Machine protection for CNGS : commissioning & operation

J. Wenninger AB-OP

- Description
- Commissioning & testing : selected topics
- Operation : the good, the bad and the ugly
- Conclusions

Acknowledgements :
Etienne, Nicolas, Verena, Rossano, Ben, Bruno (x2), Rudiger, Vitaly, Markus, Alexandre, Michel, Lars, Stephen, Stephane (x2), Thierry, Mathieu, Alessandro & many others

CNGS interlock system

The commissioning and operation of the CNGS extraction interlock that will be presented today consists of :

- 4 Beam Interlock Controllers (BICs) connected to an EXTRACTION_PERMIT loop.
  - 2 BICs (CIBC.TT40A/B) handle interlocks associated to the SPS LSS4 and to the TT40 transfer line.
  - 2 BICs (CIBC.TT41A/B) handle interlocks associated to the TT41 transfer line and to the CNGS target area.
  - There is no MASTER BIC in 2006.
- 31 USER_PERMITs (and associated CIBUs…):
  - 11 un-maskable USER_INPUTs
  - 20 maskable USER_INPUTs
- The EXTRACTION PERMIT signal is provided to the extraction kicker (MKE). Extraction is only allowed when EXTRACTION_PERMIT = TRUE.

BICs & User signals

CIBC.TT40A	CIBC.TT40B	CIBC.TT41A	CIBC.TT41A
Vacuum TT40	OP Inhibit (CCC button)	Vacuum TT41	TBSE TT41
WIC TT40	TED TT40	WIC TT41	CNGS Shutter
MKE status	BTV TT40	TT41 PC	T40 Target
MSE magnet + girder	BLM TT40	Main Bend PC	BTV TT41
TT40 PC	BPM LSS4	Main Bend DCCT	BLM TT41
MSE PC	Beam Intensity	FMCM MBSG	BPM TT40+TT41
Bumper PC	**SIS TT40 + LSS4**	FMCM Main Bend	T40 Target
FMCM MSE		**SIS TT41 + CNGS**	Horn/Reflector Status
			Hadron Stop Cooling
			Fire Alarm

Red = un-maskable, Green = maskable, Magenta = Soft. Interlock

For more details & explanations : https://cern.ch/sps-mp-operation/

Interlock ‘types’

For the CNGS/TIx fast extractions there are 3 types of interlocks based on :

- Continuous surveillance of parameters. The associated permits change their state rather ‘rarely’ .
  - Vacuum, WIC, TEDs, target…
- Pre-extraction surveillance where the permits are evaluated a short time BEFORE extraction. The associated permit is FALSE by default and switches to TRUE for a short time interval around extraction if all conditions are correct.
  - Surveillance of the beam position around extraction point and of the PC currents.
- Post-extraction surveillance where the permits are evaluated AFTER extraction. This type of surveillance concerns beam instrumentation. The associated permit is switched to TRUE for a short time around extraction. The permit is latched (FALSE) if a measured beam parameter is out of tolerance. A latched permit must be reset manually.
  - Beam losses and beam positions in the transfer lines.

- Both Pre- and Post-extraction surveillance tasks are *triggered by machine timing events* coupled to the main extraction event.

Commissioning documents

Two specifications describe the equipment and the tests :

1. INTERLOCKED EQUIPMENT OF THE CNGS AND LHC TRANSFER LINES, **LHC-CIB-ES-003**

2. PROCEDURES FOR THE COMMISSIONING OF THE BEAM INTERLOCK SYSTEM FOR THE CNGS AND SPS-LHC TRANSFER LINES, **LHC-CIB-TP-001**

But the specification and approval exercise is **disappointing**, because if one excludes the author and the approval leader :

- Document 1 was approved by ONLY 1 (!!!) member of the MPWG.
- Document 2 was approved by ONLY 2 members of the MPWG.

We are not terribly credible : one cannot present grand schemes with approved procedures etc at workshops and other events … and not put them into practice !

Manpower & documentation

The commissioning of the CNGS interlock system was documented in detail. This also allows me to estimate the man-hours spent on the commissioning.

System	No. Documents	No. Pages	Time (hours)
Beam instrumentation	**14**	**24**	**24**
Powering	**16**	**35**	**17**
Absorbers & targets	**5**	**7**	**5**
Kicker	**2**	**4**	**2**
Miscellaneous	**6**	**8**	**6**
Operation	**2**	**11**	**-**
Total	**45**	**89**	**54**

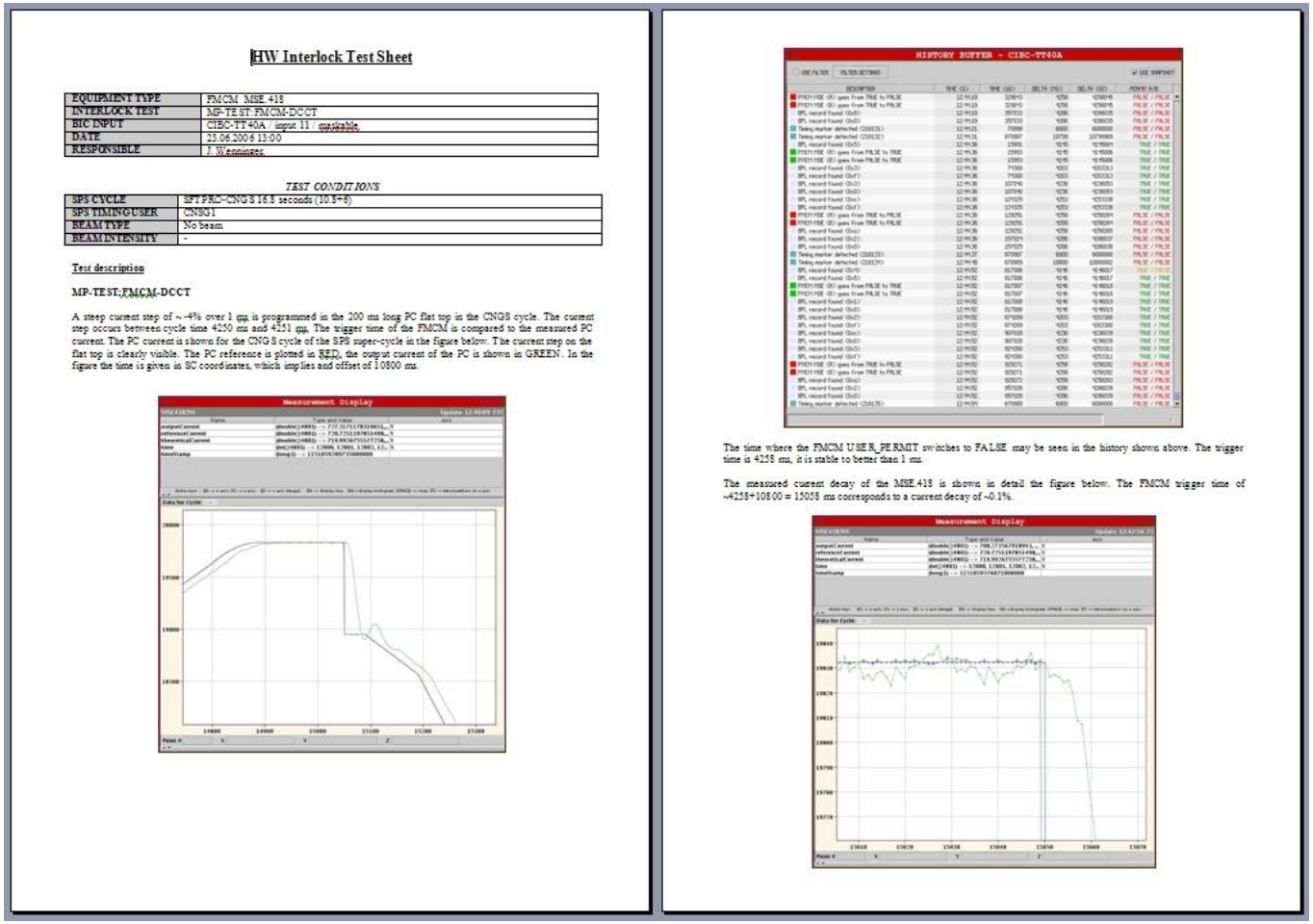
Comment on time estimates:

- Writing up the tests is not included in the time estimates.
- Some tests were repeated (~6-8 hours).
- Test that could be automated efficiently represent ~ 10-12 hours maximum.
- Most tests are very specific – essentially 'unique'.
- An optimized and concentrated test sequence should gain at least ~ 10 hours.

→ Without repetitions + concentrated tests → ~ 30 hours – 3 to 4 shifts

Interlock test documents

Documents have a standard header and contain all relevant parameters, timing information, BIC history buffer data, plots…



HW Interlock Test Sheet

EQUIPMENT TYPE	FMCM_MSE_418
INTERLOCK TEST	MP-TEST:FMCM-DCCT
BIC INPUT	CIBC-TT40A / input 11 / available
DATE	23.06.2006 13:00
RESPONSIBLE	T. Wenninger

TEST CONDITIONS

SPS CYCLE	SFTPRO-CNGS 16.8 seconds (10 3+6)
SPS TIMING USER	CNGS1
BEAM TYPE	No beam
BEAM INTENSITY	-

Test description

MP-TEST:FMCM-DCCT

A steep current step of ~-4% over 1 cyc is programmed in the 200 ms long PC flat top in the CNGS cycle. The current step occurs between cycle time 4250 ms and 4251 cyc. The trigger time of the FMCM is compared to the measured PC current. The PC current is shown for the CNGS cycle of the SPS super-cycle in the figure below. The current step on the flat top is clearly visible. The PC reference is plotted in RED, the output current of the PC is shown in GREEN. In the figure the time is given in SC coordinates, which implies and offset of 10800 ms.

The time where the FMCM USER_PERMIT switches to FALSE may be seen in the history shown above. The trigger time is 4258 ms, it is stable to better than 1 ms.

The measured current decay of the MSE.418 is shown in detail the figure below. The FMCM trigger time of ~4258+10800 = 15058 ms corresponds to a current decay of ~0.1%.

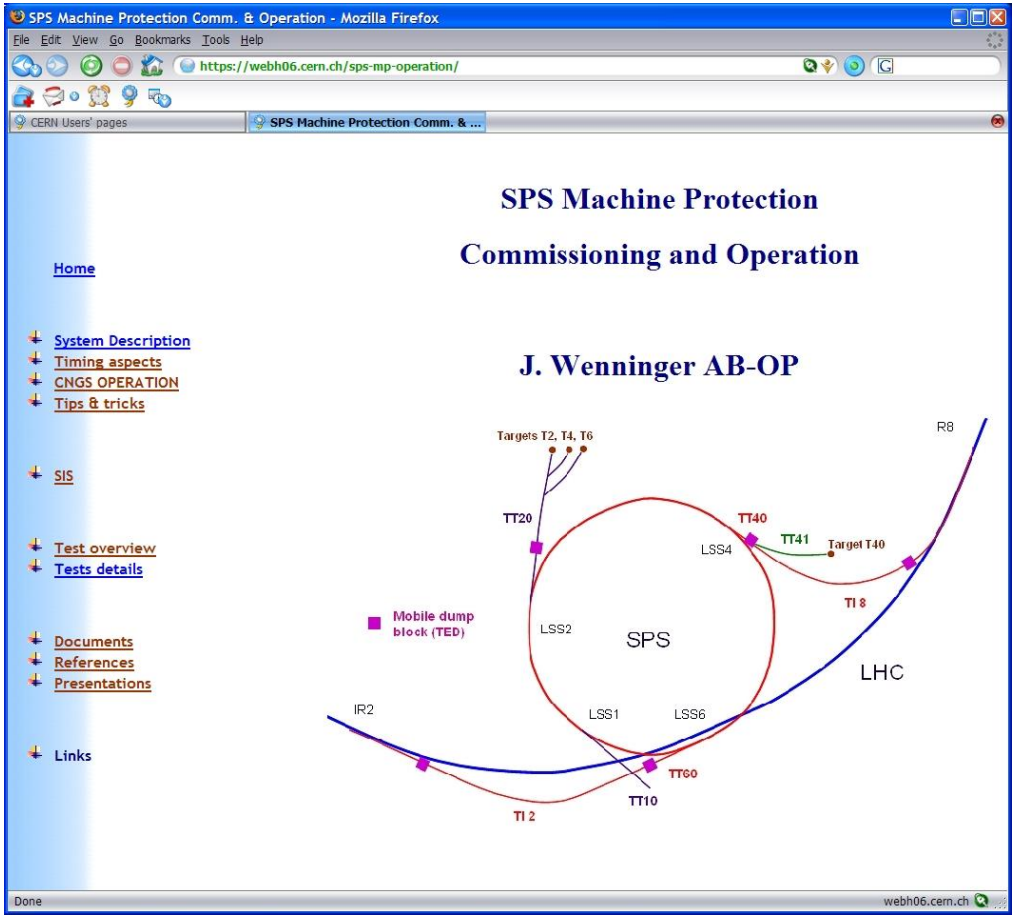
WEB documentation

https://cern.ch/sps-mp-operation/

A WEB page was installed for MP operation at the SPS:

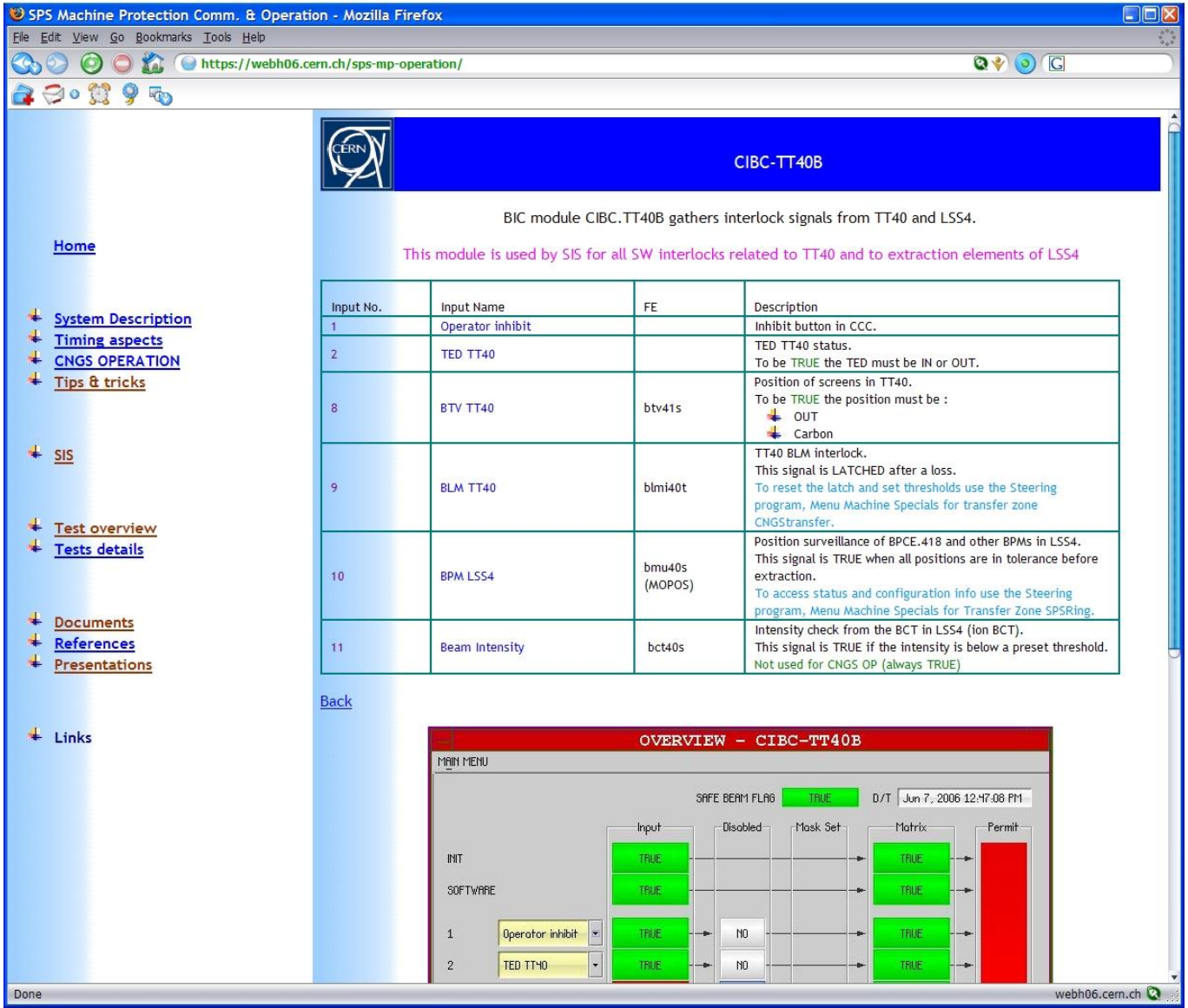
- Detailed system description
- Test documents & system status
- Settings:
  - References
  - SPS timings relevant for MP/extraction
- Trouble-shooting
- Sample screen shots for important information
- …

For use by the expert and by OP crews !



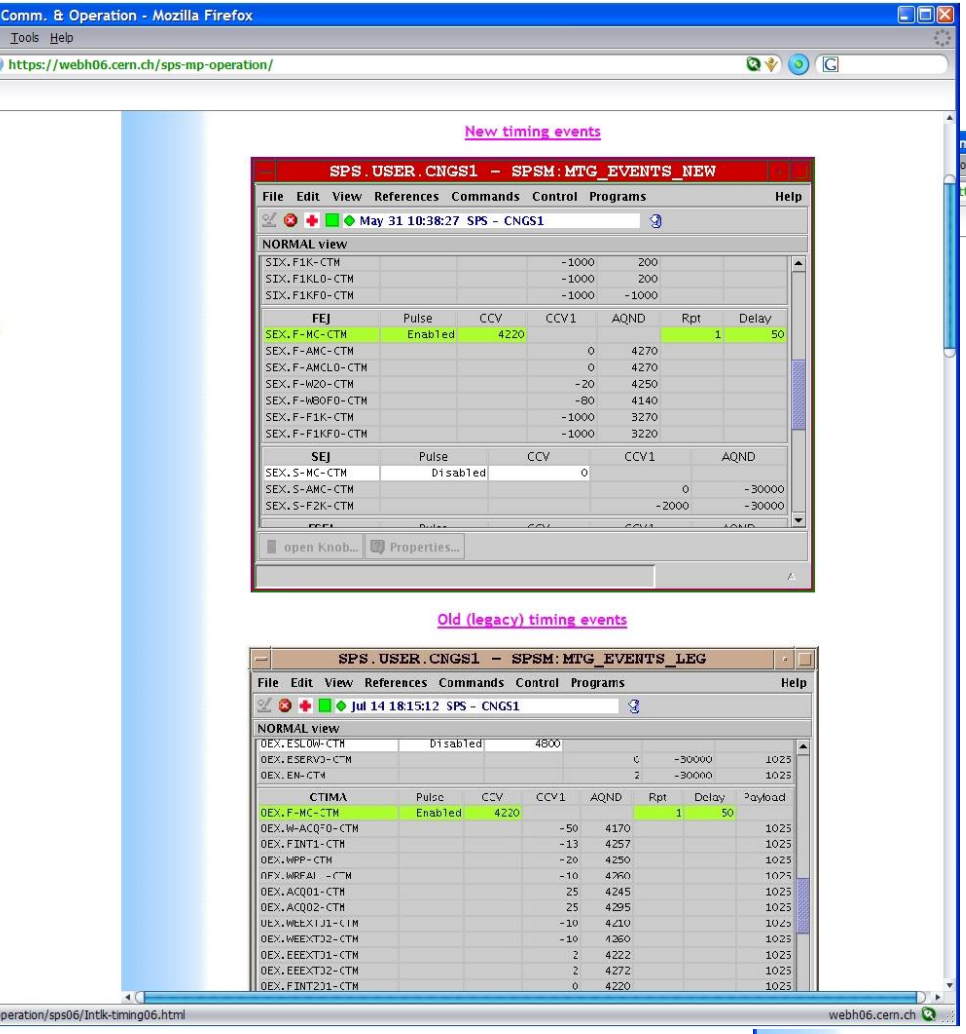
WEB documentation : example 1

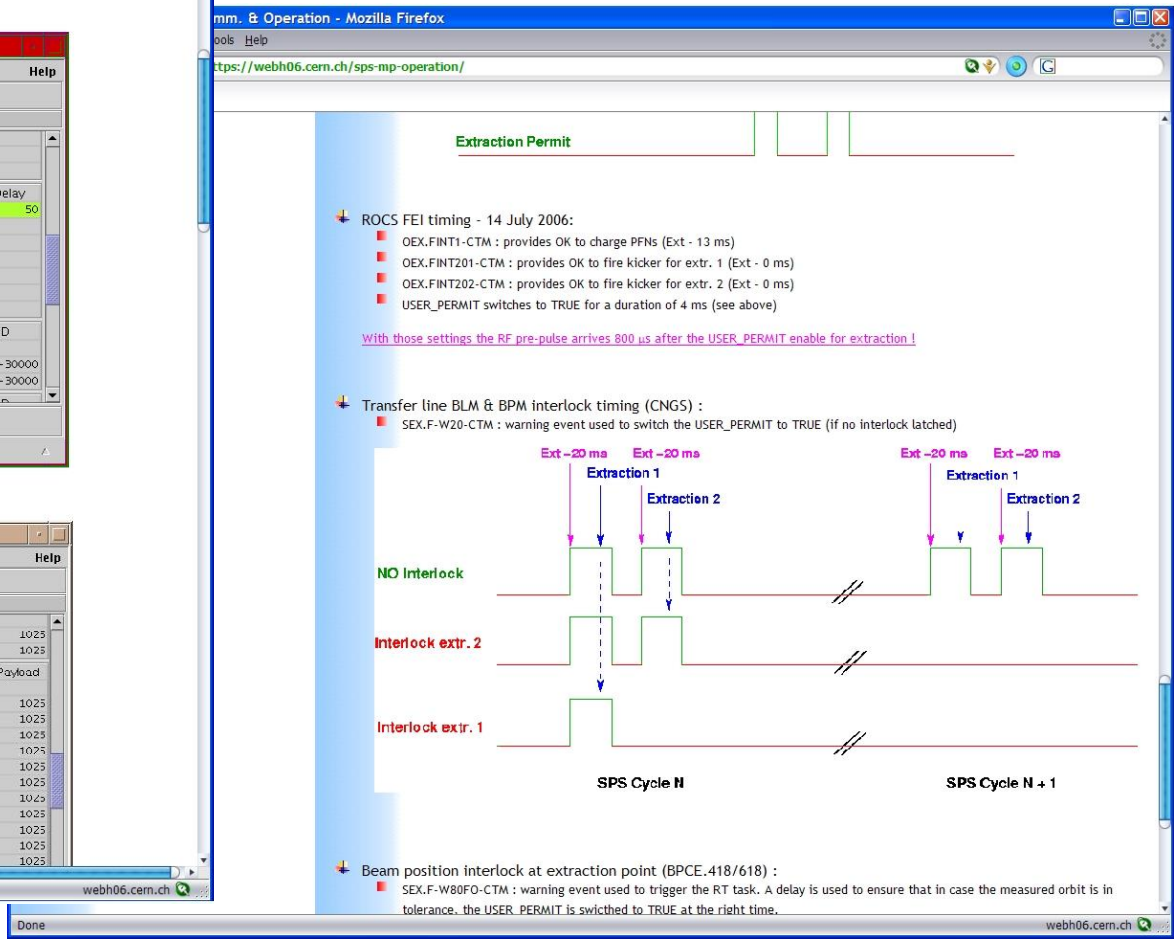
Details on BICs and inputs – example for CIBC-TT40B



WEB documentation : example 2

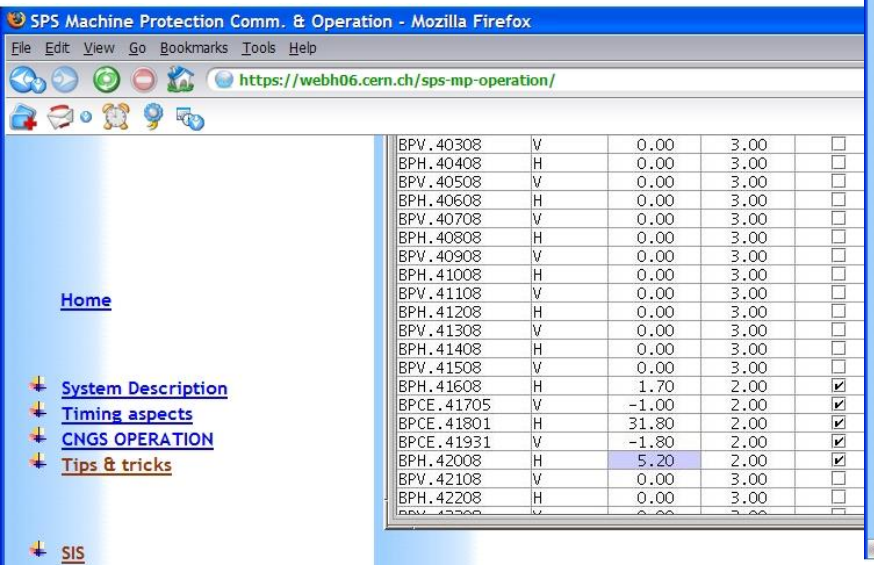
Details on machine timings :



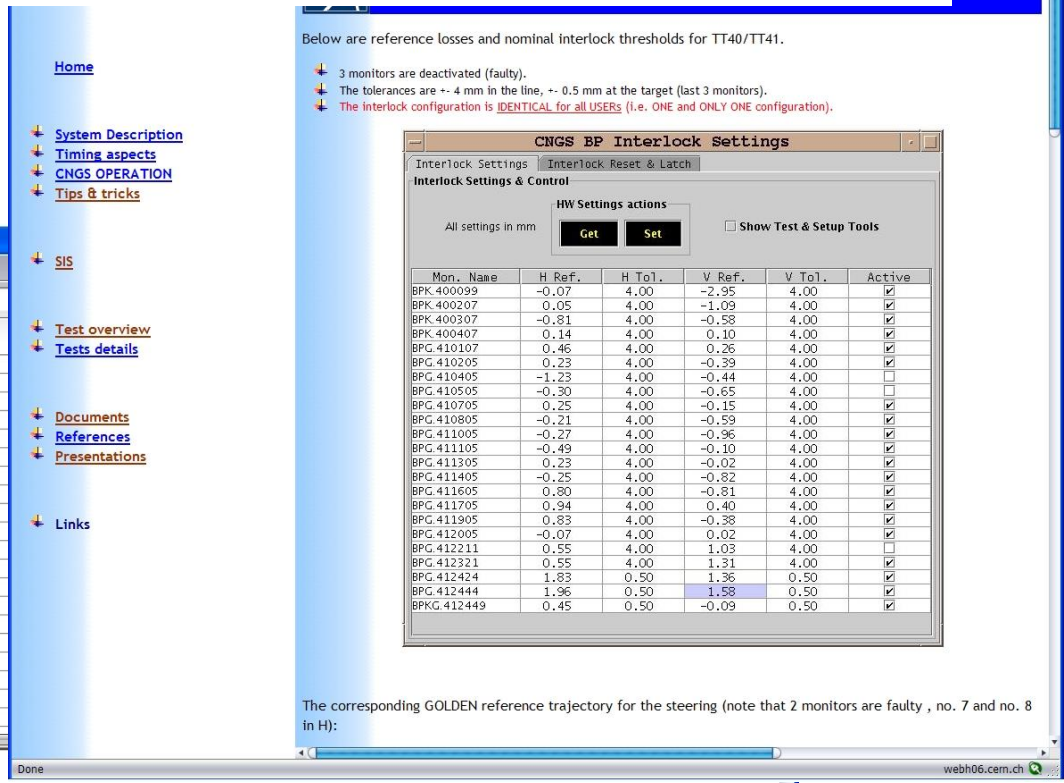


WEB documentation : example 3

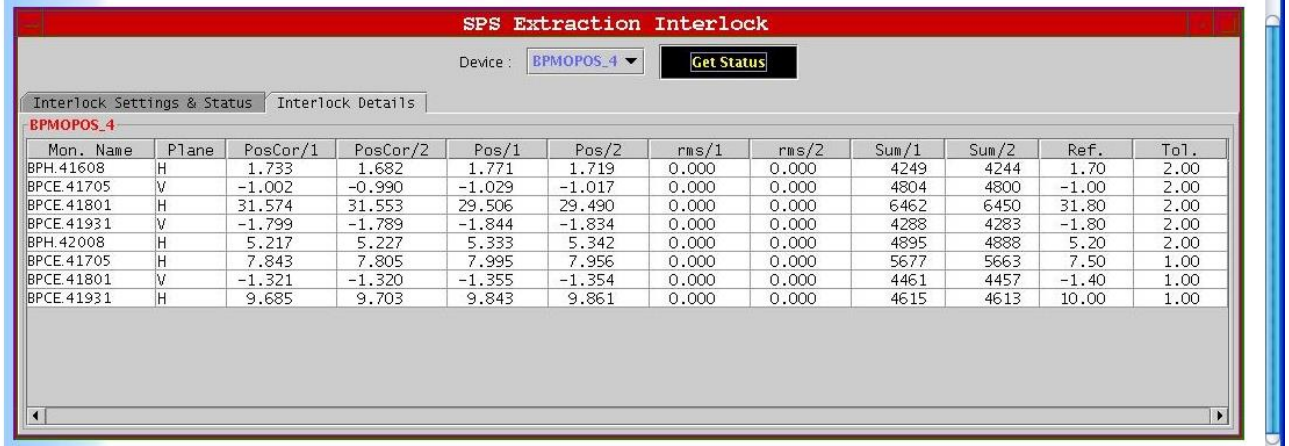
Details on BPM interlock settings :



BPV.40308	V	0.00	3.00	☐
BPH.40408	H	0.00	3.00	☐
BPV.40508	V	0.00	3.00	☐
BPH.40608	H	0.00	3.00	☐
BPV.40708	V	0.00	3.00	☐
BPH.40808	H	0.00	3.00	☐
BPV.40908	V	0.00	3.00	☐
BPH.41008	H	0.00	3.00	☐
BPV.41108	V	0.00	3.00	☐
BPH.41208	H	0.00	3.00	☐
BPV.41308	V	0.00	3.00	☐
BPH.41408	H	0.00	3.00	☐
BPV.41508	V	0.00	3.00	☐
BPH.41608	H	1.70	2.00	☑
BPCE.41705	V	-1.00	2.00	☑
BPCE.41801	H	31.80	2.00	☑
BPCE.41931	V	-1.80	2.00	☑
BPH.42008	H	5.20	2.00	☑
BPV.42108	V	0.00	3.00	☐
BPH.42208	H	0.00	3.00	☐



Mon. Name	H Ref.	H Tol.	V Ref.	V Tol.	Active
BPK.400099	-0.07	4.00	-2.95	4.00	☑
BPK.400207	0.05	4.00	-1.09	4.00	☑
BPK.400307	-0.81	4.00	-0.58	4.00	☑
BPK.400407	0.14	4.00	0.10	4.00	☑
BPG.410107	0.46	4.00	0.26	4.00	☑
BPG.410205	0.23	4.00	-0.39	4.00	☑
BPG.410405	-1.23	4.00	-0.44	4.00	☐
BPG.410505	-0.30	4.00	-0.65	4.00	☐
BPG.410705	0.25	4.00	-0.15	4.00	☑
BPG.410805	-0.21	4.00	-0.59	4.00	☑
BPG.411005	-0.27	4.00	-0.96	4.00	☑
BPG.411105	-0.49	4.00	-0.10	4.00	☑
BPG.411305	0.23	4.00	-0.02	4.00	☑
BPG.411405	-0.25	4.00	-0.82	4.00	☑
BPG.411605	0.80	4.00	-0.81	4.00	☑
BPG.411705	0.94	4.00	0.40	4.00	☑
BPG.411905	0.83	4.00	-0.38	4.00	☑
BPG.412005	-0.07	4.00	0.02	4.00	☑
BPG.412211	0.55	4.00	1.03	4.00	☐
BPG.412321	0.55	4.00	1.31	4.00	☑
BPG.412424	1.83	0.50	1.36	0.50	☑
BPG.412444	1.96	0.50	1.58	0.50	☑
BPKG.412449	0.45	0.50	-0.09	0.50	☑



Mon. Name	Plane	PosCor/1	PosCor/2	Pos/1	Pos/2	rms/1	rms/2	Sum/1	Sum/2	Ref.	Tol.
BPH.41608	H	1.733	1.682	1.771	1.719	0.000	0.000	4249	4244	1.70	2.00
BPCE.41705	V	-1.002	-0.990	-1.029	-1.017	0.000	0.000	4804	4800	-1.00	2.00
BPCE.41801	H	31.574	31.553	29.506	29.490	0.000	0.000	6462	6450	31.80	2.00
BPCE.41931	V	-1.799	-1.789	-1.844	-1.834	0.000	0.000	4288	4283	-1.80	2.00
BPH.42008	H	5.217	5.227	5.333	5.342	0.000	0.000	4895	4888	5.20	2.00
BPCE.41705	H	7.843	7.805	7.995	7.956	0.000	0.000	5677	5663	7.50	1.00
BPCE.41801	V	-1.321	-1.320	-1.355	-1.354	0.000	0.000	4461	4457	-1.40	1.00
BPCE.41931	H	9.685	9.703	9.843	9.861	0.000	0.000	4615	4613	10.00	1.00

Interlock clients commissioning & performance

selected topics

PC current surveillance

- The PC system provides a *pre-extraction surveillance*. The current of selected converters is compared to a reference before extraction.
- This system provides in total 6 inputs to the BICs.
- The PC surveillance has not been changed fundamentally since 2004 because the ROCS system was not ported to FESA.
- Operational tolerances :

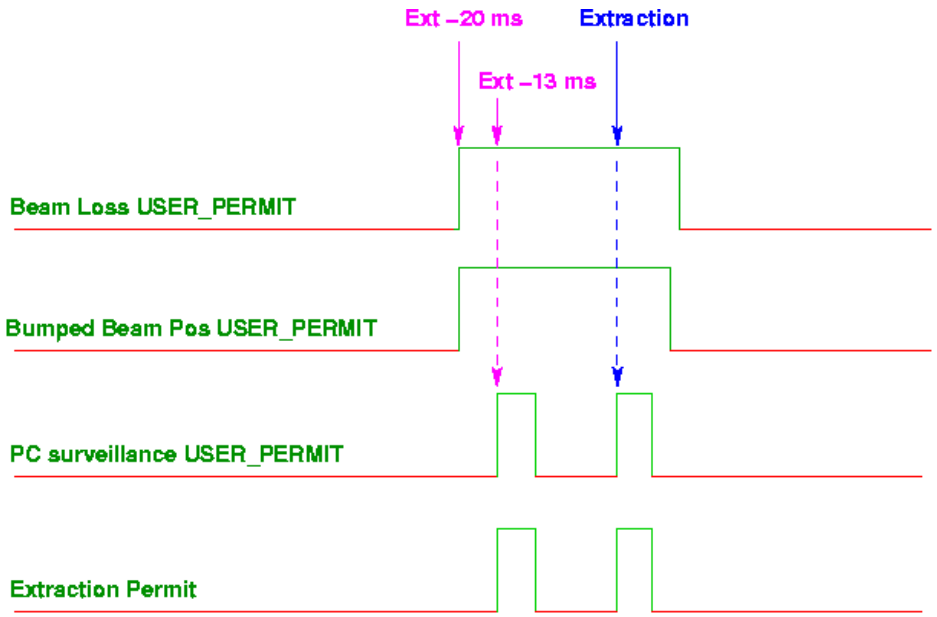
MBHA, MBHC dipole strings	**0.2%**
Main dipole string	**0.1%**
MBSG dipole string	**0.1%**
Septum	**0.1%**
Main quad strings (D/F)	**0.2%**
Matching quads	**0.5%**
Corrector magnets	**~ 10 μrad**
Bumpers	**~ 1 μrad**

- Settings are not (yet) cycle dependent. This simplifies settings management for this year.
- Settings changes are expert actions.

PC current surveillance timing

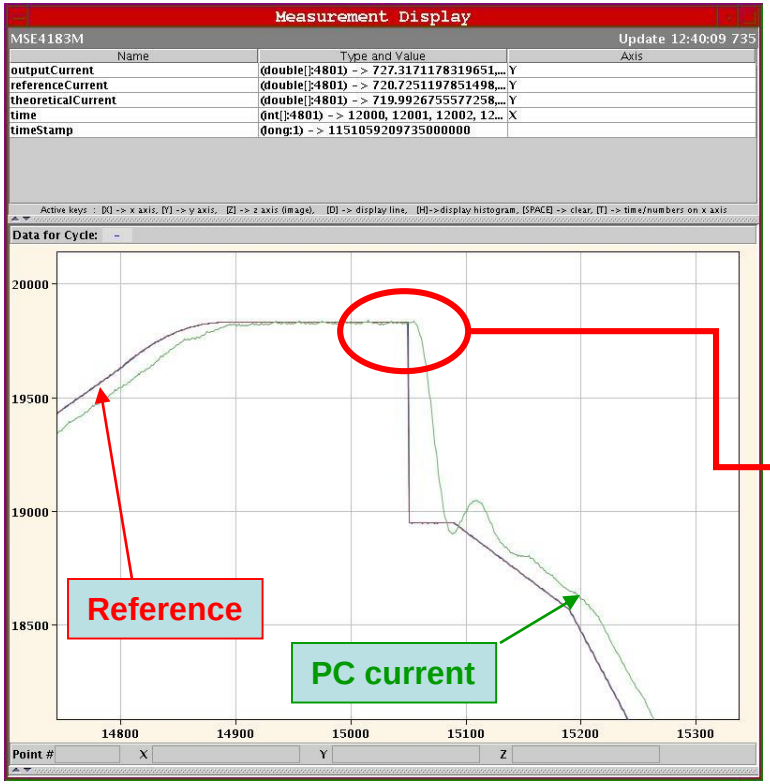
- For each extraction, two 3 ms long pulses are provided with PERMIT = TRUE (if all OK). Sets a strong constraint on the timing event sequence (minimizes possible errors).
- First pulse at Nominal Extraction Time – 13 ms.
- Second pulse at Nominal Extraction Time – 0 ms. The current surveillance is done some 1-2 ms before the actual extraction.

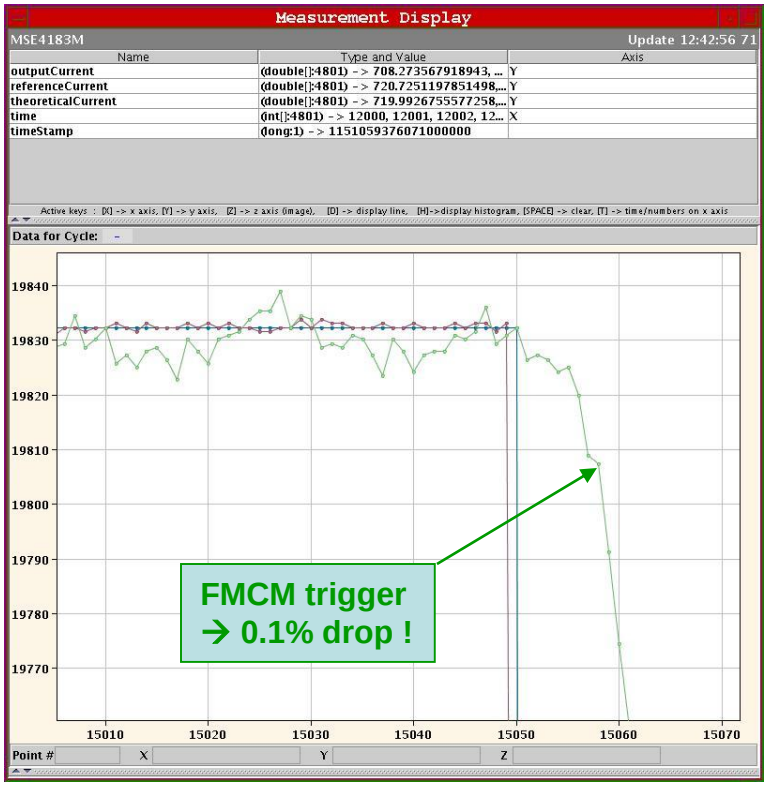
→ Extraction kicker triggers ~ Nominal Extraction Time + 800 μs (arrival time of pre-pulse)



FMCM

- 3 FMCMs are installed on MSE.418, MBSG.4000 and MBG dipole string.
- Tested using steep reference changes to trigger FMCM. The trigger threshold is measured using BIC history buffer + read out of current (1 ms step).





FMCM beam tests

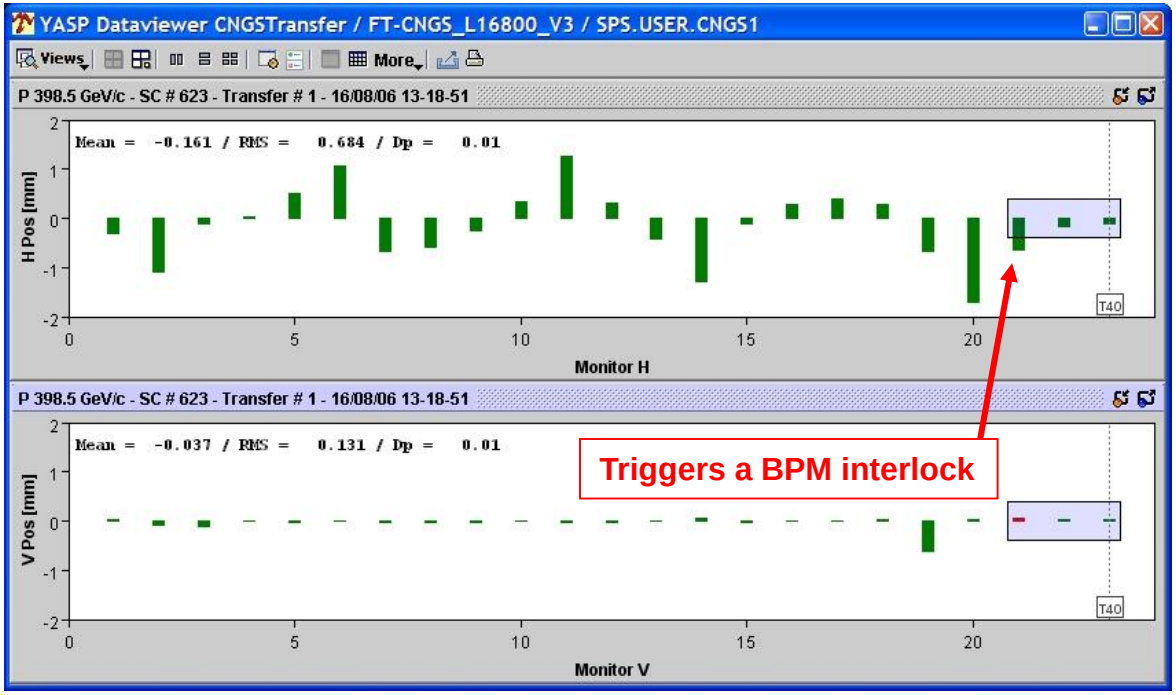
The tests were repeated with beam by adjusting the step and FMCM trigger to occur ~ nominal extraction time → record max. trajectory excursion – confirms current measurements.

PC	FMCM trigger	ROCS tol.
MSE.418	**< 0.1%**	0.1%
MBSG.4000	**< 2.5×10^{-4}**	0.1%
MBG/MBI.816	**< 2.5×10^{-4}**	0.1%

In all cases the position change @ target is < 0.5 mm (as specified).

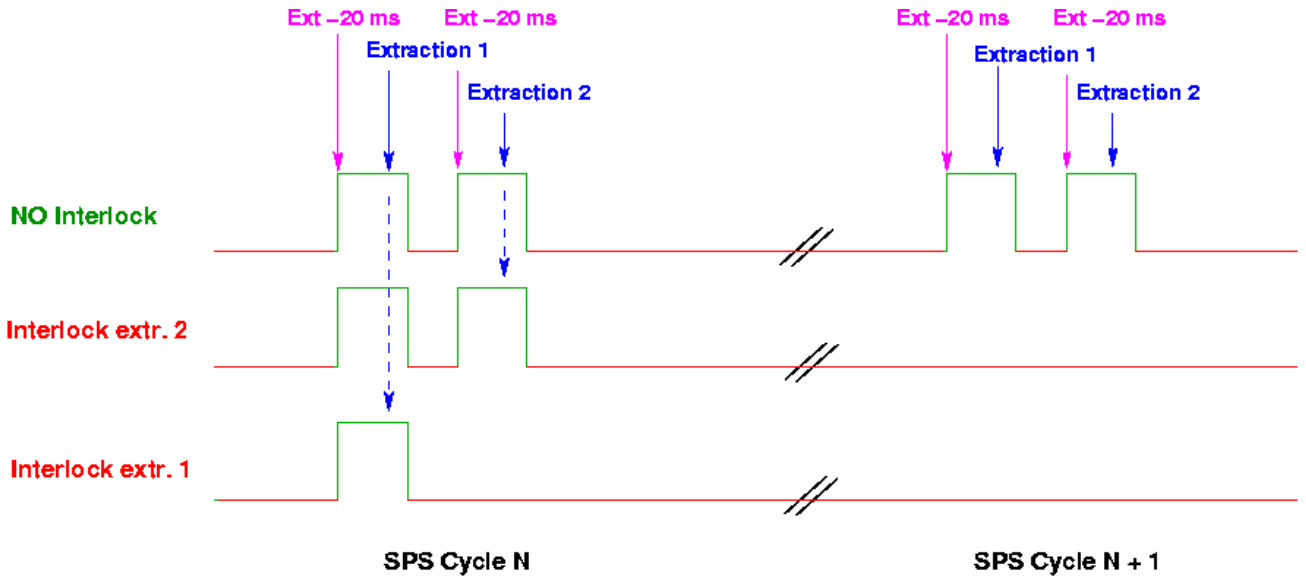
Example :

- Max. trajectory excursion due to MSE @ time of FMCM trigger.
- Trajectory interlock tolerances :
  - ±4 mm BPMs no. 1 to 20.
  - ±0.5 mm last 3 BPMs.



Transfer line BLMs

- This system provides *Post-extraction surveillance* : since BLMs can only measure AFTER the 'action', the USER_PERMIT is latched to prevent further extractions if an excessive loss is detected.
- The reset is done manually (for the moment via steering program).
- The USER_PERMIT transition from FALSE to TRUE is triggered by the '-20 ms extraction pre-warning' event. If there is no (abnormal) loss, the USER_PERMIT resets to FALSE a few milliseconds after the extraction.



Transfer line beam loss & thresholds

- Beam losses in the TT40 & TT41 are very low (< 0.3 mGray for 10^{13} protons).
- When the C OTR screens are inserted losses increase to ~ 2 mGray in some locations.

  → Thresholds to 5 mGray in TT41.

TT40 BLM losses & thresholds

BLM Interlock Settings

Device : BLMITT40

Interlock Settings | Interlock Reset & Latch

BLMITT40

Values in milliGray | HW Settings Actions: Get, Set | Show Test & Setup Tools

BLM Name	Gain	Loss/Ex1	Loss/Ex2	Threshold
BLM400103	16	0.0143	0.0143	20.000
BLM400117	16	0.0071	0.0214	20.000
BLM400206	16	0.0214	0.0143	20.000
BLM400306	16	0.0071	0.0000	20.000
BLM400316	16	0.0000	0.0000	20.000
BLM400406	16	0.0000	0.0071	100.000
BLMI80104	16	0.0071	0.0000	5.000
BLMI81755	16	0.0000	0.0000	5.000
BLMI82104	1	0.0000	0.0000	5.000
BLMI82304	1	0.0000	0.0000	5.000
BLMI82904	1	0.0000	0.0000	5.000
BLMI83104	1	0.0000	0.0000	5.000
BLMI83704	1	0.0000	0.0000	5.000
BLMI83904	1	0.0000	0.0000	5.000
BLMI84504	1	0.0000	0.0000	5.000

BLM after TED : high threshold to avoid interlocks when beam is sent to the TED.

TT41 BLM losses & thresholds

Device : BLMICNGS

Interlock Settings | Interlock Reset & Latch

BLMICNGS

Values in milliGray | HW Settings Actions: Get, Set | Show Test & Setup Tools

BLM Name	Gain	Loss/Ex1	Loss/Ex2	Threshold
BL410024	16	0.0000	0.0000	25.000
BL410145	16	0.0499	0.0428	5.000
BL410307	16	0.0641	0.0641	5.000
BL410607	16	0.0855	0.0855	5.000
BL410707	16	0.0926	0.0926	5.000
BL410907	16	0.1069	0.1140	5.000
BL411107	16	0.2423	0.2494	5.000
BL411507	16	0.0000	0.0000	5.000
BL411807	16	0.0000	0.0000	5.000
BL411907	16	0.0000	0.0000	5.000
BL412007	16	0.0000	0.0000	5.000
BL412243	16	0.0214	0.0285	5.000
BL412445L	16	1.5461	1.5176	5.000
BL412445R	16	1.5889	1.5604	5.000
SPARE	16	0.0071	0.0000	5.000
SPARE	16		0.0000	5.000
SPARE	16		0.0000	5.000
SPARE	16		0.0000	5.000
XGBL400002	16	1.6102	1.5889	10.000
XGBL400003	16	1.8311	1.8169	10.000
XGBL400094	16	6.0990	6.0135	10.000
XGBL400095	16	5.7784	5.7143	10.000

Ignore…

Extraction channel BLMs

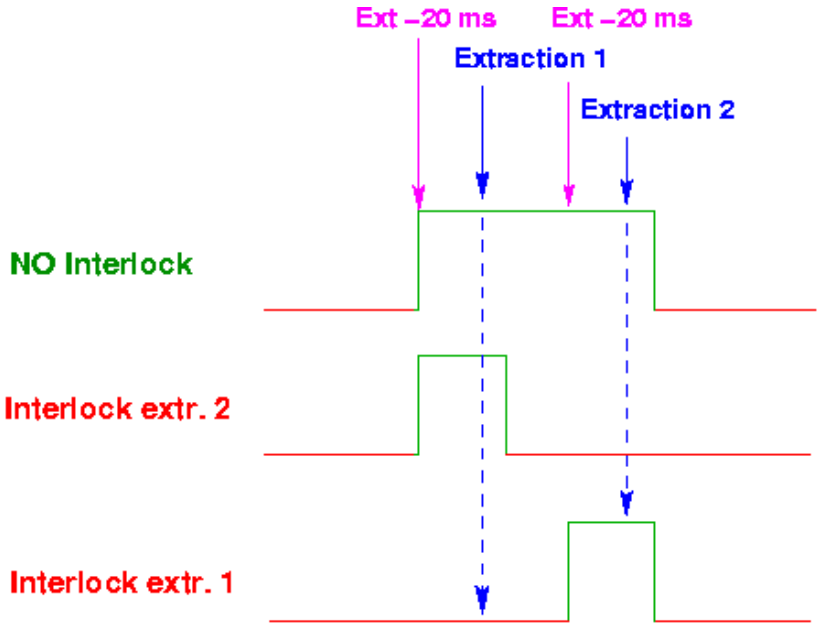
- BLMs located in the extraction channel are connected to the SPS ring BIC system.
- Interlocks lead to a beam dump in the SPS.

→ Presented in details by Verena.

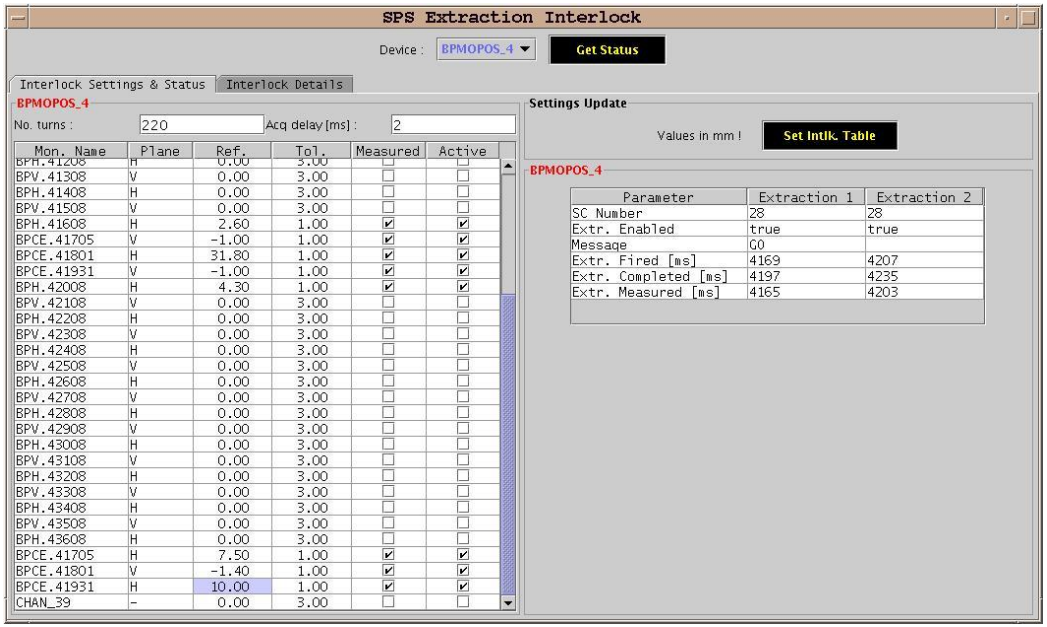
Ring BPMs

- Some SPS BPMs in LSS4 are used to interlock the beam position at extraction as a *pre-extraction surveillance* (extraction bump amplitude).
- There is a large overlap with the current surveillance on the bumper magnets.
- The interlock logic is implemented within the MOPOS system (SPS ring BPM system) that has been ported to FESA in 2006.
- Unfortunately MOPOS remains fragile (~ one reboot required / day, gain changes) and rather slow, even after optimization: the beam position is evaluated from data recorded ~ 50 ms before extraction.

>>> The system is blind to fast position changes in the last 50 ms before extraction.



Ring BPM settings



References & tolerances

8 positions (5 H and 3 V) have been interlocked to improve the coverage in amplitude and phase and provide some redundancy.

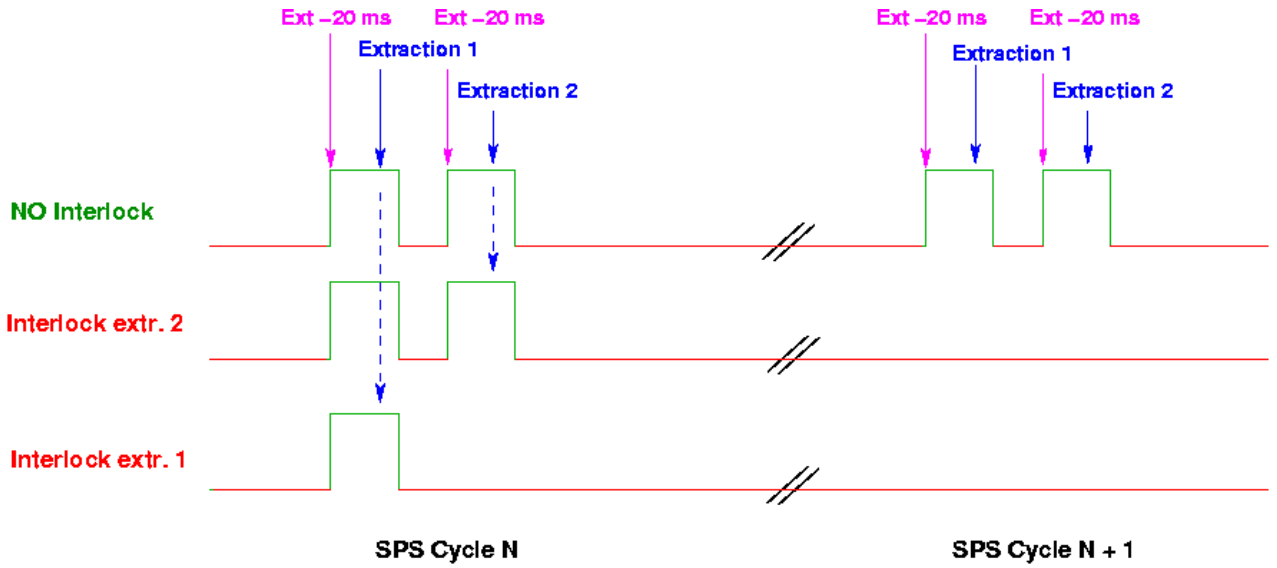
The tolerance values were verified experimentally by changing the beam position at the extraction point by+2mm and by observing the position change at the target:

± 1 mm tol. good, ± 2 mm tol. ~ at the limit.

SPS position	Δx (mm) @ target
H418	-0.7
H416	0.1
V417	-0.4
V419	-0.4

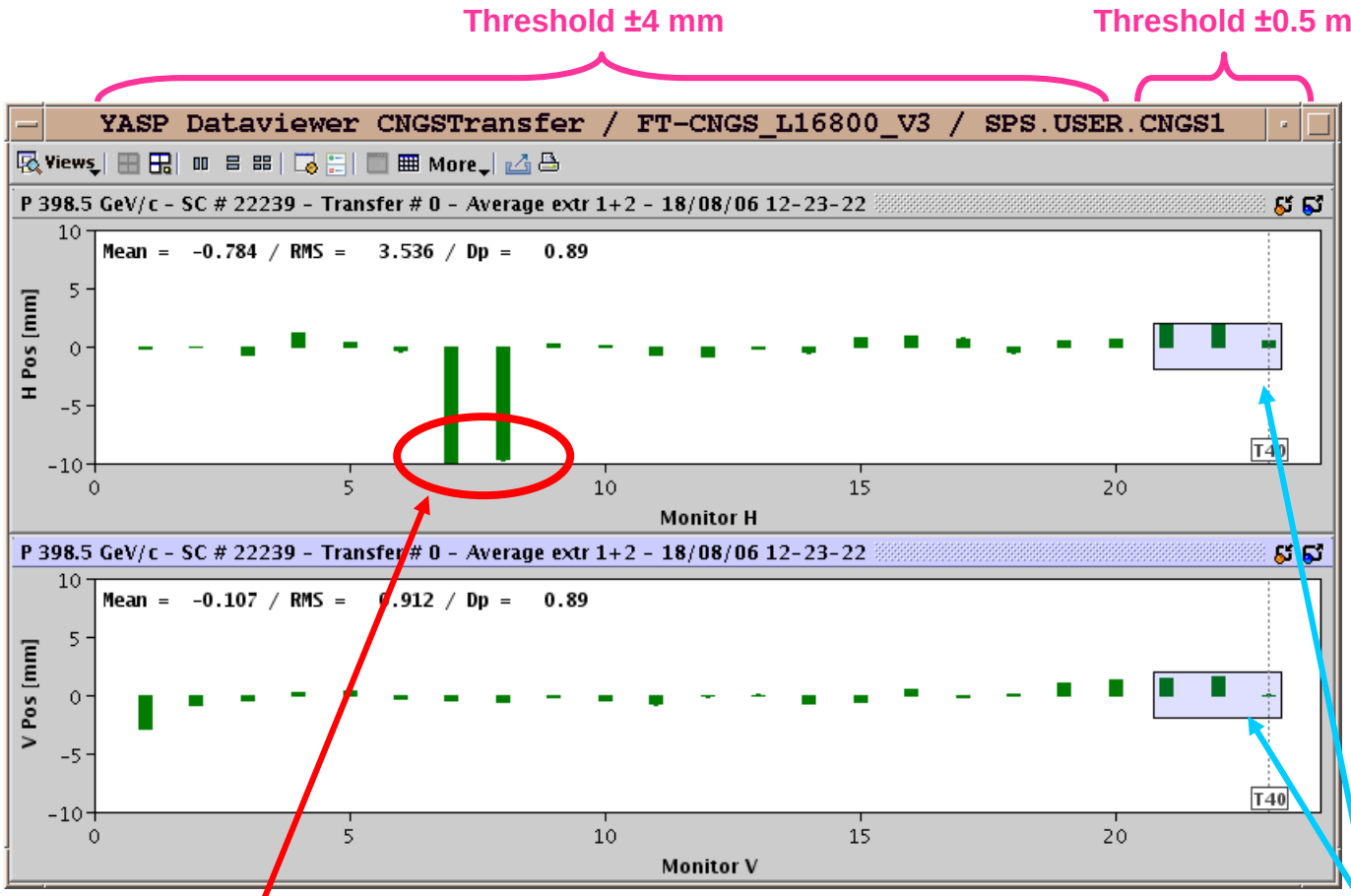
Transfer line BPMs

- This system provides *Post-extraction surveillance*.
- 23 H+V BPMs can be interlocked in TT40 (4 BPMs) and TT41. They can be activated individually. Tolerances:
  - ±4 mm for 20 transfer line BPMs
  - ±0.5 mm for last 3 BPMs (after last magnet elements)
- The interlock is latched (reset through steering application).
- A position is used for interlocking only if the BPM has seen beam (auto-triggered).
- The interlock timing follows the same logic than for transfer line BLMs.



Transfer line BPMs /2

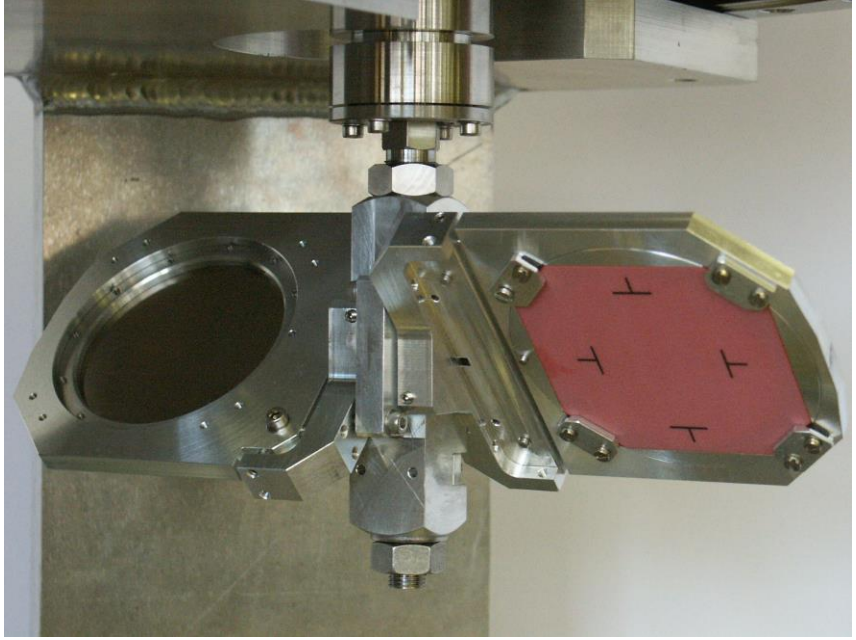
Example : reference trajectory for the CNGS pilot run



Short-circuit on one electrode. De-activated for interlocking.

Misalignment transfer line-target-horn

Screens



- User permit logic :
  - TRUE : OUT position + Carbon OTR
  - FALSE : Al screen + Titanium OTR
  - FALSE : device moving

- To test this system the history buffer is absolutely great. It is possible to spy in detail on the time and duration of the movement (checked to be always during the ‘beam out’ part of the cycle).

- The test for the 11 screens is quite lengthy, since one has to cycle through all positions and check visually that the screen is in the correct position.

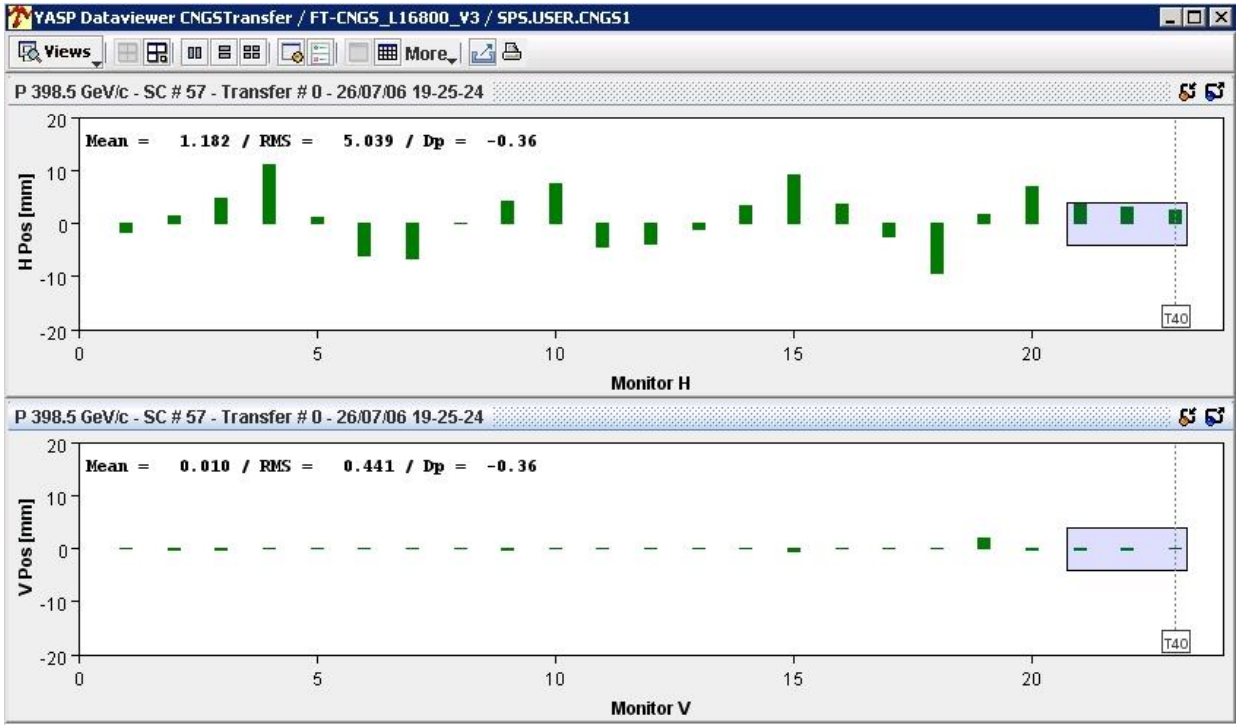
TEDs

- In the absence of the master BIC, the TED user permit is:
  - TRUE : TED is IN beam or OUT of beam.
  - FALSE: TED moving or at an intermediate position.

MKE energy tracking

- A BETS system has been installed for the MKE, the ‘energy’ is obtained from a DCCT (SPS main dipoles) in SPS BA3.
- Interlock tolerances:
  - **Kicker voltage > 48 kV** (50 kV nominal). At 48 kV the beam passes ‘comfortably’ through the line and hits the target with an offset of ~ 0.5 mm. Could be increased to 49 kV.
  - **Energy must be in a window of 400 ± 5 GeV.** Energy acceptance of TT40/TT41 ~ ±0.8 permill.

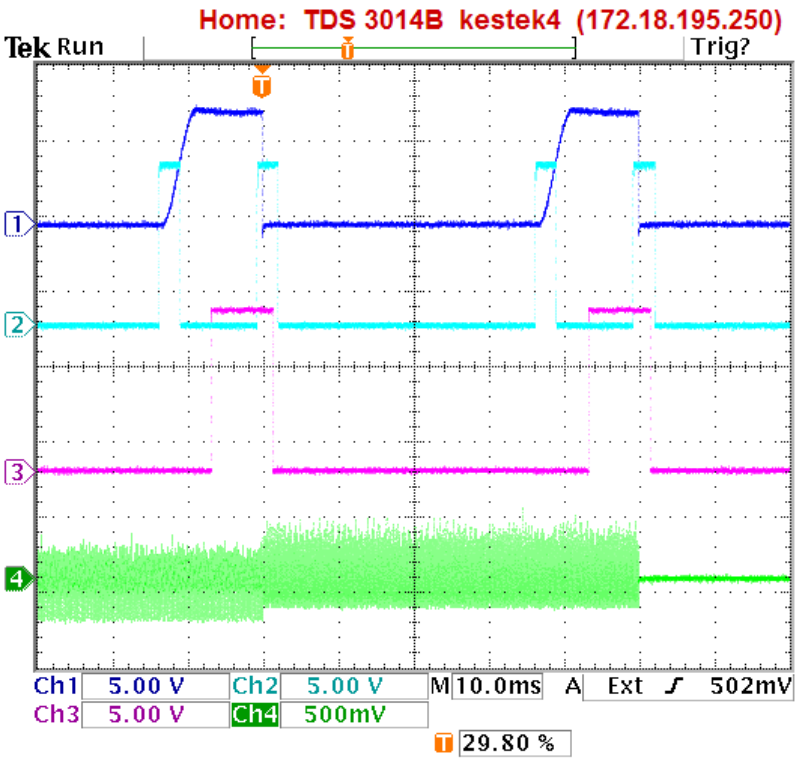
Traj. change for MKE voltage 41 kV (reference 50 kV). Δx @ T40 ~ 2.3 mm.



Extraction kicker MKE

- After initial worries due to erratics, the MKE kicker eventually performed well.

Timing of kicker, BIC permit and BETS:



- PFN voltage

- BIC permit

- BETS window

- Beam

Safe Beam Flag

- The SPS safe beam flag distribution to the extraction BICs has been activated before the CNGS high intensity extraction tests. It has worked extremely well. And it was sometimes annoying for certain commissioning tests !

- SBF Generation:
  - The SPS high intensity BCT is used to measure the intensity 1 second after the start of the ramp (triggered by a timing event).
  - The intensity is sent to the SPS MTG and compared to the safe beam threshold (intensity only) to generated the SBF. The SBF is then distributed over the timing system to the BICs.

- Presently the limit for a safe beam is set to 10^{12} protons. This is a rather conservative limit and it is difficult to obtain CNGS beams of such a low intensity. I therefore suggest to increase the limit to 3×10^{12} protons which should be sufficiently safe.

‘Safer’ settings

First steps were taken toward ‘protected settings’ – simple but effective…

- Interlock settings changes require passwords for :
  - Transfer line BPM surveillance
  - Transfer line BLM surveillance
  - Surveillance of the beam position at the extraction point

- As a test, SIS (Software Interlock System) surveys the BLM system once per CNGS cycle:
  - Thresholds must be < 40 mGray
  - Gains must be <= 16 (avoid saturation !)
  - SIS also generates an additional SW interlock if the loss at any point exceeds 50 mGray (i.e. for severe cases).

CNGS operation

18-30 August 2006

CNGS Operation : general comments

- During the entire period of CNGS operation, with beam intensities of 1.2 to 1.8×10^{13} p/extraction, the interlock system did its job perfectly – at least from the point of view of the protection.

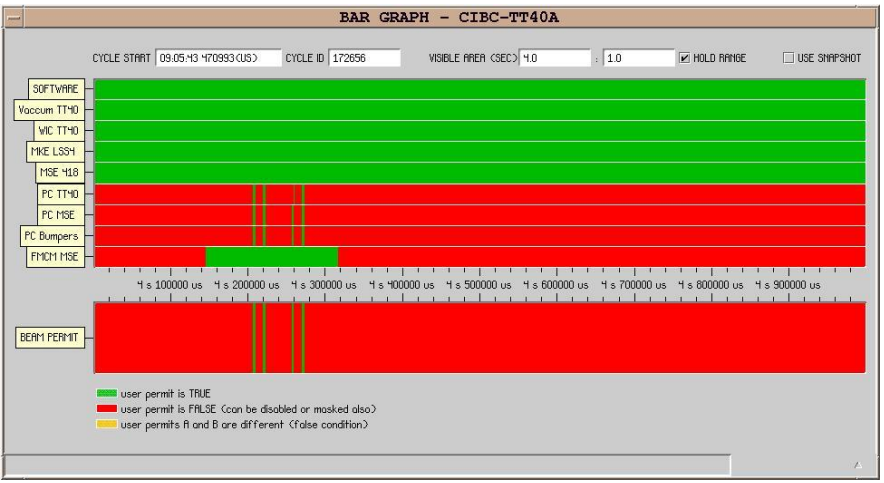
- Running conditions were complicated due to out-gassing of the SPS beam dump block (new in 2006 and not yet properly conditioned). 5-10 consecutive dumps of the CNGS beam lead to a vacuum pressure rise sufficient to stop the nearby SPS injection kickers. It then takes ~ 15 minutes for the vacuum to recover and for beam operation to resume.

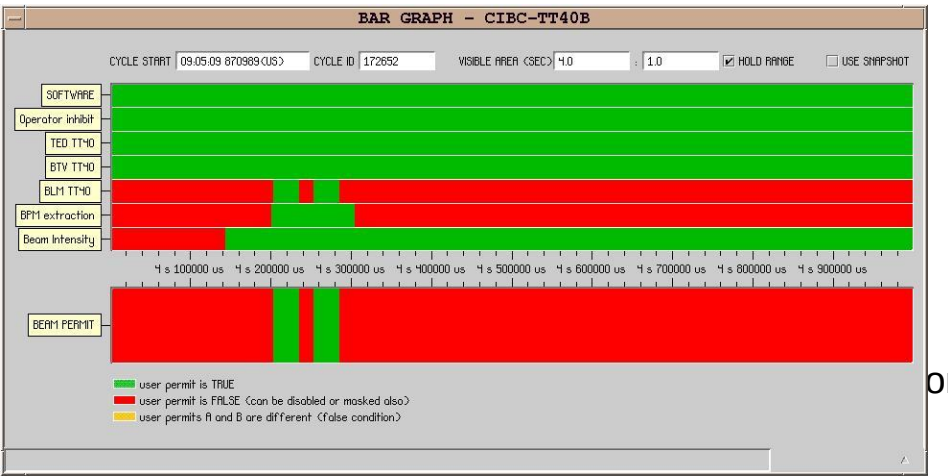
- In this context:
  - The first half of the CNGS run was smooth – no problems.
  - In the second half, spurious (incorrect) interlocks led to vacuum problems (as explained above) and somewhat rocky conditions for the shift crews !

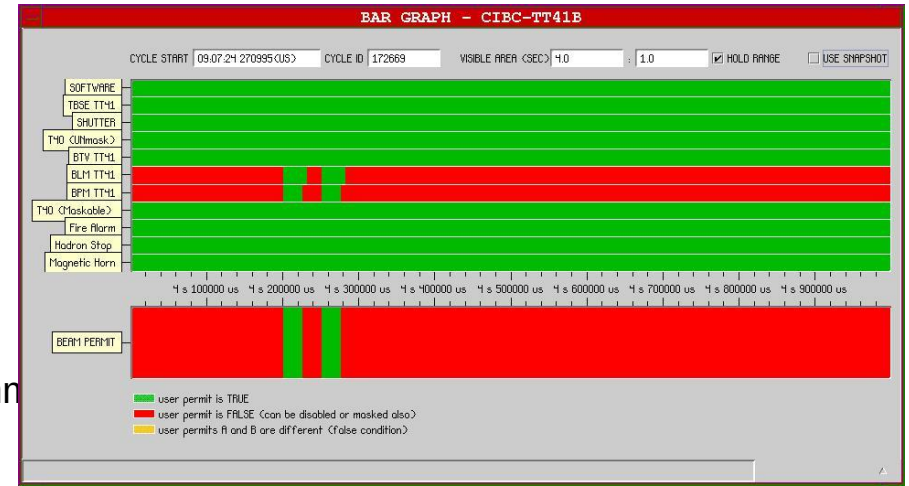
BIC supervision for CNGS operation

- Supervision is greatly improved wrt 2004. The graphical display is excellent, sometimes a bit ‘fast’ for un-experienced persons.
- Some improvements may have to be done to provide concentrated summary information.

Graphical display of all signals for a (successful) CNGS extraction…





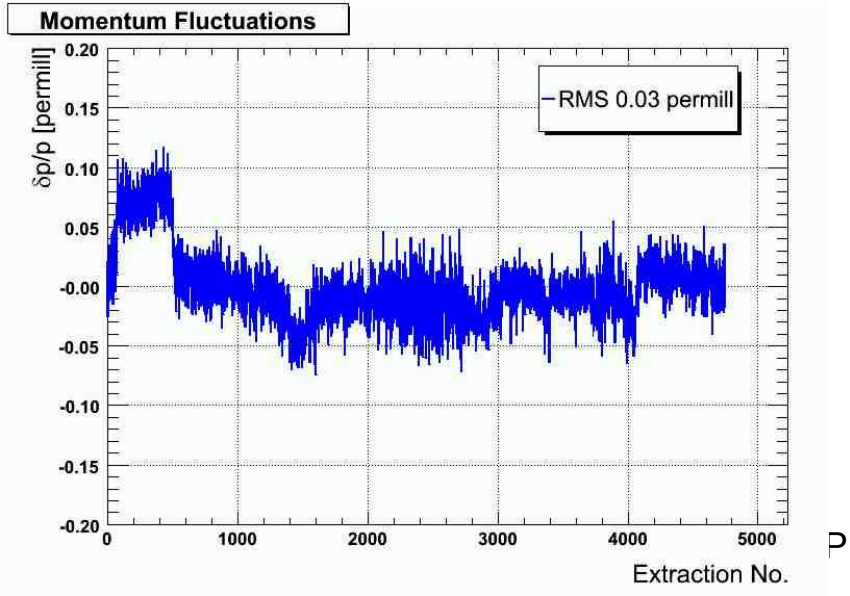


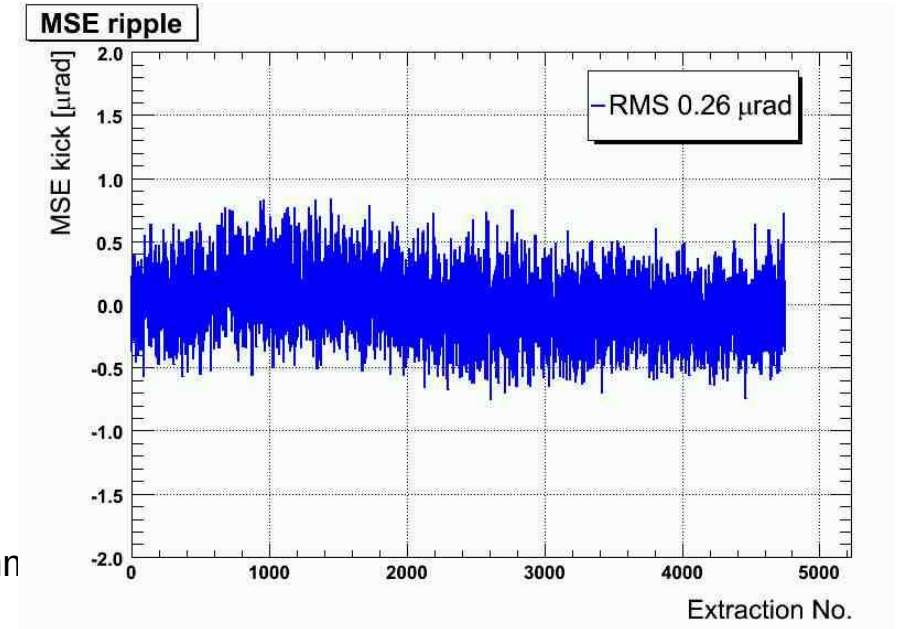
Extraction & TL stability : short term

- The short term stability of the entire extraction (SPS ring @ 400 GeV + TLs) is excellent. The r.m.s. trajectory stability over 24 hours is
  - **~ 100 μm in the horizontal plane,**
  - **~ 40 μm in the vertical plane.**
- The additional 'noise' in the horizontal plane is due to well defined sources:
  - **MSE septum ripple of ~ 10^{-4} .**
  - **Energy fluctuations from the SPS 200 MHz RF radial loop of 3×10^{-5}.**

  Without those sources, H + V stability are ~ identical.
- This excellent stability was predicted from the LEP orbit data….

Energy fluctuation and MSE ripple over 24 hours (19-20 Aug. 2006)





Extraction & TL Stability : long(er) term

- The excellent short term stability also translates into an excellent long(er) term stability.
- Observed changes during the CNGS pilot run (28 Aug to 30 Aug):
  - **Total drift in horizontal plane** **0.2 mm rms**
  - **Total drift in vertical plane** **0.4 mm rms (dominated by drift in SPS ring)**
  - **Vertical position change in the SPS** **~ 0.5 mm**
- Trajectory corrections using 1-2 correctors were performed for each plane ~ once every 1-2 days (to maintain the rms change around 0.1 mm). The corrections were performed with nominal intensity. With the exception of one case, the required corrector strengths were ≤ 5 μrad (tolerance is ~8 μrad).

  → A priori possible to operate for a week (or longer) without touching the PC interlock current references (for correctors) – good news !
- One correction of the vertical beam position of ~ 0.5 mm at the extraction point in the SPS was performed after ~ 10 days.
- NO CHANGE of interlock reference for the current surveillance had to be made for any of the dipoles, septa and quadrupoles over the ENTIRE period of JUNE to AUGUST as long as the magnet settings were not touched. The only changes were associated to actual changes of the magnet settings.

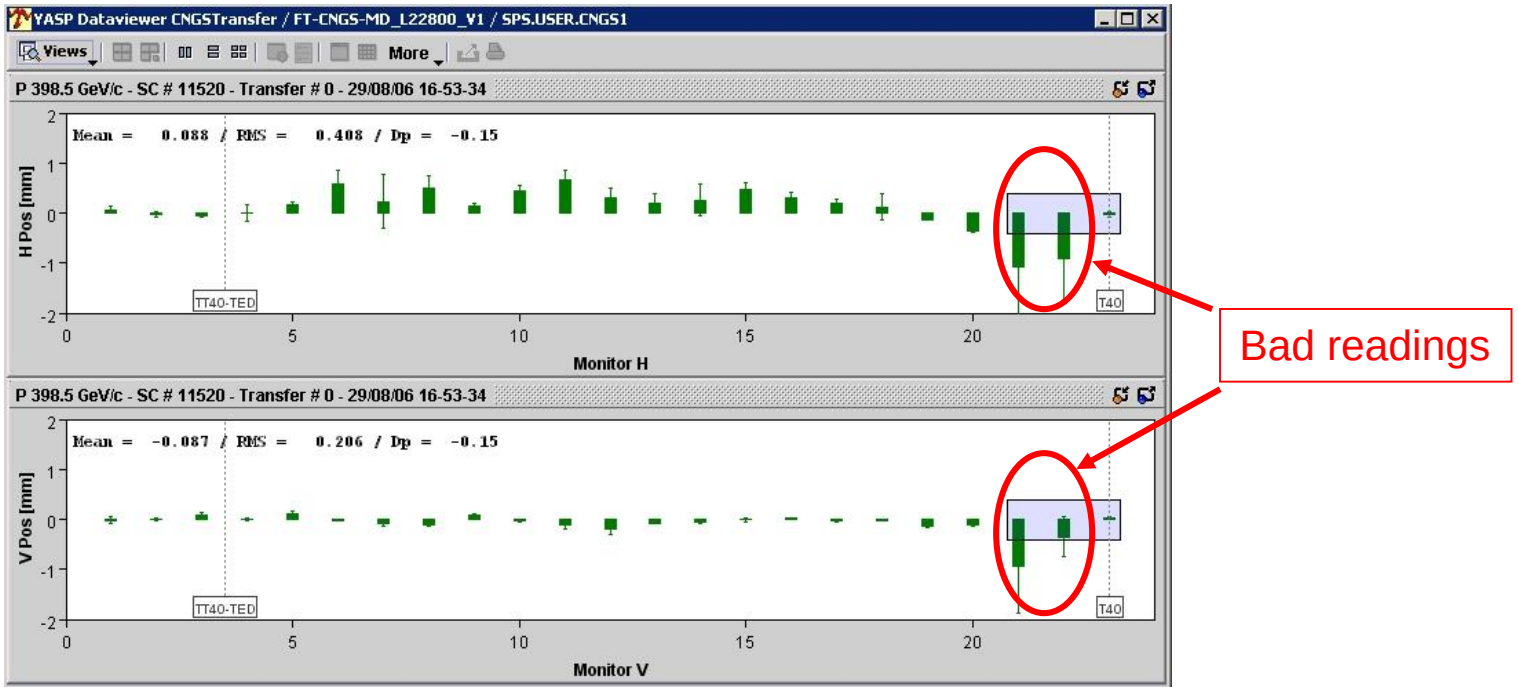
Interlock problems : case no. 1

Occasional FAKE interlocks (unphysical displacements) were generated by 2 BPMs of the transfer line near the target that are interlocked to ±0.5 mm:

- Observed on 2 occasions (at the beginning and near the end of the run).
- False readings always occurred after a period without beam (at least a few cycles).
- After reset the readings are OK again.
- During the last 24 hours, those 2 BPMs were de-activated for interlocking. As a compensation the threshold of the upstream BPM was reduced to ±0.5 mm.

Not really understood – seems to be a problem with the acquisition…

Example for a bad trajectory (difference wrt reference) leading to a fake interlock



Interlock problems : case no. 2

- The second source of spurious interlocks was due to the surveillance of the beam position before extraction by MOPOS.
- During the first week of CNGS operation:

  The BPM signal amplitudes were ~ in the middle of the range for the optimum gain setting (20 dB). No problems were encountered, although occasional interlocks were observed from this system – probably un-justified.

- In the second week, the intensity was increased:

  The signal amplitudes were now near the lower part of the range for the optimum gain setting (10 dB).

  - Gain increases (necessary to measure the first turn) led to saturated signals → interlock.
  - Intensity drops (PS) led to insufficient signal amplitudes → interlock.
  - We also observed that some MOPOS settings seemed to be occasionally 'corrupted'. On 2 occasions during this period, the gain of the system changed without any actions from the shift crews (as far as I was told!). On such occasions the gain always returns to 20 dB! Has been observed again during recent MD periods.

→As a consequence operations became quite delicate and we were frequently stopped by pressure rise from the beam dump block due to interlocks generated by the MOPOS system.

→During the second weekend I therefore removed some of the BPMs from the interlock and increase the tolerances for all but the central BPM to 2 mm – this improved the situation…

Summary

- The machine protection system for CNGS with 4 BICs and 32 clients was commissioned in ~ 50-60 hours. This time only includes the specified tests (mostly from CCC). It does not include the hardware tests to connect the clients…
- All documentations and information for operation is available on a WEB page.
- No major problems were encountered during the commissioning and the transition to high intensity operation was smooth.
- Almost all interlock systems performed very well, with special mention for the powering interlocks (current surveillance & FMCM) that were quite outstanding !
- The only problem was due to the beam position interlock in the SPS ring – this became a major issue due to the simultaneous out-gassing problems of the SPS beam dump.

  I think we must consider installing a more robust (no gains) and faster system, even at the price of a reduced accuracy.
- The SBF was introduced for the first time with success.
- The next challenge will be operation with CNGS cycles in a super-cycle in October. This is going to be an interesting problem of settings management !

  If the beam dump continues to outgas, operation may be *VERY* delicate!