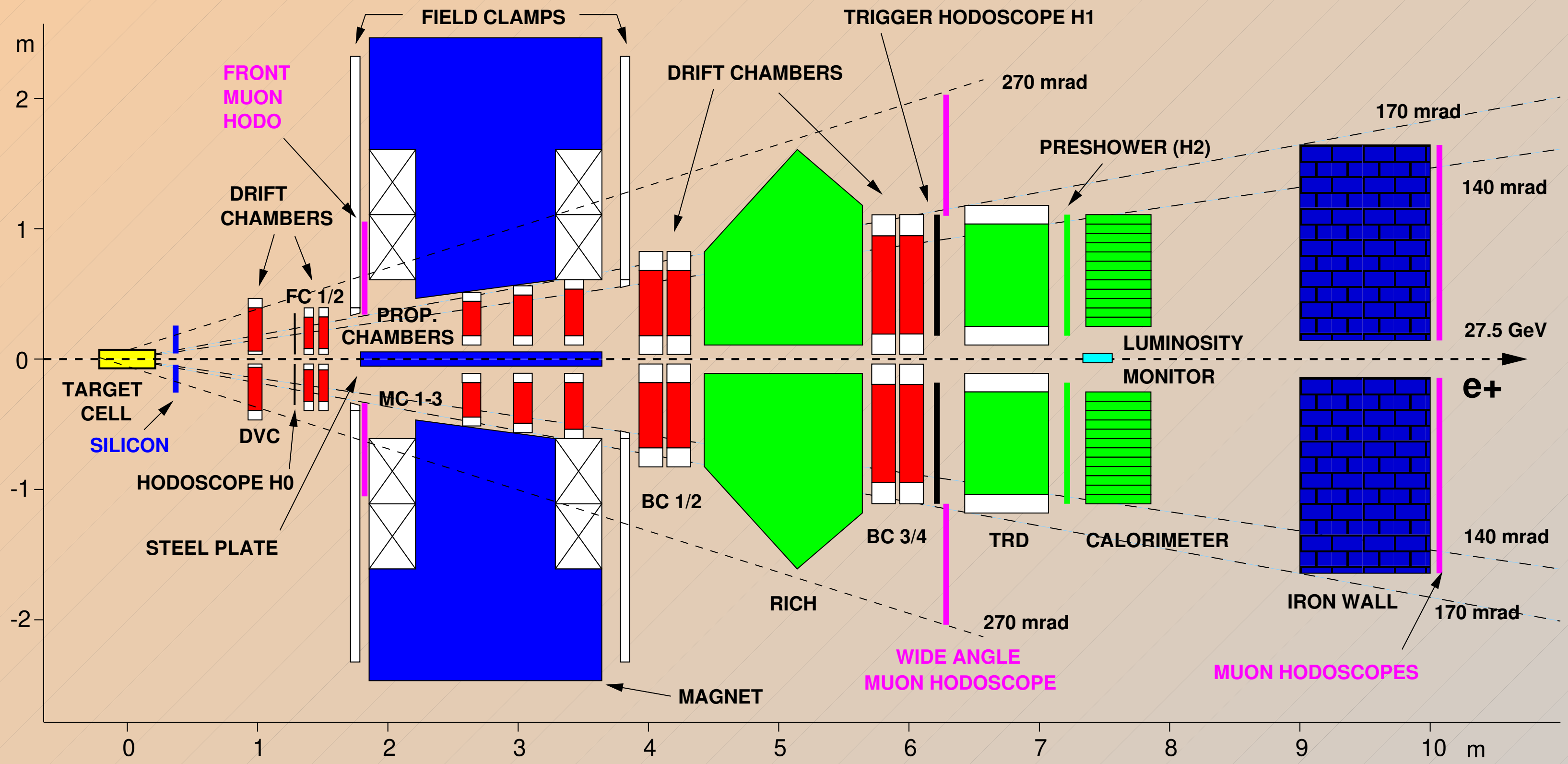
Workshop on Current and Future Directions at RHIC, BNL, Aug. 2002

Extraction Of Polarized Parton Distributions From Semi–inclusive HERMES Data

- Hermes and its Old and New Data
- Inclusive and Semi–inclusive Asymmetries
- Unfolding of Semi–inclusive Asymmetries
- The Purity Formalism
- The Most Recent Hermes Results on
  - The Flavor Separation of Quark Polarizations
  - The Symmetry of the Polarized Light Sea

Patricia Liebing
DESY Zeuthen
On behalf of the hermes Kollaboration

HERMES - Featuring ...



polarized internal gas targets: ^{1}H (1996/97), ^{2}H (1998–2000)
^{3}He (1995)

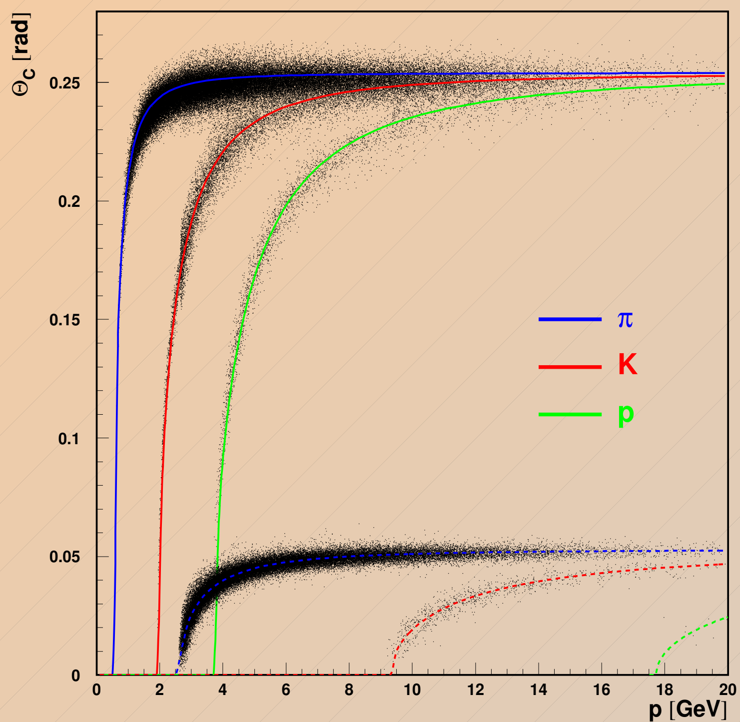
lepton/hadron–ID with contaminations < 1%, efficiency ≈ 98%

major upgrade in 1998: dual radiator RICH for π/K/p–Separation

The HERMES Rich Detector

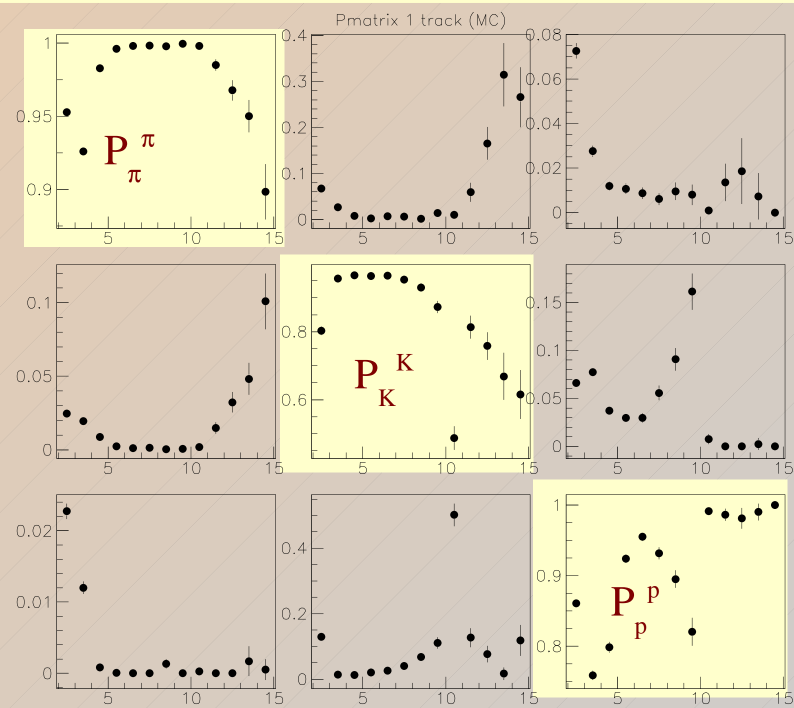
Rich – Cherenkov Angles

2 Radiators: Aerogel
C_4F_{10}



Probability Matrix P

P_t^i = Probability that a particle of true type t will be identified as a particle of type i



π/K/p–Separation between
1 and 15 GeV with high efficiency.

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Data Used For Inclusive and Semi-inclusive Asymmetries

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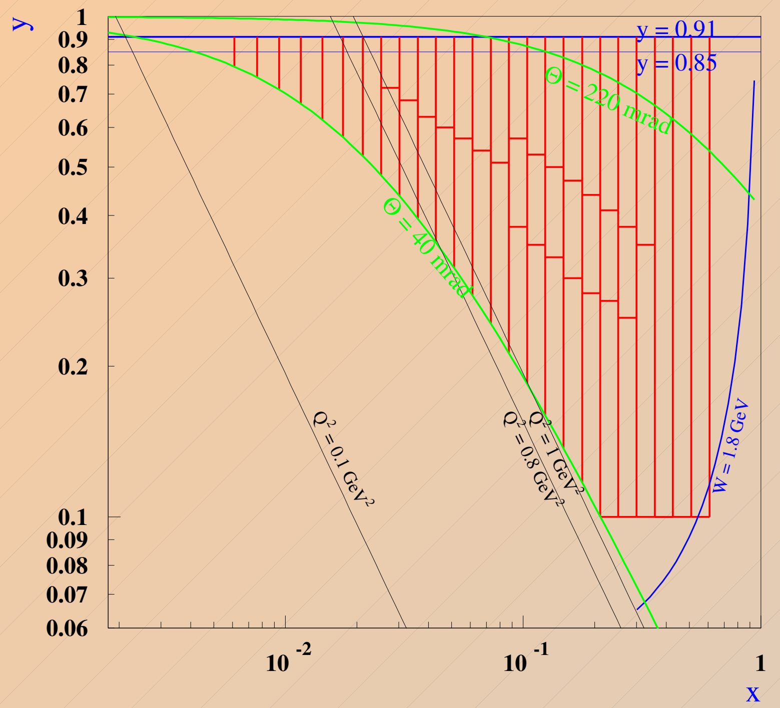
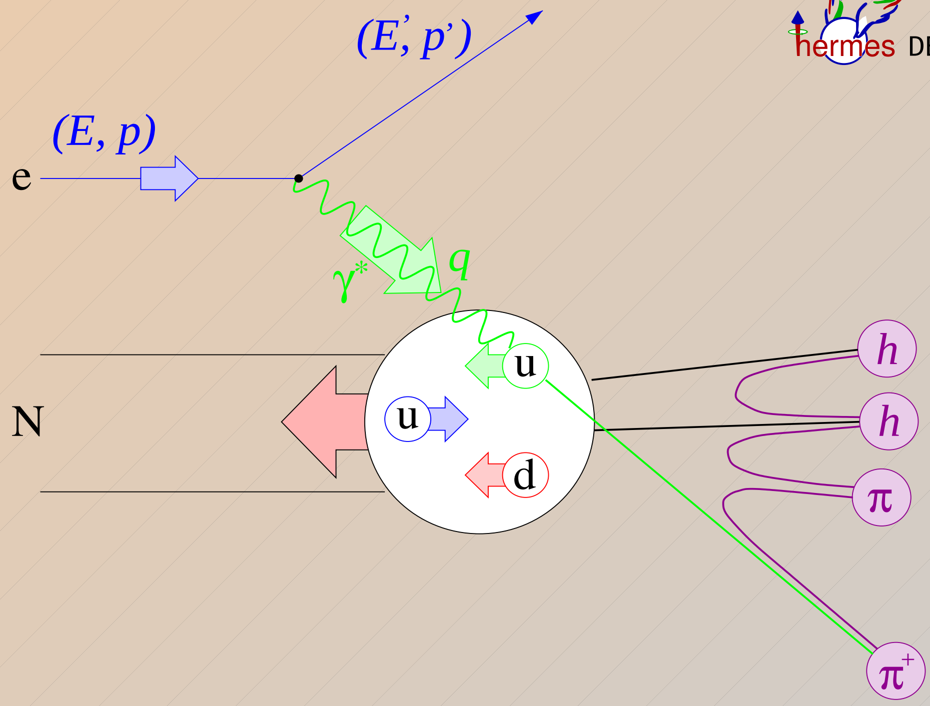




Inclusive Data including low–x_{Bj} Points:

$$\begin{aligned} Q^2 &> 0.1\,\mathrm{GeV}^2 \\ W^2 &> 3.24\,\mathrm{GeV}^2 \\ y &< 0.91 \end{aligned}$$

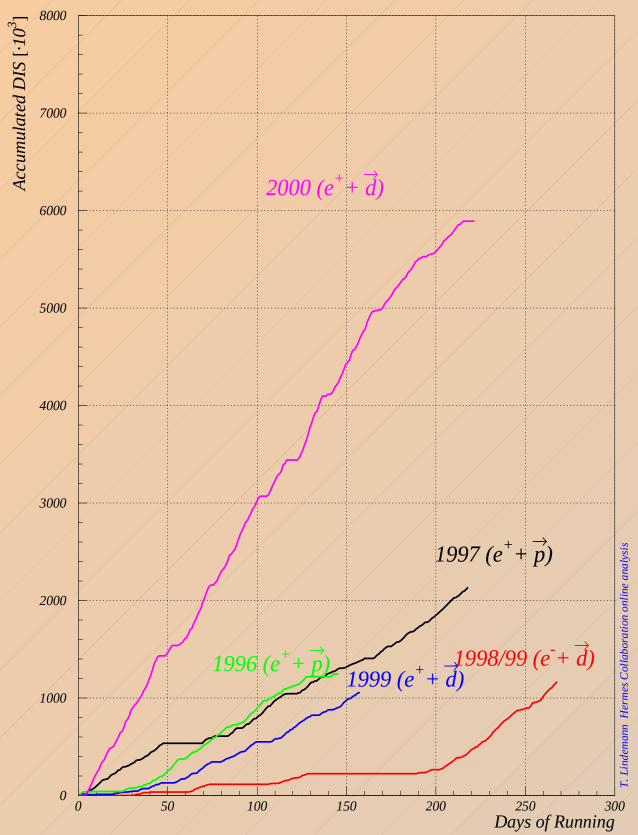
Standard DIS cuts:

$$\begin{aligned} Q^2 &> 1\,\mathrm{GeV}^2 \\ W^2 &> 4\,\mathrm{GeV}^2 \\ y &< 0.85 \end{aligned}$$

Semi–inclusive Data:

$$\begin{array}{lll} W^2 > & 10\,\mathrm{GeV}^2 & \\ 0.2 < & z = E_h/\nu & < 0.8 \\ x_F \simeq & 2p_{\|}/W & > 0.1 \end{array}$$

The HERMES Data



Type	*Proton*	*Deuterium*
DIS–e+ (low–x)	**2.5 M (97)**	**11.7 M (98+00)**
DIS–e+ (standard)	**2.37 M**	**8.63 M**
DIS–e+ (SIDIS)	**1.77 M**	**6.48 M**
h+	275 K	952 K
h–	158 K	628 K
π+ (4<p<13.8 GeV)	118 K	446 K
π– (4<p<13.8 GeV)	82 K	359 K
K+ (4<p<13.8 GeV)	–	**89.9 K**
K– (4<p<13.8 GeV)	–	**35.2 K**

- High statistics after applying data quality and kinematic cuts
- First semi–inclusive asymmetries with identified hadrons
- Statistics dominated by 1997(p) and 2000(d) data taking

Longitudinal Cross Section Asymmetries

What we measure:

$$A_{\parallel}^{(h)} = \frac{1}{\langle P_B P_T \rangle} \frac{(N^{(h)}/L)^{\rightleftarrows} - (N^{(h)}/L)^{\rightrightarrows}}{(N^{(h)}/L)^{\rightleftarrows} + (N^{(h)}/L)^{\rightrightarrows}}$$

$N^{(h)}$: #of measured DIS positrons (semi–inclusive hadrons)
L : Luminosity
$P_{B,T}$: Beam (Target) Polarizations

g_1 from virtual photon asymmetry A_1

$$\frac{A_{\parallel}^{(h)}(x,Q^2)}{D(x,Q^2)[1+\eta\gamma]} = A_1^{(h)}(x,Q^2) \overset{g_2=0}{\simeq} \frac{g_1^{(h)}(x,Q^2)}{F_1(x,Q^2)}$$

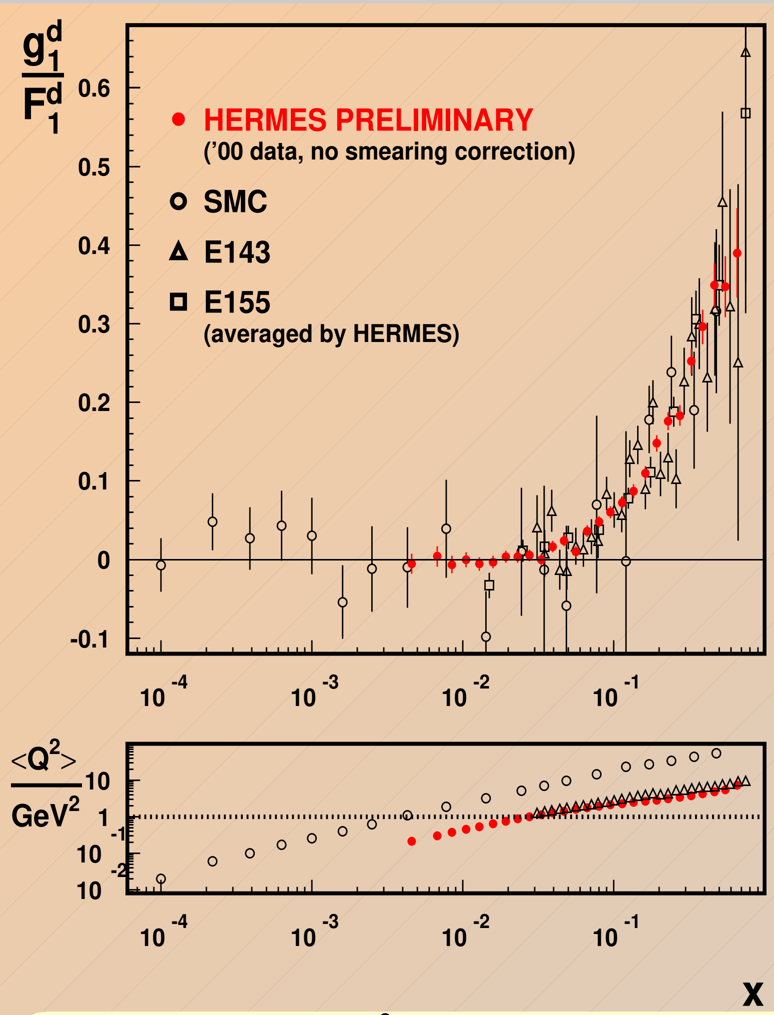
$D(x,Q^2)$: Depolarization factor
F_1: from $F_2 = 2xF_1 \frac{1+R}{1+\gamma^2}$

Flavor separation in LO QCD:

$$A_1^h(x,Q^2) \overset{g_2=0}{\simeq} C \cdot \frac{\sum_q e_q^2\, \Delta q(x,Q^2) \int_{z_{min}}^{z_{max}} dz\, D_q^h(z,Q^2)}{\sum_q e_q^2\, q(x,Q^2) \int_{z_{min}}^{z_{max}} dz\, D_q^h(z,Q^2)}$$

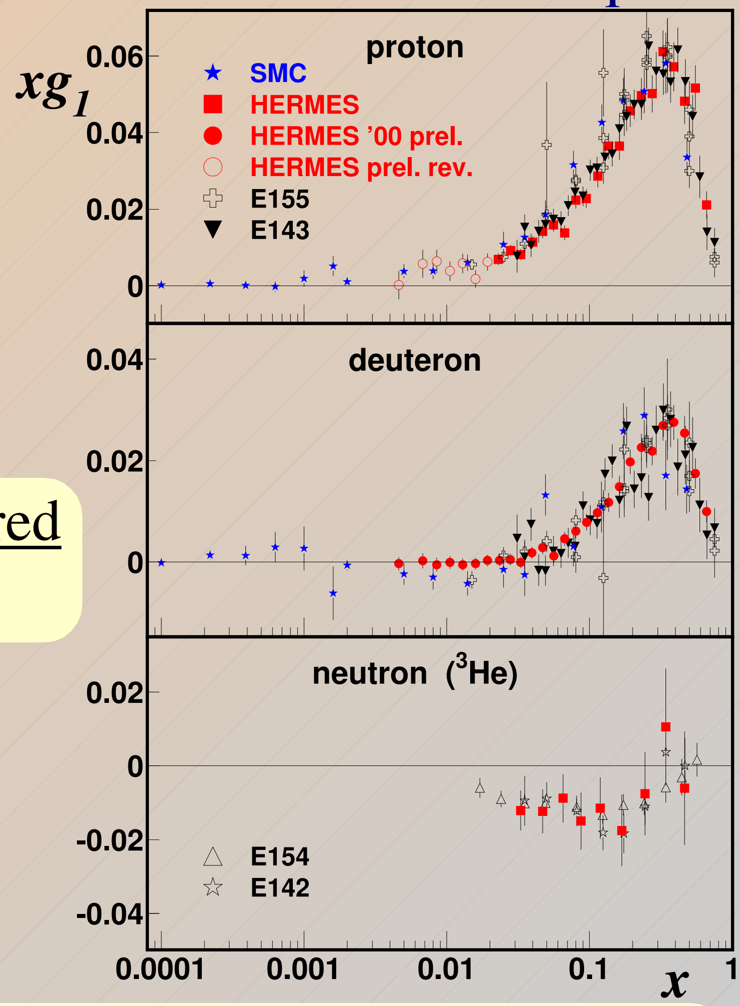
$D_q^h(z,Q^2)$: Fragmentation function
$q(x,Q^2)$: unpolarized quark densities
C : $(1+R)/(1+\gamma^2)$

INCLUSIVE ASYMMETRIES AND g_1



All Data at measured Q^2

World Data on xg_1



No significant Q^2–dependence of g_1/F_1 observed ...

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... but small Q^2–dependence of g_1 visible

Unfolding Of Asymmetries

Measured observables are subject to corrections from :

- Detector Smearing
  - ➔Migration between kinematic bins
  - ➔losses due to π/K–decays
- QED radiative corrections
  - ➔Migration between kinematic bins
  - ➔Background due to contribution of elastic tails

Compute 'Smearing Matrix' S from MC for each experimental bin i and each generated (Born) bin j and for each spinstate.

$$S_{ij} = \frac{\partial\sigma^{meas}}{\partial\sigma^{Born}} = \frac{\partial N^{meas}}{\partial N^{Born}} = \frac{N(i,j)}{N^{Born}(j)}$$

describes the ratio of events in (measured) bin i coming from generated bin j to events generated in bin j

Derive Born yields from measured ones using S^{-1}

Migration Of Events Over Bins

True bin = 0 Events smeared into acceptance

True bin ≠ 0 Events smeared within acceptance

Error enlargement:

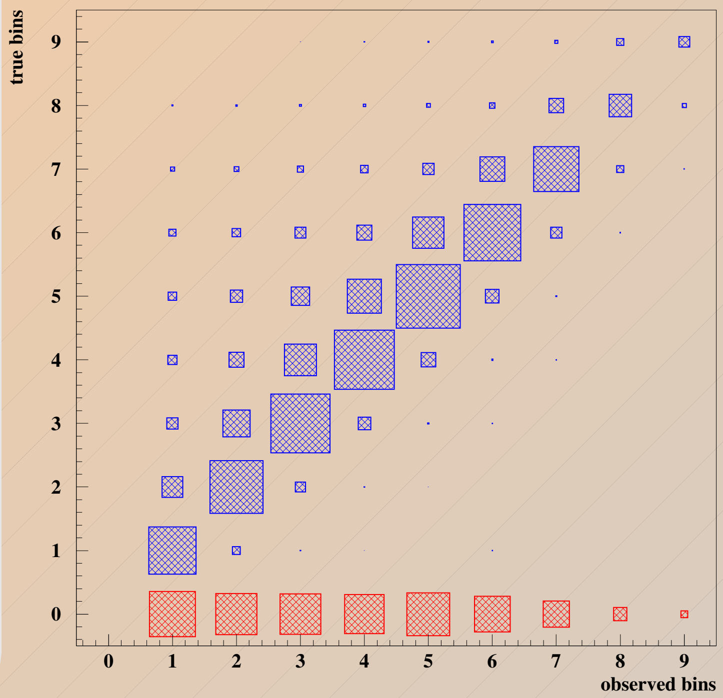
$$\delta^2\left(A_{Born}(j)\right) = \sum_{i=1}^{n_X} D_{ji}^2\, \delta^2\left(A_X(i)\right)$$

where

$$D_{ji} = 2 S_{ji}^{-1} \frac{n_u^X(i)}{n_u^{Born}(j)}$$

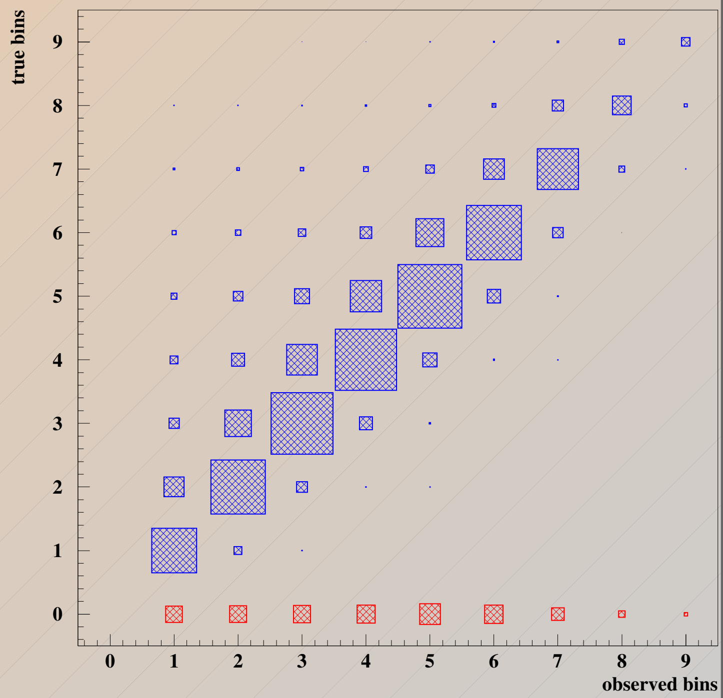
n_u : unpolarized yields

DIS–Positrons



S_{ij} mainly dominated by QED radiative tails

SIDIS–positive Hadrons



S_{ij} mainly dominated detector smearing effects

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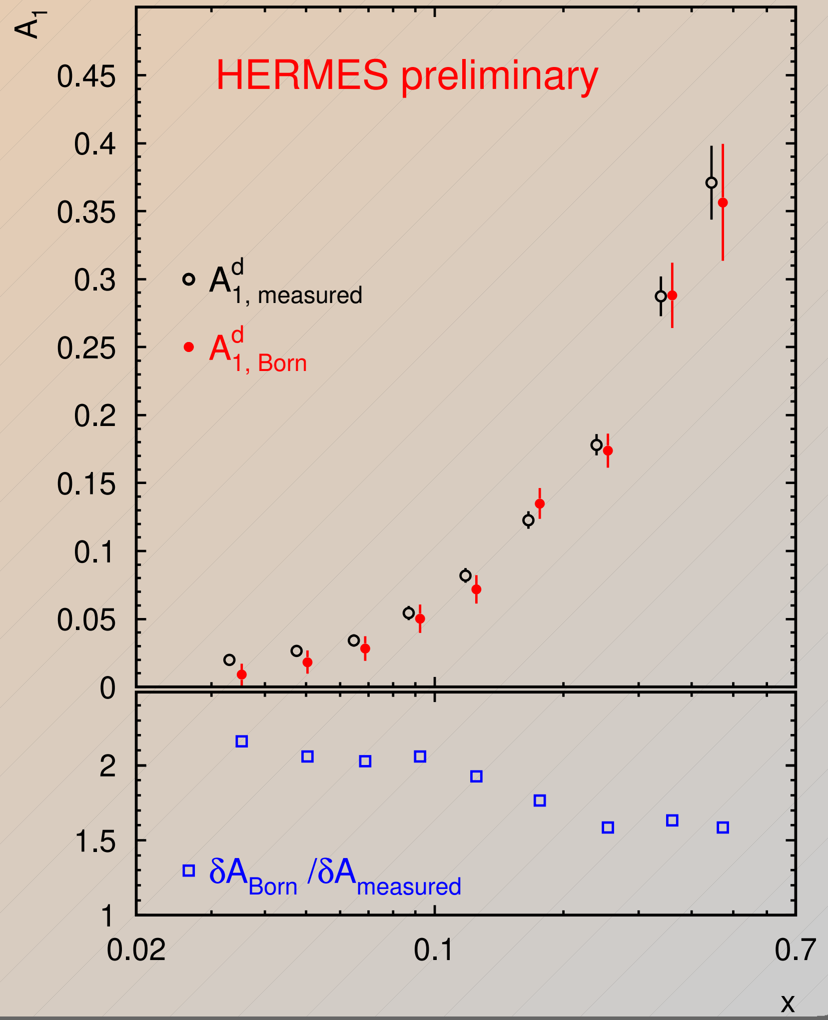
Unfolding Of Asymmetries

Error Enlargement due to Unfolding

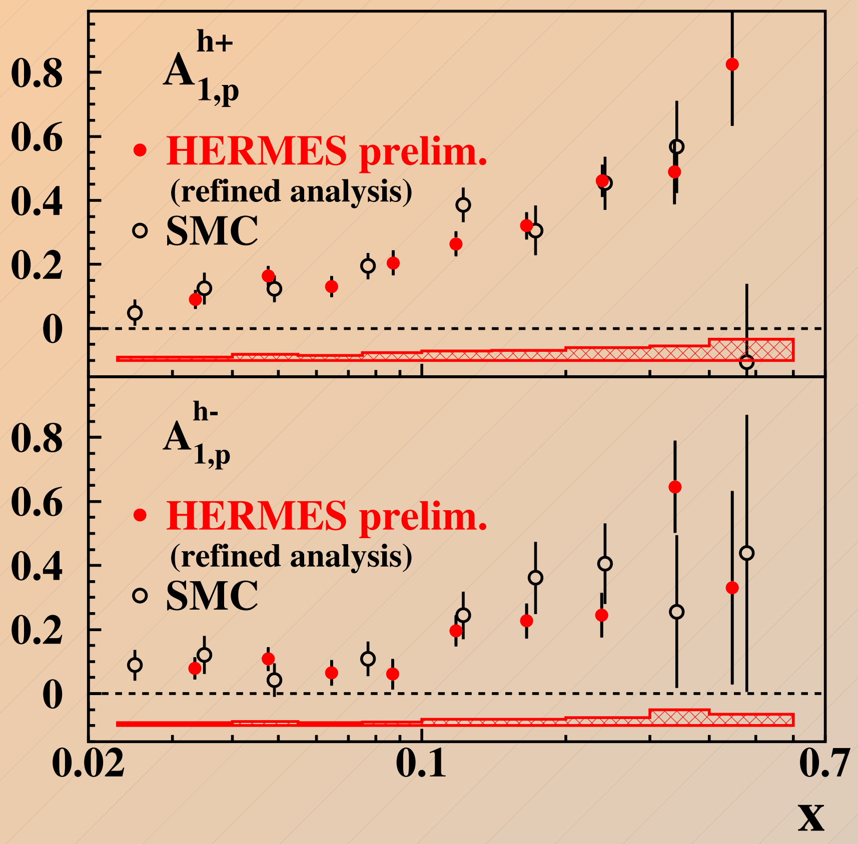
- Derivation of A_1 from $A_{||}$ using S^{-1} takes statistical correlations between bins and background properly into account
  - ➔ Statistical uncertainties of unfolded asymmetries are enlarged
  - ➔ reason: no underlying assumption of smoothness of background
- Enlargement of uncertainties dominated by
  - ➔ QED radiative effects ($x_{Bj}<0.1$)
  - ➔ Detector smearing effects ($x_{Bj}>0.1$)

Inclusive A1 in the kinematic range of SIDIS Analysis



The SEMI-INCLUSIVE Asymmetries

Hadrons (Proton)



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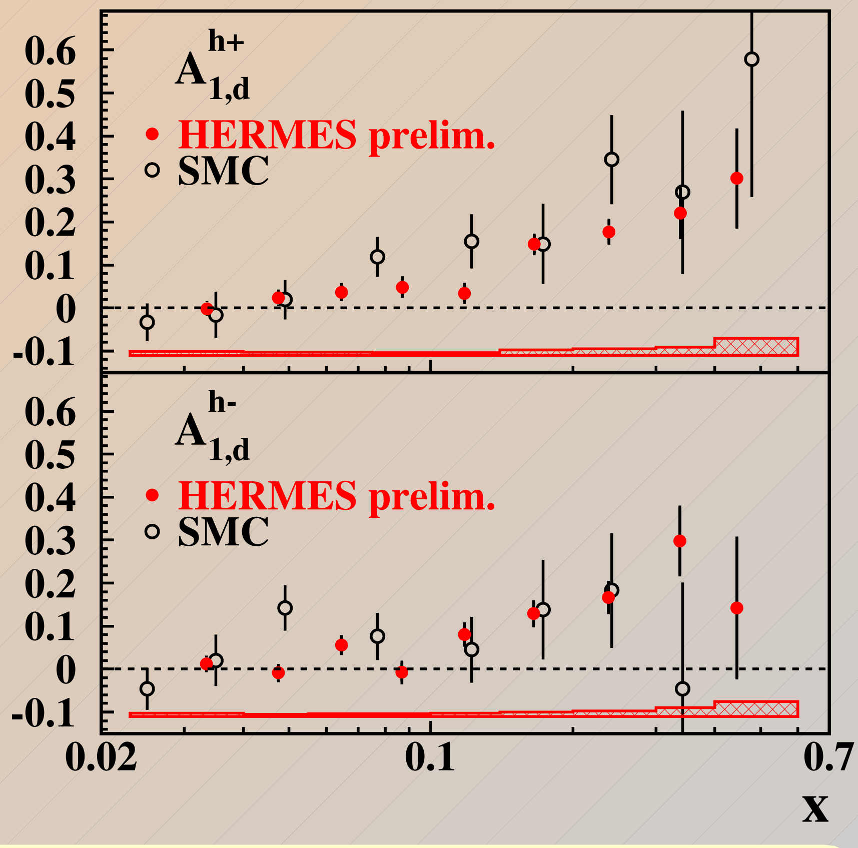
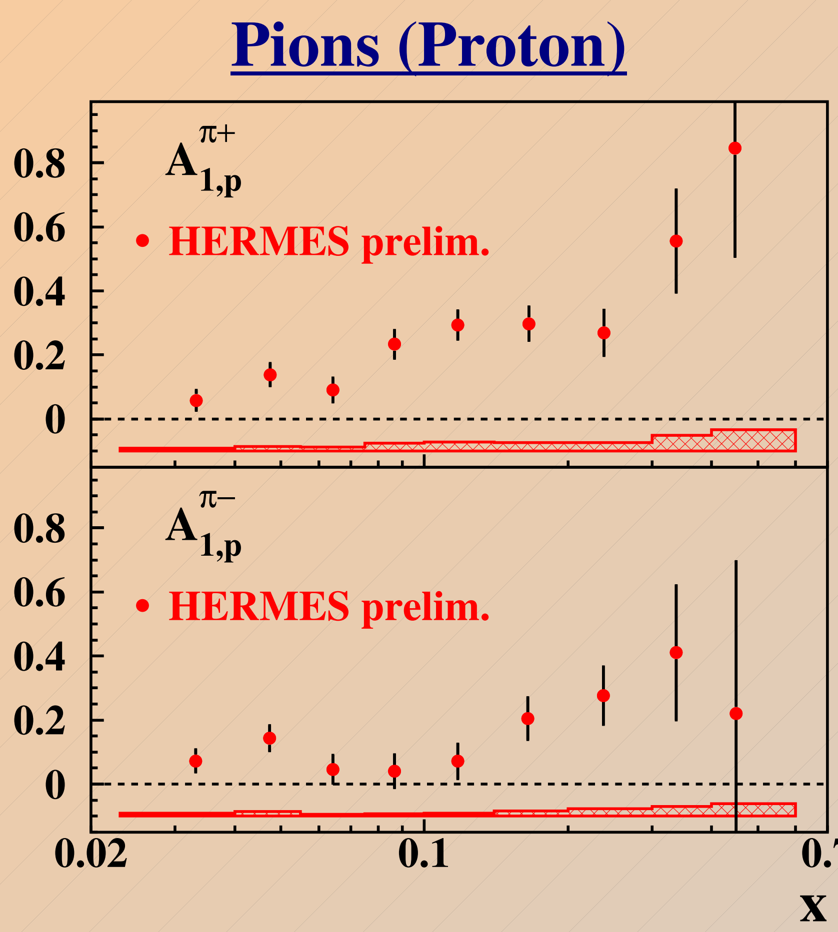
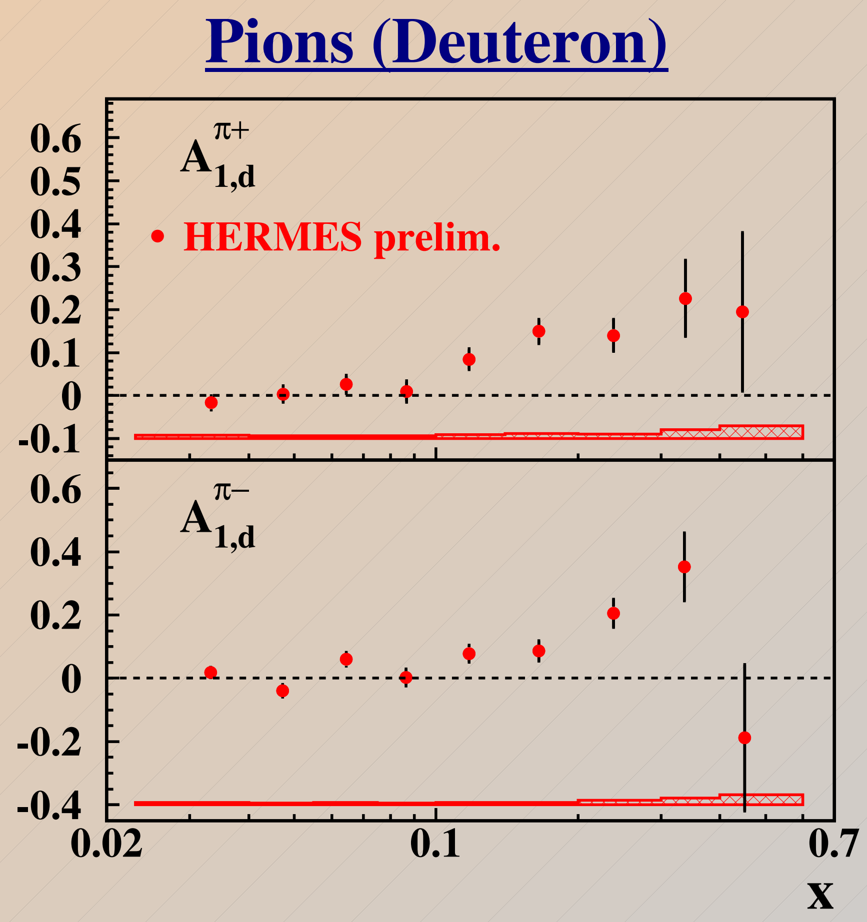
Hadrons (Deuteron)



Proton data: Revised analysis with unfolding and new target polarization value 0.82±0.05 (cf. 0.86±0.05 in HERMES Coll., PL B464 (1999))

The SEMI-INCLUSIVE Asymmetries





$4 < p_\pi < 13.8$ GeV

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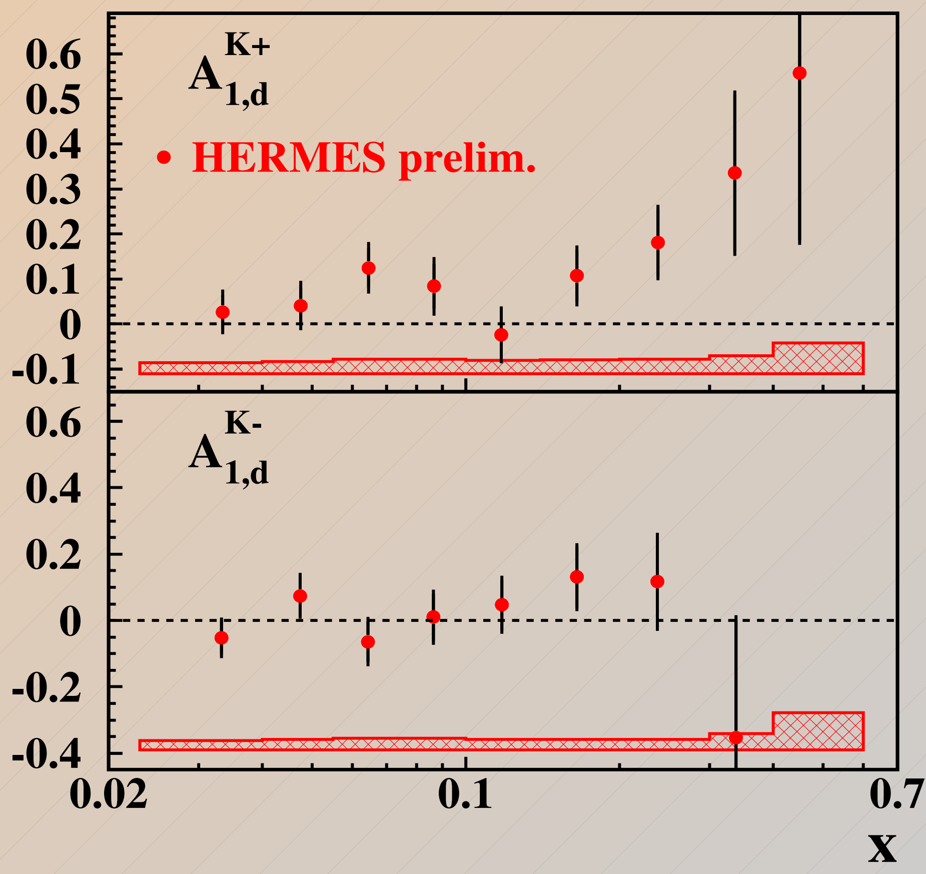
The Semi-Inclusive Asymmetries

First measurement of semiinclusive Kaon Asymmetries !

- K^+–Asymmetry positive
  ➔ dominated by u–quark?
- K^-–Asymmetry ≈ 0
  ➔ K^-= sea–object!

$4 < p_K < 13.8$ GeV

Kaons(Deuteron)



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Asymmetries And Purities

A_1^h revisited:

$$A_1^h(x_i) = C_i \cdot \sum_q \underbrace{\frac{e_q^2\, q(x_i, Q_i^2) \int_{z_{min}}^{z_{max}} dz\, D_q^h(z, Q_i^2)}{\sum_q e_q^2\, q(x_i, Q_i^2) \int_{z_{min}}^{z_{max}} dz\, D_q^h(z, Q_i^2)}}_{\equiv P_q^h(x_i)} \frac{\Delta q(x_i, Q_i^2)}{q(x_i, Q_i^2)}$$

where $Q_i^2 = \langle Q^2(x_i) \rangle$.

Solve:

$$\begin{pmatrix} A_1^{h_1}(x) \\ \vdots \\ A_1^{h^m}(x) \end{pmatrix} = C \cdot \begin{bmatrix} P_{q_1}^{h_1}(x) & \dots & P_{q_n}^{h_1}(x) \\ \vdots & \ddots & \vdots \\ P_{q_1}^{h^m}(x) & \dots & P_{q_n}^{h^m}(x) \end{bmatrix} \begin{pmatrix} \frac{\Delta q_1(x)}{q_1(x)} \\ \vdots \\ \frac{\Delta q_n(x)}{q_n(x)} \end{pmatrix}$$

$$\vec{A} = C \cdot P\vec{Q}$$

To get $\vec{Q} = \left(\frac{\Delta u}{u}, \frac{\Delta d}{d}, \frac{\Delta \bar{u}}{\bar{u}}, \frac{\Delta \bar{d}}{\bar{d}}, \frac{\Delta s + \Delta \bar{s}}{s + \bar{s}} \right)$

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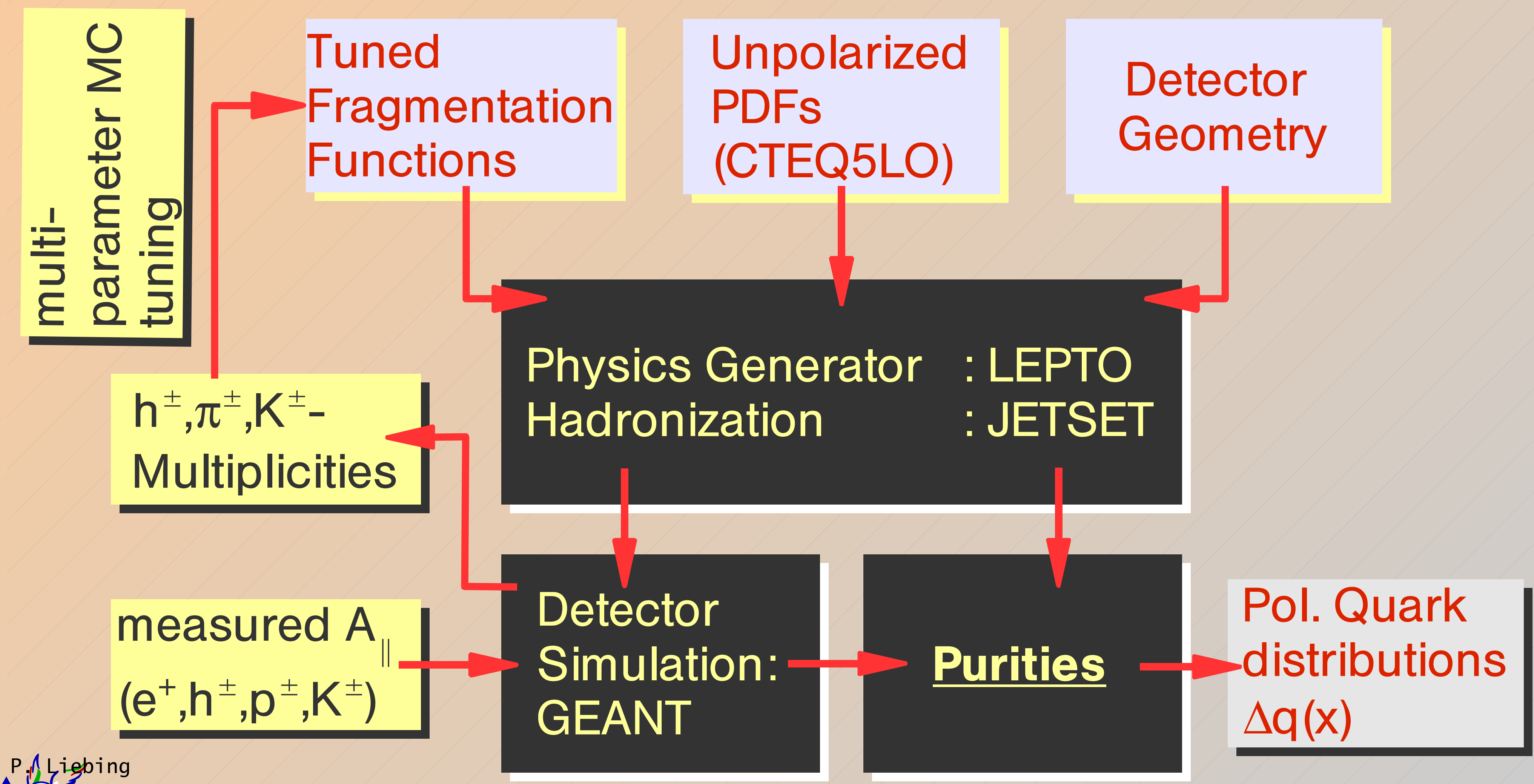
MONTE CARLO TUNING



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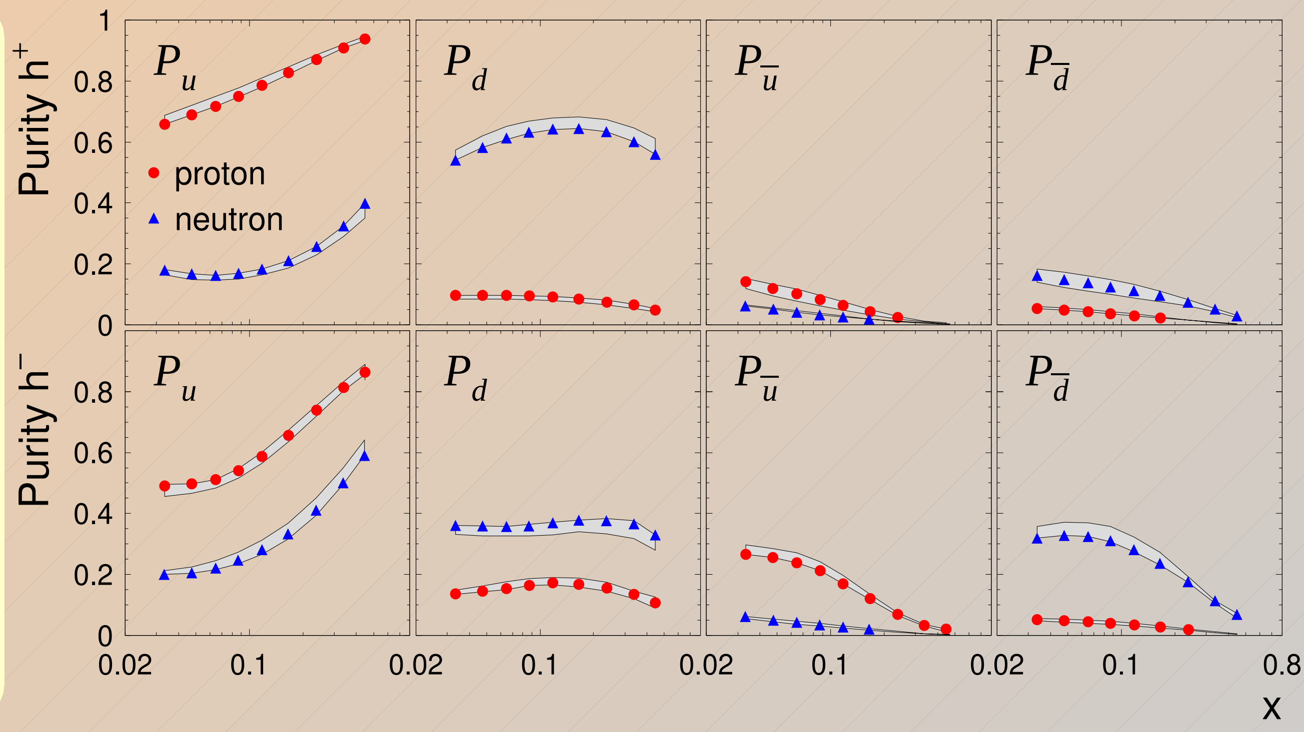
EXTRACTED PURITIES

Charged Hadron Purities for Proton and Neutron

- $h^{\pm}$–Asymmetries on proton dominated by Δu
- $h^{\pm}$–Asymmetries on neutron sensitive to Δd
- Sensitivity to $\Delta\bar{u}$ and $\Delta\bar{d}$ $\geq 20\%$ for $x < 0.2$

➔ Only combined data from p and n (d) can give information on quark sea.



Systematic errors estimated by varying fragmentation parameters and changing PDFs to GRV98LO

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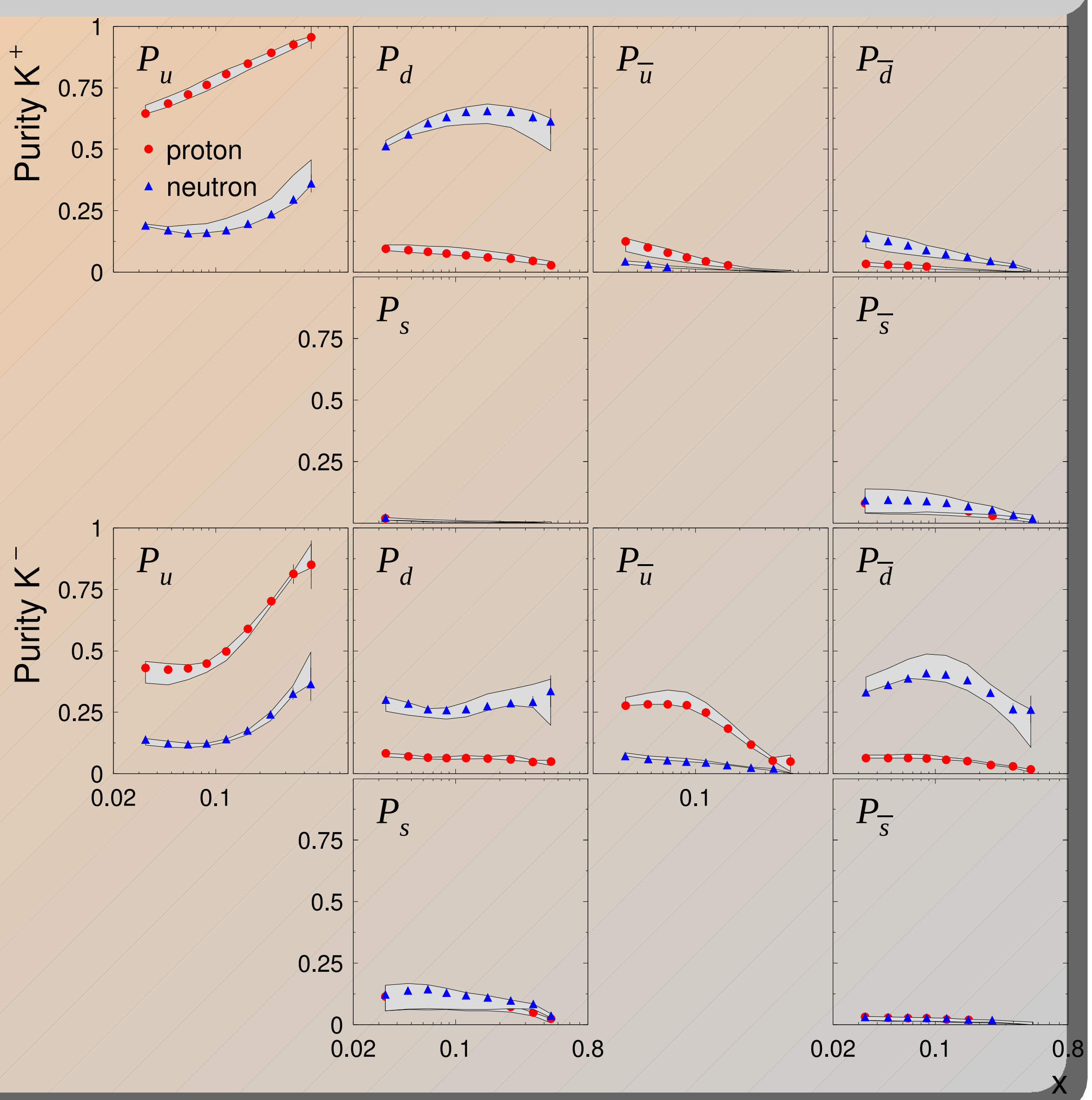
Extracted Purities

Charged Kaon Purities

- Kaon Asymmetries show ≈ 10% sensitivity to Δs, $\Delta\bar{s}$ for x<0.2
- Large systematic errors due to uncertainties in the fragmentation model and in the unpolarized parton distributions
- $\delta s(x) \approx 100\%$

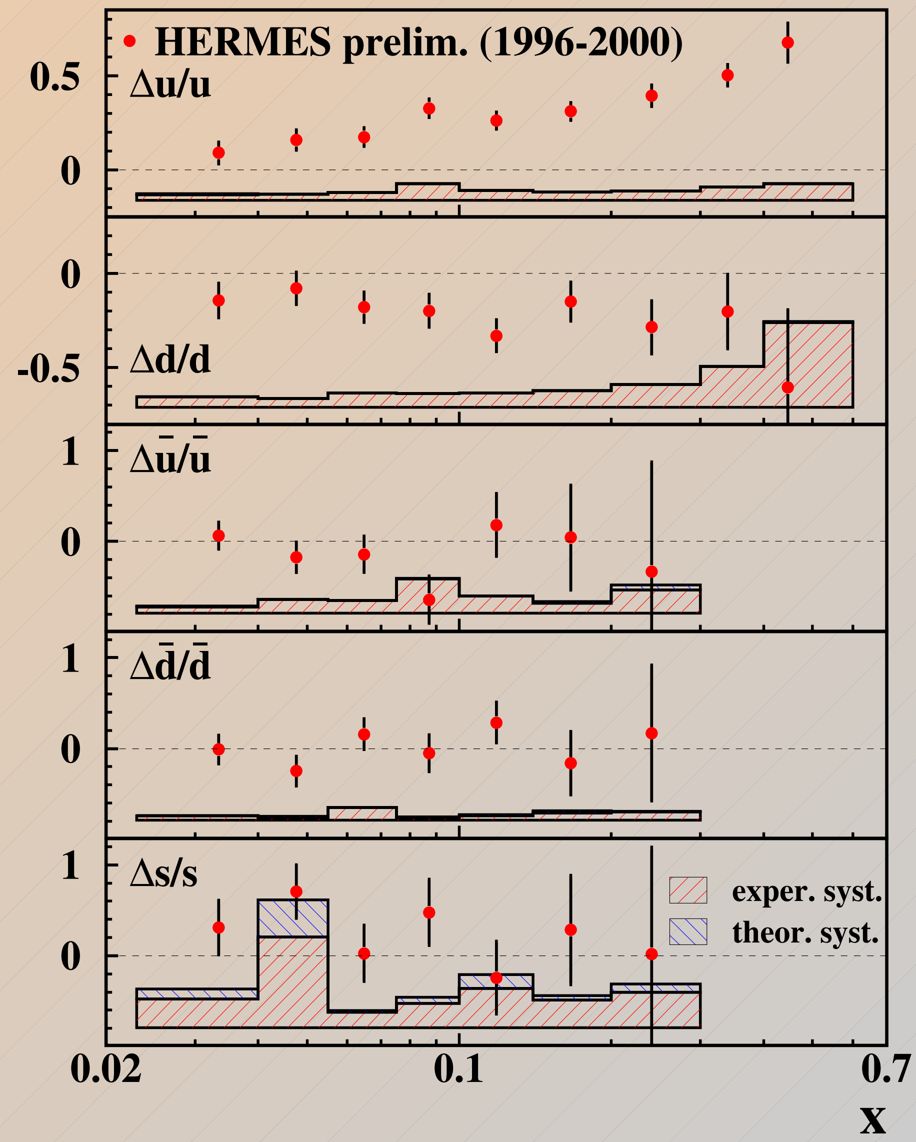


Quark Polarizations

Symmetry assumption used:

$$\frac{\Delta s}{s} = \frac{\Delta \bar{s}}{\bar{s}}$$

- u quark polarized parallel, d quark polarized antiparallel to the nucleon spin
- light sea quark polarization ≈ 0
- Systematic uncertainty for the sea flavors dominated by the theoretical uncertainties.



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Polarized Quark Distributions

x–weighted polarized Quark Densities

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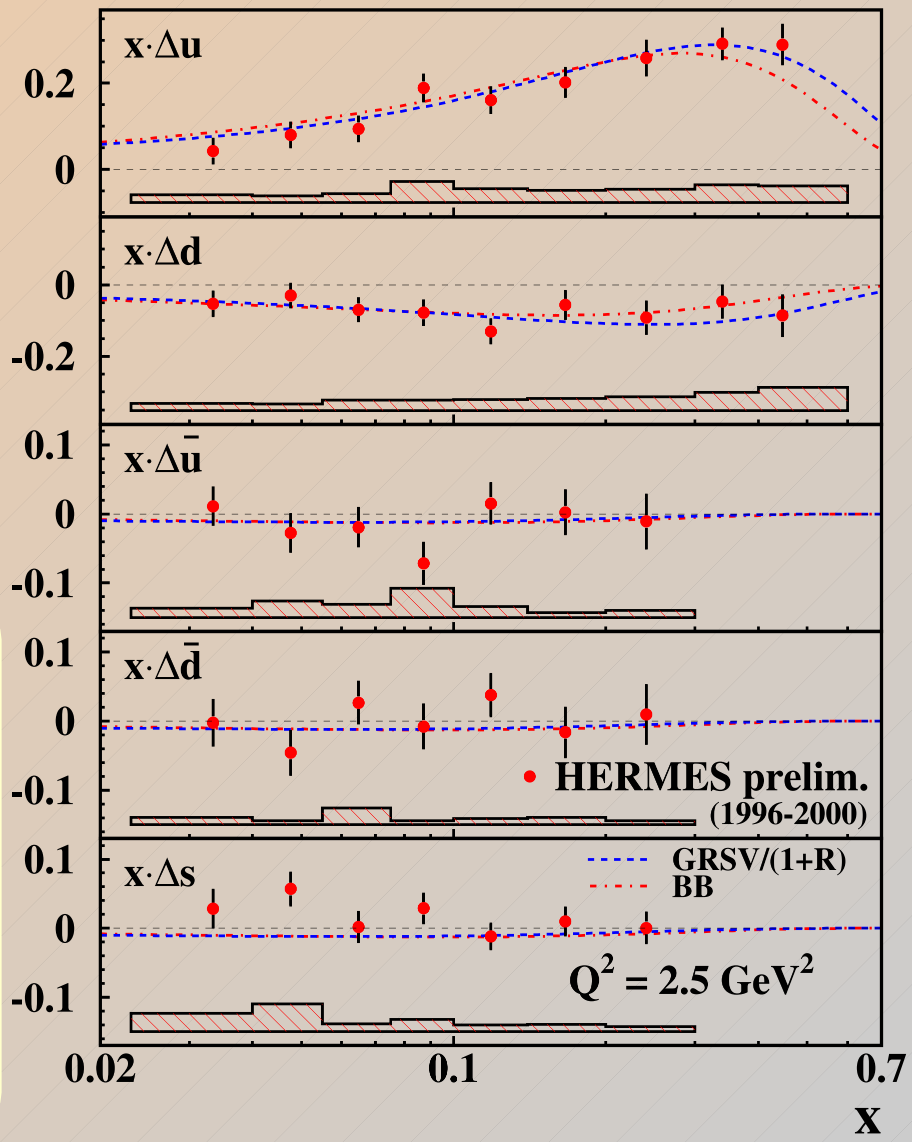
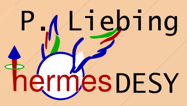
$$\Delta q(x_i, Q^2 = 2.5\ \mathrm{GeV}^2) = \underbrace{\frac{\Delta q(x_i, Q_i^2)}{q(x_i, Q_i^2)}}_{\text{HERMES data}} \cdot \underbrace{q(x_i, Q^2 = 2.5\ \mathrm{GeV}^2)}_{\text{CTEQ5LO}}$$

- Theoretical curves from
  - ➔GRSV(Phys. Rev. D53 (1996) 4775, 'standard' scenario,leading order)
  - ➔Blümlein–Böttcher(hep–ph/0203155, leading order – Scenario 1)
- No negative strange sea!!



A?-Symmetry of the Light Polarized Sea

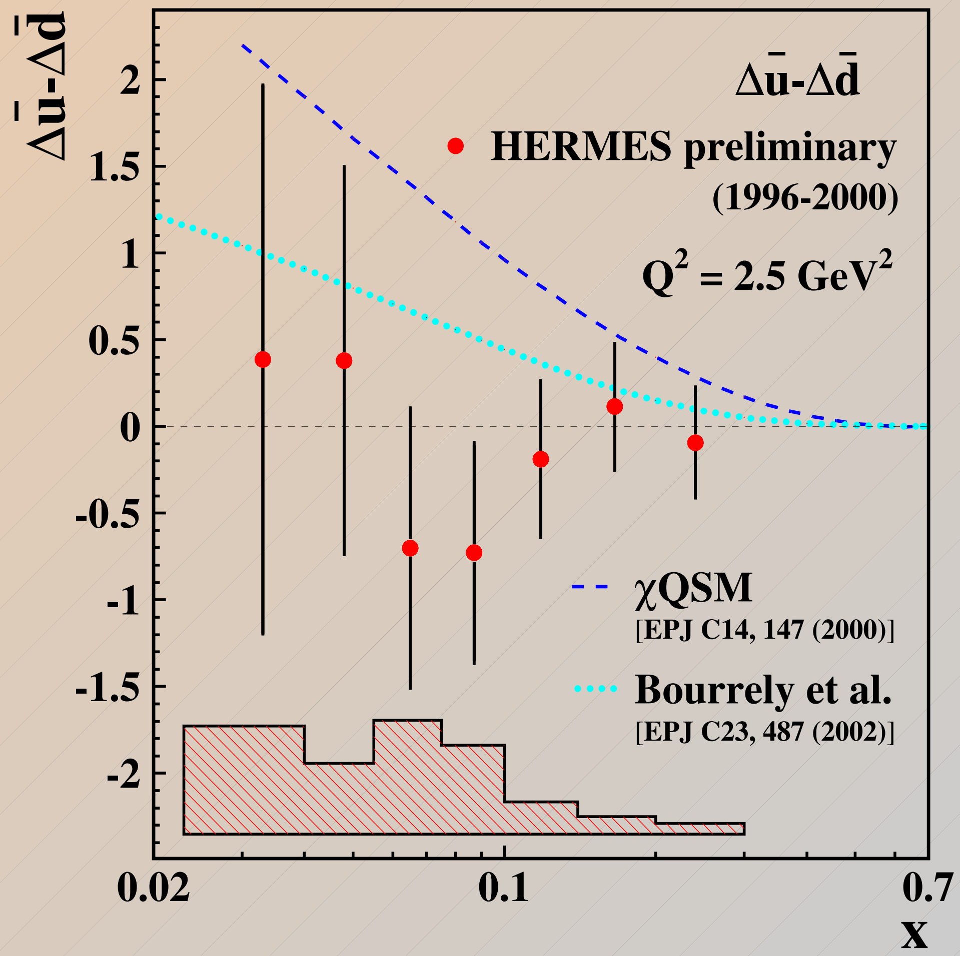
$$\Delta\bar{u} - \Delta\bar{d}$$



- A variety of models for SU(3)–breaking

  $$\Delta\bar{u} \neq \Delta\bar{d} \neq \Delta s$$

  exists, e.g.:
  - ➔Chiral Quark Soliton model (Dressler et. al., EPJC14(2000) 147)
  - ➔Statistical model (Bourrely et al., EPJC23(2002)479)
- Data show no significant breaking of the light sea symmetry
  - ➔χQSM model not favoured



A?-Symmetry Of The Light Polarized Sea

$$\Delta\bar{u} - \Delta\bar{d}$$

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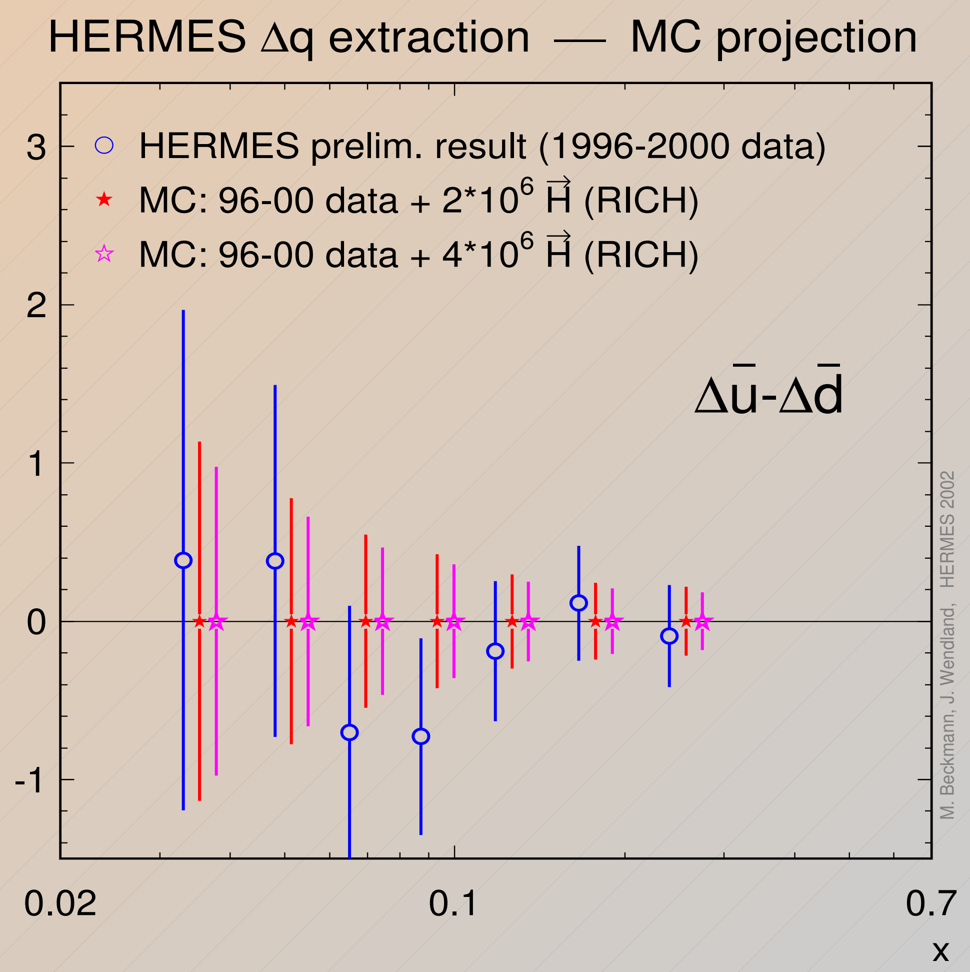
Statistical projection for

$$\Delta\bar{u} - \Delta\bar{d}$$

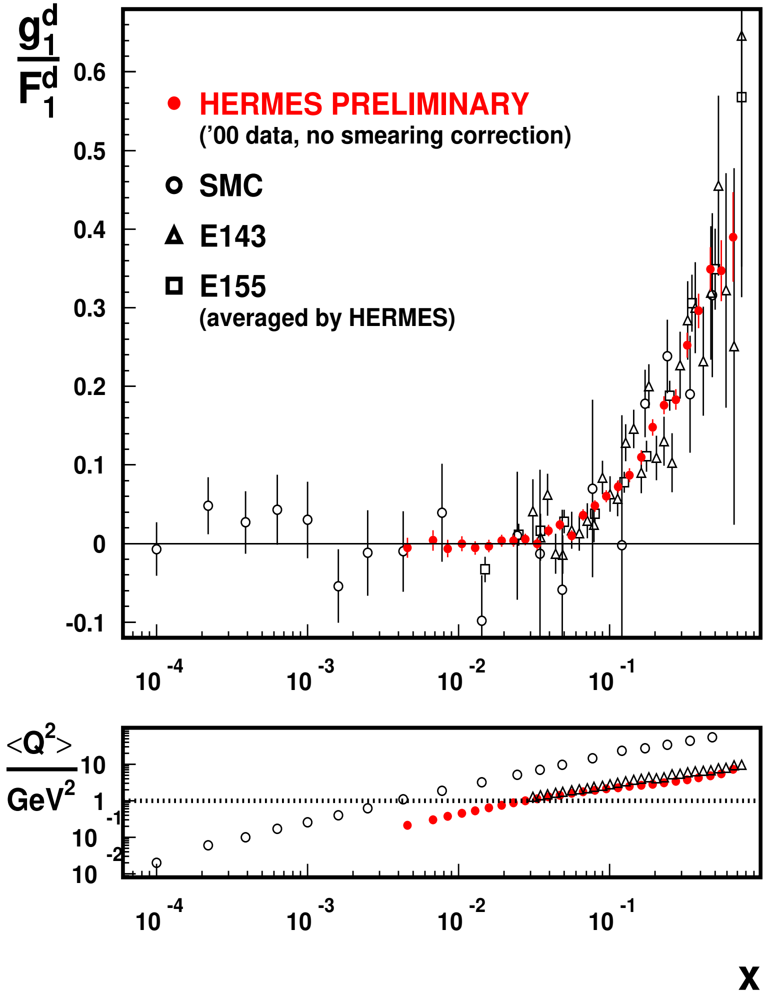
using the collected data from 1996–2000 and
assuming additional running with a longitudially polarized H–target during HERMES run II.



Conclusions and Outlook

- New high precision data on g_1^d with low–x_{Bj} points
- Extraction of polarized quark distributions from a LO QCD analysis
  - identified $\pi^{\pm}$ and $K^{\pm}$ used for the first time
  - consistent results with published data, largely improved precision
- First 'direct' extraction of light sea quark polarizations without symmetry assumptions (except $\Delta s = \Delta \bar{s}$)
- First results on strange sea polarization
  - first moment of Δs slightly positive
- First results on $\Delta \bar{u} - \Delta \bar{d}$
  - no significant asymmetry observed
- To do list: Constrain unpolarized input using HERMES data and improved MC models

INCLUSIVE ASYMMETRIES AND G$_1$



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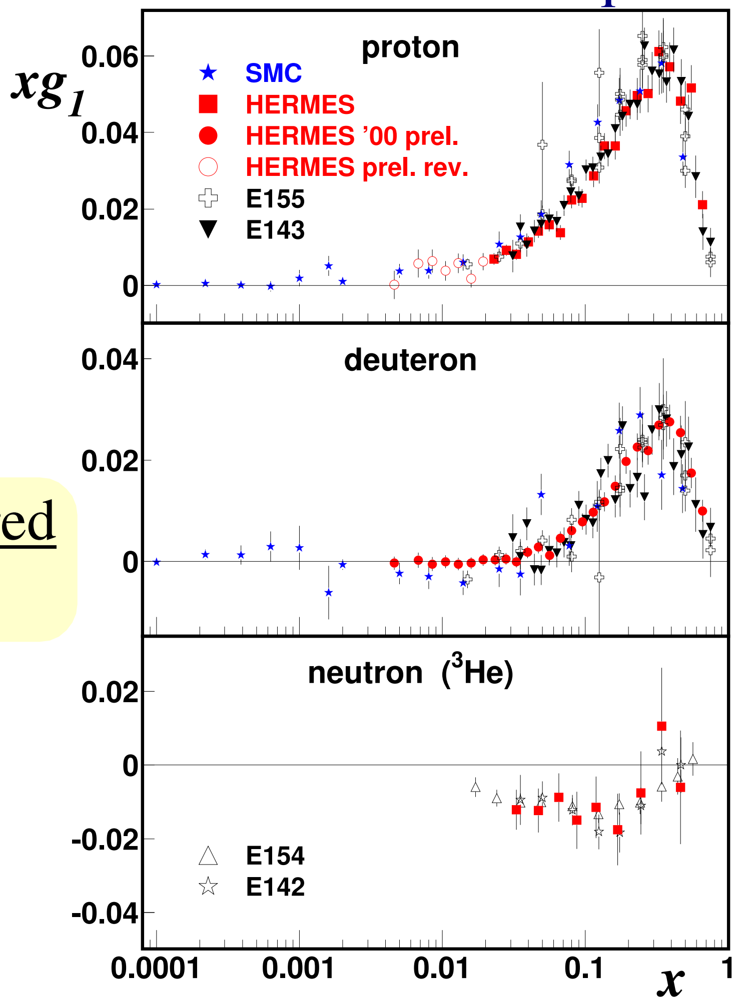

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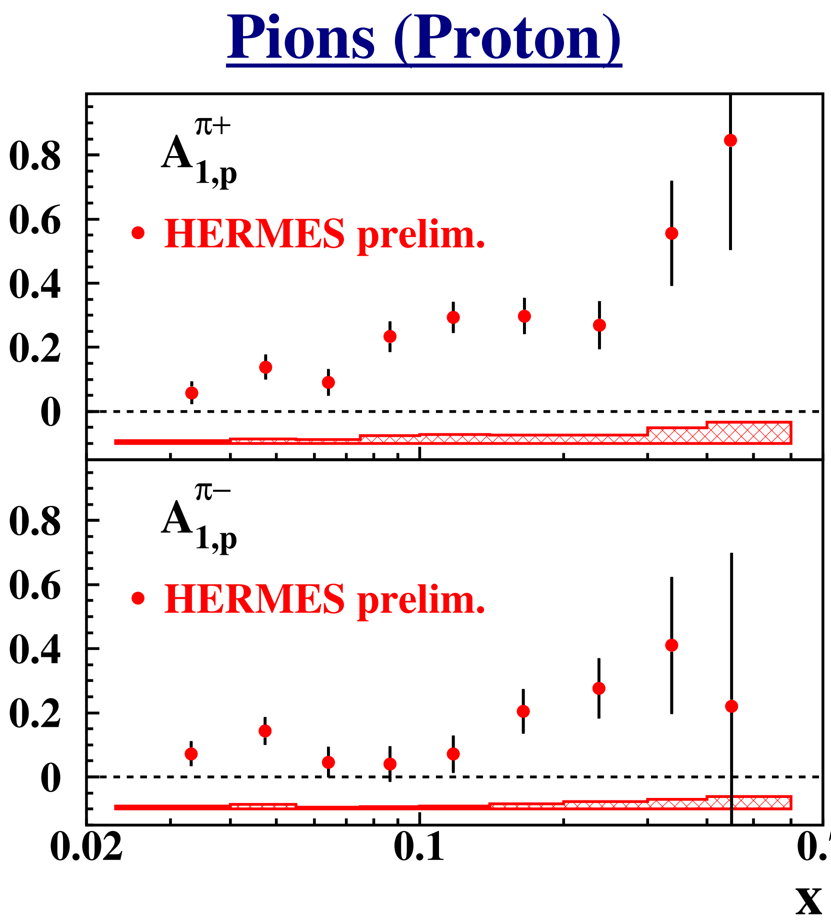

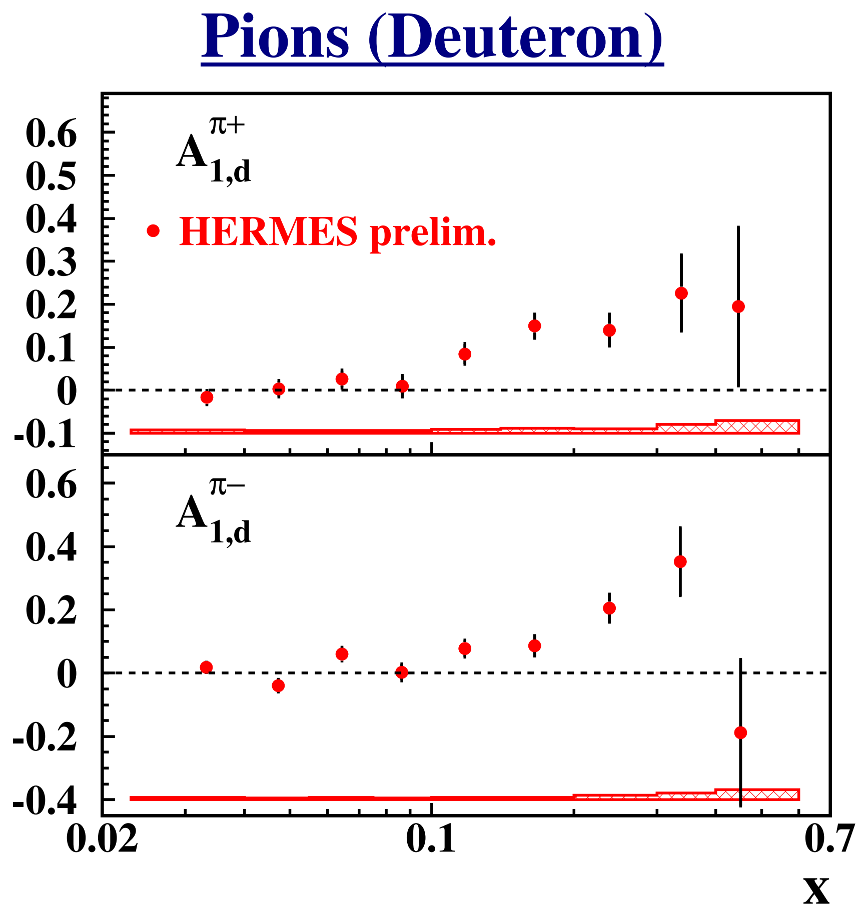

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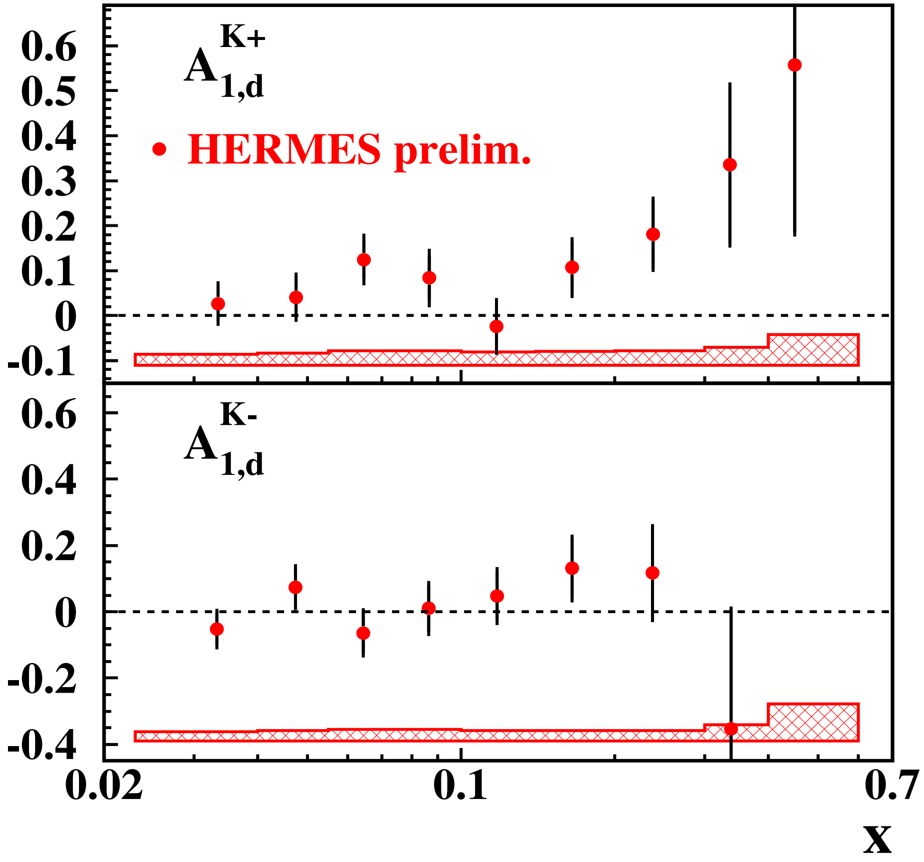

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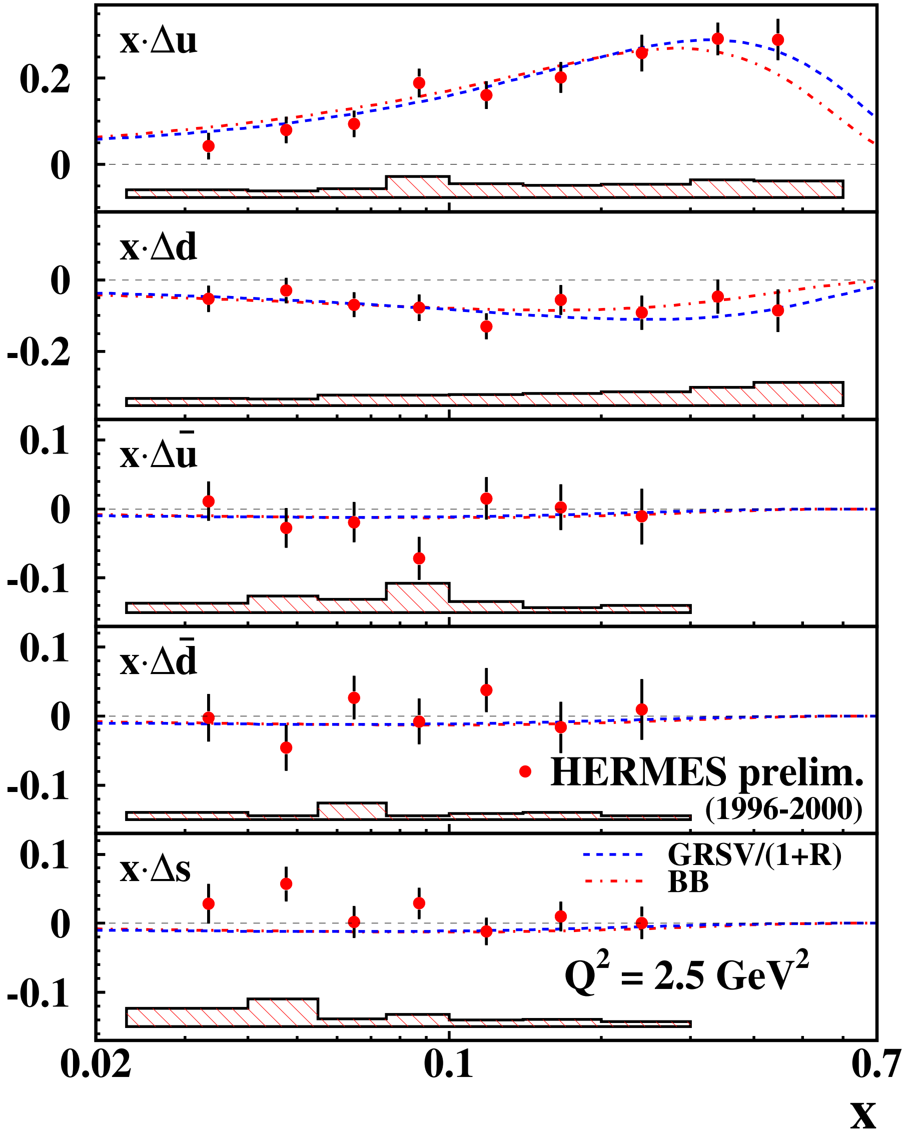

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$\Delta\bar{u} - \Delta\bar{d}$