H1-Tracking Note #24
S.J.Maxfield and
D.P.C.Sankey
December 15 1990

Preliminary Calibration Constants for the Radial Drift Chambers

Introduction

This document describes the methods which will be used to determine space points in the Radial Drift Chambers with sufficient precision to initiate pattern recognition and track fitting. It also mentions the first steps towards achieving the desired gain calibration for effective particle identification. It does not address the longer term goal of obtaining the best possible precision which will require detailed correction and fine calibrations only obtainable after a period of “real data taking”.

We deliberately plagiarise H1-tracking note #23 ([a]), which addresses similar problems for the Central Jet Chambers. The test pulsing procedures described in H1-tracking note #22 ([b]) will also be used essentially unchanged for the Radials. We attempt to set out a list of calibration constants which has maximum overlap with those described in [a]. The overall goal is to have a unified approach and in particular to define a calibration database structure which satisfies the needs of all the H1 DC’s.

Drift Distance

We take as basis [a]. Essentially the same procedure may be adopted for the Radials. However the greater difference in amplitude between the two pulses emerging from either end of the wire for hits near the outer radius of the tracker leads us to favour a weighted mean (eqn 1) for determining the average drift time calculated from the drift times for each wire end.

$$T = \frac{1}{(Q_+ + Q_-)}\,(Q_+ . T_+ + Q_- . T_-) \qquad [1]$$

This causes a slight (≤3 nS) systematic effect arising from signal propagation delays along the sense wires to be introduced into the measured time. This may be removed in the time to distance relation (eqn 2):

$$D = \left(T - \left(T_0 + T_{FTDC} + t_0\,(w) + \frac{1}{2}\left(\alpha\,(D_+ - D_-) - \alpha^2 \Delta T\right)\right)\right).V_D \qquad [2]$$

where α is defined as:

$$\alpha \equiv \frac{\left(Q_+ - \frac{g_+}{g_-} Q_-\right)}{\left(Q_+ + \frac{g_+}{g_-} Q_-\right)} \qquad [3]$$

$(D_+ - D_-)$ is the difference in propagation delay down the signal cables and electronics and ΔT is the propagation time along the sense wires. T_0 and t_0 are the overall and individual wire timing offsets, and T_{FTDC} is bunch crossing time offset. Q_+ and Q_- are the pulse integrals from the FRRE bank (strictly speaking the gain correction, measured as $\frac{g_+}{g_-}$ by the test pulse program, should not be included in α here, but it is necessary for the charge division). $(D_+ - D_-)$, ΔT, T_0 and t_0 are determined by the test pulse program.

In the first instance, the corrections to the drift velocity, V_D, close to the sense wire plane will have the same form as for the CJC (eqn 4). Furthermore and in addition, these will quite possibly use the same initial values. Initially we do not envisage correcting the drift distance for quirks close to the cathode planes.

$$D_c = \begin{cases} 0.01\ \text{cm} & D \le D_0 \\ (D - D_0)\,C_0 & D_0 < D \le D_1 \\ (D - D_1)\,C_1 + (D_1 - D_0)\,C_0 & D_1 < D \le D_2 \\ D & D > D_2 \end{cases} \qquad [4]$$

Tracks angled in Rϕ will be corrected using the same model of drift as for the CJC (figure i). However the correction will be applied to the drift distance, since this is required at the Z of the wire, rather than by shifting the Z of the hit. The drift distance at the Z of the wire, d, is given by eqn 5, where D_r is the radius at which the trajectory of the electron swarm becomes approximately radial.

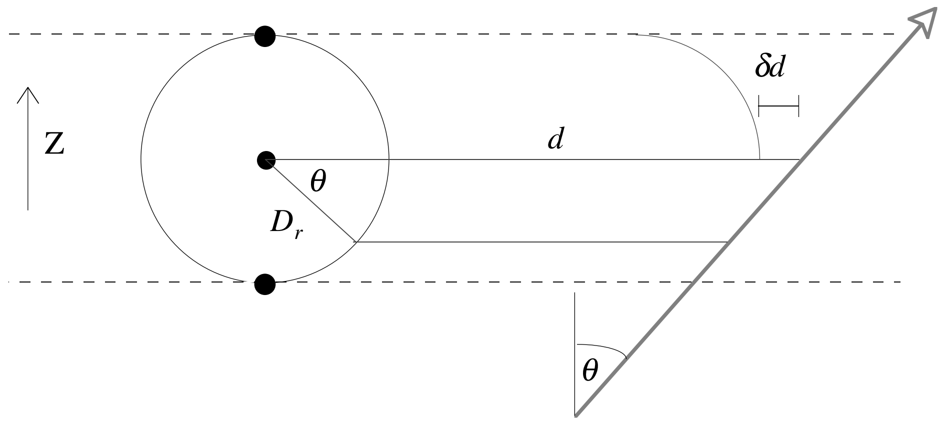

Figure i Schematic diagram of drift cell.

$$d = D_c + D_r\,(\sec(\theta) - 1) \approx D_c + D_r\,\frac{\theta^2}{2} \qquad [5]$$

In summary the Radials require the same timing constants as the CJC.

Charge Division

The determination of the 'other' coordinate of each hit by charge division is a slightly more complex exercise in the case of the Radial Drift Chambers. Whereas the CJC has single wires read out at each end which are parallel to the magnetic field, the Radials have two separate wires orthogonal to the field and joined together (at the inner radius), each read out at the outer radius. This leads to complications in the derivation of the radius of the hit, with a dependence on which cell was hit; in addition the effect of the magnetic field produces a shift along the radius which depends on the resolved left/right ambiguity and the drift distance of the hit. There is moreover significant distortion in the reconstructed radial coordinate arising from the differing pulse shapes seen at each end of the wire-pair.

Effect of having two separate wires

The arrangement of resistances in a sense wire pair is sketched in figure ii.

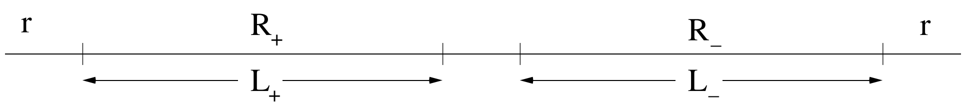

Figure ii Schematic diagram of Radial sense wire pair.

R_+, R_- are the resistances of the two sense wires, which can differ by 10% and L_+, L_- their lengths. r is the input impedance of the preamps, which are assumed to be the same. The radius of the hit on either wire is given by eqn 6;

$$R_{\pm} = R_{\pm}^{Inner} \pm \frac{L_{\pm}}{2R_{\pm}}(\Sigma\alpha + \Delta) \qquad [6]$$

α is as defined in eqn 3. The constants required are defined in eqn 7.

$$\begin{aligned} \Sigma &\equiv 2r + R_+ + R_- \\ &= (R_+ + R_-)\frac{L_{eff}}{L} \\ \Delta &\equiv R_+ - R_- \end{aligned} \qquad [7]$$

In the database we intend to keep the measured resistance and resistivity of each wire and $\frac{g_+}{g_-}$ and $\frac{L_{eff}}{L}$, which are measured by the test pulse program, from which we can derive the actual parameters used in the algorithm.

Lorenz Angle Correction

This is a large correction; with Ar/C_2H_6 50/50, our initial gas, the Lorenz angle is expected to be 45°. This produces a shift of up to 5 cm in the radial coordinate at the maximum drift distances at the outer radius of the chambers. To the precision we require however we can always assume that this shift is proportional to the drift distance. This correction can only be applied after the pattern recognition has resolved the left/right ambiguity.

Pulse Shape Effect

The assumptions leading to the use of charge division to derive the coordinate along the wire are only strictly true if the charge is integrated over several milliseconds (however the effects of the AC coupling in the FADCs would come into play were this in any case feasible). The two pulse shapes are affected by the differing L, C, R characteristics seen by the charge flowing out each end of the wire[1]. Integrating over differing time intervals results in differing amounts of distortion. The magnitude of this non-linearity is illustrated in figure iii for data taken with an X-ray source.

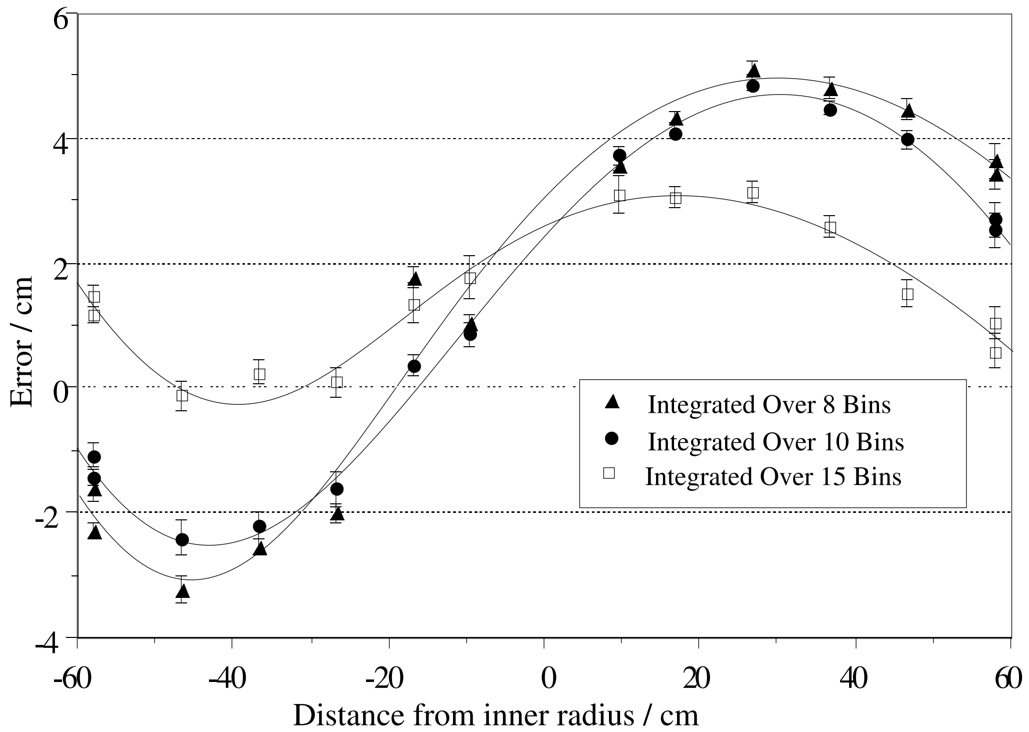

Figure iii Systematic charge division error as a function of position along the wire pair[2].

In order to make this tractable we integrate over a fixed number of FADC time slices (~12) and apply a polynomial correction. To first order this can be of fixed shape so that only two parameters are required. We can determine sufficiently accurate independent measurements of the radial coordinate by comparison with the planar chambers.

Geometry

The nominal geometry of the Radials is specified in the `FGAP` bank (this bank is also used in the simulation). The wire locations, defined by a nominal ϕ, Z, stagger in Rϕ and inner radius, are derived from this data. The deviations in ϕ, stagger and inner radius will be kept for each wire. We expect to be relatively insensitive to individual deviations in Z, and may not need to correct for these.

Gain Corrections for Particle Identification

The relative electronic gains are all that are required for track fitting. Particle identification, however, requires equalisation of the overall gain between different wires. There are two factors in this overall gain; the gas gain and the electronics gain. The test pulses yield $\frac{g_+}{g_-}$ and $g_+ . g_-$, the ratio and product of the electronics gain for each pair of preamp channels. The gas gain can only be determined from real data. In the long term we will need to track the gas gain at around the 1% level in order to fully exploit the particle identification potential. To start on the process of achieving this goal we must immediately correct for the grossest effects. The constants described below are all expected to depend on the specific operating conditions (gas mixture, HV settings…) at any one time.

Wire by Wire Calibration

The gain is exceptionally sensitive to any variation in the electron drift optics. The 285 μm sense wire stagger alone causes a 20 - 30% variation in gain. It will be necessary to calibrate for this on a wire-by-wire basis. Because of the wedge shaped drift cells we need to allow for radial dependences. We therefore envisage a minimum of 8 factors for each channel; for each side of each physical wire we specify the gain factor at the inner and outer radius. We initially assume a linear interpolation along each wire.

Temperature and Pressure

Also serious is the variation of gain with pressure and temperature. Typical diurnal temperature variations are 1 - 2°C, seasonal variations are of course much larger; moreover it is not unusual to see pressure variations of ~2% over a few hours. The gain variation with pressure is given by[3]:

$$\frac{\ln\,(\mathrm{G})}{K} = \Psi\left(\frac{\mathrm{E}_a}{\mathrm{P}}\right) \qquad [8]$$

where G is the gain, K is a constant of proportionality and Ψ is a function of $\frac{\mathrm{E}_a}{\mathrm{P}}$ where E_a is the electric field at the surface of the anode and P is the pressure. Assumption of ideal gas behaviour gives an equivalent equation for the temperature dependence. For small variations in gain this may be approximated by:

$$\frac{\Delta \mathrm{G}}{\mathrm{G}} = -\kappa\frac{\Delta \mathrm{P}}{\mathrm{P}} \qquad [9]$$

The observed gain variation for a set of 25 consecutive runs taken in test beam with a prototype Radial chamber over a period of 100 minutes is shown in figure iv. None of the chamber settings were altered during this period. Atmospheric pressure was monitored during these runs, and is also indicated on this graph. These give $\kappa \approx 25$.

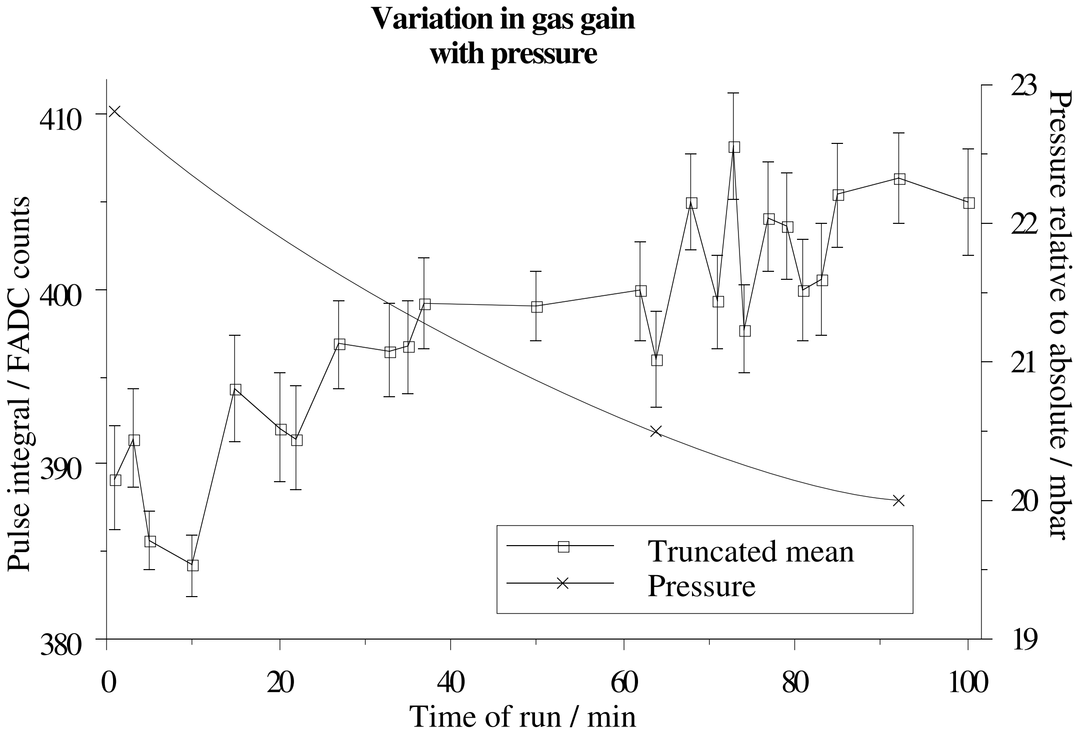

Figure iv Gain variation with pressure, Ar/C_2H_6 50/50.

Track Length

To first order this may simply be assumed to be a $\dfrac{1}{\cos\theta}$ effect.

Calibration Constants For The Radials

In summary we list the preliminary set of calibration constants that we envisage. The organisation of the constants within the database will be addressed at a later stage.

Overall Calibration Constants

T_0	time offset from test pulse trigger
$(D_+ - D_-)$	average difference in propagation delay down the signal cables and electronics
ΔT	average propagation time along the sense wires
V_D	drift velocity
D_0, D_1, D_2, C_0, C_1	constants for 'close to wire' correction

D_r	radius at which the trajectory of the electron swarm becomes approximately radial
α_L	Lorenz angle
ξ	magnitude of charge division distortion
ζ	scale of charge division distortion
`FGAP`	Nominal geometry bank
κ	temperature and pressure correction to gas gain.

Individual Calibration Constants

t_0	time offset relative to test pulse trigger
$(D_+ - D_-)$	difference in propagation delay down the signal cables and electronics
ΔT	propagation time along the sense wires
$\frac{g_+}{g_-}$	relative electronic gain
$g_+ . g_-$	electronic gain product
R_+, R_-	resistance of each sense wire
ρ_+, ρ_-	resistivity of each sense wire
$\frac{L_{eff}}{L}$	ratio of total resistance to resistance corresponding to active detector
R_+^{Inner}, R_-^{Inner}	inner radii of sense wires
G_+^i, G_-^i	8 gas gain parameters per wire pair.

Conclusions

There is no fundamental difference between the calibration constants required for the Radials and the CJC. The above list is in essence a super-set of the constants for the CJC that have already been outlined in [a].

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1 see for example V.Radeka & P.Rehak IEEE Trans. Nuc. Sci. NS-26 #1, 1979

2 Measurements carried out by D.Gillespie, Liverpool

3 see for example S P Beingessner, R K Carnegie and C K Hargrove, NIM A260 (1987) 210