Real Photon Collaboration Technical Note RPC-2
8 Mar, 2001

TRACKING BACKGROUND

Tex file in ~ser/coherent_photon_beam/daq/tracking_background.tex by Steve Rock

Abstract

I have studied the effects of background sprinkle hits on tracking. I calculated the number of garbage tracks reconstructed as a function of the background (sprinkle) hits. I recommend 9 planes followed by lead absorber followed by 1 coarse plane.

METHOD

The detector consisted N planes of hodoscopes. The total number of fingers is fixed at 960 as in the proposal. More planes means fewer fingers per plane. For each accelerator burst, each finger was given sprinkle hits distributed randomly in time over the specified spill length. The number of hits in each finger was Poisson distributed about a mean rate. Probabilities were assigned to each hit from the Poisson distribution. For purposes of tracking the detector was divided into 4 quadrants and I assumed that tracks would stay in one quadrant (not quite correct). I looked for tracks in time windows of 3ns full width. (For a 300 ns spill length, there were 100 time windows). This underestimates the tracks since there could be tracks lost on the time window boundaries. In each time window, The probability of finding a track was the product of probabilities of there being a hit on at least N-1 of the planes. We cannot require all N planes because the efficiency for real tracks would be very small.

RESULTS

Table 1. is a summary of the results for selected values of number of planes (N), spill length and total hits/plane. The proposal has 6 fine grained planes and I assume that the mean number of sprinkle hits are the same in each plane, regardless of position or the number of fingers. Hence the same background would give 2 hits/finger for 12 planes and 1 hit/finger for 6 planes. No position information is used in Table 1. For a 400ns spill, 160 hits/plane, and 6 planes, the track rate is 16. This is very high. For 9 (12) planes and the same number of hits/plane there are 0.73 (0.024) tracks respectively.

TABLE 1 –<u>N Planes, N-1 required for track. Timing only.</u>

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Tue Mar  6 09:36:40 2001
(PROGRAM  ~ser/coherent_photon_beam/daq/random_tracking.cc
(TRACKING FROM RANDOM HITS IN  6 PLANES OF  160 FINGERS EACH
(TRACKING FROM RANDOM HITS IN  9 PLANES OF  107 FINGERS EACH
(TRACKING FROM RANDOM HITS IN 12 PLANES OF  80 FINGERS EACH
(TOF CUTS = 3.0 FULL WIDTH
(TRACKS REQUIRE  N-1  PLANES
(DISTRIBUTION OF HITS IS POISSON, WITH MEAN/FINGER LISTED IN TABLE.
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Spill Length=300.

	6 planes			9 planes			12 planes		
		finger			finger			finger	
tot_hits/ plane	tot hits	mean rate	tracks/ spill	tot hits	mean rate	tracks/ spill	tot hits	mean rate	tracks/ spill
80	480	0.5	2.59	720	0.8	0.036	960	1.0	.00034
160	960	1.0	35.1	1440	1.5	3.92	1920	2.0	0.311
240	1440	1.5	141.	2160	2.3	49.9	2880	3.0	11.85
320	1920	2.0	357.	2880	3.0	268	3840	4.0	130.4
480	2880	3.0	1308	4320	4.5	2192	5760	6.0	1174

Spill Length=400.

tot_hits/ plane	tot hits	mean rate	tracks/ spill	tot hits	mean rate	tracks/ spill	/ tot hits	mean rate	tracks/ spill
80	480	0.5	1.22	720	0.8	0.0076	960	1.0	0.00004
160	960	1.0	16.1	1440	1.5	0.729	1920	2.0	0.0240
240	1440	1.5	70.3	2160	2.3	10.8	2880	3.0	1.15
320	1920	2.0	93.8	2880	3.0	63.5	3840	4.0	13.6
480	2880	3.0	666.	4320	4.5	550	5760	6.0	137

Spatial Rejection

Sprinkle hits that are in time, must also form a straight line to be considered a track. Let us divide the number of planes so that 1/3 of the planes are vertical (non-bend plane) and 2/3 bend plane measuring (horizontal). Almost all the tracks have N-1 and only N-1 planes on a track (rarely are there N planes on a track). Spatially, we can require that the vertical (non bend plane) tracks head back toward the target making an additional hit. Assume a resolution of RF fingers or RF/nfinger where nfinger = 240/N for a quadrant with 960/4=240 fingers.. This gives a fractional resolution of N*RF/240. For N planes, there are N/3 +1 vertical positions if all the planes have a hit and N/3 - 1 must be on the line determined by the other two. This becomes N/3-2 if one vertical plane is missing. This gives a rejection of (N*RF/240)**(N/3-1-MV), where MV is the number of missing vertical planes (0 or 1).

In the bend plane, The rejection factor becomes (N*RF/240)**(2N/3 -2 -MH). The combined rejection is (N*RF/240)**(N-4) since MV+MH=1. Table 2 shows the inverse of this rejection factor as a function of the number of planes and the resolution. There are additional factors coming from unphysical angle/positions.

TABLE 2 –Spatial rejection factor. Requiring straight line thru detector. RF is the resolution in fingers.

RF	6 planes	7 planes	9 planes	12 planes
2	400	5E3	4E5	1E8
3	180	1.5E3	5E4	4E6
4	100	600	1E4	4E5

The total rejection is a product of timing and spatial effects. Table 3 is a summary of this product in the mean case of RF=3 with a spill of 400 ns. The symbol * indicates that the rate/finger is less than about 3 and hence the tracking efficiency due to dead-time is greater than 90%. (see Technical Note RPC-1). This corresponds to about 3000 total hits/spill.

TABLE 3. –Tracks/Spill after spatial rejection assuming track resolution of 3 tracks and a 400 ns spill. The symbol * indicates that the rate/finger is less than about 3.

tot_hits/ plane	6 planes tracks	9 planes tracks	12 planes tracks
80	* 0.0069	* 1.4e-07	* 7.8e-12
160	* 0.091	* 1.3e-05	* 6.2e-09
240	* 0.4	* 0.00019	* 2.9e-07
320	* 1.1	* 0.0011	3.5e-06
480	* 3.7	0.0099	3.5e-05

Hence the example for 6 planes and 16 tracks is reduced to 0.09/spill for a finger resolution (RF) of 3 counters. For 9 (12) planes), the tracks are reduced to 1.3E-5 (6E-9). This compares to about 0.014 high $P_T\mu$ (150K/day) in the E161 proposal. For signal to background to be less than 1% the tracks/spill should be less than 1.4E-4 which is just missed by 9 planes with 240 hits/plane.

TABLE 4. –-Example of 9 planes. Random Tracks/Spill before and after spatial rejection, assuming track resolution of 3 tracks and a 400 ns spill. Four real tracks/spill are included and the effeciency for reconstruction is shown in the last column. Ineffeciency is caused by a deadtime of the TDCs of 11 ns.

Spill Length= 400 ns

(tot_hits/ (plane	tot hits	mean rate	random tracks/ spill	space_rej tracks	real tracks
80	720	0.8	0.00079	1.4e-08	0.99223
160	1440	1.5	0.16607	3e-06	0.98208
240	2160	2.3	3.33696	6e-05	0.97134
320	2880	3.0	26.78729	0.00048	0.96491
480	4320	4.5	418.05334	0.0075	0.96275

Non Uniform Background Hits

The results above assume that all planes are illuminated equally with sprinkle hits. However, if the background changes with z position, the reconstruction of random tracks might be differnent. I have varied the distribution of background hits keeping the same approximate total number of hits. The planes were divided into 5 noisy planes in "front" and 4 quieter planes "behind". Two cases were considered: a) when the front planes had twice as many hits as the back planes and b) when the front planes had 7 times as many hits as the back planes. Figure 1. shows the number of reconstructed tracks as a function of total hits in all the planes for these two case and for the standard case of equal number of hits in each plane. The secwed distribution results in fewere tracks, because the back planes are relatively quiet. No deadtime was considered.

CONCLUSIONS

Six planes of counters are insufficient to reject random tracks from sprinkle hits. Nine planes can handle up to 240 hits/plane, which is 50% more than the proposal value of 167 (1000 hits over 6 planes) with a rejection sufficient to give about 1% AVERAGE background. The background will be higher at high P_T. The total hits would be 2000/spill. Twelve planes gives several orders of magnitude better rejection at a cost of more total hits (3000) and lower tracking efficiency. A compromise is to have 9 planes (107 fingers/plane) replacing the 6 in the proposal, with a 10th, perhaps less granular plane behind lead absorber as shown as the 7th plane in the proposal. This would have lower rate and add perhaps an extra order of magnitude rejection. For E161, A possible size of each finger is shown in Table 5. This numbers match the model assumption of equal number of fingers per plane. It does not meet the requisite resolution in some cases.

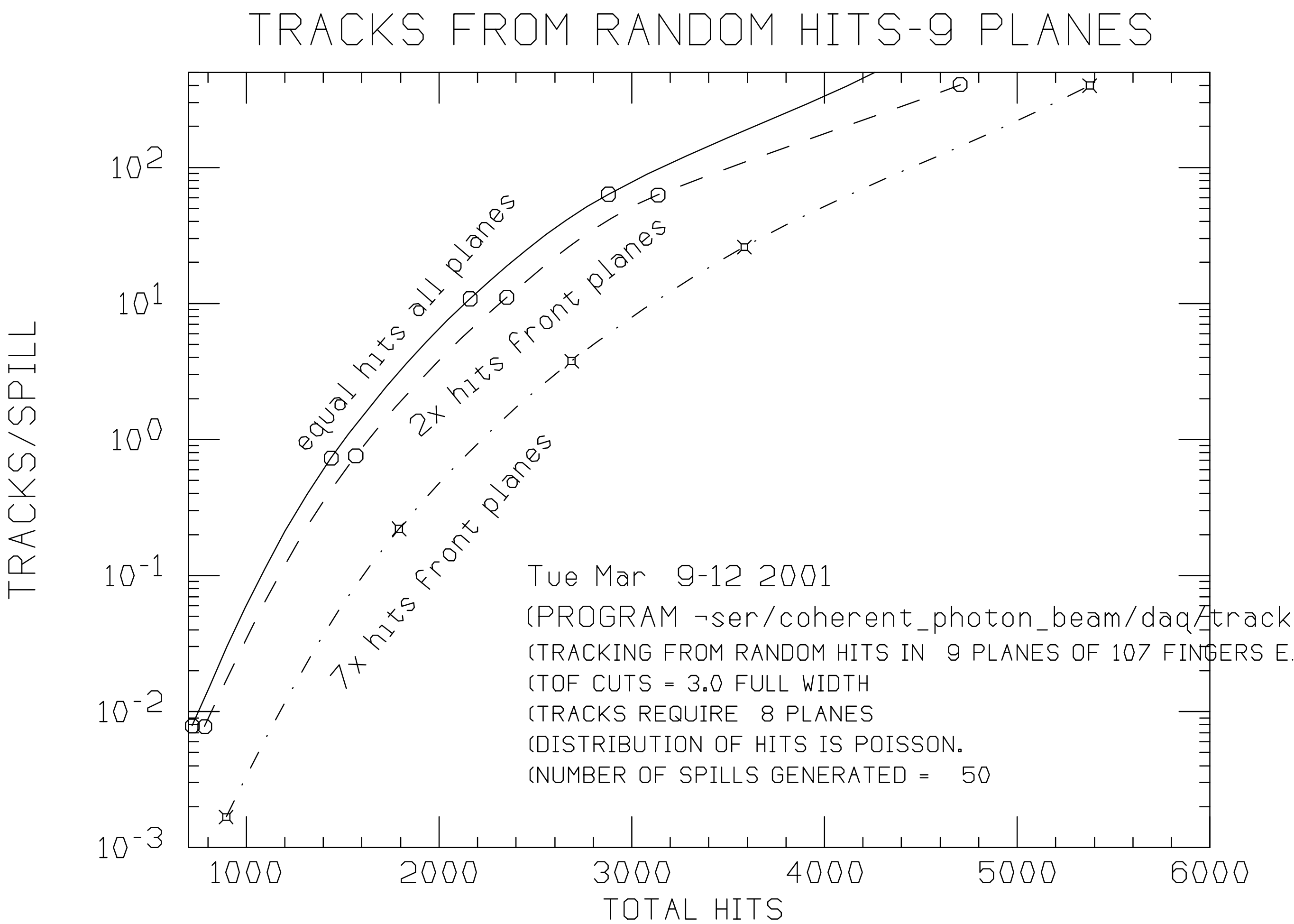

Figure 1: Number of Random Tracks reconstructed as a function of total number of sprinkle hits in the entire detector for three different distributions of hits in the planes

Table 5 –Possible finger size for the 9 fine grained planes, grouped into 2 superplanes as in the proposal.

(Taken from Table 3 of E161 proposal)

Plane Group	measure	number planes	length	finger width	fingers/ plane	resoluton(FW)/ proposal
1	x(+/-55 cm)	2	+/-55	2 cm	110	1 cm/2cm
	y(+/-55 cm)	3	+/-55	2 cm	110	.7 cm/.7cm
2	x(+/-90)	1	+/-75	3 cm	120	3 cm/2cm
	y(+/-75)	3	+/-90	2.5	120	.8 cm/.7cm

DAQ REQUIREMENTS

The calculations show that we should be able to handle up 2000 hits/spill with sufficient background rejection. To be on the safe side, and to be able to accomodate higher background rates or better resolution, we request a safety margin of 50% leading to a request for the DAQ to be able to handle 3000 TDC hits/spill leading edge only.