LAL 97-94
December 1997

Laboratoire de l'Accélérateur Linéaire

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Talk given by A.M. Lutz at the Second Workshop on
Backgrounds at Machine-Detector Interface
Hawaï, March 1997

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Abstract

A mini-TPC is under construction in Orsay, and will be installed at the end of 1997 at SLAC for the commissioning of the PEP-II machine in the intersection region of the beams.

1 Why a mini-TPC ?

A TPC is a radiation hard detector that is as sensitive as the BaBar detector. Located in the intersection region of the beams, close to the beam pipe, it will allow, prior to the installation of the detector, to monitor the level, distributions and composition of the machine backgrounds.

The main feature of a TPC is its tracking capabilities : it will allow one to count charged particles, to measure their positions in space, and to determine their angular distribution. A second characteristic of a TPC is its dE/dx capability, contributing to the estimation of the energy of the charged particles, and to their identification.

Three main issues will be addressed with the mini-TPC :

- the online monitoring of the level and the spatial origin of the machine backgrounds will allow one to check the mask design and improve the beam tuning,
- from the energy and angular distributions of charged particles, it will be possible to trace the physical origin of backgrounds (discrimination of direct sweep-out particles, characterized by GeV energies, shallow angles, and located in the horizontal plane, from lost particles, characterized by low energies and large angles), and to measure

the forward-backward asymmetry resulting from the energy asymmetry of the PEP-II beams.

- the particle identification will allow one to determine the background composition, especially to distinguish between electromagnetic and hadronic components. This measurement is important for trigger issues: the expected trigger rate from hadrons is 2 kHz, and approximatively 100 protons will cross the mini-TPC every second.

2 The mini-TPC

2.1 Realisation

The mini-TPC consists of a 20 cm long cylinder covering 73% of the total azimuth (61% for the sensitive part), the remaining wedge being occupied by a Si-detector. The inner and outer radii are 4.5 and 10 cm, respectively, allowing insertion very close to the beam pipe.

The mechanical structure is made of a 3 mm G10 shell, with an external skin of 1 mm Al glued around the outer cylinder (Fig. 1).

A 3 kV high voltage is applied to one of the end plates. The inside face of the cylindrical shell of the mini-TPC is covered by 36 annular copper electrodes, 3 mm wide. They are fed with potentials stepped down through a chain of resistors so that a constant drift field of about 200 V/cm parallel to the cylinder axis is created in the chamber volume.

The gas mixture is Ar(90%)-CO2(5%)-CH4(5%) at atmospheric pressure, ensuring a low transverse diffusion ($<$ 1 mm for the maximum drift distance), and giving an electron drift velocity of 3 cm/μs. This velocity is monitored by a Nitrogen laser.

2.2 Wiring, readout and electronics

After crossing a dynamic gate grid and a shield grid, the drifting electrons are collected by an array of 8 proportional wires (20 μm in diameter, approximative gain of 10^4), with a separation of 4.6 mm, strung across 6 sectors of 43° in azimuth (Fig. 1). Each sector of the sensitive end plate is equipped with 8 parallel pad rows, located in front of a segment of proportional wire and divided into four pads. The choice of the pad geometry (two parallelograms in the central region, and two triangles on the edges) has been optimized in such a way that the avalanche created on the wire generates signals on two adjacent pads in a ratio that allows a determination of its coordinate along the wire to better than 200 μm. The pad height (2 mm) and the distance between the pad plane and the proportional wire plane (1.8 mm) have also been chosen in order to simultaneously decrease the cross-talk between two adjacent pad rows and increase the amplitudes of the signals induced by the avalanche on the pads.

The small number of pads (192) makes possible the re-use of spare electronics and DAQ developed for the DELPHI and ALEPH experiments at CERN. The charges collected on

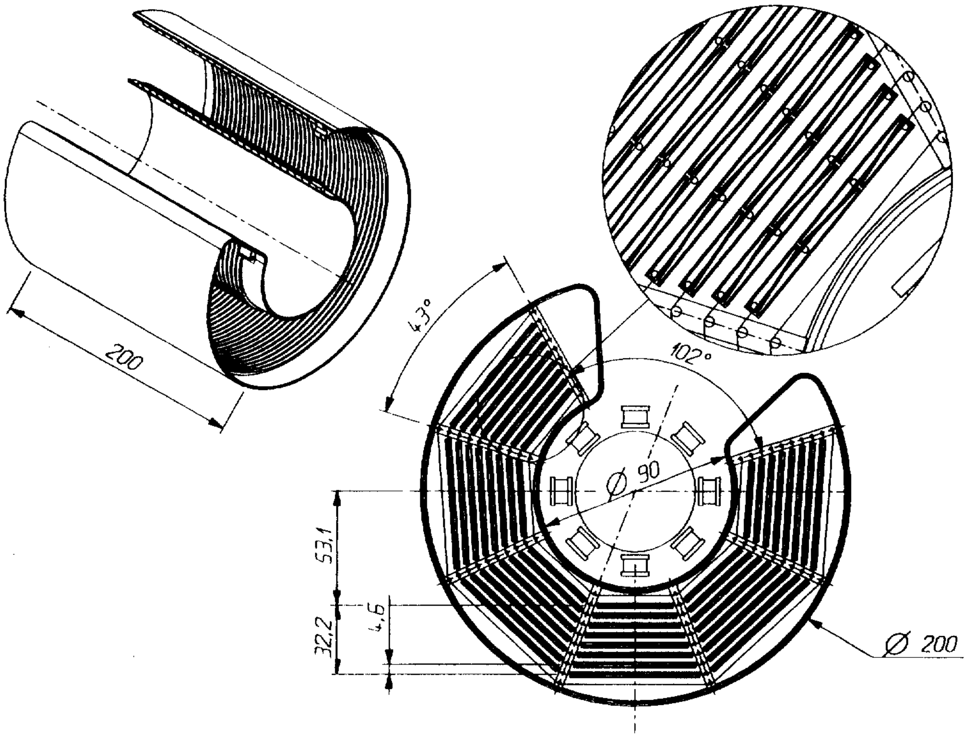

Figure 1: Electrostatic cage, proportional wire and pad arrangement

the pads ($\sim$ 1 pC) are pre-amplified near the mini-TPC, then after running along 20 meter cables, are shaped to normalized 150 ns FWHM pulses. The signals are then sampled by an 8-bit FADC at 15 MHz (in fact the dynamic range is extended to 9-bit, with a double slope on the digitisation). Zero-suppression is performed for data storage.

2.3 Operating mode

The mini-TPC will work without solenoidal magnetic field, and without external trigger, because the bunch crossing period of 4.2 ns is too short for beam related triggers. It is planned to operate the mini-TPC with the following scenario: open the gate grid at a low frequency ($\sim$ 1 Hz), and register the data during $\sim$ 100 μs. This time is long enough to detect particles produced by a few 10^4 beam crossings; at nominal background level, the expected number of tracks crossing the mini-TPC is approximately 1 per sector per full drift time frame of 5 μs. The mini-TPC will therefore be capable of working at $\sim$ 10 times the nominal background. After 100 μs, the first ions will start entering the drift region. It is then necessary to close the gate grid with a small differential potential ($\pm$40 V) between two adjacent wires, and wait for at least a few 10 ms for all the ions to be collected by the HV electrode before opening the mini-TPC gate again (Fig. 2).

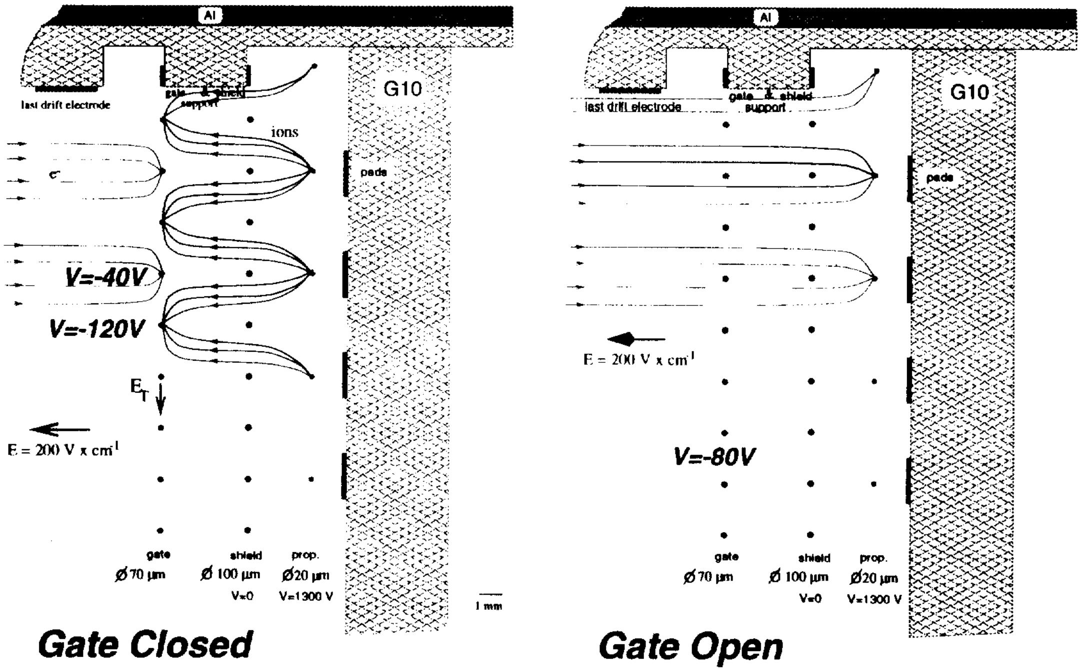

Figure 2: Structure of the mini-TPC end plate and HV settings for the two phases of the operating scenario.

3 Expected performances

3.1 Tracking resolution

The tracking information is obtained from a maximum of 8 three-dimensional points per track. The $r - \phi$ resolution is expected to be $150 - 200\,\mu$m per point, allowing a very good ϕ precision of $1 - 3\,$mrad. The z resolution can be estimated from the readout time sampling and the drift velocity to $300\,\mu$m per pad cluster, giving a 5 mrad resolution in θ. For very shallow tracks, the θ measurement can be extracted from the signal duration with a reduced accuracy.

Without an external trigger related to the beam crossing as a reference time origin, the absolute z of the particle origin is only constrained by the fact that the measured track segment is confined between the two mini-TPC end plates. For tracks crossing one of the end plates, with N pad row measurements ($\mathrm{N} < 8$), the z coordinate is known to $300\,\mu\mathrm{m}/\sqrt{\mathrm{N}}$. For the other 40% of tracks the z precision is $\sim 3\,$cm on average, due to the generally small polar angle of the particle. For a typical $\theta = 20°$ track, the z precision of the origin is 1 cm.

3.2 dE/dx capabilities

The mean ionization loss will be 50 electrons per pad row for a MIP at 90° (samplings of 4.6 mm of gas). For tracks with 8 radial samplings, the expected dE/dx resolution is 25%.

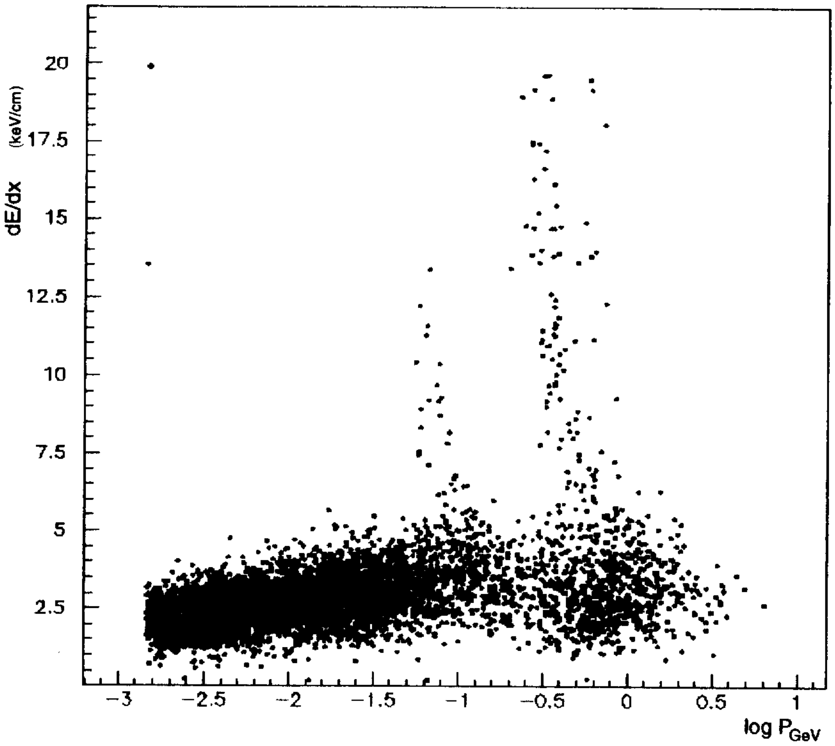

Figure 3: Ionisation loss .vs. track momentum

The longitudinal samplings of 2 mm, corresponding to the FADC 70 ns time buckets, will provide dE/dx information for tracks at shallow angles with a similar accuracy.

A simulation performed with 25% dE/dx resolution (Fig. 3) shows that it will be possible to see the relativistic rise of ionisation loss (for electrons and positrons) and to select high energy ($\sim$ 1 GeV) sweep-out particles by an appropriate cut on this loss. Figure 4 shows the expected azimuthal distribution of particles, after an ionisation loss selection (dE/dx between 4 and 7.5 keV/cm) has been applied: it exhibits two sharp peaks in the horizontal plane, corresponding to sweep-out particles from the two beams. It also shows that the dE/dx cut enables one to perform a selection almost equivalent to the ideal energy selection, and that the mini-TPC can give a clear idea of what is being seen by the silicon vertex detector of BaBar. In the same way, it will be possible to select low energy hadrons, characterised by a very large ionisation loss ($>$ 7.5 keV/cm), frequently leading to saturation of the electronics signal.

4 Conclusions

The mini-TPC is under construction at Orsay, it will be tested with a particle beam at CERN in September 1997, installed at SLAC at the end of the year, and run during the full PEP-II commissioning year 1998, with the electron and positron beams.

The mini-TPC will provide detailed diagnostic tools for PEP-II optimisation:

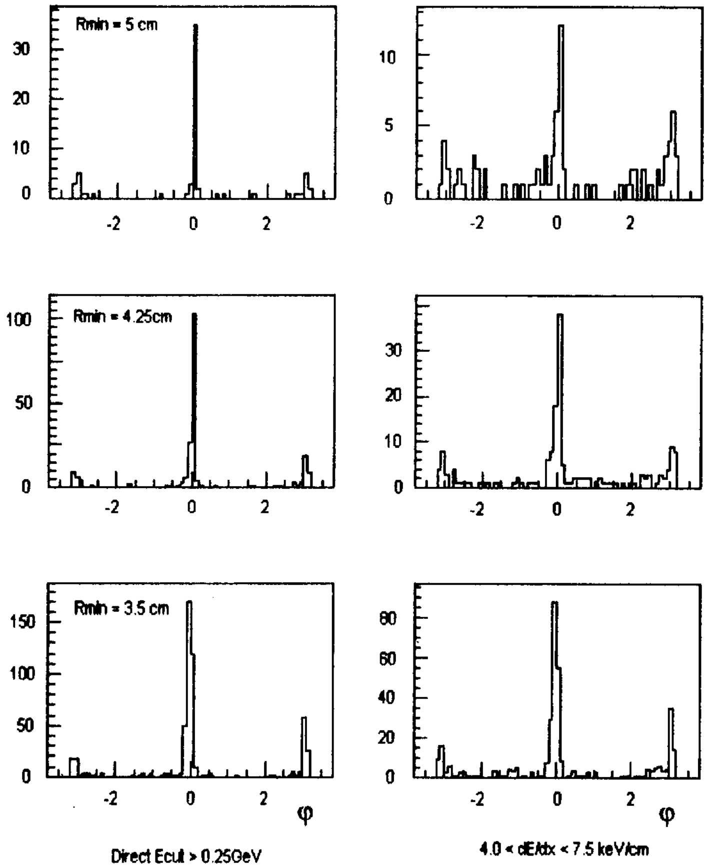

Figure 4: Azimuthal distributions of sweep-out particles, selected by a direct ideal energy cut or by a dE/dx cut. Each pair of plots corresponds to tracks scored in a mini-TPC placed at different radii: nominal mini-TPC location (top), BaBar vertex detector location (bottom).

- the online reconstruction of events will give an immediate feed-back to the machine, via event displays, and by sending some information to the operators (track rates and single rates, corresponding to synchroton radiation or Compton scattering). It will also provide the instantaneous rates of γ, charged tracks and sweep-outs, and the spatial origin and angular distributions of particles.
- the offline analysis will improve the understanding of the background and the validation of its simulations. It will make extrapolations to lower radii possible (for example at the silicon detector location), and improve the estimation of trigger rates due to hadronic beam-induced backgrounds.