The nucleon helicity as seen by HERMES

From $g_1$ to $\Delta G$

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for the hermes collaboration

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Outline

• Nucleon helicity structure has been studied by Hermes mainly in 3 ways
  ▪ Inclusive DIS -> $g_1$
  ▪ Semi-inclusive DIS -> purity analysis
  ▪ High-$p_T$ hadrons with sensitivity to $\Delta g$
• No data with longitudinally polarized data since 2000, but
  ▪ Ongoing, refined and complementary analyses
  ▪ Analysis of unpolarized data for $F_2$, $d_\nu/u_\nu$ and FF
HERA ep collider at DESY (Hamburg)
Polarized \(e^\pm\) with 27.5 GeV
Hermes cms energy (fixed target) 7.2 GeV
Hermes

Internal longitudinally polarized H, D target $P \approx 0.085$ Flip every 60, 90s

Resolution: $\Delta p/p \approx 1-2\%$, $\Delta \Theta \approx 1\text{ mrad}$

Beam polarization 50%

$\pi/k/p$ separation w/dual radiator RICH
$2 < p < 15$ GeV
$\pi$ ID $4 < p < 13$ GeV w/threshold Cherenkov

$\approx 0.8855$

$\Delta \Theta \approx 1\text{ mrad}$

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$\pi/k/p$ separation w/dual radiator RICH
$2 < p < 15$ GeV
$\pi$ ID $4 < p < 13$ GeV w/threshold Cherenkov

$\approx 0.8855$
• $g_1^{p,d}$ corrected (unfolded) for instrumental smearing and QED radiative effects
  ▪ Points *statistically* correlated
  ▪ Only diagonal elements of covariance matrix shown in plots

• Error bars include systematics from $F_2$, $R$ parametrization and $Q^2$ evolution (within $x$ bin)
Final Results on $g_1$

\[ xg^p_1 \sim g^p_1 - g^n_1 \]

\[ xg^n_1 \sim g^n_1 - g^p_1 \]

\[ xg^d_1 \sim g^d_1 - g^p_1 \]

\[ xg^{NS}_1 \sim g^{NS}_1 - g^{p-n}_1 \]
**$g_1$ Integrated**

- Integrals for $0.021 < x < 0.9$
- Integral seems to saturate at $x < 0.04$ for Deuteron
  - Use $\Gamma_1^d$ to extract

\[
a_0(Q^2) = \frac{1}{\Delta C_S} \left[ \frac{9 \Gamma_1^d}{1 - \frac{3}{2} \omega_D} - \frac{1}{4} a_8 \Delta C_{NS} \right]
\]

\[
\Delta \Sigma_{MS} = \Delta u + \Delta \bar{u}, \ \Delta d + \Delta \bar{d}, \ \Delta s + \Delta \bar{s}
\]

<table>
<thead>
<tr>
<th>NNLO</th>
<th>central value</th>
<th>uncertainties</th>
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<td>$a_0$</td>
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<td>$\Delta u + \Delta \bar{u}$</td>
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<tr>
<td>$\Delta d + \Delta \bar{d}$</td>
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<td>0.004</td>
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<tr>
<td>$\Delta s + \Delta \bar{s}$</td>
<td>-0.085</td>
<td>0.013</td>
</tr>
</tbody>
</table>
$\Delta s$ vs. $\Delta s$?

- Extraction of $\Delta u + \Delta \bar{u}$, $\Delta d + \Delta \bar{d}$ uses SU(2) flavor symmetry - Bjorken Sum Rule
- Extraction of $\Delta s + \Delta \bar{s}$ uses SU(3) flavor symmetry
- But: $\Delta s + \Delta \bar{s} < 0$, even with 20% SU(3) breaking while semi-inclusive Hermes data give $\Delta s + \Delta \bar{s} \approx 0$
- Consistent?
  - Negative contribution at lower $x<0.02$?

Published isoscalar method:
Assumed FF from BKK
(Phys. Rev. D 52, 4947 (1995))
SIDIS Asymmetries

All asymmetries unfolded to correct for smearing and QED radiative effects.
Analysis of SIDIS Data

- Quark polarizations obtained from DIS+SIDIS (identified pion, kaon) asymmetries on proton and deuteron, using purity formalism:

\[ A_1^h = c \sum_q \frac{e_q^2 q(x) \int_d z D_q^h}{\sum_q e_{q'}^2 q'(x) \int_d z D_q^h} \frac{\Delta q(x)}{q(x)} \]

Purity: \[ P_q^h(x) \]

\[ \vec{A}_1 = P \vec{Q} \]

- Purities determined by MC
- Caveat: LO analysis, dependent on MC fragmentation model

Study of Lund Fragmentation

• LUND string fragmentation parameters are tuned by minimizing the difference of MC and data (identified) hadron multiplicities
  ▪ Find agreement within ~10% (for pions)
• But: What are the errors?
  ▪ Estimate systematic uncertainties of values extracted using LUND MC (e.g. on $\Delta q/q$ from purity method)
  ▪ Usual method: Compare an old “historical” fit with the current one $\Rightarrow$ normally gives large uncertainties
• Error scan using Hessian matrix (similar to CTEQ)
LUND Error Scan

$\chi^2$-contours in correlated LUND parameter space

$\chi^2$-contours in uncorrelated Hessian parameter space

2-dim ($i,j$) rendition of d-dim ($-16$) PDF parameter space

- contours of constant $\chi^2$ global
- $\mathbf{u}_i$: eigenvector in the $i$-direction
- $\mathbf{p}(i)$: point of largest $a_i$ with tolerance $T$
- $\mathbf{s}_i$: global minimum

- diagonalization and rescaling by the iterative method
- Hessian eigenvector basis sets

Original parameter basis

Orthonormal eigenvector basis
Result of Error Scan

- Black line = total systematic error estimate on $\Delta q/q$
- Grey line = contribution from comparing old and new tunes
- Colored points = Sample $\Delta q/q$ with parameters along 68% Hessian contour
  - “True” error from LUND tune is much smaller than estimate
- But: The overall $\chi^2$/ndf $\approx 20$ for the best tune $\Rightarrow$ MC model itself is not perfect
  - Uncertainty due to “use of MC” unknown
  - Studies are ongoing
Model Dependent, Leading Order Result on $\Delta g/g$

- Black and green curves from pQCD fits to $g_1$
- Red curves: Fits to HERMES high-$p_T$ hadron data using LO MC+pol. PDF model and 2 functional forms
- Red point: Average $\Delta g/g$ from fits.

A lot of the analysis is in the determination of the systematic error and the mean $x$. 
From Measurements ...

- "Antitagged" data:
  - Scattered lepton not in the acceptance
  - \( p_T \) measured w/respect to beam axis

- Curves from MC+asymmetry model using
  - \( \Delta g/g(x)=0 \): central
  - \( \Delta g/g(x)=-1 \): upper
  - \( \Delta g/g(x)=+1 \): lower

\( \Delta g/g=0 \): asymmetry is due to quarks only! Gluons become important for the cross section (asymmetry) above \( p_T \approx 1 \) GeV
(More Asymmetries)

- “Tagged” inclusive charged hadrons
  - Scattered lepton detected
  - $Q^2 > 0.1 \text{ GeV}^2$, $W^2 > 4 \text{ GeV}^2$
  - $p_T$ w/respect to virtual photon

- Inclusive Pairs of charged hadrons
  - No regard to scattered lepton
  - All charge combinations
  - $p_T$ w/respect to beam axis
  - $p_T(h1,h2) > 0.5 \text{ GeV}$

$\sum P_T^2(beam) = P_T^2(beam)(h_1) + P_T^2(beam)(h_2)$
Fractions of contributing subprocesses
- From PYTHIA 6.2 model
- Tuned and adapted for HERMES data (see later)

Their asymmetries
- Initial state partons
- Kinematics of the hard subprocess
  - Scale, x, p_T
- Subprocess kinematics of hard processes with gluons in the nucleon in initial state -> Signal
... and an Asymmetry Model

- Event-by-event calculation from MC kinematics, flavors, subprocess type
  - Hard processes: Use pol. LO PDF (GRSV 2000)
  - Hard resolved photon processes: Use 1/2(maximal+minimal) scenarios from GRS
  - Soft processes: Use assumptions
    - $A=0$ for exclusive/diffractive processes
    - $A\sim A_1$ (low $x$) from world data for soft nondiffractive (“low-$p_T$”)
- Vary PDFs/assumptions for syst. error
(Fractions and Asymmetries)

**Subprocess Fraction**

- **VMD (elast.+diffr., low-\(p_T\))** decreasing w/\(p_T\)
- **DIS** increasing with \(p_T\)
- **QCDC/QCD2->2(q)** increasing with \(p_T\)
- Signal processes are PGF and QCD2->2(g) (resolved photon)

**Subprocess Asymmetries** (using GRSV std.)

- **DIS** increasing with \(p_T\) (x) - positive
- **QCDC/QCD2->2,VMD** flat and small
- Important for background asymmetry!
- \(|\text{PGF}|\) increasing with \(p_T\) - negative
- QCD2->2(g) opposite to PGF, small

**Average Subprocess Weight**

- ed→h^+X (e^+ not in acc.)

**Deuteron data**

![Graphs showing subprocess fractions and asymmetries with data points and lines for different processes.](image-url)
Once we know everything necessary: How do we get $\Delta g/g$ out of this?

$\Delta g/g$ in antitagged region, from MC

Everything (hard, soft)

Contribution from hard gluons in nucleon $\sim \Delta g/g$

$x$-range covered by data (unpolarized): $0.07 < x < 0.7$
Methods for $\Delta g/g$ Extraction

• Method I:
  - Factorize
  
  \[ A_{||}^{sig} \approx \langle \hat{a} \rangle (p_T) \left( \frac{\Delta g}{g} \right) (p_T) \]
  
  - Assumes
    - No sign change in $\hat{a}(x)$
    - “flat” $\Delta g/g(x)$
  - No information on $<x>$ of measurement
  - Gives average $\Delta g/g$ over covered $x$ range
    
    (0.07 < $x$ < 0.7)

• Method II:
  - Fit: find a $\Delta g/g(x)$ such that

  \[ A_{||}^{MC} = A_{||}^{meas} \]

  - Assumes functional form for $\Delta g/g(x)$
  - Only small range in $p_T$
  - Gives $\Delta g/g(x)$ and average $x$ of measurement
\[ \langle \frac{\Delta g}{g} \rangle (p_T) = \frac{A_{\text{meas}} - R_{BG} A_{BG}}{R_{\text{sig}} \langle \hat{\alpha} \rangle} \]

**h^+, h^- antitagged:**
- 4 points between 1.05 < p_T < 2.5 GeV

**h^+, h^- tagged:**
- 1 point for p_T > 1 GeV

**Pairs:**
- 1 point for \( \sum p_T^2 > 2 \text{GeV}^2 \)

Only statistical

- Results for different data samples agree within statistics
- Dominating sample: Deuteron antitagged -> Used for Method II and syst. error analysis (charge combined)
Δg/g from method II

Fit results

- Final 2 functions used are polynomials with 1(2) free parameters
- Fix:
  - Δg/g→x for x→0 and
  - Δg/g→1 for x→1 (Brodsky et al.)
- |Δg/g(x)|<1 for all x
- Difference between functions is a systematic uncertainty
- χ²/ndf≈5 due to highest p_T point
  - Model syst. not included in fit
  - 1-2 parameter function is too smooth

Light shaded area: range of data
Dark shaded area: fit center of gravity
PYTHIA 6.2 has been tuned

- Fragmentation parameters for $Q^2>1 \text{ GeV}^2$
- VMD Model for $Q^2>0.1 \text{ GeV}^2$

**Tagged region:**
Comparison of cross sections for charged hadrons (in HERMES acceptance:)

- Get fair agreement in tagged region ($Q^2>0.1 \text{ GeV}^2$) when integrating over $p_T$
How Good is the Model Really?

- The very same tuned PYTHIA fails to describe cross sections vs. $p_T$
  - For both tagged and antitagged regions
  - Consistent with missing NLO corrections in MC

Application of k-factor to relevant processes in MC gives better agreement with data

Antitagged region: Comparison of cross sections of charged hadrons (in HERMES acceptance:)

\[
\frac{d\sigma}{dp_T} \quad \text{[\text{pb}/\text{GeV}]} \\
\]

\[
\frac{MC}{Data} \\
\]
LO MC vs. NLO pQCD

• Why can we not (yet) use NLO pQCD calculations to extract $\Delta g/g$?
  - Example: simple PGF process (LO)

  Cross sections

  - Magenta curves are what LO pQCD would give
  - Dashed curves are for intrinsic $k_T$ is included (0.4 GeV)
  - Solid curves are intrinsic and fragmentation $p_T$ (0.4 GeV) included
What Does This Result Tell Us?

- Despite the obvious shortfalls stick with LO MC
  - Includes effects of intrinsic transverse momentum ($k_T$) and transverse momentum acquired in fragmentation ($p_T(frag)$)
    - Impact on cross section larger than NLO correction
    - $p_T \leftrightarrow x$ relation changes
- Result is in LEADING ORDER, with model uncertainties
  - Scale variation $1/2 \cdot \text{scale} - 2 \cdot \text{scale}$ (NLO effects!)
  - Variation of $k_T$ and $p_T(frag)$ within range allowed by HERMES and world SIDIS ($p_T < 1 \text{ GeV}$) data
  - Variation of crucial PYTHIA parameters
  - Variation of (pol. and unpol.) PDFs and low-$p_T$ asymmetry
  - Variation of functional form for $\Delta g/g(x)$ (for Method II)
Method I

What Does That Look Like?

- Uncertainties from each group
  - PYTHIA params.
  - PDFs
  - low-\(p_T\) asym.
- summed linearly to “Models” uncertainty
  - Conservative approach
- Experimental (stat.+syst.) added in quadrature
  - syst. uncertainty from 4% scaling uncertainty 14% on \(\Delta g/g\)
For an accurate $\Delta g/g$ extraction:

- Need NLO MC and/or NLO pQCD with initial/ final state radiation effects (resummation?)

From our results:

- $\Delta g/g$ is (likely) mostly small

Need to combine all available data to get a better picture
Summary

- Hermes has collected a wealth of unpolarized and longitudinally polarized data on H and $^2$D targets
- Analyses are being refined, including more and more understanding of the data (experimentally) and the physics (theoretically)
  - E.g., LUND parameter tuning and error scan
  - “Overload” purity method for $\Delta q$, including $\pi^0, k^0, \Lambda$ asymmetries
  - More multiplicities to come (maybe Fragmentation functions)
- $\Delta G$ results soon to be published
Pythia simulates the total ep ($\gamma^*p$) cross section using a mixture of different subprocesses:

- VMD (exclusive, diffractive, soft nondiffractive, hard nondiffractive)
- Anomalous ($\gamma^* \rightarrow q\bar{q}$) processes
- Direct photon processes (QCDC, PGF)
- LO DIS ($\gamma^* q \rightarrow q$)

\[
\begin{align*}
\text{QCD} \\
2 \rightarrow 2
\end{align*}
\]
MC vs. LO QCD

- Comparison of LO cross section for hard subprocesses from pQCD (M. Stratmann) and MC (no JETSET, Kretzer FF instead)
- Magenta lines: Results from varying scale
  - Scale definition different for MC and calculation
**Δg/g Extraction: Cuts**

- Cuts are defined to balance statistics with sensitivity (S/B ratio)
- Also possible systematics under consideration
- Important: Correlation between measured $p_T$ and hard $p_T$ (x, scale)

### Lower cuts on $p_T$

<table>
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<tr>
<th>Cuts</th>
<th>$p_T$ (GeV)</th>
<th>$p_T$ (GeV)</th>
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<td>tagged</td>
<td>$&lt;\hat{p}_T^2&gt;$=p_T^2</td>
<td>$&lt;\hat{p}_T^2&gt;$=p_T^2</td>
</tr>
<tr>
<td>antitagged</td>
<td>$\hat{p}_T^2$</td>
<td>$\hat{p}_T^2$</td>
</tr>
<tr>
<td>pairs</td>
<td>$&lt;\hat{p}_T^2&gt;$=(Σ$p_T^2$)/2</td>
<td>$\Sigma p_T^2$ (GeV^2)</td>
</tr>
</tbody>
</table>

![Graph showing cuts on $p_T$]
Systematics: PDFs

- Standard PDFs used:
  - CTEQ5L(SaS2) for Pythia (unpol., Nucleon(Photon))
  - GRSV std./GRV98 for $\Delta q/q$ going into asymmetries

- Variation:
  - GRV98(GRS) for Pythia (unpol, Nucleon(Photon))
  - GS-B/GRV94, BB2006/CTEQ5L for $\Delta q/q$(nucleon) going into asymmetries

- Error:
  - For Pythia (unpol) the difference is taken as a $1\sigma$ error
  - For $\Delta q/q$I(nucleon) the maximum difference is taken as a $1\sigma$ error
• Besides PDFs, there are 2 more sources of uncertainties
  - Asymmetry of “low-p_T” VMD process
    - Std: $A_{\text{low-p}_T} = A_{\text{inclusive}}$ (from fit to $g_1/F_1$)
    - Variation: $A_{\text{low-p}_T} = 0$ (asymmetric error!)
  - Unknown polarized photon PDFs needed for hard resolved processes
    - Std: Arithmetic mean of maximal and minimal scenarios of Glück et al., Phys. Lett. B503
    - Variation: maximal and minimal scenarios (symmetric, 1 $\sigma$ error)
Systematics: pT smearing

- Initial state (intrinsic kT of partons in nucleon and photon) and final state (fragmentation) radiation generate additional pT with respect to the collinear “hadron pT”.
 \[ p_T^h = z \hat{p}_T \]

  - Huge effects on measured cross sections, and the correlation between measured pT and hard subprocess pT, and x
  - Also large effects on subprocess fractions
  - See Elke’s study in the paper draft

- Std.: kT (0.4 GeV) and pTFragm. (0.4 GeV) from \( \chi^2 \) minimization

- Variation: 1σ error from \( \chi^2 \) minimization (±0.04/0.02 GeV)
Systematics: Scale Dependence

- Scale in Pythia was varied by factors $1/2$ and 2
- Same variation for asymmetry calculation
- Error: Maximum difference to std. is taken as $1\sigma$ uncertainty
Systematics: Cutoffs

• A number of cutoffs in Pythia (to avoid double counting) can influence subprocess fractions.
• Most important one: PARP(90) sets the dividing line between
  ▪ PGF/QCDC and hard resolved QCD
  ▪ Hard and soft (low-$p_T$) VMD
• Std: Default Pythia (0.16)
• Variation: 0.14-0.18 (from comparing Pythia LO cross section with theory LO cross section)
Systematics: Method 2

- An additional uncertainty is assigned for Method 2 due to the choice of functional shape
- Std: Function 1 (1 free parameter)
- Variation: Function 2 (2 free parameters)
- Error = difference (!asymmetric!)
Mean values, syst. and stat. errors in Method I are independent between $p_T$ points.

They are correlated in Method II (band).

Error bars/bands: stat. and total errors (including exp. systematics from polarization measurements (4%)).

For Method 2 the errors are dominated by high statistics points.
Modifying/Tuning PYTHIA

- Changes to the VMD model in PYTHIA
  - The $Q^2$ slope of the total (resolved) $\gamma^*p$ cross section:
    \[
    \frac{\sigma(Q^2)}{\sigma(Q^2 = 0)} = \left(\frac{M^2_{\rho}}{M^2_{\rho} + Q^2}\right)^m
    \]
    \[m = 2 \rightarrow 2.6\]
  - The parametrization of $\gamma$–VM couplings
  - The angular distribution of the $\rho^0$ decay products
    \[
    \frac{d\sigma}{dQ^2} (Q^2 = 0) \sim A \sin^2 \theta^* + B \cos^2 \theta^*
    \]
    \[
    \frac{d\sigma}{dQ^2} (Q^2 > 0) \sim \frac{\sigma_L}{\sigma_T}
    \]
- And implementing QED radiative corrections...
**NLO QCD Analysis of SIDIS Data**

- Fit to inclusive and Hermes/SMC SIDIS asymmetries
  - With error analysis
- Additional input: Fragmentation functions
- SIDIS data constrain sea quark densities better
  - Uncertainties still very large

- Results very sensitive to choice of fragmentation function
  - Need more precise FF from data
NLO SIDIS Fit Errors

\[ \chi^2 \]

- KRE NLO
- KKP NLO
- \( \chi^2_{NC} \)

\[ \delta \]

(a) \quad (b) \quad (c)

\[ \delta u, \delta d, \delta s \]

\[ \chi^2 \]

(d) \quad (e) \quad (f)

\[ \delta u + \delta \bar{u}, \delta d + \delta \bar{d}, \delta g \]

\[ \chi^2_{5\%}, \chi^2_{1\%}, \chi^2_{2\%} \]
Unpolarized Data

- Knowledge of unpolarized input to PDF fits very important
  - SIDIS multiplicities of identified hadrons (together with $e^+e^-$-data from BELLE+LEP) provide valuable information for new, more precise Fragmentation functions
  - Understanding the unpolarized cross section (e.g., $F_2$) helps evaluating the validity of pQCD assumptions

Sorry, later …
Extraction of multiplicities at HERMES

Unpolarized H and D data

MC input

Multiplicities at $Q^2=2.5, 25 \text{ GeV}^2$

Correction for exclusive VM production

Unfolding of smearing and QED radiative effects

Acceptance correction

Evolution to common $Q^2$

Multiplicities at $Q^2=2.5, 25 \text{ GeV}^2$

Correction for RICH efficiency

and misidentification

1

$\frac{dN_{\pi^\pm,k^\pm}}{N_{DIS}} \frac{dz}$

4 $\pi$ Born multiplicities
SIDIS Multiplicities (Pions)

• VMD correction large at $z > 0.7$
• $\pi^+/\pi^-$ ratio $\approx 1.2$

Multiplicities on Proton

- HERMES Preliminary
- $Q^2 = 2.5$ GeV$^2$/c$^2$
- proton target

- excl. VM subtracted
- excl. VM included
SIDIS Multiplicities (Kaons)

- VMD correction small
- $k^+/k^-$ ratio $\approx 2$

**Multiplicities on Proton**

- Watch the scale!
Including excl. VMD contribution may get $Q^2$ evolution (gluon FF) wrong!
Model Independent Extraction of $\Delta s$

- The deuteron inclusive and charged kaon asymmetries are isoscalars:

\[
A_1^d = C \frac{1}{5Q(x) + 2S(x)} \left[ 5Q(x) \frac{\Delta Q(x)}{Q(x)} + 2S(x) \frac{\Delta S(x)}{S(x)} \right]
\]

\[
A_1^{k^+ + k^-} = C \frac{1}{Q(x)D_Q^k + S(x)D_S^k} \left[ Q(x)D_Q^k \frac{\Delta Q(x)}{Q(x)} + S(x)D_S^k \frac{\Delta S(x)}{S(x)} \right]
\]

with:

\[
(\Delta) Q(x) = (\Delta) [u(x) + \bar{u}(x) + d(x) + \bar{d}(x)]
\]

\[
(\Delta) S(x) = (\Delta) [s(x) + \bar{s}(x)]
\]

and:

\[
D_Q^k = 4 \int_{z_{\text{min}}}^{z_{\text{max}}} dz D_u^k(z) + \int_{z_{\text{min}}}^{z_{\text{max}}} dz D_d^k(z)
\]

\[
D_S^k = \int_{z_{\text{min}}}^{z_{\text{max}}} dz D_s^k(z)
\]

\[
D_u^k = D_u^k
\]

\[
D_d^k = D_d^k
\]

\[
D_s^k = D_s^k
\]
Inclusive and Charged Kaon Asymmetries

Asymmetries measured on deuteron, unfolded to correct for smearing, PID efficiency (RICH) and QED radiative effects.
Model Independent Extraction of $\Delta s$

- From $A_1^{incl}$ and $A_1^k$ we can extract $\Delta Q$ and $\Delta S$ assuming only
  - Isospin invariance
  - Charge conjugation symmetry of FF
- Use charged kaon multiplicities to get $D_Q^k$ and $D_S^k$
  \[
  \frac{dN^k/Q}{dN^{DIS}/dx} = \frac{Q(x)D_Q^k + S(x)D_S^k}{5Q(x) + 2S(x)}
  \]
- Use CTEQ6LO for unpolarized PDFs
Charged Kaon Multiplicities

Multiplicities measured on deuteron, unfolded to correct for smearing, PID efficiency (RICH) and QED radiative effects

Very large difference between FF fit to data and Kretzer (PRD 62 054001 (2000)) or KKP (Nucl. Phys. B582, 514(2000)) predictions

Have to regard light quark suppression in k fragmentation
Results for $\Delta Q(x)$ and $\Delta S(x)$

Results on $S(x)$:
- consistent with published 5 parameter fit
- Statistical and systematic uncertainties significantly reduced
- Polarized strange quark density consistent with 0
  - No hint that it is negative

Comparison with Previous Hermes Results

Published isoscalar method:
- Assumed FF from BKK
MC and data vs. $p_T \ Q^2 > 0.1$

Cross section on deuteron, within Hermes acceptance
Semi-inclusive hadrons, $p_T$ measured w.r.t. $\gamma$ direction