The STAR TPC Pad Resolution Function

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Abstract:

A study of the STAR TPC pad resolution function has been undertaken. Values for the contributions to the expected uncertainty in space point reconstruction 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 resolution function is given by [1,2],

$$\sigma^2 = \sigma_A^2 + \sigma_B^2 \lambda e^{\gamma\lambda} \sec\alpha + \sigma_C^2 e^{\gamma\lambda} \cos\alpha \tan^2\alpha \qquad (1)$$

where,

λ- is the drift length (in meters)
α - is the wire crossing angle
$e^{\gamma\lambda}$ - is the inverse of an attenuation factor appearing in the denominator

The three terms correspond to an intrinsic resolution σ_A, determined by the signal-to-noise ratio on the pads, a diffusion term σ_B, and a term which accounts for the crossing angle of the track relative to the normal of the pad row. Experience with the EOS TPC has found the effect of attenuation, due to electron capture, to be negligible, whereby $\gamma \rightarrow 0$ and $e^{\gamma\lambda} \rightarrow 1$.

The signal-noise term, σ_A :
The effect on the spatial resolution due to electronic noise on the pads can be determined from the simple prescription of G. Lynch [3]. Here, the hit position is calculated from the pads with the two largest pulse heights. For a given x-position of the hit $\bar{x}$, the pulse height is determined from the gaussian response function,

$$h = Ae^{-(x-\bar{x})^2/2\sigma^2} \qquad (2)$$

where σ is the width of the pad response, x is the pad position and A is the maximum pulse height. For a hit at some point between two pads with centers x_1 and x_2 the hit position may be determined using,

$$\bar{x} = \frac{\sigma^2}{\Delta x} \ln\left(\frac{h_2}{h_1}\right) + \frac{x_1 + x_2}{2} \tag{3}$$

where Δx is the pad pitch (8 mm) and the uncertainty in $\bar{x}$ is then given by,

$$\delta\bar{x} = \frac{\sigma^2}{\Delta x}\left(\frac{\delta h_2^2}{h_2^2} + \frac{\delta h_1^2}{h_1^2}\right)^{1/2} \tag{4}$$

Arbitrarily setting A = 1 and assuming a signal-to-noise ratio of 20:1, $\delta h_2 = \delta h_1 = 0.05$. The best resolution is obtained when the track crosses between the two pads, whereupon the calculated resolution, assuming $\sigma = 0.362$ cm [4], is 213 μm. In the worst case scenario when the hit is centered above one pad, the resolution deteriorates to 949 μm. However, if a three pad hit was registered, this would considerably improve the resolution [3]. In this case the resolution would be approximately 666 μm.

The diffusion term, σ_B:
The coefficient of the diffusion term may be written as [1],

$$\sigma_B^2 = \frac{\sigma_D^2}{N_O} \tag{5}$$

where σ_D is the coefficient of the diffusion from the pad response function [4] and N_O is the total number of electrons liberated along the pad length. For a P9 gas mixture at atmospheric pressure the mean ionization for a minimum ionizing particle is 100 electrons per cm [5]. Thus for 20 mm and 12 mm pads the value of σ_B was calculated to be 166 μm and 213 μm respectively.

The angular wire term, σ_C:
This term has been measured in the case of PEP4 [1], with B = 0.4 T, E = 15 kV/m using a P20 gas mixture at atmospheric pressure. Here, a value of $\sigma_C(8 \times 8\ mm^2) = 665 \pm 25$ μm was reported. Scaling this value by the pad length, calculated

values of σ_C for 20 mm and 12 mm long pads are 1663 μm and 998 μm respectively. ALEPH identify this term as the angular pad effect [5],

$$\sigma_C^2 = \frac{h^2}{12N_{eff}} \tag{6}$$

where h is the pad length and N_{eff} is the effective number of electrons per unit length sampled by the wire. The value of N_{eff} depends on diffusion which provides a declustering effect for ionization fluctuations along the track. Equation (6) justifies the simple scaling assumption applied to the PEP4 data. Furthermore, using the measured result from the ALEPH prototype TPC-90, it can be shown that a suitable number for N_{eff} is $N_{eff} = 12$. Inserting this value into equation (6), σ_C for 20 mm and 12 mm long pads is found to be 1667 μm and 1000 μm respectively. These values agree with those derived from scaling the PEP4 measurements above.

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

	8 x 12 mm^2	8 x 20 mm^2
σ_A (μm)	440†	440†
σ_B (μm)	213	166
σ_C (μm)	999	1665

† Average value

Table (1): Summary of the final values obtained for the coefficients in the pad resolution 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] G. Lynch, TPC-LBL-78-17

[4] P.G. Jones and G. Rai, STAR note 33

[5] ALEPH Handbook, ALEPH 89-77