2026, October 27

PacificSpin2026, Academia Sinica

PacificSpin Symposium — An introduction

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'Circum-Pan-Pacific Symposium on High Energy Spin Physics'

1st: 1996 at Kobe in Japan by Prof. T. Morii, 30 years ago.

Aims:

- to enhance communications among physicists working for high energy spin physics in circum-pan-pacific region
- to encourage young physicists and provide them with an opportunity to present their research results



1st	1996	Kobe University,	Toshiyuki Morii
2nd	1999	RIKEN,	Koichi Yazaki
3rd	2001	Peking University,	Bo-Qiang Ma
4th	2003	University of Washington,	Xiang-Dong Ji
5th	2005	Tokyo Tech,	Toshi-Aki Shibata
6th	2007	Vancouver,	Andy Miller
7th	2009	Yamagata University,	Takahiro Iwata
8th	2011	Cairns,	Anthony W. Thomas
9th	2013	Shandong University,	Zuo-Tang Liang
10th	2015	Academia Sinica,	Hai-Yang Cheng, Wen-Chen Chang
11th	2019	Miyazaki	Takahiro Iwata, Tatsuro Matsuda, Toshi-Aki Shibata
12th	2024	Hefei	Xiao-Rui Lyu, Qun Wang, Yang Li, Xinyang Wang
13th	2026	Academia Sinica,	Wen-Chen Chang, Po-Ju Lin, Di-Lun Yang

- In this symposium, discussions are regarded as important as talks.

  Talks (presentations) are inputs for the discussions.

Discussion sessions:

Oct.28, 11:20 'Lattice QCD for the nucleon spin structure'

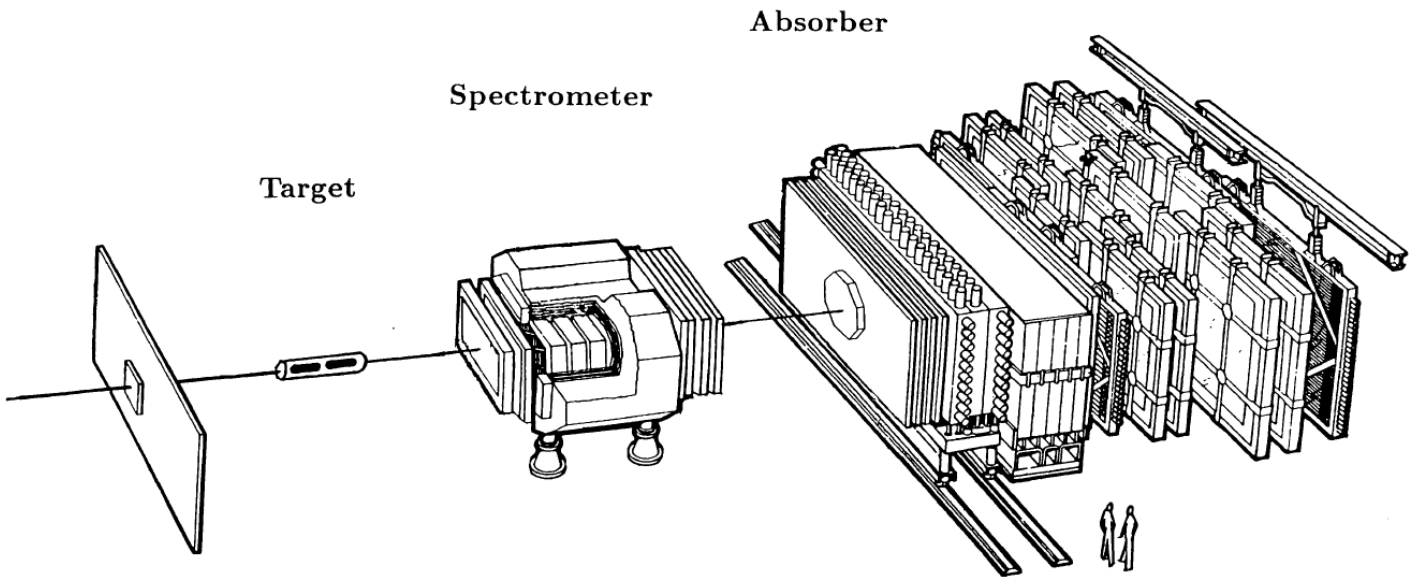
Oct.30, 11:40 '3D structure of hadrons'

1996:

EMC spin experiment, 1988, 1989

RHIC experiments (2000-2026) in preparation

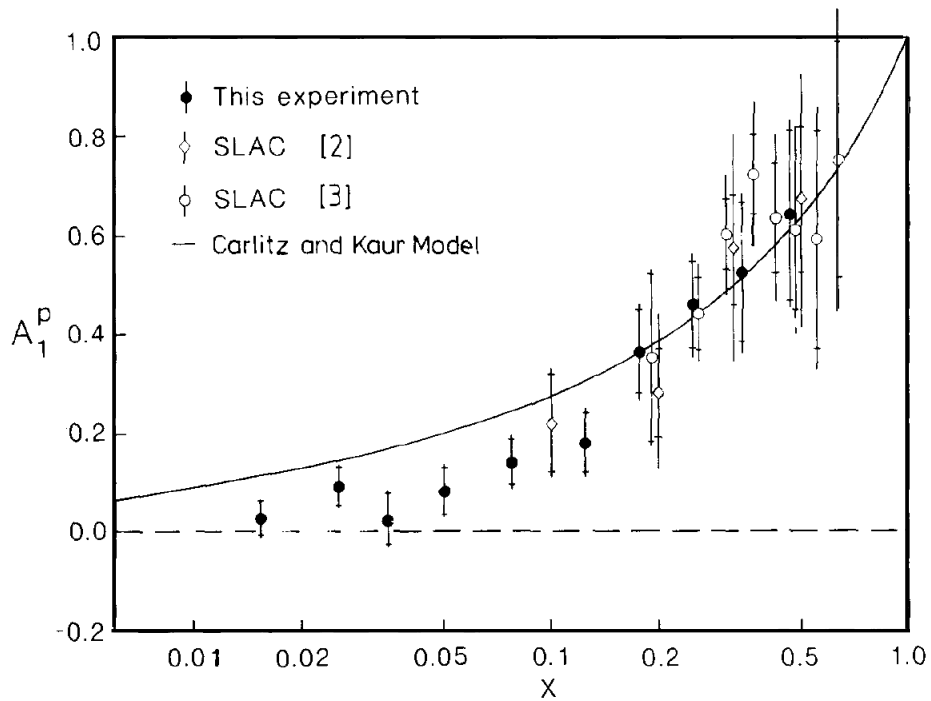
EMC (European Muon Collaboration) μ $100, 120, 200$ GeV



J. Ashman et al., EMC, Nucl. Phys. B328 (1989) 1.

Spin sum rule : $$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + L^{q,\bar{q}} + \Delta G + L^{G}$$

$\Delta\Sigma$: Contribution of quark's spin and anti-quark's spin to the proton spin, $(12 \pm 9 \pm 14)\%$



$$A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \approx \frac{g_1(x)}{F_1(x)} \qquad (1)$$

2026:

About 100 years of spin physics

1925 Heisenberg equation

1926 Schrödinger equation,

$$i\hbar \frac{\partial \psi}{\partial t} = \left[\frac{(p - e A)^2}{2m} + e\phi \right] \psi. \qquad \text{scalar}$$

1927 Pauli equation,

$$i\hbar \frac{\partial \psi}{\partial t} = \left[\frac{1}{2m} (\sigma \cdot (p - e A))^2 + e\phi \right] \psi, \qquad \psi = \begin{cases} \psi(r, t; \uparrow) \\ \psi(r, t; \downarrow) \end{cases}$$

spinors

Coefficients $\sigma's$ were introduced. 2x2. Pauli matrices

$$\sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad \sigma_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \quad \sigma_3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}.$$

1928 Dirac equation, relativistic kinematics

$$(i\hbar\,\gamma^{\mu}\,\partial_{\mu} - m)\,\psi = 0, \qquad \text{free particle}$$

$$i\hbar\frac{\partial}{\partial t}\psi = \hat{H}\,\psi,$$

With α_i and β matrices, $\hat{H} = \alpha \cdot \hat{p} + m\beta, \quad \alpha_i,\ \beta$ 4x4.

$$\hat{H} = \begin{bmatrix} m\,1 & \sigma \cdot \hat{p} \\ \sigma \cdot \hat{p} & -m\,1 \end{bmatrix} \qquad 4x4$$

in Pauli-Dirac representation.

As a result, the wave function has four components.

The Hamiltonian can have four eigenvalues.

The plane waves are expressed as

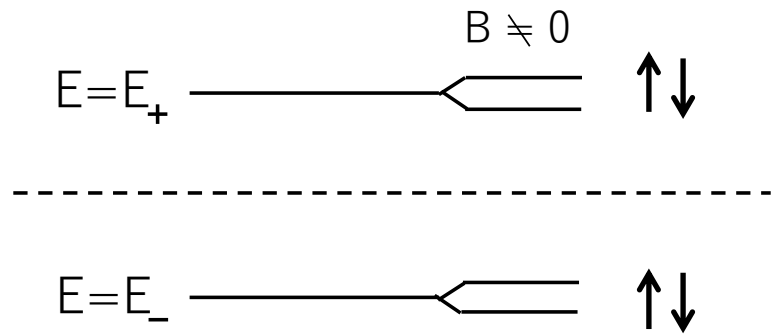
$$\psi_1 = \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} e^{i\,(k\cdot x - \omega t)}, \qquad \psi_2, \qquad \psi_3, \qquad \psi_4.$$

Spinors and space-time wave function.

The eigenvalue equation gives

$$E = E_+ = \sqrt{p^2 + m^2}, \qquad E = E_- = -\sqrt{p^2 + m^2}.$$

Two quantum states are degenerate at $E = E_+$, and also at $E = E_-$.



· Relativistic kinematics,

· Negative eigenvalue E_- $\longrightarrow$ prediction of anti-particles,

· Spin degree of freedom

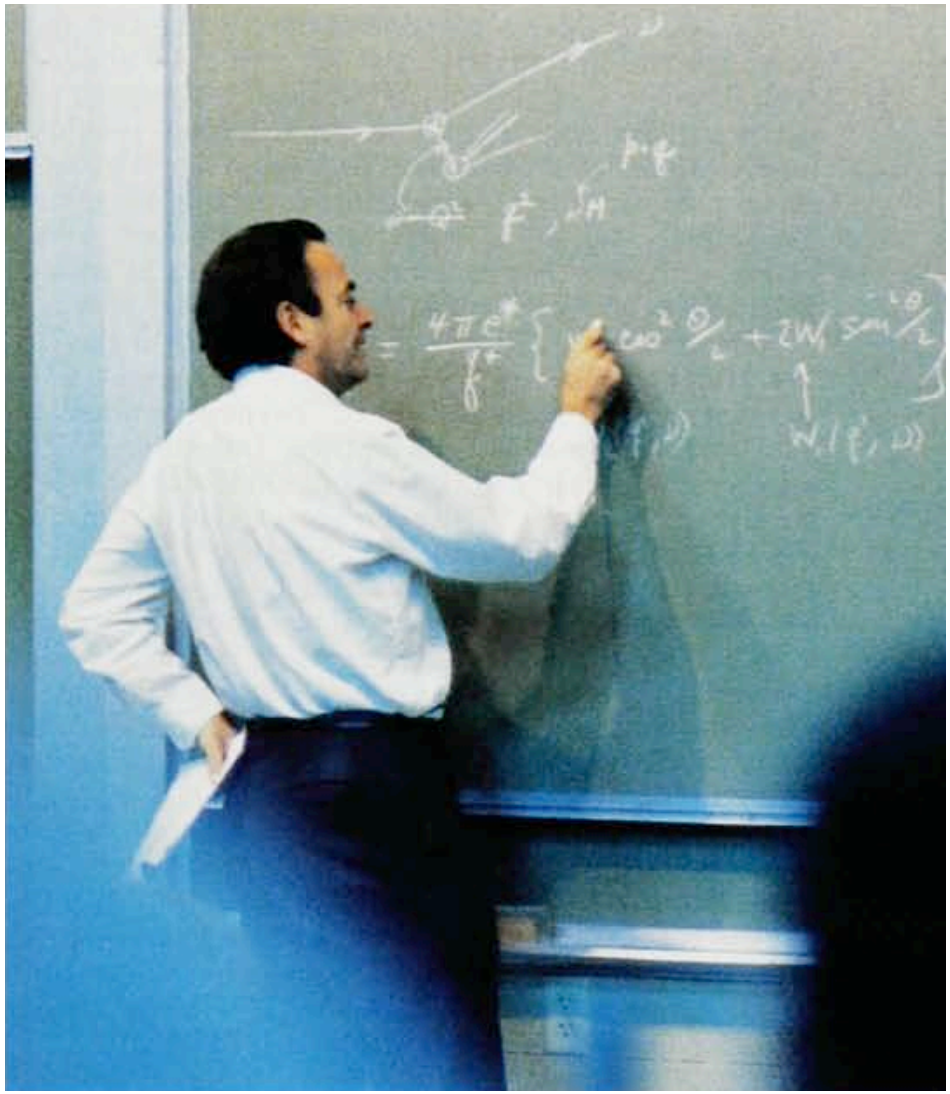
$$J = L + \frac{1}{2}\Sigma, \qquad \Sigma = \begin{pmatrix} \sigma & 0 \\ 0 & \sigma \end{pmatrix}.$$

$$[\Sigma, \hat{H}] \neq 0, \qquad [L, \hat{H}] \neq 0, \qquad [J, \hat{H}] = 0.$$

J commutes with $\hat{H}$.

1968, 1969 Bjorken scaling, Parton model

'Feynman and Partons' by James D. Bjorken, Physics Today 42, 2, 56 (1989), https://doi.org/10.1063/1.881193



1968 at SLAC

1969 SLAC deep inelastic scattering experiments
J. I. Friedman, H. W. Kendall, R. E. Taylor
Phys. Rev. Lett. 23 (1969) 930-934
Phys. Rev. Lett. 23 (1969) 935-939

1973 Theoretical discovery of asymptotic freedom — QCD50
D. Gross, F. Wilczek, and D. Politzer

1990- TMD,
D. Sivers, Phys. Rev. D41 (1990) 83, D43 (1991) 261
....

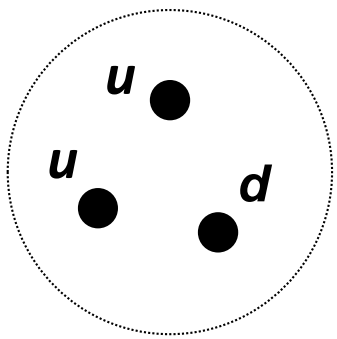
1994- GPD

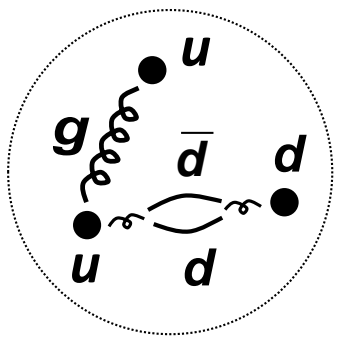
[1996 1st PacificSpin symposium]

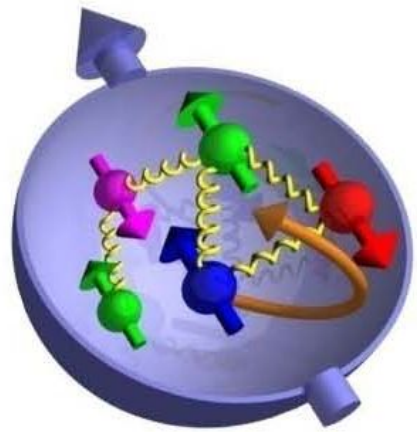
Experiments: single spin asymmetry,
deeply virtual Compton scattering,
hard exclusive meson production, etc.

Proton Spin: Physics of Spins of 3 Quarks

$\longrightarrow$ Physics of Spins and Orbital Angular Momenta of Partons







Data analyses are continuing and new facilities are being built.

We are looking forward to the interesting program for the 4 days here.