

An important activity of FBSL, together with other PNPI groups, is participation in the HERMES experiment at the HERA accelerator facility. The experiment was triggered by a surprising EMC Collaboration result (1988) according to which the total contribution of quarks to the nucleon spin is much less than unity and, in principle, compatible with zero ("Spin crisis"). This result showed that nucleon spin structure is much more complicated than that given by the naïve Constituent Quark Model (CQM). Remember that the CQM described successfully the hyperon magnetic momenta and many other low energy phenomena.

Goal of the HERMES experiment was to answer to the question: *"How do the quarks and gluons, nucleon constituents, conspire to produce its overall spin of 1/2?"*

A good way to study nucleon spin structure is Deep Inelastic Scattering (DIS) of a high energy polarized charged lepton (muon or electron) off a polarized nucleon target. In this case the virtual photon "sees" quark-partons, point-like objects, and the cross section in Leading Order (LO) of QCD depends strongly on their spin orientation in respect to the virtual photon spin. In Next to Leading Order (NLO), the cross section is sensitive to the gluon polarization. The orbital motion of quarks and gluons must also be investigated as it may contribute to the nucleon spin, too.

In the HERMES experiment spin structure of nucleons is studied in inclusive, semi-inclusive and exclusive scattering of polarized electrons using polarized or unpolarized gas target with a storage cell and the positron (electron) 27.5 GeV beam. The beam is self-polarized perpendicular to the ring plane due to the Sokolov-Ternov effect with a polarization rise time of 25 minutes. Spin rotators located upstream and downstream the HERMES setup precess the spin direction in order to obtain longitudinally polarized beam at the HERMES target according to the Siberian snake scheme. Typical beam polarization is about 50%. The longitudinal beam polarization can be reversed by changing the positions of the spin rotators on a few hour basis. Polarized hydrogen and deuterium targets with polarization of 80-90% is used, target polarization being flipped every 10 sec.

The HERMES detector (Fig.1) is a forward magnetic spectrometer with an angular acceptance of  $\pm 270$  mrad in horizontal plane and  $\pm (40-140)$  mrad in vertical plane and angular resolution of track reconstruction of 1 mrad. The momentum resolution of the spectrometer is  $\frac{\Delta p}{p} \approx 0.01$ .

Due to combination of the EM calorimeter, TRD and preshower, HERMES detector provides electron/hadron separation better than 1%. An important feature of the HERMES detector is a capability of good identification of hadrons: pions, kaons, protons and their anti particles, which is performed with the help of the RICH detector.

The MCs placed in the magnet gap are used to detect low momentum particles strongly deflected by the magnetic field of the dipole, and thus, not giving complete tracks in the rear part of the detector. The latter is particularly important for detection of decaying particles (like  $\Lambda$  or  $K_S$ ). The lowest momentum reconstructed with MCs is of about 0.4 GeV.

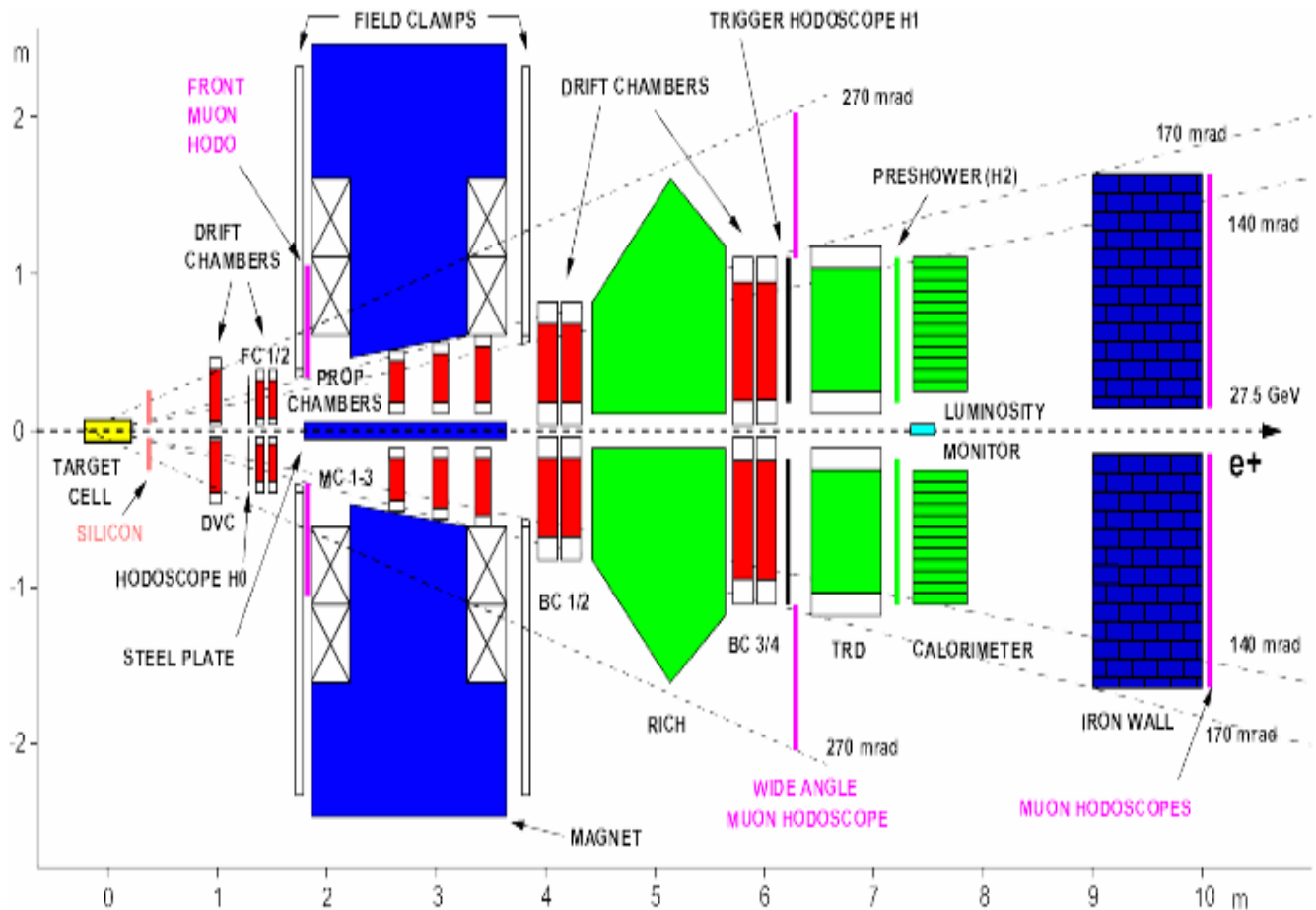


Fig. 1. The HERMES detector, side view.

The PNPI group was involved in the experiment from very beginning (in 1991) starting from its design phase.

Contribution of the PNPI to the experiment:

- Hermes spectrometer dipole magnet. Conceptual design, organization of fabrication, field mapping;
- Multi Wire Proportional Chambers (MCs) , 11,000 channels in the magnet gap. Design, fabrication, tests, etc.;
- Under atmospheric pressure self-controlled water cooling system for frontend electronics PCOS-4 and TRD;
- Water cooling system for forward silicon-strip detector Lambda Wheels (LW).

Software

- HERMES Decoding program HDC;
- Working out HERMES TC, the program of improved HERMES tracking;
- HERMES data production (HRC /DST files);
- Working out SLOW CONTROL;programs.

DATA TAKING

- Maintenance of MCs, TRD;
- Maintenance of LW;
- Maintenance of DAQ;
- Maintenance of gas supply system;
- Maintenance of Slow Control;

- Data taking coordination and shift leadership.

In June 2007 the HERMES experiment stopped data taking because of HERA shutdown. Summary of HERMES data taking is given in Table 1.

Table 1. Summary of HERMES data taking.

<u>Run I.</u> 1995-2000 годы, поляризация пучка  <b>P<sub>B</sub>=51%</b>	<u>Longitudinally- polarized targets</u> H,D,He3  <b>P<sub>T</sub>≈80%</b>  <u>Unpolarized gas targets</u> H, D, <sup>3</sup> He, <sup>4</sup> He, <sup>14</sup> N, <sup>20</sup> Ne, <sup>84</sup> Kr	<u>Integrated luminosity</u>  <b>259 pb<sup>-1</sup></b>  <b>619 pb<sup>-1</sup></b>	<u>Number of registered DIS positrons (electrons) with Q<sup>2</sup>&gt;1 GeV<sup>2</sup> (DIS)</u>  <b>11.8*10<sup>6</sup></b>  <b>27.9*10<sup>6</sup></b>
Years 2001-2002 HERA collider upgrade			
<u>Run II.</u> 2002-2007 годы, поляризация пучка <b>P<sub>B</sub>=36%</b>  <u>Детектор отдачи</u> 2006-2007 годы	<u>Transversely- polarized target H</u> <b>P<sub>T</sub>≈80%</b> <u>Unpolarized gas targets</u> H, D, <sup>3</sup> He, <sup>4</sup> He, <sup>14</sup> N, <sup>20</sup> Ne, <sup>84</sup> Kr	<b>150 pb<sup>-1</sup></b>  <b>2180 pb<sup>-1</sup></b>	<b>7.44*10<sup>6</sup></b>  <b>98.2*10<sup>6</sup></b>

By the end of data taking in 2007 HERMES has published more than 80 papers. Partly, the main results published by the HERMES collaboration are summarized below:

- ✓ HERMES has measured Double Spin Asymmetries in inclusive DIS From Inclusive DIS the integral of deuteron spin-dependent structure function has been found and, with the help of well-known SU(3) flavor symmetry constants, the integrated contribution of quarks to the nucleon was found to be

$$\Delta\Sigma = 0.330 \pm 0.025(\text{exp.}) \pm 0.011(\text{theo.}) \pm 0.028(\text{evol.}),$$

the last term being an uncertainty due to Q<sup>2</sup>- evolution. The HERMES measurement is in a very good agreement with recent COMPASS result. From these experiments, one may conclude that only 33% of the nucleon spin is contributed from the quarks.

- ✓ HERMES has measured Double Spin Asymmetries in Semi Inclusive DIS (SIDIS). In this case a well identified hadron (pion or kaon) is detected in coincidence with a DIS positron. This helps to study kinematical dependence of polarization for various quarks, e.g., to build quark helicity distributions over Bjorken x-variable using purity method. This analysis is however model-dependent insofar as the purities are calculated using Lund fragmentation model incorporated in Monte Carlo program, the latter being tuned to multiplicity distributions for pion and kaon production in DIS measured by the HERMES.

- ✓ Processes involving gluons in the nucleon are enhanced by selecting hadrons with  $p_T > 1 \text{ GeV}$ . Longitudinal double-spin asymmetry has been measured by HERMES for hadron produced with high  $p_T$  and gluon polarization was extracted:

$$\Delta g / g(x, \mu^2) = 0.049 \pm 0.034(\text{stat}) \pm 0.010(\text{sys}) \pm 0.0120(\text{Model})$$

at  $\langle \mu^2 \rangle = 1.35 \text{ GeV}^2$  and  $\langle x \rangle = 0.22$ .

Despite the result is model dependent (Lund MC is always strongly involved in the high  $p_T$  analysis), this is most reliable estimation of gluon polarization with lowest error bar.

A very close result, but with larger error bars, has been recently obtained by the COMPASS collaboration.

- ✓ Using transversely polarized target, Hermes has measured for the first time Collins fragmentation function and Sivers distribution function, the effects related to orbital motion of quarks in the nucleon.
- ✓ HERMES intensively studied exclusive reactions, such as polarized vector meson production, Deep Virtual Compton scattering (DVCs), etc.;
- ✓ HERMES has studied also various nuclear effects using heavy nucleus gas targets.

The PNPI group seriously contributes to analysis of experimental data both during the data taking period and also after the shutdown.

An important contribution of PNPI to the HERMES data sample files was upgrade (HTC) of the HERMES track reconstruction program resulted in much better angular and momentum resolution, much better quality of vertex reconstruction and reducing the invariant mass peak widths by some 30%. While using HTC, the data quality is so much improved that it has been recently decided to reanalyze all the data obtained in RUN II. Reanalysis of RUN I is still under discussion among the Collaboration.

The topics covered by the members of PNPI group:

- Lambda hyperon polarization and spin transfer;
- Vector meson production;
- Quark helicity distributions;
- Upgrade of the HERMES track reconstruction program;
- HERMES computing and data production.

The PNPI group plays a leading role in these trends of analysis. It is planned to continue HERMES analysis till the end of 2011 year. This program is being realized according to **Agreement** between PNPI and DESY on scientific cooperation.