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π^--induced production of $K^0\Lambda$ pairs on nuclei at 1.15 GeV/c momentum

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Abstract. In this article we present study of π^- induced production of $K^0\Lambda$ pairs on nuclei at 1.15 GeV/c momentum. Experiment was performed at FOPI spectrometer in GSI in Germany. In order to differentiate the $K^0\Lambda$ pair production in single-step ($\pi^- p \to K^0\Lambda$) from multi-step ($\pi^- N \to \cdots \to K^0\Lambda$) processes, the missing mass (MM) analysis was performed. The spectra of MM for C and Pb targets show two prominent structures at positive (around m_p) and negative values. For single-step process $\pi^- p \to K^0\Lambda$ a broad peak somewhat the proton mass (m_p) was expected and it is observed. The Monte-Carlo simulations of two-step process π^-N→ R, RN→N$K^0\Lambda$ lead to formation of broad structure at negative MM and positive MM peak close to m_p. The evolution of the observed structure can be interpreted as increase of the role of multi-step process with the target mass.

1 Introduction

One of the main directions of research in nuclear physics is to analyze the properties of nuclear matters. For this purpose, we are looking for nuclear equation of state, which should describe such a properties of the matter as temperature, pressure or density. One way to research equation of state is analysis of strangeness production in heavy ion collisions around energy 1 AGeV.

2 FOPI spectrometer and experiment

FOPI spectrometer is located in GSI in Germany. It uses beams from the SIS18 accelerator. It was designed for fixed-target experiment and it has nearly full 4π coverage. Spectrometer allows partial charge and mass identification up to $A \approx 20$. High granulation is allowing tracking many particles in the same time. Experiment with π^- beam was carried in 2004. π^- beam was produced by collisons ^{14}N beam on B_4C target. Intensity of the π^- beam with momentum 1.15 GeV/c was about 3000 π^-/s. In the experiment five different targets was used: carbon, aluminium, copper, tin and lead.

3 Identification of $K^0\Lambda$ pairs

One of the main problem in study $K^0\Lambda$ pairs is fact that both particles have no charge. However both of them have very short half-life. Fortunately, main channels for the decay for both particles are into charged particles (Table 1 and 2).

For that reasons, we can use invariant mass analysis for finding $K^0\Lambda$ pairs. As we can see on figure 1 by using appropriate cuts we can cut off most of the background. Therefore we first look in our event for candidates for K^0, which are in appropriate borders for their invariant mass. If we find some, then

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Table 1. $K^0_S(498)$ decay modes [1].

Mode	Fraction Γ_i/Γ
$\pi^0\pi^0$	$30.69 \pm 0.05\%$
$\pi^-\pi^+$	$69.20 \pm 0.05\%$
$\pi^-\pi^+\gamma$	$(1.79 \pm 0.05) \times 10^{-3}$

Table 2. $\Lambda(1116)$ decay modes [1].

Mode	Fraction Γ_i/Γ
$p\pi^-$	$(63.9 \pm 0.5)\%$
$n\pi^0$	$(35.8 \pm 0.5)\%$
$n\gamma$	$(1.75 \pm 0.15) \times 10^{-3}$

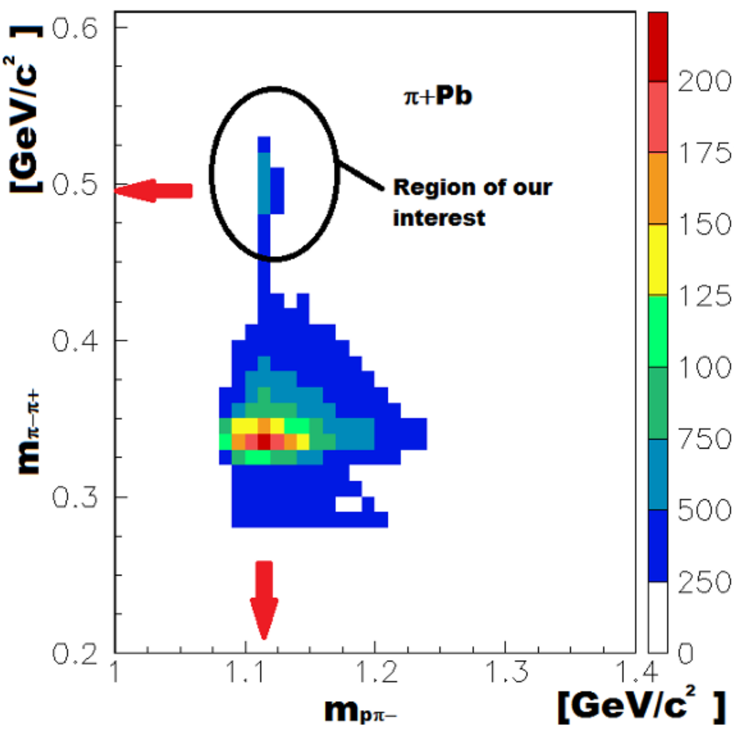

Fig. 1. Distribution of $m_{\pi^-\pi^+}$ versus m_{π^-p}.

we check whether we can find in that event $p\pi^-$ whose invariant mass is within borders for Λ mass borders. After that we subtract background, created by mixing events technique.

I was able to find quite big number of pairs (Table 3), especially for carbon and lead. Only for aluminium number of pairs was not enough for further analysis.

Table 3. Number of detected pairs per target.

Target	Number of pairs	S/B
C	3430 ± 300	0.22
Al	90 ± 30	0.13
Cu	650 ± 90	0.36
Sn	1160 ± 120	0.31
Pb	4890 ± 300	0.47

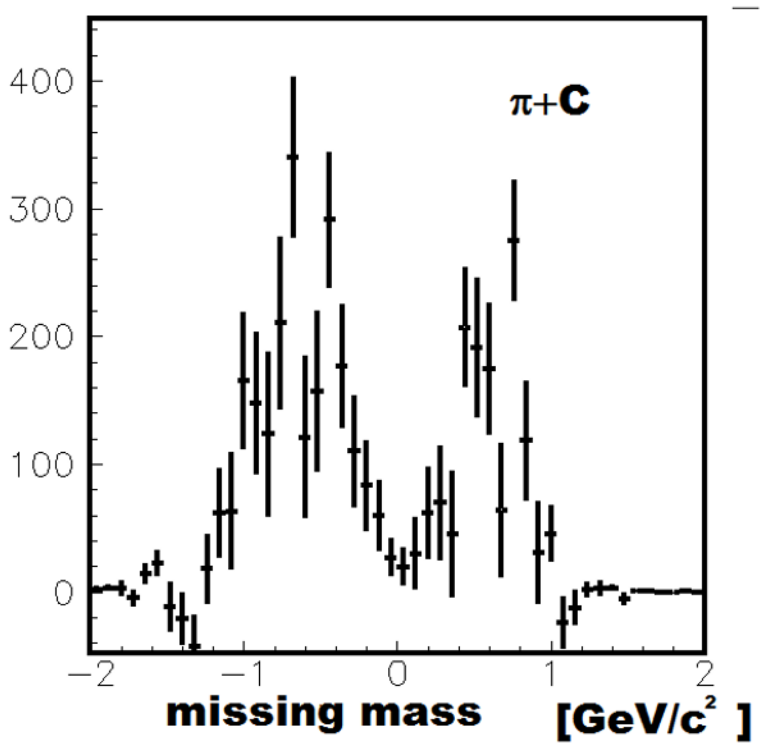

Fig. 2. MM distribution for C target.

4 Missing mass analysis

For a single-step production mechanism of ΛK^0 pair in the reaction $\pi^- X$ the missing mass (MM) can give us information on the mass and momentum of X. Missing mass is calculated from the energy and momentum conservation rules.

$$MM^2 = (E_\Lambda + E_{K^0} - E_{\pi^-})^2 - (\mathbf{p}_\Lambda + \mathbf{p}_{K^0} - \mathbf{p}_{\pi^-})^2 \tag{1}$$

MM is defined as

$$MM = sgn(MM^2) \cdot \sqrt{|MM^2|} \tag{2}$$

Missing mass analysis was performed for four targets: carbon, copper, tin and lead. Results for the carbon are shown on figure 2. Broad structure below 1 GeV/c^2 can be attributed to the effective mass of proton in the medium. Large structure at $MM < 0$ is not single-step processes: it indicates multi-step interactions for production of pairs ΛK^0. To confirm that it can be explained from the multi-step reactions simple simulation for multi-step reaction $\pi N \to R$, $RN \to \Lambda K^0 N$, (R - resonance), with kinematical constraints and the nucleon Fermi motion was performed. No further interactions of ΛK^0

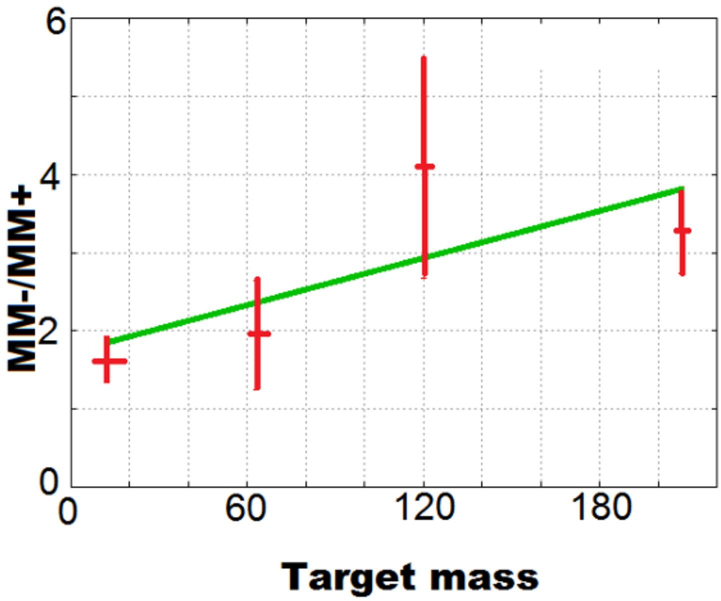

Fig. 3. MM^-/MM^+ ratio as a function of the target mass.

was taken into account. Simulation confirmed that there is possibility that negative MM are coming from multi-step reactions.

We have also compared results of missing mass analysis for different targets. For that purpose, we defined:

- MM^- =number of events with MM< 0 (multi-step);
- MM^+ =number of events with MM> 0 (single and multi-step);

and we have studied ratio MM^-/MM^+. Results are shown on figure 3. Increase of MM^-/MM^+ with target mass can be interpreted as rising role of multi-step reactions for more massive targets.

5 Summary

$K^0\Lambda$ pairs produced in π induced reactions on nuclei were identified by FOPI spectrometer at experiment at GSI Darmstadt. Missing mass analysis shows two structures:

- around and below proton mass;
- negative MM^2.

Simulation of multi-step explains the $MM < 0$. Increase of MM^-/MM^+ ratio evidences rising role of multi-step reactions for more massive targets.

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