ELECTRON CLOUD STUDY AT SX OPERATION MODE AT J-PARC MR

B. Yee-Rendon*, H. Kuboki, R. Muto, K. Satou, M. Tomizawa and T. Toyama
KEK/J-PARC, Tsukuba, Ibaraki, Japan

Abstract

Electron cloud is a main limitation for the successful operation of the high intensity proton beam in the world. Its presence at Main Ring (MR) of the Japan Proton Accelerator Research Complex (J-PARC), during the Slow extraction mode, was already observed through several systems: sweeping electron detector, beam loss detectors, vacuum gauges, beam position monitors, etc. A more detailed survey and upgrade of the beam loss system were implemented for this study. The latest results of the electron cloud study are presented here.

INTRODUCTION

The presence of the electron cloud at the high power proton accelerators represents an important challenge for their satisfactory performance. Several machines already experimented this phenomenon, and reported its negative effects [1].

MR operates in two modes: Fast Extraction (FX) for the Neutrino Experimental Facility and Slow Extraction (SX) for the Hadron Experimental Hall (See Figure 1) [2, 3].

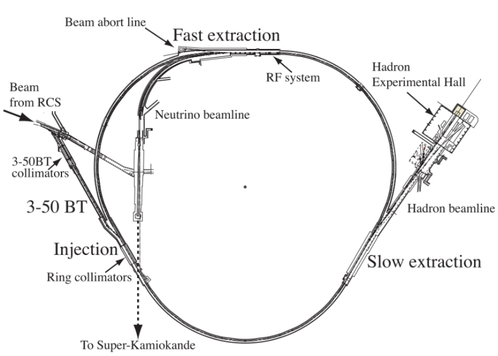

Figure 1: The MR layout shows the two beamlines for FX and SX [4].

Electron cloud is observed at SX operation, when the beam is debunching by reducing the accelerator voltage after reaching the flat top (P3). In the past, several simulations have been done to evaluate its effects at the J-PARC accelerators [5–7]. Additionally, direct and indirect evidences of the electron cloud have been reported in conferences [8, 9]. This work presents the latest results and the future study of this phenomenon at J-PARC MR.

* byee@post.j-parc.jp

MEASUREMENTS

In May 2016, an special survey was performed to investigate the dependency of beam intensity and the phase offset in the electron cloud buildup. The study was divided in two parts:

- The first part consisted in injected the beam with a phase offset of 0° (center of the bucket), in the normal operation the beam is injected with a phase offset of 60° (edge of the bucket) to avoid the formation of the electron cloud [10], and the intensities were set to 2.8, 3.4, 3.8 and 4.2 $\times 10^{13}$ proton per pulse (ppp).
- For the second part, the intensity was fixed to 4.2 $\times 10^{13}$ ppp, and the phase offset was changed in a step of 10° from the 60° to 0°. Indeed, for the phase offset of 0°, 10°, 20° and 30° the intensity was changed similarly as in the first part. Moreover, the intensity was increased to 4.7$\times 10^{13}$ ppp, except for phase offset of 0°.

At both cases several measurements were recorded in each of the configurations to generate statistics.

In addition to all the detectors (sweeping electron detector, beam position monitors, scintillation detectors, the vacuum gauge, fast current transform) used in previous studies [8, 9], a wall current monitor (wcm) was employed to measure the bunch length for the different phase offsets. The Table 1 presents the main beam parameters during the study.

Table 1: Relevant Beam Parameters during the SX Survey at MR

Parameters	Units	Value
Energy	GeV	30
Power	kW	25-40
Intensity	10^{13} ppp	2.8-4.7
Phase offset	degree	0-60
Q_x,Q_y	–	22.3, 20.8
Q_s	–	0.000119

Furthermore, the data acquisition for the scintillator plus photomultiplier detector was improved by increasing the sample rate in the oscilloscope.

RESULTS

Figure 2 makes a summary of the observations of the electron cloud at different intensities and phase offsets. The criteria to decide if the electron cloud appears was:

- The pressure rise by a factor of three or more with respect to standard value.
- The appearance of a “signal bump” in the electron cloud detector.

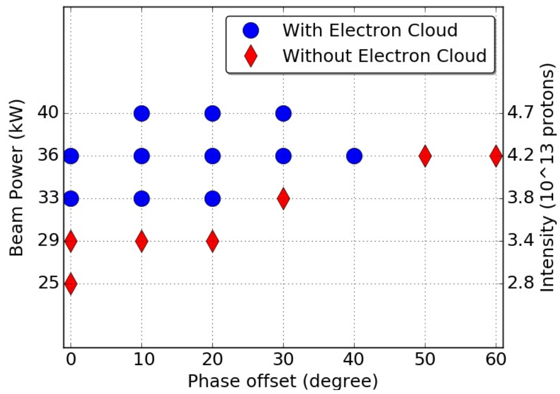

Figure 2: The presence (blue circles) or absence (red diamond) of the electron cloud as a function of the intensity and phase offset.

Previous works documented evidences of the electron cloud using several detectors [8, 9]. Those measurements exhibited a remarkable distinction, for the cases with and without electron cloud, in the frequency range of 20-40 MHz.

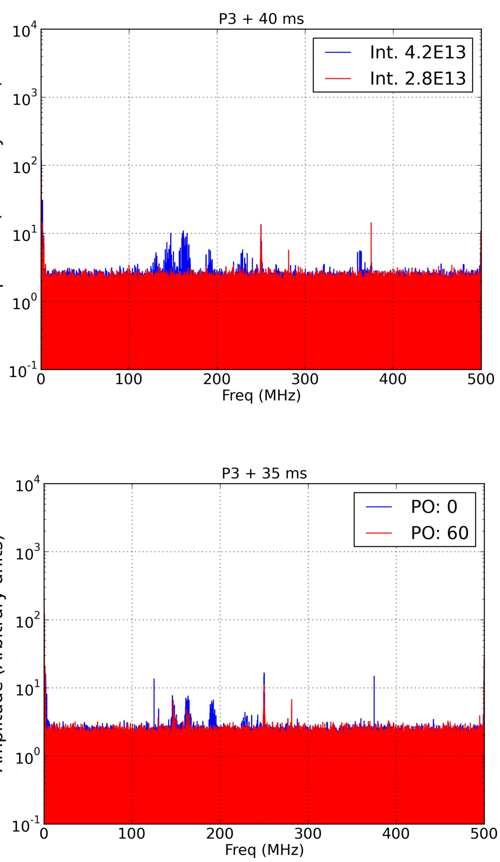

Figure 3: The Fourier analysis of the electron cloud signal at different intensities (top) and phase offsets (bottom). The contrast in the components between 150-200 MHz for the electron cloud cases is evident.

This survey verified that and found the existence of a similar behavior in the interval between 150-200 MHz (See Figure 3).

The values of the bunch length obtained from the wcm and the estimated by the simulations of the J-PARC Radio-Frequency (RF) group are plotted together in the Figure 4 [11].

The discrepancy between them can be attribute to :

- The simulations use a slightly different parameters values such as the linac current of 24.5 mA and in the measurements is 50 mA.
- In the simulations is easier to delimit the bunch length, in contrast with the measurements due to the leak in tails, it is complicated to define the complete bunch length.

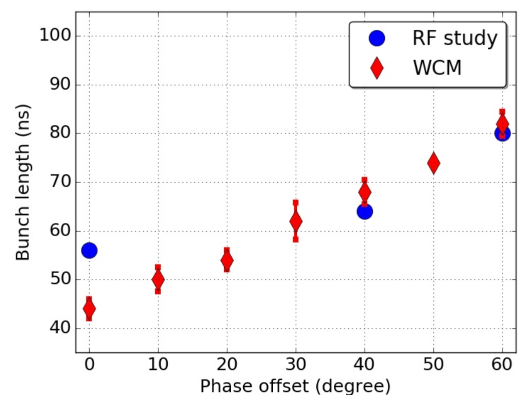

Figure 4: The bunch length using the wcm (red diamond) compare with RF study (blue circles). The measurements and simulations present a good agreement for large phase offsets.

Finally, Figure 5 compares the beam loss signal for the scintillator between the last study [9], and this one.

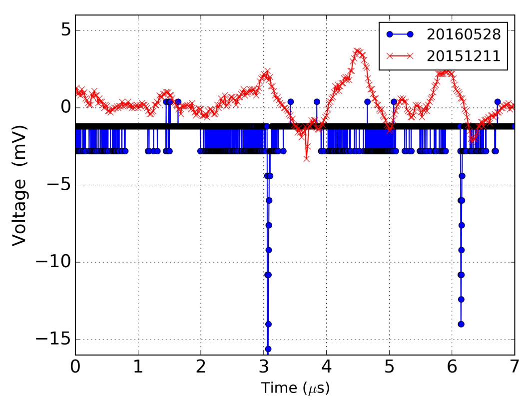

Figure 5: Comparison between the signal of the scintillator plus photomultiplier in presence of electron cloud for the measurements of 2015 (red cross) and 2016 (blue circles).

CONCLUSION AND OUTLOOK

The study proved the dependence of the beam intensity as well as the bunch length, through different phase offset, in the formation of the electron cloud at the J-PARC MR.

The results found the presence of the harmonics between the 150-200 MHz in the early stage of the electron cloud cases. These frequencies can be correlated as the electron bounce frequency assuming a non-uniform beam distribution (non-coasting beam).

Moreover, the wall current monitor and fast current transform data demonstrated that longer bunches (large phase offset) take less time to become coasting than short bunches (small phase offset). This transition time has an important effect in the electron cloud buildup as is seen in the Figure 2.

Furthermore, the measurements by beam loss detector were significantly enhanced, however, their frequency domain did not present a clear difference between the cases with and without electron cloud.

In the last years, several studies reported the presence of electron cloud at J-PARC MR, each survey improved the previous measurements and provided new details about the conditions that produce this instability [8, 9] .

Thus, using the accumulated knowledge, an electron cloud model is under develop. This code uses an update version of the early studies [5–7]. For these simulations a scheme for bunched to unbunched beam is being implemented, taking into account the data of the bunch length and its evolution from the wall current and fast currents monitors.

ACKNOWLEDGMENT

The authors thank the members of J-PARC Main Ring, in specially to K. Ohmi, C. Ohmori, Y. Sato, F. Tamura and M. Uota for their support on this work.

REFERENCES

[1] H. G. Hereward, CERN Report No. 71-15, 1971; E. Keil and B. Zotter, CERN Report No. CERN-ISR-TH/71-58, 1971; M. A. Furman, "Electron Cloud Effects in Accelerators", Proceedings, 5th Workshop on Electron-Cloud Effects (ECLOUD'12) (2013); https://inspirehep.net/record/1257435/files/arXiv:1310.1706.pdf, A. Kulikov, A. Fisher, S. Heifets, J. Seeman, M. Sullivan, U. Wienands and W. Kozanecki, "The Electron Cloud Instability at PEP-II," Proceedings of the Particle Accelerator Conference (2001).

[2] Accelerator Group JAERI/KEK Joint Project Team et al., "Accelerator Technical Design Report for J-PARC", JAERI-Tech 2003-044, KEK Report 2002-13 (2003); http://hadron.kek.jp/~accelerator/TDA/tdr2003/index2.html

[3] M. Tomizawa *et al.*, "Injection and Extraction Orbit of the J-PARC Main Ring", Proceedings of the European Particle Accelerator Conference 06 (2006).

[4] T. Koseki *et al.*, Progress of Theoretical and Experimental Physics 2012, 02B004 (2012).

[5] K. Ohmi *et al.*, Phys. Rev. ST Accel. Beams 5, 114402 (2002).

[6] K. Ohmi *et al.*, "Study of ep instability for a Coasting Proton Beam in Circular Accelerators", Proceedings of the Particle Accelerator Conference (2010).

[7] T. Toyama *et al.*, "Electron Cloud Effects in the J-PARC Rings and Related Topics", Proceedings of ECLOUD Vol. 4 (2004).

[8] T. Toyama *et al.*, "Electron Cloud Observed During Debunching for Slow Beam Extraction at J-PARC Main Ring", Proceedings of the Particle Accelerator Society of Japan (2015).

[9] B. Yee-Rendon *et al.*, "Electron Cloud Measurements at J-PARC Main Ring", Proceedings of the International Particle Accelerator Conference (2016).

[10] SX group (private communication).

[11] M. Yamamoto, "Run68 SX" Internal Meeting (2016).