FCC-hh layout and optics studies

Massimo Giovannozzi and Thys Risselada
CERN, BE Department
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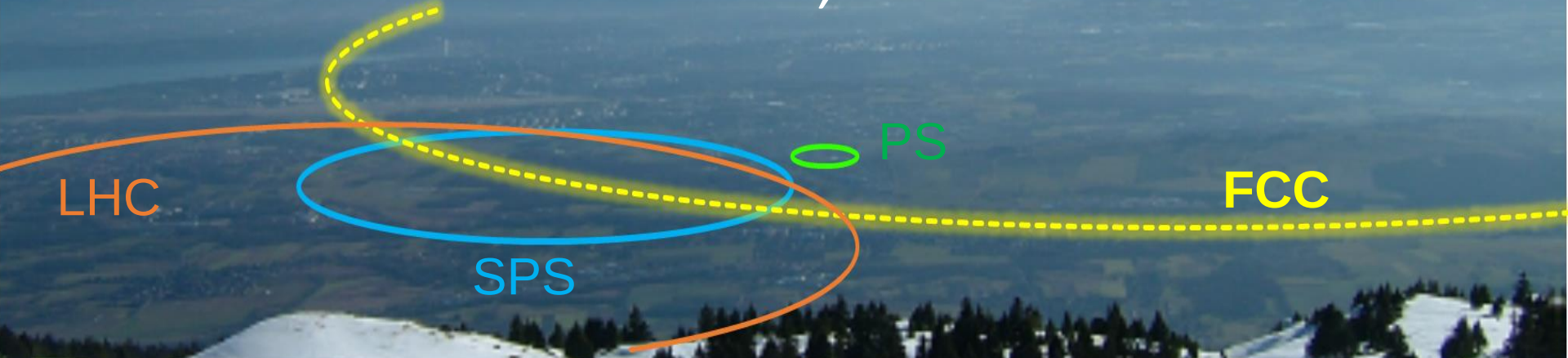

http://cern.ch/fcc

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photo: J. Wenninger

Outline

- The CDR baseline
- Layout and optics of new FCC-hh ring
- Progress with combined function lattice
- Outlook

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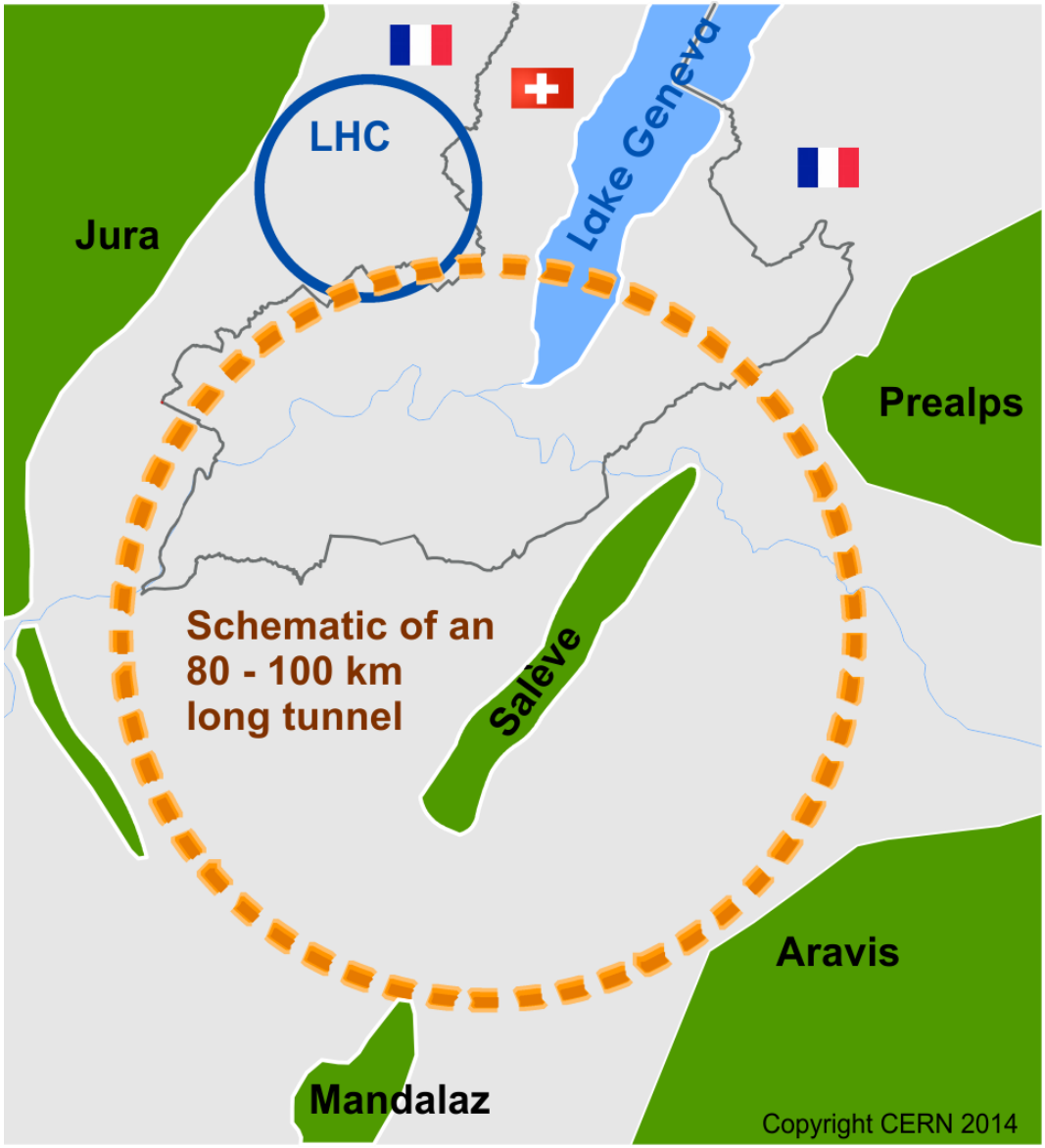
Future Circular Collider Study launched in 2014

international FCC collaboration (CERN as host lab) to study:

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km

- **80-100 km infrastructure** in Geneva area
- **e^+e^- collider (*FCC-ee*) as a possible first step**
- *p-e* (*FCC-he*) option, HE-LHC …



FCC CDR and Study Documentation

- **FCC-Conceptual Design Reports (completed in 2018):**
  - **Vol 1 Physics, Vol 2 FCC-ee, Vol 3 FCC-hh, Vol 4 HE-LHC**
  - CDRs published in **European Physical Journal C (Vol 1) and ST (Vol 2 – 4)**

  EPJ C 79, 6 (2019) 474 , EPJ ST 228, 2 (2019) 261-623 , EPJ ST 228, 4 (2019) 755-1107 , EPJ ST 228, 5 (2019) 1109-1382

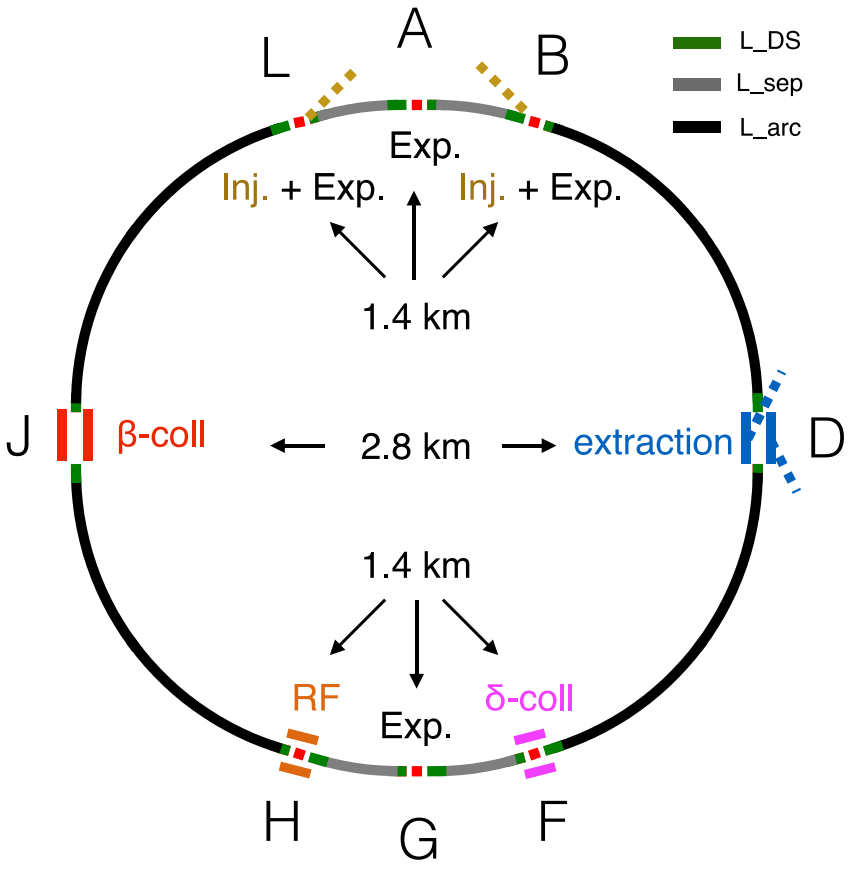
- **Summary documents provided to EPPSU SG**
  - **FCC-integral, FCC-ee, FCC-hh, HE-LHC**
  - Accessible on http://fcc-cdr.web.cern.ch/

FCC-hh (pp) collider parameters

parameter	FCC-hh		HL-LHC	LHC
collision energy cms [TeV]	100		14	14
dipole field [T]	16		8.33	8.33
circumference [km]	97.75		26.7	26.7
beam current [A]	0.5		1.1	0.58
bunch intensity [10^{11}]	1	1	2.2	1.15
bunch spacing [ns]	25	25	25	25
synchr. rad. power / ring [kW]	2400		7.3	3.6
SR power / length [W/m/ap.]	28.4		0.33	0.17
long. emit. damping time [h]	0.54		12.9	12.9
beta* [m]	1.1	0.3	0.15 (min.)	0.55
normalized emittance [μm]	2.2		2.5	3.75
peak luminosity [10^{34} $cm^{-2}s^{-1}$]	5	30	5 (lev.)	1
events/bunch crossing	170	1000	132	27
stored energy/beam [GJ]	8.4		0.7	0.36

FCC-hh layout

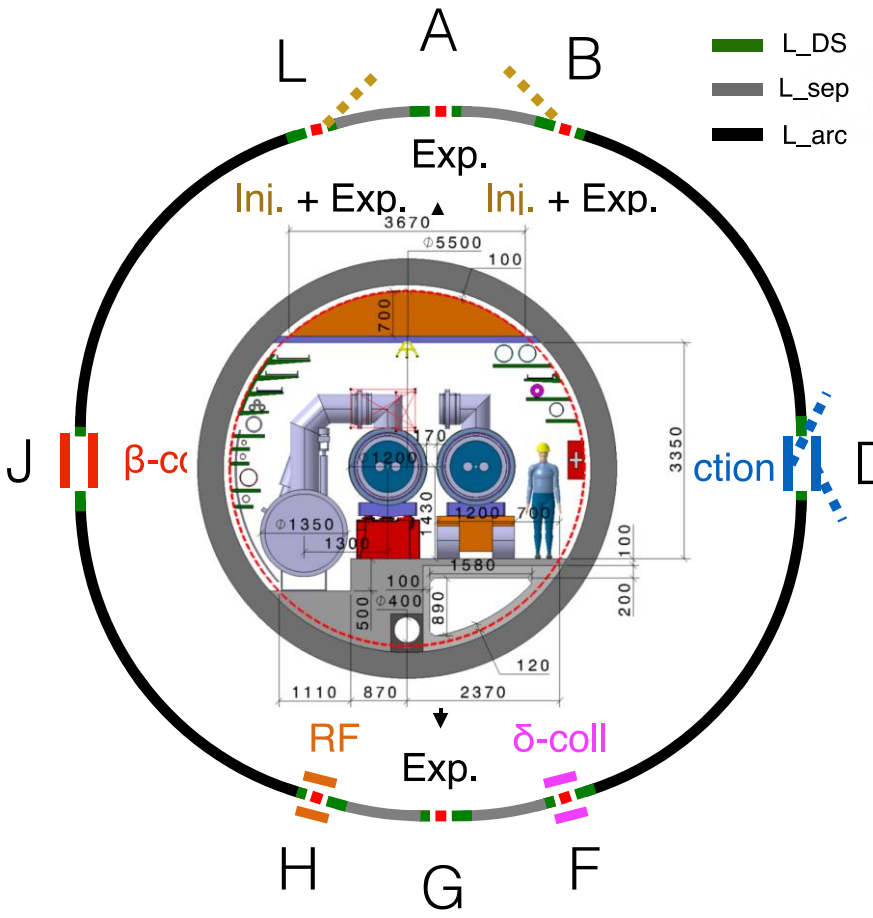
- Two high-luminosity experiments (A & G)
- Two other experiments combined with injection (L & B)
- Two collimation insertions
  - betatron cleaning (J)
  - momentum cleaning (F)
- Extraction insertion (D)
- Clean insertion with RF (H)
- Compatible with LHC or SPS as injector



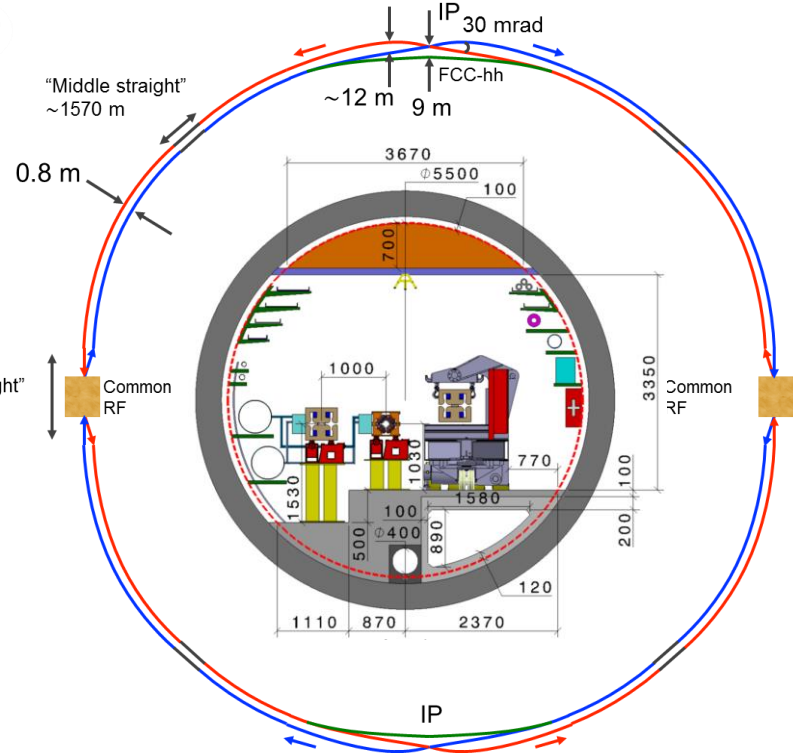
circumference: 97.75 km

FCC consistent machine layouts

FCC-hh



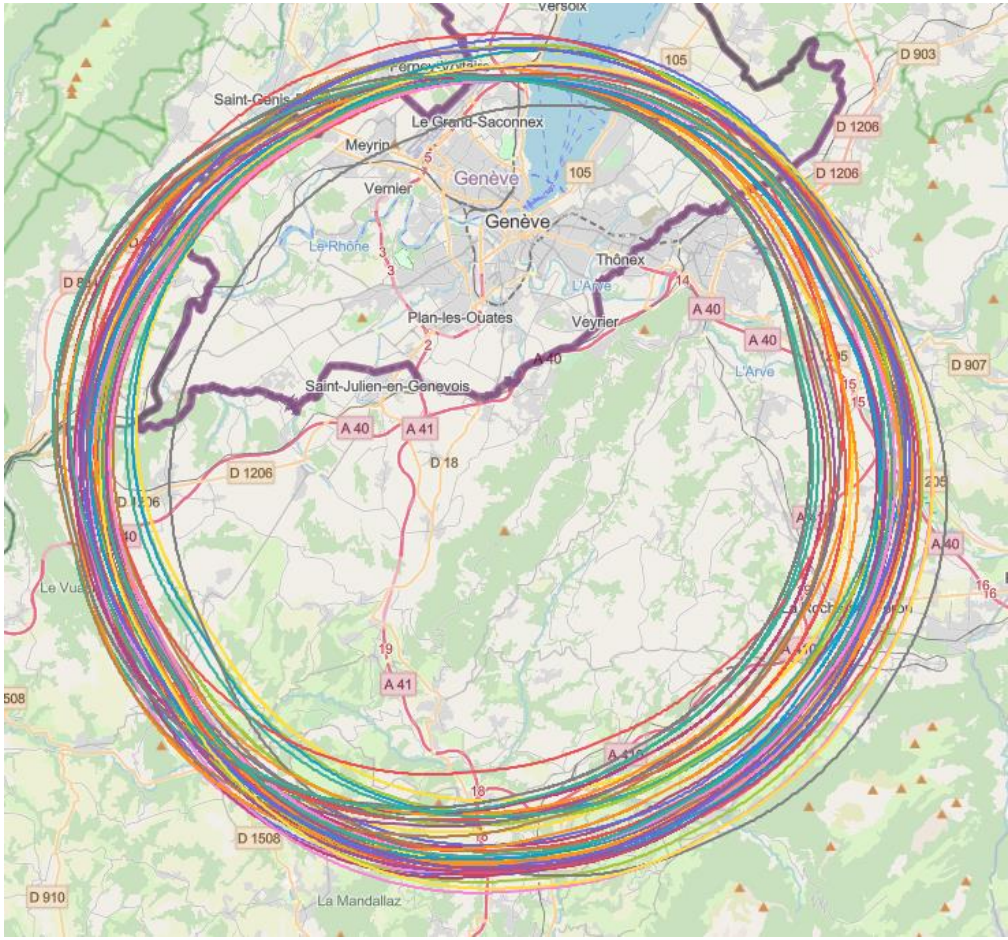
FCC-ee 1, FCC-ee 2,
FCC-ee booster (FCC-hh footprint)



Optics solutions for full ring for both machines available

Collider placement optimisation

- Overall layout and placement optimisation process across both host states
- Following the "avoid-reduce-compensate" directive of European and French regulatory frameworks
- Process integrates diverse requirements and constraints:
  - performance permitting world-leading scientific research
  - technical feasibility of civil engineering and subsurface constraints
  - territorial constraints on surface and subsurface
  - nature, accessibility, technical infrastructure, and resource needs & constraints
  - economic factors including development of benefits for, and synergies, with the regional developments
  - …

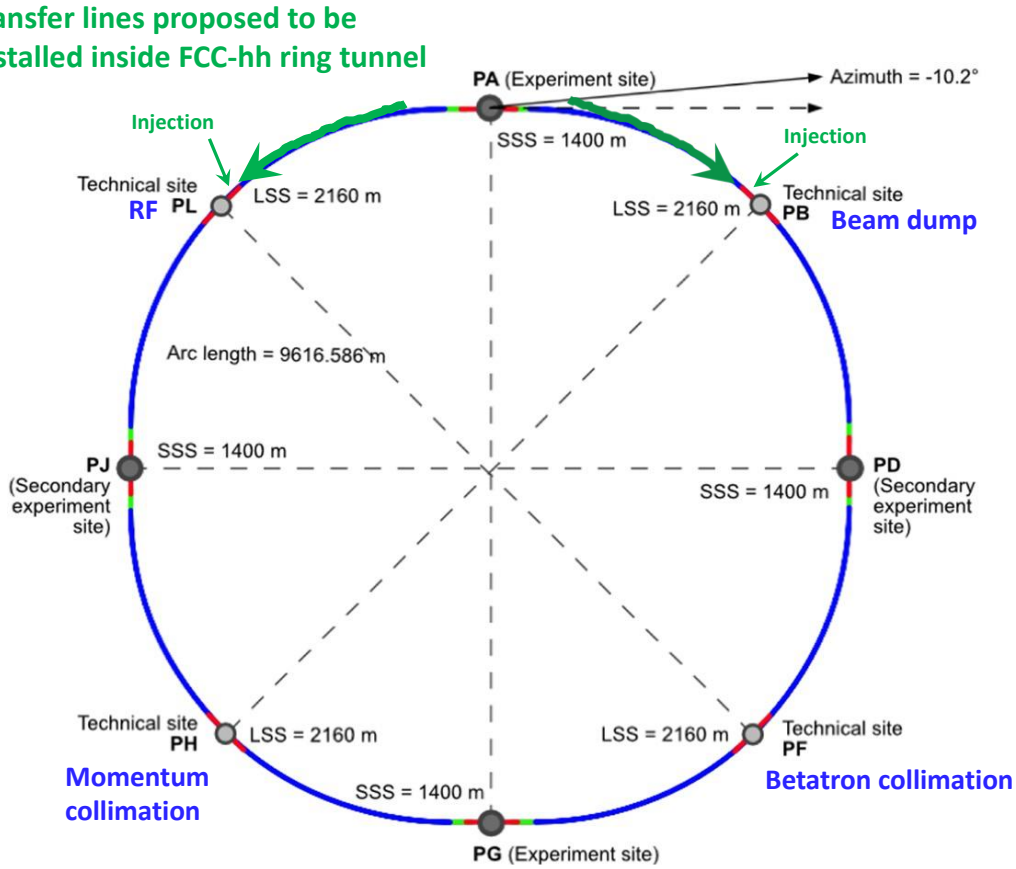


Collaborative effort of technical experts at CERN, consultancy companies and government notified bodies

See FCCIS WP3: Placement session today

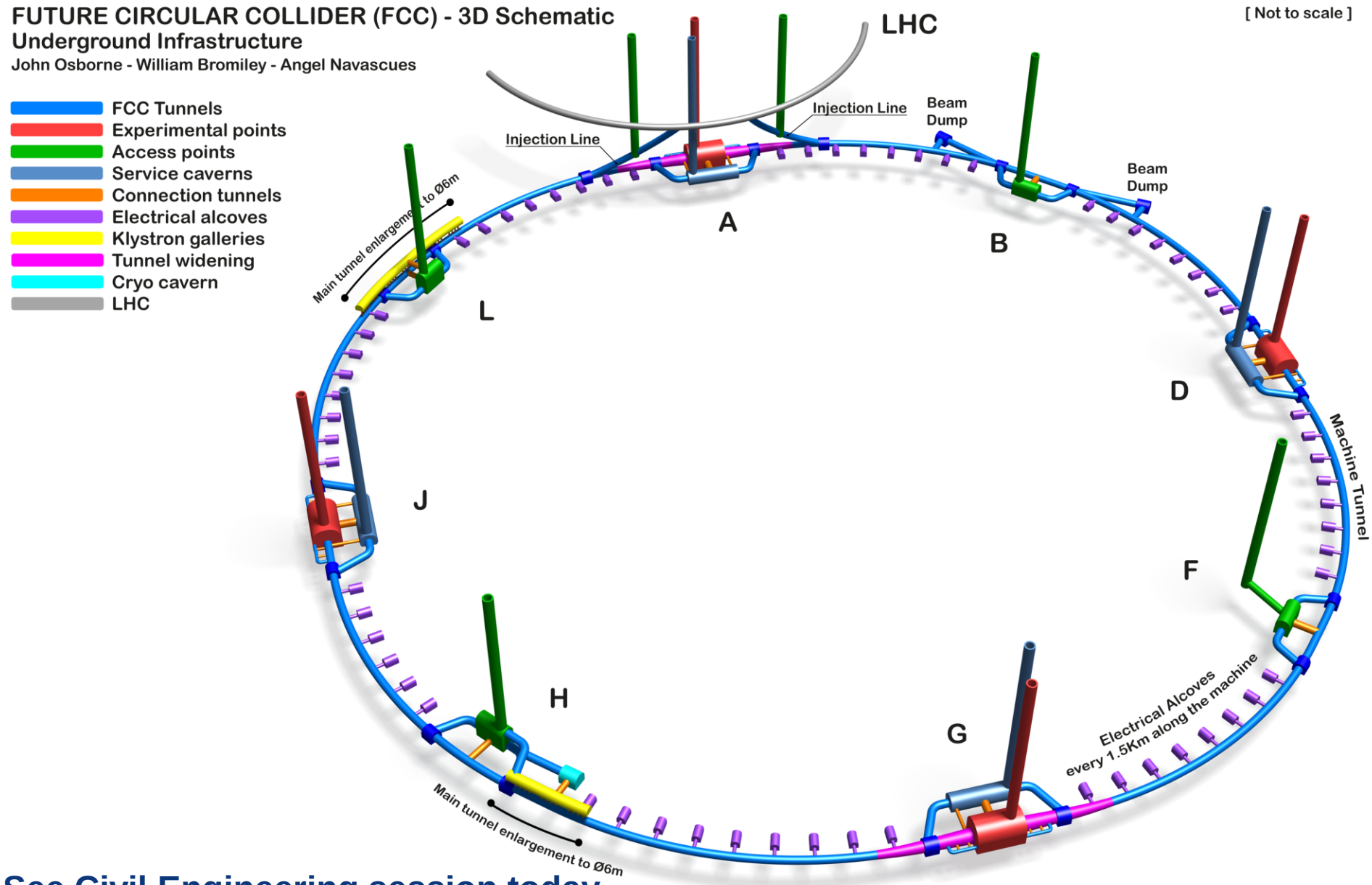
Following outcome of placement studies

- **Exact four-fold symmetry**
- Four experiments (A, D, G, & J)
- Two collimation insertions
  - betatron cleaning (F)
  - momentum cleaning (H)
- Extraction insertion + injection (B)
- RF insertion + injection (L)
- **Last part of transfer lines in the ring tunnel**
- Compatible with LHC or SPS as injector



- **Number of arc cells: 42**
- **Cell length: 215.3 m**
- **Length of experimental straight sections: 1400 m**
- **Length of technical straight sections: 2160 m**
- **Length of circumference: 91.1 km**

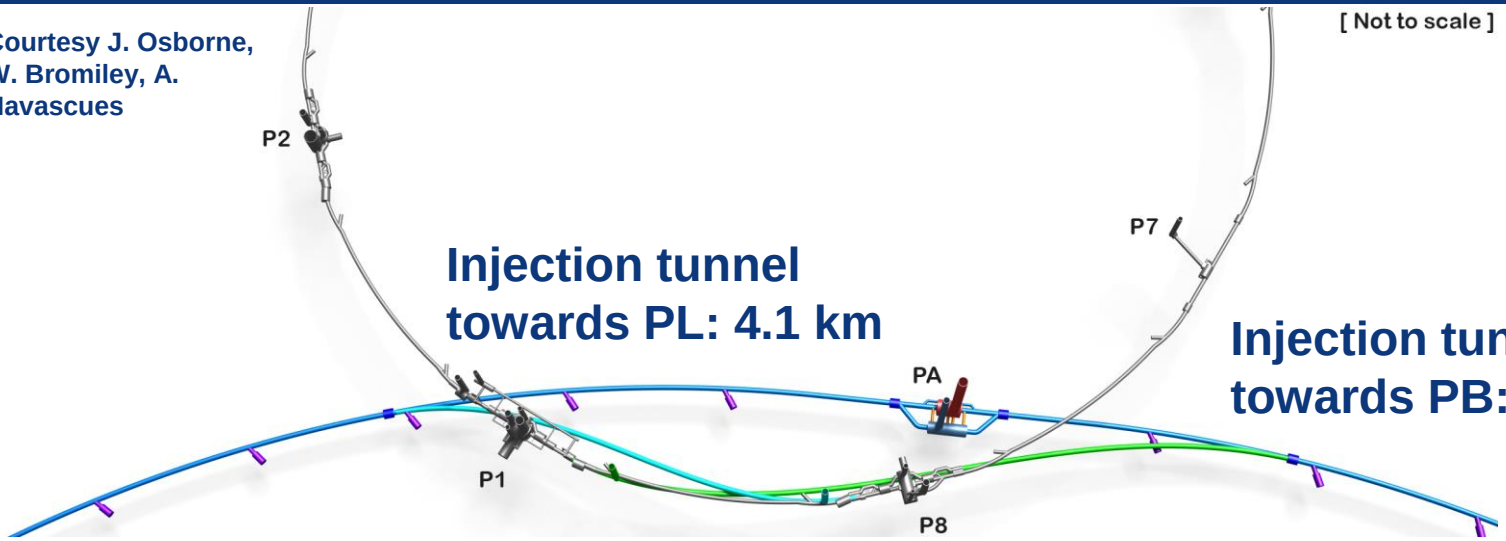
Overall FCC-hh layout



See Civil Engineering session today

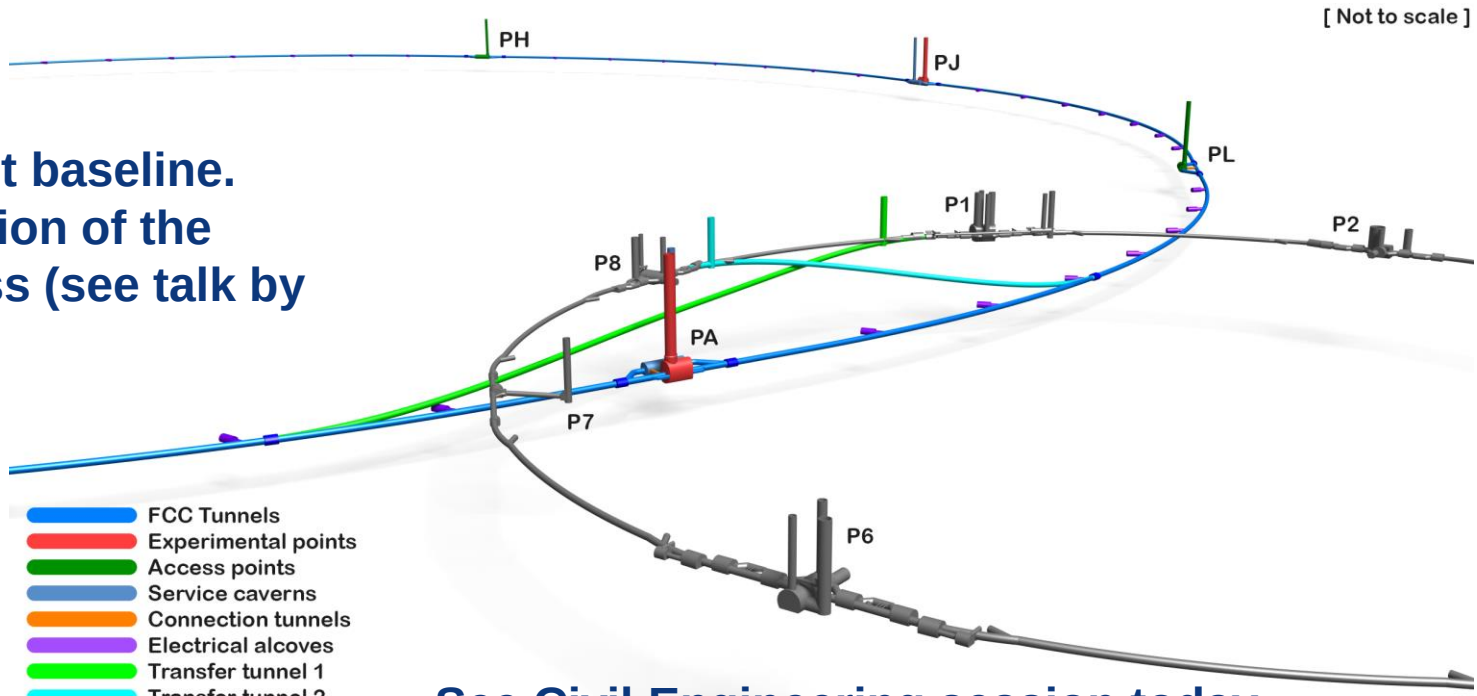
FCC-hh layout and transfer lines

Courtesy J. Osborne, W. Bromiley, A. Navascues



Injection tunnel towards PL: 4.1 km

Injection tunnel towards PB: 6.1 km



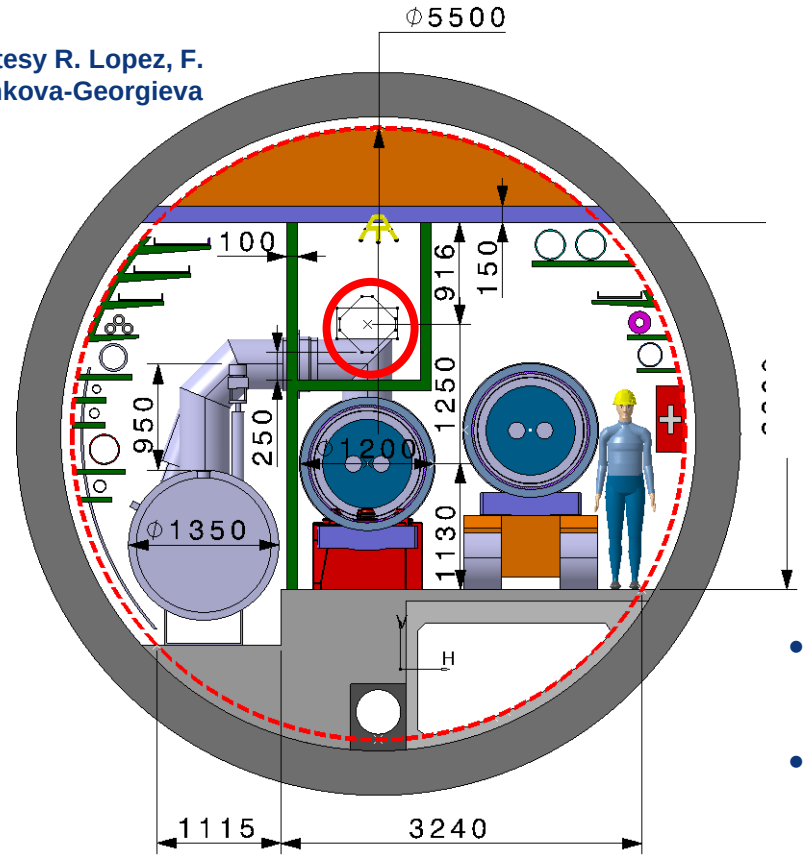
This is the current baseline. Further optimisation of the design in progress (see talk by W. Bartmann).

See Civil Engineering session today

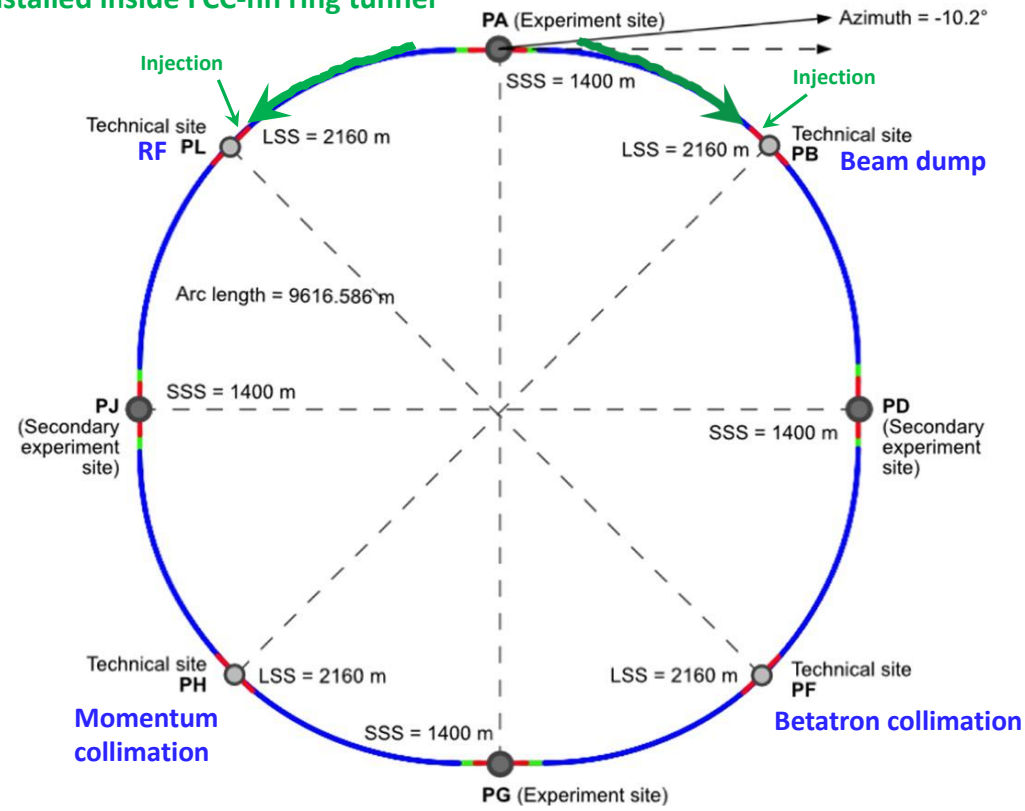
Comments on transfer lines

- The transfer lines are proposed to be installed in the ring tunnel in the arcs from PA to PB and from PA to PL:
  - Normal conducting magnets can be used.
  - Same cell design as arc cell.

Courtesy R. Lopez, F. Valchkova-Georgieva



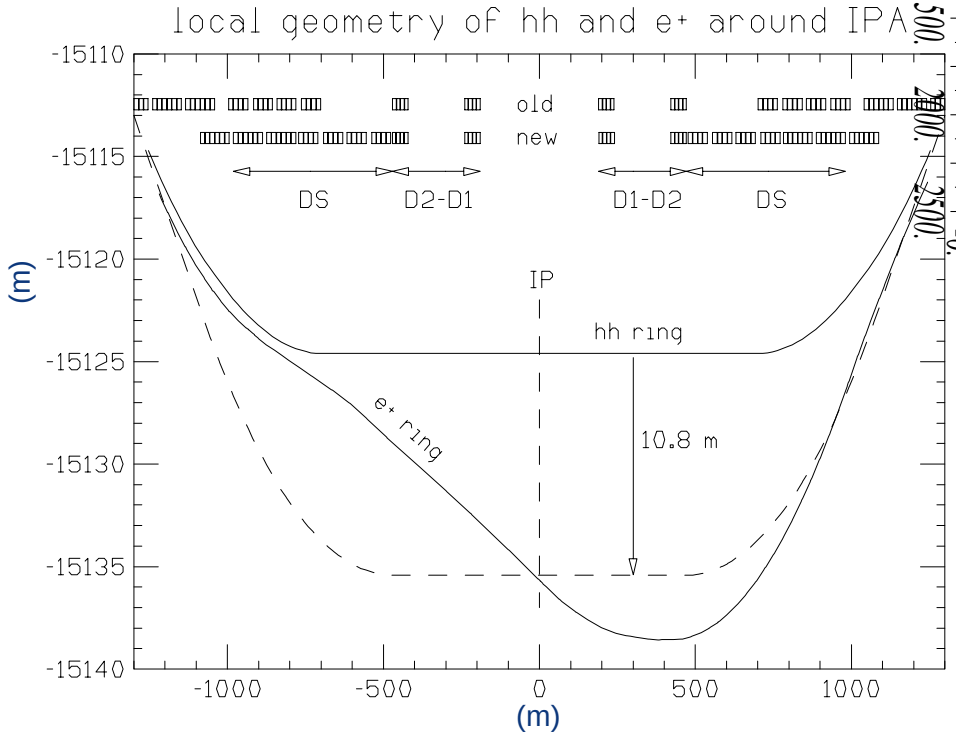
transfer lines proposed to be installed inside FCC-hh ring tunnel

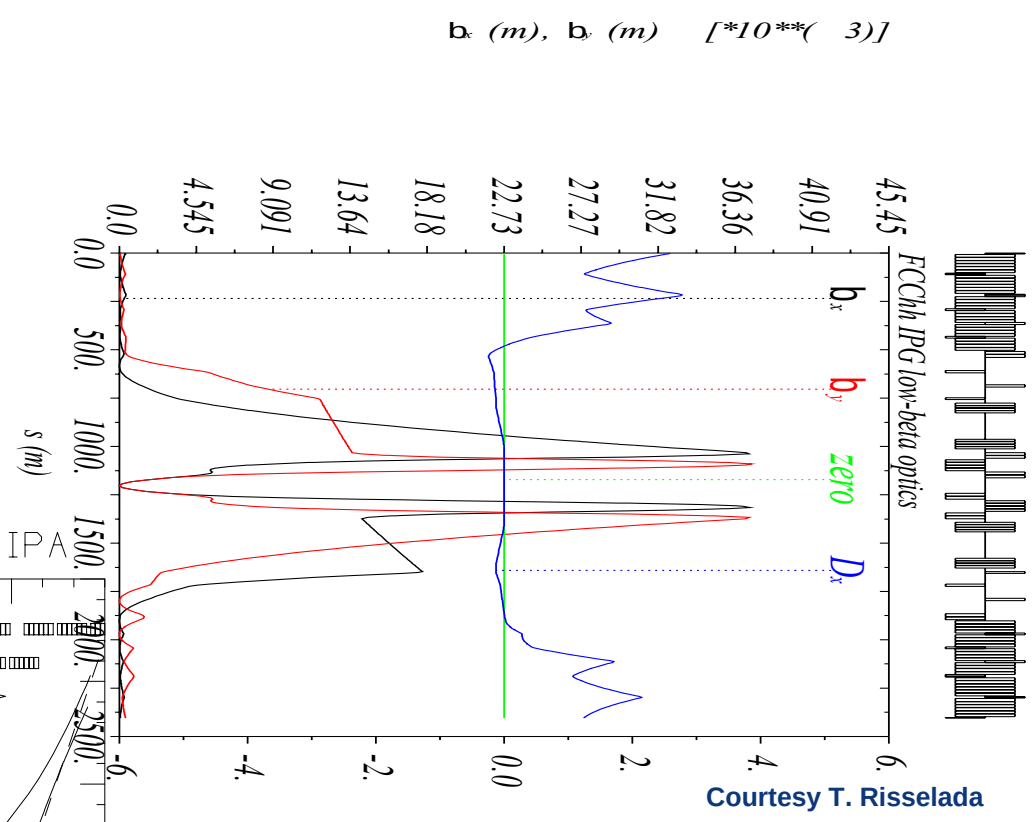


- **Integration of transfer lines in the ring tunnel in progress**
- **Analysis of the jumper design to assess whether optimisation is possible**

Experimental insertions

- **Same length as CDR**
- Very similar optics and layout as CDR
- Same optics for PA, PD, PG, and PJ
- Major change to be implemented soon (already tested for the CDR version): radial displacement of FCC-hh IP towards that o FCC-ee



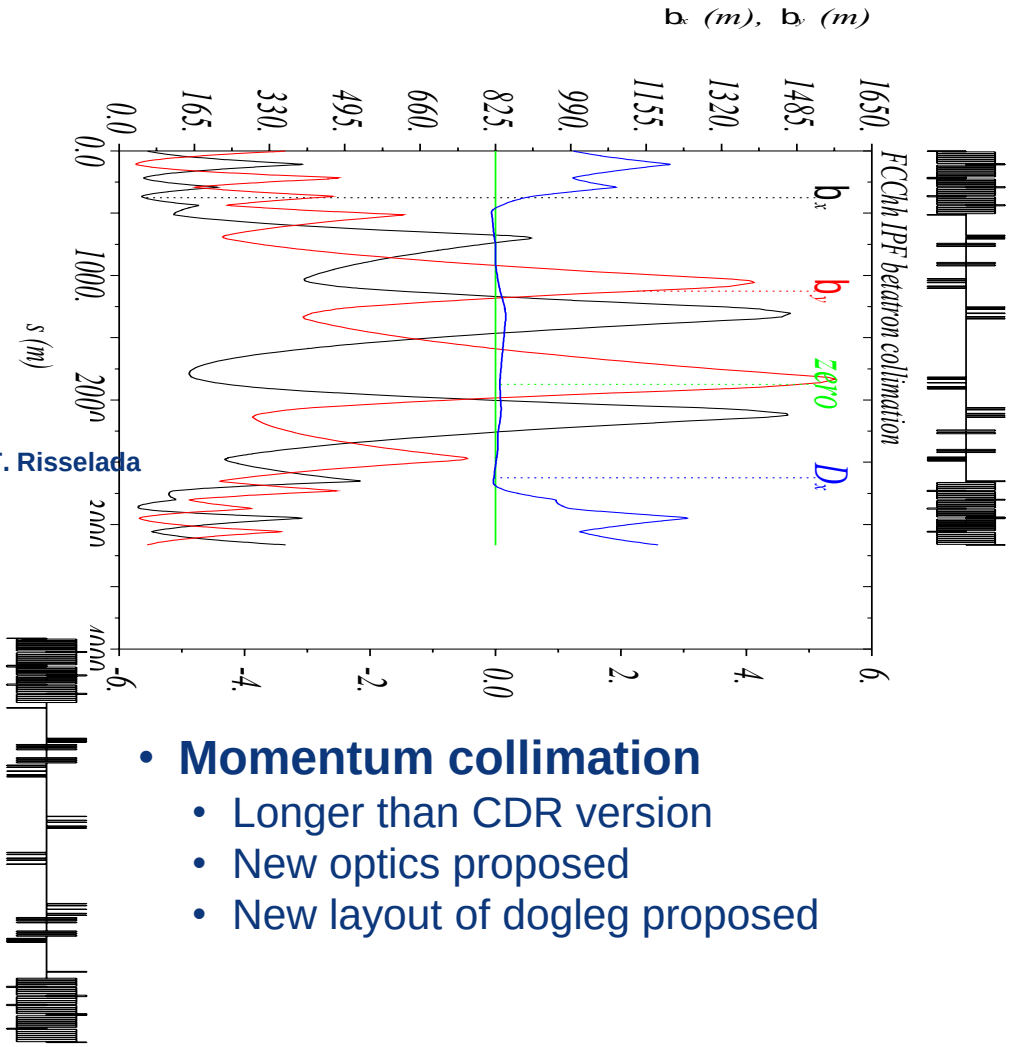


Possible advantages

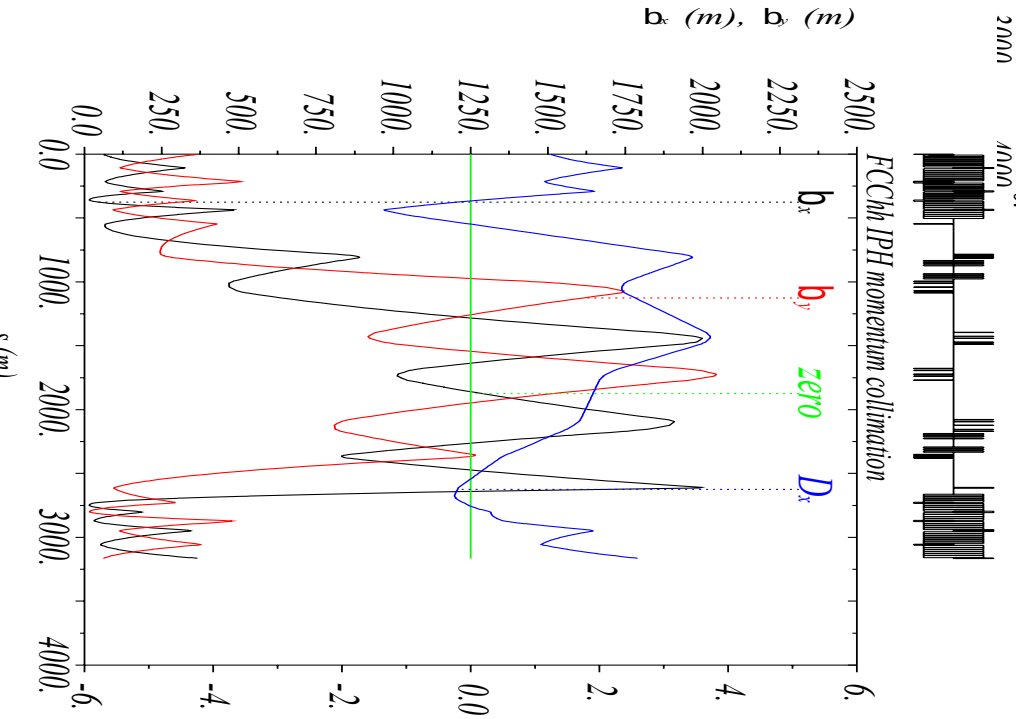
- **Minimisation of the region of increased tunnel cross section.**
- **Optimisation of the size of the experimental cavern.**
- **Reuse of detector components for FCC-ee to FCC-hh?**

Collimation insertions

- **Betatron collimation**
  - Shorter than CDR version
  - New optics proposed
  - New layout of dogleg proposed



Courtesy T. Risselada

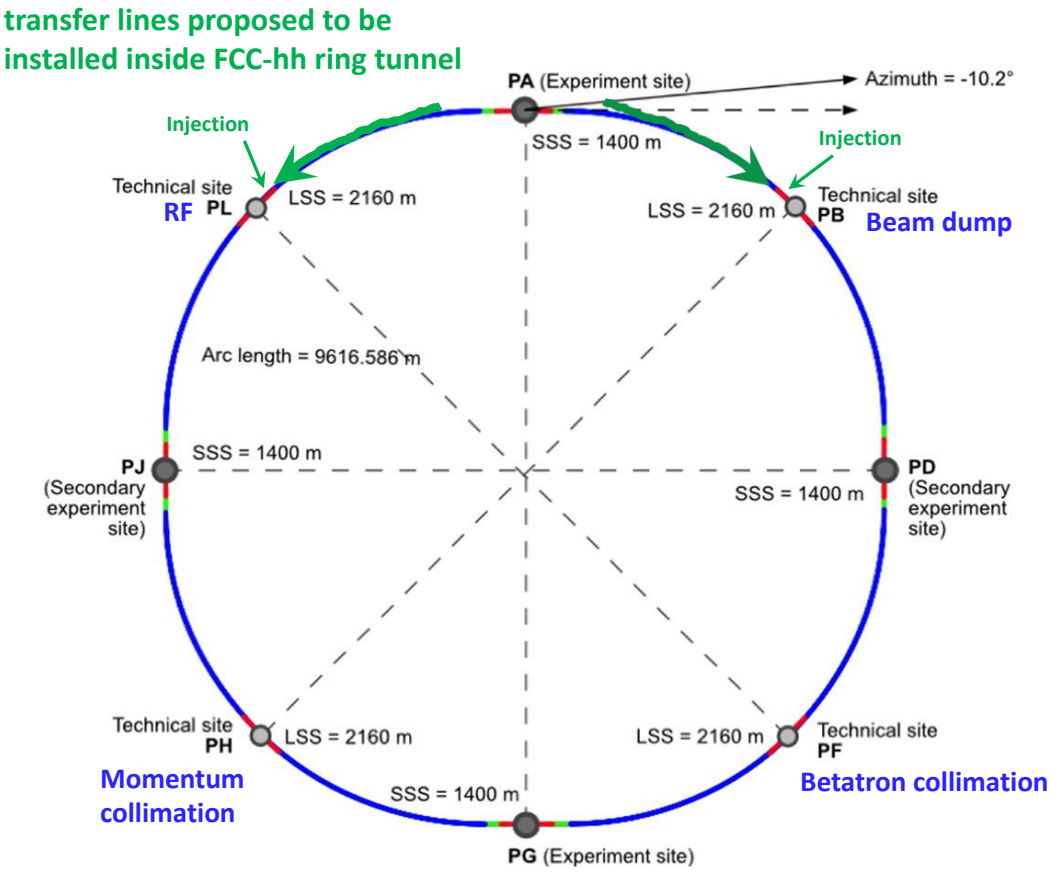


- **Momentum collimation**
  - Longer than CDR version
  - New optics proposed
  - New layout of dogleg proposed

For more detail see talk by R. Bruce in this session

Other insertions

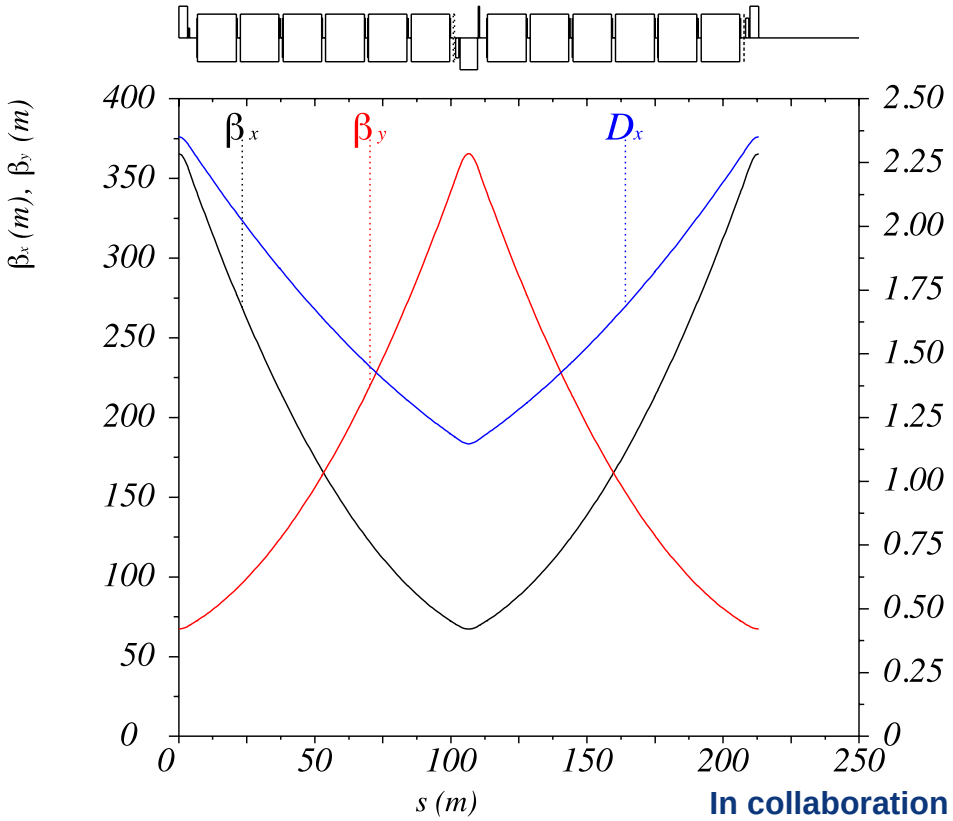
- **PL**
  - RF
  - Injection of counter-clockwise beam
  - **Optics design in progress**
- **PB**
  - Dump of both beams
  - Injection of clockwise beam
  - Optics design in progress (**see talk by W. Bartmann**)



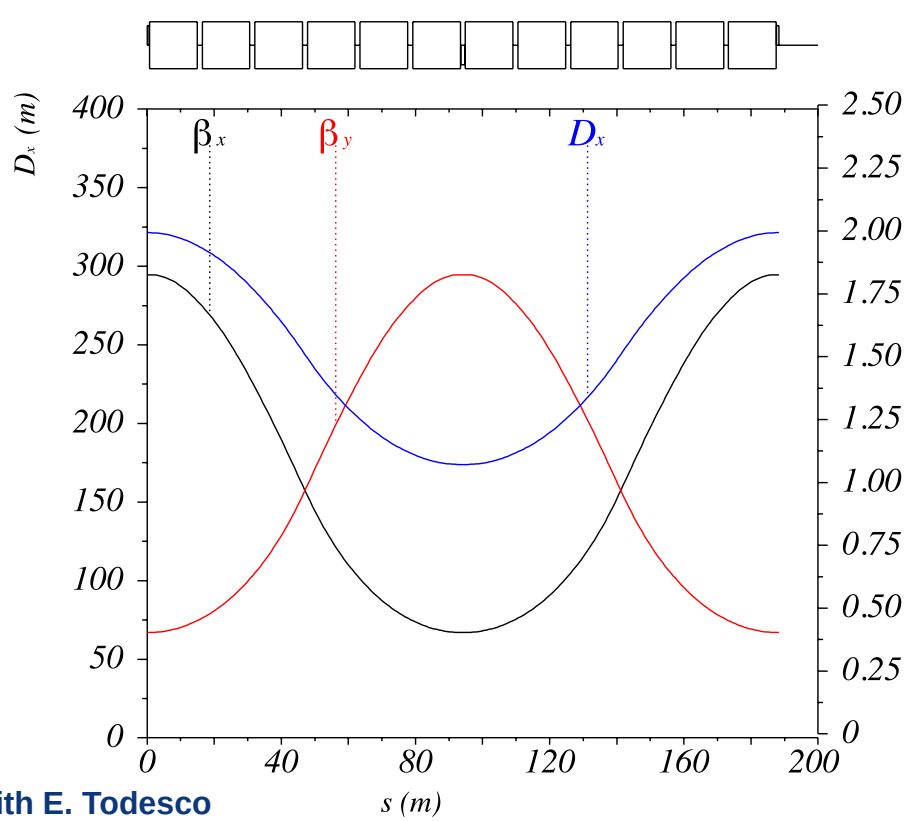
Progress with combined-function lattice

- The use of combined-function (dipole-quadrupole) might be an interesting option to
  - Increase filling factor
  - Simplify production (a single magnet type for the arcs)
- **Recent progress**
  - **Design of dispersion suppressors for a combined-function lattice**
  - **Optimisation of the regular cell length (increased length)**

Nominal FCC-hh FODO cell



FCC-hh combined-function cell



In collaboration with E. Todesco

Outlook

- The eight-point solution is being built and the main ingredients are already available.
- The next steps consists in providing a complete design of the optics of the new ring layout
  - Innovate the optics of the collimation insertion including new concepts from HL-LHC design
  - Review the dump optics merged with injection
  - Review the RF optics merged with injection
- Then, the optics design (collimation and dump) should be validated with detailed numerical simulations.
- Finally, a complete solution for the transfer lines integrated in the ring tunnel should be provided.
- The study of the combined-function solution will be pursued by considering the interplay with radiation and the layout of the cell correctors.

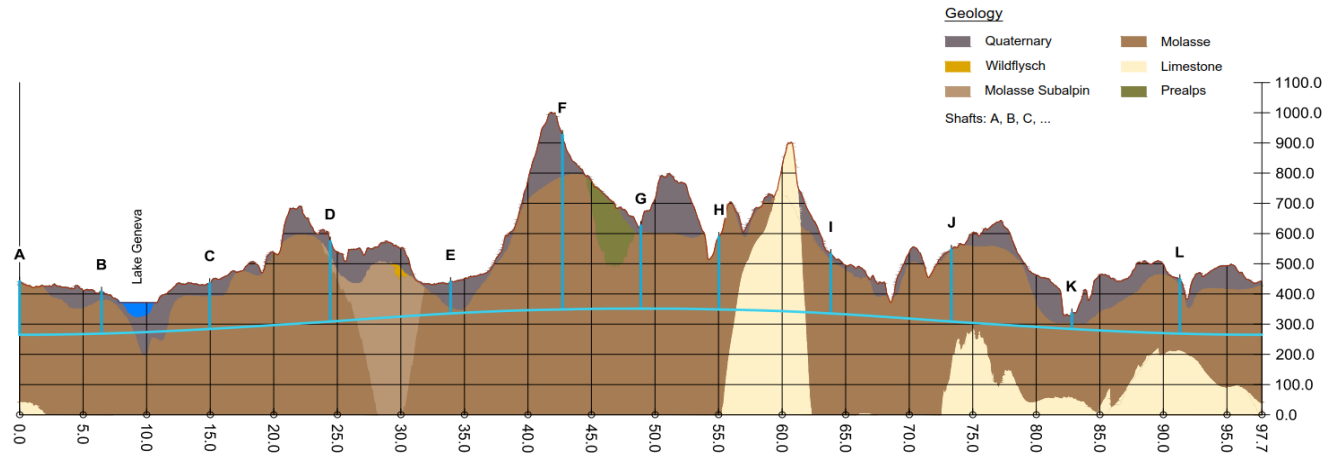
FUTURE CIRCULAR COLLIDER

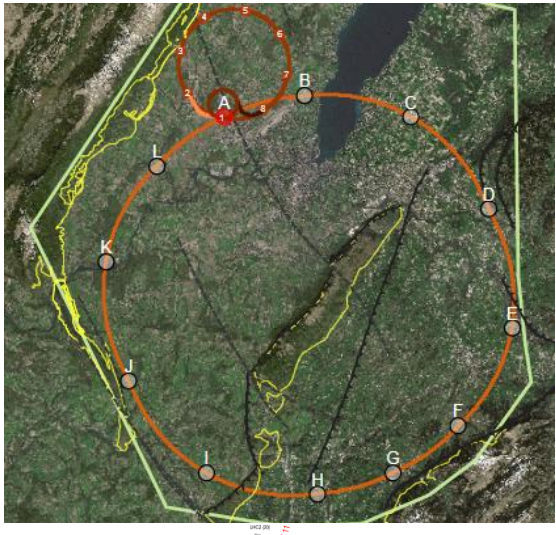
Thank you for your attention!

FUTURE CIRCULAR COLLIDER

Reserve slides

FCC implementation - footprint baseline





Current baseline position based on:

- lowest risk for construction, fastest and cheapest construction
- feasible positions for large span caverns (most challenging structures)
- **90 – 100 km circumference**
- **12 surface sites with few ha area each**