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Spin Observables in Hyperon Production

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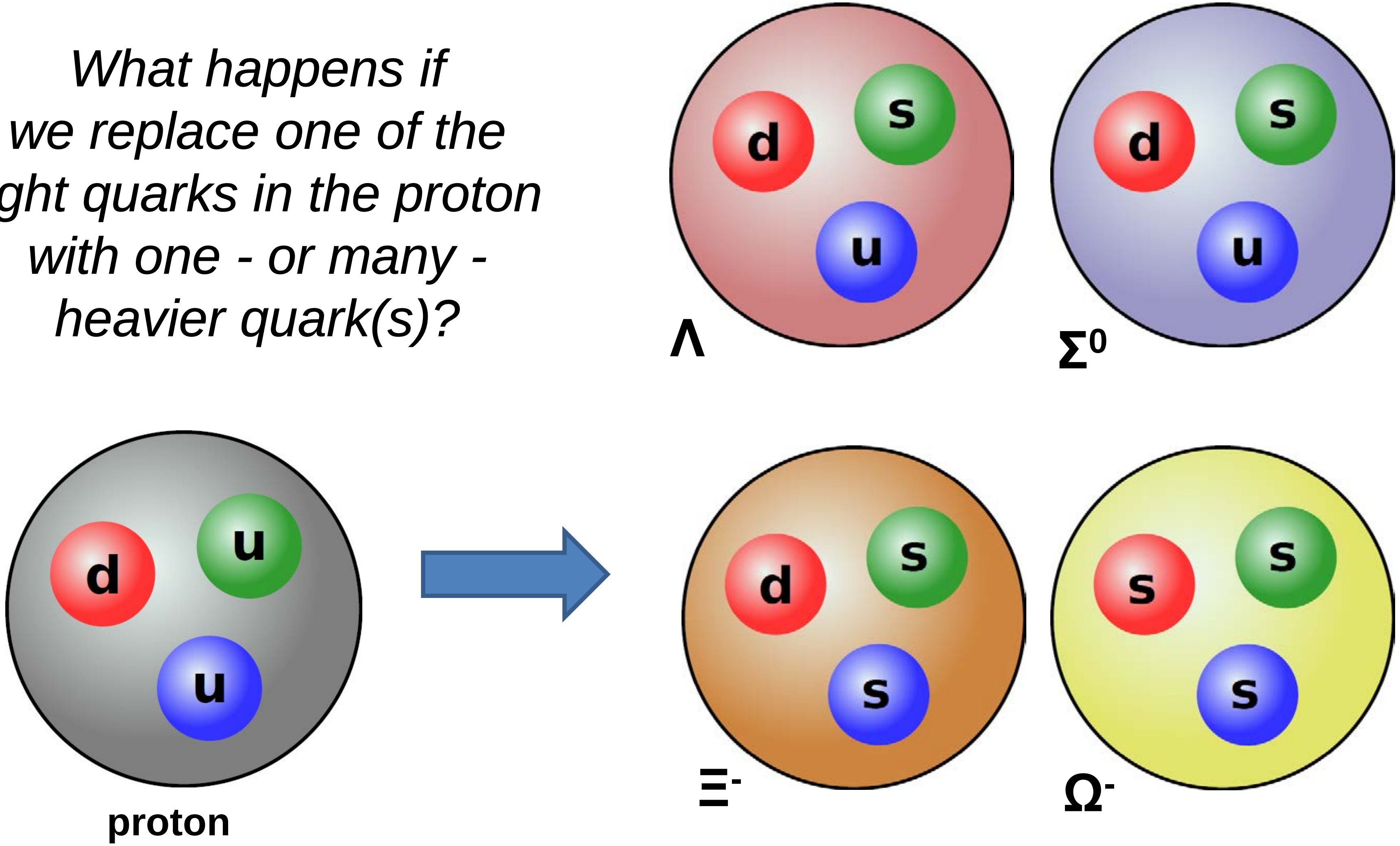
Outline

- Introduction
- Prospects for PANDA
- Current status
- Challenges in hyperon analysis
- Future strategy

Key question in hyperon physics:

What happens if we replace one of the light quarks in the proton with one - or many - heavier quark(s)?



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Introduction

- Light quark (*u, d*) systems:
  - Highly non-perturbative interactions.
  - Relevant degrees of freedom are hadrons.

- Systems with strangeness
  - Scale: $m_s \approx 100$ MeV ~ $\Lambda_{QCD} \approx 200$ MeV.
  - Relevant degrees of freedom?
  - **Probes QCD in the intermediate domain.**

- Systems with charm
  - Scale: $m_c \approx 1300$ MeV.
  - Quark and gluon degrees of freedom more relevant.
  - **By comparing strange and charmed hyperons we learn about QCD at two different energy scales.**

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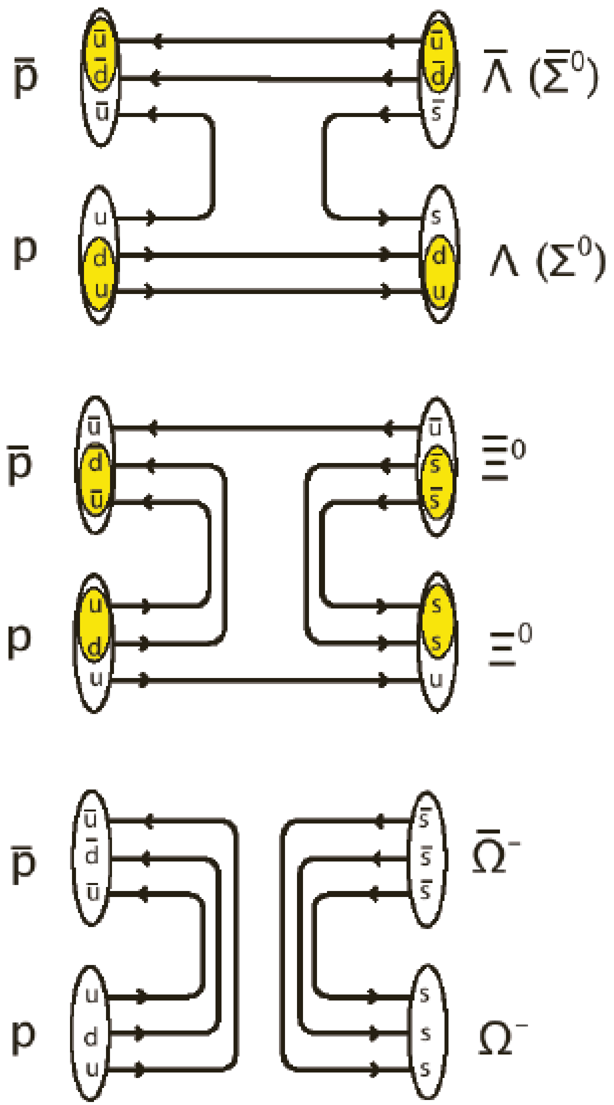
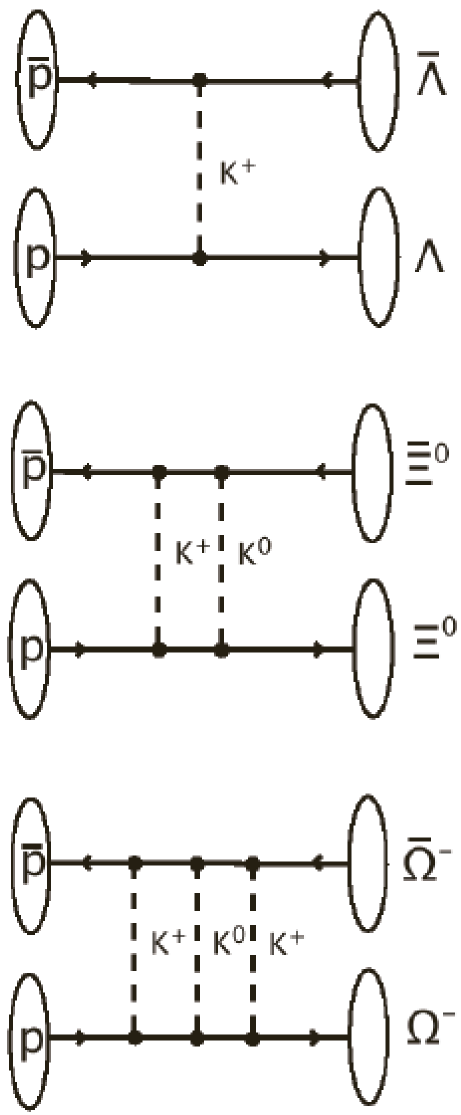
Strange and charm production





Models based on

1) quark-gluon picture*

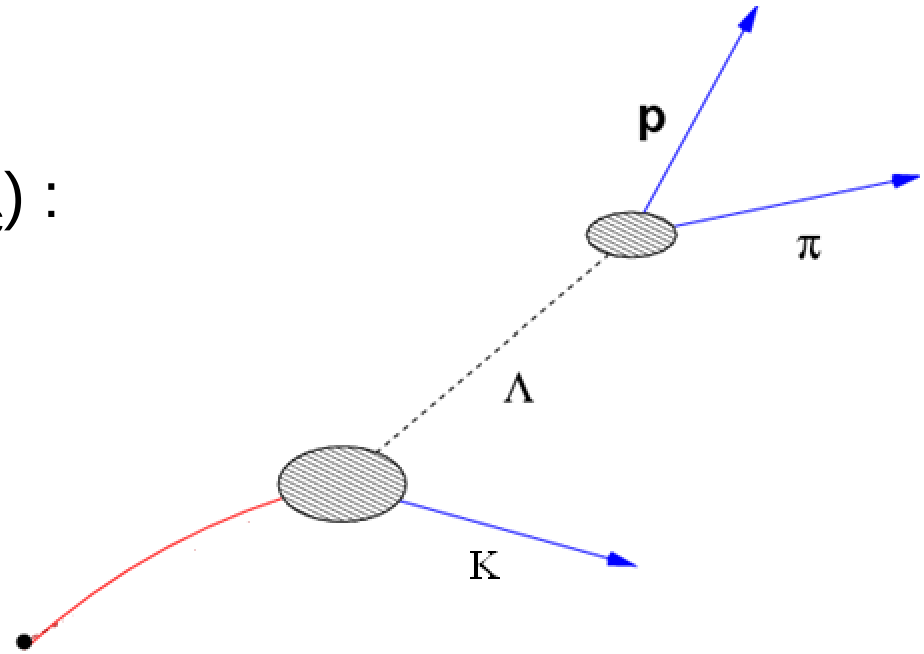
2) the hadron picture**

3) a combination of 1) and 2) ***

-B 179 (1986) 15; PLB 165 (1985) 187;
NPA 468 (1985) 669;
-RC 31(1985) 1857; PLB179 (1986) 15;
PLB 214 (1988) 317;
*** PLB 696 (2011) 352.

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

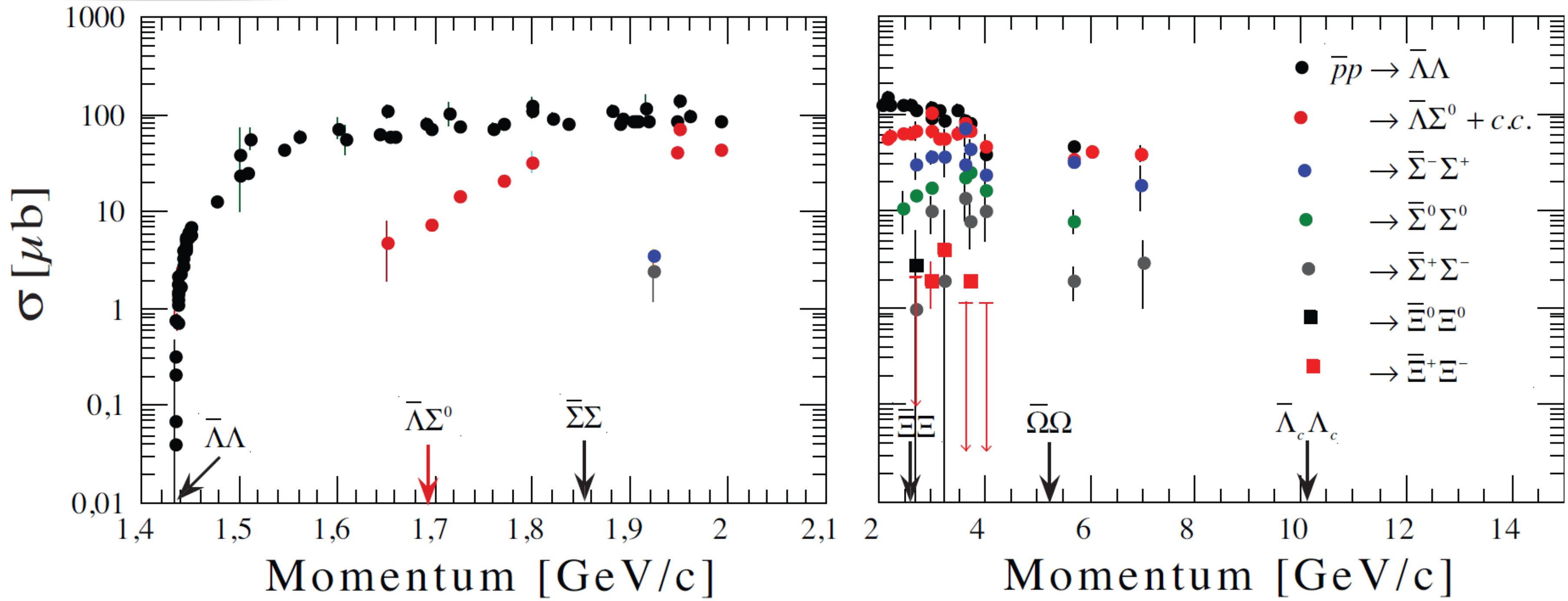
- Spin $\frac{1}{2}$ hyperons (Λ, Ξ, Λ_c) :
  - Polarisation.
  - Spin correlations.



- Spin $\frac{3}{2}$ hyperons into spin $\frac{1}{2}$ hyperons ($\Omega \rightarrow \Lambda K$):
  - 7 polarisation parameters.

Spin observables are powerful tools in testing models.

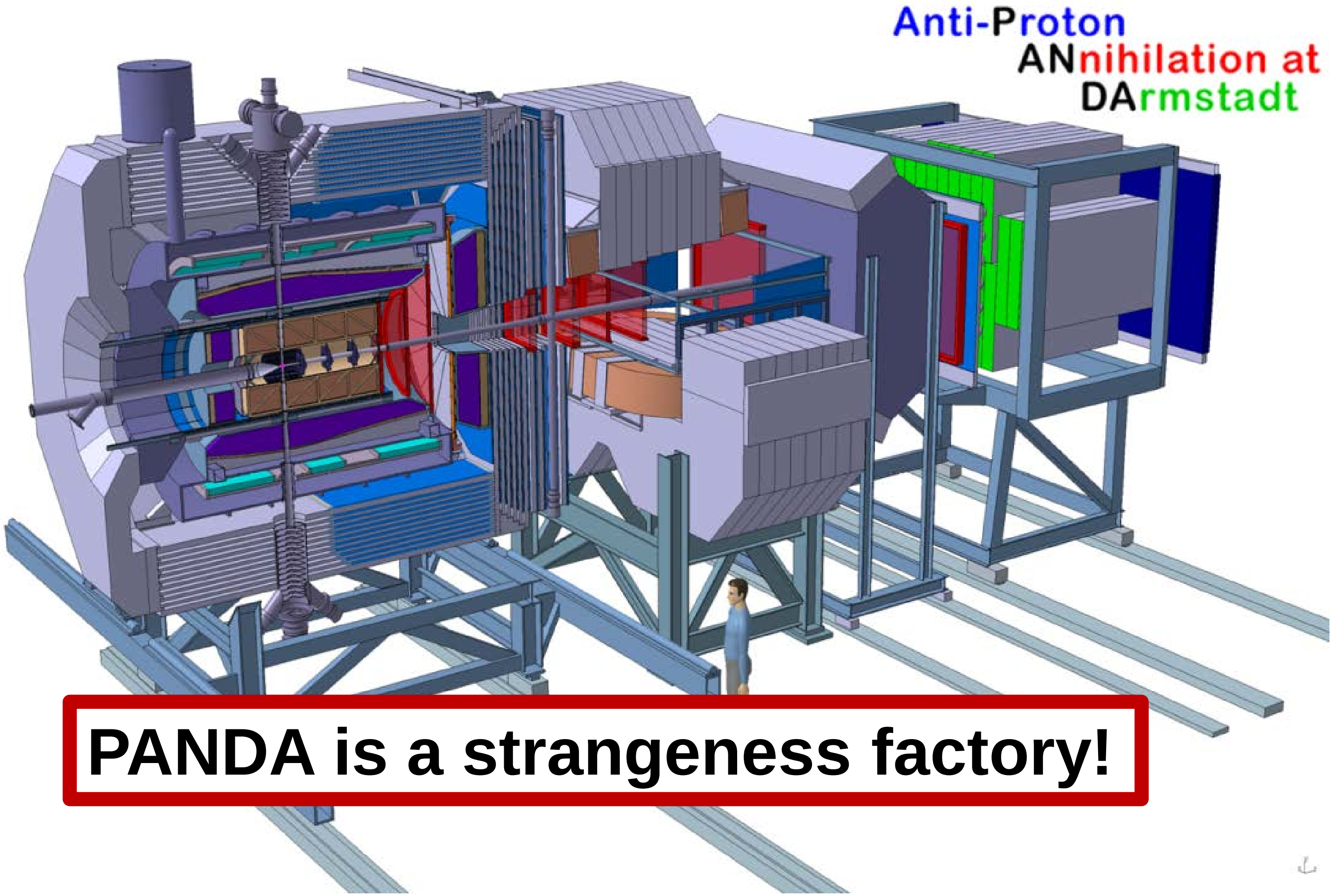
Previous measurements of $\bar{p}p \rightarrow \bar{Y}Y$



- A lot of data on $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ near threshold, mainly from PS185 at LEAR*.
- Very scarce data bank above 4 GeV.
- Only a few bubble chamber events on $\bar{p}p \rightarrow \bar{\Xi}\Xi$
- No data on $\bar{p}p \rightarrow \bar{\Omega}\Omega$ nor $\bar{p}p \rightarrow \bar{\Lambda}_c\Lambda_c$

* See *e.g.* T. Johansson, AIP Conf. Proc. Of LEAP 2003, p. 95.

Prospects for PANDA



PANDA is a strangeness factory!

Prospects for PANDA

Momentum (GeV/c)	Reaction	σ (μb)	Efficiency (%)	Rate (with 10^{31} cm^{-1}s^{-1})
1.64	$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$	64	11	29 s^{-1}
4	$\bar{p}p \rightarrow \bar{\Lambda}\Sigma^{o}$	~40	~30	50 s^{-1}
4	$\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$	~2	~20	1.5 s^{-1}
12	$\bar{p}p \rightarrow \bar{\Omega}^{+}\Omega^{-}$	~0.002	~30	~4 h^{-1}
12	$\bar{p}p \rightarrow \bar{\Lambda}_c^{-}\Lambda_c^{+}$	~0.1	~35	~2 day^{-1}

- Simulations using the old MC framework .
- Quoted rates are valid for day one luminosity of the HESR (10^{31} cm^{-2} s^{-1}).

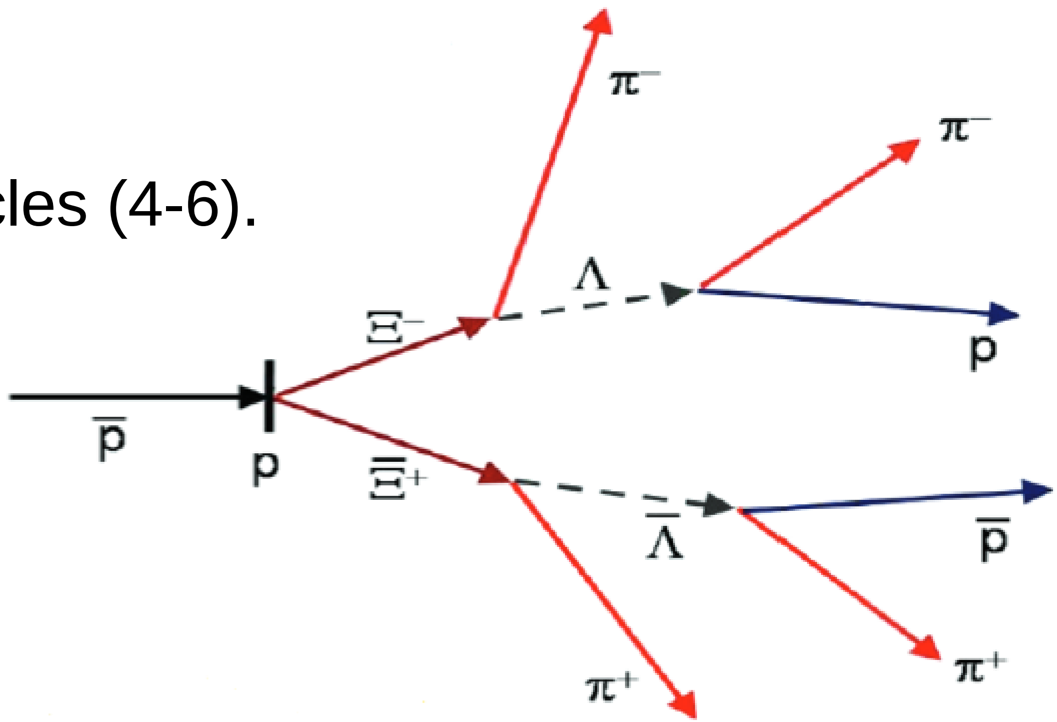
$$\bar{p}p \rightarrow \bar{\Lambda}\Lambda,\ \bar{\Sigma}^{-}\Sigma^{+},\ \bar{\Sigma}^{0}\Sigma^{0},\ \bar{\Sigma}^{-}\Sigma^{+},\ \bar{\Xi}^{0}\Xi^{0},\ \bar{\Xi}^{+}\Xi^{-},\ \bar{\Omega}^{+}\Omega^{-},\ \bar{\Lambda}_c^{-}\Lambda_c^{+}$$

Λ	Σ^{+}	Σ^{0}	Σ^{+}	Ξ^{0}	Ξ^{-}	Ω^{-}	Λ_c^{+}
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$p\pi^{-}$	$p\pi^{0}$	$\Lambda\gamma$	$n\pi$	$\Lambda\pi^{0}$	$\Lambda\pi$	ΛK	$\Lambda\pi$
64%	52%	$\approx$ 100%	$\approx$ 100%	$\approx$ 100%	$\approx$ 100%	68%	$\approx$ 1%

Requirements for hyperon physics

- Weak decay → displaced vertices
  - Good spacial resolution required
  - More difficult to handle in reconstruction.
  - Background can be reduced to
    a very low level.

- Many final state particles (4-6).



Current status

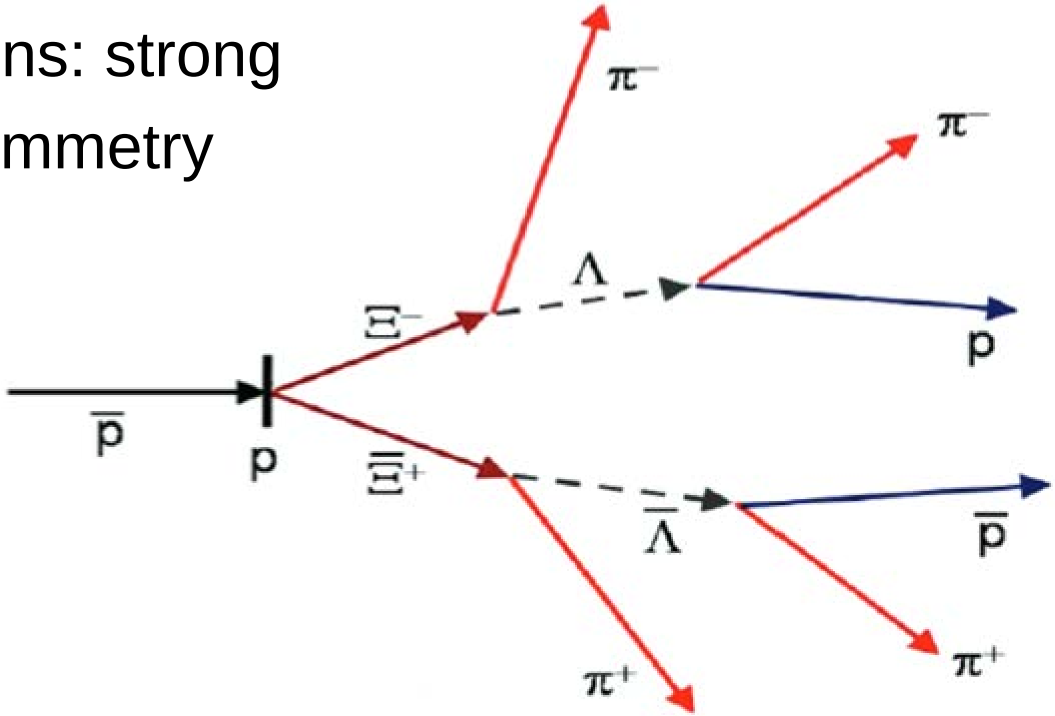
All released simulation studies of hyperon spin observables are performed with the old framework:

- Not all detector material implemented.
- Ideal pattern recognition.
- Unrealistically high efficiency for low momentum particles.

Simulations need to be validated with Pandaroot!

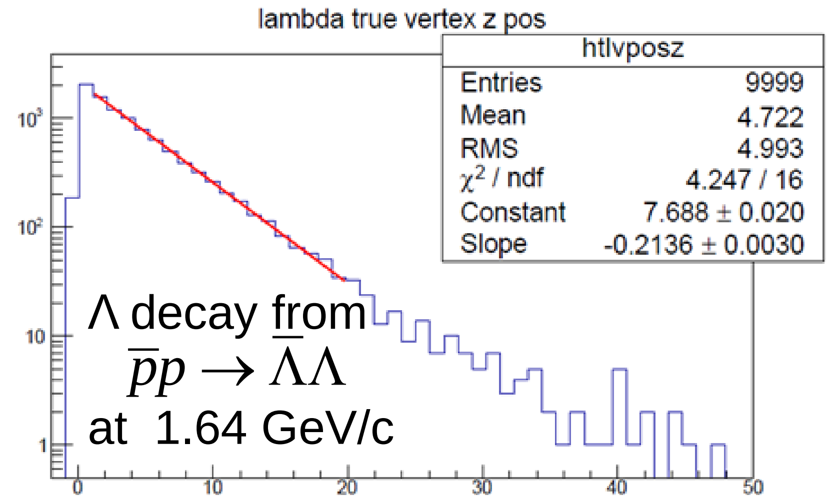
Challenges in hyperon analysis

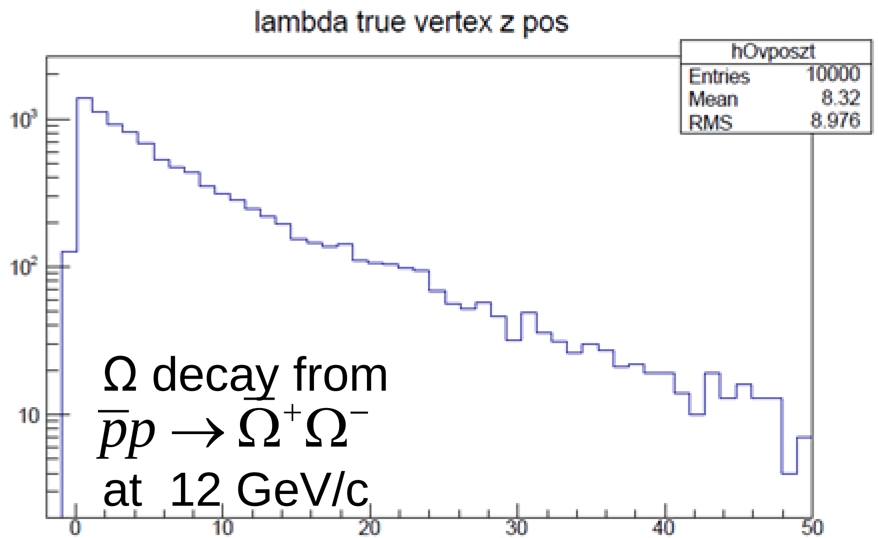
- Weak decays: displaced vertices.
  - Multi-strange hyperons: two subsequent decays with displaced decay vertices.
- Single-strange hyperons: strong forward-backward asymmetry $\rightarrow$ very slow pions.

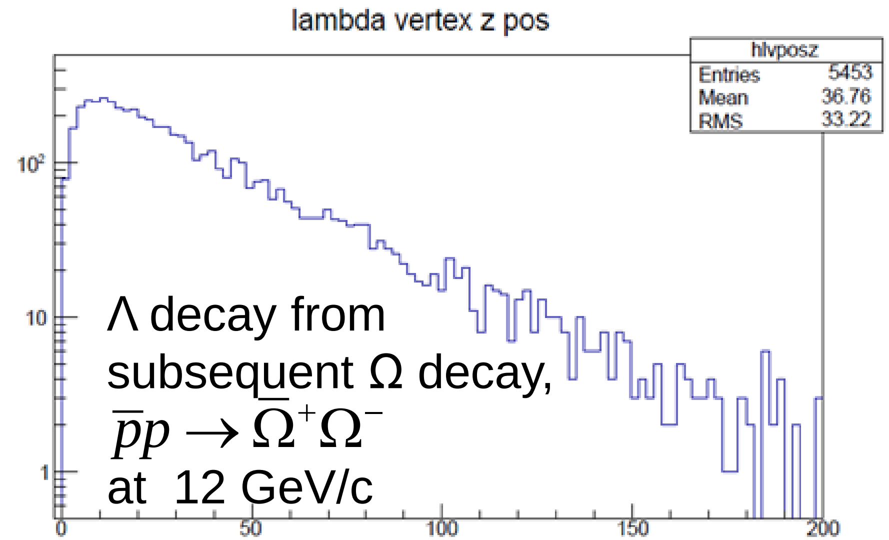


Displaced vertices

- Decay vertices between 1-100 cm.
- Multi-strange hyperons: several subsequent decays.







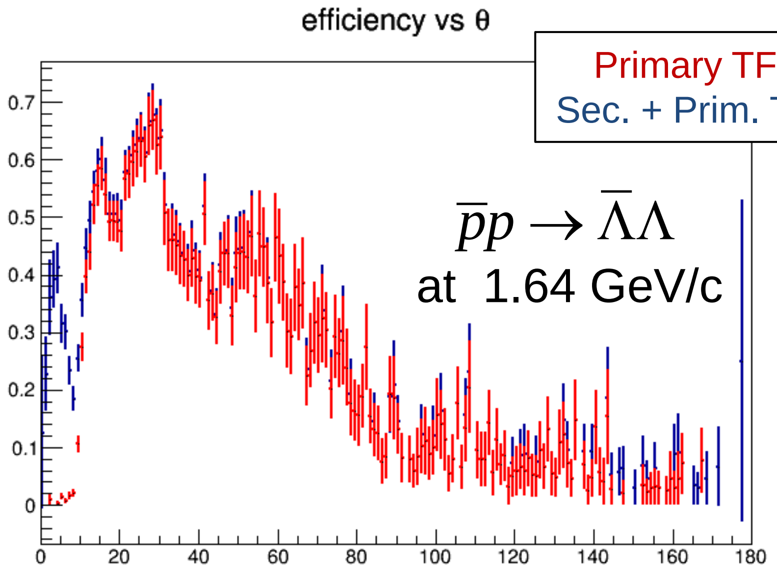
Displaced vertices

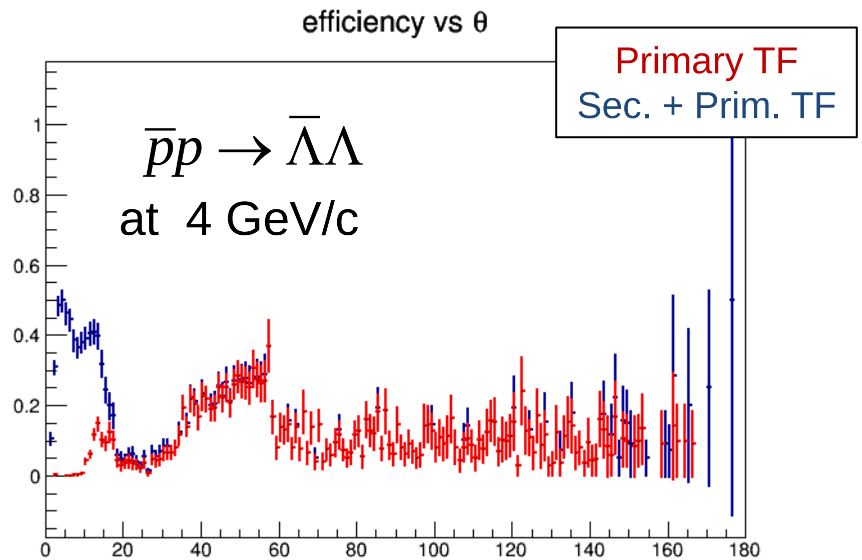
- Standard track finder for Target Spectrometer assumes track origin at IP
  - → not true for hyperons!
  - → efficiency ~ 7 times worse than with ideal pattern recognition (at 1.64 GeV/c)
- Forward Spectrometer: so far only ideal pattern recognition in Pandaroot trunk.

Track finders for hyperon reconstruction

1) Secondary track finder by Lia Lavezzi.

- Uses MVD, STT and GEMs
- Status presented at the September CM.
- Efficiency improved for low θ (more displaced vertices?).
- Available in the Pandaroot trunk including test macros
- Further testing encouraged.





Presentation by L. Lavezzi, PANDA CM Sep. 2015

Track finders for hyperon reconstruction

2) STTCellTrackFinder by Jette Schumann.

- Only STT: About ~30% of $\bar{p}p \rightarrow \bar{\Omega}^{+}\Omega^{-}$ events have ≧ 1 charged tracks with hits in STT only.
- Single-strange hyperons produced at high momenta may give NO hits in MVD (~30%)
- Possible candidate for online track reconstruction.
- z-position by skewed straws (W. Ikegami-Andersson).
- Yet to be fully integrated into the analysis chain.

Track finders for hyperon reconstruction

3) Forward track finder by Martin Galuska.

- still needs tuning and testing.
- someone needs to take over the task since Martin is about to finish his Ph.D.

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Track finders for hyperon reconstruction

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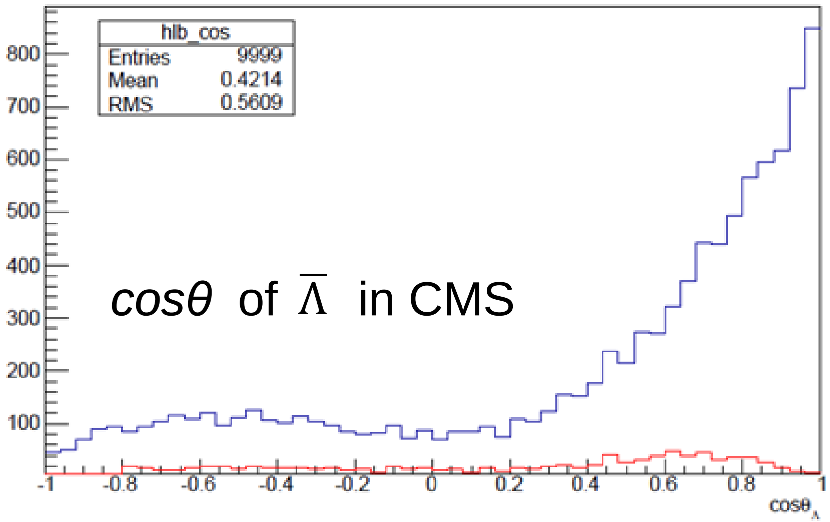
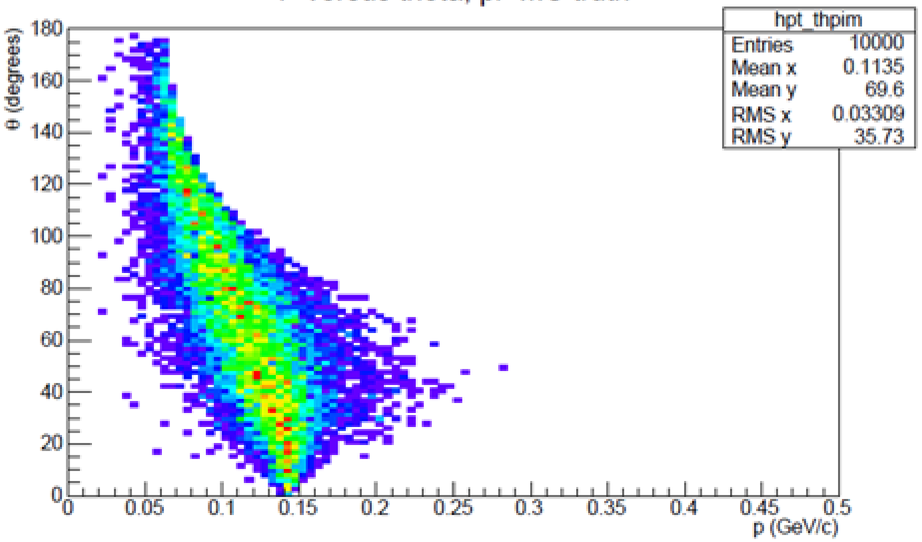
Both 2) and 3) are under development and not standard Pandaroot!

Personpower needed!

Low p_T pions

- Experimental fact: single-strange Λ and Σ hyperons are produced with strong forward-backward asymmetry in CMS.
- This means that in the lab system, π^- from Λ decays have very small *p* (and p_T) .





Low p_T pions

- Low p_T pions circle around inside the STT without leaving it → difficult to reconstruct.
- Half solenoid field improves the efficiency but gives worse resolution.
- Genfit2 should improve the efficiency by a factor of 2 but needs to be tested on the hyperon channels.

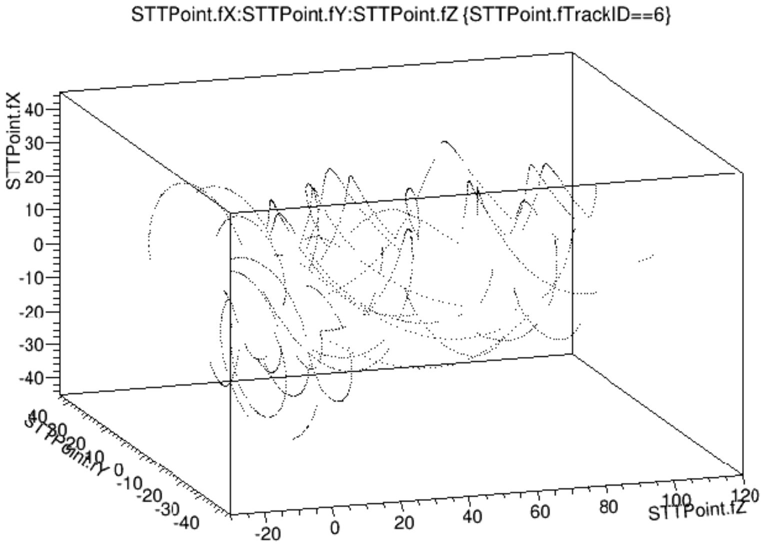


Figure from S. Spataro

Future strategy

The most urgent and time consuming task:

Track finders with realistic pattern recognition that handle displaced vertices

1) in the central part.
2) in the forward part.
3) in central AND forward part.

Both online and offline processing have to be considered.

A lot of work has been done but by primarily by people who have left / are leaving PANDA.

Future strategy

We have:

- existing track finders to develop further.
- a lot of time.

We need:

- senior people who plan to stay within PANDA for a long time (> 2 years) willing to take charge.
- people willing to put a lot of time (> 50%) into these tasks.

Summary

- Strangeness production probes the strong interaction in the confinement domain.
- Spin observables are powerful in testing models.
- PANDA is the perfect experiment for strangeness production.
- Old simulation studies need validation with Pandaroot.
- Hyperons have displaced vertices = big challenge!
  - Several secondary track finders under development.
  - Lack of personpower for tuning, testing, debugging and further development.

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Thanks for your attention!