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THE POSSIBILITY TO INVESTIGATE J/ψ PRODUCTION AND GLUON DISTRIBUTIONS USING MUON BEAM OF U-600

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A great success in the investigation of the matter structure in accelerator experiments has been achieved during the last 20 years. The x-distributions of quarks and gluons in nucleon have been measured mainly on unpolarized targets in deep inelastic charged leptons and neutrino interactions. Besides, Q^2-evolution of quark distributions was also studied and the vector nature of gluons was confirmed (we mean that x is a Bjorken scaling variable and Q^2 is a square of the momentum transferred from lepton vertex to hadron system). One of the questions which has not been enough investigated till the present moment, is the internal spin structure of the nucleon.

The recent measurements of the polarized quark distributions[1] and checking of sum rules[2-4] have shown the necessity to study constituent helicities and their orbital angular momentum contributions to the proton spin in future. The information about the quark helicity contributions can be derived from deep inelastic scattering of polarized leptons on polarized targets, and the antiquark contributions - from measurements of "massive" Drell-Yan muon pairs in $p\bar{p}$-interactions[5]. The data on the gluon contribution to nucleon spin can be obtained from the direct photon[6] or hadronic jet[7] analysis in polarized pp-collisions. The rare possibility to measure gluon structure functions, both: polarized and unpolarized, can be realized investigating J/ψ production in reaction

$$\mu N \longrightarrow \mu J/\psi X \qquad (1)$$

The method to measure gluon structure functions is based on the assumption of J/ψ pruduction in (1) via gluon-photon fusion mechanism[8-11](see Fig.1). The measured quantity containing the information on spin-dependent structure function is asymmetry

$$A = \frac{d\sigma^{\downarrow\uparrow} - d\sigma^{\uparrow\uparrow}}{d\sigma^{\downarrow\uparrow} + d\sigma^{\uparrow\uparrow}} \quad , \text{ where}$$

$d\sigma^{\uparrow\uparrow(\downarrow\uparrow)}$ is the interaction cross-section when the muon and nucleon spins are parallel(antiparallel).

For the subprocess $\mu^h(l)g^\lambda(q') \longrightarrow \mu(k')g(k)J/\psi(P)$ in reaction (1) let us define the following common variables:

$$x=Q^2/2q'q, \quad y=qq'/q'l, \quad z=q'P/q'q \ ,$$

where l (q') is the momentum of the muon (gluon) of helicity h(λ) and q is the momentum of the virtual photon ($q^2=-Q^2$). Consequently, defining a new invariant at a hadronic level, $x_H=Q^2/2P_Nq$, where P_N is the momentum of the nucleon, the cross-section of reaction (1) can by written in the form:

$$\frac{d\sigma_{hk}}{dx_H dy dz} = \int_{x_H}^{x_{max}} \frac{dx}{x} \left\{ G_+\left(\frac{x_H}{x},S_C\right)\frac{d\hat{\sigma}_{h\lambda=k}}{dxdydz} + G_-\left(\frac{x_H}{x},S_C\right)\frac{d\hat{\sigma}_{h\lambda=-k}}{dxdydz} \right\} \ , \quad (2)$$

where $x_{max}= zQ^2/(M^2+zQ^2)$, $S_c= M^2+ P_T^2$, $G_+(G_-)$ being the gluon distribution with helicity parallel(antiparallel) to the parent nucleon helicity. The expression for the cross-section of the process $d\hat{\sigma}_{h\lambda}/dxdydz$ is given, for example, in[12]. Further, we have applied the gluon distribution parametrization set I and set II from[13]. In case of set I the valence quarks carry 62%, gluons carry 33% and sea quark(antiquark) carry 5% of the proton spin. In case of set II sea quark(antiquark) contribution to the proton spin is -13%[13].

Using expression (2) for cross-section, the asymmetry can be read:

$$A(x_H,y,z) = \frac{\displaystyle\int_{x_H}^{x_{max}} \frac{dx}{x}\, \Delta G(\,x_H/x,S_c)\, \frac{d\Delta\hat{\sigma}}{dxdydz}}{\displaystyle\int_{x_H}^{x_{max}} \frac{dx}{x}\, G(x_H/x,S_c)\, \frac{d\hat{\sigma}}{dxdydz}} \ ,$$

where $\Delta G(x_H/x,S_c)=G_+(x_H/x,S_H)-G_-(x_H/x,S_c)$ is the spin-dependent gluon distribution and $G(x_H/x,S_c) = G_+(x_H/x,S_c)+G_-(x_H/x,S_c)$ is the unpolarized gluon distribution. In the analysis, following[9,11], we restrict ourselves considering only region $P_T^2>0.4$ GeV^2, $0.3<z<0.7$ and we have used the following constants: $\Gamma_{e^+e^-}=4.8$ KeV is the electronic width of the J/ψ, $M_{J/\psi}=3.1$ GeV, Λ=200 MeV. The polarization for the beam and the target were chosen equal to 0.8.

In Fig.2 we plot the z-dependence of asymmetry A(z) for $Q^2=10$ GeV^2 and two values E_μ, 200 GeV and 400 GeV, using parametrization set I and set II for gluon distribution. Let us stress that asymmetry decreases with the E_μ increasing. It happens due to $\Delta G(y_{min})/G(y_{min})$ increasing while E_μ increases and Q^2 and z are fixed.

In Fig.3 the A(z) versus Q^2 is shown. When Q^2 increases, - y_{min} also increases that leads to the larger asymmetry. However, when Q^2 increases - the cross-section of J/ψ production is rapidly going down. To illustrate it in Fig.4 we have plotted cross-section dσ/dz versus Q^2.

Fig.5 shows cross-section dσ/dz versus E_μ for z=0.3 and z=0.7, $P_T^2>0.4$ GeV^2(the integration runs from $Q^2_{min}=0.5$ GeV^2). It is clear that in the given interval of E_μ the maximal cross-section growth lies in the region less than 200 GeV.

At the energies which are big enough for $b\bar{b}$ production, the contribution to the asymmetry comes also from the Υ production (see fig.6) Here the sign of the sea quark polarization is chosen as positive(set I).

In ref.[14,15] it was stressed that the difference between the differential cross-sections and the gluon-photon fusion model prediction, requires to introduce normalization factors ≃2.5. To understand the reason of this difference it is necessary to perform a more substantial theoretical and experimental analysis of the process.

It is possible to investigate the considered problems at U-600 in the experiment with Superconducting Toroidal Spectrometer(STORS) which provides large luminosity and large acceptance in a wide range of x and Q^2[16]. The proposed layout of the experiment includes the possibility to measure muon momenta and angles between them with a resolution ≃1%. The estimation has shown that at these experimental conditions the mass resolution in J/ψ and Υ region is ≃2%, the acceptance for J/ψ is ≃15%.

Exposing STORS[16] with two 1 m ammonia(NH_3) targets polarized in opposite direction by $1.4*10^{14}$ muons at $E_\mu=200$ GeV*, one can record $\simeq 7*10^8$ μN-events in the region $0.01<x<0.9$, $4.<Q^2<160.$GeV^2. This is by $\simeq 4.3*10^2$ times more than the number of events in experiment EMC[1] and by $\simeq 2.3*10^2$ times more than in experiment SMC[17] where polarized structure function g_1 have been measured. The quantity given above, approximately corresponds to the integrated muon flux during 200

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* The estimation of muon flux on U-600 has been done by the Beams Department at IHEP.

working days of the accelerator with 50% efficiency.

The designed intensity of the UNK muon beam will allow to study the asymmetry caused by J/ψ production on the polarized target. The estimation has shown that when exposing STORS[16] with two 1 m polarized targets of ammonia by $1.4*10^{14}$ muons at E_μ=200 GeV, it is possible to record $\simeq 7*10^3$ J/ψ events in the region $0.25 < z < 0.75$, decaying into two muons. In the table there are the estimated asymmetries and uncertainties, averaged over Q^2.

z	0.3	0.4	0.5	0.6	0.7
A(z)	0.081	0.090	0.099	0.107	0.115
ΔA/A	0.84	0.53	0.37	0.29	0.26

In the conclusion, let us stress that the muon energies at U-600 are convenient to investigate the muoproduction of J/ψ. The extended polarized targets(≃2 m or longer each) and the time increase of data taking will allow to measure the asymmetry with the better precision. From this experiment the gluon polarized structure functions can be extracted and the gluon-photon fusion model predictions can be checked. However, such an experiment requires precision measurements (large luminosity and large acceptance) in the wide range of kinematic variables.

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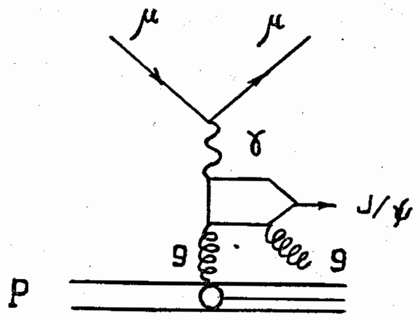

Fig.1 Leading order Feynmann diagram for muoproduction of J/ψ via gluon-photon fusion model.

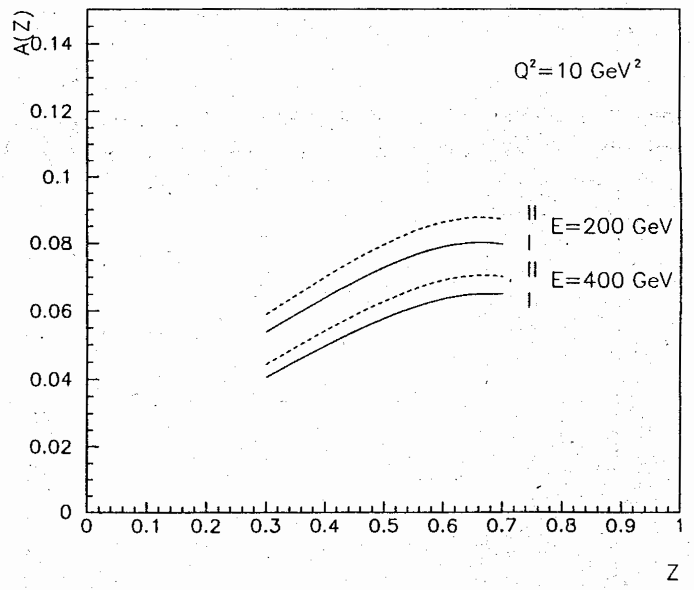

Fig.2 The z-dependence of asymmetry A(z) for Q^2=10 GeV^2, E_μ= 200 GeV and 400 GeV. I - prediction using positive sea polarization, II - prediction using negative sea polarization.

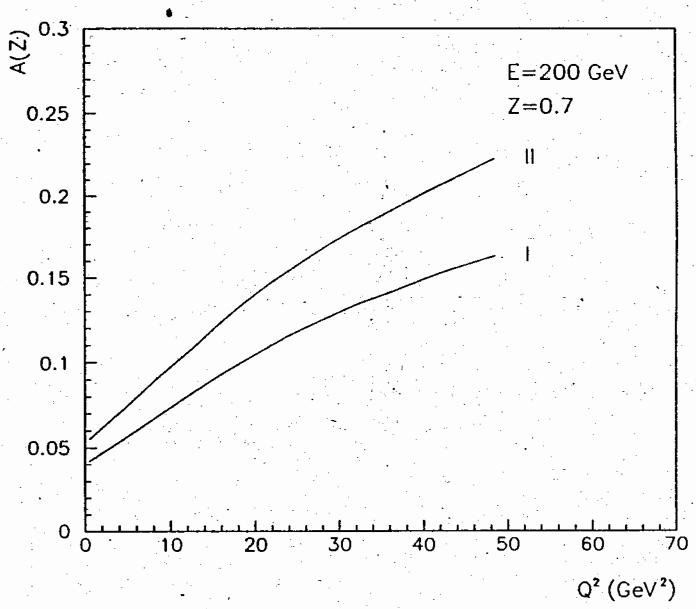

Fig.3 The Q^2 dependence of the asymmetry A(z) for E_μ=200 GeV and z=0.7. The curves I and II are the same as in Fig.2.

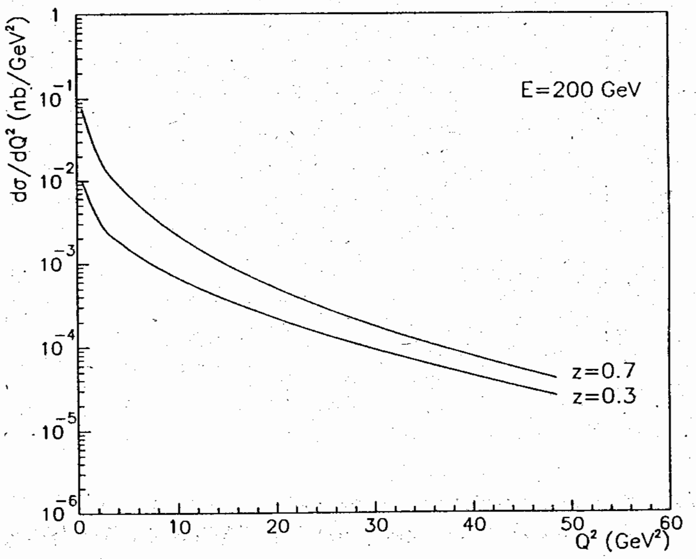

Fig.4 The Q^2 dependence of the cross-section $d\sigma/dz$ for E_μ=200 GeV, z=0.3 and z=0.7.

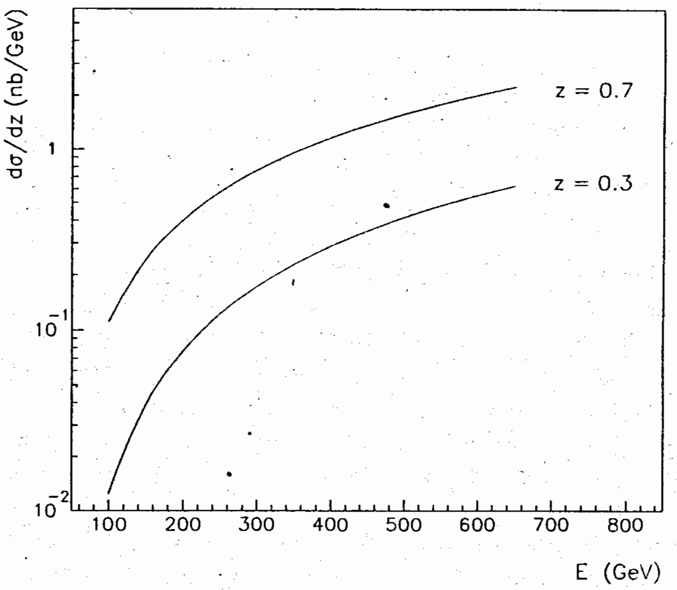

Fig.5 The E_μ dependence of J/ψ production cross-section for z=0.3 and z=0.7.

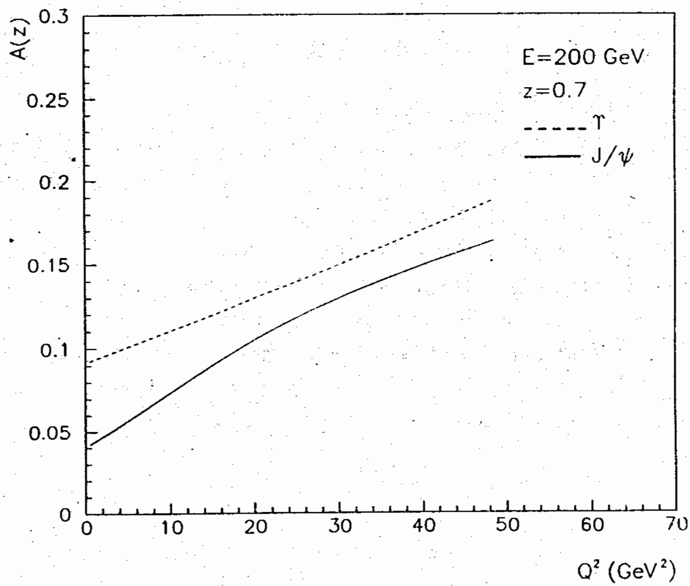

Fig.6 The Q^2 dependence of the cross-sections $d\sigma/dz$ in J/ψ and Υ production for E_μ=200 GeV, z=0.7.

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Алиев Р.М., Кривохижин В.Г., Усубов З.У. E1-94-228
О возможности исследований рождения J/ψ частиц
и глюонных распределений на мюонном пучке У-600

При энергиях мюонного пучка У-600 для реакции $\mu N \to \mu J/\psi X$ приведены предсказания для дифференциальных сечений и асимметрии, рассчитанные в модели глюон-фотонного слияния.

Работа выполнена в Лаборатории сверхвысоких энергий ОИЯИ.

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Aliyev R.M., Krivokhizhin V.G., Usubov Z.U. E1-94-228
The Possibility to Investigate J/ψ Production
and Gluon Distributions Using Muon Beam of U-600

This paper presents the differential cross section and asymmetry predictions for reaction $\mu N \to \mu J/\psi X$ in the gluon-photon fusion model at the U-600 energies.

The investigation has been performed at the Particle Physics Laboratory, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1994