RECENT MEASUREMENTS OF THE η PRODUCTION IN *pd* COLLISIONS AT CELSIUS*

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The reactions $pd \to \eta + X$ have been measured at four beam energies: 930, 965, 1037 and 1100 MeV. The reactions were identified by detecting charged particles in plastic scintillator detectors and the η photons in two arrays of CsI(Na) crystals. A preliminary estimation of the cross section of the $^3\mathrm{He}\eta$ channel has been made. It is in agreement with previous measurements done at lower energies.

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Recently extensive measurements of $pd \to \eta + X$ reactions were carried out at the CELSIUS storage ring in Uppsala. The experiment was a part of the long term research program of the PROMICE/WASA collaboration to study the production of mesons in light ion collisions. The main goal of this experiment was to measure the total cross-section for the $^3\mathrm{He}\eta$ and

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$pd\eta$ reaction channels and angular distributions at beam energies not far from the reactions thresholds. These two reactions are not well known both experimentally and theoretically. The second goal of the experiment was to explore the η tagging possibilities for the future rare decay studies of this meson within the WASA program.

The measurements were done at four beam energies: 930, 965, 1037 and 1100 MeV. A phase space Monte Carlo simulation shows that at these energies the acceptance of the Forward Detector (see Fig. 1) for charged particles accompanying η is much larger than the acceptance of the CsI arrays for 2 γ's from the η decay. Therefore an attempt was made to use the Forward Detector (FD) alone to measure the ^{3}He and proton-deuteron pairs and to identify the η by inspecting the missing mass spectra.

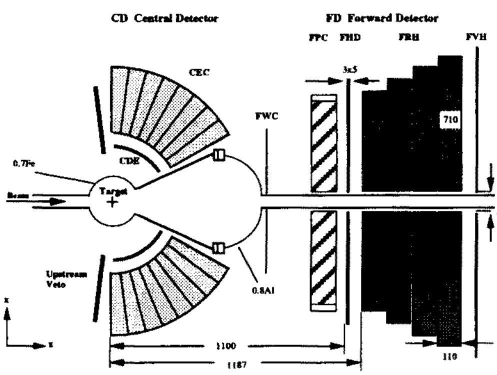

Fig. 1. Schematic layout of the PROMICE-WASA experimental set-up.

Working with the FD offers in addition to a larger acceptance also much better angular resolution due to the presence of the tracker (8 layers of cylindrical proportional counters) and higher energy resolution. Consequently, the reactions can be studied in greater detail. The price to be paid is a high background in the forward direction [1], elaborate detector acceptance estimations and tedious calibration procedure. The latter because the calibration constants depend not only on the amount of deposited energy but also on the ionization density and the position of the impact point.

The amount of background in the selected events was minimized by requiring the recorded particles to go through the Forward Window Counters (FWC in Fig. 1). In addition, the FWC were used to select events with ^{3}He in the final state by setting a threshold higher than average energy losses of fast protons and deuterons in 3 mm of plastic scintillator (thickness of FWC). The requirement, that the selected particle was stopped within the

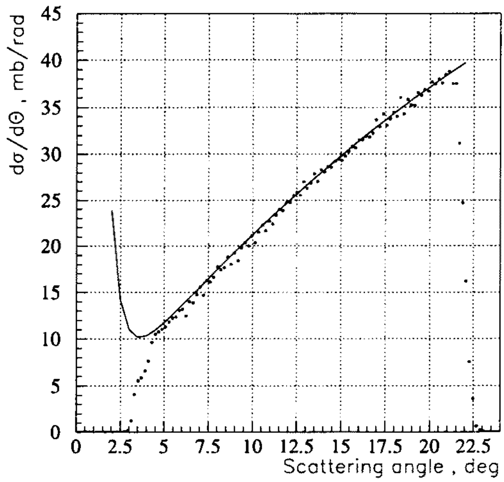

Fig. 2. Comparison of the experimental and calculated $d\sigma/d\theta$ obtained for $pp \rightarrow pp$ at 400 MeV.

Forward Range Hodoscope (FRH) and the energy deposit in the first layer of the FRH was $\geq$40 MeV, constituted a relatively clean trigger of ^{3}He events. The $pd\eta$ reaction channel was selected by demanding at least two charged particles to pass through FWC, Jülich Hodoscope (FHD) and stop inside the FRH. Due to the presence of a strong background from the deuteron breakup and $pd \rightarrow \pi + X$ reactions only every 1/32 event selected in this way was recorded. Apart from these two triggers a third one, based on the presence of two photons in two arrays of CsI arrays, was used.

The FD acceptance was checked with elastic scattering of 400 MeV protons, since at this energy the rate of nuclear reactions in the FRH ($\approx$20% [2]) changes only slightly over the angular range of the FD. For the selected $pp \rightarrow pp$ events, the $d\sigma/d\theta$ distribution has been extracted and is plotted in Fig. 2, together with a theoretical $d\sigma/d\theta$ curve obtained from a compilation of NN phase shift analysis data by Arndt *et al.*[3]. For convenience the experimental data were normalized to the theoretical curve in the θ range of 15–18°. From the deviation of the data points from the curve one can see that for this energy, the acceptance drops by about 6 % between angles 20° and 5°.

The energy calibration of the FD modules was done using a special CELSIUS cycle with a slow ramp followed by a short flat top. The proton energy during the ramp was changing linearly in time from 48 MeV (injection energy) to 320 (or 400) MeV on the flat top. The selected $pp \to pp$ events in this energy range allowed us to find the relation between the deposited energy and the detector response for all FD modules and different impact points. In order to use the proton calibration constants for deuterons and ^{3}He, we have parameterized the relation between the deposited energy and light output measured for different particles by Becchetti *et al.*[4]. With this parameterization it is possible to convert the amount of collected light Δl (found with the proton calibration constants) to the energy deposit, if the particle is known (identified). The particle identification is staightforward using the Δl signals (see Fig. 3).

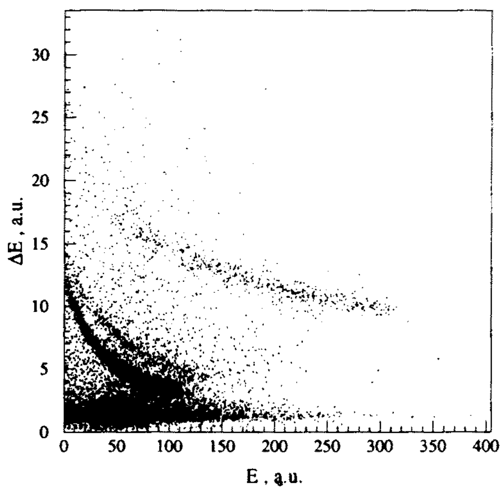

Fig. 3. ΔE-E plot obtained for the third layer of the FHD (ΔE) and the first layer of the FRH (E).

In the next step of the analysis missing mass spectra for $pd \to ^3\mathrm{He}+X$ and $pd \to pd + X$ reactions were calculated for all beam energies. As an example, distributions obtained for both reactions at 1037 MeV are plotted in Fig. 4 and 5. In both cases prominent peaks corresponding to the η mass are seen. The total cross section can be obtained by finding the number of $^3\mathrm{He}\eta$ or $pd\eta$ events (peak contents) if the integrated luminosity and the detector acceptance are known. In the acceptance we also included losses due to nuclear reactions in the detector material.

A rough estimate of the total cross section has been made for $^3\mathrm{He}\eta$ channel. The geometrical acceptance shown in Fig. 2, was assumed and a phase space Monte Carlo program was used to find the percentage of events

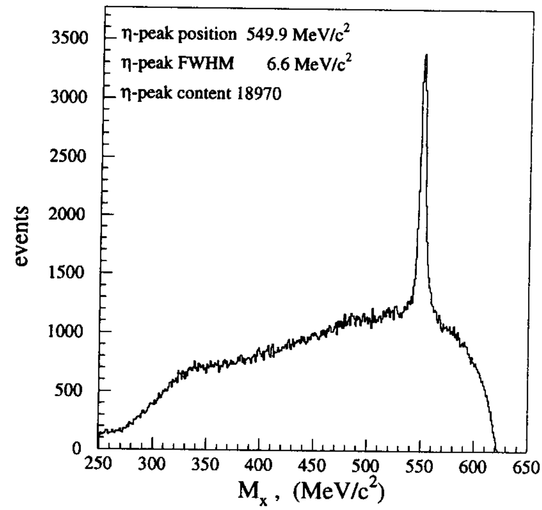

Fig. 4. Missing mass distribution for $pd \rightarrow {}^3$He$+X$ at 1037 MeV beam energy.

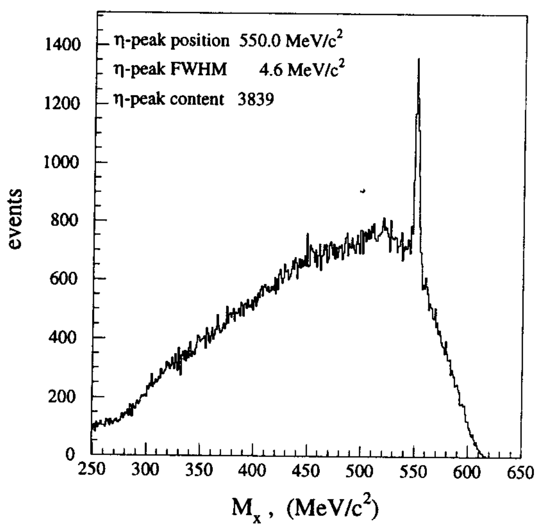

Fig. 5. Missing mass distribution for $pd \rightarrow pd + X$ at 1037 MeV beam energy.

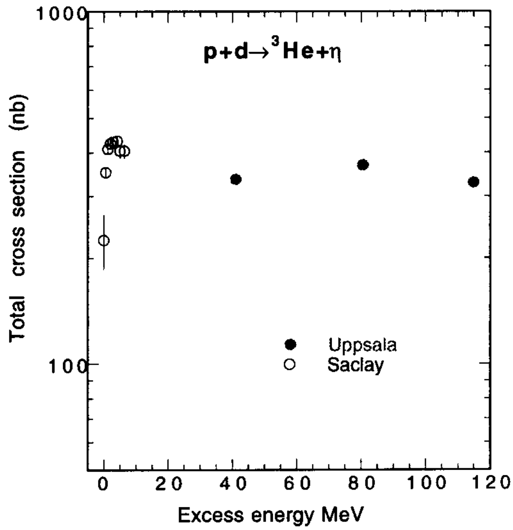

Fig. 6. Total cross section of the ^{3}Heη channel as a function of the energy above the threshold.

with ^{3}He entering the FD. The rate of nuclear reactions of ^{3}He in the plastic scintillators is estimated to be lower than 15 % by extrapolating the result obtained for ^{3}He stopping in NaI(Tl) [5]. The integrated luminosity was found by measuring the pd elastic scattering with a small silicon detector in coincidence with the FD.

Results obtained for the three energies: 965, 1037 and 1100 MeV are plotted in Fig. 6 (the point at 930 MeV is still being analyzed) together with the available Saclay data [6]. The total cross section is rather constant in this energy interval, in contrast to the strong energy dependence of the threshold data. This indicates how η-nucleon interaction, containing only s-wave interaction via the N*(1535) resonance close to the threshold, is gradually influenced by p-wave at higher energies. A comparison with data from the $pd \to ^3$He$+\pi^0$ reaction [7] shows significant differences in the energy variation at mass excess less than 15 MeV, but about the same pattern at higher energies.

The analysis is in progress to extract angular distributions for ^{3}He and total cross section for $pd\eta$. Also the acceptance problems are being studied in more detail.

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