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Abstract

A mini-TPC has been designed and used for PEP-II commissioning and background studies relevant for the BaBar detector. Installed successively near and around the interaction point with some other specific detectors between January 1998 and February 1999, it has proved to be very efficient for the understanding and reduction of the machine background, before the beginning of the BaBar experiment in May 1999.

Introduction

During Spring 1999, the BaBar experiment at SLAC began to take data on the new PEP-II e^+e^- colliding ring. The high statistics of events required for BaBar studies motivated the design of a new type of collider, with asymmetric energies (3 and 9 GeV), and high intensities (1 and 2 Amps) allowing to reach a luminosity as high as 3 x $10^{33}cm^{-2}$ x s^{-1}, with the danger of high machine induced background in the BaBar detector.

Between the achievement of the high-energy electron ring (HER) in Spring 1997 and the installation of the BaBar detector in Spring 1999, a long dedicated period of optimization and commissioning of the PEP-II collider was made possible with the contribution of various detectors installed near the interaction point (IP). Some of them were reduced-scale BaBar sub-detectors, and the others were specially designed for the synchrotron radiation (SR) and lost particles (LP) measurements [1].

Among these detectors a mini-TPC (Time Projection Chamber) was proposed by the LAL-Orsay and developed in collaboration with LBL-Berkeley and University of Cincinnati. A TPC presents many advantages : it is a compact and precise 3-D tracking device, giving the position, direction and number of charged particles tracks; it is a simple, low cost and radiation hard detector; it can support very high rates; it has a dE/dx capability contributing to the particle identification [2].

1 Mini-TPC description

The size and the shape of the TPC were constrained by its location around the IP, and the presence in the same region of other detectors (Si vertex detector, PIN diodes and straw chamber). In order to save time and money, another constraint on the design was to re-use 192 existing electronic channels (amplifiers, shapers and digitisers) from the DELPHI experiment at CERN [3].

A few original solutions were developed for the mini-TPC (fig.1) :

- the use of only one mechanical shell, with a missing wedge of 110 deg. in azimuth, with the advantages of a very good rigidity, a very homogeneous electric field, and a great facility to install the TPC around the beam pipe and to insert the Silicon module in the wedge. The shell is made of 3mm G10 covered by a 1mm Aluminium skin, with inner and outer radii of 4.5 and 10cm respectively, and a total drift length of 15cm.
- the use of a very efficient pulsed gating system, from the TPC built by LBL for the STAR experiment now installed on the RHIC ion collider at Brookhaven; the gate is open only during a few 10μs at a few Hz for the DAQ, but most of the time it is closed, preventing ions to fill the TPC volume, and also stopping the drifting electrons, so protecting the proportional wires from dangerous high currents.
- only 8 proportional wires, segmented in 6 sectors 43 deg. wide in azimuth, are stretched, but the information on the avalanche position is got from cathode pads arranged in 8 rows of 4 pads for each sector, located in front of the wires. The trapezoidal shape of the pads and their size have been optimized to maximize the rϕ resolution by charge sharing.

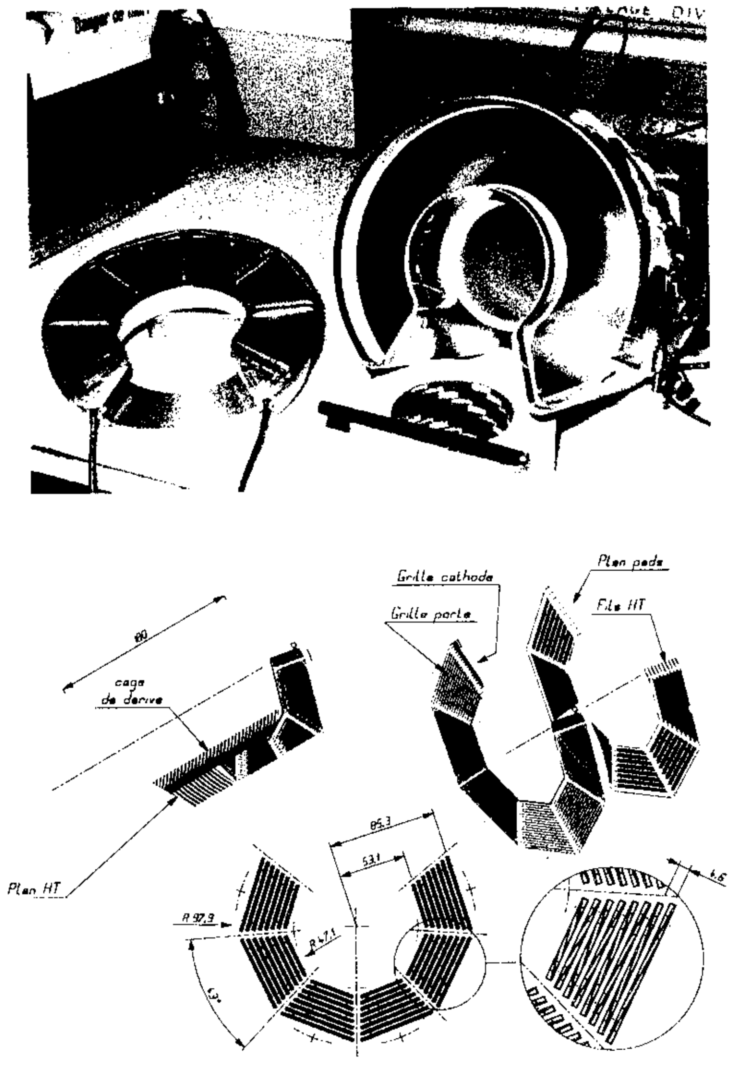

Figure 1: The mini-TPC : picture of the cage and of the cathode plane, and cross-section with details of the trapezoidal pads and of the grids.

From tests performed at CERN in September 1997, the measured spatial resolutions are 120 μm in rϕ, and $70\mu m\sqrt{L_{cm}} \otimes 170\mu m$ in z (the first term is due to the longitudinal diffusion in the $Ar - CH_4 - CO_2$ 90-5-5% gas mixture); the corresponding polar and azimuthal resolutions are 9 and 4 mrad respectively. The specific energy loss, dE/dx is measured with a 25% resolution.

Many informations were sent in real time from the mini-TPC to the PEP-II Main Control Center during the commissioning periods : permanently the total proportional current on the wires, and when the DAQ was working, an event display (fig. 2), and the measurements of the energy deposition in the TPC, and the pads hits and tracks rates.

2 The PEP-II backgrounds

Two main background sources in the BaBar region are expected from PEP-II [4] :

- Synchrotron Radiation (SR) photons emitted by the beam in the magnetic elements,
- Lost beam Particles (LP) produced by interaction of the beam particles with residual gas in the beam-pipe (Bremsstrahlung or elastic Coulomb scattering).

Particles originating from these background sources can either enter the detector region or, after interaction, generate secondary particles reaching the same region. SR photons, in the 1-100 keV energy range, are mostly stopped by specially designed energy absorbing masks in the beam-pipe. Due to their small energy their contribution to the mini-TPC signal is in any case expected to be negligible, as it was measured during the first commissioning period for this detector in January 1998. Lost particles are the main background source in the mini-TPC : Bremsstrahlung and Coulomb scattering on the gas create high energy photons, electrons and positrons interacting with materials (beam pipe, magnetic elements, masks, flanges, etc.). The electromagnetic showers produced are made of e^+/e^-, photons and a few hadrons, with energies generally in the MeV range, but extending sometimes up to a few GeV (beam energy).

The residual gas in the beam pipe is mainly originating from photodesorption of the internal walls induced by synchrotron radiation; this gas desorption decreases as the integrated current in the rings increases, because more and more gas molecules trapped on the pipe walls are removed and pumped. After a few hundred A x hours of integrated current, corresponding to a few months of normal activity, the rings are generally cleaned. This desorption was mainly observed in the LER (low energy ring or positrons) which is a completely new ring, as the HER (high energy electron ring) was cleaned during many months, before the installation of the commissioning detectors.

3 Results from the commissioning periods

The mini-TPC was operated during all commissioning periods between January 1998 and February 1999. During the first period, in January 1998, only the HER was active and the TPC was installed close to the beam pipe in the IR2 interaction region devoted to the BaBar detector (fig. 3a). For the following periods, the IP was in its nominal configuration, corresponding to the BaBar data-taking conditions, except for the 1.5T solenoid BaBar coil that was never implemented during the commissioning periods; the mini-TPC was located around the beam pipe, inside the final support tube with the Silicon Vertex prototype module, the pin diodes, and the straw chambers (fig. 3b).

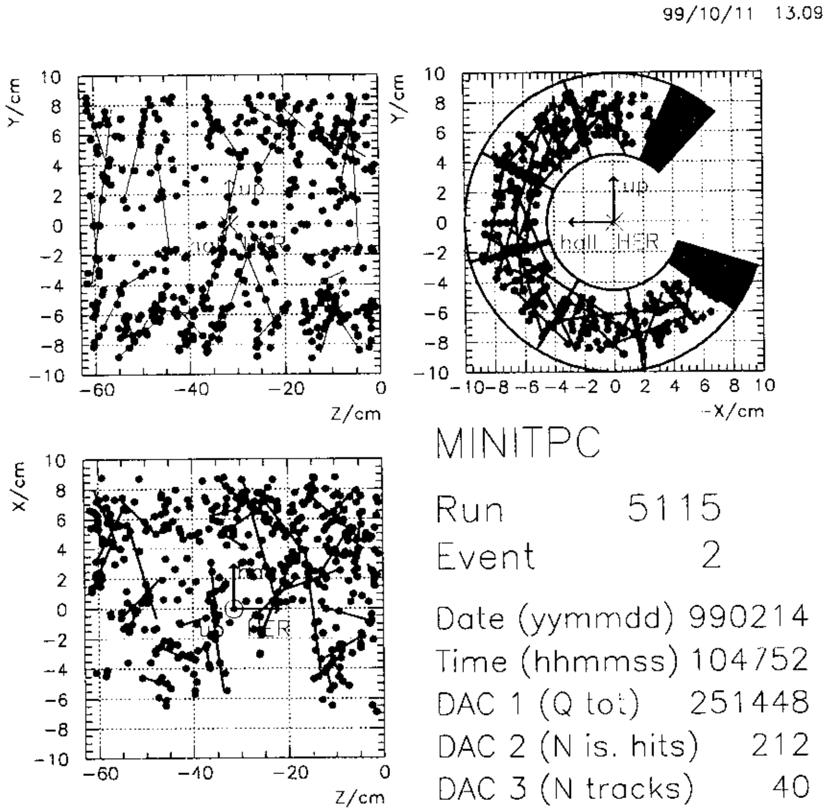

Figure 2: Event display at high beam intensity. The blue points represent the 3D hits, and the red lines the reconstructed tracks, in the three projections (Z is the high energy beam-HER-direction, Y the vertical and X the horizontal). DAC 1, 2 and 3 are respectively the total "charge" of the event (sum of the hits amplitudes), the number of isolated hits (not belonging to a track), and the number of reconstructed tracks. The track rate is $\approx$ 2 MHz.

Figure 3: The mini-TPC near the HER ring in January 1998 and the interaction region after May 1998.

3.1 HER optimisation in January 1998

During this first activity period for the TPC, it was possible to measure the rate of reconstructed tracks ϱ, as a function of the circulating current I in the electron ring, as shown on fig. 4, and to fit the experimental points with the expected dependence :

$$\varrho = a \text{ x } I + b \text{ x } I^2$$

where the linear term, dominant at low intensity, corresponds to the "base pressure", mainly due to thermal outgasing, and the quadratic term corresponds to the "dynamic pressure", caused by desorption from the internal walls of the pipe by SR photons. On the same figure is shown the comparison between data and Monte Carlo simulations : the agreement is good within a factor 1.8 at 1A, 0 and the same level of agreement is observed for other commissioning detectors, which can be considered satisfactory.

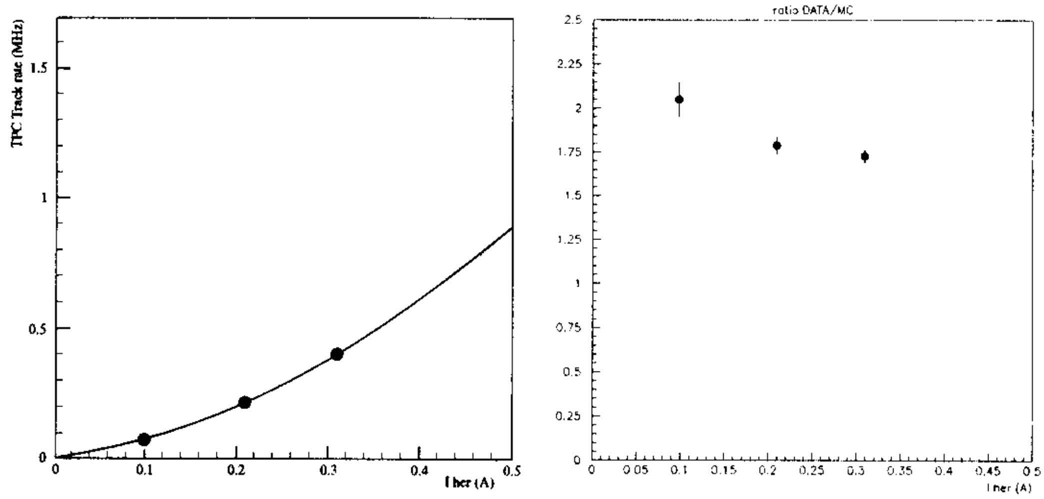

Figure 4: Measured track rate in the mini-TPC, and comparison with the MC expectation, as a function of the electron beam current.

The disagreement can partly be attributed to the lack in the simulation of background due to particles scattered along the ring with very little energy loss, and travelling several turns in the ring before interacting in the material around the IP.

The specificity of a TPC is also to determine the direction and origin of charge particles tracks; an illustration of its ability is given on figure 5, showing the origin of the tracks along the beam pipe : data and Monte Carlo exhibit a peak at ~ -20cm, which has been very well identified as a beam pipe region hit by lost particles scraping a SR mask located approximatively 2m upstream.

3.2 HER and LER optimisation in autumn-winter 1998-99

The PEP-II program for this period was :

- to accumulate high integrated currents in both rings in order to "scrub" the pipes,
- to make the beams collide and improve the luminosity (it reached 5 x $10^{32} cm^{-2}$ x s^{-1}),
- to understand and minimize the background in HER and LER; for that purpose PEP-II people performed many current scans, multibunch and steering experiments , and changed the vacuum and collimation conditions.

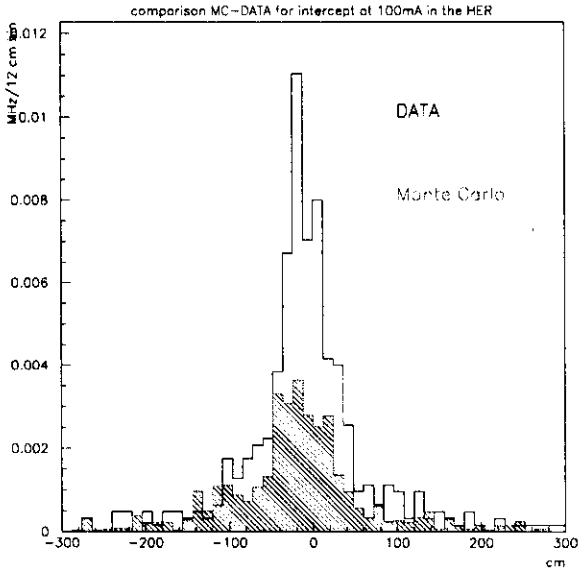

Figure 5: Origin along the beam pipe of the tracks crossing the TPC (100mA in the HER).

The mini-TPC can support track rates as high as hundred of MHz, but above a few MHz the occupation is so high that it is no more possible to reconstruct any track of particle crossing it. Nevertheless the proportional current in the chamber has been measured to be proportional to the track rate at low intensity; this was very useful to estimate the track rate from the mini-TPC current in high background conditions.

3.2.1 HER studies

On figure 6 is shown the mini-TPC track rate as a function of the HER current in December 1998 and February 1999 : a significant reduction is observed, due to the pump activation as well as to the accumulation of A x hours in the ring.

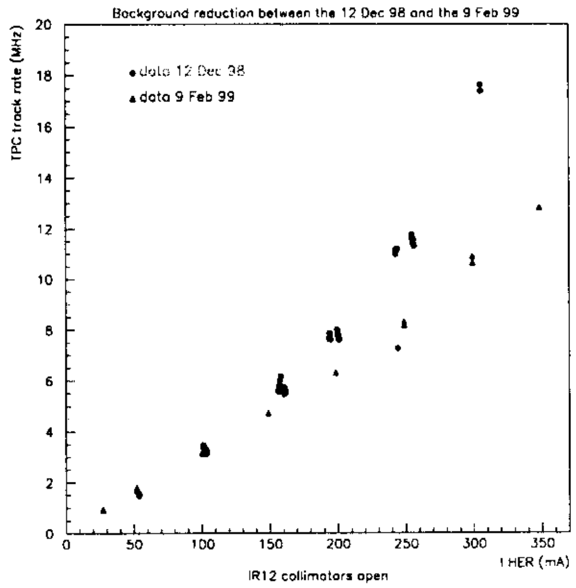

Figure 6: TPC track rate vs HER current : evolution with time.

Collimators have been installed in IR12 (Intersecting Region 12, located $\sim$ 300m upstream in the ring) in order to stop a large fraction of lost particles : the effect of closing these collimators is important, as shown on figure 7.

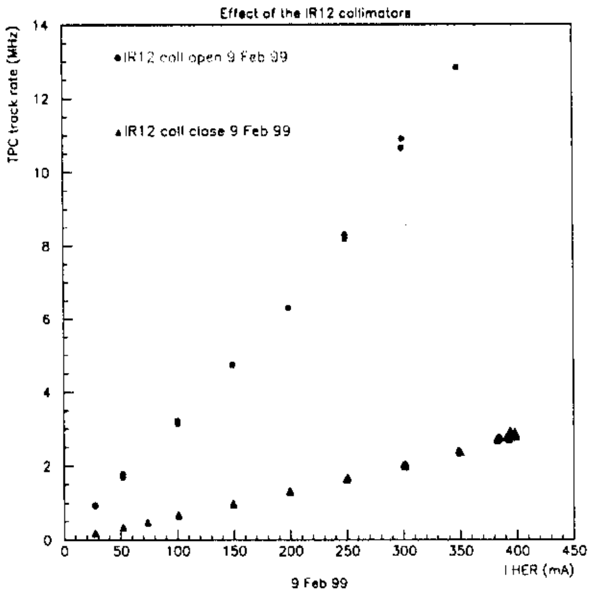

Figure 7: The track rate vs HER current : influence of the collimators.

The ratio between data and simulation with collimators closed is presented on figure 8. The agreement is as good as in January 1998 (2.2 as compared with 1.8 at 1A). This is a very satisfactory result, as the running conditions during the two periods were very different.

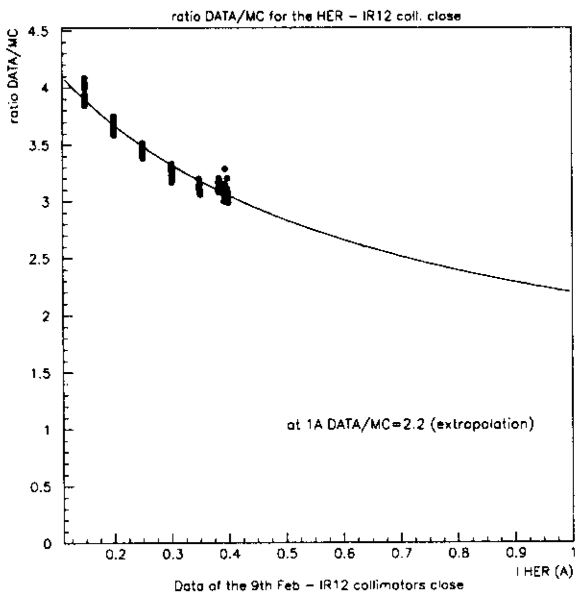

Figure 8: The track rate vs HER current : comparison between data and MC simulation.

3.2.2 LER studies

Figure 9 shows the improvement on the TPC track rate as a function of the positron current : between November 20th and 28th the reduction is attributed to the natural "scrubbing" effect; between November 28th and December 6th, some TSP (Titanium Sublimation Pumps) have been activated, so trapping an important amount of residual gas. The small increase observed between December 6th and 12th could be explained by the slow degradation of vacuum after the TSP activation.

On February 14th, a multibunch experiment has been performed, consisting in varying the number of bunches accumulated in the LER ring (the maximum is 1658). Figure 10 exhibits a clear dependence of the track rate with the bunch population which can be attributed to a "multipacting" effect : photoelectrons

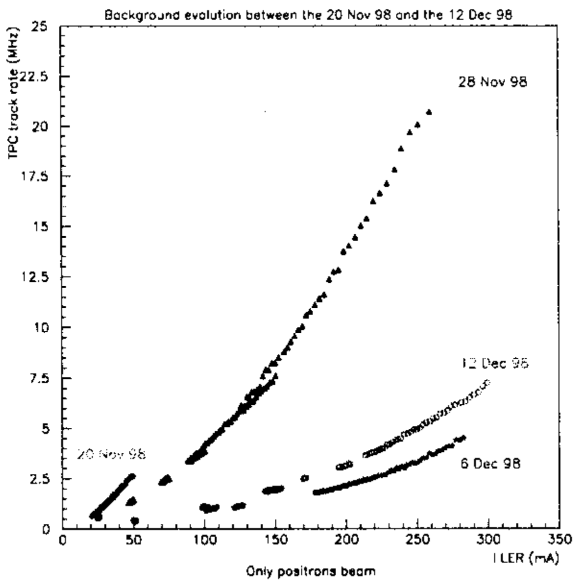

Figure 9: Evolution of the LER background with time.

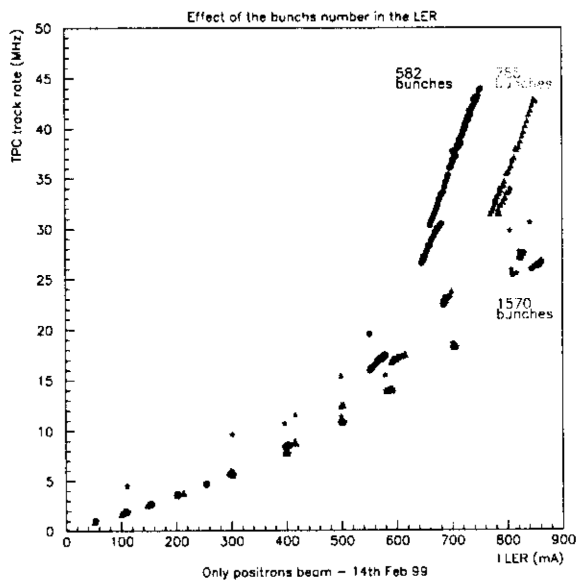

Figure 10: Effect of the LER bunch number on the TPC track rate.

produced by ionisation or by SR photons on the pipe walls are attracted by the positron bunch electric field, accelerated during the bunch passage and then reach the pipe so creating electrons by secondary emission and heating the wall, the net result being an increase of the pressure; the electron energy due to this acceleration being proportional to the bunch electric field and consequently to the bunch population, the background is expected to increase, for a given total current, with a decreasing number of total bunches, as observed on figure 10.

In principle, the way to suppress the effect of this multipacting process is to generate a small longitudinal magnetic field along the straight sections of the LER, in order to remove all these low energy electrons. This has been tested later, with the BaBar detector in IR2, with a small but not definitive success.

As for the HER, the comparison has been made between measurements and simulation, and a ratio data/MC ~8 has been obtained at 1A. This discrepancy can be explained : at first there is the same lack in the simulation of scattered particles interacting near the IP after several turns ; then the expected effect of collimators, located now in IR4 (~300m upstream) but not yet installed at that time, is a background reduction by a factor 3 at 1A; in fact, taking into account scattered particles, a bigger factor is to be expected, and data/MC agreement is expected to improve.

Conclusion

The mini-TPC was active and efficient throughout PEP-II commissioning runs between January 1998 and February 1999. It had a significant impact on the background understanding and reduction of both HER and LER rings. The mini-TPC results were generally in good agreement with those obtained by the other commissioning detectors. Thanks to this effort, it was possible to start very efficiently physics with BaBar, and reach very quickly a high luminosity with reasonable background conditions.

The mini-TPC is still working : it is installed now at Brookhaven near the RHIC ions collider in order to contribute to the background reduction of this very new and intense machine, for the STAR experiment.

Acknowledgements

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