SUMMARY REPORT OF SESSION VI

W. Chou, Fermilab, Batavia, IL 60510, USA
O. Brüning, M. Giovannozzi, E. Metral, CERN, Geneva, Switzerland

Abstract

This report gives a brief review of the presentations in Session VI of the Ecloud'02 Workshop and summarizes the major points during the discussions. Some points (e.g., the critical mass phenomenon) are not conclusive and even controversial. But it has been agreed that further investigations are warranted.

1 REVIEW OF TALKS

The topic of Session VI in the Ecloud'02 workshop is *"Discussions of future studies, collaborations and possible solutions."* Half of the session is devoted to presentations, another half to discussions. This report will focus on the latter.

There are six presentations:

- R. Macek, *Possible cures to the e-cloud problem.*
- G. Rumolo, *Driving the electron-cloud instability by an electron cooler.*
- U. Iriso Ariz, *RF test benches for electron-cloud studies.*
- F. Caspers, *Stealth clearing electrodes.*
- F. Ruggiero, *Future electron-cloud studies at CERN.*
- E. Perevedentsev, *Beam-beam and transverse impedance model.*

Macek gives an extensive list of possible cures to the e-cloud effects (ECE). Among them, the most interesting ones are those that have been proved to be either effective or ineffective. For example, the PSR has found three effective cures: beam scrubbing, inductive inserts and sextupoles. The inductive insert is a new idea that was originally suggested for compensating space charge effects. It works well for giving a "cleaner" gap (i.e., reduced population of electrons in the gap) and, thus, raises the e-p instability threshold. The effectiveness of the sextupoles comes with a pleasant surprise. Because the e-p instability in the PSR is in the vertical direction, these sextupoles give a skew quadrupole field, which couples the x and y motion that helps stabilize the beam. The PSR has also tried TiN coating, solenoids and a better vacuum. Although these measures greatly reduce the prompt electrons, they show no effect on the threshold. On the other hand, however, KEK-B and PEP-II have both found TiN coating and solenoids useful in suppressing ECE.

Rumolo proposes to carry out an e-cloud experiment in the GSI cooler ring. Iriso Ariz has built two rf stands that can be used for bench test of ECE. Caspers introduces a clearing electrode that was used in the CERN Antiproton Accumulator. A special design makes it invisible to the beam. Ruggiero gives a comprehensive work list of future ECE study at CERN. Perevedentsev introduces an analytical model that takes into account both beam-beam and coupling impedance of the machine.

2 SUMMARY OF DISCUSSIONS

2.1 "Critical Mass" Phenomenon

During the discussion, attempts are made to identify a few key parameters that are most crucial for studying ECE. One seems to be the volume density of the particles. Table 1 lists the machine parameters obtained from a survey during this workshop. First take a look at the existing (or existed) proton machines. Six machines have reported observations of ECE. They are: ISR, CERN PS (CPS), SPS with LHC beams, SPS with fixed target beams, PSR, and RHIC in proton operations. The parameters listed in the table are the ones when a machine starts to observe ECE before taking any curing measures. As a comparison, the parameters of the ISIS are also listed, which never sees this effect. The energy (E), protons per bunch (N_b), and r.m.s. beam sizes (σ_x, σ_y and σ_z) are drastically different in the six machines. Nonetheless, the particle volume density of these machines when reaching the e-cloud threshold takes a remarkably similar value: about $(0.2 \pm 0.1) \times 10^8$ /mm^3. By contrast, this number of the ISIS is much lower (0.006). We call this a "critical mass" phenomenon. This is solely an empirical observation. But it may not a pure coincidence. Different explanations exist and further investigation is warranted. To the very least, one may use this critical value to judge how likely or unlikely ECE could become a problem for a machine under design or under construction. For example, from Table 1 one may say that the SNS and JHF 50-GeV Ring should pay more attention to the e-cloud problem than the JHF 3-GeV Ring or the Fermilab Proton Driver.

The "critical mass" of positron machines is in a rather different regime. Three machines (APS, KEK-B and PEP-II) have observed ECE. The onset values of the particle volume density are more than three orders of magnitude higher than that of the proton machines. Moreover, unlike proton machines, these values are not close to each other. One hand waving explanation is that, the mechanism of the primary electron generation in positron machines is very different from that in proton machines (see Section 2.2). Furthermore, some positron machines have antechambers, some don't. This could be the reason for different critical mass values. On the other hand, the low volume density of the DAΦNE may explain why it does not see ECE.

2.2 Comments on Primary Electrons

One difference between proton and positron machines concerning ECE is the source of the primary electrons. For proton machines, it is believed that the primary electrons come from proton losses and the stripping foil (in the case of H^- injection), whereas for positron machines, it is photoemission. Ionization (i.e., vacuum) is not considered to be important in this process.

However, reducing primary electrons does not seem to be helpful. ECE is mainly due to secondary electron yield from the wall. Someone even claims that, one primary electron is enough to cause ECE.

2.3 A Puzzle

From the PEP-II experience, the solenoid is an effective way to suppress ECE. When only 8% of the machine was equipped with solenoids, there was already a significant increase in beam intensity. The more solenoids are in place, the higher the beam current is. Now more than 70% of the machine has solenoids. However, The PSR experience is quite different. When 15% of the machine was equipped with clearing electrodes, there was no effect on the beam.

2.4 DC vs. AC Operations

By far, all ECE that have been observed are either in DC machines (accumulators and storage rings) or AC machines in DC operation (i.e., on flat top or flat bottom). No ECE has been reported in AC machines during ramping. (The SPS does see electron clouds during ramping. But it does no harm to the beam.)

This fact has important implication in choosing between two types of high intensity proton machines: linac-based or synchrotron-based, if the latter is indeed immune to ECE.

2.5 Collaborations

Two collaborations have been formed at the workshop:

- Comparison of measurements on e-cloud generation. Three labs will compare their results. The point-of-contacts are: F. Ruggiero at CERN, F-J. Decker at SLAC, and S. Kato at KEK.
- Development of a reliable theory: Three people will work together on this. A. Chao on a non-perturbative method, M. Furman on e-cloud build-up, and S. Heifets on beam dynamics.

2.6 Code Benchmarking

There are a number of codes that have been written for simulating ECE. An incomplete list is as follows:

- E-cloud build-up codes: LBL (M. Furman), CERN (F. Zimmermann), KEK (K. Ohmi, L. Wang), LANL (T. Wang).
- Instability codes: CERN (G. Rumolo), KEK (K. Ohmi, L. Wang), SLAC/LBL (Y. Cai), BNL (M. Blaskiewicz), USC (T. Katsouleas), PPPL (H. Qin), LANL (T. Wang).

It is important that these codes are benchmarked so that the results can be compared with each other. The workshop asks F. Zimmermann to coordinate this work.

3 CONCLUSIONS

Significant progresses have been made on the ECE study in the past several years, including simulations, bench measurements and machine experiments. However, lack of a reliable theory remains to be a problem in this field. Several empirical observations discussed at this workshop (e.g., the critical mass phenomenon, AC *vs.* DC) cannot be explained or overruled without a deeper understanding of this effect. The collaborations formed at the workshop provide a useful environment to further the study.

Table 1: Particle Volume Density in Proton and Positron Machines
(Note: Existing machines with * have not observed ECE)

Machine	E (GeV)	N_b	σ_x (mm)	σ_y (mm)	σ_z (mm)	$N_b / (\sigma_x\sigma_y\sigma_z)$ (10^8 / mm^3)
Proton, existing (or existed)						
ISR	30	1×10^{14}	12.5	2.5	236,000	0.14
CPS	26	4×10^{10}	1.6	1.2	750	0.28
SPS (LHC beam)	26	3×10^{10}	2.2	2.2	300	0.21
SPS (fixed target beam)	100	5×10^{9}	2	1	190	0.13
PSR	0.8	3×10^{13}	10	10	19,500	0.15
RHIC	25	1×10^{11}	3	3	1,125	0.10
ISIS (*)	0.07	1.25×10^{13}	38	38	15,000	0.006
Proton, under construction						
SNS	1	2×10^{14}	15	15	30,000	0.30
JHF (3-GeV Ring)	3	4.15×10^{13}	19	19	27,500	0.04
JHF (50-GeV Ring)	50	4.15×10^{13}	11	11	20,500	0.17
LHC	7000	$1.1\text{x}10^{11}$	0.3	0.3	77	159
Proton Driver proposal						
Fermilab 8-GeV Proton Driver	0.6	3×10^{11}	23	13	300	0.033
Positron, existing						
APS	7	5×10^{10}	0.2	0.02	10	12,500
KEK-B	3.5	2.2×10^{10}	0.5	0.05	6	1,470
PEP-II	3.1	5×10^{10}	0.7	0.1	12	600
DAΦNE(*)	0.55	4×10^{10}	2	0.063	24	132