HERMES Status Report

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for the hermes Collaboration

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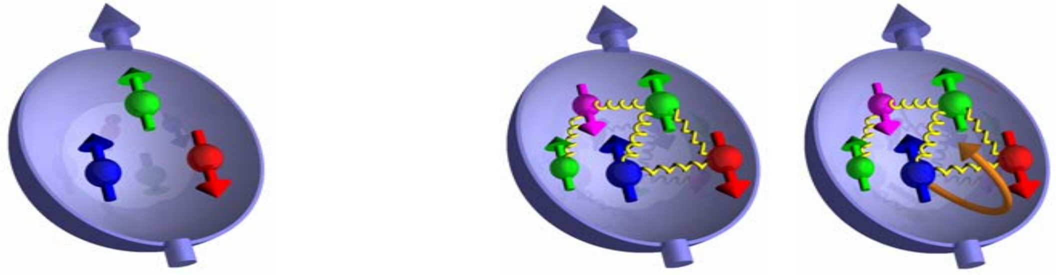
Outline

- Introduction
- Physics Highlights from HERMES
  - Isoscalar extraction of ΔS
  - Model-dependent constraint on J_u, J_d
- Recoil Detector Status
  - Detector calibration
  - Noise studies
  - Tracking and alignment
  - Particle identification
- Summary and Outlook

Spin Structure of the Nucleon

$$\boxed{\Delta u_s + \Delta d_s + \Delta\bar{u} + \Delta\bar{d} + \Delta s + \Delta\bar{s}}$$

$$\frac{1}{2} = \frac{1}{2}\underbrace{(\Delta u_v + \Delta d_v + \Delta q_{sea})} + \underbrace{\Delta G} + \underbrace{L_q + L_g}$$



- Quark spin $\Delta\Sigma = \Delta u + \Delta d + \Delta\bar{u} + \Delta\bar{d} + \underbrace{\Delta s + \Delta\bar{s}}_{\Delta S}$
  $\Delta\Sigma$ is small ~1/3 (HERMES, …)
  Phys. Rev. D 75, 012007 (2007)
- Gluon spin ΔG
- Orbital angular momentum $\boxed{L_q} + L_g$

Physics Highlights

- Isoscalar extraction of ΔS

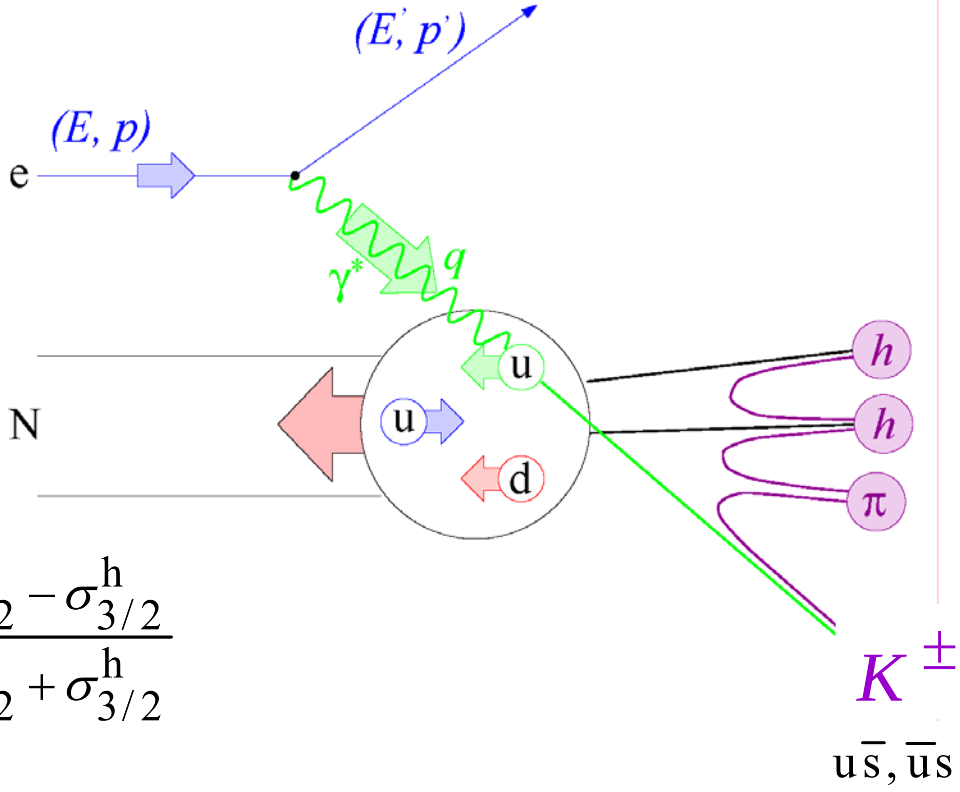
  arXiv:0803.2993, DESY 07-223, submitted to PRL,
  A. Airapetian et al., Measurement of Parton Distributions of Strange Quarks in the Nucleon from Charged Kaon Production in Deep-Inelastic Scattering on the Deuteron

- Model-Dependent Constraint on J_u, J_d

  arXiv:0802.2499, DESY 07-225, submitted to JHEP,
  A. Airapetian et al., Measurement of Azimuthal Asymmetries with Respect to Both Beam Charge and Transverse Target Polarization in Exclusive Electroproduction of Real Photons

Semi-Inclusive DIS

- Semi-inclusive DIS, observation of a coincident hadron, allows probing of flavor in more detail because of the correlation between flavor structure of the hadron and struck quark



- Measure asymmetries $A_1^h = \frac{\sigma^h_{1/2} - \sigma^h_{3/2}}{\sigma^h_{1/2} + \sigma^h_{3/2}}$

$$A_1^h\left(x,Q^2,z\right) \overset{LO}{=} \sum_q P_q^h\left(x,Q^2,z\right) \frac{\Delta q\left(x,Q^2\right)}{q\left(x,Q^2\right)}, \qquad z = \frac{E_h}{\upsilon}$$

$P_q^h(x,Q^2,z)$ 'Purity' is a conditional probability that a hadron of type h observed in the final state originated from a struck quark of flavor q.
'Purity' depends on fragmentation functions and unpolarized PDFs

Isoscalar Extraction of ΔS

- Longitudinally polarized deuterium target
  - Strange quark sea in proton and neutron identical
  - Analysis of purities simplifies

- All needed information can be extracted from HERMES data alone:
  - Inclusive $A_{1,d}(x,Q^2)$ and Kaon $A_{1,d}^{K^+ + K^-}(x,Q^2,z)$ double spin asymmetries
  - Kaon multiplicities

- Only assumptions used
  - Isospin symmetry between proton and neutron
  - Charge-conjugation invariance in fragmentation

Isoscalar Extraction of ΔS

$$\begin{pmatrix} A_{1,d}(x) \\ A_{1,d}^{K^+ + K^-}(x) \end{pmatrix} = \begin{pmatrix} P_Q & P_S \\ P_Q^{K^+ + K^-} & P_S^{K^+ + K^-} \end{pmatrix} \begin{pmatrix} \Delta Q(x)/Q(x) \\ \Delta S(x)/S(x) \end{pmatrix}$$

- Extract

$$\Delta S(x) \equiv \Delta s(x) + \Delta \bar{s}(x)$$

$$\Delta Q(x) \equiv \Delta u(x) + \Delta \bar{u}(x) + \Delta d(x) + \Delta \bar{d}(x)$$

- Inclusive purities are simple combinations of unpolarized PDFs

$$P_Q(x) = \frac{5Q(x)}{5Q(x) + 2S(x)}, P_S(x) = \frac{2S(x)}{5Q(x) + 2S(x)}$$

- Kaon purities can be computed from the unpolarized Kaon multiplicity assuming only charge symmetry in fragmentation

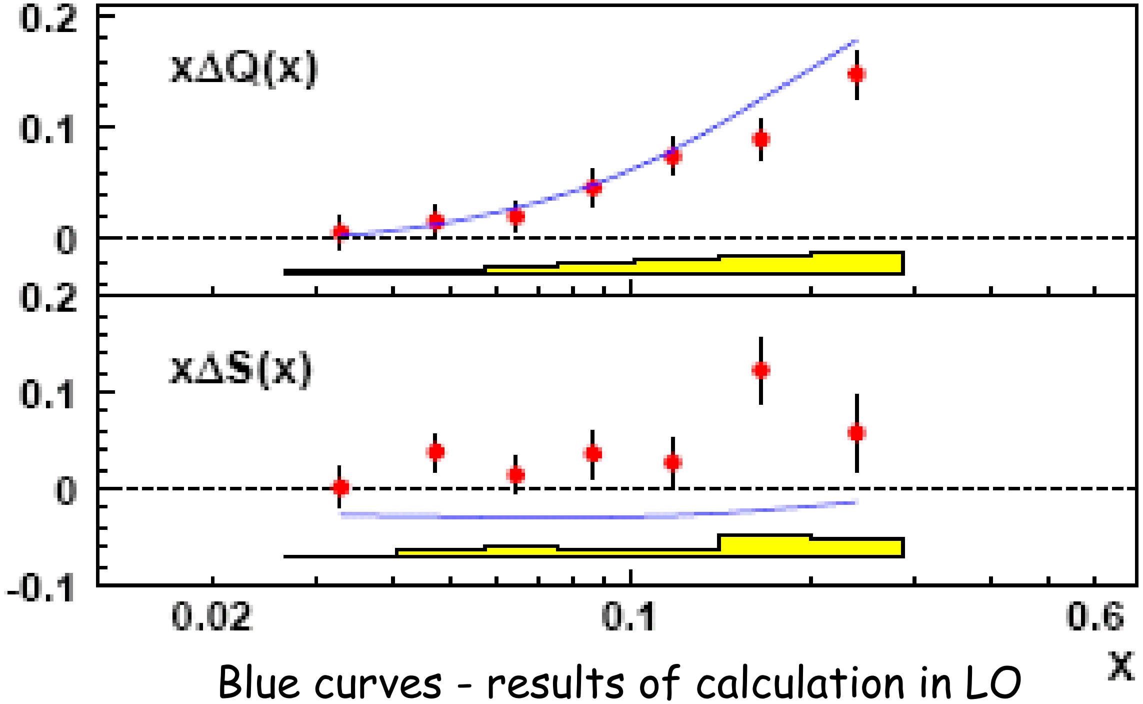
$$D_q^{K^+ + K^-}(z) = D_{\bar{q}}^{K^+ + K^-}(z)$$

Results on Isoscalar Extraction of ΔS

- No dependence on fragmentation model
- No hint of negative strange sea in measured range

$$\Delta Q = 0.359 \pm 0.026 \pm 0.018$$

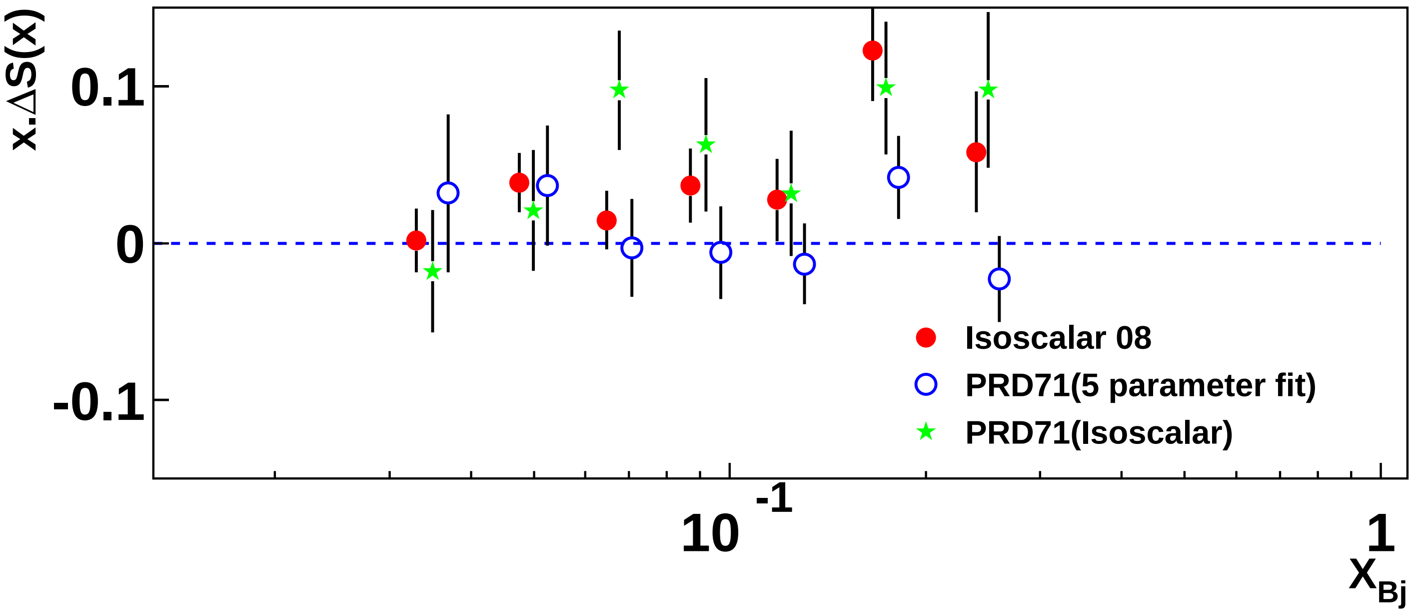
$$\Delta S = 0.037 \pm 0.019 \pm 0.027$$



Blue curves - results of calculation in LO
[Phys. Rev. D 73 (2006) 034023]

Results on Isoscalar Extraction of ΔS

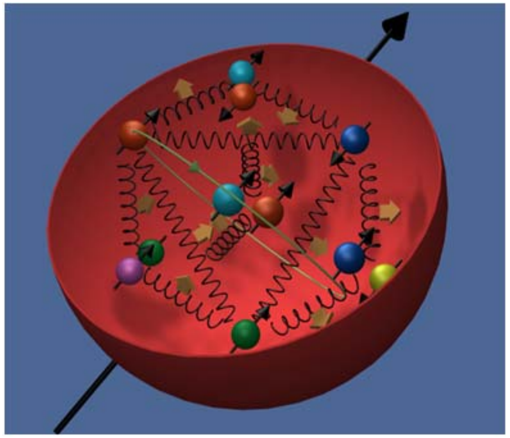
- No dependence on fragmentation model
- No hint of negative strange sea in measured range
- Result is consistent with full 5 flavor extraction at HERMES



Access to the Orbital Angular Momentum

Nucleon spin:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_q + J_g$$



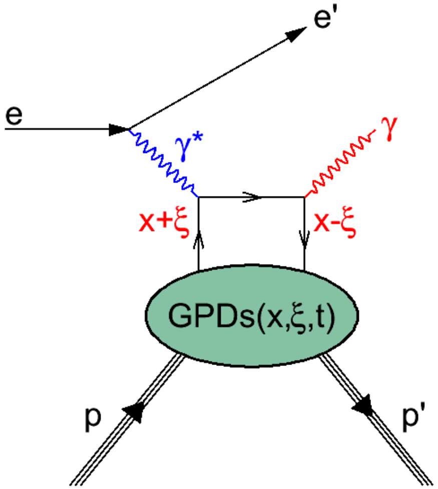
- Quark spin: $\Delta\Sigma$ measured ~1/3 (HERMES, …)
- Quark orbital momentum: Lq unknown

Generalized parton distributions (GPDs)

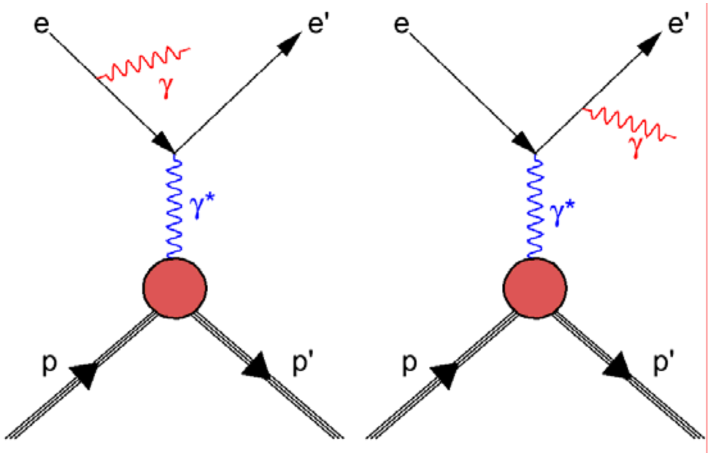
- Incorporate our knowledge about PDFs and FF to a new theoretical framework
- Access the orbital angular momentum of quarks in nucleon

Access to GPD via Deeply Virtual Compton Scattering (DVCS)

Cleanest way to access GPDs: DVCS



Bethe-Heitler



$$d\sigma(eN \rightarrow eN\gamma) \propto |T_{BH}|^2 + |T_{DVCS}|^2 + \underbrace{T_{BH}T^*_{DVCS} + T^*_{BH}T_{DVCS}}_{\text{interference term}}$$

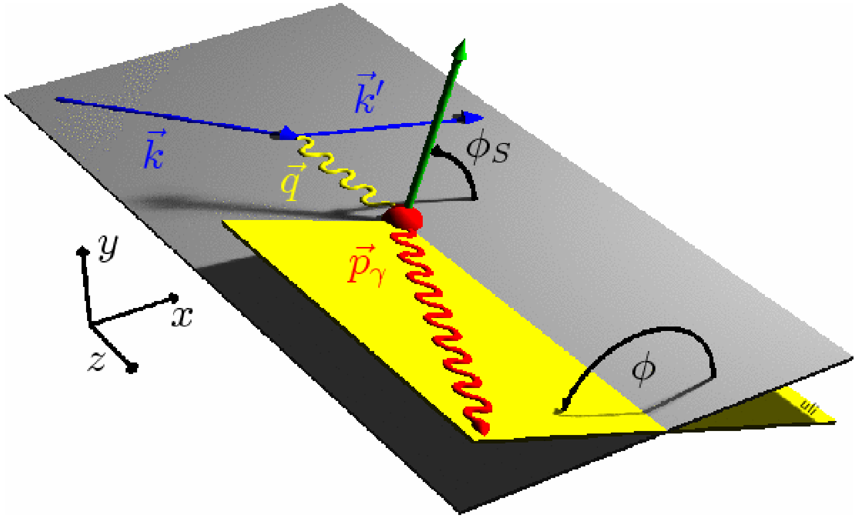
- DVCS and Bethe-Heitler: the same initial and final state
- Bethe-Heitler dominates at HERMES kinematics
- GPDs accessible through cross-section differences and azimuthal asymmetries via interference term

Transverse Target Spin Asymmetry (TTSA)

- Ji relation → access to the total angular momentum of quarks

$$J_q = \lim_{t\to 0}\int_{-1}^{1} dx\, x\left[\underbrace{H_q(x,\xi,t)+E_q(x,\xi,t)}_{\text{GPDs}}\right]$$

- Bethe-Heitler - DVCS interference term in ep→epγ induces azimthal asymmetries → access to GPDs H and E

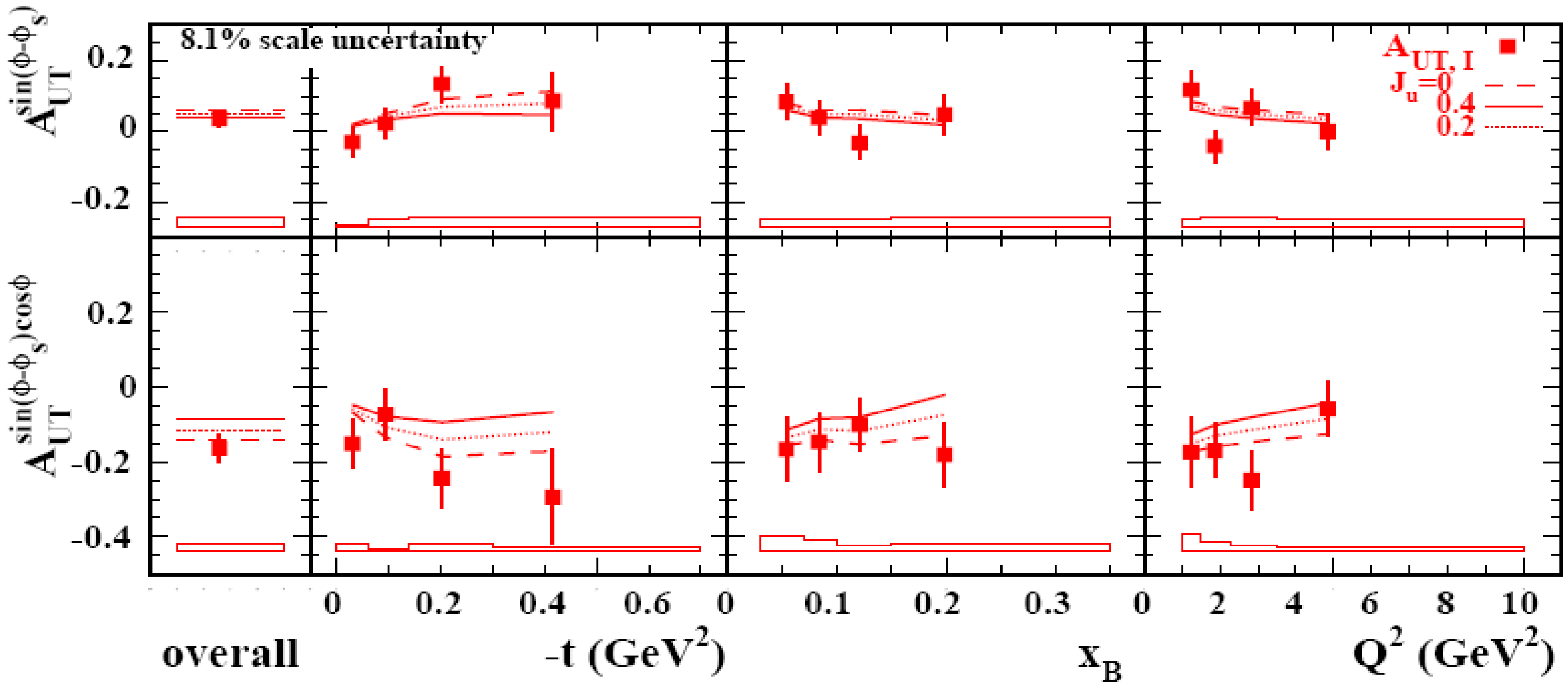


- Measure Transverse Target Spin Asymmetry (TTSA)

$$A^{I}_{UT}(\phi,\phi_S) \propto \left[d\sigma^{+}(\phi,\phi_S) - d\sigma^{-}(\phi,\phi_S)\right] - \left[d\sigma^{+}(\phi,\phi_S+\pi) - d\sigma^{-}(\phi,\phi_S+\pi)\right]$$

- TTSA provides access to GPD E

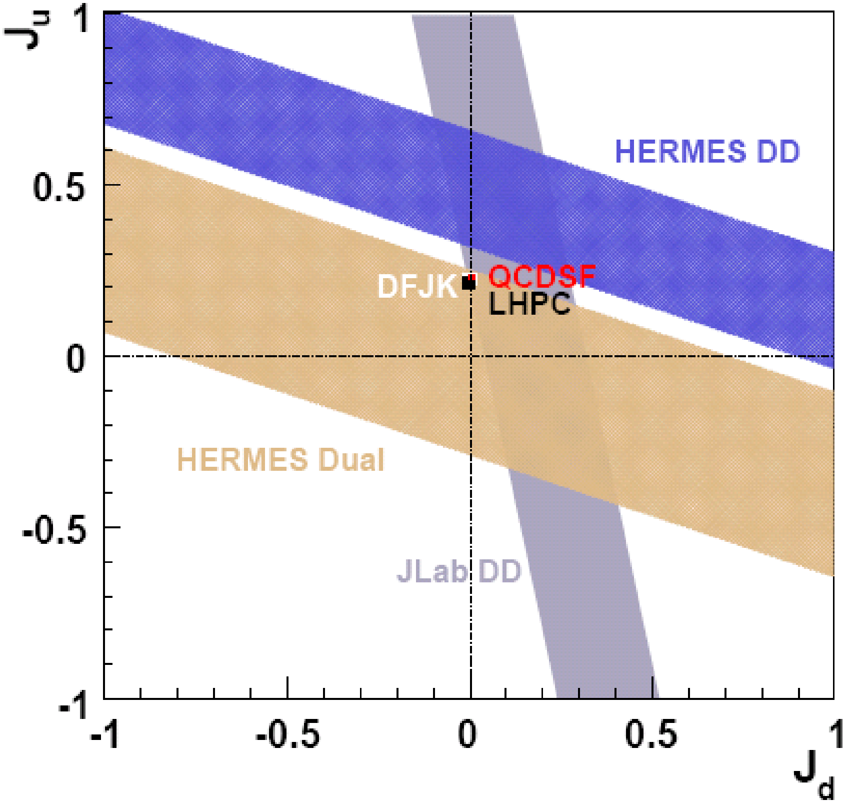
Results on TTSA Asymmetry Amplitudes



Sensitivity of GPD model predictions to J_u at fixed J_d=0
[Phys. Rev. D74(2006) 054027]

Model-Dependent Constraint on J_u, J_d

$$\chi^2(J_u,J_d) = \left(A_{UT,I}^{\sin(\varphi-\varphi_s)\cos n\varphi}\Big|_{exp} - A_{UT,I}^{\sin(\varphi-\varphi_s)\cos n\varphi}\Big|_{theo}(J_u,J_d) \right)^2 \Big/ \left(\delta A_{stat}^2 + \delta A_{syst}^2 \right)$$



- J_u, J_d are free parameters in GPD models
- Double Distribution (DD)
  [Phys.Rev.D 60 (1999) 094017,
  Prog. Part. Nucl. Phys. 47(2001)401]

$$J_u + J_d/2.8 = 0.48 \pm 0.17$$

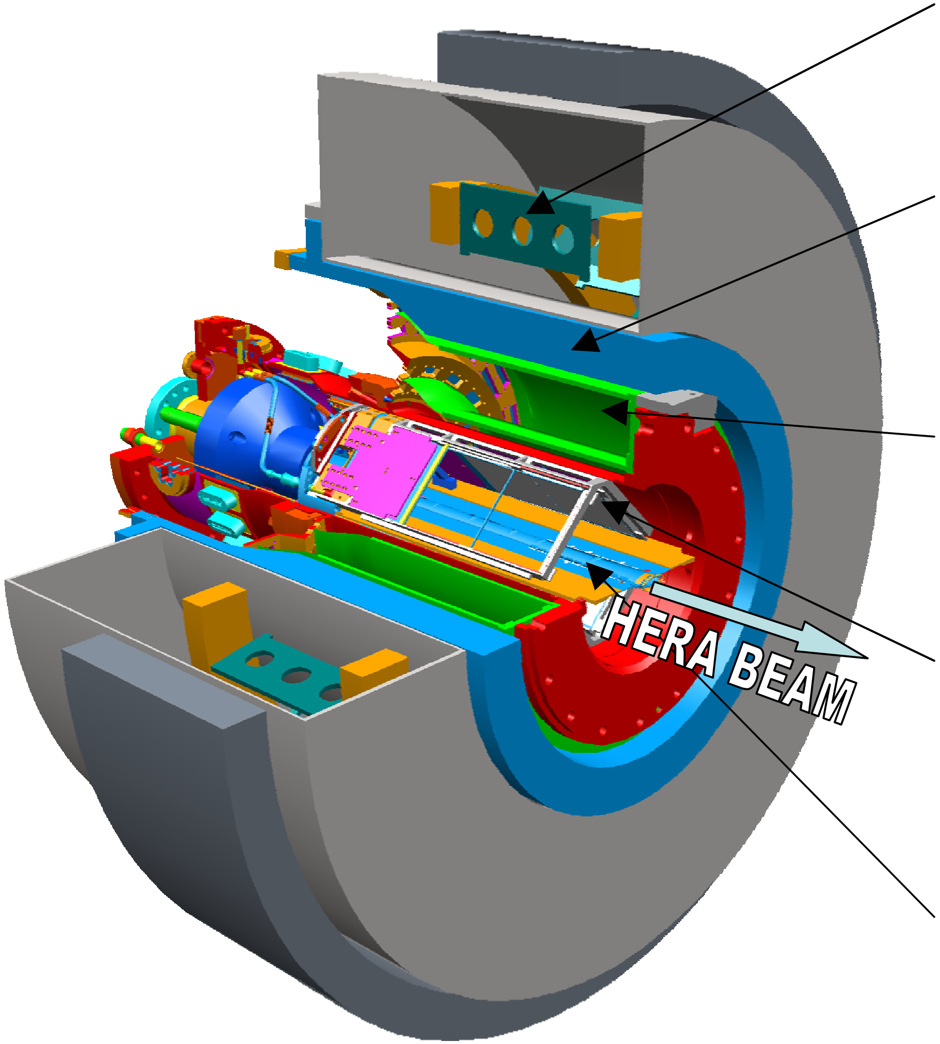
- Dual Parameterization (Dual)
  [hep-ph/0207153,
  Phys. Rev. D74(2006) 054027]

$$J_u + J_d/2.8 = -0.02 \pm 0.27$$

- Jlab DD (neutron cross section data)
  [Phys. Rev. Lett. 99(2007)242501]
- Lattice calculations QCDSF, LHPC

Recoil Detector

Motivation: exclusivity, background suppression, t-resolution



1 Tesla Superconducting Solenoid

Photon Detector (PD)

detect gammas

p/π PID for momentum > 650 MeV/c

Scintillating Fiber Tracker (SFT)

Momentum reconstruction by bending in magnetic field

Silicon Strip Detector (SSD)

Momentum reconstruction by energy deposit for low-momentum protons and deuterons

Target Cell

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- Introduction
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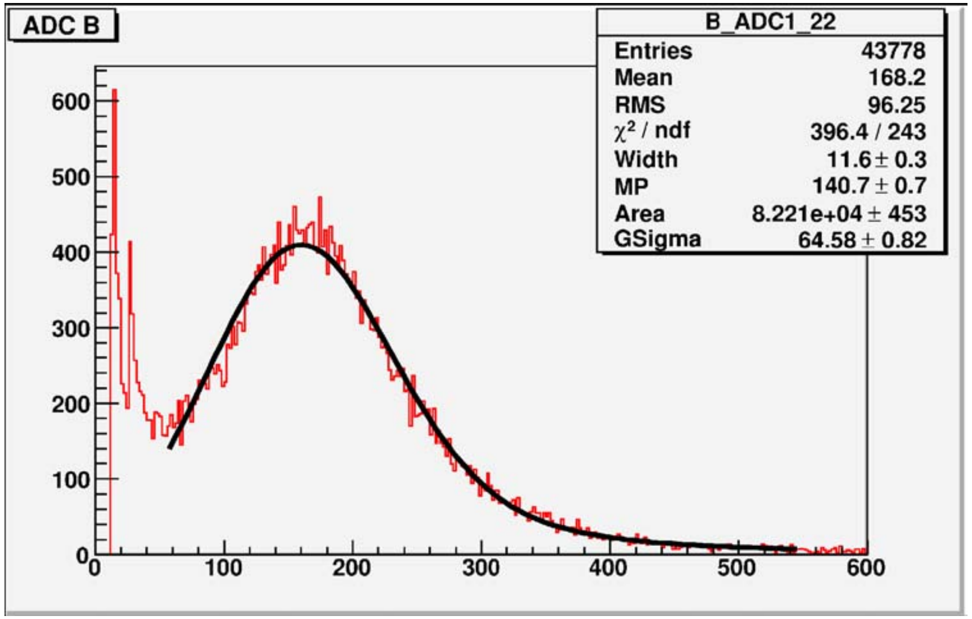
- Recoil Detector Status
  - Detector calibration
    - Use MIPs for calibration by selecting π^+ and π^-
  - Noise studies
  - Tracking and alignment
  - Particle identification
- Summary and Outlook

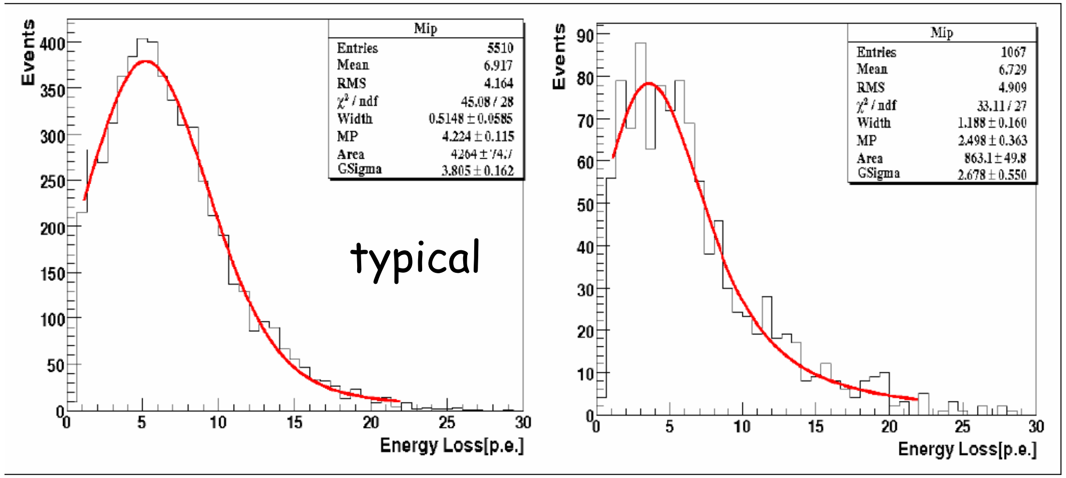
Detector Calibration: Photon detector

- MIP peaks seen for all strips in all layers
- Fit Landau-Gaussian convolution to all ADC spectra
- Need to understand large width of MIP peak
  - Implement correction for attenuation
  - Refine MC digitization
- Get absolute energy calibration
  - Final check with reconstructed π^0

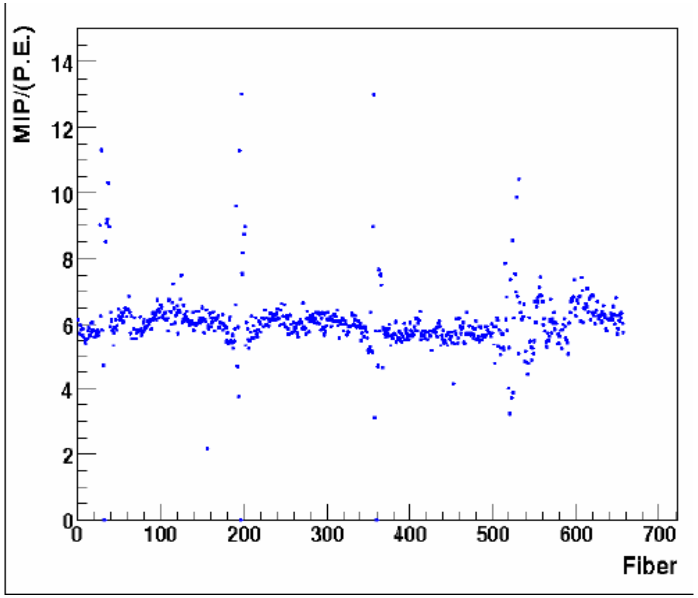


Detector Calibration: Scintillating Fiber Tracker

- MIP peak seen in all fibers
- Some fibers show higher noise
- Calibration currently in number of photoelectrons
- Use MC to get reference energy deposits and get the absolute calibration

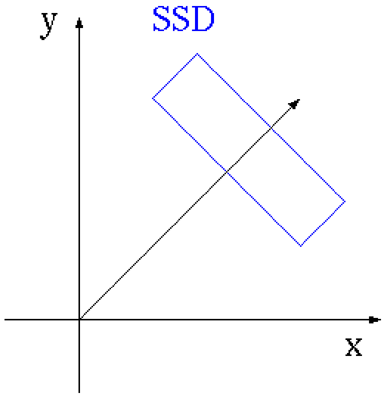


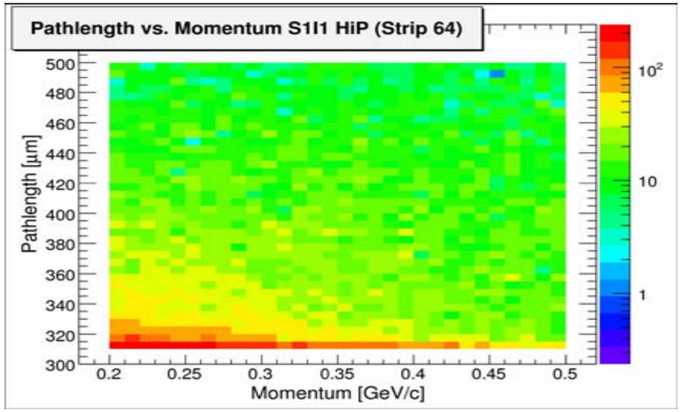
typical

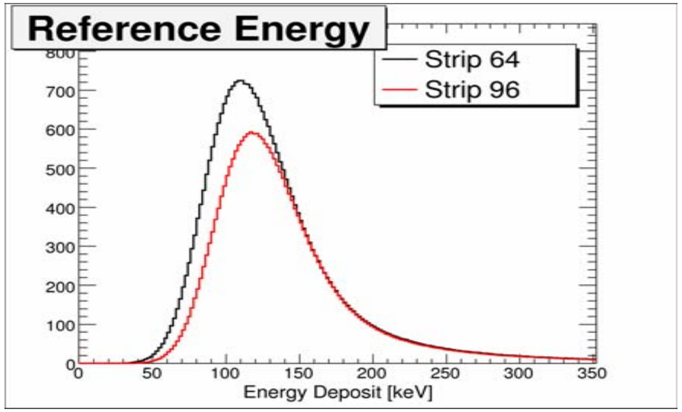


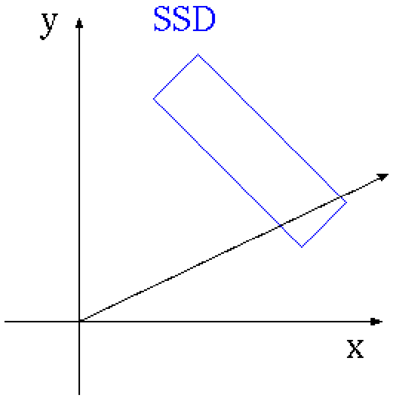
Detector Calibration: Silicon Strip Detector

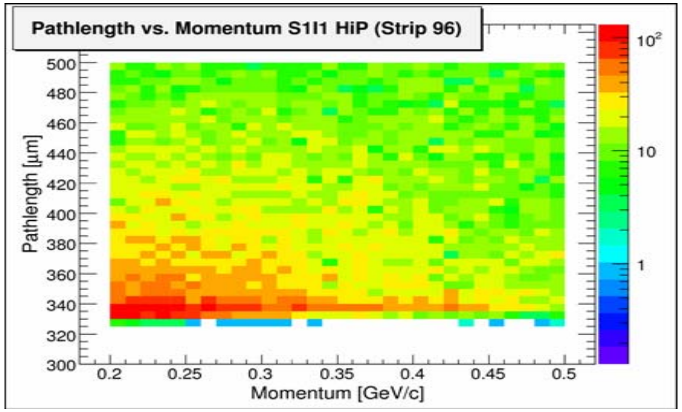
- Strong variations in momentum and path length seen by strips
  - Acceptance, geometry
- Introduce Path Length vs. Momentum histograms for each strip and lookup table to get nominal energy deposit histogram for each strip

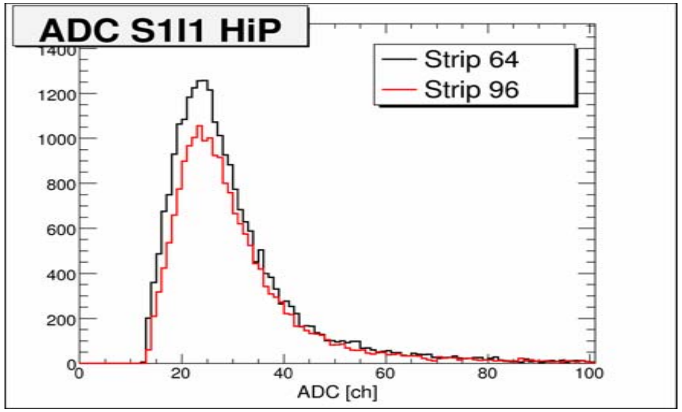








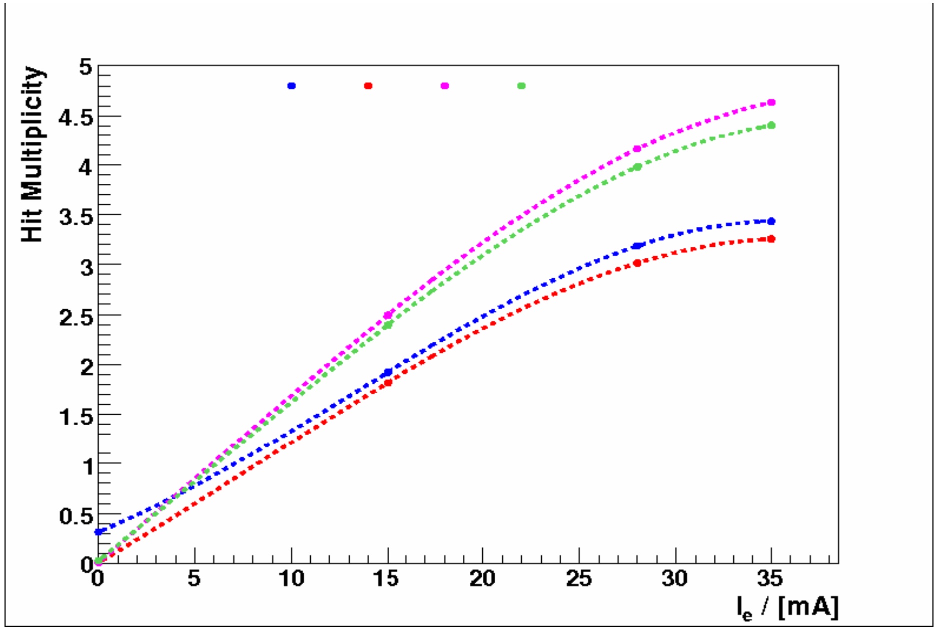




- Stability has been studied, studies of nonlinearities in progress

Noise Studies

- Noise studies with random bunches
- Different data sets
  - Beginning of the fill (positron beam current 28mA)
  - End of the fill (15mA)
  - Empty target (35mA)
- Noise studies for SFT
  - Occupancy of the background is strongly correlated with the positron beam current
  - No correlation between hits in the SFT - random distributed noise is implemented in MC
- Similar studies are done for the Silicon and Photon detectors



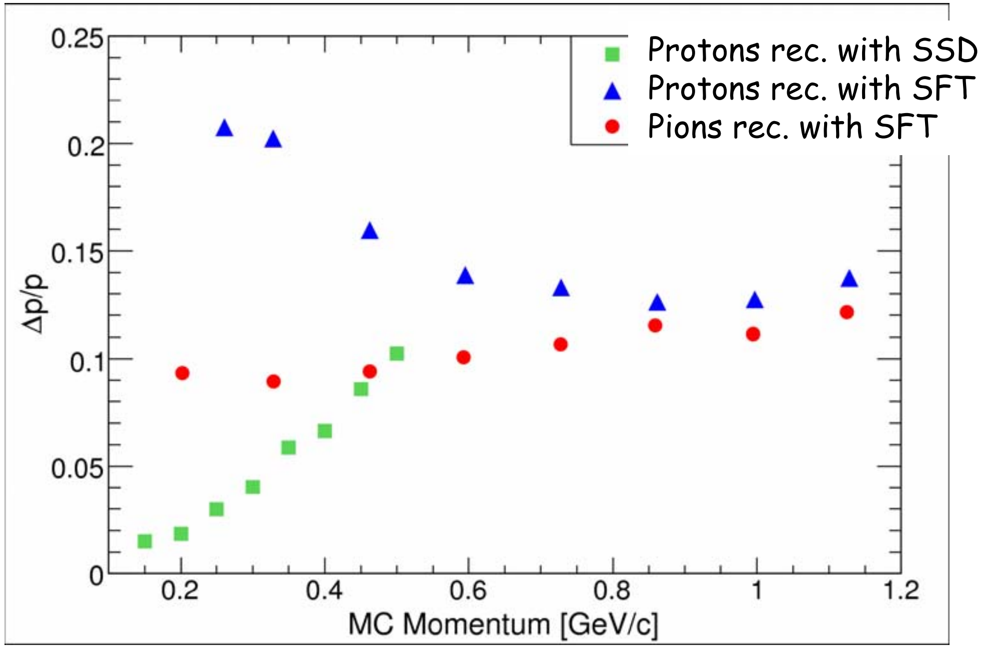
Tracking status

- Track finding works and is efficient, studies of ghost tracks in progress
- Detector alignment is done
- Track fitting takes energy losses and multiple scattering into account
- Track fitting done for proton and pion hypotheses
  - Different tracking reconstructed parameters for future PID
- Accuracy of momentum reconstruction by bending in magnetic field is in agreement with the technical design report
- Tracking is used for calibration
- Until detector calibration is done - time for improvements

Tracking status

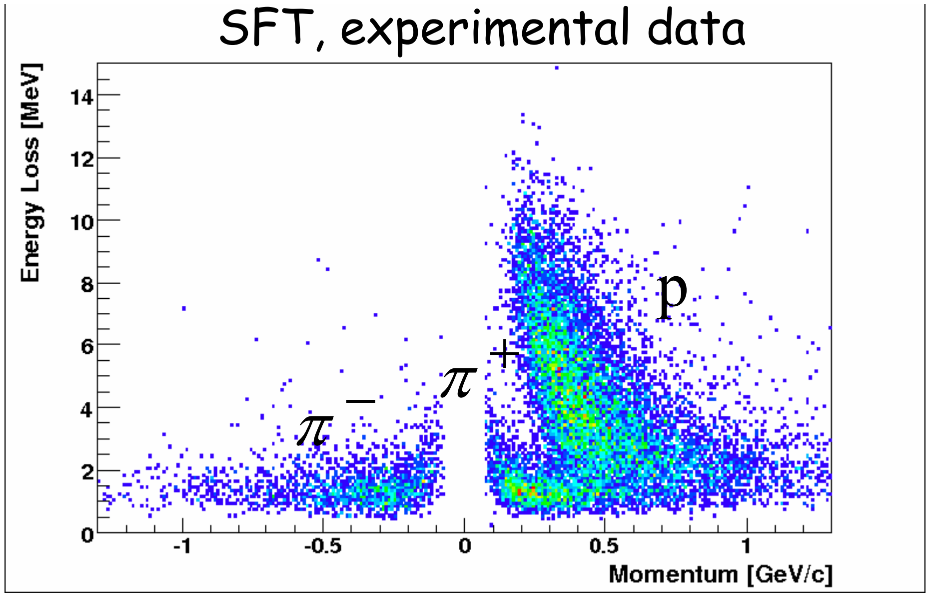
Momentum reconstruction by energy deposit in the Silicon Strip Detector

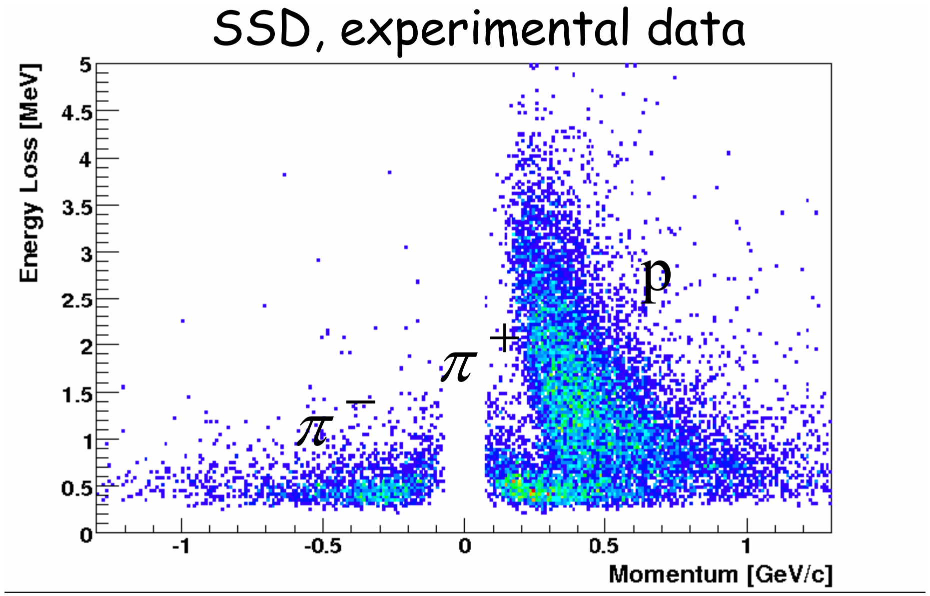
- First method with simplifications in use
- Two methods under development
  - Lookup tables for momentum as a function of energy deposit and path length, direct reconstruction of momentum
  - Fitting method – will treat energy deposits the same way as measured coordinates during track fitting



Particle Identification Plan

- Particle identification possible in all 3 subdetectors of the Recoil
- Proton-pion separation in momentum range below 700 MeV/c possible with the SSD and SFT
- Photon detector will be used for proton-pion separation at energies above 650 MeV/c


SFT, experimental data


SSD, experimental data

Summary and Outlook

- Analysis of HERMES data is ongoing, new physics results coming soon
- 10 HERMES talks accepted for DIS08
- Recoil Detector calibration and tracking nearly finished, tracking improvements under implementation
- First results from the Recoil Detector are expected this fall

Backup Slides

Method of 5-Flavor Δq Extraction

$$\vec{A}_1 = P \cdot \vec{Q}$$

$$\vec{A}_1 = \begin{pmatrix} A_{1,p} \\ A_{1,p}^{\pi^+} \\ A_{1,p}^{\pi^-} \\ A_{1,d} \\ \cdot \\ \cdot \\ \cdot \\ A_{1,d}^{K^-} \end{pmatrix}$$

Measured

$$P_q^h(x) = \frac{e_q^2 q(x) \int dz D_q^h(z)}{\sum_{q'} e_{q'}^2 q'(x) \int dz D_{q'}^h(z)}$$

Simulated

Purity is a conditional probability that a hadron of type h observed in the final state originated from a struck quark of flavor q.
Purities extracted from LUND string model MC simulation (LEPTO+JETSET) tuned to HERMES unpolarized data

$$\vec{Q} = \begin{pmatrix} \Delta u / u \\ \Delta d / d \\ \Delta \bar{u} / \bar{u} \\ \Delta \bar{d} / \bar{d} \\ \Delta s / s \end{pmatrix}$$

Extracted

System of asymmetries and purities solved through χ^2 minimization of polarizations

Generalized Parton Distributions

- GPDs → PDF

$$H_q(x,0,0) = q(x)$$

$$\widetilde{H}_q(x,0,0) = \Delta q(x)$$

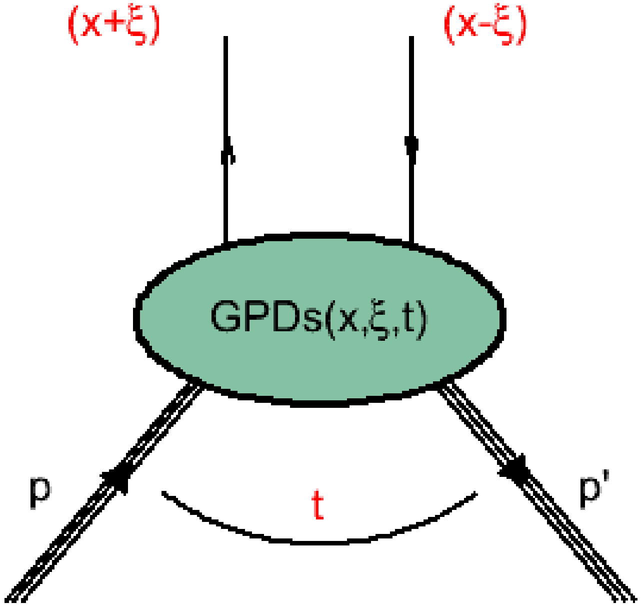
- GPD → FF

$$\int_{-1}^{1} dx H_q(x,\xi,t) = F_1^q(t)$$

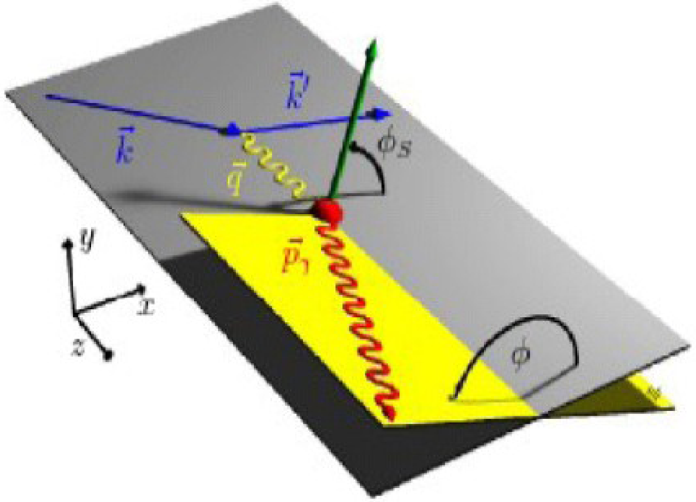
$$\int_{-1}^{1} dx E_q(x,\xi,t) = F_2^q(t)$$

- $H_q, \widetilde{H}_q$ conserve nucleon helicity
- $E_q, \widetilde{E}_q$ flip nucleon helicity

$x \pm \xi$	parton longitudinal momentum fractions
ξ	fraction of the momentum transfer
t	invariant momentum transfer to the nucleon



Asymmetries Measurable at HERMES



- Beam-Spin Asymmetry (BSA)

$$A_{LU} = \frac{d\sigma(\mathbf{e}^{\rightarrow},\phi) - d\sigma(\mathbf{e}^{\leftarrow},\phi)}{d\sigma(\mathbf{e}^{\rightarrow},\phi) + d\sigma(\mathbf{e}^{\leftarrow},\phi)} \propto \Im m(\mathcal{H}) \sin(\phi)$$

- Beam-Charge Asymmetry (BCA)

$$A_{C} = \frac{d\sigma(\mathbf{e}^{+},\phi) - d\sigma(\mathbf{e}^{-},\phi)}{d\sigma(\mathbf{e}^{+},\phi) + d\sigma(\mathbf{e}^{-},\phi)} \propto \Re e(\mathcal{H}) \cos(\phi)$$

- Longitudinal Target Spin Asymmetry (LTSA)

$$A_{UL} = \frac{d\sigma(\mathbf{p}^{\rightarrow},\phi) - d\sigma(\mathbf{p}^{\leftarrow},\phi)}{d\sigma(\mathbf{p}^{\rightarrow},\phi) + d\sigma(\mathbf{p}^{\leftarrow},\phi)} \propto \Im m(\widetilde{\mathcal{H}}) \sin(\phi)$$

- Transverse Target Spin Asymmetry (TTSA)

$$A_{UT} = \frac{d\sigma(\mathbf{p}^{\uparrow},\phi) - d\sigma(\mathbf{p}^{\downarrow},\phi)}{d\sigma(\mathbf{p}^{\uparrow},\phi) + d\sigma(\mathbf{p}^{\downarrow},\phi)} \propto f(\mathcal{H},\mathcal{E},\widetilde{\mathcal{H}},\widetilde{\mathcal{E}},\phi,\phi_S)$$