Report from hermes

“Physics using unpolarized targets“

G. Schnell (UPV/EHU Bilbao)

75. DESY PRC Meeting

DESY Hamburg - April 11th, 2013

collaboration structure

- new management
  - spokesperson: G. Schnell
  - **deputy spokesperson & analysis coordinator: A. Rostomyan**
  - **deputy analysis coordinator: C. Van Hulse**
- will lead to small changes in collaboration board to take place in next days

data preservation

- data-analysis platform completely moved from HERMES batch system to DESY's BIRD infrastructure
  - no hardware maintenance required from collaboration for data analysis
  - medium-term analysis platform secured
  - switch to 64bit system and SLD5 required some fine-tuning and lead to slow-down in analyses
  - close to 100% of analyses have moved to new system
- some remaining data and services (e.g., web pages and mailing lists) in process of migration to IT-maintained infrastructure

publications and new preliminary results since 74th PRC mtg.

- **The HERMES Recoil Detector**
  submitted to JINST, arXiv:1302.6092 and DESY 13-034
  referee comments received ("minor revision")

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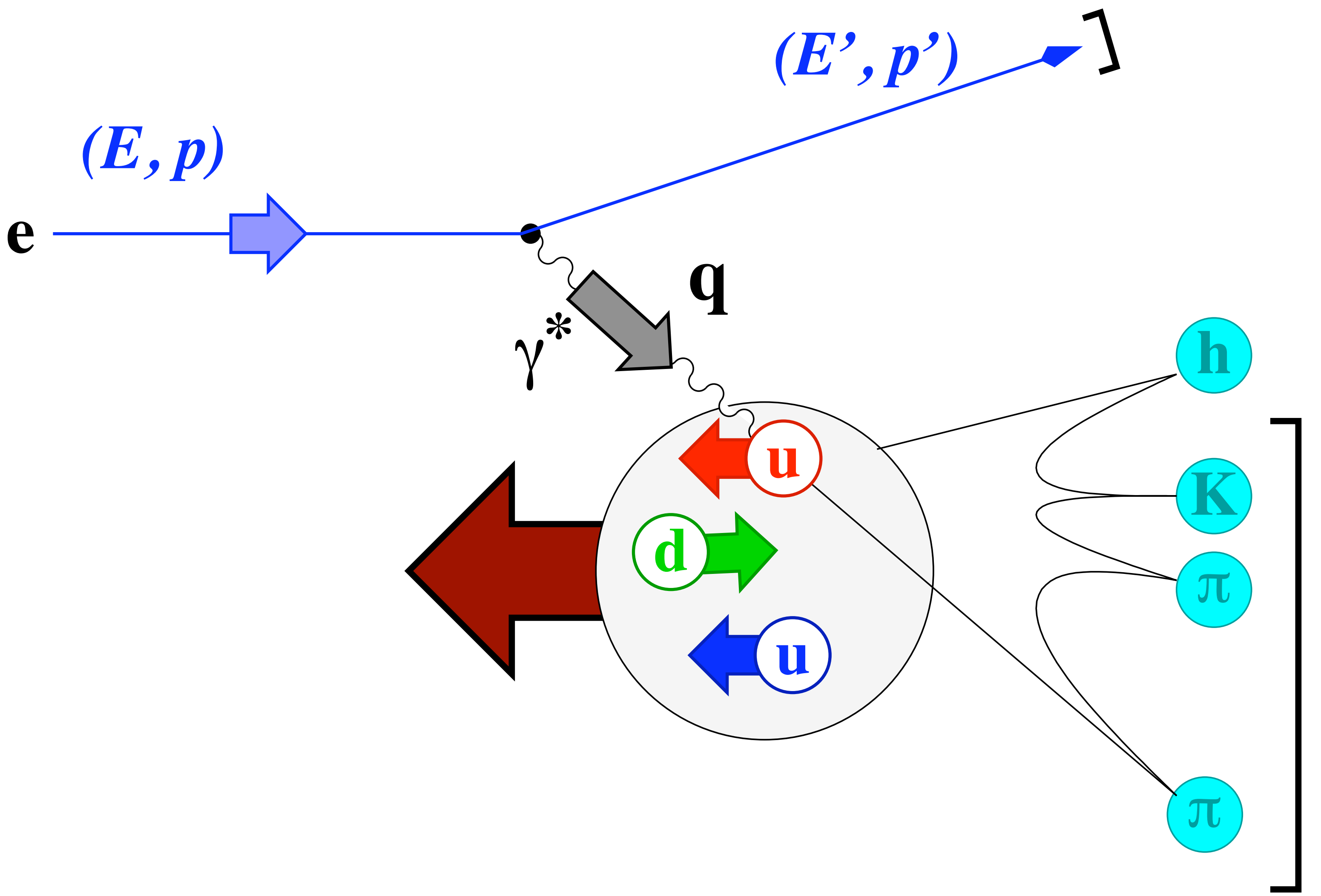
- reevaluation of the strange-quark distribution
- spin-density matrix elements for exclusive omega production

semi-inclusive DIS



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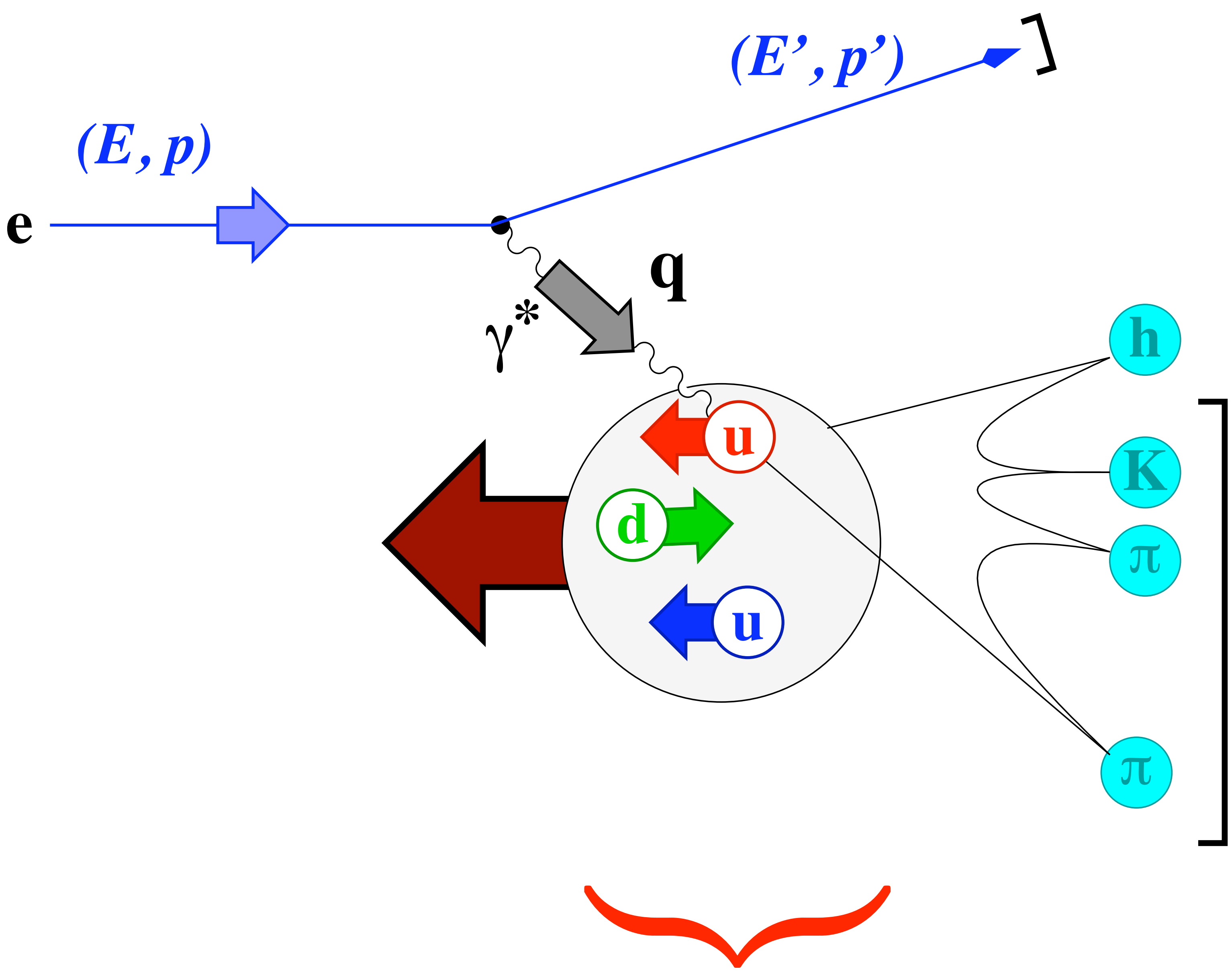

parton
distributions

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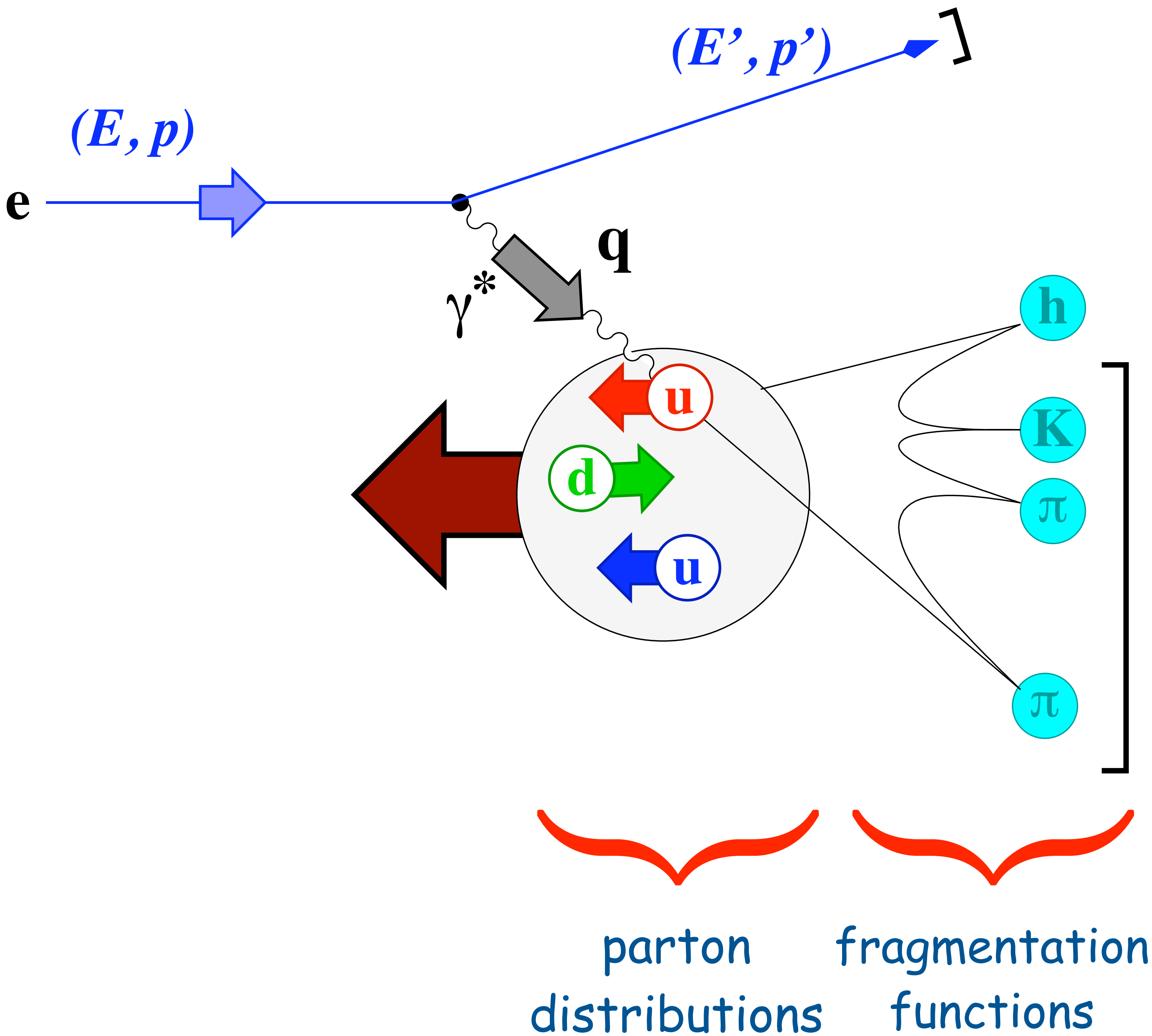
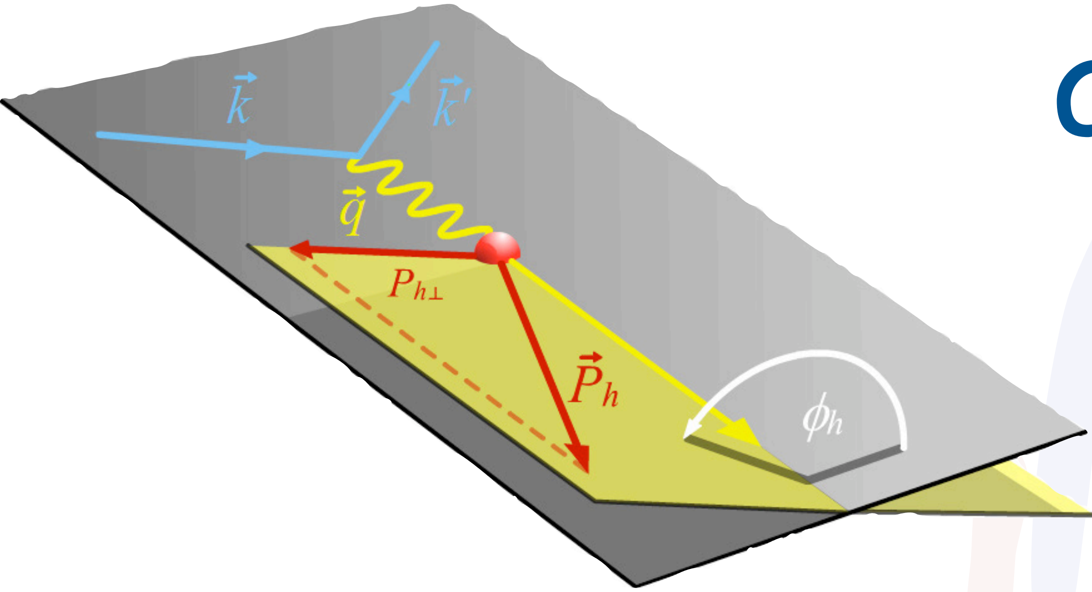


analysis of cross section



$$\frac{d^5\sigma}{dx\,dy\,dz\,d\phi_h\,dP_{h\perp}^2} \propto \left(1+\frac{\gamma^2}{2x}\right)\{F_{UU,T}+\epsilon F_{UU,L}$$

$$+\sqrt{2\epsilon(1-\epsilon)}F_{UU}^{\cos\phi_h}\cos\phi_h+\epsilon F_{UU}^{\cos 2\phi_h}\cos 2\phi_h\}$$

$$F_{XY,Z} = F_{XY,Z}(x,y,z,P_{h\perp})$$

target polarization

beam polarization

virtual-photon polarization

[see, e.g., Bacchetta et al., JHEP 0702 (2007) 093]

$$\gamma = \frac{2Mx}{Q}$$

$$\varepsilon = \frac{1-y-\frac{1}{4}\gamma^2y^2}{1-y+\frac{1}{2}y^2+\frac{1}{4}\gamma^2y^2}$$

analysis of cross section

hadron multiplicity:
normalize to inclusive DIS cross section

$$\frac{d^2\sigma^{\text{incl.DIS}}}{dx\,dy} \propto F_T + \epsilon F_L$$

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$$\approx \frac{\sum_q e_q^2\, f_1^q(x,p_T^2)\otimes D_1^{q\to h}(z,K_T^2)}{\sum_q e_q^2\, f_1^q(x)}$$

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moments:
normalize to azimuth-independent cross section

analysis of cross section

hadron multiplicity:
normalize to inclusive DIS cross section

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$$2\langle\cos 2\phi\rangle_{UU} \equiv 2\frac{\int d\phi_h \cos 2\phi\, d\sigma}{\int d\phi_h d\sigma} = \frac{\epsilon F_{UU}^{\cos 2\phi}}{F_{UU,T}+\epsilon F_{UU,L}}$$

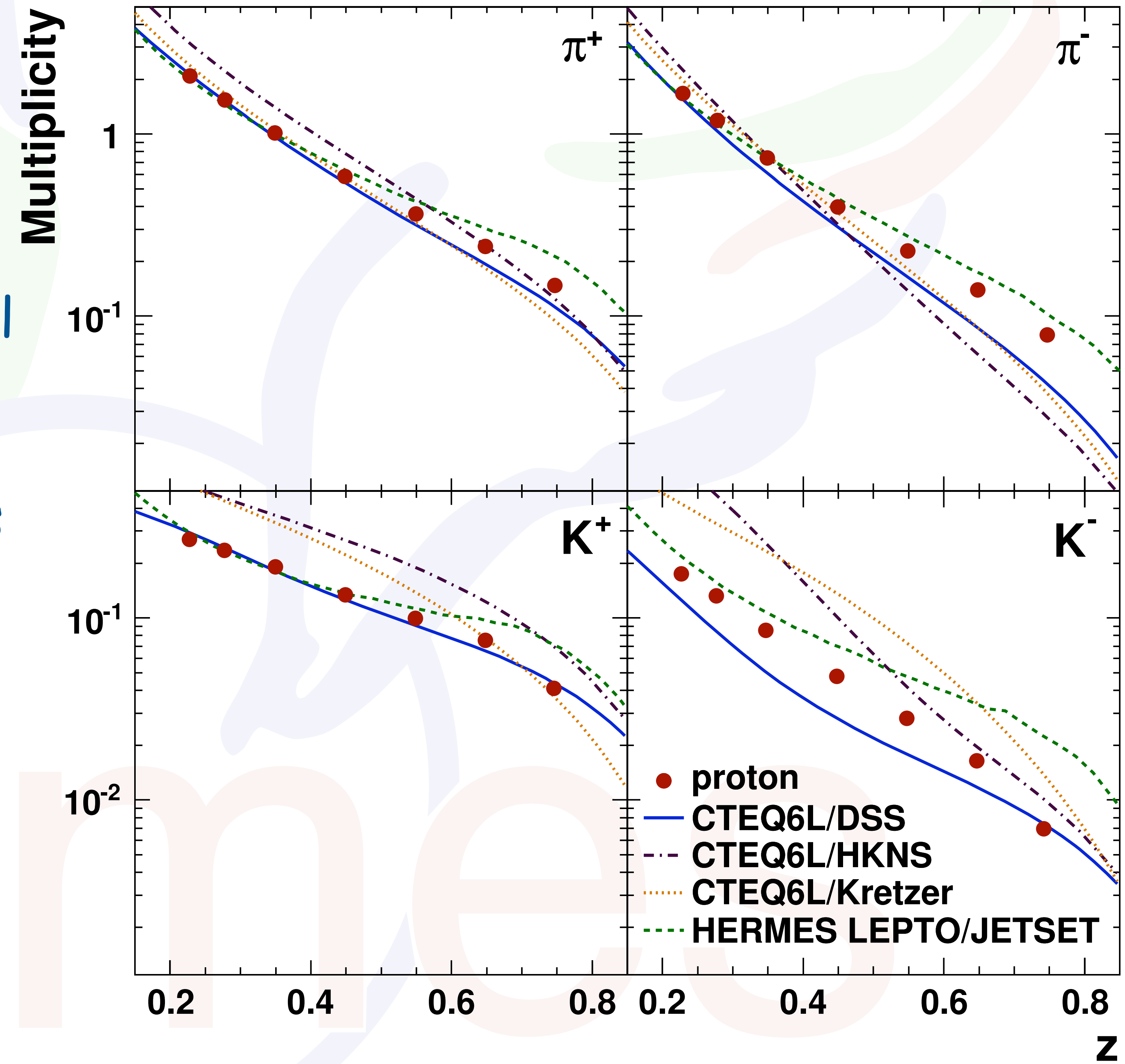
$$\approx \epsilon\frac{\sum_q e_q^2\, h_1^{\perp,q}(x,p_T^2)\otimes_{\text{BM}} H_1^{\perp,q\to h}(z,K_T^2)}{\sum_q e_q^2\, f_1^q(x,p_T^2)\otimes D_1^{q\to h}(z,K_T^2)}$$

moments:
normalize to azimuth-independent cross section

hadron multiplicities @ HERMES

- extensive data set on pure proton and deuteron targets for identified charged mesons
- extracted in a multi-dimensional unfolding procedure
- fair agreement between FF fits and pion multiplicities
- poor description of (negative) kaons

[Airapetian et al., PRD (in press); arXiv:1212.5407]



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- p/d differences due to flavor dependence of fragmentation

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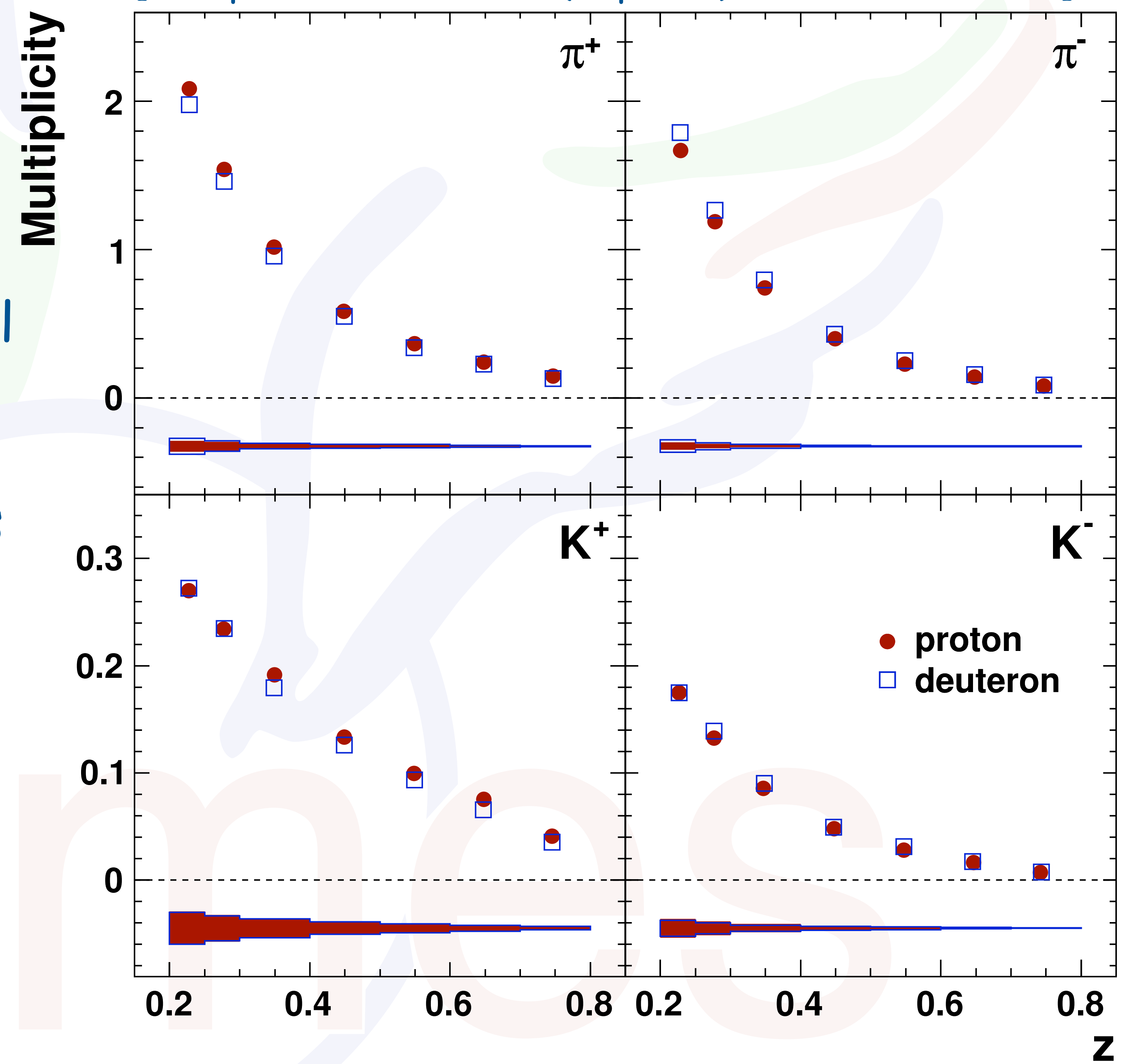

strange-quark distributions

- use isoscalar probe and target to extract strange-quark distribution
- only need K^{+}+K^{-} multiplicities on deuteron

$$\boxed{S(x)} \int \mathcal{D}_S^K(z)\,\mathrm{d}z \simeq Q(x)\left[5\frac{\mathrm{d}^2N^K(x)}{\mathrm{d}^2N^{\mathrm{DIS}}(x)} - \int \mathcal{D}_Q^K(z)\,\mathrm{d}z\right]$$

$$\begin{aligned}
\mathbf{S(x)} &= \mathbf{s(x)} + \mathbf{\bar{s}(x)} \\
\mathbf{Q(x)} &= \mathbf{u(x)} + \mathbf{\bar{u}(x)} + \mathbf{d(x)} + \mathbf{\bar{d}(x)} \\
\mathcal{D}_\mathbf{S}^\mathbf{K} &= \mathbf{D_1^{s\to K^+}} + \mathbf{D_1^{\bar{s}\to K^+}} + \mathbf{D_1^{s\to K^-}} + \mathbf{D_1^{\bar{s}\to K^-}} \\
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\end{aligned}$$

strange-quark distributions

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- assume vanishing strangeness at high x to extract non-strange fragmentation

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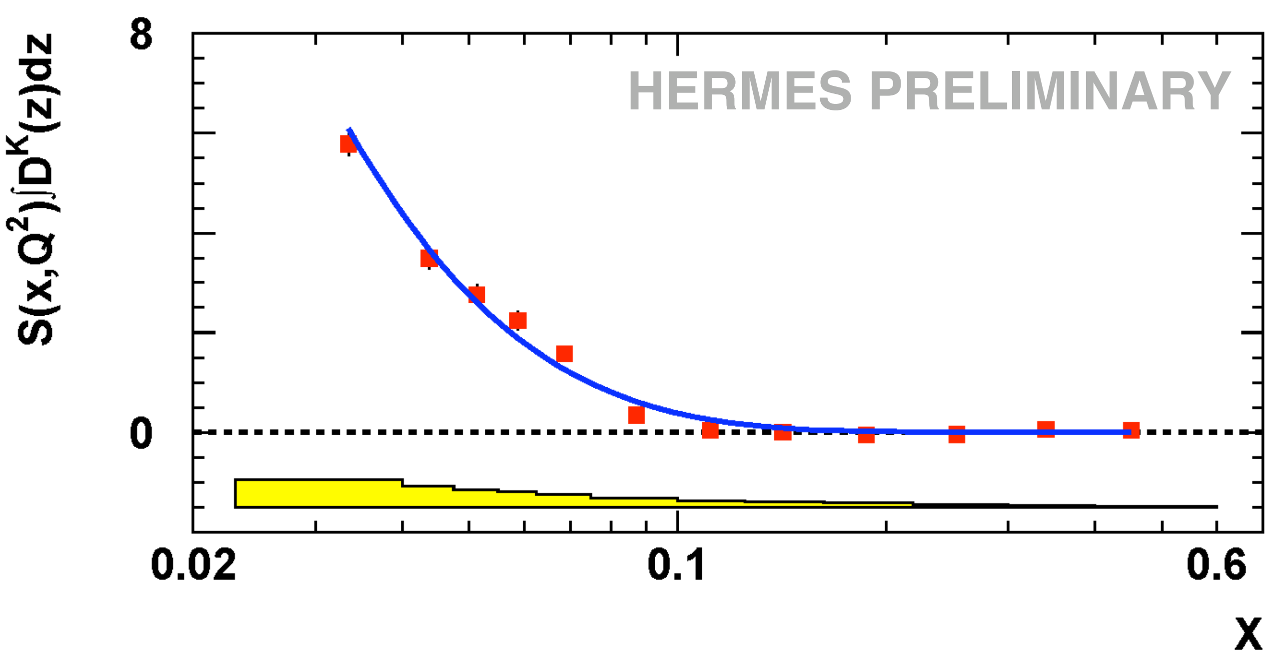

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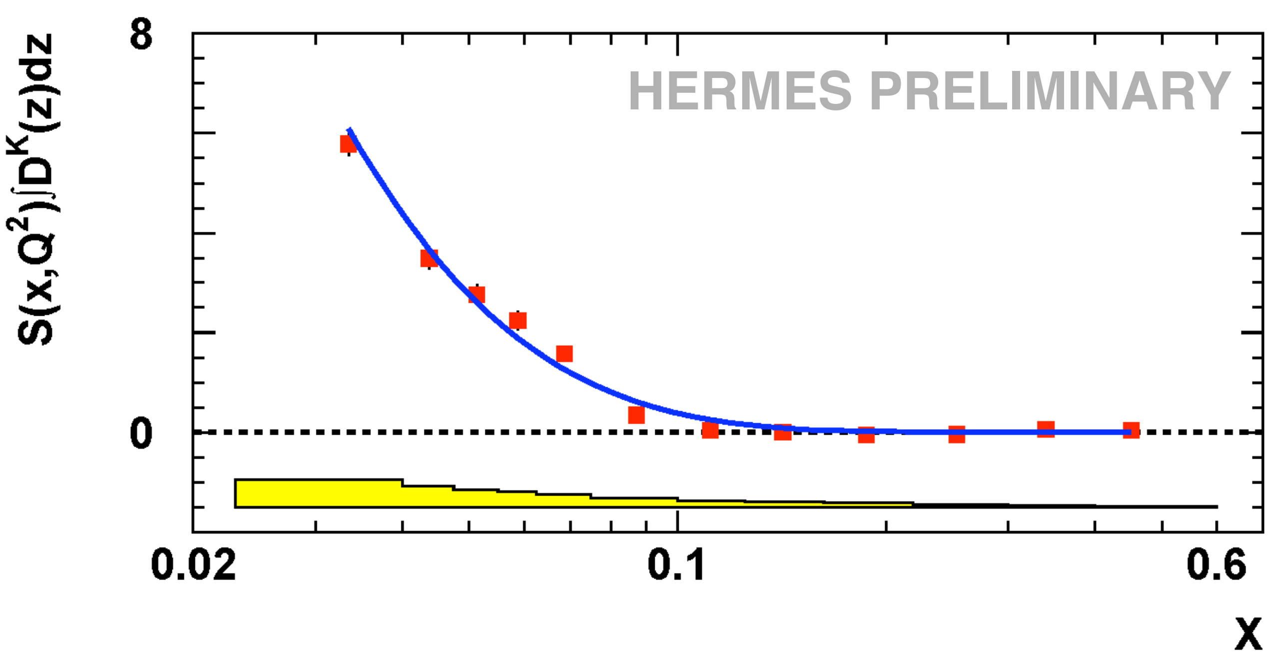

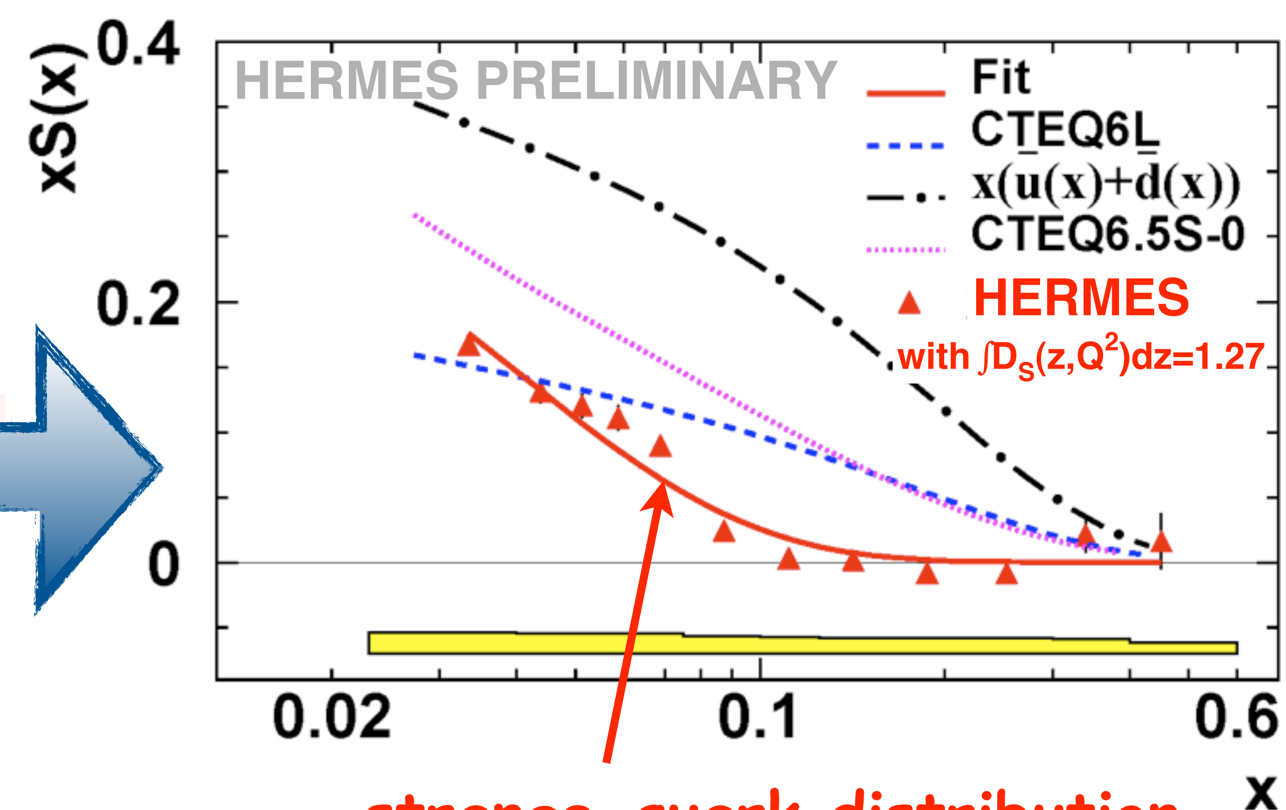

strange-quark distribution

softer than (maybe) expected

strange-quark distributions

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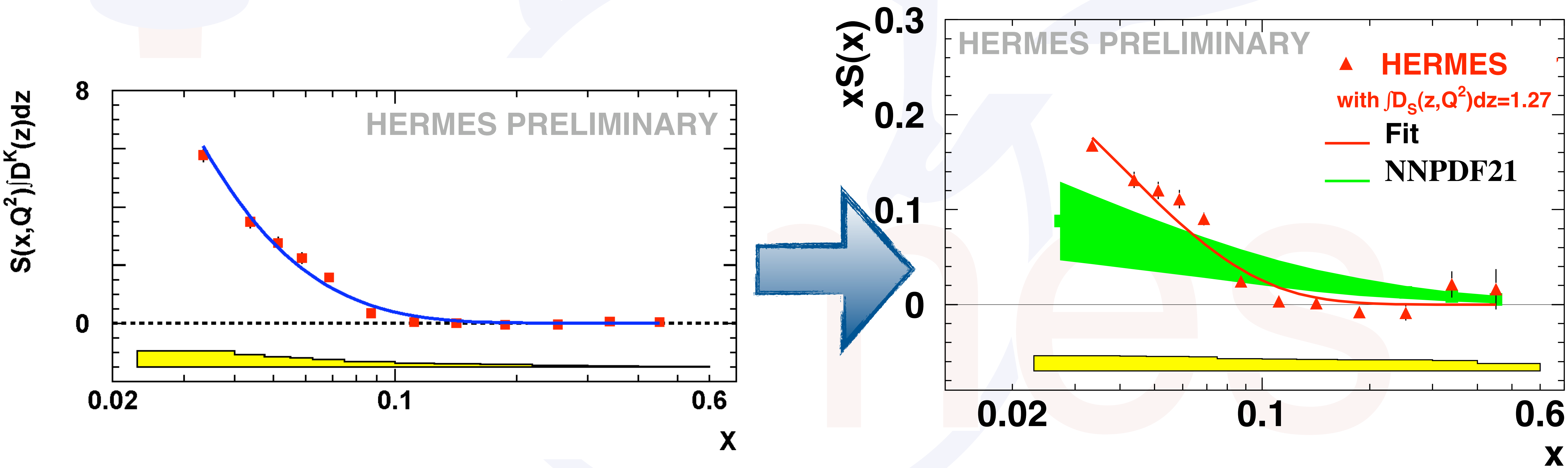
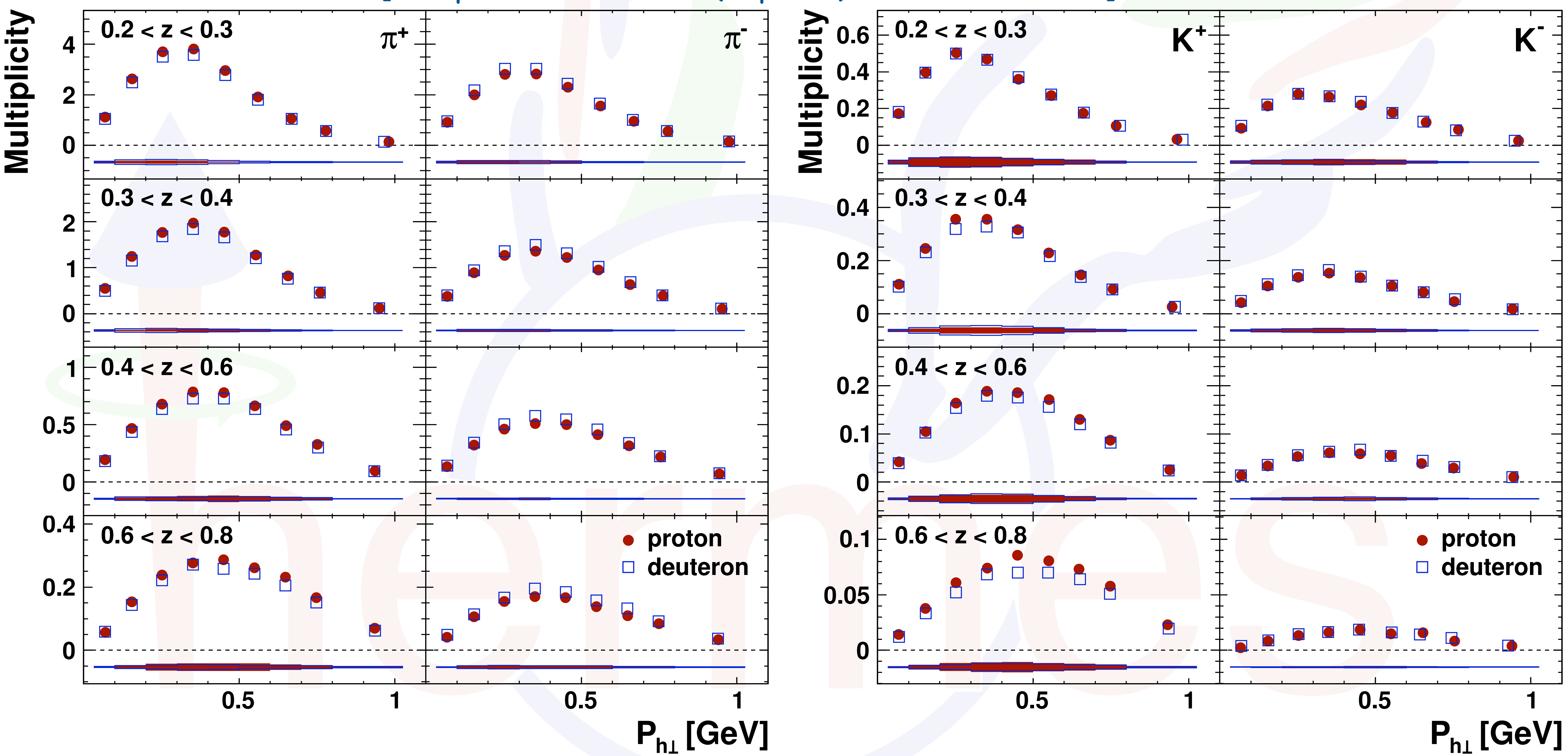


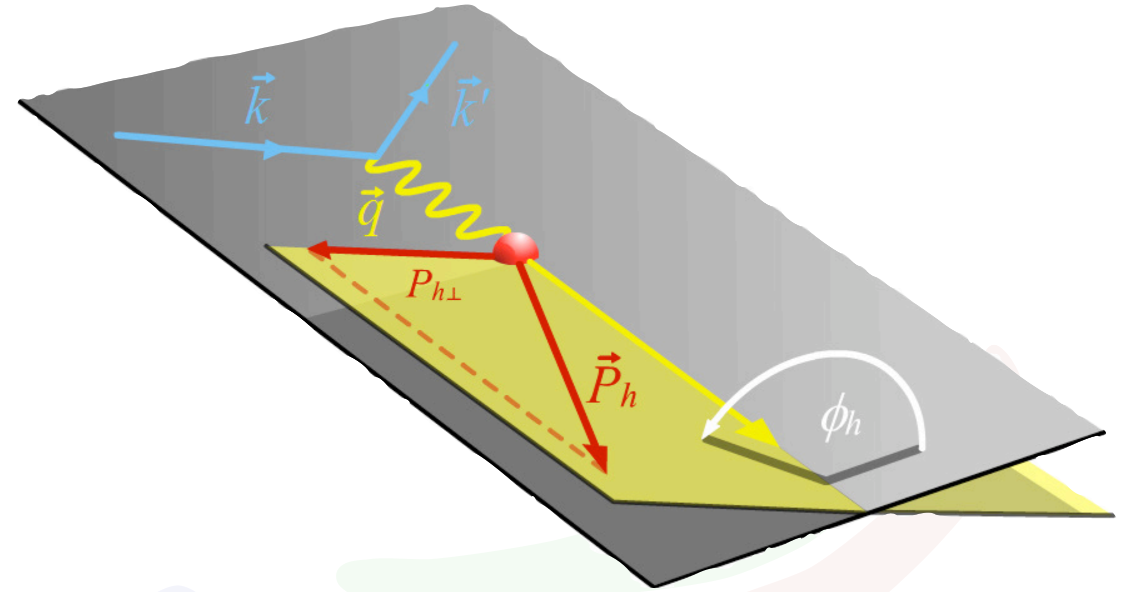
hadron multiplicities @ HERMES

multi-dimensional analysis allows exploration of new kinematic dependences

[Airapetian et al., PRD (in press); arXiv:1212.5407]



azimuthal moments



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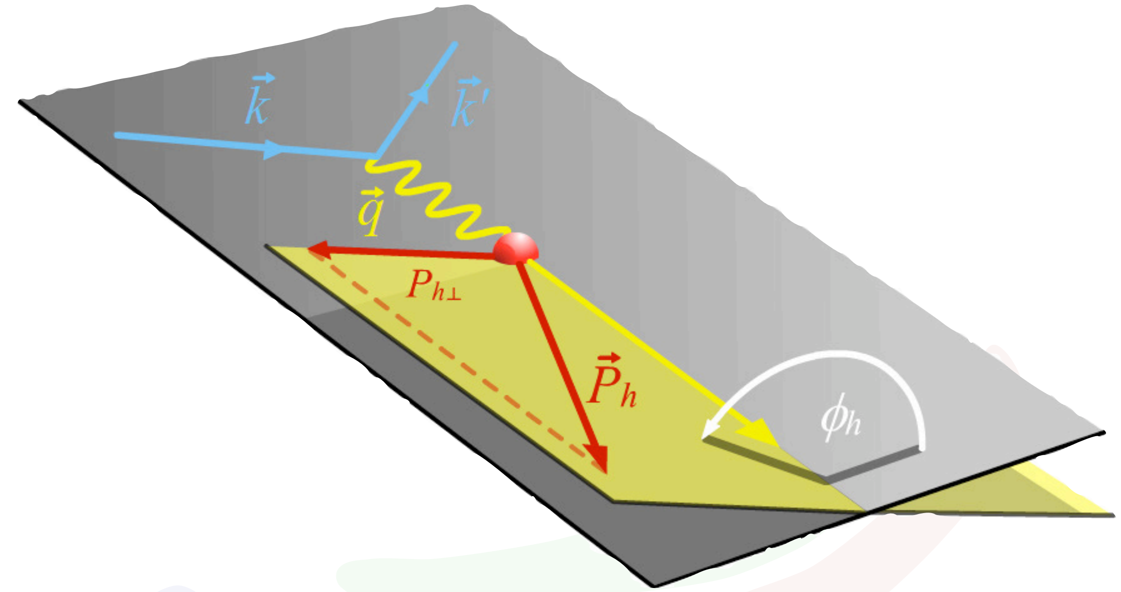

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$$+\sqrt{2\epsilon(1-\epsilon)}\,\boxed{F_{UU}^{\cos\phi_h}}\cos\phi_h+\epsilon\,\boxed{F_{UU}^{\cos 2\phi_h}}\cos 2\phi_h\Big\}$$

BOER-MULDERS EFFECT

leading twist

$$F_{UU}^{\cos 2\phi_h} \propto C\left[-\frac{2(\hat{P}_{h\perp}\cdot\vec{k}_T)(\hat{P}_{h\perp}\cdot\vec{p}_T)-\vec{k}_T\cdot\vec{p}_T}{MM_h}h_1^\perp H_1^\perp\right]$$

CAHN EFFECT

next to leading twist

$$F_{UU}^{\cos\phi_h} \propto \frac{2M}{Q}C\left[-\frac{\hat{P}_{h\perp}\cdot\vec{p}_T}{M_h}x\;h_1^\perp H_1^\perp-\frac{\hat{P}_{h\perp}\cdot\vec{k}_T}{M}x\;f_1 D_1+\ldots\right]$$

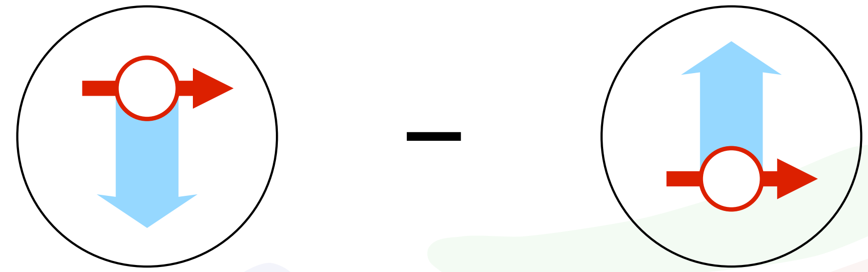
Interaction dependent terms neglected

(Implicit sum over quark flavours)

Boer-Mulders effect

parton transverse polarization

parton transverse momentum



$S_q \cdot (p_\perp \times P_N)$

Boer-Mulders effect

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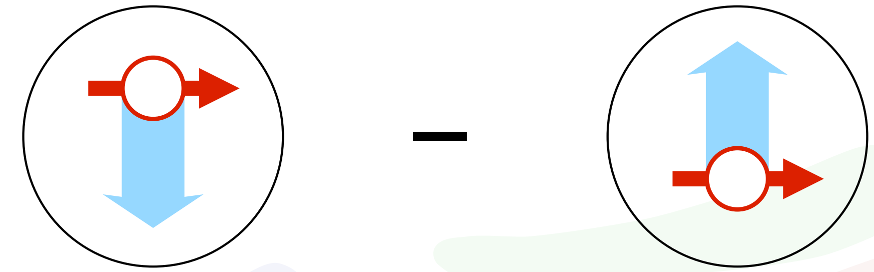

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- spin-effect in **unpolarized** reactions

Boer-Mulders effect

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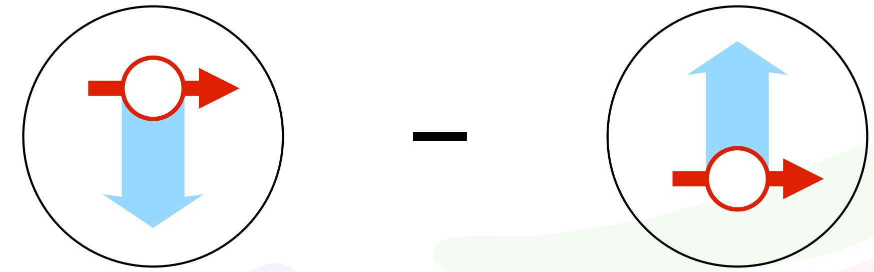

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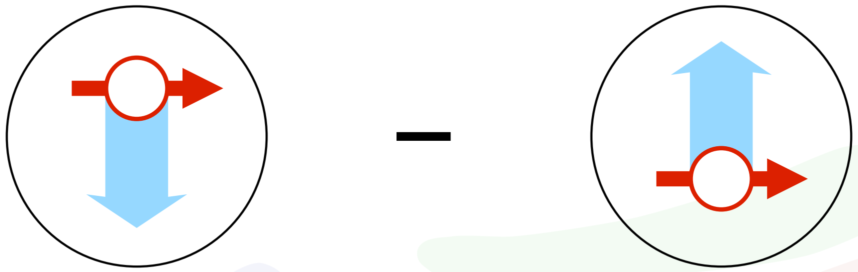

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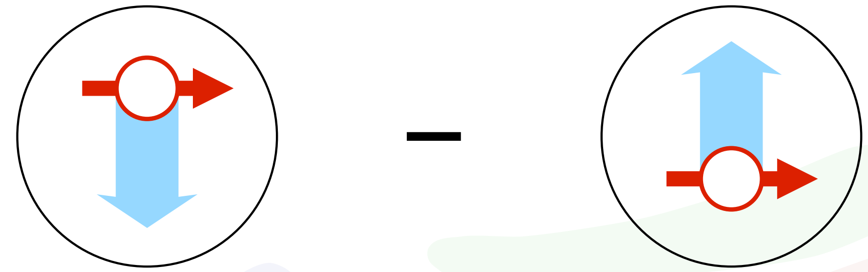
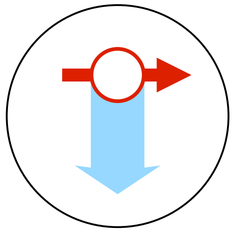


$S_q \cdot (p_\perp \times P_N)$

- spin-effect in **unpolarized** reactions
- "QCD Sokolov-Ternov effect" - transverse polarization of "orbiting" quarks
- QCD: sign change for DIS vs. Drell-Yan
- up to now little data from DIS

➡ HERMES with most comprehensive data set



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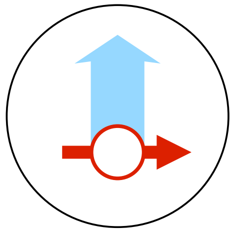
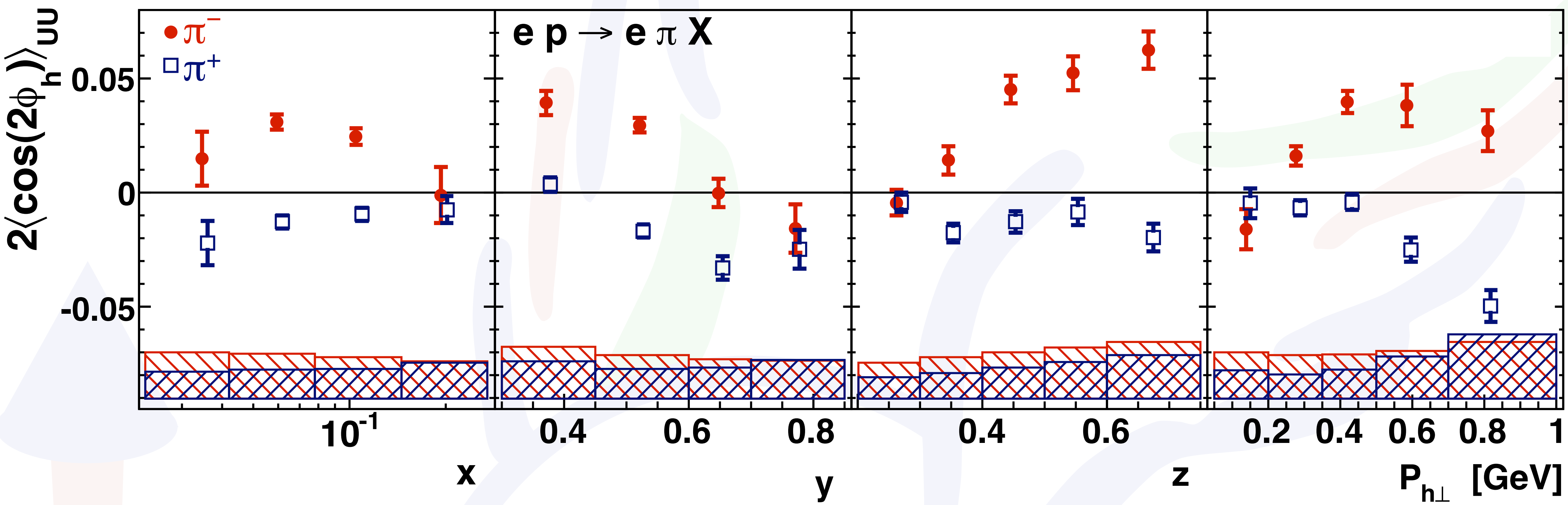
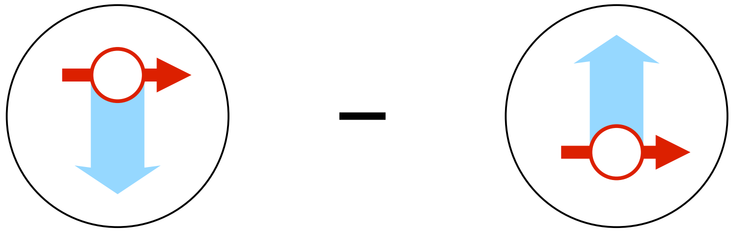


signs of Boer-Mulders

[Airapetian et al., PRD 87 (2013) 012010]





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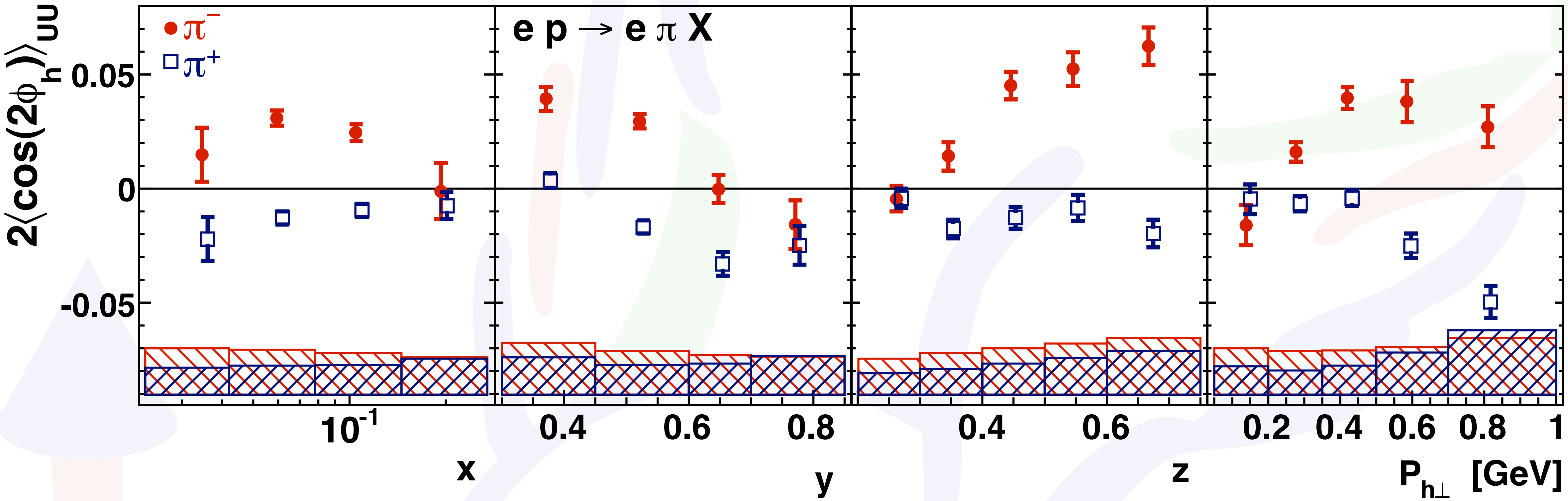
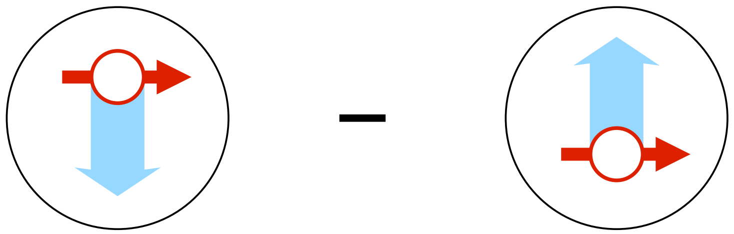


- opposite sign for charged pions with larger magnitude for π^-
  -> same-sign BM-function for valence quarks?



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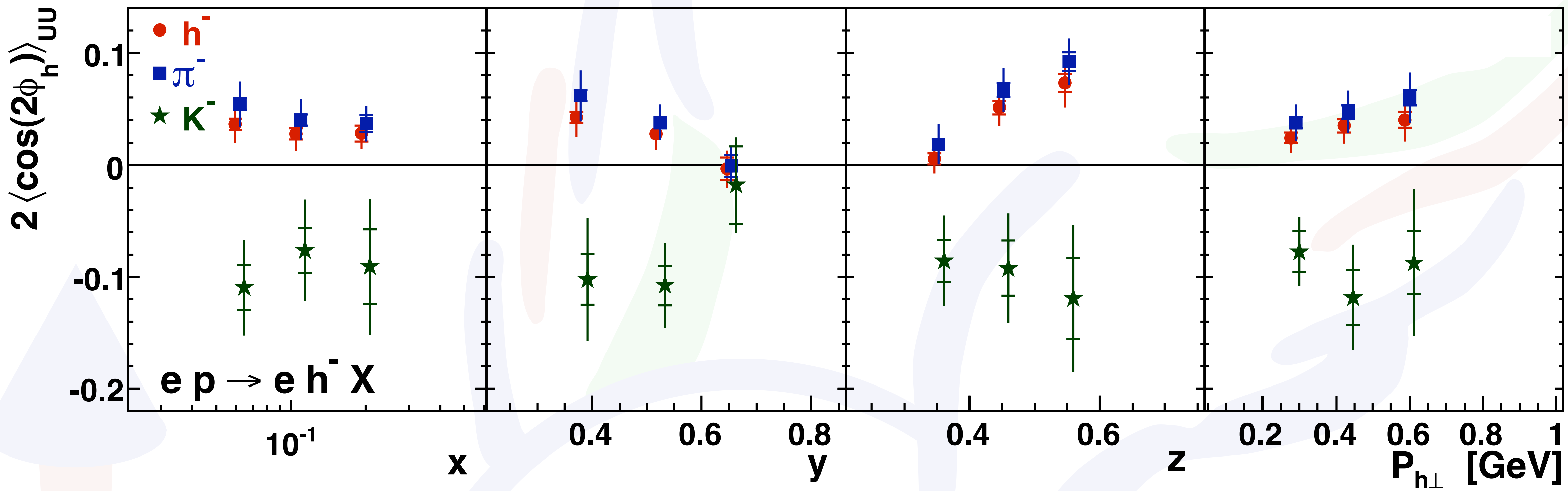
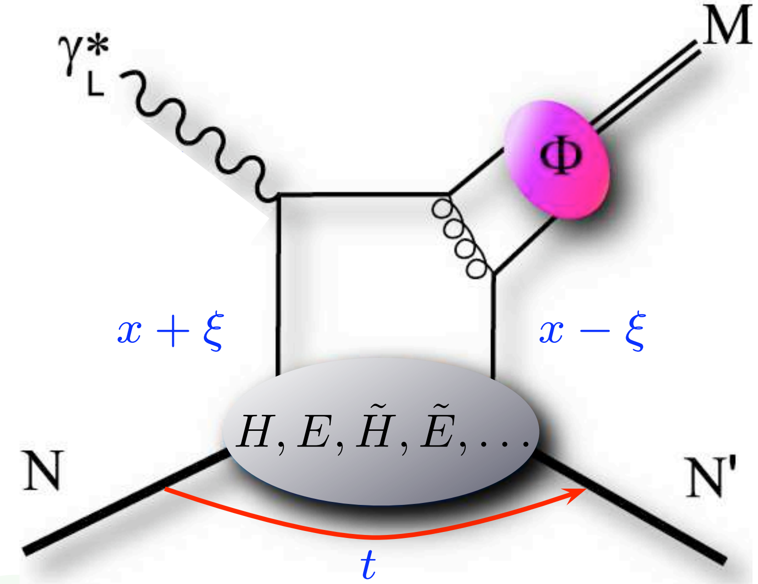


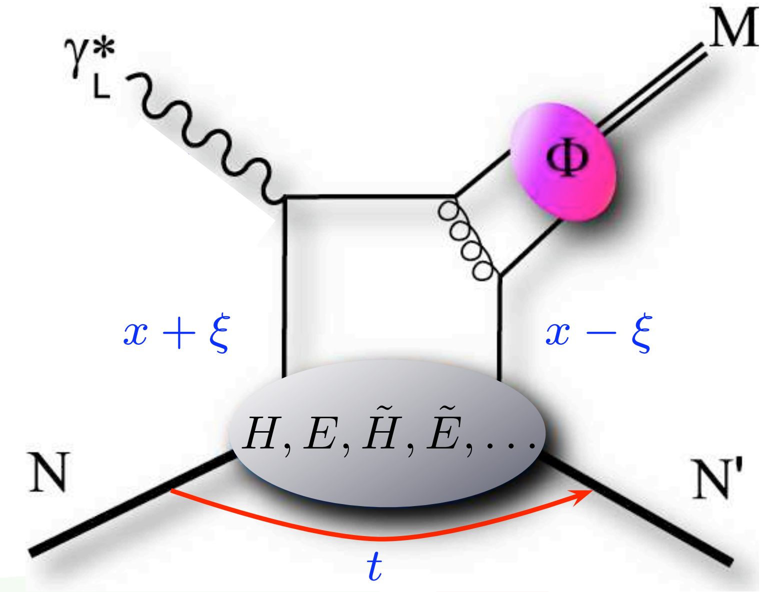
- opposite sign for charged pions with larger magnitude for π^-
  -> same-sign BM-function for valence quarks?
- intriguing behavior for kaons

exclusive vector-meson production

exclusive meson production

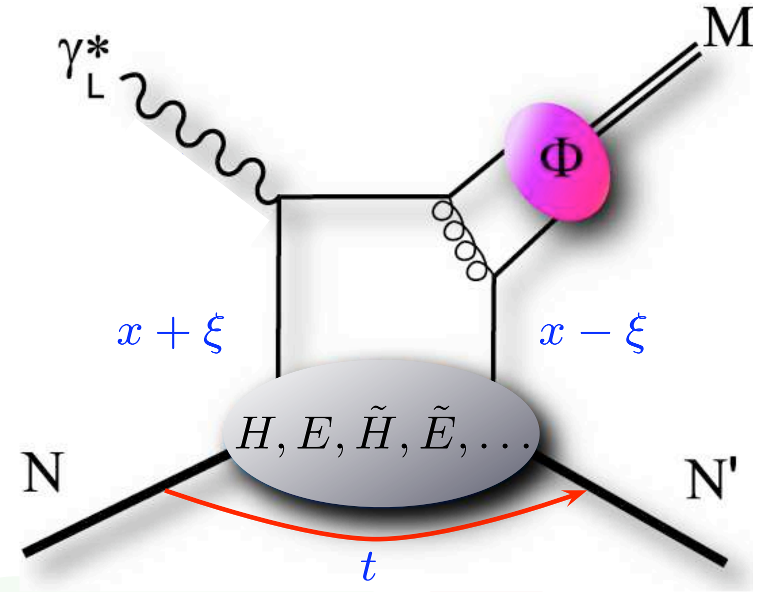


exclusive meson production



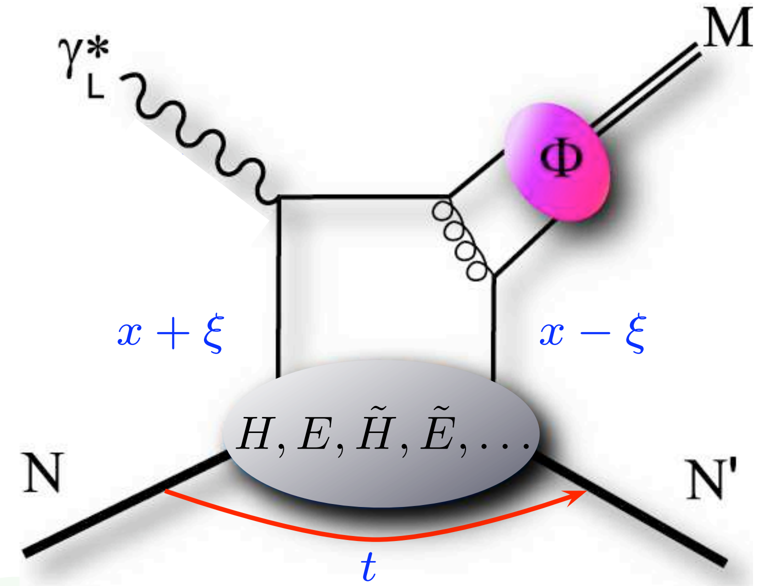
- factorization proven for longitudinal photons

exclusive meson production



- factorization proven for longitudinal photons
- GPDs convoluted with meson amplitude

exclusive meson production



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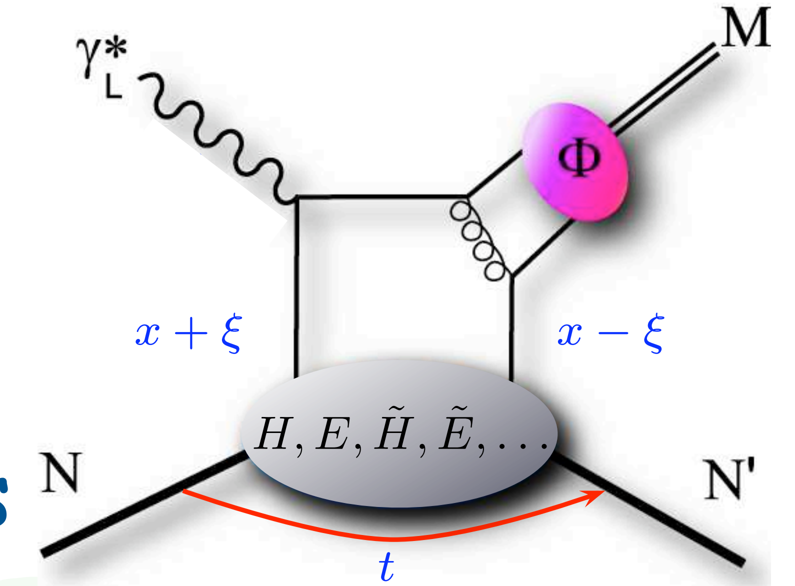
- access to various quark-flavor combinations

exclusive meson production



- factorization proven for longitudinal photons
- GPDs convoluted with meson amplitude
- access to various quark-flavor combinations
- vector-meson cross section:

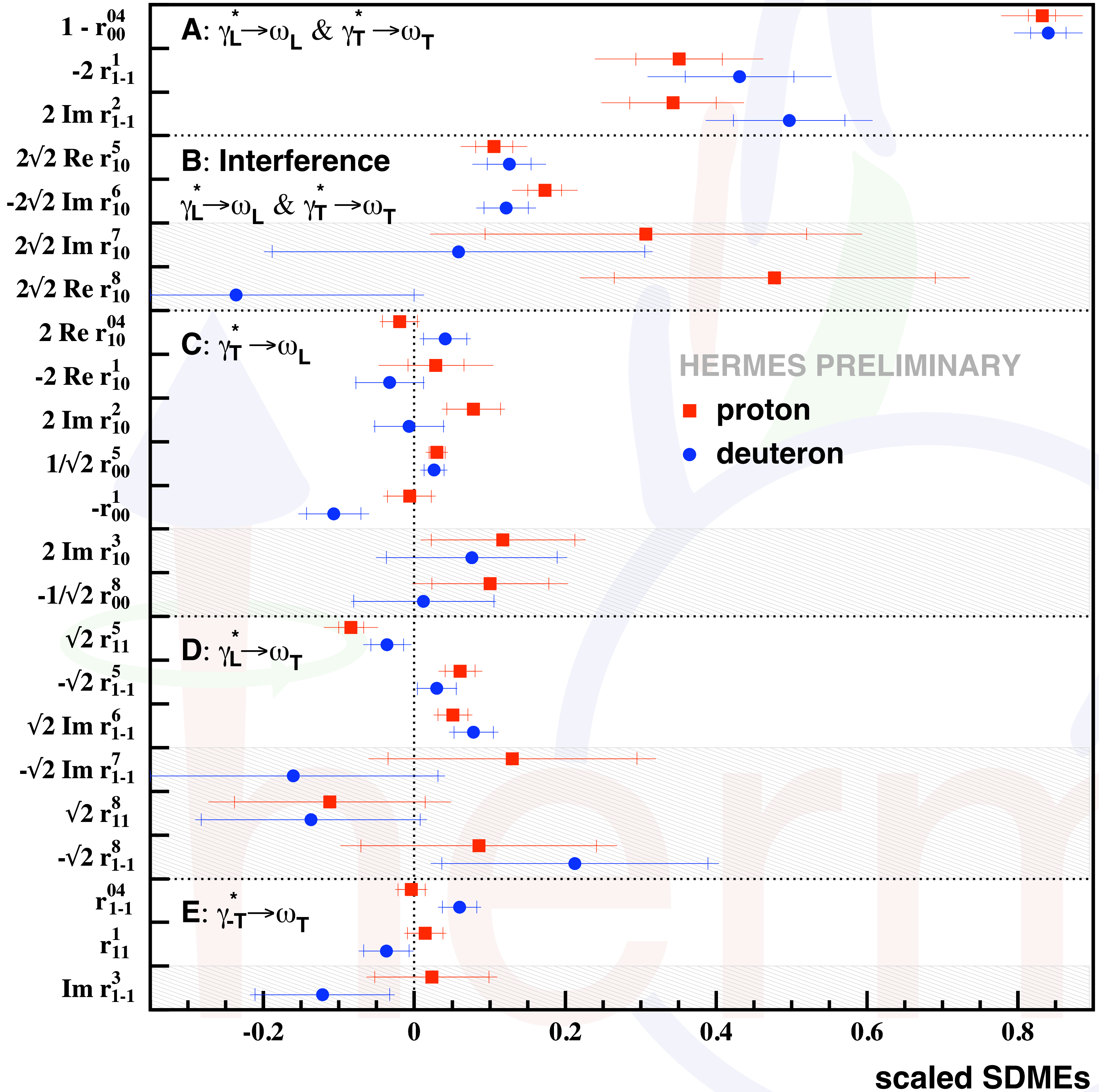
π^0	2Δu+Δd
η	2Δu−Δd
ρ^0	2u+d, 9g/4
ω	2u−d, 3g/4
ϕ	s, g
ρ^+	u−d
J/ψ	g

$$\frac{d\sigma}{dx_B\, dQ^2\, dt\, d\phi_S\, d\phi\, d\cos\theta\, d\varphi} = \frac{d\sigma}{dx_B\, dQ^2\, dt} W(x_B, Q^2, t, \phi_S, \phi, \cos\theta, \varphi)$$

$$W = W_{UU} + P_B W_{LU} + S_L W_{UL} + P_B S_L W_{LL} + S_T W_{UT} + P_B S_T W_{LT}$$

look at various angular (decay) distributions to study helicity transitions (“spin-density matrix elements”)

... exclusive ω production



- helicity-conserving SDMEs dominate
- hardly any violation of SCHC
- interference smaller than for phi and rho production
- (not shown) unnatural-parity exchange significant

summary

- changes in management
- analysis platform basically moved to BIRD system
- mile-stone analyses of unpolarized semi-inclusive DIS cross section finished
  - hadron multiplicities give essential input to hadronization phenomenology
  - azimuthal moments will give unique insights in spin-momentum structure of nucleons
- preliminary results on strange distribution and omega SDMEs