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Analysis of Double Spin Asymmetry in Vector Meson Production at HERMES

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- Motivation
- Exclusive ρ production
- Φ and J/Ψ
- Summary

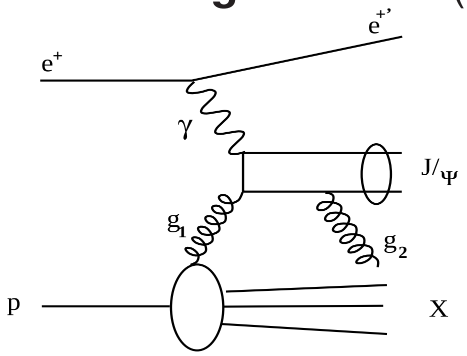
(One) Motivation

to measure double spin asymmetry in diffractive vector meson production

Measure spin contribution of the gluon ΔG
via double spin asymmetry in photon-gluon fusion

- Open Charm D, D^*, theoretically clean channel,
  but experimentally difficult
- Hidden Charm J/ψ, clean detection
  but different production models to distinguish:

  Color Singlet Model (Berger, Jones) (inelastic)



$$A^{c\bar{c}} = \frac{N^{c\bar{c}}_{\uparrow\downarrow} - N^{c\bar{c}}_{\uparrow\uparrow}}{N^{c\bar{c}}_{\uparrow\downarrow} + N^{c\bar{c}}_{\uparrow\uparrow}} \sim \hat{a}_{LL}\frac{\Delta G}{G}$$

$\hat{a}_{LL}$ hard scattering asymmetry (QCD)

estimated 25% at HERMES energy

Diffractive J/ψ production
Access ΔG via the gluonic structure of Pomeron ?
M.Vänttinen, L.Mankiewicz, hep-ph 9805338, 9807287

Extend asymmetry analysis to ρ and Φ

since diffractive vector meson production
is an interesting topic in itself
and:

Double spin asymmetry in vector meson production is an unmeasured quantity !

Diffractive Vector Meson Production

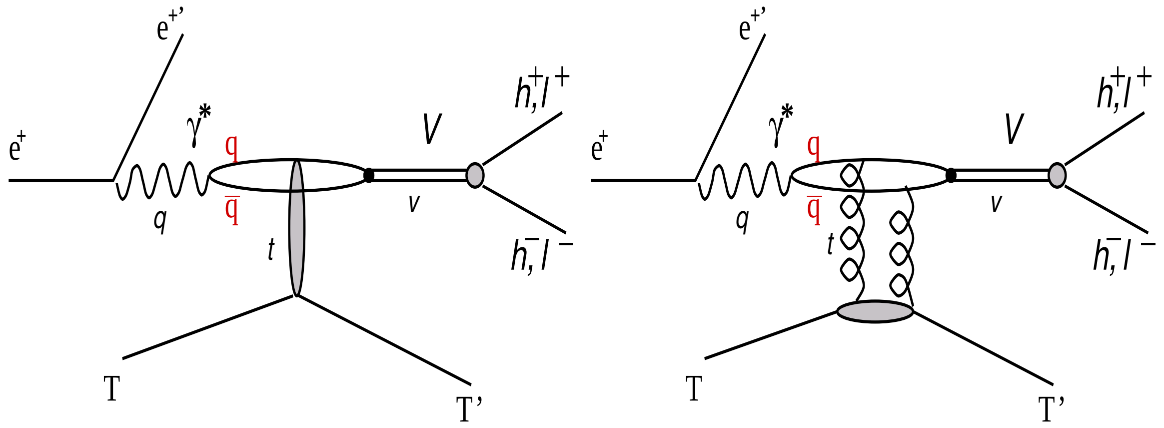
Data Sample

1996/97 data on polarised hydrogen target

$\Rightarrow$ no dilution, no nuclear effects !

Channels

$$\rho \to \pi^+\pi^-, \qquad \Phi \to K^+K^-$$
$$J/\psi \to e^+e^-, \qquad J/\psi \to \mu^+\mu^-$$



Kinematics

J/ψ: scattered e^+ not detected

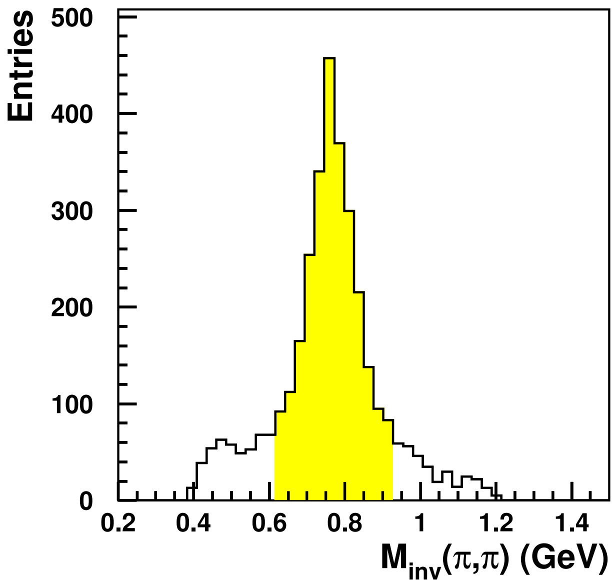
$\Rightarrow$ kinematics not fully known, separate analysis

$e^{+'}$ detected for ρ and Φ

$\Rightarrow$ complete event kinematics reconstructed

	Exclusive:
4-momentum transfer to target $t = (q-v)^2$	$-t < \mathcal{O}(1\mathrm{GeV}^2)$
minimum t $t_0 = t(\mathrm{V}\vert\vert\gamma^*)$	$t_0 \sim 0$
transverse component of t $t' = t - t_0 \sim p_t^2$	$t' \sim t$
energy transfer to the target $\Delta E = \frac{(M_X^2 - M_T^2)}{2M_T}$	$\Delta E = 0$

Exclusive ρ Sample ($\rho \to \pi^+\pi^-$)



Exactly 3 tracks: h^+, h^-, e'^+

$$0.62 < M_{inv}(\pi,\pi) < 0.92$$

$$-.6 < \Delta E < .6$$

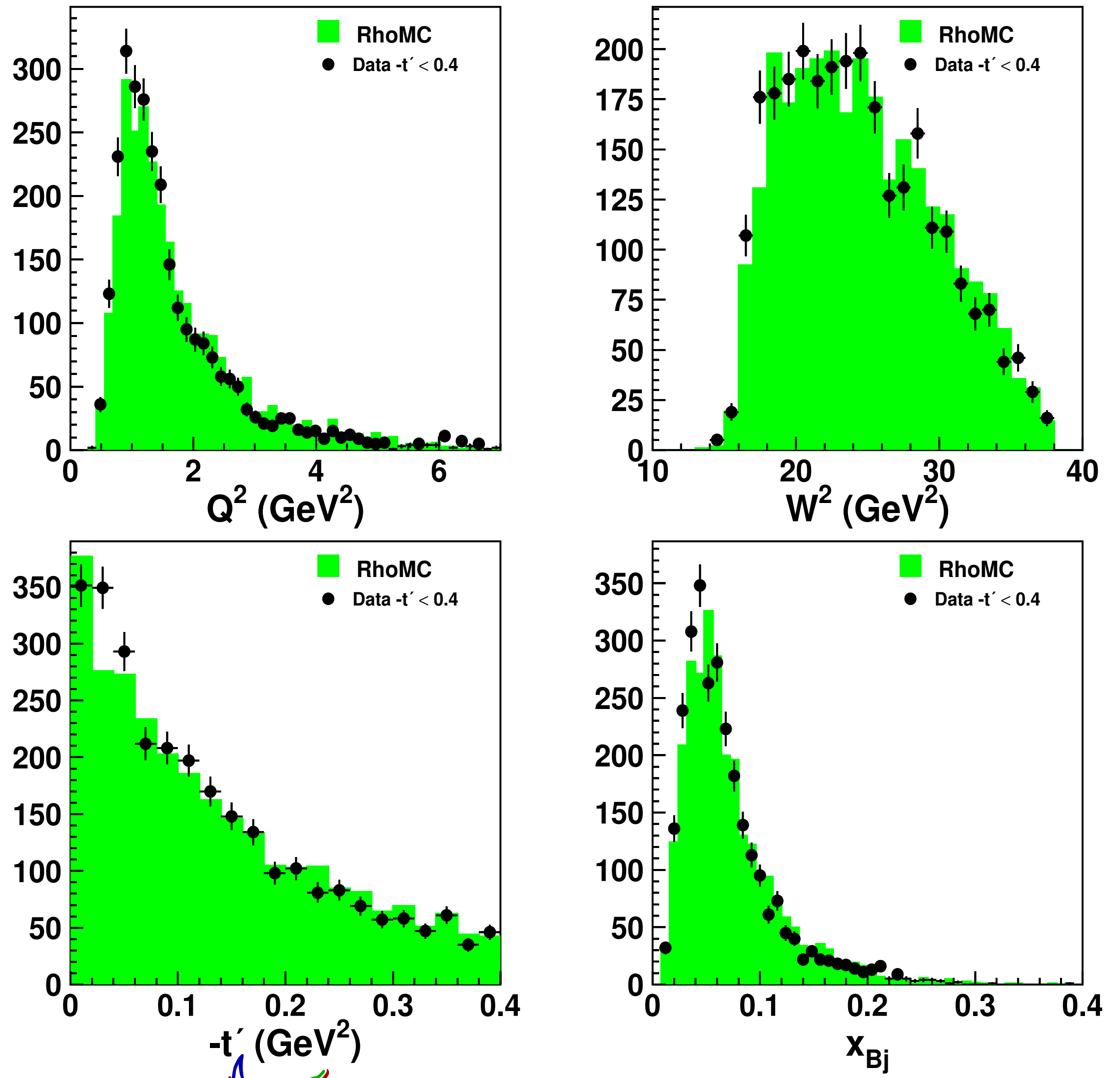
$$-t' < 0.4; \quad 9 < \nu < 20$$

+ vertex and acceptance cuts

$\Rightarrow$ 2900 ρ events

Data vs. Monte Carlo -kinematical distributions

(These four kinematical variables used for binning of $A_{\parallel}^{\rho}$)



Background Contributions

Missing energy ΔE distributions:
non-exclusive BG underneath elastic peak
$\Rightarrow$ inseparable on event by event basis

- Combinatorial Background from DIS

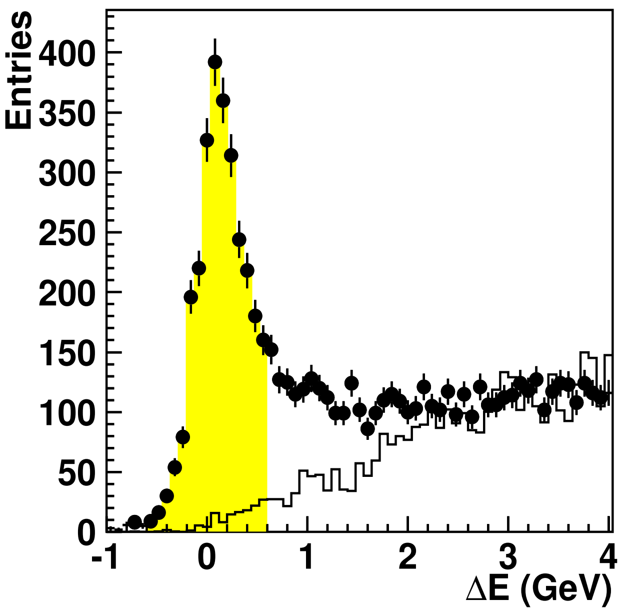
  suppressed by $-t'$ cut, remaining contribution removed with PEPSI Monte Carlo

  Points: data; Histogram: PEPSI

  Normalised at $\Delta E > 3$;

  Shaded area:

  signal region $|\Delta E| < 0.6$



  Possible BG contribution to $A_{||}$ from semi-inclusive DIS at $x_{Bj} \sim 0.05$ is small (< 0.05)

- Mis-reconstructed Φ, and ω-interference excluded by invariant mass cut

- BG from diffractive double dissociative processes small; From E665 data: 3-6% contribution in signal region $|\Delta E| < 0.6$ estimated

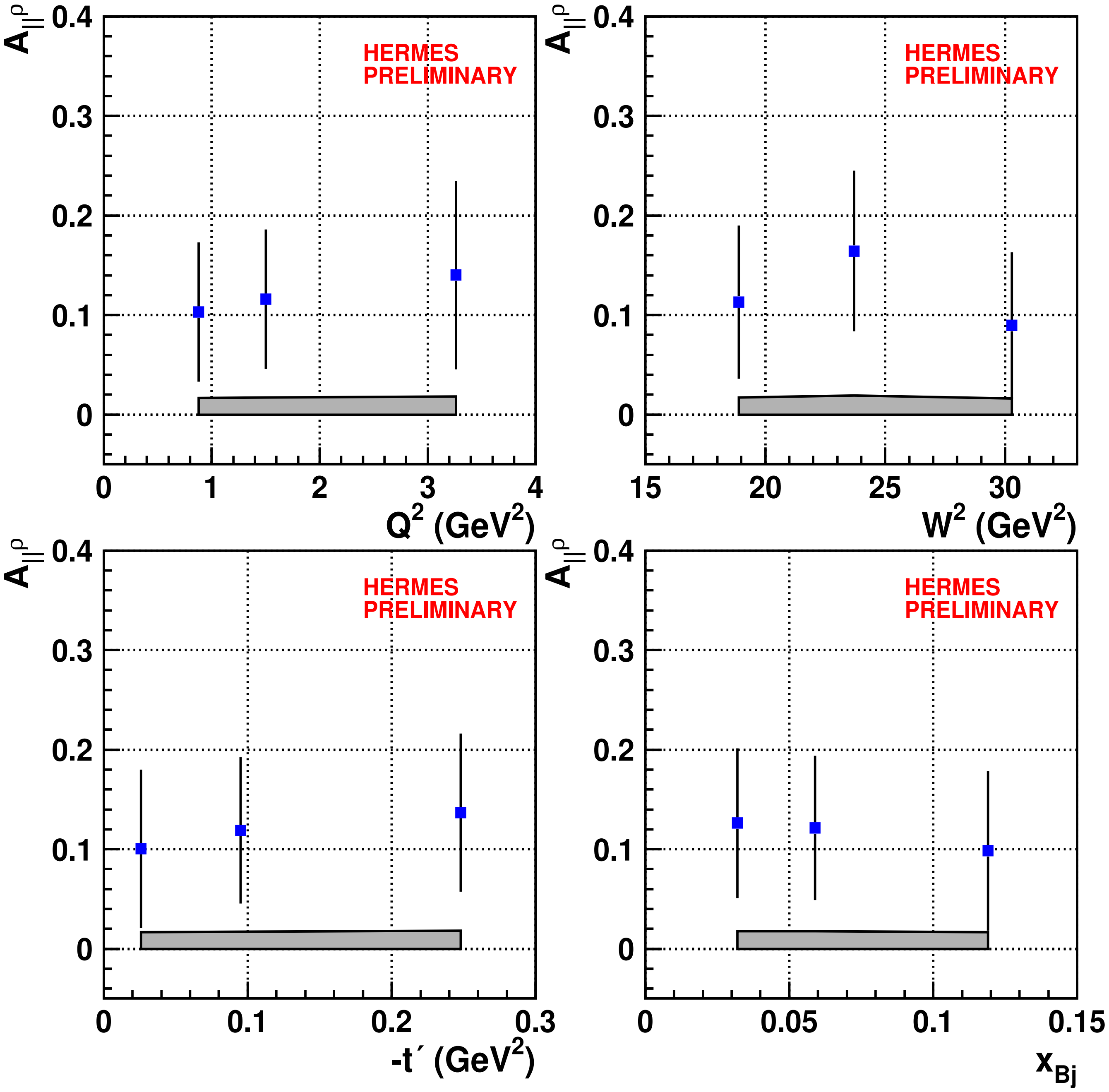
Perform background subtraction separately per beam-target spin configuration and kinematical bin to remove possible asymmetry contribution of background.

Measurement of Asymmetry $A_{\parallel}^{\rho}$

Usual formalism for extraction of Asymmetry $A_{\parallel}$

$$A_{\parallel} \approx \frac{1}{p_B \cdot p_T} \cdot \frac{N^- - N^+}{N^- + N^+}; \quad \delta(A_{\parallel}) \approx \frac{1}{p_B \cdot p_T \cdot \sqrt{N^- + N^+}}$$

Effective polarisation at HERMES: $p_B \cdot p_T \approx 0.5 \cdot 0.9$



Asymmetry is nonzero and positive

No significant trend seen in any variable

Systematic Uncertainty of $A_{\|}^{\rho}$

Many Systematic checks performed to test stability of result:

- Different methods of BG subtraction
  - no BG subtraction at all
  - data based BG subtraction
  - Monte Carlo based BG subtraction
  - empirical fits

- Variation of event selection
  Example: Exclusivity cut on ΔE,
  $A_{\|}$ is positive around elastic peak at $\Delta E \sim 0$ and consistent with zero for non-exclusive BG at $\Delta E > 1$

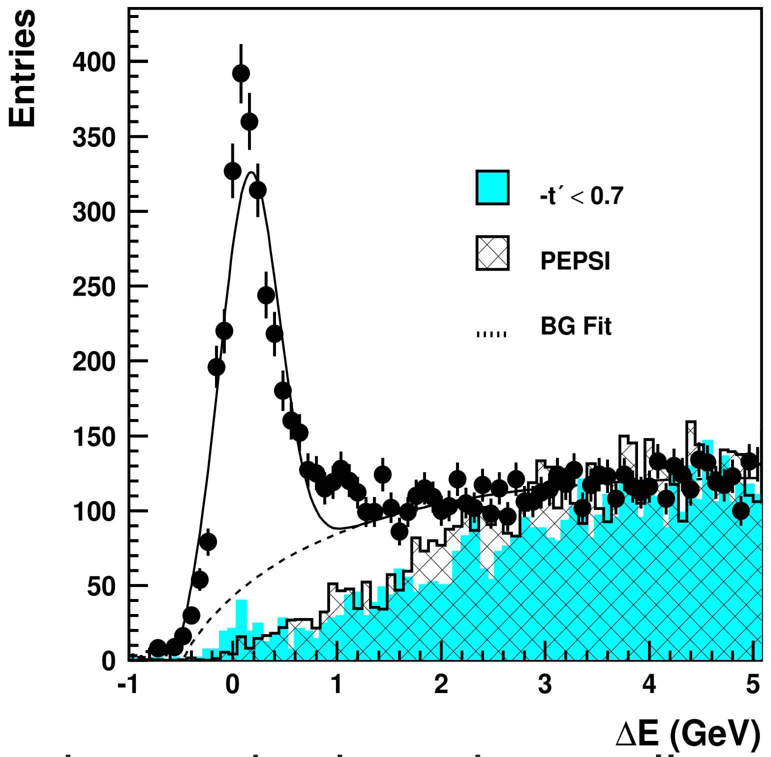
- Check of possible acceptance effects

Asymmetry stays stable !

$\Rightarrow$ Assing (conservative) systematic uncertainty for event selection and BG subtraction to $A_{\|}$ of ± 0.015

$\Rightarrow$ Systematic uncertainty due to target and beam polarisation measurement: 6% of $A_{\|}$

Methods of BG subtraction



- ▲ No Background subtraction at all

  Count all events in signal region $|\Delta E| < 0.6$

- ▼ Subtraction of DIS-BG with data at high $-t'$

  Diffractive Signal falls off as $e^{t'}$

  Non–exclusive BG has less steep t' dependence $\Rightarrow$ data at high $-t'$ used to model combinatorial DIS-BG

- ■ Subtraction of DIS-BG with PEPSI

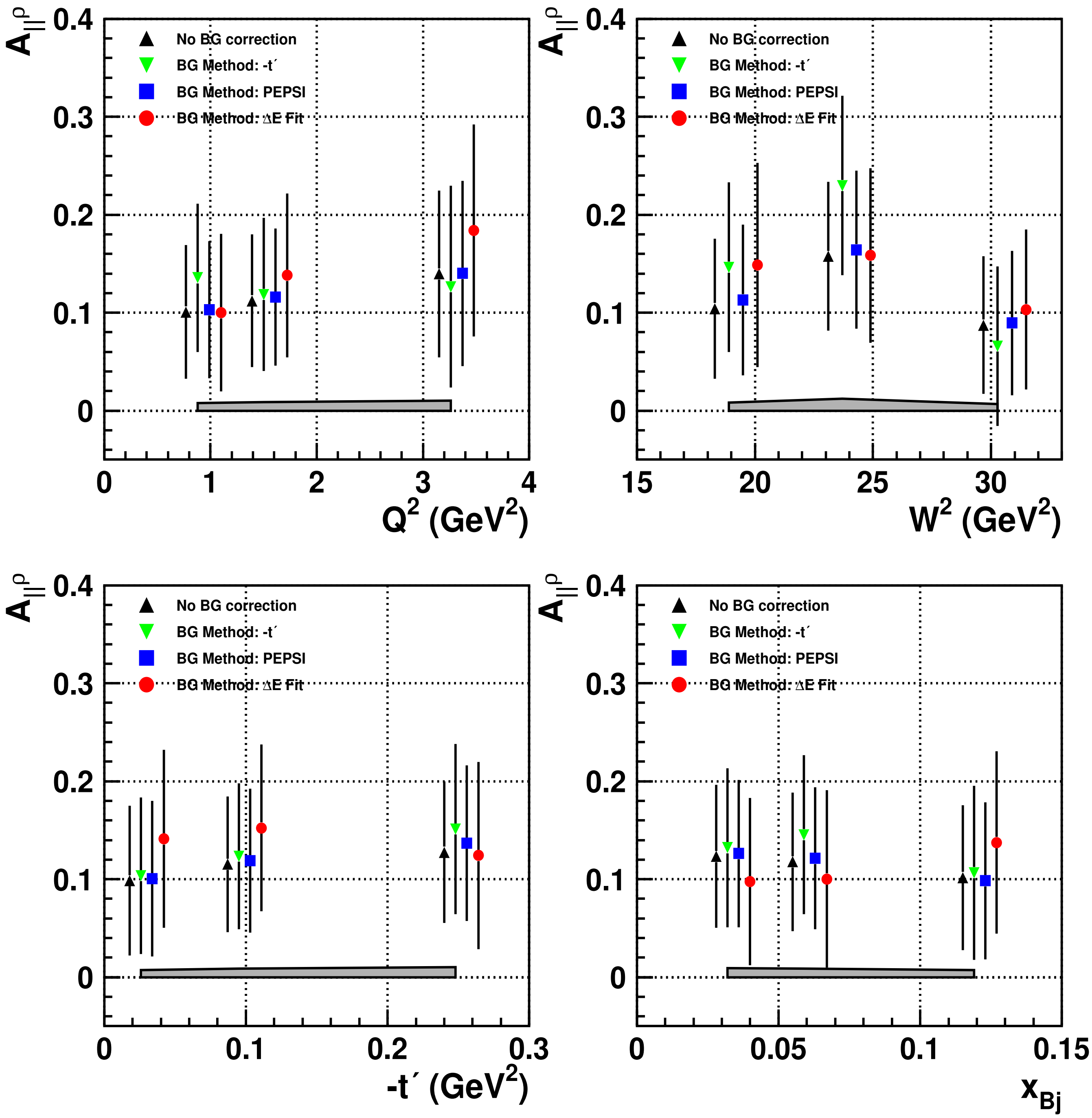
- ● Fit to the ΔE spectrum

  Use empirical background model: $x \cdot \exp -\sqrt{x}$

  Elastic peak described Gaussian

Use all four methods of background treatment separately per spin configuration and kinematical bin

$A_{\parallel}^{\rho}$ vs. BG-Method



All four methods of background treatment yield consistent result

Systematic error given contains only the systematic uncertainty due to the polarisation measurement

Photon Absorption Asymmetry A_1

$$A_1 = \frac{\sigma^{1/2} - \sigma^{3/2}}{\sigma^{1/2} + \sigma^{3/2}}$$

- Inclusive DIS: $A_1 \approx \frac{g_1}{F_1}$
- VM production: $A_1 =?$

No clear interpretation

Experimental asymmetry $A_{||}$ related to virtual photon absorption asymmetry A_1 by photon depolarisation factor D

$$A_1 = \frac{A_{||}}{D} - \eta A_2$$

Contribution from transverse asymmetry A_2

- kinematical factor $< \eta > \sim 0.05$
- $A_2 \cong 0$ in DIS
- A_2 not measured for VM-production

  Positivity limit: $A_2 < \sqrt{R}$; $A_2 \leq 1$

  $\Rightarrow$ **assign systematic uncertainty**
- $A_\perp \Rightarrow A_2$ is a possible measurement with HERMES transversally polarised target

Photon Depolarisation Factor

$$D = \frac{1-(1-y)\epsilon}{1+\epsilon R}; \qquad < D(\rho) > \sim 0.40 \quad \text{at} \quad \text{HERMES}$$

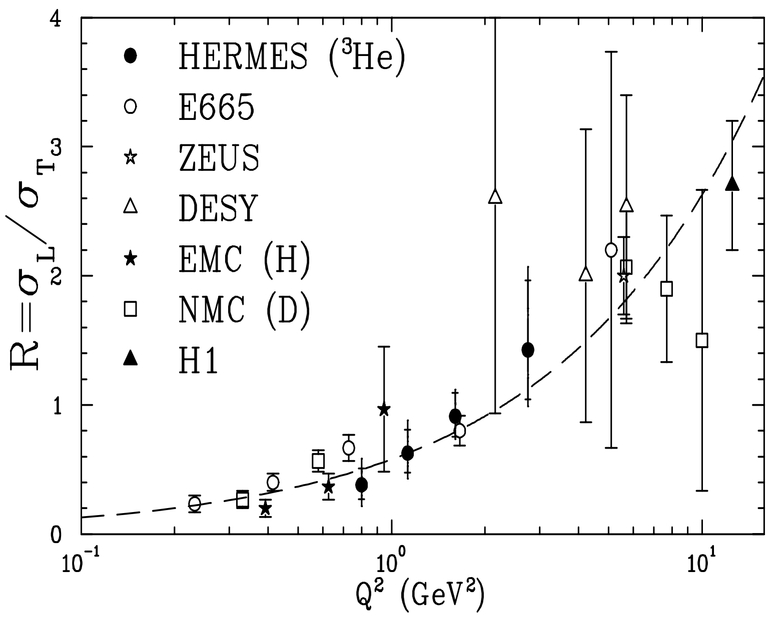
Ratio of absorption cross sections $R = \frac{\sigma_L}{\sigma_T}$
for longitudinal and transverse polarised photons

- DIS: $R = \frac{F_2}{2xF_1}(1 + \frac{4M^2x^2}{Q^2}) - 1$

  Parameterisation from fit to DIS data e.q. Whitlow et al.

- VM: $R = \frac{r_{00}^{04}}{\epsilon(1-r_{00}^{04})}$ (assuming SCHC)

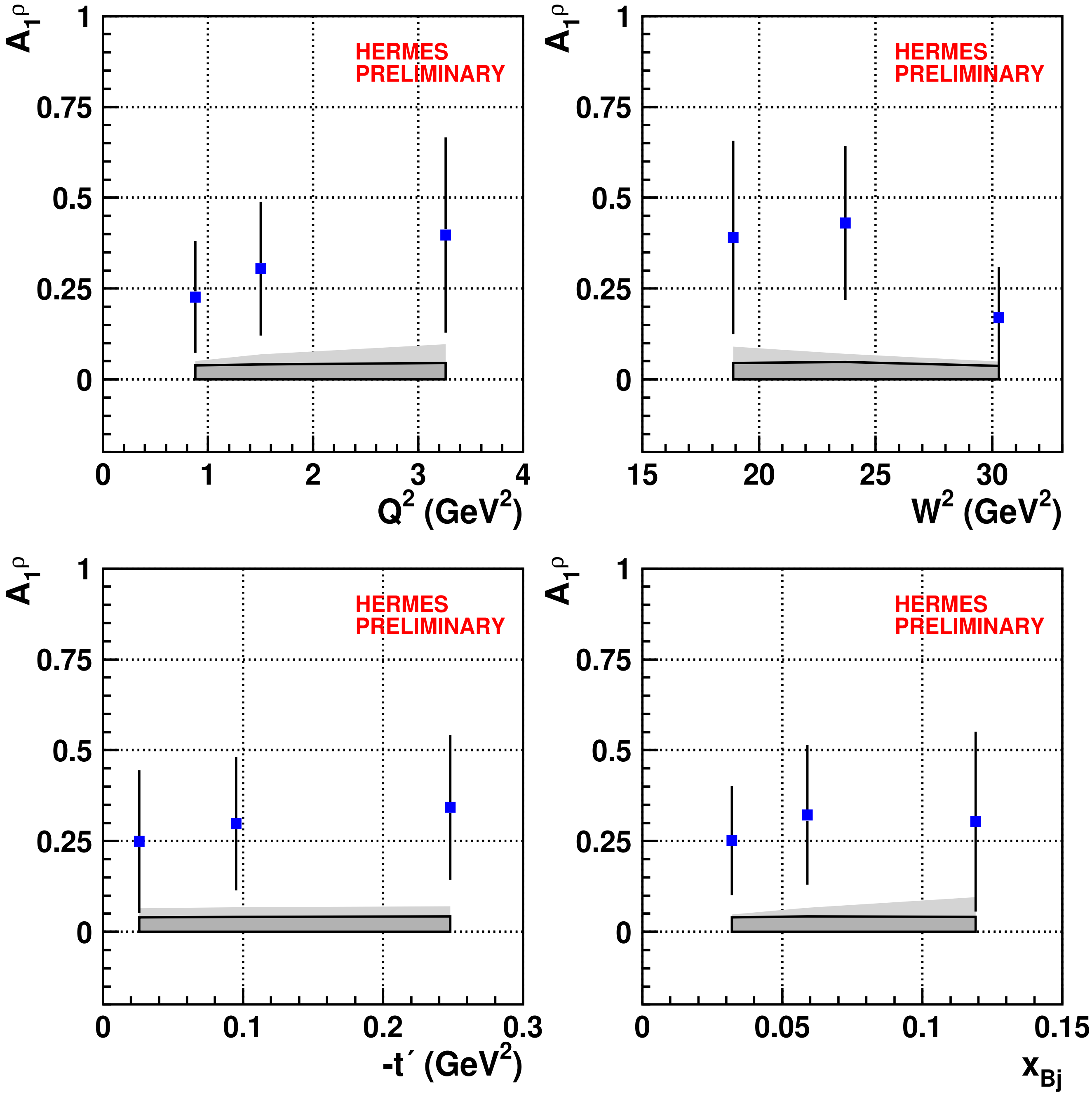
  HERMES own measurement, spin density matrix element r_{00}^{04} via angular distributions in ρ production



Use parameterisation: $R_\rho(Q^2) = c_0(W) \cdot (Q^2/m_\rho^2)^{c_1}$
Fit to world data: $c_0(W < 10) = 0.35, \; c_1 = 0.62$

Photon Absorption Asymmetry A_1^ρ

versus Q^2, W^2, $-t$' and x_{Bj}

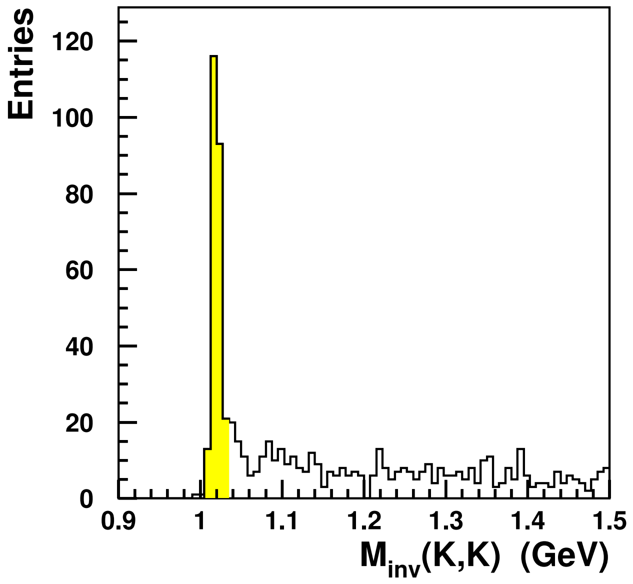


Maximal possible contribution of unknown A_2^ρ added in quadrature to experimental systematic uncertainty
$\Rightarrow$ light gray error band

Assume $A_2 = \pm \min(\sqrt{R}, 1) \Rightarrow \delta_{syst}(A_1) \leq \eta \cdot A_2$

(Theorists claim that this is probably an over estimate)

Exclusive Φ Sample ($\Phi \rightarrow K^+K^-$)



Exactly 3 tracks: $h^+, h^-, e'+$

Kaon PID for at least one hadron

$1.012 < M_{inv}(K,K) < 1.028$

$\Delta E < 1$

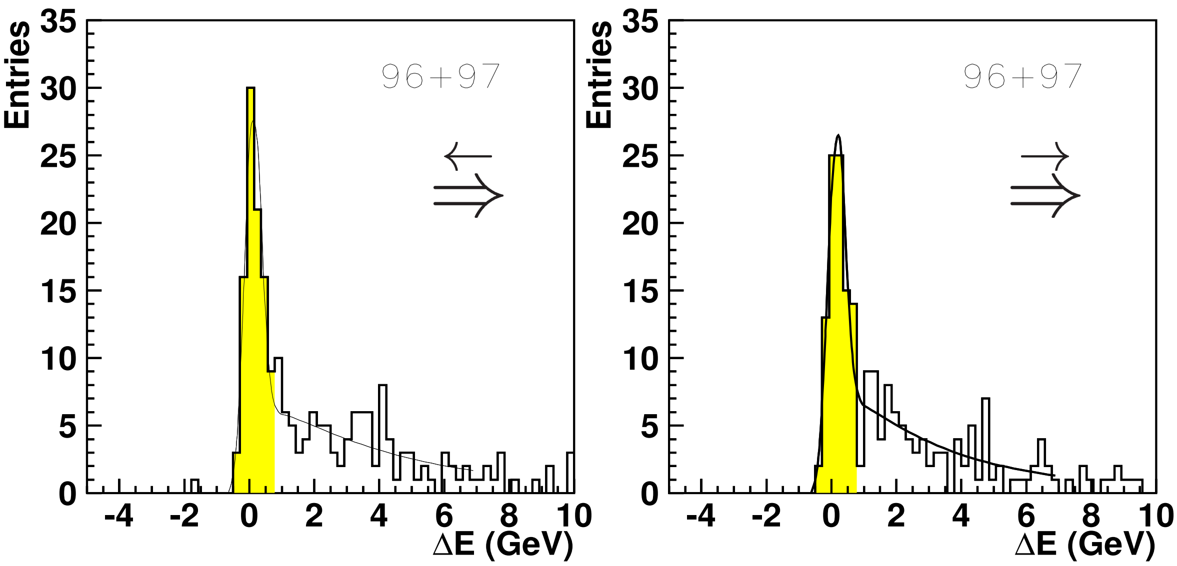
$-t' < 1$

+ vertex and acceptance cuts

$\Rightarrow 200\ \Phi$ events

Spin configuration separated ΔE spectra

Shaded areas denote events within selection cuts



- BG subtraction by fit to ΔE spectra
- Statistics low, systematic studies limited
- $A_{||}^{\Phi}$ consistent with zero within statistical error

Hidden Charm Production J/ψ

Two channels $J/\psi \to e^+e^-$ and $J/\psi \to \mu^+\mu^-$

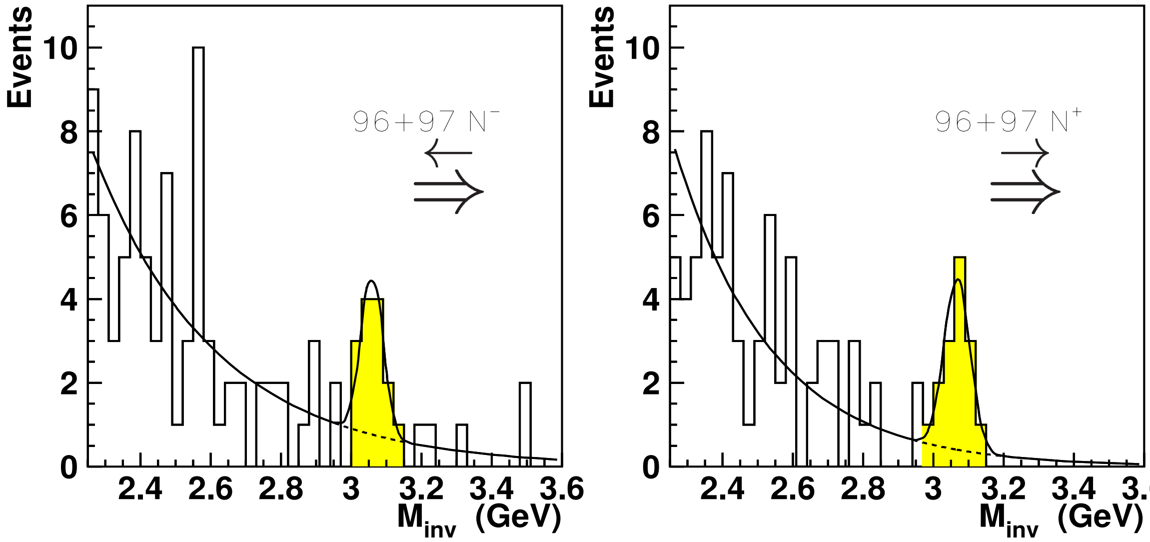
Experimental Conditions

- E_γ near threshold $\to$ low X-section
  HERMES PRELIM.: $\sigma_{\gamma N}^{J/\psi}(E_\gamma = 15) = 4.3 \pm 0.5 \pm 0.9$ nb
- Forward spectrometer: only $\sim 10\%$ J/ψ acceptance
- Low Q^2 (small scattering angles)
  only $\sim 10\%$ of J/ψ with $e^{+'}$ in Spectrometer
  no clear separation inelastic/diffractive J/ψ

$\Rightarrow$ $\sim$ 20 J/ψ's combined from both channels on $\vec{H}$ target

Separately per spin configuration

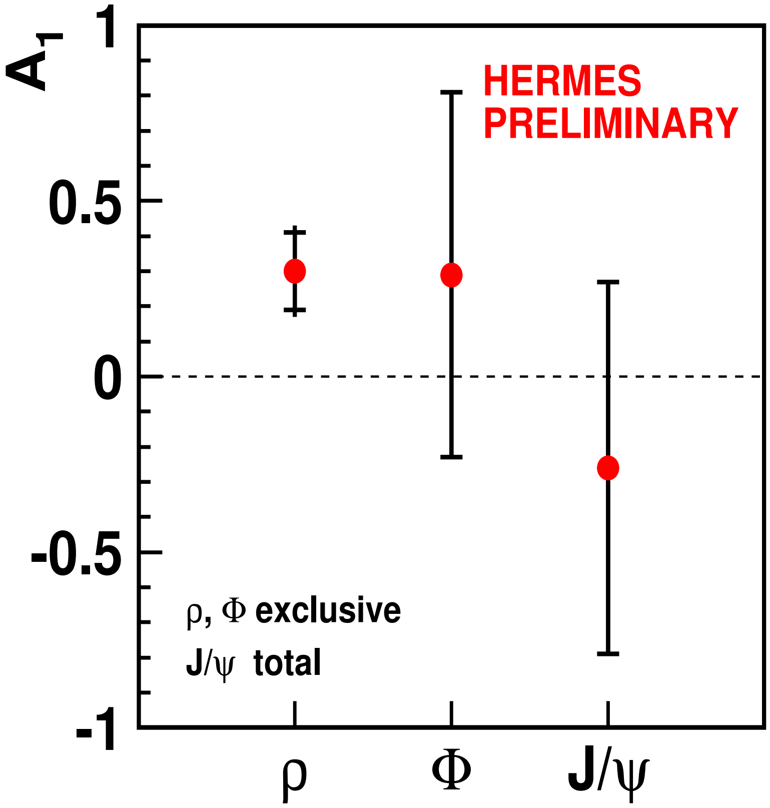
Fit of invariant mass spectrum to determine number of events over background
$\Rightarrow$ correct for possible asymmetry of BG
(Despite small statistics, fits are rather stable)



Statistical error large; $A_{\|}^{J/\psi}$ consistent with zero

Summary

Comparison of Vector Meson Asymmetries



- Clear positive asymmetry for diffractive ρ's

$$A_1^\rho = 0.30 \pm 0.11(stat.) \pm 0.04(syst.) \pm 0.05(theor.)$$

- Different photon depolarisation factors
  ($D_{\rho,\Phi} \sim 0.4$, $D_{J/\psi} \sim 1$)
  $\Rightarrow$ have to compare A_1 rather than $A_{||}$

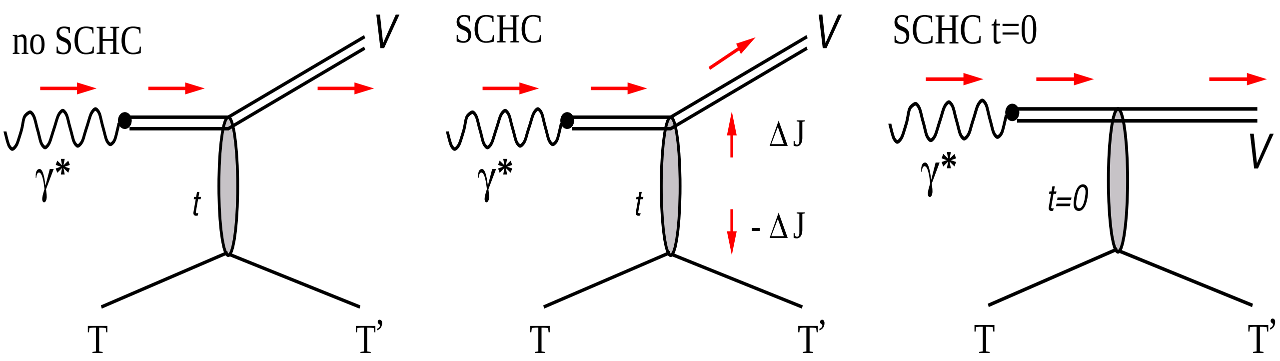
- A_1^Φ and $A_1^{J/\psi}$ consistent with zero within statistical errors

  For J/ψ no scattered positron $\Rightarrow$ kinematics not fully known, possible inelastic contribution

Possible Physics Interpretations

- **Diffractive VM production related to ΔG?**
  -already at the (low) ρ mass ?
  (M.Ryskin hep-ph 9706505)

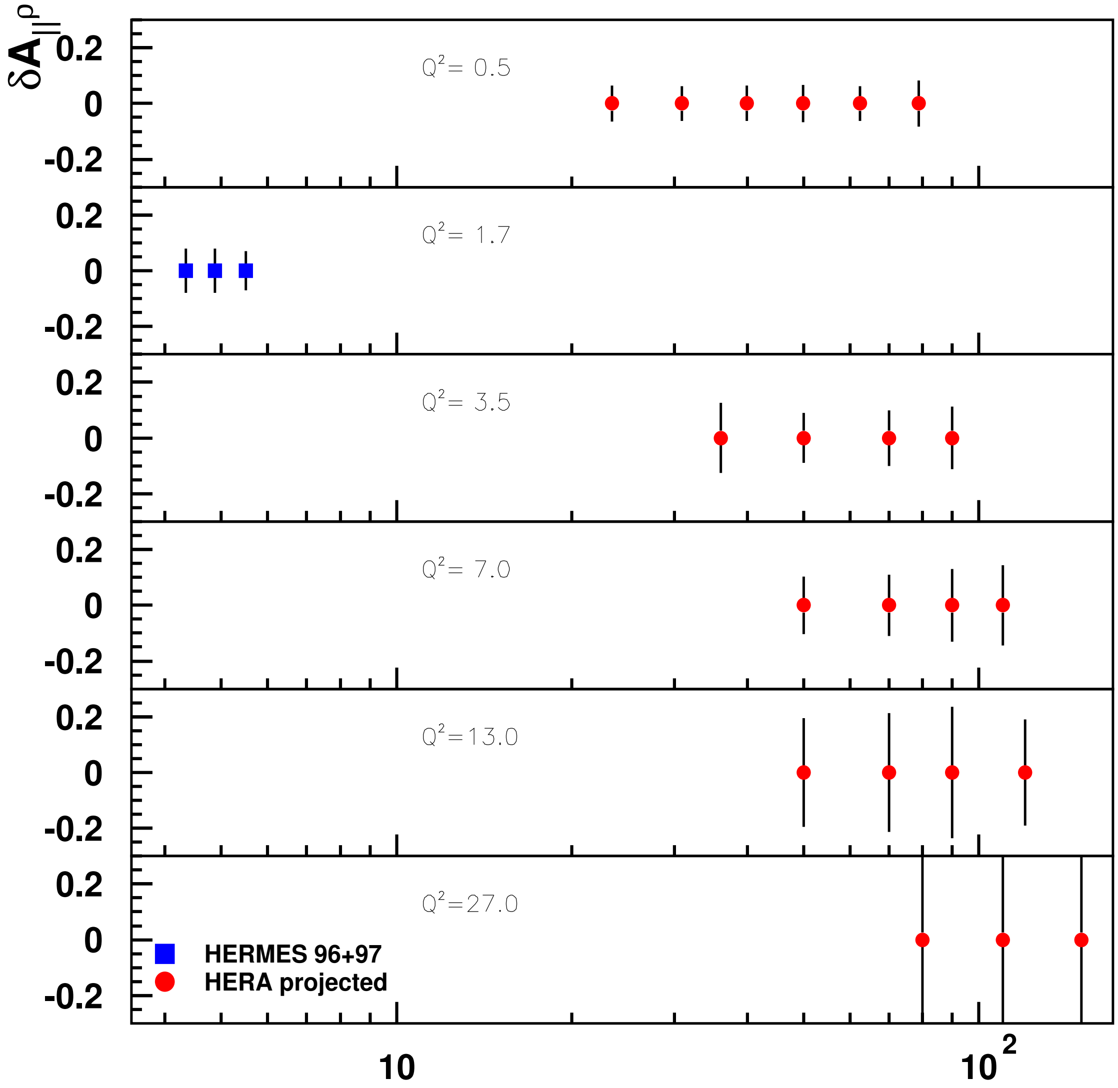
- **Spin density matrix elements**
  measured via angular distributions in VM production – extraction of $R = \sigma_L/\sigma_T$ assuming SCHC.
  Does a nonzero asymmetry at small t imply a violation of SCHC ?



- **Off–forward parton distributions**
  Asymmetry in diffractive pair production of charged mesons and exclusive ρ production may it give access to OFPD's ? (A.Schaefer et.al. hep-ph 9901283)

A significant nonzero asymmetry in ρ production is an unexpected exciting result; presently, without theoretical explanation.

HERA-$\vec{e}\vec{P}$ Projected Statistical Errors $\delta A_{\|}^{\rho}$



All asymmetries $A_{\|}$ set to zero

Statistical error estimate: $\delta A_{\|} = \frac{1}{\sqrt{N} \cdot P_B \cdot P_T}$

Using:

- Binning and number of events per bin: 1995 ZEUS ρ data; DESY 98-107
- Projected luminosity for one year of data taking: 50 pb^{-1} ($\sim$ 1999)
- e-beam polarisation: 0.5 (HERMES average)
- P-beam polarisation: 0.5