First JAM results on the determination of polarized parton distributions

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Pedro Jimenez-Delgado

Jefferson Lab
The JAM collaboration

The JAM (Jefferson Lab Angular Momentum) Collaboration is an enterprise involving theorists and experimentalists from the Jefferson Lab community to study the quark and gluon spin structure of the nucleon by performing global fits of spin-dependent parton distribution functions (PDFs).

Because of the unique capabilities of Jefferson Lab’s CEBAF accelerator in measuring small cross sections at extreme kinematics, the JAM spin PDFs are particularly tailored for studies of the large Bjorken-x region, as well as the resonance-deep inelastic transition region at low and intermediate values of W and Q^2.

Parallel effort to our unpolarized PDFs: CJ and JR

Pedro Jimenez-Delgado
The JAM Collaboration consists of the following members:

**Theory**
- Pedro Jimenez-Delgado (*Jefferson Lab*)
- Alberto Accardi (*Hampton University*)
- Wally Melnitchouk (*Jefferson Lab*)

**Database Working Group**
- Peter Bosted (*Jefferson Lab / College of William and Mary*)
- Jian-ping Chen (*Jefferson Lab*)
- Keith Griffioen (*College of William and Mary*)
- Sebastian Kuhn (*Old Dominion University*)
- Yelena Prok (*Old Dominion University*)
- Oscar Rondon (*University of Virginia*)
- Brad Sawatzky (*Jefferson Lab*)

To start with, open to further contributions
The JAM database

Public database with all data on polarized scattering experiments (DIS for now)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Description</th>
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<td>JLab Hall A (E97-103)</td>
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<td>JLab Hall A (E99-117)</td>
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<td>proton and deuteron A_par and A_perp (resonance region)</td>
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<td>SLAC E142</td>
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<td>SMC</td>
<td>proton and deuteron A1, g1</td>
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Data considered at this stage

World data on polarized DIS (for $Q^2 \geq 1 \text{ GeV}^2$, $W^2 \geq 3.5 \text{ GeV}^2$)

Mainly on measured asymmetries:

$$A_\parallel = D(A_1 + \eta A_2)$$

$$A_\perp = d(A_2 - \xi A_1)$$

$D, d$ depend on

$$R = \frac{F_L}{(1 + \gamma^2)F_2 - F_L}$$

$$\gamma^2 = 4 \frac{M^2}{Q^2} x^2$$

We *consistently* develop our own unpolarized analysis in parallel (JR NLO)

Dedicated analyses of the impact of *individual* data sets from JLab
## Data and theory comparison with other groups

<table>
<thead>
<tr>
<th></th>
<th>DIS</th>
<th>SIDIS</th>
<th>hadron collider</th>
<th>nuclear smearing</th>
<th>TMCs</th>
<th>HT $g_1$</th>
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Presently concentrated on improvements in the theoretical description of DIS

Long-term objective is to tick all the boxes (include SIDIS and RHIC data)
Current status of polarized PDFs

Worse known than the unpolarized:

\[ \Delta u^+ = \Delta u + \Delta \bar{u} \quad \text{and} \]
\[ \Delta d^+ = \Delta d + \Delta \bar{d} \quad \text{better known} \]

- Sea distributions \( \Delta \bar{u}, \Delta \bar{d} \)
do not enter in DIS asymmetries

- Rather weak constraints on \( \Delta \bar{s} \)

- \( \Delta g \) less known, determined mainly
  from RHIC data (also COMPASS)

Pedro Jimenez-Delgado

APS DNP, Newport News, Oct 26th, 2013
Simple fit without further corrections: reference

Nuclear targets treated with the “effective polarization” approximation:

\[ g_1^d = (1 - \frac{3}{2} \omega_d)(g_1^p + g_1^n) \]
\[ g_1^{\text{He}3} = P_n g_1^n + P_p g_1^p \]

More similar to DSSV, LSS than to others
Baseline for assessing the impact of additional corrections
Improved description of nuclear targets

Improved by using “smearing functions” derived from nuclear wave functions:

\[ g_i^A(x) = \sum_{j=1,2} \int \frac{d y}{y} \ f_j N(y, \gamma) \ g_j^N(\frac{x}{y}) \]

\[ \gamma^2 = 1 + 4 \frac{M^2}{Q^2} x^2 \]

Most significant for \( \Delta d \) in the medium- and large-\( x \) region
Target-mass corrections

Power corrections from finite target mass calculated in the OPE approach:

\[ g_1^{\text{TMC}}(n) = g_1(n) + \frac{M^2}{Q^2} \frac{n^2(n + 1)}{(n + 2)^2} g_1(n + 2) + \frac{M^4}{Q^4} \ldots + \mathcal{O}\left(\frac{M^8}{Q^8}\right) \]

Relevant for both \( \Delta u \) and \( \Delta d \) in the large-\( x \) region

\[ Q^2 = 1 \text{ GeV}^2 \]

[Bluemlein, Tkabladze 99]
Higher twist contributions

We consider also corrections from higher twist contributions:

\[ g_1 = g_1^{\tau=2} + g_1^{\tau=3} + g_1^{\tau=4} \]

\[ g_2 = g_2^{\tau=2} + g_2^{\tau=3} \]

The Bluemlein-Tkabladze relation: \( g_1^{\tau=3}(x, Q^2) = 4x^2 \frac{M^2}{Q^2} \left( g_2^{\tau=3}(x, Q^2) - 2 \int_x^1 \frac{dy}{y} g_2^{\tau=3}(y, Q^2) \right) \)

[Bluemlein, Tkabladze 99]

With a phenomenological parametrization:

\[ g_2^{\tau=3} = A[\ln x + (1 - x) + \frac{1}{2}(1 - x)^2] + (1 - x)^3[B + C(1 - x) + D(1 - x)^2 + E(1 - x)^3] \]

[ Braun et al. 09]

And a splines approximation for: \( g_1^{\tau=4} = \frac{h(x)}{Q^2} \)

Possible scale dependence in \( h \) and \( g_2^{\tau=3} \) has been neglected (for now)
Higher twist contributions

Considerable improvement of $\chi^2$ for some sets (globally $1.07 \to 0.98, 3\sigma$)

Very large changes in $\Delta d$
Higher twist contributions

Possible to determine *simultaneously* higher-twist contributions for $g_1$ and $g_2$

Qualitative agreement with previous (separated) determinations
Cumulative impact

These corrections are manifestly important for PDF extractions
Summary and outlook

First JAM results on the determination of polarized parton distributions:
- More accurate nuclear corrections
- Target mass corrections
- Complete inclusion of higher-twist

These corrections are manifestly important for PDF extractions

Impact of hadronic and nuclear corrections on global analysis of spin-dependent parton distributions

Dedicated analysis of the impact of JLab data

Other developments in progress or planned: OAM, SIDIS, RHIC …

Thank you for your attention!