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Hyperons in PANDA
report for the Scrutiny Group

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Outline

- Main physics goals
- Prerequisites
- Results from simulation studies
  - The benchmark $\bar{p}p \to \bar{\Lambda}\Lambda$ channel at 1.64 GeV/c
  - The $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$ channel at 4 GeV/c
  - The $\bar{p}p \to \bar{\Omega}^{+}\Omega^{-}$ channel at 12 GeV/c
- A few words on $\bar{p}p \to \bar{\Lambda}_c^{-}\Lambda_c^{+}$
- Conclusions

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Main Physics Goals

- Provide new, high statistics and high quality samples of Λ and Σ production for Partial Wave Analysis.
- Study the differential cross section, the polarisation and the spin correlations of the $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$ reaction for the first time.
- Observe $\bar{p}p \to \bar{\Omega}^{+}\Omega^{-}$ and $\bar{p}p \to \bar{\Lambda}_c^{-}\Lambda_c^{+}$ for the first time.
  - Production of hyperons of different strangeness probes QCD in the confinement regime.
  - Strange and charmed hyperon production probes two different energy scales.

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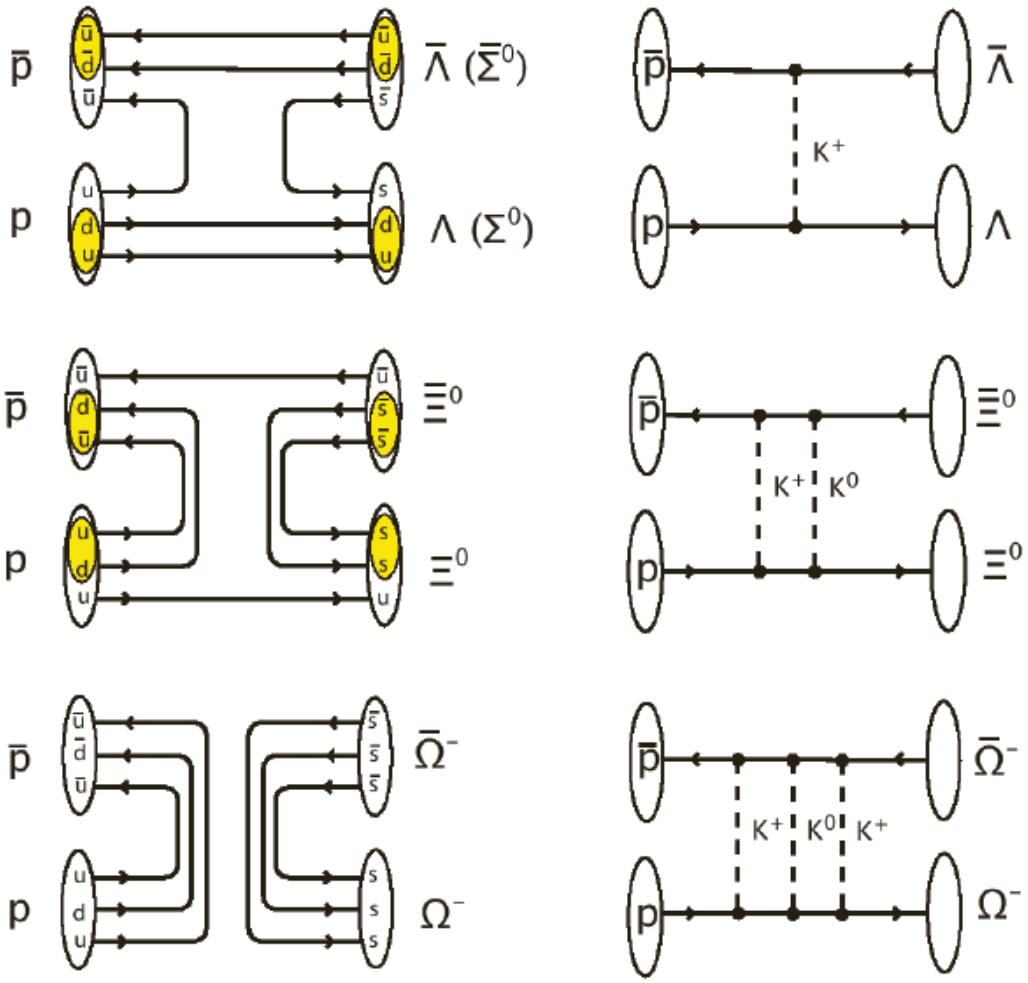
Main Physics Goals

We want to provide high quality data that serve as a guideline towards a theory that correctly describes the production of strange systems.



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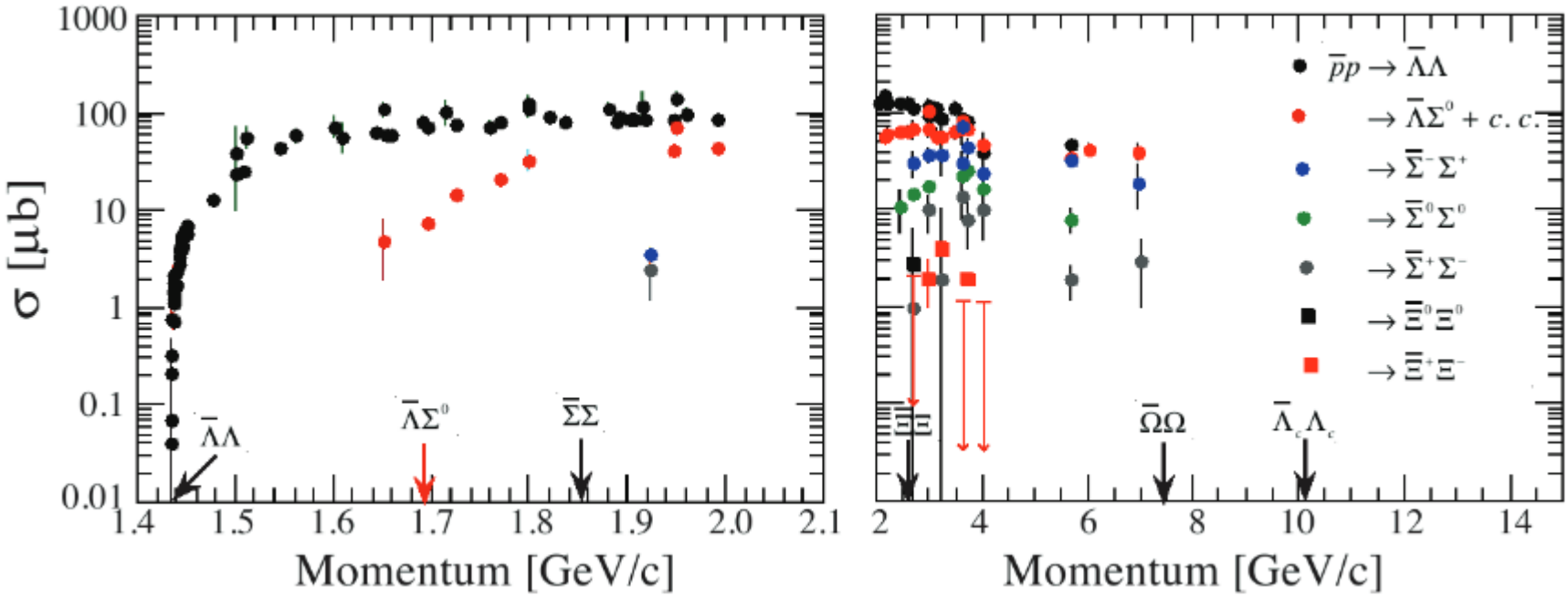
Long-term physics goals

- Provide high statistics samples of Λ and Ξ for CP violation studies.
- Measure the spin and polarisation parameters of the Ω baryon.
- Measure the angular distribution, the polarisation and the spin correlations of the Λ_c baryon.

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



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

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

PANDA – a unique experiment for hyperon physics

Hyperon production in $\bar{p}p$ production requires an antiproton beam at intermediate momenta, with high precision and high intensity.

- No other such facility exists.
- No other such facility is, to our best knowledge, planned within the timescale of PANDA.

→ It is likely that within the next 20 years, no other facility will be able to perform these measurements

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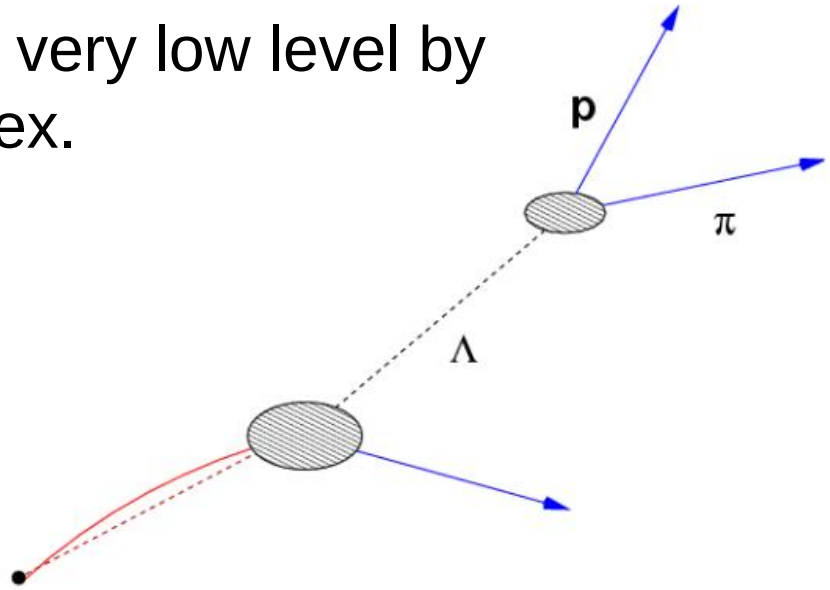
Prerequisities

Most hyperons of interest for QCD dynamics studies

decay weakly → decay vertex separated from production vertex.

- Good spacial resolution required
- Background can be reduced to very low level by requiring separated decay vertex.
  - PID detectors not crucial.



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Prerequisisties

Most hyperon channels of interest for PANDA decay with large BR into charged hadrons

→ EMC not needed.

Channels containing $\Sigma^0 \rightarrow \Lambda\gamma$ requires everything needed for Λ plus EMC.

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Simulation studies for the scrutiny campaign

- Full Pandaroot simulations with ideal pattern recognition (not fastsim).
- Three different detector scenarios:
  - Full
  - No MVD/GEM
  - No FTS

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The $\bar{p}p \to \bar{\Lambda}\Lambda$ at 1.64 GeV/c

- Well-known from other experiments.
- Studied with old PANDA framwork (Thesis by S. Grape).
- Most heavier hyperons decay into hyperons → sets a ”minimum standard”.

$\bar{p}p \to$	$\bar{\Lambda}\Lambda$,	$\bar{\Sigma}^{-}\Sigma^{+}$,	$\bar{\Sigma}^{0}\Sigma^{0}$,	$\bar{\Sigma}^{-}\Sigma^{+}$,	$\bar{\Xi}^{0}\Xi^{0}$,	$\bar{\Xi}^{+}\Xi^{-}$,	$\bar{\Omega}^{+}\Omega^{-}$,	$\bar{\Lambda}_c^{-}\Lambda_c^{+}$
	↓	↓	↓	↓	↓	↓	↓	↓
	$p\pi^{-}$	$p\pi^{0}$	$\Lambda\gamma$	$n\pi$	$\Lambda\pi^{0}$	$\Lambda\pi$	ΛK	$\Lambda\pi$
	64%	52%	≈ 100%	≈ 100%	≈ 100%	≈ 100%	68%	≈ 1%

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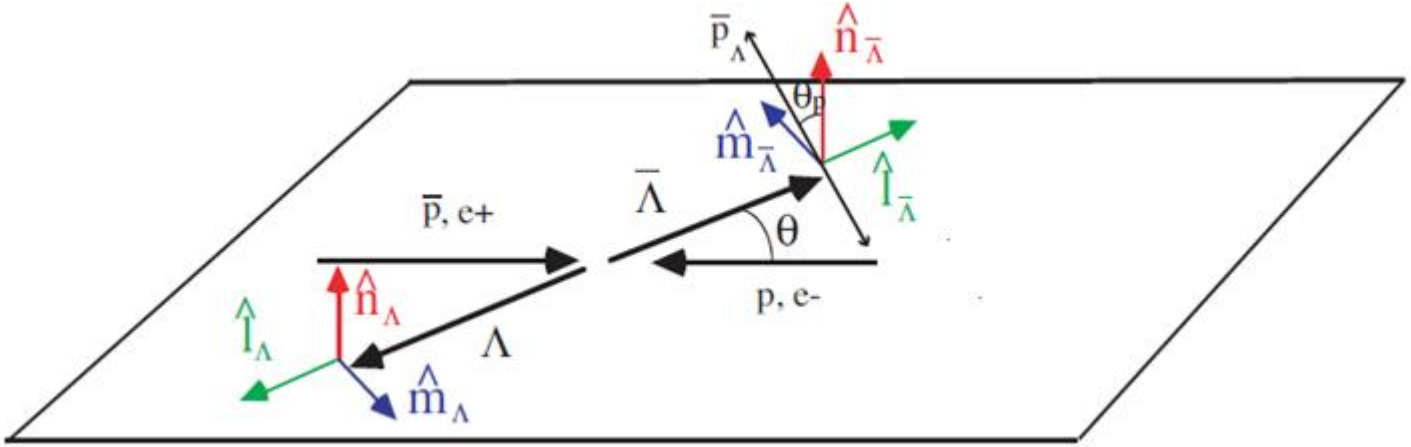
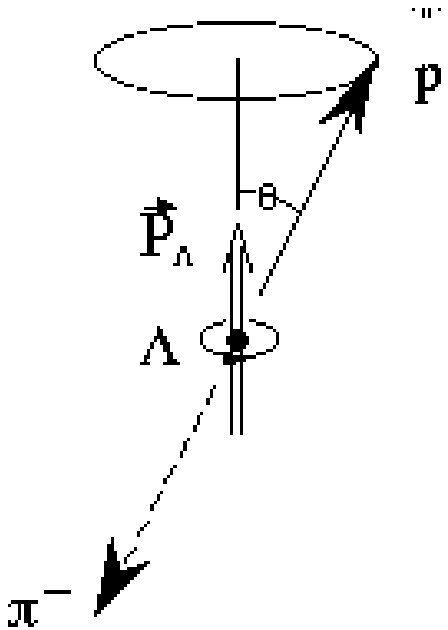
Physics goals of $\bar{p}p \to \bar{\Lambda}\Lambda$

- Test the PANDA performace
- Provide a world leading data sample (> 40000 events) at the same energy from PS185.





- Differential cross section
- Polarisation
- Spin correlations

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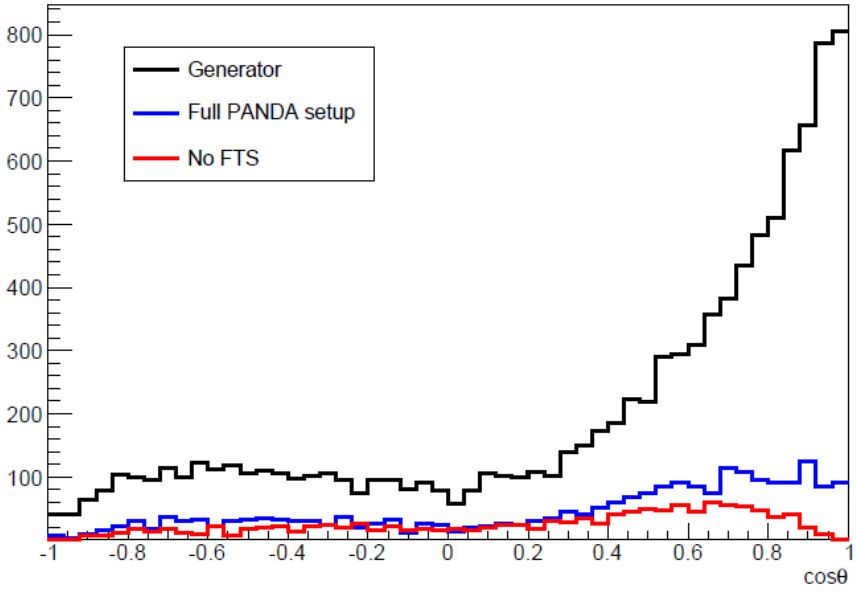
Acceptance as a function of $\cos\theta_{\Lambda bar}$

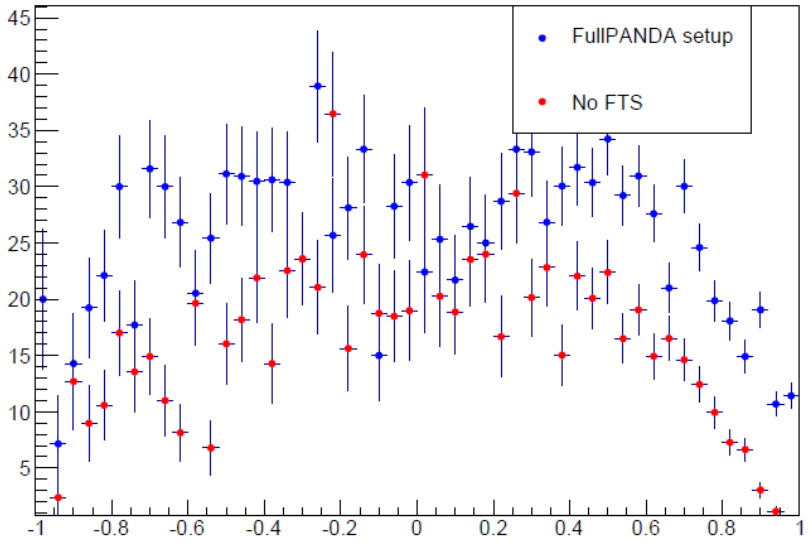
cosθ distribution



Even though the total $\bar{\Lambda}\Lambda$ yield is acceptable also without the FTS, the efficiency is zero where the cross section is the highest.

Without the FTS, PWA is not possible!

Acceptance as a function of cosθ



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Required integrated luminosity

For > 40000 events (current world record)
with σ = 64 μb (PS185)
and BR(Λ→pπ) 64%
we need:

Setup	ε(%)	L (pb^{-1})	Hours with 10^{31} cm^{-2} s^{-1}
Full	23	0.017	0.18
No FTS	12	0.032	0.35
No MVD/GEM	0.3	1.27	14

We will be able to get good physics results within short time even with reduced luminosity, but BOTH the FTS and MVD/GEM are needed to get sufficient data quality for PWA.

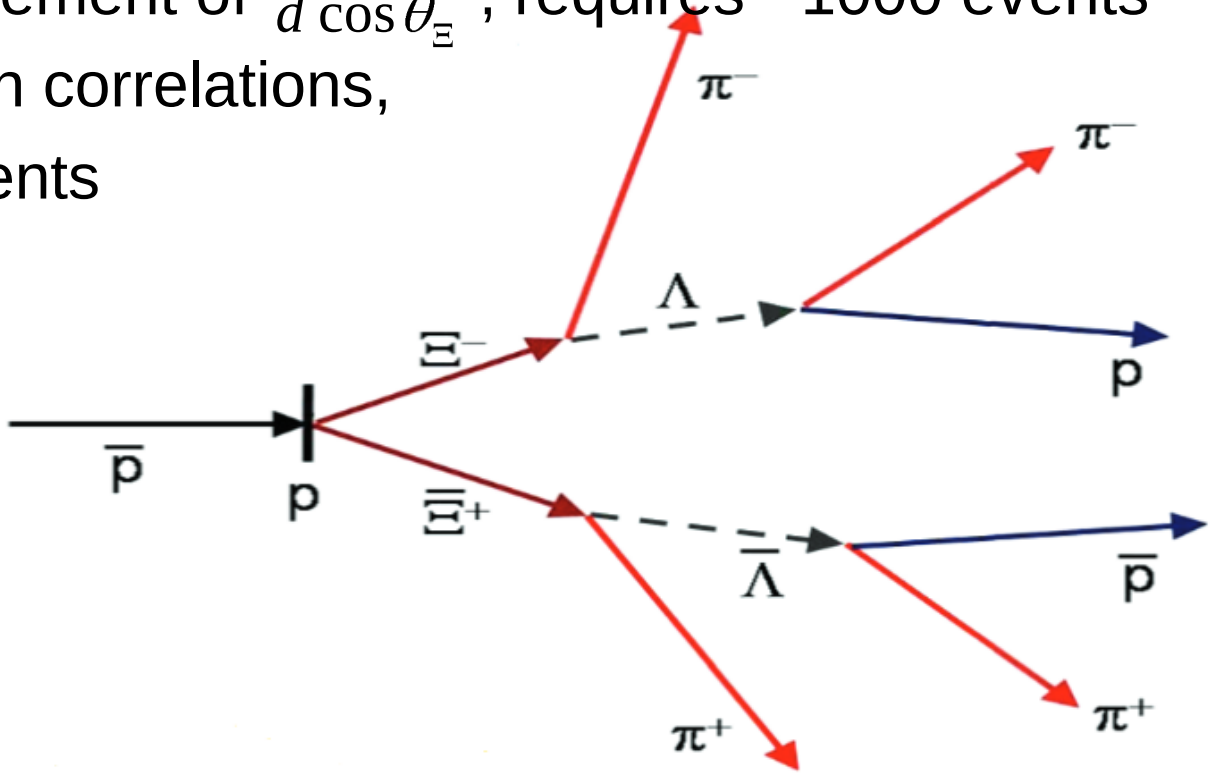
Physics goals of $\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$

Short-term goals:

- Measure σ with larger precision $\frac{d\sigma}{d\cos\theta_{\Xi}}$
- Provide first measurement of , requires ~1000 events
- Polarisation and spin correlations, requires ~10000 events

Long-term goals:

- CP tests, requires > 10000000 events



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Required integrated luminosity

For > 10000 events
with σ = 2 μb
and BR($\Lambda \rightarrow p\pi$) 64%
we need:

Setup	ε(%)	L (pb^{-1})	Hours with 10^{31} cm^{-2} s^{-1}
Full	10	0.12	3.4
No FTS	3.4	0.36	10
No MVD/GEM	0.01	122	3400

We will be able to get good physics results within short time even with reduced luminosity.

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Required integrated luminosity

For > 10 000 000 events
with σ = 2 μb
and BR($\Lambda \rightarrow p\pi$) 64%
we need:

Setup	ε(%)	L (pb^{-1})	Days with 10^{31} cm^{-2} s^{-1}
Full	10	0.12	140
No FTS	3.4	0.36	416
No MVD/GEM	0.01	122	141300

With reduced luminosity,
a lot of time is needed to compete with
world data on CP tests.

Physics goals of $\bar{p}p \to \bar{\Omega}\Omega$

Short-term:

- First measurement of the total cross section
- Measure $\dfrac{d\sigma}{d\cos\theta_\Omega}$: requires ~ 1000 events.

Long-term

- Measure polarisation parameters:

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

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

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

(+ 4 more: r^1_{-1}, r^3_{-1}, r^1_{-2} and r^3_{-3})

Requires ~ 10000 events

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Cross section of $\bar{p}p \to \bar{\Omega}\Omega$

- No measurement exist.
- Theory prediction based on Quark Gluon String Model (QGSM) of ~2 nb.*
- An estimate assuming gives a cross section of ~60 nb.

$$\frac{\sigma(p\bar{p} \to \Omega\bar{\Omega})}{\sigma(p\bar{p} \to \Xi\bar{\Xi})} = \frac{\sigma(p\bar{p} \to \bar{\Xi}\Xi)}{\sigma(p\bar{p} \to \bar{\Lambda}\Lambda)} = \frac{1}{30}$$

In our calculation we use 2 nb.

* Kaidalov & Volkovitsky, Z. Phys. C 63 517-524 (1994)

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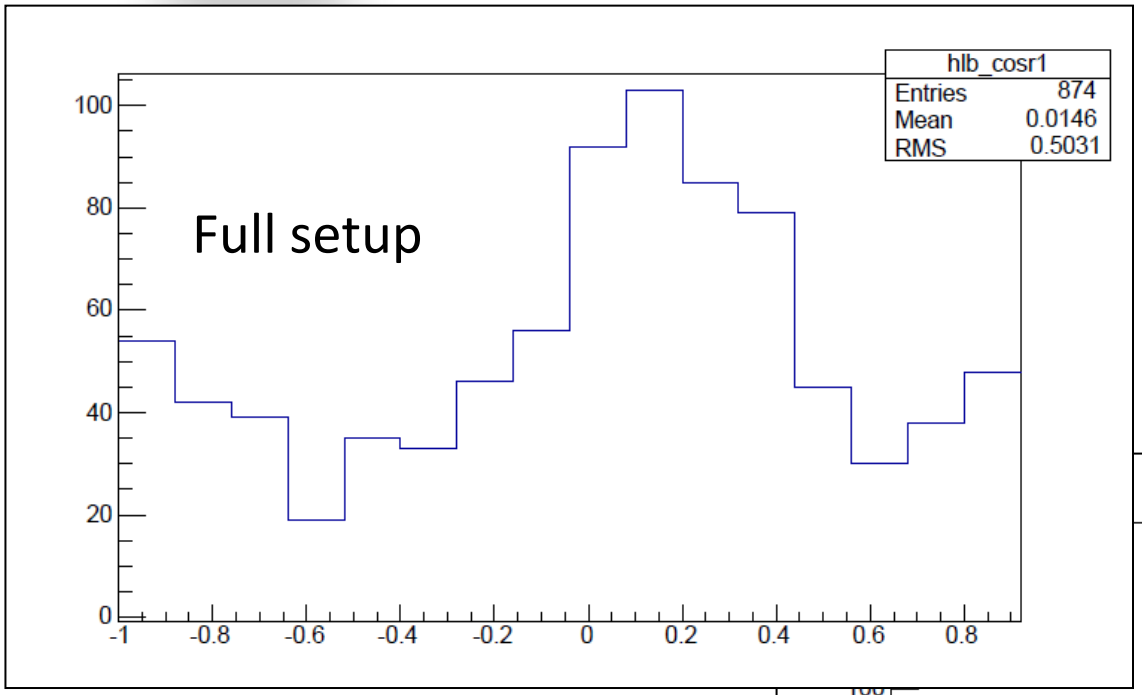
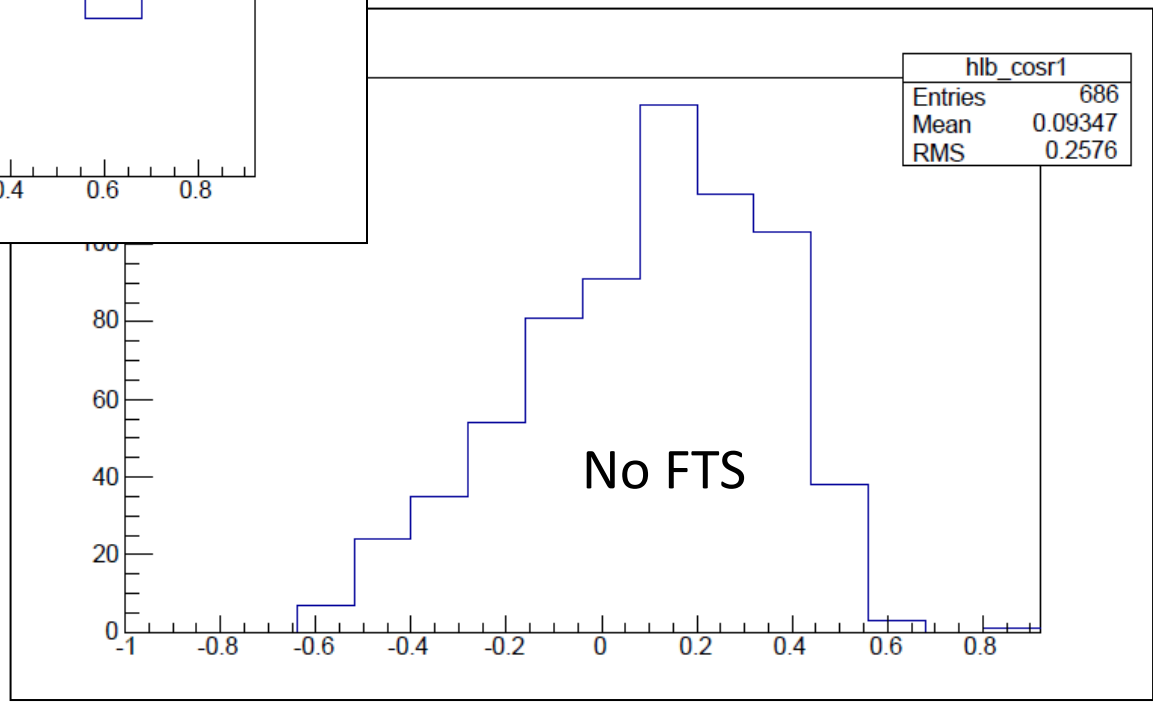
Acceptance as a function of $\cos\theta_{\Omega bar}$



Without the FTS, large parts of the $\cos\theta_{\Omega}$ have zero acceptance.

Arbitrary units, flat generated distribution



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Required integrated luminosity

For > 1000 events
with σ = 2 nb
and BR(Λ→pπ) 64% and BR(Ω→ΛK)
we need:

Setup	ε(%)	L (pb^{-1})	Days with 10^{31} cm^{-2} s^{-1}
Full	8.3	31.8	36
No FTS	2.9	91.0	6110
No MVD/GEM	0.05	5280	105

We should be able to get enough data for measurement of σ and $\frac{d\sigma}{d\cos\theta_\Omega}$ within reasonable time if the FTS and MVD/GEM are included.

Polarisation parameters (>10000 events) require high luminosity.

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A few words on $\bar{p}p \rightarrow \bar{\Lambda}_c^- \Lambda_c^+$

- Cross section predictions up to ~100 nb
- Many decay channels, small fractions (BR($\Lambda_c \rightarrow \Lambda\pi$) ~ 1%)
- Predicted rate with σ=100 nb and L=$2*10^{32}$ cm^{-2} s^{-1}:

  25 events/day
- Low luminosity: ~ 1 event/day

  → high luminosity needed for other measurements than total cross section.

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Summary

Which part of the program are adequate for the start-up of PANDA, with reduced luminosity?

- $\bar{p}p \to \bar{\Lambda}\Lambda$ at 1.64 GeV for benchmarking and spin observables for PWA
- $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$ at 4 GeV for differential cross section, polarisation and spin correlations
- $\bar{p}p \to \bar{\Omega}^{+}\Omega^{-}$ at 12 GeV for cross section and differential cross section.

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Summary

Which integrated luminosity is needed for the first physics results?

- $\bar{p}p \to \bar{\Lambda}\Lambda$ at 1.64 GeV/c for benchmarking and PWA:
  0.017 pb^{-1} (Full)
- $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$ at 4 GeV for spin observables:
  0.12 pb^{-1} (Full)
- $\bar{p}p \to \bar{\Omega}^{+}\Omega^{-}$ at 12 GeV, σ and $\frac{d\sigma}{d\cos\theta_{\Omega}}$
  31.8 pb^{-1} (Full)

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Summary

Which parts of the detector are mandatory to reach the first physics results with PANDA?

- Total cross sections: STT, MVD, GEM
- Differential cross sections: STT, MVD, GEM, FTS
- Spin observables: STT, MVD, GEM, FTS