Preparation for PS commissioning

A. Huschauer on behalf of the PS Joint Leaders Team

BE-ABP-LNO Section Meeting, 17 February 2021

Outline

- **LS2 Master Schedule**
- **Main commissioning activities**
  - The new PS injection systems
  - Beam instrumentation
  - Detailed commissioning planning
- **Start of the LIU beam commissioning**
- **Summary**

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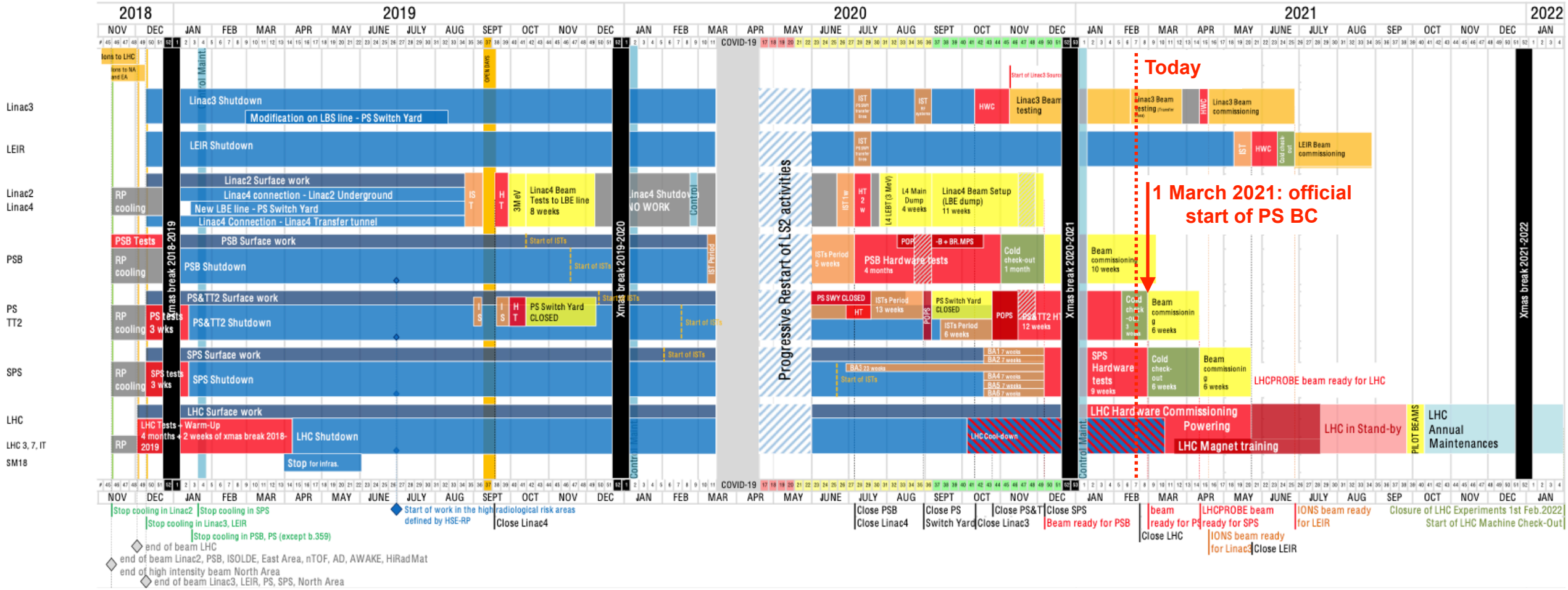
LS2 Master Schedule



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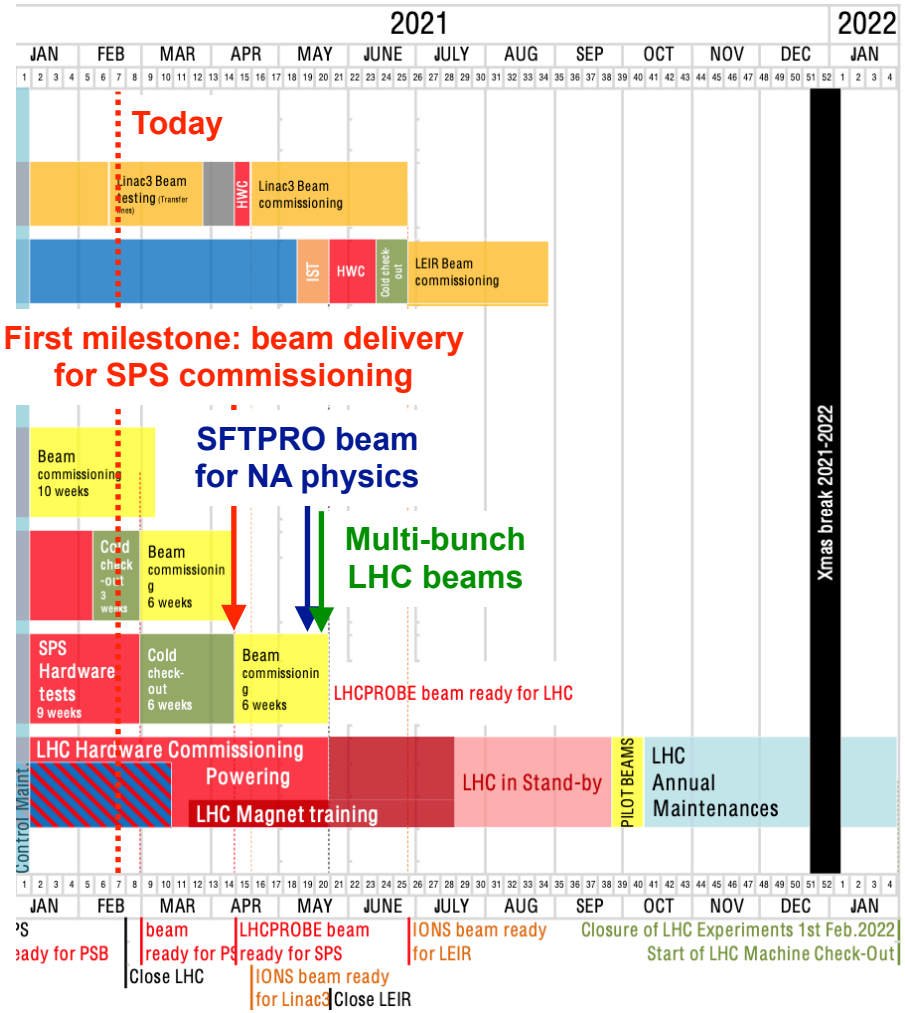
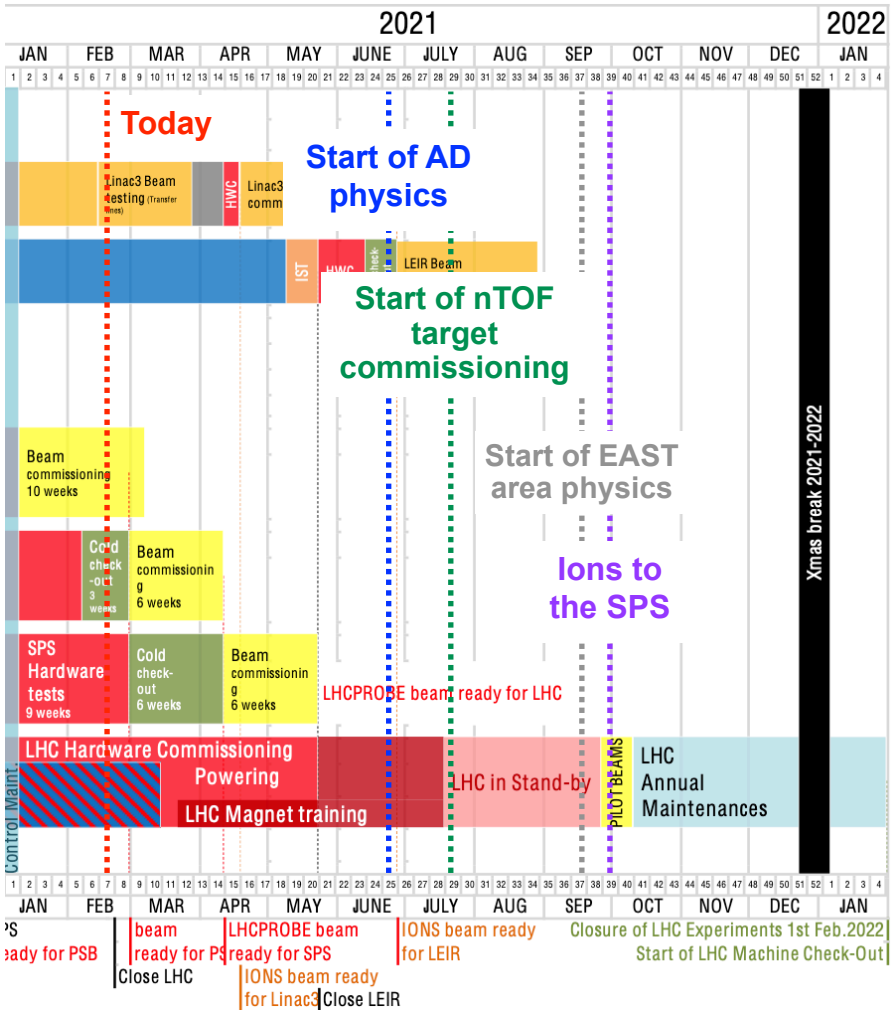
LS2 Master Schedule



- **Commissioning beams for the SPS**
  - LHCIndiv/LHCProbe
  - SFTPRO low intensity (core only)
  - SFTPRO low intensity (5-turn spill)
- **Operational beams**
  - SFTPRO beam for North Area physics
  - Multi-bunch LHC beams for SPS setup and scrubbing

LS2 Master Schedule



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  - SFTPRO beam for North Area physics
  - Multi-bunch LHC beams for SPS setup and scrubbing
  - Sequentially the other PS users will come online

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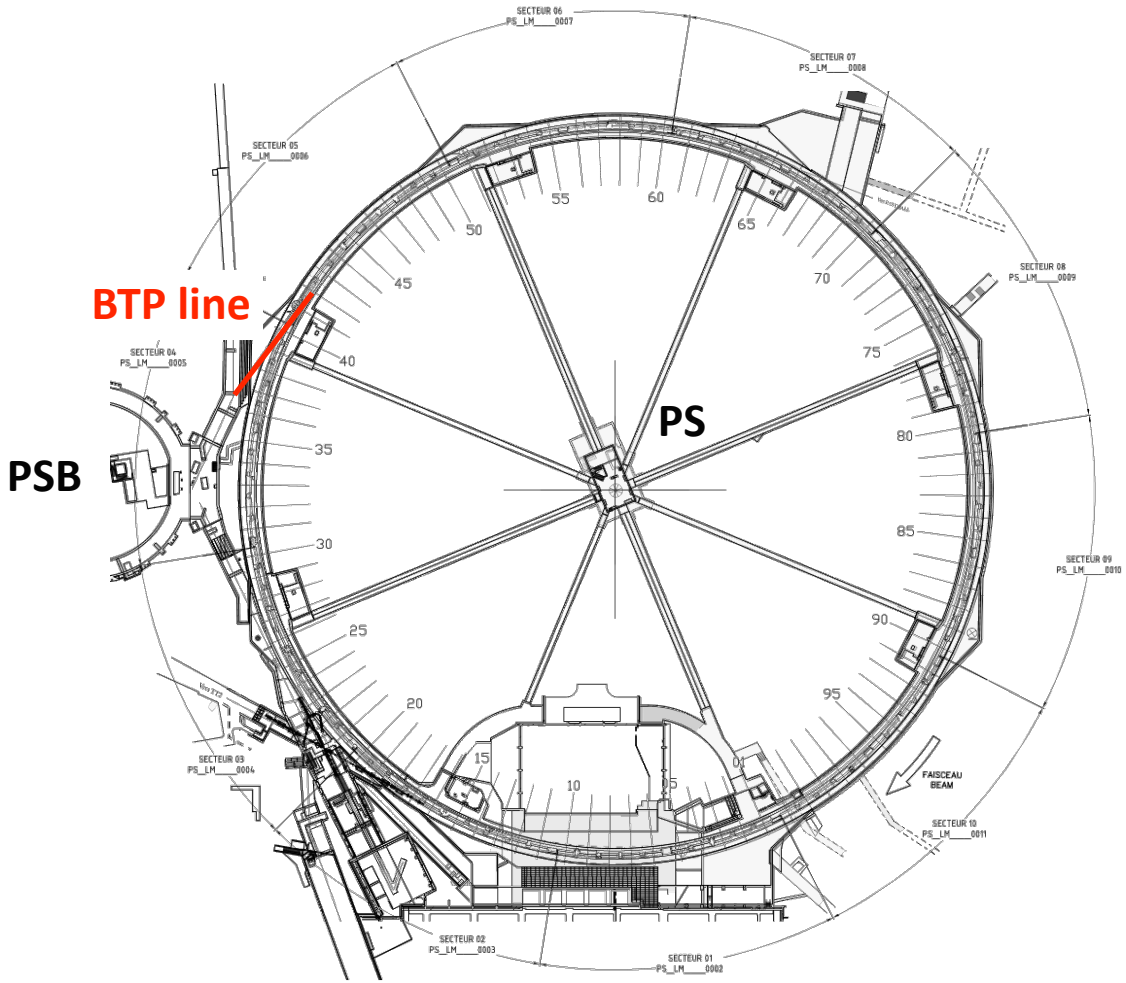
Upgrade of the PS injection systems

- **Upgrade from 1.4 to 2 GeV kinetic energy to mitigate space charge effects for high brightness LHC-type beams**

- **Requires a completely new injection transfer line and injection system in the ring**
  - New transfer line connecting the PSB and the PS to
    - ✳ transfer beams with increased rigidity
    - ✳ improve matching (especially dispersion) between TFL and ring
    - ✳ enable PPM operation
  - New PS injection equipment (septum and injection bumper magnets) compatible with 2 GeV (and 1.4 GeV as fallback solution) operation
  - Upgrade and new installation of beam instrumentation to optimise matching between ring and transfer line and to measure a large range of transverse emittance

New Booster-to-PS (BTP) transfer line



New Booster-to-PS (BTP) transfer line

- Pre-LS2 the BTP quadrupoles were not laminated → no PPM operation possible
  - Enables the possibility of operation with different optics
    - ✳ High-brightness optics
    - ✳ High-intensity optics

W. Bartmann,
EDMS2084600

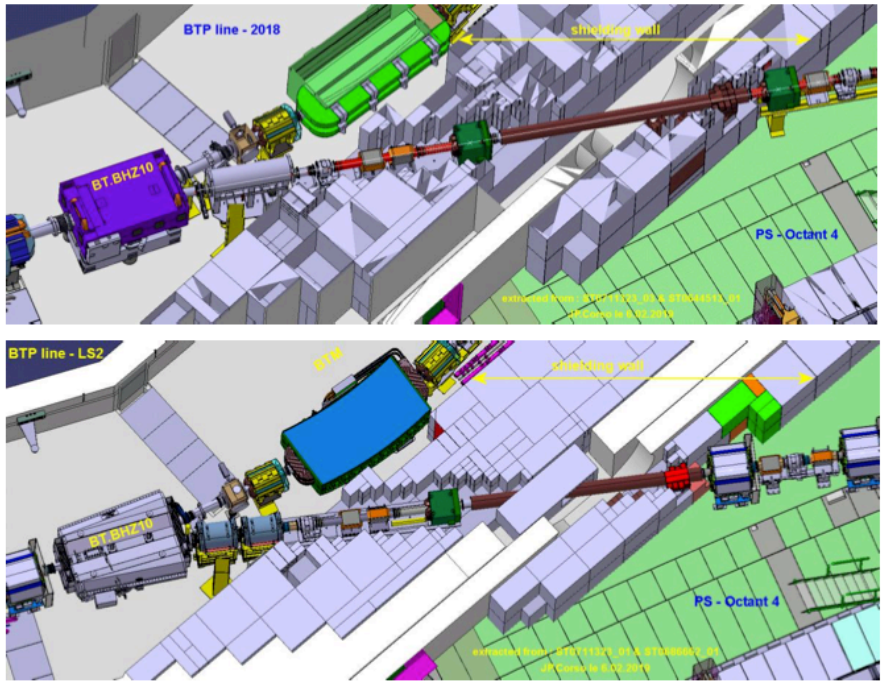


Fig. 4: Separation wall between PSB and PS zones. Minor modifications of the wall on the PS side are required to allow for the enlarged new quadrupole design. The elements inside the wall remain as present since a full understanding of the protection requirements for the wall are missing. RP studies will commence in LS2.

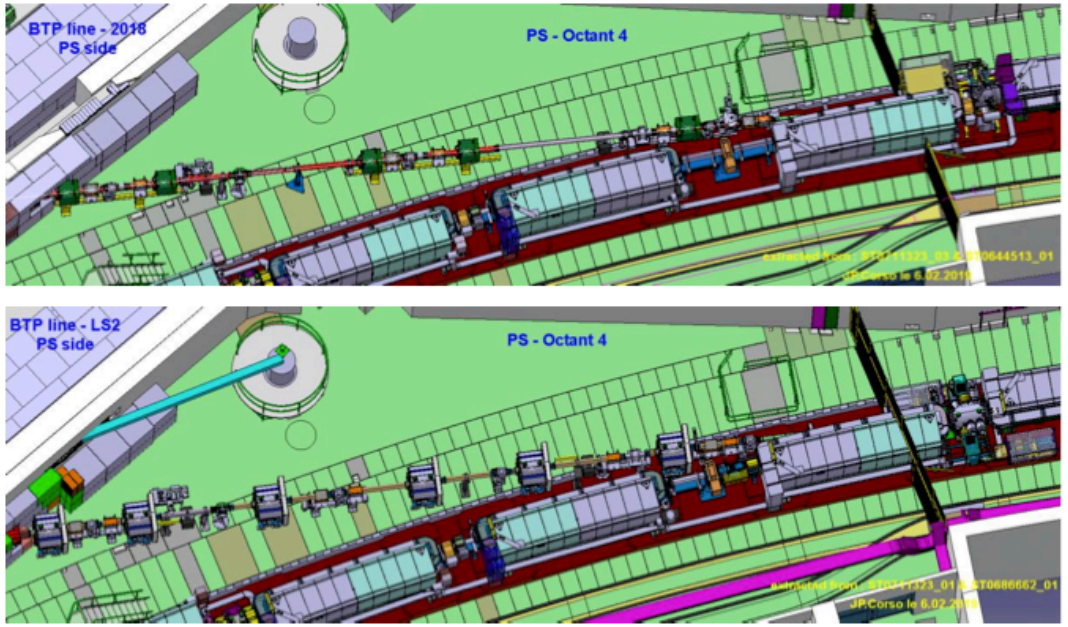


Fig. 3: BTP line configuration 2018 (top) and post LS2 (bottom). Differential layout drawing CDD reference: PSBLJ_UI0041.

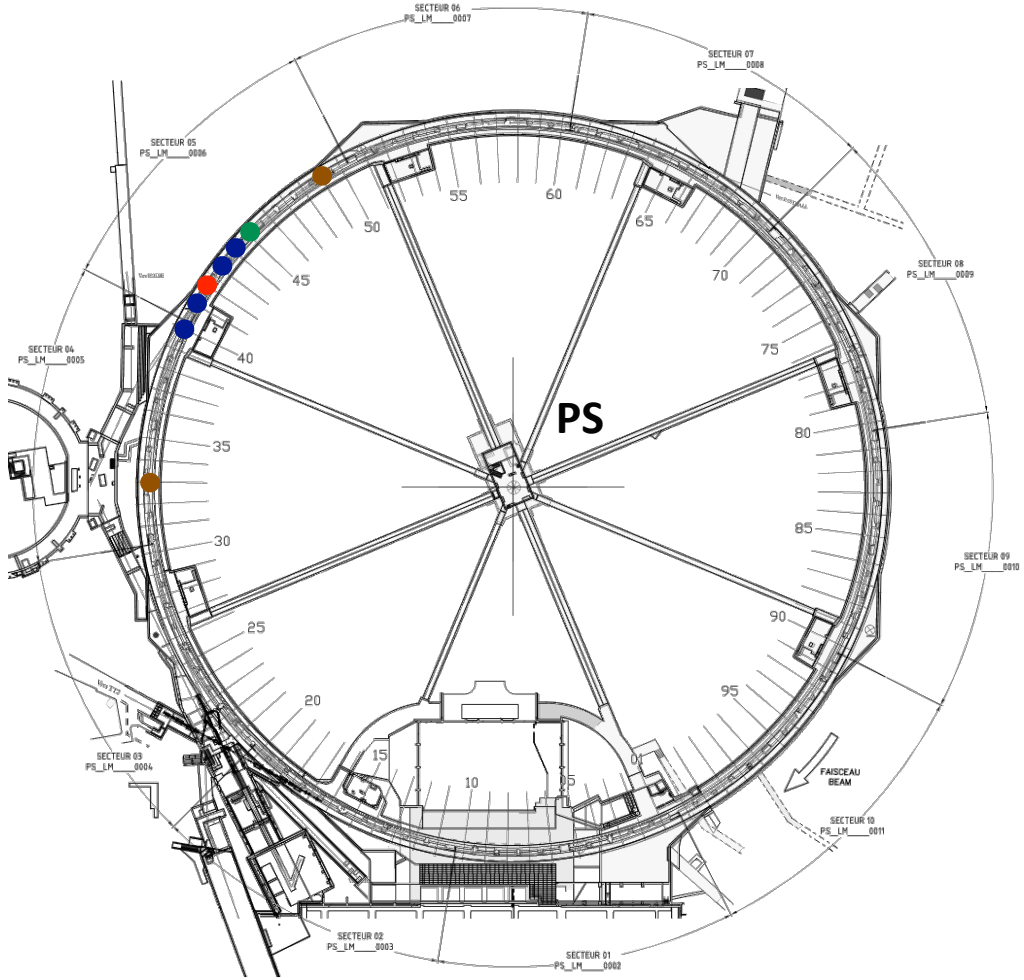
New PS injection elements

Injection septum (including bumper magnet)

Injection bump dipole magnets

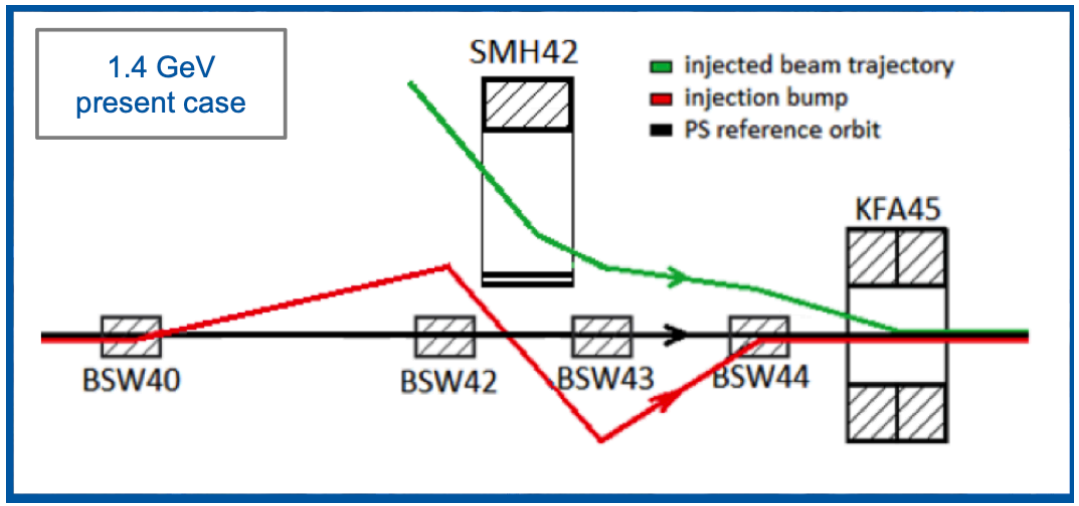
Upgraded injection kicker

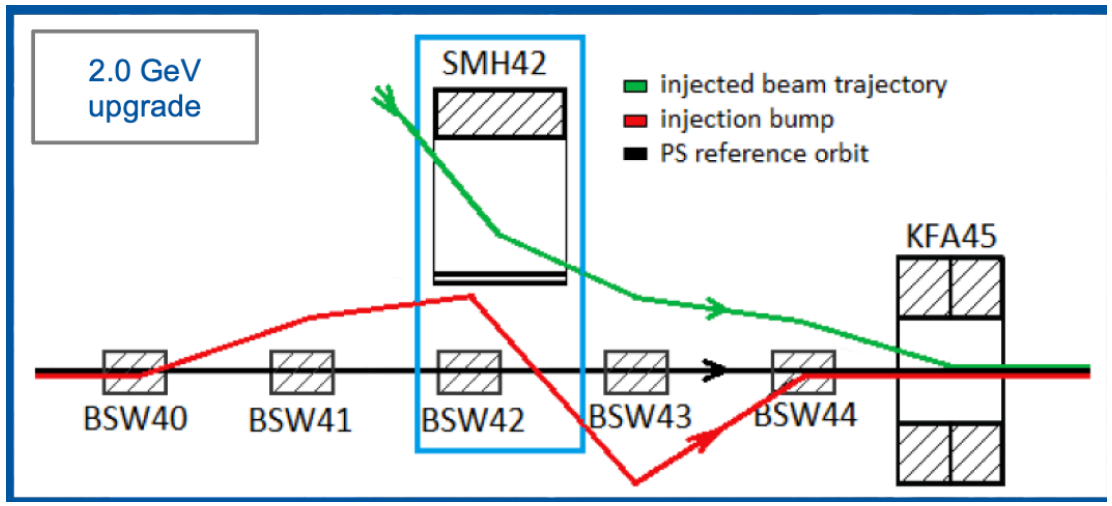
Low-Beta insertion quadrupoles



New PS injection bump

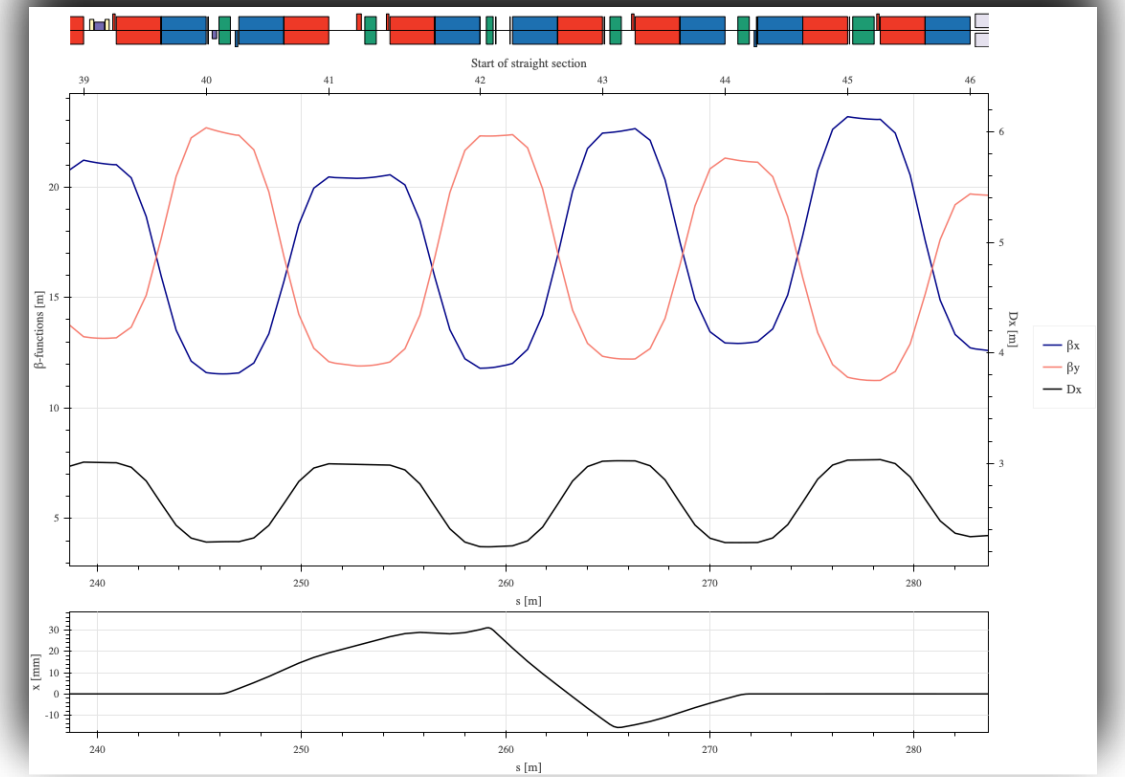
- Additional bumper in SS41 to increase flexibility
- SMH42 and BSW42 in common tank (in-vacuum bumper) → **challenge of synchronisation with conventional magnets**
- Faster bump collapse to avoid aperture restriction in MU43 (0.5 instead of 1 ms)
- **Main commissioning activities**: optimisation of bump closure and synchronisation between all five bumpers



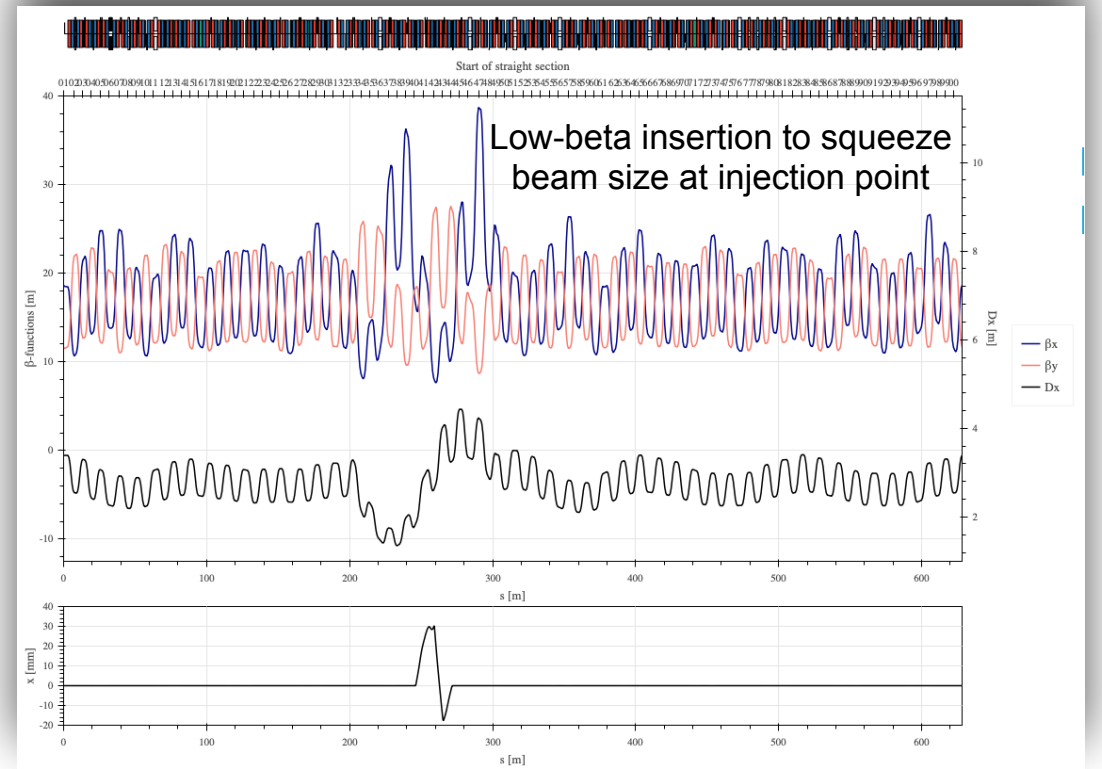


New PS injection optics

High-brightness optics

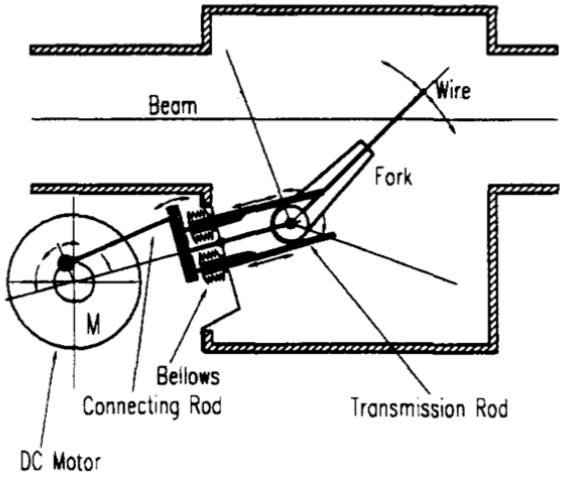


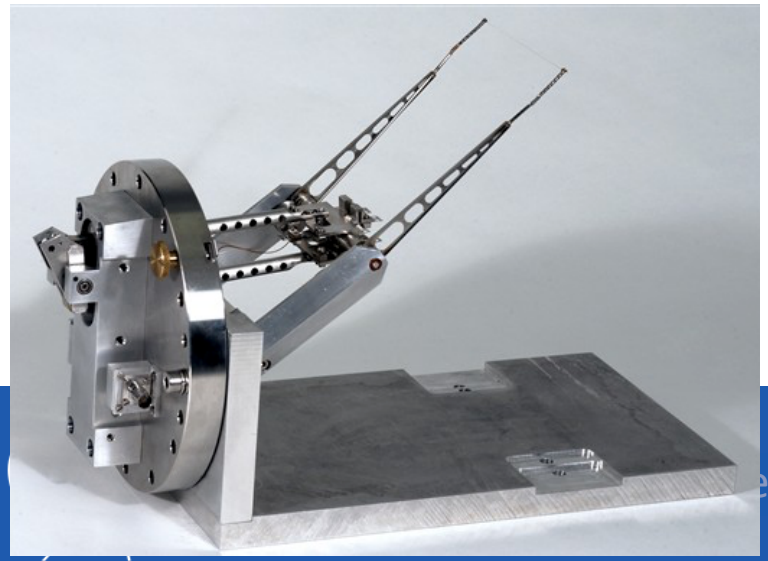
High-intensity optics

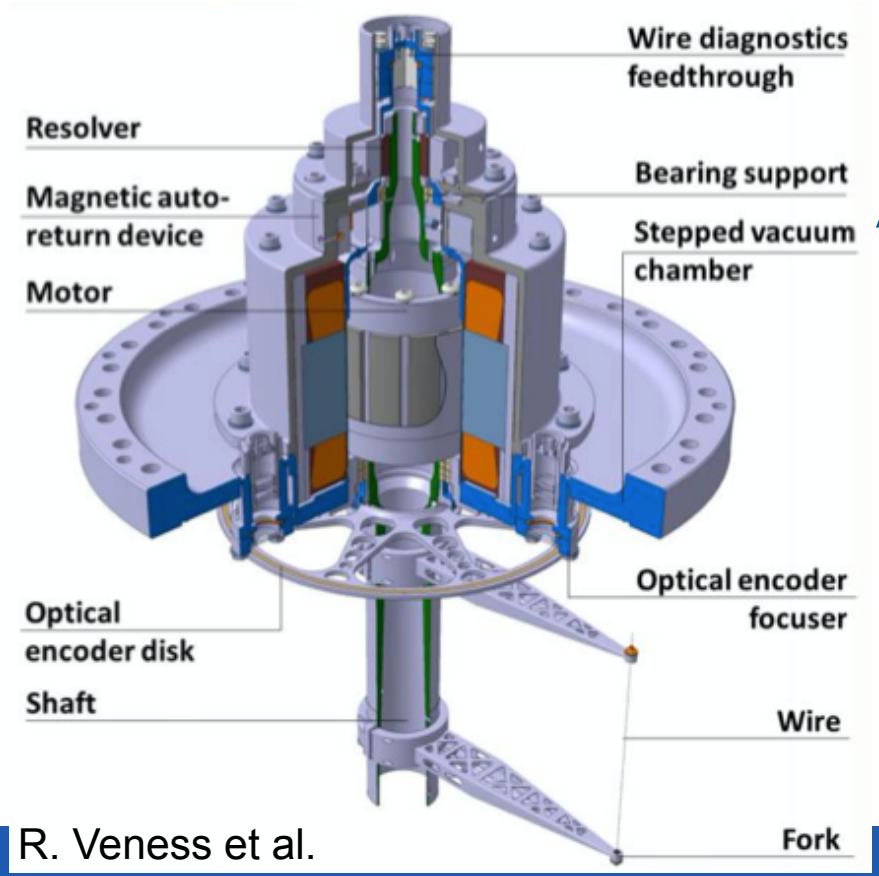


Beam instrumentation

- **Replacement of all five wire scanners by the new LIU-type scanners**







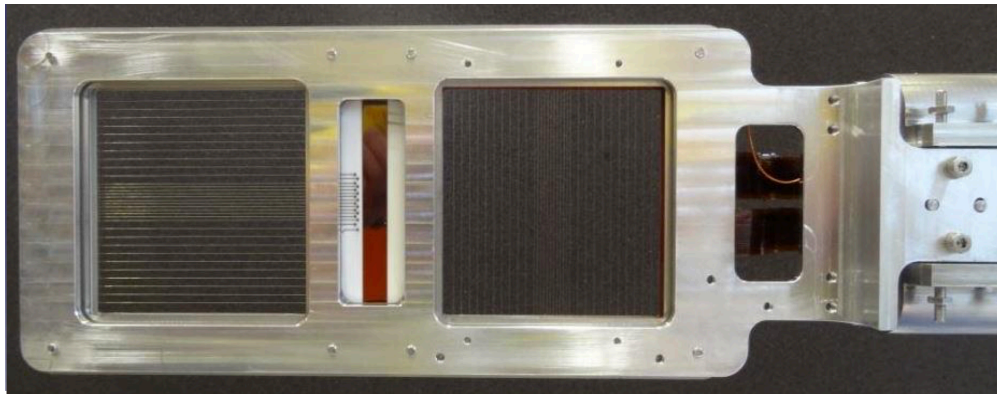
R. Veness et al.

Advantages

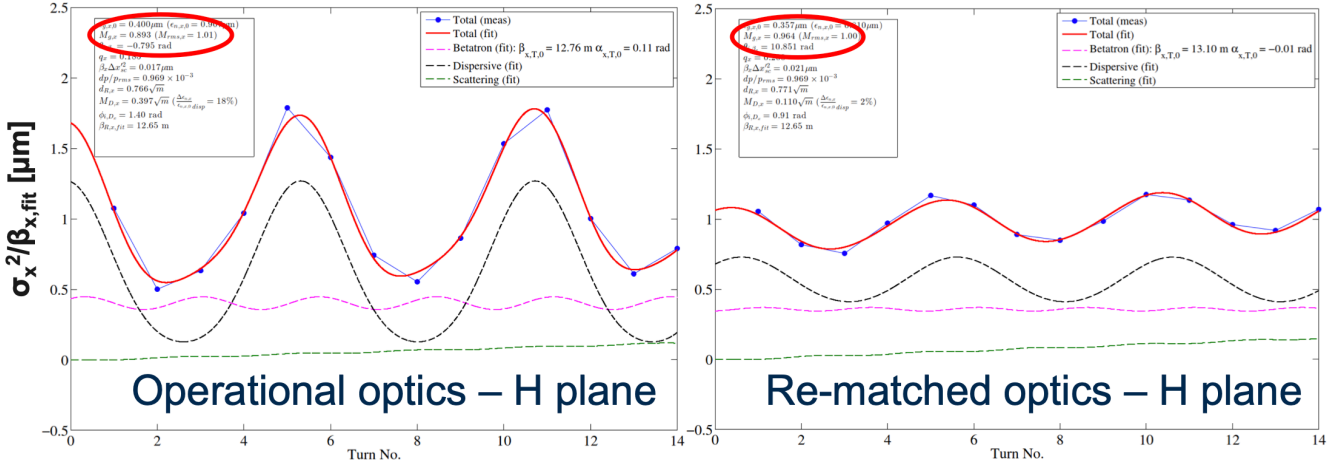
- Improved wire positioning and position measurement
- Moving parts under vacuum
- Common design for all accelerators

Beam instrumentation

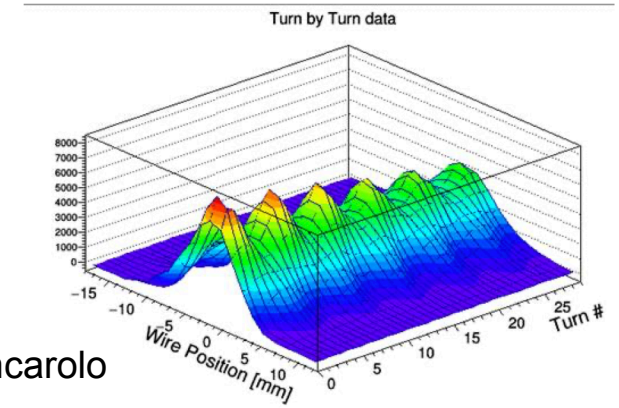
- **Turn-by-turn SEM grids for optics matching**
  - First experience with pre-LS2 prototype device
  - 2018 tests with re-matched TFL clearly showed reduced beating
  - 3 turn-by-turn SEMs installed, but software to be finalised
  - Disadvantages:
    - beam degradation
    - Wire damage after > 100 turns
    - Non-PPM, i.e. only fully dedicated studies possible



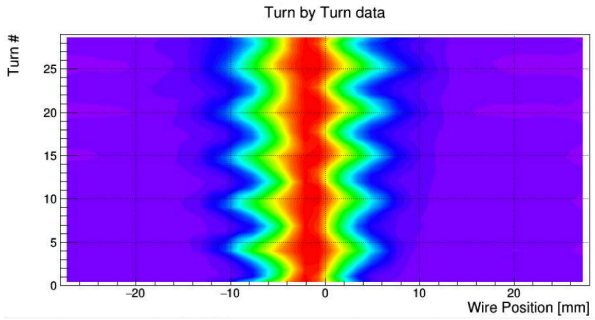
P. Martins



V. Forte,
M. Fraser

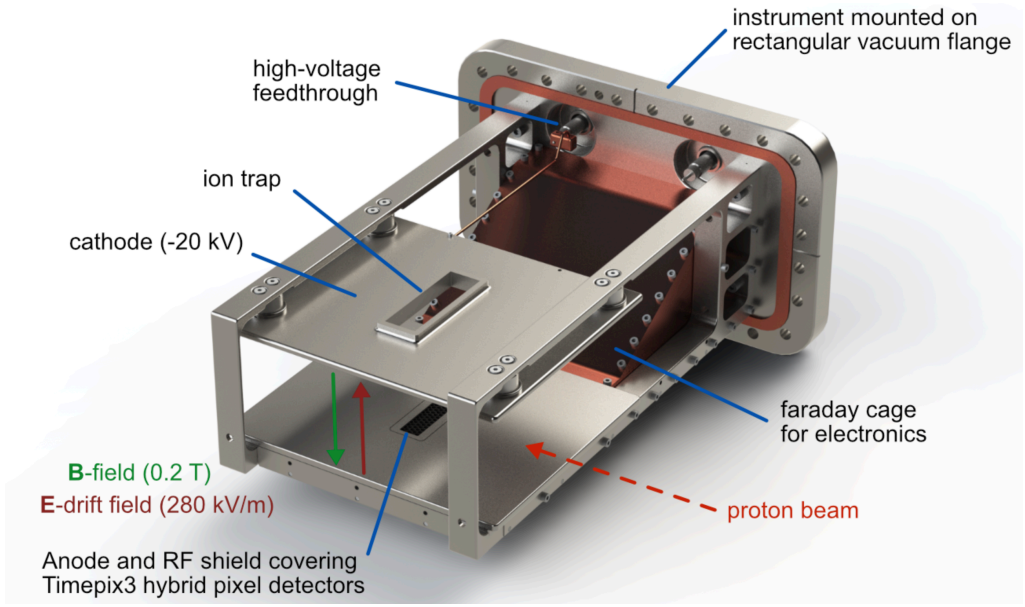


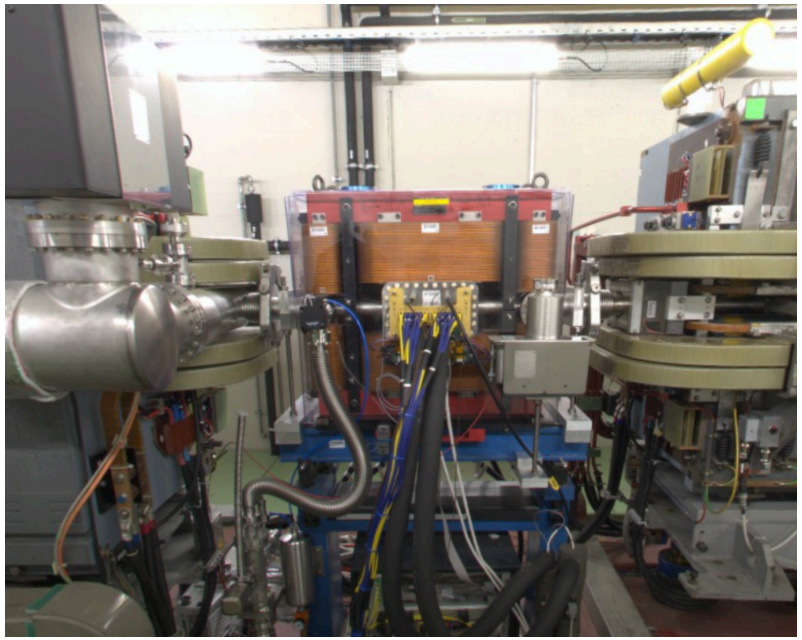
F. Roncarolo



Beam instrumentation

- **Beam Gas Ionisation (BGI) monitor**
  - First use of a pixel detector as beam instrumentation in an accelerator (using an array of **Timepix3** chips)
  - **H and V devices** installed in the PS ring, including **gas injection** systems for turn-by-turn measurements
  - Allows **non-destructive** beam size measurements all along the cycle
  - Closed orbit distortion by the magnet needs to be compensated during the commissioning





J. Storey, S. Levasseur, H. Sandberg

Beam instrumentation

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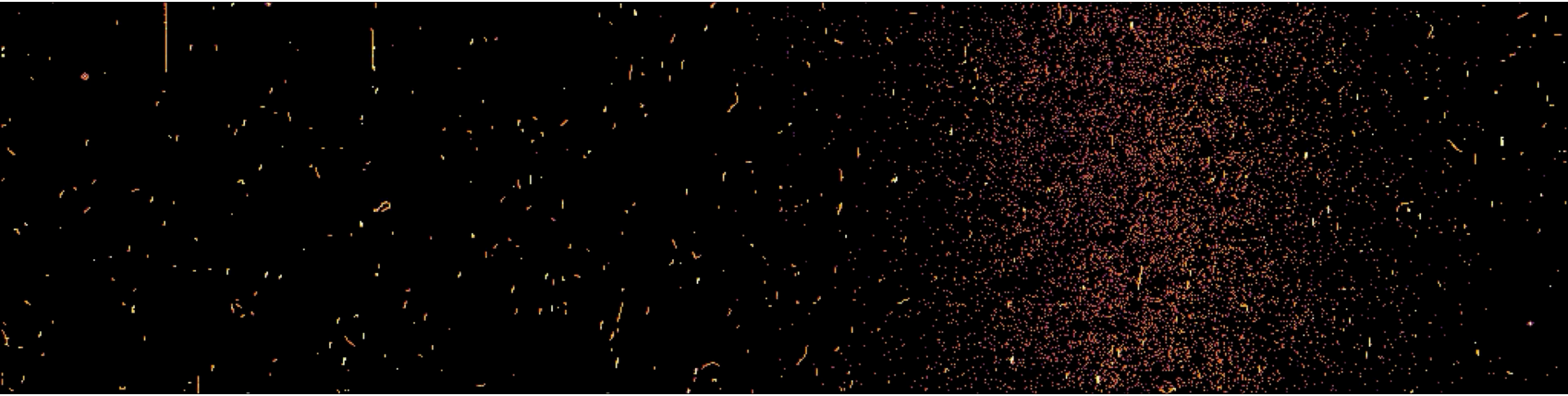

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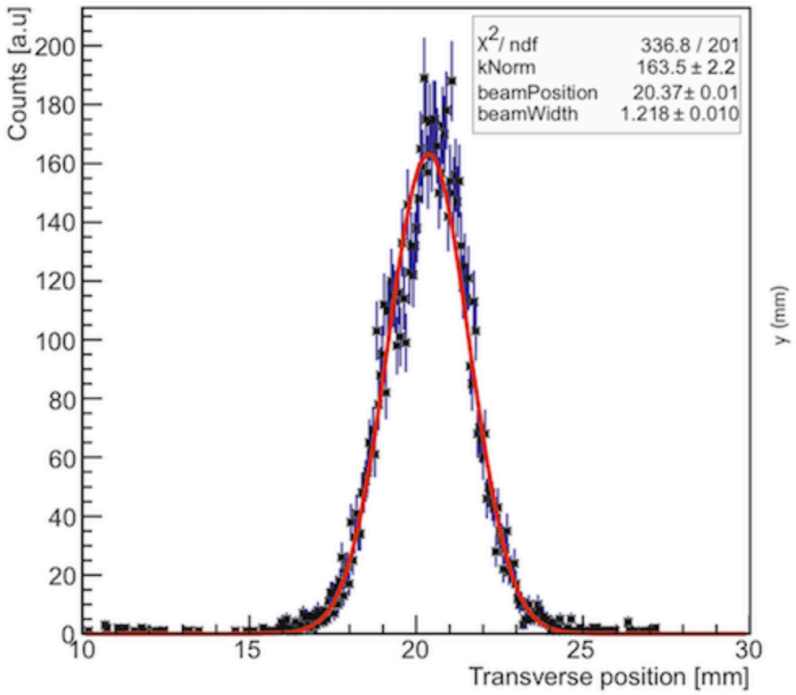
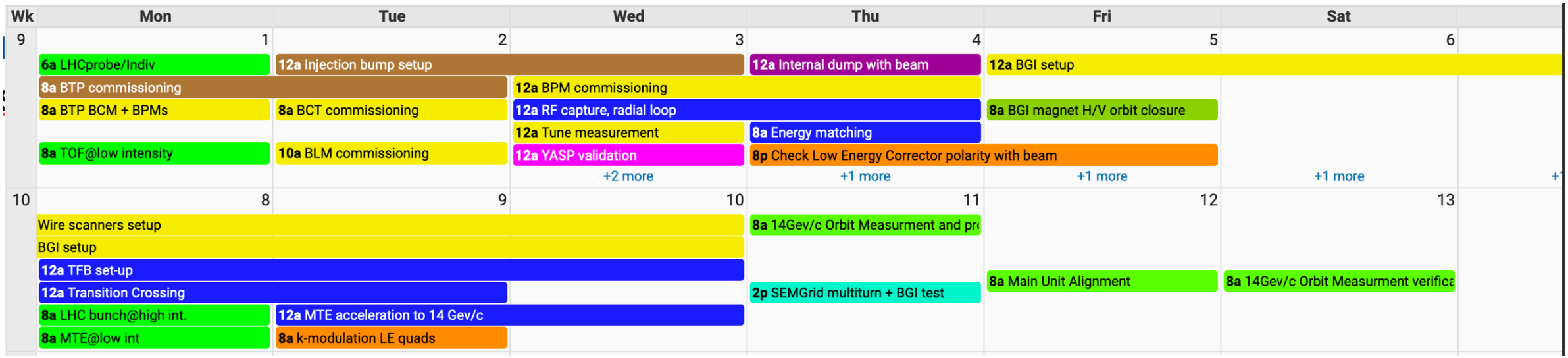
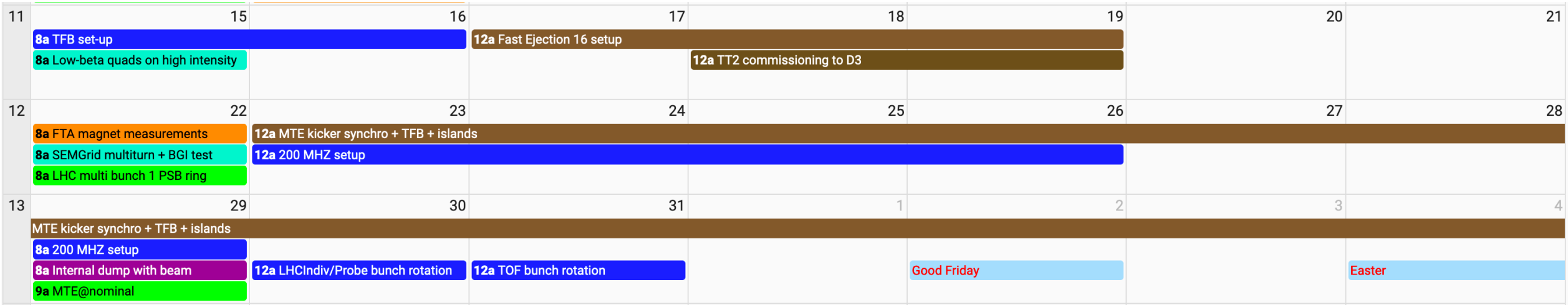


Commissioning planning weeks 9 and 10



- **First two weeks dedicated to**
  - Threading beam through BTP, coarse setup of the injection bump
  - BCT, BPM, BBQ setup
  - RF setup (capture, radial loop, PSB-PS energy matching, transition crossing, TFB)
  - BGI setup (correction of CO distortion + instrument commissioning)
  - Kick response, k-modulation to identify polarity inversions
  - Beam-based alignment at 14 GeV/c (MTE energy - most critical in terms of orbit at extraction)

Commissioning planning weeks 11 to 13



- **Further activities to establish SFTPRO, TOF and LHC single bunch beams**
  - Extraction line setup (kick response, external dump D3 commissioning)
  - MTE setup (transverse splitting, excitation with the TFB, extraction to D3)
  - Bunch rotations on LHC and TOF beams

Commissioning planning after Easter

14	5	6	7	8	9	10	11
	MTE kicker synchro + TFB + islands						
	Easter	**12a** LHC multi-bunch splittings					
	8a LHC multi bunch	**12a** 10 MHz 1-turn delay feed-back					
15	12	13	14	15	16	17	18
	MTE kicker synchro + TFB + islands						
	8a LHCIndiv to SPS		**8a** MTE core only to SPS				
	8a LHC BCMS						
16	19	20	21	22	23	24	25
	MTE kicker synchro + TFB + islands						
17	26	27	28	29	30	1	2
	8a AD					First of May	
	8a LHCprobe to SPS						
	8a MTE low int to SPS						

- **Multi-bunch setup and tuning of beams for the SPS**

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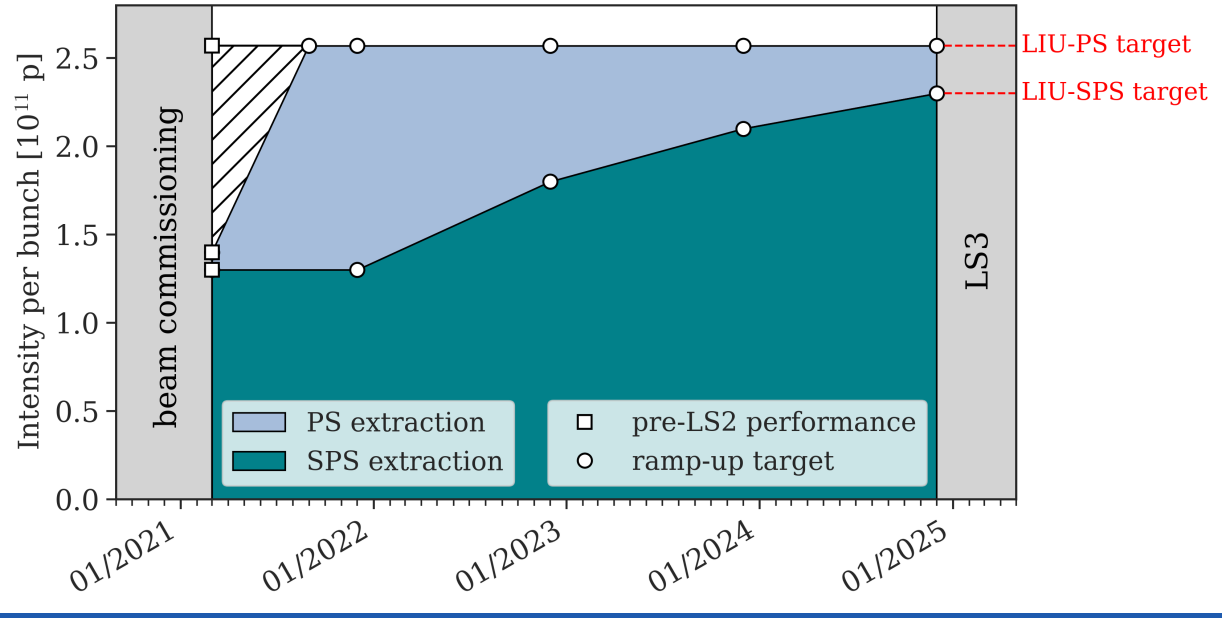
Start of the LIU beam commissioning

- **Two different beams have to be distinguished (and improved in performance) during Run 3**
  - **Standard beam with 72 bunches (HL-LHC baseline)** - gradual performance increase to be carried out in parallel MDs
  - **BCMS with 48 bunches** - operational beam during Run 3, performance increases as work on standard beam continues

- **Two main aspects of the LIU beam performance ramp-up of the standard beam**
  1) Intensity ramp-up → mainly occurring in the SPS
  2) Brightness ramp-up → determined by the PSB and PS performance

- **Intensity reach demonstrated at PS extraction pre-LS2**
  - Recovery of LIU-PS intensity target (2.6x10^{11} p/b) expected by the end of summer 2021 (pre-COVID-19 plan)



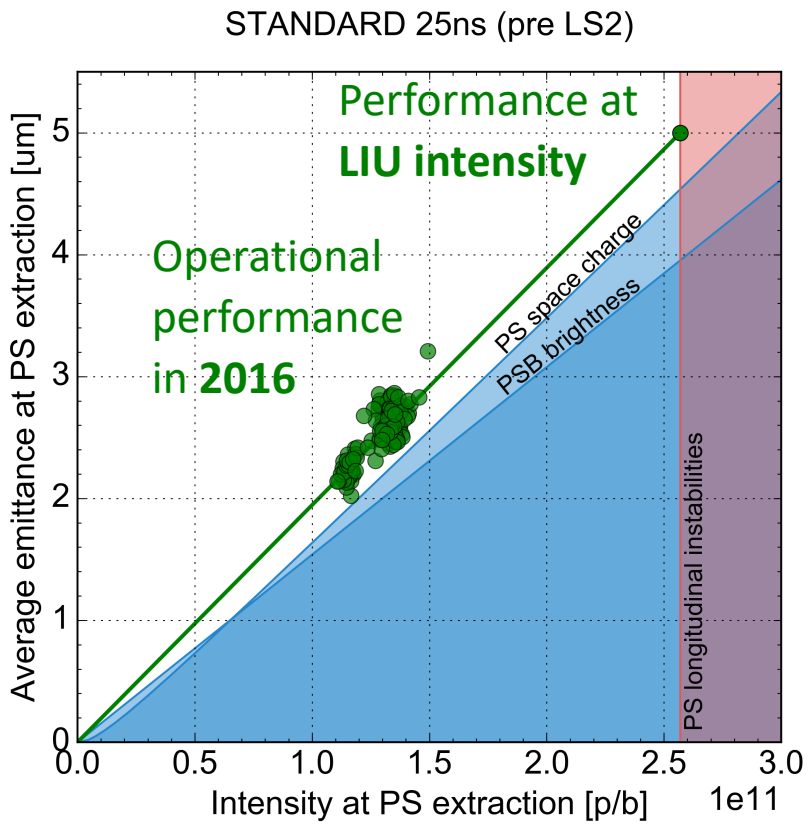
Start of the LIU beam commissioning

- **Brightness ramp-up of the standard beam**
  - Determined by the longitudinal parameters at PS injection
    - Large longitudinal emittance to mitigate space charge on long injection plateau
    - Brightness ramp-up will occur gradually until the end of 2023 to gain experience with these beams

- **2021 target**
  - Assuming that PSB will immediately deliver beams of increased brightness
  - Achievable brightness will be limited by space charge effects on PS flat bottom
  - Longitudinal target parameters for 2021

ε_z [eVs]*	σ_z [ns]*	$\delta p/p$ [10^{-3}]*
1.5	135	1.1

* parameter conventions according to EDMS1296306



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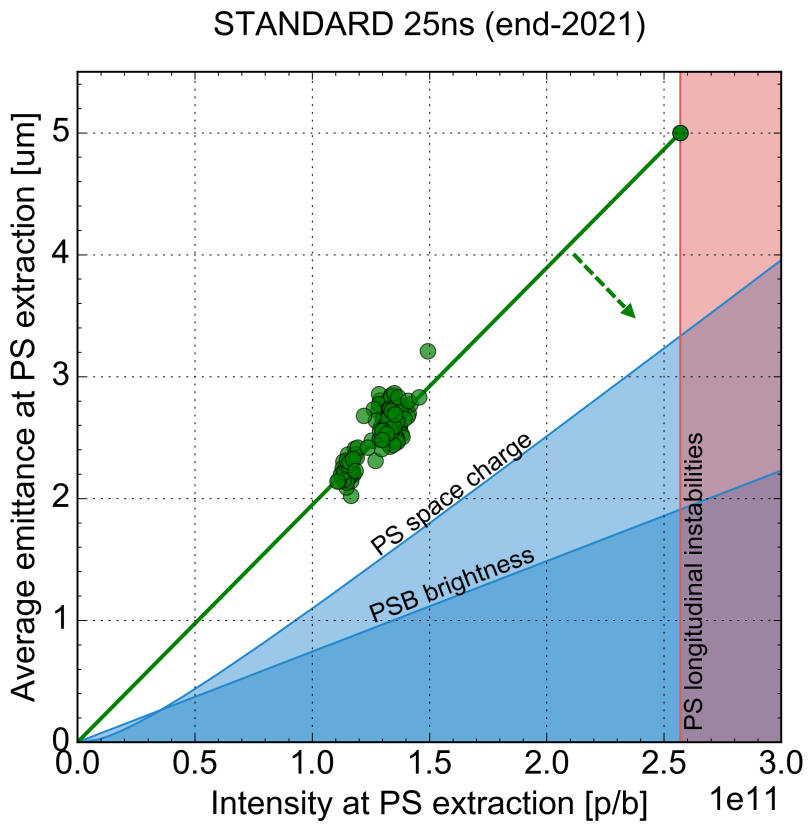

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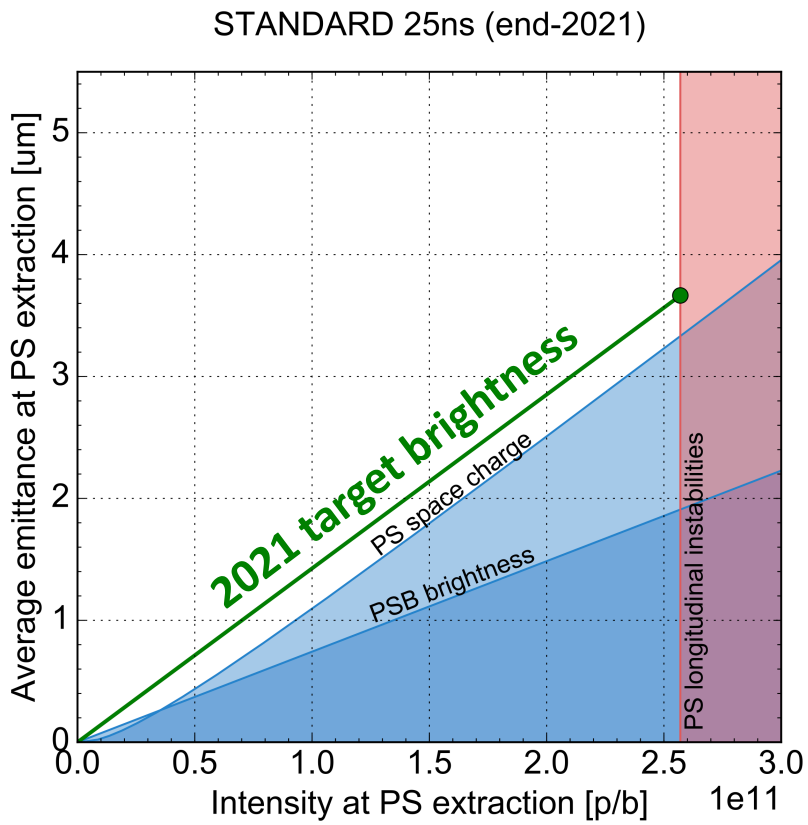

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- **The PS is currently in the "Cold Checkout" period and we expect beam at latest on 1 March 2021**

- **We'll then enter into 6 weeks of "standalone" beam commissioning, during which**
  - the new systems will be commissioned
  - the beams for the SPS will be set up

- **The main upgrades are related to the 2 GeV injection energy upgrade and the RF systems**
  - Commissioning of the TFL, the injection bump and the required beam instrumentation
  - New amplifiers for main accelerating cavities, new multi-harmonic feedbacks to reduce the impedance seen by the beam, etc.

- **By establishing the pre-LS2 beam parameters the LIU project will officially come to an end**

- **Then we'll start into the biggest challenge during Run 3: the LIU beam performance ramp-up!**

Keep fingers crossed and stay tuned for news from the injectors:)!