Electric field of CERES TPC

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The CERES experiment at CERN was upgraded in 1998 by an addition of a cylindrical Time Projection Chamber (TPC) with radial drift field. The first laser tracks, measured with the new TPC in May 1998, showed a curvature in radius r versus longitudinal coordinate z [1]. This demonstrated that the electric field in not uniform in z and thus a full three-dimensional field calculation was needed. Such calculations were indeed performed in 1998-1999. Unfortunately, the calculated field did not fully account for the observed curvature. With the good quality data taken in the Pb+Au at 158 A GeV run in 2000, understanding of the electric field became one of the factors limiting the overall momentum resolution, and thus we decided to revisit the field issue.

The relevant aspects of the TPC geometry and boundary conditions were carefully implemented in Maxwell[2], a commercial package available at CERN. To save the execution time by exploiting the azimuthal symmetry only a 1/32 ϕ-slice of the TPC was used while requiring that the ϕ-component of the field disappears at the ϕ-boundaries of the slice. The calculated potential is shown in Fig. 1.

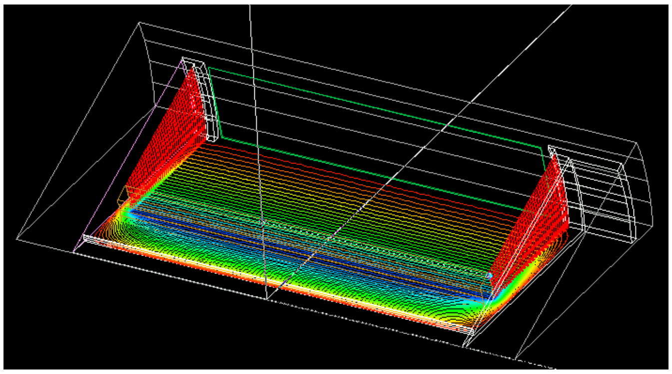

Figure 1: Equipotential lines calculated with Maxwell for an azimuthal slice of 1/32 of the TPC corresponding to half a read-out chamber.

The figure also demonstrates the field boundaries. The high voltage of -30 kV is applied to the inner electrode cylinder at R=486 mm. The ionization electrons drift radially outwards to the 16 readout chambers located 1308 mm away from the cylinder axis, the gating grid of these chambers kept at -140 V. In order to make the field uniform in z in spite of the finite TPC length of 2000 mm kapton foils with 40 concentric copper rings each are located at z=-1083 and z=+1101 mm. Two voltage divider chains supply the voltage to these rings (Fig. 2).

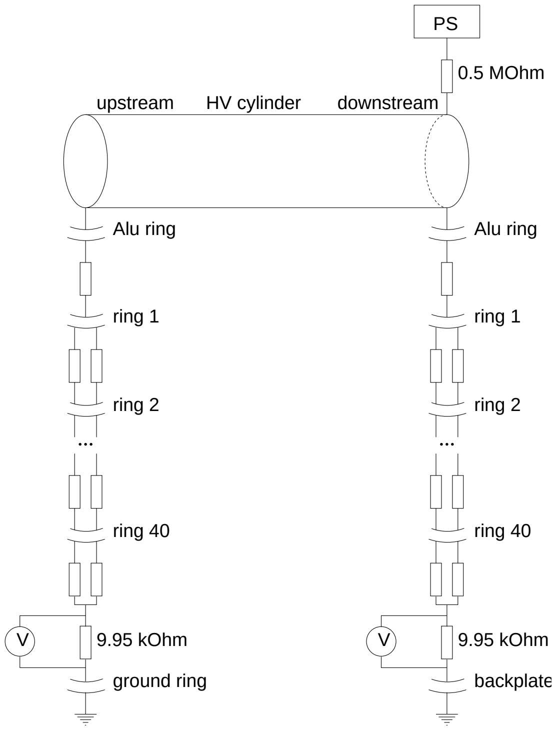

Figure 2: Voltage scheme of the field cage. A high voltage of -30 kV is applied to the cylinder. Two resistor chains supply potentials to the upstream and downstream rings. The two field cage currents are measured via the voltage drop on the 9.95 kOhm external test resistors.

Unfortunately, the calculated field again did not explain the observed track curvature. Including more and more geometry details did not lead to any improvement. A breakthrough happened after a closer look at the current vs. voltage data of the TPC field cage. It turned out that the current-to-voltage ratio was somewhat voltage dependent, i.e. the overall resistance of the field cage was changing with the applied voltage. This has been tracked down to certain brand of resistors which were changing their resistance linearly with applied voltage. A calculation with the resistances modified according to this formula, finalized in early 2002, to large extent straightened the laser tracks.

At this point the finite numerical precision started to be significant. Reducing the size of the modeled object and exploiting the symmetry allowed to increase the precision of the calculation while keeping a reasonable execution time. Still, even in a 6 CPU-days calculation of 1/4 chamber the numerical precision turned out to be not sufficient. The problem was solved by switching to a simple custom numerical calculation `mymax`. The code loops over grid points and modifies the potential of each point such as to lay between the potentials of its six neighbors which is equivalent to solving the Poisson equation. The grid points which are close to the boundaries get their potentials modified accordingly. The code is about ten times faster than Maxwell and the resulting potential map shows no irregularities.

References

[1] P. Braun-Munzinger, D. Miśkowiec, P. Zimmermann, GSI Scientific Report 1998.

[2] `http://wwwinfo.cern.ch/ce/ae/Maxwell/Maxwell.html`