Longitudinal Spin Transfer in Λ Production at HERMES

Image: Deutsches Elektronen Synchrotron

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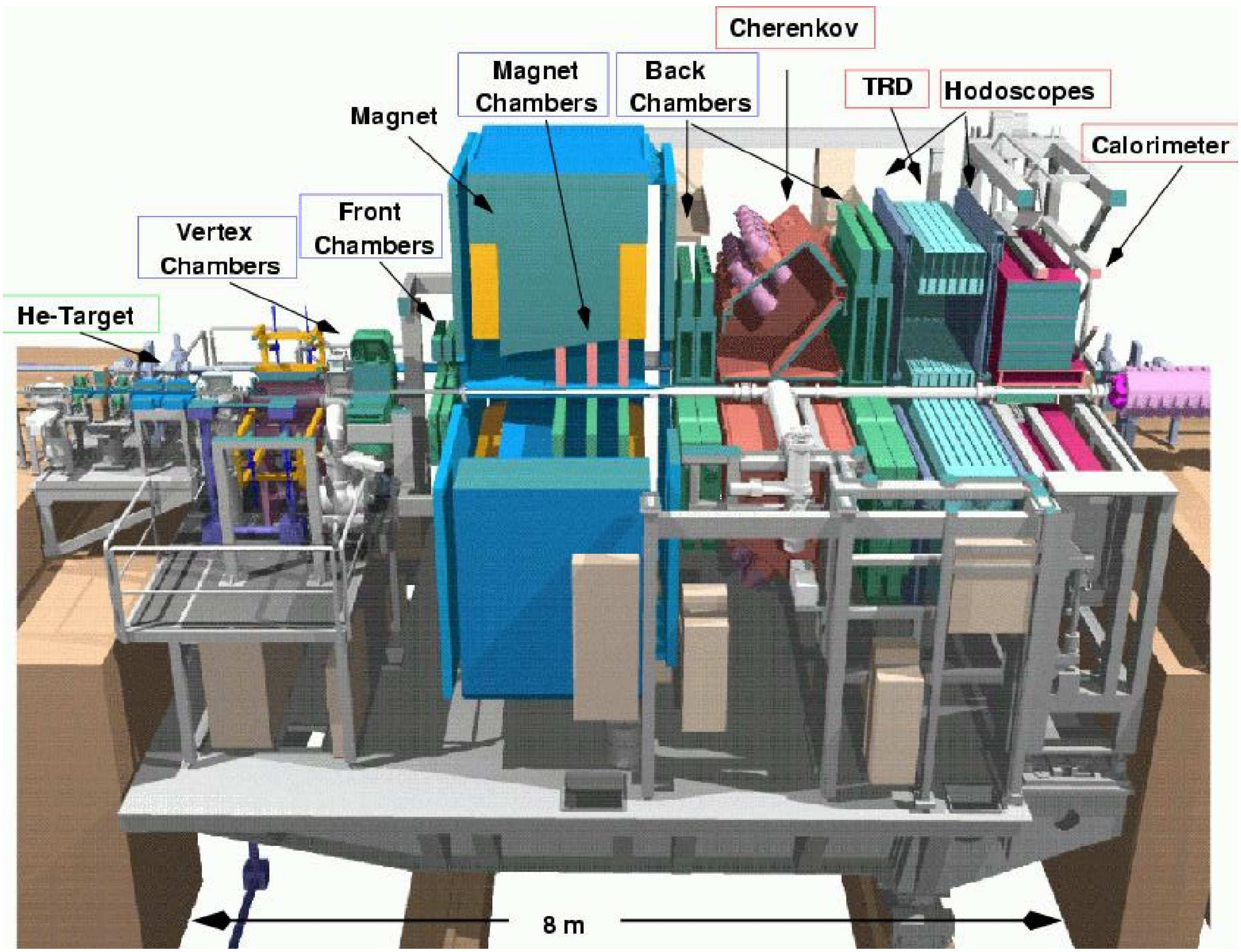
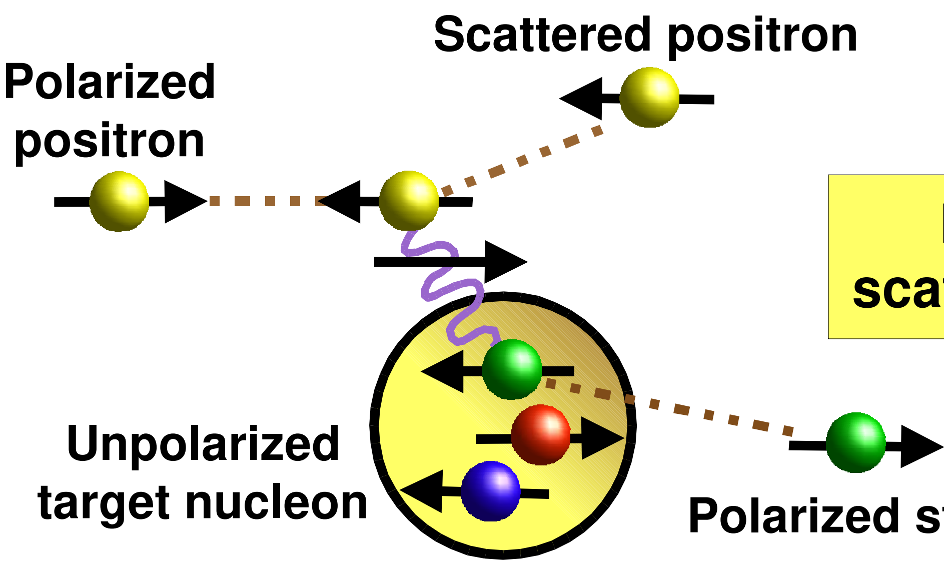
HERMES experiment

- **Longitudinally polarized 27.6–GeV positron beam**
- **This analysis: unpolarized D, H, He, Ne, Kr gas targets**
- **All data 1996–2000: about 40 million DIS events**

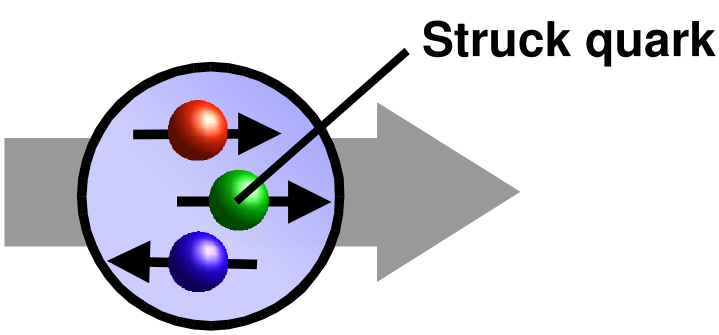


Probing fragmentation



Deep–inelastic scattering (DIS) event

THEN A MIRACLE OCCURS (a.k.a. fragmentation)



Lambda hyperon containing struck quark

How does struck quark spin influence Λ spin?

Can we use Λ hyperons as "polarimeters" for accessing structure functions (e.g. transversity)?

Extracting $D_{LL'}^{\Lambda}$

Lambda polarization

Longitudinal spin–transfer coefficient

$$P_q^{\Lambda} = P^{beam} \cdot D(y) \cdot D_{LL'}^{\Lambda}(z)$$

Beam polarization

Photon depolarization factor

Struck quark polarization

P_q^{Λ}	**Accessible via self–analyzing weak decay of** $\Lambda \to p + \pi^-$
P^{beam}	**Available from experiment**
$D(y)$	**Calculable from** $y = \nu / E$ **= relative energy transfer**
$D_{LL'}^{\Lambda}(z)$	**Depends on** $z = E_h / \nu$ **= fractional hadron energy**

Model predictions of $D^{\Lambda}_{LL'}$

Models assume "ideal situation":
(1) All lambdas contain struck quark
(2) Perfect helicity conservation in fragmentation

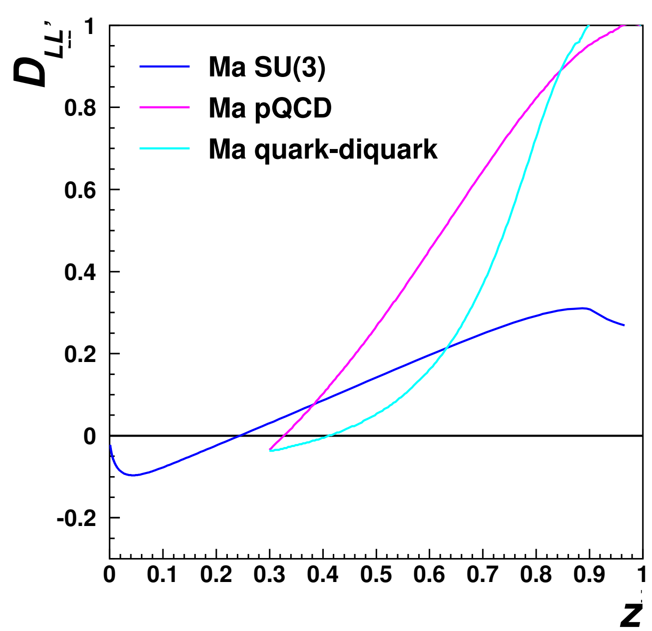
Naïve constituent quark model (NCQM)

- **Lambda (quark content = uds) spin determined by strange quark alone: $\Delta u = \Delta d = 0$, $\Delta s = 1$**
- **u–quark dominance in DIS, spin transfer is zero**

Burkardt–Jaffe SU(3)

- **Use SU(3) to relate proton spin structure to Λ spin structure**
- **Spin transfer is small and negative, about –0.2**

Phenomenological models



NCQM

B–J SU(3)

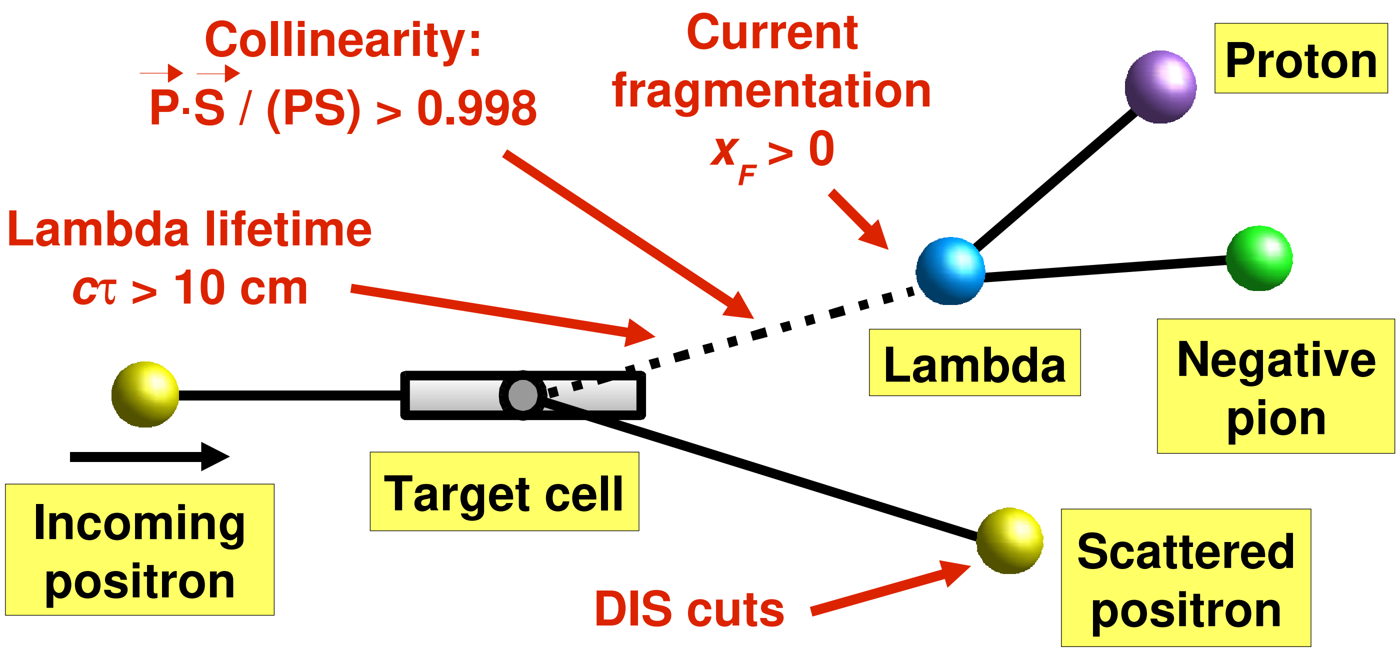
All agree that $D^{\Lambda}_{LL'}$ rises with z

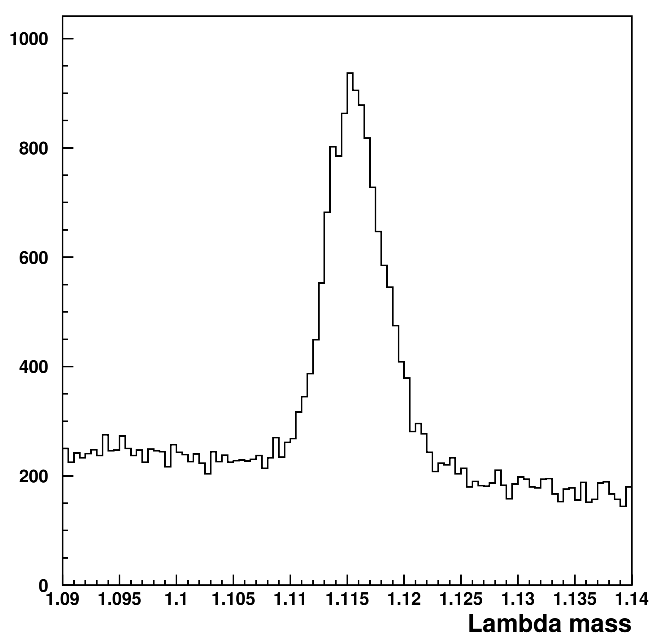
Gribov–Lipatov relation:
$\Delta q / q$ in $\Lambda \to 1$
as $x \to 1$

Lambda reconstruction

- Look for events with three tracks: DIS positron, positive hadron, negative hadron
- Assume positive / negative hadron = proton / pion

Diagram of applied cuts

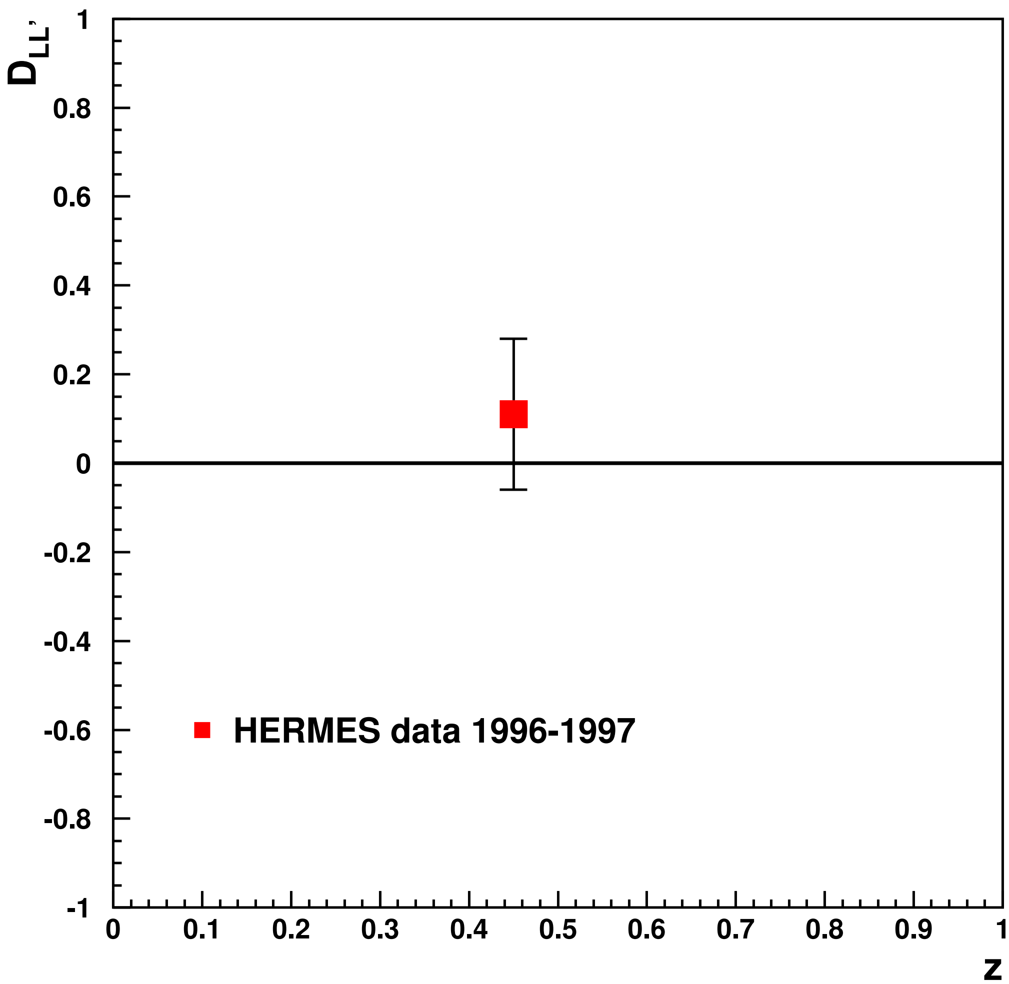


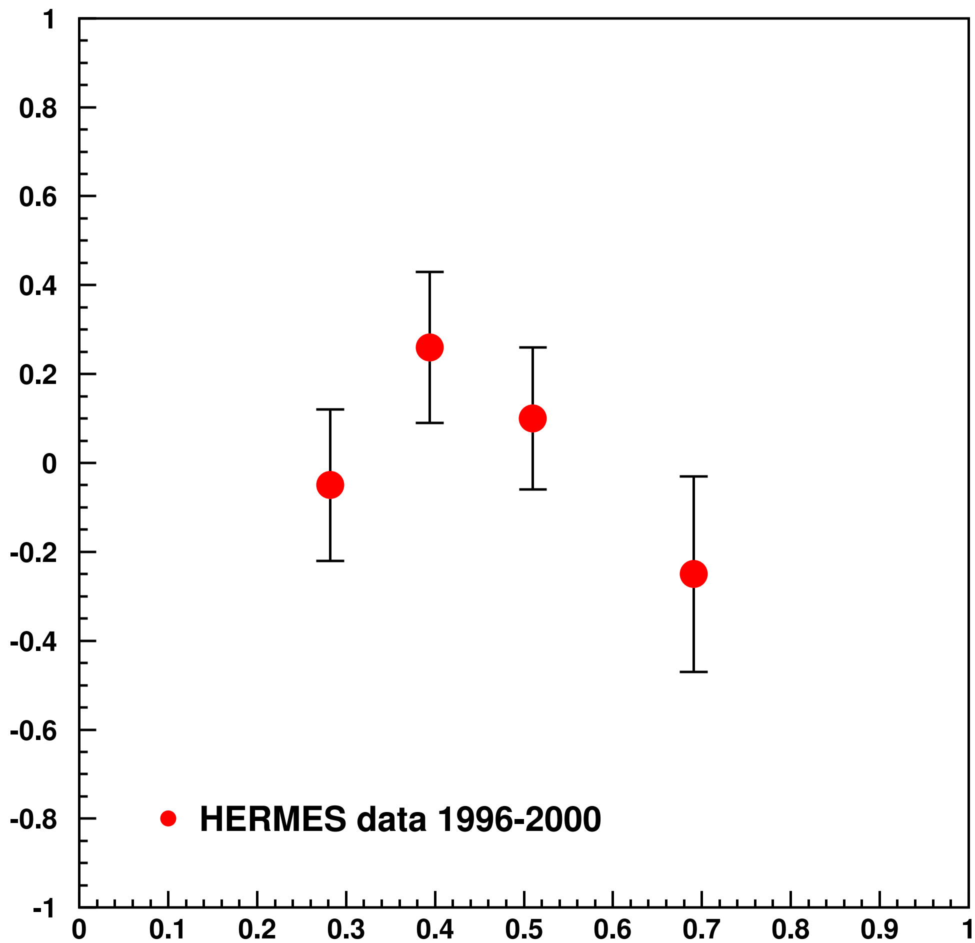


Feynman x variable:
$x_F = p_{||} / p_{beam}$
In virtual photon / target center of mass frame

Experimental results

Spin–transfer data



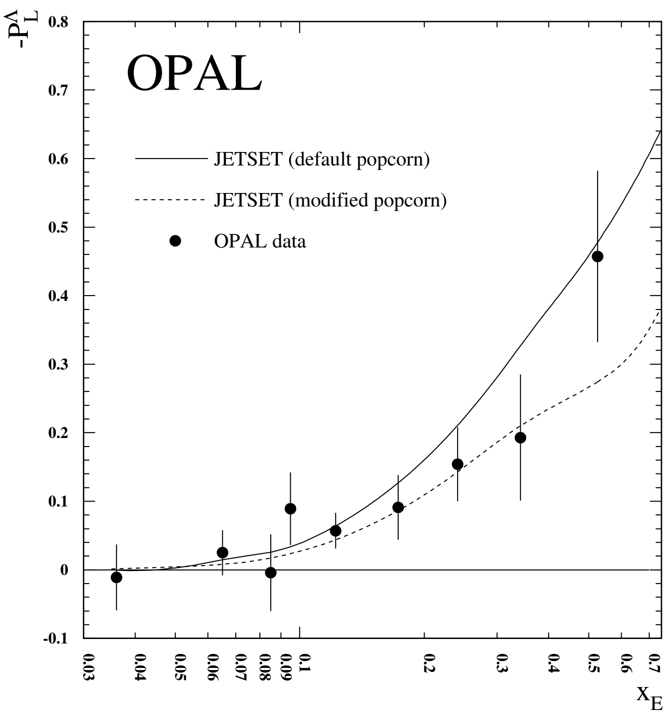


$$D^{\Lambda}_{LL'} = 0.04 \pm 0.09$$

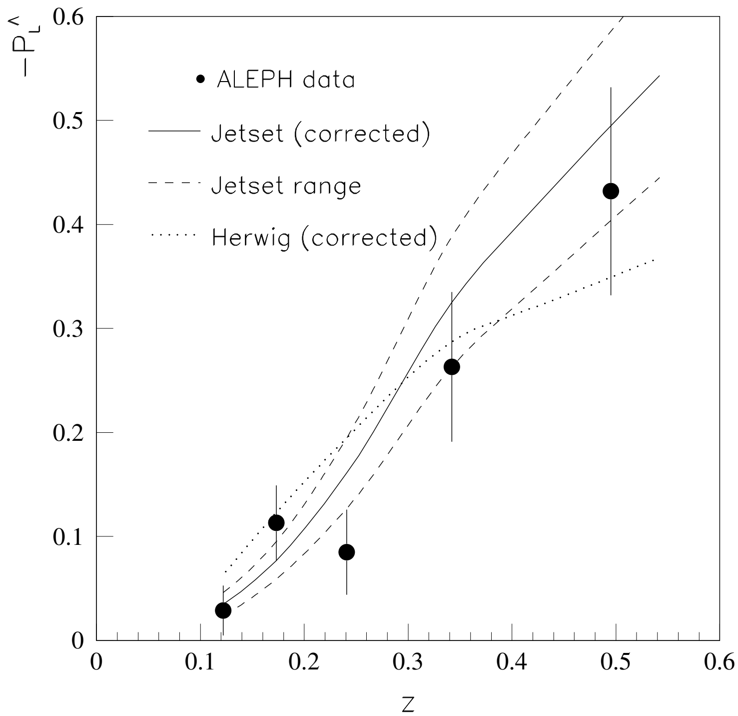
- **Spin transfer is small and appears to decrease at high *z***

ALEPH and OPAL

OPAL data



ALEPH data



- **OPAL and ALEPH data on Λ polarization sucessfully explained with monte carlo model**
- **Simple SU(3) model for hyperon spin structure**
- **Two assumptions:**
  - **(1) Hyperons not containing struck quark are unpolarized**
  - **(2) Perfect helicity conservation through fragmentation**

Monte carlo models

hermes

- Not all lambdas contain struck quark ... contamination from heavy hyperon decays: $\Sigma^*(1385)$, Σ^0, Ξ^0, Ξ^-
- Perform monte carlo studies to understand influence of each subprocess contributing to Λ production

Total spin–transfer coefficient

Sum over all subprocesses

$$D_{LL'}^{\Lambda} = \sum_Y f_q^Y C_q^Y$$

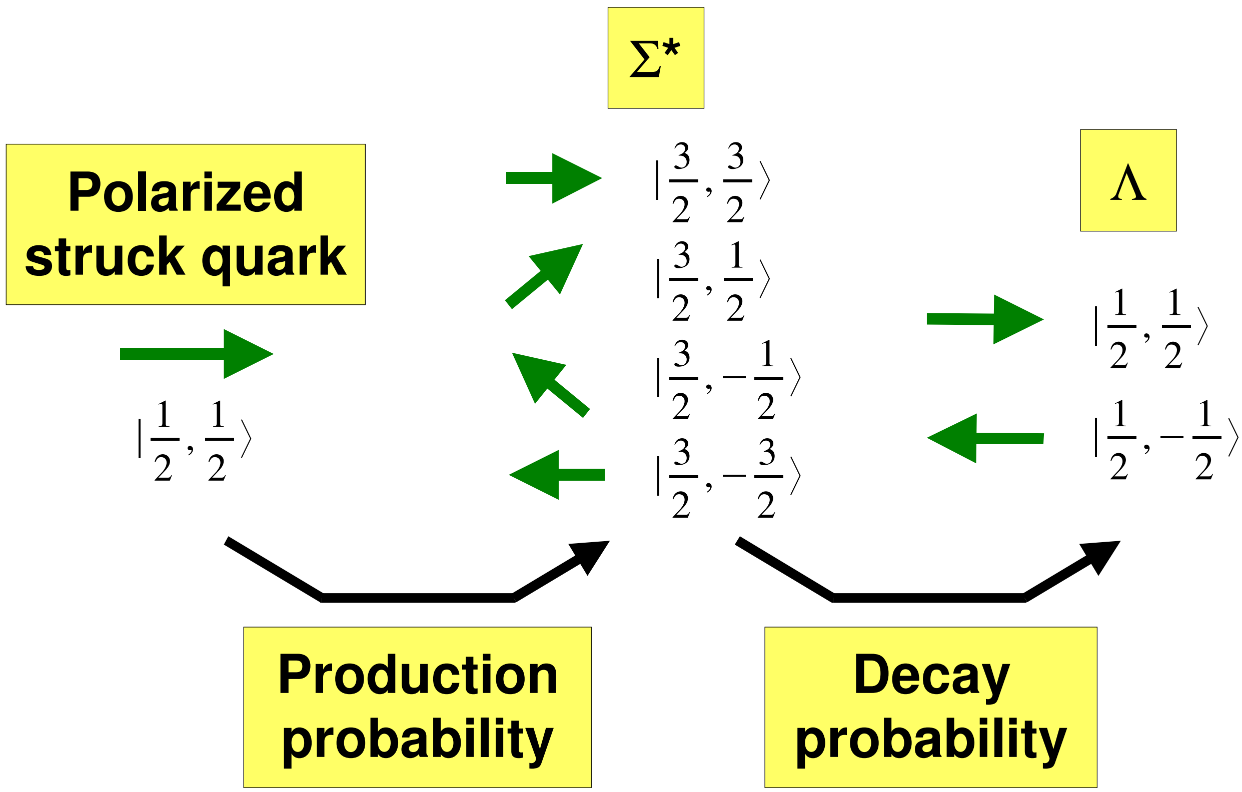
From monte carlo:
Subprocess's fractional contribution to Λ yield

- Direct Λ production
- Hyperon parent (Σ^*, Σ^0, Ξ^0, Ξ^-) containing struck quark
- Hyperon parent (Σ^*, Σ^0, Ξ^0, Ξ^-) not containing struck quark

From spin structure models:
Spin–transfer coefficient of individual subprocess

- Naïve constituent quark model
- Burkardt–Jaffe SU(3)
- Ashery–Lipkin SU(3)

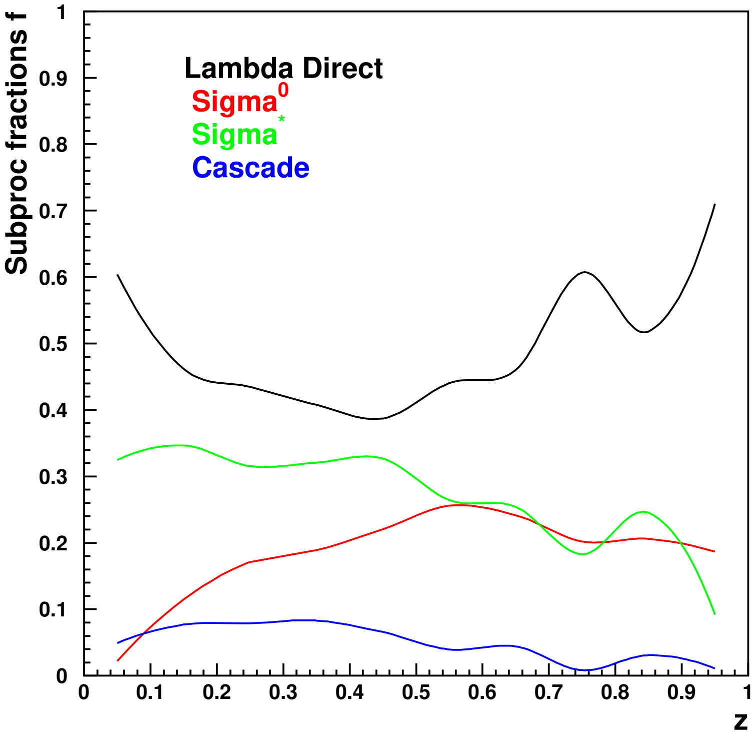
Calculating C_q^Y



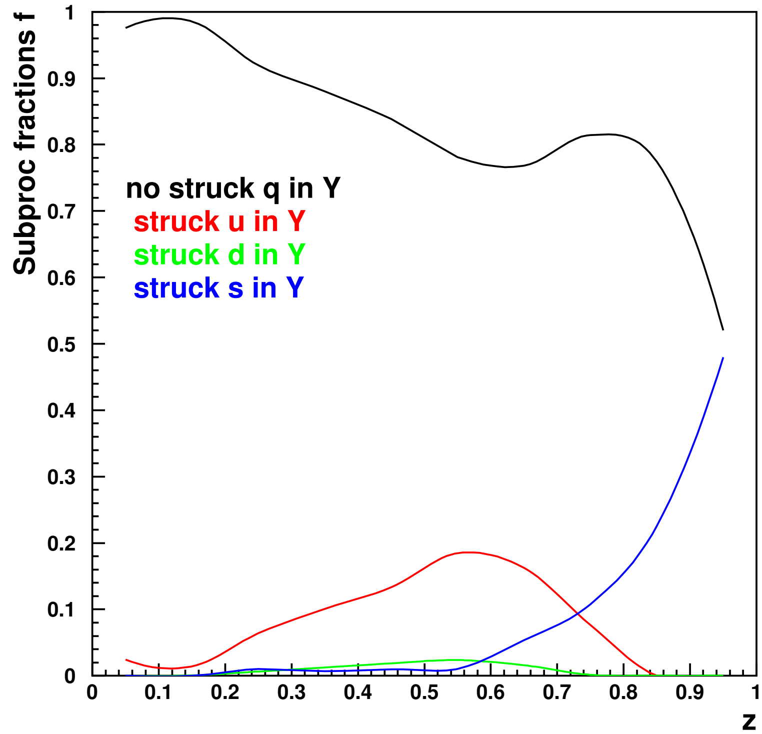
- **Following Ashery and Lipkin, calculate spin–transfer coefficients from production and decay probabilities**
- **Decay probability is model–independent, obtain from Clebsch–Gordan coefficients**
- **Production probability depends on Λ spin structure, given by NCQM, Burkardt–Jaffe SU(3), Ashery–Lipkin SU(3) models**
- **Two assumptions:**
  - **(1) Perfect helicity conservation in fragmentation process**
  - **(2) All quarks (except struck quark) have random polarizations**

Monte carlo results

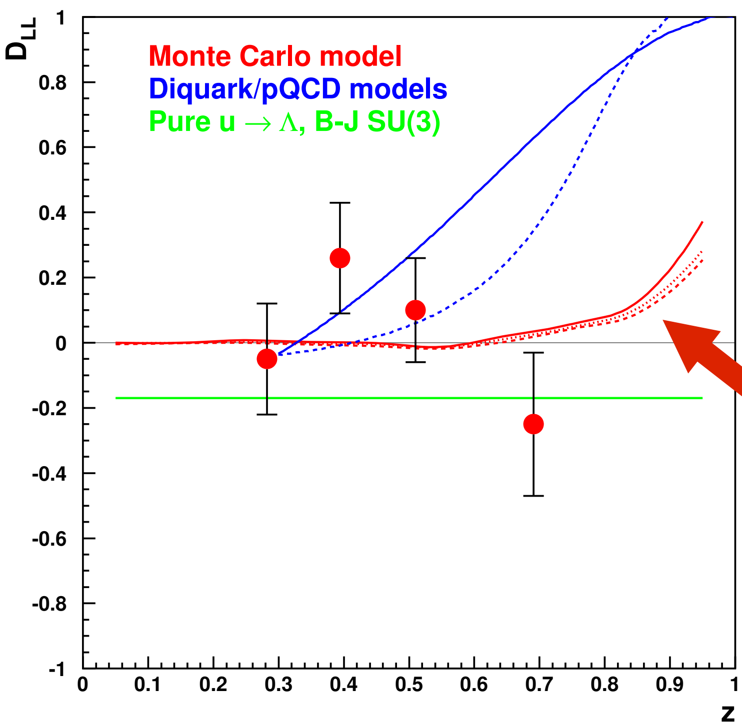
Direct sources of Λ



Quark parents of Λ



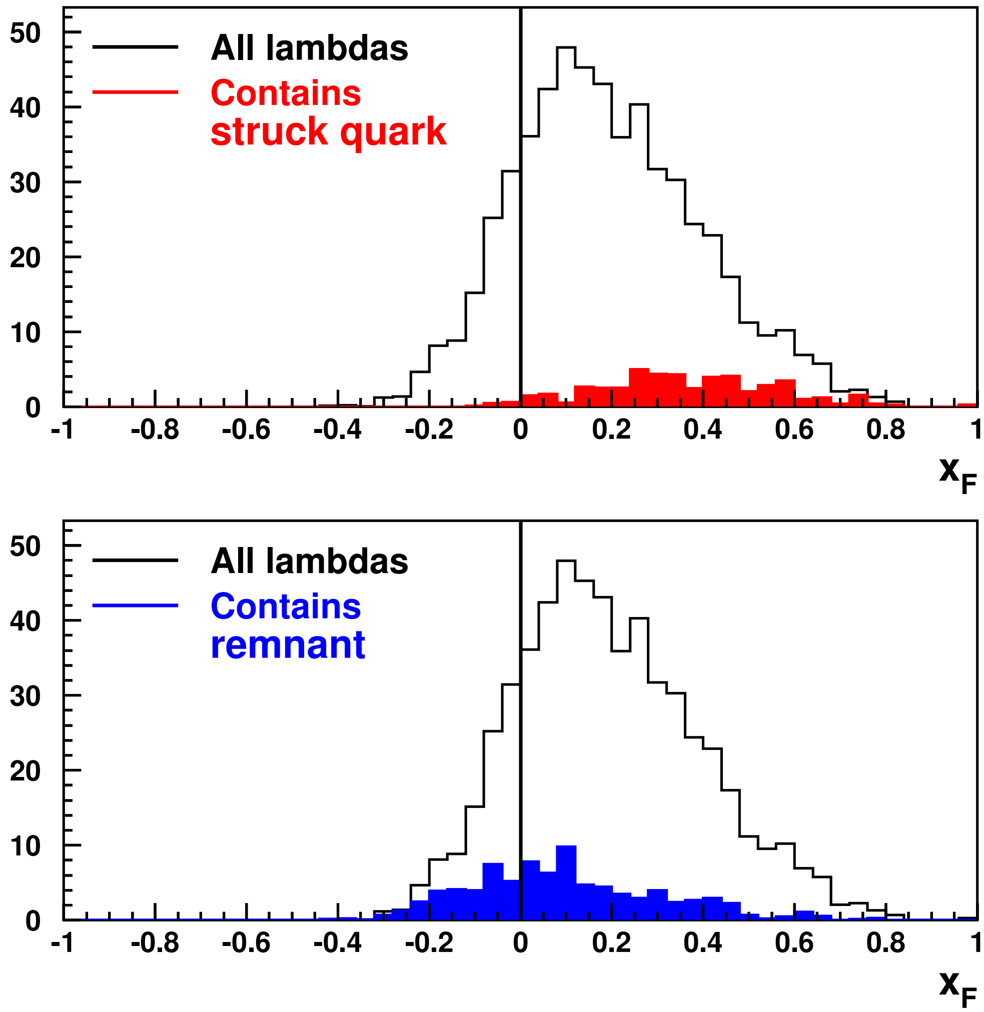
Final spin–transfer models



- **Significant contribution from heavy hyperon decays: 40% – 60% of all lambdas**
- **Very few lambdas contain struck quark: about 10% on average!**
- **Spin–structure models are relatively unimportant in comparison with monte carlo subprocess fractions**

Λ's from target remnant

Lambda x_F distributions



- **Most Λ's from struck quark are produced in forward region ($x_F > 0$)**
- **Significant number of Λ's from target remnant also have $x_F > 0$!!**
- **Lambda production mechanisms are complicated by influence of target remnant**

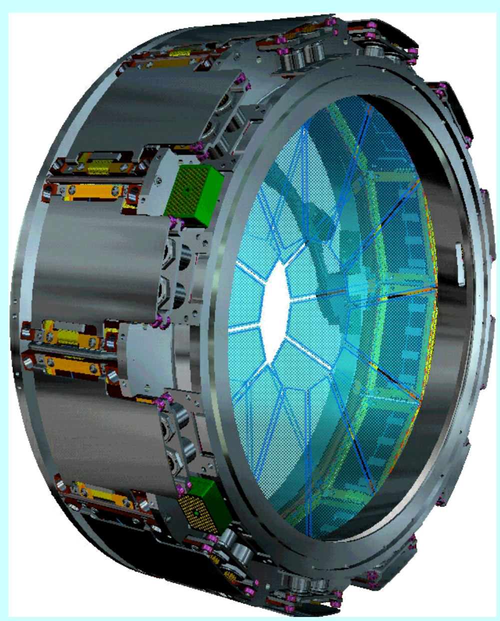
Conclusions

- **Small spin transfer observed:**

$$D_{LL'}^{\Lambda} = \mathbf{0.04 \pm 0.09}$$

- **Significant contribution from heavier hyperon decays (40% – 60%)**
- **Very few Λ's (about 10%) contain struck quark; explains why we see small spin transfer**
- **Many Λ's contain target remnant, even when $x_F > 0$**
  - **Definitely can't use Λ's as spin probes**
  - **CAN use Λ's to explore target fragmentation region ... possibly sensitive to Δs?**

- **New lambda wheels recently installed: will detect Λ's at $x_F < 0$**
- **Will soon have sensitivity to Λ's produced in target fragmentation**



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