LHC-Beam Commissioning Working Group

Notes from the meeting held on
9 November 2010

1- Comments and following from last meetings

Mike Lamont: **Ion stop** now scheduled for 17-18 November - 36h duration. Detailed program for these 36 hrs to be done - Gianluigi Arduini. On the list: 3.5 TeV with 12b filling, to compare with the one done before the scrubbing - 75ns test.

Marek Strzelczyk: **smooth squeeze hysteresis handling** (slides). Hysteresis and calibration implementation are reminded (1 A difference between the up and down curves) together with the consequences for the squeeze (smooth transition is being implemented). Ezio Todesco: effects depend on the type of magnets, the cycle used and the demanded trims while going up and down the curves. Ezio proposed that the problem is analysed case by case and confirmed that magnets do not anyway react fast enough to create problems on the power supplies.
Actual settings: for discrete setting, the ramp-up calibration is used. While incorporating to the functional beam process, the standard rules apply, calibration branch may change and discrepancy between trimmed actual settings and incorporated settings occurs. There is no obvious solution as for now.
In summary:

- Matching quads are ramped down (and up) during squeeze: Calibration branch is changed and transition is smooth;
- Actual settings trim may cause ramp down: Since it can be a small trim, calibration branch is not changed, it does not necessarily cause ramp down when incorporated to functional beam process and this needs to be handled;
- The existing optics in some cases have very small up-down variations during squeeze that may seem not physical and could be cleared.

Proposal: Review the type of magnets for which we have this kind of problem and study possible solutions. Rogelio Tomas stressed that this is now the main source of magnetic error in the machine.

2- Vacuum cleaning/scrubbing measurements in the LHC– Miguel Jimenez (slides)

Miguel Jimenez reminded that e-cloud effects have been observed in the SPS and as an illustration, the measurements taken in 2001 of the electron cloud induced pressure blow-up were shown - 25ns case.
Electron-cloud build-up driving parameters: bunch intensity, bunch train, filling pattern, secondary electron yields (thereafter SEY, δ), stimulated desorption yields (thereafter η), and other effects (size of the beam vacuum pipe, magnetic fields, temperature of the beam pipe walls).
Electron clouds limiting factors in the LHC: vacuum pressure rise, cryogenics cooling /plant capacity, beam stability, beam- gas scattering induced radiation, background to detectors.
Electron cloud build up: there are evidence that there are surviving electrons between the bunch trains, and this was again illustrated with measurements in the SPS using 25ns bunch spacing, increased the train spacing in steps up to 2.25 μs. LHC measurements with 2 trains of 24 bunches with a 50 ns bunch spacing were performed at 450 GeV, with

increasing train spacing: crosstalk between the bunch trains build-ups starts at 10 μs and increases very quickly below 3 μs bunch train spacing. Seed photo-electrons are to be considered above 2 TeV.

What are the guidelines from the SPS experience in terms of vacuum cleaning / scrubbing: measurements of the pressure decrease in the SPS as a function of the cumulated LHC-type beam time were performed. The field free conditions showed a decrease by 50 in 58 hours. Miguel reminded that to make an efficient cleaning run, the vacuum system need to be kept very close to the interlock level. Using the data taken during the LHC beam cleaning/scrubbing operation, the dynamic pressure minus the static pressure, normalized to 1, was plotted as function of cumulated beam time: the same decay is observed at all locations of the machine: There is no correlation between dynamic pressure (beam pressure) and the position along the ring. The pressure increase reduced by factor 2/3 within 3 hours. All pressures reached after the scrubbing run are compatible with the design values (100h beam lifetime).

If one look at the same pressure difference as a function of the cumulated beam time, it show that 16h of cleaning is needed for this type of beam: This conclusion is only valid for a given bunch intensity and filling pattern There is cleaning/scrubbing only if running in an e-ecoud regime! Memory effect will stay (partly/totally) for other schemes. By reducing the bunch intensity slightly, the picture will change: will maybe be below the cleaning/scrubbing effect (no e-cloud build up).

The plot of the pressure difference as a function of the number of charges shows a linear runaway (no exponential) of the effect observed.

Mitigation proposed by Miguel:

- Scrubbing Runs
  - Use maximum bunch intensity
  - Increase the number of bunches per train
  - Keep the beam potential at the highest – avoid beam emittance blow-up to keep the energy lick of the electrons to the maximum
  - Adjust the pressure interlocks to higher value where feasible
- Solenoids
  - Only applicable on Cold/Warm transitions and bellows of the long straight sections housing the Experimental Areas (IR1/2/5/8)
- Re-cooling sequence of SAM in case of failure of the cryogenics
  - Beam Screen is kept at a higher temperature than Cold Bore during normal cool down – Standard procedure
  - In case of stoppage of a cryoplant, same procedure shall be applied during the re-cooling of the SAMs
    - Takes longer BUT is absolutely required to avoid gas condensation on Beam Screens!

Closing remarks on vacuum cleaning versus beam scrub:

- Log scale for η versus linear scale for δ (scrubbing)
- 6 orders of magnitude on η while δ goes down to 1.4
- η impacts the pressure rise as δ affects the electron cloud density
- Electrons with energies between 5 and 50 eV decrease η BUT their efficiency on the reduction of δ is significantly lower.
- Finally the evolution of the SEY as a function of the energy was shown with the conditioning from 4 to 90h (limit is 1.1 SEY)

Discussion:

How would 75 ns bunch spacing compare with 50 ns? No measurements exist at 75ns yet but saturation level should be at the same values.

How long do we need to scrub with 50 ns, with 10^{15}: 20 hrs.

How does it change when the intensity increases? Desorption yield and δ max were showed as a function of dose (from laboratory measurements). Each step in dose level would require a factor 20 in time.
Is scrubbing at 450 GeV also valid to operate at 3.5 TeV? This is to be verified.
It can be said that cold-warm transitions are problem. No problems in the NEG areas.

3- Cryogenics system observations during the 50 ns bunch spacing operation – Laurent Tavian (slides)

Laurent Tavian reminded the basic cooling scheme of the beam screens. There are two circuits operating in parallel with a control of the mixing temperature. During the 50 ns operation, all the temperature outlets reacted in the same way and peaks were correlated with the beam current (heat deposition on the beam screen). To note: data with no intensity correlation are linked to the lost of FBCT data. These peaks are present in the continuous cryostats of all sectors. The questions to answer:

- What is the relation between temperature variation and beam screen heat load?
- What are the expected heat loads due to synchrotron radiation (SR) and image current (IC)?
- What is the level of additional heat loads due to e-clouds?

In his presentation, Laurent Tavian gave example of half-cell 33L6.
The relation between temperature increase and beam screen heating was reminded. At constant flow, an increase of the beam screen outlet of 1 K corresponds to a heat deposition of 2.2 W. Time response: 100s (residence time of He flow in BS capillaries) and 10 min (specific heat of BS).
The SR and IC loads were calculated according to beam parameters and are clearly dominated by the image current. The difference wrt the total heat loads comes from the extra heat load induced by e-clouds.
Various beam cases were discussed and are summarized in the following table.
When a 50 ns case is compared to a very similar one dating of Sep'10, at 3.5 TeV, 104 bunches/beam but with 150-ns spacing, it is observed that for 150 ns there is no relevant e-clouds activity.
Summary of the different cases:

Run / Zoom#	Beam energy	Nb bunches per beam	e-cloud	e-cloud per bunch
	[TeV]	[-]	[mW/m per aperture]	[mW/m per bunch]
1	0.45	84	12	0.14
2	0.45	108	12	0.11
3	3.5	108	40	0.37
4	0.45	60	12	0.20
5	0.45	48	11	0.23
6	3.5	144	42	0.29
7	0.45	132	8	0.06
8	0.45	228	30	0.13
9	0.45	228	12	0.05
10	3.5	108	30	0.28

Do we observed cleaning process? Yes, some cleaning process is being seen with beam accumulated time!
Gianluigi Arduini: More detailed analysis must be done. In particular, at 3.5 TeV a ramp is to be done with exactly the same filling patterns as before the scrubbing run.

4- E cloud instabilities: expectations, observation and outlook – Frank Zimmermann (slides)

Frank Zimmermann gave a presentation on the simulation and theoretical work done on e-cloud instabilities. He reminded that other machines did experience ecloud effects (SPS, Tevatron) and LHC does sits in the dangerous region in this respect. Frank Zimmermann presented the effects of the electron clouds, the modeling tools which are used and reminded of the LHC e-could strategy and predictions. Frank Zimmermann also summarised the extensive work done on secondary emission yield & conditioning and recalled the (old) simulations performed for nominal LHC & 50 ns spacing. Very recently, new simulations have been launched for LSS for 150 ns bunch spacing, and for 24-bunch 50-ns trains.

Summary of the simulation results for 4x24 bunches [at injection] (1.85 μs spacing between batches):

δ_{max}	N_b	P [mbar]	R	dP/ds [mW/m]	total e- flux [μA/m]	e- flux > 30 eV [μA/m]
2.4	1.2×10^{11}	1	0.5	**0.001**	0.034	**0.011**
2.5	1.2×10^{11}	1	0.5	**0.18**	0.697	**0.239**
2.5	1.2×10^{11}	**10**	0.5	**3.3**	12.3	**4.34**
2.5	1.2×10^{11}	1	**1.0**	**61**	268	**69.8**
2.4	1.2×10^{11}	1	**1.0**	**46**	200	**52.7**
2.5	**1.0×10^{11}**	1	0.5	**0.44**	2.1	**0.71**
2.5 (top!)	1.2×10^{11}	1	0.5	**59**	356	**93.8**

30 days continuous running at 70 μA/m gives CO pressure corresponding to 100-hr beam lifetime. 2 days continuous running at 70 μA/m gives 1 mC/mm^2 !

Simulations are continuing to analyse in details the recent observations. These new simulation results are very encouraging and confirm the preliminary conclusions from the vacuum and cryogenics groups.

Summary:

- at 50-ns spacing strong evidence for large electron cloud build up in warm and cold sections - cold sections are of bigger concern;
- both heat load & instability in 3rd and 4th train indicate SEY δ_{max}~2.5 in the arcs (larger than expected) at R=0.5
    - av. e-cloud density ~6×10^{11} m^{-3} (from Q' effect)
    - expected tune shift: $DQ \sim r_p \rho_e C\beta/(2\gamma) \sim 0.0025$
    - new simulations for LSS and more simulations for arcs are in progress
    - determine R from memory effect between trains

5- LHC ion beam commissioning: progress and issues – John Jowett, Jan Uythoven, Joerg Wenninger – DETAILED ION BEAM COMMISSIONING SUMMARY, by JOHN JOWETT, IS POSTPONED TO NEXT WEEK .

Monday morning summary of Week 44 - slides from Jan Uythoven and Joerg Wenninger
And summary of the 50ns observation done by Gianluigi Arduini (draft summary)

6- AOB

Daily 8:30 HWC meeting in the CCC conference room (09:00 at weekends).
Next meeting: **16 November 2010,** 15:30, 874-1-01.

Malika Meddahi

LAST NAME	FIRST NAME	DEP/GROUP	Present
ALABAU PONS	Maria Carmen	BE-ABP-LCU	X
ALEMANY FERNANDEZ	Reyes	BE-OP-LHC	
AQUILINA	Nicholas	TE-MSC-MDA	X
ARDUINI	Gianluigi	BE-ABP-LIS	X
ASSMANN	Ralph Wolfgang	BE-ABP-LCU	X
BAER	Tobias	BE-OP-SPS	X
BAILEY	Roger	BE-OP-LHC	
BARTMANN	Wolfgang	TE-ABT-BTP	
BAU	Jean-Claude	BE-CO-HT	
BAUDRENGHIEN	Philippe	BE-RF-FB	
BELLESIA	Boris		
BELLODI	Giulia	BE-ABP-HSL	X
BHAT	Chandrashekhara	BE-ABP	X
BOCCARDI	Andrea	BE-BI-PM	
BOTTURA	Luca	TE-MSC-SCD	
BRACCO	Chiara	TE-ABT-BTP	
BRUCE	Roderik	BE-ABP-LCU	X
BRUNING	Oliver	BE-ABP	X
BRUNNER	Olivier	BE-RF-KS	
BUFFAT	Xavier	BE-OP-LHC	X
BURKHARDT	Helmut	BE-ABP-LCU	
BUTTERWORTH	Andy	BE-RF-CS	
CALAGA	Rama	BE-ABP-LCU	X
CALVIANI	Marco	EN-STI-EET	X
CARLI	Christian	BE-ABP-LIS	X
CARLIER	Etienne	TE-ABT-EC	
CAUCHI	Marija	BE-ABP-LCU	
CHAPOCHNIKOVA	Elena	BE-RF-BR	X
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DEHNING	Bernd	BE-BI-BL	
DENIAU	Laurent	TE-MSC-MDA	
DOMINGUEZ SANCHEZ	octavio	BE-ABP	X
DROSDAL	Lene	BE-OP-LHC	X
DUBOURG	Sylvia	BE-ASR-AS	
FARTOUKH	Stephane	BE-ABP-LCU	X
FERRO-LUZZI	Massimiliano	PH-LBD	
FORAZ	Katy	EN-MEF-LPC	
FUCHSBERGER	Kajetan	BE-OP-SPS	
GAROBY	Roland	BE	
GIACHINO	Rossano	BE-OP-LHC	
GIANFELICE	Eliana	TE-ABT	
GIOVANNOZZI	Massimo	BE-ABP-LCU	X
GODDARD	Brennan	TE-ABT-BTP	X
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GRUWE	Magali	BE-ASR-SU	
HAGEN	Per	TE-MSC-MDA	X
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HERR	Werner	BE-ABP-CC3	
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HOFLE	Wolfgang	BE-RF-FB	
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HOLZER	Eva Barbara	BE-BI-BL	X
IKEDA	Hitomi		
JACQUET	Delphine	BE-OP-LHC	
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JONES	Rhodri	BE-BI	
JOWETT	John	BE-ABP-LCU	X
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MACLEAN	Ewen	BE-ABP	X
MACPHERSON	Alick	BE-OP-LHC	
MANGLUNKI	Django	BE-OP-SPS	X
MARSILI	Aurelien	BE-BI-BL	
MEDDAHI	Malika	TE-ABT-BTP	X
MERTENS	Tom	BE-ABP-LCU	X
METRAL	Elias	BE-ABP-ICE	X
MONTABONNET	Valerie	TE-EPC-OMS	
MUELLER	Gabriel Johannes	BE-OP-LHC	
NEBOT DEL BUSTO	Eduardo	BE-BI-BL	X
NORDT	Annika	BE-BI-BL	
NORMANN	Lasse	BE-OP-LHC	
PAPOTTI	Giulia	BE-OP-LHC	X
PIELONI	Tatiana	BE-ABP-ICE	X
POJER	Mirko	BE-OP-LHC	X
PONCE	Laurette	BE-OP-LHC	
PUCCIO	Bruno	TE-MPE-MI	X
REDAELLI	Stefano	BE-OP-LHC	
ROESLER	Stefan	DGS-RP-AS	
RONCAROLO	Federico	BE-BI-PM	
ROSSI	Adriana	BE-ABP-LCU	
ROY	Ghislain	BE-ASR-SU	
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SLIWINSKI	Wojtek	BE-CO-IN	
SOLFAROLI CAMILLOCCI	Matteo	BE-OP-LHC	
STEINHAGEN	Ralph	BE-BI-QP	X
STRZELCZYK	Marek	BE-ABP-LCU	X
TERRA PINHEIRO FERNANDES	Mario	BE-OP-LHC	
THIESEN	Hugues	TE-EPC-MPC	
TODD	Benjamin	TE-MPE-MI	
TODESCO	Ezio	TE-MSC-MDA	X
TOMAS GARCIA	Rogelio	BE-ABP-CC3	X
UYTHOVEN	Jan	TE-ABT-BTP	X
VALENTINO	Gianluca	BE-ABP-LCU	
VALUCH	Daniel	BE-RF-FB	
VANBAVINCKHOVE	Glenn	BE-ABP-LCU	X
VENTURINI DELSOLARO	Walter	BE-OP-LHC	X
VINCKE	Heinz	DGS-RP-AS	
VINCKE	Helmut	DGS-RP-AS	
WENNINGER	Jorg	BE-OP-SPS	
WHITE	Simon	BE-ABP	X
WIENANDS	Uli	BE-OP	X
WOLLMANN	Daniel	BE-ABP-LCU	X
ZANETTI	Marco	PH-UCM	
ZIMMERMANN	Frank	BE-ABP-LCU	X
TAVIAN	Laurent	TE-CRG	X
JIMENEZ	J. Miguel	TE-VSC	X
MAURY CUNA	Humberto	BE-ABP-LCU	X
DE MANIA	Riccardo	BE-ABP	X
RUMOLO	Giovanni	BE- ABP	X
BREGLIOZZI	Giuseppe	TE-VSC	X