Transverse Λ^0 polarization in quasi-real photo-production at HERMES: s-quark scattering model

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- $\surd$ Quark multiple scattering model: $q \longrightarrow q$ kinematics
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- $\surd$ Comparison with HERMES data
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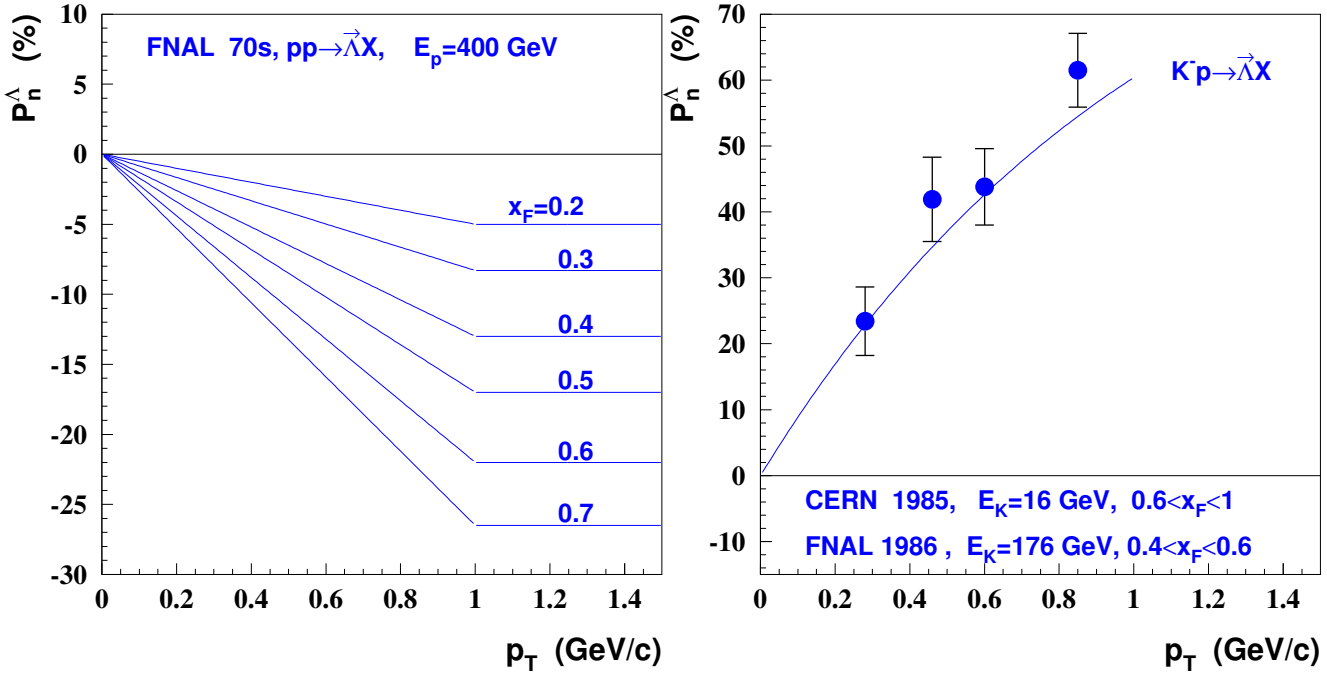
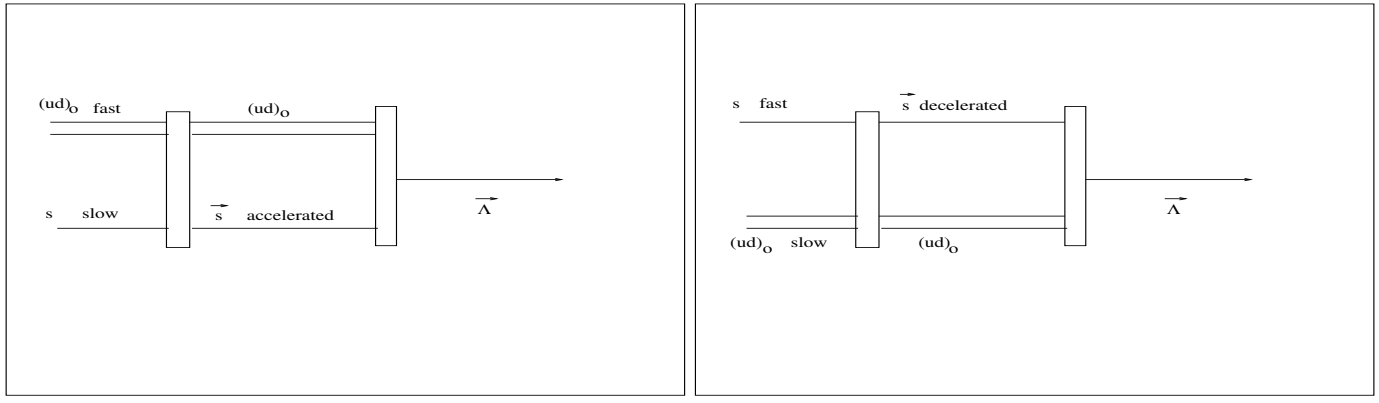
Introduction. Λ polarization in Λ hadroproduction

$$\vec{P}^{\Lambda} = P^{\Lambda}\frac{\vec{p}_b \times \vec{p}_{\Lambda}}{|\vec{p}_b \times \vec{p}_{\Lambda}|}$$



DeGrand & Miettinen



Models

- J. Szwed, Phys. Lett. B 105 (1981) 403.
  Multiple scattering of the strange quark.

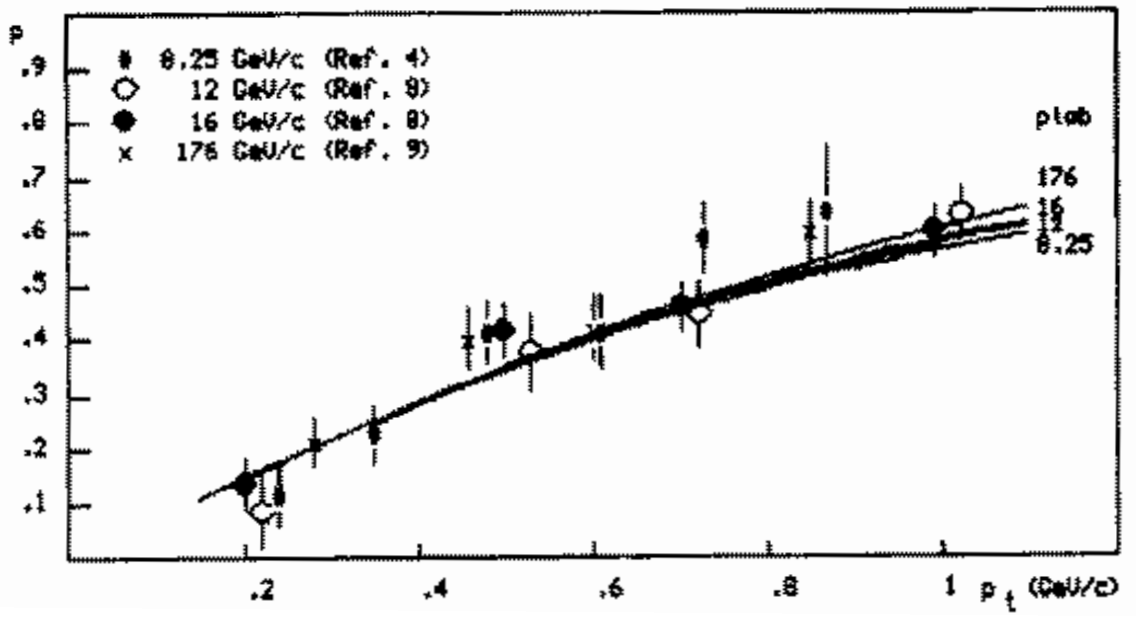
- J. M. Gago, R. Vilela Mendes and P. Vaz, Phys. Lett. B 183 (1987) 357.
  Reproduces p_T and energy dependences of the Λ-polarization in $K^- + p \to \Lambda + X$.

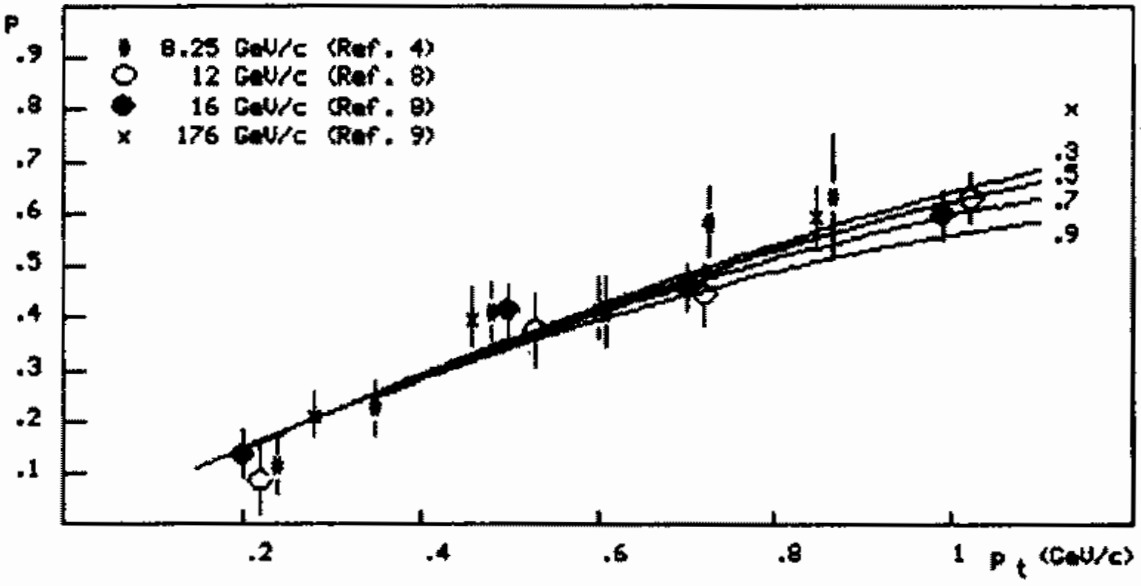
- K.I. Kubo, Y. Yamamoto and H. Toki, Prog. Theor. Phys. 98 (1997) 95.
  H.Toki, N. Nakajima, K. Suzuki and I. Kubo, hep-ph/9906451.
  Quark-Recombination Model reproduces polarization of Λ and Σ^0.
  Predictions for $\gamma + N \to \Lambda \uparrow (\Sigma^0 \uparrow)$.

- M. Anselmino, D. Boer, U. D'Alesio and M. Murgia, hep-ph/0109186.
  Predictions for electroproduction case, however in the high Q^2 regime of DIS.

As yet, no model is able to account for the complete set of available measurements!

$$K^- p \to \vec{\Lambda}^0 X \Rightarrow sp \to \vec{s} X$$





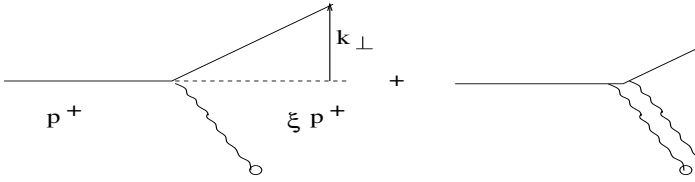
Model proposed by J.Szwed [Phys. Lett., B105(1981)403] and by J.M.Gago, R.Vilela Mendes and P. Vaz [Phys. Lett., B183(1987)357] :

- √ spin projection of the Λ^0 is entirely given by the spin projection of the s-quark;
- √ s-quark obtains the considerable transverse momentum $k_\perp$ by multiple scattering on quark-gluon matter, which is approximated by the external gluonic field;
- √ Polarization appears already in the second order of the perturbation calculation.

$q \to q$ scattering kinematic

Let

$$p_i = (p^+, \vec{0}, \frac{m_q^2}{2p^+}) \,, \qquad p_f = (\xi p^+, \vec{k}_\perp, \frac{m_q^2 + k_\perp^2}{2\xi p^+})$$



be the initial and final momenta of the quark in the light cone notations.

Quark polarization depends on only two variables : $k_\perp$ and $\xi \equiv \frac{p_f^+}{p_i^+}$

For the s-quark

$\xi < 1$	:	$K^- \to \Lambda^0$	(s-quark is decelerated)
$0.3 \leqslant \xi \leqslant 1.7$	:	$\gamma^* \to s \to \Lambda^0$	(HERMES)
$1 < \xi$	:	$p \to \Lambda^0$	(s-quark is accelerated)

The transverse velocity of the final quark

$$V_\perp \equiv \frac{k_\perp}{m_q} \,. \qquad \text{Assumed that } V_\perp = V_\perp^\Lambda = \frac{p_T}{m_\Lambda} \,. \qquad \text{Typically } \langle V_\perp \rangle \simeq 0.5$$

Polarization of scattered quark

First step is to find the velocity V and scattering angle θ of the quark in the frame where the energy of the quark is not changed during the scattering

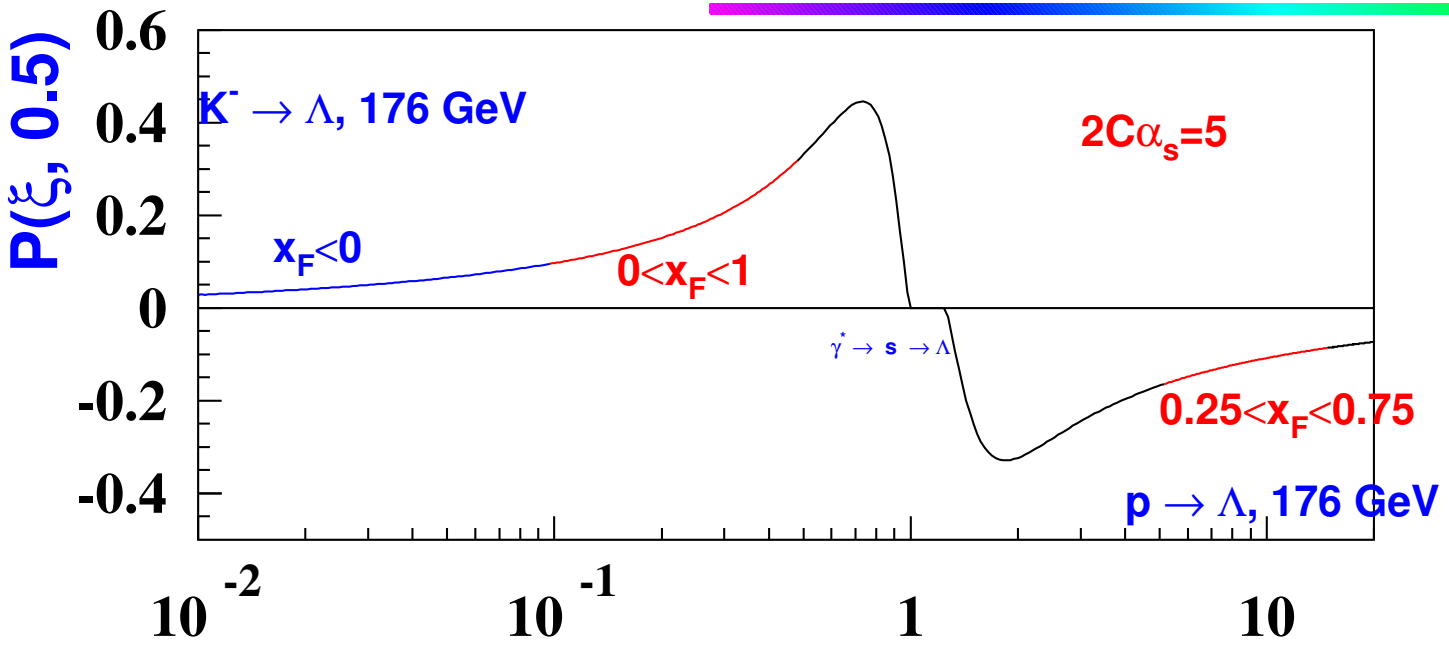
$$\left\{ \begin{array}{c} \xi = \frac{p_f^+}{p_i^+} = \frac{\sqrt{1+V^2}+V\cos\theta}{\sqrt{1+V^2}+V} \\ V_\perp = V\sin\theta \end{array} \right. \Rightarrow \left\{ \begin{array}{c} \cos\frac{\theta}{2} = \frac{\xi V_\perp^2}{(1-\xi)^2+V_\perp^2} \\ V = \frac{(1-\xi)^2+V_\perp^2}{2\sqrt{\xi}\sqrt{(1-\xi)^2+(1-\xi)V_\perp^2}} \end{array} \right.$$

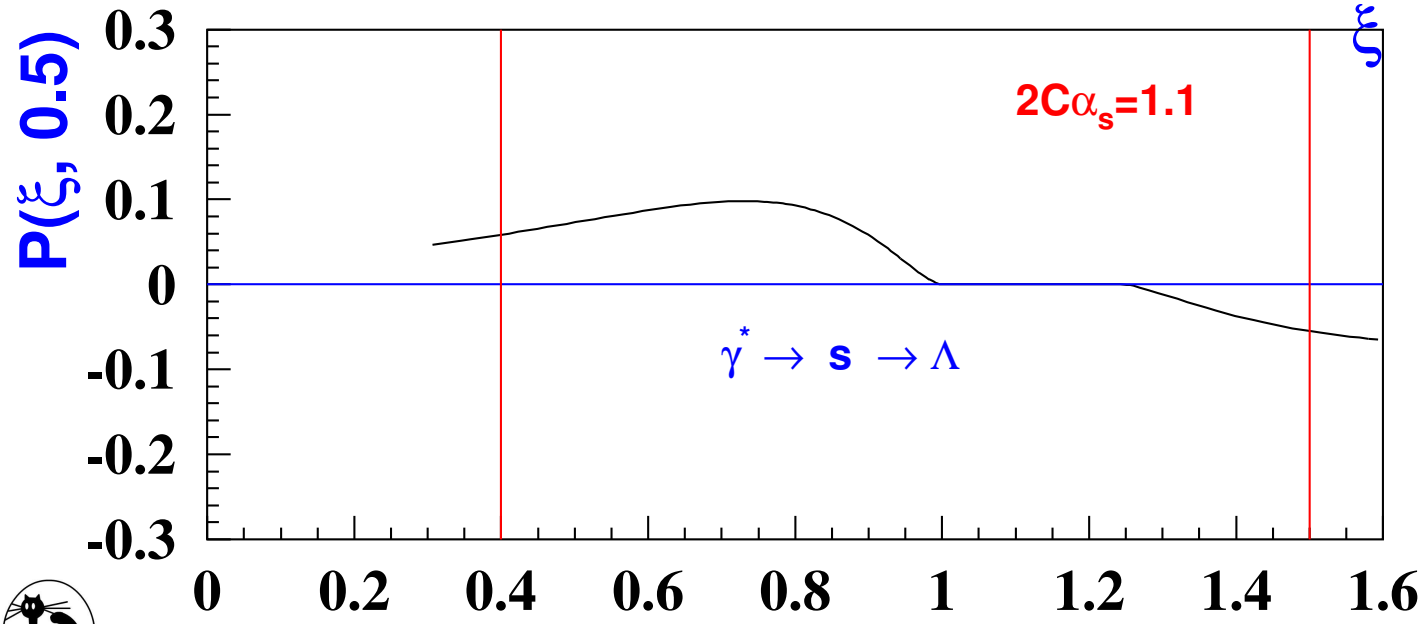
Then the polarization appearing in the second order of the perturbation calculations reads

$$P(\xi, V_\perp) = 2C\alpha_s \frac{V}{1+V^2\cos^2\frac{\theta}{2}} \cdot \frac{\sin^3\frac{\theta}{2}\cdot \ln\sin\frac{\theta}{2}}{\cos\frac{\theta}{2}} \cdot \mathrm{sign}(\xi-1)$$

C is the factor characterizing the intensity of the color field, α_s is the strong coupling constant. Theoretical estimation done by Gago et al. [Phys. Lett., B183(1987)357] is $2C\alpha_s \simeq 2.5$ however $2C\alpha_s$ is used it as free parameter.

$P(\xi)$ **at** $V_\perp = 0.5$

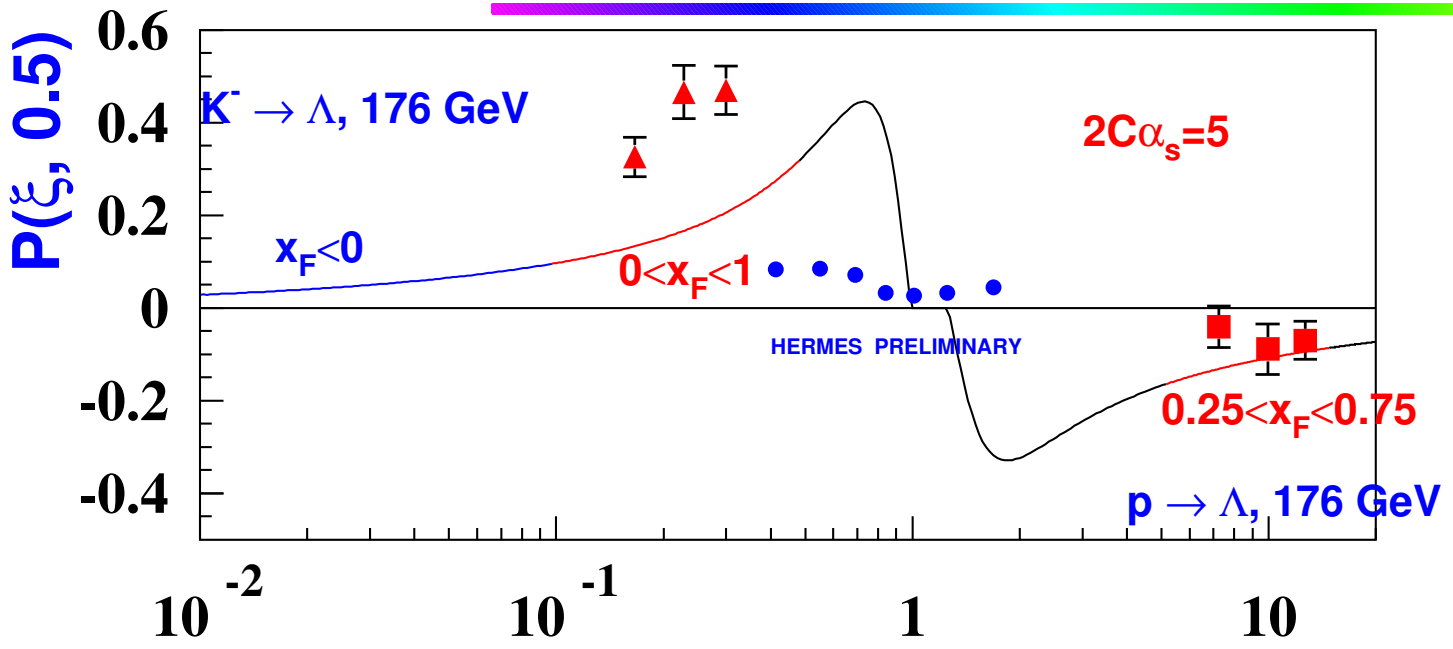


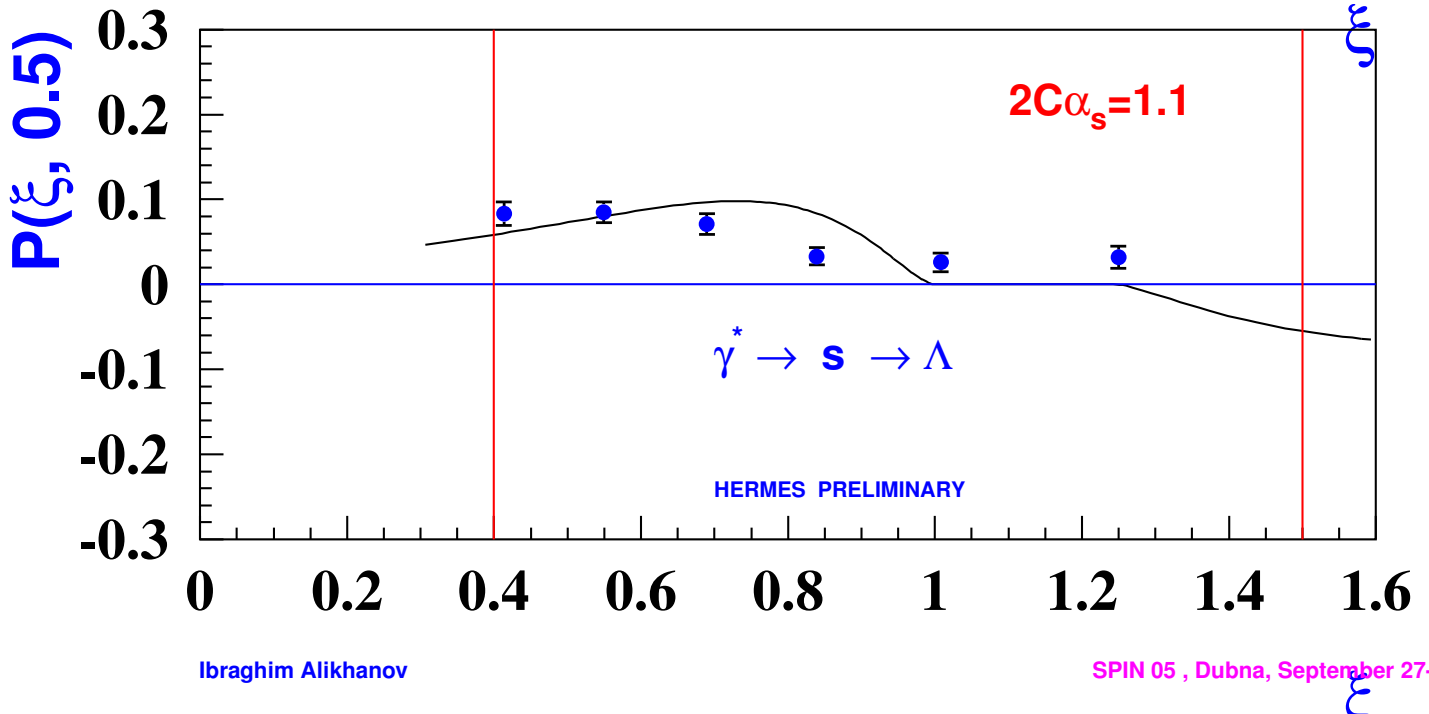


Unphysical $\cos\frac{\theta}{2} > 1$ in the interval

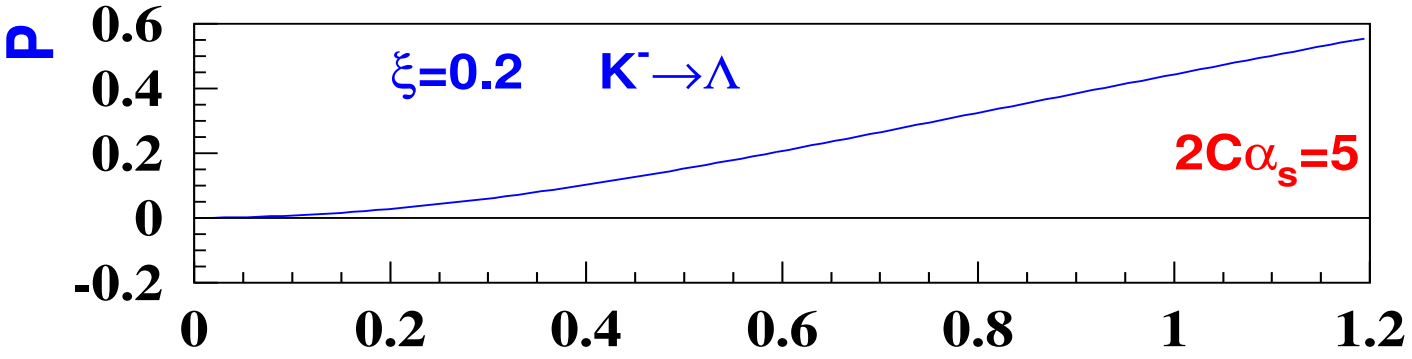
$$1 < \xi < 1 + V_\perp^2$$

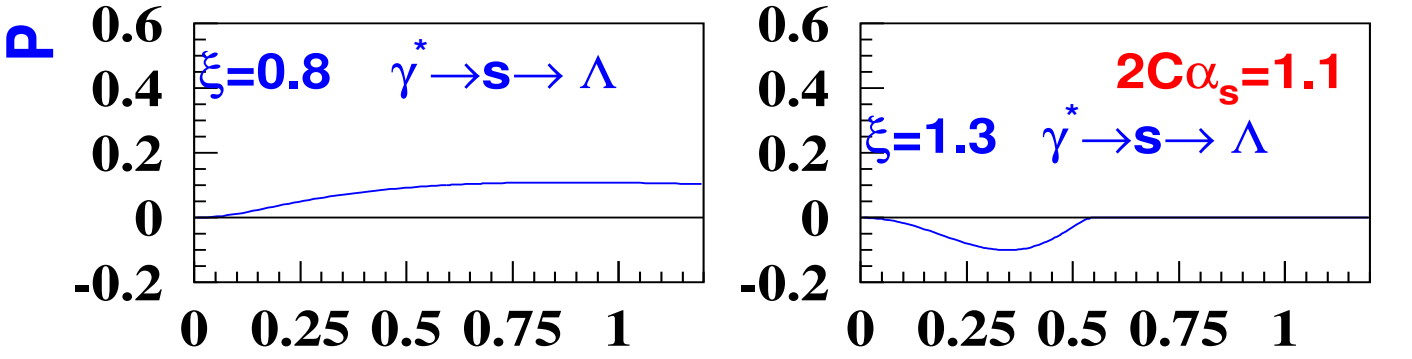
$P(\xi)$ **at** $V_\perp = 0.5$

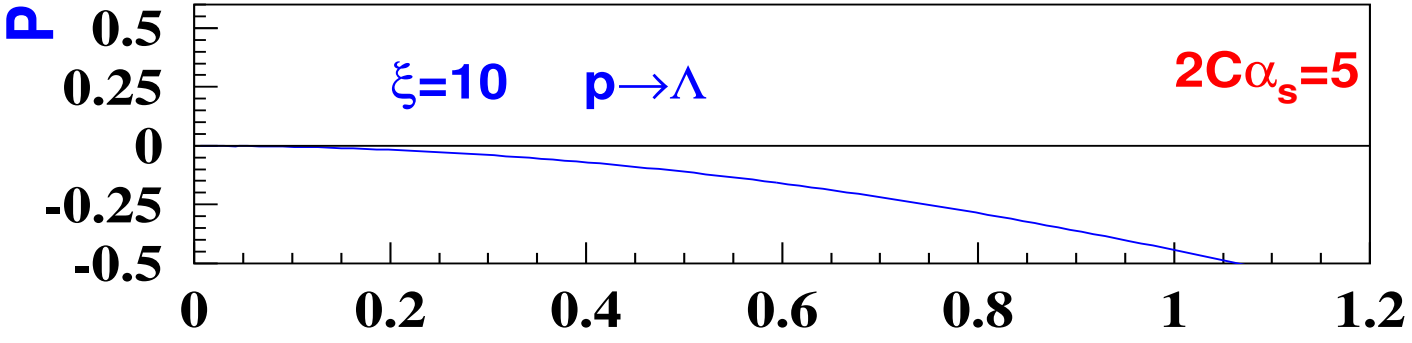




$P(V_\perp)$ *at different* ξ



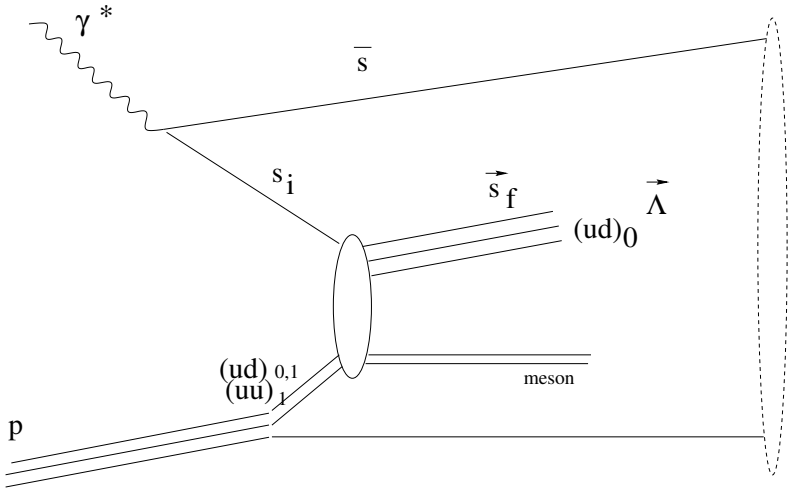


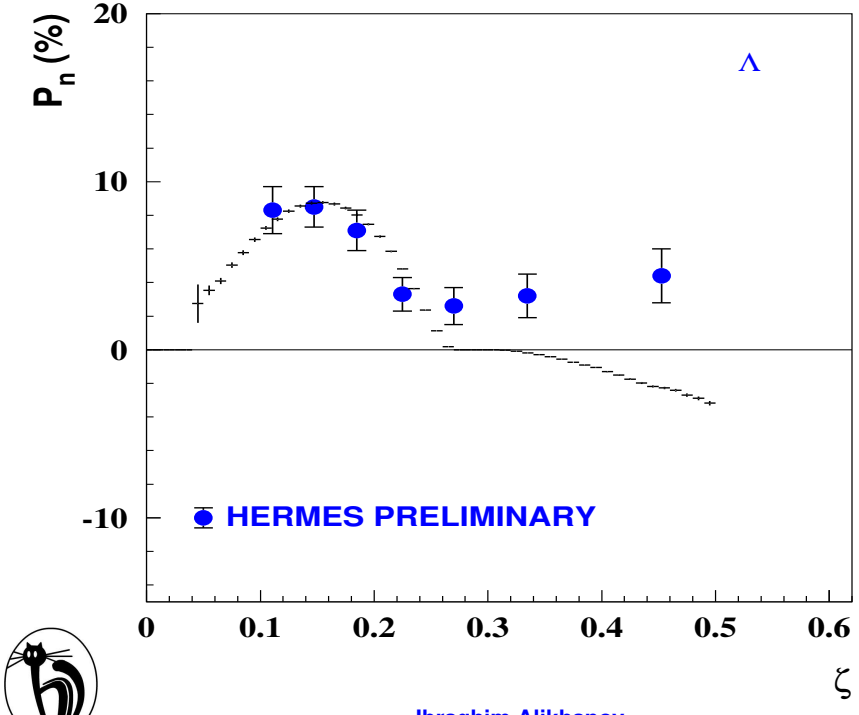


If $\xi > 1$ then $V_\perp^{max}$ exists

$$V_\perp^{max} = \sqrt{\xi - 1}$$

HERMES: ζ dependence





HERMES data are presented versus

$$\zeta \equiv \frac{p_\Lambda^+}{p_e^+}$$

- light cone momentum fraction of the positron carried by Λ and p_T - transverse momentum. ζ_f and transverse velocity of the final s-quark are calculated then as

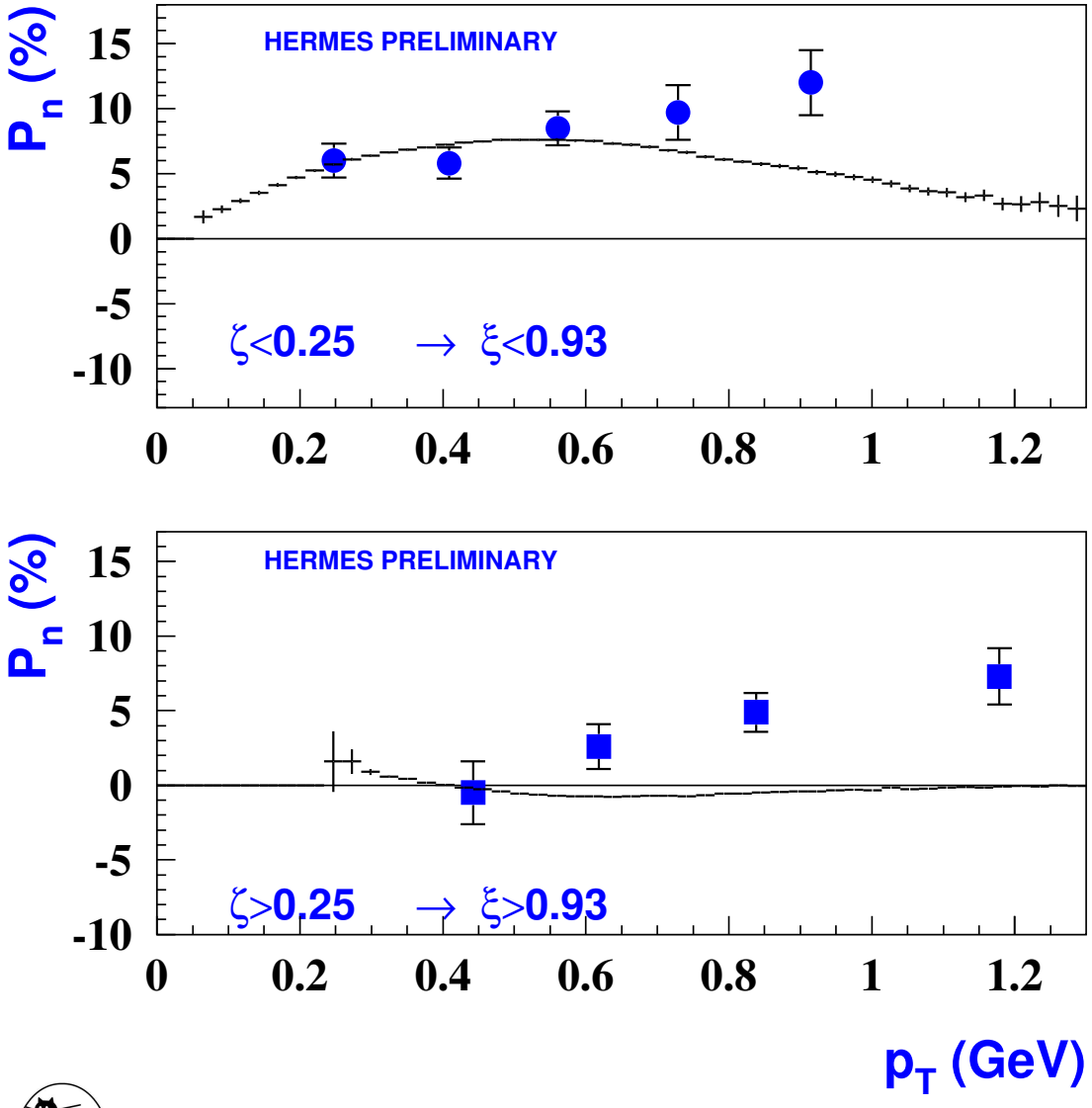
$$\zeta_f = \frac{m_s}{m_\Lambda}\zeta\,, \qquad V_\perp = \frac{p_T}{m_\Lambda}$$

It is assumed that the electron beam provides the monochromatic collinear s-quarks with the ζ_i to be fitted by the measured polarization, the second free parameter being $2C\alpha_s$:

$$P^\Lambda(\zeta) = \frac{1}{n}\sum_k^n P(\xi = \frac{\zeta_f}{\zeta_i}, V_\perp^k)$$

$$\zeta_i = 0.12\,, \qquad 2C\alpha_s = 1.1$$

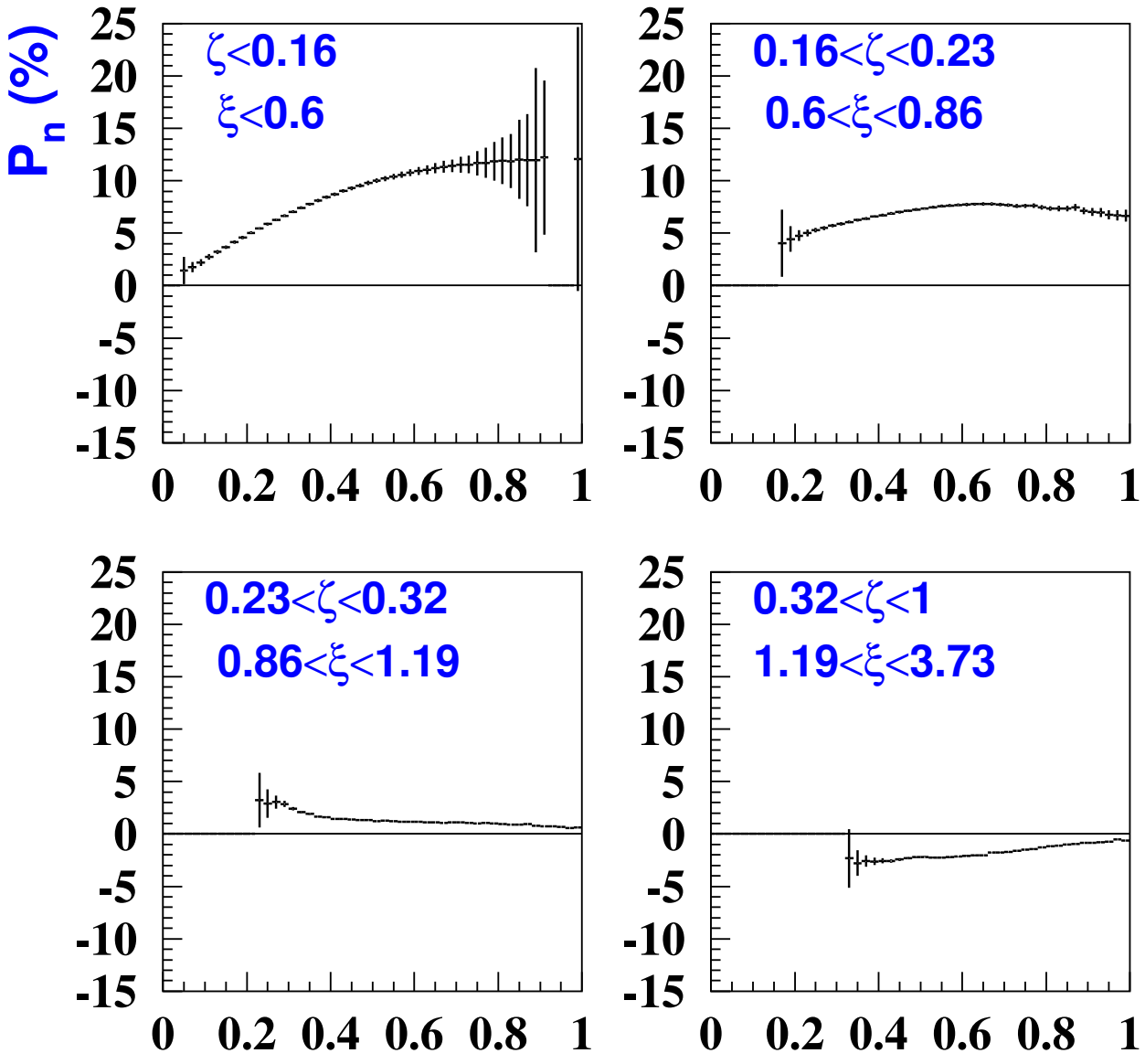
HERMES: p_T dependence



Once the parameters ζ_i and $2C\alpha_s$ were fixed by the total ζ dependence, the Λ polarization measured versus p_T have been compared with the model:

$$P^{\Lambda}(p_T) = \frac{1}{m}\sum_{k}^{m} P(\xi = \frac{\zeta_{f,k}}{\zeta_i}, V_{\perp} =$$

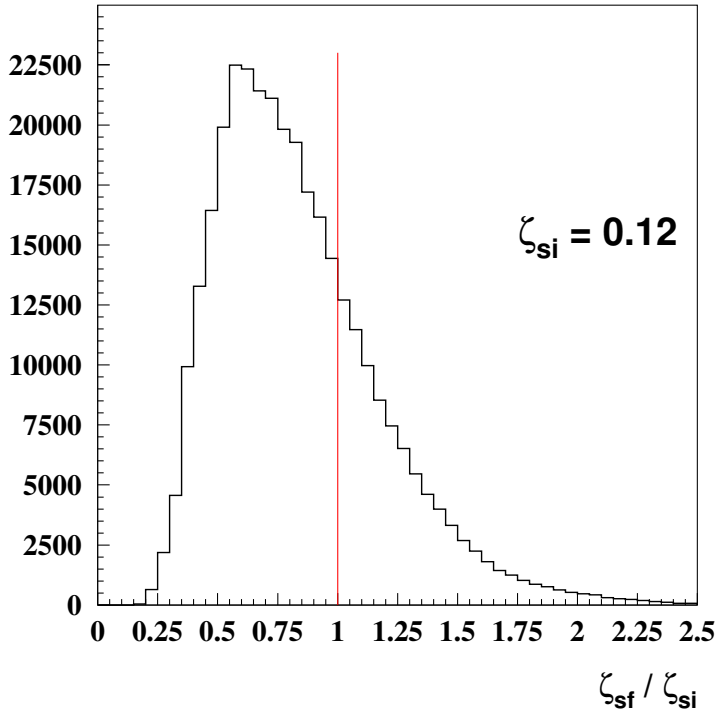
More detailed predictions for p_T dependence



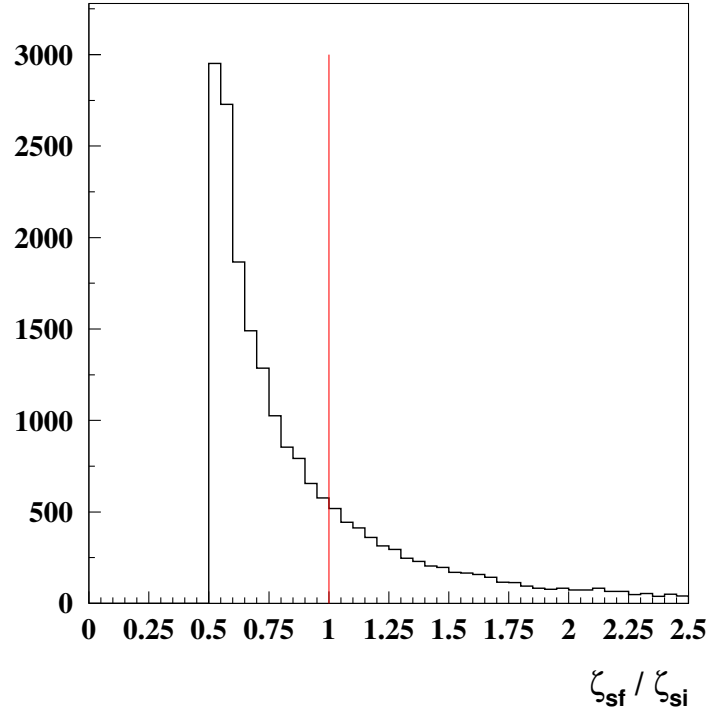
More detailed transition from $\xi < 1$ to $\xi > 1$. Qualitatively confirmed by the HERMES data (to be published)

PYTHIA : ζ_f/ζ_i distribution

$\xi \equiv \frac{\zeta_f}{\zeta_i}$ distribution from the detected Λs at $\zeta_i = 0.12$



$\xi \equiv \frac{\zeta_f}{\zeta_i}$ distribution obtained from PYTHIA



PYTHIA : other hyperons contribution

PYTHIA: fractions of the Λ parents

Parent	Decay mode	Fraction , %
String		56.8
Cluster		3.6
Σ^0	$\Lambda + \gamma$	16.2
Σ^{*0}	$\Lambda + \pi^0$	6.0
Σ^{*+}	$\Lambda + \pi^+$	9.0
Σ^{*-}	$\Lambda + \pi^-$	3.5
Ξ^0	$\Lambda + \pi^0$	3.3
Ξ^-	$\Lambda + \pi^-$	1.7

SU(6) : average spin of the hyperons with respect to each quark type

Hyperon	d	u	s
Λ	0	0	1
Σ^0	$\frac{2}{3}$	$\frac{2}{3}$	$-\frac{1}{3}$
Ξ^0	0	$-\frac{1}{3}$	$\frac{2}{3}$
Ξ^-	$-\frac{1}{3}$	0	$\frac{2}{3}$
Σ^*	$\frac{5}{9}$	$\frac{5}{9}$	$\frac{5}{9}$

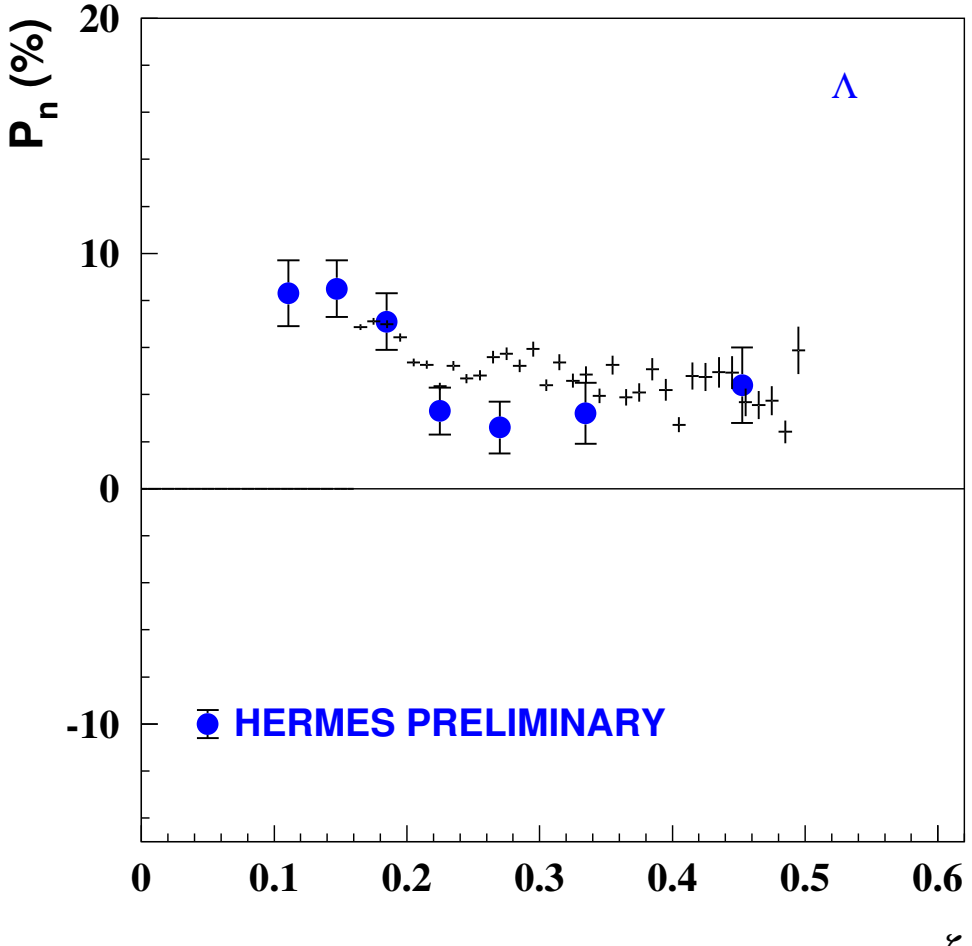
$\vec{\Sigma}^0 \to \vec{\Lambda}^0 : -\frac{1}{3}$

$\vec{\Xi} \to \vec{\Lambda}^0 : -0.9$

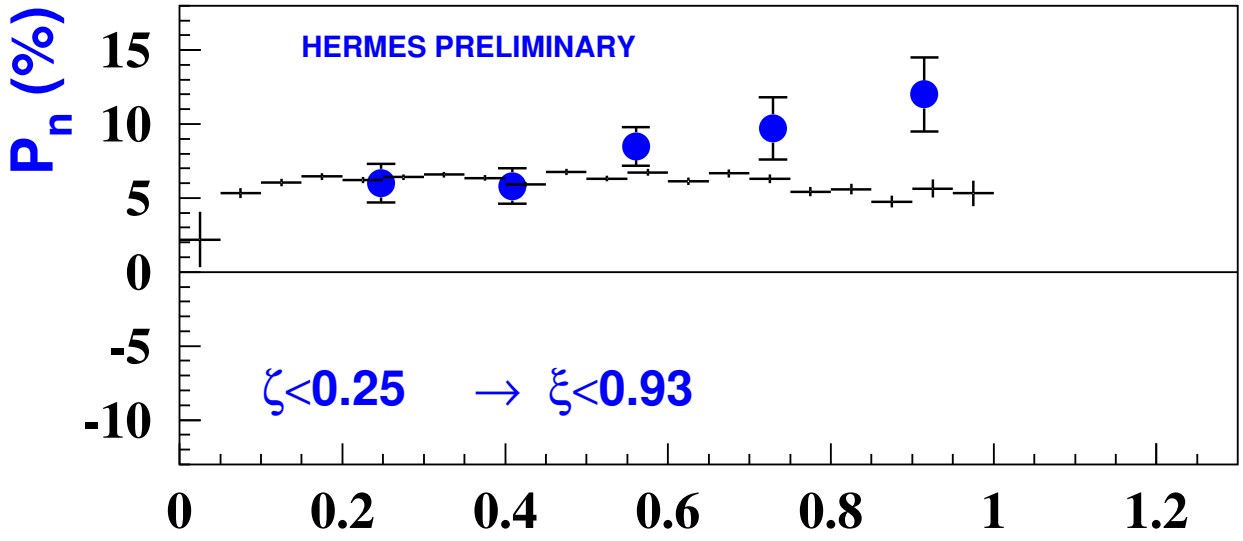
$\vec{\Sigma}^* \to \vec{\Lambda}^0 : -0.92$

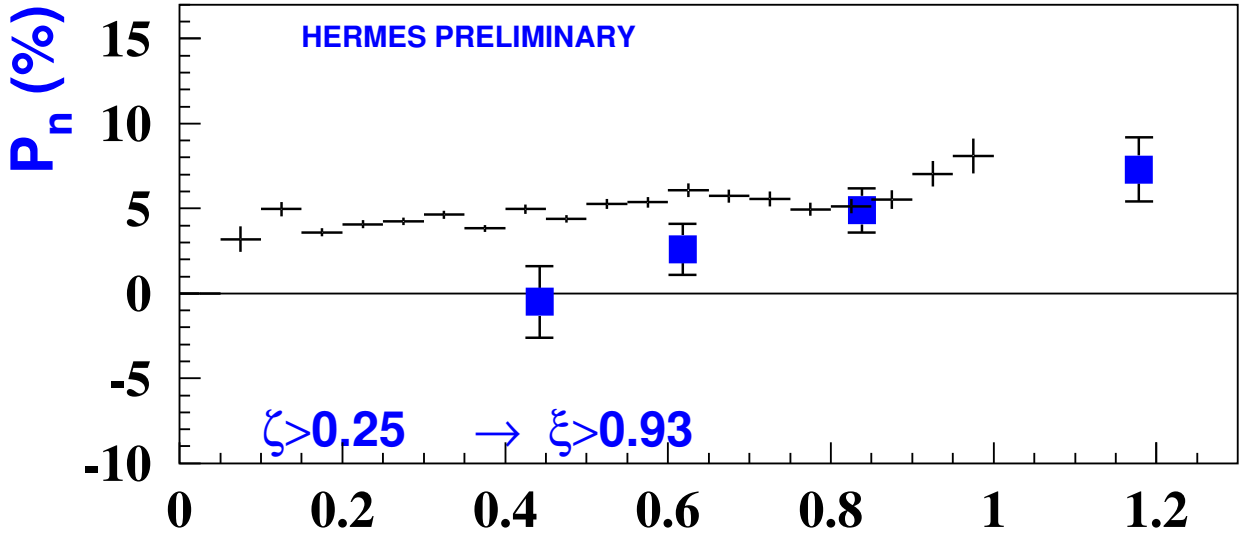
PYTHIA: ζ dependence

The theoretical value (Gago et al.[Phys. Lett., B183(1987)357]) $2C\alpha_s = 2.5$ has been chosen and hence the model has no free parameters. As result the mean Λ polarization turned out to be 6.0 % which coincides with the experimental value (O.Grebenyuk [Acta Phys.Polon. B33(2002)3797])



PYTHIA: p_T dependence





Summary and Outloo

- √ s-quark multiple scattering model definitely demonstrates the ability to describe qualitatively in unified way the Λ transverse polarization in transitions $K^- \to \Lambda$, $p \to \Lambda$ and HERMES $\gamma^* \to \Lambda$, HERMES contributing to the most interesting transitive region from s-quark acceleration to s-quark deceleration regimes;

- √ Assumption that Λ polarization mechanisms in $K^- p$ and $e^+ p$ coincide gives reasonable description of the experimental tendencies for electroproduction observed at HERMES;

- √ The results of the model application to PYTHIA simulated events exhibit main features of the experimental Λ polarization dependences.

- √ Outlook: More accurate calculations based on PYTHIA taking into account the Σ- and Ξ-hyperons.

- √ Prediction of Σ^0 and Ξ^- polarizations (measurable at HERMES)