1. The Okubo-Zweig-Iizuka (OZI) rule:

- states that processes with disconnected quark lines are forbidden.
- explains suppressed decay modes and production of vector mesons.

\[ R(\phi_1 \to \phi_2) = \frac{f(\phi_1 \to \phi_2)}{f(\phi_1 \to \pi^0 \pi^0)} \approx 4 \times 10^{-3} \]

where A, B are hadrons without strangeness.

The OZI prediction is fulfilled in pion-induced reactions and in proton-antiproton annihilations in flight.

2. The COMPASS experiment:

- two stage spectrometer
- high resolution, large acceptance
- \( \geq 2 	imes 10^6 \) data / year

3. Analysis

Event selection, common cuts for \( \phi / \omega \):
- primary vertex in target volume
- charged tracks, charge conservation
- beam proton (tagged with CEDARs)
- recoil proton (tagged by PID)
- exclusivity and completeness
- \( a < \phi / \omega < 0.1 \)
- \( a < \phi / \omega < 1.4 \text{ GeV}^2 / c^4 \)

Specific cuts for \( \phi / \omega \):
- \( a < \phi / \omega < 0.4 \text{ GeV}^2 / c^4 \)
- \( a < \phi / \omega < 4.5 \text{ GeV}^2 / c^4 \)

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4. \( R(\phi / \omega) \) as a function of \( x_F \) of \( p_{\text{fast}} \)

- sensitive to the production mechanism.
- \( R(\phi / \omega) \) depends significantly on the production mechanism.

5. \( R(\phi / \omega) \) as a function of \( x_F \) with \( p_{\text{fast}} > 1 \text{ GeV} / c \)

- The acceptance as a function of the cosine of the helicity angle is flat (left plot below).
- The acceptance as a function of the mass distribution of the \( p_{\text{fast}} \) system is also given (right).

6. Spin alignment measurements:

- Sensitive to the production mechanism, but also to the structure of the initial system.
- Low energy hadron experiments show that \( \phi \) is produced unpolarised whereas \( \omega \) is produced polarised.
- The differential cross section of a 3-body decay is given by:

\[ W_{\omega}(m_{\omega}) = N_{\omega} - m_{\omega} \cdot (3m_{\omega} - m_{\omega}) \]

- For a 2-body decay:

\[ W_{\phi}(m_{\phi}) = N_{\phi} - m_{\phi} \cdot (3m_{\phi} - m_{\phi}) \]

where \( m_{\omega} \) is the zeroth element of the spin-density matrix and \( N \) a proportionality constant.

- Unpolarised when \( p_{\text{fast}} \rightarrow 1 \)
- In this work, we study the helicity angle, i.e. as reference axis we take the direction of the \( p_{\text{fast}} \) system in the rest frame of the vector meson \( V \).

- Analysed in the \( \phi \) case:

\[ \phi_c \pm \epsilon \quad (\text{see figure}) \]

- Analysed in the \( \omega \) case:

\[ \omega_c \pm \epsilon \quad (\text{see figure}) \]

- The acceptance as a function of the mass distribution of \( p_{\text{fast}} \) system is also given (right).

7. Results: spin alignment and \( M(p_{\text{fast}}) \) of \( \phi / \omega \)

- If diffractive production (i.e., there are intermediate baryon resonances) we expect high sensitivity to the helicity angle.
- The acceptance as a function of the cosine of the helicity angle is flat (left plot below).
- The \( \omega \) distribution is insensitive to the helicity axis but the deviation from flatness is small (right plot below).

8. Results: spin alignment and \( M(p_{\text{fast}}) \) of \( \omega \) in \( x_F(p_{\text{fast}}) \) bins

High statistics and signal-to-background ratio allows for extraction of \( p_{\text{fast}} \) and \( M(p_{\text{fast}}) \) sub-regions of \( x_F(p_{\text{fast}}) \). The results reveal how strongly the physical processes depend on \( x_F \).

The cut on the helicity angle in different \( x_F(p_{\text{fast}}) \) sub-regions, indicated in the figures. The \( \omega \) mesons are significantly aligned at low \( x_F(p_{\text{fast}}) \), whereas the alignment is weaker in the \( 0.5 < x_F(p_{\text{fast}}) < 0.7 \) region and completely arbitrary (unpolarised) within \( 0.7 < x_F(p_{\text{fast}}) < 0.8 \). At higher \( x_F(p_{\text{fast}}) \), the \( \omega \) mesons are again aligned but in the opposite direction.

The \( M(p_{\text{fast}}) \) distribution in different \( x_F(p_{\text{fast}}) \) sub-regions, indicated in the figures. Different structures appear in different \( x_F(p_{\text{fast}}) \) regions. For a reliable identification of the observed structures, Partial Wave Analysis would be needed.

9. Summary and Outlook

- The cross section ratio \( R(\phi / \omega) \) has been measured as a function of \( x_F(p_{\text{fast}}) \), the OZI rule was found to be violated with a factor of 2.9-4.4.
- For \( p_{\text{fast}} > 1 \text{ GeV} / c \), the OZI violation is 4.5-9.1.
- The \( \phi \) mesons are very weakly aligned.
- No obvious structures were found in the \( M(p_{\text{fast}}) \) spectrum.
- The alignment of the \( \omega \) mesons depends significantly on \( x_F(p_{\text{fast}}) \).
- Clear structures were observed in the \( M(p_{\text{fast}}) \) spectrum, but PWA is needed for identification of any baryon resonances.
- The character of the \( M(p_{\text{fast}}) \) distribution depends strongly on \( x_F(p_{\text{fast}}) \).

\[ x_F(p_{\text{fast}}) = \pm 0.5 \]