FCC-ee injector complex siting and transfer lines

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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 Prevessin 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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Courtesy T. Watson

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Depth of injector complex to be defined wrt radiation constraints

Courtesy T. Watson

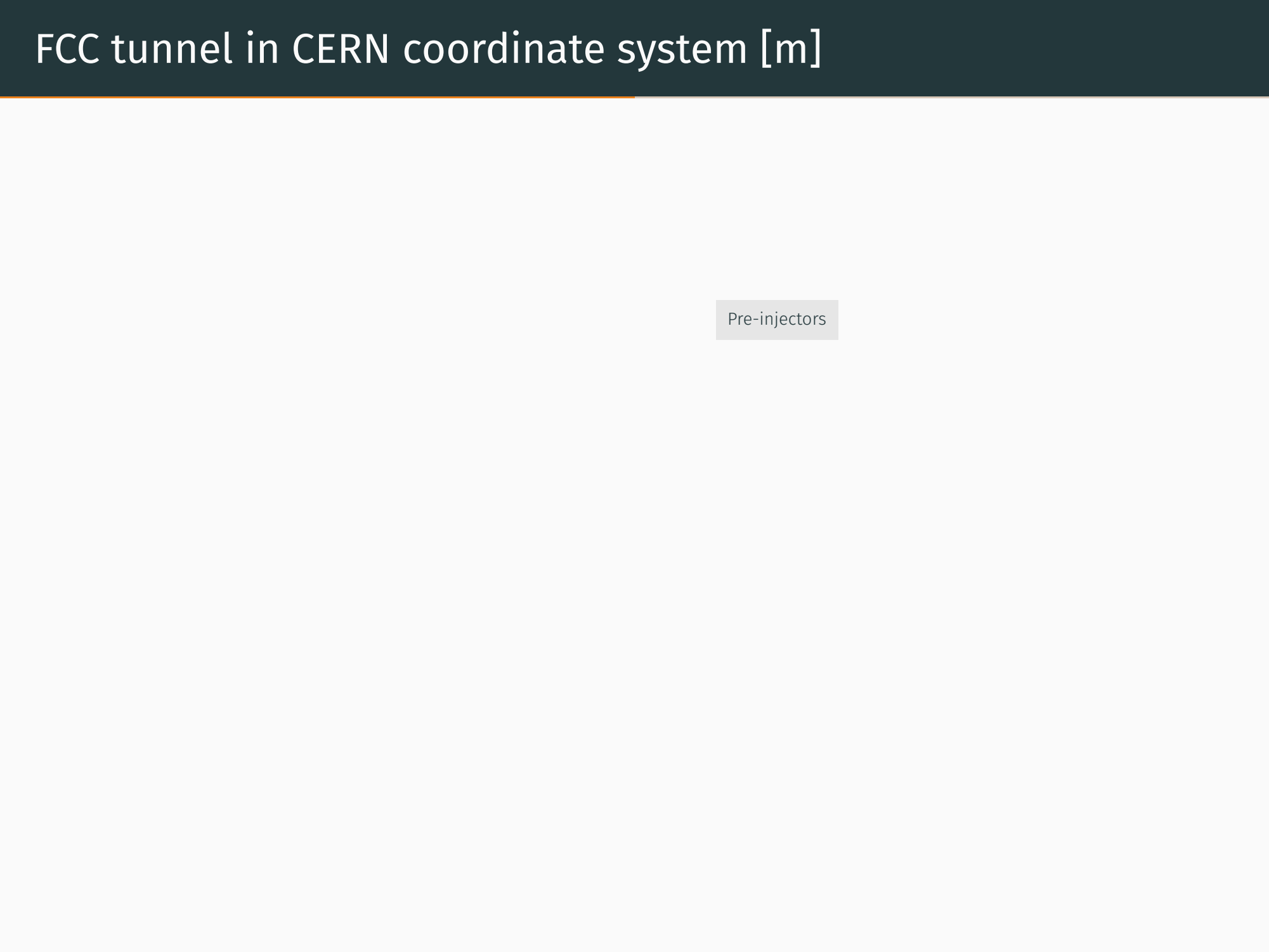
Cell design of transfer lines

- 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

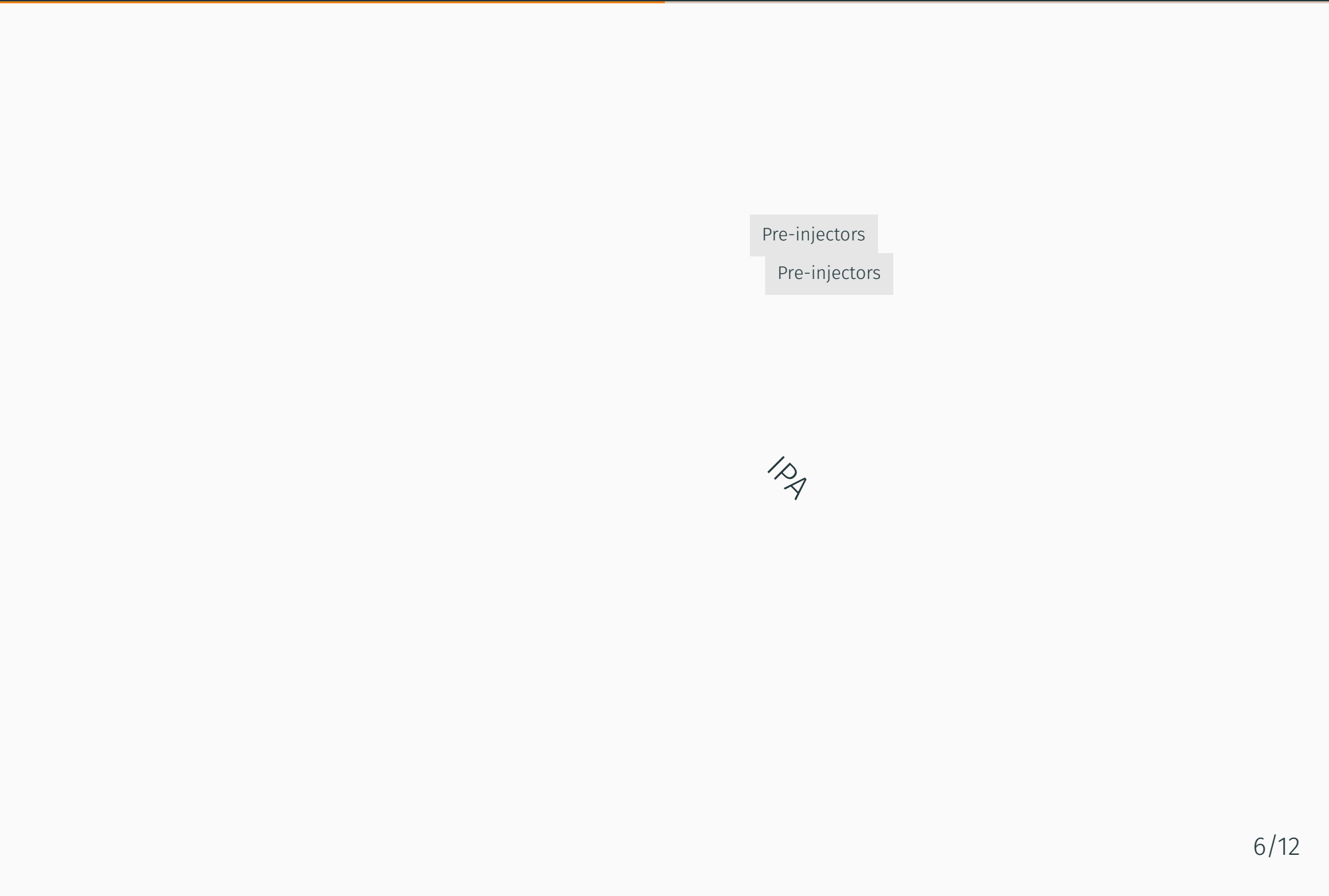
Disclaimer

- 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

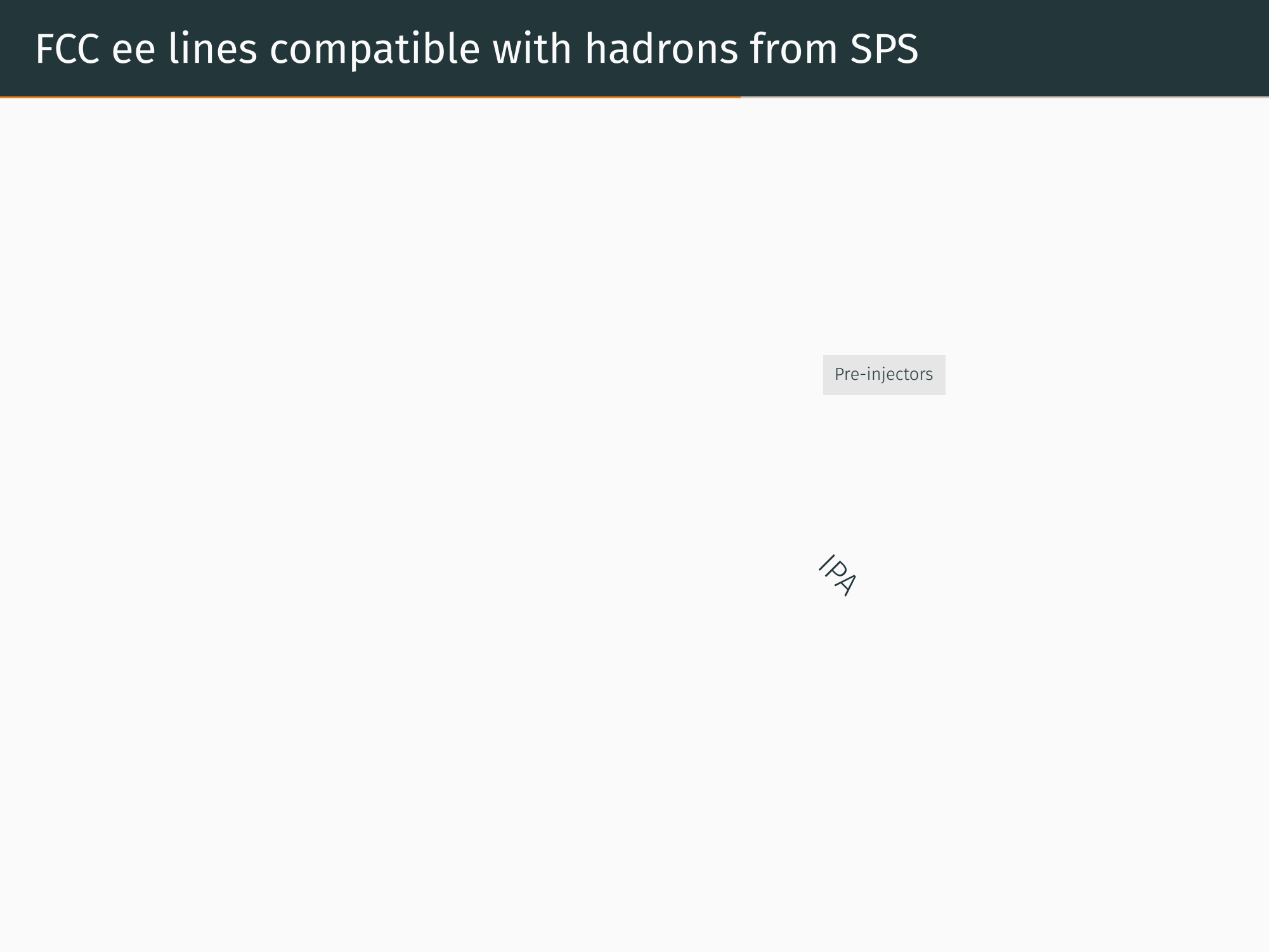
FCC tunnel in CERN coordinate system [m]



FCC tunnel in CERN coordinate system [m]



FCC ee lines compatible with hadrons from SPS



FCC ee lines compatible with hadrons from SPS

- 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

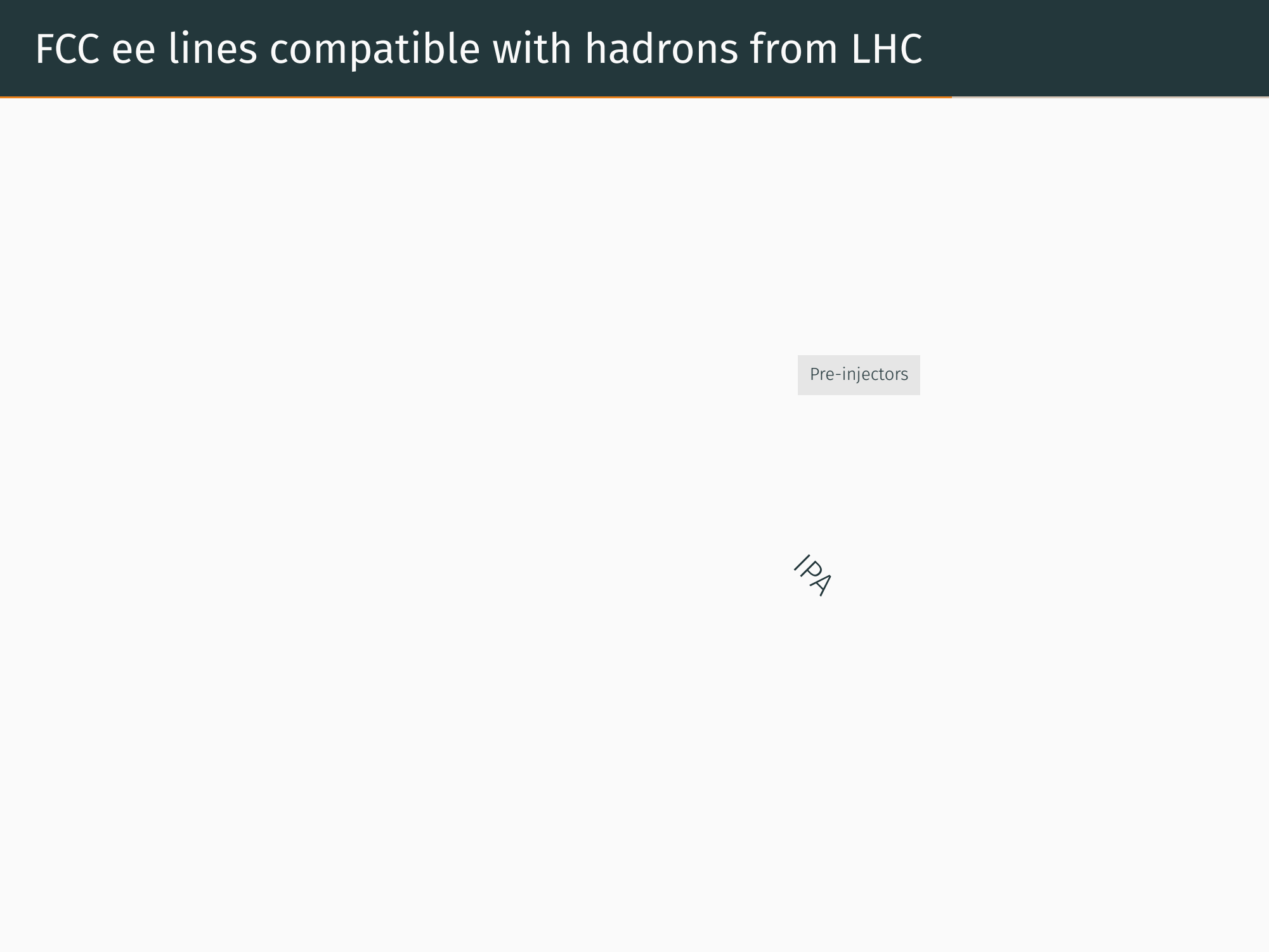
Pre-injectors

Side view of transfer lines

Pre-injectors

- 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



FCC ee lines compatible with hadrons from LHC

- 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[illegible]	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[illegible]	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[illegible]	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

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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[illegible]	3.8	1.0	34/9e-4	via TI8 tunnel; No synergy with hadrons
SPS-LSS4 to PL[illegible]	1.4	1.1	14/8e-4	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

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 *!* 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