Studies of the Nucleon and Hadron Structure at CERN
Project COMPASS-II (NA58),
theme 02-0-1085-2009/2016,
extention for 2017-2019

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Форма № 25

Studies of the Nucleon and Hadron Structure at NA-58, CERN

COMPASS-II

THEME CODE: 02-0-1085-2009/2019

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Изучение структуры нуклонов и адронов в ЦЕРН

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УТВЕРЖДЕН ДИРЕКТОРОМ ОИЯИ

СОГЛАСОВАНО

ВИЦЕ-ДИРЕКТОР ОИЯИ

ГЛАВНЫЙ УЧЕНЫЙ СЕКРЕТАРЬ

ПОМОЩНИК ДИРЕКТОРА ПО ЭКОНОМИЧЕСКИМ И ФИНАНСОВЫМ ВОПРОСАМ

ГЛАВНЫЙ ИНЖЕНЕР

НАЧАЛЬНИК НОО

ДИРЕКТОР ЛАБОРАТОРИИ

ГЛАВНЫЙ ИНЖЕНЕР ЛАБОРАТОРИИ

РУКОВОДИТЕЛЬ ПРОЕКТА

ЗАМ. РУКОВОДИТЕЛЯ ПРОЕКТА

ОДОБРЕН
ПКК ПО НАПРАВЛЕНИЮ

CONTENT

1. INTRODUCTION.

The COMPASS experiment has been proposed by the International Collaboration of 30 Institutions from 12 countries. The program of this experiment includes the nucleon spin structure studies in SIDIS of muons and studies of hadron structure in pion beams. It was approved at JINR and CERN in 1998.

The COMPASS-II proposal [1], suggested by the same Collaboration as continuation of COMPASS project, has been approved in May, 2010, and the corresponding theme at JINR was prolonged for 2014-2016. This stage of the Experiment is related to continuation the SIDIS measurements, particulary with studies of TMD PDFs, measurements of Generalized Parton Distributions (GPD) and Matveev-Muradyan-Tavkhelidze[1] or Drell-Yan (MMT-DY, further - DY) reactions.

In this document we request to prolong the COMPASS-II project and theme at JINR up to the end of 2019. This period covers a continuation of analysis of the muon and hadron data taken up to 2016, preparations of equipment, additional data taking in 2017-2018 and analysis in 2017-2019.

2. COMPASS RESULTS.

Up to now in the context of COMPASS Collaboration 53 papers were published (see the list in Appendix), 23 of them in 2014-2016. During this period COMPASS members have gave about 250 talks at the International Conferences and workshops. There are COMPASS results included in the meson tables of the latest version of the PDG (see Appendix).
The annual international workshop on hadron structure and spectroscopy took place in Suzdal, Russia, on 18th-20th of May. COMPASS and JINR group organized this event.

The recent main COMPASS results, that have been in 2014-2016, are presented in this Section.

The Spin Structure Function g_1 of the Proton and a Test of the Bjorken Sum Rule

New results for the double spin asymmetry A_1^p and the proton longitudinal spin structure function g_1^p were obtained by the COMPASS collaboration using polarised 200 *GeV* muons scattered off the longitudinally polarised NH_3 target [2] (Fig.1). The data were collected in 2011. They complement those recorded in 2007 at 160 *GeV*, in particular at lower values of x, improving the statistical precision of $g_1^p(x)$ by about the factor of two for $x < 0.02$.

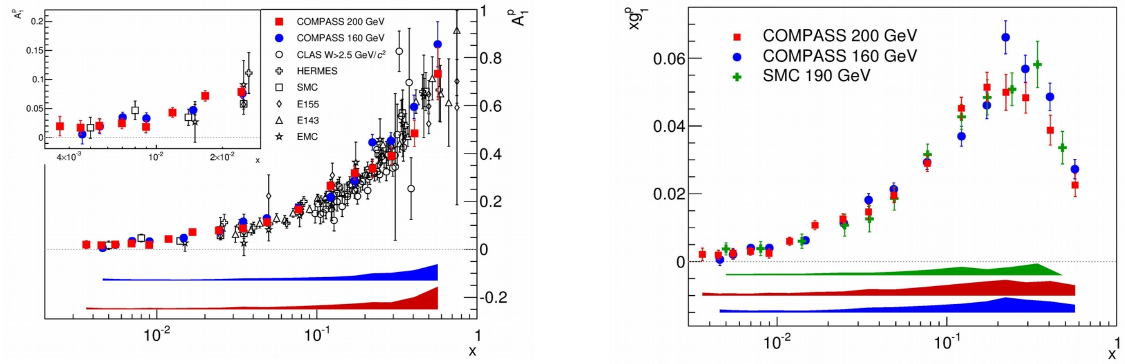

Figure 1. Left panel:The asymmetry A_1 as a function of x at the measured values of $Q^2 > 1(Gev/c)^2$ as obtained from the COMPASS data at 200 GeV. Right panel: The spin-dependent structure function xg_1 at the measured values of Q^2 as a function of x.

A next-to-leading order QCD fit to the g_1^p world data is performed. It leads to a new determination of the quark spin contribution to the nucleon spin, $\Delta\Sigma$, ranging from 0.26 to 0.36, and to a re-evaluation of the first moment of g_1^p.

[1] V. A. Matveev, R. M. Muradian, and A. N. Tavkhelidze, Preprint OIYaI R2_4543 (Dubna, 1969); Preprint SLAC_TRANS_0098.

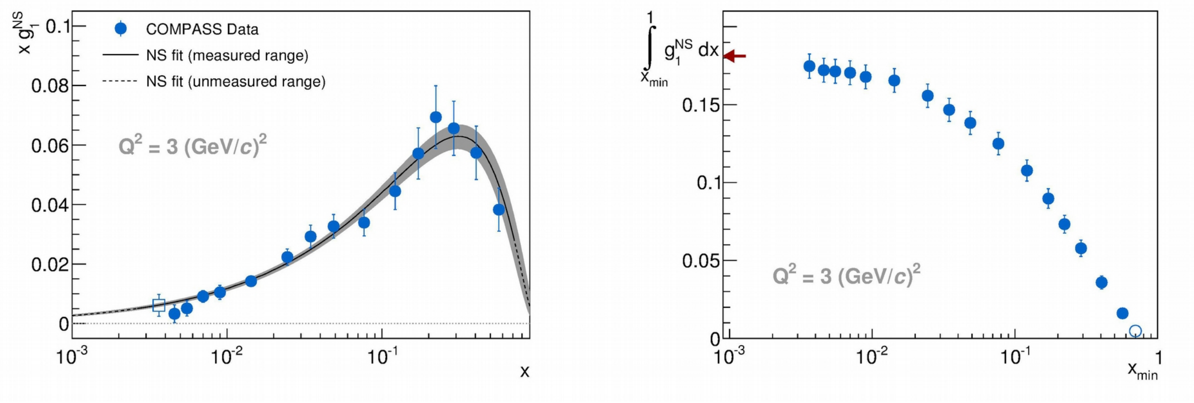

Figure 2: Left panel: Values of $xg_1^{NS}(x)$ at $Q^2 = 3\ (GeV/c)^2$ compared to the non-singlet NLO QCD fit using COMPASS data only. Right panel:Values of integral of g1NS over x for region between x_{min} and 1 as a function of x_{min} .

The uncertainty of ΔΣ is mostly due to the large uncertainty in the present determinations of the gluon helicity distribution. A new evaluation of the Bjorken sum rule based on the COMPASS results for the non-singlet structure function $g_1^{NS}(x,Q^2)$ yields as ratio of the axial and vector coupling constants $|g_A/g_V|$ = 1.22 ± 0.05 (stat.) ± 0.10 (syst.), which validates the sum rule to an accuracy of about 9% (Fig.2).

Leading-order determination of the gluon polarisation using a novel method.

A re-evaluation of the gluon polarisation Δg/g in the nucleon is presented, it is based on the measurement of the longitudinal double-spin asymmetry using semi-inclusive events with photon virtuality $Q^2 > 1 (GeV/c)^2$ [3]. The data were obtained by the COMPASS experiment at CERN using a 160 GeV/c polarised muon beam scattering off the polarised ^6LiD target. The gluon polarisation is evaluated for three intervals of the nucleon momentum fraction carried by gluons, x_g , covering the range $0.04 < x_g < 0.28$ (Fig.3).

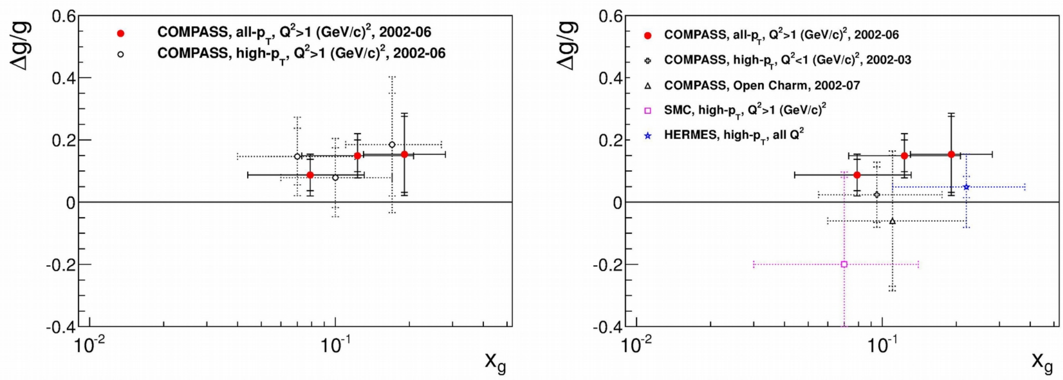

Figure 3: The new results for $\Delta g/g$ in three x_g bins compared to world data on $\Delta g/g$ extracted in LO (right panel).

A novel method that covers the full range of hadron transverse momentum p_T and a neural network approach are used. The values which were obtained at leading order in pQCD do not show any significant dependence on x_g. Averaged over the three intervals, the result is $\Delta g/g$ = 0.113 ± 0.038 (stat.) ± 0.036 (syst.) at $x_g \approx 0.10$ and a hard scale of $\mu^2 = Q^2 = 3 (GeV/c)^2$. The obtained result suggests that the gluon polarisation is positive in the measured x_g range (Fig.4).

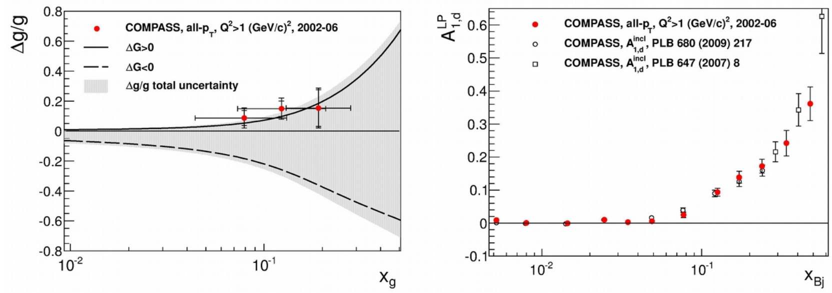

Figure 4:Left panel: Comparison of the new LO results with the newest COMPASS NLO QCD fit. Right panel: Extracted values of $A_{1,d}{}^{LP}(x_{Bj})$ and $A_{1,d}{}^{incl}$, see explanation in Ref.[3].

Azimuthal asymmetries of charged hadrons produced in high-energy muon scattering off longitudinally polarised deuterons.

Single hadron azimuthal asymmetries in the cross sections of positive and negative hadron production in muon semi-inclusive deep inelastic scattering off longitudinally polarised deuterons are determined using the 2006 COMPASS data and also all deuteron COMPASS data. For each hadron charge, the dependence of the azimuthal asymmetry on the hadron azimuthal angle *φ* is obtained by means of a five-parameter fitting function that besides a φ-independent term includes four modulations theoretically predicted: *sinφ* , *sin2φ* , *sin3φ* and *cosφ* [4] (Fig.5).

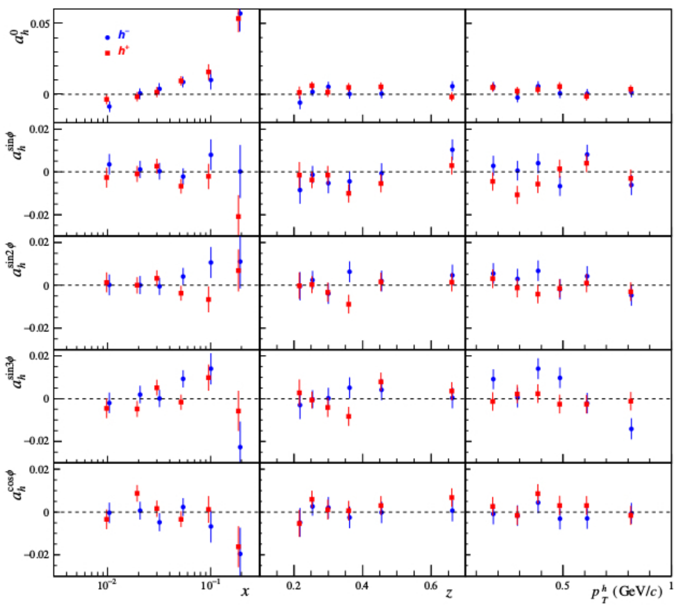

Figure 5:The modulation amplitudes of the h^+ and h^- azimuthal asymmetries as a function of x , z and $p_T{}^h$ obtained from the combined 2002–2006 data on the muon SIDIS off longitudinally polarised deuterons.

The amplitudes of the five terms first were extracted for the data integrated over all kinematic variables. In further fits, the φ-dependence is determined as a function of one of the three kinematic variables (Bjorken-x, fractional energy of virtual photon taken by the outgoing hadron and hadron transverse momentum), while disregarding the other two. Except the *φ*-independent term, all the modulation amplitudes are very small, and no clear kinematic dependence could be observed within experimental uncertainties. Still, there are indications for a possible *x*-dependence of the sin2*φ* and cos*φ* amplitudes.

The sin2φ amplitude for h^- is mostly positive and rises with increasing x, while for h^+ it is mostly negative and decreases with *x* (Fig5a).

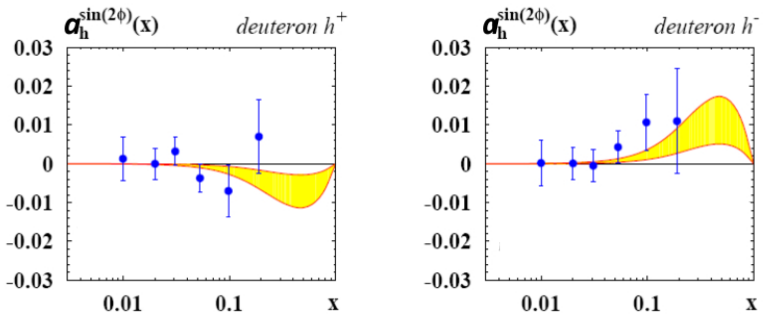

Figure 5a: Longitudinal target SSA a sin2 φ as function of x. The COMPASS data are from 2002-2006, the theoretical curves are from the PRD 77, 014023 (2008).

Measurement of the charged-pion polarisability

The COMPASS collaboration at CERN has investigated pion Compton scattering, $\pi^-\gamma\rightarrow\pi^-\gamma$, at centre-of-mass energy below 3.5 pion masses. The process is embedded in the $\pi^-Ni\rightarrow\pi^-\gamma$ Ni reaction, which is initiated by 190 GeV pions impinging on the nickel target. The exchange of quasi-real photons is selected by isolating the sharp Coulomb peak observed at smallest momentum transfers, $Q^2 < 0.0015\ (GeV/c)^2$. From the analysed 63 000 events, the electric pion polarisability is determined to be $\alpha_\pi = (2.0 \pm 0.6\ stat \pm 0.7\ syst) \times 10^{-4}\ fm^3$ under the assumption $\alpha_\pi = -\beta_\pi$ that relates the electric and magnetic dipole polarisabilities [5](Fig.7). This result is in tension with previous dedicated measurements, while it is found in agreement with the expectation from chiral perturbation theory (see Fig7a). An additional measurement replacing pions by muons, for which the cross-section behavior is unambigiously known, was performed for an independent estimate of the systematic uncertainty.

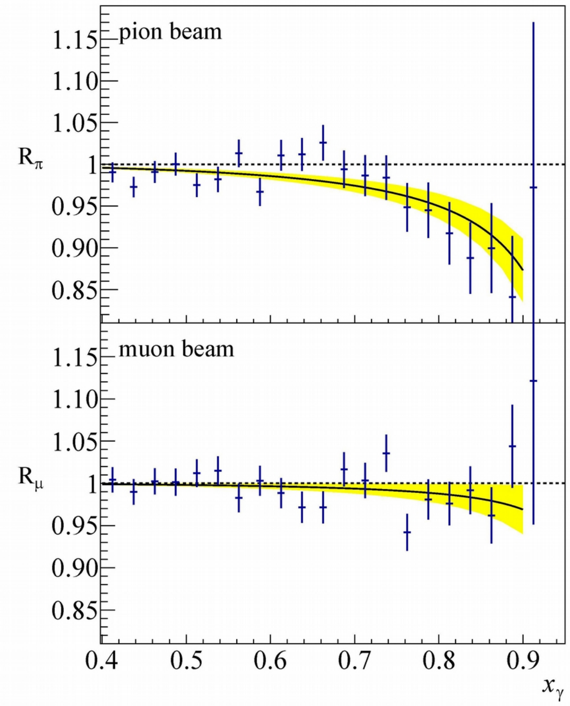

Figure 7:The x_γ dependence of the ratio of the measured differential cross section $d\sigma/dx_\gamma$ over the expected cross section for point-like particles. Top (bottom) panel: measurement with pion (muon) beam.

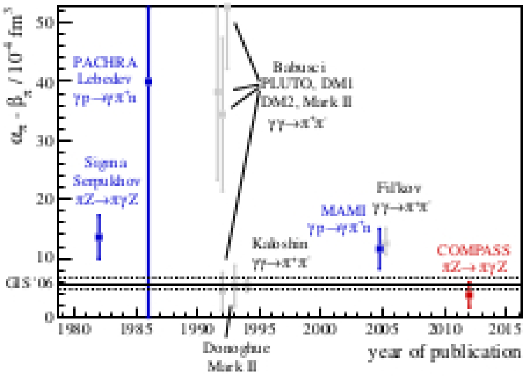

Figure 7a: The world data on pion polarizability in comparison with predictions from chiral perturbation theory.

Search for exclusive photoproduction of $Z_c^{\pm}$(3900)

The search for the exclusive production of the $Z_c^{\pm}$ (3900) hadron by virtual photons was performed in the channel $Z_c^{\pm}$ (3900)-> J/Ψ$\pi^{\pm}$ [6] . The data cover the range from 7 *GeV* to 19 *GeV* in the centre-of-mass energy of the photon-nucleon system (Fig.8).

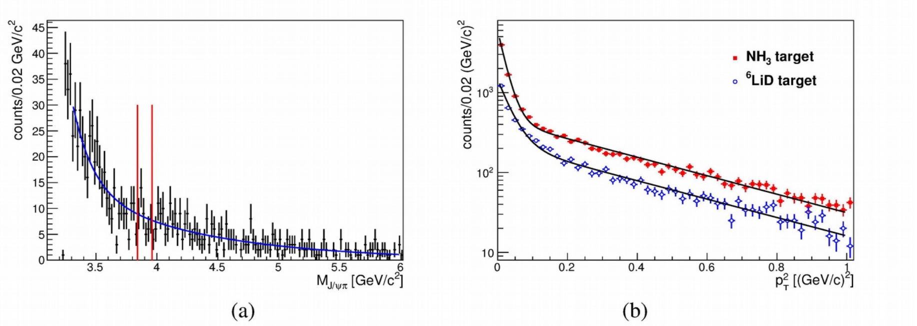

Figure 8: (a) Mass spectrum of the J/ψ$\pi^{\pm}$ state. The fitted function is shown as a solid line.
(b) p_T^2 distributions for exclusively produced J/ψ mesons off the ^{6}LiD (blue, lower) and NH_3 (red, upper) targets.

The full set of the COMPASS data collected with a muon beam between 2002 and 2011 has been used. No signal in the region of J/ψπ± mass is observed. An upper limit for the ratio *BR($Z_c^{\pm}$ (3900)-> J/Ψ$\pi^{\pm}$) x* $\sigma_{\gamma N\text{->}J/\Psi N}$ *of 3.7x10^{-3}* was established at level of confidence of 90% .

Observation of the new narrow axial-vector meson *a_1(1420)*

The COMPASS collaboration has measured diffractive dissociation of 190 *GeV/c* pions into the $\pi^-\pi^-\pi^+$ final state using the stationary hydrogen target. The partial-wave analysis (PWA) was performed in bins of 3π mass and four-momentum transfer using the isobar model and the largest PWA model that includes 88 waves. A narrow $J^{PC} = 1^{++}$ signal is observed in the *f_0(980)π* channel (see Fig.9, upper left plot). In the resonance-model study of a subset of the spin-density matrix selecting 3π states with $J^{PC} = 2^{++}$ and 4^{++} decaying into *ρ(770) π* and with $J^{PC} = 1^{++}$decaying into *f_0(980)π* , a new *a_1* meson with mass *(1414_{-13}^{+15}) MeV/c* and width *(153_{-23}^{+8}) MeV/c* [7] was identified and called *a_1 (1420). It* decays only into *f_0(980)π*, suggesting its exotic nature (Fig.9) . Such a state has never been predicted.

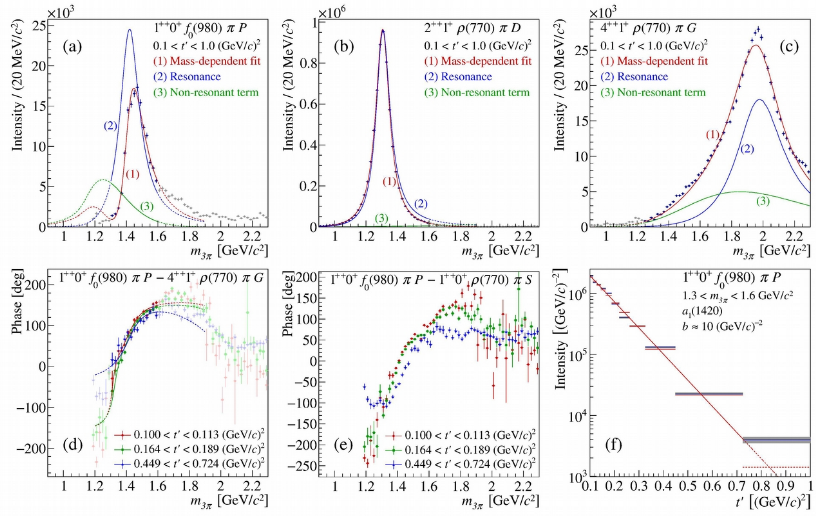

Figure 9:Results of the PWA in 3π mass bins of 20 MeV/c².

2.2 New electromagnetic calorimeter ECAL0.

One of the main objectives of the COMPASS-II is to study Generalized Parton Distributions (GPD) in nucleons. The GPD concept has attracted great attention of scientists after it shown that the total angular momentum of a certain type of partons, J^f for quarks ($f = u; d$ or s) or J^g for gluons, which depends on the second moment of the sum of two GPDs H and E. Measurements of these GPDs via exclusive Deep Virtual Compton Scattering (DVCS), $\mu\, p \rightarrow \mu\gamma p$, or Virtual Deep Scattering with meson production (DVMP), $\mu\, p \rightarrow \mu M p$, is the only known method to determine the "contribution" of all partons to the nucleon spin $1/2 = \sum_{f=u;d;s} J^f + J^g$. The DVCS and DVMP reactions are exclusive. In order to measure their cross-sections, the existing setup COMPASS should be upgrated by 2 new detectors – Proton Recoil Detector (the RPD), which measures characteristics of protons, and the electromagnetic calorimeter ECAL0 in front of the first spectrometer magnet (SM1) (Fig.10).

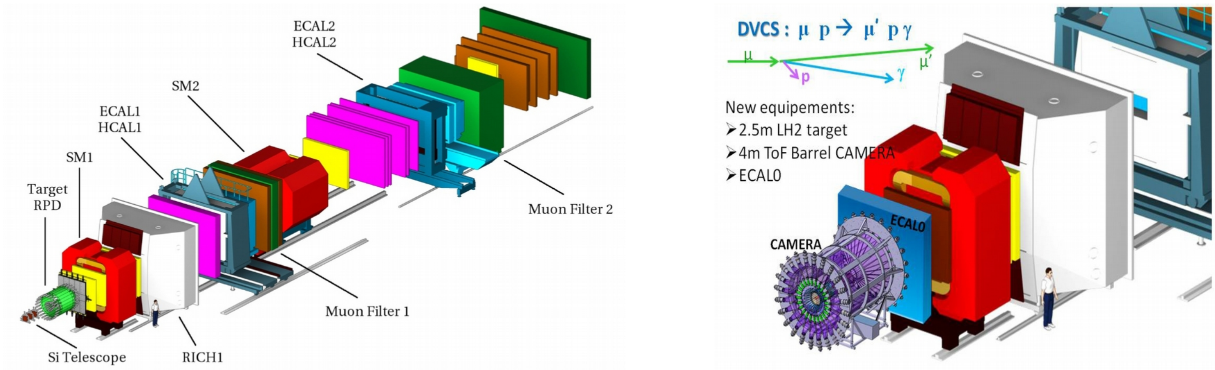

Figure 10: Experimental COMPASS setup (left) and the front of the spectrometer, upgrated by the detectors for studying of generalized parton distributions.

A liquid hydrogen target, 2.5 *m* length, was installed inside of the RPD. The new electromagnetic calorimeter ECAL0, suggested by JINR, provides registration of events in significantly wider kinematic region in addition to the existing calorimeters ECAL1 and ECAL2. ECAL0 was developed at JINR in collaboration with groups of physicists from Munich, Freiburg, Warsaw, Saclay, Prague, CERN and colleagues from Kharkov. The ECAL0 is a unique device, of the "shashlyk"-type (scintillator, lead), in which the most advanced photodetectors – Micro-pixel Avalanche Photo Diodes (MAPD) with ultra-high pixel density (up to 15 thousand pixels / mm²) instead of the traditional photomultipliers are used. So, it was the first time when the MAPD were applied for the electromagnetic calorimeter at the large physical setup. It should be noted that this type of photo detector has been developed and tested in many institutions for more than 20 years, and JINR is one of the leading centers in this field. The MAPD with the pixel density (15 thousand pixels / mm^2) were developed in our institute and were used in the calorimeter as a part of the experimental setup COMPASS in 2012 during the pilot data taking. To serve this purpose, more than a quarter of the calorimeter modules were produced. After successful tests, the final stage of the calorimeter modules production was begun. 250 modules were produced and tested at Institute of Scintillation Materials (ISMA, Kharkiv, Ukraine). In December 2013 the modules were delivered to CERN. Further tests of the MAPD calorimeter were associated with new physical tasks – use of this detector in intense hadron beams – led to the need to utilize a new fast MAPD of MPPC S12572-10P-type of Hamamatsu company (10 thousand pixels / mm^2). Development, production and testing of the registration blocks on the basis of these MAPD took almost one year and a half, and were successfully completed in cooperation with the Russian company Rusalox (Vladimir). This company is a manufacturer of motherboards with high thermal conductivity of the aluminaoxid-based technology that provides high cooling efficiency of electronic components. Printed circuit boards manufactured using this technology are made of a conducting layer of aluminum and dielectric material with nanoporous structure. A new technological process was developed: drilling holes, their oxidation and metallization, with leakage currents on the level of a pA at the voltage of 100 V. Additionally JINR performed soldering of the pins, gluing the MAPD to the alumina board, gluing Winston cones to the MAPD and other assembly operations. The first recording blocks were ready by the beginning of June 2015 and by the end of June 2015 recording blocks were delivered to CERN and tested in the beam. As a result - after many years of development and tests at CERN, DESY (Hamburg) and at the ELSA (Bonn) complex, the final version of the calorimeter module was developed, see Figure 11.

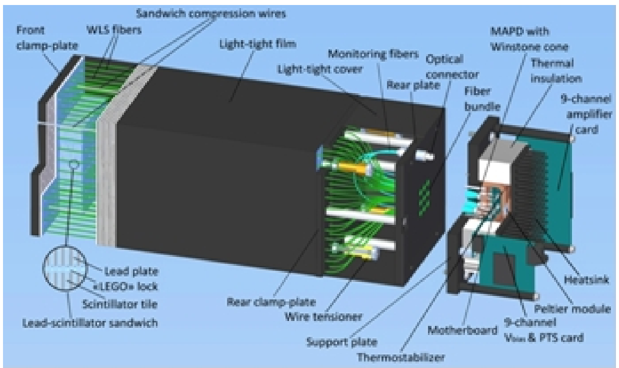

Figure 11:ECAL0 calorimeter module.

In addition to the group mentioned above, the power supply systems of MAPD, their temperature stabilisation and monitoring developed by HVSYS were used. Readout system (ADC) and amplifiers were developed by groups from Munich and Warsaw, and the group from Prague produced optical splitters for the ECAL0 slow control systme. In March-April 2016 the ECAL0 was fully assembled, tested and included to the COMPASS setup (Fig.12). Now it effectively registers photons of the DVSC and DVMP reactions in a wide energy range (0.2 – 40 GeV); and effectively registers π^0 (Fig.13). The ECAL0 consists of: 194-tower modules, 1746 MAPDs and readout channels; 28 MSADCs and HV system with temperature stabilization, power suppliers and slow control (Fig.12). Stable operation of the calorimeter was appreciated by the COMPASS collaboration. The obtained experience will be used for development of similar calorimeters for MPD and SPD set-ups at the NICA complex.

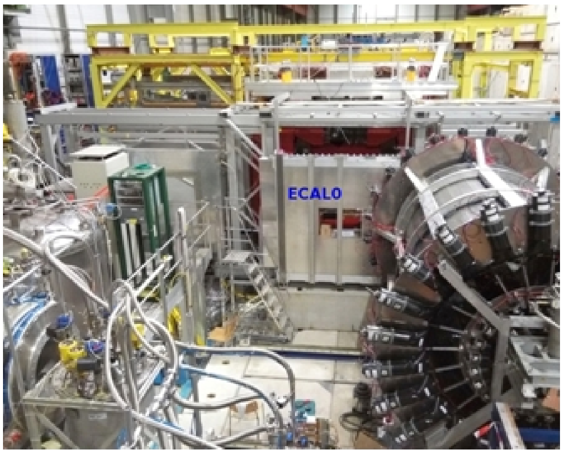

Figure 12: ECAL0 in the COMPASS set-up.

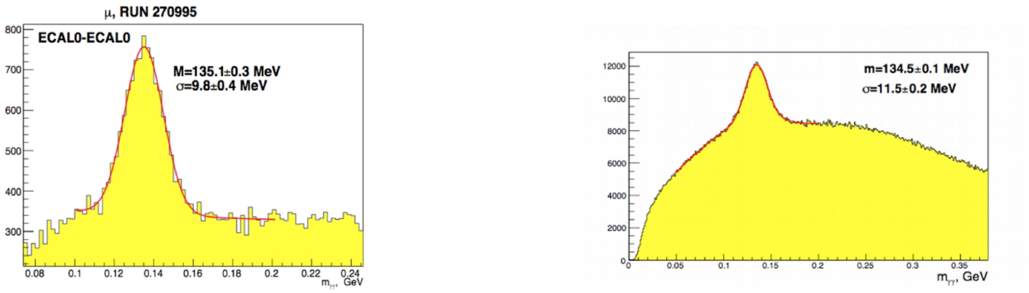

Figure 13: Typical $\gamma\gamma$ spectra from ECAL0 (2016 data taking) with muon(left panel) and pion (right panel) beams.

3. COMPASS-II MEASUREMENTS IN 2017-2019.

The COMPASS-II measurements started in 2012 with pion/kaon polarisability via Primakoff reactions and with GPD feasibility test using partially upgraded COMPASS-II spectrometer. The further measurements continued in 2014 after the accelerator shutdown. They are focused on studies of transverse momentum dependent (TMD) parton distributions in nucleons via Drell-Yan lepton pair production (2014-2015 and possibly in 2018) and measurements of GPDs H via hard exclusive meson production and DVCS (2016-2017 and possibly in 2018) (Fig.14). In parallel with the GPD program, high statistic data for TMD PDFs in SIDIS will be collected.

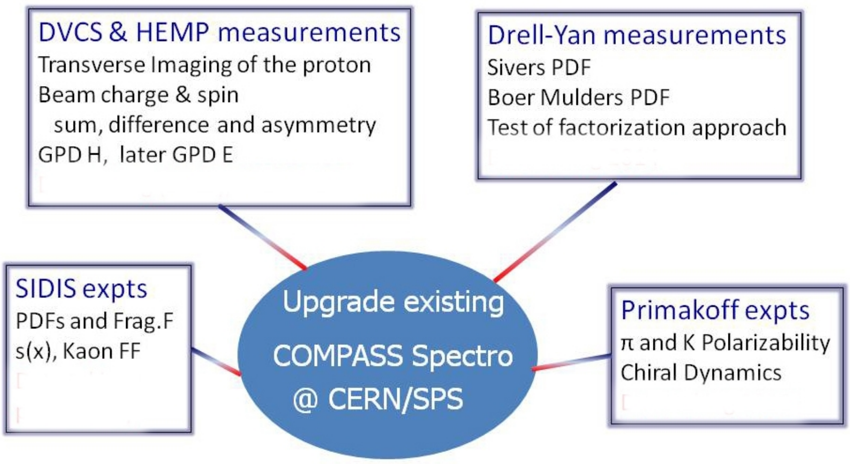

Figure 14: The schematic view of the COMPASS-II tasks for 2012-2019.

The main activities on data analysis in framework of COMPASS-II project will focused on the GPD and SIDIS analysis. The Drell-Yan and Primakoff studies will be mostly performed in framework of new project proposed by LNP.

3.1 GPD measurements.

The GPDs [8] are universal distributions which contain nucleon form factors as limiting cases on the one hand and parton distribution functions (PDFs) on the other. The GPDs H^f and tilda-H^f ($f = u, d, s, g$) describe processes where the nucleon helicity is preserved and contain the PDFs f_1 as a limiting case. Processes where the nucleon helicity is flipped are described by the GPDs E^f and tilda-E^f for which no such limiting case exists. GPDs correlate transverse spatial and longitudinal momentum and thus provide a kind of «nucleon tomography». They depend on four variables x, ξ, t, and Q^2. The cleanest process to assess GPDs is DVCS. It is shown in Fig.15, where the relevant momentum fractions x (not the Bjorken scaling variable) and ξ, and the momentum transfer t and Q^2, are defined.

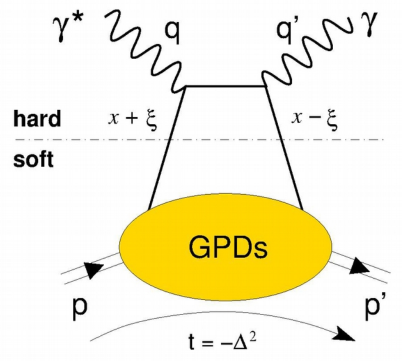

Figure 15: The diagram of the DVCS process.

The interest in these distributions was boosted, when X.D. Ji proved that there is the sum rule for the total angular momentum J of quarks and gluons [9]. The DVCS process interferes with the Bethe-Heitler (BH) process due to identical final states. In this case the cross-section then consists of five terms

$$\mathrm{d}\sigma^{\mu p\to\mu p\gamma} = \mathrm{d}\sigma^{\mathrm{BH}} + \mathrm{d}\sigma_0^{\mathrm{DVCS}} + P_\mu \mathrm{d}\Delta\sigma^{\mathrm{DVCS}} + e_\mu \Re\mathrm{e}\, I + P_\mu e_\mu \Im\mathrm{m}\, I, \quad (1)$$

where I denotes the DVCS-BH interference term. An important feature is that the BH contribution can be normalized at small x_B , where it dominates. From Eq.1 one can build the sum S and difference D of the $\mu p \to \mu p\gamma$ cross-section for simultaneous change of lepton charge e_μ and polarization P_μ of the incoming lepton beam (+ to - and $\rightarrow$ to $\leftarrow$)

$$\begin{aligned} \mathcal{D} &= \mathrm{d}\sigma^{\overset{+}{\leftarrow}} - \mathrm{d}\sigma^{\overset{-}{\rightarrow}} &&= 2(\mathrm{d}\sigma_0^{\mathrm{DVCS}} + \Re\mathrm{e}\, I) \\ \mathcal{S} &= \mathrm{d}\sigma^{\overset{+}{\leftarrow}} + \mathrm{d}\sigma^{\overset{-}{\rightarrow}} &&= 2(\mathrm{d}\sigma_0^{\mathrm{BH}} + \mathrm{d}\sigma_0^{\mathrm{DVCS}} + \Im\mathrm{m}\, I) \end{aligned} \quad (2)$$

At COMPASS, the DVCS ($\mu\, p \rightarrow \mu\, p\gamma$) will be measured using the high intensity polarized muon beam. DVCS is a relatively low cross-section process. So its luminosity will be maximized with a 2.5 meter long liquid hydrogen target. In the DVCS kinematics, the virtual photon is produced at small angles while the proton recoils at the very large angles. To measure and identify the recoil proton, a 4-meter long Time-Of-Flight detector called CAMERA is surrounding the target. To extend the kinematic coverage of DVCS detection to the higher x_{Bj}, a large angle electromagnetic calorimeter (ECAL0) was also been added. With such an apparatus, COMPASS can measure the DVCS process on a wide x_{Bj} range (from 0.005 to 0.3) with a Q^2 up to 20 GeV^2 (limited by integrated luminosity).

The GPD H is studied with DVCS measurements on unpolarized hydrogen. The first proof of the principle for the possibility to measure DVCS in COMPASS was brought by a 10-day long run test in

2009 with a reduced setup (40 cm liquid hydrogen target, short recoil proton calorimeter, no additional calorimetry). A pilot run was performed in 2012. The full DVCS runs in 2016-2017 (and possibly - in 2018).

In 2012, a four-week long pilot run has been performed, with a almost complete DVCS setup (full scale recoil proton detector, full luminosity, partially equipped ECAL0). The exclusive photon sample selected for data analysis is shown in Fig.16, as a function of the azimuthal angle, $\varphi_{\gamma*\gamma}$, between the leptonic plane (defined by the incident and scattered lepton) and the hadronic plane (defined by the virtual and real photon). The data are given in 3 x_{Bj} bins.

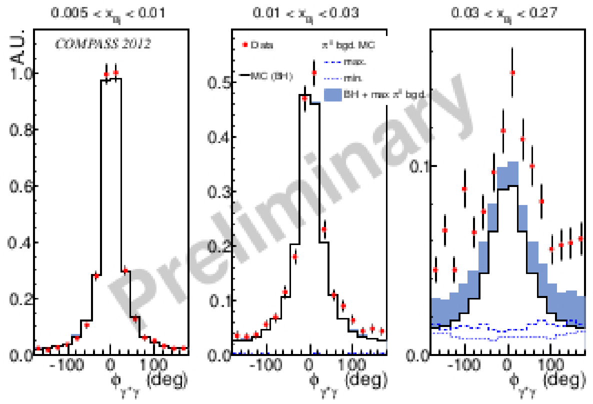

Figure 16: The single photon events obtained in the 2012 sample as a function of $\varphi_{\gamma*\gamma}$ (red dots) compared to the Bethe-Heitler estimation (black histogram) and the π^0 contamination estimated by LEPTO and HEPGEN. The visible π^0 background has been subtracted from these data.

The Bethe-Heitler process has the same final state as DVCS, but the photon is radiated by the incident or by the scattered lepton instead of the proton. The amplitude of the Bethe-Heitler process can be calculated with very good accuracy, and in Figure 16, the Monte-Carlo estimation (black histogram) only includes Bethe-Heitler. In the lower x_{Bj} bin, where the DVCS contribution is negligible, the $\varphi_{\gamma*\gamma}$ distribution for the data (red dots) agrees remarkably well in shape with the Bethe-Heitler estimation by Monte-Carlo.

The DVCS cross-section depends on the squared momentum transfer t from the initial to final nucleon. At small x_B one has the relation $\langle r_{\perp}^{2}(x_B)\rangle$ � $2B(x_B)$ if the exclusive cross-section is parameterized as $d\sigma / dt$ � $\exp(-B(x_B)|t|)$ |. The transverse distance $r_{\perp}$ is measured between the struck quark and the centre of mass of the spectator system. Thus, independent of any GPD parameterization, one obtains a measure of the transverse nucleon size as a function of x_B. Using a parameterization of the type $B(x_B) = B_0 + 2\alpha' \log(x_0 / x_B)$, one can characterize the t' slope of the cross-section by the parameter α'. Preliminary results of the t-slope of the DVCS cross section and its comparison with HERA data are shown in Fig.17.

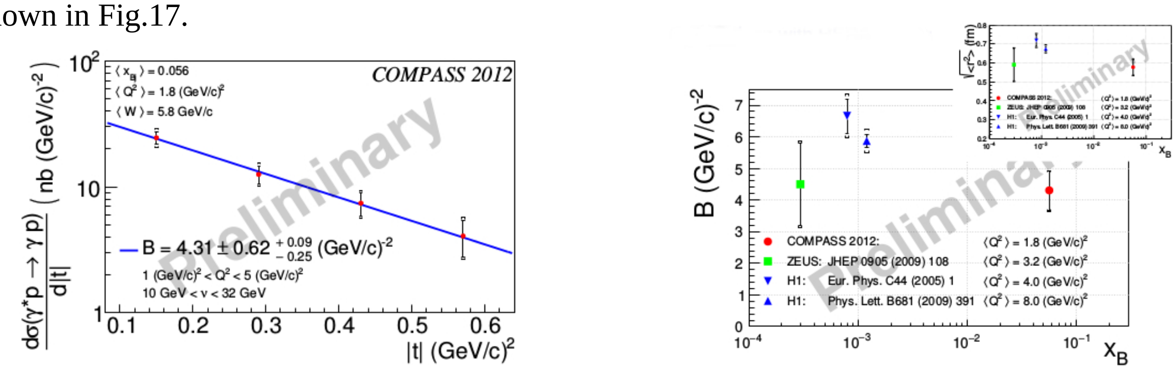

Figure 17: DVCS cross section and t-slope extraction (left panel).
Comparison on B and <r^2> with HERA results (right panel).

The GPD run has been started in 2016 and is to be continued in 2017. The main tasks of GPDs investigations with Hard Exclusive Photon and Meson Production are as follows.

- Measurements of the t-slope of the DVCS and HEMP cross section (transverse distribution of partons).
- Studies of the beam-charge-and-spin sum and différence of amplitudes ($Re\ T^{DVCS}$ and $Im\ T^{DVCS}$ for the GPD *H* determination).
- Measurements of the longitudinal contribution of Vector Mesons $\rho^0, \rho^+, \omega, \varphi$ (GPD *H).*
- Measurements of total contributions of π^0 (GPDs *E* and E_T).

The projected precision of a *t*-slope measurements for two year of data taking is presented in Fig.18.

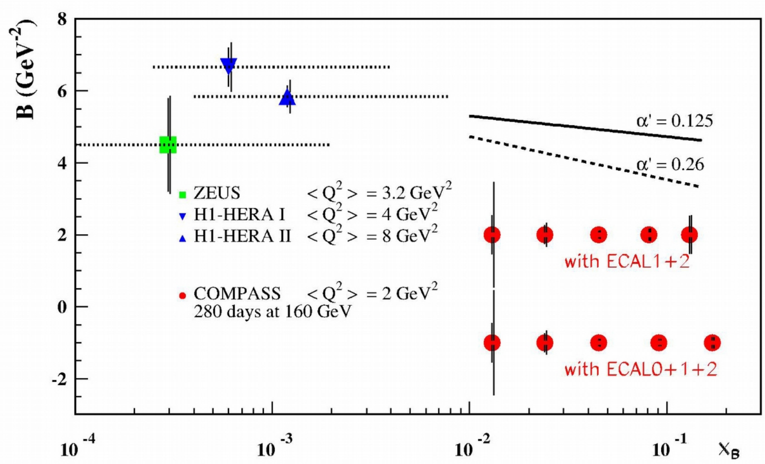

Figure 18: Projected precisio nof measurements of the x_B dependence of the t-slope parameter $B(x_{Bj})$ (red filled dots) using only ECAL1 and ECAL2 (upper row) and with an additional ECAL0 calorimeter (lower row).

With an unpolarized target, DVCS results will mostly provide information on the GPD *H*. The projected precision for the beam-charge and spin-asymmetry measurements in comparison with some models is shown in Fig.19.

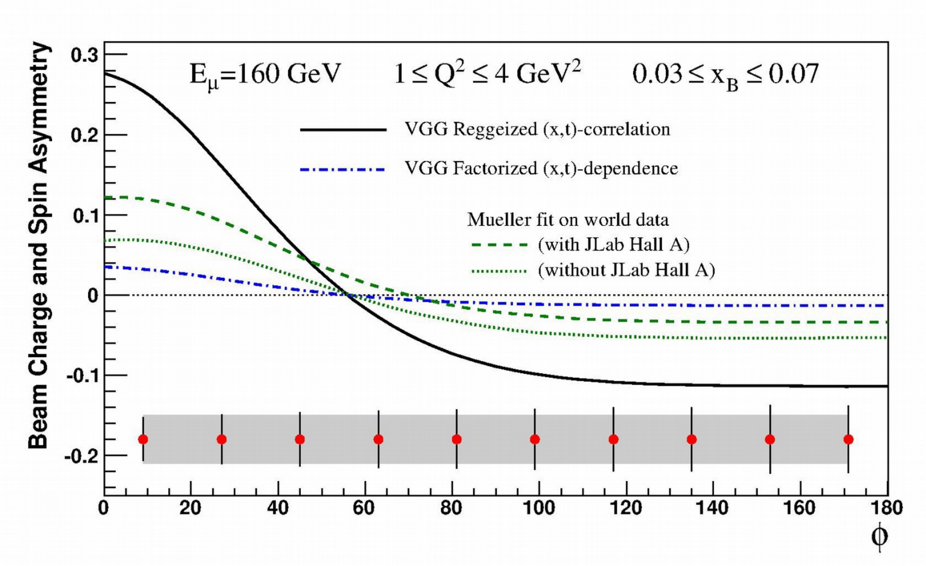

Figure 19: Projected precision of the beam charge and spin asymmetry measurements compared to various models.

\3.2 Drell-Yan measurements.

An access to transverse momentum dependent (TMD) PDFs in polarized nucleons via the Drell-Yan lepton pair production at COMPASS is shown in Fig.20.

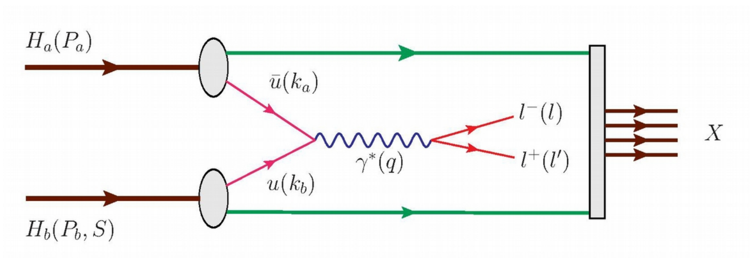

Figure 20: The diagram of the Drell-Yan process.

The polarized DrellYan process gives an alternative access to TMD PDFs, with the advantage over SIDIS that no fragmentation functions involved. The measured spin asymmetries are related to convolutions of 2 TMD PDFs. In the leading order QCD, when having a transversely polarized target, the DrellYan cross-section can be written in a form that highlights these azimuthal asymmetries, see Equation below.

$$\frac{d\sigma}{d^4qd\Omega} = \frac{\alpha^2}{Fq^2}\hat{\sigma}_U \Big\{ (1 + D_{[\sin^2\theta]} A_{UU}^{\cos 2\phi} \cos 2\phi) + |\vec{S}_T| \Big[A_{UT}^{\sin\phi_S} \sin\phi_S + D_{[\sin^2\theta]} \Big(A_{UT}^{\sin(2\phi+\phi_S)} \sin(2\phi+\phi_S) + A_{UT}^{\sin(2\phi-\phi_S)} \sin(2\phi-\phi_S) \Big) \Big] \Big\}$$

The four azimuthal asymmetries give access to the following convolutions: $A_{UU}^{\cos 2\varphi}$ to the BoerMulder TMD from pion with BoerMulders from proton; $A_{UT}^{\sin\varphi_S}$ to the unpolarized TMD from pion with Sivers TMD from proton; $A_{UT}^{\sin(2\varphi+\varphi_S)}$ to the BoerMulders TMD from pion with pretzelosity TMD from proton; and $A_{UT}^{\sin(2\varphi-\varphi_S)}$ to the BoerMulders TMD from pion with transversity TMD from proton. Due to their naive time reversal odd nature, Sivers and BoerMulders TMD PDFs change sign when accessed from DY or from SIDIS.

For the DrellYan measurement at COMPASS, a negative pion beam of 190 *GeV/c* momentum will be used.The target will consist of 2 target cells, with 55 *cm* length and 2 *cm* radius each, and spaced by 20 *cm*. As used in the past COMPASS SIDIS measurements, the target material will be solid state ammonia (NH_3) with a dilution factor (which refers to the fraction of polarizable material in the target) of 22%. One can reach up to 90% polarization using a dipole field to keep the proton spins in the target transversely polarized with respect to the pion beam direction. The 2 target cells are oppositely polarized, and spin reversal is performed every few days, in order to minimize time-dependent systematic errors in the azimuthal spin asymmetries extraction. In order to have meaningful statistics, the relatively low cross-section of the DrellYan process must be compensated by the high intensity pion beam. The maximum beam intensity that can be reached at COMPASS is 10^8 particles per second. The limit is dictated by the beam line itself, the allowed radiation dose in the hall, and by the local heating of the target. In order to keep the detectors occupancy at reasonable level below 5%, a thick hadron absorber is placed right down the polarized target (see Fig.21).

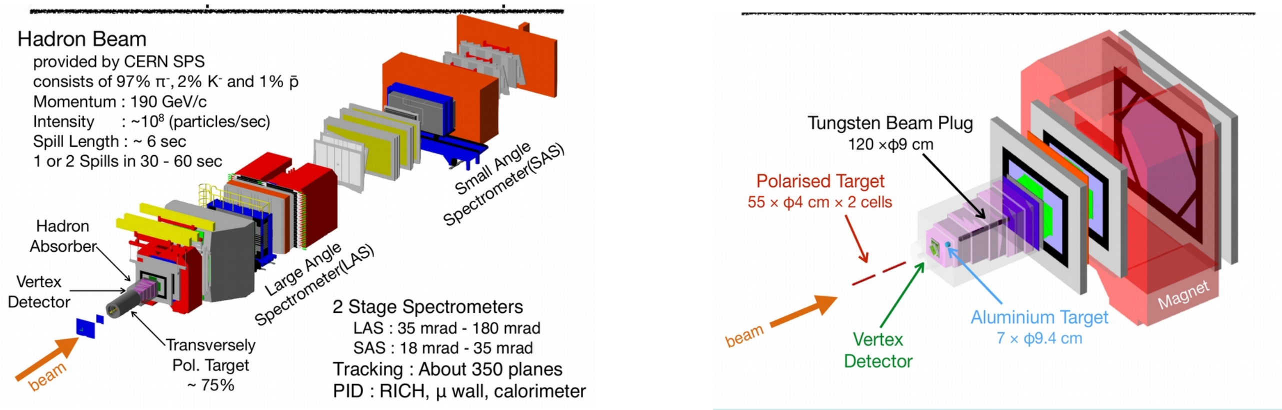

Figure 21:The COMPASS spectrometer for DY measurements (left panel). The target region with hadron absorber (right panel).

The Drell-Yan data taking was started in 2014 with the pilot run. About 7K DY events and 200 K J/Ψ events were collected during three weeks of stable data taking. In 2015 COMPASS has took about 80K DY events and 200 K J/Ψ events in 4.5 months of stable data taking. The analysis of the collected data is in progress. The di-muon spectra obtained with about 30% of collected in 2015 data is shown in Fig.22. The estimated uncertainties on above mentioned asymmetries are given in Fig.23.

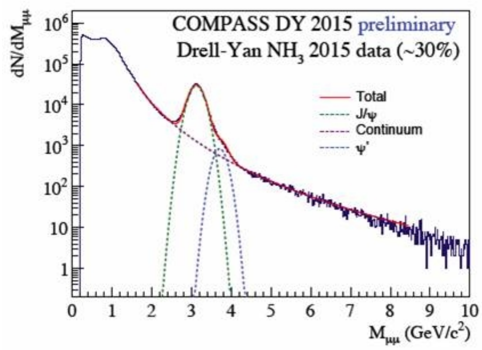

Figure 22: The di-muon spectra from 2015 data.

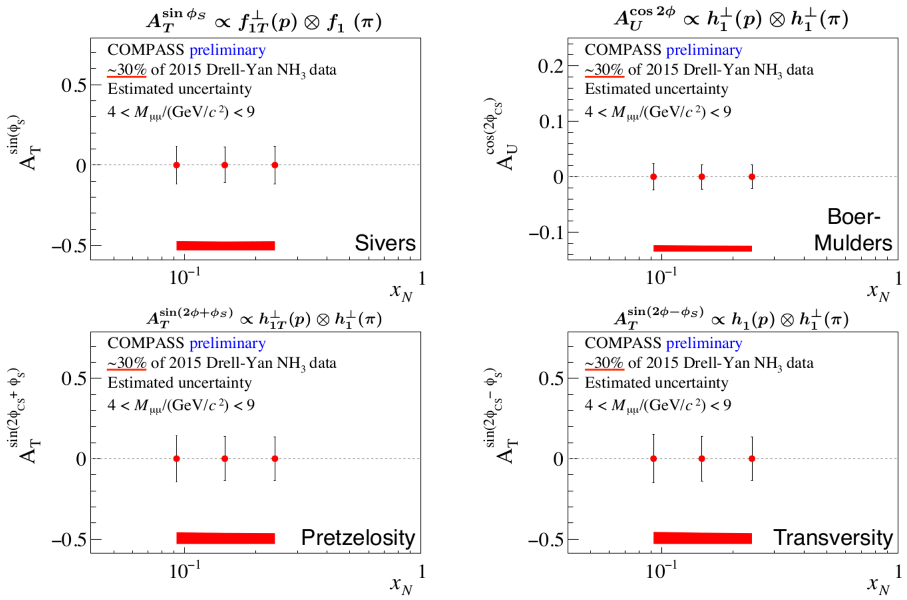

Figure 23: The estimated uncertainties on asymmetries (details are given in text) from 2015 data.

Currently COMPASS proposes to continue DY measurements in 2018. In case of approval of this proposal by SPSC CERN committee, the DY statistics will be essentially increased. As example, Fig.24 presents the projection for Sivers asymmetry.

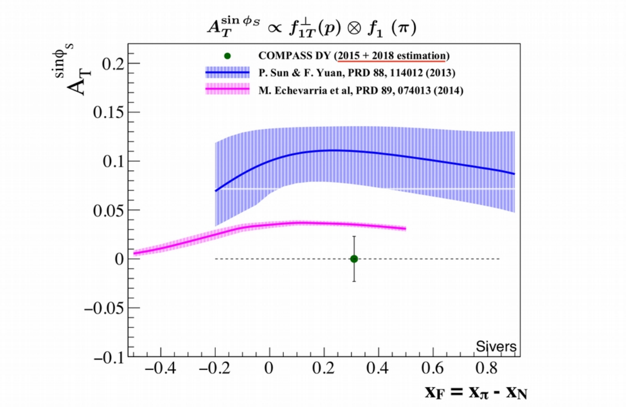

Figure 24: The projection of Sivers asymmetry in DY measurements for 2015 and 2018 data taking.

3.3 SIDIS studies.

High-statistics data on semi-inclusive deep inelastic scattering (SIDIS) on the unpolarised proton, $\mu\, p \rightarrow \mu\, h\, X$, will be taken simultaneously with the DVCS and HEMP measurements using the long liquid hydrogen target. Combined with existing SIDIS data on the deuteron, they will permit to improve precision of unpolarized quark flavour distributions. The new proton data will be obtained in a region of Bjorken-*x* (denoted by *x* in the rest of this section), where measurements from other experiments are either not available or have limited precision. The new data will be used in the global QCD analysis to constrain structure functions of unpolarized nucleons. They also allow to improve measurements of quark Fragmentation Functions (FFs), which describe quark fragmentations into hadrons. The latter functions are necessary also for determination of polarized parton distributions. Presently, FFs are still poorly known quantities introducing large systematic uncertainties in determinations of parton distributions in nucleons, particularly in distributions of strange quarks. The new data will permit determination of the unpolarized strange quark distribution function $s(x)$ in the region $0.001 < x < 0.2$, where its shape is unknown. In addition, using the same data, it will be possible to measure with high statistics asymmetries in the azimuthal distributions of hadrons produced in SIDIS on an unpolarized proton target. These measurements, already performed at the deuteron target, are sensitive to the T-odd transverse-momentum-dependent (TMD) Boer–Mulders function [10] and also to the Cahn effects [11], both depending on the intrinsic transverse momentum of quarks k_T .

4 . COMPASS-III PREPARATION

In 2016 the preparation of COMPASS-III proposal was started. In March, the first workshop "COMPASS beyond 2020» took place at CERN [12]. The goal of this workshop was to explore opportunities for fix-target COMPASS-like experiment at CERN beyond 2020. The scientific program comprises the reviews in the various physics domains (TMDs, GPDs, FFs, spectroscopy, exotics, tests of ChPT, astrophysics), and reviews of physics results expected in the 10 next years from labs around world. More than 100 physicists have participated in the workshop. The main outcomes of the workshop are as follows:

- Existing muon and hadron beam allows to extend current COMPASS program by doing unique or first class measurements of exclusive processes, SIDIS and Drell-Yan;
- RF Separated antiproton/kaon beam would provide a unique opportunity for future fixed target COMPASS-like program at CERN.

The RF separated anti-proton beam can reach intensity ~8 x 10^7antiprotons per second, i.e. by a factor of 50 higher compared to the standard pion beam for Drell-Yan measurements. Using the same assumption for RF separated kaon beam, possible kaon beam intensity can be about 8 x 10^6 /s, i.e. by the factor of 80 higher compared to to the standard “spectroscopy” pion beam. High intensity RF separated beam will provide unique opportunities for Hadron Spectroscopy and Drell-Yan physics.

The future GPD and DY programs can be based on new recoil detector which has to be inserted in the COMPASS polarised target (PTwithRD). JINR group has started the preparation the R&D tests of this detector. This upgrade of the COMPASS polarised target allows to get access to GPD E via two processes that are measured with muon beam: DVCS (μ p→ μ p γ) and DVMP (μ p → μ ρ (ω) γ). The projections for two years of data taking is given in Fig.25.

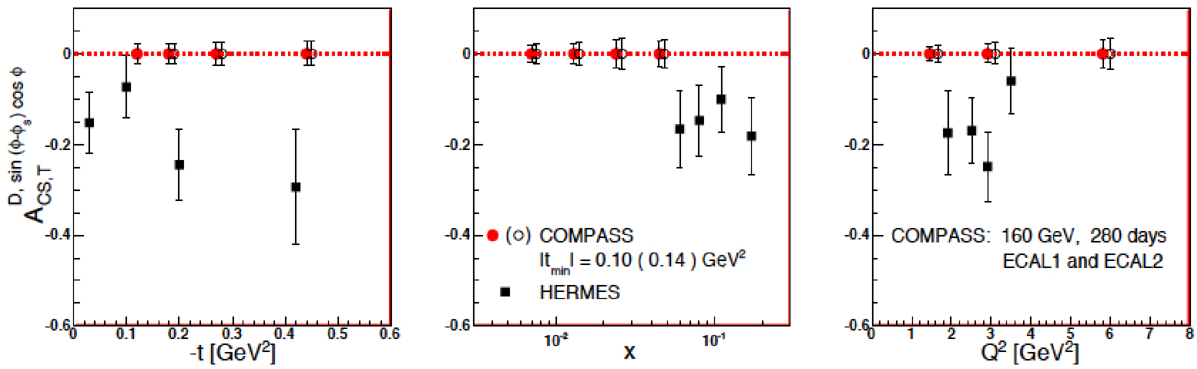

Figure 25: Expected statistical accuracy of measured asymmetry with 160 GeV muon beam, 280 days of data taking in comparison with HERMES data.

Note, that currently no measurements planned in COMPASS kinematic range (small xBj).

5. JINR OBLIGATIONS AT COMPASS

According to the COMPASS-II MoU, the obligations of JINR are the technical support of the HCAL1, MW1, and new electromagnetic calorimeter ECAL0 . The MoU for COMPASS-II sets:
- The COMPASS collaboration existing on the basis of the 1998 MoU, which consists of a group of collaborating institutions from CERN Member and non-Member States as well as CERN, have proposed to expand the original program and carry out a set of measurements to study the structure of hadrons in Deep Virtual Compton Scattering (DVCS), Hard Exclusive Meson Production (HEMP) and SIDIS, Polarized Drell-Yan and Primakoff reactions.
- At the end of each year a provisional budget for the next year is established, based on the foreseen running costs and contingencies. It should to be approved by the FRC (Financial Resources Committie). To cover the running costs, an M&O fund, with contributions from all the Collaborating Institutions, is setup. The contribution due by each Collaborating Institution for the following year is calculated “Per Capita” based on the number of members carrying a financial contribution to the M&O at July 1st of the running year.

The SIDIS and DVSC are tasks in COMPASS data analysis for this project.

The MoU enters into force on January 1, 2013, and will be valid until December 31, 2017. Extensions of this MoU for three year without changes will be approved by the FRC with recommendations from SPSC (SPS and PS experiments Committie).

6. TIME LINES and FINANCIAL PROFILE OF THE PROJECT.

In 2017-2019 the COMPASS collaboration is going to plan to take the experimental data with muon (2017 and it is possible in 2018) and with a pion beams (it is possible in 2018). The analysis of the experimental data will be continued and work on preparation of proposal of the new physical program after 2020 is continued. The detailed scheduled plan of work is presented below.

2017:
- Participation in COMPASS data taking ;
- Maintenance of MW1, HCAL1 and ECAL0 during running;
- Development/support of MW1/HCAL1/ECAL0 software;
- Analysis of COMPASS experimental data;
- Preparation of COMPAS-III project.

2018:
- Participation in COMPASS data taking;
- Maintenance of MW1, HCAL1 and ECAL0 during running ;
- Development/support of MW1/HCAL1/ECAL0 software;
- Analysis of COMPASS experimental data;
- Preparation ofvCOMPAS-III project.

2019:
- Analysis of COMPASS experimental data;
- Preparation of COMPASS-III project;
- Detector's upgrade for COMPASS-III.

Common JINR expenses on the project (theme 1085) during 2014-2016 were equal to about $770 thousand. About $130 thousand were allocated by CERN (NA58, COMPASS-II) for support of experts from JINR in CERN in 2014-2016. The collaboration of NA58 allocates also 40 thousand swiss francs per year for payment of the common works performed by JINR engineers in CERN during preparation and support of an experiment for a data taking. In the last three years about $25 thousand were spent from a Czech Republic grants. Also funds from LHEP themes were spent for holding workshops in Suzdal (May 2015).

The sum of necessary financing for 2017 - 2019 equals to $842 thousand from the JINR budget. The main part of these expenses are required for participation of JINR physicists in data taking, for maintenance of detectors and the program on-line complexes of monitoring of their work, and also for contributions payment to the common fund of collaboration according to obligations from MoU, for computer and hardware of works on simulations, processing and the analysis of the collected experimental data. Financial support from other sources will be not less than $40 thousand a year. The resources necessary for realization of the 2017 – 2019 stage of the project, are given below in the form No. 26, and as well the list of the project expences (form No. 29).

The finance profile includes the travel expences for JINR physicists, contribution to the common COMPASS fund, money for maintenance of HCAL1, ECAL0 and MW1.

The resources allocated to materials and equipments equal to 60 thousand dollars per year. Mostly these resources will be spent for repairation and modernization of the low-voltage power supply system of MW1, modernization and maintenance of modules of the electromagnetic calorimeter of ECAL0 (in particular - monitoring system) and the hadron calorimeter of HCAL1, for creation of remote system of expert control on detectors and for tests for preparation of COMPASS-III. The year-by-year plan of these works is presented in the table below.

№	Item	Year											
		2017				***2018***				***2019***			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Data taking		■	■	■		■	■	■				
2	ECAL0 maintenance		■	■	■		■	■	■				
3	Monitoring system and repair of ECAL0/HCAL1	■	■			■							
4	HCAL1 maintenance		■	■	■		■	■	■				
5	MW1 maintenance		■	■	■		■	■	■				
6	Low voltage system of MW1	■	■			■							
7	MW1/HCAL1/ECAL0 software	■	■	■	■	■	■	■	■				
8	Data analysis	■	■	■	■	■	■	■	■	■	■	■	■
9	Detector remote control system	■	■										
10	COMPASS-III preparation	■	■	■	■	■	■	■	■	■	■	■	■
11	Detector's upgrade for COMPASS-III									■	■	■	■

TABLE: JINR FINANCE PROFILE FOR 2017-2019 (IN K$)

#	ITEM	TOTAL	2017	2018	2019
1.	DESIGN BUREAU (MAN-H)	300	100	100	100
2.	WORKSHOPS (MAN-H)	700	500	100	100
3.	MATERIALS	**110**	**40**	**35**	**35**
4.	EQUIPMENT	**75**	**25**	**25**	**25**
5.	SUBCONTRACTS (COLLAB COMMON FUND)	**222**	**72**	**75**	**75**
6.	TRAVELS, INCLUDING OUTSIDE RUSSIA INSIDE RUSSIA	 **420** **15**	 **150** **5**	 **150** **5**	 **120** **5**
	TOTAL K$ (MAN-H)	**842** 1000	**292** 600	**290** 200	**260** 200

Project Leader A. Nagaytsev

Scientific Leader I. Savin

LHEP Director V. Kekelidze

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2. COMPASS Collaboration," PLB 753 (2016) 18
3. COMPASS Collaboration, CERN-PH-EP-2015-328, submitted to EPJC
4. COMPASS Collaboration, CERN-EP/2016-245, submitted to PLB
5. COMPASS Collaboration, PRL 114 (2015) 062002
6. COMPASS Collaboration, PLB 742 (2015) 330
7. COMPASS Collaboration, PRL 115 (2015) 082001
8. A. V. Radyushkin, Phys. Lett. B385 (1996) 333.
   A. V. Radyushkin, Phys. Rev. D56 (1997) 5524.
9. X.¬D. Ji. Phys. Rev. Lett. 78 (1997) 610.
10. D. Boer et al., Phys. Rev. D57 (1998) 5780
11. R. N. Cahn, Phys. Lett. B78 (1978) 269
12. https://indico.cern.ch/event/502879/

Appendix: The list of the COMPASS publications
(*updated on September 23, 2016)*.

1.”Measurement of the spin structure of the deuteron in the DIS region”, PLB 612 (2005) 154
2. “First measurement of the transverse spin asymmetries of the deuteron in semi-inclusive deep inelastic scattering”, PRL 94 (2005) 202002
3. “Search for the Φ(1860) pentaquark at COMPASS”, EPJ C41 (2005) 469–474
4. “Gluon polarization in the nucleon from quasi-real photoproduction of high-p_T hadron pairs”, PLB 633 (2006) 25–32
5.”The Deuteron Spin-dependent Structure Function g1d and its First Moment”, PLB 647 (2007) 8–17
6.”A new measurement of the Collins and Sivers asymmetries on a transversely polarised deuteron”, NP B765 (2007) 31–70
7.”The Compass Experiment at CERN”, NIMA 577 (2007) 455–518
8.”Spin asymmetry A1d and the spin-dependent structure function g_1^d of the deuteron at low values of x and Q^2 “,PLB 647 (2007) 330–340
9.”Double spin asymmetry in exclusive ρ^0 muon-production at COMPASS”, EPJ C52 (2007) 255–265
10.”The Polarised Valence Quark Distribution from semi-inclusive DIS”, PLB 660 (2008) 458–465
11.”Collins and Sivers asymmetries for pions and kaons in muon-deuteron DIS”, PLB 673 (2009), 127–135
12.”Direct Measurement of the Gluon Polarisation in the Nucleon via Charm Meson Production”, CERN-PH-EP/2008-003
13.”Gluon Polarisation in the Nucleon and Longitudinal Double Spin Asymmetries from Open Charm Muon production”, PLB 676 (2009) 31–38
14.”Flavour Separation of Helicity Distributions from Deep Inelastic Muon-Deuteron Scattering”, PLB 680 (2009) 217–224
15.”Measurement of the Longitudinal Spin Transfer to Λ and anti-Λ Hyperons in Polarized Muon DIS”, EPJC 64 (2009) 171–179
16.”Observation of a $J^{PC} = 1^{-+}$ exotic resonance in diffractive dissociation of 190 GeV/c π– into π–π–π+”, PRL 104 (2010) 241803
17.”The spin-dependent structure function of the proton g1p and a Test of the Bjorken Sum Rule”, PLB 690 (2010) 466–472
18.”Measurement of the Collins and Sivers asymmetries on transversely polarised protons”, PLB 692 (2010) 240–246
19.”Azimuthal asymmetries of charged hadrons produced by high energy muons off longitudinally polarized deuterons”, EPJC 70 (2010) 39–49
20.”Quark Helicity Distributions from Longitudinal Spin Asymmetries in Muon-Proton and Muon-Deuteron Scattering”, PLB 693 (2010) 227–235
21.”First Measurement of Chiral Dynamics in π–γ → π–π–π+ “, PRL 108 (2012) 192001
22.”Leading order determination of the gluon polarisation from DIS events with high-p_T hadron pairs”, PLB 718 (2013) 922
23.”Transverse spin effects in hadron-pair production from semi-inclusive deep inelastic scattering”, PLB 713 (2012) 10
24.”Experimental investigation of transverse spin asymmetries in muon-p SIDIS processes: Collins asymmetries”, PLB 717 (2012) 376
25.”Experimental investigation of transverse spin asymmetries in muon-p SIDIS processes: Sivers asymmetries”, PLB 717 (2012) 383
26.”Measurement of the Cross Section for High-pT Hadron Production in Scattering of 160 GeV/c Muons off Nucleons” , CERN-PH-EP/2012-189
27.”Exclusive □^{0} muoproduction on transversely polarised protons and deuterons”, NPB 865 (2012) 1
28.”D* and D Meson Production in Muon-Nucleon Interactions at 160 GeV/c”, EPJC 72 (2012) 2253
29.”Leading and Next-to-Leading Order Gluon Polarisation in the Nucleon and Longitudinal Double Spin Asymmetries from Open Charm Munoproduction”, CERN-PH-EP/2012-350

30. «Study of Σ(1385) and Ξ(1321) hyperon and antihyperon production in deep inelastic scattering», EPJC 73 (2013) 2581.
31. «Hadron transverse momentum distributions in muon deep inelastic scattering at 160 GeV/c», EPJC 73 (2013) 2531.
32. «Erratum: Hadron transverse momentum distributions in muon deep inelastic scattering at 160 GeV/c», EPJC 75 (2015) 94
33. «Transverse target spin asymmetries in exclusive ρ0 muoproduction», PLB B731 (2014) 19
34. «Measurement of azimuthal hadron asymmetries in semi-inclusive deep inelastic scattering off 35. «A high statistics measurement of transverse spin effects in dihadron production from muon-proton semi-inclusive deep-inelastic scattering», PLB 736 (2014) 124
36. «Measurement of radiative widths of a2(1320) and π2(1670)»,EPJA 50 (2014) 79
37.»Spin alignment and violation of the OZI rule in exclusive ω and φ production in pp collisions», NPB 886 (2014) 1078
38. «Measurement of the charged-pion polarisability»,PRL 114 (2015) 062002
39. «Search for exclusive photoproduction of Z±c (3900) at COMPASS», PLB 742 (2015) 330
40. «Odd and Even Partial Waves of ηπ− and η'π− in π−→ η(')π−p at 191 GeV/c», PLB 740 (2015) 41. «Collins and Sivers asymmetries in muonproduction of pions and kaons off transversely polarised proton», PLB 744 (2015) 250
42. «The COMPASS setup for physics with hadron beams», NIMA 779 (2015) 69
43. «Observation of a new narrow axial-vector meson a1(1420)», PRL 115 (2015) 082001
44. «The spin structure function g1 p of the proton and a test of the Bjorken sum rule», PLB 753 (2016) 18
45. «Interplay among transversity induced asymmetries in hadron leptoproduction», PLB 753 (2016) 406
46. «Resonance Production and ππ S-wave in π−+p→π−π−π++precoil at 190 GeV/c», CERN-PH-EP/2015-233, submitted to PRD
47. «Longitudinal double spin asymmetries in single hadron quasi-real photoproduction at high pT», PLB 753 (2016) 573
48. «Leading-order determination of the gluon polarisation using a novel method», CERN-PH-EP-2015-328, submitted to EPJC
49. «Multiplicities of charged pions and unidentified charged hadrons from deep-inelastic scattering of muons off an isoscalar target», CERN-EP/2016-095, accepted by PLB
50. «Exclusive ω meson muoproduction on transversely polarised protons», CERN-EP/2016-157, submitted to NPB
51. «Multiplicities of charged kaons from deep-inelastic muon scattering off an isoscalar target», CERN-EP/2016-206, submitted to PLB
52. «Azimuthal asymmetries of charged hadrons produced in high-energy muon scattering off longitudinally polarised deuterons», CERN-EP/2016-245, submitted to PLB
53. «Sivers asymmetry extracted in SIDIS at the hard scale of the Drell-Yan process at COMPASS», CERN-EP/2016-250, submitted to PLB

COMPASS results included in the meson tables of the latest version of the PDG are:

* the radiative width of the a_2(1320) and pi_2(1670) from 2004 data
(EPJA 50 (2014) 79):
http://pdg.lbl.gov/2016/
http://pdg.lbl.gov/2016/

* mass and width of the a_4(2040) and a_2(1320) (though the latter is omitted from the PDG average) and their ratios of the branchings into pi eta'/pi eta
(PLB 740 (2015) 303):
http://pdg.lbl.gov/2016/
http://pdg.lbl.gov/2016/

* mass and width of the novel a_1(1420) from the 3pi letter
(PRL 115 (2015) 082001):
http://pdg.lbl.gov/2016/

* non-observation of the X(3900) (PLB 742 (2015) 330):
http://pdg.lbl.gov/2016/

The proposed schedule and the necessary resources for the project realization

Name of items on components, systems, resources and funding. Resource requirements (in thousands of USA dollars) Proposal from laboratory on funding and resources				2017	2018	2019
Necessary resources	Norм	Workshop -mechanical works Design bureau	700 300	500 100	100 100	100 100
Finances sources		Expenses from the JINR budget	842	292 295	265	
		Contribution from other sources	120	40	40	40

		Year											
№	Item	***2017***				***2018***				***2019***			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Data taking		■	■	■		■	■	■				
2	ECAL0 maintenance		■	■	■		■	■	■				
3	Monitoring system and repair of ECAL0/HCAL1	■	■			■							
4	HCAL1 maintenance		■	■	■		■	■	■				
5	MW1 maintenance		■	■	■		■	■	■				
6	Low voltage system of MW1	■	■			■							
7	MW1/HCAL1/ECAL0 software	■	■	■	■	■	■	■	■				
8	Data analysis	■	■	■	■	■	■	■	■	■	■	■	■
9	Detector remote control system	■	■										
10	COMPASS-III preparation	■	■	■	■	■	■	■	■	■	■	■	■
11	Detector's upgrade for COMPASS-III									■	■	■	■

Форма 26

Предлагаемый план-график и необходимые ресурсы для осуществления проекта.

Наименование узлов и систем установки, ресурсов, источников финансирования			Потребности в ресурсах (тыс. долл.)	Предложения лаборатории по распределению финансирования и ресурсов		
				2017	2018	2019
Необходим ресурсы	Нормо	ОП ОИЯИ - механические работы - КБ	 700 300	 500 100	 100 100	 100 100
Источник финансир		Затраты из бюджета, в том числе инвалютные средства	842	292	295	265
		Другие источники	120	40	40	40

		Год											
№	Название	**2017**				**2018**				**2019**			
		I	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**
1	Набор данных		■	■	■		■	■	■				
2	Обслуживание ECAL0		■	■	■		■	■	■				
3	Система мониторирования и ремонт ECAL0/HCAL1	■	■			■							
4	Обслуживание HCAL1		■	■	■		■	■	■				
5	Обслуживание MW1		■	■	■		■	■	■				
6	Система низковольтного питания MW1	■	■			■							
7	MW1/HCAL1/ECAL0 программное обеспечение	■	■	■	■	■	■	■	■				
8	Анализ данных	■	■	■	■	■	■	■	■	■	■	■	■
9	Создание системы удаленного контроля	■	■										
10	Участие в подготовке проекта COMPASS-III	■	■	■	■	■	■	■	■	■	■	■	■
11	Модернизация детекторов для COMPASS-III									■	■	■	■

Form 29

Total cost of the Project :
COMPASS-II. Study of the Nucleon and Hadron Structure at CERN.
Theme code: 02-0-1085-2009-2019

# Item	**Total**	**2017**	**2018**	**2019**	
1.	design bureau (man-h)	300	100	100	100
2.	workshops (man-h)	700	500	100	100
3.	Materials	**110**	**40**	**35**	**35**
4.	Equipment	**75**	**25**	**25**	**25**
5.	Subcontracts (collab common fund)	**222**	**72**	**75**	**75**
6.	Travels, including outside RUSSIA inside RUSSIA	 **420** **15**	 **150** **5**	 **150** **5**	 **120** **5**
	Total K$ (man-h)	**842** 1000	**292** 600	**290** 200	**260** 200

Форма 29

Смета затрат по проекту:
Изучение структуры нуклонов и адронов в в ЦЕРН (эксперимент COMPASS-II).
Шифр темы: 02-0-1085-2009/2019

#		**Сумма**	**2017**	**2018**	**2019**
1.	конструкт. бюро (чел.-ч.)	300	100	100	100
2.	Опытное производство(чел.-ч)	700	500	100 100	
3.	Материалы	**110**	**40**	**35**	**35**
4.	Оборудование	**75**	**25**	**25**	**25**
5.	Контракты (взнос в коллабор.)	**222**	**72**	**75**	**75**
6.	Командирование За пределы России По России	 **420** **15**	 **150** **5**	 **150** **5**	 **120** **5**
	Сумма (тыс.долл.) (чел-ч.)	**842** 1000	**292** 600	**290** 200	**260** 200