





LHC Injectors Upgrade

LHC Injectors Upgrade Workshop

Montreux, 13-15 February 2019



LHC Injectors Upgrade

PS Beam Commissioning Schedule

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Many thanks to

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LS2 Master Schedule

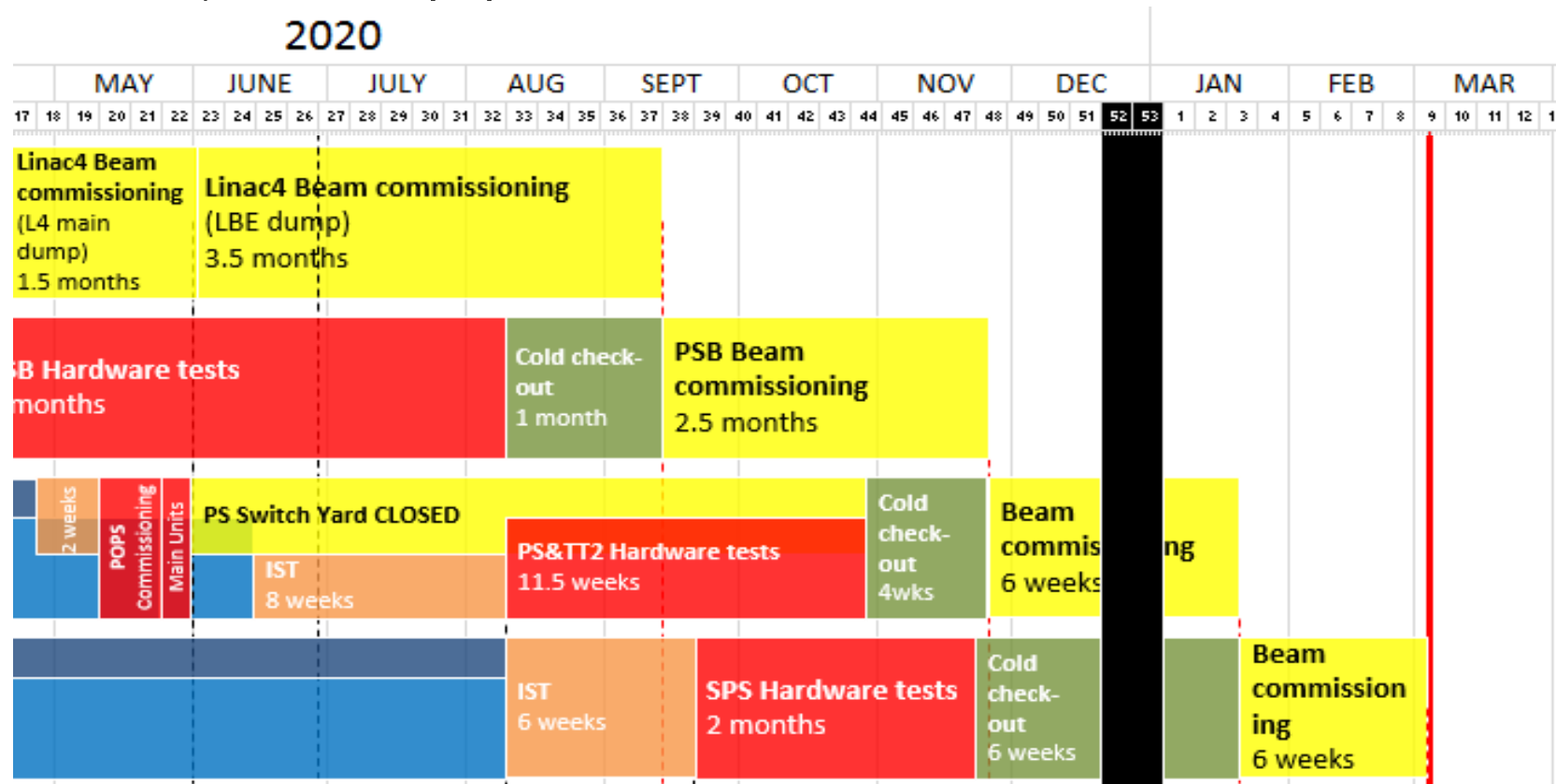
- 6 weeks foreseen for standalone PS beam commissioning
- Interrupted by 2 weeks Christmas shutdown !!!

- Keep services running (CO, water, etc.) => need piquet services
- No lock-out
- Access system by TI
- People's holidays

=> effective 4.5-5 weeks!

- Fast restart examples

- 2010 AMS run
- 2013 Jan restart





Beams required

- **SPS (from week 3/2021) (from K.Li's presentation)**
 - LHCIndiv ($1.2e11$)
 - MTE low intensity (core only, $5e11$, $2\mu s$) after 2 days
 - MTE low int ($5e12$, $10\mu s$) after 1 week
 - LHCProbe after 2 weeks
 - MTE full beam after 3 weeks
 - Multi-bunch beams (12b, 24, 36, 48, 72) after 4 weeks
 - Standard 25ns or BCMS (not big difference for the PS RF)
- **NTOF from week 3/2021 (new target, assume intensity ramp-up later)**
- **AD from week 12/2021 (RF side should follow other beams)**
- **EAST from week 18/2021**



Assumptions / Prerequisites

- **Hardware tests/Cold checkout finished, all possible tests without beam done**
 - New injection equipment (polarity,...)
 - BPM alignment offsets after main unit renovation
 - new RF beam control validated without beam, existing one prepared for beam, 10 MHz cavity phasing
 - Interlocks (new internal dump, interlock when in chamber to PSB extraction BIC + SIS interlock, interlock from BCT (TOF parasitic beam on EAST not extracted), BLM,...)
 - External conditions (will have been renovated), some will have to be done when EIS are working
 - Optics definitions, YASP configuration
 - Magnetic checks of PFW circuits foreseen
- **Injection line PSB->PS commissioned up to BT dump**
 - known Twiss parameters
 - BTP line magnets polarity checks, HW tests done
- **2 GeV injection cycles prepared (had a first check for RF already)**
 - Shorter ramp time needed (~30 ms less)
 - POPS regulation should allow first ramp up modification
- **Plan in DSO tests for SPS, TOF, (AD, EAST later), ...**



Beam commissioning time line I - Injection

▶ Circulating low intensity beam (TOF-like or LHCIndiv)

Week 1

Week 2

Week 3

Week 4

Week 5

Week 6

| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|--------------------|----------------------------|-----------------------------|---------------|---|--------------------|
| Safety chain tests | | | | | 1 day |
| Interlock tests | Ext. conditions, SIS | | New equipment | Ext. conditions renovated | ½ day |
| BTP line | BPM setup Kick response | YASP | | - 30m, 6 quadrupoles - BPM should be like BT line | 2 days |
| BPM commissioning | First turn, orbit | | | | 1 day |
| Injection | Bump setup | YASP, bump closure (MatLab) | New equipment | - Delay and amplitude optimization - Synchronization studies - To be redone after main magnet alignment | 2 days |



Beam commissioning time line I (cont.)

▶ Circulating low intensity beam (TOF-like or LHCIndiv)

Week 1

Week 2

Week 3

Week 4

Week 5

Week 6

| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|---------------------|-------------------------------------|---------------------------------------|--|---|--|
| LE orbit, optics | kick response | YASP | | | 1 day |
| Multi-turn SEM grid | Ralentisseur verification with beam | Analysis tool (to be (re-) developed) | New equipment 1 st prototype successfully tested, 2 more to be commissioned | <ul style="list-style-type: none">- Dedicated time, circulating beam <~30 turns- Essential for injection matching- Time for analysis needed- Maybe several iterations | Interleaved with other tasks 2-3 days (+2 days) |
| BLM system | Interlock | VISTAR (new) | | Works well in the PS ring, higher bandwidth, sensitivity, and no saturation | 1 day |
| MTV | | | | According to progress of beam | In parallel |



Beam commissioning time line I (cont.)

▶ Circulating low intensity beam (TOF-like or LHCIndiv)

Week 1

Week 2

Week 3

Week 4

Week 5

Week 6

| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|---------------------------|---|-------------------|--|--|--|
| RF capture, radial loop | Phase loop lock before injection | | New equipment | <ul style="list-style-type: none">- New RF beam control from the start- Old system kept as much as possible as backup, PPM switch possible- with RF experts | 1-2 days |
| Transverse feedback setup | Optimize damping time of injection oscillations | Analysis scripts | New digital control (similar to PSB) and power amplifier | <ul style="list-style-type: none">- Standard HW-check verification of knob, functions (gain, tune offset), BPM attenuation and gain procedure, kicker response- Commissioning with expert- Essential for MTE and LHC beams | 1-3 days per beam, in parallel with other activities |



Beam commissioning time line II – 14 GeV orbit

► Single bunch beam to 14/26 GeV

Week 1

Week 2

Week 3

Week 4

Week 5

Week 6

| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|---|---------------|--------------------|-------------------|---|---------------------------|
| Transition crossing | | | | RF experts | 1 day |
| Acceleration to 14/26 GeV | | | | RF experts | 1 day |
| Orbit check at 14 GeV for main unit alignment | | Analysis framework | 40 MU refurbished | - Most critical for MTE beam at dummy septum 15 / septum 16 - Consider local orbit when calculating correction - Could require another iteration of main magnet movements | 3 days (+2/3 days) |
| Internal dump | interlocks | | New equipment | | In parallel |
| K-modulation at low energy | | Analysis script | | Low energy quads polarity and optics check | 1 day in parallel |



Beam commissioning time line II

► Single bunch beam to 14/26 GeV

| Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 |
|--------|--------|--------|--------|--------|--------|
|--------|--------|--------|--------|--------|--------|

| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|----------------|--|-------------------|----------------------|--|---------------------|
| Wire scanners | | | New equipment | - Extensive cross-checks done for 54H - Commissioning with BI experts | 10 days in parallel |
| BGI | H/V BGI magnet effect on orbit | Application | New equipment | - with experts - Non-critical | ? in parallel |
| TT2 extraction | - Shadowing TPS15/SMH16 - Bumper optimization - QKE16 (except MTE) | Diamond BLMs | Bumper new equipment | - Final setup for all other beams after MTE shadowing | 2-3 days |
| TT2 setup | Kick response | YASP, BPMs | | | 1 day |
| | Twiss parameters | SEM grids | | | 1 day |
| TOF -> D3 dump | | | | | |



Beam commissioning time line III

▶ Christmas shutdown

| Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 |
|--------|--------|--------|--------|--------|--------|
|--------|--------|--------|--------|--------|--------|

| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|---|--|-------------------------|-------------------------------|--|--------------------|
| 200 MHz setup | | | New system (old as backup) | - Blowup for high-intensity beams - 8e12 needed - At least 2 days for cavity setup | 5 days |
| Start MTE core/islands | Synchronisation MTE kickers KFA4/9/13/21 | Q-meter Wire scanner | | TFB excitation mode setup | |
| Make machine safe for Xmas shutdown | | | | | 1 day |



Beam commissioning time line IV

LHCIndiv/probe and TOF ready



Week 1

Week 2

Week 3

Week 4

Week 5

Week 6

| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|--|-----------------------------------|-------------------|----------------|---|--------------------|
| Restart and recover previous commissioning state | | | | - Piquet and equipment experts need to be available | 2-3 days |
| Finalize LHCIndiv, LHCprobe and TOF | Bunch rotation 40/80 MHz cavities | | New controller | RF expert needed | 1 day |
| Continue MTE setup | TT2 trajectories by turns | | | | 1 day |
| BLM thresholds | | | | For higher intensity beam | In parallel |



Beam commissioning time line V

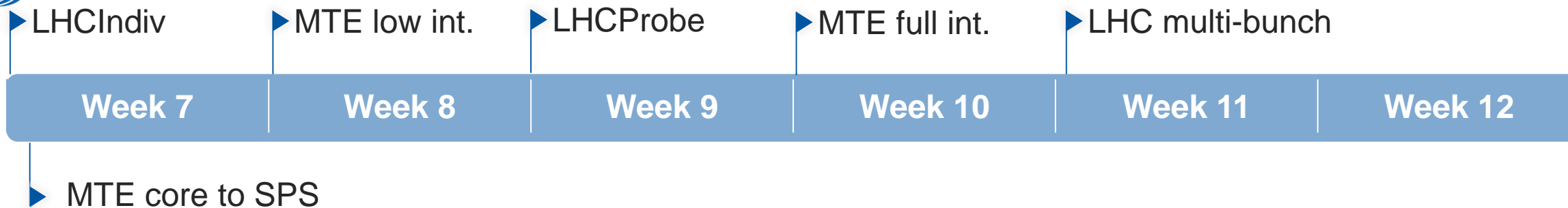
MTE ready 

| Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 |
|--------|--------|--------|--------|--------|--------|
|--------|--------|--------|--------|--------|--------|

| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|-----------------------------|----------------------------------|-------------------|----------------|------------------|--------------------|
| Start multi-bunch LHC setup | 20 MHz 40/80 MHz cavities | | New controller | RF expert needed | 2-3 days |
| | 10 MHz 1-turn delay feed-back | | | For multi-bunch | 2 days |



Non-standalone commissioning – beam for SPS/nToF



| Activity | Related tasks | Tool requirements | Risks | Remarks | Estimated duration |
|-------------------------------|-------------------|-------------------|-------------------------------------|---|--------------------|
| Finalize MTE setup | Loss optimization | | - Intensity limit - Many systems | 2e13 higher than 2018 operation | ? |
| Finalize multi-bunch LHC beam | RF splitting | | | 12, 24, 36, 48, 56, 72 bunches 25ns, BCMS Priorities/order to be detailed | |



Remarks

- Equipment groups work mainly during daytime, it would be essential to have the **beam commissioning coordinators** also **on normal working hours** (at least during the first 6 weeks of the start-up).
This would improve communication and would help everybody to keep up with planning changes according to the technical progress
- **Expert availability** needs to be arranged shared with other machines
- **More time needed between TOF/EAST beam permits and physics start!**
 - Had delays on the experimental zone readiness this year -> delayed beam permit
- **Reference magnet**
 - measurement system dis-/reassembled
 - Setup with eddy current compensation card in reference magnet (was not present this year)



Conclusion

- **Hardware commissioning progress very important**
- **Christmas shutdown needs to be incorporated as well as possible**
 - Reduces effective time
- **A lot of new essential equipment / instrumentation needs to be commissioned**
 - RF beam control
 - Transverse feedback
 - bumpers
 - Wire scanners, BGI
 - Multi-turn SEM grids
 - Internal dumps, ralentisseur, external conditions
- **Should be able to get the required beams ready in time for the SPS if there are no major hiccups**



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