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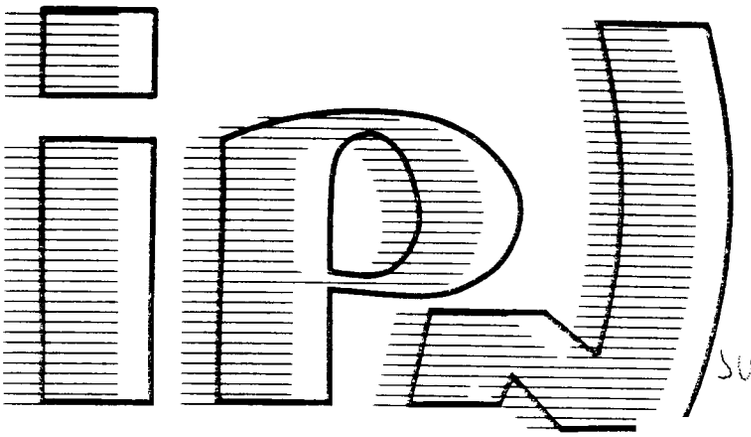

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η-MESON PRODUCTION NEAR THRESHOLD IN FEW BODY SYSTEMS

R. Frascaria and F. Roudot
Institut de Physique Nucléaire
F-91406 Orsay, France

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Representing the experiment 285 at LNS:

M.-A. Duval[a], J. Ernst[c], L. Goldzahl[d], F. Hinterberger[c], R. Jahn[c], R. Joosten[c], T. von Oepen[c], W. Spang[b], and R. Wurzinger[b].

[a] *Institut de Physique Nucléaire, IN2P3–CNRS, 91406 Orsay, France*
[b] *Laboratoire National Saturne, CEN Saclay, 91191 Gif-sur-Yvette, France*
[c] *Institut für Strahlen und Kernphysik, 53115 Bonn, Germany*
[d] *IN2P3-CNRS, 75016 Paris, France*

ABSTRACT

The total cross section for η–production near threshold in deuteron-deuteron interactions has been recently measured at four different energies, from 0.7 to 3.7 MeV above threshold. Low energy η–α scattering parameters are extracted. With a low energy η–A scattering model, the evolution of scattering lenght with A is studied for $1 \leq A \leq 4$. Assuming a dominant π^0–η mixing reaction mechanism a prediction for the differential cross section $\left(\frac{d\sigma}{d\Omega}\right)_{\pi^0}$ in the isospin-forbiden reaction $dd \rightarrow \alpha\pi^0$ is given.

The total cross section for η–production near threshold in $dd \rightarrow \alpha\eta$ reaction has been recently measured at L.N.S. (Saclay France) from 0.7 to 3.7 MeV above threshold [1]. The determination of this cross-section is of great interest for at least two reasons :

- The η–meson and the α–particle being produced at low relative energy, information on the S–wave part of the ^{4}He–η potential can be extracted. A comparison between the η–n, η–^{3}He and η–^{4}He cross section at very low relative energies expressed in terms of scattering lenghts should give information about the dependence of the attractive part of the η–A potential as a function of A, the atomic number of the nuclei.
- The charge symmetry breaking (CSB) reaction $dd \rightarrow \alpha\pi^0$ has been observed at LNS near the η–threshold [2], with a large cross section as compared to the expected cross section from a pure electromagnetic process. A precise determination of the $dd \rightarrow \alpha\eta$ cross section can be used in models which express the CSB $dd \rightarrow \alpha\pi^0$ reaction as due to the η–π^0 mixing [3].

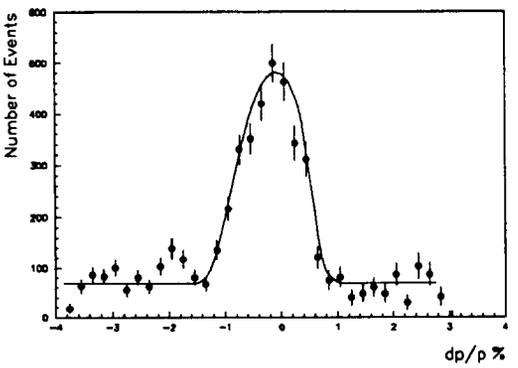

Figure 1: Experimental results for the $dd \rightarrow \alpha\,\eta$ as a function of the α-particle momentum relative to the central value of 2030 MeV/c (dots) and Monte Carlo simulation with the same experimental conditions (continuous line).

The main characteristics of the SPES4 beam line at L.N.S. and of the detectors can be found in [4]. After α–discrimination, by time of flight and energy loss measurements, the trajectories are reconstructed to the target position and momentum spectra at the SPES4 final focal plane are finally extracted. One of the momentum spectra which are obtained is shown on fig.1 in comparison of a full Monte-Carlo simulation of the experiment. Position and width of the η–signal are well reproduced. The generator of events supposes a production proportional to p_η, the c.m. momentum of the η–meson.

The measured total cross section is presented on fig.2. On the same figure are also shown the $\pi^-\,p \rightarrow \eta\,n$ [5, 6, 7] and $pd \rightarrow {}^3\mathrm{He}\,\eta$ [8] data close to η-threshold. One should note the six order of magnitude difference between the $dd \rightarrow \alpha\eta$ and the $\pi^- p \rightarrow \eta n$ total cross sections.

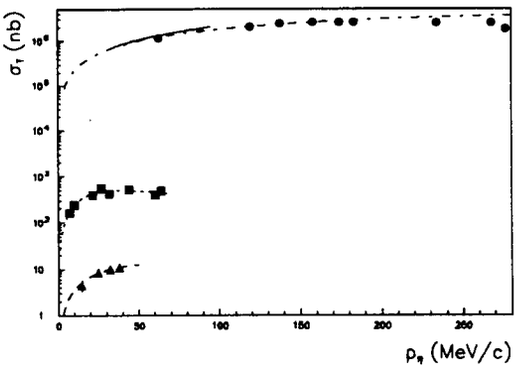

Figure 2: Comparison of η–production in different reaction near threshold. Total cross section for elementary process $\pi^- p \rightarrow \eta n$ (full line) [4] (full circles) [5,6]; $pd \rightarrow {}^3\mathrm{He}\eta$ (full squared) [7] ;and $dd \rightarrow \alpha\eta$ (full triangles) [1]. Fit to the data using eq.1 are presented on the same plot for the 3 reactions respectively dot-dashed line, dot-line and dashed-line.

In a way to treat consistently the three systems η-n, η-^{3}He and η-^{4}He at very low relative energy (l=0) a simplified quantitative model has been used, where the nuclei are approximated by spheres with well–defined surfaces [9]. Applying the detailed–reciprocity theorem for nuclear reactions, one can express the total inelastic reactions $\eta n \rightarrow \pi^- p$, ${}^3\mathrm{He}\eta \rightarrow pd$ and $\alpha\eta \rightarrow dd$ as:

$$\sigma_{r,0} = \frac{-4\pi\hbar c R_x}{p_d^2} \times \frac{p_\eta Im(f_0)}{Re(f_0)^2 + \left(Im(f_0) - \frac{p_\eta R_x}{\hbar c}\right)^2} \qquad (1)$$

where f_0 is the logarithmic derivative of the wave function. The boundary condition is the continuity of f_0 at $r = R_x$, where R_x is the root mean square of the concerned nucleon or nucleus.

This low energy model has been applied for the three reactions with a mininization χ^2 search. The results are presented on fig.2. It allows the determination of scat-

tering lenghts for either of these three η-A few body systems. The scattering lenghts a are given in Table.I. They are found all positive, allowing the existence for bound states. There seems to be a small decrease of a/A for A=4. This A–dependence goes in the right direction as far as η–nuclei are expected to exist.

Table.I

Reaction	R_x	Ref_0	Imf_0	a (fm)	$\frac{a}{A}$ (fm)
$\pi^- p \rightarrow \eta n$	1.10	-1.098	-0.326	2.021	2.021
$pd \rightarrow {}^3\mathrm{He}\eta$	1.78	-0.347	$-0.544\ 10^{-4}$	6.911	2.304
$dd \rightarrow \alpha\eta$	1.63	-0.604	$-0.350\ 10^{-5}$	4.329	1.082

The η-^{4}He scattering lenght is independent on p_η on a wide range of c.m. momentum, which shows that the spin-isospin averaged squared amplitude,

$$|f|^2 = \frac{p_d}{p_\eta} \times \frac{\sigma_T}{4\pi} \tag{2}$$

is constant, with a value of $(24.6 \pm 1.2 \pm 1.7)$ nb/sr [1]. This value is shown by the dashed line on fig.3.

A model for the $dd \rightarrow \alpha\eta$ scattering process near threshold in terms of a complex scattering lenght **a** has been proposed by Wilkin [10]. The spin–isospin averaged amplitude f is then proportionnal to $|1 - i\mathbf{a}p_\eta|^{-1}$. With the scattering lenght **a**=-2+i fm [10] a weak momentum dependance for $|f|^2$ is found. This result is shown on fig.3.

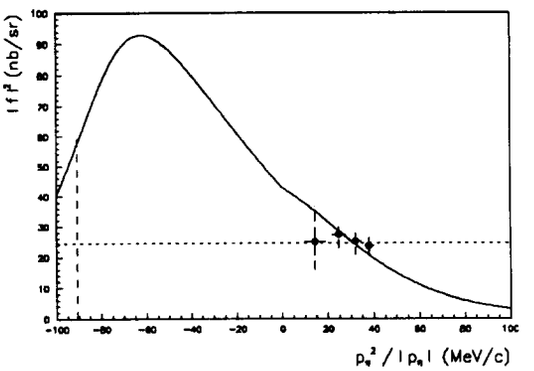

Figure 3: Squared amplitude $|f|^2$ extrapolated obove threshold, defined by Eq.2, as a function of the η c.m. momentum. Fit by a constant value (dashed line) and using a zero range model to calculate cusp effect [12] with a scattering lenght of $-2 + i$ fm [10] (full line).

With the value of $|f|^2 = (24.6 \pm 1.2 \pm 1.7)$ nb/sr extracted from the first model, it is possible to make an estimation for the isospin–forbidden $dd \rightarrow \alpha\pi^0$ differential cross section using the Coon and Preedom external $\pi^0 - \eta$ mixing model [3]. Through virtual η–production Coon and Preedom deduce that

$$\left(\frac{d\sigma}{d\Omega}\right)_{\pi^0} = \frac{p_{\pi^0}}{p_\eta} \times \lambda_\eta^2 \times \left[1 + \frac{\lambda_{\eta'}}{\lambda_\eta} \tan\phi\right]^2 \times \left(\frac{d\sigma}{d\Omega}\right)_\eta . \tag{3}$$

Using the parameter values of $\tan\phi = 0.95$ from [11], $\lambda_\eta = 0.021$, $\lambda_{\eta'} = 0.006$, we find at a deuteron energy of 1120.3 MeV (the η–meson threshold energy, for which $p_\pi = 488$ MeV/c)

$$\left(\frac{d\sigma}{d\Omega}\right)_{\pi^0} = (8.3 \pm 0.5 \pm 0.6) \text{ pb/sr}. \tag{4}$$

The result of Goldzahl [2] has been obtained at a kinetic energy which is 20 MeV below the η–threshold. If $|f|^2$ depends on p_η, an extrapolation for $|f|^2$ below threshold is needed. Using a zero-range model proposed by Dalitz [12] to calculate cusp effects near threshold at a new opening channel, we are able to extrapolate $|f|^2$ below threshold to the energy where the $dd \rightarrow \alpha\pi^0$ has been measured. This calculation with the scattering lenght given by Wilkin [10] is shown on fig.3. The value of about 60 nb/sr for $|f|^2$ at $p_\eta^2/|p_\eta| = -90$ MeV/c allows a prediction of $(19.8 \pm 1.2 \pm 1.4)$ pb/sr for $dd \rightarrow \alpha\pi^0$ cross section at $\theta_\alpha = 0.^o$.

These large cross sections which are obtained either with $|f|^2$ constant or slighlty momentum dependent show that the π^0–η external mixing is a dominant process in $dd \rightarrow \alpha\pi^0$ near the η threshold and could explain the observation of a π^0 signal by Goldzahl et. al [2].

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