Quasi-real photo-production of hyperons

and their impact on Λ^0 polarization measurements

Andreas Reischl

NIKHEF

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Outline: Why measuring hyperon rates?

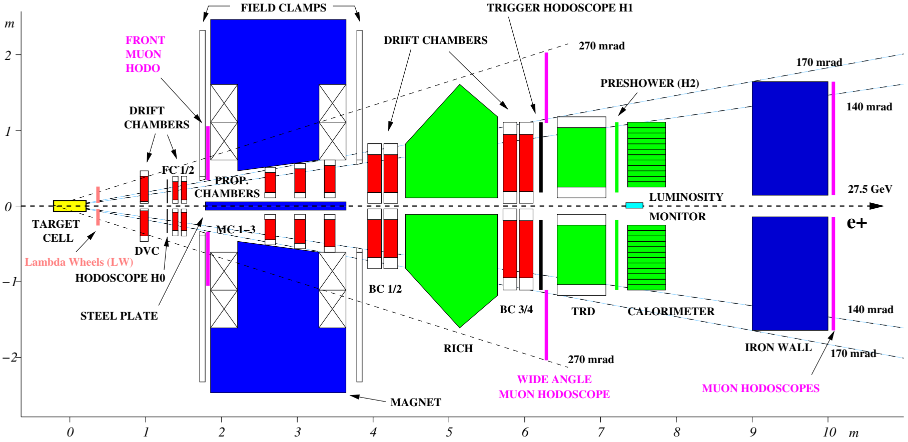
1. Instrumentation
   - HERMES experiment
   - Lambda Wheels
2. Analysis
   - Physics motivation
   - Hyperon reconstruction
3. Results
   - Cross sections
   - Feeding fractions

Σ Λ Σ^*

Ξ Ξ^*

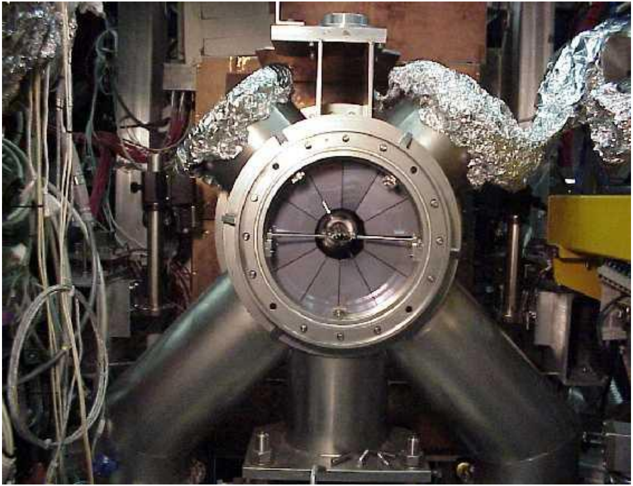
Ω

The HERMES experiment



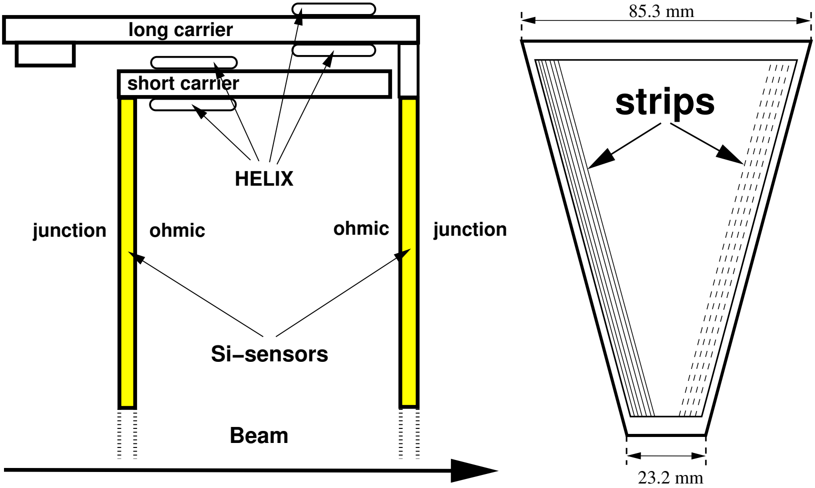
acceptance of $|\theta_x| < 170$ mrad and $40 < |\theta_y| < 140$ mrad
kinematic $0.02 < x < 0.8$ and $0.2 < Q^2 < 20$ GeV^2

The Lambda Wheels (LW)



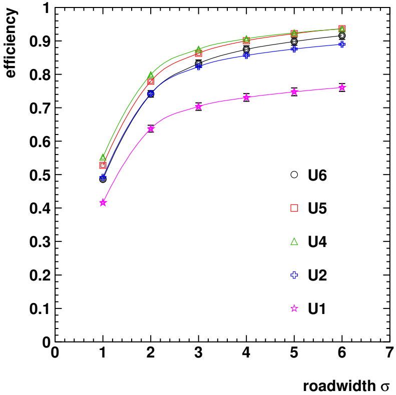
Wheel shaped silicon strip detector with two double sided sensors
Increased geometrical acceptance for the reconstruction of Λs

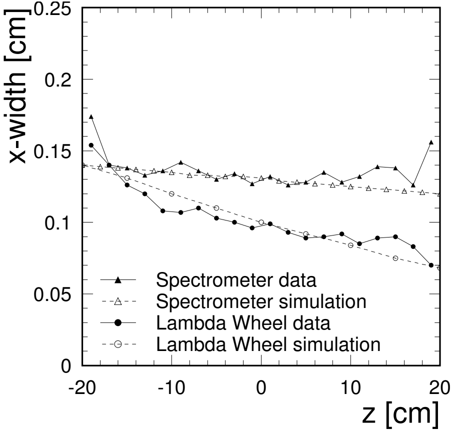
LW: closer look at the detector



module consists of two sensors; 516 strips; pitch 160μm
trapezoidal shape with an apex of 30° degrees

LW: results of the commissioning





Result

- efficiency reaches above 90 %
- Vertex resolution @ $z = 0$ cm of 0.1 cm

What is a baryon and hyperons?

Definition

A hyperon is a baryon which contains at least one strange quark.

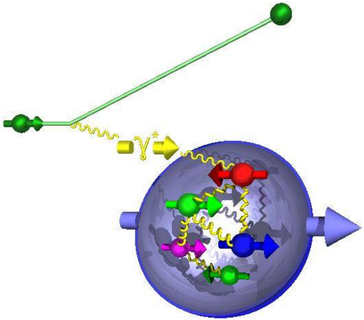
Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$
Baryons are fermionic hadrons.
These are a few of the many types of baryons.

Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
p	proton	**uud**	1	0.938	1/2
$\bar{\mathbf{p}}$	antiproton	$\bar{\mathbf{u}}\bar{\mathbf{u}}\bar{\mathbf{d}}$	–1	0.938	1/2
n	neutron	**udd**	0	0.940	1/2
Λ	lambda	**uds**	0	1.116	1/2
Ω^-	omega	**sss**	–1	1.672	3/2

Example

the Λ^0 is a hyperon containing a up a down and a strange-quark

How to measure polarization?



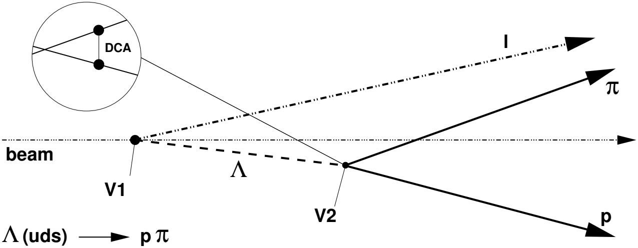
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z \quad (1)$$

- measure $\Delta\Sigma$ by evaluating asymmetries of cross sections
- alternatively via e.g. Λ decay distributions

Goals

- reconstruct as many hyperons as possible
- calculate production cross-section
- with MC evaluate 4π cross-section
- calculate feeding via decay of heavier hyperons

How to reconstruct a hyperon?



Requirements

- positive hadron PID requirement for p and π
- at least two hadrons of opposite sign
- one identified as a proton by the RICH
- energy of proton $>$ energy of pion
- distance of closest approach DCA $<$ 1.5 cm

How to measure the Λ polarization?

the decay protons are distributed like

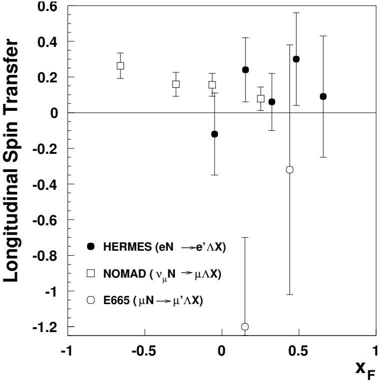
$$\frac{dN}{Nd\Omega} = \frac{1}{4\pi}(1 + \alpha\vec{P} \cdot \vec{k}) \quad (2)$$

the spin transfer to a Λ^0 can be measured

$$P^\Lambda = P_b \cdot D(y) \cdot D^\Lambda_{LL'} \quad (3)$$

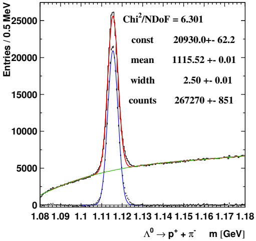
with the spin transfer coefficient

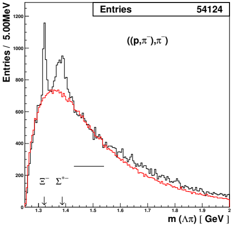
$$D^\Lambda_{LL'} = \frac{G^\Lambda_{1,f}(z)}{D^\Lambda_{1,f}(z)} \approx \frac{\Delta q^\Lambda_u}{q^\Lambda_u} \quad (4)$$

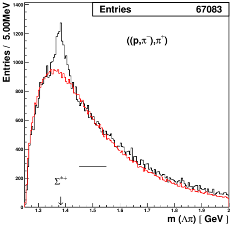


How to get the yield?

$\Lambda = p + \pi$ $\Xi = \Lambda + \pi^-$ $\Sigma^* = \Lambda + \pi^+$





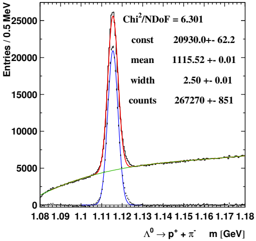


analyze invariant mass spectrum

- fit peak to determine position and width
- determine background shape for subtraction
- count the content of the peak
- evaluate error from content and background

How to get the yield?

$\Lambda = p + \pi$



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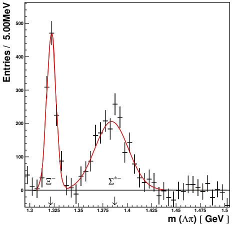
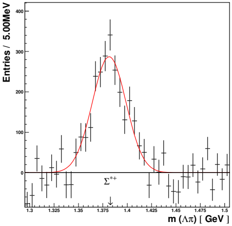


$\Sigma^* = \Lambda + \pi^+$



analyze invariant mass spectrum

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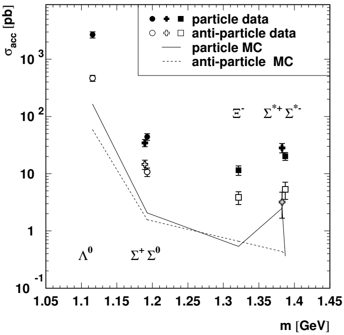
Cross sections in the HERMES acceptance



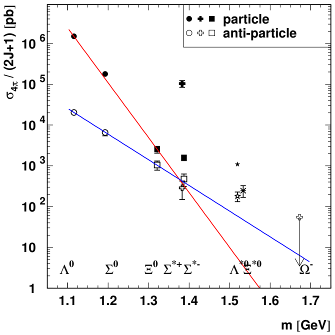
$$\sigma_{acc} = \frac{N}{\mathcal{L} \cdot B \cdot \epsilon_d \cdot \epsilon_t} \quad (5)$$

- N : number of counts
- $\mathcal{L}$: luminosity normalization
- B : branching ratio
- ϵ : efficiencies

Result

- possible to reconstruct an manyfold of hyperons
- Monte Carlo does not describe the production well

Cross sections extrapolated to 4π



$$\sigma_{4\pi} = \sigma_{acc}/\epsilon_g \cdot (2J+1) \quad (6)$$

- σ_{acc} : cross section in the HERMES acceptance
- ϵ_g : MC efficiency of the acceptance divided by the 4π efficency

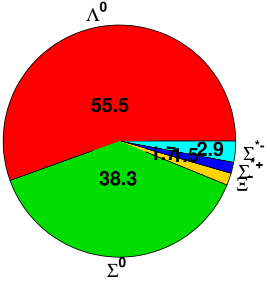
Result

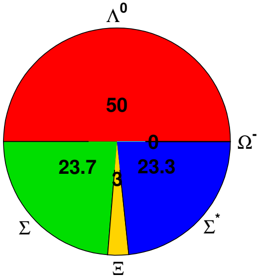
- difference in slope for particles and anti-particles

Contribution to the Λ^0 sample from other hyperons

DATA: $F_L^Y = N^Y \cdot C_L^Y$

Simulation: $f = \frac{N_L^Y}{N_L}$





Result

- about 50 % of the Lambdas are coming from heavier hyperons
- Simulations based on theory does not describe the production well
- has to be taken into account for Λ polarization measurements!

Summary and Outlook

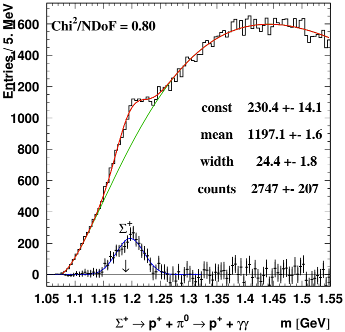
Summary

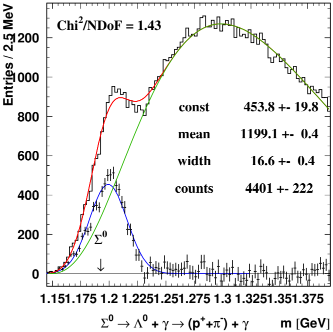
- test, build and commission a novel detector: LW
- reconstruct a manyfold of hyperons: Λ^0, Σ^{0+}, Ξ^- and $\Sigma^{*\pm}$
- determined cross sections and feeding of hyperons

Outlook

- participate in novel detector research: RPC
- contribute to more new (hyperon) physics: FOPI
    - determination of inclusive cross section of strange particles
    - In-Medium effects on π induced strangeness production
    - Kaonic nuclear cluster and excited Λ^*

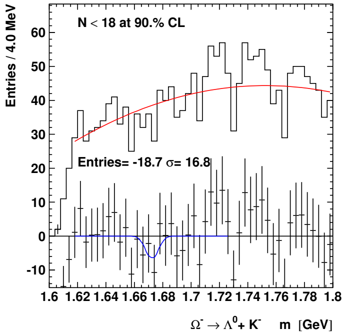
Sigmas

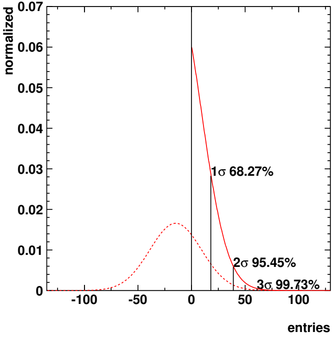




Σ^+ and Σ^0 (and $\bar{\Sigma}^+$ and $\bar{\Sigma}^0$) have been reconstructed as well

Omega

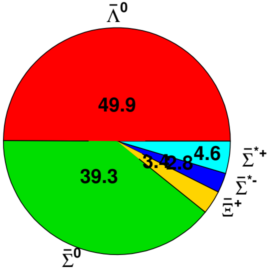




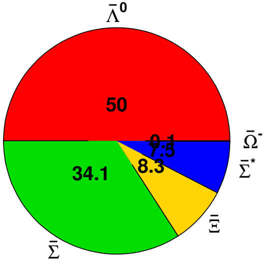
upper limit for the Ω^- is < 61 @ 3σ confidence

Contribution to the $\bar{\Lambda}^0$ sample

DATA result



Simulation result



result

the result is quite similar

Hyperon table

	spin	iso	mass [MeV/c^2]	quark	$c\tau$ [cm]	width [MeV]	decay	BR [%]
Λ^0	1/2	0	1115.683	uds	7.89		p π^-	63.9
Σ^+	1/2	1	1189.37	uus	2.404		p π^0	51.6
Σ^0	1/2	1	1192.642	uds	22.2E-7		Λ^0 γ	100
Σ^-	1/2	1	1197.449	dds	4.434		n + X	98.8
Ξ^0	1/2	1/2	1314.83	uss	8.71		Λ^0 π^0	98.5
Ξ^-	1/2	1/2	1321.31	dss	4.91		Λ^0 π^-	98.9
Σ^{*+}	3/2	1	1382.8	uus		35.8	Λ^0 π^+	88
Σ^{*0}	3/2	1	1383.7	uds		36	Λ^0 π^0	88
Σ^{*-}	3/2	1	1387.2	dds		39.4	Λ^0 π^-	88
Ξ^{*0}	3/2	1/2	1531.8	uss		9.1	Ξ π	100
Ξ^{*-}	3/2	1/2	1535.0	dss		9.9	Ξ π	100
Ω^-	3/2	0	1672.45	sss	2.461		Λ^0 K^-	67.8

Physics motivation