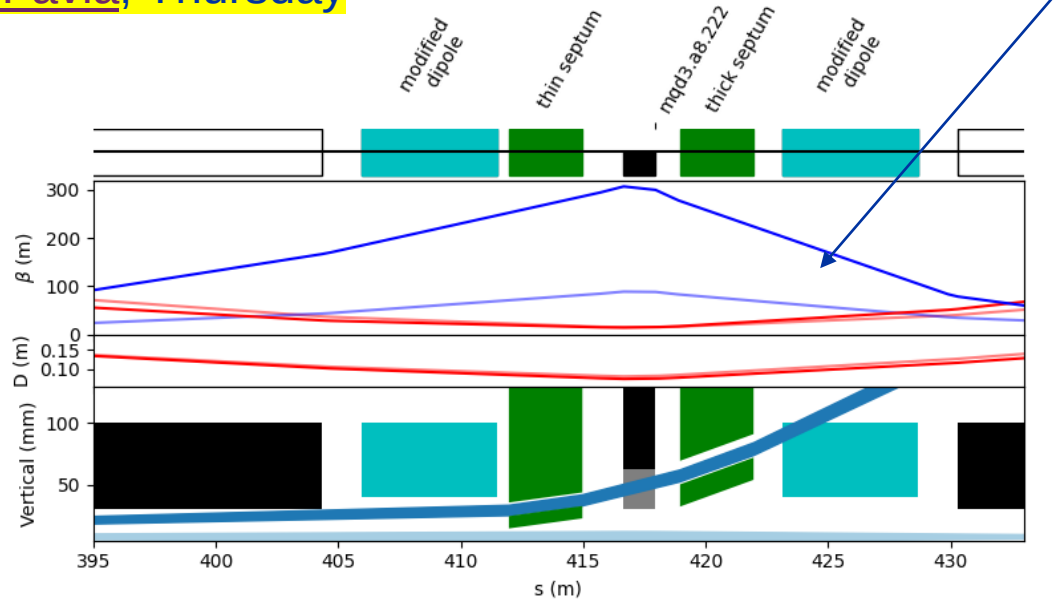
Booster - Vertical Injection



Status:

See talk of J. Borburgh and G. Favia, Thursday

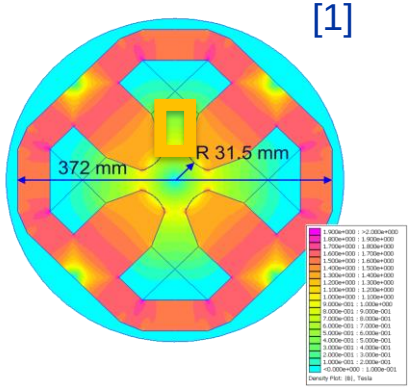
- Kicker
  - Deflection angle: 90 μrad, Rise time < 25 ns
- Septa
  - Deflection angle: 4.5 mrad, Thickness: 10, 18 mm
- Injection bump of 8 mm
- Concept allows lossless transport of the linac beam and injection with high efficiency



Challenges and next steps:

- Injection damper is required due to beam transverse jitter from linac[2]
- Need beam impedance budget for the ring and injection devices impedance simulations

[1]



- 1 quadrupole with side channel for the injected beam

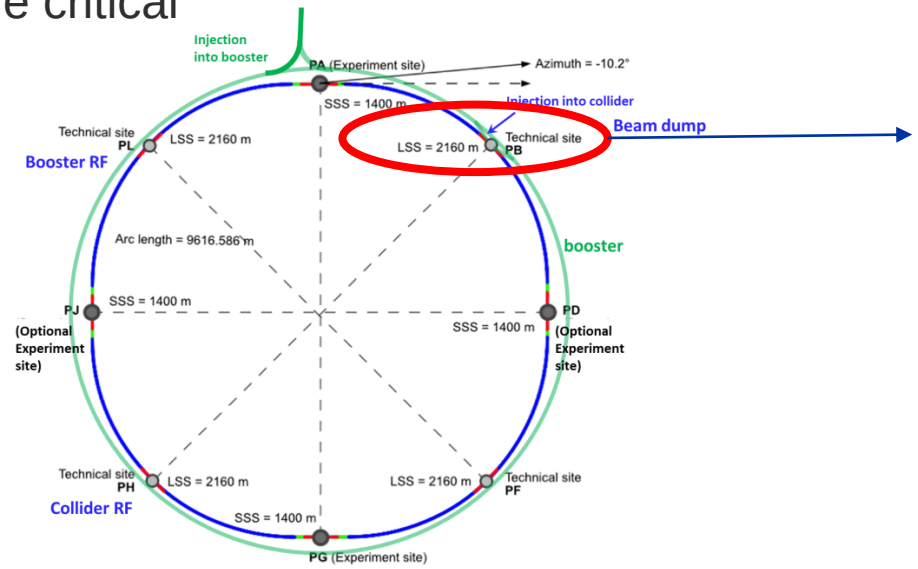
[1] FCC-ee Magnet Developments, FCCweek2023 [2] Trajectory jitter specification for the FCCee injector

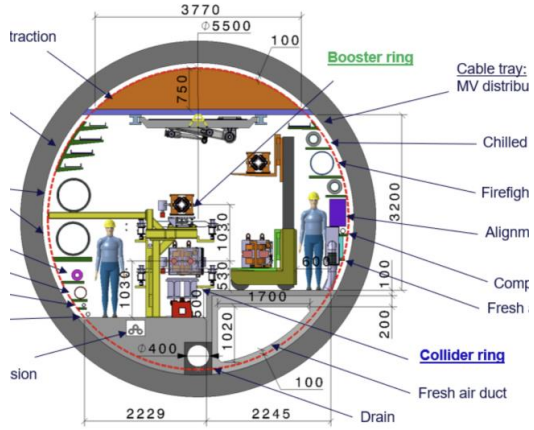
Integration at PB

See talk of Y. Dutheil, Tuesday

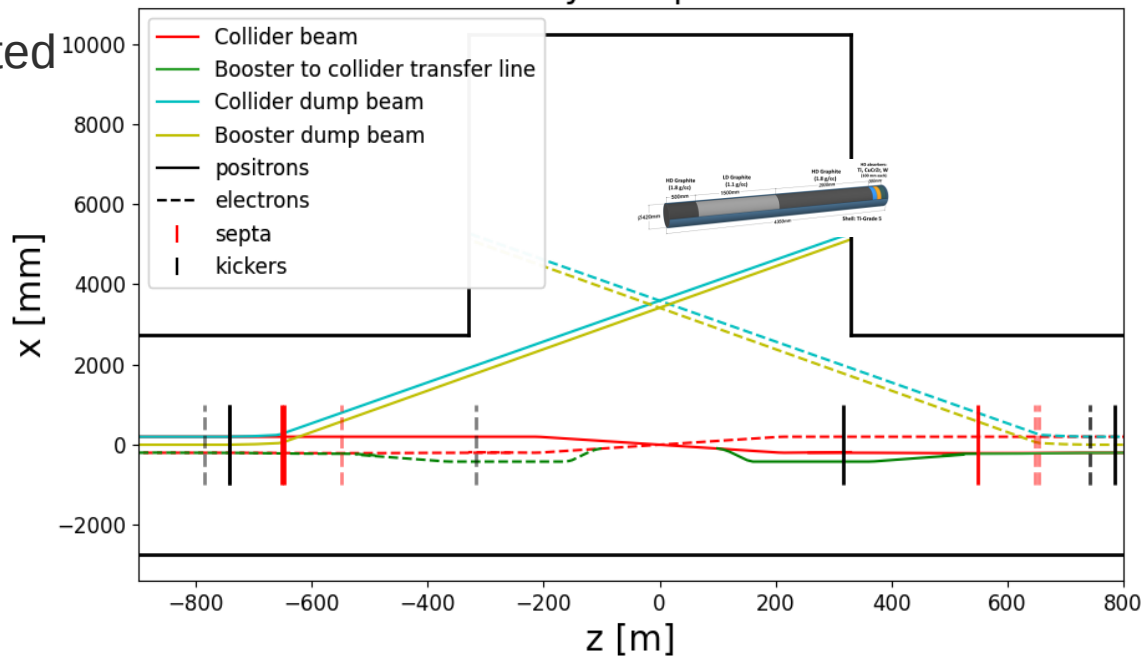
Layout in PB

- Booster extraction, collider and booster beam dumps[1], collider injection (e+ & e-)
- Preliminary review of survey lines with integration did not show any specific issues, but comprehensive integration of every elements remains to be done
- Cable lengths between kicker/septa and generators located in alcoves, are critical





Survey in top view



Layout can be found in Gitlab

[1] A. M. Krainer,FCC-ee Beam Dumping System, IPAC22

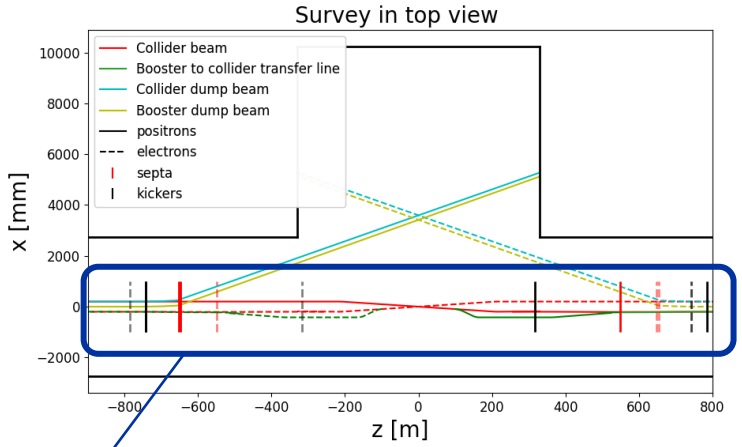
[2]FCC Underground Civil Engineering, FCCweek2023

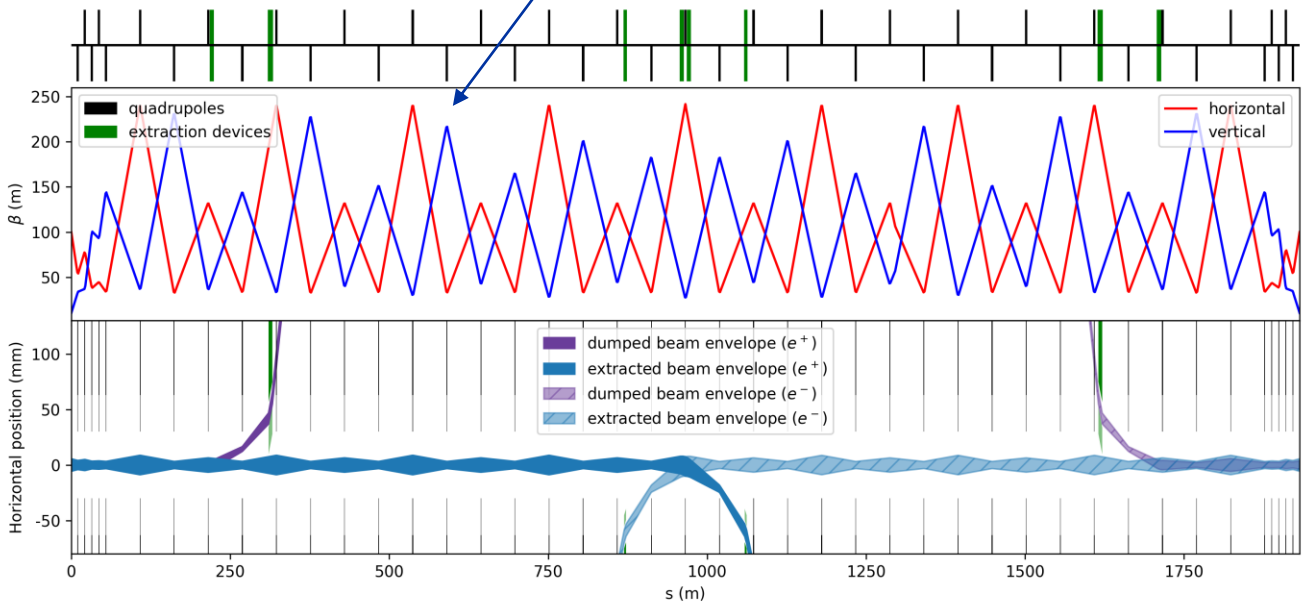
Booster extraction and dump

- **Booster accumulates 1/10 of the bunches in the collider [1]**
  - as outcome of machine protection discussions
- **Machine protection challenges due to the large beam power (0.2 MJ)[2]**
  - Failure cases and mitigation methods remain to be studied in detail

Dumped and extracted beam envelope (e+ & e-) :

- 4 septa systems, and 4 kicker systems





[1] FCCee beam transfer meeting #8 : special integration

[2] A. Abramov, FCCee_Collimation, FCCweek23

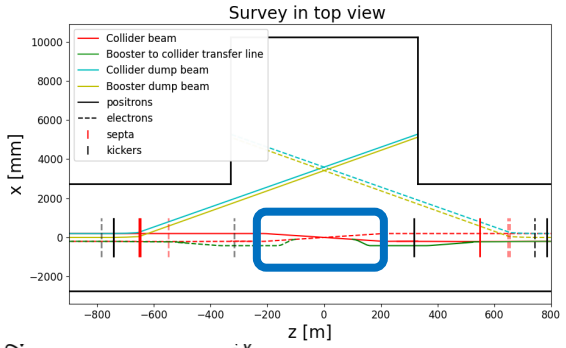
Booster - Horizontal extraction

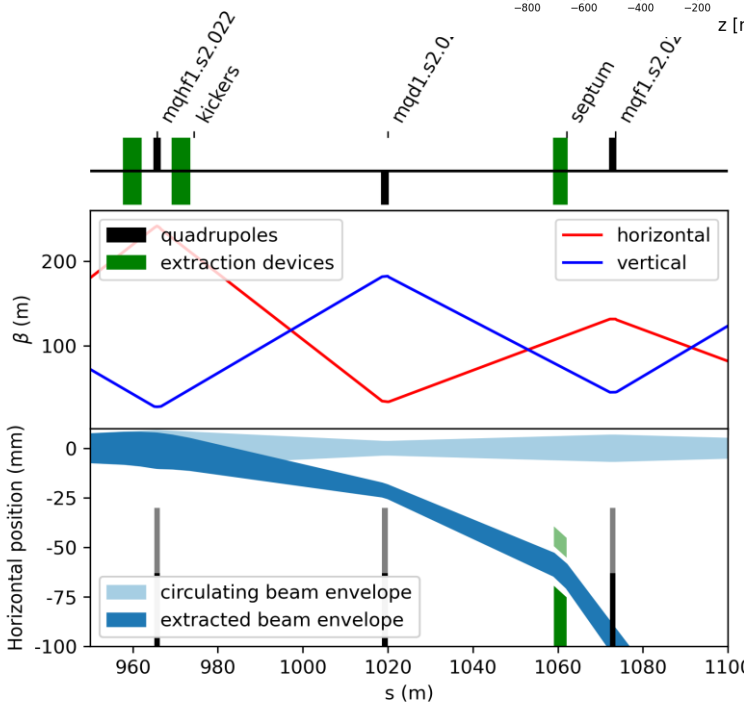
Status:

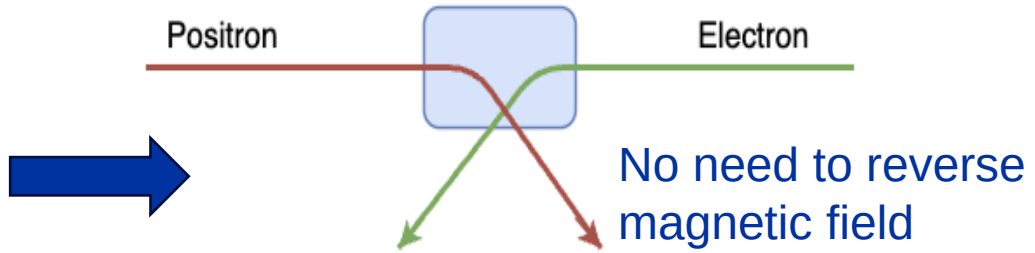
- Kicker at the center of the section
  - Deflection angle: 0.43 mrad, Rise time: 1.1 μs
- Septa
  - Deflection angle: 2 mrad, Thickness: 10 mm
- Distance between booster extraction and collider injection point: 500 m

Challenges:

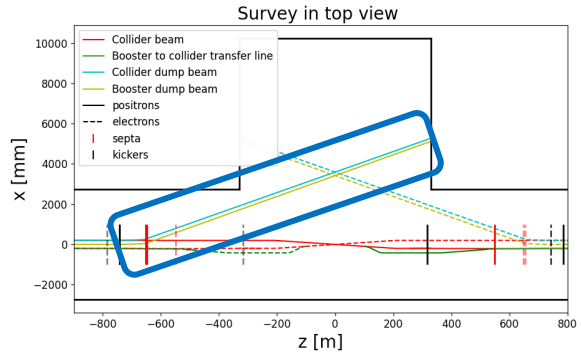
- Flat-top stability is important to correctly inject into the collider
- Requires precise control of vertical dispersion
  - 1 m elevation
- e- and e+ beams could share the same kicker at the section center





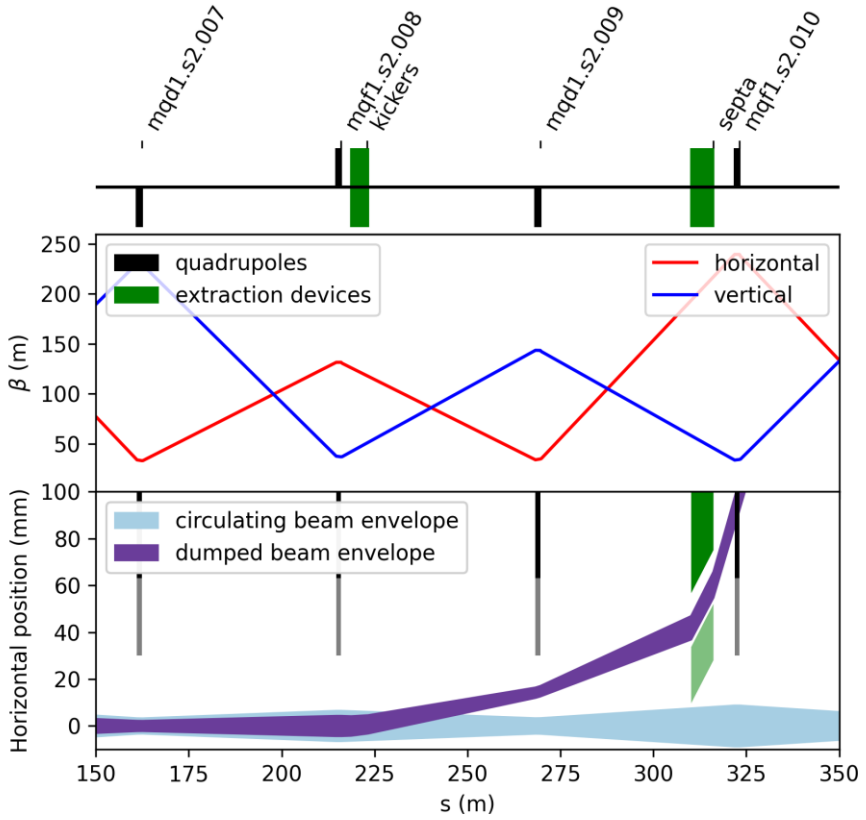


Booster dump



Status:

- Extraction transfer line to the dump is 1200 m
- Kicker
  - Deflection angle: 0.3 mrad, Rise time: 1.1 μs
- Septa
  - Deflection angle: 5 mrad, Thickness: 25 mm



Challenges and next steps:

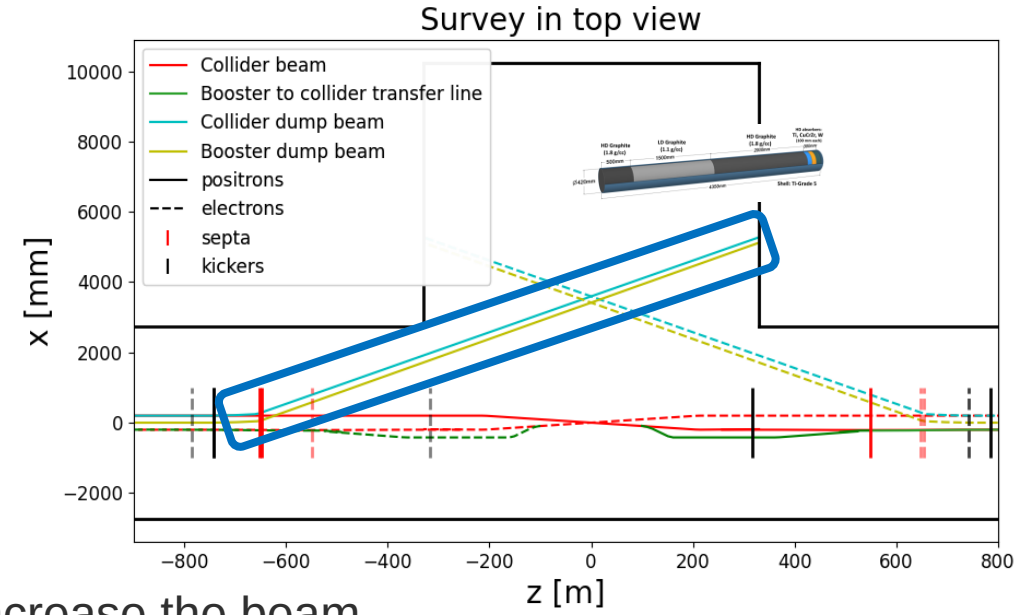
- Magnets follow the beam energy
  - Dump systems design without septa could be investigated
- Current using 5 m horizontal distance between dump system and beamline

Collider dump

See talk of A.P. Marcone, Thursday

Status:

- 1200 m transfer line for collider dump
  - Similar kicker and septa design with booster dump
  - Fixed beam energy for dump
- A beam passive dilution system was studied in 2020[1]



Challenges and next steps:

- Considering leveraging horizontal and vertical dispersion to increase the beam size at the dump
- Dump lines optics and beam specifications are being reviewed with CERN beam-matter interaction experts (SY-STI)
  - Combining with the booster dump is investigated
- For slow systems: septa, dipoles, quadrupoles (also for booster dump)
  - Failure could be mitigated by a fast dump trigger system (≤ 1 turn)
  - Feasibility of a system with reaction time ≤ 1 turn remains to be studied

[1] A. Krainer, Beam dump for the FCC-ee, EPJTI

Conclusion

- **Damping ring:** Need a frozen design for inj & extra concept for FSR
- **Booster injection:**
  - Possible limitations on vertical injection at arc: 1) celling, 2) alcove location
  - Damper is required in booster ring for beam jitter from linac
- **Booster extraction:**
  - e- and e+ could share the same kicker system
  - Precise vertical dispersion control
- **Booster & Collider dump:** Machine protection is under studied
- **PB Integration:**
  - No obvious show stopper at this early stage, still a lot of integration work
  - Cable lengths between kicker/septa and generators located in alcoves is crucial
- **For polarized beams transport:** Because of vertical bending, matching of the stable spin direction between machines will need to be considered carefully