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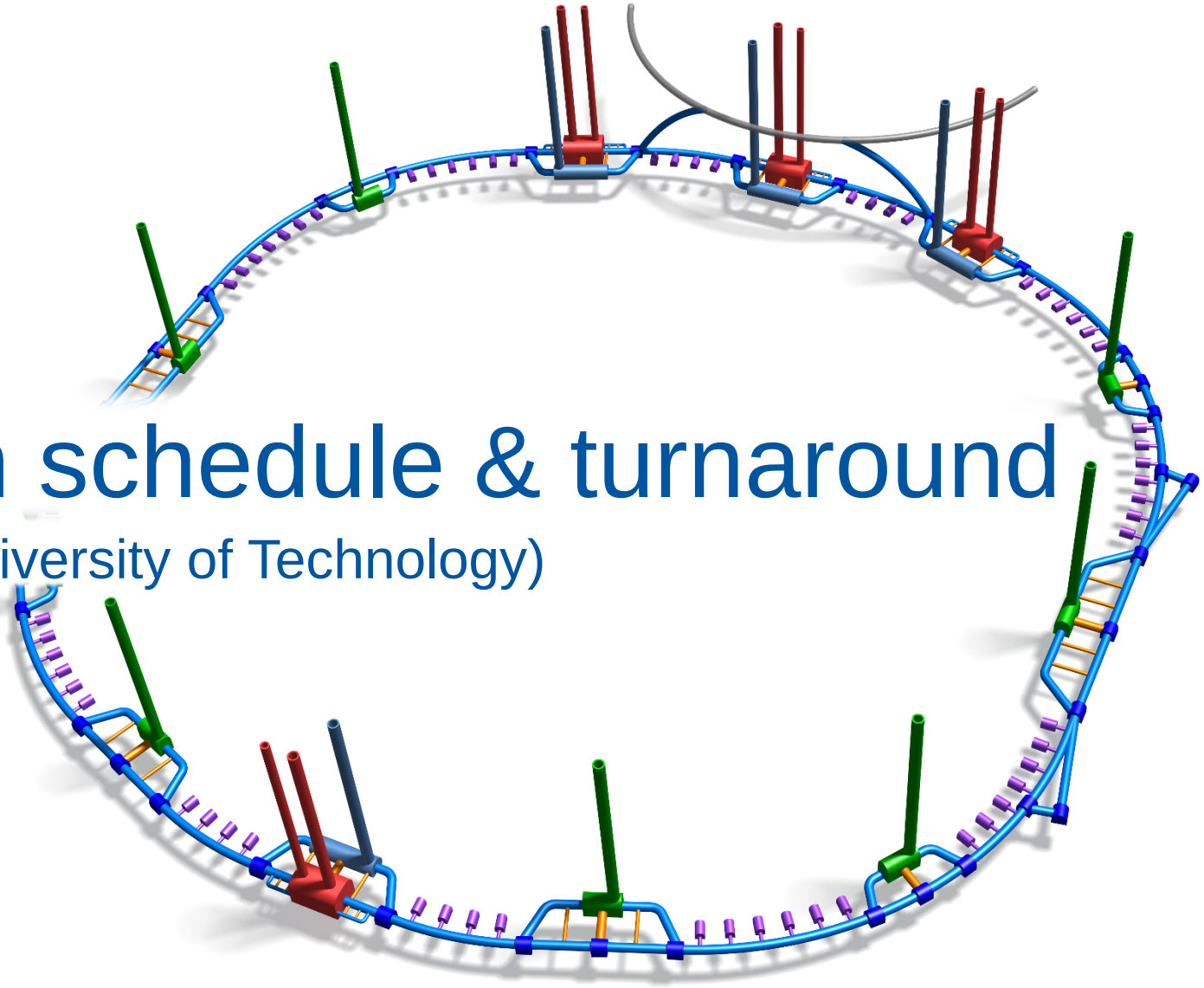


FCC-hh operation schedule & turnaround

Arto Niemi (CERN / Tampere University of Technology)

Acknowledgements: R. Alemany, A. Apollonio, F. Burkart, J. Gutleber, V. Mertens, M. Schaumann, D. Schulte, L. Ponce, M. Zerlauth …

Contents

- FCC physics goals & baseline run plan
- Comparison with HL-LHC plans
- FCC operation schedule
- Update on turnaround cycle & comparison to LHC
- Conclusions

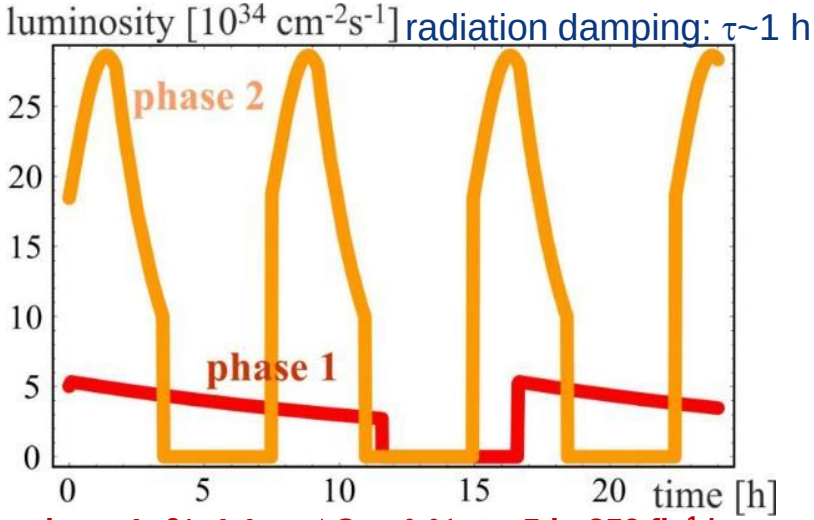
FCC-hh operation & luminosity

5 year long operation periods

- 3.5 years operation periods with
  - 1 year HW comm., MDs, short stops
  - 2.5 years lumi. run with 70% availability
- 1.5 year shutdown

2 periods at baseline parameters (10 yrs)

- **Peak luminosity $5 \times 10^{34} cm^{-2} s^{-1}$**
- **Total of $2.5 ab^{-1}$ (per detector)**



phase 1: β*=1.1 m, ΔQ_{tot}=0.01, t_{ta}=5 h, 250 fb^{-1} / year

phase 2: β*=0.3 m, ΔQ_{tot}=0.03, t_{ta}=4 h, 1 ab^{-1} / year

3 periods at ultimate parameters (15 yrs)

- **Peak luminosity $<= 30 \times 10^{34} cm^{-2} s^{-1}$**
- **$5 ab^{-1}$ per period total of $15 ab^{-1}$**

consistent with physics goal: 20 ab^{-1} in total

O(20) ab^{-1} integrated luminosity/experiment

Detectors must sustain a total of >20ab^{-1} and >5ab^{-1} between maintenance stops

Machine design to support 3.5 year operation periods w/o warm up or long stops

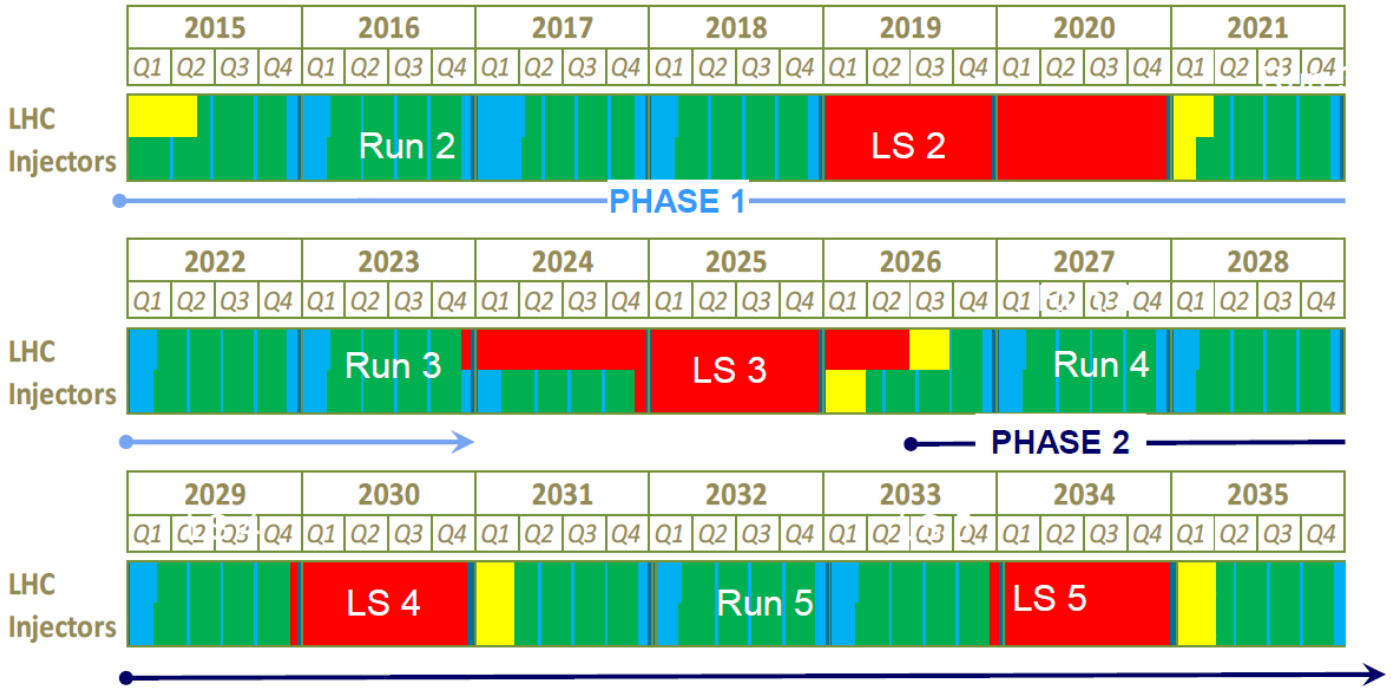
FCC ions & scheduled time for physics

- Plan 3 months of ion physics per run *
- Pb-Pb Goals:
  - Phase 1: 35 nb^{-1} per month
  - Phase 2: 110 nb^{-1} per month

Total: Protons 30 months + Ions 3 months
= 33 months for physics in 5 years
→ 165 months of physics during lifecycle

*Values are for one experiment taking data, for more detailed analysis see M. Schaumann presentation

HL-LHC plans: Long term schedule



Plan V1 (F. Bordry 2015)

- 1 year Long shutdown
- 3 months commissioning
- 3 years of operations
- V2 has 4 years of op. after shutdown

HL-LHC plans: Standard year of operations

	Jan				Feb				Mar				
Wk	1	2	3	4	5	6	7	8	9	10	11	12	13
Mo	30	6	13	20	27	3	10	17	24	2	9	16	23
Tu													
We													
Th													
Fr													
Sa													
Su													

	Apr				May					June			
Wk	14	15	16	17	18	19	20	21	22	23	24	25	26
Mo	30	6	13	20	27	4	11	18	25	1	8	15	22
Tu													
We													
Th													
Fr													
Sa													
Su													

	July				Aug					Sep			
Wk	27	28	29	30	31	32	33	34	35	36	37	38	39
Mo	29	6	14	21	27	3	10	17	24	31	7	14	21
Tu													
We													
Th													
Fr													
Sa													
Su													

	Oct				Nov					Dec			
Wk	40	41	42	43	44	45	46	47	48	49	50	51	52
Mo	28	5	12	19	26	2	9	16	23	30	7	14	21
Tu													
We													
Th													
Fr													
Sa													
Su													

Maintenance & setup

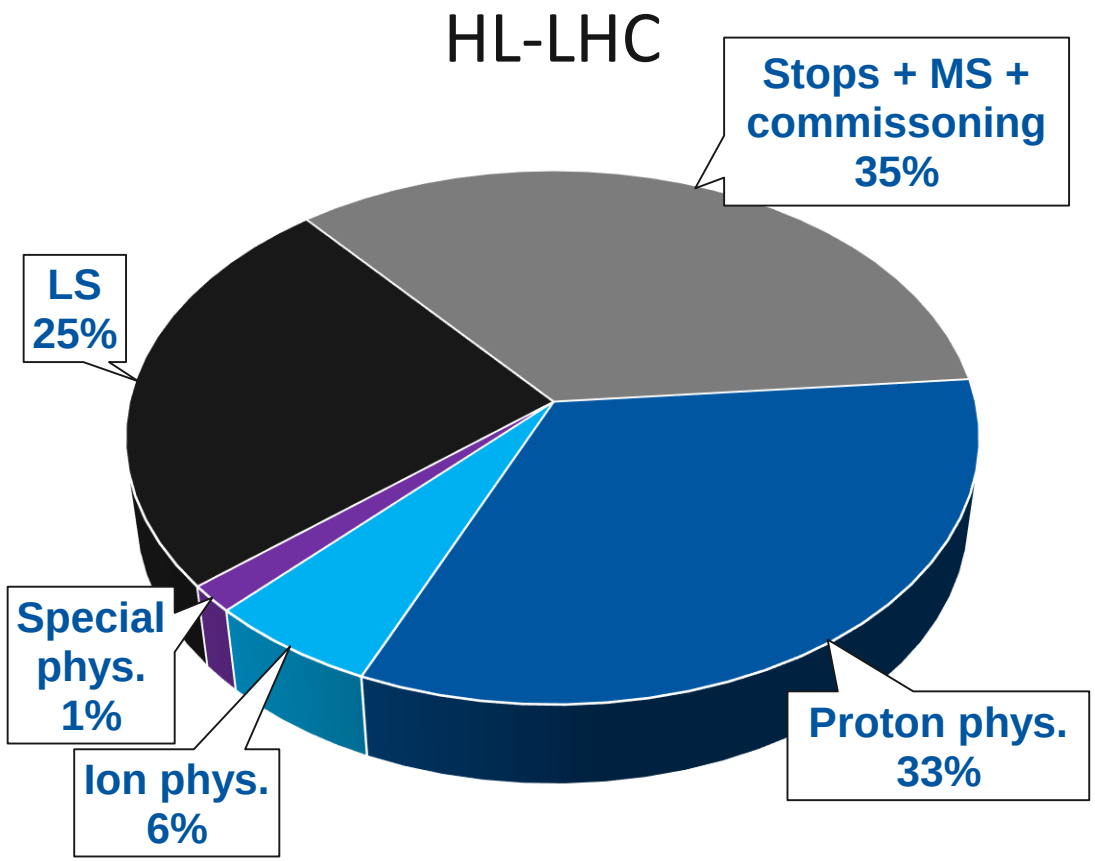
- 100 days YETS + HW comm.
- 21 days beam comm.
- 7 – 14 days scrubbing
- 3 tech. stops combined with MS (≈ 45 days)

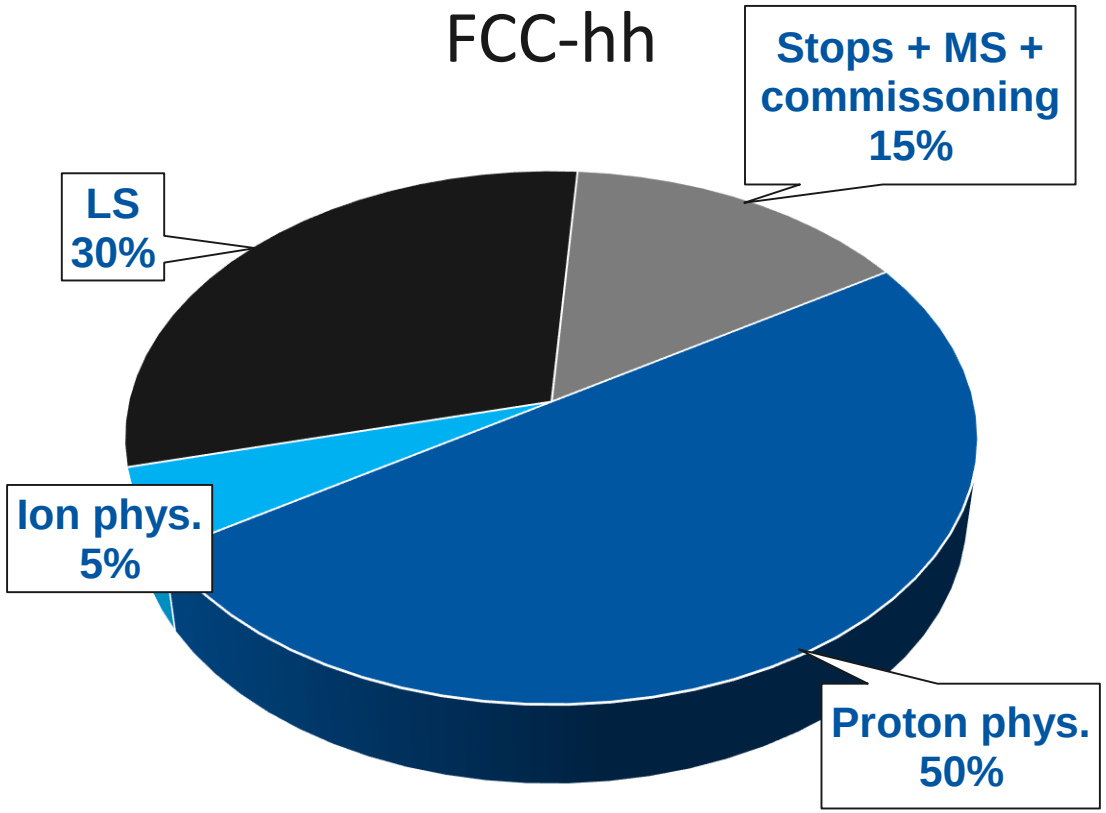
Physics

- 160 days proton phys.
- 7 days special phys.
- 28 days Ion phys. + setup

Based on M. Lamont et al. in HL-LHC preliminary design report

Comparison of schedules

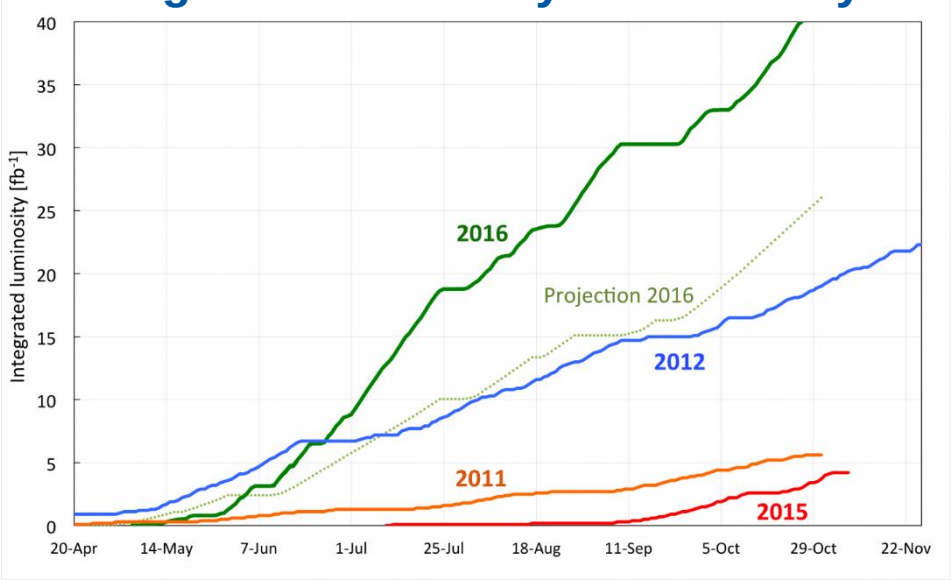




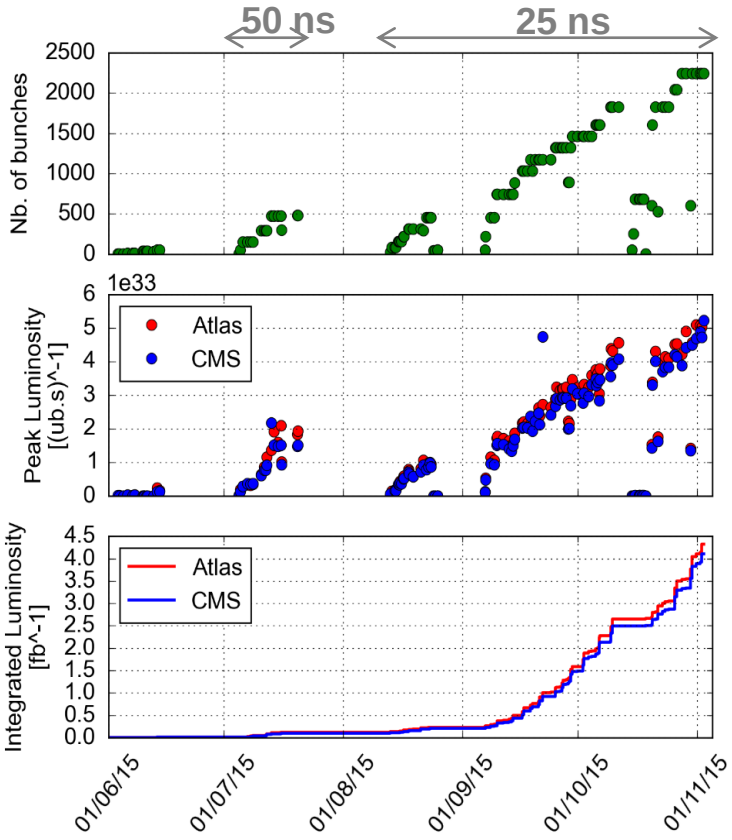
At FCC-hh long time reserved for physics leaves short time for other activities during runs

LHC luminosity production & intensity ramp-up

LHC integrated luminosity in different years



2015 intensity ramp*



- Learning & upgrades increase performance over time
- Commissioning limits production at start of runs
  - 2010: No production
  - 2015: Long intensity ramp up

*G. Papotti Chamonix 2016

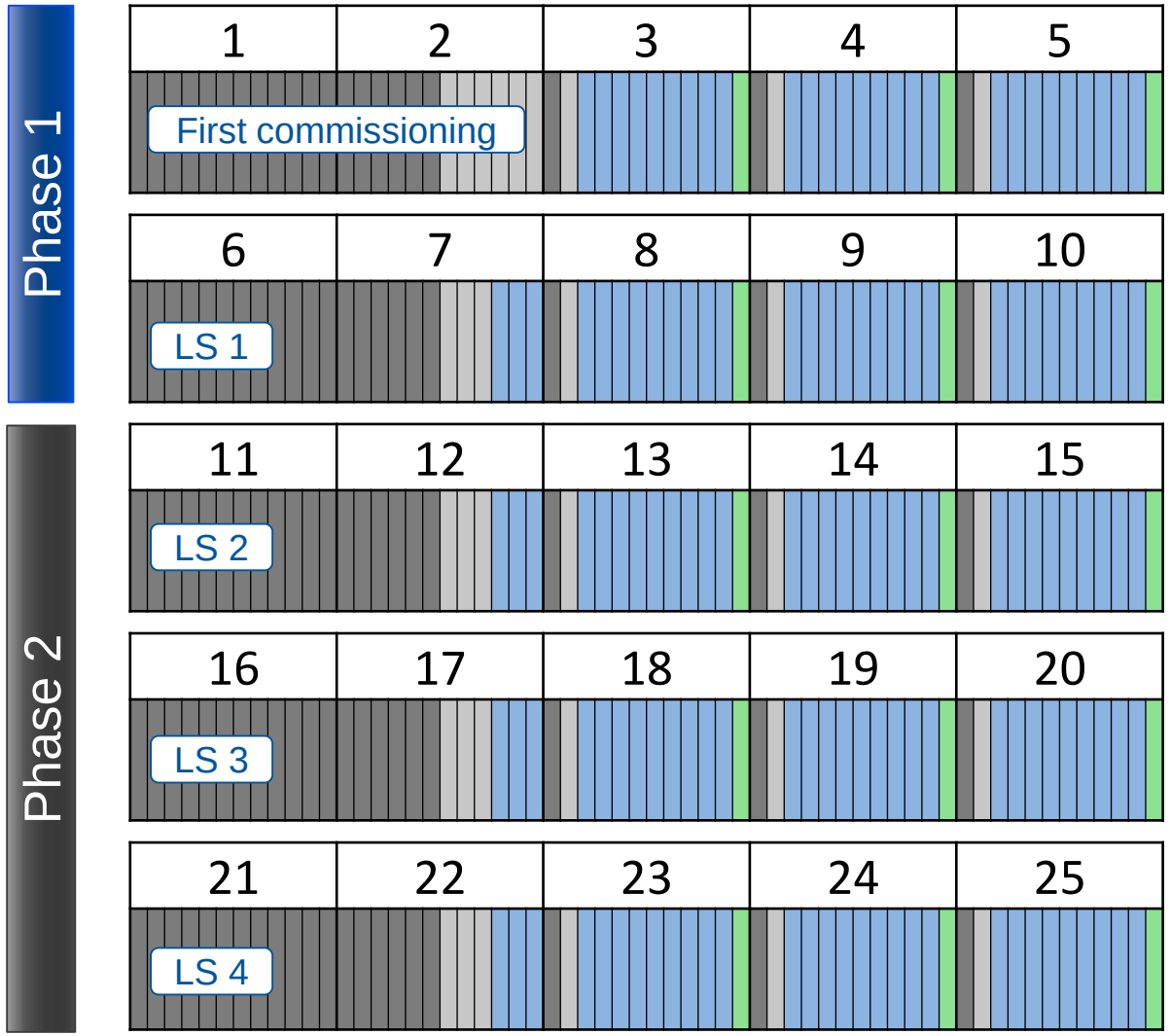
Initial schedule

Assumptions:

- 1.5 year LS periods
- First op. year no production
- 3 months comm. after LS
- 1 month year end tech. stops
- 1 month comm. After YETS

Results:

- 162 months for physics (Goal 165)
- No time for MDs or short stops



Long shutdown & tech. stops | Commissioning | Proton phys. | Ion phys.

Notes on initial plan

- Maintenance stop will require
  - cooldown before stop
  - commissioning after stop
- Limited optimization possibilities to shorten these times

→ Can we do maintenance less often?

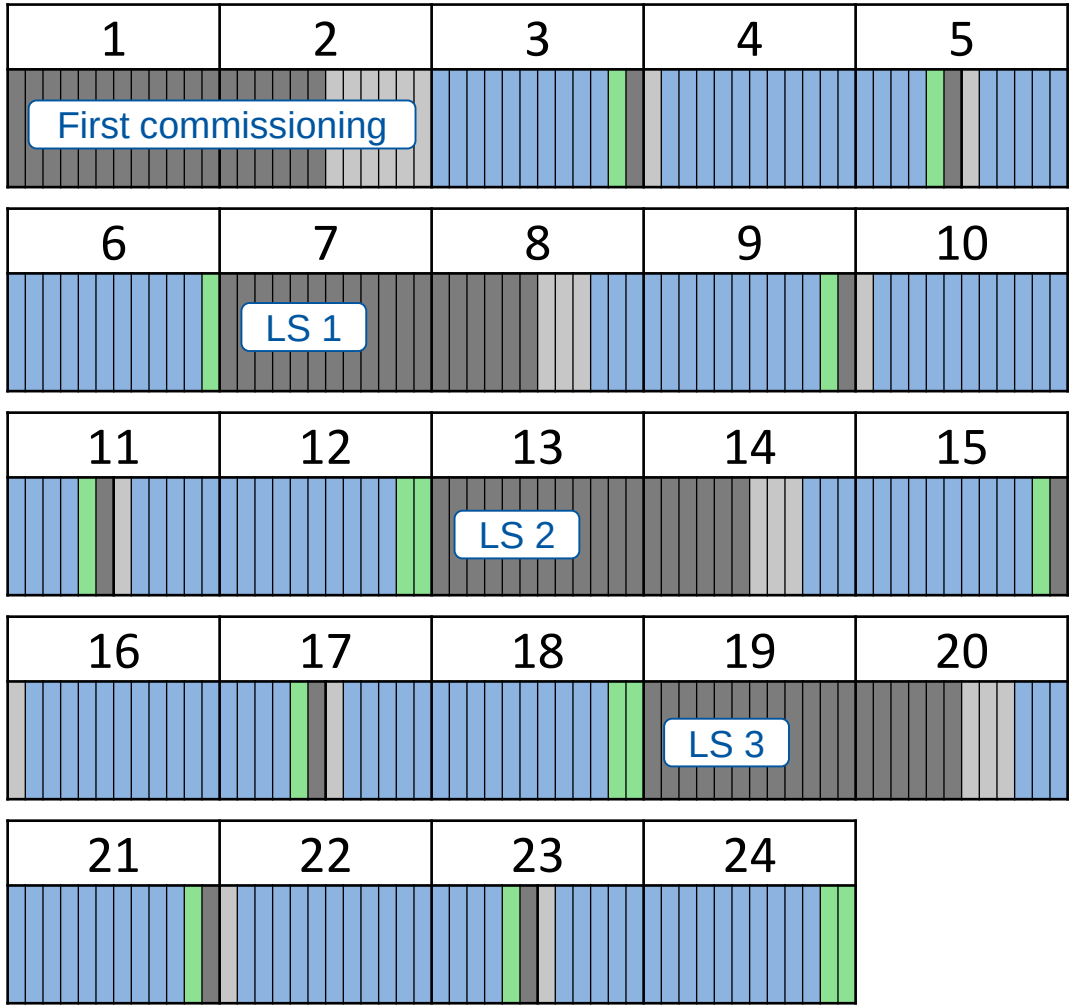
Potential in reduced maintenance

Assumptions:

- 1.5 year LS periods
- 4.5 years of operations
- YETS like stop every 1.5 years
- For fair comparison no changes to YETS & comm. periods lengths

Results:

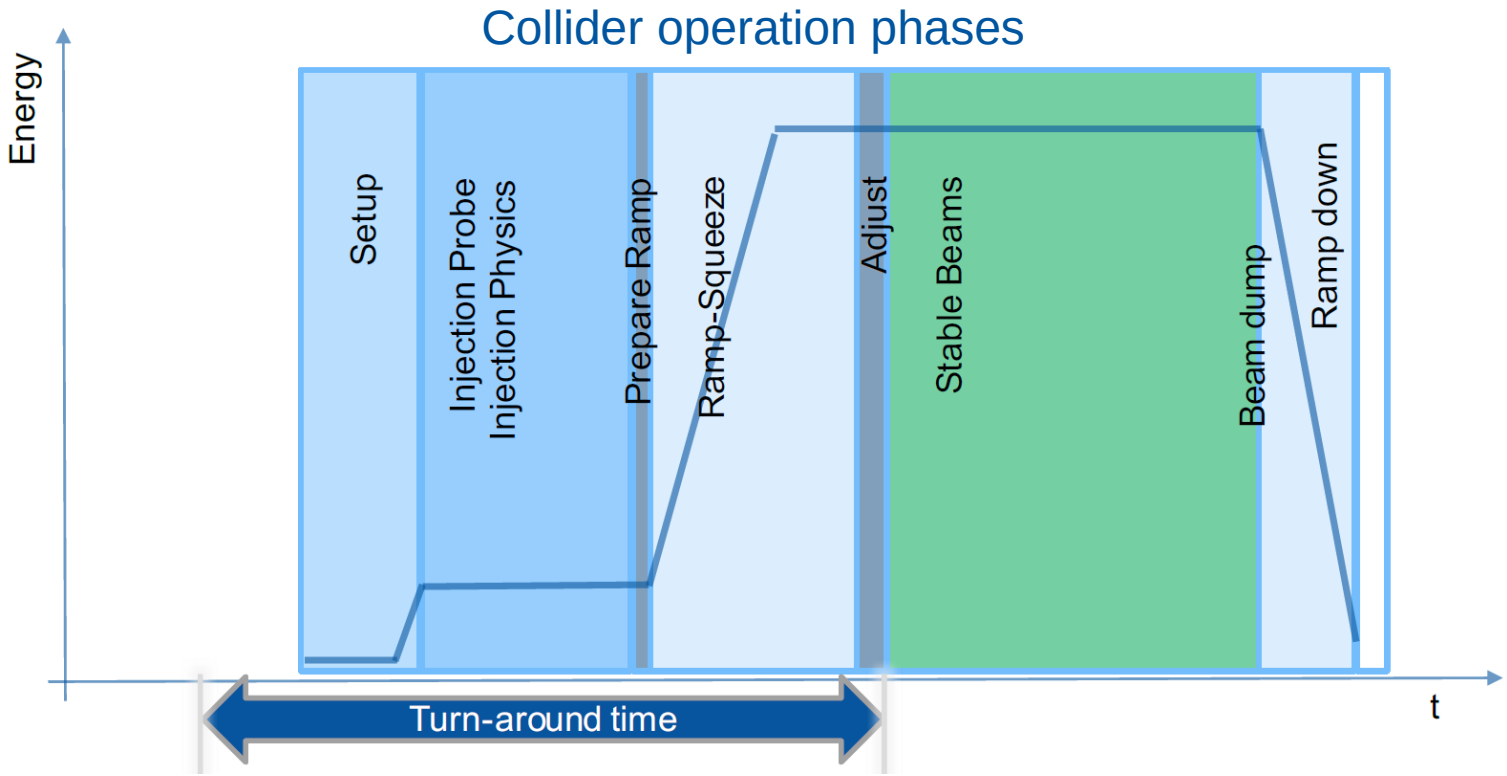
- 184 months for physics in 24 years
- Some margin for MDs & short stops



Long shutdown & tech. stops | Commissioning | Proton phys. | Ion phys.

Update on theoretical turnaround cycle times

- Turnaround = time from end of the SB to the start of the next one
- Last year initial values presented by R. Alemany Fernandes*



Note: This theoretical number should not be seen as achieved turnaround time during operations

*CERN-ACC-2016-0341

FCC-hh theoretical turnaround

Phase	2016 Estimate [min]
Setup	10
Injection*	40
Pre-ramp	5
Ramp	20
Flattop	5
Squeeze	3
Adjust	5
Ramp down	20
Total	108 (1.8 h)

Changes to injection time:*

- LHC 44 min
- Pre-filled LHC 36.5 min
- sc-SPS 37 min

*From F. Burkart (See also dedicated FCC-week presentations from W. Bartmann & F. Burkart)

LHC turnaround times

Phase	Theory	2015	2016
Setup	10	222.7	158.5
Injection	38	58.1	51.6
Pre-ramp	4	5.4	4.2
Ramp	20	20.4	20.4
Flattop	5	4.8	4.2
Squeeze	18	13.1	18.0
Adjust	10	12.5	14.1
Ramp down	31	41.0	41.0
Total	132 min (2.2 h)	378 min (6.3 h)	312 min (5.2 h)

- These are median values for phases
- Mean turnarounds are longer
  - 2015: 6.6 h
  - 2016: 7.1 h

From D. Nisbet & K. Fuchsberger

LHC turnaround times

Phase	Theory	2015	2016
Setup	10	**222.7**	**158.5**
Injection	38	58.1	51.6
Pre-ramp	4	5.4	4.2
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- Long setup time in LHC is mainly due to system failures
- System failures are foreseen in FCC

➢ Theoretical turnaround time is not a direct estimate for operation performance

LHC turnaround times

Phase	Theory	2015	2016
Setup	10	222.7	158.5
Injection	**38**	**58.1**	**51.6**
Pre-ramp	4	5.4	4.2
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Total	132 min (2.2 h)	378 min (6.3 h)	312 min (5.2 h)

- Injection is one of current issues in LHC
- Performance depends on:
  - Injector availability
  - Beam quality control
  - Operational decisions
- FCC needs more beam and with higher energy

➢ Good injection performance is crucial for FCC-hh

Conclusions

- Operation goals affect system design requirements

- Schedule has significant limits on planned downtimes
  - Limited gains on optimizing commissioning & intensity ramp
  - Large potential in extending time between planned shutdowns
  - Achieving this requires high operational readiness before runs

- Short stable beams time (3.5 h) → Multiple turnarounds in day
  - Short turnaround time is crucial for high luminosity production
  - LHC experience: Focus on availability & injection phase


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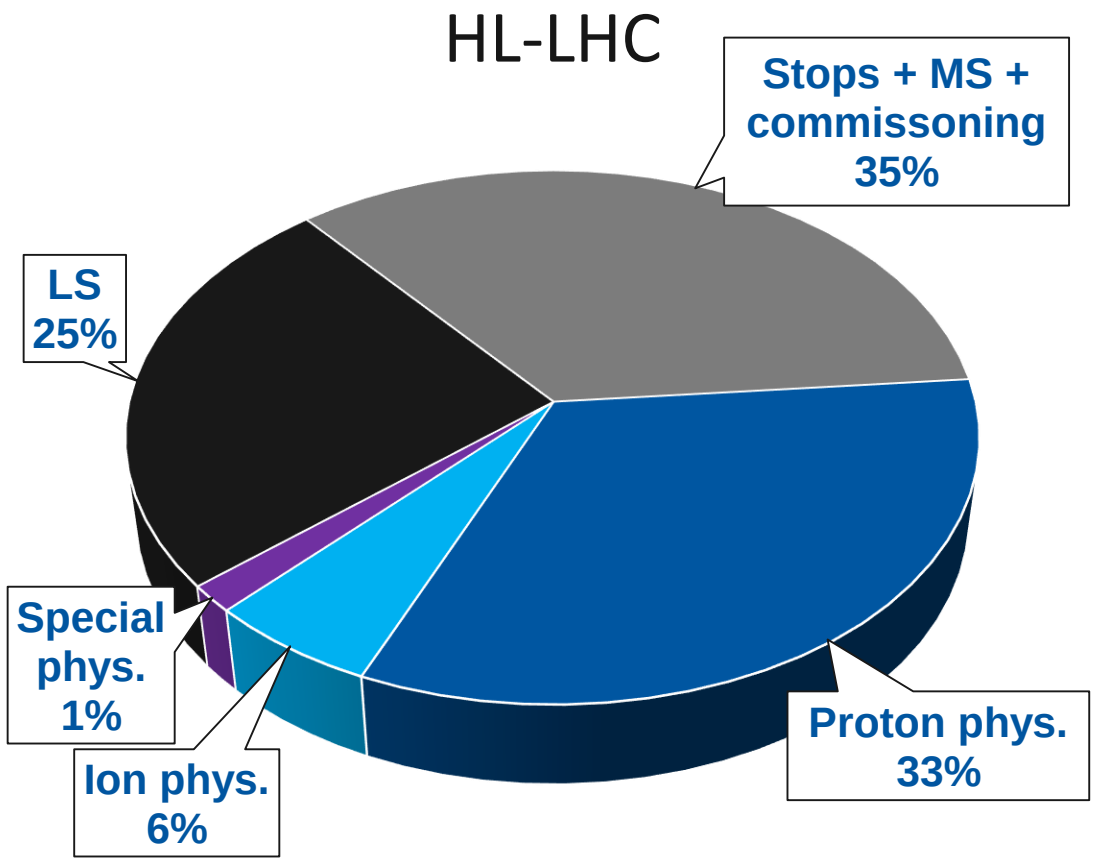
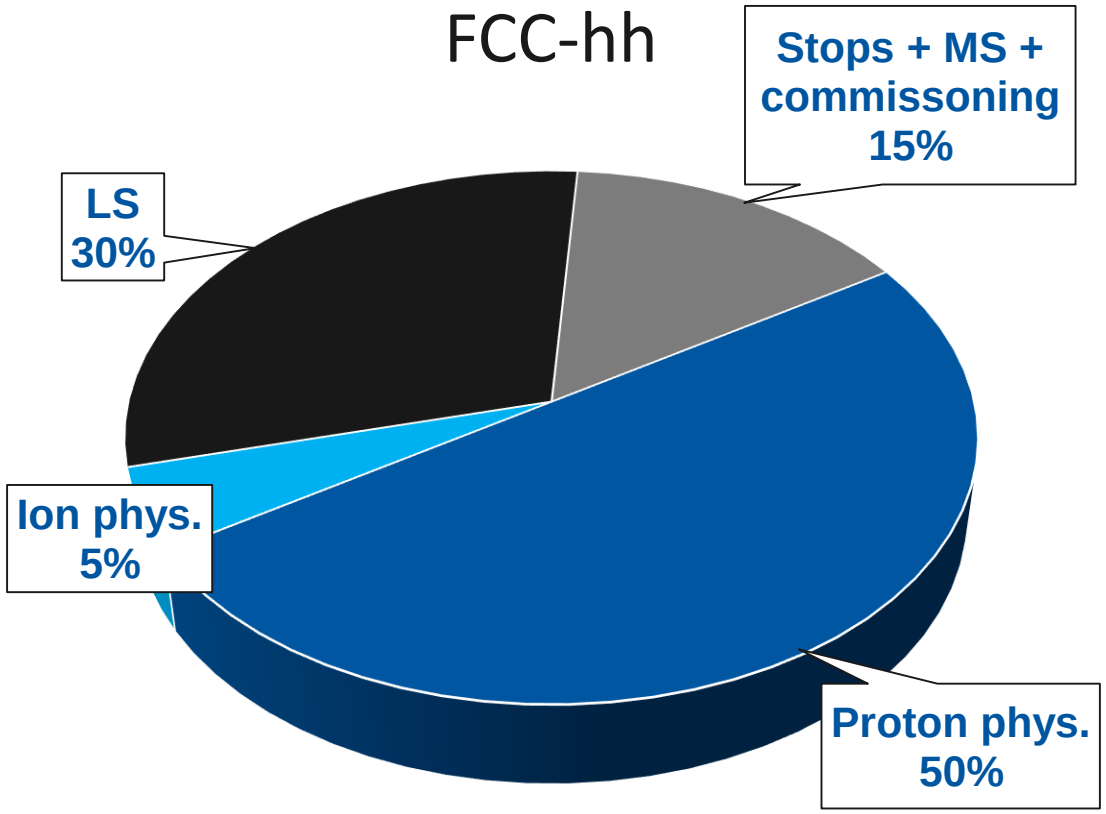
Extras

Comparison of schedules





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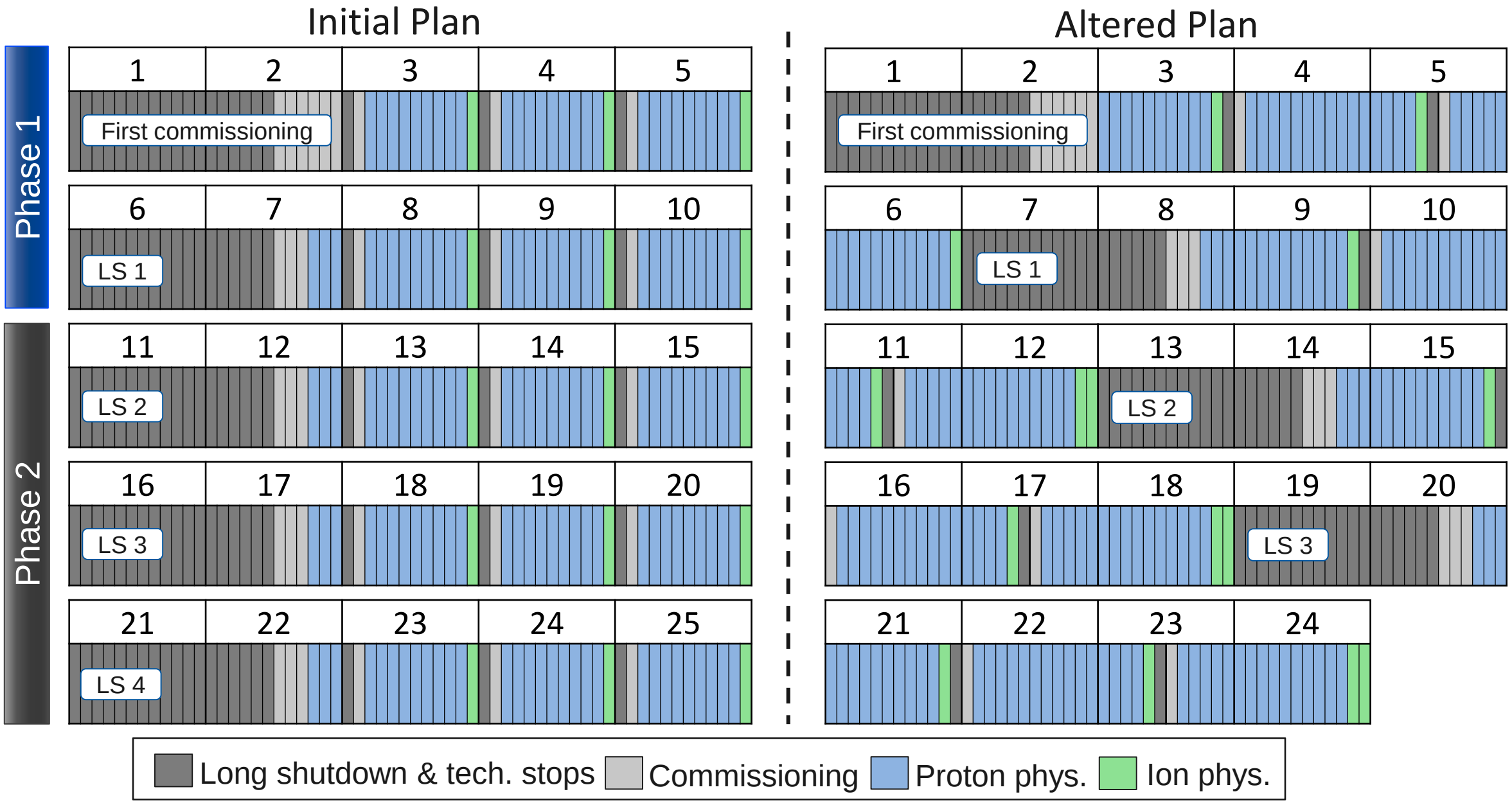
Initial Plan
Altered Plan
Phase 1
Phase 2
First commissioning
LS 1
LS 2
LS 3
LS 4
Long shutdown & tech. stops
Commissioning
Proton phys.
Ion phys.