A Summary of Straw-tube Chamber Tests

GlueX-doc-280

Curtis A. Meyer and Zebulun Krahn
Carnegie Mellon University

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Abstract

A brief abstract of the note that will be placed on the search sites to allow searching the document

Introduction

This document summarizes the tests and studies that have been performed with the straw tube chambers to date.

1 The BNL EVA Chamber

Before embarking on the construction of a straw-tube chamber, the CMU group was able borrow a prototype chamber that was built for the Brookhaven EVA experiment [17]. The chamber has $2\,m$ long, $2\,cm$ diameter straw tubes. The tubes were designed to be read out at both ends, and then to use charge division to determine the coordinate along the length of the wire. The results of all of our work are written up in reference [8]. A setup which reads out four tubes in the chamber using a 4-channel digital oscilloscope, and then transfers the data to a local computer for analysis was built. Signals are produced from a $^{44}Ru_{106}$ source, (see Figure 1). The β's from the source are collimated through a $1\,mm$ diameter, $1\,cm$ long tube. The source is placed about $30\,cm$ below the chamber and aligned as shown in the figure. The system is triggered on a signal in the upper tube, and events with signals in all four tubes are read out. Gas mixtures can be varied using a locally built three-component gas-mixing system. This allows for detailed studies of the chamber performance in different gas mixtures [8].

2 Glue Studies

An issue that is common with straw-tube chambers has been the conductive glue joints that both hold the straws to the feed throughs as well as the feed throughs to the chamber end plates. Careful examination of an existing straw tube chamber from the Brookhaven EVA experiment showed that all of these joints tend to develop leaks over time. In order to try to alleviate this leak problem, a detailed study of many conducting and non-conducting epoxies were carried out to see if a good glue could be found. The conclusion of this work was that the particular choice of glue did not matter. Instead, the act of inserting one part of a feed through into another part tended to scrape much of the epoxy off the contact surface. This led to a joint with many weak spots that over a short period of time, developed leaks.

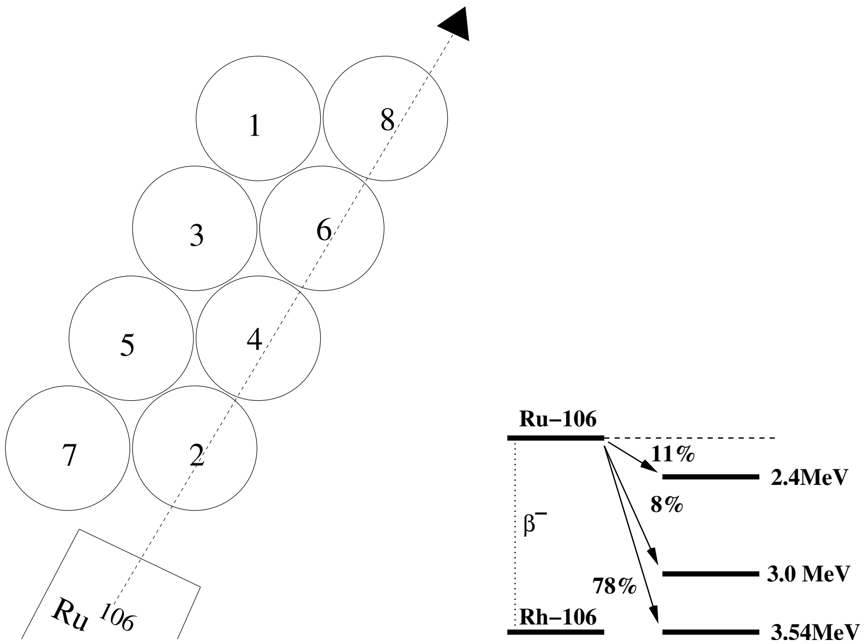

Figure 1: Setup of the straw-tube prototype chamber used in studying signals and gas properties. Note the ^{106}Ru source emits primarily 3.54 MeV electrons but there are also up to 1.14 MeV photons.

Upon careful study of this, it was decided that the only way to guarantee a good glue connection was to develop a system in which one is certain the the glue is actually making solid contact with both surfaces. The result of this is a feed through system as shown in Figure 2. The *donut* is a small tube with a small *glue trough* machined into its perimeter. From one end of the donut, a small *glue port* is drilled from the outside to the *glue trough*. Once the donut has been inserted into the straw tube, a known amount of conducting epoxy can be injected through the *glue port* into the *glue trough*. The strength of the resulting glue joint is solid, independent of the tested epoxies. In fact several test sells have maintained several psi overpressure for nearly nine months without leaking.

Into the donut, it is necessary to glue the insert that both holds the straw tube the chamber end plate and holds the crimp pin. In order to guarantee a good glue joint between the donut and the insert, a small *glue lip* has been machined on the tip of the insert. If a uniform coat of glue is applied to the outside of the *insert*, then when it is inserted into the donut, the epoxy tends to collect in both the *glue lip* and between the *insert* and the chamber end plate. Exactly where we need it to guarantee a good epoxy seal.

Using these specially designed feed through systems, we are able to obtain a conducting gas-tight joint will all conducting epoxies that we have tried.

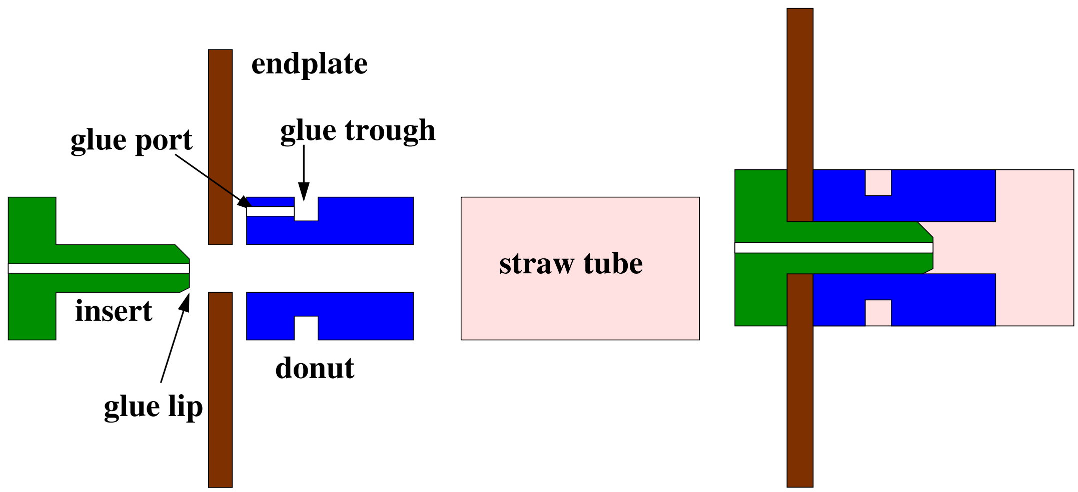

Figure 2: The CMU designed feed throughs which provide a solid glue joint between the straw-tube and the end plate. The left-hand figure shows an expanded view, while the right-hand shows the feed throughs in the chamber end plates.

3 Gas Studies

Of relevance to straw tube chambers is making sure that there is gas flowing through each tube in the chamber. While it is not necessary to guarantee that there is a uniform gas flow through all tubes, it is crucial to make sure that there are no stagnant tubes. A common way to accomplish this is using a plumbing system which brings the gas in via a large tube, a progressively splits the flow into an increasing number of smaller tubes. Eventually, these tubes individually feed each straw tube. At the collection end, the process is reversed and the and the gas is eventually carried out through a single large tube. Unfortunately, each of the junctions where the size of the tubes change, as well as the points where the gas goes into and out of the chambers is subject to a leak.

In order to address this issue in the GlueX chamber, we are planning to design a pair of plenums; one for each end of the chamber. Gas will be fed into the upstream plenum and will then flow through the straw tubes to the downstream end of the chamber where it will be collected. It will then pass through several special tubes that will bring the gas back to the upstream end. A crucial feature of such a design is to make sure that gas is actually flowing through all the tubes. In order to try and test this, we designed a built a system that emulates the end plates of the chamber, and is connected to 49 tubes. At the far end of each tube, an oil bubbler was attached. All of these bubblers were adjusted to make sure that they had nearly the same amount of oil.

Gas was then fed into the upstream plenum, and out flow was seen in each of the 49 bubblers. This plenum simulation was a can about 70 cm in diameter and 10 cm thick. In order to mimic the electronics and other material in the true chamber, cardboard plates and crumpled paper were placed between the input and the forty-nine outputs. Steady flow was again observed in all output channels.

4 Gas Mixture Studies

A set of detailed gas studies [11] has been carried out using the GARFIELD program to simulate the drift of electrons in both electric and magnetic fields. These studies indicate that it will be possible to get a gas mixture that provides a reasonable maximum drift time and a gain of the order of 10^4. Many of the traditional chamber gases were tested, including mixtures of Argon-Ethane as well as Argon-Carbon Dioxide. While the faster Argon-Ethane gas is well suited to situations where the magnetic field is not so large, it was found to have a Lorentz-angle that was unacceptable for our purposes. The Lorentz-angle was so large that the drifting electrons we actually spiraling into the wire, and the spiral was so exaggerated that this actually increased the total drift time by a significant amount.

Argon-Carbon Dioxide mixtures on the other hand, seem to work better, as we can effectively tune the values of the drift time and the Lorentz-angle by slight adjustments to the amount of Carbon Dioxide in the system. According to the simulations the ideal mixture of Argon and Carbon Dioxide would be roughly 80% Argon, and 20% Carbon Dioxide. This is a gas that still provides for reasonable gain, and allows for a reasonable drift time and a moderate

Lorentz-angle in a large magnetic field.

5 Heating Studies

We also tried to mimic the heat produced by preamps mounted on the end of the straw-tube chamber. The test was set up using a Plexiglas box of similar volume to the proposed upstream plenum, assuming that the preamps would be enclosed within the plenum system. To best determine how to remove the heat generated by the preamps we first needed a rough estimate of how much heat would be generated by the electronics enclosed. A brief search found that the heat generated by typical preamp chips to be on the order of 40-50mW per channel. With the current design of 3250 tubes, this would indicate 130-165W of total heat that would need to be dissipated.

To best simulate this, we used a Plexiglas box, with a pair of light bulbs mounted inside, and we flowed compressed air through the box, at the equivalent rate of 1-2 chamber volumes per day (2.5 - 5.0 $ft^3/hour$). Originally, we used a pair of 60W light bulbs, and finally we switched to a pair of 100W light bulbs. With the 100W light bulbs, the maximum temperature found in the box was 117 degrees Fahrenheit. While this is warm, this should certainly within the functional temperature of electronics and we will not run a risk of serious failure. There was hope that the flow of gas into the plenum with the electronics would be enough to sink some of the heat from the electronics. Unfortunately, the flow rate for the chamber is too low for the gas flow itself to remove any of the unwanted heat from the CDC. A suitable solution to removing the heat generated by the preamps will be found that works conveniently with the plenum gas system we have envisioned.

If it is decided that the preamps should not be enclosed inside the gas plenum, then the issue of heat can be answered simply by traditional means of sinking and we have much more flexibility in our solution. However, the most likely solution at this point is not to have the preamplifiers in the gas volume.

6 Resolution Studies

Resolution studies of the charged tracking system were carried out in a series of studies carried out over the last several years. Simple momentum resolution studies were first carried out early in the project design [2]. The results of these studies were confirmed with the current GlueX geometry in the summer of 2004, and indicate that the earlier results are still valid. In addition to the resolution studies, full Partial Wave Analysis have been carried out, with particular emphasis in looking for leakage in the detector system [16]. The entire detector system has been designed in such a way that leakage does not appear to be a significant issue.

7 Acceptance Studies

Original acceptance studies were carried out with a number of mixed final states [14]. These studies were repeated in 2004 for a set of expected exotic-quantum number hybrid decays [15]. These studies indicate that the charged particle acceptance is about 99%, while the single photon acceptance is about 97%.

8 dE/dx

While dE/dx measurements are not typically cited as functions for straw-tube chambers, in certain situations it is possible to carry them out [18]. In particular, the task in the GlueX detector requires that the straw-tube chambers be able to separate protons, pions and kaons for total momentum up to about $500\,MeV/c$. This is a momentum regime where one has the maximum separation using dE/dx. The main criteria for doing a good measurement is to accurately know the path length in the active gas volume. This requires one of two possible approaches, both of which require a good track fit. In the first, the track is used to estimate the patch length in each tube, and a traditional approach using about 18 measurements is performed. In the second, the total track length in the active gas volume is computed, and then the total dE signal is summed. The bottom line is that there are demonstrations that this technique has been carried out in straw tubes, and that we will have sufficient samples to be able to carry out the separation in the limited region where it is necessary.

9 Calculations

9.1 Gravitational Sag

The gravitational sag of a wire of mass per unit length σ, length L and Tension T is given as:

$$\mathrm{sag}_{\mathrm{grav}} = \frac{\sigma_w L^2}{8T}. \tag{1}$$

For $20\,\mu m$ diameter gold-plated tungsten wires, $\sigma_w = 5.75 \times 10^{-3} g/m$. We anticipate at most $2\,m$ long wires under a tension of $T = 50\,g$, we obtain a gravitational sag of:

$$\mathrm{sag} = 57\,\mu m$$

For a wire of length $1.75\,m$, the sag is reduced to about $43\,\mu m$.

9.2 Electrostatic Displacement

The electrostatic displacement due to a wire being off center in the tube is given by:

$$h = \frac{L^2 \delta V^2 (4\pi\epsilon_o)}{(9.8)(16) T R^2 (\cosh^{-1}(R/2r))^2}. \tag{2}$$

where δ is the displacement from the center of the straw, R is the radius of the straw and r is the radius of the wire. For $\delta = 100\,\mu m$, the we find a displacement of about $9\,\mu m$.

9.3 Time Resolution

Using reasonable time-to-distance relations, we find that it takes about 500ns for charge to drift in the 8mm from the outside of the straw tube to he anode wire. This yields a radial drift speed of

$$v_r = \frac{8000\,\mu m}{500\,ns} = 16\,\mu m/ns \tag{3}$$

In order to achieve the $150\,\mu m$ resolution for the drift chamber, we budget about half this amount to timing, or at most $75\,\mu m$. This corresponds to an uncertainty in the drift time of $4.7\,ns$. If we use $125\,MHz$ Flash ADCs, then the nominal bin size is $8\,ns$. Timing algorithms can easily yield an accuracy about $\frac{1}{3}$ of this, or about $2.7\,ns$. This would yield a radial position resolution of about $43\,\mu m$.

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