

# GENERAL LAY-OUT INTEGRATION UPDATE RF SYSTEMS

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## FCC-ee Underground Structure Overview

## FCC-ee Machine tunnel Layout

## FCC-ee RF/Cryogenic Layout

- *FCC-ee RF/Cryogenic Layout point L*

## FCC-ee Underground Structure point L

- *FCC-ee RF Machine tunnel cross sections*
- *FCC-ee Klystron Gallery cross sections*
- *FCC-ee Underground structure Isometric views*

## FCC-ee RF/Cryogenic Layout

- *FCC-ee RF/Cryogenic Layout point H*

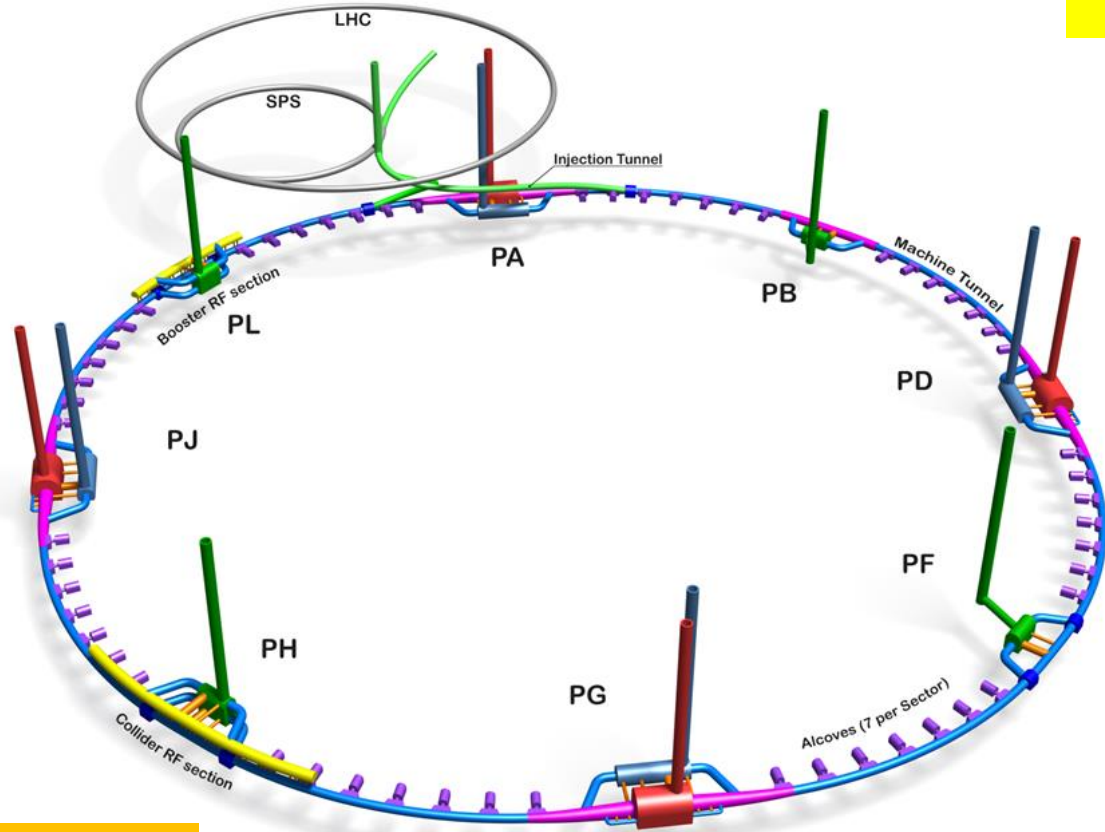
## FCC-ee Underground Structure point H

- *FCC-ee RF Machine tunnel cross sections*
- *FCC-ee Klystron Gallery cross sections*
- *FCC-ee Underground structure Isometric views*

# FCC-ee Underground Structure Overview

Only schematic, and not to scale.

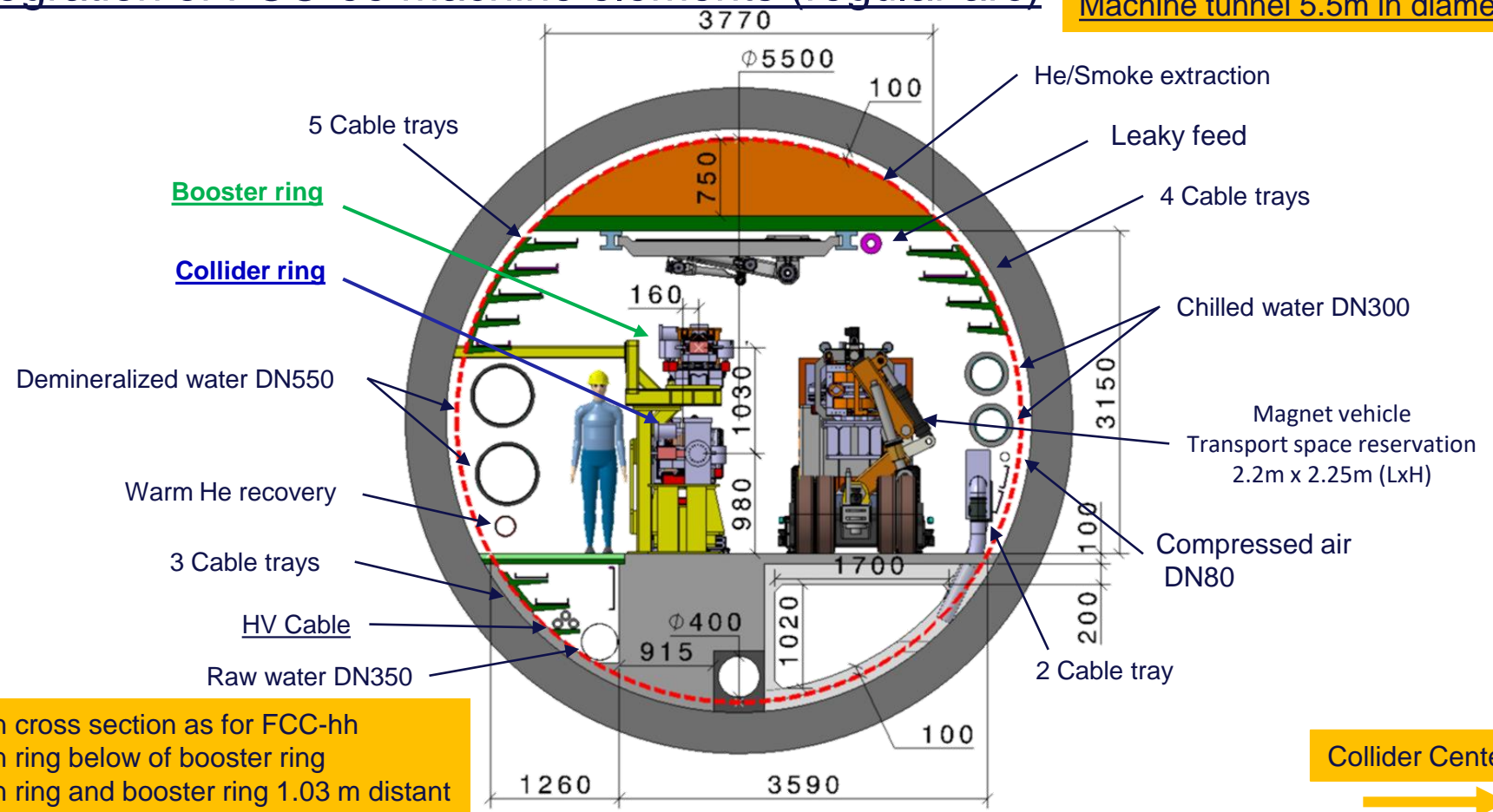
- █ FCC Tunnels
- █ Experimental points
- █ Access points
- █ Service caverns
- █ Connection tunnels
- █ Electrical alcoves
- █ Klystron galleries
- █ Tunnel widening
- █ LHC



Courtesy A. Navascues Cornago

# Integration of FCC-ee machine elements (regular arc)

Machine tunnel 5.5m in diameter



Main cross section as for FCC-hh  
 Main ring below of booster ring  
 Main ring and booster ring 1.03 m distant

Collider Center

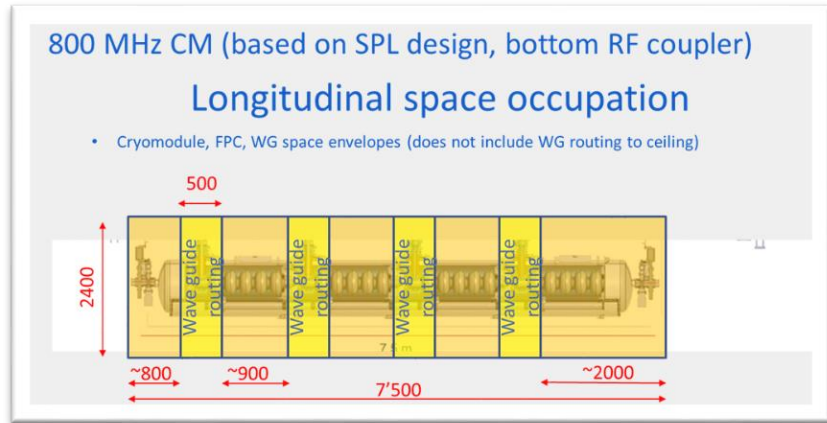
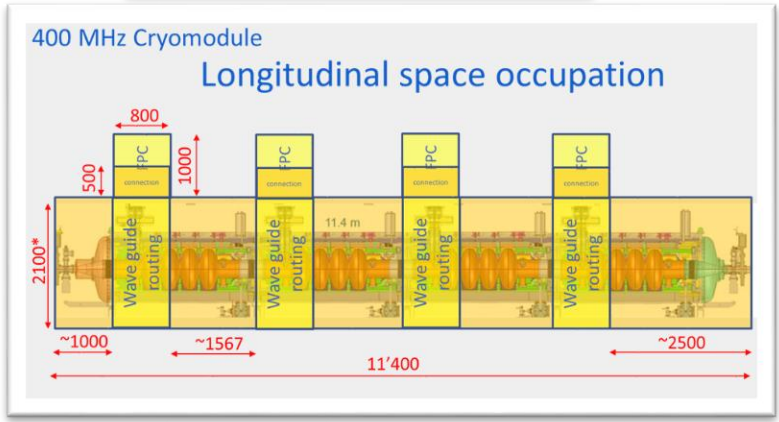
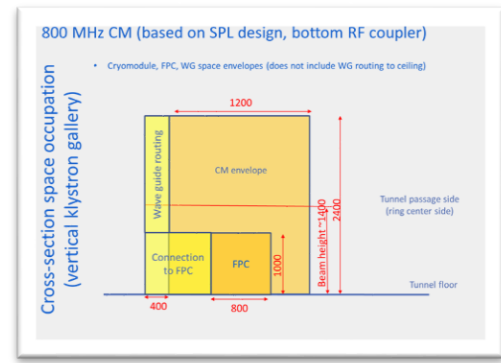
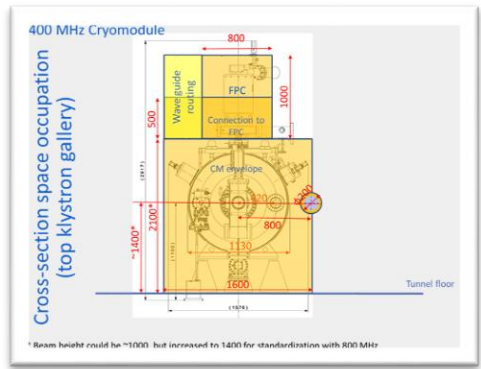


# FCC-ee RF reference table

Courtesy F. Peauger and O. Brunner

12-May-23	Z		W		H		ttbar2		
	per beam	booster	per beam	booster	2 beams	booster	2 beams	2 beams	booster
RF Frequency [MHz]	400	800	400	800	400	800	400	800	800
RF voltage [MV]	120	140	1050	1050	2100	2100	2100	9200	11300
Eacc [MV/m]	5.72	6.23	10.61	20.01	10.61	20.76	10.61	20.12	20.10
# cell / cav	1	5	2	5	2	5	2	5	5
Vcavity [MV]	2.14	5.83	7.95	18.75	7.95	19.44	7.95	18.85	18.83
#cells	56	120	264	280	528	540	528	2440	3000
# cavities	56	24	132	56	264	108	264	488	600
# CM	14	6	33	14	66	27	66	122	150
+ #CM	14	6	33	8	0	13	0	122	123
- #CM			14						
T operation [K]	4.5	2	4.5	2	4.5	2	4.5	2	2
dyn losses/cav * [W]	19	0.3	129	3	129	4	129	23	3
stat losses/cav * [W]	8	8	8	8	8	8	8	8	8
Qext	5.8E+04	3.1E+05	9.2E+05	7.6E+06	9.1E+05	1.6E+07	4.5E+06	4.2E+06	8.1E+07
Detuning [kHz]	9.885	4.385	0.575	0.140	0.106	0.012	0.009	0.056	0.002
Pcav [kW]	901	210	378	89	382	47	78	163	8
energy loss / turn ** [MV]	39.40	39.40	370.00	370.00	1890.00	1890.00	10100.00		10100.00
cos phi	0.33	0.28	0.35	0.35	0.90	0.90	0.98	0.86	0.89
Beam current [A]	1.280	0.128	0.135	0.0135	0.0534	0.003	0.010	0.010	0.0005
Lacc [m]	0.375	0.937	0.749	0.937	0.749	0.937	0.749	0.937	0.937
#cav/CM	4	4	4	4	4	4	4	4	4
R/Q [ohm]	87.6	521	181.1	521	181.1	521	181.1	521	521
G [ohm]	238.50	272.90	234.70	272.90	234.70	272.90	234.70	272.90	272.90
Q0	2.7E+09	3.0E+10	2.7E+09	3.0E+10	2.7E+09	3.0E+10	2.7E+09	3.0E+10	3.0E+10
Ep/Eacc	2.20	2.05	2.00	2.05	2.00	2.05	2.00	2.05	2.05
Bp/Eacc	5.36	4.33	5.33	4.33	5.33	4.33	5.33	4.33	4.33
Ep [MV/m]	12.58	12.76	21.23	41.03	21.23	42.55	21.23	41.25	41.21
Bp [mT]	30.65	26.96	56.57	86.66	56.57	89.87	56.57	87.13	87.05
Cavity design	QUASI-LHC	UROSS	2CELLV2	UROSS	2CELLV2	UROSS	2CELLV2	UROSS	UROSS
Prf no beam [kW]	225.14	52.53	94.60	22.30	95.57	11.68	19.49	40.68	2.10

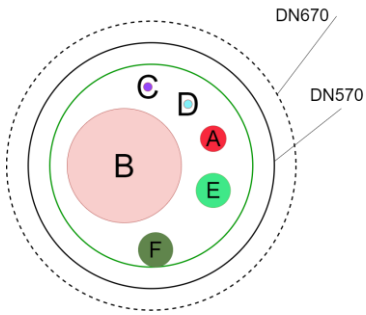
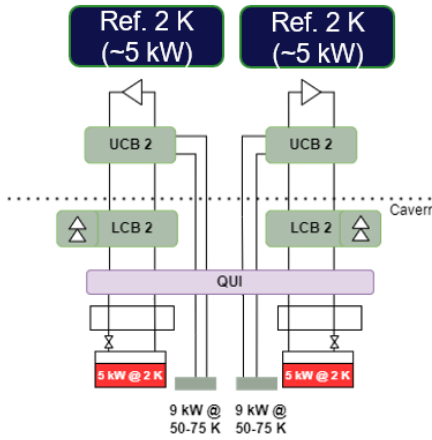
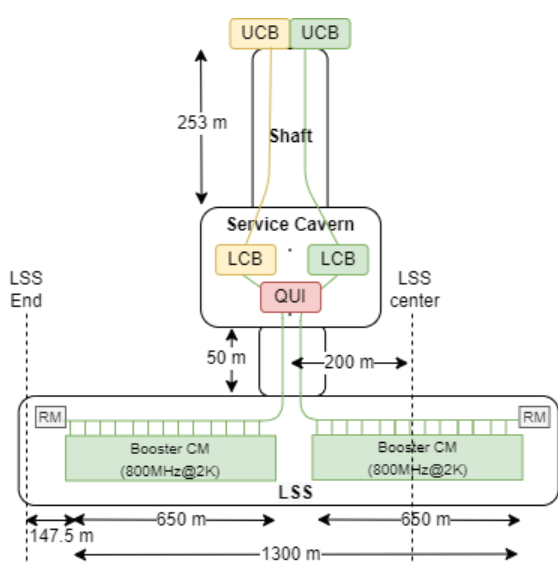
# FCC-ee Cryomodule space occupation for Integration study (since 2022)



Replaced by RF team integration study with conceptual 3D models

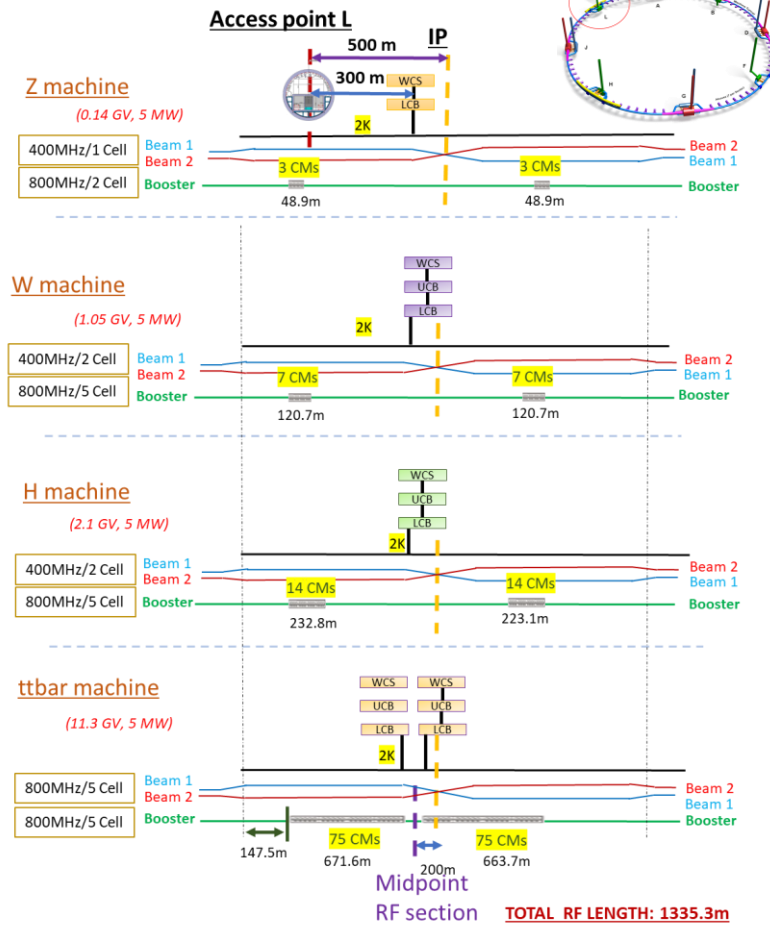
# FCC-ee RF/Cryogenic Layout point L

Courtesy Cryo team



- 2K Booster CMs near to cryoplants

TLSS length: 2032 m

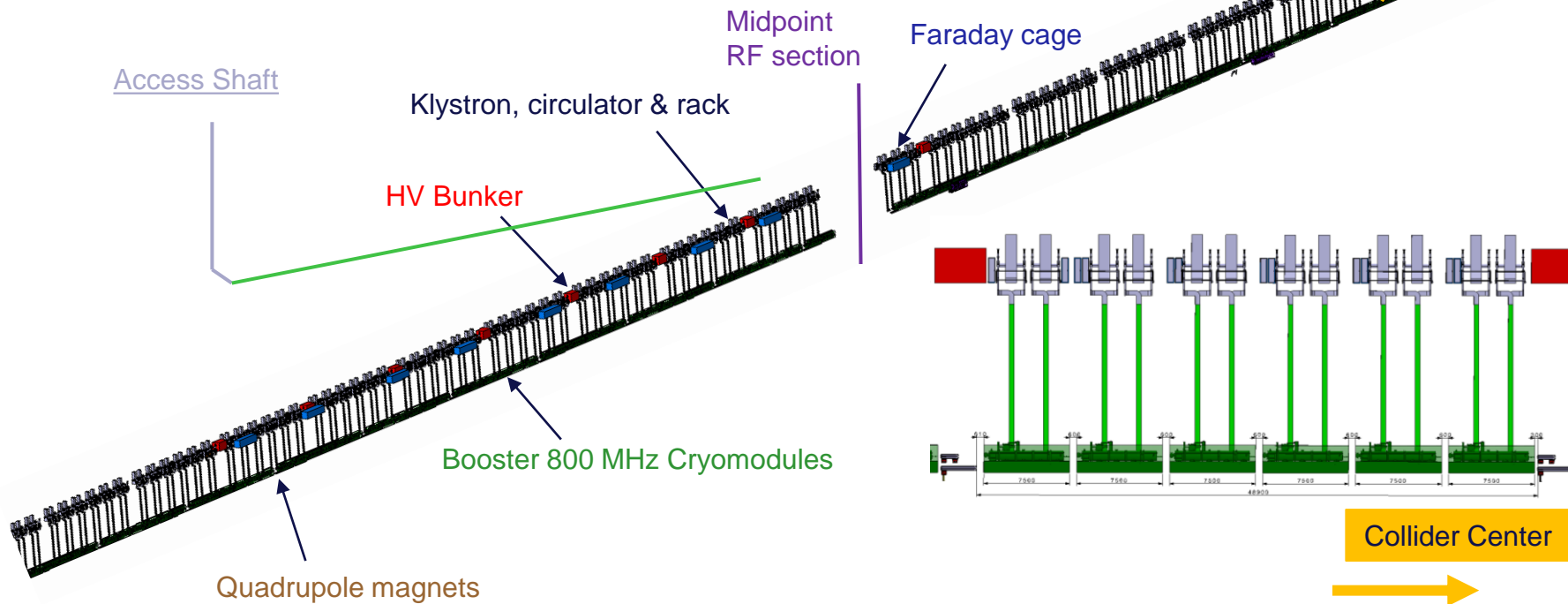


# FCC-ee RF Machine tunnel longitudinal view (ttbar machine)

- Distance between  $e^+e^-$  quadrupoles 52 m, length 3.1 m.
- Distance between booster quadrupoles 52 m, length 1.5 m.

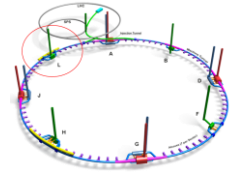
800 MHz cryomodules ( $\varnothing$  1.09 m x 7.5 m), half RF LSS

- 75 **booster** CM (671.6)
- 150 klystrons





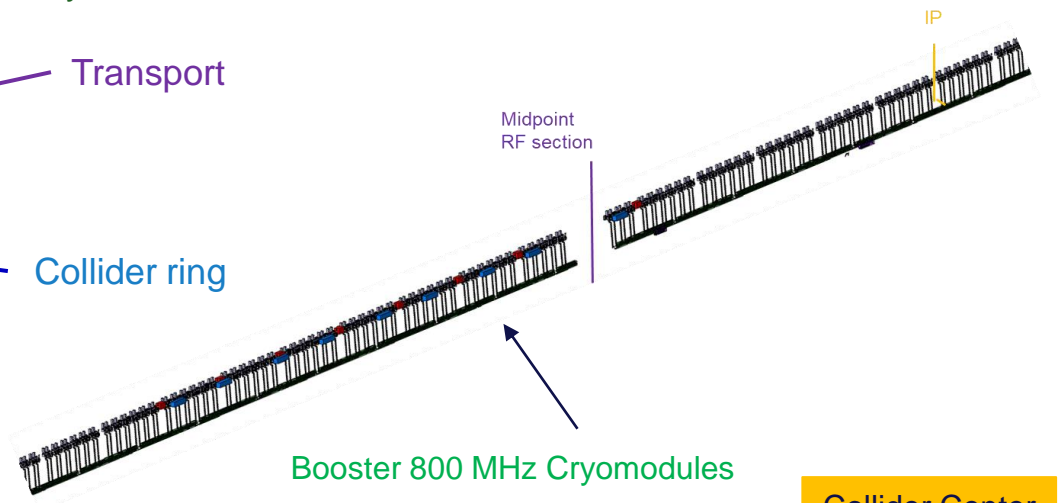
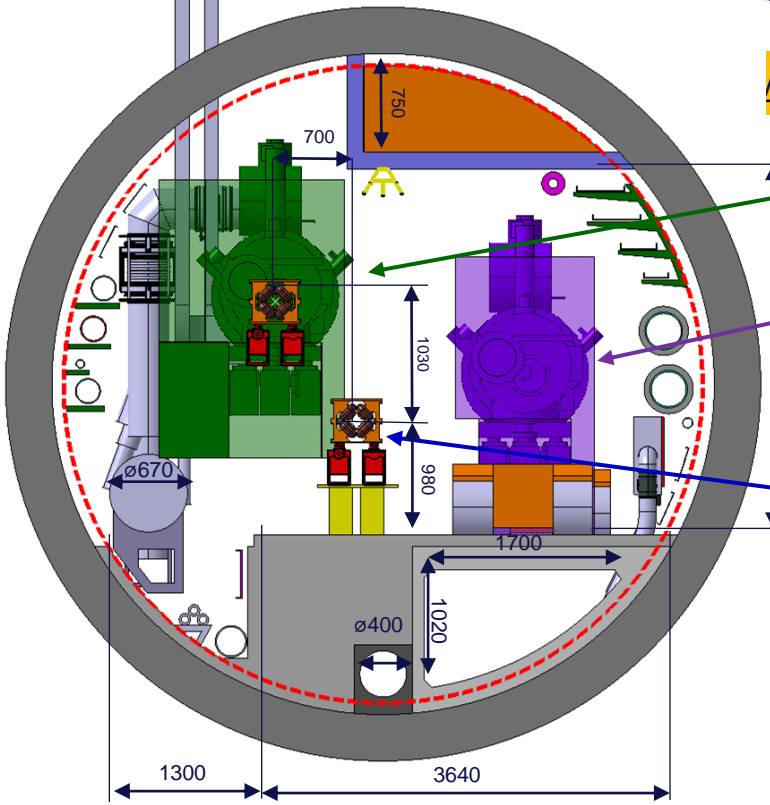
# FCC-ee RF Machine tunnel cross section (ttbar machine)



Waveguide

- QRL Ø along 800 MHz section 0.67 m.
- Distance between e<sup>+</sup>e<sup>-</sup> quadrupoles 52 m, length 3.1 m.
- Distance between booster quadrupoles 52 m, length 1.5 m.

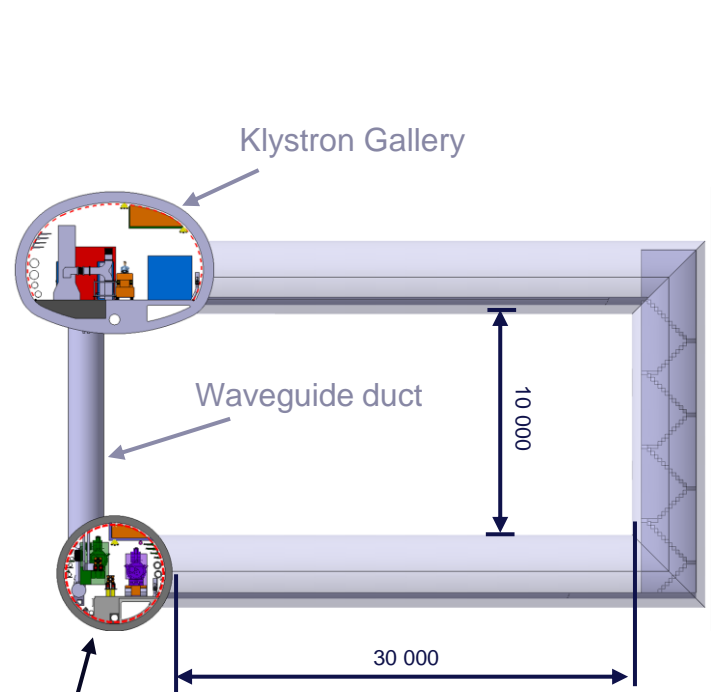
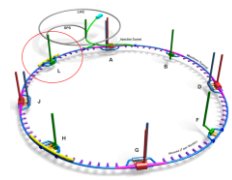
**Machine tunnel 5.5 m in diameter**



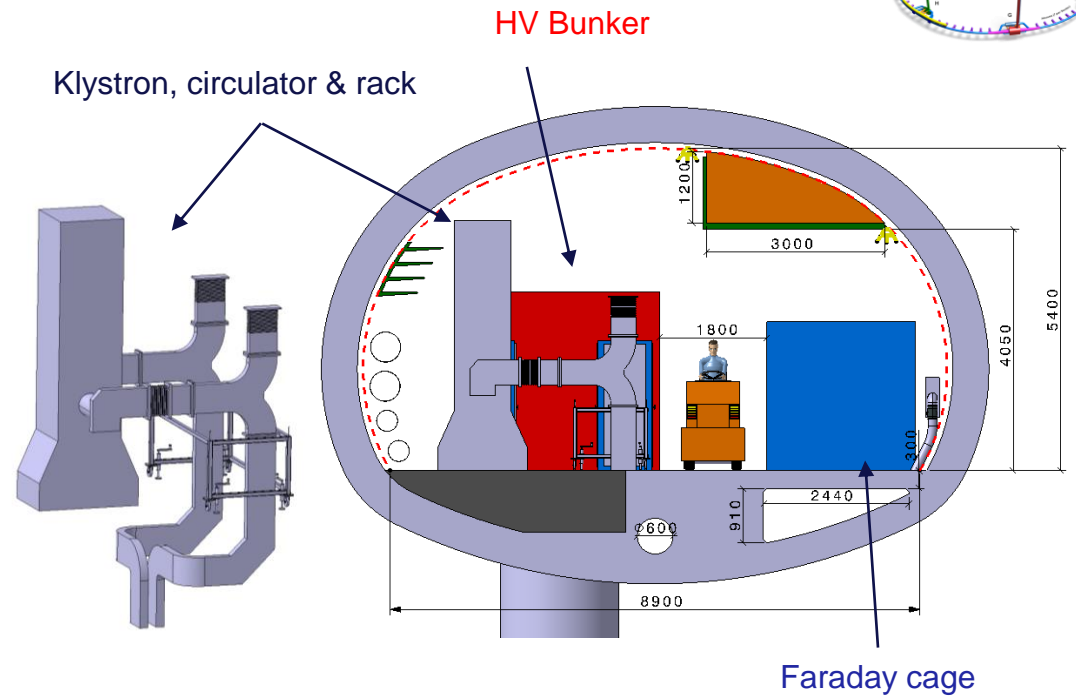
**Collider Center**



# FCC-ee RF Machine tunnel & Klystron Gallery cross section (ttbar machine)



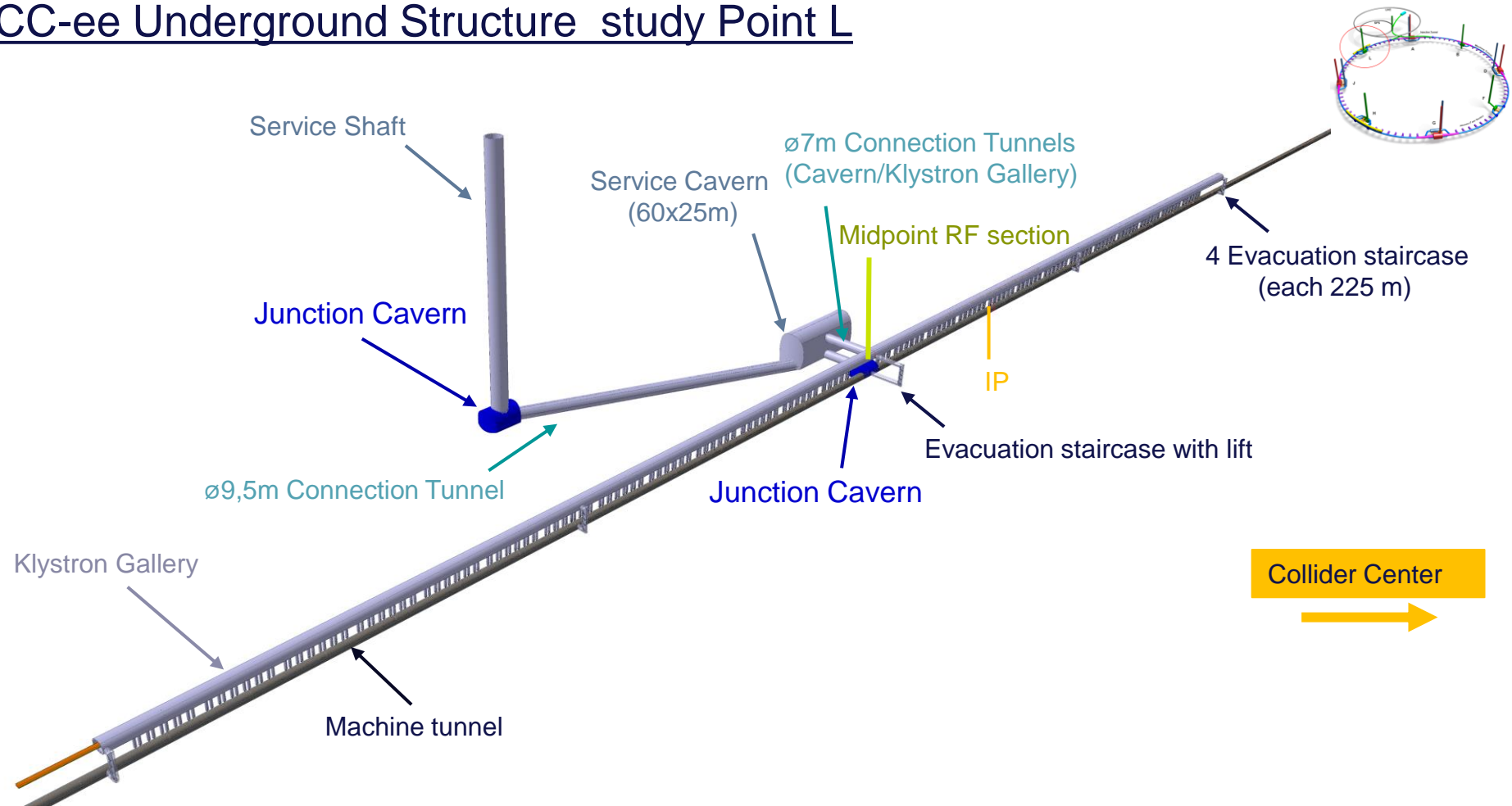
Machine tunnel



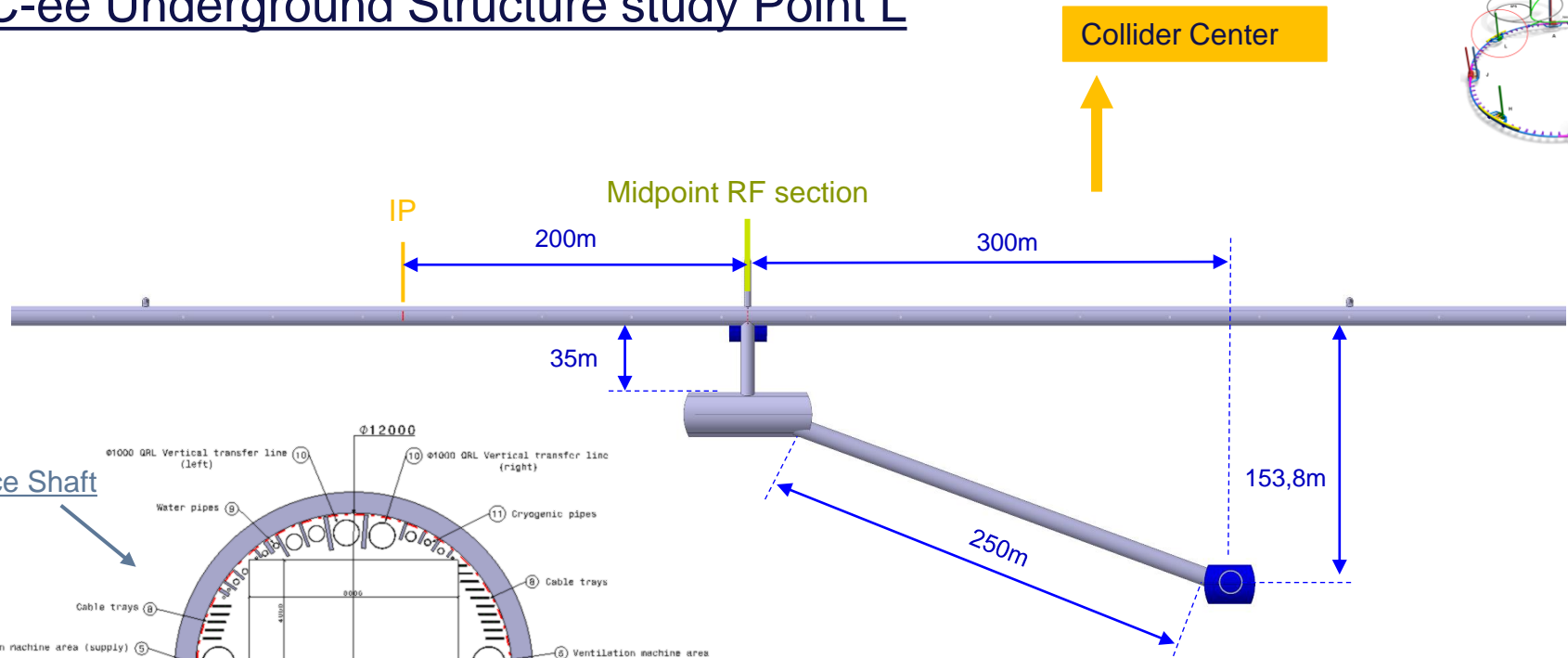
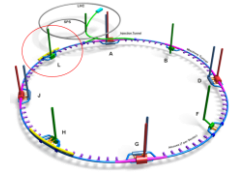
Collider Center



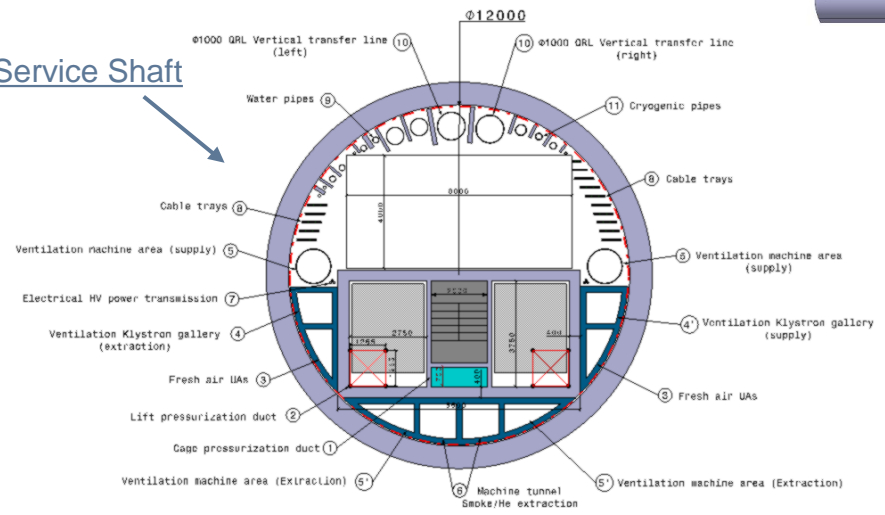
# FCC-ee Underground Structure study Point L



# FCC-ee Underground Structure study Point L

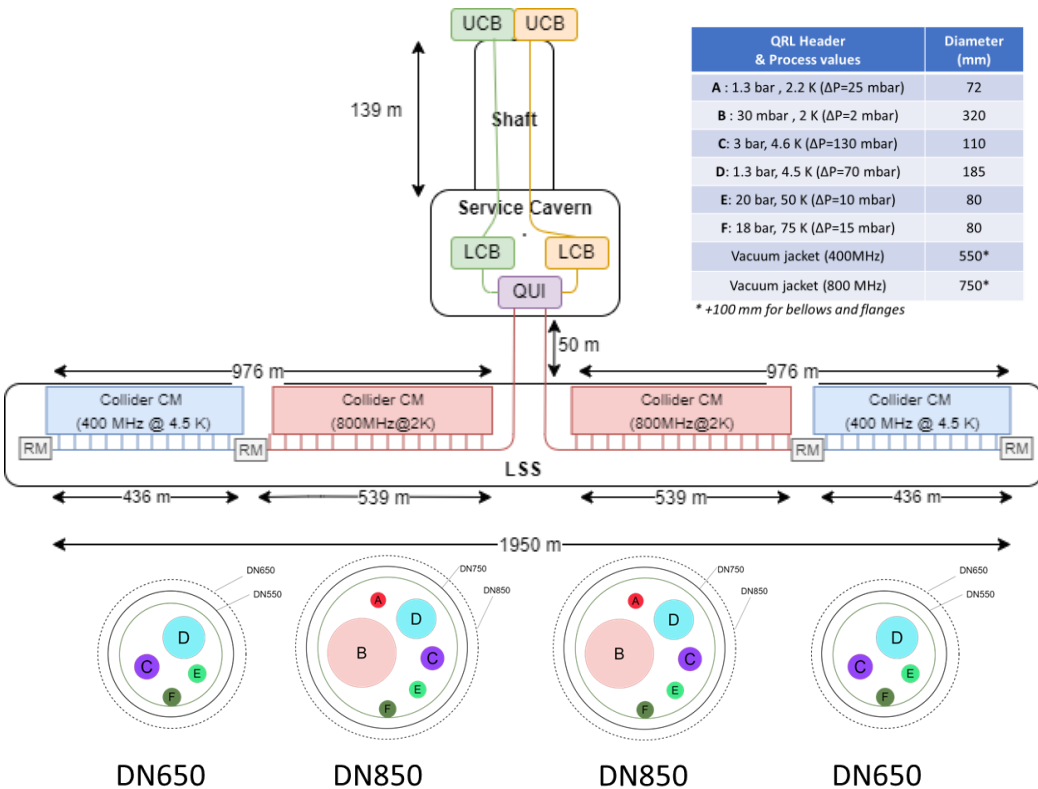


## Service Shaft

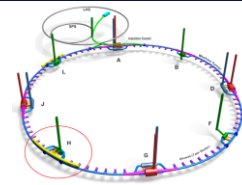


# FCC-ee RF/Cryogenic Layout point H

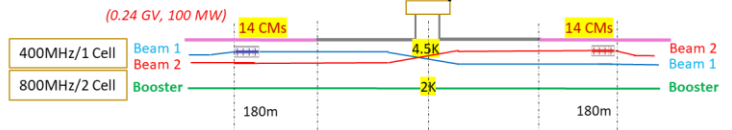
Courtesy Cryo team



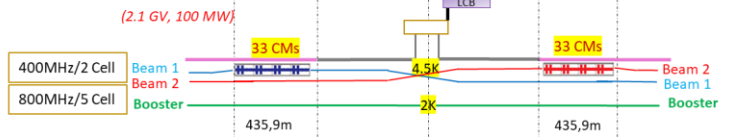
TLSS length: 2032 m



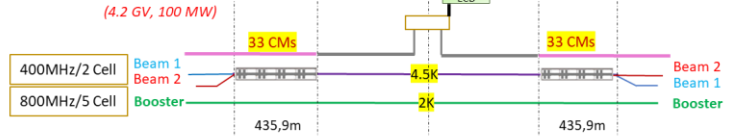
### Z machine



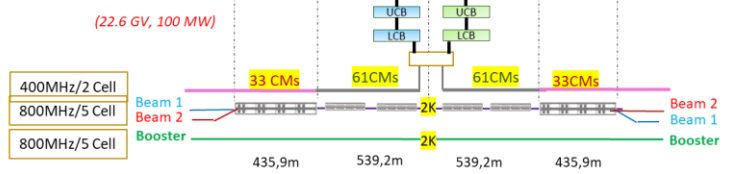
### W machine



### H machine



### ttbar machine



TOTAL RF LENGTH: 1950,2 m

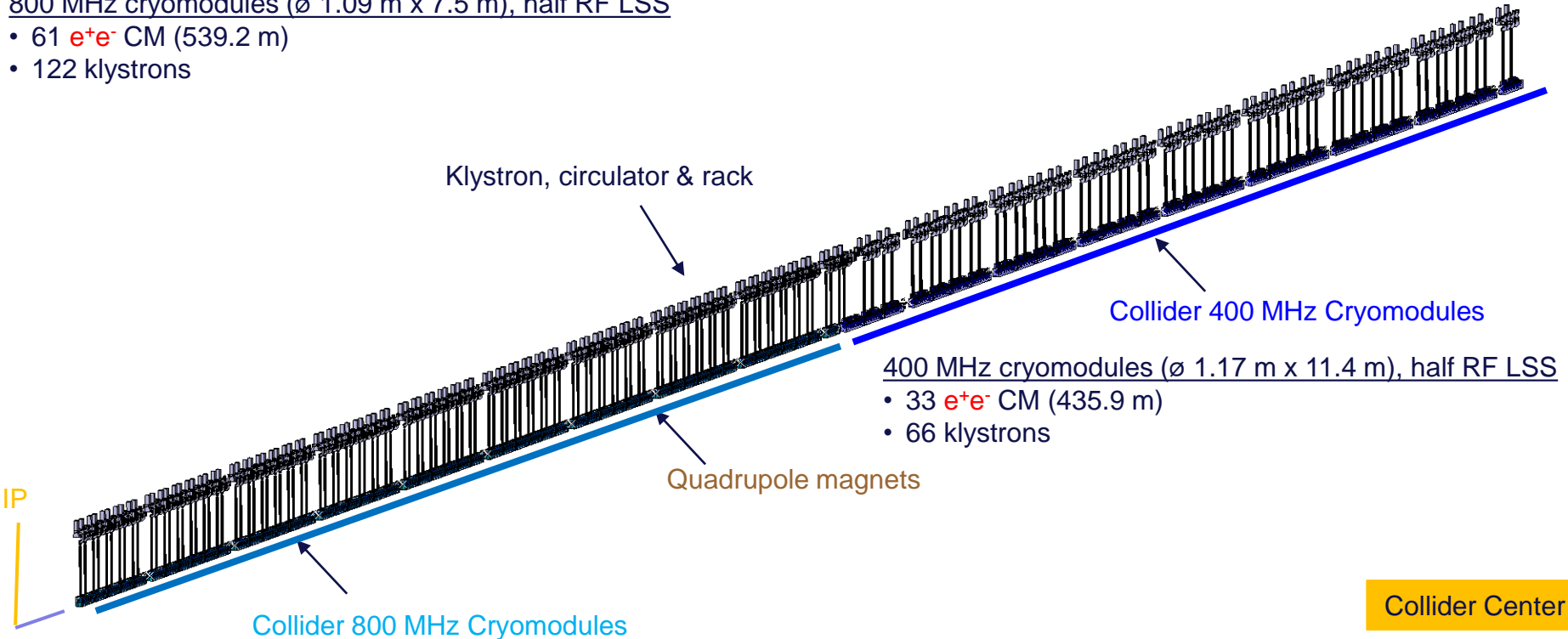
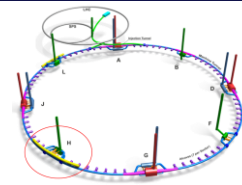
- 2K Booster CMs near to cryoplants then 4.5K Collider CMs

# FCC-ee RF Machine tunnel longitudinal view (ttbar machine)

- Distance between  $e^+e^-$  quadrupoles 52 m, length 3.1 m.
- Distance between booster quadrupoles 52 m, length 1.5 m.

## 800 MHz cryomodules ( $\varnothing$ 1.09 m x 7.5 m), half RF LSS

- 61  $e^+e^-$  CM (539.2 m)
- 122 klystrons



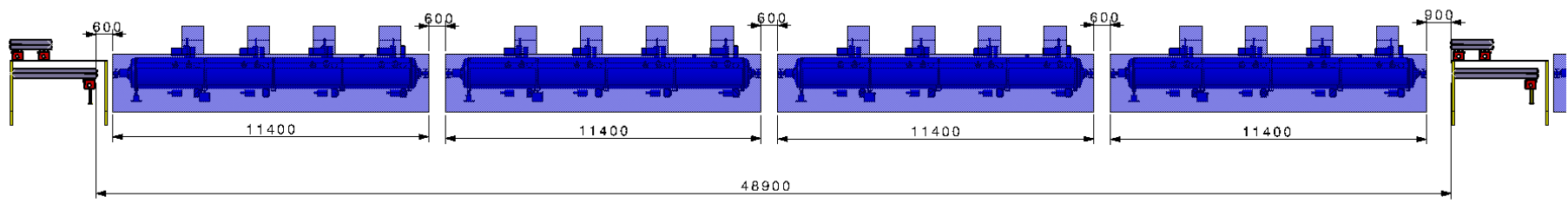
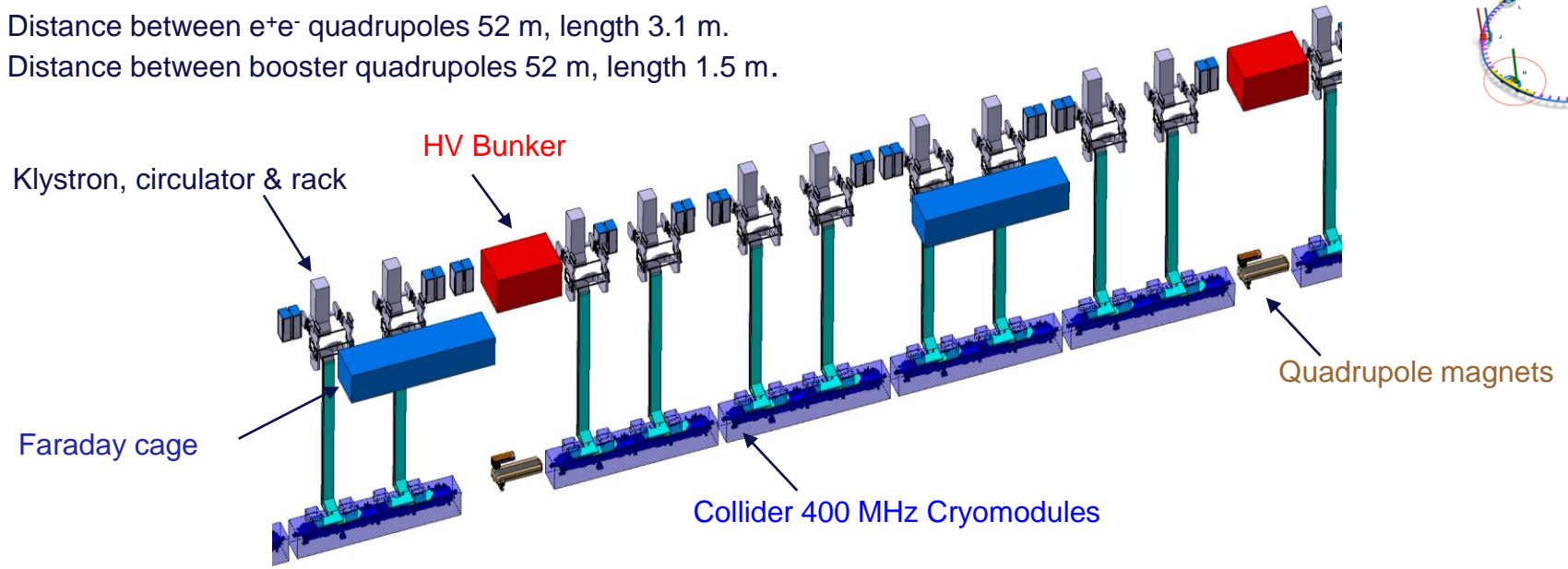
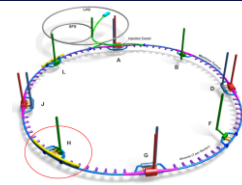
- 33  $e^+e^-$  CM (435.9 m)
- 66 klystrons

Collider Center

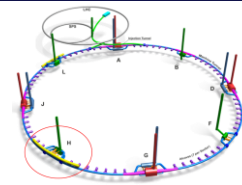


# FCC-ee RF Machine tunnel 400 MHz CMs (ttbar machine)

- Distance between e<sup>+</sup>e<sup>-</sup> quadrupoles 52 m, length 3.1 m.
- Distance between booster quadrupoles 52 m, length 1.5 m.



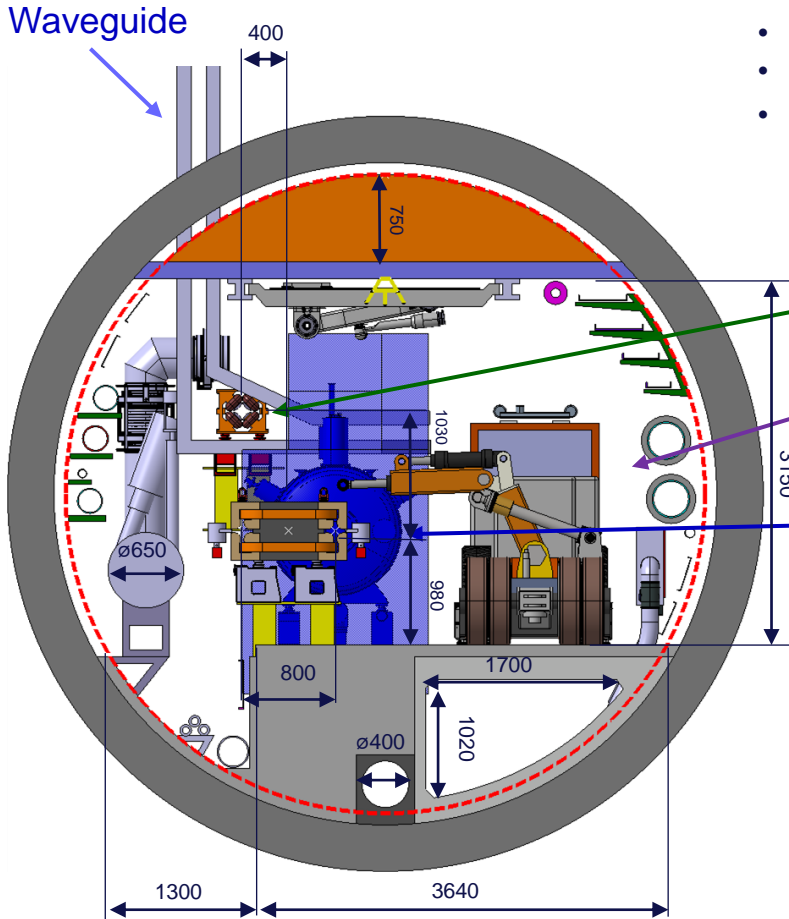
# FCC-ee RF Machine tunnel cross section (ttbar machine)



Waveguide

- QRL Ø along 400 MHz section 0.65 m.
- Distance between e<sup>+</sup>e<sup>-</sup> quadrupoles 52 m, length 3.1 m.
- Distance between booster quadrupoles 52 m, length 1.5 m.

Machine tunnel 5.5 m in diameter



Booster ring

Transport

Collider ring  
Cryomodule 400 MHz

IP

Collider 400 MHz Cryomodules

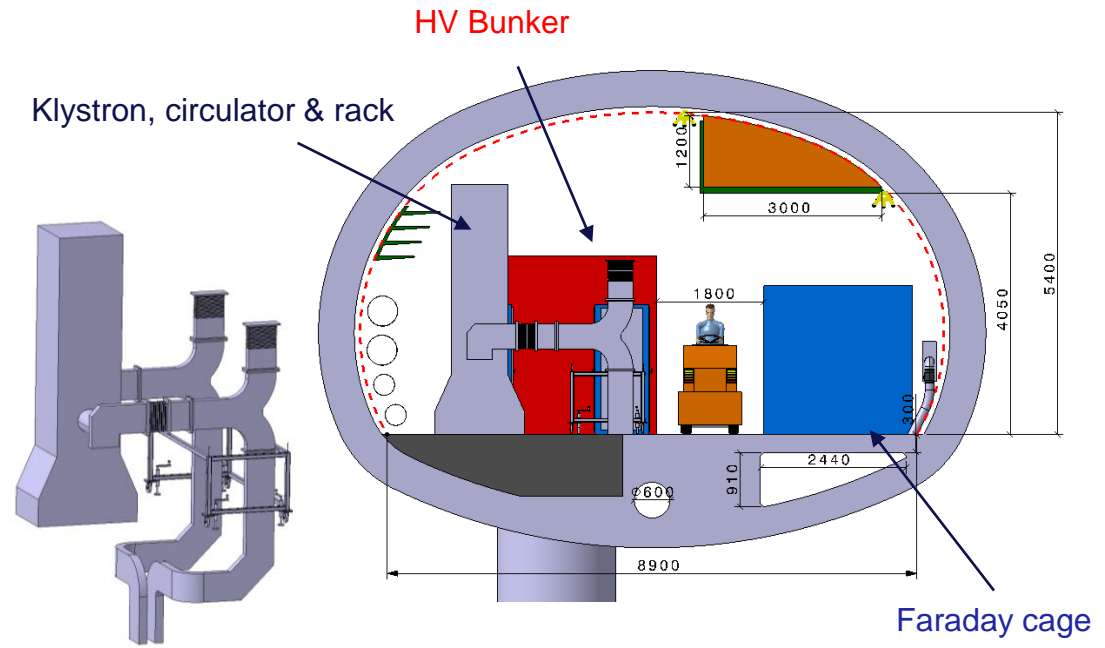
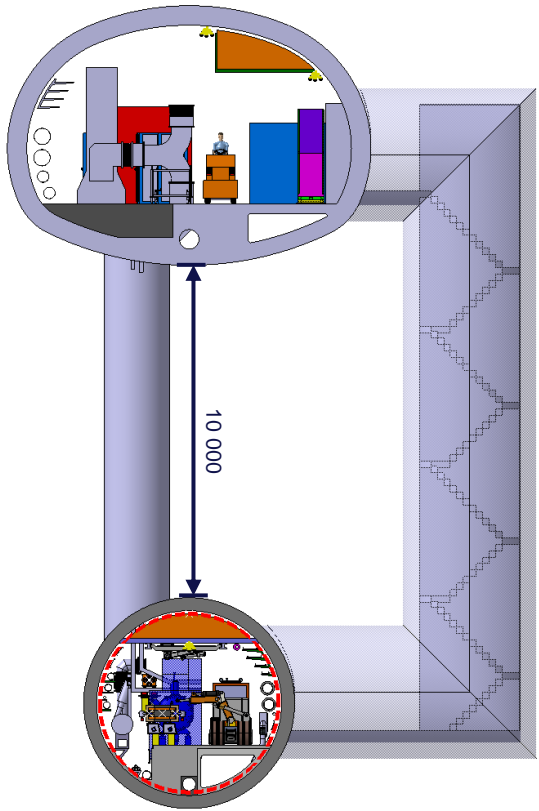
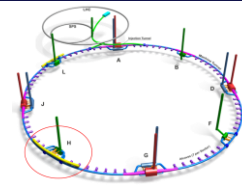
Collider 800 MHz Cryomodules

Collider Center





# FCC-ee RF Machine tunnel & Klystron Gallery cross section (ttbar machine)

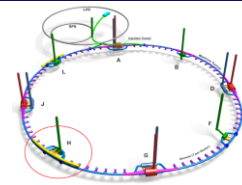


Collider Center





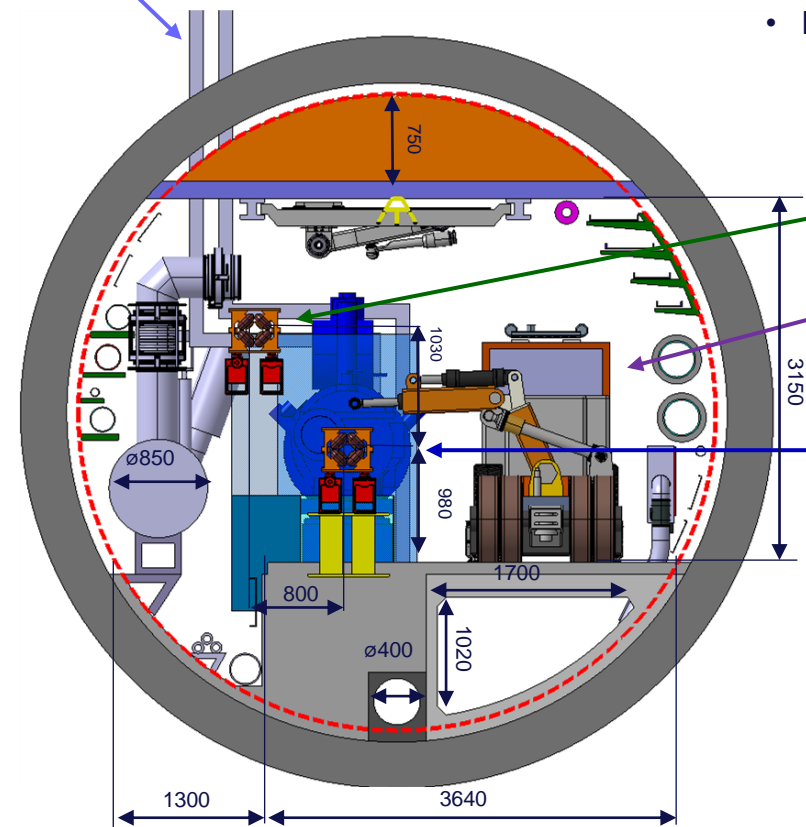
# FCC-ee RF Machine tunnel cross section (ttbar machine)



Waveguide

- QRL Ø along 800 MHz section 0.85 m.
- Distance between e<sup>+</sup>e<sup>-</sup> quadrupoles 52 m, length 3.1 m.
- Distance between booster quadrupoles 52 m, length 1.5 m.

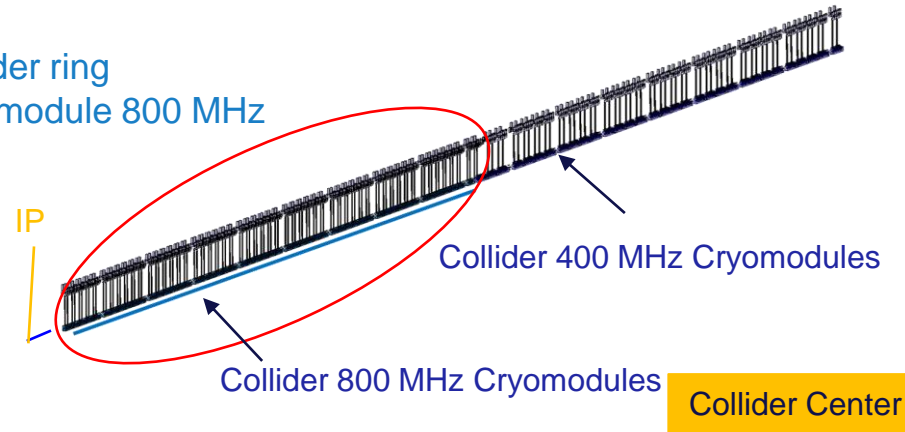
**Machine tunnel 5.5 m in diameter**



Booster ring

Transport

Collider ring  
Cryomodule 800 MHz

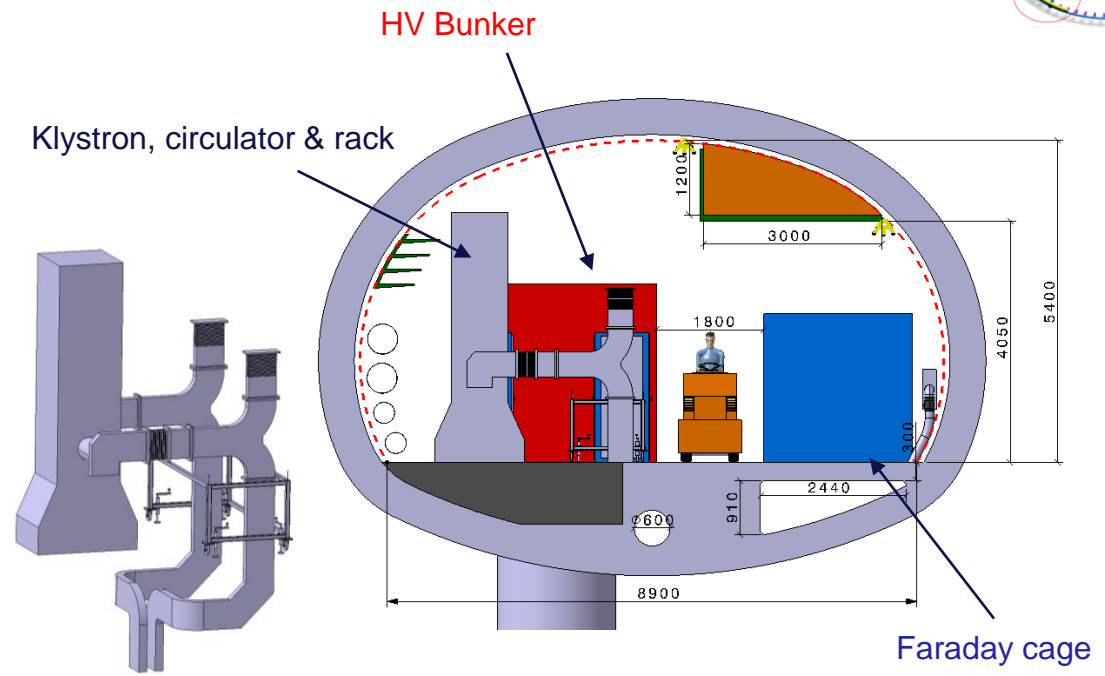
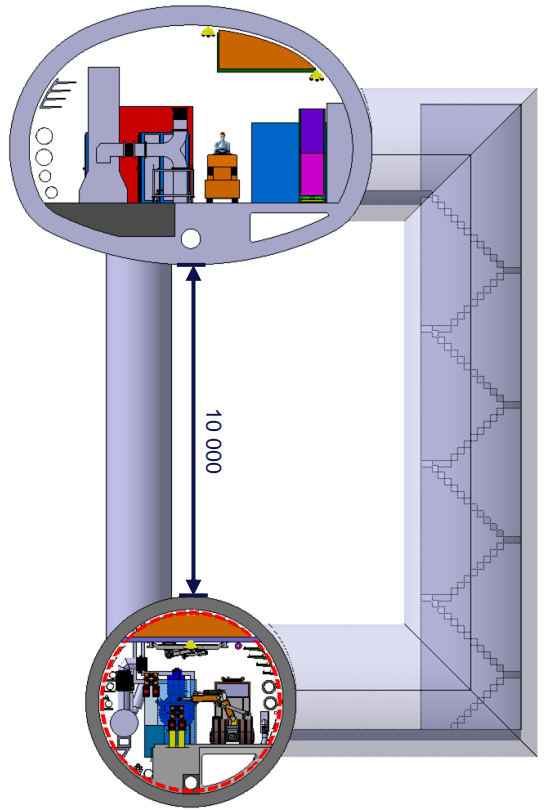
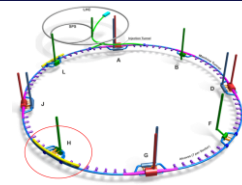


Collider 400 MHz Cryomodules

Collider 800 MHz Cryomodules

**Collider Center**

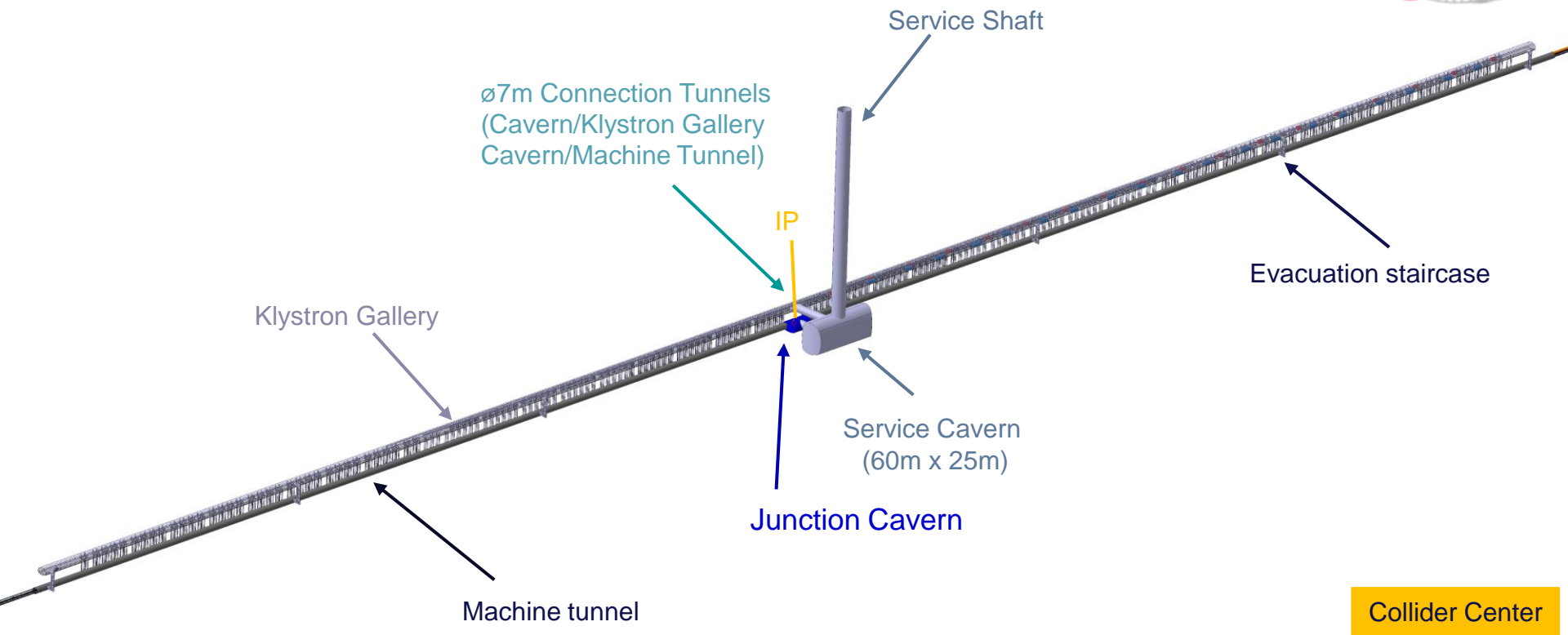
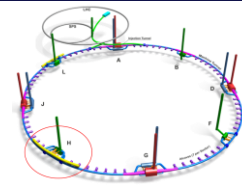
# FCC-ee RF Machine tunnel & Klystron Gallery cross section (ttbar machine)



Collider Center



# FCC-ee Underground Structure study Point H



Collider Center



## Conclusion

- For Collider Z, W, H and ttbar machine all 400MHz Cryomodules will be housed at point H.
  - For Collider ttbar machine 800MHz Cryomodules will be housed at point H.
  - For Booster Z, W, H and ttbar machine all 800MHz Cryomodules will be housed at point L .
- The integration study is still at a conceptual level and needs to be regularly updated with the evolution of the design of the CMs, the cryogenic lines, and other machine elements. The layout of the klystron galleries will further evolve with the technical design of all services.
- The objective of integration studies is to provide realistic 3D models of RF Sections by September 2024 to the Civil Engineering team.

Please follow Vittorio Parma's presentation "Update of RF layout and cryomodules"

I would like to acknowledge the FCC  
Technical Infrastructure Coordination team  
and the FCC Accelerator Technology team  
for their input and support in the  
integration studies.



Thank you  
for your attention.