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DECAY ANGULAR DISTRIBUTIONS IN DIFFRACTIVE ONE-PION PRODUCTION AT ISR ENERGY

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ABSTRACT

New experimental results are reported on decay angular distributions in diffractive dissociation of protons into $(n\pi^+)$ in proton-proton collisions at a centre-of-mass energy of $\sqrt{s}$ = 45 GeV. There is strong evidence for two distinct components of diffraction dissociation which have different decay angular distributions in the Gottfried-Jackson frame; the resonant and the non-resonant component with $(n\pi^+)$ invariant mass in the interval $1.6 < m < 1.7$ GeV are separated by their different t dependence. We find strong violation of s-channel and t-channel helicity conservation for both the resonant and the non-resonant component.

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In the preceding letter[1] we have reported on diffractive one-pion production in the reaction

$$(1) \qquad pp \rightarrow p(n\pi^+)$$

at a centre-of-mass energy of $\sqrt{s}$ = 45 GeV. The aim of this letter is to describe the decay angular distributions of the $(n\pi^+)$ system and to discuss questions concerning the helicity structure of the diffractive process.

While for ρ^0 photo-production and elastic pion proton scattering helicity conservation in the s-channel is fairly well established[2], s-channel helicity conservation (SCHC) has been disproved for diffraction dissociation[3]. On the other hand, extensive studies[4] of t-channel helicity conservation in the two-body dissociation $N \rightarrow N\pi$ have not lead to a clear answer.

In the present investigation of diffraction dissociation at very high energy where non-diffractive exchange contributions to reaction (1) have been shown experimentally to be negligible[5] we find strong violation of both SCHC and TCHC for the resonant and for the non-resonant part of the reaction.

If helicity is conserved in a particular reference frame, the total helicity of the $(n\pi^+)$ system is the same as that of the dissociating proton. We consider the two cases of s-channel and t-channel helicity conservation which are thought to be singled out by dominant dynamical mechanisms, e.g. the latter by Pomeron exchange. In the Gottfried-Jackson system[6] the polar angle Θ_J of the neutron in the $(n\pi^+)$ rest frame is measured against the direction of the dissociating proton, and the azimuthal angle ϕ_J against the production plane. These angles can be reconstructed with a probable experimental error of $\Delta\cos\Theta_J \sim 0.017$ and $\Delta\phi_J \sim 1.8^0$, on average.

The observed angular distributions for different intervals of the invariant mass of the $(n\pi^+)$ system are shown in figure 1. We note a forward and a backward peaking of $d\sigma/d\cos\Theta_J$, and an asymmetry, favoring the forward direction, which is increasing with increasing mass. The distributions in ϕ_J are peaking in the production plane, at $\phi_J = 0^0$, for all mass intervals. There appear to be two distinct components[1] of diffraction dissociation, resonance production and non-resonant pion production. We expect these components to have different polar and azimuthal angular distributions in the Gottfried-Jackson system; production of a single resonance will be reflected by forward-backward symmetry in $d\sigma/d\cos\Theta_J$ and by symmetry in $d\sigma/d\phi_J$ with respect to the normal to the production plane, whereas in non-resonant pion production, if it is assumed to be dominated by a double-peripheral mechanism, the neutron will be produced predominantly forward and in the production plane[7]. There is qualitative evidence in the data for both components. To help demonstrating this we also show results of a model calculation in figure 1. Non-resonant pion production has been described by a simple Deck model[8]; assuming a reggeized pion exchange leads to the following double-peripheral matrix element squared[7]:

$$|M|^2 = g^2 \frac{-t_2 e^{4(t_2-m_\pi^2)}}{(t_2-m_\pi^2)^2} \cdot s_2^{2\alpha'_\pi(t_2-m_\pi^2)} \; s_1^{\,2} \, e^{8t_1} \qquad (2)$$

where t_1 and t_2 designate the momentum transfers between incoming and outgoing proton and dissociating proton and outgoing neutron, respectively; s_1 and s_2 are the subenergies squared of the outgoing proton and the pion and the outgoing neutron and the pion, respectively; the differential cross section for πp elastic scattering is taken proportional to e^{8t_1}, and an empirical form factor, $e^{4(t_2-m_\pi^2)}$, is used to obtain a better description of the data in the variable t_2. α'_π is the slope of the pion Regge trajectory.

To perform a sensitive test of TCHC we have tried to separate the two components on the basis of these expectations. A mass region including the peak at 1650 MeV was selected as the most prominent resonant contribution[1], and another region, $1.30 < m < 1.40$ GeV which is dominated by non-resonant pion production. Owing to the large statistics of this experiment we can investigate $d\sigma/d\phi_J$ in these mass regions for different intervals of $\cos\Theta_J$.

A necessary condition for TCHC is isotropy in the azimuthal angle ϕ_J[9]. The observed angular distributions are shown in figure 2a and 2b. We note strong deviations from isotropy for both the predominantly non-resonant mass interval $1.3 < m < 1.4$ GeV and for the resonant mass region $1.6 < m < 1.7$ GeV. A tendency for an increase of $d\sigma/d\phi_J$ at $\phi_J \sim 180^0$ for backward produced neutrons can be attributed to a baryon exchange contribution[10] in a double-peripheral mechanism.

One may argue that the resonant contribution in figure 2b may interfere with the non-resonant background and that a test of TCHC is not meaningful. We have therefore attempted to separate resonant and non-resonant events occurring in the same mass interval, $1.6 < m < 1.7$ GeV. In the preceding letter[1] we have studied the variation of the slope of $d\sigma/dt$ as a function of the $(n\pi^+)$ mass for various regions of $\cos\Theta_J$; we find that for the region $-0.3 < \cos\Theta_J < +0.3$ there is a minimum of the slope in the resonance region. Hence, selecting events in this region of $\cos\Theta_J$ with $|t| < 0.2$ GeV^2 and $0.2 < |t| < 0.5$ GeV^2, respectively, we expect an enrichment in non-resonant and resonant events. An enrichment of each component is indeed observed in the mass spectra of figure 3. Investigating again the distributions in ϕ_J of these samples we observe in figure 3 a strong peaking in the production plane for non-resonant events and approximate symmetry with respect to the normal to the production plane for resonant events, as expected for a single resonance. However, we do not observe isotropy. In the s-channel we observe even stronger deviations from isotropy.

Hence, we conclude that helicity conservation is strongly violated in the t-channel and in the s-channel for both components of diffraction dissociation. Violation of TCHC may be reconciled with Pomeron exchange by assuming that the Pomeron is transferring spin.

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FIGURE CAPTIONS

Figure 1 - (a) Decay angular distribution of the neutron in polar angle Θ_J in the Gottfried-Jackson system[6] for various mass regions of the $(n\pi^+)$ system.

(b) Azimuthal angular distribution $d\sigma/d\phi_J$ in the Gottfried-Jackson system. $\phi_J = 0$ corresponds to the production plane. The solid curves represent the results of a model calculation of a non-resonant diffractive process.

Due to phase-space limitations in the experiment[1] the distributions are shown for $|t| > 0.1$ GeV^2 and $\cos \Theta_J > -0.9$. The cut at $\cos \Theta_J = -0.3$ in the first mass bin is also due to these limitations.

Figure 2 - $d\sigma/d\phi_J$ in the Gottfried-Jackson system for two mass regions,
(a) of predominantly non-resonant processes, $1.3 < m < 1.4$ GeV, and
(b) containing resonant processes, $1.6 < m < 1.7$ GeV, in three intervals of $\cos \Theta_J$ with the cut $|t| > 0.1$ GeV^2.

Figure 3 - Enrichment of the mass spectra in (a) non-resonant and (b) resonant events by cuts on $|t|$. Selecting the mass interval $1.6 < m < 1.7$ GeV (the cross-hatched regions) $d\sigma/d\phi_J$ is plotted with the same $|t|$ cuts. The distributions are distinctly different; both are non-isotropic and hence do not support TCHC.

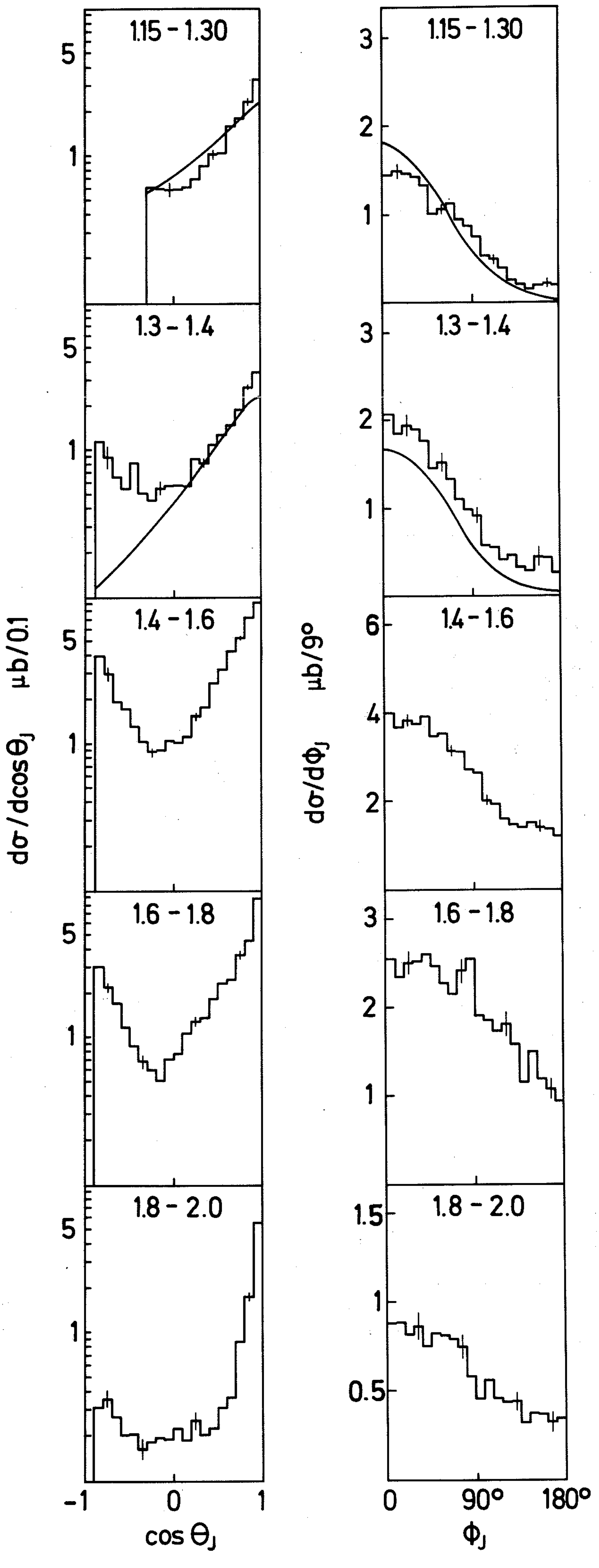
1.15 - 1.30
1.3 - 1.4
1.4 - 1.6
1.6 - 1.8
1.8 - 2.0
dσ/dcos Θ_J μb/0.1
dσ/dΦ_J μb/9°
-1
0
1
cos Θ_J
0
90°
180°
Φ_J

FIG. 1a

FIG. 1b

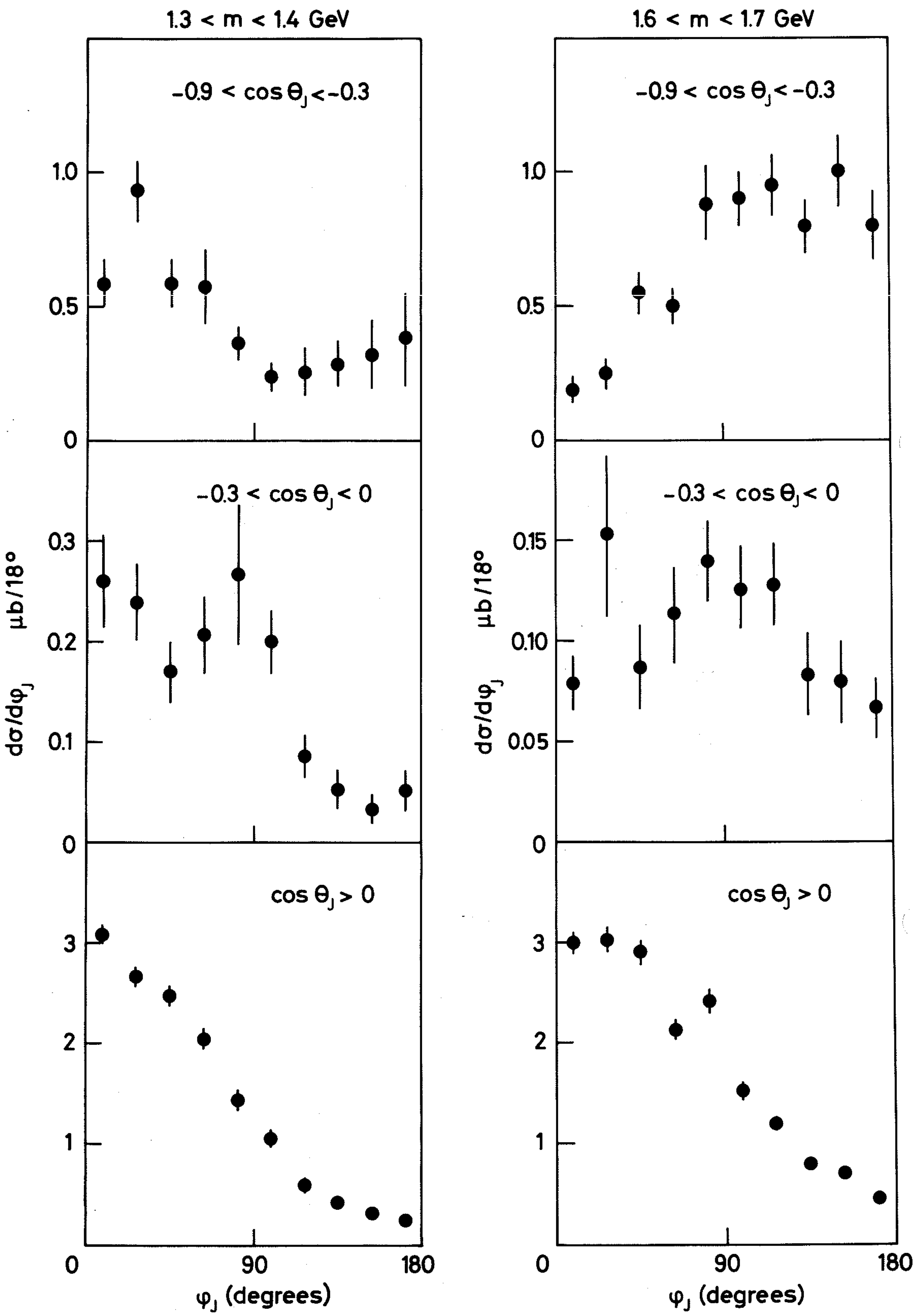
1.3 < m < 1.4 GeV
1.6 < m < 1.7 GeV
-0.9 < cos Θ_J < -0.3
-0.3 < cos Θ_J < 0
cos Θ_J > 0
dσ/dφ_J μb/18°
φ_J (degrees)
0
90
180
1.0
0.5
0.3
0.2
0.1
0.15
0.10
0.05
3
2
1

FIG. 2

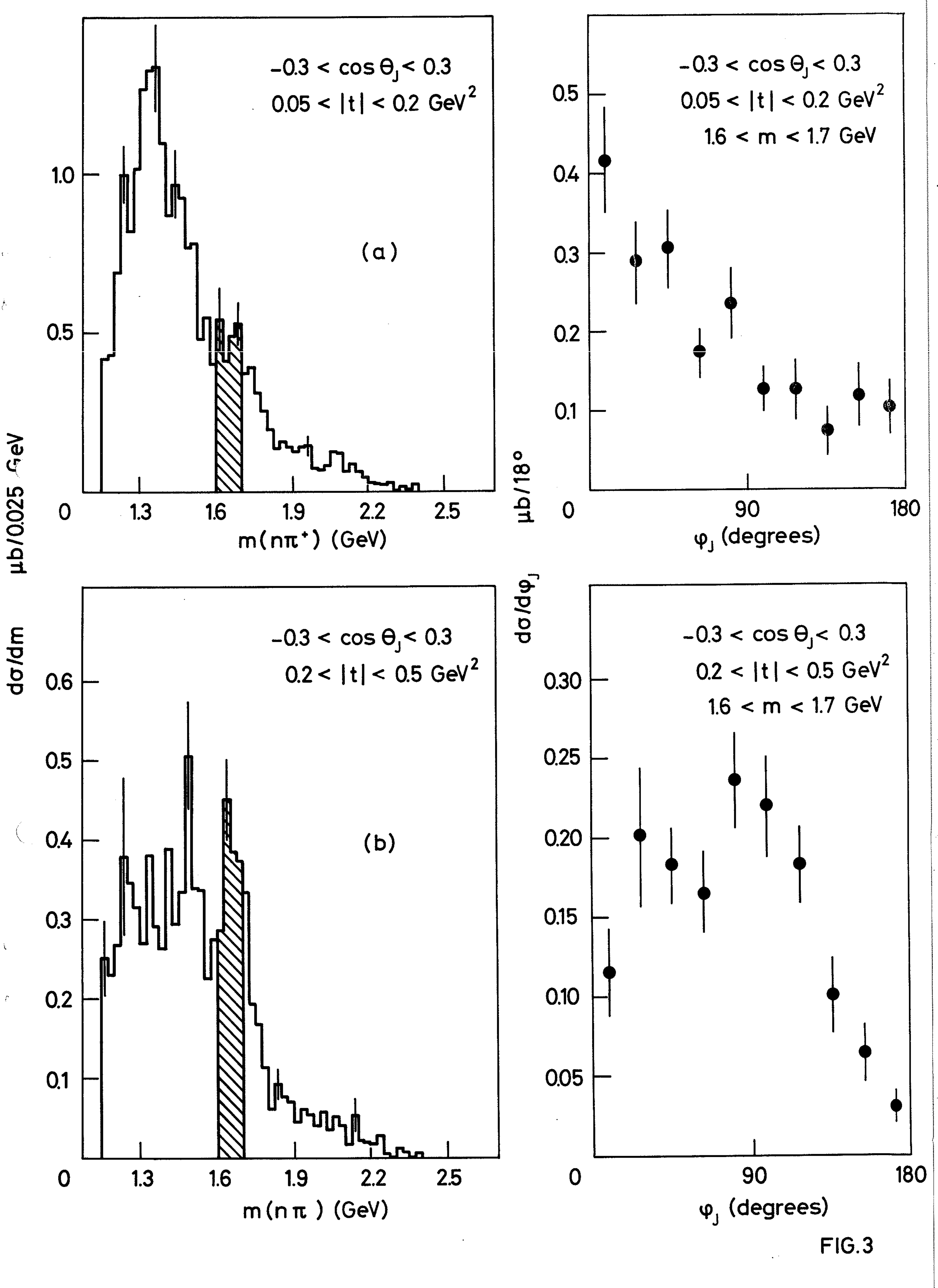
-0.3 < cos θ_J < 0.3
0.05 < |t| < 0.2 GeV²
(a)
μb/0.025 GeV
dσ/dm
m(nπ⁺) (GeV)
1.6 < m < 1.7 GeV
μb/18°
dσ/dφ_J
φ_J (degrees)
0.2 < |t| < 0.5 GeV²
(b)
m(nπ) (GeV)

FIG.3