NUMERICAL MODELING FOR CesrTA MEASUREMENTS OF ELECTRON TRAPPING IN A QUADRUPOLE MAGNET

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Abstract

We describe a modeling simulating time-resolved measurements of the formation of long-lived electron clouds in a quadrupole magnet in the CESR storage ring using a shielded stripline detector. The detector measures the electron flux incident on the vacuum chamber wall directly in front of one of the poles of the magnet. The numerical model includes photo-electron production by synchrotron radiation, electrostatic forces from the bunched positron beam and the cloud, macroparticle tracking in the field of the quadrupole, secondary electron emission from the 9.5-cm-diameter cylindrical stainless steel beam-pipe and an analytic calculation of the acceptance of the shielded pickup detector. Approximately 5% of the cloud produced by a train of twenty 18-mm-long bunches 14-ns apart each carrying 1.3e11 5.3 GeV positrons survives the entire 2.3-μs time interval between bunch trains, unless intermediate bunches are used to clear the cloud. These studies have been performed in the context of the CESR Test Accelerator program, which aims to quantify and mitigate performance limitations on future low-emittance storage and damping rings.

INTRODUCTION

The Cornell Electron Storage Ring Test Accelerator (CesrTA) program [1] Electron cloud (EC) development results from the photoelectron production, the EC dynamics, and the secondary yield (SEY) properties of the vacuum chamber. The EC buildup simulation code ECLOUD [7] has been extended to model the

SHIELDED STRIPLINE DETECTOR

Figure 1 a) shows the circular stainless steel vacuum chamber of inner diameter 95.5 mm in the 60-cm-long quadrupole magnet. The detectors are placed directly in front of magnet poles, as shown in Fig. 1 b). Electrons are collected on the 6-mm-wide copper collector shown in Fig. 1 c). The collector is etched on one side of a 0.12-mm-thick Kapton sheet, forming a transmission line with the grounded copper on the other side. A pattern of 5 x 60 parallel holes 0.8 mm in diameter (see Fig. 1 d) in the beam-pipe allows transmission of cloud electrons to the detector shown on the upper right in Fig. 1 b).

* Work supported by the US National Science Foundation PHY-0734867, PHY-1002467, and the U.S. Department of Energy DE-FC02-08ER41538

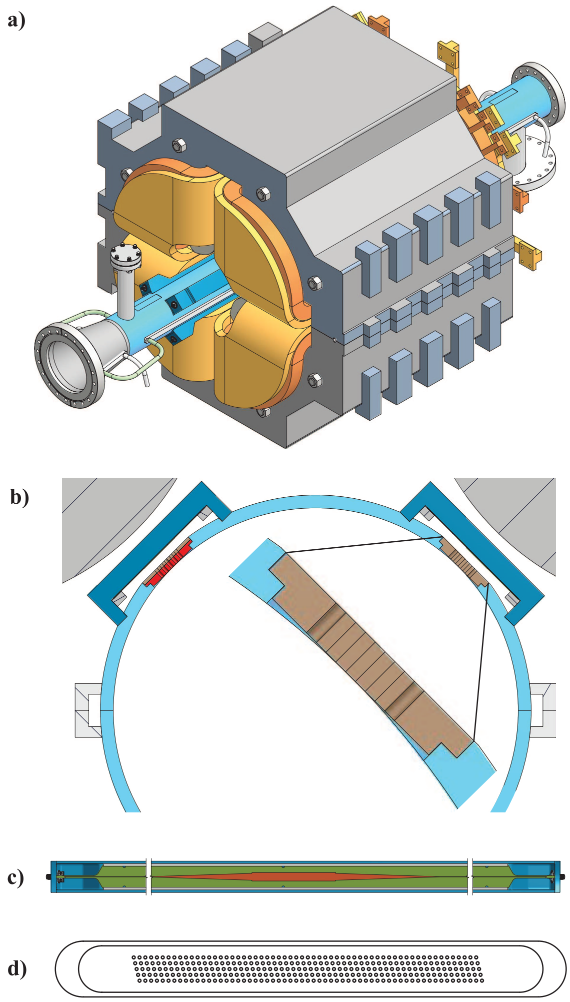

Figure 1: a) Vacuum chamber equipped with electron detectors in the quadrupole magnet. b) Arrangement of two detectors in front of the magnet poles as seen from the positron arrival direction. c) Geometry of the copper electrode biased at 50 V to collect electrons entering through the pattern of holes in the beam-pipe shown in d). The rectangular region of the collector and the pattern of holes are each about 10 cm long.

ECLOUD SIMULATION CODE

The ECLOUD EC buildup simulation code consists of a photoelectron generation model, the time-sliced EC dynamics driven by space-charge, beam-kick, and magnetic forces, and a detailed model for secondary electrons produced by EC electrons striking the vacuum chamber wall. A model for the acceptance of the TR-RFAs has been added. The TR-RFA signals are modeled by counting macroparticle charges reaching the upper surface of the beam-pipe. The charges are weighted with the transparency to provide the signal charge, while the remainder of the charge produces secondary macroparticles. An angular acceptance function deduced from standalone Monte Carlo studies was used, and it was found necessary to impose a dependence on incident energy in order to adequately describe the observed signals. The charge thus obtained in 2-ns time bins provides the current which is converted to the voltage signal using the 50 Ω input impedance of the amplifiers and their gain of 100. In contrast to the earlier studies of the shielded-pickup signals, with their sub-nanosecond time resolution, the TR-RFA signals clearly show the necessity for an RC time constant convolution. Consistency was obtained with a 25-ns time integration function, determined to an accuracy of better than 5 ns.

SUMMARY

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