First Look at the $\overline{p}p \to \overline{\Omega}^{+}\Omega^{-}$ Reaction

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Outline

- Motivation
- Formalism
- Outlook

Motivation

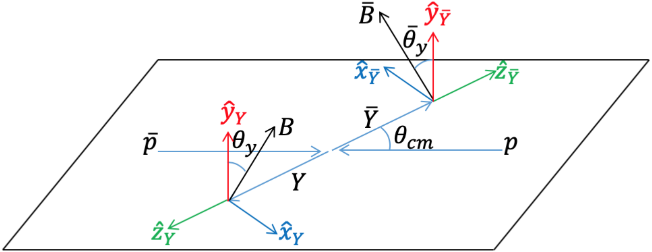
Feasibility studies of $\overline{p}p \to \overline{\Lambda}\Lambda$ and $\overline{p}p \to \overline{\Xi}^{+}\Xi^{-}$ reactions have been carried out.

- The reactions can be exclusively reconstructed while suppressing background to $S/B > 100$
- In addition to differential cross sections, polarizations and spin correlations can be measured
  $\to$ probe the spin dependence of the reactions

The $\overline{p}p \to \overline{\Omega}^{+}\Omega^{-}$ reaction is the next step

- Reaction has never been measured
- Study relevant degrees of freedom
- Measuring Λ, Ξ^{-}, Ω^{-} allows for systematic checks of *e.g.* OZI rule

Spin Observables in $\bar{p}p \to \overline{Y}Y$



Density matrix of a hyperon given by

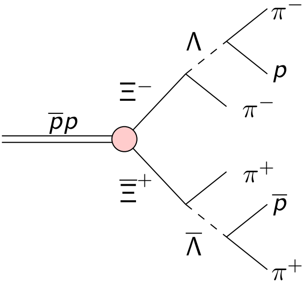
$$\rho = \frac{1}{2j+1}\mathcal{I} + \sum_{L=1}^{2j} \frac{2j}{2j+1} \sum_{M=-L}^{L} Q_M^L r_M^L$$

Angular distribution of daughters given by operating T and taking trace

$$I = Tr(T\rho T^{\dagger}),\ T\,|\Psi_i\rangle = |\Psi_f\rangle$$

Polarization in $\overline{\Xi}^+\Xi^-$

- Consider decays: $\Xi^- \to \Lambda\pi^-$, $\Lambda \to \pi^- p$
- Three polarization parameters: r^1_1, r^1_0, r^1_{-1}
- Directly related to P_x, P_y, P_z. Two are zero due to symmetry: $P_x = P_z = 0$



Looking at the first decay $\Xi^- \to \Lambda\pi^-$, the polarization P_y is accessible:

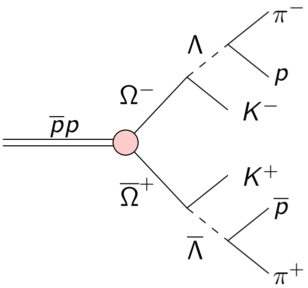
$$I(\cos\theta_y) = \frac{1}{4\pi}(1 + \alpha P_y \cos\theta_y)$$

Polarization can be extracted by calculating moments

$$\langle \cos\theta_y \rangle = \int_{-1}^{1} I(\cos\theta_y) \times \cos\theta_y \, d\cos\theta_y = \frac{3}{\alpha} P_y)$$

Polarization in $\overline{\Omega}^+\Omega^-$

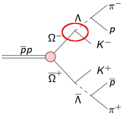
- Consider decays: $\Omega \to \Lambda K$, $\Lambda \to \pi p$
- Fifteen polarization parameters: r^L_M, $L = 1, 2, 3$, $M = -L, ..., L$
- Eight are zero due to symmetry



The angular distribution of the first decay $\Omega \to \Lambda K$ is:

$$I(\theta_\Lambda, \phi_\Lambda) = \frac{1}{4\pi}[1 + \frac{\sqrt{3}}{2}(1 - 3\cos^2\theta_\Lambda) r^2_0 - \frac{3}{2}\sin^2\theta_\Lambda \cos 2\phi r^2_2 + \frac{3}{2}\sin 2\theta_\Lambda \cos\phi r^2_1$$
$$- \frac{1}{40}\alpha \sin\theta_\Lambda (8\sqrt{15} r^1_{-1} \sin\phi_\Lambda + 9\sqrt{10} r^3_{-1}(3 + 5\cos 2\theta_\Lambda \sin\phi_\Lambda)$$
$$+ 30(3 r^3_{-2} \sin 2\phi_\Lambda \sin 2\theta_\Lambda + \sqrt{6} r^3_{-3} \sin 3\phi \sin^2\theta_\Lambda))]$$

Polarization in $\overline{\Omega}^{+}\Omega^{-}$



Three polarization parameters r_0^2, r_1^2, r_2^2 are extracted with the following expectation values:

$$\langle \sin\theta_\Lambda \rangle = \int_0^\pi \int_0^{2\pi} I(\theta_\Lambda, \phi_\Lambda) \times \sin\theta_\Lambda \sin\theta_\Lambda d\theta_\Lambda d\phi_\Lambda$$

$$= \frac{\pi}{32}(8 + \sqrt{3} r_0^2)$$

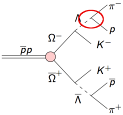
$$\langle \cos\theta_\Lambda \cos\phi_\Lambda \rangle = \int_0^\pi \int_0^{2\pi} I(\theta_\Lambda, \phi_\Lambda) \times \cos\theta_\Lambda \cos\phi_\Lambda \sin\theta_\Lambda d\theta_\Lambda d\phi_\Lambda$$

$$= -\frac{3\pi}{32} r_1^2$$

$$\langle \sin^2\phi_\Lambda \rangle = \int_0^\pi \int_0^{2\pi} I(\theta_\Lambda, \phi_\Lambda) \times \sin^2\phi_\Lambda \sin\theta_\Lambda d\theta_\Lambda d\phi_\Lambda$$

$$= \frac{1}{4}(2 + r_2^2)$$

Polarization in $\overline{\Omega}^+\Omega^-$



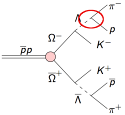
When considering the $\Lambda \to \pi p$ decay and integrating over the $\theta_\Lambda, \phi_\Lambda$ angles:

$$I(\theta_p, \phi_p) = \frac{1}{4\pi}\Big(1 + \alpha_\Omega \alpha_\Lambda \cos\theta_p + \alpha_\Lambda \left(\sqrt{\frac{3}{5}} r^1_{-1} + \frac{1}{2\sqrt{10}} r^3_{-1} \right) (\beta_\Omega \cos\phi_p + \gamma_\Omega \sin\phi_p) \sin\theta_p \Big)$$

From this distribution, the ratio $\beta_\Omega/\gamma_\Omega$ can be extracted

$$\frac{\beta_\Omega}{\gamma_\Omega} = \frac{\langle \cos\phi_p \rangle}{\langle \sin\phi_p \rangle}$$

Polarization in $\overline{\Omega}^{+}\Omega^{-}$



Extract remaining polarization parameters with following expectation values:

$$r^{1}_{-1} = \sqrt{\frac{2}{3}}\left(\sqrt{10}\frac{\langle(15\cos\theta_\Lambda - 1)\sin\phi_p\rangle}{\pi\alpha_\Lambda\gamma_\Omega} + r^{3}_{-1}\right)$$

$$r^{3}_{-1} = -\frac{4\sqrt{10}\,\langle(3\cos\theta_\Lambda - 1)\sin\phi_p\rangle}{\pi\alpha_\Lambda\gamma_\Omega}$$

$$r^{3}_{-2} = -\frac{1024\,\langle\sin\phi_\Lambda\cos\phi_p\rangle}{3\pi^2\alpha_\Lambda\gamma_\Omega}$$

$$r^{3}_{-3} = \sqrt{\frac{1}{15}}\left(-64\sqrt{10}\frac{\langle\sin\phi_\Lambda\cos\phi_\Lambda\sin\phi_p\rangle}{\pi\alpha_\Lambda\beta_\Omega} + 2\sqrt{6}r^{1}_{-1} + r^{3}_{-1}\right)$$

This requires the joint angular distribution

$$I(\theta_\Lambda, \phi_\Lambda, \theta_p, \phi_p) = \ldots$$

Outlook

New ongoing simulation study of $\overline{p}p \to \overline{\Omega}^+\Omega^-$:

- In total, eight polarization parameters and β/γ available:
  - Three parameters available in first decay $\Omega^- \to \Lambda K^-$
  - Ratio of decay parameters $\beta_\Omega/\gamma_\Omega$ available in second decay $\Lambda \to p\pi^-$
  - Remaining four polarization parameters available in joint distribution of $\Omega^- \to \Lambda K^- \to pK^-\pi^-$
- Studies just started
  - Preliminary studies shows good reconstruction efficiencies $\sim 10\%$
  - Reconstruction of r_0^2, r_1^2, r_2^2 and $\beta_\Omega/\gamma_\Omega$ looks promising
- To do:
  - Study relevant background channels
  - Implement joint angular distribution extract remaining parameters