Trigger prescaling and event loss in October 2007 beam time

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The analysis by V. Kurbatov et al [1] of the $pp \to pp\pi^0$ reaction in the beam times of October'07 and June'10, where the data were collected at $T_p = 2.4$ GeV in similar conditions, has revealed a significant lack of two-track events in the first beam time. This deficiency was attributed to a wrongly assumed prescaling factor of the T1=FdAnd trigger in October'07. Below are the results of an investigation showing that this assumption was not correct, but the loss of events was connected to missing meantimer signals of the forward hodoscope.

1 Prescaling of T1 trigger

In October'07 each of the triggers fired in an event was recorded independently by the trigger TDC module. The easiest way to define the prescaling factor of T1 is to count the fraction of events of the T2=FdDouble trigger that have the TDC channel of T1 fired. Without the prescaling, each of T2 triggers must be accompanied by a T1 signal. When T1 is prescaled, that fraction will be inverse of the prescaling factor modified by the ratio of the dead time factors for the two triggers. Due to a relatively small ($\sim 10\%$) fraction of T1 in the total count rate, the dead times introduce a rather small difference.

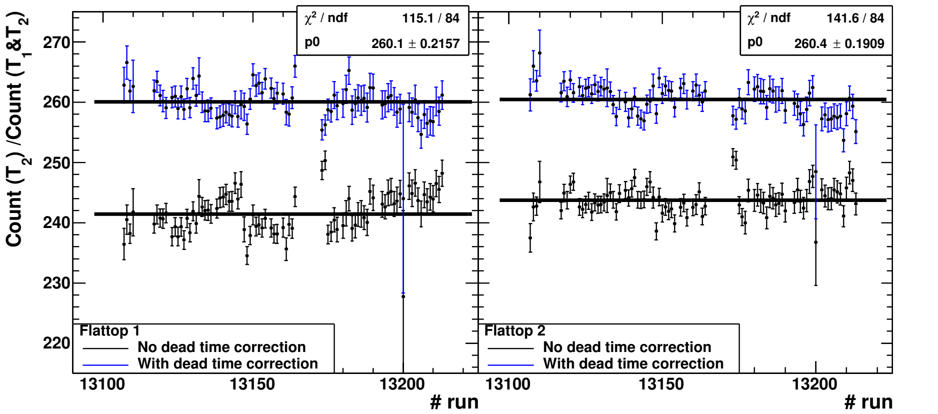

Figure 1: Ratio of the total number of T2 events, to those having both the T2 and T1 signals, with (blue error line) and without (black error line) dead time difference correction. The fit parameters are given for the corrected data.

In Fig. 1 the above described ratio is shown for each run with the prescaling factor of 256. One can see that it is close to the expected value of 256, but deviate from it by 1.7% on average. This deviation as well as some systematic drift with time, may be subjects of further investigation, or should be included to the total systematic error. A possible reason for them is the scaler trigger, that causes a longer system dead-time, or variations of the dead-time of the regular triggers. A rather strong deviation of the uncorrected ratios in the runs 13173 and 13174 is connected to the double-double mode temporarily enabled in T2, that increased the T2 trigger rate by few times.

Another example: let us consider data with a prescaling factor 16 (run 13069). The uncorrected ratio $R = T_2/(T_1\&T_2) = 5023006/338176 = 14.85 \pm 0.03$, the dead time factors $R_{dt} = dt(T_1)/dt(T_2) = 0.584/0.544 = 1.074 \pm 0.001$, the corrected ratio $R \cdot R_{dt} = 15.95 \pm 0.03$, just as expected.

From this one can conclude that **there is no reason to apply in the analysis a prescaling factor twice different from the nominal one.** In addition, the dead time correction can and should be properly applied in the analysis, and the approach taken in [1] is acceptable for a preliminary analysis only.

2 Instability of the two-track reconstruction efficiency in October'07

The deficiency of two-track events was shown by V. Kurbatov with the use of an intense $pp \to pn\pi^+$ process. The data were obtained in October'07 and June'10 at the same beam energy of 2.4 GeV and at very close D2 settings. There was only one trigger used in June'10, and in a first approximation, the T1 prescaling factor in October'07 could be deduced from the comparison of ratios of the number of $pp \to pn\pi^+$ events to that of $pp \to pp$, defined in the two beam times. Although there were few factors including some difference of the setup acceptances, the difference of dead times in October'07, and possible difference in the trigger efficiency for the $pp \to pn\pi^+$ events, such a comparison was a reasonable way to detect a significant loss of events.

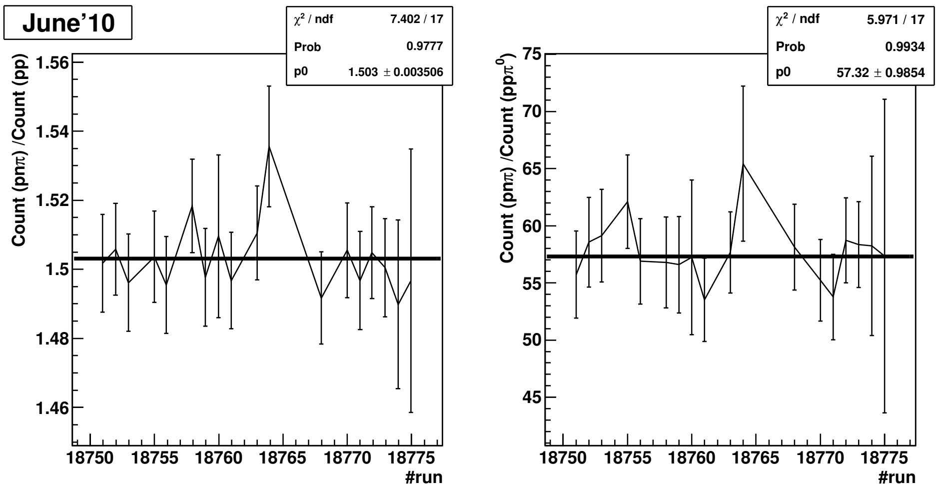

Figure 2: June 2010 beam time. Left: Ratio of the number of $pp \to pn\pi^+$ events to that of $pp \to pp$, the latter scaled down by a factor of 100. Right: Ratio of $pp \to pn\pi^+$ to $pp \to pp\pi^0$.

As a first step, the ratio of $pp \to pn\pi^+$ to the elastic events was defined for each run in the two beam times. In Fig. 2 this ratio is shown for the June'10 beam time together with the ratio of the $pp \to pn\pi^+$ events to $pp \to pp\pi^0$. As one could expect, the ratios do not change in the constant conditions of the experiment.

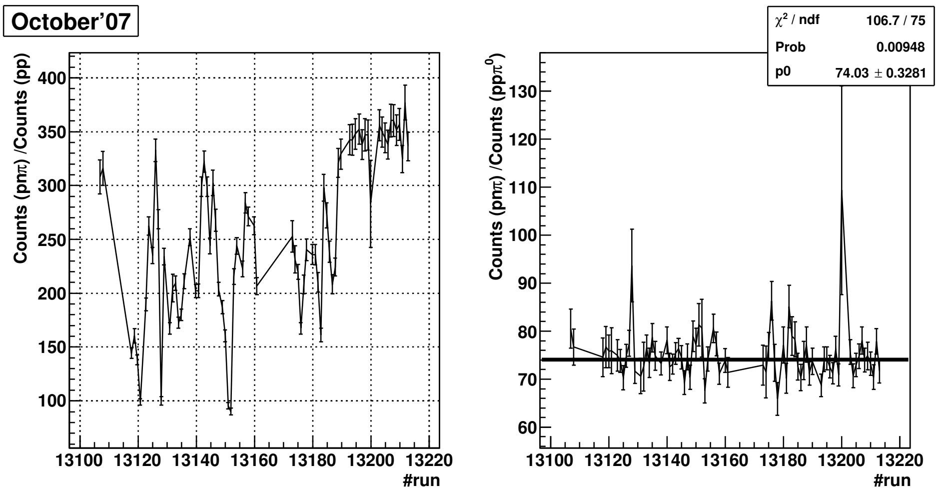

Figure 3: October 2007 beam time. Left: Ratio of the number of $pp \to pn\pi^+$ events to that of $pp \to pp$, the latter scaled down by a factor of 100. Only events with T1 trigger (inclusive) were used for $pp \to pp$. Right: Ratio of $pp \to pn\pi^+$ to $pp \to pp\pi^0$.

The results for October'07 shown in Fig. 3 demonstrate a substantial instability of the efficiency of the two-track events reconstruction. In this conditions, any further comparison of the beam times made little sense, and the focus shifted to the reason of this instability.

3 Loss of meantimer signals of Forward hodoscope in October'07

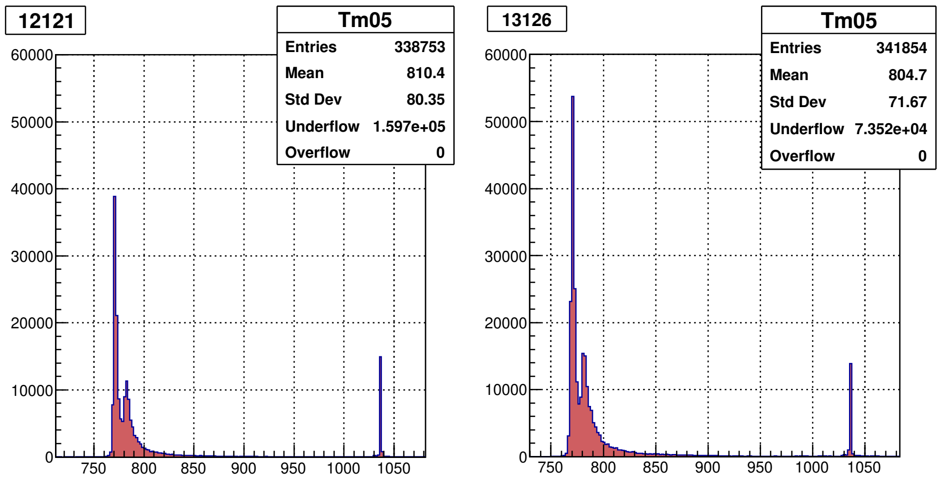

Figure 4: Raw meantimer distribution for counter #5 for two runs. Spectra obtained with "-uncond" sorter option and without trigger selection.

In Fig. 4, raw meantimer distributions are shown for two runs demonstrating very different two-track outcome in Fig. 3 (left). The total number of events in these runs is very close, 14526292 event in run 13121, and 14496642 in run 13126. The two groups at about Tm=800 and Tm=1040 correspond to the events recorded with triggers T2 and T1, correspondingly. One can immediately see that while the height of the T1 peaks is similar in these figures, the T2 group in 13121 lacks a large part of events.

In the default mode of RootSorter, the counter information is made available in the analysis (added to the REvent in the EMSFilter) only when the meantimer signal is present in the event. If one uses the "-uncond" option, like it was done for Fig. 4, presence of any of the time or amplitude signals becomes sufficient. In this case, the events lacking meantimers are added to the underflow count, which is twice higher in run 13121 in Fig. 4. In the histograms of Tu and Tb the number of underflows is negligible, that limits the problem to the missing meantimer signals.

The percentage of under- and overflow events was defined for each counter in every run. Below is an example table for run 13121 (Table 1). The noise events were rejected by amplitude thresholds of 30 channels for both Qu and Qb. The data were analysed separately for each trigger.

One can see, that the meantimer signals are mostly missing in the T2 data, but also, to a smaller extend, in T1. The Tu/Tb signals are mostly fine, some of them missing in e.g. counters #8 and #9 may be connected to a higher noise level in these counters. The counter #17 systematically demonstrates a behaviour different from the rest, and will be excluded from the following consideration. In Fig. 5 the hodoscope meantimer efficiency is shown for the two triggers for each run. It is calculated as an average over all counters but #17. In Fig. 6 the efficiency for T2 is compared to the ratio of $pn\pi^+/pp$ shown in the left panel of Fig. 3.

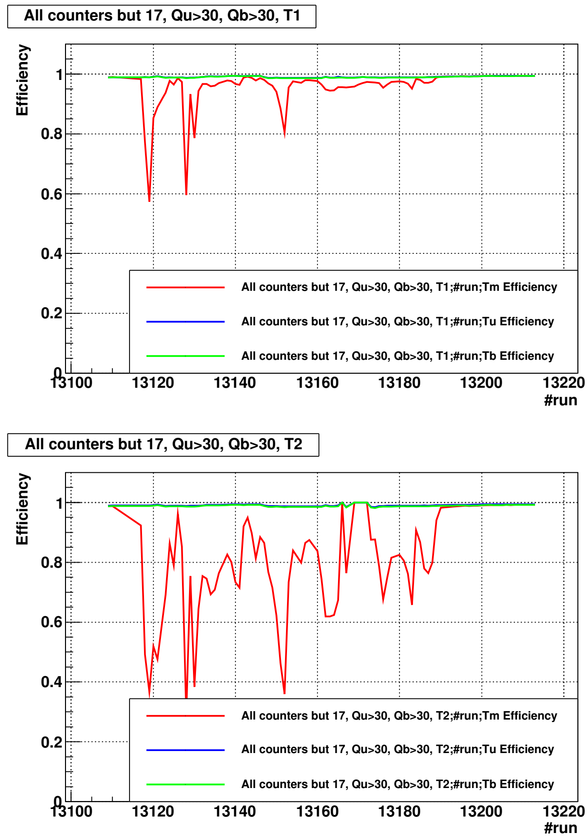

Figure 5: Average meantimer efficiency as function of run number for two triggers.

--------- Run 13121 ----------			
----------- T1 ---------------			
#Counter\ U/OFlow:	Tu,%	Tb,%	Tm,%
01	0.7/ 0.0	0.8/ 0.0	13.8/ 0.0
02	0.9/ 0.0	0.9/ 0.0	16.9/ 0.0
03	0.5/ 0.0	0.5/ 0.0	8.6/ 0.0
04	0.6/ 0.0	0.6/ 0.0	8.5/ 0.0
05	0.5/ 0.0	0.5/ 0.0	9.0/ 0.0
06	0.6/ 0.0	0.6/ 0.0	9.8/ 0.0
07	0.7/ 0.0	0.8/ 0.0	11.0/ 0.0
08	0.8/ 0.0	0.9/ 0.0	7.9/ 0.0
09	0.8/ 0.0	1.0/ 0.0	16.1/ 0.0
10	1.4/ 0.0	1.8/ 0.0	13.8/ 0.0
11	0.8/ 0.0	0.8/ 0.0	10.1/ 0.0
12	0.5/ 0.0	0.5/ 0.0	9.5/ 0.0
13	0.6/ 0.0	0.6/ 0.0	8.6/ 0.0
14	0.7/ 0.0	0.7/ 0.0	10.4/ 0.0
15	0.8/ 0.0	0.8/ 0.0	11.3/ 0.0
16	0.8/ 0.0	0.9/ 0.0	12.1/ 0.0
17	1.8/ 0.0	1.7/ 0.0	6.4/ 0.0
----------- T2 ---------------			
#Counter\ U/OFlow:	Tu,%	Tb,%	Tm,%
01	1.7/ 0.0	1.9/ 0.0	49.4/ 0.0
02	0.3/ 0.0	0.2/ 0.0	46.8/ 0.0
03	0.3/ 0.0	0.3/ 0.0	53.8/ 0.0
04	0.4/ 0.0	0.3/ 0.0	51.8/ 0.0
05	0.2/ 0.0	0.2/ 0.0	53.7/ 0.0
06	0.2/ 0.0	0.2/ 0.0	53.5/ 0.0
07	0.5/ 0.0	0.5/ 0.0	53.2/ 0.0
08	2.8/ 0.0	2.9/ 0.0	45.5/ 0.0
09	2.0/ 0.0	3.2/ 0.0	45.5/ 0.0
10	0.8/ 0.0	1.9/ 0.0	53.7/ 0.0
11	0.4/ 0.0	0.4/ 0.0	52.8/ 0.0
12	0.2/ 0.0	0.2/ 0.0	54.0/ 0.0
13	0.3/ 0.0	0.2/ 0.0	54.9/ 0.0
14	0.2/ 0.0	0.2/ 0.0	55.5/ 0.0
15	0.3/ 0.0	0.3/ 0.0	57.1/ 0.0
16	1.2/ 0.0	1.7/ 0.0	56.3/ 0.0
17	2.7/ 0.0	2.6/ 0.0	17.1/ 0.0

Table 1: Percentage of under-/over- flow entries in the raw time spectra in run #13121.

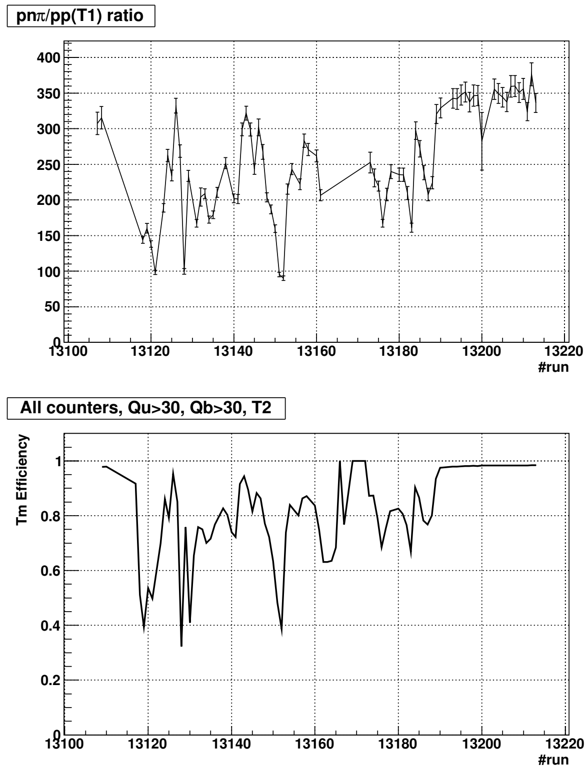

Figure 6: Two-track reconstruction efficiency (top) and meantimer efficiency for T2 (bottom) as functions of run number.

3.1 Correlation of meantimer efficiencies

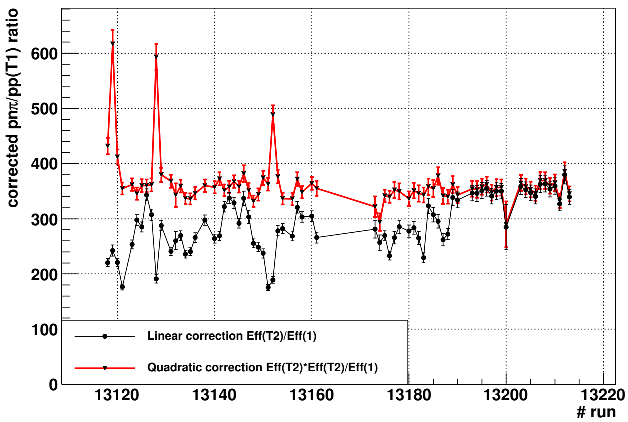

Figure 7: $pn\pi/pp$ ratio corrected to Tm inefficiency.

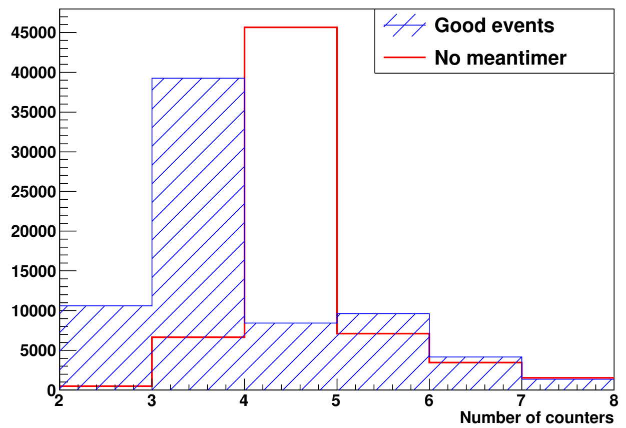

Figure 8: Number of events with and without meantimer signals in run 13121.

If one studies the counter signals event by event, it is easy to notice that there are only two possibilities present: either all of the meantimers in the event are absent, or all of them are present. A more accurate study shows that there are only 1% of events in both triggers that do not follow this rule. From the point of view of the double-track event loss, this means that the reconstruction inefficiency should be proportional to T2 efficiency, but not to the efficiency squared, as it would be in a case of independent meantimer loss.

In order to check that, the $pn\pi/pp$ ratio from Fig. 3 (left) was corrected to *i)* ratio of $Eff(T_2)/Eff(T_1)$ efficiencies from Fig 5, *ii)* a quadratic ratio of $Eff(T_2) \cdot Eff(T_2)/Eff(T_1)$, the results are shown in Fig. 7. As one can see, contrary to the expectations, the quadratic correction fits the data better, except for only three runs. This can be understood from Fig. 8, where one can see that the inefficiency is strongly correlated with the number of counters fired in an event.

To estimate the effect of the meantimer loss on the cross section, one can average over the whole beam time the efficiencies weighted with the number of events in each runs. For the cases of linear and quadratic corrections, this yields factors 1.23 and 1.69, correspondingly.

4 Conclusion

For the data of October'07 beam time:

- There is no reason to change the T1 prescaling in the analysis
- Significant fraction of events lacks meantimer signals, what leads to a loss of reconstructed tracks in both one- and two-track events
- The Tu and Tb signals are intact, thus a software meantimer can be calculated and used when the hardware one is missing. The data should be processed with the "-uncond" sorter option
- One should check that the chamber efficiency and the time spectra of the drift chambers are not affected by the loss of meantimers
- A proper dead time correction must be used
- **The data must be reanalysed** starting from the track reconstruction step
- It is likely that the current cross section value is overestimated by 15-40%

As a general remark, it was a big surprise to find this kind of problem in the data at such a late stage of the analysis. Of course, checking of the raw signals should have been the very first step of investigation of the two-track event loss. Not to mention the trivial check of the prescaling factor, which required the trigger information alone.

Unfortunately, the internal report [1] was not sent to me directly (but kindly forwarded to me by Dima in November), and the results to be presented by V. Kurbatov at a conference were sent to me in a form of abstract only. It literally took me a single day to find out the first tree points from the list above, thus a significant work time of the whole group could have been saved if I was informed about the problem.

Список литературы

[1] *Анализ данных по рождению дипротона в pp соударениях в интервале энергий 0.8 - 2.8 Гэв.* В. Курбатов, Д. Цирков, А. Кунсафина, Ж. Курманалиев. Internal report. 3 июля 2018 г.