

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



Cracow Epiphany Conference on Hadron Spectroscopy
Cracow, 6–8 January 2005

Oleg A. Grajek

HEP Division, SINS, Warsaw

On behalf of the COMPASS Collaboration

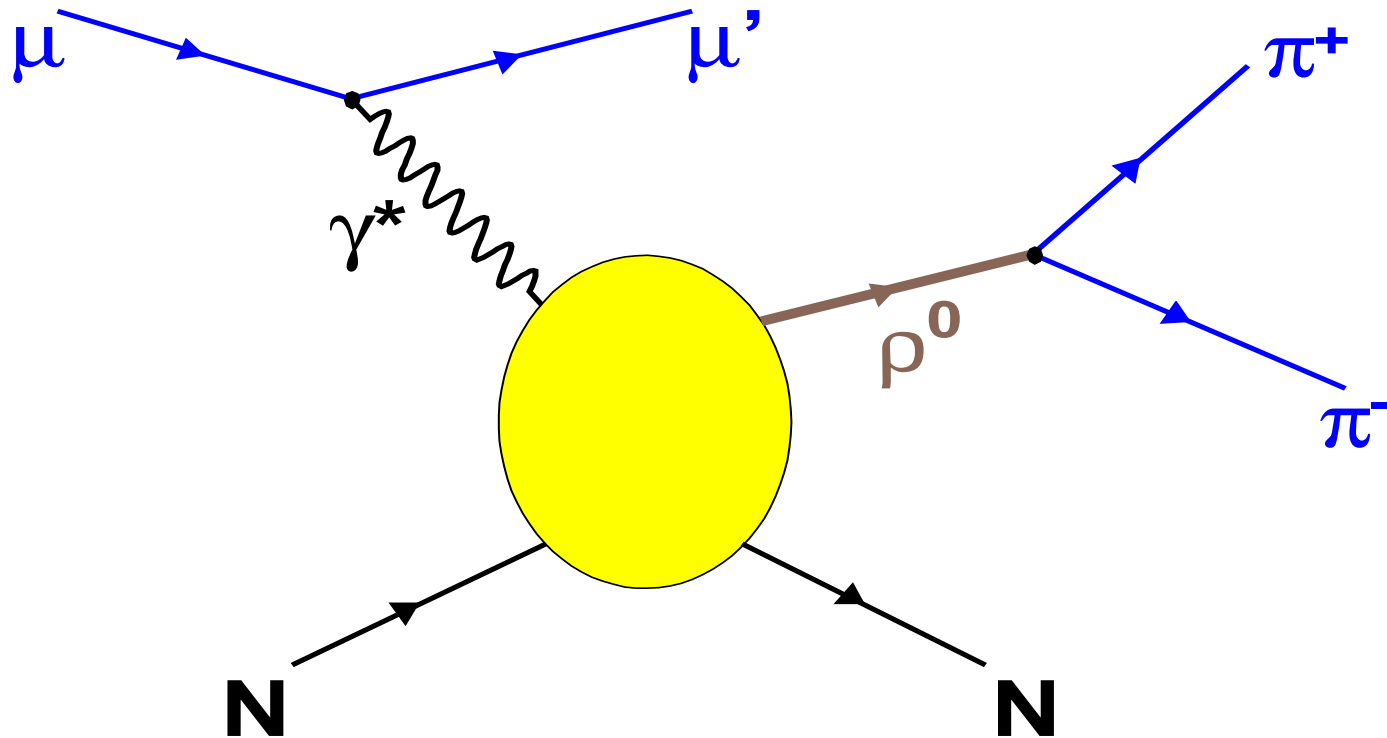
Outline:

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



Process under study at COMPASS

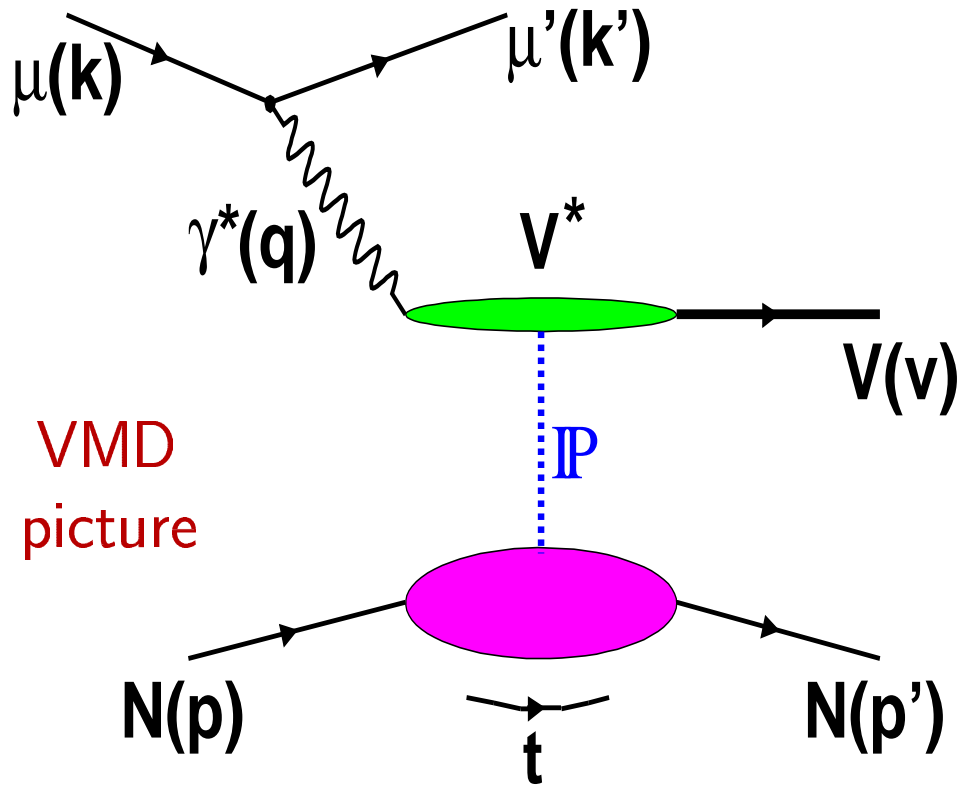
Exclusive *incoherent* production of ρ^0 meson



In blue \implies particles (tracks) **detected** at COMPASS spectrometer

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

Reaction of exclusive vector meson production (EVMP)



VMD
picture

$$q = k - k'$$

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

$$v^2 = m_V^2$$

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

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

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

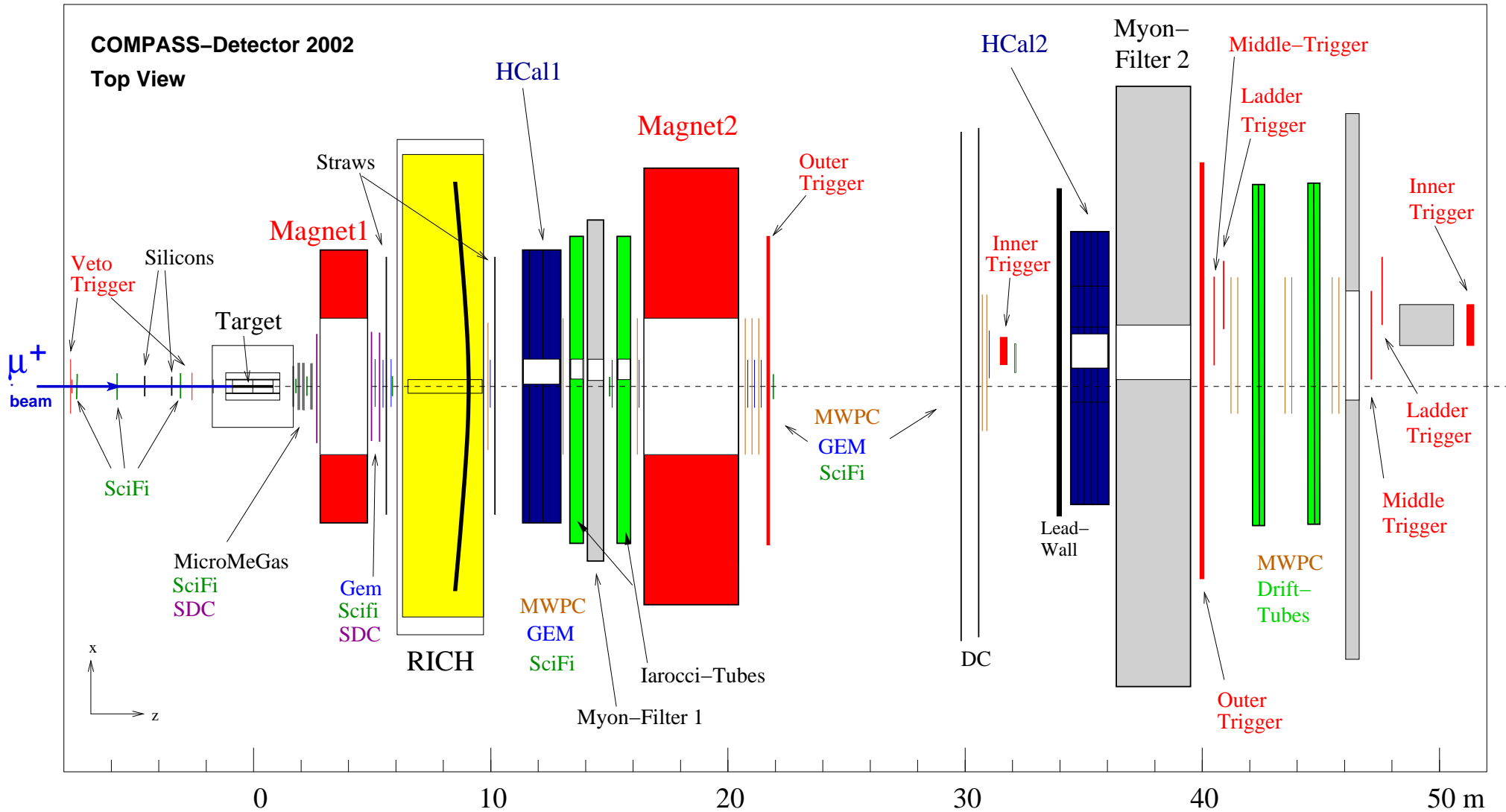
$$m_X^2 = (p + q - v)^2 \quad \text{— hadronic mass produced in a nucleon vertex}$$

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

Motivation for studying EVMP (& particularly spin effects)

- probing of hadronic structure of a *virtual photon*
- **diffractive** process \implies at large W exchange of the **pomeron** in a t -channel dominates \implies studying of its physical nature, couplings etc.
- **exclusive** process \implies 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 $\gamma^* N \rightarrow V N$
 \implies testing of *s-channel helicity conservation* (SCHC) hypothesis
 - probing of a *parity* P of an object exchanged in t -channel
 - if all **23** elements determined \implies *complete* knowledge of helicity structure of EVMP
 - **double spin asymmetries** of cross sections \implies analysis in progress

COMPASS experiment at CERN (2002 setup)

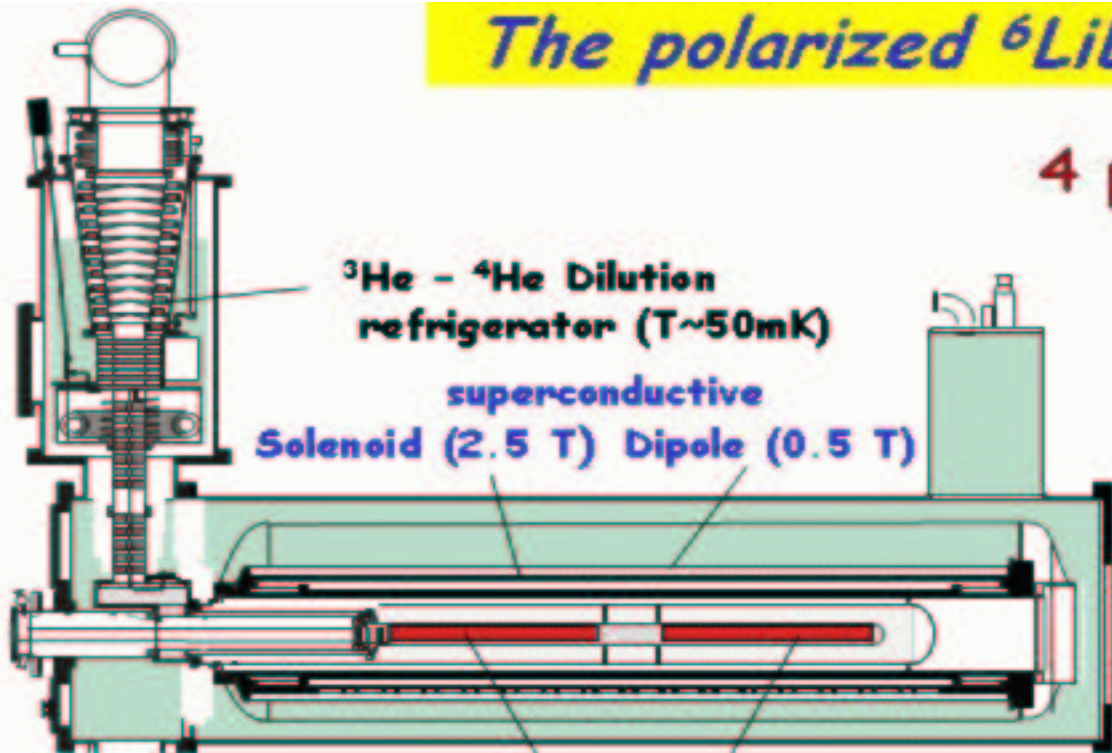


Beam	$2 \cdot 10^8 \mu^+/\text{spill}$ (4.8s / 16.2s)	Beam momentum	160 GeV/c
Luminosity	$\sim 5 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$	Beam polarization	-76%

COMPASS — polarized ${}^6\text{LiD}$ target



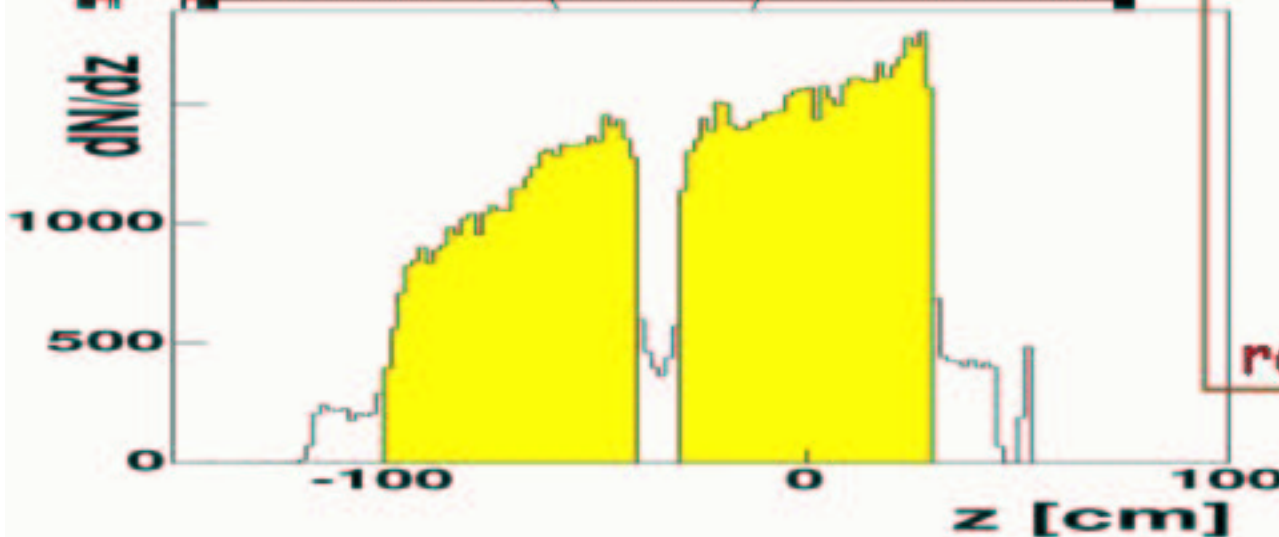
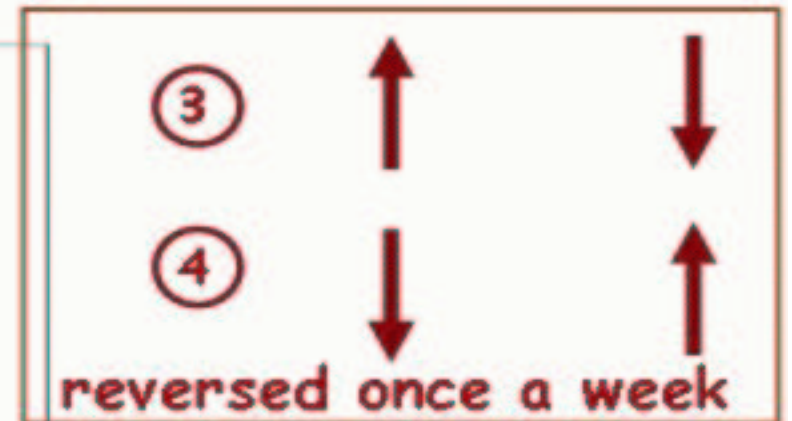
The polarized ${}^6\text{LiD}$ -Target



4 possible spin combinations:



or:



Polarization: ~50%

COMPASS merits for exclusive ρ^0 production

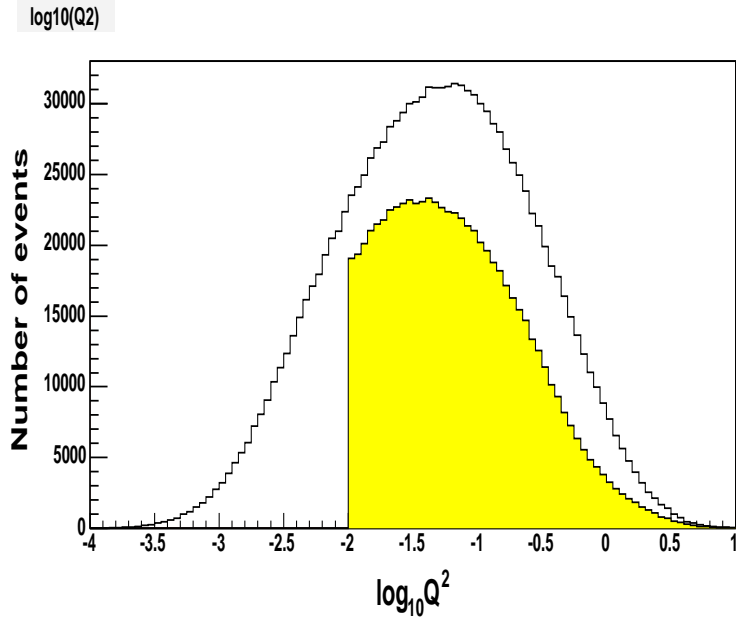
- high beam intensity of 2×10^8 μ /spill & large nuclear target
 \implies large luminosity
- coverage of a broad Q^2 range of $\sim 5 \times 10^{-4} \div \sim 10$ GeV^2
 \implies possibility to test nonperturbative & pQCD regimes of EVMP
as well as a *transition* region
- $\langle W \rangle \approx 10$ GeV \implies *pomeron* exchange expected to become dominant

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

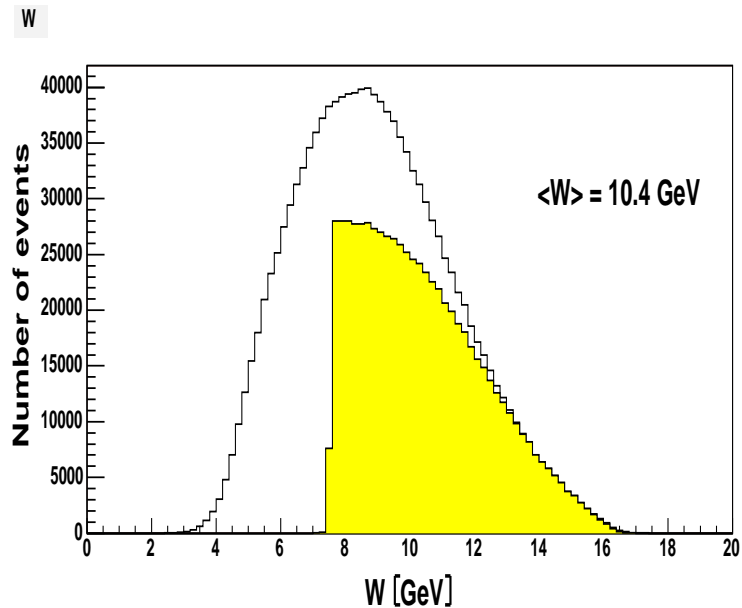
- a primary vertex ($\mu \rightarrow \mu' \gamma^*$) within a target must be present
- only events with exactly 3 tracks outgoing from primary vertex selected
- one of 3 tracks has to be μ' , remaining 2 have to be hadronic ones of opposite charges
- RICH not used for PID $\implies m_{\pi^\pm}$ & m_{K^\pm}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

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

muonic variables

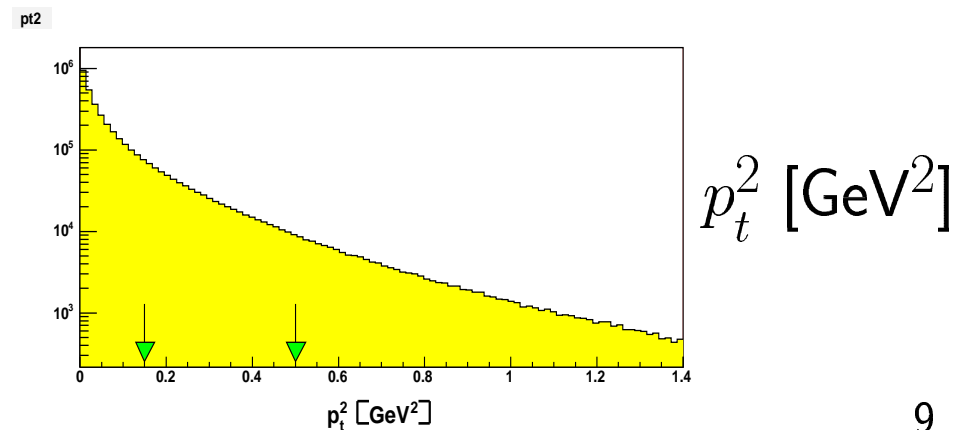
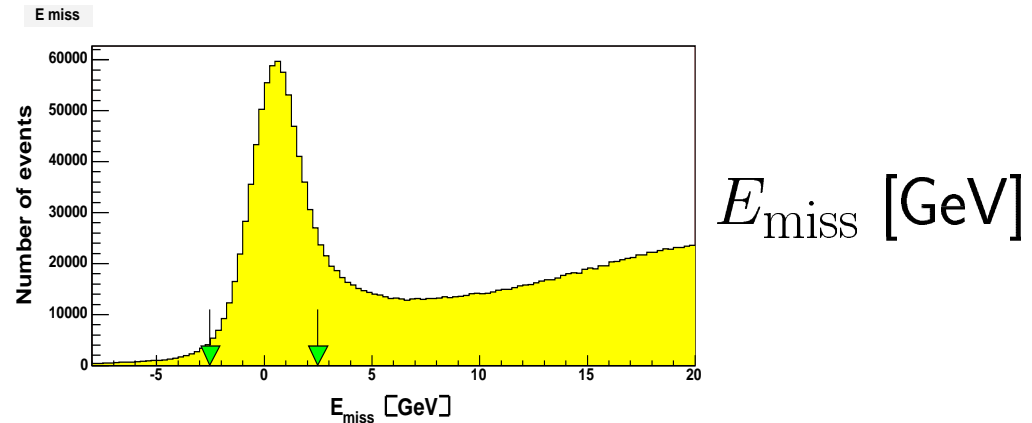
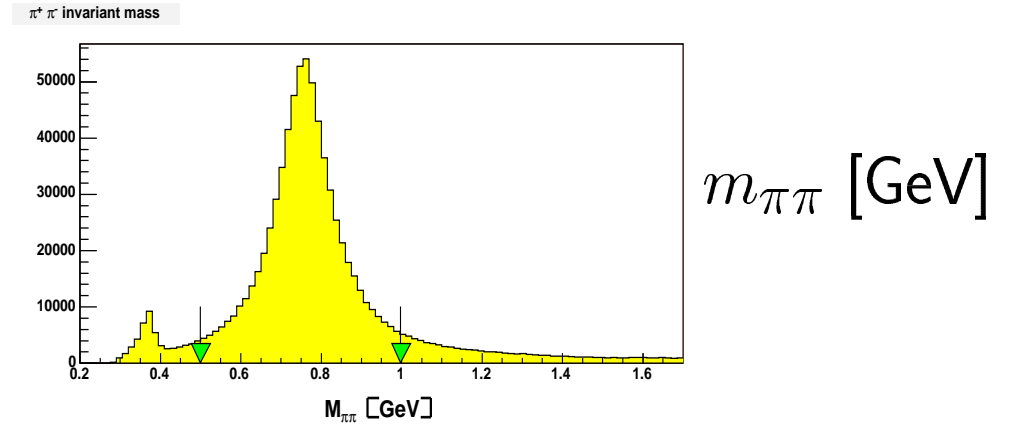


log₁₀ Q²



W [GeV]

hadronic variables



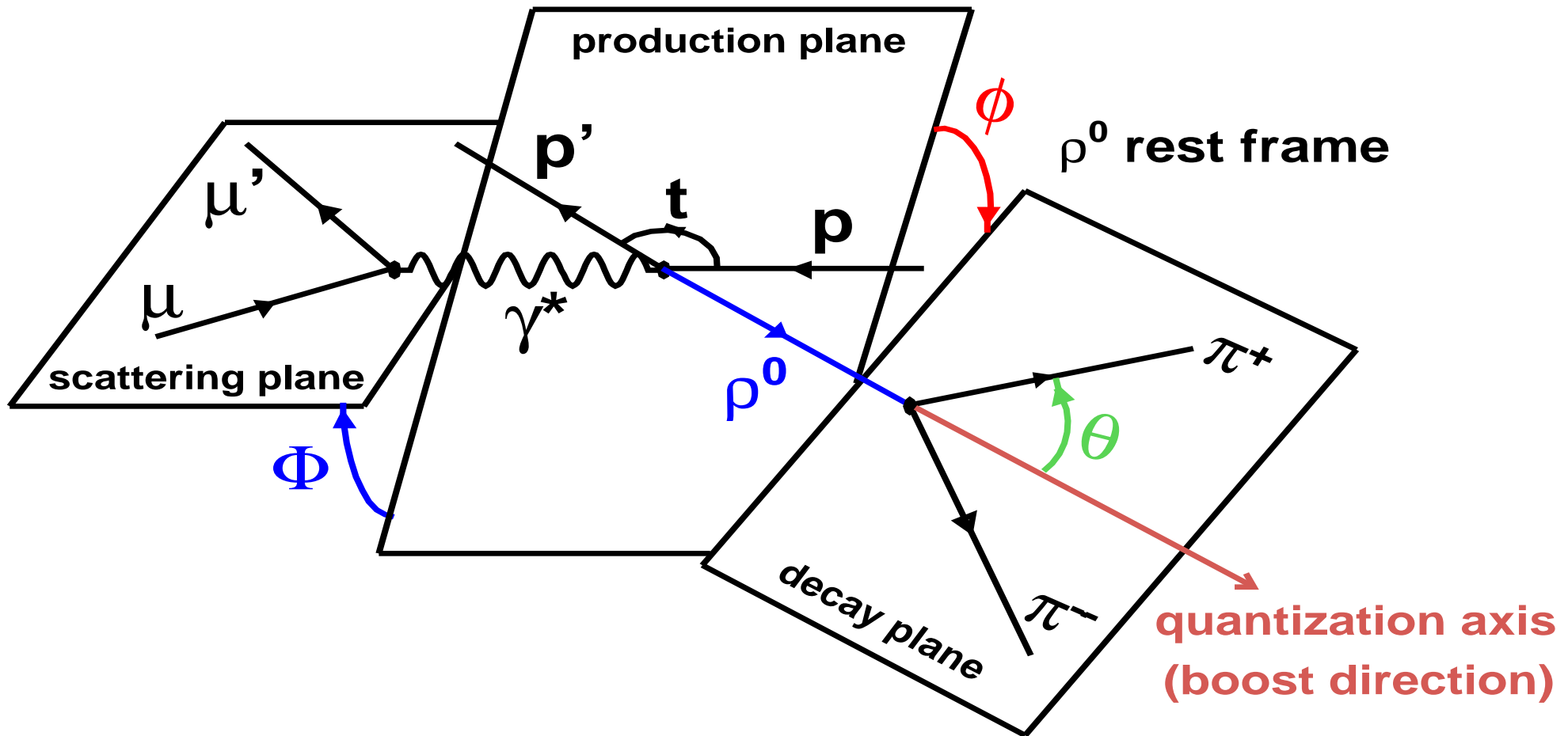
COMPASS exclusive ρ^0 sample characteristics

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

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

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

$\gamma^* p$ center-of-mass frame



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

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

s -channel helicity conservation (SCHC) hypothesis

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

$$\gamma_L^* \implies V_L$$

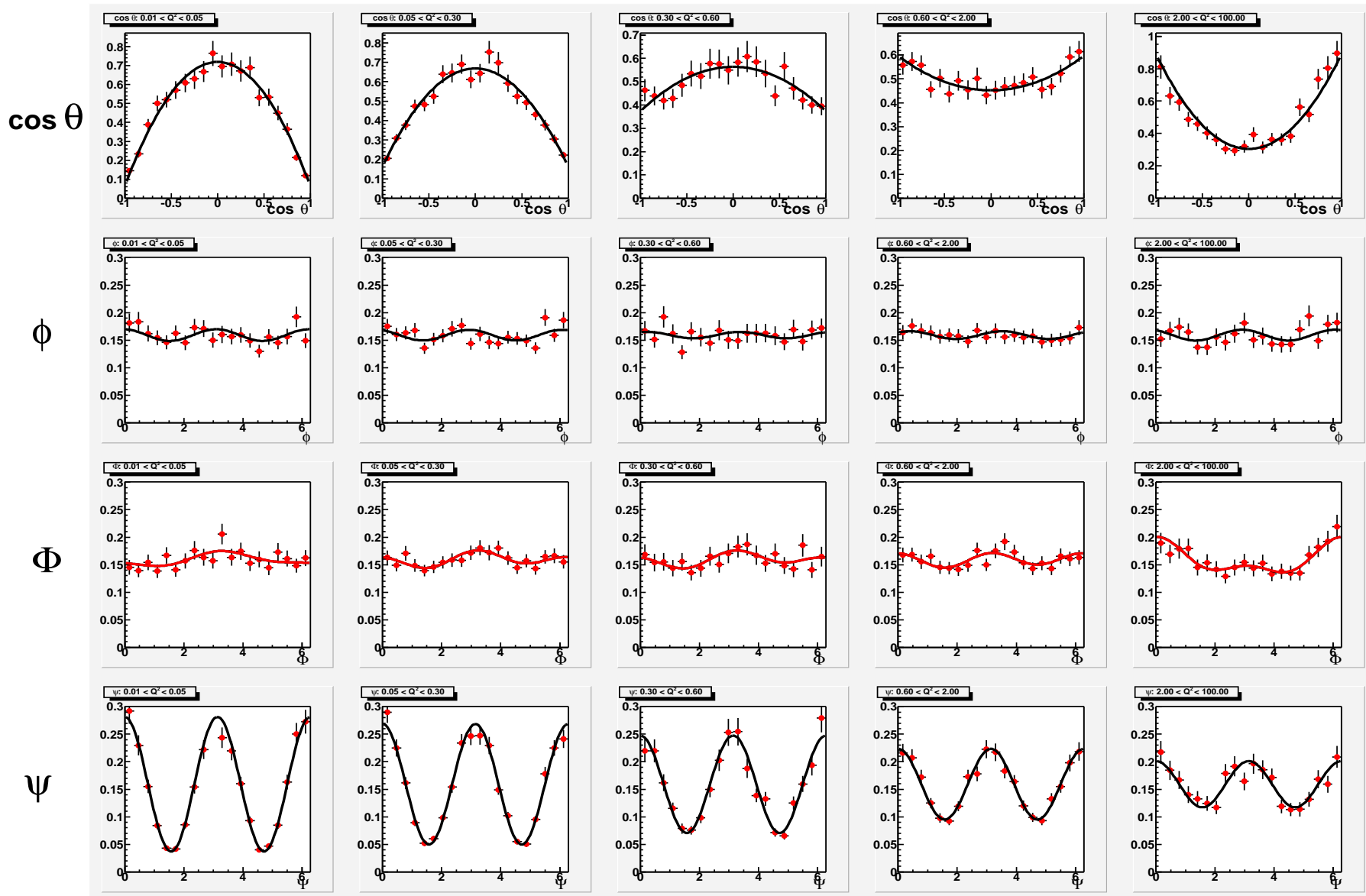
$$\gamma_T^* \implies V_T$$

~~$$\gamma_L^* \implies V_T$$~~

~~$$\gamma_T^* \implies V_L$$~~

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

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

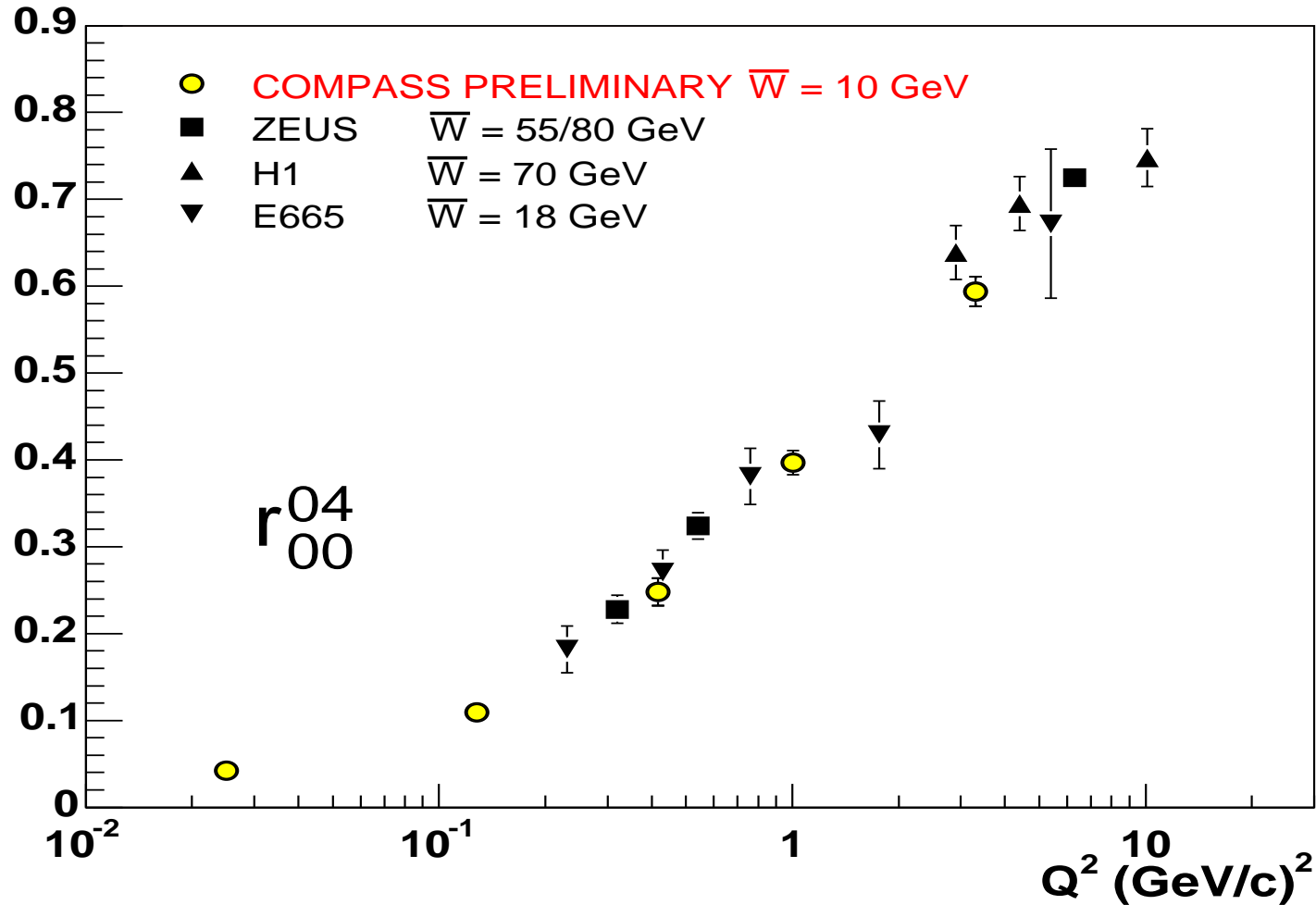


$$\Rightarrow r_{00}^{04}$$

$$\Rightarrow r_{1-1}^{04}, \text{Im } r_{1-1}^3$$

$$\Rightarrow r_{1-1}^1$$

COMPASS — spin density matrix element r_{00}^{04} for ρ^0 meson (2002 data)



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

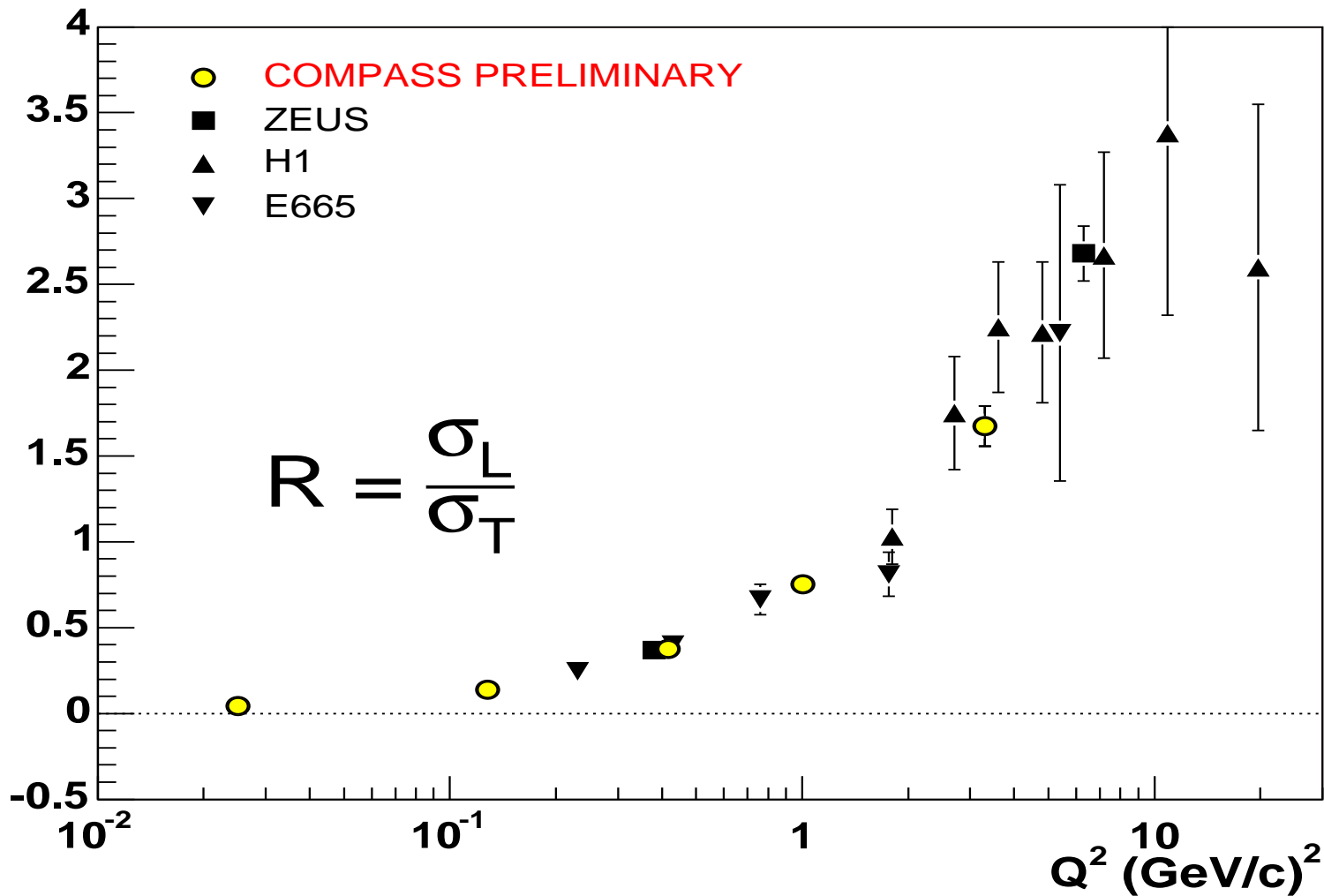
$$r_{00}^{04} = \frac{|T_{01}|^2 + a |T_{00}|^2}{N_T (1 + aR)},$$

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

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

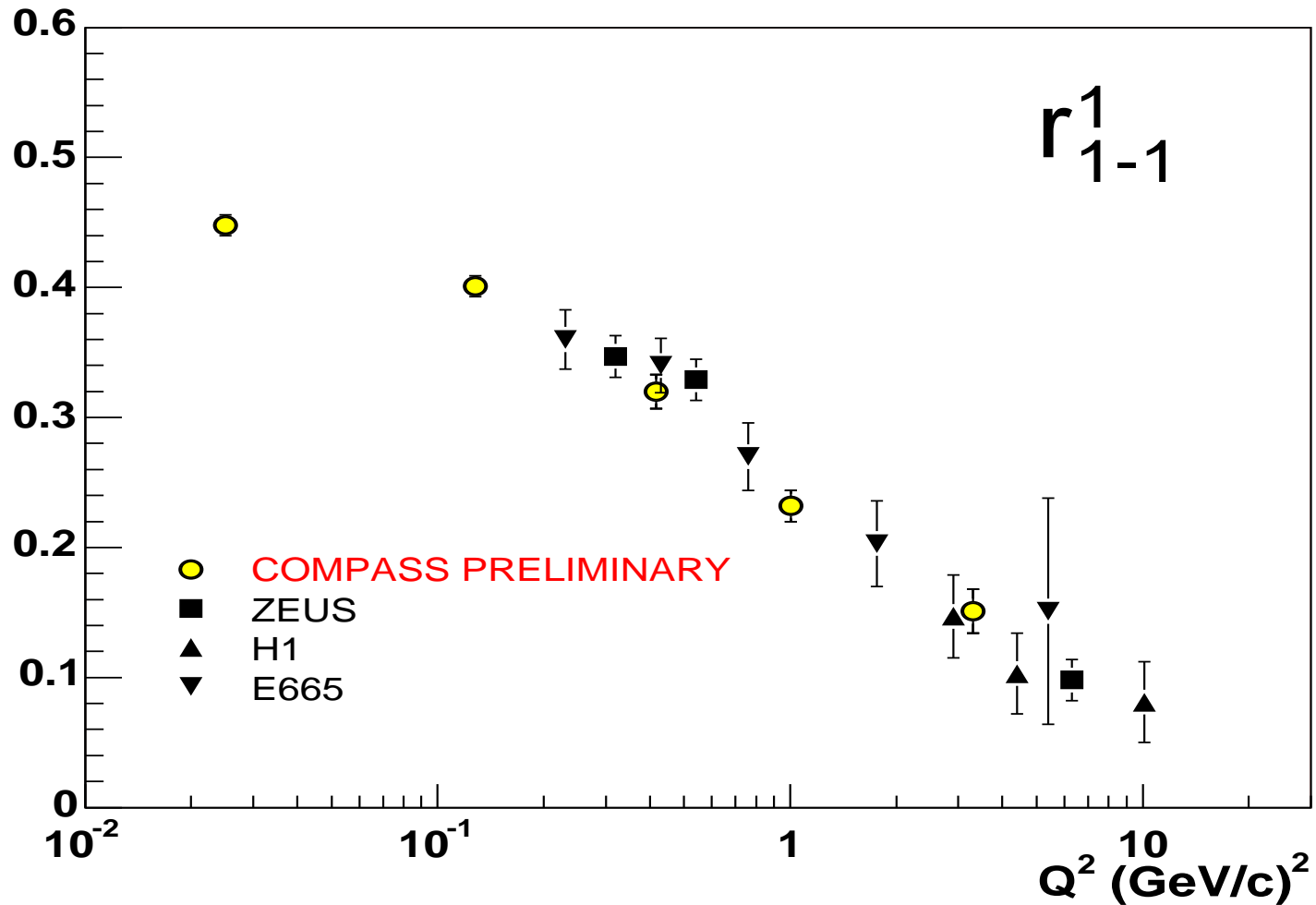
COMPASS — determination of $R = \sigma_L/\sigma_T$ (2002 data)

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



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

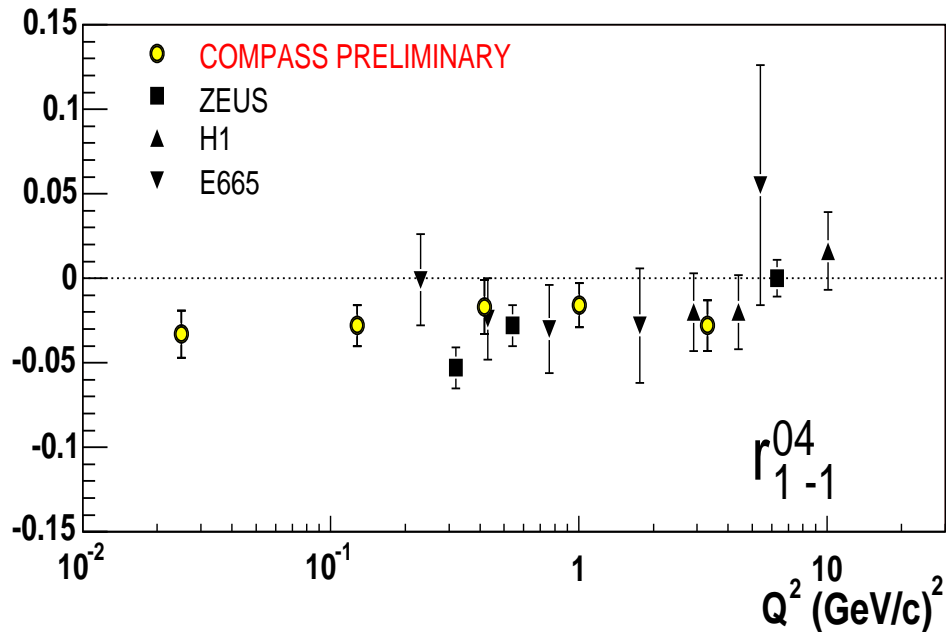
COMPASS — spin density matrix element r_{1-1}^1 for ρ^0 meson
(2002 data)



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

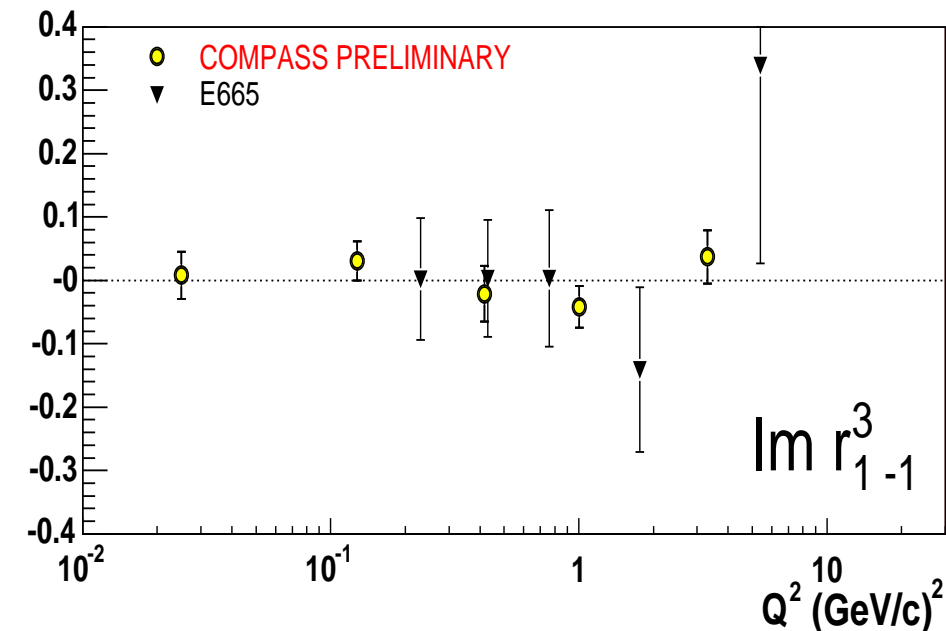
$$W(\psi) = \frac{1}{2\pi} (1 + 2\epsilon r_{1-1}^1 \cos 2\psi)$$

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



if **SCHC holds** $\implies r_{1-1}^{04} = 0$
 $\text{Im } r_{1-1}^3 = 0$

$\text{Im } r_{1-1}^3$ available only when beam leptons **polarized**



Violation of SCHC for r_{1-1}^{04}
 observed at COMPASS ?

Summary

- **preliminary** results for SDM elements r_{00}^{04} , r_{1-1}^1 , r_{1-1}^{04} & $\text{Im } r_{1-1}^3$ & $R = \sigma_L/\sigma_T$ from COMPASS **2002** data in a wide range $0.01 < Q^2 < 10 \text{ GeV}^2$ & at $\langle W \rangle \approx 10 \text{ GeV}$ 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_{1-1}^{04} SDM element ? (vide ZEUS)
- expected changes of results due to bkg corrections should be **comparable** or **smaller** than present statistical errors
- similar analysis with 2003 & 2004 data planned ($\sim 5 \times$ more events)