Formation of heavy hyperons and antihyperons in DIS at COMPASS

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on behalf of the COMPASS collaboration

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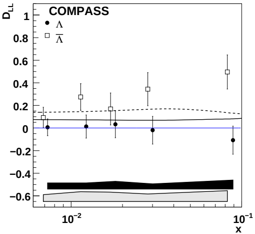
Physics motivation

- To determine to what extent the yields of heavy hyperons and antihyperons are different.
- To check the hypothesis that polarization of Λ and $\bar{\Lambda}$ are different due to different contribution of indirect Λ and indirect $\bar{\Lambda}$.



COMPASS Collaboration, M.Alekseev et al., Eur.Phys.J. C64 (2009) 171.

- To tune MC we need additional ratios of reconstructed particles ($\Sigma^{\pm}(1385)/\Lambda$, $\bar{\Sigma}^{\pm}(1385)/\bar{\Lambda}$).

Yields of heavy hyperons and antihyperons

Decay of heavy strange hyperons is one of possible sources of Λ ($\bar{\Lambda}$) production.

$$\mu^+ + d \rightarrow \mu^+ + \Lambda\,(\bar{\Lambda}) + X \qquad (1)$$

direct

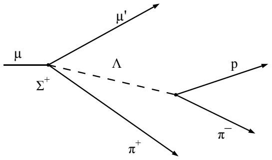
$$\mu^+ + d \rightarrow \mu^+ + \Sigma^+(1385) + X \quad (2)$$
$$\searrow \Lambda + \pi^+$$

$$\mu^+ + d \rightarrow \mu^+ + \bar{\Sigma}^-(1385) + X \quad (3)$$
$$\searrow \bar{\Lambda} + \pi^-$$

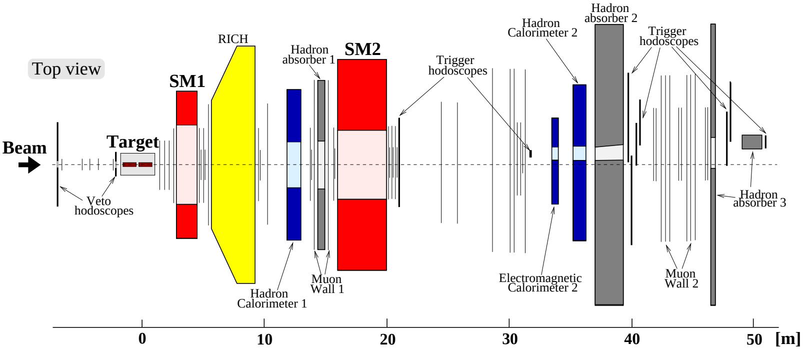
$$\mu^+ + d \rightarrow \mu^+ + \Sigma^0(1385) + X \quad (4)$$
$$\searrow \Lambda + \gamma$$

$$\mu^+ + d \rightarrow \mu^+ + \Xi^-(1321) + X \quad (5)$$
$$\searrow \Lambda + \pi^-$$

indirect



COMPASS spectrometer



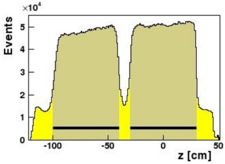
Muon beam
160 $GeV/c\ \mu^+$
$2\cdot 10^8 \mu/16.8s$
Target material ^6LiD

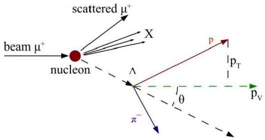
Spectrometer
Two magnets (1 T, 4.4 T)
PID: π, K, p RICH
ECAL, HCAL, muon filter

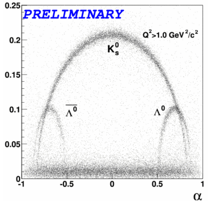
Criteria for the primary and Λ^0 vertex selection

2003 - 2004 data were used for this analysis.

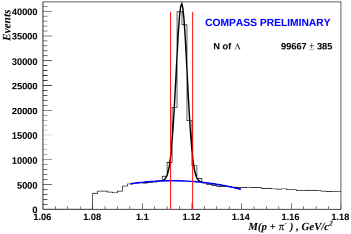
- Primary vertex inside the target.
- Secondary vertex: 5 cm downstream of the last tardet cell.
- The χ^2 value of the secondary vertex is $\chi^2 < 2$.
- $\theta_{coll.} < 0.01$ rad.
- $p_t > 23$ MeV/c – to reject e^+e^- pairs from the γ conversion.
- $p_\pm > 1$ GeV/c.
- Cut on x_F: $0.05 < x_F < 1.0$
- The DIS cuts were $Q^2 > 1\ (\text{GeV}/c)^2$ and $0.2 < y < 0.9$.

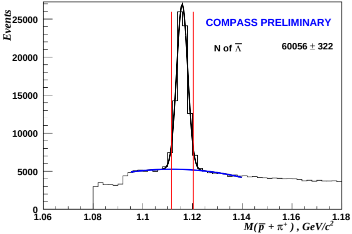






Distributions of $p\pi^-$ and $\bar{p}\pi^+$ invariant mass for experimental data



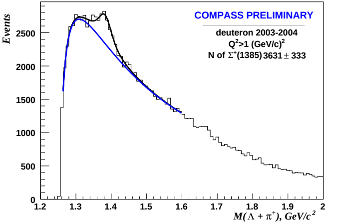


$N(\Lambda) = 99667 \pm 385$ $\quad$ $N(\bar{\bar{\Lambda}}) = 60056 \pm 322$

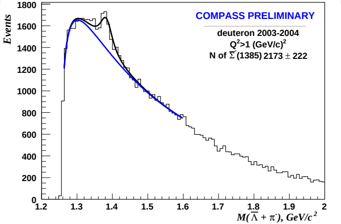
	N(Λ)	($\bar{\Lambda}$)
E665	750	650
NOMAD	8087	649
HERMES	7300	1687
RHIC	13000	10000
COMPASS	100000	60000

To determine the $\Lambda\ \pi$ invariant mass, the events with an invariant mass of $p\pi^-$ within a $\pm 2\ \sigma$ interval from the mean value of the Λ ($\bar{\Lambda}$) peak are taken.

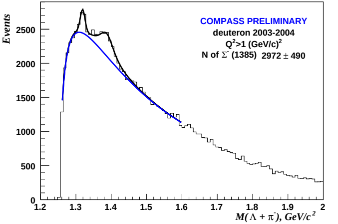
Distributions of $\Lambda\pi^\pm$ and $\bar{\Lambda}\pi^\pm$ invariant mass for experimental data



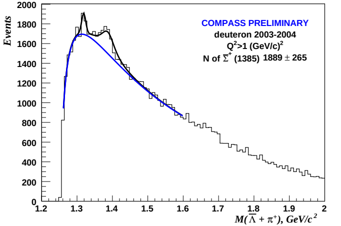
$N(\Sigma^+) = 3631 \pm 333$



$N(\overline{\Sigma}^-) = 2173 \pm 222$



$N(\Sigma^-) = 2970 \pm 490$



$N(\overline{\Sigma}^+) = 1889 \pm 265$

Fitting procedure

These distributions have been fitted by a sum of Breit-Wigner convoluted with gaussian

$$R(x) = \frac{\Gamma}{2\cdot\pi} \cdot \int \frac{Ndt}{(t-M)^2+(\frac{\Gamma}{2})^2} \cdot \frac{1}{\sqrt{2\cdot\pi}} \cdot e^{-0.5(\frac{t-x}{\sigma})^2}$$

and the background function

$$B(x) = A \cdot (x - M_l)^B \cdot e^{-C\cdot(x-M_l)^D}$$

Fit parameters:

N - total numbers

M - mass of resonance (fixed)

Γ - width of resonance (fixed)

σ - width of Gaussian

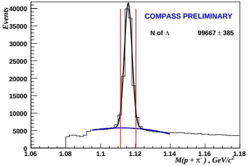
A - amplitude of background

B, C, D - free parametres

Ml - reaction threshold mass (1.254 GeV mass of $\Lambda + \pi$)

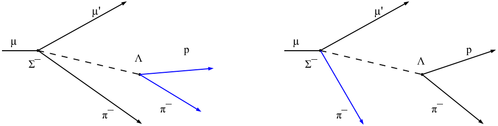
Estimation of the systematic effects

- **Selection cut:**
  To estimate the systematic error connected with the particular choice of the selection cut of the Λ ($\bar{\Lambda}$) sample we change the width of the central band from $\pm 2\,\sigma$ to ± 2.5 and $\pm 1.5\,\sigma$.



  Contribution of cut variation to the systematic error was found to be negligible.

- **Background shape:**
  To estimate this effect we evaluate the background using mixed event method, in which the shape of the background distribution in the $\Lambda\pi$ invariant mass was determined combining Λ and π from different events of the same topology.



  Systematic error due to background shape is comparable with statistic error.

Yields of heavy (anti-)hyperons

The relative yields of heavy (anti-)hyperons production in DIS were measured at COMPASS spectrometer:

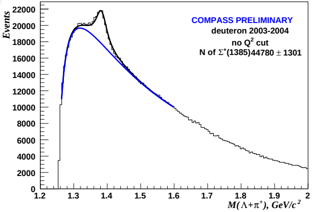
$$R^{+} = \Sigma^{+}(1385)/\Lambda = 0.055 \pm 0.005 \pm 0.0045$$
$$\bar{R}^{-} = \overline{\Sigma}^{-}(1385)/\bar{\Lambda} = 0.047 \pm 0.006 \pm 0.0053$$
$$R^{-} = \Sigma^{-}(1385)/\Lambda = 0.056 \pm 0.009 \pm 0.0074$$
$$\bar{R}^{+} = \overline{\Sigma}^{+}(1385)/\bar{\Lambda} = 0.039 \pm 0.006 \pm 0.0064$$

Without DIS cuts: $Q^2 > 0$ and $0 < y < 1$.

- Primary vertex inside the target.
- Secondary vertex: 5 cm downstream of the last tardet cell.
- The χ^2 value of the secondary vertex is $\chi^2 < 2$.
- $\theta_{coll.} < 0.01$ rad.
- $p_t > 23$ MeV/c – to reject e^+e^- pairs from the γ conversion.
- $p_\pm > 1$ GeV/c.
- Cut on x_F: $0.05 < x_F < 1.0$
- There is no cuts $Q^2 > 1\ (\mathrm{GeV}/c)^2$ and $0.2 < y < 0.9$ anymore.

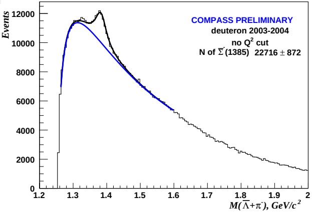
DIS cuts:	Without DIS cuts:
$N(\Lambda) = 100000 \pm 380$	$N(\Lambda) = 1060000 \pm 1200$
$N(\overline{\Lambda}) = 60000 \pm 320$	$N(\overline{\Lambda}) = 580000 \pm 1000$

Distributions of $\Lambda\pi^\pm$ and $\bar{\Lambda}\pi^\pm$ invariant mass for experimental data without DIS cuts



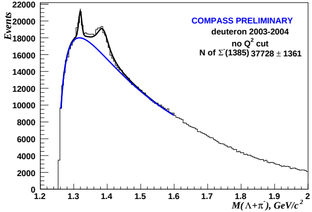
$N(\Sigma^+) = 40000 \pm 1250$

DIS cuts: $N(\Sigma^+) = 3600 \pm 330$



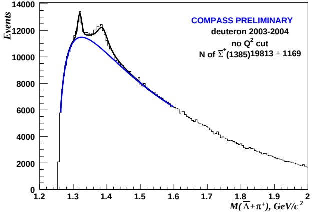
$N(\overline{\Sigma}^-) = 20000 \pm 850$

$N(\overline{\Sigma}^-) = 2200 \pm 220$



$N(\Sigma^-) = 35200 \pm 1500$

DIS cuts: $N(\Sigma^-) = 3000 \pm 500$



$N(\overline{\Sigma}^+) = 19500 \pm 1200$

$N(\overline{\Sigma}^+) = 1900 \pm 260$

Yields of heavy (anti-)hyperons

Table: The ratios of the hyperon yields for the events with and without the DIS cuts

Σ/Λ (no cut)/Σ/Λ (DIS cut)	
Σ^+/Λ	1.03 ± 0.08
$\bar{\Sigma}^-/\bar{\Lambda}$	0.97 ± 0.11
Σ^-/Λ	1.03 ± 0.16
$\bar{\Sigma}^+/\bar{\Lambda}$	0.97 ± 0.13

Comparison with other experiments

The yield of the heavy hyperons in DIS was measured by the NOMAD collaboration in neutrino DIS.

Ratios	Present data	NOMAD
$\Sigma^+(1385)/\Lambda$	0.055 ± 0.005	0.058 ± 0.011
$\overline{\Sigma}^-(1385)/\bar{\Lambda}$	0.047 ± 0.006	–
$\Sigma^-(1385)/\Lambda$	0.056 ± 0.009	0.026 ± 0.009
$\overline{\Sigma}^+(1385)/\bar{\Lambda}$	0.039 ± 0.006	–

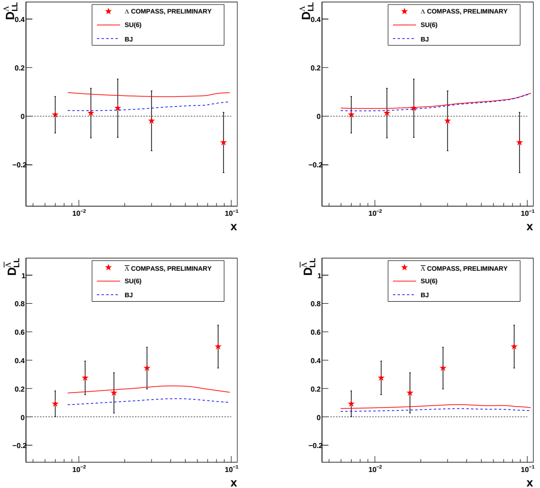
Tuned MC

The column LEPTO COMPASS corresponds to the LEPTO with tuned parameters.

Ratios	LEPTO Default	R	LEPTO COMPASS
$\Lambda/\bar{\Lambda}$	1.22 ± 0.01	1.71 ± 0.02	1.68 ± 0.01
K/Λ	6.06 ± 0.01	6.21 ± 0.05	6.22 ± 0.01
Σ^+/Λ	0.082 ± 0.001	0.055 ± 0.005	0.055 ± 0.001
$\bar{\Sigma}^-/\bar{\Lambda}$	0.074 ± 0.001	0.047 ± 0.006	0.049 ± 0.001
Σ^-/Λ	0.084 ± 0.001	0.056 ± 0.009	0.061 ± 0.001
$\bar{\Sigma}^+/\bar{\Lambda}$	0.060 ± 0.001	0.039 ± 0.006	0.039 ± 0.001

Influence on the $\Lambda(\bar{\Lambda})$ polarization

LEPTO Default: LEPTO COMPASS:



Λ

$\bar{\Lambda}$

LEPTO(Default) - J.Ellis, A.M.Kotzinian, D.Naumov, M.G.Sapozhnikov, Eur.Phys.J.C52,283(2007)

Conclusion

- The yields of heavy (anti-)hyperons in DIS are measured:

$$R^+ = \Sigma^+(1385)/\Lambda = 0.055 \pm 0.005 \pm 0.0045$$
$$\bar{R}^- = \bar{\Sigma}^-(1385)/\bar{\Lambda} = 0.047 \pm 0.006 \pm 0.0053$$
$$R^- = \Sigma^-(1385)/\Lambda = 0.056 \pm 0.009 \pm 0.0074$$
$$\bar{R}^+ = \bar{\Sigma}^+(1385)/\bar{\Lambda} = 0.039 \pm 0.006 \pm 0.0064$$

- The relative yields of indirect Λ and $\bar{\Lambda}$ production are similar
- The ratios Σ/Λ are not dependent on Q^2 (DIS cuts).
- The LEPTO generator parameters have been tuned to reproduce the yields
- The values of Σ/Λ are important for correct description of $\Lambda(\bar{\Lambda})$ spin transfer.

Backup slides

Backup slides

In Table a comparison between the default LEPTO parameters and the NOMAD tuned ones is given. The results of the COMPASS tuning are given in the last column.

Parameters	Default	NOMAD	COMPASS tuning
PARJ(1)	0.1	0.05	0.055
PARJ(2)	0.3	0.21	0.2
PARJ(3)	0.4	0.07	0.97
PARJ(4)	0.05	0.001	0.007
PARJ(5)	0.5	0.97	3.0
PARJ(6)	0.5	0.5	0.5
PARJ(7)	0.5	0.39	0.97

PARJ(1) is $P(qq)/P(q)$, the suppression of diquark-antidiquark pair production in the colour field, compared with quark(antiquark) production;
PARJ(2) is P(s)/P(u), the suppression of s quark pair production in the field compared with u- or d- pair production;
PARJ(3) is (P(us)/P(ud))/(P(s)/P(d)), the extra suppression of strange diquark production compared with the normal suppression of strange quarks;
PARJ(4) is $(1/3)P(ud_1)/P(ud_0)$, the suppression of spin 1 diquarks compared with spin 0 ones (excluding the factor 3 coming from spin counting);
PARJ(5) is parameter determining relative occurence of baryon production by $BM\bar{B}$ and by $B\bar{B}$ configurations in the popcorn baryon production model, roughly $P(BM\bar{B})/(P(B\bar{B}) + P(BM\bar{B}))$ = PARJ(5)/(0.5+PARJ(5));
PARJ(6) is extra suppression for having a ss pair shared by the B and $\bar{B}$ of a $BM\bar{B}$ situation;
PARJ(7) is extra suppression for having a strange meson M in a $BM\bar{B}$ configuration.