Baryon Spectroscopy in COMPASS

\[ pp \rightarrow p_f \pi^+ \pi^- p_s \]

\[ pp \rightarrow p_f K^+ K^- p_s \]

Alex Austregesilo
for the
COMPASS Collaboration

XIV International Conference on Hadron Spectroscopy
München, June 13-17 2011
Outline

Introduction

Event Selection

Invariant Mass Distributions

Outlook on Partial Wave Analysis

Summary
**The COMPASS Experiment**

COmmom Muon and Proton Apparatus for Structure and Spectroscopy

**Setup**
- Fixed target experiment at CERN SPS
- Two-stage magnetic spectrometer
- Tracking, calorimetry, particle ID

**190 GeV/c Secondary Hadron Beam**
- 97% $\pi^-$, 3% $K^-$ on $\mathrm{IH}_2$, Pb, Ni, W targets
- **75% proton**, 24% $\pi^+$, 1% $K^+$ on $\mathrm{IH}_2$ target
Central Production:

Data primarily recorded to study the formation of glue-rich meson resonances at central rapidities.

- No bias introduced by the principal trigger (*diffractive trigger*)
  → high contribution of *diffractive dissociation of the beam proton* in analogy to pion beam data [c.f. COMPASS presentations in Light Mesons session]
Motivation

- Hadro-production complementary to existing photo- and electro-production experiments (CLAS, CBELSA, ..)
- High resolution spectrometer with flat acceptance
- Large data set
- High mass and high angular momentum states poorly known

**** Existence is certain, and properties are at least fairly well explored
*** Existence ranges from very likely to certain, but further confirmation is desirable and/or are not well defined
** Evidence of existence is only fair
Event Selection

- Diffractive trigger
- Exactly one primary vertex
  - in target
  - 3 outgoing charged tracks
  - charge conservation
- Beam proton (CEDAR)
- RICH identification
  - $\pi^+$ or $K^+$
- Exclusivity
  - Energy sum
  - $\Phi$ angle between forward system and recoil particle
→ very low background

Graphs showing distributions of primary vertex positions and energy sums.
Particle Identification

Recoil Proton Identification
- Energy loss of recoil particle vs. velocity
- Very clean proton signal

Final State Particle ID
- Distinction between 2 positively charged particles in forward direction
  → RICH (Ring Imaging CHerenkov) detector
- Proton ID not effective in this kinematic range
  → $\pi^+ / K^+$ identification
$p p \rightarrow p_f \pi^+ \pi^- p_s$
Unambiguous assignment of resonances difficult

for example: $N(1440)P_{11}$, $N(1520)D_{13}$, $N(1535)S_{11}$ and $N(1650)S_{11}$, $\Delta(1700)D_{33}$, $N(1710)P_{11}$, $N(1720)P_{13}$
Invariant Mass of $p_f \pi^+ \pi^-$ System

Unambiguous assignment of resonances difficult
For example: $N(1440)P_{11}, N(1520)D_{13}, N(1535)S_{11}$ and $N(1650)S_{11}, \Delta(1700)D_{33}, N(1710)P_{11}, N(1720)P_{13}$

⇒ Spin Parity (= Partial Wave) Analysis
Invariant Mass of Subsystems

COMPASS 2009

\[ p p \rightarrow p \pi^+ \pi^- p_s \]

W33 (≈ 30% of 2009)

not acceptance corrected

preliminary
Invariant Mass of Subsystems

COMPASS 2009
$p p \rightarrow p \pi^+ \pi^- p$

$W33 \approx 30\%$ of 2009

not acceptance corrected

(1232) $\Delta^+(1232)$

A. Austregesilo (aaust@tum.de) — Baryon Spectroscopy at COMPASS
$p_f \pi^+ \pi^-$ System vs. Subsystems

COMPASS 2009

$p p \rightarrow p \pi^+ \pi^- \pi_f$

$W33 (\approx 30\%$ of 2009)
Introducing Strangeness:

\[ pp \rightarrow p_f K^+ K^- p_s \]
Invariant Mass of Subsystems

COMPASS 2009

- $p p \rightarrow p K^+ K^-$
- $W_33 = 30\%$ of 2009
- Not acceptance corrected

COMPASS 2009

- $p p \rightarrow p K^+ K^-$
- $W_33 = 30\%$ of 2009
- Not acceptance corrected

A. Austregesilo (aaust@tum.de) — Baryon Spectroscopy at COMPASS
Invariant Mass of Subsystems

COMPASS 2009

\[ p p \rightarrow p K^+ K^- p \]
W33 (~ 30% of 2009)

not acceptance corrected

\[ \times 10^0 \]

Invariant Mass of \( p K^+ K^- \) System (GeV/c^2)

\[ \times 10^1 \]

Invariant Mass of \( K^+ K^- \) System (GeV/c^2)

\[ \times 10^0 \]

Invariant Mass of \( p K^* \) System (GeV/c^2)

\[ \times 10^1 \]

Invariant Mass of \( p K^- \) System (GeV/c^2)
Techniques for Partial Wave Analysis
Partial Wave Analysis

- Target proton remains intact
- Pomeron exchange dominates at high energies
- Isobar model
  - Subsequent two-body decays
  - Two different decay topologies
  - Isobars: $R_{\pi\pi}$, $R_{p\pi^+}$, $R_{p\pi^-}$
- Both mesons and baryons as intermediate states
  - $R_{\pi\pi}: (\pi\pi)_S, \rho^0(770), f_0(980), f_2(1270), ..$
  - $R_{p\pi}: \Delta^0(1232)P_{33}, N(1440)P_{11}, N(1650)S_{11}, \Delta(1700)D_{33}, ..$
Summary

Conclusion

- Interesting data set including diffractive dissociation of the beam proton
- Light baryon spectrum accessible in great detail
- $N\pi$, $NK$, $\pi\pi$ and $KK$ decay modes
- PWA analysis formalism developed
Conclusion

- Interesting data set including diffractive dissociation of the beam proton
- Light baryon spectrum accessible in great detail
- $N\pi$, $NK$, $\pi\pi$ and $KK$ decay modes
- PWA analysis formalism developed

Outlook

- Adaptation of PWA software
- Acceptance correction with Monte Carlo
- Perform PWA
  - Determine poorly known parameters (widths, branching ratios, ..)
  - Identify new decay modes ($N\rho$, $N\phi$, ..)
  - Gain insight into production mechanism
### Conclusion
- Interesting data set including diffractive dissociation of the beam proton
- Light baryon spectrum accessible in great detail
- $N\pi$, $NK$, $\pi\pi$ and $KK$ decay modes
- PWA analysis formalism developed

### Outlook
- Adaptation of PWA software
- Acceptance correction with Monte Carlo
- Perform PWA
  - Determine poorly known parameters (widths, branching ratios, ..)
  - Identify new decay modes ($N\rho$, $N\phi$, ...)
  - Gain insight into production mechanism

Thank you.
**Introduction**

**Event Selection**

**Invariant Mass Distributions**

**Outlook on PWA**

**Summary**

$p_f K^+ K^-$ System vs. Subsystems

A. Austregesilo (aaust@tum.de) — Baryon Spectroscopy at COMPASS
Momentum Transfer

\[ p \, p \rightarrow p_f \, \pi^+ \pi^- \, p_s \]

\[ p \, p \rightarrow p_f \, K^+ K^- \, p_s \]
Feynman $x_F$ Distribution

$p p \rightarrow p_f \pi^+ \pi^- p_s$

$p p \rightarrow p_f K^+ K^- p_s$

COMPASS 2009

$p p \rightarrow p_f \pi^+ \pi^- p_s$

$W33 (= 30\%$ of 2009)

not acceptance corrected

COMPASS 2009

$p p \rightarrow p_f K^+ K^- p_s$

$W33 (= 30\%$ of 2009)

not acceptance corrected

preliminary