STAR Note # 54

Wire Aging Effect of Anode Wires for STAR TPC

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Internal Report to STAR

In this note I shall report on my calculation on the wire aging effect of anode wires for STAR TPC. This calculation used particle density information from Fritiof event generator and dealt with minimum ionizing particles only. Given the safe margin obtained from this calculation, I concluded that the charge loading on the anode wires does not compromise the chamber performance and a detailed Geant simulation on this issue is not necessary.

The charge loading on the anode wires of TPC, when the TPC is in an operating mode, are from three sources: 1) ionizing particles from the triggered event; 2) ionizing particles from leak-through event when the gating grid is open; and 3) ionizing particles traversing the multiplication region of the TPC of which the charges cannot be suppressed by the gating grid. We shall study these three cases after a brief introduction.

1 Introduction

The understanding of wire aging is still on a very superficial level. No quantitative model exists to explain wire aging yet. Various results indicated that the maximum charge loading without aging effect varies from 0.1 Coul/cm to 8 Coul/cm on sense wires for gas chambers. We shall assume a conservative number of 0.1 Coul/cm for this calculation. What listed here are some important variables for good aging results from reference[1].

- High purity of a system and gases.
- Addition of H_2O, alcohols, methylal, and other oxygen-containing molecules.
- High gas flow.
- Avoid silicon contamination (oil, raw G-10, etc.).

- Avoid soft glues (one part RTV, urethane, etc.).
- Avoid some halogen impurities (Freon-11, etc.).
- DME works, but worry about its solvent capabilities.
- Avoid glow discharges.

The luminosity of RHIC is assumed to be $5 \times 10^{26}/cm^2/sec$ for Au beams. With a cross section of 6 barns the interaction rate is about 3000 per second.

The TPC geometry is taken to be 50cm in inner radius, 200cm in outer radius and 210cm in length. The anode wire pitch is 0.4cm and the multiplication region is of a gap of 0.8cm. The operating gain in the multiplication gain region is 10^4.

2 Ionizing Particles from Triggered Events of Central Collisions

For a central Au + Au collision the pseudo-rapidity density in 700 in the mid-rapidity region. The maximum physical coverage of the TPC is from 0.0 to 2.14 (we only concern half the TPC here). therefore, the total number of primary tracks inside the TPC volume is 1500. Typically, Geant simulation has shown that the number of secondaries is about 1.5 times the number of primary particles. The total number of charged particles traversing the TPC active drift volume is, therefore, about 3750 for a central Au + Au collision.

The maximum track length inside the drift volume is 217.5cm. For a MIP the deposited $\frac{dE}{dx}$ inside the Argon gas creates, most probably, 40 electron-ion pairs per cm of track length. Assuming an average value of 100 ionization pairs per cm of track length, the total number of charges collected on the endplate is

$$3750(\text{mult})\times\ 100(\text{pairs/cm})\times\ 217.5(\text{cm})\ \times\ 10000(\text{gain}) = 8.2\ \times\ 10^{11}(\text{pairs})$$

Given the area of 1.2×10^5 cm^2 for the endplate, the charge density on the endplate is 6.8×10^6 e-ion pairs per cm^2. Since the anode wire pitch is 0.4cm, the average charge density per cm on the anode wire is 2.7×10^6 electrons.

Note that we only calculated the average charge density on anode wire and we used maximum track length for all particles. The angular (θ) dependence has been neglected which may not be so crucial here, since the large particle density in the forward angle is compensated by the relative short path length inside the drift volume.

3 Ionizing Particles from Leak-Through Events

The total drift time of the TPC is about 40μs. Let's assume that the gating grid will remain open for about 50μs after a valid trigger. Given an interaction rate of 3000 per second, the number of collisions within that 50μs period is about 0.15.

Assuming these events have 1/3 of the total charge for central Au + Au events, the total charge contribution on the anode wire is

$$0.15 \times \frac{1}{3} \times 2.7 \times 10^6 = 0.14 \times 10^6 \text{pairs/cm}$$

In reality, the average charge from the minimum bias events should be much smaller than the number used here.

4 Ionizing Particles Traversing the Multiplication Region

Particles traversing the multiplication region directly will cause ionization in the multiplication gap also. Charges from these ionization cannot be suppressed by the gating grid. Instead, they will be amplified near the anode wire and electrons are collected on the anode wires continuously during the operation of the TPC.

We shall first estimate the total charge from a central Au + Au collision. The pseudo-rapidity η coverage of the endplate is from 0.916 to 2.14. Assuming the pseudo-rapidity density of 700, the number of primary tracks is 857 and the total number of charged tracks is about 2140(secondaries= $1.5\times$ primaries). For a multiplication gap of 0.8cm, the maximum track length is 1.1cm. The total charges on the anode wires are

$$2140(\text{mult})\times\ 100(\text{pairs/cm})\times\ 1.1(\text{cm})\ \times\ 10000(\text{gain})\ =\ 2.4\ \times\ 10^9(\text{pairs})$$

Note that the total area is 1.2×10^5 cm^2 and the anode wire pitch is 0.4cm. The collected charge density per cm on the anode wire for a central Au + Au event is 8.0×10^3 e-ion pairs.

Assuming an interaction rate of 3000 per second and an average multiplicity for the ensemble of minimum bias events in the endplate region is half of the central Au + Au events, we arrive at a rate of total charge collection on an anode wire to be 1.2×10^7 e-ion/s/cm.

5 Summary and Discussion

Assuming a data-taking rate of N events per second, the rate of charge collection on an anode wire is

$$N \times 2.7 \times 10^6 + N \times 0.14 \times 10^6 + 1.2 \times 10^7 \text{electrons/cm/sec}$$

$$= \begin{cases} 1.5 \times 10^7 & \text{if } N = 1 \\ 4.0 \times 10^7 & \text{if } N = 10 \end{cases}$$

For an allowable charge loading of 0.1 Coul/cm on the anode wires, the expected life time is

$$= \begin{cases} 1340 & \text{years if } N = 1 \\ 502 & \text{years if } N = 10 \end{cases}$$

This estimate has been quite conservative in terms of both the track path length and the charged particle multiplicity inside the drift volume. Although we have not taken into account the angular distribution of particles, we can still conclude that the wire aging is not a problem for the anode wires of STAR TPC.

I thank Howard Wieman for his comment on the average number of ionizing electron-ion pairs in Argon gas.

References

[1] J. Va'vra Nucl. Inst. Meth., A252 (1986) 547.