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HADRON STRUCTURE STUDY IN FORTHCOMING DRELL-YAN EXPERIMENTS: COMPASS PROJECT AT CERN

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The study of Drell-Yan (DY) processes involving the collision of an (un)polarised hadron beam on a (un)polarised proton target can result in a fundamental improvement of our knowledge on the transverse momentum dependent (TMDs) parton distribution functions (PDFs) of hadrons. The production mechanism of J/ψ and J/ψ - DY duality can also be addressed. One of the forthcoming polarised DY experiments (COMPASS (SPS, CERN)) is discussed in this context. The most important features of this project are briefly reviewed, as well as its sensitivity to the various transverse momentum dependent spin asymmetries.

Keywords: Drell-Yan; TMD; J/ψ.

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1. Transverse spin dependent structure of the nucleon

At leading twist, the quark structure of the hadron is completely described by three parton distribution functions (PDF): the unpolarized distribution function $f_1(x)$, describing the probability of finding a quark with a fraction x of the longitudinal momentum of the parent hadron, regardless of its spin orientation; the helicity distribution $g_1(x)$, describing the difference between the number density of quarks with spin parallel and anti-parallel to the spin of the longitudinally polarised parent hadron; and the transversity $h_1(x)$, similar to $g_1(x)$ but for transversely polarised hadrons. The latter is very poorly constrained because it mixes parton helicities [1] (in jargon, it is a chiral-odd function), while QCD in massless and collinear approximation, as it is actually calculable with perturbative methods, does preserve them. There are also several experimental observations of large azimuthal and spin asymmetries, also at high energy, that perturbative QCD in collinear approximation can not explain. In particular, large asymmetric azimuthal distributions of final leptons, measured in high-energy collisions of pions and antiprotons on nuclei [2–5], show a striking deviation from the so-called Lam-Tung sum rule based on collinear perturbative QCD, and seem to indicate the need to go beyond the collinear approximation.

If we admit a non-zero quark transverse momentum $\mathbf{k}_T$ with respect to the hadron momentum, the nucleon structure function is described, at leading twist, by eight PDF (Jaffe-Ji-Mulders classification scheme): $f_1(x, \mathbf{k}_T^2)$, $g_{1L}(x, \mathbf{k}_T^2)$, $h_1(x, \mathbf{k}_T^2)$, $g_{1T}(x, \mathbf{k}_T^2)$, $h_{1T}^{\perp}(x, \mathbf{k}_T^2)$, $h_{1L}^{\perp}(x, \mathbf{k}_T^2)$, $h_1^{\perp}(x, \mathbf{k}_T^2)$ and $f_{1T}^{\perp}(x, \mathbf{k}_T^2)$. The first three functions, integrated over $\mathbf{k}_T^2$, give $f_1(x)$, $g_1(x)$ and $h_1(x)$, respectively. The last two ones are T-odd PDFs. The former, known also as Boer-Mulders function describes the unbalance of number densities of quarks with opposite transverse polarization with respect to the unpolarized hadron momentum. The latter, known as Sivers function describes how the distribution of unpolarized quarks is distorted by the transverse polarization of the parent hadron. The correlation between $\mathbf{k}_T$ and parton/hadron transverse polarization is intuitively possible only for a non vanishing orbital angular momentum of the quarks themselves. Hence, extraction of $h_1^{\perp}$ and $f_{1T}^{\perp}$, as well as of the poorly known h_1, is of great interest in revealing the partonic (spin) structure of hadrons (see ref. [1] for review). Here, we concentrate mainly on the leading twist transversity h_1, T-odd Boer-Mulders ($h_1^{\perp}$) and Sivers ($f_{1T}^{\perp}$) functions.

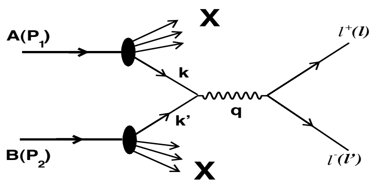

Fig. 1. Feynman diagram of the Drell-Yan process; annihilation of a quark-antiquark pair with the production of a lepton pair.

The Drell-Yan (DY) quark-antiquark annihilation process is an excellent tool to study the transversity and $\mathbf{k}_T$-dependent T-odd PDFs. In the DY process, as shown in Fig.1, quark and antiquark annihilate with the production of a lepton pair. Other kinds of hard processes, like semi-inclusive deep-inelastic scattering (SIDIS), can also access chirally odd PDFs, but the chirality is conserved through the convolution with polarised quark fragmentation functions. The fragmentation process is absent in DY.

1.1. *Unpolarised Drell–Yan processes*

The angular distribution for the unpolarised case is known since long [6, 7] and can be parametrised as

$$\frac{1}{\sigma}\frac{d\sigma}{d\Omega} = \frac{3}{4\pi}\frac{1}{(\lambda+3)}[1 + \lambda\cos^2\theta + \mu\sin 2\theta\cos\phi + \frac{\nu}{2}\sin^2\theta\cos 2\phi]\,, \qquad (1)$$

where in general the coefficients λ, μ and ν are functions of the photon's invariant mass M, its transverse momentum $\mathbf{q}_T$ and of $y = (1+\cos\theta)/2$. The solid angle $\mathrm{d}\Omega$ of the lepton and the angle θ are defined in the centre-of-mass (c.m.) system of the lepton pair (Collins–Soper frame).

In the collinear parton model the coefficients λ, μ and ν are not independent and the Lam–Tung sum rule [8] holds: $1-\lambda = 2\nu$, which is trivial in collinear approximation at Born level: $\lambda = 1$ and $\nu = 0$. QCD corrections to the Born cross-section allow $\lambda \neq 1$ and $\nu \neq 0$, nevertheless the Lam–Tung sum rule remains valid up to $\mathcal{O}(\alpha_s)$ corrections. However, large azimuthal asymmetries in the distribution of the final leptons observed in high-energetic collisions of pions, respectively of anti-protons, with nuclei [2–5], imply a strong violation of the Lam–Tung sum rule and indicate the need to go beyond collinear approximation. Such a strong violation of the Lam–Tung sum rule and large values of ν can arise —even at Born level—in the kinematical region $\mathbf{q}_T^2 \ll M^2$ from the Boer–Mulders functions [9]. For the process $H_1\, H_2 \to \ell\bar{\ell}X$ the parameter ν is given by a convolution of the Boer–Mulders functions of the two hadrons

$$\nu = \frac{2\sum_q e_q^2 \mathcal{F}_q\left[(2\hat{\mathbf{h}}\cdot\mathbf{k}_{1T}\,\hat{\mathbf{h}}\cdot\mathbf{k}_{2T})\frac{\bar{h}_1^\perp h_1^\perp}{M_1 M_2}\right]}{\sum_q e_q^2 \mathcal{F}_q[\bar{f}_1 f_1]}, \tag{2}$$

where $f_1(x, \mathbf{k}_T^2)$ is the unpolarised PDF and $\hat{\mathbf{h}} = \mathbf{q}_T/|\mathbf{q}_T|$. The convolution $\mathcal{F}_q$ of a PDF f for hadron 1 and a PDF g for hadron 2 and flavour q is defined by

$$\begin{aligned}\mathcal{F}_q[w\bar{f}g] = \int \mathrm{d}^2\mathbf{k}_{1T}\,\mathrm{d}^2\mathbf{k}_{2T}\delta^2(\mathbf{k}_{1T}+\mathbf{k}_{2T}-\mathbf{q}_T)w(\mathbf{k}_{1T},\mathbf{k}_{2T})f^{\bar{q}}(x_1,\mathbf{k}_{1T}^2)g^q(x_2,\mathbf{k}_{2T}^2)+\\ +(\bar{q}\leftrightarrow q)\,,\end{aligned} \tag{3}$$

where w stands for any function of $\mathbf{k}_{1T}$ and $\mathbf{k}_{2T}$. Thus, a measurement of ν (see for example Refs. [2–5]) from the amplitude of the $\cos(2\phi)$ modulation of the Drell–Yan πp cross-section will yield first data on the Boer–Mulders functions of the pion and the proton in the valence region. These data can be obtainned simultaneously with the data for polarised Drell–Yan described in the next section. A separate measurement with a liquid hydrogen target could be considered in a second step.

1.2. *Transversely polarised Drell–Yan processes*

In the single transversely polarised Drell–Yan process $H_1 H_2^{\uparrow} \to \ell^+\ell^- X$ the polarised contribution to the cross-section can be written as [9,10]

$$\frac{\mathrm{d}\Delta\sigma^{\uparrow}}{\mathrm{d}\Omega\,\mathrm{d}x_1\,\mathrm{d}x_2\,\mathrm{d}\mathbf{q}_T} = \frac{\alpha^2}{3Q^2}\,|\mathbf{S}_{2T}|\sum_q e_q^2 \Bigg\{ A(y)\,\sin(\phi-\phi_{S_2})\,\mathcal{F}_q\left[\frac{\hat{\mathbf{h}}\cdot\mathbf{k}_{2T}}{M_2}\bar{f}_1 f_{1T}^{\perp}\right]$$
$$-B(y)\,\sin(\phi+\phi_{S_2})\,\mathcal{F}_q\left[\frac{\hat{\mathbf{h}}\cdot\mathbf{k}_{1T}}{M_1}\bar{h}_1^{\perp}\,h_1\right] -$$
$$-B(y)\,\sin(3\phi-\phi_{S_2})\,\mathcal{F}_q\Bigg[\frac{1}{2M_1\,M_2^2}\Big(4\hat{\mathbf{h}}\cdot\mathbf{k}_{1T}\,(\hat{\mathbf{h}}\cdot\mathbf{k}_{2T})^2 -$$
$$-2\hat{\mathbf{h}}\cdot\mathbf{k}_{2T}\,\mathbf{k}_{1T}\cdot\mathbf{k}_{2T} - \hat{\mathbf{h}}\cdot\mathbf{k}_{1T}\,\mathbf{k}_{2T}^2\Big)\,\bar{h}_1^{\perp}\,h_{1T}^{\perp}\Bigg]\Bigg\}\,, \qquad (4)$$

where $M_{1,2}$ are the hadron masses, ϕ_{S_2} is the azimuthal angle of the hadronic transverse spin vector $\mathbf{S}_{2T}$ in the Collins–Soper frame and $A(y)$ and $B(y)$ are kinematic factors. The three terms of Eq. (4) each involve a convolution of a TMD PDF from hadron 1 (the pion) with a TMD PDF from hadron 2 (the polarised proton) and a unique angular dependence on ϕ and ϕ_{S_2}. The first term is responsible for the so-called Sivers effect. The second and third term involve the Boer–Mulders function of the pion convoluted either with the transversity or with the $h_{1T}^{\perp}$ function (sometimes called prezelosity) of the proton.

The single-spin asymmetries A_{UT} corresponding to the three contributions are given by the amplitude of the corresponding azimuthal modulation and can be determined separately by weighting the cross-sections with their typical azimuthal dependence.

Let us stress that some TMD PDFs like the Sivers and the Boer–Mulders functions are T-odd. Their field theoretical definition involves a non-local quark–quark correlator which contains the so-called gauge-link operator. While ensuring the colour-gauge invariance of the correlator, this gauge-link operator makes the Sivers and the Boer–Mulders functions process dependent. In fact, on general grounds it is possible to show that the $f_{1T}^{\perp}$ and the $h_1^{\perp}$ functions extracted from Drell–Yan processes and those obtainned from semi-inclusive DIS should have opposite signs [15], i.e.

$$f_{1T}^{\perp}\Big|_{DY} = -f_{1T}^{\perp}\Big|_{DIS} \qquad \text{and} \qquad h_1^{\perp}\Big|_{DY} = -h_1^{\perp}\Big|_{DIS}\,. \qquad (5)$$

An experimental proof of the sign-reversal property of the Sivers function would be a crucial test of QCD in the non-perturbative regime.

1.3. *J/ψ production mechanism study and J/ψ-DY duality*

Nowadays we see the growing interest [11–13] to the close analogy (duality) between Drell-Yan (DY) $H_1H_2 \to \gamma^* X \to l^+l^- X$ and J/ψ $H_1H_2 \to J/\psi X \to l^+l^- X$

production mechanisms (see textbook [14] for review). It is assumed that a such analogy/duality occurs at relatively low energies, when the gluon-gluon fusion (gg) mechanism of J/ψ production is dominated by the quark-antiquark fusion ($\bar{q}q$). Then, since J/ψ is a vector particle like γ and the helicity structure of $\bar{q}q(J/\psi)$ and $(\bar{q}q)\gamma^*$ couplings is the same, one can get the J/ψ production cross-section from the DY process cross-section applying the simple replacement

$$16\pi^2\alpha^2 e_q^2 \to (g_q^{J/\psi})^2\,(g_\ell^{J/\psi})^2, \quad \frac{1}{M^4} \to \frac{1}{(M^2 - M_{J/\psi}^2)^2 + M_{J/\psi}^2\Gamma_{J/\psi}^2}\,, \tag{6}$$

where $M^2 \equiv Q^2$ is the squared mass of dilepton pair, $M_{J/\psi}^2 \simeq 9.59\,GeV^2$ is the squared J/ψ mass and $\Gamma_{J/\psi}$ is the full J/ψ width. It is believed that the duality model (6) can be applied in both unpolarized [?] and polarized [?] cases. The later is due to the identical helicity and vector structure of γ^* and J/ψ elementary channels (all γ^μ couplings).

The advantage of duality model (6) is that in the region of u-quark dominance (large Bjorken x) all couplings exactly cancel out in the ratios of cross-sections (like asymmetries), so that they become absolutely the same for the DY and J/ψ production processes. Thus, in this kinematical region it does not matter for the u quark PDFs extraction where do the dilepton pair production events come from: from continuum or from J/ψ production region. Certainly, the such possibility to use J/ψ production for PDFs extraction is very attractive because the dilepton production rate in the J/ψ production region is two orders of magnitude higher than in the continuum region above the J/ψ mass. In particular, the duality model (6) give us the possibility to extract transversity h_{1u} as well as the first moments of Boer-Mulders $h_{1u}^{\perp(1)}$ and Sivers $f_{1T}^{\perp(1)u}$ from J/ψ production region. For instance, in the large x region the equations for available to COMPASS DY single spin asymmetries (process $\pi^- p^\uparrow \to \gamma^* X \to \mu^+\mu^- X$) should be the same for the respective J/ψ production process $\pi^- p^\uparrow \to J/\psi X \to \mu^+\mu^- X$, providing us an access to h_{1u} and $h_{1u}^{\perp(1)}$ as a result of combined analysis of DY and J/ψ data.

Certainly, the individuality model (6) is applicable only in the such kinematical regions where among the elementary processes contributing to J/ψ production the quark-antiquark fusion process dominates over the gluon-gluon fusion. In COMPASS the energy of the secondary hadron beam (pions) can be selected in the range $50 - 200\ Gev/c$, what makes possible the test of the duality hypotheses at different energies.

One need also to stress, that at present there is no data available on both DY and J/ψ production processes in collisions of polarized hadrons. At the same time this is of especial importance for the check of duality model.

2. Drell–Yan measurements at COMPASS

The measurements of polarised and unpolarised Drell–Yan process at COMPASS concentrate on the study of transversity (h_1) and of the Boer–Mulders ($h_1^\perp$) and

Sivers ($f_{1T}^{\perp}$) functions. The COMPASS DY program is focused on valence quark-antiquark ($x_B > 0.1$) annihilation study to access the spin-dependent PDFs in the energy scale $Q >> 1$ GeV/c. Valence antiquarks can be provided by using intense pion beams (6×10^7 particles per second).

The multi-purpose large acceptance COMPASS spectrometer, in combination with the SPS M2 secondary beams and the large acceptance COMPASS Polarised Target, has following important features:

- transversely polarized solid state proton target with a large relaxation time and high polarization, when going to spin frozen mode;
- a detection system designed to stand relatively high particle fluxes;
- a Data Acquisition System (DAQ) that can handle large amounts of data at large trigger rates;
- the possibility to use intense secondary hadron beams (intensity up to 5×10^7 hadrons/second);
- a dedicated muon trigger system able to distinguish the DY process from the background.

We consider two step DY programme with COMPASS spectrometer. The first step - the possibility to study the DY process with pion beam at COMPASS (CERN, SPS) was first proposed at the SPSC Meeting at Villars (September 2004) [?]. As a second step we consider the DY processes study with antiproton beam.

2.1. *Drell-Yan at COMPASS: kinematic range, COMPASS apparatus acceptance and expected statistics*

2.1.1. *COMPASS DY apparatus acceptance*

The acceptance of the COMPASS spectrometer for Drell-Yan events with $\mu^+\mu^-$ pairs in the final state was evaluated using a Monte-Carlo simulation from the PYTHIA 6.2 [16] generator and Comgeant, the COMPASS Monte-Carlo simulation program based on Geant 3.21 [17].

The Drell-Yan elementary mechanism is dominated by the annihilation between the valence quark from proton and the antiquark from π^-. We generated events in the invariant mass intervals $4. < M_{\mu^+\mu^-} < 9.0$ GeV/c^2 and $2. < M_{\mu^+\mu^-} < 2.5$ GeV/c^2, which are considered to be the regions for Drell-Yan analysis, avoiding the large combinatorial background that shall dominate at lower dimuon masses, and exclude the ϕ, J/ψ and Υ vector-meson resonances. The first region (dimuons with high mass $4. < M_{\mu^+\mu^-} < 9.0$ GeV/c^2) certainly provides a cleaner sample of DY events, because of the very small contribution from combinatorial and $D\bar{D}$ decays background, but the DY cross-section for such masses is almost a factor 10 smaller than in the second mass region (intermediate masses $2. < M_{\mu^+\mu^-} < 2.5$ GeV/c^2).

The probability density functions for the sea quarks fall steeply with x_1 and x_2, the momentum fractions of the annihilating antiquark and quark from the projectile

π^- and the target hadron p respectively. When both x_1 and x_2 are larger than 0.1, the parton distribution functions are dominated by the valence quark contribution. To be sensitive to the transverse polarization of the target proton one has to stay in the region $x_2 > 0.1$. We choose the momentum of the pion beam in order to select events falling in the valence quarks/antiquarks region but having, at the same time, cross-sections large enough to provide reasonable statistics in the dimuon mass interval between 4. GeV/c^2 and 9.0 GeV/c^2.

The value $\sqrt{s} = \sqrt{357.\ GeV^2} = 18.9\ GeV$, corresponding to a pion beam momentum of 190 GeV/c, was found to be an optimal choice. Hereafter the studies of the COMPASS spectrometer acceptance for DY muons pairs generated at $\sqrt{s} = 18.9\ GeV$ are presented.

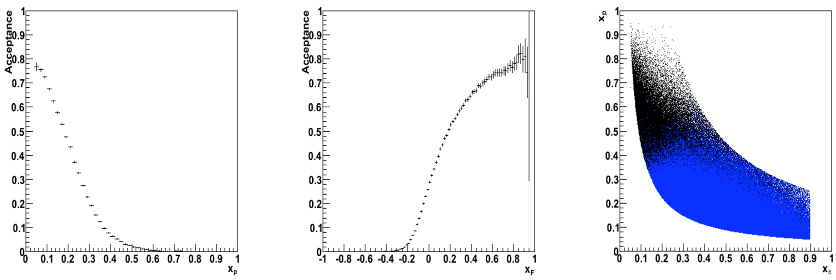

Fig. 2. In the left and center panels the COMPASS acceptance as a function of x_p and x_F is shown, respectively. The right panel shows the COMPASS covered kinematic region in x_p versus x_π.

In Fig.2 the COMPASS acceptance is shown as function of x_p, x_p versus x_π, and x_F, for $4. < M_{\mu^+\mu^-} < 9.0\,GeV/c^2$. One has to stress that the COMPASS acceptance in x_p reaches its maximum value in the region where one expect the largest value of the Sivers asymmetry [18]. It is also very important that COMPASS is sensitive to the contribution from the kinematical region where both quark and antiquark are valence. In case of π^-p interactions it means pure u-dominance in the DY process.

2.1.2. *Expected statistical errors and theoretical predictions*

In Fig.3 the different predictions on the Sivers asymmetry are given together with the expected COMPASS DY measurement statistical errors (assuming two years of running with the luminosity of $\approx 1.18 \times 10^{32}\ s^{-1}cm^{-2}$ and NH_3 polarized target). COMPASS spectrometer total efficiency (0.1) as well as CERN SPS efficiency (0.8) were taken into account. As one can see from the figure, depending on number of bins, a statistical error of 1% to 2% is reachable.

The three lower curves (solid, dashed and dot-dashed lines) represent the estimate of the Sivers single spin asymmetry for COMPASS, with 160 GeV/c π^- beam (Ref. [19], Ref. [20]) . Solid and dashed lines correspond respectively to fits I (Eq.8)

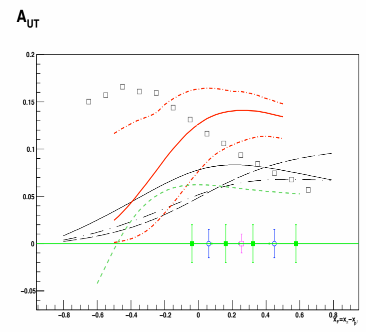

Fig. 3. Theoretical predictions and expected statistical errors on asymmetries in the DY process $\pi^- p \to \mu^+\mu^- X$ in the safe dimuon mass region $4.0 < M_{\mu^+\mu^-} < 9.0\ GeV/c^2$.

and II (Eq.9) for Sivers function from Ref. [19] and dot-dashed line corresponds to fit from Ref. [20] (fit III – Eq.9).

$$\text{Fit I:}\quad x f_{1T}^{\perp(1)u} = -x f_{1T}^{\perp(1)d} = 0.4x(1-x)^5, \tag{7}$$

$$\text{Fit II:}\quad x f_{1T}^{\perp(1)u} = -x f_{1T}^{\perp(1)d} = 0.1x^{0.3}(1-x)^5, \tag{8}$$

$$\text{Fit III:}\quad x f_{1T}^{\perp(1)u} = -x f_{1T}^{\perp(1)d} = (0.17...0.18)x^{0.66}(1-x)^5 \tag{9}$$

The three upper curves represent the asymmetry $-A_{UT}^{\sin(\phi_S-\phi_\gamma)}$ estimated in the same mass range ($4. < M < 9.\ GeV/c^2$) and q_T integrated up to 1 GeV/c, obtainned in the model [21]: the central curve (solid line) shows the expected asymmetry value and dot-dashed lines represents the corridor of errors on the predicted asymmetry value. Here the asymmetry $A_{UT}^{\sin(\phi_S-\phi_\gamma)}$ is defined as:

$$A_{UT}^{\sin(\phi_S-\phi_\gamma)} = \frac{\int_0^{2\pi}(d\sigma^\uparrow - d\sigma^\downarrow)\sin(\phi_S-\phi_\gamma)d\phi_\gamma}{\frac{1}{2}\int_0^{2\pi}(d\sigma^\uparrow + d\sigma^\downarrow)d\phi_\gamma}\,, \tag{10}$$

where ϕ_S and ϕ_γ are the azimuthal angles of the proton spin-vector and of the virtual photon direction with respect to the hadron plane. Notice that this definition implies a minus sign with respect to the definition in Ref. [22]. Therefore in order to compare this asymmetry with the others, the sign of $A_N^{\sin(\phi_S-\phi_\gamma)}$ appears reversed in Fig.3. The predictions obtainned in Ref. [10] and Ref. [23] are shown by squares and short-dashed line correspondingly.

One has to stress that the asymmetries estimated in Ref. [20] and in Ref. [21] are slightly different: the first one is q_T integrated (as a factor $\frac{q_T}{M_N}$ is present in the asymmetry); while the second is a non-weighted asymmetry. But taking into account the kinematics of Drell-Yan at COMPASS ($\langle q_T\rangle \approx 1.\ GeV$) the difference in the asymmetry values are on the level of $\approx 10\%$, which is acceptable for our purposes.

The abscissa of the experimental points, indicating the projection on the statistical error, is calculated from the x_F distribution of the simulated Drell-Yan events accepted in the COMPASS apparatus. The covered x_F range was divided into one, two or three bins of almost equal statistics, and the weighted mean value of the bins was computed. A statistical error bar of 1% was assigned to the red point, 1.5% for the blue ones and 2% for the green ones.

The expected asymmetry value in the intermediate dimuon mass region $2.0 < M_{\mu^+\mu^-} < 2.5$ GeV/c^2 together with statistical error estimates, are presented in Fig.4. The signal to background ratio ≈ 1 was assumed for the statistical error estimation.

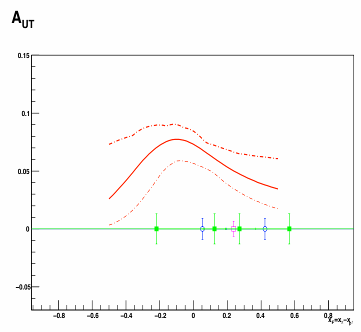

Fig. 4. Theoretical predictions and expected statistical errors on the asymmetries in the DY process $\pi^- p \to \mu^+\mu^- X$, in the intermediate dimuon mass region $2.0 < M_{\mu^+\mu^-} < 2.5$ GeV/c^2.

As one can see from the figure, depending on the number of bins, a statistical error of 0.65% to 1.3% is reachable. As in the dimuon high mass range case, the points represent the statistical error, and their position is calculated from the distribution in x_F of the Drell-Yan events accepted by the COMPASS apparatus. A statistical error bar of .65% was assigned at the red point, 0.95% for blue ones and 1.3% for green ones.

3. Competition and complementarity

There are plans for future polarised DY experiments at BNL, CERN, Fermilab, GSI, J-PARK and JINR. Some of them are presented in Tab. 1. Only PAX at FAIR (GSI-Darmstadt) and NICA at JINR (Dubna) plan to measure transverse double polarised Drell–Yan processes. In Dubna it is proposed to study Drell–Yan in proton–proton or deuteron–deuteron polarised beams collisions (access only to interactions between valence quarks and sea anti-quarks). The PAX collaboration plans to polarise anti-protons to study the interactions between valence quarks and valence antiquarks. However the possibility to get a beam of polarised anti-protons

Table 1. Future Drell–Yan experiments.

Facility		Type		s (GeV^2)	Timeline
RHIC (STAR)	[24]	collider,	$p^\Uparrow p$	200^2	> 2013
E906 (Fermilab)	[25]	fixed target,	pp,	250	> 2011
J-PARC	[26]	fixed target,	$pp^\Uparrow$, $\pi p^\Uparrow$	$60 \div 100$	> 2015
GSI (PAX)	[27]	collider,	$\overline{p}^\Uparrow p^\Uparrow$	200	> 2017
GSI (Panda)	[28]	fixed target,	$\overline{p}p$	30	> 2016
NICA	[29]	collider,	$p^\Uparrow p^\Uparrow$, $d^\Uparrow d^\Uparrow$	676	> 2014
COMPASS	(this letter)	fixed target,	$\pi^\mp p^\Uparrow$	$300 \div 400$	> 2010

still has to be demonstrated. Both these collaborations plan to study e^+e^- final states.

The Drell–Yan programs at RHIC and J-PARC both foresee, like COMPASS, to measure single-spin asymmetries in the Drell–Yan process, but, unlike COMPASS, they have only access to valence-sea quarks interactions in pp collisions. The E906 project is oriented to the study of the sea quark distribution in the proton and can be considered as a good complementary measurement with respect to COMPASS DY.

The Panda experiment is rather designed for J/ψ formation mechanism study than for DY physics, because of the very small anti-proton beam energy (15 GeV).

One has to note, that the most similar to the COMPASS future experiment—the PAX experiment—is designed to reach a luminosity of at most 5×10^{31} cm^{-2} s^{-1}.

4. Conclusion

Single polarised Drell-Yan is a powerfull tool to study hadron spin structure. Because ot its nature it can provides us with new and compelmentary information with respect to what we can learn from polarised SIDIS.

The COMPASS experiment, seems, will be the first ever experiment to perform SSA study in Drell–Yan processes to access the spin-dependent PDFs in the valence quark region and the statistical significance of the result will be high. The first data on the J/ψ formation mechanism in πp interactions will be also obtainned, what is very important for the understanding of hadron–hadron interaction dynamics.

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