Status & Future Plans for COSY-TOF*

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Content

- Introduction
- The COSY-TOF experiment
- Physics at COSY-TOF
- Future physics at COSY-TOF
- Summary
- Outlook

W. Schroeder, CGSWHP, 4. Sep. 2006
Information: structure + dynamics $\rightarrow$ degrees of freedom

Strangeness production at COSY-TOF: $pN \rightarrow KYN$

different reaction channels: $N = p, n$ $Y = \Lambda, \Sigma^0, \Sigma^+, \Sigma^-$

**Meson Exchange Model**

$p\Lambda$ final state interaction

Search for exotic $\Theta^+$

W. Schroeder, CGSWHP, 4. Sep. 2006
Comparison of the calculations

No discrimination between models !!!!

\[ \text{differential observables} \]

\[ \rightarrow \text{COSY-TOF} \]

\[ \rightarrow \text{Dalitz plot} \]

W. Schroeder, CGSWHP, 4. Sep. 2006
Strangeness production at COSY-TOF

- exclusive observables
- threshold region → only few partial waves, no Y*
- full phase space → Dalitz Plots
- polarization: Λ-polarization, polarized beam, (polarized target)
COSY - Facility

Cooler Synchrotron
Jülich

Circumference: 180 m

Phase space cooling:
electron and stochastic

Beam momentum:
maximum: 3.6 GeV/c
COSY - TOF - Detector

large angle (non magnetic) spectrometer with modular vacuum vessel

stop detector system

W. Schroeder, CGSWHP, 4. Sep. 2006
large angle (non magnetic) spectrometer with modular vacuum vessel

W. Schroeder, CGSWHP, 4. Sep. 2006
“Erlangen Start Detector“: Ring microstrip detector

Frontside 100 rings

Rearside 128 sectors
Experiment upgrade 2004

New fibre hodoscope with three layers

→ increase of efficiency and purity

Two layers

Three layers

W. Schroeder, CGSWHP, 4. Sep. 2006
Reaction $pp \rightarrow K^+\Lambda p$

- **Optimized** for track- and vertex reconstruction
  - Starttorte doublesided Si-micro strip detector two fiber hodoscopes
- **complete geometric reconstruction** of all charged particles
- **TimeOfFlight measurement**
- **Unique Strangeness-Trigger**
  - Increase of charged multiplicity: $2 \rightarrow 4$
  - for the reaction $pp \rightarrow K^+\Lambda p$
  - $\Lambda \rightarrow \pi^-p$

W. Schroeder, CGSWHP, 4. Sep. 2006
Reaction $pp \rightarrow K^0\Sigma^+p$

- **Optimized** for track- and vertex reconstruction
- **Starttorte**
  - doublesided Si-micro strip detector
  - two fiber hodoscopes
- **Complete geometric reconstruction** of all charged particles
- **TimeOfFlight** measurement
- **Unique Strangeness-Trigger**
  - increase of charged multiplicity: $2 \rightarrow 4$
  - for the reaction $pp\rightarrow K^0\Sigma^+p$
  - $K^0_s \rightarrow \pi^-\pi^+$
• **Strangeness Production in pp reaction**
  \[ pp \rightarrow K^0\Sigma^+p, pp \rightarrow K^+\Lambda p \]

• Meson - Production in pp reaction (e.g. \( \omega \))

• ....
Strangeness Production

\[ \text{pp} \rightarrow \Sigma^+ K^0 p: \text{reconstructed masses} \]

\[ P_{\text{beam}} = 2.95 \text{ GeV/c} \]

\[ \text{Runs 2000 + 2002} \]

W. Schroeder, CGSWHP, 4. Sep. 2006
pp → Σ⁺K⁰p: K⁰p mass spectra

P_{beam} = 2.95 GeV/c

\[ \text{significance: } 4 - 6 \sigma \]
(depending on method)

\[ \frac{NS}{\sqrt{NB}} = 5.9 \sigma \]
\[ \frac{NS}{\sqrt{NS + NB}} = 4.7 \sigma \]
\[ \frac{NS}{\sqrt{(NS + NB) + NB}} = 3.7 \sigma \]

W. Schroeder, CGSWHP, 4. Sep. 2006
pp → Σ⁺K⁰p: efficiency corrected K⁰p spectrum

Mass 1530 ± 5 MeV/c²
Width ≤ 18 ± 4 MeV/c² (FWHM)
Strangeness S = + 1
Cross section: 0.4 ± 0.1_{stat} ± 0.1_{sys} µb

Measurement (Oct./Nov. 2004): \( pp \rightarrow K^0 \Sigma^+ p \)

- improved experimental setup
- \( 10^9 \) raw events taken to tape
- expect about factor 5 in \( pK_\pi \) events over published result
  (> 5000 \( pK_\pi \) events, 300 in peak if signal persists)
- analysis ongoing and improved with respect to
  - blind analysis: ½ of the data to optimize analysis, rest for result
  - independent analysis at several institutes in parallel with different codes,
    emphasis on different detector aspects
  - systematics of Monte-Carlo treatment
  - use of redundant information (ToF of proton and pions, energy losses, ...)
  - common calibration database

Subsample of \( pp \rightarrow \Lambda K^+ p \):
0.7% of data
**pp → K⁺Λp: Reconstruction of Λ events**

Beam momentum: 2.95 / 3.20 / 3.30 GeV/c

**Data**
16465 events
2.95 GeV/c

**MC**
pp → K⁺Λp: Dalitz plot analysis

Data 2.95 GeV/c
Data 2.95 GeV/c

pp → K⁺Λp: Dalitz plot analysis

W. Schroeder, CGSWHP, 4. Sep. 2006
$\frac{d^2 \sigma}{dm_{K\Lambda}^2 dm_{p\Lambda}^2} = (\text{flux}) \cdot \left| \sum_R \left( C_R \cdot A_R + C_N \right) \cdot (1 + C_{FSI} \cdot A_{FSI}) \right|^2$
Data 2.95 GeV/c

$\frac{d^2 \sigma}{dm_{K\Lambda}^2 dm_{p\Lambda}^2} = (\text{flux}) \cdot \left( \sum_R (C_R \cdot A_R) + C_N \right) \cdot (1 + C_{FSI} \cdot A_{FSI})^2$

only FSI

W. Schroeder, CGSWHP, 4. Sep. 2006
Data 2.95 GeV/c

**pp → K^+Λp: Dalitz plot analysis**

Model calculation of Sibirtsev

\[
\frac{d^2 \sigma}{dm_{K\Lambda}^2 dm_{p\Lambda}^2} = (\text{flux}) \cdot \left( \sum_R \left( C_R \cdot A_R + C_N \right) \right) \cdot \left( 1 + C_{FSI} \cdot A_{FSI} \right)^2
\]

included resonances:

- N*(1650)
- N*(1710)
- N*(1720)
pp → K⁺Λp: Dalitz plot analysis

Model calculation of Sibirtsev

\[
\frac{d^2\sigma}{dm_{K\Lambda}^2 dm_{p\Lambda}^2} = (\text{flux}) \cdot \left| \sum_R \left( C_R \cdot A_R + C_N \right) \cdot (1 + C_{FSI} \cdot A_{FSI}) \right|^2
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only resonances
**pp → K⁺Λp: Dalitz plot analysis**

**Model calculation of Sibirtsev**

\[
\frac{d^2\sigma}{dm_{K\Lambda}^2 dm_{p\Lambda}^2} = (\text{flux}) \cdot \left[ \sum_{R} (C_R \cdot A_R) + C_N \right] \cdot \left( 1 + C_{FSI} \cdot A_{FSI} \right)^2
\]

- only resonances
- only FSI

W. Schroeder, CGSWHP, 4. Sep. 2006
pp $\rightarrow K^+\Lambda p$: Dalitz plot analysis

Model calculation of Sibirtsev

\[
\frac{d^2\sigma}{dm_{K\Lambda}^2 dm_{p\Lambda}^2} = (\text{flux}) \cdot \left( \sum_R (C_R \cdot A_R) + C_N \right) \cdot (1 + C_{FSI} \cdot A_{FSI})^2
\]

Full Model

only resonances

only FSI

W. Schroeder, CGSWHP, 4. Sep. 2006
pp → K⁺Λp: Dalitz plots

Results with unpolarized beam

DATA

MODEL by Sibirtsev

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pp → K+Λp: Results of analysis 2

Change of the dominant resonance at about $p_{\text{beam}}=3$ GeV/c:

$N^*(1650) \rightarrow N^*(1710) / N^*(1720)$
pp → K⁺Λp: Calculation of Shyam


Data: Bubble chamber measurements

σ\text{tot} : solid line
influence of each single N*-resonance:
1710: dashed line
1650: dotted line
1720: dash-dotted line

Change of the dominant resonance at 3 GeV/c beam momentum:
N*(1650) → N*(1710)
pp $\rightarrow$ $K^+\Lambda p$: Results of analysis 1

Strong contribution of N*-Resonances:

$\rightarrow$ $\pi$ - exchange dominant

$\rightarrow$ $K$ – exchange small contribution
Future physics at COSY-TOF

- Strangeness Production in $\bar{p}p$ reaction
- Strangeness Production in $pn$ reaction
- Strangeness Production in $\bar{p}p$ reaction
Motivation for using polarized beam

At the moment: No discrimination between $N^*(1710)$ and $N^*(1720)$

<table>
<thead>
<tr>
<th>$N^*(1710)$</th>
<th>$P_{11}$</th>
<th>$I(J^P) = 1/2(1/2^+)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N^*(1720)$</td>
<td>$P_{13}$</td>
<td>$I(J^P) = 1/2(3/2^+)$</td>
</tr>
</tbody>
</table>

Goal: Separation with polarized beam

Search for other resonances
Further motivation for using polarized beam

Hyperon production in $\gamma$-induced reactions:

Partial Wave Analysis


$N(1650)_{S_{11}}$ $M=1705 \pm 30$ MeV

$N(1710)_{P_{11}}$ not seen!!

Open questions!!

$\rightarrow$ COSY -TOF
Motivation $D_{NN}$

Spin transfer coefficient
component of the beam polarization along the production plane normal that is retained by the final state lambda

Fractional longitudinal momentum of the $\Lambda$

DISTO

$\nu_{\mu}$Nucl.Phys.A691(2001)329-335


COSY-TOF measurement at 2.95 GeV/c (lowest point of DISTO)

W. Schroeder, CGSWHP, 4. Sep. 2006
\[ D_{NN} = \frac{1}{2P_B \langle \cos \psi \rangle} \left[ P_{\Lambda \uparrow} (1 + A_N P_B \langle \cos \psi \rangle) - P_{\Lambda \downarrow} (1 - A_N P_B \langle \cos \psi \rangle) \right] \]

\( \psi \) is the angle between the normal to the \( \Lambda \) production plane and spin direction of the beam proton

with \( A_N \) small (<0.2)

\[ D_{NN} \approx \frac{1}{2P_B \langle \cos \psi \rangle} \left[ P_{\Lambda \uparrow} - P_{\Lambda \downarrow} \right] \]
Beam Polarization is measured using elastic scattering by comparison with EDDA

Beam Polarization = Asymmetry / Analyzing Power

\[ Asy = \frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}} \]

@2.95 GeV/c, SAID database

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Asymmetry measurement with TOF:

Fit in several $\theta_{cm}$-steps:

- $30. < \theta_{cm} < 34.$
- $34. < \theta_{cm} < 38.$
- $38. < \theta_{cm} < 42.$
- $42. < \theta_{cm} < 46.$
- $46. < \theta_{cm} < 50.$
- $50. < \theta_{cm} < 54.$

W. Schroeder, CGSWHP, 4. Sep. 2006
Beam Polarisation 2002 @ $p_{\text{beam}}$ 2.95GeV/c

COSY-TOF is a polarimeter

Average Beam Polarization = 24% (±2% stat)

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The \( \Lambda \) polarization is calculated with the "weighted sum method". The formula is:

\[
P_{\Lambda} = \frac{1}{\alpha} \frac{\sum_i \cos \Theta_{i}^{**}}{\sum_i \cos^2 \Theta_{i}^{**}}
\]

Very Preliminary

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**D\textsubscript{NN} Estimation**

**Estimate for a future beam time of 1 week:**

Number of events $I$: estimated using the 2004 run:

With the upgraded apparatus about 10000 events per day → factor of 5 compared to the pilot run (2002).

Polarization: expected 50% compared to 24% in the pilot run

**Gain in figure of merit: $P^2 \times I = 20$**

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![Graph](attachment:graph.png)

**Expected errors**
- pilot run 2002
- C.Pizzolotto

**Very Preliminary**
Motivation \( \bar{p}n \) reaction

NEW PHYSICS @ COSY (no exclusive data in the COSY range)

\[ \text{pp} \rightarrow \text{pK}^+\Lambda \]

\[ \text{pn(p)} \rightarrow \text{pK}^0\Lambda(p) \]

Exclusive measurement with COSY-TOF

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Motivation


\[
\frac{\sigma(pn \rightarrow nK^+\Lambda)}{\sigma(pp \rightarrow pK^+\Lambda)}
\]

Compared to isospin algebra:


Experimental difficulty:

Separation of the $\Lambda$-reaction-channel from the other hyperons ($\Sigma^0, \Sigma^+$) in the inclusive $K^+$-meson-momentum-spectra.

Additional important information from exclusive measurement of the reaction: $pn(p) \rightarrow pK^0\Lambda(p)$: COSY-TOF
Reaction Pattern

pn(p) → pK^0\Lambda(p)

Unique signature:
2 „V‘s“ corresponding to the delayed decays of \(\Lambda\) and \(K^0\)

Event candidate
pn(p) → pK^0\Lambda(p) from test run

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Event candidate

$pn(p) \rightarrow pK^0\Lambda(p)$

from test run
Summary

- Strong contribution of N*-Resonances in the channel $pp \rightarrow K^+\Lambda p$

- Existence of other resonances?

- Measurements with LD$_2$-target
  $pn \rightarrow K^0\Lambda p$

- Measurements with polarized beam
  $D_{NN}$
• Existence of the penta-quark state $\Theta^+$?

• Existence of the isospin partner $\Theta^{++}$?
In the case of $\Theta^+$ confirmation

**Future measurements**

\[ \vec{p}n \rightarrow \Lambda K^0p \text{ using a LD}_2 \text{ target, successful tests in 2002/04} \]

pol. beam + $\Lambda$-polarization $\rightarrow$ towards parity of $\Theta^+$

\[ \vec{p}p \rightarrow \Sigma^+K^0p \text{ polarized beam + polarized target } \rightarrow \Theta^+ \text{ parity} \]

**Experiment upgrade**

2006/7: additional tracker (straw - tubes) $\rightarrow$ $p\Lambda$ – scattering - length

2007: polarized target

W. Schroeder, CGSWHP, 4. Sep. 2006
Polarized frozen spin target for TOF

- Frozen spin technique well suited for low intensity external beams
- High polarization ~ 80%
- PS185/3 set up will be used
- Preparation at Bochum and Bonn
  → Installation at COSY-TOF

Set up at COSY-TOF

New components:
- polarized target
- straw tracker

Acceptance: ± 32°
Dimensions: 9mm x 6mm
$P_{\text{max}}$ (butanol): p ~ 80%
alternative material in test
Measurement of the parity of $\Theta^+$

Observable: $^3\sigma_\Sigma = \frac{1}{2}\sigma_0(2+A_{xx}+A_{yy})$

Outlook

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