STUDIES OF THE NUCLEON AND HADRON STRUCTURE AT CERN
Project COMPASS-II,
theme 02-0-1085-2009/2016,
extension for 2017-2019

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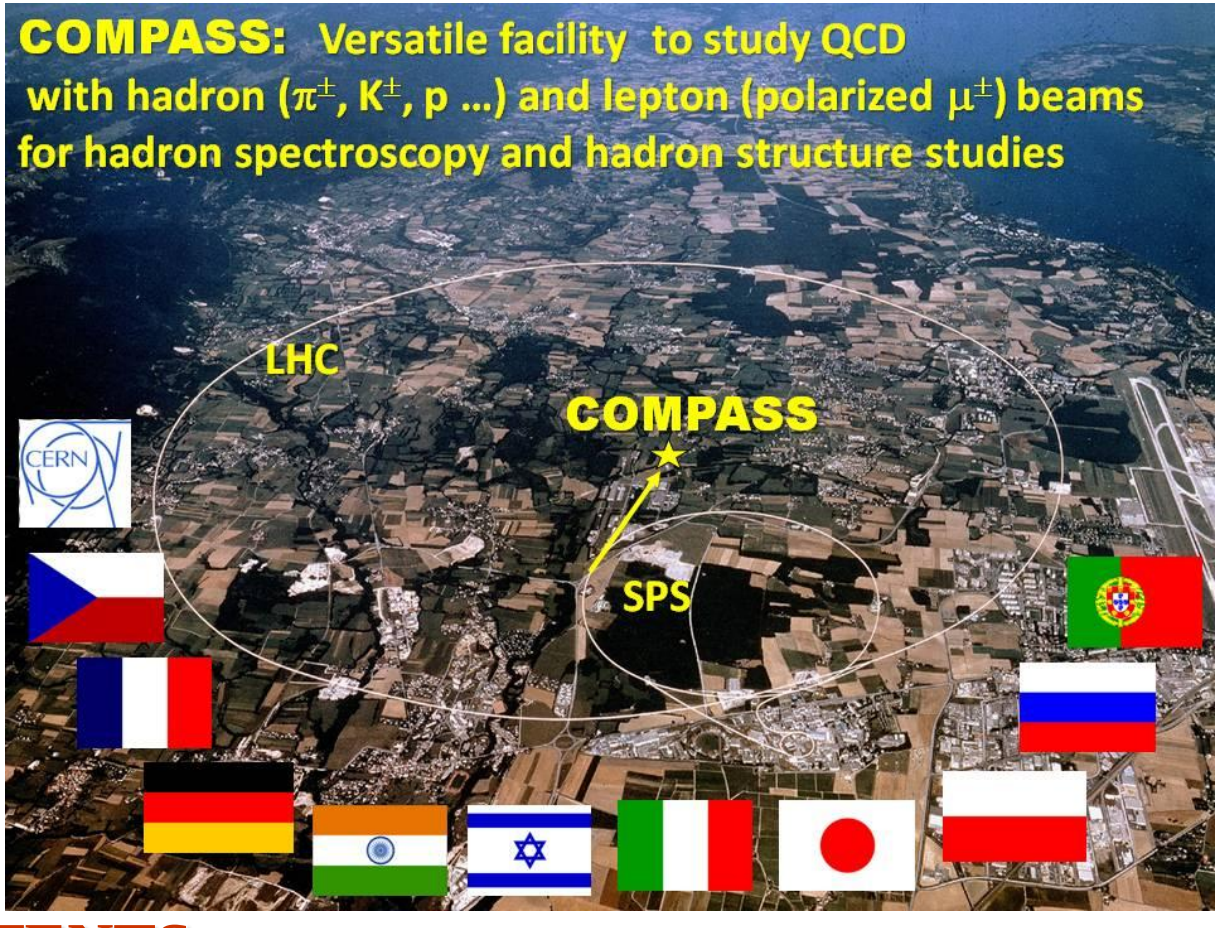


CONTENTS

1.INTRODUCTION

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

The COMPASS-II proposal, suggested by the same Collaboration as continuation of COMPASS, has been approved in May 2010 and corresponding theme at JINR has been prolonged for 2014-2016.

This stage of the Experiment is related to continuation the SIDIS measurements, particulary for studies of TMD PDFs measurements of Generalized Parton Distributions (GPD) and Matveev-Muradyan-Tavkhelidze or Drell-Yan (DY) reactions.

We request to prolong the COMPASS-II project and theme at JINR up to end of 2019.

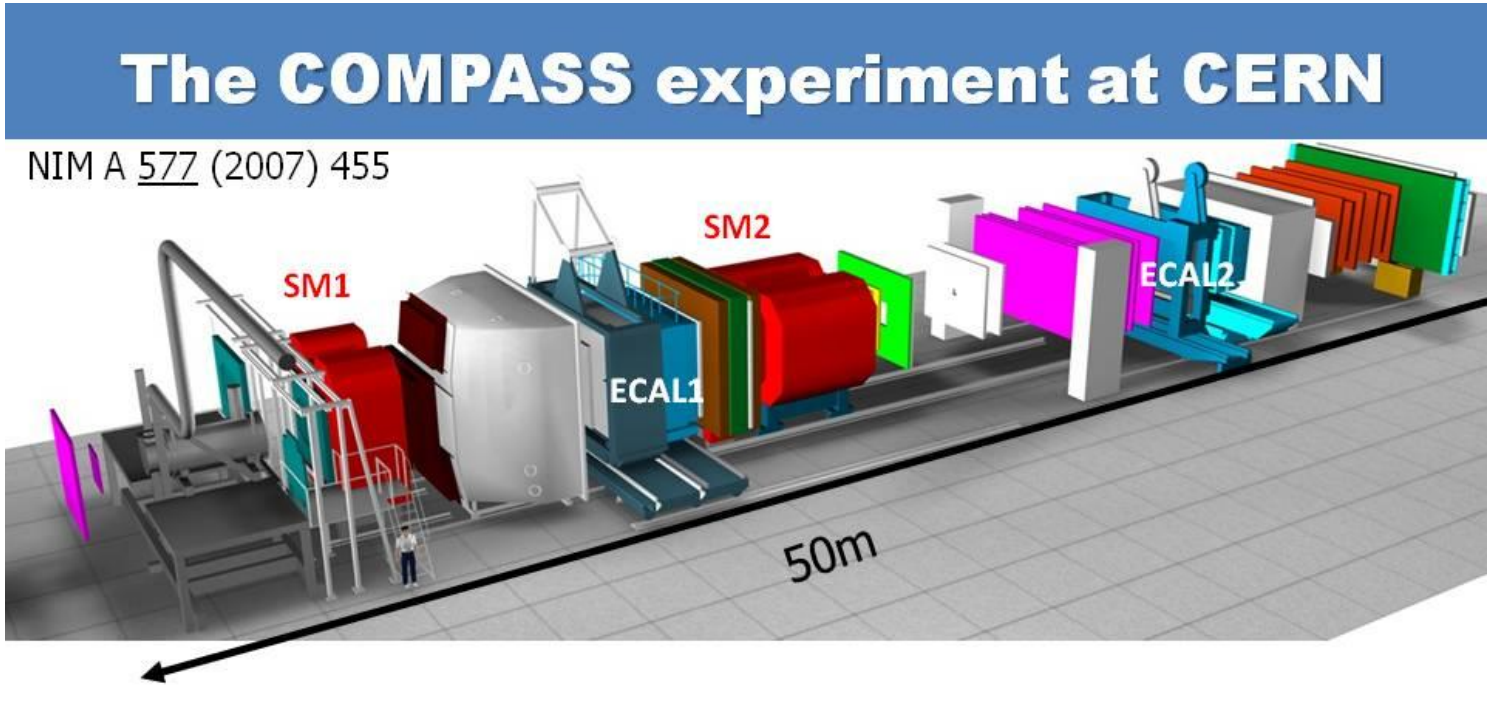
This period covers a continuation of analysis of the muon and hadron data taken up to 2016, preparations of equipments, data taking and analysis in 2017-2019.

2. MAIN COMPASS RESULTS IN 2014-2016.

Up to now the COMPASS Collaboration has published and submitted 53 papers, 23 of them in 2014-2016.

For this period COMPASS members have presented about 250 talks at the International Conferences and workshops.

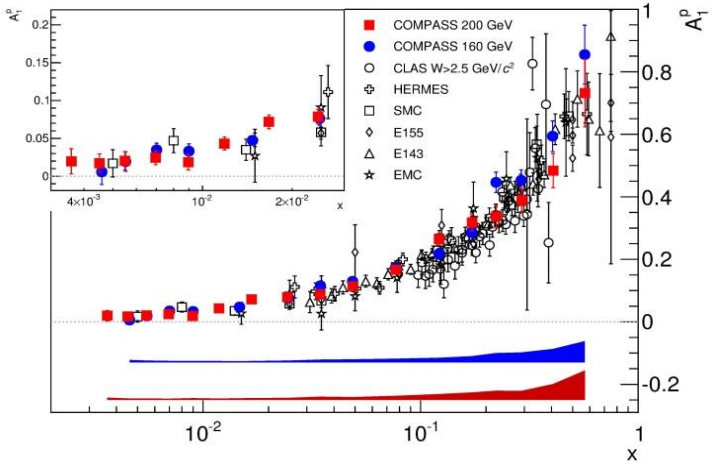
The annual international workshop on hadron structure and spectroscopy took place in town Suzdal on 18th-20th of May. COMPASS and JINR group were organizers of the event.



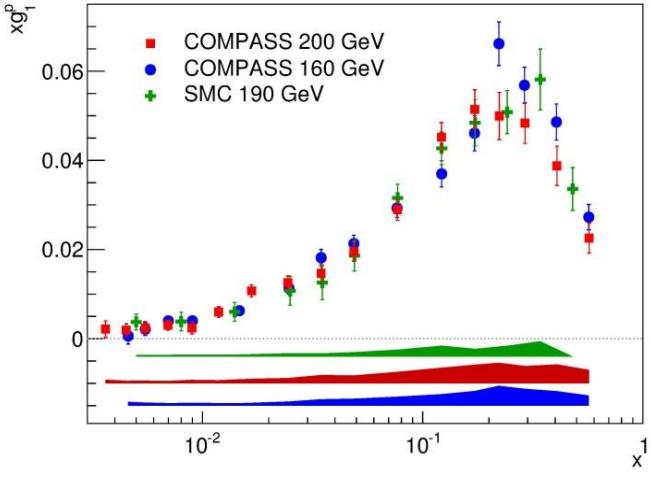
2. MAIN COMPASS RESULTS IN 2014-2016.

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

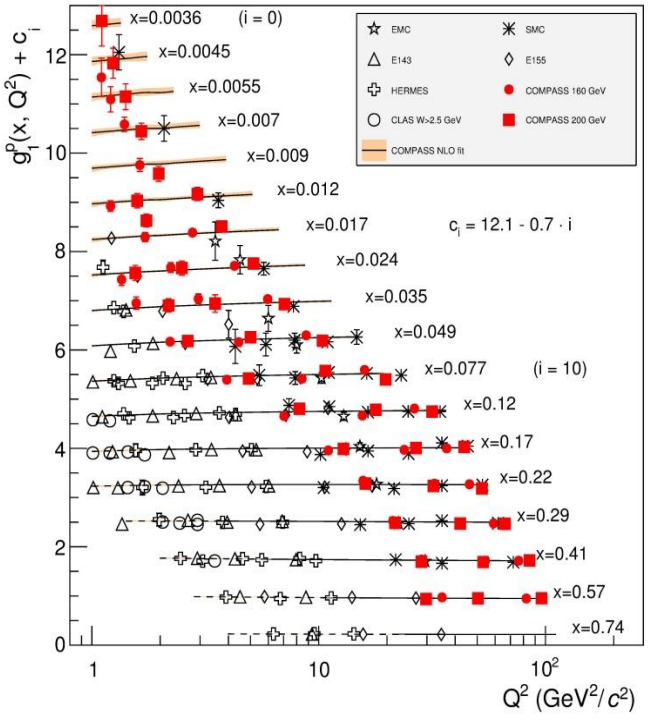
PLB 753 (2016) 18



The asymmetry A_1^p as a function of x at the measured values of Q^2 as obtained from the COMPASS data at 200 GeV.



The spin-dependent structure function xg_1^p at the measured values of Q^2 as a function of x.



World data on the spin-dependent structure function g_1^p as a function of Q^2 for various values of x with all COMPASS data in red (full circles: 160GeV, full squares: 200GeV).

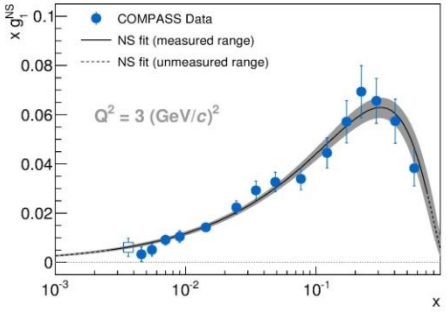


Figure : Values of $xg_1^{NS}(x)$ at $Q^2 = 3\,(\mathrm{GeV}/c)^2$ compared to the non-singlet NLO QCD fit using COMPASS data only. The errors bars are statistical. The open square at lowest x is obtained with g_1^d taken from the NLO QCD fit.

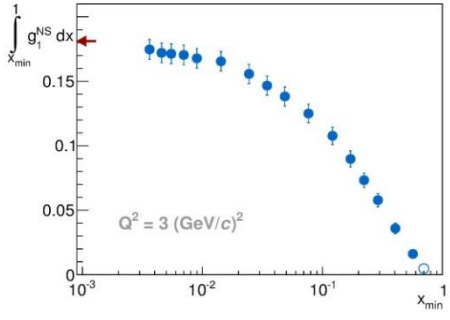


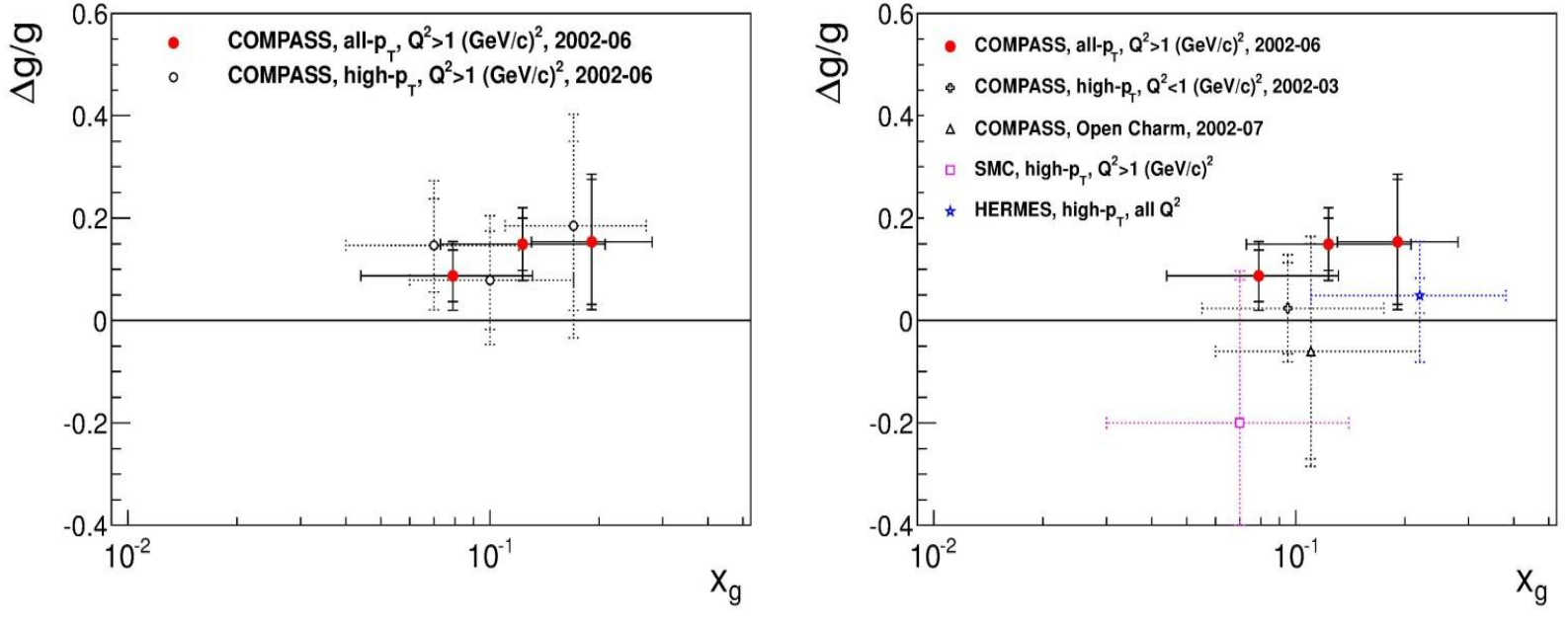
Figure : Values of $\int_{x_{min}}^{1} g_1^{NS} dx$ as a function of x_{min}. The open circle at $x = 0.7$ is obtained from the fit. The arrow on the left side shows the value for the full range, $0 \le x \le 1$.

2. MAIN COMPASS RESULTS IN 2014-2016.

Leading-order determination of the gluon polarization using a novel method

CERN-PH-EP-2015-328, subm . to EPJC

A re-evaluation of the gluon polarisation Δg/g in the nucleon is presented, which is based on the measurement of the longitudinal double-spin asymmetry using semi-inclusive events with photon virtuality $Q^2 > 1$ (GeV/c)^2. The data were obtained by the COMPASS experiment at CERN using a 160 GeV/c polarised muon beam scattering off a polarised ^{6}LiD target.



The values obtained at leading order in pQCD do not show any significant dependence on x_g
Averaged over the three intervals, the result is

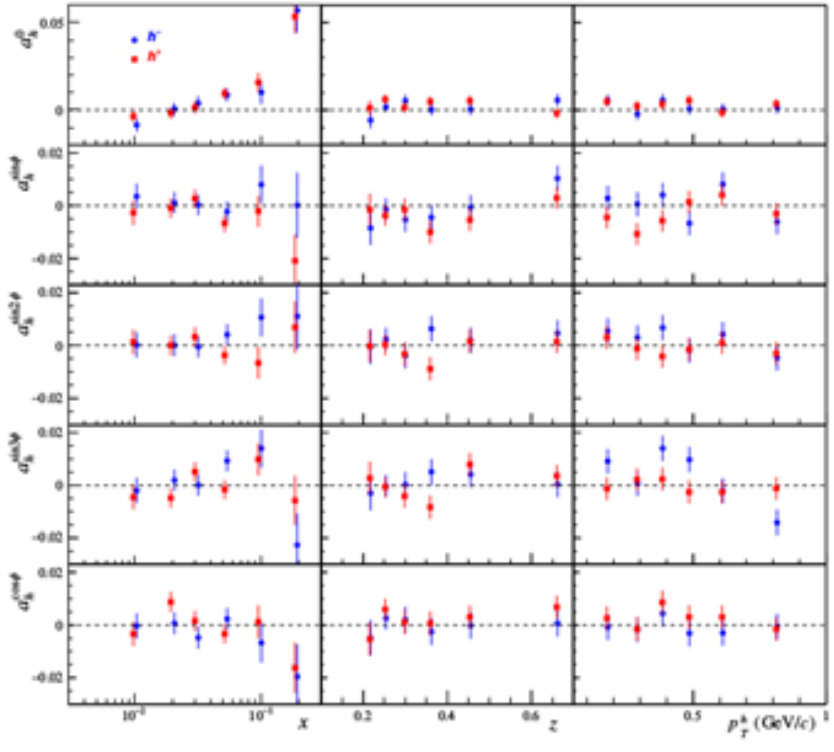
$< \Delta g/g > = 0.113 \pm 0.038(\text{stat.}) \pm 0.036(\text{syst.})$ at

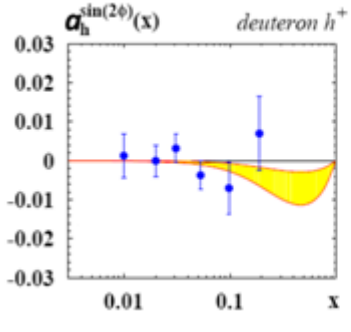
$\langle x_g \rangle \approx 0.10$ and a hard scale of $\mu^2 = \langle Q^2 \rangle = 3(\text{GeV/c})^2$.

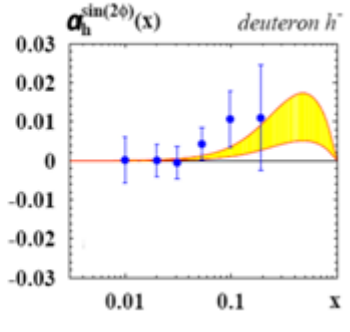
2. MAIN COMPASS RESULTS IN 2014-2016.

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

CERN-EP/2016-245, submitted to PLB







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 predicted by theory: sinφ , sin2φ , sin3φ and cosφ.

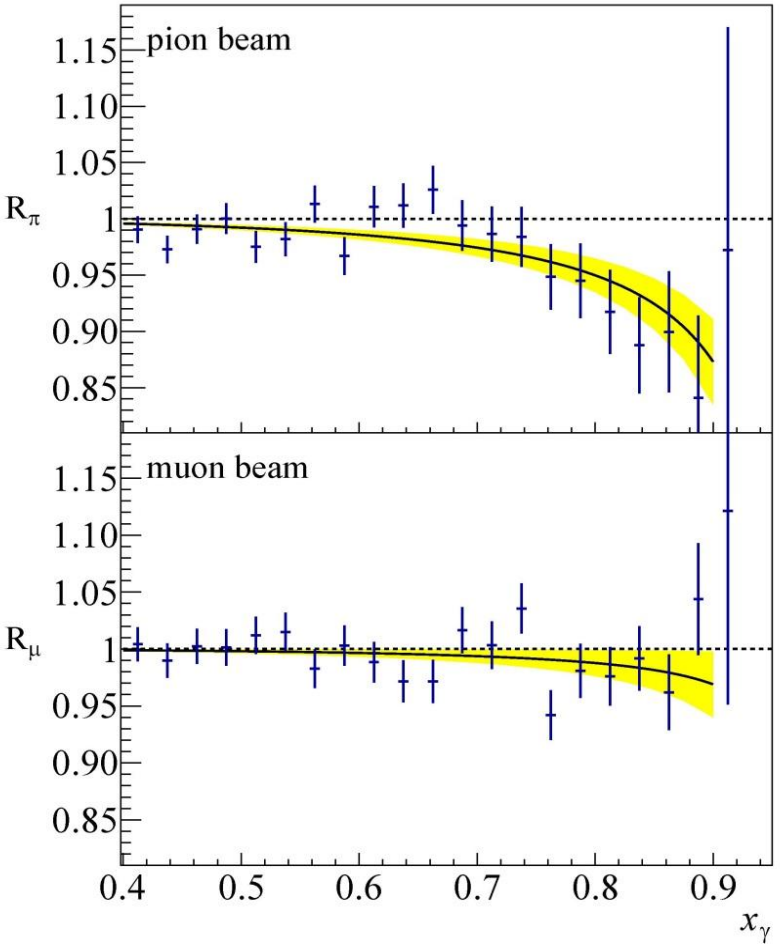
Except the φ-independent term, all the modulation amplitudes are very small, and no clear kinematic dependence could be observed within experimental uncertainties. Still, there are indications for a possible x-dependence of the sin2φ and cosφ amplitudes. The sin2φ amplitude for h- is mostly positive and rises with increasing x, while for h+ it is mostly negative and decreases with x

2. MAIN COMPASS RESULTS IN 2014-2016.

Measurement of the charged-pion polarizability

PRL 114 (2015) 062002

$$R_\pi = \left(\frac{d\sigma_{\pi\gamma}}{dx_\gamma}\right) \Big/ \left(\frac{d\sigma^0_{\pi\gamma}}{dx_\gamma}\right) = 1 - \frac{3}{2}\cdot\frac{m_\pi^3}{\alpha}\cdot\frac{x_\gamma^2}{1-x_\gamma}\,\alpha_\pi$$



The COMPASS collaboration at CERN has investigated pion Compton scattering, π-γ-> π-γ, at centre-of-mass energy below 3.5 pion masses. The process is embedded in the reaction π- Ni-> π-γNi, which is initiated by 190 GeV pions impinging on a 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 a sample of 63 000 events, the electric pion polarisability is determined to be $\alpha_\pi=(2.0\pm0.6\text{stat}\pm0.7\text{syst})\text{x}10\text{-}4\text{fm}^3$ under the assumption $\alpha_\pi=-\beta_\pi$ that relates the electric and magnetic dipole polarisabilities. This result is in tension with previous dedicated measurements, while it is found in agreement with the expectation from chiral perturbation theory. 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.

The x_γ dependence of the ratio of the measured differential cross section dσ/dxγ over the expected cross section for point-like particles.

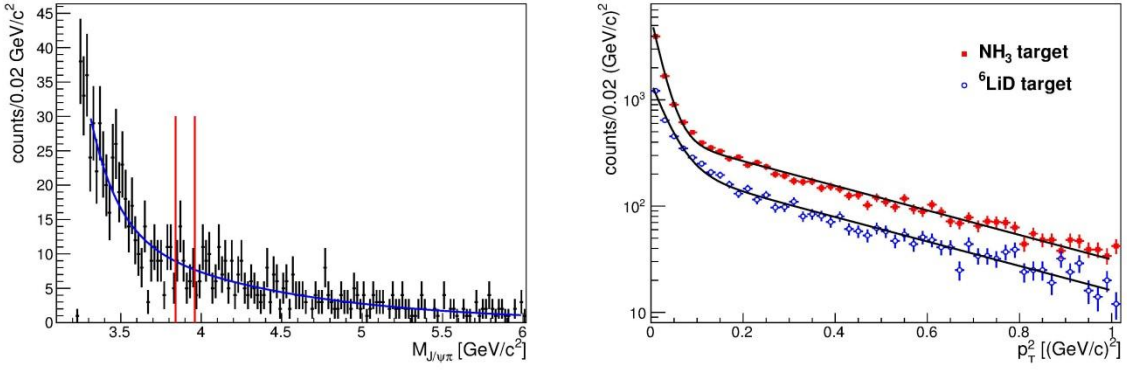
2. MAIN COMPASS RESULTS IN 2014-2016.

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

PLB 742 (2015) 330

Upper limits for $Z_c^{\pm}(3900)$ production rate for intervals of $\sqrt{s_{\gamma N}}$.

Interval	$\langle\sqrt{s_{\gamma N}}\rangle$, GeV	$BR(J/\psi\pi)\times\sigma_{Z_c}/\sigma_{J/\psi}$, 10^{-3}
Full	13.8	3.7
$\sqrt{s_{\gamma N}} < 12.3$ GeV	10.8	10
12.3 GeV $< \sqrt{s_{\gamma N}} < 14.1$ GeV	13.2	3.7
14.1 GeV $< \sqrt{s_{\gamma N}} < 15.4$ GeV	14.7	4.5
15.4 GeV $< \sqrt{s_{\gamma N}}$	16.4	6.0



(a) (b)

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

A search for the exclusive production of the $Z^{\pm}_c$ (3900) hadron by virtual photons has been performed in the channel $Z^{\pm}_c$ (3900)-> J/Ψπ± . The data cover the range from 7 GeV to 19 GeV in the centre-of- mass energy of the photon-nucleon system. The full set of the COMPASS data set collected with a muon beam between 2002 and 2011 has been used. An upper limit for the ratio BR($Z^{\pm}_c$ (3900)-> J/Ψπ±)xσ_{γ}^{N}->J/Ψ_N of 3.7×10^{-3} has been established at the confidence level of 90%.

2. MAIN COMPASS RESULTS IN 2014-2016.

Observation of a new narrow axial-vector meson $a_1(1420)$

PRL 115 (2015) 082001

The COMPASS collaboration at CERN has measured diffractive dissociation of 190 GeV/c pions into the π-π-π+ final state using a stationary hydrogen target. A partial-wave analysis (PWA) was performed in bins of 3π mass and four-momentum transfer using the isobar model and the so far largest PWA model consisting of 88 waves.

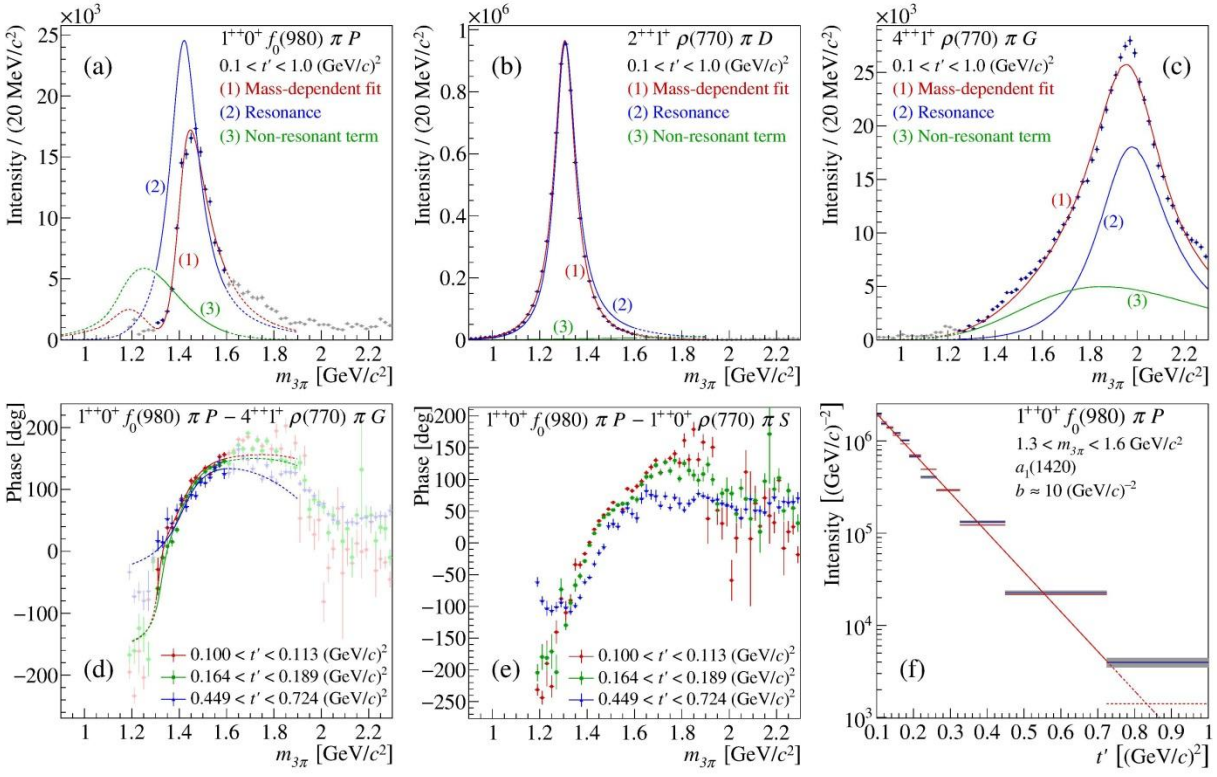
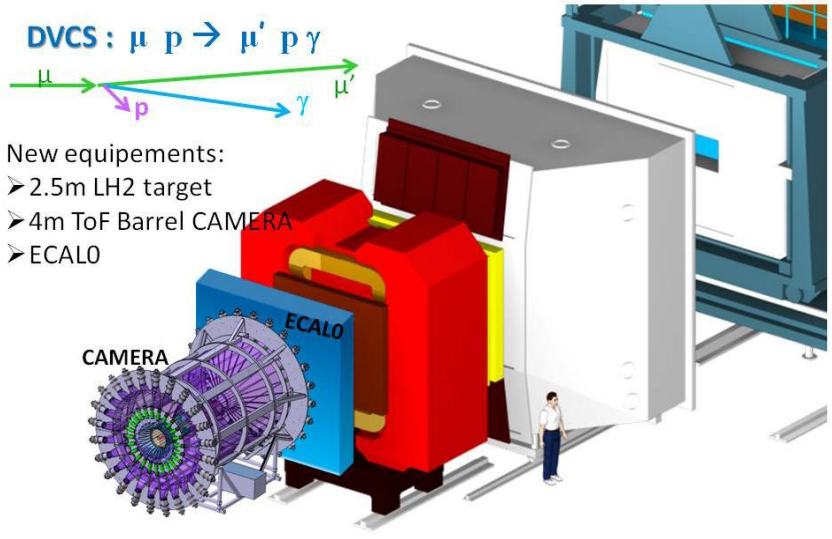
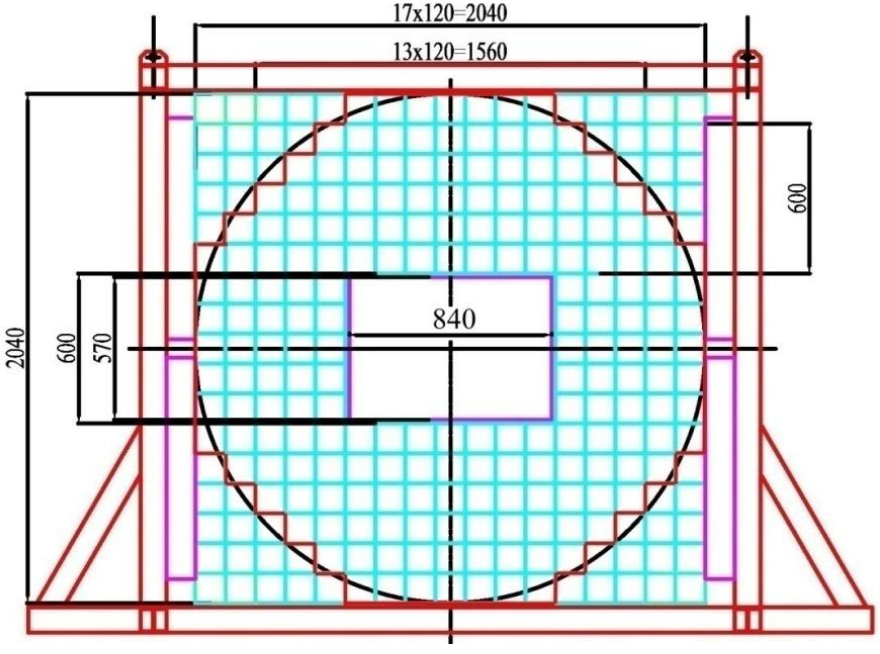


Figure : (Color online) Results of the PWA in 3π mass bins of 20 MeV/c^2 width (data points with statistical errors only) showing the intensity of the three waves $1^{++}\,0^+\,f_0(980)\,\pi P$ (a), $2^{++}\,1^+\,\rho(770)\,\pi D$ (b), and $4^{++}\,1^+\,\rho(770)\,\pi G$ (c), summed over t' in the region 0.1 to 1.0 (GeV/c)^2. The curves depict the result of the resonance-model fit (red) and the individual components (blue: resonances, green: non-resonant contributions). As an example, (d) shows the relative phase between 1^{++} and 4^{++} together with the model curves and (e) the phase between two 1^{++} decay modes, in both cases for 3 t' bins. Data points not used in the resonance-model fit are indicated in gray or light colors, the extrapolated fit model by dashed curves. The t'-dependence of the $a_1(1420)$ intensity in the $1^{++}\,0^+\,f_0(980)\,\pi P$ wave, integrated over the 3π mass range from 1.3 to 1.6 GeV/c^2, is shown in (f). The red lines represent a single-exponential fit to the data in the range $0.100 < t' < 0.724$ (GeV/c)^2.

A narrow $J^{PC} = 1^{++}$ signal is observed in the $f_0(980)\pi$ channel. We present a 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 $f_0(980)\pi$.
We identify a new a_1 meson with mass (1414^{+15}_{-13})MeV/c^2 and width (153^{+8}_{-23})MeV/c^2. Within the final states investigated in our analysis, we observe the new $a_1(1420)$ decaying only into $f_0(980)\pi$, suggesting its exotic nature.

2. MAIN COMPASS RESULTS IN 2014-2016. ECAL0.





The COMPASS-II upgrade for GPD measurements includes construction of the new electromagnetic calorimeter ECAL0 and Recoil Particle Detector (ToF barrel CAMERA).

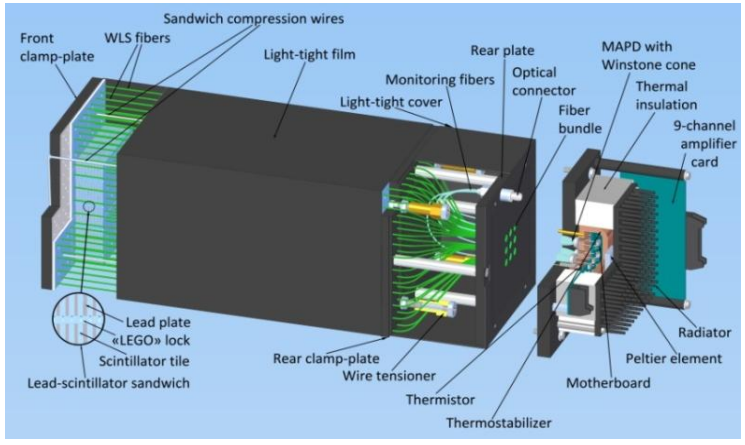
New calorimeter ECAL0 covering a wide photon angles is suggested by the JINR Dubna.

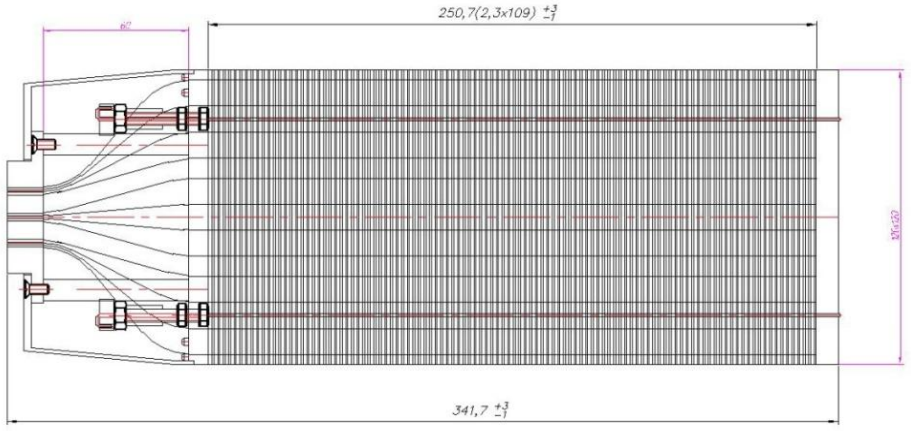
The ECAL0 will supplement the COMPASS spectrometer for the GPD studies via the exclusive DVCS process $\mu+p\rightarrow\mu'+p'+\gamma$.

The main tasks of the ECAL0 are the following:
- together with the ECAL1 and ECAL2, to ensure a hermiticity of the setup for photons from DVCS,
-to help in reduction of a background from the SIDIS process $\mu+p\rightarrow\mu'+p'+\pi^0+X$,
- to enlarge the kinematic domain of the DVCS registered by COMPASS.

The ECAL0 consists of:
194 9-tower modules,
1746 MAPDs and readout channels;
28 MSADCs and HV system (temperature stabilization, power suppliers and slow control).

2. MAIN COMPASS RESULTS IN 2014-2016. ECAL0.

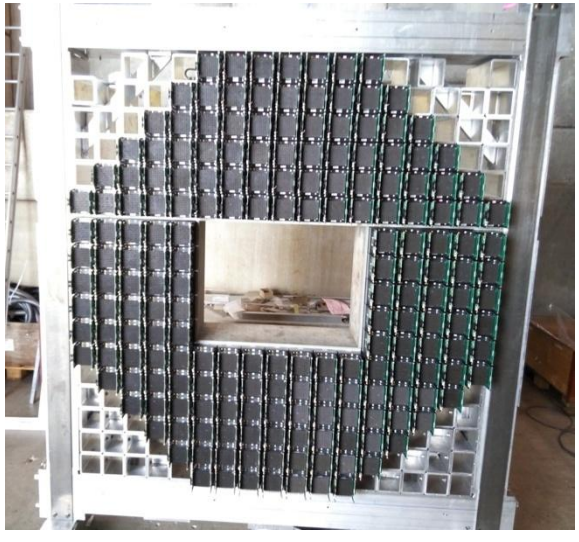


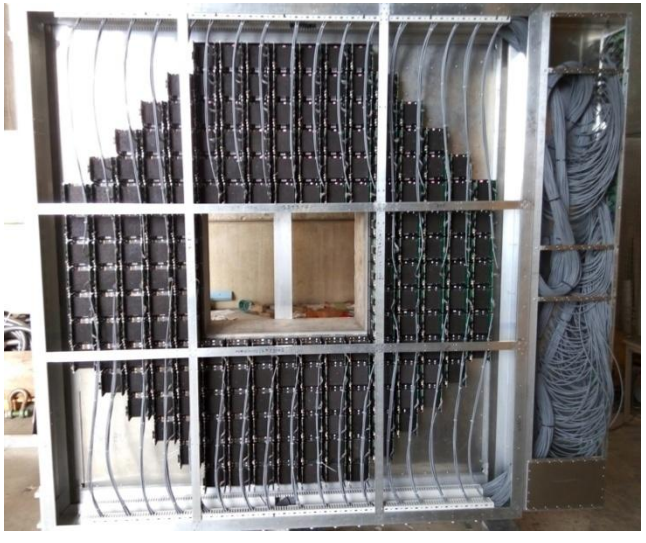


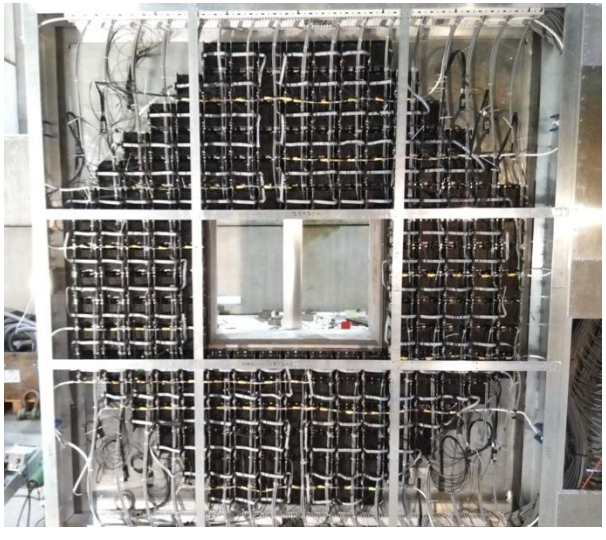
Technology	Shashlyk
Scintillator	Polystyrene, Kharkov
Absorber	Lead
Number of layers	109
Sc / Pb plates thickness, mm	1.5/0.8
Pb/Sc plates dimension, cm	12.0 /3(4x4)
Moliere radius, cm	3.5
Radiation length, cm	1,64
Number of tower	9
Fiber	BICRON BCF91AMC, d=1.2 mm
Number of fibers per tower	16
Diam. of bundle, mm	6.5
Light guide	Winston cone glued to photodetector
Photon detector	Hamamatsu S12572-10P
Total thickness, cm	25.2(~ 15 X_0)
Electronics	FEE+MSADC
Temperature stabilization	Peltier cooler

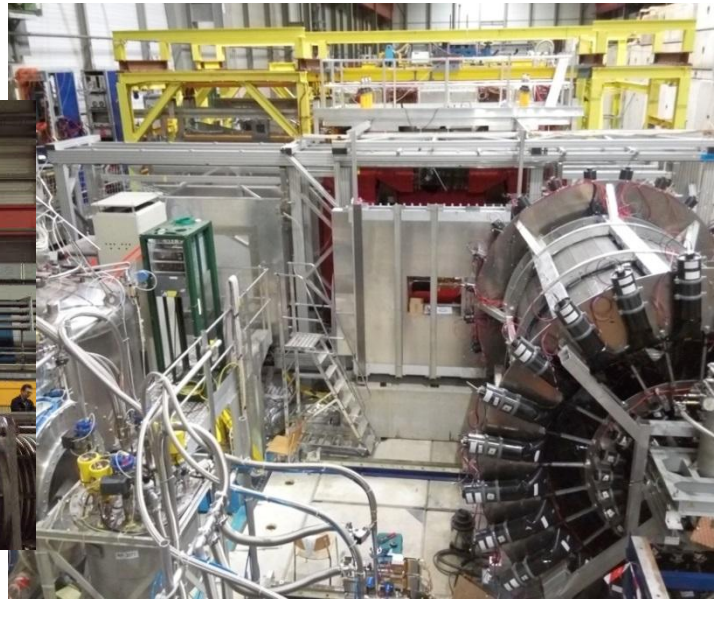
Development of the ECAL0 has started in 2008. In 2011 JINR group with the help from Collaboration has performed tests of the part of the new electromagnetic calorimeter ECAL0 (3x3 module matrix) with T9 and COMPASS beams. The main aim of the tests was to get "green light" for mass production of ECAL0 modules in ISMA, Kharkov, registration units in JINR, Dubna, MSACDs in TUM, Munchen , FEE electronics in WUT, Warsaw.

2. MAIN COMPASS RESULTS IN 2014-2016. ECAL0.

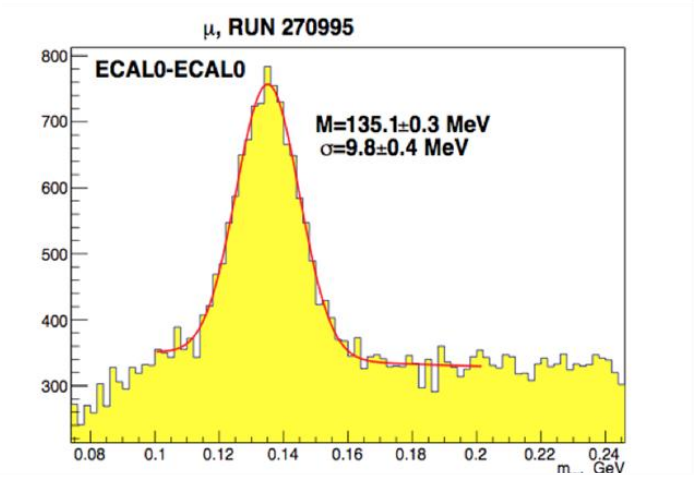


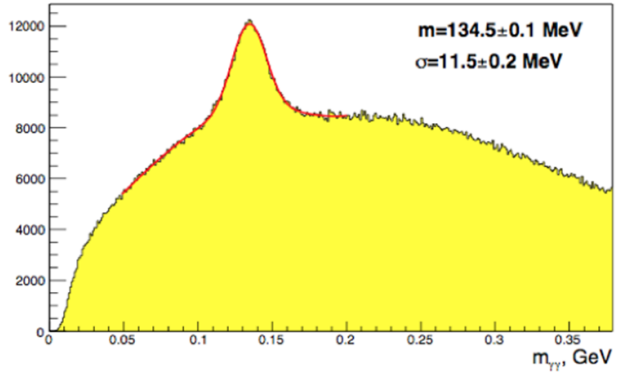




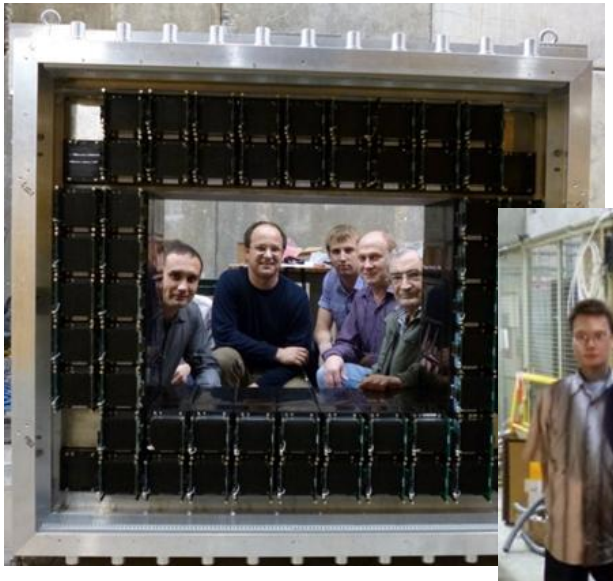


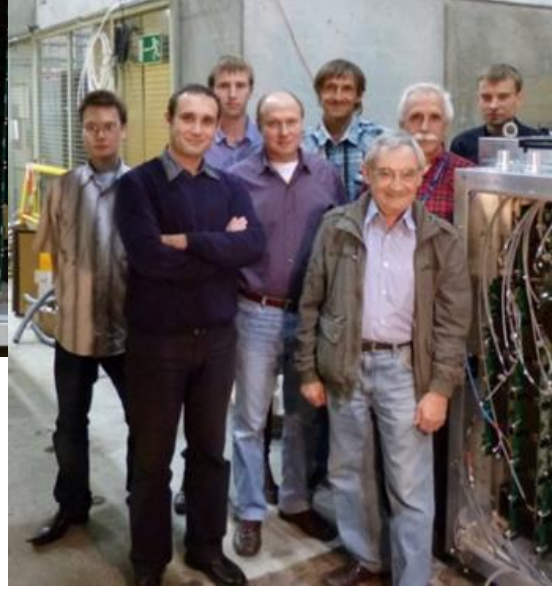
2. MAIN COMPASS RESULTS IN 2014-2016. ECAL0.





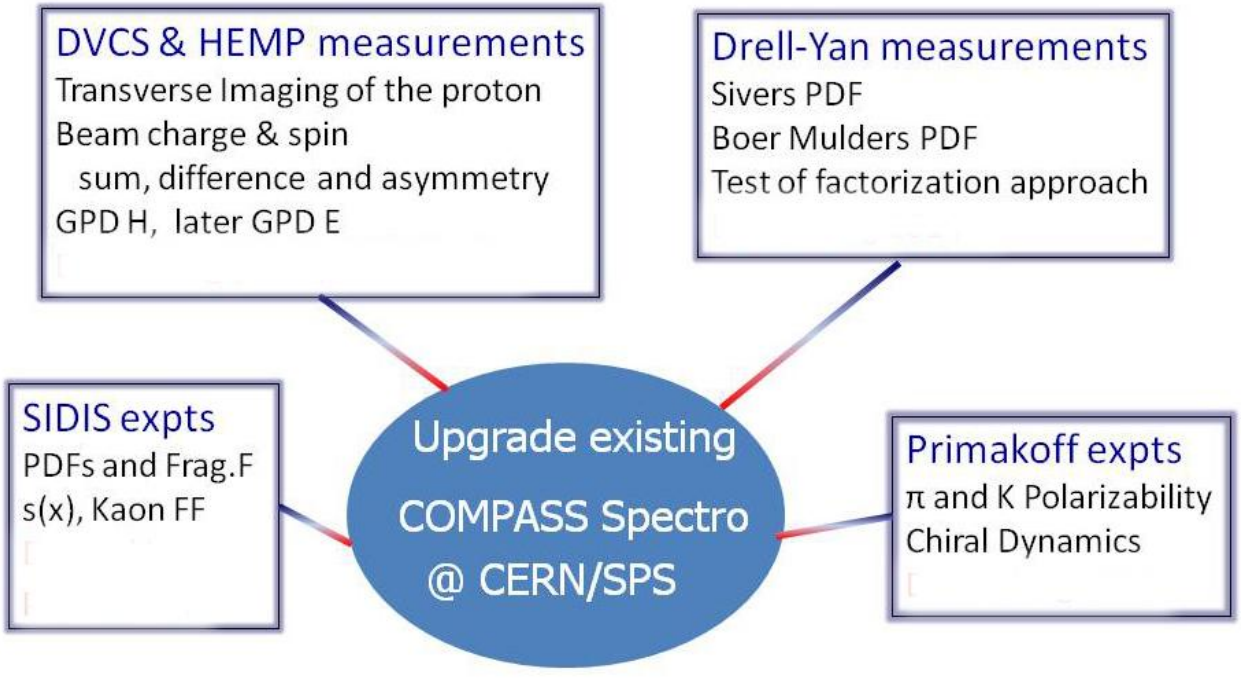
Groups of other scientific centers and production companies took part in development of systems of a calorimeter. Except the COMPASS colleagues, ISMA and Rusalox, power system, monitoring and thermostabilizaton systems were developed and produced by HVSYS firm, system of reading (ADC) and amplifiers were created by groups from Munich and Warsaw, and the group from Prague produced optical splitters for system of ECAL0 slow control and monitoring.





Stable operation of the calorimeter within the first months of a data taking was appreciated by the COMPASS collaboration.

3. COMPASS-II measurements and analysis in 2017-2019



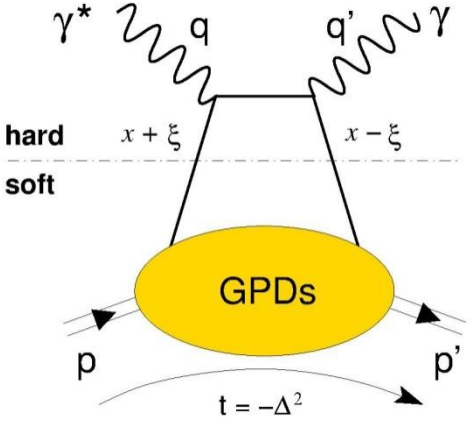
The COMPAS-II measurements have started in 2012 with a pion/kaon polarisability via Primakoff reactions and with GPD feasibility test using partially upgraded COMPASS-II spectrometer.

The further measurements will start in 2014 after the accelerator shutdown.
They will be focused on studies of transverse momentum dependent (TMD) distributions of partons in nucleons via Drell-Yan lepton pair production (running in 2014-2015, 2018) and measurements of Generalized Parton Distributions (GPDs) via hard exclusive meson production and DVCS (running in 2016-2017) .

In parallel with the GPD program, high statistic data for unpolarized SIDIS will be taken.

3. COMPASS-II measurements and analysis in 2017-2019.

The GPDs are universal distributions which contain as limiting cases nucleon form factors on the one hand and parton distribution functions (PDFs) on the other. The GPDs H^f and $\tilde{H}^f$ (f = u, d, s, g) describe processes where the nucleon helicity is preserved and contain as limiting cases the PDFs f_1 and g_1, respectively. Processes where the nucleon helicity is flipped are described by the GPDs E^f and $\tilde{E}^f$ 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.



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

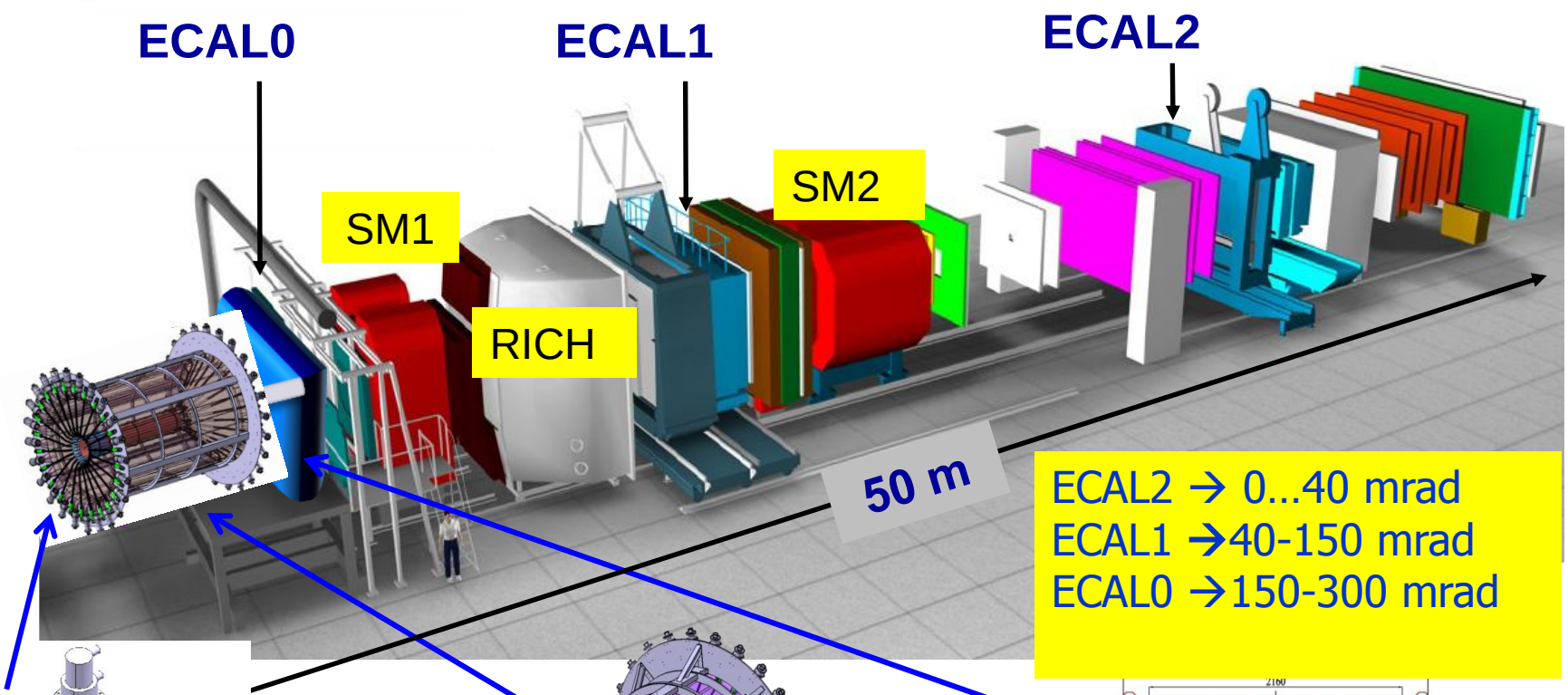
$$\mathcal{D} = d\sigma^{\overleftarrow{\pm}} - d\sigma^{\overrightarrow{-}} = 2(d\sigma_0^{DVCS} + \Re e\, I)$$

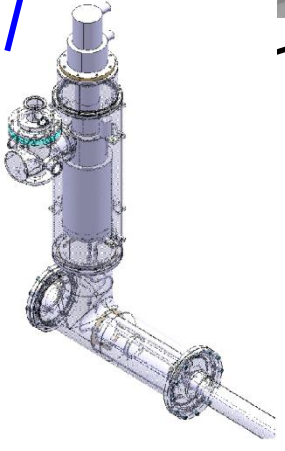
$$\mathcal{S} = d\sigma^{\overleftarrow{\pm}} + d\sigma^{\overrightarrow{-}} = 2(d\sigma_0^{BH} + d\sigma_0^{DVCS} + \Im m\, I)$$

The main tasks of GPDs investigations with Hard Exclusive Photon and Meson Production are as follows:

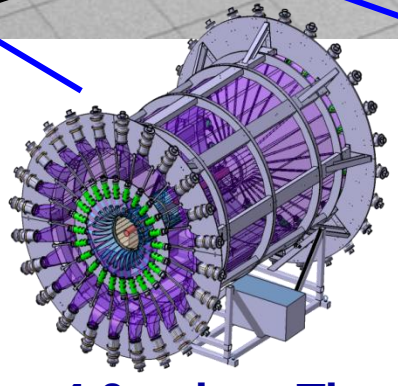
- **Measurements of the t-slope of the DVCS and HEMP cross section (transverse distribution of partons).**
- **Studies of the beam-charge-and-spin sum and difference of amplitudes for the GPD H determination.**
- **Measurements of longitudinal contribution of Vector Mesons ρ^0,ρ+,ω, φ (GPD H).**
- **Measurements of total contributions of π^0 (GPDs E and E_T).**

3. COMPASS-II measurements and analysis in 2017-2019.

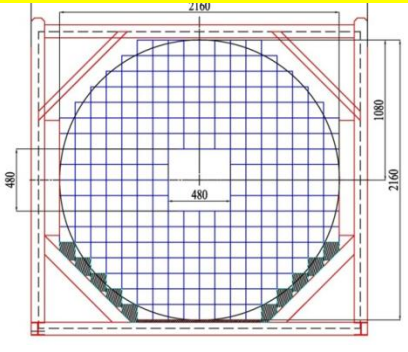




2.5 m long LH target

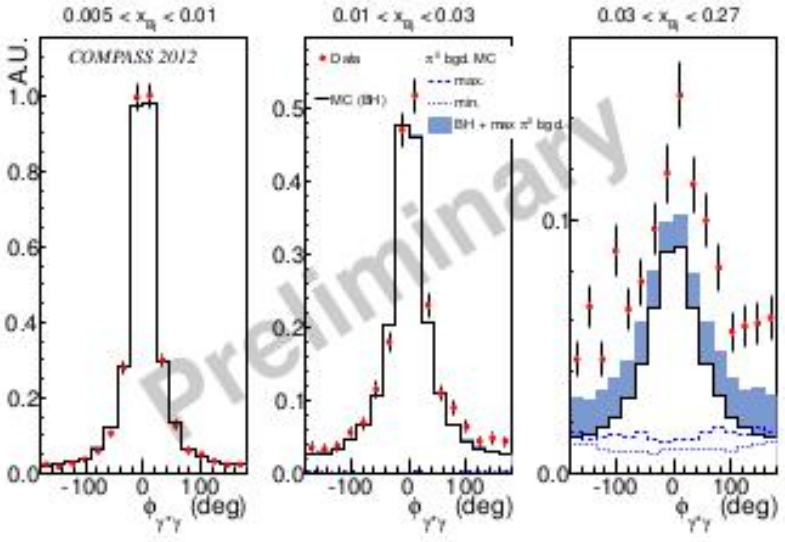


4.0 m longTime-Of-Flight detector: 24 inner and 24 outer slabs

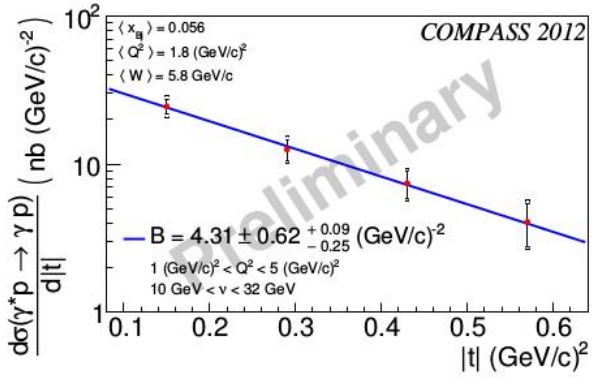


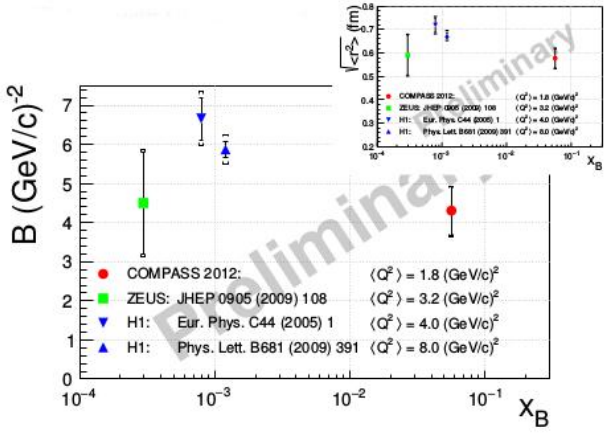
2x2 m² electromagnetic calorimeter, ECAL0

3. COMPASS-II measurements and analysis in 2017-2019



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 large angle calorimeter). The exclusive photon sample selected for data analysis, as a function of the azimuthal angle between the leptonic plane (defined by the incident and scattered lepton) and the hadronic plane (defined by the virtual and real photon).





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 $\left\langle r_\perp^2(x_B)\right\rangle \approx 2B(x_B)$ ve cross-section is parameterized as $d\sigma/dt \propto \exp(-B(x_B)|t|)$. The slope is measured between the $r_\perp$ truck 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'.

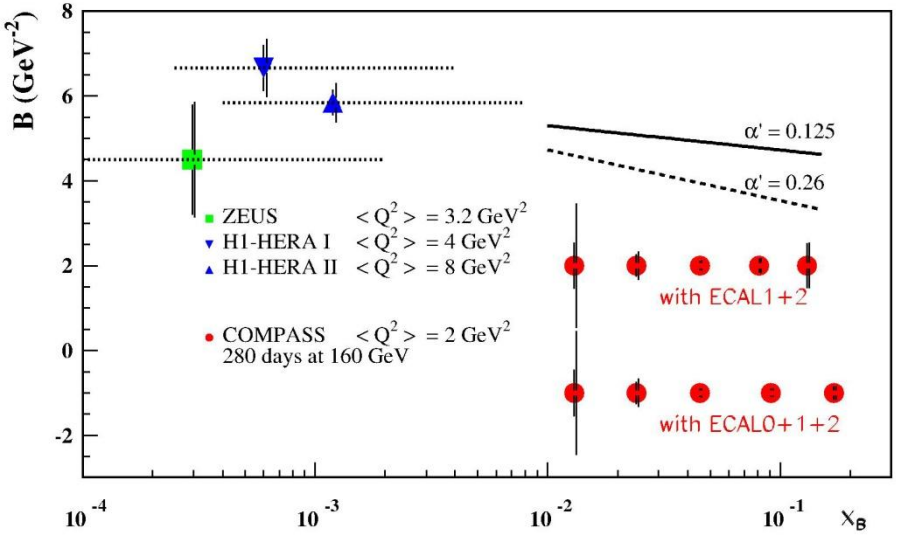
3. COMPASS-II measurements and analysis in 2017-2019

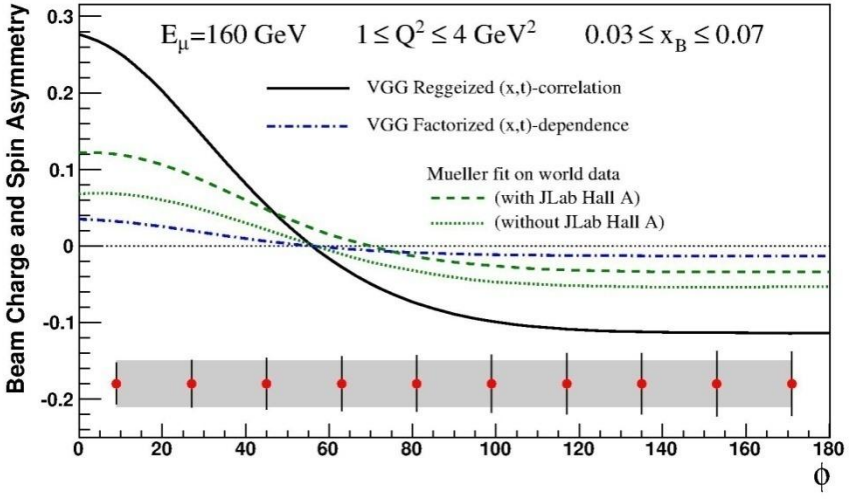
The GPD run has started in 2016 and will be continued in 2017.

The projected precision of a t-slope measurements for two year of data taking is presented using only ECAL1 and ECAL2 and with an ECAL0 calorimeter (left panel).

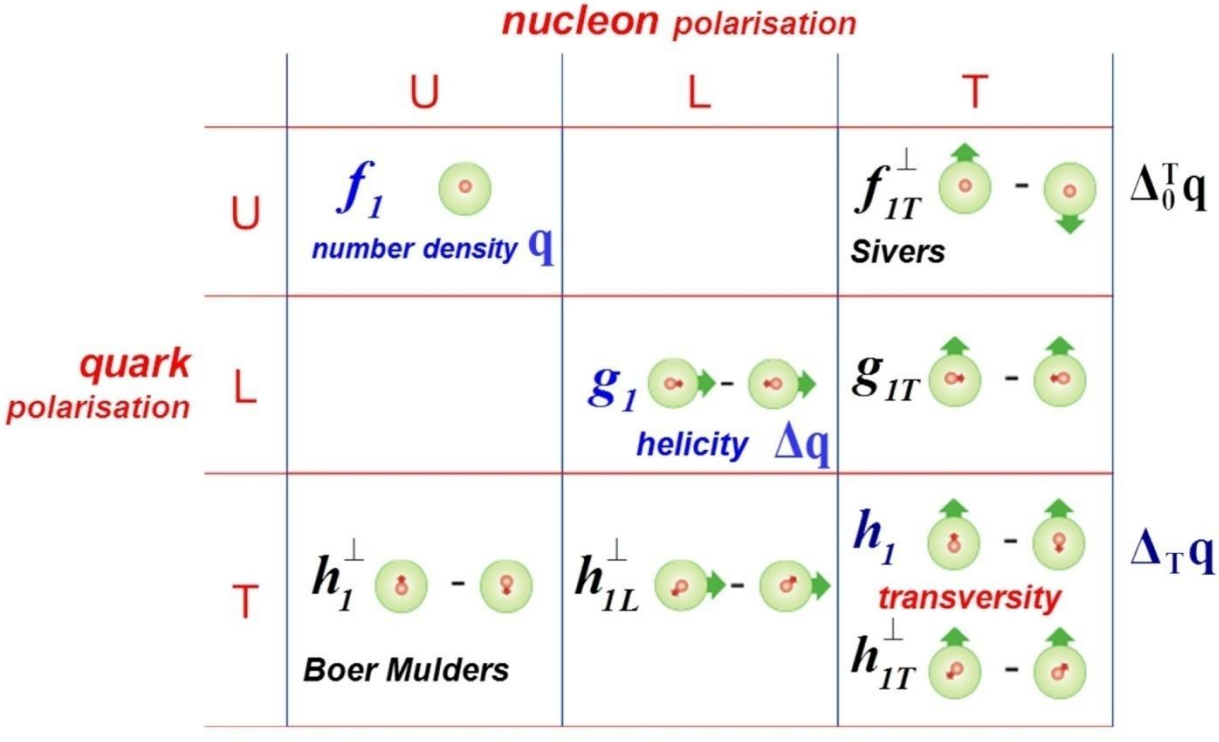
Projected precision of the beam charge and spin asymmetry measurements compared to various models is given (right panel).

Data analysis is in progress.





3. COMPASS-II measurements and analysis in 2017-2019



The 5 new TMD PDFs have different azimuthal modulations

- Consider the transverse parton momentum, k_T: 5 new TMD PDFs appear.

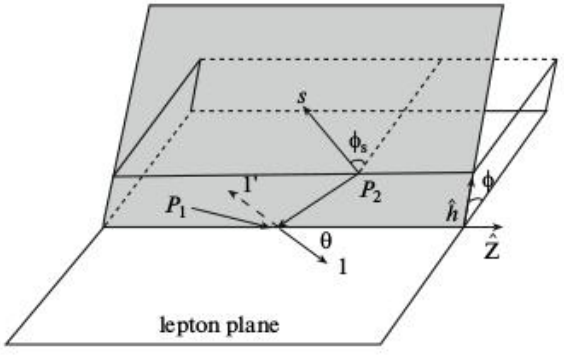
Large amount of COMPASS data: longitudinally polarized, transversely polarized, and unpolarized proton and deuteron targets
Last decade: giant steps both experimentally and theoretically

3. COMPASS-II measurements and analysis in 2017-2019

- Full formalism for two spin ½ hadrons
- COMPASS: access 4 TMDs:
  - Boer-Mulders, Sivers, Pretzelosity, Transversity

Arnold, Metz and Schlegel, Phys. Rev. D79 (2009) 034005.

- Access 4 TMDs – asymmetry modulations:



Boer-Mulders $A_U^{\cos 2\phi} \propto 1 + \bar{h}_1^{\perp} \otimes h_1^{\perp} \cos 2\phi$

Sivers $A_T^{\sin \phi} \propto S_T \left[\bar{f}_1 \otimes f_{1T}^{\perp} \sin \phi_s) \right]$

Pretzelosity $A_T^{\sin(2\phi+\phi_s)} \propto S_T \left[\bar{h}_1^{\perp} \otimes h_{1T}^{\perp} \sin(2\phi + \phi_s) \right]$

Transversity $A_T^{\sin(2\phi-\phi_s)} \propto S_T \left[\bar{h}_1^{\perp} \otimes h_1 \sin(2\phi - \phi_s) \right]$

Worm-Gear Not possible: needs double polarization

All four TMDs are also measured in SIDIS

3. COMPASS-II measurements and analysis in 2017-2019

- SIDIS vs TMD
  - SIDIS: TMD and FF
  - Drell-Yan: two TMDs

$$\sigma^{SIDIS} \propto TMD_p(x,k_T) \otimes D_f^h(z,Q^2)$$

$$\sigma^{DY} \propto TMD_\pi \otimes TMD_p$$

- Factorization and gauge invariance:

Collins, Soper, Sterman,
Adv. Ser. High En Phys. 5, 1988.

  - TMDs (unlike PDFs) can be process dependent ("non-universality")
  - Opposite sign in SIDIS and DY processes for T-odd TMDs:

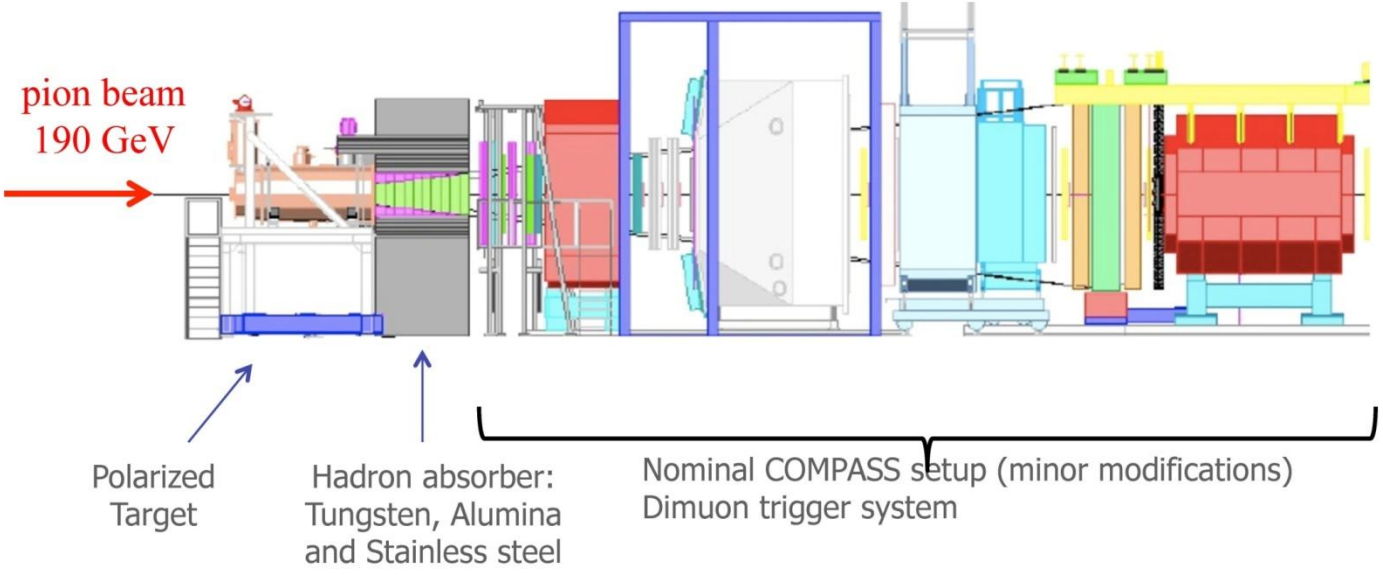
Sivers:
$$f_{1T}^{\perp}(SIDIS) = -f_{1T}^{\perp}(DY)$$

Boer-Mulders:
$$h_1^{\perp}(SIDIS) = -h_1^{\perp}(DY)$$

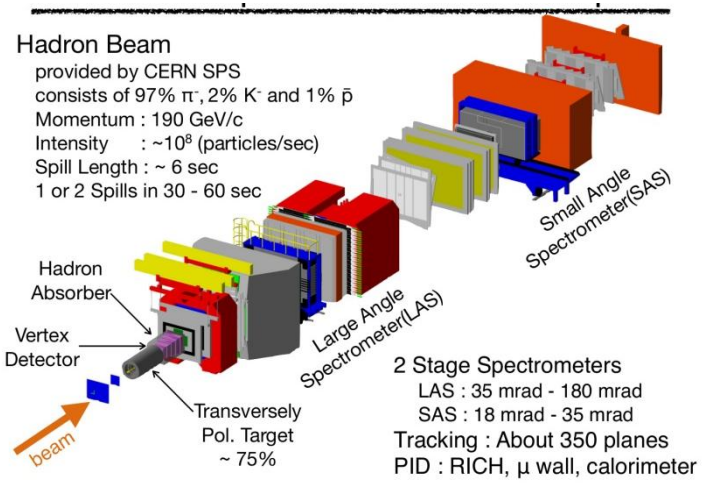
Crucial test of the QCD factorization approach

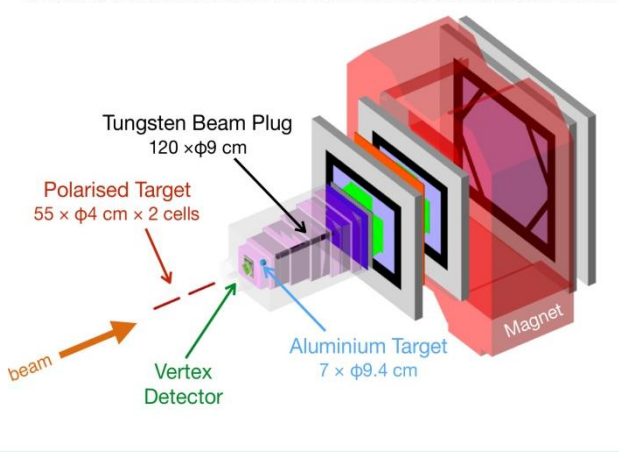
NB: Recent results of TSA for W/Z prod:
STAR@RHIC: arXiv: 1511.06003

3. COMPASS-II measurements and analysis in 2017-2019

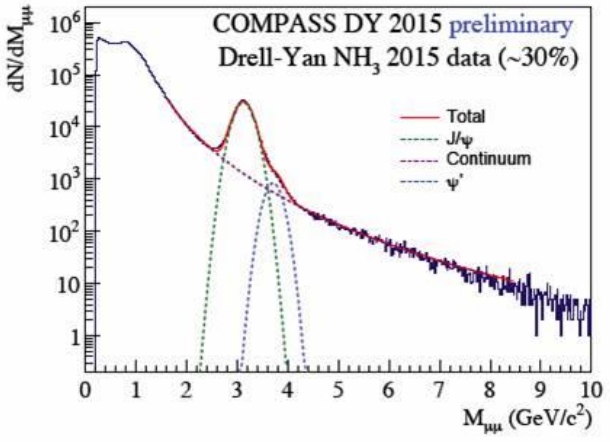


- Small cross sections – high intensity h beam (~10^9/spill of 10 sec)
- Nuclear targets: Al and W



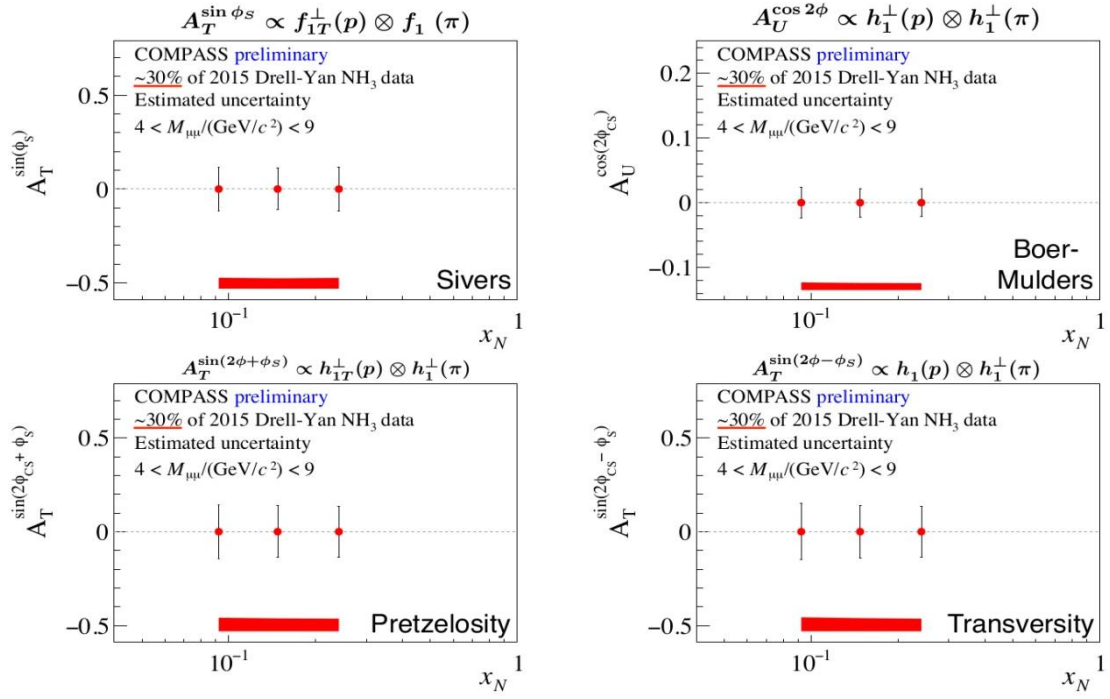


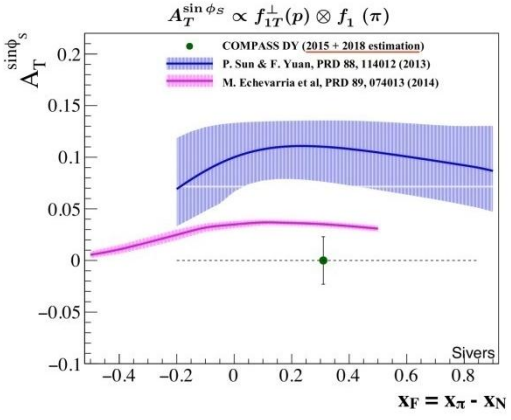
3. COMPASS-II measurements and analysis in 2017-2019



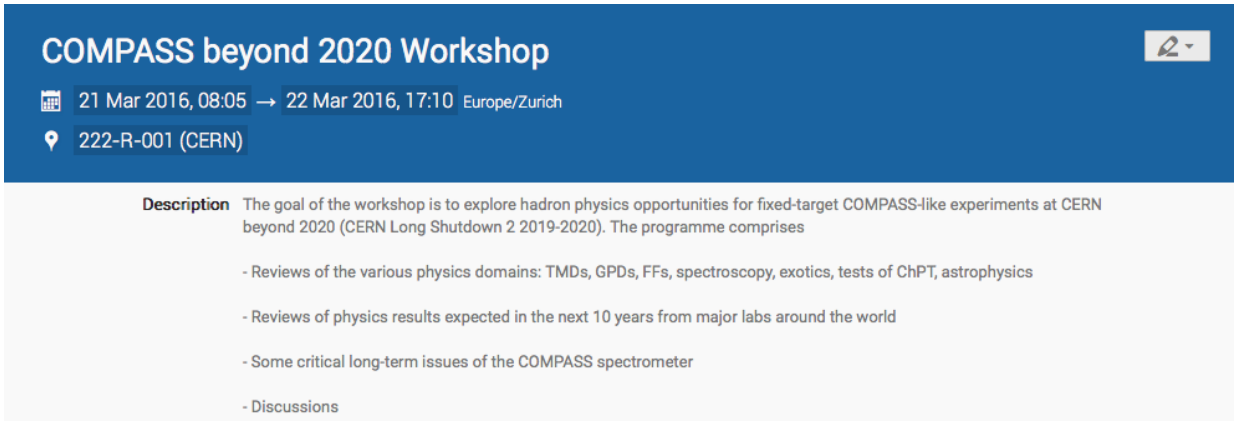
The Drell-Yan data taking has started in 2014 with pilot run. About 7K DY events and 200 K J/Ψ events were collected during three weeks of stable data taking. In 2015 COMPASS has taken about 80K DY events and 200 K J/Ψ events in 4.5 months of stable data taking. The analysis of the collected data is in progress.

COMPASS will continue DY measurements in 2018, the DY statistics will be increased essentially.





4. COMPASS-III Preparation


COMPASS beyond 2020 Workshop

21 Mar 2016, 08:05 → 22 Mar 2016, 17:10 Europe/Zurich

222-R-001 (CERN)

Description The goal of the workshop is to explore hadron physics opportunities for fixed-target COMPASS-like experiments at CERN beyond 2020 (CERN Long Shutdown 2 2019-2020). The programme comprises

- Reviews of the various physics domains: TMDs, GPDs, FFs, spectroscopy, exotics, tests of ChPT, astrophysics
- Reviews of physics results expected in the next 10 years from major labs around the world
- Some critical long-term issues of the COMPASS spectrometer
- Discussions

In 2016 the preparation of COMPASS-III proposal has been started. In March, the first workshop "COMPASS beyond 2020» took place at CERN . The goal of this workshop was to explore opportunities for fix-target COMPASS-like experiment at CERN beyond 2020. The scientific program comprises of reviews of 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 then 100 physicists have participated in 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.

One of these opportunities can be the studies of antiproton-induced polarised DY to get access to model independent TMDs. Also one allows to profit from good knowledge of proton PDFs (from SIDIS) and as alternative probe, and permits to test TMDs universality. The new data on all TMDs induced asymmetries in both high Mass and J/Ψ regions allows us to investigate: model independent Boer-Mulders PDF, model independent Transversity PDF, Lam-Tung relation for antiprotons (QCD effects), Sivers asymmetry, Sivers function for gluons (J/Ψ regions), flavour separated TMDs, EMC effects and flavour dependent EMC effects.

4. COMPASS-III Preparation

Exclusive measurements Polarised Target :
Generalised Parton Distributions (GPD) *E* and access to Orbital Angular Momentum
Recoil detector to be inserted in the COMPASS PT magnet (with active participation JINR group).

- Muon beam, access to GPD *E* processes to be measured:

  ✓ DVCS ($\mu\, p^{\uparrow} \rightarrow \mu\, p\, \gamma$)
  ✓ DVMP ($\mu\, p^{\uparrow} \rightarrow \mu\, \rho\, (\omega)\, \gamma$)

  Projections: ➔
  Competitors: No competitors in COMPASS kinematic range (small x_{Bj})

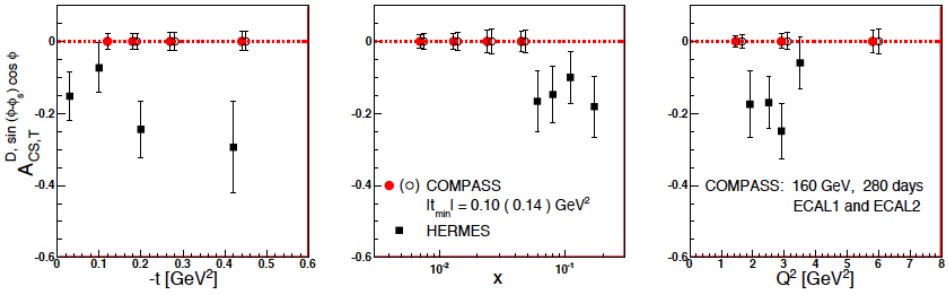


Figure 13: Expected statistical accuracy of $A_{CS,T}^{D,\sin(\phi-\phi_s)\cos\phi}$ as a function of $-t$, x_B and Q^2 from a measurement in 280 days, using a 160 GeV muon beam and ECAL1+ECAL2. Solid and open circles correspond to the simulations for the two hypothetical configurations of the target region (see text). Also shown is the asymmetry $A_{U,T}^{\sin(\phi-\phi_s)\cos\phi}$ measured at HERMES [41] with its statistical errors.

- Hadron beam (π^- dominated), processes to be studied:

  ✓ $\pi\, p^{\uparrow} \rightarrow \mu^+ \mu^-\, p$
  ✓ $\pi\, p^{\uparrow} \rightarrow \mu^+ \mu^-\, \pi\, p$

  Projections & feasibility: under investigation
  Competitors: No competitors in our kinematical domain

O.Denisov, «COMPASS, a Universal Facility for Hadron Structure and Spectroscopy Studies. Long-term plans.», Talk given in workshop «Physics Beyond Colliders», CERN, September 7, 2016

5. JINR responsibilities in COMPASS-II

According to the COMPASS-II MoU, the obligations of the JINR consist of 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 has 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 of changes will be approved by the FRC with recommendations from SPSC (SPS and PS experiments Committie).

6. Time lines and finance profile

The common expenses of JINR during a stage of 2014-2016 on the project (theme 1085) was equal to about $770 thousand. About $130 thousand are 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 SF 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 three years about $25 thousand were spent from a Czech Republic grants.

The sum of necessary financing for 2017 - 2019 is equal 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 payment of contributions to the common fund of collaboration according to obligations from MoU, for computer and a 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.

		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												

6. Time lines and finance profile

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

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

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

2019:
- Analysis of COMPASS experimental data;
- Preparation of detectors for COMPASS-III project.

We request to approve further JINR participation in COMPASS-II for 2017-2019 with first priorities.