The Transverse Spin Effects in Kaon Production at HERMES

Ulrike Elschenbroich

QCD-N'06, Frascati, Italy 14.06.2006

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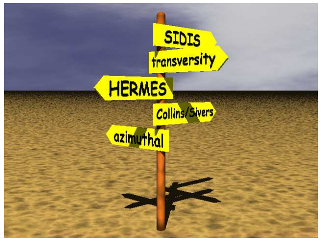
hermes

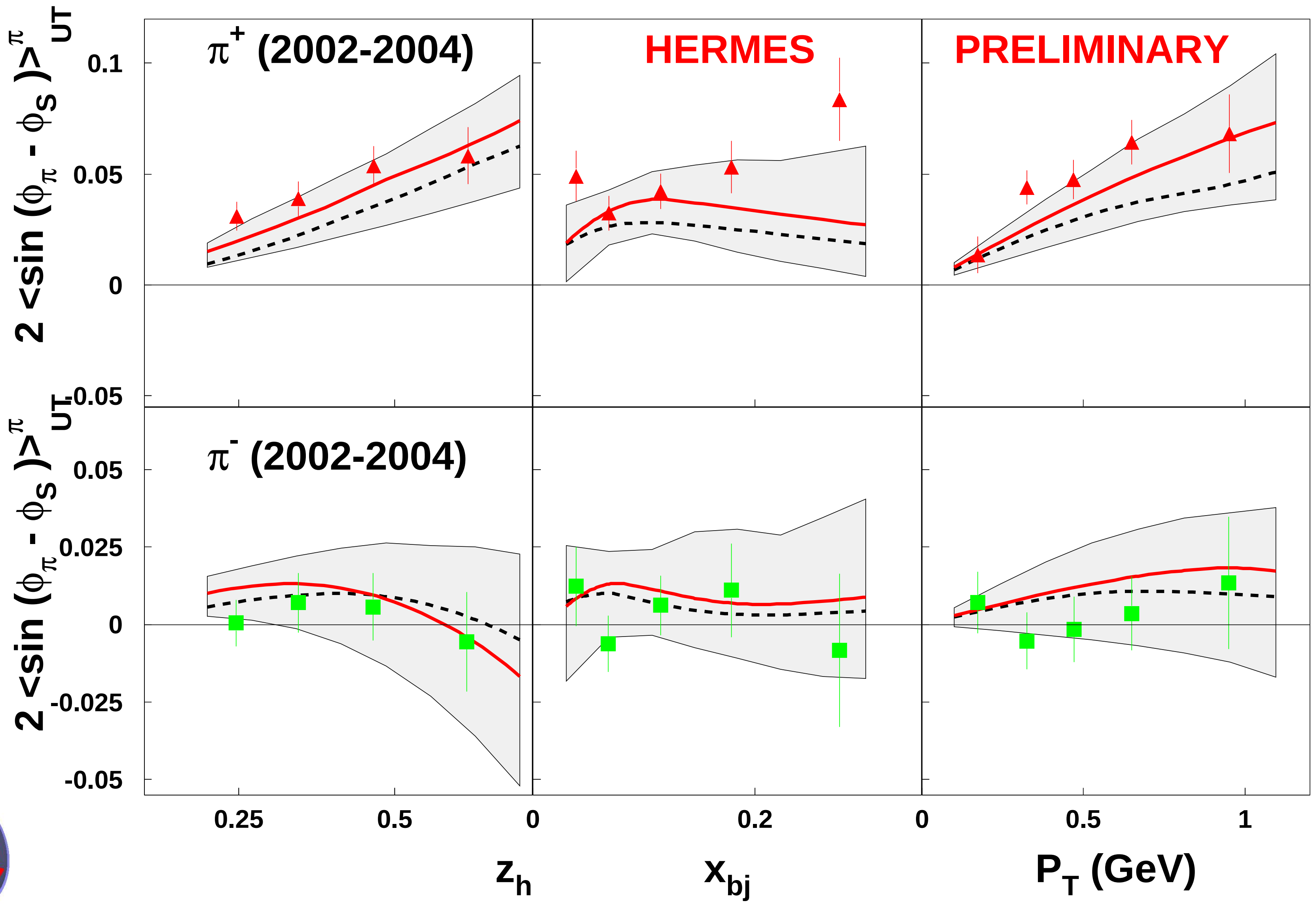
Outline

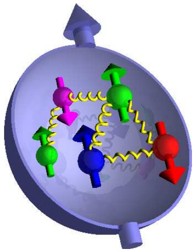
- Appetiser
- The RICH Detector
- The Measured Azimuthal Asymmetry Moments for Kaons
- Conclusions



Appetiser

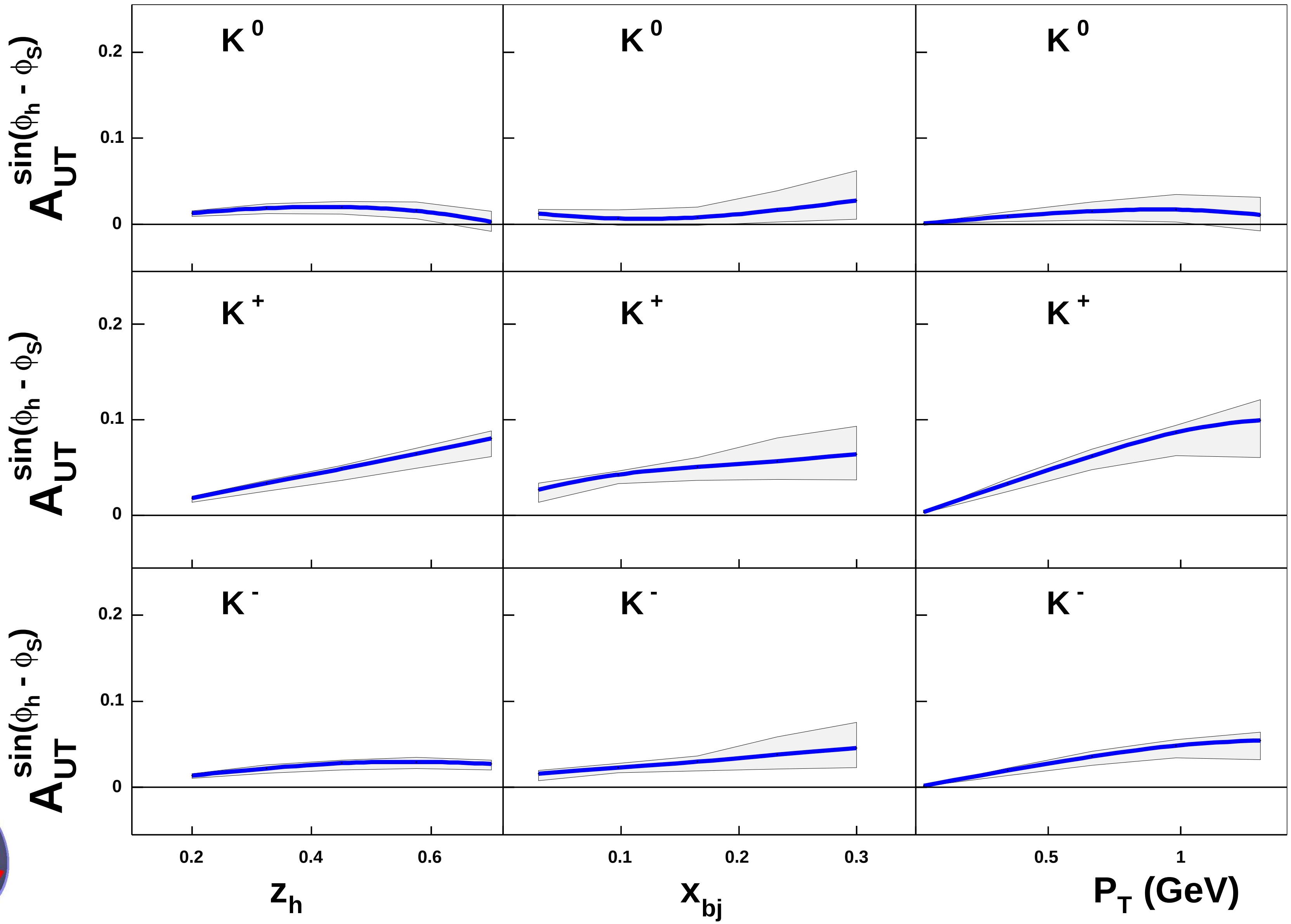
Fit to the Sivers moments of charged pions by Anselmino et al.

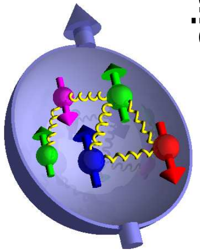




Appetiser

➜ predictions for the kaon Sivers moments neglecting sea quarks





u–quark Dominance

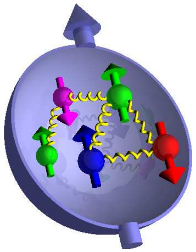
$$\sigma^{ep\rightarrow eh} \sim \sum_q e_q^2 \cdot \mathrm{DF}^q \otimes \mathrm{FF}^{q\rightarrow h}$$

Distribution Functions and Fragmentation Functions

- quark content:
  - proton: uud
  - $\pi^+ : u\bar{d},\ \ \pi^- : \bar{u}d,\ \ K^+ : u\bar{s},\ \ K^- : \bar{u}s$
- quark charge is additional factor

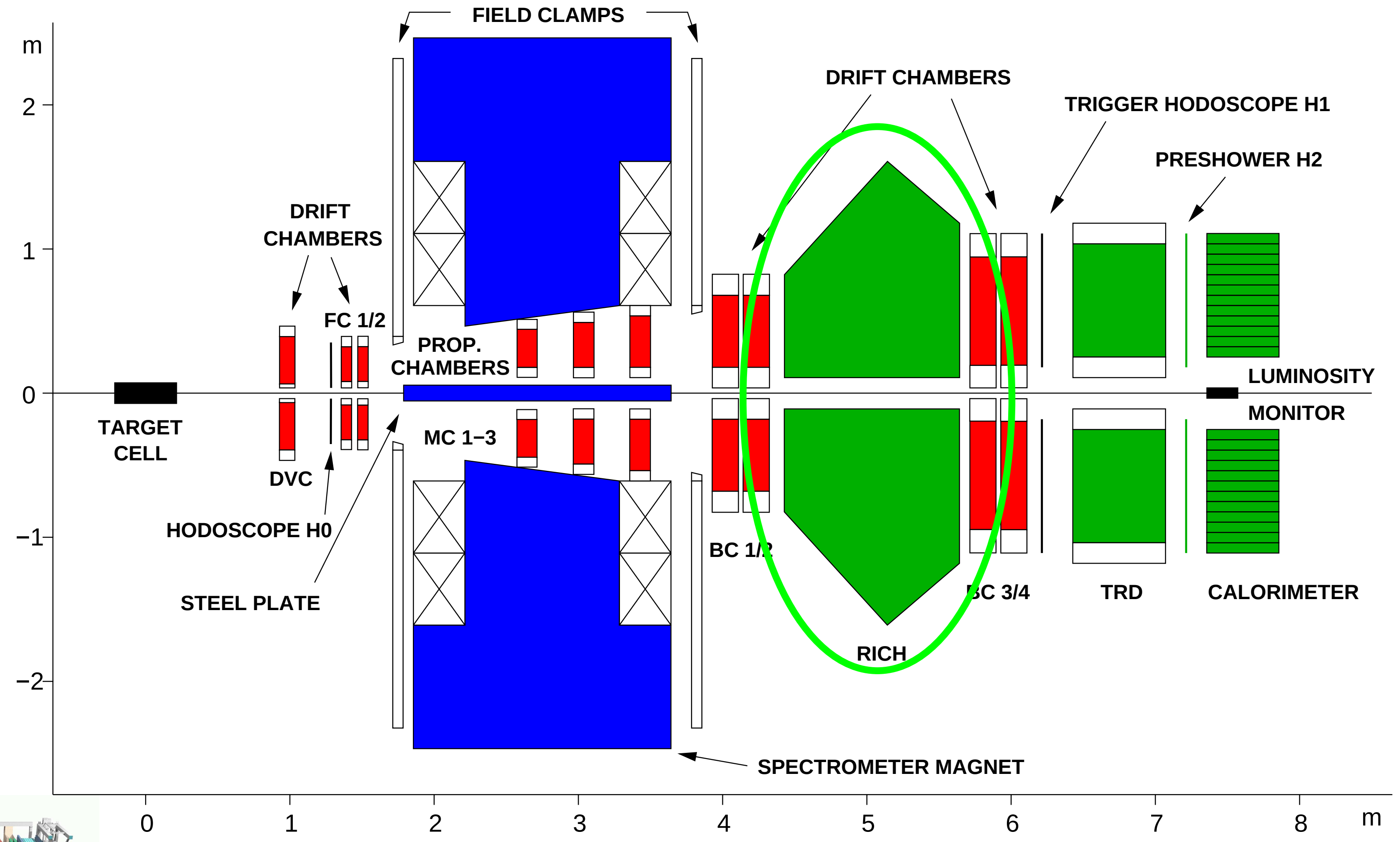
➜ unpol. scattering off a proton is dominated by scattering off a u quark

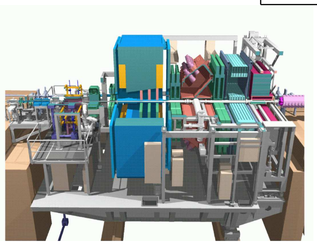
- favoured unpolarised FF is much larger than unfavoured FF
  (e.g. $u \rightarrow \pi^+, \bar{d} \rightarrow \pi^+, u \rightarrow K^+, \bar{s} \rightarrow K^+ >$
  $\bar{u} \rightarrow \pi^+, d \rightarrow \pi^+, \bar{u} \rightarrow K^+, s \rightarrow K^+$)



The HERMES Spectrometer

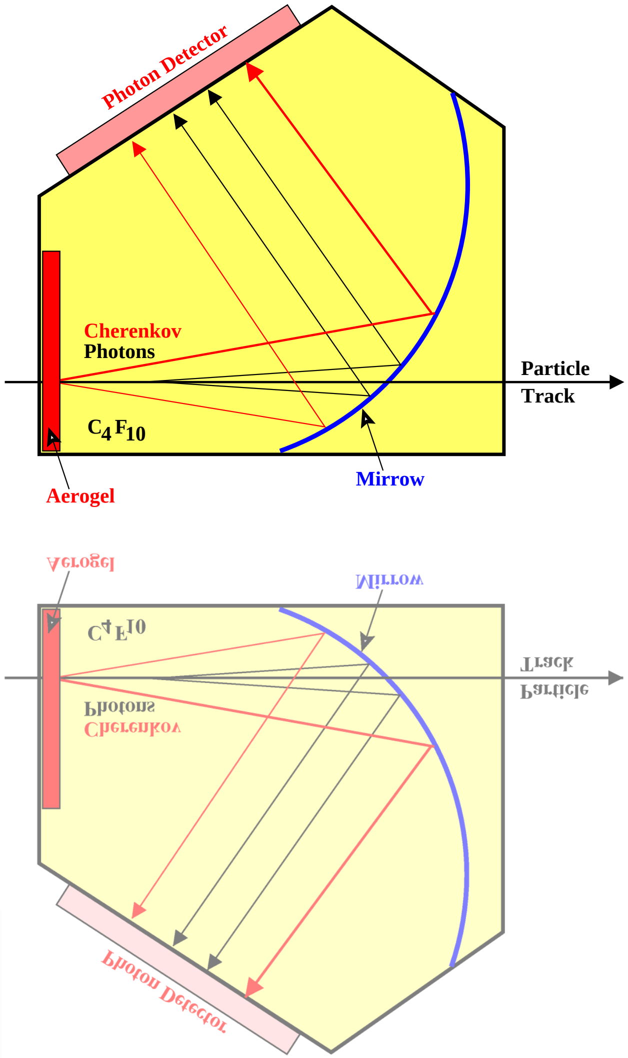
Hadron identification with the RICH detector

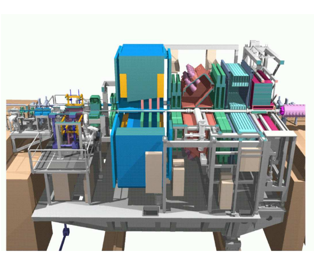




The RICH Detector

Dual radiator Ring Imaging Čerenkov detector





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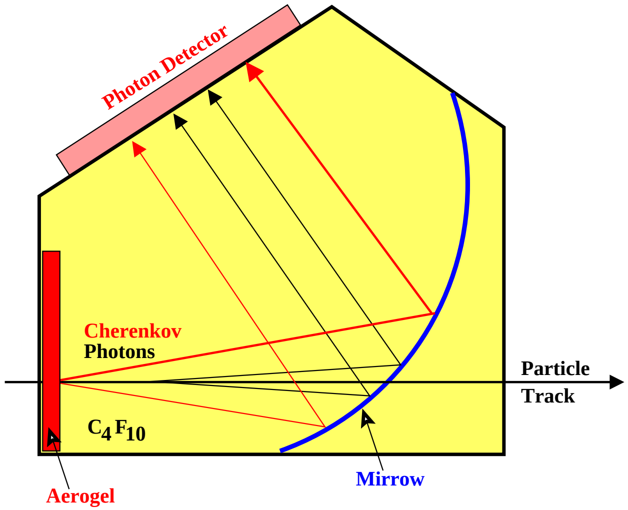
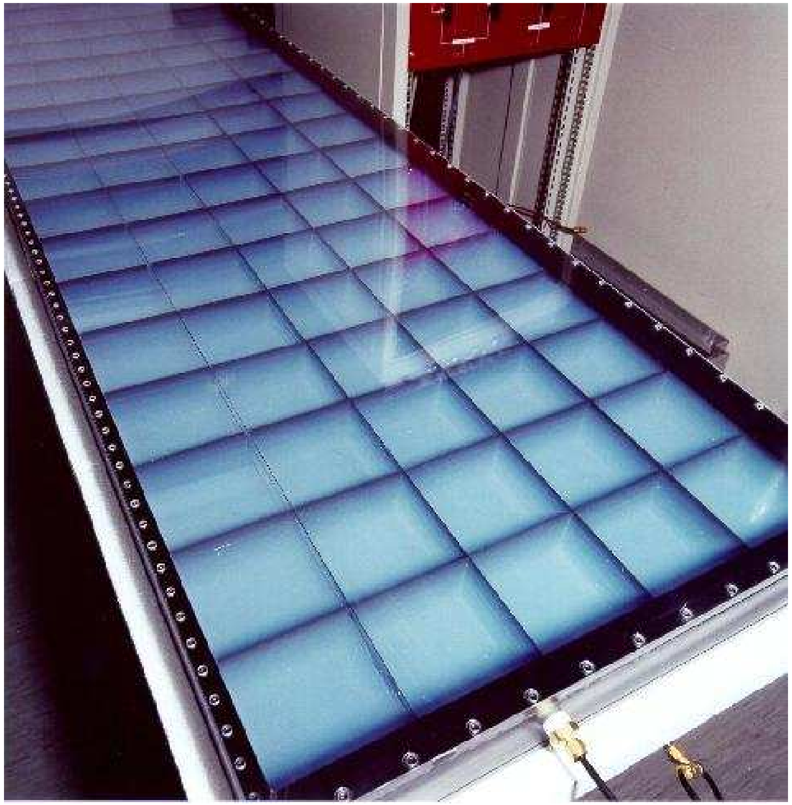
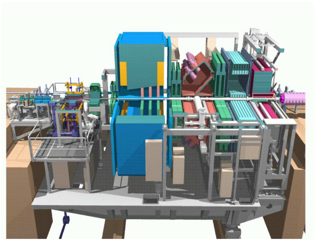




Aerogel : n = 1.03



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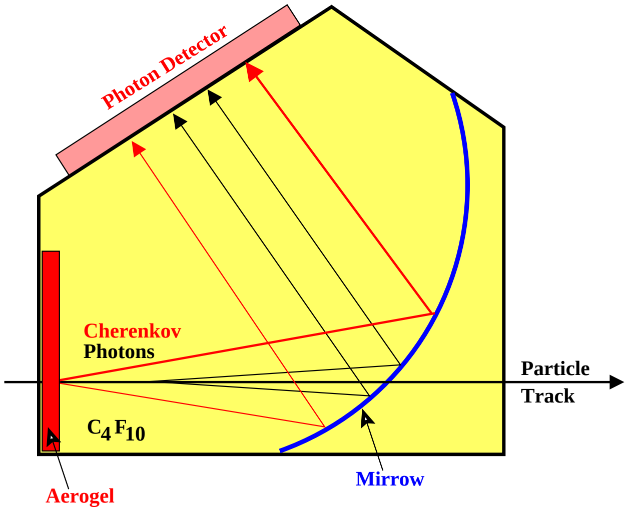
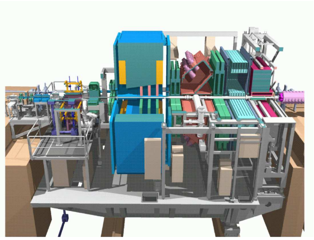


Aerogel : n = 1.03

C_4F_{10} : n = 1.0014



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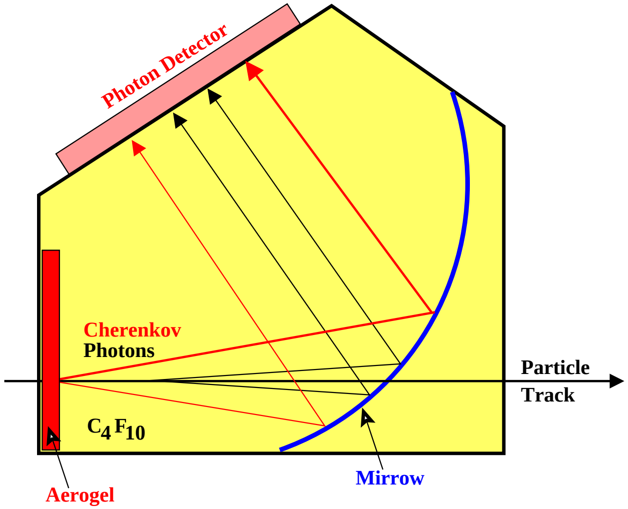

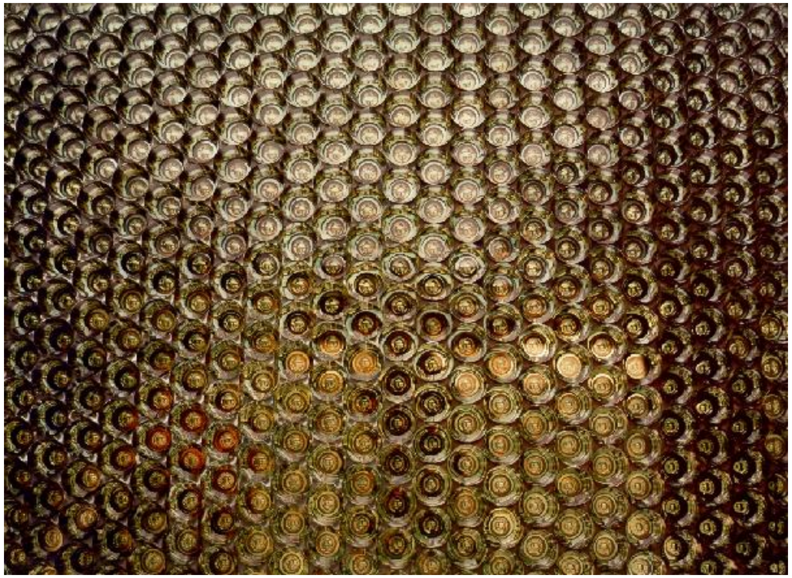

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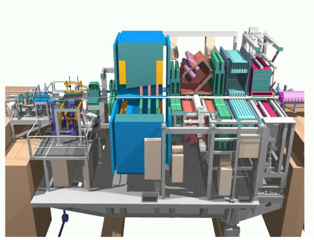
PMT matrix with 1934 PMTs



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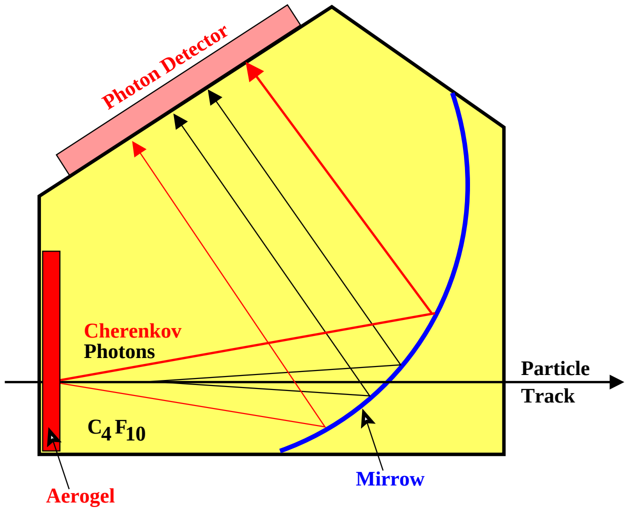

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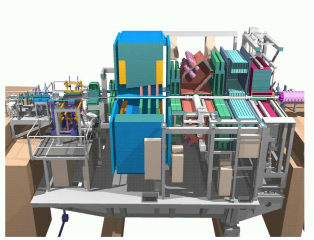
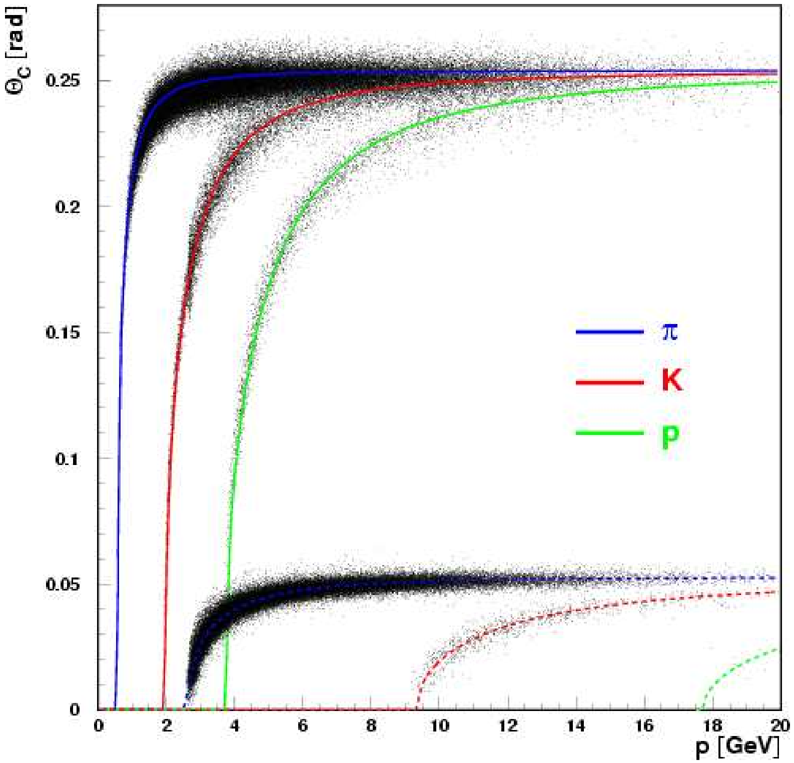
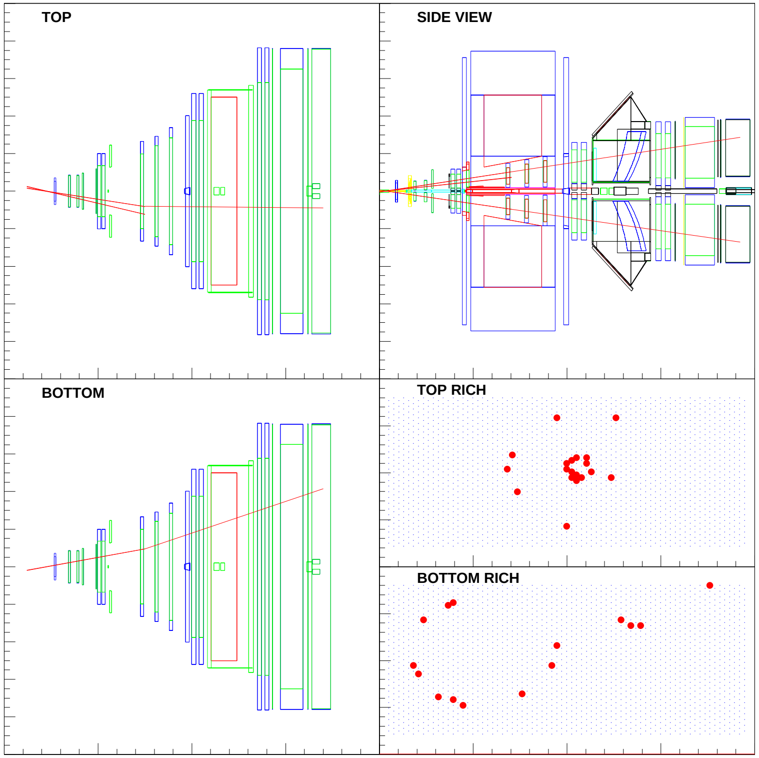


Hadron Identification





opening angle:

$$\cos\Theta_c = \frac{1}{\beta n}$$

threshold momentum:

$$p = \frac{m\beta c}{\sqrt{1-\beta^2}}$$

real π K event

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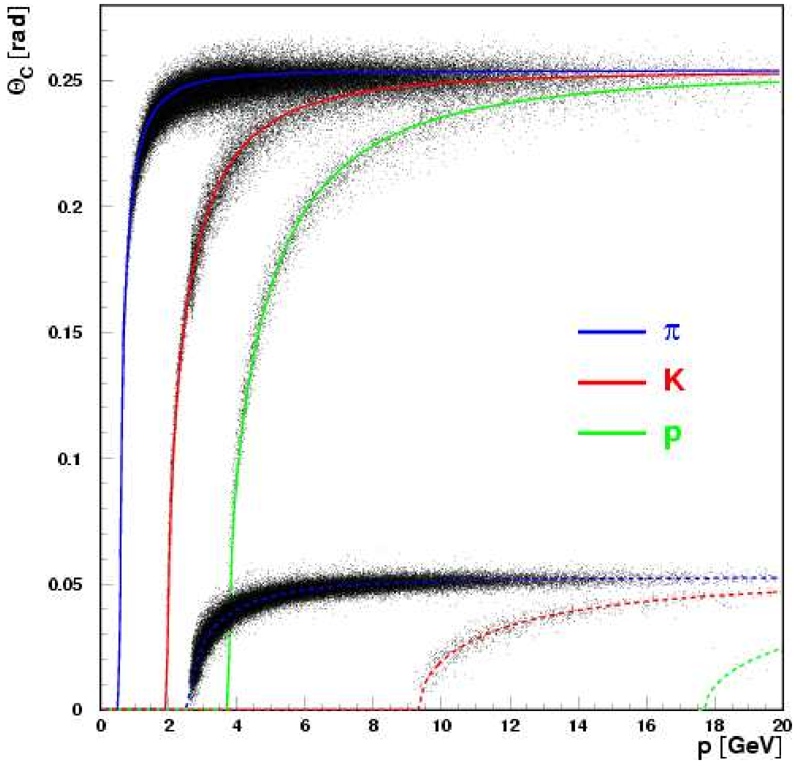

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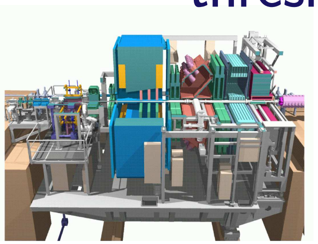

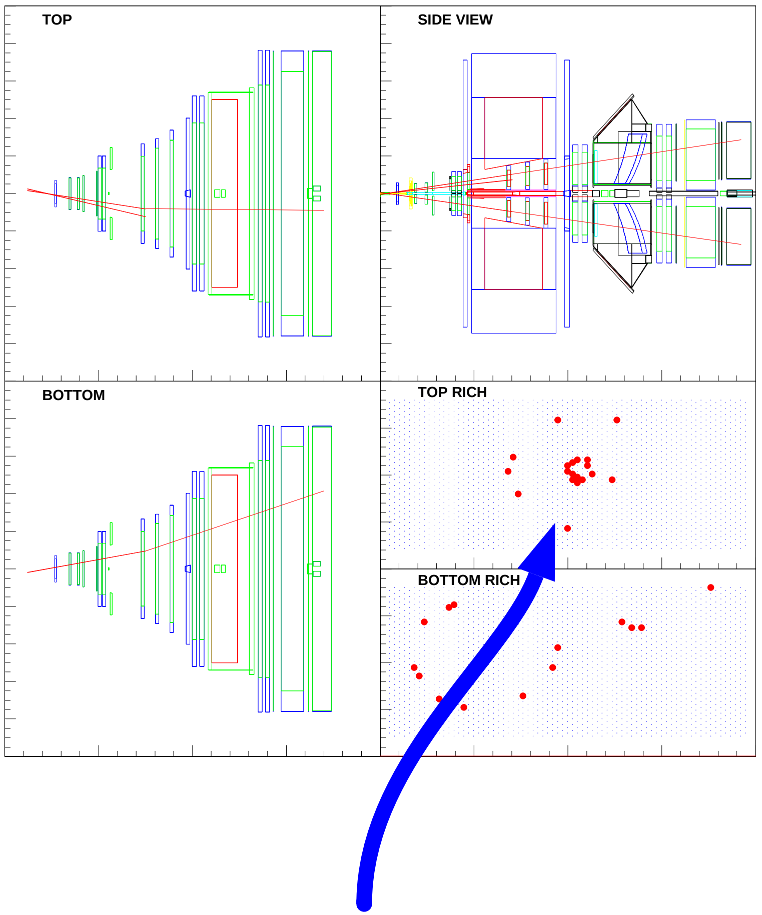

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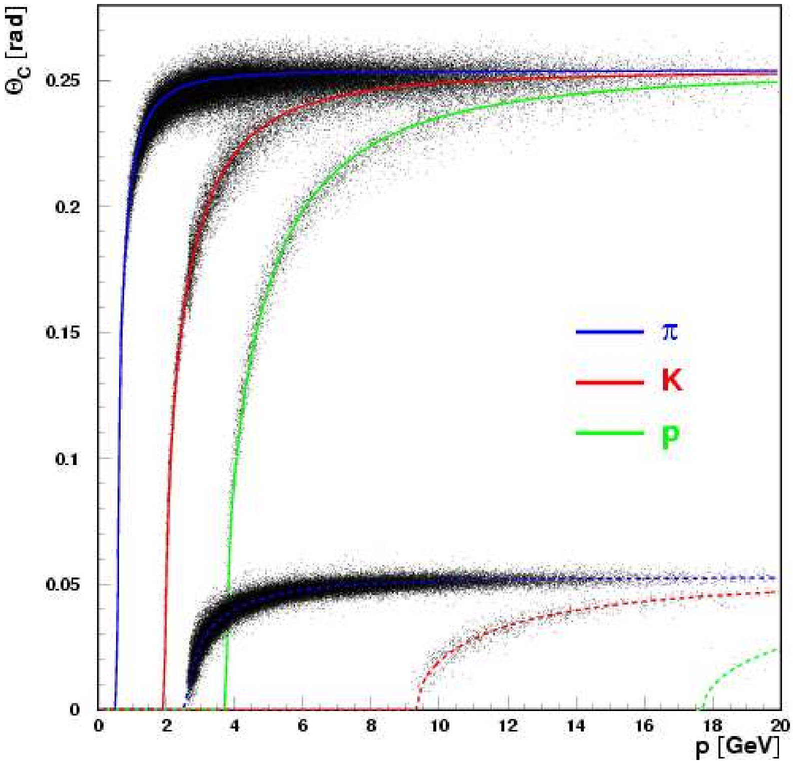

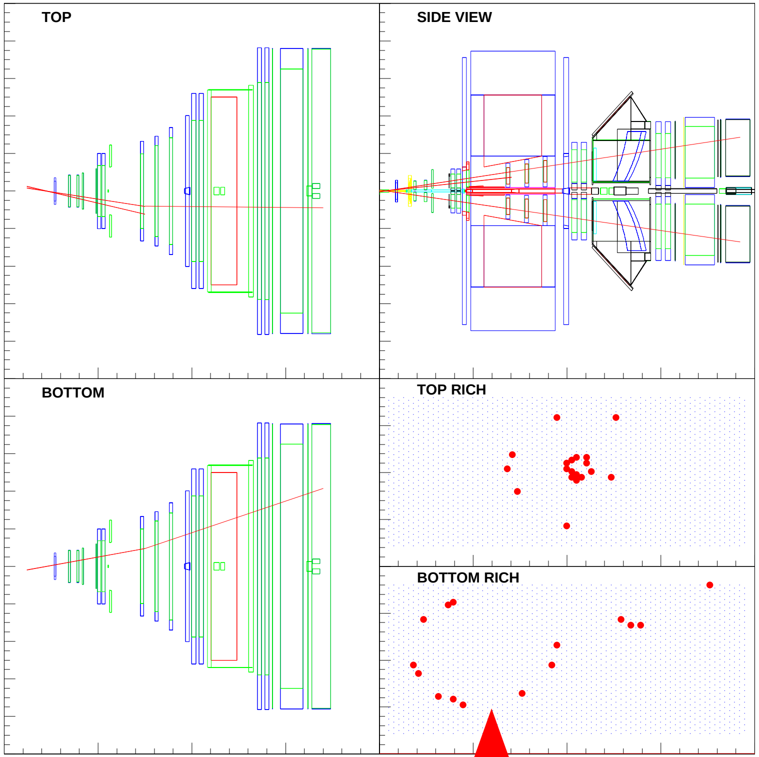

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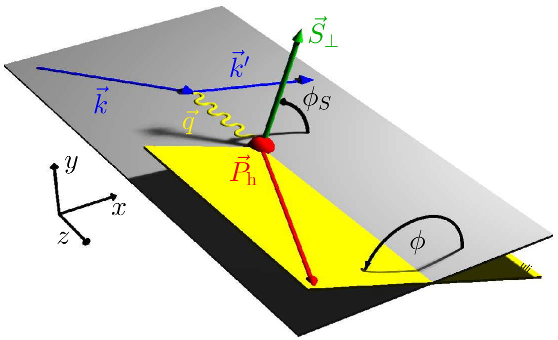
Azimuthal Asymmetries

Measurement of cross section asymmetries depending on the azimuthal angles ϕ and ϕ_S:

$$A_{\mathrm{UT}}(\phi, \phi_S) \;=\; \frac{1}{S_\perp} \frac{N^\uparrow(\phi, \phi_S) - N^\downarrow(\phi, \phi_S)}{N^\uparrow(\phi, \phi_S) + N^\downarrow(\phi, \phi_S)}$$



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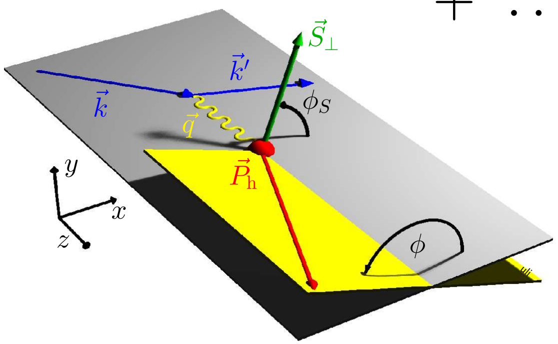
$$A_{\mathrm{UT}}(\phi,\phi_S) = \frac{1}{S_\perp}\frac{N^\uparrow(\phi,\phi_S)-N^\downarrow(\phi,\phi_S)}{N^\uparrow(\phi,\phi_S)+N^\downarrow(\phi,\phi_S)}$$

$$\sim \ldots \sin(\phi+\phi_S)\frac{\sum_q e_q^2\,\mathcal{I}\left[\ldots\delta q(x,\vec{p}_T^{\,2})\cdot H_1^{\perp q}(z,\vec{k}_T^{\,2})\right]}{\sum_q e_q^2\, q(x)\cdot D_1^q(z)}$$

$$+ \ \ldots \sin(\phi-\phi_S)\frac{\sum_q e_q^2\,\mathcal{I}\left[\ldots f_{1T}^{\perp q}(x,\vec{p}_T^{\,2})\cdot D_1^q(z,\vec{k}_T^{\,2})\right]}{\sum_q e_q^2\, q(x)\cdot D_1^q(z)}$$

$$+ \ \ldots$$



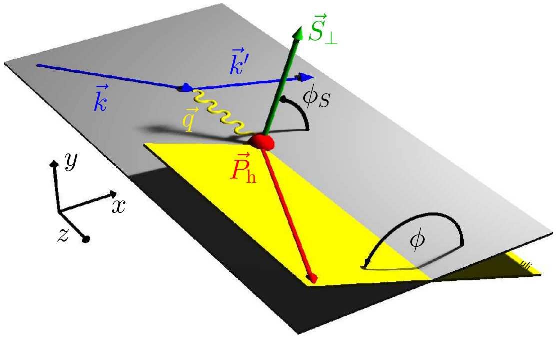
How to Disentangle . . .

. . . distribution and fragmentation functions?

Assume a Gaussian distribution for $\vec{p}_T$ and $\vec{k}_T$ dependence:

$$A_{\mathrm{UT}}(\phi,\phi_S) \sim \ldots \sin(\phi+\phi_S)\sum_q e_q^2 \cdot \delta q(x) \cdot H_1^{\perp(1/2)\,q}(z)$$
$$+ \ \ldots \sin(\phi-\phi_S)\sum_q e_q^2 \cdot f_{1T}^{\perp(1/2)\,q}(x) \cdot D_1^q(z)$$
$$+ \ \ldots$$

(1/2): $|\vec{p}_T|$, $|\vec{k}_T|$ moment of distribution / fragmentation function



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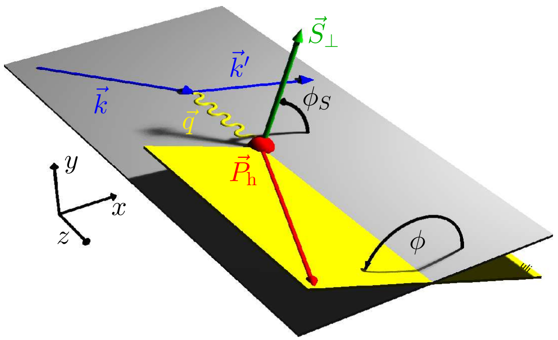
$$+ \ldots \sin(\phi - \phi_S) \sum_q e_q^2 \cdot f_{1T}^{\perp(1/2)\,q}(x) \cdot D_1^q(z)$$
$$+ \ldots$$

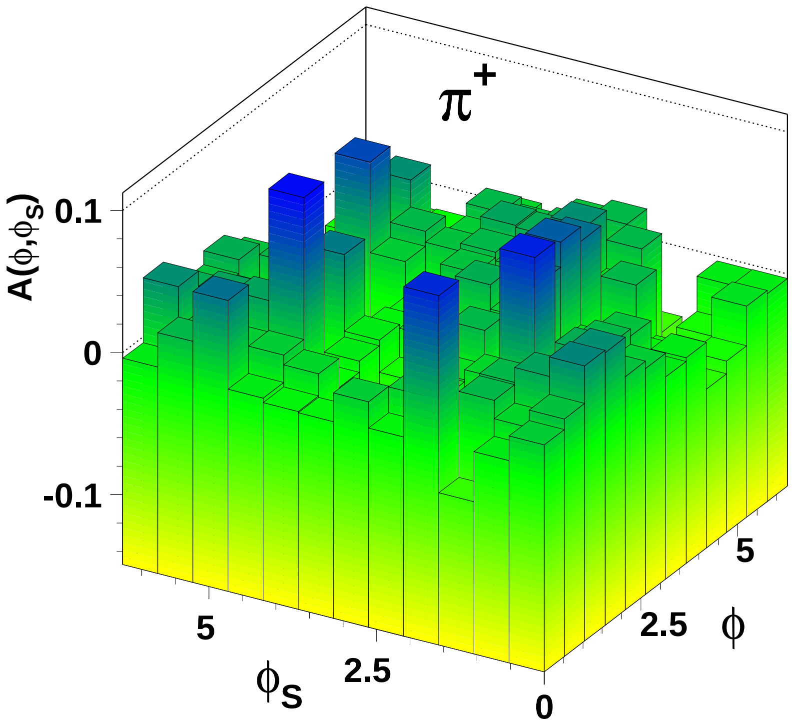
asymmetry amplitudes

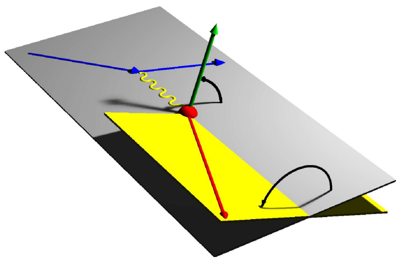
$A_{\mathrm{UT}}^{\sin(\phi+\phi_S)}$ and $A_{\mathrm{UT}}^{\sin(\phi-\phi_S)}$



Extraction of the Asymmetry Amplitudes

- pions with large statistics:
  bin $A_{UT}(\phi, \phi_S)$ in 12×12 $\phi \times \phi_S$ bins, perform least–squares fit





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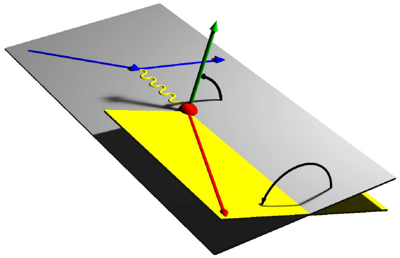
- kaons with low statistics:
  perform maximum–likelihood fit ➜ no azimuthal binning
  - probability density function:

$$F_{\uparrow(\downarrow)}\,(A_{\mathrm{UT}}^{\sin(\phi\pm\phi_S)}, \ldots, \phi, \phi_S) =$$

$$\epsilon \cdot \sigma_{\mathrm{UU}} \cdot \frac{1}{2}\left(1+(-)A_{\mathrm{UT}}^{\sin(\phi\pm\phi_S)}\sin(\phi \pm \phi_S)+(-)\ldots\right)$$

acceptance ϵ and cross section σ_{UU} independent of $A_{\mathrm{UT}}^{\sin(\phi\pm\phi_S)}, \ldots$



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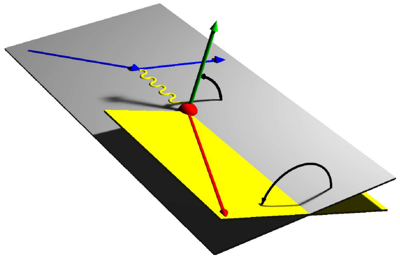
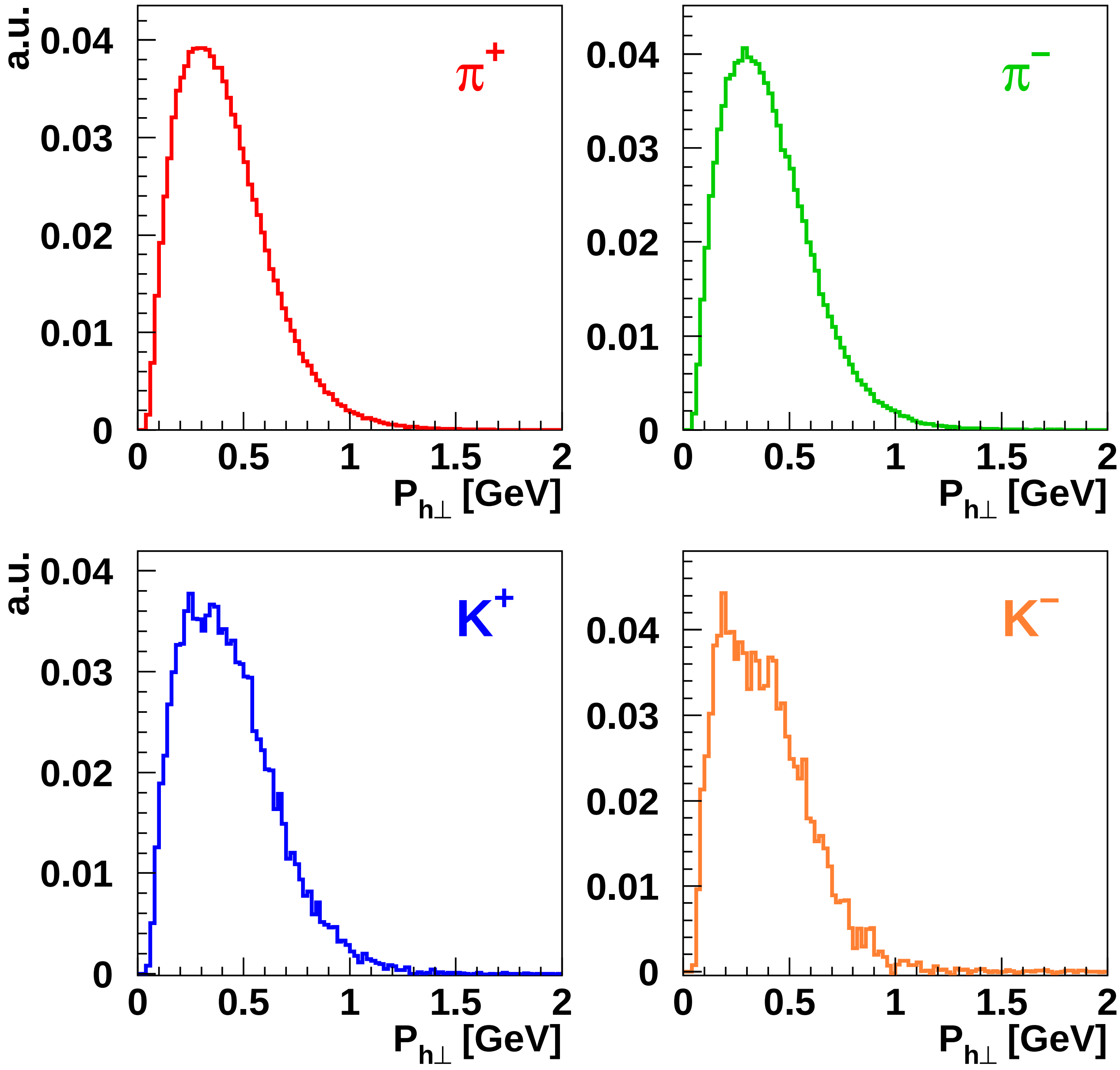
  acceptance ϵ and cross section σ_{UU} independent of $A_{UT}^{\sin(\phi\pm\phi_S)}, \ldots$

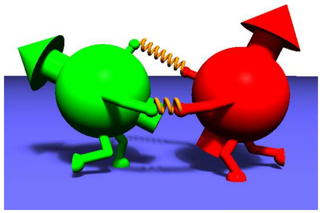
  - maximise $\log\mathcal{L}$, i.e., logarithm of the likelihood function:



$$\mathcal{L}(A_{UT}^{\sin(\phi\pm\phi_S)}, \ldots) = \frac{1}{\mathcal{N}}\prod_{i=1}^{N_\uparrow} F_{\uparrow i}\prod_{i=1}^{N_\downarrow} F_{\downarrow i}$$

$P_{h\perp}$–distributions

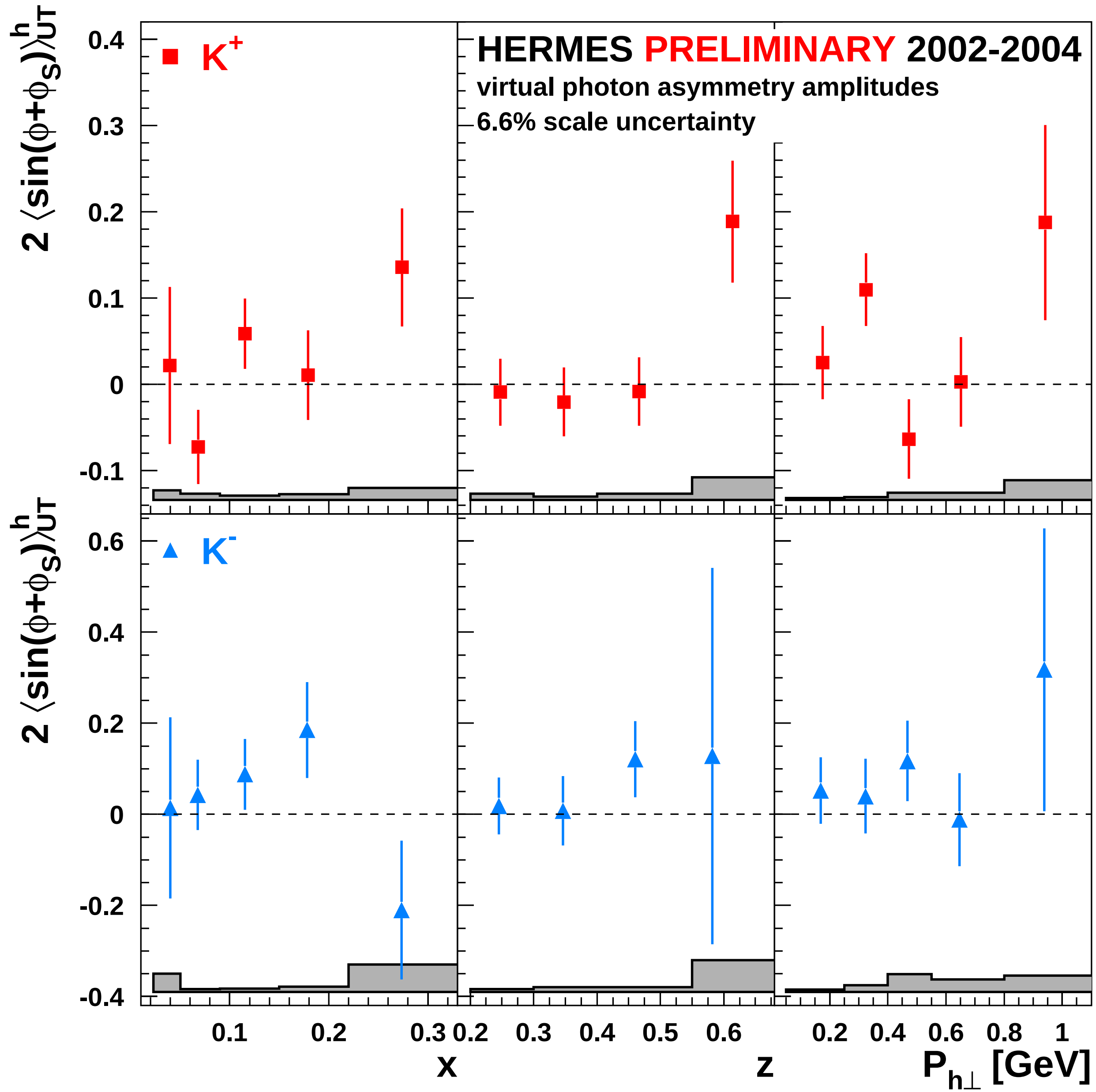


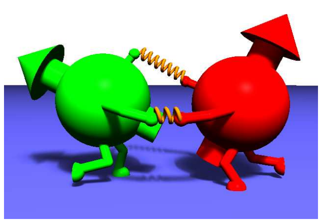


Kaon Collins Amplitudes

$$A_{\mathrm{UT}}^{\sin(\phi+\phi_S)} \sim \delta q \cdot H_1^{\perp(1/2)}$$

- no significant non–zero kaon amplitudes
- systematic uncertainty: PID, acceptance, smearing, unpolarised cosine moments
- overall scale uncertainty 6.6 %



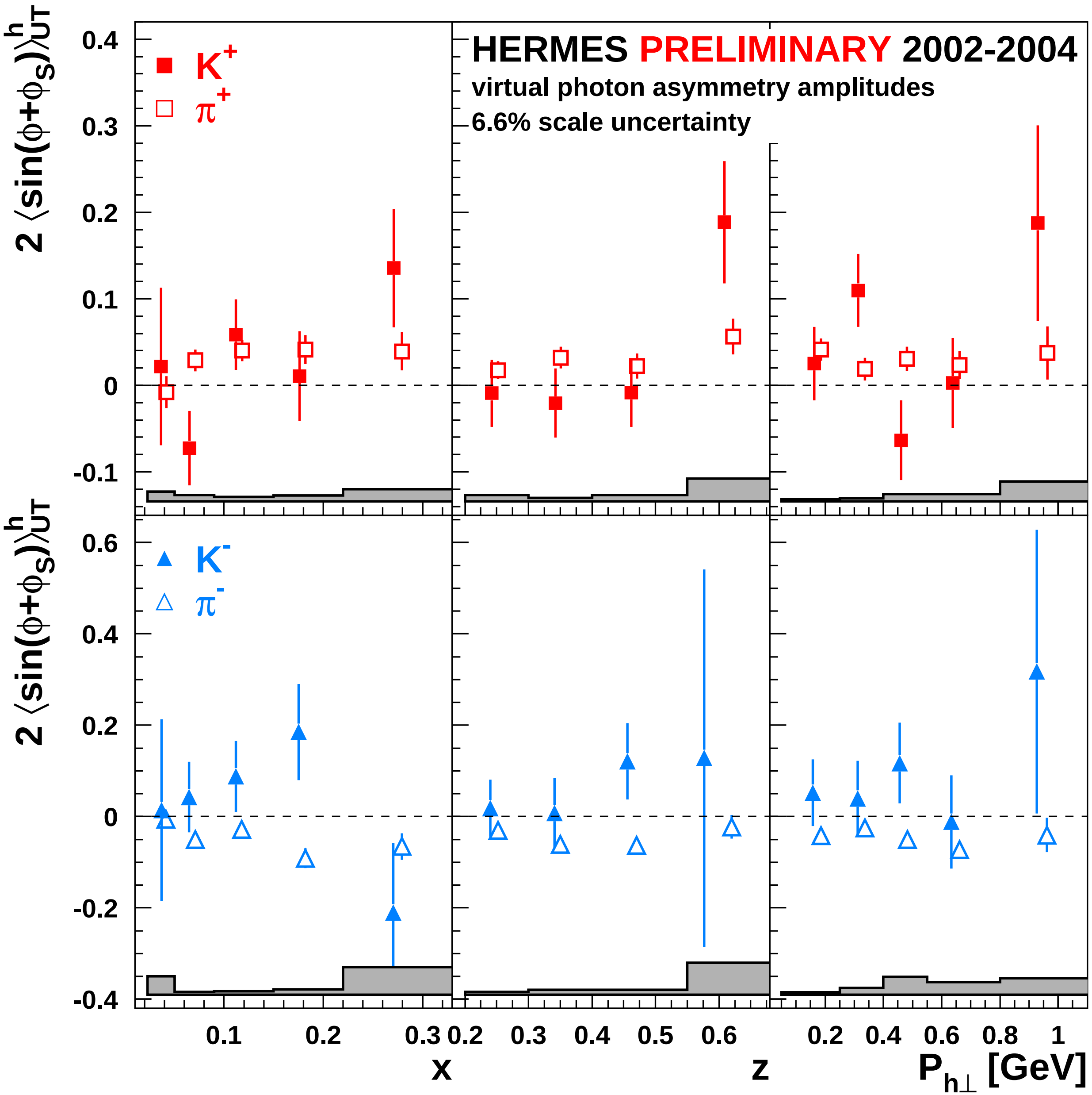


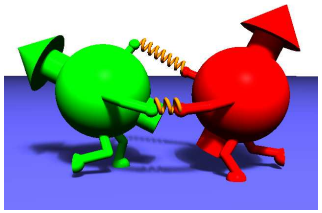
Kaon Collins Amplitudes

$$A_{UT}^{\sin(\phi+\phi_S)} \sim \delta q \cdot H_1^{\perp(1/2)}$$

- K^+ amplitudes consistent to π^+ amplitudes
- u–quark dominance

→ Collins FF seems to be similar for pions and kaons?

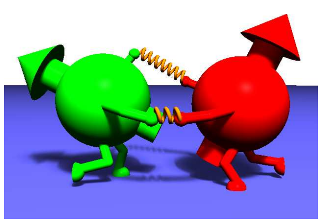


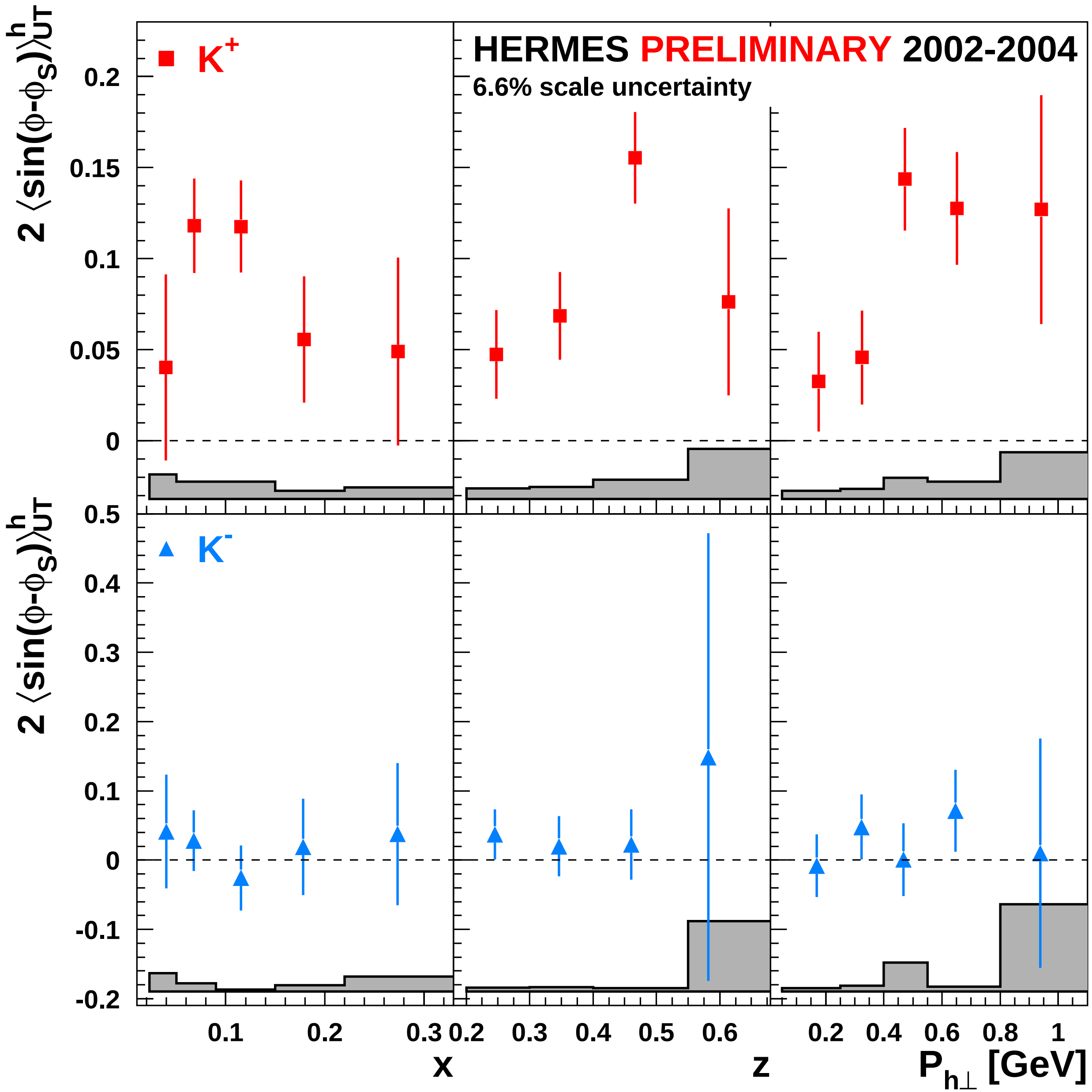


Kaon Sivers Amplitudes

$$A_{UT}^{\sin(\phi-\phi_S)} \sim f_{1T}^{\perp(1/2)} \cdot D_1$$

- positive K^+ amplitude
- K^- amplitude consistent with zero
- systematic uncertainty: PID, acceptance, smearing, unpolarised cosine moments
- overall scale uncertainty 6.6 %



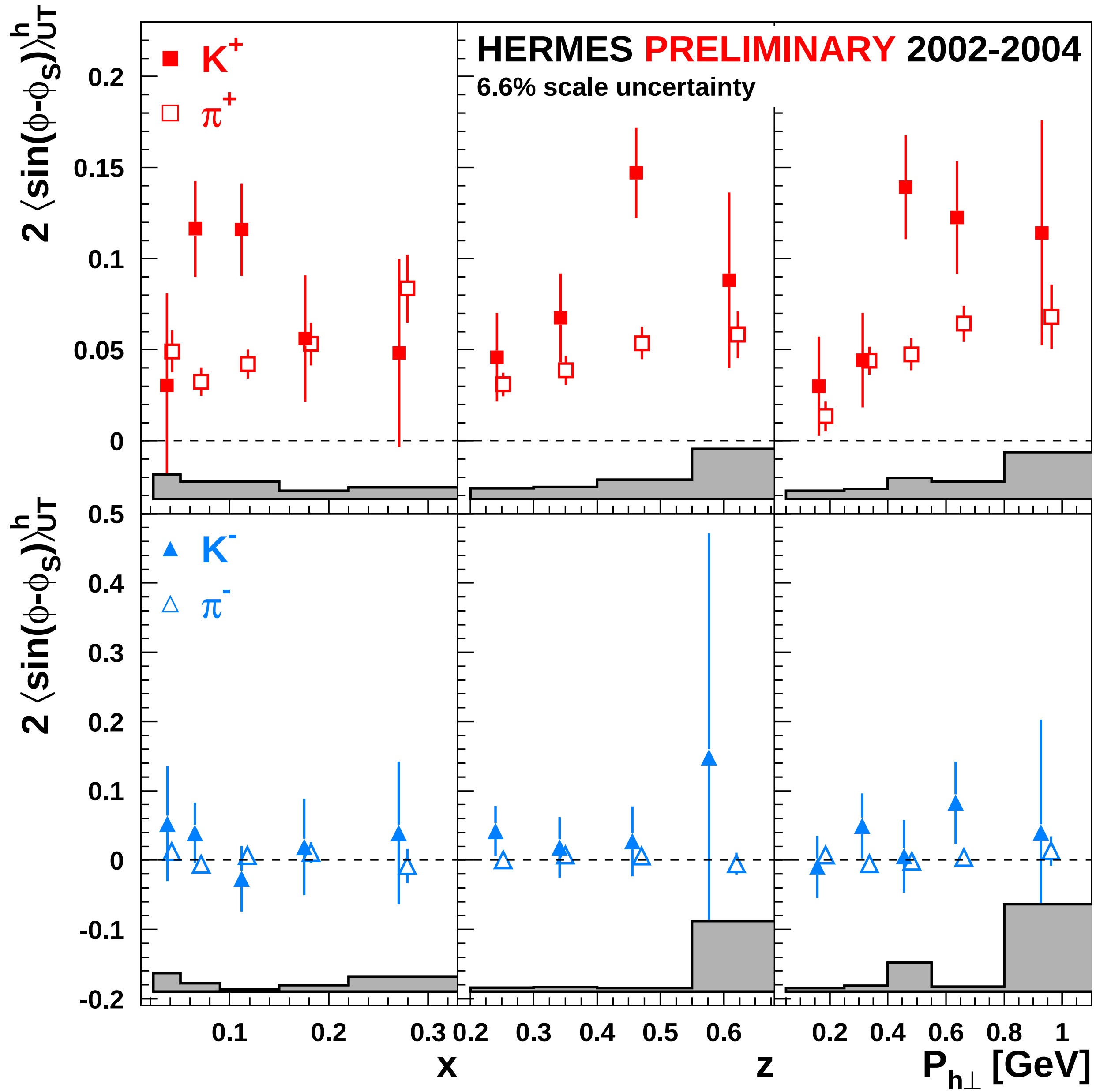


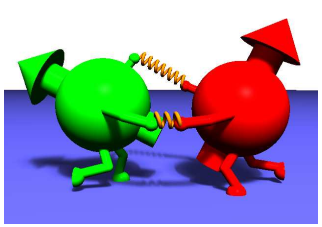
Kaon Sivers Amplitudes

$$A_{UT}^{\sin(\phi-\phi_S)} \sim f_{1T}^{\perp(1/2)} \cdot D_1$$

- K^+ amplitudes in some bins larger than π^+ amplitudes
- u–quark dominance

➜ sea quark contribution to Sivers moment important?





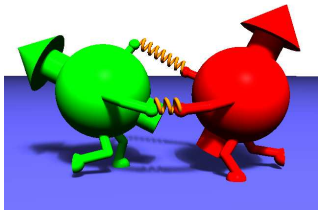
Kaon Sivers Amplitudes

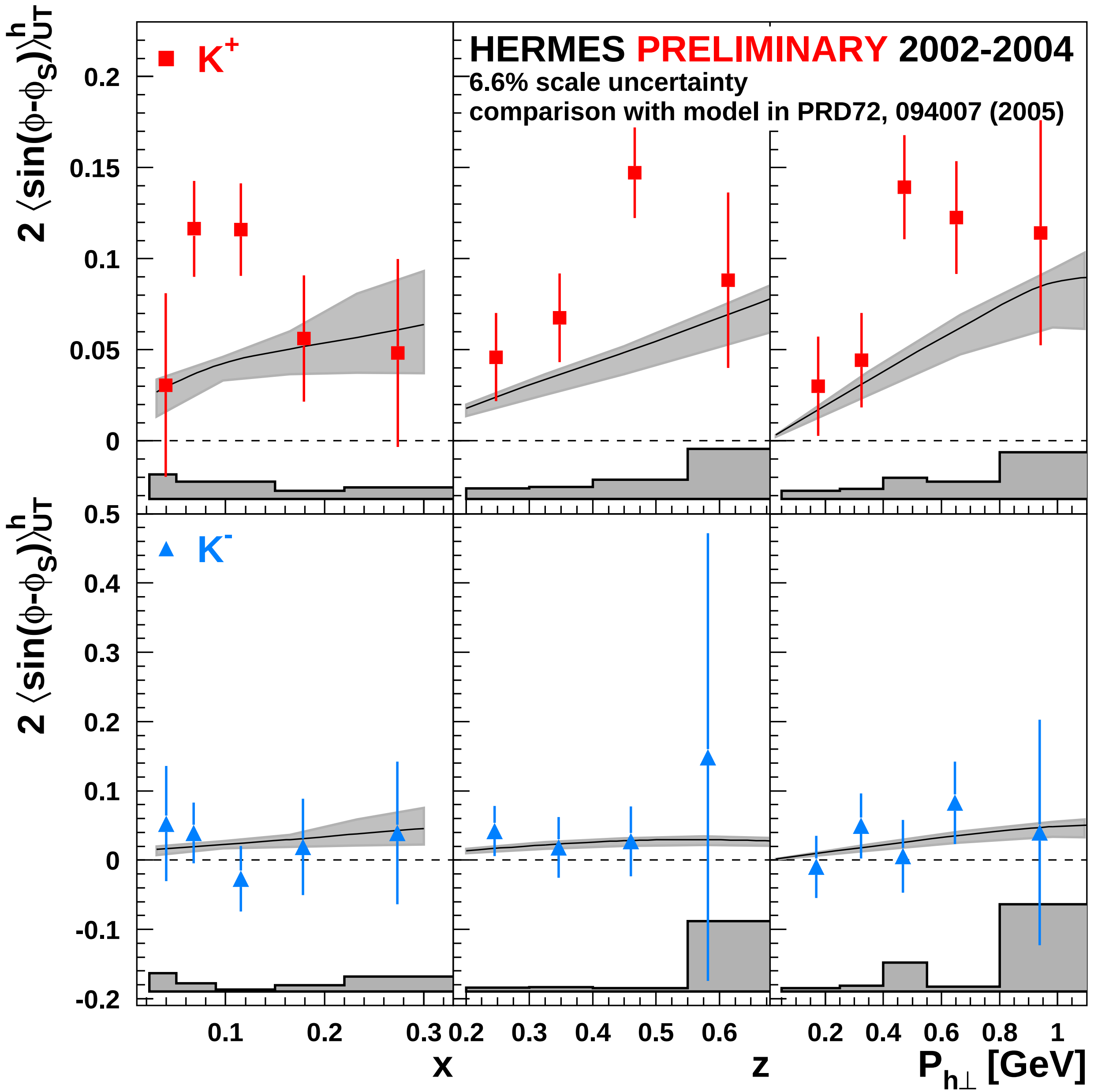
$$A_{UT}^{\sin(\phi-\phi_S)} \sim f_{1T}^{\perp(1/2)} \cdot D_1$$

- fit to pion amplitudes by Anslemino et al.

➜ prediction for K^+ amplitudes slightly too small

➜ sea quark contribution to Sivers moment important?





Conclusions

- First measurement of Collins and Sivers moments for kaons in semi–inclusive DIS.
- Sea–quark contribution to the Sivers moments might be not negligible.
- Data taken in 2005 will double the statistics.
- We are working on the extraction of the Sivers function.
- Belle results will allow transversity extraction.
- The determination of $P_{h\perp}$–weighted asymmetry amplitudes is under study.

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Ulrike Elschenbroich

QCD-N'06, Frascati, Italy 14.06.2006

Extraction of the Asymmetry Amplitudes

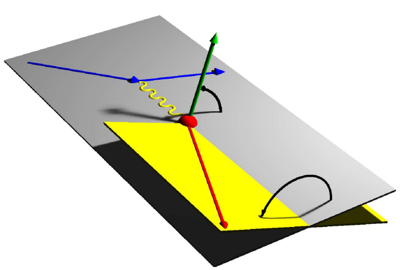
- likelihood function:

$$\mathcal{L}(A_{\mathrm{UT}}^{\sin(\phi\pm\phi_S)},\ldots) = \frac{1}{\mathcal{N}} \prod_{i=1}^{N_\uparrow} F_{\uparrow i} \prod_{i=1}^{N_\downarrow} F_{\downarrow i}$$

with normalisation:

$$\mathcal{N} = \mathcal{N}_\uparrow^{N_\uparrow} \cdot \mathcal{N}_\downarrow^{N_\downarrow}$$

$$\mathcal{N}_{\uparrow(\downarrow)} = \sum_{i=1} N_\uparrow + N_\downarrow \left(1 + (-) A_{\mathrm{UT}}^{\sin(\phi\pm\phi_S)} \sin(\phi_i \pm \phi_{Si}) + (-) \ldots\right)$$



Vector Meson Contribution