SIDIS WG meeting

SIDIS Working Group

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- Editing phase for the second iteration of the pre-TDR ends today

Updates:

- Introductory text about TMDs was included

- Discussion on detector requirements for SIDIS measurements was added

- Final plot on A_{UT} (Ralf) was added

- Intoduction and final plot on A_{LL} (Charlotte) was added

➔ We have now included evrything we planed to add from the SIDIS WG

2.4.2 Origin of Nucleon Spin

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When extracting the double spin asymmetries for semi-inclusive measurements, $A_1^{p,h}$, the selection of final state hadrons, h, provides further sensitivity to the flavor of the struck parton. Given that DIS is generally u-quark dominated, the detection of a negative pion or a kaon with high momentum fraction relative to the initial parton momentum increases the sensitivity to down quarks, and particularly strange quarks. The role of sea quarks and particularly strange quarks in the decomposition of the proton spin is still only poorly understood and is in most global fits only constrained using hyperon decays and the assumption of $SU(3)_F$ symmetry. Using this assumption, the strange spin contribution is pushed toward negative values in the so far inaccessible region. The ePIC measurements will be able to access its contribution over a wide range in x and determine whether these symmetry assumptions are really valid. Similarly, the contributions by sea quarks can be determined using semi-inclusive DIS.

Figure 2.7 shows the expected kinematic coverage for selected bins in x_B, Q^2 and z for semi-inclusive production of positively charged pions for beam energies of 5x41 and 18x275 GeV^2 together with the expected measurement uncertainties. The vertical error bars represent the statistical uncertainties, for a luminosity of 10 fb^{-1}, while the error bands represent the total uncertainty. As can be seen from the figures, the low and high beam-energy configurations cover complementary kinematic regions, allowing for a coverage in x_B from high x_B values down to $x_B = 10^{-4}$.

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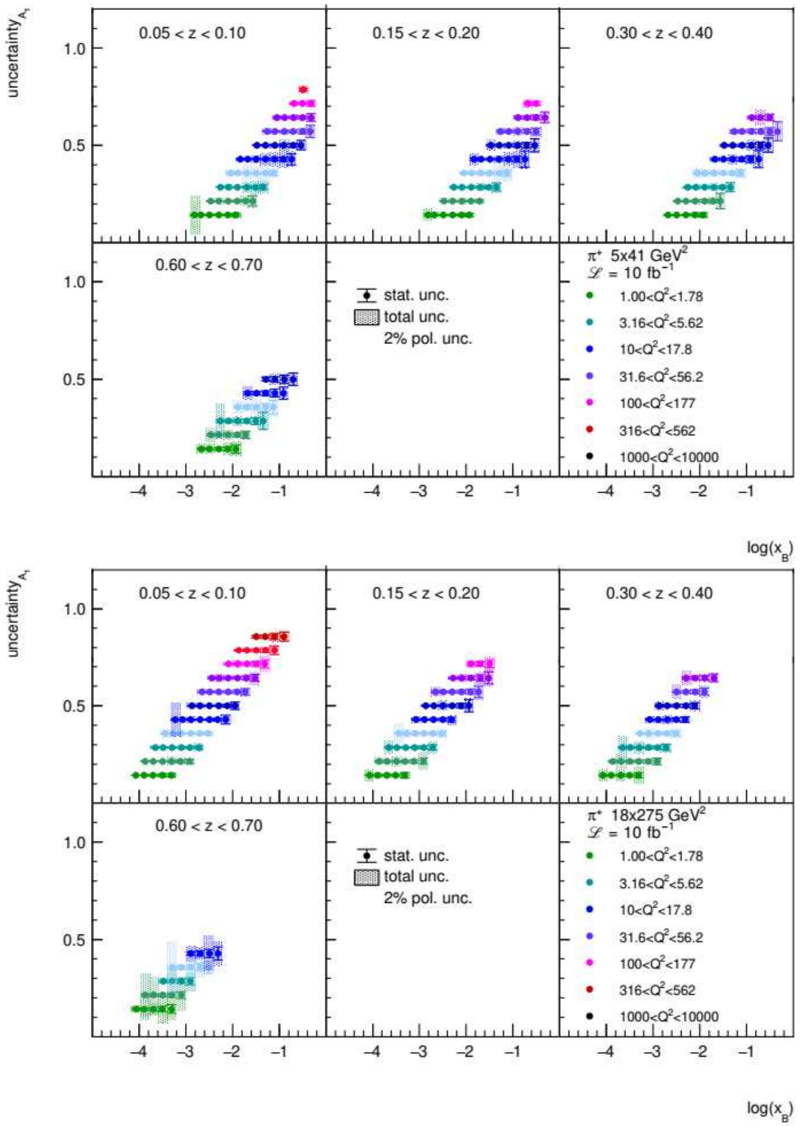

Figure 2.7: Statistical (error bars) and total (error bands) uncertainty for each selected bins in x_B and Q^2 and for selected ranges in z, for positive-pion A_1 asymmetries at 5×41 GeV^2 (top two rows) and 18×275 GeV^2 (bottom two rows). An additional global scale uncertainty of 2% accounts for the uncertainty in the beam polarizations, as indicated in the figure. The central value on the vertical axis of the data points has no meaning.

2.4.3.1 Imaging in Momentum Space

Using semi-inclusive DIS, it is possible to extract information on the three-dimensional momentum structure of the nucleon by making use of transverse momentum dependent parton distribution functions (TMDs-PDFs or shortly TMDs). Depending on the polarization of the nucleon and the parton within the nucleon, there are in total 8 twist-2 TMDs, while the 16 TMDs, which exist at the twist-3 level, also take quark-gluon correlations into account. Table 2.1 provides an overview on the TMDs up to twist-3.

Since the semi-inclusive DIS process also involves the hadronization of the parton which is kicked

N \q	**U**	**L**	**T**		twist 3
U	f_1		$h_1^\perp$		$f^\perp, g^\perp, h, e$
L		g_{1L}	$h_{1L}^\perp$		$f_L^\perp, g_L^\perp, h_L, e_L$
T	$f_{1T}^\perp$	g_{1T}	$h_1, h_{1T}^\perp$		$f_T, f_T^\perp, g_T, g_T^\perp, h^\perp, e_T, h_T^\perp, e_T^\perp$

Table 2.1: The 8 twist-2 and the 16 twist-3 TMDs and their dependence on the nucleon N and the quarks q polarisation (unpolarized: U, longitudinally polarized: L, transversely polarized: T).

out of the nucleon during the scattering process, the observables are typically sensitive to a convolution of a TMD and a fragmentation function (FF), which describes this hadronization. These fragmentation functions are typically studied in hadron production in e^+e^- collisions, like at BELLE or BESIII, where they can be accessed in a clean way [9].

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The measurement of cross sections and their angular modulations as well as beam, target and double spin asymmetries in semi-inclusive DIS, allows us to access a series of model independent structure functions, which can be directly related to a convolution of different TMDs and and FFs [10, 11]. The measurement of different hadrons in the final state allows a flavor separation of the TMDs. Besides the classical DIS variables Q^2 and x_B, semi-inclusive DIS observables are typically studied in terms of the energy fraction of the virtual photon carried by the outgoing hadron z and the transverse momentum of the outgoing hadron relative to the virtual photon direction P_T to access the full kinematic dependence of the TMDs.

For all SIDIS measurements, a few key requirements have to be fulfilled by the ePIC detector. First of all, an excellent particle identification over an as large as possible fraction of the kinematic and angular range of the scattered electrons and hadrons is required, since no exclusivity variables are available to further constrain the final state. Here especially a good pion to Kaon and proton separation up to high momenta is desirable. Furthermore, a differential binning of the observables in terms of the relevant kinematic variables requires a good momentum resolution to reduce distortions from bin migration effects. Both aspects will directly affect the achievable systematic uncertainties and therefore the total precision of the measurement.

Already with an un-polarized nucleon the ePIC experiment can provide flavor-separated TMDs over a large range in x_B and Q^2, and for transverse momenta that reach from the low, TMD-dominated region into the perturbative region. The wide range of scales, as shown in Fig.2.8 (left) will also solve the existing uncertainties in the TMD evolution where non-perturbative contributions require experimental input. As shown in Fig.2.8 (right), the data expected from ePIC will significantly reduce the uncertainties of the extraction of unpolarized TMDs over most of the kinematic range.

The unpolarized TMD PDFs also serve as the unpolarized baseline for any polarized TMD observable which are obtained as single or double spin asymmetries. The most relevant are the Sivers function $f_{1T}^{\perp}$ [12,13] and the quark transversity $h_1^{\perp}$ which is obtained together with either the Collins fragmentation function or a di-hadron fragmentation function. Examples of the expected uncertainties on these asymmetries are displayed in Fig. 2.9 where one can see that over a larger range of phase space very precise uncertainties can be obtained. Those will in turn then provide flavor-separated Transversity extractions and their first moments, the tensor charges. These tensor charges are of particular interest as they can relate to interactions outside the standard model. Lattice-QCD can model the tensor charges very well and any differences with the measurements would provide a hint for BSM physics.

Collins asymmetries of identified hadrons in jets are also sensitive to the Collins Fragmentation Function (FF), which describes the azimuthal distribution of hadrons fragmented by a transversely polarized quark as a function of the parent quark momentum fraction carried by the hadron (z) and the hadron momentum transverse to the quark direction (κ_T). Figure 2.10 illustrates projected statistical precision for Collins asymmetry measurements of charged π, K and p in jets as a function of hadron z and jet p_T. An absolute statistical uncertainty of less than XXX can be achieved for jet $p_T = 20$ GeV/c for protons. When integrated over jet $5.0 < p_T < 51.9$ GeV/c, the statistical uncertainty becomes negligible for the range of $0.1 < z < 0.8$. These high precision measurements will provide stringent constraints for quark transversity in the proton.

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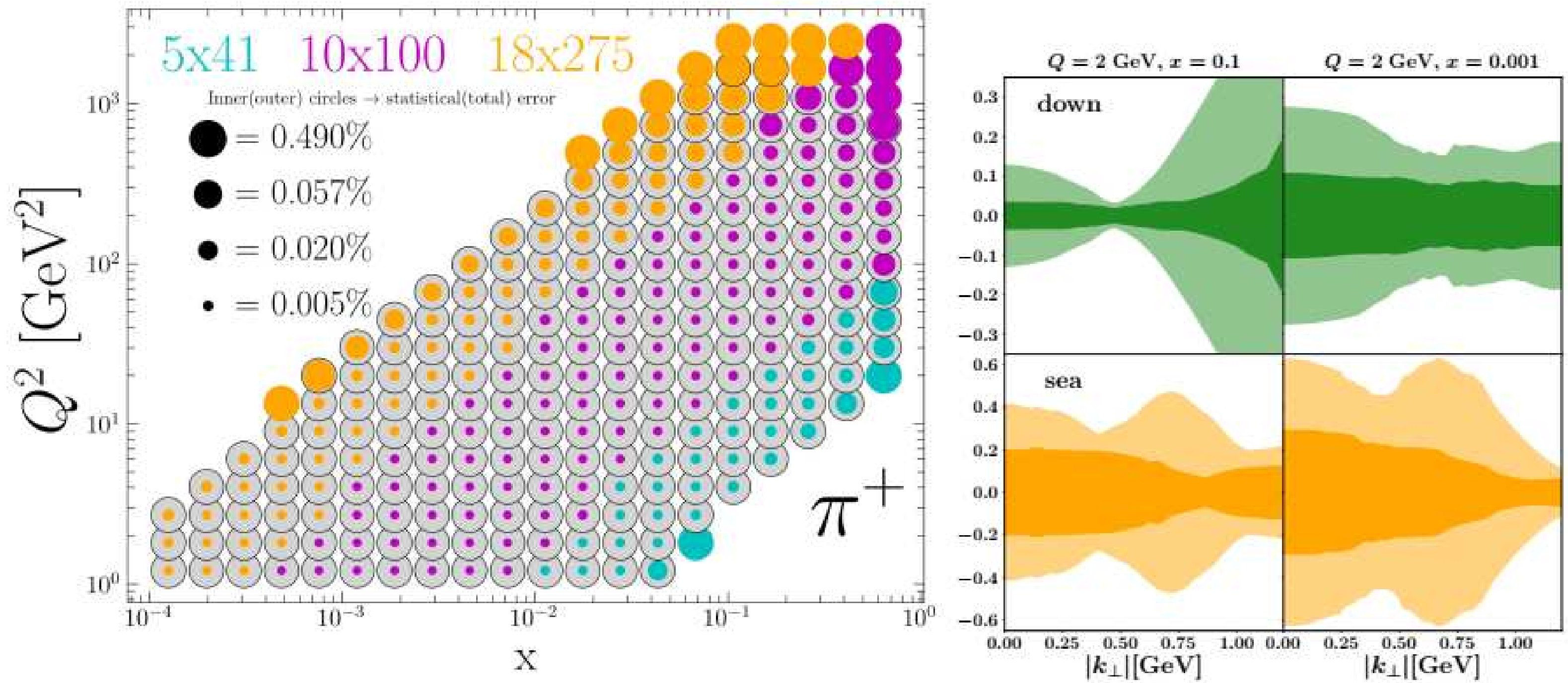

Figure 2.8: Left: Expected statistical and total uncertainty of un-polarized TMD PDFs for π^+ in the $Q^2 - x_B$ plane. The inner (colored) circle shows the statistical uncertainty, while the outer circle provides the total uncertainty for each $Q^2 - x_B$ bin. The color shows the beam energy configuration which provides the highest statistics in a specific bin. Right panel: Expected uncertainties of valence down (green) and sea quark (orange) TMD PDFs at $x = 0.1$ (left) and $x = 0.001$ (right) as obtained based on the MAP24 [1] global TMD fit. The lighter shaded regions show the uncertainties based on existing data while the darker shaded regions show the expected uncertainties after including ePIC data.

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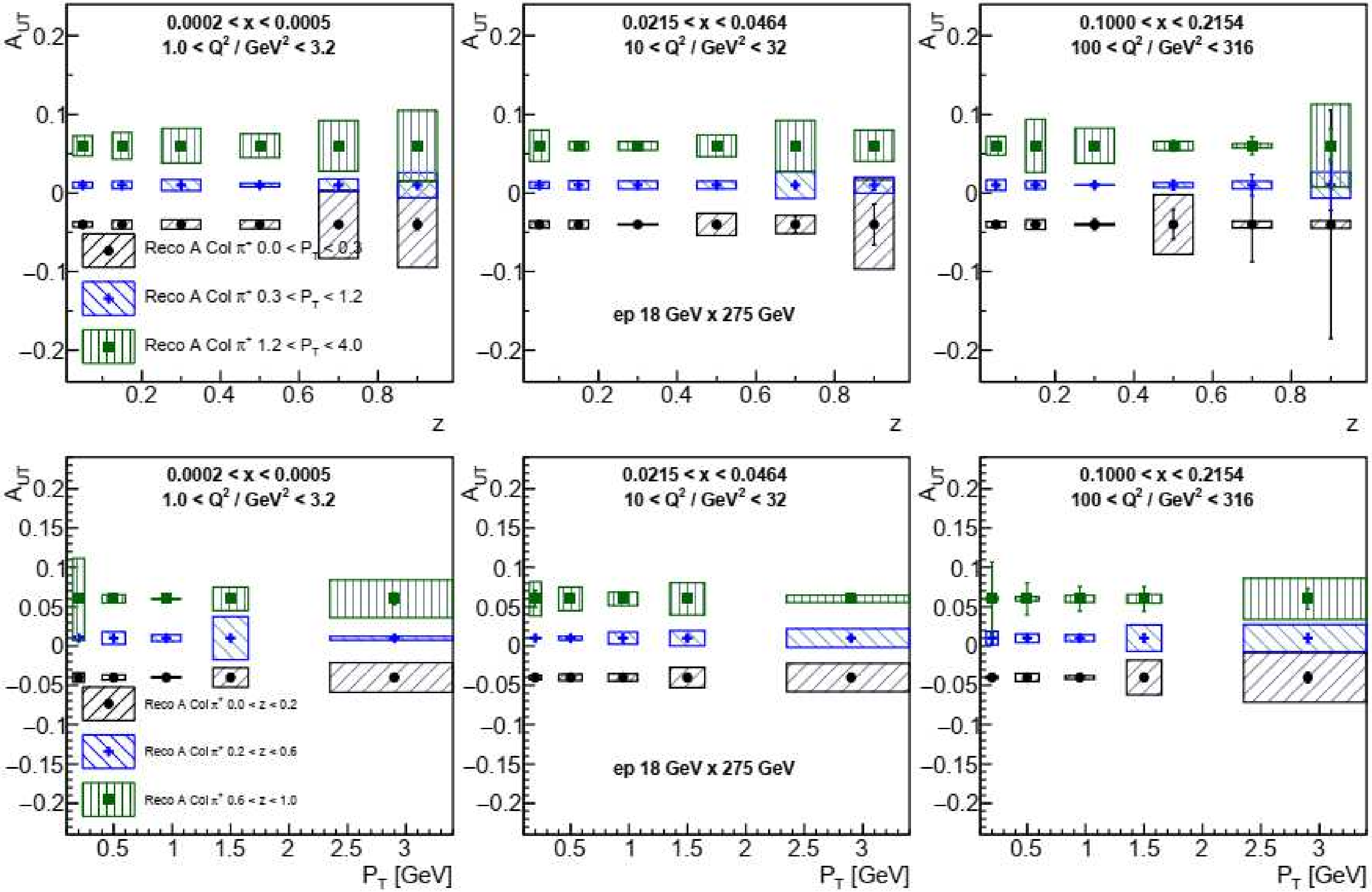

Figure 2.9: Top: Expected uncertainties in three example x-Q^2 bins for the Collins asymmetries for positive pions as a function of the momentum fraction z and in three bins of hadron transverse momentum relative to the virtual photon direction assuming a luminosity of 10 fb^{-1}. Bottom, the same but as a function of the hadron transverse momentum in bins of z.

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EIC Early Science

- There will be an EIC Early Science – plenary session in Frascati: Wed. Jan 22nd, 9AM-1PM

- We were asked to provide SIDIS Projections for early science

  ➔ Any input is welcome!

Year 1: 10 GeV electrons on 115 GeV/u heavy ion beams (Ru or Cu)

Year 2: 10 GeV electrons on 130 GeV/u Deuterium

Year 3: 10 GeV electrons on 130 GeV transversely polarized protons
+ Last weeks switch to longitudinal proton polarization

- Limitted luminosity ➔ No fully differential measurements ePIC

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➔ Perspective for year 1:

- Nuclear PDFs and nuclear FFs are poorly known in the EIC kinematic domain

  ➔ Even with very low statistics, 1D (nPDF)/2D(nFF) studies would be usefull first results

Any projections???
Scale projection on eA from yellow report?

➔ Perspective for year 2:

- Proton and neutron PDFs and FFs can be studied, improvement on strange and d PDFs (based on deuterium target)?
- early unpol. TMD measurements (first look at TMD evolution?)

➔ Perspective for year 3:

- SIDIS structure functions with target polarzation (depeding on luminosity): early look at A_{UT} asymmetries
- Early A_{LL} asymmetries?