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INVESTIGATION OF CHARGE EXCHANGE REACTIONS ON A HYDROGEN TARGET (PROPOSAL)

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Investigations of inclusive cross sections in the charge exchange reaction $p(t, {}^3\mathrm{He})$ are suggested to check the validity of theoretical predictions on the strength of the mechanism of projectile excitation. It is expected that in the suggested experiment the inclusive spectrum should be quite different than in the «classical» reaction $p({}^3\mathrm{He}, t)$ and there will be no problems with the interpretation of obtained data. The experiment is scheduled for a new facility designed in cooperation of the spectrometers SPHERE, DELTA and GIBS. It is shown that additional data on neutral pion production will be obtained. The suggested experiment is a start point of the programme for investigations of charge exchange reactions, for example, coherent pion production.

The investigation has been performed at the Laboratory of High Energies, JINR.

Исследование зарядово-обменных реакций на водородной мишени (проект)

С.В.Афанасьев и др.

Предложена проверка теоретических предсказаний о значении механизма возбуждения пролетающего ядра в зарядово-обменной реакции $p(t, {}^3\mathrm{He})$. Ожидается, что в предложенном эксперименте инклюзивный спектр должен сильно отличаться от спектра, измеренного в «классическом» эксперименте $p({}^3\mathrm{He}, t)$, и поэтому не будет проблем с интерпре-

тацией результатов. Эксперимент запланирован для новой установки, объединяющей спектрометры СФЕРА, ДЕЛЬТА и ГИБС. Показано, что в эксперименте также будут получены дополнительные данные о рождении нейтральных пионов. Предложенный эксперимент является первым из программы, нацеленной на исследования зарядово-обменных реакций, например когерентного рождения пионов.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Motivation

Investigations of inclusive cross sections in the charge exchange reaction (^{3}He, t) have shown [1,2] that the Δ peak in the triton energy spectrum is broader and shifted towards a high energy region in case of nuclear targets in comparison with charge exchange on hydrogen. In subsequent experiments this effect was confirmed for a wide energy scale [3] and different projectiles [4]. The effects like de-excitation of delta via the nonmesonic channel [5,6] $\Delta N \rightarrow NN$ or collective effects associated with the Δh propagation [7—10] were suggested to explain these features. One of the by-products of the theoretical studies of this reaction was the finding of coherent pion production as a relevant channel [10—12]. Some measurements of this channel have already been reported [13]. The mechanism of Δ excitation in the projectile (DEP) was considered in [14,15] where it was shown to produce a shift of strength to lower excitation energies although the peak position did not move. So, we presented here a short list of ideas explaining a very complicated process of charge exchange reaction when resonances are excited and propagate in nuclear matter.

However, most approaches neglect the DEP mechanism and regard delta excitation in the target (DET) and the response of nuclear matter as a strongly dominating process. In any case, during six years no experimental test was performed to check the validity of the DEP mechanism in charge exchange reactions. On the other hand, it is expected that in ^{3}He beams the DEP mechanism does not exceed a 10% level and therefore Oset, Shiino and Toki have suggested [14] to investigate the reaction $n(^3\text{He}, t)$ on a deuteron target or (see [15]) an inversed reaction — charge exchange on proton target in a tritium beam available in Dubna. In this reaction the strength of the DEP and DET mechanism is expected to be equal while the shape of energy distribution for both mechanisms is quite different (see Fig.1). So, the aim of this program is to test the validity of the idea of delta excitation in the projectile and to measure the strength of one of the basic diagrams.

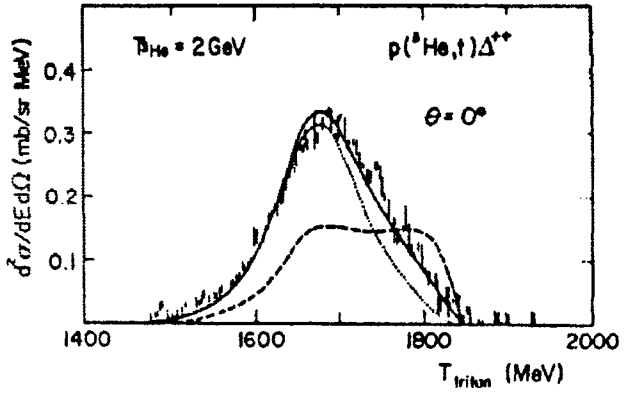

Fig.1. Double differential cross section in the p (^{3}He, t) π^+p reaction in the p lab. system. The experimental points are from ref.16. Dotted line: result with DET mechanism alone, solid line: results including the DEP mechanism and s-wave, dashed line: results for the n (^{3}He, t) πN reaction, including DET, DEP and s-wave mechanisms

In the next item it is suggested to investigate the properties of neutral pion production in the same process. The motivation of this approach is clear from our previous experiments (see the section «Current Experiments») where it was established that the pion momentum spectra were quite different in comparison with the spectra calculated for quasi-free delta excitation in the target nucleus. The suggested experiment dedicated to the properties of neutral pion production is complementary to our previous research where the spectra of negative pions were analyzed.

It should be noted that the triple coincidence experiment suggested by B.Erazmus (Nantes, France) as a development of our experiment as well as of investigations in low energy beams [17], is very interesting and will be discussed in detail later. Briefly, the study of the exclusive reaction:

$$^{12}C + {}^{12}C \rightarrow {}^{12}C(1^+, T = 1, E^* = 15.1 \text{ MeV}) + {}^{12}C + \pi^0 \qquad (1)$$

is suggested which allows one to analyze delta excitation and coherent pion production in both projectile and target nuclei using some additional information given by the Doppler shift of the 15.1 MeV photon. The process is rather complicated, and different parameters (cross sections, angular distributions, momentum spectra) should be scanned in this experiment.

In other words, the new approach is a natural extension of successive investigations of charge exchange reactions on the synchrophasotron beams and the ground for a new scientific programme.

2. Method

The main facility expected to be used in the suggested experiment is the SPHERE spectrometer. The spectrometer is rather complicated, and so only necessary for the suggested experiment details are reproduced in a schematic drawing in Figure 2. The spectrometer is triggered with coincidence of the detectors A and C tuned to register a beam particle of unit charge (tritium nucleus) in the detector A and He nucleus (charge equal to 2) in the detector C. The efficiency and background suppression in the approach are reasonable as measured in the previous experiments.

In case of the reaction p (^{3}He, l) there are problems to use the traditional method of measuring the inclusive spectrum with a single-arm spectrometer: one should take into account that the tritium beam is a secondary one and that the beam momentum spread-out is large: FWHM is equal to 0.5 GeV/c for a 6.0 GeV/c mean value. Therefore the classical single-arm SPHERE spectrometer should be sophisticated with the time of flight (TOF) projectile spectrometer (GIBS). The TOF system was tested in the last GIBS experiment (October 1994) when a 100 ps resolution was obtained: it is good enough for a 0.3% momentum resolution in case of the 6 GeV/c tritium beam.

During the suggested experiment the projectile-ejectile spectrometers, designed to measure the inclusive spectrum, will be accompanied with the lead glass Cerenkov γ-spectro-

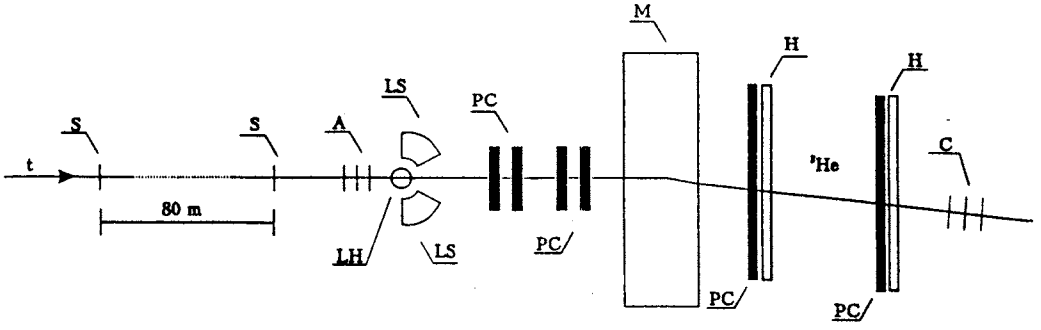

Fig.2. A schematic display of the spectrometer. S — start and stop counters of the TOF system, LH — liquid hydrogen target, A and C — trigger counters, H — hodoscopes, LS — blocks of the lead glass spectrometer, M — analyzing magnet, PC — blocks of the proportional chambers

meter for registering π^0 mesons. The gamma spectrometer surrounds the liquid hydrogen target (see Fig.2). The spectrometer is designed to determine the energies and exit angles of γ-quanta from π^0 for a pion energy interval of 0.03—2.0 GeV. The measured energy resolution is $\sigma = 1.62 \times (E)^{1/2}$, where E is measured in MeV. Two blocks of 150 cells in each block can register pions at a 10—12 msr solid angle. In spite of rather a low (a few per cent) efficiency of the γ-spectrometer several thousands of π^0 will be registered. The expected statistics are sufficient to investigate the pionic spectra and to find out the features of the production mechanism. Efficiency calculations are preliminary, and there is a hope to increase the efficiency during optimizing. All parts of the spectrometers were tested in the previous experiments (except the proportional chambers).

It should be noted that the spectrometers were used in different experiments (SPHERE, GIBS, DELTA). When collected together, they will provide more intensive data flow, and therefore it is suggested to use more powerful computer station. Another source of an increased data flow are new proportional chambers which will be used to improve the accuracy of the SPHERE spectrometer.

3. Current Experiments

In our previous experiments [18—20] the charge exchange reaction (t, ^{3}He) on carbon and magnesium targets was investigared using a streamer chamber of the GIBS spectrometer. The experimental momentum spectrum for pions was compared with the calculated spectrum, and only 50—70% of pions were shown to be emitted by the delta isobars produced on a quasi-free nucleon in the target nucleus. The momentum of other pions was significantly higher than for delta pions. Therefore the production in the projectile was suggested in addition to coherent production via N(1440) or/and N(1520) in the target nucleus. It should be stressed that all models and calculations before this experiment have analyzed delta excitation as a single possible intermediate state in coherent pion production.

However, to identify unambiguously such unusual production channels, more statistics is needed and the analysis of transferred momentum in each event should be used. This poroblem can be solved in additional GIBS experiments. On the other hand, the investigation of π^0 spectra, as suggested in this proposal, will provide complementary and very useful data.

The results were discussed at the International Conferences (Delta Excitation in Nuclei, RIKEN, May 1993, Japan; Mesons in Nuclei, Dubna, May 1994; Problems of High Energy Physics, Dubna, September 1994). The program is supported in part by the Russian Fundamental Research Foundation.

4. Summary

The theoretical prediction of the projectile excitation contribution in the charge exchange reaction will be tested, and the strength of this channel will be measured.

The production of neutral pions will be investigated to compare different production channels and to estimate their strength.

The experiment will be performed with cooperation of three spectrometers: GIBS, DELTA and SPHERE.

The experiment is a start point of a new programme dedicated to a complicated problem: investigation of the charge excange reactions as well as excitation and propagation of resonances in nuclear matter.

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