# HIGHLIGHT OF DUBNA-SPIN97 WORKSHOP

A. EFREMOV [a]
*JINR, Dubna, 141980 Russia*

Processes with polarized particles have been always among the most difficult and complicated problems both for experimentalists and theorists.

First, working with polarized targets, experimentalists have to battle with thermal "chaos" which trends to break the polarized order. For this one needs the liquid helium temperatures. More difficulties, like depolarizing resonances, are met in acceleration of polarized particles and in controlling a polarized beam. Second, spin effects are very perfidious: as a rule, they are most strong in kinematical regions where the process itself is the least probable.

As for the theory, I hardly recall a case when its first prediction was correct! As a rule, it was wrong and forced theorists to think more fundamentally to repair the theory. This resulted in a deeper understanding of particle interaction mechanics. Nevertheless many puzzles like why hyperons are produced so strongly polarized or what is the structure of the nucleon spin stay yet unsolved during decades. All these problems were the subject of those 15 invited and 45 original talk presented at VII-th Workshop on High Energy Spin Physics (Dubna-SPIN97) which held in Dubna July 7–12, 1997. What new have we learned there?

## 1 The nucleon spin problem

It is yet a problem although less sharp than ten years ago. The most important thing is that it seems everything OK with the very fundamental Bjorken Sum Rule if the whole experimental material and theoretical corrections (up to $\alpha_S^3$!) are taken into account [1]. Also it was argued [2], based on more accurate calculations of QCD Sum Rules, that the high twist corrections are much smaller than thought earlier:

$$\Gamma_{p-n}^{\mathrm{tw}-4} = -\frac{0.006 \pm 0.012}{Q^2}$$

(i.e. $\leq 2\%$ at $Q^2 \geq 5\,GeV^2$).

The Ellis-Jaffe Sum Rule is definitely violated and the violation is especially large (up to $9\sigma$) if one assumes for asymmetry $A(x=0)=0$ and $A(x=1)=1$, what has some grounds [1]. One should have in mind however

[a] Supported by RFBR Grant No 96-02-17631

that high twist contributions to singlet $\Gamma_{p+n}$ are theoretically rather indefinite and that there is a noticeable difference in $\alpha_S$ from E154 and other experiments combined.

Other problems discussed were the radiative and nuclear corrections. It was shown [3] that the former are rather small and for $^3He$ do not exceed 5% in the measured kinematical region. A new method for extracting neutron structure functions from deuteron data was proposed [4] based on the Lorentz covariant Bethe-Salpeter equation. Though it was shown that the contribution of the antinucleon degrees of freedom are suppressed, there are another distinctions with the commonly accepted approach and the method should be tested for some concrete experimental data.

An open problem in checking the Sum Rules is the small $x$ extrapolation of spin–dependent structure functions. In recent years it has become still more clear that the Regge–behavior extrapolation is inadequate, owing to double log contributions in this region: $\sum_n (\alpha_S \log^2 x)^n$. This problem was discussed in the Manaenkov talk [5] who argued that effective ladder diagram summation (with constituent quarks and Goldstone-pion steps) changes the power of $x$ obtained from QCD. The change is especially big for the isoscalar contribution to the nonsinglet part of $g_1$. The author prediction is $g_1^{NS,I=0} \propto x^{-0.5}$.

The natural question arises as to what is the reason of Ellis-Jaffe SR violation? Is it a large strange quark contribution or a large gluon contribution $\Delta G$?

Some indication for the polarized $s\bar{s}$ sea comes from $\Lambda$ polarization in the target fragmentation region in WA59 experiment [6]. That the strange sea in the proton is really strange was demonstrated by the OBELIX Collaboration who discovered [7] that the ratio of $\phi\pi^0/\omega\pi^0$ annihilation of $p\bar{p}$ is about 20 times as high as the naive OZI prediction and $\phi$'s are dominantly produced from the triplet state. This was explained by assuming a strong polarized strange sea in the nucleon [8]. However, very recently the collaboration has shown [9] that a very similar channel with $\phi\eta$ production comes dominantly not from the triplet but from singlet state.

On the other hand there are strong arguments [10] from the analysis of existing experimental data in favor of rather large positive $\Delta G$. Similar arguments were presented at this workshop too [11]. So, one has to be patient and wait for results of future dedicated experiments. These includes the semi–inclusive $J/\psi$ and $\Lambda$ production in DIS at COMPASS and HERA [6,12,13] and asymmetry in direct $\gamma$ production at RHIC [14,15]. Also we heard of original proposals for measuring the strangeness content. These are some double polarization observables in $\phi$ photoproduction from the proton [16] and strange particle production $N + N \to N + K + Y$ ($Y = \Lambda$ or $\Sigma$) near the threshold or in a collinear kinematics [17].

The density matrix positivity constrain for the NLO Evolution Equation [18] and the connection of the hadron spin structure with the magnetic moments and axial coupling constants was also discussed [19,20].

About two years ago a possibility to measure an orbital momentum contribution to the proton spin was discovered [21]. It is Deeply Virtual Compton Scattering (DVCS) process. The leading order QCD predictions for the DVCS was reviewed shortly [22]. It was pointed out that the conformaly covariant OPE possesses the predictive power for non-forward two-photon processes in the light-cone dominated region.

Study of the spin–dependent fragmentation function by the OPAL Collaboration via measuring of vector mesons spin alignment and polarization of $\Lambda$'s from jets in $e^+e^- \to Z^0 \to 2\,jets$ process was also reviewed [23].

## 2 Single spin asymmetries

This is another domain full of puzzles. I have mentioned earlier the inclusive hyperon transversal polarization which yet is the problem for 20 years. Almost so old is the high $p_T$ left-right inclusive pion asymmetry. It has to be very small from the naive QCD application:

$$A \propto \frac{m_q}{p_T}\alpha_S$$

Experimentally, however, as we have learned from the Nurushev review talk [24], the asymmetry increases with $p_T$ and $x_F$ up to 40%. A new measurement of the $\pi^0$ raw asymmetry at $70\,GeV/c$ and $90^\circ$ in the cms was presented [25]. It is close to zero in the region $1.3 < p_T < 2.5\,GeV/c$ and getting negative in the $2.5 < p_T < 3.2$ GeV/c region. Also the spin measurements in inclusive pion production have been carried out in the polarized target fragmentation region. The experiment has given an indication of the $x_R$ scaling. A wider investigation of scalings in the pion asymmetry shows however [26] that the existing data do not allow one to make a firm conclusion on the $x_R$ or $x_T$ scaling. As for me, it seems quite natural since the twist-3 QCD predicts a more complicated form of the $x_F$ and $p_T$ dependence

$$A = \frac{Mp_T}{p_T^2 + M^2}\Phi(x_F, y)a(x_F)$$

where M is the polarized hadron mass, $x_F = -u/s$, $y = -t/(s{+}u)$ and $a(x_F)$ is a short range sub-process dependent function calculated in Perturbative QCD.

The first observation of transverse handedness in diffractive production of pion triples in the process $\pi^-(40\,GeV) + A \to (\pi^-\pi^+\pi^-) + A$ was reported [27].

It was found that the handedness is rather large ($10 \pm 1\%$) and behaves like the transverse polarization, i.e. increases with $p_T$ and $x_F$.

A new progress in twist-3 QCD single spin asymmetry was reported [28] It was shown that the so-called "gluonic poles" are reducible to a time-reversal odd spin distribution function. The question remains however, as to what forbids this pole to appear in physical region of some exotic processes like $e^+e^-p \to e^+e^-X$? Also the anomalous dimension calculations which govern the $Q^2$-dependence of the higher twist structure and fragmentation functions of the nucleon were presented in [29].

## 3 Diffractive and intermediate range spin processes

A few talks dealt with spin processes in the diffractive region and in first place with spin–flip Pomeron. A contribution of that sort follows from some dynamic models which take into account the meson–cloud structure of hadrons and do not vanish as $s \to \infty$ and $|t|/s \to 0$. It was shown [30] that this effect could be seen in *pp*2*pp* experiment at RHIC in measuring $A_{NN}$ in the region of the first diffractive minimum and also in $A_{LL}$ in diffractive $q\bar{q}$ production in COMPASS and HERA. The effect is especially large for heavy quarks and could form an important background in measuring $\Delta G$. The interference of the spin-flip contribution with the Coulomb one is very peculiar and could serve as a polarimetry effect for RHIC [31].

The experimental data on *pp*-total cross-sections including the spin-dependent parts were analyzed with the goal to determine the contribution of spin interactions at high energies [32]. Based on the Regge model with cuts, the energy dependence of such contributions are estimated for two spin-dependent terms: 1) the total spin dependent term, $\sigma_1$, 2) the spin projection dependent term, $\sigma_2$. The estimates show that their contributions to the unpolarized total cross section, $\sigma_0$, decrease with energy from several per cent around $2\,GeV/c$ to $10^{-2}\%$ around $200\,GeV/c$. There is a clear indication that the spin effects are sensitive to the Pomeron intercept. In order to pin down such effects, the spin dependent total cross-sections must be measured with precision better than 10 $\mu b$ at $200\,GeV/c$.

Very interesting observations were reported from the Dubna Synchrophasatron polarized deuteron and monochromatic neutron beams. The behavior of tensor analyzing power $T_{20}(k)$ and polarization transfer $\kappa(k)$ versus the nucleon internal momentum $k$ up to $k = 1\,GeV/c$ and the initial energy dependence of neutron-proton total cross sections $\Delta\sigma_L(np)$ and $\Delta\sigma_T(np)$ in the energy range $1 - 3.7\,GeV$ disagree with all traditional nuclear models, based on low energy $NN$ data, but seems to agree with QCD motivated predictions with almost fully overlapping nucleons [33,34]. The experiments are planned to be continued with a higher accuracy.

I have to apologize that I cannot touch many talks in intermediate energy spin physics coming from ITEP and PNPI accelerators, since I do not feel myself competent enough in this region. The only words I want to tell are the words of encouraging to people who continue to obtain interesting physical results in spite of all difficulties which came down on science in Russia.

## 4 Future experiments

The problems raised by nucleon spin and single spin asymmetries puzzles caused an increasing interest in the Spin Physics and initiated a series of new dedicated experiments. The programs of some future experiments were discussed at the Workshop. We were told the abilities of the COMPASS spectrometer for measurements of the gluon contribution, $\Lambda$ polarization and charm production [6,13], of the possibility of HERA-N, which could provide unique information on higher twist contributions via single spin asymmetry measurements. Once the HERA proton beam becomes polarized, measurements of the polarized gluon and light sea quark distributions in the region of fantastically small $x$ might be possible [35].

Several talks concerned to physics of future RHIC experiments [14,30,31,15]. Especial attention was drawn by the *pp*2*pp* experiment where the difference in the total cross sections as a function of initial transverse spin states, the analyzing power, $A_N$, and the transverse spin correlation parameter $A_{NN}$ will be measured. Also, the behavior of the analyzing power $A_N$ at RHIC energies in the elastic scattering dip region will be studied [36].

The most important problem at RHIC now seems to be the polarimetry of polarized beam. Except of a more or less standard method using the Coulomb-Nuclear interference [37] which could provide an accuracy $\leq 5\%$ (after additional precise measurement at AGS), several other methods were proposed: asymmetry in elastic *ep*-scattering [38] which allows an accuracy $\leq 3\%$, the inclusive high $p_T$ $\pi^0$ production [39] and even a spin dependent part of synchrotron radiation in a bent crystal [40]. From my dilettante point of view, at least two of them should be used for mutual control.

Last but not least, a very good news was told by Kondratenko [41]: The Dubna's Nuclotron could be capable to accelerate polarized protons. This rises a new hope that the history of spin physics in Dubna, told by Nurushev [42], will obtain a new development.

In concluding, I would like to thank the JINR Directorate, the Russian Foundation for Basic Research (Grant 97-02-26098) and the International Or-

ganizing Committee of Spin Symposia for financial support of the Workshop.

## References


1. I.A.Savin. Spin of proton: experimental status. *Proceedings of VII-th Workshop on High Energy Spin Physics, Dubna, Jul 7–12, 1997, JINR E2-97-413,* [b] *p.27.*
2. B.L.Ioffe. The Sum Rules for structure functions of polarized $e(\mu)N$ scattering. Theory vs. Experiment *Proceedings, p.109.*
3. I.Akushevich and A.Nagaitsev. The systematical uncertainties in measurements of the spin-dependent structure function $g_1^n$ with $^3$He target due to radiative correction procedure. *Proceedings, p.66.*
4. V.V.Burov and A.V.Molochkov. The deuteron spin structure functions in the Bethe-Salpeter formalism. *Proceedings, p.72.*
5. S.I.Manayenkov, M.G.Ryskin. Infrared contribution to the double-logarithmic small $x$ asymptotics of structure functions. *Proceedings, p.119.*
6. A.Kotzinian. Lambda polarization in lepton induced reactions. *Proceedings, p.77.*
7. A. Bertin et al.,(OBELIX Collab.) *Proc. HADRON'95 Conference, Manchester, 1995.*
8. J.Ellis et al., *Phys.Lett.* **B353** *(1995) 319.*
9. V.Nomokonov (for OBELIX Collab.) Study of reaction $\bar{p}p \to \phi\eta$ of antiproton annihilation at rest at three hydrogen target densities. *Proceedings, p.241.*
10. G.Altarelli, R.D.Ball, S.Forte and G.Ridolphy. *Nucl. Phys.* **B496** *(1997) 337.* S.Forte, *SPIN96 Proc., World Sci. PC, 1957, p.55.*
11. M.V.Tokarev, W.-D.Nowak, A.V.Sidorov. On possibility to determine the sign of polarized gluon distribution. *Proceedings, p.99.*
12. O.Teryaev, A.Tkabladze. Color octet contribution to double-spin asymmetries in $J/\psi$ hadroproduction. *Proceedings, p.145.*
13. M.G.Sapozhnikov, (for COMPASS Collab.). Search for $\Lambda$-hyperon longitudinal polarization in COMPASS. *Proceedings, p.349.*
14. G.P.Škoro, M.V.Tokarev. Asymmetry of jet production in $PP$ collisions at high energies. *Proceedings, p.158.*
15. Yu.A.Panebratsev. Spin physics at RHIC and STAR experiments. *Not published.*
16. A.I.Titov, Y. Oh, S.N.Yang and T.Morii. Polarization observables in $\phi$-meson photoproduction and the strangeness content of the proton. *Pro-*


[b] Cited below as Proceedings.

*ceedings, p.89.*
17. M.P.Rekalo, J.Arvieux and E.Tomasi-Gustafsson. Polarization phenomena for strange particles production in nucleon-nucleon collisions. *Proceedings, p.382.*
18. C.Bourrely, E.Leader and O.Teryaev. Positivity of NLO spin-dependent parton distributions. *Proceedings, p.83.*
19. S.B.Gerasimov. On electroweak moments of baryons and spin-flavor structure of the nucleon. *Proceedings, p.202.*
20. L.L.Jenkovszky, A.I.Lengyel and B.V.Struminsky. Relating the proton and neutron structure functions. *Proceedings, p.107.*
21. X.Ji, *Phys. Rev* **D55** *(1997) 7114. SPIN96 Proc., World Sci. PC, 1957, p.68.*
22. D.Mueller. A short review of deeply virtual Compton scattering. *Proceedings, p.129.*
23. P.Bock, (OPAL Collab.) Spin alignment of leading vector mesons multihadronic $Z^0$ decays. *Published elsewhere.*
24. S.B.Nurushev. Survey of recent experimental data on high energy spin physics. *Proceedings, p.45.*
25. N.I.Belikov, et al. (IHEP-JINR PROZA-M Collab.) Preliminary results on raw asymmetry in the $\pi^o$-production on a polarized target at 70 GeV. *Proceedings, p.229.*
26. E.A.Andreeva, S.B.Nurushev, V.A.Okorokov, and M.N.Strikhanov The scaling hypotheses for single spin asymmetry in inclusive hadron production. *Proceedings, p.152.*
27. A.V.Efremov, Yu.I.Ivanshin, L.G.Tkatchev and R.Ya.Zulkarneev. Observation of transversal handedness in the diffractive production of pion triples. *Proceedings, p.237.*
28. D.Boer, O.V.Teryaev and P.J.Mulders. Single spin asymmetries in the Drell-Yan process. *Proceedings, p.139.*
29. A.Belitsky. Scale dependence of the twist-3 observables. *Not published.*
30. S.Goloskokov. Spin effects in diffractive high energy reactions. *Proceedings, p.177.*
31. O.Selyugin. Energy dependence of the structure of the high energy spin amplitude at small transfer momenta. *Proceedings, p.188.*
32. E.A.Andreeva, S.B.Nurushev and M.N.Strikhanov. The spin contribution to the $PP$-total cross section at high energy. *Proceedings, p.194.*
33. V.P.Ladygin at al. Preliminary results on the tensor analyzing power $A_{xx}$ in $C^{12}(\vec{d}p)X$ reaction at large transverse momenta of proton. *Proceedings, p.257.*
34. V.I.Sharov et al. Measurements of energy dependence of the $\vec{n}\vec{p}$ to-

tal cross section differences over 1.2–3.7 $GeV$ for pure longitudinal and transversal spin states. *Proceedings, p.263.*
35. V.A.Korotkov and W.-D.Nowak. Spin physics with HERA-$\vec{N}$. *Proceedings, p.369.*
36. W.Guryn. Experiments to measure total cross sections, differential cross sections and polarization effects $PP$ elastic scattering at RHIC. *Proceedings, p.358.*
37. N.Akchurin et al. Test of the coulomb-nuclear-interference polarimeter with the extracted polarized proton beam of AGS at 23 $GeV/c$. *Proceedings, p.322.*
38. I.V.Glavanakov, Yu.F.Krechetov, G.M.Radutsky and A.N.Tabachenko. High energy proton beam polarimetry by elastic $Pe$-scattering. *Proceedings, p.310.*
39. E.A.Andreeva et al. The inclusive $\pi^0$ polarimeter for RHIC. *Proceedings, p.311.*
40. A.P.Potylitsyn. Radiation from polarized protons in a bent crystal. *Proceedings, p.299.*
41. A.M.Kondratenko, V.Balandin and N.Golubeva. Depolarization of protons in the Nuclotron ring of JINR. *Proceedings, p.336.*
42. S.B.Nurushev. Debut of spin physics at Dubna. *Proceedings, p.45.*