Prospects for $\bar{p}p \to \bar{Y}Y$ studies at PANDA

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Motivation

- The Okubo-Zweig-Iizuka (OZI) rule states that processes with disconnected quark lines are suppressed. Since in $\bar{p}p \to \bar{Y}Y$, different $\bar{Y}Y$ are produced by annihilation of $\bar{u}u$ or $\bar{d}d$ and creation of different number of $\bar{s}s$, the OZI rule can be checked by studying the formation of Y with different number of disconnected lines (see left side of fig 1).

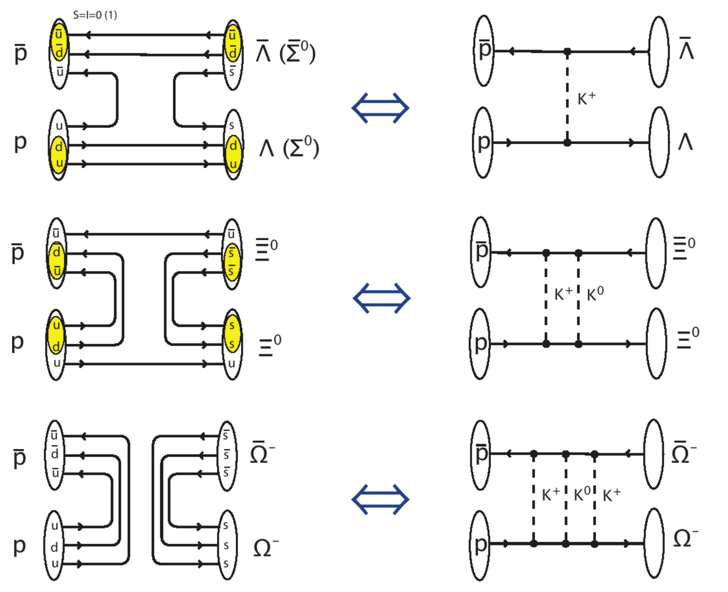

Fig 1: Quark line (left) and meson exchange picture (right) for $\bar{p}p \to \bar{Y}Y$

- Since the mass of the strange quark is close to the QCD cut-off (Λ_{QCD}), the degrees of freedom are ambiguous. Meson exchange and quark-gluon models exist (see fig 1) but more data are needed to find out which picture is the most relevant.
- Most ground state hyperons decay by weak decay (parity violating). By studying the distribution of the decay products one has access to spin degrees of freedom in strangeness and charm production (e.g. hyperon polarisation and spin correlations).
- PANDA experiment can energetically access all strange hyperons and single charmed hyperons. For multiple strangeness or charm production above 2 GeV/c beam momentum, no differential cross-sections or spin observables have been studied.

PANDA experiment

Specially important for $\bar{p}p \to \bar{Y}Y$ is a good vertex reconstruction (Micro Vertex Detector).

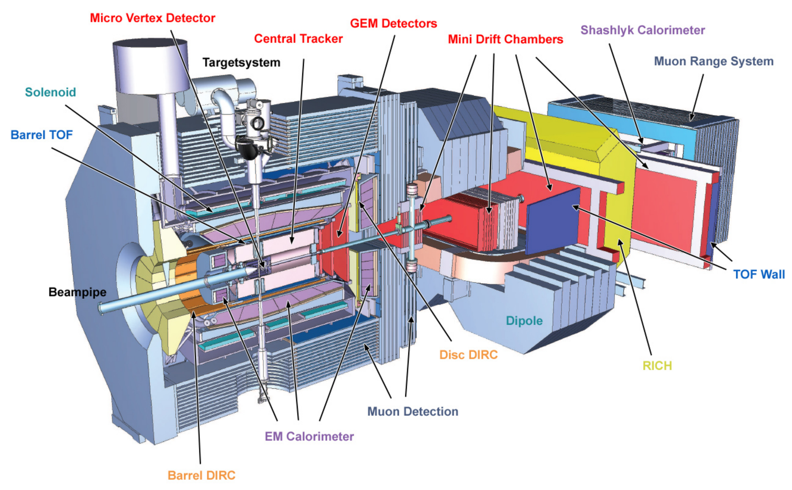

Fig 2: The PANDA detector [2]

Spin Variables for spin 1/2 particles

The spin variables are defined in the reference system of fig 3. The center of mass production angle θ is used in the following sections.

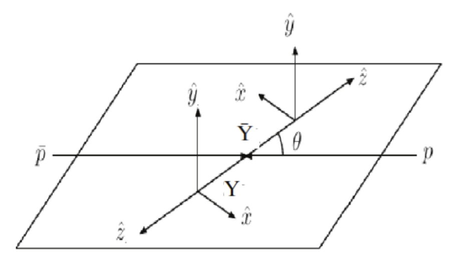

Fig 3: Reference system for spin variables.

In PANDA both target and beam are unpolarized, so the accessible spin variables are polarisation and spin correlations.

Simulations of $\bar{p}p \to \bar{\Xi}^+\Xi^-$

- With $\Xi^- \to \Lambda\pi^-$ (BR$\approx 100\%$) and $\Lambda \to p\pi^-$ (BR$= 64\%$)
- Generated $4 \cdot 10^6$ events isotropically, beam momentum 4 GeV/c
- Background assumed small (because of the 4 displaced vertices). $\bar{p}p \to \bar{\Sigma}(1385)^+\Sigma(1385)^-$ studied as main background: signal to noise ratio at least 5000. Direct $\bar{p}p \to \bar{\Lambda}\Lambda\pi^+\pi^-$ should be studied.
- Expect 30 reconstructed events/s

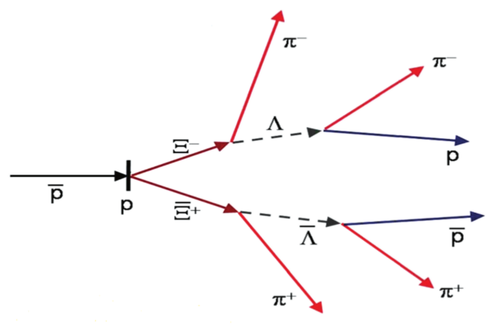

Fig 4: Schematic view of the reaction

By measuring the weak decay of the daughter hyperon more information can be obtained.

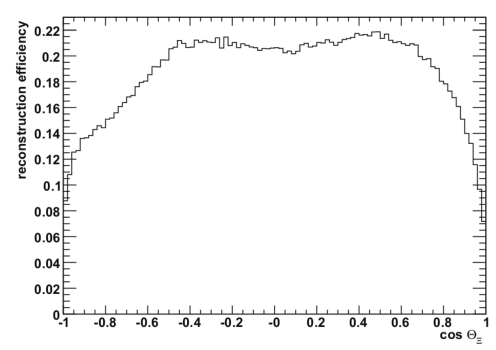

Fig 5: Reconstruction efficiency

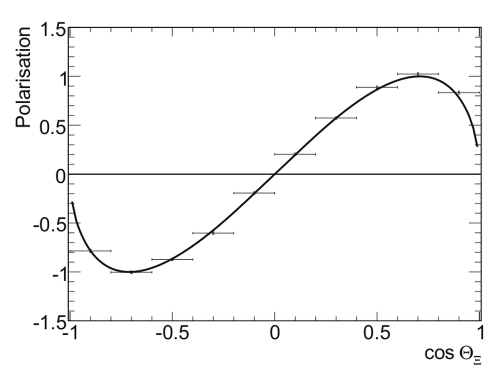

Fig 6: Ξ polarisation (average of $\bar{\Xi}^+$ and Ξ^-). Line shows input.

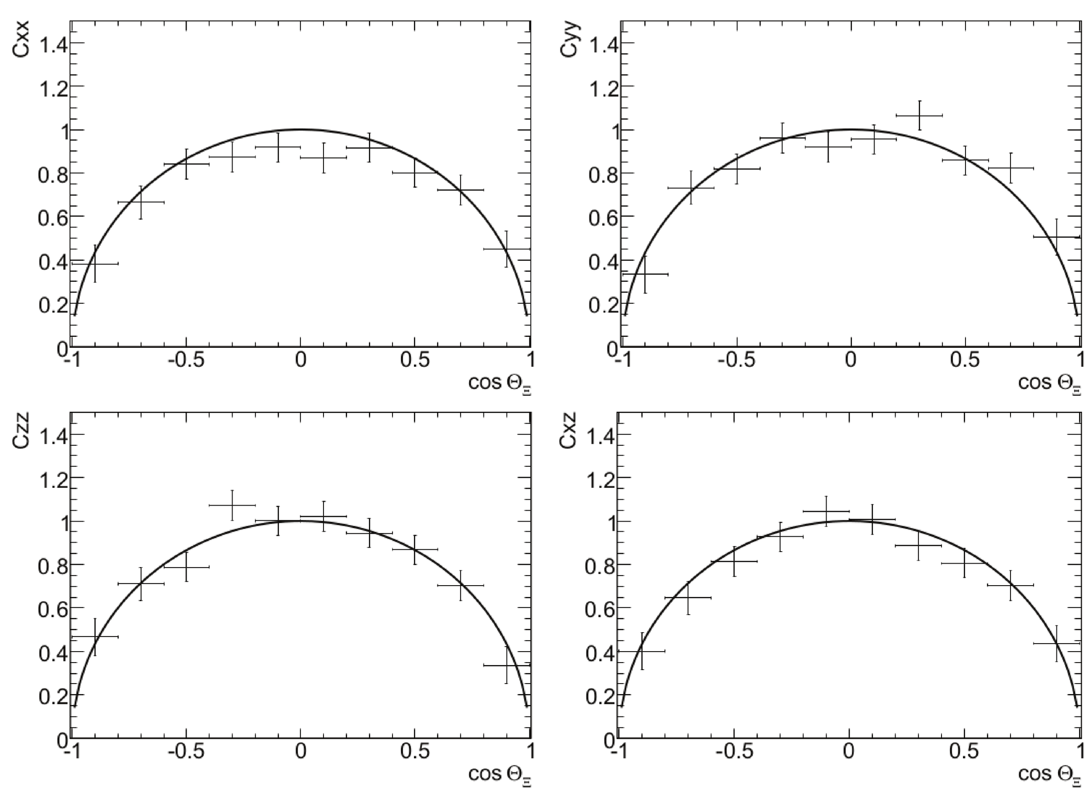

Fig 7: $\bar{\Xi}^+\Xi^-$ spin correlations as function of CM production angle. Black line shows input. Cxz is taken as average of Cxz and Czx.

Simulations of $\bar{p}p \to \bar{\Lambda}_c^-\Lambda_c^+$

- With $\Lambda_c^+ \to \Lambda\pi^+$ (BR$= 1\%$) and $\Lambda \to p\pi^-$ (BR$= 64\%$)
- Generated $1 \cdot 10^5$ events isotropically, beam momentum 12 GeV/c
- Background situation probably not as good as other decays (Λ_c^+ decays close to interaction point). For example $\Sigma(2030)$ and $\Sigma(2250)$ decaying to $\Lambda\pi$ could give background.
- Expect 25 reconstructed events/day

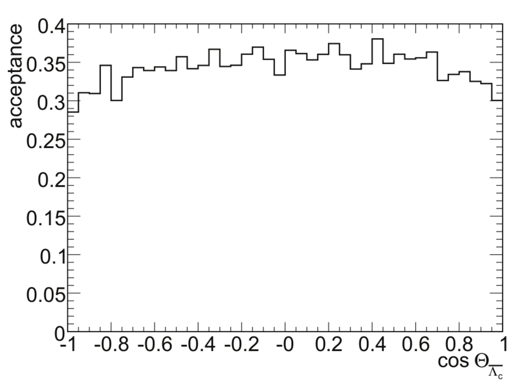

Fig 8: Reconstruction efficiency

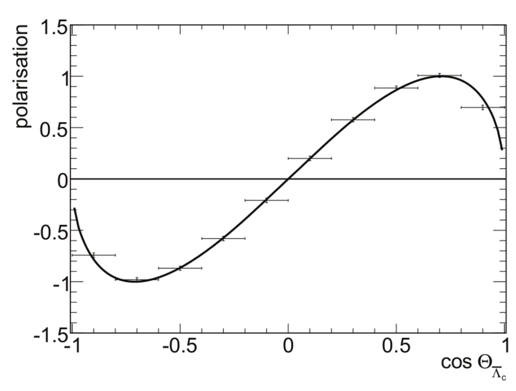

Fig 9: Λ_c polarisation (av. of $\bar{\Lambda}_c^-$ and Λ_c^+). Line shows input.

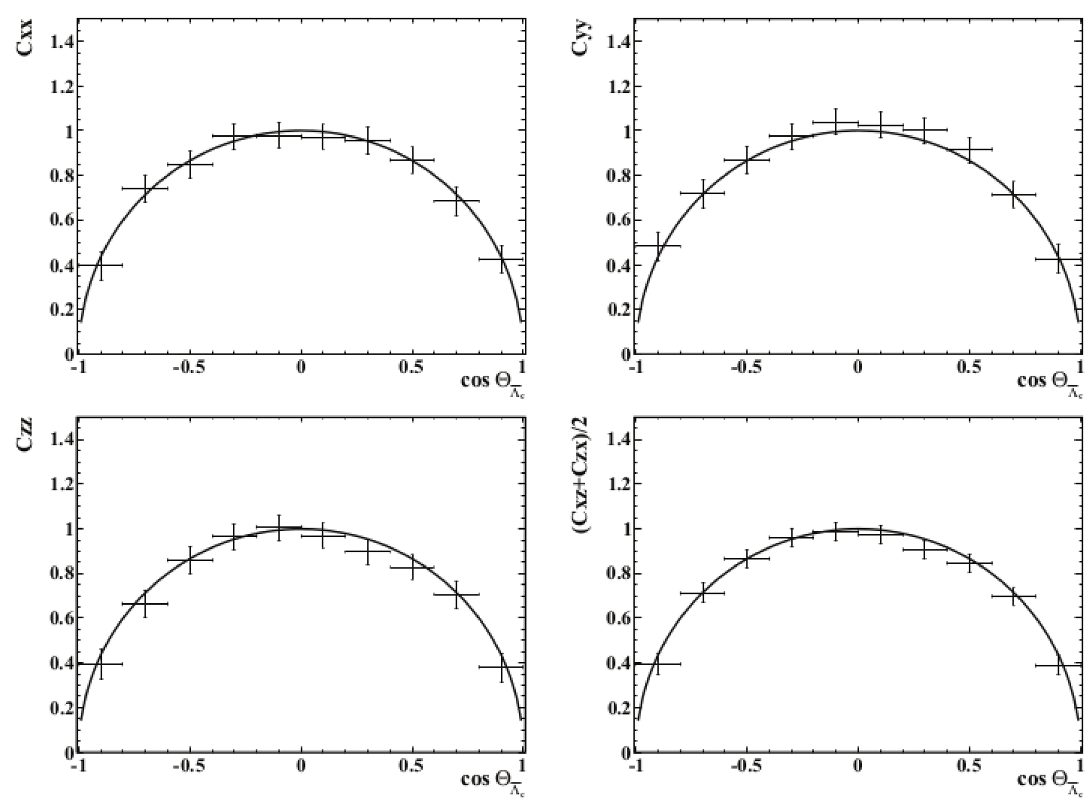

Fig 10: Λ_c spin correlations as function of CM production angle. Black line shows input. Cxy is taken as average of Cxz and Czx.

Simulations of $\bar{p}p \to \bar{\Omega}^+\Omega^-$

- With $\Omega^- \to \Lambda K^-$ (BR$= 68\%$) and $\Lambda \to p\pi^-$ (BR$= 64\%$)
- Generated $1 \cdot 10^5$ events isotropically, beam momentum 12 GeV/c
- Background assumed small (because of the 4 displaced vertices). However, the resonances $\Sigma(1670)$ and $\Sigma(1775)$ decaying to $\Lambda\pi$ have unknown production cross-section and could contribute to background.
- Expect 80 reconstructed events/hour (assumed $\sigma = 2$nb)

For all parameters, the average between Ω^- and $\bar{\Omega}^+$ is taken

The polarisation parameter L (up to a sign) and ϕ ($\tan\phi = \frac{\beta_\Omega}{\gamma_\Omega}$) [1] can be measured (specially for $\alpha_\Omega \approx 0$).

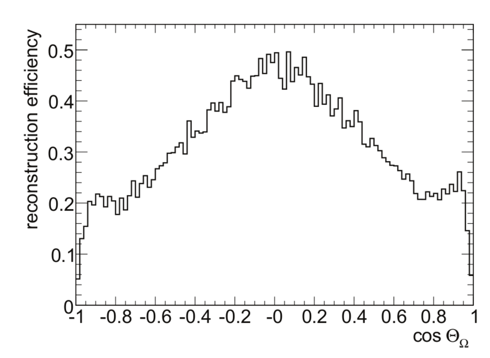

Fig 11: Reconstruction efficiency

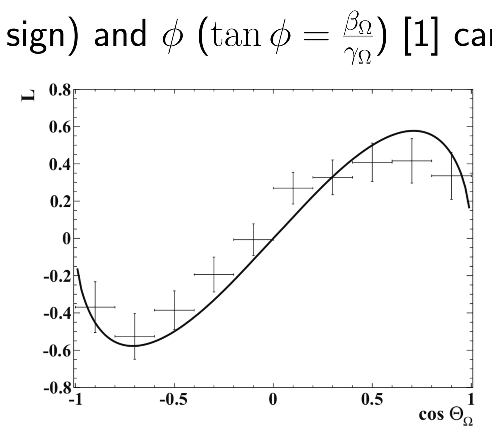

Fig 13: L for assumed $\phi = 0$.

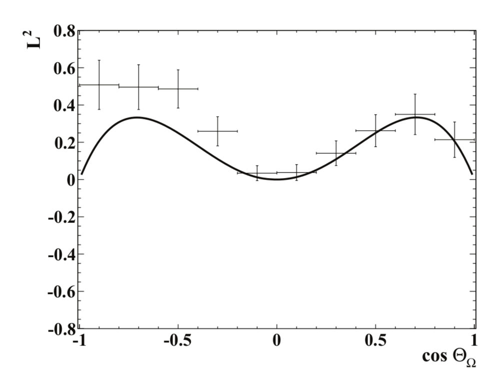

Fig 15: L^2 for assumed $\phi = 45°$.

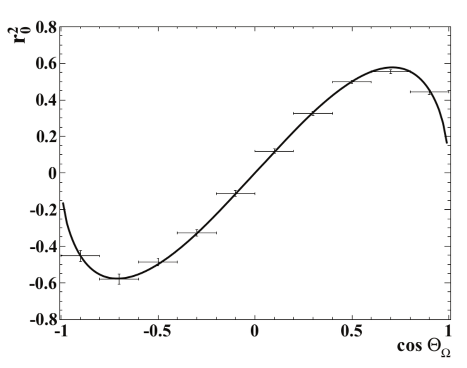

Fig 12: Polarisation parameter r_0^2.

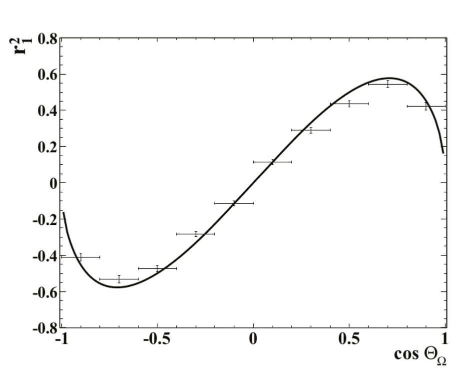

Fig 14: Polarisation parameter r_1^2.

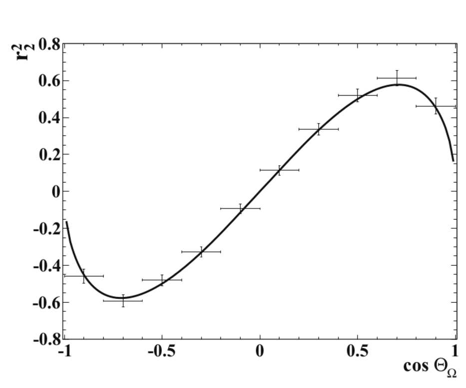

Fig 16: Polarisation parameter r_2^2.

Conclusions

- Since the reconstruction efficiency is non-zero for all three studied channels (see fig 5, 8 and 11), differential cross-section and spin variables can be reconstructed for all production angles.
- Spin variables are well reconstructed over the range of possible values.
- CP violation parameter $A = \frac{\alpha+\bar{\alpha}}{\alpha-\bar{\alpha}}$, with competitive accuracy, can be reconstructed for $\bar{p}p \to \bar{\Lambda}\Lambda$ in approximately 80 days (with beam momentum 1.64 GeV/c).
- CP violation parameter A should be reconstructable also for $\bar{p}p \to \bar{\Xi}^+\Xi^-$.
- For $\bar{p}p \to \bar{\Lambda}_c^-\Lambda_c^+$ and $\bar{p}p \to \bar{\Omega}^+\Omega^-$ PANDA can provide first differential cross-section measurements.

Outlook

- These studies will be repeated with the new analysis tool PANDAROOT, for more realistic detector and readout implementation.
- More careful background studies will be performed.

References

[1] E. Thomé, *Multi-Strange and Charmed Antihyperon-Hyperon Physics for PANDA*, PhD thesis ISBN 978-91-554-8497-2 (2012)

[2] M.F.M. Lutz *et al.* [PANDA Collaboration], *Physics Performance Report for PANDA: Strong INteraction Studies with Antiprotons*, arXiv:0903.3905 [hep-ex]