What do we need to access spin dependent parton distribution functions through Drell-Yan?

\[ \frac{dN^{\mu^+\mu^-}}{dM_{\mu^+\mu^-}} = \frac{C_{\mu^+\mu^-}}{2} \left( (1 + P_{\text{had}}) A_{\text{spin}}(x, F) \cos(2\phi) + |S_T| [A_{\text{transverse}} + D_{\text{transverse}}(x, F) \sin(2\theta + \phi)] \right) \]

\( D: \) depolarisation factor; \( S_T: \) transverse target spin; \( F: \) flux of incoming hadrons; \( \sigma_{\text{spin}}: \) part of the cross-section surviving integration over \( \sigma_T \) and \( \phi_S: \) azimuthal angle of \( S_T \) in the target rest frame; \( \phi_S: \) azimuthal angle of the lepton momentum in the Collins-Soper frame.

Polarised Drell-Yan experiments:
- High luminosity (DY cross section is a fraction of the hadron cross section)
- Large angular acceptance
- Sufficiently high energy to access ‘safe’ background free \( M \) range (\( 4 < M_{\mu^+\mu^-} < 9 \) GeV/c²)
- Good acceptance in the valence quark range
- Good figure of merit, which can be represented as a product of the luminosity, target polarisation and dilution factor

COMPASS-II experimental layout:
- Large angular acceptance spectrometer
- \( \pi^- \) beam at 190 GeV/c with intensity up to \( 1 \times 10^9 \) particles/second
- Large acceptance COMPASS Superconducting Solenoid Magnet
- Transversely polarised NH\(_3\) target working in frozen spin mode with long relaxation time
- Hadron absorber downstream of the target
- 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
- New neutrino trigger in the first stage of the spectrometer
- Vertex detector to improve the cell separation of events

Feasibility:
- In 2007, 2008 and 2009 short Drell-Yan beam tests were performed, to check the feasibility of the measurement.
- In 2007, with a \( \pi^- \) beam of 160 GeV/c on a NH\(_3\) target, and without hadron absorber: \( \approx 90000 \) dimuon events (\( \approx 12 \) hours of data taking)
- In 2008 a second beam test was performed, also with an open configuration of the spectrometer, a \( \pi^- \) beam of 190 GeV/c, and polyethylene target

Beam test 2009
\( \pi^- \) beam of 160 GeV/c on 2-cells polyethylene target.
Setup including hadron absorber and a beam plug (3 days of data taking)

Summary & Plans:
- COMPASS has the possibility to access TMD PDFs with SIDIS and Drell-Yan processes.
- COMPASS experimental conditions probe the valence quark region, where TMD effects are expected to be sizeable.
- The feasibility of Drell-Yan measurement was proven in a series of beam tests.

The COMPASS-II Proposal has been recommended by SPSC and is approved by the Research Board for a first period of 3 years including 1 year for Drell-Yan. 2015 Single polarised Drell-Yan with \( \pi^- \) beam \( \rightarrow \) TMDs (Sivers, Boer-Mulders, and Pretzelosity), transversity PDF.

Change of sign of Sivers and Boer - Mulders functions?
\[ f_{1\text{DY}} = -f_{1\text{SIDIS}} \quad \text{and} \quad h_{1\text{DY}} = -h_{1\text{SIDIS}} \]

Critical test of universality of transverse momentum dependent (TMD) factorisation approach for the description of single spin asymmetry. In COMPASS, we have the opportunity to test the Sivers function sign change using the same spectrometer and a transversely polarised target in overlapping range of \( x_F \) and \( Q^2 \) for SIDIS and DY.

The phase spaces of the two processes overlap at COMPASS.

Event rates and statistical precision

Expected event rates
- 280 days of data taking
- a beam intensity of \( 6 \times 10^9 \) particles/second
- a luminosity of \( L = 1.2 \times 10^{36} \text{cm}^{-2}\text{s}^{-1} \)

2.5 \( \times 10^8 \) DY events with \( 4 < M_{\mu^+\mu^-} < 9 \) GeV/c²
1.4 \( \times 10^7 \) DY events with \( 2 < M_{\mu^+\mu^-} < 2.5 \) GeV/c²

The expected statistical error in the asymmetries

Asymmetry
<table>
<thead>
<tr>
<th>Dimuon mass (GeV/c²)</th>
<th>2 &lt; ( M_{\mu^+\mu^-} &lt; 2.5 )</th>
<th>2 &lt; ( M_{\mu^+\mu^-} &lt; 9 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta A_{\text{spin}}^{\mu^+\mu^-} )</td>
<td>0.0123</td>
<td>0.0123</td>
</tr>
<tr>
<td>( \delta A_{\text{transverse}}^{\mu^+\mu^-} )</td>
<td>0.0285</td>
<td>0.0285</td>
</tr>
</tbody>
</table>

\( \delta A_{\text{spin}}^{\mu^+\mu^-} \): Possibility to study the asymmetries in \( x_F \) or \( p_T \) bins.

Asymmetries: comparing with theory prediction
2 years of data taking DY with \( 4 < M_{\mu^+\mu^-} < 8 \) GeV/c²