Angular distributions of vector mesons

Johannes Bernhard

Institut für Kernphysik Mainz

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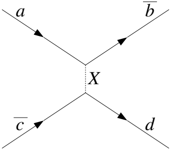
Cross section

Consider the reaction

$$a + b \longrightarrow c + d, (\text{e.g. } p + p \longrightarrow p\omega + p)$$

which holds for the crossed channel

$$a + \bar{c} \longrightarrow X \longrightarrow \bar{b} + d$$



where X is the exchange particle with a given J^{PC} defining the production mechanism. The cross section reads[1]:

$$\frac{d\sigma}{d\Omega} = \frac{1}{(2s_a+1)(2s_b+1)} \frac{p'}{sp} \sum_{\lambda} \left| \langle \lambda_d \bar{\lambda_b} | F(s,t) | \bar{\lambda_c} \lambda_a | \rangle \right.$$

[1]K. Gottfried, J.D. Jackson, Nouvo Cim. 33 (1964) 302

Cross section cntd.

Boost to rest frame of d, use $\Delta = \vec{p_a} - \vec{p_c}$ as quantisation axis
$|m\rangle$: spin states of d with amplitude

$$\langle m; \lambda_c | G(s,t) | \lambda_b \lambda_a \rangle = \sum_{\bar{\lambda_b} \bar{\lambda_c} \lambda_a} \left\langle m \bar{\lambda_b} | F(s,t) | \bar{\lambda_c} \lambda_a \right\rangle \cdot \text{d-functions for } \lambda_{a,b,c}$$

d-functions take care of rotations from s to t channel. Construct spin-density matrix

$$\left\langle m | \rho | m' \right\rangle = N \sum_{\bar{\lambda_b} \bar{\lambda_c} \lambda_a} \left\langle m \bar{\lambda_b} | F(s,t) | \bar{\lambda_c} \lambda_a \right\rangle \left\langle m' \bar{\lambda_b} | F(s,t) | \bar{\lambda_c} \lambda_a \right\rangle^*$$

Spin density matrix[2]

Characteristics of ρ:

- Hermeticity $\rho^\dagger = \rho$
- Positive semi-definite: $Tr\{\rho\} \leq 1,\ Tr\{\rho^2\} = 1$
- symmetric: $\rho_{ij} = \rho_{ji}$

for spin 1 particles additionally dim(ρ)$= 2J + 1 = 3$ which also gives in combination $Tr\{\rho\} = 1 = \rho_{00} + 2\rho_{11}$.

$$\frac{d\sigma}{d\Omega} \propto \rho_{11}\ \sin^2(\theta) + \rho_{00}\ \cos(\theta) - \sqrt{2}\rho_{10}\ \cos(\phi)\ \sin(2\theta) \\ -\rho_{-11}\ \cos(2\phi)\ \sin^2(\theta)$$

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

Spin density matrix cntd.

For unpolarized beam and target[3] $\Rightarrow$ independent of ϕ

$$\frac{d\sigma}{d\cos(\theta)} \propto \rho_{11}\ \sin^2(\theta) + \rho_{00}\ \cos(\theta)$$

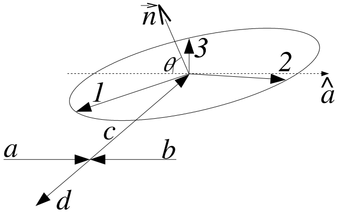
Q: θ is defined in which reference frame again?
A: Depends! Different definitions of frames make θ sensitive to different aspects of production process.

Q: And which vector defines θ?
A: So-called analyser.

[3] K. Schönning, Dissertation, Uppsala (2009)

Analyser

1. Analysing production mechanism:
   Analyser is the decaying resonance $\bar{b}$ itself.
2. Analysing polaristion of resonance:
   - for 2-body decay, use a decay particle
   - for 3 body decay, the story is more complicated
     - decay in one plane at one vertex (no isobars assumed), vertex contribution reads $ig\vec{n}\cdot\vec{e}$, where g coupling, $\vec{n}$ analyser, $\vec{e}$ polaristion vector
     - $\vec{e}$ axial, product $\vec{n}\cdot\vec{e}$ cannot be 0 $\Rightarrow$ $\vec{a}$ needs to be axial, too
     - for three spinless decay products $\pi_{1,2,3}$ off a vector meson: $\vec{n} = vec\pi_i \times vec\pi_j, i \neq j$



Reference frames

N.b.: Only $\cos(\theta)$ interesting, *i.e.* $\hat{z}$ and analyser to be defined

- Production plane: $\hat{z} = |\vec{a} \times \vec{b}|$, overall CM system
- Gottfried-Jackson frame: $\hat{z} = |\vec{a}|$, a is beam, in CM system of b
- Helicity frame: $\hat{z} = |\vec{b}|$, overall CM system
- production-relevant Gottfried-Jackson: $\hat{z} = |\vec{X}|$, X is beam, in CM system of b

Examples[4]: t-channel helicity conserved when $\sin^2(\theta)$ distribution in production-relevant Gottfried-Jackson frame ($J^P(X) = 0^+$). s-channel helicity conserved when $\sin^2(\theta)$ distribution in helicity frame, deviation means spin-flip

[4] J.Barth, Dissertation, Bonn (2002)

Reference frames cntd.

So far only relevant for single X exchange (photo-production, diffractive scattering, *etc.*)

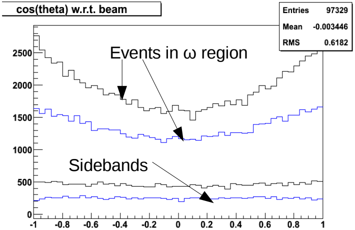
double X exchange (central production, double Reggeon exchange, *etc.*) must be treated separately:
two production planes relevant, define with either $\hat{z}_1 = |\vec{a} \times \vec{b}|$ and $\hat{z}_2 = |\vec{c} \times \vec{d}|$ or $\hat{z}_1 = |\vec{a} - \vec{b}|$ and $\hat{z}_2 = |\vec{c} - \vec{d}|$[5].

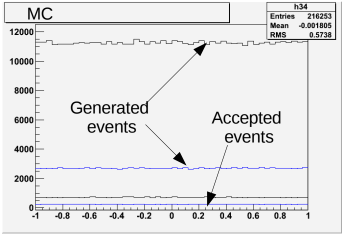
[5]Symmetrisation not yet clear to me, to be clarified.

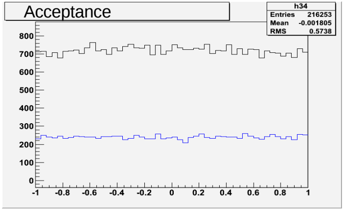
Some first results

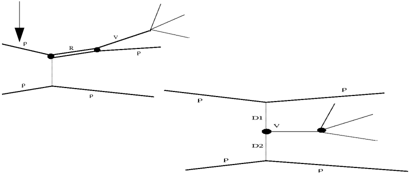
Cf. Karin's talk at last hadron meeting (Nov. 30th), $p\,p \rightarrow p\,\omega\,p$:

Cos θ w.r.t. beam direction. Black: $x_F(p_{fast}) < 0.7$, blue: $x_F(p_{fast}) > 0.7$



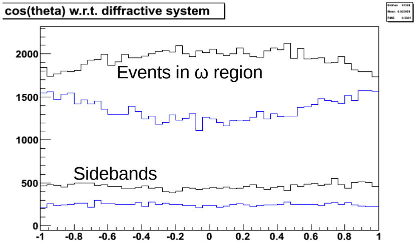


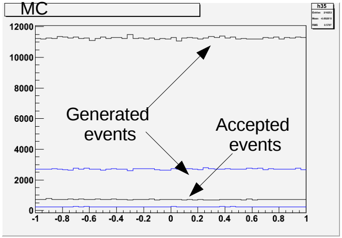


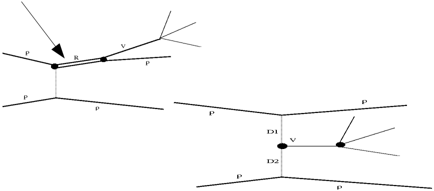


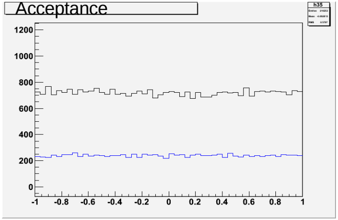
Some sensitivity to the beam directions also for high x_F

Some first results cntd.



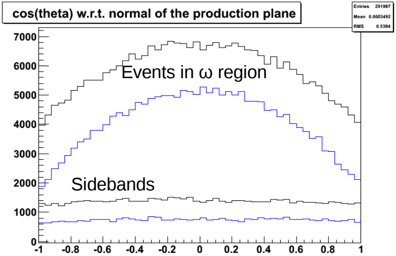


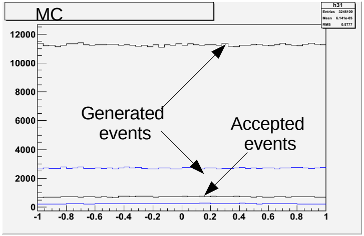


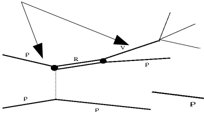


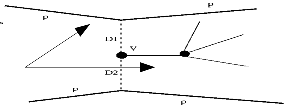
Polarisation changes sign when going from low to high x_F!

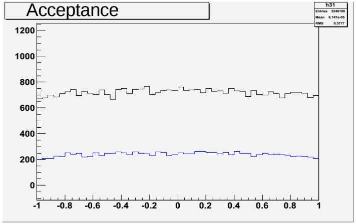
Some first results cntd.





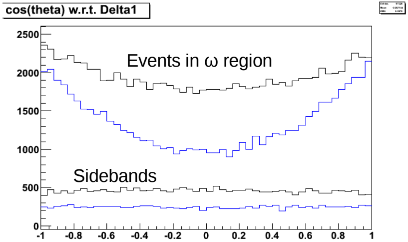


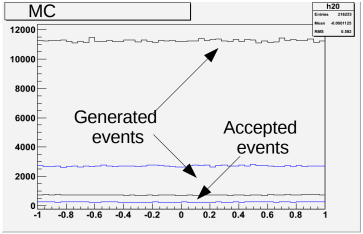


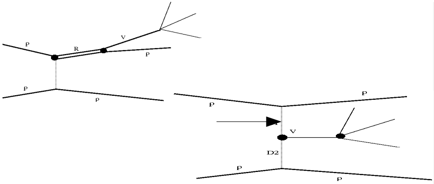


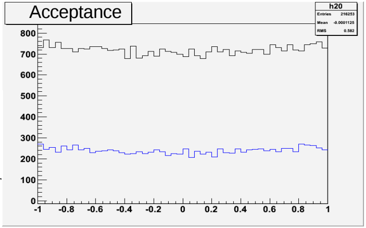
Difficult to draw conclusions about x_F dependence by eye.

Some first results cntd.



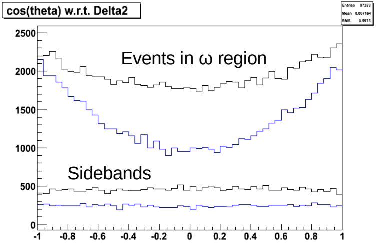


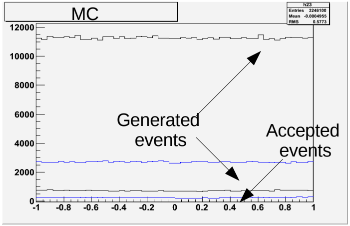


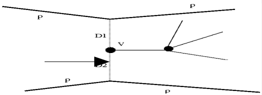


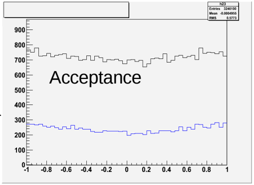
Polarisation much stronger at high x_F

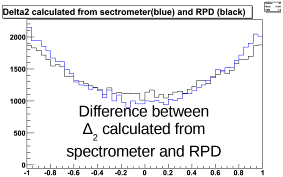
Some first results cntd.











Polarisation much stronger at high x_F

Next

Check for x_F dependence of ρ_{00} as suggested in PRD 68 (2003) 034023:

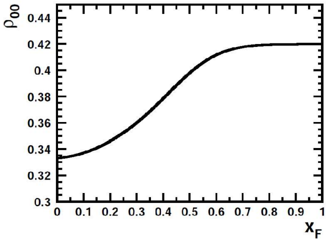


FIG. 1. Spin alignment of K^{*+} along the normal of the production plane in unpolarized $pp \to K^{*+}X$ at $p_{inc} = 200$ GeV.

Publications possible: OZI violation and angular distributions (spin alignment), both x_F, t dependent

Results from summer