Studies of the nucleon and hadron structure at CERN
(Project COMPASS-II, theme 02-0-1085-2021/2022)
extention of the theme for next 2 years

ABSTRACT

COMPASS is a high-energy physics experiment at the Super Proton Synchrotron (SPS) at CERN in Geneva, Switzerland. The purpose of this experiment is the study of hadron structure and hadron spectroscopy with high intensity muon and hadron beams.

On February 1997 the experiment was approved by CERN and the final Memorandum of Understanding was signed in September 1998. The spectrometer was installed in 1999–2000 and commissioned during a technical run in 2001. The physics experiments started in summer 2002 with a muon beam and polarised proton and deuteron targets. These semi-inclusive deep inelastic scattering (SIDIS) experiments reveal details of the quark-gluon structure of the nucleon, in particular the gluon polarisation and transverse-momentum-dependent correlations. After the shutdown in 2005, COMPASS resumed the SIDIS experiments in 2006 and 2007 with a new large-aperture target magnet. The spin structure measurements were continued in 2010 and 2011.

The years 2008 and 2009 were dedicated to the hadron spectroscopy programme with pion and proton beams scattering off a liquid hydrogen target and nuclear targets. An unprecedented amount of data was collected and has allowed for a much refined analysis of the final states, and is still revealing subtle details of the light-meson spectrum. Part of 2009 was dedicated to the study of the pion polarisability using Primakoff scattering of pions from heavy nuclei. This measurement had been prepared by a pilot run in 2004. The programme was continued in 2012 under COMPASS phase-II.

The COMPASS-II proposal, suggested by the same Collaboration as continuation of COMPASS project, has been approved in May, 2010, and the corresponding theme at JINR was prolonged up to 2020.

COMPASS-II is primarily dedicated to the transverse and 3D structure of nucleons using Deeply Virtual Compton scattering (DVCS), Hard Exclusive Meson Production (HEMP), SIDIS and polarised Matveev-Muradyan-Tavkhelidze or Drell-Yan (further - DY) reactions. Approved in 2010, it started in 2012 with a Primakoff run and a DVCS pilot run using a muon beam and a long liquid hydrogen target with a huge recoil detector. The first-ever polarised Drell-Yan measurement with a beam of negative pions and a polarised proton target was successfully performed in 2015 and the data taking was resumed in 2018. The years 2016 and 2017 were dedicated to DVCS measurement and simultaneously data on HEMP and SIDIS were collected.

For 2021 after long shut-down, further measurements of SIDIS off transversely polarised deuterons were approved.

In 2018, COMPASS-II continued the data taking for the program of studying parton distributions that depend on the transverse parton momentum in DY processes with a pion beam at energy of 160 GeV and with a polarized target. The JINR group actively participated in the preparation of the setup and in the data taking. It is important to note the tasks that are done with the active participation of JINR physicists and engineers: maintenance of the hadron calorimeter (HCAL1), coordinate detector systems (MW1), support for the polarized target, support for the data acquisition system (DAQ), the engineering structure of the experimental hall, and analysis of the experimental data.

In 2018-2020, the analysis of data obtained in 2002-2017 was continued. During the reporting period, the collaboration prepared and published 10 articles. Three articles were prepared with significant contributions from JINR physicists.

To continue research of TMDs COMPASS-II prepared a proposal [8] to extend SIDIS measurements in 2021. This proposal was approved by CERN SPSC in 2018.

The study of the transverse spin structure of nucleons is one of the most important topics of recent theoretical and experimental research in the field of high-energy physics. A good knowledge of the dependencies of parton distributions on the transverse proper momentum of the parton and the relationship of this dependence to the spins of the parton is necessary for understanding the orbital motion of the parton and moving towards a more structured picture that goes beyond the collinear representation of the parton distributions. In QCD, for the leading twist, the nucleon structure is described by eight parton distributions that depend on the parton's transverse proper momentum (TMDS):): $F_1(x, k^2_T)$, $g_1^L(x, k^2_T)$, $H_1(x, k^2_T)$, $g_1^T(x, k^2_T)$, $h_1^T(x, k^2_T)$, $h_1^L(x, k^2_T)$, $h_1(x, k^2_T)$, и $f_1^T(x, k^2_T)$. One of the main methods for investigating the above-mentioned parton distributions is to measure semi-inclusive deep-inelastic scattering processes of polarized leptons on polarized nuclear targets. Such measurements are the most important point of the physical program of the COMPASS and COMPASS-II experiments. The data set periods for this topic were performed in 2002-2004, 2007, and 2010 with polarized targets. The main experimental objectives of such measurements are the following:

- measurement of the Collins and Sivers asymmetries;
-getting data on the batch distribution of h_1 (transversity);
- measurement of the tensor charge;
- new data on the g_2 structure function;
-measurement of asymmetries in processes with the two hadrons production;
- exclusive vector mesons production.

COMPASS-II plans to perform a standard one-year data set by studying the scattering of a muon beam of the M2 channel with a pulse of 160 GeV/s on a transversely polarized deuteron target.

The setup that will be used for the data set in 2021 is basically a COMPASS spectrometer, as it was used in the 2010 muon wound.

Two detectors supported by the JINR group are to be used in the 2021 data set, MW1 and HCAL1. The two-year work plan is presented below.

2021:

- Participation in COMPASS data taking;
- Maintenance of MW1, HCAL1 during running ;
- Development/support of MW1/HCAL1software;
- Analysis of COMPASS experimental data;

2022:

-- Completion of work with MW1, HCAL1 and ECAL0 detectors
(utilization, export to JINR or transfer to another experiment);
- Analysis of COMPASS experimental data;

JINR's total expenses on the project (theme 1085) for the period 2017-2019 amounted to about $ 624 thousand. Scientific trips – $ 374 thousand, materials and equipment - $ 250 thousand.

CERN has allocated about $ 30,000 (NA 58, COMPASS-II) to support JINR experts at CERN. The amount of necessary funding for 2021-2022 is $ 310 thousand from the JINR budget. The main part of these expenses is required for participation of JINR physicists in data collection, for maintenance of detectors and online software systems for monitoring their operation, as well as for contributions to the Common Fund of the collaboration in accordance with the obligations under the Memorandum of understanding.

This extension of the COMPASS-II project is the last one, in the future, the project is planned to close and continue the analysis of COMPASS-II data within the JINR theme activity.

Total estimated cost of the theme

№№	Activities	Total cost	Costs per years (thousand USD)	
			2021	2022
1.	Preparation and maintenance of HCAL1 and MW1	30	20	10
2.	Contribution to common fund	90	50	40
3.	Scientific missions	190	120	70
Total		**310**	190	120

Cost estimates for the theme (in k$)

№№ of items	Budget items	Total 2021–2022
4	Scientific missions	190
5,6	Material, equipment, common fund	120
Total		**310**