Polarized Parton Distributions Measured at the hermes Experiment

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- Polarized Deep-Inelastic Scattering
- The HERMES Experiment at HERA
- Asymmetry Measurements
- Polarized Parton Distributions
- The Spin Carried by the Quark Spins

The Proton Spin Crisis

- Relativistic quark models:

$$\Delta\Sigma = \Delta u_v + \Delta d_v + \Delta q_s \approx 0.6$$

- First measurements by EMC in 1988 found

$$\Delta\Sigma = 0.006 \pm 0.058 \pm 0.117$$

$\Rightarrow$ "PROTON SPIN CRISIS"

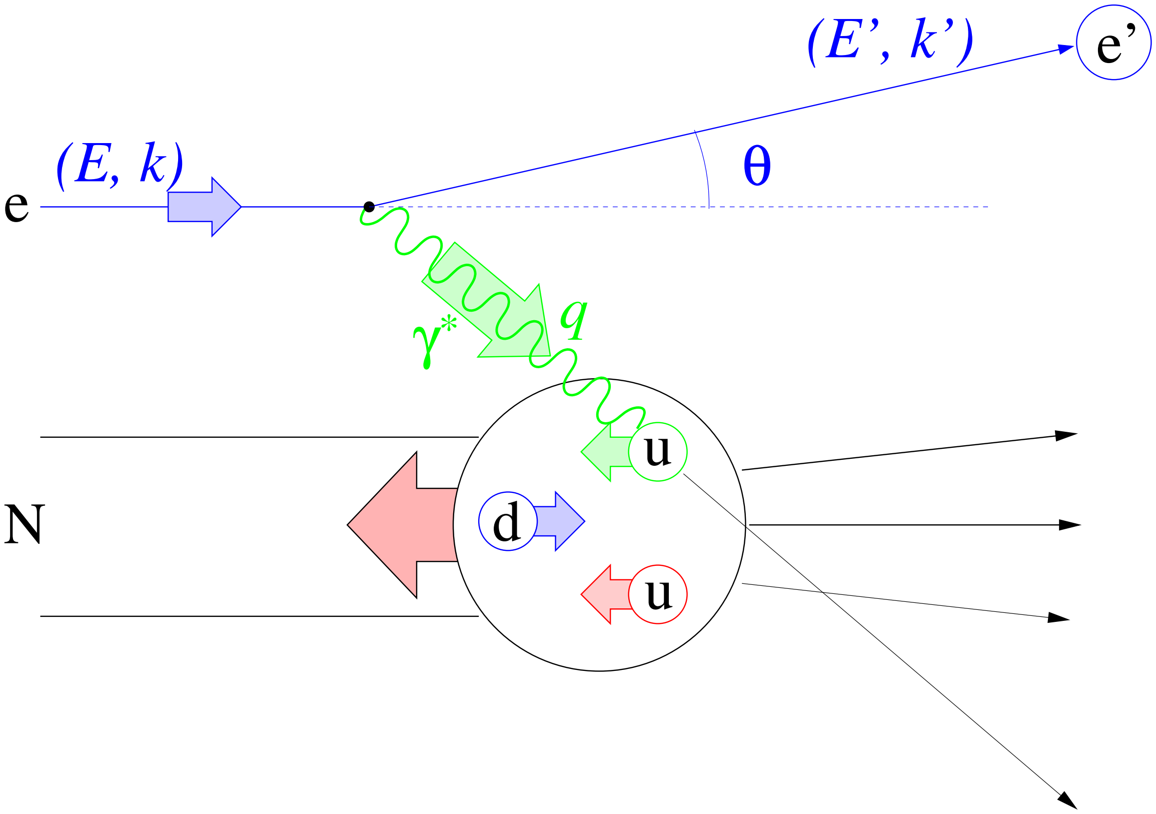
- More recently:

$$\Delta\Sigma = 0.23 \pm 0.04 \pm 0.06 \quad \text{(E155 in 2000)}$$
$$\Delta\Sigma = 0.167 \pm 0.169 \pm 0.150 \quad \text{(HERMES in 2003)}$$

- Spin carried by quark, gluon spins, and their orb. ang. momenta:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_q + (\Delta G + L_g)$$

Polarized Deep-Inelastic Scattering



Inclusive DIS:

$$e + N \to e' + X$$

$$\rightsquigarrow \Delta\Sigma = \sum_q \Delta q$$

$$x \stackrel{\text{lab}}{=} Q^2/(2M(E - E'))$$

$$Q^2 \stackrel{\text{lab}}{=} 4EE' \sin^2(\theta/2)$$

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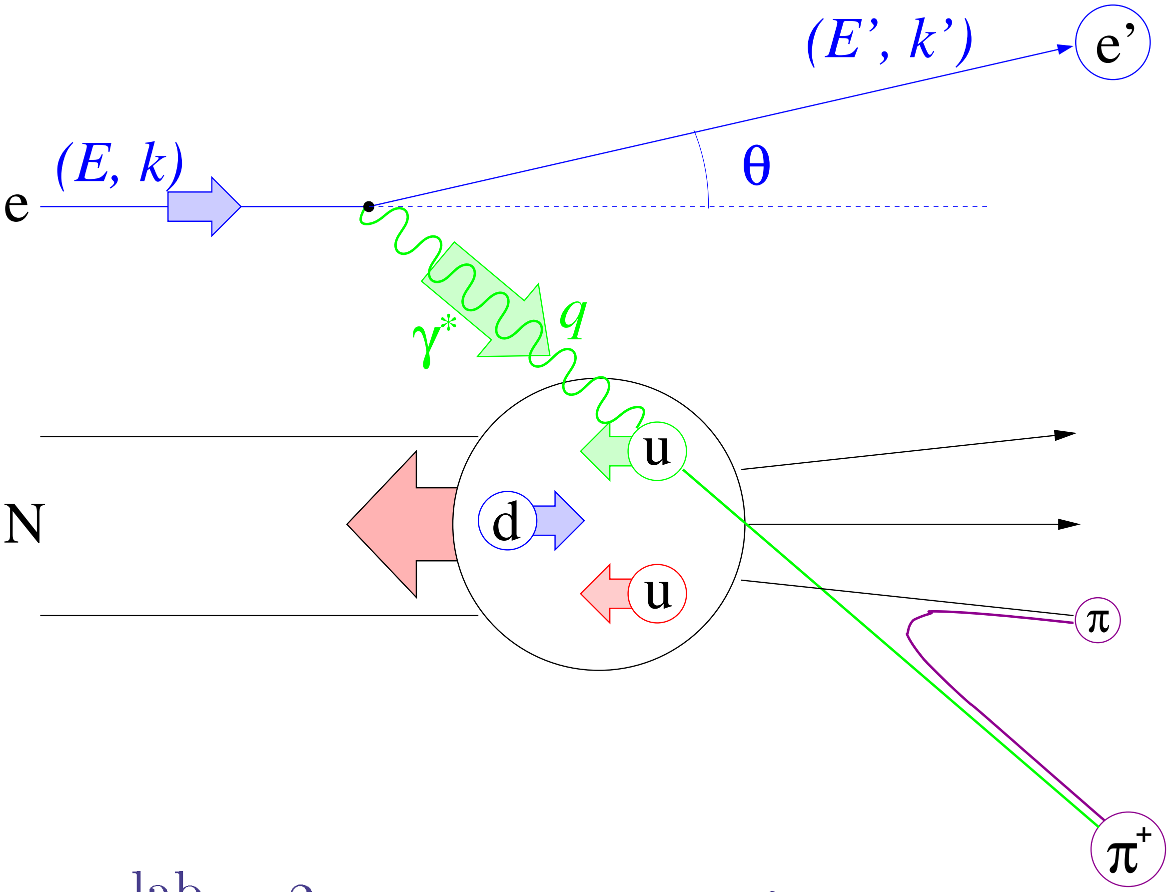


Inclusive DIS:

$$e + N \rightarrow e' + X$$

$$\rightsquigarrow \Delta\Sigma = \sum_q \Delta q$$

Semi-inclusive DIS:

$$e + N \rightarrow e' + h + X$$

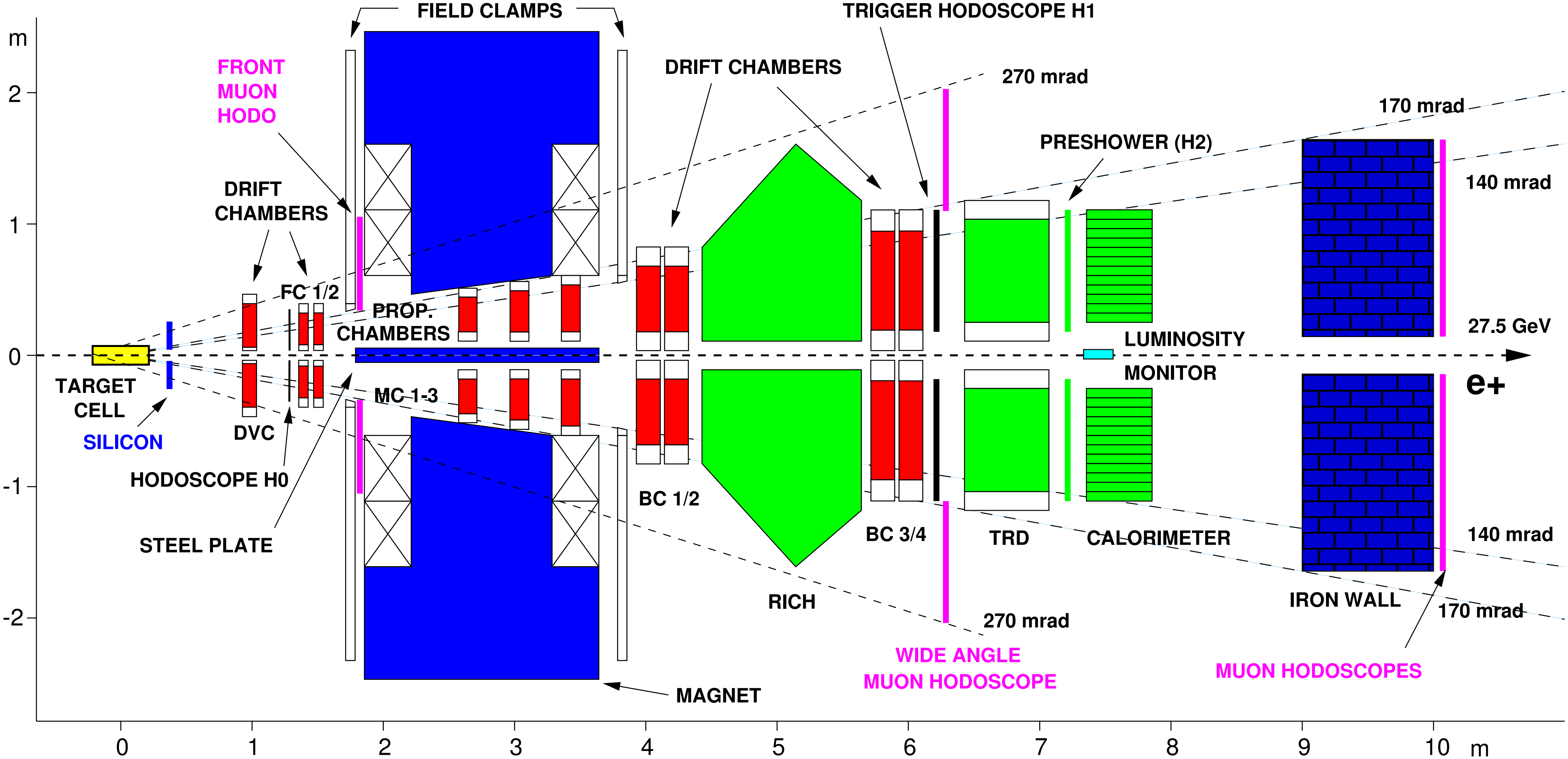
$$\rightsquigarrow \Delta u,\ \Delta\bar{u},\ \Delta d,\ \ldots$$

$$x \stackrel{\text{lab}}{=} Q^2/(2M(E - E'))$$

$$Q^2 \stackrel{\text{lab}}{=} 4EE' \sin^2(\theta/2)$$

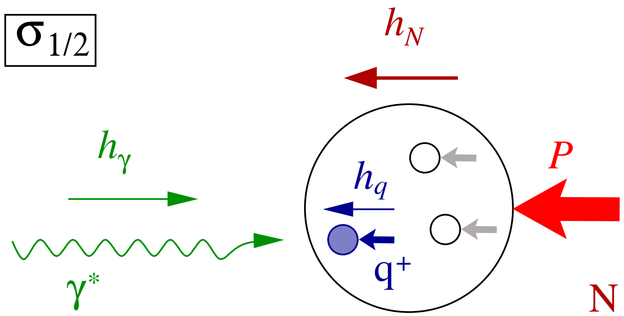
$$z \stackrel{\text{lab}}{=} E_h/(E - E')$$

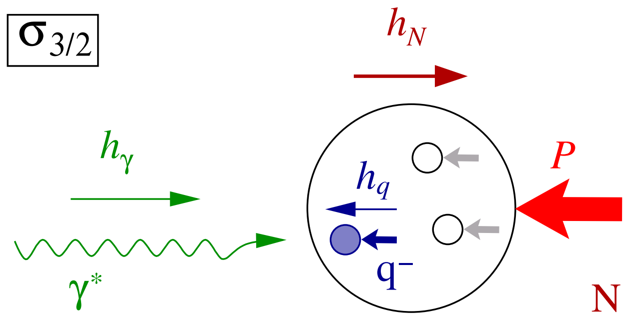
HERMES



- Large forward acceptance
- Excellent particle identification $(e^{\pm}, \pi^{\pm}, K^{\pm}, p, \bar{p})$

Cross Section Asymmetries





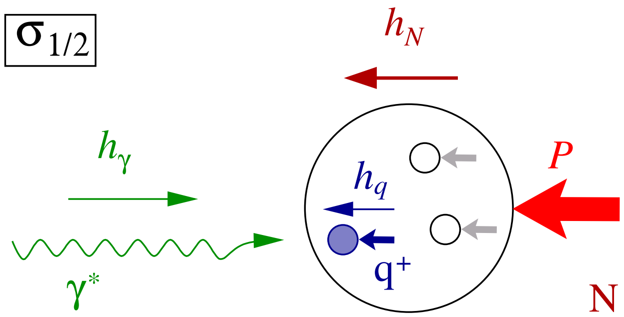
$$\Delta q \equiv q^{+} - q^{-}$$
$$q \equiv q^{+} + q^{-}$$

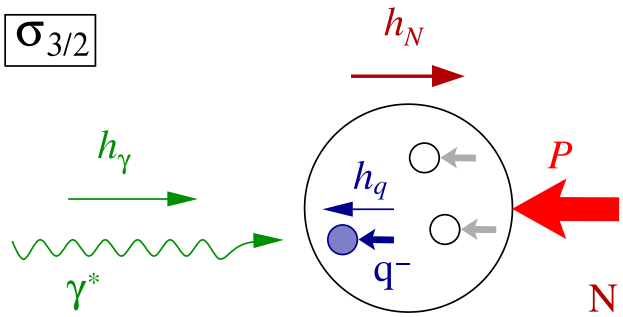
$$A_1(x,Q^2) \simeq \frac{1}{D} \underbrace{\frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}}}_{\equiv A_{||}(x,Q^2)}$$

Inclusive DIS:

$$A_1(x,Q^2) = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \overset{\text{QPM}}{=} \frac{\sum_q e_q^2\, \Delta q(x,Q^2)}{\sum_{q'} e_{q'}^2\, q'(x,Q^2)}$$

Cross Section Asymmetries





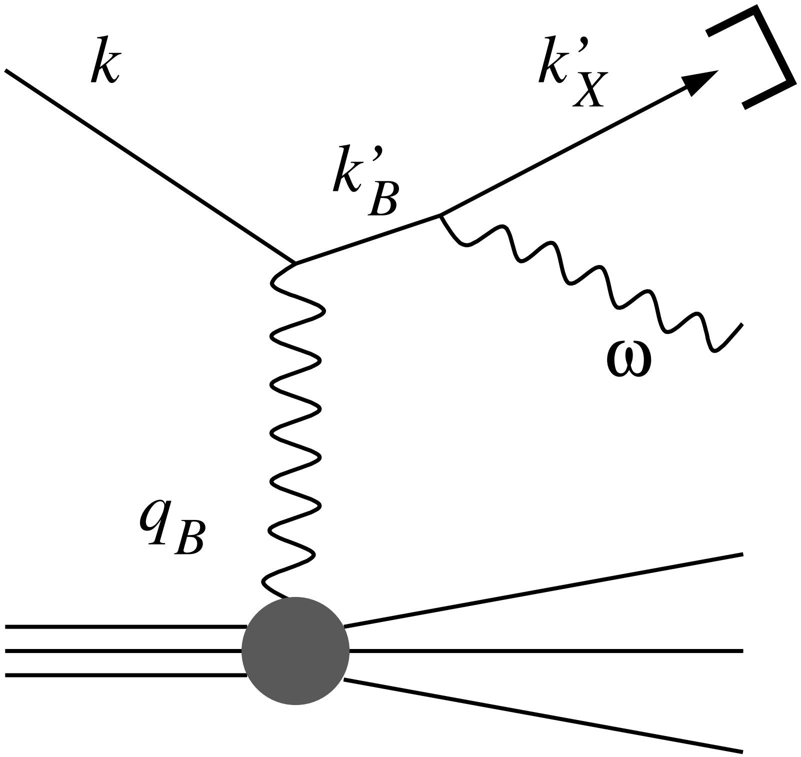
$$\Delta q \equiv q^{+} - q^{-}$$
$$q \equiv q^{+} + q^{-}$$

$$A_1^h(x,Q^2) \simeq \frac{1}{D} \underbrace{\frac{\sigma^{h\uparrow\downarrow} - \sigma^{h\uparrow\uparrow}}{\sigma^{h\uparrow\downarrow} + \sigma^{h\uparrow\uparrow}}}_{\equiv A_{||}^h(x,Q^2)}$$

Semi-Inclusive DIS:

$$A_1^h(x,Q^2) = \frac{\sigma_{1/2}^h - \sigma_{3/2}^h}{\sigma_{1/2}^h + \sigma_{3/2}^h} \overset{\text{QPM}}{=} \frac{\sum_q e_q^2 \, \Delta q(x,Q^2) \int dz \, D_q^h(z,Q^2)}{\sum_{q'} e_{q'}^2 \, q'(x,Q^2) \int dz \, D_{q'}^h(z,Q^2)}$$

Detector and QED Rad. Effects



Detector effects:

Multiple scattering . . .

higher order QED effects:

Bremsstrahlung . . .

$$x_X \neq x_B \qquad Q^2_X \neq Q^2_B$$

E.g.

Elastic scattering
can appear to be DIS

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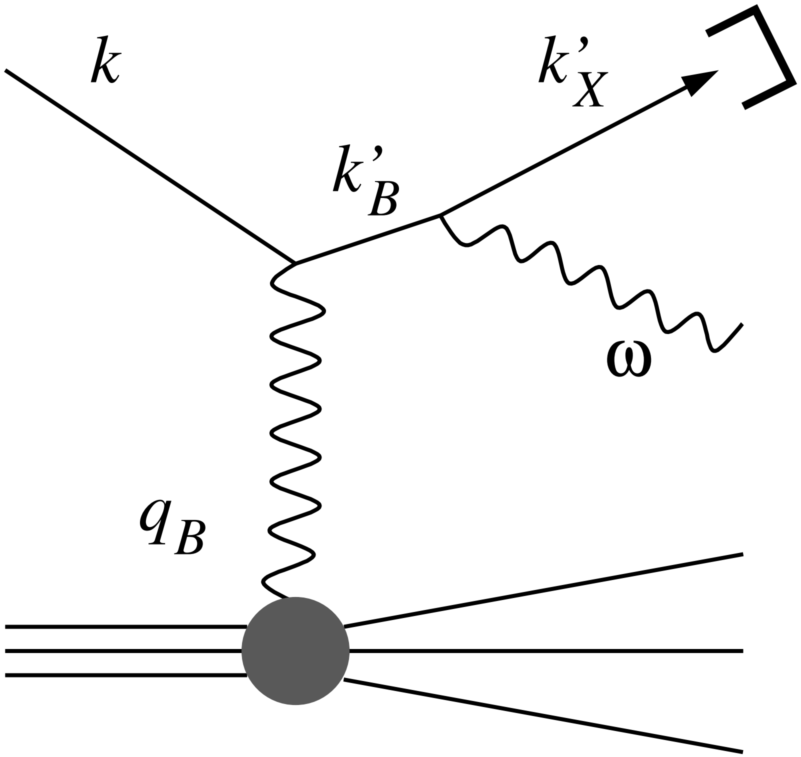

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Elastic scattering can appear to be DIS

Simulate effects in Monte Carlo that keeps track of measured and of Born kinematics.

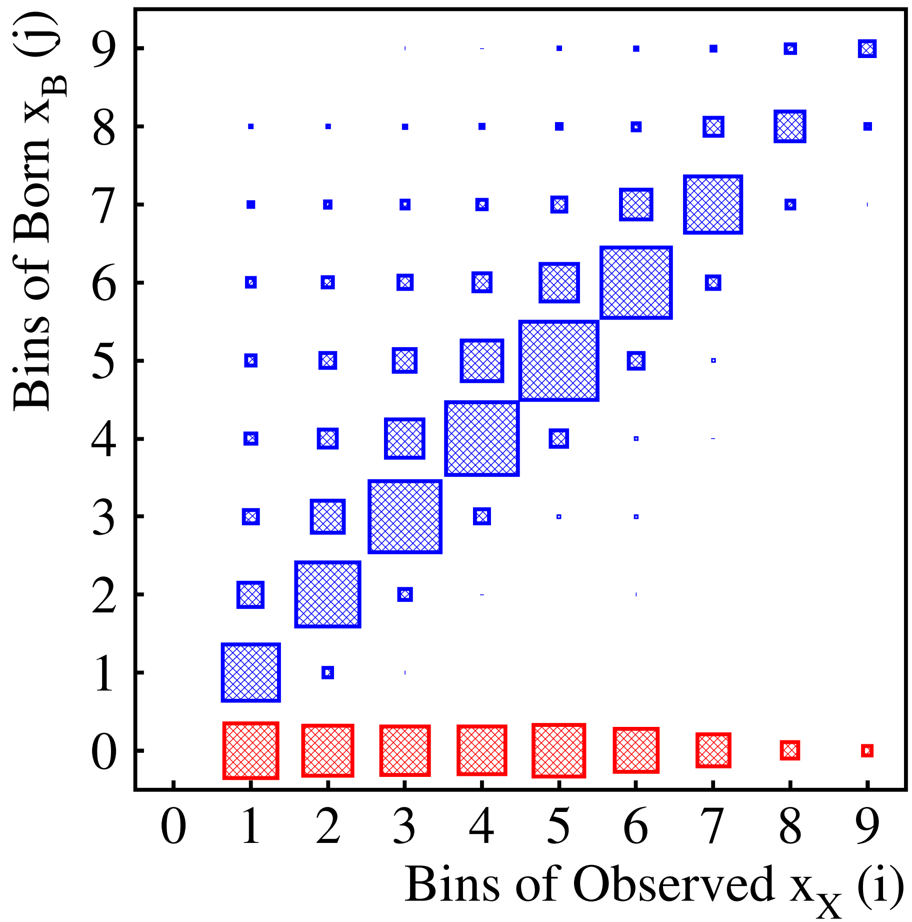
Unfolding Kinematic Migration

From the MC data in bins of x:

- Compute matrices $n_\pm(i,j)$
  - $i\ldots$ measured kinematics
  - $j\ldots$ Born kinematics
- Form

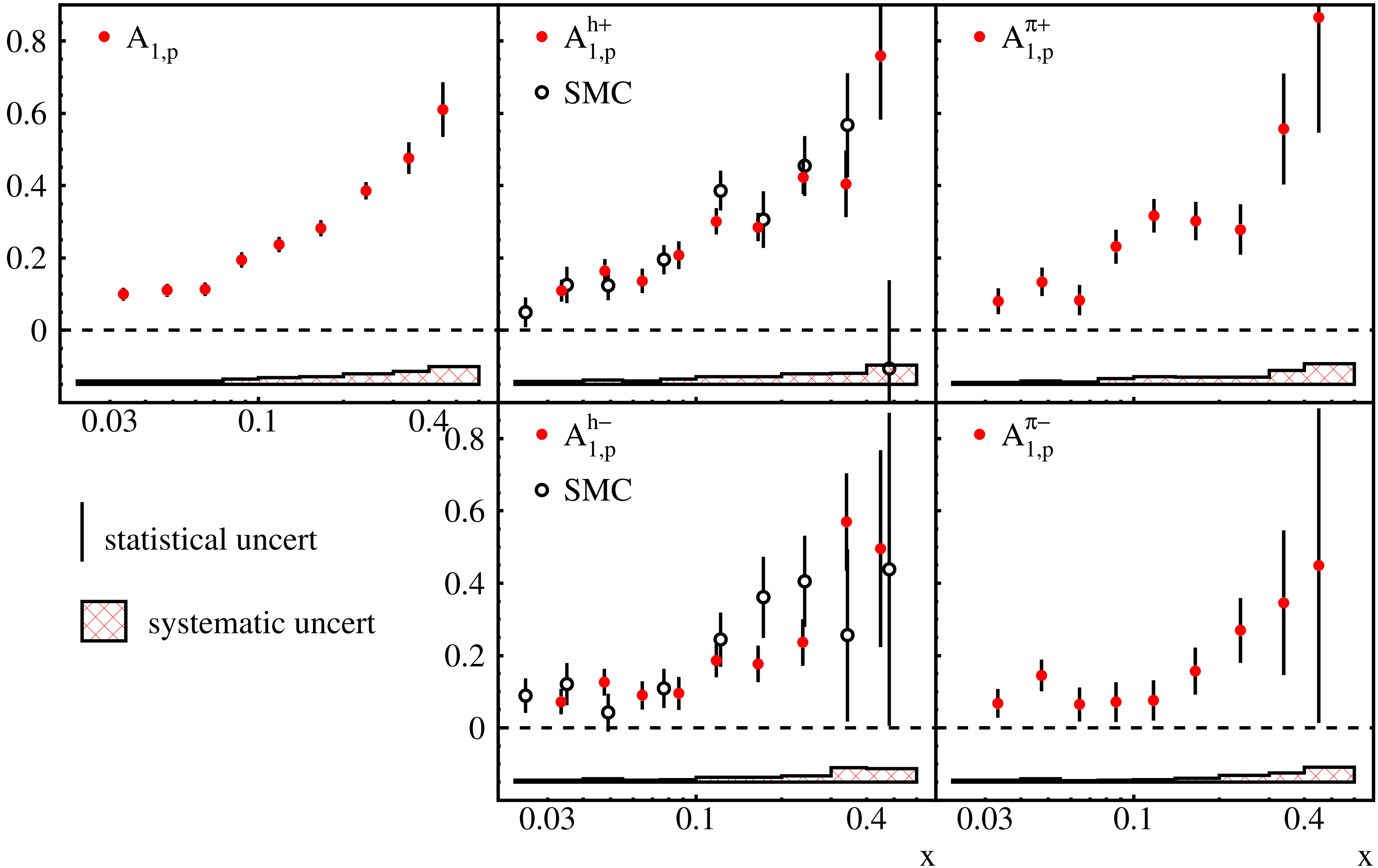
$$\mathcal{S}_\pm(i,j) \equiv \frac{\partial\sigma_\pm^X(i)}{\partial\sigma_\pm^B(j)} = \frac{n_\pm(i,j)}{n_\pm^B(j)}$$

Inclusive migration matrix

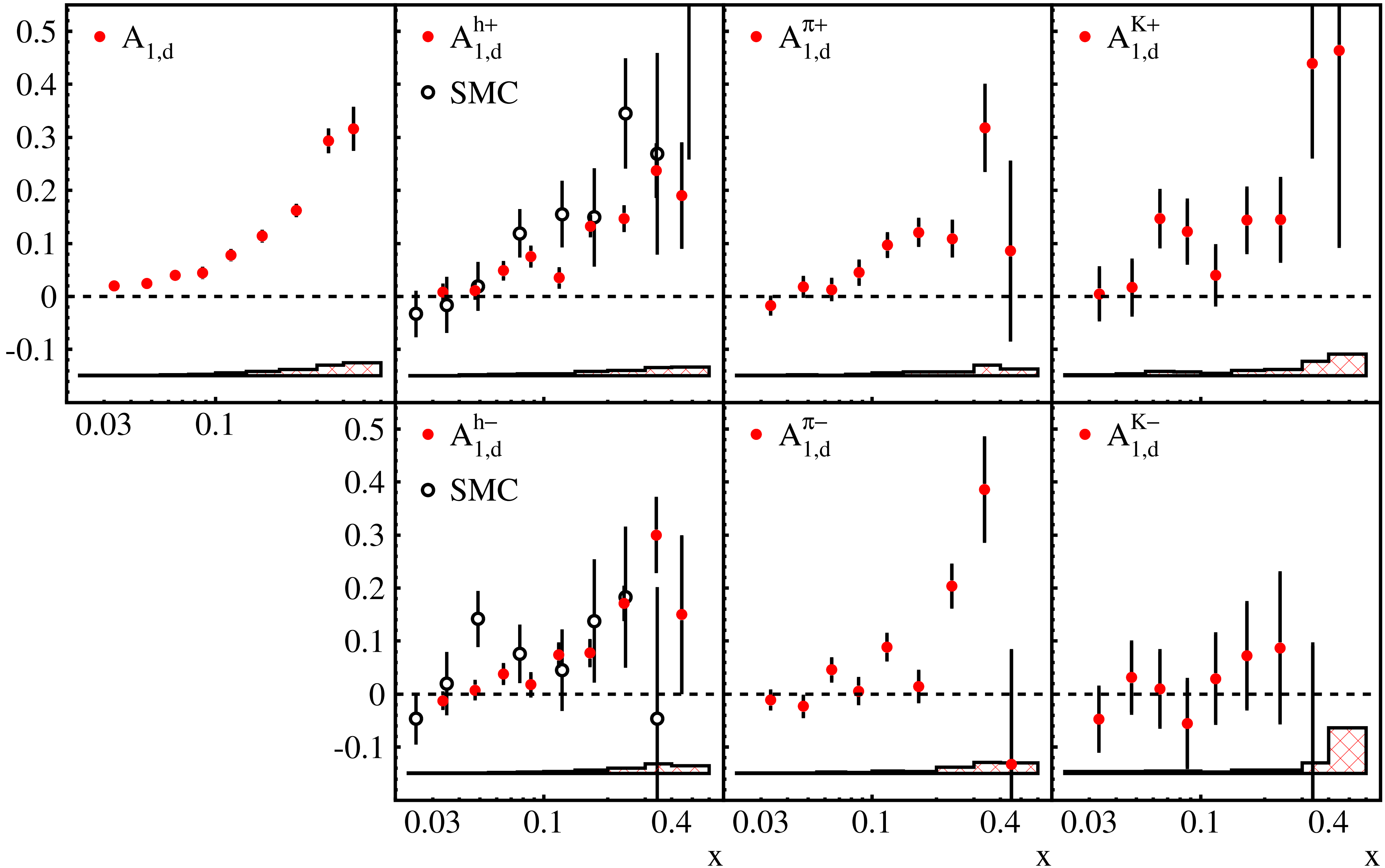


$$A_\parallel^B(j) = -1 + \sum_{i=1}^{N_X} \frac{2\,\mathcal{S}^{-1}(j,i)}{n_u^B(j)} \left[A_\parallel^X(i)\, n_u^X(i) \; - n_p(i,0) + \sum_{k=1}^{N_B} \mathcal{S}_+(i,k)\, n_u^B(k) \right]$$

Born Asymmetries on the Proton



Born Asymmetries on the Deuteron



The Purity Formalism

Rewrite semi-inclusive asymmetry in QPM:

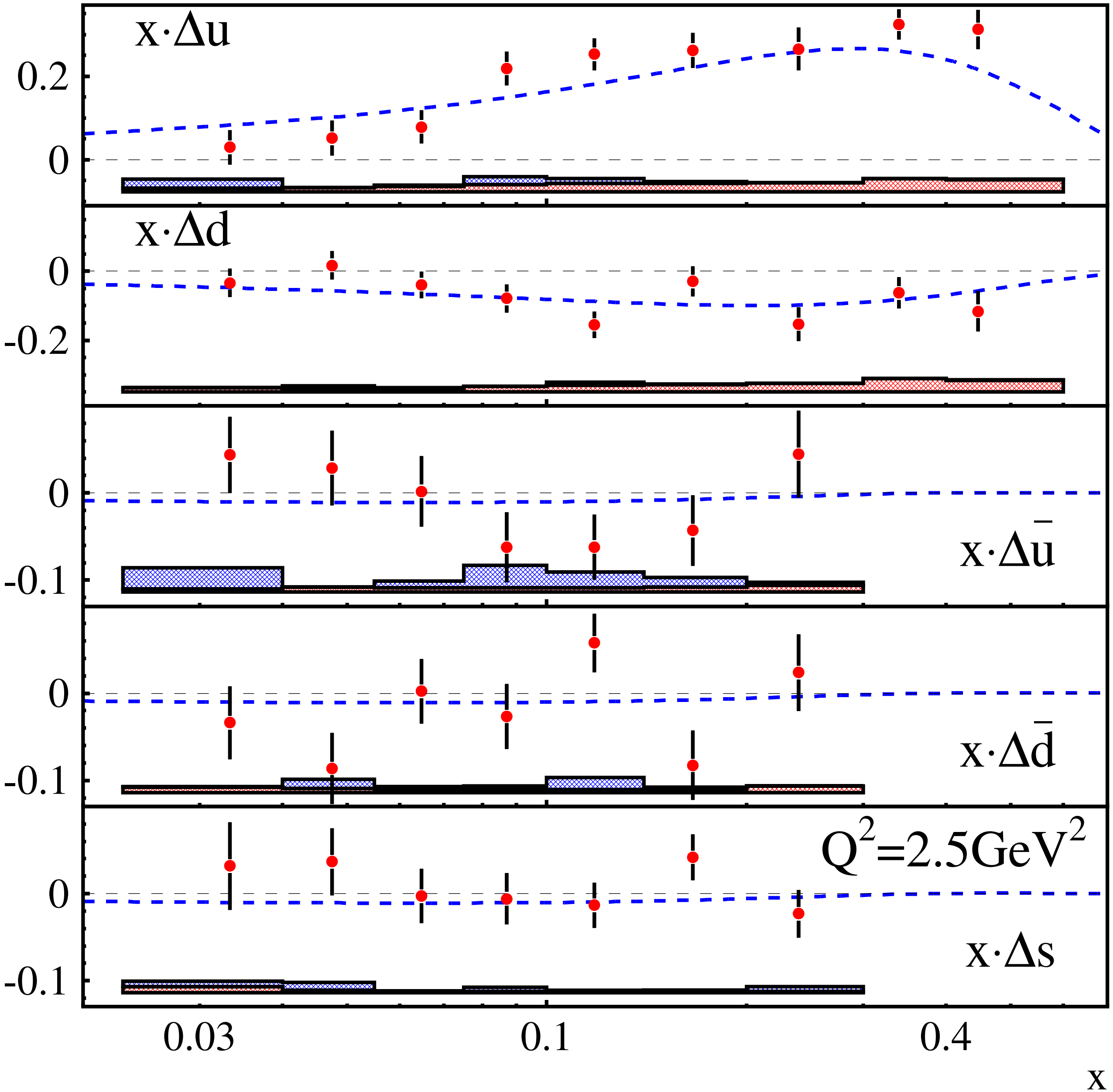
$$A_1^h(x) \simeq \frac{\sum_q e_q^2\, \Delta q(x) \int dz\, D_q^h(z)}{\sum_{q'} e_{q'}^2\, q'(x) \int dz\, D_{q'}^h(z)} = \sum_q \underbrace{\frac{e_q^2\, q(x) \int dz\, D_q^h(z)}{\sum_{q'} e_{q'}^2\, q'(x) \int dz\, D_{q'}^h(z)}}_{\equiv P_q^h(x)} \frac{\Delta q}{q}(x)$$

$P_q^h(x)$ are known from UNPOLARIZED MC

Combine inclusive and semi-inclusive asymmetries and fit for quark polarizations $(\Delta q/q)(x)$,

$\rightsquigarrow \Delta u(x),\ \Delta d(x),\ \Delta \bar{u}(x),\ \Delta \bar{d}(x),\ \Delta s(x)$

The Polarized Parton Densities



Assumes $\Delta\bar{s}(x) \equiv 0$

– – – GRSV2000

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The Spin Carried by the Quarks

In Measured Range:

$$\Delta q(Q_0^2 = 2.5\,\mathrm{GeV}^2) = \int_{0.023}^{0.6} dx\, \Delta q(x, Q_0^2 = 2.5\,\mathrm{GeV}^2)$$

$$\Delta u(Q_0^2) = 0.601 \pm 0.039 \pm 0.049 \qquad \Delta d(Q_0^2) = -0.226 \pm 0.039 \pm 0.050$$

$$\Delta \bar{u}(Q_0^2) = 0.002 \pm 0.036 \pm 0.023 \qquad \Delta \bar{d}(Q_0^2) = -0.054 \pm 0.033 \pm 0.011$$

$$\Delta s(Q_0^2) = 0.028 \pm 0.033 \pm 0.009$$

$$\Delta\Sigma(Q_0^2) = \sum_q \Delta q(Q_0^2) = 0.347 \pm 0.024 \pm 0.066$$

Summary

- (Semi-)inclusive asymmetries on the proton and the deuteron
- Pion and kaon asymmetries measured for the first time
- A new algorithm to correct for QED rad. and detector effects
- $\Delta u(x, Q_0^2)$ and $\Delta d(x, Q_0^2)$ measured with high precision
- Sea polarizations decomposed for the first time:

$$\Delta \bar{u}(x, Q_0^2) \simeq 0\,, \quad \Delta \bar{d}(x, Q_0^2) \simeq 0, \quad \Delta s(x, Q_0^2) \simeq 0$$

- The total spin carried by the quark spins:

$$\Delta\Sigma(Q_0^2) = \sum_q \int_{0.023}^{0.6} dx \Delta q(x, Q_0^2) = 0.347 \pm 0.024 \pm 0.066$$

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