Longitudinal target polarization dependence of $\bar{\Lambda}$ polarization and polarized strangeness PDF

Aram Kotzinian

CEA-Saclay, IRFU/Service de Physique Nucléaire, 91191 Gif-sur-Yvette, France

On leave in absence from YerPhI, Armenia and JINR, Russia

DIS 2009, 26-30 April 2009, Madrid

- $\bar{\Lambda}$ polarization
  - Unpolarized target
    - Strangeness distribution in nucleon
  - Polarized target
    - Polarized strangeness in polarized nucleon
- Conclusions

Simple model: LO, independent fragmentation for current fragmentation region

$$P_T = 0 \quad \Rightarrow \quad P^{\bar\Lambda} = P^{\bar\Lambda}_{P_B,0} = D(y) P_B \frac{\sum_q e_q^2 q(x) \Delta D_q^{\bar\Lambda}(z)}{\sum_q e_q^2 q(x) D_q^{\bar\Lambda}(z)}$$

$SU(6)$ Model for spin transfer in fragmentation:

only $\Delta D_{\bar s}^{\bar\Lambda}(z) \neq 0,$

$$\Delta D_{\bar s}^{\bar\Lambda}(z) = D_{\bar s}^{\bar\Lambda}(z)$$

$$S_x^{\bar\Lambda} = \frac{P^{\bar\Lambda}}{D(y)P_B} \approx \frac{\frac{1}{9}\bar s(x) D_{\bar s}^{\bar\Lambda}(z)}{\sum_q e_q^2 q(x) D_q^{\bar\Lambda}(z)} := F_{\bar s}^{\bar\Lambda}(x,z)$$

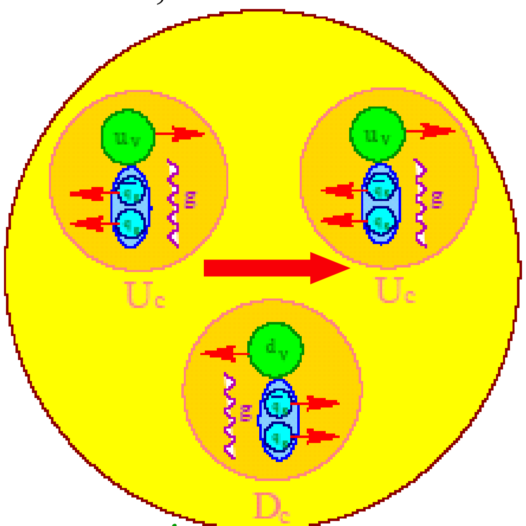
Fraction of events with hard scattering off s-bar (s-bar purity)

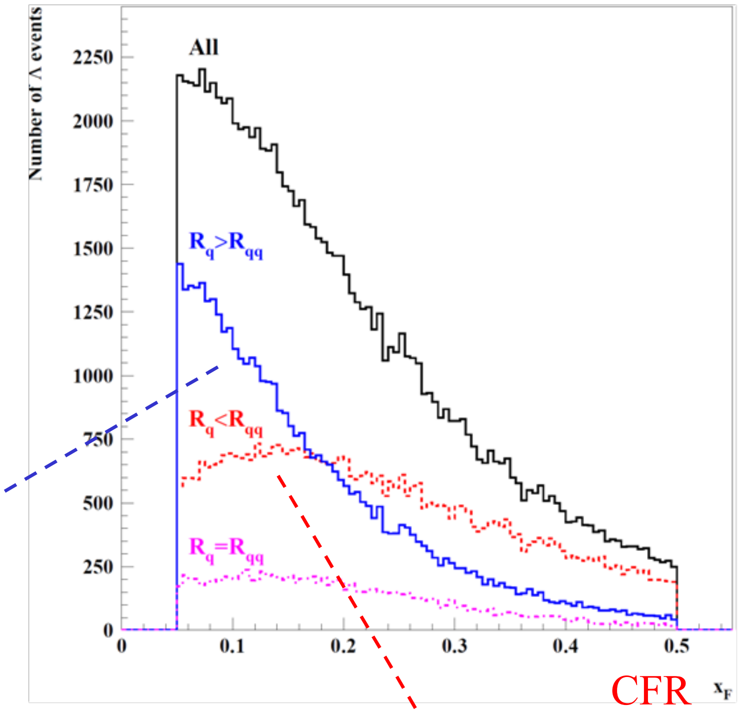
Intrinsic Strangeness Model (ISM) for Λ polarization

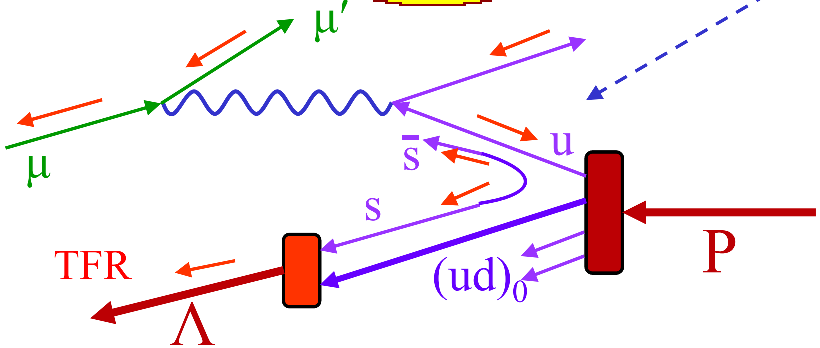
J.Ellis,M.Karliner,D.Kharzeev,M.G.Sapozhnikov, 1995

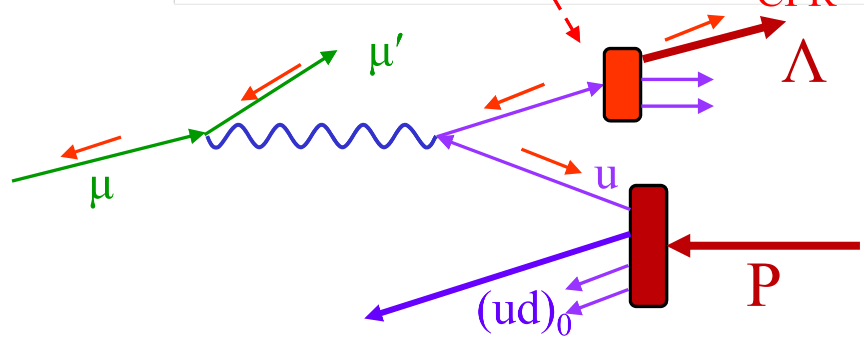
J.Ellis, D.Kharzeev, A.K., 1996

J. Ellis, A. K. & D. Naumov, 2002









$R_{qq}<R_q$: spin transfer from intrinsic strangeness and polarized diquark via heavier hyperons

$R_q<R_{qq}$: spin transfer only from final quark

Spin transfer in SIDIS

Spin transfer from qq side

$$P_\Lambda^{\nu\, d}(\text{prompt};N) = P_\Lambda^{\bar\nu\, u}(\text{prompt};N) = P_\Lambda^{l\, u}(\text{prompt};N) = P_\Lambda^{l\, d}(\text{prompt};N) = C_{sq}\cdot P_q,$$

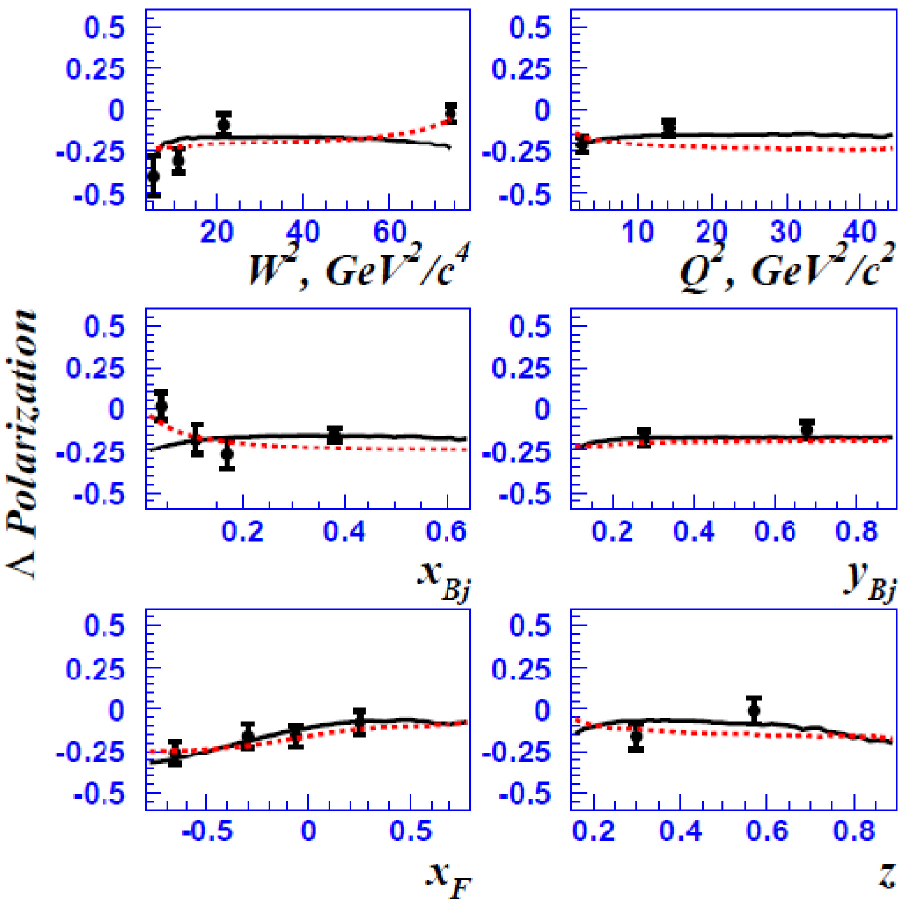
$$P_\Lambda^{\nu\, d}(\Sigma^0;n) = P_\Lambda^{\bar\nu\, u}(\Sigma^0;p) = P_\Lambda^{l\, u}(\Sigma^0;p) = P_\Lambda^{l\, d}(\Sigma^0;n) = \frac{1}{3}\cdot\frac{2+C_{sq}}{3+2C_{sq}}\cdot P_q,$$

$$P_\Lambda^{\nu\, d}(\Sigma^{\star 0};n) = P_\Lambda^{\nu\, d}(\Sigma^{\star +};p) = P_\Lambda^{\bar\nu\, u}(\Sigma^{\star 0};p) = P_\Lambda^{\bar\nu\, u}(\Sigma^{\star +};n) = P_\Lambda^{l\, u}(\Sigma^{\star 0};p) = P_\Lambda^{l\, d}(\Sigma^{\star 0};n) = P_\Lambda^{l\, d}(\Sigma^{\star +};p) = P_\Lambda^{l\, u}(\Sigma^{\star -};n) = -\frac{5}{3}\cdot\frac{1-C_{sq}}{3-C_{sq}}\cdot P_q.$$

Spin transfer from q side

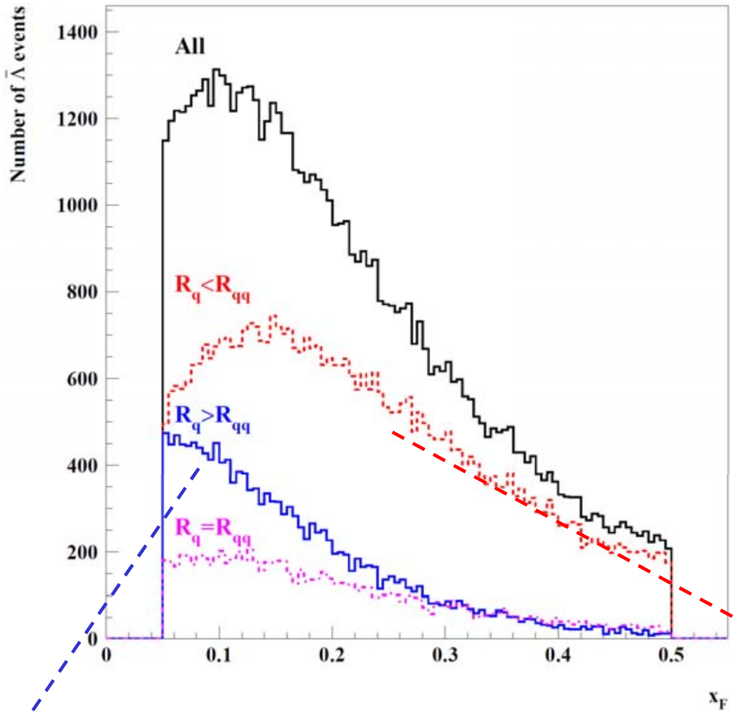
Λ^0's parent	$C_u^{\Lambda^0}$		$C_d^{\Lambda^0}$		$C_s^{\Lambda^0}$	
	$SU(6)$	BJ	$SU(6)$	BJ	$SU(6)$	BJ
quark	0	−0.18	0	−0.18	1	0.63
Σ^0	−2/9	−0.12	−2/9	−0.12	1/9	0.15
Ξ^0	−0.15	0.07	0	0.05	0.6	−0.37
Ξ^-	0	0.05	−0.15	0.07	0.6	−0.37
$\Sigma^\star$	5/9	–	5/9	–	5/9	–

NOMAD data



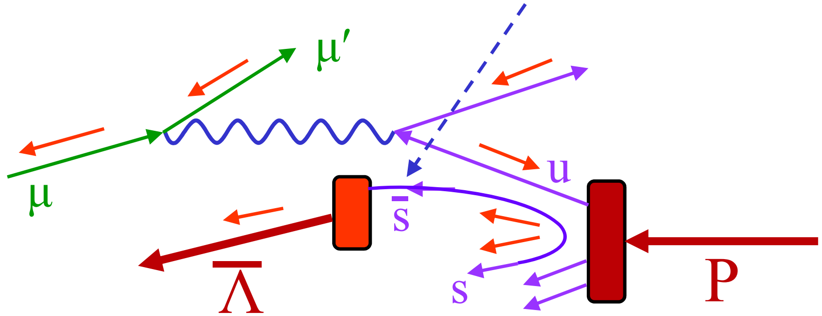
Model A: $C_{sq\,\mathrm{val}} = -0.35 \pm 0.05$, $C_{sq\,\mathrm{sea}} = -0.95 \pm 0.05$,
Model B: $C_{sq\,\mathrm{val}} = -0.25 \pm 0.05$, $C_{sq\,\mathrm{sea}} = 0.15 \pm 0.05$.

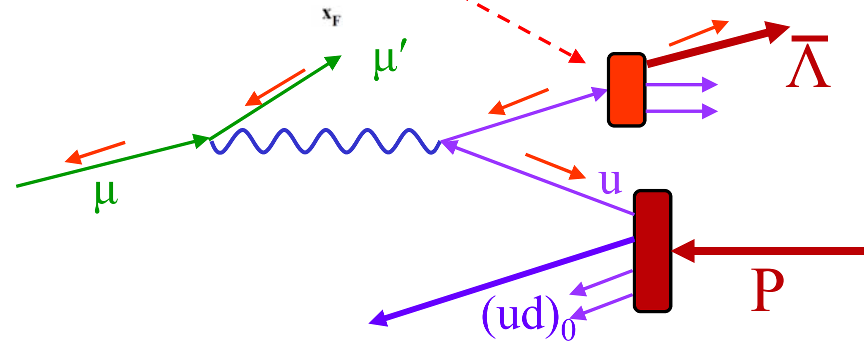
$\bar{\Lambda}$ polarization



J.Ellis, A.K., D.Naumov and M.Sapozhnikov

EPJ.C52:283-294,2007

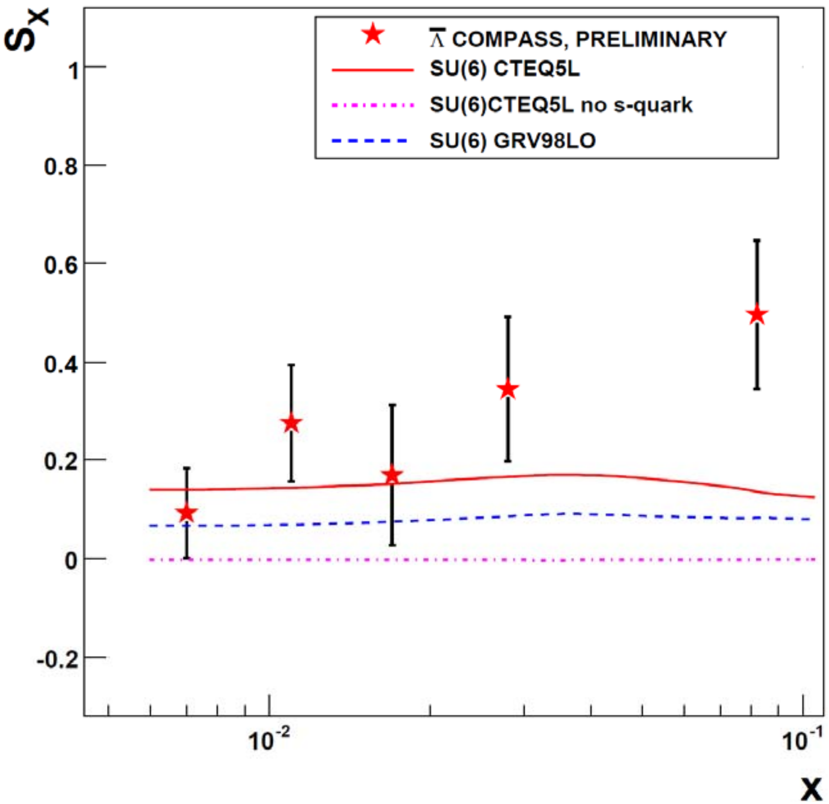


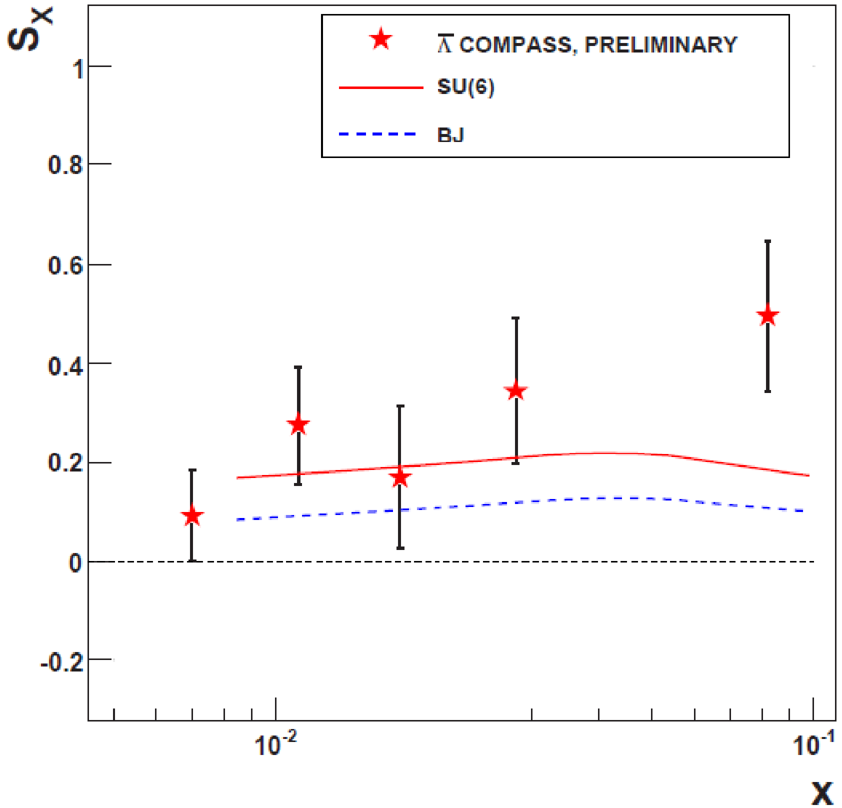


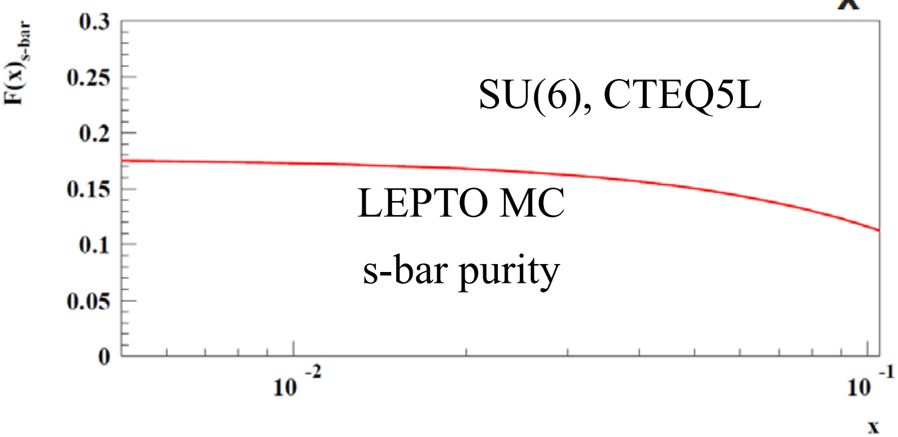
$R_{qq}<R_q$: spin transfer only from intrinsic strangeness

$R_q<R_{qq}$: spin transfer only from final quark

Unpolarized target





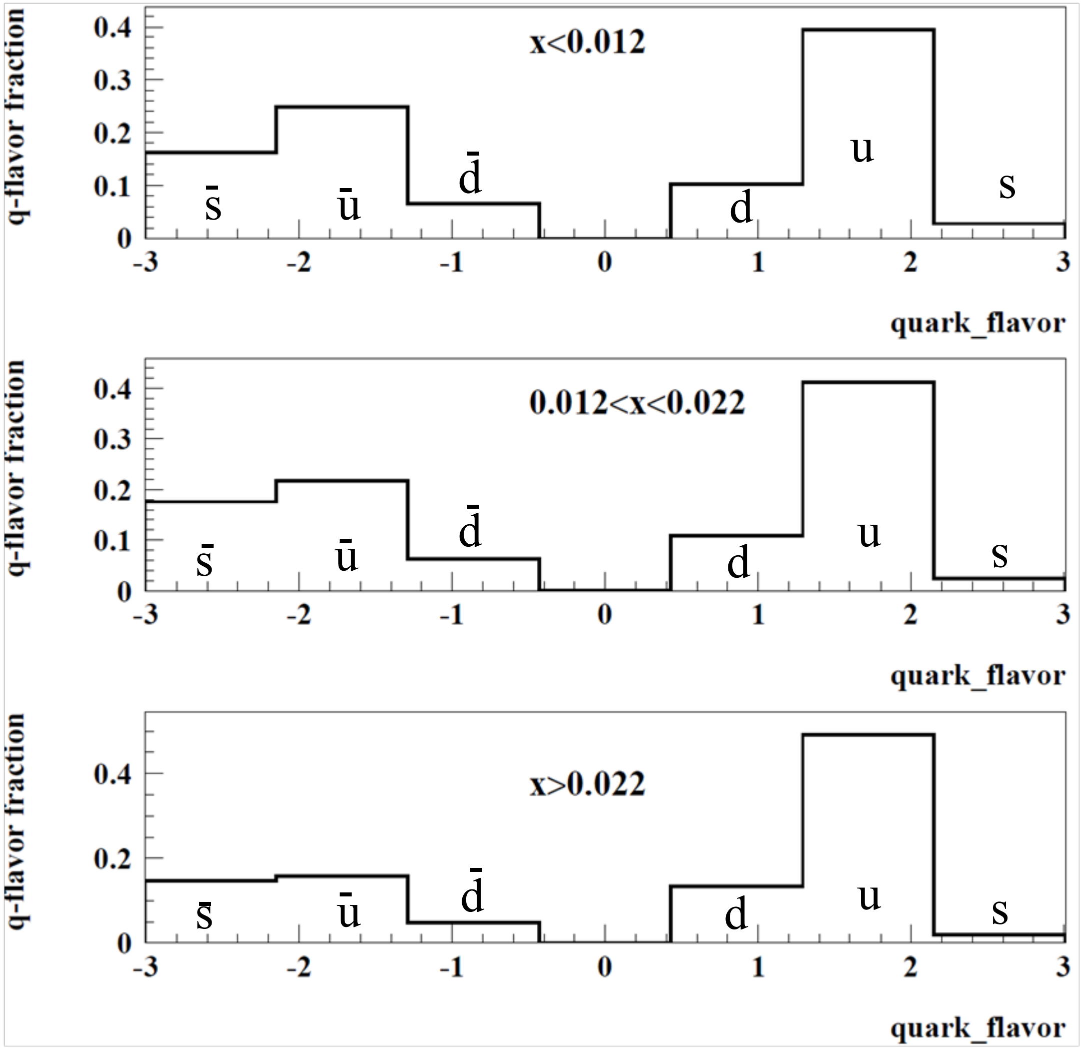


NOMAD tuning used

Best description with SU(6) model for spin transfer.

$\bar{\Lambda}$ polarization = s(x) filter

Quark type fraction in anti-Lambda production



LEPTO MC

with CTEQ5L

and COMPASS cuts

In contrast to K

production asymmetry,

here mainly s-bar

contributes to

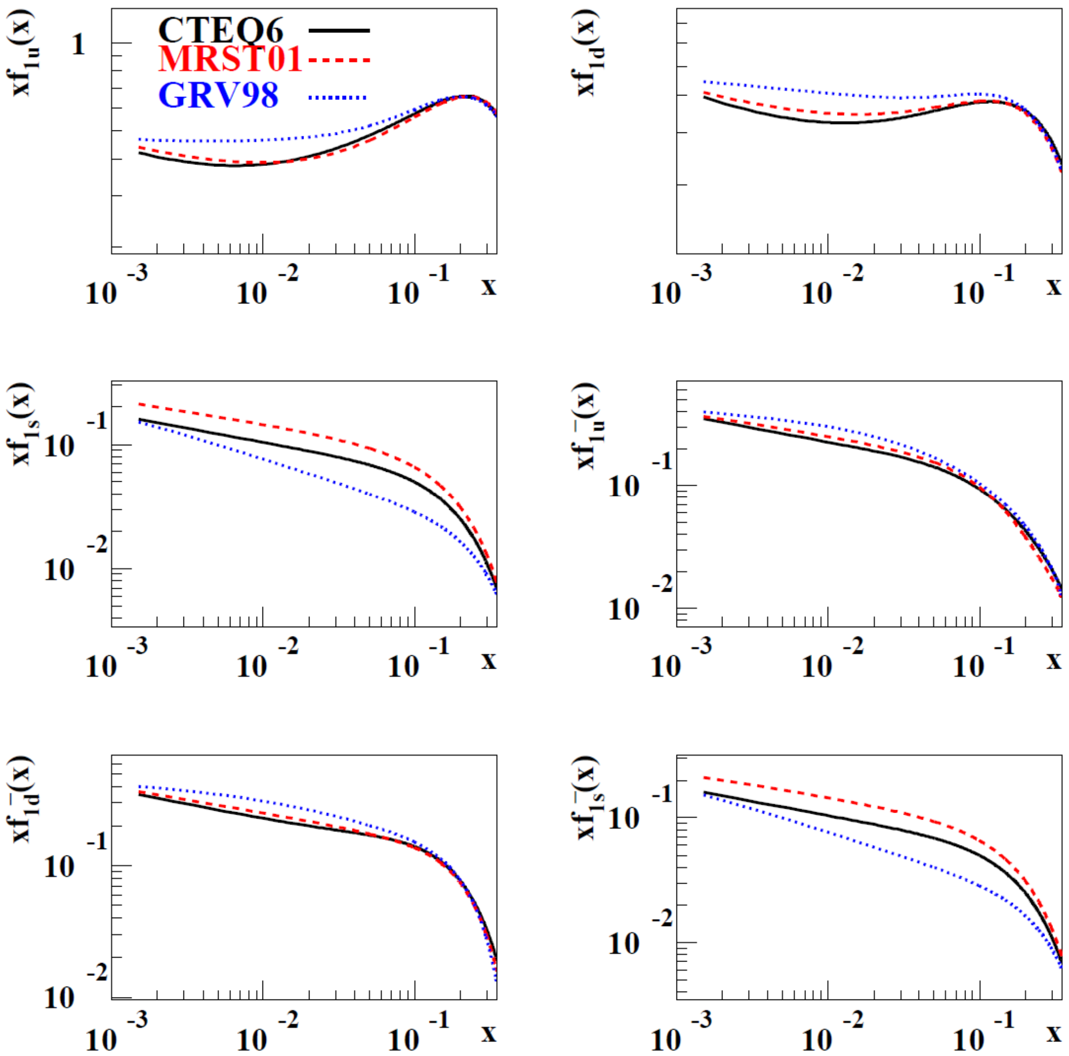
$P^{\bar{\Lambda}}$ and $\Delta P^{\bar{\Lambda}}$

$F_{\bar{s}}^{\bar{\Lambda}}(x) \approx 0.15 \div 0.2$

for $x \leq 0.1$

PDFs

LO



$$Q^2 = 2.5\ (\mathrm{GeV/c})^2$$

Hyperon production x-section and polarization for polarized beam and target

From general considerations for double and triple longitudinal polarization observables:

$$\sigma^{\bar{\Lambda}}_{P_B,\pm P_T} = \sigma^{\bar{\Lambda}}\left(1 \mp P_B P_T \frac{\Delta\sigma^{\bar{\Lambda}}}{\sigma^{\bar{\Lambda}}}\right)$$

$$P^{\bar{\Lambda}}_{P_B,\pm P_T} = \frac{P_B S_B \pm P_T S_T}{1 \mp P_B P_T \dfrac{\Delta\sigma^{\bar{\Lambda}}}{\sigma^{\bar{\Lambda}}}}$$

Triple-spin effect

Target polarization sign is written explicitly

Beam polarization contains sign

Polarization Asymmetry $A_{P^{\bar{\Lambda}}}(x)$

$$P^{\bar{\Lambda}} := \frac{1}{2}\left(P^{\bar{\Lambda}}_{P_B,-P_T} + P^{\bar{\Lambda}}_{P_B,P_T}\right)$$

$$\Delta P^{\bar{\Lambda}} := P^{\bar{\Lambda}}_{P_B,-P_T} - P^{\bar{\Lambda}}_{P_B,P_T}$$

Polarization asymmetry

$$A_{P^{\bar{\Lambda}}}(x) := \frac{\Delta P^{\bar{\Lambda}}(x)}{P^{\bar{\Lambda}}(x)}$$

Factorized LO QCD parton model

$$P^{\bar{\Lambda}}_{P_B,P_T} = \frac{\sum_q e_q^2 \left[D(y)P_B - fP_T \frac{\Delta q(x)}{q(x)} \right] q(x) \Delta D_q^{\bar{\Lambda}}(z)}{\sum_q e_q^2 \left[1 - D(y)P_B\, fP_T \frac{\Delta q(x)}{q(x)} \right] q(x) D_q^{\bar{\Lambda}}(z)}$$

$$P_T^{eff} = fP_T \approx \begin{cases} 0.2 \; for \; \text{Deuteron} \\ 0.14 \; for \; \text{Proton} \end{cases}$$

$$\langle D(y) \rangle \approx 0.5 - 0.85, \quad \left| \frac{\Delta q(x)}{q(x)} \right| \le 0.5$$

$$\left| D(y)P_B\, fP_T \frac{\Delta q(x)}{q(x)} \right| \le 0.85 \cdot 0.8 \cdot 0.2 \cdot 0.5 = 0.068$$

We can neglect pol.dep. part in denom.

ISM expression is more complicated, but results are almost unchanged

$A_{P^{\bar\Lambda}}(x)$ in LO QCD parton SU(6) model

$$P^{\bar\Lambda} \approx \langle D(y)\rangle P_B \frac{\frac{1}{9}\bar{s}(x) D_{\bar{s}}^{\bar\Lambda}(z)}{\sum_q e_q^2 q(x) D_q^{\bar\Lambda}(z)}, \quad \Delta P^{\bar\Lambda} \approx 2\, f P_T \frac{\Delta\bar{s}(x)}{\bar{s}(x)} \frac{\frac{1}{9}\bar{s}(x) D_{\bar{s}}^{\bar\Lambda}(z)}{\sum_q e_q^2 q(x) D_q^{\bar\Lambda}(z)}$$

$$\frac{\Delta\bar{s}(x)}{\bar{s}(x)} \approx \frac{\langle D(y)\rangle P_B}{2\, f P_T} \frac{\Delta P^{\bar\Lambda}(x)}{P^{\bar\Lambda}(x)} = \frac{\langle D(y)\rangle P_B}{2\, f P_T} A_{P^{\bar\Lambda}}(x)$$

$$\left| \frac{\langle D(y)\rangle P_B}{2\, f P_T} \right| \approx 1, \text{ for COMPASS Deuteron target}$$

$$A_{P^{\bar\Lambda}}(x) = \frac{\Delta P^{\bar\Lambda}(x)}{P^{\bar\Lambda}(x)} (COMPASS) \approx \frac{\Delta\bar{s}(x)}{\bar{s}(x)}$$

ISM calculations using LEPTO

Nomad settings and $c_{\bar{s}q} = c_{sq}$

Symbolic notations: Lund Model is realization of Fracture Functions.

Spin transfer via heavy hyperons is taken into account.

$$P^{\bar{\Lambda}}_{P_B,P_T}(x, x_F, \ldots) = \frac{N_q(x, x_F, \ldots) + N_{qq}(x, x_F, \ldots)}{N(x, x_F, \ldots)}$$

$$N_q(x, x_F, \ldots) = \sum_{q(R_q \le R_{qq})} e_q^2 \left[D(y) P_B - f P_T \frac{\Delta q(x)}{q(x)} \right] q(x) D_q^{\bar{\Lambda}}(z) S_q^{\bar{\Lambda}}$$

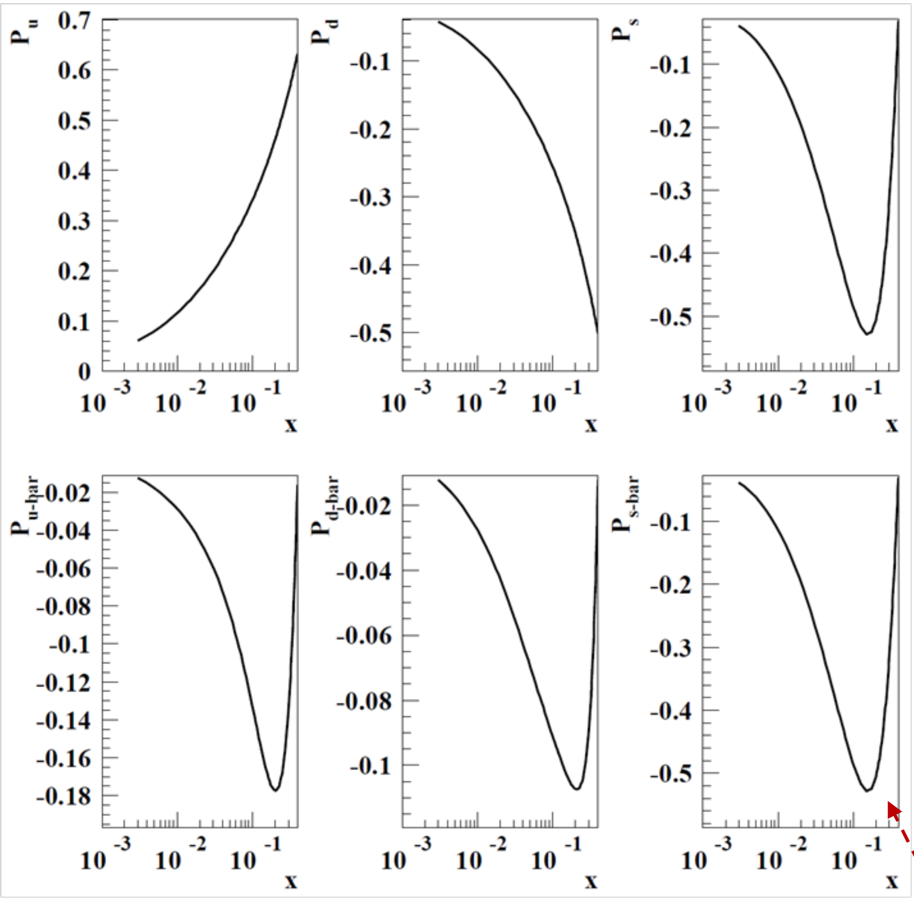
$$N_{qq}(x, x_F, \ldots) = -\sum_{q(R_q > R_{qq})} e_q^2 \left[D(y) P_B - f P_T \frac{\Delta q(x)}{q(x)} \right] q(x) D_q^{\bar{\Lambda}}(z) c_{\bar{s}q}$$

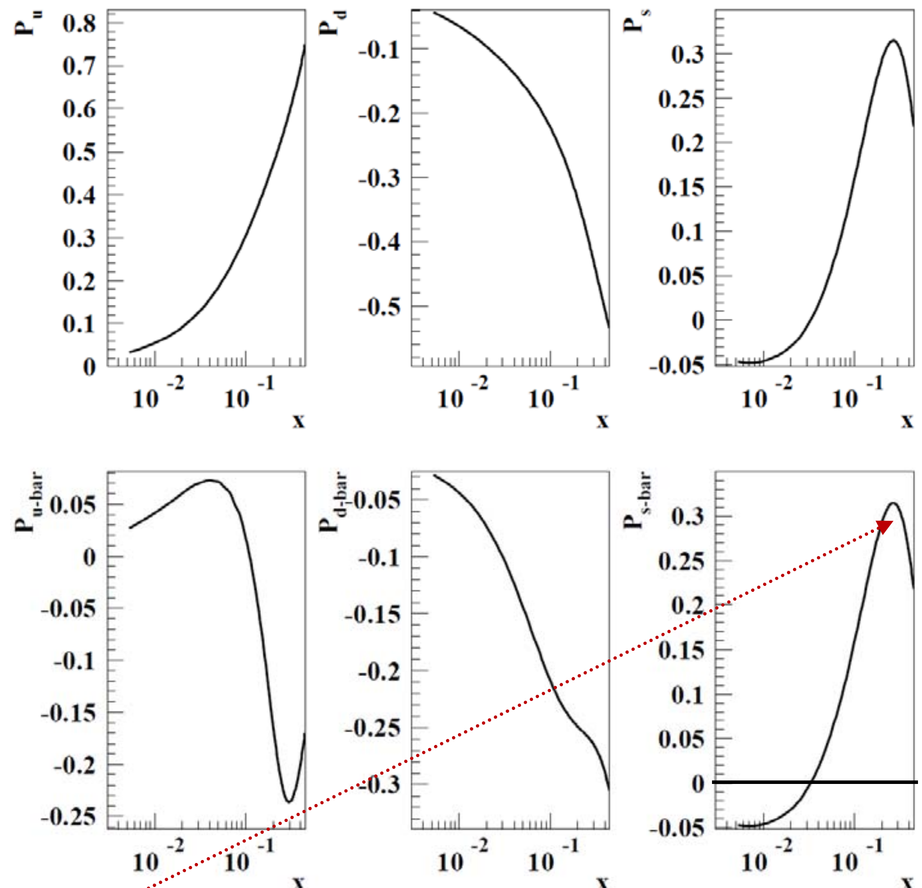
$$N(x, x_F, \ldots) = \sum_q e_q^2 \left[1 - D(y) P_B f P_T \frac{\Delta q(x)}{q(x)} \right] q(x) D_q^{\bar{\Lambda}}(z)$$

Separately calculate numerator and denominator by

reweighting each generated event

Two inputs for $P_q = \Delta q / q$





DSSV+MRST02

2008

$P_{\bar{s}}$

GRSV+GRV

2000

COMPASS cuts

$Q^2 > 1\ (\mathrm{GeV}/c)^2$; $0.2 < y < 0.9$

Primary vertex: $-100 < z < 100$ or $-30 < z < 30$ (cm)

Decay vertex: $35 < z_{dec} < 140$ (cm)

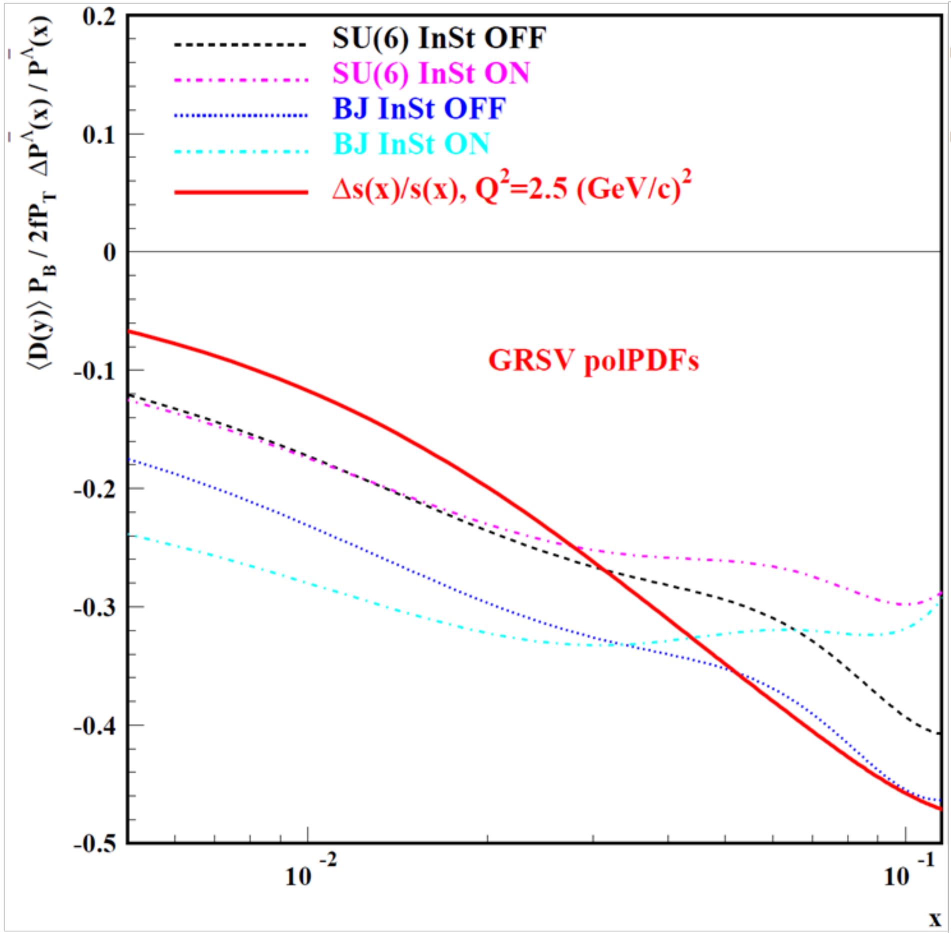
Vertexes colinearity cut: $\theta_{col} = 0.01$

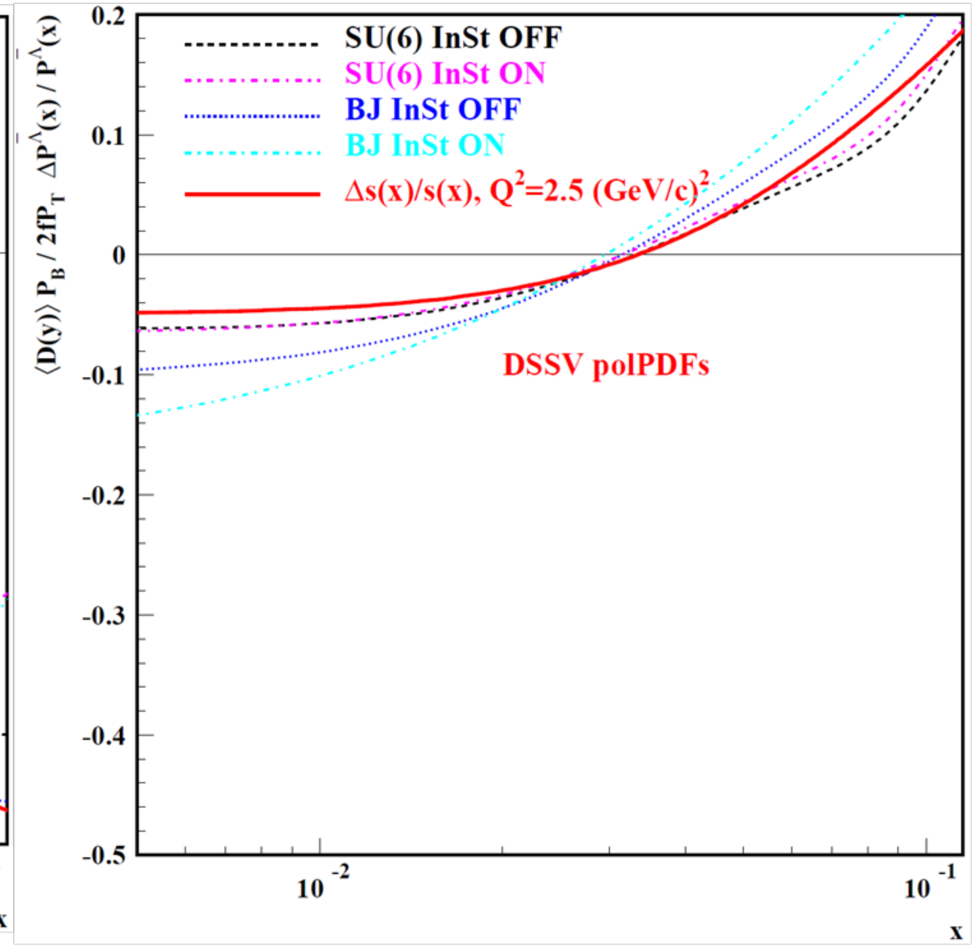
Decay particles momentum: $p > 1$ GeV/c

Feynman variable: $0.05 < x_F < 0.5$

Λ rest frame decay angle cut: $\cos(\theta^*) < 0.6$

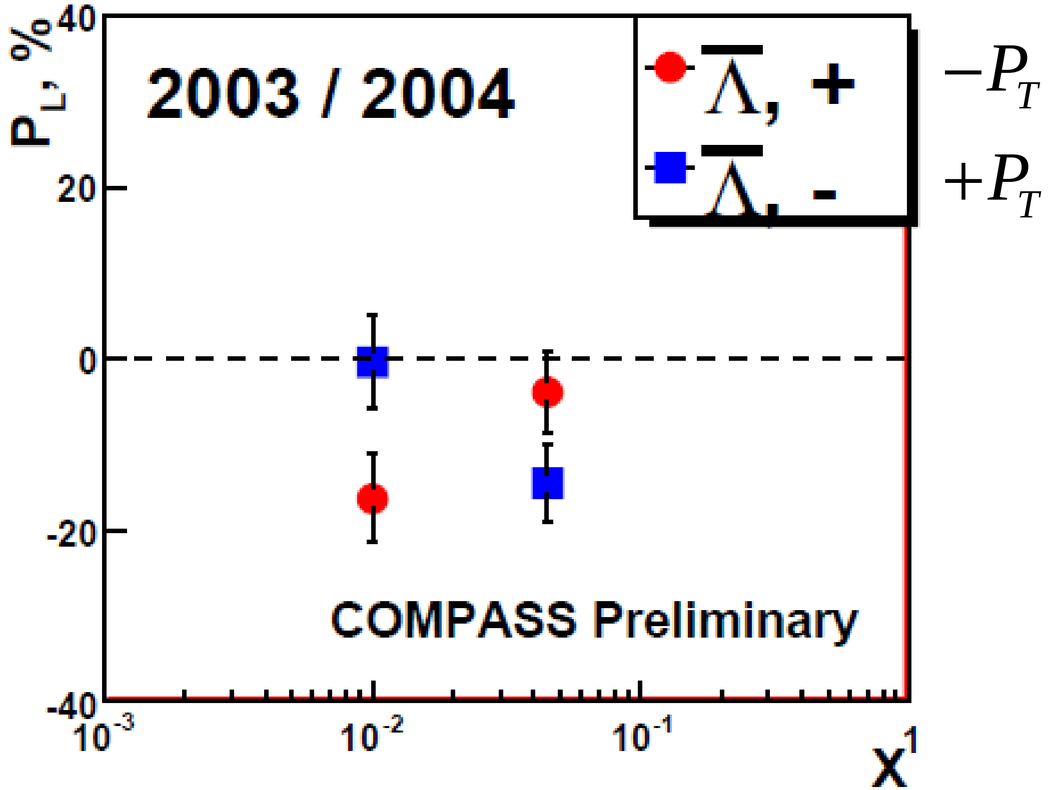
Dependence on pol. PDFs





To verify sign change of $\Delta\bar{s}$
measure in two bins of x: x < 0.03 and 0.03 <x

COMPASS preliminary



Sing change of ΔP corresponds to DSSV PDFs

Conclusions

- (Anti)Lambda polarization measurements in SIDIS of polarized leptons off unpolarized and polarized targets can shed light unpolarized and polarized s-bar distributions in nucleon
  - (Anti)Lambda polarization on unpolarized target strongly depends on strangeness PDF
  - Polarization asymmetry strongly depends on strangeness polarization shape
- (Anti)Lambda polarization in SIDIS is well suited filter for nucleon strangeness study