



**Injection and dump for FCC-hh**

and

**Synergy of hh and ee transfer lines**

**W. Bartmann, FCC week 2022, Paris**





## Questions to be addressed

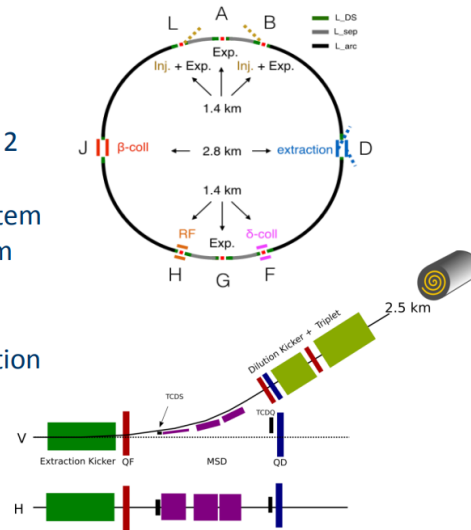
- Can we combine in one straight section of 2.16 km the FCC-hh injection and dump systems?
- What are the lengths/technologies of transfer lines from SPS and LHC to the FCC tunnel?
- How can transfer lines be designed with most synergy between hadron and lepton machines?



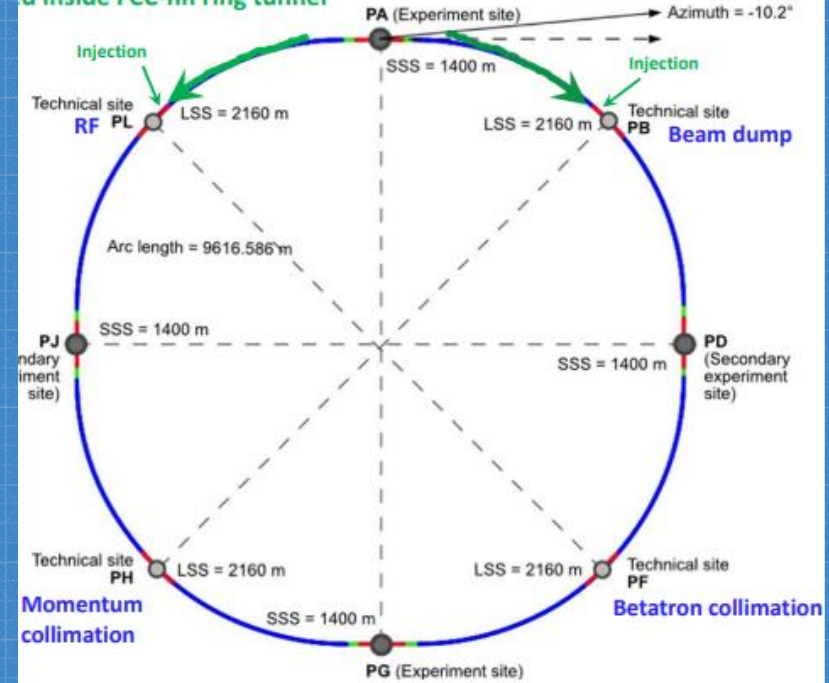
# Injection/extraction - old vs new layout

## OLD Baseline:

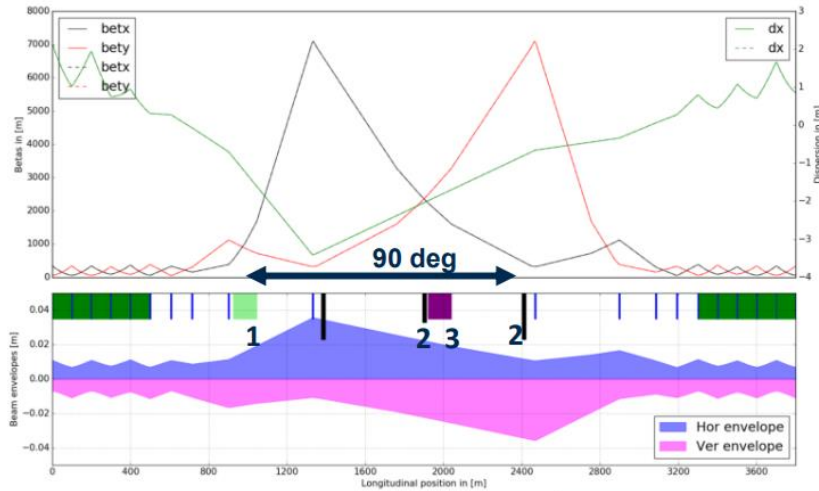
- IPD, 2.8 km for extraction of beam 1 and 2
- 2.5 km dumpline with dilution kicker system to create sweep pattern at graphite beam dump
- Design mainly driven by machine protection
  - Safely extract 8.5 GJ beam
  - Reduce failure probabilities
  - Avoid downtime in case of failure



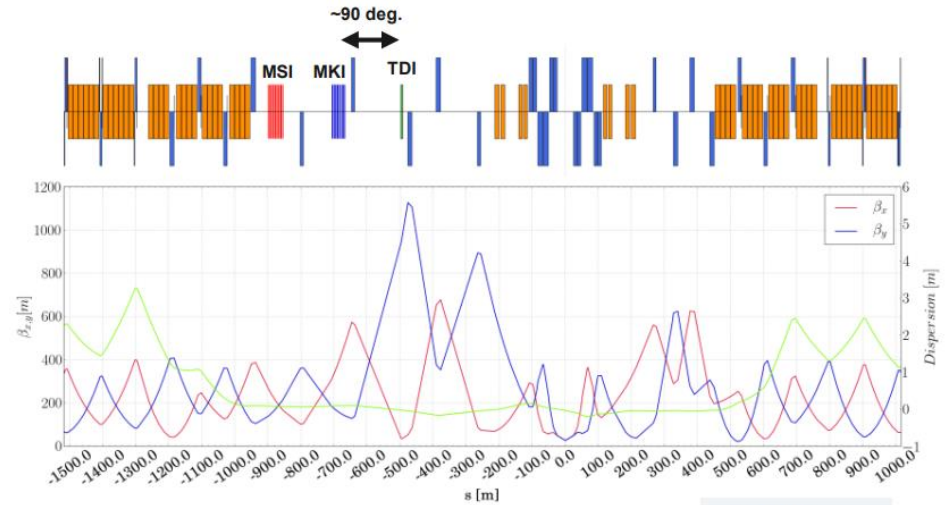
## Proposed lines to be installed inside FCC-hh ring tunnel



# Injection/extraction - from where we started



W. Bartmann

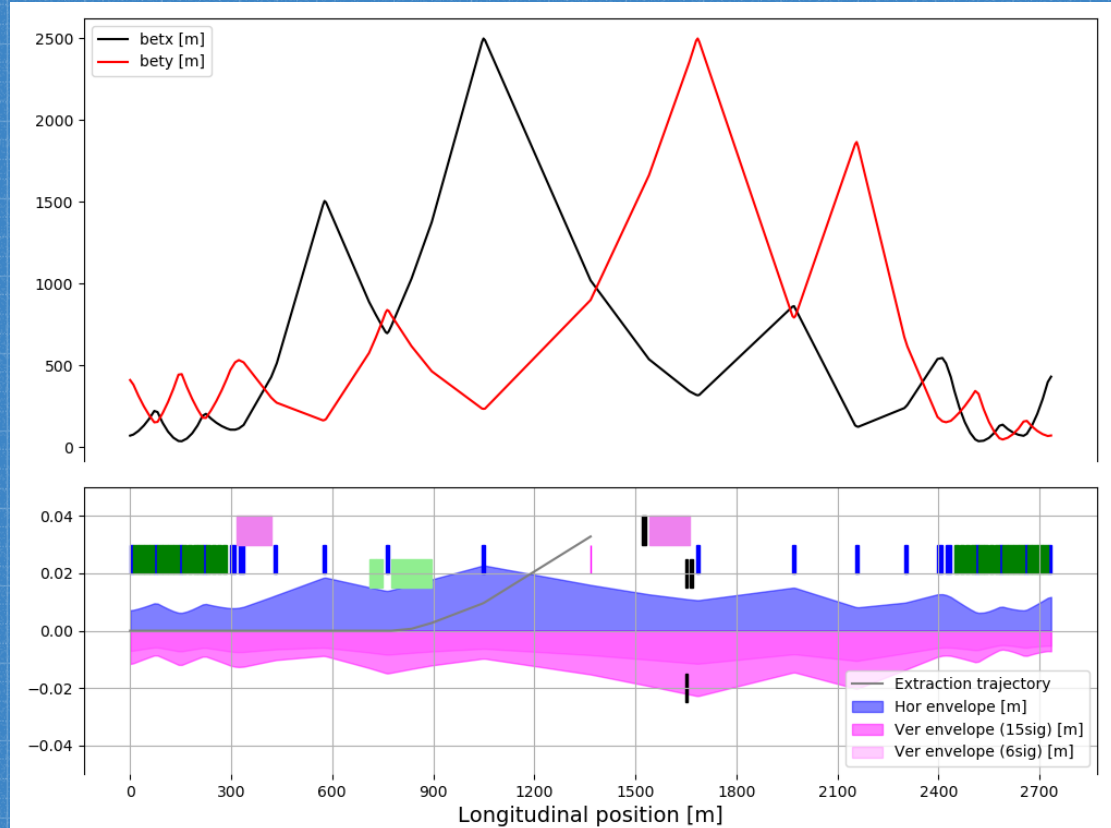


M. Hofer



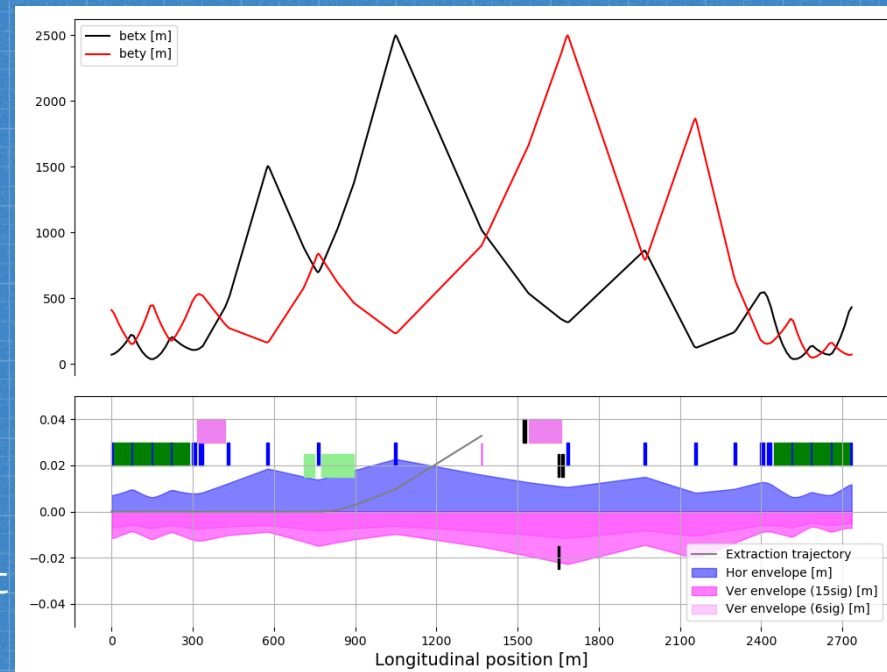
# Injection and dump combined

- Overlay main optics constraint of kicker-absorber = 90 deg phase
- Most critical is injection failure impacting all extraction elements



# Injection and dump combined

- Kickers and absorbers for inj and extr at about same location
- Move injection septum into better phase wrt kicker
  - kick strength factor 1.8 reduced
  - also reduces mis-kicked trajectory offset
- Extraction design with HW parameters not far from CDR (aperture impacted though)
- Injection failure impact
  - Focussing/defocussing in right sequence → both systems in vertical
  - Extra MKD clearance of 5 mm (21 cf 16 mm)
  - 27 mm extra at quadrupole
  - MSD protection needs careful design (impact on the outside, most likely increased aperture as well)





## Injection/dump next

- Update list of HW parameters and check for impact on previously chosen technologies and rough cost estimate
- Run through different failure scenarios of injection and extraction elements, incl global MP studies
- Consider dilution untouched - some impact on dump line optics, envisage focusing triplet there, so room for adaptation
- Probably not ideal to copy injection concept to other straight - however we should copy the HW



## Transfer lines for FCC-hh

- Consider as injectors machines in either the SPS or the LHC tunnel
  - scSPS at  $\sim 1.3$  TeV
  - LHC modified or superferric machine at  $\sim 3.3$  TeV
- With updated 8P layout need to direct injection lines into the arc tunnel to avoid excessive tunnel lengths

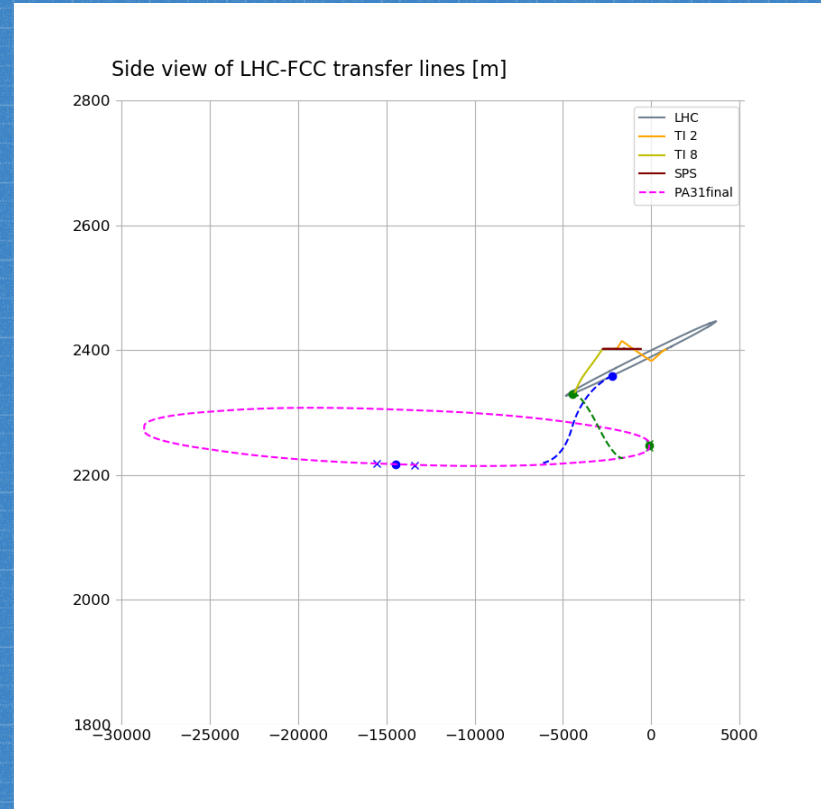
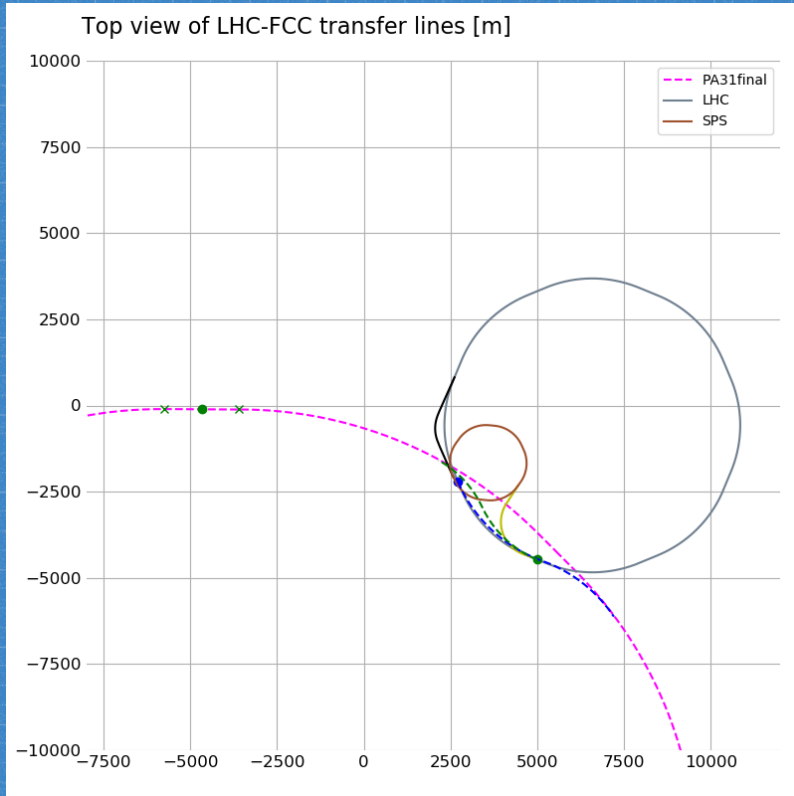


## Study approach

- LHC magnet technology as upper limit, 8 T, apertures are made for 450 GeV
- 64 m long FODO cell with 6 dipoles of 5 m length each •  
Quadrupoles with 3 m length, reasonable pole tip field, beta max between 70-80 m
- Quadrupole-dipole interconnects of 1.5 m are assumed to house correctors and BPMs
- Dipole-dipole interconnects of 1 m
- Fill factor of 65% (cf LHC 80%)
- Madx twiss and survey files generated for each case



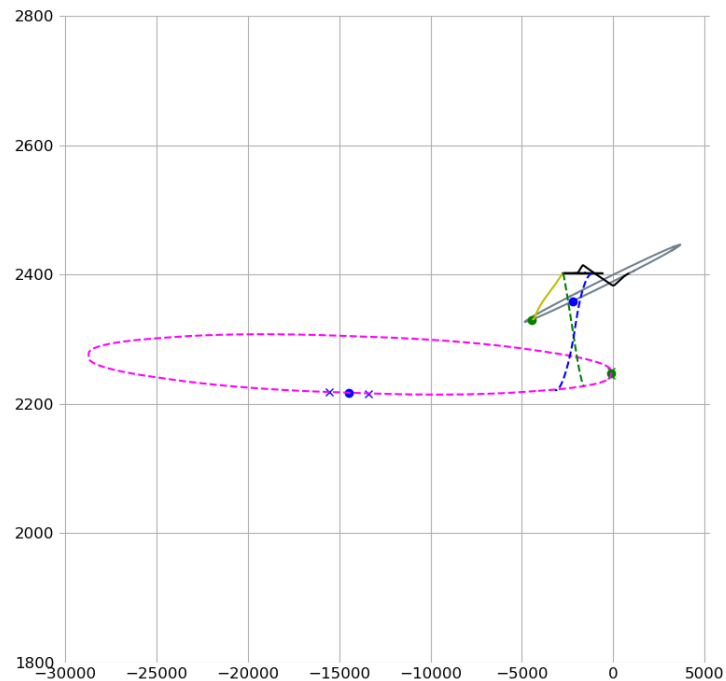
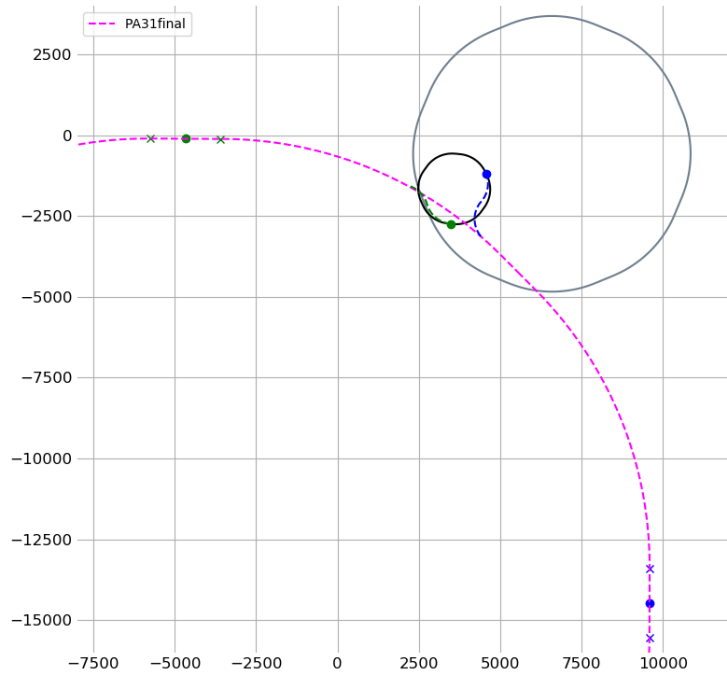
# LHC as injector





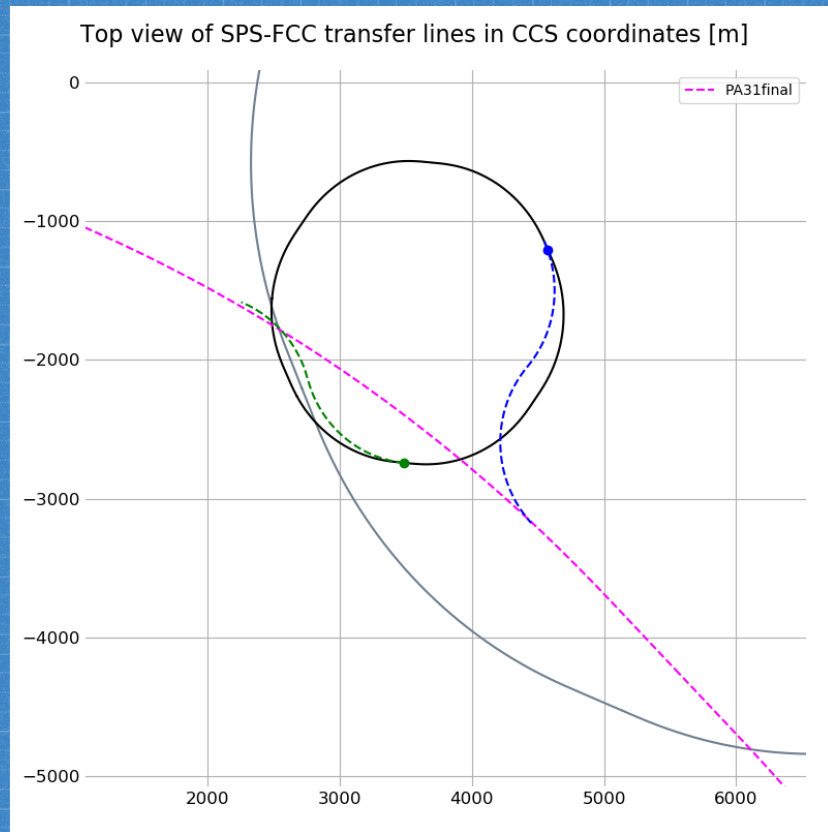
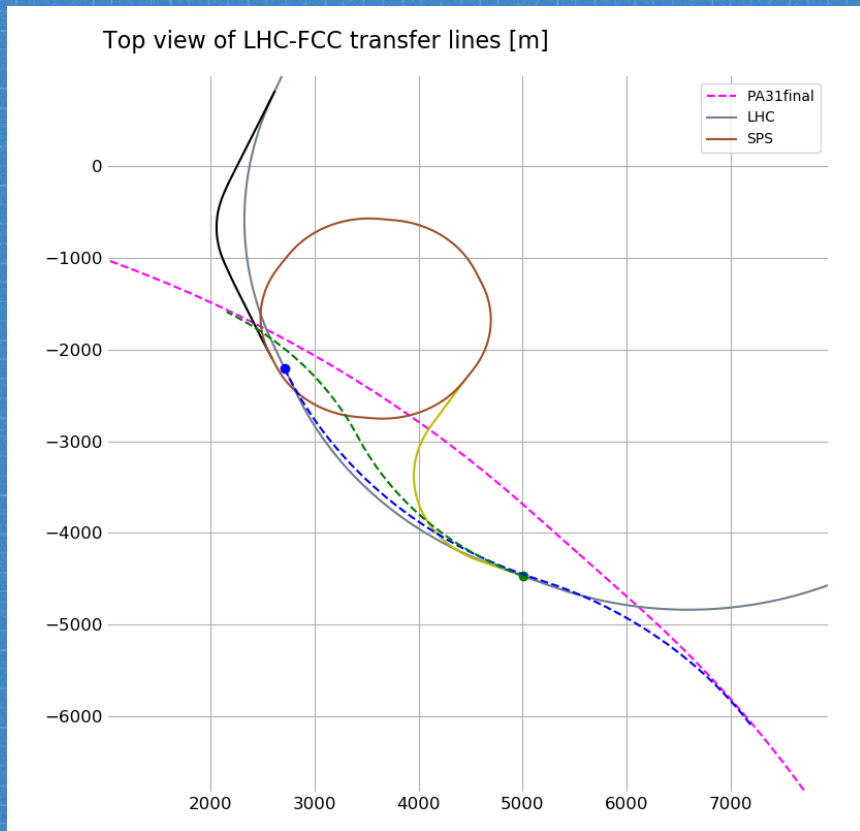
# SPS as injector

Top view of SPS-FCC transfer lines in CCS coordinates [m]





# Top views for LHC and SPS



## Transfer tunnels and lines

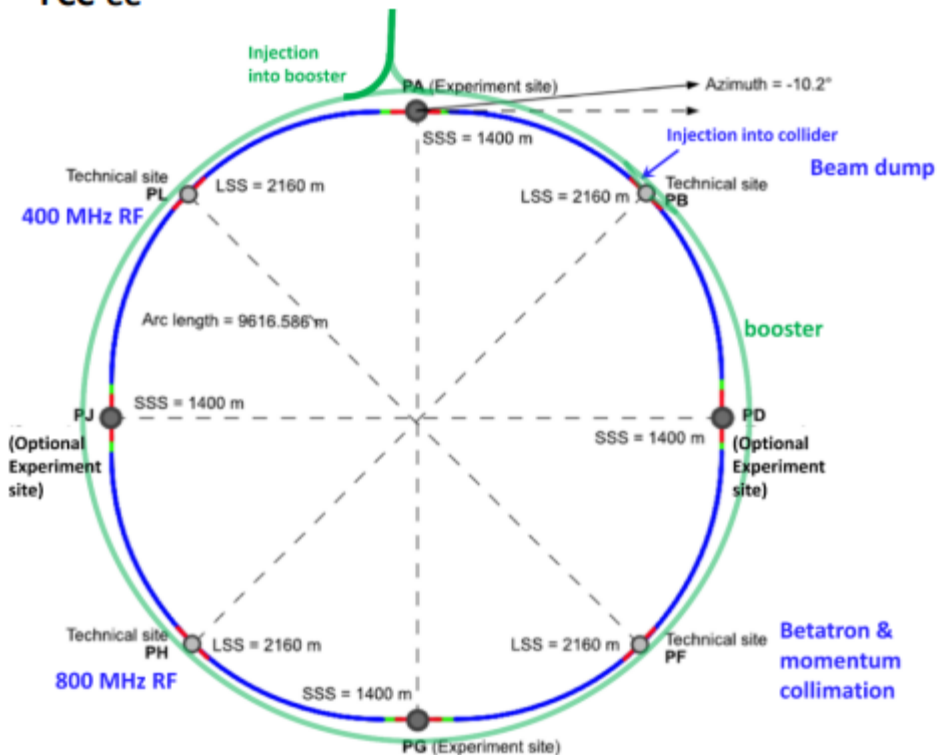
- Total lengths of transfer tunnel 5-7 km
- A solution but not optimized wrt civil engineering, collider layout, TL cell,... to be iterated, also from LHC could invert inj points, ie P1toPL; but iterations should not impact massively the cost estimate
- Total of beam lines ~30 km
- From SPS tunnel could envisage NC magnet technology, some impact on length



# FCC-ee layout consistent with FCC-hh

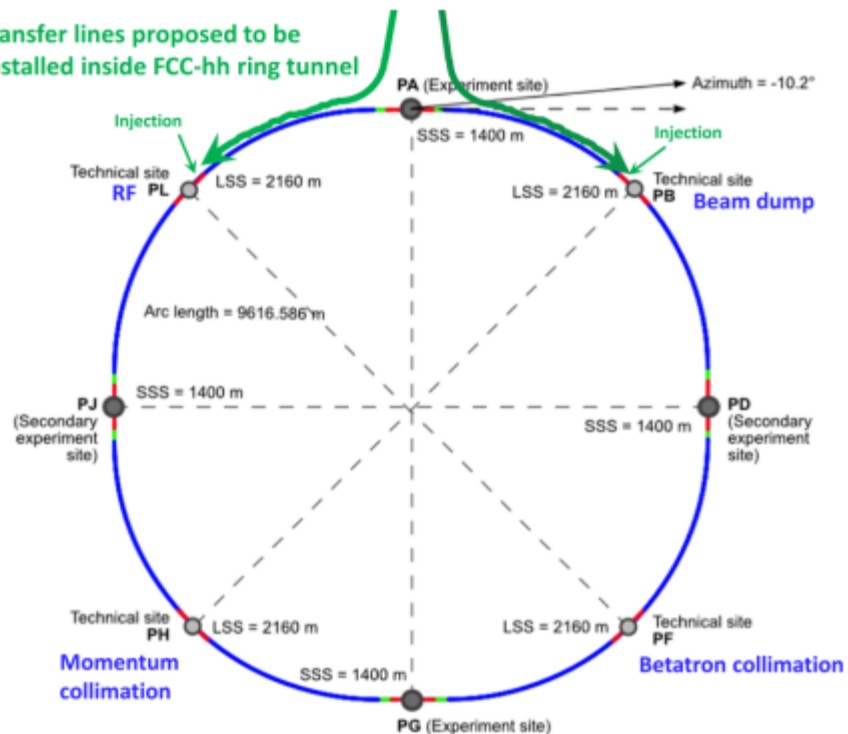
Frank Zimmermann

FCC-ee

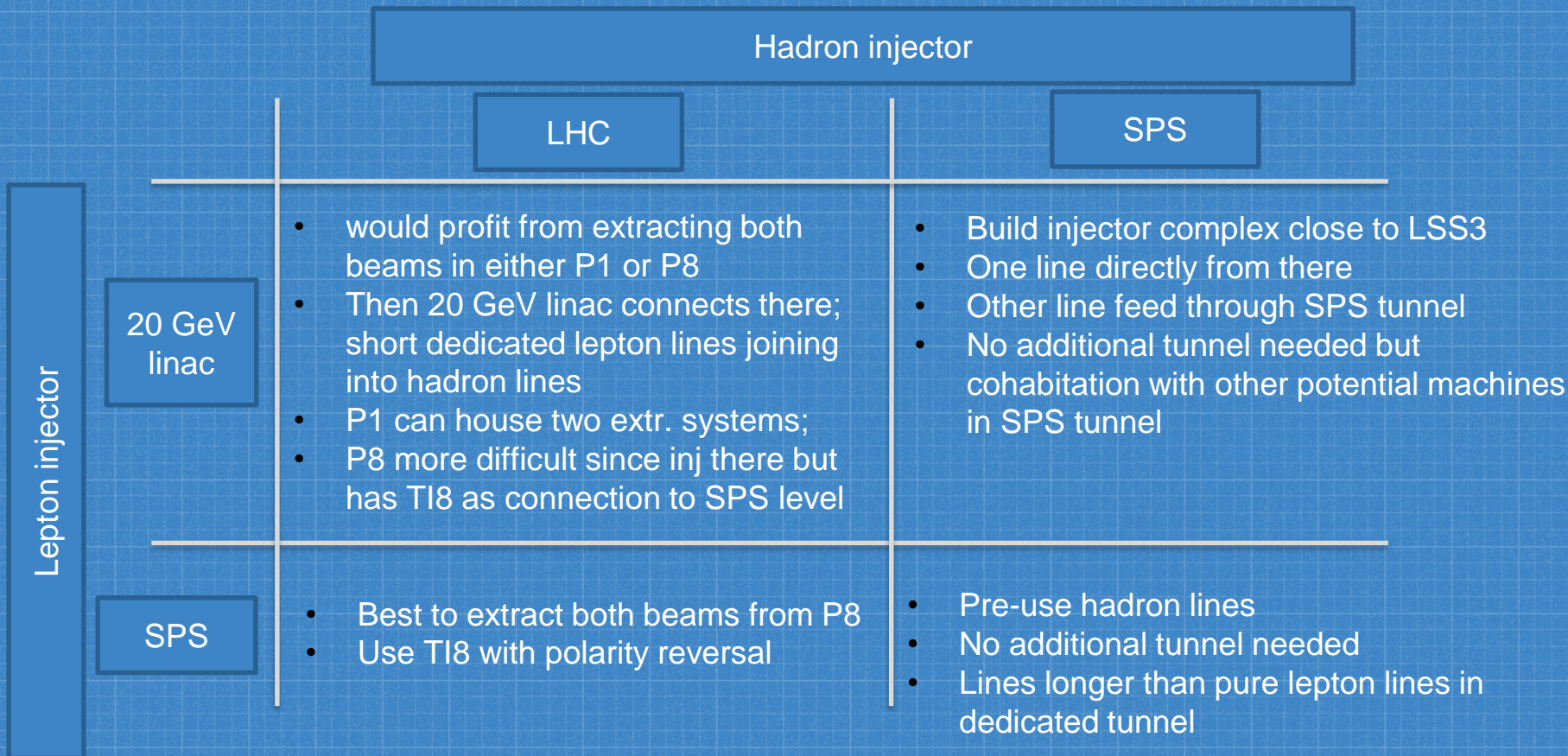


FCC-hh

transfer lines proposed to be installed inside FCC-hh ring tunnel



# Synergy of hadron and lepton transfer lines





## Synergy of hadron and lepton transfer lines

- In all cases the lepton lines need to reach SPS level – not in comparison
- If SPS serves as hadron injector – more obvious synergy between hadron and lepton lines
- For the LHC option should study possibility of extracting both beams in either P1 or P8 and envisage re-use of TI8



# Conclusion

- Can we combine in one straight section of 2.16 km the FCC-hh injection and dump systems?
  - Yes ... with more complicated HW, failure scenarios and operation, but no fundamental performance limit identified
  - Next: HW check + cost, failure scenarios, inj+rf design
- What are the lengths/technologies of transfer lines from SPS and LHC to the FCC tunnel?
  - From SPS can chose nc or sc, from LHC need sc
  - Tunnels of 5-7 km, lines of ~30 km
  - Next: iterate with CE, machine layout,...OK for cost estimate
- How can transfer lines be designed with most synergy between hadron and lepton machines?
  - Quite some synergy possible, easier for SPS option
  - For LHC option revise extraction from single LSS