CERN

FCC maintenance aspects and operational cycle

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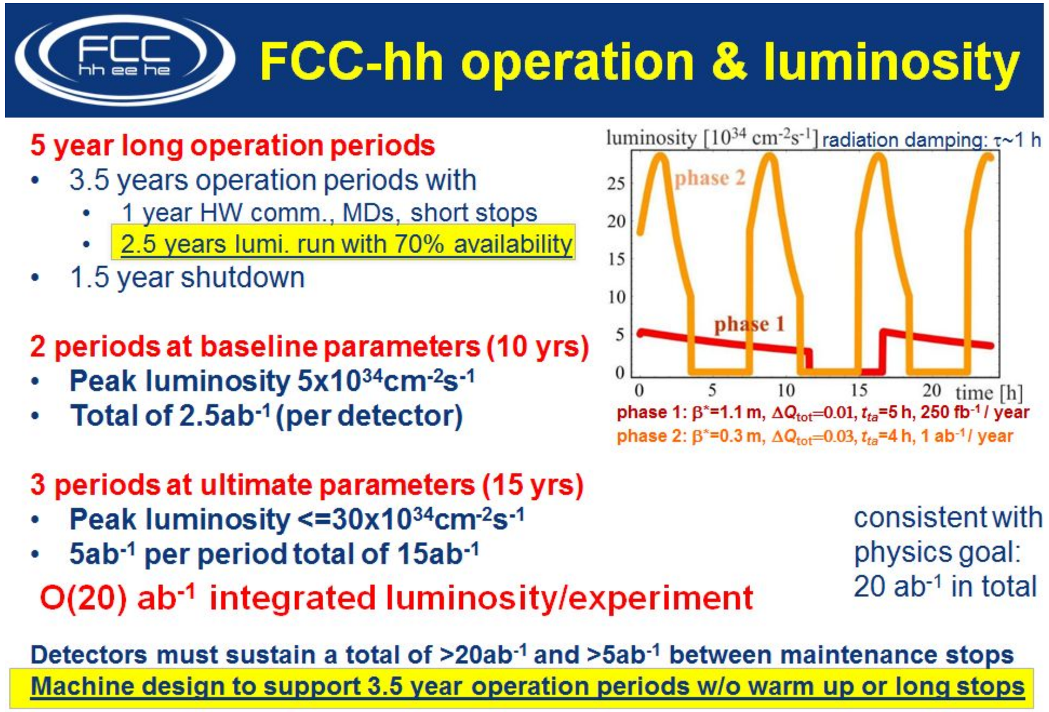
Recap on requirements

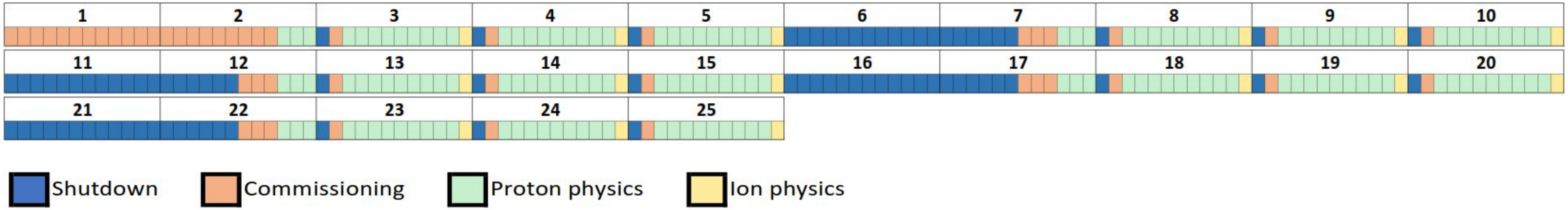
About 150 months of proton physics[1] + 15 months of ion physics[2] =



165 months of physics during the FCC lifecycle

1) M. Benedict FCC-week, Rome, 2016
2) M. Schaumann, private communication

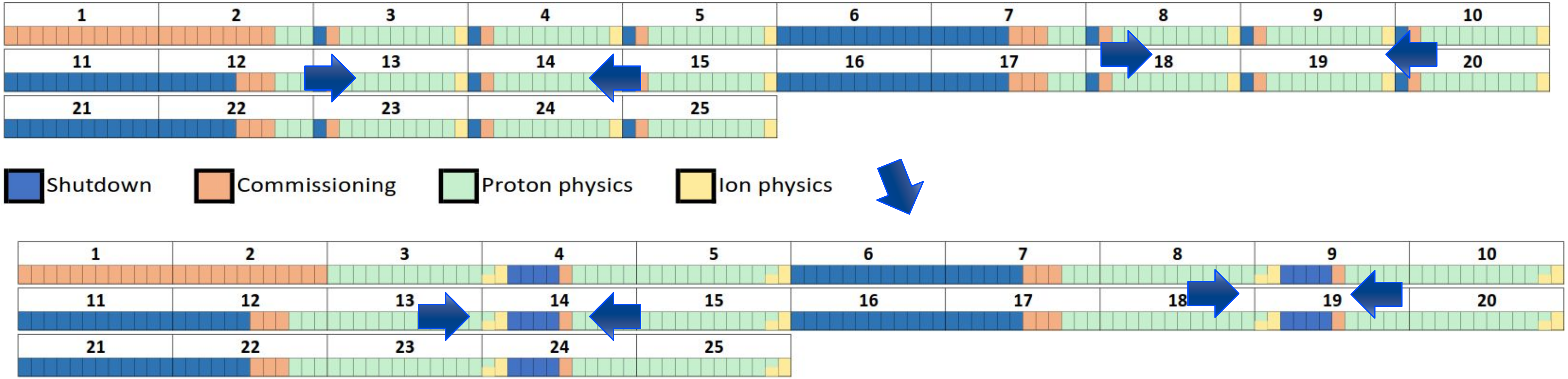
Operation schedule version 1



- First version assumed annual technical stops (LHC like)
- Combined time for a stop + commissioning was only 1 month

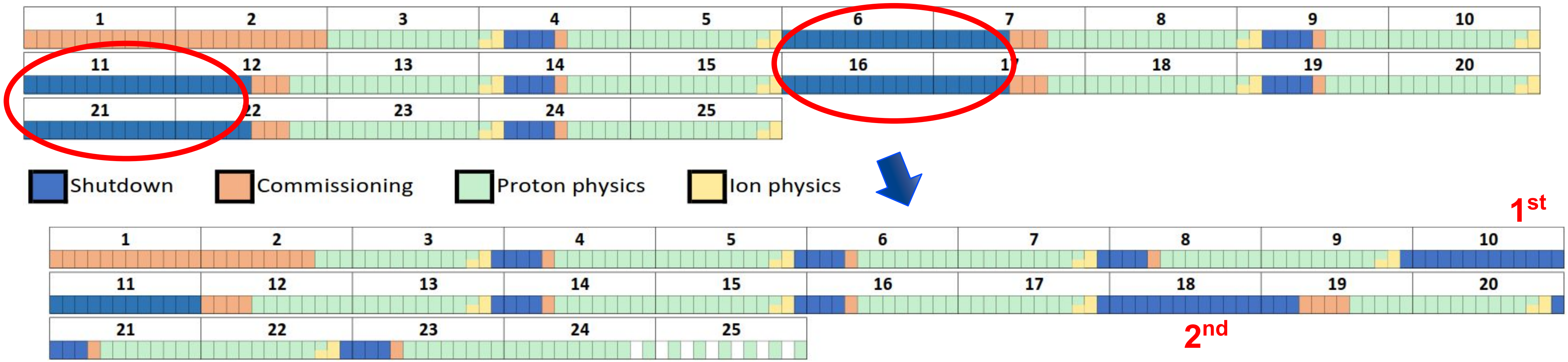
→ Activities to be performed cannot fit in this time window

Operation schedule version 2



- Lumping the stops together makes a stop length sufficient
- +3.5 months stop allows performing cryogenics system maintenance and injector maintenance

Operation schedule version 3



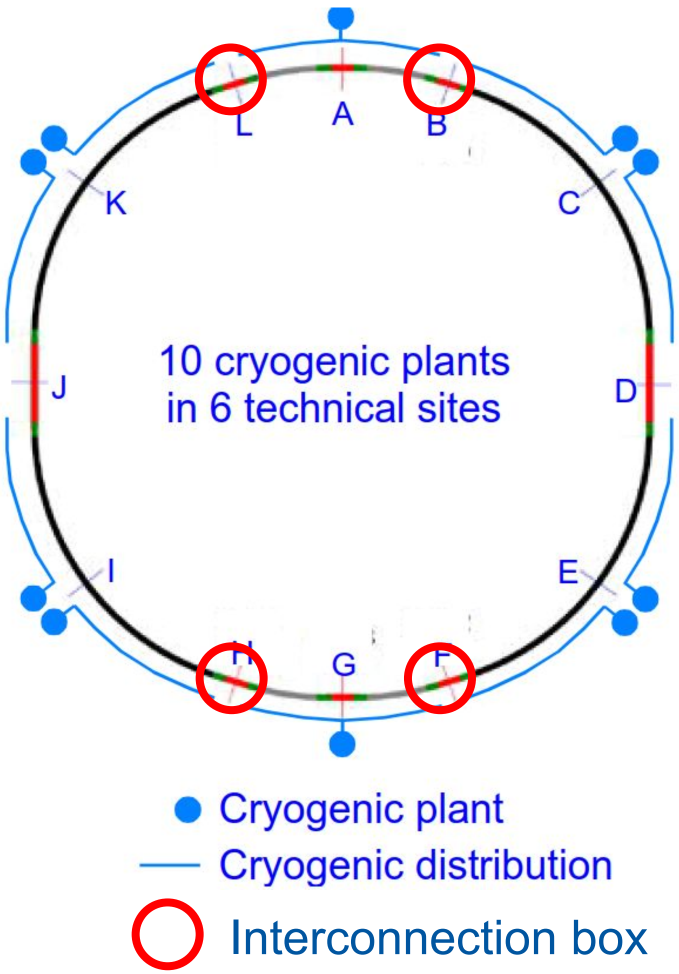
- A question was raised: Why do we have long shutdowns?
- Change 2: make shutdowns meaningful:
  - First shutdown after 10 years when FCC starts to use ultimate parameters
  - Second shutdown in middle of the run with ultimate parameters

Identified challenges with the new schedule

- 2.5 years interval between stops should be OK for rotating machines in cryogenics system
- 3.5+ month stop should allow injector chain maintenance even with LHC as an injector
- Designing system to operate long periods with limited maintenance + injector & experiment maintenance interval
- Cooling system maintenance[1]
- Maintaining machine alignment

Cryogenics maintenance

- Cryogenics was chosen as it is the maintenance time driver
- Assumptions: Water system is maintained with the cryo,
- Three cases
  1. Redundant cooling towers + interconnection boxes
  2. Redundant cooling towers + no interconnection boxes
  3. Non redundant cooling towers + no interconnection boxes

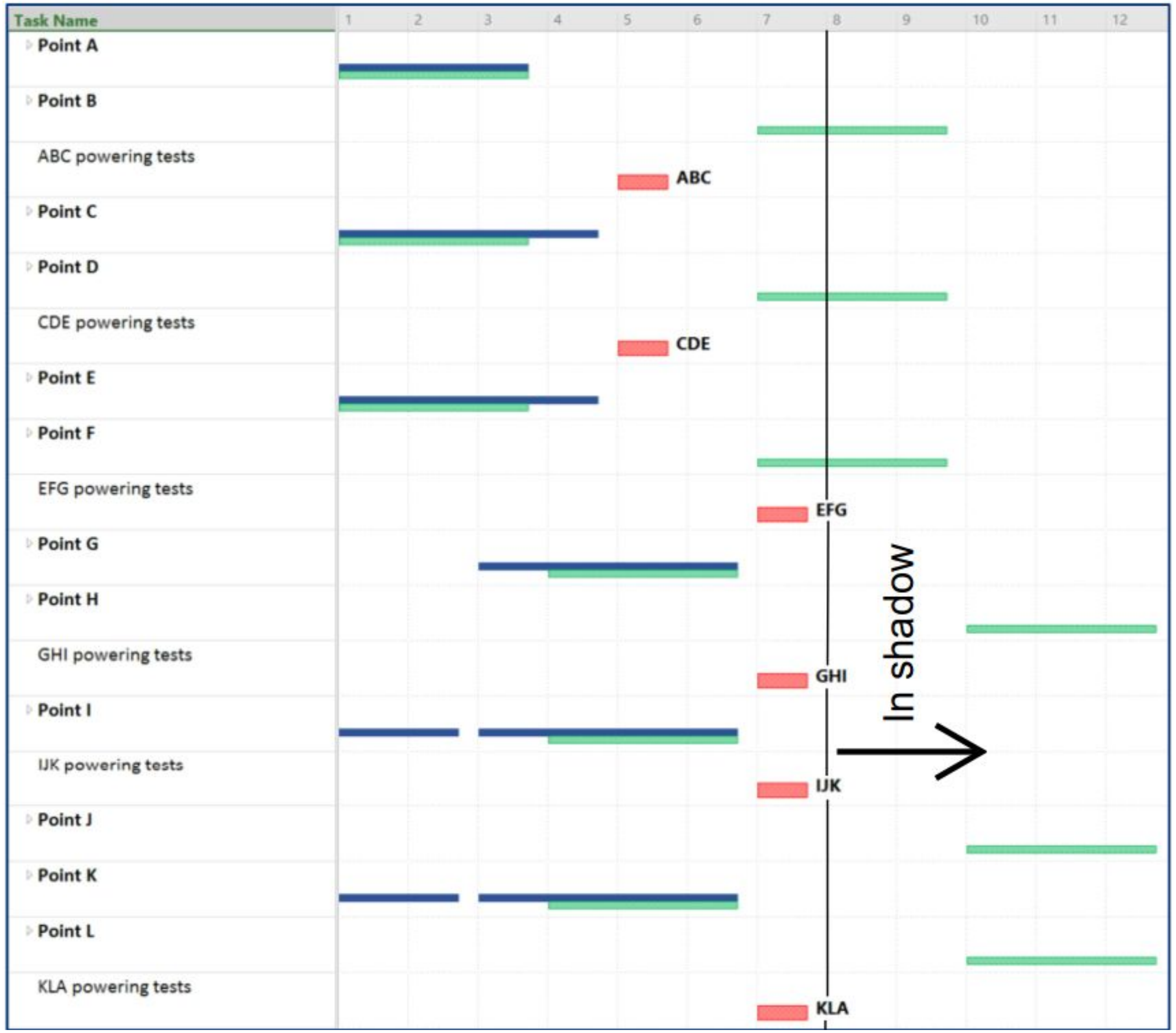


Case 1

Redundant water systems allow cryogenics system to operate while the water system is maintained

Total 7 weeks

Cryoplant maintenance	*Lhe emptying*
Cooling towers maintenance	*Cool-down*
Powering tests	*ELQA*



Case 2

Without interconnection boxes sectors LAB and FGH need to be warmed up during maintenance

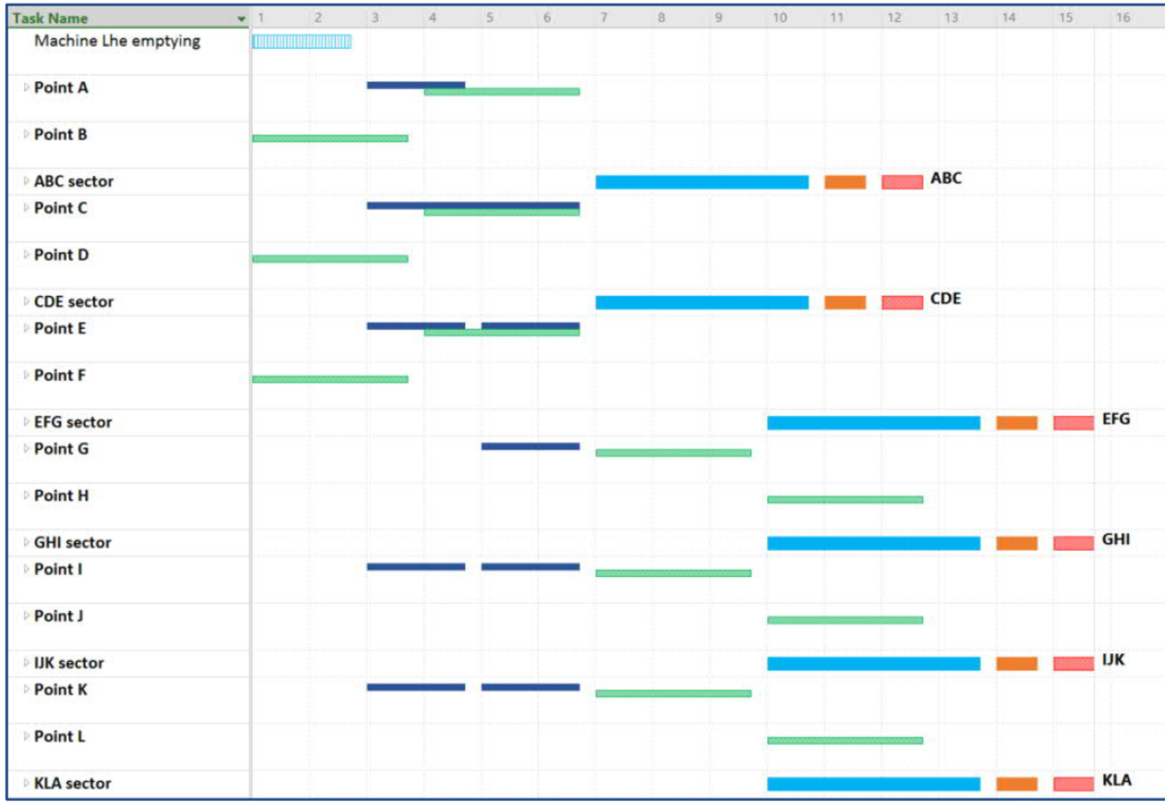
Total 11 weeks

- *Cryoplant maintenance*
- *Cooling towers maintenance*
- *Powering tests*
- *Lhe emptying*
- *Cool-down*
- *ELQA*

Case 3

Without redundant water system all sectors need to be warmed during the maintenance

Total 15 weeks



Cryoplant maintenance

Lhe emptying

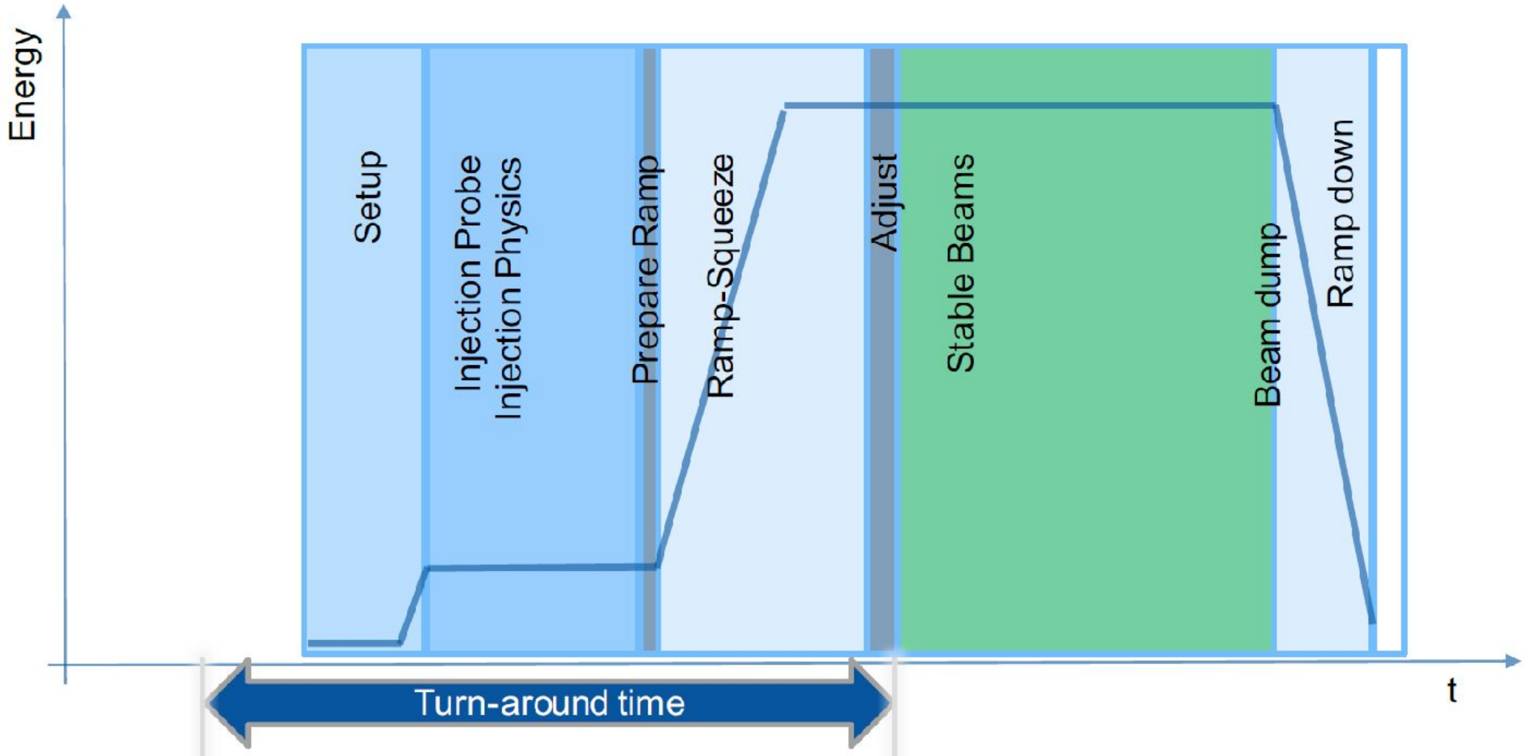
Cooling towers maintenance

Cool-down

Powering tests

ELQA

Operations cycle



Recap on technical requirement

Phase	FCC target	LHC theoretical	LHC min 2017	LHC mean 2017
Setup	10	10	-	-
Injection	40	16[a]	28.0	77.1
Prepare ramp	5	-	2.3	5.0
Ramp-Squeeze-Flat top	20+ 5+3	20	20.2+13.4+2.8	20.5+18.1+4.5
Adjust	5	-	3.3	7.9
Ramp down	20	20	36	153.2[b]
Total	108 (1.8 h)	≈ 70 (1.2 h)	106.0 (1.8 h)	286.3 (4.8 h)

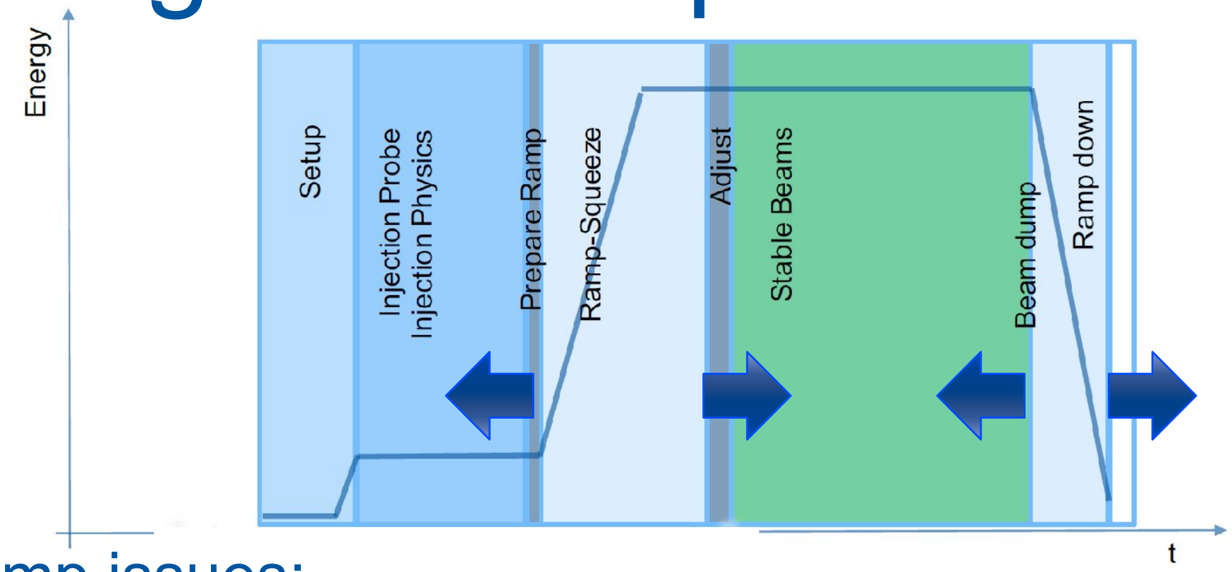
[a] This assumes 20 seconds-long SPS cycles.
[b] The ramp down phase includes the recovery time from failures.

Note: Production calculations assume 4 h turnaround, technical performance has margin!

Times in minutes

- FCC target from: R. Alemany Fernandes et al. CERN-ACC-2016-0341.
- LHC theoretical from: LHC Design report, V. 1, Ch. 3.1.5, p. 24.
- LHC 2017 values from: M. Pojer, LHC operation, in 8th LHC Operations Evian Workshop.

Key challenge 1: Ramp and Ramp-down



Fast (20 min) ramp issues:

- Peak power consumption;
- Dynamic heat load to cryogenics;
- Requirements for power converters;
- More RF-cavities

If ramp is extended, we need to understand the trade off: Ramp rate vs. luminosity production, cost & system complexity

Magnet powering: Francisco R. Blánquez FCC-Week 2018
Transient modes impact on cryogenics: Laurent Tavian FCC-Week 2018

Key challenge 2: Injection

Upgraded LHC:

- Flat-top energy 3.3 TeV
- 4 Cycles to fill the FCC
- 66 Injections to FCC / cycle
- Cycle duration = 10-12 min

Superconducting SPS:

- Flat-top energy 1.3 TeV
- 33 Cycles to Fill the FCC
- 4 Injections to FCC / cycle
- Cycle duration = 1 min

- Challenges today in the LHC: beam is not or injections are rejected, according W. Bartmann this should be solvable
- So, **if** both options are technically feasible, question is: Which one is cheaper to build and operate?
- LHC & SPS (upgrades & consolidation) + SC transfer lines **vs.** New SC machine in SPS tunnel + NC transfer lines

Conclusions

Future studies should include:

- Operation schedule feasibility study → repeating the presented cryo-analysis with other systems
- Benefit / trade-off analysis of increasing the ramp times
- Injector phase operations & cost study

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