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LHC Injectors Upgrade

LHC Injectors Upgrade Workshop

Montreux, 13-15 February 2019

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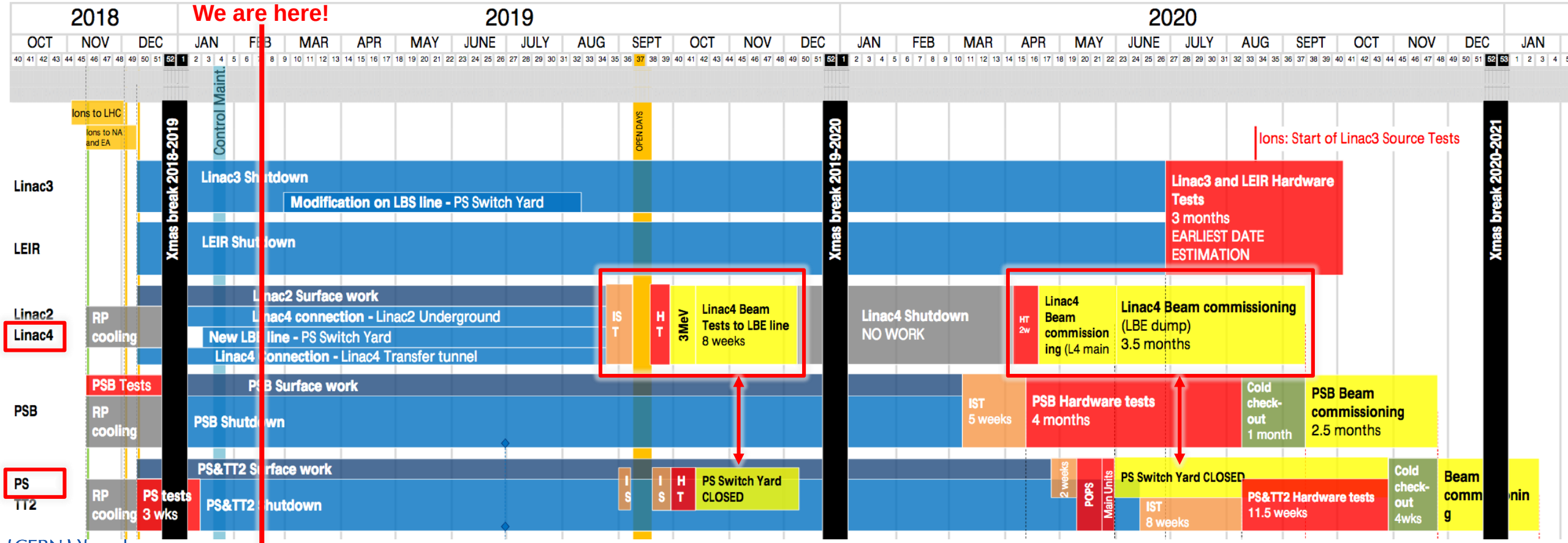
LHC Injectors Upgrade

Linac4 and LBE Line Commissioning

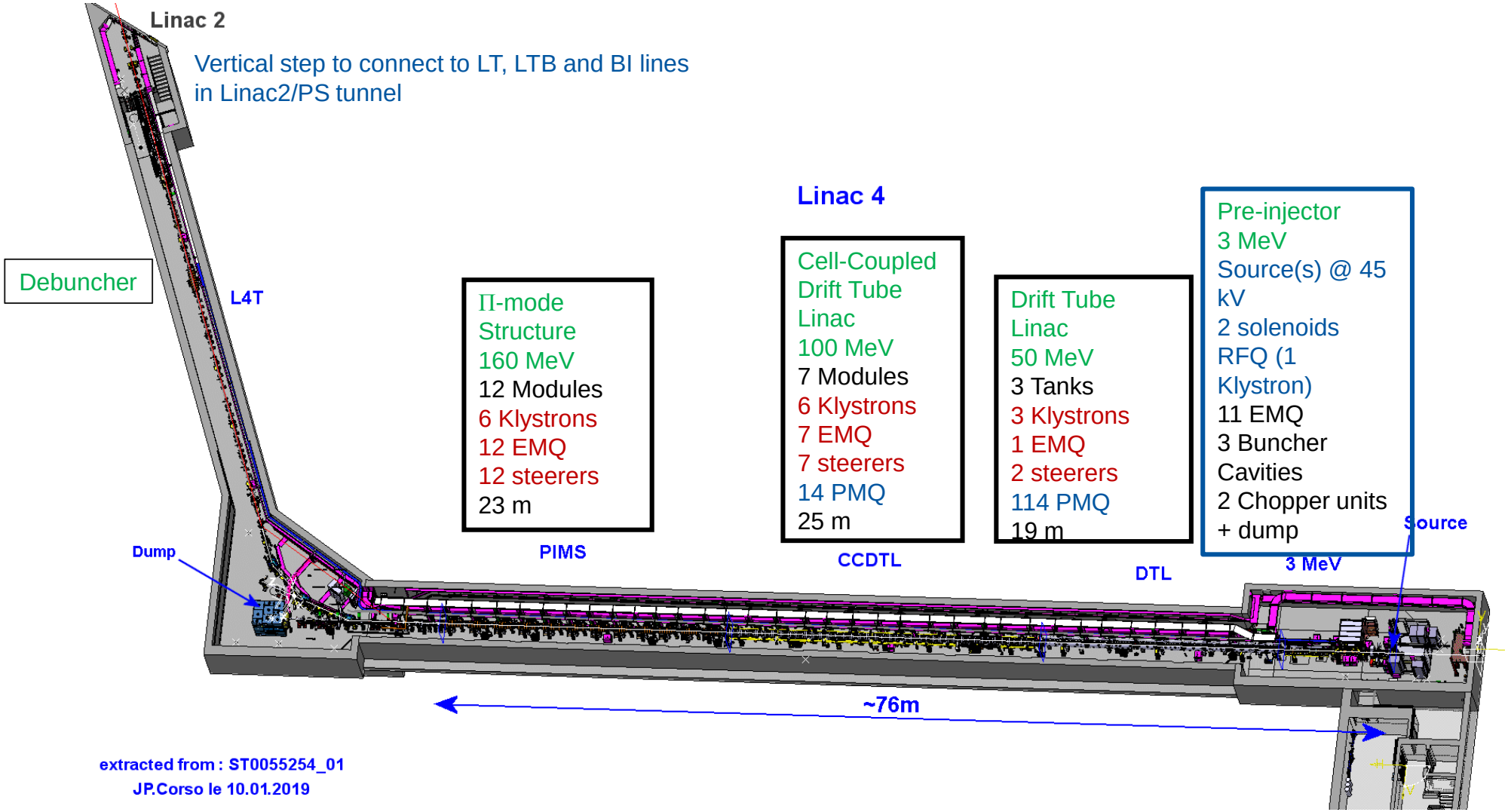
B. Mikulec for the Linac4 team

LS2 Master Schedule

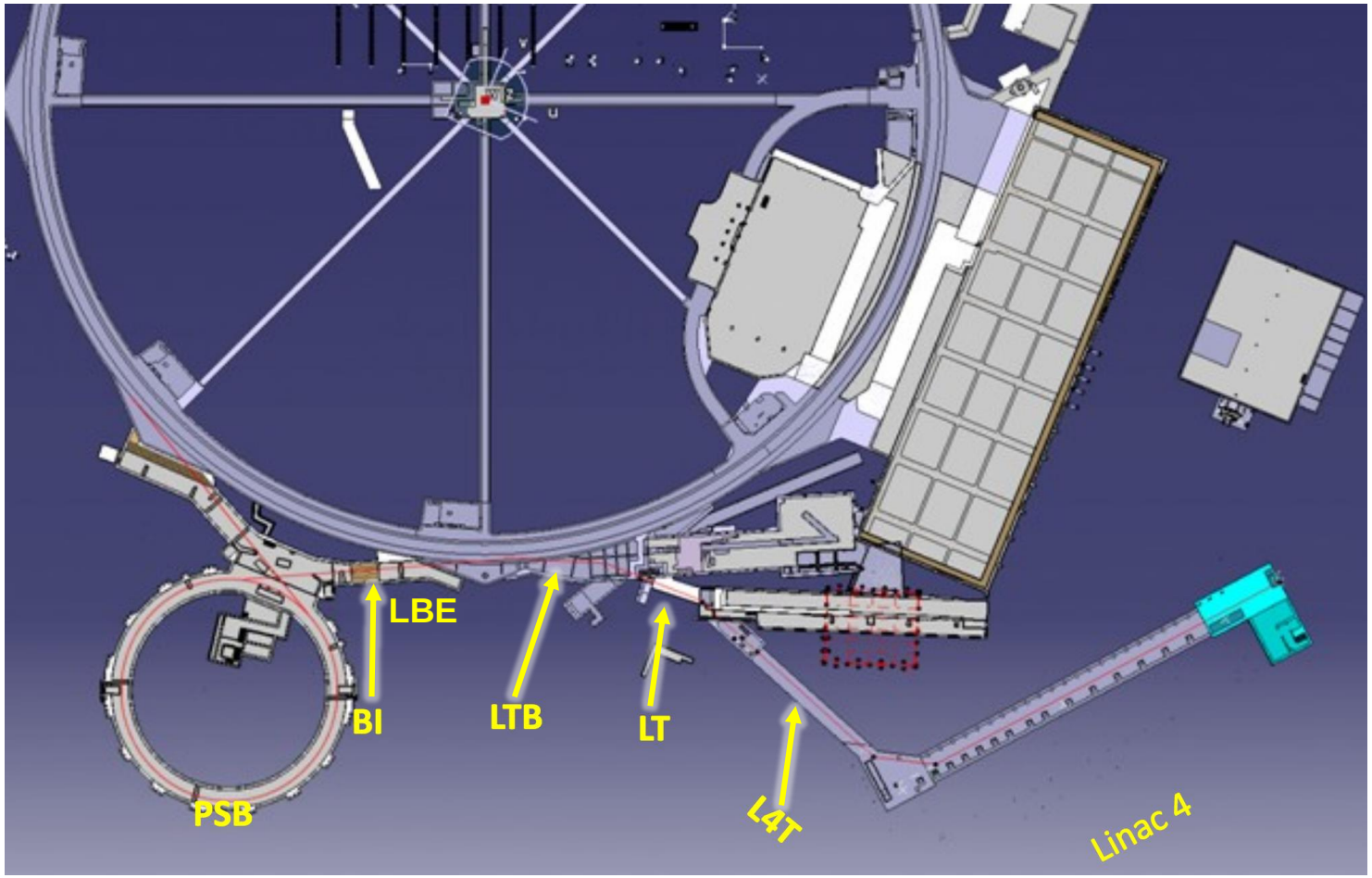
- For Linac4 commissioning, beam to LBE line most relevant, although difficult to arrange (blocks access to PS Switchyard)
- First LBE line run September - December 2019 to mitigate risks for post-LS2 restart



LINAC4 - layout



Transfer Lines



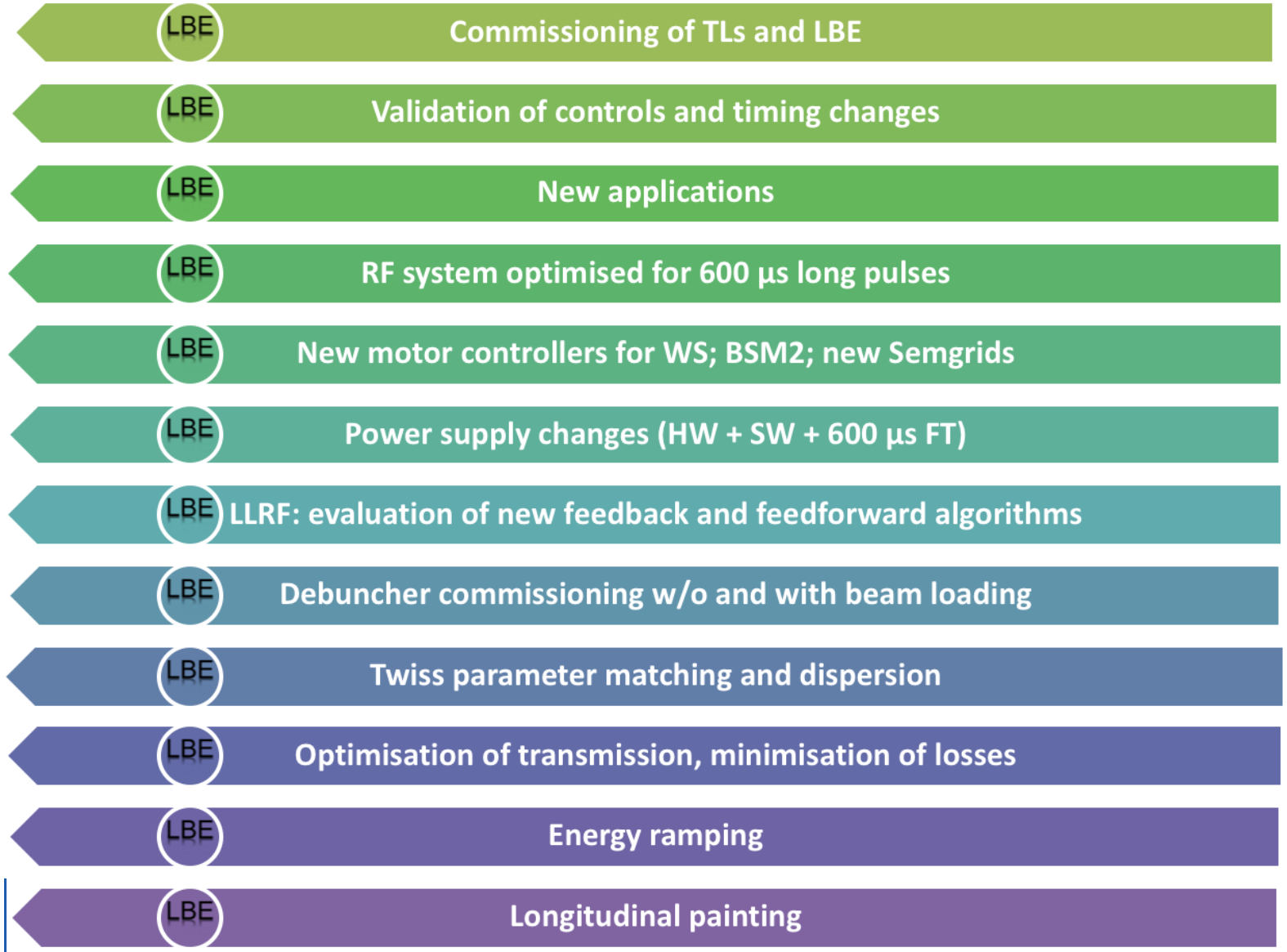
- ~177 m from PIMS exit to PSB foil: L4T ~70 m (to LT.BHZ20) and LT/LTB/BI lines ~107 m
- Commissioning of end of L4T, LT, LTB and the LBE emittance measurement line in 2019 run

2019 LBE Run Goal

- **Approach specified* beam quality as closely as possible before LS2 commissioning and identify potential remaining issues → risk mitigation for provision of post-LS2 beams in time and within specifications**
  - Many important parameters could not be tested before (not possible with Linac4 in stand-alone)
  - Various modifications during LS2:
    - Renewed transfer lines and LBE line → new equipment
    - Cabling/decabling campaigns (in particular in PS)
    - Controls changes (LS2 baseline, new FESA3 version and 64-bit OS, Linac4 → PSB timing domain, MTG…)
    - Interlock changes
    - Important new features for LL-RF: **feedback and feedforward algorithms**, energy/phase ramping, **600 µs pulse length compatibility**…
    - New applications
  - Transfer lines with several bending magnets → need to control dispersion and explore matching phase space
  - Transverse and longitudinal beam characterisation not far from PSB injection point

* https://edms.cern.ch/document/1898179/1.1

The 12 Top Ingredients of the 2019 LBE Line Run



In 2019:

- **4 weeks of beam tests to LBE (excluding HW + beam commissioning)**
- **Test principles and identify issues**
- **Not sufficient time to go into all details**

2020 Linac4 Restart - Goals

- **Timely provision of all requested beams to the PSB with pre-LS2 specifications**
  - For commissioning of PSB and all downstream machines
  - First physics beams
- **In theory no modifications planned after 2019 LBE line run, BUT**
  - Might require changes to LL-RF in case cavity beam loading could not be sufficiently compensated by new proposed algorithms
  - Will need to go into more detail for optimisations of LL-RF algorithms, longitudinal painting + chopping, optics
    - Might need to test potential LL-RF modifications (as result of LBE line run)
  - Increased functionality of source Autopilot and evaluation of steering/matching automatization algorithms
    - No source modifications planned after 2019 LBE line run → expect ~26 mA at LBE
- **Set up and test all operational beams**
  - Optimise all cycle-dependent settings, including interlocks/watchdogs/BLM thresholds
  - Evaluate under final conditions full ppm operation (e.g. for debuncher and long. painting)

Milestones for Pre-Requisites

2019:

- **Q1 2019:** Upstream electrical lockout for Linac4 implemented as for downstream injectors
- **End June 2019:** CO Linac4 LS2 baseline deployed, FESA classes ready
- **End July 2019:** settings management/LSA changes implemented for LBE line run
- **End August 2019:** most applications ready (with very few agreed exceptions)
- **Successful 2019 LBE line run and clear identification of all remaining open issues**

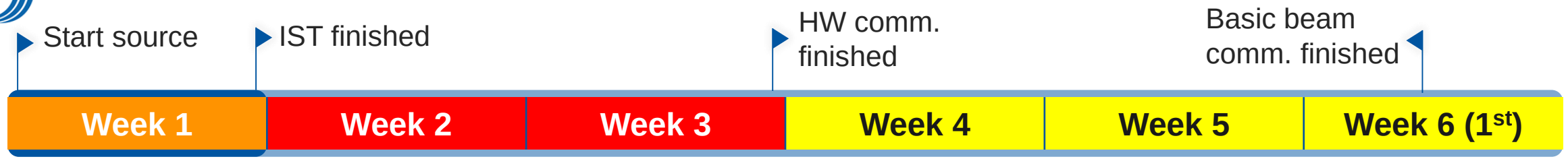
2020:

- **13th January 2020:** final CO LS2 baseline release for injectors
- **End January 2020:** update of checklists finished; release of online planning (ASM)
- **Mid-March 2020:** all services available (full power available from EN-EL?), settings management/LSA changes (incl. optics) implemented for PSB connection, DB logging reviewed; all applications ready
- **DSO tests and HW/beam permits OK in time for start of IST/HW commissioning**

Linac4 LS2 Restart – a few Remarks

- **OP will invest in this period to evaluate for future reference the minimum Linac4 restart time after periods with only minor modifications (like after a YETS)**
  - Deploy the usual number of shifts for this period (M/A shifts during HW commissioning, full MAN during beam commissioning, then reduce to M/A shifts once basic beam commissioning finished)
  - Remark: the PSB will also restart HW commissioning in April 2020 (same team of operators)
  - Question: will there be a piquet service available for BC (for representative BC time evaluation)?
- **Planned start in LS2 Master Schedule: w15 2020 with HW commissioning (2 weeks)**
  - Plan to start actually with **1 week of IST**, followed by **2 weeks of HW commissioning** (2 weeks from summer 2018 experience where HW commissioning was under OP responsibility) → total: 3 weeks
- **Continue with beam commissioning to the Linac4 dump with aggressive schedule**
  - OP will gain experience with Linac4 beam commissioning during 2019 LBE line run (before this was under ABP responsibility), which will help refining the 2020 beam commissioning planning
  - Current estimate for this phase: 2.5 weeks (was 1 month after summer 2018); beam commissioning running in parallel with RF setup, which requires 2 weeks from RFQ to the last PIMS cavities; half a week for final equipment tests at 160 MeV and longitudinal + transverse beam characterisation
  - Will adapt ‘online’ to advancement

Beam Commissioning to Linac4 Dump



For beam commissioning:

Activity	Related tasks	Tool requirements	Remarks	Estimated duration
Start-up of Linac4 source	- Check source stability, e- dump current etc. - Partial verification of Autopilot	Faraday Cup, BCT, Semgrid applications; Pre-chopper; correctors; source BIC; Autopilot	ABP specialists	3 weeks
Start-up of Linac4 RF systems	- LLRF setup of all cavities (excl. debuncher)	Inspector	RF + EPC specialists	2 weeks
- LEBT/MEBT tuning, phasing in linac - Recommissioning of instrumentation	- RFQ transmission - Pulse flatness - Chopping efficiency - Beam loading and ToF	Trajectories, ToF, BSM1… (full set of beam instruments and related applications)	Could profit from optimisation algorithms for transm./flatness	2 weeks
Beam Characterisation	- Long. + transv. measurements - Steering to dump	Emittance meas. application	Check new optics (vert. emitt. meas.)	0.5 weeks

Beam Studies to Linac4 Dump

Stripping foil tests etc.

Beam tests to Linac4 dump in parallel to LBE line tests

Week 6 (2nd)	Week 7	Week 8	Week 9	Week 10	…

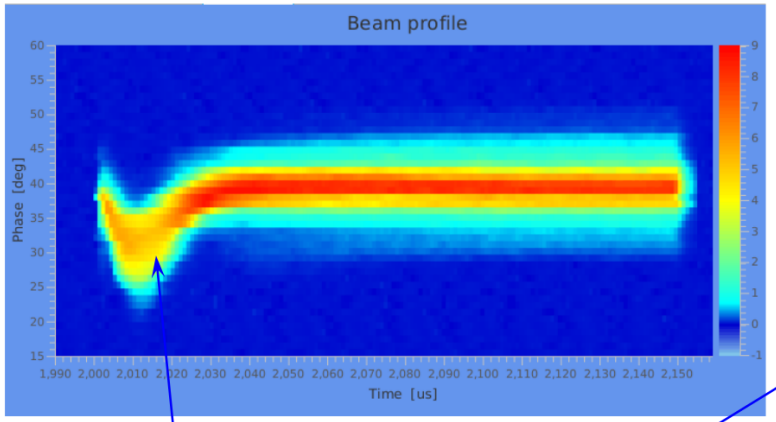
These activities could mostly run in parallel to beam being sent to LBE:

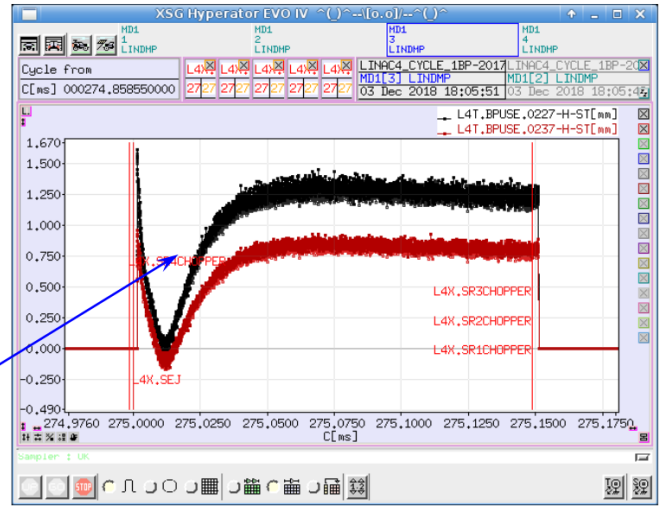
Activity	Related tasks	Tool requirements	Remarks	Estimated duration
Stripping foil tests	- Test graphene foil for 1 new manufacturer - Test another GSI amorphous C foil		Incompatible with beam operation to LBE and other measurements	2 days
Tuning of Autopilot	- Source stability along pulse and pulse-to-pulse - Check transmission and pulse flatness - Cesiation	Autopilot, BCTs, Timber	In parallel; reserve one cycle for this task	4 weeks
Optimisation of LL-RF feed-back and feed-forward algorithms	- Check compensation for cavity beam loading at each transition (R4!)	BSM, RF monitoring with Inspector	Small part can be done with beam to L4 dump, but then beam to LBE is needed.	Tbd based on experience from LBE line run

Effects of Cavity Beam Loading

Open issues – beamloading transient

- **'Risk' item, as no experience yet at Linac4 with compensation algorithms**
- **First evaluation possible during 2019 LBE line run**
- **Affects injection position/angle at PSB injection → degradation of transverse emittance**
  - Appears always for Ring 4 and at any abrupt transition in beam current (if longer than ~a few µs)





Beam energy and position in the transfer line varies over the first ~50 µs due to the beamloading transients in all RF cavities.

The LLRF team is working on improvements of the feed back system and on a feed forward algorithm to reduce those transients (! beam current dependent)

=> see presentation from Robert and Bartosz

See slide R. Wegner @
2nd Linac4 towards Operation Review
https://indico.cern.ch/event/778856/

Part 2: Beam to LBE

- **Most important part of Linac4 beam commissioning (debuncher in TL, dispersion…) starting beg. of June 2020 (w23)**
- **Last chance to solve outstanding issues; final beam preparation and characterisation before injection into PSB**
- **Manpower: operators back to M/A shift; have to handle in parallel PSB HW commissioning**
- **Co-activity issues: will certainly have to cede some beam time to PS/PSB**
  - IST and HW commissioning in parallel in PS Switchyard → in case of access need to stop beam to LBE
  - HW commissioning in parallel in PSB → in case of access need to stop beam to LBE (removal of BI beam stoppers)
  - ➢ Need careful cross-machine optimisation of access requests
- **For many studies need full pulse length → only 1 pulse every 10 s (RP limitations)**
- **Question: piquet service during beam commissioning? Training of piquets?**

Beam to Linac4 LBE Line

TLs + LBE re-commissioned

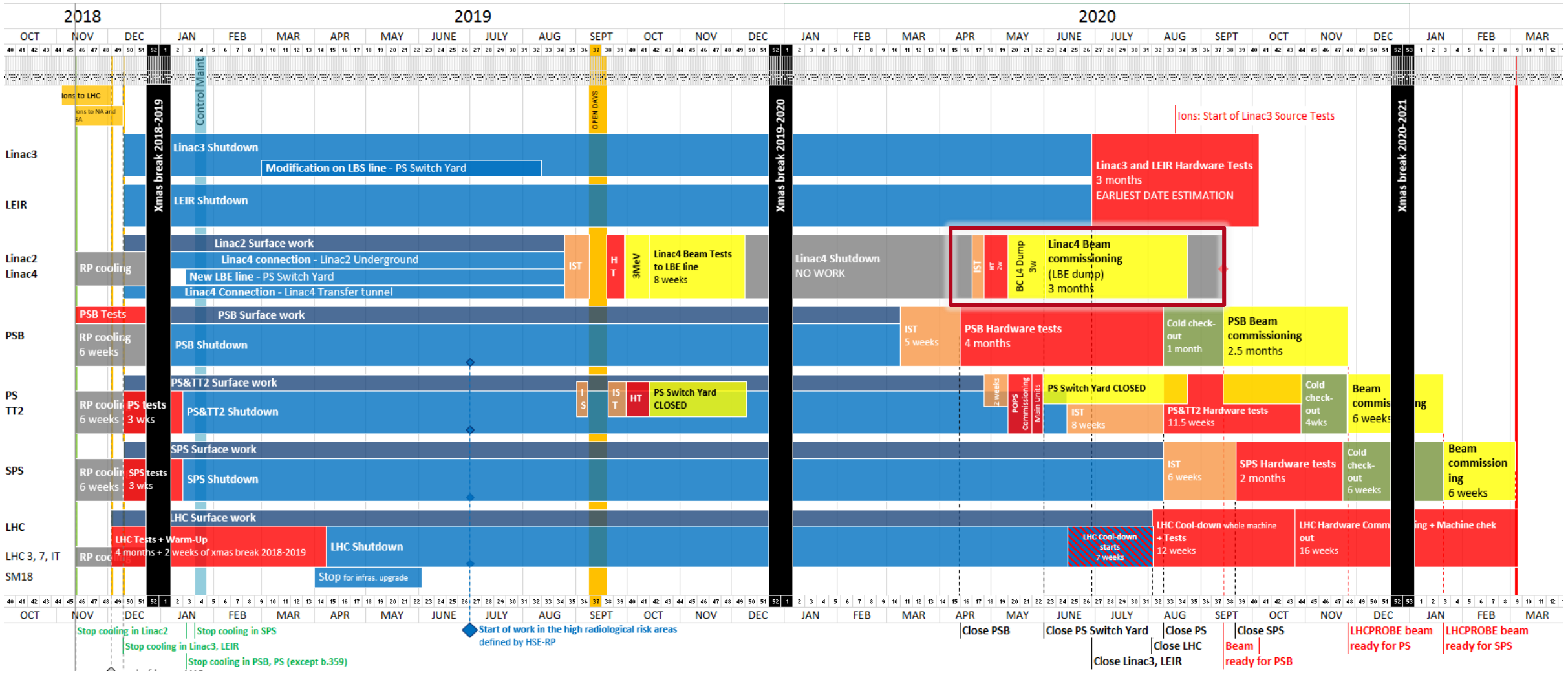
All beams ready for PSB

Week 1	Week 2	Week 3	Week 4	…	Week 12

Activity	Related tasks	Remarks	Estimated duration
Recommissioning of transfer lines and LBE	- Magnet/power converter checks - Interlock checks - Instrumentation checks		0.5 weeks
Further optimisation of LL-RF feed-back and feed-forward algorithms	- Have to include tests with by-ring interlocks	Highest risk item	Will depend on LBE line run outcome (estimate 4 weeks as risk mitigation)
Further optimisation for longitudinal painting (PIMS11/12, debuncher, chopper, controls, by-ring interlocks)		Detailed studies (not possible during 2019); use all cycles due to low duty cycle	4 weeks
Steering/matching studies for all use-cases			1-2 weeks
Work on final details to improve machine availability			Whole duration in parallel
Final optimisation of Autopilot, continuous caesiation in view of PSB beam quality			Whole duration in parallel
Set up each operational beam	- Take transverse and longitudinal reference measurements	½ day per beam	2 weeks

Proposed Modification to LS2 Master Plan

Courtesy J. Coupard



Summary

- **All beams necessary for the first few months will be prepared during the Linac4 beam commissioning to be ready for the PSB beam commissioning start**
- **Proposed changes to LS2 Master Schedule: start with Linac4 commissioning 2 weeks later with 1 week of IST and target end of beam commissioning 3 weeks earlier than originally foreseen (mainly to free manpower)**
  - BUT: should keep this margin in case of issues with LL-RF algorithms (highest risk item)
  - Might help in case PSB HW commissioning could be finished a few days earlier…
- **Simulation of min. startup time for Linac4 after a YETS**
- **Longitudinal painting could be considered as 'optional' → could gain 4 weeks and delay Linac4 commissioning planning (gain time for PS SWY activities)**
  - Long. painting foreseen for highest intensity beams only (ISOLDE, TOF) → would mean to live without long. painting until ~2022)
- **Proposal to re-assess the final planning in January 2020 once the LBE line run results are known → opportunity to optimise the planning across accelerator complex**

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