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MOMENTUM SMEARING AND FALSE TRIGGER RATES IN A SCINTILLATING FIBER TRACKING TRIGGER

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Abstract

Simple analytical expressions are derived for the accidental rates and threshold curve for the trigger in a barrel tracking system. They are evaluated using the present design for the SDC scintillating fiber tracking system.

Introduction

One of the important performance requirements for the SDC outer tracking system is to provide a trigger signalling the presence of tracks with transverse momentum above a trigger threshold around 10 Gev/c. This information is then combined with that from the calorimeter or muon system to indicate the presence of a stiff electron or muon. The performance of the trigger is characterized in terms of its efficiency and false trigger rate. Here we consider two sources of false triggers and estimate them from the positions, granularities and occupancies of the trigger layers.

The trigger is formed by measuring phi in two or more tracking layers requiring that each layer have a hit along a stiff road from the beam line. One source of background is accidental overlaps where hits from different tracks accidentally line up to make such a road. Another source is smearing where, due to the finite width of the road, a track with momentum below the threshold cannot be distinguished from one above. Of course, it is possible to envision more complex scenarios in which the two effects are combined or other correlations are taken into account. We do account for these and emphasize that the simplistic calculations here should be backed up with detailed Monte Carlo simulations.

Barrel Trigger

The simplest way to form a tracking trigger is to use a series of concentric barrels each providing a measurement of phi. We assume the track comes from the beam line ($r = 0$) and obtain the following to a very good

approximation:

$$phi(r) - phi0 = 0.5 * C * r$$

where r and phi are polar coordinates. Here C is the curvature which can be expressed in terms of the transverse momentum C = K / pT where K = 0.006 GeV/c/cm for a 2 Tesla field. We assume there are N such layers with radii r1, r2, ..., rN and each is broken up into phi-bins of width dphi1, dphi2, ..., dphiN. We denote the fraction of occupied bins (occupancy) by o1, o1, ... oN. The trigger is characterized by the mininum transverse momentum pTmin or equivalently a maximum curvature Cmax = K /pTmin. Note that the momentum threshold pTmin = 10 Gev/C corresponds to Cmax = 0.0006 /cm.

Accidental Overlaps

We begin by calculating the number of accidental overlaps between the inner and outer layers. The number of occupied bins in layer 1 is n1 = o1*(2*pi)/dphi1. In order for hits in layers 1 and N to lie along a stiff road we must have

$$phi1 - phiN < 0.5\ Cmax\ (r1 - rN)$$

and we must consider a phi range twice this size to allow for either charge. This implies we must consider a phi-range of Cmax*(r1-rN) in the outer layer. This corresponds to Cmax*(r1-rN)/dphiN bins of which oN*Cmax*(r1-rN)/dphiN are occupied on average. Thus the total number of trigger candidates from layers 1 and N alone is

$$R1N = o1*2*pi/dphi1\ oN*Cmax*(r1-rN)/dphiN$$

$$= \frac{2\ pi\ Cmax\ (r1-rN)}{dphi1\ dphiN}\ o1\ oN.$$

The inner and outer layers define the road and any intermediate layers are used to confirm the track. We assume that 2 bins must be considered in each intermediate layer and find the probability for a confirmation is twice the occupancy. Thus, the number of false triggers/crossing using all N layers is

$$Rtrig = \frac{2**(N-1)\ pi\ Cmax\ (r1-rN)}{dphi1\ dphiN}\ o1\ o2\ ...\ oN.$$

In many of the systems considered, the bin size is fixed in r*phi and it is convenient to introduce w = r * dphi as the bin size. In this case our expression becomes

$$Rtrig = 2**(N-1)\ pi\ Cmax\ \frac{r1\ rN\ (r1-rN)}{w**2}\ o1\ o2\ ...\ oN.$$

Accidentals in the Scintillating Fiber Barrel

As an example we consider the current design for the scintillating fiber tracking system as discussed in the scifi CDR [1] and a previous SDC note [2]. There are a total of five layers with radii and occupancies indicated in table 1. The occupancies here are those from the mininum bias background and were obtained by subtracting Higgs from Higgs plus background in reference 2. We assume that the trigger bin size will be the same as the fiber spacing (870 um) and will have the same occupancy as the fibers. Two triggers are defined -- one which uses only layers 3, 4 and 5 and another which uses all five layers. Using the above formula we obtain rates of R345 = 0.194 and R12345 = 0.00034 triggers/crossing. These value are for design luminosity: L0 = 10**33 /cm**2/sec. Since the occupancy scales with the luminosity, we find these rates scale with the Nth power of the luminosity:

R345 = 0.19 (L/L0)**3

R12345 = 0.00034 (L/L0)**5

giving values of R345 = 24 and R12345 = 5.3 at L = 5*10**33.

	r (cm)	occupancy
1	165.2	0.0017
2	135.3	0.0030
3	107.4	0.0062
4	91.5	0.0094
5	75.5	0.0129

Table 1. Radii and design luminosity occupancies for the proposed scifi tracking system.

The above values are the number of accidental triggers/crossing in each half of the proposed scifi system. We are interested in the rate of accidental triggers/crossing/(trigger bin). The numbers of trigger bins and their connection to the tracking system are discussed in reference 3. Here we repeat their values: the calorimeter barrel is broken up into 64 phi towers and the tracker is expected to provide 4 bits of phi information to match the granularity of the shower max system (1024 phi bins). In the present plan, the shower max system is not present in the trigger and so our accidental rate must be small compared to 64 if the trigger is to be useful. In an upgraded system using the shower max and allowing the tracker to pass more than one trigger to a calorimeter tower, 1024 becomes the relevant value.

Occupancy Fluctuations

The above estimate assumed that the occupancy was constant from crossing to crossing or at least not correlated between layers. In reality we expect significant variations in the occupancy with very strong correlations between

layers. This is significant because the false trigger rate is proportional to all of the occupancies and if the occupancies are all increased by some factor for some of the crossings, then the accidental rate will be increased by the Nth power of that factor during those crossings.

We can estimate the size of this effect with a simple model. Assume that the occupancies all increase or decrease by the same factor F each event and that this factor varies uniformly form zero to two. This is roughly consistent with spectra observed from single events in Pythia/GEANT simulation runs. Then the average occupancy will be increased by a factor <F**N>/<F>**N = <F**N> where again N is the number of layers. In our simple model, the occupancy is increased by a factor

$$\langle F^{**}N\rangle = \frac{2^{**}N}{N+1}$$

which gives 2.0 for a 3-layer trigger and 5.3 for a five-layer system. We expect the occupancy variations and consequently this factor to decrease somewhat as the luminosity is increased.

Momentum Smearing

Next we consider the effects of momentum smearing due to the finite resolution of the trigger system. The effect is described in terms of a trigger threshold curve which gives the efficiency as a function of pT. Here we develop a simple formula which expresses this curve in terms of a single parameter which depends on the geometry and momentum threshold.

We assume that the inner and and outer layers of the trigger system determine the momentum resolution. This will generally be the case unless the intermediate layers have significantly better position resolution than the first or last. We demand that the trigger be fully efficient for pT > pTmin, i.e. for dphi < dphimax where dphi is the change in phi between the two layers and dphimax is the change in phi for a track with the threshold momentum:

$$\mathrm{dphimax} = 0.5\ \mathrm{Cmax}\ (\mathrm{r1}-\mathrm{rN})$$

$$= \frac{(0.003\ \mathrm{GeV/c/cm})\ (\mathrm{r1}-\mathrm{rN})}{\mathrm{pTmin}}\ .$$

In order to get full efficiency, we must allow for fluctuations of one half the bin size in each layer, i.e. we must accept |dphi| < dphimax + sphi/2 where

$$\mathrm{sphi} = \mathrm{dphi1} + \mathrm{dphiN}\ .$$

Again dphi1 and dphiN are the bin sizes in the two layers. This results in the following distribution for the efficiency:

$$
\mathrm{eff} = \begin{cases} 1 & \mathrm{dphi} < \mathrm{dphimax} \\ 1 + \dfrac{\mathrm{dphimax} - \mathrm{dphi}}{\mathrm{sphi}} & \mathrm{dphimax} < \mathrm{dphi} < \mathrm{dphimax} + \mathrm{sphi} \\ 0 & \mathrm{dphi} > \mathrm{dphimax} + \mathrm{sphi} \end{cases}
$$

which can be expressed in terms of the momentum:

$$
\mathrm{eff} = \begin{cases} 0 & \mathrm{pT} < \mathrm{pTmin}/(1+\mathrm{Rphi}) \\ 1 + \dfrac{1}{\mathrm{Rphi}} \left(1 - \dfrac{\mathrm{pTmin}}{\mathrm{pT}} \right) & \mathrm{pTmin}/(1+\mathrm{Rphi}) < \mathrm{pT} < \mathrm{pTmin} \\ 1 & \mathrm{pT} > \mathrm{pTmin} \end{cases}
$$

where the characteristic parameter Rphi is defined by

$$
\mathrm{Rphi} = \mathrm{sphi} / \mathrm{dphimax}
$$

$$
= \frac{\mathrm{dphi1} + \mathrm{dphiN}}{(0.003\ \mathrm{GeV/c/cm})\ (\mathrm{r1} - \mathrm{rN})}\ \mathrm{pTmin}\ .
$$

Figure 1 shows the trigger threshold curve for different values of Rphi.

We calculate Rphi for the scintillating fiber trigger discussed above and find Rphi = 0.21 for the three-layer trigger and Rphi = 0.06 for the trigger using all barrels. Comparing with figure 1, we see that the threshold is quite sharp for the latter case and still good for the three-layer system. In order to calculate trigger rates due to momentum smearing, the trigger threshold must be folded with a charged particle spectrum. We generated 100 Pythia mininum bias events and found only three tracks with pT btween 8 and 10 GeV/c integrated over all eta. From this, we conclude that, even with the three-layer trigger, the false track rate at design luminosity will be less than 0.01/crossing which is small compared to the accidental rate discussed above.

Trigger resolution is also important for momentum matching at the calorimeter and muon systems. This is beyond the scope of our discussion here but we point out that the sharp trigger threshold curves imply that this resolution is quite good at 10 GeV/c. We expect to get useful information from the trigger as long as pT is at or below the characteristic momentum pT0 = pTmin / Rphi which depends only on the geometry. This value is 160 GeV/c for the full scifi system and 50 GeV/c for three-layer trigger.

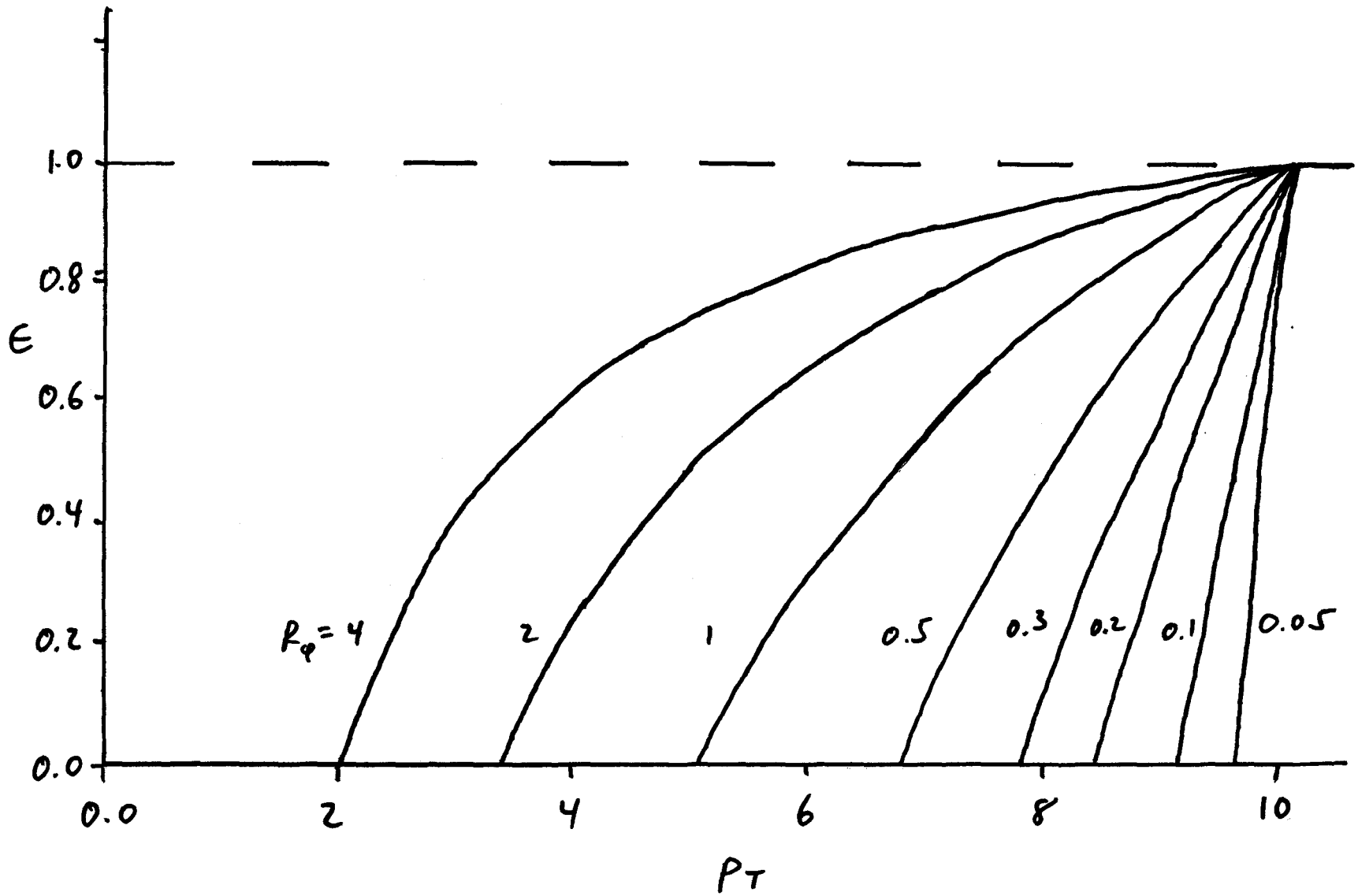

Fig 1. Trigger Efficiency as a function of p_T for various values of R_φ.

References

1. Outer Tracker Conceptual Design Scintillating Fiber Option, SDC, Nov. 1991

2. D. L. Adams, G. Eppley and J. Skeens, "Pattern Recognition in a Silicon and Scintillating Fiber SDC Tracking System", SDC-91-[redacted], Nov 1991.
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3. A. Lankford et al., "Conceptual Design of the SDC Trigger from the SDC Trigger Group", SDC-91-00098, Sep. 1991.