Exclusive processes at COMPASS – present and future

Materials for discussion

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workshop on 'Hard Exclusive Processes at JLab 12 GeV and a Future EIC'

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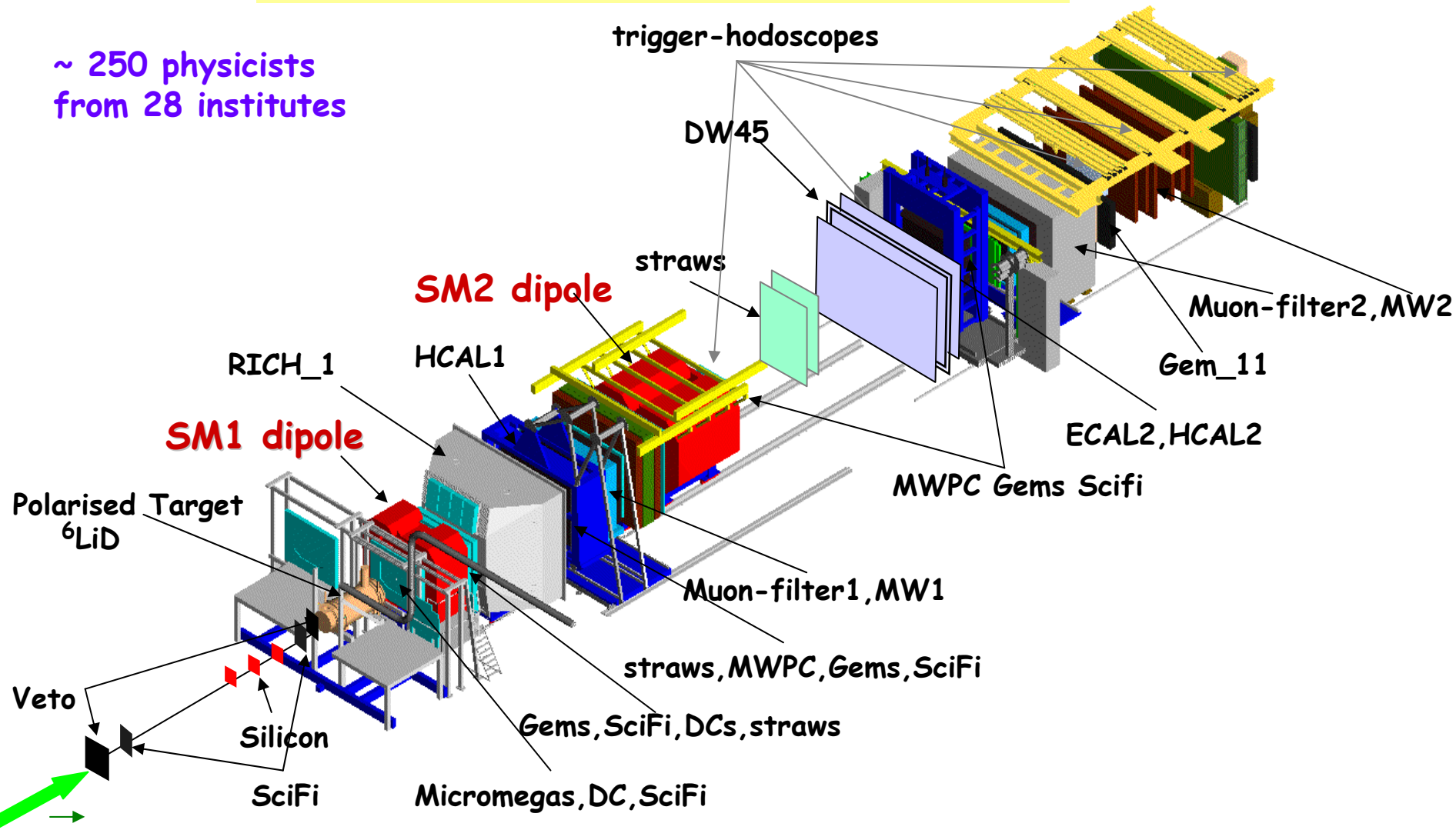
COMPASS experiment

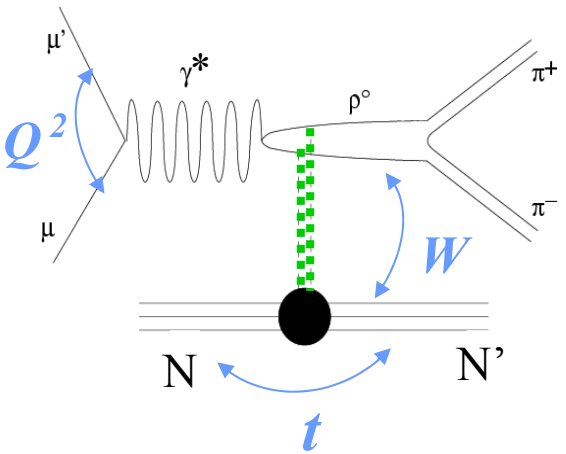
~ 250 physicists
from 28 institutes



$\vec{\mu}$ 160 GeV
from CERN SPS
Beam Polarization ~ -76%

Beam intensity $2 \cdot 10^8$ μ^+/spill (4.8 s / 16.2 s)
Luminosity ~ $5 \cdot 10^{32}$ cm^{-2}s^{-1}

Incoherent exclusive ρ^0 production



^{6}LiD polarized target

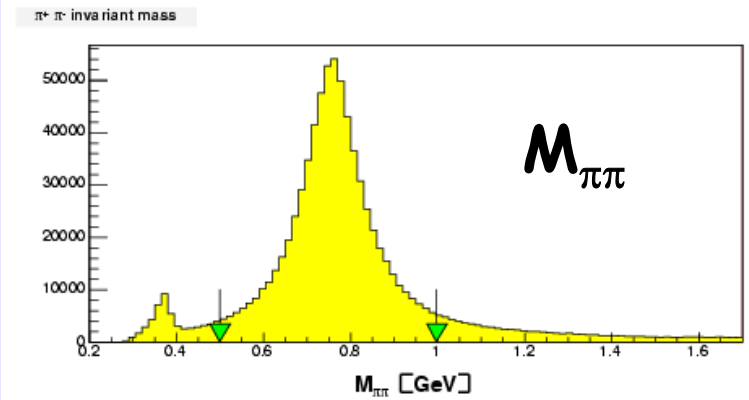
Kinematics:

$\nu > 30$ GeV

$E_{\mu'} > 20$ GeV

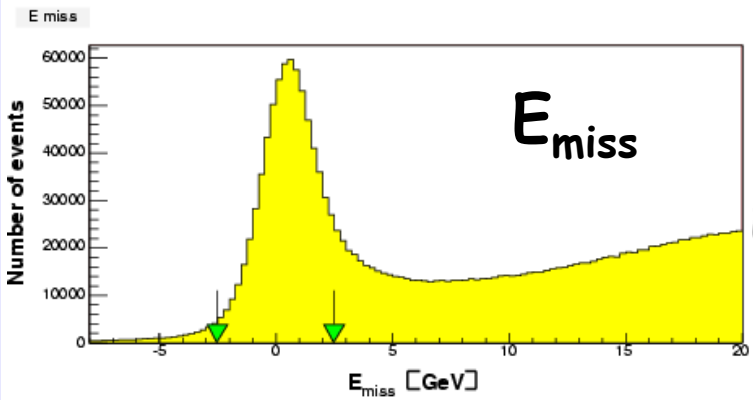
$Q^2 > 0.01$ GeV^2

(Q^2 cut applied only in SDME analysis)



Assuming both hadrons are π

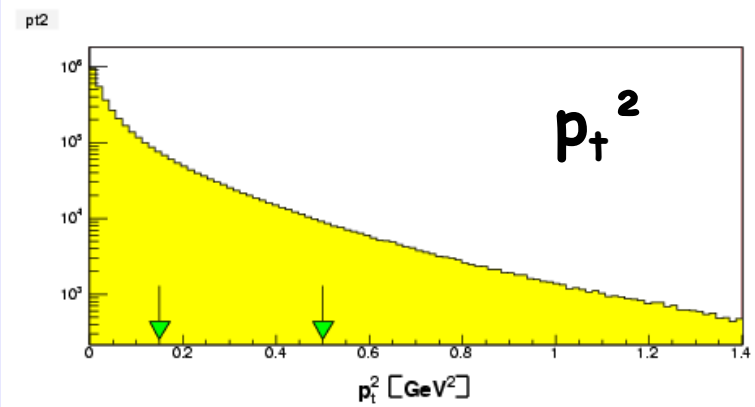
$0.5 < M_{\pi\pi} < 1$ GeV



Exclusivity of the reaction

$E_{miss} = (M^2_X - M^2_N) / 2M_N$

$-2.5 < E_{miss} < 2.5$ GeV



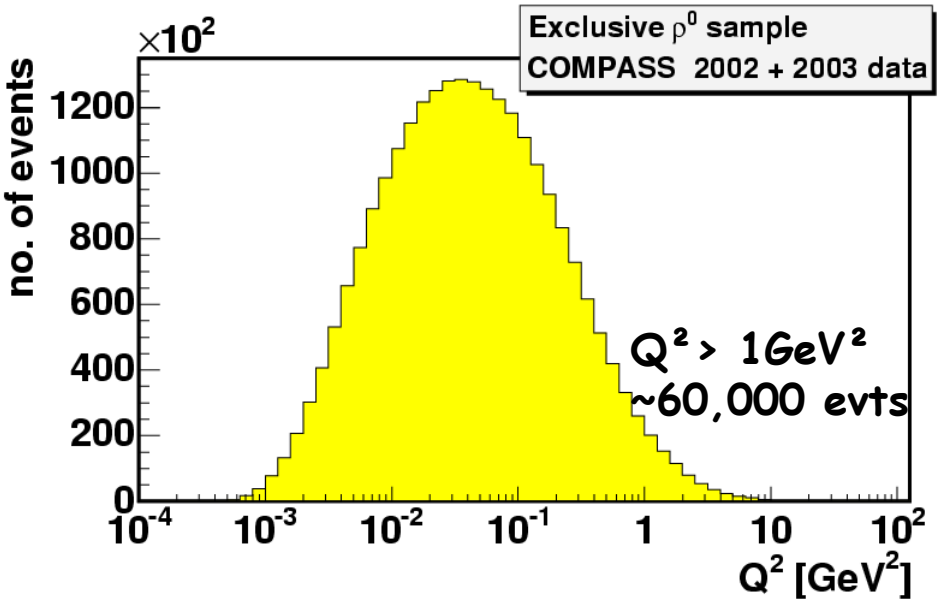
Incoherent production

$0.15 < p_t^2 < 0.5$ GeV^2

scattering off a quasi-free nucleon

Background ~12%

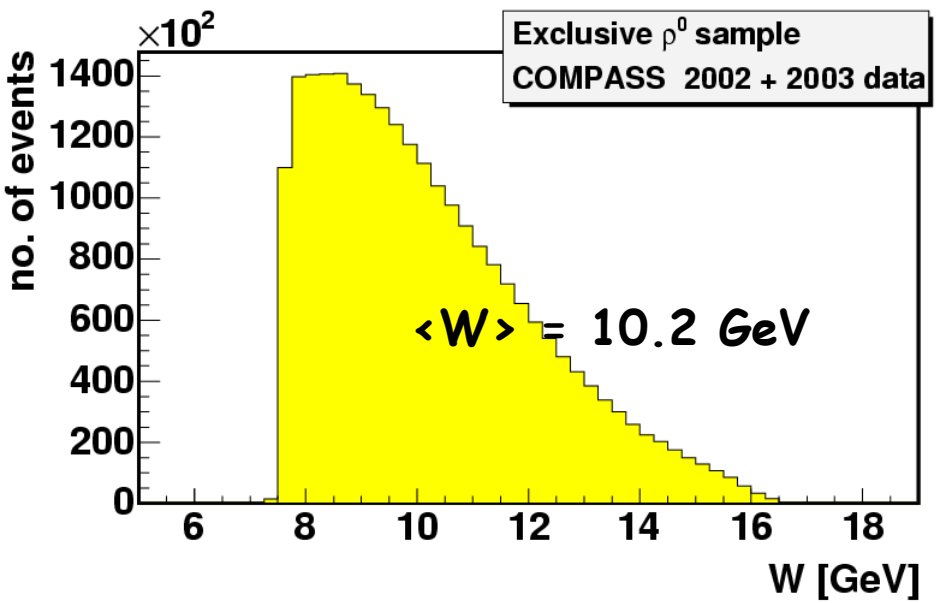
Kinematical domain of the final sample

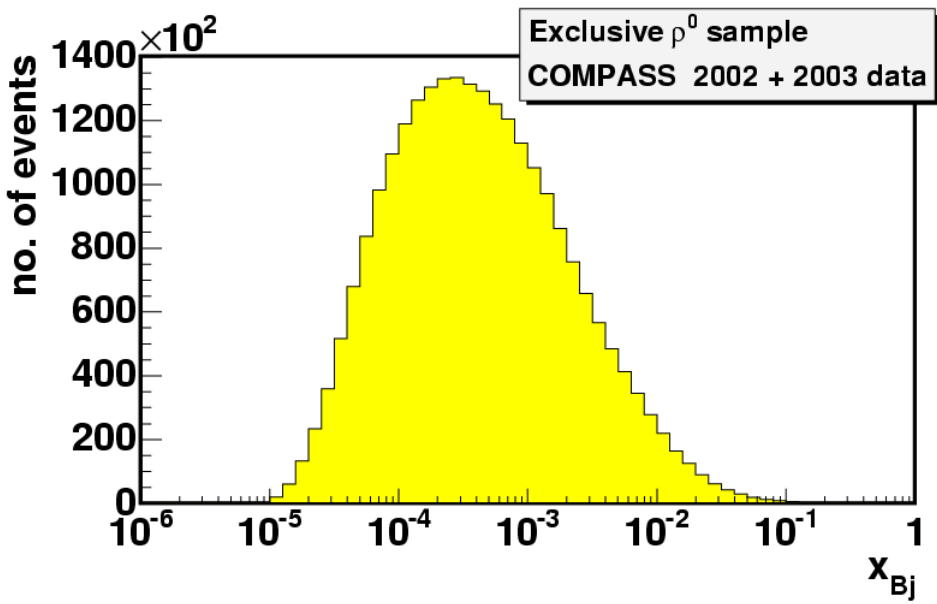


2002 : 800,000 evts
2003 : 1,600,000 evts

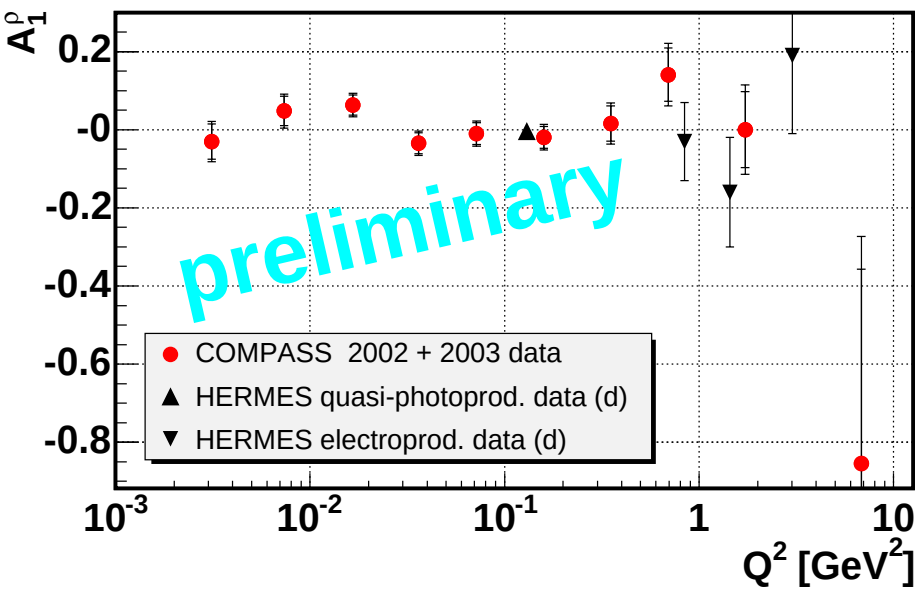
+ 2004 : not yet analyzed
~ will double the data sample

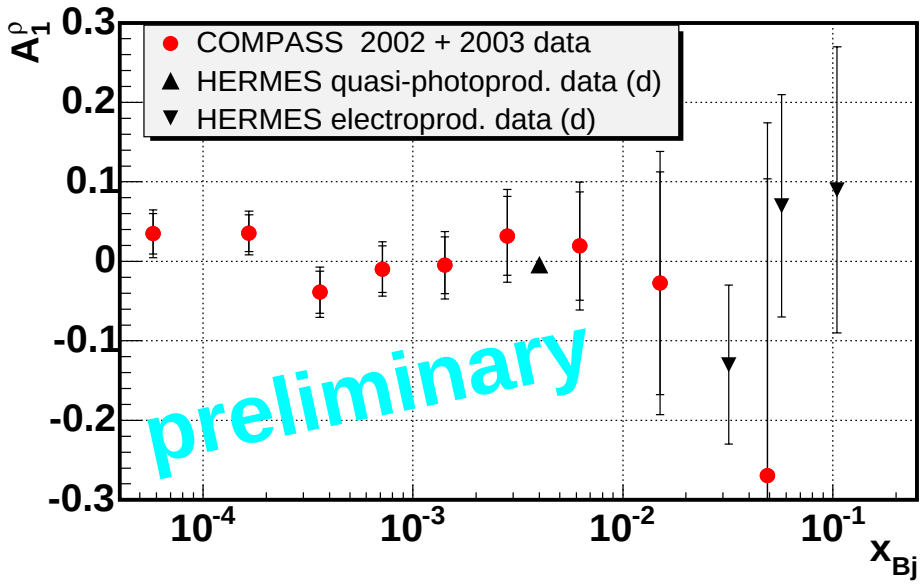
$\langle p_t^2 \rangle$ = 0.27 GeV²





COMPASS results on A_1^p (d)





COMPASS results on A_1^p on polarized deuteron target consistent with 0

Extended kinematical range of COMPASS by almost 2 decades down both in Q^2 and x

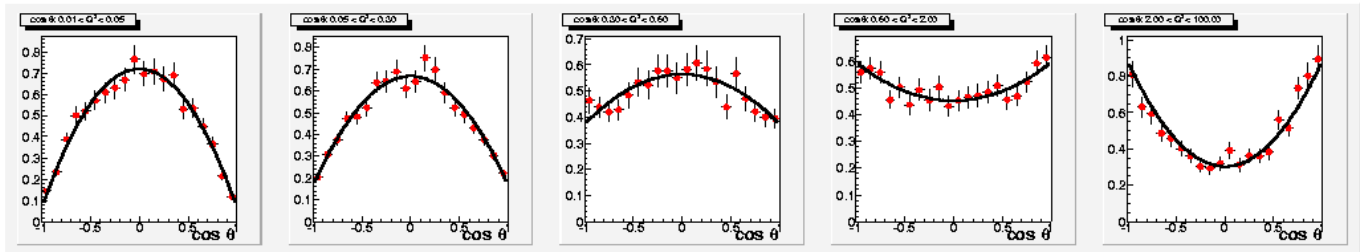
COMPASS : inner bars –stat. outer – total errors
HERMES: total errors

➡ at small ***x*** (< 0.01) contribution of unnatural parity exchanges small

for exclusive ρ^0 production

Measurement of r_{00}^{04}

$0.01 < Q^2 < 0.05 < Q^2 < 0.3 < Q^2 < 0.6 < Q^2 < 2.0 < Q^2 < 10\ GeV^2$



Distribution :

$$W(\cos\theta) = \frac{3}{4}\left[(1-r_{00}^{04}) + (3r_{00}^{04}-1)\cos^2\theta\right]$$

Spin density matrix element:

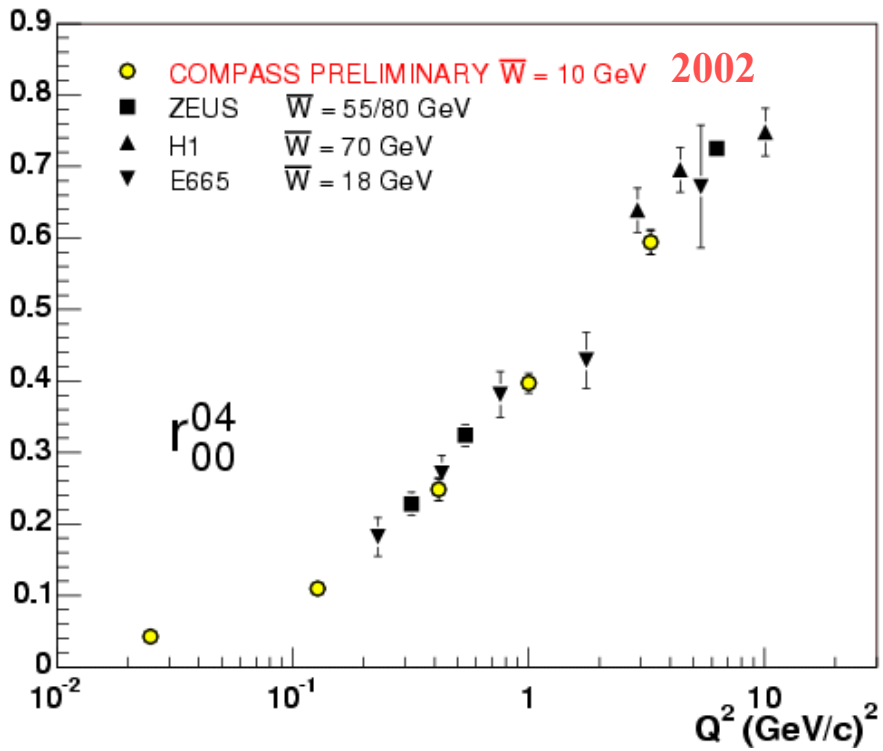
$$r_{00}^{04} = \frac{|T_{01}|^2 + (\varepsilon+\delta)|T_{00}|^2}{N_T(1+(\varepsilon+\delta)R)} \xrightarrow{SCHC} \frac{\sigma_L}{\sigma_T}$$

$$R = \sigma_L/\sigma_T \qquad N_T = |T_{11}|^2 + |T_{-11}|^2 + |T_{01}|^2$$

$$\Gamma_L/\Gamma_T = \varepsilon + \delta$$

$T_{\lambda\rho\,\lambda\gamma}$ helicity amplitudes

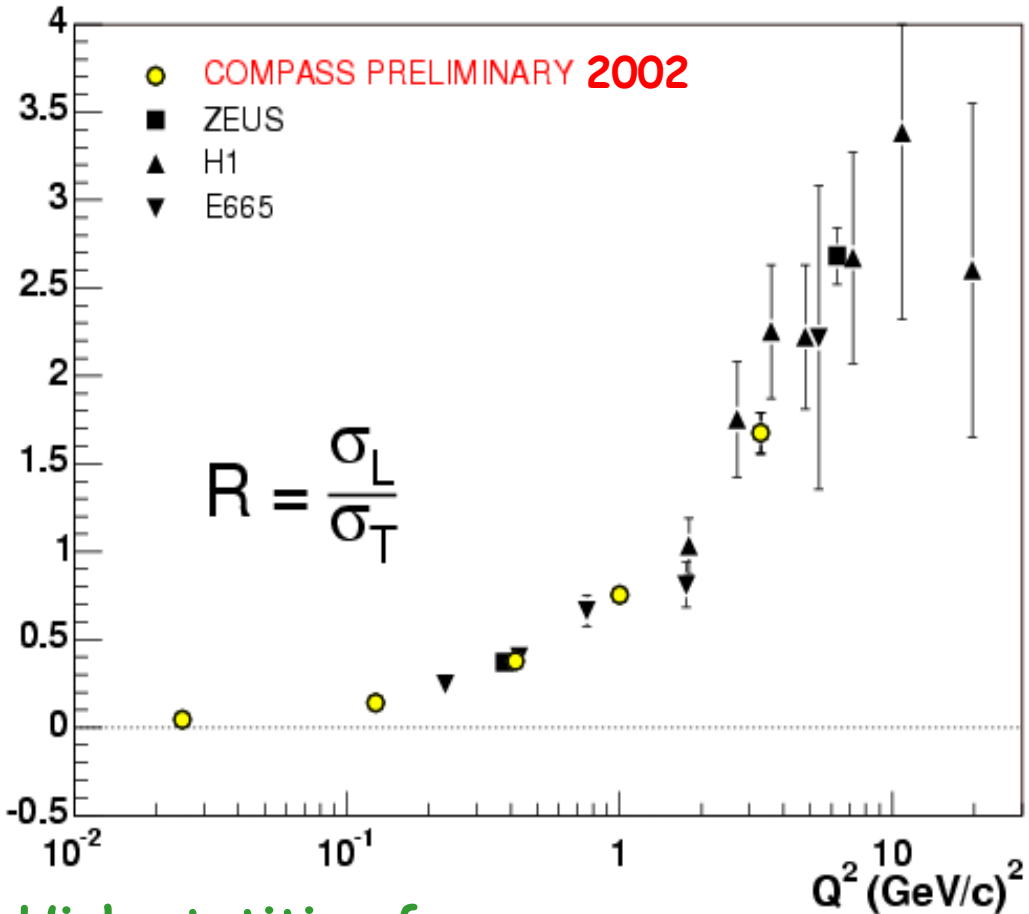
meson photon



Determination of $R = \sigma_L/\sigma_T$

If SCHC holds :
only $T_{00} \neq 0$
$T_{11} \neq 0$
Then :

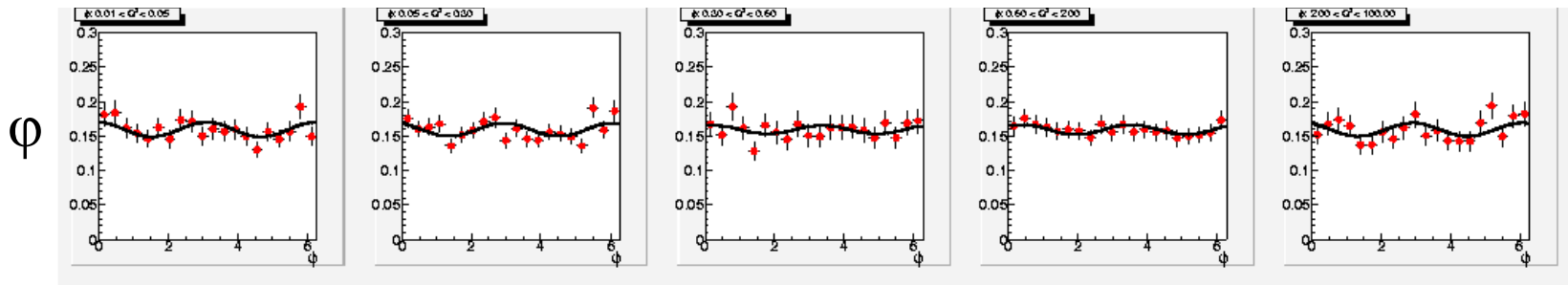
$$R = \frac{\sigma_L}{\sigma_T} = \frac{1}{(\varepsilon + \delta)} \frac{r_{00}^{04}}{1 - r_{00}^{04}}$$



Impact on GPD study:
determination of σ_L
σ_L is dominant at $Q^2 > 2$ GeV^2

- High statitics from quasi-photoproduction to hard production
- Better coverage at high Q^2 with 2003 and 2004 data

Measurement of r^{04}_{1-1} and Im r^{3}_{1-1}



Distribution :

$$W(\varphi) = \frac{1}{2\pi}[1 - 2r^{04}_{1-1}\cos 2\varphi + 2\,\mathrm{Im}\,r^{3}_{1-1} P_\mu \sqrt{1-\varepsilon^2}\sin 2\varphi]$$

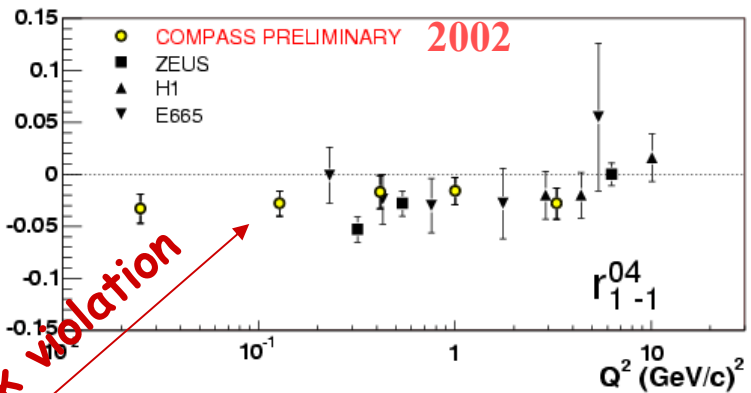
beam polarisation

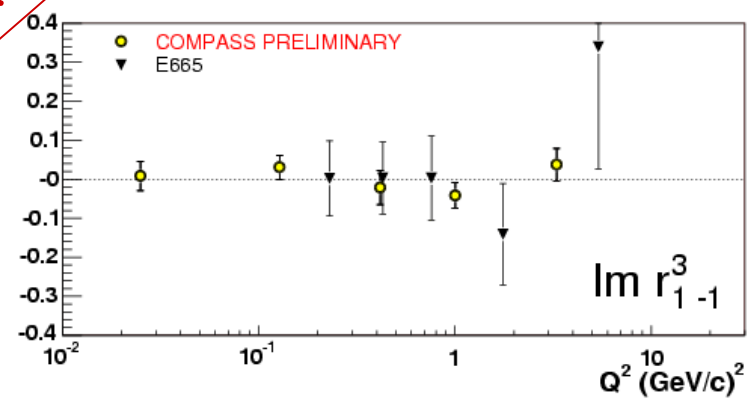
Spin density matrix elements:

$$r^{04}_{1-1} = \frac{\mathrm{Re}(T_{11}T^{*}_{-11}) - (\varepsilon+\delta)|T_{10}|^2}{N_T(1+(\varepsilon+\delta)R)} = 0$$

$$\mathrm{Im}\,r^{3}_{1-1} = \ldots = 0$$ ← If SCHC holds

weak violation

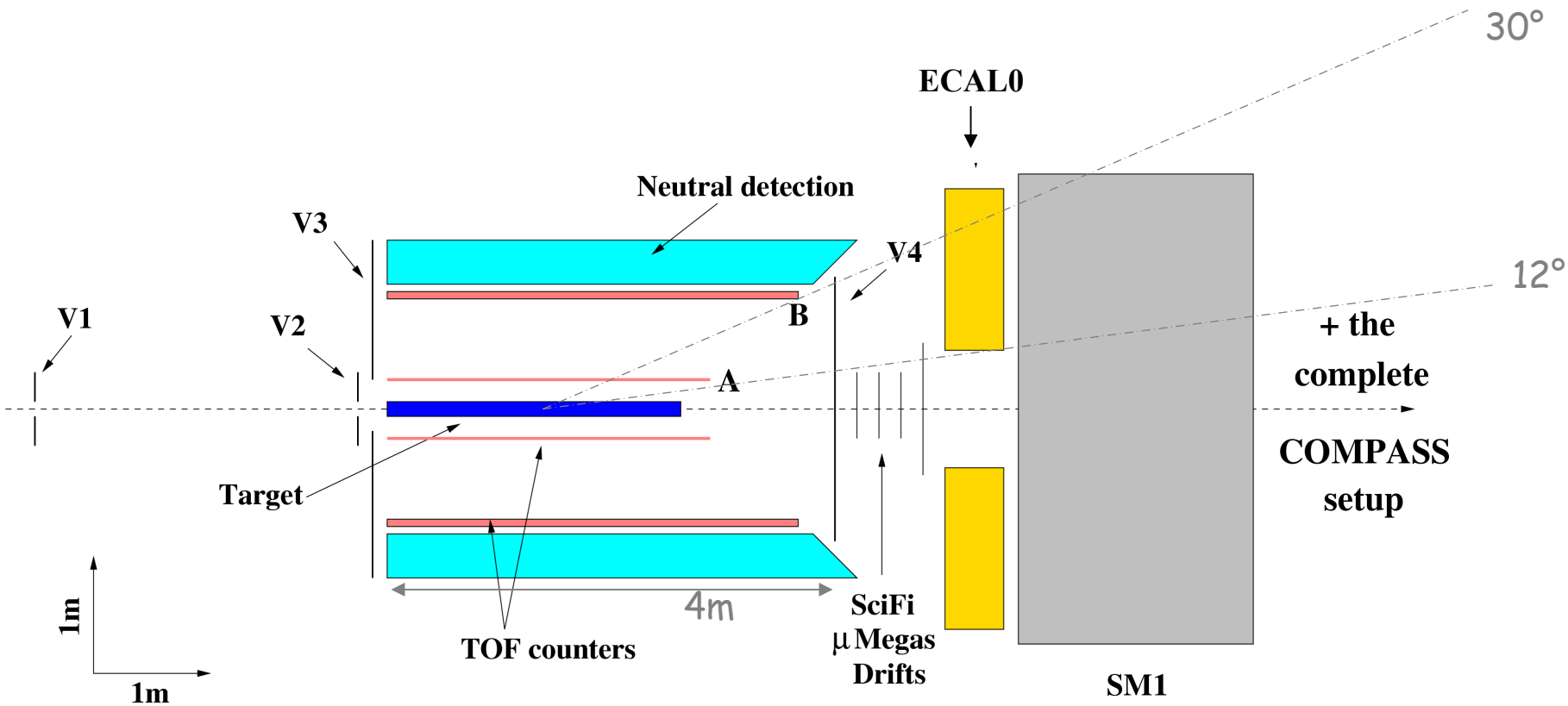




Summary and outlook for vector mesons

- Asymmetry A_1^p (d) consistent with zero over wide range of Q^2 and x
  small contribution of unnatural parity exchanges at $x < 0.01$
  first measurement at small Q^2 and small x
- High-statistics data on SDM elements and R for incoherent exlusive ρ^0 production
  in a wide Q^2 range (including small Q^2 not covered previously)
  weak violation of SCHC observed
- Significant improvement of accuracy expected after including 2004 (and 2003 data)
  extraction of 23 SDMEs under way
- Studies of coherent exclusive ρ^0 production foreseen
- Single spin asymmetry for transversely polarized target → E/H GPDs
- Analysis of exlusive φ and J/ψ production in progress

possible solution to complete the COMPASS setup

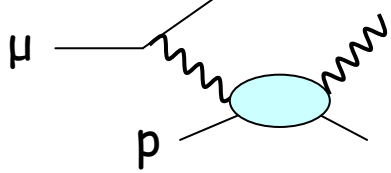


2004-2007:

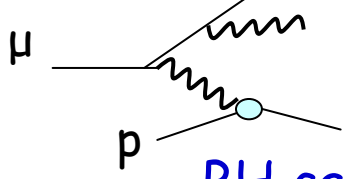
Received funding by EU FP6 (Bonn-Mainz-Warsaw-Saclay)

Goal: full test of feasibility of a 45° sector recoil detector

- scintillating material studies (200ps ToF Resolution over 4m)
- fast triggering and multi-hit ADC/TDC system



DVCS+ Bethe Heitler



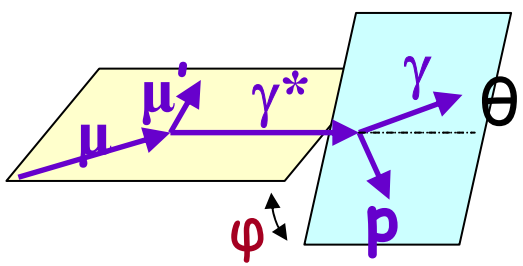
BH calculable

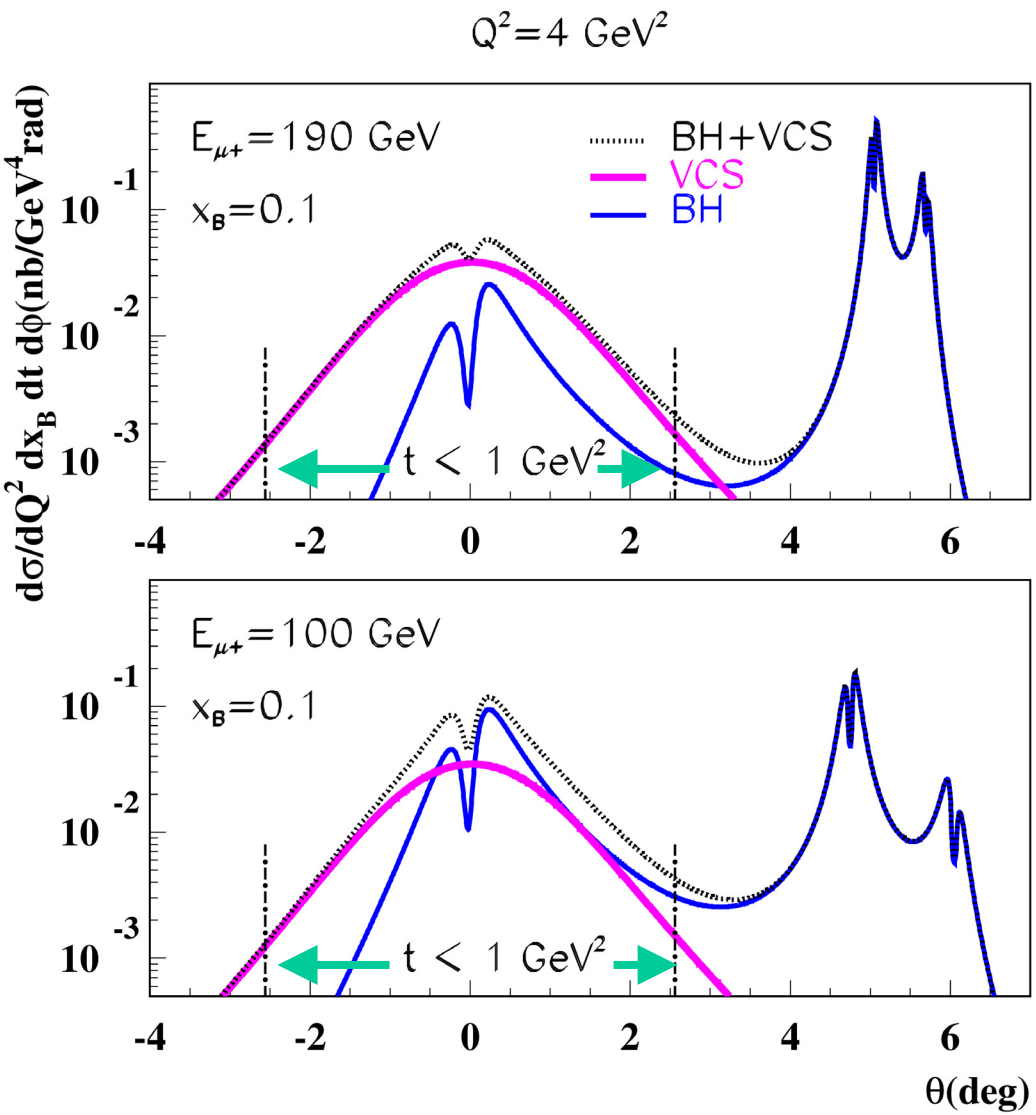
The high energy muon beam at COMPASS allows to play with the relative contributions DVCS-BH which depend on

$$1/y = 2\, m_p\, E_\ell\, x_{Bj}\, /Q^2$$

Higher energy: DVCS>>BH
⇒ DVCS Cross section

Smaller energy: DVCS~BH
⇒Interference term will provide the DVCS amplitude





Advantage of $\overleftarrow{\mu}^+$ and $\vec{\mu}^-$ for Deeply virtual Compton scattering (+Bethe-Heitler)

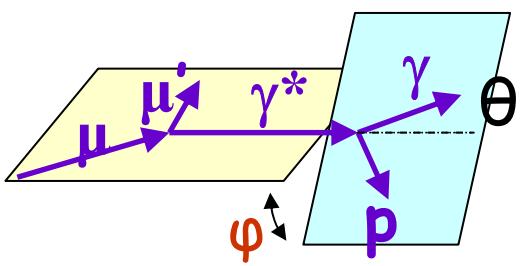
$$A^{DVCS}_{(\mu p\to\mu p\gamma)} = \int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi+i\varepsilon} = \mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi} - i\,\pi\, H(x=\xi,\xi,t)$$

t, $\xi \sim x_{Bj/2}$ fixed

$$d\sigma_{(\mu p\to\mu p\gamma)} = d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + P_\mu\, d\sigma^{DVCS}_{pol}$$

$$+ e_\mu\, a^{BH}\, \mathcal{R}e\, A^{DVCS} + e_\mu P_\mu\, a^{BH}\, \mathcal{I}m\, A^{DVCS}$$

$\times \cos n\varphi$ $\times \sin n\varphi$



P_{μ^+}=-0.8 P_{μ^-}=+0.8

$$\sigma^{\overleftarrow{\mu}+} + \sigma^{\vec{\mu}-} \sim H(x=\xi,\xi,t)$$

$$\sigma^{\overleftarrow{\mu}+} - \sigma^{\vec{\mu}-} \sim \mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi}$$

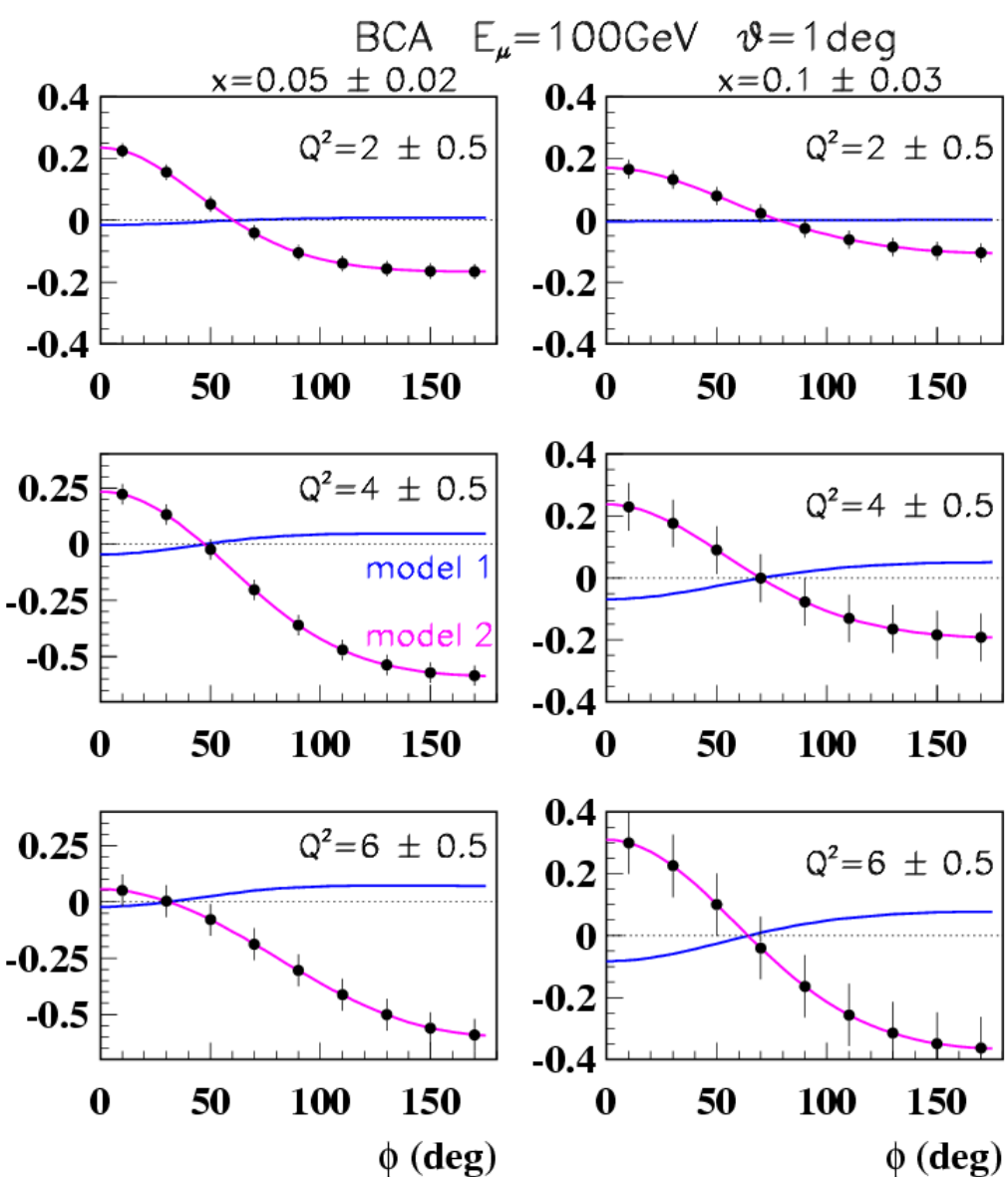
Diehl

COMPASS

6 angular distributions

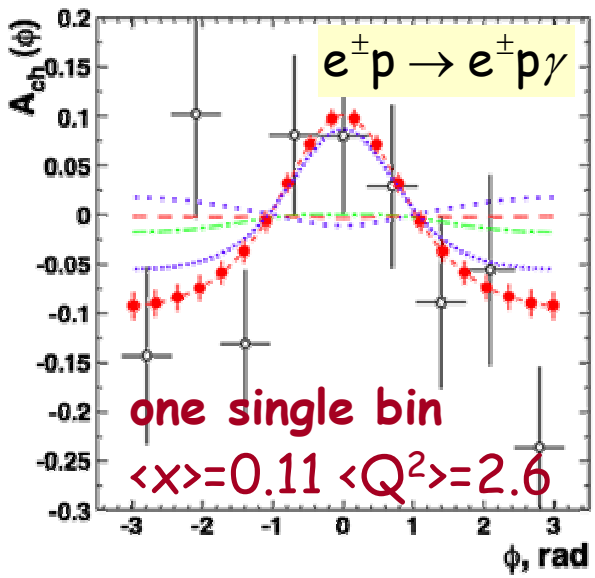
among 18: 3 bins in x_{Bj}=0.05, 0.1, 0.2

6 bins in Q^2 from 2 to 7 GeV^2



BCA in DVCS projections for 1 year

HERMES



if $N\mu \times 5 \Rightarrow Q^2 < 17\ GeV^2$ for DVCS

Benefit of a higher muon intensity for GPDs study

if $N\mu \times 2 \Rightarrow Q^2 < 11\ GeV^2$ for DVCS

Limitation by luminosity

now $N\mu = 2.10^8 \mu$ per SPS spill

for DVCS $\Rightarrow Q^2 < 7.5\ GeV^2$

At fixed x_{Bj}, study in Q^2