Neutral strange particle production in high transverse momentum $\pi^{-}$ nucleus interactions at $\sim 40$ GeV/c

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Abstract. Measurements of $K_{S}^{0}$, $A$ and $\bar{A}$ production in $\pi^{-}$ nucleus (C, Cu, Pb) interactions are presented. The experiment was carried out with the streamer chamber spectrometer RISK using a $\pi^{-}$ beam of $\sim 40$ GeV/c and a trigger requiring a secondary charged particle with transverse momentum above 1.1 GeV/c. Production cross sections, relative production rates and distributions of Feynman $x$ and transverse momentum squared as well as correlations between the $\nu^{0}$ and the trigger particle are presented. The results are compared and found to be in agreement with $K_{S}^{0}$, $A$ and $\bar{A}$ data from untriggered $\pi^{-}p$ and $\pi^{-}C$ interactions, except for the relative production rate of antilambdas which is about to times larger in high-$p_{T}$ collisions. Our results can be well interpreted within the dual topological unitarization model.

1 Introduction

In this paper neutral strange particle production in high transverse momentum $\pi^{-}$-nucleus collisions at a beam momentum of $\sim 40$ GeV/c is investigated. In studies of hadron-hadron scattering only asymptotic states are measured and very little insight into the nature of hadronic matter at the time of its creation exists. It is however possible to affect the early stages of an interaction and learn about hadronic matter at nascently by using nuclear targets. When a high-energy projectile collides with a nucleus and interacts with one of the nucleons, the remaining nucleons serve as secondary targets for reinteractions of the states produced in the initial collisions. By varying the atomic number of the target, differences may be observed which can be attributed to the details of
the strong interactions over short space-time intervals.

In this work we analyze $V^0$-events from $\pi^-$-nucleus interactions selected under special triggering conditions: one of the charged secondaries produced in the central region of the $\pi N$ c.m. system ($x_F = 2p_T^+/\sqrt{s} \sim 0$) has a transverse momentum above $p_T = 1.1$ GeV/c. The study of collisions producing an $s\bar{s}$-quark pair at nascently together with a final state particle of large transverse momentum provides some challenge for current models of particle production in high energy hadron-nucleus interactions. Neutral strange particles are particularly interesting for this purpose, since their decays to charged pairs provide an excellent experimental signature for the production of strangeness over a large range of phase space.

Comparing our results with $K^0$s, lambda and antilamda produced in $\pi^-$-proton [1] and $\pi^-$-carbon [2] collisions in a bubble chamber at the same incident momentum may help to disentangle the underlying production mechanisms. The hydrogen data are not affected by reinteractions while the carbon data involve possible nuclear effects. Both bubble chamber data do not involve large transverse momentum particle selection, but include effects due to the creation of an additional strange-antistrange quantum number pair.

The paper is organized as follows. Section 2 describes our apparatus and the trigger condition. The event analysis is described in Sect. 3. Section 4 presents the results for the cross sections, relative production rates, differential cross sections and correlation studies. Discussion and comparison with $\pi^- p$ and $\pi^- C$ bubble chamber data as well as with the predictions of a dual topological unitarization model are also involved in this section. Conclusions are drawn in Sect. 5.

2 Experimental set-up and trigger

The study has been performed with a streamer chamber spectrometer. The main part of the apparatus was the three gap streamer chamber RISK filled with a 50% - 50% helium-neon gas mixture at atmospheric pressure. A memory time of 1 - 2 μs was achieved through a small admixture of SF6. The size of the streamer chamber ($4.7 \times 0.9 \times 0.8$ m³) was chosen such that it fits into the magnet gap. The electrodes were constructed by stainless wire meshes with a transparency of 85%. A Marx-generator provided via a bipolar Blumlein-line the high voltage pulse of about ±400 kV height and 19 ns duration.

The sensitive volume of the chamber was viewed by eight lenses each equipped with two-stage image intensifiers. Details on the chamber, the high voltage system and the optics may be found elsewhere [3-5].

The chamber was positioned in a $\sim 1.5$ T magnetic field. The main field component normal to the film plane was known with an accuracy better than 0.5%. The other two components were negligible within the visible chamber volume.

The chamber was exposed at the Serpukhov proton synchrotron to an unseparated beam of negatively charged particles with a mean momentum of 38 GeV/c and with an intensity of $\sim 3 \times 10^5$ particles in a 0.5 s spill. The beam spot at the entrance window of the chamber was defined by a telescope of scintillation counters. The identification of the beam particles was achieved by a set of four threshold Cherenkov

![Fig. 1. Schematic lay-out of the streamer chamber spectrometer RISK for the high-$p_T$ experiment](image-url)
counters. The beam composition turned out to be $\pi^{-}:K^{-}:p = 100:1.8:0.3$.

Carbon, copper and lead disks were used as targets, with pion absorption length of 1.9%, 1.3% and 0.74%, respectively. The exchangeable targets were placed in the streamer chamber about 30 cm downstream of the entrance window. To avoid discharges of the electric field of the streamer chamber the targets were contained in a small mylar box flushed by the electronegative gas freon-12.

The $p_t$-trigger was formed by two proportional chambers (MWPC's) placed, as seen in Fig. 1, above the streamer chamber inside the magnet 3.6 m downstream from the target. Each chamber had two sensitive planes of 3 mm pitches spaced by 16 mm measuring $y$- and $z$-coordinates. Dimensions of sensitive areas of the chambers were $1.0 \times 0.5$ m$^2$ (horizontal and vertical, respectively) and the distance between the chamber was 0.6 m. The MWPC-telescope covered the polar angle interval $12^\circ < \theta < 22^\circ$ for particles originating from the target which corresponds to $85^\circ < \theta^* < 120^\circ$ in the $nN$ c.m.s. The $y$-hits of a particle in the MWPC's, $y_1$ and $y_2$, together with the target position allow to estimate the momentum projection in the $x$, $y$-plane, $p_{xy}$. If this quantity is combined with the range of the dip angle viewed by the telescope, a determination of a threshold for the transverse momentum is possible.

The total event trigger consists of the logical AND of (1) an incident beam particle; (2) an interaction in the streamer chamber by the absence of the beam particle in the downstream scintillation counter; (3) $y_1$ and $y_2$ in a region preselected by a hardwired coincidence matrix and (4) $z_1$ and $z_2$ correlated in a way to suppress background hits.

Data were taken with $p_t$-thresholds between 1.1 and 1.7 GeV/c.

3 Data analysis

Some 45000 photographs, nearly equally distributed on the C, Cu and Pb targets, were scanned for $p_t$-interactions with at least one $V^0$. We found 1720 event candidates. Only the high-$p_t$ track, the $V^0$, the primary track and two further secondary tracks (to ensure good primary vertex reconstruction) were measured on semiautomatic devices. The events were processed through the geometrical reconstruction program HYGEOM [6] and only retained for further analysis if

1. the momentum error of the secondaries and of the $V^0$-decay tracks is less than 10% and the residual (in space) does not exceed 1800 $\mu$m;
2. the primary vertex is reconstructed within the target;
3. the $V^0$'s decay inside the fiducial volume. The cut imposes a target dependent minimum $V^0$-path length and a maximum downstream length of 1 m. The radius of the fiducial volume (being a cylinder) was chosen to ensure a minimum track length of 15 cm.

If an event failed the quality requirements (1) it was remeasured and reconstructed. After three unsuccessful trials it was rejected from the event sample.

To resolve the $V^0/\gamma$-ambiguity, photon conversions were rejected by demanding $M(e^+e^-) > 30$ MeV/c$^2$. This cut is sufficient to reject all $\gamma$'s and removes less than 5% of the $V^0$'s. Figure 2 shows the effective mass distributions $M(\pi^+\pi^-)$, $M(p\pi^-)$ and $M(\bar{p}\pi^+)$ before and after (hatched histograms) photon rejection. Clear signals for $K^0_L$, $A$ and $\Lambda$ particles can be seen. The widths are consistent with the detector resolution [7], while the central mass values are slightly above* the Particle Data Group values [8].

* The $K^0_L$ mass lies $\sim 3$ MeV/c$^2$ and the lambda mass $\sim 1.5$ MeV/c$^2$ above their respective table values. A calibration error of the magnetic field of 0.3% may account for such mass shifts [7].
Table 1. Number of $K^0_s$, $A$ and $\bar{A}$ events observed in high-$p_t$ $\pi^-A$ collisions at 40 GeV/c

<table>
<thead>
<tr>
<th></th>
<th>$K^0_s$</th>
<th>$A$</th>
<th>$\bar{A}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>75</td>
<td>68</td>
<td>12</td>
</tr>
<tr>
<td>Cu</td>
<td>48</td>
<td>96</td>
<td>11</td>
</tr>
<tr>
<td>Pb</td>
<td>41</td>
<td>51</td>
<td>8</td>
</tr>
</tbody>
</table>

The $A$ ($\bar{A}$) sample is defined if $M(p\pi^-)$ ($M(\bar{p}\pi^+)$) is between 1.109 and 1.125 GeV/c$^2$. For the $K^0_s$ sample we required $M(n+n^-)$ between 0.475 and 0.530 GeV/c$^2$ and the transverse momentum of the positive track with respect to the $V^0$ flight path must exceed 0.120 GeV/c. The last condition removes $A/\bar{A}$ reflections in the $K^0_s$ event sample. After the cuts background is negligible for the $K^0_s$ and lambdas, while about 15% is present in the $\Lambda$ sample (see also Fig. 2). The $V^0$ mean lifetimes were measured to be $\tau_{K^0}= (0.91 \pm 0.12) \times 10^{-10}$ s, $\tau_{A}= (2.67 \pm 0.13) \times 10^{-10}$ s and $\tau_{\bar{A}}= (2.54 \pm 0.28) \times 10^{-10}$ s, in good agreement with the Particle Data Group values [8].

The $K^0_s$, $A$ and $\bar{A}$ event samples were checked for possible losses due to our selection criteria by analyzing the $\cos\theta_{cm}$-distribution. The angle $\theta_{cm}$ is defined as the angle between the direction of the positive decay track in the rest frame of the $V^0$ and the direction of the $V^0$ in the laboratory frame. For the $A$ and $\bar{A}$, the distribution is isotropic. Some losses of $K^0_s$ occur near $|\cos\theta_{cm}|=1$ due to the transverse momentum cut for the positive decay track.

We conclude, the $K^0_s$ and $A$ samples are essentially pure. Contaminations do not exceed few percent. Background of $\sim 15\%$ in the $\bar{A}$ sample will be subtracted in the following analysis. Losses of $K^0_s$ are accounted for by requiring isotropy in the $\cos\theta_{cm}$-distribution.

Table 1 summarizes the accepted numbers of $K^0_s$, $A$ and $\bar{A}$ (after background subtraction) for the three targets.

4 Experimental results

4.1 $K^0_s$, $A$ and $\bar{A}$ cross sections

The cross section for the reactions

\[ \pi^- + A \rightarrow K^0_s + \text{trigger particle} + X \]  \hspace{1cm} (1)
\[ \pi^- + A \rightarrow A + \text{trigger particle} + X \]  \hspace{1cm} (2)
\[ \pi^- + A \rightarrow \bar{A} + \text{trigger particle} + X \]  \hspace{1cm} (3)

with $A=C$, Cu or Pb and $X=$ anything, are determined from the relation

\[ \sigma = N/(L \cdot \text{Acc}) \].  \hspace{1cm} (4)

$N$ is the number of events, $L$ the luminosity and Acc the spectrometer acceptance for the trigger particle. The number of events for reactions (1)-(3) is obtained from the selected $K^0_s$, $A$ and $\bar{A}$ samples after background subtraction and after corrections for scanning, measuring and reconstruction losses, losses due to our selection criteria, fiducial volume cuts and neutral decay modes. Table 2 lists the correction factors applied.

The spectrometer acceptance for the trigger particle, Acc, has been determined from $\pi^-A$ high-$p_t$ $V^0$-events modelled by the dual topological unitarization (DTU) scheme [9]. These events were used as input for an experimental set-up simulation program. The program tracked the charged particles through the apparatus, took into account decays of neutral and charged secondaries, photon conversions and inefficiencies of the MWPC's. The hits recorded in the MWPC's were subjected to the trigger condition. The limited azimuthal angle region of the trigger particle determines mainly the spectrometer acceptance and amounts to $\sim 6\%$ in the $p_t$-range from threshold to $\sim 2.5$ GeV/c. Other effects are less stringent, so that typical acceptance values were found to be 3-4%. The systematic uncertainty of the acceptance calculation has been estimated to be 15%.

The luminosity $L$ was obtained from beam monitor informations, the dead time of the apparatus and the target properties.

All cross sections were normalized to a common acceptance.

* In a different estimation each DST-event has been randomly rotated around the beam direction. The ratio of the number of the events triggered to that of the rotated events determines the spectrometer acceptance for each event. Their average values agree within 10% with the results as described above. In addition, for the carbon target, bubble chamber data [2] were also used as input for the set-up simulation program. The acceptances obtained agree well with the other ones.
Table 3. Cross sections for reactions (1)-(3) with a transverse momentum threshold of 1.1 GeV/c for the $p_T$-particle

<table>
<thead>
<tr>
<th>Reaction</th>
<th>C</th>
<th>Cu</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi^- A \to K^0_s + p_T$-particle + X</td>
<td>$0.99 \pm 0.36$</td>
<td>$4.43 \pm 1.59$</td>
<td>$12.96 \pm 3.92$</td>
</tr>
<tr>
<td>$\pi^- A \to A + p_T$-particle + X</td>
<td>$0.32 \pm 0.12$</td>
<td>$1.73 \pm 0.58$</td>
<td>$4.92 \pm 1.72$</td>
</tr>
<tr>
<td>$\pi^- A \to \bar{A} + p_T$-particle + X</td>
<td>$0.03 \pm 0.01$</td>
<td>$0.09 \pm 0.05$</td>
<td>$0.59 \pm 0.32$</td>
</tr>
</tbody>
</table>

Table 4. Relative production rates for $K^0_s$, $A$ and $\bar{A}$'s in $\pi^- A$ high-$p_T$ collisions compared with those from $\pi^- p$ and $\pi^- C$ bubble chamber data

<table>
<thead>
<tr>
<th>Material</th>
<th>$\langle n_{K^0} \rangle$</th>
<th>$\langle n_A \rangle$</th>
<th>$\langle n_{\bar{A}} \rangle$</th>
<th>$\langle n_{K^0} \rangle$</th>
<th>$\langle n_A \rangle$</th>
<th>$\langle n_{\bar{A}} \rangle$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>$0.12 \pm 0.02$</td>
<td>$0.11 \pm 0.02$</td>
<td>$0.019 \pm 0.003$</td>
<td>$0.113 \pm 0.007$</td>
<td>$0.065 \pm 0.006$</td>
<td>$0.008 \pm 0.002$</td>
</tr>
<tr>
<td>C</td>
<td>$0.18 \pm 0.03$</td>
<td>$0.34 \pm 0.03$</td>
<td>$0.030 \pm 0.003$</td>
<td>$0.12 \pm 0.01$</td>
<td>$0.08 \pm 0.01$</td>
<td>$0.008 \pm 0.001$</td>
</tr>
<tr>
<td>Cu</td>
<td>$0.28 \pm 0.03$</td>
<td>$0.37 \pm 0.03$</td>
<td>$0.044 \pm 0.004$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
</tr>
<tr>
<td>Pb</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
</tr>
</tbody>
</table>

trigger $p_T$-threshold of 1.1 GeV/c. The normalization procedure relies on inclusive transverse momentum spectra of charged particles produced under the same conditions. The spectra were simple parametrized as exponentials above the run-dependent $p_T$-threshold and extrapolated to $p_T = 1.1$ GeV/c. Uncertainties caused by this procedure were taken into account by an additional cross section error of 10%.

Table 3 summarizes the cross sections for reactions (1)-(3) at C, Cu and Pb targets. The minimum transverse momentum for the trigger particle is 1.1 GeV/c.

In Table 4 are presented the relative production rates for $K^0_s$, $A$ and $\bar{A}$'s as obtained in this experiment as well as those from $\pi^- p$ and $\pi^- C$ bubble chamber experiments [2]. Apart from the general growing of $\langle n_{K^0} \rangle$, $\langle n_A \rangle$ and $\langle n_{\bar{A}} \rangle$ with increasing atomic weight, differences for the $K^0_s$ and $A$ production probabilities in carbon between the triggered and untriggered interactions cannot be observed. However, $A$'s are produced by about a factor 2 more abundantly in $\pi^- C$ high-$p_T$ collisions. Whether this observation holds for heavier targets and also for $K^0_s$ and $A$'s cannot be answered since minimum bias $V^0$ production rates are not yet available from this collaboration.

4.2 Atomic weight dependence of $K^0_s$, $A$ and $\bar{A}$ production

The cross sections for reaction (1)-(3) as function of the atomic weight $A$ are shown in Fig. 3. The rates for $K^0_s$, $A$ and $\bar{A}$ production increase with increasing $A$ and may be parametrized as

$$\sigma = \sigma_0 \cdot A^\alpha.$$ (5)

The fitted values for $\alpha$ and $\sigma_0$ are listed in Table 5. In a kinematic region in which multiple interactions are reduced (as, for example, in hadron production at large transverse momentum) perturbative QCD predicts $\sigma \propto A$, since in the impuls approximation the cross section depends on the number of quarks [10]. In practice, effects due to the nuclear environment such as Fermi motion, rescattering, and final-state interacions which occur as the quarks hadronize reduce $\alpha$ by 10-20% [11].

4.3 Differential $K^0_s$, $A$ and $\bar{A}$ distributions

Figure 4 shows the Feynman $x$ (defined in the $\pi^- N$ c.m.s.) distributions of $K^0_s$ produced at C, Cu and Pb targets. The $K^0_s$ are essentially produced in
Table 5. Values of $x$ and $\sigma_0$ obtained from fits with the parametrization $\sigma = \sigma_0 A^x$

<table>
<thead>
<tr>
<th></th>
<th>$x$</th>
<th>$\sigma_0$, mb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K^0_s$</td>
<td>$0.90 \pm 0.17$</td>
<td>$0.10 \pm 0.07$</td>
</tr>
<tr>
<td>$\Lambda$</td>
<td>$0.95 \pm 0.16$</td>
<td>$0.03 \pm 0.02$</td>
</tr>
<tr>
<td>$\bar{\Lambda}$</td>
<td>$1.02 \pm 0.38$</td>
<td>$0.01 \pm 0.01$</td>
</tr>
</tbody>
</table>

Fig. 4. Feynman $x$ distributions of $K^0_s$ produced in high-$p_t$, $\pi^- A$ collisions. The continuous histograms are the DTU predictions normalized to the data.

Fig. 5. Feynman $x$ distributions of lambdas produced in high-$p_t$, $\pi^- A$ collisions at 40 GeV/c. The continuous histograms are the DTU predictions normalized to the data.

* The $d$-quark of the incoming $\pi^-$ may be carried on the $K^0$ so that it might be forward produced.

the central region. Beam fragmentation into $K^0_s$ supported by their valence quark content, seems not to be present*. An estimate of 10–20% backward produced $K^0_s$ is obtained when reflecting the $x_F$-spectra at $x_F = 0$. Such $K^0_s$ might be due to nucleon fragmentation into a hyperon and a kaon (with additional pions) or due to rescattering effects within the nuclei. Since backward $K^0_s$ production is evidently present in hydrogen interactions [1], rescattering within the nuclei should not be solely responsible for backward produced $K^0_s$.

Distinct variations of $K^0_s$ production properties with the atomic number $A$ cannot be observed.

Figure 5 shows the $x_F$-spectra of the lambdas. They are characterized by a broad bump between $-1 < x_F < 0$ with the maximum near $x_F = -0.3$, independent of the atomic number $A$. The lambdas are consistent with being produced as target fragmentation products. This can be well understood since the lambdas may have two quarks in common with the target nucleon.

It is interesting to note that our $K^0_s$ and $\Lambda$ distributions are very similar to those from bubble chamber $\pi^- p$ and $\pi^- C$ data [1, 2]. The latter ones are from untriggered events while our $K^0_s$ and lambdas are only produced in association with a charged particle of large transverse momentum.

Figures 6 and 7 show the $p_t^2$-distribution for the $K^0_s$ and lambdas, respectively. All follow an exponential form. No significant variation with the atomic
number $A$ can be observed. It is however evident that the $A$'s are produced less peripheral than the kaons.

Table 6 summarizes the average $x_F$-values as well as the slopes of the $p_T^2$-spectra obtained from exponential fits.

Figure 8 presents the $x_F$ and $p_T^2$-distributions for the $\bar{A}$'s, combined for the three targets because of low statistics and negligible $A$-dependence for $K^0_S$ and $A$ production. The $\bar{A}$'s are produced in the central region with a slight tendency of negative $x_F$. The $p_T^2$-spectrum falls off with an exponential slope $1.62 \pm 0.41$ (GeV/c)$^{-2}$ which seems somewhat smaller than that of the lambdas (see Table 6). A possible $\bar{A}$ production mechanism might be the formation of a central cluster which decays into a $\bar{A}A$ pair [12]. If in 80% of the cases $\bar{A}$ production proceeds via an $\bar{A}A$ pair, the expected number of such events taking into account the $A$ detection probability is $\sim 1$, which is consistent with no $\bar{A}A$ event observed in our experiment.

It is again worthwhile to note the close similarity of our $\bar{A}$ spectra with those from the 40 GeV/c bubble chamber experiments [1, 2].

The agreement of the main properties of $K^0_S$ and $A$'s produced in $\pi^-A$ high-$p_T$ collisions and in untriggered $\pi^-p$ and $\pi^-C$ (soft-$p_T$) interactions suggests that mechanisms for the creation of a strange-antistrange particle pair, which is a common feature of the reac-

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**Table 6.** Collection of average $x_F$-values and slopes of exponential fits to the transverse momentum squared distributions for $K^0_S$ lambdas and antilambdas produced in high-$p_T$ $\pi^-A$ interactions at 40 GeV/c.

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Cu</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\langle x_F \rangle_{K^0_S}$</td>
<td>$0.01 \pm 0.01$</td>
<td>$0.00 \pm 0.02$</td>
<td>$-0.06 \pm 0.03$</td>
</tr>
<tr>
<td>$\langle x_F \rangle_A$</td>
<td>$-0.25 \pm 0.02$</td>
<td>$-0.30 \pm 0.03$</td>
<td>$-0.32 \pm 0.03$</td>
</tr>
<tr>
<td>slope$_{K^0_S, (GeV/c)^{-2}}$</td>
<td>$2.84 \pm 0.37$</td>
<td>$3.40 \pm 0.67$</td>
<td>$2.86 \pm 0.44$</td>
</tr>
<tr>
<td>slope$_{A, (GeV/c)^{-2}}$</td>
<td>$2.10 \pm 0.31$</td>
<td>$2.18 \pm 0.27$</td>
<td>$2.15 \pm 0.35$</td>
</tr>
<tr>
<td>$\langle x_F \rangle_{\Lambda}$</td>
<td>$-0.18 \pm 0.05$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slope$_{\Lambda, (GeV/c)^{-2}}$</td>
<td>$1.62 \pm 0.41$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Fig. 6.** Transverse momentum squared distributions for $K^0_S$ produced in high-$p_T\pi^-A$ interactions at 40 GeV/c. The continuous histograms are the DTU predictions normalized to the data.

**Fig. 7.** Transverse momentum squared distributions for lambdas produced in high-$p_T\pi^-A$ interactions at 40 GeV/c. The continuous histograms are the DTU predictions normalized to the data.
4.4 Correlations between $K_s^0/\Lambda/\bar{\Lambda}$ and the high-$p_t$ trigger particle

Effective mass distributions between the $V^0$ and the trigger particle* were looked for resonance production. Neither significant $K^*$ nor $\Sigma^*$ resonances were observed.

Since the $V^0$ is often produced near $x_F=0$ close to the trigger particle, local transverse momentum compensation between these particles may occur. Figure 9 shows the angle between the $V^0$ and the high-$p_t$ track, $\phi_\perp$, in the plane perpendicular to the beam. The kaons tend to be produced back-to-back with the trigger particle, while for the lambdas and antilambdas an isotropic distribution is observed. The DTU-model (continuous histogram) accounts well for this different behaviour, because local transverse momentum conservation of the quark-antiquark ($s\bar{s}$) pair created manifests itself in opposite $p_t$ of the final hadrons, which may be sometimes the trigger particle and the kaon. For the lambdas and antilambdas,

In the DTU scheme, $\bar{\Lambda}$ production is achieved in 80% of the cases via the creation of an $s\bar{s}$-quark pair and a diquark $(u\bar{d})$-antidiquark $(\bar{u}\bar{d})$ system which form via recombination a $\Lambda(u\bar{d}s)$ and an $\bar{\Lambda}(\bar{u}\bar{d}s)$. As seen in Fig. 8, such mechanism (continuous histogram) describes our $\bar{\Lambda}$ spectra reasonably well.

* The pion mass has been assigned to the trigger track
which are mainly target fragmentation products respectively created mainly as $\bar{A}A$ pairs, such correlation is not expected. Similar results were found in [13] by the EHS-RCBC collaboration. This collaboration demonstrated that dynamical $p_T$-correlations exist for particles which originate close in rapidity space and having quantum numbers to accommodate a created $s\bar{s}$-quark pair.

5 Conclusions

We have studied the production characteristics of kaons, lambda and anti-lambdas in $\pi^- A$ ($A = C, Cu$ or Pb) interactions at $\sim 40$ GeV/c. The events were selected by triggering on a charged secondary with transverse momentum above $1.1$ GeV/c at $x_F < 0$ in the $\pi N$ c.m. system.

The $K^0$, $\Lambda$ and $\bar{\Lambda}$ cross sections vary as $A^n$, where $n \approx 0.9$ with an error of about 20%. The relative production rates for $K^0$, $\Lambda$ and $\bar{\Lambda}$'s are presented. It is found that for $\Lambda$'s the creation probability is $\sim 2$ times larger in high-$p_T$ $\pi^- C$ collisions than in untriggered interactions.

$K^0$, $\Lambda$ and $\bar{\Lambda}$ particles are mainly produced centrally in the $\pi N$ c.m.s. The $\Lambda$'s are dominantly due to target fragmentation and concentrate near $x_F = -0.3$. The $p_T^2$-spectra of the $K^0$, $\Lambda$ and $\bar{\Lambda}$ have an exponential shape and indicate in this order a less steep behaviour. For the $K^0$ and $\Lambda$'s no significant shape variations with respect to the atomic number of the target are observed.

Back-to-back correlations are observed between the $K^0$ and the high-$p_T$ trigger particle in the plane perpendicular to the beam, but not for the $\Lambda$ or $\bar{\Lambda}$ particle.

The general agreement of our $K^0$, $\Lambda$ and $\bar{\Lambda}$ spectra with those from untriggered $(soft-p_T)$ $\pi^- p$ and $\pi^- C$ bubble chamber data leads us to conclude that no hard scattering effects dominate. The properties observed are consistent with being due to soft hadron production on the large transverse momentum tail.

The DTU-model which creates $(di)quark$-anti$(di)quark$ pair(s) within the colour field of the interacting partons is able to describe the properties observed. Since this model does not involve hard scattering subprocesses, additional support is obtained for our general conclusion of soft $K^0$, $\Lambda$ and $\bar{\Lambda}$ production in high-transverse momentum ($p_T > 1.1$ GeV/c for at least one charged particle) $\pi^-$-nuclei interactions at 40 GeV/c.

References

10. S.J. Brodsky: Proceedings of Summer Institute on Particle Physics, p. 133, Stanford, 1979