FUTURE CIRCULAR COLLIDER

ENERGY MANAGEMENT FOR FUTURE CIRCULAR COLLIDER

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Technical and Infrastructure Working Group
Electricity & Energy Management Work Package

http://cern.ch/fcc

6th Workshop
Energy for Sustainable Science
at Research Infrastructures

Abstract

The FCC-ee will be the largest accelerator ever built with kilometers of different accelerator devices.
The identification of the main loads is crucial for designing the electricity infrastructure and for evaluating its energy consumption.
An update of the FCC power demand is ongoing with the evaluation of its annual energy consumption depending on the machine configurations.
The next step is to identify how energy consumption can be reduced, by design and optimization of equipment and systems, and by optimization of the operation mode of the accelerators and their infrastructures.
The goal is to identify where the effort needs to be focused to reduce the environmental impact of the project.

Content

- Introduction to FCC
- Update of the power demand / main loads for FCC-ee
- Distribution of the power demand by points and by the beam energies
- Estimation of energy consumption per machine configurations
- Optimization of the accelerator systems to reduce the power demand
- Ways to reduce the energy consumption

INTRODUCTION TO FCC

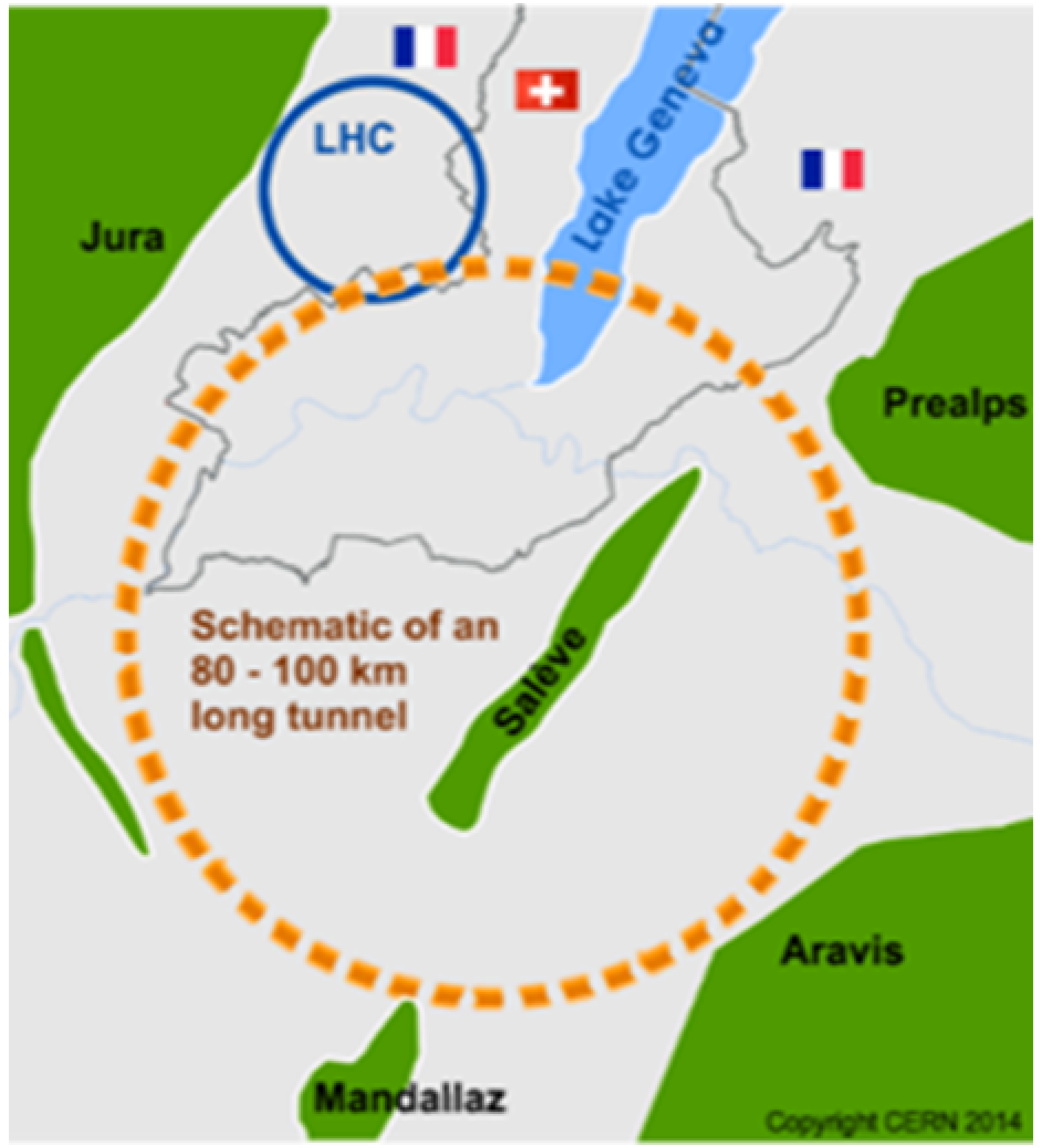
The FCC integrated program

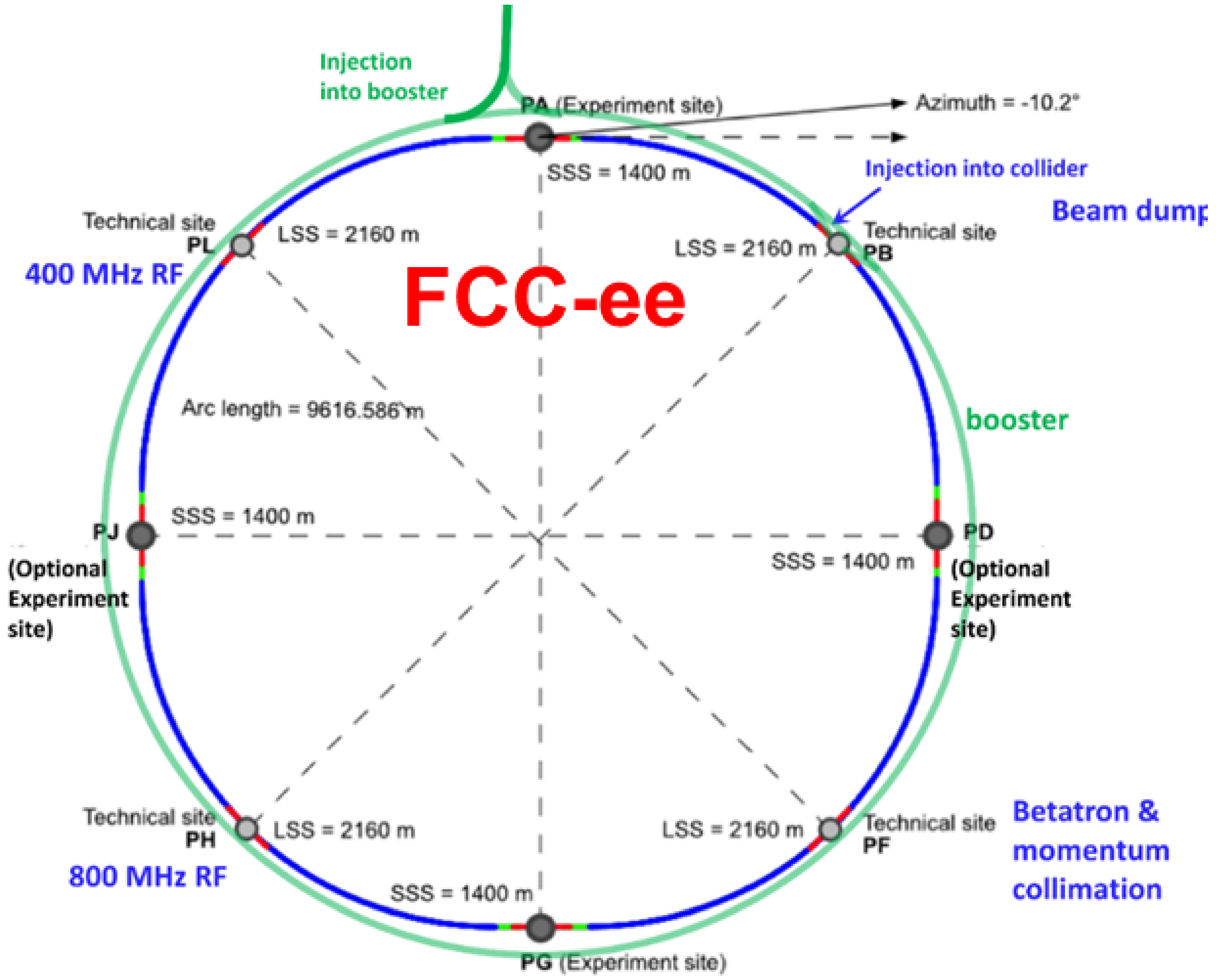
From M. Benedikt, FCC study leader

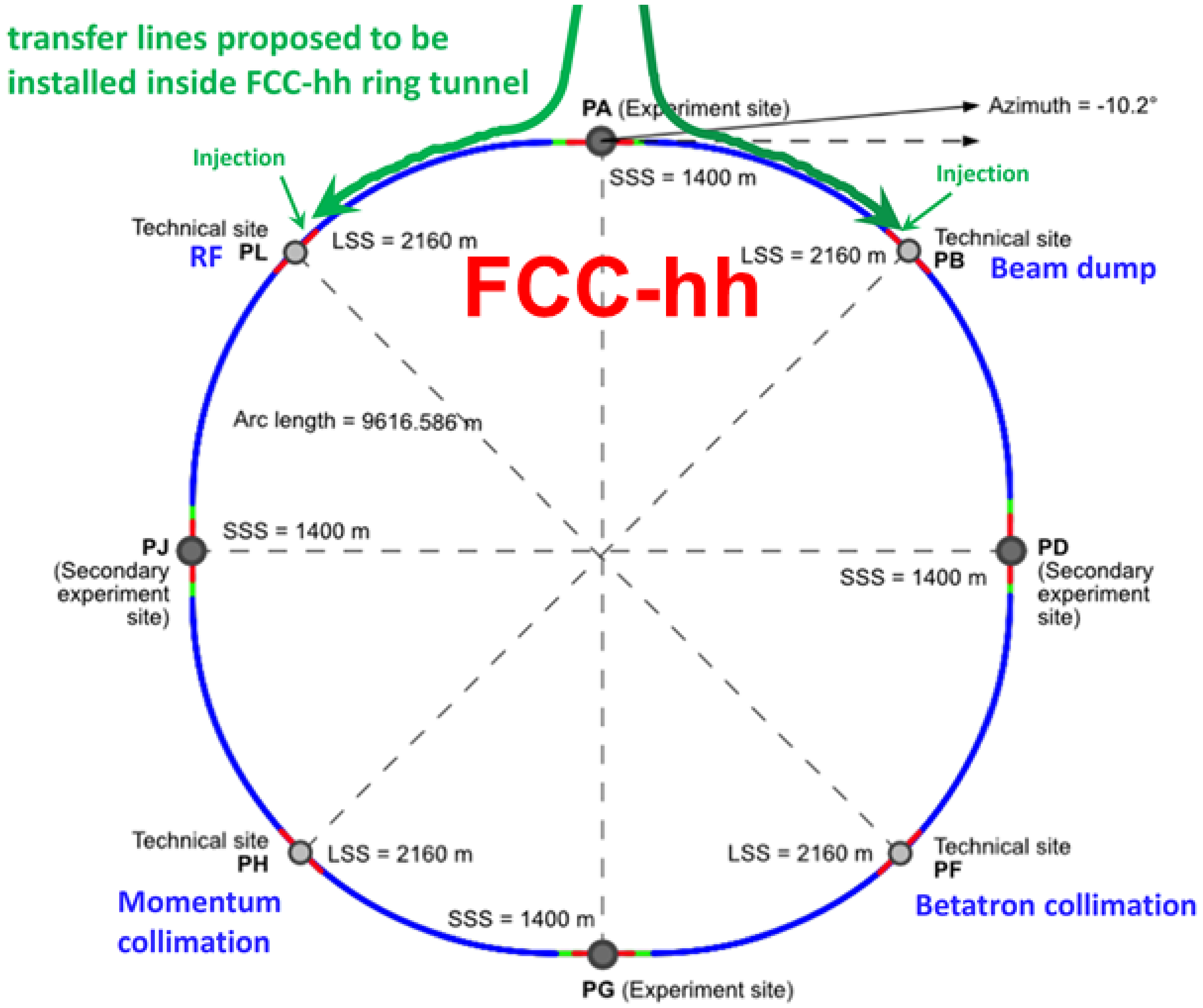
inspired by successful LEP – LHC programs at CERN

comprehensive long-term program maximizing physics opportunities

- **stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & top factory at highest luminosities**
- **stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options**
- complementary physics
- common civil engineering and technical infrastructures, building on and reusing CERN's existing infrastructure
- FCC integrated project allows seamless continuation of HEP after completion of the HL-LHC program

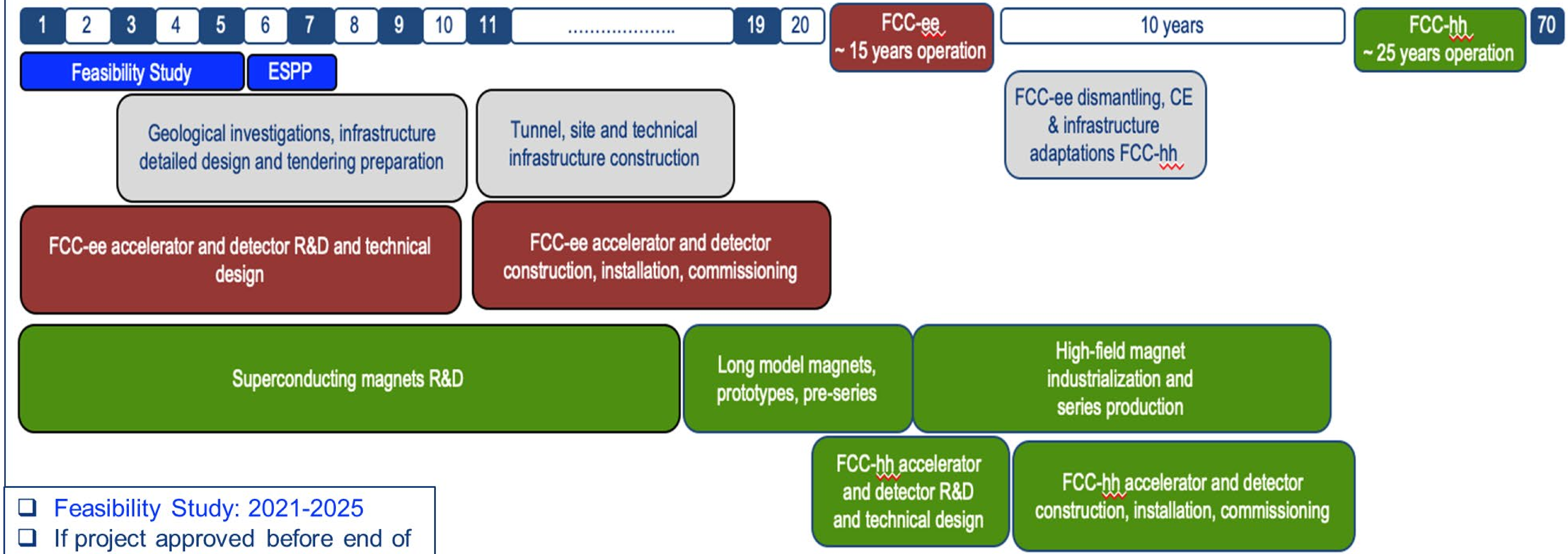






2020 - 2040 | **2045 - 2060** | **2070 - 2090++**

Timeline of the FCC integrated program



- Feasibility Study: 2021-2025
- If project approved before end of decade → construction can start beginning 2030s
- FCC-ee operation ~2045-2060
- FCC-hh operation 2070-2090++

F. Gianotti

FCC roadmap towards first e^+e^- collisions

Highest priority goals:

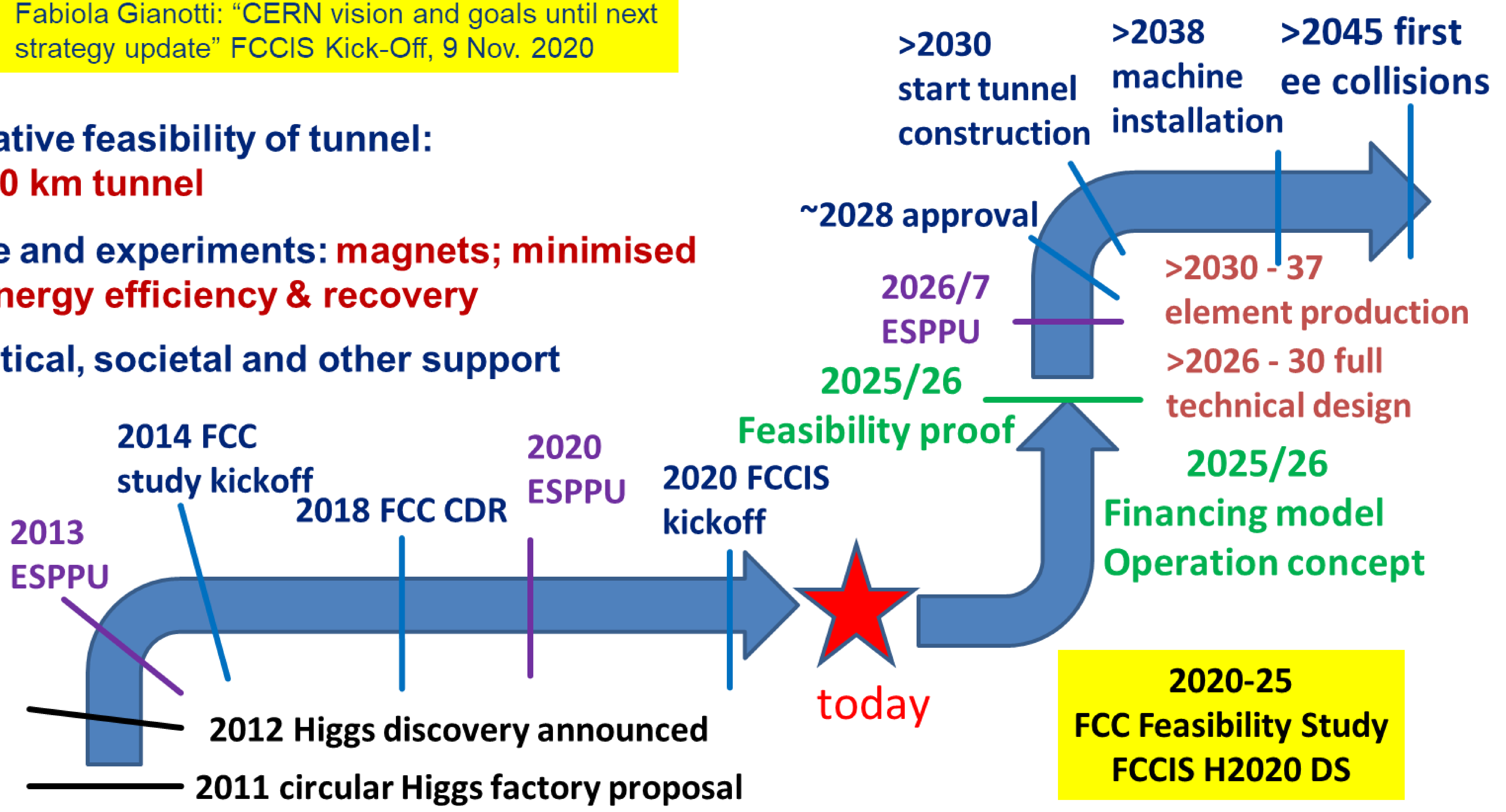
Fabiola Gianotti: "CERN vision and goals until next strategy update" FCCIS Kick-Off, 9 Nov. 2020

Financial feasibility

Technical and administrative feasibility of tunnel: no show-stopper for ~100 km tunnel

Technologies of machine and experiments: magnets; minimised environmental impact; energy efficiency & recovery

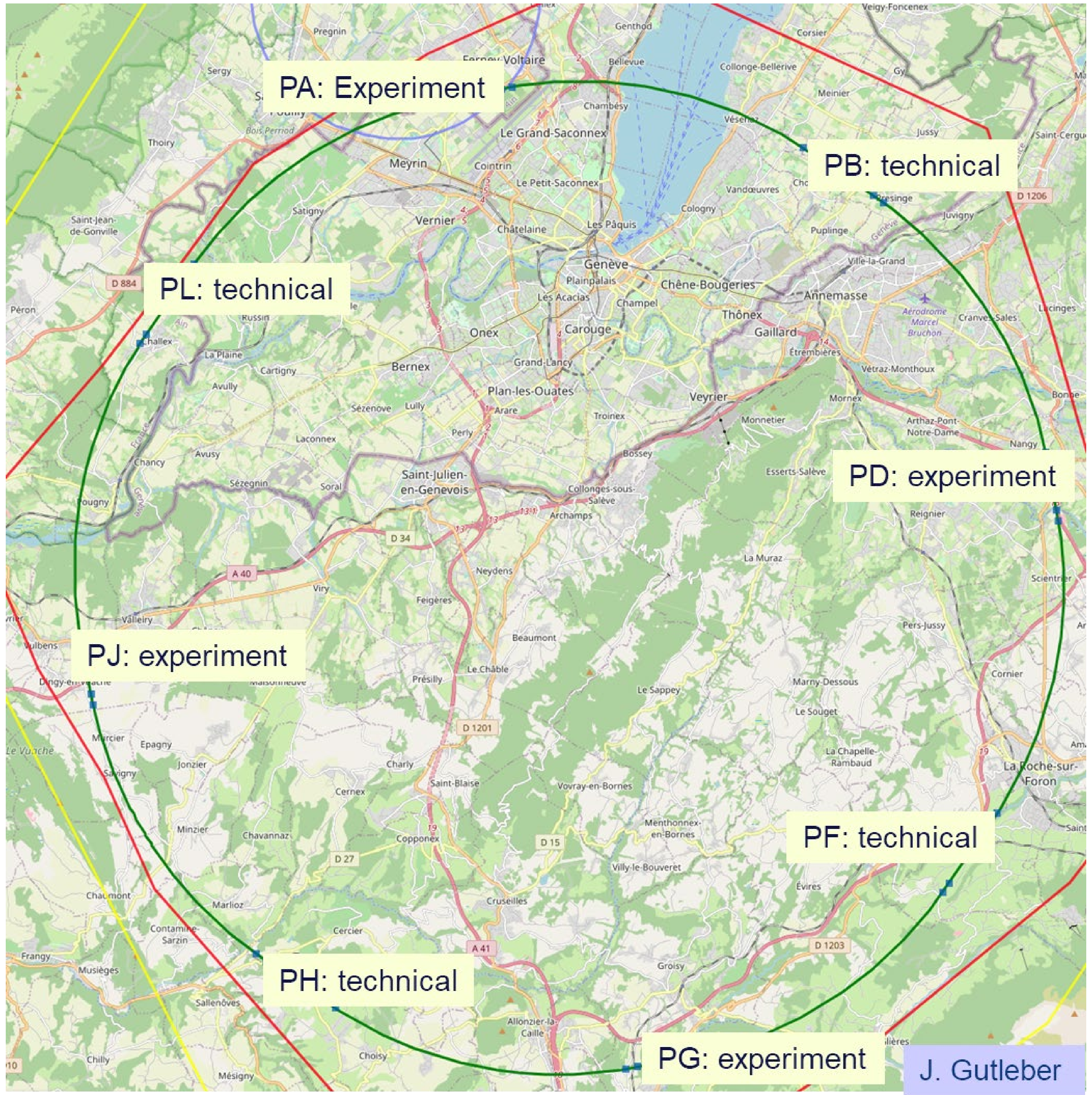
Gathering scientific, political, societal and other support

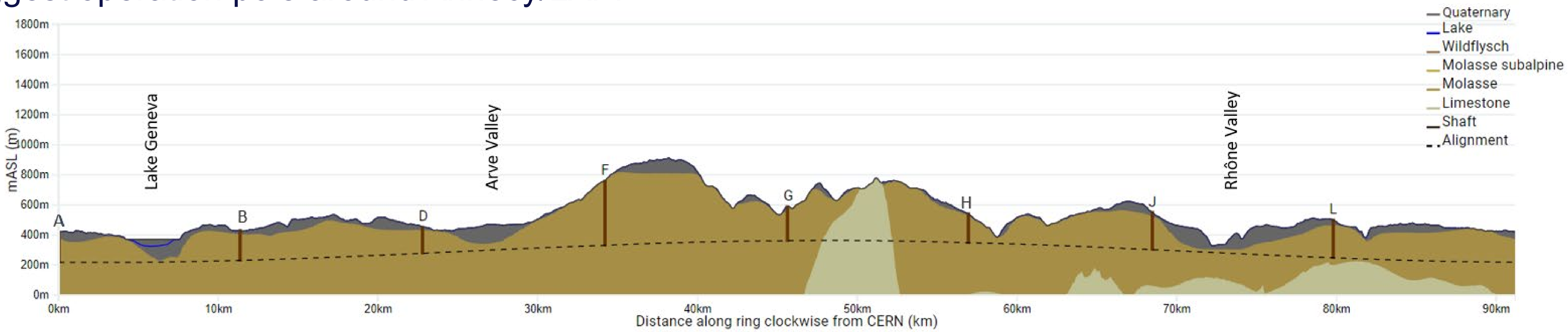


FCC 8-site baseline

Number of surface sites	8
LSS@IP (PA, PD, PG, PJ)	1400 m
LSS@TECH (PB, PF, PH, PL)	2143 m
Arc length	9.6 km
Sum of arc lengths	76.9 m
Total length	**91.1 km**

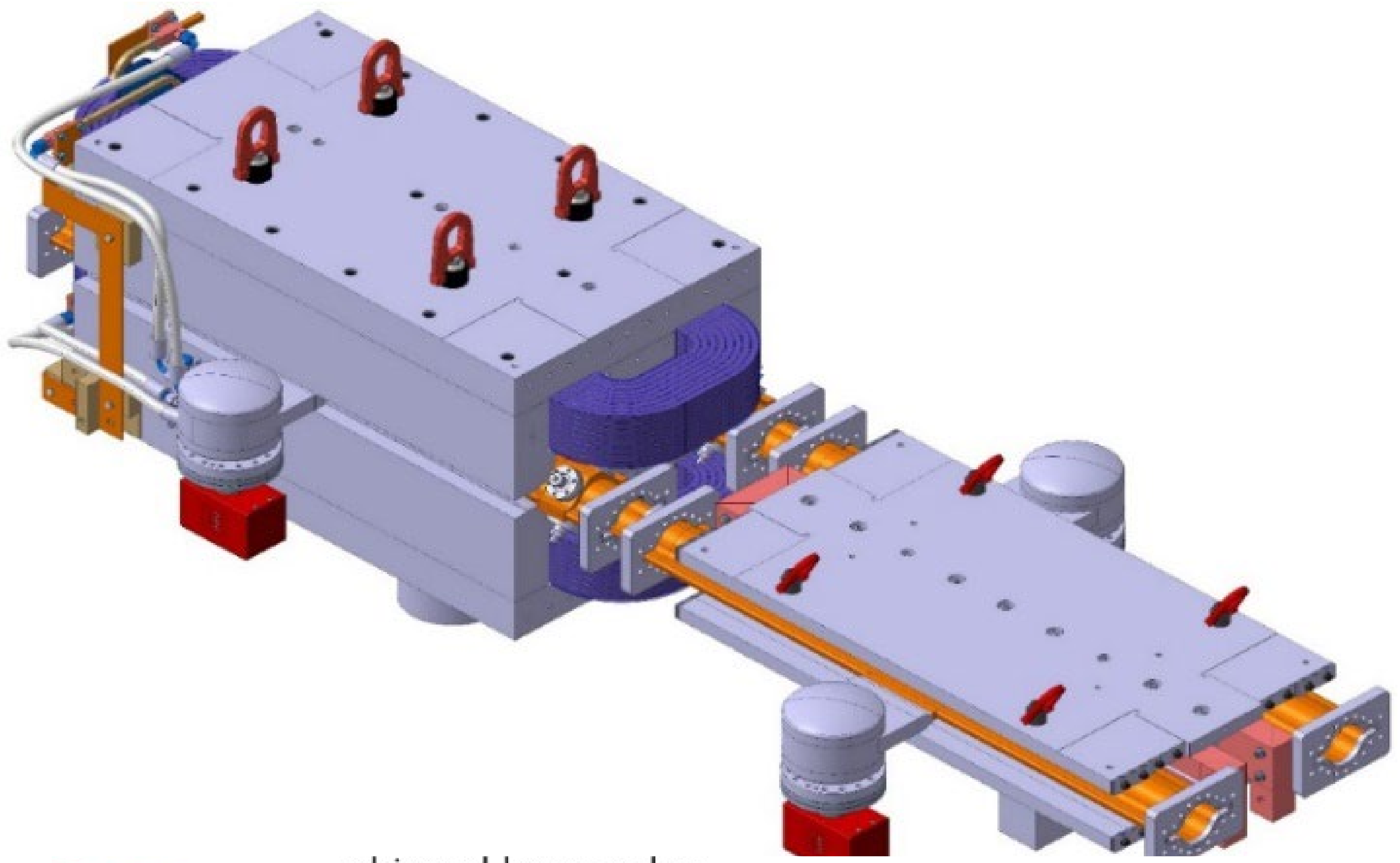
- 8 sites – less use of land, <40 ha instead 62 ha
- Possibility for 4 experiment sites in FCC-ee
- All sites close to road infrastructures (< 5 km of new road constructions for all sites)
- Vicinity of several sites to 400 kV grid lines
- Good road connection of PD, PF, PG, PH suggest operation pole around Annecy/LAPP



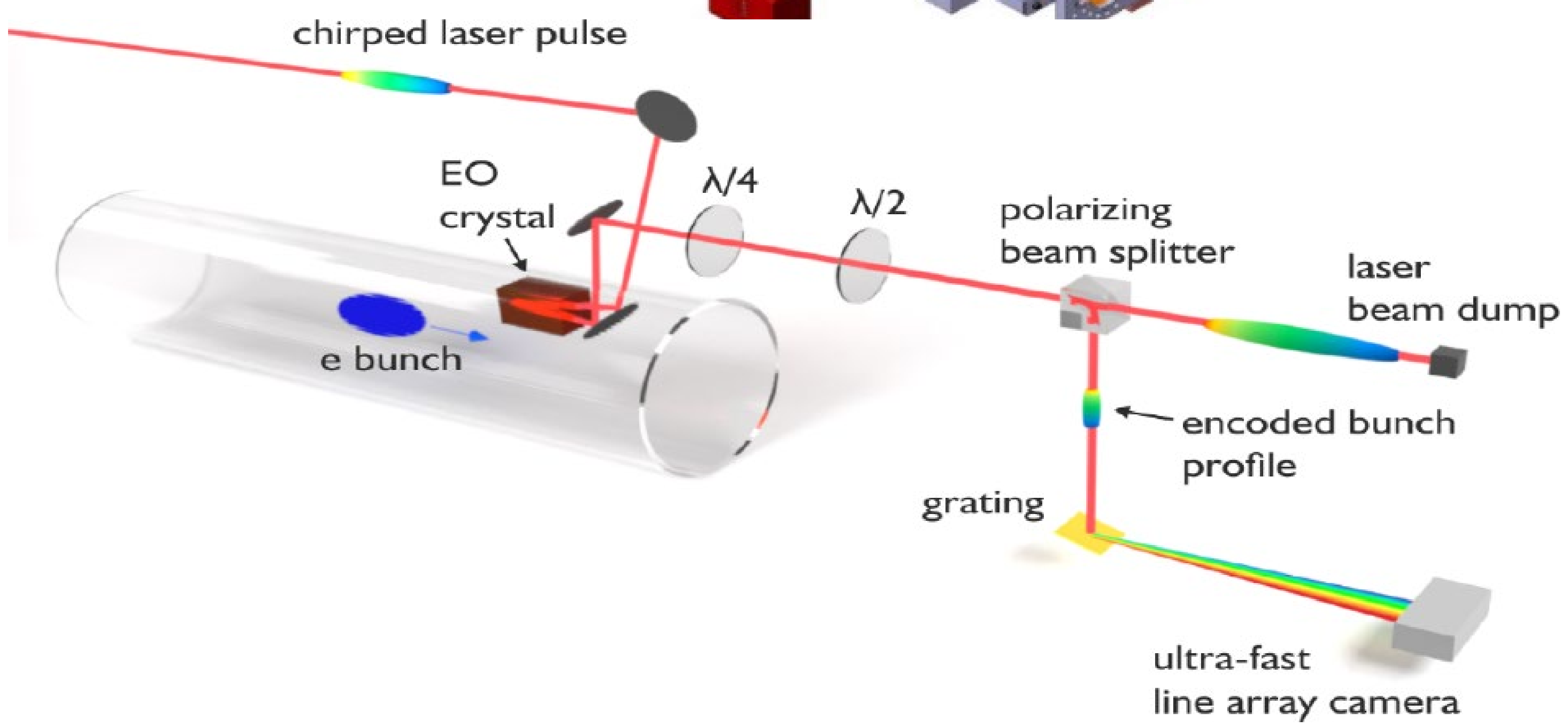


FCC key deliverables: prototypes by 2025

Accelerator systems design



FCC-ee complete arc half-cell mock up
including girder, vacuum system with antechamber + pumps, dipole, quadrupole + sext. magnets, BPMs, cooling + alignment systems, technical infrastructure interfaces.



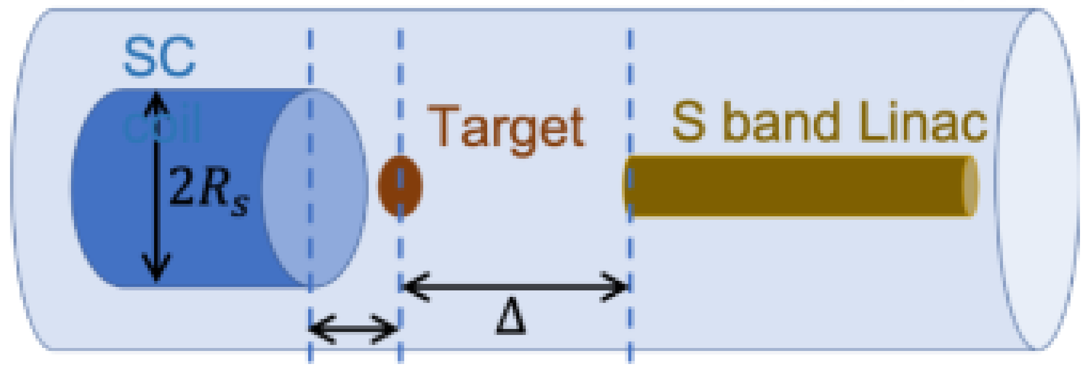
key beam diagnostics elements
bunch-by-bunch turn-by-turn **longitudinal charge density profiles** based on electro-optical spectral decoding (beam tests at KIT/KARA) ;
ultra-low emittance measurement (X-ray interferometer tests at SuperKEKB, ALBA) ;
beam-loss monitors (IJCLab/KEK?) ;
beamstrahlung monitor (KEK);
polarimeter ; **luminometer**

FCC key deliverables: prototypes by 2025

SRF cryomodule mock-up,
+ prototype multi-cell cavities
for FCC ZH operation
High-efficiency RF power sources

high-yield positron source

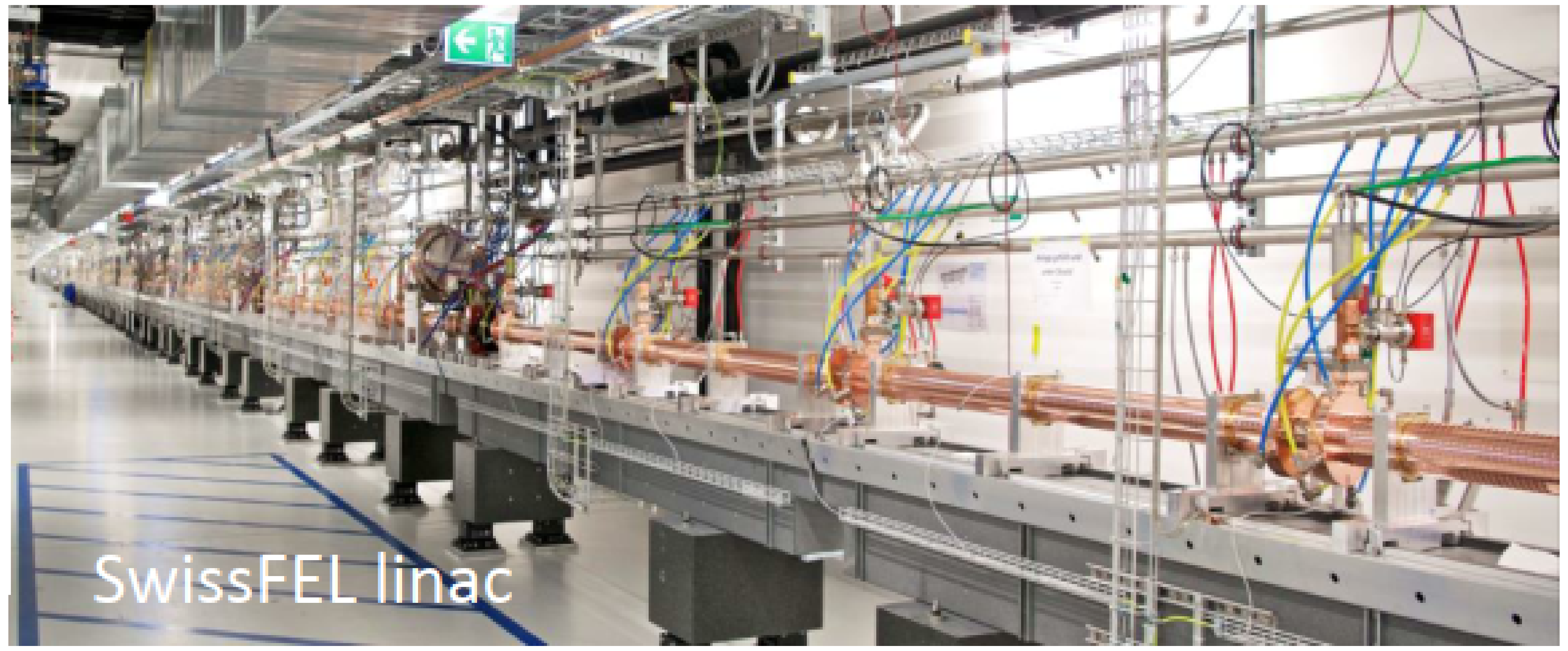
target with DC SC solenoid or flux concentrator



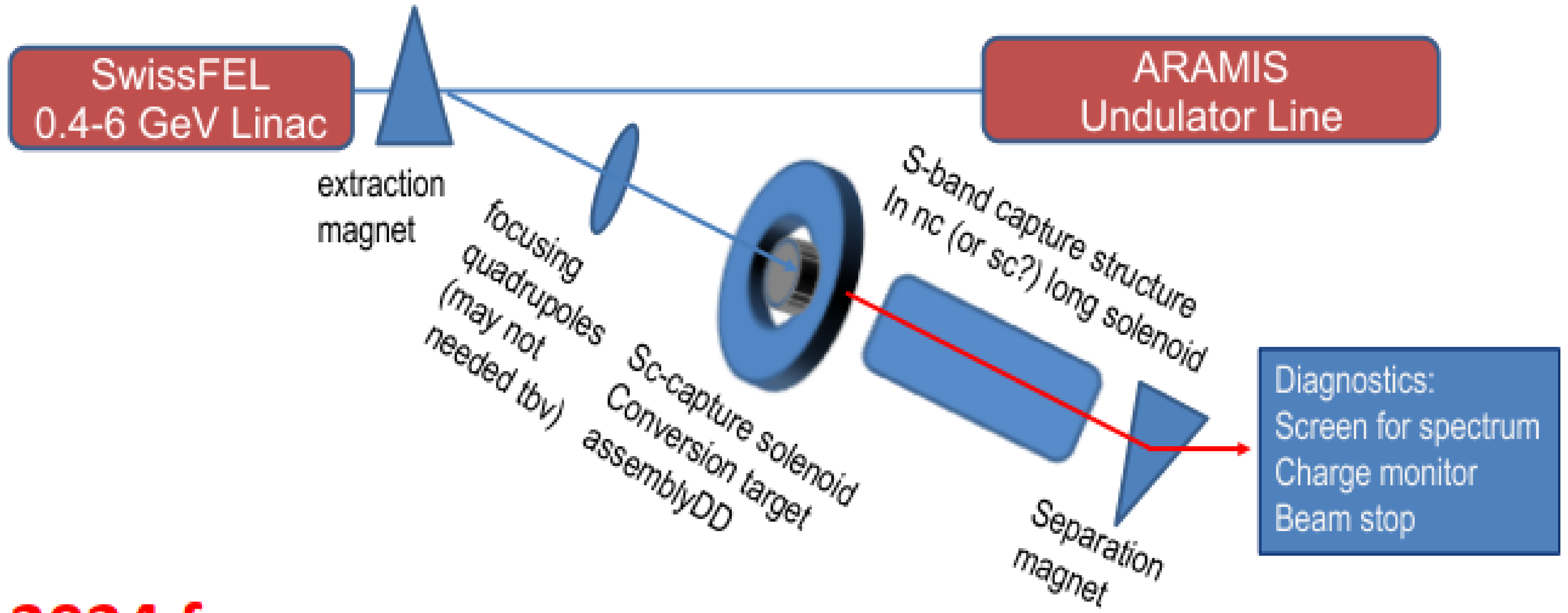
positron capture linac

large aperture S-band linac

- Freq : 2.856 GHz
- 90 cells per structure
- Length: 3.254 m
- Distance between two TWs: 45 cm
- Gradient: 20 MV/m
- Aperture: 30 mm



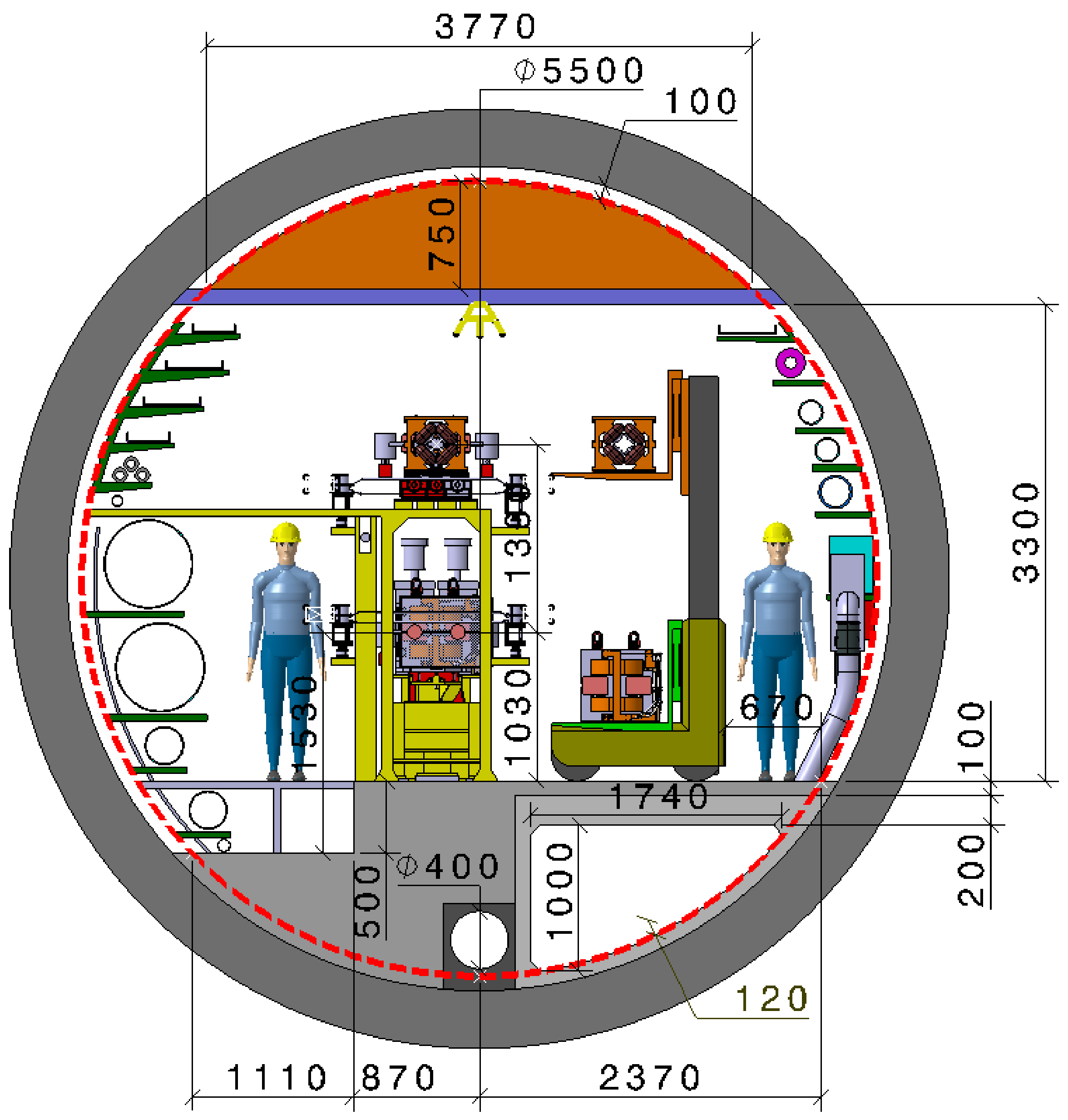
beam test of e^+ source & capture linac at SwissFEL – yield measurement



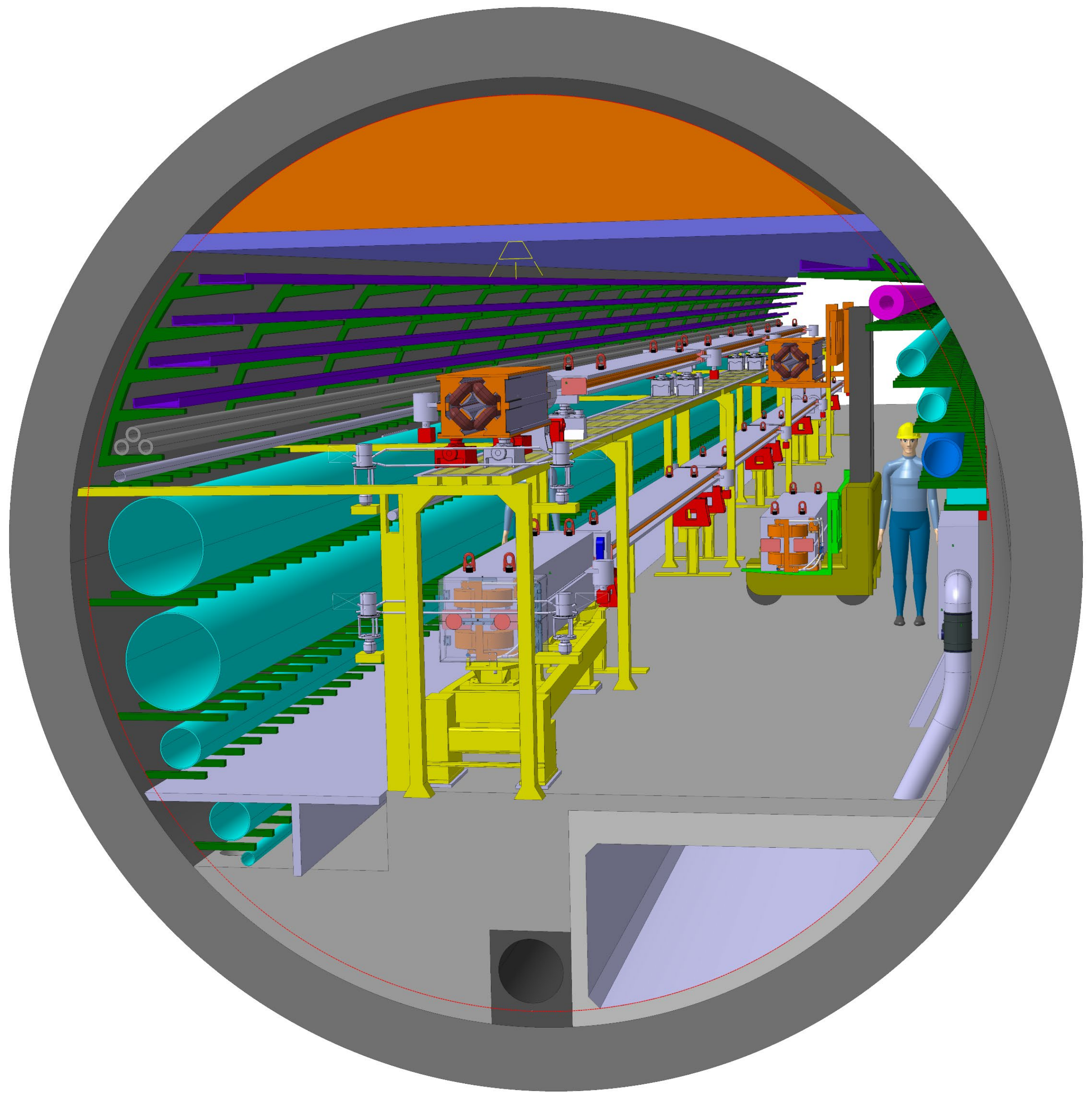
strong support from Switzerland via CHART II program 2019 – 2024 for FCC-ee injector, HFM, beam optics developments, geology and geodesy activities.

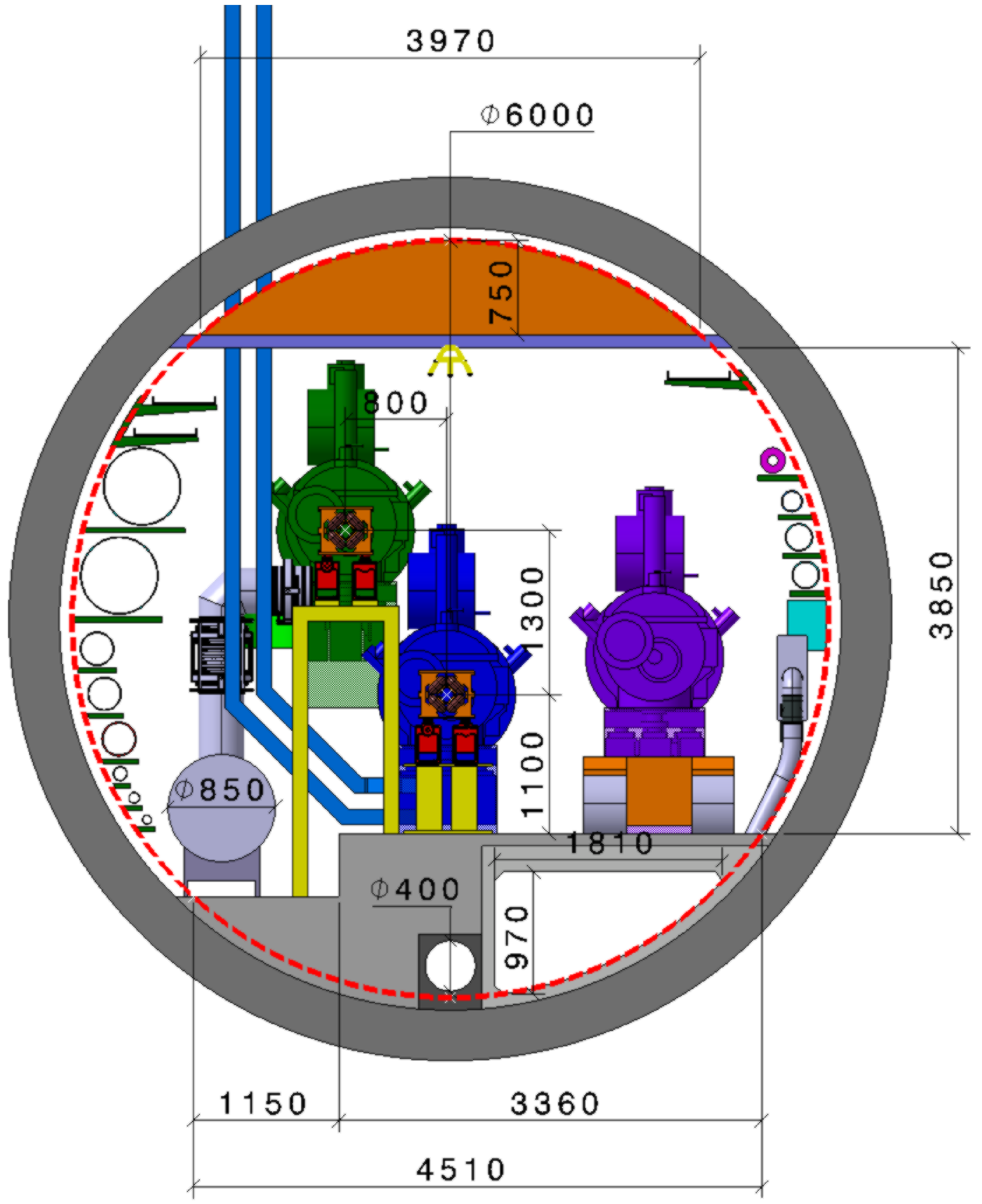
P. Craievich, H. Braun,
A. Grudiev, I. Chaikovska

Integration of FCC-ee machine elements



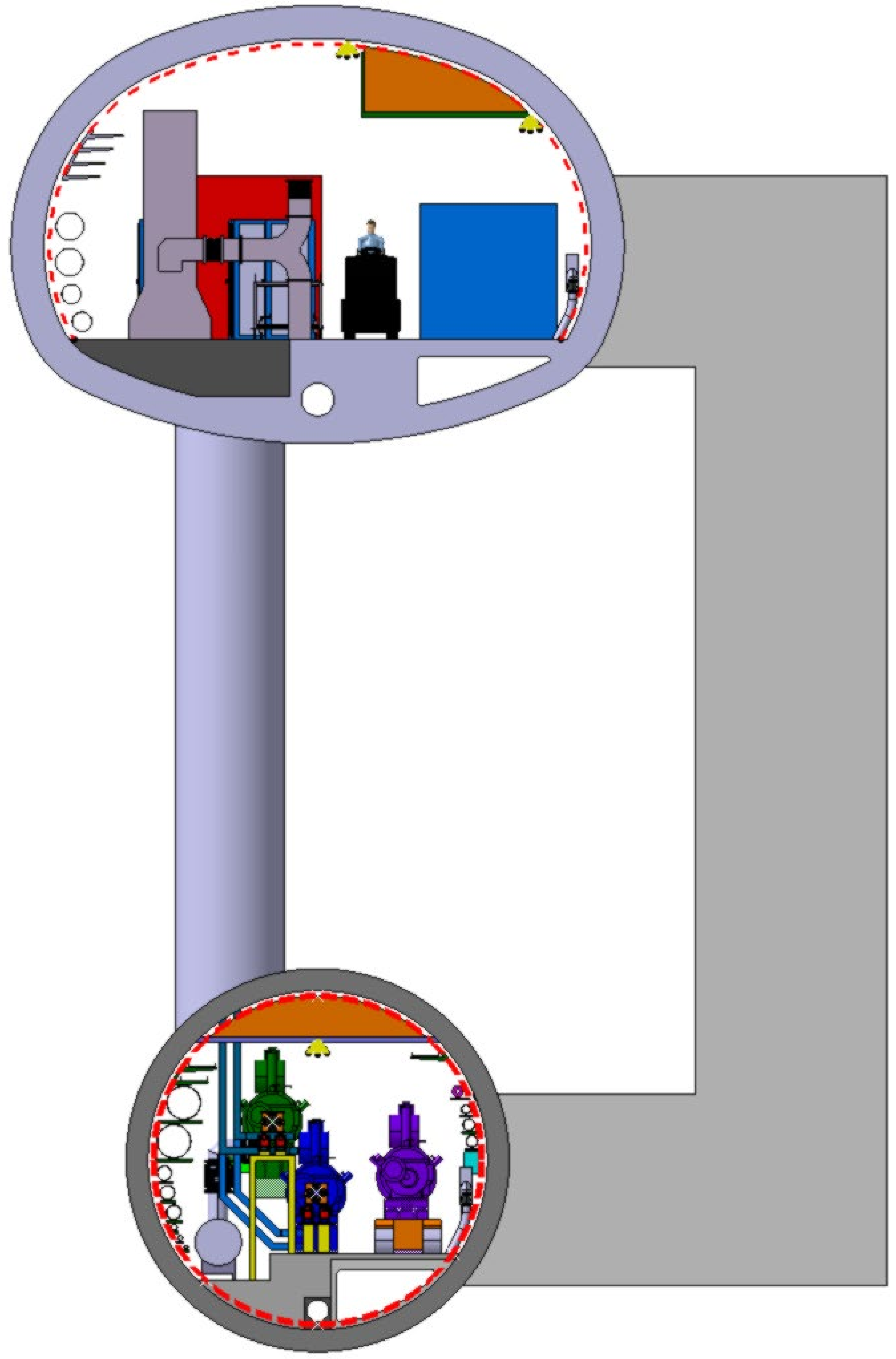
Arc section with magnets





Superconducting RF cavities

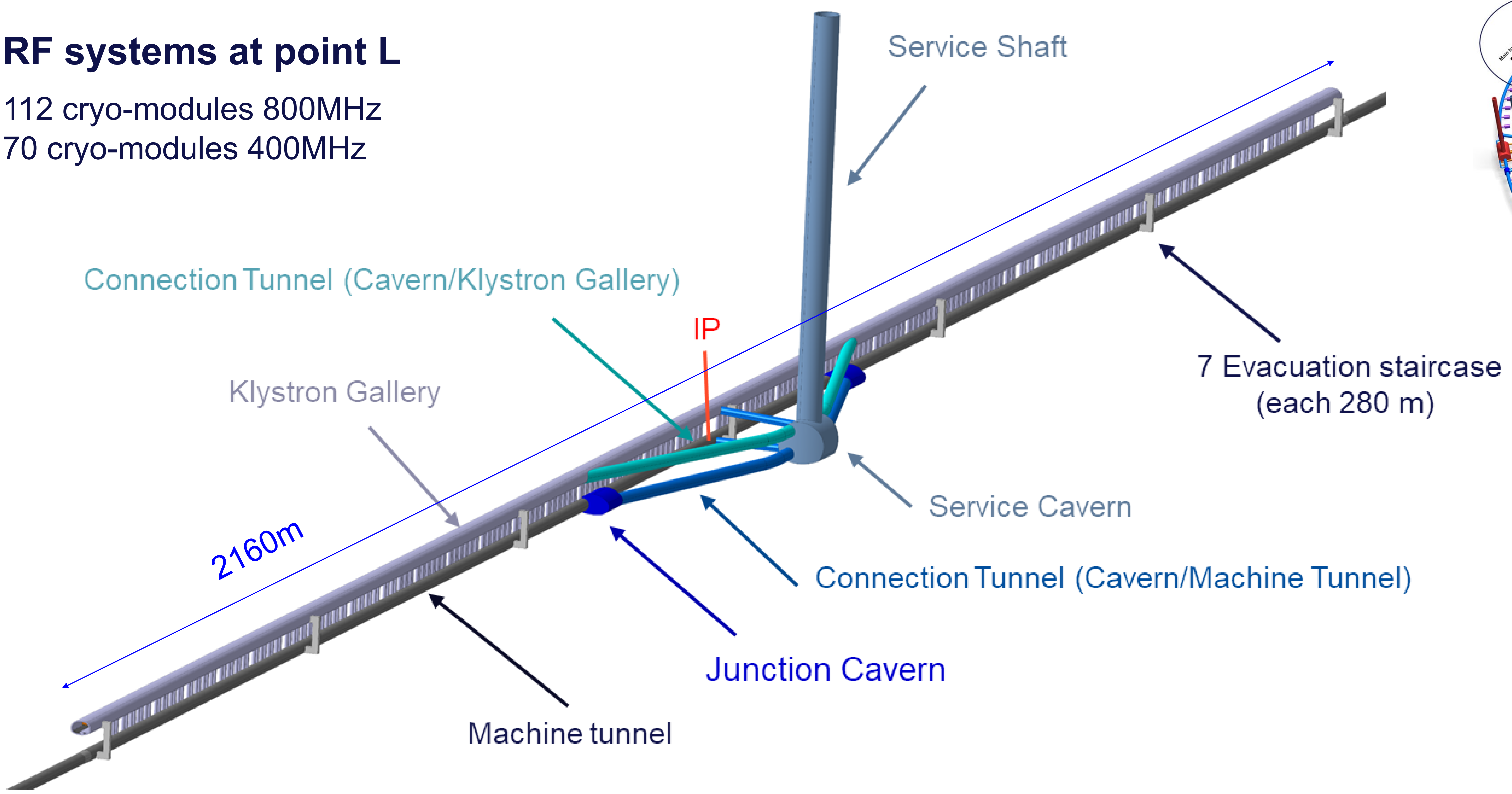
Klystron gallery

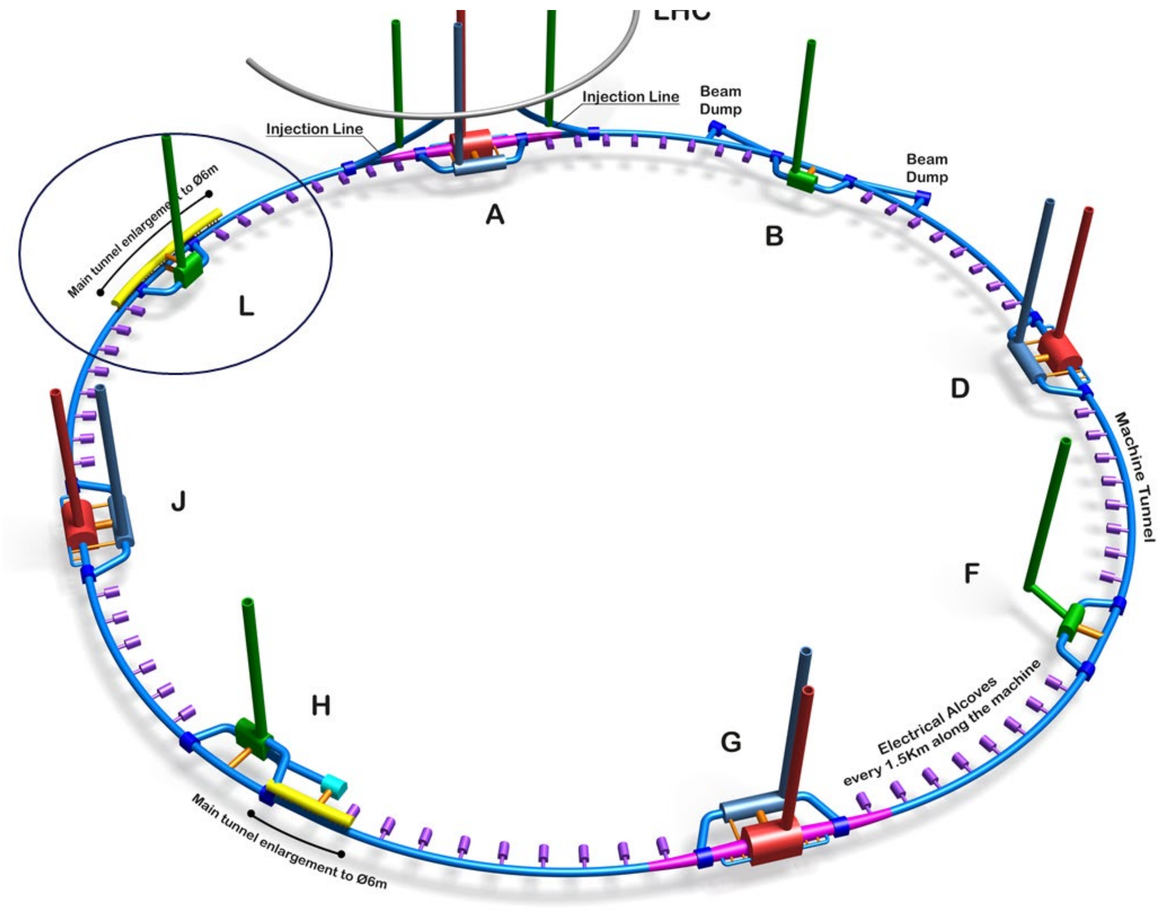


FCC-ee underground structure

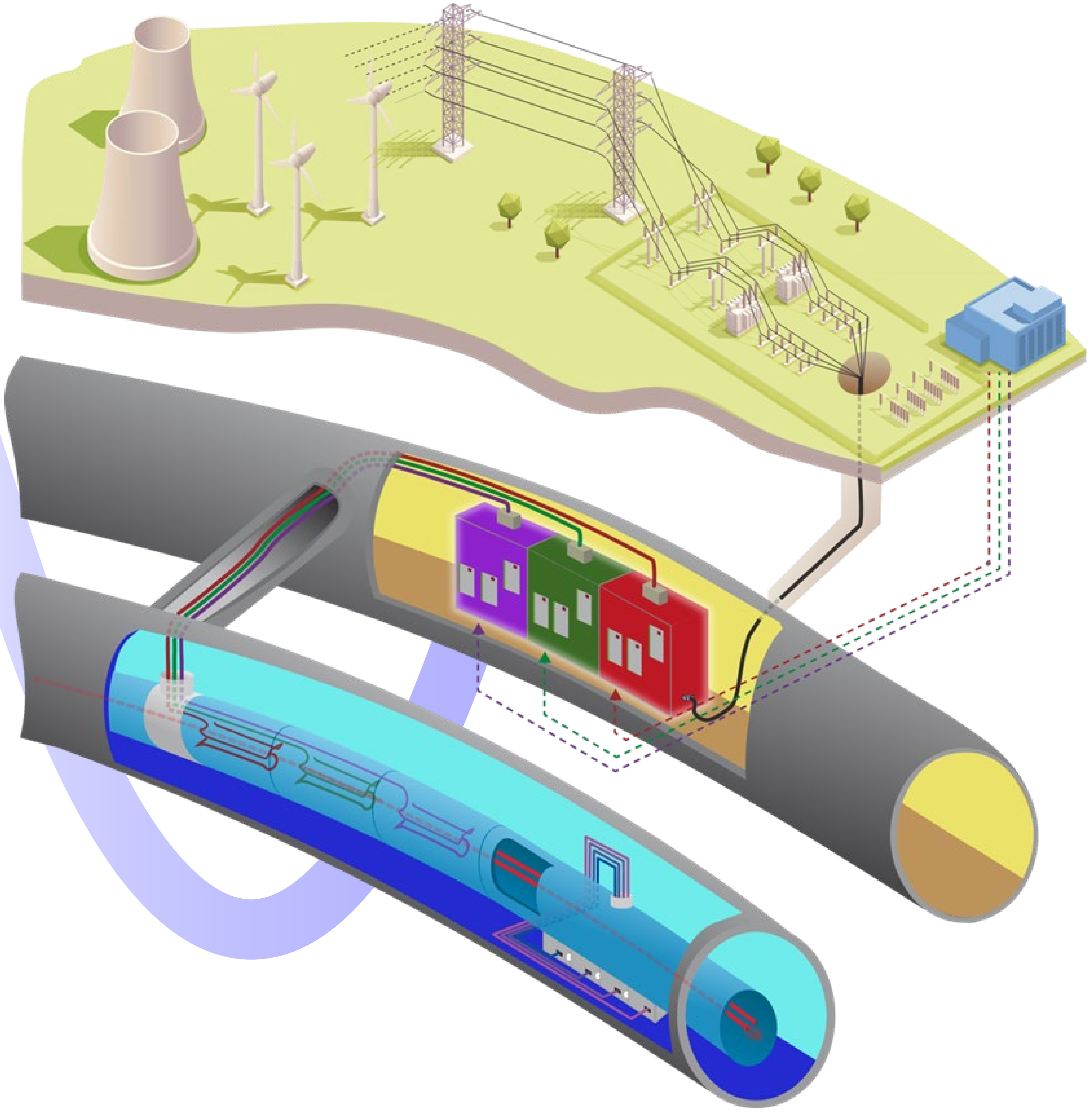
RF systems at point L

112 cryo-modules 800MHz
70 cryo-modules 400MHz

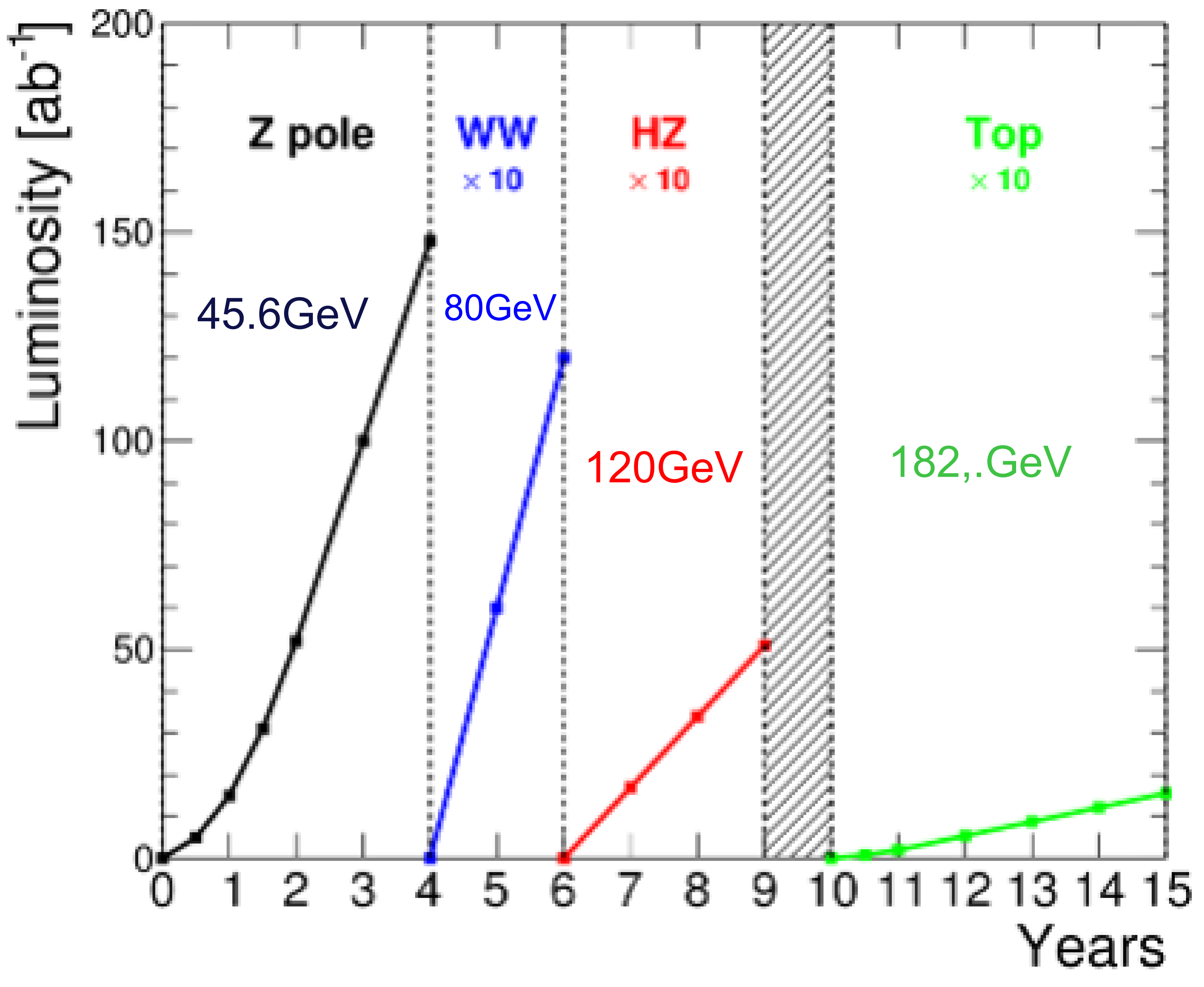




FCC POWER DEMAND



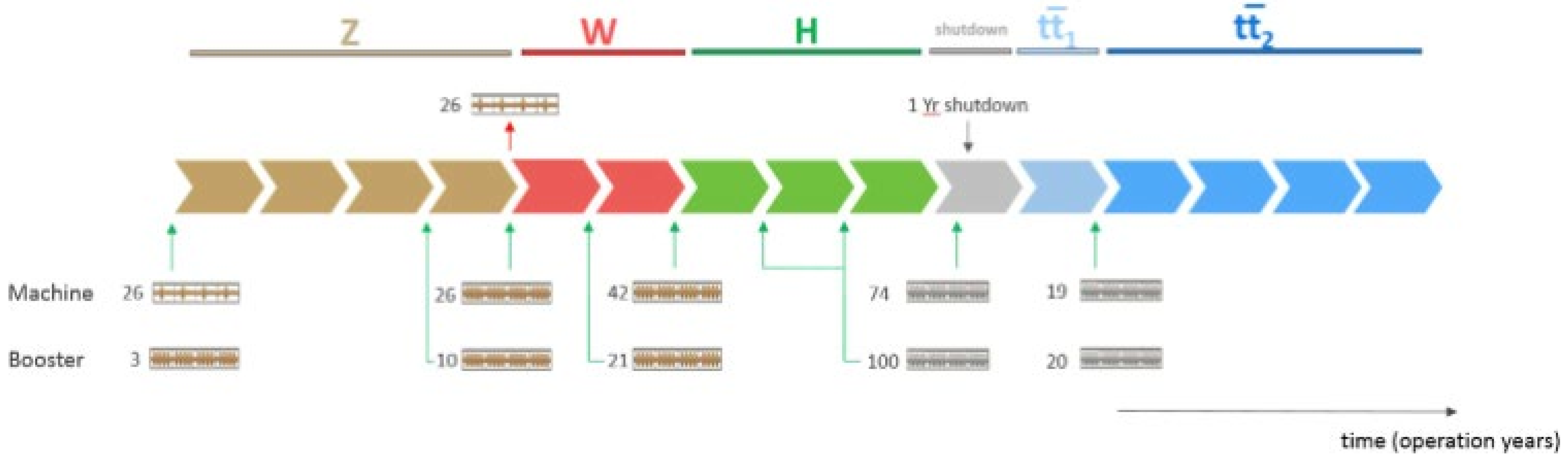
FCC-ee operation model



Physics program and machine configuration

Operation model for the FCC-ee, is based on the evolution of the machine for different types of physics program. They are called the Z pole (black), the WW threshold (blue), the Higgs factory (red), and the top-pair threshold (green) and shown as a function of time with the expected luminosity. The hatched area indicates the shutdown time needed to prepare the collider for the highest energy runs.

The evolution depends on radio-frequency systems and on the beam energy expressed in GeV.



Powering of radio-frequency systems

Energy loss from synchrotron radiation limited to 50MW per beam

Power demand for RF Storage ring Z, W, H
P_{RF} = 100MW
P_{EL} = 100 / ηklystron / ηmodulator / ηdistribution
P_{EL}= 100 / 0.8 / 0.9 / 0.95 = 146MW

Booster
P_{RF} = 15% P_{RF} storage (1 beam) = 7.5MW
P_{EL} = 7.5 / ηklystron / ηmodulator / ηdistribution
P_{ELav} = P_{EL} * booster duty cycle = 1.7MW

The Booster duty cycle has a huge impact on its power demand. With a low duty cycle, the power demand is very low

Storage ring	Z	W	H	TT
Beam Energy (GeV)	45.6	80	120	182.5
PRF (MW)	100	100	100	100
Klystron efficiency	0.8	0.8	0.8	0.8
PRF EL (MW)	146	146	146	146

Booster	Z	W	H	TT
Beam Energy (GeV)	45.6	80	120	182.5
PRFb (MW)	7.5	7.5	7.5	7.5
Klystron efficiency	0.8	0.8	0.8	0.8
Booster duty cycle	0.15	0.15	0.15	0.15
PRFb EL (MW)	2	2	2	2

CERN launched a R&D High-efficiency klystron, today 50%, target 80%

Cryogenic systems

Cryogenic systems needed for RF cavities

Storage ring
Cryo power demand varies Z, W, H, ttbar
Low static losses
High-dynamic losses (beam loads)
20 tons of Helium (140 tons for LHC)

24th May 2022	Z		W		H		ttbar2		
	per beam	booster	per beam	booster	2 beams	booster	2 beams	2 beams	booster
Frequency [MHz]	400	800	400	800	400	800	400	800	800
RF voltage [MV]	120	140	1000	1000	2480	2480	2480	9190	11670
Eacc [MV/m]	5.72	6.23	11.91	24.26	11.82	25.45	11.82	24.52	25.11
# cell / cav	1	5	2	5	2	5	2	5	5
Vcavity [MV]	2.14	5.83	8.93	22.73	8.86	23.85	8.86	22.98	23.53
#cells	56	120	224	220	560	520	560	2000	2480
# cavities	56	24	112	44	280	104	280	400	496
# CM	14	6	28	11	70	26	70	100	124
T operation [K]	4.5	2	4.5	2	4.5	2	4.5	2	2
dyn losses/cav [W]	19	0.5	174	7	171	8	171	51	8
stat losses/cav [W]	8	8	8	8	8	8	8	8	8
Qext	6.6E+04	3.2E+05	1.2E+06	8.9E+06	1.5E+06	1.2E+07	8.3E+06	4.9E+06	5.3E+07
Detuning [kHz]	8.939	4.393	0.430	0.115	0.123	0.031	0.025	0.040	0.005
Pcav [kW]	880	205	440	112	352	95	62	207	20
rhob [m]	9937	9937	9937	9937	9937	9937	9937	9937	9937
Energy [GeV]	45.6	45.6	80.0	80.0	120.0	120.0	182.5		182.5
energy loss [MV]	38.49	38.49	364.63	364.63	1845.94	1845.94	9875.14		9875.14
cos phi	0.32	0.27	0.36	0.36	0.74	0.74	0.70	0.90	0.85
Beam current [A]	1.280	0.128	0.135	0.0135	0.0534	0.005	0.010	0.010	0.001

RF cavities with very low static losses
High-efficiency cryoplant 250Welec/W@4.5K (as LHC)

Storage ring	Z	W	H	TT
Beam Energy (GeV)	45.6	80	120	182.5
Pcryo (MW)	1,3	12,6	15,8	47,5

Storage Ring Magnet systems

Energy loss in magnets

Magnet losses storage ring
Very low field, 0.1T
$P_{magnets}$ = 56MW from CDR
P_{cables} = 20MW (rough estimation)
$P_{ELmagnets}$ = 76 / ηconversion / ηdistribution
$P_{ELmagnets}$ = 76 / 0.9 / 0.95 = 89MW

A lot of magnet families still unknown, inner triplet, single quadrupoles, octupoles, correctors…
They should have a limited impact on the power demand <10%.

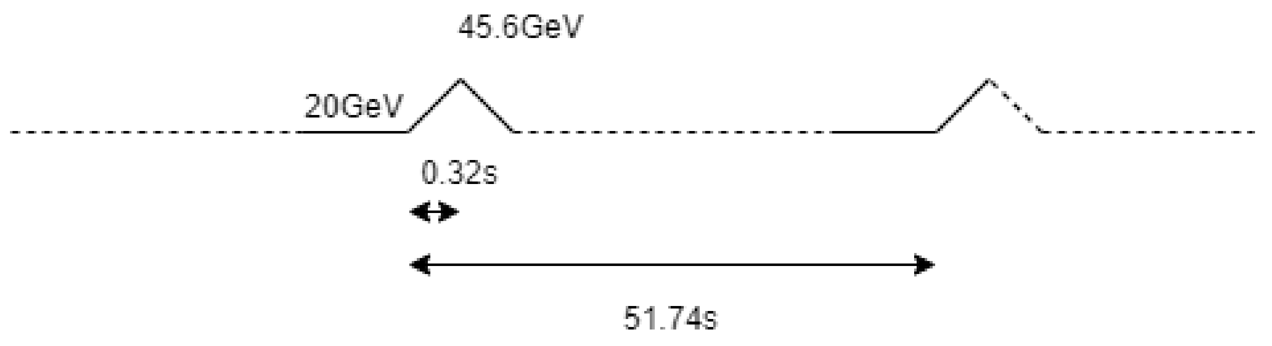
Storage Ring	Z	W	H	TT
Beam Energy (GeV)	45.6	80	120	182.5
Magnet current	25%	44%	66%	100%
Power ratio	6%	19%	43%	100%
Dipoles (MW)	0.8	2.6	5.8	13.3
Quadrupoles (MW)	1.4	4.3	9.8	22.6
Sextupoles (MW)	1.3	3.9	8.9	20.5
Power cables (MW)	1.2	3.8	8.6	20
Total magnet losses	4.8	14.7	33.0	76.4
Power demand (MW)	5.6	17.2	38.6	89

Low-loss magnets design

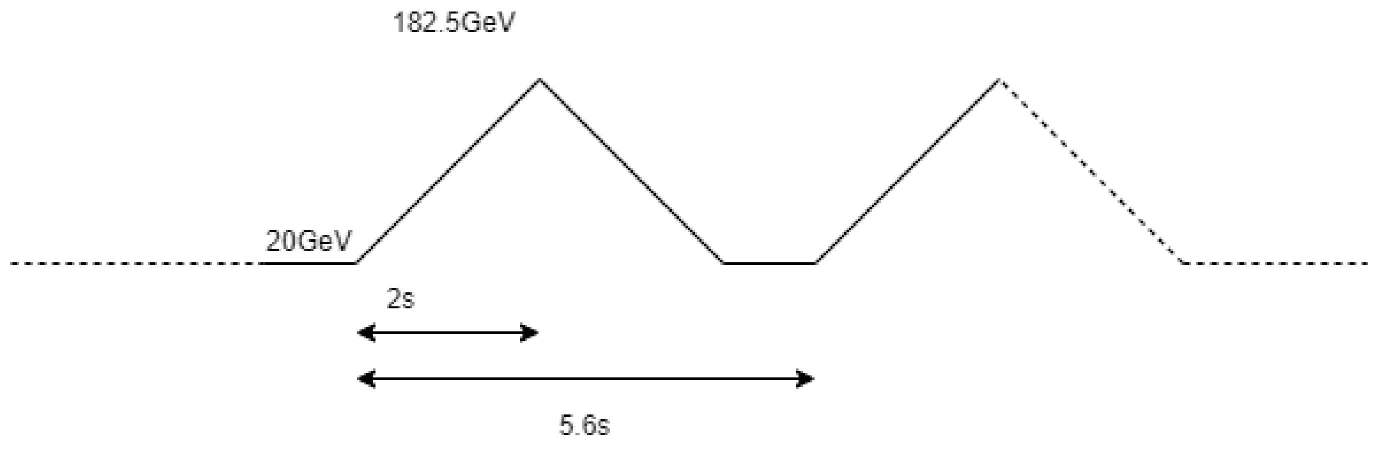
Booster Magnet systems

Energy loss in magnets

We made the assumption that the magnets are the same as the storage ring, except sextupole (half power).
The duty cycle taken for calculation is 15%, one Booster cycle of 4s every 26.6s.
However, in CDR, the repetition rate is up to 1 cycle every 5.6s.



Booster Top-up operation



Booster Top-up operation

Booster	Z	W	H	TT
Beam Energy (GeV)	45.6	80	120	182.5
Magnet current	25%	44%	66%	100%
Power ratio	6%	19%	43%	100%
Dipole (MW)	0.8	2.6	5.8	13.3
Quads (MW)	1.4	4.3	9.8	22.6
Sextupoles (MW)	0.6	2.0	4.4	10.25
Power cables (MW)	1.2	3.8	8.6	20
Booster duty cycle	0.15	0.15	0.15	0.15
Total magnet losses	0.6	1.9	4.3	9.9
Power demand (MW)	0.7	2.2	5.0	12

Low-loss magnets design

Cooling and Ventilation systems

Power demand for cooling and ventilation systems

Power demand is constant for RF loads.
It varies for cryogenics and magnets depending on the machine configuration Z, W, H, ttbar.

Electrical consumption (MW)	Cooling	Chillers	Ventilation	Total
POINT				
A	1.7	1.2	1.3	**4.2**
B	0.3	1.0	1.3	**2.6**
D	1.7	1.1	1.3	**4.2**
F	0.3	1.0	1.3	**2.6**
G	1.7	1.2	1.3	**4.2**
H	3.3	2.1	2.1	**7.5**
J	1.7	1.1	1.3	**4.2**
L	5.5	2.6	2.5	**10.6**
Total	**16.3**	**11.2**	**12.7**	**40.2**

		Z	W	H	TT
Beam energy (GeV)		45.6	80	120	182.5
Pcv (MW)	all	33	34	36	40.2

Total power demand by machine configuration

FCC-ee power demand

Physics program		Z	W	H	TT
Beam energy (GeV)		45.6	80	120	182.5
Magnet current		25%	44%	66%	100%
Power ratio		6%	19%	43%	100%
PRF EL (MW)	Storage	146	146	146	146
PRFb EL (MW)	Booster	2	2	2	2
Pcryo (MW)	all	1,3	12,6	15,8	47,5
Pcv (MW)	all	33	34	36	40.2
PEL magnets (MW)	Stroage	6	17	39	89
PEL magnets (MW)	Booster	1	3	5	11
Experiments (MW)	Pt A & G	8	8	8	8
Data centers (MW)	Pt A & G	4	4	4	4
General services (MW)		36	36	36	36
Max Power beam operation (MW)		237	263	292	385

Estimation uncertainties

Power demand uncertainties

The main loads are known for the storage ring, still, a lot of equipment is not defined.
Also, a lot of unknown on the Booster, equipment and operation mode (types of cycle)
Power cables, 20MW, can be optimized, 50% gain?
Option for 4 experiments, 4 * 4MW
General services are over-estimated (estimation based on LHC, but with mixed loads), should be below 26MW

Despite of a lot of unknown of the accelerator systems, the global uncertainty is < 5%

		Z	W	H	TT
Beam energy (GeV)		45.6	80	120	182.5
Experiments (MW)	Pt A, D, G, J	16	16	16	16
Data centers (MW)	Pt A, D, G, J	8	8	8	8
General services (MW)		26	26	26	26
Compare to previous slide (MW)		+2	+2	+2	+2
Power during beam operation (MW)		239	264	293	386

Power demand during the year

Machine schedule

The machine schedule defines different periods during the year.
The power demand varies from the minimum during the winter shutdown to the maximum during beam operation.

Power during, in MW	Z	W	H	TT
shutdown	65	68	69	78
Technical stop	82	88	92	112
Downtime	86	105	122	187
Commissioning	159	172	188	236
Machine Development	163	182	210	287
Beam operation	237	263	292	385

- Technical stops are planned stops during operation to perform maintenance and repairs, last 5 consecutive days.
- Downtime is when the machine is in fault, repair is on going with no beam operation.
- Commissioning, is the period before beam operation where all systems are restarted and tested.
- Machine development are planned activities with beam operation to improve the beam operation. No physics production.
- Beam operation is when the beam is stable and in collision for experiments
- Shutdown is scheduled when electricity is too costly (winter time). The machine is stopped and open for work, maintenance, and repair activities.

Power demand during the year Z configuration

Z machine schedule

The machine schedule defines different periods during the year.
The table bellow presents the power demand during the year for the Z machine.

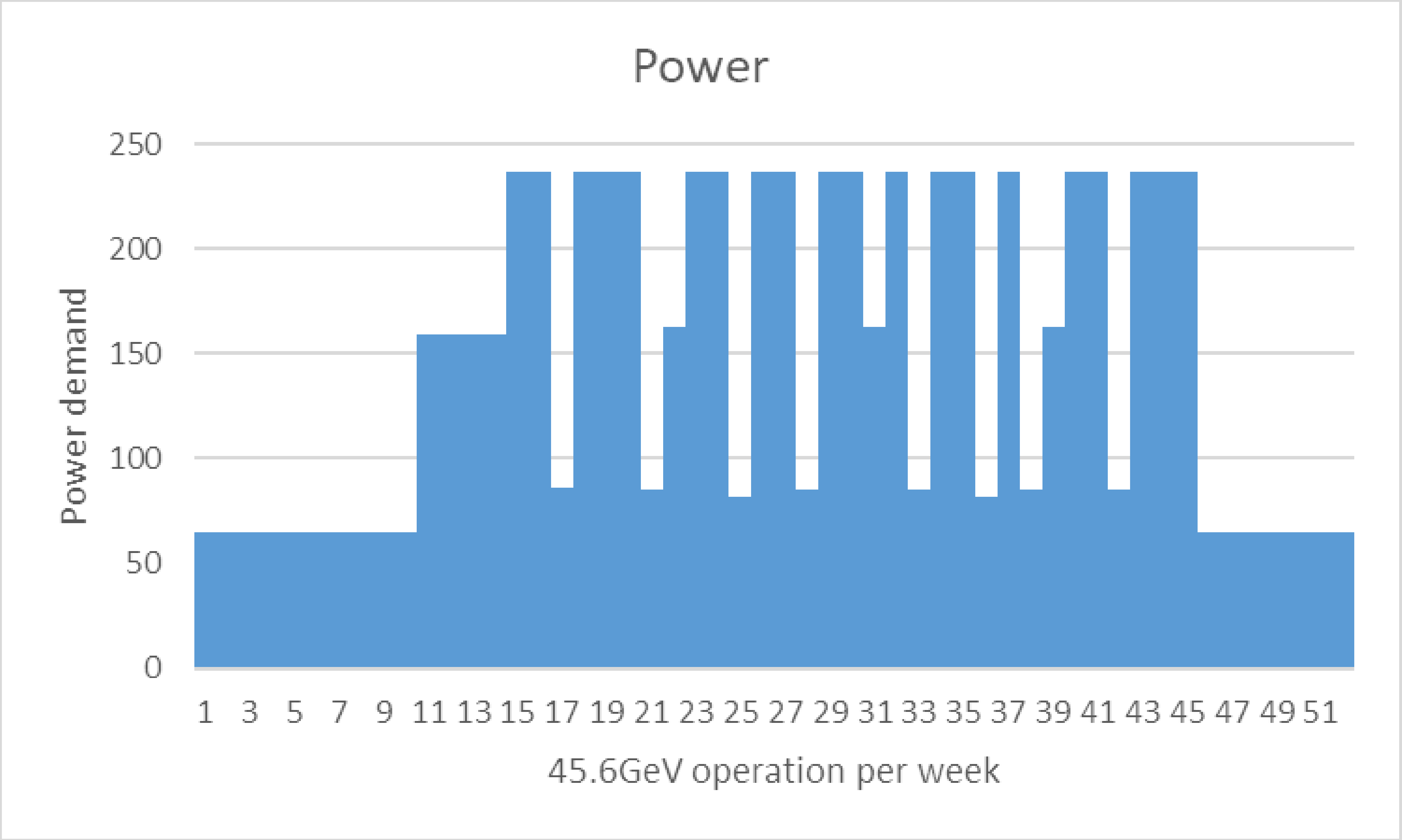
Z configuration			Beam Operation	Commissioning	Machine Development	Technical Stop	Winter Shutdown			
	Days	Hours	MW	MW	MW	MW	MW			
Beam operation	143	3432	237					814167	MWh	63%
Downtime operation	42	1008	86					86534	MWh	7%
Hardware + Beam commissioning	30	720		159				114562	MWh	9%
Machine Development	20	480			163			78071	MWh	6%
technical stop	10	240				82		19598	MWh	2%
Shutdown	120	2880					65	186517	MWh	14%
	365	8760						1.30	TWh	
Average power								148	MW	

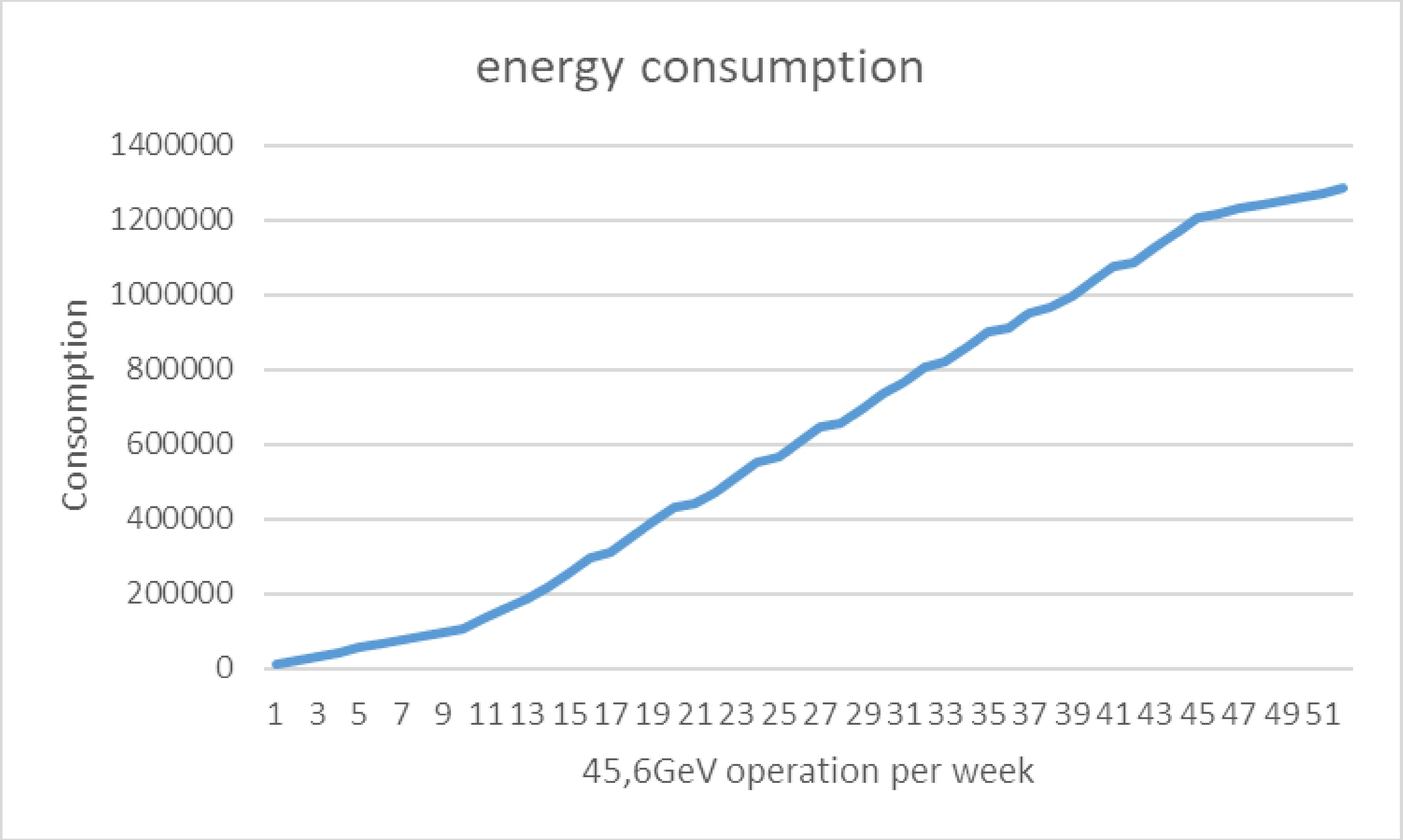
Beam period (Beam operation through technical stop)

Power demand during the year Z configuration

Z machine schedule 2045 - 2048

Power demand during the year is shown below as well as the energy consumption during the year.





Power demand during the year W configuration

W machine schedule

The machine schedule defines different periods during the year.
The table bellow presents the power demand during the year for the W machine.

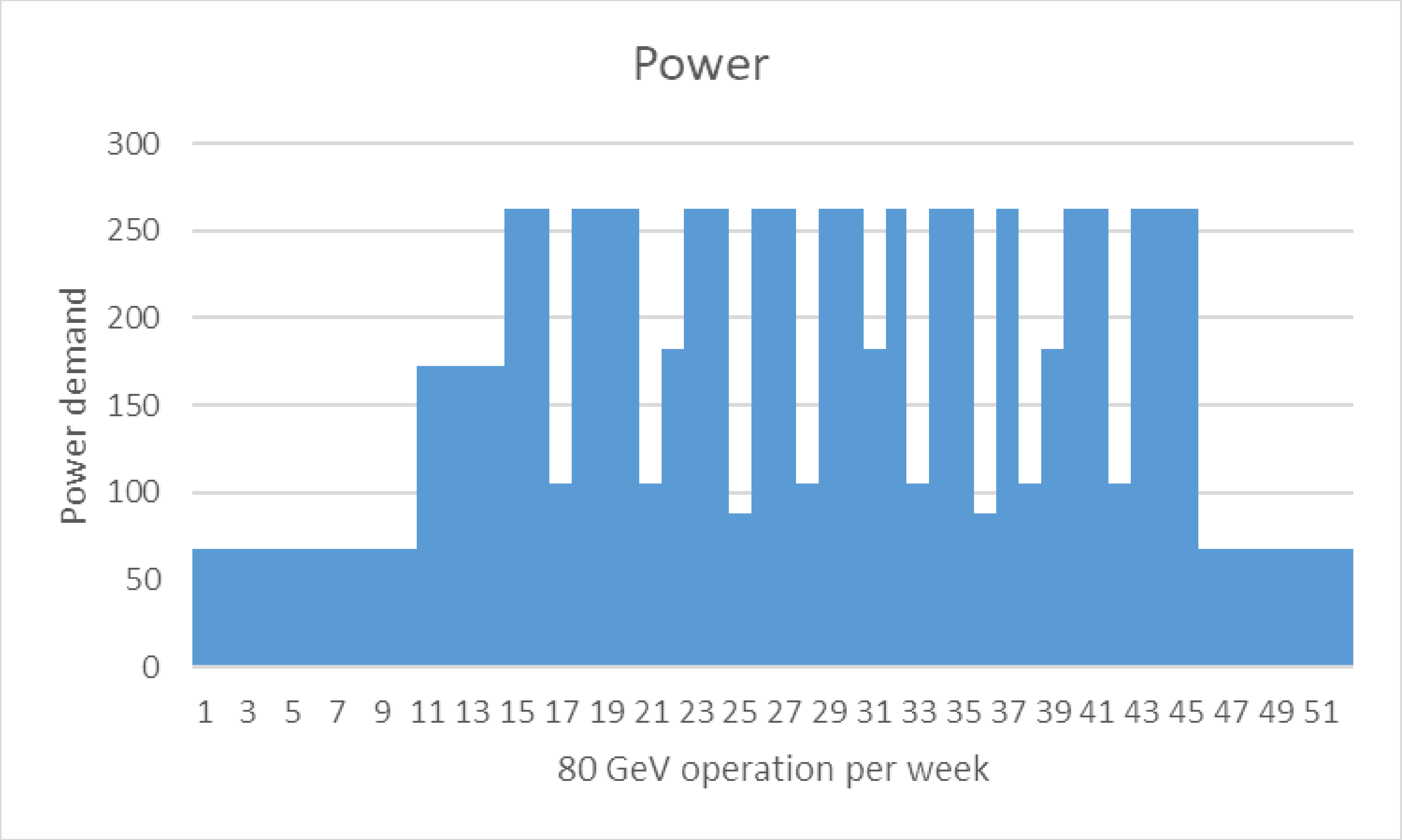
W configuration			Beam Operation	Commissioning	Machine Development	Technical Stop	Winter Shutdown			
	Days	Hours	MW	MW	MW	MW	MW			
Beam operation	143	3432	263					901246	MWh	63%
Downtime operation	42	1008	105					105585	MWh	7%
Hardware + Beam commissioning	30	720		172				124056	MWh	9%
Machine Development	20	480			182			87507	MWh	6%
technical stop	10	240				88		21209	MWh	1%
Shutdown	120	2880					68	194539	MWh	14%
	365	8760						1.43	TWh	
Average power								164	MW	

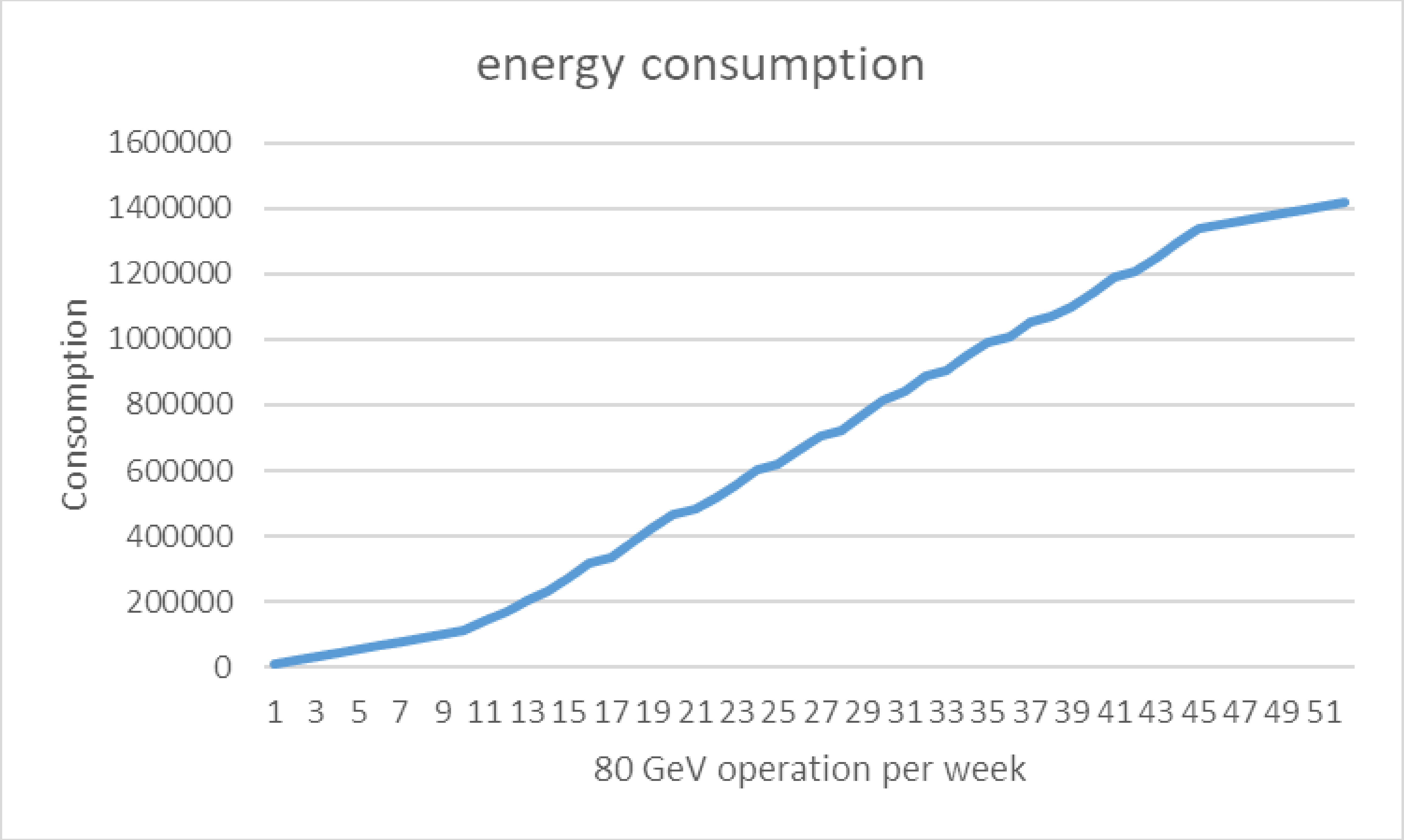
Beam period

Power demand during the year W configuration

W machine schedule 2049 - 2050

Power demand during the year is shown below as well as the energy consumption during the year.





Power demand during the year H configuration

H machine schedule

The machine schedule defines different periods during the year.
The table bellow presents the power demand during the year for the H machine.

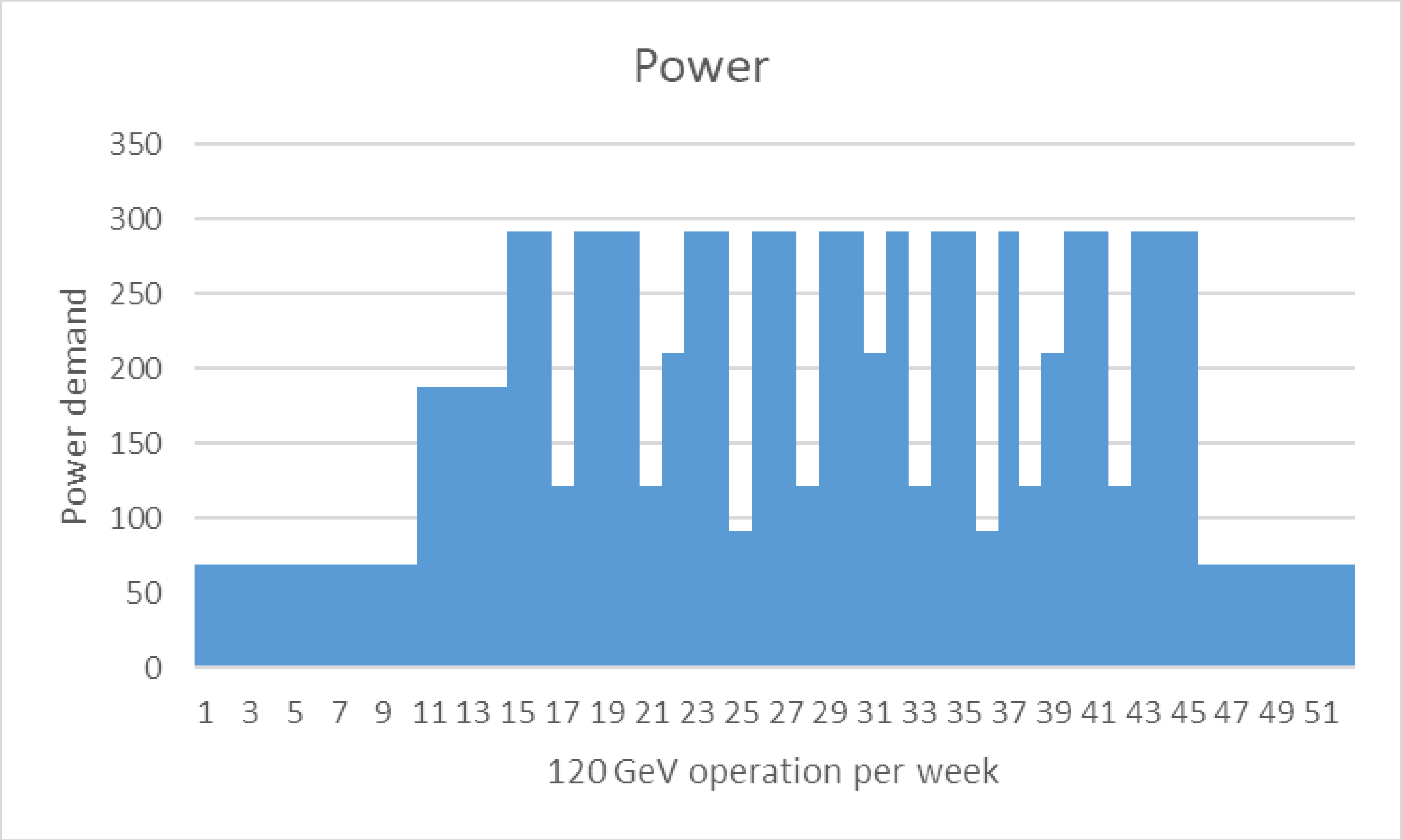
H configuration			Beam Operation	Commissioning	Machine Development	Technical Stop	Winter Shutdown			
	Days	Hours	MW	MW	MW	MW	MW			
Beam operation	143	3432	292					1001479	MWh	63%
Downtime operation	42	1008	122					122944	MWh	8%
Hardware + Beam commissioning	30	720		188				135290	MWh	9%
Machine Development	20	480			210			100749	MWh	6%
technical stop	10	240				92		22077	MWh	1%
Shutdown	120	2880					69	199283	MWh	13%
	365	8760						1.58	TWh	
Average power								181	MW	

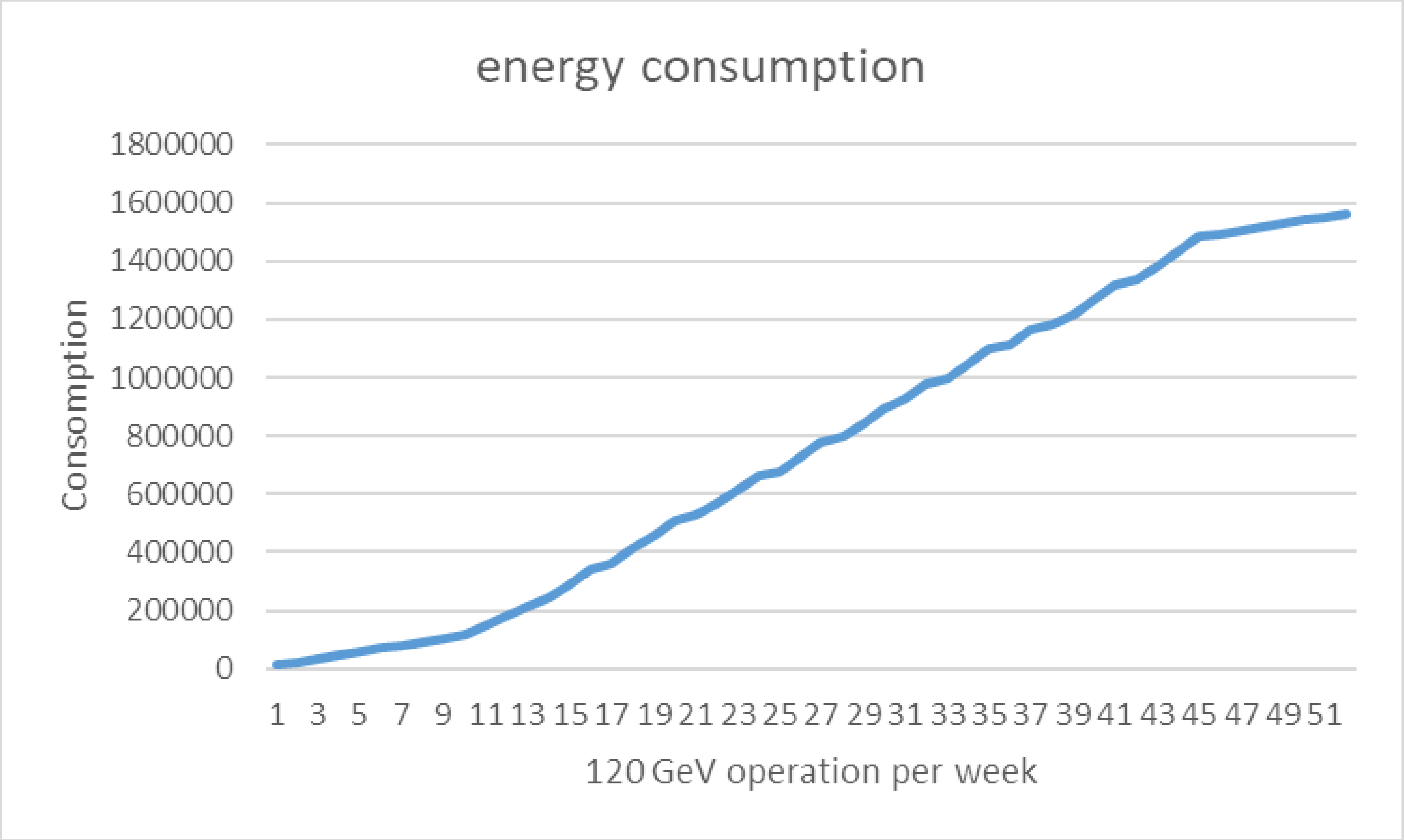
Beam period

Power demand during the year H configuration

H machine schedule 2051 - 2053

Power demand during the year is shown below as well as the energy consumption during the year.





Power demand during the year TT configuration

TT machine schedule

The machine schedule defines different periods during the year.
The table bellow presents the power demand during the year for the TT machine.

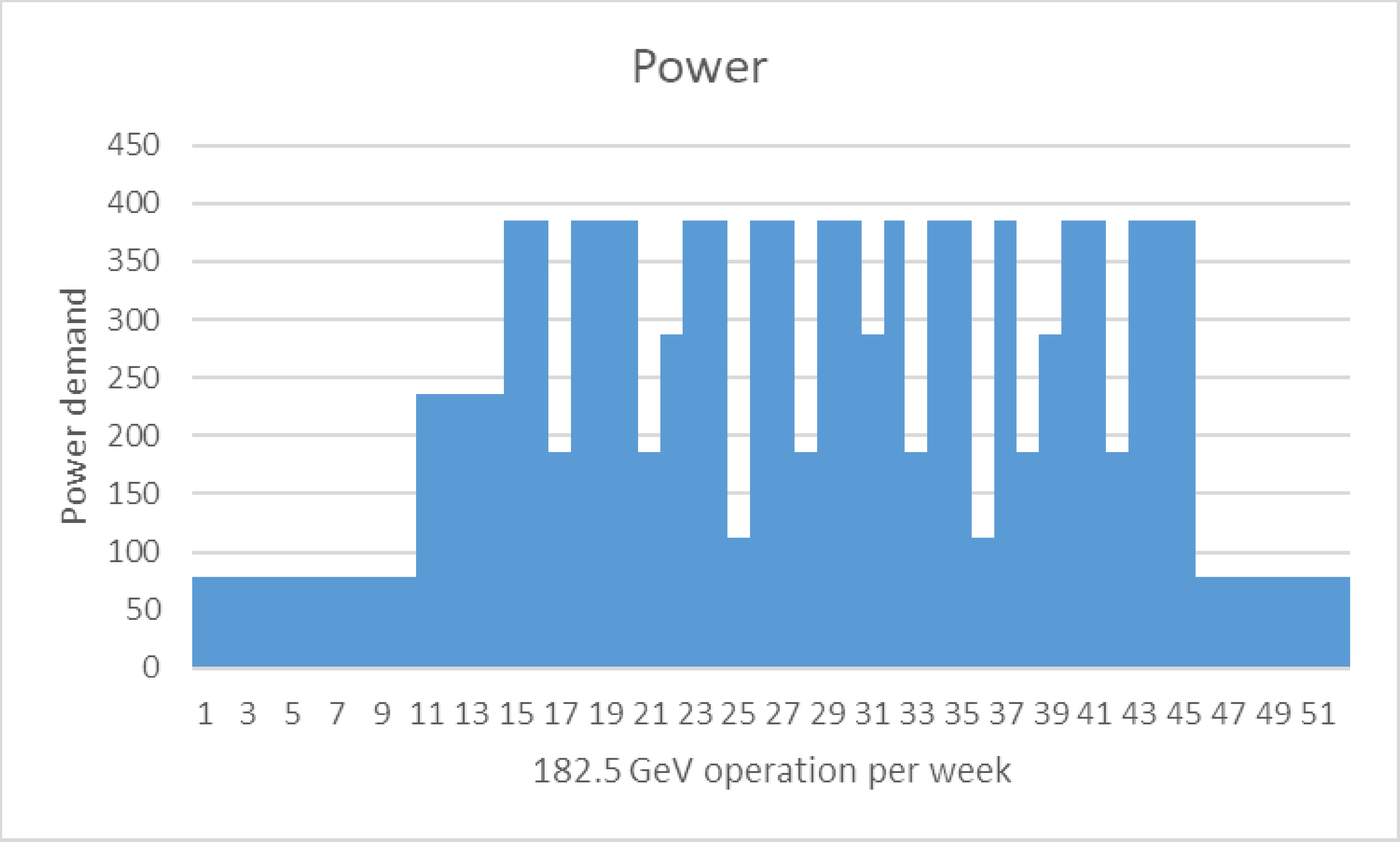
TT configuration			Beam Operation	Commissioning	Machine Development	Technical Stop	Winter Shutdown			
	Days	Hours	MW	MW	MW	MW	MW			
Beam operation	143	3432	385					1320325	MWh	64%
Downtime operation	42	1008	187					188041	MWh	9%
Hardware + Beam commissioning	30	720		236				170248	MWh	8%
Machine Development	20	480			287			137649	MWh	7%
technical stop	10	240				112		26932	MWh	1%
Shutdown	120	2880					78	223796	MWh	11%
	365	8760						2.07	TWh	
Average power								236	MW	

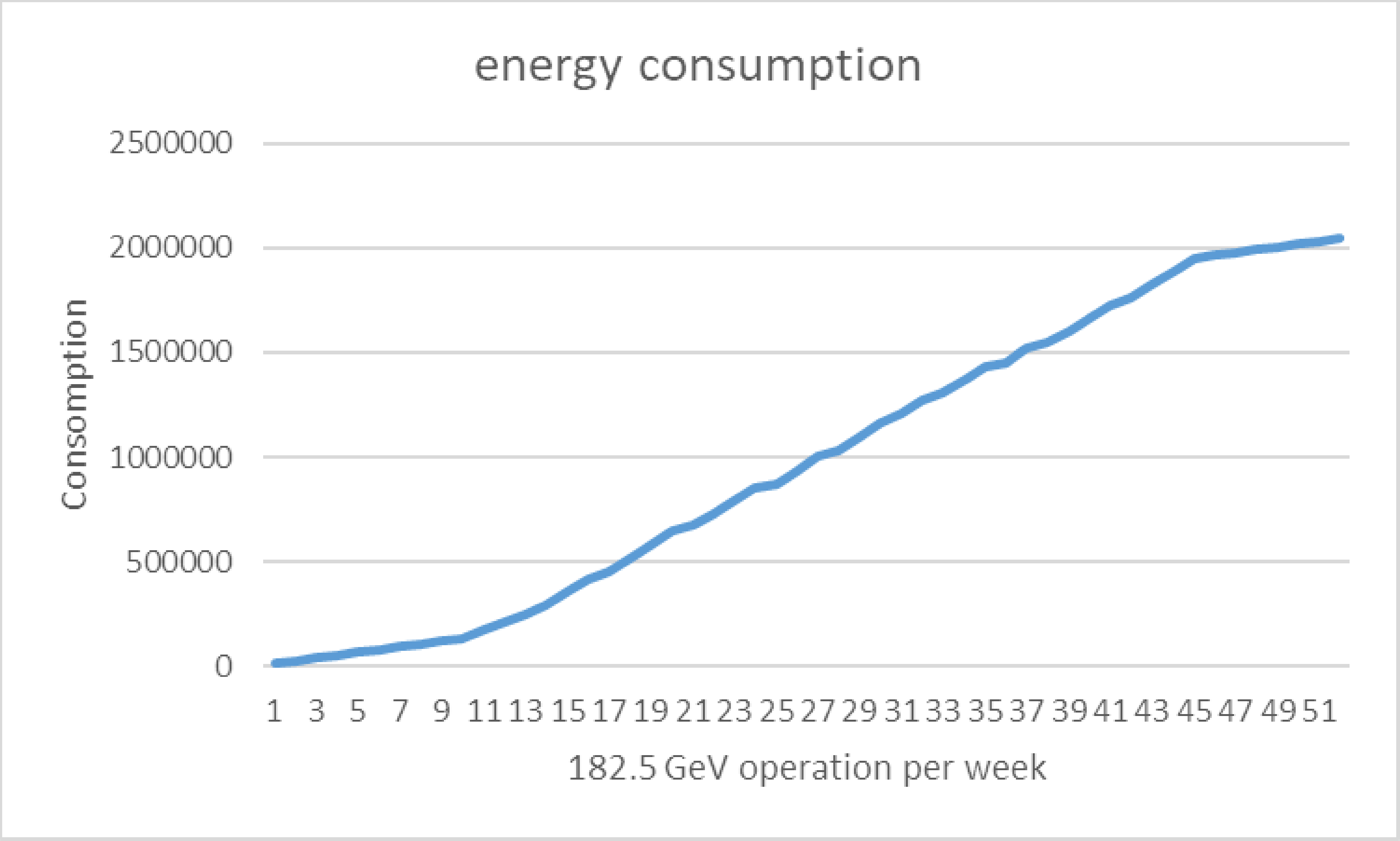
Beam period

Power demand during the year TT configuration

TT machine schedule 2055 - 2058

Power demand during the year is shown below as well as the energy consumption during the year.





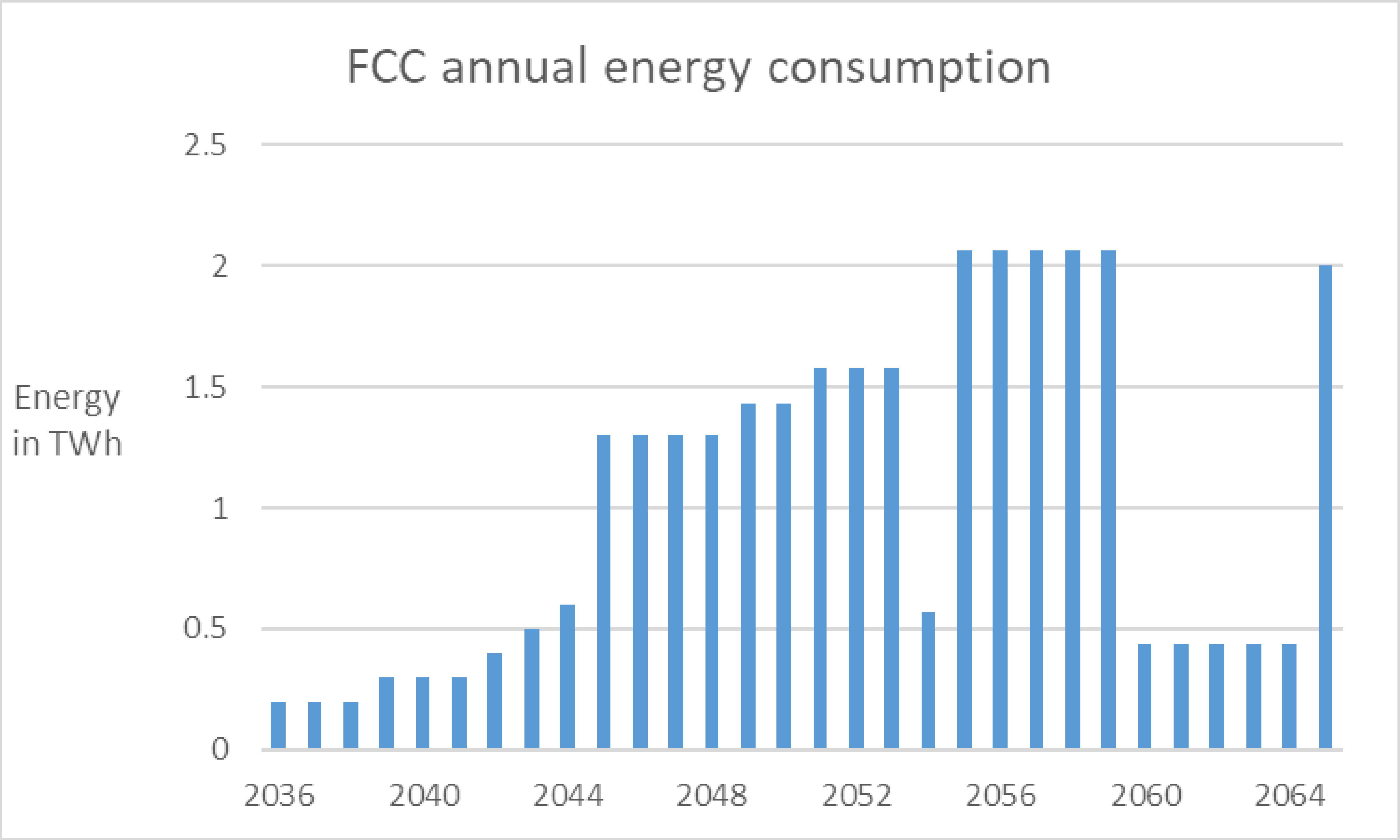
Electricity supply 2036 - 2060

Electricity supply for FCC-ee from 2036 to 2060

Schedule of the annual consumption during the FCC-ee lifetime.

Lifetime	25	Years
Total consumption	27	TWh
annual average consumption	1.1	TWh/y

FCC-ee operation	15	Years
Total consumption	24	TWh
annual average consumption	1.6	TWh/y



CERN 1.3TWh/y
LHC 0.6TWh/year
Swiss railways 3TWh/year
French railways 7TWh/year
Electricity production in France 510TWh/year

Year	Type	Beam	Min power	Max power	Annual consumption
		GeV	MW	MW	TWh
2036	Construction		20	50	0.2
2037	Construction		20	50	0.2
2038	Construction		20	50	0.2
2039	Construction		20	50	0.3
2040	Construction		20	50	0.3
2041	Construction		20	50	0.3
2042	Construction		20	50	0.4
2043	Construction		20	50	0.5
2044	Construction		20	50	0.6
2045	Z operation	45.6	65	237	1.30
2046	Z operation	45.6	65	237	1.30
2047	Z operation	45.6	65	237	1.30
2048	Z operation	45.6	65	237	1.30
2049	W operation	80	68	263	1.43
2050	W operation	80	68	263	1.43
2051	H operation	120	69	292	1.58
2052	H operation	120	69	292	1.58
2053	H operation	120	69	292	1.58
2054	Long shutdown		65	65	0.57
2055	TT operation	182.5	78	385	2.07
2056	TT operation	182.5	78	385	2.07
2057	TT operation	182.5	78	385	2.07
2058	TT operation	182.5	78	385	2.07
2059	TT operation	182.5	78	385	2.07
2060	Upgrade		50	50	0.44
2061	Upgrade		50	50	0.44
2062	Upgrade		50	50	0.44
2063	Upgrade		50	50	0.44
2064	Upgrade		50	50	0.44
2065	HH operation		50	500	2

Energy consumption, 182.5 GeV (TT),by system

Estimation of energy consumption by system

Energy consumption FCC alone.

182.5 GeV	Days	Hours	Power OP	Power Downtime	Power Com	Power MD	Power TS	Power Shutdown			Ratio per system
Days	365		143	42	30	20	10	120			
RF systems			148	0	74	74	0	0	596121.9	MWh	28%
Magnets			101	50	50	101	0	0	480599	MWh	23%
Cryo			48	48	24	24	24	10	310109.9	MWh	15%
CV			40	40	40	40	40	20	294264	MWh	14%
General services	365	8760	36	36	36	36	36	36	315360	MWh	15%
Exp + data center	365	8760	12	12	12	12	12	12	105120	MWh	5%
Power / period			385	187	236	287	112	78			
Energy / Period			1320325	188041	170248	137649	26932	223796	2101575	MWh	
Ratio per period			62.8%	8.9%	8.1%	6.5%	1.3%	10.6%	2066990	MWh	

FCC GRID CONNECTION

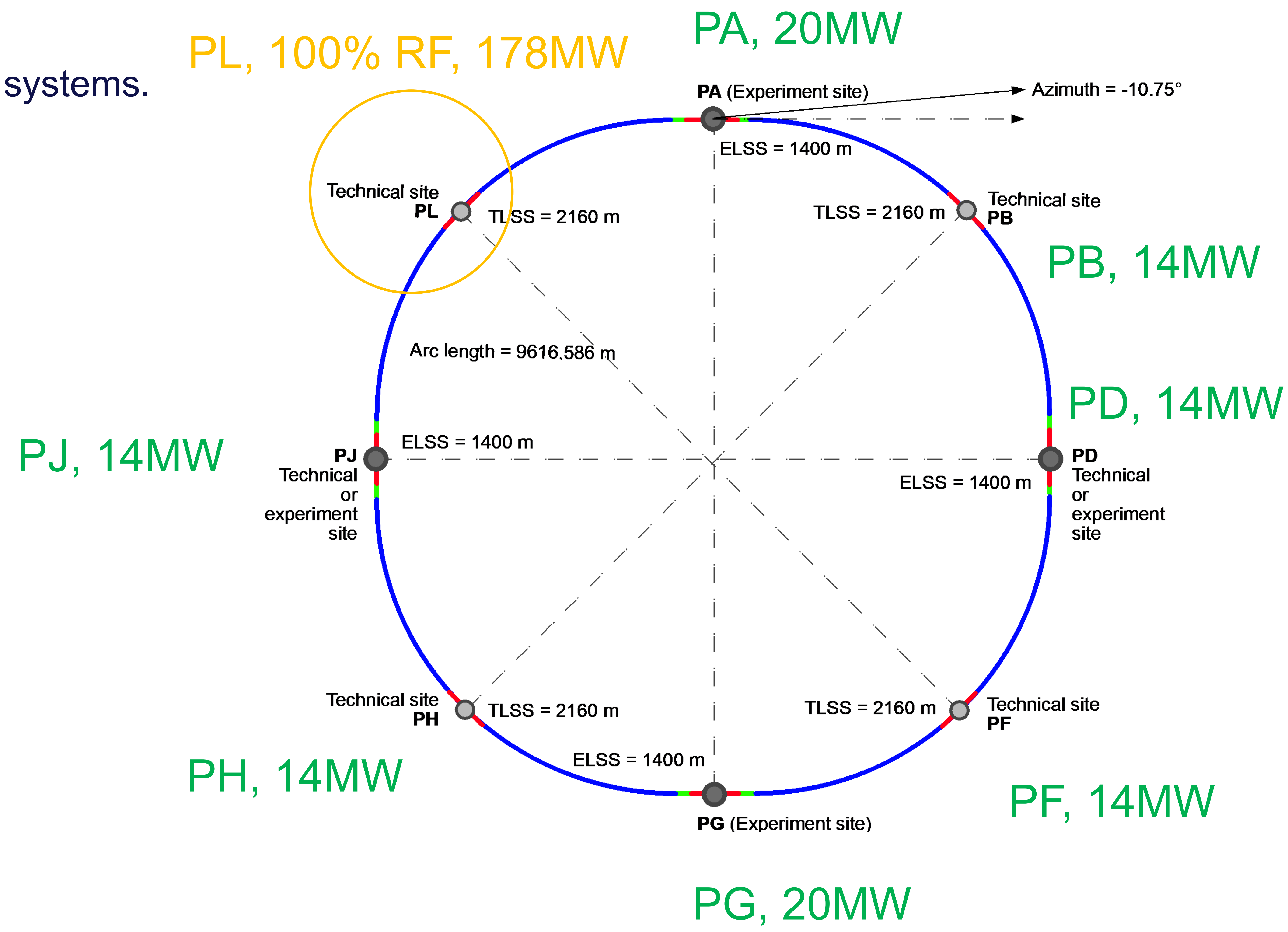
Power demand per points, configuration Z, W, H

Infrastructure needed for FCC-ee Z, W, H

Very high power demand on point L, 180MW due to RF systems.

2 experiments, point A and G.

		Max power (MW)
Point A	Experiment	20
Point B		14
Point D		14
Point F		14
Point G	experiment	20
Point H	RF TT	14
Point J		14
Point L	RF Z,W,H	178

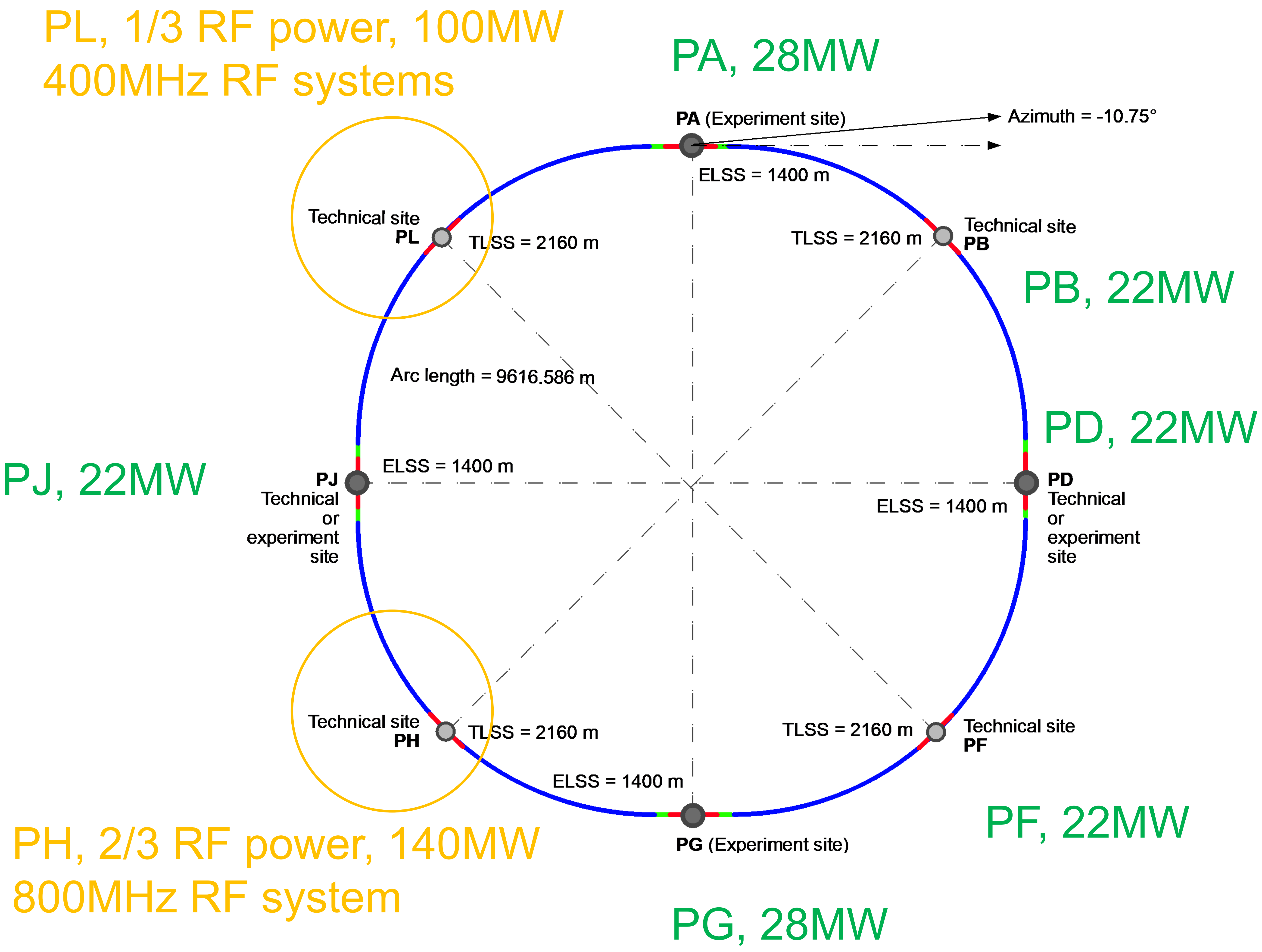


Power demand per points, configuration TTbar

Infrastructure needed for FCC-ee TTbar

2 high power demands,
Point L 100MW, 40% 400MHz
Point H, 140MW, 60% 800MHz

		Max power (MW)
Point A	Experiment	28
Point B		22
Point D		22
Point F		22
Point G	experiment	28
Point H	RF TT	140
Point J		22
Point L	RF Z,W,H	100



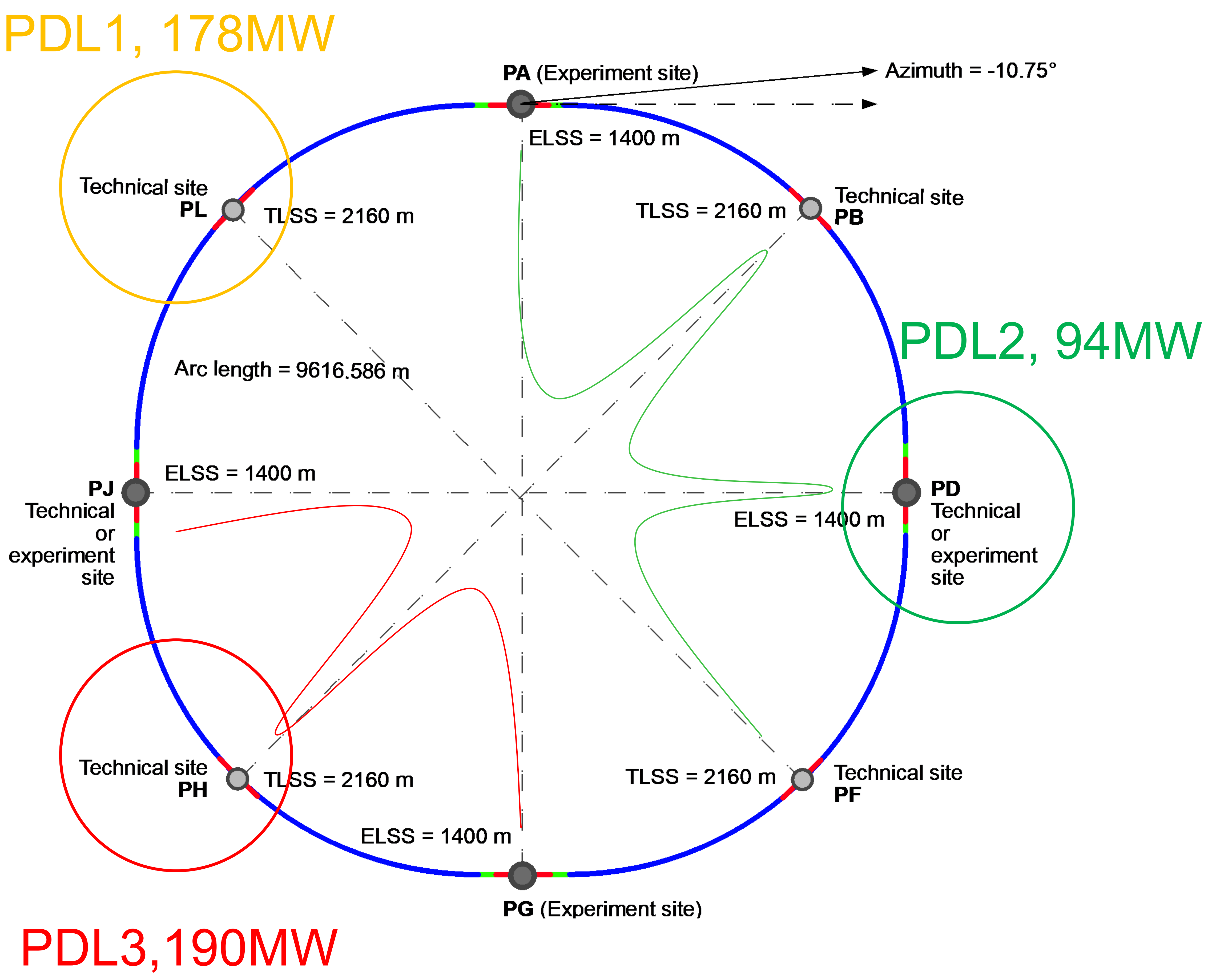
Electrical sub-stations, FCC-ee, 2036-2060

Infrastructure needed for FCC-ee

The proposal is to have 3 connections to the French grid. The other points will be supplied through the FCC internal electrical network.

Point L with a dedicated sub-station
Point H, with a sub-station covering PH - PJ - PG
Point D, with a sub-station covering PA - PB – PD - PF

		Max power (MW)
PDL1	PL	178
PDL2	PD	94
PDL3	PH	190



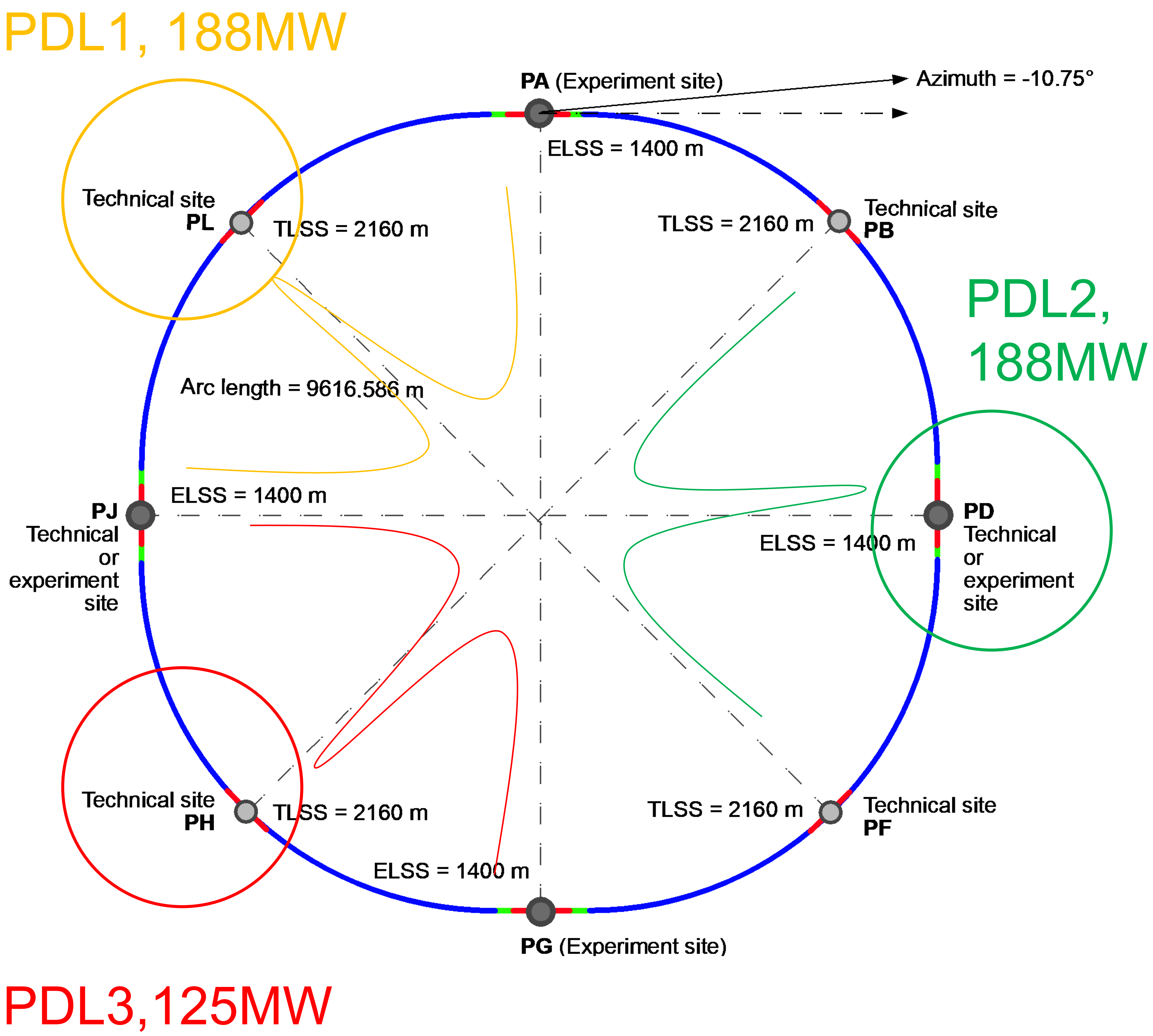
Electrical sub-stations, FCC-hh, after 2060

Infrastructure needed for FCC-hh

The power demand will be spread all around the machine, due to the cryogenic needed for superconducting magnets distributed all around the machine.
500MW / 8 = 62.5 MW per point

Need 3 substations for hh configuration, rated at ~200MW .

		Max power (MW)
PDL1	PL	188
PDL2	PD	188
PDL3	PH	125



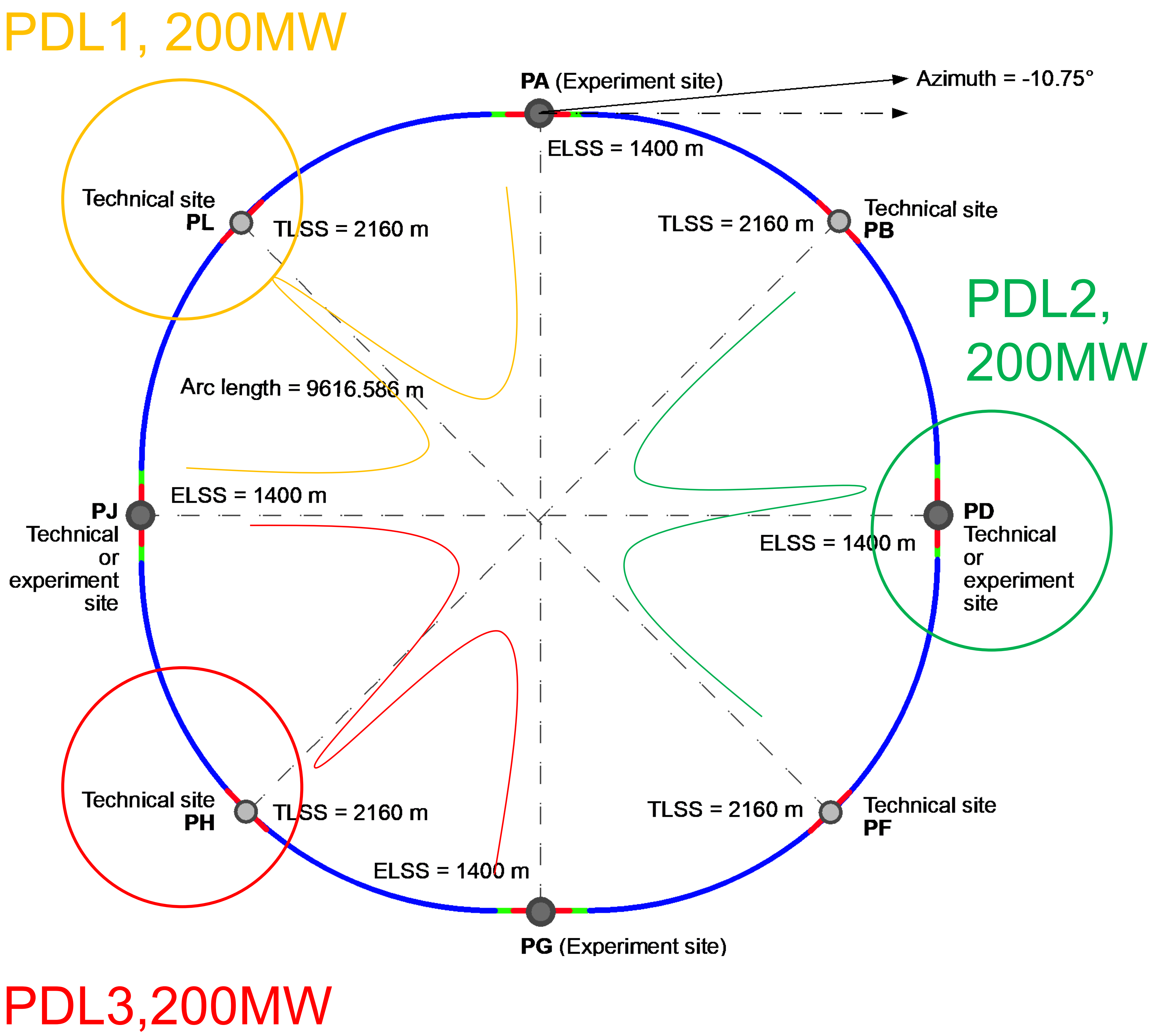
Proposal for grid connection points

Infrastructure needed to cover all FCC configuration

The goal is to built an electrical infrastructure which will cover all the configuration of the FCC machine without need to built new sub-stations.
This proposal includes also the possibility to operate the FCC-ee machine without one sub-station, which will ease the maintenance and repairs.

The proposal is to have 3 grid connection points rated at 200MW.

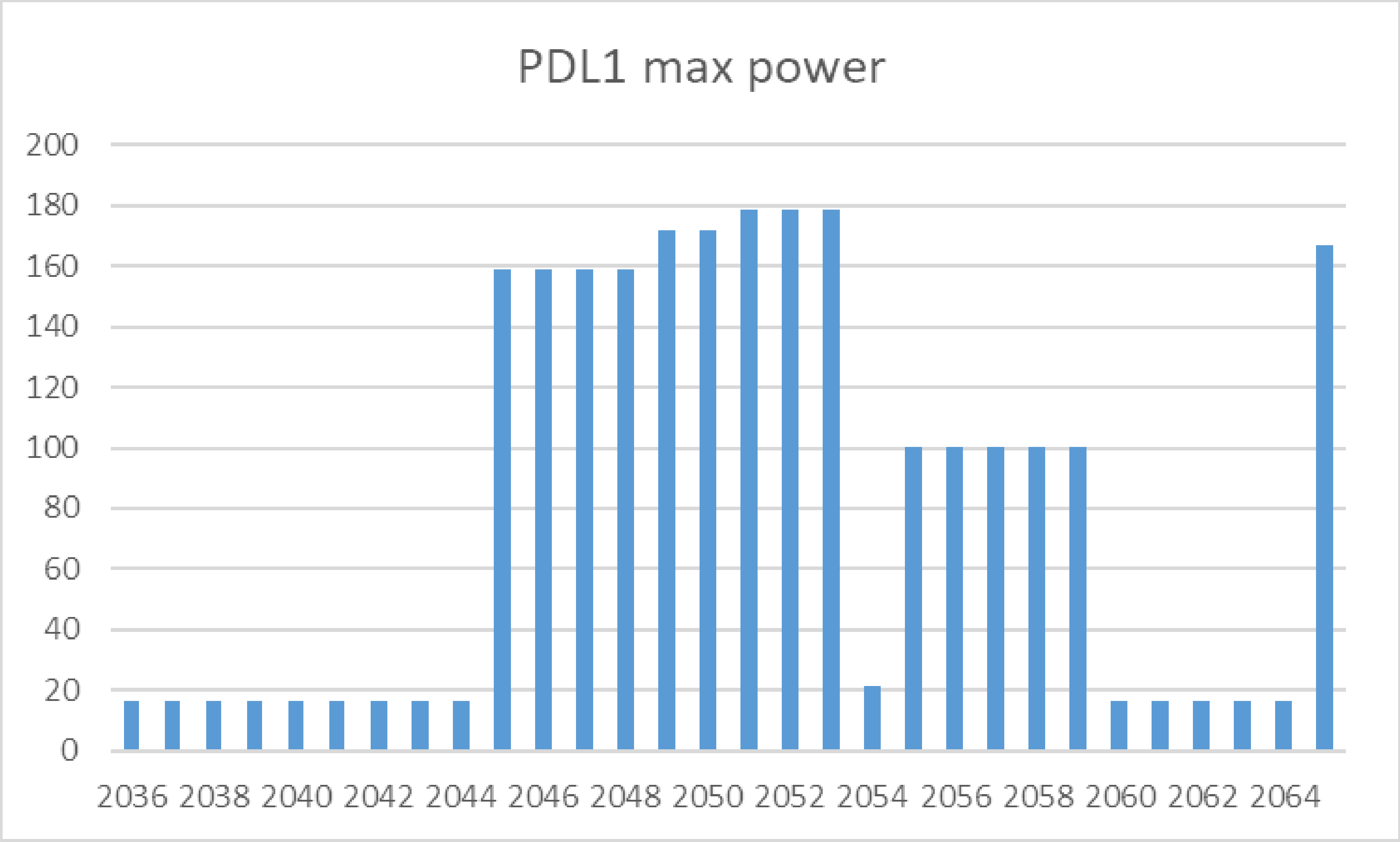
Under study with French transmission system operator (RTE).

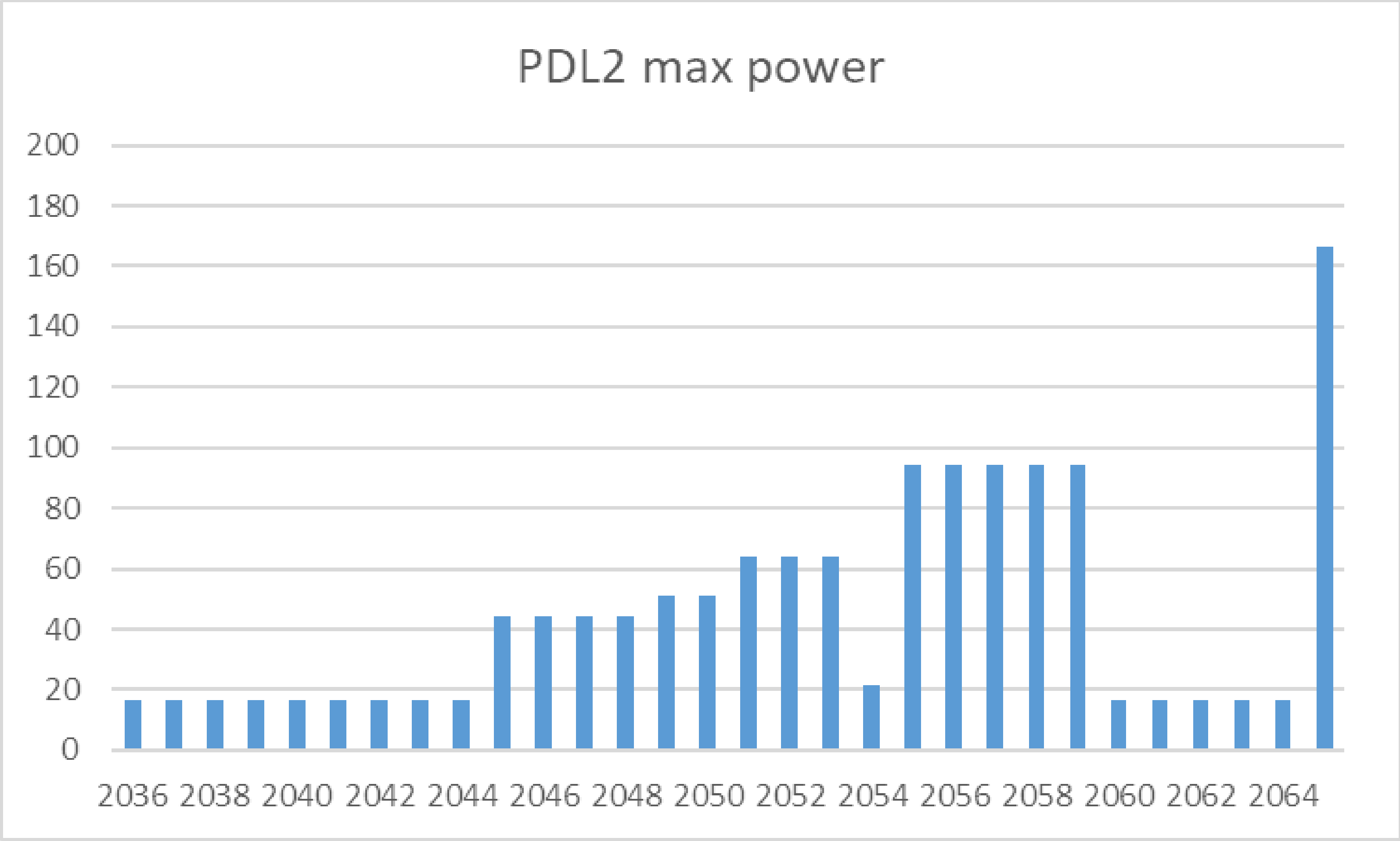


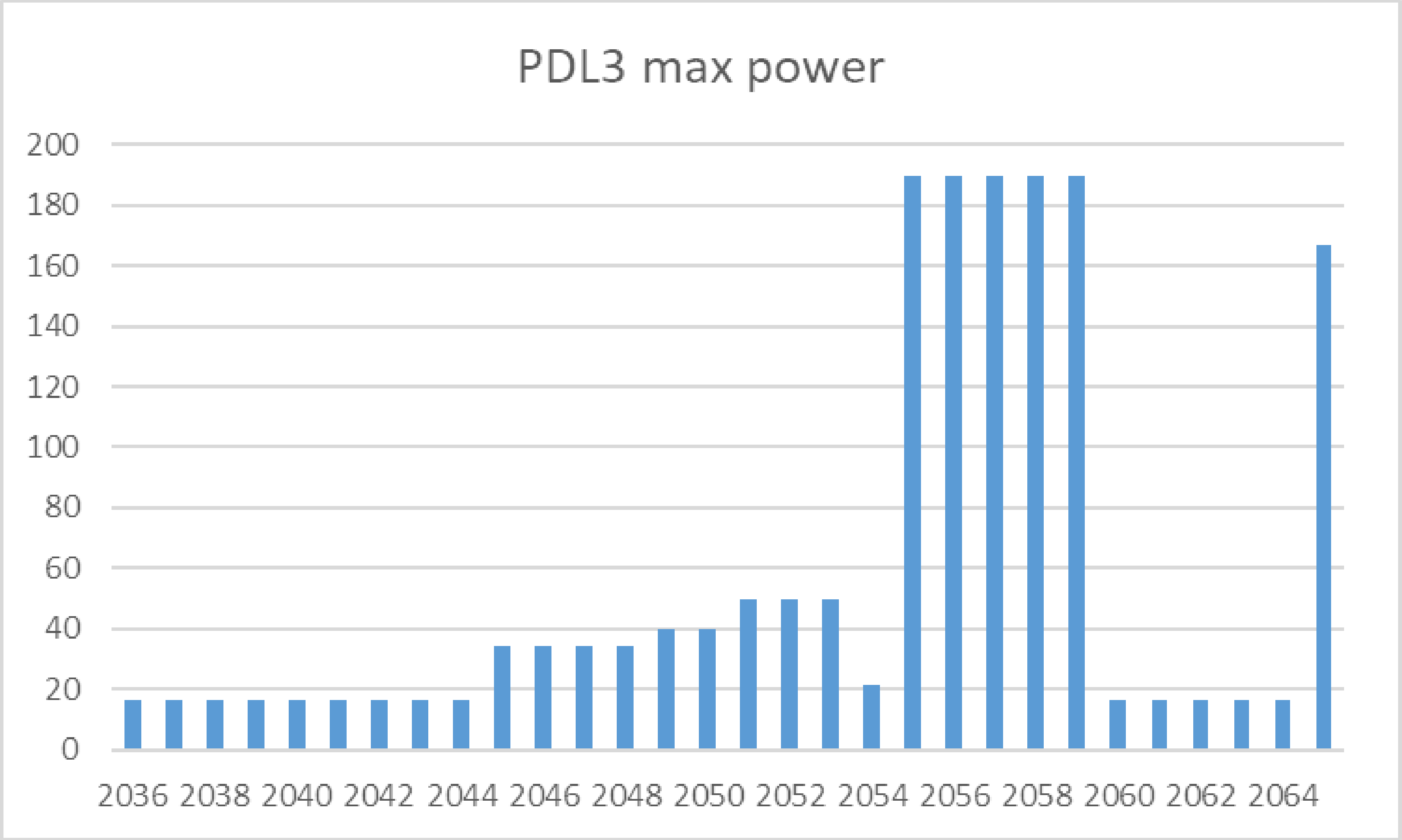
Power by grid connection point 2036-2065

Max power demand per year and per point

The max power demand by grid connection point will vary depending on the machine configuration.
The estimation is shown below for the FCC-ee life time.







OPTIMISATION AND WAYS TO REDUCE ENERGY CONSUMPTION

Optimization of the accelerator systems

Focus on reduction of the power demand

Recall 85-90% of the energy consumption is with beam operation. Basic infrastructure consumption is less than 15%.

FCC team has already identified the main accelerator systems which need to be optimized to reduce the energy consumption.

Low-loss magnets
High-efficiency klystrons, target 80% (corresponding to 0.5TWh energy saving)
Low static losses of RF cavities,
High-Q cavities, which could bring down the Cryo power demanded by 50%, R&D effort to be pursuit
High-efficiency cryogenic plant

The power demand estimation is already based on these optimisations!

Nice behaviour of FCC-ee: RF power (150MW) is present only with beam operation!

Power demand drops when there is no beam, be careful with electrical network stability!

Ways to reduce energy consumption

Focus on reduction of the energy consumption

The management of the accelerator systems and of the infrastructure has a large impact on energy consumption.

Usually priority to physics but with special care to energy consumption.

Always too much energy consume without beams, an energy-saving strategy shall be developed.

Economic mode for magnets (Switch-off magnets during short or long stops)
Economic mode for cryoplant (Static losses represent less than 10%, can we operate cryoplants at 20%,50% for short or long stop?)
Economic mode for cooling and ventilation

- can we reduce the tunnel ventilation when nobody is inside or regulated it on temperature? Different from fixed speed.
- can we adapt the water flow rate depending on the power dissipation? Motor drive systems regulated on power demand.
- can we modulate the cooling tower with the power dissipation? Motor drive systems regulated on power demand.

Economic mode for experiments

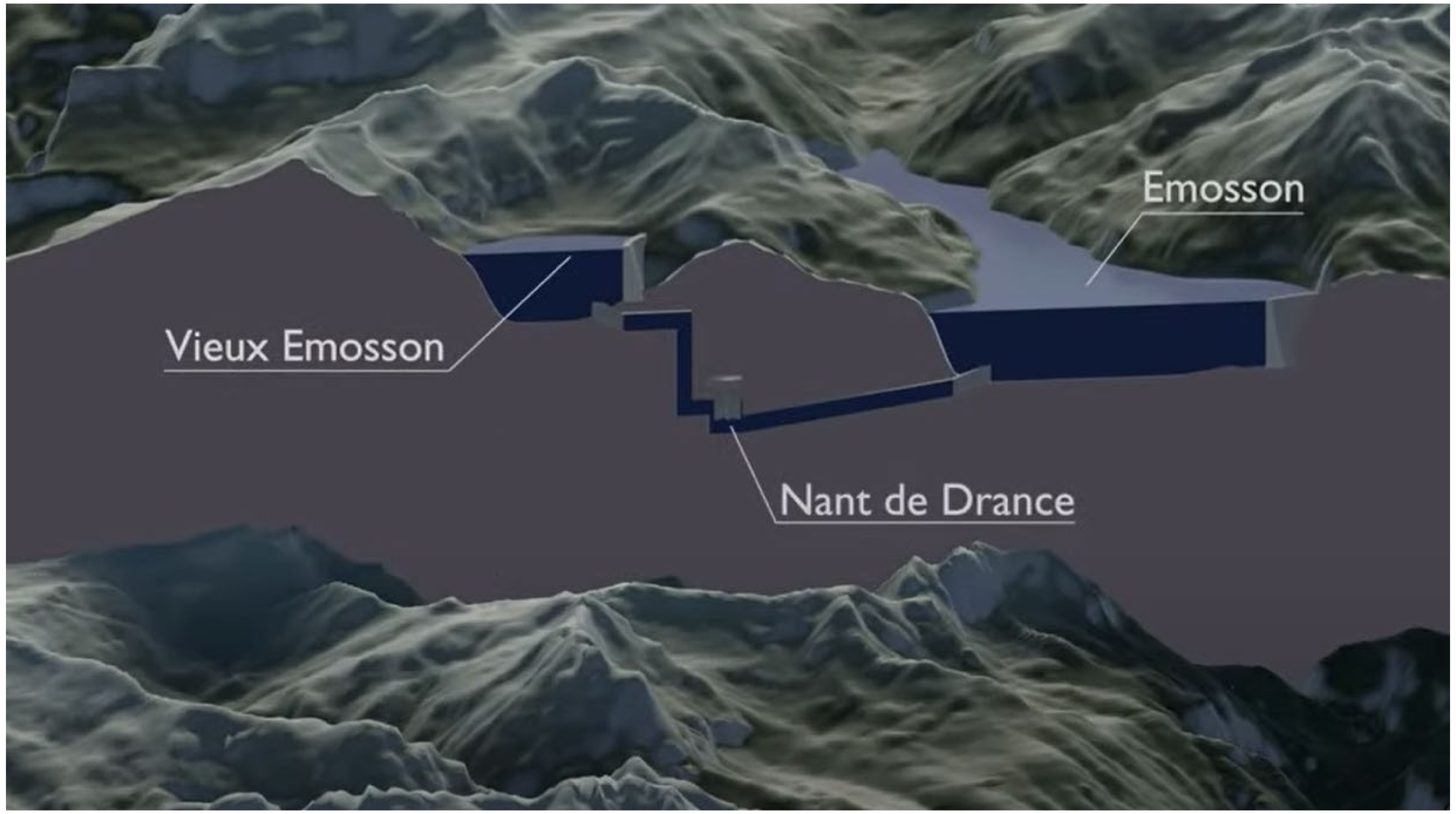
- can we identify some systems that can be put in sleep mode?
- …

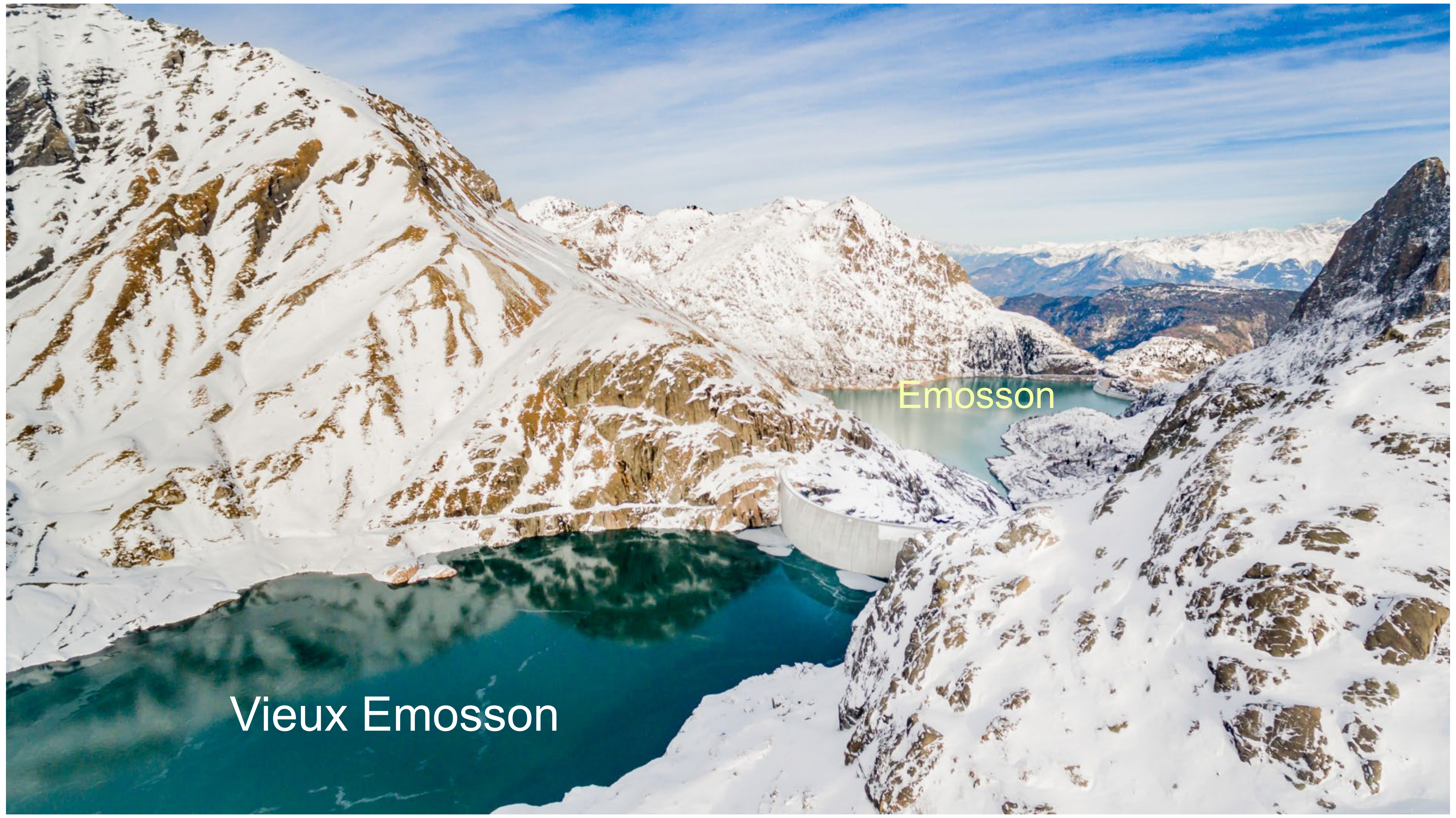
Under preparation, a working group on energy saving and sustainability

Target 10% ? 200GWh

What is 20GWh?

Nant de Drance (Switzerland) – Pumped storage power plant started operation July 2022

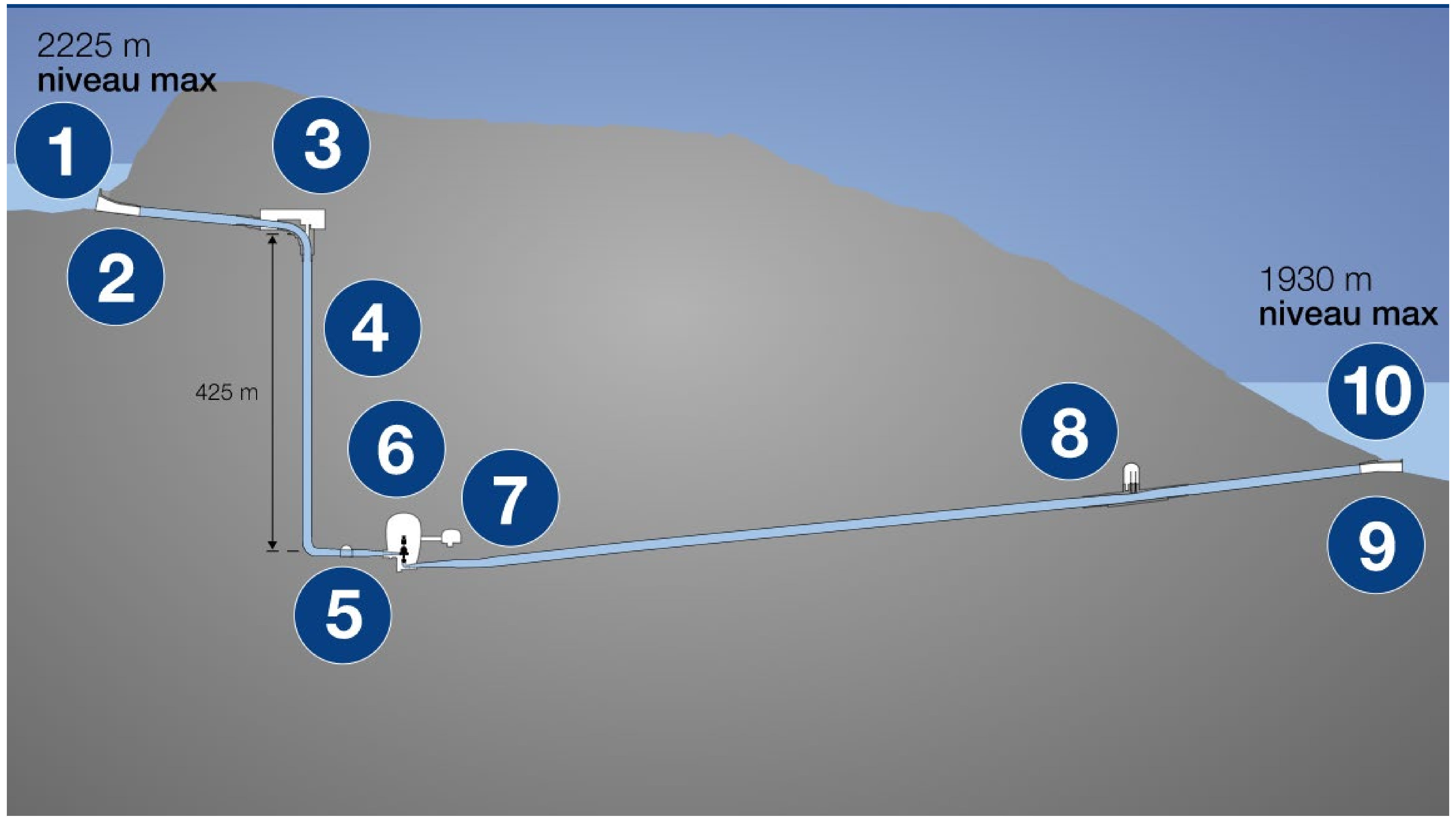




What is 20GWh?

Nant de Drance – pumped storage plant parameters

20GWh energy storage
25.10^6 m^3 capacity of upper lake
425m vertical penstocks, 7m diameter
6 * 150MW generator sets
360m^3/s, half of the Rhone flow in Geneva
18GWh = 900 MW * 20h



What is 20GWh?

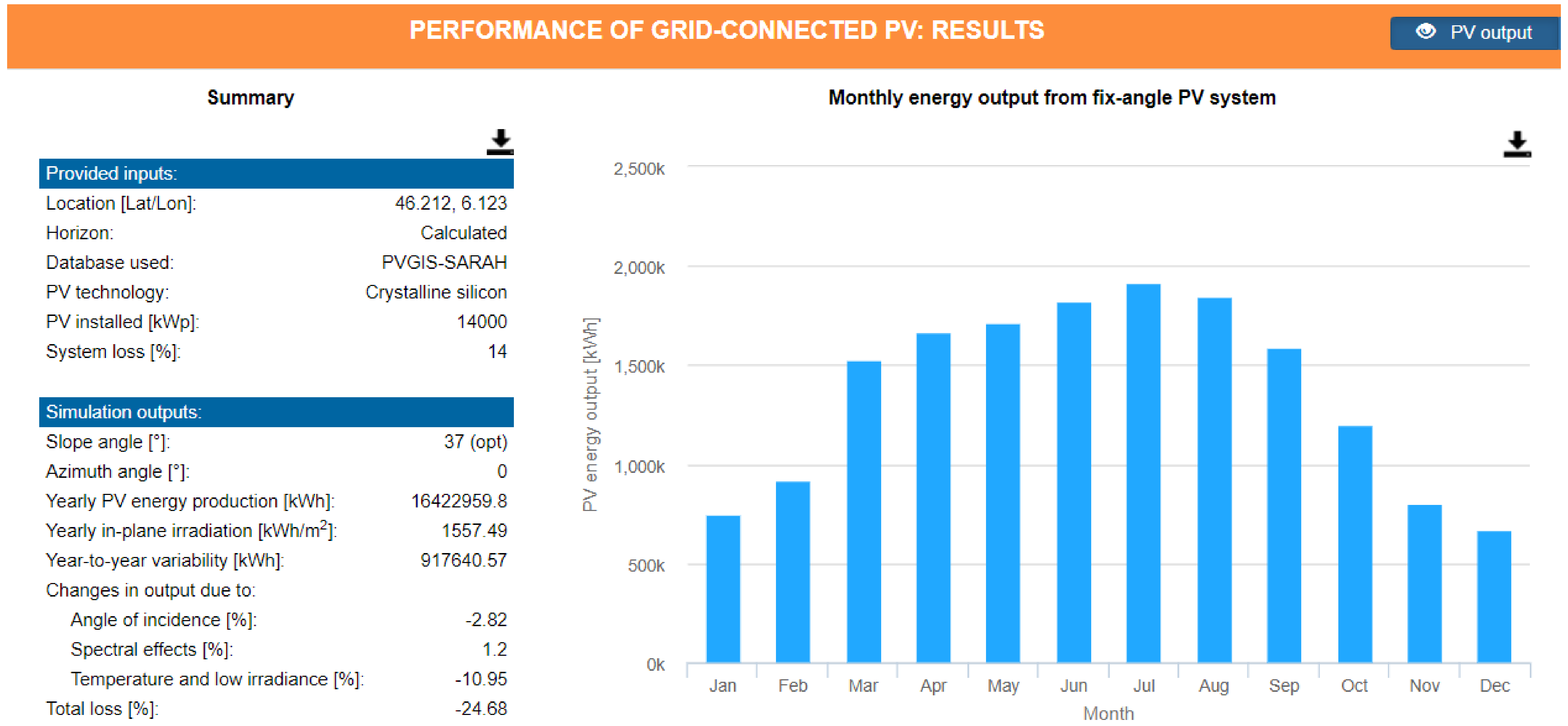
Energy production

The FCC machine is a multi-site complex that may be considered for photovoltaic production.

Possible integration of solar panels on the new buildings.

Assumed available surface per point: 10000 m²
Assumed power density: 170 W/ m²
Total installed power on 8 points ~ 14 MW

Yearly energy production(*) ~ 16 GWh



(*) Simulation based on EU PVGIS web platform - Solar Radiation Database: PVGIS SARAH – Selected area: Geneva

Study how energy production can be integrated in the project
Sustainability: The focus should be on energy savings by design and heat recovery

Summary

6th Workshop
Energy for Sustainable Science
at Research Infrastructures

- The main loads of the machine FCC-ee are known
- An estimation of the power demand was presented depending on the machine configuration, with an uncertainty around 5%
- The power demand is known by point of the machine which allows for defining the electrical infrastructure
- The energy consumption of FCC was detailed as well as its optimisation
- The way to develop energy-saving was highlighted

Next steps

- Define the electrical infrastructure based on these numbers for the feasibility study
- Work on the reduction of the energy consumption
- Study energy production, energy recovery and sustainability

FCC → Building a future for the next generation of physicists
And
Pursuing the development of knowledge

Thank you for your attention