Double-sided detector for electron beam alignment and measurement of back-streaming electrons in ExtendedEBIS at BNL

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Abstract

We developed an electron beam detector installed between the superconducting solenoids in ExtendedEBIS. The detector is two-sided. Each side has 4 quadrant plates with an aperture slightly larger than the electron beam radius. The gun-side is for alignment of primary electron beam. The collector side detectors are to measure the electrons back-streaming from the collector or the downstream electrodes to the cathode. It is important to understand how the back-streaming electrons behave and how to control it. The detector was designed with considerations of heat load and influence on primary beam. A detector test showed that the back-streaming electrons were affected by the external electromagnetic fields and the space charge of the primary electron beam. It was proved that the behavior of the electrons can be observed by this detector.

Introduction

RhicEBIS at BNL has provided several types of ions to RHIC and NSRL. A high current electron beam (up to 10 A) is compressed in 5T-superconducting solenoid to have 500 A/cm^2. The upgrade of the EBIS, called ExtendedEBIS, is now in progress in our test laboratory. Figure 1 is a schematic drawing. Two identical 5T-superconducting solenoid have been placed in series with cryostats separated by 200 mm. The purposes of the development of ExtendedEBIS are to increase of the ion trap capacity, to inject gas efficiency especially for H and He (2), and to provide polarized 3He ions.

In ExtendedBEIS, it is not easy to perfectly align the solenoids, so transverse correction coils are used to adjust the magnetic field. If there is a detector for electron beam position, it will be helpful for this correction.

Meanwhile, the primary electrons from the gun enter the collector. Then they are deflected toward the collector wall by a reflector. Some electrons are back-scattered in the wall without large energy loss and go back to the gun. In addition, some electrons moving near the central axis are reflected directly to the gun. These back-streaming electrons propagate and are reflected by the gun and enter the collector again. Some of them may repeat the reflection several times. The electrons may affect or break the primary beam. To avoid this, the transverse magnetic fields and drift tube potentials are adjusted.

A double-sided detector for ExtendedEBIS shown in Fig.2 was developed. One of the purposes is help to align the primary beam with the gun-side detector. The other is to observe the back-streaming electrons with the collector-side one. The detector is composed of Molybdenum quadrants with an aperture. The aperture diameter is 6 mm. This is larger than the beam (4 mm). This detector is installed into a chamber between the two superconducting solenoids.

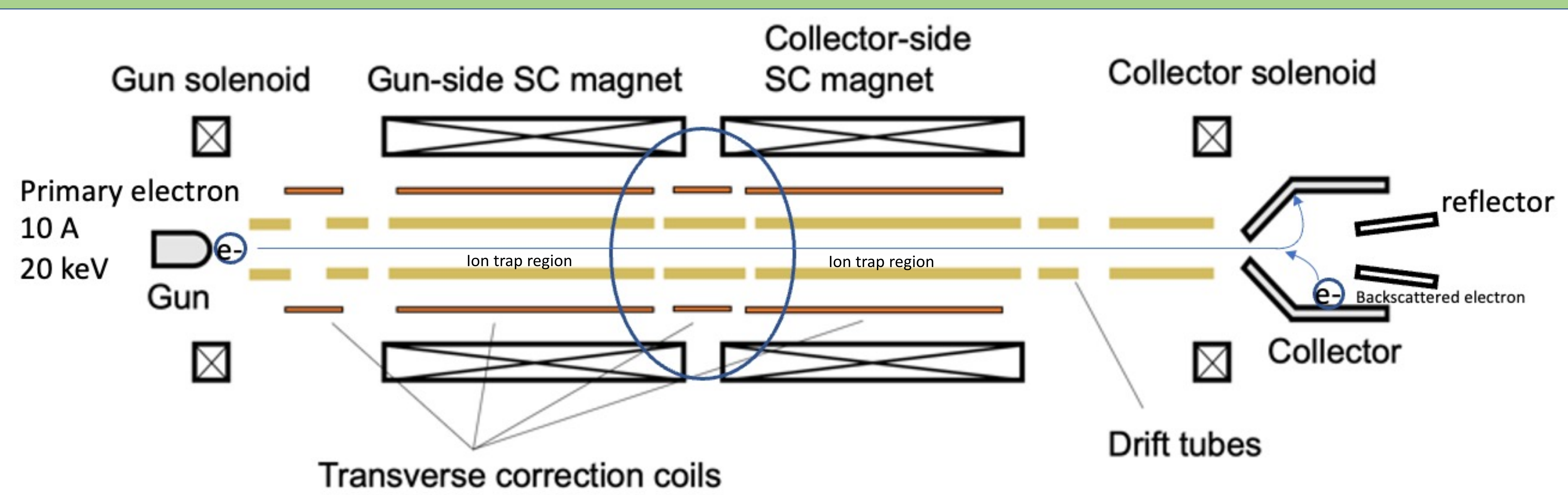


Figure1: Schematic drawing of ExtendedEBIS

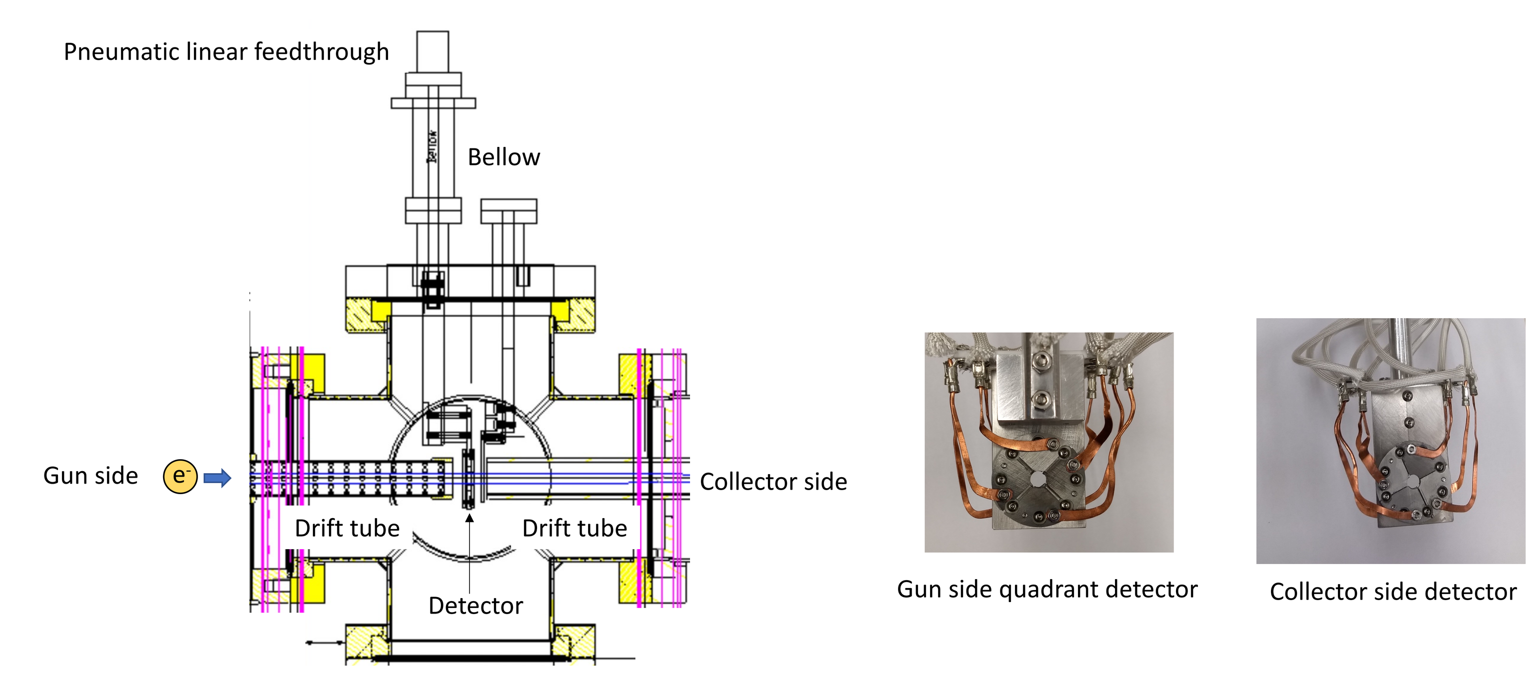


Figure 2: Double sided detector in mid-chamber between superconducting solenoids

Thermal consideration

Primary beam from gun and back streaming electrons hit detector.
Up to 100 mA, 20 keV, 100 ms, 1/4 Hz -> 2 kW peak, 50 W average.

- Temperature rise
  - by 50 W average: 100 C
  - by 1 pulse, 200 J (2.4 J/C heat capacity of detector): 84 C

Melting point
Al : 660 C (1220F)
Mo : 2617 C (4743F)

(If something is failed and all the electrons (1A-10 A, ϕ4mm beam) hit detector, temperature rise of surface = 700 C after 1 us. To avoid this, beam current should be increased gradually in time)

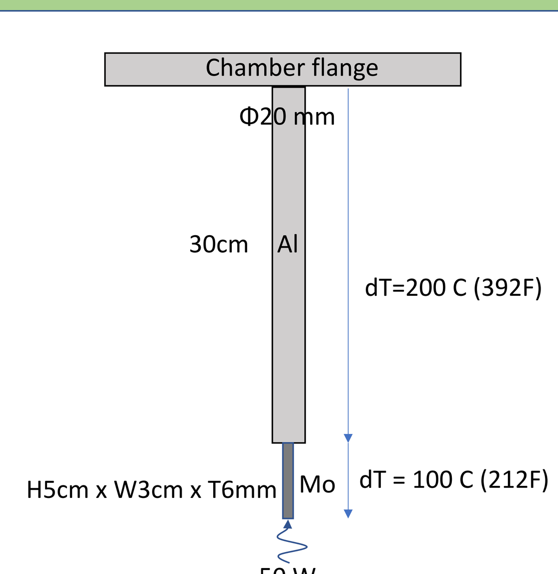


Figure 3: Conceptual model for heat conduction through detector

Influence of detector insertion on electric potential

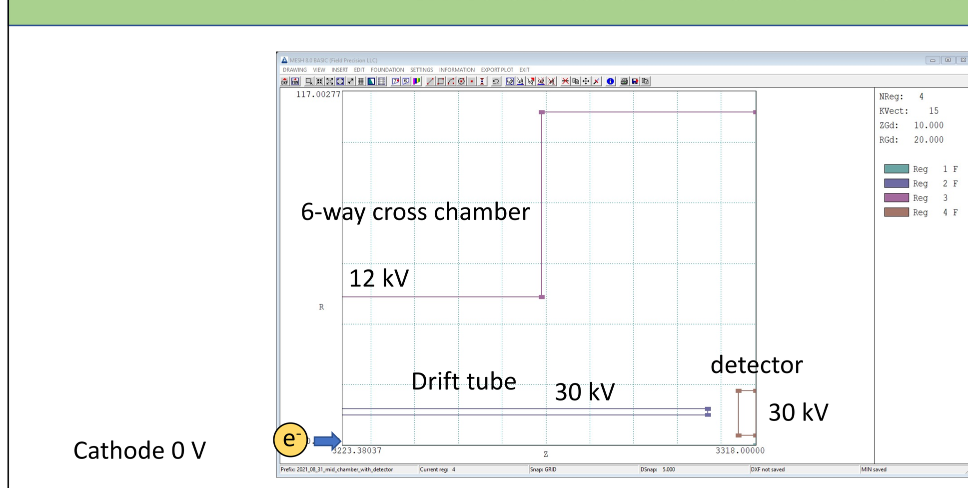


Figure 4: TRAK model in mid-chamber to simulate electric potential

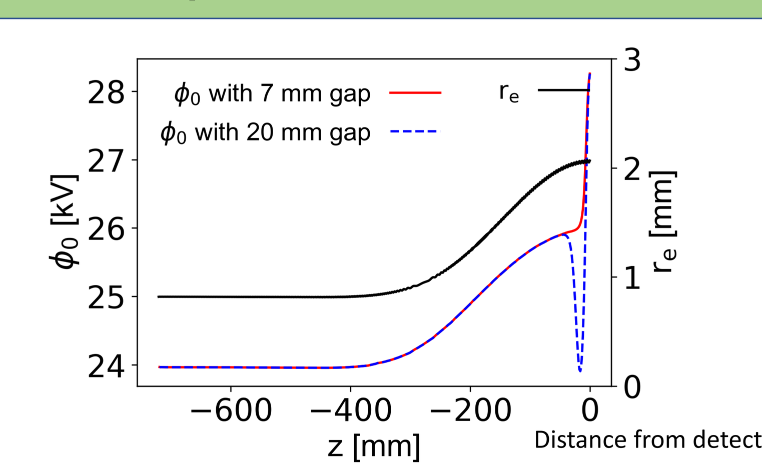


Figure 5: Beam radius (right y axis) and electric potential distribution along central axis (left y axis)

The detector is inserted between drift tubes. There is a 7 mm gap between the drift tube and the detector. The potential drop due to this gap was estimated with a simulation code, TRAK. The result showed that 7 mm gap makes almost no drop. It was also shown that 20 mm gap makes a potential drop comparable to one in the trap region. 7 mm gap is small, and therefore, the beam deceleration is small and no ion trap is generated.

Detector test 1: observation of back streaming electrons

The detector was tested with a 2.7-A primary beam. The pulse shape was trapezoidal (200us-500us-200us)

With a transverse field configuration, no signals were observed on the collector side detector (Fig.6).

By changing transverse magnetic field, signals appeared on the collector-side detector (Fig. 7 blue). This shows that the signals were from back-streaming electrons.

By applying 2 kV on a drift tube after the detector, signals were changed (Fig.7 green). This means that the electric field also affects the amount of the back-streaming electrons.

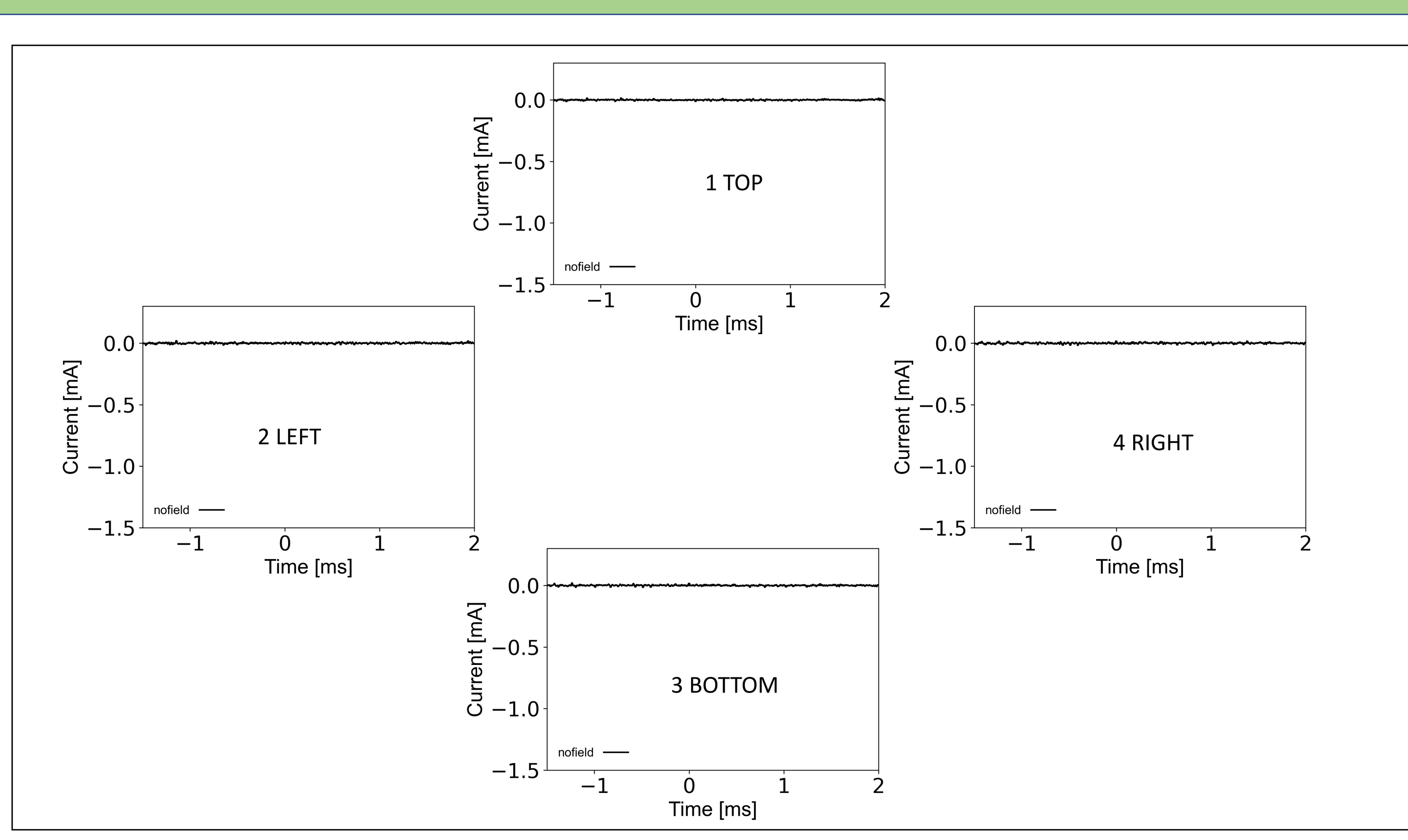


Figure 6: Signals on collector-side detectors with an optimized transverse field configuration

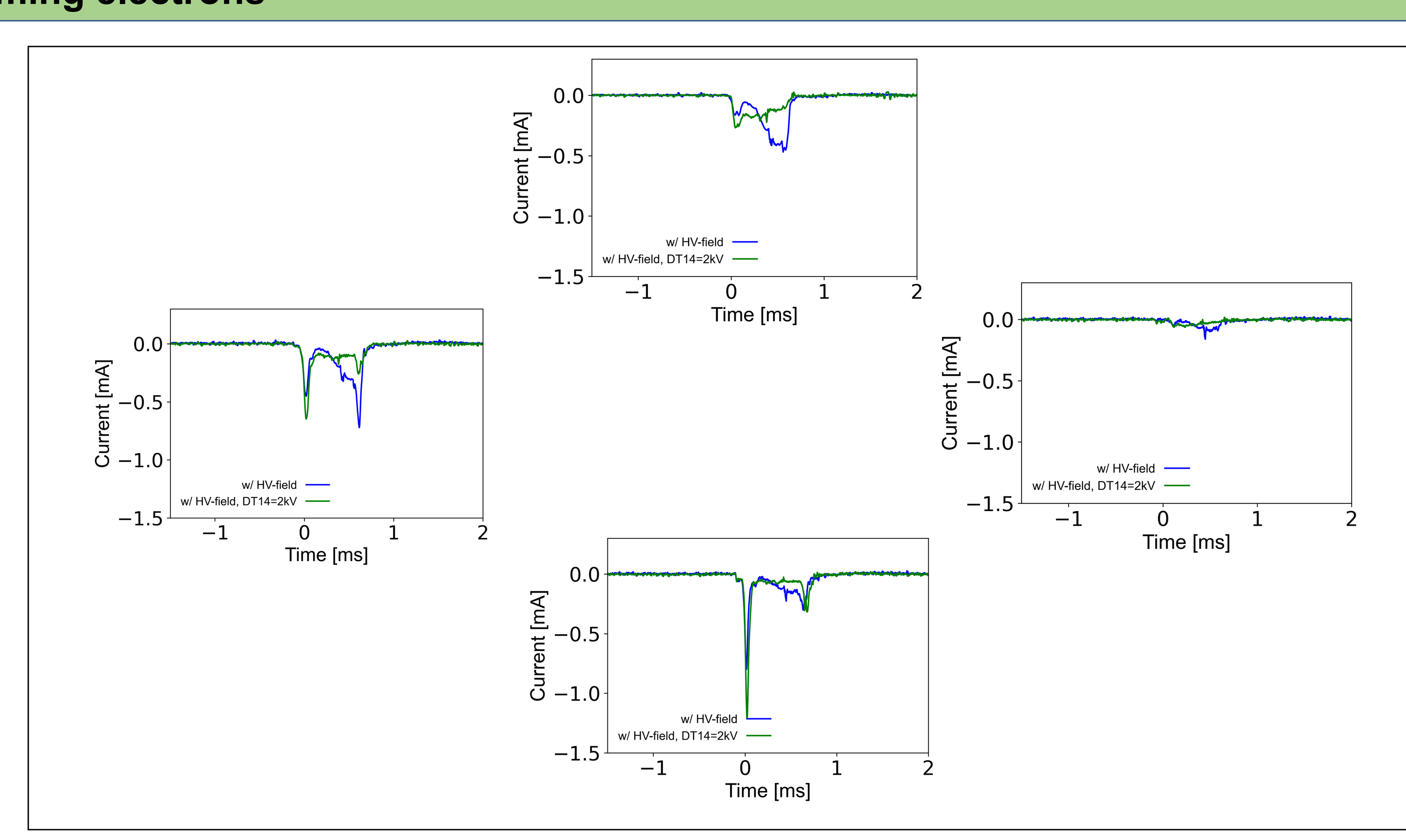
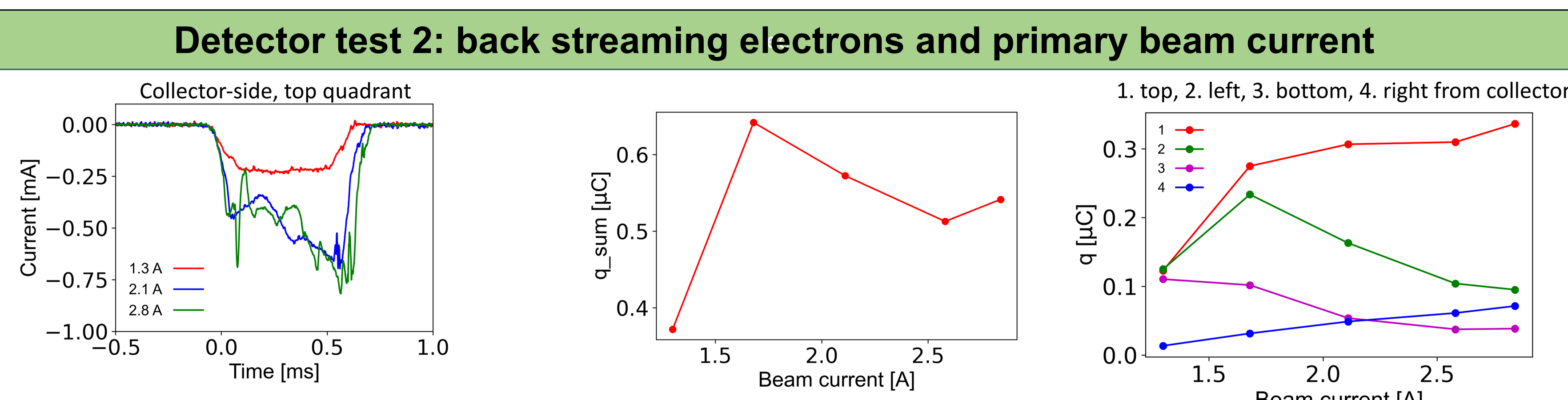


Figure 7: Signals on collector side detector;
BLUE: with stronger transverse fields in second SC solenoid, GREEN: transverse fields and 2kV on drift tubes behind the detector

Detector test 2: back streaming electrons and primary beam current



The current waveform was distorted as the primary current increased. The current waveforms on the quadrants were integrated (q_sum) and plotted as a function of primary beam current. It did not increase monotonically. The integrated values for each quadrant (q) are plotted. The tendency were different for quadrants. This indicates that the space charge of the primary beam affects the back-streaming electrons and does not just push out.

Acknowledgements

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