Diffractive ρ^0 production at COMPASS experiment

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On behalf of the COMPASS *Collaboration*

DIFFRACTION 2004
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Plan

- COMPASS experiment
- Ongoing analyses of exclusive VM production
- Results on SDME's for ρ^0 production
- Other released results for EVMP
- Prospects for the future

COMPASS physics program

Hadron structure and spectroscopy

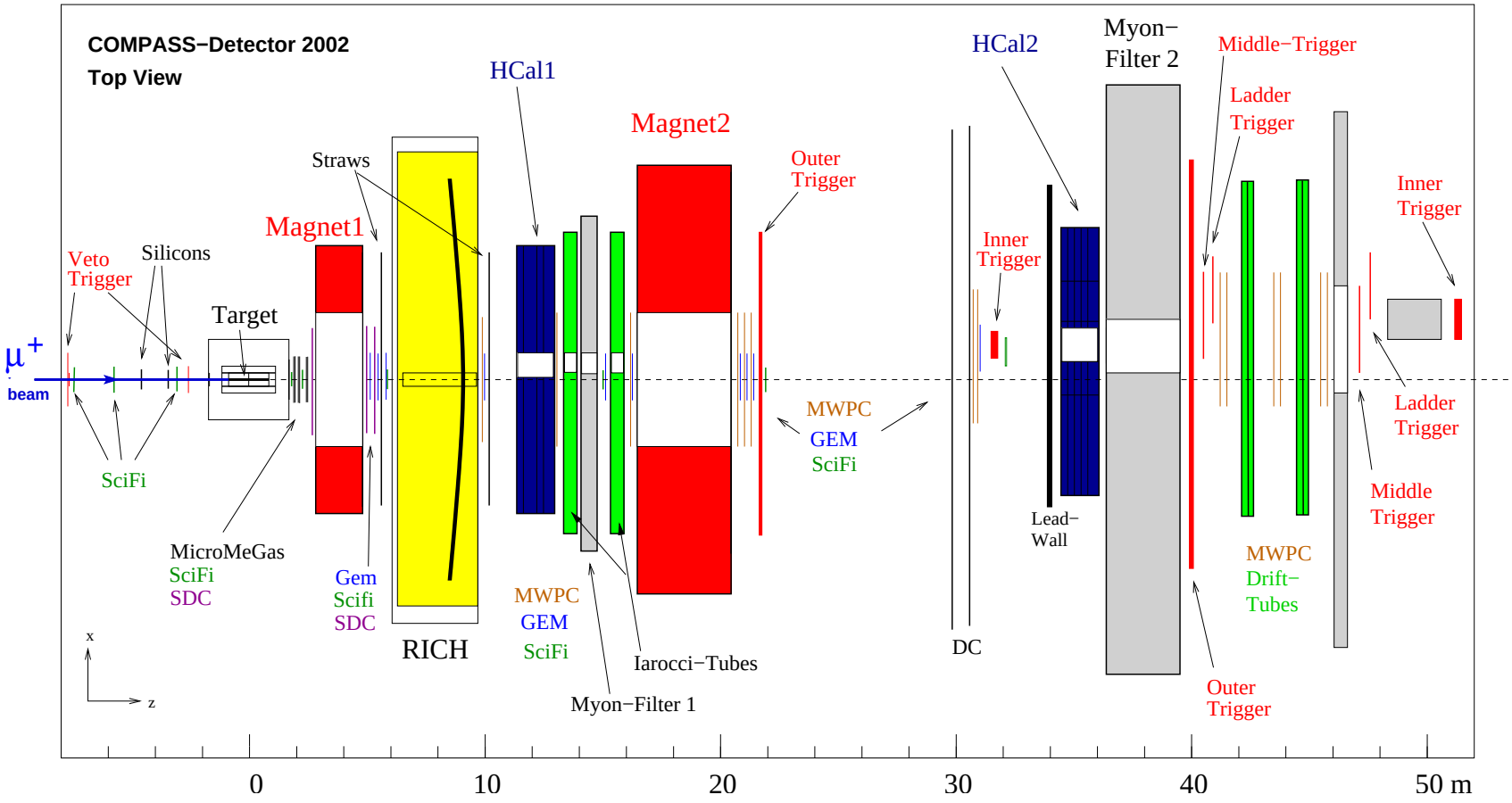
Muon beam program

- Gluon polarization $\Delta G/G$
- Flavour dependent quark helicity distributions $\Delta q(x)$
- Transverse spin distributions
- Diffractive VM production
- Polarisation of Λ and $\bar{\Lambda}$ in DIS
- DVCS (after 2010)

Hadron beam program

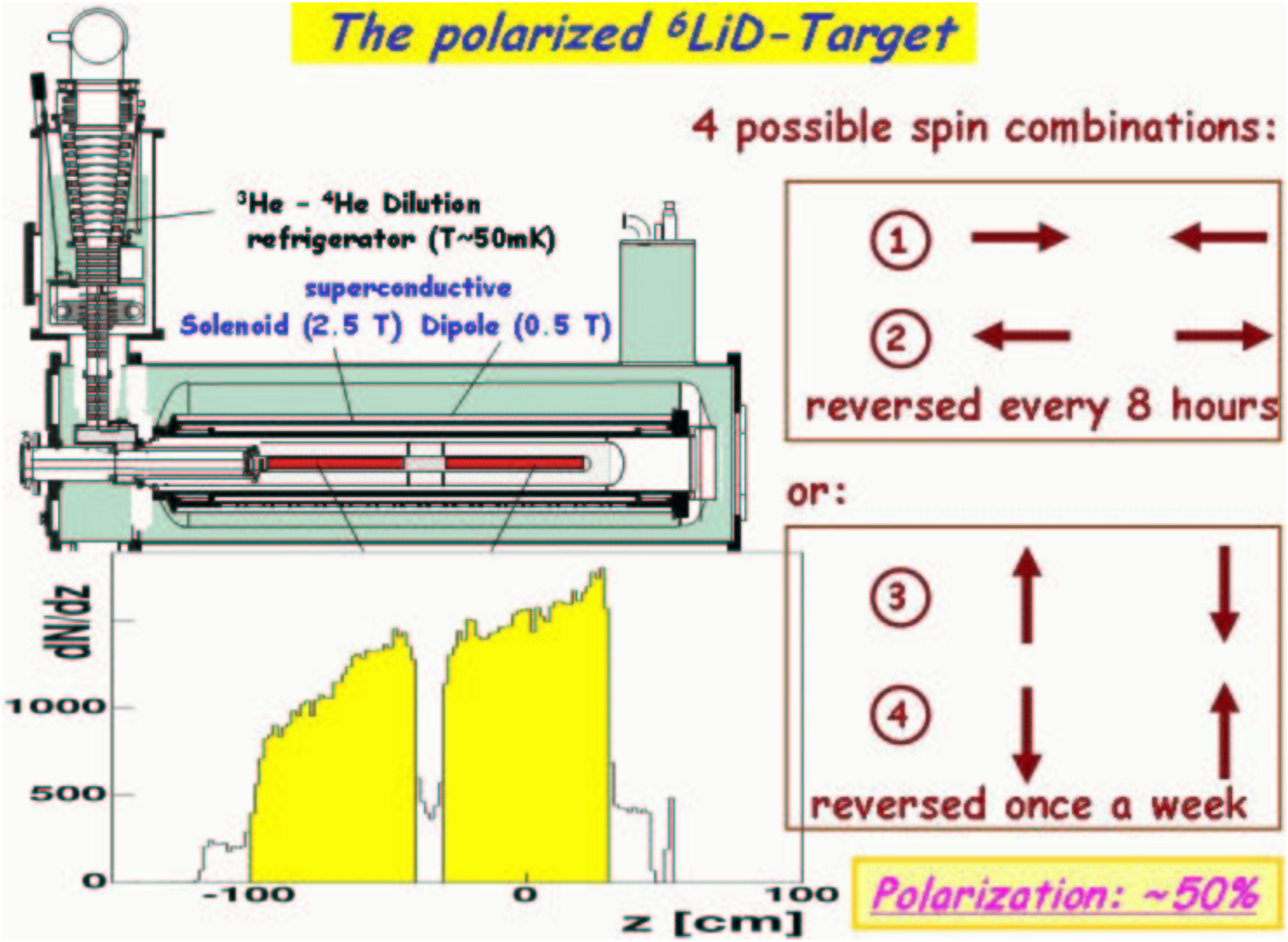
- Polarizability of π and K (Primakoff reactions)
- Glueballs and hybrid states
- Semi−leptonic decays of charmed hadrons
- Double−charmed baryons

COMPASS experimental setup

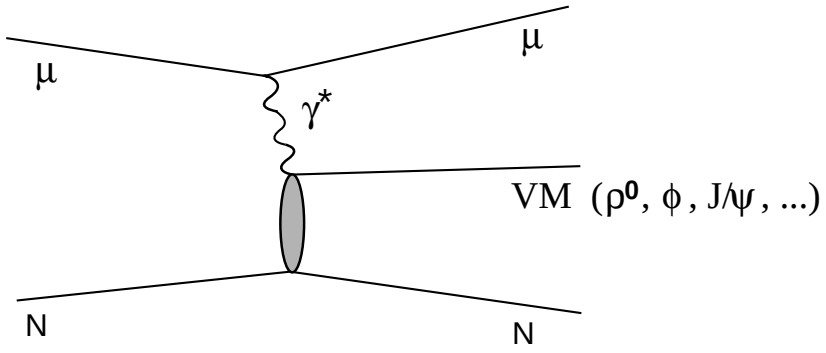


Beam $2 \cdot 10^8 \mu^+$/spill (4.8s / 16.2s) **Beam momentum** 160 GeV/c

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


The polarized ⁶LiD-Target
4 possible spin combinations:
³He – ⁴He Dilution refrigerator (T~50mK)
superconductive
Solenoid (2.5 T) Dipole (0.5 T)
1
2
reversed every 8 hours
or:
3
4
reversed once a week
dN/dz
1000
500
0
-100
0
100
z [cm]
Polarization: ~50%

Ongoing analyses of exclusive VM production



⇒ • Angular distributions and $R = \sigma_L/\sigma_T$ for ρ^0 production

→ • ρ^0 and $\pi\pi$ interference in $M_{\pi\pi}$ distributions

• Q^2 dependence of the diffractive peak slope for ρ^0 production

• Double spin longitudinal asymmetry for ρ^0 production

→ • ϕ production

→ • J/ψ production

• Exclusive production of $\pi^+\pi^+\pi^-\pi^-$

Angular distributions for production and decay of ρ^0

Angular distributions for production and decay of ρ^0

$\rightarrow$

Spin density matrix elements and $R = \sigma_L/\sigma_T$

$\rightarrow$

Information on the spin structure of the production amplitudes

23 matrix elements could be determined for production by polarised leptons
Aim of the present analysis is to determine several elements accessible through single-dimensional angular distributions

First we concentrate on the incoherent production i.e. quasi-free production on nucleons from a target nuclei $\mu N \rightarrow \mu N \rho^0$
This allows direct comparison with other experiments and theoretical predictions

Release of results for coherent production $\mu A \rightarrow \mu A \rho^0$ foreseen
However, COMPASS PT is a mixture (essentially) of light nuclei, thus providing predictions not straightforward

Selections and cuts

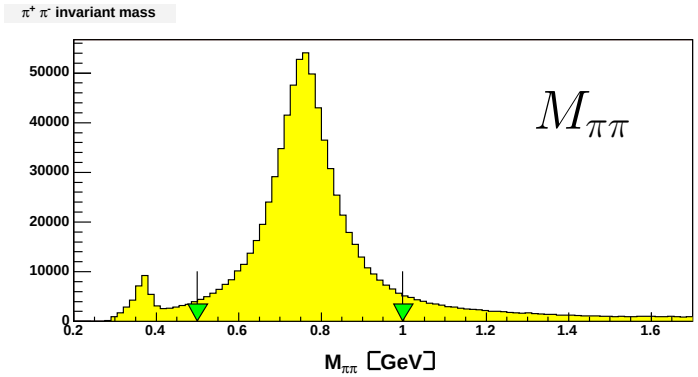
2002 data with longitudinally polarised target

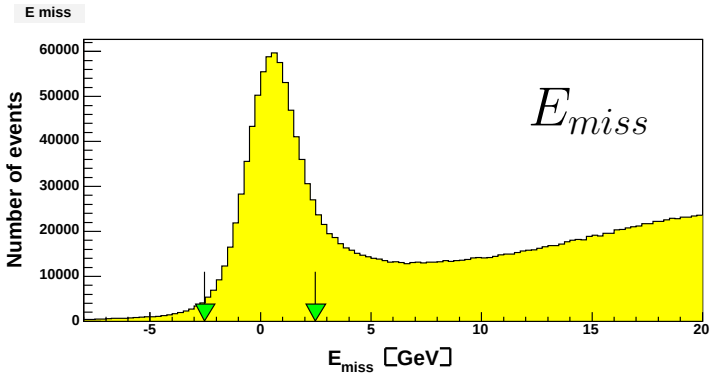
Beam, scattered muon and only two hadrons of opposite charge from primary vertex

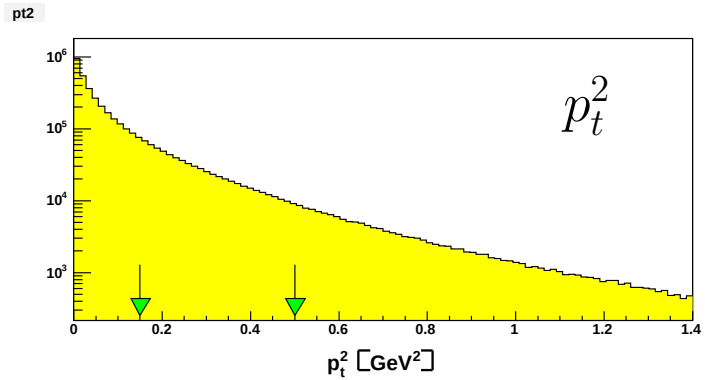
Primary vertex in the target

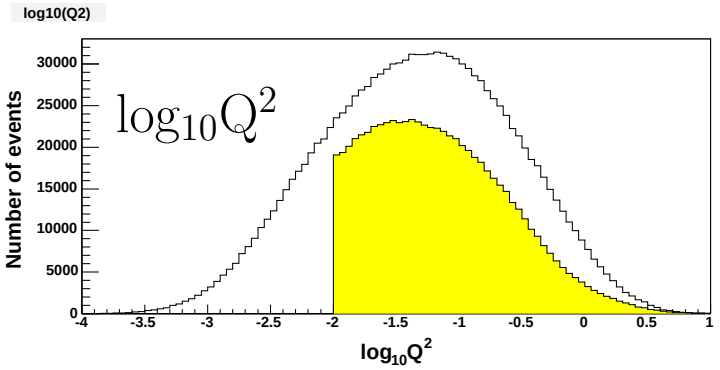
- $\nu > 30$ GeV
- $E_{\mu'} > 20$ GeV
- $Q^2 > 0.01$ GeV^2
- $0.5 < M_{\pi\pi} < 1.0$ GeV
  assuming pion mass for both hadrons
- $-2.5 < E_{miss} < 2.5$ GeV, where $E_{miss} = (M_X^2 - M_N^2)/2M_N$
- $0.15 < p_t^2 < 0.5$ GeV^2

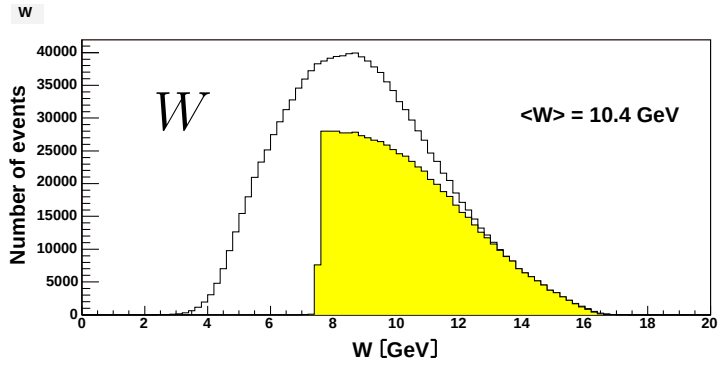
Kinematical distributions











Data sample

Total number of accepted events for incoherent sample - **695 564**

Q^2 bin $[\mathrm{GeV}]^2$	0.01-0.05	0.05-0.3	0.3-0.6	0.6-2.0	2.0–>
Number of events	306 121	292 637	55 616	35 219	5 971
$< Q^2 >$	0.025	0.128	0.416	1.01	3.30
$< \epsilon >$	0.86	0.86	0.87	0.87	0.87
$< \delta >$	0.15	0.033	0.007	0.003	0.001

When coherent production included ($0 < p_t^2 < 0.5\mathrm{GeV}^2$) about **3.5 M** events

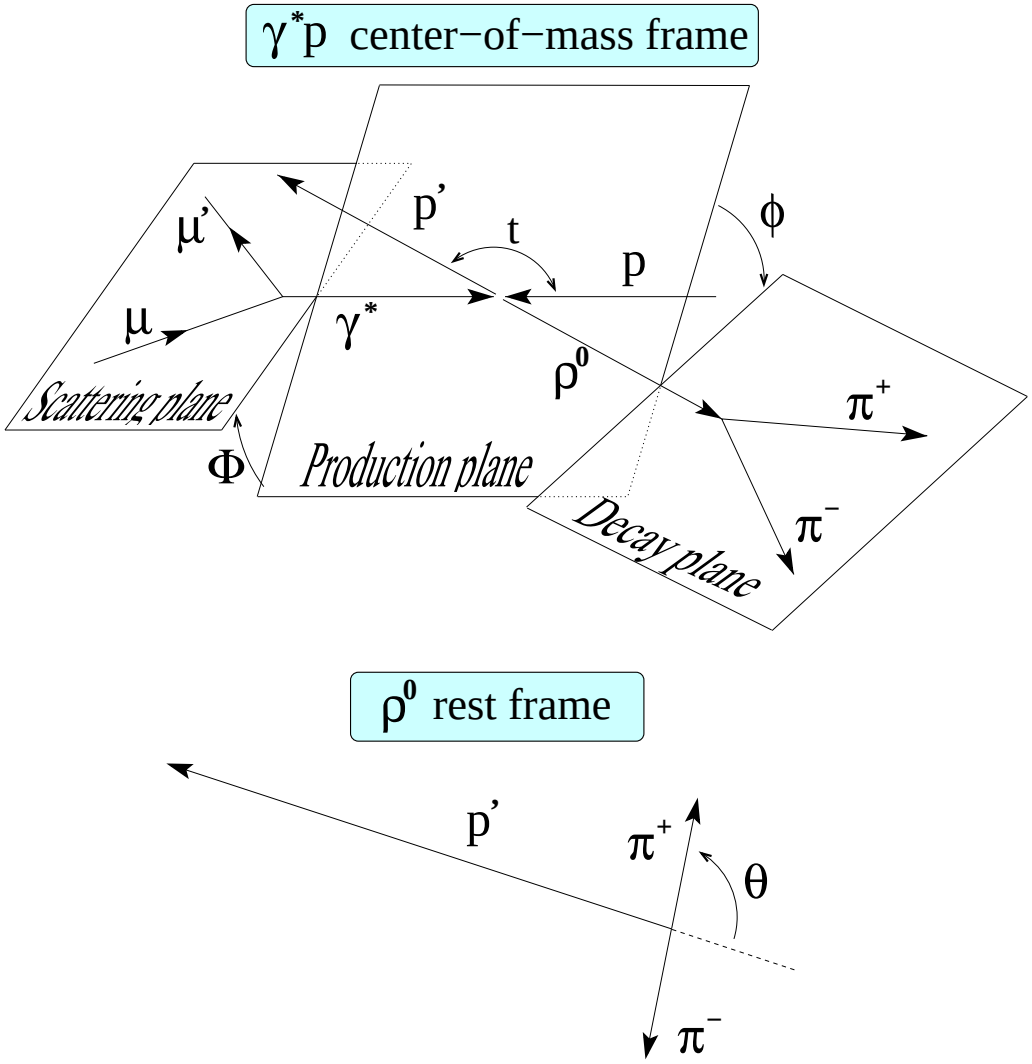
Virtual photon polarisation parameter $\epsilon = \{1 + 2\,(Q^2 + \nu)/[Q^2(1 - \frac{Q^2_{min}}{Q^2})^2] \cdot \tan^2 \frac{1}{2}\Theta\}^{-1}$
where $Q^2_{min} = -2m_\mu^2 + 2(E_\mu E_{\mu'} - |p_\mu||p_{\mu'}|)$

$\delta = \frac{2m_\mu^2}{Q^2}(1 - \epsilon)$ it is the correction to the ratio of the longitudinal and transverse virtual photons due to the finite lepton mass

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

For muon beam and $Q^2 < 0.3\,\mathrm{GeV}^2$ exact formula for ϵ and δ must be used
Approximations for electron mass and/or large Q^2 used in other analyses not justified here

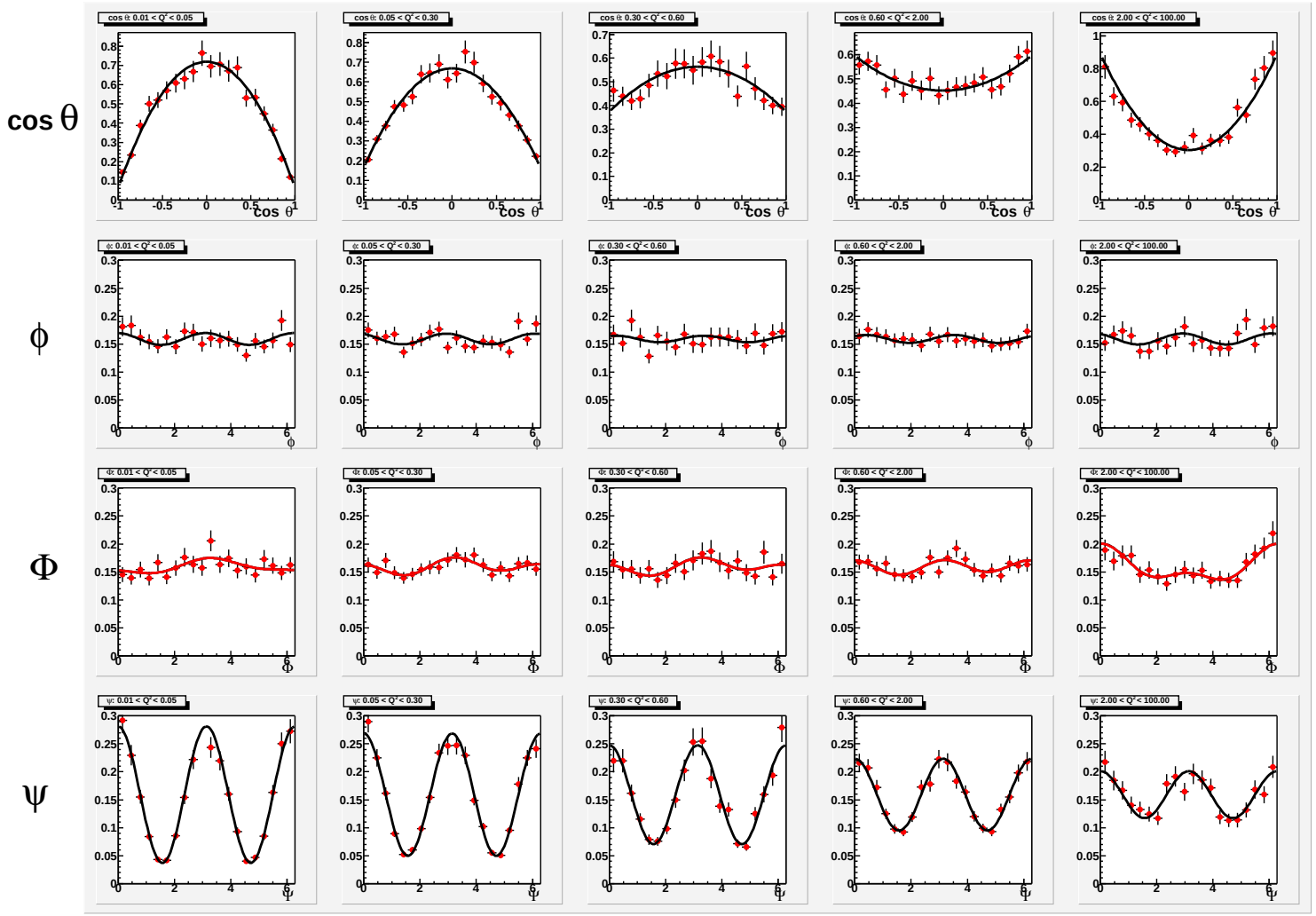
Definitions of angles



also used $\psi = \phi - \Phi$

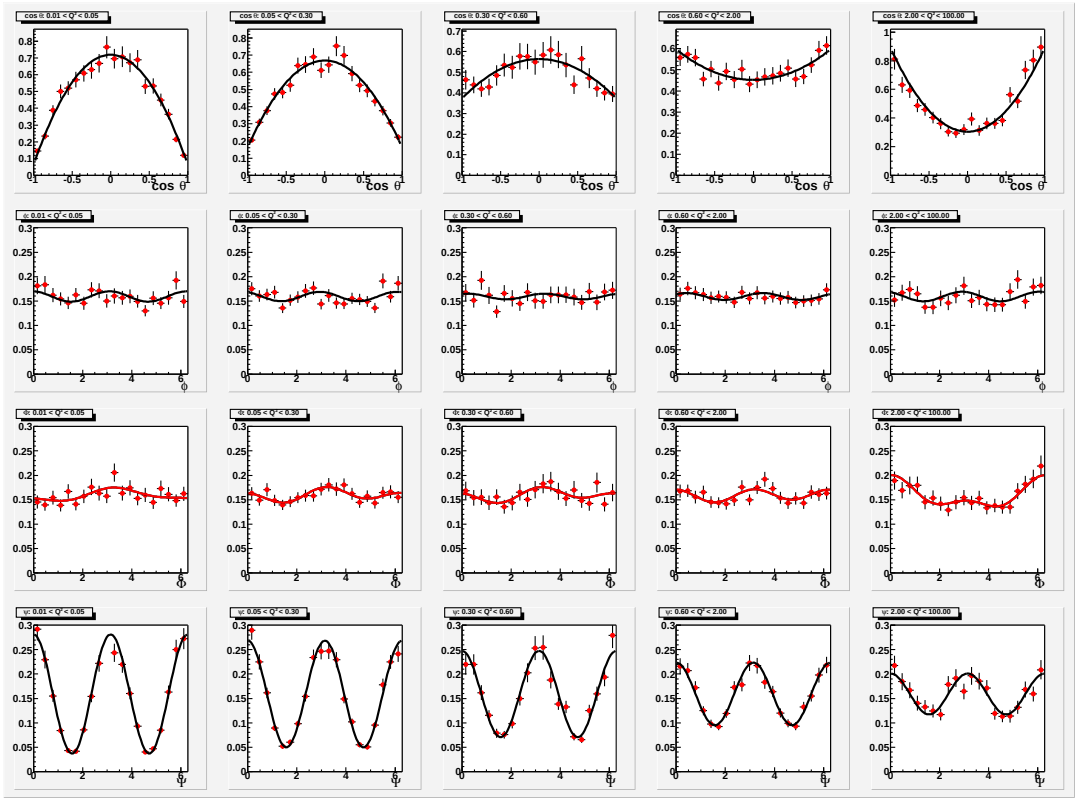
Angular distributions (1)

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



Angular distributions (2)

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



$$W(\cos\,\theta) = \tfrac{3}{4}[(1-r^{04}_{00})+(3r^{04}_{00}-1)\cos^2\theta]$$

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

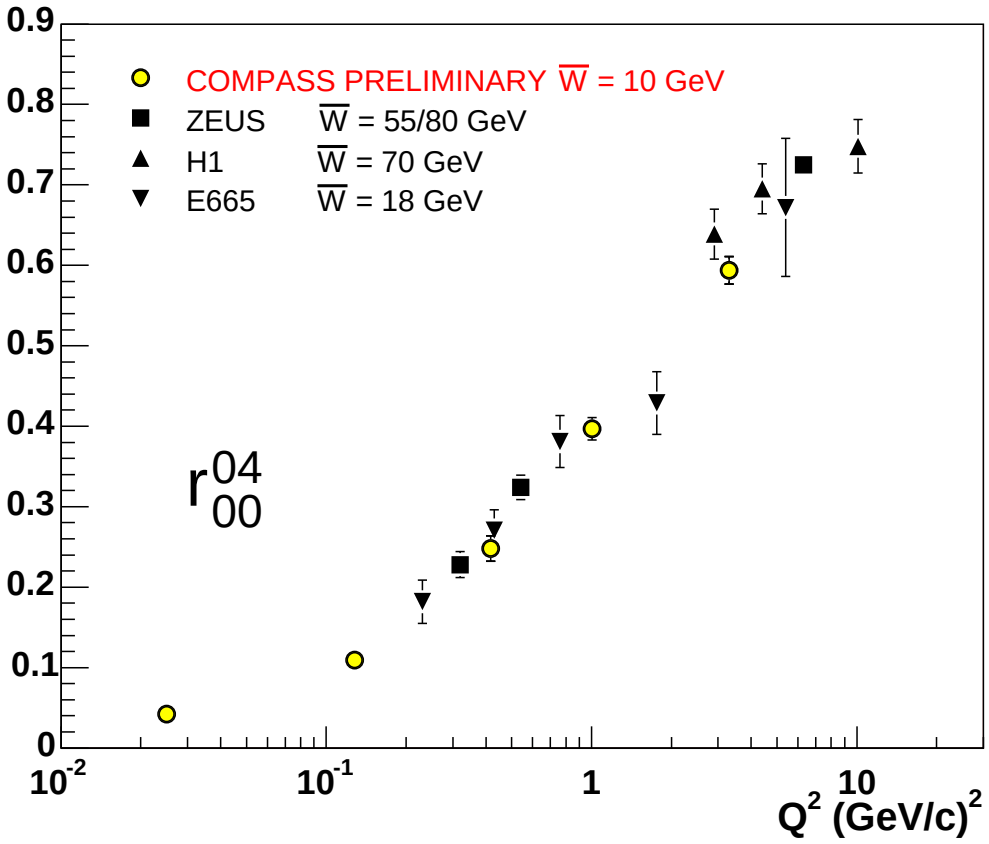
$$\begin{aligned} W(\Phi) = \tfrac{1}{2\pi}[1 &- (2r^{1}_{11}+r^{1}_{00})\epsilon\cos 2\Phi \\ &+ (2r^{5}_{11}+r^{5}_{00})\sqrt{2\epsilon(1+\epsilon)}\,\cos\Phi \\ &+ (2r^{8}_{11}+r^{8}_{00})P_\mu\sqrt{2\epsilon(1-\epsilon)}\,\sin\Phi] \end{aligned}$$

$$W(\psi) = \tfrac{1}{2\pi}[1+2\epsilon\; r^{1}_{1-1}\cos 2\psi]$$

This equation valid if SCHC

P_μ is polarisation of the muon beam

r_{00}^{04}



$$r_{00}^{04} = \frac{|T_{01}|^2 + (\epsilon + \delta)|T_{00}|^2}{N_T(1 + (\epsilon + \delta)R)}$$

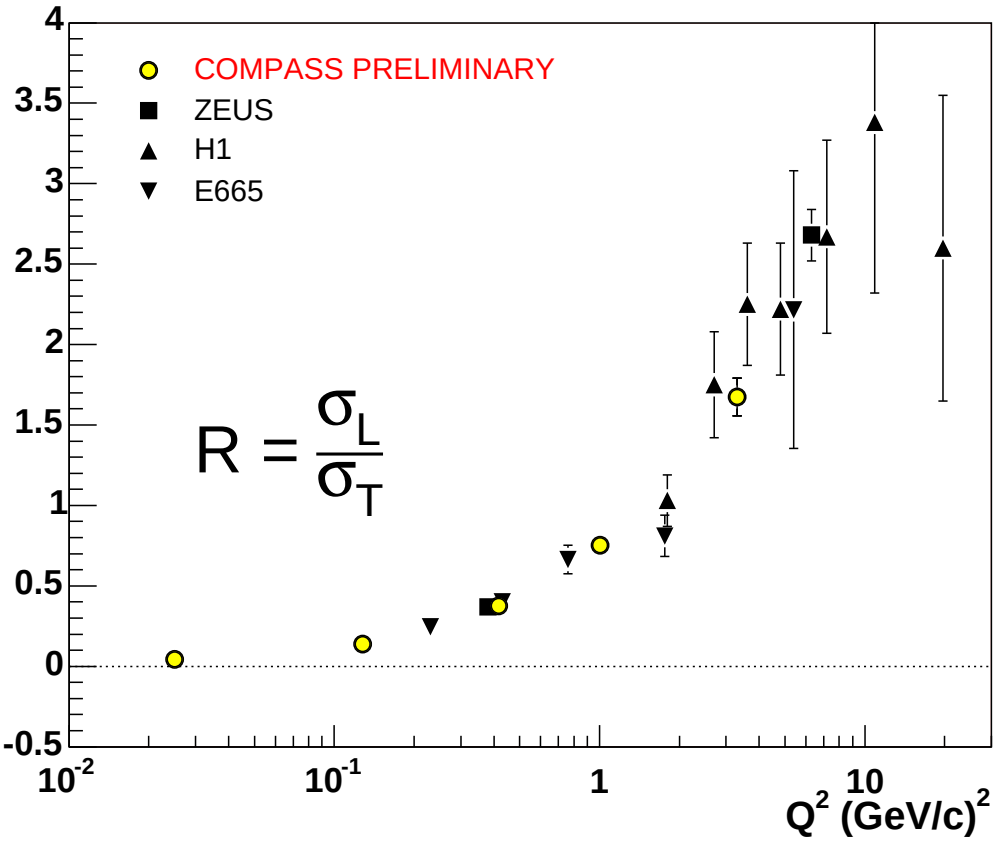
$$R = \sigma_L/\sigma_T, \quad N_T = |T_{11}|^2 + |T_{-11}|^2 + |T_{01}|^2 (\sim \sigma_T)$$

first (second) subscript corresponds to helicity of ρ^0 (γ^*)

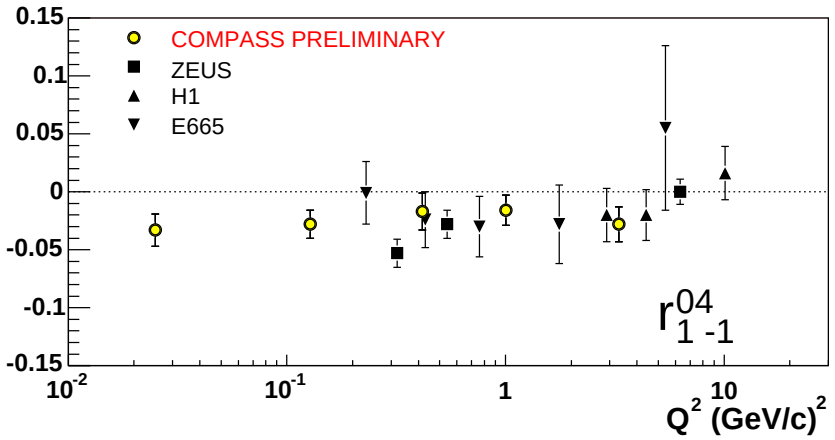
Determination of R

If SCHC holds

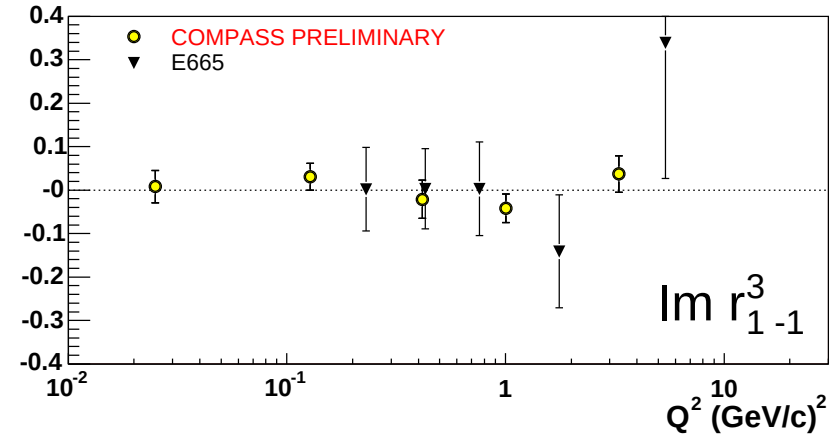
$$R = \frac{1}{(\epsilon + \delta)} \frac{r_{00}^{04}}{1 - r_{00}^{04}}$$



r^{04}_{1-1}, Imr^{3}_{1-1}



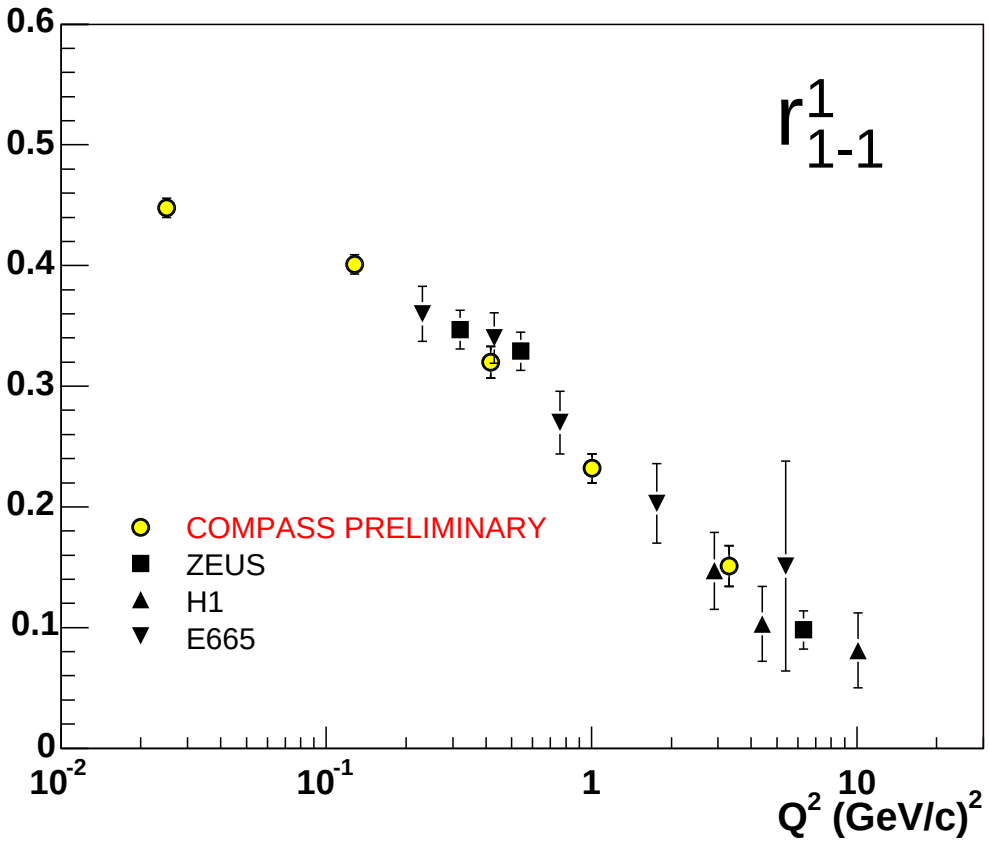
← small violation of SCHC (?)



If SCHC
$r^{04}_{1-1} = 0$
and
$\Im m\, r^{3}_{1-1} = 0$

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

r^1_{1-1}



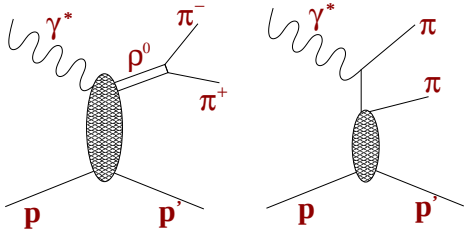
$$r^1_{1-1} = \frac{1}{2}\,\frac{|T_{11}|^2 + |T_{1-1}|^2}{N_T(1+(\epsilon+\delta)R)}$$

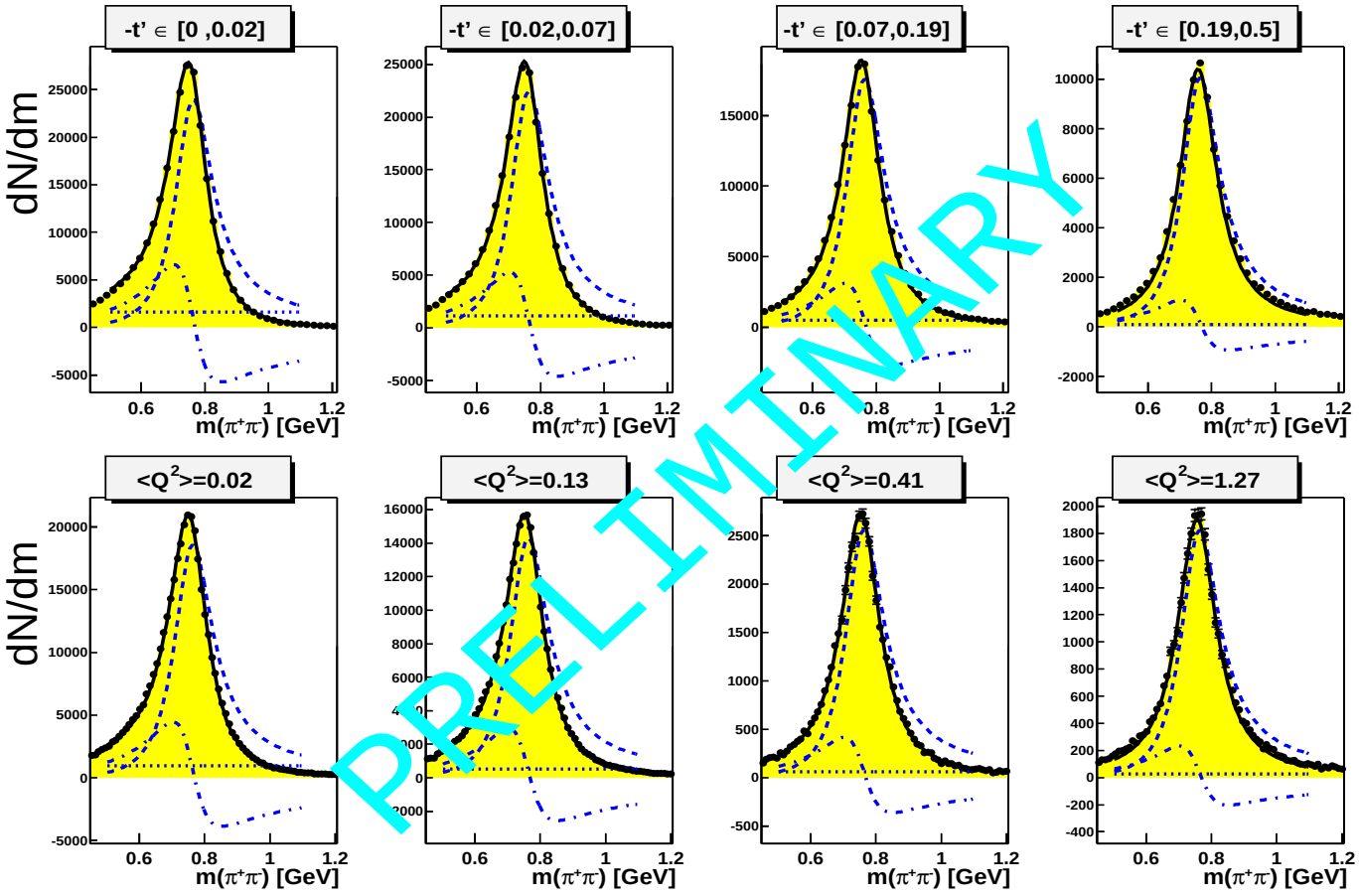
If SCHC and natural parity exchange in $t-$channel $\quad r^1_{1-1} = \frac{1}{2}(1 - r^{04}_{00})$ (!)

Summary for the SDME analysis

- First determination of r^{04}_{00}, r^{04}_{1-1}, $\Im m\, r^{3}_{1-1}$, r^{1}_{1-1} and R for incoherent exclusive ρ^0 production from COMPASS 2002 data
- High statistics data in a wide range of Q^2, $0.01 < Q^2 < 10\,\mathrm{GeV}^2$, at $< W >= 10\,\mathrm{GeV}$
- The results corrected for acceptance, smearing and efficiency of event reconstruction. The background is not subtracted
- Expected background correction may result in changes of the results which are comparable or smaller than the present statistical errors. An exception is r^{04}_{00} at $Q^2 < 0.3\,\mathrm{GeV}^2$, where the correction will be of the order of –0.02
- Only statistical errors shown at present. The errors of the COMPASS results from the 2002 data alone are comparable to the statistical errors of ZEUS and smaller than for other experiments
- The statistical accuracy of the present results is dominated by the limited MC sample used to correct the data. More MC production is foreseen

ρ and $\pi\pi$ interference





no acceptance correction yet

Söding model fit

non-exclusive background subtracted

Non-resonant contribution decreases with increasing $|t'|$ or Q^2

Prospects for VM in COMPASS

- Large MC for exclusive ρ^0 soon $\Rightarrow$ determination of 23 SDME
- 2003 (and 2004) - improved coverage at large Q^2
  $\Rightarrow$ substatial gain for Hard EVMP
  - at $Q^2 > 5\,\mathrm{GeV}^2$ 3 times more ρ than from 2002
  - reasonable statistics up to $Q^2 \simeq 25\mathrm{GeV}^2$
- 2003 (and 2004) - dedicated J/ψ trigger
  $\Rightarrow$ diffractive production of J/ψ feasible
- 2004 data - enlarged coverage of EM calorimetry
  $\Rightarrow$ VM's decays with neutral paricles
- **VM analyses well on the tracks**

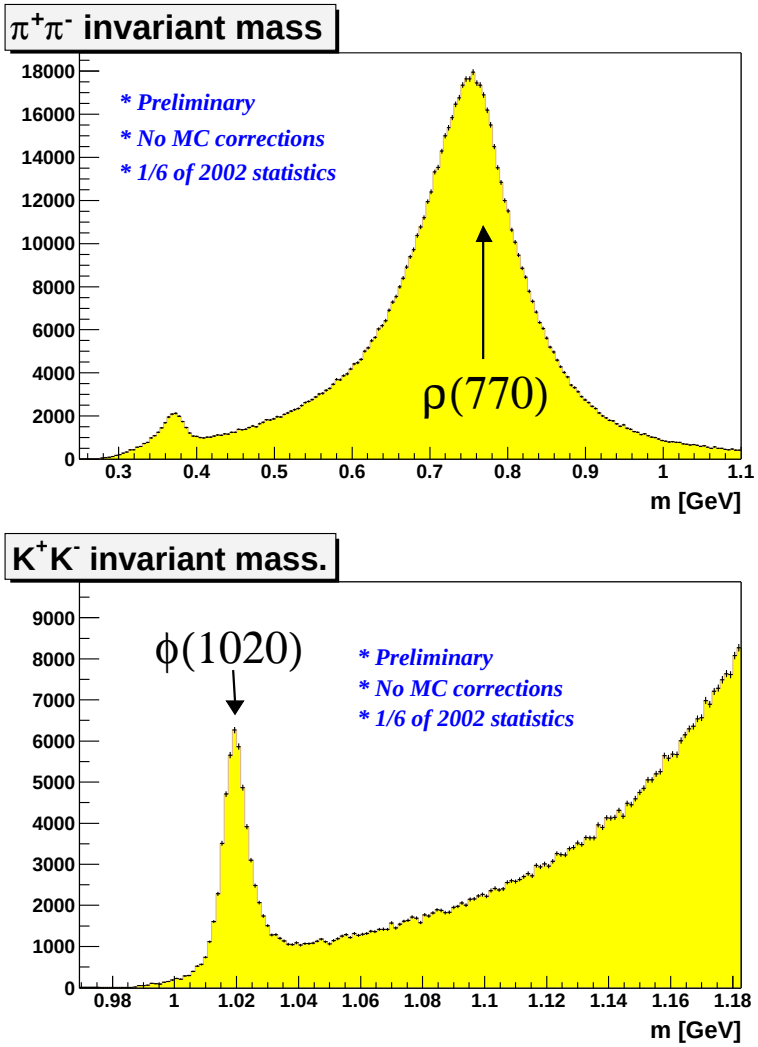
Additional slides

Exclusive ϕ production

The same selections as for exlusive incoherent ρ^0 sample except

- no selection on Q^2
- $p_t^2 < 0.5\,\mathrm{GeV}^2$

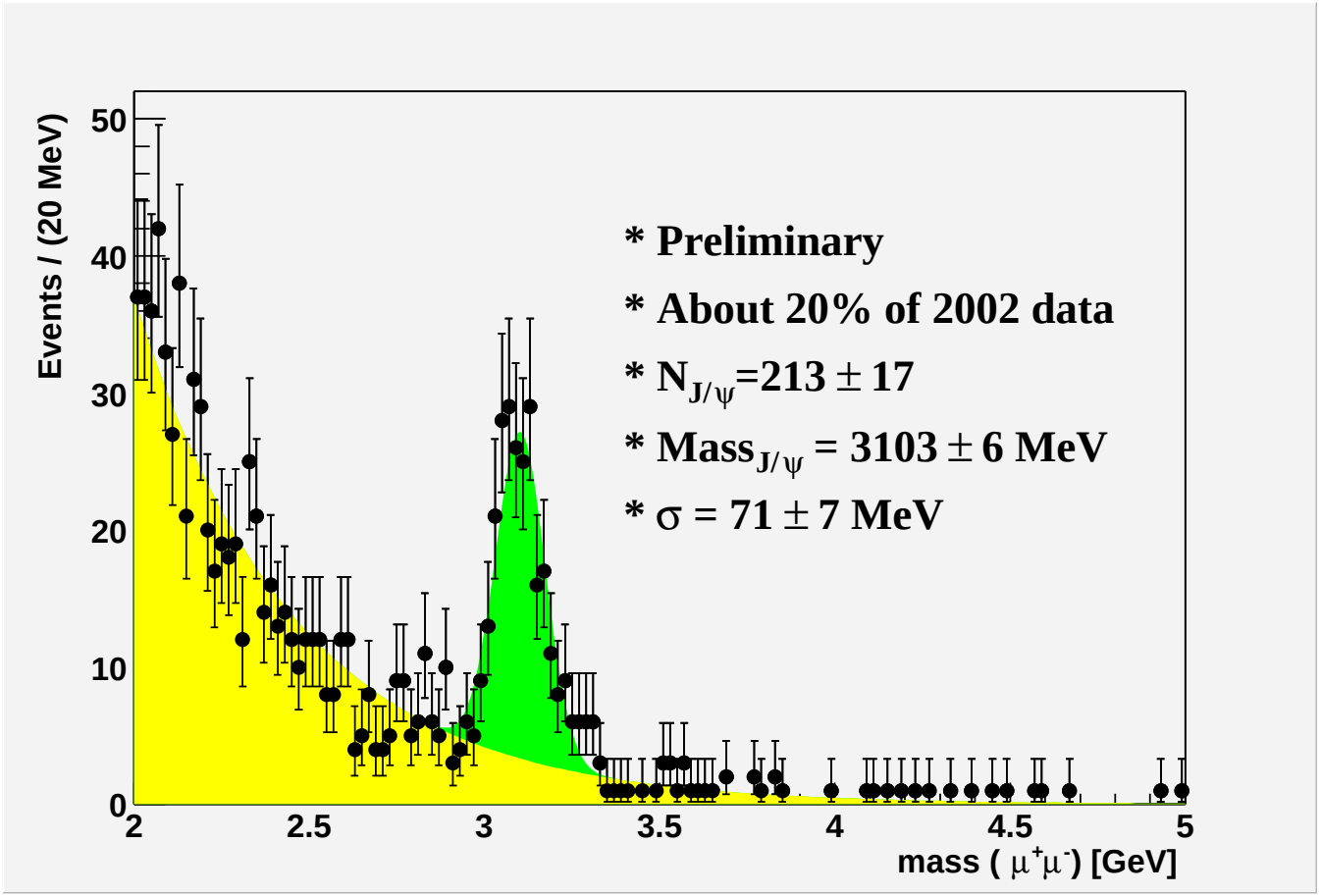
no hadron identification for presented results



From 2002 data alone
$N_\phi \approx 70\,000$ for $Q^2 > 0.01\mathrm{GeV}^2$
$(\simeq 1/50 N_{\rho^0})$

Effects of background under ϕ peak to be studied with subsample with identified kaons

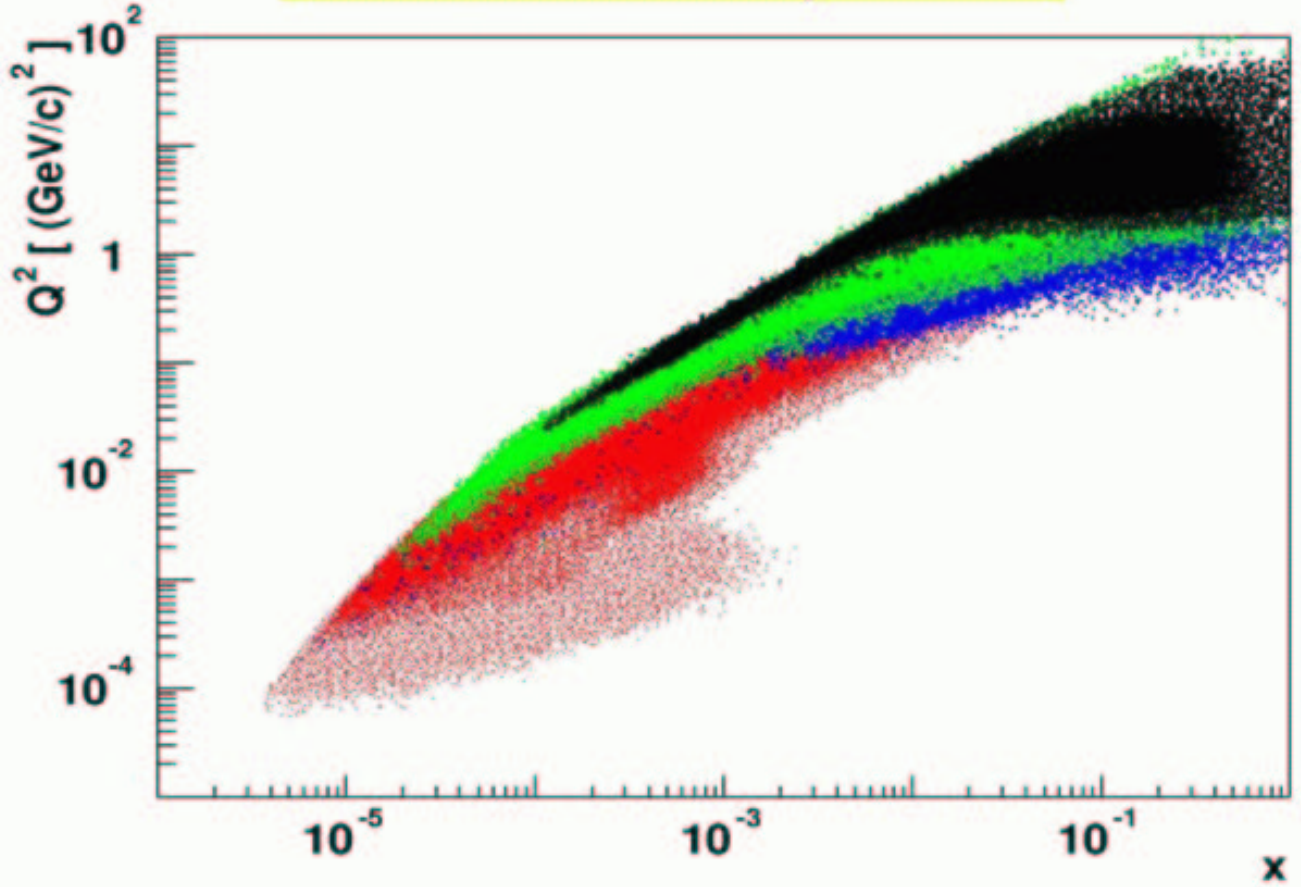
J/ψ production



2002: mostly inelastic
diffractive suppressed

2003 & 2004: dedicated J/ψ trigger
good coverage of diffractive and inelastic

COMPASS Acceptance



Excellent for non-perturbative & perturbative physics

- *small x_{Bj}*
- *very small Q^2 → Q^2 > 100 (GeV/c)^2*

Accumulated data

2002	260 Tb in 106 days	for physics 76 days
2003	225 Tb in 90 days	for physics 83 days

2002 & 2003

- 10^{10} events with **longitudinal** polarization
- $3{\cdot}10^{9}$ events with **transverse** polarization
- 0.1% with $Q^2 > 1\text{GeV}^2$ (after cuts)

COMPASS running in 2002, 2003 and 2004

	2002	2003	2004	2004
scheduled	106 d	90 d	*110 d*	*21 d*
ε_{SPS}	.89	.63	*.80*	*.80*
preparation	~30 d	7 d	*7 d*	*~7 d*
$\varepsilon_{Spectro}$ (*.90$_{TGT}$)	.77	.85	*.85*	*.85*
data taking	44 d	39 d	*62 d*	*~8 d*
L /T	**33** /11	**30** /9	***49*** */13*	

160 GeV muons **hadrons**

COMPASS after 2004

2005-2010

- SPS off in 2005, restart in 2006
- COMPASS is in the '5 years mid-term plan' of CERN
- principal SPS users (apart LHC) are neutrinos/CNGS and COMPASS

Beyond 2010

Thinking about physics projects started (Villars meeting)

One of the COMPASS projects is DVCS and HEMP with LH target and Recoil Detector

COMPASS Collaboration