DELPHI 87-78 CAL 48
25 September 1987

**ALIGNMENT IN MAGNETIC FIELD, CHARGE
TRANSMISSION AND DRIFT VELOCITY MONITORING
FOR THE TPC-LIKE ELECTROMAGNETIC CALORIMETER
OF THE DELPHI EXPERIMENT AT LEP**

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7th September, 1987

**Alignement in Magnetic Field, Charge Transmission and Drift
Velocity Monitoring for the TPC-like Electromagnetic
Calorimeter of Delphi Experiment at LEP**

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ABSTRACT:

The HPC, electromagnetic calorimeter for the LEP Delphi experiment, is a TPC-like detector working in $\mathbf{B}$ field. Its response depends much on charge transmission to reading plane, which requires a good alignment between $\mathbf{E}_d$ and $\mathbf{B}$ fields, and on drift velocity. To align $\mathbf{E}_d$ and $\mathbf{B}$ fields and to monitor charge transmission, the signal of α particles, emitted by a source in a drift channel near HT-plane, will be measured. Some HPC modules will be equipped with a P-I-N photodiode, faced to the source, in order to trigger α particles so to monitor drift velocity. Tests in a drift channel simulating HPC were performed and gave good results for this monitoring method also for what drift velocity is concerned.

Presented at the London Conference on Position Sensitive Detectors

7th-11th September 1987, London, UK

1. Introduction

Recently a new TPC-like calorimeter, the High Density Projection Chamber (HPC), has been proposed for Delphi-LEP detector and is now being built^(1,2,3). Each module of this calorimeter (fig. 1) is, in fact, made up by many narrow and long drift channels separated by lead converters and works as follows. A primary photon or an electron generates a shower in the drift channel structure, made up of lead wires acting as converters and drift field shaping electrodes, and ionizes the gas (80%Ar+20%CH₄ mixture). The ionization electrons drift along the channels under the action of a uniform electric field E_d and finally enter a proportional chamber with pad read-out. Each pad is faced to a number of drift channels between 3 and a multiple of 3 or 4 and a multiple of 4, depending on the pad. Appropriate encoding electronics gives then a three dimensional view of the shower profile together with the energy deposited by the showering particle. Moreover this calorimeter has to work inside a solenoidal magnetic field B parallel to the electric drift field E_d .

The response of such a type of calorimeter to given energy releases essentially depends on :

- i) Ionization charge transmission to the reading plane, which in turn depends on :
 - a) Good alignment between E_d and B fields.
 - b) E_d uniformity and gas purity (e.g. absence of electronegative pollutants) in drift structure.
- ii) Uniformity of reading pads response, that means uniformity of gain of proportional tubes of which pads are made.

The spatial resolution of the detector depends on :

- iii) Drift velocity of ionization electrons in gas.

Quantities related to points i), ii) and iii) above must be monitored in order to know the response of the calorimeter at every time during data taking.

More in detail these quantities may be chosen as :

- 1) Pulse height response of a given pad to a fixed quantity of energy released by ionization in a position next to HT side of a corresponding drift channel (fig. 1).
This energy release should be of the same order of magnitude of the energy

released by an electromagnetic shower. In this way ionization charge transmission to reading plane is monitored and it is possible to get a calibration point.

Charge transmission monitoring is a good method to align E_d and B fields, as it will be discussed later.

- 2) Drift time of ionization electrons, generated by particles used to obtain the energy release mentioned in point 1) above, allowing so a measurement of drift velocity of electrons in gas.
- 3) A periodical check of the uniformity of response of all pads to m.i.p. traversing orthogonally the drift structure (e.g. cosmic rays). This permits equalization of pads at run-time. Of course this procedure, which exploits cosmic rays, is very long and may be done from time to time in between data-taking runs.

Exploiting ideas exposed in points 1) and 2) above, we developed a system which allows on-line monitoring of ionization charge transmission and electrons drift velocity.

2. Implementation of the method using an alpha source

The energy released in the gas filling a HPC drift channel by a typical shower is of the order of some hundreds KeV as from MC simulations. So, as every pad is faced to a minimum number of 3 drift channels (see above) - depending on position along the longitudinal development of the shower - a good enough energy release in the gap, to get a calibration point, might be between 100 and 400 KeV.

Such an energy release may be obtained using α particles emitted perpendicularly to drift direction by a collimated radioactive source; source is located near HT side of a HPC drift channel (fig.1). Normally α particles emitted by sources have energies of the order of 5 ÷ 6 MeV (e.g. main line of ^{241}Am is at 5.48 MeV): α particles of such energies loose by ionization, in a gas mixture at S.T.P. (Standard Temperature and Pressure), an energy of the order of 100 KeV for each millimeter of gas traversed ⁽⁴⁾. This means a maximum of ≈ 800 KeV of energy released if collimated α particles are emitted in a direction perpendicular to the lead planes defining the drift channels and are allowed to ionize for the full height of the drift channel (8 mm) without absorbing them; smaller energy releases are possible by means of an absorber in front of the source.

Therefore, monitoring during the data taking the pulse height response of the pad faced

to α particle ionization, it is possible to know the evolution in time of the response of the calorimeter, concerning charge transmission in the drift region provided gas proportional gain is monitored. This allows to obtain a calibration of the HPC.

2.1 Alignment in magnetic field

The response of the pad to α particle ionization depends on charge transmission inside the drift channel which, in turn, is strongly dependent on the alignment between E_d and B fields, and is maximum when the two fields are parallel to each other. The measurement of this response is, so, a good method to align the module in the magnetic field.

This alignment procedure relies upon the results of a previous work⁽⁵⁾ performed by one of the authors: the aim of such a work was to measure attenuation lengths of electrons drifting in 80%Ar+20%CH₄ in a narrow (≈ 8 mm height) and long (≈ 1 m) drift channel when a solenoidal magnetic field, parallel to the drift electric field, is present. The drift channel was built in such a way as to simulate a HPC drift channel and it was similar, but longer, to the one described below in paragraph 3.2. In this long drift channel a collimated ²⁴¹Am source, emitting α particles, was located near the HT side of the drift channel and the response of the proportional tube, as a function of the relative orientation between E_d and B fields, was measured. Two angular scans were made, one in the vertical plane (angle ϕ) and one in the horizontal plane (angle θ) in order to display respectively the so called $(E \bullet B)B$ effect and EXB effect; results are reported in fig.2; see fig. 5 for reference frame.

From these data it is evident that the signal of the proportional tube, due to α particles, is maximum when E_d and B fields are aligned. As a conclusion, this procedure may be exploited to align HPC modules in B field when an ²⁴¹Am α source is installed on the HT side of a HPC drift channel.

2.2 Drift velocity monitoring

It is important to monitor, in some HPC modules, drift velocity of ionization electrons in HPC drift channels under real operating conditions. A real-time knowledge of drift velocity is, infact, fundamental for a reliable spatial resolution of the detector. To measure drift velocity a "zero time " is needed and this may be obtained by detecting the

collimated α particles, used to monitor the HPC module, after they have traversed the gas gap. Alpha particle detection may be accomplished by means of a P-I-N photodiode settled in front of the α source (fig. 1). The signal of the diode is used to give the start to a clock which is stopped by the signal of the pad faced to the concerned drift channel.

3. Feasibility tests of the drift velocity monitoring system

3.1 Preliminary tests on P-I-N photodiode

As a preliminary test for the drift velocity monitoring system, we exposed to an ^{241}Am α source (Main line at 5.48 MeV) a P-I-N photodiode type SIEMENS BPX 61 (dimensions $3 \times 3 \text{ mm}^2$), chosen for its low reverse current ($\approx 1.5 \text{ nA}$) and its low capacitance ($\approx 10 \text{ pF}$) under a reverse polarization of 27 V; P-I-N photodiodes of this type were already used as α source spectrum detector ⁽⁶⁾. The P-I-N photodiode preamplifier, developed by J.C.Santiard at CERN ⁽⁸⁾, is a fast (risetime 20 ns) charge sensitive type with FET input.

Spectra of diode signal, which, after preamplification, has a risetime of 20 ns, have been measured in vacuum (fig. 3) and in air at S.T.P. (fig.4) for a distance between diode and source of $\approx 8 \text{ mm}$. The spectrum of α particles in air (fig. 4) shows a displacement of peak toward lower values, due to energy lost by α particles in collisions with air molecules. The difference between positions of peaks in figs. 3 and 4 allows to measure the energy released by α particles in 8 mm of air, provided the linearity of the diode reading chain is checked.

The result is

$$E_{\text{rel}} = 0.82 \pm 0.14 \text{ MeV}$$

This measurement is in a good agreement with what foreseen by Range-Energy tables for 5.48 MeV α particles from ^{241}Am that traverse 8 mm of air ^(4,7) that is

$$E_{\text{rel}} = 0.76 \text{ MeV}$$

From this test we obtained confidence that the P-I-N photodiode has a good performance as a fast and cheap α particle detector and is a good candidate to trigger α particles.

3.2 Installation of a P-I-N photodiode in a drift channel

To test the feasibility of α particle triggering system by means of a P-I-N photodiode in

a situation pretty analogous to the real one we have installed an α source, with a P-I-N photodiode in front, on the HT side of a drift channel simulating a HPC drift channel (see fig. 5).

The single drift channel of HPC was built using lead wire ribbon, i.e. the same technique⁽³⁾ chosen for the construction of the final calorimeter. Seventeen ribbons, each made up of 20 parallel lead wires, 1.7 mm thick, separated by 0.2 mm and glued on both sides of a thin vetronite support, were bent to form U-shaped pieces which were aligned all together on a plexiglass support in order to constitute a single drift channel. Resistors were placed between each contiguous lead wires to let them act as field shaping electrodes. The size of the drift channel is $616 \times 100 \times 8$ (XxYxZ)mm³. The α source is installed below the lead wires and the α particles are injected into the channel through a $\varnothing 1$ mm hole at 610 mm from reading proportional tube. The P-I-N photodiode, of the same type as in previous paragraph, is inside the drift channel in front of the hole injecting α particles in the drift channel. The path of α particles in gas inside the drift channel is ≈ 6 mm before being absorbed and detected by the P-I-N photodiode so that they loose about 600 KeV in gas. The ionization signal is read by a proportional tube of the same type as the ones making up the pads of the HPC reading chamber: in order to accomplish this test the signal is taken out of the proportional wire and is fed into a standard LABEN charge preamplifier. The P-I-N photodiode is inserted in a floating circuit in series with a 10 M Ω resistor and with a polarizing battery insulated from the ground. This is done as the P-I-N photodiode is settled in the HT side of the drift channel so it sets at high tension when drift voltage is switched on. The P-I-N photodiode signal is therefore fed into the preamplifier through a HT capacitor as may be seen from the scheme (fig. 6). The P-I-N photodiode preamplifier is of the same type mentioned in previous paragraph.

3.3 Operation of the system - Experimental results

As in the real situation the system was operated in a 80%Ar+20%CH₄ gas mixture: the result was a good and fast (risetime 20 ns) signal from the P-I-N photodiode which, in turn, allowed a stable trigger for the proportional tube signal. An evident example of this may be clearly seen in fig.7 where the two signals are added on the scope. The drift time in fig.7 is 14.3 μ s with an electric drift field $E_d \approx 80$ V/cm corresponding to a drift velocity $v_d \approx 4.3$ cm/ μ s, so in fair agreement with literature data⁽⁹⁾; for a measurement at a different value of E_d see table 1. The spectrum of the corresponding wire

signal, triggered by the diode, is reported in fig. 8. The response of the proportional tube to α particles has been measured at different voltages of the sense wire; the measurements are reported in fig. 9 where it can be seen that, only for a proportional wire tension larger than 1300 V, there is saturation, the gain still increasing in an exponential way for lower values of tension. As the HPC reading chamber is foreseen to be operated at ≈ 1250 V this makes us confident that this system may be used for data-taking calibration and monitoring despite the fact that ionization density due to α particles is much higher than the one due to a shower.

Just for sake of comparison the spectrum of the wire signal due to α particles with no photodiode trigger is presented in fig. 10 where it may be seen that the position of the peak is always the same but the FWHM of the distribution is $\approx 40\%$ larger.

4. Conclusion

We have described a method to monitor charge transmission and drift velocity in HPC drift channels using an α source and a P-I-N photodiode facing the source. This procedure is also useful to align the drift electric field of HPC in the Delphi solenoidal magnetic field. A collimated α radioactive source (e.g. ^{241}Am) is installed on the HT side of a HPC drift channel: the ionization electrons due to α particles are collected on the pickup chamber. Therefore, measuring the corresponding pulse height in a facing pad, we get a monitor of charge transmission in the drift structure. The P-I-N photodiode, installed in front of the source, detects α particles giving a "zero time" and so allowing a monitor of drift velocity in the gas under real operating conditions. Tests in a long drift channel simulating HPC gave good results.

Acknowledgments

We are particularly grateful to V. Gracco for many interesting and very useful discussions and for his constant stimulus and encouragement. One of us (MS) is grateful to G. Matthiae and O. Ullaland for a fruitful discussion on the method. M. Castoldi is gratefully acknowledged for an interesting discussion on preamplifiers for solid state detectors. The gas system was a skillful work by A. Morelli.

Table 1

Measured drift velocities for different electric drift fields

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$ E_d $	v_d
[V/cm]	[cm/ μ s]
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80	4.3
140	5.7
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FIGURE CAPTIONS :

- Fig.1 Detail of a HPC module. The sketch of a shower is superimposed to the drawing in order to illustrate how the calorimeter works (see text for details). An indicative sketch of the installation of the ^{241}Am radioactive α source and P-I-N photodiode is shown too.
- Fig.2 From ref. 5: Mean pulse amplitude due to α particles ionization generated near HT side of a $\approx 1\text{m}$ long and narrow (8mm) drift channel read by a proportional tube at different orientations between electric drift field and magnetic field: $(\mathbf{E} \bullet \mathbf{B})\mathbf{B}$ (angle ϕ) and $\mathbf{E} \times \mathbf{B}$ (angle θ) effects are shown (reference frame as the one defined in fig.5), the solid lines are simulations results (for more details see ref.5).
- Fig.3 Spectrum in vacuum of P-I-N photodiode exposed to ^{241}Am α source at a distance $\approx 8\text{mm}$ (see text).
- Fig.4 Spectrum in air at STP of P-I-N photodiode signals exposed to ^{241}Am α source at a distance $\approx 8\text{mm}$ (see text).
- Fig.5 Schematic view of drift channel simulating one HPC drift channel with α source and P-I-N photodiode near HT side; the reference frame, valid also for fig. 2, is shown.
- Fig.6 Scheme of the P-I-N photodiode reading circuit (see text).
- Fig.7 P-I-N photodiode trigger signal due to α particles and triggered proportional wire signal seen after drift time added on the scope ($HV_{\text{wire}} = 1250\text{ V}$).
Hor. scale $2\mu\text{s}/\text{div}$, Vert. scale $10\text{mV}/\text{div}$ for both signals (see text).
- Fig.8 Spectrum of proportional wire signal triggered by α particles signal on P-I-N photodiode for $HV_{\text{wire}} = 1250\text{ V}$.
- Fig.9 Mean pulse height of proportional wire signal due to α particles vs. proportional wire voltage.
- Fig. 10 Spectrum of proportional wire signal due to α particles when no P-I-N photodiode trigger signal is present for $HV_{\text{wire}} = 1250\text{ V}$.

Fig.1

Fig. 2

Fig.3

Fig.4

Fig.5

Fig. 6

Fig. 7

Fig.8

Fig.9

Fig.10