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CVS: docs/tof_rates.tex
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CLAS TOF Rates in an Electron Beam

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1 Introduction

The design luminosity for the CLAS detector is $10^{34}\text{cm}^{-2}\text{s}^{-1}$. Current experiments, such as e1-6, has been collecting data at 90% of this luminosity. For the e1-6 run period, operating with a 5.0-cm hydrogen target at nominal CLAS center, the design luminosity corresponds to a beam current of 7.65 nA. The design goal for the 12-GeV upgrade is to be able to increase the luminosity capability of the detector by an order of magnitude to $10^{35}\text{cm}^{-2}\text{s}^{-1}$.

In order to reliably predict counting rates in scintillation detectors in an upgraded CLAS detector, we have studied the rates as a function of threshold at two different beam currents. A list of the data used for this investigation along with their main characteristics are given in Table 2.

Table 1: Data runs used for rate studies. The current corresponds to the live average current for the run.

Run Number	Current (nA)	Threshold (mV)	Target
31029	26.6	20	Empty
31029	26.6	100	Empty
30587	3.8	20	Full
31397	6.0	20	Full
31470	6.4	30	Full
31471	6.4	50	Full
30921	6.6	100	Full
31472	6.4	200	Full

2 Pretrigger or Scaler Rates

A few special runs were taken on January 29, 2002, with the pretrigger threshold set between 30 and 200 mV. The pretrigger threshold determines the counting rates of the tof scalers, as well as the scintillator inputs to the trigger. The proportionality coefficient between threshold and ADC units is 1.73 ADC counts/mV. Assuming the minimum ionizing peak (10 MeV) is set to 600 counts, then a threshold of 100 mV corresponds to approximately 2.9 MeV.

It is worth recalling the meaning of the scaled pretrigger channels [1]. Each channel discriminates the analog sum of the dynode signals of left and right pmts of two adjacent scintillators. Channels 1 through 16 correspond to "doubles," each counting the rate in two adjacent counters, overlapping one counter included in the previous channel. Therefore, the summed rate in scalers 1-16 is twice the rate in the corresponding 16 scintillators. Channels 17-32 cover scintillators 17-48 and use the "triples" outputs. These count the sum of three adjacent scintillators with an overlap of one counter. Therefore the sum value of the "triples" is 5/3 the count rate in the scintillators.

The scaler rates are shown in Figures 1-4 for thresholds corresponding to 30, 50, 100 and 200 mV. The correspondence between scintillator panels and scaler channels is as follows: panel 1 is scaled by channels 1-16 doubles and 17-19 triples, panel 2 by channels 20-25 triples, panel 3 by channels 26-29 triples and panel 4 by channels 30-32 triples. The integrated numbers shown on the plots include correction factors of 0.5 (doubles) and 0.6 (triples) and are summed over all six sectors.

3 TDC accidentals

It is also of interest to investigate the singles rates into the readout electronics consistent with the time resolution which is achieve for particle identification. The TDCs are feed by the anode signal of each pmt discriminated at 20 mV for nominal operation. Therefore we have also estimated the rates of the pmt signals using the TDC spectra. Four sample TDC spectra are shown in Figs. 5-8 for counters 5, 15, 25 and 35 for sector 1 for a typical run at a nominal current of 7 nA. The spectra were fit to a gaussian plus a linear background. The fits do not describe the data in detail, but are adequate to obtain rate estimates. The background term was integrated over the range of the TDC and used to determine the single rates in each counter. The gaussian peak gives the rate of the signals which are in time with the trigger, but were not included in the rates reported here. As can be seen from the figures, the in-time rate is comparable or somewhat higher than the accidental rate.

[1] For an electronics diagram of the logic, refer to Ref. [1].

The plots display the count rate per pmt averaged over all six sectors. The integrated rates on the plot take those rates and multiply by 6 (there are six sectors) and use scintillators 1-19 (7 to 40 degrees) for the forward angle and scintillators 20-48 (40 to 140 degrees) for the large angle.

4 Dependence on Threshold

The integrated count rates are displayed as a function of threshold in figure 9. The rates at 20 mV are taken from the accidentals in the TDC spectra and all other rates were obtained from the scalers. When the threshold is increased by a factor of 2 the count rates drop by a factor of between 2 to 3.

The TDC accidental rates for the forward angle follow the trend of the scaler rates at higher threshold very well, while the rates at large angle seem to be higher by a factor of two from the trend of scaler rates. The TDC rates at large angle seem to be somewhat anomalous both as a function of threshold and beam current (see below). While the measured increase may be real, the rates may reflect extreme instrumental sensitivity of the large angle detectors to low energy background. For the present summary we take the rates at face value, realizing that the precise count rate in a given detector depends in detail on the electronic circuits that feed the readout and trigger.

5 Dependence on Beam Current

The rates were recorded during a low intensity run at 3.8 nA as well as during a typical production run at 6 nA. The empty target runs were used to subtract a small background due to target walls. The rates (averaged over six sectors) are plotted as a function of scaler channel (100 mV threshold) in figures 10-11, and as a function of scintillator (20 mV threshold) in figures 14-15 for the low-intensity run, nominal run and empty target runs. Each plot gives the summed rates over all sectors for the forward angle, large angle and totals separately. The 20 mV rates at large angle are again problematic and do not seem to scale with beam current. We note that the run at 3.8 nA was taken early in the run and the high voltage on some of the backward counters did not have their final adjustment, which might contribute to the anomalously high rate at this current setting.

To determine the rates at the nominal luminosity of $10^{34}\text{cm}^{-2}\text{s}^{-1}$, we have fitted the rates (with empty target subtracted) to a linear function (Fig. 13 and 17). The fitted rates are given in recorded on the figure and summarized in Table 2.

Table 2: The scaler rates (100 mV threshold) and TDC accidentals (20 mV threshold) extrapolated to a current of 7.65 nA. The rates are summed over six sectors. To obtain the rates at a luminosity of $10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ increase these rates by a factor of ten.

Angular Range	Threshold (mV)	Rate (MHz)
Forward	100	3.22
Large	100	0.78
Total	100	4.29
Forward	20	21.4
Large	20	24.3
Total	20	45.9

6 Discussion

The extrapolated rates at 20 mV to a luminosity of $10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, give a typical rate per counter of 214 MHz / 6 / 23 = 1.5 MHz per counter. The scaler rates, typical of trigger input rates (100 mV threshold) is 32.2 MHz / 6 / 23 = 233 KHz per counter. This assumes that the forward counter system remains in its current configuration. The integrated rates for the large angle counters are 243 MHz and 7.8 MHz respectively. This roughly corresponds to the angular range proposed for the barrel for the CLAS upgrade, so can be used to estimate the scintillator segmentation in this region. If we assume that a single pmt can handle a rate of 4 MHz, this means that we need at least 60 scintillators to operate at a threshold of 20 mV. This number is reduced by a factor or 30 by increasing the threshold to 100 mV. Therefore, careful determination of threshold requirements for the system is needed. The rate capability of the detector system clearly must be studied as part of the R&D and prototyping effort.

References

[1] E.S. Smith *et.al.*, "The Time-of-flight system for CLAS", Nucl. Inst. and Meth. A432, 265 (1999).

Rates in TOF counters

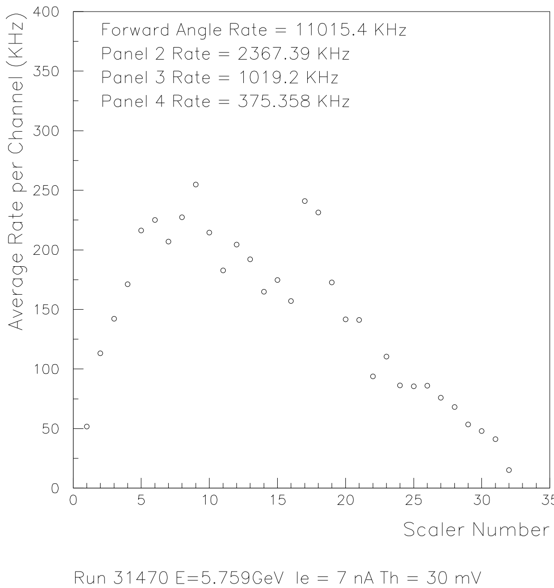

Figure 1: Run 31470, threshold = 30 mV. Note that 1-16 are doubles, 17-32 are tripples.

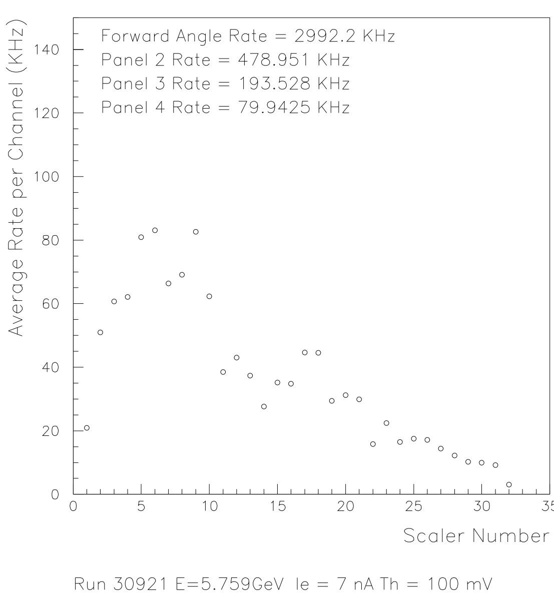

Figure 2: Run 30921, threshold = 100 mV. Note that 1-16 are doubles, 17-32 are tripples.

Scalers

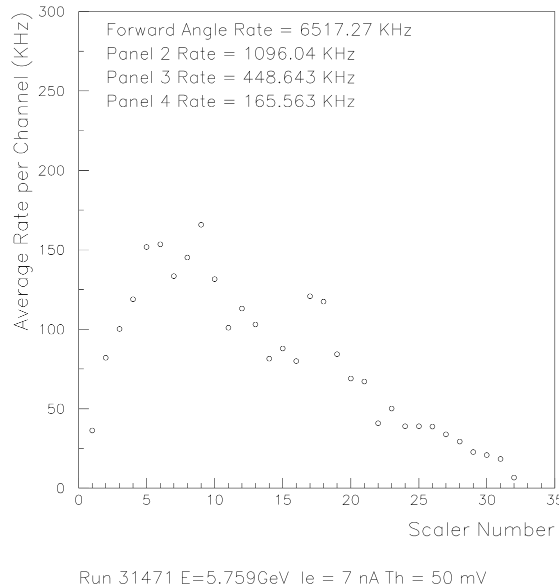

Figure 3: Run 31471, threshold = 50 mV. Note that 1-16 are doubles, 17-32 are tripples.

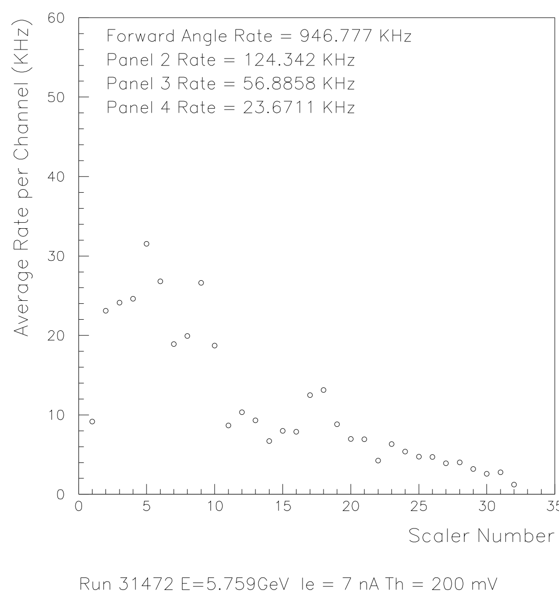

Figure 4: Run 31472, threshold = 200 mV. Note that 1-16 are doubles, 17-32 are tripples.

TOF counters TDC spectra

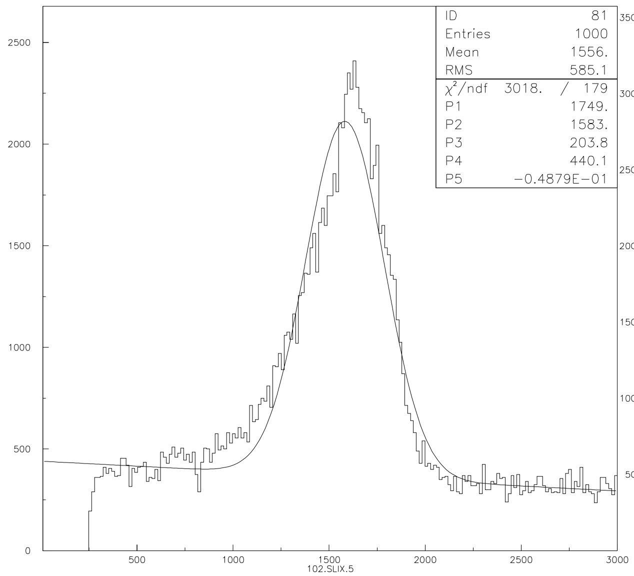

Figure 5: Run 31397, fit to TDC peak plus accidentals, counter 5.

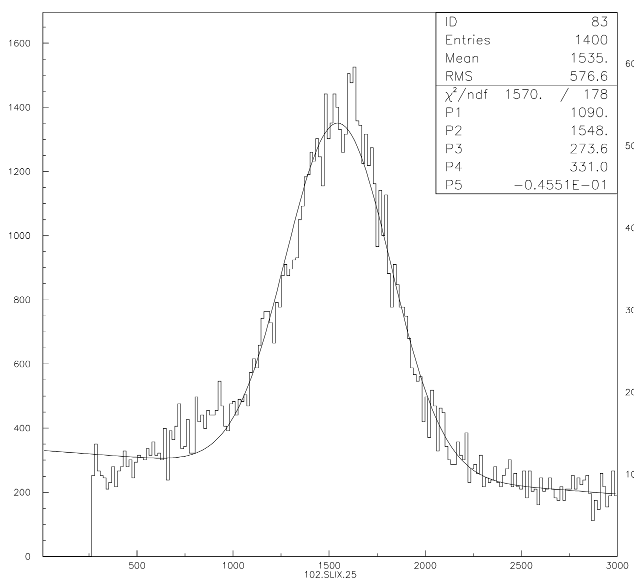

Figure 6: Run 31397, fit to TDC peak plus accidentals, counter 25.

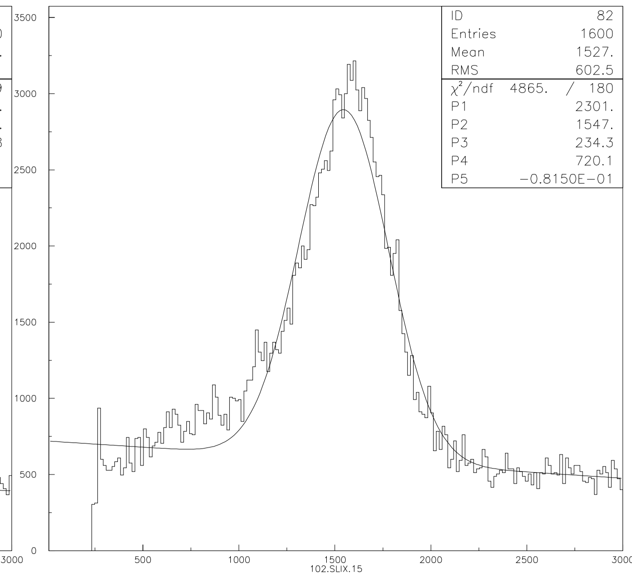

Figure 7: Run 31397, fit to TDC peak plus accidentals, counter 25.

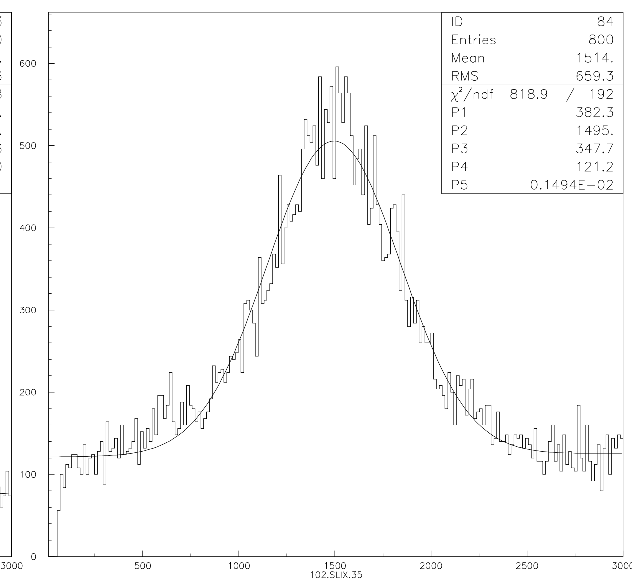

Figure 8: Run 31397, fit to TDC peak plus accidentals, counter 35.

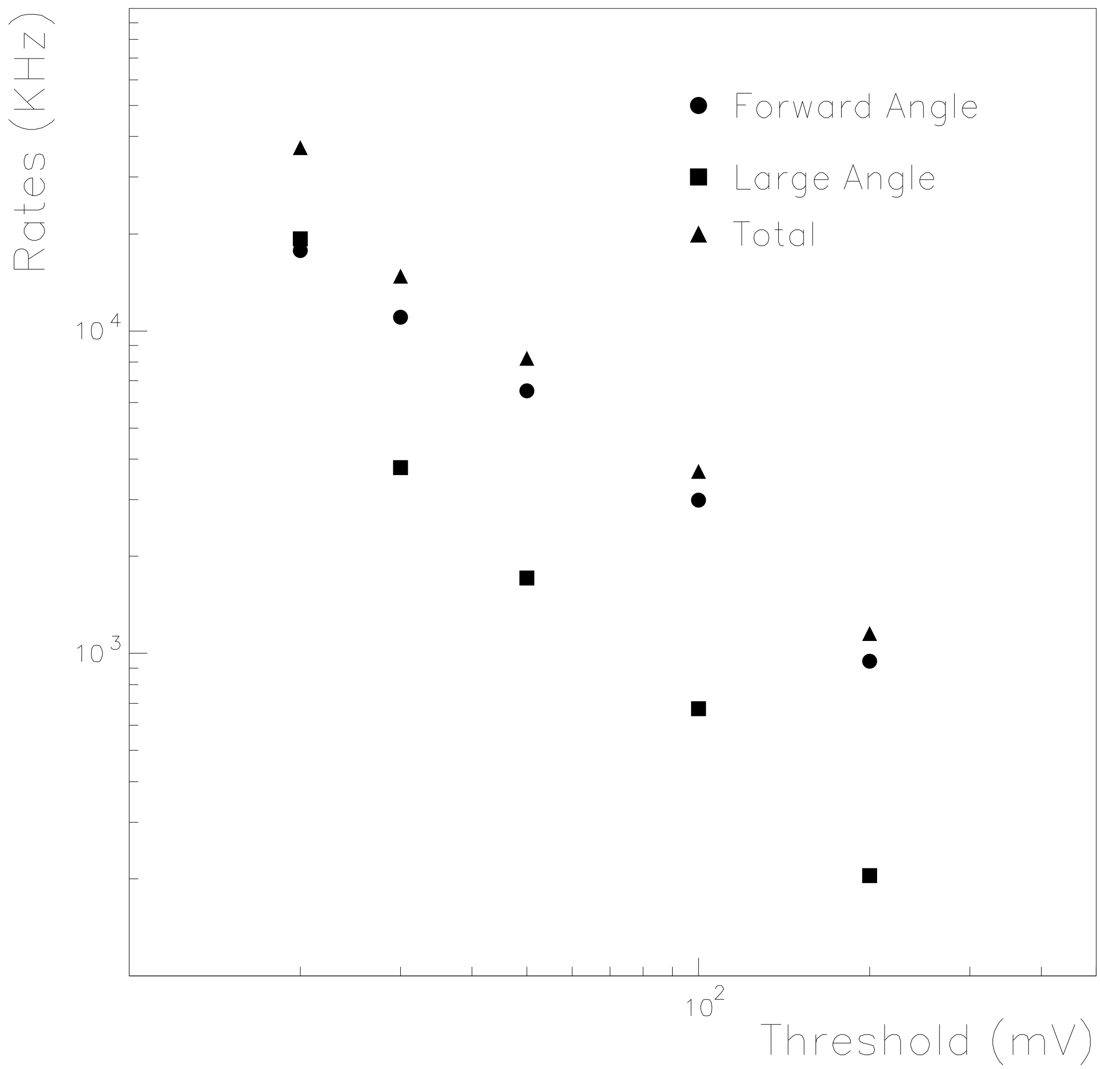

Figure 9: Rates summed over all six sectors are plotted as a function of threshold. The rates at 20 mV are obtained from TDC accidentals. All other values are derived from scaler rates.

Rates in TOF counters

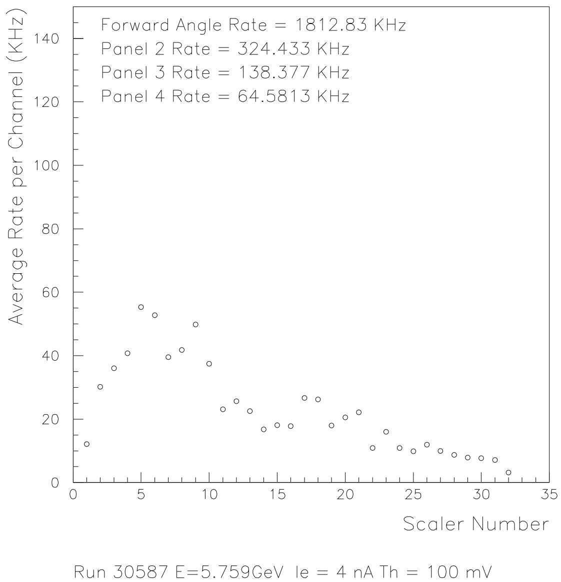

Figure 10: Run 30587, data at 3.8 nA. Note that 1-16 are doubles, 17-32 are tripples.

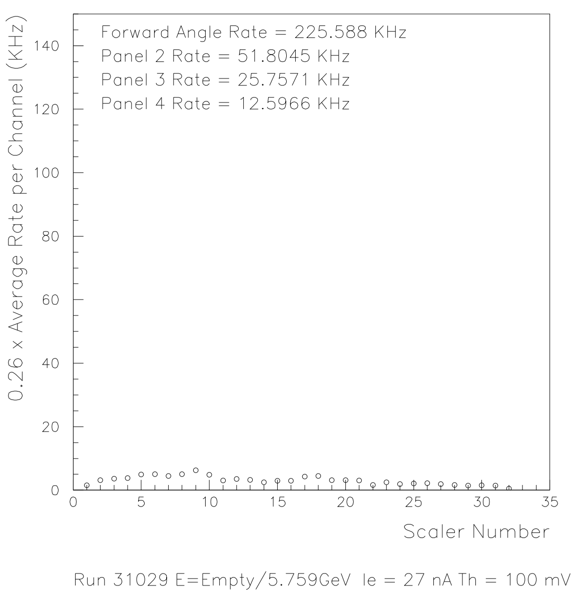

Figure 11: Run 31029, empty target at 27 nA, normalized by 0.26.

Scalers

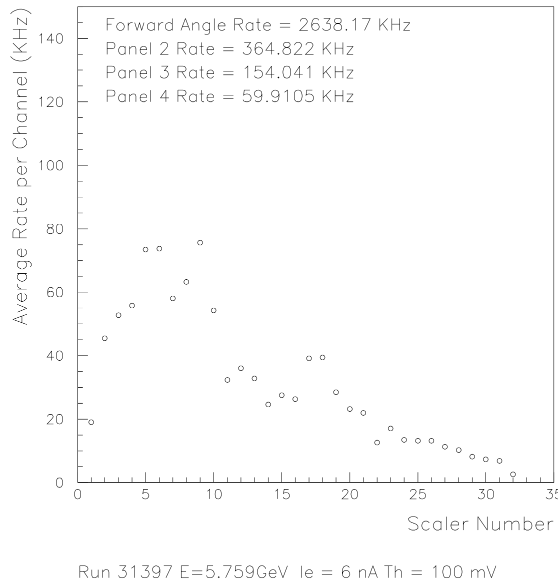

Figure 12: Run 31397, data at 6 nA. Note that 1-16 are doubles, 17-32 are tripples.

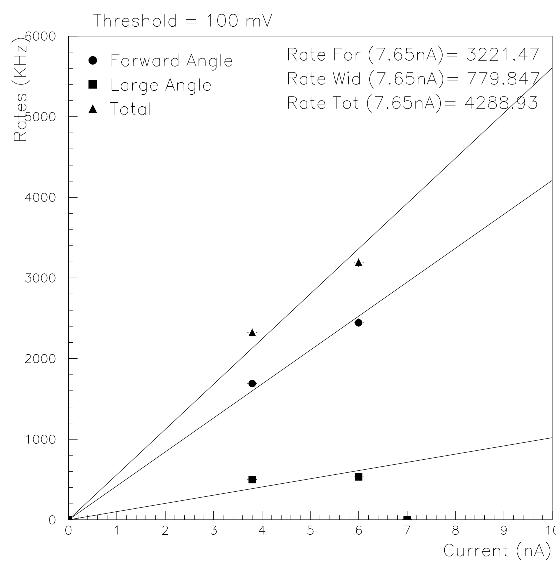

Figure 13: Fits to scaler rates as a function of beam current at the nominal pretrigger threshold of 100 mV.

Rates in TOF counters

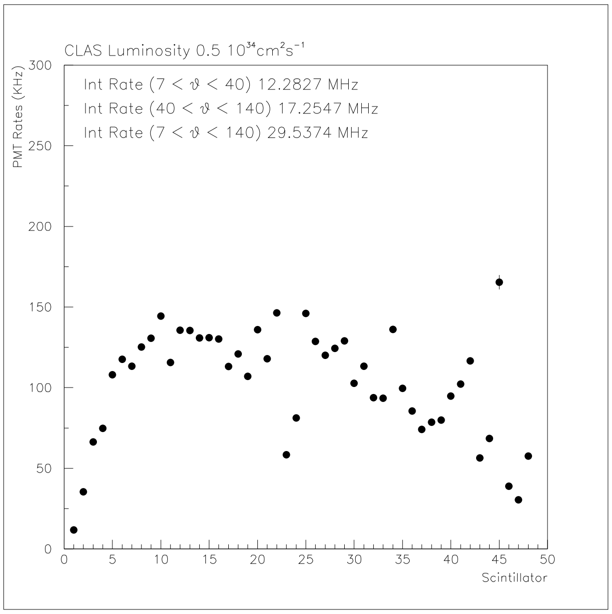

Figure 14: Run 30587, data at 3.8 nA.

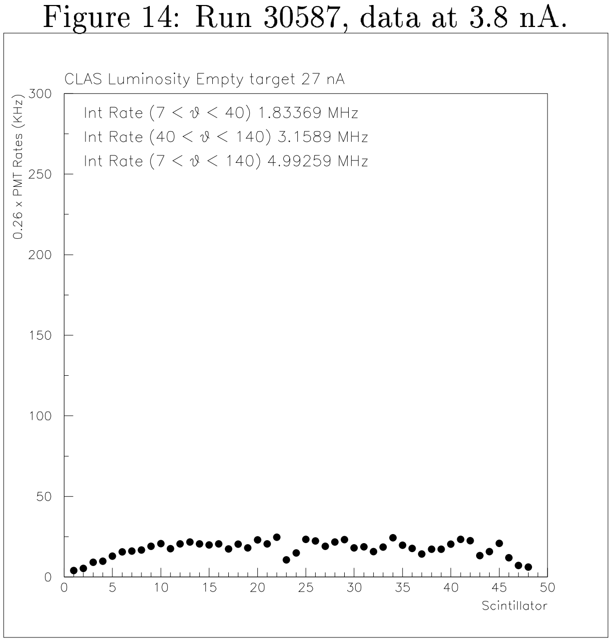

Figure 15: Run 31029, empty target at 27 nA, normalized by 0.26.

TDC Accidentals

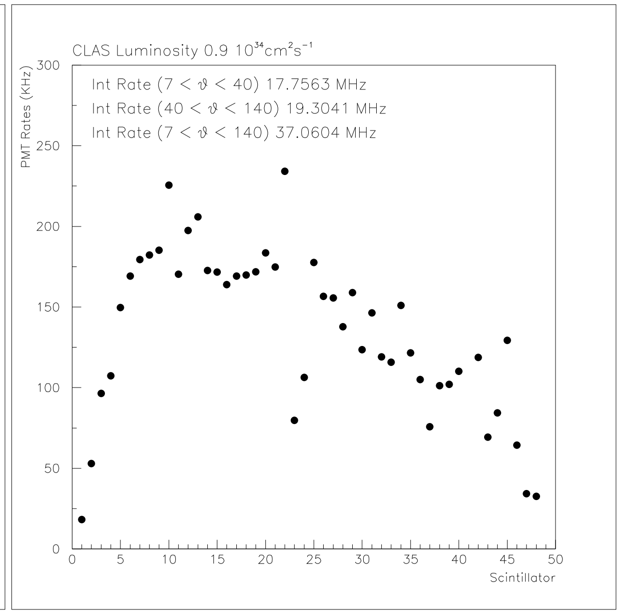

Figure 16: Run 31397, data at 7 nA.

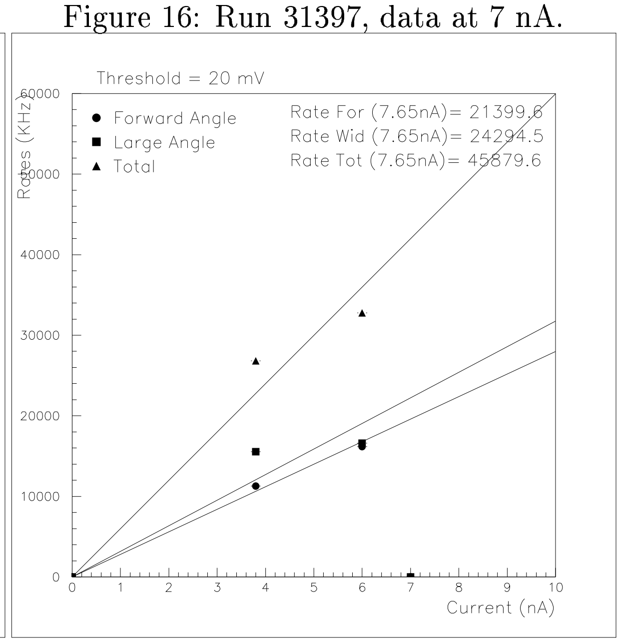

Figure 17: Fits to TOF accidental rates as a function of beam current.