EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE/97-31
Internal Note/TPC
14. October 1997

Computation of ionization-load in the traditional TPC and the RCC readout

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Abstract

The comparison of the expected sense-wire current for traditional TPC readout chamber and for the Ring Cathode Chamber (RCC) is presented. The influence of the RCC materials on a number of electrons produced in the sensitive gas volume of RCC is discussed.

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1 Introduction

One of the major problems in operating a TPC detector in the ALICE experiment will be the flux of particles traversing the readout modules. The total ionization produced by interaction of the particles with materials of the readout structure is simulated with GEANT [1] for the geometry of a traditional TPC and the RCC. Moreover, the expected current in the sense-wires is computed based on the assumption of expected particle flux and gas gain.

2 The particle flux in central and peripheral collisions

The total particle multiplicity in central events will be in the order of 10^4 particles per unit rapidity (Fig. 1, right). Therefore within a recorded central event 10^4 particles will in the same moment directly cross each of the two readout planes. Moreover we expect a rate of minimum bias events with a frequency of 5 kHz (this corresponds to an impact parameter range of 0 to $2 * R_{Pb}$, where R_{Pb} is the lead nucleus radius) producing an average multiplicity of 1800 charged particles crossing as well directly through each of the readout planes. It has to be mentioned that up to now no real minimum bias events exist on the ALICE data base, in these simulations the rapidity and transverse momentum distributions obtained from the very early version of HIJING have been used [2]). The readout modules cover a pseudo-rapidity range of ≈ 0.9 units. The particle density varies strongly from the inner to the outer area of the readout. Formula 1 shows the particle density in the TPC readout-modules (r_s is the radial distance in respect to the beam and r_b is the distance of the readout plane from the interaction point, here fixed to 2.5 m).

$$\frac{dn}{dr_s} = \frac{dn}{d\eta} * \frac{r_b}{4\pi r_s (r_b^2 - r_s^2)} * \csc(0.5 \cdot \arctan(r_s/r_b)) * \sec(0.5 \cdot \arctan(r_s/r_b)) \qquad (1)$$

In Fig. 2 the differential density as function of radius is plotted according to formula 1. From the inner to the outer radius a change of particle-density by a factor of ≈ 8 can be expected. However, the absolute number of particles/unit area is finaly depending on the dn/dy distribution.

3 The geometry and material distribution of the readout-structures

The traditional TPC with pad readout, as it was used for experiments like NA49 or ALEPH consists of 3 wire-planes (Gating-, Frisch- and Field/Sense-plane), (Fig. 3, left). The spacing of the wire-planes lead to a total gating-wire to pad distance of $\approx 12-14$ mm. In comparison the RCC readout we develop for the ALICE-TPC (Fig. 3, right) consists of single pad-elements with a ring thickness of 70 to 100 μm (Cu-Be) that are coupled electrically together to form one pad. (We investigate as well the production of Al pads with a thickness of 400 μm). The gating-elements are solid strips (Stesalit coated with 30 μm Cu) sitting in-between the ring elements. In this geometry the distance of the gating element to the sense wire depends on the diameter of the single ring element and is in the order of 3 to 5 mm. Table 1 gives a summary of the used materials with their radiation and nuclear interaction lengths.

4 Computation of the specific ionization

In case of experiments where the particles do either not cross the gating plane or do that only with a low rate, the sense-wire current during operation is mainly caused by amplification of the arriving electrons produced by interaction of the particles in the

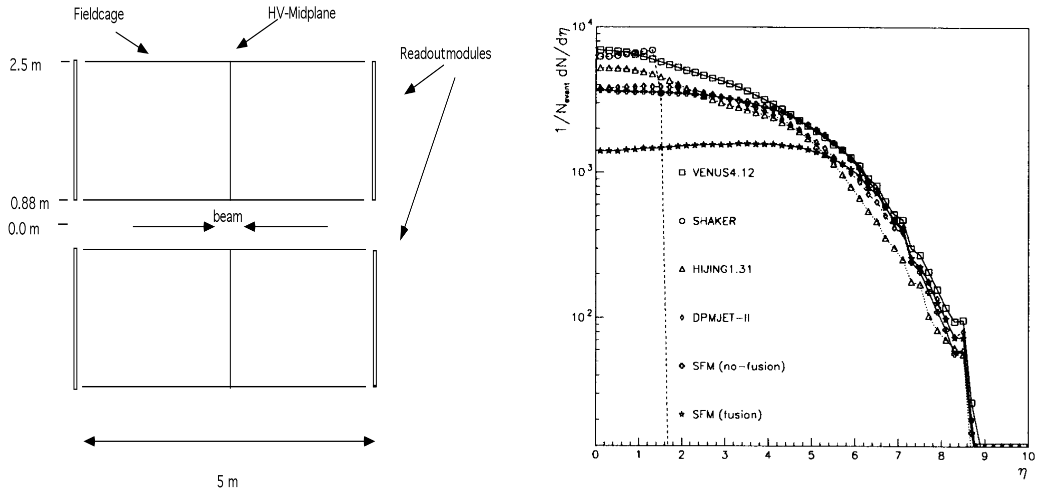

Figure 1: Schematic vue of the ALICE-TPC (left) and the expected particle distribution as function of pseudorapidity, according to different generators for central Pb-Pb at beam energy of 3 TeV per nucleon (right)

Material	Rad. length X0 , cm	Nucl. int. length, λ , g/cm^2
Cu	1.43	134.9
G10	19.4	90.2
Al	8.9	106.4
Ar	10983	117.2
Ne	32148	96.6
CO_2	18310	90.5

Table 1: Materials used in the readout chambers

drift volume. However particles that cross the readout plane cause ionization in the gas gap between the gating-grid and the pad plane. Therefore we expect ionization caused by either interaction of the primary particles with the drift gas molecules or the material of the readout-structure. The contribution of the following different physical processes have to be computed :

- dE/dx of primary [1)] charged particles in the gas gap
- conversion of gammas to electrons in the material of the readout
- nuclear interaction of particles with the material of the readout.

The GEANT [1] simulation (here used with FLUKA [3] interface) takes into account all possible interactions while a cut-off energy is introduced at 10 keV. The particle distribution in case of the minimum-bias events was assumed to be flat over the rapidity interval from 0.9 to 1.8 resulting in a mean multiplicity of 2000 charged particles. Furthermore we assumed a frequency of 5 kHz for this kind of events. For the computation of the specific current in the sense-wire circuit a gas-gain of 10^4 in case of the traditional TPC and $2.5 * 10^3$ in case of the RCC was assumed. The geometry of the readout chambers, both traditional and RCC, used in the simulations is that of Fig. 3, left and right respectively.

1) Here primary means: not originated from the solid material of the readout chamber

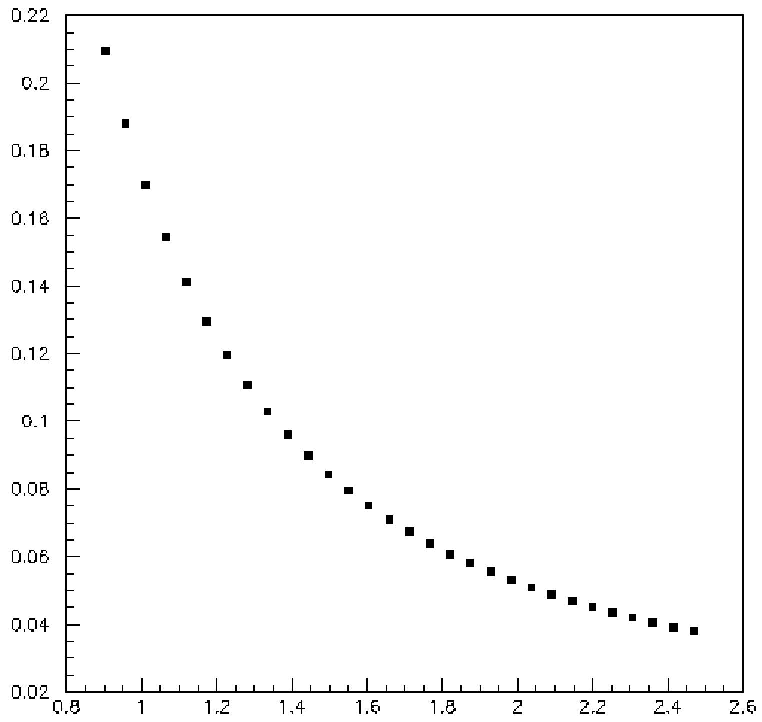

Figure 2: The relative particle density variation from the inner to the outer radius of the TPC

The position of the readout in the spoke of the ALICE TPC was choosen to be at radius of 0.9 m which represents the region of highest particle densities. It has to be mentioned, that no back-splash from other ALICE detector components etc. have been taken into account for these simulations.
The multiplicities of charged particles (pions) and π^0 in a full phase-space were assumed to be 12000 and 6000 respectively. Given the rapidity and transverse momentum distribution from HIJING, this leads to appox. 0.0155 charged particles/cm^2 per event crossing the readout which is placed in this case at the inner part of the spoke ($0.88 < R < 0.95$). Table 4 shows the expected number of electrons originated from the particles (hadrons and conversion electrons) crossing the readout chamber in case of the traditional readout and for the RCC assumming three different ring thicknesses; for both types of readout a Ne/CO_2 (90:10) gas mixture was assumed. The current (Table 4) in the sense wire circuit is computed assuming a gas-amplification of $2.5 * 10^3$ in case of the RCC and $1 * 10^4$ in case of the traditional TPC. Table 4 shows the fraction of electrons that are produced due to the material of gating and ring elements. Fig. 4 shows the distribution of electrons (Landau-distribution) produced in the sensitive gas volume of the RCC for ring thickness of 100 μm(CuBe) and in the gas-gap of traditional TPC.

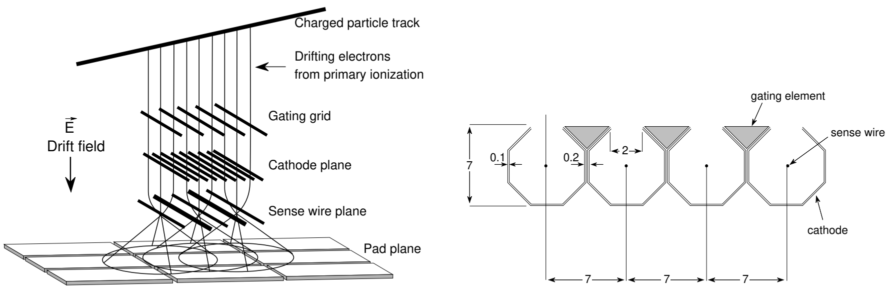

Figure 3: Traditional wire-pad geometry for TPC (left) and Ring Cathode Chamber (RCC) (right)

Ring thickness, μm	$< N_{tot} >$/event/cm^2	N$_{most\ prob.}$/event/cm^2
0	1.6	0.69
100	1.85	0.78
500	1.89	0.86
Traditional chamber, Gatig grid – pad plane distance = 12 mm	2.615	1.515

Table 2: Number of electrons per unit area originated from particles crossing the readout chamber. "0" thickness means: all solid material elements have been substituted with vacuum. The inner-ring radius of RCC was the same in all three cases.

5 Conclusions

The material of the RCC does not contribute significantly to the load of the detector as can be concluded from the number of produced electrons computed for the different thicknesses of material. This means the major fraction of ionization is produced by interaction of the charged particles with the drift gas. Therefore, the load on the traditional readout is expected to be higher by a factor of two due to the bigger gas-gap between gating-wires and pad-plane. On top of this the higher gas gain ($\approx$ factor of 4) in case of the traditional readout compared to RCC results in total sense-wire current of $\approx$ 210 nA/m^2 for the traditional readout and 37 nA/m^2 for the RCC with a ring-radius of 3 mm. These values assume 5 kHz minimum bias event rate with a mean multiplicity of 2000 charged particles in the rapidity interval 0.8 to 1.9 simulating the most inner part of the detector.

Ring thickness, μm	$< N_{tot} >$/event/cm^2	Sense-wire current,nA/m^2
0	1.6	32.0
100	1.85	36.95
500	1.89	37.845
Traditional chamber, Gatig grid – pad plane distance = 12 mm	2.615	209.45

Table 3: Current measured for the RCC (gas gain=$2.5 * 10^3$) and the traditional TPC readout (gas gain=$1 * 10^4$) assuming the particle densities as discribed in the above tables.

Origin of e$^-$	Fraction of the total number
Gating element	$< 1\%$
Ring element	$\approx 15\%$

Table 4: Fraction of electrons due to the presence of ring and gating elements.

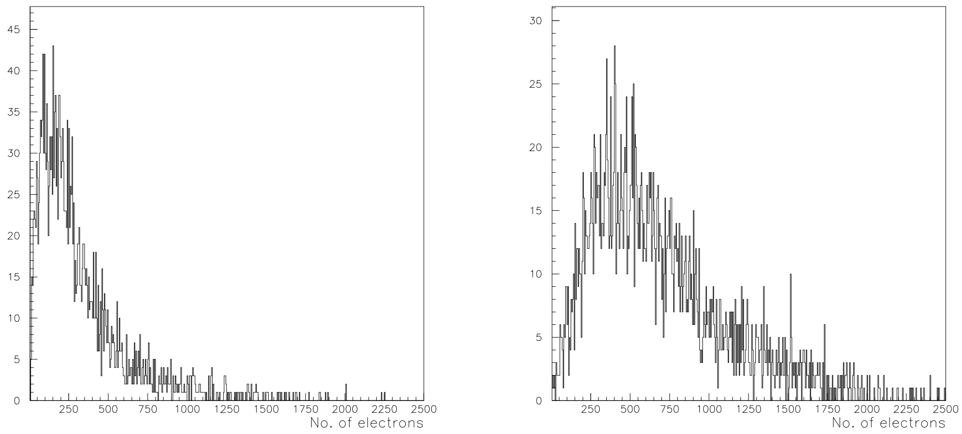

Figure 4: Distribution of electrons produced in the sensitive gas volume of RCC, 100 μm CuBe (left) and of conventional TPC readout (right).

These expected sense-wire currents are still moderate however it's important to mention, that no additional background caused by beam halo or backscattering from other detector components is taken into account. Especialy the high neutron flux producing low-energy charged particles with high ionization potential might increase, especcialy in case of the traditional TPC, the current to magnitudes that could lead to self-stable discharges.

References

[1] GEANT, Detector Description and Simulation Tool, CERN Program Library W5013.

[2] N. Slavin, private communication.

[3] P.A. Aarnio et al., FLUKA User's Guide, Technical Report TIS-RP-190, CERN, 1987, 1990.