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A New Gaseous Detector for Tracking : the Blade Chamber

The LAA-LAD Group

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Abstract
As part of the LAA project at CERN a prototype of a streamer-chamber has been built in which a blade, instead of a wire, is used as the amplification electrode. A big advantage is that the blade can be bent to follow a curve so that a chamber can be built with cells ideally matched to the geometry of the experiment. Moreover a blade is very rugged, it can withstand severe mechanical shock and also it is resistant to damage by sparks. The drift-time has been measured and a spatial resolution of 250 μm has been achieved. Left right ambiguity can be solved by measuring the charge asymmetry on the walls. The coordinate along the blade is read by external pickup strips.

Introduction

The "Large Area Devices" (LAD) group of the LAA project at CERN is devoted to R & D for muon detection at a future multi-TeV hadronic collider. Results reported in this paper are a part of the LAA-LAD work. In a hadron collider muon measurements in the forward and backward directions are of fundamental value. In these regions muon spectrometers require toroidal magnetic fields. In a toroidal field polar coordinate readings are desirable to improve trigger capability and momentum measurements. Our problem is: how can we build a circular cell? The idea being investigated is whether we can use a blade, instead of a wire, as the amplification electrode in a chamber working in the limited streamer mode. This is an adaption of a cell design already in use for X-ray spectroscopy [1,2]. There are several advantages with this technique. One is that a blade is very rugged, it can withstand severe mechanical shock and also it is resistant to damage by sparks. Another advantage is that it can be bent to follow a curve so that a chamber can be built with cells ideally matched to the geometry of the experiment. The problem with a blade is that the high field region needed for the avalanche process is only at the tip of the blade. We therefore have to find a geometry such that the primary electrons are drifted to the high field region.

Geometry of the cell

The cross section of the first chamber that we built and tested is shown in figure 1. The blade is 20 μm thick steel (this is commercially available as a shim material). The blades are spaced 10 mm apart. Between each blade there is a wall of 0.5 mm steel, which supports a roof made of copper clad p.c. board, located 15 mm above the tip of the blade. The walls and the roof are conducting

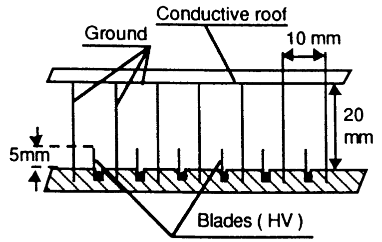

Figure 1. Cross section of conductive roof blade chamber

and are at ground potential. The blade is at positive high voltage and is readout via a 1nF decoupling capacitor. We fill the chamber with pure isobutane and find that we can achieve

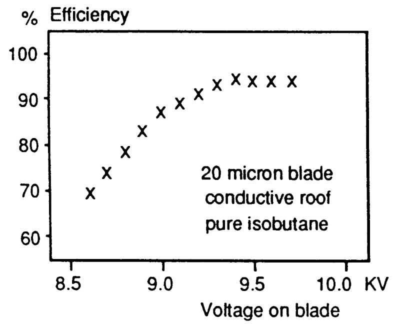

Figure 2. Detection efficiency versus high voltage on the blade

full efficiency. The plot (figure 2) shows the result for particles perpendicular to the roof of the chamber. Due to the dead area introduced by the thickness of the walls we only expect 95% efficiency. If we change the shape of the cell, such that the roof is lower (closer to the blade), we get a lower efficiency as primary electrons produced by tracks close to the wall are not drifted to the high field region. Many alternative designs have been attempted in order to optimise the detector performances. The current chamber, shown in figure 3, consists of a 30 µm thick blade with a 4mm blade distance. The roof is made of an insulat-

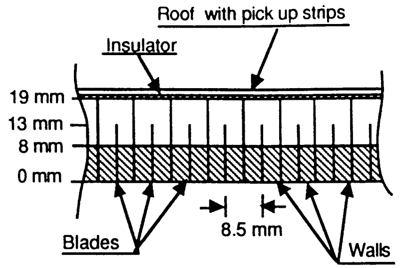

Figure 3. Cross section of insulating roof chamber

ing Kapton foil and is located 6mm above the tip of the blade. With this geometry the roof is charged and the field lines are bent (figure 4). As a consequence, primary electrons liberated near the wall are drifted to the high field region, even though the roof is close to the

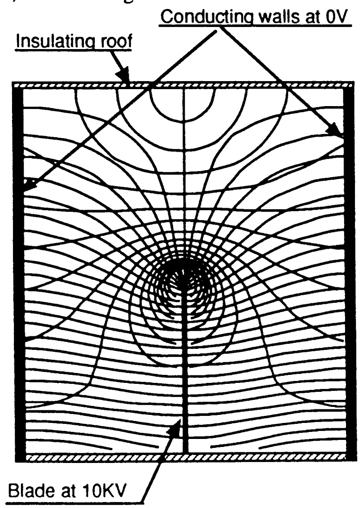

Figure 4. Field and Equifield lines for a Blade chamber cell

blade. Furthermore this design allows a reduction of the cell size shortening the maximum drift-time. An insulated roof also allows an easy placement of pickup strips. These are located on the outside of the roof and are used to determine the position of the streamer along

the length of the blade. We filled with pure isobutane. The remainder of this report describes results obtained with this chamber.

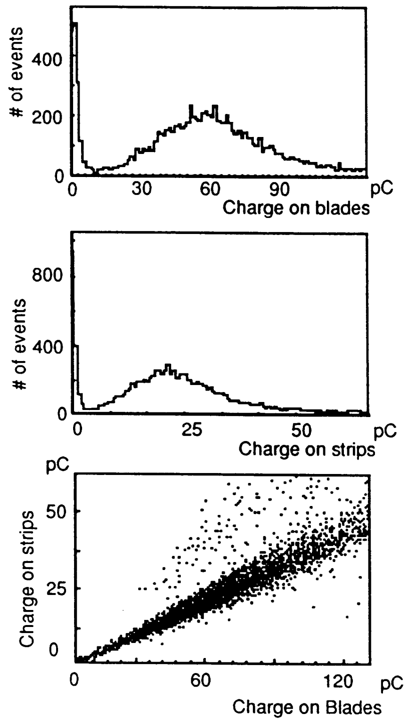

Figure 5. Charge spectrum on blades, strips and their correlation

Test Set-up

The chamber was mounted between two drift chambers. These chambers are equipped with wires in the x and y direction. The active area is 15 x 15 cm^2. Three scintillation counters are used to select through going tracks. This set-up was used to test the blade chamber with cosmic rays and with a pion beam of 3.5 GeV at CERN PS. Figure 5 shows the charge spectrum of the signal observed on the blades, on the sum of the strips and the correlation between the two. The main features are that the signal is large and there is a very strong correlation. The reason for this correlation is that the streamer can only grow in the direction away from the tip - towards the roof (where the pickup strips are located). This is different from the case of a wire, where the streamer can grow either towards or away from the pickup strips located on one side of the chamber.

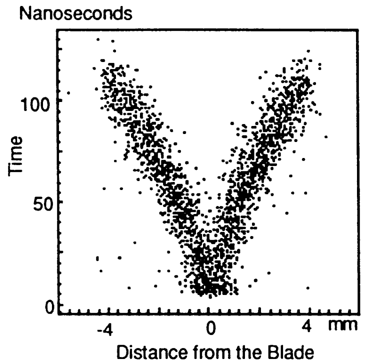

Figure 6. Particle distance from blade versus time of blade signal

Resolution

We reconstruct tracks using the auxiliary drift chambers and plot the distance from the blade versus the time of the blade signal. This is shown in figure 6. The left-right ambiguity can be solved using the charges measured on the walls. When a cell fires the charges induced on the delimiting walls are found to be different. We define a charge asymmetry A :

$$A = (Q_R - Q_L) / Q_M$$

where Q_R, Q_L are the charges on the right and left wall respectively and Q_M is the average of the two. The sign of A is found to be related to the left or right position of a track. This asymmetry is shown in figure 7. The two peaks are related to the left right position of the tracks. In fact one peak disappears when, by means of external chambers, only tracks on one side of the blade are selected.

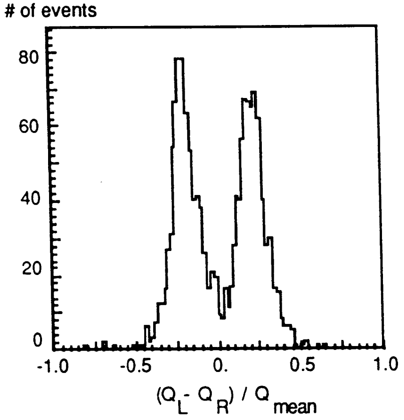

Figure 7. Asymmetry of charge collected on walls

We use this method to solve the left right ambiguity and then the drift time measurement is used to determine the position inside a cell. A spatial accuracy of 250 μm has been achieved (figure 8). It should be noted that this is an upper limit because the contribution of the external chambers and multiple scattering are still included in the residuals.

The coordinate along the blade was mea

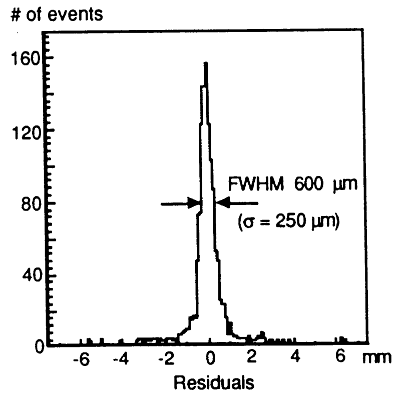

Figure 8. Residuals of coordinate measured by drift time

sured by means of pickup strips. These were 11 mm wide. Due to this width most of the induced charge was collected by one or two strips. With this limited distribution the centre of gravity algorithm does not produce a

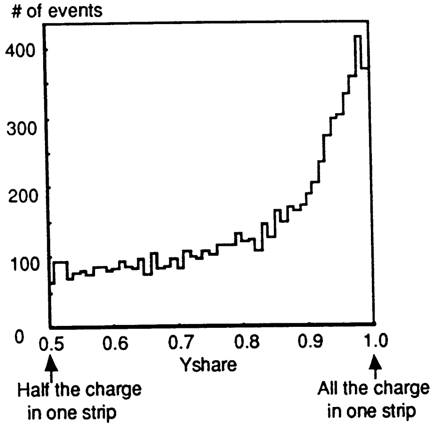

Figure 9. Yshare Distribution

good result. We have defined a quantity called Y_{share} as follows:

$$Y_{share} = Q_1 / (Q_1 + Q_2 - Q_3)$$

where Q_1 is the charge on the strip with the largest signal, Q_2 the charge on the neighbouring strip with the larger pulse height and Q_3 the charge on the other. The minus sign in

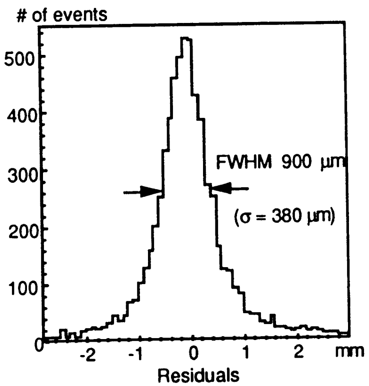

Figure 10. Residuals of coordinate measured by pickup strips

front of Q_3 is used to reduce the effects of cross talk, but its contribution is in any case very small. A histogram of Yshare is shown in figure 9. Solving the left-right ambiguity on the basis of which of the neighbours has the higher charge we obtain a resolution of σ = 380 μm (figure 10). Again it should be stressed that this is an upper limit.

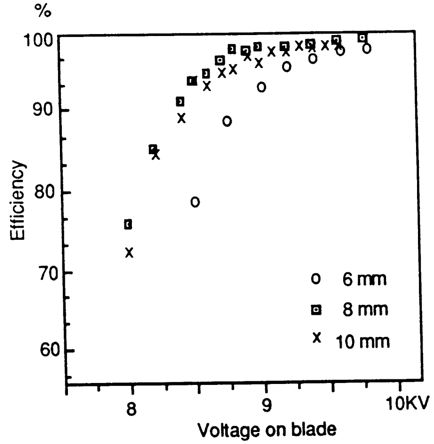

Figure 11. Efficiency of blade chamber for various blade to roof distances

Efficiency and Rate Dependence

We have investigated various cell geometries during the beam test in order to learn the optimal cell design. In figure 11 we show the efficiency for 3 different blade tip to to roof distances. The full geometric effiency is 96% due to the finite thickness of the walls. Another investigation that we are performing is the dependence of the chamber on the rate. We can operate the chamber above 90% efficiency at fluxes of 700 particles / cm^2, this is shown in figure 12.

Conclusion

We have shown that the blade chamber works with full efficiency for minimum ionizing particles with good spatial resolution.

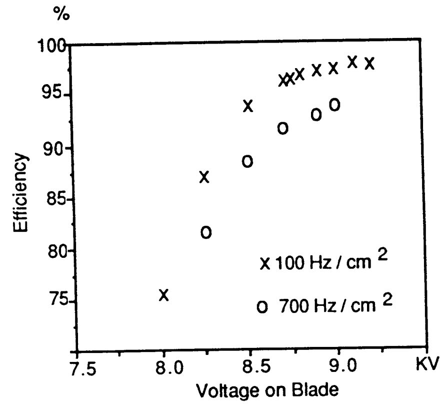

Figure 12. Efficiency of blade chamber for different particle flux

We can solve the left-right ambiguity with charge asymmetry measurement on the walls. During the last beam test we also tested a chamber built with curved blades. This chamber worked extremely well. This technique allows us to build detectors with very small limitations in the geometry, with high mechanical reliability; requirements needed for the construction of Large Area Devices for μ detection at a future multi-TeV hadron collider.

Future Developments

Further work is needed on the effect of particle rate on the chamber efficiency and resolution. We have also started the construction of large scale prototype, it will have curved cells.

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