Simulation studies of the HADES first level trigger.
PART II: Performance in hadron induced reactions

R. Schicker\(^1\) and H. Tsertos

*University of Cyprus, Nicosia, Cyprus*

Abstract

The HADES first level trigger is studied for the system p+Ni at a beam energy of 2 AGeV. The timing properties of the trigger signal are reported. The efficiency loss due to deadtime is specified. A trigger requirement of a time overlap window with the start detector is described. The trigger rates for different overlap windows are given.

\(^1\) Corresponding author, e-mail "schicker@alpha2.ns.ucy.ac.cy"
Dept. Nat. Science, Univ. Cyprus, PO 537, 1678 Nicosia, Cyprus
1 Introduction

The dilepton spectrometer HADES is currently being built at the heavy-ion synchrotron SIS at GSI Darmstadt[1]. HADES will measure dielectron pairs emitted in proton-proton, proton-nucleus and nucleus-nucleus collisions in the beam energy range of 1-2 AGeV. Additionally, a secondary pion beam facility of momenta between 0.5 GeV/c and 2.5 GeV/c will allow the measurements of dilepton observables in pion induced reactions[2].

The reconstruction of dileptons from in-medium decays of $\rho$, $\omega$ and $\phi$ mesons allows to test conjectures about in-medium behavior of these mesons[3]. Model calculations predict a change of the in-medium meson mass as a function of the nuclear density reached in the collision. Hence, proton and pion induced reactions yield information at ground state density, whereas heavy-ion induced collisions do so at densities up to three times the ground state density.

HADES is designed to operate at proton beam intensities of $10^8$ per second. A 1% interaction target results in $10^6$ minimum bias events per second. The maximum pion beam intensity, on the other hand, reaches values of about $2\times10^7$ per spill at a momentum of 1 GeV/c. The proton beam is therefore more demanding on the first level trigger, and simulation results are shown below only for proton induced reactions.

The purpose of this paper is to present simulation studies of the HADES first level trigger in hadron induced reactions. Simulation results are shown for the system p+Ni at 2 AGeV, in order to illustrate the trigger performance in a hadron induced very low multiplicity collision system.

This paper is organized as follows: Section 2 gives a summary on the HADES first level trigger requirements in hadron induced reactions. In Section 3, the production and analysis of the first level trigger simulation data are described. In Section 4, the performance characteristics of the first level trigger in the very low multiplicity system p+Ni are presented.

2 First level trigger requirements

In hadron induced reactions, the HADES first level trigger has to provide a reaction trigger. This reaction trigger can be derived from the multiplicity of the highly segmented time of flight (TOF) array. A condition on the number of TOF paddles carrying coincident signals will provide this trigger.

Depending on the specific reaction channel to be measured, the total mul-
Multiplicity condition imposed on the TOF paddles can be as low as two. This multiplicity value corresponds to the two charged leptons of the pair. To illustrate this point, we mention here the $p(\pi^-, e^+ e^-)n$ reaction which is tagged by a multiplicity condition of two. This reaction attracts considerable interest for the investigation of the time-like nucleon form factor below the threshold accessible in nucleon-antinucleon annihilation. Thus, a versatile first level trigger for hadron induced reactions is characterized by a multiplicity condition of two or larger.

The trigger signal derived from the multiplicity condition of the TOF paddles is used as gate for the ADCs of the RICH detector and as common STOP for the TDCs. Thus, the delay of this signal with respect to the time of reaction as well as the time jitter are of particular interest. The time jitter of the first level trigger signal arises from different sources. First, trajectory length variations over the polar angular range of the spectrometer induce particle TOF variations. Second, velocity variations of the particles defining the trigger add to the TOF variations. Third, the different signal propagations in the TOF paddles, depending on the location of the hit point, add varying delays to the TOF signals.

A multiplicity condition of two is triggered by the two fastest particles of the event, i.e., by the two leptons ($\gamma \geq 20$) of the pair. The contribution to the time jitter due to particle velocity variations mentioned above therefore vanishes. Thus, for a multiplicity condition of two, the trigger time jitter of dilepton events is considerably reduced as compared to events without dileptons. This time correlation allows an additional timing condition for the trigger signal derived from the fastest two particles of the reaction. Events containing a dilepton will meet this condition, but most of the events without dileptons will not. Hence, this requirement will considerably improve the deadtime of the first level trigger system. Such a timing condition necessitates, however, an independent measurement of the reaction time by another detector system.

The first level trigger performance in the $p+Ni$ system depends weakly on the duration of the TOF paddle signals[4]. In this report, all the results shown have been derived with a TOF signal length of 15 nsec.

3 First level trigger data production and analysis

As in the earlier investigations, the full HADES geometry was implemented into the GEANT package[5]. A realistic field map of the toroidal magnetic field is used for tracking of the charged particles[6].

The collisions of the $p+Ni$ system are modeled by a transport equation of the
Boltzmann-Uehling-Uhlenbeck (BUU) type. The dynamical evolution of the collisions is determined by calculating the phase space evolution for nucleons, Delta and N* resonances. With this code, good agreement is found between data and model predictions in proton induced collisions in the energy range 1-2 AGeV[7].

In the system p+Ni presented here, the production and analysis of the first level trigger data proceed in a similar manner as for the heavy-ion systems reported [5].

4 First level trigger in p+Ni collisions

4.1 Minimum total multiplicity

Due to the very low multiplicity of the p+Ni system, a large fraction of reactions has no tracks in one or more of the azimuthal sectors. As in the Ne+Ne system studied earlier[5], the minimal total multiplicity condition $M_L$ is therefore used in order to define the trigger. For all of the results shown in this report, a multiplicity condition $M_L \geq 2$ is used. Thus, the two fastest particles of an event define the trigger.

4.2 Trigger timing

Fig. 1 shows the trigger timing of p+Ni events with different impact parameters. Here, the trigger is defined by the condition of minimum total multiplicity $M_L \geq 2$. The time zero is the time of reaction. Events with impact parameter $b = 1 \text{ fm}$ are represented by the solid line. The FWHM of their time distribution amounts to about 10 nsec. Events with impact parameters of 2 and 3 fm exhibit a very similar behavior. The distributions in Fig. 1 have considerable tails for high $\Delta T_0$ values. These tails result from events in which the second particle of the trigger condition is very slow.

4.3 Trigger timing of events containing $e^+e^-$ pairs

The width of the trigger timing shown in Fig. 1 results from three different sources as discussed in Section 2. For reactions containing dileptons, the trigger timing derived from the two fastest particles, the two leptons, does not include the jitter contribution due to particle velocity variations. Thus, the timing of the trigger signal is expected to be considerably improved as compared to
events without dileptons. The dashed line in Fig. 2 shows the timing of the trigger derived from the \( M_L \geq 2 \) condition for p+Ni events which do not contain dileptons. The solid line in Fig. 2 shows the trigger timing if the fastest two particles of the event are leptons of momenta larger than 100 MeV/c. The width of this distribution is about 3 nsec. In Fig. 2, the events without dileptons are downscaled with respect to the dilepton events. The relative intensity of these two classes of events is therefore arbitrary.

The width of the trigger timing of e\(^+\)e\(^-\) events shown in Fig. 2 results from variations in signal propagation delays in the TOF paddles and from trajectory length variations over the polar angle of the spectrometer. However, this width can be further reduced by using a mean timer circuit which provides TOF paddle timing independent of particle hit location. Additionally, the mean timer TOF signal can be corrected for the average trajectory length of the different paddles by introducing appropriate cable delays. Only second order length variations within one TOF paddle of the two oppositely charged leptons remain in such a scheme.

The improved timing of e\(^+\)e\(^-\) events allows to reject triggers which do not arrive within a time window \( \Delta T_0 \) following the reaction. This additional trigger condition is, however, contingent upon an independent measurement of the time of reaction with an accuracy comparable or better than the 3 nsec achieved by the TOF paddles. This independent measurement of the time of reaction can, for example, be achieved by the HADES start detector. A suitable time overlap coincidence between the HADES start detector and the trigger signal from the TOF paddles rejects a large fraction of events without dileptons. These rejected events do not generate a trigger, and the deadtime of the first level trigger system is therefore significantly improved.

In this report, deadtime losses are treated in the same way as in the heavy-ion systems studied earlier[5]. A factor \( R_{DT} \) is defined which contains the losses due to the system deadtime. Thus, the first level trigger rate is given by the reaction rate multiplied by the product of trigger efficiency times \( R_{DT} \).

Table 1 lists trigger rates and \( R_{DT} \) values derived from the multiplicity condition \( M_L \geq 2 \). These rates are shown for deadtimes \( T_0 = 0,6 \) and 10 \( \mu \)sec and for time windows of \( \Delta T_0 = 12,16 \) and 60 nsec. Here, the time window \( \Delta T_0 \) represents the time interval after the time of reaction during which the trigger signal has to arrive in order to generate a trigger. The condition \( \Delta T_0 = 60 \) nsec represents a wide open time window and is therefore equivalent to no time condition. For each deadtime, the rate is shown in the left column in units of \( 10^5 \) per second. The \( R_{DT} \) value is displayed in the corresponding column on the right. The improvement of the first level trigger performance with narrower time windows \( \Delta T_0 \) is clearly seen in Table 1. For the expected deadtime of 10 \( \mu \)sec, a time window condition \( \Delta T_0 = 12 \) nsec increases the number of dilep-
ton events passed to the next trigger stage by a factor larger than three. This factor assumes, however, that the losses of dilepton events due to applying this time window condition $\Delta T_0$ can be neglected. As indicated in Fig. 2 by the vertical dotted line, a $\Delta T_0 = 12$ nsec cut eliminates about 10% of the dilepton events in the present simulations. It is, however, anticipated that the timing of the dilepton events can be further improved as discussed above. Hence, the present loss of 10% dilepton events will be reduced to a negligible level. The information shown in Table 1 represents therefore realistic expectations for the HADES first level trigger performance in the very low multiplicity system p+Ni.

5 Conclusions

Simulations of the HADES first level trigger in the p+Ni system indicate that a reaction trigger can be implemented by a multiplicity condition imposed on the TOF paddles. A significant improvement of the first level trigger performance is possible by making use of the timing derived from the fastest two particles of the event. The achieved suppression of events not containing dileptons results in a much reduced system deadtime. The number of dilepton events passed to the next trigger stage is correspondingly increased by a factor larger than three. The first level trigger of the p+Ni system resulting from such an architecture fulfills the rate requirement of $10^5$ events per second.

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Figure Captions

Fig. 1. Timing of first level trigger from condition $M_L \geq 2$ for impact parameters of $b=1,2$ and 3 fm. The time zero is the time of reaction.

Fig. 2. Timing of first level trigger from condition $M_L \geq 2$ for $p+Ni$ events with dileptons (solid line) and for events without dileptons (dashed line). The vertical dotted line represents a time window condition $\Delta T_0 = 12$ nsec (see text). The time zero is the time of reaction.

Tables

| p+Ni | $T_0 = 0$ µsec | $T_0 = 6$ µsec | $T_0 = 10$ µsec |
|------|----------------|----------------|-----------------|
|      | rate $[10^5]$ | $R_{DT}$       | rate $[10^5]$   | $R_{DT}$       |
| $\Delta T_0 = 60$ nsec | 4.99 1.0      | 1.27 .25       | .840 .17        |
| $\Delta T_0 = 16$ nsec | 2.03 1.0      | .926 .46       | .676 .33        |
| $\Delta T_0 = 12$ nsec | .771 1.0      | .529 .69       | .435 .56        |

Table 1

First level trigger rates from condition $M_L \geq 2$ in the system $p+Ni$ for deadtimes $T_0 = 0,6$ and 10 µsec and for window conditions $\Delta T_0 = 12,16$ and 60 nsec. In the left column, the rates are shown in units of $10^5$ per second. In the right column, the deadtime reduction factor $R_{DT}$ is shown.
FIG. 1
FIG. 2