First results from the CERES radial TPC

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The CERES/NA45 experiment at the CERN SPS was upgraded in 1998 by the addition of a cylindrical Time Projection Chamber. The aim is to improve the mass resolution of e^+e^- pairs in the $\rho/\omega/\phi$ region to $\Delta m/m < 2\%$. A progress report is given on the TPC performance during the 1998 commissioning runs (laser rays, beam halo muons, and particles produced by proton/π and lead beams hitting Pb and Au targets).

1. CERES upgrade

The CERES/NA45 experiment is dedicated to the measurement of low-mass e^+e^- pairs identified by two ring-imaging Cerenkov counters [1]. The CERES spectrometer was upgraded during 1998 by the addition of a Time Projection Chamber (TPC) with a radial electric drift field [2,3]. The TPC is located downstream of the existing spectrometer and placed inside two coils of a warm magnet to provide a momentum analysis. It exhibits an azimuthally symmetric acceptance in the pseudorapidity range $2.1 \leq \eta \leq 2.6$. The sensitive volume of the TPC has a length of 2 m, an inner radius of 48.6 cm and an outer radius of 132 cm (Fig. 1).

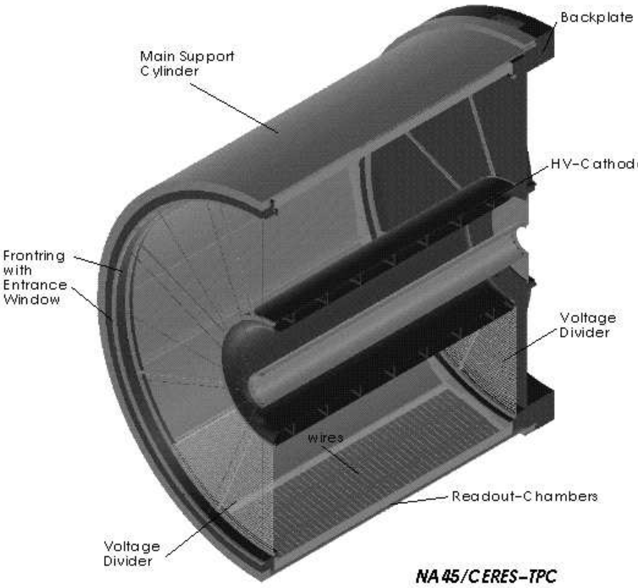

Figure 1. Cross section of the CERES TPC.

The gas system provides a gas mixture of Ne (80%) and CO_2 (20%) that was selected after optimization on diffusion, multiple scattering, Lorentz angle, primary ionization and drift velocity. It operates at atmospheric pressure. The radial electric field is provided by a cylindrical aluminium electrode at a potential of -30 kV and the cathode wire plane of the readout chambers at ground potential. The 1/r electric field varies with radius between 0.2 and 0.6 kV/cm, corresponding to drift velocities (v_D) between 0.7 and 2.4 cm/μs. Each of the 16 readout chambers has three wire planes with wires running in azimuthal direction: gating grid, cathode wire, and anode wire plane. The avalanche produced close to the anode wires induces a signal in the chevron-type cathode pads [4].

The chevron pad shape was selected because of its efficient charge sharing in azimuthal direction and was optimized to minimize the differential non-linearity [5]. A measurement of the charge sharing in azimuthal direction shows that the charge is mainly distributed over three pads with a size of 6×10.3 mm^2. The measured pad response function is approximately Gaussian with a standard deviation of 0.5 pads. As an example, for the case of a cloud arriving exactly in the middle of one pad, this central pad will contain 80% of the charge. The expected position resolution is 250-350 μm in azimuthal and 400-500 μm in radial direction, depending on the polar angle.

The TPC comprises a total of $48\times16\times20$ (=15360) readout channels and provides a measurement of up to 20 space points per particle track. Each channel is equipped with low noise electronics [6] which samples the analog signals with an 8-bit ADC in 256 time bins per channel, thereby providing 4 million pixels in total. The mean electronic noise under operating conditions was measured to be 1.1 ADC counts, corresponding to 1265 electrons. A slight variation of this value with the electronic channel is understood in terms of different trace lengths on the board. The TPC was operated with a gas gain of $8\cdot10^3$ and an electronic gain of 46 mV/fC.

2. Slow Control: Gas conditions

The working conditions of the setup (gas mixture, pressure, drift velocity, temperature, HV for the electric field, etc.) are recorded periodically by the slow control of the experiment. The level of impurities needs to be kept as low as possible to avoid electron attachment in the Ne-CO_2 gas mixture. Although the TPC has about 200 m of o-ring sealing for a volume of 9 m^3, during the commissioning runs levels of 4 to 5 ppm of O_2

and of 15 to 20 ppm of H_2O were achieved, measured in the TPC gas outlet. These values correspond to a recirculation gas speed of 15% Vol/h and fresh gas injection of 1.3% Vol/h. A cross-check of the O_2 level was done studying the attenuation of the signal as a function of the drift time. The measured O_2 content agrees well with the observed maximum attenuation of 15% for the longest drift time of 70 μs.

The temperature of the TPC is stabilized to better than 0.2 K in order to keep temperature induced variations in the drift velocity below 0.1 %.

3. Commissioning runs: Preliminary Analysis

During 1998 several commissioning runs took place. First, laser beams were used to produce straight tracks even in the presence of a magnetic field. The laser system presents two important features; it provides tracks parallel to the beam direction at different radii in each chamber and due to stray ligth it produces ionization at the surface of the inner HV cathode all along the detector fixing the integral of the drift path. This information is currently used to understand the electric field, which is at present calculated by the 3D finite element program MAFIA [7].

Second, two external multiwire proportional chambers were used, in front and behind the TPC, to trigger on muons that come together with the beam. These chambers provide external tracking information that can be compared with the TPC measurements.

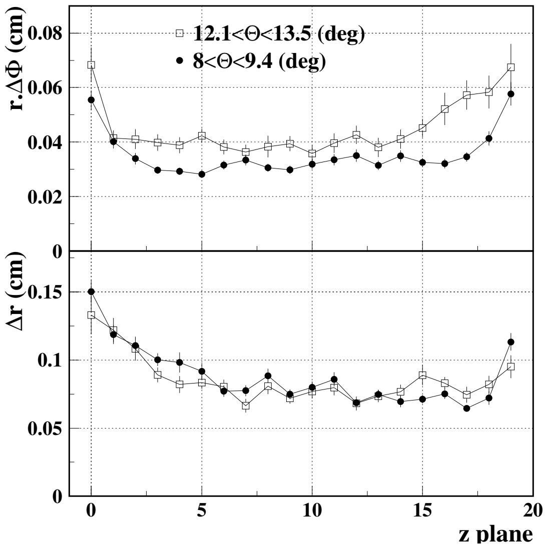

Figure 2. Position resolution in azimuthal (top) and radial (bottom) direction for tracks for Pb+Au collisions.

The position resolution was studied as a function of the voltage at the sense wires during the muon run period. Position resolution, both in radial and azimuthal direction, improves with increasing voltage. Values of 330 μm in azimuthal direction and 770 μm in radial direction were measured at a voltage of 1300 V and a radius of the primary ionization between 100 and 120 cm. A compromise between ageing and position resolution results in an operating voltage of 1330 V.
Furthermore, data were taken with p/π-beams and two targets, one in the nominal CERES target position, and the other close to the TPC entrance window. Finally, the TPC was triggered on central heavy-ion collisions. The TPC occupancy is at most 5% in a central Pb+Au collision.

The TPC was tested at high beam intensity ($1.7 \cdot 10^6$ ions/spill) and high trigger rate ($1.7 \cdot 10^3$ triggers/spill). The anode wire currents were found to scale linearly with the trigger rate and reached values of 300 nA/chamber at about $2 \cdot 10^6$ ions/spill.

The position resolution was also studied in heavy ion collisions (Fig. 2). The position resolution varies as a function of the polar angle θ between 300 and 400 μm in azimuthal direction and between 600 and 800 μm in radial direction. The improvement in the resolution with decreasing θ (radius) reveals the focusing feature of a radial TPC. The worsening of the resolution towards the edges of the TPC reflects the fact that the electric field is not yet completely understood in the vicinity of the two voltage dividers. These results will improve upon the completion of the TPC calibration.

4. Conclusion and Outlook

During several commissioning runs in the course of 1998 the CERES radial TPC was operated under stable conditions; first results are presented here.

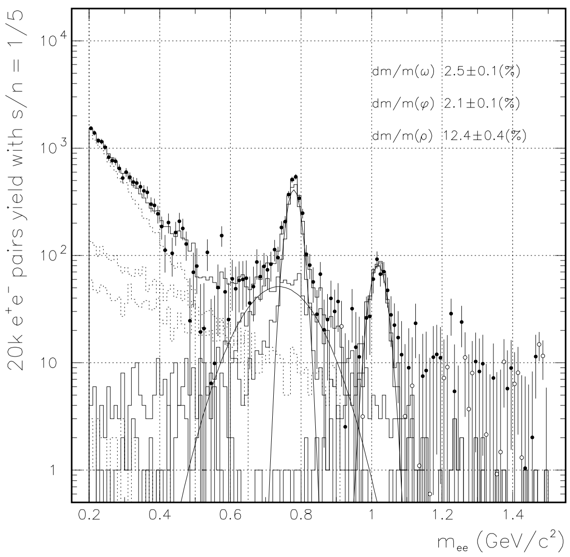

Figure 3. Simulated dilepton invariant mass spectrum assuming the expected mass resolution and the natural line width.

The chamber response is in good agreement with the specifications. Preliminary analysis results are very promising concerning the achievement of the design position resolution. The simulated e^+e^- mass spectrum assuming the design resolution and unchanged natural widths of the vector mesons is shown in Fig. 3 for 20k e^+e^- pairs that can be optimistically recorded in the yearly SPS ion period with the upgraded experiment. The experiment intends to take data with a Pb-beam of 40*A* GeV in the fall of 1999 and of 158*A* GeV in the fall of 2000. These data will help to improve the understanding of the dilepton production mechanism in hot and dense hadronic or quark matter.

5. Acknowledgment

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