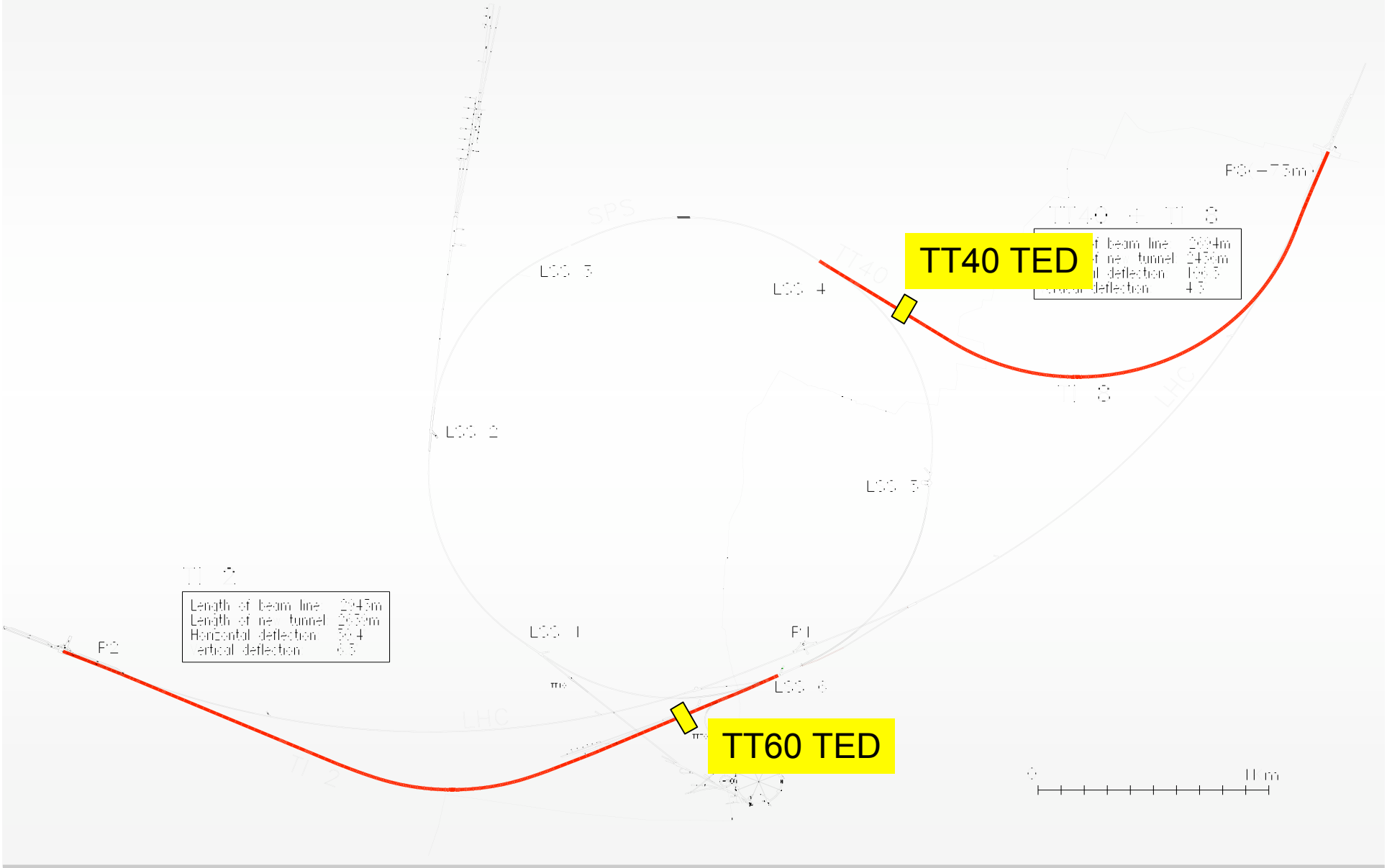
# LSS4/6 and TT40/60 beam commissioning

- Organisation and responsibilities
- Preparation and procedures
- Results from the test
- Technical and organisational issues arising

# LSS4/TT40 and LSS6/TT60



# Main objectives in 2007

- **1st August 2007**
  - Low-intensity interleaved TT40/TT60 beam extraction and measurements
  - Preparation for low intensity TI 2 (and TI 8) tests
- **26th September 2007**
  - High-intensity LHC beam commissioning of LSS6 and TT60
  - Interleaved extraction of high-intensity LHC beam 1 and beam 2 to TT60 and TT40

# Organisation and responsibilities

- **Overall coordination by BT (BG)**
  - In LHC terms : only EiCs and System Commissioners
- **Commissioning team : the people doing TT40, TT60 and TL commissioning since 2003**
    - 2003 – LSS4 and TT40 beam commissioning
    - 2004 – LSS4 high intensity and TI 8 beam commissioning
    - 2006 – TT40 collimator tests and LSS6/TT60 commissioning
    - 2007 – TT40/60 high intensity interleaved and TI 2 commissioning
  - OP, equipment and technical support groups fully involved
    - B.Balhan, E.Carlier, L.Ducimetiere, B.Goddard, M.Gourber-Pace, A.Macpherson, J.Ridewood, B.Todd, J.Uythoven, Heinz Vinke, J.Wenninger, M.Barnes, E.Calvo Giraldo, P.Collier, D.Forkel-Wirth, M.Grill, E.Hatziangeli, L.Jensen, R.Jones, V.Kain, T.Kramer, G.Kruk, A.Koschik, D.Manglunki, V.Mertens, E.Metral, B.Puccio, G.Roy, Helmut Vincke, N.Gilbert
  - Dry-runs and machine ‘checkout’ managed by OP (VK and JW)
  - Scheduling issues dealt with directly with OP (PC)

# Preparation #1

- **Meetings and documentation**
  - Coordination meetings once per month, for 6 months before the test
    - Almost identical pattern in 2006 for first LSS6/TT60 beam tests
    - Factor ~3 less than in 2003 for first beam tests. Less time, more knowledge…
  - Simple web documentation
    - Main objectives
    - Dry run plans and schedule
    - Action/issue list
    - Test programmes / procedures
    - Expert lists
    - Safety-related information
    - Useful documentation (drawings, optics files, …)
      - This last part was only partially complete due to lack of time / resources / priority to do a proper job

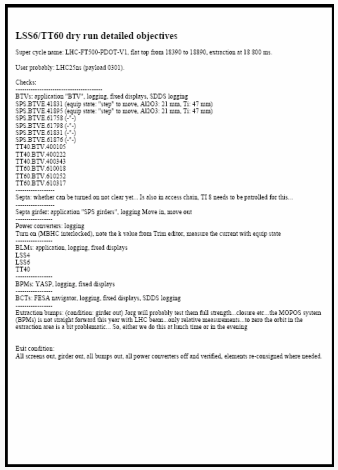
# Preparation #2

- **Follow-up**
  - Tasks, actions, issues etc. by ad-hoc web pages
  - OK for this small scope
  - Need a better system if more complexity

| What | Who | Status |
|---|---|---|
| Access system test with MKE in final configuration | James | done |
| Scheduling of dry-runs | Verena/Elias/Brennan | done |
| Definition of new extraction settings | Verena/Thomas | done |
| Beam instrumentation inventory and status | Lars | done |
| New TT60 BPMI electronics installed & tested | Lars/Rhod | done |
| Locking-off extraction elements during regular operation | Brennan/Joerg | not needed |
| High level application SW inventory and status | Mike/Eugenia | done |
| Proton numbers expected on TEDs | Brennan | done |
| Timing/prepulse/user/destination concept & tests | Mike/Joerg/Verena/Etienne | done |
| SPS intensity interlock | Joerg/Brennan | as per 2006 |
| RP issues and formalities | Heinz/Helmut | as per 2006 |
| BIC system test procedures and tests | Bruno/Joerg | as per 2006 |
| Optics measurements and tools | Joerg/Verena/Alex | as per 2006 |
| Shot-by-shot logging data and Fixed-Display requirements | Verena | done |
| Screen matching application | Verena | done |
| MSE transformer repair | PO (M.Royer) | done |
| Check need for test description document | Brennan | done |
| Acceptance test of MKE system at final voltage/pulse length | Mike B | done |
| Test operator CCC switches | Bruno P/Jorg | done |
| Detailed test breakdown | Brennan | done |
| Retour d'experience from 2006 for INB doc | Brennan | done (draft) |
| Test of all aspects with beam1/beam2 LHC cycle | Jorg | done (not MKE) |
| MAD-X extraction & TT40/TT60 sequence with aperture in db | Verena | done |
| Prepulse reception check | Etienne | done |
| MKE pulsing in remote from CCC | Etienne/Jorg | done |
| New FMCMs | Bruno P | done |
| TAG42 door acceptance test | Manfred Grill | done |
| Modify MKE to go to standby for extraction inhibit | Etienne | done |
| Test SW interlocks | Jorg | done |
| Decision on MKE4 interlock actions | Etienne | *pending* |
| Test of FMCMs with magnets | Jorg/Ben | *pending* |
| Confirmation of the TPSG intensity limits | Bruno | done |
| Test date to 26th September? | Brennan | *pending* |
| Dry run planning | Brennan | *pending* |
| Access system prepration details | James | *pending* |
| | | |
| **Bugs from test #1** | . | . |
| Pre-test checklist for cooling and power supplies | Brennan | *pending* |
| MSE delay and sum fault interlock tests | Jorg | *pending* |
| Modification of TT40 BLM thresholds - and back for CNGS | Heinz | *pending* |
| Logging checks for BPKs and MKE kick waveforms | Marine | *pending* |
| Follow-up of BTV problems | Brennan/Anna | *pending* |
| Decision on MKE4 interlock actions | Etienne | *pending* |
| Screen matching application | Verena | *pending* |

# Procedures

- **Test “Procedures” defined and used**
  - Worked out with OP and equipment groups
  - al checking or approval…
  - es adhered to (problems solved ad-hoc)



**LSS6/TT60 dry run detailed objectives**

Super cycle name: LHC-PT500-PDOT-V1, flat top from 18360 to 18890, extraction at 18 800 ms.

User probably: LHC25ns (psyland 0301).

Checks:

---

BTVs: application "BTV", logging, fixed displays, SDDS logging
SPS.BTVE.41831 (equip state "inej" to move, ADJ3: 21 mm, T1: 47 mm)
SPS.BTVE.41895 (equip state "inej" to move, ADJ3: 21 mm, T1: 47 mm)
SPS.BTVE.41798 (-/-)
SPS.BTVE.61831 (-/-)
SPS.BTVE.61876 (-/-)
TT40.BTV.400105
TT40.BTV.400320
TT40.BTV.400343
TT60.BTV.610018
TT60.BTV.610253
TT60.BTV.610317

---

Septa: whether can be turned on not clear yet… Is also in access chain, TI 8 needs to be petrolled for this…

---

Septa girder: application "SPS girders", logging Move in, move out

---

Power converters: logging
Turn on (MSHC interlocked), note the k value from Trim editor, measure the current with equip state

---

BLMs: application, logging, fixed displays
LSS4
LSS6
TT40

---

BPMs: YASP, logging, fixed displays

---

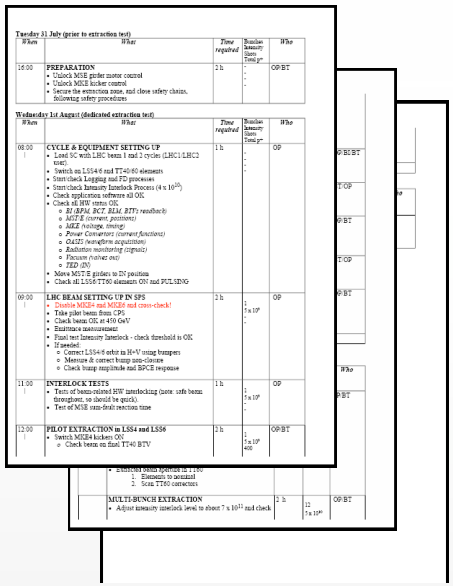
BCTs: FBSA navigator, logging, fixed displays, SDDS logging

---

Extraction bumps: (condition: girder out) Jorg will probably not them full strength…closure etc…the MOPOS system (BPMs) is not straight forward this year with LHC beam…only relative measurements…to zero the orbit in the extraction area is a bit problematic… So, either we do this at lunch time or in the evening

---

Exit condition:
All screens out, girder out, all bumps out, all power converters off and verified, elements re-consigned where needed.

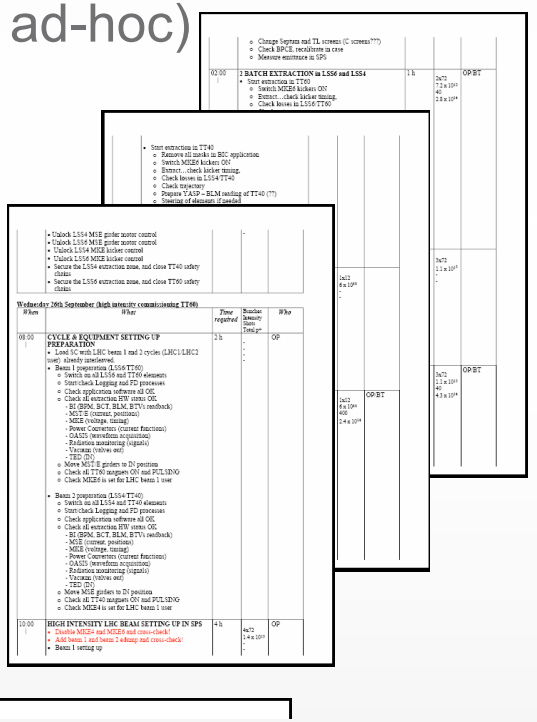


**Tuesday 31 July (prior to extraction test)**

| When | What | Time required | Bunches Intensity Alarm Total p+ | Who |
|---|---|---|---|---|
| 16:00 | **PREPARATION**<br>• Unlock MSE girder motor control<br>• Unlock MSE kicker control<br>• Secure the extraction zone, and close safety chains, following safety procedures | 2 h | - - - | OP BT |

**Wednesday 1st August (dedicated extraction test)**

| When | What | Time required | Bunches Intensity Alarm Total p+ | Who |
|---|---|---|---|---|
| 08:00 | **CYCLE & EQUIPMENT SETTING UP**<br>• Load SC with LHC beam 1 and 2 cycles (LHC1/LHC2 tune).<br>• Switch on LSS4.6 and TT40/60 elements<br>• Start check Logging and FD processes<br>• Start check Intensity Interlock Process (4 x $10^{10}$)<br>• Check application software all OK<br>• Check all HW status OK:<br>o *BI (BPM, BCT, BLM, BTV's readback)*<br>o *MST-E (current, positions)*<br>o *MSE (voltage, timing)*<br>o *Power Converters (current functions)*<br>o *OASIS (waveform acquisition)*<br>o *Radiation monitoring (signals)*<br>o *Vacuum (valves out)*<br>o *TED (IN)*<br>• Move MST-E girders to IN positions<br>• Check all LSS6-TT60 elements ON and PULSING | 1 h | - - - | OP |
| 09:00 | **LHC BEAM SETTING UP IN SPS**<br>• Enable MSE4 and MSE6 and cross-check!<br>• Take pilot beam from CPS<br>• Check beam OK at 450 GeV<br>• Emittance measurement<br>• Final low Intensity Interlock - check threshold is OK<br>• If needed:<br>o Correct LSS4-6 orbit in H+V using bumpers<br>o Measure & correct bump non-closure<br>o Check bump amplitude and BPCE response | 2 h | - $7 \times 10^{9}$ - | OP |
| 11:00 | **INTERLOCK TESTS**<br>• Tests of beam-related HW interlocking (note: safe beam throughout, so should be quick).<br>• Test of MSE non-first-turn time | 1 h | - $7 \times 10^{9}$ - | OP |
| 12:00 | **PILOT EXTRACTION in LSS4 and LSS6**<br>• Switch MSE4 kickers ON<br>o Check beam on final TT40 BTV | 2 h | - $7 \times 10^{9}$ 400 | OP BT |
| | • Extract beam (pilot) in TT40<br>1. Elements to nominal<br>2. Scan TT60 correctors | | | |
| | **MULTI-BUNCH EXTRACTION**<br>• Adjust intensity interlock level to about $7 \times 10^{11}$ and check | 3 h | 12 $7 \times 10^{9}$ | OP BT |



- Change Septum and TL screens (C screens???)
- Check BPCE, recalibrate in case
- Measure emittance in SPS

| | | | | |
|---|---|---|---|---|
| 02:00 | **2 BATCH EXTRACTION in LSS6 and LSS4**<br>• Start extraction in TT60<br>o Switch MSE6 kickers ON<br>o Extract…check kicker timing<br>o Check losses in LSS6-TT60 | 1 h | 2x72 $7 \times 10^{9}$ 40 $2.8 \times 10^{11}$ | OP BT |

• Start extraction in TT40
- o Remove all masks in BIC application
- o Switch MSE6 kickers ON
- o Extract…check kicker timing
- o Check losses in LSS4-TT40
- o Check trajectory
- o Prepare YASP – BLM reading of TT40 (??)
- o Insertion of elements if needed

• Unlock LSS4 MSE girder motor control
• Unlock LSS6 MSE girder motor control
• Unlock LSS4 MSE kicker control
• Unlock LSS6 MSE kicker control
• Secure the LSS4 extraction zone, and close TT40 safety chains
• Secure the LSS6 extraction zone, and close TT60 safety chains

**Wednesday 26th September (high intensity commissioning TT60)**

| When | What | Time required | Bunches Intensity Alarm Total p+ | Who |
|---|---|---|---|---|
| 08:00 | **CYCLE & EQUIPMENT SETTING UP**<br>**PREPARATION**<br>• Load SC with LHC beam 1 and 2 cycles (LHC1/LHC2 tune), already interleaved.<br>• Beam 1 preparation (LSS6-TT60)<br>o Switch on all LSS6 and TT60 elements<br>o Start check Logging and FD processes<br>o Check application software all OK<br>o Check all extraction HW status OK<br>- BI (BPM, BCT, BLM, BTVs readback)<br>- MST-E (current, positions)<br>- MSE (voltage, timing)<br>- Power Converters (current functions)<br>- OASIS (waveform acquisition)<br>- Radiation monitoring (signals)<br>- Vacuum (valves out)<br>- TED (IN)<br>o Move MST-E girders to IN position<br>o Check all TT60 magnets ON and PULSING<br>o Check MSE6 is set for LHC beam 1 user<br>• Beam 2 preparation (LSS4-TT40)<br>o Switch on all LSS4 and TT40 elements<br>o Start check Logging and FD processes<br>o Check application software all OK<br>o Check all extraction HW status OK<br>- BI (BPM, BCT, BLM, BTVs readback)<br>- MSE (current, positions)<br>- MSE (voltage, timing)<br>- Power Converters (current functions)<br>- OASIS (waveform acquisition)<br>- Radiation monitoring (signals)<br>- Vacuum (valves out)<br>- TED (IN)<br>o Move MSE girders to IN position<br>o Check all TT40 magnets ON and PULSING<br>o Check MSE4 is set for LHC beam 1 user | 2 h | - - - | OP |
| 10:00 | **HIGH INTENSITY LHC BEAM SETTING UP IN SPS**<br>• Enable MSE4 and MSE6 and cross-check!<br>• Add beam 1 and beam 2 setup and cross-check!<br>• Beam 1 setting up | 4 h | 4x72 $1.4 \times 10^{11}$ - | OP |

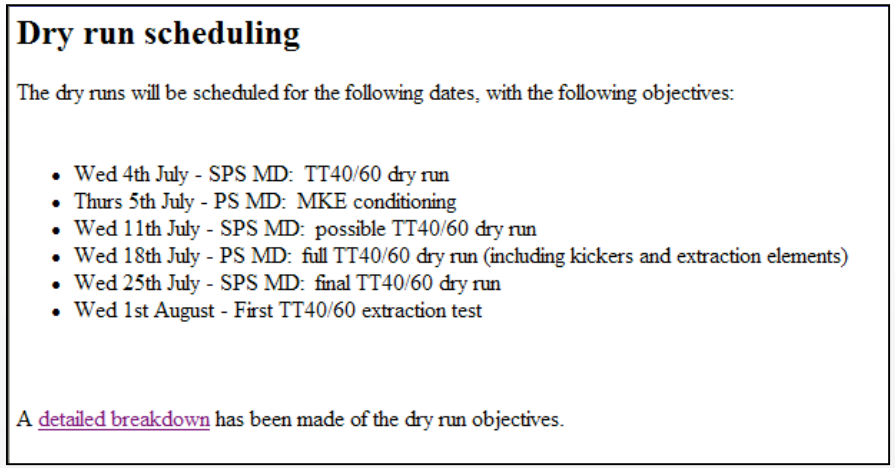
Dry runs

1st August
low intensity

26th September
high intensity

# Scheduling

- **Test schedule changed about 3 times…**
  - Knock-on from delay/cancellation of TI 2/TI 8 tests
  - Ended up with 8 week gap between low and high intensity dates
- **Dry-runs were difficult to accommodate**
  - Need real machine cycle to be really useful
  - Difficult to deploy in parasitic way during other MD
  - Lots of limitations coming from access, EIS, kickers, …
  - Maybe more useful to apportion real machine time (3-4h)



**Dry run scheduling**

The dry runs will be scheduled for the following dates, with the following objectives:

- Wed 4th July - SPS MD: TT40/60 dry run
- Thurs 5th July - PS MD: MKE conditioning
- Wed 11th July - SPS MD: possible TT40/60 dry run
- Wed 18th July - PS MD: full TT40/60 dry run (including kickers and extraction elements)
- Wed 25th July - SPS MD: final TT40/60 dry run
- Wed 1st August - First TT40/60 extraction test

A detailed breakdown has been made of the dry run objectives.

# Test program & overview – low intensity 01/08/07

| | |
|---|---|
| PREPARATION | OK (but missed cooling water off in TT40) |
| | |
| CYCLE & EQUIPMENT SETTING UP | OK |
| PILOT LHC BEAM SETTING UP IN SPS | OK |
| INTERLEAVED PILOT EXTRACTION | OK |
| INSTRUMENTATION CHECKS | OK |
| KICKER WAVEFORM MEASUREMENT | OK |
| STEERING AND OPTICS CHECKS | OK |
| QFA418/618 FIELD MEASURMENT | Skipped |
| | |
| RECOVERY | OK |
| | |
| *OPTIONAL: APERTURE CHECKS* | *Skipped* |
| *OPTIONAL: MULTI-BUNCH EXTRACTION* | *Skipped* |

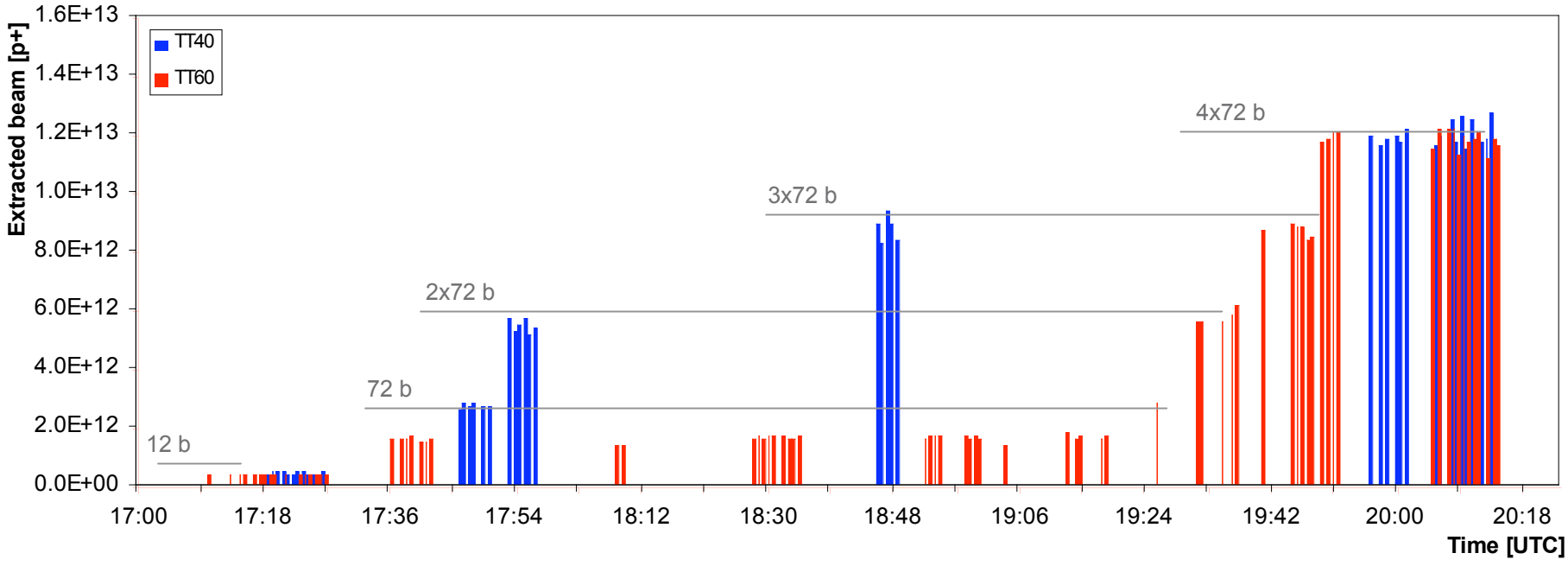
**Remark: no chance to do any of the low priority or optional stuff**

# Test program & overview – high intensity 26/09/07

| | |
|---|---|
| PREPARATION | OK |
| | |
| CYCLE & EQUIPMENT SETTING UP | Problem with TT60 magnet functions |
| HIGH INTENSITY LHC BEAM SETTING UP IN SPS | OK |
| HIGH INTENSITY CIRCULATING BEAM INTERLOCK TESTS | OK |
| PILOT LHC BEAM SETTING UP IN SPS | Problems with pilot beam setting-up |
| PILOT INTERLEAVED EXTRACTION | OK |
| SWITCH TO INTERMEDIATE (12b) BEAM | OK |
| INTERMEDIATE INTERLEAVED EXTRACTION | OK |
| INTERMEDIATE EXTRACTED BEAM INTERLOCK TESTS | OK |
| SWITCH TO 1 BATCH (1x72b) BEAM | OK |
| 1 BATCH INTERLEAVED EXTRACTION | Problems with BTVs, BCT, BPCKs in TT60 |
| SWITCH TO 2 BATCH (2x72b) BEAM | OK |
| 2 BATCH INTERLEAVED EXTRACTION | OK |
| SWITCH TO 3 BATCH (3x72b) BEAM | OK |
| 3 BATCH INTERLEAVED EXTRACTION | OK |
| SWITCH TO 4 BATCH (4x72b) BEAM | OK |
| 4 BATCH INTERLEAVED EXTRACTION | OK |
| SIMULATED LHC INTERLEAVED FILLING SEQUENCE | OK |
| | |
| RECOVERY | OK |

# Increasing extraction intensity…

- **Procedure : increase bunch number (12→72 →1,2,3,4x72) and $I_{tot}$**
- **Looked OK with 12b intermediate beam**
- **Too a "break" for 1.5 hours spent with 72b in TT60 to sort out BCT (reading low)**
  - Problem was MKE prepulse kick delay, needed 2 turns adjustment
  - Diagnostics made complicated by, unfamiliar BTV screen shots from MST and MSE in LSS6, Sporadic BPCK readings from couplers in the TT60 line, no BLMs in TT60.



# Interlocking

- **"Full" HW interlocking system for LSS4/6 and TT40/60**
  - Missing still the "master" BICs configured with OR logic
  - All active inputs included (FMCMs, extraction elements, bump positions, SPS intensity limit, WIC, BTV positions, magnet currents, beam loss, vacuum, TEDs, …, …)
- **Some SW interlocking also deployed**
  - Magnet status, extraction element status, …
- **Both gave excellent results**
  - Good availability once system was set up with pilots.
  - Good diagnostics in case of interlock condition (easy to trace origin).
  - Interlocks stopped some extractions, for good reasons (e.g. vertical instability caused losses in MSE, latched next cycle).
- **Few issues discovered**
  - Some adjustment of bumped beam tolerance needed (BPCE noise in LSS6…)
  - MUGEF comparison did not take current sign into account – gave false "OK" when we had wrong current sign on MDLH (polarity switch) due to way we ran with 2 cycles…found with low intensity beam…!

# Technical issues from low intensity 1/08/07

## Fixed on the day

- No cooling water in TT40 at start of test – improve checking procedure.
- 2 TT40 corrector power supplies still 'consigned' at start – improve checking procedure
- Threshold on TT40 rad.mon interlock too low (CNGS access settings)
- MSE4 strength needed increasing by ~15 urad per magnet – known issue (but forgotten)

## Fixed before high-intensity test

- Large (6 um) SPS beam emittance (from PS) changed to nominal of 3.5 um
- MST/E 6 interlock delay needed adjusting – done and tested.
- MSE4 sum fault signal not working – fixed and tested.
- No logging of TT60 BPCKs - control system / logging config mismatch – config maintenance
- Logging of OASIS MKE waveforms not working.
- LSS6 BTVE screens giving poor images –tunnel CCD boxes radiation damaged and replaced.
- TT40 BTV40343 knocked out by first shot – camera was replaced.
- Application SW bugs for MKE control (and MSE girders?) – not sufficiently tested
- Access system: TAG42 + TT41 not “closed” mode – last minute access reception

## Pending or non-issues

- Interlocks on the beam1 cycle inhibited the next beam 2 cycle
- EMC/extraction kicker pulse seen on TT40/60 BCT measurement
- Screen matching fitting routine to be updated

# Organisational issues

- **Dry runs and preparation deployment still crucial**
  - Could have been improved: some (small) problems could have been avoided.
    - Equipment not ready (especially extraction kickers)
    - Difficult to make parasitically on other SPS cycles
  - Would make life much easier to allocate some real machine time for this
    - 1 or 2 periods of 3-4 hours?
  - 2008 - still intend coordinating these by ‘system’ with OP and “HWC” - reporting?
- **The clear and simple definition of responsibility helped**
  - Balance between pre-defined test programme ↔ leaving OP/experts do what they do best
  - Still some ad-hoc problem solving, twiddling, parallel activities, …
  - Still not obvious how this will work in CCC for LHC operation
    - Coordinators + System commissioners + CiCs + EiCs + HWCiCs
  - Needs a control freak in charge…
- **Only the usual suspects from OP/LHCCWG involved**
  - Those already working for some years with BT and SPS machine protection
  - Difficult to get others involved into well-established setup
    - Has to be said we did not try very hard, as the bases were covered

# Outlook for 2008 from BT systems

- **Things to be done for/in 2008**
  - Operations to take over SPS extractions as “commissioned”
    - Final interlock system (Master BICs) available, installed and tested
    - Modifications to MKE6 PFN to improve flat-top
    - Investigate a few outstanding instrumentation issues
    - Rationalisation of logging for parameters in two extractions
    - Interleaved extraction and LHC injection sequencing
  - SPS to LHC transfer lines commissioned with high intensity
    - Build on 2003 – 2007 experience, so far organised by LTI
  - Commission LHC injection systems
    - Dry runs started, so far organised by OP
  - Commission LHC beam dump system
    - Now finalising ISTs and HWC – moving to reliability run and CCC
    - Dry runs planned for week 7 onwards, so far organised by LBDS
  - Commission LHC MKQA system

# Some concluding remarks/issues

- **The general organisation for TT40/60 was OK**
  - It worked, we didn't break anything, no fisticuffs, …
  - Small scale and manageable (but some sense of working in a vacuum…)
  - Only limited "diffusion" to general LHC commissioning team
- **More effort can be made to prepare tests**
  - Documentation (drawings, optics, reference information, …)
  - Dry runs beefed up (real scheduling in the accelerator programme?)
- **What method should be used for follow-up?**
  - Many issues and open actions arise – how to keep track?
- **Maintenance of logging configuration gave difficulties**
  - Who is responsible for this? Equipment groups? End-users?
- **Simple and clear responsibility was useful in the CCC**
  - Especially when decision points arise, procedures needed to be adapted
  - Doubly especially when decisions were needed on MP issues.
- **Any plans for 2008 for "operational phase" of LHCCWG?**
  - e.g. More "real time" coordination of transition from HWC to Checkout & OP?
  - Or carry on as we are? (LBDS / LTI / LHCCWG / LTC / HWC / ABSIS / LSA)