Evidence for a Single-Spin Asymmetry in two-pion Semi-Inclusive DIS on a transversely polarized hydrogen target

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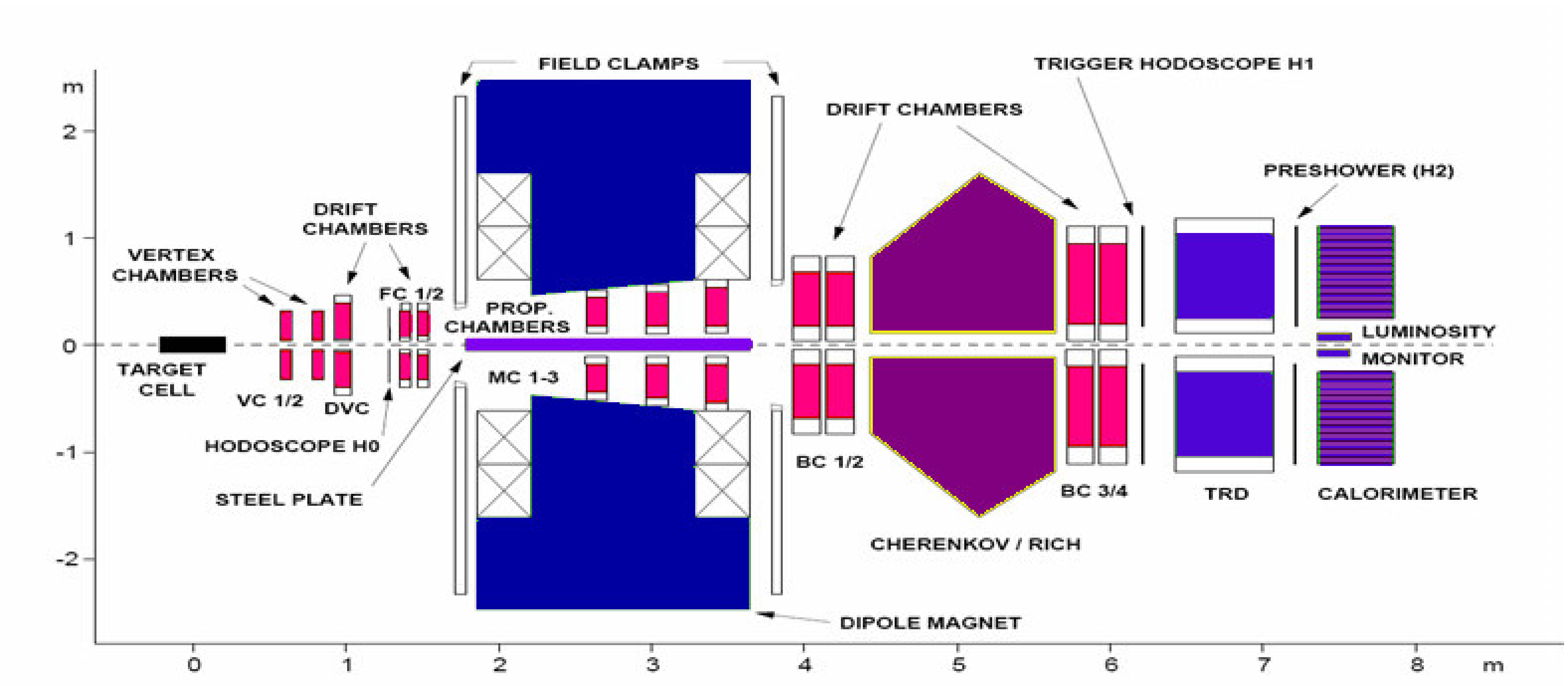
HERMES@DESY

HERMES SPECTROMETER

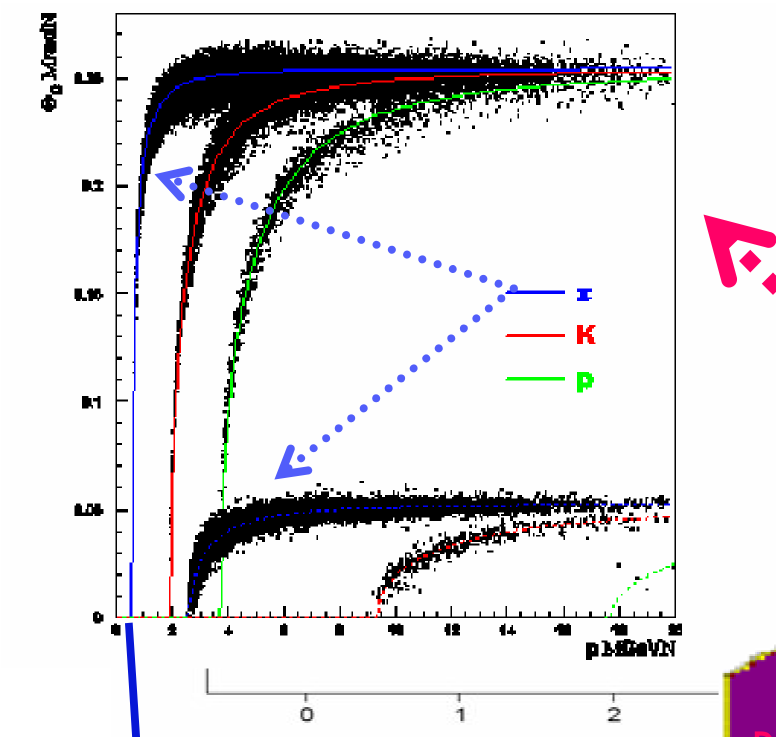


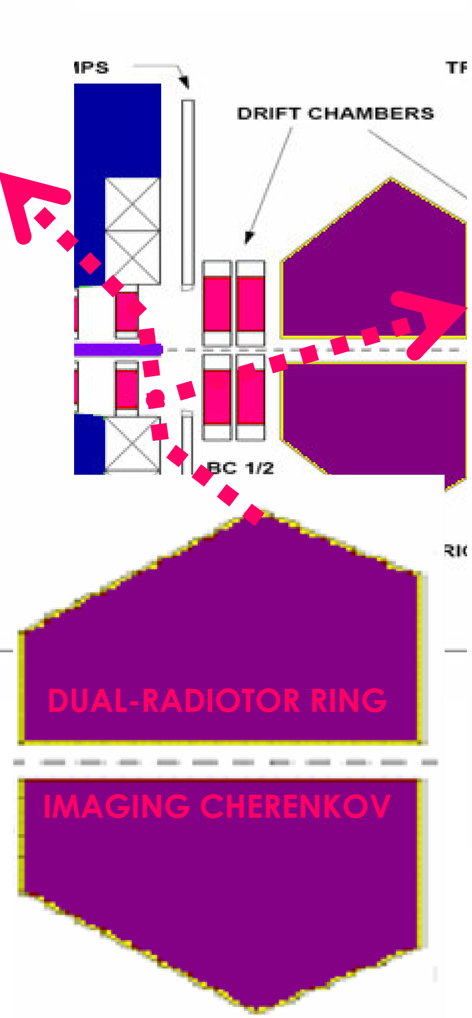
Electron beam (27.5 GeV/c) on a fixed polarized H-target

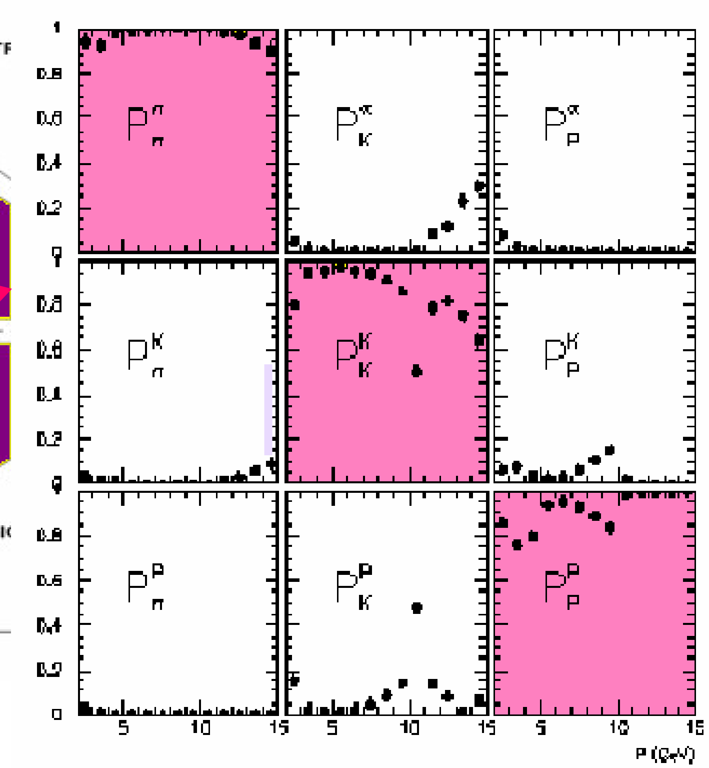
$\Delta p/p \sim$ 1-2%

Electron identification efficiency ~ 98-99%

HERMES RICH



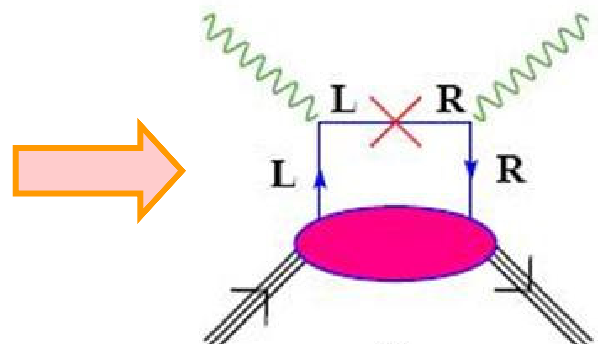


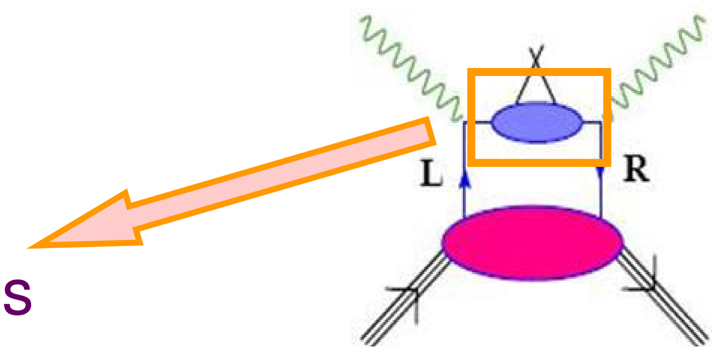


1 GeV/c

TRANSVERSITY

Since the transversity is a **chiral-odd** function, it cannot be probed in Inclusive Deep Inelastic Scattering, but has to be coupled to another **chiral-odd** function.

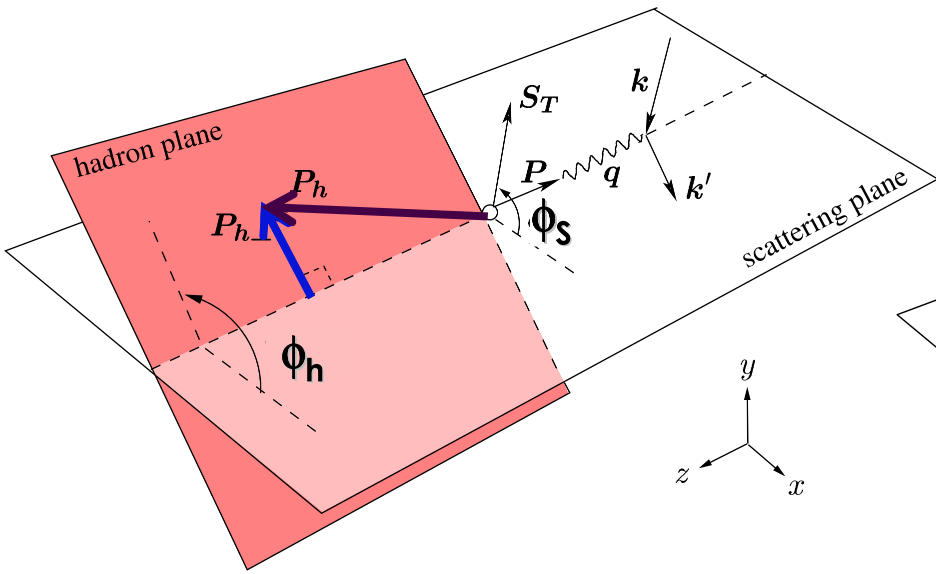




Semi Inclusive Deep Inelastic Scattering (SIDIS): transversity is coupled to a chiral-odd **fragmentation function**;

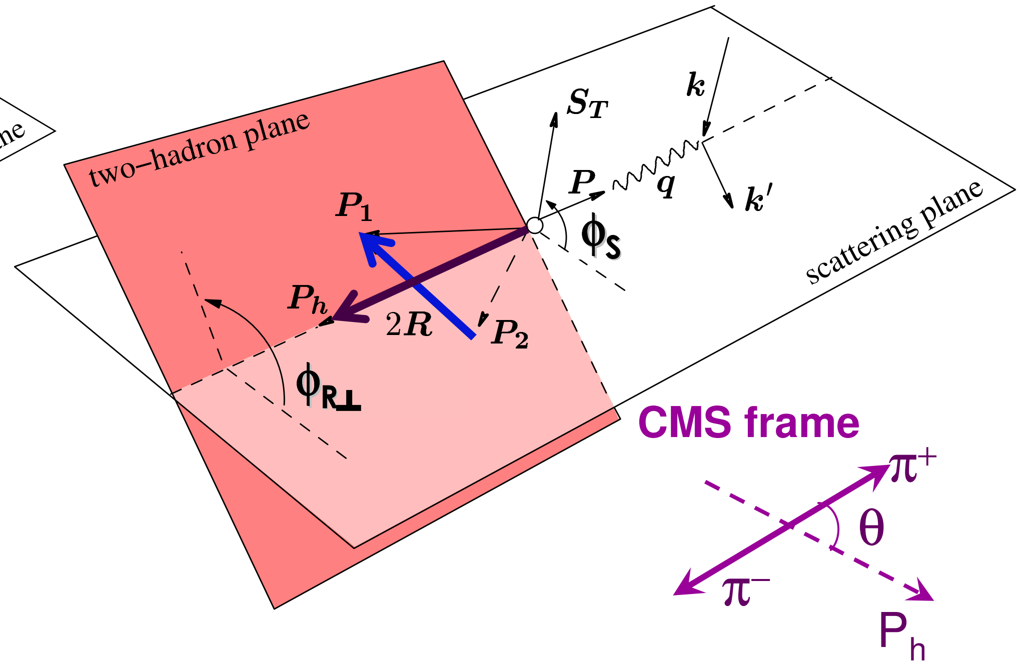
Semi Inclusive Deep Inelastic Scattering

1-pion production



$$\sigma_{UT} \propto S_T \sin(\phi_h+\phi_S)\sum_q e_q^2 \, I\left[\frac{k_T\cdot \hat{P}_{h\perp}}{M}\, h_{1,q}\cdot H_{1,q}^{\perp}\right]$$

2-pion production

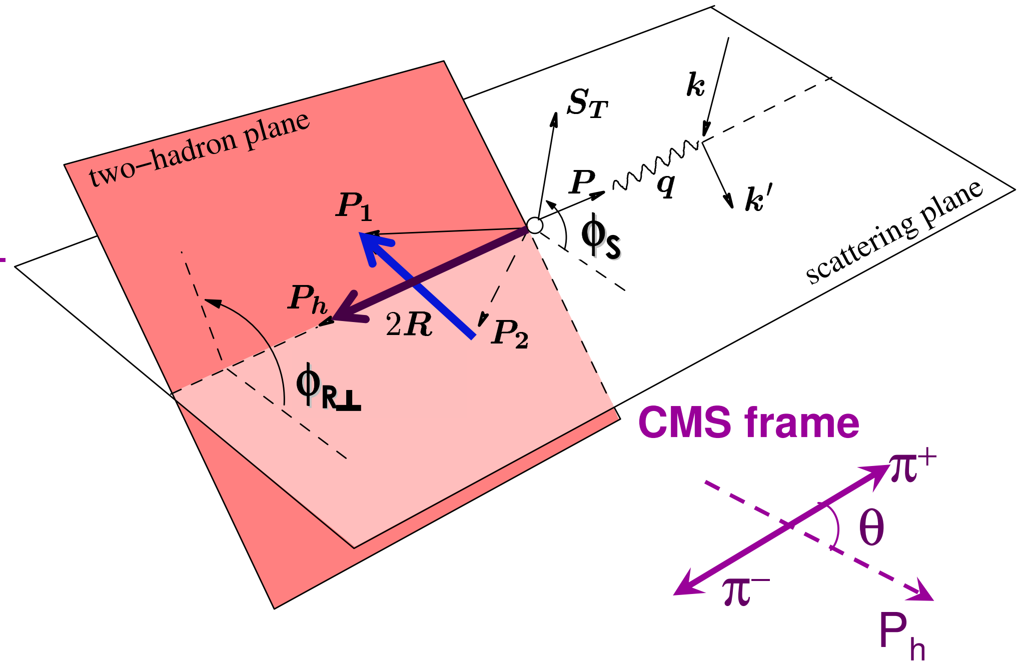


$$\sigma_{UT} \propto \left|S_T\right| \sin\theta \sin\left(\phi_{R\perp}+\phi_S\right)\sum_q e_q^2 \; h_{1,q}\cdot H_{1,q}^{\sphericalangle}$$

Semi Inclusive Deep Inelastic Scattering

- **Collinear physics:** the relative momentum of the pion-pair has a transverse component R_T even after the integration over the transverse momentum of the pion-pair P_h
- A completely independent method to extract h_1.
  - BUT: **poorer statistics!!**

2-pion production



$$\sigma_{UT} \propto |S_T| \sin\theta \sin(\phi_{R\perp} + \phi_S) \sum_q e_q^2 \, h_{1,q} \cdot H_{1,q}^{\sphericalangle}$$

Event topology

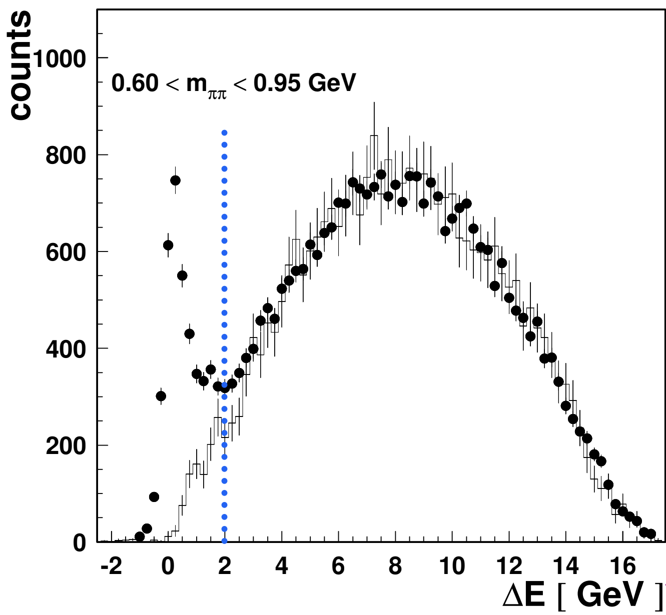
Kinematical range

$W^2 \geq 4\ GeV^2$

$Q^2 \geq 1\ GeV^2$

$0.023 \leq x_{bj} \leq 0.6$

$0.1 < y_{bj} < 0.85$



- *Pions identified with RICH*
- $P_\pi > 1 GeV/c$
- *All possible combination of detected pions were included for each event*
- $|S_T| \geq 70\%$
- $\Delta E \equiv (M_x^2 - M_P^2)/2M_P > 2 GeV$

$$A_{UT}(\phi_{R\perp}+\phi_S,\theta) \equiv \frac{\sigma_{UT}}{\sigma_{UU}} = \frac{1}{|S_T|}\frac{N^{\uparrow}_{SIDIS}(\phi_{R\perp}+\phi_S,\theta) - N^{\downarrow}_{SIDIS}(\phi_{R\perp}+\phi_S,\theta)}{N^{\uparrow}_{SIDIS}(\phi_{R\perp}+\phi_S,\theta) + N^{\downarrow}_{SIDIS}(\phi_{R\perp}+\phi_S,\theta)}$$

Partial wave expansion

$$A_{UT} \sim \frac{\sum_q \sin(\phi_R + \phi_S) \sin\theta \, h_{1,q} H_{1,q}^{\sphericalangle}}{\sum_q f_{1,q} D_{1,q}}$$

$$z = z_1 + z_2$$

Partial wave expansion

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$$H_1^{\sphericalangle}(z, M_h^2, \theta)$$

$$H_1^{\sphericalangle,sp}\left(z, M_h^2\right) + \cos\theta \, H_1^{\sphericalangle,pp}\left(z, M_h^2\right)$$

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The contribution to the Asymmetry is due to interference of different partial waves of the final state $\pi^+\pi^-$

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$$z = z_1 + z_2$$

$$\sum_q f_{1,q} \left(D_{1,q}^{ss,pp} + \cos\theta \, D_{1,q}^{sp} + 1/4(3\cos^2\theta - 1) D_{1,q}^{pp}\right)$$

First step: linear approximation

$$A_{UT} \sim \frac{\sum_q \sin(\phi_{R\perp} + \phi_S) h_{1,q} (\sin\theta \, H_{1,q}^{\sphericalangle,sp} + \sin\theta \, \cos\theta \, H_{1,q}^{\sphericalangle,pp})}{\sum_q f_{1,q} \, (D_{1,q}^{ss,pp} + \cos\theta \, D_{1,q}^{sp} + 1/4(3\cos^2\theta - 1) D_{1,q}^{pp})}$$

First step: neglect denominator partial wave expansion

$$A_{UT} \sim \frac{\sum_q \sin(\phi_{R\perp} + \phi_S) h_{1,q} (\sin\theta \, H_{1,q}^{\sphericalangle,sp} + \sin 2\theta \, H_{1,q}^{\sphericalangle,pp})}{\sum_q f_{1,q} \, D_{1,q}}$$

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Linear fit

The azimuthal moments are extracted from A_{UT} using a 2-dimensional χ^2 fit

$$A_{UT} = a + \sin(\phi_{R\perp} + \phi_S)\ (A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\ \sin\theta} \sin\theta + b \sin 2\theta)$$

compatible with zero

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compatible with zero

$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \sim \frac{\sum_q e_q^2 h_1^q H_{1,q}^{\sphericalangle,sp}}{\sum_q e_q^2 f_1^q D_{1,q}}$$

Linear fit

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$$A_{UT} = a + \sin(\phi_{R\perp} + \phi_S)\ (A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\ \sin\theta} \sin\theta + b \sin 2\theta)$$

compatible with zero

THE EXTRACTED VALUES OF THE MOMENTS ARE NOT INFLUENCED BY THE PRESENCE OF THIS TERM IN THE FIT FUNCTION

$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \sim \frac{\sum_q e_q^2 h_1^q H_{1,q}^{\sphericalangle, sp}}{\sum_q e_q^2 f_1^q D_{1,q}}$$

Extra-terms like the ones below do not influence the value of the extracted moments

$$\sin \phi_S, \quad \cos \phi_{R\perp} \sin \theta$$

Results with linear fit

$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \propto \frac{\sum_q e_q^2 h_1^q H_{1,q}^{\sphericalangle,sp}}{\sum_q e_q^2 f_1^q D_{1,q}}$$

Results with linear fit

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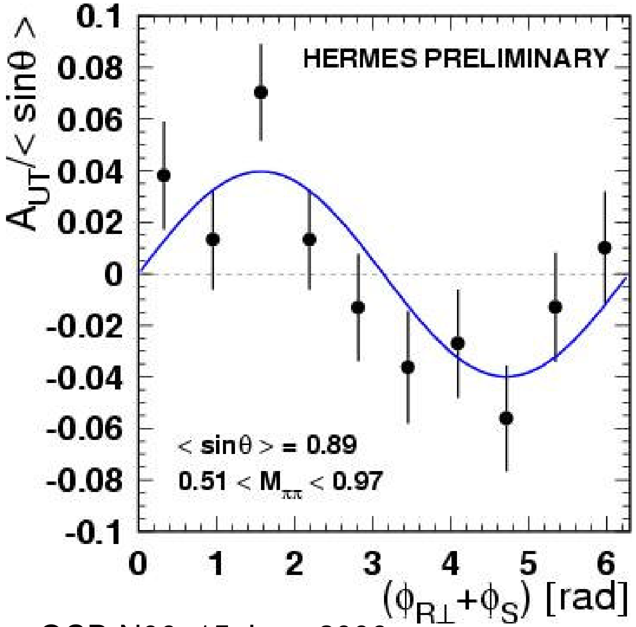
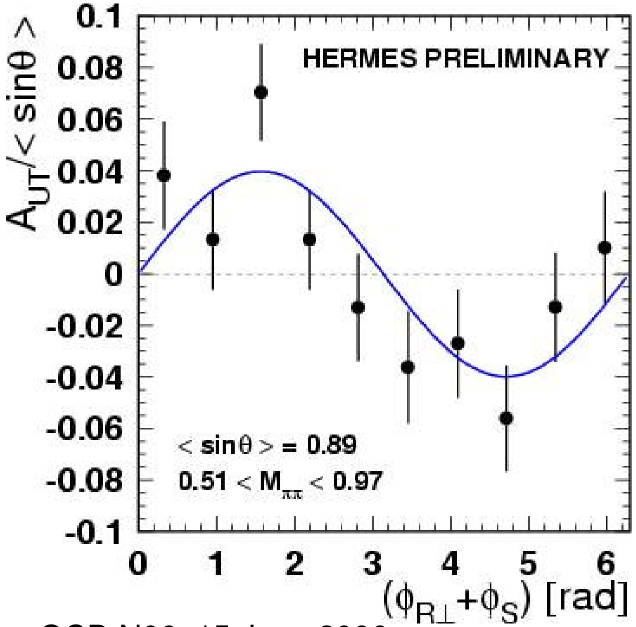


Significant sinusoidal behavior!

Results with linear fit

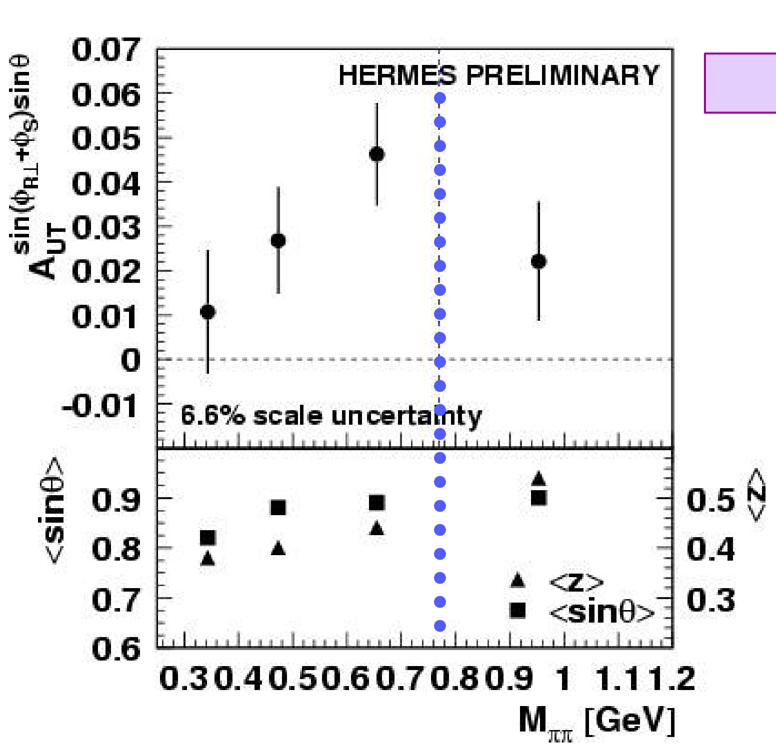
$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \propto \frac{\sum_q e_q^2 h_1^q H_{1,q}^{\sphericalangle,sp}}{\sum_q e_q^2 f_1^q D_{1,q}}$$

$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\ \sin\theta} = 0.040 \pm 0.009\ (stat) \pm 0.003\ (syst)$$



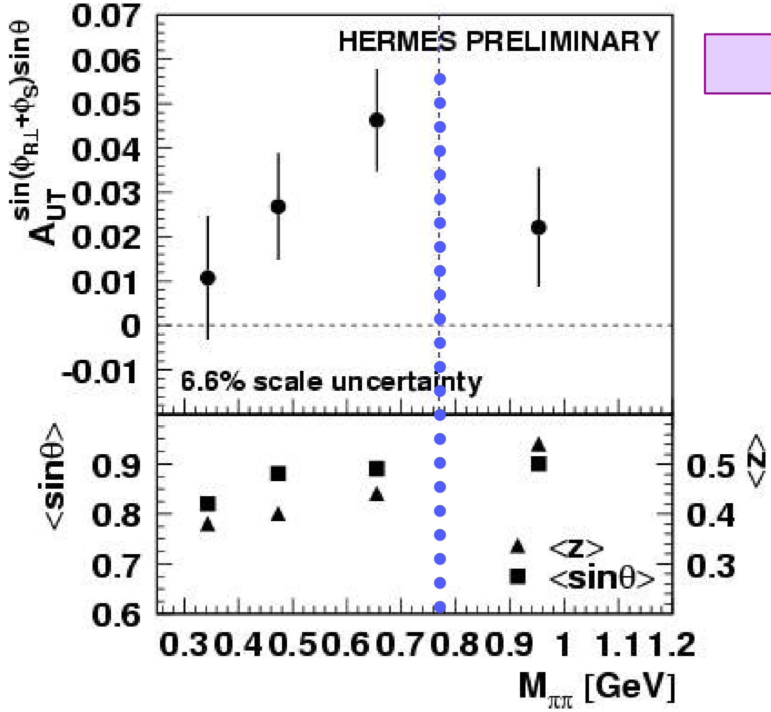
First evidence of a T-odd and chiral-odd dihadron fragmentation function (it can be measured at Belle!)

$M_{\pi\pi}$-dependence



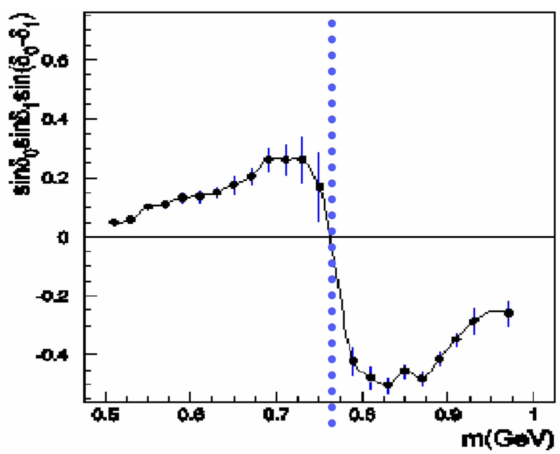
POSITIVE ASYMMETRY in the whole range of $M_{\pi\pi}$-mass

$M_{\pi\pi}$-dependence

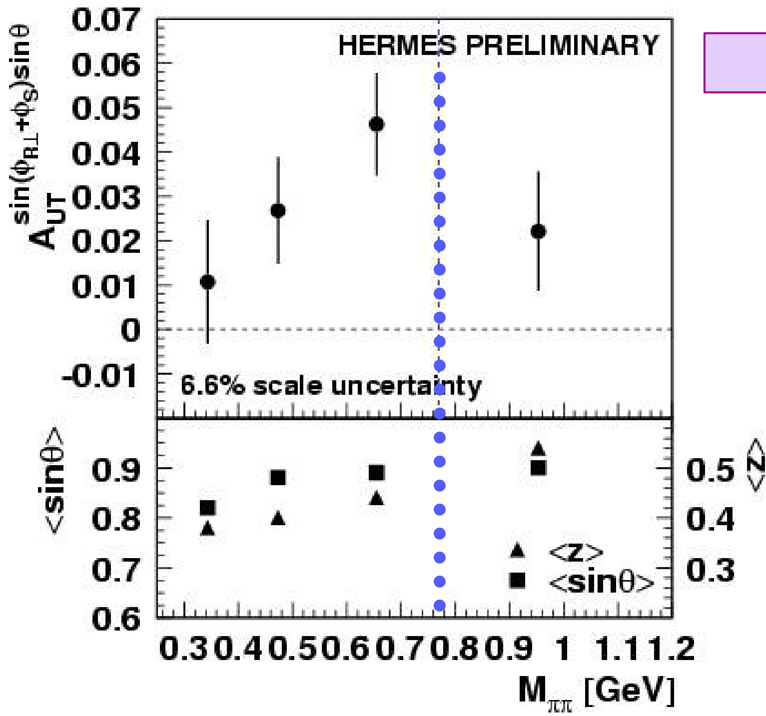


POSITIVE ASYMMETRY in the whole range of $M_{\pi\pi}$-mass

No evidence of the sign-change at the ρ^0 mass predicted by
Jaffe et al.
(Phys.Rev.Lett.80,1166(1998))

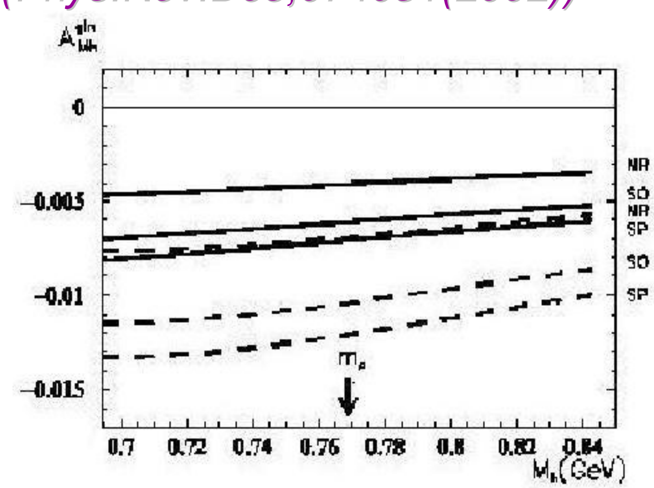


$M_{\pi\pi}$-dependence



POSITIVE ASYMMETRY in the whole range of $M_{\pi\pi}$-mass

Different models don't predict
a sign change of the asymmetry around the ρ^0 mass
Radici et al.
(Phys.Rev.D65,074031(2002))



WORK IN PROGRESS...

In progress….

$$A_{UT} \sim \frac{\sum_q \sin(\phi_{R\perp} + \phi_S) h_{1,q} (\sin\theta \, H_{1,q}^{\sphericalangle,sp} + \sin\theta \, \cos\theta \, H_{1,q}^{\sphericalangle,pp})}{\sum_q f_{1,q} (D_{1,q}^{ss,pp} + \cos\theta \, D_{1,q}^{sp} + 1/4(3\cos^2\theta - 1) D_{1,q}^{pp})}$$

In progress….

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1-DIMENSIONAL LINEAR FIT

(INTEGRATED OVER θ)

$$A_{UT} = a + A_{UT}^{\sin(\phi_{R\perp}+\phi_S)} \sin(\phi_{R\perp}+\phi_S)$$

In progress….

$$A_{UT} \sim \frac{\sum_q \sin(\phi_{R\perp}+\phi_S)\, h_{1,q}\left(\sin\theta\, H_{1,q}^{\sphericalangle,sp} + \sin\theta\,\cos\theta\, H_{1,q}^{\sphericalangle,pp}\right)}{\sum_q f_{1,q}\left(D_{1,q}^{ss,pp} + \cos\theta\, D_{1,q}^{sp} + 1/4(3\cos^2\theta - 1) D_{1,q}^{pp}\right)}$$

1-DIMENSIONAL LINEAR FIT

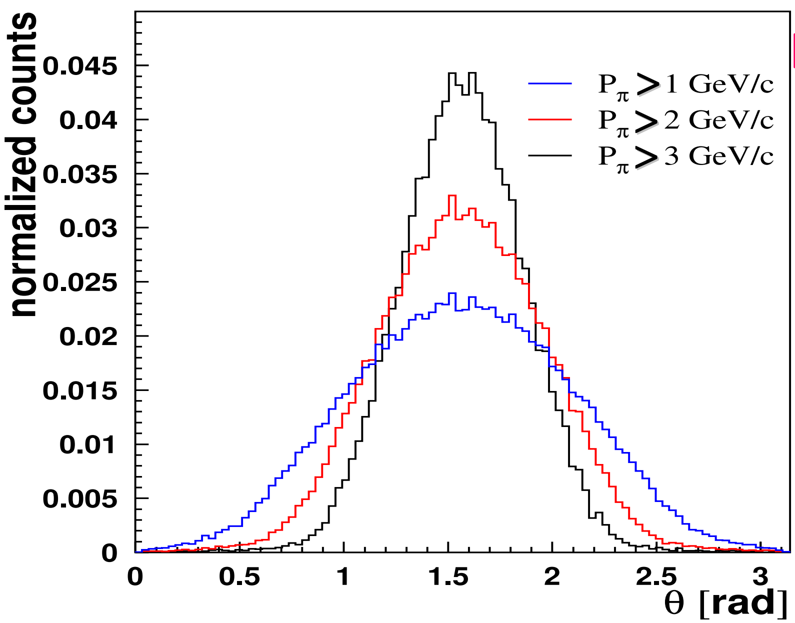
(INTEGRATED OVER θ)

$$A_{UT} = a + A_{UT}^{\sin(\phi_{R\perp}+\phi_S)} \sin(\phi_{R\perp}+\phi_S)$$

$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)} \propto \frac{\sum_q e_q^2 h_1^q H_{1,q}^{\sphericalangle,sp}}{\sum_q e_q^2 f_1^q D_{1,q}^{ss,pp}}$$

Can we integrate over θ ?

$$A_{UT} = a + A_{UT}^{\sin(\phi_{R\perp}+\phi_S)} \sin(\phi_{R\perp} + \phi_S)$$



If 2-π pair are isotropically distributed in the phase-space θ-distribution is proportional to sinθ:

A CUT ON THE MOMENTA BIASES SIGNIFICANTLY THE θ DISTRIBUTION!!

In progress….

$$A_{UT} \sim \frac{\sum_q \sin(\phi_{R\perp}+\phi_S) h_{1,q} (\sin\theta\, H_{1,q}^{\sphericalangle,sp} + \sin\theta\, \cos\theta\, H_{1,q}^{\sphericalangle,pp})}{\sum_q f_{1,q}\, (D_{1,q}^{ss,pp} + \cos\theta\, D_{1,q}^{sp} + 1/4(3\cos^2\theta - 1) D_{1,q}^{pp})}$$

NON-LINEAR FIT:

$$A_{UT} = \frac{(A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \sin\theta + b\sin 2\theta)}{1 + c\cos\theta + d\cos^2\theta} \sin(\phi_{R\perp} + \phi_S)$$

In progress….

$$A_{UT} \sim \frac{\sum_q \sin(\phi_{R\perp}+\phi_S) h_{1,q} (\sin\theta \, H_{1,q}^{\sphericalangle,sp} + \sin\theta \, \cos\theta \, H_{1,q}^{\sphericalangle,pp})}{\sum_q f_{1,q} \, (D_{1,q}^{ss,pp} + \cos\theta \, D_{1,q}^{sp} + 1/4(3\cos^2\theta - 1) D_{1,q}^{pp})}$$

$$A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \propto \frac{\sum_q e_q^2 h_1^q H_{1,q}^{\sphericalangle,sp}}{\sum_q e_q^2 f_1^q (D_{1,q}^{ss,pp} - 1/4 D_{1,q}^{pp})}$$

NON-LINEAR FIT:

$$A_{UT} = \frac{(A_{UT}^{\sin(\phi_{R\perp}+\phi_S)\sin\theta} \sin\theta + b\sin 2\theta)}{1 + c\cos\theta + d\cos^2\theta} \sin(\phi_{R\perp} + \phi_S)$$

Conclusion

- *For the first time a non-zero Single Spin Asymmetry (SSA) is measured in two-pion production;*
- *The measured SSA allows to probe transversity in 2-pion SIDIS and is the first evidence for a non-zero chiral-odd interference fragmentation function;*
- *No evidence of a sign change of SSA at ρ^0 mass;*
- *A non-linear fit is in progress to take into account all the partial-wave terms;*
- *2005 data will double current statistics;*

THANK YOU!!!!