CALIBRATION OF RHIC ELECTRON DETECTORS*

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Abstract

To characterize the electron cloud in RHIC, eleven custom electron detectors have been designed, fabricated and installed at a few RHIC warm-bore vacuum sectors for data collection during FY2003 runs. Prior to installation, the transmission and collection efficiencies of these detectors at various grid and collector bias voltages were measured using an electron gun with energy up to 1500 eV. This paper describes the design of the detector and the test system set-up, and summarizes the calibration results. In addition the calibration of a commercial micro-channel plate is also reported.

INTRODUCTION

The Brookhaven Relativistic Heavy Ion Collider (RHIC) consists of two counter-rotating rings, labeled Blue and Yellow. During the FY2001/2002 physics runs, which included gold on gold and gold on protons, unwanted vacuum pressure rises occurred as the beam intensity increased (the number of ions per bunch was continually increased up to the design value of 10^9) in both 55-bunch and 110-bunch filling patterns [1]. These pressure "bumps" primarily occurred in the warm bore sectors, most notably at the interaction regions. The observed relevant factors include bunch intensity, bunch spacing, beam loss, and less understood, the locations. Electron multi-pacting appears to be the dominant mechanism and diagnostics are needed to correlate these vacuum pressure bumps with the electron cloud. Since no dedicated electron detectors were available in the RHIC FY2001 run, the coherent tune shift along the bunch train was used to detect the electron cloud density [2]. Some complications, however, may make this approach less reliable. The more straightforward way to detect the electron cloud will the use of electron collectors placed at the intersection region or at the warm bore. These electron detectors allow the measurement of both the electron line density and the energy spectrum of the collected electrons. A comparison between electron density and the observed pressure rise can provide valuable information in understanding the pressure rise.

For this goal, eleven custom electron detectors are installed in the RHIC tunnel for data collection during FY2003 runs. The majority of electron detectors were installed at IR12, IR2 (interaction region) and adjacent insertion sections, where most vacuum bumps occurred (Fig.1). Prior to installation, the transmission and collection efficiencies of these detectors at various grid and collector bias voltages were measured using an electron gun with energy up to 1500eV. This report will present the design of the detector, the laboratory test set-up, and the preliminary bench test results.

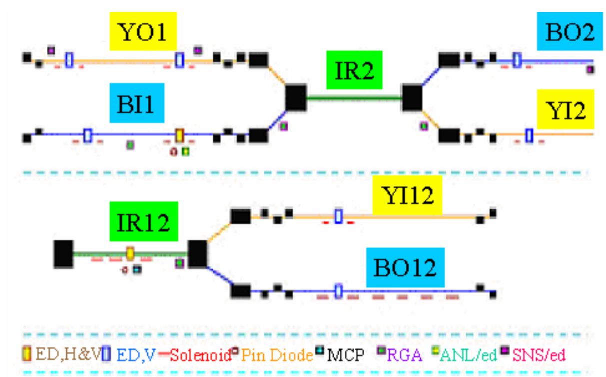

Figure 1. Electron detectors located at RHIC warm bore.

INSTRUMENTATION

Two types of electron detectors were evaluated, the BNL design and a commercial micro-channel plate.

BNL Electron Detector(ED)

An electron detector, similar to ANL's Retarding-Field Analyzer(RFA) [3], was developed to measure the electrons produced at RHIC. A schematic of the electron detector is shown in Fig.2.

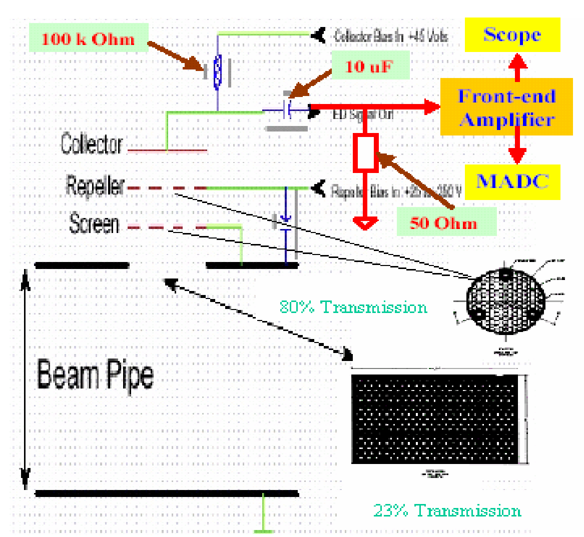

Figure 2. Schematic diagram of the electron detectors.

The detector, mounted normal to the beam line, consists of three layers, two 118mm diameter mesh grids (stainless steel with ~80% transmission) and a collector plate of equal diameter. Additionally, the mounting port is RF-

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shielded, as are all beam-line ports and bellows in RHIC, using a grounded screen with 23% transmission to allow for the passage of beam image currents. The outermost grid is grounded to present a uniform field to the incoming electrons while the second grid can be used to impose a retarding or repelling field by applying a bias voltage (Vs) to scan electron energy. The collector is biased at a DC voltage +45V with a battery to increase the collection efficiency. The assembled detector was mounted on a 6 ¾-inch Conflat flange with four SHV feedthroughs.

Microchannel Plate (MCP)

The other type of electron detector uses a microchannel plate (MCP) to obtain a high gain output signal. The MCP (Fig.3) is a 1mm-thick sheet of lead glass with a honeycomb pattern of 25µm-diameter holes. It has ~ 10^6 channels, with a glass surface area of ~$1m^2$ The length/diameter aspect ratio of each channel is 40. The electron gain at 900 volts is > $4x10^3$. The MCP is vacuum compatible, but requires a long pump down period. The CEMA Model 6025MA detector assembly contains one MCP and a metal anode readout mounted using stainless steel hardware. The assembly is bakeable to 300°C. The specifications are shown in Table 1.

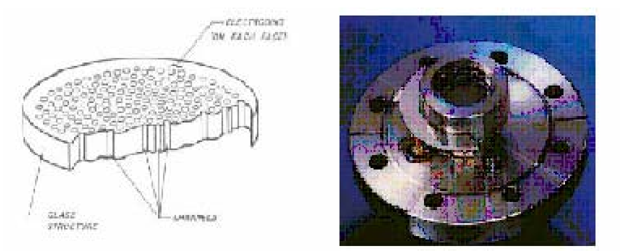


Figure 3. MCP and MCP-anode assembly.

Table 1. Electrical Characteristics of Detector

Electron Gain@900 Volts:	$4x10^3$ Minimum
Bias Current@900 Volts:	3~125 µA
Resistance:	7~30 MΩ
Dark Noise:	$5x10^{-12}$ A Max.
Linear Output Current Density: ($µA/cm^2$)	Typically 10% of Bias Current Density

BENCH MEASUREMENTS

For bench measurements, each detector was installed in a vacuum chamber tee with a 127mm diameter, the same as RHIC warm-bore beam pipe. The vacuum chamber tee includes the RF screen required for RHIC beam lines. The test chamber set-up is shown in Fig.4. The electron gun was mounted opposite the detector with the electron beam impacting normal and approximatelynon-divergent. The distance from chamber center to collector is 84mm.

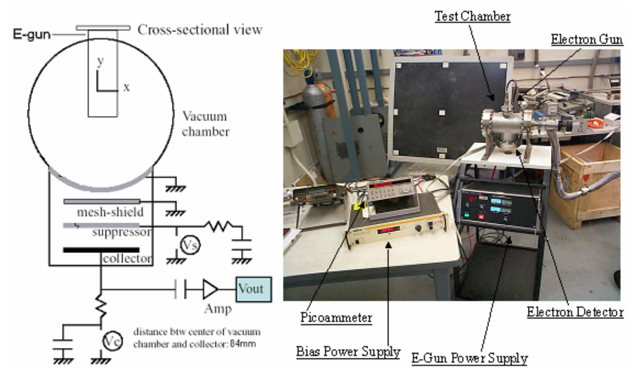
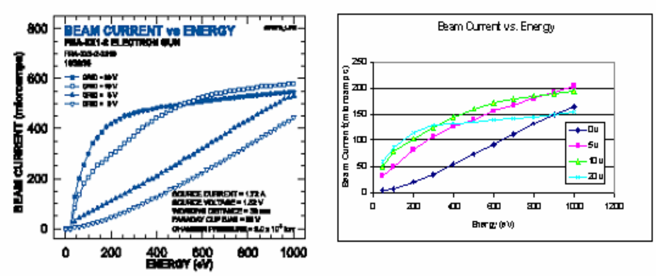


Figure 4. Bench test system set-up.

BNL Electron Detector

The first test measured the collector current as a function of electron energy. Measured results were similar to manufacturer's published values (Fig.5).

Typical Performance(Manual) **Bench Test Results(Measured)**



Source Current = 1.72 A; Source Voltage = 1.52 V
Working Distance = 30 mm
Chamber Pressure = 3.0 x10(-6) Torr

Source Current = 1.65 A; Source Voltage = 1.40 V
Working Distance = 84 mm
Chamber Pressure = 1.3 x10(-7) Torr

Figure 5. Beam current vs energy.

The second test characterized the filtering ability of the device by measuring the collector current while varying the grid bias voltage (V1g) for primary electron energies (Ue) of 5, 20, 50, 100 and 500 eV. The device shows good resolution, even at the low electron energies produced by electron clouds. The output is reasonably flat, as expected, where V1g < Ue, with good drop-off for

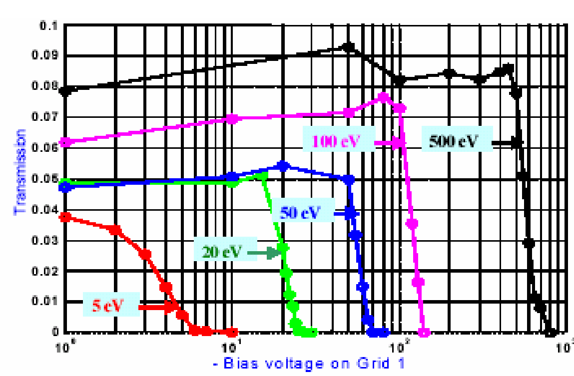


Figure 6. Current obtained as a function of V1g

Vg1 > Ue, at which point electrons are unable to pass the grid and reach the collector.

MCP-Anode Assembly

Due to saturation effects, the CEMA Model 6025MA detector assembly only works with pulsed beams. Unfortunately, the existing electron gun (FRA-2X1-1) does not have a pulse mode option, so a pulse generator is used to power a small light source. The visible blue light passes through a quartz view port to the MCP's anode plate. The test chamber is evacuated to 2.0x10^{-6} Torr and held for 15hours to thoroughly degass the assembly. Upon initial start-up, the CERA model electrical test procedure [4] is followed with the typical wiring diagram shown in Fig.7. Fig.8 gives the output signal of the MCP for selected voltages of Va=0.9kV and Vo=1.0kV. The plot of anode current vs Va (maintaining Vo=1.0kV) is shown in Fig.9.

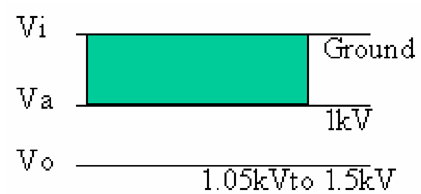


Figure 7. Typical bias settings for MCP.

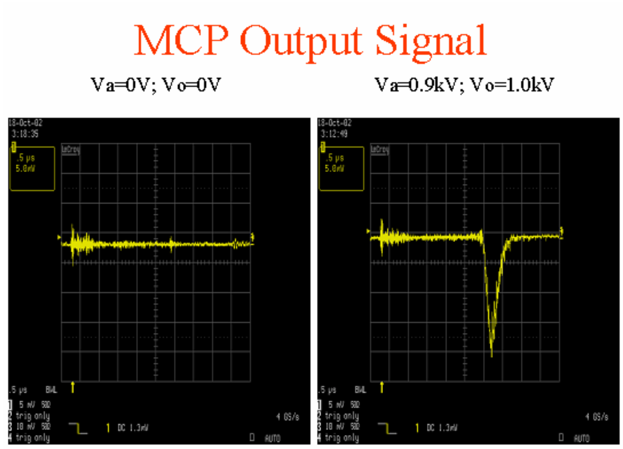


Figure 8. MCP output signal for two voltage (Va ,Vo) settings.

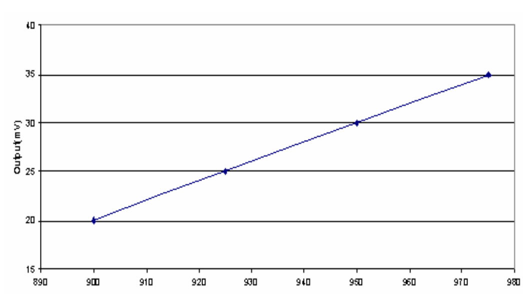


Figure 9. Output current vs Va.

SUMMARY

Two types of electron detectors were evaluated for use in studying electron cloud effects in RHIC. Bench testing was used to make preliminary measurements. Results show the transmission of the BNL electron detector is between 0.04~0.08 over a wide range of energies. Varying the grid voltage will repel low energy electrons, allowing measurement of the energy spectrum of collected electrons. Also a commercial MCP-anode assembly has been tested and by selecting the appropriate voltages of Va and Vo, a reasonable output signal can be observed.

Eleven electron detectors and one MCP-anode assembly have been installed in RHIC warm bore sectors and will be used to characterize the RHIC electron cloud during the FY 2003 run.

ACKNOWLEDGEMENTS

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