# First measurement of $A_N$ in *ep* scattering

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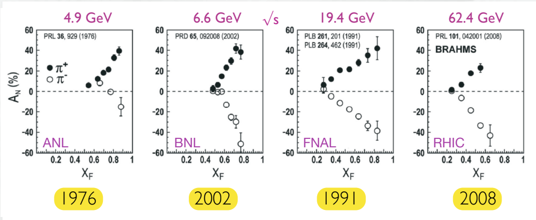
$A_N$ is a left-right asymmetry observed in the distribution of hadrons detected in inclusive measurements at proton-proton collisions. Large asymmetry values have been measured several times since the 70s at different center-of-mass energies $\sqrt{s}$ for several hadron species [1]. Interpretation of these data led D.W. Sivers to formulate the mechanism carrying his name in the early 90s [2]. $A_N$ is typically measured as a function of the transverse hadron momentum $p_T$ and Feynman-x, defined as $x_F = 2p_L/\sqrt{s}$ and related to the longitudinal hadron momentum.

1 U. D'Alesio and F. Murgia, Prog. Part. Nucl. Phys. 61, 394 (2008)
2 D.W. Sivers, Phys. Rev. D41, 83 (1990)

## Motivation: $A_N$ in *pp* scattering




Two approaches have been proposed to explain such asymmetries, one based on the use of transverse-momentum-dependent distribution and fragmentation functions (TMDs) [3]; the other related to high-twist quark-gluon correlations [4]. Both approaches provide a complementary picture of the spin structure of the proton, and predict that $A_N$ goes to zero at low transverse hadron momentum. More data in this region, and as well at moderate-higher $p_T$, are needed. These data can be also obtained from lepton-proton (*ep*) collisions, as now done at HERMES.

3 M. Anselmino, M. Boglione, and F. Murgia, Phys. Lett. B362, 164 (1995)
4 J. Qiu and G. F. Sterman, Phys. Rev. D59, 014004314 (1999)

## Why $A_N$ in *ep* scattering

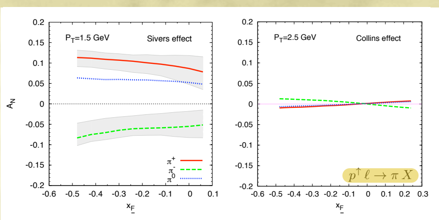
The measurement is equivalent to the existing ones in *pp* scattering,, but in addition:

* It is a cleaner channel to access $A_N$ as it involves only one quark channel from the proton target.
* It provides a test of the validity of the TMD factorization for processes with one large scale ($p_T$).
* It provides a link between the large inclusive asymmetries from purely hadronic interactions in *pp* collisions, and the large spin asymmetries measured in last years from semi-inclusive deep-inelastic scattering (SIDIS) data, where TMDs play a key role.
* Data already exist, collected at different facilities and HERMES has a lot of them!

(120 million charged **pion** tracks and 10 million charged **kaon** tracks were used in this analysis )

## Theory predictions

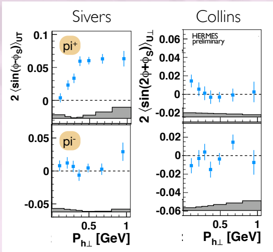
Predictions from TMDs models estimate sizeable left-right asymmetries in inclusive hadron production off *ep* scattering based on the Sivers effect, and negligible for the Collins effect, based on previous HERMES data.




From M. Anselmino et al., Phys. Rev. D81, 034007 (2010)

## Connection to SIDIS results

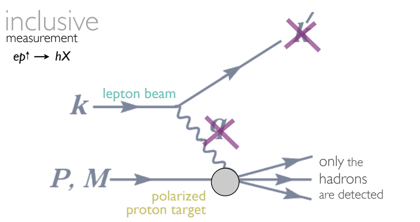
Some good reasons suggest Sivers' mechanism as responsible for the large values of $A_N$, like for example the correspondance, at moderate-low $p_T$, of the azimuthal angle $\Phi$ with the angle modulating the Sivers term in SIDIS [5].



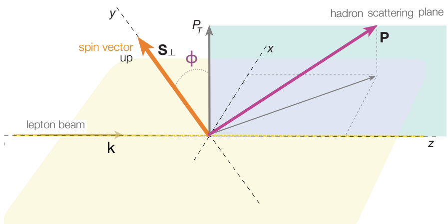

5 A. Airapetian et al, Phys. Rev. Lett. 103 (2009) 152002

## Experimental method

The data were taken at the HERA accelerator (DESY) with the HERMES experiment using an unpolarized lepton beam and a fixed, transversely-polarized proton target and a forward spectrometer.




The asymmetry is experimentally accessible via the distributions in the azimuthal angle $\Phi$, defined between the hadron and the target spin vector.




The cross section of the process can be written as

$$\sigma = \sigma_{UU} + \sigma_{UT}$$

Only $\sigma_{UT}$ depends on the transverse target spin $S_\perp$

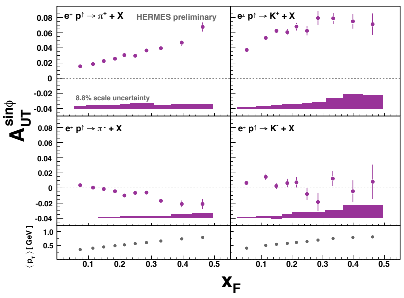
$$\sigma_{UT} = \sigma_{UU}\, S_\perp\, A_{UT}^{\sin\phi}\, \sin(\phi)$$

The asymmetry was extrated as moments of $\sin\Phi$ in bins of $p_T$ and $x_F$. The $\sin\Phi$ amplitudes do not depend on the acceptance of the detector and are related to $A_N$ as

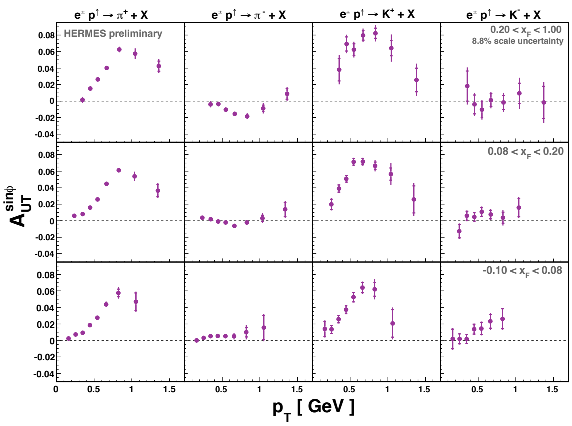
$$A_N = \frac{2}{\pi} A_{UT}^{\sin\phi}$$

## Results

Pions and kaons asymmetries as a function of $x_F$. The smaller amplitudes measured for negative hadrons in comparison to *pp* scattering can be understood given the **u**-quark dominance in *ep* scattering.




$A_N$ was also extracted as a function of $p_T$ for different bins of $x_F$. Positive mesons show a significant positive asymmetry, while for negative mesons, this is close to zero. This is in agreement with an asymmetry dominated by the Sivers mechanism. Further studies, not shown here, indicate that a simulation of the process based on the present understanding of TMDs (including e.g. the Sivers and Collins terms) manages to reproduce the measured inclusive asymmetries to a very good extent. The region of $p_T$ between 1.5 and 2 GeV was also recently investigated, showing a significant rise of the asymmetries, particulary for positive pions. This is the region where the TMDs are correctly defined, while the low-$p_T$ corresponds to the regime of quasi-real photoproduction.






Poster for the PANIC11 conference. MIT