Implementation of pellet tracking in physics experiments - initial studies at WASA

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Introduction

A pellet tracking (PTR) system for PANDA has been designed in Uppsala [1]. With such a system one can reconstruct the positions of the individual pellets at the time of a hadronic interaction in the offline event analysis. This gives information on the position of the primary interaction vertex with an accuracy of a few hundred microns, which is very useful e.g. for reconstruction of charged particle tracks and secondary vertices and for background suppression.

The PTR data will be collected by a standalone system that is synchronized with the main DAQ, so that it takes about 100 ms to collect all measurement data relevant for reconstructing a pellet track and this time scale is very different from the time scale handled by a hadron physics experiment DAQ (parts of ns to a few µs). To get experience of how to synchronize and use PTR information in data analysis, information from a long-range (LR) TDC, read out by a standalone system working in parallel to the WASA DAQ, was processed. This LR TDC system operates with a similar time scale as pellet tracking (between some µs and several seconds). The synchronization was achieved by writing a common time stamp (and event number) to both DAQ systems.

This study gives a simple demonstration of one possibility with pellet tracking. Using information from pellet tracking, the number of pellets in the accelerator beam region at the time of an interaction can be reconstructed. This information alone allows suppression of effects due to events not originating from accelerator beam - pellet interactions. The suppression can be done in two ways:

Event-by-event: reject events occurring when no pellet was present.

In measurement distributions: use the no-pellet event sample (properly normalized) for background subtraction.

"Empty target" corrections are normally difficult to make in high luminosity internal target experiments. To just switch off the target doesn’t make sense since the presence of the target may influence both the accelerator beam and vacuum conditions significantly.

The LR TDC information

There are pellets in the beam only for some fraction of the time, while events due to rest-gas and beam halo happen all the time. When a pellet is in the beam, it is most probable that the event came from the pellet. The integrated rate of interactions is exploited, to know when there are pellets in the beam. When a pellet passes through the beam, there are more interactions. For this purpose one of the trigger signals for collecting elastic scattering events (originating from the nominal interaction point) was connected to the LR TDC and used to monitor accelerator beam - pellet interactions. A typical 5 ms time spectrum from the LR TDC is shown in Figure 1. It takes $\approx 70 \mu$s for a pellet to cross the COSY beam at its center. Structures of such duration are visible in the time spectrum. A simplified classification of time bins, each of length 25 µs, was done (as indicated in Figure 1):

- "Non-pellet-class" = low signal rate 0 - 20 / bin $\leftrightarrow$ probably no pellet in the beam region.
- "Pellet-class" = high signal rate $> 20$ / bin $\leftrightarrow$ probably pellets in the beam region.

The signal rate ranges were adjusted to correct for accelerator beam decay ($\approx 50 \%$) during the 50 s period in the accelerator cycle when the beam hit the pellet stream.

To check the feasibility of using a standalone (pellet tracking like) system together with a hadron experiment, a 16 min short test run at WASA was performed. Based on the collected data, the possibility to suppress background events by implementing the LR TDC information in the event analysis was studied. The pellet rate was about 8 k/s and in this case one expects that during 50 % of the time there are no pellets in the beam region.

Data analysis

As test reaction, $pp \rightarrow pp\pi^0 \rightarrow pp\gamma\gamma$ at a beam proton kinetic energy of 0.45 GeV was chosen. Events where both protons hit the forward detector and the two gammas hit the very forward part of the electromagnetic calorimeter (nominal scattering angles $\Theta = 20^\circ - 40^\circ$) were specially studied since it is fairly easy to see effects from rest-gas interactions in this kind of events. Figure 2 shows $\gamma\gamma$ invariant mass and $p-p$ missing mass distributions for events collected during LR TDC “Non-pellet-class” time intervals and Figure 3 shows the same for events during LR TDC “Pellet-class” time intervals. Expectations from WASA Monte-Carlo (WMC) simulations, including rest-gas according to a realistic distribution, are also shown.
As anticipated, the "Pellet-class" event sample (Figure 3) is in good agreement with WMC with a low rest-gas contribution, while the "Non-pellet-class" event sample (Figure 2) contains many more events originating in rest-gas, beam pipe walls and other background events not coming from the nominal interaction region. The structure in experimental data at low $\gamma\gamma$ invariant mass, most clearly seen in Figure 2a is probably due to beam-halo interactions in the beryllium beam pipe walls, an effect that is not included in the WMC simulations. This structure is strongly suppressed in the "Pellet-class" event sample.

The method, using the integrated rate of interactions to know when there are pellets in the beam, could well be exploited in real experiments. Compared to pellet tracking it has some drawbacks, e.g. the monitoring signals and the reactions under main study, both contain contributions from background. Due to this and limited statistics it may be difficult to separate "Pellet" from "Non-pellet" time intervals.

**Summary**

Initial studies on how to synchronize and implement pellet tracking information in a hadron physics experiment has been done at WASA. A detailed comparison between $\pi^0$ event candidates from different time intervals confirms that this works according to expectations.

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**References**


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