E160 Technical Note RPC-14

Backgrounds in hodoscopes in E160 spectrometer design with the D3 magnet

Piotr Decowski, Smith College

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The results presented in this note simulate the following situation:

- The spectrometer is made out of the E158 D3 magnet (length along z axis 3.45 m, magnetic field 22 kGs, in the system of coordinates that was used the magnet extends from z = -380 cm to -35 cm) filled with 3.45 m thick alumina absorber. The first hodoscope plane is placed at the distance of 1 m from the magnet (z = 65 cm), the second plane is 2 m farther (z = 265 cm). Inside the magnet the beam goes through a collimator defining aperture and minimizing background in hodoscopes caused by interactions of gamma rays Compton scattered in the target. The details of the collimator are shown in Fig.1. Outside of the magnet the beam is confined within an aluminum pipe with ID 7 cm, shielded by 1.5 cm thick layer of lead.

- The realistic flux of $4 * 10^8$ bremsstrahlung photons (about 1/2 of expected number of photons/spill), produced in a diamond irradiated by 45 GeV electrons, interacts with a 1.2 b^{-1} target placed at the beginning of the magnet (files with all interaction products having p_z larger than 1 GeV were provided by Peter Bosted). Two versions of gamma flux were used: with main coherent peak at 15 GeV ('tune 1') and at 25 GeV ('tune2'). In total tunes 1 and 2 yielded 172513 and 110699 particles, respectively.

- The x-y dimensions of the hodoscope planes were 55*55 cm^2 and 80*80 cm^2 for plane 1 and 2, respectively. To assess backgrounds caused by secondary interactions in the hodoscopes, the simulations were performed for four different thicknesses of the scintillator planes: 0.5 cm, 1 cm, 2 cm and 3 cm. The active area of hodoscopes starts at radius larger than 5 cm.

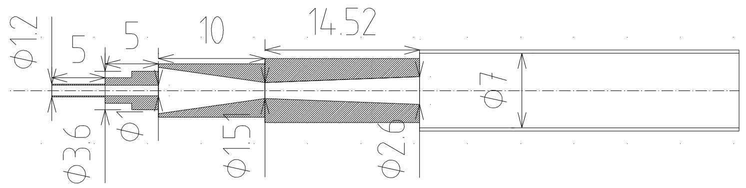

Figure 1: Drawing of the collimator placed inside of the alumina absorber. The scale along the collimator axis is compressed by factor of 10, it means that numbers represent 10 cm units, along the radius numbers are in 1 cm units.

The analysis of the results focused on the number of hits in hodoscope planes. They can be divided into two categories: hits caused by particles leaking through the alumina absorber or through the collimator ("track hits") and hits induced by interactions in the hodoscopes and in material surrounding them ("sprinkle hits"). The easy way to separate two kinds of hits is by setting condition on z of track origin: $z_{or} > 60$ cm selects almost exclusively sprinkle hits.

The Tables below show total numbers of charged particles and gammas passing hodoscope planes. Though gammas do not produce direct hits, their number should be kept as small as possible because of chance of secondary interactions in the planes.

Tune 1:

Hod. plane	Plane thickness	Charged particles	Gammas
1	0.5 cm	19	110
1	1.0 cm	64	192
1	2.0 cm	89	298
1	3.0 cm	88	163
2	0.5 cm	8	58
2	1.0 cm	10	84
2	2.0 cm	29	160
2	3.0 cm	24	60

Tune 2:

Hod. plane	Plane thickness	Charged particles	Gammas
1	0.5 cm	64	308
1	1.0 cm	76	318
1	2.0 cm	97	309
1	3.0 cm	116	306
2	0.5 cm	11	128
2	1.0 cm	32	159
2	2.0 cm	42	163
2	3.0 cm	68	153

It is clearly seen that the number of background hits increases with plane thickness. However, if sprinkle hits would deposit small amount of energy in the planes, it could be profitable to use thicker planes to enhance signal amplitude of passing muons versus background hits.

The following Tables present detailed inventory of background hits sorted according to the particle type and origin (sprinkle hits or track hits originating in the magnet/absorber volume). Average kinetic energies and average energy losses in hodoscope plnes are expressed in MeV.

Tune 1, Electrons:

Origin	Hod. plane	Thickness	Hits	$<E_k>$	$<E_{loss}>$
Sprinkle	1	0.5 cm	0		
Track	1	0.5 cm	0		
Sprinkle	1	1.0 cm	24	32.9	4.63
Track	1	1.0 cm	0		
Sprinkle	1	2.0 cm	32	66.3	5.36
Track	1	2.0 cm	3	489	5.50
Sprinkle	1	3.0 cm	16	4.17	3.61
Track	1	3.0 cm	0		
Sprinkle	2	0.5 cm	1	2.18	1.18
Track	2	0.5 cm	0		
Sprinkle	2	1.0 cm	0		
Track	2	1.0 cm	0		
Sprinkle	2	2.0 cm	10	152	4.05
Track	2	2.0 cm	0		
Sprinkle	2	3.0 cm	2	1.65	
Track	2	3.0 cm	0		

Tune 1, Muons:

Origin	Hod. plane	Thickness	Hits	$<E_k>$	$<E_{loss}>$
Sprinkle	1	0.5 cm	0		
Track	1	0.5 cm	3	19900	
Sprinkle	1	1.0 cm	0		
Track	1	1.0 cm	6	8750	1.61
Sprinkle	1	2.0 cm	0		
Track	1	2.0 cm	5	10750	2.53
Sprinkle	1	3.0 cm	0		
Track	1	3.0 cm	3	14580	3.60
Sprinkle	2	0.5 cm	0		
Track	2	0.5 cm	3	19900	1.79
Sprinkle	2	1.0 cm	0		
Track	2	1.0 cm	1	28500	1.68
Sprinkle	2	2.0 cm	0		
Track	2	2.0 cm	3	14750	4.35
Sprinkle	2	3.0 cm	0		
Track	2	3.0 cm	2	14500	5.87

Tune 1, Pions:

Origin	Hod. plane	Thickness	Hits	$<E_k>$	$<E_{loss}>$
Sprinkle	1	0.5 cm	0		
Track	1	0.5 cm	5	1715	0.70
Sprinkle	1	1.0 cm	0		
Track	1	1.0 cm	6	1408	1.96
Sprinkle	1	2.0 cm	0		
Track	1	2.0 cm	13	2182	3.63
Sprinkle	1	3.0 cm	0		
Track	1	3.0 cm	8	4825	5.22
Sprinkle	2	0.5 cm	0		
Track	2	0.5 cm	0		
Sprinkle	2	1.0 cm	0		
Track	2	1.0 cm	1	2225	1.73
Sprinkle	2	2.0 cm	0		
Track	2	2.0 cm	2	1340	3.80
Sprinkle	2	3.0 cm	0		
Track	2	3.0 cm	2	9900	7.10

Tune 1, Protons:

Origin	Hod. plane	Thickness	Hits	$<E_k>$	$<E_{loss}>$
Sprinkle	1	0.5 cm	9	1.02	1.02
Track	1	0.5 cm	2	303	1.76
Sprinkle	1	1.0 cm	22	7.50	5.70
Track	1	1.0 cm	2	530	2.22
Sprinkle	1	2.0 cm	30	1.17	1.17
Track	1	2.0 cm	3	196	12.8
Sprinkle	1	3.0 cm	55	1.61	1.61
Track	1	3.0 cm	2	380	24.3
Sprinkle	2	0.5 cm	4	0.72	0.72
Track	2	0.5 cm	0		
Sprinkle	2	1.0 cm	8	0.59	0.59
Track	2	1.0 cm	0		
Sprinkle	2	2.0 cm	12	1.00	1.00
Track	2	2.0 cm	0		
Sprinkle	2	3.0 cm	17	0.76	0.76
Track	2	3.0 cm	0		

Tune 2, Electrons:

Origin	Hod. plane	Thickness	Hits	$<E_k>$	$<E_{loss}>$
Sprinkle	1	0.5 cm	5	29.2	5.6
Track	1	0.5 cm	0		
Sprinkle	1	1.0 cm	17	7.12	2.40
Track	1	1.0 cm	0		
Sprinkle	1	2.0 cm	28	46.6	3.63
Track	1	2.0 cm	0		
Sprinkle	1	3.0 cm	47	14.4	5.36
Track	1	3.0 cm	3	110	11.6
Sprinkle	2	0.5 cm	1	1.28	
Track	2	0.5 cm	0		
Sprinkle	2	1.0 cm	23	10.3	2.27
Track	2	1.0 cm	0		
Sprinkle	2	2.0 cm	23	14.4	4.13
Track	2	2.0 cm	0		
Sprinkle	2	3.0 cm	39	13.0	8.32
Track	2	3.0 cm	0		

Tune 2, Muons:

Origin	Hod. plane	Thickness	Hits	$<E_k>$	$<E_{loss}>$
Sprinkle	1	0.5 cm	0		
Track	1	0.5 cm	6	8333	1.06
Sprinkle	1	1.0 cm	0		
Track	1	1.0 cm	2	9570	1.69
Sprinkle	1	2.0 cm	0		
Track	1	2.0 cm	11	8205	3.39
Sprinkle	1	3.0 cm	0		
Track	1	3.0 cm	5	12740	5.65
Sprinkle	2	0.5 cm	0		
Track	2	0.5 cm	1	12250	0.97
Sprinkle	2	1.0 cm	0		
Track	2	1.0 cm	0		
Sprinkle	2	2.0 cm	0		
Track	2	2.0 cm	3	12750	4.15
Sprinkle	2	3.0 cm	0		
Track	2	3.0 cm	2	12750	6.10

Tune 2, Pions:

Origin	Hod. plane	Thickness	Hits	$<\mathrm{E}_k>$	$<\mathrm{E}_{loss}>$
Sprinkle	1	0.5 cm	0		
Track	1	0.5 cm	16	2850	3.26
Sprinkle	1	1.0 cm	0		
Track	1	1.0 cm	7	5957	1.86
Sprinkle	1	2.0 cm	0		
Track	1	2.0 cm	8	2013	7.93
Sprinkle	1	3.0 cm	0		
Track	1	3.0 cm	6	2433	7.06
Sprinkle	2	0.5 cm	0		
Track	2	0.5 cm	3	11030	0.93
Sprinkle	2	1.0 cm	0		
Track	2	1.0 cm	2	13050	2.14
Sprinkle	2	2.0 cm	0		
Track	2	2.0 cm	1	3050	
Sprinkle	2	3.0 cm	0		
Track	2	3.0 cm	14	1088	14.4

Tune 2, Protons:

Origin	Hod. plane	Thickness	Hits	$<\mathrm{E}_k>$	$<\mathrm{E}_{loss}>$
Sprinkle	1	0.5 cm	17	1.22	1.22
Track	1	0.5 cm	9	538	2.17
Sprinkle	1	1.0 cm	29	1.05	1.05
Track	1	1.0 cm	6	433	4.21
Sprinkle	1	2.0 cm	44	0.82	0.82
Track	1	2.0 cm	4	428	7.26
Sprinkle	1	3.0 cm	48	0.96	0.96
Track	1	3.0 cm	7	384	23.4
Sprinkle	2	0.5 cm	3	0.70	0.70
Track	2	0.5 cm	2	1010	1.58
Sprinkle	2	1.0 cm	5	1.60	1.60
Track	2	1.0 cm	2	885	2.64
Sprinkle	2	2.0 cm	14	0.76	0.76
Track	2	2.0 cm	1	385	
Sprinkle	2	3.0 cm	13	13.4	
Track	2	3.0 cm	1	590	

Practically all sprinkle hits originate from electrons ejected by gammas in hodoscope planes and approximately in equal number from protons knocked out in hodoscopes by neutrons. Quite often electron hits are multiplied by effect of spiralling along hodoscope plane in the residual magnetic field leaking from the magnet. Track hits are made by muons, pions and high energy protons.

Figure 2 shows dependence of number of sprinkle and track hits on the thickness of the planes. As expected, the number of sprinkle hits increases approximately linearly with the thickness, whereas the number of track hits is fairly constant (though the numbers fluctate very much because of low statistics). The number of track hits per plane is about 20 - 30 for plane 1 and less than 20 for plane 2 (note that these numbers should be multiplied by factor of 2 to get an estimate of number of hits per electron spill). Sprinkle hits contribute additional 10 - 20 hits for the 0.5 cm thick scintillator and up to 80 - 100 hits for the 3 cm thick scintillator. Tune 1 produces 30% - 50% less sprinkle hits than the tune 2 and about 20% less track hits.

In Figure 3 are compared energy losses of track and sprinkle hits in hodoscope planes. The dependence of energy losses of track particles on the hodoscope thickness is roughly linear, however, the results show huge fluctuations probably due to increasing with thickness possibility of hard interactions. Energy losses of sprinkle hits, uniformely distributed over hodoscope plane volume, are rather independent on the thickness and average around 2 MeV, though they also show large fluctuations. The average energy deposited by sprinkle protons alone is about 1 MeV, sprinkle electrons deposit energy of a few MeV, comparable with energy loss of track particles. Thus hodoscope signal pulse height discrimination could eliminate only the half of sprinkle hits associated with protons. Using hodoscope fingers 2 - 3 cm thick and eliminating signals smaller than 2 MeV would bring down number of sprinkle hits per hodoscope plane to 60 - 100 per spill. On the other hand using fingers 0.5 - 1 cm thick, which would make discrimination based on pulse height difficult, would produce a similar total number of sprinkle hits. Both approaches give similar results and there is no clear preference which one is better.

Assuming that the number of sprinkle hits per plane should be less than 100 per spill we see that we are very close to this limit. Most of gammas passing hodoscopes originate from the absorber volume close to its surface. It will be interesting to study if covering the alumina absorber face with a layer of more heavy material will reduce the number of sprinkle hits.

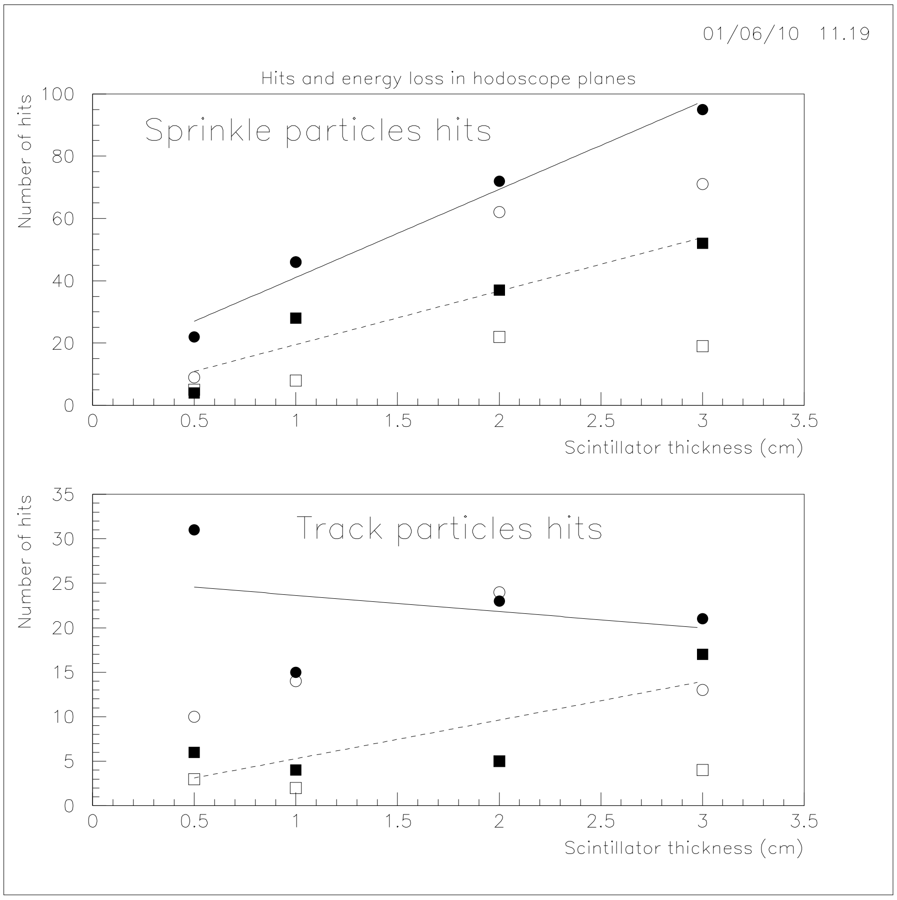

Figure 2: Number of sprinkle and track hits for tune 1 (open points) and tune 2 (filled points) as a function of hodoscope plane thickness. Circles refer to plane 1, squares to plane 2. To guide the eye solid and dashed lines are fitted to the tune 2 data for planes 1 and 2, respectively.

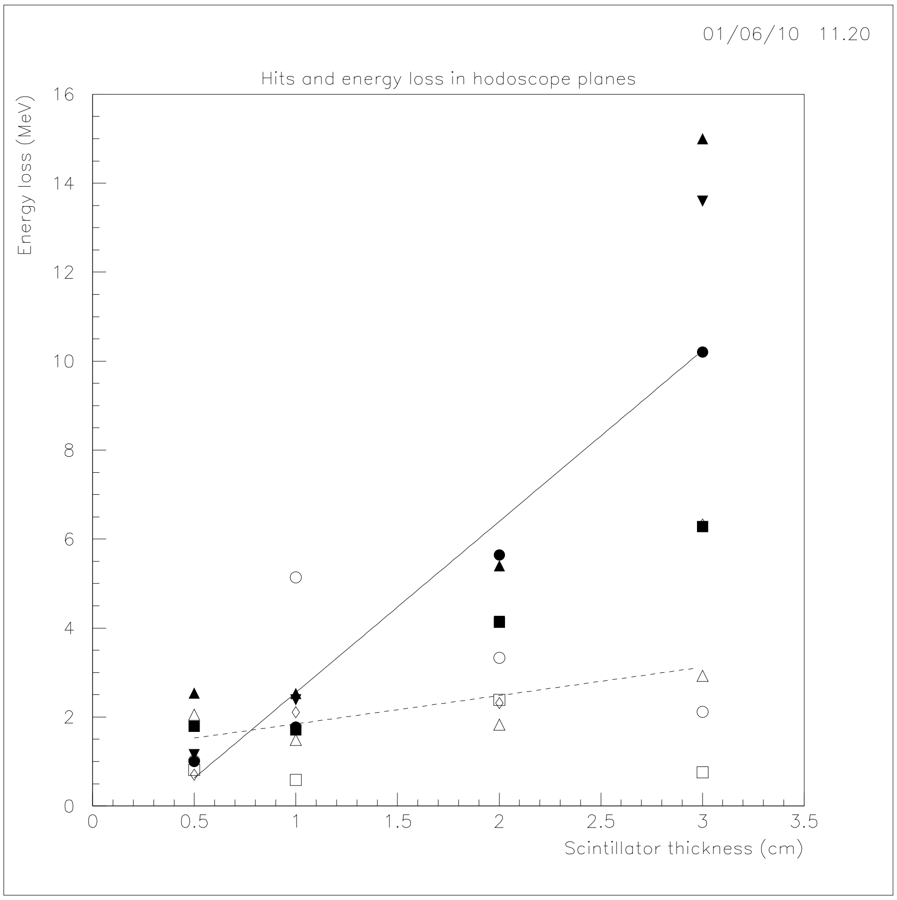

Figure 3: Average particle energy loss as a function of hodoscope plane thickness. Filled and open points describe track and sprinkle particles, respectively (circles - tune 1, plane 1, squares - tune 1, plane 2, triangles - tune 2, plane 1, flipped triangles - tune 2, plane 2). Solid and dashed lines are fitted to energy loss data for track and sprinkle particles, respectively.