Test of the OZI rule and spin alignment measurements with the COMPASS experiment

MENU 2013

Johannes Bernhard[1]

Institut für Kernphysik Mainz

on behalf of the COMPASS collaboration

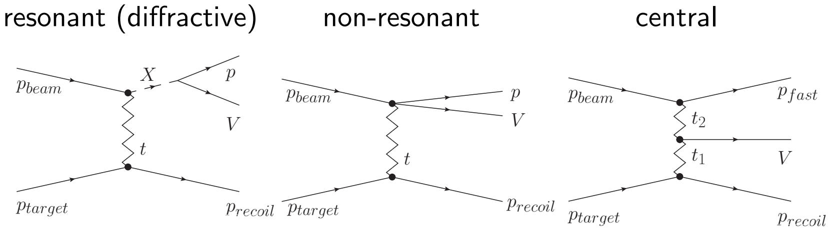
October 2nd 2013

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

bmb+f - Förderschwerpunkt COMPASS Großgeräte der physikalischen Grundlagenforschung

[1] Contact: johannes.bernhard@cern.ch

Production mechanisms at beam energies $\mathcal{O}(100\,\text{GeV})$



Try to understand interplay by studying strangeness transfer in well-understood vector meson production ("strangeness chemistry"):

- $\phi(1020)$ is close to pure $s\bar{s}$ state
- $\omega(782)$ is close to pure $u\bar{u}/d\bar{d}$ state

OZI rule

Okubo-**Z**weig-**I**izuka rule:
processes with disconnected quark lines suppressed

prediction for $\phi(1020)$ to $\omega(782)$ production ratios:

$$\sigma(pp \to \phi X)/\sigma(pp \to \omega X) \simeq \tan^2(\theta - \theta_0) \simeq 4.2 \cdot 10^{-3}$$

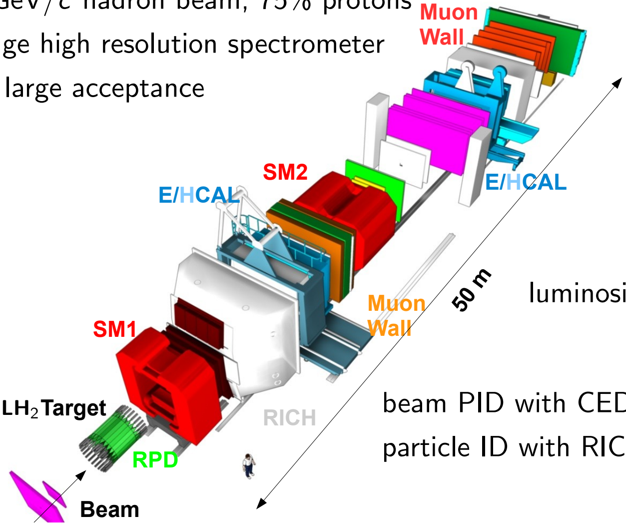
- Violation of ratio hints at flavour-neutral exchange processes

The COMPASS spectrometer at CERN

190 GeV/c hadron beam, 75% protons

2 stage high resolution spectrometer

with large acceptance



luminosity $0.15\,\mathrm{pb}^{-1}/\mathrm{day}$

beam PID with CEDAR detectors

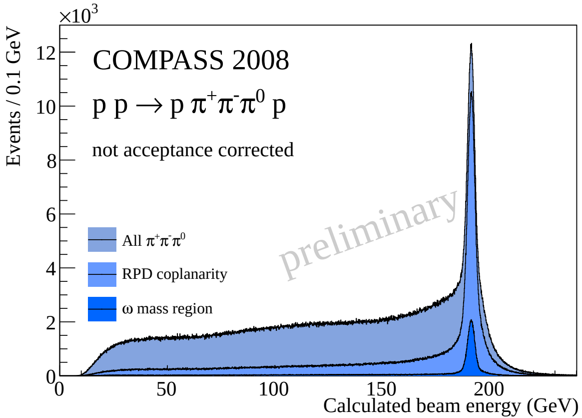
particle ID with RICH and Calorimetry

hep-ex/0703049, NIM A 577, 455 (2007)
update in preparation

Event selection of exclusive vector meson production

Study at COMPASS:
Compare $\phi(1020) \longrightarrow K^+K^-$ to $\omega(782) \longrightarrow \pi^+\pi^-\pi^0$ production

Exclusive events:



Analysis

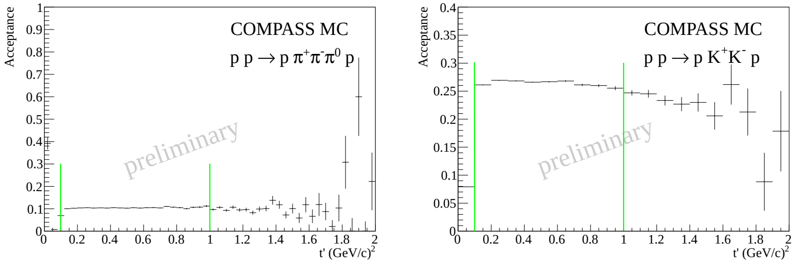
Restriction to similar, well-known phase space for both ω and ϕ by cuts on

- longitudinal momentum share: $0.6 < x_F < 0.9$
- momentum transfer: $0.1\,(\text{GeV}/c)^2 < t' < 1\,(\text{GeV}/c)^2$
- mass of pV system
  1. $1.8\text{GeV}/c^2 < \text{M}(\text{p}\omega) < 4.0\text{GeV}/c^2$
  2. $2.1\text{GeV}/c^2 < \text{M}(\text{p}\phi) < 4.5\text{GeV}/c^2$

Method:

1. Monte-Carlo simulation of apparatus acceptance, correction in t', x_F and M_{pV}
2. fit acceptance corrected invariant mass distributions in x_F bins
3. correct for branching
4. calculate $R = \frac{\text{Number of } \phi}{\text{Number of } \omega}$

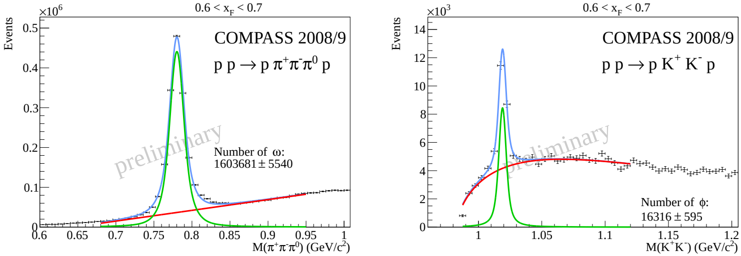
Analysis



Method:

1. Monte-Carlo simulation of apparatus acceptance, correction in t', x_F and M_{pV}
2. fit acceptance corrected invariant mass distributions in x_F bins
3. correct for branching
4. calculate $R = \frac{\text{Number of } \phi}{\text{Number of } \omega}$

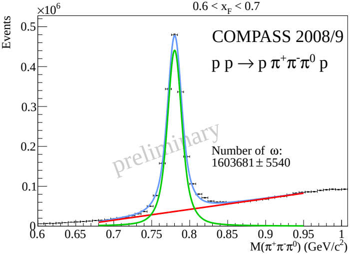
Preliminary Results $R_{\phi/\omega}$

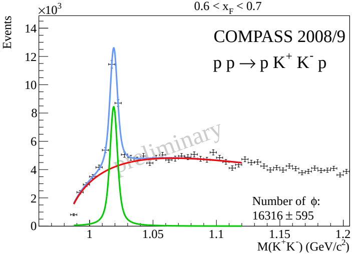


Systematic uncertainties:

- background subtraction
- apparatus knowledge (ECAL+RICH efficiencies)

Preliminary Results $R_{\phi/\omega}$





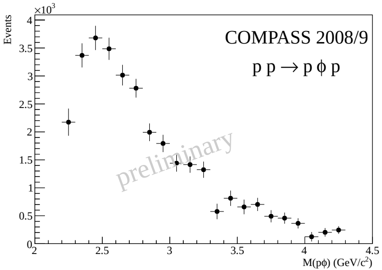
Differential cross section ratio $R_{\phi/\omega}(x_F)$ (*preliminary*):

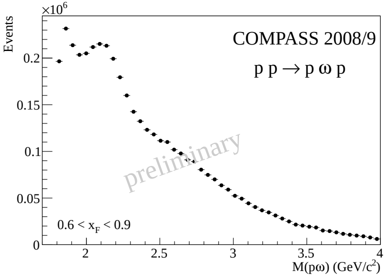
x_F	$R_{\phi/\omega}$	*OZI violation factor*
0.6-0.7	0.019	4.5 ± 0.6
0.7-0.8	0.017	4.0 ± 0.5
0.8-0.9	0.012	2.9 ± 0.4

OZI violation

Observation: Lower violation than found by previous experiments

Investigate mass distribution of pV system:





$p\phi$: phase-space-like, no structures

$p\omega$: resonances

Preliminary Results $R_{\phi/\omega}$ - II

cut on vector meson momentum p_V

- independent of ω/ϕ mass differences

	$p_V > 1.0$ (GeV/c)		$p_V > 1.4$ (GeV/c)	
x_F	$R_{\phi/\omega}$	*OZI viol.*	$R_{\phi/\omega}$	*OZI viol.*
0.6-0.7	0.032	7.6 ± 1.0		
0.7-0.8	0.038	9.0 ± 1.1	0.033	7.9 ± 1.1
0.8-0.9	0.019	4.5 ± 0.6	0.032	7.6 ± 1.0

preliminary!

Spin Alignment

another handle to distinguish production mechanisms:
cross section linearly parameterised[2] in terms of
spin density matrix element ρ_{00}

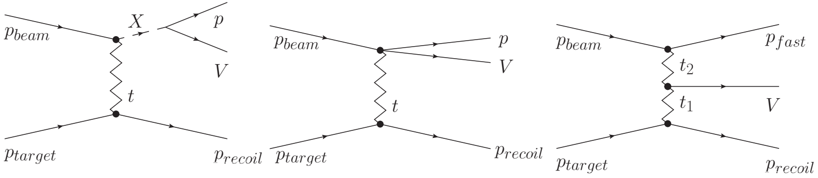
$$\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta} = \frac{4}{3}\left(1 - \rho_{00} + (3\rho_{00} - 1)\cos^2\theta\right)$$

$\rho_{00} = 0$ long. alignment, $\rho_{00} = 0.33$ arbitrary alignment, $\rho_{00} = 1$ transverse alignment

[2] K. Schilling, P. Seyboth and G. Wolf, Nucl. Phys. B 15 (1969) 397

Spin Alignment

Spin density matrix has representation depending on reference frame
resonant (diffractive) non-resonant central



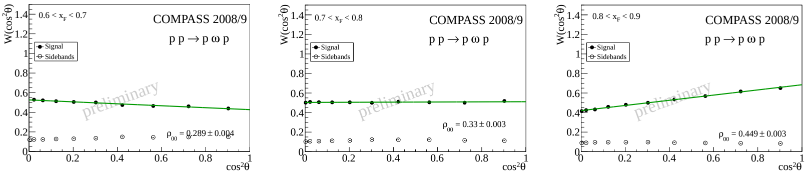
- helicity frame: $\hat{z} = |\vec{X}|$ in CM(V) system
  sensitive to diffractive / resonant production
- exchange frame: $\hat{z} = |\vec{p}_{beam} - \vec{p}_{fast}|$
  sensitive to central mechanisms / two particle exchanges

Spin Alignment

another handle to distinguish production mechanisms:
cross section linearly parameterised[2] in terms of
spin density matrix element ρ_{00}

$$\frac{d\sigma}{d\cos\theta} = \frac{4}{3}\left(1 - \rho_{00} + (3\rho_{00} - 1)\cos^2\theta\right)$$

ω, helicity frame:



$\rho_{00} = 0.289 \pm 0.004$ $\rho_{00} = 0.33 \pm 0.003$ $\rho_{00} = 0.449 \pm 0.003$

preliminary!

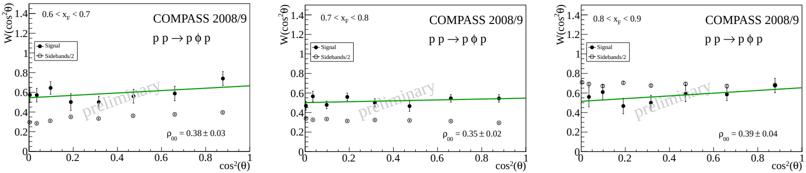
[2]K. Schilling, P. Seyboth and G. Wolf, Nucl. Phys. B 15 (1969) 397

Spin Alignment

another handle to distinguish production mechanisms:
cross section linearly parameterised[2] in terms of
spin density matrix element ρ_{00}

$$\frac{d\sigma}{d\cos\theta} = \frac{4}{3}\left(1 - \rho_{00} + (3\rho_{00} - 1)\cos^2\theta\right)$$

ϕ, helicity frame:



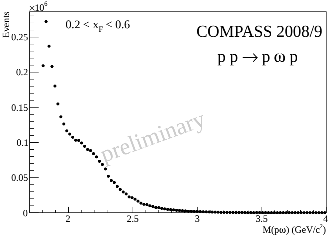
$\rho_{00} = 0.38 \pm 0.03$ $\rho_{00} = 0.35 \pm 0.02$ $\rho_{00} = 0.39 \pm 0.04$

preliminary!

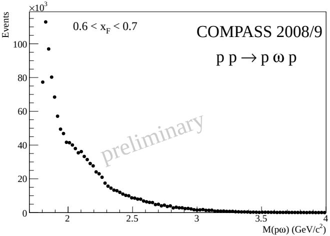
[2]K. Schilling, P. Seyboth and G. Wolf, Nucl. Phys. B 15 (1969) 397

Resonances in the $p\omega$ system

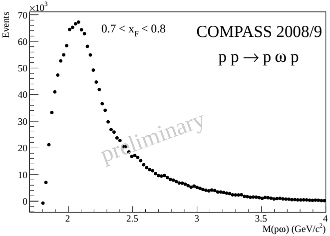
$0.2 < x_F < 0.6$



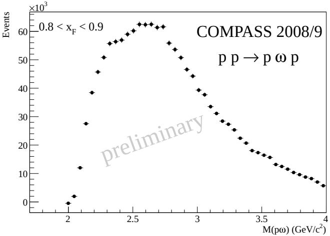
$0.6 < x_F < 0.7$



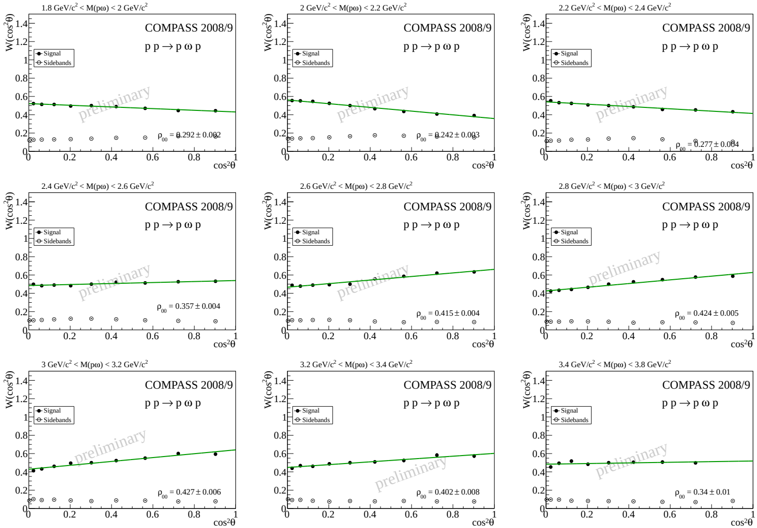
$0.7 < x_F < 0.8$



$0.8 < x_F < 0.9$

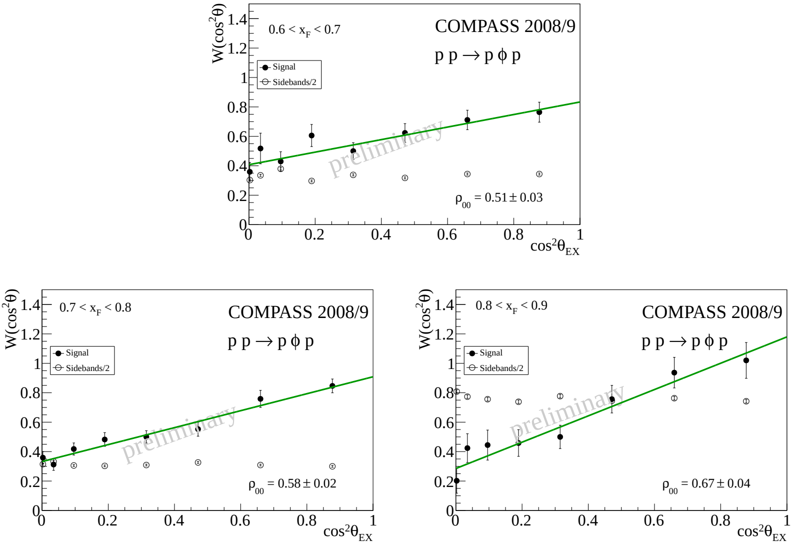


Helicity frame: scan over $p\omega$ mass

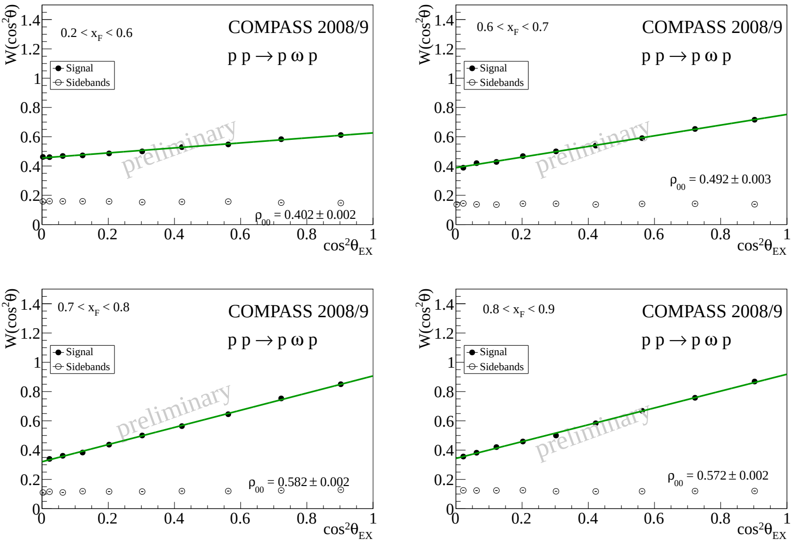


mass range 1.8-3.8 GeV/c^2

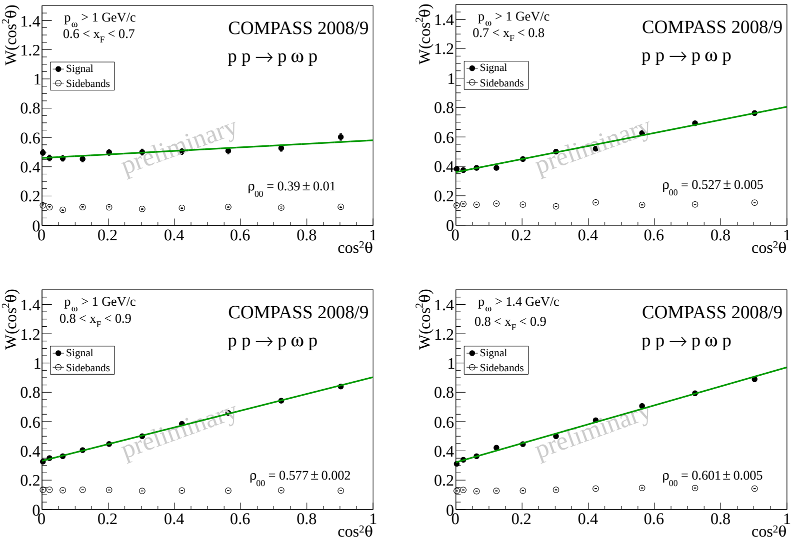
Exchange frame: Spin alignment ϕ



Exchange frame: Spin alignment ω



Exchange frame: Spin alignment ω with mass cuts



Summary

Study of production mechanisms *via*

1. OZI rule violation / production ratio $R(\phi/\omega)$
2. spin alignment

Results:

- found OZI violation of factor 3-4, low violation due to $p\omega$ resonances
- OZI violation universally 8 when visible $p\omega$ resonances excluded (interestingly, also for low energy measurements near threshold!)
- weak alignment of ϕ mesons, no obvious structures in $p\phi$ mass spectrum due to OZI suppression
- resonances in $p\omega$, sensitivity in helicity frame
  $\rightarrow$ diffractive production
- strong sensitivities in exchange frame for ω and ϕ
  $\rightarrow$ central production / knock-out

Backup

Reaction	x_F	ρ_{00}	*Unc.*
$pp \to pp\phi$	0.6-0.7	0.38	0.03
$pp \to pp\phi$	0.7-0.8	0.35	0.02
$pp \to pp\phi$	0.8-0.9	0.39	0.04
$pp \to pp\omega$	0.2-0.6	0.232	0.003
$pp \to pp\omega$	0.6-0.7	0.289	0.004
$pp \to pp\omega$	0.7-0.8	0.330	0.003
$pp \to pp\omega$	0.8-0.9	0.449	0.003
$pp \to pp\omega, p_V > 1.0$ GeV/c	0.2-0.6	0.30	0.01
$pp \to pp\omega, p_V > 1.0$ GeV/c	0.6-0.7	0.34	0.01
$pp \to pp\omega, p_V > 1.0$ GeV/c	0.7-0.8	0.306	0.006
$pp \to pp\omega, p_V > 1.0$ GeV/c	0.8-0.9	0.463	0.003
$pp \to pp\omega, p_V > 1.4$ GeV/c	0.8-0.9	0.37	0.03

helicity frame, *preliminary!*

Reaction	x_F	ρ_{00}	*Unc.*
$pp \to pp\phi$	0.6-0.9	0.39	0.02
$pp \to pp\omega$	0.2-0.6	0.408	0.002
$pp \to pp\omega$	0.6-0.7	0.492	0.003
$pp \to pp\omega$	0.7-0.8	0.582	0.002
$pp \to pp\omega$	0.8-0.9	0.572	0.002
$pp \to pp\omega,\ p_V > 1.0\,\mathrm{GeV}/c$	0.6-0.7	0.39	0.01
$pp \to pp\omega,\ p_V > 1.0\,\mathrm{GeV}/c$	0.7-0.8	0.527	0.005
$pp \to pp\omega,\ p_V > 1.0\,\mathrm{GeV}/c$	0.8-0.9	0.577	0.002
$pp \to pp\omega,\ p_V > 1.4\,\mathrm{GeV}/c$	0.8-0.9	0.601	0.005

exchange frame, *preliminary!*