
CERN

Beam commissioning major phases and planning

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Based on studies of Run3 WG (https://cds.cern.ch/record/2790409)
Thanks to: S. Fartoukh, J. Wenninger

Outline

2022 LHC commissioning

Machine check-out

Beam commissioning

Scrubbing

Intensity ramp-up

Physics production

Global and machine protection tests

From first turn until first stable beams

Intensity ramp-up to:

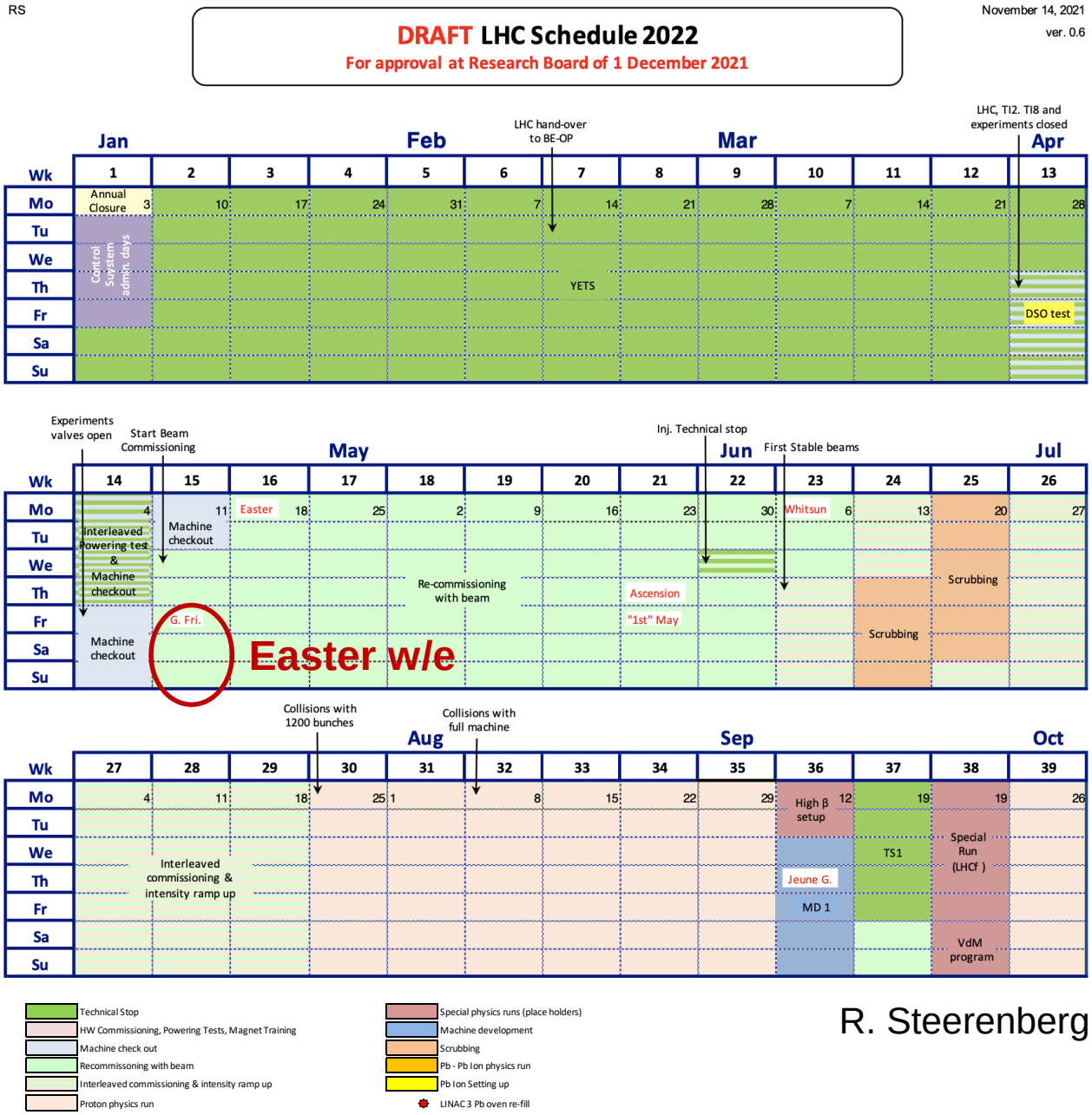
- establish operational cycle
- identify and mitigate issues
- identify issues related to stored beam intensity and other beam parameters

Intense period of mostly stable beams to provide large set of data to the experiments

Planning

Closure of tunnel and experimental caverns **31st March**

- **2 wks** of MC (interleaved with S23 training)
- **8 wks** of Beam commissioning
- **10 days** of scrubbing
- **5+2 wks** of intensity ramp-up
- …



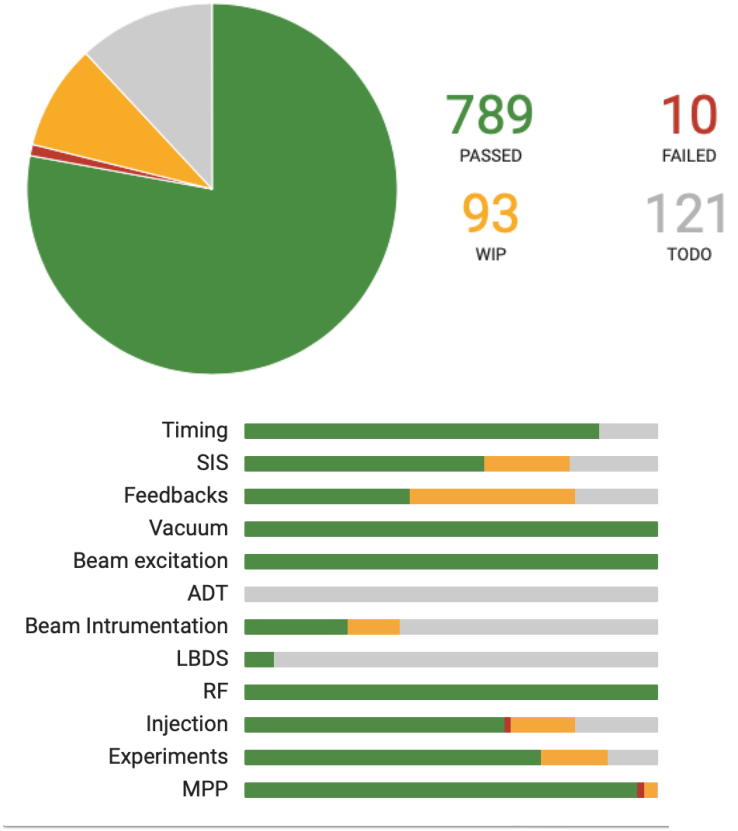
R. Steerenberg

Machine check-out

Machine check-out is meant to ensure that all systems work together in the correct way and communicate with each other as expected!

Checklist to be completed:

- All MP tests to be done
- Powering tests, including global powering
- Individual System Tests
- LBDS BETS MP tests
- ALICE spectrometer fault MP tests
- Vacuum interlock tests
- Collimation system cycles and setup
- Orbit feedback configuration tests
- Sequences dry-run
- Settings check
- ...and **many many others!!**



See C.Wiesner's slides

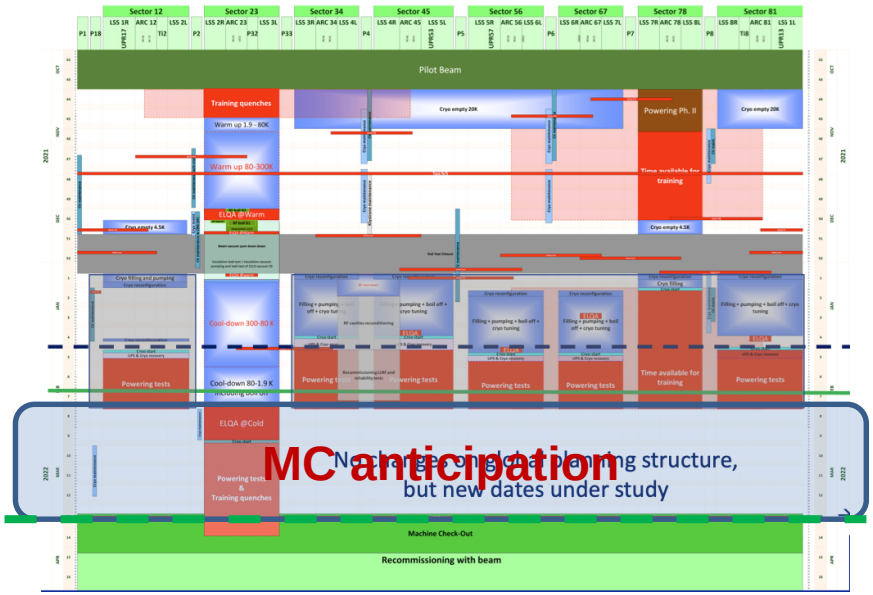
Machine check-out

Due to **limited intensity**, most of the systems were **not or only partially** used/tested for the pilot beam test:

- Injection Quality Check
- Post Mortem
- UFO buster
- BPM-PM issue to be solved
- BRANs
- SFB, SMP,…
- BETS-TCDQ/TDI
- Full setup of inj/dump systems
- Asynchronous dumps
- Lumi server
- PC interlock
- RF blow-up
- …

Machine check-out

As seen during the beam test, due to the early preparation of the majority of the sectors, **many activities can be anticipated**



31st March

EN-ACE

- **Seven out of eight sectors** will be ready 5 weeks before the MC official start
- **S23** is not included in the BETS configuration -> possibility to perform **BIS-LBDS tests**, while training S23
  - Disabling PIC (vac?) inputs of S23
  - **Strap** of interlock inputs from access system and WIC of IP3/IP7?
- Interleave some **training and MC tests**
- Not an easy operation, but some activities can be done

Beam commissioning goals

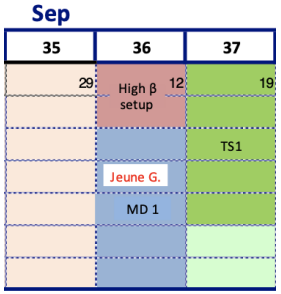
Prepare the machine for first physics fill, followed by intensity ramp-up:

- **Commission with beam** the key accelerator **systems** (feedbacks, RF, ADT, injection, dump, collimation, instrumentation,…), with particular emphasis at the LS2 changes
- Test all **Machine Protection** systems and functionalities
- Establish and validate the **machine configuration**
- **Prepare** for later foreseen **changes**

Additional bonus

Pre-commissioning of special cycles (VdM, 90 m, LHCb rotation,…) during beam commissioning proved in the past to be an efficient strategy:

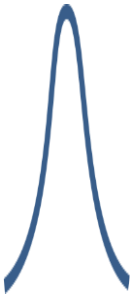
- Rather **easy** commissioning
- Many activities can be done by **OP** (nights filling)
  - First go to bring a pilot to the end of the cycle
  - Feedforward, cleaning after optics, collimation, etc
- Very fast way into the cycle when dedicated period for operation -> **high efficiency**
- Allows to have other options in the pocket to establish collisions, **in case of needs**
- Perform **machine development/operational studies**



Beam and optics parameters for 2022

Parameter	Value @inj	Value @FT	Value @coll
Energy [TeV]	0.45	6.8	6.8
β* (1/2/5/8) [m]	11/10/11/10	2/10/2/2	0.6/10/0.6/2 down to 0.3/10/0.3/2
(half) **Xing** angle [urad] IP1(V)/IP2(V)/IP5(H)/IP8(H)	-170/170/170/-170	-160/200/160/-200	
Sep (1/2/5/8) [mm]	-2/3.5/2/-3.5	-0.55/1/0.55/-1	
Tune (H/V)	.27/.295 (to be checked)	.28/.31	.31/.32
Emittance (BCMS standard) [um]	1.3	1.8	1.8 -> 2.5
Bunch intensity [p]	$1.1E^{11}$ to start, towards $1.4E^{11}$ later		
Bunch length [ns]	1.2	1.2	1.2
COLL (TCP/TCSG/TCSP) [σ]	5.7/6.7/7.5	5.0/6.5/7.3	5.0/6.5/7.3

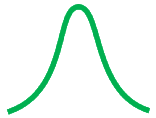
Main decision points



450 GeV injection, threading, capture…

Systems setup (RF, ADT, BI,…)

Optics



- Nominal bunch setup
- Nominal orbit and trajectory
- COLL alignment and LMs
- Aperture
- Inj and LBDS validation
- 450 GeV collisions
- More system tests
- Train injection setup

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- CRS validation
- Squeeze in steps
- Optics corrections
- Magnetic measurements
- Systems commissioning
- CRS validation with bumps

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- Special cycles setup
- 90 m cycle
- VdM cycle
- Intermediate energy
- Machine development studies

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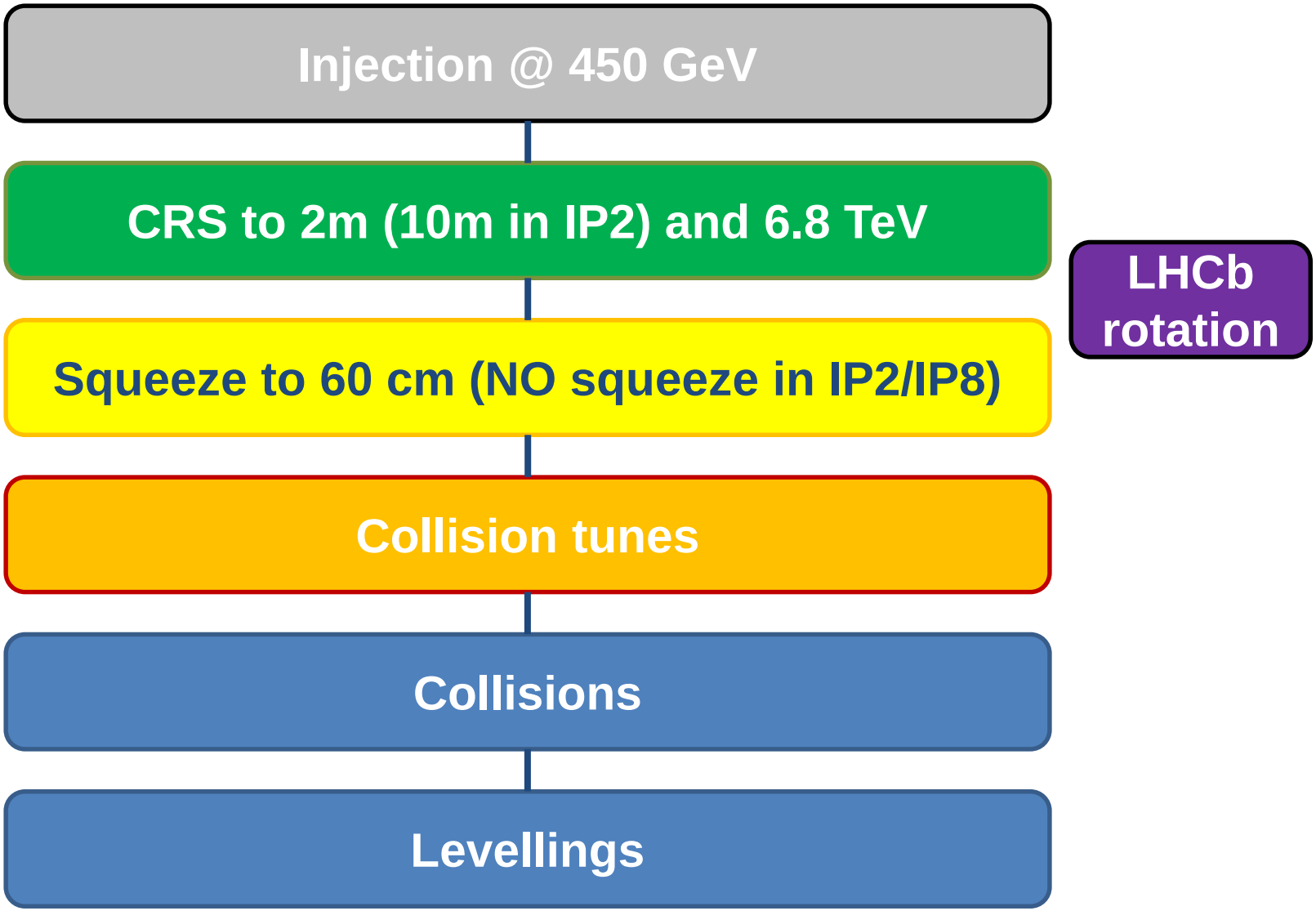
The 2022 cycle

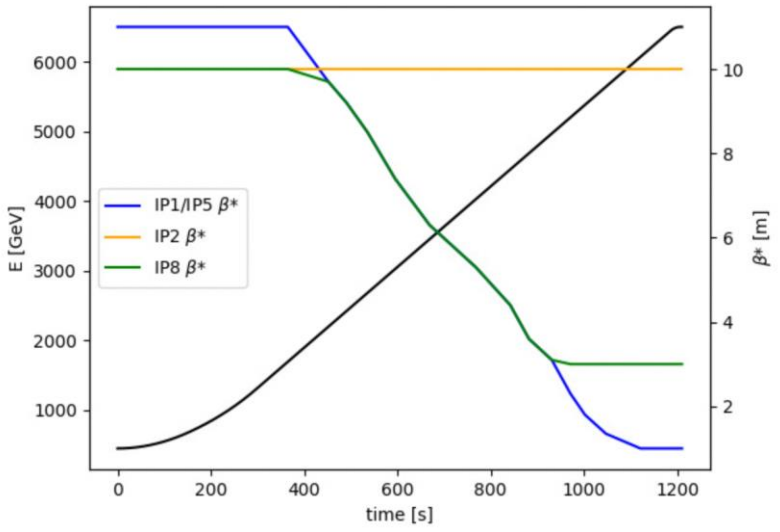


The 2022 cycle - CRS

PELP ramp to 6.8 TeV: 1275 sec (vs 1210 sec of 6.5 TeV)

- Most of the **optics changes** in the ramp, with the aim to arrive at flat-top with β* =< 2 m in IP1/IP5/IP8 (10 m in IP2)
- This **conservative choice** also takes into account some synergies with the configuration to be used for 2023/24
- **Squeeze** starts at 1.7 TeV, already tested in MD in Run2 (earlier starts used in the past)
- **β* = 2m** is reached at 4.5 TeV to allow space for (future!) optics changes (anti-telescope and/or more squeeze)
- Some additional squeeze could be added
- **More margin** for the “tune change” (.27/.295 -> .28/.31) are available thanks to the new QFB with dynamic reference

Optic Name	Energy	Time	Parabolic Fract...
R2021a_A11mC11mA10mL10m	450.0	0	0.1
R2021a_A11mC11mA10mL10m	452.2	15	0.1
R2021a_A11mC11mA10mL10m	459.0	30	0.1
R2021a_A11mC11mA10mL10m	470.2	45	0.1
R2021a_A11mC11mA10mL10m	486.0	60	0.1
R2021a_A11mC11mA10mL10m	530.9	90	0.1
R2021a_A11mC11mA10mL10m	593.9	120	0.1
R2021a_A11mC11mA10mL10m	705.2	160	0.1
R2021a_A11mC11mA10mL10m	840.9	200	0.1
R2021a_A11mC11mA10mL10m	1048.0	250	0.1
R2021a_A11mC11mA10mL10m	1306.0	300	0.1
R2021a_A11mC11mA10mL10m	1694.5	368	0.1
R2021a_A10mC10mA10mL10m	1905.9	405	0.1
R2021a_A970cmC970cmA10mL970cm	2105.9	440	0.1
R2021a_A930cmC930cmA10mL930cm	2305.9	475	0.1
R2021a_A880cmC880cmA10mL880cm	2505.9	510	0.1
R2021a_A810cmC810cmA10mL810cm	2705.9	545	0.1
R2021a_A700cmC700cmA10mL700cm	2905.8	580	0.1
R2021a_A600cmC600cmA10mL600cm	3105.8	615	0.1
R2021a_A510cmC510cmA10mL510cm	3305.8	650	0.1
R2021a_A440cmC440cmA10mL440cm	3505.8	685	0.1
R2021a_A370cmC370cmA10mL370cm	3705.8	720	0.1
R2021a_A310cmC310cmA10mL310cm	3905.8	755	0.12
R2021a_A250cmC250cmA10mL250cm	4202.9	807	0.1
R2021a_A200cmC200cmA10mL200cm	4505.7	860	0.1
R2021a_A200cmC200cmA10mL200cm_6-8TeV	6499.8	1209	0.1
R2021a_A200cmC200cmA10mL200cm_6-8TeV	6800.0	1275	0.1

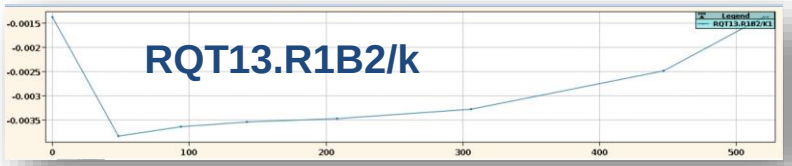


The 2022 cycle - squeeze & Q change

SQUEEZE

- A squeeze to **β* = 60 cm** will be performed at the end of the ramp
- **Duration 531 sec**, mainly dominated by the decay time of the Q6 current in IR1 and IR5 (2m-1.5m optics transition time is dominated by RQT13.R1B2)
- **Six intermediate matched points** (155, 133, 118, 104, 89, 71 cm) to minimize the peak β-beating during optics transition

Optic Name	Energy	Time	Paraboli...
R2021a_A200cmC200cmA10mL200cm_6-8TeV	6800.0	0	0.0
R2021_A155cmC155cmA10mL200cm	6800.0	76	0.131579
R2021_A133cmC133cmA10mL200cm	6800.0	122	0.217391
R2021_A118cmC118cmA10mL200cm	6800.0	170	0.208333
R2021_A104cmC104cmA10mL200cm	6800.0	236	0.151515
R2021_A89cmC89cmA10mL200cm	6800.0	334	0.102041
R2021_A71cmC71cmA10mL200cm	6800.0	475	0.070922
R2021_A60cmC60cmA10mL200cm	6800.0	528	0.188679
R2021_level_A60cmC60cmA10mL200cm	6800.0	531	0.0



Q-change

- Tunes are moved **from .28/.31 to .31/.32**
- **historically** performed at **flat-top**
- will be performed **before collisions**, offering more margin for coupling and better DA during the squeeze (systematically tested during ATS MD's in Run2)

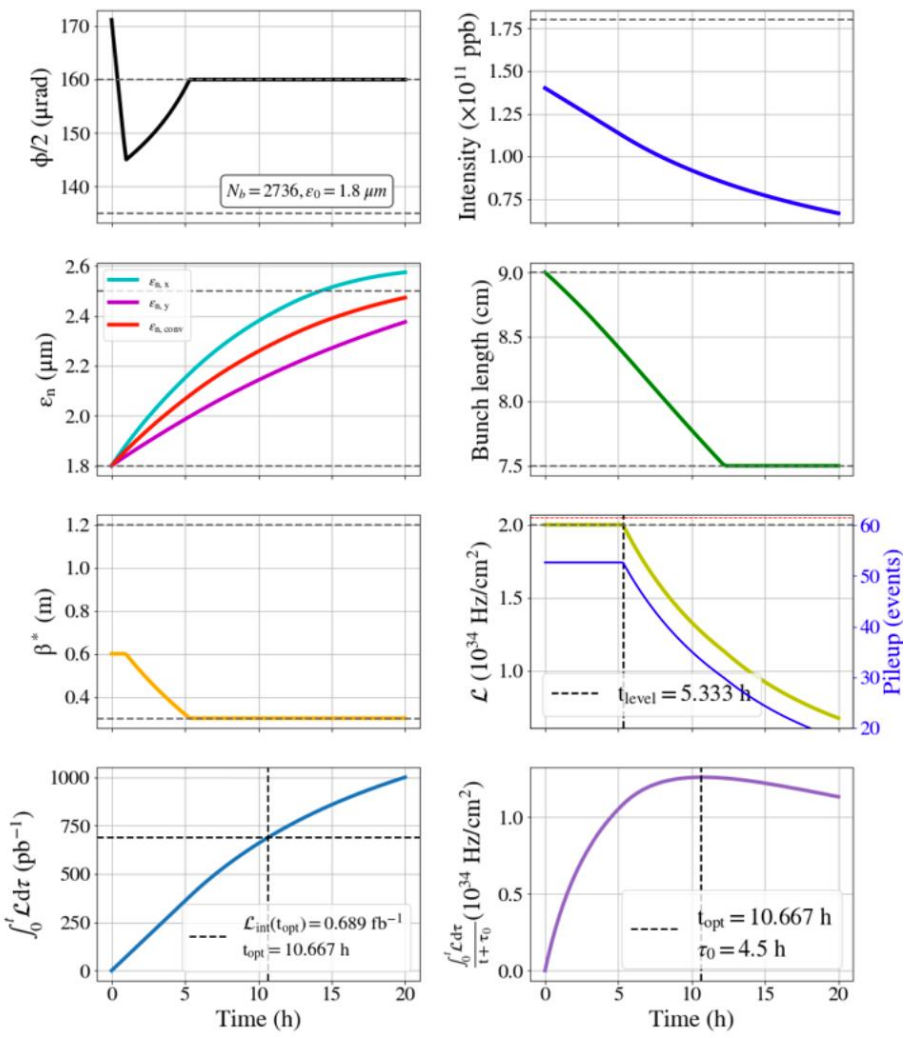
The 2022 cycle – collisions+levelings

BP should be **shorter than in Run2** (120 sec), as IP2 and IP5 shifts have been “cured” during LS2

Luminosity levelling (keep it easy):

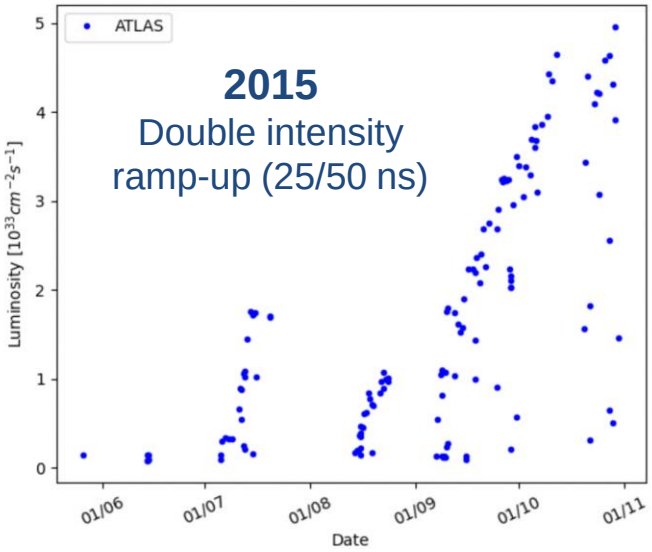
- **Initial reduction** of Xing will not be applied in 2022 to limit complexity
- **β* levelling** from 60cm to 30cm
- **TCT position** will be kept constant in mm during β*

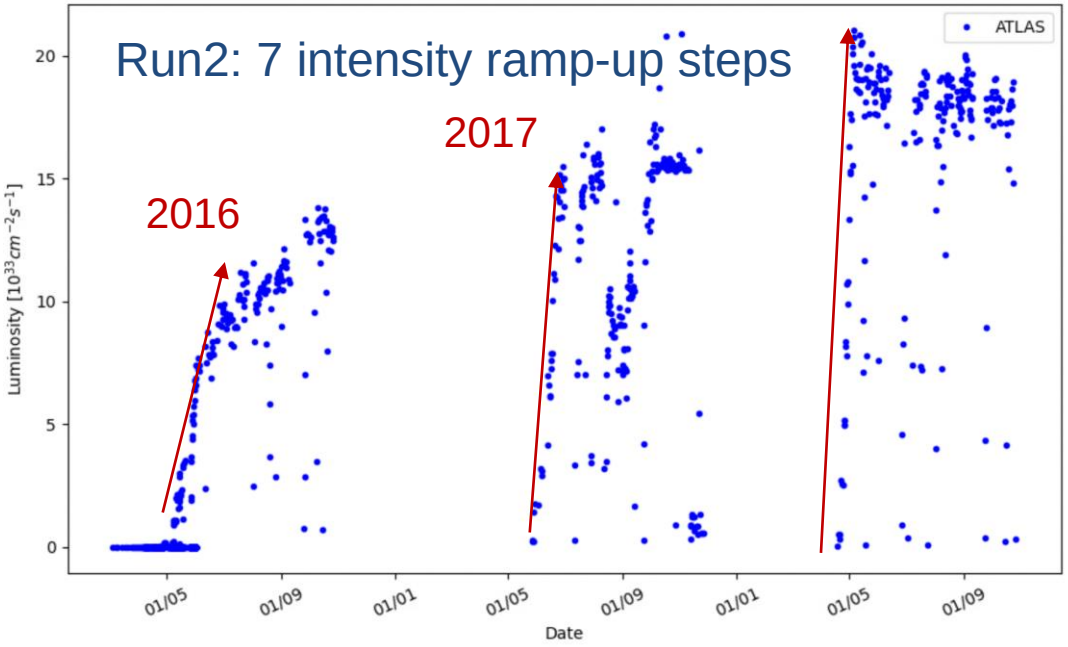
Working point will have to be adjusted, due to the **large variations of head-on beam-beam tune shift** during β∗ levelling, (intensity decrease and emittance blow up, bunch length shrinking, optics parameter changes)



The **optimal amount of steps in β* levelling** has to be found once final confirmation that the experiments will take data during the dynamic phases

Intensity ramp-up





Intensity ramp-up was designed to:

- Validate machine configuration and optics
- Spot potential issues in machine protection system
- Identify issues related to increased beam intensity

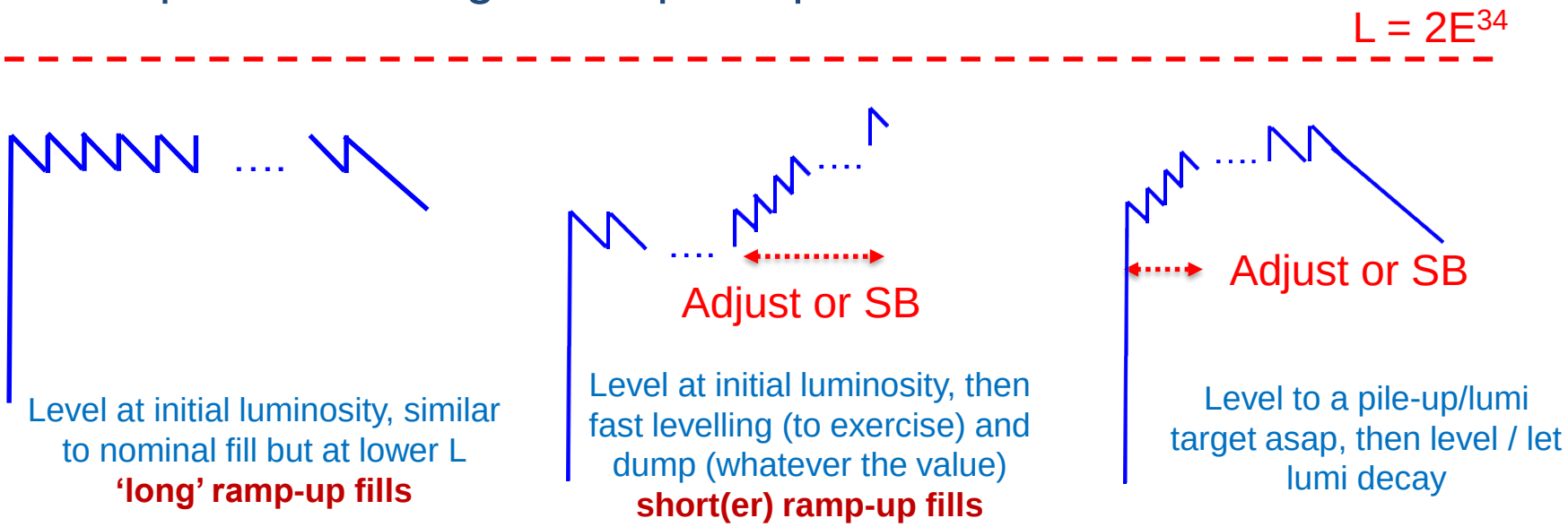
Proposal for 2022:

3/12-75-300-600-900-1200-1800- 2400–2700 (see C.Wiesner's talk)

Trade between increasing N of bunches and bunch intensity

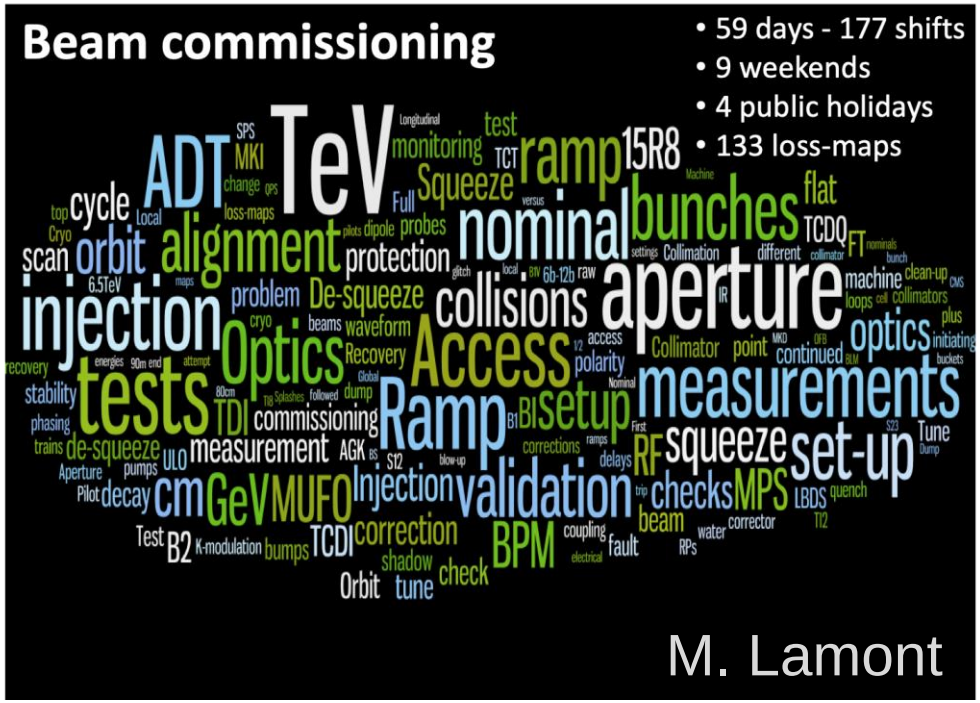
Intensity ramp-up & β* levelling

- Aim to do the **initial ramp-up on N of bunches** with ~1.1-1.2E^{11} p/bunch until full machine, then increase bunch intensity
- During the ramp-up we should **already exercise β* levelling** extensively, even if at L < 2E^{34}
- A **strategy** needs to be **agreed upon**, in particular with respect to fill length and β* steps



Timing

Preliminary detailed **planning** (with margin for access & problems) indicate **49 days** until first stable beams



2015 commissioning was done in 59 days (~8 weeks), but:

- **Energy increase** 4TeV -> 6.5 TeV
- **25 ns** beam setup, after initial commissioning with **50 ns**
- Fight with **ULO in 15R8** (investigation and quench recovery)
- Everything had to be commissioned from scratch (**NO beam test** prior to commissioning)

Everything will have to be redone…What we gained is the confidence in the systems and that NO major problem is present

However, more complex cycle wrt 2015 will require longer setup

Conclusions

- Even besides the RF finger discovery, the **beam test was extremely useful**. **However**, the activities done will have to be repeated
- The **operational cycle** for 2022 operation is **designed** (few details still to be finalized), to maximize synergies with the rest of Run3
- **Beam commissioning planning** is being established. Some margin will allow to slot in some fundamental activities for the global success of Run3
- **We are ready** and eager to start again…waiting for the machine