LHC Beam Operation Committee

Notes from the meeting held on 29th March 2011 (PRESENT)

1. SPS Beams – K. Cornelis (slides)

Karel presented the status of beams produced up to the SPS to clarify what is available for the LHC scrubbing run. As a general comment Karel mentioned that not all beams requested for this year have been prepared yet to keep radiation levels at minimum at the beam dump. This was asked by radiation protection since major works are planned for the technical stop of next week.
So far the following beams have prepared:

The 25 ns beams are ready since 11th March 2011 since they are needed for SPS scrubbing. Beams are prepared with nominal parameters: emittances in the range of [3.3-3.5 μm] and intensities of [1-1.2 10^{11} p/bunch]. So far only 2 batches have been used in the SPS. If more batches are needed then the SPS will need more scrubbing time since they have a new MKE4 kicker magnet which needs to be further conditioned. By experience this kind of kicker magnet out-gases fast, so no limitations are expected for producing 25 ns beams for the LHC scrubbing run with more batches.
The 50 ns beams are ready since 18th March with up to 4 batches with single batch from the PS Booster. Beams have the following parameters: the emittances are smaller than nominal [2.4 μm] and intensities are higher than nominal [1.35-1.45 10^{11} p/bunch], the plot shown underestimates the intensities achieved. With 4 batches the MKE4 is still outgassing. The double batch from the Booster is ready in the PS, the intensities in PS are nominal but with smaller than nominal emittances.

Karel then pointed out some possible delays in beam production due to interventions in the SPS during the next technical stop. He highlighted (with a plot) the main interventions (RED elements) and possible recovery problems (GREEN elements) since the vacuum chamber has to be opened (BLUE arrows).

- **Scraper** (first RED element): the installation of a new scraper for the LHC is already on going. This new scraper should be used operationally, the LSS5 scrapper becoming a spare scraper. This will reduce the radiation in LSS5 where a number of instruments are installed (UA9, vacuum etc). A half day conditioning should be sufficient based on experience with kicker outgassing rates.
- **Septum magnet** (second RED element): the replacement of the septum magnet can be a problem since the intervention requires breaking the vacuum at the beam dump (GREEN element). Opening the vacuum will require a conditioning of the dump, which can take some time since it shows a strong out gassing.

- **Quadrupole** (third RED element): the quadrupole will be hopefully repaired in situ but if this in situ replacement will not be possible, then the vacuum up to the injection kickers will have to be broken. These elements need typically 1 week conditioning which could therefore delay the production of beams by a significant time.

The hope is to recover from the technical stop as fast as possible; the final answer will come on Friday morning when the speed of conditioning of the MKE will be clear with high intensities beams.

Comments:

Concerning the beam types:

Gianluigi asked when the 50 ns beams with 2 batches would be ready. And when the 25 ns 4 batches? Karel answered that the preparation of the 50 ns beam with double batch injection in the PS will be fast, requiring some RF setting up. For the 25 ns the SPS needs 2 hours on Friday morning to qualify the beams. The single batch transfer beams are ready, but for 4 batches can take some time.

Concerning machine protection issues:

Jorg reminded that since beam emittances are smaller than nominal and intensities well above nominal, we are pushing towards ultimate beam parameters. The protection devices have been designed for ultimate and therefore should all be checked for given beam which goes beyond these parameters and check for saturation of signals in the LHC dump.

2. Scrubbing run plan– G. Arduini (slides)

The aim of the scrubbing run is to reduce the electron secondary emission yield (SEY) in the arcs and LSS to allow operation with 75 ns or with 50 ns beams. Heat load, vacuum pressure rise and beam blow-up coming from electron cloud should be acceptable. The 50 ns beam has higher potential in terms of bunch population in the injectors operation with that beam offers more potential in terms of luminosity performance.

Beam requirements for the scrubbing run:

- 50 ns beams with intensities up to 1.5 10^{11} p/bunch and emittances of 2-3.5 μm.
- 25 ns beams with 1.15 10^{11} p/bunch with nominal emittances

Machine settings:

- Solenoids and experimental dipoles OFF.
- Vacuum interlock levels increased from 4 10^{-7} to 10^{-6} mbar if needed.
- Cryo valve regulation for the beam screen in the arcs set to 25 K at least for a few cells

Preparation:

- Heat load calibration for a few cells (3-4 hours with no powering and no beam at the end of technical stop on Thursday).
- Injection of up to 96 bunches with 75 ns spacing.
- Injection of up to 144 bunches with 50 ns spacing.

It is expected that injected intensity ramp up and scrubbing will have to be interleaved to progressily clean the vacuum chamber. **Plan:**

DAY 1-3: Inject up to >1000 bunches in trains up to 4x36 bunches (1.3 10^{11} p/b) with 50 ns spacing and nominal emittances if compatible with vacuum rise, heat load and beam stability.

DAY 4: Evaluation of sensitivity to orbit distortion and radial position at 450GeV, ramp/squeeze/collisions with 50 ns beams (number of bunches as achieved with 75 ns). Check of the local orbit sensitivity by reducing separation bumps and crossing angles for one beam. Vacuum interlocks restored to nominal for ramp. To enhance the scrubbing one may reduce the bunch length.

DAY 5-7: Inject 50 ns trains of 4x36 bunches with smaller emittances. If we reach saturation with 50 ns beams then move to 2v72 bunches (1.1-1.2 10^{11} p/bunch) with 25 ns beams with nominal emittances up to approximately 2000 bunches. To enhance the scrubbing reduce the bunch length.

DAY 8: Ramp/squeeze/collision with 50 ns beams (same number of bunches as achieved with 75 ns beams if vacuum allows). Vacuum interlocks restored to nominal for ramp.

Decision for OPERATION of 2011:

50 ns beams: injection of 900 bunches with vacuum pressure below 10^{-8} mbar, heat loads lower than 10 mW/m/aperture and transverse blow-up limited to less than 20% at injection plateau.

75 ns beams: if the criteria for 50 ns not achieved.

Gianluigi also presented the impact on the scrubbing plan caused by the injection septum replacement in the SPS and a list of measurements to be followed during the scrubbing run with names of possible link persons.

Comments:

Concerning 1000 bunches in the machine: M. Lamont raised some doubts concerning the high number of bunches needed. Gianluigi reminded that we are not going beyond what was achieved in 2010 in terms of stored energy. The stored energy of 1000 bunches at injection is as high as 300 bunches at 3.5 TeV..

Concerning the ramp: E. Ciapala mentioned that we should check RF capture. Mike reminds the issues they had this year with instrumentation (BBQ) only with one batch with 75 ns spacing. W. Hofle mentioned the need to test the abort gap cleaning. M. Ferro-Luzzi stated that if scrubbing run is objectively needed as the observations show, then he would go for the most aggressive strategy to be more effective in the cleaning and with biggest potential for the after/scrubbing run operation of the collider. He

also asked why not test the ramp at the beginning of the scrubbing run and not only at middle and end. Gianluigi reminded that last year with 16 hours of scrubbing the vacuum pressure reached 10^{-7} mbar which means no way to ramp 50 ns beams before some scrubbing is achieved Mike expressed B. Goddard's and M. Meddahi's preferences for the scrubbing run: they think it is too pushy to think of physics with 50 ns beams, they propose to ensure physics with 75 ns beams.
Decisions on the strategy will be taken tomorrow at the LMC.

3. Injection Status – Towards 144 bunches– V. Kain (slides)

Verena presented the status of the injection system for the scrubbing run:

Injection: so far trains of 24 and 48 bunches have been injected. The maximum losses at the TDI are 3% for beam2 and 8% for beam 1. The higher values for beam 1 may be due to imperfect horizontal trajectory through the transfer line collimators. Transverse losses are controlled by scraping in the SPS. So far there are no issues for increasing the beam intensity due to transverse losses. Longitudinal losses profit from the larger capture voltage. Losses at the end of a 200 bunches filling shows a maximum loss of 5-10% for beam 1 and 8-16% for beam2, all located downstream of the TDI. More analysis is needed to conclude on the longitudinal losses since only 3 fills have been studied.

Abort gap cleaning: sub-sequences have been created to configure and operate (on/off) abort gap cleaning. The sequences have been tested with beam on the first bucket but not on the last one. The sub-sequences are not part of the nominal sequences and the MCS checks have to be tested yet.

Injection Cleaning: sequences for the injection cleaning have been prepared but none have been tested with beam. The system works as follow: from the injections sequencer a next injection requests switches on the injection cleaning. If no injection event arrives, the cleaning switches back off. If the injection is arriving then the cleaning switches off automatically. At the end of filling, amplitude and excitation are reset to zero.

Proposed planning to setup injection with 144 bunches:

- The first thing is to quantify the **effect of the TI8** shielding just installed during the technical stop (**1 hour**).
- **For 75 ns spacing with 96 bunches**, losses in the line, oscillations and SPS scraping must be checked. If required the collimators may have to be re-adjusted (**0.5-1.0 shift**).
- **For 50 ns spacing and 144 bunches,** setup will start with 12 bunches before increasing step by step the number of bunches (36-72-108-144 bunches, after checking losses, injection oscillations and scraping). **Injection of 25 ns beams** will only begin when experience is gained with 144 bunches injections and abort gap and injection gap cleaning (**no time estimate for this point**).

Comments: Mike asked if the 0.5-1 shift required is sufficient to validate the 50 ns beams injection with 144 bunches? Verena answered yes, if there are no issues of transfer line collimators. Jan commented that they will need to gain experience with the 50 ns beams before moving t**o 25 ns beam spacing**, moreover for the abort gap cleaning and injection gap cleaning they will profit of the start-up after shut down since low intensity beams are needed.

4. RF Status. P. Baudrenghien (slides)

Philippe presented the current status of the LHC RF.

Higher Voltage: The 4 sigma bunch length at extraction from the SPS is 1.5 ns (same as 2010). The RF capture profits from a higher voltage with respect to 2010. For the moment the voltage of the 8 cavities of beam 1 is 6 MV, the voltage of the 6 cavities of beam 2 is 4.5 MV. During the ramp the voltage rises linearly to 12 and 9 MV for beam 1 and beam 2 respectively. The longitudinal blow up during the ramp brings the bunch length to 1.2 ns at top energy. **Capture Loss:** the higher voltage used result in less than 1% losses at capture as confirmed by calculations by T. Argyropoulos. Measurements of capture losses shows 0.13% losses in both beams for 32 nominal bunches while for 200 nominal bunches the capture losses are 0f 0.2 to 0.3%. Op should see the improvement during the filling compared to 2010. **Bunch lengthening:** during physics run with higher voltages the bunch lengthening for both beams in the range of 7.5-17 ps/hour, while last year the average was15 ps/hour. Results are similar to 2010.

Longitudinal blow-up: after capture in the LHC the bunch lengths are approximately 1.25 ns with a target value of 1.2 ns to be achieved at FT. The excitation should start as soon as the ramp starts to reach the target due to the faster ramp and the larger voltage both leading to shorter bunches.

Klystron trip and debunching: calculations predict 0.8% losses due to a single klystron trip. Philippe went through three examples of klystron trips. His summary is that losing one out of 6 klystrons at 9 MV will lead to losses of 0.2 % out of the buckets which is equivalent to a peak of less than 0.02% in total intensity in the abort gap. Calculations are more pessimistic due to the different 2-D distribution assumed for the longitudinal phase space. Assuming the dump threshold at $2\ 10^{10}$ for the total abort gap population at 3.5 TeV, we can accept to trip one klystron with approximately 1000 bunches circulating in the machine. To allow higher intensities they will have to either increase the voltage further (12 MV also for B2) and use all the available klystrons, reduce the bunch length to 1 ns, or simply wait longer until the abort-gap intensity spike disappears.

Klystron/Cavities problems: Philippe listed the problems encountered over the last four weeks on cavities and klystrons.

The intensity increase after the scrubbing run requires all cavities to be operational in both rings, allowing RF capture on both beams with 6 MV and operation during physics with 12 MV. He also proposed to reduce the bunch length to 1 ns and open discussions to the experiments.

Comments: E. Shaposhnikova commented that having more bunches does not mean that the losses will get worse because not all bunches contribute to populate the abort gap. Jorg commented that a constant monitoring of the abort gap population should be available. So far no interlock has been activated on the measurement.

Jan commented about the dynamic range of the abort gap population, which is not compatible between diagnosing dangerous levels and detecting very low levels of beam for diagnostics.

Massi commented about the possibility to reduce bunch length to 1 ns, nothing against it in principle from the experiments, it will be discussed at the next LPC meeting next Monday.

5. AOB

The next LBOC meeting will be held in two weeks time.