# FCC-ee injector complex siting and transfer lines

W. Bartmann with valuable input from S. Bettoni, M. Benedikt, A. Chance, P. Craievich, B. Dalena, Y. Dutheil, B. Goddard, F.M. Velotti, T. Raubenheimer, T. Watson, F. Zimmermann

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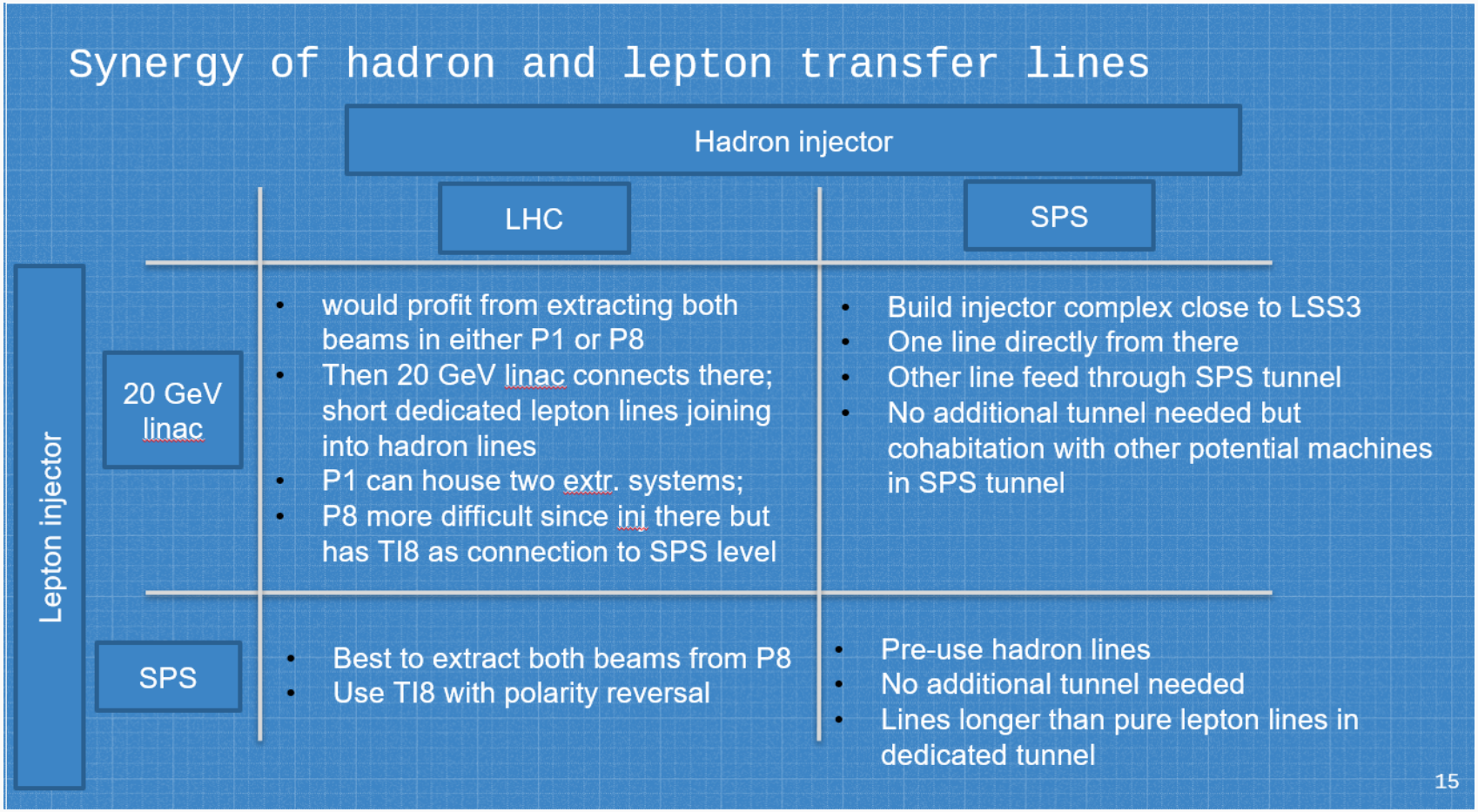
Midterm review deliverable 5.1.9

# Task

Site the pre-injector complex such that tunnels for lepton lines from either a 20 GeV linac or a 16 GeV SPS can be re-used for hadrons from either a 1.3 TeV scSPS or a 3.3 TeV LHC by taking advantage of existing tunnels where possible.

# Synergy between lepton and hadron lines



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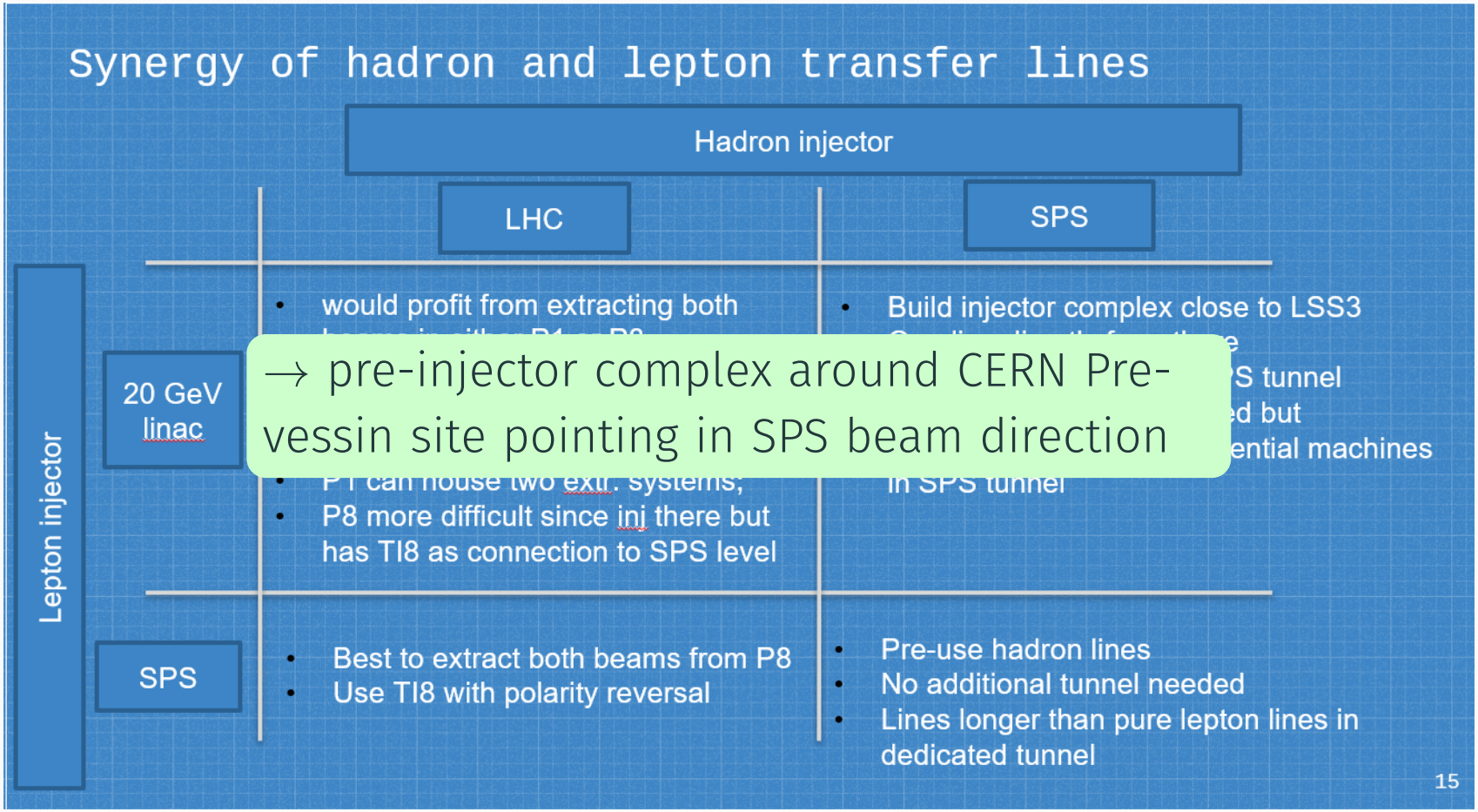
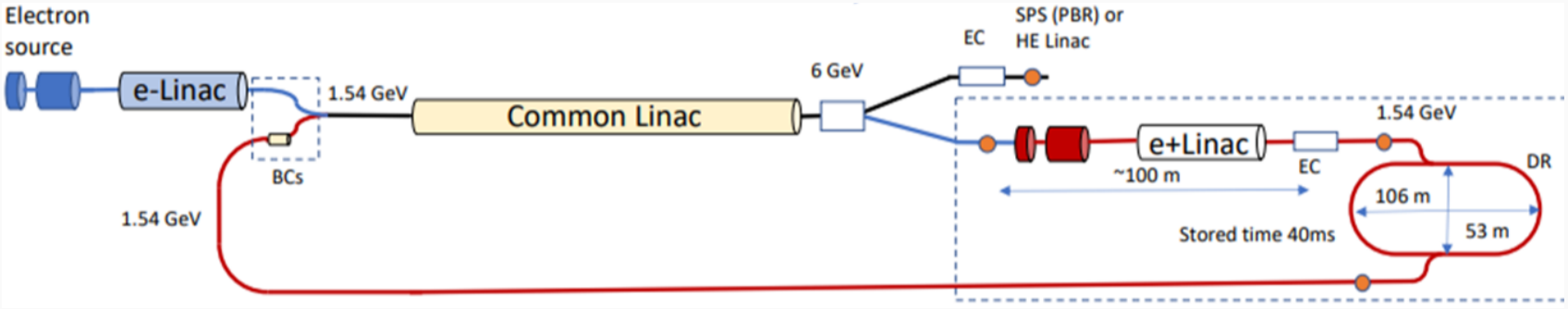



→ pre-injector complex around CERN Pre-vessin site pointing in SPS beam direction

# Injector complex dimensions

Need ≈ 1-1.2 km length and 65 m width for half the complex



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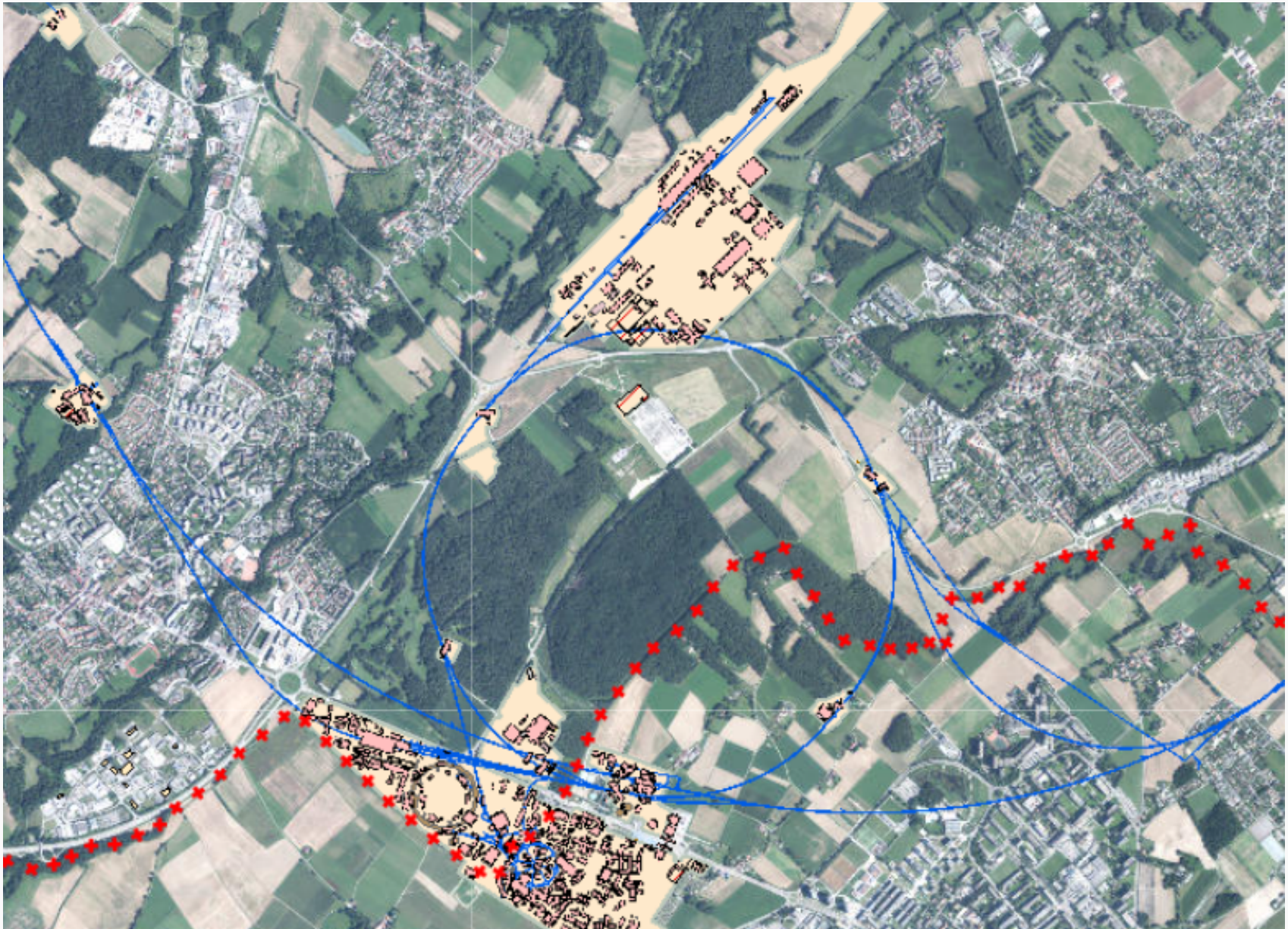

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Courtesy T. Watson

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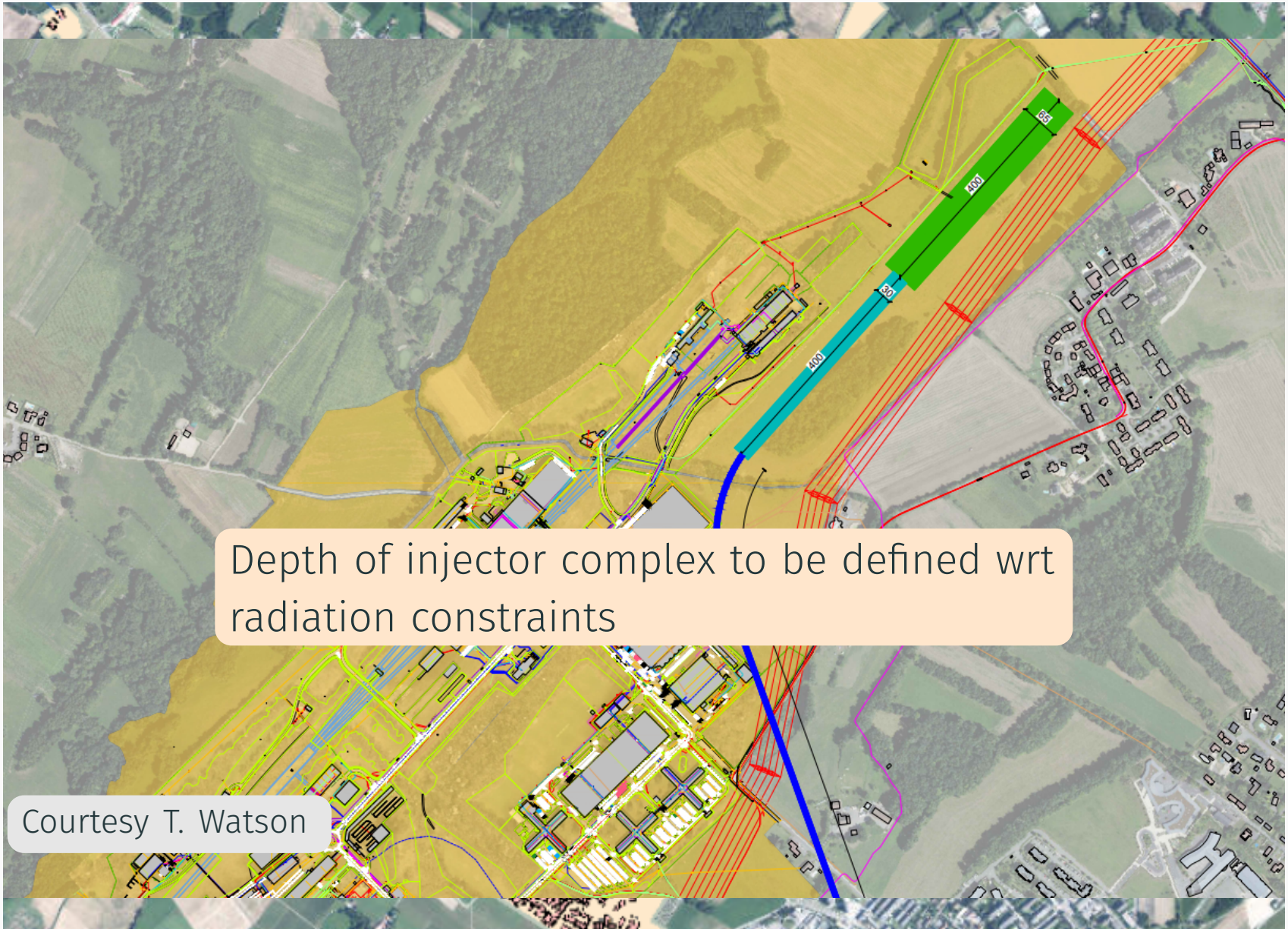



Depth of injector complex to be defined wrt radiation constraints

Courtesy T. Watson

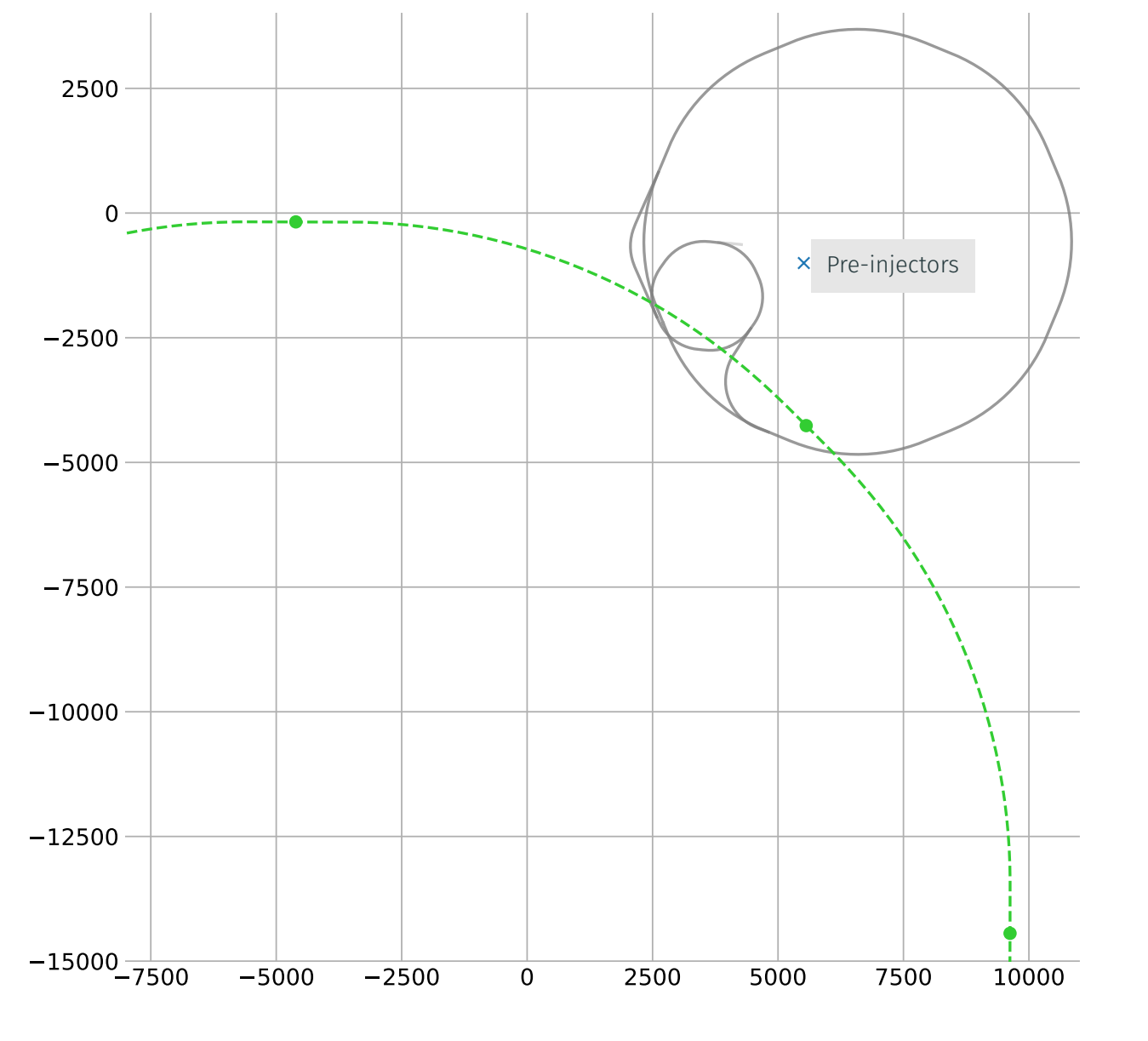
# Cell design of transfer lines

- cell length of 46 m, max betas ≈ 80 m, dispersion a few meters
- quadrupoles of 1 m length, gradient ≈2T/m, pole tip field of ≈60 mT
- 6 dipoles per cell, each 6 m long, dipole interconnects of 1 m, fields of ≈7-200 mT
- drifts around quadrupoles > 1.75 m to allow for BPMs and correctors
- 78% fill factor
- MADX twiss and survey files created for all options
- present assumptions, cell design can be adjusted to mimick booster cell if useful for integration

# Disclaimer

- so far this week have seen different designs of transfer lines
- option for civil engineering costing is possible but not optimised
- suggest for midterm report to align on the geometries, and scale cost - should reduce

# FCC tunnel in CERN coordinate system [m]



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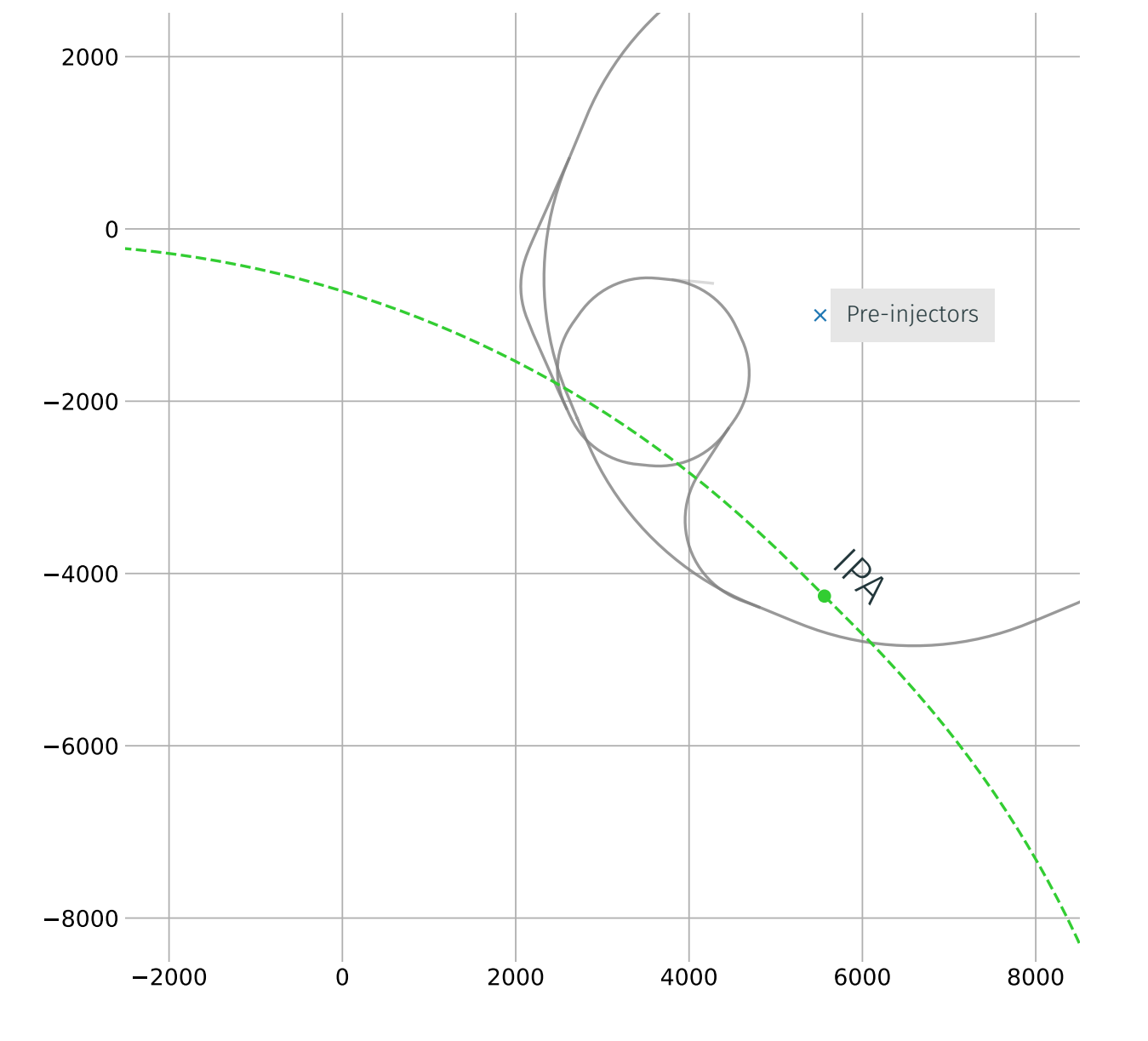
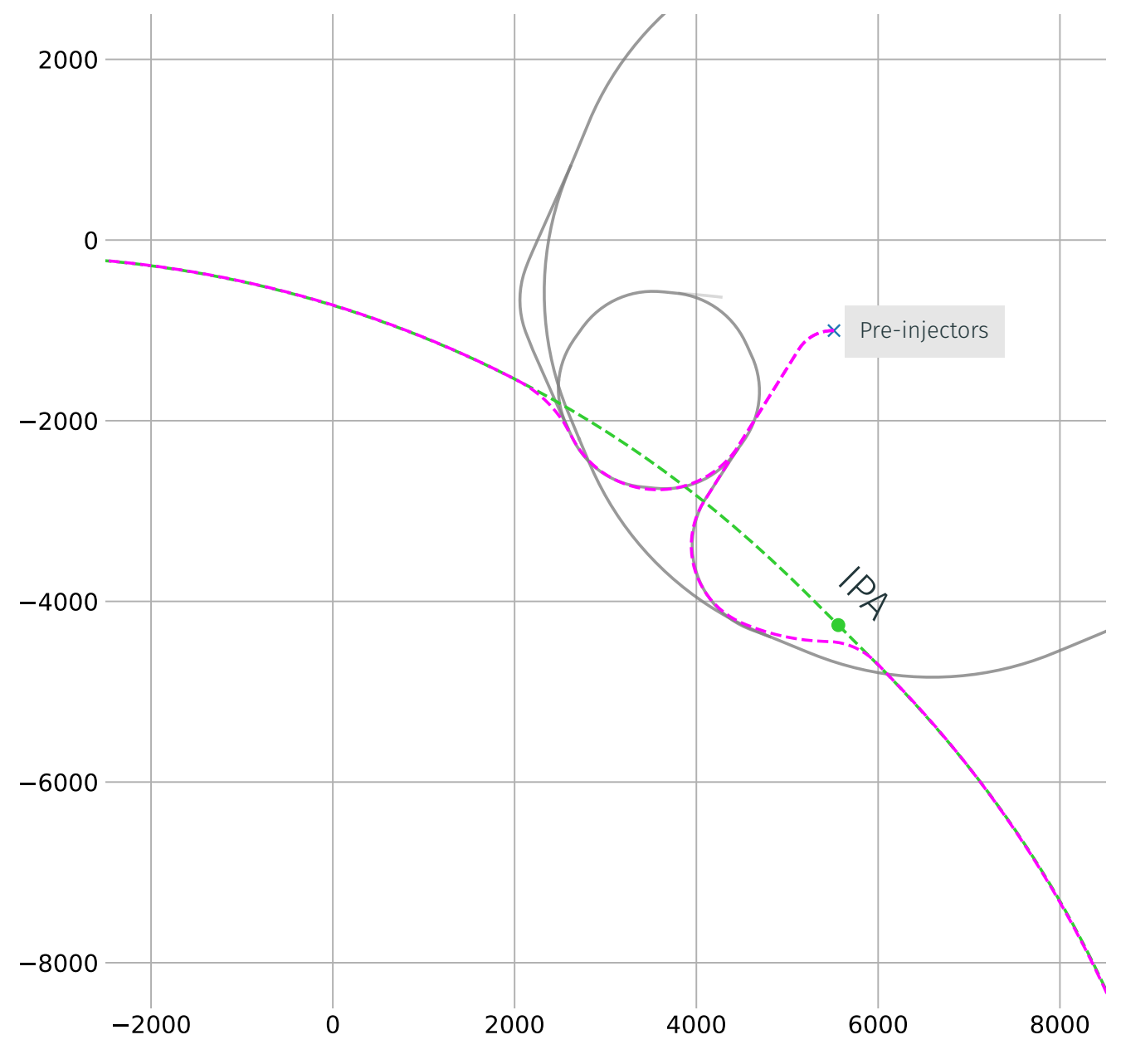


# FCC ee lines compatible with hadrons from SPS



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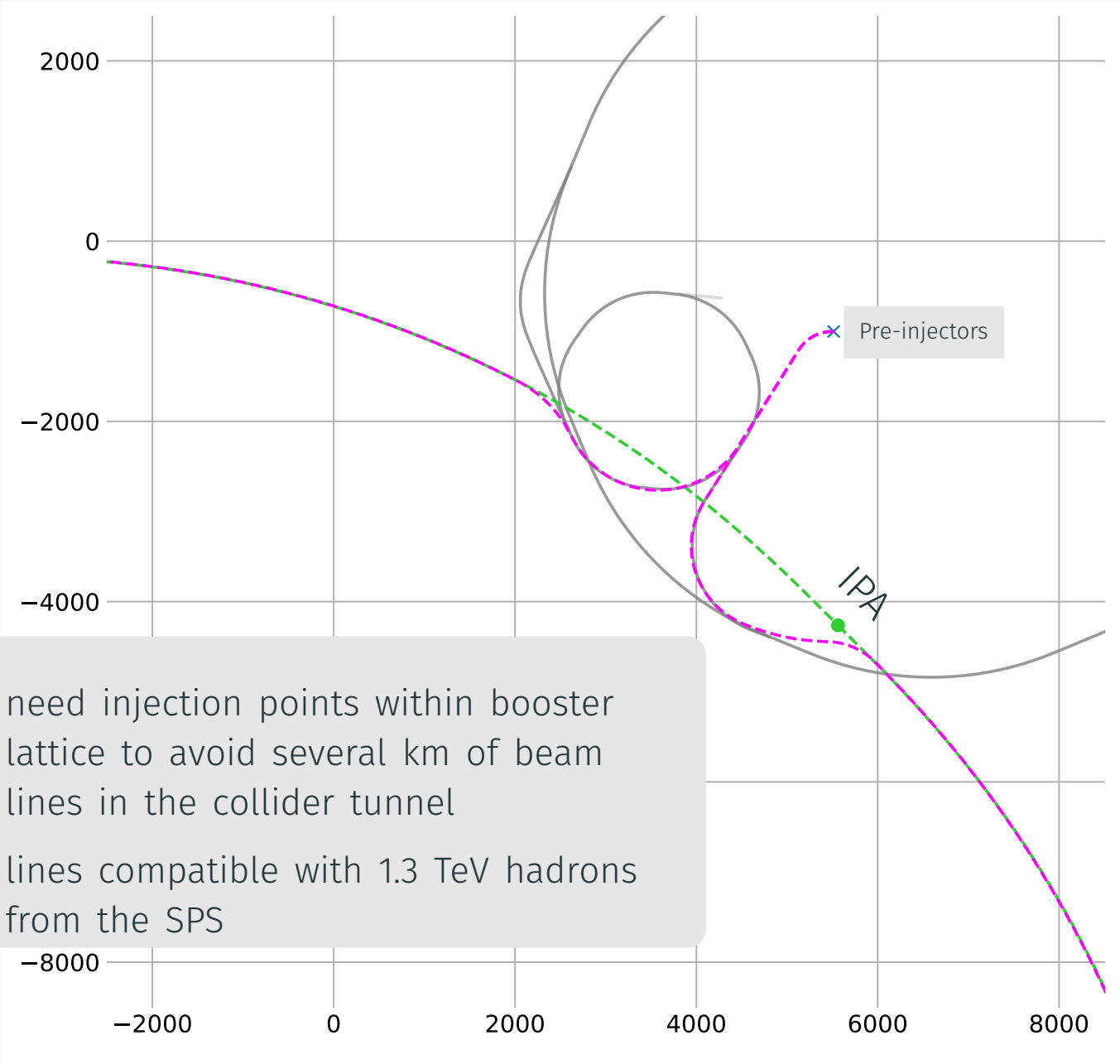
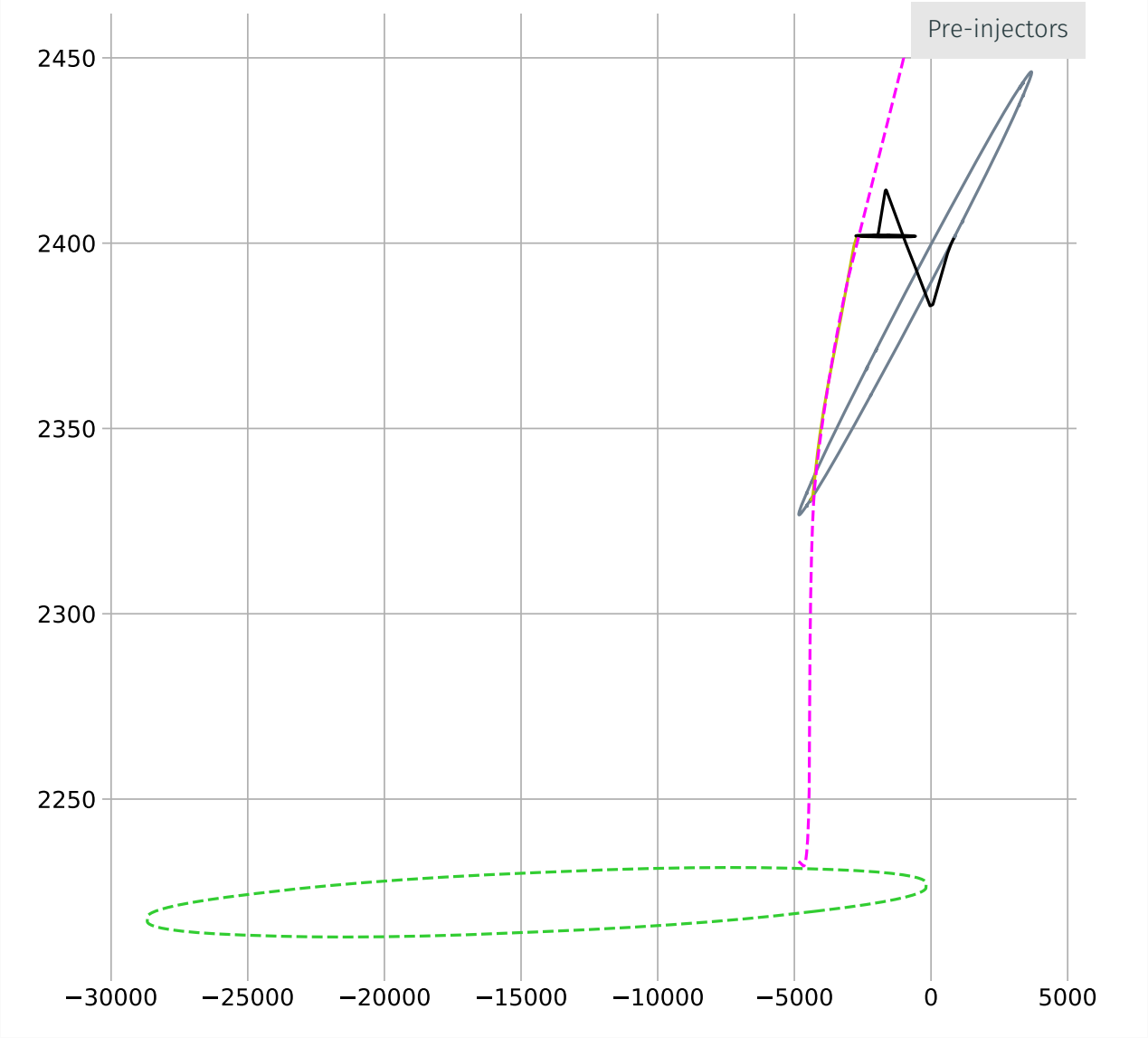



- need injection points within booster lattice to avoid several km of beam lines in the collider tunnel
- lines compatible with 1.3 TeV hadrons from the SPS

# Side view of transfer lines



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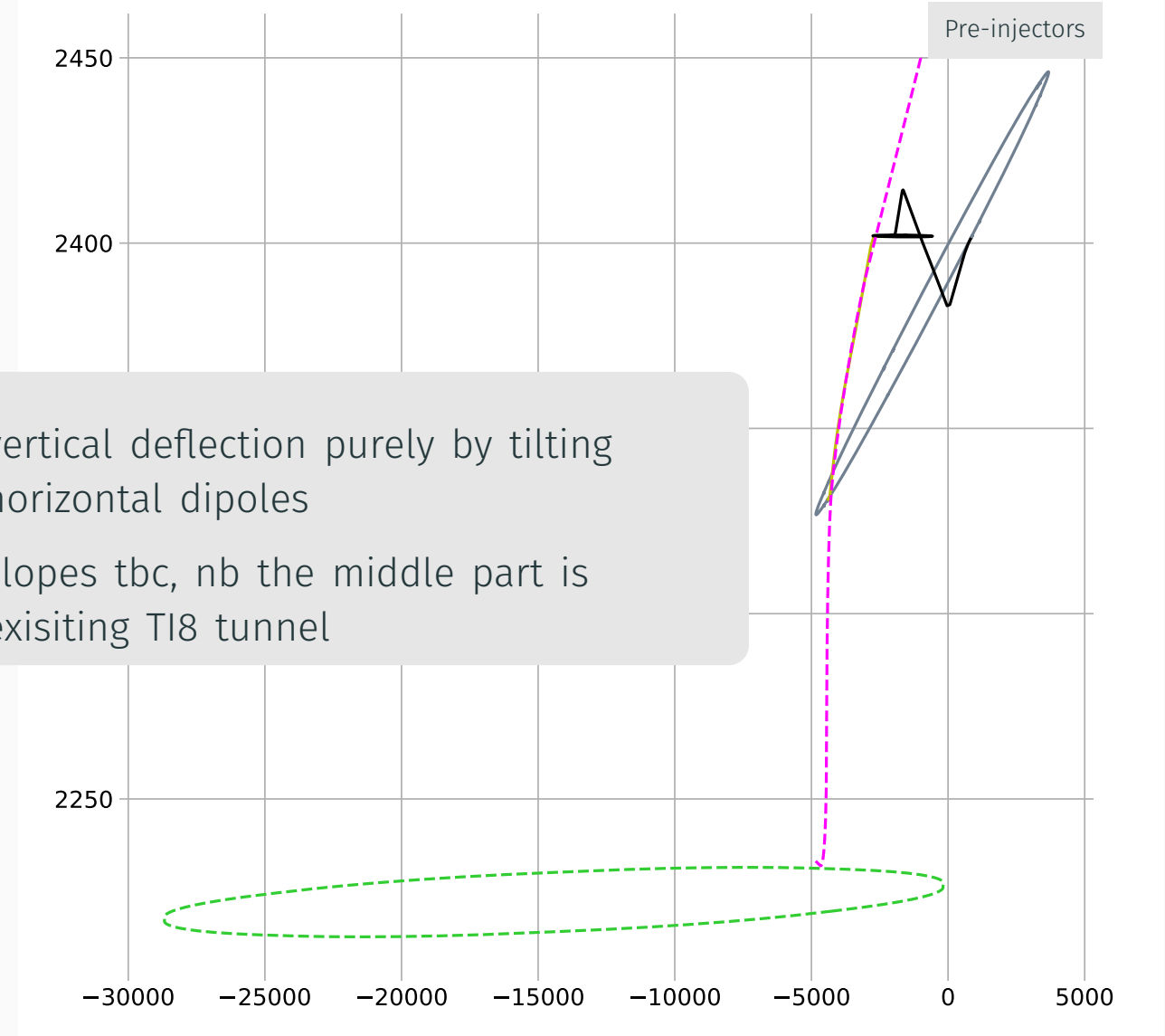
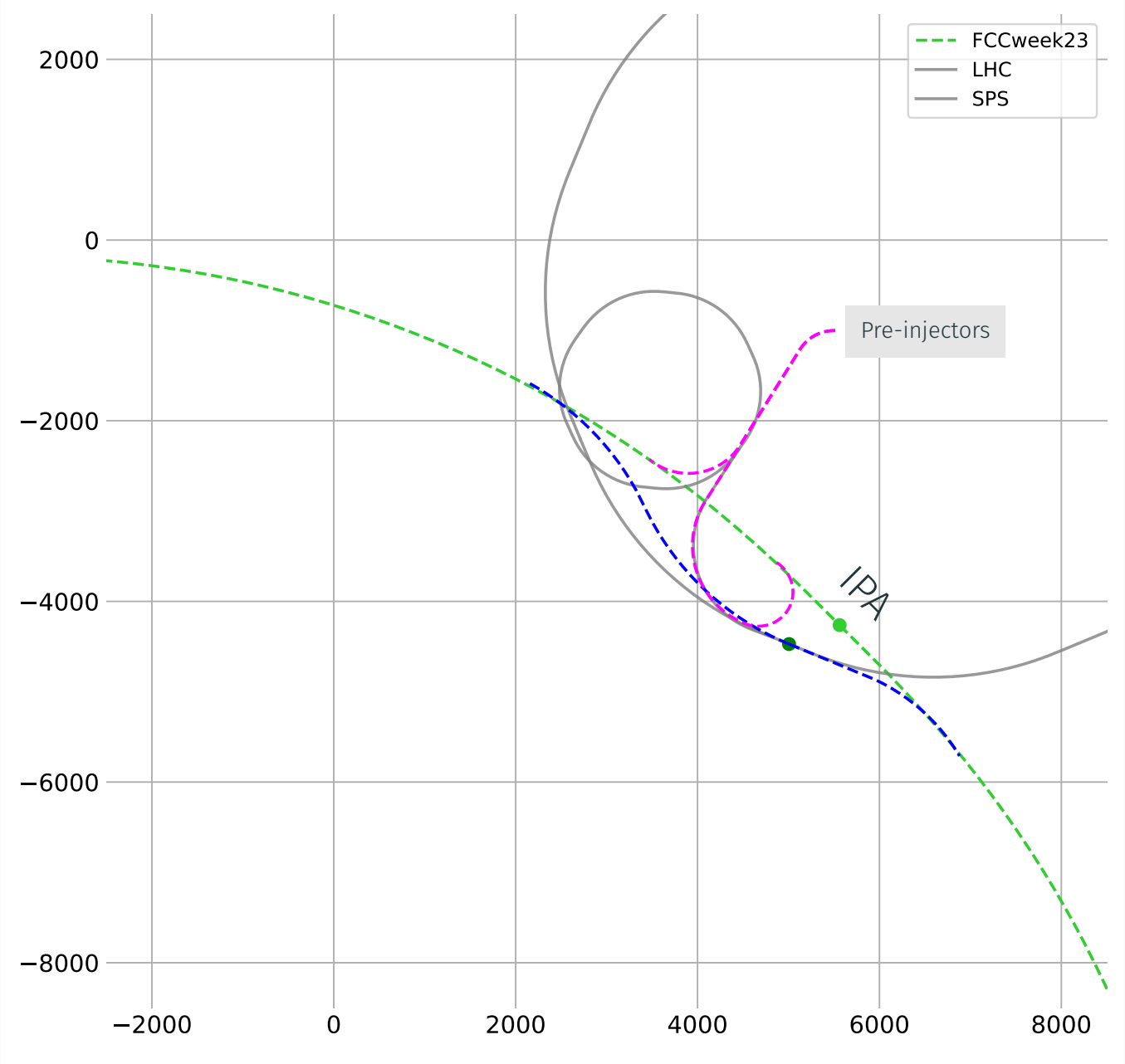



- vertical deflection purely by tilting horizontal dipoles
- slopes tbc, nb the middle part is exisiting TI8 tunnel

# FCC ee lines compatible with hadrons from LHC



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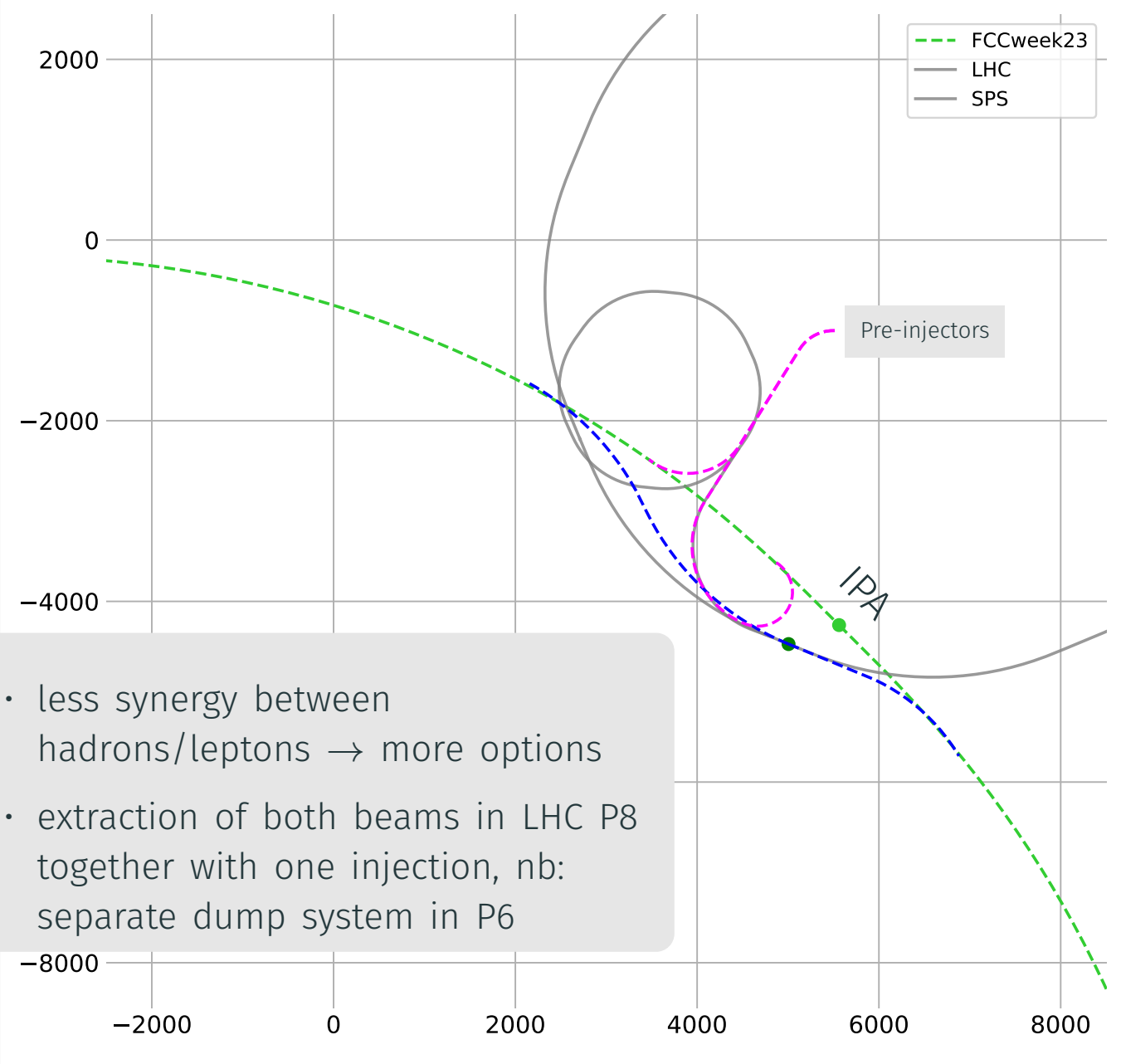


- less synergy between hadrons/leptons → more options
- extraction of both beams in LHC P8 together with one injection, nb: separate dump system in P6

# Summary table

| SPS[1] | TL length[2] [km] | tunnel length [km] | SR en. loss [MeV]/spread | Comments |
|---|---|---|---|---|
| Common line | 1.7 | 1.7 | -/- | electromagnets with polarity reversal |
| SPS-LSS4 to PB | 4.4 | 1.8 | 16/8e-4 | Uses existing TI8 tunnel (3 km) |
| SPS-LSS4 to $PL_{SPS}$ | 3.6 | 0.9 | 14/8e-4 | Feeding line for 2.3 km through SPS tunnel; Cross talk with SPS proton machine? |
| SPS-LSS4 to $PL_{uturn}$ | 3.8 | 1.0 | 34/9e-4 | Backup in case SPS can't be used; via TI8 tunnel; No synergy with hadrons |
| SPS-LSS4 to $PL_{direct}$ | 1.4 | 1.1 | 14/8e-4 | Backup in case SPS can't be used; direct connection from SPS-LSS4 down to collider; No synergy with hadrons |

[1] lepton lines compatible with 1.3 TeV hadron lines from scSPS

[2] For the lenghts of transfer line, 5 cells are assumed inside the collider tunnel to reach the injection point, exact value tbc

[3] lepton lines compatible with 3.3 TeV hadrons beams from LHC

# Summary table

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| LHC[3] | TL length [km] | tunnel length [km] | SR en. loss [MeV]/spread | Comments |
|---|---|---|---|---|
| Common line | 1.7 | 1.7 | -/- | electromagnets with polarity reversal |
| PB | 4.5 | 1.9 | 15/8e-4 | Uses existing TI8 tunnel (3 km) |
| SPS-LSS4 to $PL_{uturn}$ | 3.8 | 1.0 | 34/9e-4 | via TI8 tunnel; No synergy with hadrons |
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[1] lepton lines compatible with 1.3 TeV hadron lines from scSPS

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[3] lepton lines compatible with 3.3 TeV hadrons beams from LHC

# Energy compression

- Assuming need for energy compression for both e+/e-
- From first arc get r56 of 2.6 m from geometry
  - Here both beams still passing, also technical integration of compressor cavities probably better around SPS straight section than in the tunnel
- We also get close to 1 permille of energy spread from the line $\rightarrow$ tbd if acceptable for booster momentum acceptance or if second compression needed at the end of the line
- r56 from arcs hardly tunable, if needed, a dedicated chicane needs to be designed

# Conclusions

- Transfer lines have been optimized for re-using existing tunnels as much as possible and for compatibility between leptons and hadrons
- There is also synergy for the lepton injection options of 20 GeV linac or 16 GeV SPS
- Injection into the booster lattice should happen in the arc to avoid extensively long transfer line (reduce length by 2/3) which seems feasible from discussions during this week
- Energy compression can be included in the transfer line, most elegantly by using the r56 from the arcs - looks feasible, details to be confirmed between linac and booster constraints
- Upcoming
  - prepare cost lines for all required equipment
  - further optics studies on cell adaption, dispersion matching, energy compression and injection
  - specificaton of TL HW to enter into the engineering phase, in particular for magnets