Investigation of Gas attachment with GEM-TPC detector*

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Abstract This paper mainly summarizes investigation of TU GAS ($Ar:CH_4:CF_4$=90:7:3) with the GEM-TPC detection system that had been developed , especially, the gas's bigger attachment coefficient was obtained and the result does not agree with the results of theoretical calculation seriously. Through repeated verification experimental, the attachment coefficient of measurement acquired. It's 0.1/cm and it's much bigger than the simulated value of 0.003/cm by Garfild. Finally, some analysis results and discussion were given.

Key words GEM detector, TPC(Time Projection Chamber), attachment of Gas

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1 Introduction

GEM[1, 2] detector was developed by Professor Fabio Sauli at the CERN, which was composed of twice or triple GEM foil popularly. A GEM is a 50 μm foil product consisting of a dielectric sheet clad on both sides with a thin layer of copper. The copper-clad sheet is photo-lithographically etched on both sides and a high density array of holes is created on it. When a high voltage (300—400 V) is applied between the copper layers, an enormous electric field (as much as 10^5 V/cm) is developed within the small holes. The electrons generated in drift field can be avalanche amplified in the holes and transmitted along electric lines direction. Subsequently, the readout anode in the circuit board collected the electron charge. The range of one GEM foil's gain was from 10^2—10^3, it's better effect in the actual application with the twice and triple GEM foil and the gain can be increased to 10^5.

The TPC (Time Projection Chamber) detector is a gas detector with long drift distance[3, 4]. It's a three-dimensional tracking device for charged particles, which uses a two-dimensional array of pickup electrodes together with a measurement of the drift time. The typical gas filled TPC consists of a long uniform drift region generated by a precision concentric cylindrical high-voltage field cages within a uniform, parallel strong magnetic field. When the charged particle reached the drift region and ionized, the ionization electron can be moved in electric field and magnetic field and be recorded with the side micro-pattern readout. The track reconstruction, particle momentum and particle identification acquired with analysis of signal's charge and time information.

GEM-TPC was a new type gaseous detector with advantages of a good position resolution and track reconstruction. It's mainly composed of TPC detector with the large drift region and micro-pattern GEM readout as its apex detector. It will be become a important detecting equipment in ILC (International Linear Collider)[5] and will be regarded as a mainly detector device at inner-target experimental terminal in CSR (Cooling Store Ring) of Institution Modern Physics, CAS[6]. With international cooperation and

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the scientific research resource in our lab, the GEM-TPC detector prototype was developed successfully and its performance was studied recently[7].

2 Measurement of attachment

2.1 Attachment of gas

When the energy of an electron in drift region became lower in the electronegative working gas, the attachment effect of the electron with other gas molecules decreased and some the stable negative ions came into being. It caused the life of the electron very short and many electrons can't be collected by the apex readout detector. So it's important that the selection of working gas for TPC should has a slight attachment.

2.2 Gas selection

Considering of the drift life of electron, velocity and electron diffusion, the gas of P_5(Ar:CH_4=95:5), P_{10}(Ar:CH_4=90:10), Iso(Ar:CF_4:iC_4H_{10}) and TESLA TDR(Ar:CH_4:CO_2=93:5:2) were regarded as the usual selection working gas for GEM-TPC , Some other gases were also tested. Comparing some our simulation results, a new mixture gas with three parts indicated some better performance (it's has bigger velocity, smaller diffusion and lower electric field than other usual gas). We named it TU gas that is Ar:CH_4:CF_4=90:7:3.

Table 1. Performance parameters of several typical working gas for TPC detector (B=0 T).

	P_5 Ar:CH_4(95:5)	P_{10} Ar:CH_4(90:10)	TESLA TDR Ar:CO_2:CH_4(93:2:5)	TU GAS Ar:CH_4:CF_4(90:7:3)	KEK GAS Ar:Iso:CF_4(94:3:3)
E_{max}/(V/cm)	95	130	240	250	300
V_{drift}@E_{max}/(cm/μs)	4.03	5.48	4.55	8.80	7.50
Trans. Diff/(μm/$\sqrt{cm}$)	720	570	453	318	310
Long. Diff/(μm/$\sqrt{cm}$)	440	378	279	222	180
Attachment Coef./(/cm)	0.006	0.003	0.002	0.002	0.004

Table 1 shows that some performance parameters of TU gas and several typical working gas for TPC detector. The TU gas has some obvious advantages: small longitudinal dispersion and transversal diffusion, good velocity obtained with not higher electric field and very little attachment coefficient. Accordingly, the TU was a better working gas for GEM-TPC and its actual capability should be tested.

2.3 Measurement method

The main parts of the GEM-TPC detector system are as follows: a 300 μm diameter chamber with 500 μm drift distance, a triple GEM readout detector with 100 mm×100 mm effective area, 312 readout pads on circuit board, VME data acquisition system, the cosmic parallel hodoscopes and several high voltage power supply modules. All tests of TU gas were done on it.

One cosmic parallel hodoscopes were placed on the test point P_0(z = 39.5 mm) that is a shortest drift distance of the GEM-TPC detector. When the point test was completed, the hodoscopes moved with 20 mm step length along z direction until no signal could be measured. The testing time of every point was four hours and the events rate was 0.15/s. There were four test points (P_0, P_1, P_2 and P_3) in all test of gas TU. Fig. 1 shows the schematic diagram of measurement attachment with TU working gas and the parallel hodoscopes.

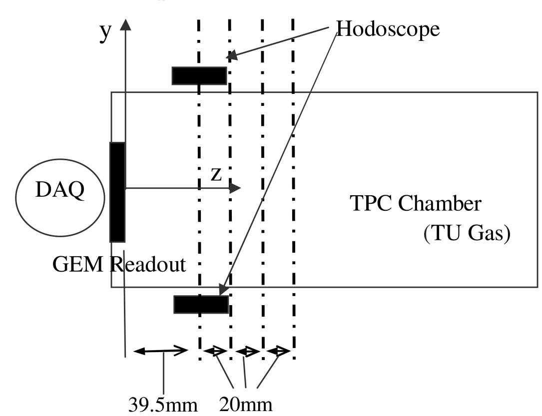

Fig. 1. The diagram of measurement attachment.

3 Discussion

Firstly, the total charge of all channels were fitted using Landau curve fitting to calculate the peak value of Landau distribution, the value converted its corresponding charge value. Fig. 2 shows the relation between the charge value of each test points and its corresponding drift distance. X axis is the actual position of four test points and the unit is millimeter, Y axis is the charge value and the unit is fc. $\eta_{\rm exp.} = 0.1 \pm 0.006/{\rm cm}$ of attachment coefficient was acquired by using decay fitting and was much higher than 0.003/cm from Garfield simulation, and the drift velocity of $\sim$ 10 cm/μs agrees with the result from Garfield simulation. An repeated test of TU GAS(Ar:CH_4:CF_4=90:7:3, the purity of gas is 99.999%, 99.99% and 99.9% respectively.) using GEM-TPC were also done, and the analysis results indicate that the selection gas indeed has an obvious attachment different from the theoretical simulation by Garfield. This has not been reported before.

Analysed all results, two possible reasons should be considered, they could cause the obvious attachment. One is that the gas purity of CF_4 is not enough too high and other gas (likely oxygen) was mixed in it. Another possible reason is that the Garfield software should be corrected and improved in some sections. All possible reasons and results will be studied further.

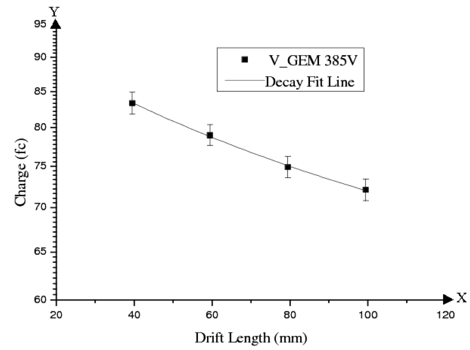

Fig. 2. Attachment coefficient of TU GAS.

References

1 Sauli F. Nucl. Instrum. Methdos A, 1997, **386**: 531
2 LI J, LAI Y F, CHENG J P et al. Nucl. Scie. and Tech., 2005, **16**: 225
3 Blum W, Rolandi L. Particle Detection with Drift Chambers. Springer-Verlag, Second Printing, 1994, 120—150
4 LI Jin. Handouts for modern radiation and detection. Version 2. Beijing: Tsinghua University, 2005. 76—77 (in Chinese)
5 http://www.linearcollider.org/
6 LI Zhan-Kui, XU Hu-Shan, ZHANG Xue-Ying et al. Science in China (Physics Astronomy), 2005, **5**: 211
7 LI Yu-Lan, KANG Ke-Jun, LI Jin et al. HEP & NP, 2007, **31**: 223 (in Chinese)