INTEGRATION OF FCC-EE/HH

Released work

- Integration of FCC-ee machine elements at Point A and G
  - *FCC-ee/hh Underground Structure*
  - *FCC-ee/hh enlargement*
  - *FCC-ee/hh Experiment Cavern*
  - *FCC-ee/hh Service Cavern*
  - *FCC-ee/hh Connection Tunnel*
  - *FCC-ee/hh Transport Tunnel*
  - *FCC-ee Machine Tunnel Section 1 at Tunnel A*
- FCC-ee/hh Underground Structure and Surface at Point B
- FCC-ee/hh Underground Structure at Point C
- Integration of FCC-ee machine elements in SSS (Short Straight Section) Point A, B, G and L
  - *FCC-ee main ring machine elements*
  - *FCC-ee booster ring machine elements*
- Integration of FCC-ee RF machine elements at Point D and J
  - *FCC-ee RF machine elements (H)*
  - *FCC-ee RF cross section (ttbar2)*

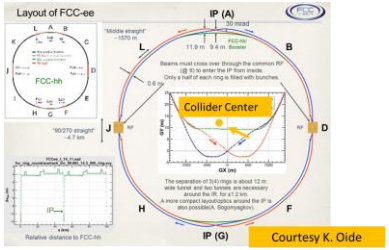
What's next

- Integration FCC-ee Underground Structure at Point A and G
- Integration of FCC-ee machine elements at Point A
- Integration of FCC-ee machine elements in SSS (Short Straight Section) Point A, B, G and L
- Integration FCC-ee Underground Structure at Point D
- Integration of FCC-ee RF machine elements at Point D
- FCC-ee extraction areas
- FCC-ee injection areas
- Outlines of surface sites (Experiment and Technical surface sites), determine the size of buildings for the needs of services.

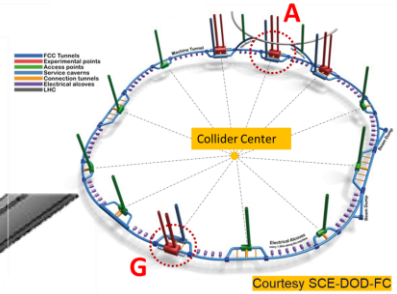
RELEASED WORK

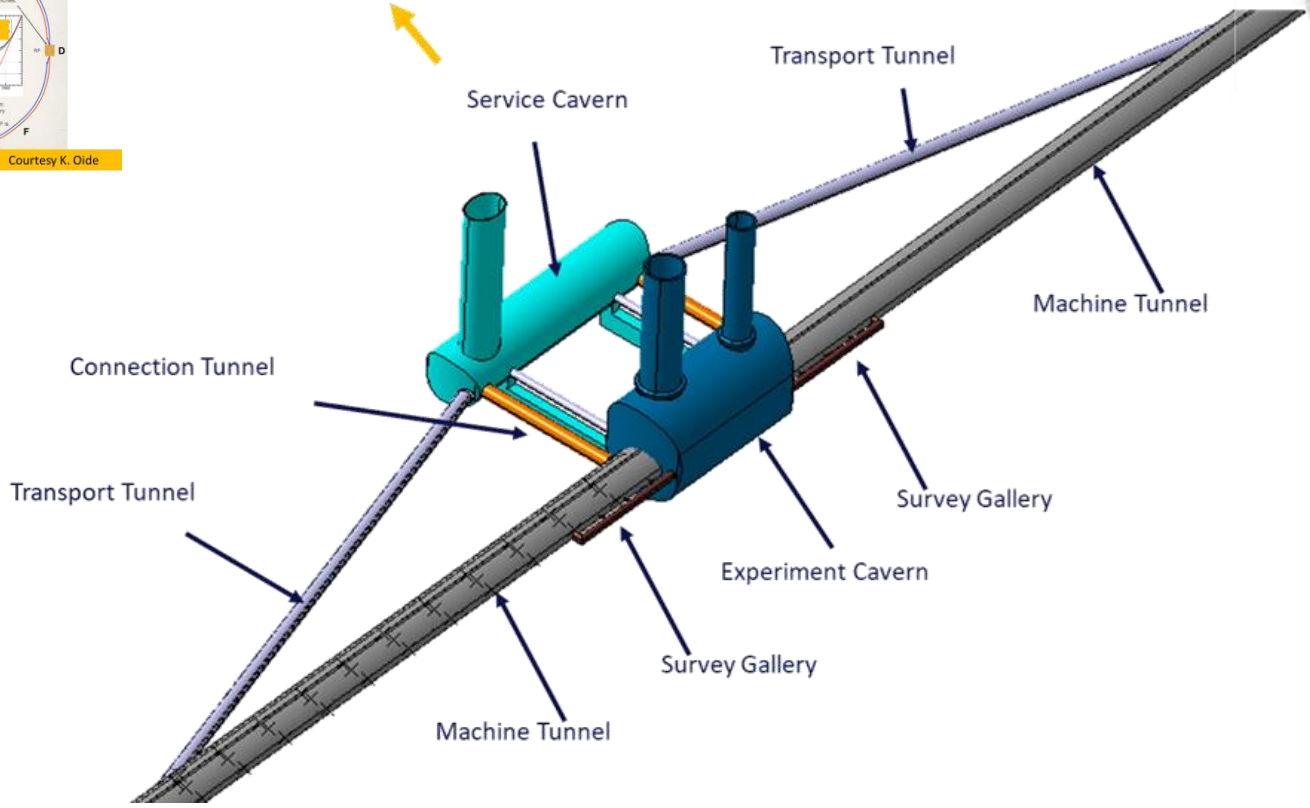
Remind : All studies take into account both requirements from ***ee*** AND ***hh*** Colliders

FCC-ee/hh Underground Structure at Point A and G

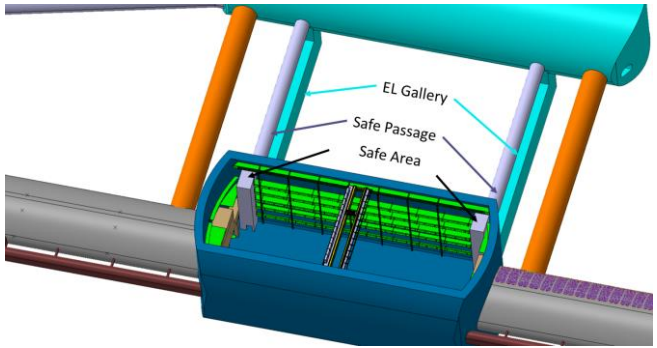


Collider Center

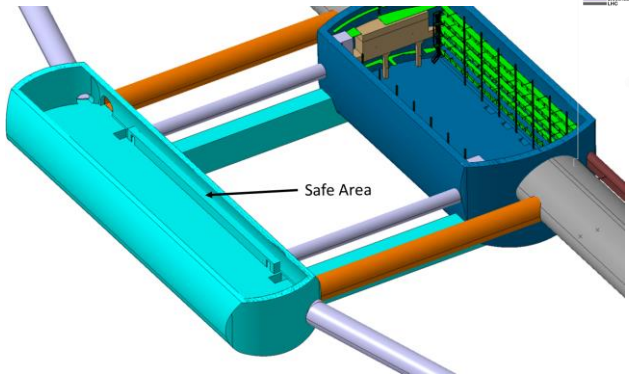


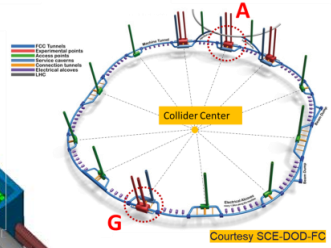


FCC-ee/hh Underground Structure at Point A and G

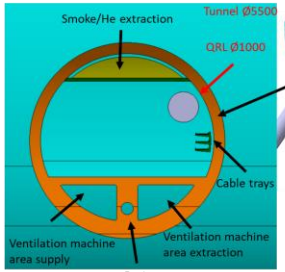


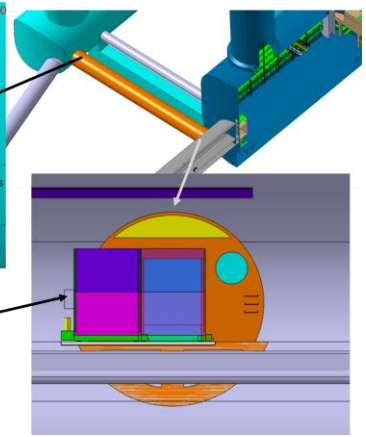
- *FCC-ee/hh Experiment Cavern*





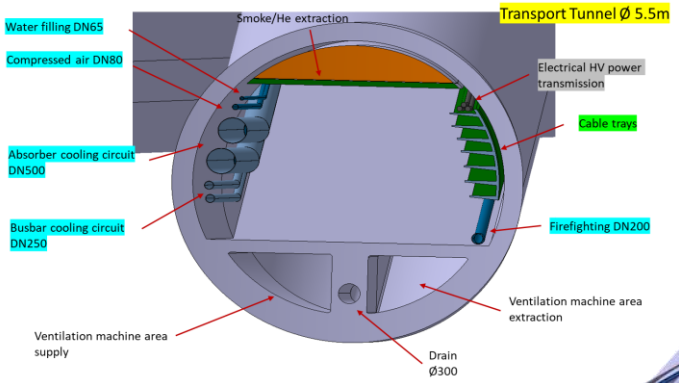
- *FCC-ee/hh Services Cavern*

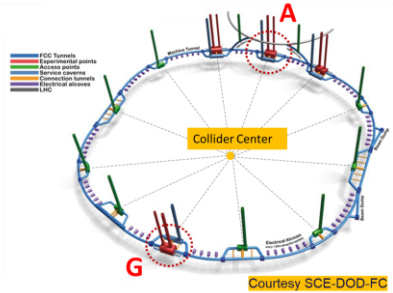




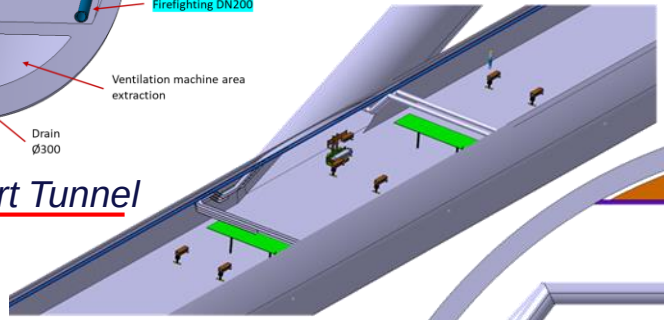
- *FCC-ee/hh Connection Tunnel*

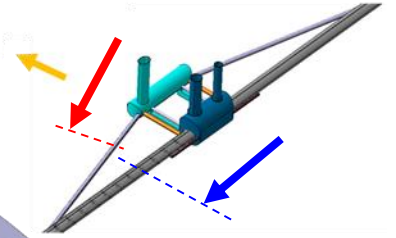
FCC-ee/hh Underground Structure at Point A and G

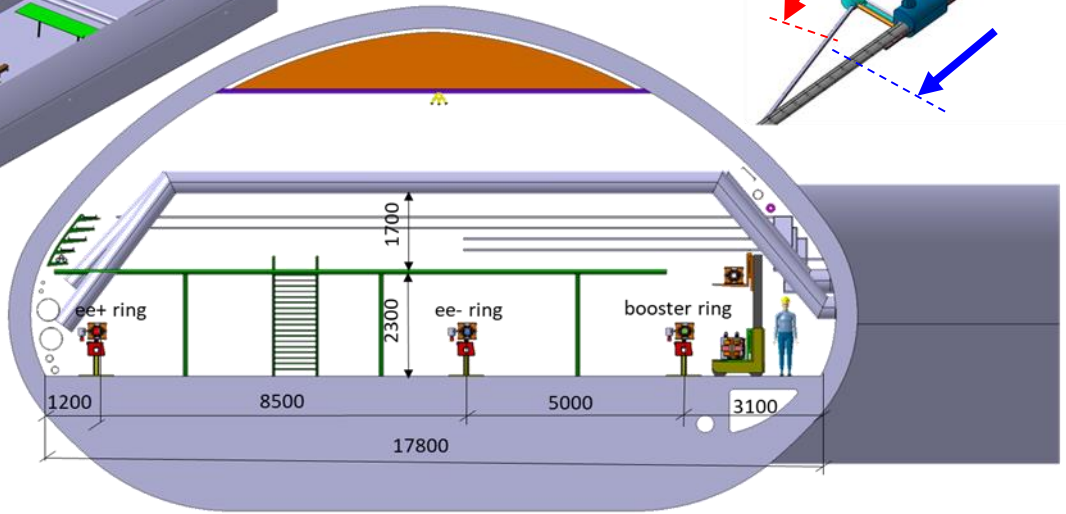




- *FCC-ee/hh Transport Tunnel*

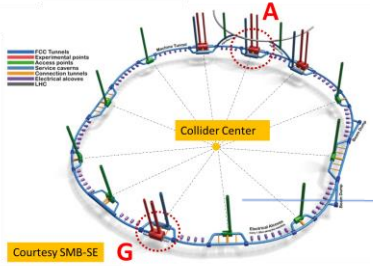


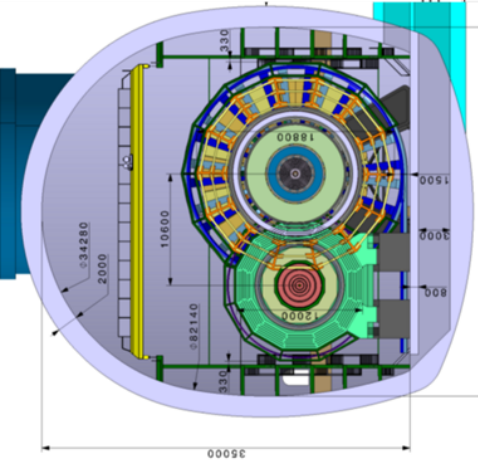




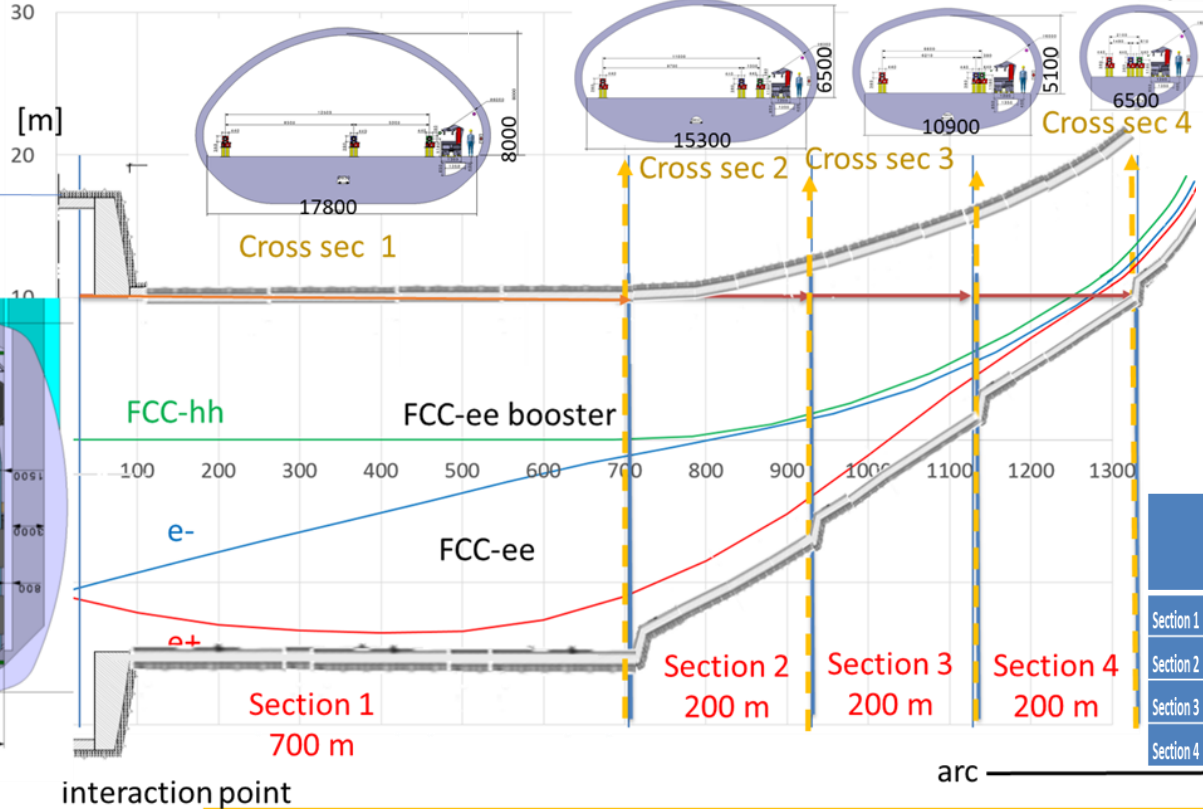
- *FCC-ee Machine elements at Section 1 Tunnel*

FCC-ee/hh enlargement

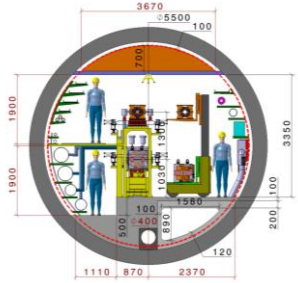




Experiment Cavern



interaction point

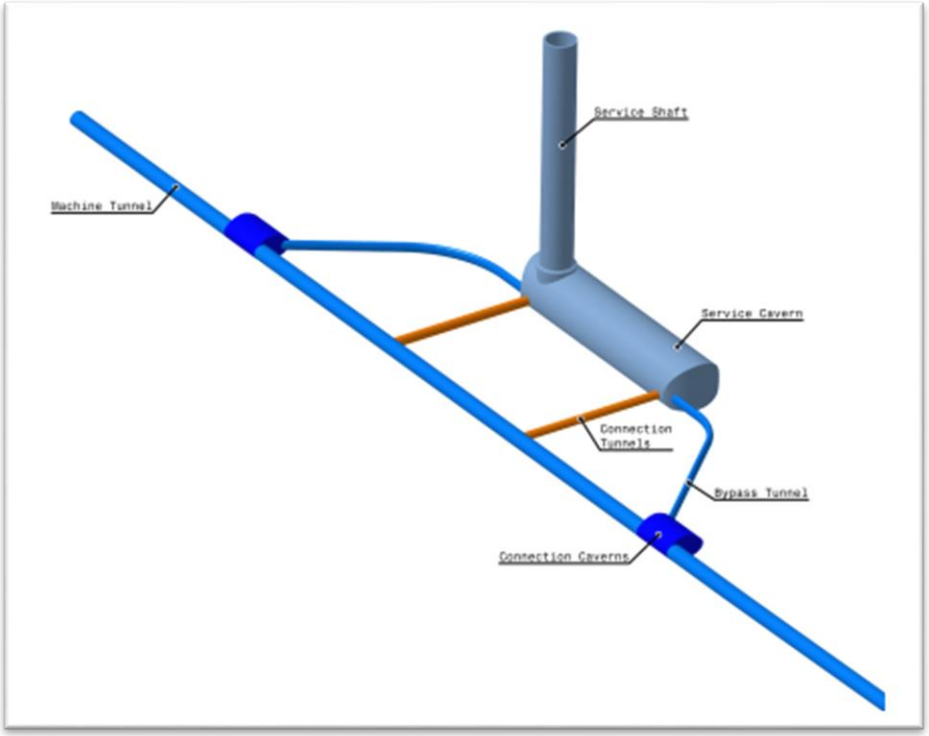


Regular arc

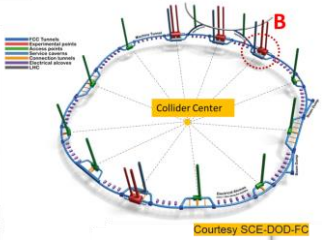
	Length of the tunnel (m)	ee ring and booster ring separation (m)
Section 1	700	13.5
Section 2	200	11
Section 3	200	6.6
Section 4	200	2.1

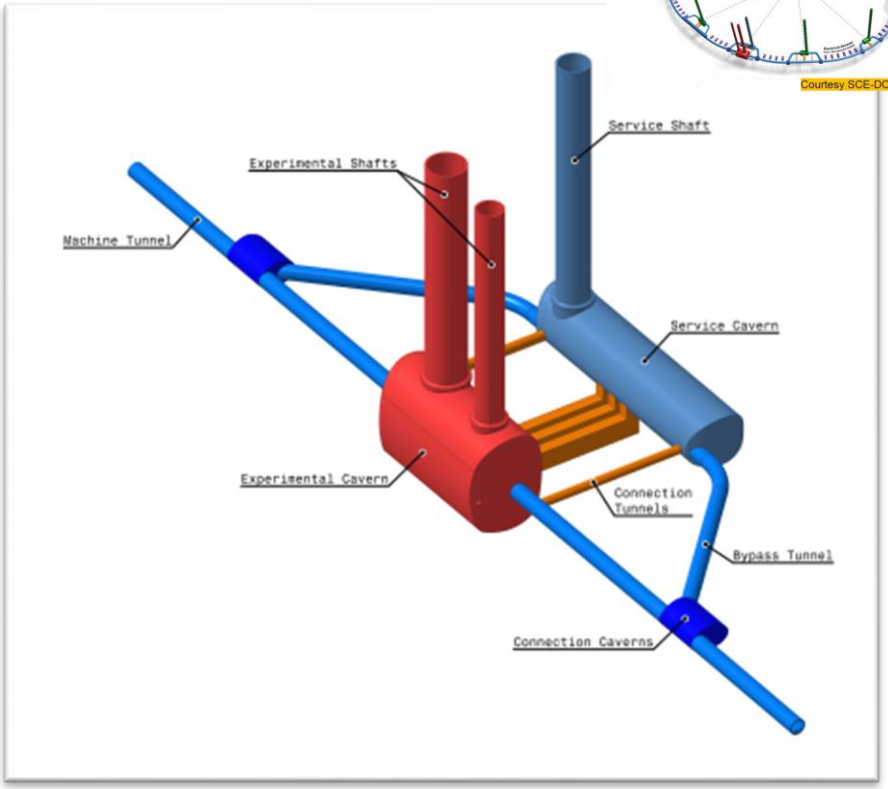
Data: K. Oide (FCC-ee), A. Langner (FCC-hh = FCC-ee booster); enlargement steps: M. J. Stuart

FCC-ee/hh Underground Structure at Point B *(L)*



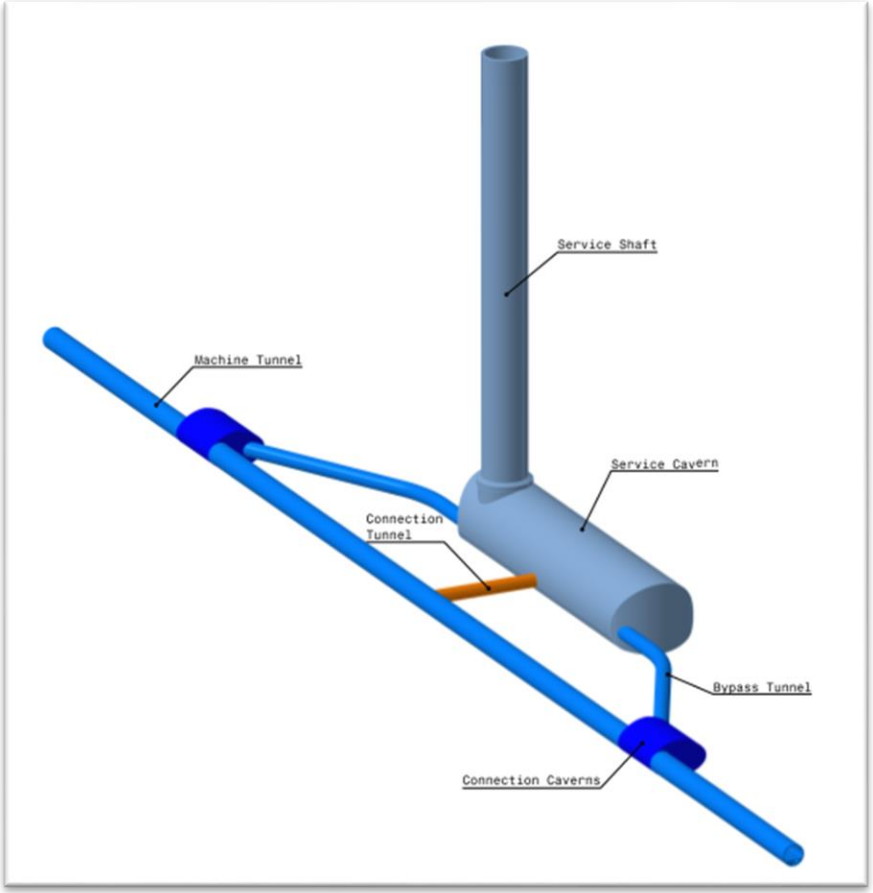
FCC-ee Underground Structure at Point B

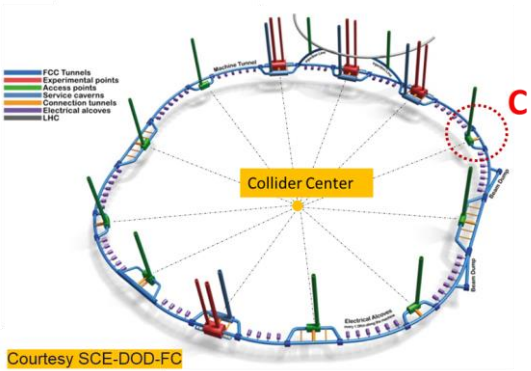




FCC-hh Underground Structure at Point B

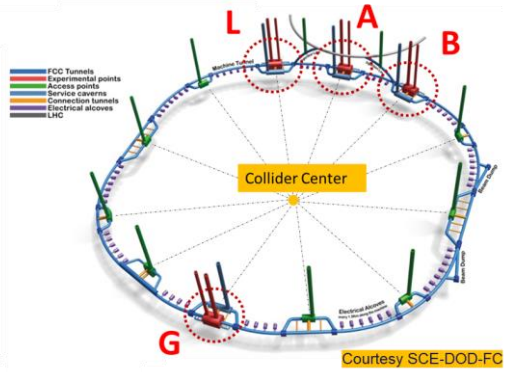
FCC-ee/hh Underground Structure at Point C *(E,F,H,I,K)*





Standard Access point Configuration

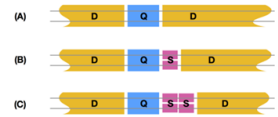
Integration of FCC-ee machine elements in SSS (Short Straight Section) Point A, B, G and L



FCC-ee main ring

D: dipole, Q: quadrupole, S: sextupole

Spacing Between Magnets (m)	
D-Q	0.3
Q-S	0.3
S-S	0.1
S-D	0.3



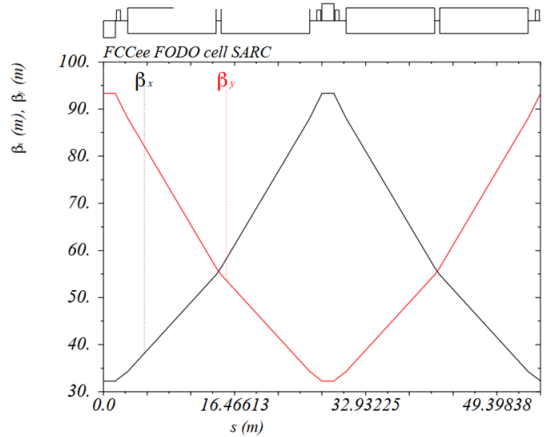
Case	Arrange	Numbers	Length of D (m)
(A)	Dx-Q-Dx	492	24.432
(B)	Dx-Q-S-Dx	1256	22.732
(C)	Dx-Q-S-S-Dx	1152	21.232

Length (m)		
Q	2.9	twin aperture
S	1.4	single aperture

Table provided by Katsunobu Oide on 24.7.2018

FCC-ee booster ring

Circumference:	97749.3853618 m
Length LSS:	1400.00012067 m
Length ESS:	2800.00001315 m
Length LARC:	15539.1945862 m
Length SARC:	3183.45094234 m
Length DShh:	553.675156092 m
Cell length in LSS:	50.0000043098 m
Cell length in ESS:	100.000000526 m
Cell length in SARCs	54.8870852127 m
Cell length in LARCs:	53.9555367575 m
Cell length in DShhs:	55.3675156092 m
Number of cells per LSS:	28
Number of cells per ESS:	29
Number of cells per SARC:	58
Number of cells per LARC:	288
Number of cells per DShh:	10
Length of dipoles:	11.1 m
Length of quadrupoles:	1.5 m
Length of sextupoles:	0.5 m
Distance quad-sext:	0.15 m
Distance sext-bend (SARC):	0.896771303179 m
Distance sext-bend (LARC):	0.663884189371 m
Distance bend-bend:	0.65 m



Data and diagram provided by Bastian Harer on 27.7.2018

Integration of FCC-ee machine elements in SSS

Main ring magnet information
(if half-cell length reserved for a single – long – dipole is distributed over 3 – shorter – dipoles):

Case A:

Magnet	Length	Weight	Number of magnets
Dipole	7.94	~2000	8700
Quadrupole	2.9	~4500	3480

Case B:

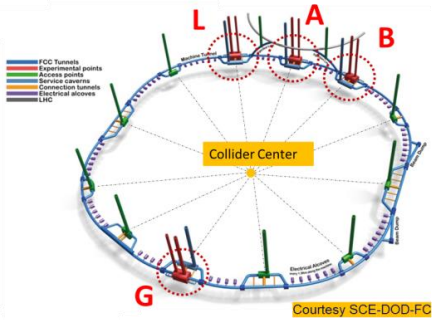
Magnet	Length	Weight	Number of magnets
Dipole	7.37	~1840	8700
Quadrupole	2.9	~4500	3480
Sextupole	1.4		832

Case C :

Magnet	Length	Weight	Number of magnets
Dipole	7.21	~1800	8700
Quadrupole	2.9	~4500	3480
Sextupole	1.4		2336

Booster magnet information
(if half-cell length reserved for 2 dipoles is distributed over 3 dipoles):

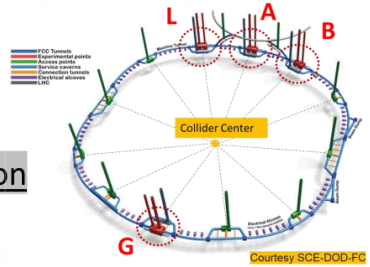
Magnet	Length/m	Weight	Number of magnets
Dipole	7.4		9020
Quadrupole	1.5		3540
Sextupole	0.5		1568



Metallic structure:

Profile	Dimension in mm	kN m	Weight kg/m
	120x60x6	625	15.6

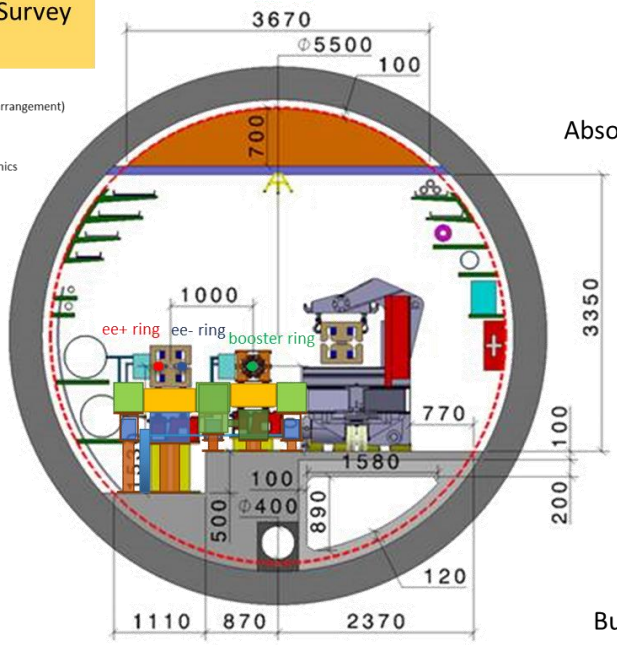
Integration of FCC-ee machine elements in SSS



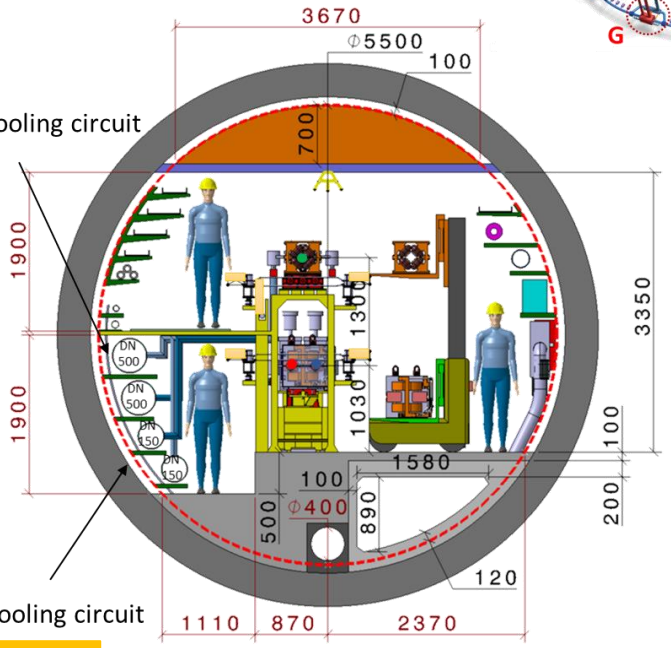
Space reservations for Survey elements

- 3 x WPS sensors + Wire Space (vertical arrangement) height x width → 0.3 x 0.3 (m)
- WPS Wire Replacement System: mechanics height x width → 0.5 x 0.3 (m)
- WPS Wire Replacement System: suction height x width → 0.3 x 0.3 (m)
- HLS Pipe (curved in horizontal plane) Slope = 1.4%, length 38 m height x width → 0.65 x 0.1 (m)
- HLS Refill System height x width → 0.3 x 0.4 (m)
- HLS sensor height x width → 0.2 x 0.15 (m)
- Element Girder
- Survey Equipment Support

Layout cross section:



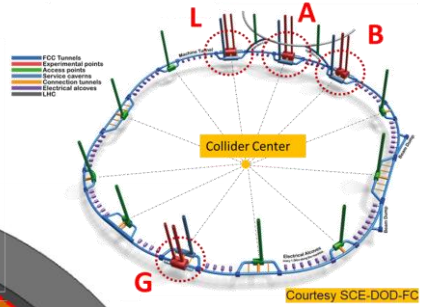
Alternative cross section



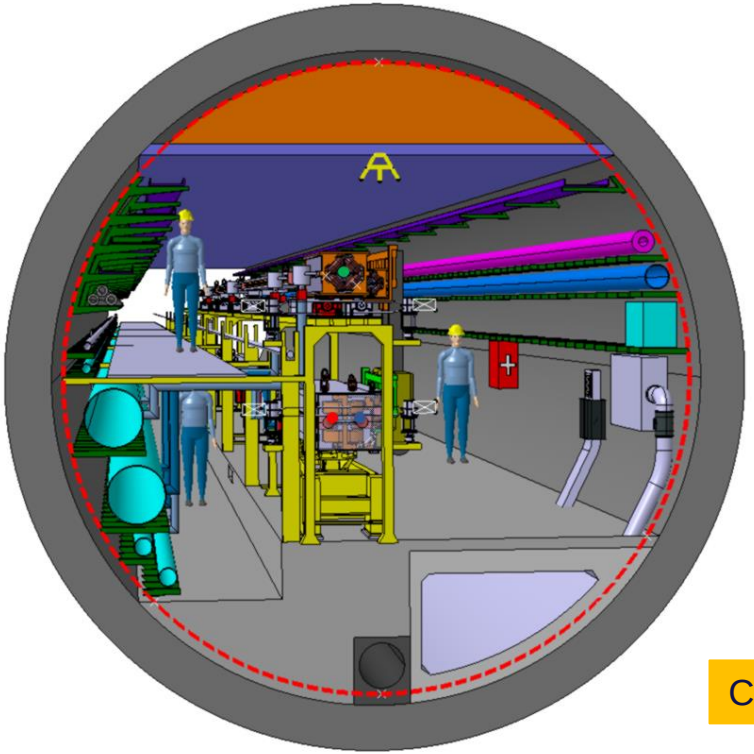
Collider Center

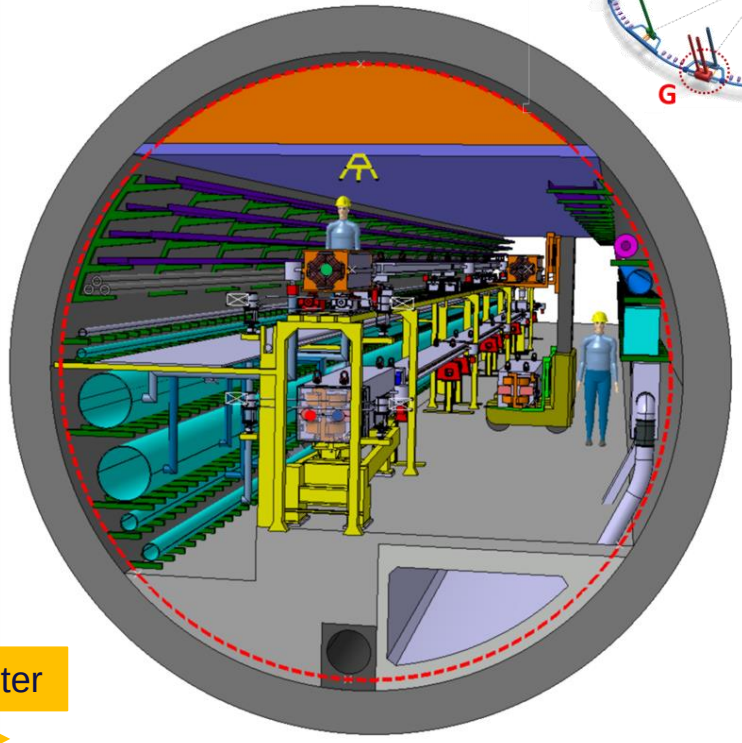
Alignment space reservation

Integration of FCC-ee machine elements in SSS



Perspective view

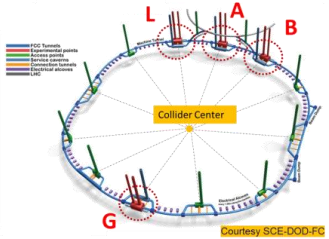




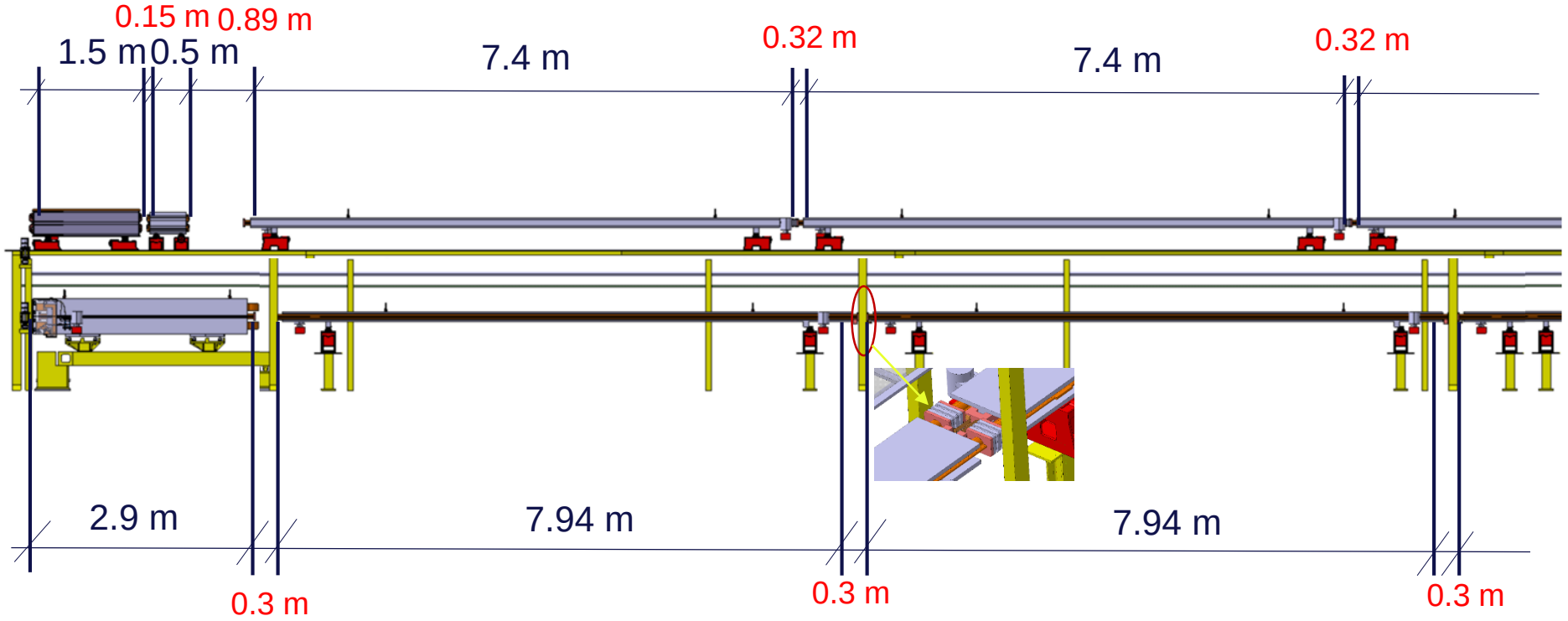
Collider Center

Integration of FCC-ee machine elements in SSS

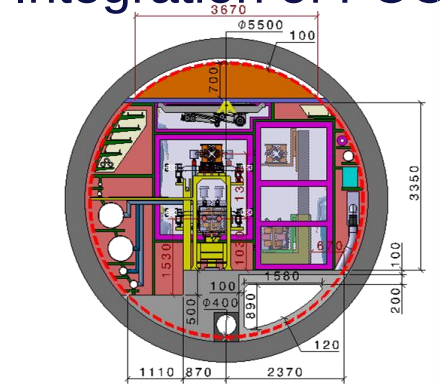
“Case A”: main ring SSS without sextupole; followed by 24.432 m for dipole(s)

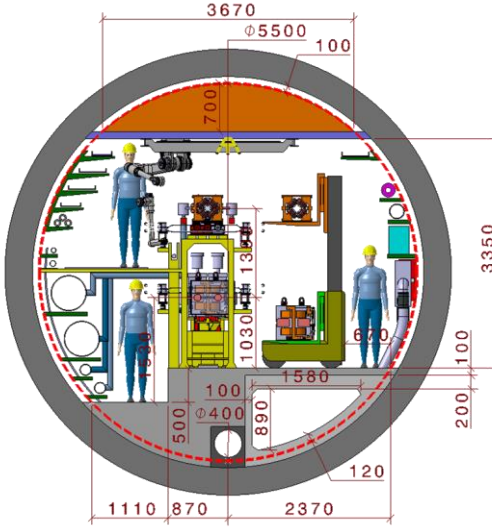


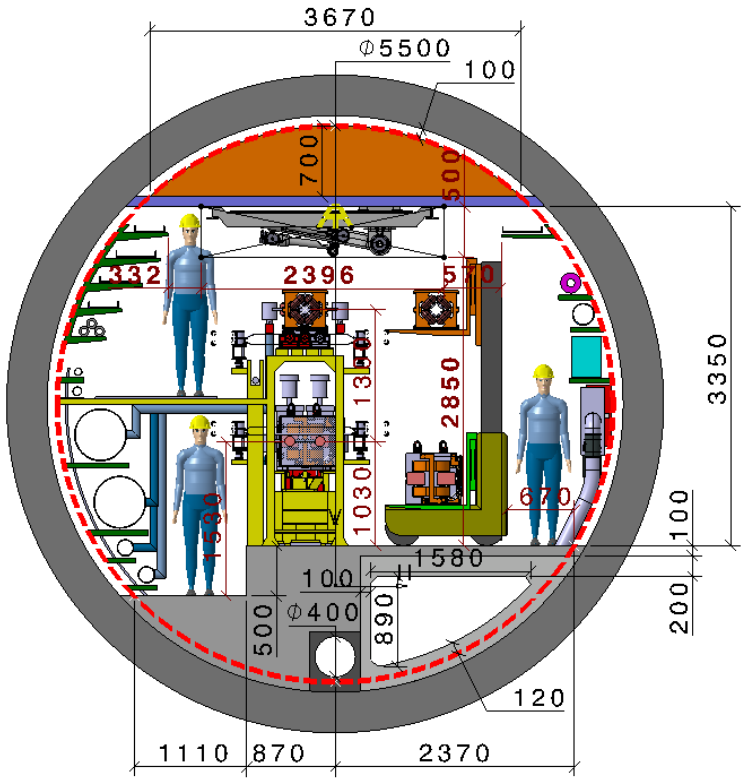
Side view

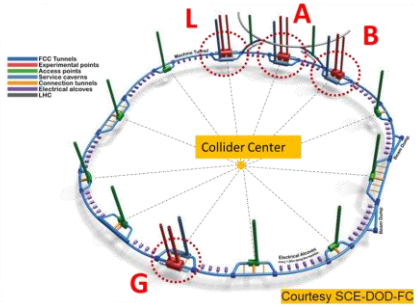


Integration of FCC-ee machine elements in SSS

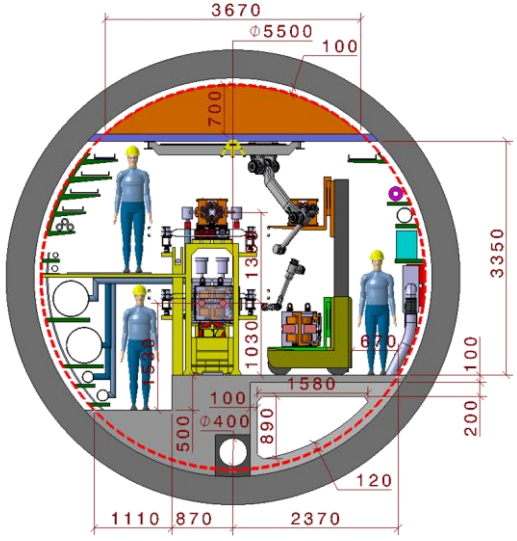








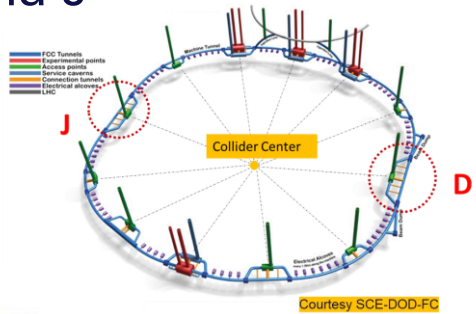
Collider Center



Robot positions in the tunnel

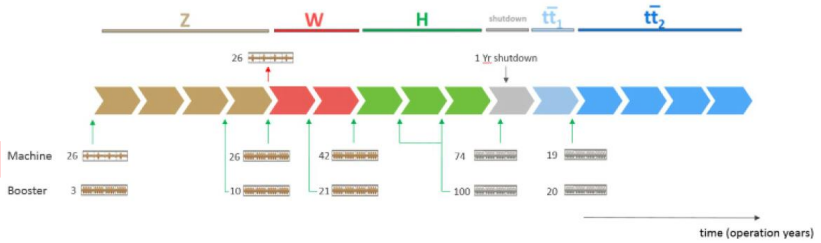
Integration of FCC-ee RF machine elements at Point D and J

	Z		WW		ZH		$t\bar{t}$ 1		$t\bar{t}$ 2	
	per beam	booster booster	per beam	boo-ster	per beam	booster booster	2 beams	booster	2 beams	booster
Total RF voltage [MV]	100	140	750	750	2000	2000	9500	9500	10 930	10 930
Frequency (MHz)	**400**									
RF voltage [MV]	100	140	750	750	2000	2000	4000	2000	4000	2000
E_{acc} (MV/m)	5.1	8	9.6	9.6	9.8	9.8	10		10	
# cell / cav	1	4	4		4		4		4	
V_{cavity} (MV)	1.92	12	14.4	14.4	14.7	14.7	15		15	
# cavities	52	12	52	52	136	136	272	136	272	136
# CM	13	3	13	13	34	34	68	34	68	34
T operation (K)	4.5		4.5		4.5		4.5		4.5	
Dyn losses/cav (W)	14	11	210	26	202	29	210	30	210	30
Stat losses/cav (W)	8		8		8		8		8	
Q_{ext}	4.4×10^4		6.6×10^5		1.9×10^6		4×10^6		4.7×10^6	
P_{cav} (kW)	962		962		368		175		149	
Frequency (MHz)	**800**									
RF voltage (MV)							5500	7500	6930	8930
E_{acc} (MV/m)							19.8	20	19.8	19.8
# cell/cav							5		5	
V_{cavity} (MV)							18.6	18.75	18.6	18.6
# cavities							296	400	372	480
# CM							74	100	93	120
T operation (K)							2		2	
Dyn losses/cav (W)							66	10	66	10
Stat losses/cav (W)							8		8	
Q_{ext}							3.9×10^6		5.6×10^6	
P_{cav} (kW)							176		155	



400 MHz

800 MHz

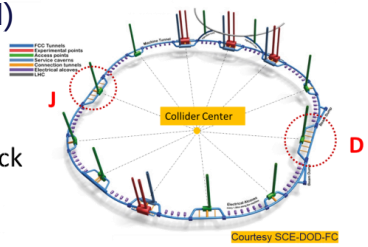


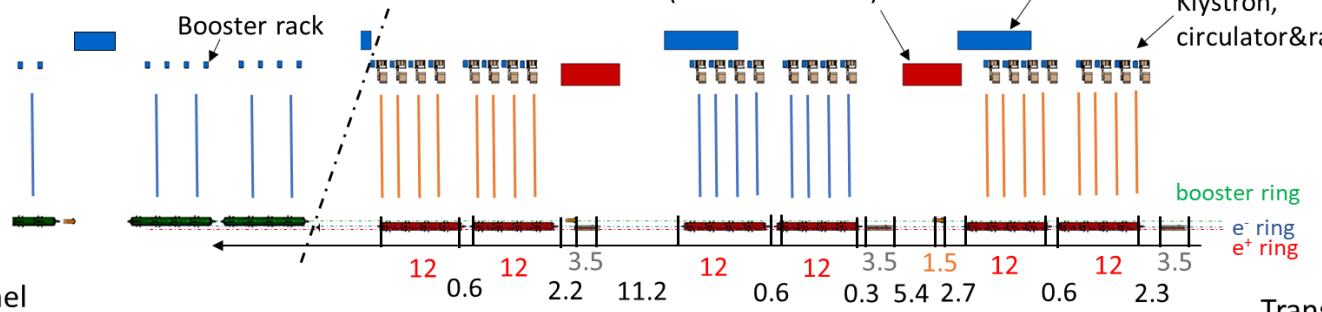
Courtesy O. Brunner

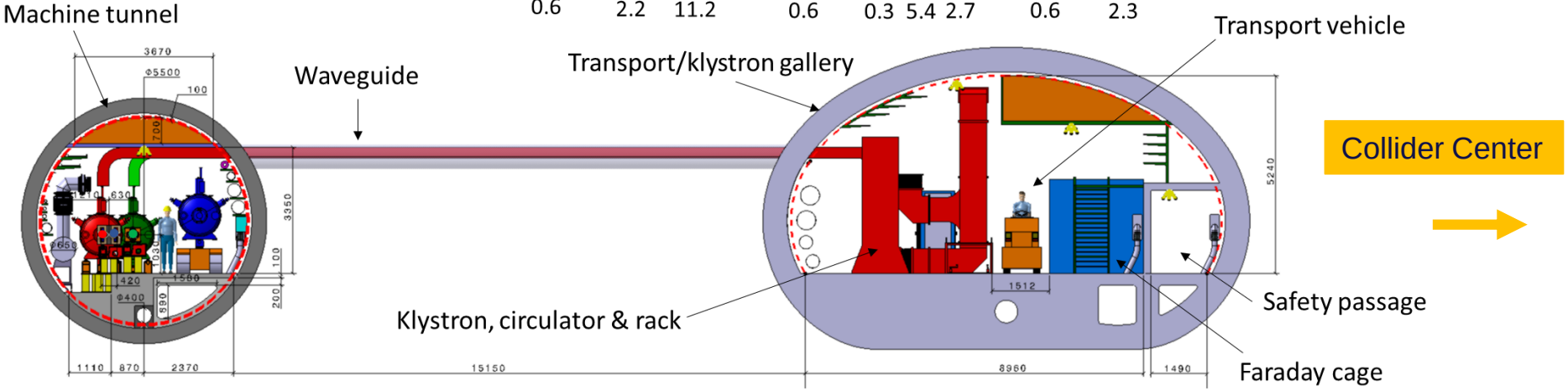
Detailed RF configuration of each machine and booster ring

Integration of FCC-ee RF machine elements at Point D and J (H)

400 MHz cryomodules (ø 1.14 m x 12 m), half LSS
- 17 e^+e^- CM + 9 booster CM = 26 CM (476.2 m)
- 68 klystrons







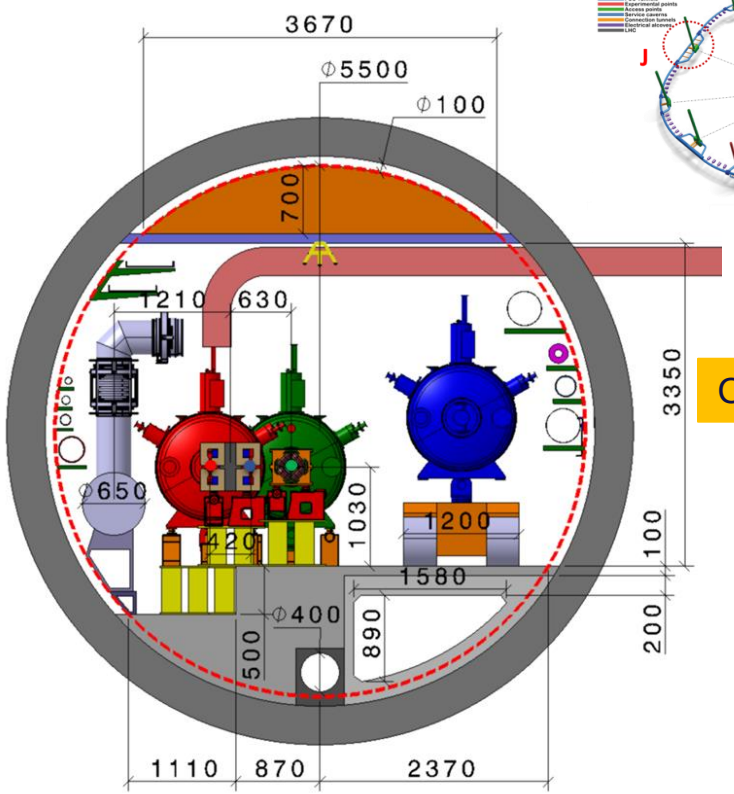
Integration of FCC-ee RF machine elements at Point D and J (H)

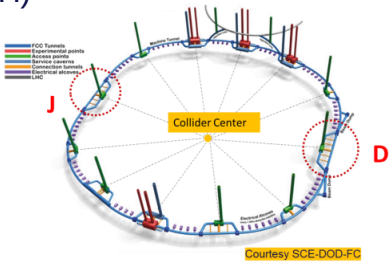
QRL Ø along 400 MHz section 0.65 m.

Preliminary length of half LSS 400 MHz 476.2 m (H machine)
(nota: inner 2 x 645.7 m left empty for later ttbar installation)

Distance between e^+e^- quadrupoles 40 m, length 3.5 m.

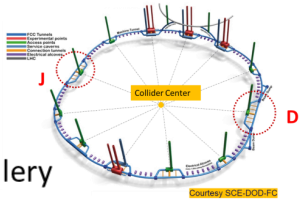
Distance between booster quadrupoles 50 m, length 1.5 m.





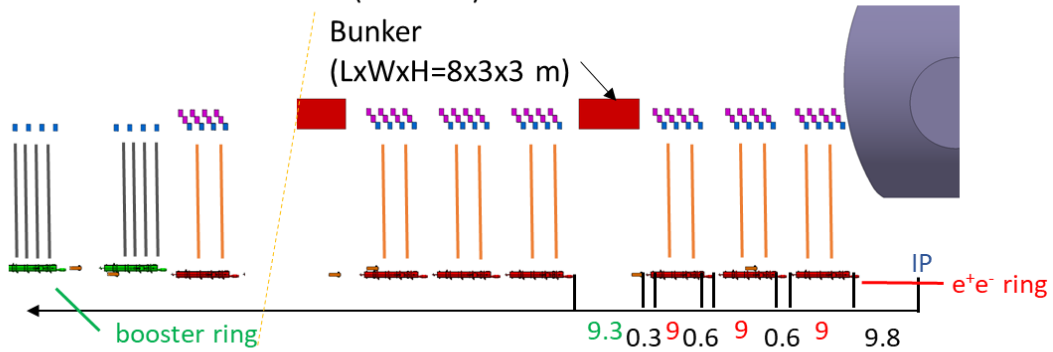
Collider Center

Integration of FCC-ee RF machine elements at Point D and J (ttbar2)



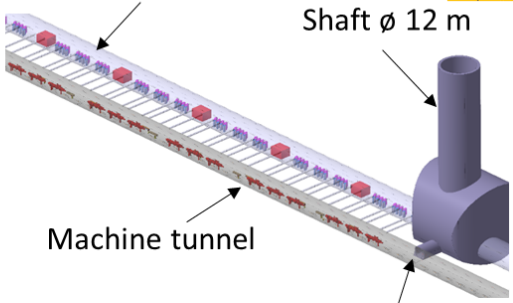
800 MHz cryomodule (ø 1.09 m x 9 m), half LSS

- 24 e^+e^- CM + 30 booster CM = 54 CM (645.7 m)



Transport/klystron gallery

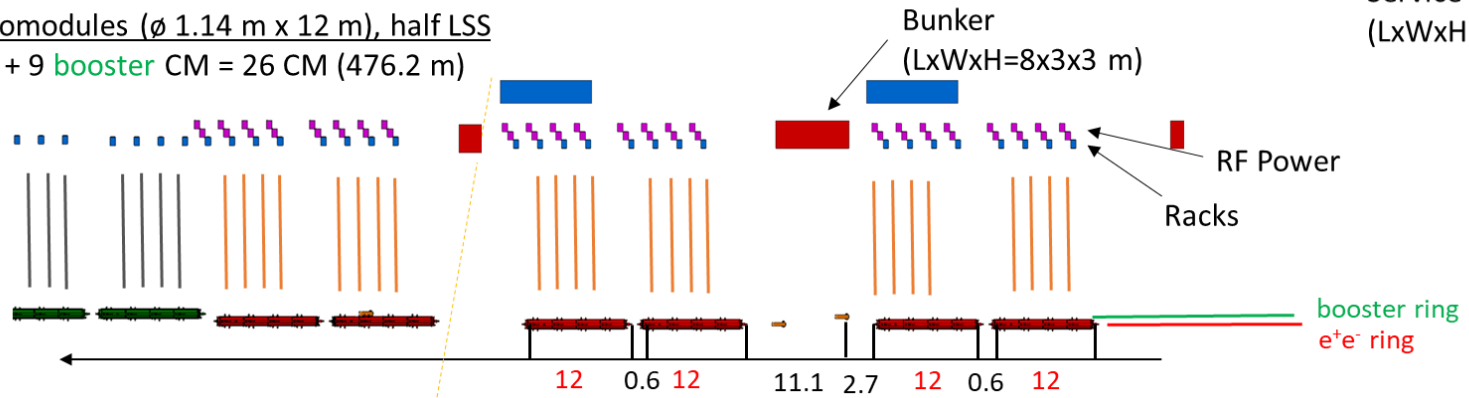
Shaft ø 12 m



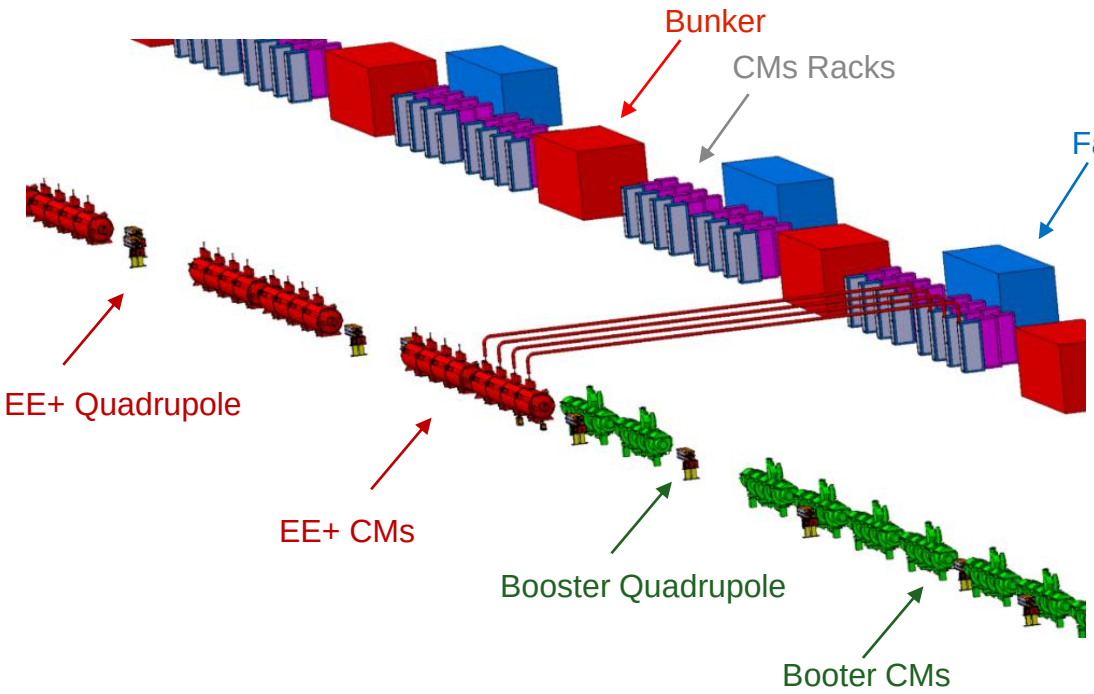
Service cavern
(LxWxH=15x25x15 m)

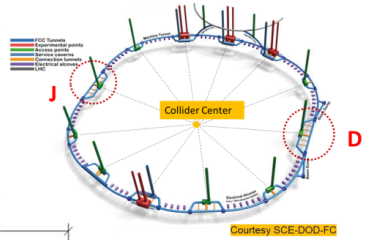
400 MHz cryomodules (ø 1.14 m x 12 m), half LSS

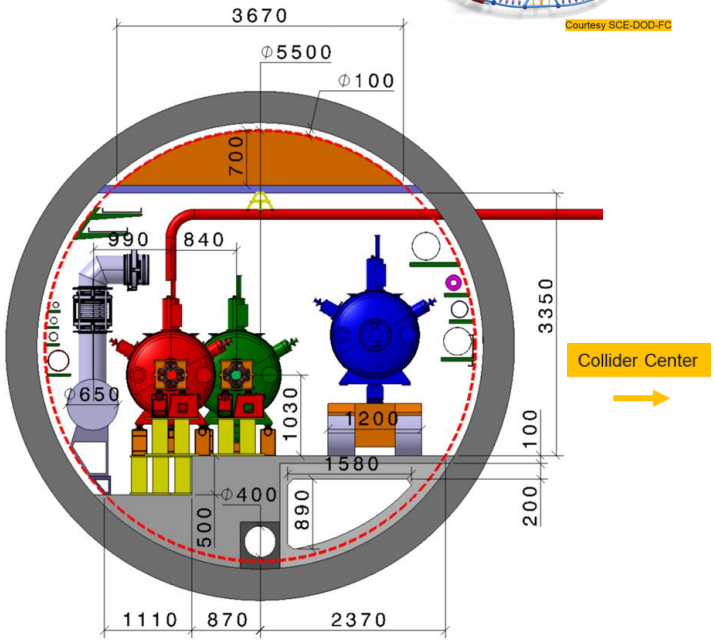
- 17 e^+e^- CM + 9 booster CM = 26 CM (476.2 m)



Integration of FCC-ee RF machine elements at Point D and J (ttbar2, 400 MHz)

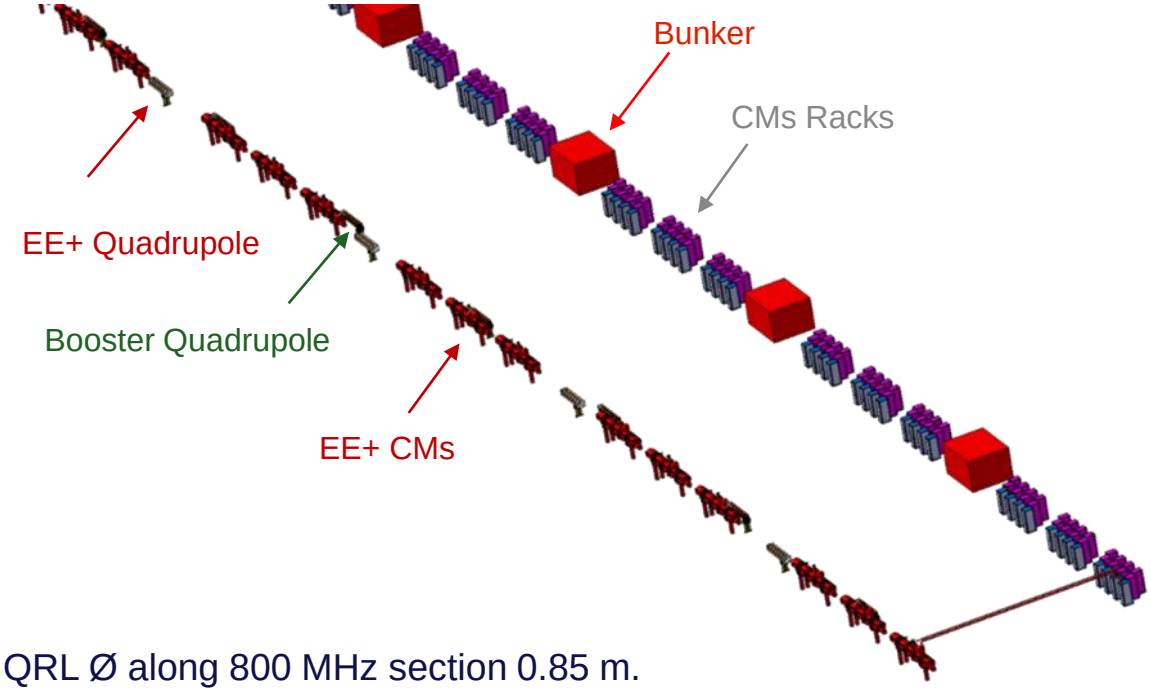


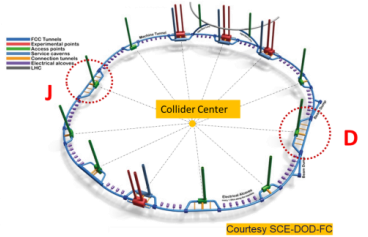


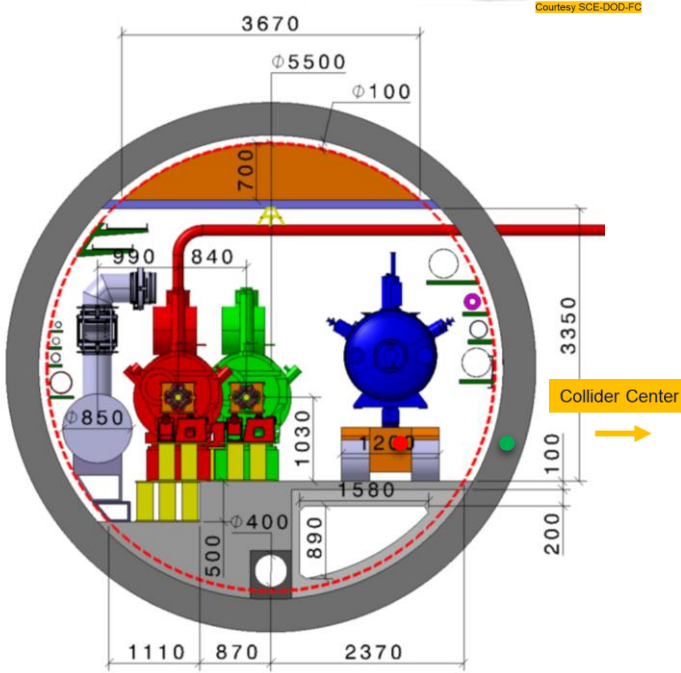


QRL Ø along 400 MHz section 0.65 m.
Preliminary length of 400 MHz section 476.2 m.
Distance between e^+e^- quadrupoles 40 m, length 3.5 m.
Distance between booster quadrupoles 50 m, length 1.5 m.

Integration of FCC-ee RF machine elements at Point D and J (ttbar2, 800 MHz)



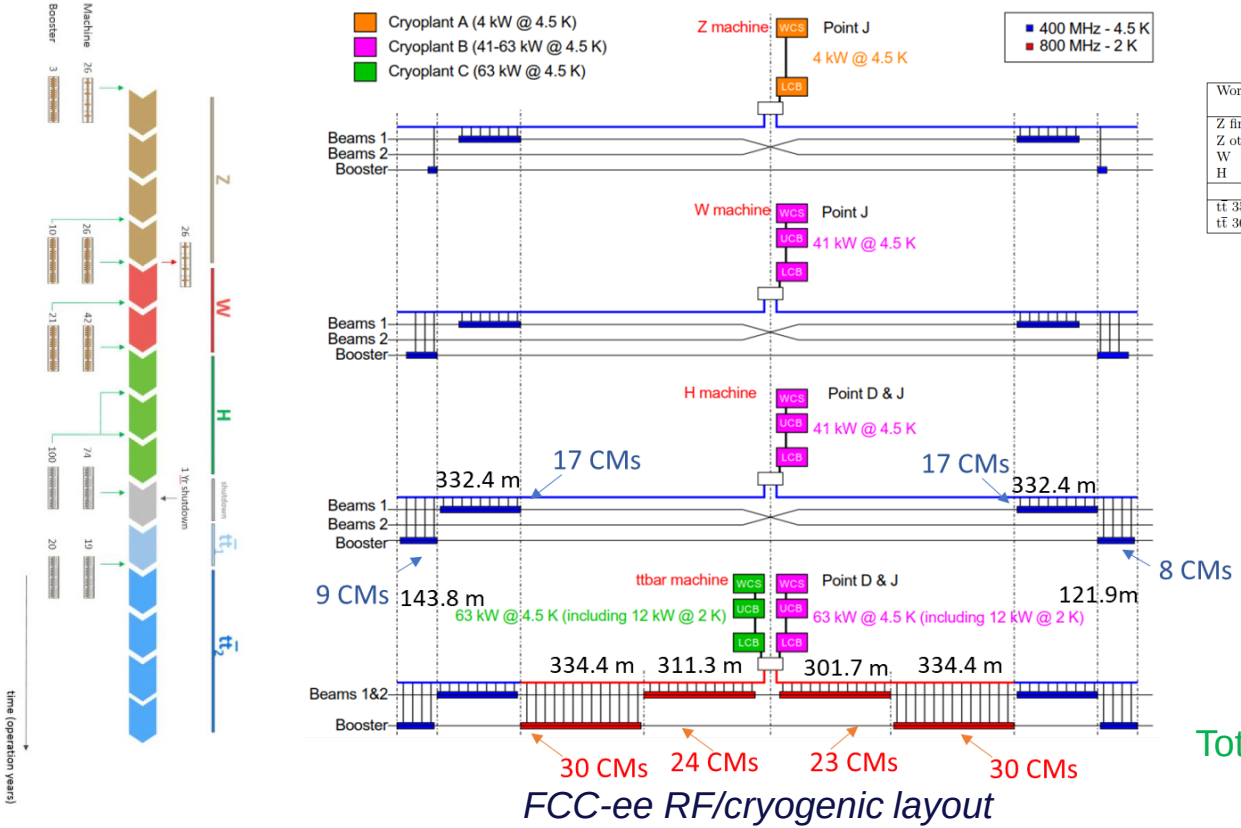




QRL Ø along 800 MHz section 0.85 m.
Preliminary length of 800 MHz section 645.7 m.
Distance between e^+e^- quadrupoles 40 m, length 3.5 m.
Distance between booster quadrupoles 50 m, length 1.5 m.

Integration of FCC-ee RF machine elements at Point D and J

Courtesy L. Tavian



FCC-ee RF/cryogenic layout

Working point	Luminosity (10^{34} cm^{-2} s^{-1})	Tot. lum./year (ab^{-1})/year	Goal (ab^{-1})	Run time (years)
Z first two years	100	24	150	4
Z other years	200	48		
W	25	6	10	1–2
H	7.0	1.7	5	3
RF reconfiguration				1
tt̄ 350 GeV (first year)	0.8	0.20	0.2	1
tt̄ 365 GeV	1.4	0.34	1.5	4

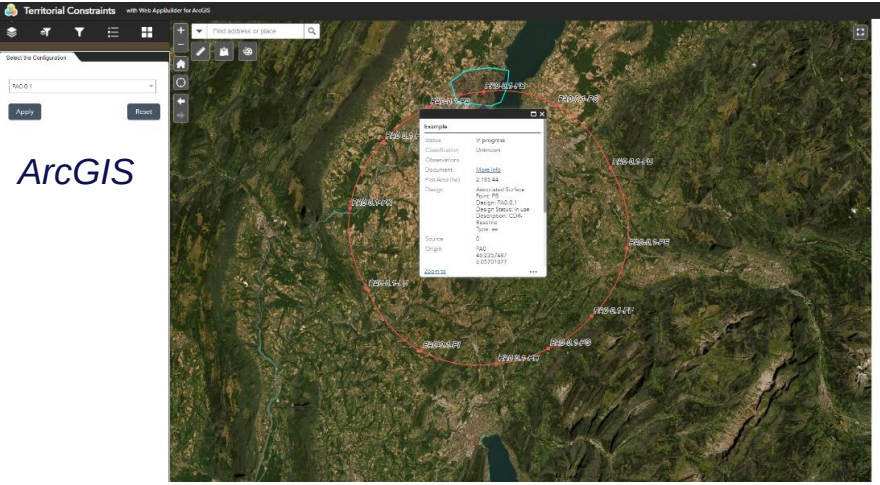
Peak luminosity per IP, total luminosity per year (two IPs), luminosity target, and run time for each FCC-ee working point.

Shutdown	No. cryomodules	Length of shutdown
Shutdown 1	–	12 weeks
Shutdown 2	–	12 weeks
Shutdown 3	10 CM	12 weeks
Shutdown 4	26 CM	20 weeks
Shutdown 5	21 CM	14 weeks
Shutdown 6	42 CM	18 weeks
Shutdown 7	30 CM	15 weeks
Shutdown 8	30 CM	15 weeks
Long shutdown	104 CM	1 year
Shutdown 11	39 CM	17 weeks
Shutdown 12	–	–
Shutdown 13	–	–
Shutdown 14	–	–

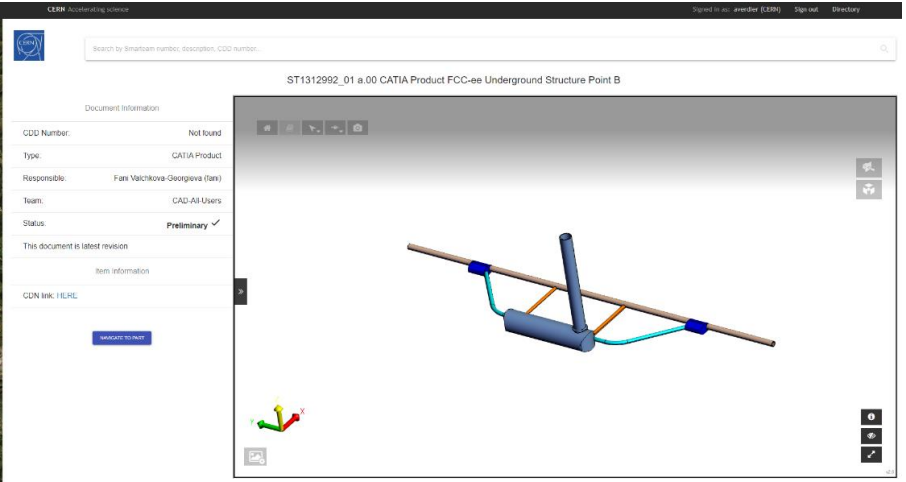
Minimum lengths of FCC-ee extended shutdowns based on the number of cryomodules (CMs) to be installed and a special 12 week margin for the first three years; shutdown no. 1 refers to the first shutdown after one year running on the Z pole.

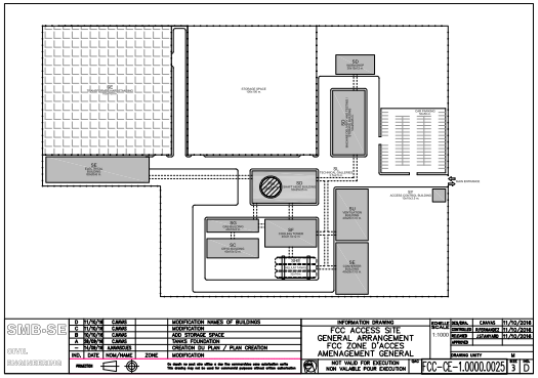
Total length without kickers:
2212.3 m

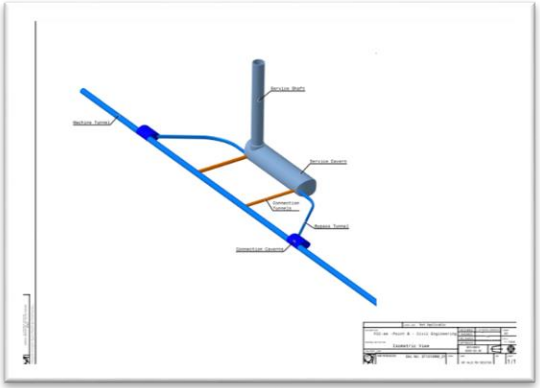
FCC ArcGIS database



ArcGIS

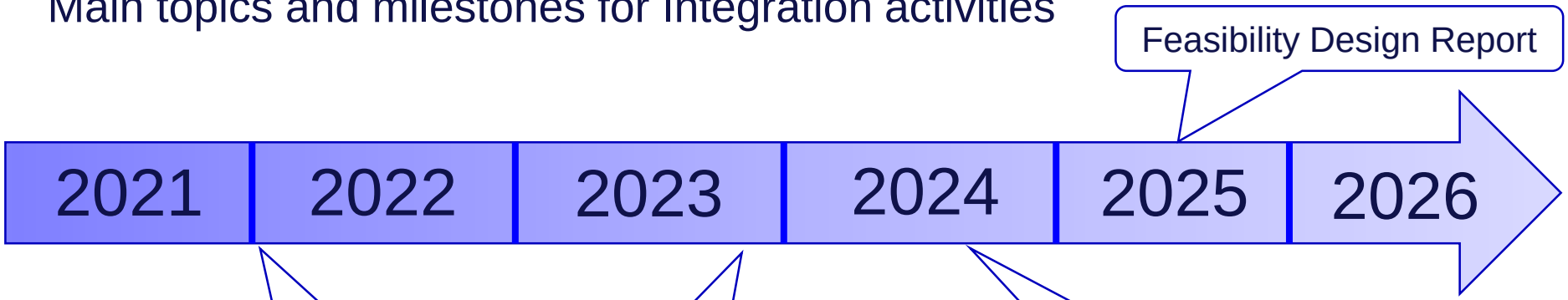






WHAT'S NEXT

Main topics and milestones for Integration activities



Collection, review and update of EL, CV, GC,, HE, BE, SY,TE and HSE user requirements for FCC-ee/hh for each surface and underground points

Refined concept integration design of FCC-ee with bear in mind for later evolution to FCC-hh

(Pre-) technical design of FCC-ee surface and underground infrastructure with inputs from EL, CV, GC,, HE, BE, SY,TE and HSE and other systems

- input for the Feasibility Design Report

Thank you for your attention.