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THE POSSIBILITY TO INVESTIGATE J/ψ PRODUCTION AND GLUON DISTRIBUTIONS IN NUCLEONS AND NUCLEI WITH SUPERCONDUCTING TOROIDAL SPECTROMETER (STORS) AT U-600

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The investigation of J/ψ in lepto- and hadroproduction is a good tool to analyse the gluon distribution functions and influence of the nuclear matter in them. Since the middle of 70-ies such invistigations have attracted theorists as well as experimentalists. Recently it has been shown[1], that the J/ψ production cross section ratio measured in hadron interactions(see table in ref.[1]) can be described taking into account the following: 1) modification of gluon and sea quark distributions caused by parton recombinations[2]; 2) the EMC effect and 3) J/ψ interactions in nuclear debris. In ref.[3] it is stressed that the fermi-motion also results in the gluon distribution modification in nucleus.

The nuclear effects on J/ψ muoproduction cross sections were investigated by EMC[4] and NMC[5] groups. The NMC experiment has studied the ratio of cross section per nucleon for J/ψ production on tin and carbon. Some enhancement for coherent and inelastic J/ψ production and suppression for quasielastic J/ψ production was found. The data precisions of the NMC group do not allow to investigate the reason of such behaviour of the cross section ratios.

The deep inelastic J/ψ leptoproduction can be described in the framework of QCD with the colour singlet model[6]. The method is based on the assumption of J/ψ production via photon-gluon fusion mechanism[7]. This description of the process allows one to extract correctly the gluon distribution function $G(x,Q^2)$*) (x is the momentum fraction of the nucleon carried by the probed parton, Q^2 is a square of the momentum transferred from the lepton vertex to the hadron system). In this model the following expression presents the cross section of J/ψ production by real photons(Q^2=0.) on the nucleon:

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*) Shifman M.A. et al.[8] were among the first to offer the leptoproduction of heavy-quark states as a unique possibility to extract the information on the gluon constituents of the nucleon.

$$\frac{d^2\sigma}{dz\, dP_T^2} = \frac{128\pi^2 G(x,Q^2) m_\psi\, \alpha_s^2 \alpha\, e_q^2 |R_s(0)|^2}{3s[m_\psi^2(1-z)+P_T^2]} \left[\frac{1}{M_T^4} + \frac{(1-z)^4}{K_T^4} + \frac{z^4 P_T^4}{M_T^4 K_T^4}\right], \quad (1)$$

where $\sqrt{s}$ is the photon-nucleon center of mass energy, m_ψ is the mass of the J/ψ, P_T^2 - transeverse momentum squared of the J/ψ meson with respect to photon direction, $z=E_\psi/\nu$ is the hadrons energy fraction carried by the J/ψ; e_q is the electric charge of the charmed quark, α and α_s - the QED and QCD coupling constants, respectively, $M_T^2=m_\psi^2+P_T^2$, $K_T^2=m_\psi^2(1-z)^2+P_T^2$. The J/ψ radial wave function $R_S(0)$ is determined from the measured leptonic width using

$$\Gamma(J/\psi \rightarrow ee) = 16\pi\alpha^2 e_q^2 |R_S(0)|^2/m_\psi^2 = 4.7\ \mathrm{KeV}.$$

The momentum fraction of the nucleon carried by the gluon can be defined as follows:[6]

$$x = \frac{1}{s}\left[\frac{m_\psi^2}{z} + \frac{P_T^2}{(1-z)z}\right].$$

At present the gluon distribution function is measured with poor precision. It is true for the data coming from the singlet analysis of the structure function Q^2-dependence as well as from J/ψ production described above. For example, parameter η which defines the gluon structure function shape, in EMC[9] experiment was determined with 26% of the statistical error, in NMC[10] - 17%.

Now the Letter of Intent has been prepared for the experiment on deep inelastic scattering of muons on hydrogen, deuterium and heavy targets using the high quality and intensity muon beam at CERN and UNK(SERPUKHOV)[11]. The usage of Superconducting TOroidal Spectrometer(STORS) with the air gap, releases the main restrictions of the iron toroids: a relatively poor resolution ($\simeq$10%) and difficulties to fulfil calibrations. The high luminosity, high precision determination of kinematic variables in a wide range, and the possibility of simultaneous data collection with different targets allow one to reach a qualitatively new level in the above mentioned task using STORS.

Early we present[11,12] the results of acceptance and resolutions of kinematic variable calculations to investigate deep inelastic muon nucleon scattering. The simulation was made with programm GEATORS[13] based on GEANT[14]. For this paper the STORS set up acceptance was calculated to register the J/ψ production in the reaction $\mu N \to \mu' J/\psi X$. We have generated about 10^4 μN-interactions with J/ψ decaying into two muons. The following conditions and restrictions were used. The energy of muon beam was chosen equal to 200 GeV. The target consisted of four sections, each 5 m long: two - in front of the first supermodule, and two - inside of the first supermodule. The momentum of the scattered muon - $P'_{\mu}>10$ GeV and $Q^2>4$ GeV^2. The P_T^2 and z for J/ψ were generated according to (1). We have used a flat θ-distribution where θ is the polar angle of the decay muon from the J/ψ relative to the line of the J/ψ flight in its rest frame. The multiple scattering in the targets was neglected. The gluon distribution function was chosen as $xG(x,Q^2) \propto \frac{1+\eta}{2}(1-x)^{\eta}$ with $\eta=5.0$, well adjusted with the value, obtained in refs.[9,10]. The region of the colour singlet model application was chosen: $P_T^2>0.1$ GeV^2, $0.4<z<0.9$ and one more - $50.<\nu<200.$GeV was used to reject the region of the small or rapidly varying acceptance. The mean value of the positive muons momentum from J/ψ decay is 50 GeV and the negative one - 43 GeV, $\Delta P/P \simeq 1\%$, $\Delta\theta/\theta \simeq 2\%$, where θ is the angle between the decay muons. Such experimental conditions allow one to obtain the mass resolution in J/ψ region $\simeq 3\%$. Fig.1 shows the acceptance for STORS versus generated variables.

Exposing STORS with four hydrogen targets, each 5 m long, by $2.08 \cdot 10^{13}$ muons at $E_{\mu}=200$ GeV, one can record 2124 J/ψ decaying into two muons. The quantity given above, approximately corresponds to the integrated muon flux during 30 working days of the accelerator with efficiency of 50%. The cross section of J/ψ in the region $0.044>x>0.359$, has been taken from ref.[9]. Fig.2 gives the z- and P_T^2-distributions for J/ψ produced in μN-interactions via the photon-gluon fusion mechanism. Fig.3 presents the distribution of quantity $(m_{meas.}-m_{tab.})/m_{tab.}$, where $m_{meas.}$ is the reconstructed mass and $m_{tab.}$ is the true mass value of J/ψ. We stress that in the hydrogen target exposition the mass resolution in the J/ψ mass region is ≈2.3%. The accuracy shown in Fig.4, can be achieved in the gluon distribution function measurement by 30 days exposing of hydrogen target in STORS, where $\int xG(x)dx=0.5$[15]. The gluon distribution function into the region of $x< 0.044$ was approximated as constant. The solid curve in Fig.4 is the fitting result of the generated data. From such statistics parameter η can be determined with accuracy of ≈3%. The EMC[9] and NMC[10] measured data are also shown in Fig.4 for comparison.

The possibility of simultaneous data collection with different targets sufficiently decreases the systematic errors in the measurements of the gluon distribution function ratio. The accuracy which can be achieved by $2.08*10^{13}$ muon with E_{μ}=200 GeV exposing the carbon and tin targets, is shown in Fig.5, where ratio $G_{Sn}(x,Q^2)/G_C(x,Q^2)$ is given. The tin target consists of one section, the carbon target - of three, each 5 m long, with 3655 g/cm^2 and 3397 g/cm^2, respectively. Following ref.[2], we suggest in ratio calculations that in the region of $x<0.1$ the parton recombination effects lead to shadowing, in the region of $x>0.1$ - to antishadowing of the gluon distributions. The value of $|\Delta xG/xG|$ was chosen equal to 5%. The probability that the ratio of simulated gluon distributions can be described with constant equal to 1 is less than 1%. Fig.5 also shows the NMC data[5].

In the conclusion, we would like to stress that the high precision determination of the J/ψ production cross section in the experiment will be provided by Superconducting Toroidal Spectrometer. The large luminosity of muon beam at 200 GeV, high precision measurements in a wide range of kinematic variables, the possibility of simultaneous data collection with different targets will also provide good precision measurements of gluon distribution function in nucleons and nuclei during a comparatively short period of time while data taking. From this experiment the colour singlet model predictions can be checked, the influence of nuclear matter on J/ψ production cross section and gluon distribution function can be investigated.

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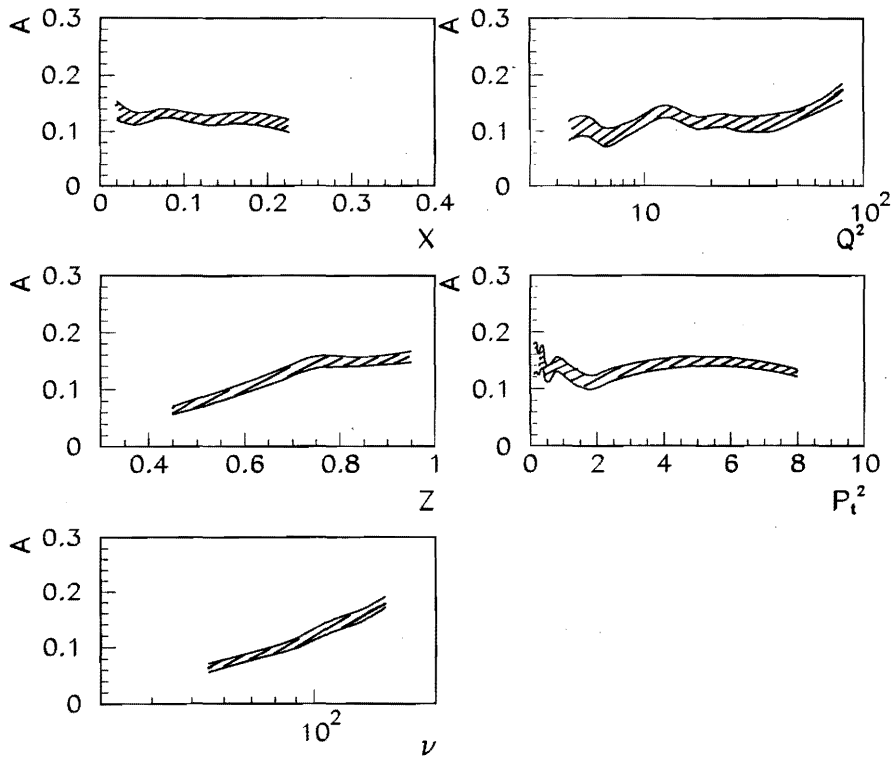

Fig.1 The 1σ-areas of the statistical uncertainty of STORS acceptance versus kinematic variables for two muons from J/ψ decay. The target consists of four sections, each 5 m long.

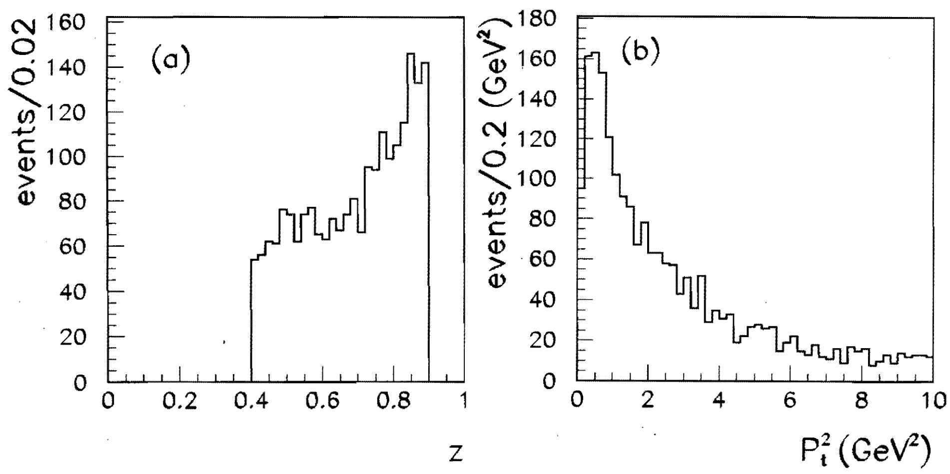

Fig.2 Z (a)- and P_T^2 (b) - distributions for J/ψ produced in μN-->μ'J/ψX via photon-gluon fusion mechanism.

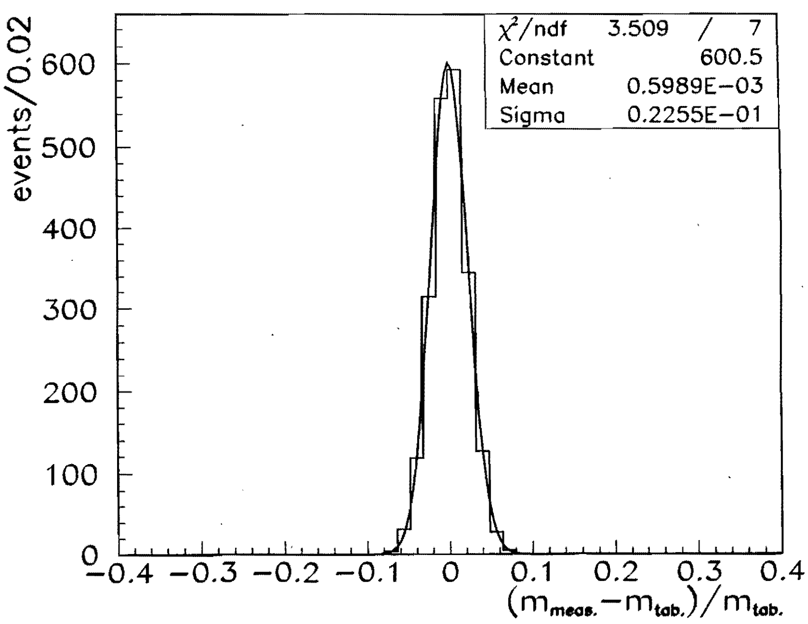

Fig.3 Distribution of quantity $(m_{meas.}-m_{tab.})/m_{tab.}$ (see the text). Also , the fitting result is shown.

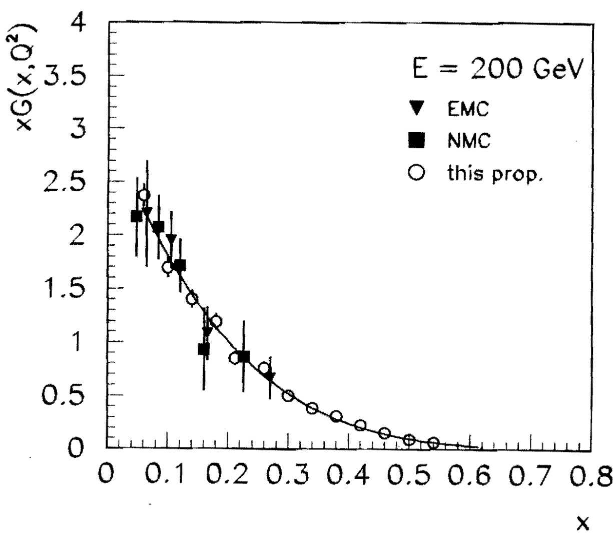

Fig.4 The normalized gluon distribution, $xG(x,Q^2)$ (only statistical errors are shown) together with the J/ψ data from EMC[9] and NMC[10]. The curve presents the fitted parametrization of the simulated data.

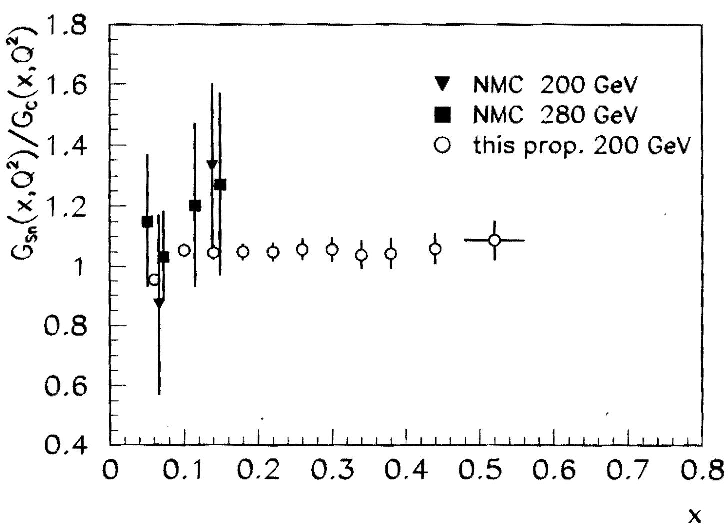

Fig.5 The ratio of gluon distributions on tin and carbon from simulated data(see the text).

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О возможности исследований рождения J/ψ-частиц
и распределений глюонов в нуклонах и ядрах
с использованием сверхпроводящего тороидального спектрометра
(СТОРС) на У-600

В работе рассмотрена возможность исследования рождения J/ψ-частиц на мюонном пучке У-600. Показано, что сверхпроводящий тороидальный спектрометр (СТОРС) позволит с высокой точностью измерить сечение рождения J/ψ-частиц, распределение глюонов в нуклонах и ядрах, проверить предсказания «колор синглет»-модели, исследовать влияние ядерного вещества на распределение глюонов.

Работа выполнена в Лаборатории сверхвысоких энергий ОИЯИ.

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Aliyev R.M. et al. E1-95-103

The Possibility to Investigate J/ψ Production
and Gluon Distributions in Nucleons and Nuclei
with Superconducting Toroidal Spectrometer (STORS) at U-600

This paper considers the possibility to investigate the J/ψ production cross section using the muon beam of U-600. It is shown that Superconducting Toroidal Spectrometer can provide high precision measuring of the cross section of J/ψ production and gluon distribution from reaction $\mu N \to \mu J/\psi X$. This experiment can also help to check the colour singlet model predictions and investigate the influence of nuclear matter in gluon distribution.

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

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