Longitudinal Polarization of $\Lambda/\bar{\Lambda}$ Hyperons in Lepton-Nucleon SIDIS

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JINR

JLAB Seminar. April 10 2009

Basic conclusions of our work:

- We demonstrate that new COMPASS data can sharpen two free parameters of our model.
- An accurate measurement of $\Lambda, \bar{\Lambda}$ longitudinal polarization in COMPASS and HERA gives a new method to measure $s(x), \bar{s}(x)$ in the nucleon.
- The spin structure of $\Lambda, \bar{\Lambda}$ hyperons could be extracted from the same data (SU(6) $\tilde{N}$ BJ models).
- Finally, we emphasize that the nucleon polarized strangeness is reflected in a longitudinal polarization of $\Lambda$ hyperons which can be measured in COMPASS, HERA, JLAB.
What do we know about the proton?

- Non relativistic description
- Probing inside of the proton
- Nucleon strangeness
- Why \( \Lambda/\bar{\Lambda} \)?

What say experiments and theories?

- Experiments with charged particles
- Neutrino experiments

Our modelling

Results

- What are the source of \( \Lambda/\bar{\Lambda} \)
- Spin transfer to \( \Lambda/\bar{\Lambda} \)
- What about \( \Delta s \)?
- “Fit” of \( \bar{s}(x) \)

Conclusions

Backup slides
Outline

1. What do we know about the proton?
   - Non relativistic description
   - Probing inside of the proton
   - Nucleon strangeness
   - Why $\Lambda/\bar{\Lambda}$?

2. What say experiments and theories?
   - Experiments with charged particles
   - Neutrino experiments

3. Our modelling

4. Results
   - What are the source of $\Lambda/\bar{\Lambda}$
   - Spin transfer to $\Lambda/\bar{\Lambda}$
   - What about $\Delta s$?
   - “Fit“ of $\bar{s}(x)$

5. Conclusions

6. Backup slides
What is a proton?

- A particle of matter with mass 938 MeV
- Electric charge +1
- Consists of three (valence) quarks: $uud$
- Spin 1/2

$SU(3)$ model is able to host 8 baryons with $J^P = 1/2^+$:

$p(uud), n(udd), \Sigma^+(uus), \Sigma^0(uds), \Sigma^-(dds), \Lambda^0(uds), \Xi^0(uss), \Xi^-(dss)$,

and 10 excited baryonds with $J^P = 3/2^+$:

$\Delta, \Sigma^*, \Xi^*, \Omega^-$.
Octet and decuplet of baryons

\[ SU(3) \text{-octet} \]

\[ SU(3) \text{-decuplet} \]
**SU(3) × SU(2) wave functions of baryons**

\[ p^\uparrow = \frac{1}{\sqrt{18}} (2u^\uparrow u^\downarrow d^\downarrow - u^\uparrow u^\downarrow d^\uparrow - u^\downarrow u^\uparrow d^\uparrow + \text{cycl. permutations}) \]

\[ n^\uparrow = \frac{1}{\sqrt{18}} (2d^\uparrow d^\downarrow u^\downarrow - d^\uparrow d^\downarrow u^\uparrow - d^\downarrow d^\uparrow u^\uparrow + \ldots) \]

\[ \Sigma^{+\uparrow} = \frac{1}{\sqrt{18}} (2u^\uparrow u^\downarrow s^\downarrow - u^\uparrow u^\downarrow s^\uparrow - u^\downarrow u^\uparrow s^\uparrow + \ldots) \]

\[ \Sigma^{0\uparrow} = \frac{1}{6} \left( 2(u^\uparrow d^\downarrow + d^\uparrow u^\downarrow) s^\downarrow - s^\uparrow (u^\downarrow d^\uparrow + d^\downarrow u^\uparrow) - d^\downarrow s^\uparrow u^\uparrow - u^\downarrow s^\uparrow d^\uparrow + \ldots \right) \]

\[ \Sigma^{-\uparrow} = \frac{1}{\sqrt{18}} (2d^\uparrow d^\downarrow s^\downarrow - d^\uparrow d^\downarrow s^\uparrow - d^\downarrow d^\uparrow s^\uparrow + \ldots) \]

\[ \Lambda^{0\uparrow} = \frac{1}{\sqrt{12}} \left( u^\uparrow d^\downarrow s^\uparrow - u^\uparrow d^\uparrow s^\uparrow - d^\uparrow u^\downarrow s^\uparrow + d^\uparrow u^\uparrow s^\uparrow + \ldots \right) \]

\[ \Xi^{0\uparrow} = \frac{1}{\sqrt{18}} \left( 2s^\uparrow s^\downarrow u^\downarrow - s^\uparrow s^\downarrow u^\uparrow - s^\downarrow s^\uparrow u^\uparrow + \ldots \right) \]

\[ \Xi^{-\uparrow} = \frac{1}{\sqrt{18}} \left( 2s^\uparrow s^\downarrow d^\downarrow - s^\uparrow s^\downarrow d^\uparrow - s^\downarrow s^\uparrow d^\uparrow + \ldots \right) \]
Magnetic moments of baryons

Static magnetic-dipole moments of baryons are defined by:

\[ \mu_B = \sum_q \mu_q \sigma_q, \]

where \( \mu_q = e_q/2m_q \) — magnetic dipole moment of quark \( q \). Magnetic moment of a baryon \( B \), described by a ket-vector \( |B\rangle \), can be computed as:

\[ \mu(B) = \langle B|\mu_B|B\rangle. \]
## Magnetic moments of baryons

<table>
<thead>
<tr>
<th>Magnetic moment</th>
<th>formula</th>
<th>value (in $\mu_N$)</th>
<th>Experiment (in $\mu_N$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu(p)$</td>
<td>$\frac{4}{3}\mu_u - \frac{1}{3}\mu_d$</td>
<td>(input)</td>
<td>2.793</td>
</tr>
<tr>
<td>$\mu(n)$</td>
<td>$\frac{4}{3}\mu_d - \frac{1}{3}\mu_u$</td>
<td>-1.86</td>
<td>-1.913</td>
</tr>
<tr>
<td>$\mu(\Lambda^0)$</td>
<td>$\mu_s$ (input)</td>
<td></td>
<td>$-0.613 \pm 0.004$</td>
</tr>
<tr>
<td>$\mu(\Sigma^+)$</td>
<td>$\frac{4}{3}\mu_u - \frac{1}{3}\mu_s$</td>
<td>2.69</td>
<td>$2.458 \pm 0.010$</td>
</tr>
<tr>
<td>$\mu(\Sigma^-)$</td>
<td>$\frac{3}{2}\mu_d - \frac{1}{3}\mu_s$</td>
<td>-1.04</td>
<td>$-1.16 \pm 0.025$</td>
</tr>
<tr>
<td>$\mu(\Xi^0)$</td>
<td>$\frac{4}{3}\mu_s - \frac{1}{3}\mu_u$</td>
<td>-1.44</td>
<td>$-1.25 \pm 0.014$</td>
</tr>
<tr>
<td>$\mu(\Xi^-)$</td>
<td>$\frac{4}{3}\mu_s - \frac{1}{3}\mu_d$</td>
<td>-0.51</td>
<td>$-0.679 \pm 0.031$</td>
</tr>
<tr>
<td>$\mu(\Omega^-)$</td>
<td>$3\mu_s$</td>
<td>-1.84</td>
<td>$-1.94 \pm 0.22$</td>
</tr>
</tbody>
</table>
Scatter high energy leptons off protons

Measuring polarized cross-sections we can access the proton structure:

\[
\frac{d^2 \sigma^{\uparrow \uparrow}}{d\Omega dE'} + \frac{d^2 \sigma^{\uparrow \downarrow}}{d\Omega dE'} = \frac{8\alpha^2 E'^2}{MQ^4} \left[ 2\sin^2 \theta / 2 \ F^\text{em}_1(x, Q^2) + \frac{M}{\nu} \cos^2 \theta / 2 \ F^\text{em}_2(x, Q^2) \right]
\]

\[
\frac{d^2 \sigma^{\uparrow \downarrow}}{d\Omega dE'} - \frac{d^2 \sigma^{\uparrow \uparrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{Q^2 EM\nu} \left[ (E + E' \cos \theta) \ g_1(x, Q^2) - 2xM \ g_2(x, Q^2) \right].
\]

- \( F^\text{em}_1(x) = \frac{1}{2} \sum q e_q^2 q(x) \)
- \( F^\text{em}_2(x) = 2x F^\text{em}_1(x) \)
- \( g_1(x) = \frac{1}{2} \sum q e_q^2 \Delta q(x) \)
What do we know about the proton?

**Probing inside of the proton**

**Structure of proton**

\[ Q = \sum_i \int dx x q_i(x) \sim 0.5 \]  
SLAC ('70s)

\[ S = \int dx x s(x) \sim 1\% \]

\[ \Delta S = \int dx \Delta s(x) \sim -10\% \]

\[ \nu_l s \rightarrow l^- c \]

from global fits

\[ \Delta \Sigma = \sum_i \int dx \Delta q_i(x) \sim 0.3 \]  
EMC, SMC, HERMES, JLAB ('80-now)

**SU_F(3) \times SU_S(2) w.f.**

**Dmitry V. Naumov (JINR)**

\[ \Lambda = \frac{\nu_{NC} - \bar{\nu}_{NC}}{\nu_{CC} - \bar{\nu}_{CC}} \]

**Spin structure of \( \Lambda \)**

**Longitudinal \( P_\Lambda, P_{\bar{\Lambda}} \)**

**Quark fragmentation functions**

**(Di)quark fracture functions**

10/04/2009
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Dmitry V. Naumov (JINR)  
\( \Lambda/\bar{\Lambda} \) polarization  
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Dmitry V. Naumov (JINR)  
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$\Lambda/\bar{\Lambda}$ polarization

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Quark fragmentation functions

Dmitry V. Naumov (JINR)
What do we know about the strangeness in nucleon?

- $s$ quarks carry about 4% of the nucleon momentum at $Q^2 = 20$ GeV ©CCFR.
- Combination of electric and magnetic form-factors is small:
  \[ G_E + 0.39G_M = 0.025 \pm 0.020 \pm 0.014 \] ©HAPPEX,
  \[ G_E + 0.225G_M = 0.039 \pm 0.034 \] ©A4.
- $s$ quark contributes little to the magnetic moment of nucleon:
  $-0.1 \pm 5.1\%$ ©SAMPLE.

On the other hand:

“Spin crysis” suggests that the quarks carry only $\sim 1/3$ of the nucleon spin with $\Delta s \approx -10\%$!
How else the strangeness can be measured?

- di-muon events in (anti) neutrino
  - needs large neutrino statistics... seems doable at short time scale only with NOMAD
  - involves large uncertainties in $m_c$ and hadronization. Not sensitive to $\Delta s$...

- neutrino and anti-neutrino cross-sections asymmetry:
  \[ A = \frac{\nu_{NC} - \bar{\nu}_{NC}}{\nu_{CC} - \bar{\nu}_{CC}} \]

gives a road to strange form-factors and thus to $\Delta s$.

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- unfortunately this is VERY difficult experimentally...
What do we know about the proton? Why $\Lambda/\bar{\Lambda}$?

### $\Lambda$ and $\Delta s$

In SU(6) model the $\Lambda/\bar{\Lambda}$ spin is carried by $s/\bar{s}$, thus a possible $\Delta s$ can be transferred to $\Lambda$ hyperon and measured in $\Lambda \to p + K_s^0$

**Idea**

Measure $P_\Lambda$ in lepton-nucleon DIS to feel $\Delta s$ in the nucleon
Bukrhard, Jaffe noted that using SU(6) and the “spin crisis“ for the proton one gets the same “spin crisis“ for $\Lambda$:

\[ \Delta u_\Lambda = \Delta d_\Lambda \approx -20\% \]
Today $s(x)/\bar{s}(x)$ are badly known

Various parametrizations differ by 100% (as GRV98 and CTEQ5L)

If $\Lambda/\bar{\Lambda}$ are produced from fragmentation of $s(x)/\bar{s}(x)$ than one can expect the final hyperon polarization to be proportional to $s(x)$ for $\Lambda$ and $\bar{s}(x)$ for $\bar{\Lambda}$. The $\Lambda$ polarization is a complicated issue as it involves both quark and target remnant fragmentation including the resonances ($\Sigma^*, \Sigma^0, \Xi$)

$$P_\Lambda = P_B D(y) \frac{\sum_q e^2_q q(x)(\Delta D^\Lambda_q(z) + \Delta F^\Lambda_{p\otimes q}(z))}{\sum_q e^2_q q(x)(D^\Lambda_q(z) + F^\Lambda_{p\otimes q}(z))}$$

Considering an anti-baryon $\bar{\Lambda}$ essentially simplifies the life:

$$P_{\bar{\Lambda}} = P_B D(y) \frac{e^2_s \bar{s}(x) \Delta D^\Lambda_{\bar{s}}(z)}{\sum_q e^2_q q(x)(D^\Lambda_q(z) + F^\Lambda_{p\otimes q}(z))}$$
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Conclusions

Backup slides
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Experiments with charged particles

Experiments in the game. HERMES

**HERMES SPECTROMETER**

27.6 GeV longitudinally polarized e-beam $P_e \approx 50\%$, flipped monthly; longitudinally and transversely polarized pure gaseous H, D targets $P_T \approx 80\%$, flipped every 60 sek

**HERMES dipole** $BL=1.3$ $TM$ $\Delta p / p \approx 1\%$ $\Delta \theta_x, \Delta \theta_y = 1 \text{mrad}$

$-170 < \theta_x < +170 \text{mrad}$

$-140 < \theta_y < -40 \text{mrad}$

$140 > \theta_y > 40 \text{mrad}$

$40 < \theta < 220 \text{mrad}$

*Very good PID!!*

What say experiments and theories?

Experiments with charged particles

Experiments in the game. COMPASS
Experiments in the game. JLAB
What say experiments and theories?

Neutrino experiments

The NOMAD detector and $V^0$ reconstruction

- Drift chambers used as a target (2.7 tons) and for momentum measurement (3.5% resolution)
- Magnetic field: 0.4 T
- TRD and Preshower for electron identification
- ECAL and HCAL for energy measurement
- Muon chambers: detect and identify muon

Dmitry V. Naumov (JINR)
What say experiments and theories?

Neutrino experiments

Identification of $K_S^0$, $\Lambda^0$, $\bar{\Lambda}^0$

- Kinematic fit of $V^0$ like vertices for four hypotheses: $K_S^0 \rightarrow \pi^+\pi^0$, $\Lambda^0 \rightarrow p\pi^-$, $\bar{\Lambda}^0 \rightarrow \bar{p}\pi^+$, $\gamma \rightarrow e^+e^-$
- Good mass resolution

$M_{K_S^0}$: mean = 497.9, sigma = 9.7 (MeV)
$M_\Lambda$: mean = 1115.8, sigma = 3.8 (MeV)
$M_{\bar{\Lambda}}$: mean = 1116.0, sigma = 3.1 (MeV)
World data on longitudinal polarization of $\Lambda$s

taken from S. Belostotski talk, Trento 2008
World data on longitudinal polarization of $\bar{\Lambda}$s
Almost all models ignore nucleon target end and deal with a quark fragmentation...

- $SU(6)$: $\Delta u_\Lambda = \Delta d_\Lambda = 0$, $\Delta s_\Lambda = 1$
- DIS-spin crisis picture (Burkardt-Jaffe): $\Delta u_\Lambda = \Delta d_\Lambda = -0.2$, $\Delta s_\Lambda = 0.6$
- B.Ma: $\Delta u_\Lambda = \Delta d_\Lambda = \Delta s_\Lambda$
- Lattice calculations: $\Delta u_\Lambda = \Delta d_\Lambda \approx 0$, $\Delta s_\Lambda = 0.68$

However it is not enough just to assume a quark polarization in $\Lambda$. The quark should fragment somehow into it and it will lose partially its original polarization.

- How much?
- Is it a dominant production mechanism?
What say experiments and theories?

Neutrino experiments

Models

Almost all models ignore nucleon target end and deal with a quark fragmentation...

- $SU(6)$: $\Delta u_\Lambda = \Delta d_\Lambda = 0, \Delta s_\Lambda = 1$
- $DIS$-spin crysis picture (Burkardt-Jaffe):
  $\Delta u_\Lambda = \Delta d_\Lambda = -0.2, \Delta s_\Lambda = 0.6$
- B.Ma: $\Delta u_\Lambda = \Delta d_\Lambda = \Delta s_\Lambda$
- Lattice calculations: $\Delta u_\Lambda = \Delta d_\Lambda \approx 0, \Delta s_\Lambda = 0.68$

However it is not enough just to assume a quark polarization in $\Lambda$. The quark should fragment somehow into it and it will lose partially its original polarization.

- How much?
- Is it a dominant production mechanism?
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However it is not enough just to assume a quark polarization in \( \Lambda \). The quark should fragment somehow into it and it will lose partially its original polarization.

- How much?
- Is it a dominant production mechanism?
Unfortunately not. The situation is much more complicated and requires a lot of work:

- Target nucleon remnant is in most cases the **dominant process** (Factorization “theorem“ is not working)
  - a model pretending to describe polarized data must describe \( \Lambda, \bar{\Lambda} \) unpolarized properties because they are defined by production mechanisms (di-quark, string, quark)
  - difficult to make a realistic model for the di-quark fragmentation. [Needs to develop a theory for it which should be confronted to data and tuned if needed]

- Heavy resonances contribute significantly
  - to understand the data many unpolarized measurements are needed (yields of \( \Sigma^*, \Xi, \Sigma^0 \)
Outline

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5. Conclusions

6. Backup slides
Ingredients

- Interaction of lepton with nucleon
- Hadron fragmentation
- What is the mother of a hadron?
- Polarization of hadrons
- Uncertainties
We use LEPTO 6.1 package to model interactions of lepton (charged or neutrino) with nucleon. The following bugs were corrected by us:

- In LEPTO 6.1 it was missing the lepton scattering off sea $u, d$ quarks
  - the bug was corrected and the author of LEPTO 6.1 was informed
- To model a nucleus LEPTO 6.1 “reweight“ quark distributions of protons and neutrons according to their fractions. This is OK for unpolarized case but wrong for polarized physics.
  - We first generate samples with protons and neutrons targets, perform polarization analyses and then mix events proportionally to the cross-sections.
We use JETSET7.4 package to model hadron fragmentation of quarks, di-quarks. JETSET has many free parameters tunable from experiments:

- we used the parameters tuned by the NOMAD Collaboration, which describe yields of $\Lambda$ and $\bar{\Lambda}$ hyperons, produced promptly or from decays of $(\Sigma^*, \Sigma^0, \Xi)$. ©Artem Chukanov
Our modelling

Hadron rank or what is the hadron mother

In order to assign a polarization to the hadron one has to order hadrons in the hadrons string: decide is the considered hadron close to fragmenting quark or close to the target nucleon remnant. To account this we introduce two ranks:

- $R_q$ - hadron number from the quark end of the string
- $R_{qq}$ - hadron number from the target nucleon remnant
Our modelling

**Hadron rank or what is the hadron mother**

We consider two extreme cases to get an estimate of theory uncertainty.

- **Model A:** Restrict spin transfer in (di)quark fragmentation to hyperons with \( R_{qq} = 1, R_q \neq 1 \) \( R_{qq} \neq 1, R_q = 1 \);

- **Model B:** Allow spin transfer in (di)quark fragmentation to hyperons with \( R_{qq} > R_q \) \( R_{qq} < R_q \).
Polarization of hadrons. Quarks fragmentation

If a hadron is produced from the quark fragmentation (promptly or via heavier resonance), it could be polarized. The spin transfer is computed for SU(6) and “spin crysis“ BJ models:

<table>
<thead>
<tr>
<th>Λ’s parent</th>
<th>$C^Λ_u$</th>
<th>$C^Λ_d$</th>
<th>$C^Λ_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>quark</td>
<td>SU(6)</td>
<td>BJ</td>
<td>SU(6)</td>
</tr>
<tr>
<td>Σ$^0$</td>
<td>0</td>
<td>-0.18</td>
<td>0</td>
</tr>
<tr>
<td>Ξ$^0$</td>
<td>-2/9</td>
<td>-0.12</td>
<td>-2/9</td>
</tr>
<tr>
<td>Ξ$^-$</td>
<td>-0.15</td>
<td>0.07</td>
<td>0</td>
</tr>
</tbody>
</table>
Our modelling

Polarization of hadrons. Di-quarks fragmentation

Model of polarized strangeness

1. small mass of pseudo scalar mesons $\pi, K, \eta$ means strong attraction with quantum numbers $J^P = 0^-$. 
2. Vacuum density of strange pairs is quite large 

$$\langle 0|\bar{u}u|0\rangle \approx \langle 0|\bar{d}d|0\rangle \approx (250\text{MeV})^3,$$

$$\langle 0|\bar{s}s|0\rangle \approx (0.8 \pm 0.1)\langle 0|\bar{u}u|0\rangle.$$ 

This model was suggested in works of Ellis, Sapozhnikov, Kotzinian and Kharzeev
Polarization of hadrons. Di-quarks fragmentation

We do not know how strong is the correlation between spins of struch quark and sea strange (anti)quark. We introduce two free parameters $C_{sq\text{sea}}, C_{sq\text{val}}$. We fit these parameters from the NOMAD data:

**Model A:** $C_{sq\text{val}} = -0.35 \pm 0.05, C_{sq\text{sea}} = -0.95 \pm 0.05$.

**Model B:** $C_{sq\text{val}} = -0.25 \pm 0.05, C_{sq\text{sea}} = 0.15 \pm 0.05$.

Spin transfer to $\Lambda$ is computed as:

\[
\begin{align*}
C_{\Lambda}^{l\text{u}}(\text{prompt}; N) &= C_{\Lambda}^{l\text{d}}(\text{prompt}; N) = C_{sq}, \\
C_{\Lambda}^{l\text{u}}(\Sigma^0; p) &= C_{\Lambda}^{l\text{d}}(\Sigma^0; n) = \frac{1}{3} \cdot \frac{2 + C_{sq}}{3 + 2C_{sq}}, \\
C_{\Lambda}^{l\text{u}}(\Sigma^{*0}; p) &= C_{\Lambda}^{l\text{d}}(\Sigma^{*0}; n) = C_{\Lambda}^{l\text{d}}(\Sigma^{*+}; p) = \\
C_{\Lambda}^{l\text{u}}(\Sigma^{*-}; n) &= -\frac{5}{3} \cdot \frac{1 - C_{sq}}{3 - C_{sq}}.
\end{align*}
\]
Description of the NOMAD data

Assigning ranks (close to a quark or di-quark end) by construction displays two extreme cases - however nobody knows which way is correct - this is a source of uncertainty.

Related to this the spin correlation coefficients $C_{sq}$ fitted from the NOMAD data at moderate $x_{Bj} \sim 0.1$ could not be accurate enough for electromagnetic interaction for which $x_{Bj} \sim 10^{-3}$ is typical.

This implies that a new data in previously not explored domains can better fix only two parameters of our model.
What is our aim in this work 5 years later?

1. Predictions for $\bar{\Lambda}$ for COMPASS, HERA
2. Predictions for $\Lambda$ for JLAB, COMPASS, HERA
   - The NOMAD data are restricted to $x > 0.05$. We need smaller $x$ to better fix $C_{sq_{sea}}, C_{sq_{val}}$. For this purpose the COMPASS data is essential.
3. Study a dependence of spin transfer to $s(x)/\bar{s}(x)$ ДМС COMPASS, HERA
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6. Backup slides
Distributions of $x_F$ for $\Lambda/\bar{\Lambda}$

- Let us examine distributions of $x_F$ for $\Lambda/\bar{\Lambda}$ in different kinematic domains.
- What is the fraction of $\Lambda/\bar{\Lambda}$ produced from fragmentation of quark, di-quark, or resonance?
Distributions of $x_F$ for $\Lambda$ in COMPASS

Model B
- all
- light-quark-prompt
- resonances from struck quark
- resonances from target
- s-prompt
- target nucleon end
Distributions of $x_F$ for $\bar{\Lambda}$ in COMPASS

Model B
- **all**
- light-quark-prompt
- resonances from struck quark
- resonances from target
- sbar-prompt
- target nucleon end

Entries, a.u.

$x_F$

- $10^{-1}$
- $10^{-2}$
- $10^{-3}$
For the COMPASS energy the dominant mechanism of $\Lambda$ production is the di-quark fragmentation. $\bar{\Lambda}$ are produced mainly from $\bar{s}$ fragmentation.

For the HERA energy quark and diquark mechanisms are well separated, however a new mechanism becomes effective - quark-antiquark string fragmentation, like in $e^+ - e^-$ collisions. Thus it is not instructive to require really very large energies for such studies (pictures moved to backup slides).
Spin transfer to $\Lambda/\bar{\Lambda}$

- How it depends on kinematics?
- How large it is?
- What are the main sources?
Spin transfer to $\Lambda$ in COMPASS

SU(6), Model B

Model B
- all
- light-quarks-transfer-off
- strange-quark-transfer-off
- strangeness-transfer-off
Spin transfer to $\bar{\Lambda}$ in COMPASS

SU(6), Model B
Resume

- Apparent domains in $x_F$, $x$ - sources of $\Lambda/\bar{\Lambda}$ polarization - due to di-quark (only for $\Lambda$) and quark fragmentations.
- Polarization of $\bar{\Lambda}$ is essentially defined by $\bar{s}$ fragmentation. Thus it could be an instrument to study $\bar{s}(x)$.
Spin transfer to $\Lambda$ in COMPASS for various $s(x)$, BJ, SU6

- GRV98, SU(6)
- GRV98, BJ
- CTEQ5L, SU(6)
- CTEQ5L, BJ

Dmitry V. Naumov (JINR)
Spin transfer to $\bar{\Lambda}$ in COMPASS for various $\bar{s}(x)$, BJ, SU6

![Graph showing spin transfer to $\bar{\Lambda}$](image)

Dmitry V. Naumov (JINR)
Comparison of SU(6) and BJ for $\Lambda$ in HERA

Spin transfer vs. $x_F$ for $\Lambda / \bar{\Lambda}$ polarization.

- **GRV98, SU(6)**
- **GRV98, BJ**
Comparison of SU(6) and BJ for $\bar{\Lambda}$ in HERA

Spin transfer

$\bar{\Lambda}/\Lambda$ polarization

Dmitry V. Naumov (JINR)

10/04/2009
An accurate measurement of spin transfer to $\Lambda/\bar{\Lambda}$ gives a possibility to study the spin structure of $\Lambda/\bar{\Lambda}$.
Sensitivity to polarized strangeness of $\Lambda$

- What will change if we switch off the spin transfer from nucleon strangeness, i.e. $C_{sq} = 0$?
What about $\Delta s$?

Sensitivity to polarized strangeness of $\Lambda$ in JLAB

Model B

- all
- light-quarks-transfer-off
- strange-quark-transfer-off
- strangeness-transfer-off

Spin transfer vs. $x_F$
Results

What about $\Delta s$?

Sensitivity to polarized strangeness of $\Lambda$ in JLAB (Projection for 1000 hours)

![Graph showing sensitivity to polarized strangeness of $\Lambda$ in JLAB](image)

- CLAS12
- HERMES
- NOMAD
- WA59

Dmitry V. Naumov (JINR)  
$\Lambda/\bar{\Lambda}$ polarization  
10/04/2009  
55 / 86
Spin transfer to $\Lambda$ in JLAB is defined by polarized strangeness. Thus JLAB could be essential to define $C_{sq}$. 
"Fit" of $\bar{s}(x)$

- Examine: MRST04, CTEQ06M, ALEKHIN02, GRV98
- We can "reweight" $s(x), \bar{s}(x)$ by hand trying to fit predictions to PRELIMINARY COMPASS DATA (could be done in a more consistent way fitting COMPASS results with all the world data by authors of distributions)
Spin transfer to $\bar{\Lambda}$ in COMPASS for various $\bar{s}(x)$

![Graph showing spin transfer to $\bar{\Lambda}$ in COMPASS for various $\bar{s}(x)$]
Spin transfer to $\Lambda$ in COMPASS for various $\bar{s}(x)$
Spin transfer to $\bar{\Lambda}$ in COMPASS. MRST 04

Results

"Fit" of $\bar{s}(x)$

Spin transfer to $\bar{\Lambda}$ in COMPASS. MRST 04

- $s(x)$
- COMPASS PRELIMINARY
- mrst04 with $s(x) \times 2.00$

Dmitry V. Naumov (JINR)
Spin transfer to $\bar{\Lambda}$ in COMPASS. MRST 04

![Graph showing spin transfer to $\bar{\Lambda}$ versus $x$. The graph includes data points and error bars and is labeled with different curves indicating various models and fits.]

- Red curve: $\text{mrst04}$
- Blue curve: $\text{mrst04 with } \bar{s}(x) \times 2.00$
- Black curve: COMPASS PRELIMINARY

Legend:
- $\bar{s}(x)$
- $x$
Spin transfer to $\Lambda$ in COMPASS. MRST 04

Results

"Fit" of $\bar{s}(x)$

Spin transfer to $\Lambda$ in COMPASS. MRST 04

Dmitry V. Naumov (JINR)

$\Lambda/\bar{\Lambda}$ polarization

10/04/2009
Spin transfer to $\Lambda$ in COMPASS. MRST 04

Results

"Fit" of $\bar{s}(x)$

Spin transfer to $\Lambda$ in COMPASS. MRST 04

Spin transfer

-0.4 -0.2 0 0.2 0.4 0.6 0.8

xF

Spin transfer

-0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4

mrst04

mrst04 with $s(x) \times 2.00$

COMPASS $\Lambda$ PRELIMINARY

Dmitry V. Naumov (JINR)

$\Lambda/\bar{\Lambda}$ polarization

10/04/2009

63 / 86
Resume

- Spin transfer to $\bar{\Lambda}$ is sensitive to $\bar{s}(x)$ which could be fitted
- Spin transfer to $\Lambda$ is less sensitive to $s(x)$ - more statistics is needed
- COMPASS with a factor $X$ increase of statistics of $\bar{\Lambda}$ will improve our knowledge of $\bar{s}(x)$
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5. Conclusions

6. Backup slides
New data of COMPASS can sharpen domain of two free parameters of our model

An accurate measurement of polarization of $\Lambda, \bar{\Lambda}$ in COMPASS and HERA gives a new method to measure $s(x), \bar{s}(x)$ in nucleon

Spin structure of $\Lambda, \bar{\Lambda}$ can be extracted from the same data

Polarized nucleon strangeness can be extracted from measured $\Lambda$ polarization in COMPASS, HERA, JLAB
Outline

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6. Backup slides
Distributions of $x_F$ Λ/Λ polarization in HERA
Distributions of $x_F$ \( \overline{\Lambda} \) in HERA

**Model B**
- **all**
- light-quark-prompt
- resonances from struck quark
- resonances from target
- sbar-prompt
- target nucleon end

**Entries, a.u.**

- $10^{-1}$
- $10^{-2}$
- $10^{-3}$

**$xF$**

- $-0.1$ to $0.8$
Spin transfer to $\Lambda$ in COMPASS

SU(6), Model B
Spin transfer to $\bar{\Lambda}$ in COMPASS

SU(6), Model B
How sensitive are our predictions on model of tagging of particles?

Is it possible to reduce theor. uncertainty?
Models A and B for $\Lambda$ in COMPASS

Spin transfer vs. $x$

- Model A
- Model B
Models A and B for \( \Lambda/\bar{\Lambda} \) in COMPASS

Spin transfer vs. \( x \) for models A and B.
Models A and B for $\Lambda$ in COMPASS

Spin transfer vs. $xF$

- Model A
- Model B
Models A and B for $\bar{\Lambda}$ in COMPASS

Spin transfer

$xF$

-0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8

$\Lambda/\bar{\Lambda}$ polarization

Dmitry V. Naumov (JINR)
Predictions for $\Lambda$ strongly depend on models A and B. This dependence is due to much smaller $x$ accessible in COMPASS and not accessible in NOMAD used to tune the parameters. We need the COMPASS data to fix the parameters and reduce systematics.

Predictions for $\bar{\Lambda}$ are practically insensitive to A and B tagging. This is very valuable to have a model independent probe of $\bar{s}(x)$!
Comparison of GRV98 and CTEQ5L for $\Lambda/\bar{\Lambda}$

- How sensitive our predictions on parametrizations of strange sea in the nuclen?
Comparison of GRV98 and CTEQ5L for $\Lambda$ in COMPASS

- $\Lambda$/$\bar{\Lambda}$ polarization

Dmitry V. Naumov (JINR)
Comparison of GRV98 and CTEQ5L for $\bar{\Lambda}$ in COMPASS
Comparison of GRV98 and CTEQ5L for $\Lambda$ in HERA

Dmitry V. Naumov (JINR)  
$\Lambda/\bar{\Lambda}$ polarization  
10/04/2009
Comparison of GRV98 and CTEQ5L for $\bar{\Lambda}$ in HERA

Spin transfer

$xF$

$GRV98, SU(6)$

$CTEQ5L, SU(6)$
An accurate measurement of spin transfer to $\Lambda/\bar{\Lambda}$ can be probes($x$) $\bar{\Omega}$ $\bar{s}(x)$.

For COMPASS this effect is present for both $\Lambda/\bar{\Lambda}$, while HERA would be sensitive only with $\Lambda$.

There is no sense to require large energy because new mechanisms (like in $e^+e^-$) becomes more and more effective thus loosing sensitivity to $s(x)$ and $\bar{s}(x)$. 
Can we learn from an experiment about the “spin crysis“ for $\Lambda/\bar{\Lambda}$?
Comparison of SU(6) and BJ for Λ in COMPASS

Spin transfer

\( x_F \)

GRV98, SU(6)
GRV98, BJ
Comparison of SU(6) and BJ for $\bar{\Lambda}$ in COMPASS