The STAR TPC Pad Response Function

P.G. Jones and G. Rai
Lawrence Berkeley Laboratory

Abstract:
A study of the STAR TPC pad response function has been undertaken. Values for the contributions to the expected response width have been deduced from the literature. Two pad configurations, 8 x 12 mm^2 and 8 x 20 mm^2, have been considered.

Introduction:
The pad response function is approximately gaussian in shape with a characteristic width given by [1,2],

$$\sigma^2 = \sigma_o^2 + \sigma_D^2 \lambda \left(1 + \tan^2\alpha\right) + D^2 \left\{ \frac{1}{12} \left(\tan\alpha - \tan\beta\right)^2 + S_2 \tan^2\alpha \right\} \qquad (1)$$

where,

- λ - is the drift length (in meters)
- D - is the sense wire spacing (4 mm)
- β - is the Lorentz angle
- α - is the wire crossing angle
- $\sigma_2 = \Sigma_i \, i \, \omega_i$ - is the sum over wire weights ω_i (where $\Sigma_i \, \omega_i = 1$)

The three terms correspond to an intrinsic pad response σ_o, determined by the wire-pad geometry in the amplification region, a diffusion term σ_D and a term which accounts for the crossing angle of the track relative to the normal of the wire direction. The angular dependence in the diffusion term originates from the projection of the effective track width onto the sense wire. By ignoring E x B effects† , $\beta = 0$ and the third term reduces to,

$$\sigma_\alpha^2 \tan^2\alpha \qquad (2)$$

---

† The tanβ term accounts for the displacement of an electron trajectory along the sense wire due to the non-parallel E and B field components in the vicinity of the wire. The parameterization assumes a straight line approximation when in fact the actual v x B force is dependent on the local electrostatic field.

where,

$$\sigma_{\alpha}^{2} = D^{2}\left(\frac{1}{12} + S_{2}\right) \tag{3}$$

The intrinsic pad response, σ_o:
This has been measured by D.L. Fancher and A.C. Schaffer [3] for 8 x 8 mm^2 pads, using a wire-pad geometry similar to that proposed for the STAR TPC. Here the measured value of 0.362 cm was found to be in close agreement with a value obtained from the EOS simulation utilizing 8 x 12 mm^2 pads‡.

The diffusion term, σ_D:
The coefficient of the diffusion term may be written as,

$$\sigma_{D}^{2} = \frac{\sigma_{D}^{2}(0)}{\left(C + \omega^{2}\tau^{2}\right)} \tag{4}$$

where $\sigma_{D}^{2}(0)$ the free field single electron diffusion, ω is the electron cyclotron frequency, τ the mean collision time and C is a constant. A value of σ_D (0) = 0.0671 $cm^{1/2}$ was chosen, which is an intermediate value comparing the theoretical calculations of S.F. Biagi, et al [4] and experimental tests from the NA35 TPC [5] utilizing a P9 gas mixture at E = 113 V/cm. Biagi obtains excellent agreement between theory and various experimental data. The value of $\omega\tau$ was determined from the measurements made by S.R. Amendolia, et al [6], which yielded a value of $\omega\tau$ = 2.34 (B = 0.5 T) and C = 2.8. Inserting these values into equation (4) a value of σ_D = 0.233 cm per meter of drift was obtained.

The angular wire term, σ_α:
The final term in equation (1) arises from the fact that the pad response is broadened for inclined tracks, due to the effect of adding displaced gaussian distributions from the contributing wires. The functional form of the summation S_2 is derived simply from calculating the dispersion in the signals induced on the pad due to each sense wire. The weights measure the relative wire-to-pad couplings of the wires. This was deduced from the measurements of the pad response function for 8 x 8 mm^2

† Similar values were also obtained from the ALEPH and EOS prototypes, DELPHI and PEP4.

and 4 x 4 mm^2 pads by D.L. Fancher and A.C Schaffer [3], who measured the pad response both perpendicular and parallel to the direction of the sense wires. The results are consistent with an approximately gaussian response with equal width in the perpendicular and parallel directions. The pad response for an 8 x 12 mm^2 and 8 x 20 mm^2 pad may thus be built up from summing the contributions of an appropriate number of 8 x 8 mm^2 and 4 x 4 mm^2 pads. This procedure had already been undertaken for the 8 x 12 mm^2 pad case to calculate the response for the EOS TPC [7] and was calculated separately for the 8 x 20 mm^2 pads, also under consideration in this study. These values are summarized in table (1) together with other calculated and measured responses.

	σ_α (cm) 8 x 8 mm^2	σ_α (cm) 8 x 12 mm^2	σ_α (cm) 8 x 16 mm^2	σ_α (cm) 8 x 20 mm^2
G.L. [8]	0.415			
G.R. [9]	0.400	0.490†	0.567	0.632†
H.W. [7]		0.446		
P.J. - this study				0.637
DELPHI [10]	0.382			

†Result of simply scaling by the pad length, h. Scale factor = $\sqrt{\frac{h_2}{h_1}}$

Table (1): Summary of the values for σ_α for various pad sizes.

Summary:
The final values obtained for the coefficients of the three terms in the pad response function in equation (1) are listed in table (2).

	8 x 12 mm^2	8 x 20 mm^2
σ_o	0.362	0.362
σ_D	0.233	0.233
σ_α	0.446	0.637

Table (2): The final values for the coefficients of the pad response function for 8 x 12 mm^2 and 8 x 20 mm^2 pads.

References:

[1] R. Sauerwein, TPC-LBL-83-18

[2] H. Aihara, et al, IEEE NS-30(1983)76

[3] D.L. Fancher and A.C. Shaffer, IEEE NS-26(1979)150

[4] S.F. Biagi et al, NIM A283(1979)716

[5] R. Brockmann et al, GSI Annual Report 1989

[6] S.R. Amendolia et al, NIM A244(1986)516

[7] H. Wieman, EOS note

[8] G. Lynch, TPC-LBL-85-17

[9] G. Rai, EOS TPC simulations

[10] DELPHI note 85-56