Bremsstrahlung radiation in the deuteron–proton collision

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Bremsstrahlung radiation created in the collisions of nucleons is still the subject of interest since it is highly sensitive to the kind of the nucleon–nucleon potential, and hence may serve as a tool to discriminate between various existing potential models [1, 2]. At the COSY–11 experiment [3] a signal from γ–quanta was observed in the time–of–flight distribution for the neutral particles measured between the target and the neutral particle detector [4]. This encouraged us to analyse the data in view of the Bremsstrahlung radiation in a free $dp \to dp\gamma$ and a quasi–free $np \to np\gamma$ reactions. Data have been taken using a proton target and a deuteron beam with a momentum close to the threshold of the $dp \to dp\eta$ process. Events corresponding to the $dp \to dp\gamma$ and $dp \to ppn\gamma$ reaction have been identified by measuring the outgoing charged as well as neutral ejectiles. Details of the functioning of all detectors and the method of measurement can be found in references [3, 4, 5]. In order to identify the $dp \to dp\gamma$ reaction events with two tracks in the drift chambers and a simultaneous signal in the neutron detector have been selected. In figure 1 the squared mass of one particle is plotted versus the squared mass of the second registered particle.

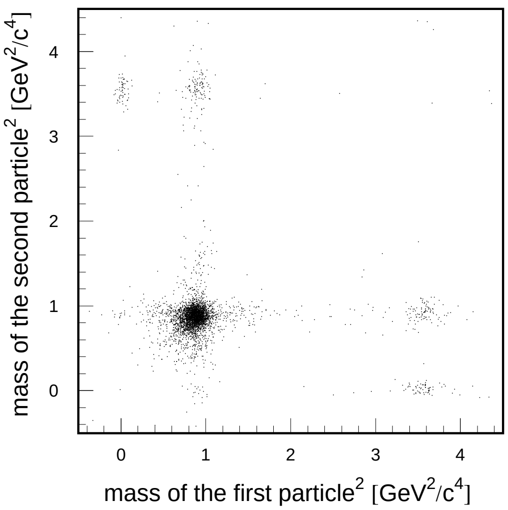

Fig. 1: Scatter plot of invariant masses determined for events with two charged particles measured in coincidence. The measurement was conducted using a hydrogen target and a deuteron beam with momentum of 3.204 GeV/c.

Based on this figure the measured reactions can be grouped according to the type of ejectiles. Thus reactions with two protons, proton and pion, proton and deuteron, and pion and deuteron can be clearly selected. Next for neutral particles the distribution of the time–of–flight between the target and the neutron detector was determined under the condition that one of the charged particles was identified as a proton and the other as a deuteron. In such case gamma quanta – due to the baryon number conservation – are the only one possible source of a signal in a neutron detector. Indeed a clear peak around the time corresponding to the time–of–light of the light was visible [5]. The gamma quanta may originate from Bremsstrahlung reaction or from the decay of produced mesons eg. via the $dp \to dp\pi^0 \to dp\gamma\gamma$ reaction sequence.

In order to distinguish between these hypotheses, one need to calculate the missing mass produced in the $dp \to dpX$ reaction. Figure 2 shows the distribution of the squared missing mass as obtained for the $dp \to dpX$ reaction. A significant peak around 0 MeV^2/c^4 — the squared mass of a gamma quanta — constitutes evidence for events associated to the deuteron–proton bremsstrahlung. In addition a broad structure at higher masses originating from two pions emitted from the $dp \to dp\pi^0\pi^0$ – or two gamma quanta from the $dp \to dp\gamma\gamma$ reaction is visible. However, to certify that the peak at zero MeV is indeed due to the gamma quanta from the bremsstrahlung process, one more issue needs to be clarified. At a value of 0.02 GeV^2/c^4 a peak originating from one pion production in the $dp \to dp\pi^0$ reaction is expected. The peak is not seen in the figure 2, however, since it is expected only about two standard deviations of the mass resolution from the center of the peak assigned to the γ production, we can not exclude a priori a systematical shift. Extensive Monte Carlo studies have to be performed.

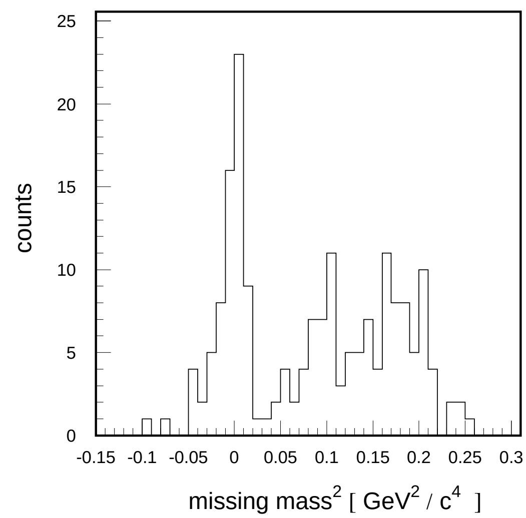

Fig. 2: Distribution of the squared missing mass for the $dp \to dpX$ reaction.

The analysis of the quasi–free $n\,p \to n\,p\,\gamma$ process via the $dp \to np\gamma p_{sp}$ reaction is more complicated, however in this case all three baryons, namely two protons and the neutron can be measured in the drift chambers and in the neutron detector, respectively, and the tentative identification of this reaction has been successfully performed [5].

References:

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