FUTURE
CIRCULAR
COLLIDER

STATUS OF ELECTRICITY AND ENERGY MANAGEMENT WORK PACKAGE

gratefully acknowledging the contributions of
Nicolas Bellegarde, Davide Bozzini, Mario Parodi (EN-EL)
Francisco Blanquez, Karsten Kahle, Manuel Colmenero, Davide Aguglia (SY-EPC)

Table of content

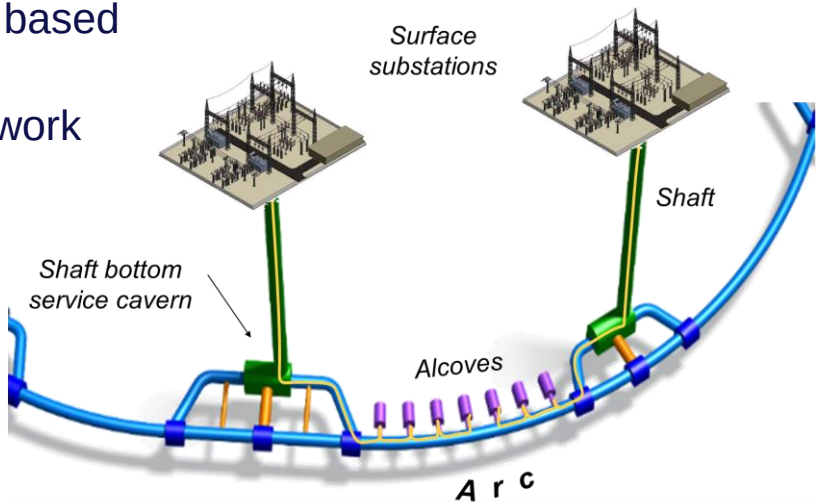
From M. Benedict's roadmap

Concepts for electricity supply and distribution; optimise electrical system efficiency and stability

Status of the electrical design

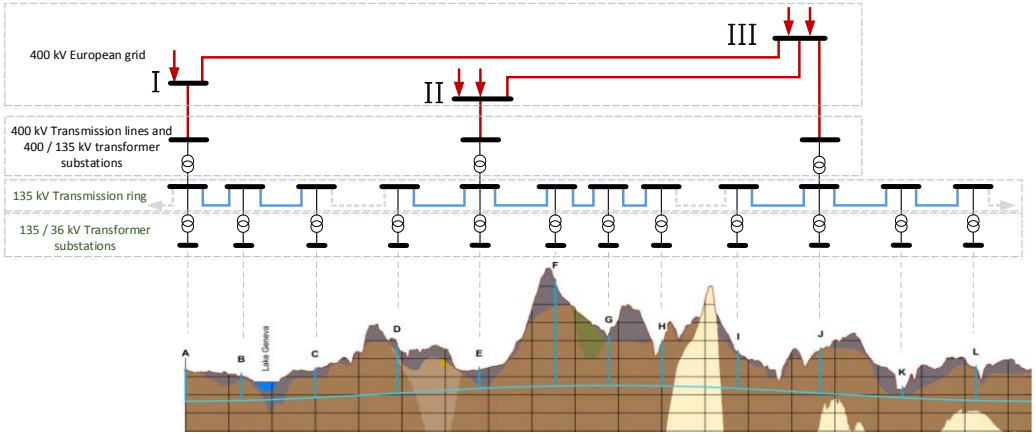
A complete powering study was performed by Davide Bozzini (EN-EL) from 2014 to 2018.

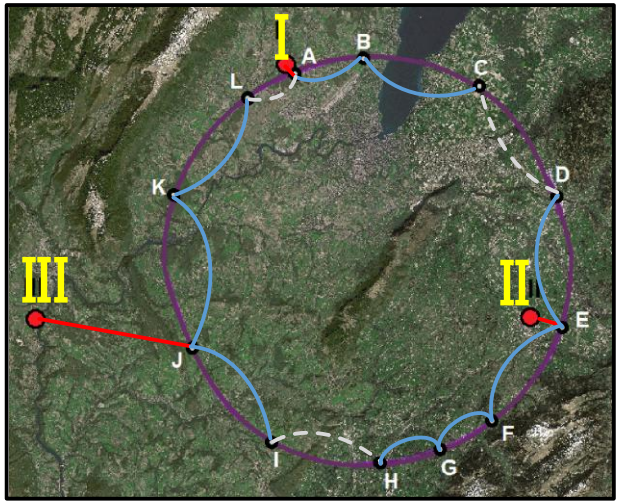
- An estimation of the power demand was completed based on the available information.
- A design of the powering layout was proposed based on 3 potential 400kV sub-stations as sources.
- A complete design of the internal electrical network was done including transmission lines to cover failures of a power source.



Status of the electrical design

3 connection points to the French national grid at 400kV level were identified.
Point III needs new overhead 400kV lines.
Point II needs new buried 400kV lines.





Power demand by machines

FCC-hh power demand

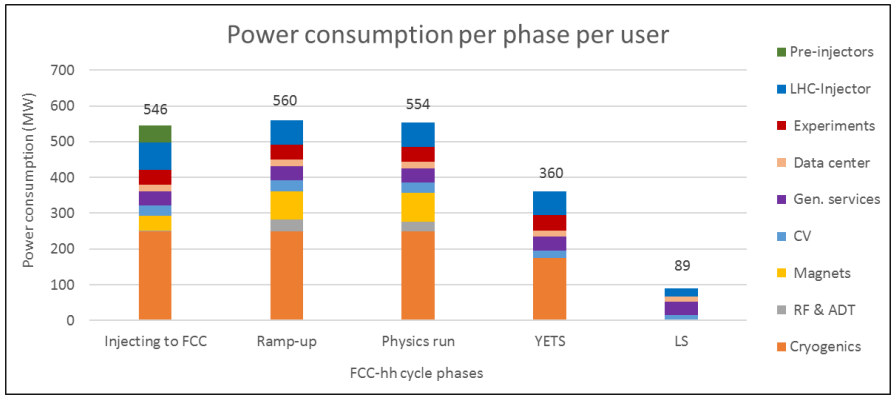
The power demand for FCC-hh is estimated at 554MW

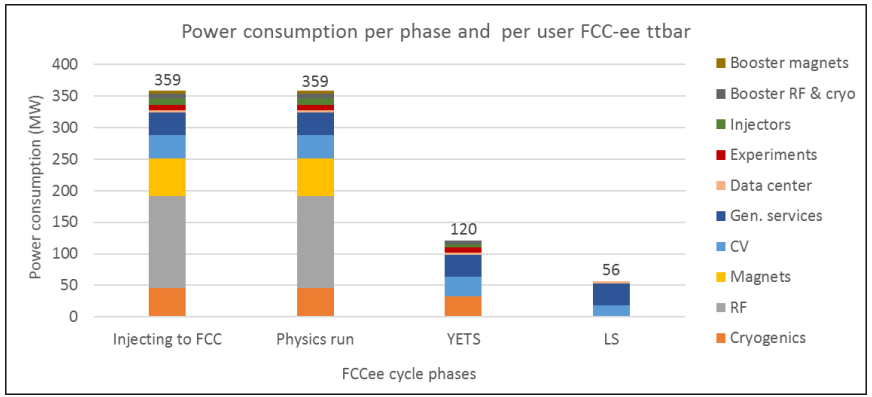
System	Power [MW]
Cryogenics	250
RF	26
Magnets	80
Cooling	30
Ventilation	
General services	40
Experiments (4)	42
Data centres (4)	18
Injectors	68
Total	**554**

FCC-ee power demand

The power demand for FCC-ee is estimated from 259 to 359MW

System	Power [MW]			
	Z	W	H	tt
RF	163	163	145	145
Collider cryogenics	1	9	14	46
Collider magnets	4	12	26	60
Booster RF & cryogenics	3	4	6	8
Booster magnets	0	1	2	5
Pre-injector complex	10	10	10	10
Physics detectors (2)	8	8	8	8
Data centres (2)	4	4	4	4
Cooling & ventilation	30	31	33	37
General services	36	36	36	36
Total	**259**	**278**	**284**	**359**





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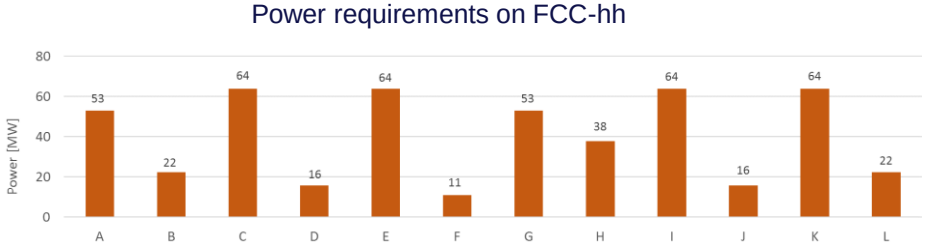
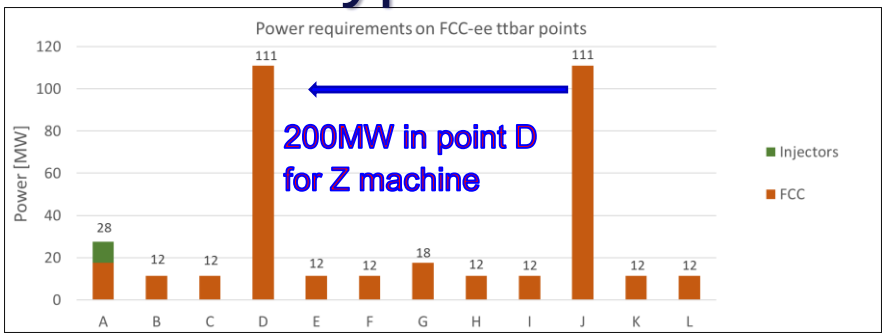
Strong discrepancy between machine types

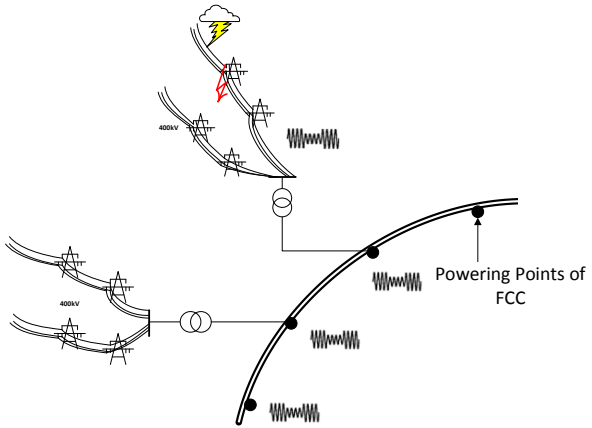


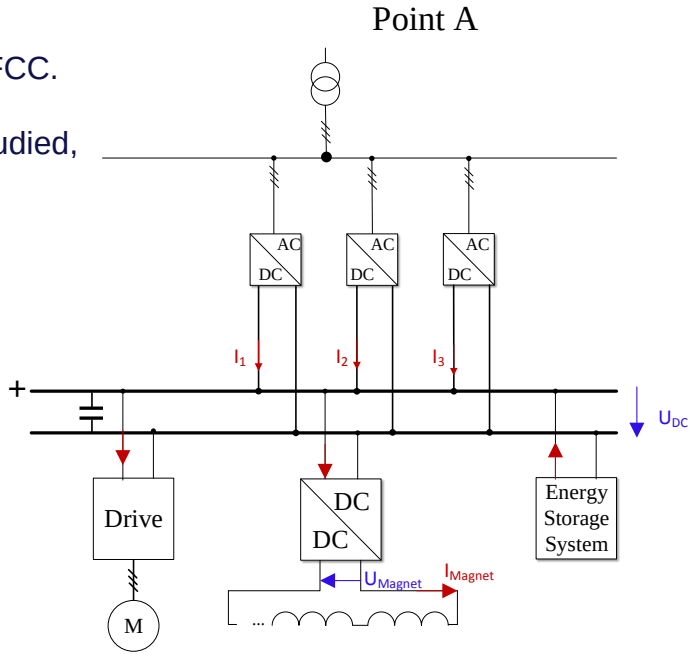


Power quality

Power quality and immunity against transient disturbances

Lightning strikes in the 400kV overhead lines could be a major concern for FCC.
Expected number of: 100-200 events per year
FCC needs to be decoupled from the national grid, many options already studied, as fro example DC grid.





OBJECTIVES OF PHASE 2 (2021-2025)

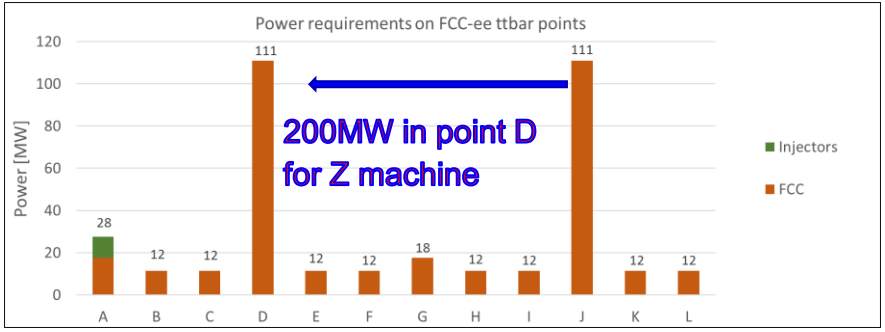
Roadmap for the FCC Feasibility Study

Phase 2: Review of the power demand

Review the power demand

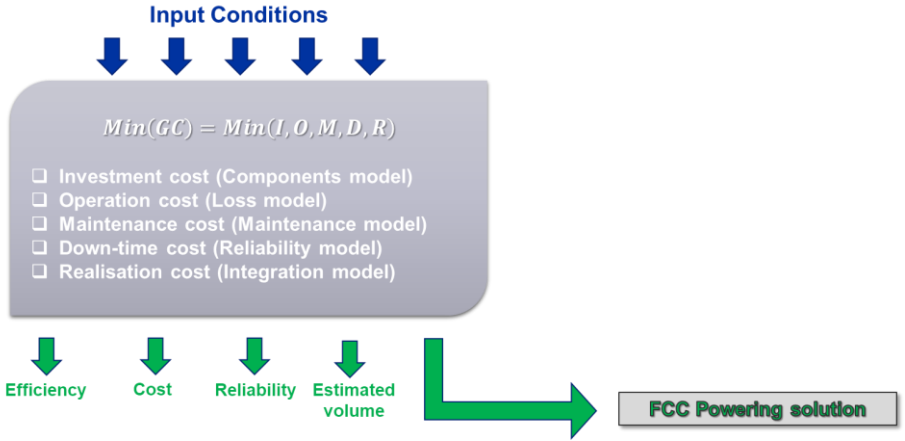
To continue the study, more details of the loads are required to review the power demand. The booster of FCC-ee can have a large impact on the power demand.
Design of the major accelerator systems is needed.

Goal: Update the FCC parameters



Optimization of the layout between machines

The present powering schemes of the different machines will require large infrastructure construction for a very short exploitation time, especially, FCC-ee and the Z machine.
Global optimization will help to define the right infrastructure.



Phase 2: Review of grid connection

Grid connection

The present design is based on 400kV power sources.
In this case, CERN will operate the 3 400kV sub-stations.
Alternative solutions need to be evaluated with the French transmission system operator (RTE).
Option1, 63kV/60MVA sub-stations at each point.
Option 2, xxkV/100MVA sub-stations at even points.
Option3…

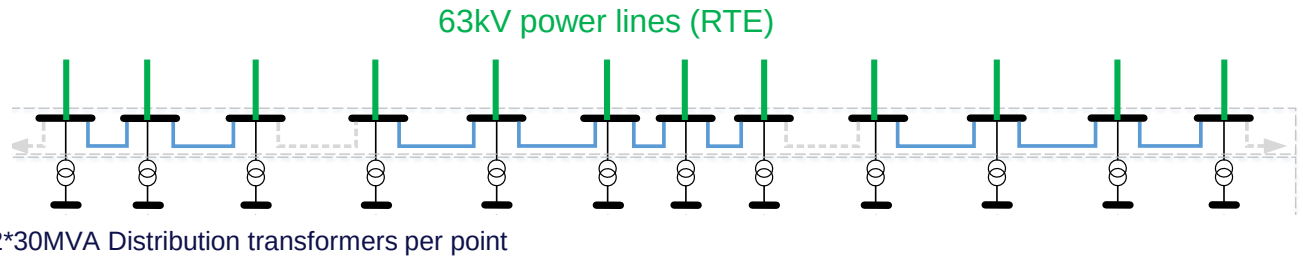
Goal: Reduce the FCC infrastructure

Transmission lines

Depending on the number of connection points to the national grid, the backup transmission system can be reviewed.

The main interest is to optimize and reduce the investment cost charged to FCC, as well as the operation and maintenance cost.

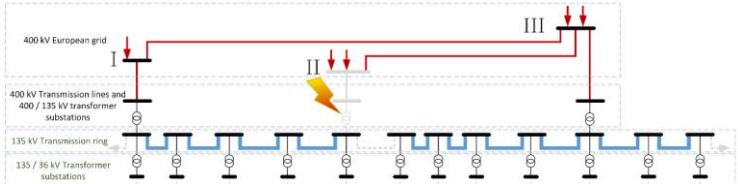
Objective: only buried lines, no overhead lines.

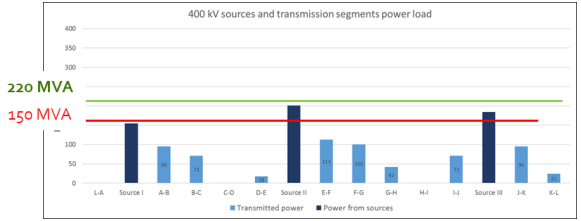


Phase 2: Review of powering backup

Failure scenario and backup

Depending on the number of connection points, different scenarios shall be studied.
A full backup is probably too costly but the standby mode of cryogenic systems shall be assured.



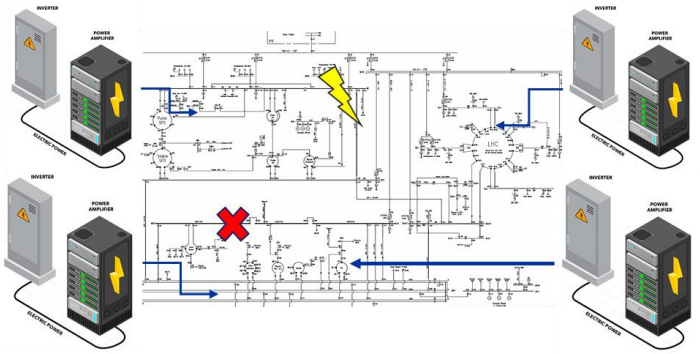


Availability depending of the machine

In the case of FCC-hh, the electricity supply needs to be robust due to the recovery time of cryogenic systems.

For FCC-ee, the recovery time is much faster thanks to warm magnets. The robustness of the grid can be reduced to limit the investment.

Goal: built a network model and develop a real-time simulator.



Phase 2: Power quality and availability

Power quality

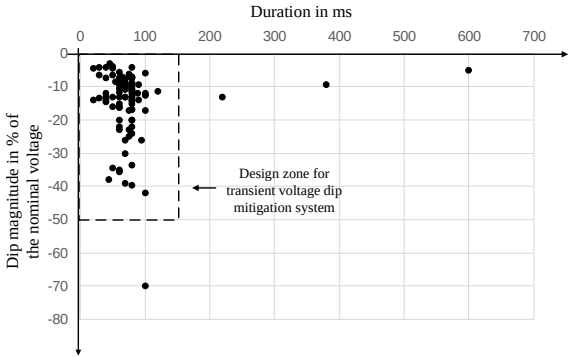
The FCC grid shall include power quality systems that assure a good FCC grid quality regarding harmonics and stability. The power factor at the level of the connection point shall be acceptable by the transmission line operator.

Immunity against transient disturbances

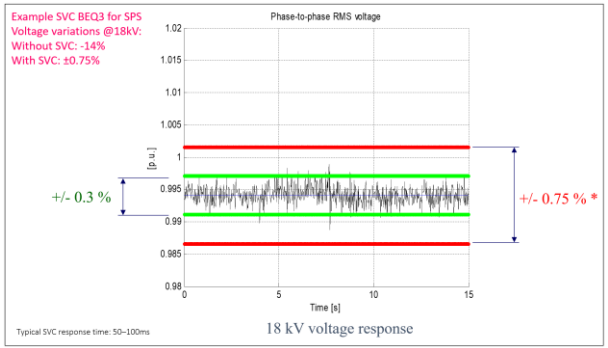
The FCC machine and experiments shall have an electricity supply not affected by external lightning strikes. Different solutions can be investigated at the level of the FCC grid, but also at the level of the equipment connected to the FCC grid.

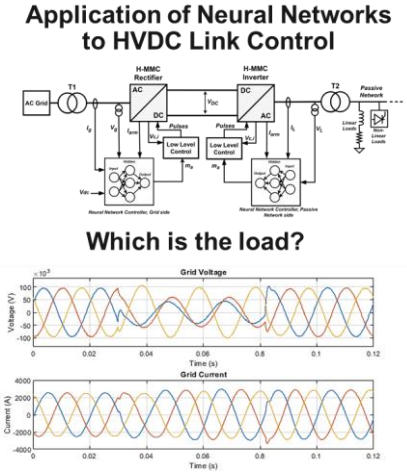
Goal: Identify the best technical solution adapted to FCC

Network disturbances



18kV network stability





Phase 2: Energy management

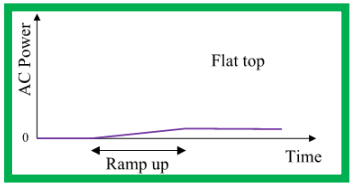
Peak demand for FCC-ee booster

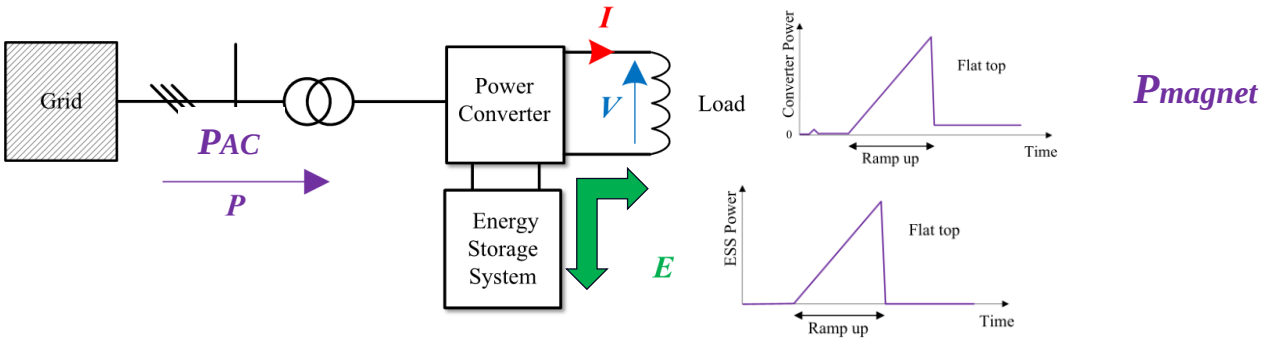
The Booster will be cycled continuously to fill the storage ring. Large power demand will be generated.
More details of the booster magnets and cycles are needed to fully evaluate the peak power demand.

Energy management

During the ramp of the beam energy, the power demand is much higher. By introducing energy storage in the power converters, the peak demand on the grid can be limited.

Goal: Reduce the electrical infrastructure by local exchange of energy.
Technology R&D on power converters.





Phase 2: Energy and sustainability

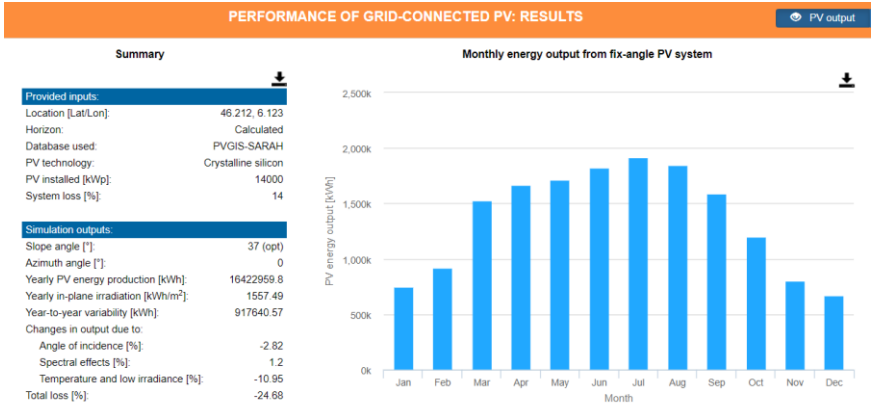
Energy production

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

Possible integration of solar panels on the new buildings.

Assumed available surface per point: 7000 m²
Assumed power density: 170 W/ m²
Total installed power on 12 points ~ 14 MW

Yearly energy production(*) ~ 16 GWh



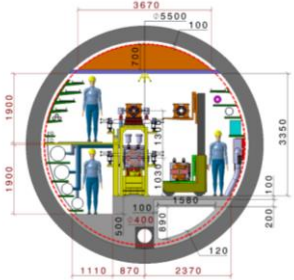
(*) Simulation based on EU PVGIS web platform - Solar Radiation Database: PVGIS SARAH – Selected area: Geneva

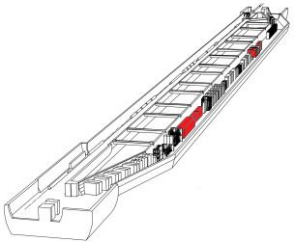
Goal: clarify if energy production has an interest
Sustainability: The focus should be on energy savings by design and heat recovery

Phase 2: Infrastructure integration

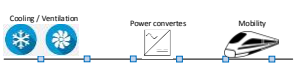
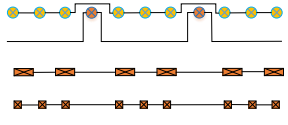
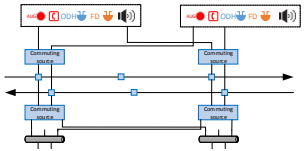
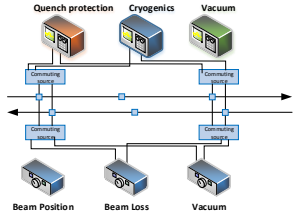
Users and system

- Loads homogeneously distributed over more than 9 km of continuous tunnel
- End users supplied at low voltage 400 V ac
- Three types of network required:
  - General services
  - Secured
  - Uninterruptable
  - Machine
- Critical systems related to:
  - Personal safety
  - Machine safety
- Critical systems requiring uninterrupted double redundant supply





Goal: design all the electrical infrastructures and define the underground and surface space needed.

Users	Network type	Schematic layout
Generic power sockets	General Services	
Users power sockets	Secured	
Controlled lightning	General Services	
Permanent lightning	Secured	
Evacuation lightning	Uninterruptable	
Antipanic lightning	Uninterruptable	
Safety systems	Uninterruptable	
Communication / Star points	Double redopundancy	
Machine Protection	Uninterruptable	
Beam protection	Double redopundancy	

Summary

A new phase is starting with the goal to define the electrical infrastructure needed by FCC.

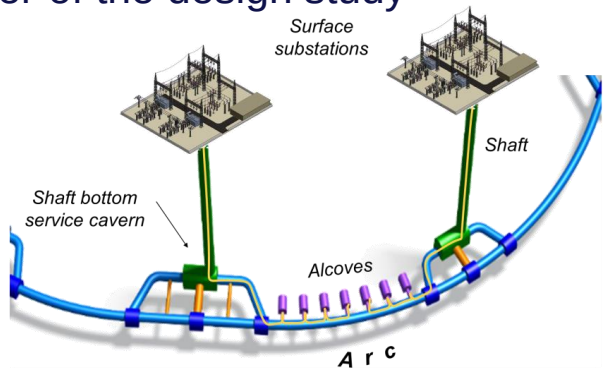
Objectives are under validation:

- A review of the power demand is needed with more detailed of the machine loads (FCC-ee).
- Optimization of the machine layout could reduce the electrical infrastructure needed
- The number of connection points to RTE is a key parameter of the design study

Then, the design of the electrical grid will be up-to-dated

- Back-up strategy, availability,
- energy management and sustainability
- Integration

Work package will be detailed soon with a milestone plan.



Thank you for your attention.