STATE RESEARCH CENTER OF RUSSIA

INSTITUTE FOR HIGH ENERGY PHYSICS

IHEP 99-54

S.B.Nurushev

STUDY OF THE TOTAL AND DIFFERENTIAL CROSS SECTIONS, AND POLARIZATION EFFECTS IN PP ELASTIC SCATTERING AT RHIC

Paper presented on behalf of PP2PP (R7) Collaboration [1] at the 8-th Blois Conference, June 28-July 2, 1999, Protvino, Russia

E-mail:nurushev@mx.ihep.su

Protvino 1999

UDK 539.1.07 M–24

Abstract

Nurushev S.B. Study of the Total and Differential Cross Sections, and Polarization effects in pp Elastic Scattering at RHIC: IHEP Preprint 99-54. – Protvino, 1999. – p. 7, figs. 1, tables 1, refs.: 17.

We present the physics program, setup and perfomance of an experiment to measure the total cross section in proton-proton interaction, the differential cross section and polarization in elastic pp-scattering at the Relativistic Heavy Ion Collider, RHIC, at Brookhaven National Laboratory, USA.

Аннотация

Нурушев С.Б. Изучение полного и дифференциального сечений и поляризационных эффектов в упругом pp-рассеяний на RHIC: Препринт ИФВЭ 99-54. – Протвино, 1999. – 7 с., 1 рис., 1 табл., библиогр.: 17.

Дается описание физической программы, экспериментальной установки и характеристик эксперимента по изучению полного и дифференциальных сечений и поляризационных эффектов в упругом рассеянии протонов на протонах на Релятивистском Коллайдере Тяжелых Ионов, RHIC, в Брукхейвенской Национальной Лаборатории, США.

Introduction

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (USA) is a dedicated machine for study of heavy ion interactions (up to gold ions) at the top beam energy of 100 GeV/amu. RHIC can be at the same time a powerful pp-collider, expanding the ISR energy domain by an order of magnitude. This collider will open a wide avenue for the measurements of the total and elastic scattering cross sections in a preasymptotic range of energy and for checking the predictions of theoretical models. Such motivation lead us to submit Proposal R7 entitled "Experiment to Measure Total and Elastic pp Cross Sections at RHIC" that was approved in 1994, and it also included a spin physics program.

Further addition of a polarized and unpolarized jet target in R7 setup allows one to extend the physics program to the fixed target domain of the RHIC. Other attractive and achievable scientific item is study of a single diffractive dissociation process. We also intend to include both items in our research program later.

1. Physics Objectives

R7 Collaboration[1] aims to measure systematically the total pp-cross section and elastic scattering from $\sqrt{s}$ =50 GeV to $\sqrt{s}$= 500 GeV. The measurements of the elastic scattering differential cross section will cover two kinematical regions: 1) $4 \cdot 10^{-4} <\mid t \mid< 0.12$ (GeV/c)^2; we

[1]**R7 Collaboration List**:

N. Akchurin[1], A. Bogdanov[2], J. Bourotte[3], M. Buenerd[4], B. Chrien[5], M. Conte[6], K. De[7], G. Dudkin[8], R. Giacomich[9], R. Gilb[6], I. Glavanakov[8], W.Guryn[6], M. Haguenauer[3], V. Kaplin[2], A. Karakash[2], Yu. Krechetov[8], D. Lynn[6], G. Naumenko[8], C. Newsom[1], S. Nurushev[2,10], Y. Onel[1], A. Penzo[9], A. Potylitsin[8], M. Pusterla[11], M. Rijssenbeek[12], M. Runtzo[2], A. Rusek[6], M. Sakitt[6], P. Schiavon[9], G. Sette[4], M. Strikhanov[2], C. Tang[12], S. Tepikian[6], A. Ufimtsev[10], A. Vartapetian[7].

1. *University of Iowa, Iowa city, USA*
2. *Moscow Engineering Physics Institute(MEPHI), Moscow, Russia*
3. *Ecole Polytechnique/IN2P3-CNRS, Palaiseau, France*
4. *Institut des Sciences Nucleaires, Grenoble, France*
5. *Brookhaven National Laboratory, USA*
6. *Universita di Genova and Sezione INFN, Italy*
7. *University of Texas at Arlington, USA*
8. *Nuclear Physics Institute, Tomsk, Russia*
9. *Universita di Trieste and Sezionne INFN, Italy*
10. *Institute for High Energy Physics, Protvino, Russia*
11. *Universita di Padova, Padova, Italy*
12. *Suny Stony Brook, USA*

shall measure and study the s dependences of the total and elastic cross sections, σ_{tot} and σ_{el}; the ratio of the real to the imaginary parts of the forward elastic spin nonflip amplitude ρ; and the nuclear slope parameter B of the pp elastic scattering. A possibility to reach the region of $|t| = 1 \cdot 10^{-4}$ (GeV/c)^2 for searching possible oscillations in the differential cross-section [1] will be analyzed by R7 Collaboration; 2) $0.006 <| t |< 1.5$ (GeV/c)^2: we plan to study the evolution of the dip structure observed at ISR in the differential elastic cross section, $d\sigma_{el}/dt$, with s, and the s and $| t |$ dependences of B.

The measurements that can be performed with transversally and longitudinally polarized protons in RHIC are: 1) the difference of the total cross-sections as a function of pure initial spin states, $\Delta\sigma_T$ and $\Delta\sigma_L$; 2) the analyzing power, A_N; 3) the spin correlation parameters, A_{NN}, A_{LL} and A_{NL}.

In order to explore the fixed target energy region of RHIC the R7 Collaboration plans to install the jet target (unpolarized at the first stage and polarized later) and add the recoil arm detectors.

Nucleon-nucleon elastic scattering is described by the 5 helicity amplitudes [2]: $\phi_1 =< + + | + + >$, $\phi_2 =< + + | - - >$, $\phi_3 =< + - | + - >$, $\phi_4 =< + - | - + >$, $\phi_5 =< + + | + - >$, where + and − refer to the nucleon helicities in the c.m. frame. Due to the helicity conservation at 0^o, $\phi_4(0) = 0 = \phi_5(0)$ and only three amplitudes survive. So, we see two amplitudes with spin nonflip ϕ_1 and ϕ_3, two others with double spin flip ϕ_2 and ϕ_4 and only one amplitude with single spin flip ϕ_5. In order to determine all the amplitudes at any fixed s and t, one must measure 9 observables. Such set of experiments is called a complete set of experiment [3]. Our strategy is to fulfill such measurements step by step using polarized protons at RHIC.

The imaginary parts of the three elastic scattering amplitudes surviving at zero degree are related to the three types of total cross sections through the generalized optical theorems in the following way [4], [5]: $\sigma_{tot} = \frac{2\pi}{k} Im[\phi_1(0) + \phi_3(0)]$, $\Delta\sigma_L = \frac{4\pi}{k} Im[\phi_1(0) - \phi_3(0)]$, $\Delta\sigma_T = -\frac{4\pi}{k} Im[\phi_2(0)]$, where k is the c.m. momentum. Here σ_{tot} is the unpolarized total cross-section, $\Delta\sigma_L$ is measured as a difference of the total cross-sections with longitudinally polarized beams, while $\Delta\sigma_T$ is measured with transversally polarized beams. Therefore, by measuring three total cross-sections one can reconstruct the imaginary parts of three nonzero amplitudes at zero degree, $\phi_1(0)$, $\phi_2(0)$ and $\phi_3(0)$.

In order to get a hint for pp total cross section at RHIC we refer to the description of the total cross-secion based on the Froissart-Martin bound [6] and given in[7]. In the RHIC domain of energy according to this paper the pp total and elastic cross sections should increase essentially (from 43 to 60 mb for total cross sections and from 8 to 13 mb for elastic ones) and such growths will be easily detected. The difference between pp and $\bar{p}p$ total cross sections is $\Delta\sigma_{tot}$=1.18 mb at the RHIC injection energy and is expected to be 40 μb at $\sqrt{s}$=500 GeV. Recently an alternative approach to this problem was proposed [8]. According to this paper the failure of production of Centauro events in $\bar{p}p$ colliders might be caused by the fact that Centauro events are originated purely from pp interaction and not from the $\bar{p}p-$events. It means that there is an extra source of interaction in pp and, therefore, at sufficiently high energy (around $\sqrt{s} = 500$ GeV) $\sigma_{tot}(pp)$ becomes equal to the $\sigma_{tot}(\bar{p}p)$ and then it grows faster. In this case one can expect that $\Delta\sigma_{tot}$ rises like $\approx \lg s$.

Another important subject is the ratio $r_{el} = \frac{\sigma_{el}}{\sigma_{tot}}$. There is an indication that σ_{el} and r_{el} continue to rise and r_{el} approaches a black body limit which is 0.5. At the RHIC energy region it is expected that r_{el} should rise from 0.174 to 0.217, which can be easily measured. This ratio for $\bar{p}p$ collision is 0.2202±0.0078 according to a recent measurement [9].

The dependence of the differential elastic cross-section $\frac{d\sigma_{el}}{dt}$ on $|t|$ can be divided into three regions: 1) the Coulomb region, 2) the CNI region, 3) the hadronic region. At small t the Coulomb term dominates, and $\frac{d\sigma_{el}}{dt}$ has a $\frac{1}{t^2}$ dependence. Since the Coulomb amplitude is precisely known, the measurement at very small $|t|$ gives direct determination of the machine's luminosity and, consequently, the absolute normalization of the hadronic amplitude. But such measurement will be hard to make.

The measurements in the CNI region allow one to determine a very crucial parameter — the ratio of the real to imaginary parts of the leading spin nonflip amplitudes. This parameter is related to the total cross-section, $\sigma_{tot}(pp)$, via dispersion relation and is a check of the basic principles of the strong interaction dynamics like analyticity, unitarity and crossing symmetry.

Near a forward direction, $|t| < 0.12$ GeV/c^2, the elastic differential cross section is well described by the simple exponential, $\exp^{-B\cdot|t|}$. In the classical Regge model the slope parameter depends on the energy like B(s)=B_0+2$\cdot\alpha$' $\log s$ if the leading pole is a pomeron. Such prediction is consistent with the experiments. The pp2pp data will extend a study of such dependence beyond the ISR energy region and improve the estimate of the effective slope of the Pomeron trajectory, α'. Beyond the above t region the $d\sigma_{el}(t)/dt$ does not follow a simple exponential form and the slope parameter B(t) for pp scattering may show a complicated t and s dependence.

At the ISR it was discovered that at $|t| > 0.5$ (GeV)^2 the pp elastic differential cross section shows a diffraction-like picture. At $|t|$=1.5 (GeV/c)^2 and $\sqrt{s}$=23.5 GeV there is a pronounced dip followed by bump. With the growth of $\sqrt{s}$ this structure shifts to the smaller $|t|$ and becomes not so pronounced. Such behaviour is described by several models, like the "impact picture" model of Bourrely et al. [10], the "multiple diffraction" model of Glauber [11], the specific Regge model [12]. They show differences in predictions at the large t-region ($> 2(GeV/c)^2$). The large luminosity of RHIC will make possible a detailed study of scattering at large momentum transfer.

As apparent from the previous discussion, the basic question to be addressed is: will a new diffraction-like structure emerge in this large $|t|$-region, or will the $|t|$-distribution be smooth and energy independent, controlled by a single QCD diagram [13]? The measurements at RHIC will be useful for checking these predictions.

2. Spin Physics Program

RHIC will have a unique capability of accelerating polarized protons up to $\sqrt{s}$=500 GeV with a high average polarization, ≈ 70% for each beam, and a high luminosity, $L = 2\cdot 10^{32} cm^{-2}\cdot s^{-1}$. This will enable us to measure the spin dependent parameters of elastic pp scattering at much higher *cms* energies compared to the highest energy data to date ($\sqrt{s}$=24 GeV).

The main polarization measurements that will be performed by R7 Collaboration are listed below. We assume that the transversly and later the longitudinally polarized proton beams will be available at the Interaction Region (IR).

By colliding two polarized protons with polarizations P_1 and P_2 we can measure the total cross section

$$\sigma_{tot}(\vec{P}_1,\vec{P}_2) = \sigma_{tot} + \sigma_1\cdot(\vec{P}_1\cdot\vec{P}_2) + \sigma_2\cdot(\vec{P}_1\cdot\vec{k})(\vec{P}_2\cdot\vec{k}), \tag{1}$$

where $\vec{k}$ is a unit vector in *cms* along the beam direction (let us say, beam 1). While σ_{tot} is the unpolarized total cross section (defined earlier), two new observables are related to the standard total cross sections in the pp singlet, σ^s, and triplet states, σ^t_0 and σ^t_+(0 and + mean the spin projections) by the relations: $\sigma_1 = \frac{\sigma_0^t - \sigma^s}{4}, \sigma_2 = \frac{\sigma_+^t - \sigma_0^t}{2}$. By measuring all the three total cross sections at RHIC: unpolarized σ_{tot}, transversally polarized $\Delta\sigma_T$, and longitudinally polarized $\Delta\sigma_L$, we can reconstruct for the first time all the three imaginary parts of helicity amplitudes at t=0. As a result, we can estimate how much the spin interactions contribute to the total cross section.

The CNI region is very attractive for the measurements of the spin effects. It stems from the fact that in this region two amplitudes interfere: the one is the Coulomb spin-flip amplitude which can be calculated in QED very precisely and has specific t-dependence and the second one is the nuclear amplitude, which varies much slower with t and can be taken in the CNI region either as a constant or having the exponential dependence with slope parameter B(t). Usually by the measurement in CNI region, the parameter ρ is determined. In the case of the polarized beam one can measure the analyzing power [14]

$$A_N(s,t) = A_{max} \cdot \frac{4 \cdot y^{3/2}}{1 + 3 \cdot y^2}, \tag{2}$$

where y=$\frac{|t|}{t_{max}}$, $t_{max} = \sqrt{3} \cdot \frac{8\pi\alpha}{\sigma_{tot}}$ and α is a fine-structure constant. This analyzing power is an interesting subject for theory and, on the other hand, it can be used for polarimetry of the high energy proton beam. The only measurement of this parameter has been recently performed by E704 collaboration [15] confirming expected behaviour. But it was measured at only one energy and with large errors. To be used as a polarimeter more precise measurements (better than 5%) and at several energies are needed. We plan to make such measurements at RHIC by using the same apparatus as it is foreseen for elastic scattering.

We will also measure the spin-correlation parameters in the CNI region, which carry rich information on the nuclear amplitudes [16].

The region for $|t| > 2$ (GeV/c)^2 is essentially unexplored and high precision measurements can shed light on a possible onset of hard regime spin effects.

3. Experimental setup

We propose to measure the previously outlined aspects of pp elastic scattering in two types of experimental setups, installed around the 2 o'clock Interaction Region (IR) of the RHIC (Fig.1).

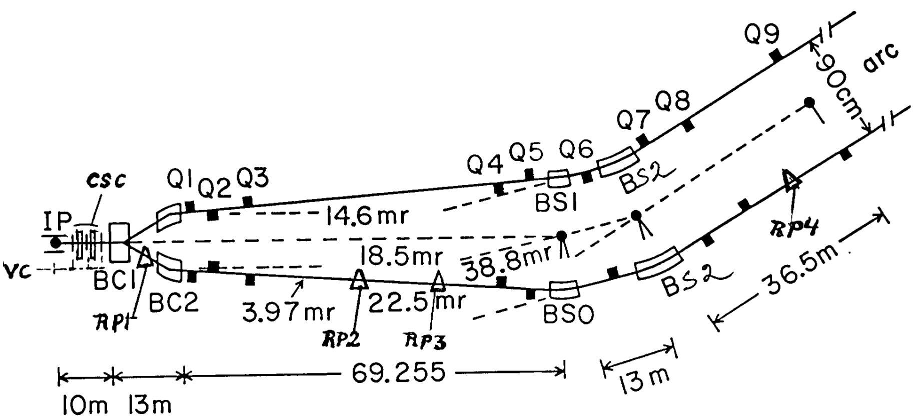

Fig. 1. The pp2pp(R7) setup at RHIC.

For the medium $\mid t \mid$-range, we define the following requirements:

- Momentum analysis with $\frac{\Delta p}{p} \leq 2\%$.
- Rejection at a trigger level of events with nearly collinear low-enegy tracks using the deflection by the magnets.
- Reconstruction of the collision point by extrapolating the observed tracks back to the crossing region, with an accuracy sufficient to reject beam-wall-interactions.
- Use the VC signals for suppressing the elastic triggers accompanied by extra charged particles.
- Acceptance of the large momentum transfer up to $\mid t \mid\simeq 1.5$ (GeV/c)^2).
- Momentum-transfer resolution better than $\Delta t = 0.02$ (GeV/c)^2 at $|t| = 1$ (GeV/c)^2.

In the standard pp-mode for top energy at RHIC, the expected normalized emittance, defined at a 95% level, is $\epsilon = 20\pi$·mm·mrad. The size and angular spread of the beam at the crossing are $\sigma_y = \pm 0.45$ mm and $\sigma_{\theta_y} = \pm 45$ μrad, respectively.

The scattered protons will be detected by telescopes of detectors in Roman Pots (RP). Each containing 2 planes of x and 2 planes of y of the silicon strip detectors (SSD). The size of each plane is 5.5×8.2 cm^2, the pitch is 0.1 mm. The detectors will be located in the vertical plane, symmetrically above and below the machine plane. The horizontal bending of BC1 allows an almost complete decoupling between the measurement of the scattering angle, essentially given by the vertical coordinate and the measurement of the momentum, obtained from the horizontal coordinate. Detector RP1 is installed at a distance of 20 m from IP and subtends the $-t$ range $(0.02 - 1.5)$ (GeV/c)^2. Due to an expected small elastic cross section a set of veto counters (VC) surrounding the IR will be used to suppress an inelastic background at a trigger level. VC and Cathode Strip Chambers (CSC) will be also used for the determination of the inelastic cross section, σ_{in}, and the measurement of the single diffractive dissociation in pp collisions.

The above consideration also applies to the analyzing power, A_N, measurement. If we take the ISR differential cross-section data as an approximate guideline for a 50% coverage, then we have at $|t| = 1$ (GeV/c)^2 N = 0.3 events/sec for a bin size of Δt =0.05 (GeV/c)^2. In this $|t|$-region, the measurement errors for the analyzing power and the double-spin asymmetry parameter after a month (about 20 days) of running will be $\delta A_N = 0.2\%$, $\delta A_{NN} = 0.3\%$.

For very small $\mid t \mid$ measurements(CNI region) the setup will include detectors RP2. RP3 and RP4 (containing the same SSD as above) installed at 57 m, 72 m and 144 m respectively from the interaction point (IP). RP2 covers the region 0.002$<\mid t \mid<$ 0.2 (GeV/c)^2, RP3$-$0.004$<\mid t \mid<$ 0.12 (GeV/c)^2, and RP4$-$0.0004 $<\mid t \mid<$ 0.03 (GeV/c)^2. At the smallest $\mid t \mid$ the detector resolution will be $\delta t < 10^{-4}$ GeV^2 (bins) $-- > \delta y \approx 0.1$ mm. In order to be able to measure the scattering angle of the protons, their scattering angle θ^*_y has to be larger than the angular spread of the beam $\sigma(y'_0)$ at the collision point. As is seen from Table 1, the beam divergence is 4 μrad. For the scattering angle of $\Theta\ = 70\mu$rad, one gets the minimum $\mid t \mid= 0.0004$ (GeV/c)^2 at the effective distance for RP4, $L_{eff}\ = 87$ m. We are studying a possible way of reaching smaller $\mid t \mid$ values.

This setup requires a special tune of RHIC, extra power supplies, modifications of the leads to some magnets. A special beam scraping will be required for the run (and during the run) in order to decrease the beam emittance from $\epsilon = 20$ πmm·mrad to 5 πmm·mrad to allow detection of scattered protons as close to the beam as possible. A tune change will be needed for the period of data taking to allow large $\beta^* = 195$ m at the IP. To accumulate $4 \cdot 10^6$ events, the run will take

4–5 days. From the experience of the UA4/2, we foresee two runs: one engineering run with up to 10^6 events, followed by the data run of $4 \cdot 10^6$ events a few months after the engineering run.

In order to evaluate the performance of the experiment with respect to possible systematic errors, we performed simulations of small angle scattering. The errors of the elastic scattering parameters σ_{tot}, ρ, B due to uncertainties in the parameters describing the experimental setup were determined. The parameters used in the Monte Carlo simulations are included in Table 1. For comparison the parameters of the UA4/2 experiment [17] are presented too. The advantage of R7 is in the RHIC high luminosity.

Table 1. Parameters of the CNI pp2pp setup(expected) and of UA4/2 setup.

Run parameters	pp2pp	UA4-2
Beam momentum, GeV/c	250	270.6
Beam momentum spread, GeV/c	0.25	0.10
Normalized beam emittance, $\pi \cdot mm \cdot$ mrad	5	26
Betatron function at IP, β^*, m	y: 195	x: 2500, y: 87
Beam vertex size in z at IR, σ_Z, cm	15	20
Beam transverse size at IR, σ_x/σ_y, mm	0.4/0.4	5/1
Beam divergence at IR, $\sigma_{x'}/\sigma_{y'}$, μrad	4/4	2.7/14.3
Angle between the beams in x/y direction, μrad	5/5	
Error of angle between the beams in x/y directios, μrad	6/6	4/15
Detector offset, μm	20	25
Detector resolution, μm	100	150
Number of the elastic events, $\times 10^6$	4.0	0.8
Closest to the beam axis position, mm	5	4
RP3 position(distance from IR), m	72	
$L_{eff}(RP3)$, m	y:37	
RP4 position(distance from IR), m	144	48
$L_{eff}(RP4)$, m	y: 87	X: 65, y: 27

The same setup, running with transversally or longitudinally polarized protons, would allow the simultaneous measurements of $\Delta\sigma_T$, A_N, A_{NN} or $\Delta\sigma_L$, A_L, and A_{LL}.

For Ł $= 10^{29}$ cm$^{-2} \cdot s^{-1}$, $|t|_{min} = 4 \cdot 10^{-4}$ (GeV/c)^2, $\frac{d\sigma_C}{dt}|_{t_{min}} = 1.6 \cdot 10^{-24}$ cm^2$\cdot$(GeV/c)$^{-2}$, acceptance = 10%, R7 counting rate per 10^{-4} (GeV/c)^2 bin will be 2.5 Hz. In the CNI region, where $|t| \simeq 1.1 \cdot 10^{-3}$ (GeV/c)^2, the rate is down to 1.3 Hz at 60% acceptance. For the measurement of ρ and σ_{tot} not to be dominated by statistics, we need the order 10^4 events per $|t|$ bin of 10^{-4} (GeV/c)^2, leading to run duration of at least 6 hours. The expected precisions in the measurements will be: $\Delta\rho = 0.01$, $\delta b = 0.05$ (GeV/c)$^{-2}$, and $\delta\sigma_{tot} \simeq 0.5$ mb for 10^6 events.

In order to measure the beam polarization within $\pm 5\%$, $2.5 \cdot 10^5$ events are needed, assuming that the analyzing power A_N is $\simeq 0.04$. As a rough estimate, the integrated differential cross section is 2.8 mbarn in the range $0.002 < |t| < 0.02$ (GeV/c)^2. If we assume a fiducial coverage of $\frac{\Delta\phi}{2\pi} = 0.25$, then:

$$N = \text{Ł} \cdot \frac{d\sigma_{el}}{dt} \cdot \frac{\Delta\phi}{2\pi} = \text{Ł} \cdot 1.4 \cdot 10^{-27}\ \text{cm}^2, \qquad (3)$$

where N is the number of events per second and Ł is the luminosity. For high β^* tune Ł $= 2 \cdot 10^{29}$ cm$^{-2} \cdot s^{-1}$, N = 280 events/sec which requires about one hour for a $\pm 5\%$ beam polarization measurement.

Conclusion

R7 Collaboration presented the programme of the following measurements at the collider RHIC:

- Total and elastic cross-sections with polarized and unpolarized beams.
- Analyzing power, A_N, and spin-correlation asymmetry, A_{NN}, with transversally polarized beams; with longitudinally polarized beams: A_L and A_{LL}.
- At a later stage we plan to study the single diffraction dissociation by the same apparatus.
- Physics with jet target (polarized and unpolarized) is under development by R7 Collaboration.

Acknowledgments

We would like to express our thanks to Profs. M. Islam, A. Martin, B. Nicolescu and O. Selyugin for useful discussions.

References

[1] P. Gauron, B. Nicolescu, O. Selyugin, *Phys. Lett.* **B 397**, 305 (1997).

[2] M. Jakob and G.C. Wick, *Ann. Phys.* (N.Y.) **7**, 404 (1959).

[3] L. Puzikov, R. Ryndin, Ya.A. Smorodinsky, *Nucl. Phys.* **3**, 436 (1957).

[4] S.M. Bilenky and R.M. Ryndin, *Phys. Lett.* **6**, 217 (1963).

[5] R.T.N. Philips, *Nucl. Phys.* **43**, 413 (1963).

[6] M. Froissart, *Phys. Rev.* **123**, 1053 (1963);
A. Martin, *Nuovo Cimento* **42**, 930 (1966).

[7] Review of Particle Properties, *Phys. Rev.* **D45**, ii.83 (1992).

[8] M.J. Menon, A conjecture on Centauro Species, ABSTRACTA C 007-98, IFGW-UNICAMP, 13083-970 Campinas, SP, Brasil.

[9] C. Avila et al., *Phys. Lett.* **B 445**, 419 (1999).

[10] C. Bourrely et al., *Z. Phys.* **C 37**, 369 (1988).

[11] R.J. Glauber and J. Velasco, *Phys. Lett.* **B 147**, 380 (1984).

[12] P. Desgrolar et al., *Z. Phys.* **C 63**, 241 (1994).

[13] A. Donnachie and P.V. Landshoff, *Z. Phys.* **C 2**, 55 (1979).

[14] L.I. Lapidus and B.Z. Kopeliovich, *Sov. J. Nucl. Phys.* **19**, 114 (1974).

[15] N. Akchurin et al., *Phys. Rev.* **D 48,** 3026 (1993).

[16] N.H. Buttimore et al., *Phys. Rev.* **D 18,** 694 (1978).

[17] C. Augier et al. (UA4/2 Collaboration), "A precise measurement of the real part of the elastic scattering amplitude at Sp$\bar{p}$S", CERN/PPE-93-115, 1993; M. Haguenauer (UA4/2 Collaboration), *Nucl. Phys.* B (Proc. Suppl.) **B 25,** 266 (1992).

Received November 29,1999

С.Б.Нурушев
Изучение полного и дифференциального сечений и поляризационных эффектов в упругом pp-рассеяний на RHIC.

Оригинал-макет подготовлен с помощью системы LaTeX.
Редактор Е.Н.Горина. Технический редактор Н.В.Орлова.

Подписано к печати 02.12.99. Формат $60 \times 84/8$. Офсетная печать.
Печ.л. 0.87. Уч.-изд.л. 0.7. Тираж 160. Заказ 42. Индекс 3649.
ЛР №020498 17.04.97.

ГНЦ РФ Институт физики высоких энергий
142284, Протвино Московской обл.

Индекс 3649

П Р Е П Р И Н Т 99-54, И Ф В Э, 1999