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# SELECTION OF SIGNAL EVENTS IN THE DUBTO EXPERIMENT

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An algorithm for selection of signal events for the experimental setup STREAMER is proposed. As a multivariate classifier for the identification of signal and background events we use a layered neural network. We discuss the feature variables used for event identification, the efficiency of the method estimated for model data, and present results of its application to real data.

В работе предлагается алгоритм отбора сигнальных событий, полученных на экспериментальной установке STREAMER. В качестве многомерного классификатора для идентификации сигнальных и фоновых событий используется многослойная нейронная сеть. Обсуждаются признаковые переменные, оценивается эффективность метода для модельных данных, и представлены результаты применения метода для анализа реальных данных.

## INTRODUCTION

DUBTO (Dubna–Torino) is a joint INFN–JINR project aimed at studying different channels of pion–nucleus interactions at energies below the $\Delta$ resonance at the phasotron of JINR's Laboratory of Nuclear Problems. It is based on the streamer chamber technique and the application of CCD videocameras for registration of nuclear reactions taking place in the working volume of the chamber.

The apparatus of the experimental setup STREAMER permits one to obtain multiparameter information concerning the nuclear reactions. Based on this information, one has to identify the event type. In order to solve this problem, we propose that the artificial neural network technique should be applied.

In Section 1 we give a brief description of the STREAMER setup and discuss the nuclear reactions studied. In Section 2 we consider an algorithm for identifying signal events based on a layered feed-forward neural network. The results of its application to real data are presented in Section 3.

## 1. EXPERIMENT

The self-shunted streamer chamber is filled with helium at atmospheric pressure and serves simultaneously as a thin target and a triggered track detector, which permits obtaining track images of very-low-energy secondary charged particles. The chamber is equipped with CCD videocameras, which significantly enhances the advantageous features of the streamer chamber technique. The arrangement of the chamber together with the CCD videocameras in the analysing magnet MC-4A is shown in Fig. 1 [1].

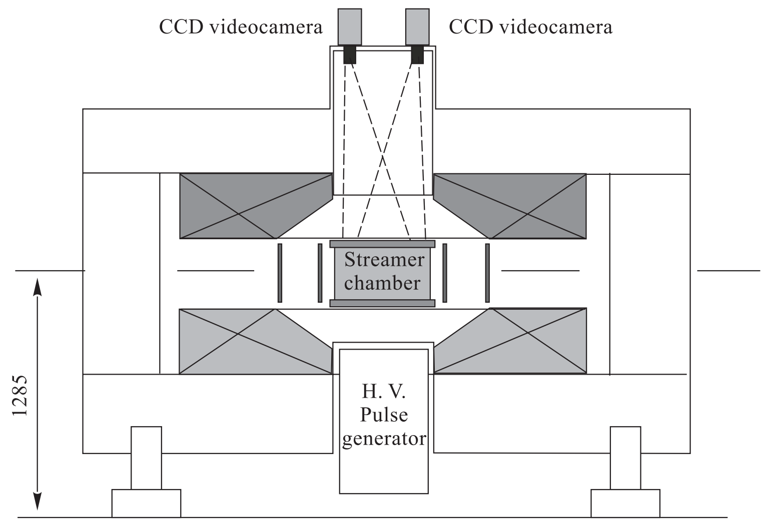


Fig. 1. Sketch of the DUBTO streamer chamber in the magnet MC-4A

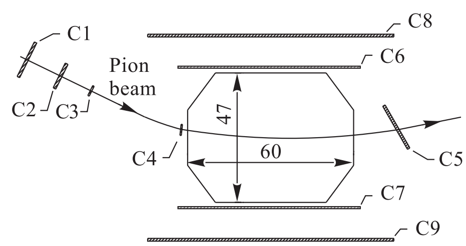


Fig. 2. Outline of the experimental setup STREAMER: $47 \times 60$ cm streamer chamber and hodoscope of scintillation counters C1 $\div$ C9

The STREAMER setup is located in the pion beam of the JINR phasotron (see Fig. 2). It involves several scintillation counters that serve for detecting the beam pions passing through the chamber and the secondary particles resulting from their interaction in the chamber gas, and for triggering the high-voltage pulse generator.

In Fig. 3 we present, as an example, the video-image of a three-prong pion-helium interaction event in the streamer chamber.

The three-prong $\pi^4$He events with a scattered pion recorded in the streamer chamber are mostly either

$$\pi^{+4}\mathrm{He} \to \pi^{+}2p2n \tag{1}$$

or

$$\pi^{+4}\mathrm{He} \to \pi^{+}p^{3}\mathrm{H}. \tag{2}$$

We consider process (1) to be the *signal* reaction, while the second process corresponds to the main *background* reaction. In order to find the criteria which can be applied for the classification of reactions (1) and (2), Monte-Carlo simulation has been applied.

Each event described above and subjected to classification was represented by a pattern of four feature variables:

— the reaction missing momentum,

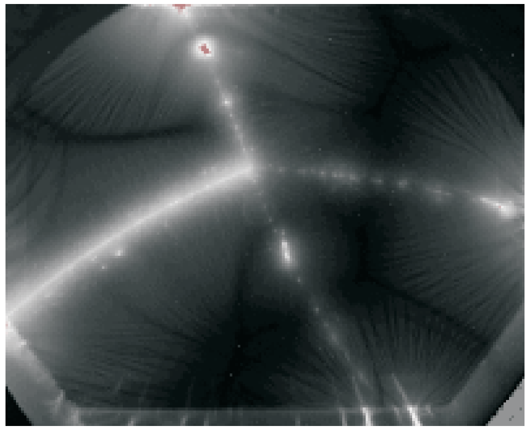

Fig. 3. Video-image of the three-prong $\pi^4$He interaction event in the streamer chamber

— the opening angle between the two strongly ionizing particles,

— the missing mass calculated from the pion and proton kinematics (in the case of knockout this variable equals the triton mass), and

— the sine of the coplanarity angle for the three secondary particles.

Figures 4, 5 present the distributions of these variables for signal and background events.

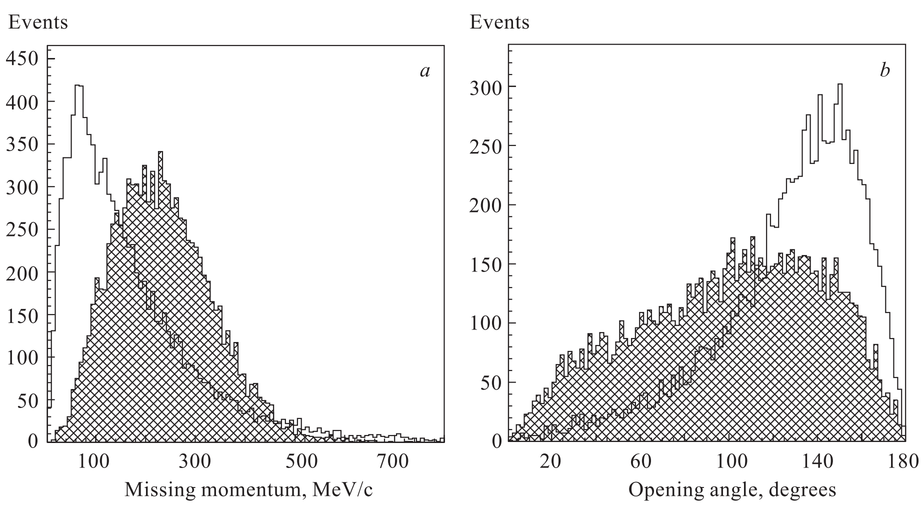


Fig. 4. Distributions of the reaction missing momentum (*a*) and of the opening angle (*b*) between the strongly ionizing particles for reaction (1) (shaded histogram) and for reaction (2) (empty histogram)

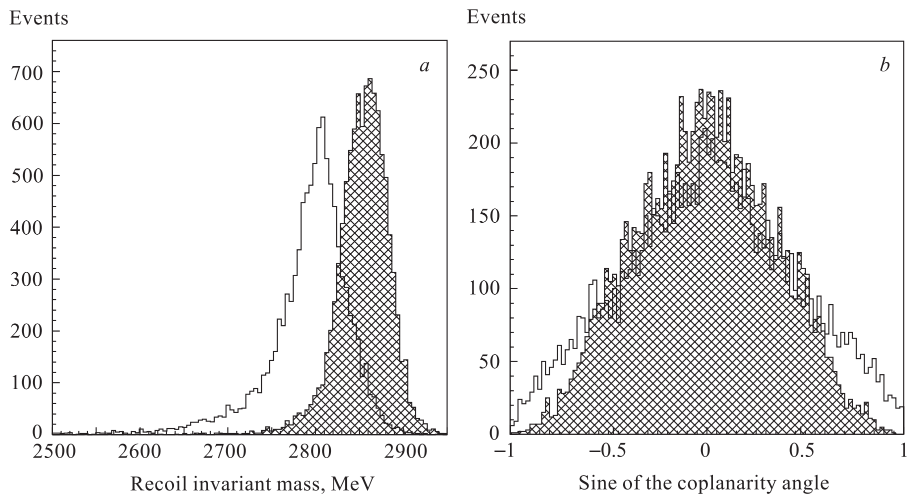


Fig. 5. Distributions of the invariant mass (*a*) of particle 3 and the sine of the coplanarity angle (*b*) for reaction (1) (shaded histogram) and for reaction (2) (empty histogram)

## 2. ALGORITHM FOR IDENTIFYING SIGNAL EVENTS

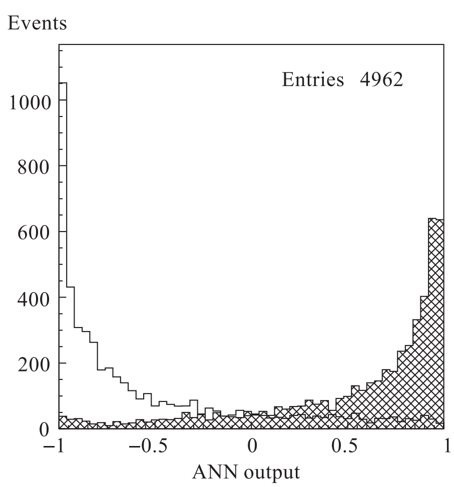


Fig. 6. Distribution of the output signal from the ANN resulting from processing the set of test patterns: events corresponding to the signal patterns are presented by the shaded histogram

As a multivariate classifier for the identification of signal and background events we applied the feed-forward Artificial Neural Network (ANN) from the JETNET 3.0 package [2].

The network has four input neurons, to which a pattern to be analysed is supplied, a single layer of hidden neurons with a varying number of neurons and one output neuron. The value of the output signal shows what kind of event was analysed.

For the ANN training and testing, the standard procedure was applied. To this end, events of two types were generated with the help of the simulation program: 10000 events of process (1), and 10000 events corresponding to the main background process (2).

All the generated events were randomly mixed and then divided into two sets of equal volume: the first set was used for the ANN training, and the second one was applied for estimation of the ANN performance.

Background and signal patterns from the first set of events were applied alternately for training the neural network. Upon all the training patterns having been processed once, one learning epoch was terminated and another started.

Correction of the weights was performed several times during each training epoch applying the *back-propagation* algorithm [3].

After each training epoch the weights were fixed and the performance of the neural network was evaluated by using the testing set. Those events for which the output signal $x$ was greater than the threshold value $x_t$ (set equal to 0) were assumed to be signal events and, otherwise, the events were assumed to be background.

Figure 6 shows the distribution of the output signals from the ANN resulting from processing the set of test patterns: events corresponding to the signal patterns are presented by the shaded histogram.

The rate of correctly recognized samples was used as a measure of the neural network performance. The recognition rate achieved for the test set was 86 %, which corresponds to errors of both the first and second types $\approx 14\,\%$.

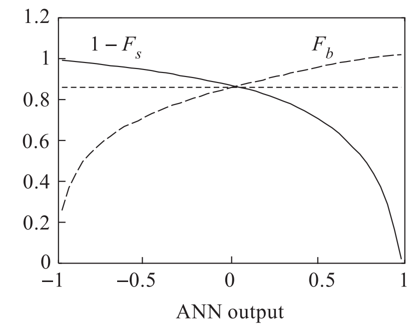


Fig. 7. Dependences of the distribution function $F_b(x)$ for the background events and the function $1 - F_s(x)$ for the signal events against the value $x$ of the output signal from the ANN

Figure 7 presents the dependences of the distribution function $F_b(x) = \Pr\{x < x_t\}$ for the background events and the function $1 - F_s(x)$ (here $F_s(x) = \Pr\{x < x_t\}$) for the signal events against the value $x$ of the output signal from the ANN. One can see that, if the threshold value $x_t$ is set to 0, then the background will be suppressed more than 6 times.

## 3. ANALYSIS OF REAL DATA

The trained ANN has been used for analysing real data. Figure 8 shows the distribution of the output signals from the ANN resulting from the processing of 212 real events. 112 events, for which the output signal was greater than the threshold value, were assumed to be signal events. The admixture of background events corresponding to the process (2) is estimated around 14 %.

The kinematic criteria used for reaction identification in the streamer chamber reveal 117 of the 212 measured events with a secondary pion to represent the breakup reaction $\pi^{+4}\mathrm{He} \to \pi^{+}2p2n$, while the remaining 95, correspond to the knockout reaction $\pi^{+4}\mathrm{He} \to \pi^{+}p^{3}\mathrm{H}$.

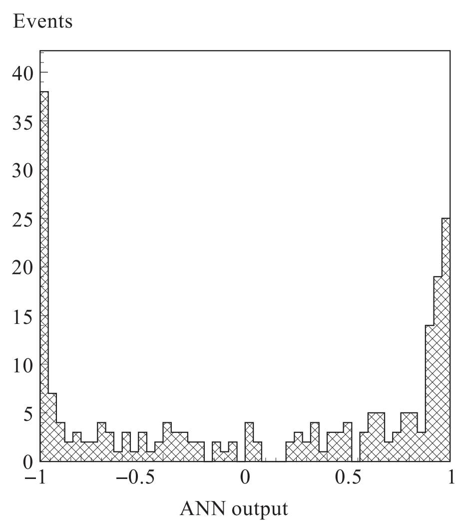


Fig. 8. Distribution of the output signals from the ANN resulting from processing of 212 real events

## CONCLUSION

We have investigated the possibility of application of a layered feed-forward neural network as a multivariate classifier for the identification of signal and background events in the DUBTO experiment. The feature variables used for the event classification permitted us to achieve a recognition rate with model data around 86 %, which corresponds to errors of both the first and second types $\approx 14\,\%$ and to a more than six-fold suppression of the background.

Application of the trained ANN for the analysis of real data demonstrated that this method altogether with kinematic criteria permits increasing the efficiency of identification of nuclear reactions registered by the magnetic spectrometer STREAMER.

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