SOME QUESTIONS IN HIGH-ENERGY SPIN PHYSICS

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This is a write-up for the discussions which I chaired at the Closing Session. It preceded the two summary talks, the experimental summary by Jen-Chieh Peng and the theory one by Stanley Brodsky.

1. Introduction

Bob Jaffe did a marvellous job in his opening keynote speech of this meeting. He laid out open questions in high energy spin physics by classifying the questions into “Focus Questions”, “Laments”, and “Worth Mentions”. He then went on to discuss in turn these questions, some in great detail. It is probably both legitimate and useful for us to remind ourselves of some of Jaffe’s questions, in order to assess what we have accomplished now, as may be reflected by the proceedings of this meeting, and to address what the leading questions we may pursue in the immediate future.

Jaffe’s list of “Focus Questions” includes:

- Implications of the large azimuthal asymmetry observed in semi-inclusive pion electroproduction at HERMES;
- Quark transversity distribution $\delta q(x, Q^2)$ in the nucleon;
- Polarized gluon distribution $\Delta G(x, Q^2)$ in the nucleon;
- Whether the Drell-Hearn-Gerasimov-Hosata-Yamamoto sum rule may somehow fail;
- The behavior of the gluon distribution $g(x, Q^2)$ at the very small x ;
- The s and $\bar{s}$ distributions in the nucleon, whether they are polarized, and the corresponding charge radii and the magnetization.

Jaffe lamented very briefly on the following questions:

- No useful total angular momentum sum rule;
- Generalized or off-forward parton distributions;
- Distribution and fragmentation function proliferation.

Jaffe referred to the following issues as being worthy of mentioning but did not even have time to lament:

- Spin-dependent quark/gluon correlations in the nucleon;
- Flavor decomposition of the nucleon spin;
- Evolution of QCD spin effects towards $Q^2 = 0$;
- A theory for fragmentation functions.

Experts in the field, both theorists and experimentalists, would tend to agree with Jaffe on the menu of the questions to be addressed in the immediate future. The soul searching in this discussion concerns where we shall end up in our endeavors, most of them strenuous and time-consuming, and whether we could anticipate some major discovery of breakthrough nature.

2. Some Soul-Searching Questions

A particular field thrives and prospers, not because there are many questions yet to be answered but because there are some major breakthroughs or prime discoveries. The fact that Jaffe has listed a number of questions but expressed his worry about proliferations of all these things is, to me, an issue that we should seriously address as we move on. Our experimental colleagues are also anxious in asking us something important and more specific which they could look for experimentally. It seems however that the major “discovery” in high energy spin physics, such as the original EMC measurement¹, like most of major discoveries in physics, did not come from any theorist’s suggestion. Therefore, it is likely to be fruitless to look for help from your theorist colleagues if you wish to launch an experiment with discovery potential.^a

The soul-searching questions which I would like to raise in this discussion may be stated as follows:

- A theorist should seriously address where all these proliferations of the parton model concept will lead us to and whether perturbative QCD is the most efficient language employable.
- An experimentalist should look for new techniques and attempt to address whether there is any major discovery ahead of us.

On the theorist’s questions, I would like to first remind ourselves that the “naive” parton distributions, as functions of x and Q^2 and including the spin-dependence features, have never been intended to represent the “full” information of the system (such as the nucleon), i.e., they contain only partial information of the system. It is not a quantum-mechanical wave-function description of the system - a presumably

^aThe statement here represents my own response to a question raised by an experimental colleague in the audience.

“full” description. It employs a probability concept. The transverse features are missing. The off-forward features are yet to be unravelled. The distinctions among flavors and the nature of gluon distributions are not completely understood. The danger here lies in what I mentioned earlier regarding too many questions yet to be answered but without some exciting discovery anticipated. The concept of “generalized”, or off-forward, parton distributions is quite natural but the field as a whole looks more and more like an old-day nuclear physics when nuclear shell model wave functions were developed.^b

My comments may sound to be fairly negative and may be discouraging for young people thinking of going into the field. Unfortunately, this is why the community involved here is aging day after day. Until we can grapple smart answers to the questions which I tried to raise here, I see no reasons for being too optimistic.

The other issue on the theoretical front concerns whether perturbative QCD is the only efficient language. Years ago, together with J. Speth (Juelich) and G. Brown (Stony Brook), we first invented the term “Generalized Sullivan Processes”² for the processes which describe the sea-quark distributions due to the meson clouds associated with the nucleon. It appears that the meson cloud nature of the nucleon is nonperturbative and it is unlikely that any summation over selected infinite series in perturbative QCD will ever be capable of giving us the meson-cloud feature of the nucleon. If the picture making use of generalized Sullivan processes can easily explain many observations, the proton spin crisis, violation of the Gottfried sum rules,³ etc., while perturbative QCD has a hard time to reproduce the meson-cloud picture, I personally see the need of choosing the appropriate representation of QCD, such as effective chiral perturbation theory, as an alternative framework.

Now, coming back to the experimentalist’s urge for a major discovery, I would like to urge them not to focus on the theory details. Most theorists are doing useless things.^c An experimentalist should try to focus on the “physics” issues, especially those “exotic” ones (such as PV & anapoles, extra Z, SUSY, and so on) but may become accessible one way or the other through your ingenious designs. In physics, the potential for discovery is always there but it takes ingenuity and perseverance, and perhaps the luck as well, to actually make one.

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^bFan Wang at Nanjing University responded that the inventors of the shell model were awarded the Nobel Prize in Physics and that this fact alone should still be consider as encouraging.

^cThis provocative remark was intended to stimulate the discussions from the audience.

References

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