Study of the Photo-electric Wires for TPC Spatial Calibration

W.G. Gong[1], H. Wieman[1], G. Rai[1], M. Justice[2], D. Cebra[3], I. Huang[3], L. Wood[3], X.M. Chen[4], R. Dass[4], G.W. Hoffman[4], F. Moore[4]

[1] Lawrence Berkeley Laboratory, [2] Kent State University;
[3] University of California at Davis; [4] University of Texas at Austin.

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1 Introduction

The traditional method for spatial calibration of a TPC uses multiple laser beams to create ionized tracks in the gas volume through two photon ionization. Past experience has shown difficulty in maintaining the stability of an optic path within 200 microns. For the STAR TPC, we investigated an alternative approach which uses photo-electric wire arrays aligned along potential surfaces in the drift volume. Flashed with a diffused pulsed UV laser beam, photo-electrons are emitted from the wire surface. This approach can provide more stable, better positioned electron tracks. It may also be more economical and effective than the traditional method. The goal of our investigation is to study the feasibility of this approach for the STAR TPC.

We have addressed the following issues in our R&D : (1) what material to use which is of high photo-electric efficiency in gas; (2) how to install wires inside the TPC; (3) how to illuminate wires uniformly; (4) what to be learned from a test using the EOS TPC.

2 Measurement of photo-efficiency

Figure 1 shows the experimental setup for measuring photo-efficiencies of various materials in gas environment. A frequency quadrupled Nd:YAG laser produced an ultraviolet beam of 266nm wavelength and 80mJ maximum energy. An ion chamber was built to measure the number of electrons emitted from the cathode material. A field cage was used to maintain uniform drift field over a distance of 20cm. The UV beam was collimated to a spot of 6mm in diameter and delivered to the cathode through a quartz window. The number of UV photons was measured by an energy meter. The ion chamber was filled with P10 gas and its humidity was monitored by a hygrometer to ensure low attenuation of electrons in the gas. Electrons were collected by a guarded anode plate. The pulse height of electron signal was read out on a digitalscope after preamplifying and shaping.

Three types of material were prepared for the cathode. Type I cathodes included aluminum, copper, Cu-Be alloy, and gold which were in sheet form and have work functions larger than 4eV. Type II cathodes included erbium, gadolinium, halfnium, holmium, and samarium which have work functions less than 4eV and were vacuum-coated onto standless plates. Type III cathodes included conductive plastic and Aquadaq (a carbon-loaded paint). Type I cathodes showed stable results measured at different times and at different laser intensities. The highest photo-efficiency was around 2×10^{-8} measured from aluminum in a variety of forms (aluminum plate, aluminum wire and aluminized mylar). Thpe II cathodes have smaller work functions, but they were not so stable and the photo-efficiencies measured were not as high as that of aluminum in the gas. The lowest photo-efficiency was around 1×10^{-9} measured from Cu-Be. The cathode of low photo-efficiency is suitable for coating a region to suppress photo-emission.

Figure 2 shows representative photo-efficiencies measured for aluminum and copper at three laser intensities. Photo-efficiency was observed to increase linearly with electrical field applied on the cathode surface. A 30% increase in photo-efficiency was measured for a 50% increase in cathode E-field.

3 Test with the EOS TPC

Having identified aluminum wire of high photo-efficiency, we prepared for a test with the EOS TPC. A schematic layout of wires and Mylar strips inside the EOS TPC was shown in Figure 3. Seven aluminized Mylar strips

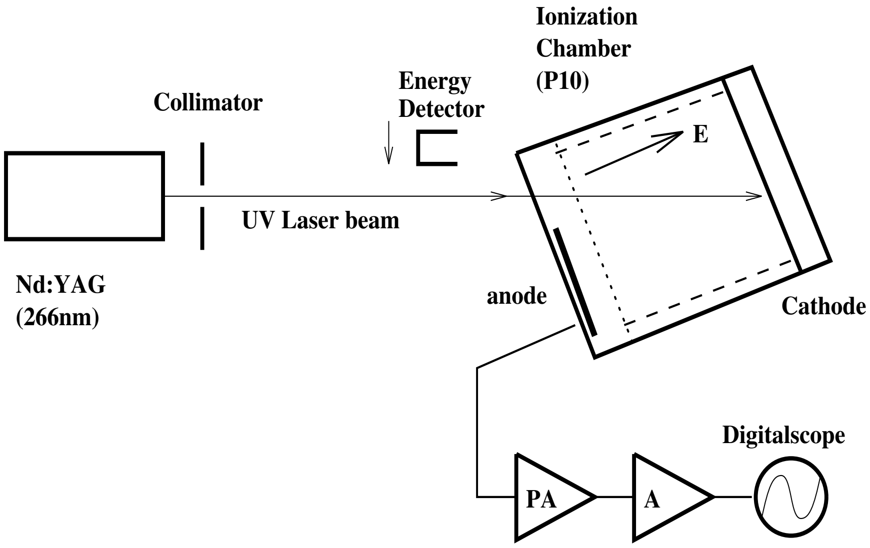

Figure 1: Setup for measuring photo-efficiency.

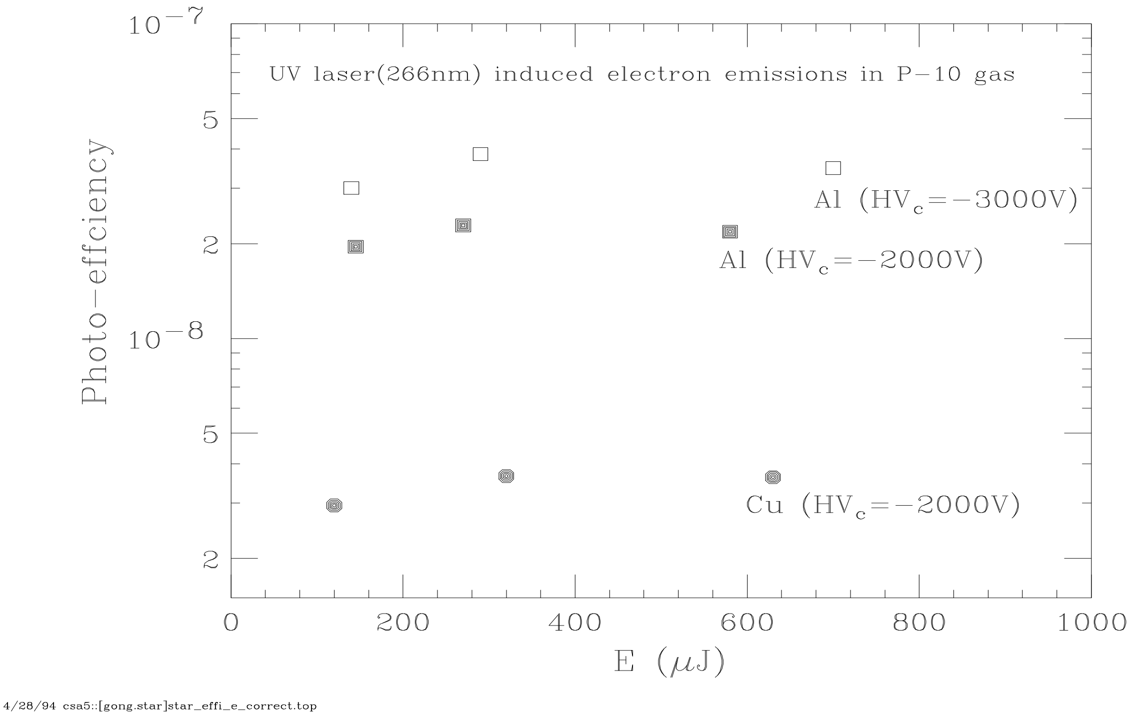

Figure 2: Photo-efficiencies of aluminum and copper measured in P10 gas at λ= 266 nm as a function of the laser energy.

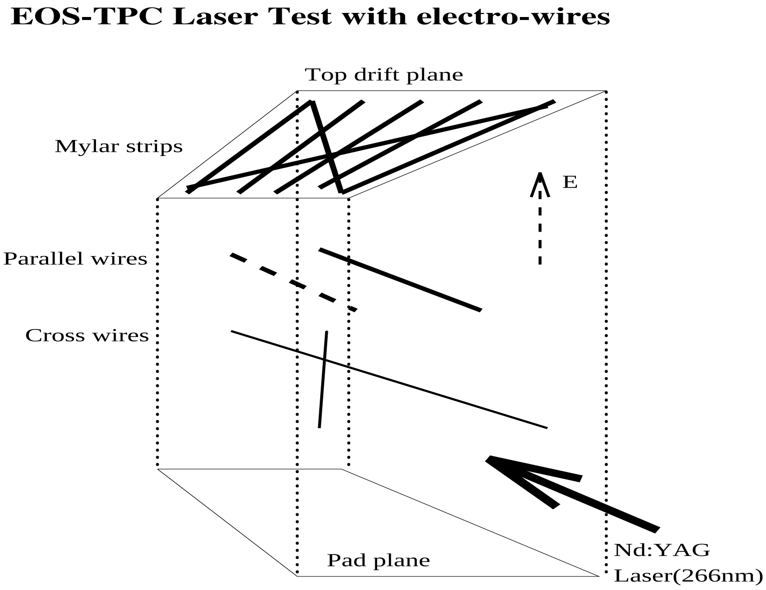

Figure 3: A schematic layout of Mylar strips and wires inside the EOS TPC.

of 3 mm width were glued onto copper drift plane. Such patterns can provide a calibration of electron drift velocity. Three aluminum wires of 1 mm diameter were strung in the drift volume. One was in parallel position, and the other two were in cross position. They were all parallel to the pad plane and attached to the field cage with springs in order to avoid sagging. (A conceptual design has been developed for supporting wires in the STAR TPC.) Another parallel wire was nylon line coated with alternating copper and aluminum films. The nylon line has lower mass and Z than the aluminum wire, thus leads to less multiple scattering. Thanks to a large difference in photo-efficiency between aluminum and copper (see Figure 2), the alternating pattern can produce segmentation of tracks. This feature can provide additional spatial calibration.

An ultraviolet beam, delivered by the same Nd:YAG laser, was diffused inside the TPC volume by using a special reflector at one corner of the field cage. This reflector is a white plastic material (spectralon) and has lambertian reflectivity of 95% at $\lambda = 266$nm.

Figure 4 shows two surface plots of pulse height distributions for electrons emitted from top drift plane (part a) and from two parallel wires (part b). In Figure 4(a), the pattern of Mylar strips were clearly reproduced although the uniformity of light illumination needed to be improved. One Mylar strip appeared weak, which may be shadowed by the wire underneath (to be discussed in next section.) In Figure 4(b), the aluminum wire on the right hand side emitted electrons rather uniformly in consideration of light attenuation. The aluminum and copper coated nylon wire on the left hand side emitted electrons in a pattern as intended. Very few electrons emitting from one half of the nylon wire could be caused by electrostatic charge-up when poor electrical continuity existed.

The overall results from our EOS TPC test was satisfactory. It demonstrated for the first time that electron tracks can be generated using the electro-wires and diffused UV beams, although problems with light uniformity and wire shadowing need further studies.

4 Effect of wire shadowing

To access the effect of wire shadowing, we first performed an electrostatic calculation using the GARFIELD (a drift-chamber simulation program in the CERN Library). The actual geometries and voltages of the EOS TPC were used for the calculation. The wire potential was defined by the field cage at that drift distance. Figure 5 shows the E-field line distribution around an aluminum wire of 1 mm diameter. The wire would terminate or distort E-field lines coming from a region of three times wire diameter above the wire.

We then analyzed data from the EOS TPC test. There were several points where wire shadowing existed. In Figure 3, two cross wires could shadow both parallel wires and Mylar strips, and two parallel wires could shadow two Mylar strips. We extracted electron pulse heights around those shadowing points. As an example, Figure 6

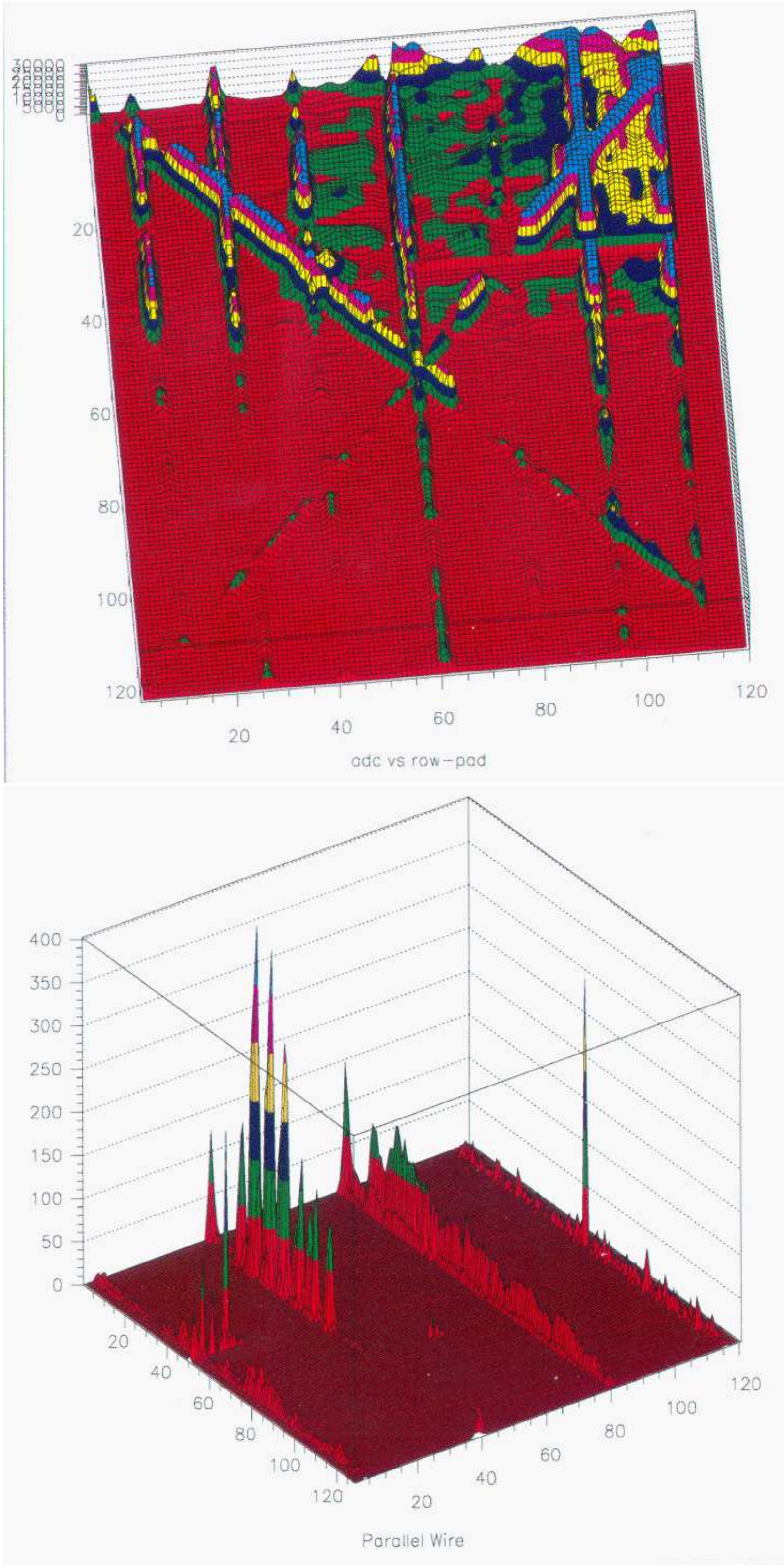

Figure 4: Surface plots of pulse height distributions for electrons emitted from (a-top) Mylar strips on the drift cathode plane; (b-bottom) Aluminum wires in the drift volume.

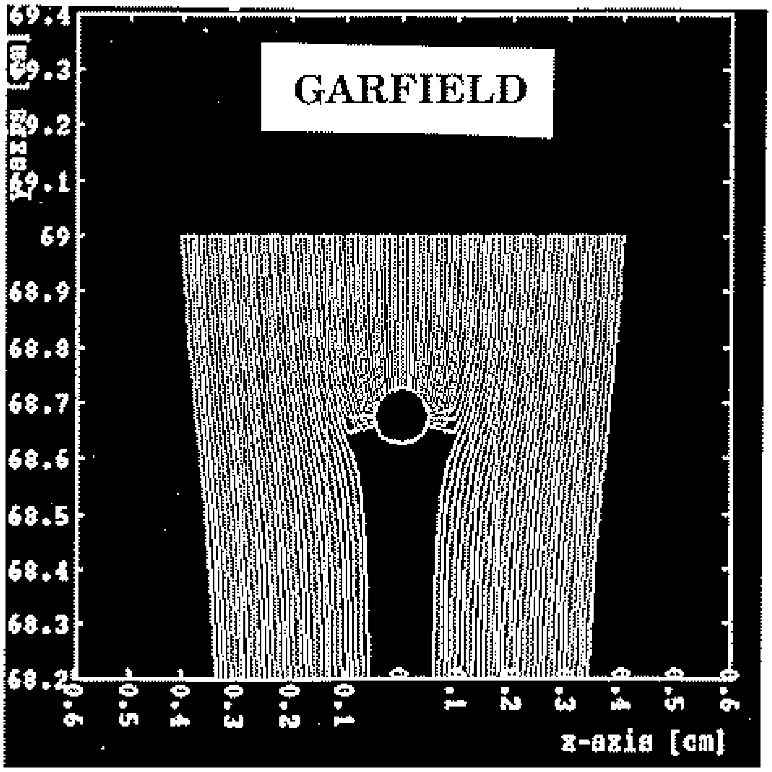

Figure 5: Distortion of the electric field lines around an electro-wire predicted by the GARFIELD calculation.

shows one Mylar strip was affected by one parallel wire underneath. Along the pad row number of 60 and 61, pulse height distributions were plotted as a function of pad number for electrons emitted from one parallel aluminum wire (lower figure) and from one Mylar strip above the wire (upper figure). On the pads around Nos. 81 and 82 where electrons were measured from the aluminum wire, there was obviously less electrons measured from the Mylar strip.

The transverse diffusion constant of electrons in P10 gas is $540\mu m/\sqrt{cm}$ without any B-field. The FWHM of electron cloud measured at the pad plane is $2.36 \times 0.54mm \times \sqrt{69cm}$, which gives 10.6 mm. Therefore, the full electron cloud from a 1 mm wire at 69 cm away will likely cover 2 to 3 pads, It agrees well with what was measured in Figure 6(b).

The presence of wires in the TPC volume can cause small distortions to the drift field lines. Electrons drifting too close to the wire may be terminated. This can affect energy loss measurements from pads which are shadowed by wires. However, the B-field can reduce the electron diffusions and the wire shadowing effect should be smaller than what was presented here.

5 Summary

We have completed the R&D project for studying spatial calibration of the STAR TPC with photo-electric wires. In this project, we have measured photo-efficiencies of various materials in the gas environment using an ultraviolet beam of $\lambda = 266nm$. We found that aluminum has a high photo-efficiency of $2. \times 10^{-8}$, and copper has a low value of $2. \times 10^{-9}$. We performed tests in the EOS TPC using aluminum wire, aluminized-Mylar strip, and aluminum-copper coated nylon line. Clear patterns were reproduced. It demonstrated the feasibility of generating electron tracks with photo-electric wires. However, problems with uniformity of illumination and wire shadowing existed. We feel that our approach using photo-electric wires may be useful when a few wires are needed and less wire shadowing is present. It may not necessarily offer an optimum solution for spatial calibration of a large volume of the STAR TPC.

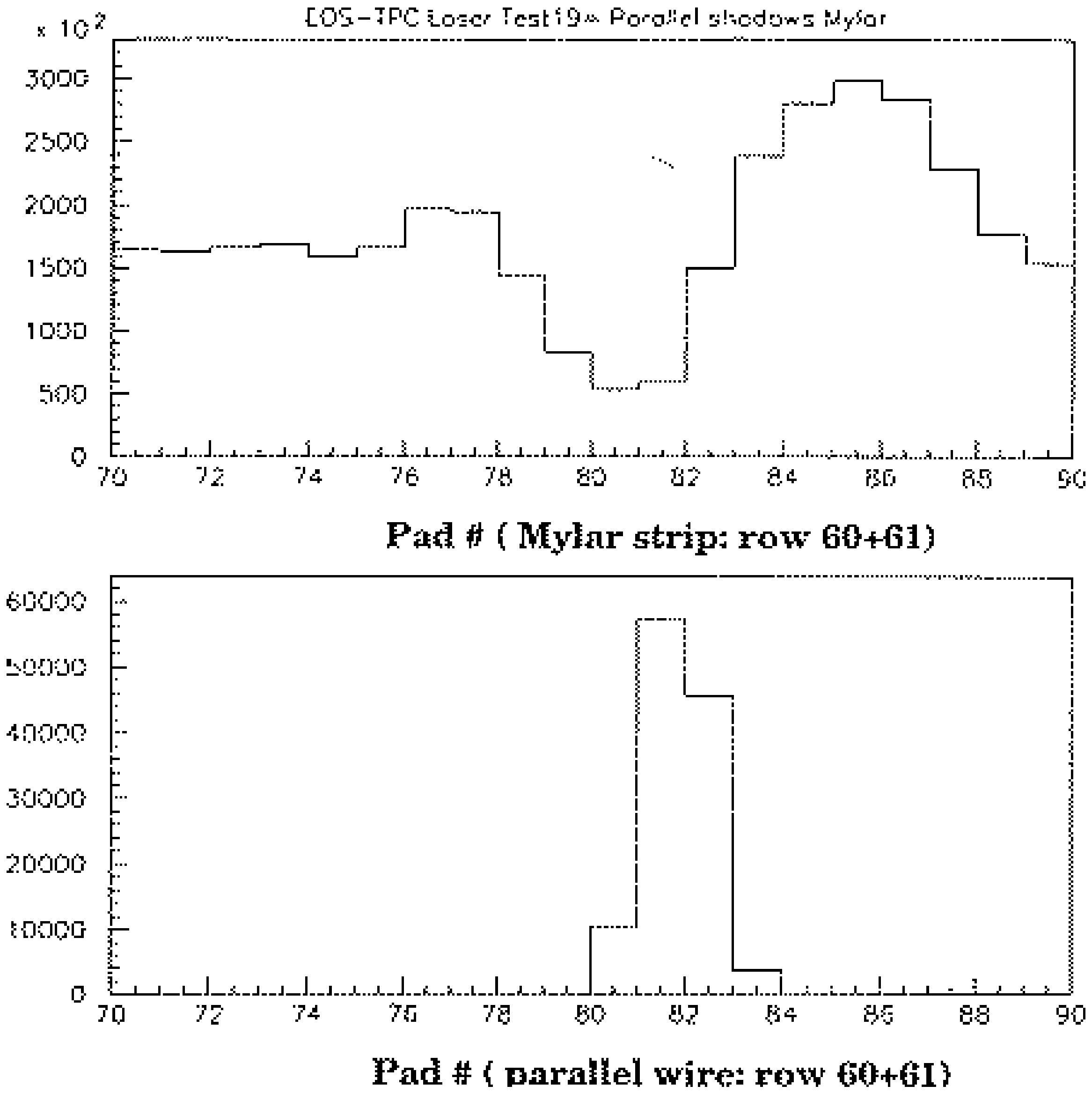

Figure 6: Pulse height distributions on two pad rows for electrons emitted from a Mylar strip (a-top) and a wire beneath it (b-bottom).