Plans for HERMES Run 2

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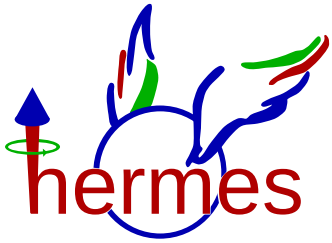
- Status of the spin structure of the nucleon
- Run 2: quark helicity
- Run 2: quark transversity
- Run 2: accessing SPD's

Motivation for HERMES Run 2: deepen our understanding of the remarkable results from Run 1.



HERMES Program

The primary goal of the HERMES program has been and continues to be determination of the spin structure of the nucleon.

- How do the constituents of the nucleon combine to give its spin?

$$\underbrace{\Delta valence + \Delta sea}_{\Delta\Sigma} + \underbrace{\Delta gluons}_{\Delta G} + \underbrace{\Delta orb.\ ang.\ mom}_{L_{q,g}} = 1/2$$

- HERMES can make a first measurement of the leading twist description of the structure of the nucleon:

$$q(x), \Delta q(x), \delta q(x)$$

$q(x)$ = quark number density (e.g. ZEUS&H1)

$\Delta q(x)$ = quark helicity (CERN, DESY, SLAC)

$\delta q(x)$ = quark transversity (HERMES)

Our Understanding of Spin Structure

Status of the understanding of the spin structure of the nucleon prior to HERMES (1995):

- $\Delta\Sigma = \Sigma_q \Delta q \sim 0.3 \pm 0.1$
  (e.g. from g_1^p data from E143)
  $\rightarrow$ No full or partial x dependent quark decomposition available
- ΔG =?, $L_{q,g}$ =?, δq =?

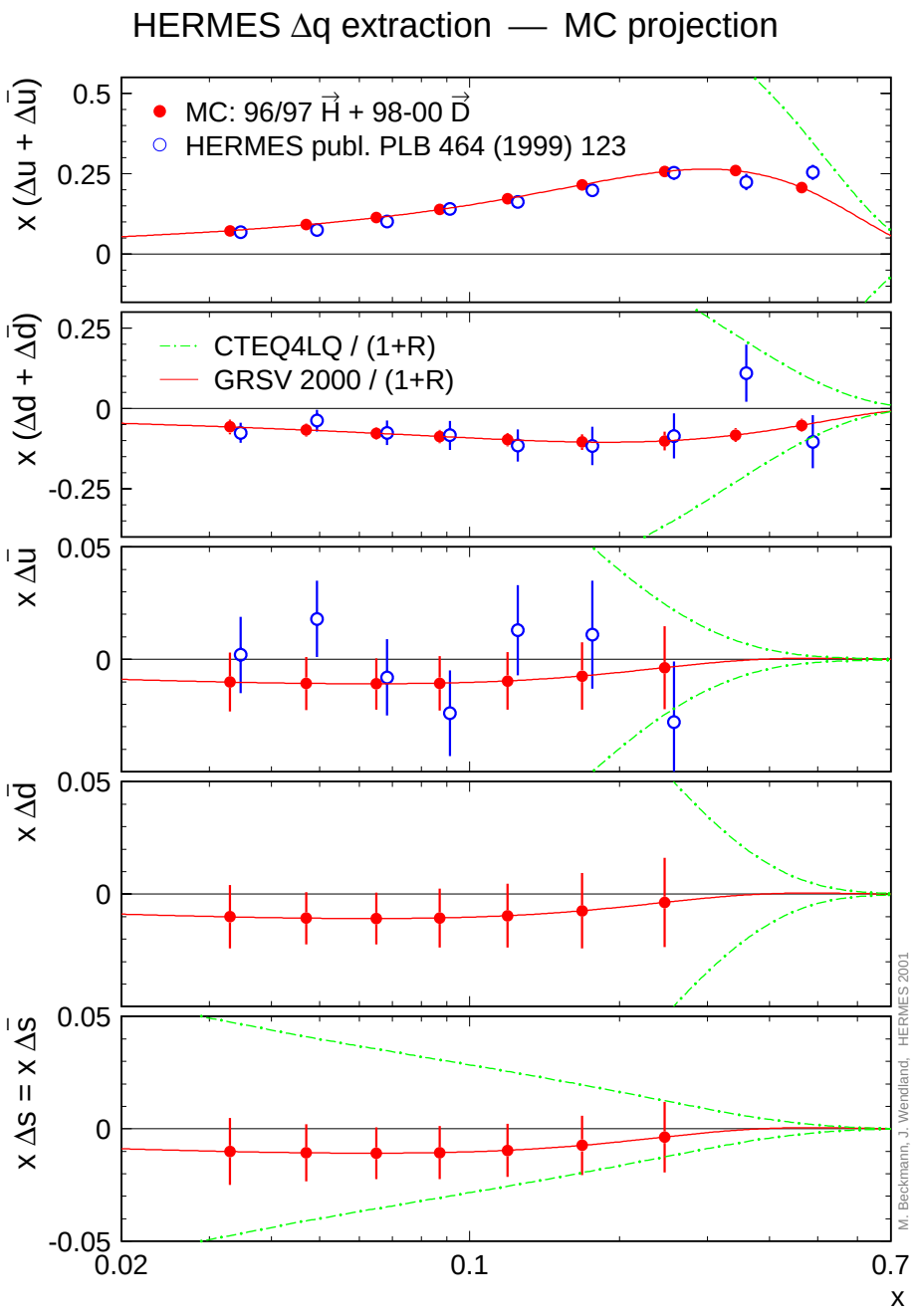
Most of the contribution to the spin 1/2 of the nucleon is undetermined

Current status of the understanding of the spin structure of the nucleon (2001):

- $\Delta\Sigma \sim 0.3 \pm \leq 0.04$
  (e.g. from pQCD fits to g_1 or from semi-inclusive determination of Δq)
  $\rightarrow$ x dependent quark decomposition available with existing data

Expected Δq Precision

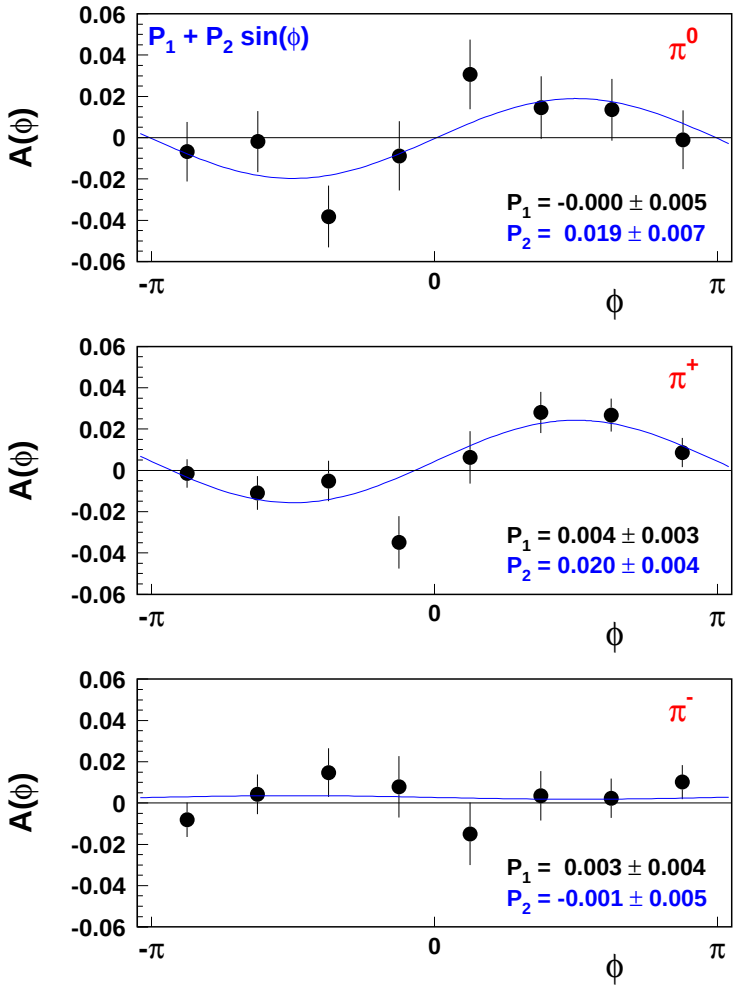
MC prediction based on 1995-2000 dataset:



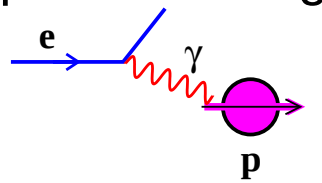
The breakdown of $\Delta\Sigma$ will be much better known with this data.

Current understanding of Spin Structure

- $\Delta G > 0$ (pQCD fits to g_1, high-P_T pairs)
- $\delta q \neq 0$ (first glimpse from HERMES semi-inclusive pion azimuthal asymmetries)



(however sensitivity to transversity is small for longitudinally polarized targets)



$e \parallel p \neq \gamma \parallel p$

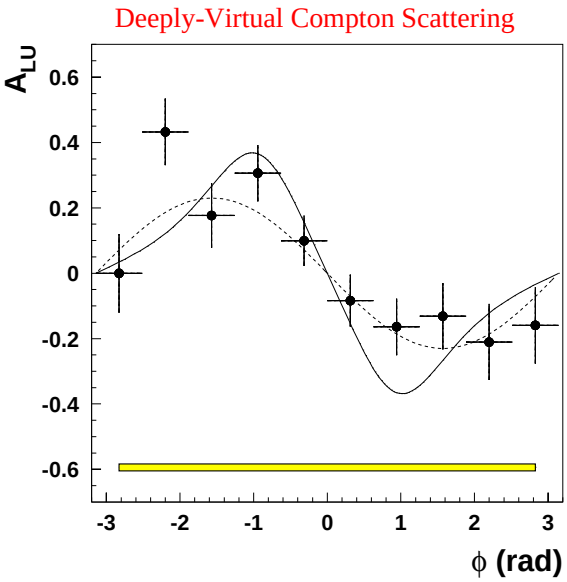
$S_T \sim 15\%$

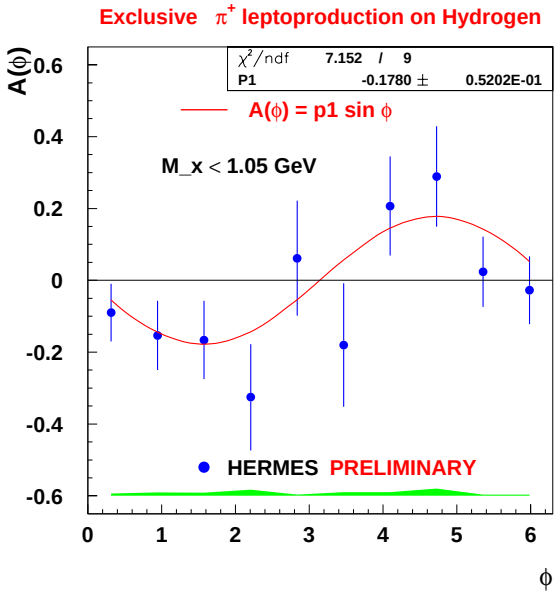
Current understanding of Spin Structure

- $L_{q,g}$ =? (at least now framework exists to access this number!)

Skewed (generalized) Parton Distributions (SPD) can be accessed through Exclusive Processes

Exclusive, real photon and meson production:





Data now exists for first extractions of SPD's.

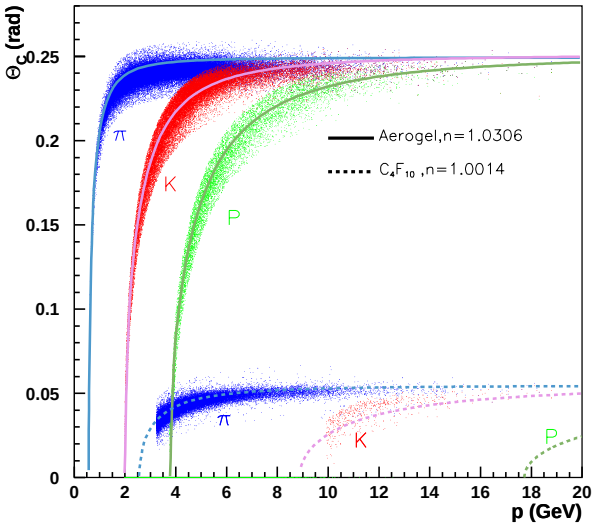
It is still true that most of the contribution to the spin 1/2 of the nucleon remains undetermined!

$\rightarrow$ only glimpses of $\Delta G, L_{q,g}, \delta q$

Motivation for Run 2 Plans

We wish to capitalize on the unique features of the HERMES detector and the HERA accelerator

- Large acceptance detector with good PID (dual radiator RICH)
  $\rightarrow$ ability to do semi-inclusive physics



- pure atomic polarized targets and the flexibility of the unpolarized high density target program
- Significant beam polarization, routine helicity flip, ability to run with either electrons or positrons

Run 2 Physics Program Scenarios

- Continue unpolarized physics program: nuclear effects with heavy targets (e.g. end-of-fill runs)

- Expand on precision measurements from Run 1

  $\rightarrow$ Polarized quark distributions Δq

- Expand on unique "first measurements" of previously unexplored quantities from Run 1

  - transversity δq but with a transversely polarized target: 2001-2003

  - SPD's from processes with exclusive final states (DVCS, mesons): 2004-200(5-6?)
    $\rightarrow$ requires detection of the recoil proton for exclusive final states

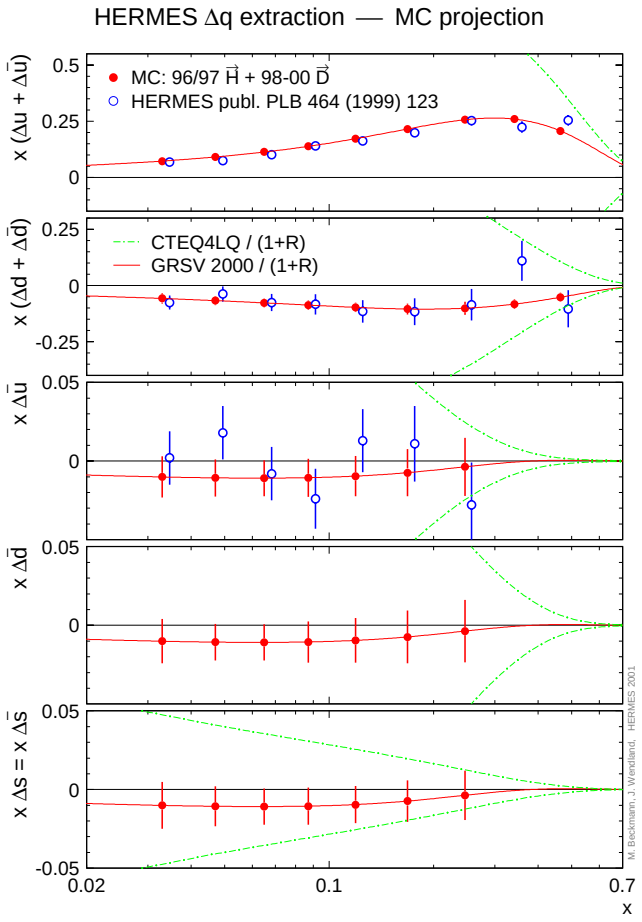
More Longitudinal Running?

The Ring Imaging Cerenkov detector did not exist when HERMES took data with longitudinally polarized hydrogen targets

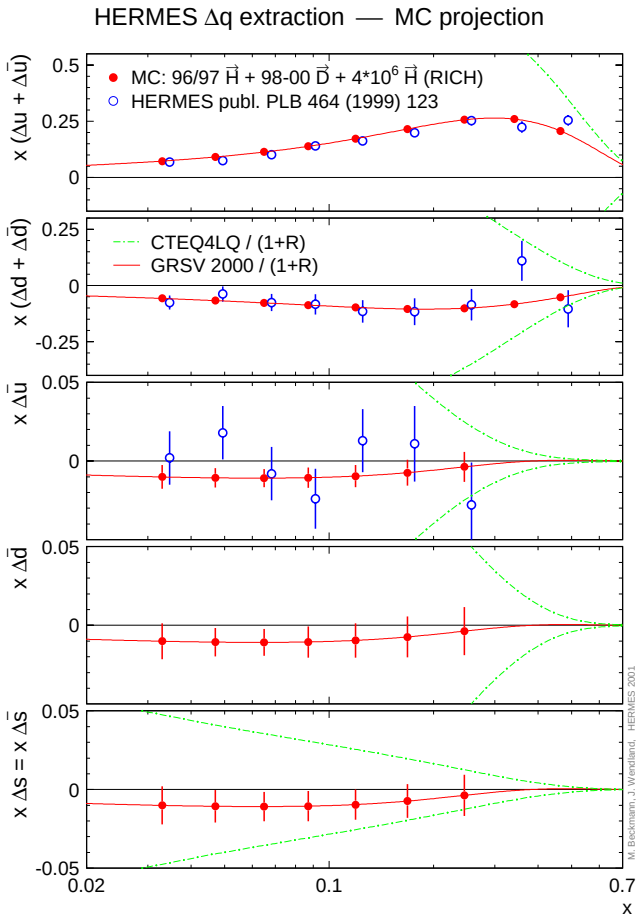
$\rightarrow$ significant improvement in Δq possible with one more year of polarized hydrogen

Expected statistical improvement based on 4M DIS additional events:

Existing stats



Existing stats+4M $\vec{H}$



Gains from Longitudinal Running

Improvement to 1996-2000 dataset:

Quark helicity	Improvement
$x(\Delta u + \Delta\overline{u})$	$30 - 40\%$
$x(\Delta d + \Delta\overline{d})$	$35 - 40\%$
$x(\Delta\overline{u})$	$40 - 50\%$
$x(\Delta\overline{d})$	$20 - 25\%$
$x(\Delta\overline{s})$	$15 - 20\%$

Most significant gain comes from better knowledge of u quark sea!

Longitudinal running not yet confirmed/scheduled in HERMES run plans.

HERMES Run 2: Transversity

Measurements of Transversity: 2001+
Determining the remaining leading twist function

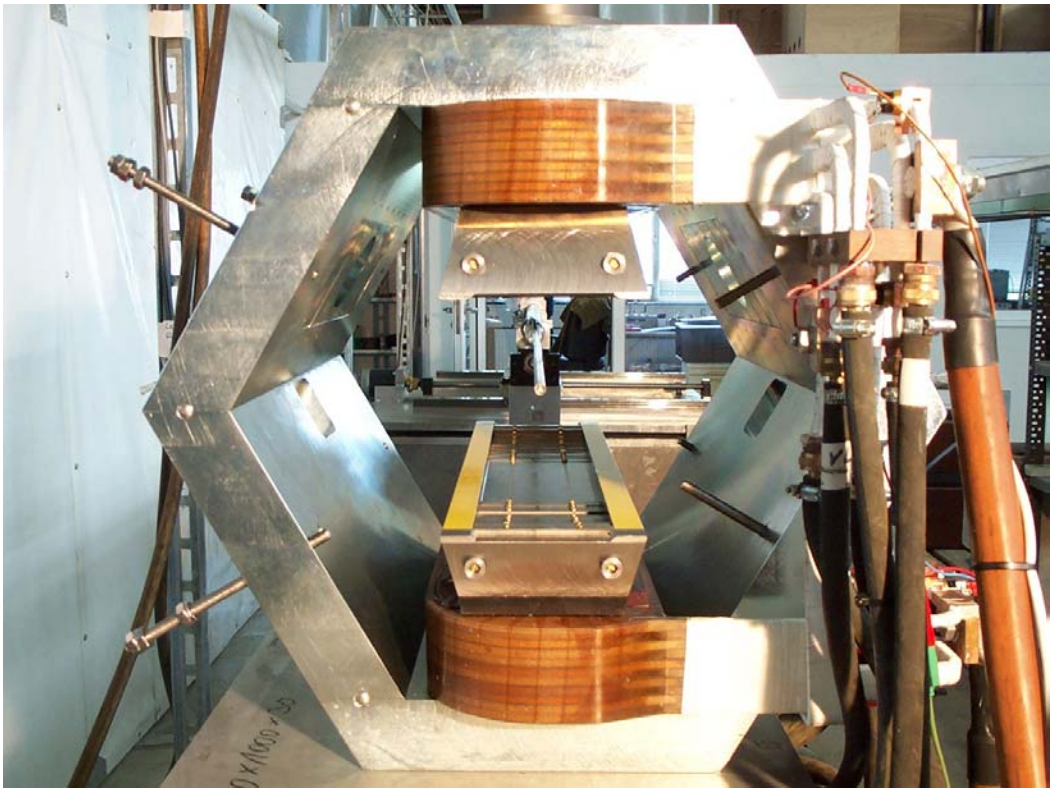
Semi-inclusive DIS off a transversely polarized target: target-spin weighted asymmetries with pions
(Mulders, Tangermann 96, Kotzinian, Mulders 97)

$$A_T = \frac{\int d\phi^l \int d^2P_{h\perp} \frac{|P_{h\perp}|}{zM_h} \sin(\phi_s^l + \phi_h^l)(d\sigma^\uparrow - d\sigma^\downarrow)}{\int d\phi^l \int d^2P_{h\perp}(d\sigma^\uparrow + d\sigma^\downarrow)}$$

$$A_T(x,y,z) \propto \frac{\sum_q e_q^2 \delta q(x) H_1^{\perp(1),q}(z)}{\sum_q e_q^2 q(x) D_1^q(z)}$$

A new transverse magnet has been installed in HERMES
$\rightarrow$ being commissioned

The New Transverse Magnet



- $B = 0.295$ T field
- Uniformity along beam direction:
  $\Delta B = 4.5 \times 10^{-5}$ T over cell length
  (design $\Delta B = 1.4 \times 10^{-4}$ T over whole volume)
- Correction coil may be necessary and is being designed

Expected Precision

HERMES Projection for 7M DIS:
(V. Korotkov, W.-D. Nowak, K. Oganessyan, hep-ph/0002268)

- assume u-quark dominance in π^+ production
- assume contribution from non-leading parton fragmentation is suppressed
- since $\Delta q_{sea}/q_{sea} << \Delta q/q$ assume $\delta q_{sea}/q_{sea} << \delta q/q$

$$A_p^{\pi^+}(x,y,z) \propto \frac{\delta u(x)}{u(x)} \frac{H_1^{\perp(1)}(z)}{D_1(z)}$$

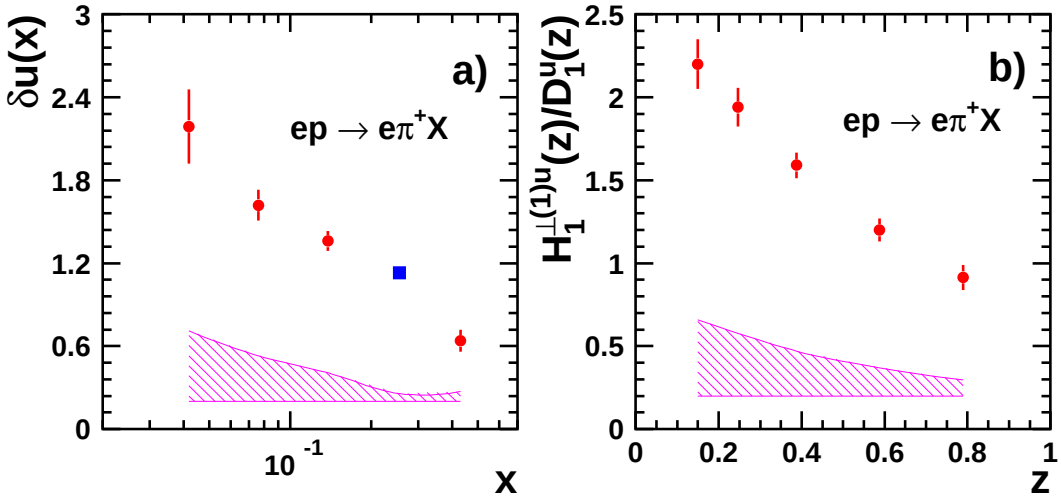
$$A_d^{\pi^+}(x,y,z) \propto \frac{\delta u(x) + \delta d(x)}{u(x) + d(x)} \frac{H_1^{\perp(1)}(z)}{D_1(z)}$$

Factorization in x and z

- one normalization point required

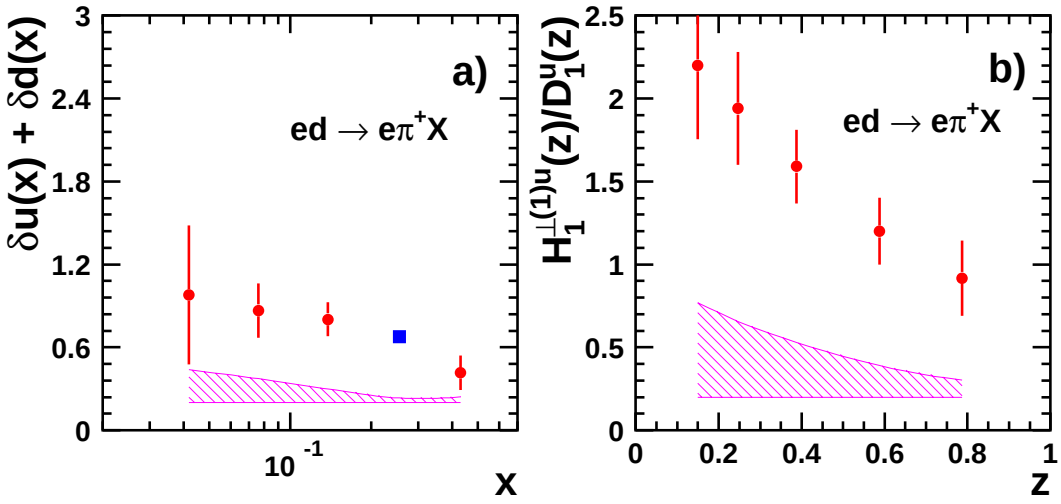
Expected Precision

- Proton Target



or

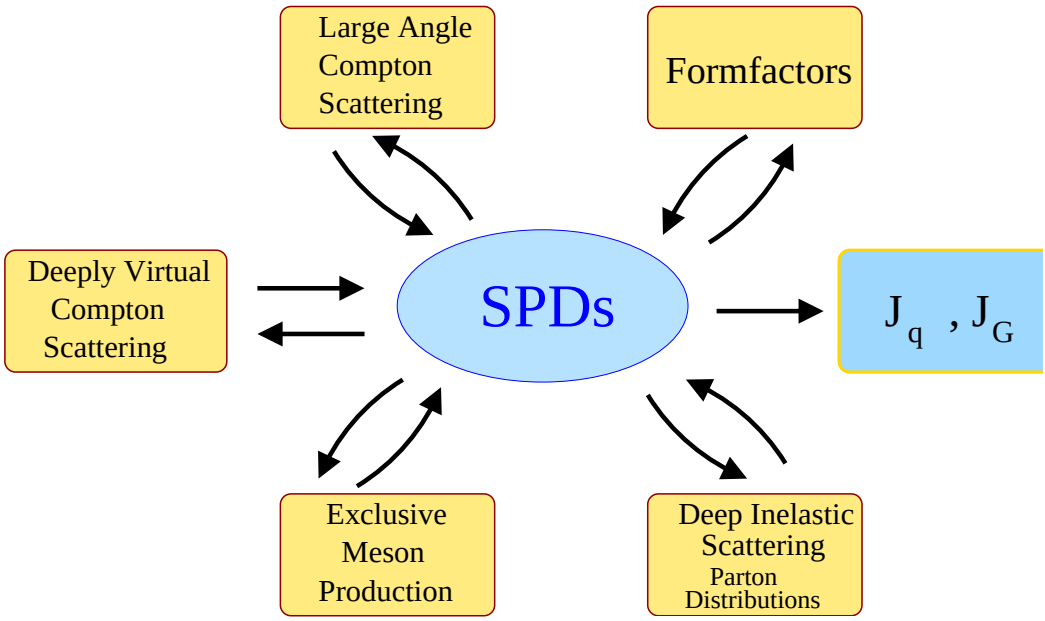
- Deuteron Target



We start with a transversely polarized proton target: Dec 2001 to 2003.

Exclusive Reactions w/ Recoil Detector

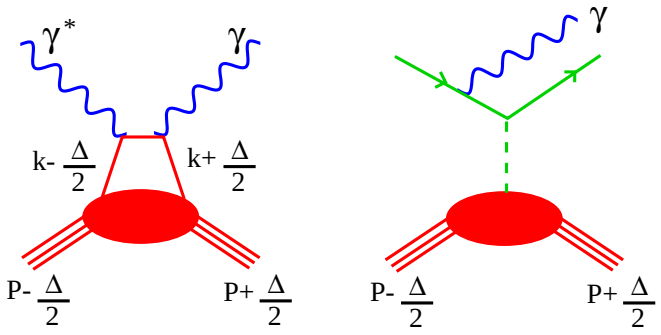
Recent theoretical work has provided a unifying framework to relate different processes: Skewed (or Generalized or Off-forward) Parton Distributions (SPD's)



- Exclusive processes such as Deeply Virtual Compton Scattering $\gamma^* p \rightarrow \gamma p$ are probes for SPD's. (DVCS theoretically cleanest avenue to study SPDs)

- Four SPD's per quark flavor: $H, E, \tilde{H}, \tilde{E}$ (two reduce to $q, \Delta q$ in the forward limit)

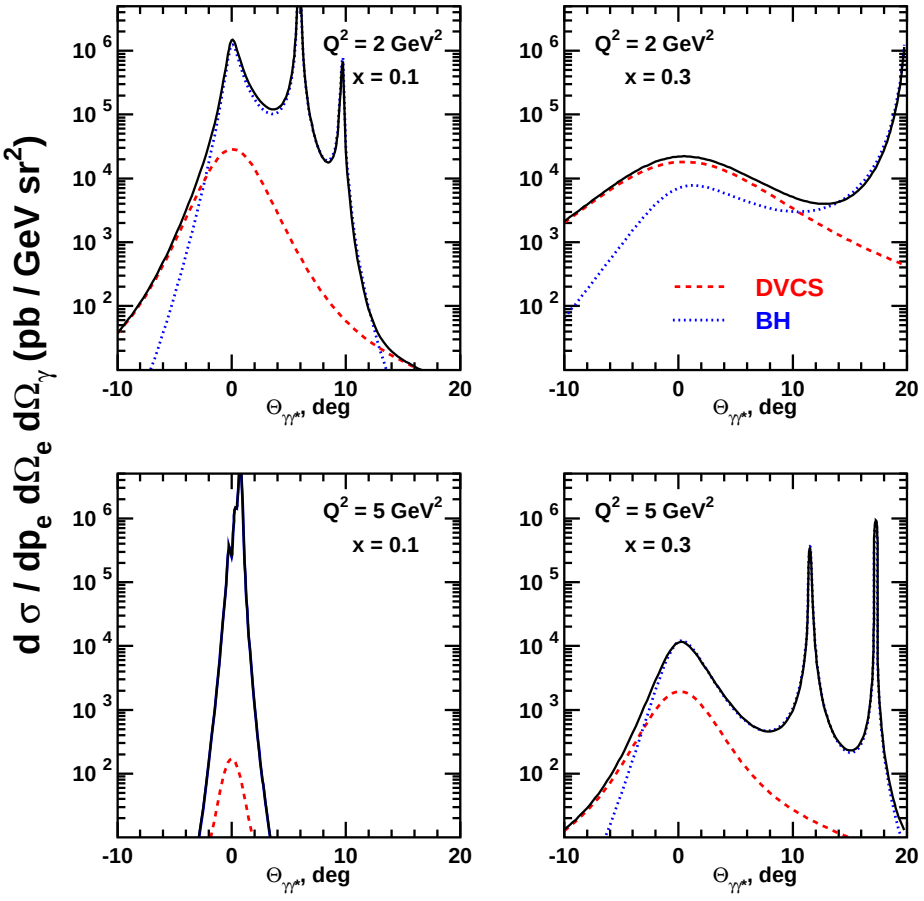
- 'Ji Sum Rule' relates the second moments of 2 SPD's (H, E) to the quark angular momentum



DVCS **B-H**

- Large contribution indistinguishable from DVCS: Bethe-Heitler process

For HERMES kinematics:



- HERMES makes use of interference → direct experimental access to DVCS amplitude

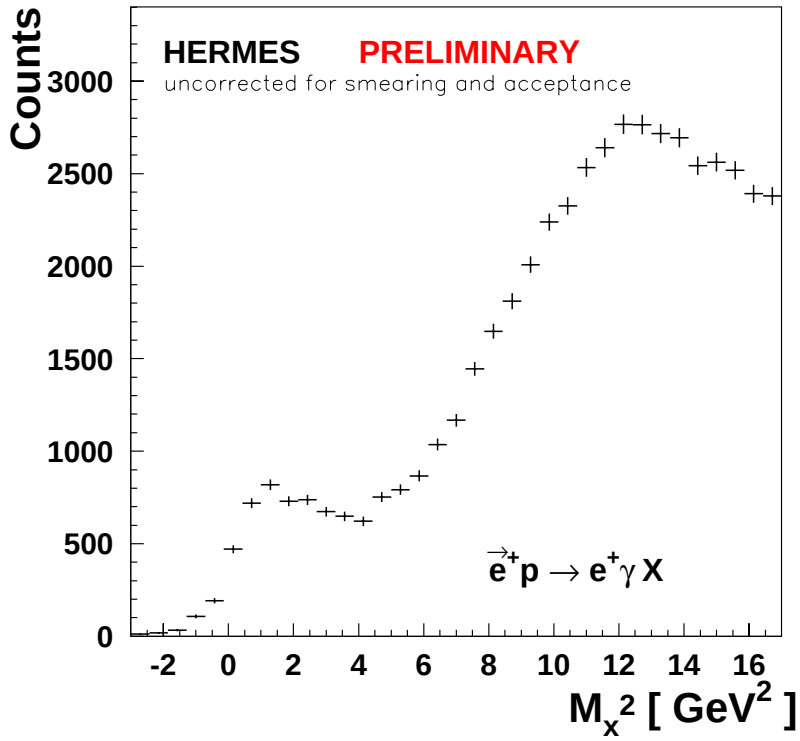
→ **Large azimuthal asymmetries expected**

Exclusive Reactions w/ Recoil Detector

Limitations of current measurements: exclusiveness of the reaction

$\rightarrow$ recoil proton not detected

e.g. DVCS: $\gamma^* p \rightarrow \gamma X$



Need to reject:

- non-exclusive background
- resonant background: e.g. $\gamma^* p \rightarrow \gamma \Delta$

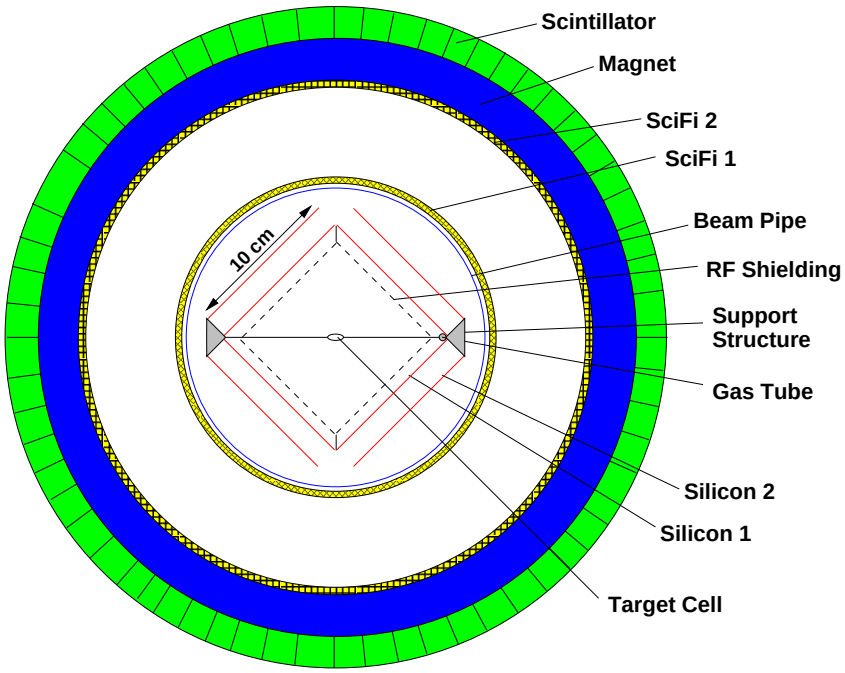
Plans for a Recoil Detector

Design requirements of the recoil detector:

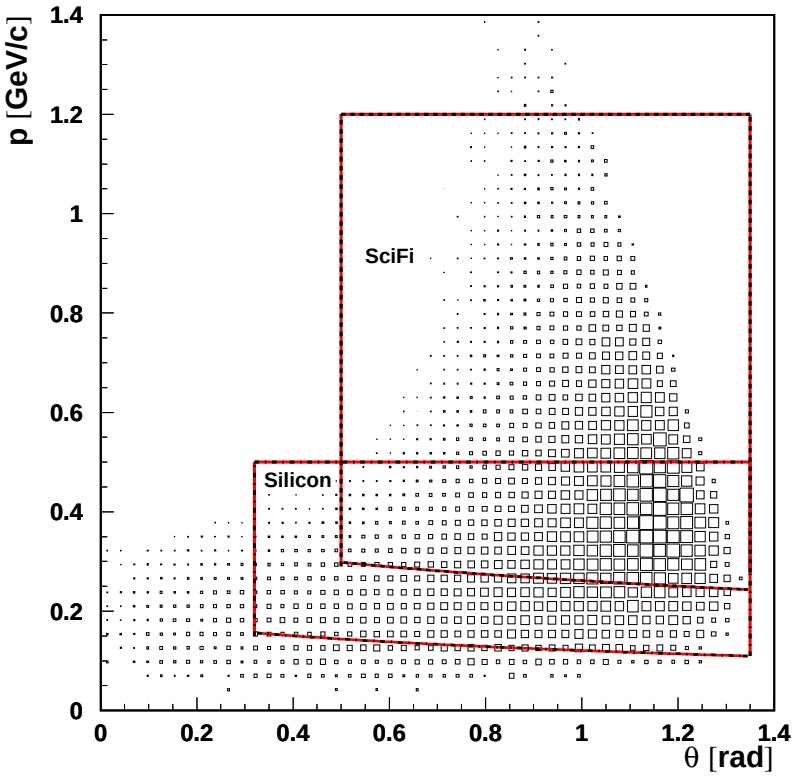
- identify recoil proton: momentum measurement in the range 100-1200 MeV/c
- identify charged, neutral pions: $\Delta \rightarrow \pi N$ (requires charged-π, p separation)
- hermeticity

Detector design:

- Two layers of silicon detectors around the target cell inside the beam pipe
- Two outer scintillating fiber trackers in a longitudinal magnetic field
- A layer of scintillator strips or pads for π^o detection using return yoke as preshower material

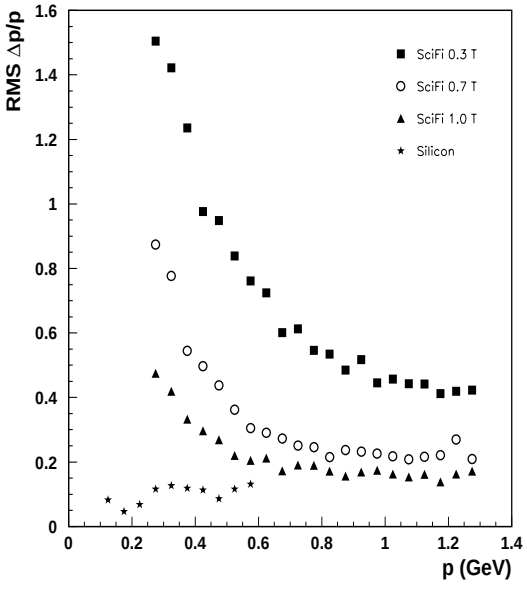


Would identify $> 85\%$ of recoil protons.

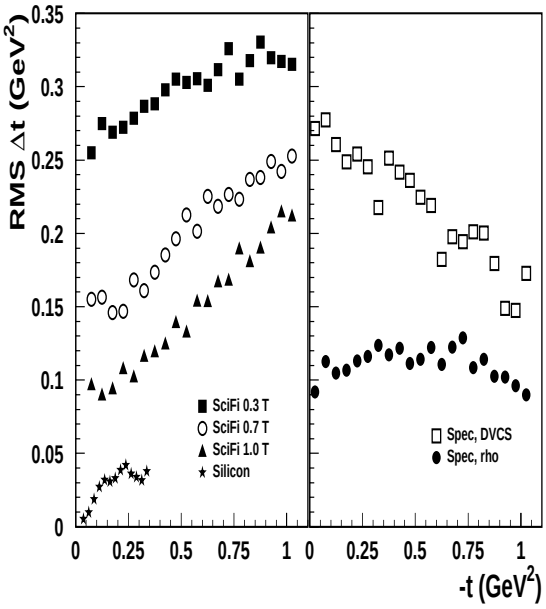


Expected Resolution:

Momentum Resolution



Momentum Transfer Resolution



$-t$ resolution best where most necessary (Ji sum rule requires extrapolation to $-t = 0$)

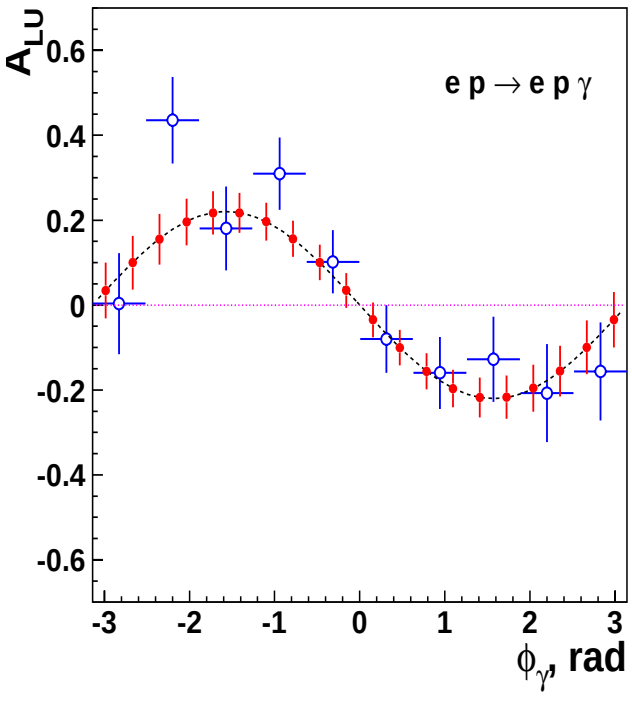
Projections for DVCS in Run 2

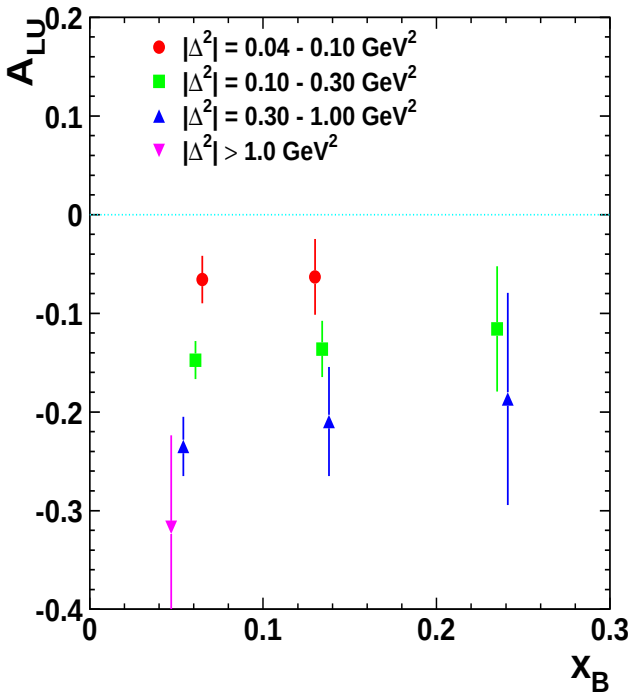
Projections [a] for DVCS in Run 2 with proposed recoil detector:

- Annual integrated luminosity of 2 fb^{-1} using unpolarized target (shorter cell required): normal running and end-of-fill high density runs
- Assume HERMES kinematics and acceptance
- SPD modeled according to Vanderhaegen, Guichon, Guidal, PRD60 (99) 094017

I - Beam-spin Asymmetry

- polarized beam on unpolarized target
- access imaginary part of DVCS amplitude



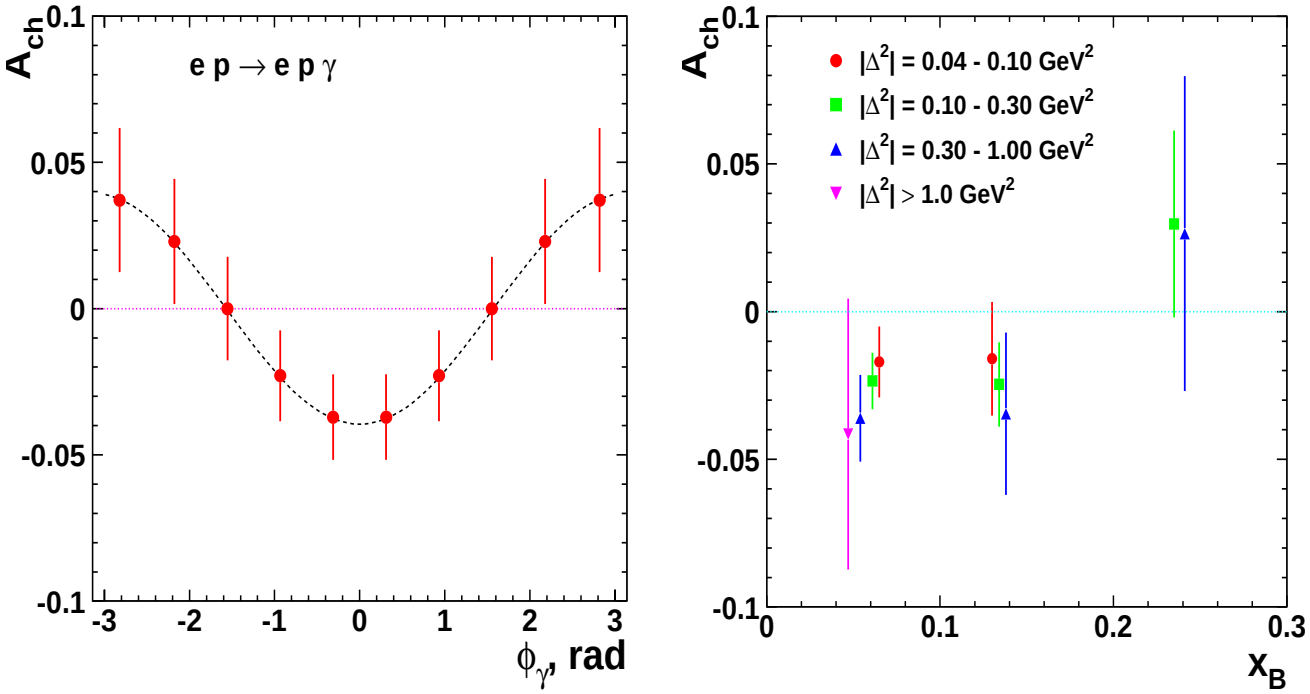


[a] (V. Korotkov, W.-D. Nowak, in preparation)

Projections for DVCS in Run 2

II - Beam-charge Asymmetry

- unpolarized beam on unpolarized target
- run with e^+ and e^- beams
- access real part of DVCS amplitude



- Two asymmetries provide complimentary information
- DVCS $\rightarrow$ access information on the SPD's: $H, \tilde{H}, E$ (E suppressed)

Conclusion

HERMES post-Run 1

- precise polarized parton distributions
  - valence quarks well constrained
  - sea quarks within reach!
  - gluons still essentially unknown
- a first glimpse of transversity
- data and tools in hand to begin accessing skewed parton distributions and orbital angular momentum

HERMES Run 2

- Continue unpolarized physics program (nuclear effects with heavy targets)
- More longitudinal running? Significant improvement of $\overline{u}$ sea
- First measurements of transversity and of the polarized fragmentation function
- High density unpolarized running with the recoil detector: access Skewed Parton Distributions