EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

FIRST RESULTS ON DIFFRACTION DISSOCIATION OF NEUTRONS AT THE ISR

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ABSTRACT

Neutron diffraction dissociation has been measured at the ISR in proton-neutron interactions at 37 GeV c.m. energy. The data were taken with the Split Field Magnet detector, during a short deuteron storage test run with colliding p-d beams. Differential mass and momentum transfer distributions are reported; the value of the total cross-section shows a weak s-dependence when compared to lower energy data.

Geneva - 10 August 1976
(Submitted to Physics Letters B)

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The recent storage of deuteron beams in the CERN Intersecting Storage Rings has opened the possibility of studying neutron-nucleon reactions in the ISR energy range.

Neutron-proton interactions, obtained by means of neutron beams or, more commonly, using deuterons as sources of quasi-free neutrons, have been the object of extensive investigations. At the lower accelerator energies [1, 2], up to the recent FNAL measurements [3], reactions involving neutrons have been studied to complement the vast amount of data on nucleon collisions provided by the basic proton-proton interaction. Neutron dissociation adds substantial new information about the behaviour of individual isospin amplitudes [4] and provides charged final states which display with particular significance and simplicity the details of the interaction.

High-energy deuteron beams offer several advantages [2, 5] for experiments on neutron interactions, since they effectively provide quasi-monochromatic tagged neutron beams. Absolute cross-section measurements, in contrast with the case of neutral beams, do not suffer from relatively large uncertainties on the incoming flux; in addition, the neutron momentum is confined within a narrow bin associated with its limited range of Fermi momentum in the deuteron rest frame.

Detection and momentum analysis of the spectator proton allow the incoming neutron vector momentum to be determined with the same accuracy as that for the final states; it also provides a clear, unambiguous signature of neutron interactions, since the spectator momentum distribution peaks at half the deuteron beam momentum. Finally, with high-energy colliding beams the dissociation products of the two interacting particles are separated by a wide rapidity gap, thus allowing an unambiguous identification of the interacting systems.

During two test runs with 26 GeV/c deuteron-deuteron and proton-deuteron beams, data were collected on a number of neutron inelastic reactions with the Split Field Magnet (SFM) detector. We present here results on the neutron dissociation reaction

$$p + d \to p + (p\pi^-) + p_{spect} \qquad (1)$$

at $\sqrt{s}$ = 37 GeV for the p-n system. The data were obtained in an 8-hour run with a deuteron current of about 4.6 A. Triggers from other single and double neutron dissociation reactions are at present being analysed and further results [6] will be reported.

The SFM has been described in detail elsewhere [7]; it consists of a full solid-angle magnetic spectrometer equipped with an all-proportional chamber detector system surrounding an ISR intersection region. The layout of the two forward arms is optimized for detecting few-body reactions with smooth efficiency and good momentum resolution; detection capability at very forward angles is enhanced by small chambers in the downstream compensator magnets.

The fast trigger, involving chambers and counters, required a beam-beam interaction; a slow trigger included particle multiplicity requirements in the two forward spectrometer arms and a veto at large angles covering the full polar acceptance to reject particles in the central region. A particularly selective condition was set by requiring a coincidence of the last three chamber planes in the deuteron arm; spectator protons satisfy this condition with almost 98% probability for Fermi momenta up to 0.3 GeV/c in the deuteron rest frame.

Pattern recognition and geometrical reconstruction were performed with the standard SFM off-line program chain; events with the correct topology were submitted to a 4C fit to reaction (1). The χ^2 and probability distributions are in good agreement with the theoretical ones; a cut for $\chi^2 < 20$ contains the entire peak of the distribution.

A closer investigation of the events below and above the χ^2 cut shows that background contaminations, in particular neutrals in the final state, are negligible; no events are found to originate outside the interaction diamond, showing that beam-gas interactions are absent in our measured sample. After the χ^2 cut we obtain 2380 events; the corresponding integrated luminosity is about 5400 μb^{-1} *).

*) The luminosity calibration was performed with the Van der Meer method to obtain the vertical density profile of the interacting beams and is therefore independent of the total p-d cross-section.

The spectator was identified as the proton with fitted momentum closer to the nominal central value of one-half the beam momentum*). The validity of this criterion is displayed in Fig. 1, where the spectator momentum distribution in the deuteron rest frame is shown, together with the expected distribution from the Hulthèn wave function. The spectator angular distribution is also in good agreement with an isotropic behaviour modified by the asymmetry introduced by the Möller flux factor.

The over-all efficiency for reaction (1), including geometrical acceptance of the apparatus as well as the trigger and pattern recognition efficiencies, was studied as a function of four-momentum transfer and of the mass of the produced $(p\pi^-)$ system. The vacuum chamber geometry determines a cut for $t = 0.05$ GeV^2; the efficiency is otherwise a smooth function of the variables up to masses of about 3 GeV and four-momentum transfers of several GeV^2.

Mass and t-distributions for reaction (1), corrected for the over-all efficiency, are shown in Figs. 2 and 3; they both show typical diffractive features, as seen in low multiplicity diffractive processes on protons. Structures around 1.5 an 1.7 GeV are visible in the $(p\pi^-)$ mass distribution; they are similar to those observed in neutron diffraction at lower c.m. energies both at FNAL and in the 30 GeV region, although perhaps more enhanced. For higher mass values the distribution falls off rapidly; a similar behaviour is observed [8] at the ISR for two-body proton diffraction which, at the dissociating vertex, is charge-symmetric to reaction (1).

The t-distribution for all events (Fig. 3a) displays a typical exponential forward peak, with a slope $b = 8.2 \pm 0.4$ GeV^{-2} for $0.05 \leq t \leq 0.2$. If events from the low-mass region are selected, structures at small t-values become evident. In Fig. 3b the differential t-distribution for $(p\pi^-)$ masses below 1.3 GeV has a clear break around $t = 0.3$ GeV^2; also the slope of the forward peak has increased to $b \simeq 22$ GeV^{-2}. Structures disappear and distributions flatten off for higher masses, showing a rather strong slope-mass and structure-mass correlation.

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*) This is equivalent to the criterion, used extensively for stationary deuteron targets, which identifies the spectator as the slowest proton in the laboratory.

The total cross-section for reaction (1) was calculated taking into account the effect of the t-cut at 0.05 GeV^2, a 5% shadow effect estimated with the Glauber model, and a small correction due to the fiducial cut on the deuteron internal momentum. We obtain a cross-section of 182 ± 45 μb where the error is mostly systematic and includes a 10% contribution from luminosity calibration and a 10% estimated uncertainty in the over-all detection efficiency. Comparison with lower energy data shows that the cross-section is falling slowly with energy; using the usual power law parametrization to link all existing data with our preliminary result, we obtain a dependence of the type p_L^{-n}, with $n \simeq 0.3$.

We conclude that the features of the mass and t-distributions for single neutron dissociation at the ISR, together with the energy dependence of the cross-section, are in agreement with observations on diffractive reactions both at low energies and in the FNAL-ISR energy range, thus showing a remarkable similarity and continuity in the general features of the diffractive picture over a wide energy interval. On the other hand, FNAL results [3] indicate, besides a substantial Deck contribution to the mechanisms of neutron dissociation, some possible inconsistency between the observed expectation values of spin components and a description of the interaction in terms of s-channel helicity amplitudes [9]. However, this description, or alternatively an absorbed Deck [10] approach, might account for the behaviour of the t-structures and the observed large slope-mass correlation. A more detailed analysis of our data, especially when more statistics will become available, is made possible by the smooth apparatus acceptance over the full range of the angular variables. Such an investigation should convey a finer understanding of two-body diffraction dissociation mechanisms at very high energies.

Thanks are due to B. Aebischer for his contributions to the early stage of the analysis. The co-operation of the CERN-Hamburg-Orsay-Vienna Collaboration and of the SFM Detector Group and the Data Handling Division at CERN is gratefully acnowledged. We also thank the CERN PS and the ISR Divisions, as well as the ISR coordinator, for their successful efforts in turning machine development runs into useful physics time. Finally, we thank Professor A. Gigli-Berzolari for continuous encouragement and support.

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Figure captions

Fig. 1 : Momentum distribution of spectator protons from reaction (1) in the deuteron rest frame with the expected distribution from the Hulthèn wave function, normalized to the total sample. The inset shows the spectator angular distribution and the normalized s-wave prediction modified by the flux factor.

Fig. 2 : Mass distribution of the $(p\pi^-)$ system produced in neutron diffraction dissociation [reaction (1)].

Fig. 3 : a) Distribution of four-momentum transfer to the $(p\pi^-)$ system for all events with t-values greater than 0.05 GeV^2 (see text).

b) Differential distribution as in (a) for $(p\pi^-)$ masses below 1.3 GeV. A sharp rise of the forward slope and the appearance of structures are correlated to mass selections in proximity of the threshold.

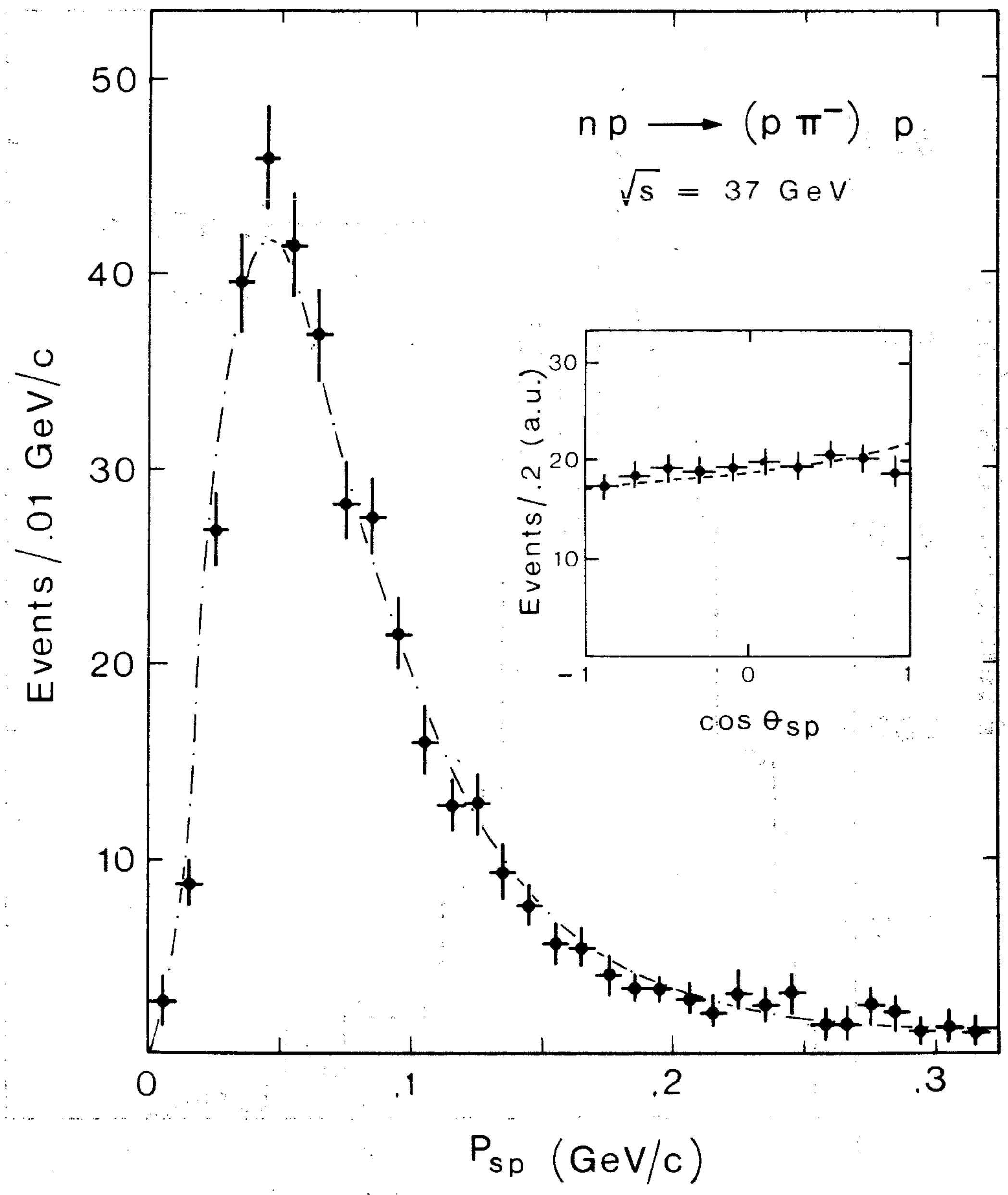


Fig. 1

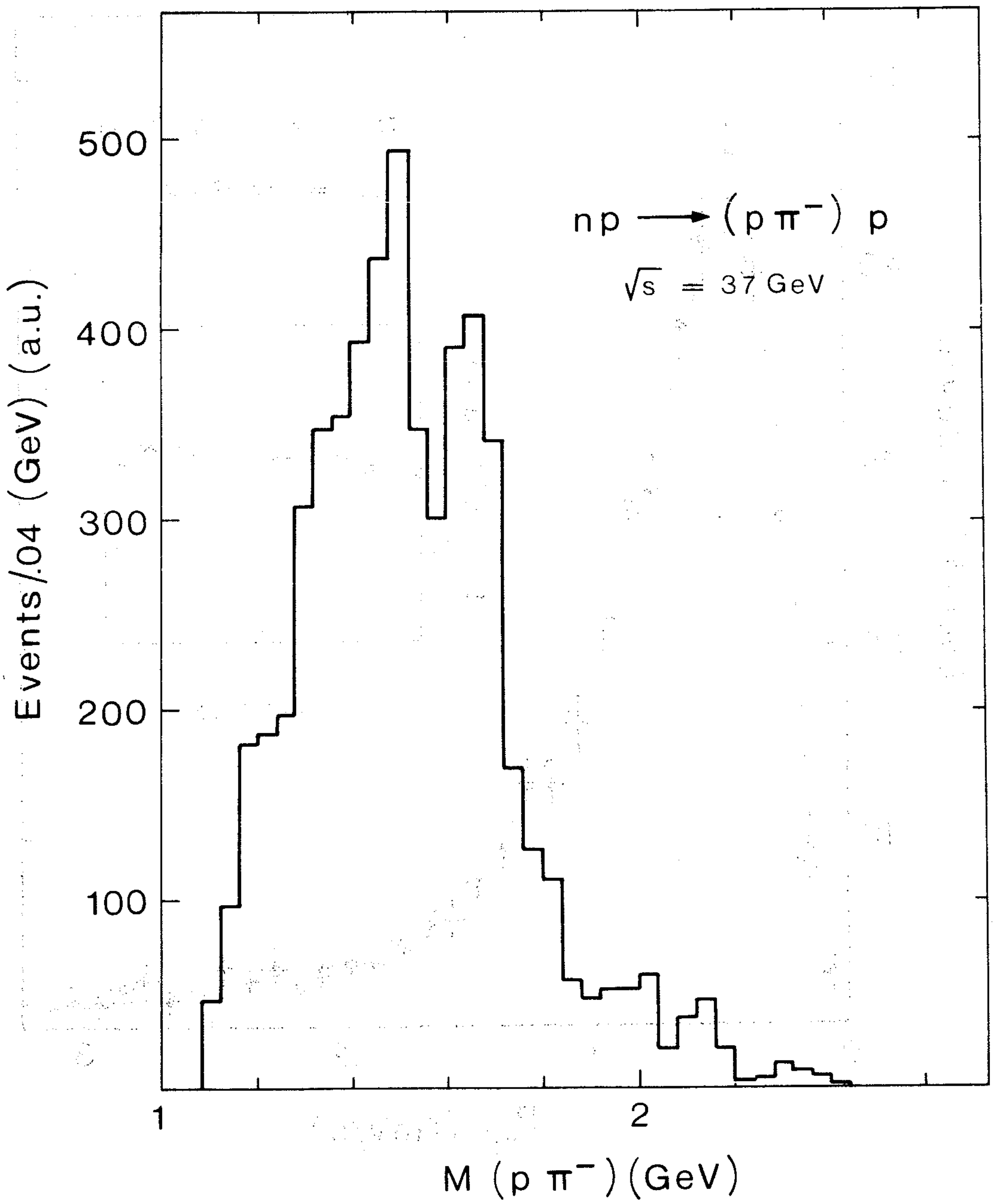
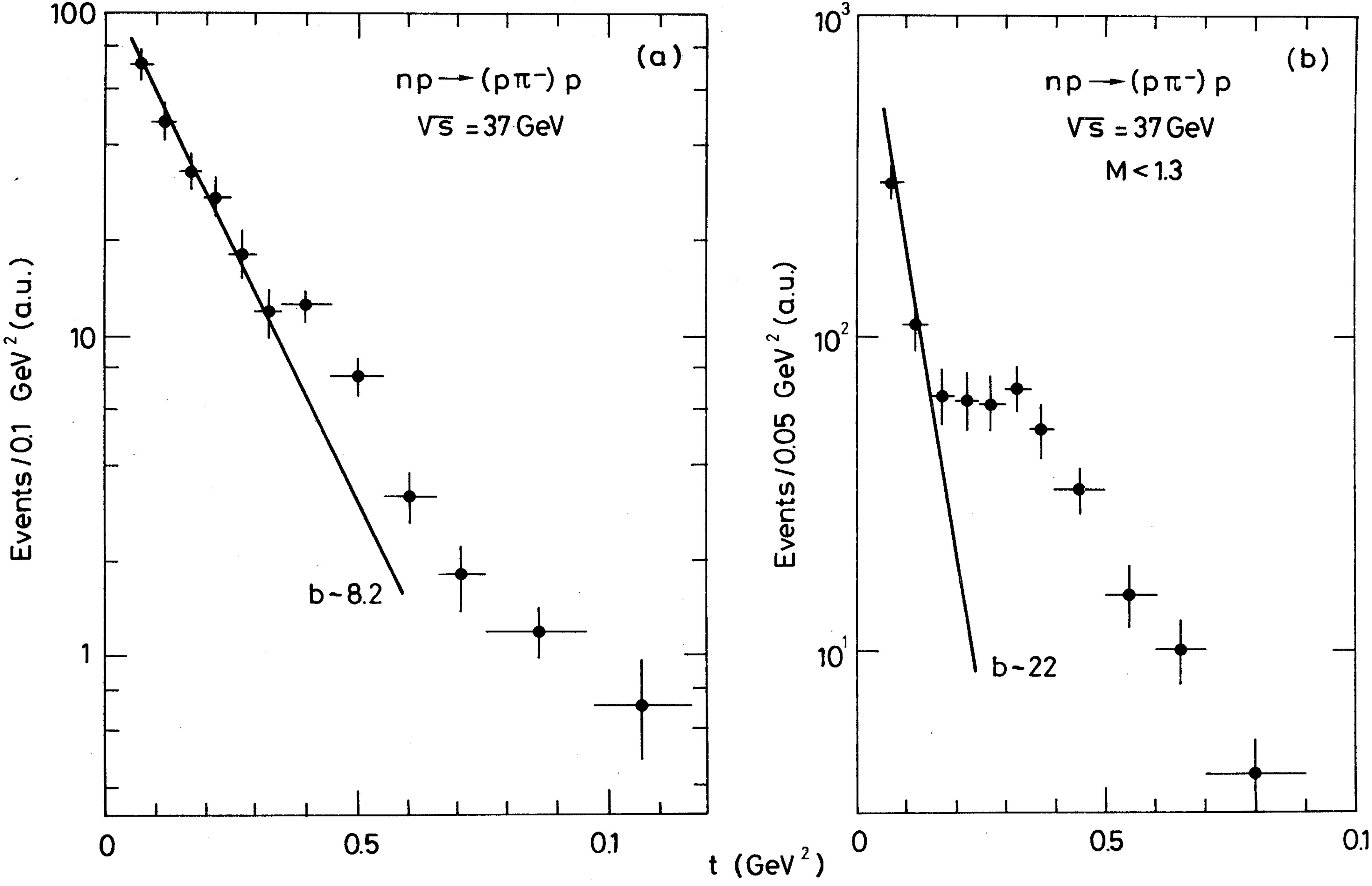


Fig. 2



(a)
np → (pπ⁻) p
√s = 37 GeV
b ~ 8.2
Events/0.1 GeV² (a.u.)
100
10
1
0
0.5
0.1
(b)
np → (pπ⁻) p
√s = 37 GeV
M < 1.3
b ~ 22
Events/0.05 GeV² (a.u.)
10³
10²
10¹
0
0.5
0.1
t (GeV²)

Fig. 3