FUTURE CIRCULAR COLLIDER

The RF System of FCC-ee - General Considerations

K Hanke, CERN

FCC week 2022, Paris

THE RF SYSTEM OF FCC-EE GENERAL CONSIDERATIONS

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Abstract

The base line for the RF system of FCC-ee is a combination of 400 and 800 MHz systems operating at 4.5 and 2 K respectively. The system is designed to evolve for the different working points of the machine. Taking into account constraints from beam physics, placement and infrastructure, we have identified two straight sections to house the cryomodules. This presentation outlines the constraints and design choices and proposes a base line scenario.

Introduction

- We base our analysis on a 400/800 MHz system operating at 4.5 / 2.0 K
- Physics arguments
- Integration constraints:

  Space requirements for cryomodules in the straight sections (see presentation by F. Valchkova)
- Infrastructure constraints:

  Electrical power, cooling / ventilation, cryo

Accelerator / Physics Constraints

In the CDR it was requested that the RF be in a **single place** to make sure that the RF energy gains do not lead to an uncertainty in the center-of-mass energy for the Z and WW threshold.

It is also essential for the ee→ H experiment that the center of mass energy is the Higgs mass within a few MeV

It appears possible to fulfill the requirement with only one RF station at e.g. point L or H for the "first phase" of FCC-ee (Z, WW, HZ, eeH)

The High Energy (top) situation requires ~10 GV of RF ("FCC-ee upgrade")
→two RF stations each accelerating both e+ and e- (shared RF)
This time we also consider the boost of the IP

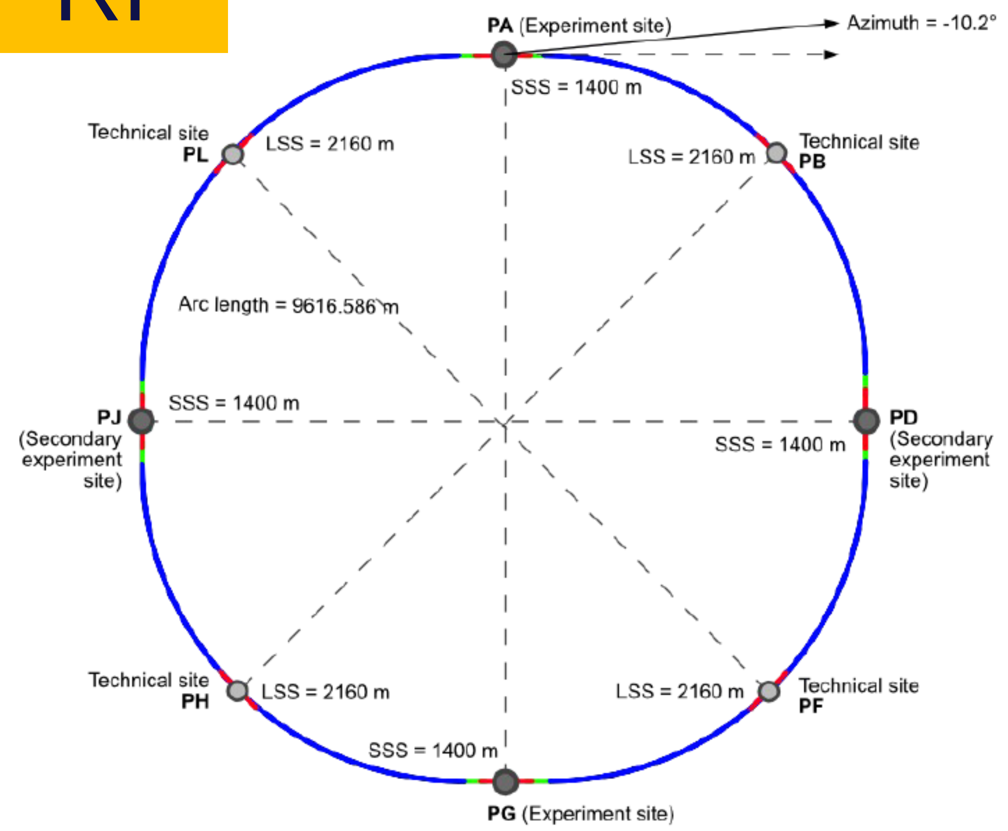
$$P_{cm} = (E(e+) – E(e-))$$

Accelerator / Physics Constraints

A Blondel

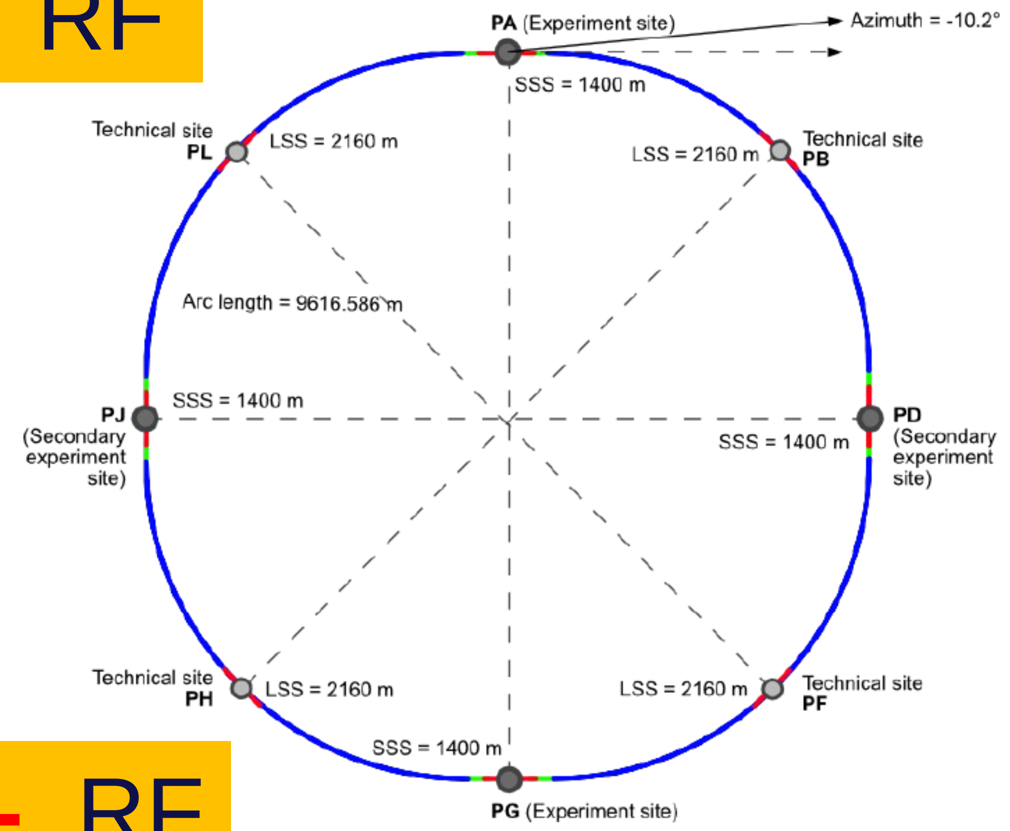
A

e- and e+ RF



B

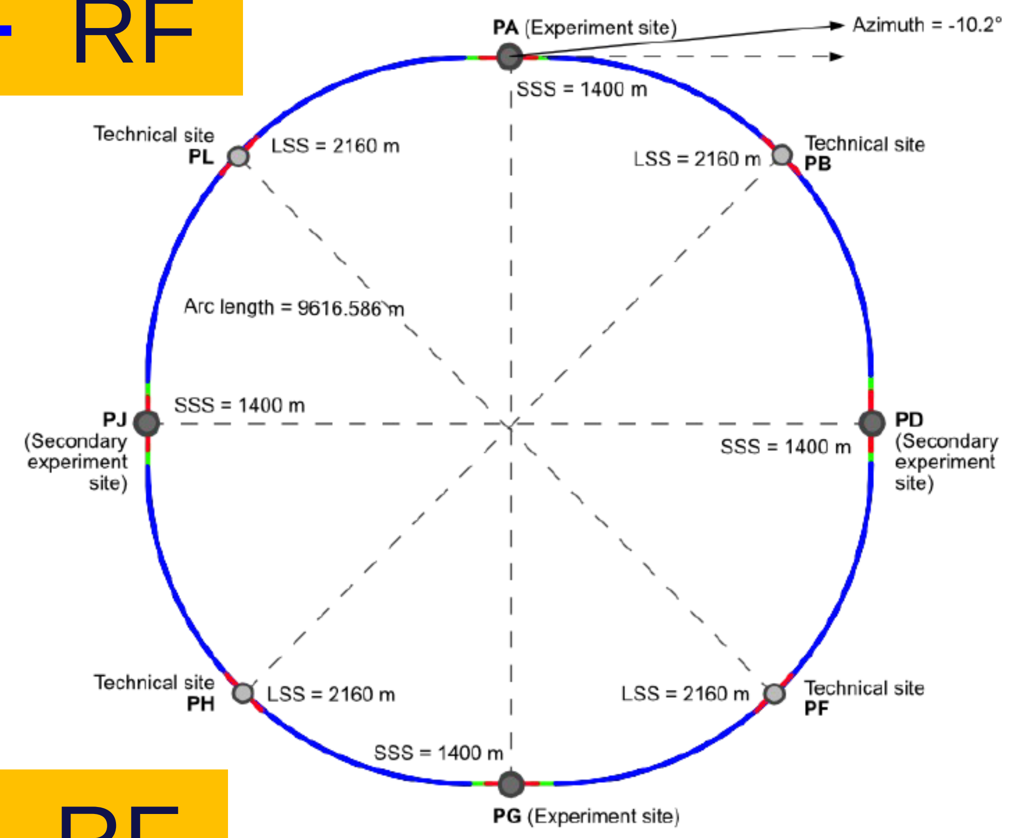
e+ RF



e- RF

C

e- and e+ RF



e- and e+ RF

RF placements for low energies (Z, W, H)

-A- It is **mandatory** to have the whole RF in a single point for the precision measurements (Z, WW, eeH)
for ee→ H one should take into account that beam energies might be different leading to a difference in the total beam energy loss by 3.6 MeV/turn (within tolerance).

-B- It might also be possible to have all e+ RF in one point and all e- RF in another point, but his will lead to large differences between collision points for 4-exp scenario and might cause issues – not preferred

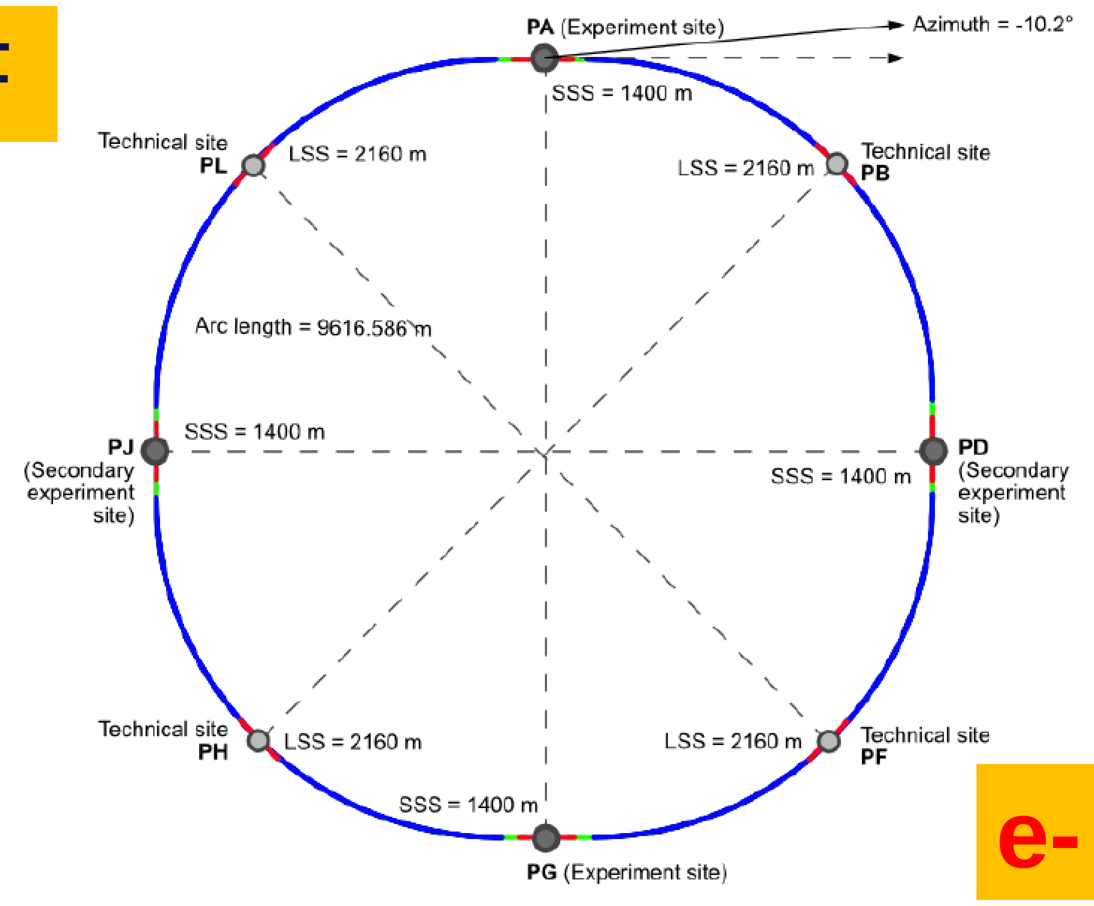
-C- for ee→ H the scheme of two RF stations where both e+ and e- get accelerated should also be investigated,
it will work if the acceleration in the RF stations can be controlled at 1% level; the RF stations do not need to be opposite.

Accelerator / Physics Constraints

A Blondel

C

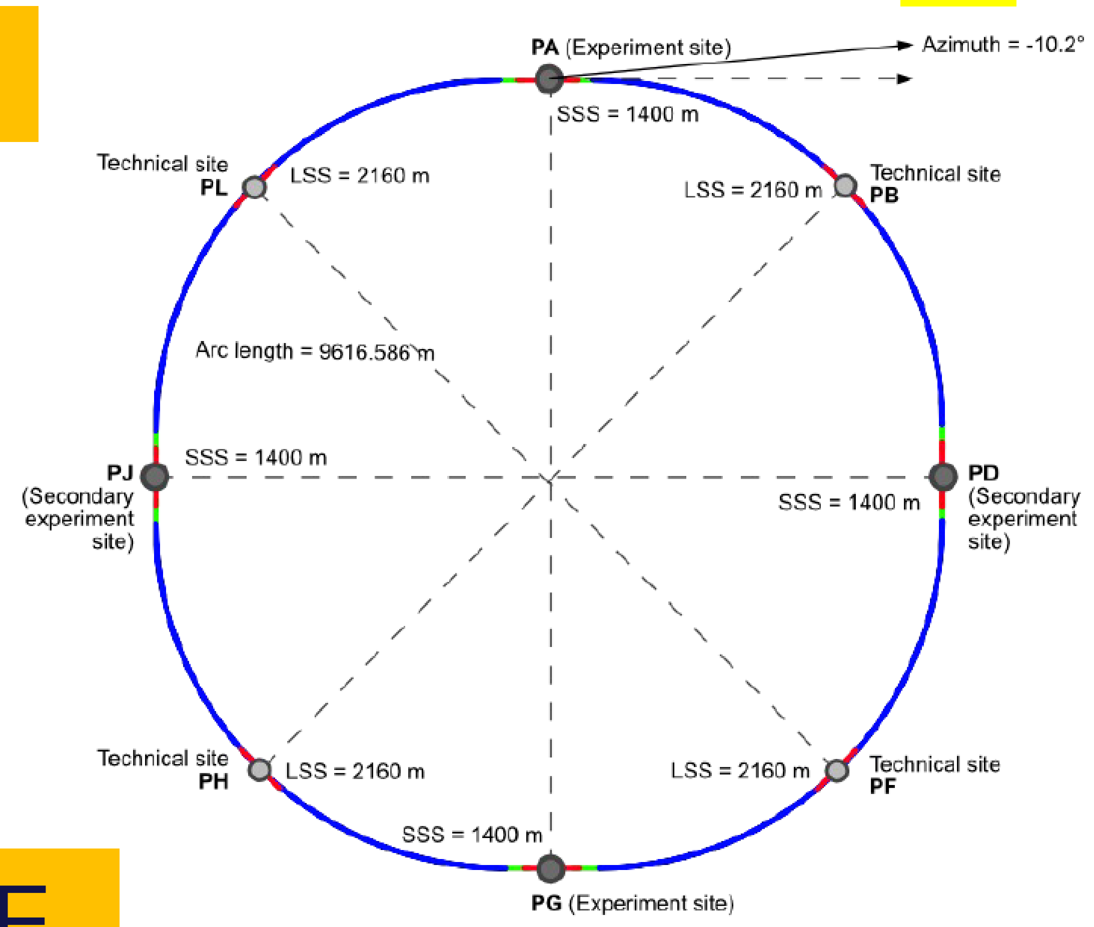
e- and e+ RF



e- and e+ RF

D

e- and e+ RF



e- and e+ RF

RF placements for high energies

After an upgrade, the FCC-ee will have two RF points with RF shared between e+ and e-
→same energy gain for e+ and e- at two different places.
No need to have opposite points (e.g. “C”), any configuration is acceptable (e.g “D”)?

See presentation by J. Keintzel: Center-of-mass energy and boosts for various RF-configurations, Wednesday morning

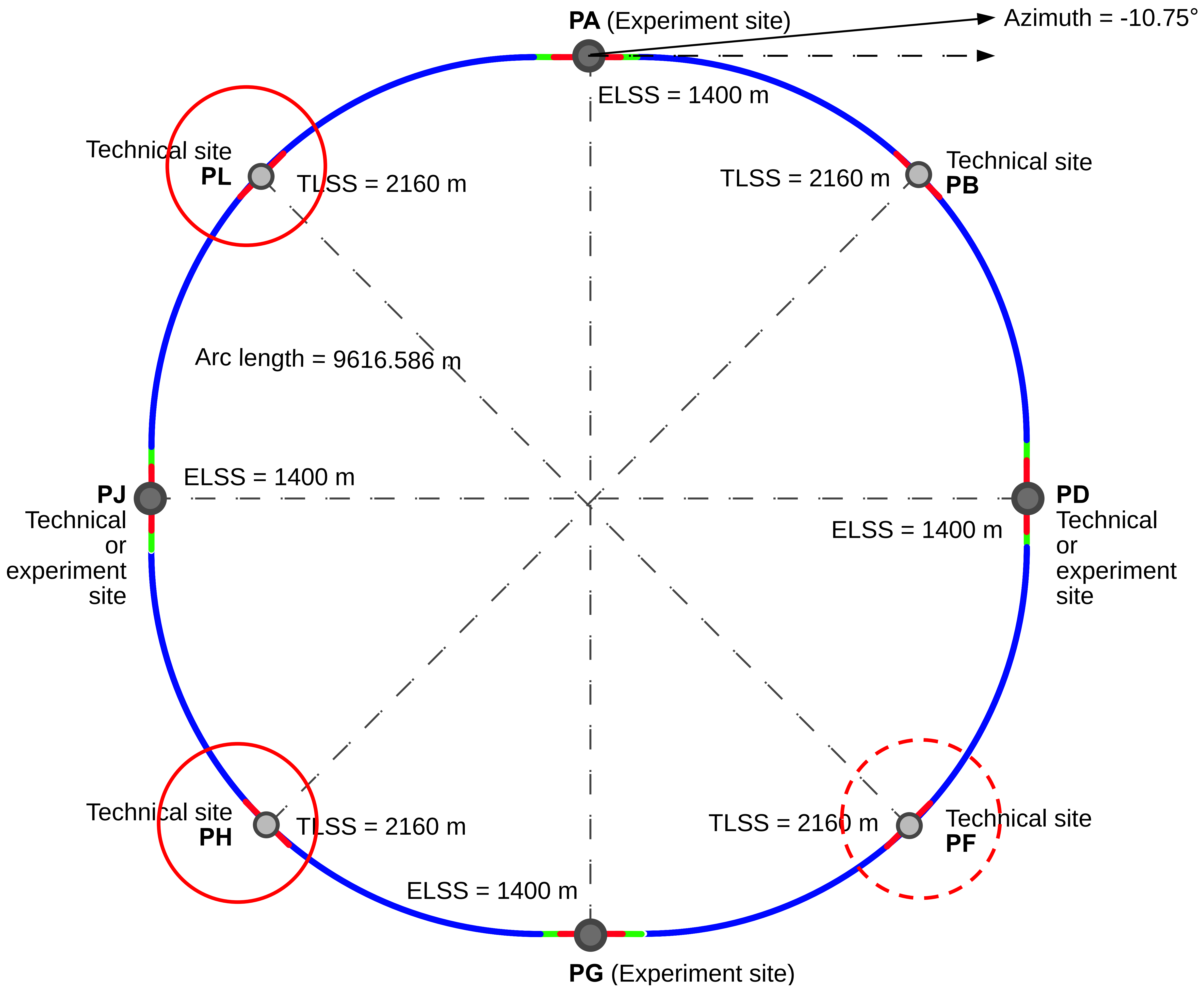
Name of the session	**FCC-ee -EPOL 1**
Name and institute of the Chairperson	Eliana Gianfelice, FNAL
Date and time	Wednesday, 1 June 2022, 09h00-10h30

Speaker (name and institution)	Contribution title	Time (minutes)
A. Blondel, U. Geneva	EPOL Status	10
J. Keintzel, CERN	RF and loss effects, boosts and control	20
K. Oide, KEK & U. Geneva	polarimeter and wigglers integration status	20
S. Muchnoi, BINP - tbc	polarimeter 3D measurement precision	20
A. Martens, CNRS	laser and laser control for polarimeter	20

Infrastructure Constraints

We exclude Experiment Sites (**A, D, G, and J**). Furthermore we recommend that point B not be an RF site (highly sensitive area, difficult access, no resources).

Therefore, from an infrastructure point of view, three of the points are eligible to house the RF for FCC-ee (**H, L, and F**).

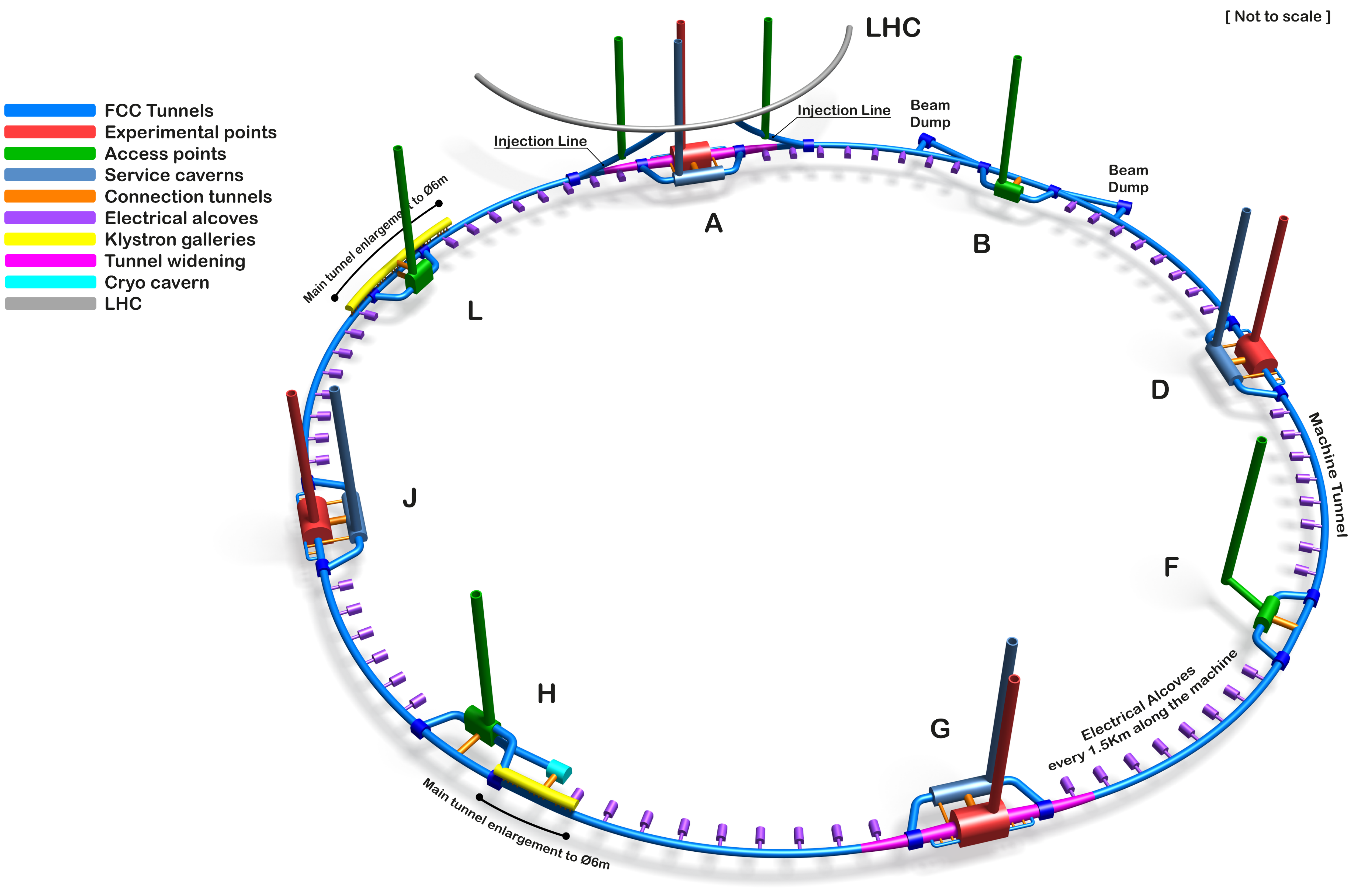


Infrastructure Constraints

Point H Good location; a 400 kV line is passing not far away in the north.

Point L Good traffic connections and access to water and electricity; access to water and electricity through CERN (additional service shaft on the CERN site) may be an option. Relatively close to the CERN site (interventions, maintenance)

Pont F features a long lateral access tunnel. However we do not exclude PF a priori to be an RF point, as the RF equipment (klystrons and klystron power supplies) would be placed underground close to the machine, and electrical power would need to be brought via relatively long cables, which is not unconceivable.


[Not to scale]
FCC Tunnels
Experimental points
Access points
Service caverns
Connection tunnels
Electrical alcoves
Klystron galleries
Tunnel widening
Cryo cavern
LHC
LHC
Injection Line
Injection Line
Beam Dump
Beam Dump
A
B
D
F
G
H
J
L
Machine Tunnel
Electrical Alcoves every 1.5Km along the machine
Main tunnel enlargement to Ø6m
Main tunnel enlargement to Ø6m

Point L Power

Point L can be powered by 2 different solutions, for a power demand up to 200 MW.

Solution 1: the electricity is coming from a 225kV sub-station not far from point L (3 km). However, the capacity is probably limited, strategy lines for Geneva.

Solution 2: A new 400 kV sub-station is built at this point to get a power up to 200 MW.

Surface needed for 200 MW: RF power supplies 6000 m^2, SVC 6000 m^2, 400 kV-63 kV-18 kV sub-stations 6000 m^2

→ See presentation J.-P. Burnet

Point L Cooling & Cryo

Cooling & Ventilation:
The cooling water need of the RF is 58.1 MW. The additional cooling needed from other users at point F is around 4.8 MW (including chillers used for air cooling in the RF area).
This gives a total of 63 MW, without contingency.

Cryo:
The number of RF cryomodules and their heat loads have both increased since CDR data published in 2019, inducing de facto an increase in the cryogenic cooling requirements

→ See presentation L. Delprat

Point H Power

Point H can be power by 2 different solutions, for a power demand up to 160 MW.

Solution 1: A new 400 kV sub-station is built at this point to get a power up to 200 MW. A 400 kV line is already passing close to point H, will need a new 400 kV sub-station and 4 km of lines.

Solution 2: the electricity is coming from point F through the FCC tunnel. This will require 132 kV lines in the tunnel. Up to 160 MW sounds feasible. With Point F as main power sub-station (400 kV).

Surface needed for 200 MW: RF power supplies 6000 m^2, SVC 6000 m^2, 400 kV-63 kV-18 kV sub-stations 6000 m^2

→ See presentation J.-P. Burnet

Point H Cooling & Cryo

Cooling & Ventilation:
In case all RF equipment is installed at point H the water cooling need from the RF equipment is around 38.7 MW. The additional cooling needed at point H is around 3.2 MW (includes chillers).

Therefore, the cooling capacity of the cooling towers is 42 MW, without additional capacity for backup.

Cryo:
The number of RF cryomodules and their heat loads have both increased since CDR data published in 2019, inducing de facto an increase in the cryogenic cooling requirements

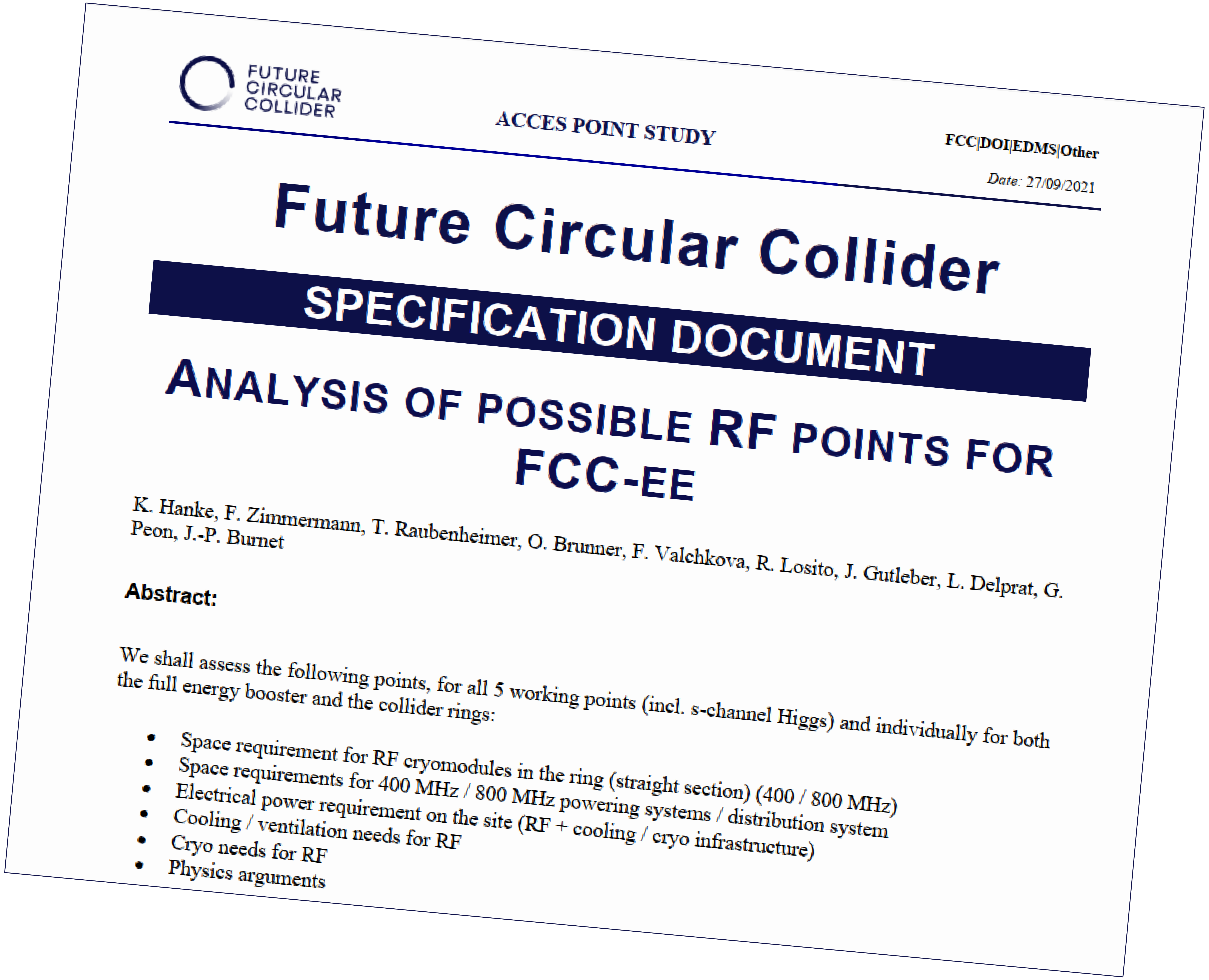
→ See presentation L. Delprat

Summary

- 2 RF points proposed for FCC-ee: L and H
- Integration wise this would nicely fit
- For Z and W and H machines all CMs (400 and 800 MHz) to be installed at point L
- For ttbar machines we will split the 400 MHz (point L) and 800 MHz (point H and L)
- Tunnel diameter will be 6 m for the RF points compared to 5.5 m for the tunnel – Civil Engineering are looking into cost and schedule; might review once engineering design of the cryomodules is available
- Klystron gallery will sit on top of collider tunnel, waveguides coming down, being elaborated by Civil Engineering (as CDR!)
- implicit assumption: Booster will sit on top of collider ring; needs also to be confirmed!

Next Steps

- Review 2nd half 2022
- Freeze and document base line



FUTURE CIRCULAR COLLIDER

ACCES POINT STUDY

FCC|DOI|EDMS|Other

Date: 27/09/2021

Future Circular Collider

SPECIFICATION DOCUMENT

ANALYSIS OF POSSIBLE RF POINTS FOR FCC-EE

K. Hanke, F. Zimmermann, T. Raubenheimer, O. Brunner, F. Valchkova, R. Losito, J. Gutleber, L. Delprat, G. Peon, J.-P. Burnet

Abstract:

We shall assess the following points, for all 5 working points (incl. s-channel Higgs) and individually for both the full energy booster and the collider rings:

- Space requirement for RF cryomodules in the ring (straight section) (400 / 800 MHz)
- Space requirements for 400 MHz / 800 MHz powering systems / distribution system
- Electrical power requirement on the site (RF + cooling / cryo infrastructure)
- Cooling / ventilation needs for RF
- Cryo needs for RF
- Physics arguments

Thank you for your attention