Exclusive Vector Meson Production at HERMES

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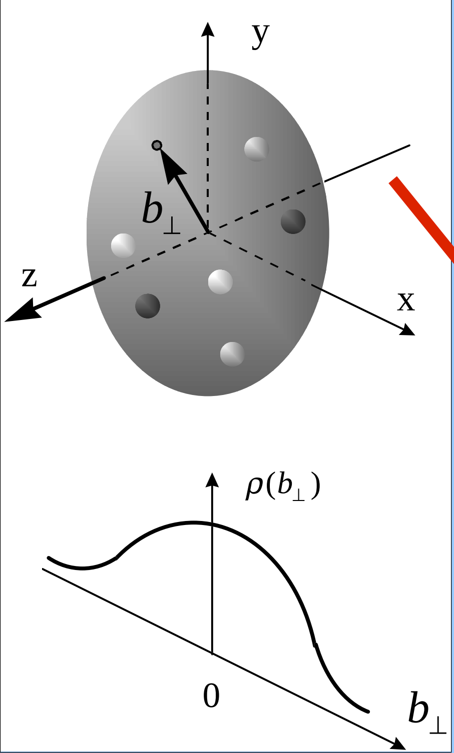
Generalized information

$l\,N \to l'\,N'$

$l\,N \to l'\,\{\gamma, \rho, \pi, \ldots\}\,N'$

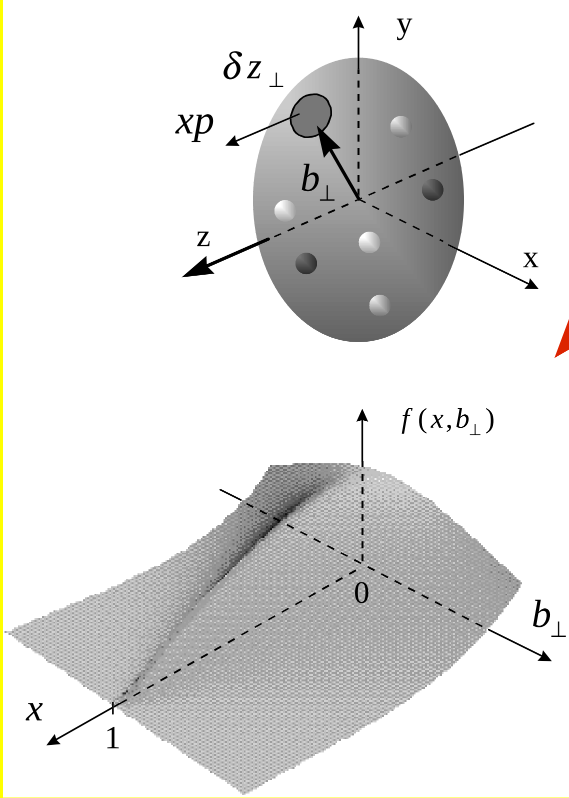
$l\,N \to l'\,X$

Form factor



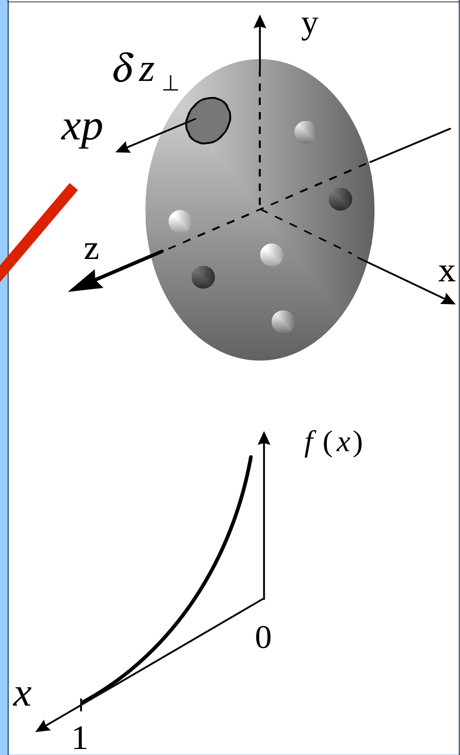
Proton form factors, transverse localization of partons

GPDs



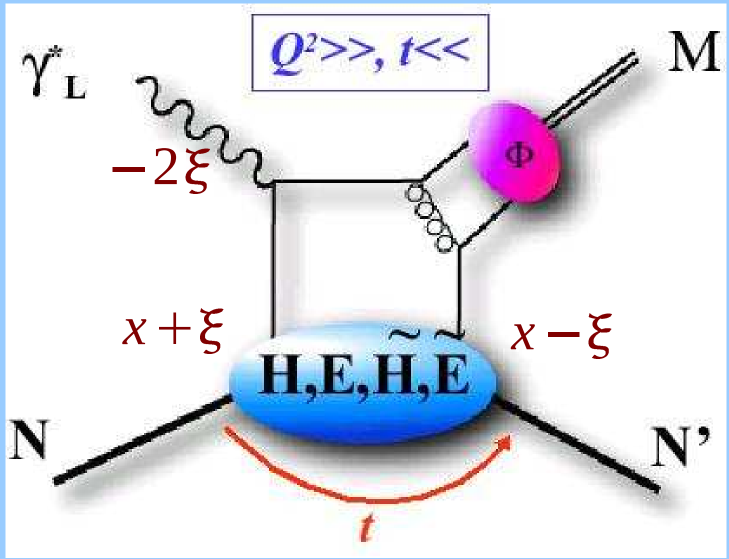
Correlated quark momentum and helicity distribution in transverse space

Parton density



Structure functions, longitudinal quark momentum and helicity distributions

Probabilistic interpretation of GPDs



4 GPDs defined for each quark flavour:

H	$\tilde{H}$	→ conserve nucleon helicity
E	$\tilde{E}$	→ flip nucleon helicity
↓ unpolarized	↓ polarized	

Described by 3 variables: x, ξ, t

$x+\xi$ longitudinal momentum fraction of the quark

-2ξ exchanged longitudinal momentum fraction

t squared momentum transfer

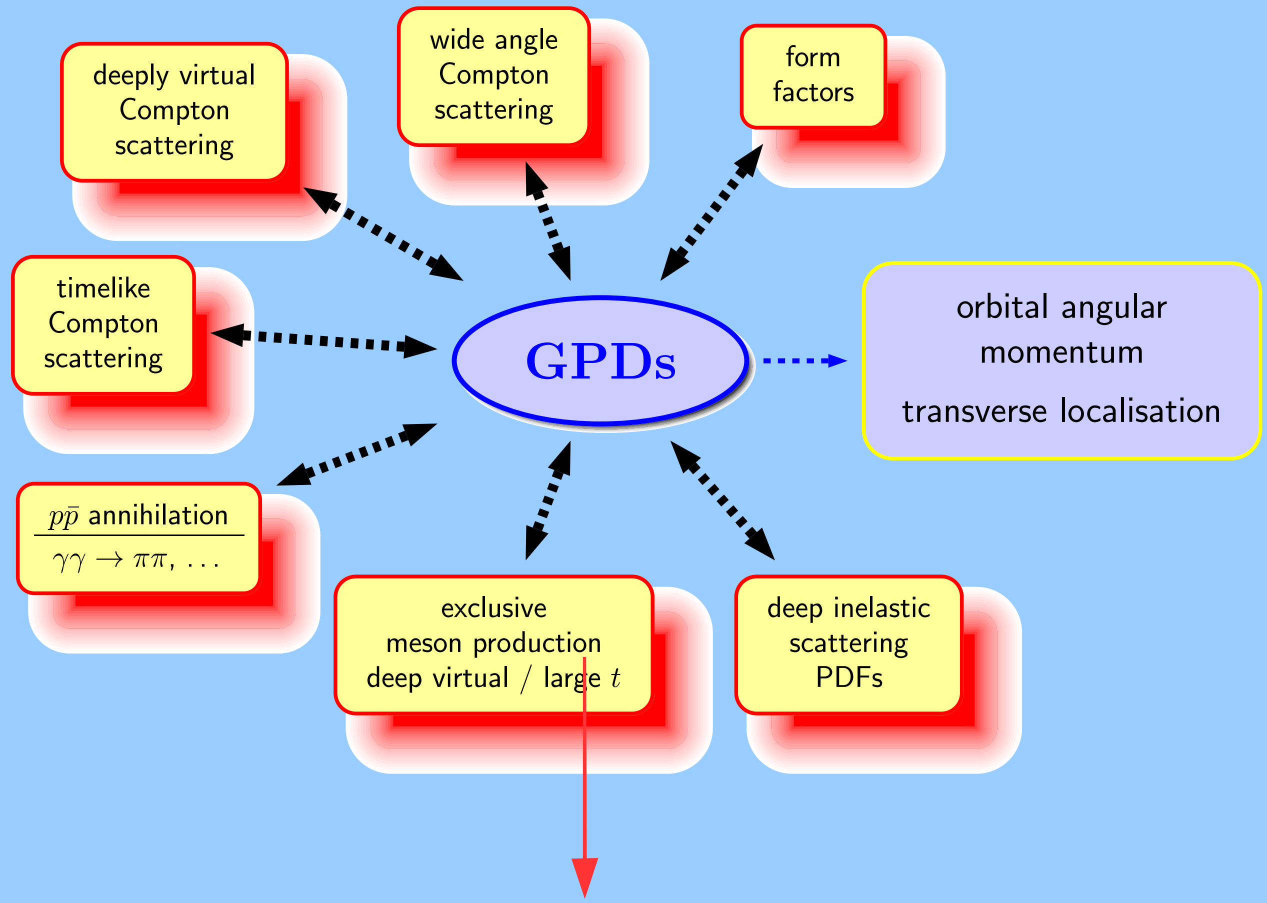
$$x \neq x_B$$

$$\xi = \frac{x_B}{2 - x_B}$$

$$-t = -(N - N')^2$$

GPDs = probability amplitude for N to emit a parton $x+\xi$
and for N' to absorb it $x-\xi$

Access to GPDs

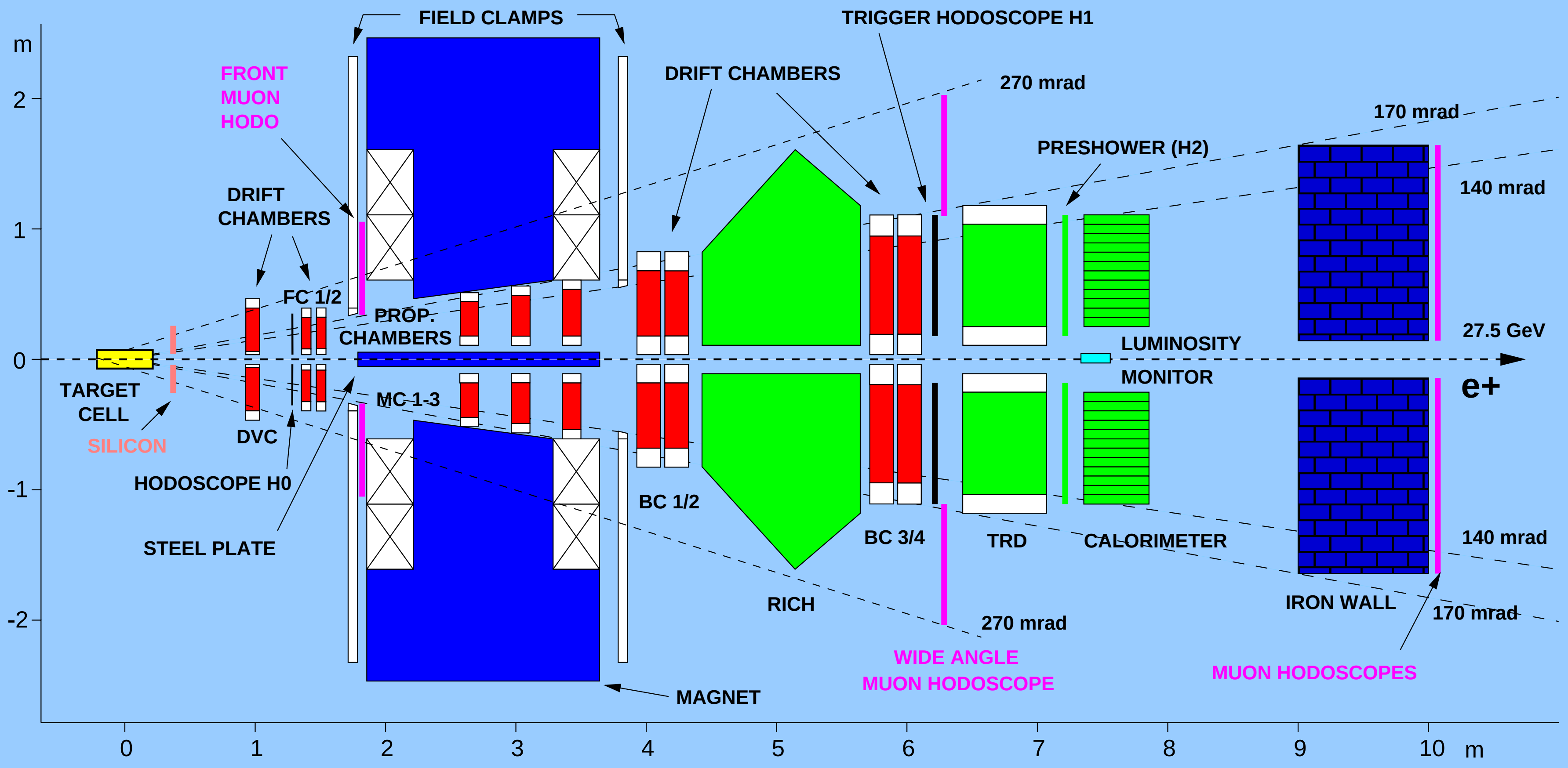


Quantum numbers of final state selects different GPDs

- vector mesons (ρ,ω,ϕ) –> unpolarized GPDs: H E
- pseudoscalar mesons (π,η) –> polarized GPDs: $\tilde{H}$ $\tilde{E}$

Factorization for *longitudinal* photons only

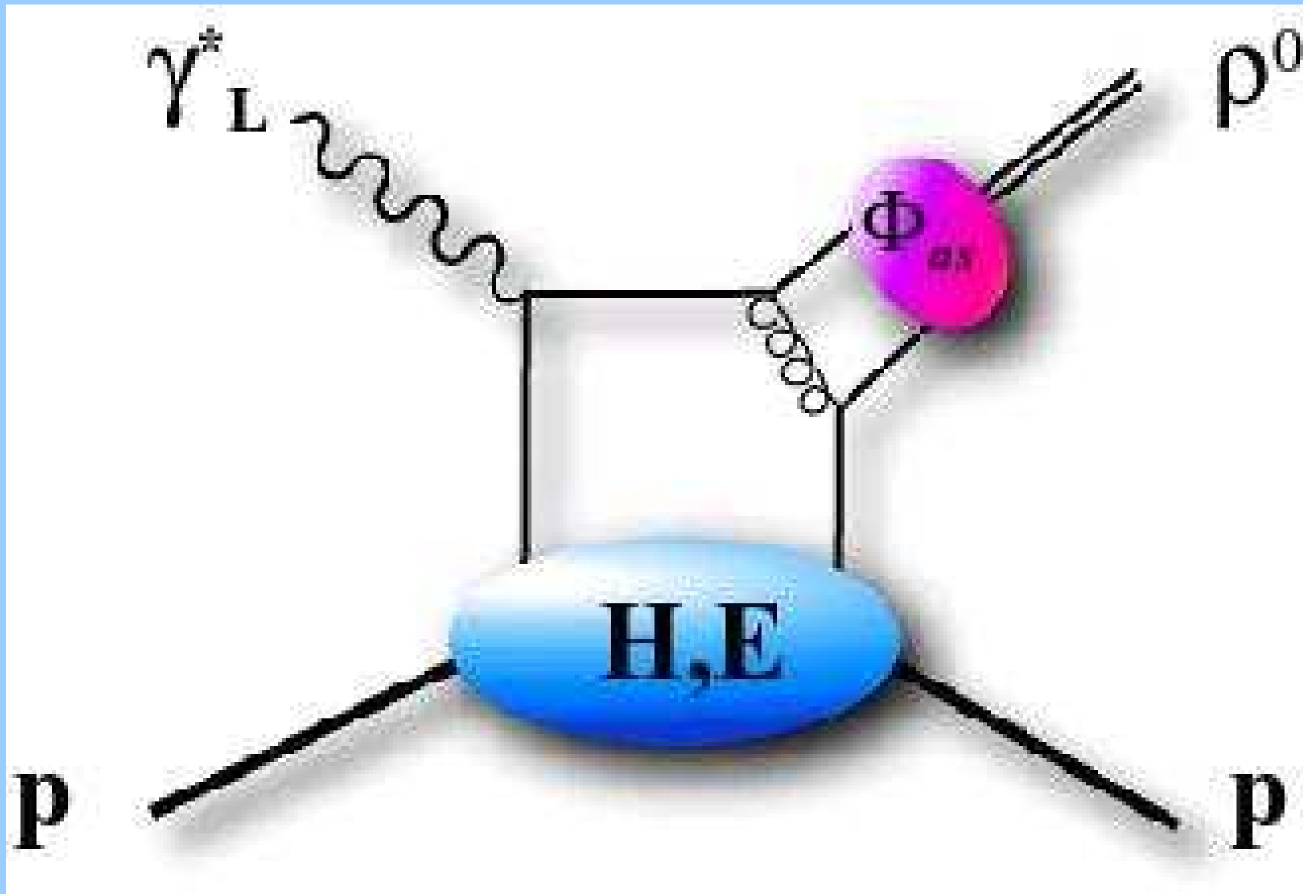
The Spectrometer



- fixed target experiment
- forward spectrometer
- no recoil detection

- Acceptance: $40\,mrad < \theta < 140\,mrad$
- Tracking: $\delta P_e / P_e < 2‰ , \delta\theta < 0.6\,mrad$
- Particle identification:
  - *TRD,Calo,Preshower*: hadron/lepton separation: $\varepsilon_e > 99‰$
  - *Rich:* hadron identification (p,π,K)

Cross-section of Exclusive Vector Mesons



Exclusive Vector Meson Selection ep→e'V(p)

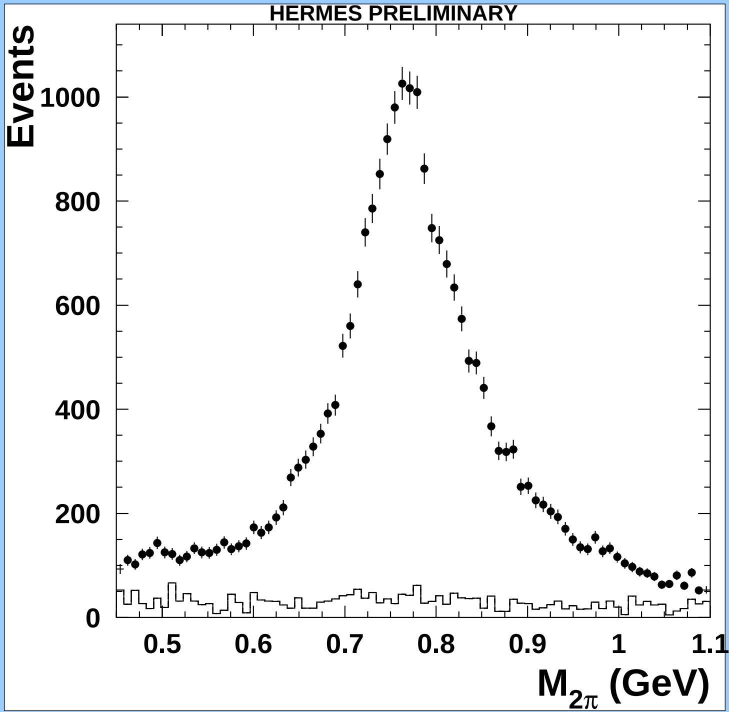
$\rho^0 \rightarrow \pi^+ \pi^-$

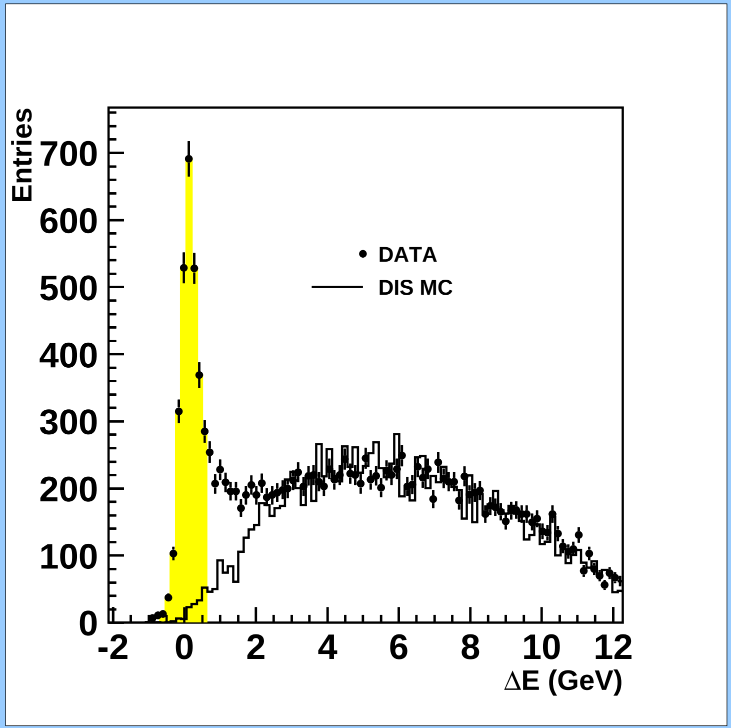
$\phi \rightarrow K^+ K^-$

- no recoil detection
- exclusive ρ^o and ϕ reaction through the energy and momentum transfer:

$$\Delta E = \frac{M_x^2 - M_p^2}{2 M_p}$$

$$t' = t - t_0$$





σ_L/σ_T Separation

- GPD calculations only for longitudinal component of the cross-section (σ_L):

$$\sigma_L = \frac{R}{1+\varepsilon R}\sigma_{\gamma^* p \to V p}$$

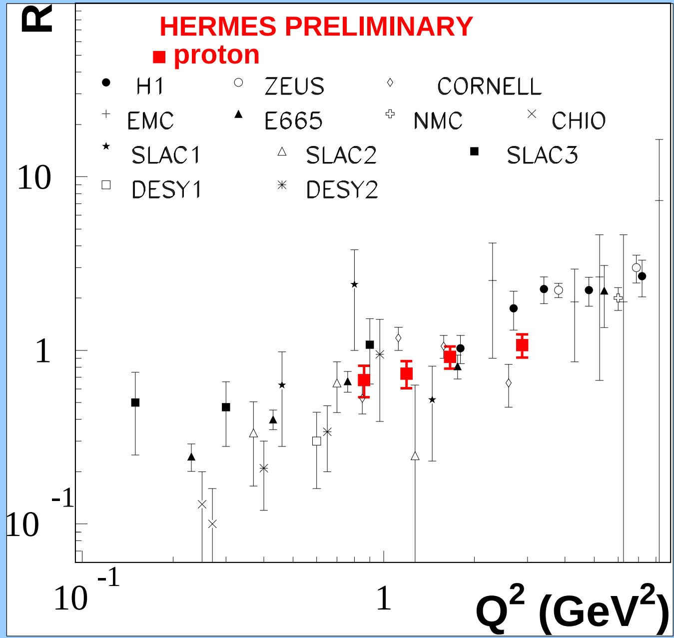
$$R = \frac{\sigma_L}{\sigma_T}$$

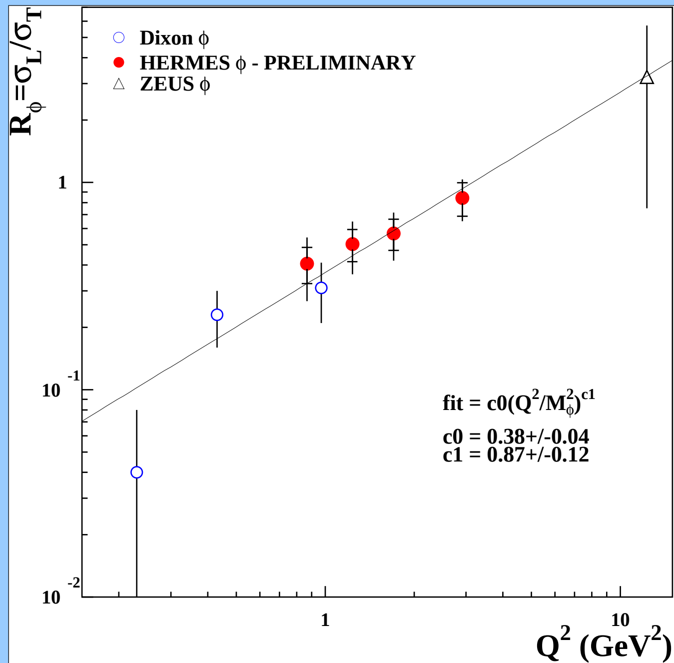
where ε - polarization of γ^*

- Assuming SCHC

$$R = \frac{1}{\varepsilon}\frac{r^{04}_{00}}{1-r^{04}_{00}}$$

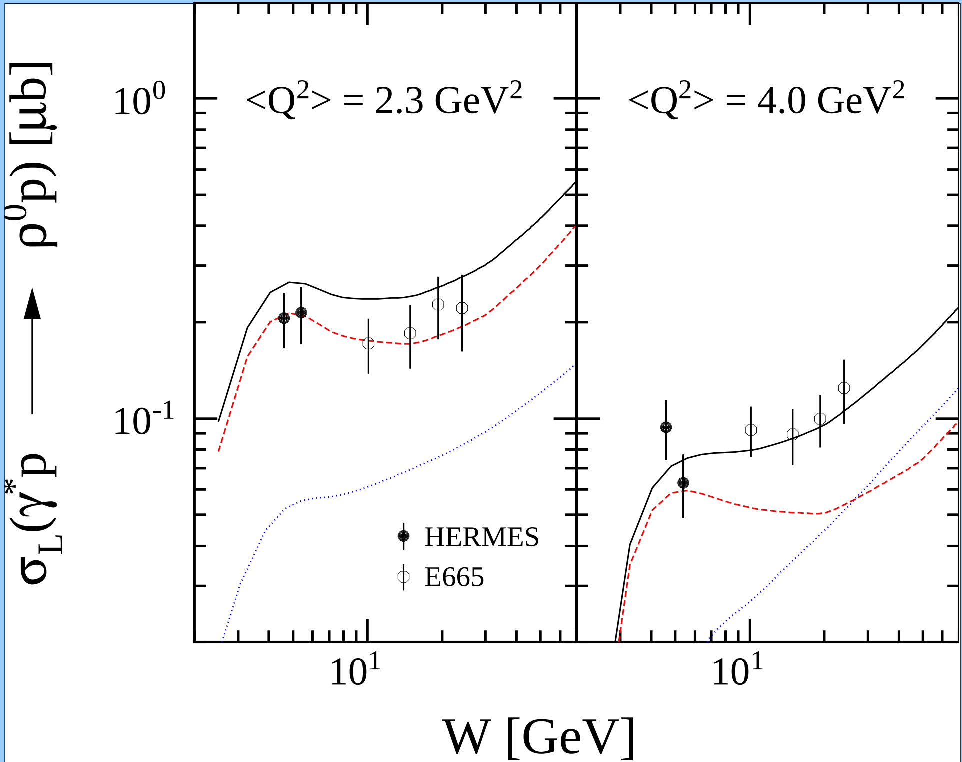
$$r^{04}_{00} \to W(\cos\theta)$$

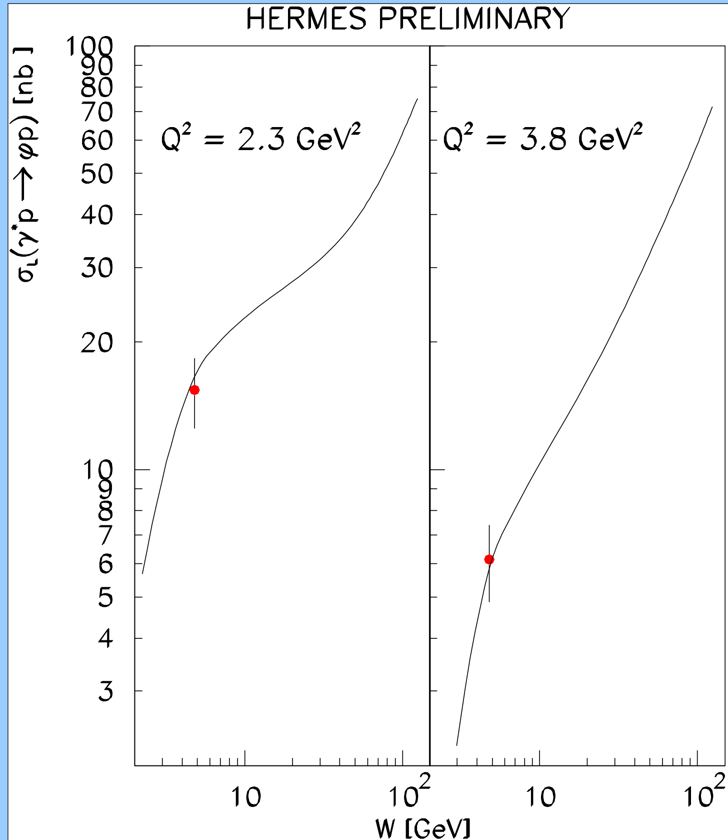




$\sigma^{\gamma^*_L p\to\rho^0 p}$ and $\sigma^{\gamma^*_L p\to\phi p}$

Vanderhaeghen,Guichon,Guidal (1999)

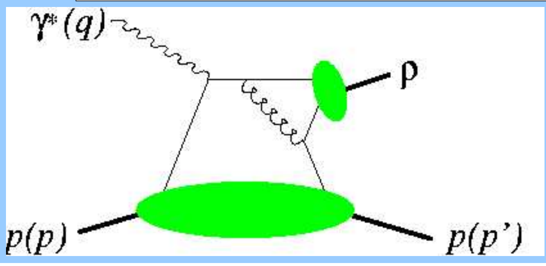


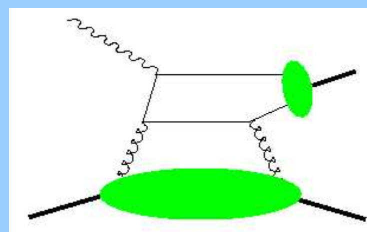


- quaks and gluons: at the same order of α_s
- gluon GPDs can be accessed

dominated by quark exchange

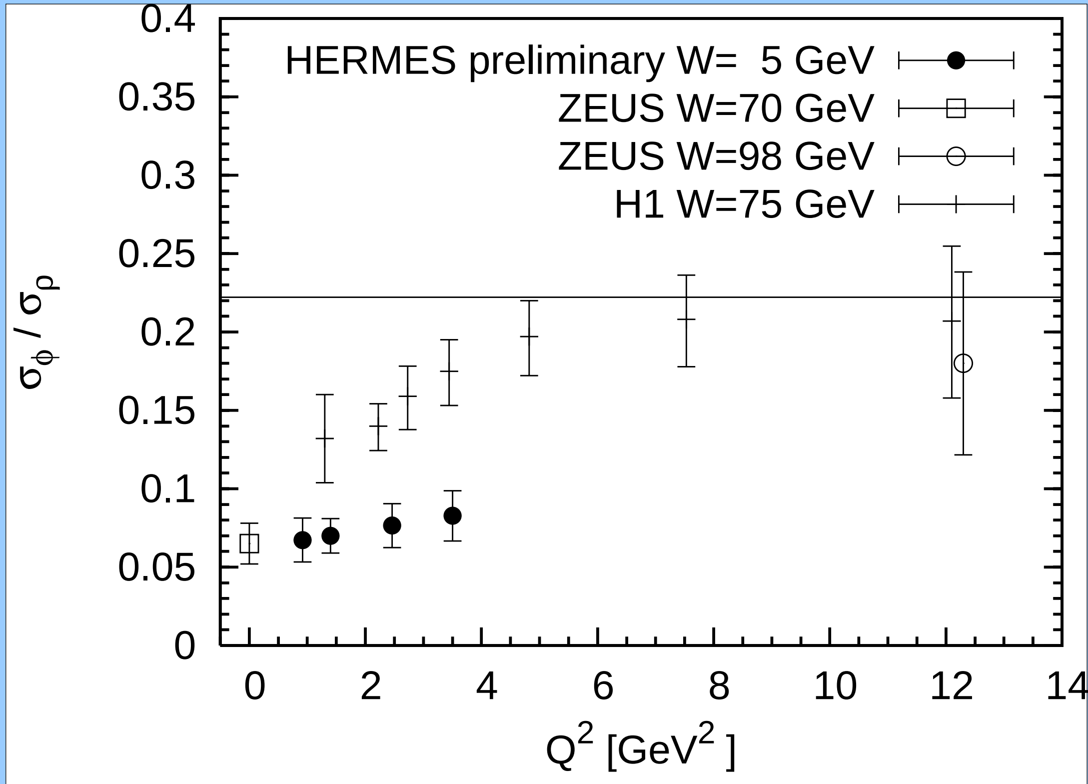
gluon exchange





$\sigma^{\gamma^* p \to \phi p} / \sigma^{\gamma^* p \to \rho^0 p}$

Diehl, Vinnikov (2005)



$$\sigma_\phi / \sigma_\rho \approx \frac{2}{9} \frac{|\tau_g|^2}{|\tau_q|^2 + 2|\tau_q||\tau_g| \cos\alpha + |\tau_g|^2}$$

$$0.38 < |\tau_g / \tau_q| < 1.5$$

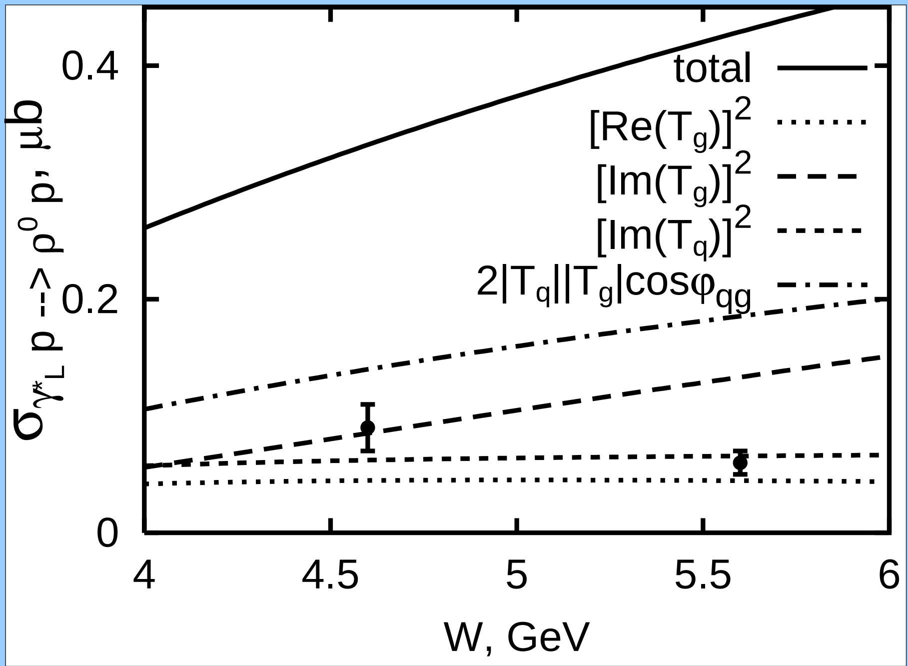
gluon contribution and quark-gluon interference can not be neglected

$\sigma^{\gamma_L^* p \to \rho^0 p}$

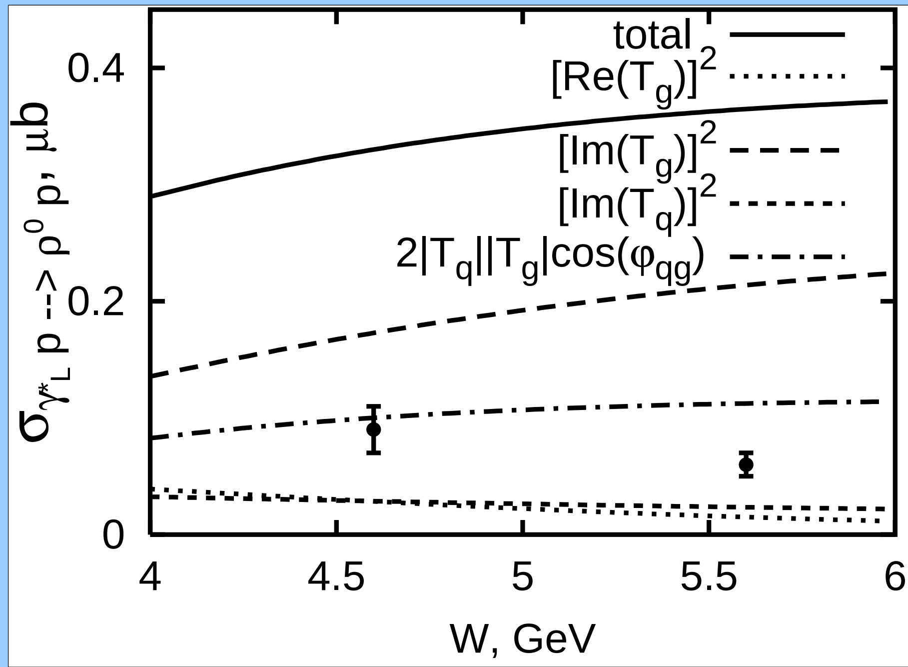
parametrizations for: H^q, H^g, E^q, *no hint for E^g*

Ellinghaus, Nowak, Vinnikov, Ye(2005)

factorizes GPD model



Regge GPD model



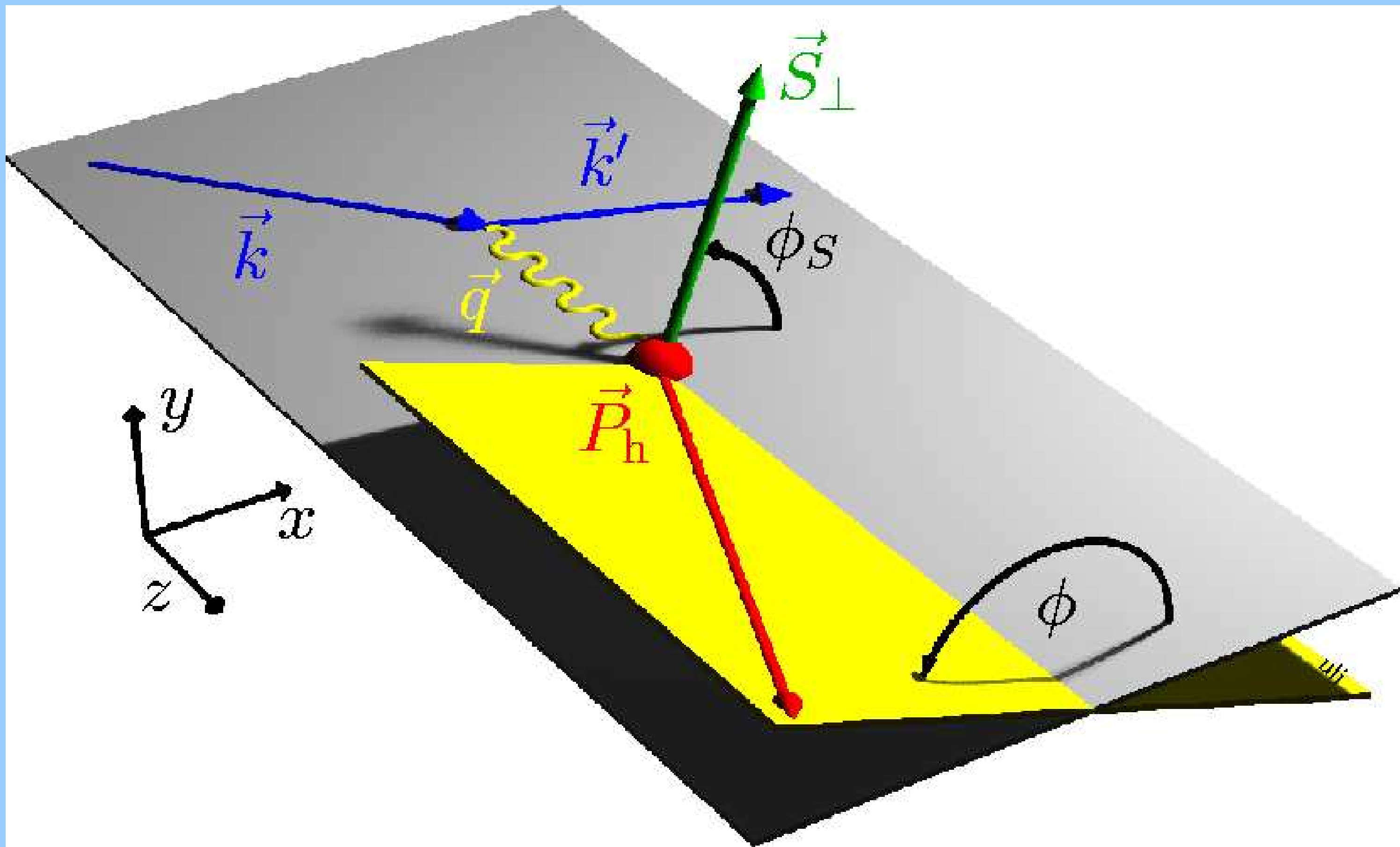
Theory

- the calculation overshoots the experimental data
- $k_\perp$ is not taken into account
- quark and gluon amplitudes have to be scaled down in a similar proportion, a factor of 5 suppression of the cross section

Experiment

- provide new results with higher statistics

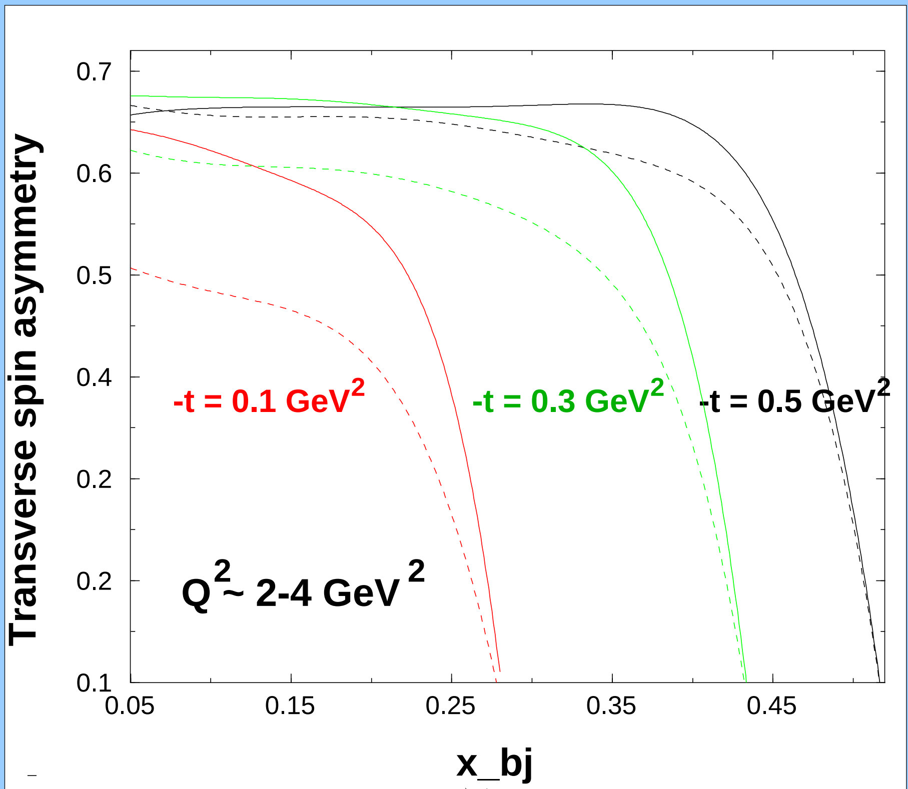
Transverse Target Spin Asymmetries (TTSA)



TTSA of Exclusive π^+ and ρ^0

Frankfurt, Polyakov, Strikman, Vanderhaeghen (2000)

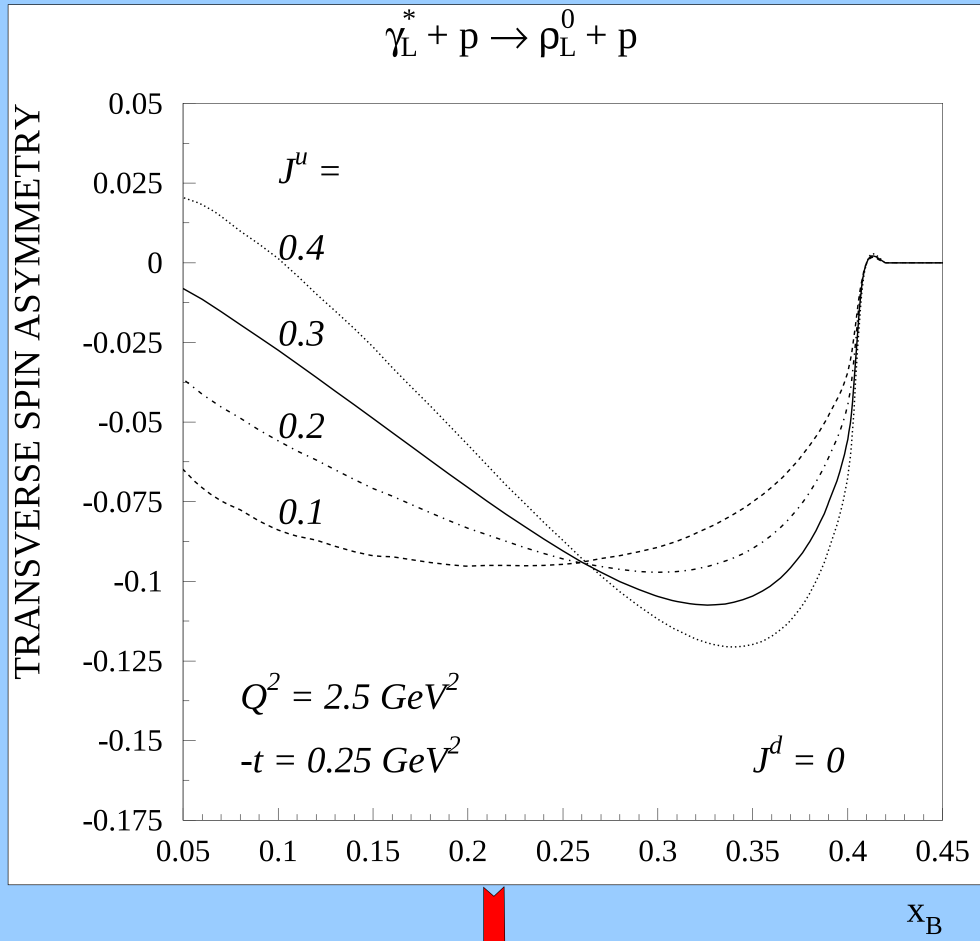
$e\, p \rightarrow e'\, \pi^{\vee}\, n$



$|S_T| \sin(\phi - \phi_s)\, \tilde{E}\, \tilde{H}$

- linear dependence on GPDs
- higher order corrections cancel

Goeke, Polyakov, Vanderhaeghen (2001)



$|S_T| \sin(\phi - \phi_s)\, E\, H$

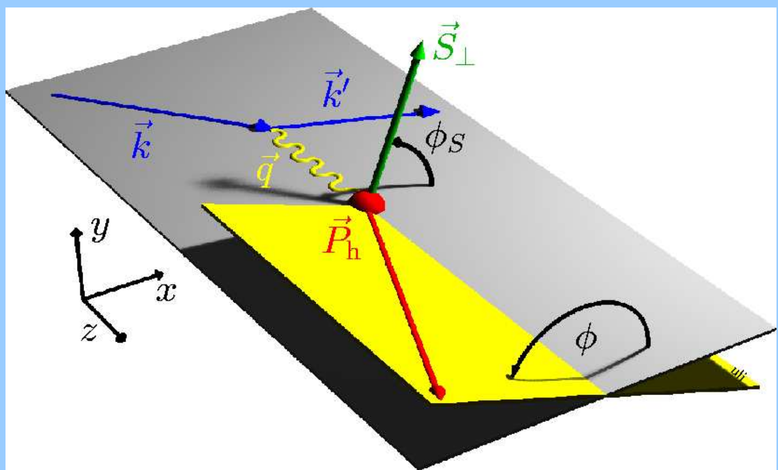
- E is kinematically not suppressed
- TTSA promising observable which allow an access to E
- E related to J^q through Ji sum rule

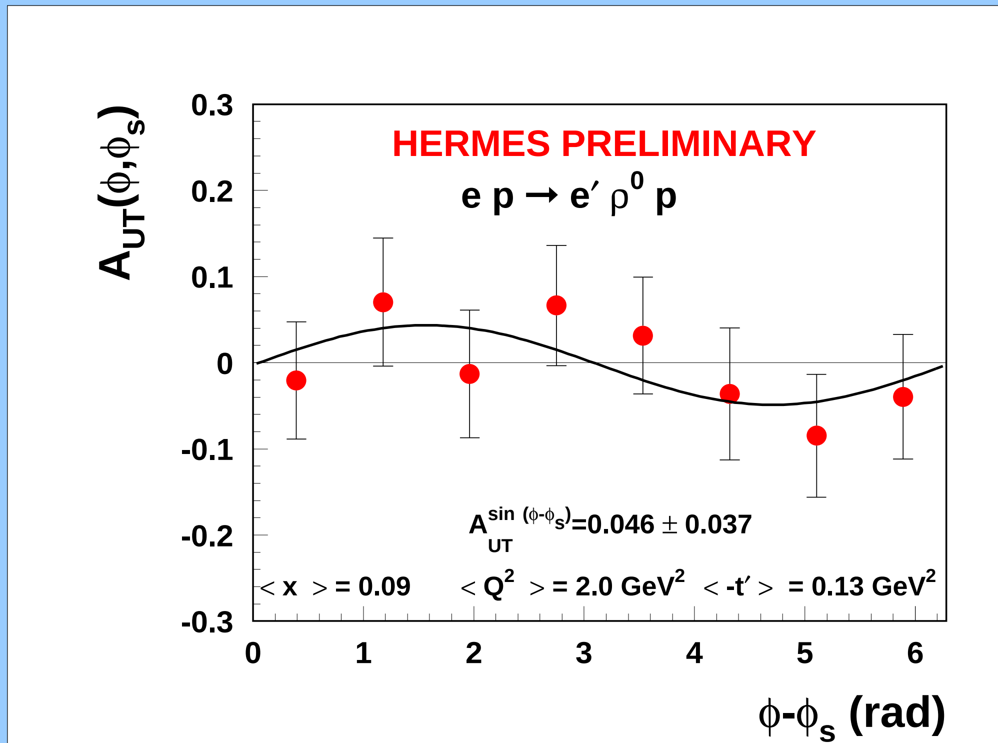
TTSA of Exclusive ρ^0

$$A_{UT} = -\frac{\pi}{2} A_{theor}$$

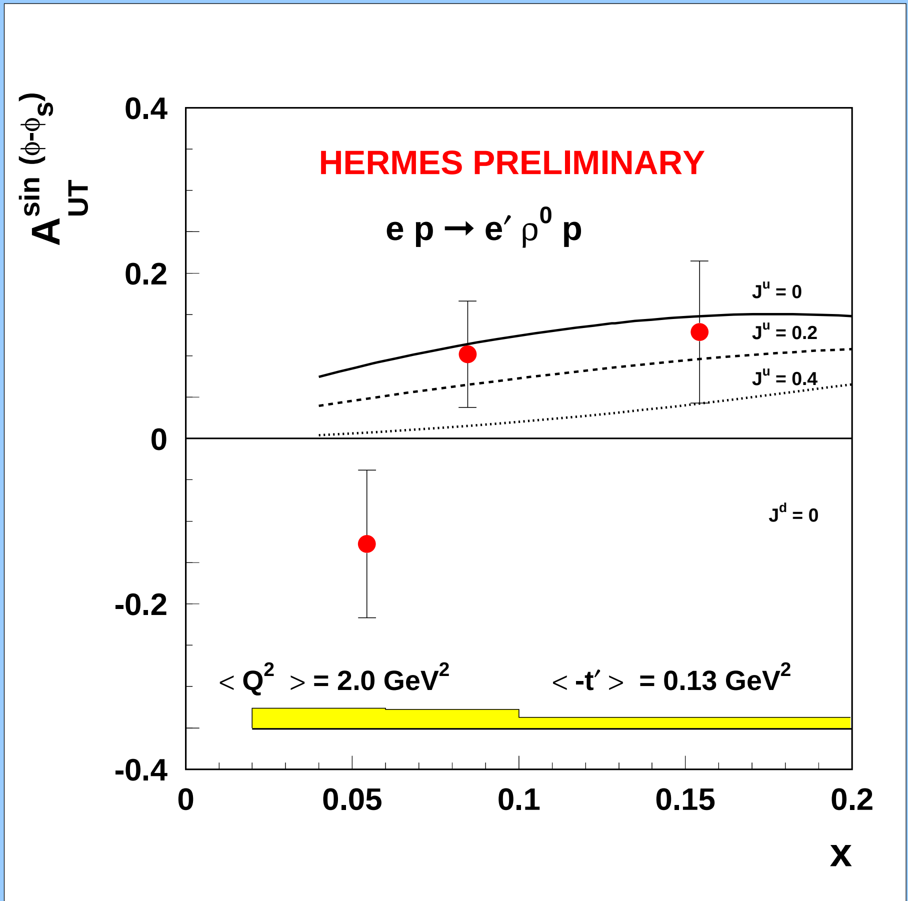
$$A_{UT}(\phi-\phi_s) = \frac{1}{|P|} \frac{N^{\uparrow}(\phi-\phi_s) - N^{\downarrow}(\phi-\phi_s)}{N^{\uparrow}(\phi-\phi_s) + N^{\downarrow}(\phi-\phi_s)}$$

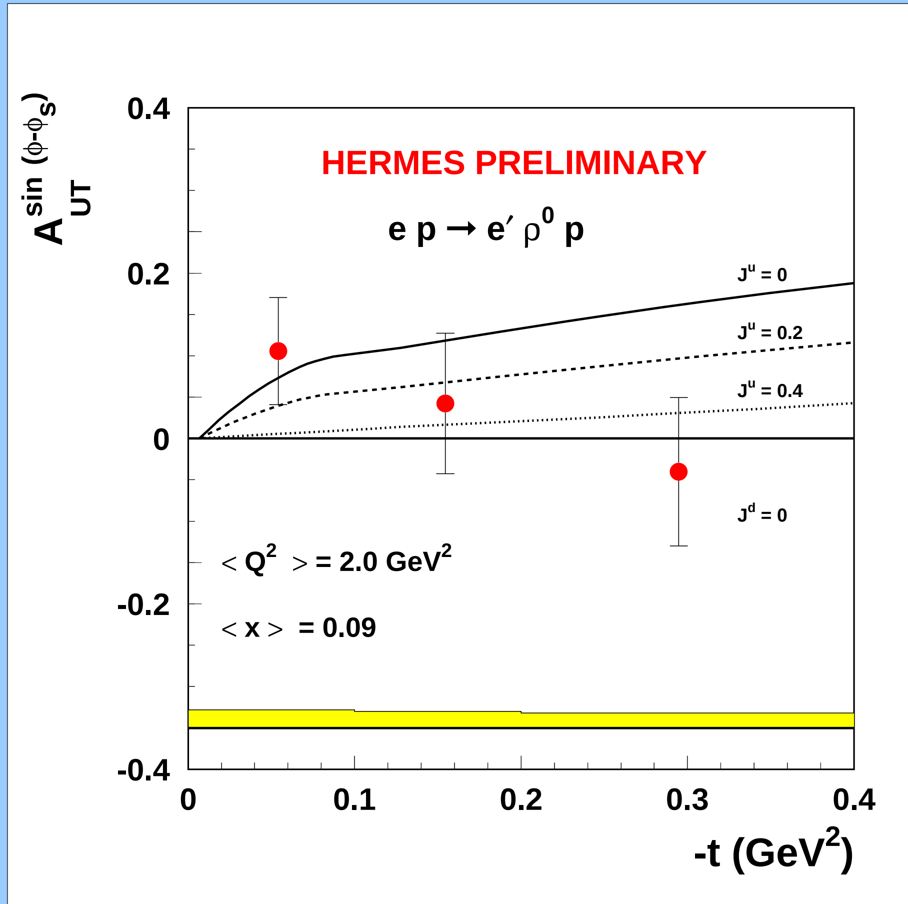
$$A_{UT}(\phi-\phi_s) = A_{UT}^{sin(\phi-\phi_s)} \cdot sin(\phi-\phi_s) + const$$





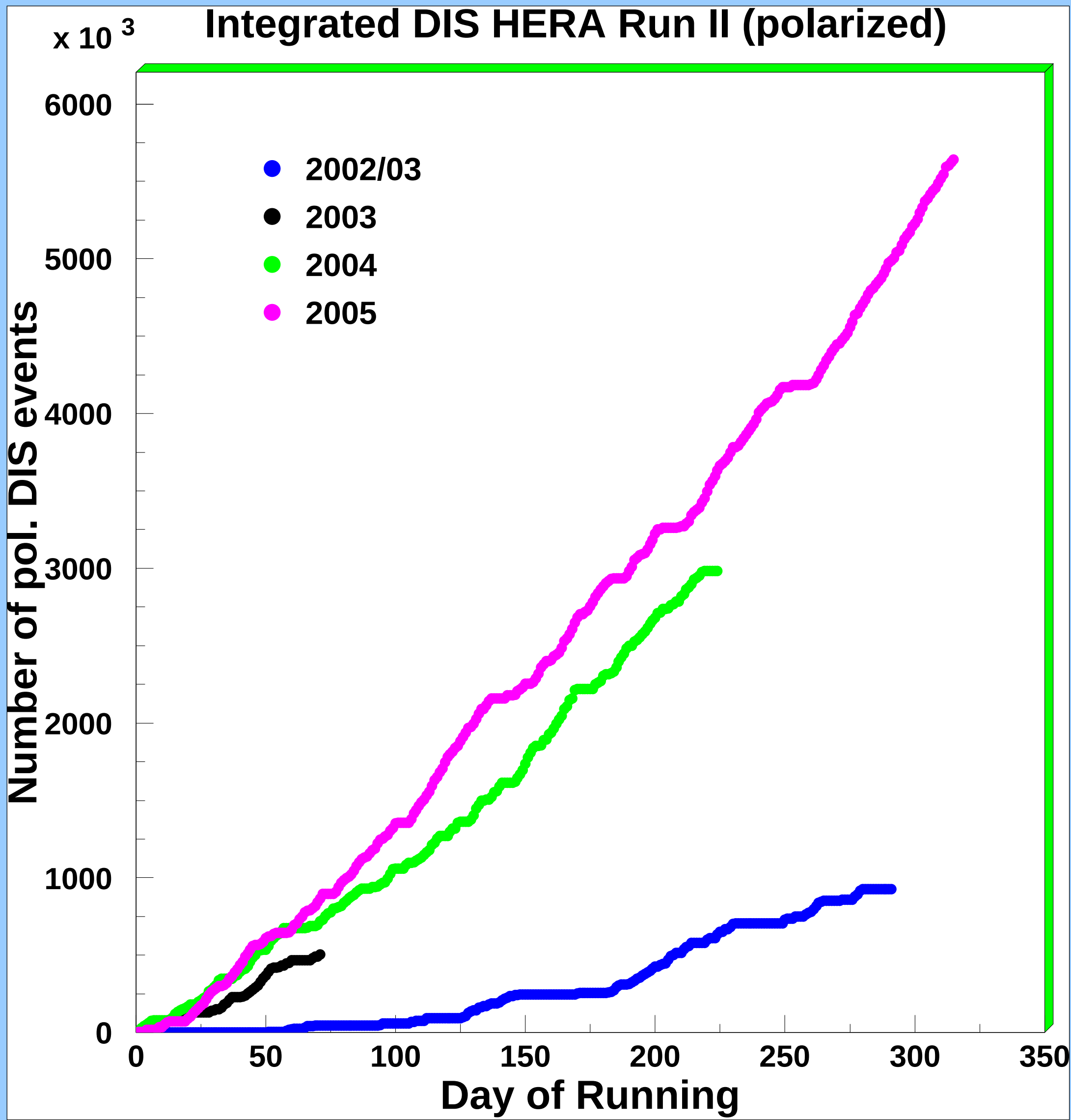
Kinematic Dependences





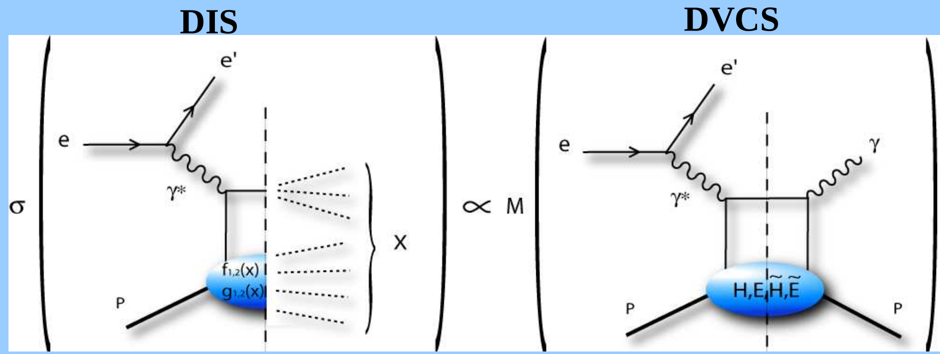
- L/T separation has not yet been done
- transverse component is suppressed at high Q^2
- within the statistical errors in agreement with theoretical calculations → *indication of small E_g*
- the statistics is not yet enough to make a statement about J^u
- more data is available

More Results are Coming...

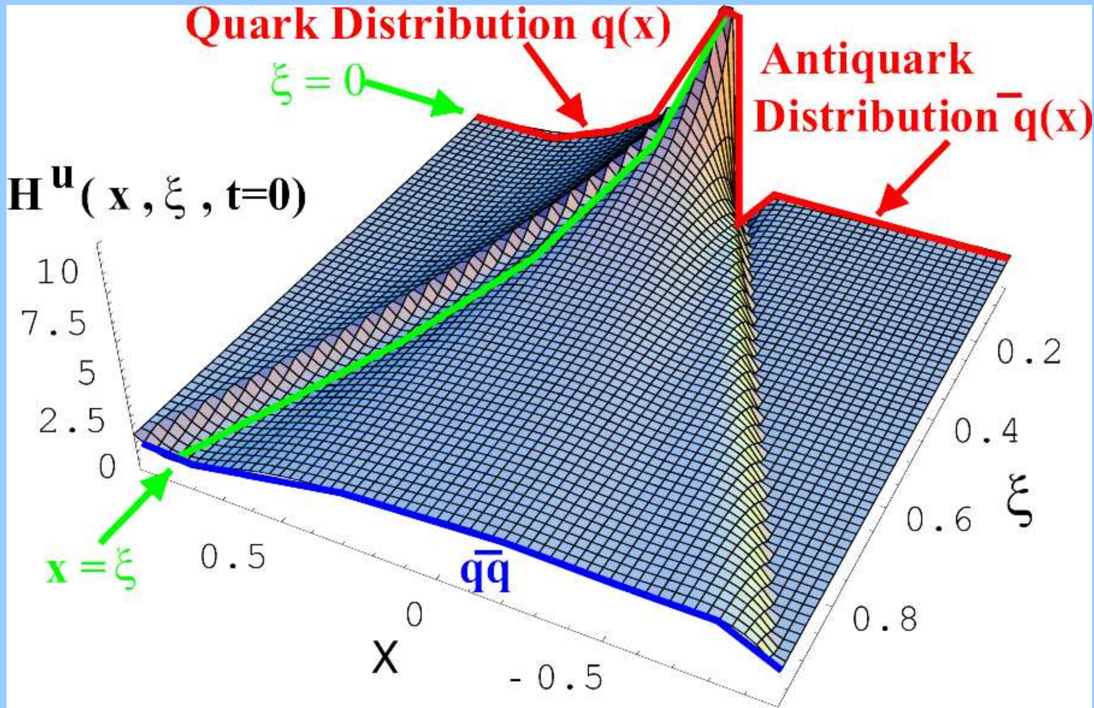


BACKUP: GPD and DIS

Forward limit ($t \rightarrow 0$, $\xi \rightarrow 0$)



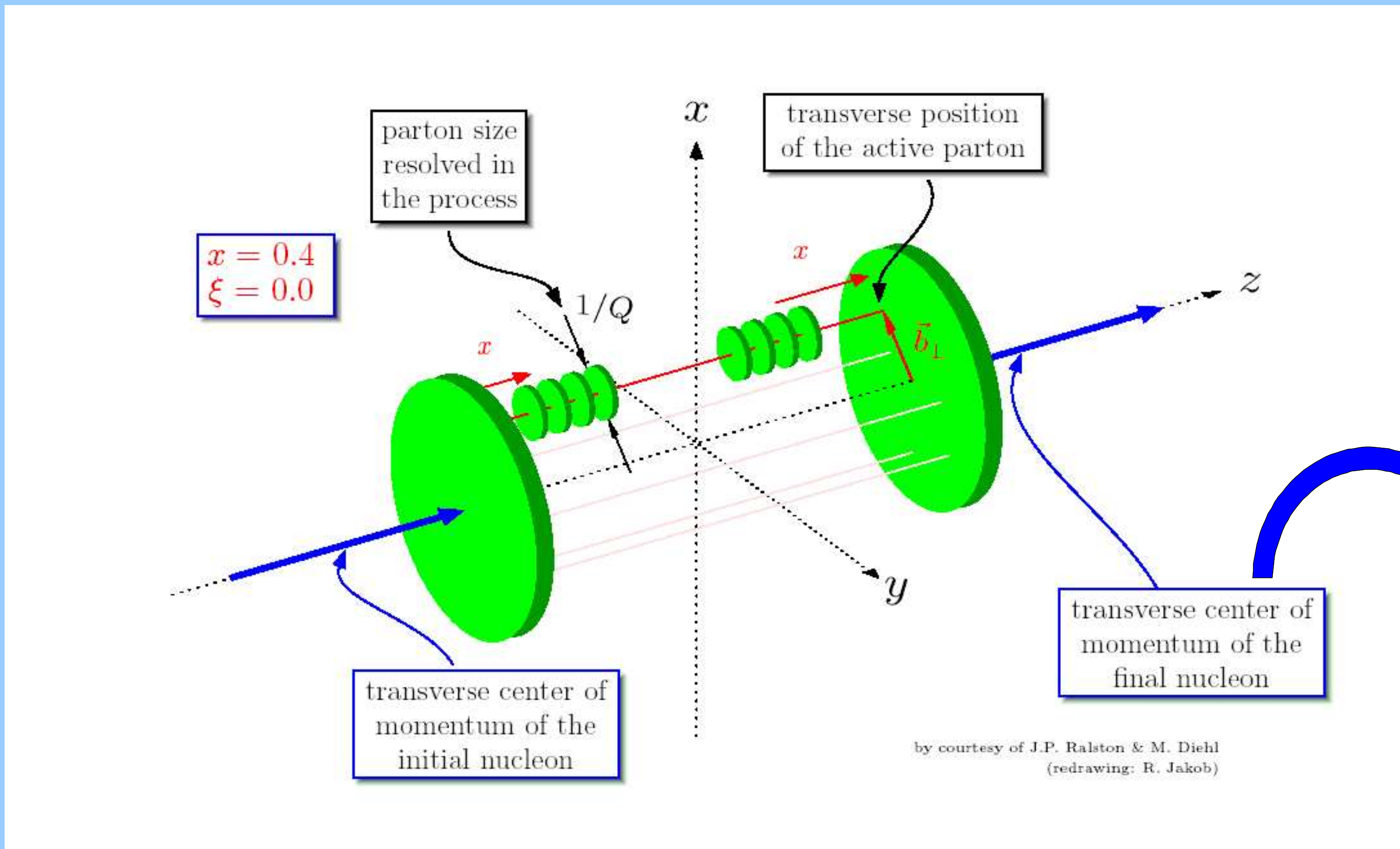
$H^q(x,\xi=0,t=0) = \mathbf{q(x)}$ $\tilde{H}^q(x,\xi=0,t=0) = \mathbf{\Delta q(x)}$



BACKUP:Geometrical interpretation of GPDs

$$q(x,\vec{b}_\perp)=\int \frac{d^2\Delta_\perp}{(2\pi)^2} H(x,\xi=0,-\vec{\Delta}_\perp^2)\, e^{i\vec{b}_\perp\vec{\Delta}_\perp}$$

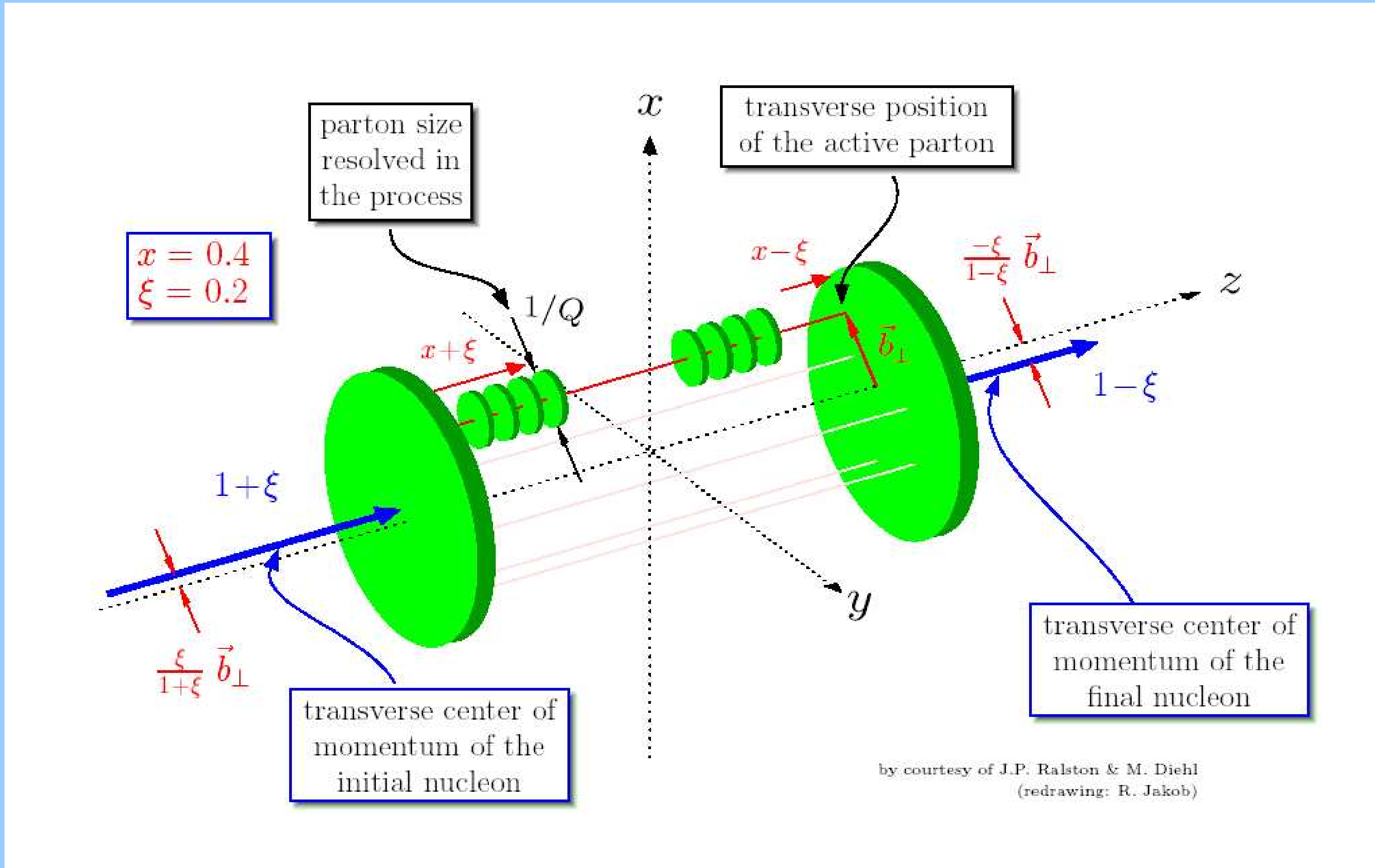
$$\int q(x,b_\perp)\, d^2 b_\perp = q(x)$$



$$\vec{b}_\perp=\sum_{i=1}^{N} x_i \vec{b}_{\perp_i}$$

BACKUP:Geometrical interpretation of GPDs

the general case: ξ≠0, by M.Diehl



BACKUP:Limiting cases and sum rules

Forward limit $(t \to 0, \xi \to 0)$

$$H^q(x,0,0) = q(x) \qquad \tilde{H}^q(x,0,0) = \Delta q(x) \qquad for\ x>0$$
$$H^q(x,0,0) = -\bar{q}(-x) \qquad \tilde{H}^q(x,0,0) = \Delta \bar{q}(-x) \qquad for\ x<0$$
$$H^g(x,0,0) = xg(x) \qquad \tilde{H}^g(x,0,0) = x\Delta g(x) \qquad for\ x>0$$

$E^q, \tilde{E}^q, E^g, \tilde{E}^g$ →

- no corresponding relations
- are visible only in exclusive processes

Sum rules

$$\int_{-1}^{+1} H^q(x,\xi,t)dx = F_1^q(t) \qquad \int_{-1}^{+1} E^q(x,\xi,t)dx = F_2^q(t)$$

$$\int_{-1}^{+1} \tilde{H}^q(x,\xi,t)\,dx = g_A^q(t) \qquad \int_{-1}^{+1} \tilde{E}^q(x,\xi,t)\,dx = h_A^q(t)$$

Ji sum rule

30% (DIS)

$$\int_{-1}^{+1} \left(H(x,\xi,t=0) + E(x,\xi,t=0)\, x\, dx \right) = \frac{1}{2}\Delta\Sigma + L_q$$