Spin effects in exclusive ρ^0 meson production at COMPASS experiment

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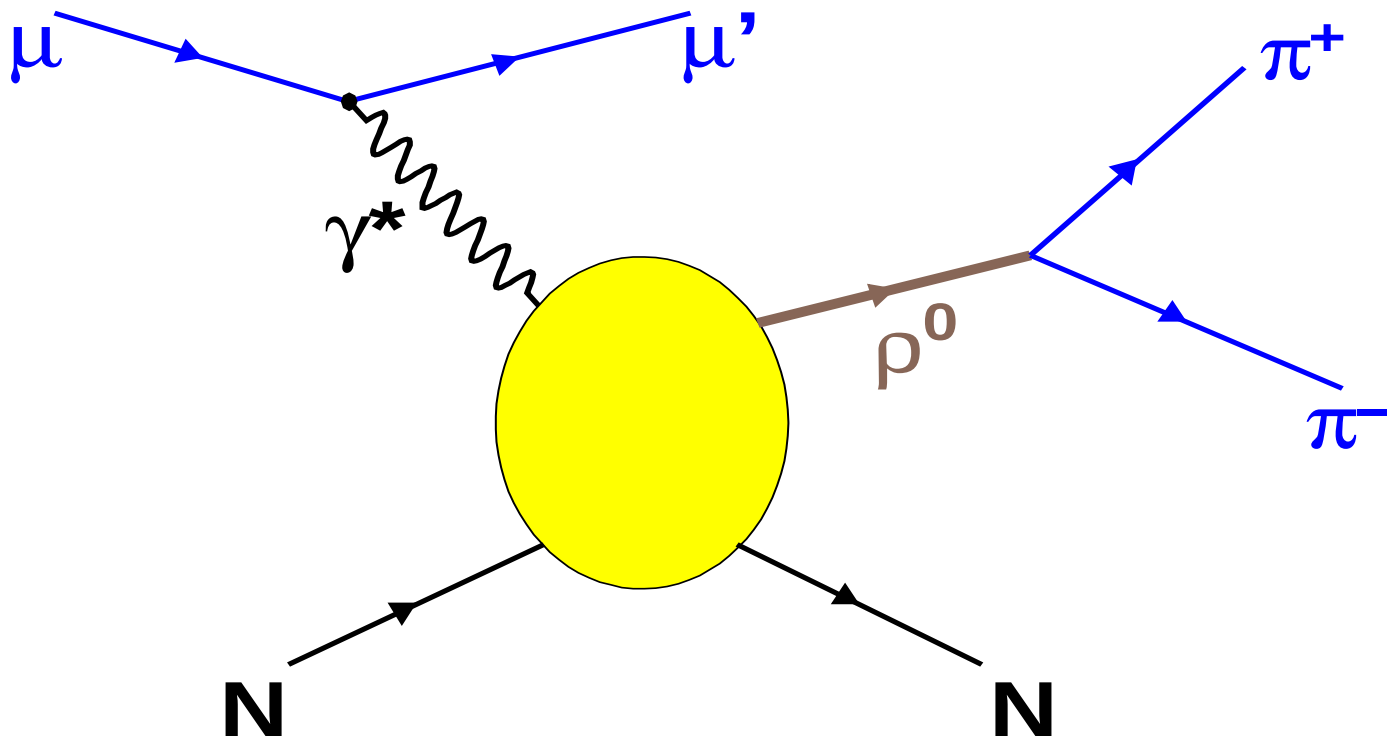
On behalf of the COMPASS Collaboration

Outline:

- process under study at COMPASS
- reaction of exclusive vector meson production
- motivation
- COMPASS experiment & data sample
- results
- summary

Process under study at COMPASS

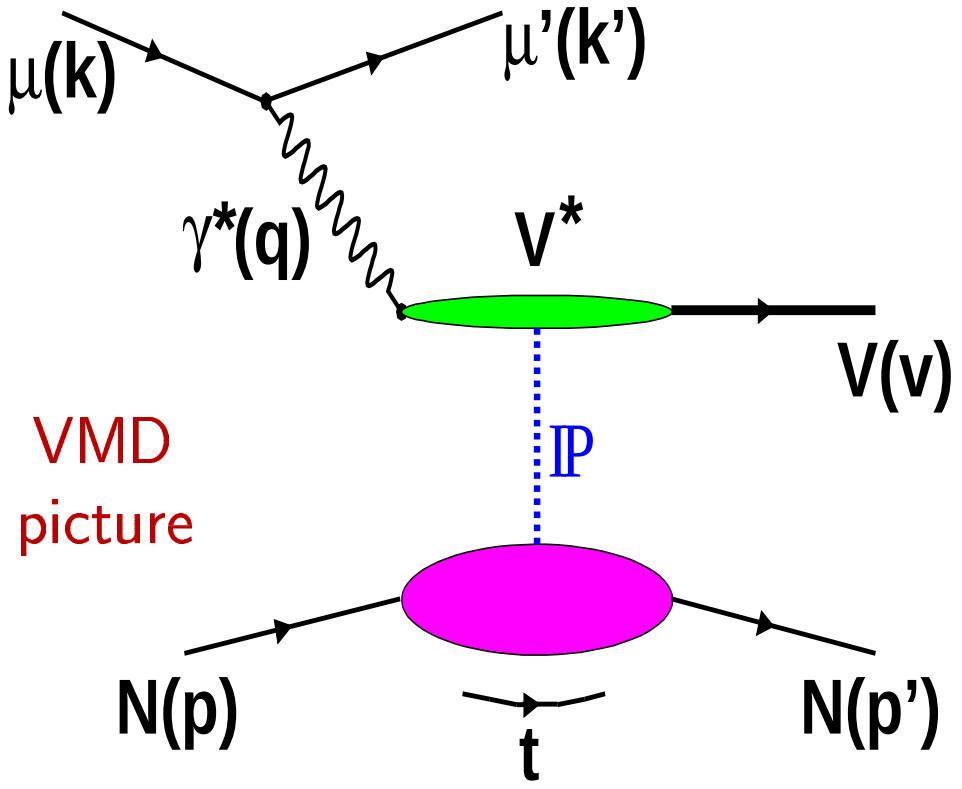
Exclusive *incoherent* production of ρ^0 meson



In blue $\Longrightarrow$ particles (tracks) detected at COMPASS spectrometer

BR($\rho^0 \rightarrow \pi^+\pi^-$) $\approx$ 100%

Reaction of exclusive vector meson production (EVMP)



$$q = k - k'$$

$$Q^2 = -q^2$$

$$v^2 = m_V^2$$

$$W^2 = (q + p)^2$$

$$t = (q - v)^2 = (p - p')^2$$

$$p_t^2 \approx |t - t_{\min}|$$

$m_X^2 = (p + q - v)^2$ — hadronic mass produced in a nucleon vertex

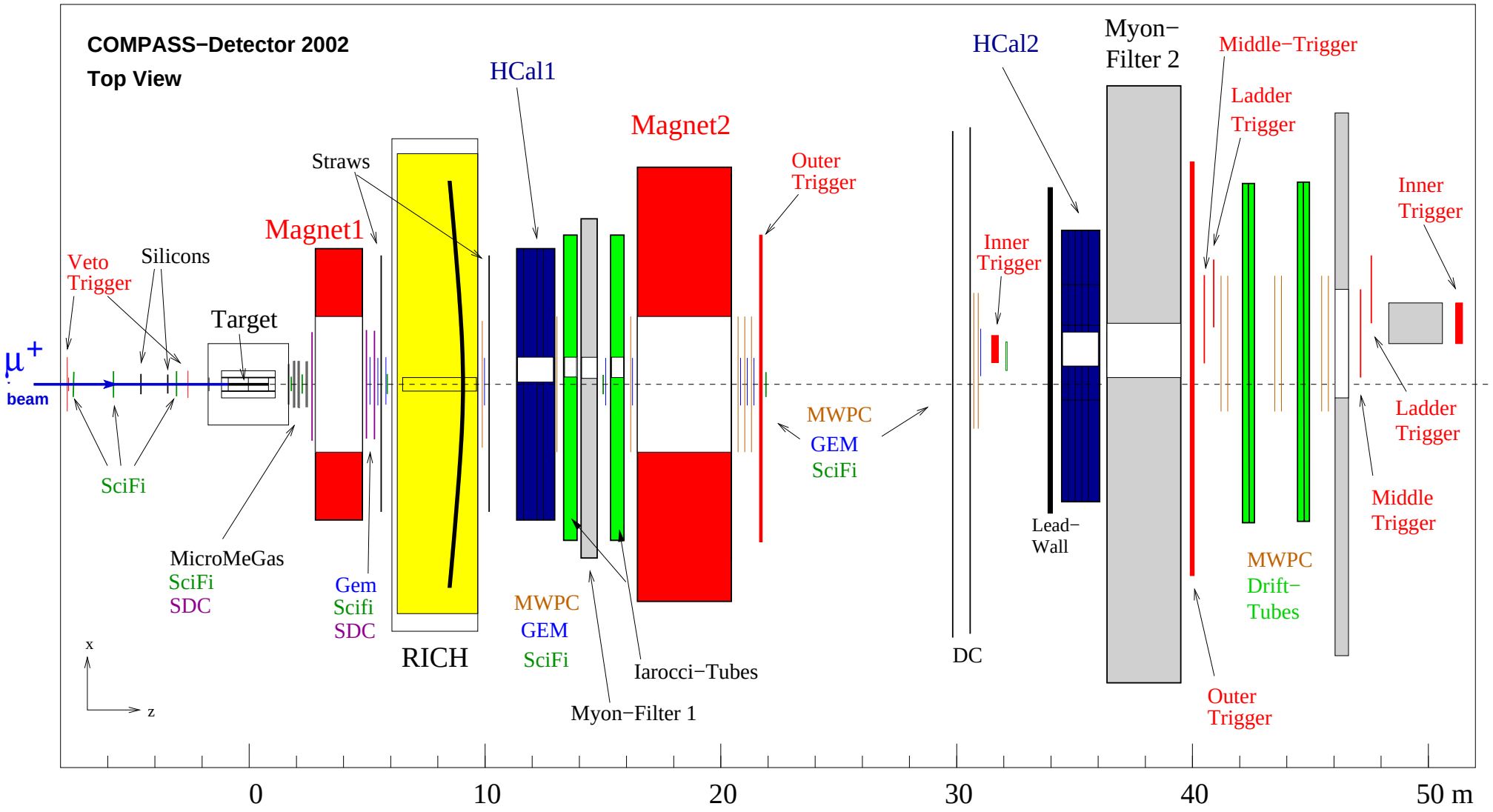
$E_{\text{miss}} = (m_X^2 - m_{\text{N}}^2) / 2\, m_{\text{N}}$ — measure of event's exclusivity

Motivation for studying EVMP (& particularly spin effects)

- probing of hadronic structure of a $virtual\ photon$
- diffractive process $\Longrightarrow$ at large W exchange of the pomeron in a t-channel dominates
  $\Longrightarrow$ studying of its physical nature, couplings etc.
- exclusive process $\Longrightarrow$ access to generalized parton distributions (GPDs)
  (within Q^2 range where pQCD is applicable)
- spin effects in EVMP
  - spin density matrix (SDM) of VM:
    - $helicity$ structure of the reaction $\gamma^* N \to V N$

      $\Longrightarrow$ testing of $s\text{-}channel\ helicity\ conservation$ (SCHC) hypothesis
    - probing of a $parity\ P$ of an object exchanged in t-channel
    - if all 23 elements determined $\Longrightarrow$ $complete$ knowledge of helicity structure of EVMP
  - double spin asymmetries of cross sections $\Longrightarrow$ analysis in progress

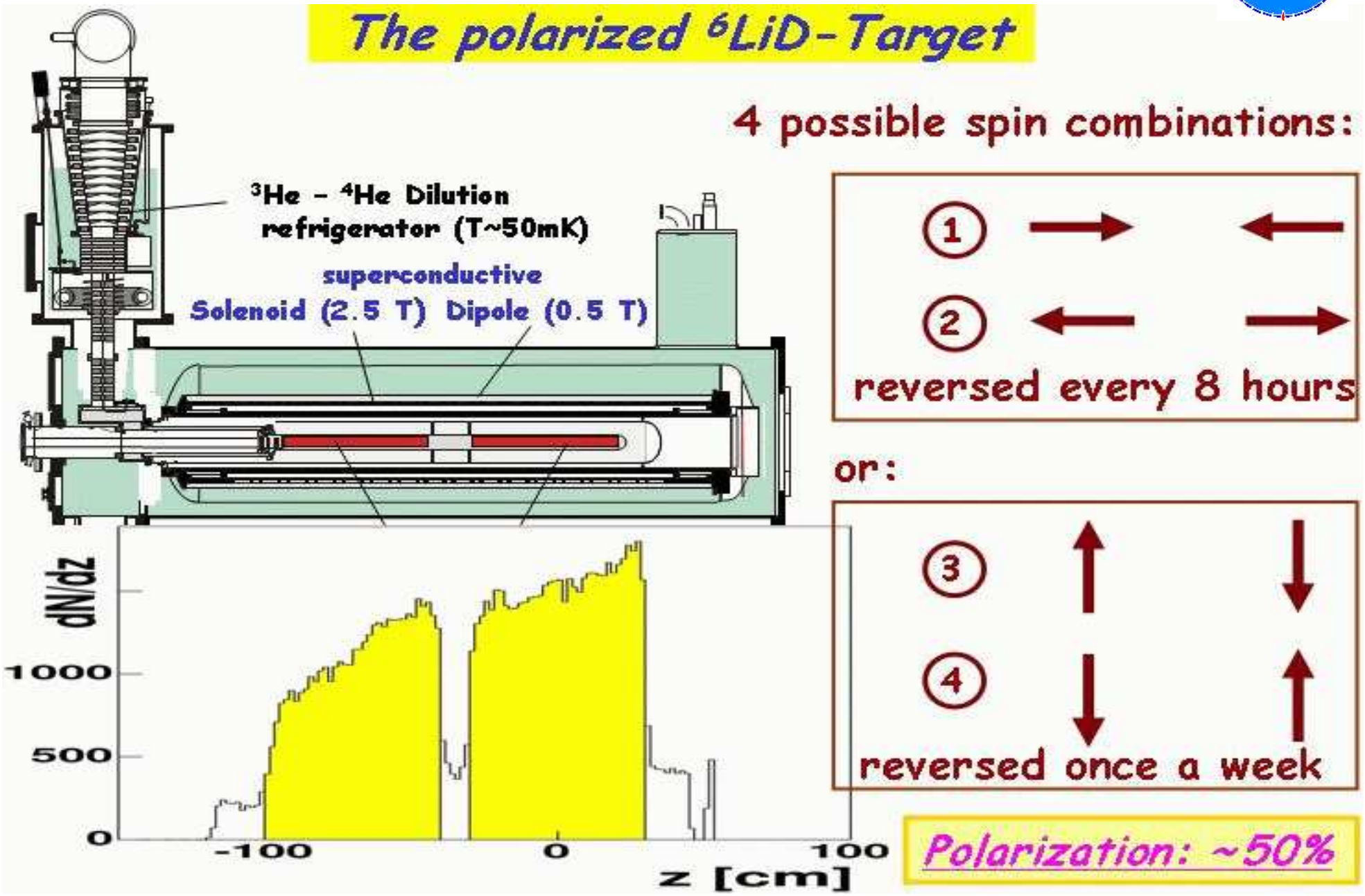
COMPASS experiment at CERN (2002 setup)



Beam $2 \cdot 10^8 \mu^+$/spill (4.8s / 16.2s) **Beam momentum** 160 GeV/c

Luminosity $\sim 5 \cdot 10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ **Beam polarization** −76%

COMPASS — polarized ^{6}LiD target



COMPASS merits for exclusive ρ^0 production

- high beam intensity of 2×10^8 μ/spill & large nuclear target

  $\Longrightarrow$ large luminosity

- coverage of a broad Q^2 range of $\sim 5 \times 10^{-4} \div \sim 10$ GeV^2

  $\Longrightarrow$ possibility to test nonperturbative & pQCD regimes of EVMP as well as a *transition* region

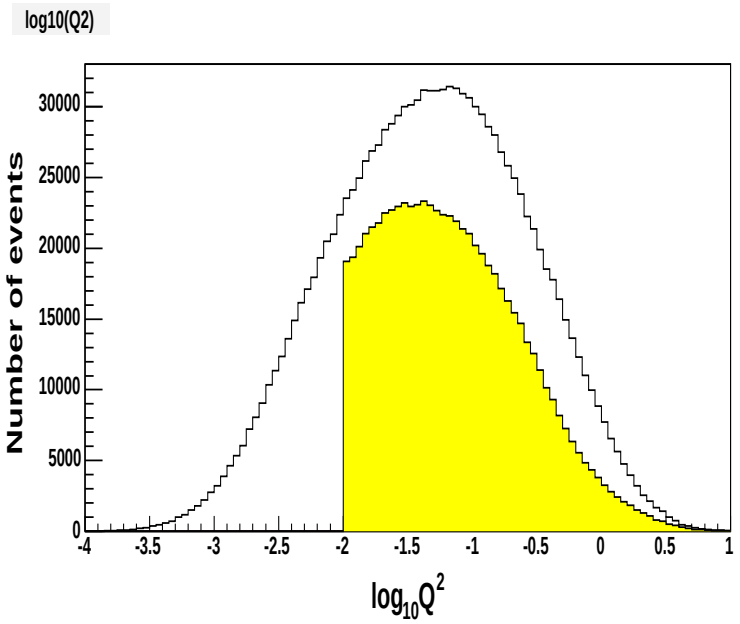
- $\langle W \rangle \approx 10$ GeV $\Longrightarrow$ *pomeron* exchange expected to become dominant

Data sample — selection of exclusive ρ^0 incoherent production events

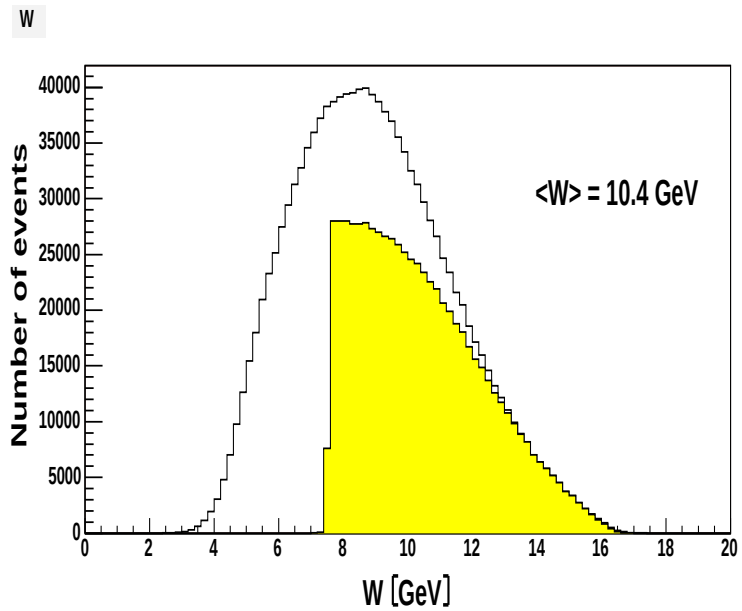
- a primary vertex ($\mu \to \mu'\gamma^*$) within a target must be present
- only events with exactly 3 tracks outgoing from primary vertex selected
- one of 3 tracks has to be μ', remaining 2 have to be hadronic ones of opposite charges
- RICH not used for PID $\Longrightarrow$ $m_{\pi^\pm}$ & $m_{K^\pm}$ mass hypotheses assigned to hadronic tracks $\Longrightarrow$ $m_{\pi\pi}$ & m_{KK} invariant masses determined
- $Q^2 > 0.01$ GeV^2
- $\nu > 30$ GeV $\quad \wedge \quad E_{\mu'} > 20$ GeV
- $0.5 < m_{\pi\pi} < 1$ GeV
- $-2.5 < E_{\rm miss} < 2.5$ GeV
- $0.15 < p_t^2 < 0.5$ GeV^2

COMPASS exclusive ρ^0 data — plots of selected kinematical variables (2002 data)

muonic variables

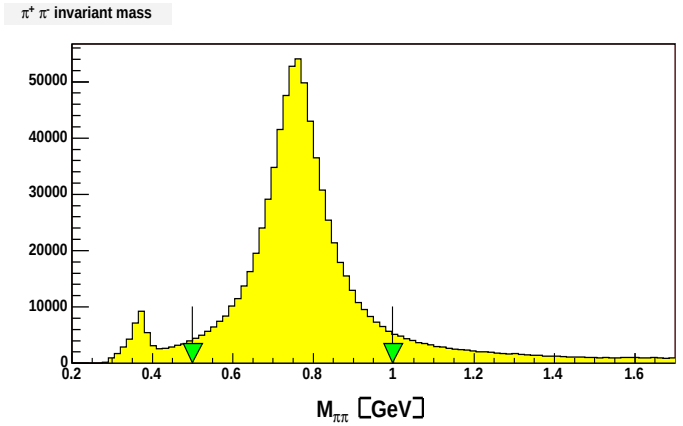


$\log_{10} Q^2$

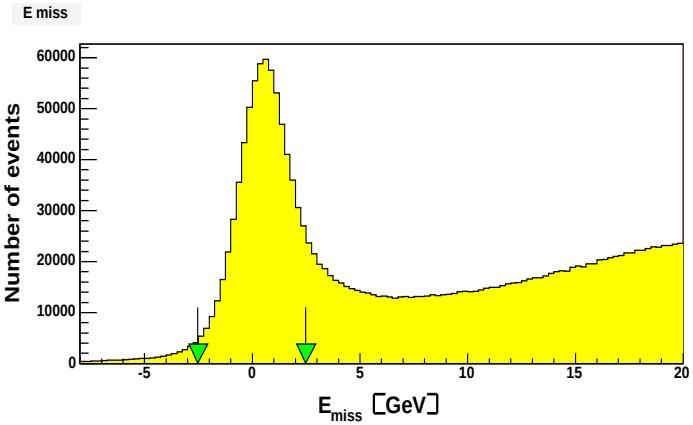


W [GeV]

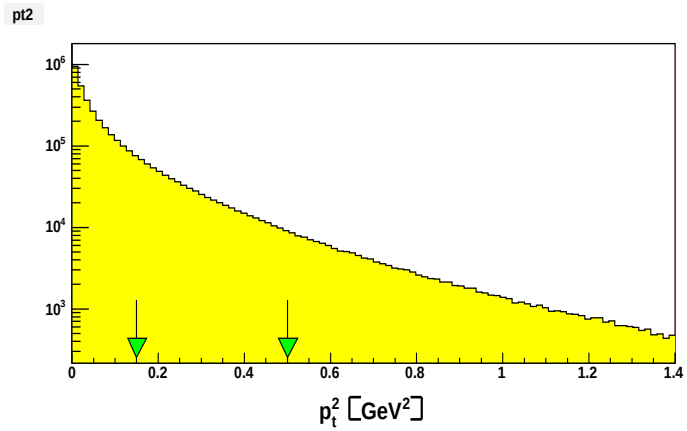
hadronic variables



$m_{\pi\pi}$ [GeV]



E_{miss} [GeV]



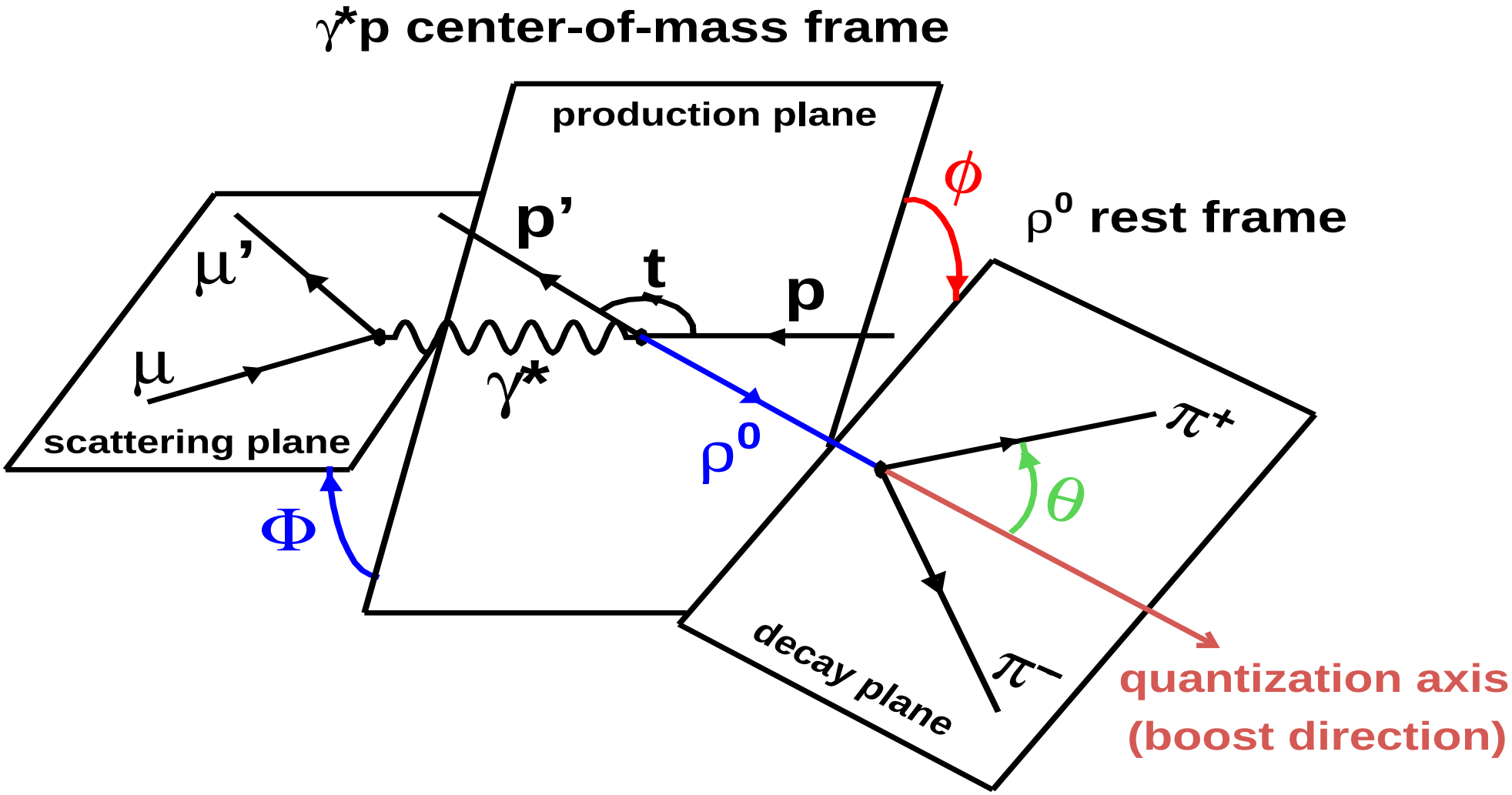
p_t^2 [GeV^2]

COMPASS exclusive ρ^0 sample characteristics

- all 2002 data with *longitudinal* target polarization used
- altogether 696 kevts within *incoherent* sample ($0.15 < p_t^2 < 0.5$ GeV^2)
  (∼3.5 Mevts within $0 < p_t^2 < 0.5$ GeV^2 range)
- $\langle W \rangle = 10.4$ GeV, $\langle p_t^2 \rangle = 0.23$ GeV^2

Bin of Q^2	1	2	3	4	5
Q^2 range [GeV^2]	0.01 ÷ 0.05	0.05 ÷ 0.3	0.3 ÷ 0.6	0.6 ÷ 2.0	$>$ 2.0
No. of kevts	306	293	56	35	6
$\langle Q^2 \rangle$ [GeV^2]	0.025	0.128	0.416	1.01	3.30

Angles Φ, θ, ϕ of exclusive production & decay of ρ^0 meson



$W(\cos\theta,\ \phi,\ \Phi)$ $\Longleftrightarrow$ SDM elements $\Longleftrightarrow$ helicity structure of VM production amplitudes

If SCHC holds: $\psi = \phi - \Phi$ $\Longrightarrow$ $W(\cos\theta,\ \phi,\ \Phi) \Rightarrow W(\cos\theta,\ \psi)$

s-channel helicity conservation (SCHC) hypothesis

VM retains helicity of a parent photon in s-channel helicity frame:

$$\gamma^*_L \quad \Longrightarrow \quad V_L$$

$$\gamma^*_T \quad \Longrightarrow \quad V_T$$

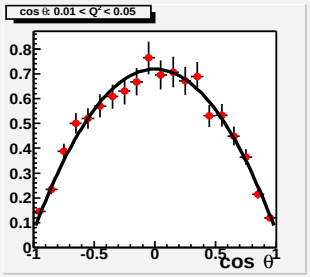
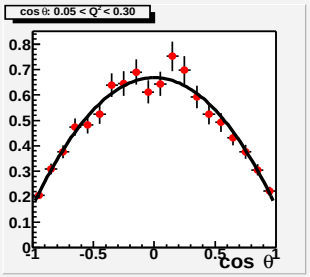
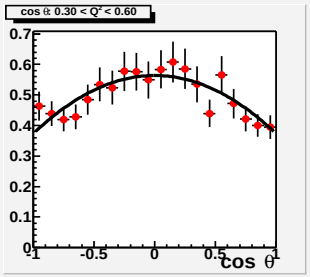
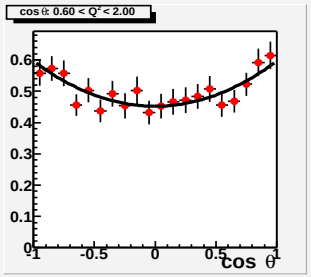
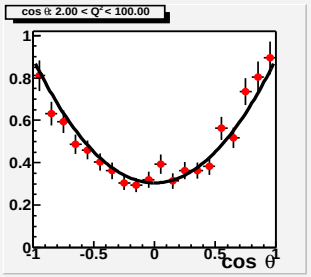
$$\gamma^*_L \quad \not\Longrightarrow \quad V_T$$

$$\gamma^*_T \quad \not\Longrightarrow \quad V_L$$

COMPASS — 1d angular distributions $W(\cos\theta)$, $W(\phi)$, $W(\Phi)$, $W(\psi)$ (2002 data)

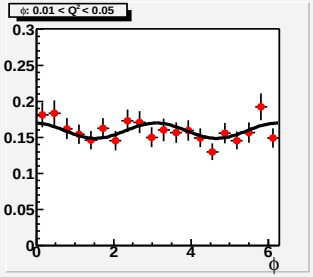
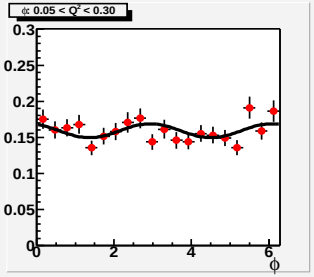
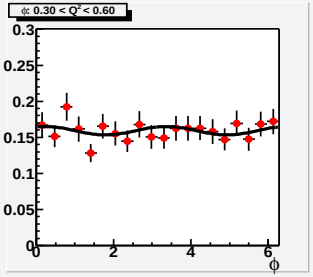
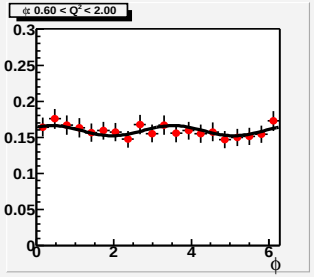
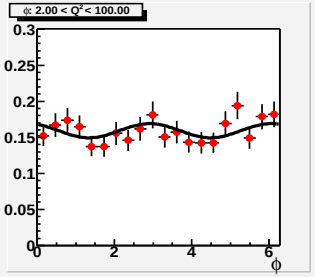
0.01 < Q^2 < 0.05 < Q^2 < 0.3 < Q^2 < 0.6 < Q^2 < 2.0 < Q^2

cos θ

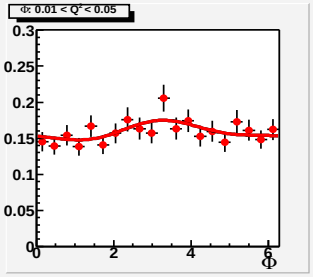
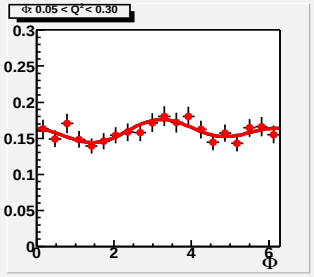
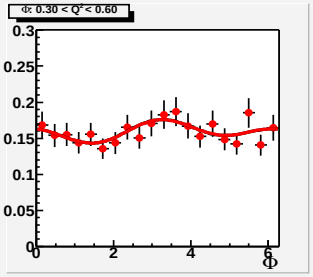
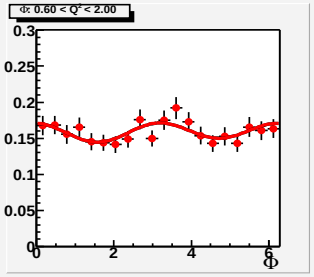
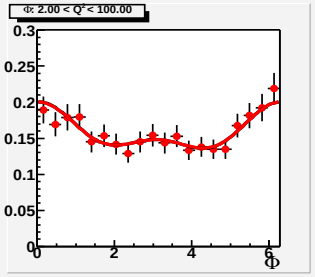
$\Rightarrow r^{04}_{00}$

ϕ

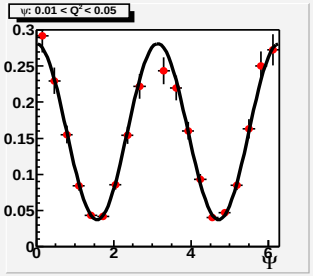
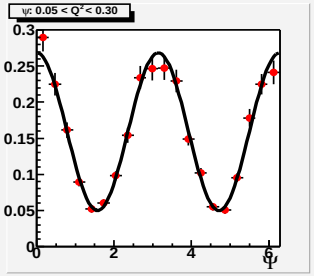
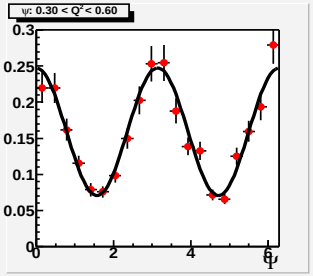
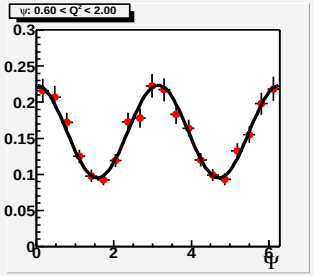
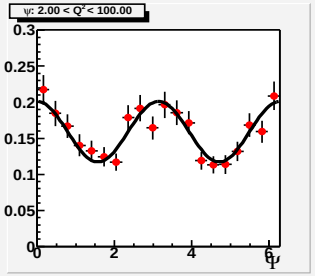






$\Rightarrow r^{04}_{1-1}$, $\mathrm{Im}\, r^{3}_{1-1}$

Φ

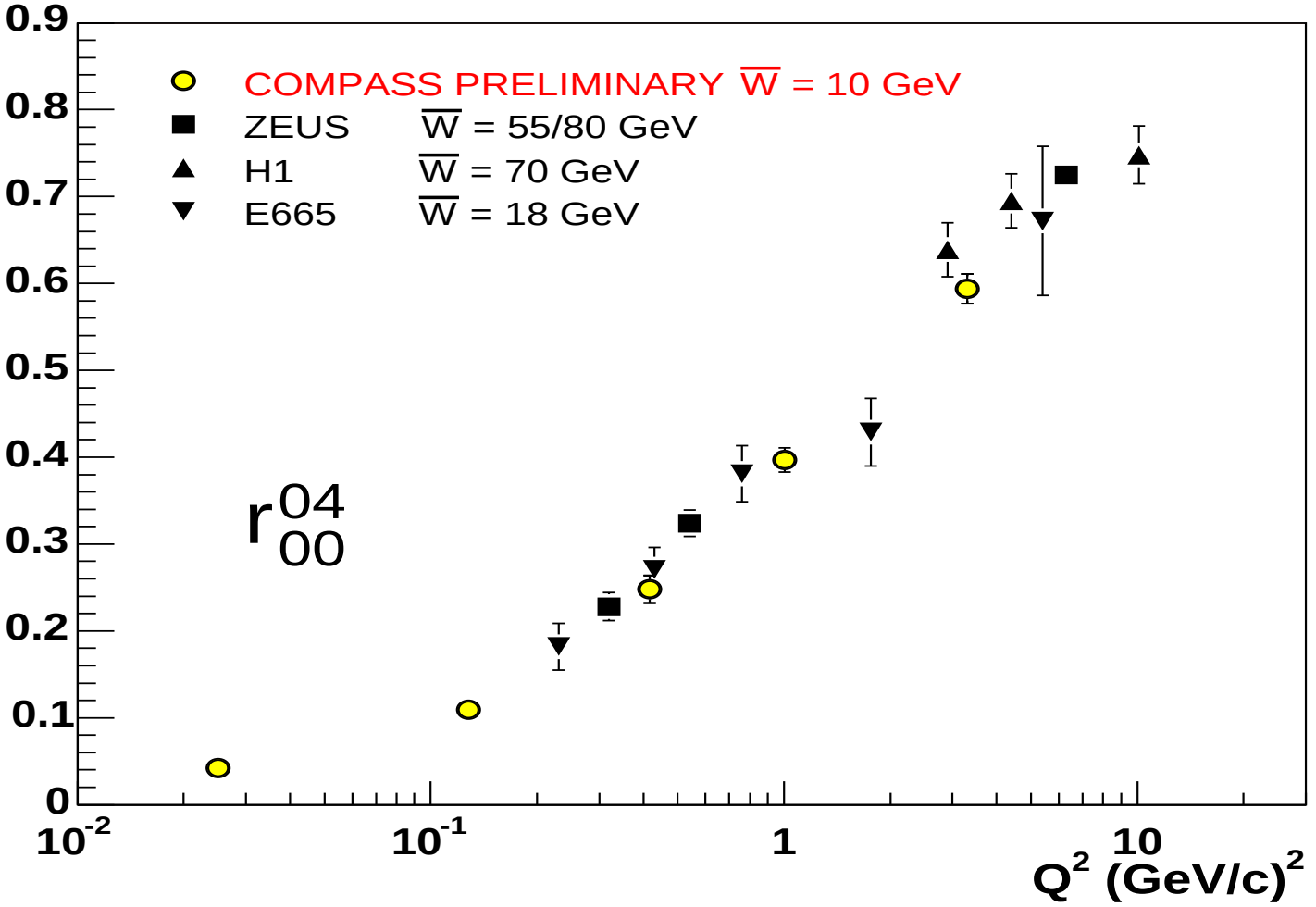
ψ

$\Rightarrow r^{1}_{1-1}$

COMPASS — spin density matrix element r_{00}^{04} for ρ^0 meson

(2002 data)



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

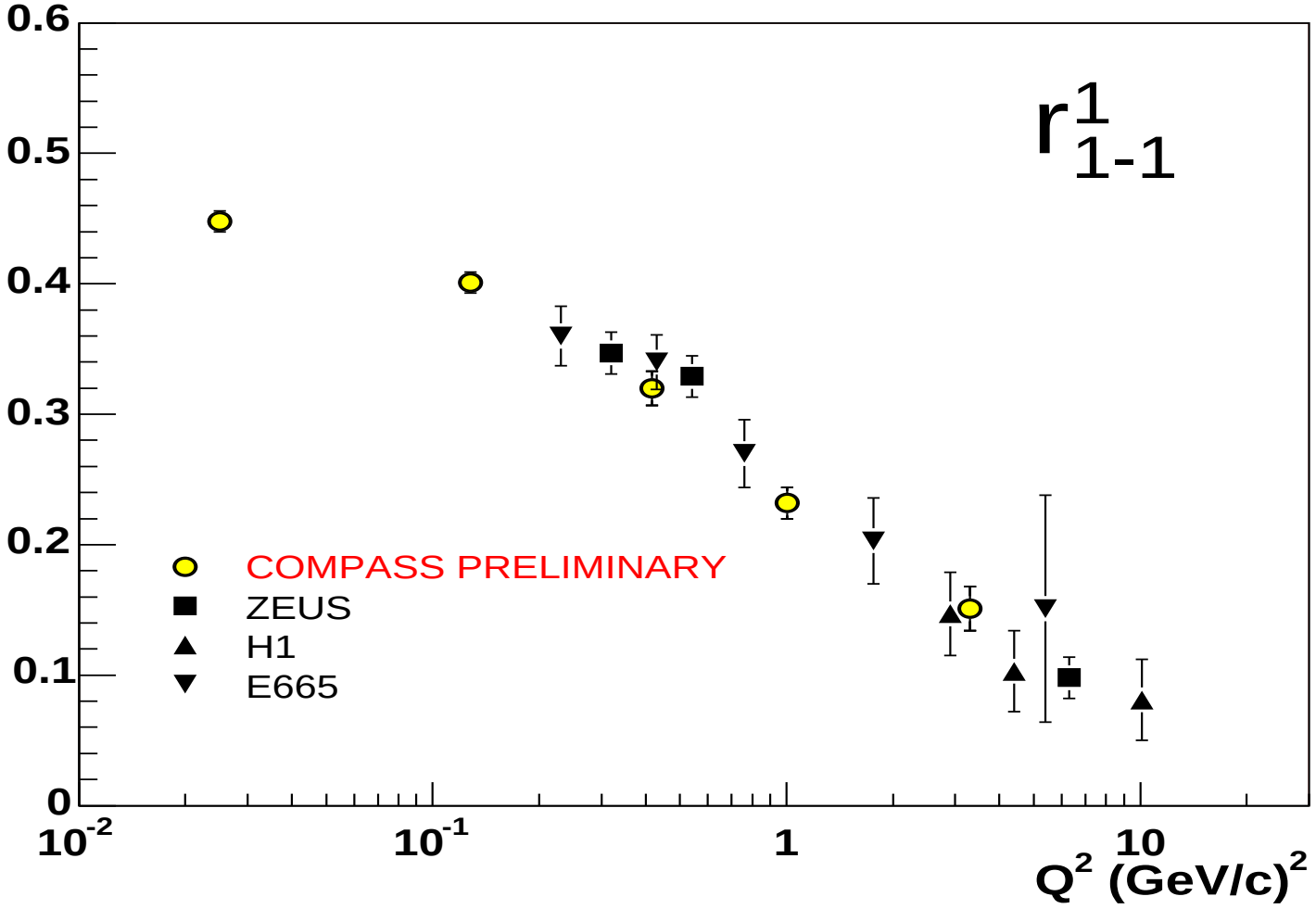
$$r_{00}^{04} = \frac{|T_{01}|^2 + a\,|T_{00}|^2}{N_T\,(1 + aR)}\,,$$

where: $R = \sigma_L/\sigma_T$, $a \equiv \epsilon + \delta = \Gamma_L/\Gamma_T$,

$$N_T = |T_{11}|^2 + |T_{-11}|^2 + |T_{01}|^2 \propto \sigma_T$$

COMPASS — spin density matrix element $r^1_{1\,-1}$ for ρ^0 meson

(2002 data)



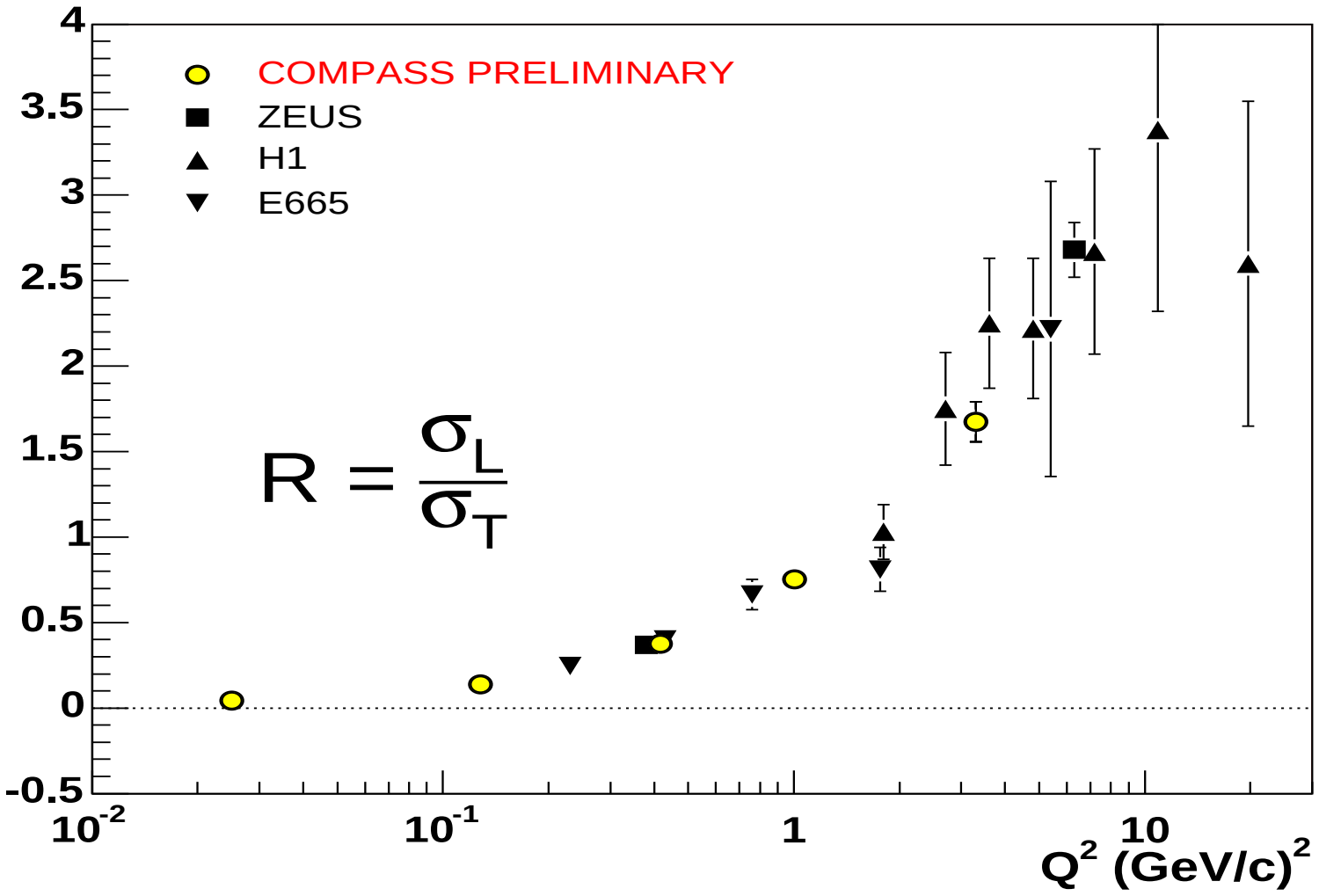
if SCHC holds & object with natural P ($P = (-1)^L$) exchanged in t-channel $\Longrightarrow$

$$W(\psi) = \frac{1}{2\pi}(1 + 2\,\epsilon\, r^1_{1\,-1} \cos 2\psi)$$

COMPASS — determination of $R = \sigma_L/\sigma_T$

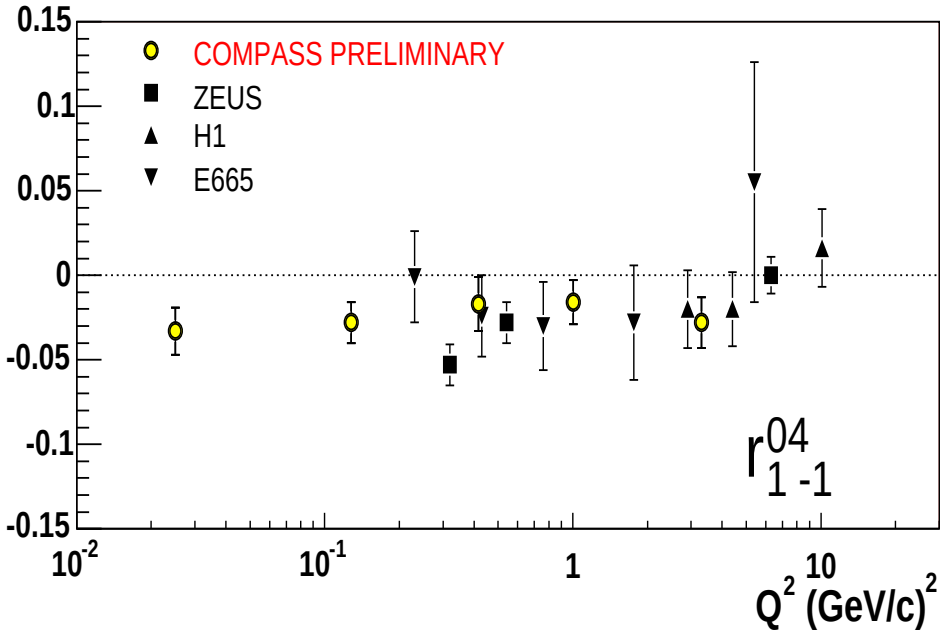
(2002 data)

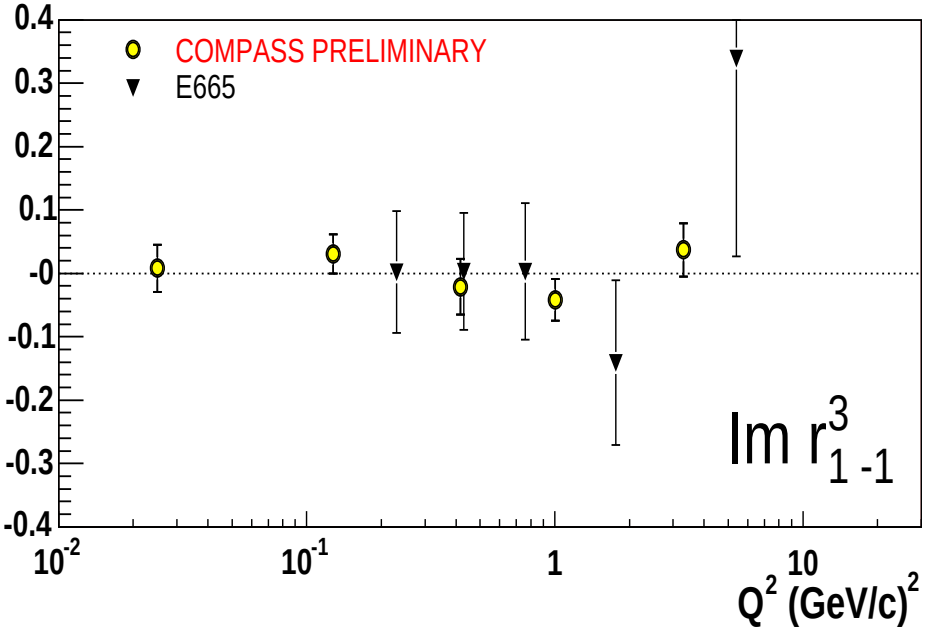
if SCHC holds $\Longrightarrow$ $R = r_{00}^{04} \,/\, [\,(1 - r_{00}^{04})\,(\epsilon + \delta)\,]$



where: $\epsilon + \delta = \Gamma_L/\Gamma_T\,,\quad \delta = 2\,m_l^2\,Q^{-2}\,(1-\epsilon)$ — lepton mass correction parameter

COMPASS — spin density matrix elements $r^{04}_{1\,-1}$ & Im $r^{3}_{1\,-1}$ for ρ^0 meson (2002 data)





if SCHC holds $\Longrightarrow$ $r^{04}_{1\,-1} = 0$

Im $r^{3}_{1\,-1} = 0$

Im $r^{3}_{1\,-1}$ available only when beam leptons polarized

Violation of SCHC for $r^{04}_{1\,-1}$ observed at COMPASS ?

Summary

- preliminary results for SDM elements r^{04}_{00}, $r^{1}_{1\,-1}$, $r^{04}_{1\,-1}$ & Im $r^{3}_{1\,-1}$ & $R = \sigma_L/\sigma_T$ from COMPASS 2002 data in a wide range $0.01 < Q^2 < 10$ GeV^2 & at $\langle W \rangle \approx 10$ GeV obtained
- good agreement with other experiments (ZEUS, H1, E665), but with significantly better statistical accuracy
- results corrected for acceptance, smearing & efficiency of reconstruction; background not subtracted yet
- observation of SCHC violation for $r^{04}_{1\,-1}$ SDM element ? (vide ZEUS)
- possible changes of results due to expected bkg corrections should be comparable or smaller than present statistical errors
- similar analysis with 2003 & 2004 data planned ($\sim 5\times$ more events)