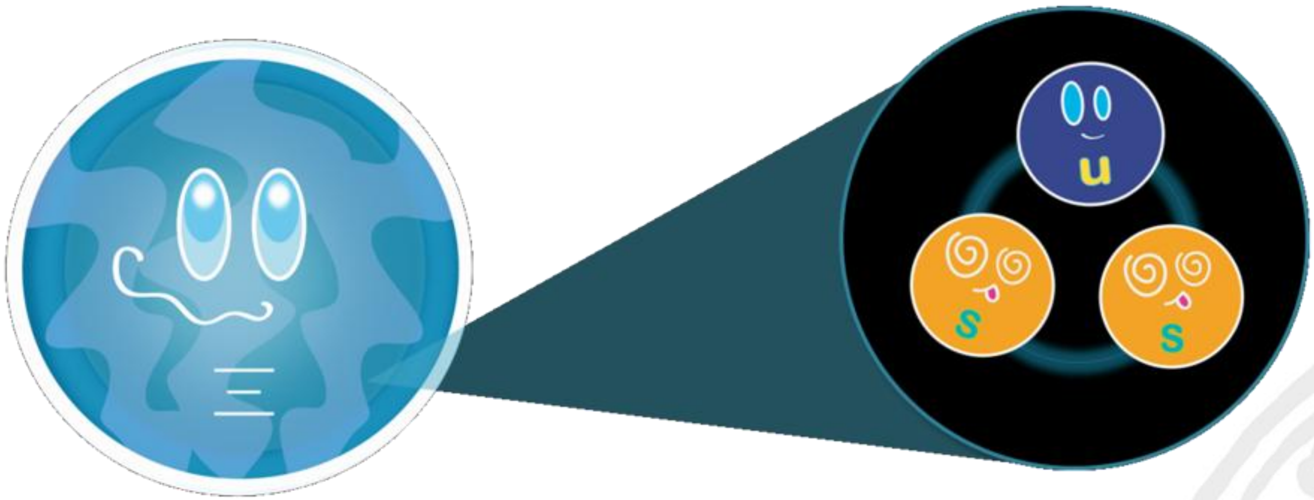
Hyperon production in antiproton-proton annihilations with PANDA



Karin Schönning, Uppsala University

at the FAIRNESS Workshop for Young Scientists,
Sept. 15-21, 2013, Berlin, Germany

Outline

- Strangeness production – a probe of QCD in the confinement domain
- Strange and charmed hyperons *Y*
- Spin observables in $\bar{p}p \to \bar{Y}Y$
  - spin $\frac{1}{2}$ hyperons
  - spin $\frac{3}{2}$ hyperons
- CP violation
- Existing data
- Prospects for PANDA

Strangeness production – a probe of QCD in the confinement domain

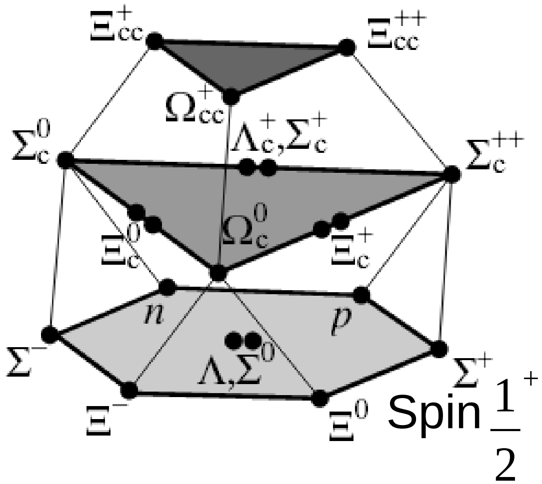
One of the most important questions in contemporary physics:

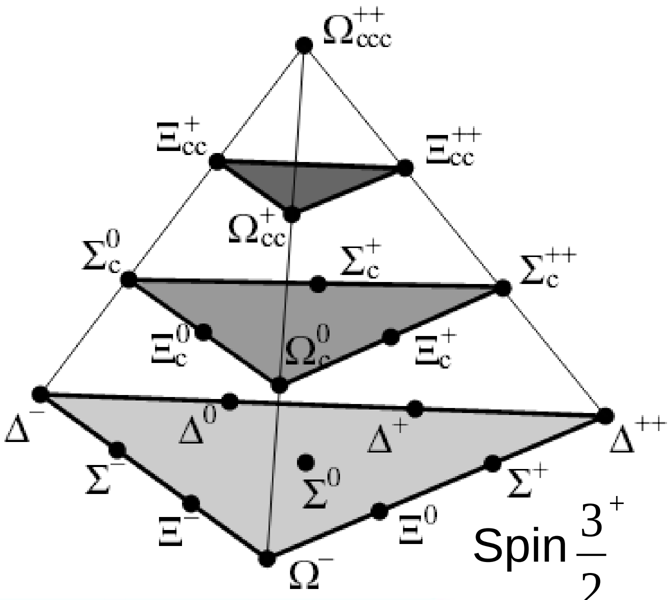
”What is the nature of the strong interaction in the confinement domain?”

- Light quark (*u, d*) production: non-perturbative, relevant degrees of freedom are hadrons, interactions described by Effective Field Theories.
- Scale of strangeness production ≈ m_s ≈ 150 MeV near QCD cut-off Λ_{QCD}≈ 200 MeV → relevant degrees of freedom ambiguous.
- Scale of charm production ≈ m_c ≈ 1300 MeV almost ten times larger. pQCD more relevant.

→ Strangeness production probes the intermediate domain which we know very little about!

Strange and charmed hyperons





Hyperons contain one or more heavy quarks (*s,c,b*). This talk: focus on strangeness and single charm.

SU(4) predicts two 20-plets.

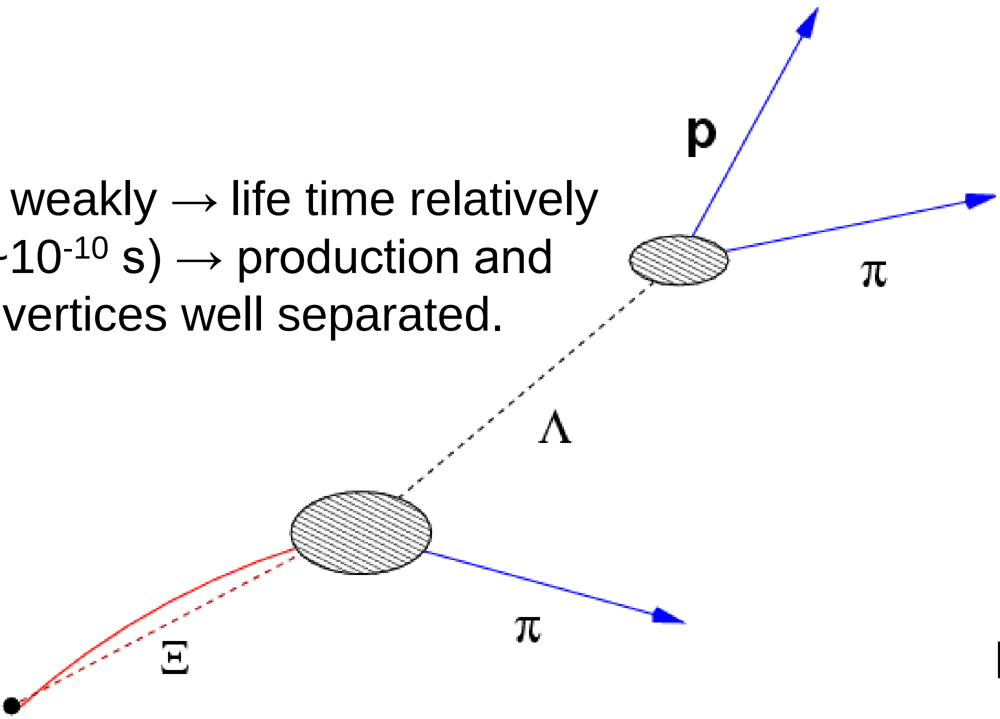
We know that SU(4) is not a good symmetry ($m_c >> m_{s,u,d}$).

SU(3) is approximately valid and the SU(3) octet and decuplet are confirmed by experiment.

Strange and charmed hyperons

$$
\begin{array}{ccccccccc}
\bar{p}p \to & \bar{\Lambda}\Lambda, & \bar{\Sigma}^-\Sigma^+, & \bar{\Sigma}^0\Sigma^0, & \bar{\Sigma}^-\Sigma^+, & \bar{\Xi}^0\Xi^0, & \bar{\Xi}^+\Xi^-, & \bar{\Omega}^+\Omega^-, & \bar{\Lambda}_c^-\Lambda_c^+ \\
& \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\
& p\pi^- & p\pi^0 & \Lambda\gamma & n\pi & \Lambda\pi^0 & \Lambda\pi & \Lambda K & \Lambda\pi \\
& 64\% & 52\% & \approx 100\% & \approx 100\% & \approx 100\% & \approx 100\% & 68\% & \approx 1\%
\end{array}
$$

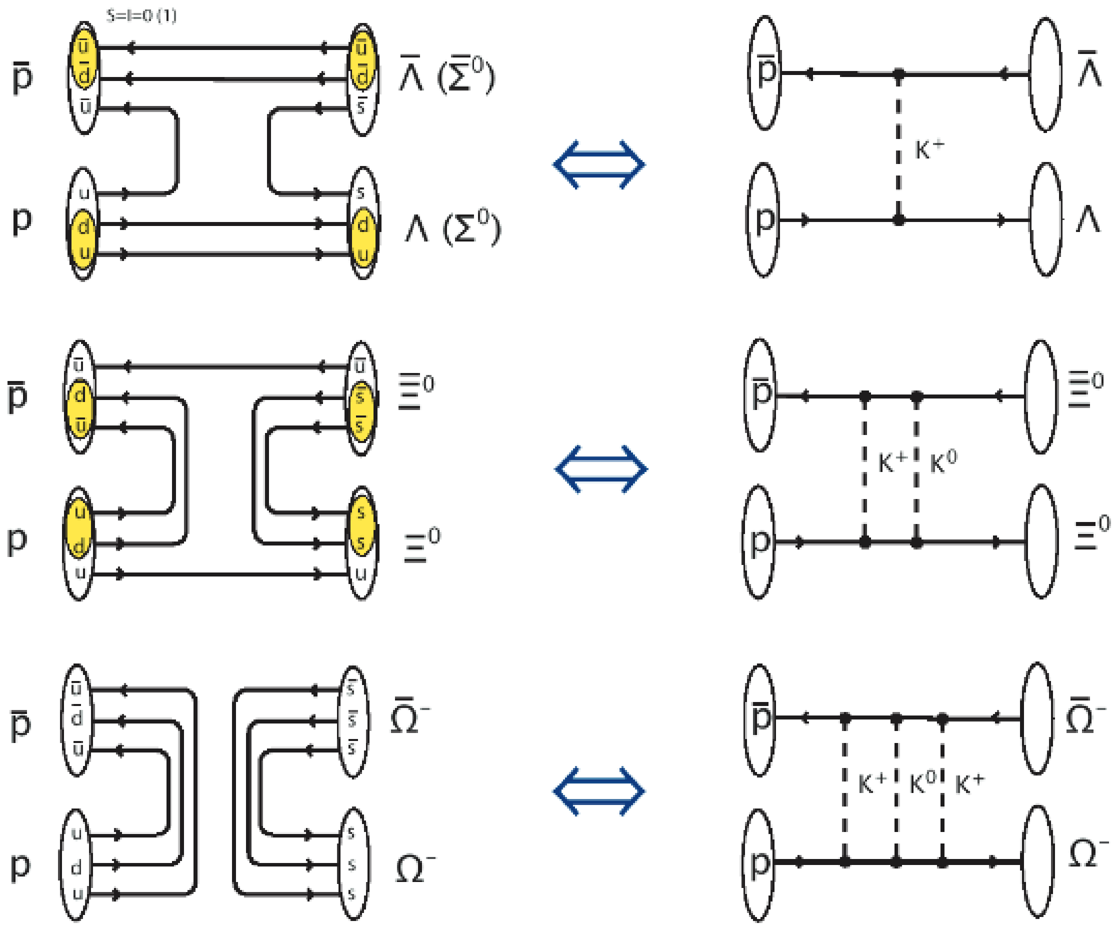
Decay weakly → life time relatively long (~10^{-10} s) → production and decay vertices well separated.



But how are they produced?

Strangeness production – a probe of QCD in the confinement domain

Models based on the quark-gluon picture* and on the hadron picture** or a combination of the two ***



*PLB 179 (1986); PLB 165 (1985) 187; NPA 468 (1985) 669;
** PRC 31(1985) 1857; PLB179 (1986); PLB 214 (1988) 317;
*** PLB 696 (2011) 352.

Open questions in hyperon physics

- What are the relevant degrees of freedom?
- To what extent is SU(3) symmetry broken?
- Do all hyperons have the expected spin and parity?
- Quark structure of hyperons?
- Universe consists of matter, not antimatter. Why?
  CP violation needed as a part of the explaination.*
  CP violation = physics beyond the Standard Model?

* A.D. Sakharov, JETP Lett 5 (1976)24

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

Spin observables is a powerful tool in testing models.

In a pure ensemble the expectation value of an observable *E* is *:*

$$\langle E \rangle = \langle \Psi | E | \Psi \rangle$$

where the $|\Psi\rangle$ ket describe every member of the ensemble.

Introduce an orthonormal basis $\{|a_k\rangle\}$:

$$\langle E \rangle = \langle \Psi | \left(\sum_k |\alpha_k\rangle\langle\alpha_k| \right) E|\Psi\rangle = \sum_k \langle\Psi|\alpha_k\rangle\langle\alpha_k|E|\Psi\rangle =$$

$$= \sum_k \langle\alpha_k|E|\Psi\rangle\langle\Psi|\alpha_k\rangle = \mathrm{Tr}\left(E|\Psi\rangle\langle\Psi|\right)$$

If the density matrix is defined by $\rho \equiv |\Psi\rangle\langle\Psi|$, then $\langle E \rangle = Tr(E\rho)$.

The density matrix transforms as

$$\rho_{final} = T\rho_{initial}T^{\dagger}$$

In case of decay of a particle with spin density matrix ρ, the angular distribution of the daughter particle is given by

$$I = Tr(T\rho_{initial}T^{\dagger})$$

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

The spin density matrix of a particle with arbitrary spin is given by

$$\rho = \underbrace{\frac{1}{2j+1}\mathscr{I}}_{\text{Unpolarised}} + \underbrace{\sum_{L=1}^{2j}\rho^L}_{\text{Polarised}} \quad \text{with} \quad \rho^L = \frac{2j}{2j+1}\sum_{M=-L}^{L} Q_M^L r_M^L$$

where Q_M^L are hermitian matrices and r_M^L polarisation parameters.

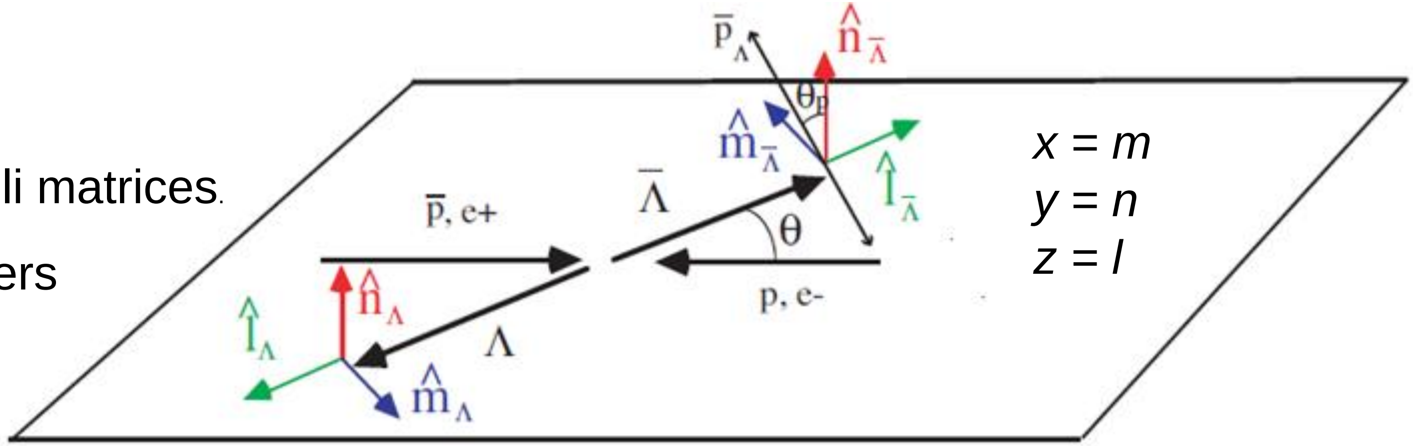
- Spin $\frac{1}{2}$: **3** polarisation parameters: $\boldsymbol{r_{-1}^1}$, $\boldsymbol{r_0^1}$ and $\boldsymbol{r_1^1}$.
- Spin $\frac{3}{2}$: **15** polarisation parameters: $\boldsymbol{r_{-1}^1, r_0^1, r_1^1, r_{-2}^2, r_{-1}^2, r_0^2, r_1^2, r_2^2, r_{-3}^3, r_{-2}^3, r_{-1}^3, r_0^3, r_1^3, r_2^3}$ and $\boldsymbol{r_3^3}$.
- Degree of polarisation given by:

$$d(\rho) = \sqrt{\sum_{L=1}^{2j}\sum_{M=-L}^{L}(r_M^L)^2}$$

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

Spin $\frac{1}{2}$:

- The Q_M^L are the Pauli matrices.
- Polarisation parameters r_0^1, r_{-1}^1 and r_1^1 are P_x, P_y and P_z.



$x = m$
$y = n$
$z = l$

The spin density matrix of one spin $\frac{1}{2}$ particle is given by:

$$\rho(1/2) = \frac{1}{2}(\mathscr{I} + \bar{P}\cdot\bar{\sigma}) = \frac{1}{2}\begin{bmatrix} 1+P_z & P_x+iP_y \\ P_x-iP_y & 1-P_z \end{bmatrix}$$

Symmetry from parity conservation (strong production) requires $P_x = P_z = 0$, which gives:

$$\rho(1/2) = \frac{1}{2}\begin{bmatrix} 1 & iP_y \\ -iP_y & 1 \end{bmatrix}$$

Polarisation normal to the production plane!

Spin observables in $\bar{p}p \rightarrow \bar{Y}Y$

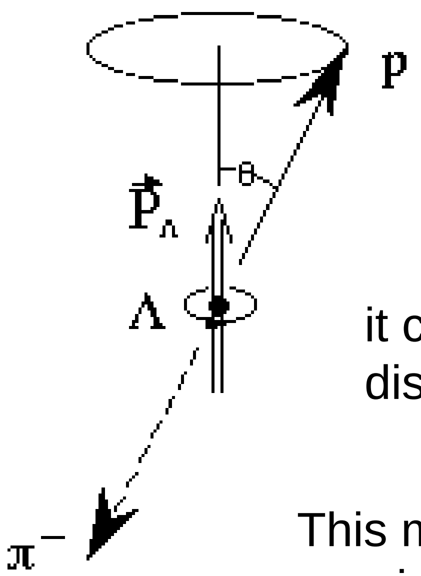
Spin $\frac{1}{2}$ hyperons:

Parity violating decay → the decay products are emitted according to the polarisation of the mother hyperon.

Angular distribution of the final state is given by $I(\theta,\varphi) = Tr(T\rho T^*)$
where T is the decay matrix with one p-conserving part T_s and one p-violating part T_p.

If one defines
$$\alpha = 2\mathrm{Re}(T_s^* T_p)$$
$$\beta = 2\mathrm{Im}(T_s^* T_p)$$
$$\gamma = |T_s|^2 - |T_p|^2$$

$\alpha^2 + \beta^2 + \gamma^2 = 1$



it can be shown that the decay angular distribution becomes

$$I(\cos\theta_p) = N(1+\alpha P_Y \cos\theta_p)$$

This makes the polarisation of hyperon experimentally accessible.

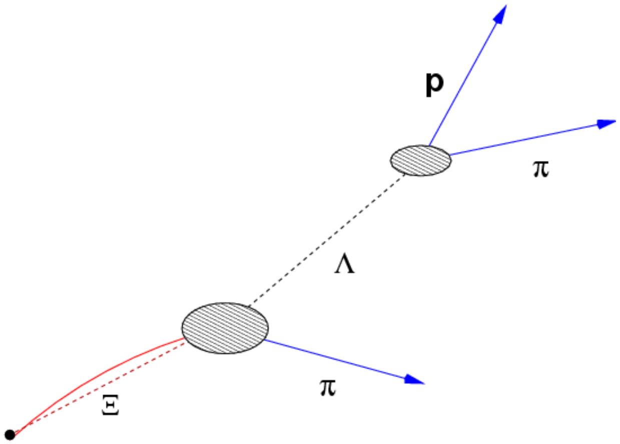
Spin observables in $\bar{p}p \rightarrow \bar{Y}Y$

If the decay product of the hyperon is a hyperon, *e.g.* $\Xi \rightarrow \Lambda K$, then also β and γ can be obtained from the decay protons of the Λ.

Redefine reference system such that:
-Spin of Ξ along ž
- p_Λ in xz-plane ($p_y = 0$)

Then the proton angular distribution becomes:

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



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

The spin observables of the full $\bar{p}p \to \bar{Y}Y$ process can be obtained from the angular distributions of decay baryons, using

$$\rho^{\bar{B}B} = \frac{I_0^{\bar{Y}Y}}{16\pi} \sum_{\mu,\nu=0}^{3} \sum_{i,j=0}^{3} P_i^{\bar{p}} P_j^{p} \chi_{ij\mu\nu} T_{\bar{Y}} T_{Y} \sigma_\mu^1 \sigma_\nu^2 T_{\bar{Y}}^\dagger T_Y^\dagger$$

where P_j^p is the polarisation vectors of the initial proton, and

$$\chi_{ij\mu\nu} = \frac{\mathrm{Tr}(\sigma_\mu^1 \sigma_\nu^2 M \sigma_i^1 \sigma_j^2 M^\dagger)}{\mathrm{Tr}(MM^\dagger)}$$ and $$I_0^{\bar{Y}Y} = \frac{1}{4}\mathrm{Tr}(MM^\dagger)$$

256 spin variables — unpol. ang. distribution

Polarised Particle	None	Beam	Target	Both
None	I_{0000}	A_{i000}	A_{0j00}	A_{ij00}
Scattered	$P_{00\mu0}$	$D_{i0\mu0}$	$K_{0j\mu0}$	$M_{ij\mu0}$
Recoil	$P_{000\nu}$	$K_{i00\nu}$	$D_{0j0\nu}$	$N_{ij0\nu}$
Both	$C_{00\mu\nu}$	$C_{i0\mu\nu}$	$C_{0j\mu\nu}$	$C_{ij\mu\nu}$

I – angular distribution
A – analysing power
P – polarisation
D – depolarisation
K – polarisation transfer
C – spin correlations
M, N – spin corr. tensor

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

The angular distribution is obtained by the trace $I_0^{\bar{\mathrm{B}}\mathrm{B}} = \mathrm{Tr}(\rho^{\bar{\mathrm{B}}\mathrm{B}})$.

With an unpolarised beam and unpolarised taget this becomes

$$I_{\bar{B}B}(\Theta_{\bar{Y}}, \hat{\bar{k}}, \hat{k}) = \frac{I_0}{64\pi^3} \left(\begin{array}{l} 1 \\ +P_{\bar{Y},y}\bar{\alpha}\bar{k}_y + P_{Y,y}\alpha k_y \\ +C_{xx}\bar{\alpha}\alpha\bar{k}_x k_x \\ +C_{yy}\bar{\alpha}\alpha\bar{k}_y k_y \\ +C_{zz}\bar{\alpha}\alpha\bar{k}_z k_z \\ +C_{xz}\bar{\alpha}\alpha\bar{k}_x k_z \\ +C_{zx}\bar{\alpha}\alpha\bar{k}_z k_x \quad . \end{array} \right)$$

k being the direction vector of the decay proton.

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

Spin $\frac{3}{2}$ case much more complicated.

Erik Thomé has derived the observables in his Ph. D. thesis.*

The spin density matrix is given by

$$\rho(3/2) =$$

$$= \frac{1}{4}\begin{bmatrix} 1+\sqrt{3}r^2_0 & i\frac{3}{\sqrt{5}}r^1_{-1} - \sqrt{3}r^2_1 & \sqrt{3}r^2_2 - i\sqrt{3}r^3_{-2} & -i\sqrt{6}r^3_{-3} \\ -i\frac{3}{\sqrt{5}}r^1_{-1} - \sqrt{3}r^2_1 & 1-\sqrt{3}r^2_0 & i2\sqrt{\frac{3}{5}}r^1_{-1} + i3\sqrt{\frac{2}{5}}r^3_{-1} & \sqrt{3}r^2_2 + i\sqrt{3}r^3_{-2} \\ \sqrt{3}r^2_2 + i\sqrt{3}r^3_{-2} & -i2\sqrt{\frac{3}{5}}r^1_{-1} - i3\sqrt{\frac{2}{5}}r^3_{-1} & 1-\sqrt{3}r^2_0 & i\frac{3}{\sqrt{5}}r^1_{-1} + \sqrt{3}r^2_1 \\ i\sqrt{6}r^3_{-3} & \sqrt{3}r^2_2 - i\sqrt{3}r^3_{-2} & -i\frac{3}{\sqrt{5}}r^1_{-1} + \sqrt{3}r^2_1 & 1+\sqrt{3}r^2_0 \end{bmatrix}$$

*Erik Thomé, *Multistrange and Charmed Antihyperon-Hyperon Physics for PANDA*
Ph. D. Thesis, Uppsala University (2012)

Spin observables in $\bar{p}p \rightarrow \bar{Y}Y$

Spin $\frac{3}{2}$ hyperons

In the case of $p\bar{p} \rightarrow \Omega\bar{\Omega}$, with the decay Ω→Λ K, the polarisation parameters $\boldsymbol{r_2^2, r_1^2, r_0^2}$ can be retrieved from the angular distribution of the Λ.

$$r_0^2 = \frac{15}{2\sqrt{3}}\left(\frac{1}{3} - \langle \cos^2\theta_\Lambda \rangle\right)$$

$$r_2^2 = \frac{8}{3}\ 1 - \langle \cos^2\theta_\Lambda \rangle - 2\langle \sin^2\theta_\Lambda \sin^2\phi_\Lambda \rangle$$

$$r_1^2 = 5\langle \cos\theta_\Lambda \sin\theta_\Lambda \cos\phi_\Lambda \rangle$$

whereas the moduli of $\boldsymbol{r_{-3}^3, r_{-2}^3, r_{-3}^3, r_{-1}^1}$ are obtained by combining angular distribution of Λ with the angular distribution of the decay proton from *Λ→pπ.**

* E. Thomé, Ph.D. Thesis, Uppsala University and later work

Joint Angular Distribution of the Two Decays

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The moduli of four polarisation parameters can be determined :

$$r^1_{-1} = -\frac{20\sqrt{10}\langle(3\cos\Theta_\Lambda - 1)\sin\phi_p\rangle}{3\pi\alpha_\Lambda\gamma_\Omega}$$

$$r^3_{-1} = \frac{2\sqrt{5}\langle(15\cos\Theta_\Lambda - 1)\sin\phi_p\rangle}{\sqrt{3}\pi\alpha_\Lambda\gamma_\Omega}$$

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

$$r^3_{-3} = -\frac{1}{5\sqrt{6}}\left(\frac{640}{\pi\alpha_\Lambda\gamma_\Omega}\langle\sin\phi_\Lambda\cos\phi_\Lambda\sin\phi_p\rangle + 4\sqrt{15}r^3_{-1} + 3\sqrt{10}r^1_{-1}\right)$$

Assumption 1: $\alpha_\Omega = 0$,
Consistent with experiment *

Assumtion 2: $\beta_\Omega \approx 0$, $\gamma_\Omega \approx 1$
(not known)

$$\langle(3\cos\Theta_\Lambda - 1)\sin\phi_p\rangle = = \int_0^\pi\int_0^{2\pi}\int_0^\pi\int_0^{2\pi} I(\Theta_\Lambda,\phi_\Lambda,\Theta_p,\phi_p)\times \sin\Theta_\Lambda(3\cos\Theta_\Lambda - 1)\sin\Theta_p\sin\phi_p d\Theta_\Lambda d\phi_\Lambda d\Theta_p d\phi_p = = -\frac{3\pi\alpha_\Lambda\gamma_\Omega r^1_{-1}}{20\sqrt{10}}$$

$$\langle(15\cos\Theta_\Lambda - 1)\sin\phi_p\rangle = = \int_0^\pi\int_0^{2\pi}\int_0^\pi\int_0^{2\pi} I(\Theta_\Lambda,\phi_\Lambda,\Theta_p,\phi_p)\times \sin\Theta_\Lambda(15\cos\Theta_\Lambda - 1)\sin\Theta_p\sin\phi_p d\Theta_\Lambda d\phi_\Lambda d\Theta_p d\phi_p = = \frac{\sqrt{3}\pi\alpha_\Lambda\gamma_\Omega r^3_{-1}}{2\sqrt{5}}$$

$$\langle\sin\phi_\Lambda\cos\phi_p\rangle = = \int_0^\pi\int_0^{2\pi}\int_0^\pi\int_0^{2\pi} I(\Theta_\Lambda,\phi_\Lambda,\Theta_p,\phi_p)\times \sin\Theta_\Lambda\sin\Theta_p\sin\phi_\Lambda\cos\phi_p d\Theta_\Lambda d\phi_\Lambda d\Theta_p d\phi_p = = -\frac{3\pi^2\alpha_\Lambda\gamma_\Omega r^3_{-2}}{1024}$$

$$\langle\sin\phi_\Lambda\cos\phi_\Lambda\sin\phi_p\rangle = = \int_0^\pi\int_0^{2\pi}\int_0^\pi\int_0^{2\pi} I(\Theta_\Lambda,\phi_\Lambda,\Theta_p,\phi_p)\times \sin\Theta_\Lambda\sin\Theta_p\sin\phi_\Lambda\cos\phi_\Lambda\sin\phi_p d\Theta_\Lambda d\phi_\Lambda d\Theta_p d\phi_p = = -\frac{\pi\alpha_\Lambda\gamma_\Omega}{640}\left(5\sqrt{6}r^3_{-3} - 4\sqrt{15}r^3_{-1} - 3\sqrt{10}r^1_{-1}\right)$$

*PDG, J. Phys. G. 33 (2006)

CP violation in hyperon systems

- CP violation of baryon system has never been observed.
- The $\bar{p}p \rightarrow \bar{Y}Y$ process suitable for CP measurements (clean, no mixing)
- According to experiment, $\alpha = \bar{\alpha}$ for Λ.
- CP violation parameters:

$$A = \frac{\Gamma\alpha + \bar{\Gamma}\bar{\alpha}}{\Gamma\alpha - \bar{\Gamma}\bar{\alpha}} \simeq \frac{\alpha + \bar{\alpha}}{\alpha - \bar{\alpha}}$$

Consistent with 0 for Λ and Ξ, but to confirm or rule out or confirm χPT, Supersymmetry , more precise measurements are needed.

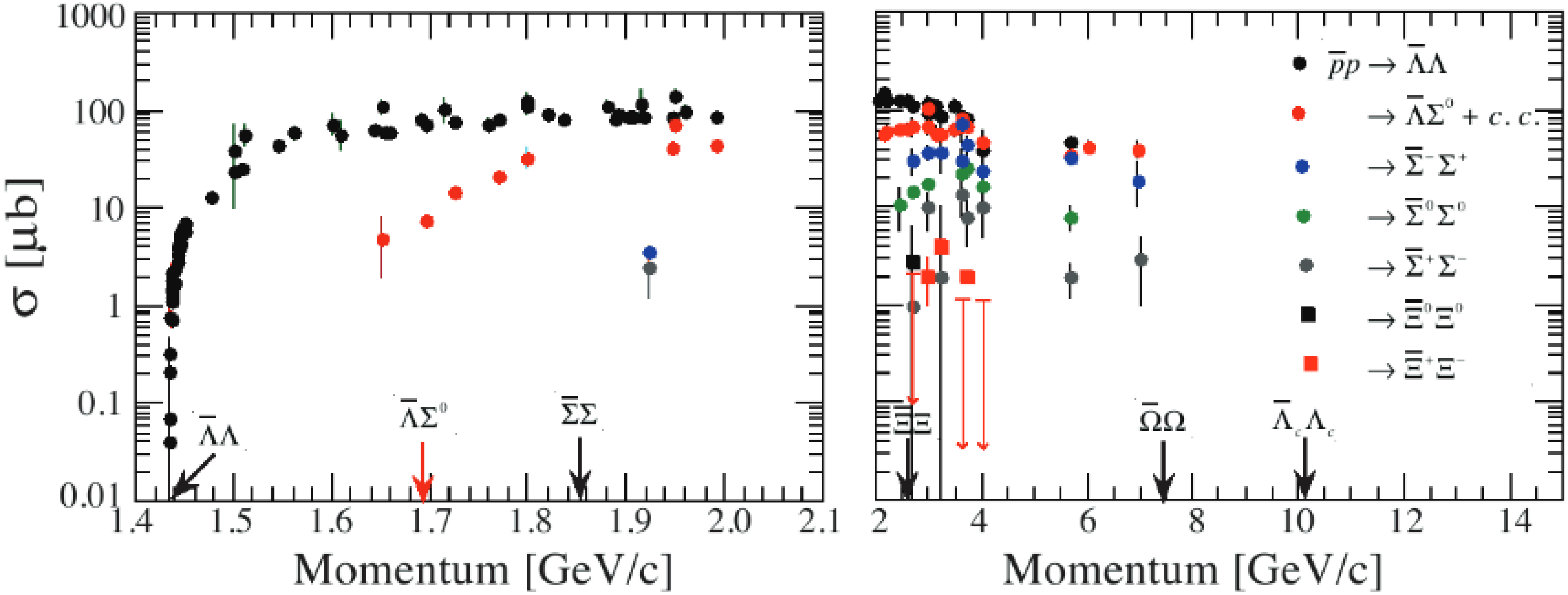
$$B = \frac{\Gamma\beta + \bar{\Gamma}\bar{\beta}}{\Gamma\beta - \bar{\Gamma}\bar{\beta}} \simeq \frac{\beta + \bar{\beta}}{\beta - \bar{\beta}}$$

$$B' = \frac{\Gamma\beta + \bar{\Gamma}\bar{\beta}}{\Gamma\alpha - \bar{\Gamma}\bar{\alpha}} \simeq \frac{\beta + \bar{\beta}}{\alpha - \bar{\alpha}}$$

Accessible for Ξ since the polarisation of the decay products can be measured.

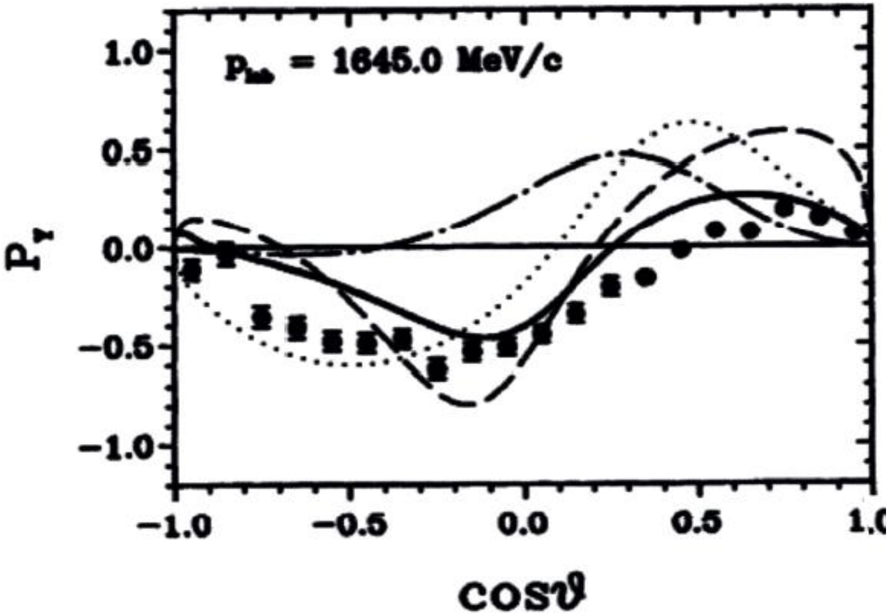
No previous measurement.

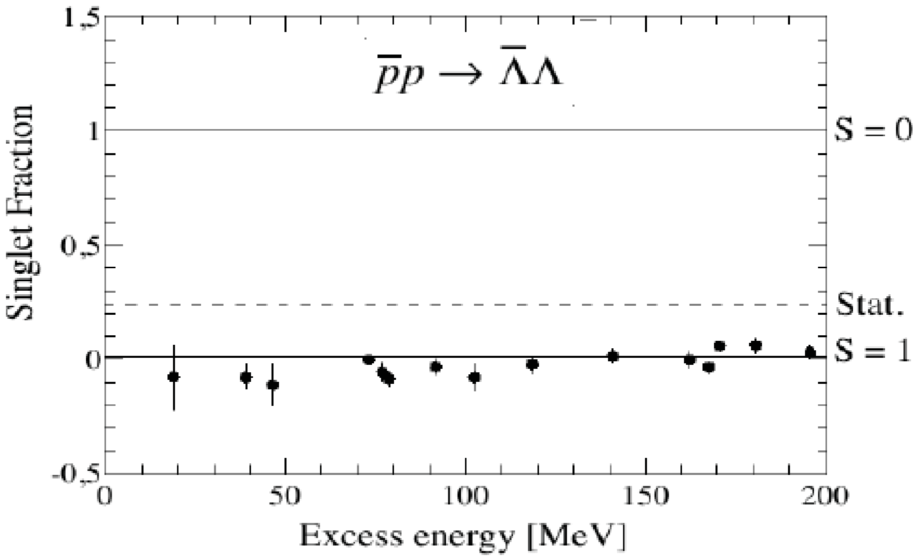
Existing data on $\bar{p}p \to \bar{Y}Y$



- Lots of data on $\bar{p}p \to \bar{\Lambda}\Lambda$ near theshold, mainly from PS185.
- Very few data above 4 GeV.
- Only a few bubble chamber events on $\bar{p}p \to \bar{\Xi}\Xi$
- No data on $\bar{p}p \to \bar{\Omega}\Omega$ nor $\bar{p}p \to \bar{\Lambda}_c\Lambda_c$

Existing data on $\bar{p}p \rightarrow \bar{Y}Y$



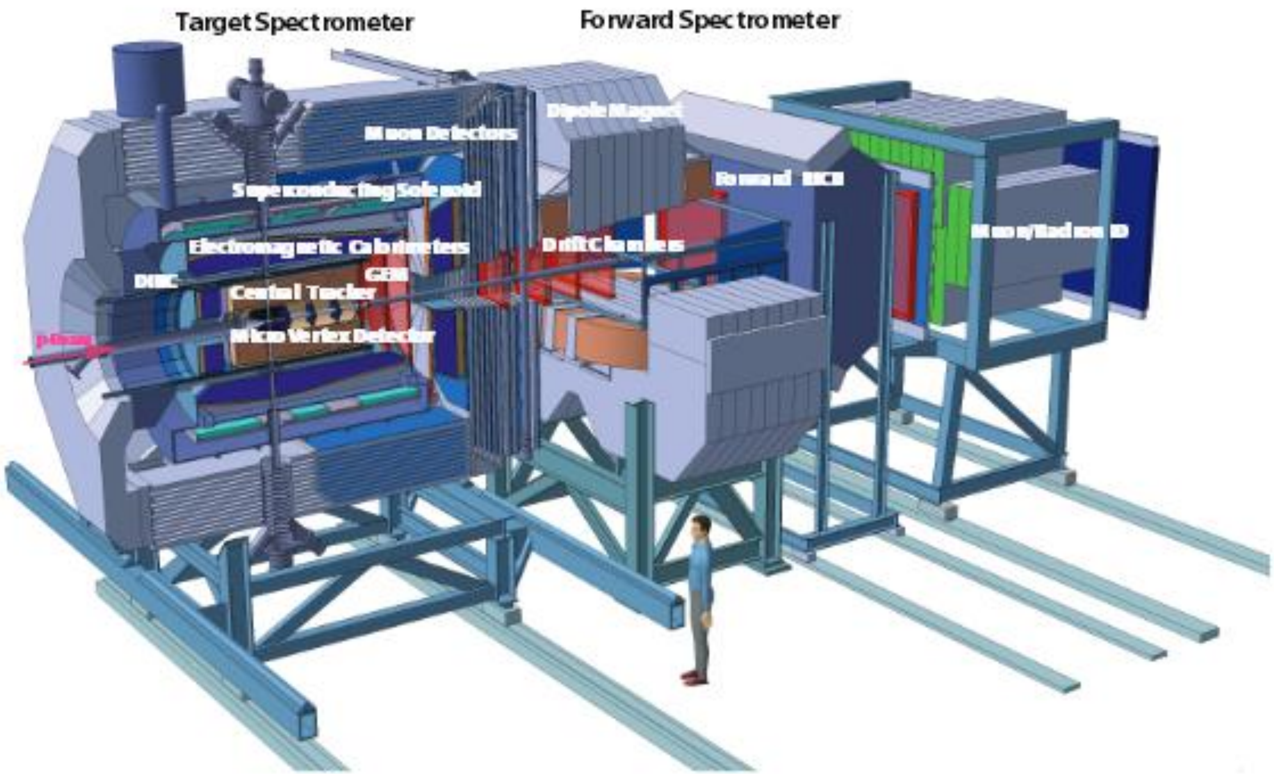


- Data on *P, D, K* and *C* for $\bar{p}p \rightarrow \Lambda\Lambda$
- $\bar{\Lambda}\Lambda$ almost always produced in a spin triplet state:

$$SF = \frac{1}{4}(1 + C_{xx} - C_{yy} + C_{zz})$$

- Neither the quark-gluon picture (dotted) nor hadron exchange (solid and dashed) describe data perfectly.

Prospects for PANDA at FAIR



- Unpolarised beam and target.
- Good vertex resolution necessary.
- For more details, see talk by E. Fioravanti, this Friday.

Prospects for PANDA at FAIR

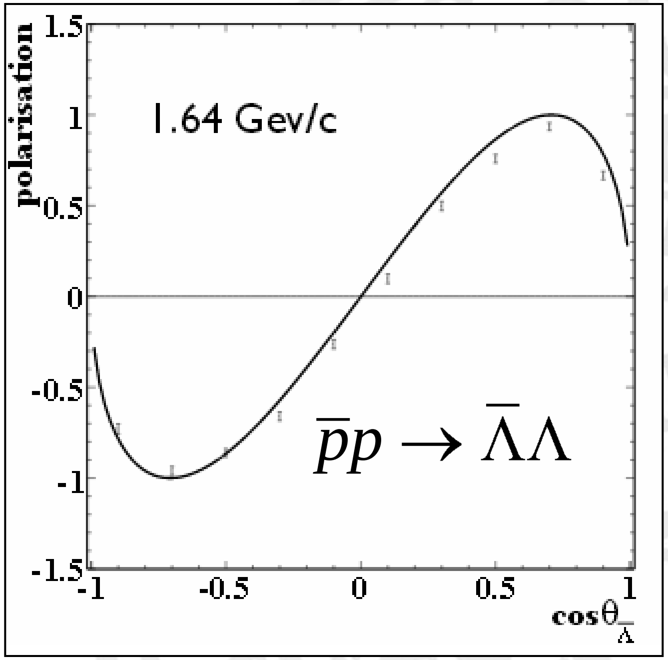
Momentum [GeV/c]	Reaction	Rate [s^{-1}]
1.64	$\bar{p}p \to \Lambda\bar{\Lambda}$	580
4	$\bar{p}p \to \Lambda\bar{\Lambda}$	980
	$\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$	30
15	$\bar{p}p \to \Lambda\bar{\Lambda}$	120

Light hyperons (Λ, Σ):

- High event rate, low background
- Acceptance over full angular range

Channel 1.64 GeV/c	Rec. eff.	σ [μb]	Signal
$\bar{p}p \to \Lambda\bar{\Lambda}$	0.11	64	1
$\bar{p}p \to \bar{p}p\pi^+\pi^-$	$1.2 \cdot 10^{-5}$	~ 10	$4.2 \cdot 10^{-5}$
Channel 4 GeV/c			
$\bar{p}p \to \Lambda\bar{\Lambda}$	0.23	~ 50	1
$\bar{p}p \to \bar{p}p\pi^+\pi^-$	$< 3 \cdot 10^{-6}$	$3.5 \cdot 10^{3}$	$< 2.2 \cdot 10^{-3}$
$\bar{p}p \to \bar{\Lambda}\Sigma^0$	$5.1 \cdot 10^{-4}$	~ 50	$2.2 \cdot 10^{-3}$
$\bar{p}p \to \bar{\Lambda}\Sigma(1385)$	$< 3 \cdot 10^{-6}$	~ 50	$< 1.3 \cdot 10^{-5}$
$\bar{p}p \to \bar{\Sigma}^0\Sigma^0$	$< 3 \cdot 10^{-6}$	~ 50	$< 1.3 \cdot 10^{-5}$
Channel 15 GeV/c			
$\bar{p}p \to \Lambda\bar{\Lambda}$	0.14	~ 10	1
$\bar{p}p \to \bar{p}p\pi^+\pi^-$	$< 1 \cdot 10^{-6}$	$1 \cdot 10^{3}$	$< 2 \cdot 10^{-3}$
$\bar{p}p \to \bar{\Lambda}\Sigma^0$	$2.3 \cdot 10^{-3}$	~ 10	$1.6 \cdot 10^{-2}$
$\bar{p}p \to \bar{\Lambda}\Sigma(1385)$	$3.3 \cdot 10^{-5}$	60	$1.4 \cdot 10^{-3}$
$\bar{p}p \to \bar{\Sigma}^0\Sigma^0$	$3.0 \cdot 10^{-4}$	~ 10	$2.1 \cdot 10^{-3}$
DPM	$< 1 \cdot 10^{-6}$	$5 \cdot 10^{4}$	$< .09$
Channel 4 GeV/c	**Rec. eff.**	**σ (μb)**	**Signal**
$\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$	0.19	~ 2	1
$\bar{p}p \to \bar{\Sigma}^{+}(1385)\Sigma^{-}(1385)$	$< 1 \cdot 10^{-6}$	~ 60	$< 2 \cdot 10^{-4}$

Results by Sophie Grape, Ph. D. Thesis, Uppsala 2009

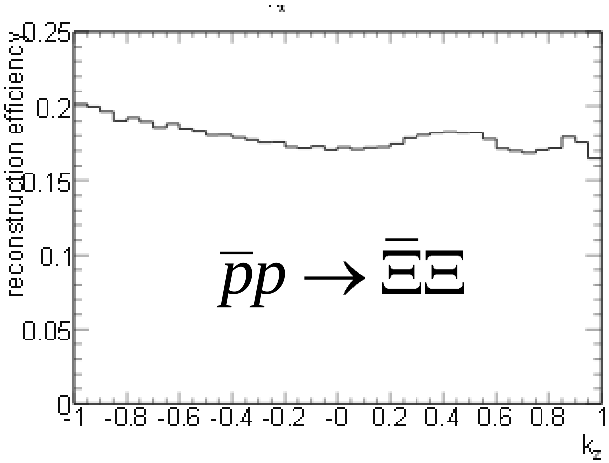


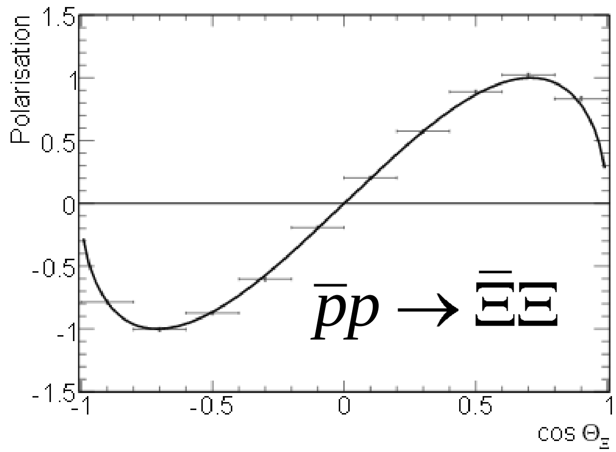
Prospects for PANDA at FAIR

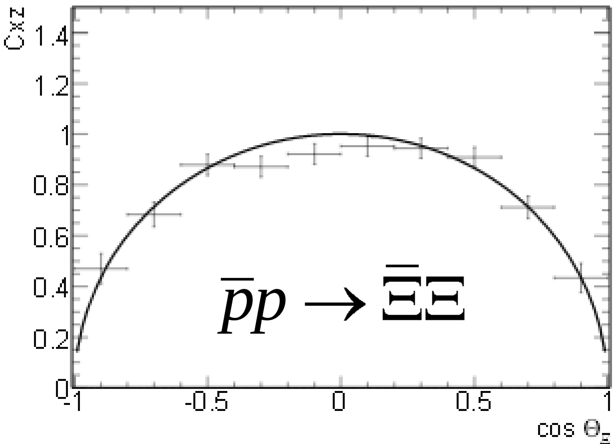
Heavy hyperons: Simulation studies show high event rate and good detection efficiency over the full angular region.

Results by Erik Thomé, Ph. D. Thesis, Uppsala University (2012)

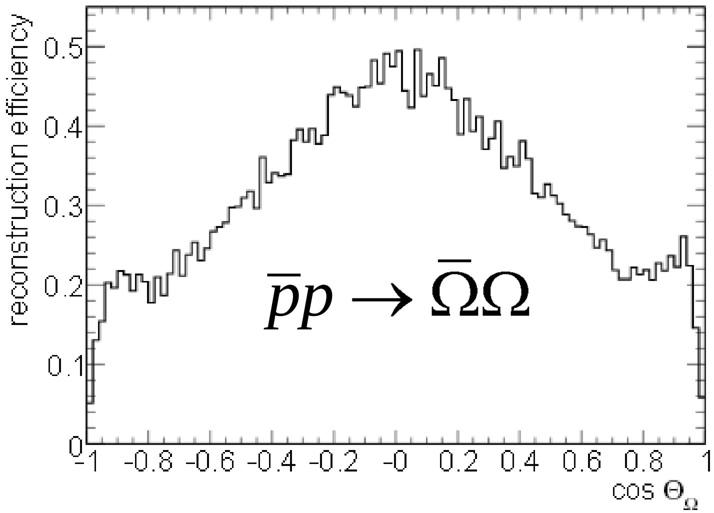
	$\bar{p}p \to \bar{\Xi}^+\Xi^-$	$\bar{p}p \to \bar{\Omega}^+\Omega^-$	$\bar{p}p \to \bar{\Lambda}_c^-\Lambda_c^+$
beam momentum [GeV/c]	4	12	12
reconstruction efficiency [%]	17	30	35
σ	$\sim$2 μb	$\sim$2 nb	$\sim$0.1 μb
expected # of events	$\sim$30/s	$\sim$80/hour	$\sim$25/day

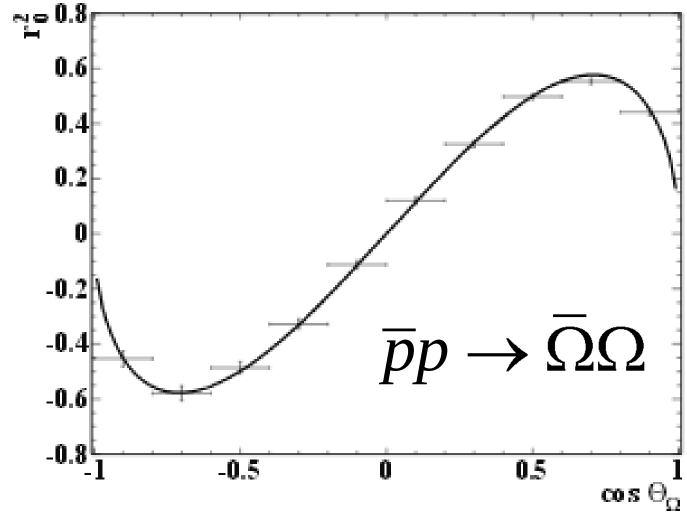


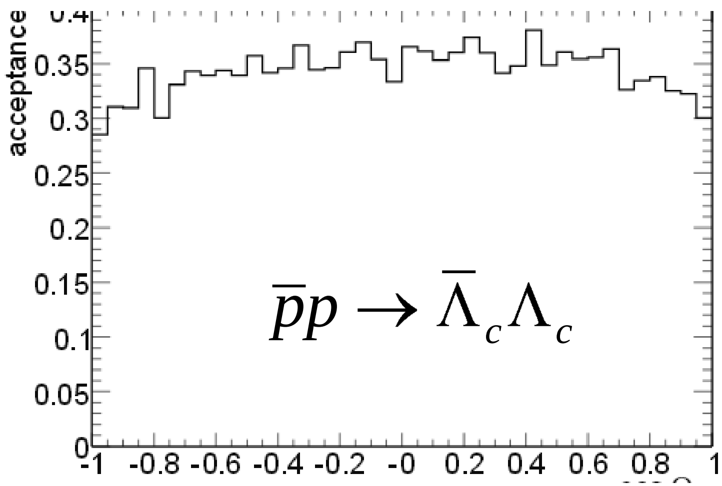


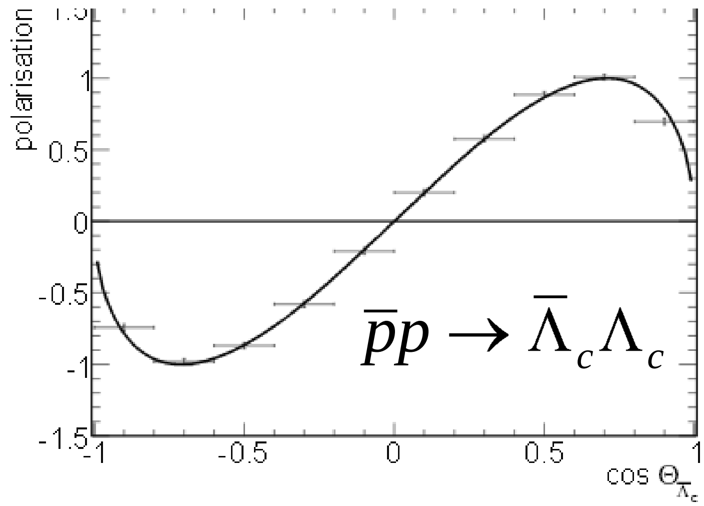


Prospects for PANDA at FAIR



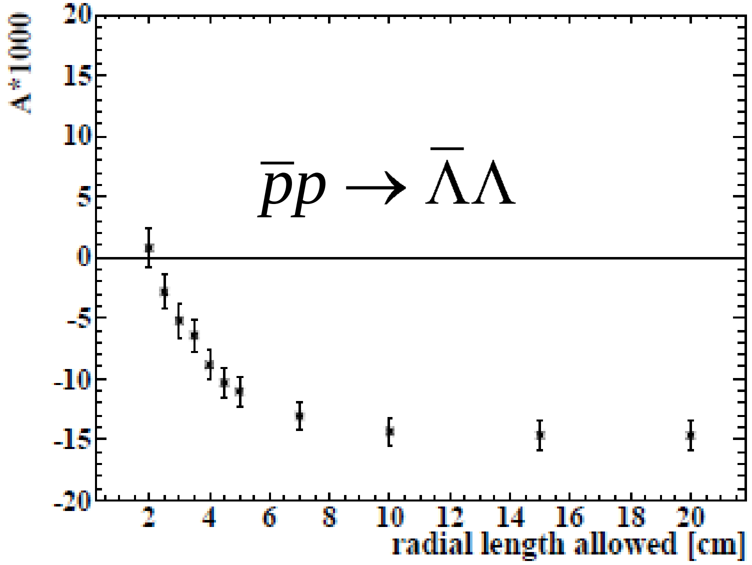


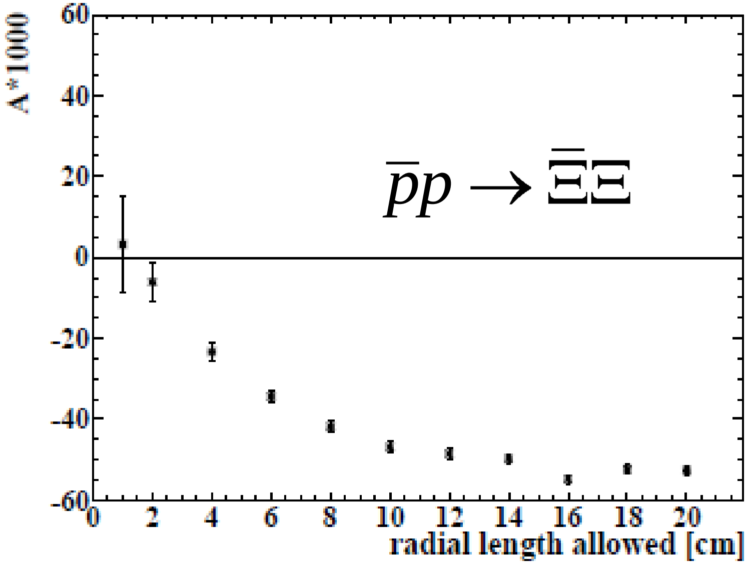




Results by Erik Thomé, Ph. D. Thesis, Uppsala University (2012)

Prospects for PANDA at FAIR





CP violation:

- Measurable in Λ and Ξ decay
- Particle ID requirement gives systematic bias – better measure without ID
- Only tracks near the beam pipe should be considered.

Results by Erik Thomé, Ph. D. Thesis, Uppsala University (2012)

Summary

- Hyperon production is a probe of the Strong Interaction in the confinement domain
- CP violation measurements of hyperon systems provide a clean test of *e.g.* physics beyond the Standard Model.
- Spin observales of the $p\bar{p} \rightarrow \Omega\bar{\Omega}$ process recently derived by the Uppsala group.
- Simulation studies by the Uppsala group show excellent prospects for ALL antihyperon-hyperon channels with PANDA:
  - High event rate
  - Low background
  - Good detection efficiency over the full phase space

Thanks to: Sophie Grape, Tord Johansson and Erik Thomé