Lambda production at HERMES

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On behalf of HERMES collaboration

- Longitudinal spin transfer $\vec{u} \to \vec{\Lambda}$ in DIS
- Transverse polarization of inclusively produced Λ
- Λ_c^+ production
- Summary

Introduction

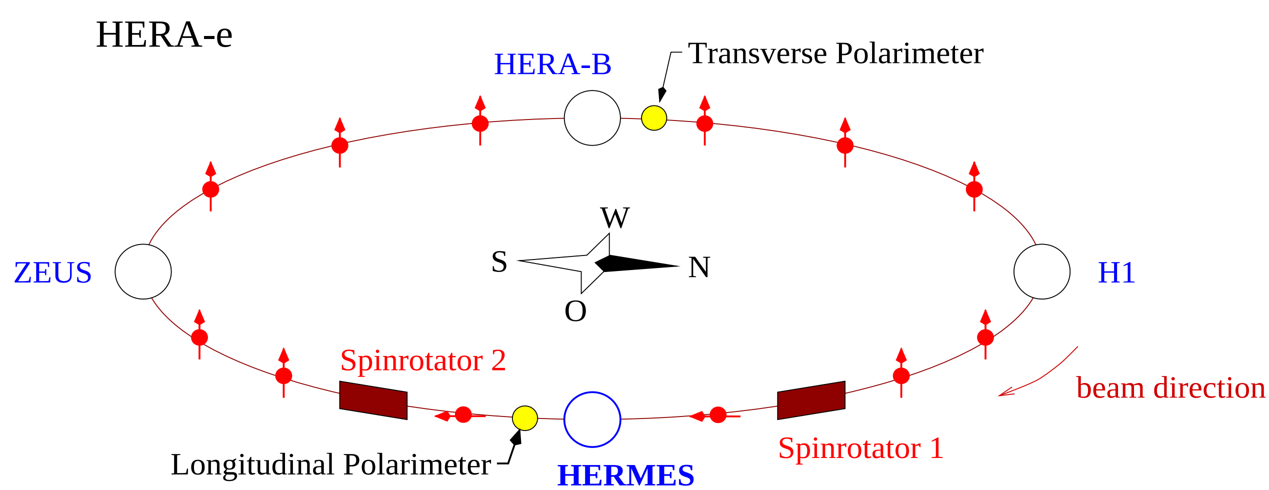
The HERMES experiment offers an opportunity to measure the polarization of Λ and $\bar{\Lambda}$ hyperons produced in SIDIS

$$eN \to e'\vec{\Lambda}X, \qquad eN \to e'\vec{\bar{\Lambda}}X, \qquad Q^2 \gtrsim 0.6$$

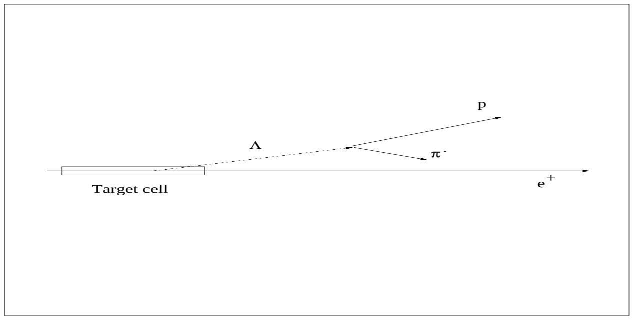
and in inclusive reactions

$$\boxed{eN \to \vec{\Lambda}X, \qquad eN \to \vec{\bar{\Lambda}}X, \qquad Q^2 \approx 0\ .}$$

using 27.5 GeV positron beam of HERA collider and the internal gas target with a storage cell.



Event selection

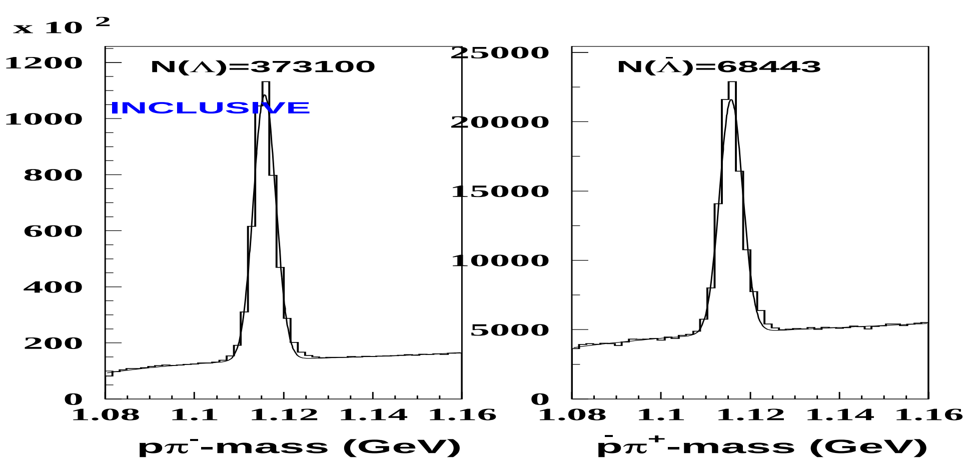


Data collected at HERMES in the years 1996-2000, the integrated luminosity of the full data sample with positron beam being equal to

$$L \approx 800 \text{ pb}^{-1}.$$

have been resulted in

	Λ	$\bar{\Lambda}$
SIDIS	$2 \cdot 10^4$	
Inclusive	$5 \cdot 10^5$	$7 \cdot 10^4$



Formalism of Λ polarization measurement

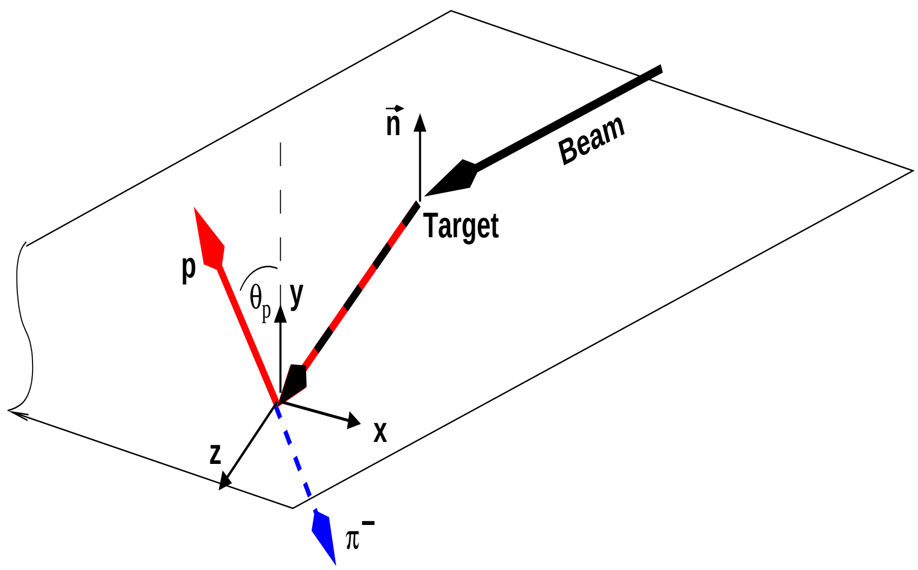
$$\Lambda \to p\pi^-$$

In Λ c.m. frame

$$\frac{1}{N}\frac{dN}{d\Omega} = \frac{1}{4\pi}\left[1 + \alpha(\vec{P}_\Lambda, \vec{k})\right],$$

where $\alpha = 0.642$ and $\vec{k}$ - the unit vector along the momentum of proton from Λ decay.

$$\vec{k} = \cos(x,p)\vec{e}_x + \cos(y,p)\vec{e}_y + \cos(z,p)\vec{e}_z = k^i\vec{e}_i$$



In case of 4π acceptance

$$\{k^i\} = \{\cos\Theta_p\} = \tfrac{\alpha}{3}P^i_\Lambda, \qquad i = x, y, z.$$

$\{\cdots\}$ - an average over the experimental date set.
Complications appear in case of restricted acceptance, when $\{k^i\} \neq 0$ even at $P^i_\Lambda = 0$.

Polarized $\vec{u} \to \vec{\Lambda}$ fragmentation.

- Polarized DIS+SU$(3)_f$+axial currents:
  $\Delta u_p = 0.79 \;\; \Delta d_p = -0.45 \;\; \Delta s_p = -0.16$,
  where Δq_p is the fraction of the proton's spin carried by quarks of flavor q.
  $\Delta\Sigma \equiv \Delta u_p + \Delta d_p + \Delta s_p \approx 0.18$ - "spin crisis"

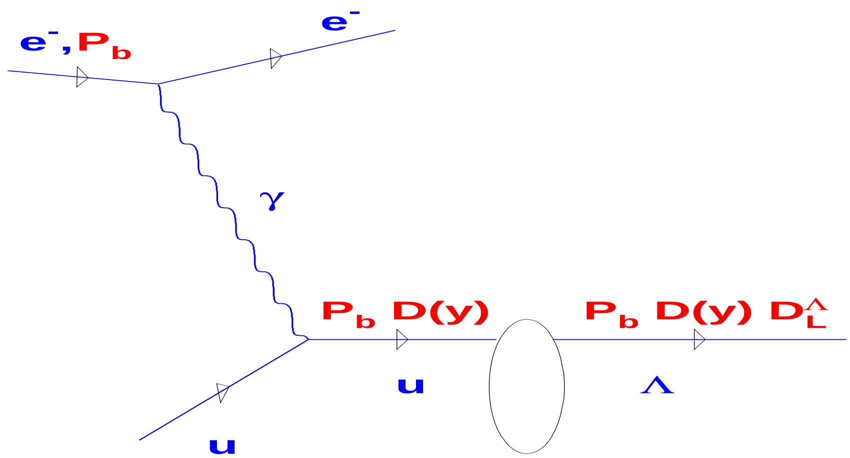
- SU$(3)_f$ $\Rightarrow$:

	Δu	Δd	Δs
p	0.79±0.04	-0.45±0.04	-0.16±0.05
n	-0.45±0.04	0.79±0.04	-0.16±0.05
Σ^+	0.79±0.04	-0.16±0.05	-0.45±0.04
Σ^0	0.32±0.04	0.32±0.04	-0.45±0.04
Σ^-	-0.16±0.05	0.79±0.04	-0.45±0.04
Λ	-0.20±0.04	-0.20±0.04	0.58±0.04
Λ_{NQM}	0	0	1
Ξ^0	-0.45±0.04	-0.16±0.05	0.79±0.04
Ξ^-	-0.16±0.05	-0.45±0.04	0.79±0.04

  Interesting to measure, but Λ target does not exist.

- Alternative to polarized DIS from Λ-
  spin transfer in $\vec{q} \to \vec{\Lambda}$ current fragmentation.

Polarization transfer from struck quark



In quark-parton model of DIS the longitudinally polarized positron polarizes the struck quark

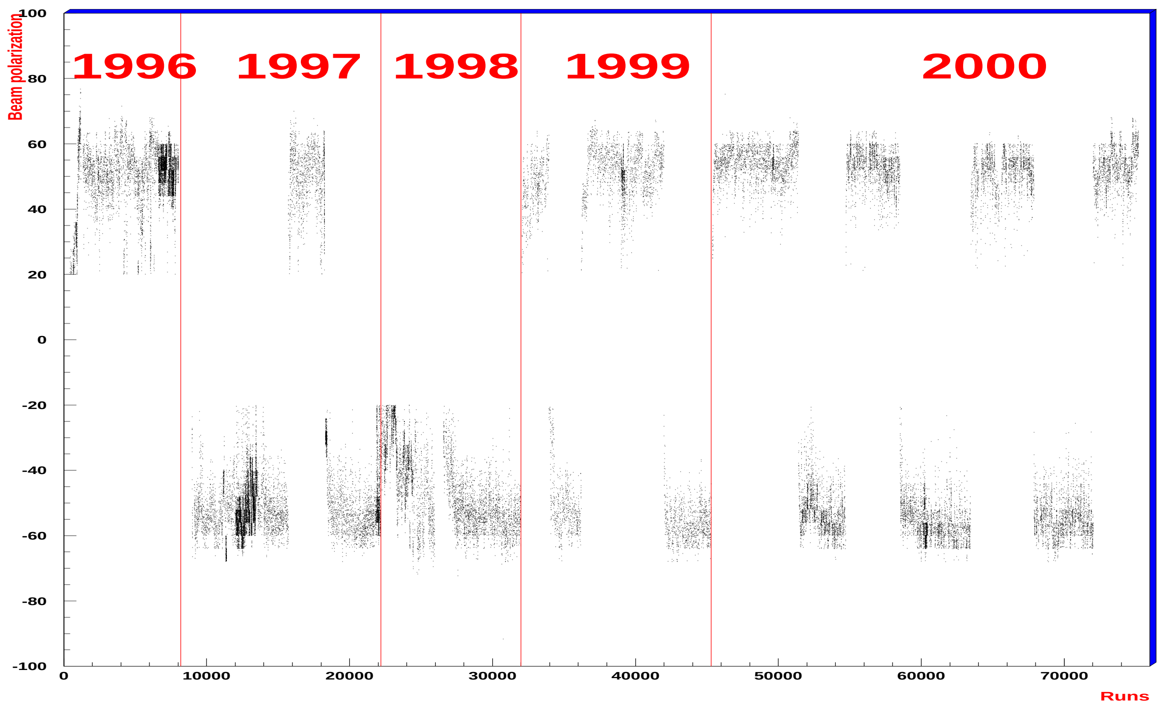
$$P_{qs} = D(y) P_b, \qquad \vec{P}_\Lambda = D(y) P_b \vec{\mathcal{D}}_L$$

where $y = (E - E')/E$ and $D(y) \simeq \frac{1-(1-y)^2}{1+(1-y)^2}$.

Expectations:

$\mathrm{SU}(3)_f$	$\mathcal{D}_L \simeq -0.2$
NQM	$\mathcal{D}_L = 0$

Helicity balanced experiment



Actually we are interested in measuring of polarization transfer from the beam to Λ. If the mean beam polarization over the full data set is equal to zero

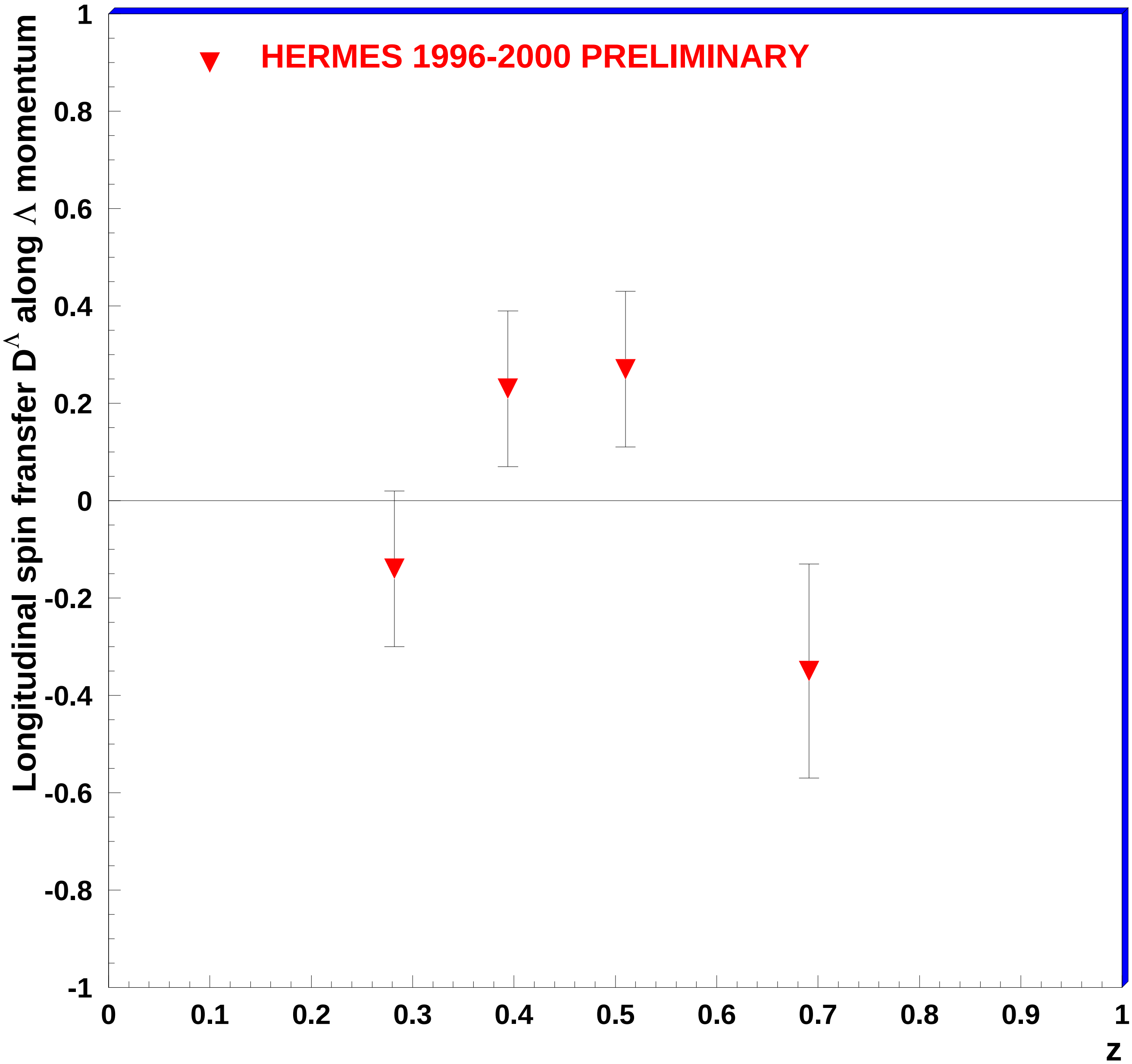
$$\langle \mathbf{P_b} \rangle = \mathbf{0},$$

then

$$\mathcal{D}_\Lambda = \frac{\{P_b \cos\Theta_p\}}{\alpha < P_b^2 > \{\cos^2\Theta_p\}}$$

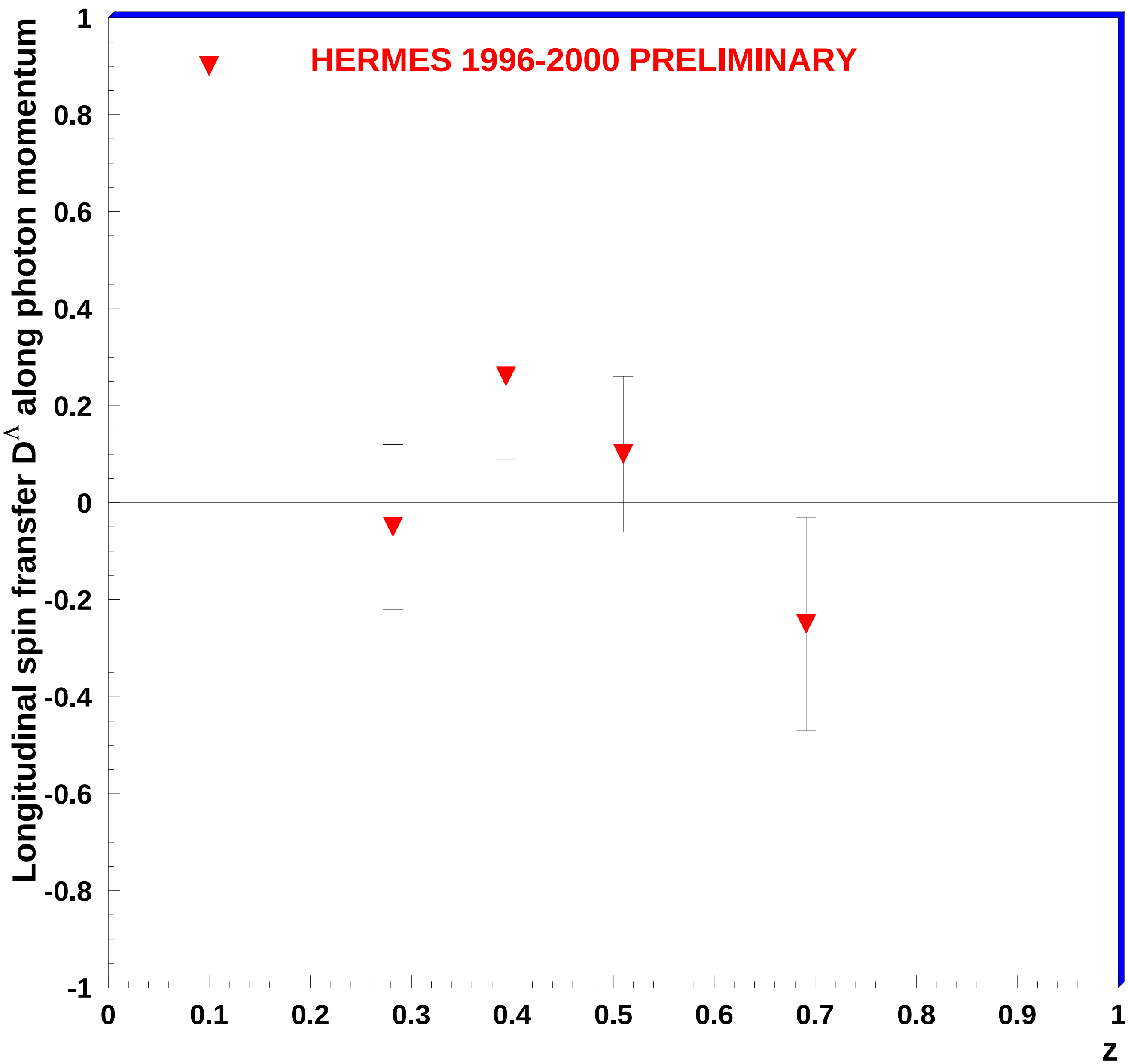
z-dependence of D_L along Λ.

$$z = \frac{E_\Lambda}{\nu}$$

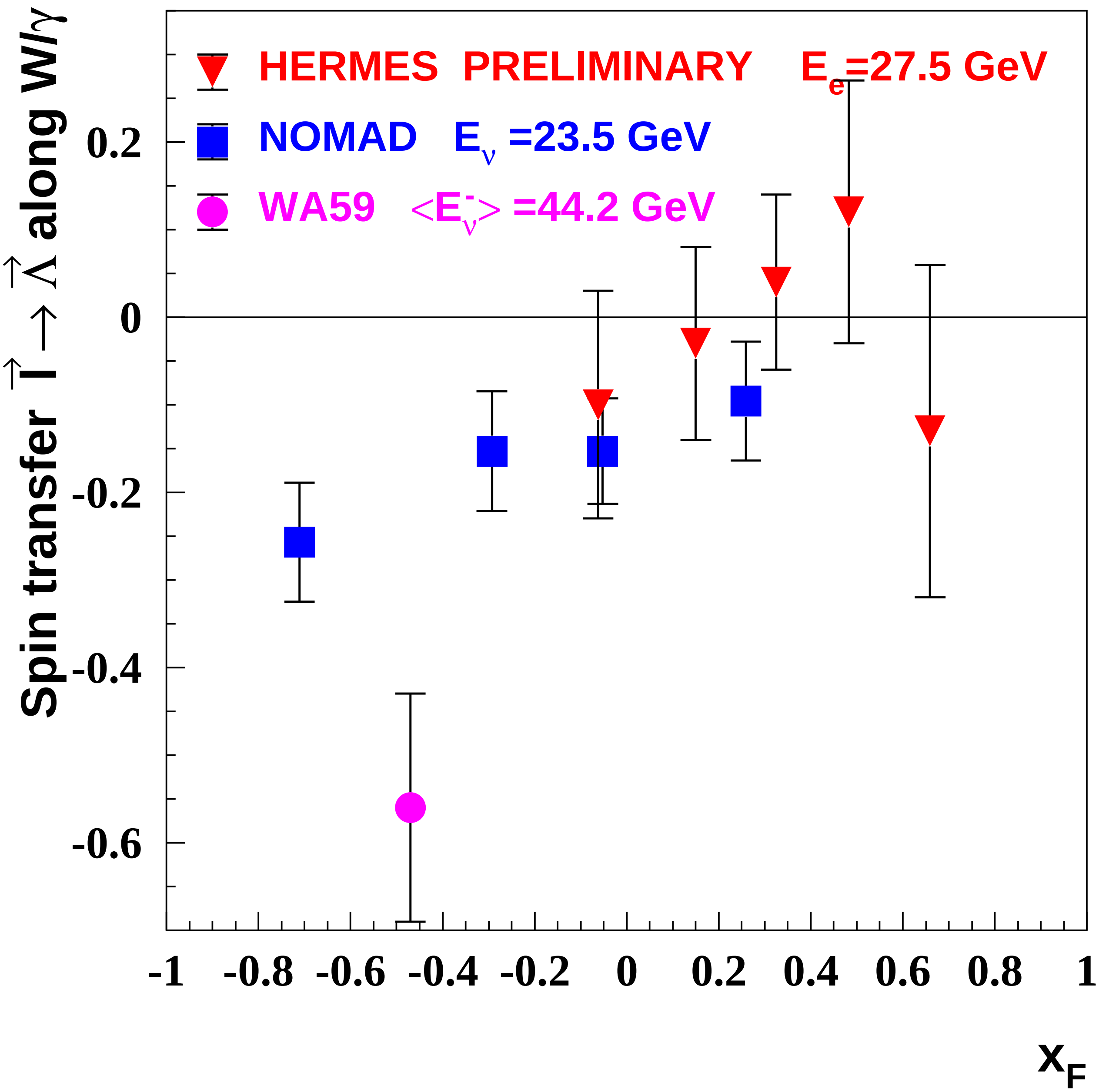


z-dependence of D_L along photon

$$z = \frac{E_\Lambda}{\nu}$$

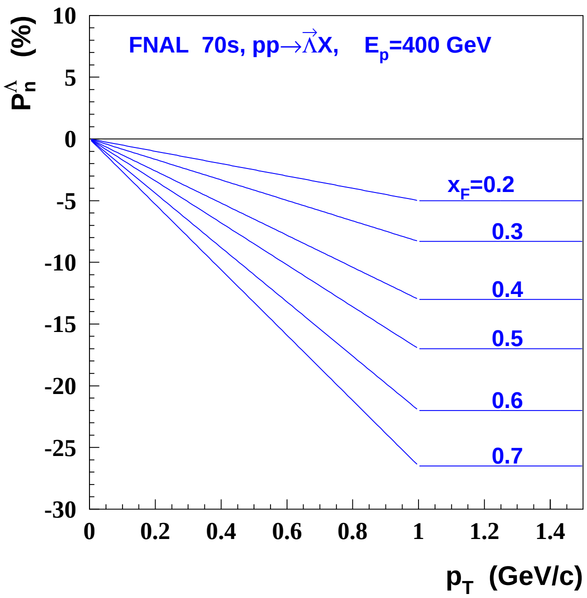


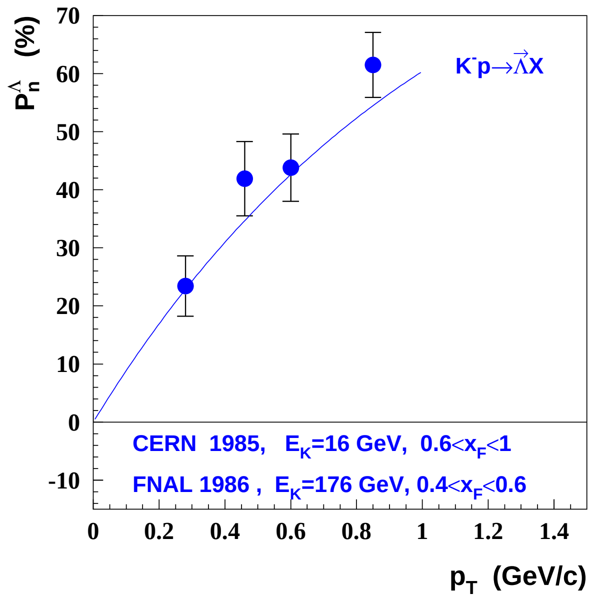
x_F-dependence of spin transfer from beam



Transverse Λ polarization. $hp \to \vec{\Lambda} X$.

$$\vec{P}^{\Lambda} = P_n^{\Lambda} \vec{n}, \qquad \vec{n} = \frac{\vec{p}_{beam} \times \vec{p}_{\Lambda}}{|\vec{p}_{beam} \times \vec{p}_{\Lambda}|}.$$





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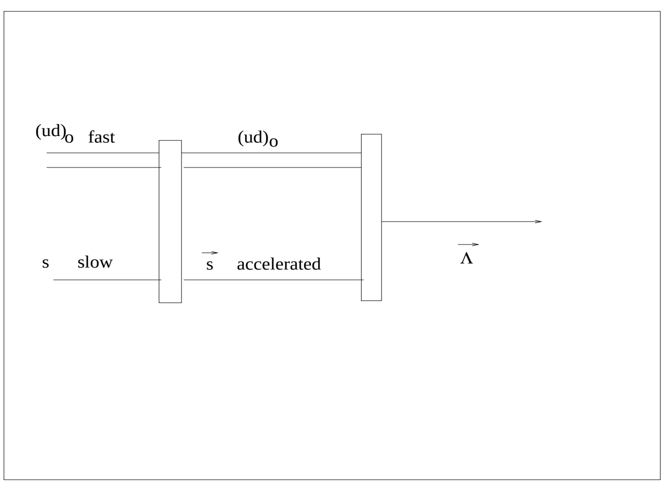
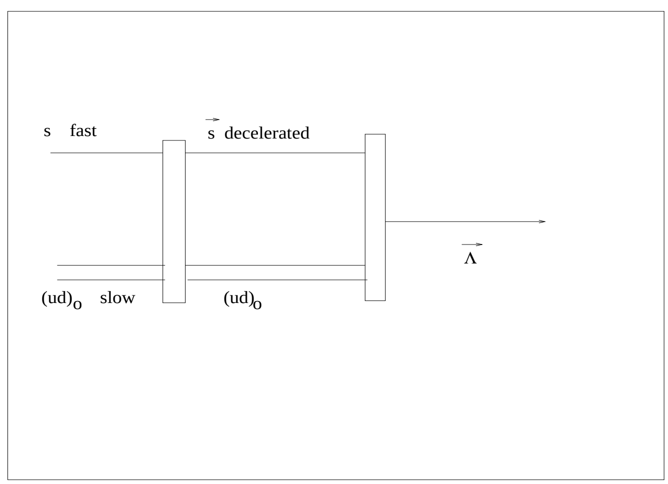
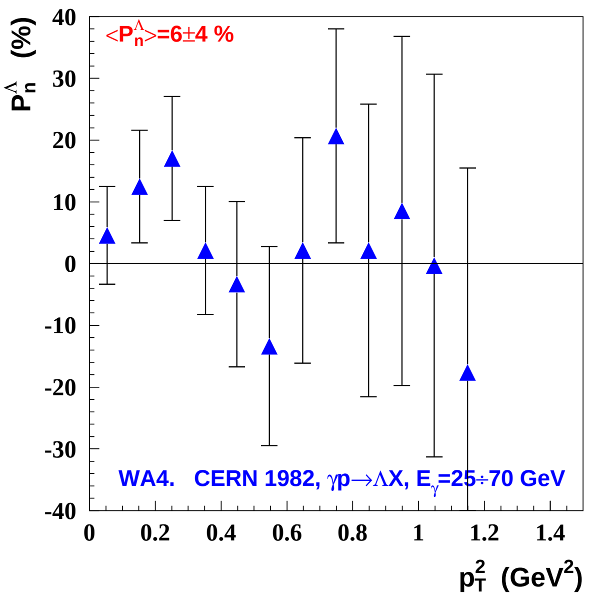


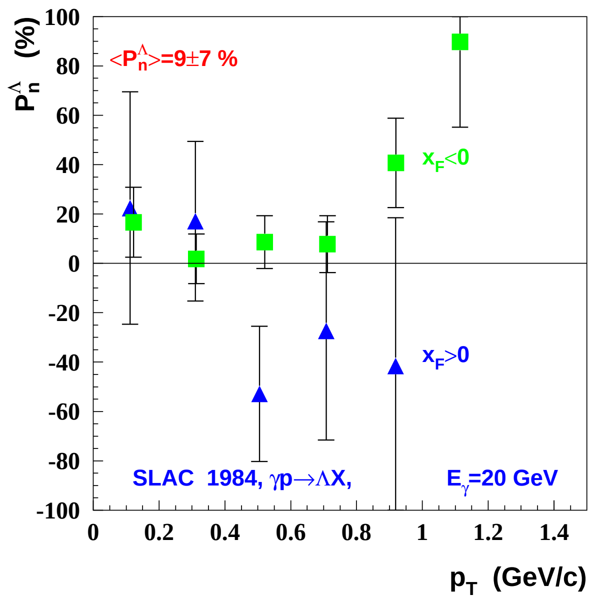


Introduction. $\gamma p \rightarrow \vec{\Lambda} X$.

It is natural to expect non-vanishing polarization also in the Λ photo-production since it is well known that the real photon has the structure : $\gamma \rightarrow q\bar{q}$.

$$\vec{P}^{\Lambda} = P_n^{\Lambda} \vec{n}, \qquad \vec{n} = \frac{\vec{p}_{beam} \times \vec{p}_{\Lambda}}{|\vec{p}_{beam} \times \vec{p}_{\Lambda}|}.$$





Average Transverse Polarizations

For the up/down symmetric detector:

$$P_n^{\Lambda} \approx \frac{\{cos\theta_p\}^{top} + \{cos\theta_p\}^{bot}}{2\alpha\{cos^2\theta_p\}}.$$

Averaged over the full kinematic range the transverse polarization of Λ and $\bar{\Lambda}$ hyperons was measured to be

$$P_n^{\Lambda} = 5.8 \pm 0.5(\mathrm{stat}) \pm 0.6(\mathrm{syst})\%$$

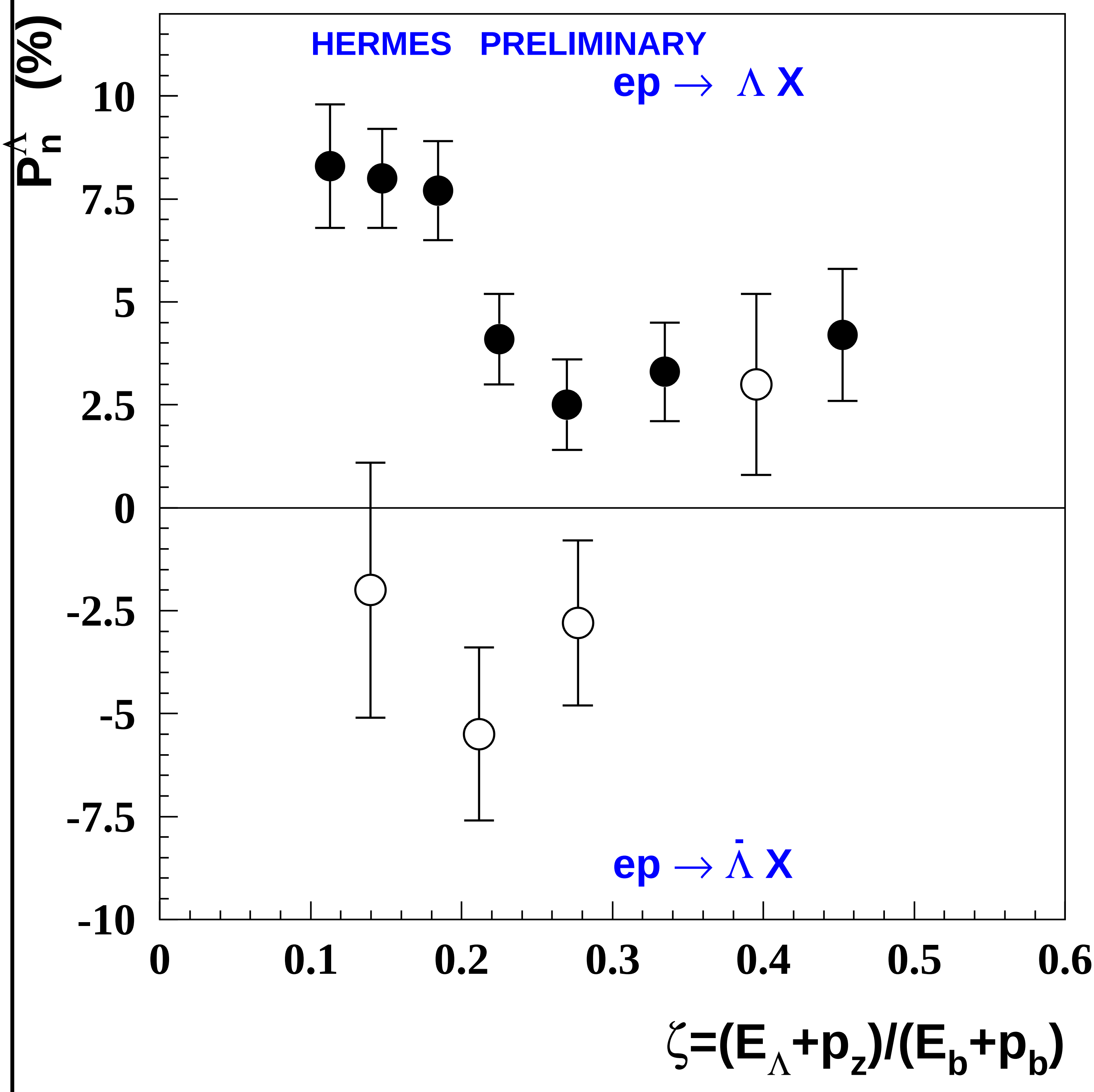
$$P_n^{\bar{\Lambda}} = -4.2 \pm 1.2(\mathrm{stat}) \pm 0.6(\mathrm{syst})\%$$

Systematic uncertainty is estimated using $K_s \to \pi^+\pi^-$ decay and h^+h^- pairs from the target, which do not contain $\Lambda/\bar{\Lambda}$ events.

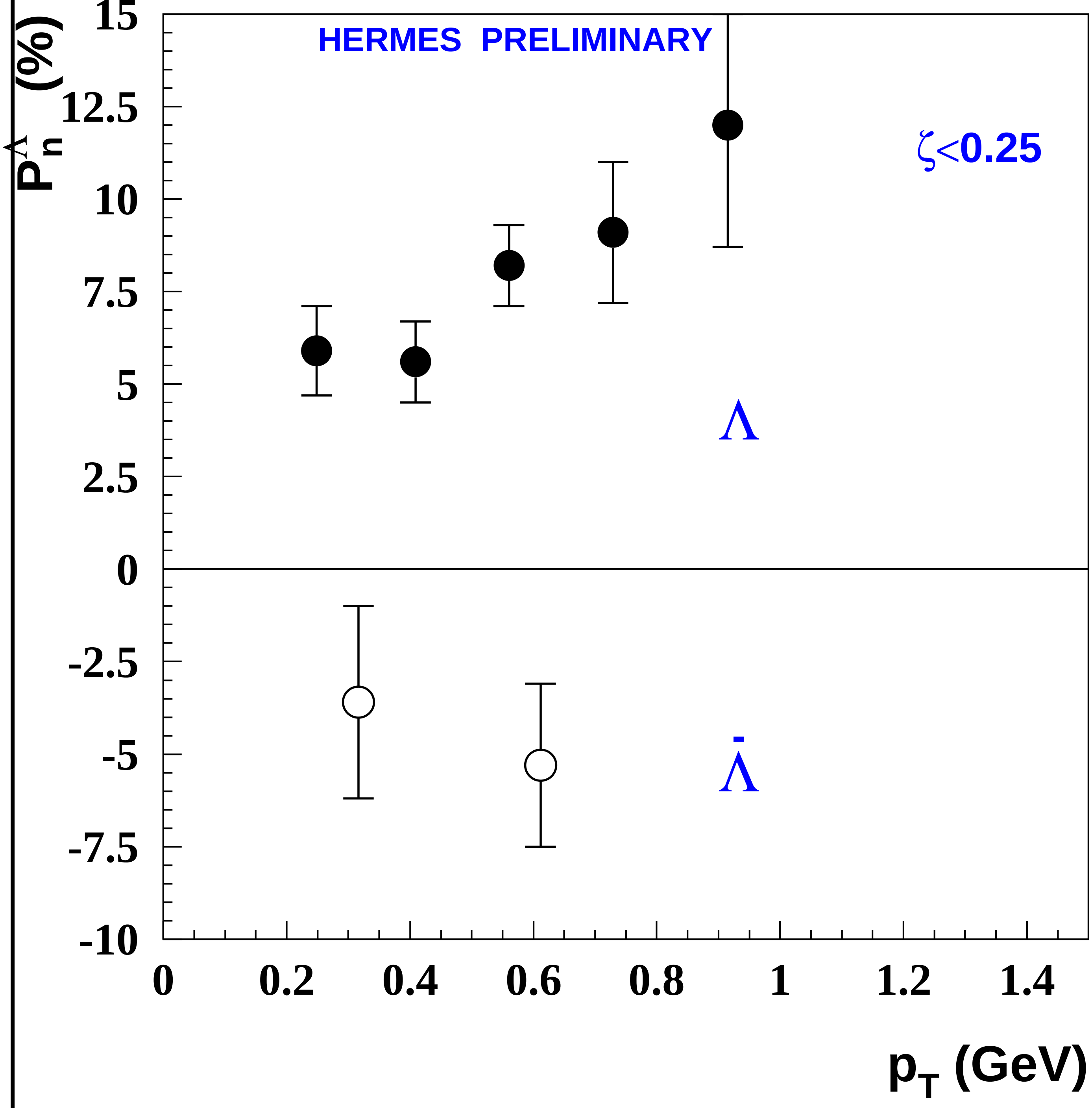
Statistic allows the dependence of the polarization on the kinematic variables to be studied. But no kinematic variables related to γN system are available (no intermediate photon tagging ! PYTHIA: $Q^2 \lesssim 0.06$ GeV^2, $\langle\nu\rangle = 16$ GeV) . Hence:

$$\zeta = \frac{E_\Lambda + p_z}{E_b + p_b} \simeq \frac{p_z}{p_b}, \qquad p_T.$$

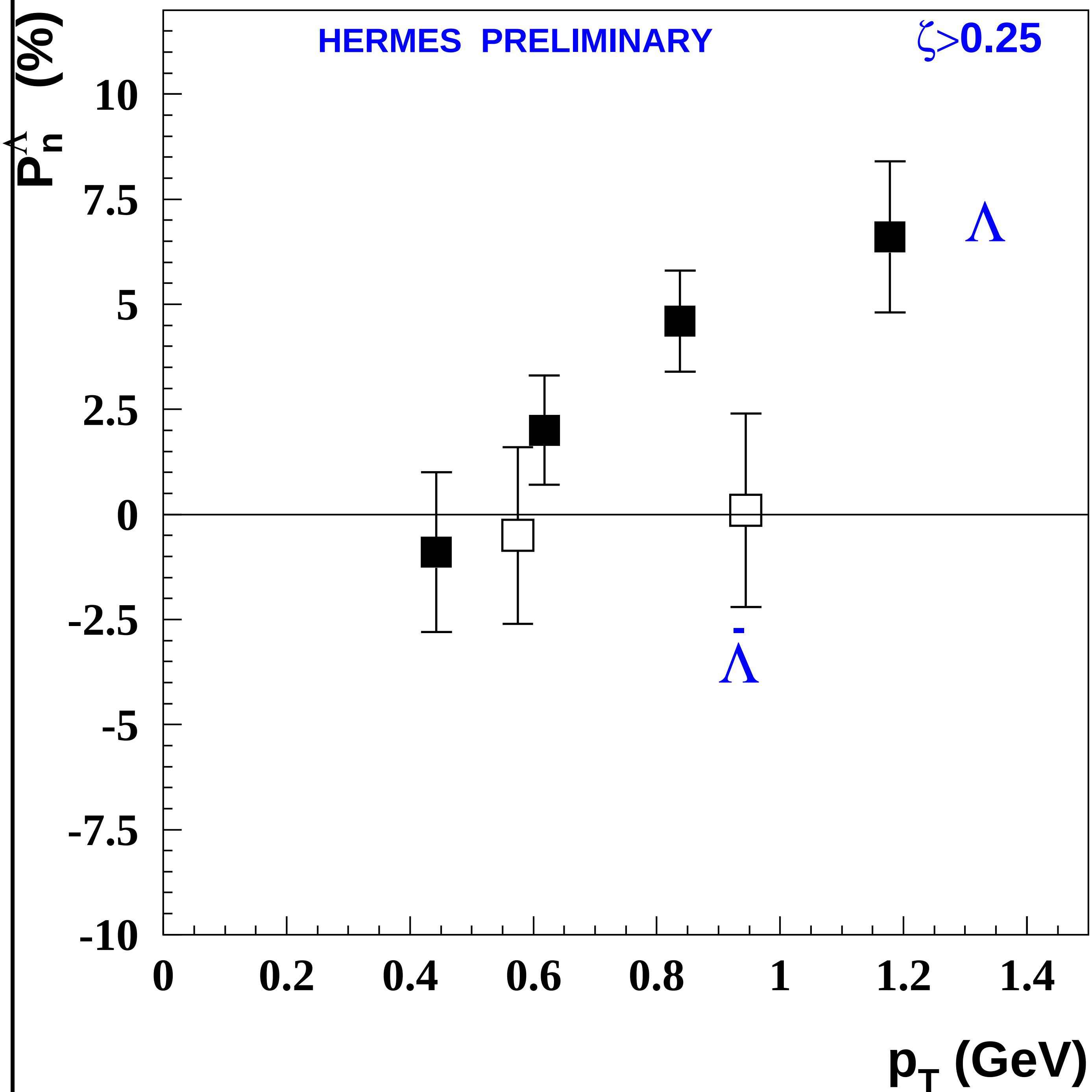
Results. ζ-dependence



Results. p_T-dependence



Results. p_T-dependence



Discussion. Quark Recombination Model

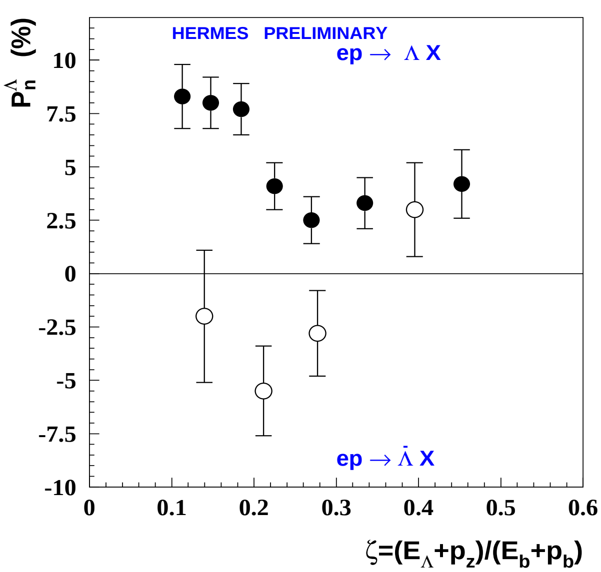
Assumption: the initial s and $\bar{s}$ quarks from the beam due to the $\gamma \to \phi \to K^+K^-$ or the direct $\gamma \to s\bar{s}$ fluctuation acquires polarization in the recombination process:

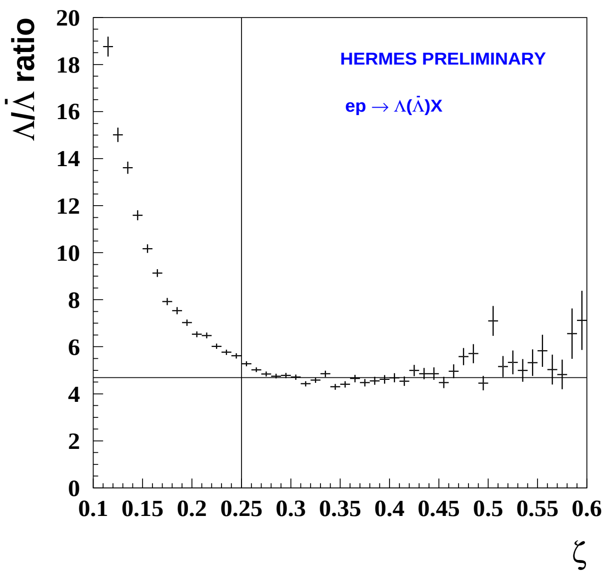
$$s + (ud)_0 \to \vec{s} + (ud)_0 \to \vec{\Lambda},$$
$$\bar{s} + (\bar{u}\bar{d})_0 \to \vec{\bar{s}} + (\bar{u}\bar{d})_0 \to \vec{\bar{\Lambda}}.$$

QRM model predicts the conjugate relation $P(h \to \Lambda) = P(\bar{h} \to \bar{\Lambda})$, which has been confirmed experimentally, and hence one might expect the approximate equation

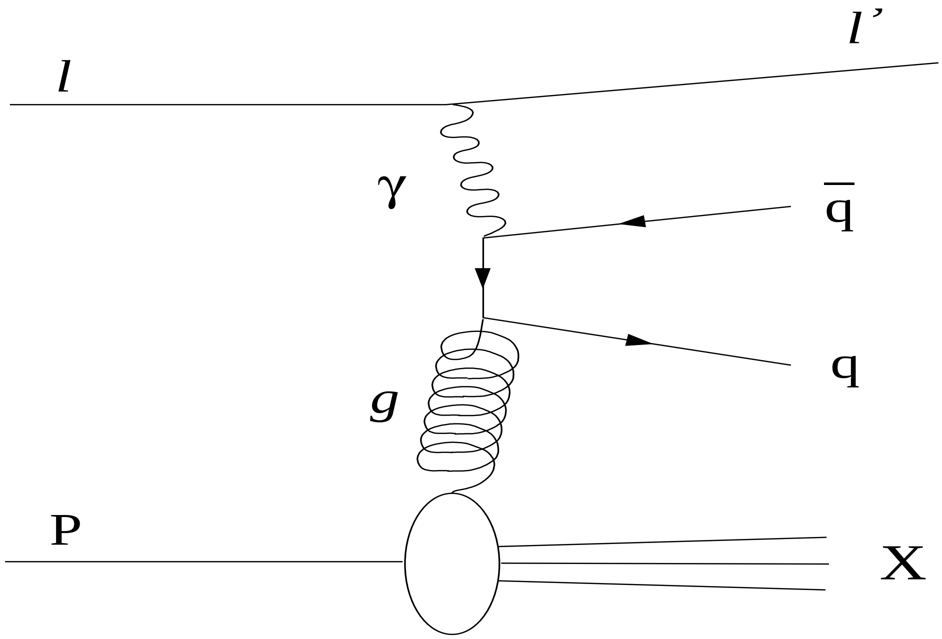
$$P(\gamma \to \Lambda) \approx P(\gamma \to \bar{\Lambda}),$$

which looks like to be confirmed by HERMES at $\zeta > 0.3$





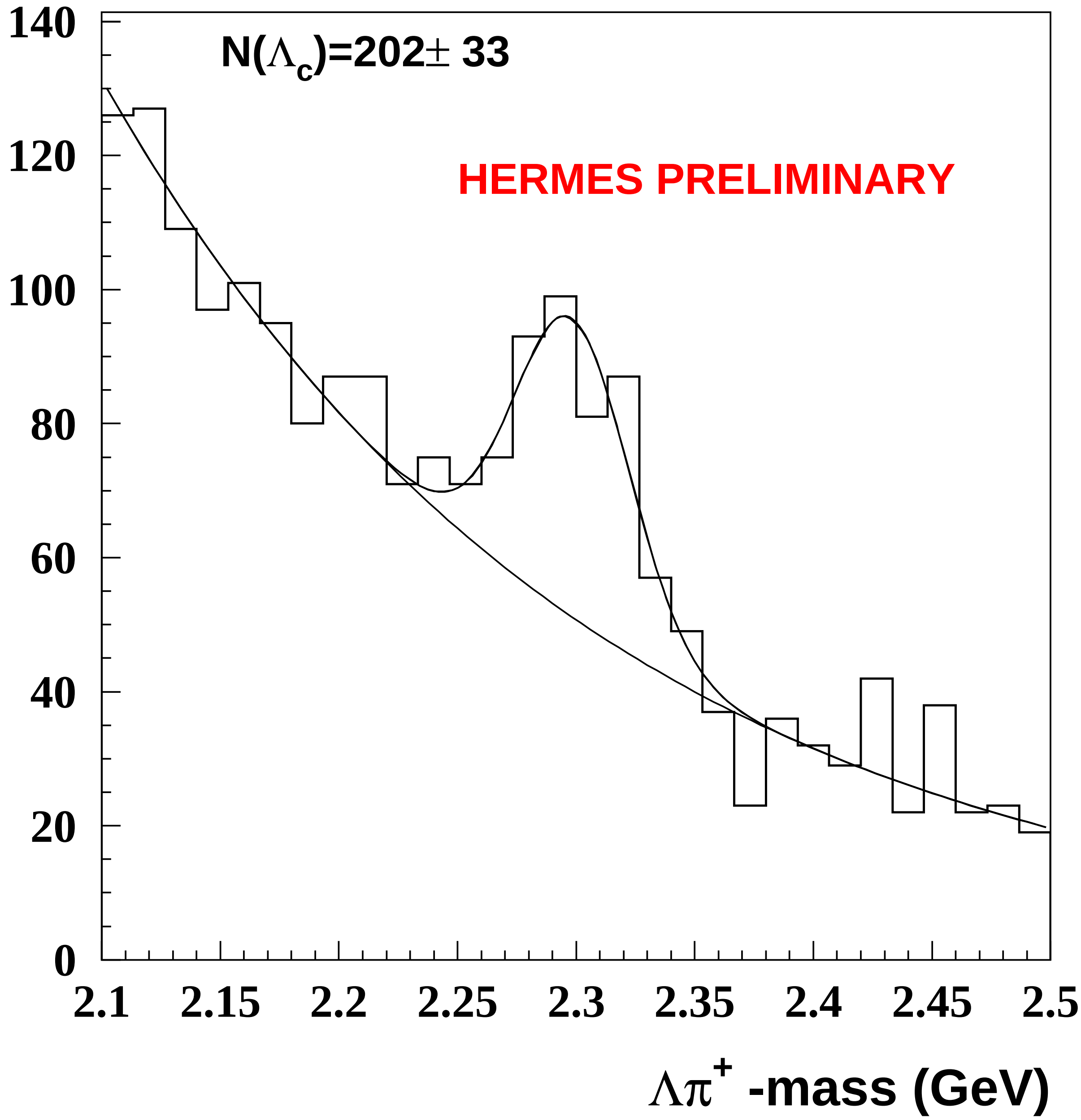
Charm production at HERMES



AT HERMES available are:

$J/\psi(c\bar{c}, 3.097, 1)$	e^+e^- or $\mu^+\mu^-$
$D^{*+}(cd, 2.010, 1)$	$D^0(c\bar{u}, 1.864, 0)\pi^+ \to (K^-\pi^+)\pi^+$
$D^{*-}(\bar{c}d, 2.010, 1)$	$D^0(\bar{c}u, 1.864, 0)\pi^- \to (K^+\pi^-)\pi^-$
$\Lambda_c^+(udc, 2.2849, \frac{1}{2})$	$\Lambda(uds, 1.1157, \frac{1}{2})\pi^+ \to (p, \pi^-)\pi^+$

Λ_c^+ production



Summary

- The longitudinal spin transfer in the electro-production from the struck u quark to Λ^0 resulting from DIS in current fragmentation region has been measured at HERMES. The obtained value: $\mathcal{D}_\Lambda = 0.04 \pm 0.09\ (stat) \pm 0.05\ (syst)$ is consistent both with the naive quark parton model prediction of zero polarization of u quarks in the Λ^0 and the Burkardt-Jaffe prediction of a $\mathcal{D}_\Lambda$ =-0.2 u quark contribution.

  Any possible false asymmetry from the spectrometer acceptance was excluded by changing the sign of the beam helicity during the data taking, which is the priority of HERMES and by using helicity balanced data set.

- The transverse polarization of inclusively produced Λ and $\bar{\Lambda}$ hyperons have been measured to be $P_n^\Lambda = 5.8 \pm 0.5(\mathrm{stat}) \pm 0.6(\mathrm{syst})\%$ and $P_n^{\bar{\Lambda}} = -4.2 \pm 1.2(\mathrm{stat}) \pm 0.6(\mathrm{syst})\%$.

  The difference in Λ and $\bar{\Lambda}$ polarizations appears to arise principally from the data in the "backward-production" region $\zeta = \frac{E_\Lambda + p_z}{E_b + p_b} < 0.3$ with the complex and poorly understood mechanism of the target fragmentation.

In contrast, in the "forward" direction ($\zeta > 0.3$) the Λ and $\bar{\Lambda}$ polarizations are rather close. In this region the data support qualitatively the expectation of Vector Meson Dominance picture, in which the quasi-real photon beam provides a source of s and $\bar{s}$ quarks on an equal footing, which enter then as valence quarks into the Λ and $\bar{\Lambda}$ hyperons.

- The analysis of all, polarized and unpolarized, data taken at HERMES in 96-00 years allowed to extract reliably about 200 $\Lambda_c^+ \to \Lambda^0 \pi^+$ events. The analysis of two kinematic distributions, the light cone variable ζ and the transverse momentum, as well as the DSA of Λ_c^+ are in progress.