ELECTRON CLOUD MEASUREMENTS AT J-PARC MAIN RING

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Abstract

Electron cloud instability is presented in most of the high intensity proton rings. During the Slow beam extraction (SX) mode at Main Ring of J-PARC, signals related with its formation were observed. An electron cloud detector is installed downstream of the Electro Static Septum (ESS), to measure the electron signal. Additionally, scintillation detector with photomultiplier, a proportional counter and photo-diode were set closely to the electron cloud detector to observe the beam lost. This paper presents the measurements of the electron cloud and some of the conditions which support its creation, for instance the signal of lost particle from the beam loss monitors, the residual gas in the vacuum duct by using vacuum pressure gauges, etc.

INTRODUCTION

Electron cloud is one of the main limitations for the beam power increase in proton accelerators. It is associated with detrimental effects in the machine performance as beam instability, pressure rises, beam loss, among others [1, 2].

J-PARC is project which contains a set of high proton beam accelerators [3], it has two circular synchrotrons: the Rapid Cycling Synchrotron (RCS) and the Main Ring (MR).

Electron cloud studies have been performance for the J-PARC accelerators to evaluate its effects [4, 5]. In addition, the installation of electron cloud detectors at the MR and the results of measurements have been reported in conferences [6]. This work presents the latest measurements of the electron cloud including signal of the beam loss monitors and pressure gauges.

MEASUREMENTS

MR accelerates protons until energy of 30 GeV. It operates in two modes: Fast Extraction (FX) and Slow Extraction (SX) [7]. Electron cloud is observed at SX operation, when the beam is debunching by reducing the accelerator voltage after reaching the flat top (P3).

During the last SX running, December of 2015, the electron cloud surveys were performed. The Table 1 presents the main beam parameters during the study.

To detect evidence related with the electron cloud a series of monitors were installed (See Figure 1). An electron cloud detector similar than the one used at the Los Alamos Proton Storage Ring [8] were added at the MR. In addition, an array of beam loss detectors: scintillation with photomultiplier, a proportional counter and photo-diode to collected the beam losses were set also close to the electron cloud detector. Moreover, the vacuum pressure was monitoring using cold-cathode and ionization gauge.

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Table 1: Relevant beam parameters during the SX operation at MR.

Parameters	Units	Value
Energy	GeV	30
Power	kW	38.2
Q_x,Q_y	–	22.284, 20.790
Q_s	–	0.000119

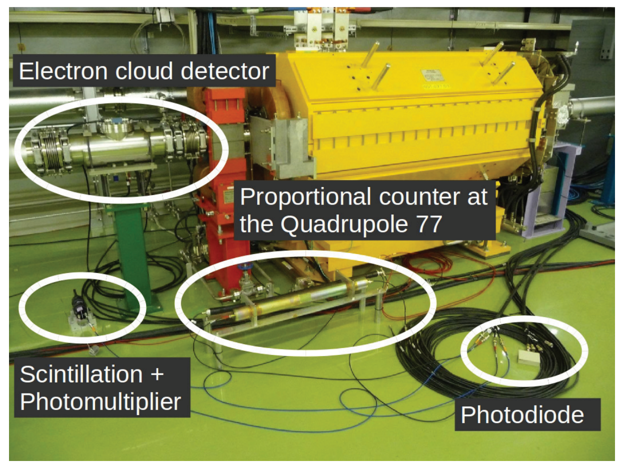

Figure 1: The electron cloud and beam loss monitors detectors at the MR.

RESULTS

The plots show a comparison of the measurements for events with and without electron cloud. The data recorded by the electron cloud detector for both cases are presented in Figure 2. The vertical axis represents the time of the signals were acquired with respect to the P3, the data were taking every 5 ms with a length interval of 2 ms.

Similarly, Figure 3 shows the beam current for the corresponding shot. Signals were obtained by using a fast current transform with the same time settings as the electron cloud detector. Figures 2 and 3 indicate that between 70-90 ms from P3, the electron cloud signal reaches its maximum.

The electron cloud induces instabilities in the beam, thus, we searched the data of the beam position monitors for possible disturbances. Figure 4 presents the difference for the horizontal signal in the frequency domain at 80 ms and 110 ms.

For the beam loss, only the measurements using the scintillation detector plus photomultiplier provided relevant information. Figure 5 shows the values obtained between 80-ms to 85 ms and the integrated signal for the same interval.

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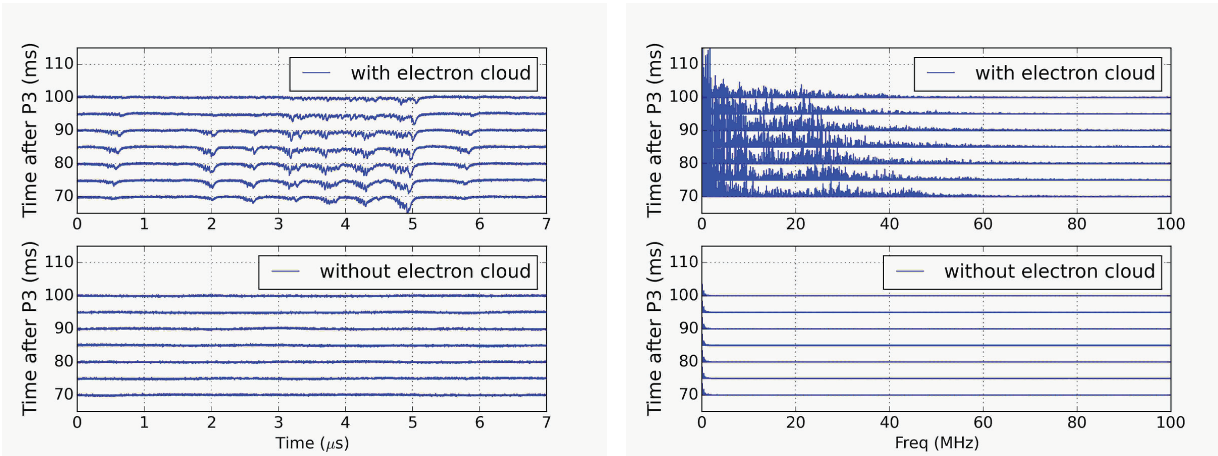

Figure 2: The electron cloud detector signals for events with and without electron cloud in the time domain, top and bottom left, respectively. The correspoding Fourier transform plots are shown in right side in the same order.

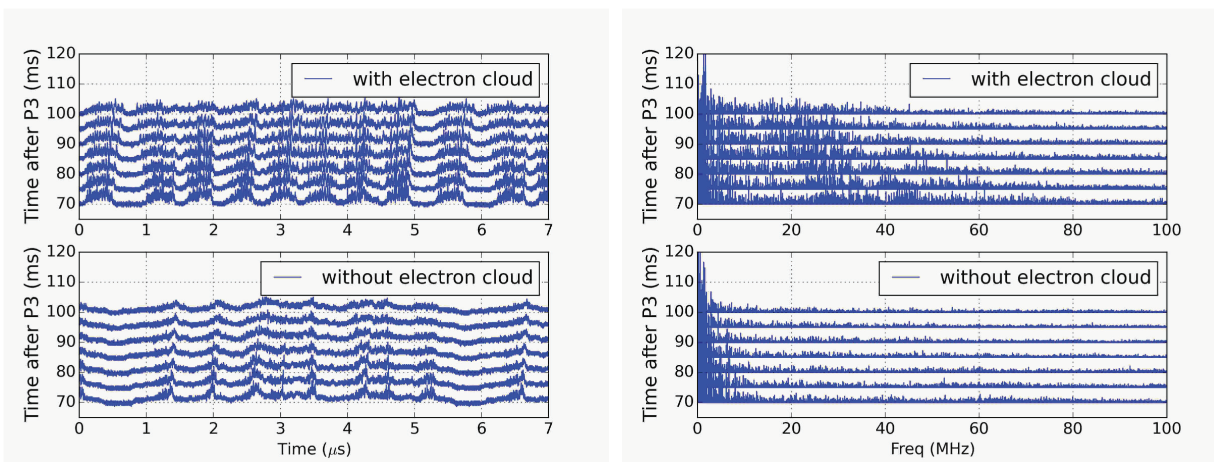

Figure 3: The beam current in the time (left) and the frequency (right) domain when the electron cloud appears (top) and when it is absent (bottom).

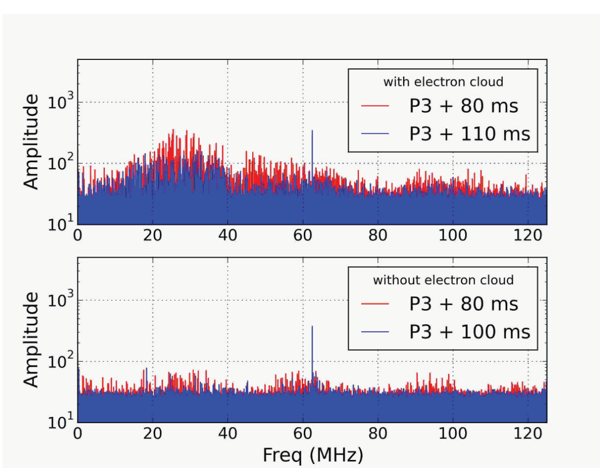

Figure 4: The comparison of the ΔX signal for the beam position monitors with and without electron cloud, top and bottom, respectively.

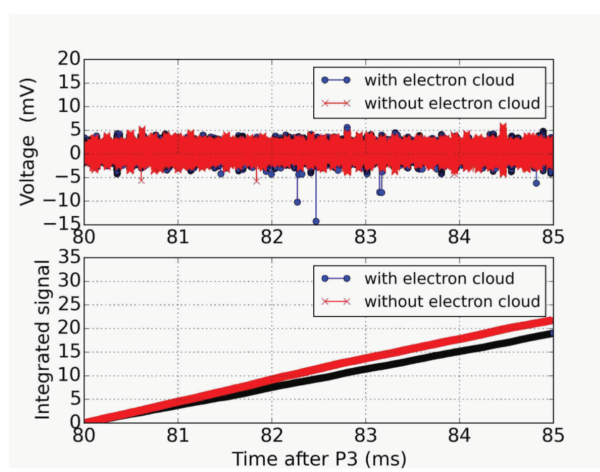

Figure 5: The scintillation detector measurements (top) and their corresponding integrated signal (bottom).

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The data of vacuum pressure during the electron cloud study are shown in the Figure 6. The pressure rises correspond to the shots in which the electron cloud is presented.

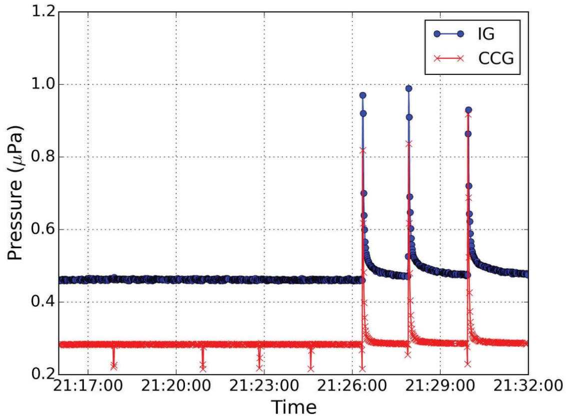

Figure 6: The pressure measurements detected using the cold-cathode (red-start) and ionization (blue-circle) gauge. The data are from monitors close the electron cloud detector.

CONCLUSION AND OUTLOOK

The signals for the electron cloud detector and fast beam current provide a clear evidence of the electron cloud presence and show that its formation occurred in the transition time between bunched to coasting beam (See Figures 2 and 3). Indeed, the Fourier analysis indicates an increase in the harmonics from 0-60 MHz at the beginning of the electron cloud. In addition, the horizontal signal of the beam position monitors shows a remarkable difference of the harmonics in the interval of 20-40 MHz for the cases with electron cloud appears and the time when occurs. These results are in agree with the frequency of the electron bounce estimated for the Main Ring.

The beam loss produced by the electron cloud were detected, nevertheless, the background noise is significant. The post processing techniques to reduce the noise provides poorly results due to the lower sampling rate of the measurements.

Additionally, a significant increase in the vacuum pressure with respect to standard threshold was detected during the electron cloud events, the same behavior has been reported in others machines [9,10]. Similar patterns of the pressure rises have been registered around the lattice due to the threefold symmetry of the ring.

In summary, evidences of the electron cloud were observed at the J-PARC Main Ring through several monitors such as: electron cloud detector, beam position monitors, scintillation detectors, the vacuum gauges. However, more studies are required to fully understand the conditions that support the formation of the electron cloud and improvements in the measurements are necessary. Here is a list of the tasks for the future surveys: Upgrade the acquisition data of the beam loss detectors and new design, investigate the dependence of the beam intensity and develop a computational model which can reproduce the results.

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