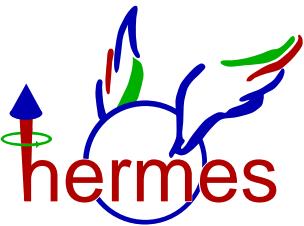


Exclusive Electroproduction of Vector and Pseudoscalar Mesons at

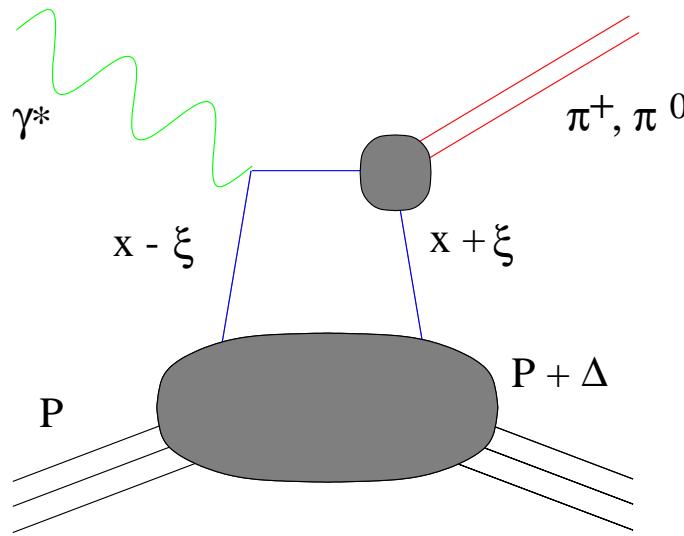


Christian Schill
on behalf of the HERMES Collaboration



SPIN 2002 conference
September 8-14, Brookhaven

-
- Generalized parton distributions (GPD)
 - Exclusive vector mesons (ρ , ω , ϕ)
 - Exclusive pseudoscalar mesons (π^+ , π^0)
-



3 variables

- x mean value of longitudinal momentum fraction
- ξ exchanged long. momentum fraction $\xi = \frac{x_B}{2-x_B}$
- momentum transfer $t = \Delta^2$

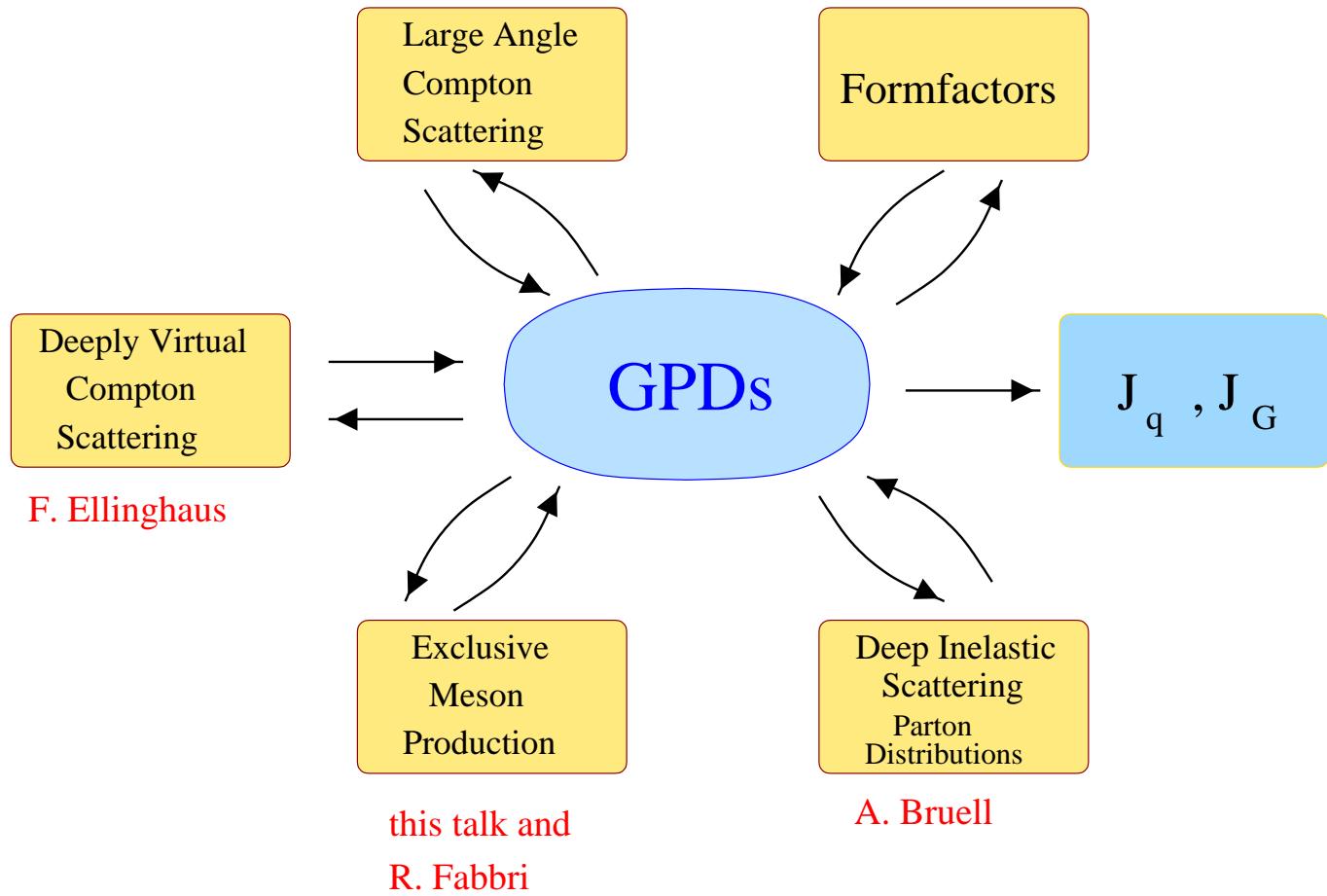
4 different GPDs per flavour:

$$\begin{array}{ll}
 H^q(x, \xi, t) & \tilde{H}^q(x, \xi, t) \text{ conserve nucleon helicity} \\
 E^q(x, \xi, t) & \tilde{E}^q(x, \xi, t) \text{ flip nucleon helicity} \\
 \downarrow & \downarrow \\
 \text{unpolarized} & \text{polarized } \gamma^*
 \end{array}$$

Quantum numbers of final states allow to select different GPDs:

- Vector mesons → unpolarised GPDs E, H
- Pseudoscalar mesons → polarised GPDs \tilde{E}, \tilde{H}

Unified theoretical description of inclusive and (hard) exclusive processes:



- **GPDs:** generalisation of usual Parton Distributions and nucleon form factors
- in the limit $\xi = 0$ and $t = 0$:

$$\begin{aligned} H^q(x, 0, 0) &= q(x_B) \\ \tilde{H}^q(x, 0, 0) &= \Delta q(x_B) \end{aligned}$$

- access to orbital angular momentum J_q

$$\int x dx (H + E) = J_q$$

- Quadratic combinations of GPDs appear in the **longitudinal** component of **unpolarized exclusive electroproduction cross sections**:

(M. Vanderhaegen et al. PRL **80** (1998) 5064):

$$\sigma_{\rho_0}^p \propto 1/2 \left(2/3 H^{u/p} + 1/3 H^{d/p} \right)^2$$

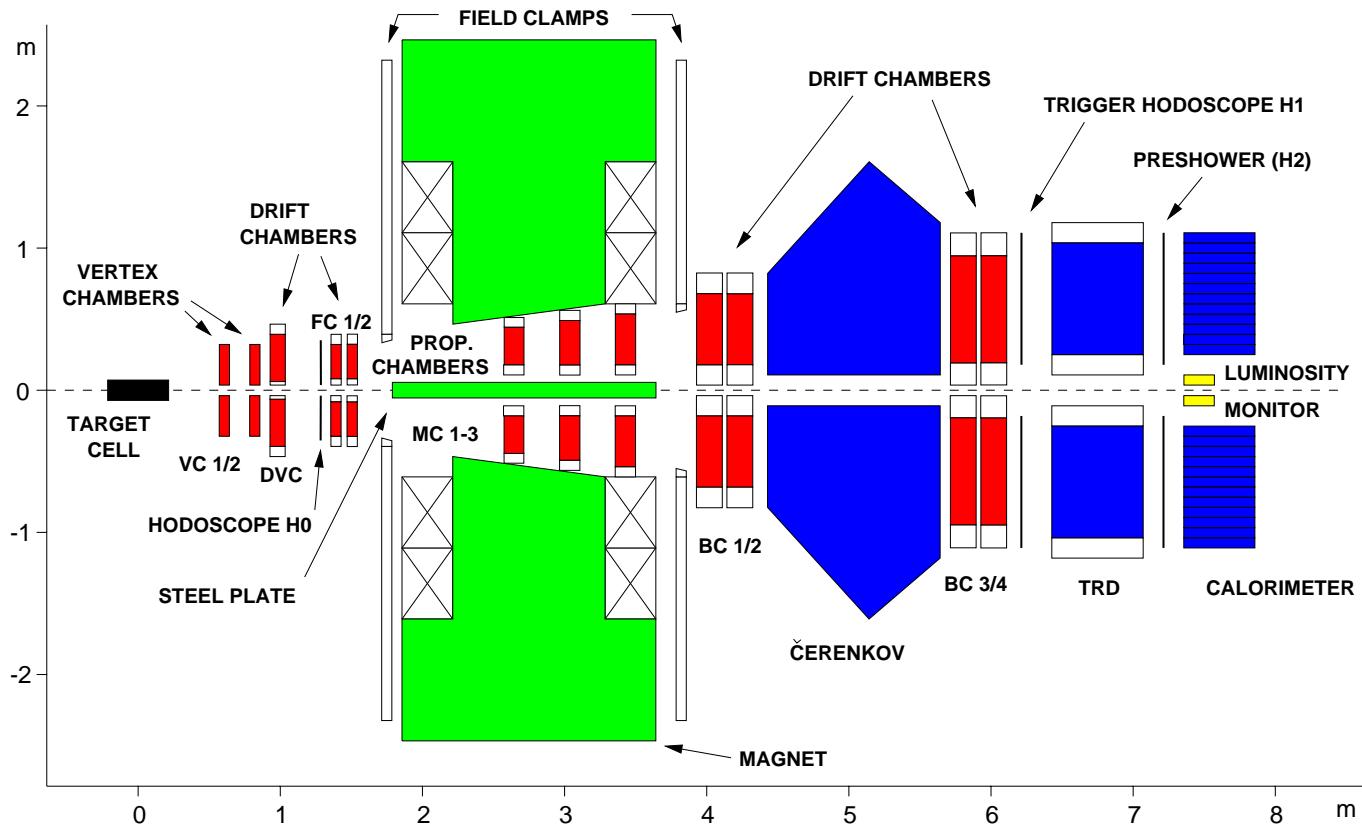
$$\sigma_{\pi_0}^p \propto 1/2 \left(2/3 \tilde{H}^{u/p} + 1/3 \tilde{H}^{d/p} \right)^2$$

- Single Spin Asymmetries for exclusive meson production on a transversely polarized target:

(L.L.Frankfurt et al. PRL **84** (2000) 2589):

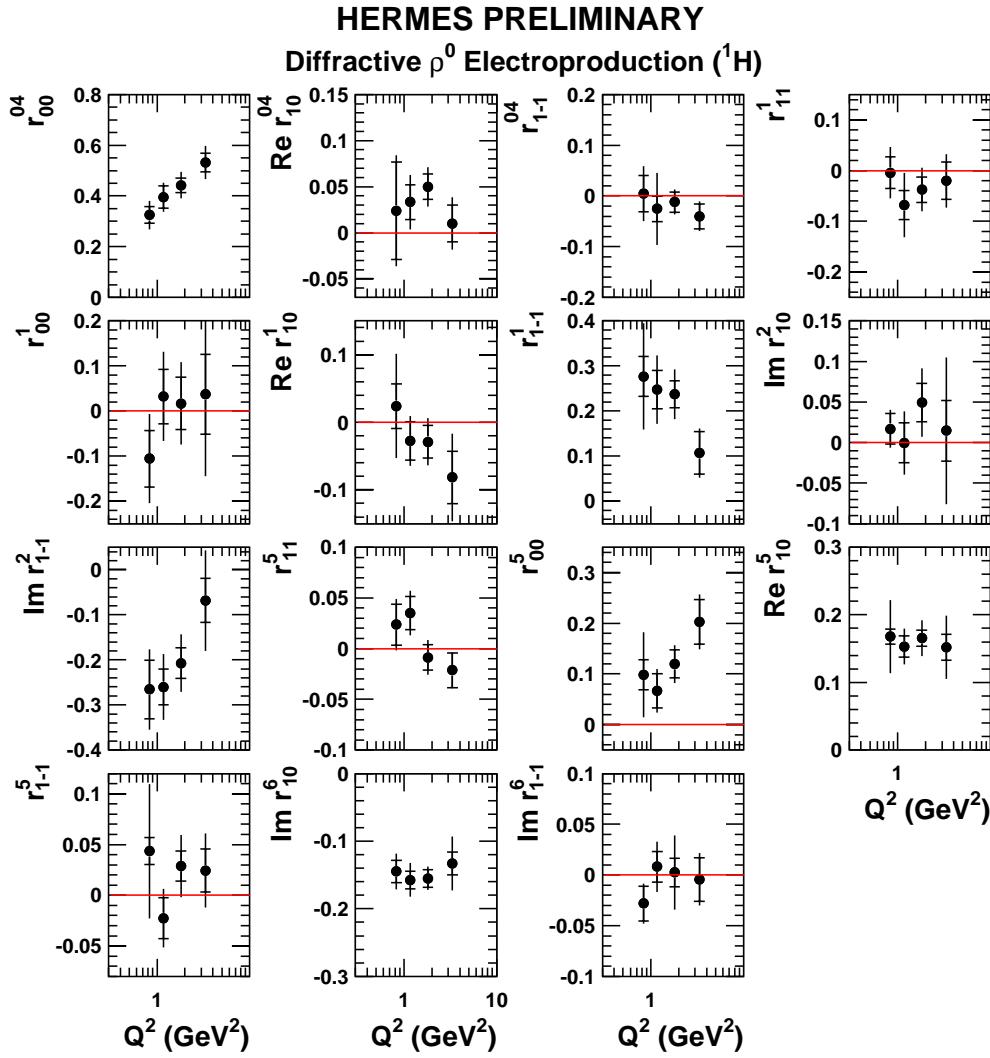
$$\sigma \propto |S_{\perp target}| \cdot \sin \phi \cdot \frac{\sqrt{t_{min}-t}}{-t+M_P^2} \cdot \tilde{H}$$

for $\gamma^* p \rightarrow n \pi^+$



- beam: 27.5 GeV Hera pol. \vec{e}^+ (\vec{e}^-)
- target: pol. (\vec{H} , \vec{D} , ${}^3\vec{\text{He}}$) and high density unpol. gas target
- **tracking: 57 tracking planes**
 $\delta P/P = (0.7 - 1.3)\%$
- **calorimetry: 840 Lead-glasses**
 $\delta E/E = 0.051/\sqrt{E} + 0.02 + 0.1/E$, $\delta\theta_\gamma \sim 1$ mrad
- **PID: Čerenkov, TRD, Preshower, Calorimeter**
- **RICH from 1998**

Factorization proof holds for the long. component only
 → extract the long. component of the ρ (ω , ϕ) cross section from the decomposition of decay-angle distr. → the polarization density matrix



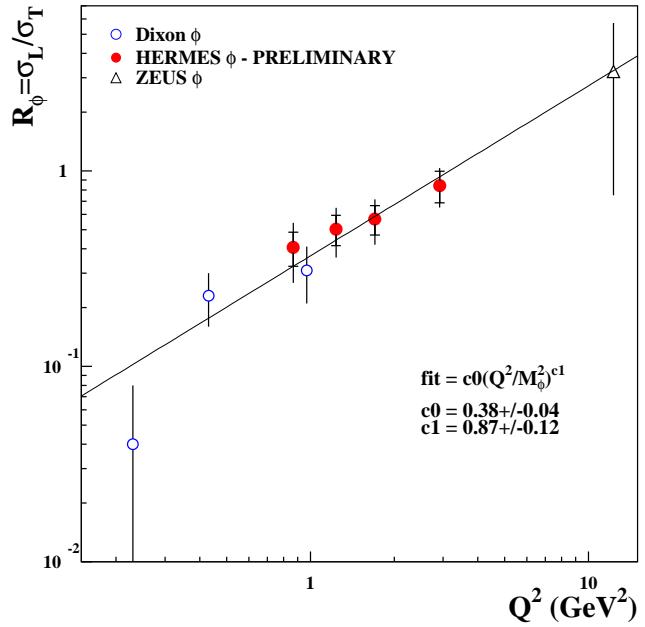
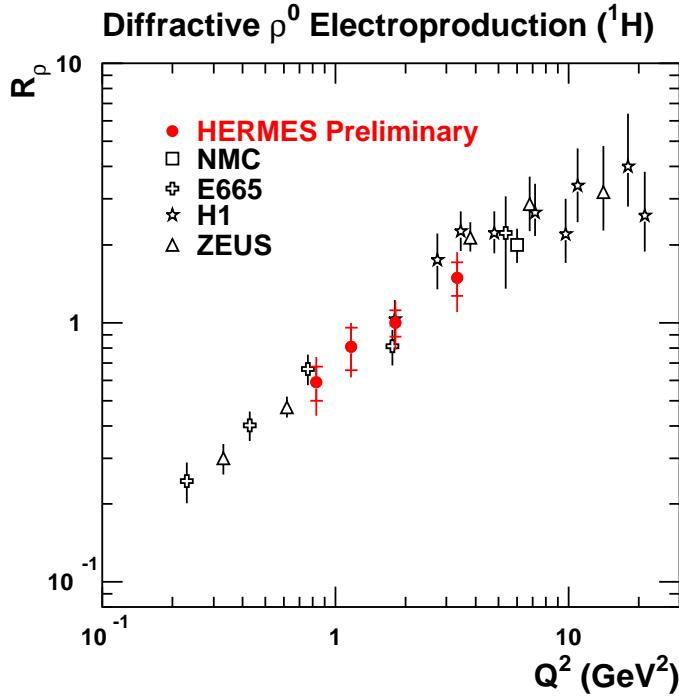
Similar results have been obtained for the ϕ .

SCHC (red line) assumption : helicity of the virtual photon is preserved by the produced VM

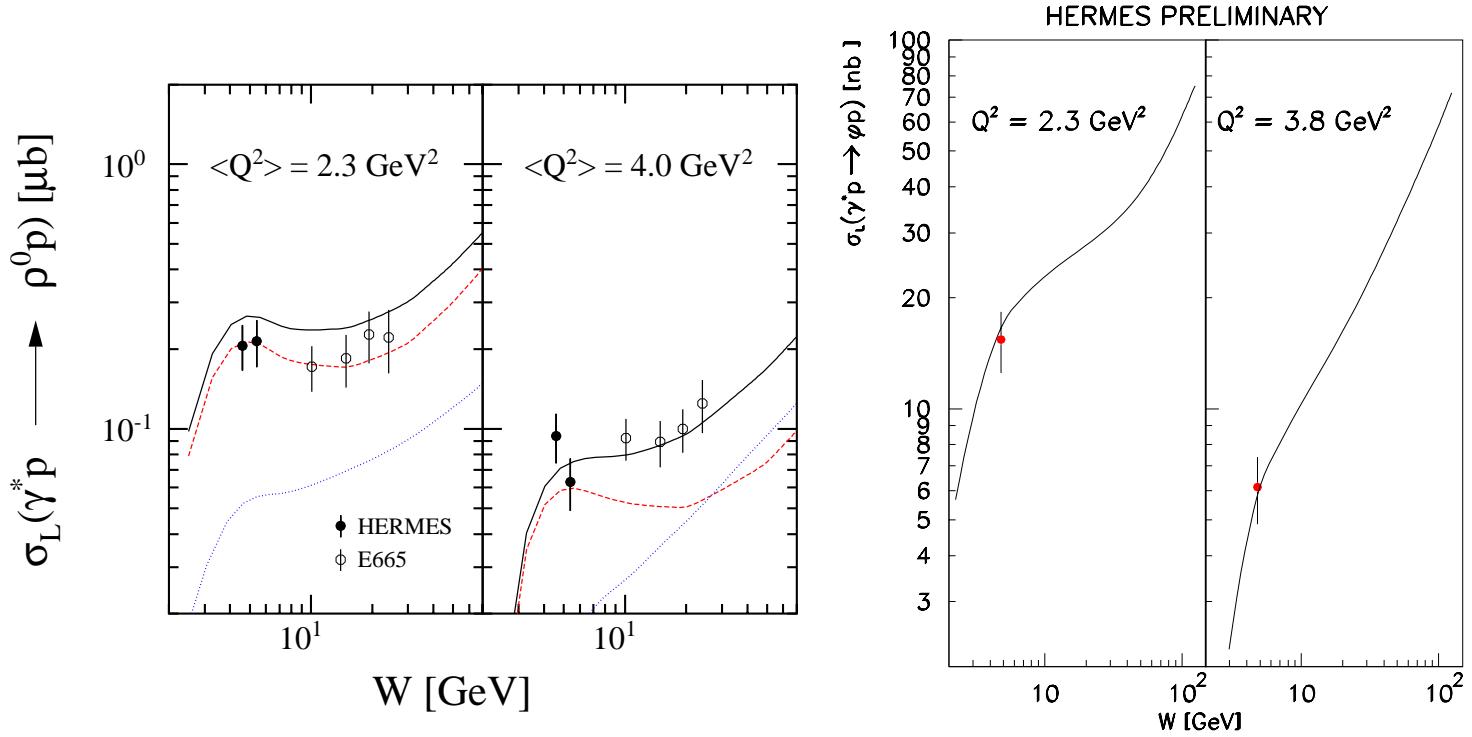
SCHC is valid except for r_{00}^5 (also in ZEUS and H1)

With the assumption of s-channel helicity conservation,
knowledge of γ^* polarization \rightarrow longitudinal component
of the ρ and ϕ

$$R = \frac{\sigma_L}{\sigma_T} = \frac{1}{\epsilon} \frac{r_{00}^{04}}{1 - r_{00}^{04}}$$



Strong increase of the longitudinal component with Q^2
Good agreement with previous data at higher W



Good agreement with GPD calculations

$H_{LO} \propto MRS$ quark distribution + higher twists

(M.Vanderhaegen, P.A.M.Guichon, M.Guidal)



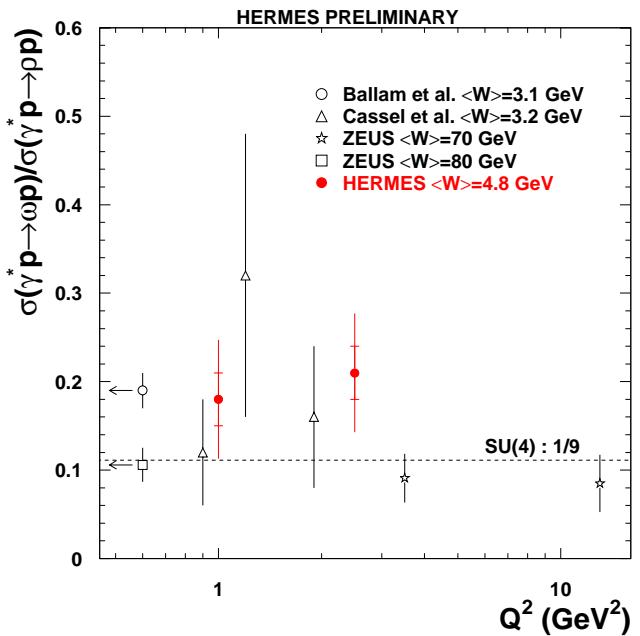
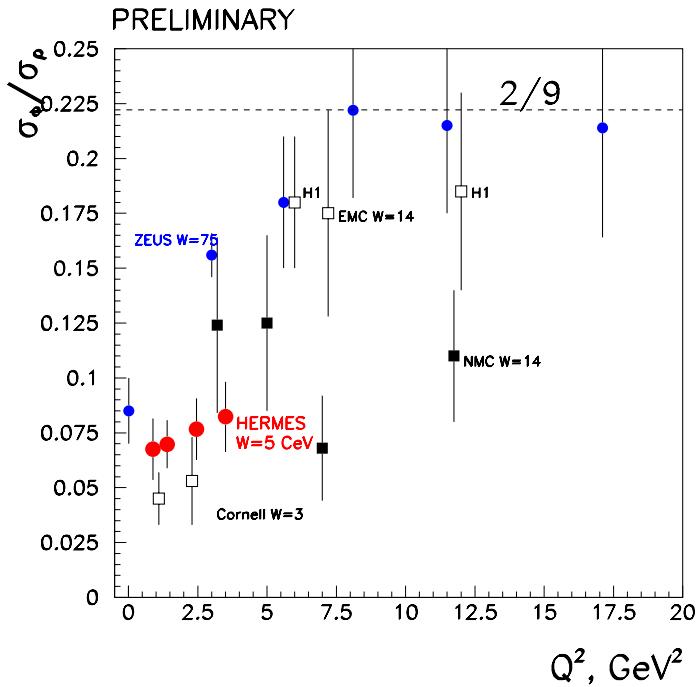
Dominance of quark exchange for $\sigma(\gamma^* p \rightarrow \rho^0 p)$

Dominance of 2-gluon exchange for $\sigma(\gamma^* p \rightarrow \phi p)$

Model dependent higher twist effects mostly cancel in cross section ratios of VM production



Precocious scaling for ϕ/ρ and ω/ρ

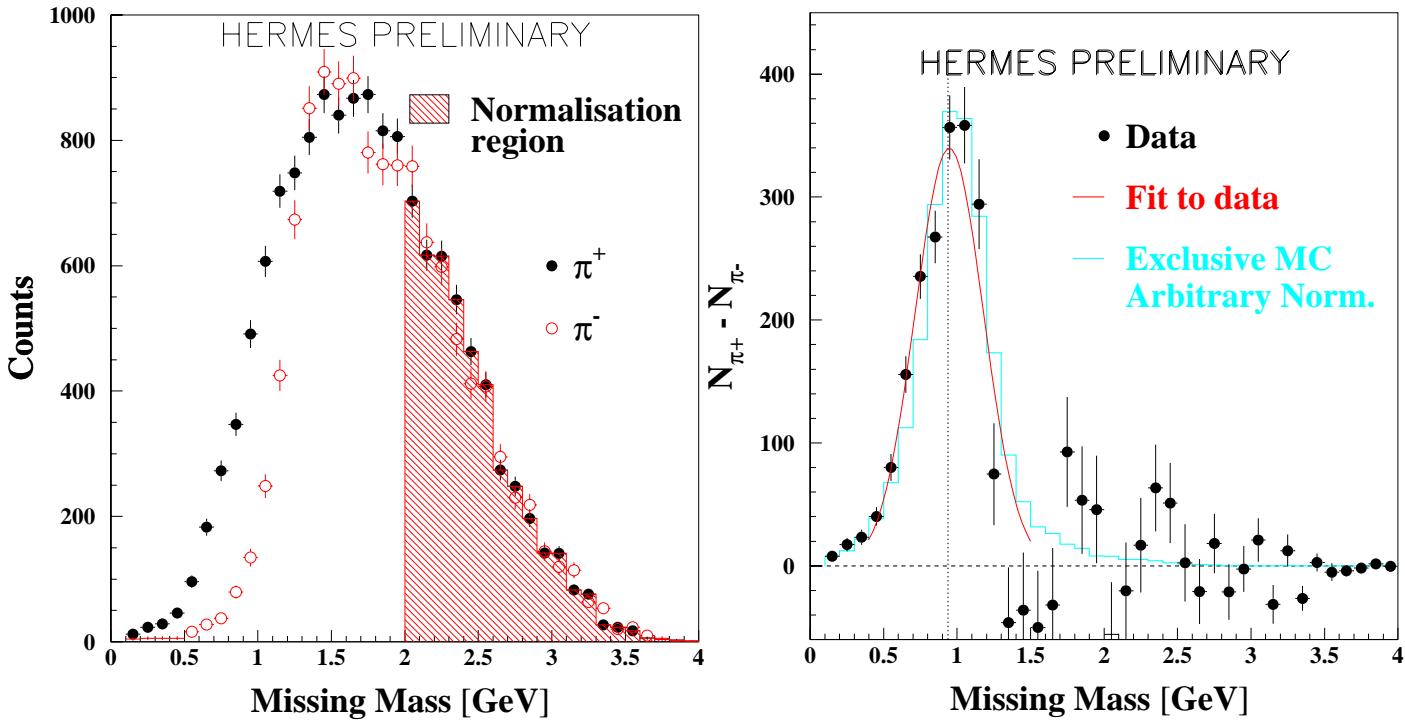


σ_ϕ/σ_ρ at low Q^2 and W well below the SU(4) prediction of $2/9 \rightarrow$ quark exchange in the ρ production.

$\sigma_\omega/\sigma_\rho$ at low W slightly above the SU(4) prediction of $1/9$ and consistent with GPDs expectation of $1/5$

(M.Vanderhaegen, P.A.M.Guichon, M.Guidal)

$e'\pi^+n$ via $(e'\pi^+X - e'\pi^-X)$



clear peak at missing mass $\approx M_n$

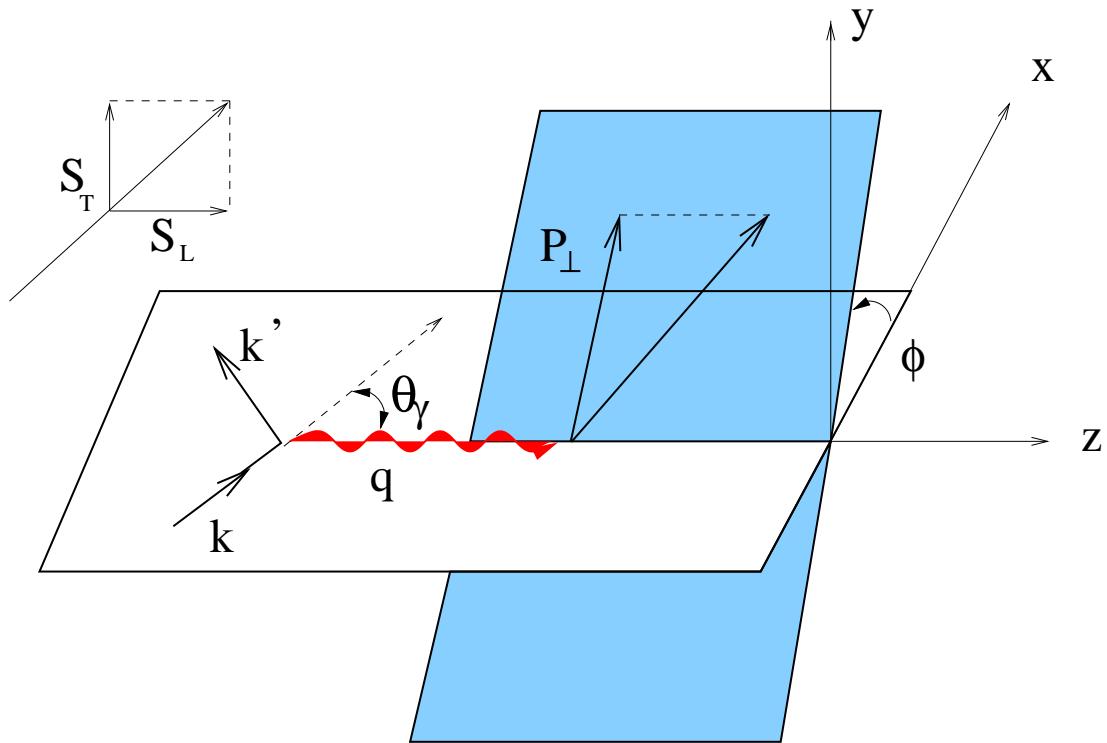
position and width agree with Monte Carlo based on GPD model for $\sigma_L(Q^2, x, t)$

(Mankiewics, Piller, Radyushkin, EPJ C10(1999), 307)

No L/T (Rosenbluth) separation is foreseen for the moment

A powerful tool in exclusive physics are Single Spin Azimuthal Asymmetries

$$A(\phi) = \frac{1}{|P|} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$



Transverse and longitudinal components in γ^* frame:

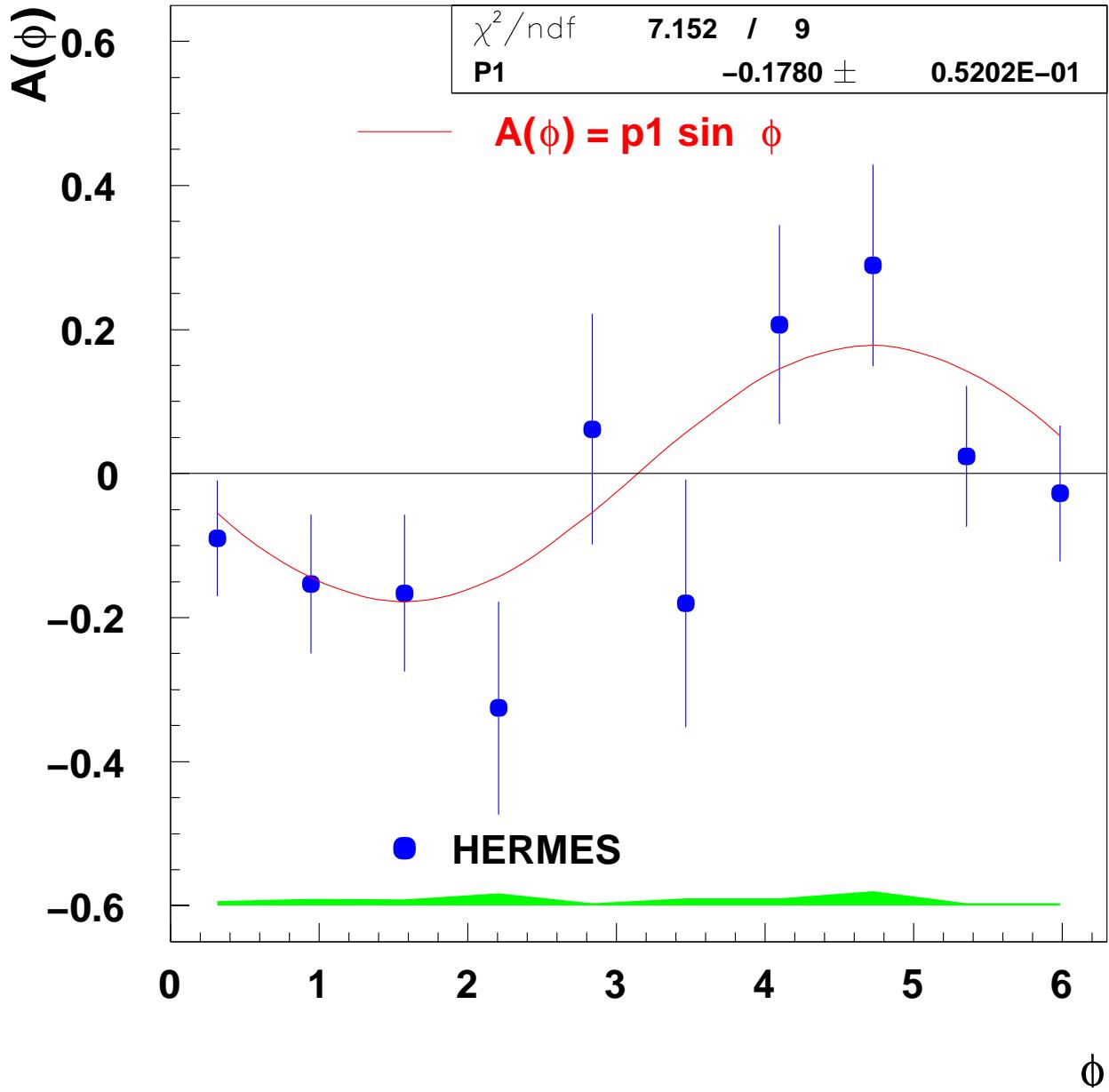
$$\sigma_S \sim [S_\perp \sigma_L + S_\parallel \sigma_{LT}] \cdot A_{UL}^{\sin \phi} \sin \phi$$

σ_{LT} suppressed by $1/Q \dots$ but $S_\parallel > S_\perp$

HERMES in 1997:

$$S_\perp/S \sim 0.17$$

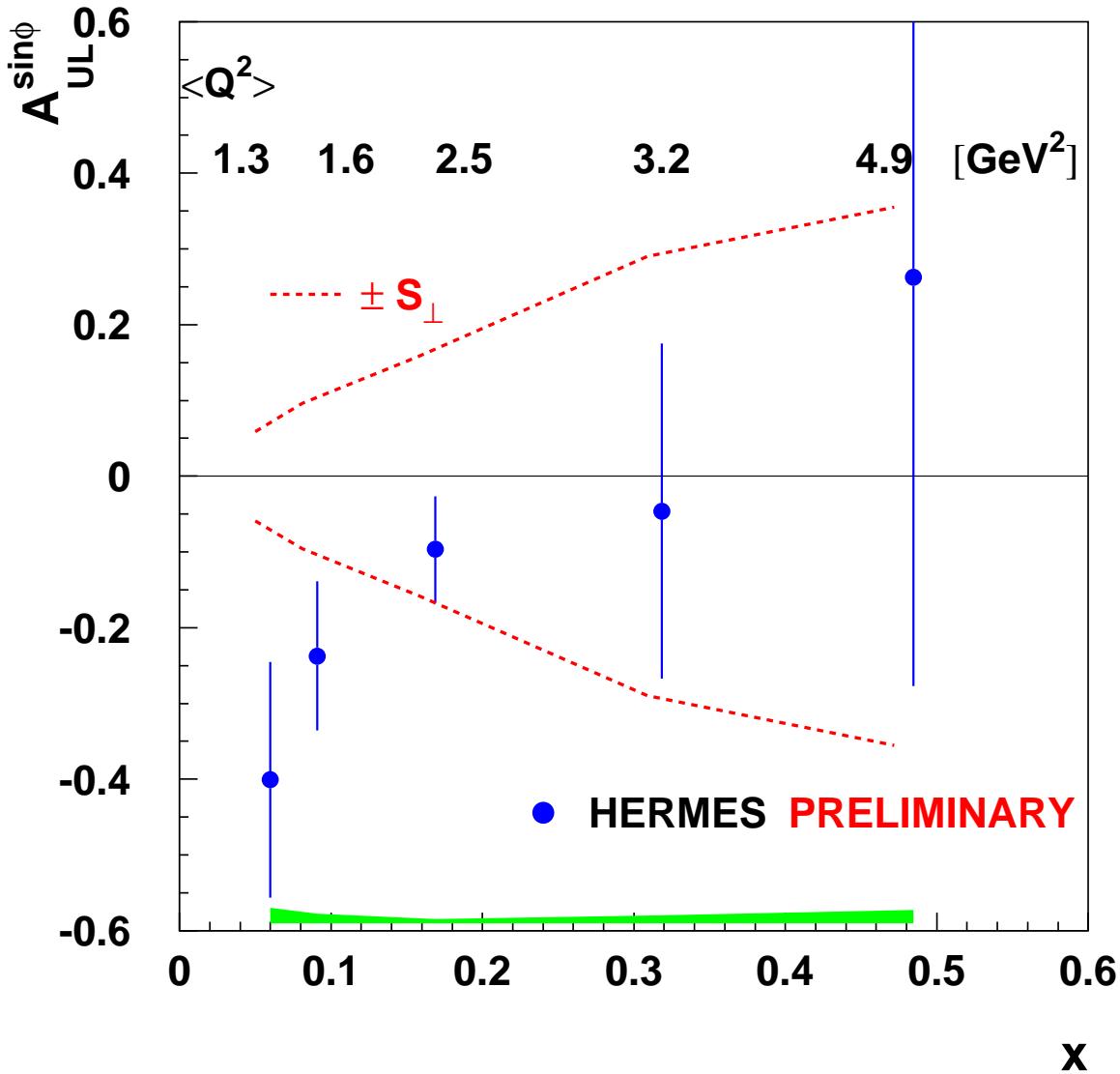
Exclusive π^+ lepto production on Hydrogen



$$A(\phi) = A_{\text{UL}}^{\sin \phi} \cdot \sin \phi \rightarrow A_{\text{UL}}^{\sin \phi} = -0.18 \pm 0.05 \pm 0.01$$

$\sin 2\phi, \cos \phi, \cos 2\phi$ moments compatible with zero

Exclusive π^+ lepto production on Hydrogen



$$\sigma_P \sim [S_{\perp}(x, Q^2)\sigma_L + S_{\parallel}(x, Q^2)\sigma_{LT}]$$

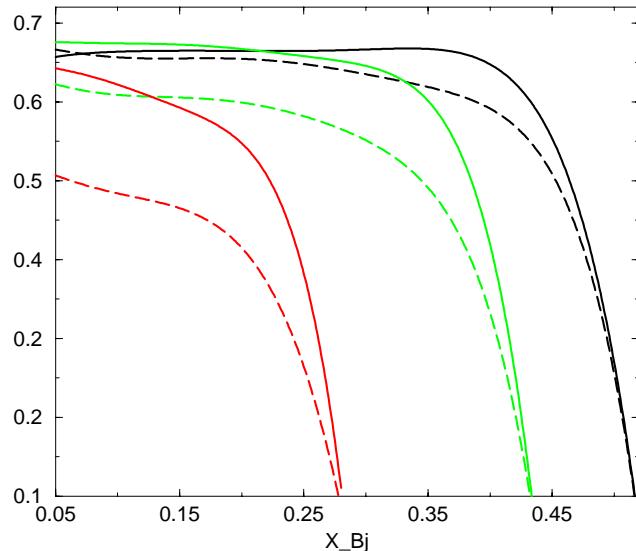


Asymmetry at low x arises from S_{\parallel} component

Large SSA expected for transverse target due to interference between pole and non-pole amplitudes

$$\sigma \propto |S_\perp| \sin \phi \quad \tilde{E} \cdot \tilde{H}$$

- \tilde{E} : π pole contribution
→ π FF
- \tilde{H} : Forward limit:
→ Δq



(Frankfurt, Pobylitsa, Polyakov, Strikman PRD 60 (1999) 014010)

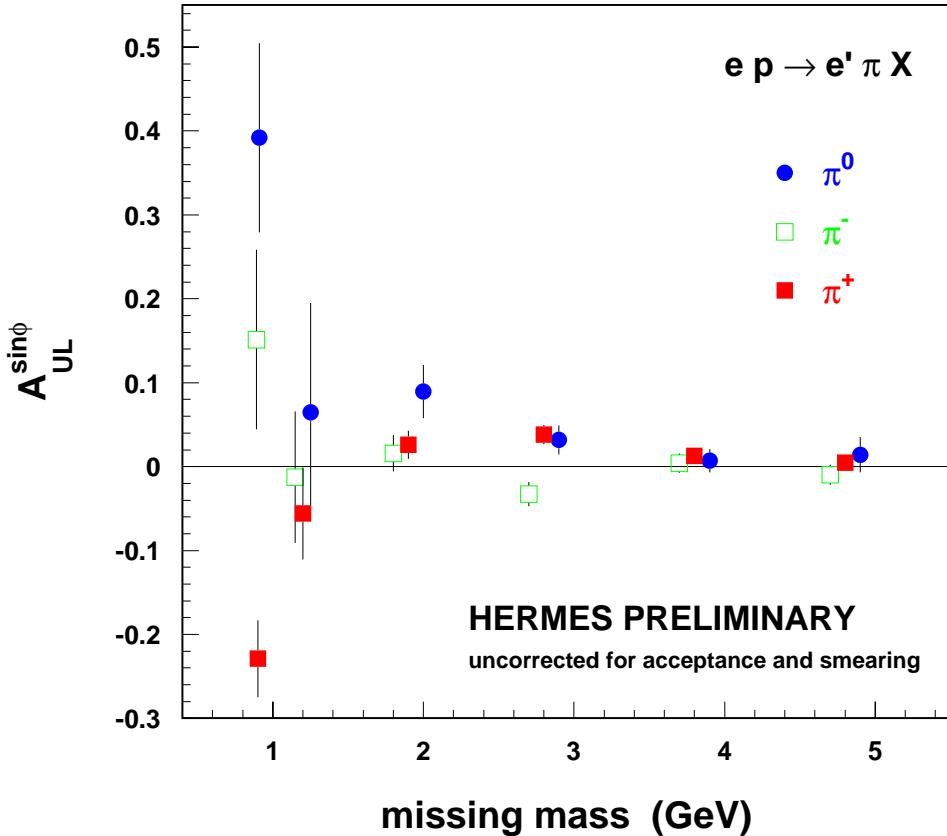
The size of the asymmetry depends on the pion f.f. :
 1- asymptotic pion distribution amplitude
 2- Chernyak-Zhitnitsky pion DA

HERMES transverse target running started this year:



Other exclusive mesons:

$e p \rightarrow e' \pi^0 p$ electroproduction and SSA



Pseudoscalar ratios:

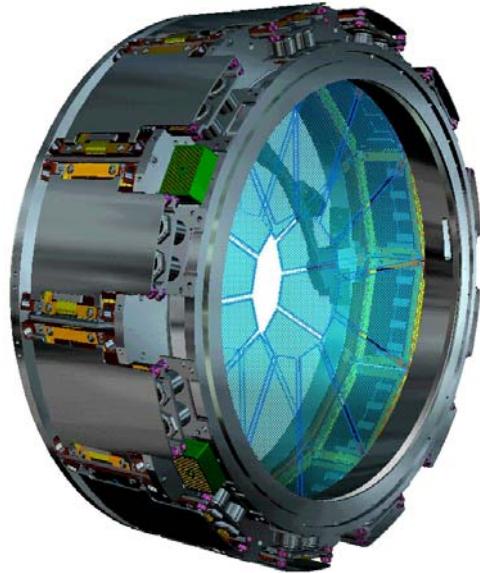
$ep \rightarrow e' \pi^+ p / ep \rightarrow e' \pi^0 p$

$ep \rightarrow e' \eta p / ep \rightarrow e' \pi^0 p$

$ep \rightarrow e' \pi^0 p / en \rightarrow e' \pi^0 n$

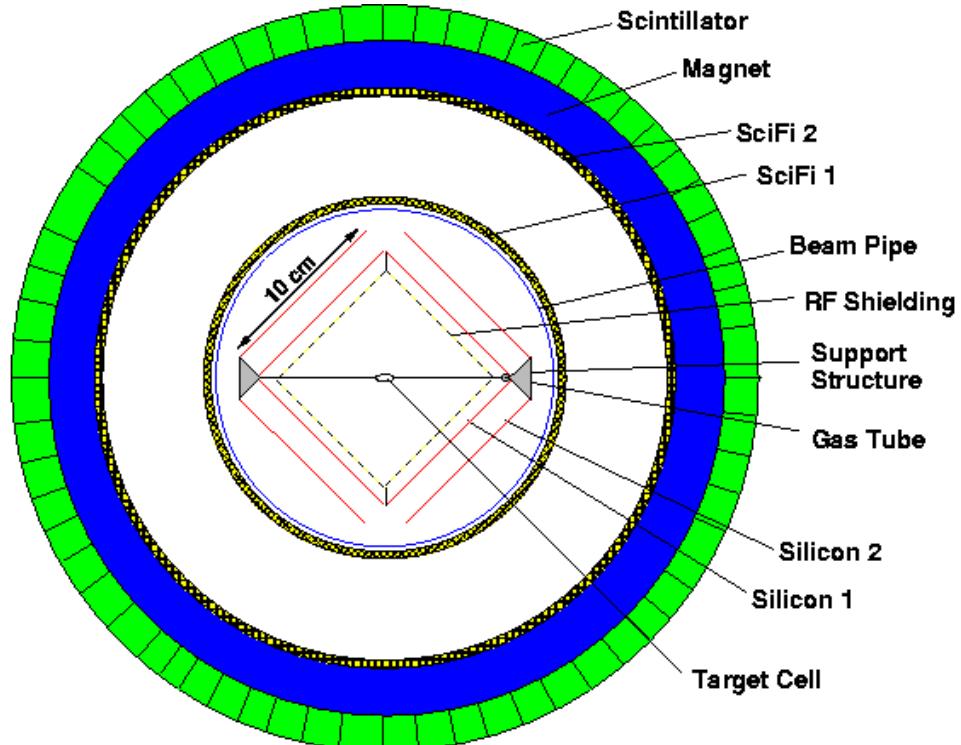
→ detection of the recoiling proton

Λ wheel detector (installed):



Large short-track acceptance

Recoil detector (2004-2005):



- First promising results from HERMES in exclusive production of vector mesons (ρ , ω , ϕ) and pseudoscalar mesons (π^+)
 - Ongoing analysis for additional exclusive processes (π^0 , η , kaons)
 - ⇒ comparison to GPD predictions
- start of measurements with transversely polarized target this year
- detector upgrades: lamda wheels and recoil detector