MEASUREMENTS OF THE ENERGY DISTRIBUTION OF THE ELECTRON CLOUD AT J-PARC MR

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Abstract

The energy of the electrons plays a relevant role in the electron cloud (EC) build-up, according to the Secondary Electron Yield (SEY) curve. Different incident electron energies create a distinct amount of secondary electrons at the beam pipes. The Electron Cloud Detector (ECD) at J-PARC MR is a Retarding Field Analyzer with a sweeping electrode. The measurements of electron energy were done by varying the voltage repeller of the grid of the ECD to select the energy of the electrons that were collected on the detector plate. The knowledge of the incident energy helps to estimate the interaction between the EC and the beam distribution, consequently, it allows us to develop a more precise model of this phenomenon.

INTRODUCTION

In the last years, a series of EC surveys at the J-PARC MR were done to understand the conditions of the EC build-up [1,2]. During this studies the ECD was the main device used to collect signals of the electrons flux that impact the beam chambers. The ECD is a Retarding Field Analyzer with a pulsed electrode developed at ANL [3,4]. The detector is located at the address 77 of the MR downstream of the SX Electro Static Septum (ESS), Figure 1 shows the actual setup of the ECD inside the MR tunnel.

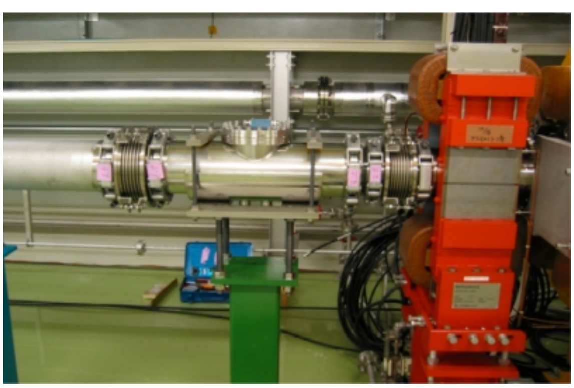

Figure 1: The ECD installed at MR of J-PARC.

Figure 2 presents a diagram of the ECD, the electron pass through the six slits (slot) on the top of the beam chamber. The electron flux between the slot (grounded) and the collector slit is controlled by putting a bias voltage. The electrons which have energy higher than the difference of voltage between the slot and the collector are detected by the collector plate of stainless steels. Additional, the electrons that impact the collector produce secondary electrons, thus, to trapped these secondary electrons a voltage repeller is applied in a grid between the collector and the slot is added [5].

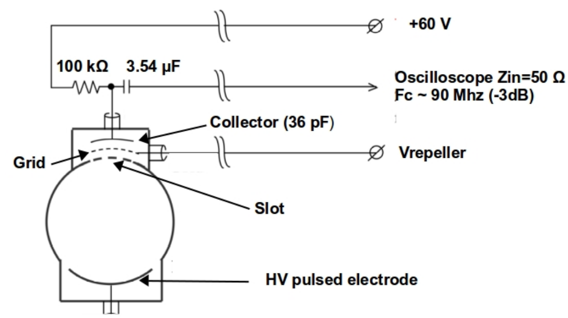

Figure 2: Schematic view of the ECD at J-PARC MR. Courtesy of R. J. Macek.

The EC simulations indicate that the low energy electrons are the large population in the electron clouds, therefore, to corroborate this result and understand more about the EC at MR, studies of EC changing the voltage repeller were done.

MEASUREMENTS

For this survey, the HV pulsed electrode is not used, the voltage of the collector remain fixed at 60 V and the voltage of the repeller is changed from the nominal value of 30 V to -420 V. Due to the electron has negative charge, the positive values of the voltage repeller has the function to attract the electrons to the collector, on the contrary, for the negative values the electron must has an energy higher than the voltage repeller to reach the collector plate.

Additionally, Table 1 presents the main parameters during the study. During this survey the voltage repeller was only the parameters that was changed.

Table 1: Relevant Parameters During the SX Survey at MR

Parameters	Units	Value
Energy	GeV	30
Power	kW	37
Intensity	10^{13} ppp	4.2
Phase offset	degree	7
Q_x,Q_y	–	22.3, 20.8
Q_s	–	0.000119
Voltage collector	V	60
Voltage repeller	V	30 to -420

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RESULTS

Figure 3 shows a summary of the observations of the electron flux peak during the debunching process for the different values of the voltage repeller. For each of the configurations five measurements were done having similar conditions (some fluctuations in the beam power can be observed in Figure 4 top) and the signal was average over 100 turns. The electron cloud reached the maximum intensity about 75 ms after P3 (the time in which the debunching started), when a significantly large signal is recorded for negative low values of the voltage repeller.

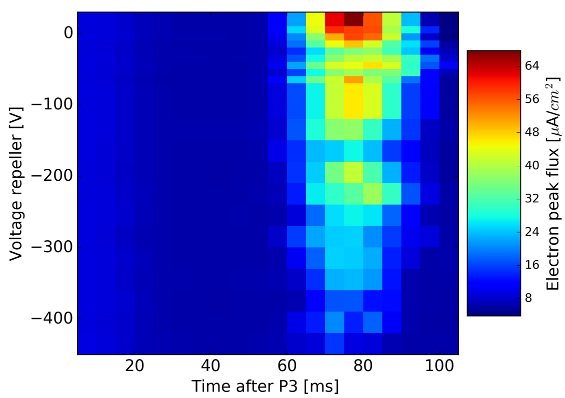

Figure 3: The surface map of the electron flux peak as a function of debunching time and the voltage repeller.

In addition, the average value of the beam power (top) and the pressure rise close to the EC detector (bottom) for the different setting of the measurements are presented in Figure 4. The beam power remained stable, except for the region from -10 V to -180 V, in constrant the pressure rise presented more fluctuating behavior having a region of flat values from -180 V to -330 V.

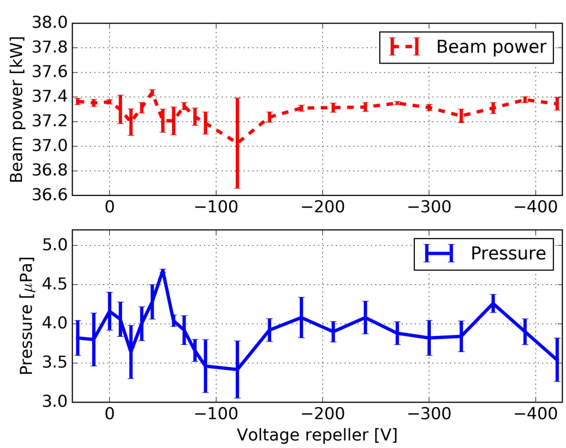

Figure 4: The average beam power (red dot line) and the pressure rise (blue solid line). The errors bars were computed using the standard error.

The values presented in Figure 3 are the cumulative energy spectrum of the electron impacting the collector. A rough estimation of the cumulative distribution of the electron energy during the measurements can be done assuming the next conditions:

- The initial setting of the voltage repeller (30 V) provide the maximum efficiency to collect electrons.
- The EC reached the highest signal at 75 ms.
- Taking only the signal of the highest peak.

Figure 5 presents the distribution of energy of the electron. A fit with an exponential function was applied,

$$y(x) = b_0 * exp(b_1 * x) \tag{1}$$

where the values b_0= 0.760 and b_1= 0.003 were the parameters of the fit which provide a coefficient of determination (R^2) of 0.856.

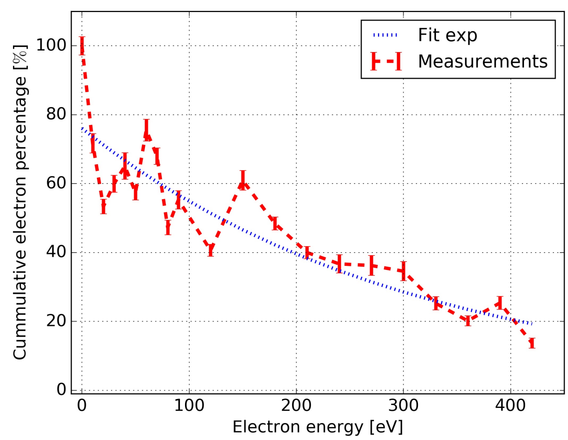

Figure 5: The cumulative of the energy spectrum of the electrons. The errors bars corresponded to the standard error.

CONCLUSION AND OUTLOOK

The study proved that a significant fraction of the electron that impact the wall chambers corresponded to the low energy regime from 0 eV to 180 eV (See Figures 3 and 5), this support the preliminary results of the simulations and shown the importance of the low energy electron in the EC build-up.

In Figure 5, the percentage of electron presented a decreased behavior (See the exponential fit) as the energy of the electrons increase, however, there are some high peaks at 60 eV and 150 eV were observed. The possible reason of the peaks could be that the region from -10 V to -180 V in Figure 4 presented variations in the beam power and the pressure rise, thus, this could affected the formation of the EC. A detailed analysis of the measurements is under process.

Finally, the measurements of the SEY are under process, this is important to corroborate our assumption of the electron production ratio and help us to improve the simulation model.

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