A mini-TPC for SLAC B-factory commissioning

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Abstract

A mini-TPC has been developed for use in PEP-II B-factory beam commissioning and background studies relevant for the BaBar detector. Installed near the intersecting region of the two beams, it has the capability to measure intensities, origins and composition of background particles coming from the e^+/e^- beams which produce charged tracks in its volume.

1 Introduction

From the first electron beam, produced by PEP-II in April 1997, to the planned installation of the BaBar detector in January 1999, a long time is available for dedicated optimization and commissioning, of the high energy electron beam first, then of the low-energy positron beam, and finally of the two very intense colliding beams. For this purpose, based on its tracking and dE/dx capabilities, and its ability to support a very high particle rate, a mini-TPC has been optimized and built for installation at the IP around the beam pipe [1]. In addition to the TPC, other specific detectors (X-ray camera, CsI crystals, Si diodes and straw chambers), as well as reduced scale elements of some BaBar subdetectors (Si layers and DIRC), have been installed in the collision region to characterize the background.

2 Mini-TPC description

2.1 Mechanics

The TPC design had to take into account at least two constraints: (a) the maximum number of channels was limited to 192, due to the existence of available preamplifiers developed for DELPHI TPC tests in 1986; (b) the shape of the detector, ideally a cylinder installed around the beam pipe, should fit within the commissioning environment. In particular the presence around the vacuum chamber of silicon diodes, and externally of straw chambers, limited the internal and external radii to 4.5 and 10 cm. Also, the presence around the IP of a silicon array limited the azimuthal coverage of the TPC to $.73 \times 2\pi$.

With this missing wedge, it was possible to build only one shell (Fig.1), made of 3mm of G10 with an external 1mm Aluminium skin, with the shape of a truncated cylinder. At one extremity of this cylinder is the HV plane, made of a 3mm G10 Cu-plated electrode; at the other end are, successively, the gating, cathode (or shielding) and proportional grids, and the pad plane, all divided into six sectors, each one with an angular coverage of 43 deg. The cage is made of a mylar foil supporting 36 3mm Cu strips glued internally on the cylinder, with 1mm gaps between two successive strips. The 3 kV negative high voltage applied between the HV plane and the cathode grid is decreased down through 36 3.95 Mohms flat resistances, creating a uniform drift electric field of 200 V/cm. The gate and cathode grids, strung on the same mechanical support,

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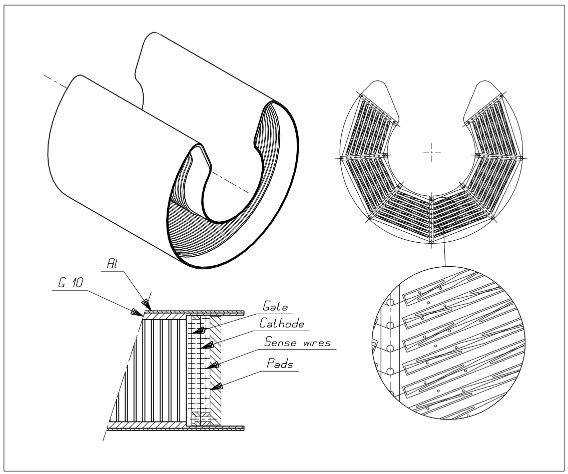


Figure 1: *Some views of the mini-TPC: electrostatic cage, transverse view of the wire region and pad arrangement.*

are made of 18 70 μm bronze wires. The gate grid is generally closed: in this case, the voltage is alternately 0 and -160V on two consecutive wires, generating a tranverse electric field stopping both electrons drifting down to the proportional wires, and ions coming from the latter. The total proportional current is then limited, and no ions can distort trajectories of electrons drifting in the chamber. The gate is open by setting all its wires at the same voltage (-80V, their natural voltage within the drift field), thus allowing electrons to drift to the proportional wires. The total opening time, which should be longer than the electron drift time (4-5 μs), and short enough to prevent the accumulation in the drift volume of the positive ions created near the proportional wires (50-100 μs), is generally set to 15 μs. The opening frequency is small enough (a few Hz) so that any residual ions not collected on the grid or cathode plane may drift slowly towards the high voltage plane and be collected there. The proportional grid has ten 20 μm W-Rh golden wires, parallel to the other grid wires, and set to a positive nominal voltage of 1350 volts to generate a total gain of $\sim 2 \times 10^4$ with the chosen gas. The information from the avalanche is not extracted from the wires, but from the pads located in front of the eight central wires on the cathode plane. A trapezoidal shape has been chosen for those pads, so that the signal induced on the corresponding pad row is shared into two adjacent pads. A precise determination of the avalanche position along the wire is obtained from the comparison between the amplitude of those two signals. Each sector is segmented into eight rows, and each row into four pads. The angle of the trapeze (between 4.25 and 9.25 degrees, depending on the row radius), the pad dimension, and the distance between the proportional grid and the pad plane have been optimized by simulation in such a way to maximize the r-ϕ resolution, and to minimize the signals induced by the avalanche on the two adjacent rows.

2.2 Gas

For the gas, the constraints are: non-flammability, low transverse diffusion, because there is no magnetic field, and slowness, for better longitudinal resolution. An Ar-CO_2-CH_4 mixture (90-5-5%) has been chosen, with a transverse diffusion of $\sim$300 $\mu\text{m} \times \sqrt{L_{cm}}$ and an electron drift velocity of $\sim$2.5 cm/μs at 200 V/cm.

2.3 Electronics and DAQ

Electronics and DAQ developed for the DELPHI TPC in 1985-1988 [2] have been reused. The charges collected on the pads are preamplified near the TPC, and after 20 meter long cables shaped to 600 ns FWHM signals, which are then sampled by a 8-bit FADC at 30 MHz (in fact the dynamic range is extended to 9-bit with a double slope on the digitisation). Zero-suppression is performed on data storage. From the pad time cluster one can extract the time formation of the signal on the pad, from which the z coordinate is determined, from the known electron drift velocity. Also, the total integrated charge on the pad is used in weighing $r - \phi$ measurements and in determining the particle dE/dx energy loss.

2.4 Laser calibration

A N_2 laser, used for the first tests of the DELPHI TPC, enables also to measure accurately the drift velocity: the laser light, after a 25m long optical fiber, creates photo-electrons on an Al wire strung on the entrance of the high voltage plane.

3 Performances

The mini-TPC performances have been determined from measurements made on a test beam at CERN in September 1997.

3.1 Experimental set-up

The device was placed in the T7 test beam, a 6 GeV/c positive beam delivering up to 10^6 particles (mainly pions) within one second, every 14 seconds. The gate opening and the DAQ were triggered by the coincidence between two signals coming from scintillators located on the beam ten meters up and downstream.

3.2 Gate effect

Fig.2 clearly shows the effect of the gate. When the gate is pulsed the pads are fully efficient, but when it is open permanently, no clusters are registered on the pad rows located near the cage: this can be interpreted by the existence of a transverse parasitic electric field generated by the presence of many ions in the TPC volume.

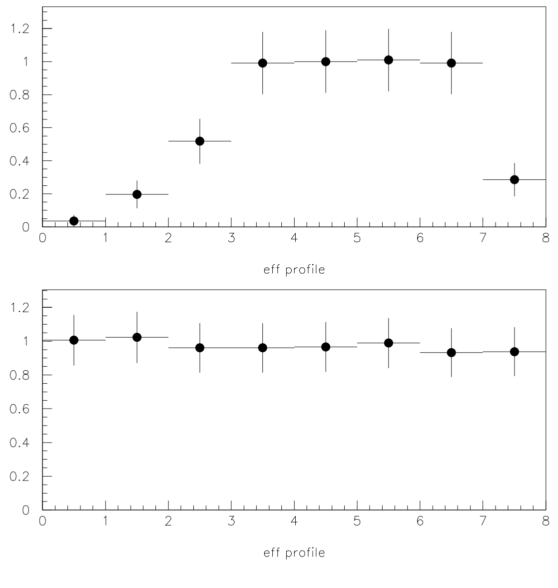


Figure 2: *Single pad efficiency for the sector traversed by the beam, as a function of the radial position of the pad (row number increasing towards the outside): (a) gate open; (b) gate pulsed.*

3.3 Resolutions

The z resolution is determined from the the differences on one chosen pad between the actual z measurement and the extrapolation of the fitted track through the pad. This has been done for two different drift distances (5 and 10 cm), so it is possible to disentangle the contribution of the longitudinal diffusion of primary electrons during their drift, which is estimated to 70 μm$\times\sqrt{L_{cm}}$ (averaged over all electrons collected on one pad, for tracks at 90° incidence to the TPC symmetry axis) and the intrinsic z resolution of the TPC, estimated to 170 μm. The polar angular resolution can be obtained from the extrapolation of fitted tracks to the opposite sector, located at a mean distance of 15 cm, and is estimated to 9 mrad. The same method is used for the transverse and azimuthal resolution, which are estimated to be respectively 210 μm and 4 mrad. From the amplitude distribution of the track clusters, after truncation of the upper 20%, the dE/dx resolution is estimated to be 27%.

4 First measurements at PEP-II

The mini-TPC has been installed at SLAC in the interaction region of the PEP-II machine near the beam pipe of the high energy beam in November 1997; it was in continuous operation during the January 1998 run, with electron currents up to 750 mA (compared to 1A nominal). During the run, relevant TPC information was sent to PEP-II controls: the current on the proportional wires, the number of clusters, the mean values of the total charge, of the total number of reconstructed tracks, and of the number of isolated clusters, and an event display. A few results are shown in order to illustrate the capacity of the mini-TPC to contribute to the understanding of PEP-II backgrounds.

4.1 Event display

Fig.3 shows the display of a typical "event" recorded with a beam current of 200 mA during the January run; at that time, the TPC was placed vertically close to the beam pipe, approximately 2m downstream from the IP. An "event" is the addition of all clusters collected by the DAQ during its open-

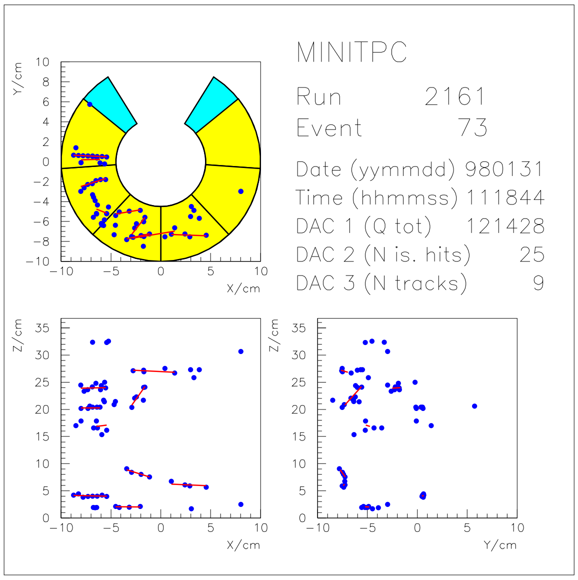


Figure 3: *Display of a mini-TPC event recorded with 200 mA e^- beam; x is parallel to the beam direction, y is also in the horizontal plane, while z (the TPC symmetry axis) points upwards.*

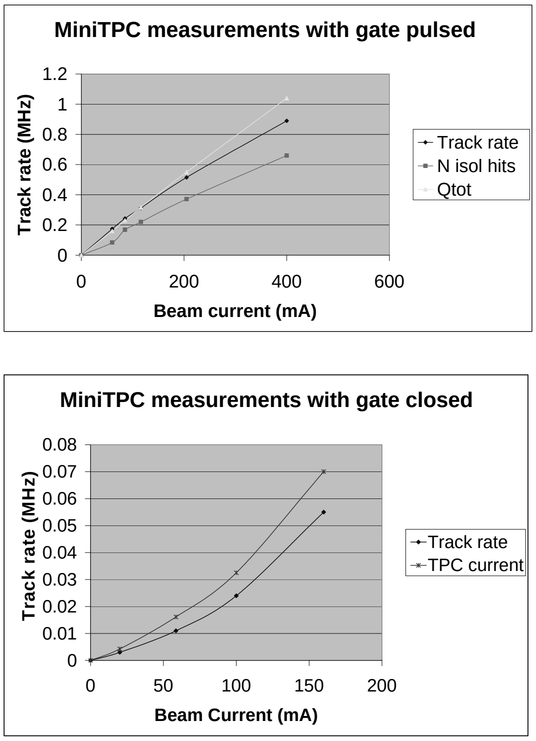


Figure 4: *Variation with beam intensity of some TPC measurements: (a) with gate pulsed; (b) with gate closed.*

ing time, corresponding to two TPC lengths; in the absence of an external trigger, no absolute position measurement was performed along the TPC drift direction. The three projections of clusters and reconstructed tracks (three or more clusters associated in space) are shown. In addition, some of the measurements sent to PEP-II, the total charge, and the number of isolated clusters and of reconstructed tracks, are also shown on the event display.

4.2 TPC behaviour with the beam current

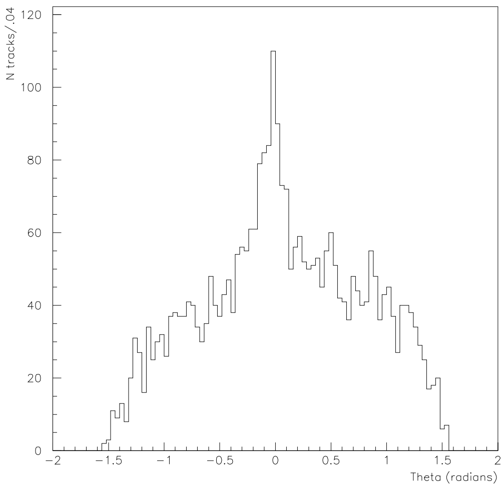
Fig.4a exhibits some measurements performed in the normal pulsed mode of operation, which follow an unexpected quasi-linear behaviour with the beam current. A quadratic increase with beam current, expected from beam-gas interactions, is found instead for the current on the TPC proportional wires (Fig.4b). As the grid is almost always closed, this current is generated in the proportional region of the mini-TPC, which during the January run was located a few cm below the horizontal plane containing the beam. For comparison, a similar behaviour is found for the track rate measured with the grid permanently closed (also in Fig.4b). These measurements need more analysis to be understood, but they suggest that there are important differences between the origins of the backgrounds found in and out of the beam plane.

4.3 Track reconstruction

Fig. 5 shows the angular distributions of reconstructed tracks with respect to the beam (in the vertical and horizontal plane), which indicate a clear accumulation of tracks around the beam direction. More analysis is being done to obtain accurately the spatial origin of those tracks.

5 Conclusion

A mini-TPC has been developed for use in PEP-II B-factory commissioning. It has been tested successfully in a high rate environment. Installed in the intersecting region of the collider, it has shown its capability to contribute to background studies by complementary means (total current, total charge and track rate), to determine the spatial origin of the tracks, and to perform an energy separation from dE/dx measurements. It will be installed around the beam pipe and will be working throughout the 1998 commissioning periods, with the PEP-II low energy beam at first, and then with the two colliding beams.



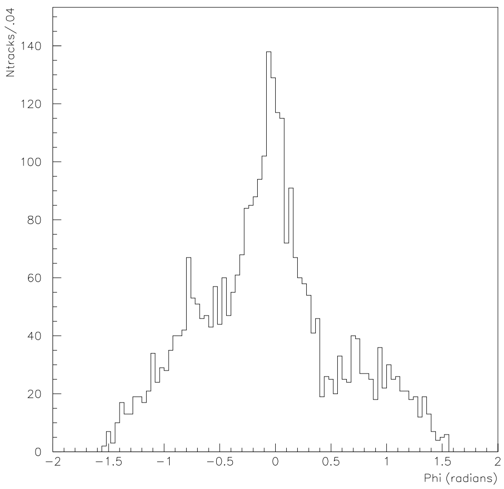


Figure 5: *Angular distributions of tracks (200 mA e^- beam) in the vertical (xz, "θ") and horizontal (xy, "ϕ") planes containing the beam.*

Acknowledgements

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