E93-026 Technical Note:

Electronics Dead-time and Asymmetry

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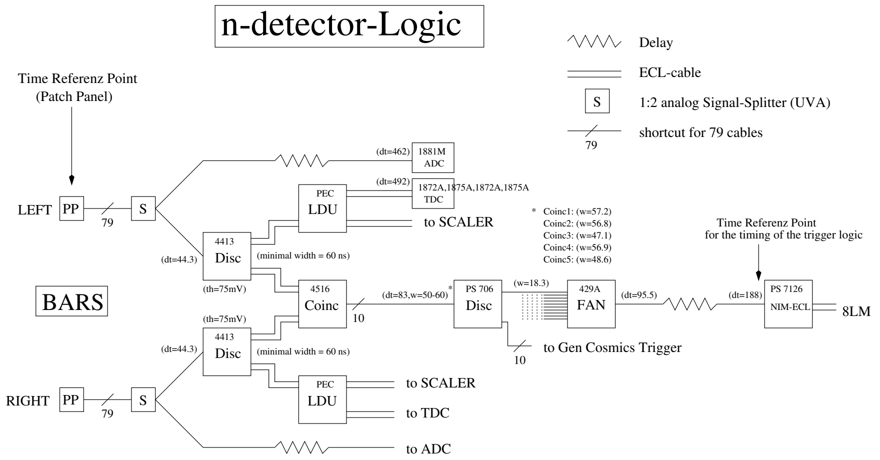
1 Electronics dead-time during Gen98

This document discusses the impact of electronics deadtime on physics asymmetries during Gen98.

The electronics deadtime during Gen98 was caused by the high rate of the neutron bars. Each OR of the output of eight L/R coincidences (Coinc 4516) was sent to a discriminator (Disc PS706) resulting in ten lines, each counting with typically 400 kHz. The width of the signals was typically 50-60ns (depending on overlap). This width was required by the logic delay units (LDU) to work properly. The output of the ten discriminators had a width of $\simeq$19 ns and was sent to a Logic Fan. The output of the Fan with a rate of 4 MHz was sent to the 8LM where the coincidence with the HMS signal (width 11 ns) was formed.



The discriminators were running in a non-updating mode which induced a certain probability that a "real" bar pulse was "eliminated" by a preceding random pulse and thus did not make the coincidence with the electron. The size of the effect can be roughly estimated: To first order it occurs whenever a random pulse appears within 60ns in front of the "real" pulse. The probability that this occurs at 400kHz is simply $60\times10^{-9}\cdot400\times10^{3}\simeq0.025$. The effect is partly compensated if the "real" pulse follows very close to the preceding random pulse or if on one of the other 9 lines either another "real" or another random pulse jumps in to make the coincidence anyway.

In a post experiment setup we simulated the experimental conditions by means of artificial random signals and measured the magnitude of the effect to be $\mathrm{DT}_{el}\simeq0.005\cdot$Bar Rate [MHz], which is in agreement with the expectations outlined above. An earlier document [1] describes the technique that was used in this test and its results.

As long as the Bar rate does not show a helicity dependence the impact on the physics asymmetry is zero, because both helicity states are affected equally. An asymmetry in the bar rate could be caused by a beam current asymmetry or the intrinsic asymmetry in the production of the bar singles.

2 Helicity dependent asymmetry of the Bar Rate

To quantify the helicity dependent asymmetry of the Bar rate A_b we can use scaler values:

$$A_b = \frac{b^{\downarrow} - b^{\uparrow}}{b^{\downarrow} + b^{\uparrow}} \;\; ; \;\; b^{\uparrow\downarrow} = \frac{B^{\uparrow\downarrow}}{T^{\uparrow\downarrow}}$$

$B^{\uparrow\downarrow}$ and $T^{\uparrow\downarrow}$ denote the scaler counts of "B Pretrigger" and "1 MHz Clock" respectively with the up arrow indicating the positive helicity[2] and the down arrow indicating the negative helicity. Note that this is the asymmetry of the raw Bar rates not normalized for beam current. According to the explanation in the previous section it is the raw rate that affects the electronics dead-time. A_b was calculated for all $Q^2 = 0.5$ runs that made the DEC99 replay. For further insight the beam current asymmetry was calculated for the same runs too. Fig. 2 shows the results of this study. The average beam current asymmetry is in the order of $6.5 \cdot 10^{-4}$ and is the same for both signs of the target polarization as one would expect. The Bar rate however has an intrinsic asymmetry of the same order as the beam current asymmetry. This intrinsic asymmetry flips sign with the orientation of the target polarization. As a consequence we have an asymmetric behavior behavior with respect to the two signs of the target polarization! The asymmetry of the raw bar rate is basically 0 for the positive target polarization and significant for the negative target polarization. The numbers are $A_b = (-7.6\pm0.2)\cdot10^{-5}$ for positive and $A_b = (-1.134\pm0.002)\cdot10^{-3}$ for negative target polarization.

Side note 1: The spread in the distribution of bar asymmetries becomes smaller and is much more correlated with the beam current after run 21000, which is due to the synchronization of the raster with the helicity.

Side note 2: The intrinsic Bar rate asymmetry has the opposite sign to the coincidence rate asymmetry and is one order of magnitude smaller.

[1] M. Zeier & Th.Petitjean: Electronics Deadtime
~cdaq/gen/Documents/n-detector/n-el_deadtime.ps

[2] Positive helicity corresponds to the higher bit set in the TS latch

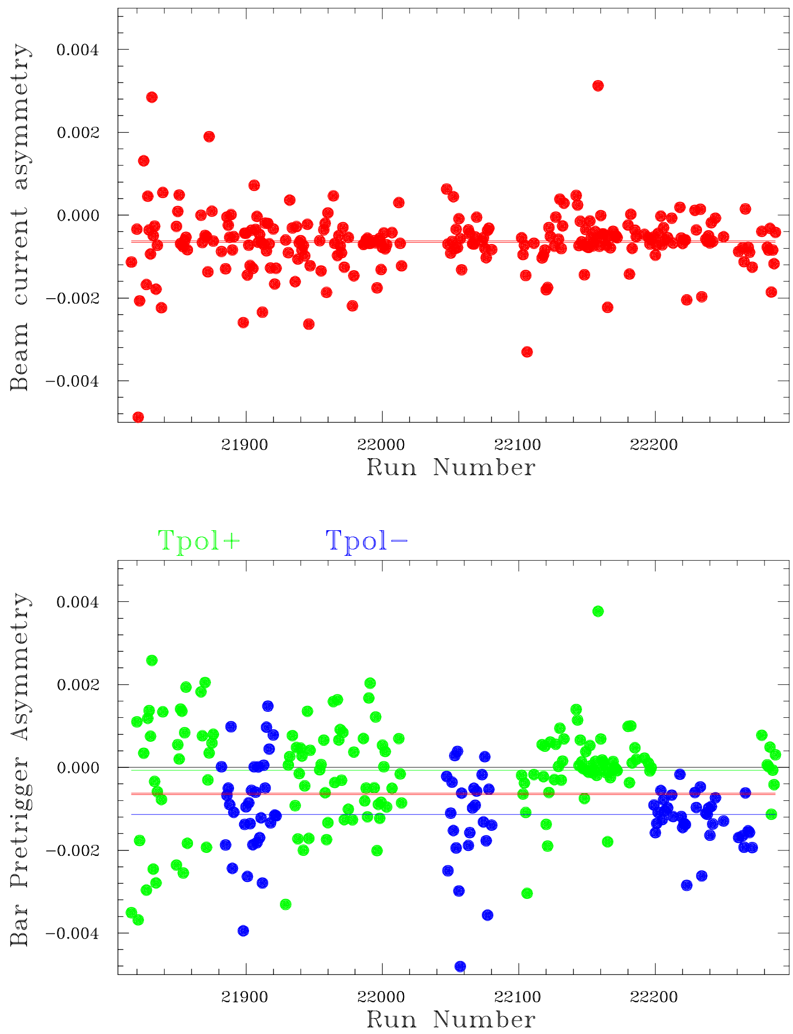


Figure 1: *The top graph shows beam current asymmetries vs. run number. The two solid red lines indicate the averages for positive and negative target polarization, which are basically equal. The bottom graph shows Bar pretrigger rate asymmetries vs. run number for positive (green) and negative (blue) target polarization. The two corresponding solid lines indicate the averages and the red line is again the average of the beam current asymmetry.*

3 Impact on Physics Asymmetries

The "true" asymmetry can be written as

$$A = \frac{n^{\downarrow} - n^{\uparrow}}{n^{\downarrow} + n^{\uparrow}}$$

$n^{\uparrow\downarrow}$ denotes normalized count rates for the two helicity states (indicated by the arrows). The measured asymmetry, affected by electronics dead-time only, can be written as

$$A_m = \frac{(1 - DT_{el}^{\downarrow}) \cdot n^{\downarrow} - (1 - DT_{el}^{\uparrow}) \cdot n^{\uparrow}}{(1 - DT_{el}^{\downarrow}) \cdot n^{\downarrow} + (1 - DT_{el}^{\uparrow}) \cdot n^{\uparrow}} \tag{1}$$

with $DT_{el}^{\uparrow\downarrow}$ denoting the electronics dead-time.

Alternatively we can express $n^{\uparrow\downarrow}$ with A:

$$n^{\downarrow} = \frac{n^{\downarrow} + n^{\uparrow}}{2}(1 + A)$$

$$n^{\uparrow} = \frac{n^{\downarrow} + n^{\uparrow}}{2}(1 - A)$$

The electronics dead-time is small in our case and can therefore be expressed as proportional to the raw Bar rate:

$$DT_{el}^{\uparrow\downarrow} = k_{el} \cdot b^{\uparrow\downarrow} \tag{2}$$

The bar rates $b^{\uparrow}$ and $b^{\downarrow}$ can be expressed with the unpolarized rate $b = (b^{\uparrow} + b^{\downarrow})/2$ and the bar rate asymmetry A_b:

$$b^{\uparrow} = b(1 + A_b)$$

$$b^{\downarrow} = b(1 - A_b)$$

Making all the substitutions in eq. **??** leads to

$$A_m = \frac{A - k_{el}b(A + A_b)}{1 - k_{el}b(1 + A_b A)}$$

Since $k_{el} \cdot b$ is small we do a Taylor expansion of A_m about $(k_{el}b = 0)$:

$$A_m = A - A_b(A^2 - 1)(k_{el}b) + O[(k_{el}b)^2]$$

A^2 is in our case very small and we can further approximate $(A^2 - 1) \cong -1$ and obtain

$$A_m \cong A - A_b k_{el} b$$

For the deviation from the true asymmetry we get

$$\Delta A = A_m - A \cong -A_b k_{el} b$$

For k_{el} we use the number determined in the above mentioned test measurement: $5 \cdot 10^{-9} s$. Using scaler information the average bar rate can be determined as $b \cong 1.8 \cdot 10^6 s^{-1}$(which is only half of what was always quoted). The size of A_b depends on the sign of the target polarization as mentioned above. Therefore we obtain a deviation from the "true" asymmetry which is dependent on the sign of the target polarization:

$$Tpol- : \; A_b = -1.134 \cdot 10^{-3} \; \Rightarrow \; \Delta A = 1.02 \cdot 10^{-5}$$

$$Tpol+ : \; A_b = -7.6 \cdot 10^{-5} \; \Rightarrow \; \Delta A = 6.84 \cdot 10^{-7}$$

4 Conclusions

The size of ΔA has to be compared to the achieved statistical accuracies in order to decide if a correction of the asymmetries for dead-time is necessary. First of all the effect is only an issue for positive target polarization. For coincidence events in Gen98 we have the following situation:

Neutron: Without applying any cuts we have roughly $6 \cdot 10^6$ neutrons for the positive target polarization. Therefore in the best case we can achieve a statistical error of $1/\sqrt{6 \cdot 10^6} = 4 \cdot 10^{-4}$, which is 40 times larger than ΔA. Applying the final cuts the number of neutrons is reduced to $< 1 \cdot 10^6$ and the statistical error is $\geq 1 \cdot 10^{-3}$ and thus at least two orders of magnitudes larger than ΔA.

Proton: For the proton the numbers are $5.2 \cdot 10^7$ (no cuts) and $\leq 1 \cdot 10^7$(final cuts) leading to statistical errors of $2 \cdot 10^{-4}$ (no cuts) and $3 \cdot 10^{-4}$ (final cuts). This is still 20 times larger than the size of ΔA.

4.1 Correction Factor

Despite the fact that the overall effect tends to be neglible a correction factor should be applied to the data since the effect can be calculated. The above estimate is for the average case and a run by run correction would be preferable since rates were changing due to gain loss in the PMs over the whole run period.

The electronics dead-time can be calculated for each run using eq. 2. This number will be put into the scaler file and can be used to correct rates and yields in the same way the computer dead-time is used. The error of this correction is determined by the knowledge of the the proportionality factor k_{el} and the bar rates $b^{\downarrow\uparrow}$. In the following a short discussion how these values are determined and what there estimated error is.

A fit to the data taken during the test simulation gives a value $k_{el} = 4.74 \cdot 10^{-9}s$. The main error associated with this value is the variation of gate length (depending on the overlap in the L/R coincidence) that occurred during the experiment. The gates varied typically between 50 and 60 ns, while the simulation was done at 60 ns gate width. Therefore we scale the measured k_{el} by 10% down and use $k_{el} = 4.27 \cdot 10^{-9}s$ with a 10% error assigned to it.

The bar rate can be calculated from the scaler values. These rates need to be corrected for beam-off periods. The fraction of beam-off period during a run can be calculated in the analyzer by setting a minimum threshold at the charge scaler value for each period between two scaler reads.

Another effect which is more complex and therefore harder to estimate is the following: The bar rate is not uniformly equal over the whole detector (the front planes counted higher then the planes further back). The same is true for the trigger rate: Protons are found predominantly in the top 5 bars of the first bar plane, while the neutron distribution peaks in the center of the detector. The impact of these non-uniformities on the electronics dead-time now depends on the details of the electronics setup, i.e. which detector channels are OR'ed together and the resulting correlation between trigger rate and bar rate in the part of the electronics which is causing the electronics dead-time. E.g. if one of the 10 lines (between Coinc 4516 and Disc PS706) has an above average trigger rate AND an above average bar rate then the actual electronics deadtime is higher than what is calculated from the average bar rate.
An estimate of this effect can be done by looking at the single rates of each photo tubes (available from asynchronous scaler readout), at the proton and neutron distribution (ntuple analysis) in the detector and at the exact electronics setup (from documentation). An exact evaluation would be rather complex and time consuming. Regarding the small size of electronics dead-time a rather crude estimate was done, leading to scaling factors of 1.02 and 1.18 for the neutron and the proton, respectively. The error assigned to this correction is 20%.

The following summarizes the correction procedure:

- Equation 2 is used to calculate the electronics dead-time for both helicity states in each run.
- The value $k_{el} = 4.27 \cdot 10^{-9}s$ is used as proportionality factor for all runs.
- The bar rate $b^{\uparrow\downarrow}$ is calculated from scaler values for each run.
- $b^{\uparrow\downarrow}$ needs to be corrected for beam-off periods
- For the neutron $b^{\uparrow\downarrow}$ needs to be scaled by a factor of 1.02.
- For the proton $b^{\uparrow\downarrow}$ needs to be scaled by a factor of 1.18.
- The overall error assigned to the correction of electronics dead-time is 25%.

- The correction will be implemented in the analyzer and a number will be available in the scaler file for each run to correct yields for each helicity state.