The 11th Circum-Pan-Pacific Symposium on High Energy Spin Physics

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This series of symposia, called the PacificSpin symposium, was started in 1996 in Kobe in Japan. Since then, it has been held in the circum-pan Pacific region: Beijing(2001), Seattle(2003), Vancouver(2007), Cairns(2011), Jinan(2013), Taipei(2015), and four other Japanese cities(1999, 2005, 2009, 2019).

It was impressive that physics outcomes from hadron and electron accelerators in Asia increased substantially during this period. Many graduate students in the circum-pan Pacific region gave talks in the symposium and many of them subsequently became senior physicists.

The symposium is dedicated mainly to high energy spin physics in strong interactions. Its objectives are 1) to enhance the communication among physicists in the circum-pan Pacific region and also with those from other regions, and 2) to provide young physicists with opportunities to present the results of their research.

The strong interaction dominates in the subatomic domain such as inside a nucleus and inside the proton. Quarks, anti-quarks and gluons are called partons and are the components of the proton. The force is mediated by gluons. Quantum chromodynamics (QCD) is the theory for the strong interaction. The coupling of QCD

Fig.1: The group photo taken on the beach during PacificSpin2019. The Pacific Ocean and Aoshima island are seen on the background.

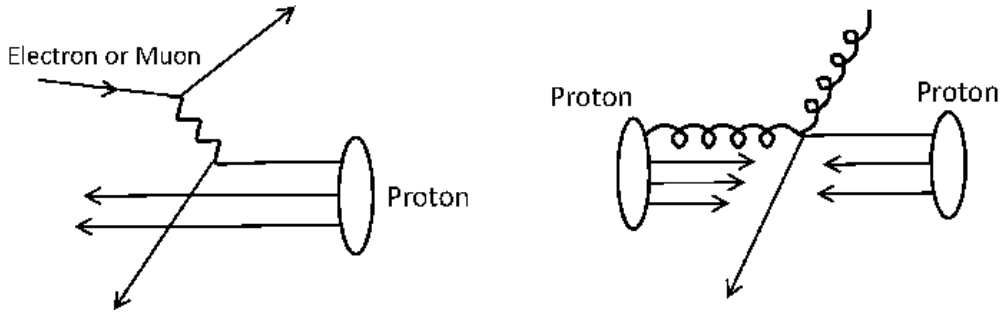

Fig. 2: Deep inelastic scattering of electrons or muons by a proton (left), and a proton-proton collision (right).

is determined by color charges. An important feature is its dependence on the energy scale: at high energy or at short distance, the coupling is small and becomes zero in the high energy limit. This is called asymptotic freedom. In this region, a perturbative calculation can be applied. On the other hand, the coupling is large at low energy, and a non-perturbative calculation is needed. Lattice QCD calculation is one of the adopted methods. Developing QCD is a challenge in particle and nuclear physics today.

The quark model was introduced in 1960's in order to classify the proton, the neutron and their family with spin 1/2, 3/2 etc. by a new quantum number called flavor. In 1988, however, a result of a deep inelastic muon scattering experiment showed that the spins of quarks and anti-quarks contribute to only a small part of the spin of the proton. The proton spin, which is 1/2, must then be a consequence not only of the spins of quarks and anti-quarks $(1/2)\Delta\Sigma$, but also of the spin of gluons ΔG, and the orbital angular momenta(OAM) of quarks and anti-quarks L^q, and of gluons L^G:

$$1/2 = (1/2)\Delta\Sigma + \Delta G + L^q + L^G$$

This experimental result in 1988 and newly planned experiments of deep inelastic scattering and proton-proton collisions at that time, along with theoretical developments, motivated the start of this symposium series in 1996.

PacificSpin2019

The symposium in 2019, PacificSpin2019, was the 11th in the series and was held August 27-30 in a conference room in a hotel at Miyazaki which is facing the Pacific Ocean. The number of participants was 44. Among them, 33 people gave talks over 4 days. All the talks were given in plenary sessions so that all the participants could listen to the same talks and participate in the same discussions. This style, with no parallel sessions, is one of the features of PacificSpin symposia. In addition to the regular presentations, a discussion session was scheduled each day. The participants made various comments as free discussions after a short introductory talk by the chairperson. Figure 1 shows the group photo of the participants taken during PacificSpin2019.

Polarized deep inelastic scattering of electrons or muons by the nucleon is a typical experimental method. Another method is polarized proton-proton collisions where gluon-quark scattering can take place. Sketches of these reactions are shown in Figure 2. Electron-positron collisions can also be used to study the hadronization process of quarks and anti-quarks and associated spin effects. Experiments at BNL, CERN, DESY, JLab, BEPCII, KEKB, Fermilab, J-PARC, ELPH and many other facilities are either in preparation or in data-taking or data analysis phases.

Longitudinal spin

In deep inelastic scattering, the nucleon targets, which are polarized parallel or anti-parallel to the lepton beam direction, are used to study the helicity distributions of quarks inside the polarized nucleon. From the accumulated data up to now, the contribution of the spins of quarks and anti-quarks to the proton spin has been determined to be about 30%. The contribution of gluon spin to the proton spin was studied by polarized proton-proton collisions and deep inelastic scattering. The contribution of the gluon spin is 30-40% in the measured kinematic region. The contribution from the yet-unmeasured region can have a positive or negative contribution, and it will be accessed in a future project of electron-ion collider (EIC). Theoretical analyses using worldwide data are in progress. Lattice QCD can now calculate

the spin contributions of quarks, anti-quarks and gluons. There were talks on recent status of this topic.

Orbital angular momenta of quarks, anti-quarks and gluons inside the proton

There have been active studies recently, experimental and theoretical, on the effects of the transverse momenta of quarks, anti-quarks and gluons inside the proton. Protons which are polarized transversely to the beam direction are mainly used in these experiments. Orbital angular momenta of quarks, anti-quarks and gluons can contribute to the proton spin. Combining the longitudinal and transverse structure, the 3 dimensional picture of the proton is being constructed. Transverse polarization of quarks inside the transversely polarized proton is also an interesting subject. There were many talks related to these subjects.

Form factors and the radius of the proton were other topics of the symposium. The participants will continue their research, keeping a close contact to each other. That will be a major achievement of this symposium.

References

All the slides of the talks are archived and can be accessed from the web-sites:
https://sites.google.com/quark.kj.yamagata-u.ac.jp/pacspin2019
https://indico2.riken.jp/event/3039/

Toshi-Aki Shibata is a professor emeritus of Tokyo Institute of Technology, a professor of Nihon University and a senior visiting scientist of RIKEN. After receiving a Dr. Sc. from the University of Tokyo, he participated in deep inelastic muon scattering at CERN as a member of Heidelberg and Mainz Universities. He also participated in polarized deep inelastic electron scattering at DESY-HERA and hadron reactions at Fermilab as a member of Tokyo Institute of Technology. His research field is experimental study of the spin structure of the proton. He served as the vice president of the Physical Society of Japan in 2015. He is a co-chair of PacificSpin2019.

Takahiro Iwata is a professor of Yamagata University. After receiving a PhD from Nagoya University, he participated in experiments at CERN as a member of Nagoya University. His research field is experimental study of the spin structure of the nucleon using polarized targets. He served as the program officer for the Japan Society for the Promotion of Science from 2014 to 2016. He is a co-chair of PacificSpin2019.

Tatsuro Matsuda is a professor of University of Miyazaki. After receiving a Dr.Sc. from Nagoya University, he participated in deep inelastic muon scattering experiments at CERN. His research field is the experimental study of nucleon spin structure using polarized targets and hadron spectroscopy. He is a co-chair of PacificSpin2019.