FCC injection lines for ee and hh

Connecting the pre-injector complex at surface level to the collider tunnel

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FCC week, 5-9 June 2024, San Francisco

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- Pre-injector complex siting
- Transfer lines to the collider tunnel
- Hadron injectors
- Next steps to Feasiblity Study Report

Pre-injector complex

- Recommendation from MTR to reduce pre-injector complex' power consumption $\rightarrow$ lower accelerating gradients resulting in longer HE-Linac and higher energy DR with larger dimensions

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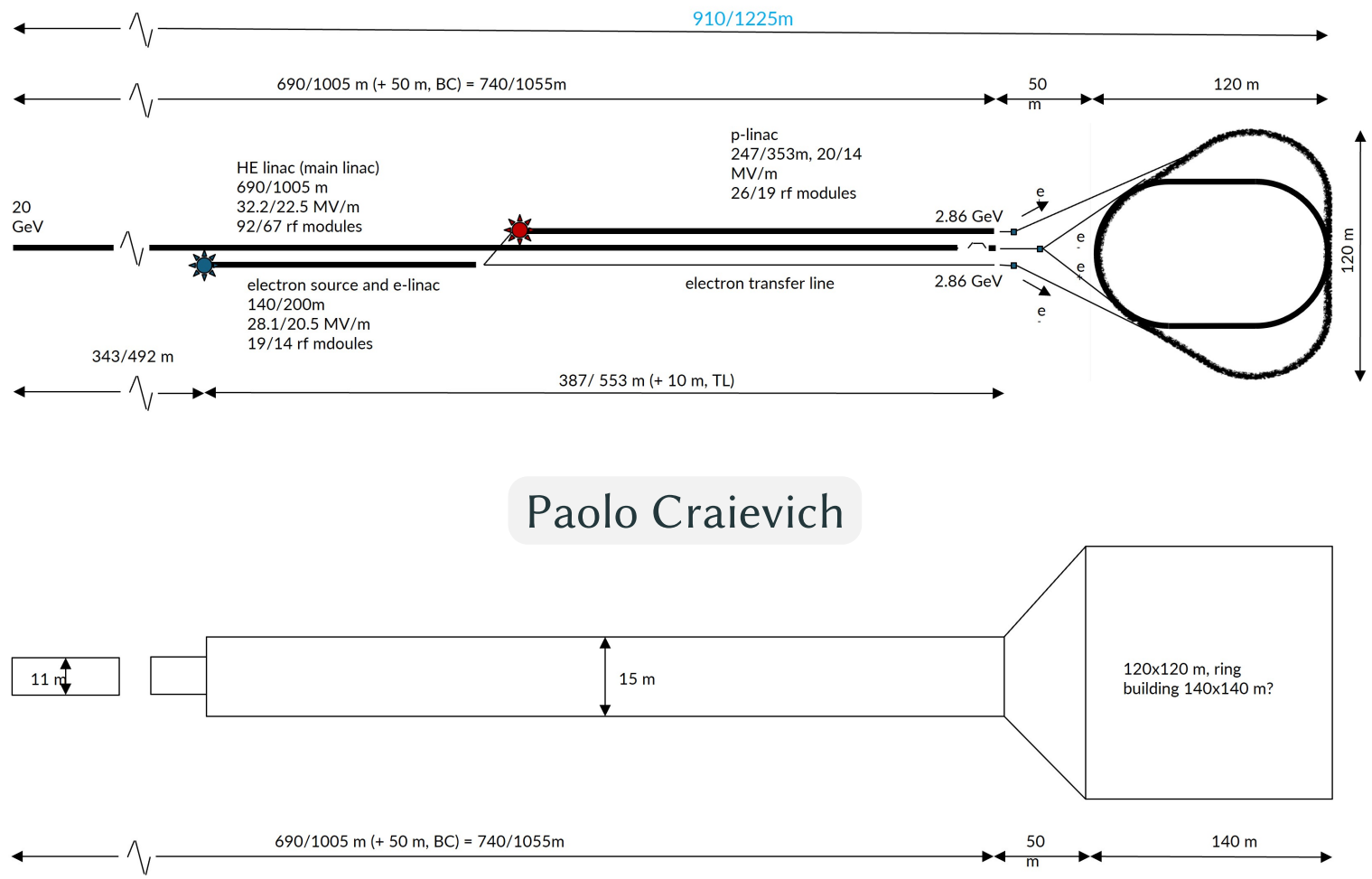
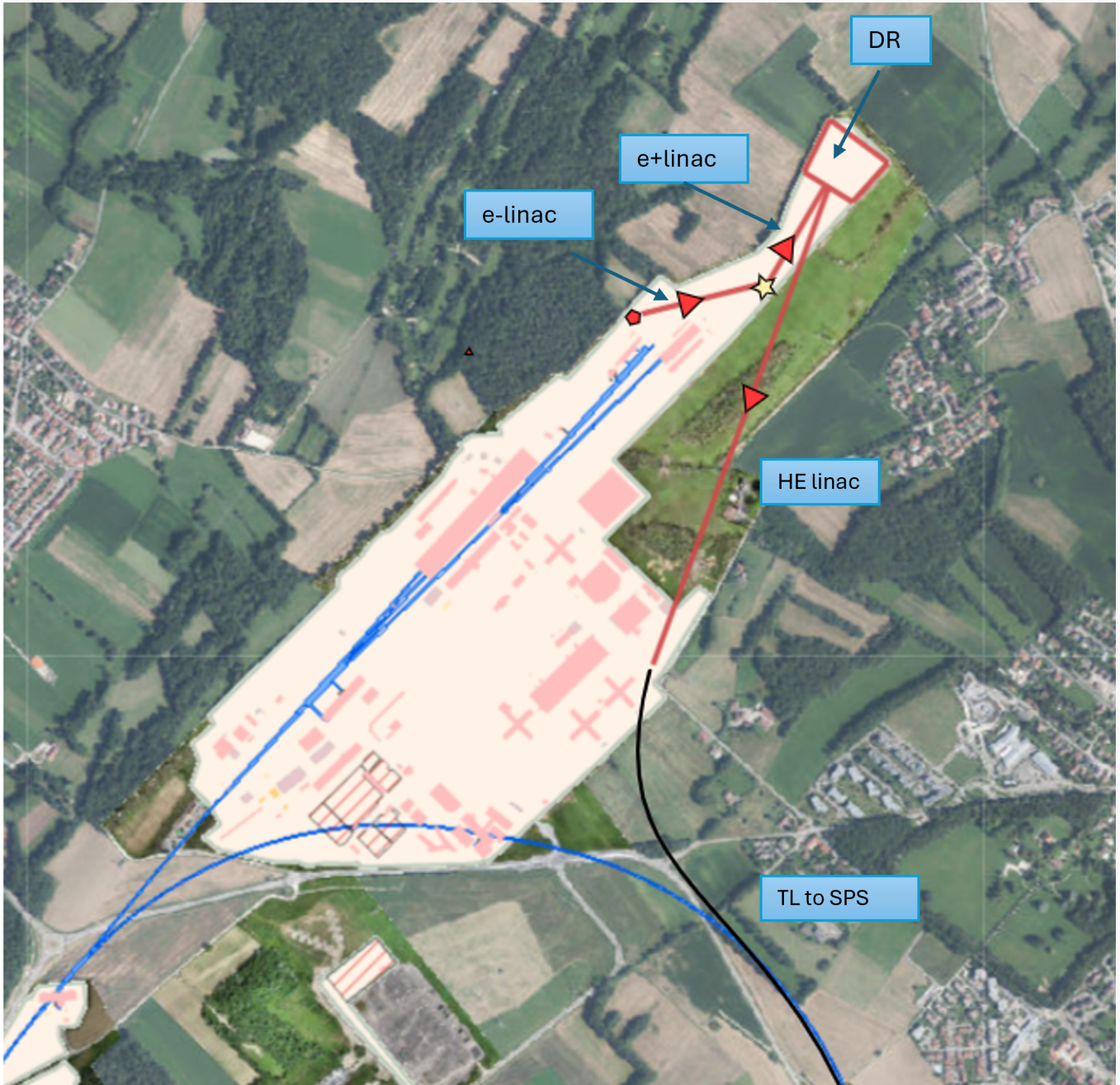
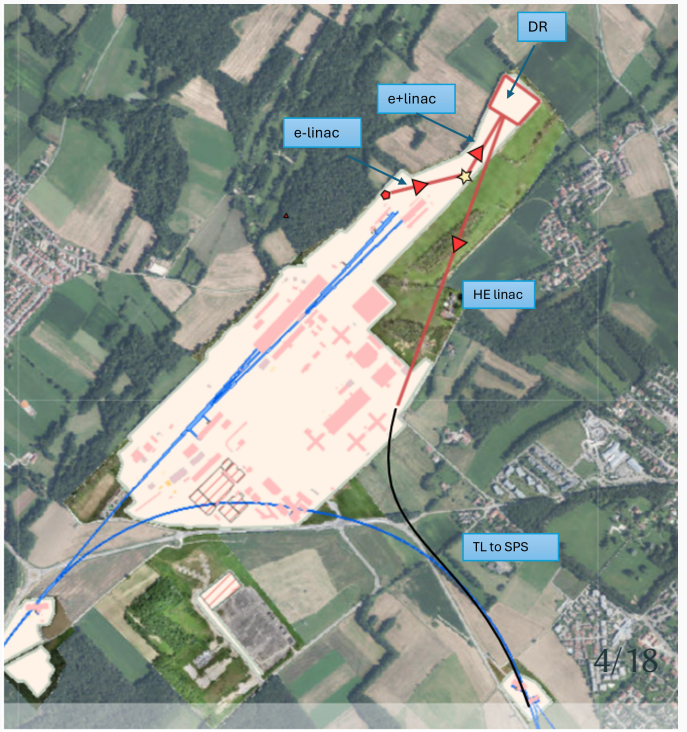


Pre-injector complex siting

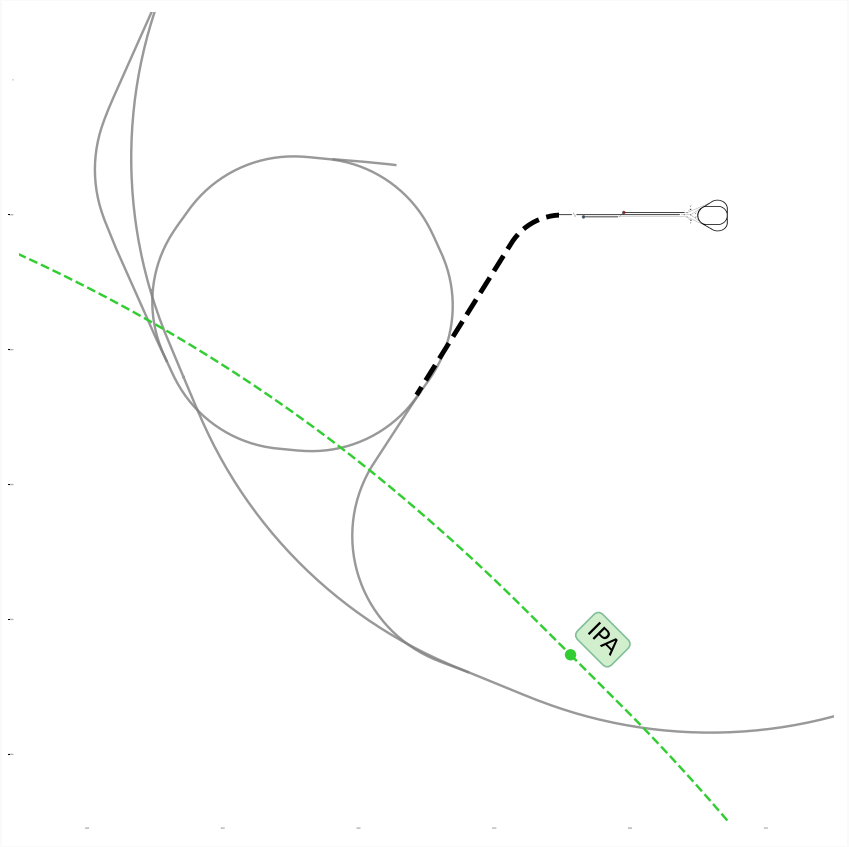


Pre-injector complex siting

- Bldg size inside CERN fence: 130m, 165m, 120m, 130m → OK for DR
- e^- source (red polygon) and linac 200 m from downstream end of NA to e^+ target (yellow star)
- Positron linac 350 m to DR with electron line in parallel
- HE Linac with length of 1150 m (incl. energy compressor), starting on surface, tbd
- Would probably dig a trench and build separation between linac and klystrons, tbc wrt radiation requirements.
- Linac tunnel inclined downwards with slope of 2% reaching a depth of 20m at Linac end
- Depth at the fence after 200m is 4 m
- Linac tunnel end is again below fenced land, for eg ventilation shaft
- 400 kV line pillars to be avoided
- TL to SPS straightforward (black line)



Common lepton line from pre-injector complex to SPS-LSS4



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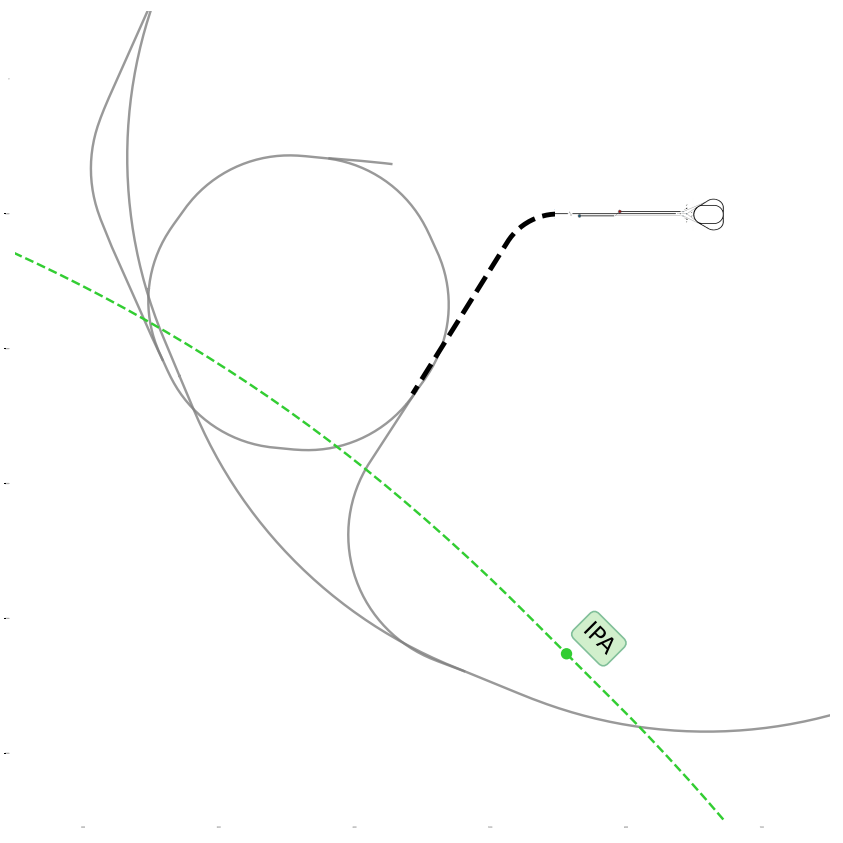

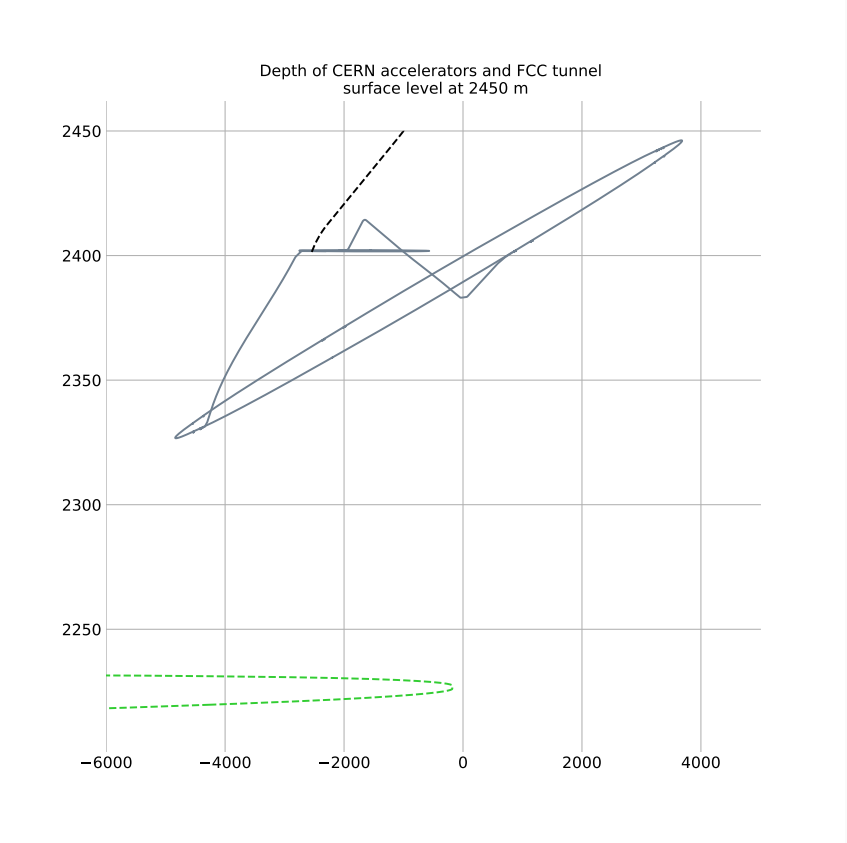

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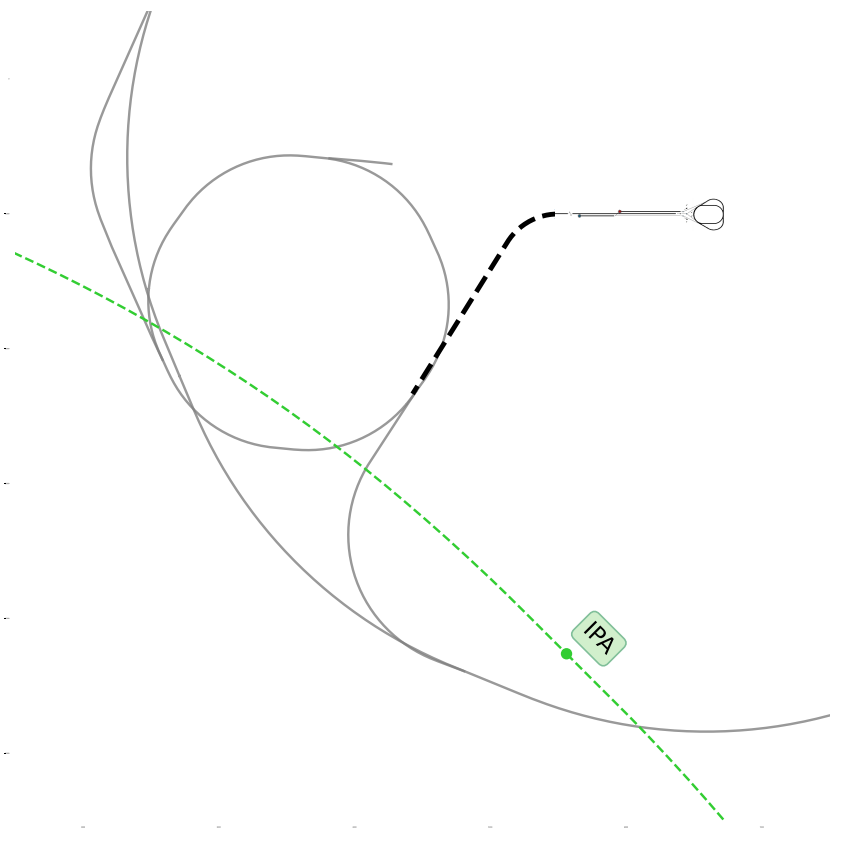
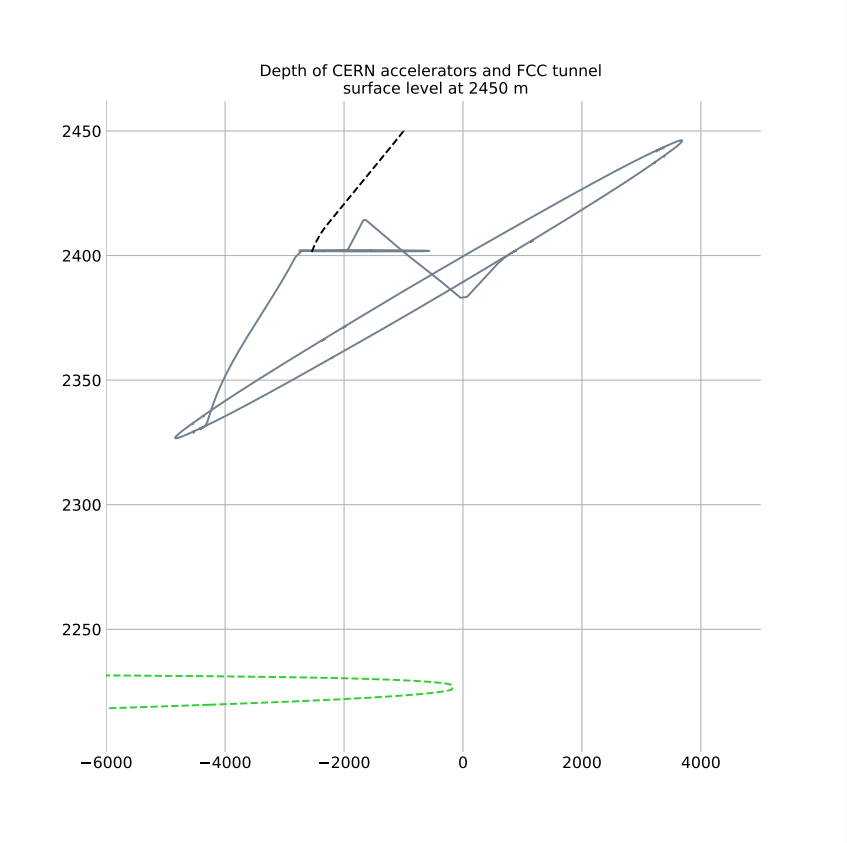
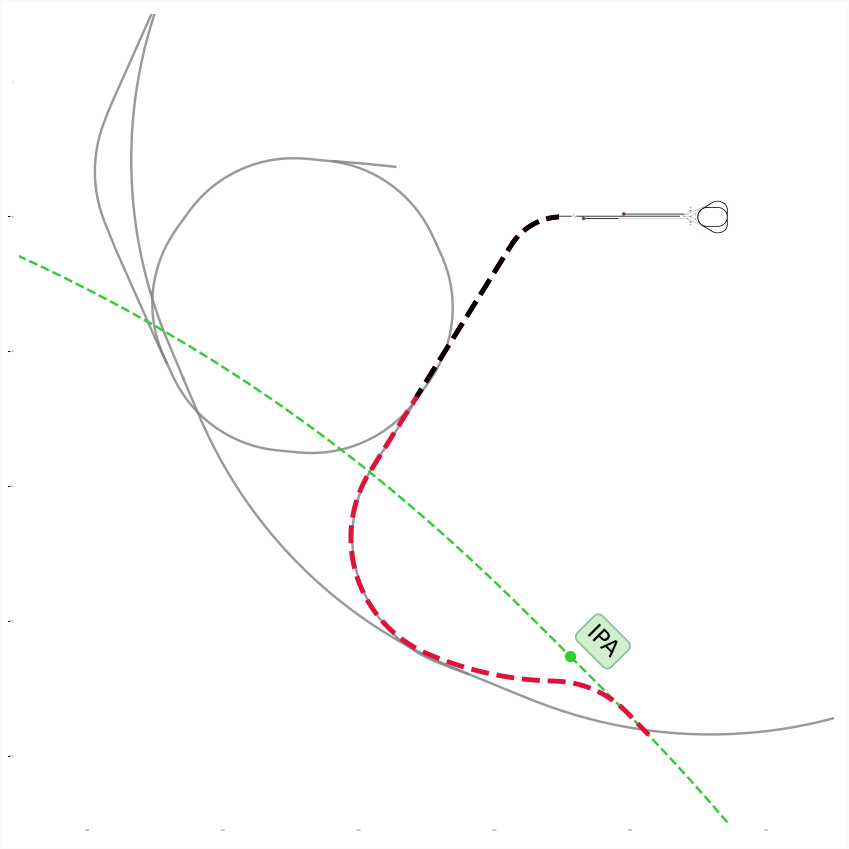




Height diff $\approx$ 230 m between pre-inj complex at surface and FCC tunnel

$\rightarrow$ TLs in the following limited to 6% slope (transport, safety)

SPS-LSS4 to FCC clockwise injection (positrons)



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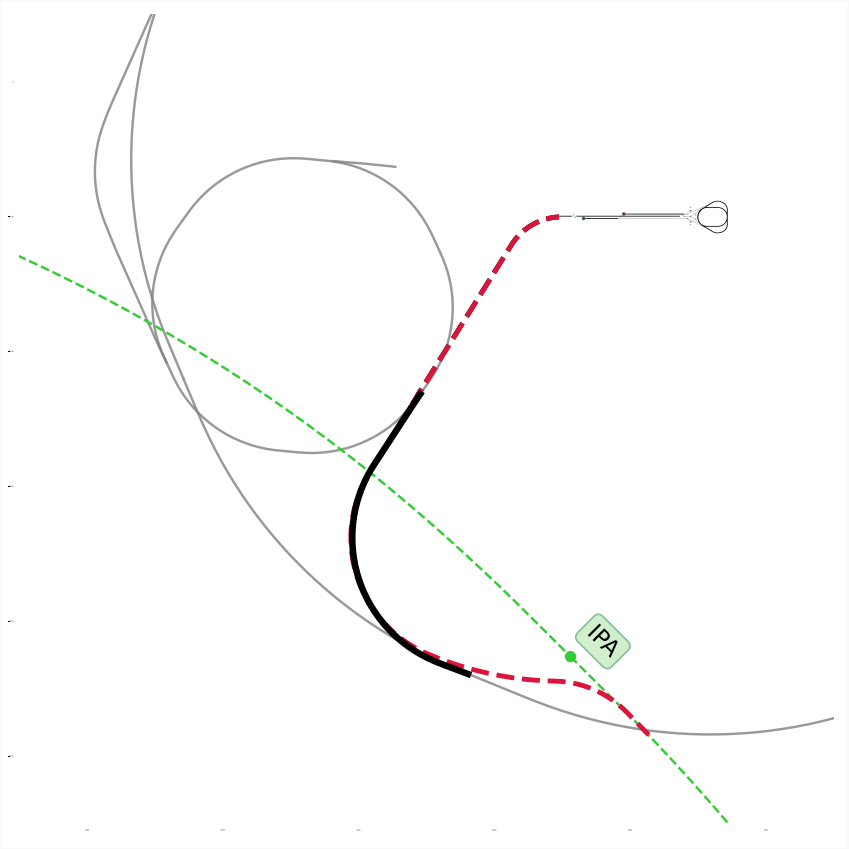
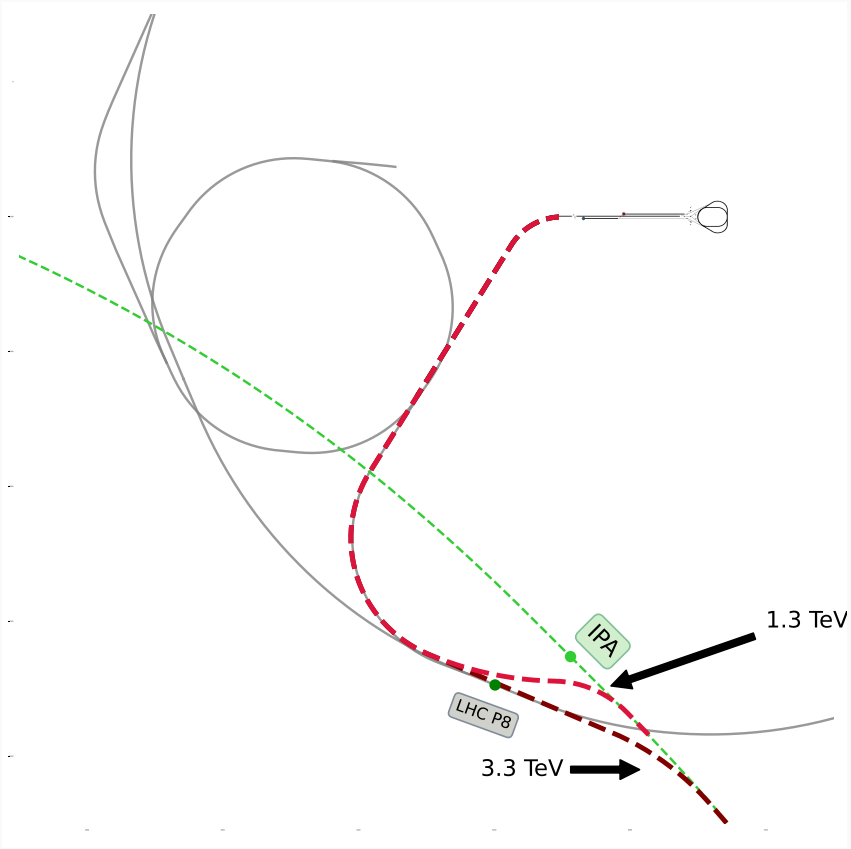


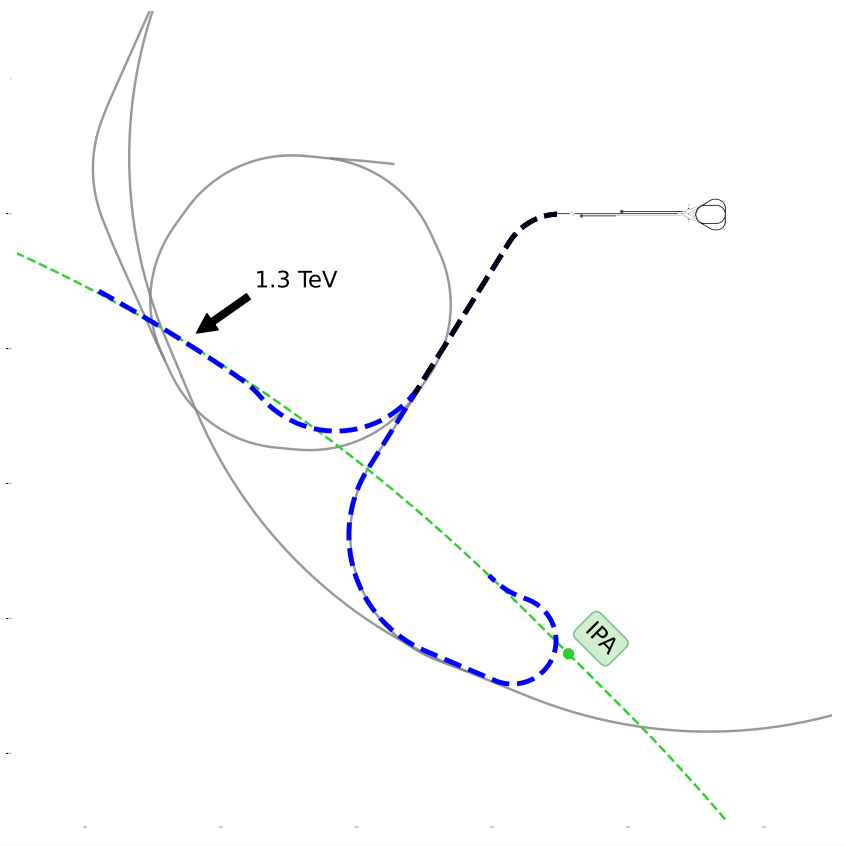
- Using existing TI8 tunnel (presently used for SPS-LHC B2 transfer) allows to reduce new tunneling by 2.6-3 km
- Need 1.8 km of new tunnel to connect to FCC
- TL radii compatible with 1.3 TeV hadrons from SPS

SPS-LSS4 to FCC clockwise injection (positrons)



- Using existing TI8 tunnel
- Need new 1.8 km tunnel to connect to FCC for 1.3 TeV hadrons compatible option
- With new 1.9 km tunnel out of LHC-P8 can transfer also 3.3 TeV hadrons

SPS-LSS4 to FCC anti-clockwise injection (electrons)

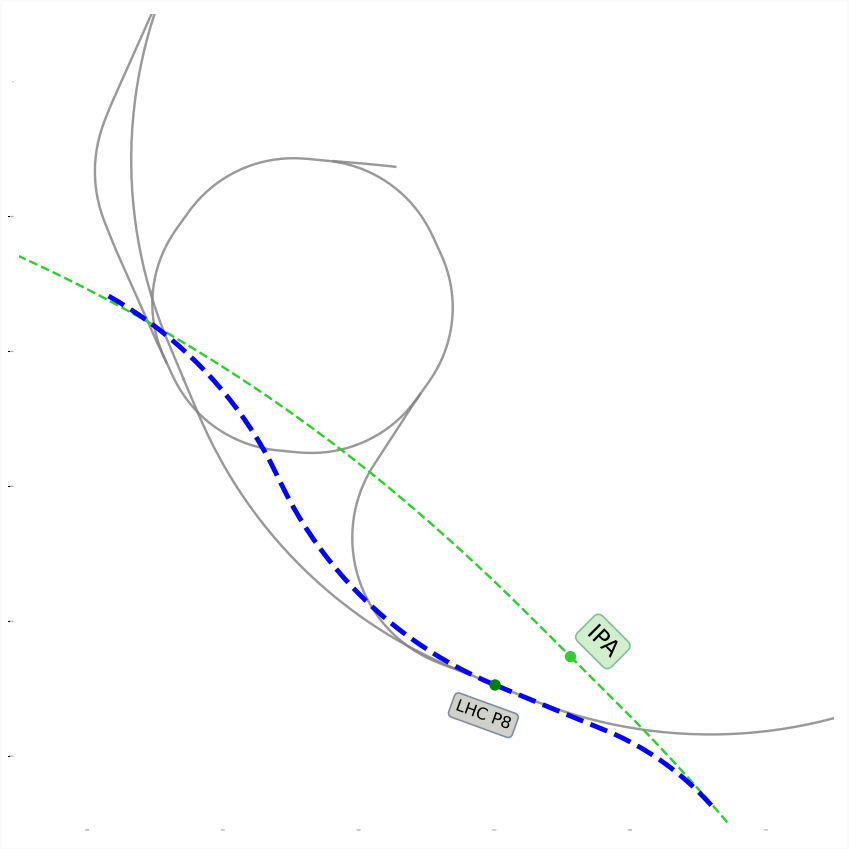


- Two options:
- direct from LSS4 via a 2.8 km long tunnel, injection into the booster arc cells (studied, see talk S. Yu)
- u-turn tunnel of 1.9 km branching off from TI8 ; injection at the end of the IPA LSS needs careful integration check wrt detector dimensions

$\rightarrow$ sharper turn of u-turn option creates more SR but difference in energy loss and spread not relevant

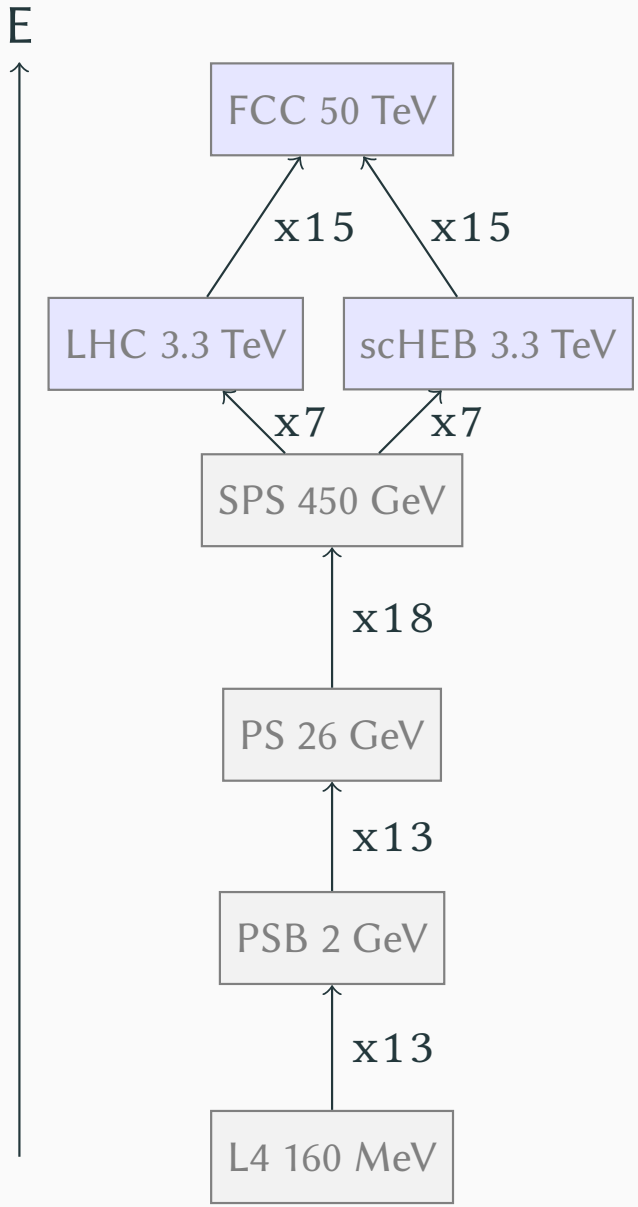
$\rightarrow$ direct option allows for 1.3 TeV hadrons at the expense of constructing additional 1 km of tunnel

FCC-hh transfer lines from LHC tunnel



- tunnel from LHC P8 to FCC clockwise injection can be re-used from positron injection - if this option is chosen for positrons
- injection of anti-clockwise hadron beam needs completely separate tunnel from leptons

Chain options



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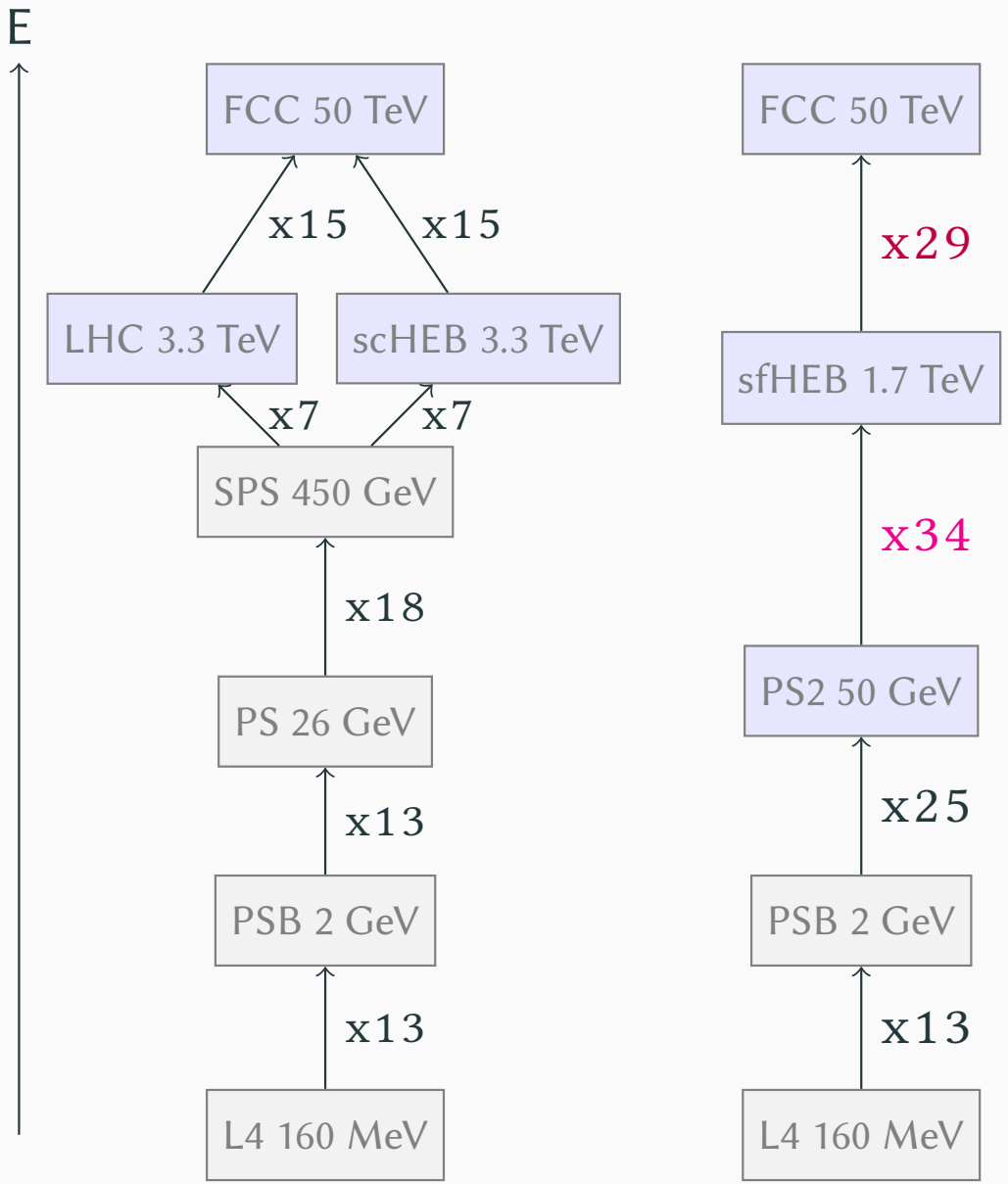

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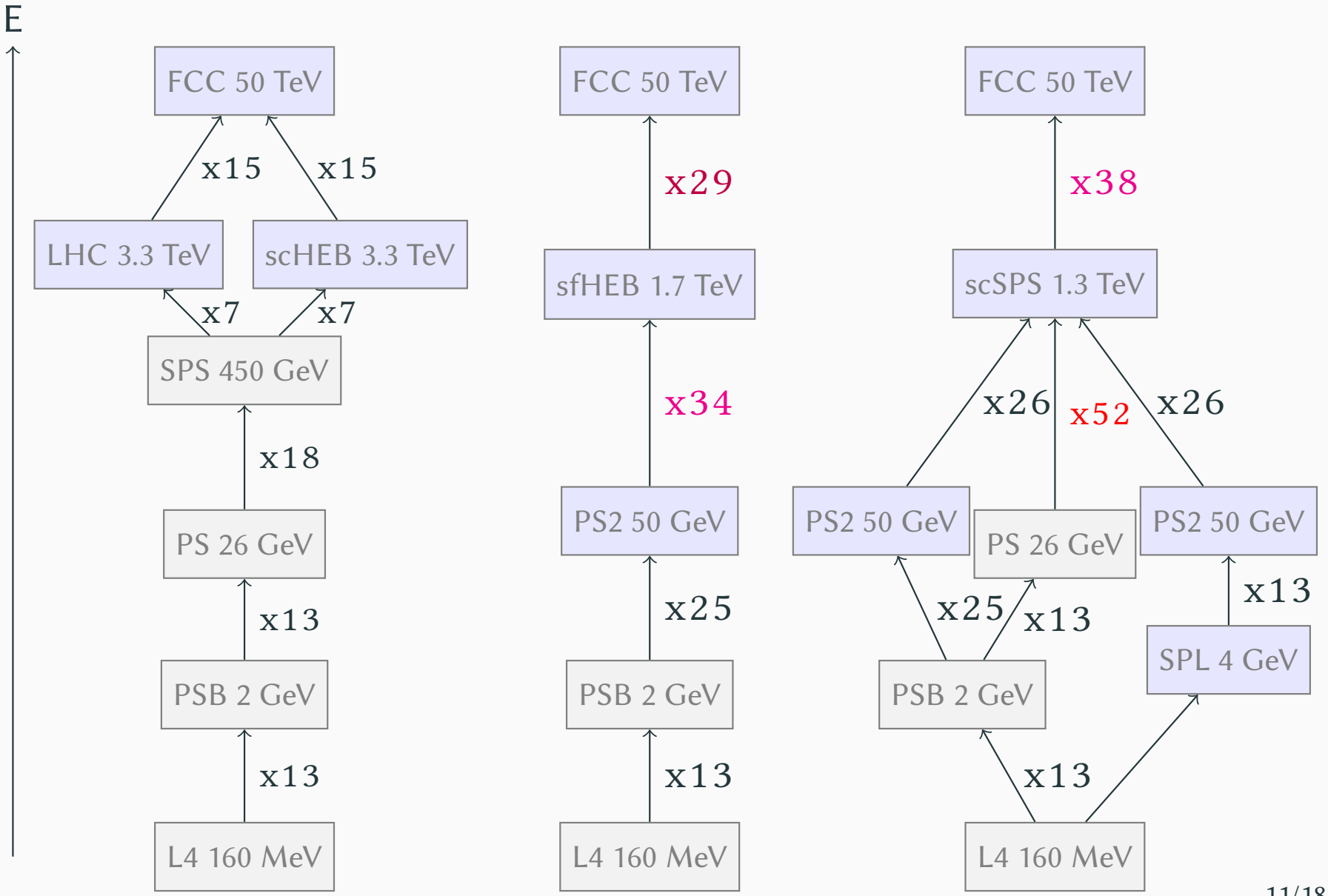


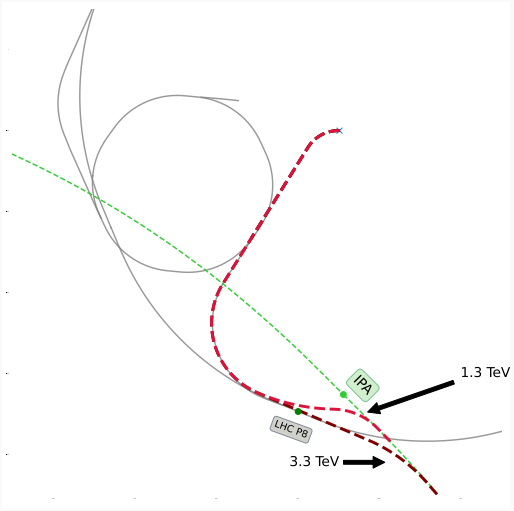
Hadron injectors and TL down selection

Collider injection energy choice crucial for injectors and transfer lines but likely not taken before 2040ies $\rightarrow$ study several options in parallel:

- scLHC: new superconducting 3.3 TeV machine in LHC tunnel
- sfLHC: superferric 1.7 TeV machine in LHC tunnel
- scSPS: superconducting 1.3 TeV machine in SPS tunnel
- scPS: superconducting 50 GeV machine in PS tunnel

Additional transfer line tunnels can be built later if present selection doesn't fit - balance between additional investment now for flexiblity between choices or complete rebuild for hh

FCC transfer lines - summary table



	Tunnel [km]	TL length [km]	SR loss/spread [MeV]/[‰]	hadrons compatible	comments
PB-1.3TeV	1.8	5.8	16/0.8	yes, 1.3 TeV	positrons and SPS hadrons
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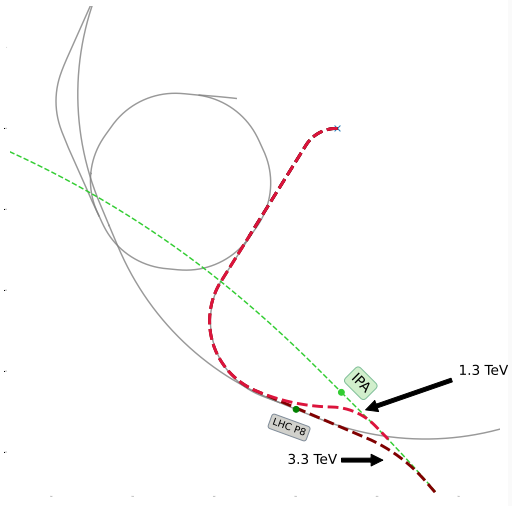

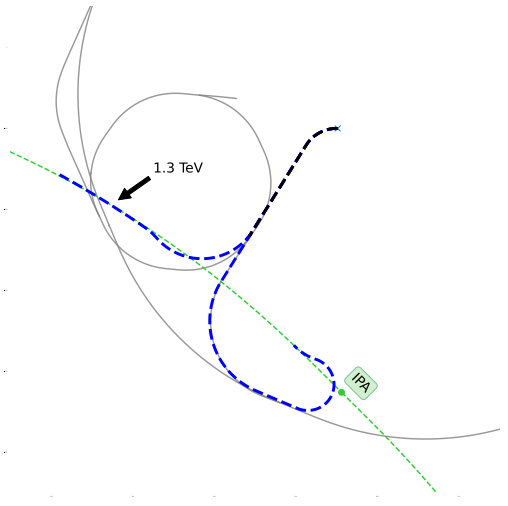

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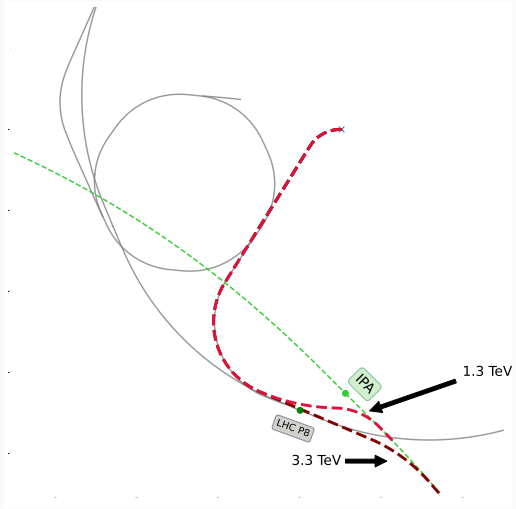

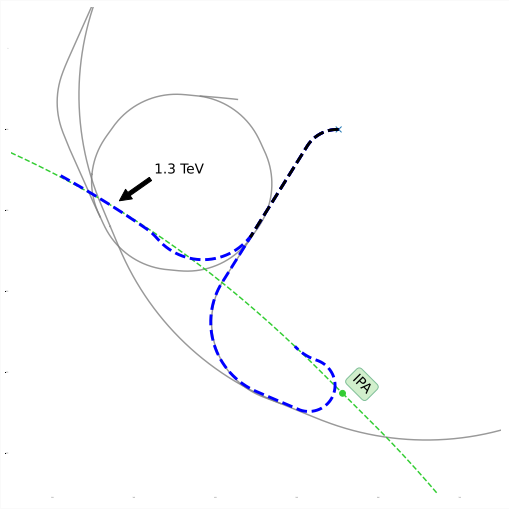

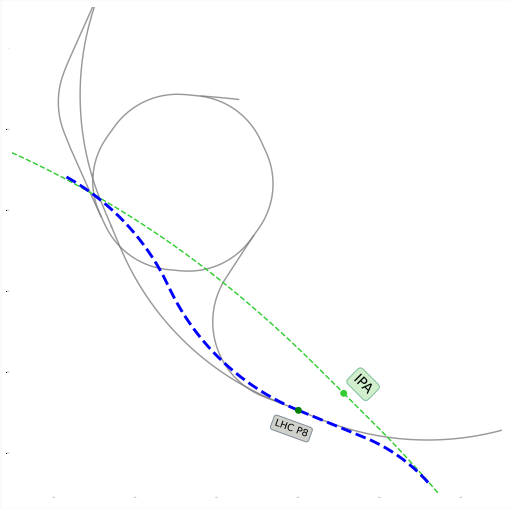

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Line features

- still to be decided if energy compression is needed in the line and where - end of linac with chicane or in SPS-LSS4 using the natural R_{56} from the arc
- preliminary magnet specs established, looking into
  - possibility of using permanent magnets vs electromagnets with polarity switching
  - increasing field and reducing number of magnets in view of cost
- transfer of significant current (5 nC) - check impedance effects and impact on vacuum system
- so far didn't look into transport of polarized beams - should be matter of polarity vector matching and no show stopper

Conclusions

- Pre-injector complex siting being reworked to fit surface buildings within CERN fence - requires HE-Linac diving underground with a 2% slope
- TL options for leptons which differ in tunnel and beam line length (10.3-12.7 km), synergy wrt hadrons and injection into booster arc or LSS
- Next towards Feasibility Study Report
  - Detail new pre-injector complex wrt site implementation, CE, radiation
  - Iterate on TL wrt CE and integration aiming at a down-selection within a few weeks
  - Iterate on magnet system and its cost (main driver)
  - Establish impedance impact on transfer and specify vacuum system, instrumentation and further technical systems

Supplemental material:

transfer line magnet specs

transfer line cell

	Unit	Quadrupoles	Dipoles	Correctors
Total number		422	1266	281
# magnets in common line		74	222	49
Length	m	1	6	tbd
Aperture (diameter)	mm	45	45	45
Gradient	T/m	2	-	-
Field	mT		7 - 200	tbd
Deflection	μrad			O(10)
Field homogeneity		O(1e-3)	O(1e-3)	tbd
Polarity switching time	s	O(1)	O(1)	

Table 1: Summary of magnet specifications.

Back to main.

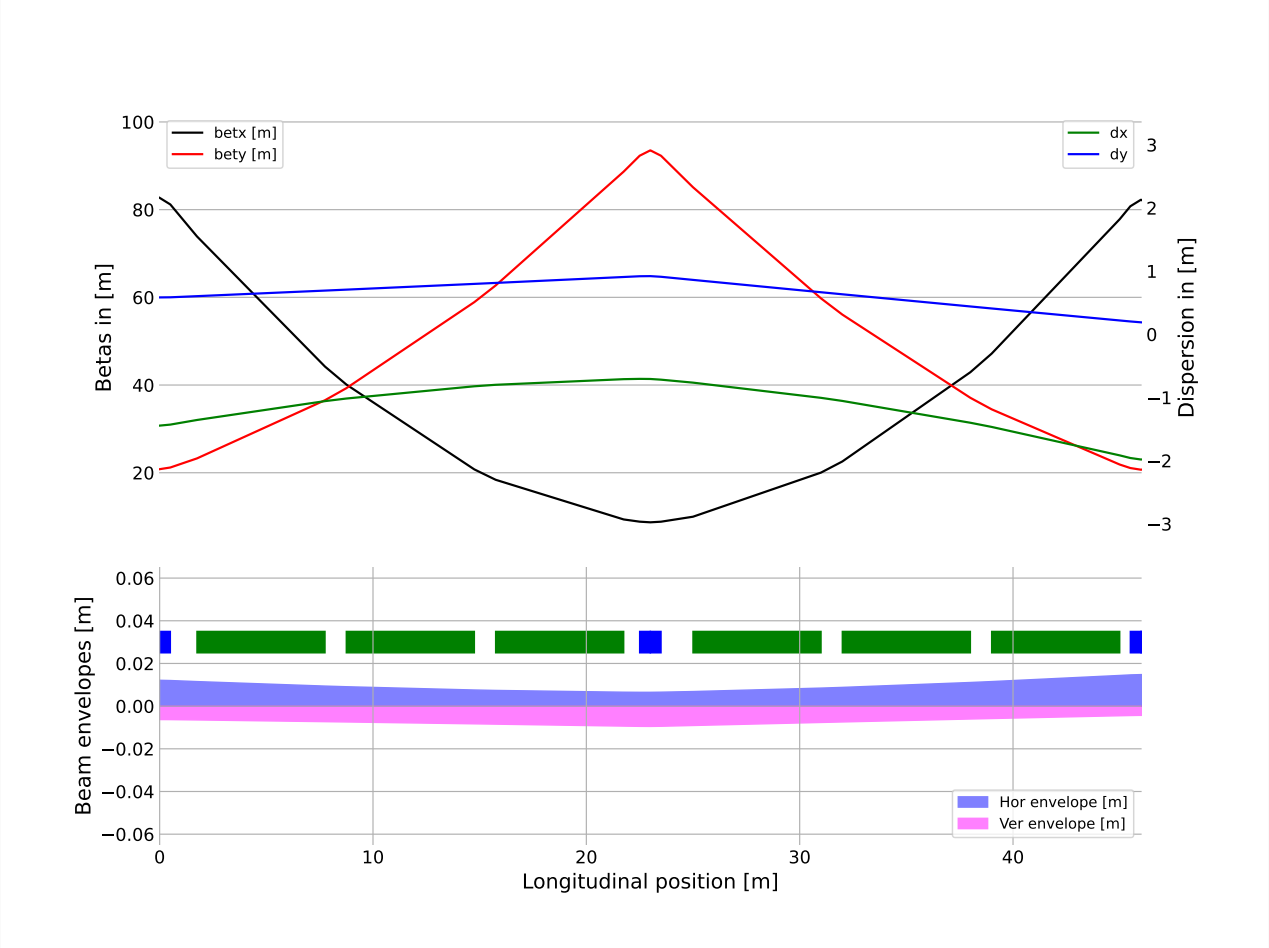

Figure 1: Optics, layout and beam envelopes of periodic FODO cell structure in the transfer lines.

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