Exclusive Electroproduction of Vector and Pseudoscalar Mesons at

hermes

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on behalf of the HERMES Collaboration

INFN Frascati

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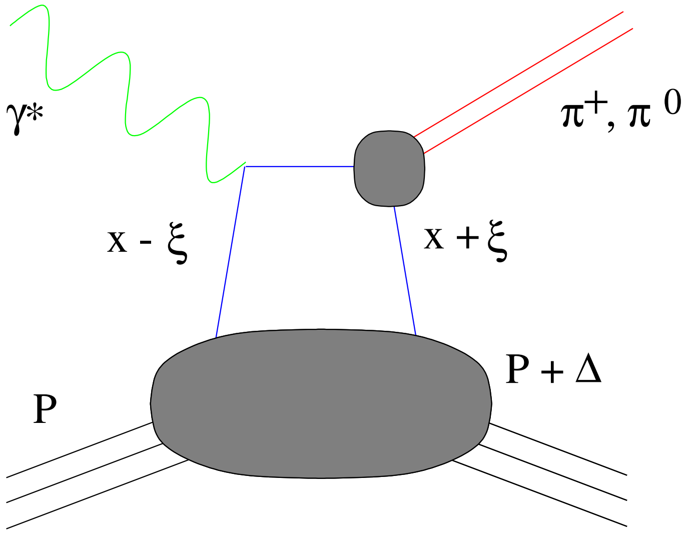
- Generalized parton distributions (GPD)
- Exclusive vector mesons (ρ, ω, ϕ)
- Exclusive pseudoscalar mesons (π^+, π^0)

GPDs



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:

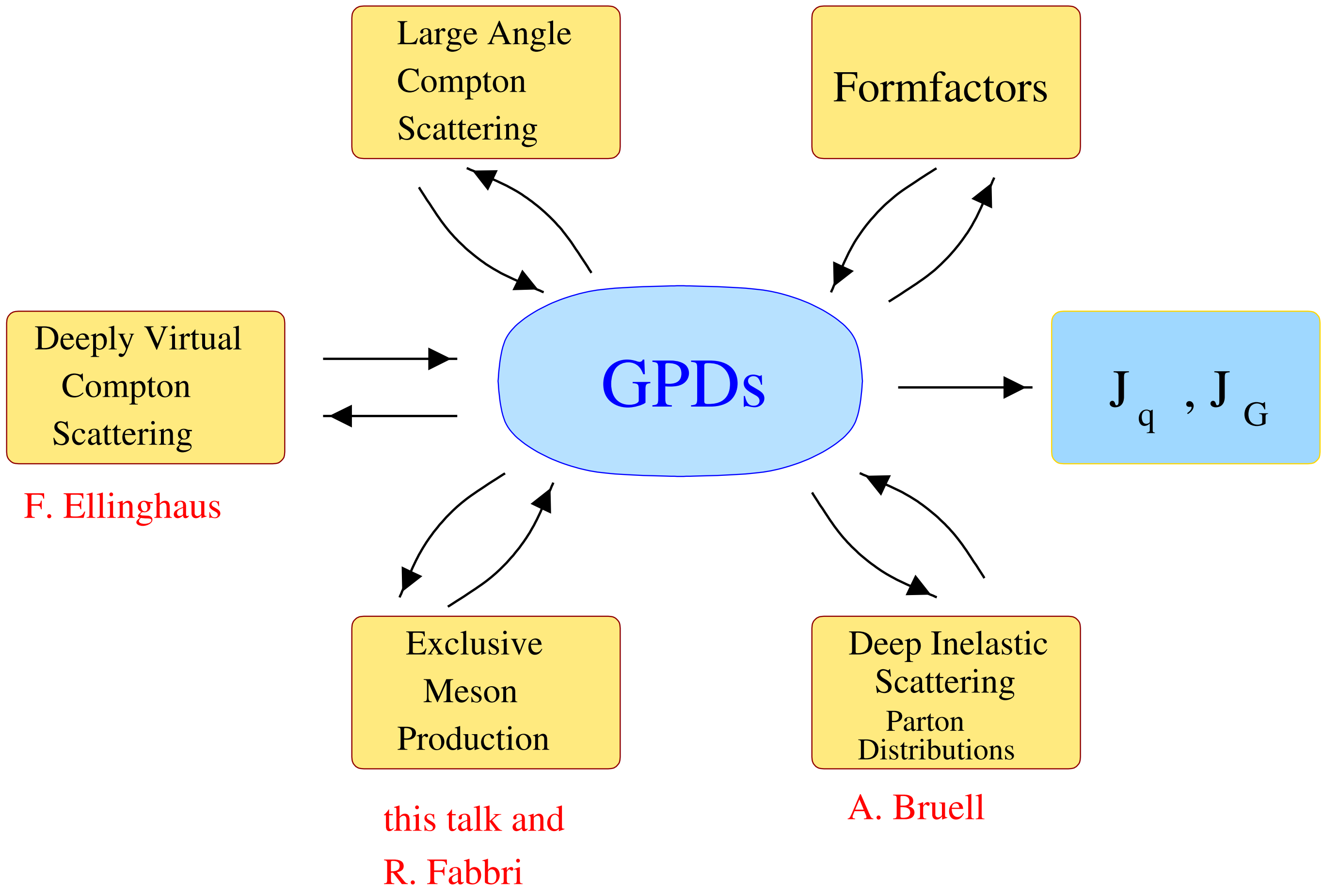
$H^q(x,\xi,t)$ $\tilde{H}^q(x,\xi,t)$ conserve nucleon helicity
$E^q\,(x,\xi,t)$ $\tilde{E}^q(x,\xi,t)$ flip nucleon helicity
$\Downarrow$ $\Downarrow$
unpolarized polarized γ^*

Quantum numbers of final states allow to select different GPDs:

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

GPDs

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 $t = 0$:

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

- access to orbital angular momentum J_q

$$\boxed{\int x \mathrm{dx}(\mathrm{H}+\mathrm{E}) = \mathrm{J_q}}$$

GPD's Observables

- Quadratic combinations of GPDs appear in the longitudinal component of unpolarized exclusive electroproduction cross sections:
  (M. Vanderhaegen et al. PRL **80** (1998) 5064):

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

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

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

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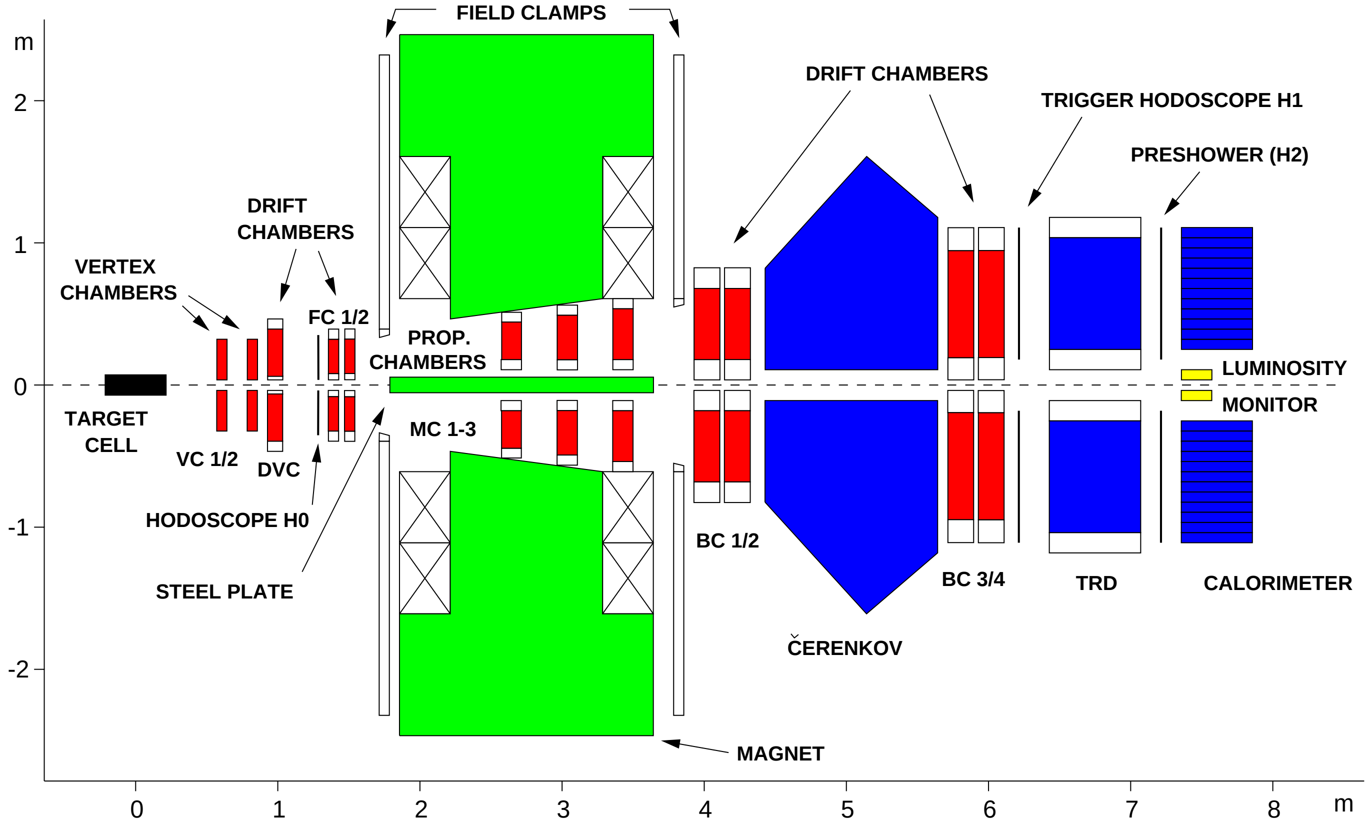

- beam: 27.5 GeV Hera pol. $\vec{e}^{+}$ ($\vec{e}^{-}$)
- target: pol. ($\vec{H}$, $\vec{D}$, $^{3}\vec{\mathrm{He}}$) and high density unpol. gas target
- **tracking: 57 tracking planes**
  $\delta P/P = (0.7 - 1.3)\%$
- **calorimetry: 840 Lead-glasses**
  $\delta E/E = 0.051/\sqrt{E} + 0.02 + 0.1/E$,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

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$ep \rightarrow e'\rho^0 p$

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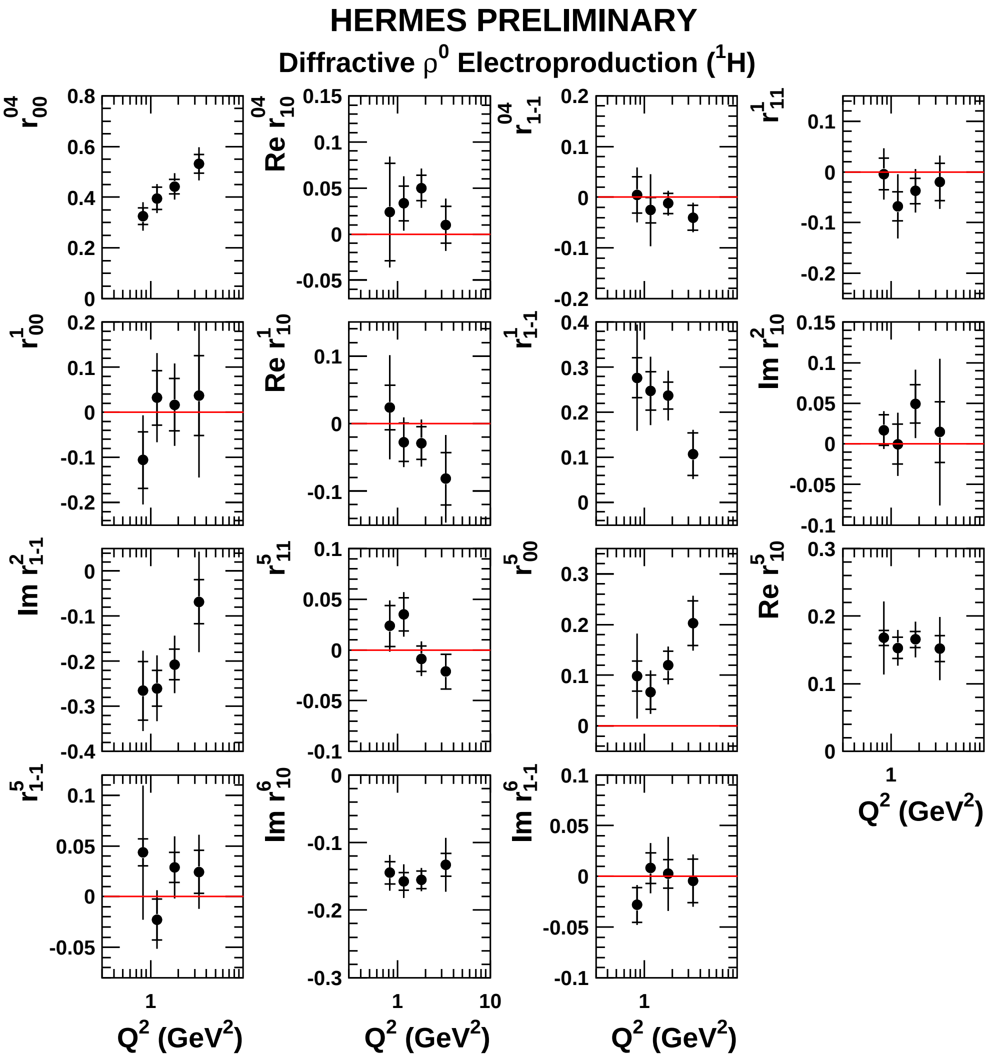
Factorization proof holds for the long. component only $\rightarrow$ extract the long. component of the ρ (ω, ϕ) cross section from the decomposition of decay-angle distr. $\rightarrow$ the polarization density matrix



Similar results have been obtained for the ϕ.

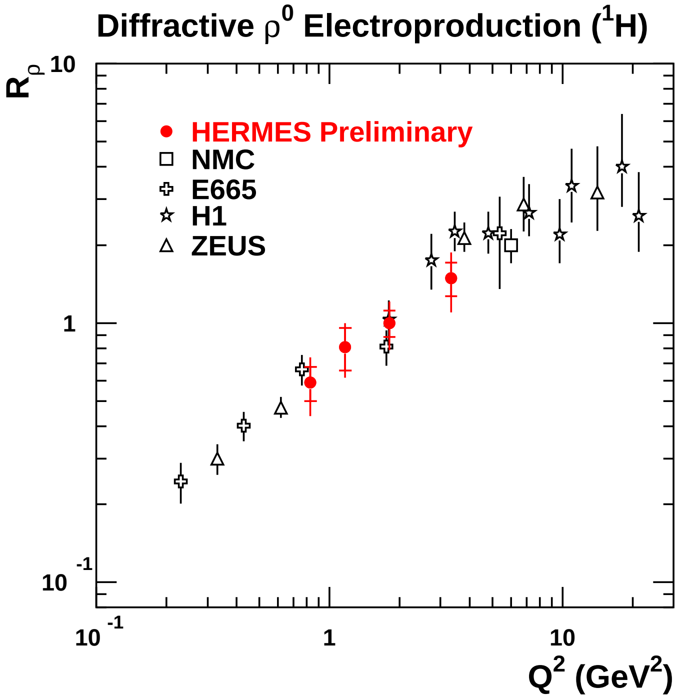
SCHC (red line) assumption : helicity of the virtual photon is preserved by the produced VM

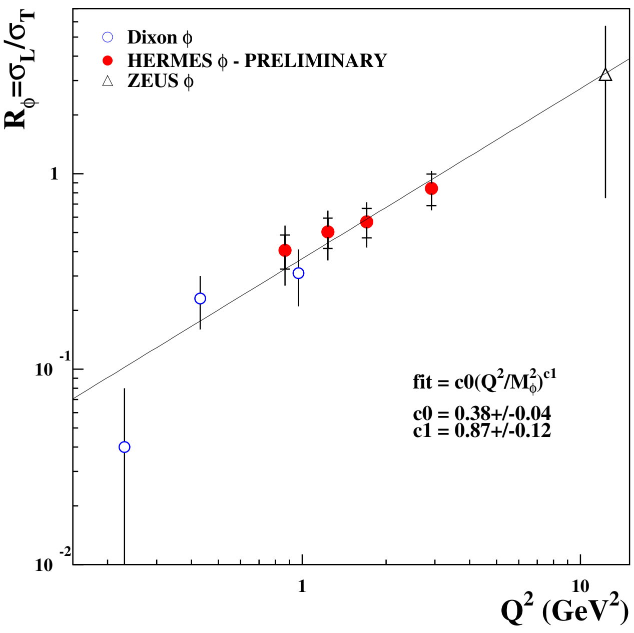
SCHC is valid except for r^5_{00} (also in ZEUS and H1)

σ_L/σ_T for ρ and ϕ

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

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

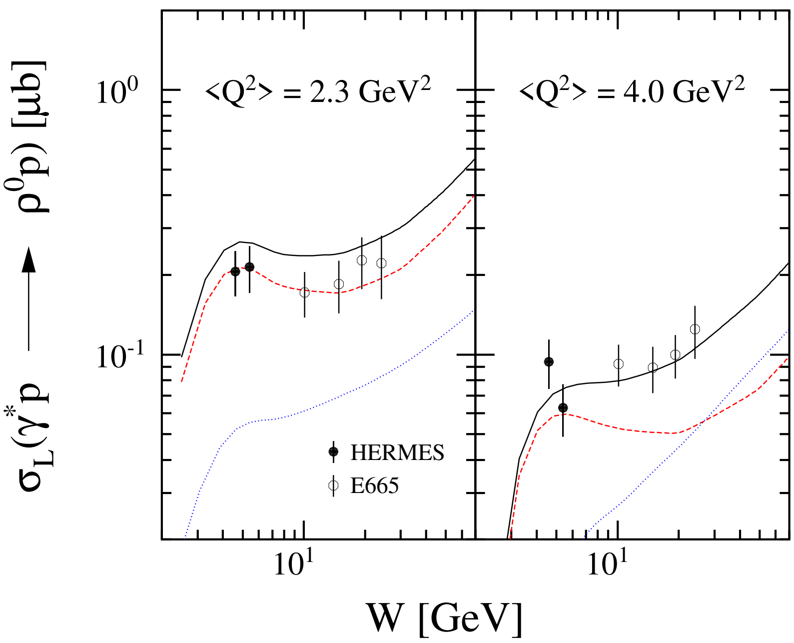


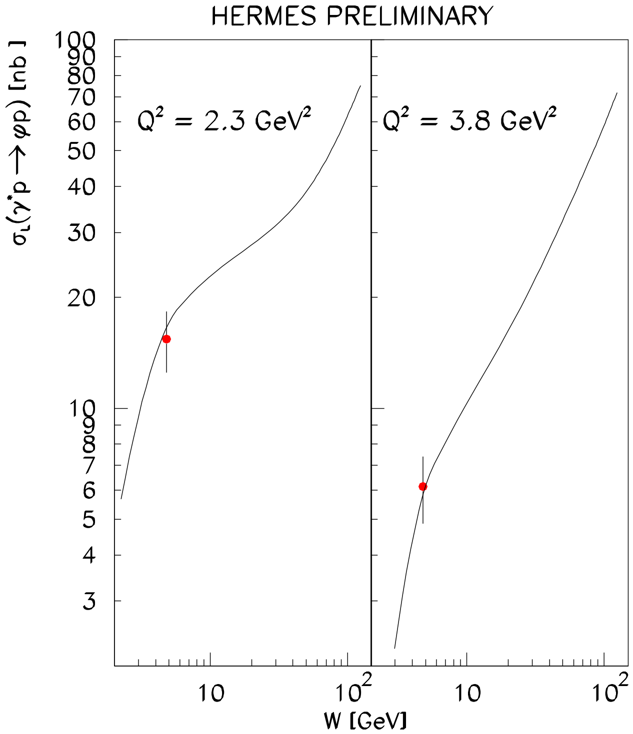


Strong increase of the longitudinal component with Q^2

Good agreement with previous data at higher W

σ_L for ρ and ϕ





Good agreement with GPD calculations

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

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

$\downarrow$

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

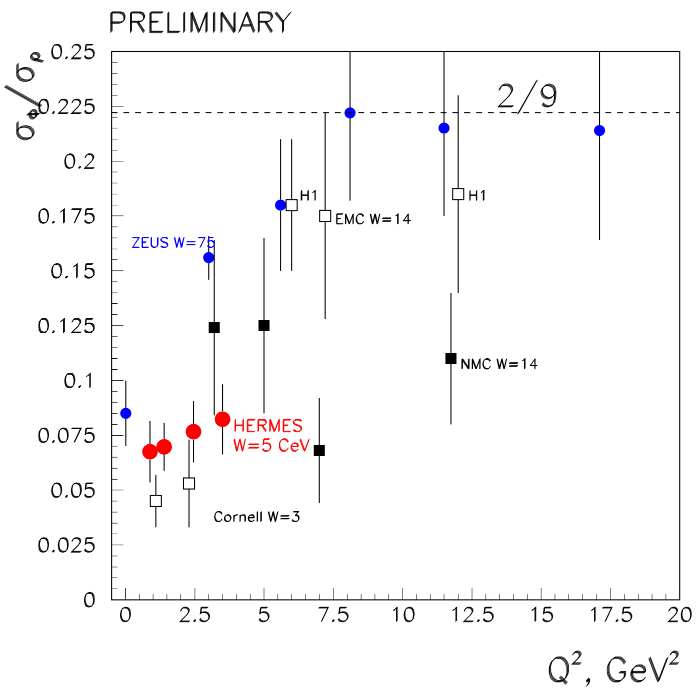
Dominance of 2-gluon exchange for $\sigma(\gamma^* p \to \phi p)$

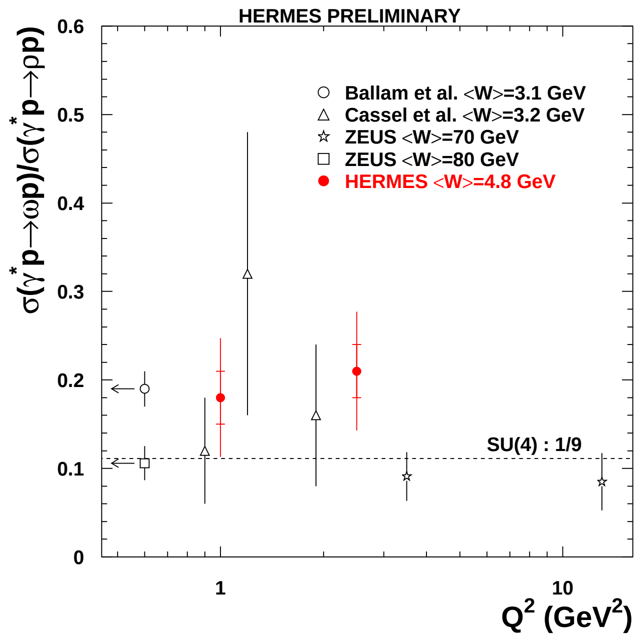
ϕ/ρ and ω/ρ

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

$\downarrow$

Precocious scaling for ϕ/ρ and ω/ρ





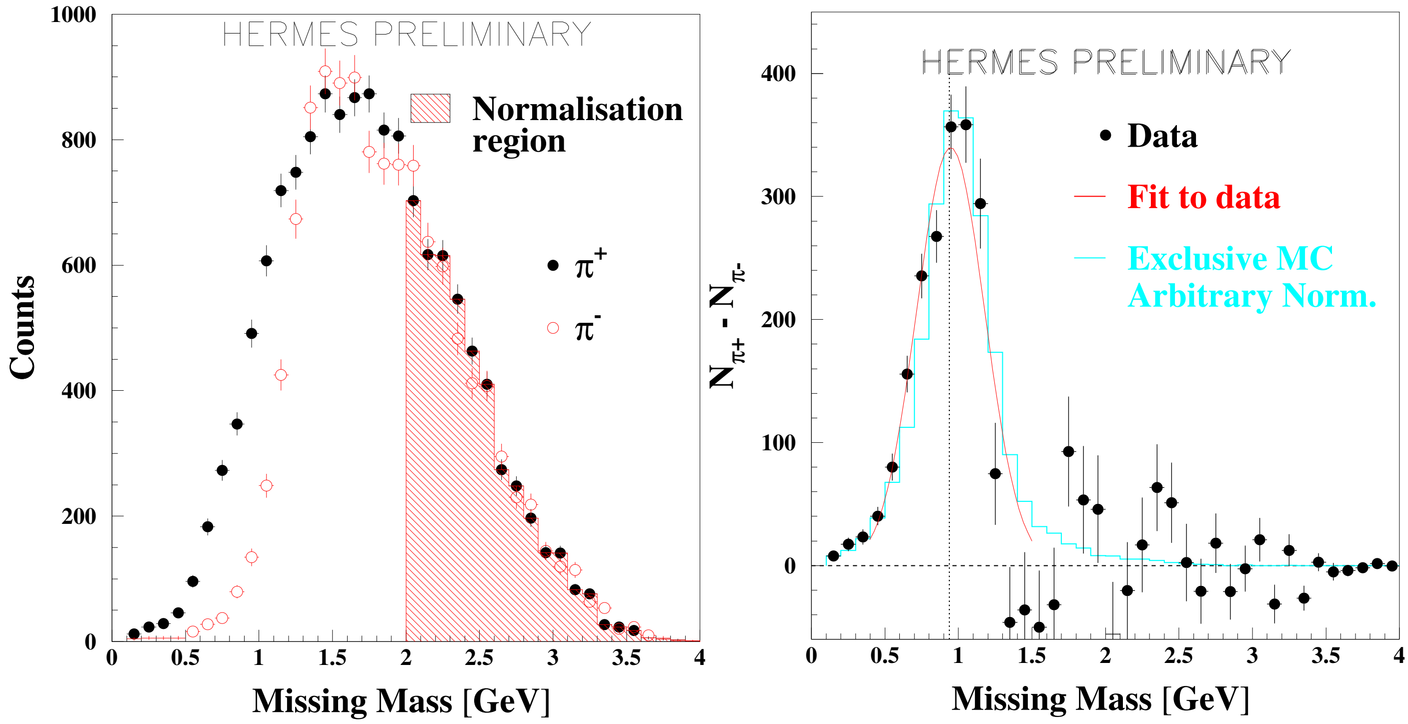
σ_ϕ/σ_ρ at low Q^2 and W well below the SU(4) prediction of 2/9 $\rightarrow$ quark exchange in the ρ production.

$\sigma_\omega/\sigma_\rho$ 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)

$ep \rightarrow e'\pi^+n$

$e'\pi^+n$ 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 $\sigma_L(Q^2, x, t)$

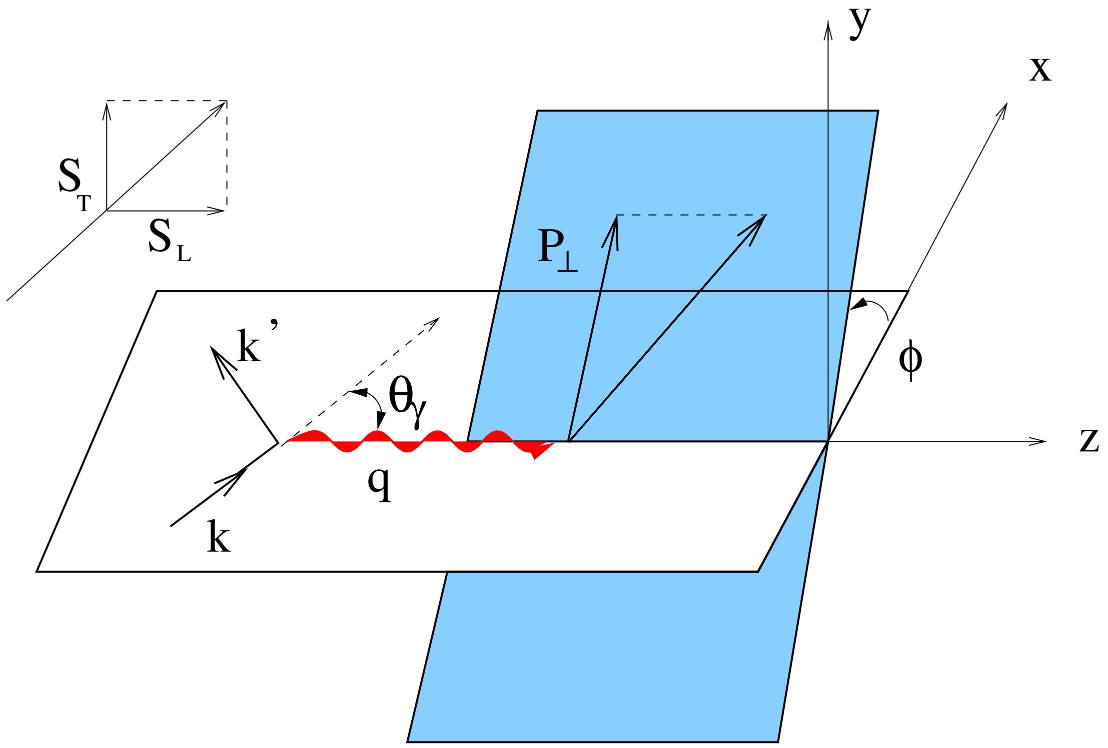
(Mankiewics, Piller, Radyushkin, EPJ C10(1999), 307)

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

$\mathbf{ep \to e'\pi^+n : SSA}$

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:

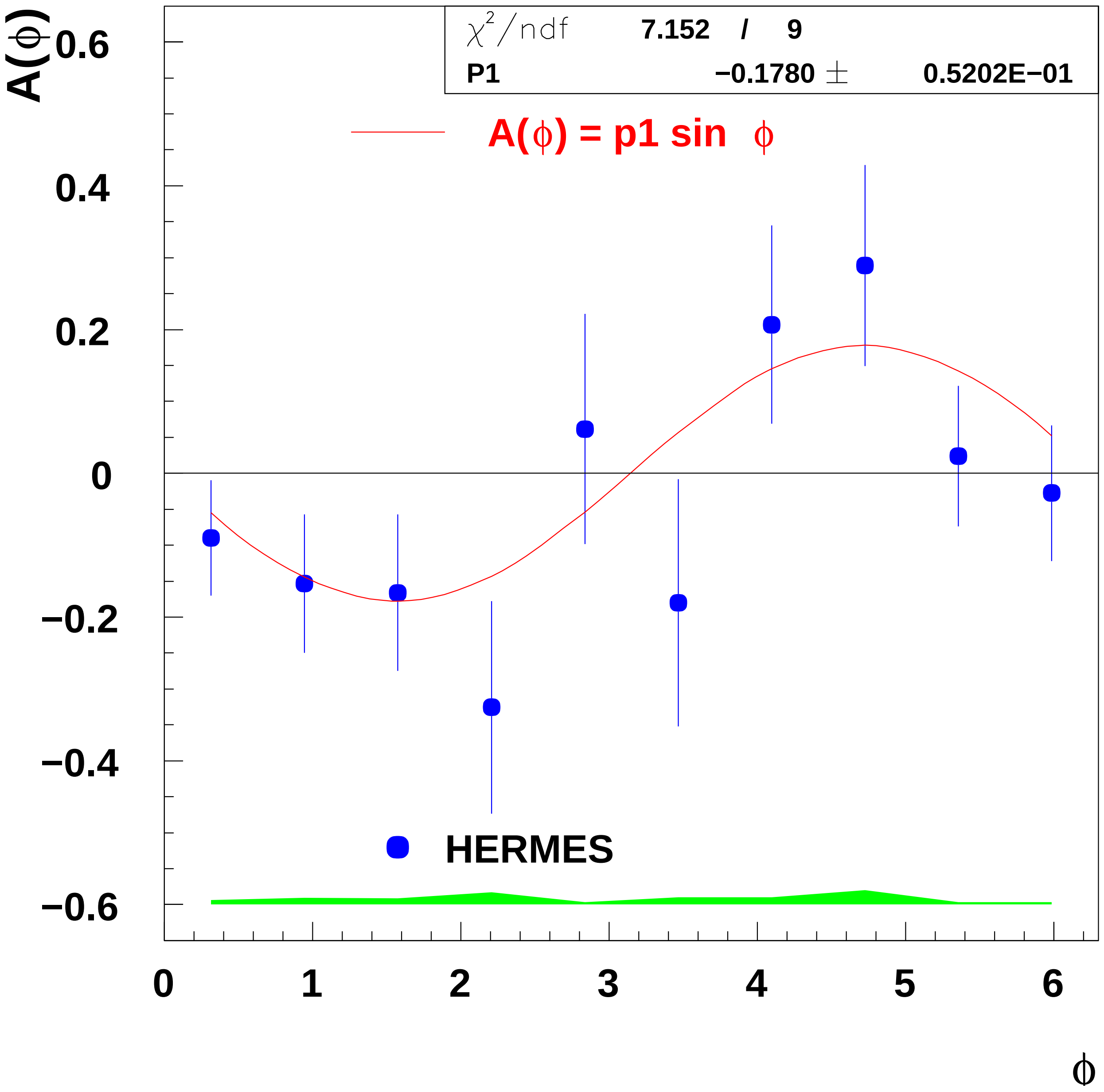
$$\boxed{\sigma_S \sim [S_\perp \sigma_L + S_\parallel \sigma_{LT}] \cdot A_{UL}^{\sin\phi} \sin\phi}$$

$\sigma_{\rm LT}$ suppressed by $1/Q \cdots$ but $S_\parallel > S_\perp$

HERMES in 1997: $\boxed{S_\perp / S \sim 0.17}$

HERMES SSA

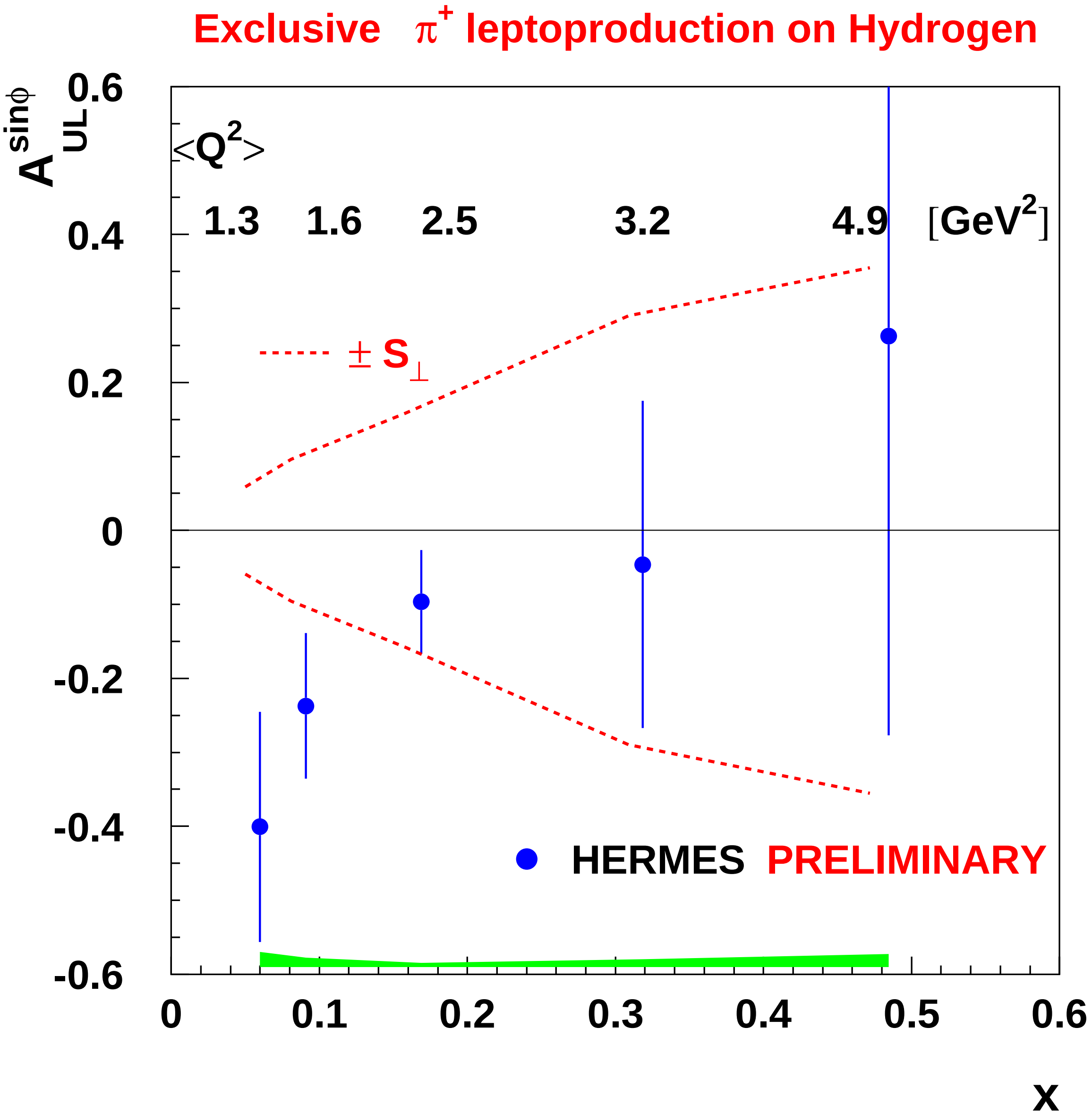
Exclusive π^+ leptoproduction on Hydrogen



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

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

$$\mathrm{ep} \to \mathrm{e}'\pi^+\mathrm{n}$$



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

$$\downarrow$$

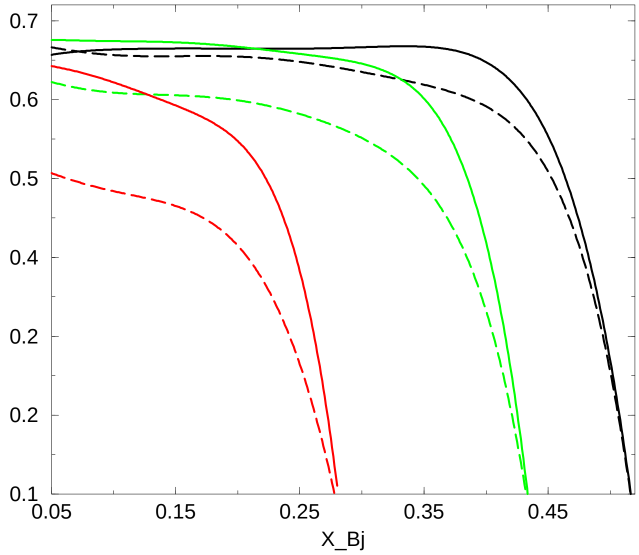
Asymmetry at low x arises from $S_\parallel$ component

Future: transverse SSA

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

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

- $\tilde{E}$: π pole contribution $\rightarrow \pi$ FF
- $\tilde{H}$: Forward limit: $\rightarrow \Delta q$



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

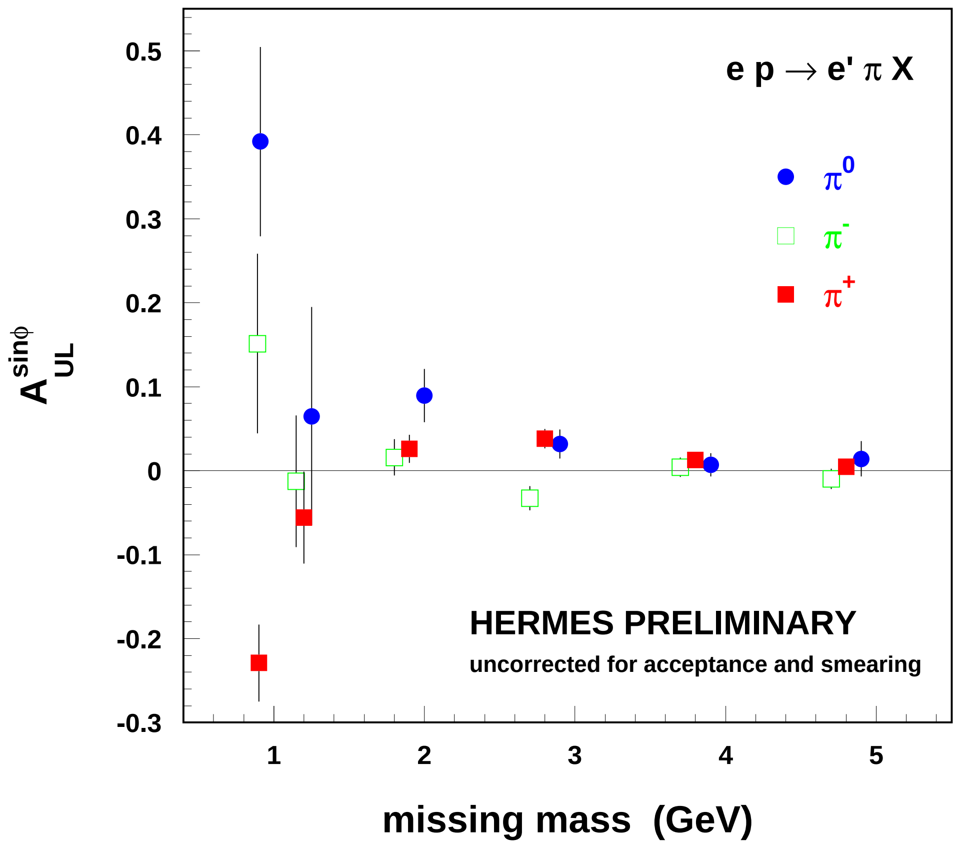
The size of the asymmetry depends on the pion f.f. :
1- asymptotic pion distribution amplitude
2- Chernyak-Zhitnitsky pion DA

HERMES transverse target running started this year:

Ongoing analysis & future

Other exclusive mesons:

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



Pseudoscalar ratios:

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

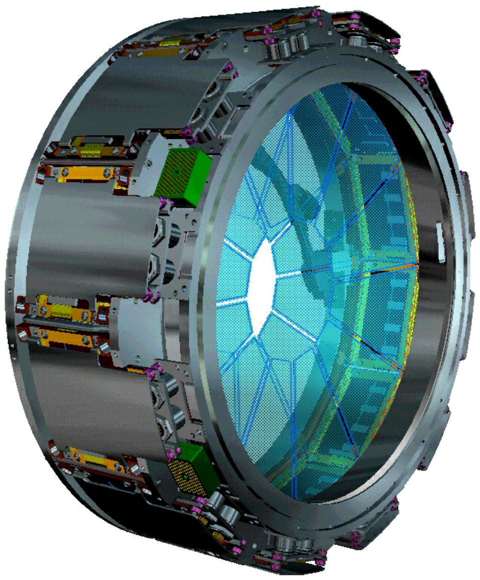
$ep \rightarrow e'\eta \; p \; / \; ep \rightarrow e'\pi^0 \; p$

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

→ detection of the recoiling proton

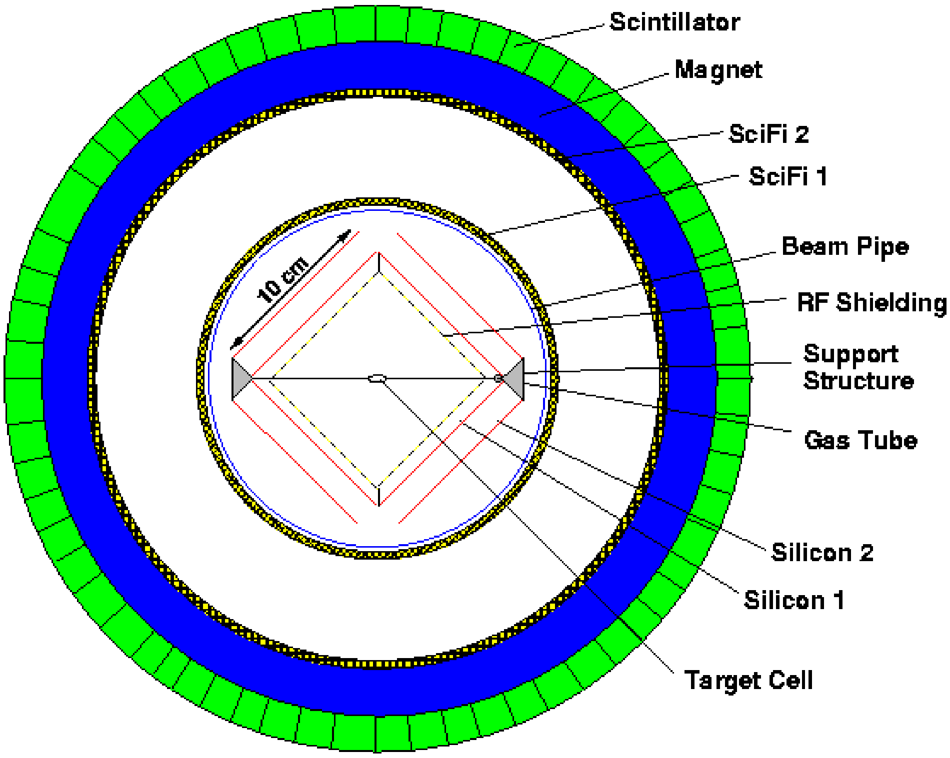
Upgrades

Λ wheel detector (installed):



Large short-track acceptance

Recoil detector (2004-2005):



Summary and outlook

- First promising results from HERMES in exclusive production of vector mesons (ρ, ω, ϕ) and pseudoscalar mesons (π^+)

  $\rightarrow$ Ongoing analysis for additional exclusive processes (π^0, η, kaons)

  $\Rightarrow$ comparison to GPD predictions

- start of measurements with transversely polarized target this year

- detector upgrades: lamda wheels and recoil detector