Report on Scintillator Efficiencies

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last updated May 2, 2002

This report will explain the steps taken in determining the scintillator efficiencies for the $\mathrm{N} \to \Delta$ experiment. Runs where T1, T2, T3, and T4 were not prescaled were used in determining these efficiencies for the S1 and S2 scintillator planes.

Type 1 triggers (T1s) are electron arm singles events and the electron arm main trigger. Type 2 triggers (T2s) are also electron singles events, but with a looser trigger. Type 3 triggers (T3s) are hadron arm singles events and the hadron arm main trigger. Type 4 triggers (T4s) are also hadron singles events, but with a looser trigger. Type 5 triggers (T5s) are the coincidence between T1s and T3s. In creating the T1 or T3 type triggers, the left and right side of each of the six scintillator paddles in each scintillator plane is first AND'd to determine if a particular paddle fired. Next, the six scintillator paddles of each scintillator plane are OR'd together to determine if the scintillator fired. Then, if one paddle of each of the S1 and S2 planes fired, a T1 or T3 trigger is made. For our purposes, only electron and hadron singles events with $\mathrm{S1} \cdot \mathrm{S2} \cdot \mathrm{SRAY}$ were counted as T1 and T3 type triggers, respectively. The SRAY refers to the fact that both the S1 and S2 scintillator planes fired but the paddle numbers differed by at most one paddle. For example, if S1 paddle 2 fired, then only events where S2 paddles 1, 2, or 3 fired caused a T1 or T3 trigger. This increases the probability that a real particle hit the scintillator. T2 and T4 events???

For the electron arm, the following formulae were used to determine the efficiencies of the S1 and S2 scintillator planes:

$$\mathrm{S1} = \frac{\mathrm{T1} \cdot \mathrm{cerenkov} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot 1\ \mathrm{track}}{\mathrm{T2} \cdot \mathrm{cerenkov} \cdot \mathrm{S2} \cdot 1\ \mathrm{track} + \mathrm{T1} \cdot \mathrm{cerenkov} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot 1\ \mathrm{track}} \tag{1}$$

$$\mathrm{S2} = \frac{\mathrm{T1} \cdot \mathrm{cerenkov} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot 1\ \mathrm{track}}{\mathrm{T2} \cdot \mathrm{cerenkov} \cdot \mathrm{S1} \cdot 1\ \mathrm{track} + \mathrm{T1} \cdot \mathrm{cerenkov} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot 1\ \mathrm{track}}, \tag{2}$$

where the numerator for each equation is T1 events with a single track that hit the cerenkov where at least one paddle of each of the S1 and S2 scintillators fired. The denominator for equation (1) corresponds to single track T2 events that hit the cerenkov and at least one paddle of the S2 scintillator, plus T1 type events with a single track that hit the cerenkov and at least one paddle of each of the S1 and S2 scintillators. The denominator for equation (2) corresponds to single track T2 events that hit the cerenkov and at least one paddle of the S1 scintillator, plus T1 events with a single track that hit the cerenkov and at least one paddle of each of the S1 and S2 scintillators.

For the first run period a third scintillator, S0, was in place in the hadron arm. For these runs (up to run 1805) the following formulae were used to determine the S1 and S2 scintillator efficiencies:

$$\mathrm{S1} = \frac{\mathrm{T3} \cdot \mathrm{S0} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot 1\ \mathrm{track}}{\mathrm{T4} \cdot \mathrm{S0} \cdot \mathrm{S2} \cdot 1\ \mathrm{track} + \mathrm{T3} \cdot \mathrm{S0} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot 1\ \mathrm{track}} \tag{3}$$

$$\mathrm{S2} \quad = \quad \frac{\mathrm{T3} \cdot \mathrm{S0} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot 1\ \mathrm{track}}{\mathrm{T4} \cdot \mathrm{S0} \cdot \mathrm{S1} \cdot 1\ \mathrm{track} + \mathrm{T3} \cdot \mathrm{S0} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot 1\ \mathrm{track}}, \tag{4}$$

where the numerators are single track T3 events that hit at least one paddle of each of the S0, S1, and S2 scintillator planes. The denominator for equation (3) corresponds to a single track T4 event that hit at least one paddle of each of the S0 and S2 scintillators, plus single track T3 events that hit at least on paddle of each of the S0, S1, and S2 scintillators. The denominator in equation (4) corresponds to a single track T4 event that hit at least one paddle of each of the S0 and S1 scintillators, plus single track T3 events that hit at least one paddle of each of the S0, S1, and S2 scintillators.

After the first run period the S0 scintillator was taken out of the hadron arm detector stack. An aerogel cerenkov was put in instead. For these runs (runs 1831+) the scintillator efficiencies were calculated using the following formulae:

$$\mathrm{S1} \quad = \quad \frac{\mathrm{T3} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot \mathrm{geom} \cdot 1\ \mathrm{track} \cdot !\ \mathrm{aero}}{\mathrm{T4} \cdot \mathrm{S2} \cdot \mathrm{geom} \cdot 1\ \mathrm{track} \cdot !\ \mathrm{aero} + \mathrm{T3} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot \mathrm{geom} \cdot 1\ \mathrm{track} \cdot !\ \mathrm{aero}} \tag{5}$$

$$\mathrm{S2} \quad = \quad \frac{\mathrm{T3} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot \mathrm{geom} \cdot 1\ \mathrm{track} \cdot !\ \mathrm{aero}}{\mathrm{T4} \cdot \mathrm{S1} \cdot \mathrm{geom} \cdot 1\ \mathrm{track} \cdot !\ \mathrm{aero} + \mathrm{T3} \cdot \mathrm{S1} \cdot \mathrm{S2} \cdot \mathrm{geom} \cdot 1\ \mathrm{track} \cdot !\ \mathrm{aero}}, \tag{6}$$

where the numerators are single track T3 events that hit at least one paddle of each of the S1 and S2 scintillators with some maximum x and y geometry (see table 1) and did not hit the aerogel. The denominator for equation (5) corresponds to single track T4 events that hit at least one paddle of the S2 scintillator plane with some x and y geometry (see table 1) and did not fire the aerogel, plus single track T3 events that hit at least one paddle of each of the S1 and S2 scintillators with some x and y geometry (see table 1) and did not fire the aerogel. The denominator for equation (6) corresponds to single track T4 events that hit at least one paddle of the S1 scintillator plane with some x and y geometry (see table 1) and did not fire the aerogel, plus single track T3 events that hit at least one paddle of each of the S1 and S2 scintillators with some x and y geometry (see table 1) and did not fire the aerogel.

detector geometry	min (m)	max (m)
S1 x	-1.1	0.85
S1 y	-1.25	1.05
S2 x	-0.18	0.18
S2 y	-0.32	0.32

Table 1: *Hadron arm scintillator x and y geometry cuts.*

The relative error for each efficiency was calculated using

$$\text{relative error} = \left(\frac{1}{N} + \frac{1}{N_t}\right)^{\frac{1}{2}}, \tag{7}$$

where the scintillator efficiency is $eff = \frac{N}{N_t}$.

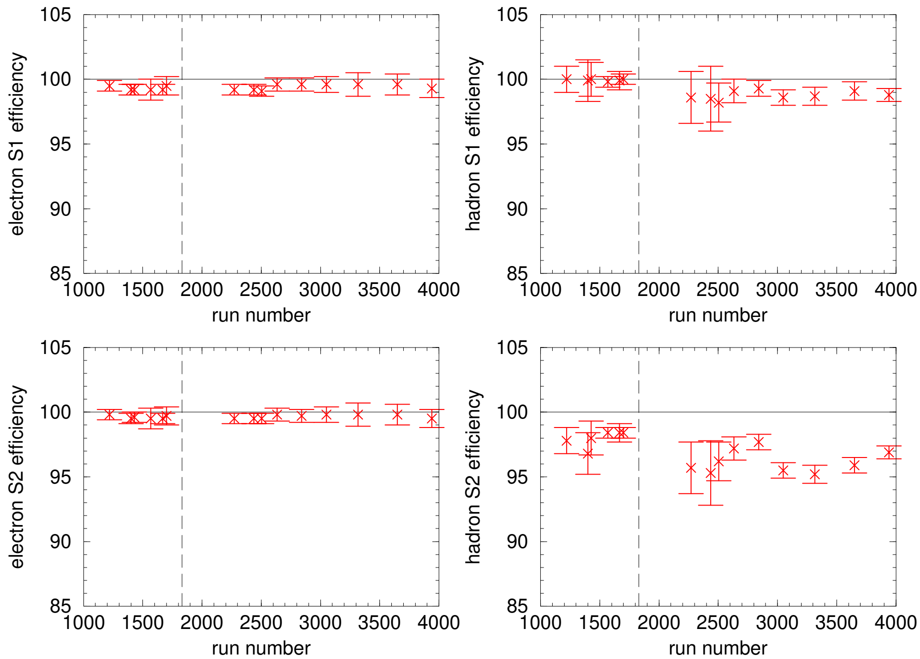

Figure 1: *Electron and hadron arm S1 and S2 efficiencies.*

The efficiencies of each of the four scintillators is shown in figure 1. The points to the left of the dotted line represent the runs from the first run period with the S0 scintillator in the hadron arm. The points to the right of the line are runs taken after the aerogel was put into the hadron arm. Tables 2 and 3 show the values for the electron S1, electron S2, hadron S1, and hadron S2 efficiencies where the S0 and aerogel were used, respectively, in determining the hadron arm scintillator efficiencies.

run	date	θ_{cm}	elec S1 (%)	elec S2 (%)	had S1 (%)	had S2 (%)
1220	May 22	$0°$	99.5±0.4	99.8±0.4	100.0±1.0	97.8±1.0
1400	May 28	$-50°$	99.2±0.4	99.5±0.4	99.9±1.6	96.8±1.6
1428	May 29	$-90°$	99.2±0.4	99.6±0.4	100.0±1.3	98.0±1.3
1568	May 31	$135°$	99.2±0.8	99.5±0.8	99.8±0.4	98.4±0.4
1668	June 1	$-135°$	99.2±0.4	99.5±0.4	99.9±0.7	98.4±0.7
1700	June 2	$155°$	99.5±0.7	99.7±0.7	100.0±0.4	98.4±0.4

Table 2: *Efficiencies where the S0 was used in the hadron arm calculations.*

run	date	θ_{cm}	elec S1 (%)	elec S2 (%)	had S1 (%)	had S2 (%)
2271	June 19	$-90°$	99.2±0.4	99.5±0.4	98.6±2.0	95.7±2.0
2437	June 22	$-50°$	99.2±0.4	99.5±0.4	98.5±2.5	95.3±2.5
2504	June 24	0°	99.1±0.4	99.5±0.4	98.2±1.5	96.2±1.5
2633	June 29	25°	99.6±0.5	99.8±0.5	99.1±0.9	97.2±0.9
2842	July 12	50°	99.6±0.5	99.7±0.5	99.3±0.6	97.7±0.6
3050	July 17	90°	99.6±0.6	99.8±0.6	98.6±0.6	95.5±0.6
3317	July 21	135°	99.6±0.9	99.8±0.9	98.7±0.7	95.2±0.7
3650	July 25	155°	99.6±0.8	99.8±0.8	99.1±0.7	95.9±0.6
3941	July 29	180°	99.3±0.7	99.5±0.7	98.8±0.5	96.9±0.5

Table 3: *Efficiencies where the aerogel was used in the hadron arm calculations.*