Experimental conditions and background in commissioning and operation

Here :

To have a (first) discussion on this subject for LHC commissioning and in preparation of my open LHCMAC21 presentation on 14 June

Still some time until LHCMAC21 :

Please let me know about further input / suggestions

In the LHCMAC I intend to also add on commissioning : getting optics and orbit right, bringing into collisions -- already discussed here and to be discussed in the LTC on 20/6.

Considerations for the LHCMAC talk

Machine Detector Interface and background calculations were already presented to the LHCMAC17 on 9 Sept. 2005 by Tsesmelis.

The collimation system has also been presented *and endorsed* **by the LHCMAC.**

Idea is this time to focus on commissioning, how to deal empirically with backgrounds and more generally experimental conditions in operation.

How to use the existing machine and instruments to operate the LHC safely and get the maximum amount of luminosity in good conditions for the experiments.

The LHC will quickly go into a new domain of energy per particle and total stored energy and may well confront us with some surprises.

We should be able to quickly diagnose background problems and allow for some flexibility to react.

Operation and Commissioning needs

“Chamonix” Divonne Jan ‘06 discussions + follow up in the LTC

Need for responsible for background from machine side (H.B.) :

My first presentation to the LHCMAC. A bit about my *“background”* :

PhD 1982 Tasso@Petra/Desy. Bbabha/Muonpair ; incl. Lumi. determination

then CERN : fixed target NA31 / CDHS ; ALEPH lumi / background monitor (‘85-90)

operation : EIC and machine coordinator for LEP + SPS (‘90-98; incl. end of SppbarS) ;
together with GvH experimental conditions and background optimisation in LEP

in Acc. Phys. Group : LHC commissioning, SPS MDs + Halo & Tail studies for CLIC / ILC ; author of various MC generators (beam gas, compton, synchr. radiation, high energy muon production - lately with implementation in Geant4)

Framework (similar to LEP) :

Continuous follow up in operation - EICs(Reyes Alemany F.), LHCCWG, Experiments (run-coordinators) collimation team, physics coordinator ;

Beam-beam, separation, crossing angle - W.Herr

Luminosity and Background : Experimental Conditions

Wanted : **high luminosity and low and stable backgrounds - no spikes**

- **Luminosity and background is linked. Increasing luminosity and intensity increases the absolute background.**

With $L \sim I^2$ signal to noise should decrease ; was not always the case in actual machines.

- **The LHC machine and experiments are designed for very high intensity and luminosity (1.e34 cm-2s-1).**

- **The LHC will anyway require very clean operation not to quench and a very gradual increase of intensity through various commissioning phase.**

Background Sources and Optimisation

- **Beam Gas -- good vacuum quality - particularly around experiments**

- **Halo -- minimise halo production and maximise cleaning efficiency**

  well corrected machine, avoid resonances, minimise any heating / vibrations

  careful with transverse feedback, orbit feedback etc.

  optimise lifetime and minimise emittance growth

- **Collisions -- unavoidable (the signal) ; also secondary side effects on which we may have some influence : avoid small offsets : 0.1 σ negligible in Lumi (0.25%), may instead still have effect on lifetime / halo a small fraction of the collision products can travel to the next IP(s)**

Collimation and Background

Collimation systems in other machines (i.e. LEP) mainly to reduce experimental backgrounds.

LHC collimation : designed for high cleaning efficiency (2e-5/m) to protect the machine from quenching - including tertiary collimators to protect the triplet which becomes an aperture limit at low beta*. Instead (to my knowledge) **nothing specifically designed for experimental background reduction**

What can be done with the available system to optimise or at least check and diagnose background issues ?

LHC will have about 100 collimators (as LEP) ; settings these all empirically is not realistic.

Some flexibility needed :

- **allow for cleaning ; scraping with primary collimators**
- **allow for opening slightly tertiary collimators ; check effect on expts.**
- **prepare settings for nominal and reduced (~2.5µm) emittances ; use as coarse / tight settings**

Complex LHC insertions ; separation and crossing angle

The LHC insertion optics are rather complex (compared to LEP with 4 equal experimental insertions and perfect e+e- symmetry).

LHC has 2 separate rings and approximately anti-symmetric insertions. IR1 (ATLAS) and IR5 (CMS) optics are identical expect for separation / crossing.

With crossing angle (142.5 µrad for nominal Φ):
Reduced - asymmetric aperture ; proposal to optimise by lateral shift.
The nominal pre-collision separations are ± 0.5 mm - off in Φ.

IR1 : horizontal separation and vertical crossing angle
IR5 : vertical separation and horizontal crossing angle

Added complication as far as backgrounds and experimental conditions are concerned : commissioning starts without crossing angle.
Go step by step.

IR2 & IR8 ; Spectrometers

ATLAS (IR1) and CMS (IR5) are designed for full (1.e34) luminosity.

Alice (IR2) and LHCb in (IR8) only require ~1.e32 luminosity and potentially suffer as far is backgrounds are concerned when intensities and luminosities are pushed for ATLAS and CMS !

Alice and LHCb have spectrometers

± 70 μrad IR2 ; ± 135 μrad IR8 switching polarity 1 / week

for operation and backgrounds this adds to the complexity ; potential source of errors and enhanced sensitivity to off-momentum background.

Note : IR8 is shifted by 3 $\lambda_{rf} \approx$ 11.25 m towards IR7

Experience from other machines. ISR

ISR : K. Hübner , CERN 77-15 :

Another current limit is imposed by the maximum background rate which can be tolerated by the most sensitive physics experiment. The main sources of such background are beam-gas scattering and the halo of the beam hitting an aperture limit upstream of the experiment. In principle, the background for an experiment should decrease linearly with current, whereas the signal, the luminosity, increases with the square of the current. Thus the signal to noise ratio should improve with increasing current. Unfortunately this is not the case - due to the fact that the beam loss-rate has been found to increase quite rapidly as a function of current. The reasons for this are not yet very well understood.

Background can be a performance limitation and is hard to predict.
Related to vacuum, losses and lifetime - which depend on operation.

Continuous background monitoring needed for operation

LEP background experience

both important at LEP1 (spikes) and LEP2 (MW synchrotron radiation)

- Background often *by design* close to limits :
  β-squeeze, beam pipe radius decrease - to what could be tolerated

- It was observed, that background depends, often critically on many parameters :
  Collimator settings, beam current, tune, orbit, chromaticity, ..

- Continuous background monitoring needed for operation + follow up in meetings bi-weekly schedule meetings chaired by the Physics coordinator

References :

Study of Beam-induced Particle Backgrounds at the LEP Detectors, von Holtey et al. **http://cdsweb.cern.ch/search.py?recid=333153&ln=en**

Collimation and Background to the Experiments, H.Burkhardt, Chamonix '93 proceedings, CERN SL/93-19 (DI) pp. 47 - 51

Need for robust, normalised figure of merit signals

Presentations in the various machine detector interface working groups :

LHC Experiment Machine Interface Committee LEMIC, 26 Sep. 2006
LHC background working group, 29 Sep. 2006
LHC Experiment Accelerator Data Exchange LEADE 9 Oct. 2006

Expecting feedback from experiments

Followed up in within <u>LHC background working group</u>

Request for two normalised Background Signals / Experiment

- **Normalised :**

  < 1 means good conditions

  > 5 means very bad conditions with danger of detector trips or significantly diminished data quality

- **2 complementary signals**

  like small / large angle or charged / neutral or beam1 / beam 2

  20 % vertex + 30 % forward chambers + 50 % ... whatever is most relevant

- **Signals and normalisation : defined and provided by the experiments.**

  at a rather modest rate, about 1 / sec adequate, for information and possible operator intervention **Not necessarily hardwired. Not connected to beam dump**

  Could be done using the Data Exchange Bus and DIP, EDMS spec 701510

- **Available before stable conditions : independent of data taking**

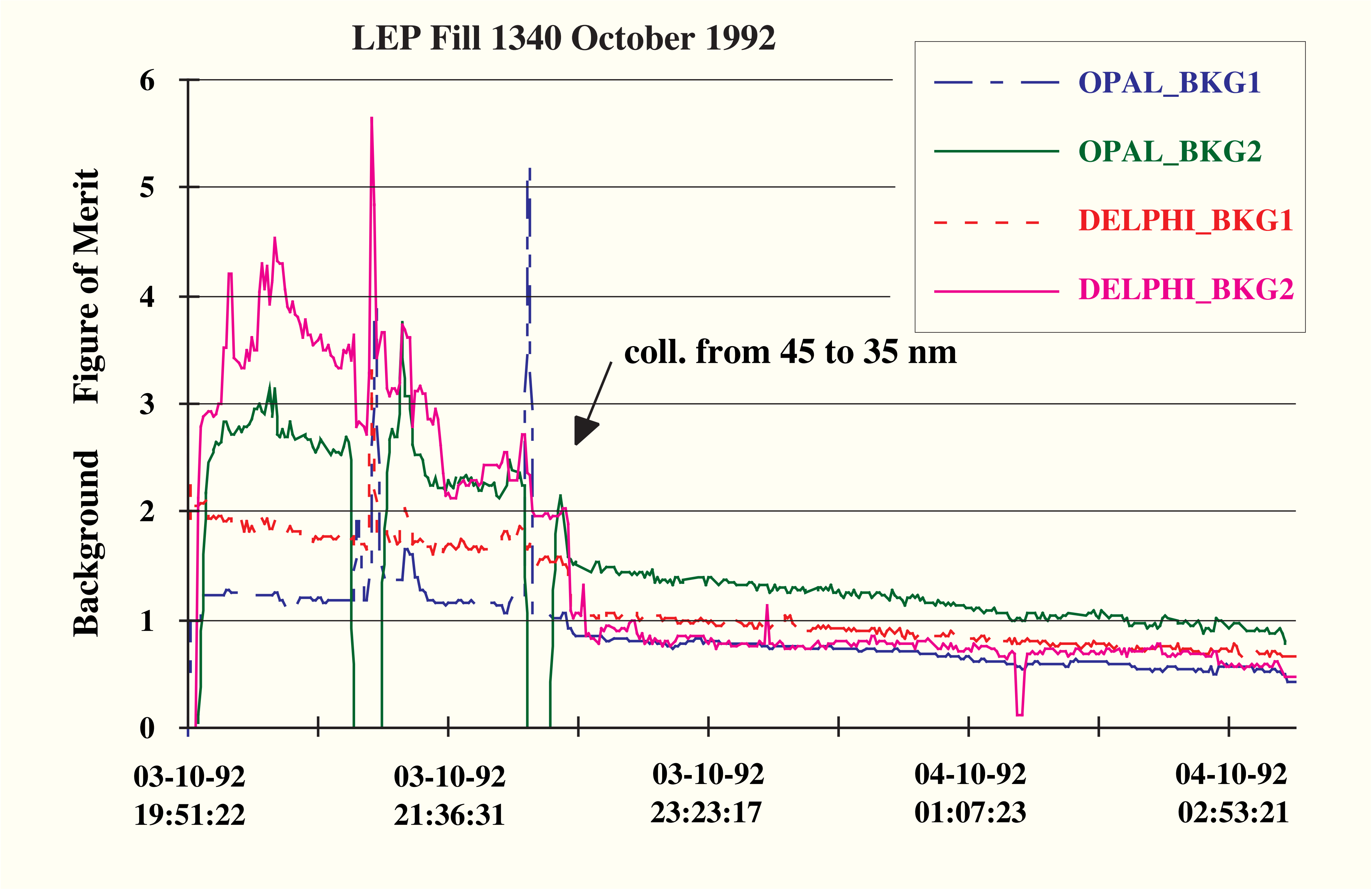
  In terms of machine modes. For Adjust, Stable Beams, Unstable Beams.

  Injection, Filling, Ramp & Squeeze : do not expect to perform operational background optimisation. Always an issue: beam-loss, radiation and possible actions inj.veto / beam dump.

in ALEPH @ LEP BKG monitoring done with extra electronics (extra crate, scalers,..), independent of main data acquisition

H.Burkhardt and J.Rothberg, “Proposal for Background Monitoring with ALEPH.” ALEPH 88-144, NOTE 88-19, CERN Geneva 11/11/1988.

LEP example

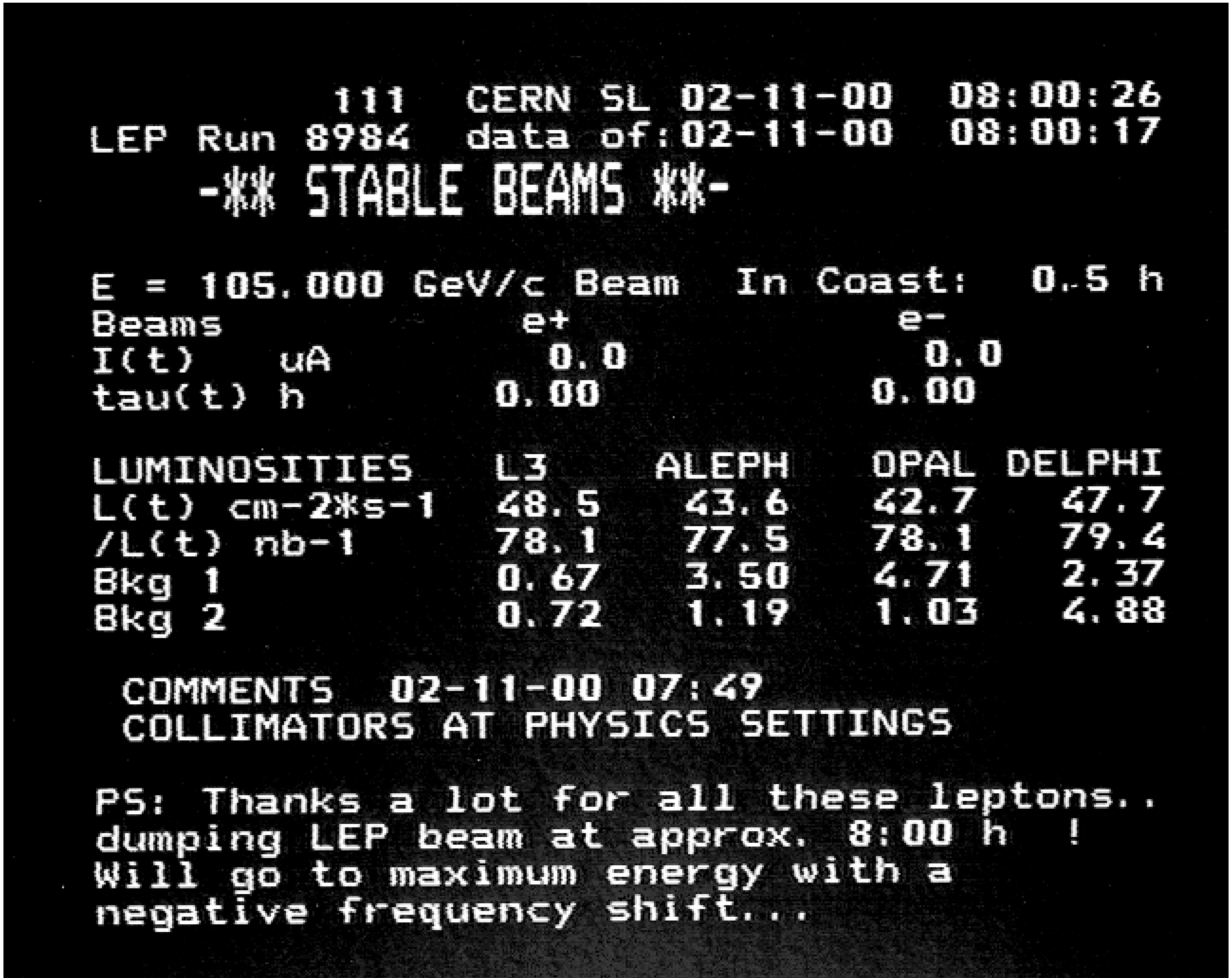


Evolution of Backgrounds in a LEP1 high luminosity fill.

Status and Communication with Experiments

Example of what we used to have in LEP

AB/CO teletext services http://hpslweb.cern.ch/teletext.html



proposed LHC status page in mode with collisions

	111	CERN AB	31-11-07	12:20:26
LHC Run 1234		data of	31-11-07	12:20:16

— ** STABLE BEAMS ** —

E = 0.450 TeV	Beam	In Coast	0.5 h
Beams	Beam 1	Beam 2	
#bun	43	43	
Nprot(t)	1.71e12	1.73e12	
tau(t) h	121	140	

Luminosities	ATLAS	ALICE	CMS	LHC-B
L(t) 1e28 cm-2s-1	5.23	6.23	7.13	1.21
/L(t) nb-1	0.78	0.68	0.78	0.12
BKG 1	1.20	0.52	0.90	0.33
BKG 2	0.85	0.82	0.50	0.60

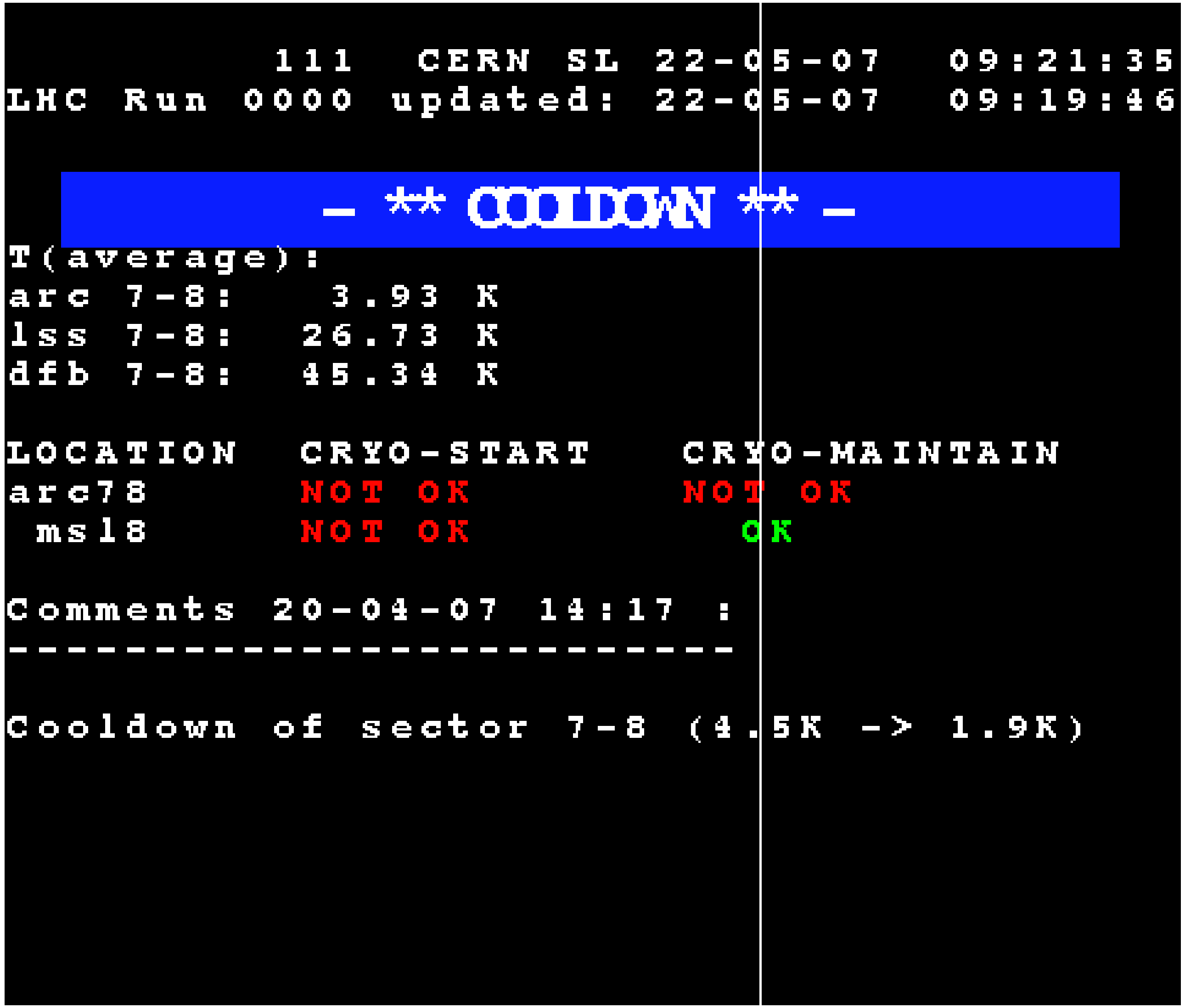
Comments 31-11-07 11:40:26

COLLIMATORS in coarse settings

Separation Scan in IR1/Atlas

Implementation, by Markus Albert

see <u>http://hpslweb.cern.ch/frame/java/1.1/view111-java.html</u>



```
           111  CERN SL 22-05-07  09:21:35
LHC Run 0000 updated: 22-05-07  09:19:46

            - ** COOLDOWN ** -
T(average):
arc 7-8:    3.93 K
lss 7-8:   26.73 K
dfb 7-8:   45.34 K

LOCATION   CRYO-START    CRYO-MAINTAIN
arc78      NOT OK        NOT OK
 ms18      NOT OK          OK

Comments 20-04-07 14:17 :
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Cooldown of sector 7-8 (4.5K -> 1.9K)
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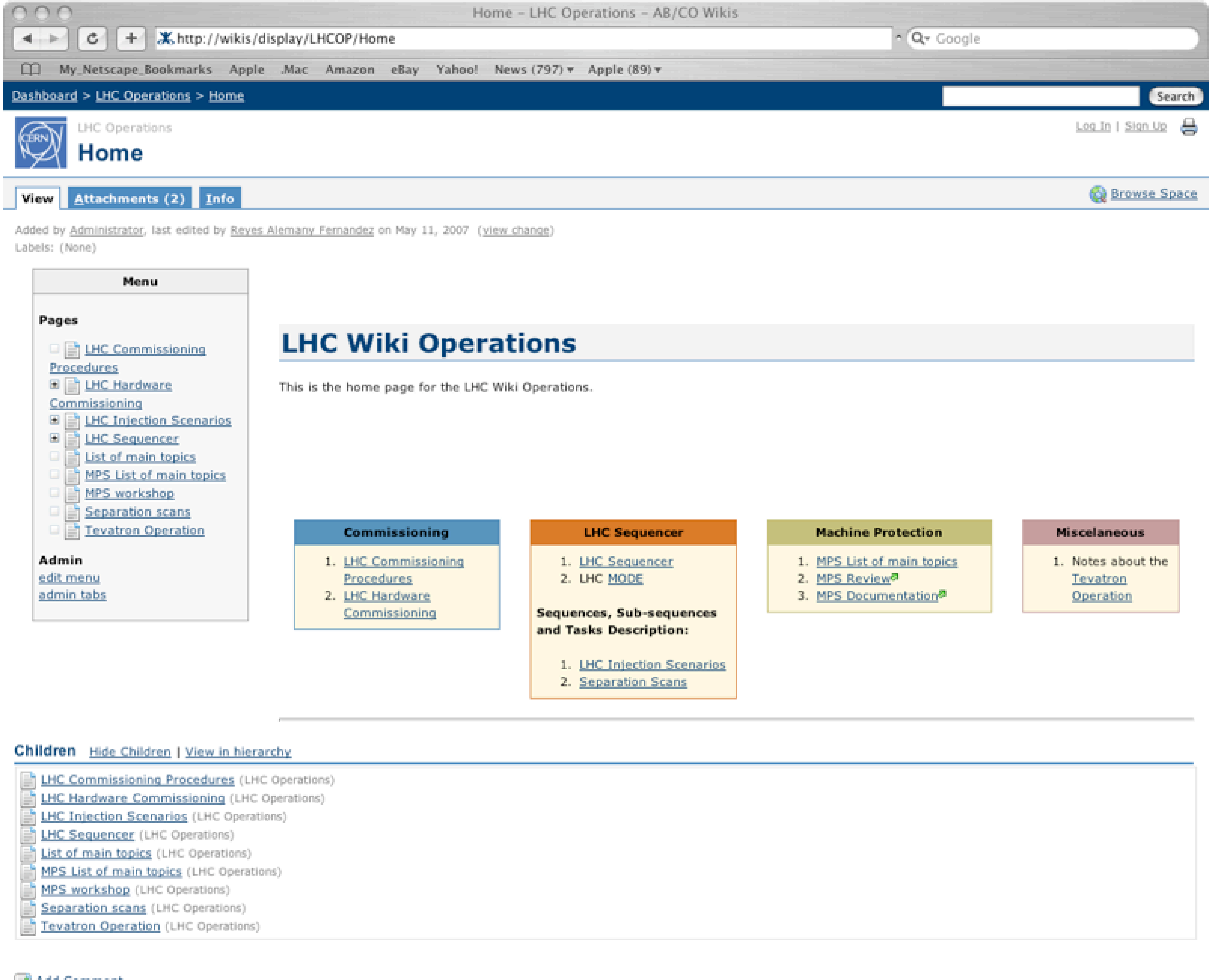
Operational procedures http://wikis.cern.ch/ LHC Operations (LHCOP)



Conclusion

We expect that background or more generally experimental conditions will be a central issue and prepare for continuous follow up in operation starting in early commissioning, through all phases towards full intensity and luminosity.