# SUMMARY SESSION II, OBSERVATIONS, LABORATORY MEASUREMENTS, MODELLING

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## 1 REVIEW OF RECENT OBSERVATIONS

An extensive review of recent observations and of new diagnostics has been presented for the following machines: PS, RHIC, PSR, APS, and SPS.

It is very significant to note that some "old" machines show electron cloud related effects when they are operated with new or with upgraded beam parameters.

This is not only the case for the PS and the SPS at CERN but most recently also for RHIC. Rather satisfactory agreement exists between models and observations increasing the confidence in the predictive power of simulation codes.

## 2 MODELLING

The modelling of the e-cloud build-up, heat load measurements using calorimeters, observations of pressure rises and the evolution of the secondary electron yield as a function of beam scrubbing have been addressed in several presentations during this session. There has been a remarkable progress in this field, the most noteworthy being the better description and parameterisation of the low energy secondary electrons (reflected electrons) (see talks by N.H., M.F., I.C.). Introducing these new input data in the codes shows that e-cloud build-up and heat load are indeed very sensitive to the very low energy part in the distribution. Since low energy electrons are notoriously difficult to measure as they are affected by very low magnetic and electric fields, it will be a challenge to obtain data, which can be used reliably for a real machine.

Complimentary measurements of the secondary electron yield *in situ* and in laboratory systems give confidence in the models used in the simulation codes.

## 3 DISCUSSIONS

A very interesting observation in the SPS has been the appearance of multipacting electron stripes in the dipoles. From the subsequent discussions it was not clear whether the horizontal position of these stripes are reproduced reliably by simulation codes. A follow-up on this question is necessary and has direct implications for the urgent decision on LHC beam screen slots.

The important question of generation and the apparently rather long survival time of electrons e.g. during bunch gaps in the PSR has been raised.

How can thresholds be defined for observable effects and used for benchmarking of simulation codes: multipactor electron signals, vacuum pressure rise, beam stability, emittance growth,.

Many machines (SPS and LHC) strongly rely on beam conditioning (scrubbing) of the surface. There seems to be consensus that more work has to be done to better understand the process. How closely is the evolution of the secondary electron yield and of the pressure rise linked together? Is it possible to relate one to the other?

For the cryogenic system of the LHC the important question remains whether beam scrubbing depends on temperature and whether room temperature results can be used for a cryogenic system

A point, which should not be overlooked, is the close relation between heat load (P) and dose rate (D):

$$D(C/s/mm^2) = \frac{P(W/m)}{F(mm^2/m) < E >}$$

For the LHC beam screen the surface which needs to be scrubbed: F~5 $10^4$ $mm^2/m$. N. Hilleret et.al. find $10^{-2}$ $C/mm^2$ for a well-scrubbed Cu surface with <1.3 for δmax. Operating the LHC within the cryogenic budget of P = 0.5 W/m and assuming a mean electron cloud energy <E> ~ 100 eV, one finds that it should take only about 30 hours to accumulate this dose.

From this simple argument one may conclude that in case the heat load is limiting the operation of the LHC, scrubbing should go fast. Conversely, if heat load is not a problem, there should be no problem and scrubbing is not an issue.

The analogous argument also applies to vacuum scrubbing, i.e. the reduction of the electron stimulated desorption yield of the surface. Most recent results from the SPS have indeed confirmed the fast clean-up of the vacuum system due to the multipacting electrons.

A detailed scenario should be worked out for the LHC to show the various options which can be followed to achieve δmax below 1.3 : bunch intensity & spacing, filling patterns, absence of synchrotron radiation and hence no photo electrons for beam energies < 2 TeV.

At CERN, the valuable possibility exists to use the SPS as a test bed for the LHC. With the installation of the COLDEX system, the cryogenic aspects can be tested. For this important program substantial beam time will need to be allocated, which are not foreseen in the present schedule.

The possible use of microwave power either as a diagnostic tool, as a means to enhance the surface conditioning or even as a remedy to suppress the electron cloud has been suggested and has been discussed at some length.

Concerning the surprising results from RHIC, it should not be overlooked that the LHC ion beams may show a similar behaviour, not necessarily in the LHC ring but perhaps in one of the pre-injector machines. Are there similarities between RHIC and LEIR, which could produce similar pressure rises?

A very attractive means to eliminate or to reduce the electron cloud will be the use of NEG-films in addition to the more conventional TiN coatings, which both have a low secondary electron yield. For those regions in the LHC, which can be baked and hence the getter film activated *in situ* (long straights and experimental vacuum chambers) this solution has been adopted. Further studies and a comparison of the relative merits of such surface coating should be encouraged.