to 72.0%. When the raster frequency goes to infinity, the minimal depolarization occurs. It depolarizes only to 73.7%, which is also what one would have for continuous wave beam, with beam spot the same size of the raster area.

In conclusion, depolarization can be minimized by

1. Larger rastering area.

2. Smaller bead size.

3. Larger beam size.

4. Using continuous beam, with rastering frequency $\geq$ 100 Hz to avoid large polarization oscillation.

3.2.5 Dead time corrections

All the signals from various detectors go through discriminators before forming various triggers. The discriminators used in E143 have an output pulse width of 25 ns with a double pulse resolution of 8 ns. Any later signal coming within the output width of the previous one (the so called "dead time") will not produce a separate output, resulting in loss of data. The discriminators were operating at an updating mode, that is, if a second signal comes into the discriminator within this 8 ns, this second one will be unseen. However, if the second one comes after 8 ns and before 25 ns, the discriminator will still output only one output, but the output width will be extended. However, the effective dead time in E143 is 32 ns instead of 25 ns, due to slight mis-timing between various signals and jitter in signals, especially from the shower counters. This dead time causes loss of data, so a dead time correction factor d is needed to multiply with the electron counts. The left and right electron rate $N^{\uparrow\downarrow}$ and $N^{\uparrow\uparrow}$ need to be replaced by

$$N^{\uparrow\downarrow} \rightarrow d_l N^{\uparrow\downarrow} \tag{3.32}$$

$$N^{\uparrow\uparrow} \rightarrow d_r N^{\uparrow\uparrow} \tag{3.33}$$

Where d_l and d_r are the correction factors for the left and right polarity beam respectively. Notice that, $d's$ are different from run to run due to different rates. They are also different for SP4 and SP7, also due to different rates for the two spectrometers. There are two methods to obtain the correction factors.

Method one

This method tries to predict the true rate from the observed P_0 (Zero trigger probability) , using Poisson distribution. For each run, define "tfreq"(i), which is the number of spills when getting i hits on "Mainor", where i goes from 0 to 16. Also bin the charge of each spill into different q bins. Now define qx(i) and qy(i) as

qx(i) charge value of ith bin.

qy(i) number of spills of ith bin.

For a given charge, for a given spectrometer and beam polarization, the number of counts should be proportional to the charge, that is, cq, where c is a constant and q is the charge. For one spill, the frequency distribution would be given by Poisson distribution if there were no dead time. However, even with the dead time, the zero trigger frequency should still be the same, which is:

$$P_0 = e^{-cq} \tag{3.34}$$

. Then summing up all the spills to get:

$$P_0 = \frac{\sum qy(i) \times e^{-c \times qx(i)}}{\sum qy(i)}$$

On the other hand, from "tfreq"(i), we have:

$$P_0 = \frac{tfreq(0)}{\sum_{i=0}^{i=16} tfreq(i)}$$

In this way, an equation can be set up to solve for c. Then the true counts R_{real} is given by

$$R_{real} = \sum c \times qy(i) \times qx(i)$$

while the observed counts R_{ob} is

$$R_{ob} = \sum_{i=1}^{i=16} \min(4, i) \times tfreq(i)$$

then the correction factor d is given by

$$d = \frac{R_{real}}{R_{ob}}$$

where "min" means the minimal, which arises because our data acquisition system could only handle up to 4 triggers.

After calculating the dead time correction factors using this method, it was found that some runs had reasonable correction factors. For example, for run with an average rate of 1 event/pulse, the factor is 1.02 . But some others do not make sense, like for run with an average rate of 0.5 event/pulse, the correction factor was calculated to be 1.2. And these runs with reasonable or unreasonable correction factors appear in groups. The transition between these groups happened when we were switching from electron runs to positron ones, or when we were changing the prescalar settings.

Why method one does not work

The failure of method one lies in the use of the prescalars. The key equation 3.34 for method one comes from assumption of Poisson distribution of the trigger frequency, when there was no dead time. This assumption falls apart in the presence of prescalars. To see this point, assuming no dead time, and consider only one single spill. Without prescalars, "tfreq" clearly obeys the Poisson distribution. But because Pion trigger is pre-scaled, that makes the "tfreq" distribution different from a Poisson distribution. A handwaving proof is that, a Poisson distribution is valid when the probability of registering one hit in a small time interval dt is proportional to dt. But with prescalars, the moment after the prescalar is cleared, there is NO probability of registering one hit, and the probability increases with time,until the next clearance. So it is no longer uniform in time. Following gives more detail:

Assume for now that only one trigger comes into the "Mainor" and is pre-scaled by a factor of N. The observed average rate is :

$$orate = \frac{\sum i \times tfreq(i)}{\sum_{i=1}^{16} tfreq(i)}$$

so the true average rate before the prescalar must be: "trate"="orate"×N , and "ppois"(i) (the probability of finding i hits in one spill BEFORE the prescalar) is Poisson distribution. Now try to produce "tfreq"(i)(which is AFTER the prescalar) from "ppois"(i). by assuming N=2 to simplify the calculation. Taking one spill during the run, at the beginning of it, the prescalar might have received 0 or 1 hit. Because the total hits during the run is much larger than the prescalar value 2, each case has the same probability 1/2 . To find out "tfreq"(0), for example in case 1 (when prescalar has received 0 hit), if this spill had 0 or 1 hit, then the prescalar still wouldn't fire. This probability is $1/2(ppois(0) + ppois(1))$; When in case 2 (prescalar has received 1 hit), then only if this spill had 0 hit, wouldn't the prescalar fire. This probability is 1/2("ppois"(0)). Summing up these 2 cases to get:

$$tfreq(0) = \frac{1}{2}(ppois(0) + ppois(1)) + \frac{1}{2}ppois(0) \tag{3.35}$$

Similarly, we can find out all the other "tfreq"(i). They are quite different from Poisson distribution. Table 3.5 lists different "orate" vs. "prate" (the rate calculated from 0 trigger probability using naive Poisson distribution) at different prescalar values, assuming all the spills have the same amount of charge.

"orate"	"prate"	N	"prate"/"orate"
.2	.218	2	1.09
.4	.464	2	1.16
.5	.595	2	1.19
.7	.869	2	1.24
.9	1.158	2	1.29
.5	.656	4	1.31
.5	.685	8	1.37
.5	.692	16	1.38

Table 3.5: Comparison of the predicted rates, from Poisson distribution ("prate"), and from the modified version of it ("orate") .

Table 3.6 is the trigger frequency distributions ("tfreq") from the data, naive poisson distribution, Monte Carlo simulation and the modified Poisson distribution respectively, for run 2558 and SP7, which is a positron run and Pion triggers are 98% of the "Mainors", with a prescalar value of 2. Clearly, the modified Poisson distribution agrees with the data best.

Things are actually more complicated than the above, because:

- In the absence of prescalar, "tfreq"(0) is not affected by the dead time. However, with prescalar, the dead time will affect the value of "tfreq"(0).

- In the E143 system, Not all the inputs into the "Mainors" are pre-scaled by the same number. The main trigger coming into "Mainor" is not pre-scaled while the Pion trigger is, that makes it more complicated.

	"tfreq"(0)	"tfreq"(1)	"tfreq"(2)	"tfreq"(3)	"tfreq"(4)	"tfreq"(5)	"tfreq"(6)
A	116378	81202	12713	1350	92	5	0
B	116378	69661	20852	4162	623	75	7
C	115673	70392	21009	4102	513	42	5
D	116378	84706	10210	452	10	0	0

Table 3.6: Various trigger frequency distributions ("tfreq") for run 2558 and SP7. A is the observed distribution from data; B is from naive poisson distribution using 0 trigger probability, assuming all the spills having the same amount of charge and with no dead time; C is generated from Monte Carlo simulation using a 32 ns dead time; and D is from the modified Poisson distribution method, taking into account of a prescalar value of 2 (the other 2% non-pre-scaled main triggers have been neglected.)

In conclusion, method one is incorrect due to the prescalars. However, when we are doing normal electron runs and prescalar values are set high, the "Mainor" is dominated by the main trigger, so method one gives reasonable results. When the prescalar values are set low, or when we are doing positron runs, pre-scaled Pion trigger is no longer negligible, that is when method one is least reliable.

Method two

This is the correct method, and is what has been used in the analysis. Assuming a spill time and a dead time, to generate the probability matrix M(i,j), which is the probability of observing i hits when there were really j hits, using Monte Carlo simulation. We have:

$$tfreq(i) = \sum_j M(i,j) \times rtfreq(j)$$

where "tfreq" ("rtfreq") is the observed (real) trigger frequency distribution. In principal, j in the sum goes to infinity, but because we are getting practically no hits beyond 10, it is safe to take j only up to 16. Then we invert this matrix M, to solve for "rtfreq" from "tfreq", and define our correction factor as

$$d = \frac{\sum_{i=1}^{i=16} i \times rtfreq(i)}{\sum_{i=1}^{i=16} \min(4, i) \times tfreq(i)}$$

Most of the runs have beam spill length around 2200 ns. Using this as beam time, and 32 ns as the dead time to obtain the matrix M and the correction factors. The correction factor vs. rate looks quite smooth. They vary from 1 (no correction) at near zero rate, to 1.07 at a rate of 2 events/pulse. Comparing the correction factors vs. rate , using method one and method two respectively, for the runs with high prescalar values (hence the un-prescaled main trigger dominates), for sp4 (because there are a fairly large percentage of Pion trigger rate in "Mainor" for sp7, so method one was not used for sp7 for comparison), they agree quite well. The correction factors vs. rates have also been calculated for sp4, using method 2, for a beam time of 1800 ns and 2600 ns respectively. Compared with the results using method one, on the "good" runs (for which the Pion trigger rates were low) , we see 1800 ns gives too high a correction, while 2600 ns gives too low a correction.

The systematic error was calculated, by using a beam time of 1800 ns and 2600 ns as the upper and lower limit. The correction factor itself is found to be accurate to a few parts in 1000, and the error for the corrected asymmetry by applying these factors is found to be less than 2×10^{-5}, which is completely negligible.

The uncertainty in the probability matrix M has been checked by using different trial numbers for the Monte Carlo program. It is also found to be negligible.

3.2.6 Dilution factor and nitrogen corrections

The asymmetries of interest are for scattering from polarized proton or deuterons. However, what the spectrometers see is the sum of the scattered particles from all the target material in the way of the beam, including slightly polarized nitrogen and