Spin structure of nucleon and anti-hyperon polarization in high energy pp collision with polarized beam

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Dspin07

References:

- Q. H. Xu, Z. T. Liang, and E. Sichtermann, Phys. Rev. D **73**, 077503 (2006).
- Y. Chen, Z. T. Liang, E. Sichtermann, Q. H. Xu and S. S. Zhou, Arxiv:0707.0534, hep-ph.

Outline

Spin structure of nucleon sea

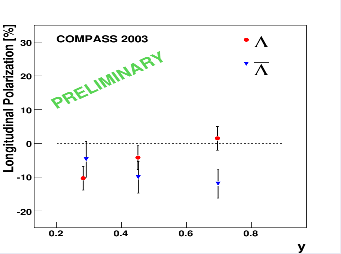
- Polarized inclusive DIS ⟶ $\Delta S = -0.10 \pm 0.02$
- Polarized SIDIS, HERMES → $\Delta S = 0.028 \pm 0.033 \pm 0.009$
- Further measurements
- Polarization of $\bar{H}$ in $\vec{p} + p \rightarrow \bar{H} + X$ could help?

P_Λ and $P_{\bar{\Lambda}}$ in $\vec{\mu}^+ + \vec{N} \rightarrow \Lambda/\bar{\Lambda} + N$ at COMPASS

Difference between P_Λ and $P_{\bar{\Lambda}}$?
$\Rightarrow$ Difference in the production and spin transfer mechanism?

↓

Study of $P_{\bar{H}}$ in other processes.



COMPASS hep-ex/0602002

Outline

Calculation method

Longitudinally singly polarized $p + p \to \bar{H} + X$ at large p_T

$$P_{\bar{H}}(\eta) \equiv \frac{d\sigma(p_+ p \to \bar{H}_+ X) - d\sigma(p_+ p \to \bar{H}_- X)}{d\sigma(p_+ p \to \bar{H}_+ X) + d\sigma(p_+ p \to \bar{H}_- X)} = \frac{\frac{d\Delta\sigma}{d\eta}(\vec{p}p \to \bar{H}X)}{\frac{d\sigma}{d\eta}(\vec{p}p \to \bar{H}X)}$$

parton distribution function

polarized parton distribution function

$$\frac{d\Delta\sigma}{d\eta}(\vec{p}p \to \bar{H}X) = \int_{p_T^{min}} dp_T \sum_{abcd} \int dx_a dx_b \, \Delta f_a(x_a) \times f_b(x_b)$$

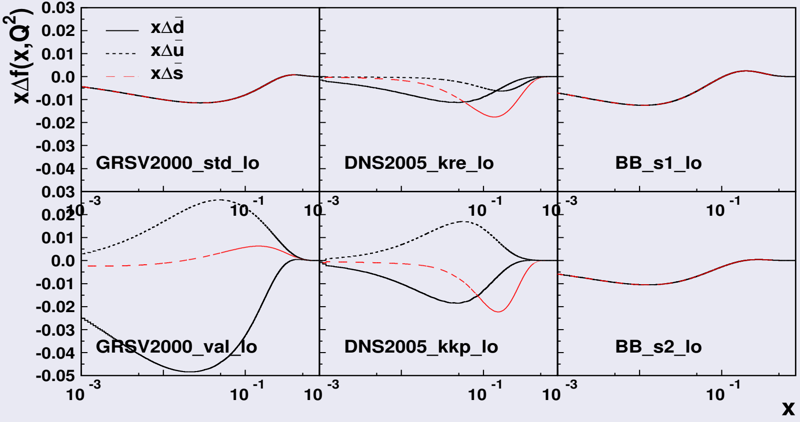
$$\times D_L^{\vec{a}b \to \vec{c}d}(y) \frac{d\hat{\sigma}}{d\hat{t}}(ab \to cd) \times \Delta D_c^{\bar{H}}(z)$$

polarized fragmentation function

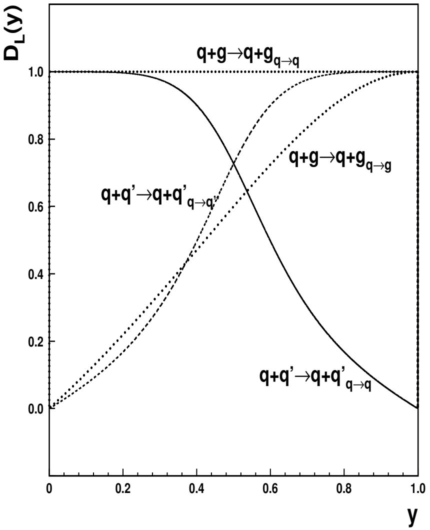
polarized cross section of elementary hard scattering

Polarized parton distribution function

- Many parametrizations exist
- Large differences for sea quark distributions



Spin transfer in elementary hard scattering



Spin transfer factor in $a(p_a) + b(p_b) \to c(p_c) + d(p_d)$ scattering :

$$D_L^{\vec{a}b\to\vec{c}d}(y) \equiv \frac{d\Delta\hat{\sigma}(\vec{a}+b\to\vec{c}+d)}{d\hat{\sigma}(a+b\to c+d)},$$

- can be calculated by PQCD
- to leading order, is function of $y \equiv p_b \cdot (p_a - p_c)/p_a \cdot p_b$
- different for different processes

Polarized fragmentation function

Definition: $\Delta D_f^{\bar{H}}(z) \equiv D_f^{\bar{H}}(z,+) - D_f^{\bar{H}}(z,-)$
Clearly: $\Delta D_f^{\bar{H}}(z) = \Delta D_f^{\bar{H}}(z;\mathrm{direct}) + \Delta D_f^{\bar{H}}(z;\mathrm{decay})$

$$\Delta D_f^{\bar{H}}(z;\mathrm{decay}) = \sum_j \int dz' t^D_{\bar{H},\bar{H}_j} K_{\bar{H},\bar{H}_j}(z,z') \Delta D_f^{\bar{H}_j}(z',\mathrm{direct})$$

- $t^D_{\bar{H},\bar{H}_j}$: spin transfer factor in $\bar{H}_j \to \bar{H} + X$. e.g.
  $\bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \quad t^D_{\bar{\Lambda},\bar{\Sigma}^0} = -1/3; \quad \bar{\Xi} \to \bar{\Lambda}\bar{\pi}, \quad t^D_{\bar{\Lambda},\bar{\Xi}} = 1/2(1+\gamma)$.
- $K_{\bar{H},\bar{H}_j}(z,z')$: probability of producing an $\bar{H}$ with z in the decay of $\bar{H}_j$ with z'.
- $\Delta D_f^{\bar{H}_j}(z';\mathrm{direct})$: cannot be calculated by PQCD.

Modeling $\Delta D_f^{\bar{H}}(z, \mathrm{direct})$

$\Delta D_f^{\bar{H}}(z, \mathrm{direct}) = \Delta D_f^{\bar{H}(\mathrm{A})}(z, \mathrm{direct}) + \Delta D_f^{\bar{H}(\mathrm{B})}(z, \mathrm{direct})$

(A) containing the fragmenting quark with flavor f.
(B) not containing the fragmenting quark.

$$\Delta D_f^{\bar{H}}(z; \mathrm{direct}) = \Delta D_f^{\bar{H}(\mathrm{A})}(z) = t_{\bar{H},f}^F D_f^{\bar{H}(\mathrm{A})}(z)$$

fragmentation spin transfer factor $t_{\bar{H},f}^F = \Delta Q_f / n_f$

- ΔQ_f: contribution of quark with flavor f to spin of $\bar{H}$.
- n_f: number of valence quarks of flavor f in $\bar{H}$.

G. Gustafson and J. Häkkinen(1993); C. Boros and Z. T. Liang(1998)

Fragmentation spin transfer factor $t^F_{\bar{H},f} = \Delta Q_f / n_f$

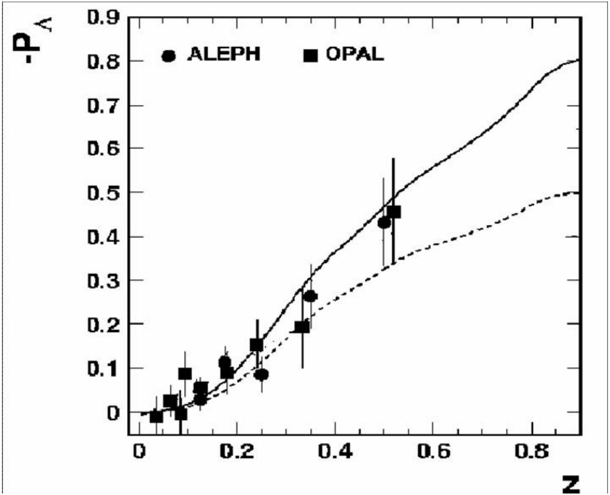
- ΔQ_f, contribution of quark with flavor f to spin of $\bar{H}$
- n_f, number of valence quarks of flavor f in $\bar{H}$.

	$\bar{\Lambda}$	
	SU(6)	DIS
$\Delta\bar{U}$	0	-0.17
$\Delta\bar{D}$	0	-0.17
$\Delta\bar{S}$	1	0.62

	$\bar{\Sigma}^-$		$\bar{\Sigma}^+$	
	SU(6)	DIS	SU(6)	DIS
$\Delta\bar{U}$	4/3	0.82	0	-0.10
$\Delta\bar{D}$	0	-0.10	4/3	0.82
$\Delta\bar{S}$	-1/3	0.44	-1/3	0.44
	$\bar{\Xi}^0$		$\bar{\Xi}^-$	
	SU(6)	DIS	SU(6)	DIS
$\Delta\bar{U}$	-1/3	-0.44	0	-0.10
$\Delta\bar{D}$	0	-0.10	-1/3	-0.44
$\Delta\bar{S}$	4/3	0.82	4/3	0.82

Polarized fragmentation function

Application of the model, e.g. P_Λ in $e^+e^- \to Z^0 \to \Lambda + X$



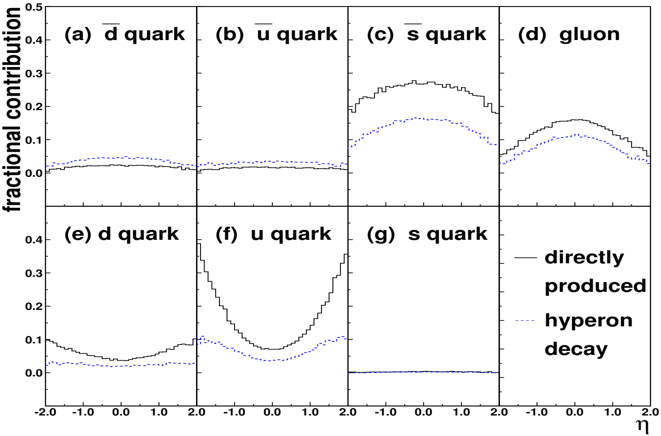
C. Boros and Z. T. Liang (1998)

Outline

Fractional contribution to $\bar{H}$ production $PP \to \bar{H}X$

Fraction contribution $R_f = \frac{d\sigma(pp \to q_f(large \quad p_T) + X, q_f \to \bar{H} + X)}{d\sigma(pp \to \bar{H}X)}$.

Independent of polarization, with PYTHIA



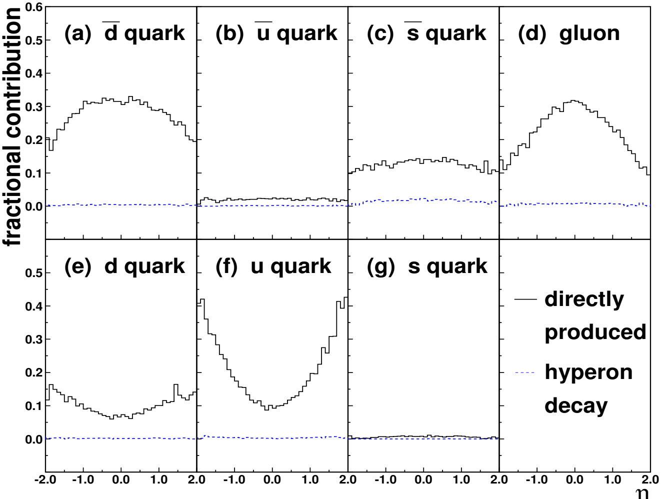
Large $\bar{s}$ contribution

Large $\Delta\bar{S}$ in $\bar{\Lambda}$

$P_{\bar{\Lambda}}$ sensitive to $\Delta\bar{s}$

Production of $\bar{\Lambda}(\bar{u}\bar{d}\bar{s})$

Fractional contribution to $\bar{H}$ production $PP \to \bar{H}X$



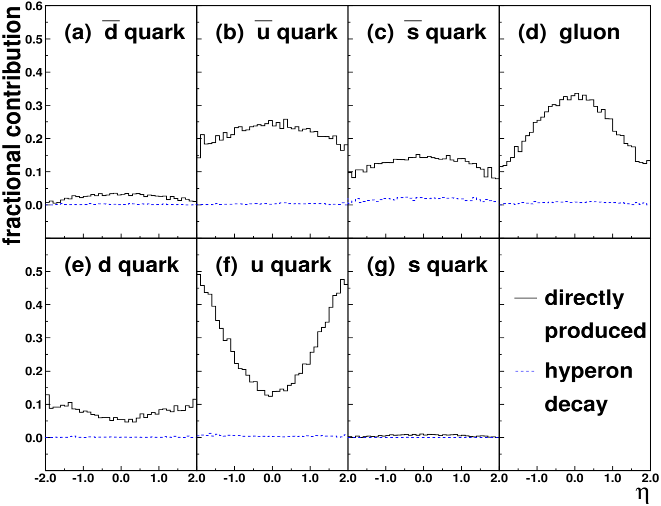
Large $\bar{d}$ contribution

Large $\Delta\bar{D}$ in $\bar{\Sigma}^+$

$P_{\bar{\Sigma}^+}$ sensitive to $\Delta\bar{d}$

Production of $\bar{\Sigma}^+(\bar{s}\bar{d}\bar{d})$

Fractional contribution to $\bar{H}$ production $PP \to \bar{H}X$



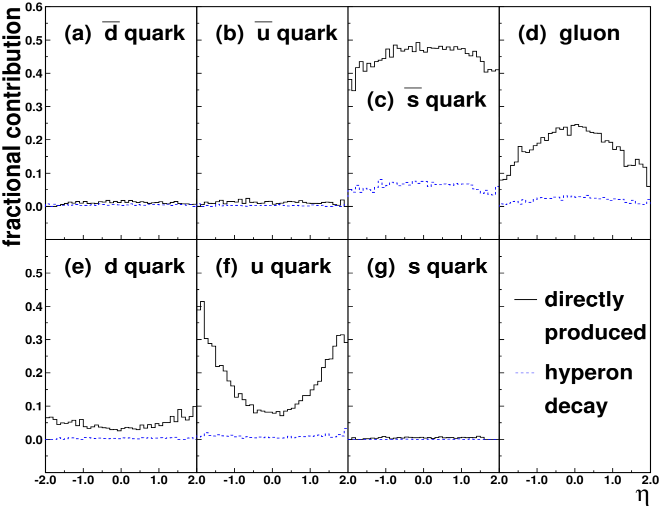
Large $\bar{u}$ contribution

Large $\Delta\bar{U}$ in $\bar{\Sigma}^-$

$P_{\bar{\Sigma}^-}$ sensitive to $\Delta\bar{u}$

Production of $\bar{\Sigma}^-(\bar{s}\bar{u}\bar{u})$

Fractional contribution to $\bar{H}$ production $PP \to \bar{H}X$



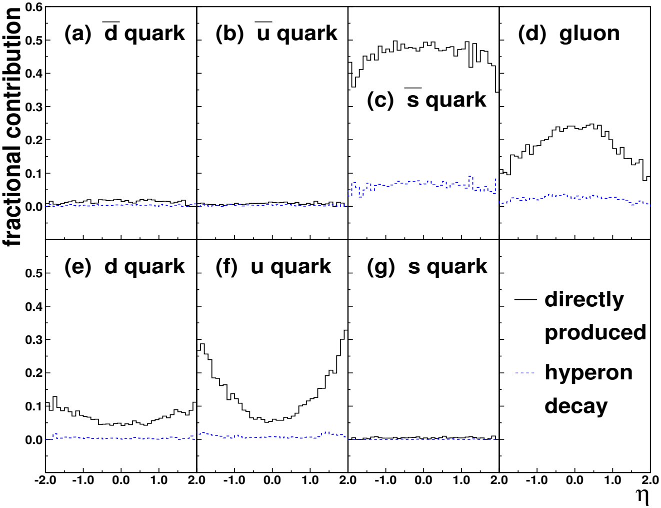
Large $\bar{s}$ contribution

Large $\Delta\bar{S}$ in $\bar{\Xi}^0$

$P_{\bar{\Xi}^0}$ sensitive to $\Delta\bar{s}$

Production of $\bar{\Xi}^0(\bar{s}\bar{s}\bar{u})$

Fractional contribution to $\bar{H}$ production $PP \to \bar{H}X$



Large $\bar{s}$ contribution

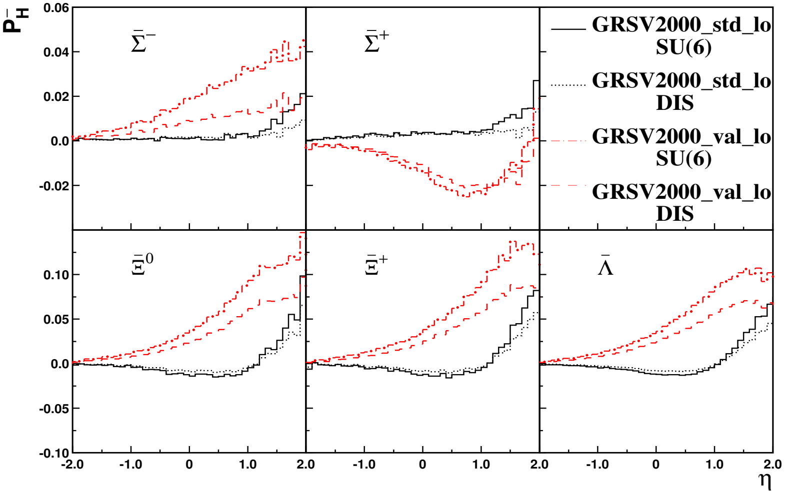
Large $\Delta\bar{S}$ in $\bar{\Xi}^+$

$P_{\bar{\Xi}^+}$ sensitive to $\Delta\bar{s}$

Production of $\bar{\Xi}^+(\bar{s}\bar{s}\bar{d})$

Polarization $\bar{H}$

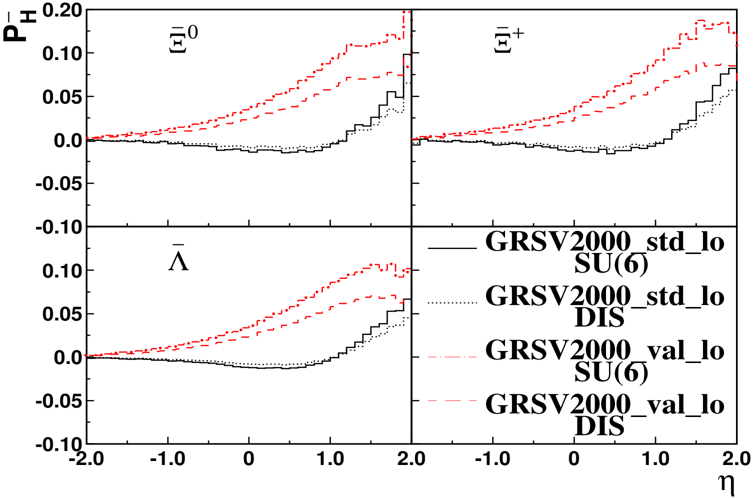
Polarized PDF v.s. Polarized FF



Polarization of $\bar{\Xi}$ and $\bar{\Lambda}$

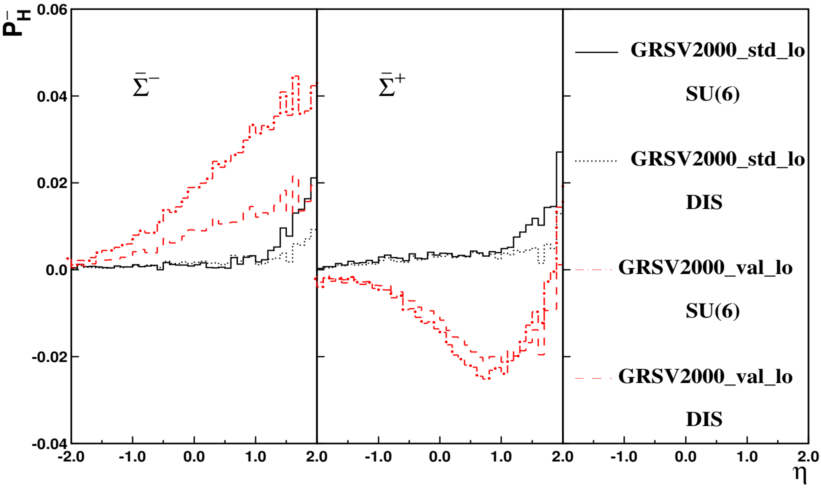
$\bar{s}$ fragmentation is dominating → $P_{\bar{\Xi}} \approx 10\%,\ \eta = 2$

$P_{\bar{\Xi}} > P_{\bar{\Lambda}} > P_{\bar{\Sigma}}$



Polarization of $\bar{\Sigma}$

$\Delta\bar{u}$ and $\Delta\bar{d}$ are asymmetrical → $P_{\bar{\Sigma}^+}$ and $P_{\bar{\Sigma}^-}$ differ in sign



Outline

Summary

- We have evaluated the longitudinal polarizations of the $\bar{\Lambda}$, $\bar{\Sigma}^-$, $\bar{\Sigma}^+$, $\bar{\Xi}^0$, and $\bar{\Xi}^+$ anti-hyperons in highly energetic collisions of longitudinally polarized proton beams. The results show sensitivity to the anti-quark polarizations in the nucleon sea. In particular,
  $\bar{\Lambda}$, $\bar{\Xi}^0$ and $\bar{\Xi}^+$ polarizations are sensitive to strange anti-quark polarization $\Delta\bar{s}(x)$;
  $\bar{\Sigma}^-$ and $\bar{\Sigma}^+$ polarizations are sensitive to the light sea quark polarizations, $\Delta\bar{u}(x)$ and $\Delta\bar{d}(x)$.
- Precision measurements at the RHIC polarized pp-collider should be able to provide new insights in the sea quark polarizations in the nucleon.

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- Precision measurements at the RHIC polarized pp-collider should be able to provide new insights in the sea quark polarizations in the nucleon.

Thank you!

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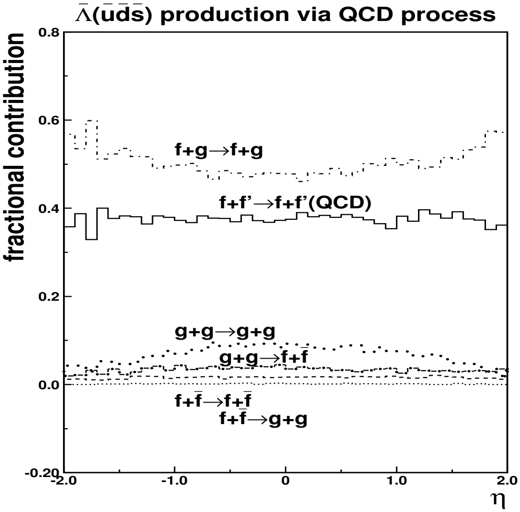

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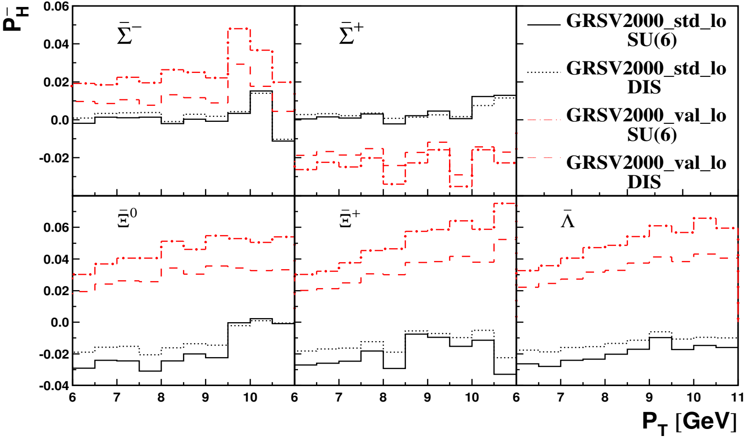

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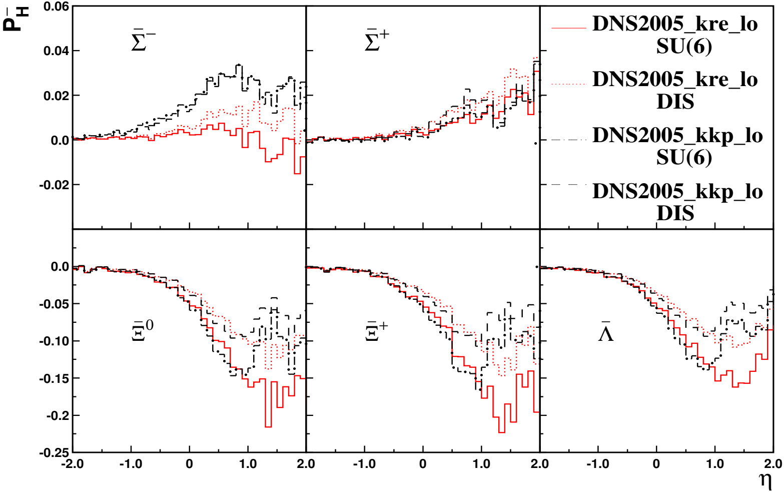

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