Future Spin Observable Measurements at $\overline{\mathrm{P}}$ANDA

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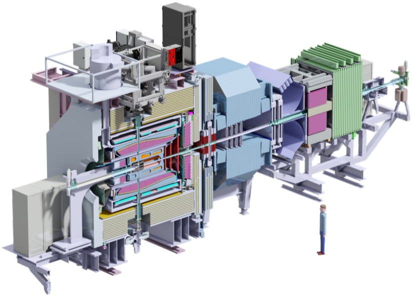
Outline

1. $\overline{\text{P}}$ANDA Detector at FAIR
2. Spin Observables
   - Polarisation in $\overline{\Xi}\Xi$
   - Polarisation in $\overline{\Omega}\Omega$
3. Previous results
4. Outlook

$\overline{\text{P}}$ANDA Detector

- Target- and forward spectrometer provide a near 4π coverage
- Antiproton $\overline{p}$ beam $1.5 \leq p_{\overline{p}} \leq 15$ GeV/c
- High resolution measurement and PID
- HESR Startup phase
  - $\mathcal{L} \sim 10^{31} \text{cm}^{-2}\text{s}^{-1}$
- HESR High Luminosity mode
  - $\mathcal{L} \sim 2 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$

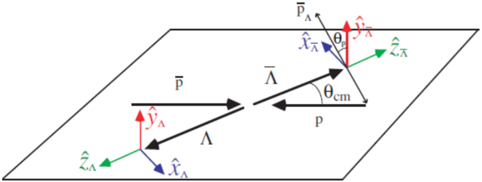


Spin Observables in $\bar{p}p \to \bar{Y}Y$

Density matrix formalism

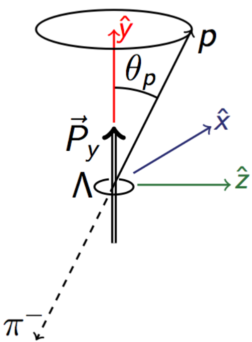
$$\rho = \frac{1}{2j+1}\mathcal{I} + \sum_{L=1}^{2j} \frac{2j}{2j+1} \sum_{M=-L}^{L} Q_M^L r_M^L$$

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



At $\overline{\text{P}}$ANDA, unpolarised beam and target:

- Polarisation
- Spin Correlation



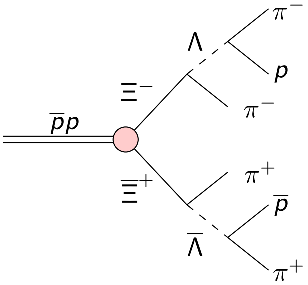
$\bar{p}p \to \bar{\Lambda}\Lambda$

Manifests in angular distributions

$$I(\cos\theta_p) \propto \frac{1}{4\pi}(1 + \alpha P_y \cos\theta_p)$$

Polarisation in $\overline{\Xi}\Xi$

- Consider decays: $\Xi \to \Lambda\pi$, $\Lambda \to \pi p$
- Three polarisation 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: $P_x = P_z = 0$
- Joint angular distribution depends on $I(\theta_\Lambda, \phi_\Lambda, \theta_p, \phi_p)$



Choosing a frame such that $\phi_\Lambda = 0$ and integrating over θ_Λ, the angular distribution is:

$$I(\theta_p, \phi_p) = \frac{1}{4\pi}\left(1 + \alpha_\Lambda\alpha_\Xi \cos\theta_p + \frac{\pi}{4}\alpha_\Lambda P \sin\theta_p(\beta_\Xi \sin\phi_p - \gamma_\Xi \cos\phi_p)\right)$$

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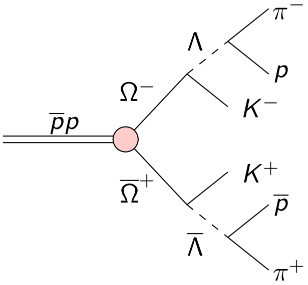
Polarisation in $\overline{\Omega}\Omega$

- Consider decays: $\Omega \to \Lambda K$, $\Lambda \to \pi p$
- Fifteen polarisation 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:

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

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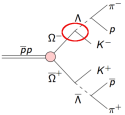
Polarisation in $\overline{\Omega}\Omega$



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

$$\langle \cos^2\theta_\Lambda \rangle = \int_0^\pi \int_0^{2\pi} I(\theta_\Lambda, \phi_\Lambda) \times \cos^2\theta_\Lambda \sin\theta_\Lambda d\theta_\Lambda d\phi_\Lambda = \frac{1}{15}(5 - 2\sqrt{3}r_0^2)$$

$$\langle \cos\theta_\Lambda \sin\theta_\Lambda \cos\phi_\Lambda \rangle = \int_0^\pi \int_0^{2\pi} I(\theta_\Lambda, \phi_\Lambda) \times \cos\theta_\Lambda \sin\theta_\Lambda \cos\phi_\Lambda \sin\theta_\Lambda d\theta_\Lambda d\phi_\Lambda = \frac{r_1^2}{5}$$

$$\langle \sin^2\theta_\Lambda \sin^2\phi_\Lambda \rangle = \int_0^\pi \int_0^{2\pi} I(\theta_\Lambda, \phi_\Lambda) \times \sin^2\theta_\Lambda \sin^2\phi_\Lambda \sin\theta_\Lambda d\theta_\Lambda d\phi_\Lambda = \frac{1}{15}(5 + \sqrt{3}r_0^2 + 3r_2^2)$$

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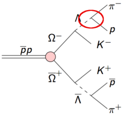
Polarisation in $\overline{\Omega}\Omega$



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

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

Extract remaining polarisation parameters with following expectation values:

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

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

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

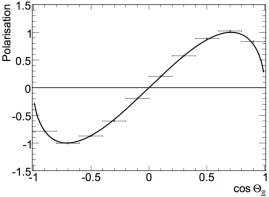
$$r^3_{-3} = \sqrt{\frac{1}{15}} \left(-64\sqrt{10} \frac{\langle \sin\phi_\Lambda \cos\phi_\Lambda \sin\phi_p \rangle}{\pi \alpha_\Lambda \beta_\Omega} + 2\sqrt{6} r^1_{-1} + r^3_{-1} \right)$$

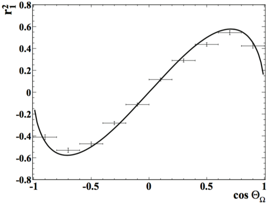
Previous results

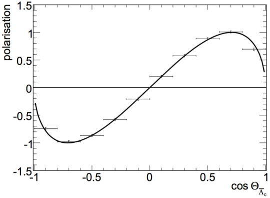
Using a simplified Monte Carlo framework:

$p_{\bar{p}}$ (GeV/c)	Reaction	σ (μb)	Eff (%)	Decay	BR (%)	Rate
1.64	$\bar{p}p \to \bar{\Lambda}\Lambda$	64	10	$\Lambda \to p\pi^-$	64	28 s^{-1}
4.0	$\bar{p}p \to \bar{\Xi}^+\Xi^-$	$\sim$2	20	$\Xi^- \to \Lambda\pi^-$	$\sim$ 100	2 s^{-1}
12.0	$\bar{p}p \to \bar{\Omega}^+\Omega^-$	$\sim$0.002*	$\sim$30	$\Omega^- \to \Lambda K^-$	68	$\sim$4 h^{-1}
12.0	$\bar{p}p \to \bar{\Lambda}_c\Lambda_c$	$\sim$0.1*	$\sim$30	$\Lambda_c \to \Lambda\pi^+$	$\sim$ 1	$\sim$2 d^{-1}

All measurements are exclusive!

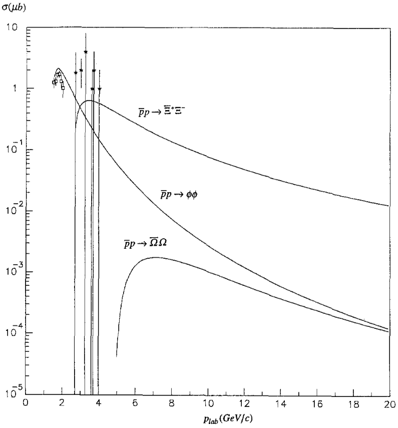






Erik Thomé, PhD thesis, Uppsala University
Sophie Grape, PhD thesis, Uppsala University

Cross section prediction



A.B Kaidalov, P.E. Volkovitsky
Z. Phys C 63, 517-524 (1994)

During first two years of data taking: 80 days beam time to X(3872) scan

- X(3872) scan operate at $p_{\overline{p}} = 7.0$ GeV/c
- Above production threshold of $\overline{\Omega}\Omega$ and $\overline{\Xi}\Xi$

Theoretical prediction shows:

- Cross section of $\overline{\Omega}\Omega$ larger at 7.0 than 12.0 GeV/c
- Cross section of $\overline{\Xi}\Xi$ smaller

Outlook

New ongoing simulation studies:

- Study $\overline{p}p \to \overline{\Lambda}\Lambda$, $\overline{p}p \to \overline{\Xi}\Xi$ and $\overline{p}p \to \overline{\Omega}\Omega$ channels
- Improved software (PANDAroot):
  - Realistic detector description
  - New software tools for track reconstruction and PID
- Different energy regimes:
  - $\overline{\Omega}\Omega$ @ 7.0 GeV/c, higher cross sections
  - $\overline{\Xi}\Xi$ @ 7.0 GeV/c, lower cross sections
- Study relevant background channels

Two papers are foreseen:

- Journal paper on $\overline{\text{P}}$ANDA starting program
- Paper on Spin Observable measurements in $\overline{p}p \to \overline{\Omega}\Omega$