



EPC group overview on FCC

Davide Aguglia & Serge Pittet, SY-EPC

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Outlook

WPs Scope for EPC

Technical issues & challenges

Organization & collaborations

Dependencies & expectations

Resources

Missing resources / inputs

Scope

3 Fundamental objectives

- **Magnet powering definition**
 - Determining circuits specs
 - Estimating converters volumes & cost vs. their location
 - Estimating efficiencies vs. mission profiles
 - Defining converters families
- **RF powering definition**
 - Footprint (surface point), cost, efficiency
 - Integration in klystron gallery (voltage regulators + klystron protection)
- **AC vs. DC energy distribution along the ring**
 - CAPEX+OPEX comparison to distribute energy to all points via AC or DC solutions

All this considering:

- Special attention to integration (alcoves, tunnel, surface points)
- Environmental impact
- Sustainability
- Availability
- Affordable control electronic platform/s
- **FCC-ee, FCC-hh, but No Pre-injector activities launched nor estimated - no resources determined**

Reverse timeline for SY/EPC systems

T_0 =installation in tunnel

Magnet powering & RF auxiliary systems

Years:	T ₀ -15					T ₀ -10					T ₀ -5				T ₀ -1
R&D	Yellow	Yellow	Yellow	Yellow	Yellow	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey
Design + prototyping				Blue	Blue	Blue	Blue	Blue	Blue	Blue					
Industrialization + pre-series											Purple	Purple	Grey	Grey	Grey
Series prod. + testing												Green	Green	Green	Green

Comments: xxx

RF powering (main converter) and UPFCs (SVC equivalent)

Years:	T ₀ -15					T ₀ -10					T ₀ -5				T ₀ -1
Collaboration w. industry	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Grey	Grey	Grey	Grey
production, install. & testing												Green	Green	Green	Green

Technical issues and Challenges

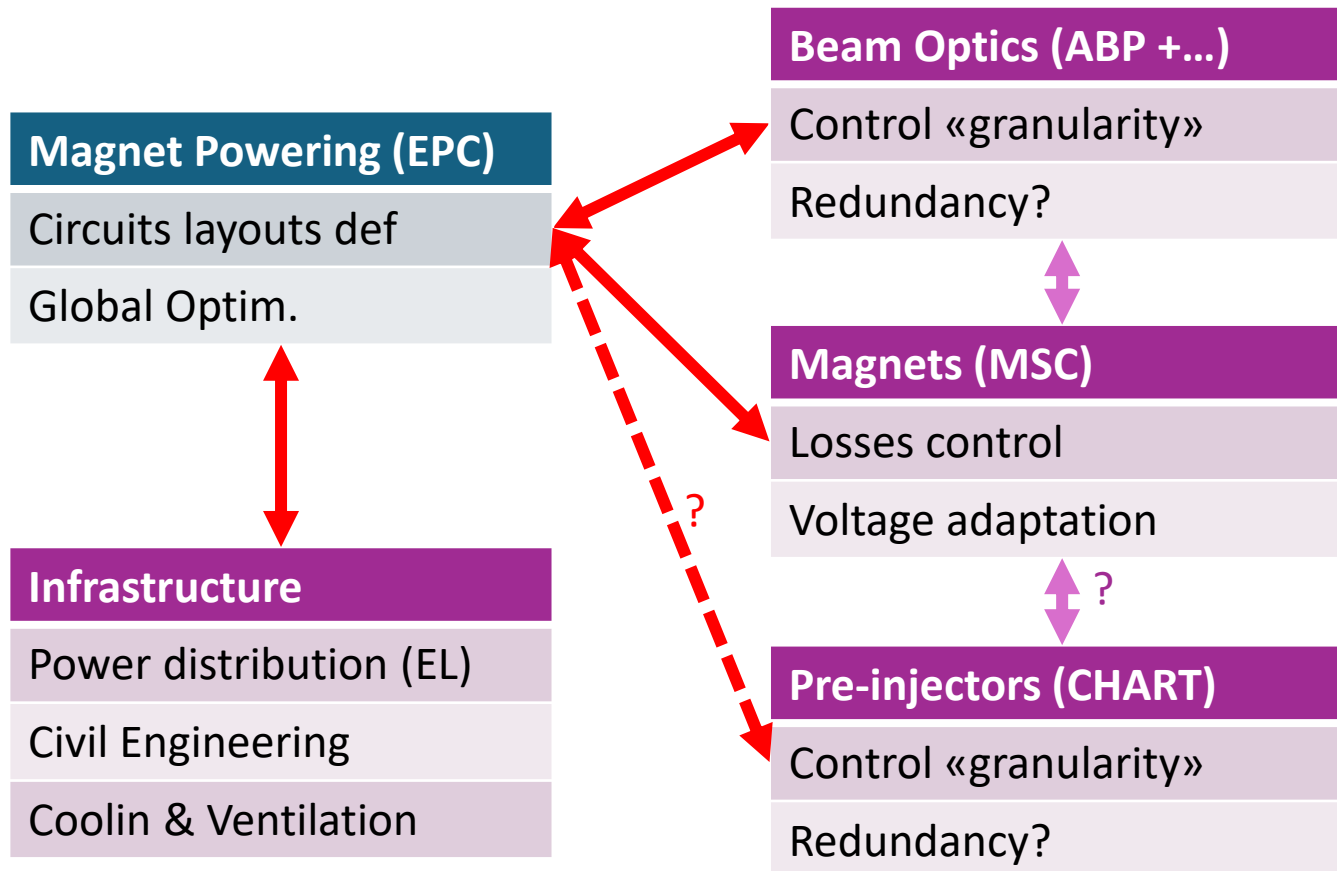
Few challenges!

- **Due to large number of converters managing 100's of MW, small design choices → big overall CAPEX-OPEX & CE impacts**
- **For magnet powering this means:**
 - Finding optimal circuit configurations / layout
 - Adopting a global optimization approach to find best compromises between power converters locations, number of alcoves, etc.
 - Standardizing / creating converter families to reduce cost
 - Control electronics allowing highest operational automation at affordable cost
- **For RF powering (160 MW electrical power) this means:**
 - Finding a reliable, efficient, and affordable solution
 - Considering klystron faults conditions
- **For AC or DC power distribution this means:**
 - Comparing power distribution concepts, integrating voltage stability controls and faults ride through for the entire complex

Dependencies & expectations

Magnet powering R&D to achieve pre-design for pre-TDR

- **Dependencies (bi-directional)**



- **Expectations**

- **FCCee**

- Tighter collaboration with beam optics
- (FS: hoping to receive more info on booster)
- **pre-TDR: Beam optics and magnet defined 1 year before pre-TDR!**
- **Pre-injectors: if EPC involved for pre-TDR**
 - **Need additional resources**
 - **Beam optics and magnet defined 1 year before pre-TDR!**

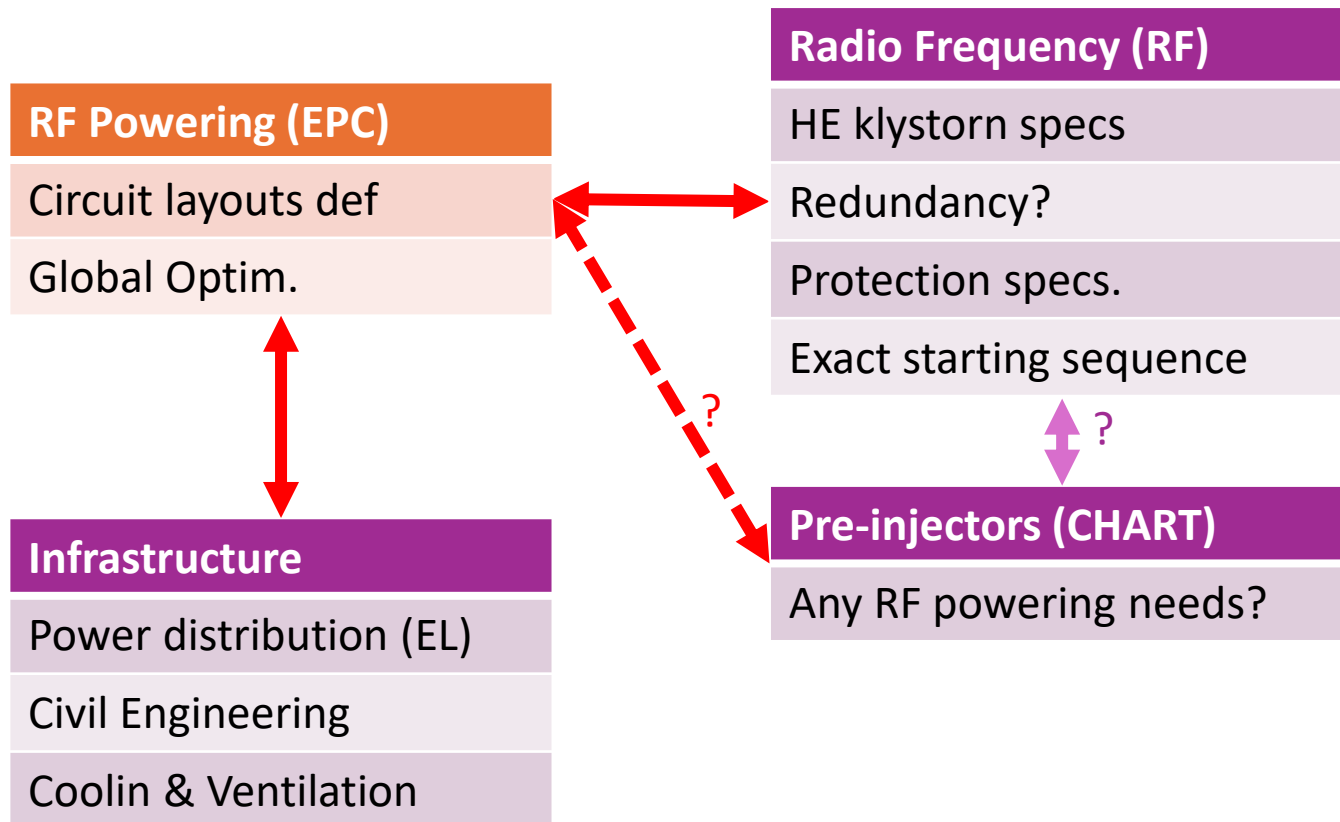
- **FCChh**

- Need for magnet designs & machine cycles to estimate power converters & storage volumes

Dependencies & expectations

RF powering R&D to achieve pre-design for pre-TDR

- **Dependencies (bi-directional)**



- **Expectations**

- **FCSee**

- Tighter collaboration with RF
- **pre-TDR: klystron specs. defined 1,5 year before pre-TDR!**

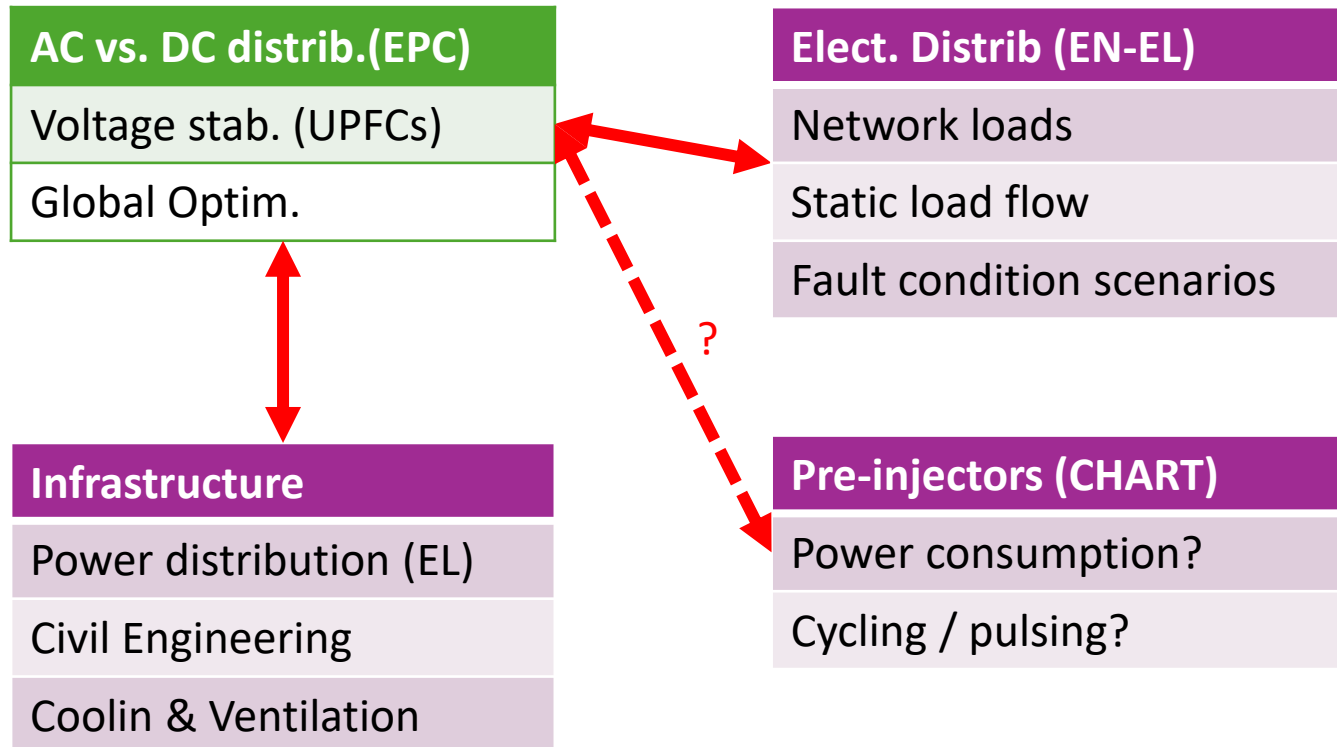
- **FCChh**

- Lower impact, but still need some figures in 2025!

Dependencies & expectations

AC vs. DC distribution R&D to achieve pre-design for pre-TDR

- **Dependencies (bi-directional)**



- **Expectations**

- **FCSee**

- Tight collaboration with EN-EL to develop design models for the AC solution (integrating UPFCs) – Ongoing!

- **FCChh**

- Need for an Electrical load spec. for each of the FCChh points by early 2026!

Collaborations

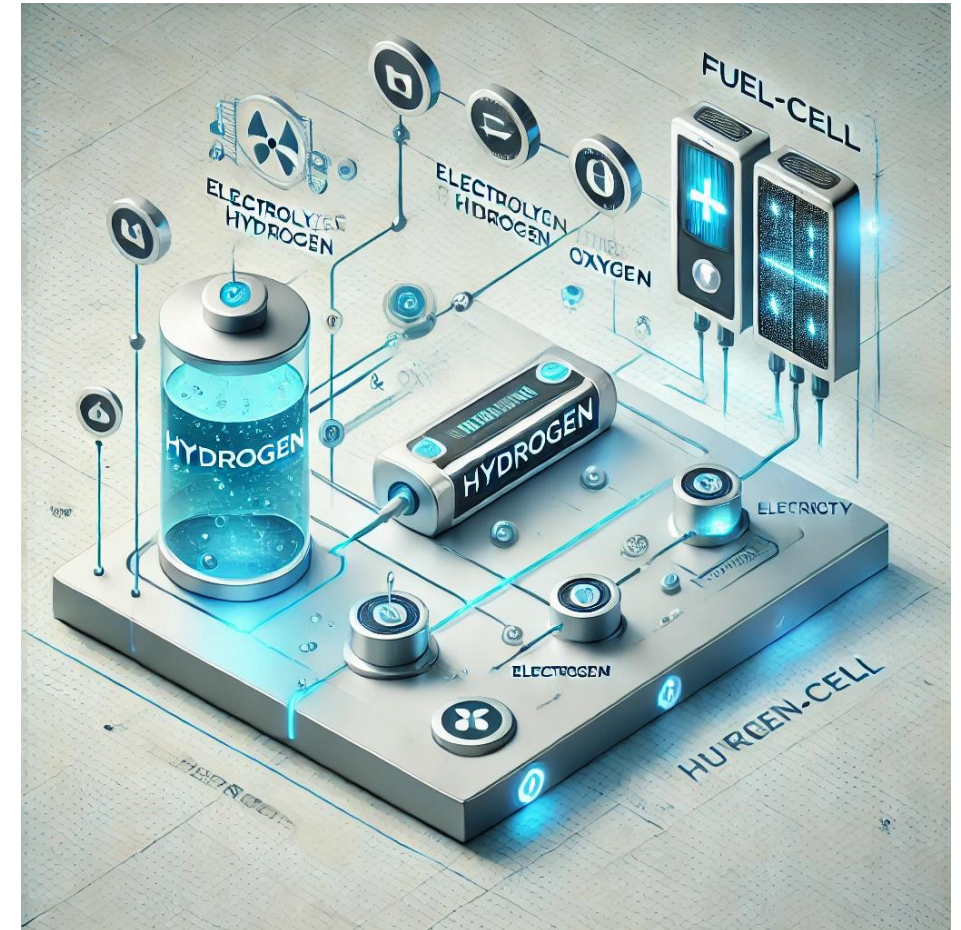
- **In contact with industrial partners for the main power converter (centralised MMC)**
 - Probable collaboration with Siemens & Hitachi
- **EPC delegation + Jean-Paul will be visiting a 1 GW/640 kV station in Spain this Nov.**
- **Collaborations with Universities**
 - Tallinn University of Technology (TalTech), Estonia - via a PhD – to evaluate efficient solutions to offer voltage trimming to each klystron in FCC.
 - Polytechnic University of Valencia, Spain - via Professors support on the HV DC distribution



Collaborations

Collaboration with LAPLACE lab. In Toulouse to evaluate multi purpose use of hydrogen in FCC

- **Energy Storage for:**
 - Reducing integration costs of purchased renewables MWhs
 - UPS (necessary for safety systems)
 - Back up diesel generators (for longer periods)
 - Better integration of local renewables (i.e. solar panels on surface sites)
- **Enhancing heat recovery**
 - Elevate accelerator waste heat for residential use, etc.
- **Absorption cooling**
 - Create cooling (needed for the accelerator) from heat dissipated by fuel-cells



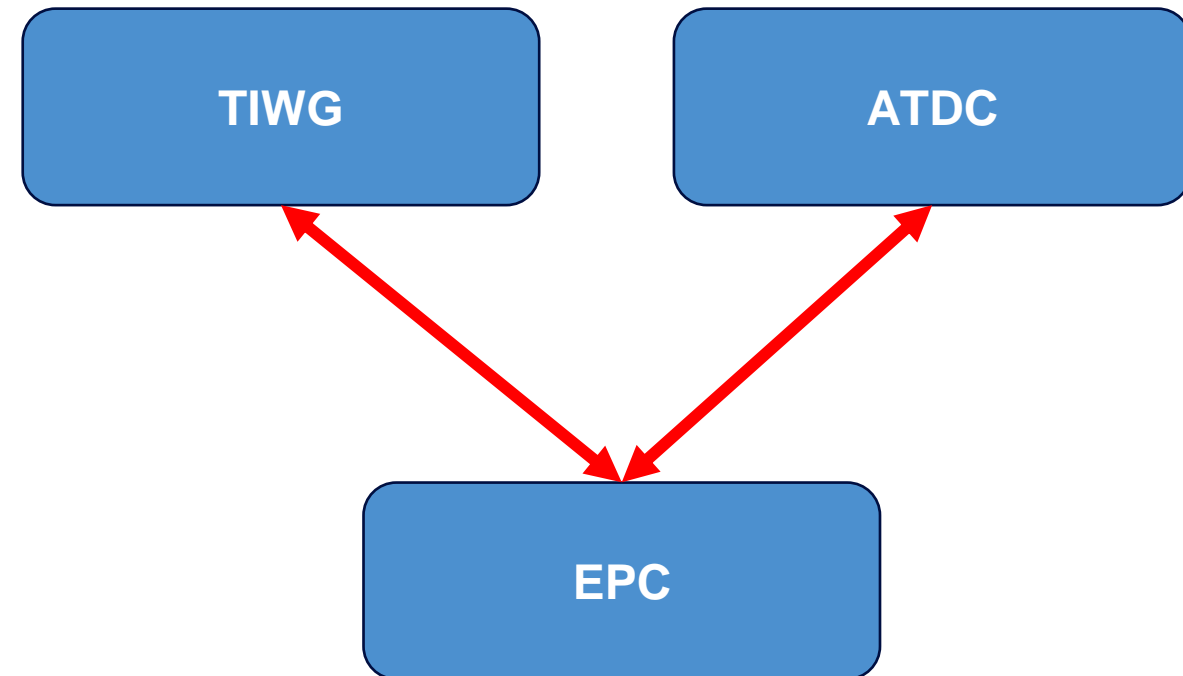
Organization

Internal organization & reporting

Internal organization

1. Manuel Colmenero (LD) – Comparison between AC & DC distribution concepts & contributing in RF powering
2. Byamba Wicki (FELL) – Circuit studies + global optimization (CAPEX-OPEX)
3. Serge Pittet (IC) – Deputy EPC coordinator, mainly focuses on magnet powering / circuits layouts & availability
4. Davide Aguglia (IC) – EPC coordinator, mainly focuses on global optimization & RF powering

Reporting



Resources

	Asked	Approved
Staff (2025)	2	2
Staff (2026)	1	0
Grads (2025)	1	1
PhD (2025)	2	1

Integrating new resources

- **Staff 1 (2025):** Magnet powering layout + CE implications for the FCCee (Booster + collider). Preliminary studies on Sustainability and environmental impacts of magnet powering systems
- **Staff 2 (2025):** RF powering studies for FCC-ee (Booster + collider) and FCC-hh. (Evaluate protection schemes +integration in klystron gallery). Preliminary studies on Sustainability and environmental impacts of RF powering systems
- ~~**Staff 3 (2026):** Full study on sustainability and environmental impacts of powering systems (magnets + RF) + centralized energy storage for renewable energy integration. Global accelerator sustainability via renewables and cogeneration/cooling via hydrogen systems~~

Resources

Integrating new resources

	Asked	Approved
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Grads (2025)	1	1
PhD (2025)	2	1

- **Grads (2025)**

- Optimization scenarios evaluation (incl. sustainability, energy cost scenarios for FCC-ee);
- Construction of the optimization tool for FCC-hh (for CE impacts *in primis*);
- Models' refinements via sensitivities analyses and accuracy evaluation for FCC-ee;
- Provides & updates tools and methods to both Staff 1 and 2 on CAPEX OPEX optim for FCC-ee & FCC-hh

- **PhD 1:** EPC (and other groups) cost models data analysis with Machine Learning to support highly non-linear cost models for the CAPEX OPEX

- ~~PhD 2: R&D into affordable & efficient power converters control platform electronics + software~~

Missing resources / inputs

Pre-injectors

- Potential missing if pre-injectors studies need to be integrated
- For now – no idea on resources amount needs for this item



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