Simulation study of the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$ channel at $\bar{P}$ANDA

Gabriela Pérez Andrade

Uppsala University

Department of Physics and Astronomy

17-19 October 2018
Uppsala, Sweden

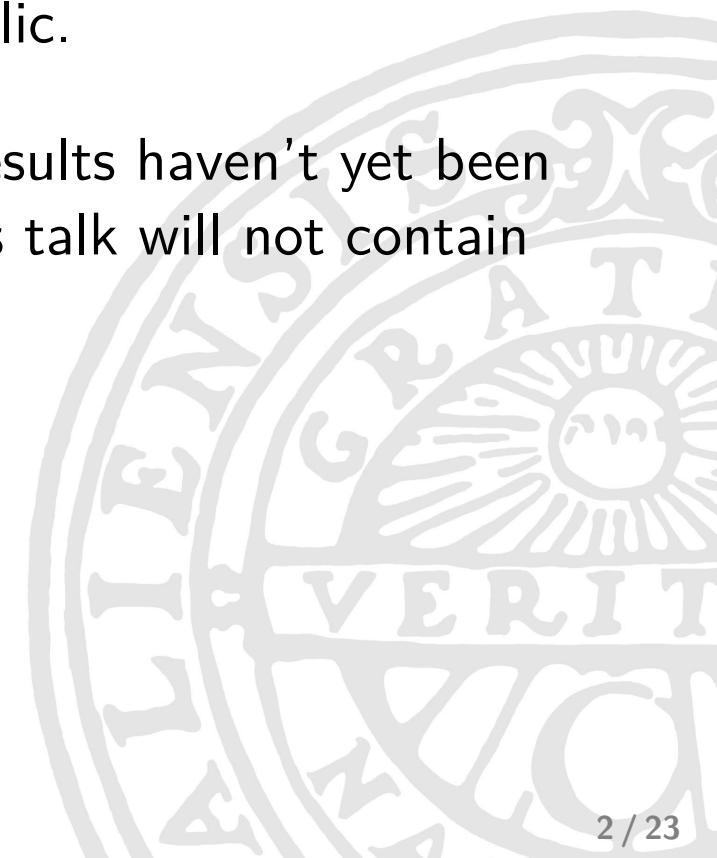
Overview

- The $\bar{P}$ANDA experiment
- The $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$ channel
  - Motivation
  - Previous studies
  - Analysis strategy
- Summary
- Outlook

Quick comment...

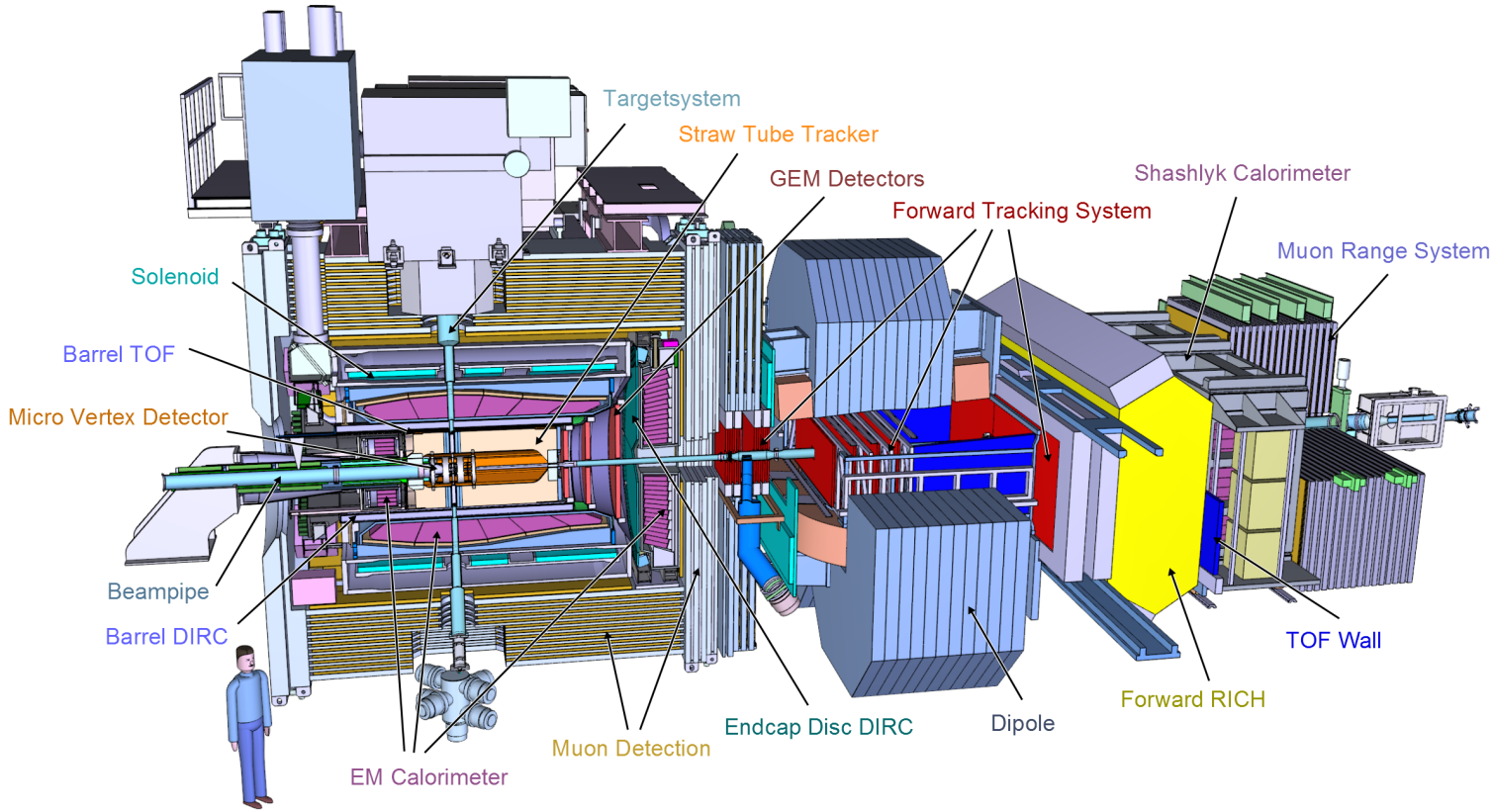
In $\bar{P}$ANDA, all results need to go through an internal review process before they can be shown to the public.

This is work in progress, meaning that the results haven't yet been submitted for internal review. Therefore, this talk will not contain any results.



The $\bar{P}$ANDA experiment

- $\bar{P}$ANDA = antiProton ANihilations at DArmstadt
- Fixed target experiment
- Aims for strong interaction studies through $\bar{p}p$ collisions
- $\bar{p}_{beam}$ from 1.5 up to 15 GeV/c

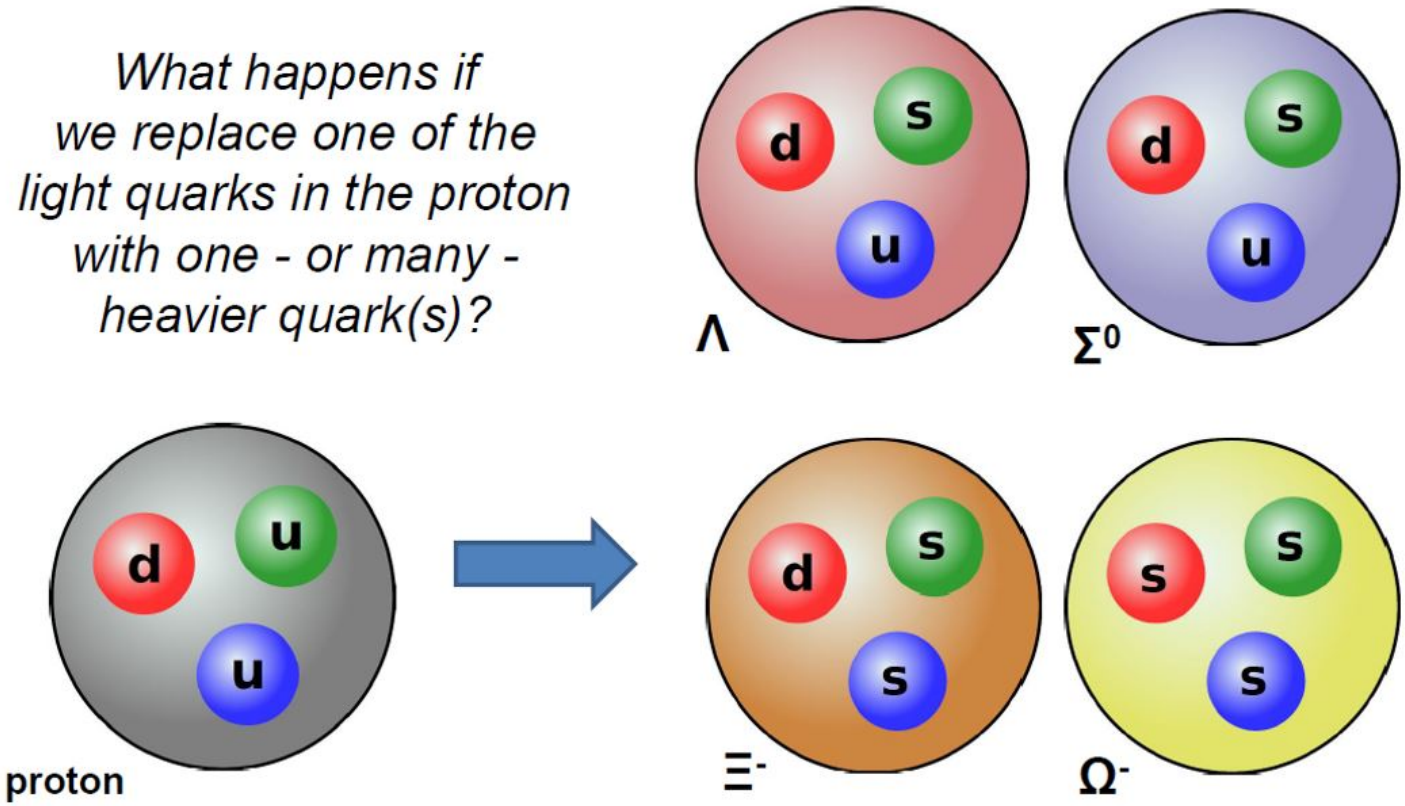


The $\bar{P}$ANDA physics programme

- Nucleon structure
- Strangeness physics
  - **Hyperon production** $\leftarrow$
  - Hyperon spectroscopy
  - Hypernuclear Physics
- Charm and exotics
  - Charmonium
  - Search for exotics
  - Light hadron spectroscopy
- Hadrons in nuclei

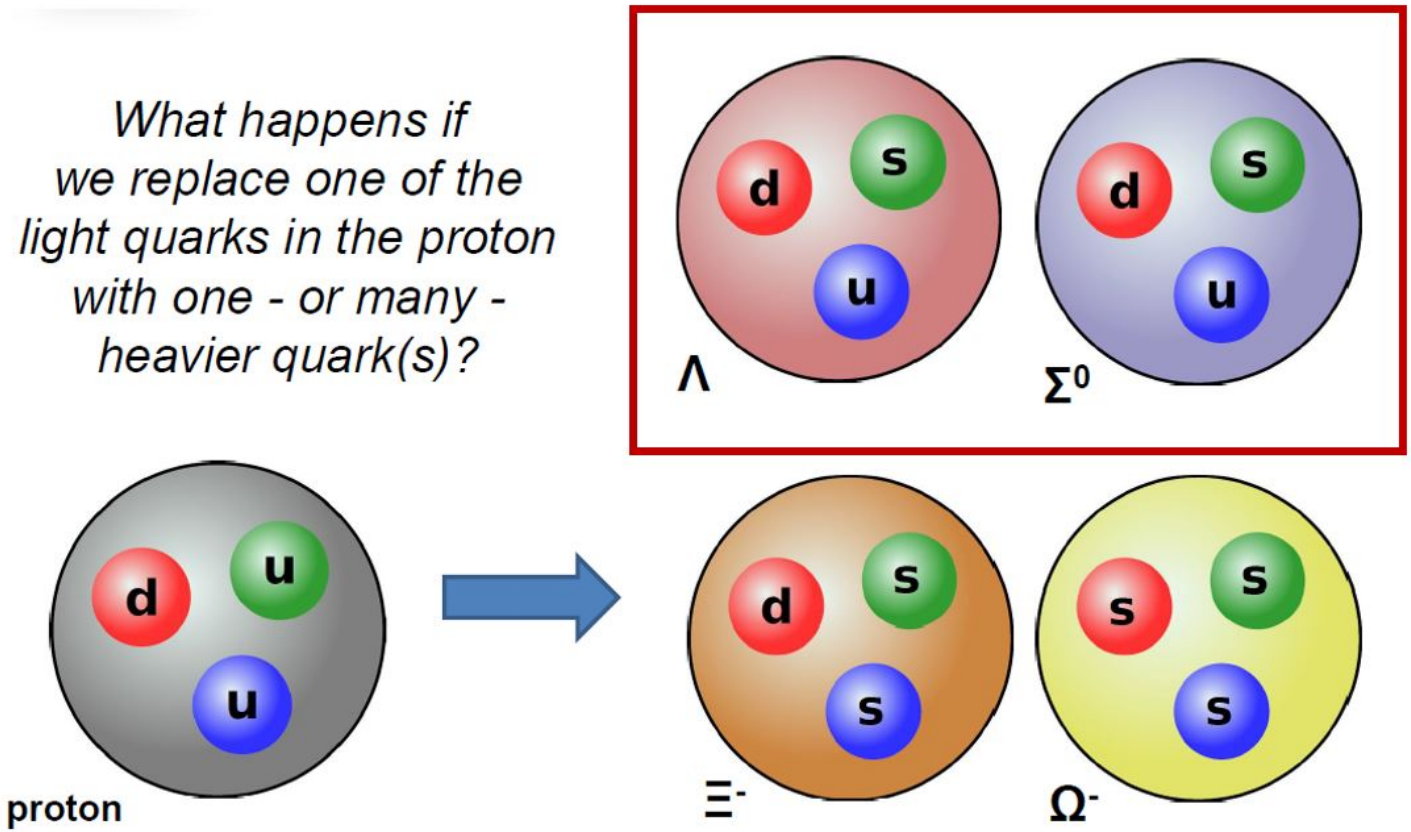
Hyperon production

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



Hyperon production

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



Motivation

Strange hyperon production is governed by $m_s \sim 100$ MeV, corresponding to the confinement domain. Moreover:

- It sheds light on the strong interaction at the low energy region ($\sim$ few GeV)
- Comparisons between isospin partners in channels such as $\bar{p}p \to \bar{\Lambda}\Lambda$, $\bar{\Sigma}^0\Lambda$ and $\bar{\Sigma}^0\Sigma^0$ provides information about the production dynamics
- The full $\bar{p}p \to \bar{\Sigma}^0\Lambda$ reaction is given by

$$\bar{p}p \to \bar{\Sigma}^0\Lambda \to \bar{\Lambda}\gamma\pi^- p \to \bar{p}\pi^+\gamma\pi^- p$$

Is it feasible to reconstruct the $\bar{\Sigma}^0\Lambda$ channel at $\bar{P}$ANDA ?

Hyperon production theoretical models

In a **quark-gluon** picture

- Occurs through the s-channel
- Quarks and gluons are relevant degrees of freedom

Information about role of the isospin.

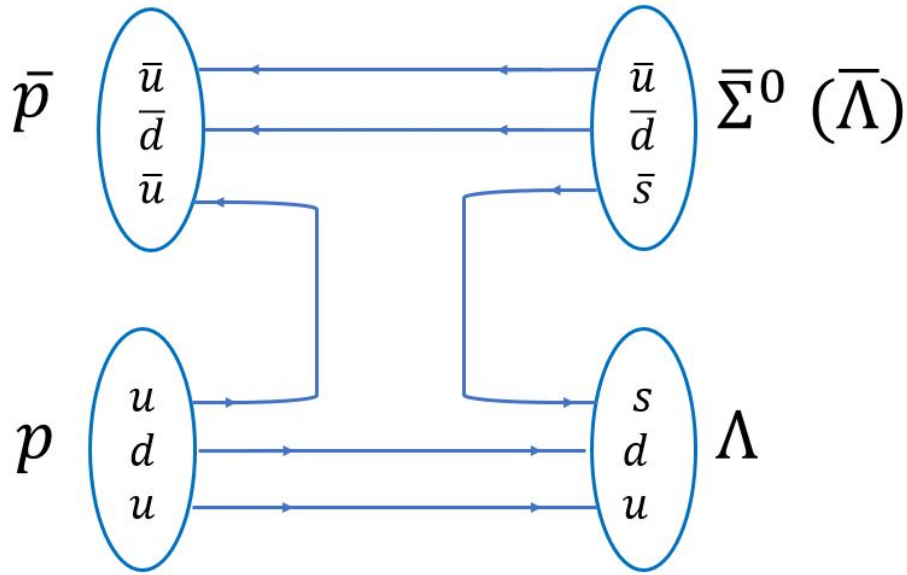


Figure: Hyperon production in quark-gluon model

Hyperon production theoretical models

In a **meson exchange** picture

- Occurs through the t-channel
- Mesons and baryons are relevant degrees of freedom

Information about coupling constants.

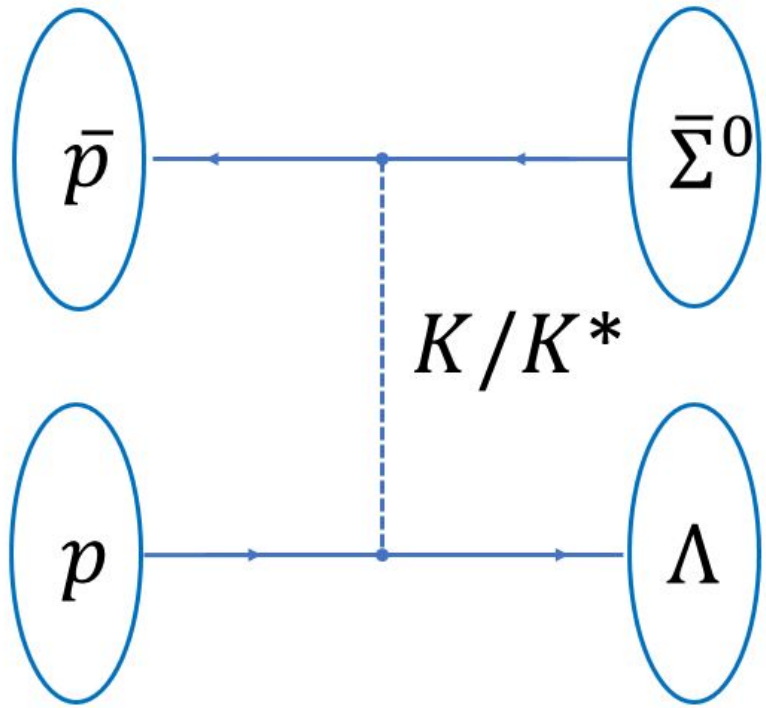


Figure: Hyperon production in meson exchange model

Previous measurements

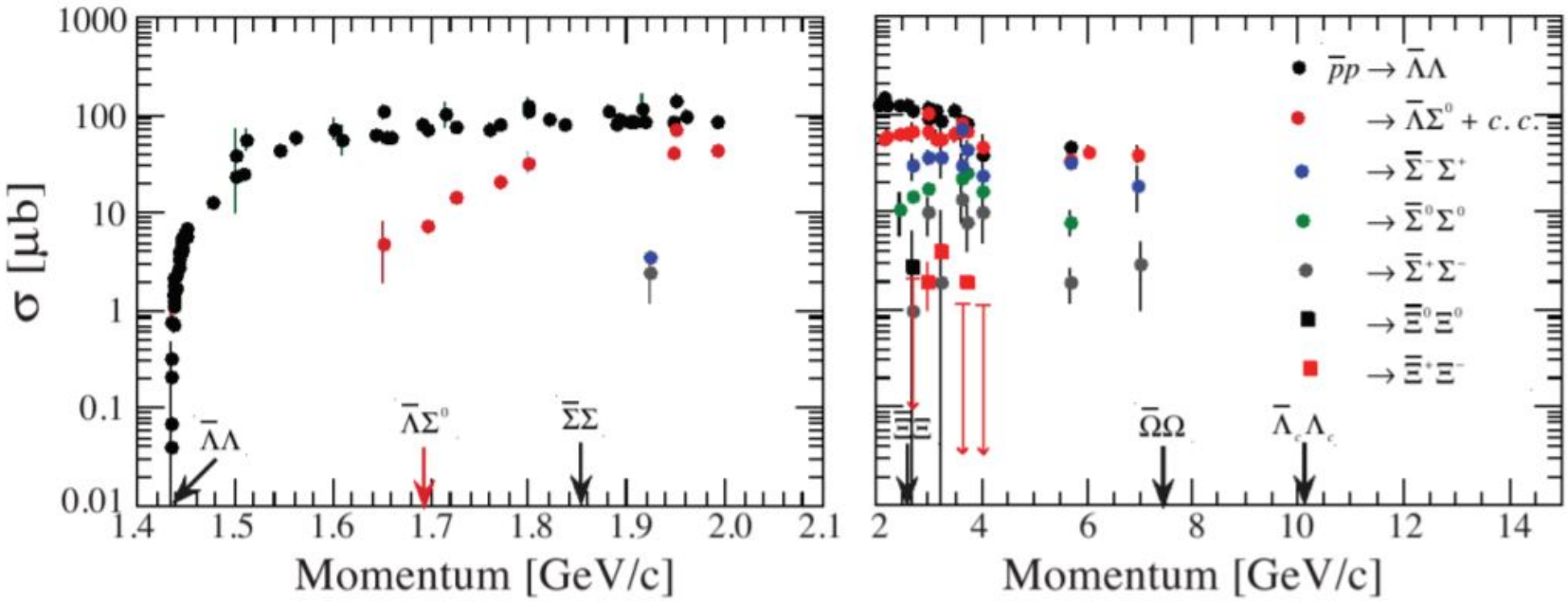


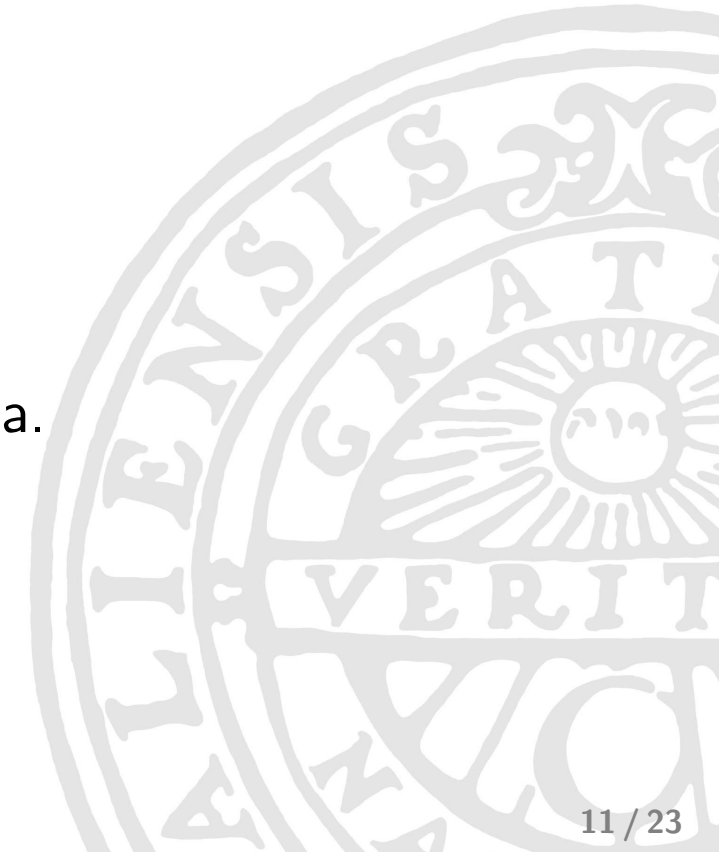
Figure: Johansson T 2003 Proceedings of 8th Int. Conf. on Low Energy Antiproton Physics 95

Previous measurements

From the $\bar{p}p \to \bar{\Lambda}\Lambda$ and $\bar{\Sigma}^0\Lambda + c.c.$ channels measurements performed at CERN, the

- Total and differential cross sections
- Polarization of outgoing hyperons
- Spin correlation

have been obtained at several beam momenta.



Previous measurements

From the $\bar{p}p \to \bar{\Lambda}\Lambda$ and $\bar{\Sigma}^0\Lambda + c.c.$ channels measurements performed at CERN, the

- **Total and differential cross sections** $\leftarrow$
- Polarization of outgoing hyperons
- Spin correlation

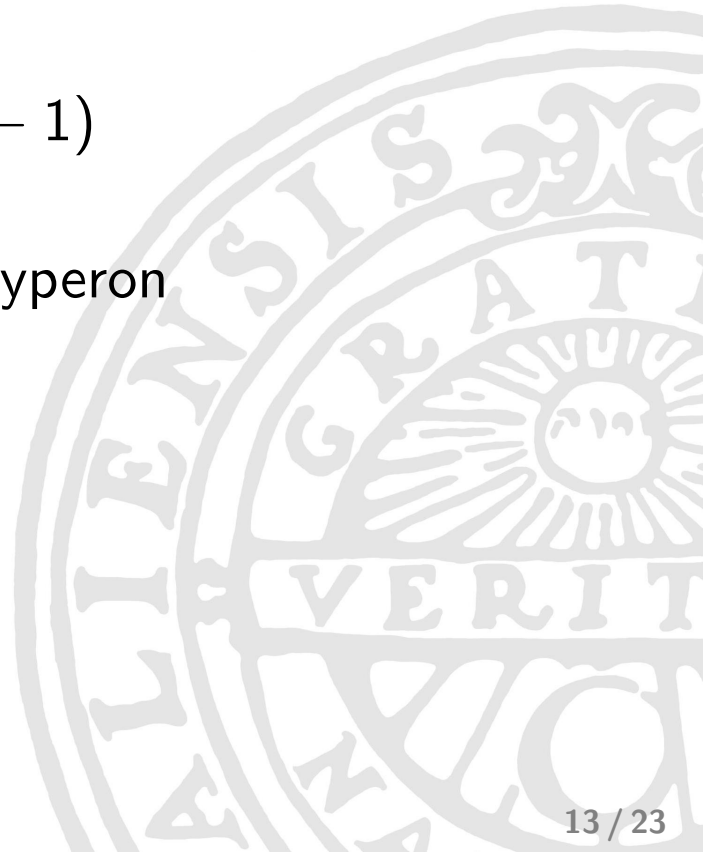
have been obtained at several beam momenta

Previous measurements

The differential cross sections at $\mathbf{p_{beam}}$**=1.771 GeV/c** and $\mathbf{p_{beam}}$**=6 GeV/c**, parametrized in terms of the reduced four-momentum transfer

$$t' = t - t_{min} = 2pq(cos\theta^* - 1)$$

- θ^* the c.m. scattering angle of the antihyperon
- p incoming c.m. momentum
- q outgoing c.m. momentum



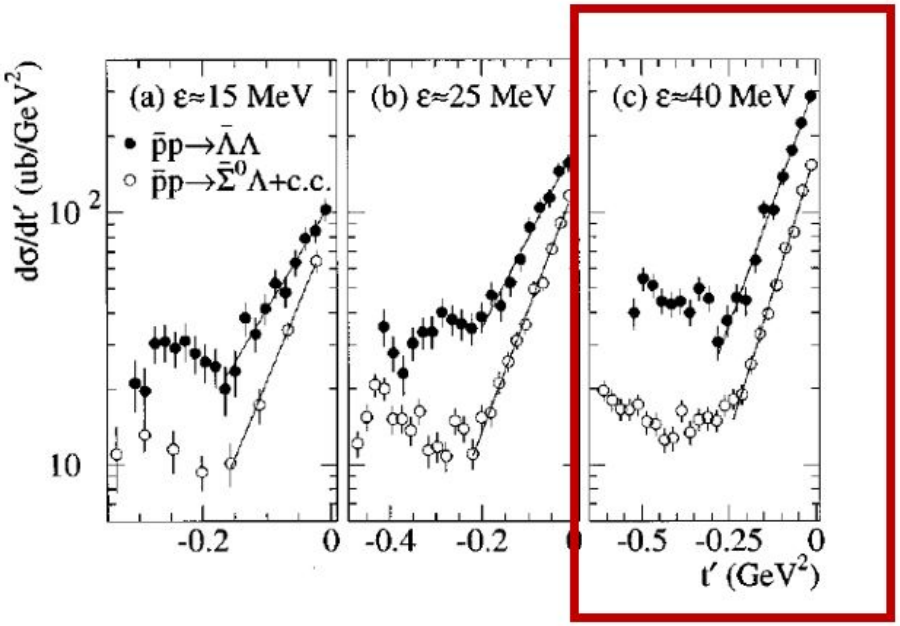
Previous measurements

At $\mathbf{p_{beam}}$**=1.771 GeV/c** parametrization of the form

$$\frac{d\sigma}{dt'} \sim e^{-b|t'|}$$

b slope parameter

- b $\sim 11 - 14$ GeV^{-2} for the $\bar{\Sigma}^0\Lambda$ channel



E. Klempt et al. Physics Reports 368 (2002) 119–316

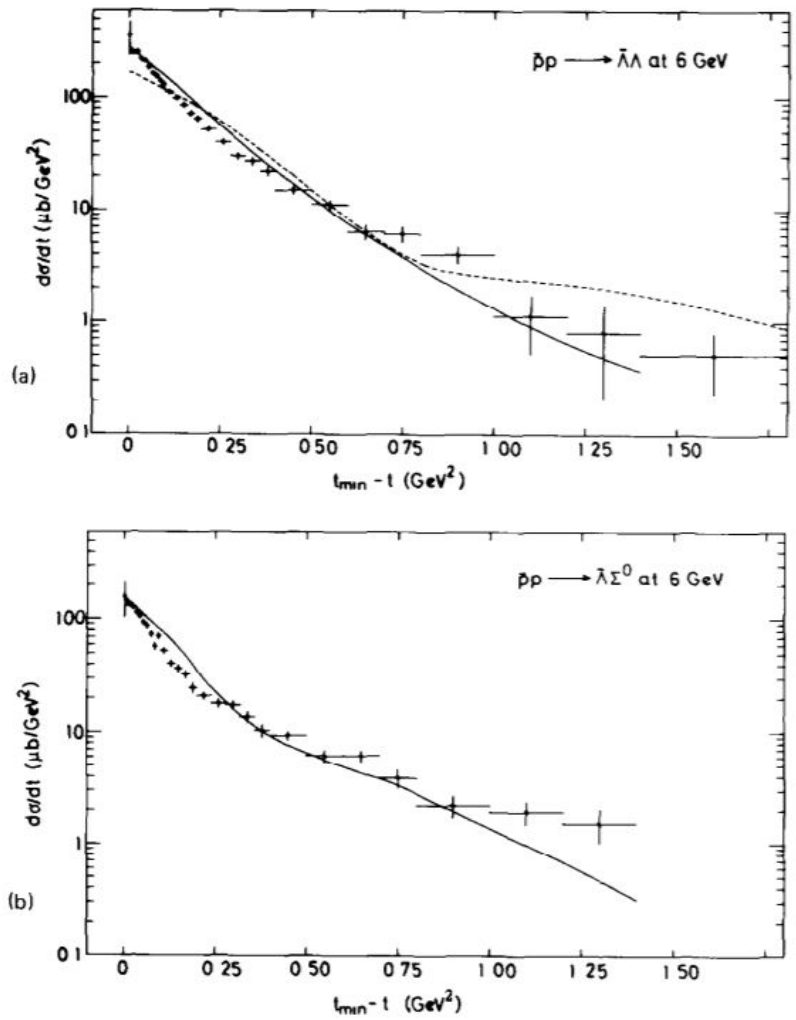
Previous measurements

At $\mathbf{p_{beam}=6\ GeV/c}$, the $\bar{\Sigma}^0\Lambda$ is parametrized with

$$\frac{d\sigma}{dt} \sim abe^{bt'} + cde^{dt'}$$

with the parameters values

- $a = 10.4 \pm 0.9\ \mu$b
- $b = 13.3 \pm 1.0\ \text{GeV}^{-2}$
- $c = 10.6 \pm 0.9\ \mu$b
- $d = 2.6 \pm \text{GeV}^{-2}$



H. Becker Nuclear Physics B141 (1978) 48-64

Previous simulation study at $\bar{P}$ANDA

Simulation of the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + c.c.$ channel at $p_{beam} = 4$ GeV/c performed by S. Grape (2009):

- Software framework based of the BaBar experiment
- Isotropic angular distribution

The study shows :

- Smooth acceptance at all values of $cos\theta^*$
- Reconstruction efficiency of 31.2 %

New simulation

- PandaRoot Software with realistic implemented detector material
- Realistic angular distribution based on experimental data from the PS and PS185 experiment (CERN)
- Two cases of the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$ channel:
  - 10k events generated at $p_{beam} = 1.771$ GeV/c
  - 10k events generated at $p_{beam} = 6$ GeV/c

Analysis strategy

- Pre-selection
  - Final state particles identification
  - Photon selection
  - $\Lambda/\bar{\Lambda}$ reconstruction
- Final selection
  - Inclusive event selection
  - Exclusive event selection

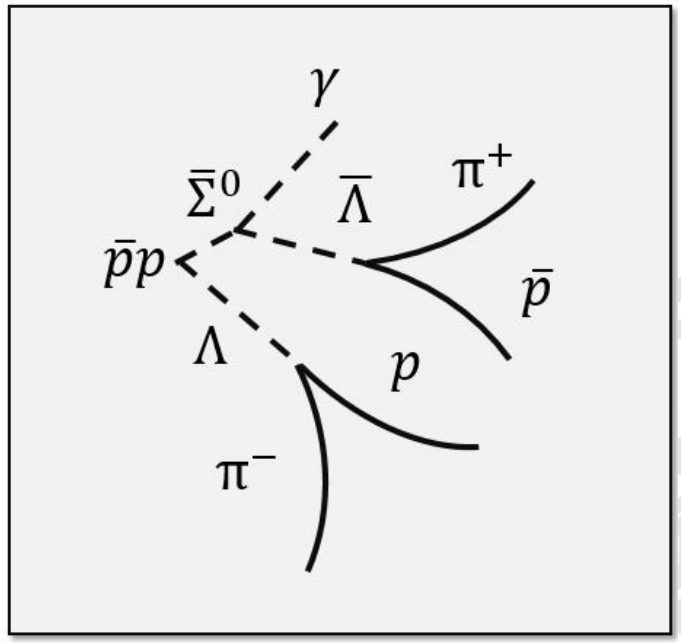
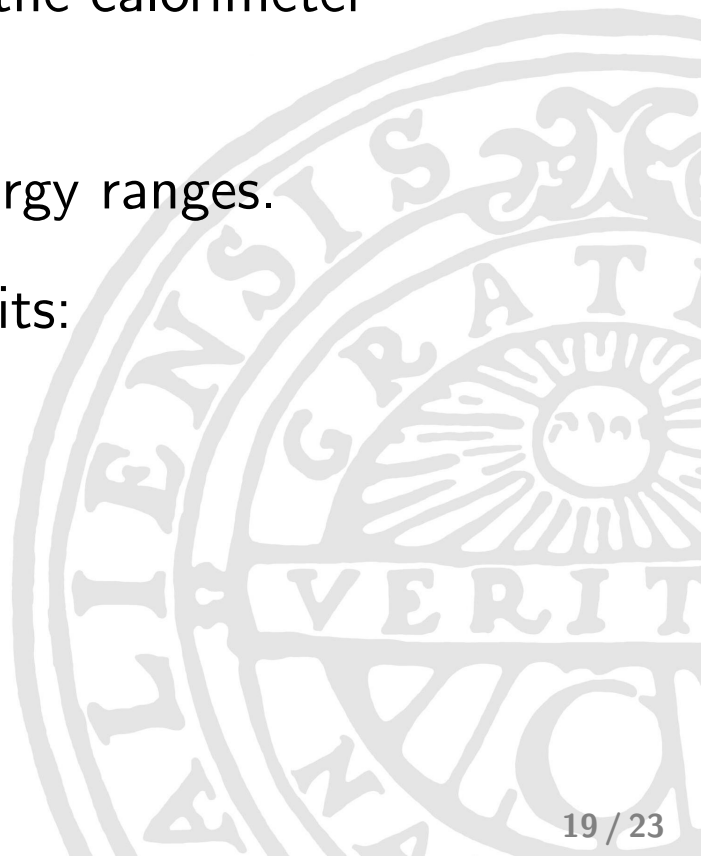


Figure: The channel reaction scheme

Pre-selection

- Charged particle identification.
- Neutral particles (γ) are identified from the calorimeter information, according to a cut value.
- Photon selection through cuts in the energy ranges.
- $\Lambda/\bar{\Lambda}$ reconstruction based on kinematic fits:
  - Vertex fit
  - Mass constraint fit



Final selection

- **Inclusive** event selection

  Reconstruction of $\bar{p}p \to \bar{\Sigma}^0 X$, with X an unknown particle reconstructed by missing kinematics.

  - **Less** kinematic constraints $\to$ **worse** background suppression
  - **Less** particles miss the detection $\to$ **better** efficiency

- **Exclusive** event selection

  Reconstruction of the full $\bar{p}p \to \bar{\Sigma}^0 \Lambda$ channel.

  - **More** kinematic constraints $\to$ **better** background suppression
  - **More** particles miss the detection $\to$ **worse** efficiency

Summary

- The $\bar{P}$ANDA experiment is very promising for hyperon production
- An updated simulation study on the reconstruction feasibility of the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda$ channel with a realistic angular distribution has been performed
- This study shows promising results for the channel reconstruction

Outlook

- Run a background generator to test the analysis strategy on this channel
- Explore the $\bar{\Sigma}^0$ dalitz decay, i.e. $\bar{\Sigma}^0 \to \bar{\Lambda} e^- e^+$

Results to come, stay tuned...

Thank You!