Λ AND K^0_s PRODUCTION IN pC COLLISIONS AT 10 GeV/c

P.Zh.Aslanyan[1,2†], V.N.Emelyanenko[1], G.G. Rikhkvitzkaya[1]

vskip 5mm (1) *Joint Institute for Nuclear Research*

(2) *Yerevan State University*

† *E-mail: paslanian@jinr.ru*

Abstract

The experimental data from the 2m propane bubble chamber have been analyzed for pC→ $\Lambda(K^0_s)X$ reactions at 10 GeV/c. The estimation of experimental inclusive cross sections for Λ and K^0_s production in the p^{12}C collision is equal to σ_Λ= 13.3±1.7 mb and $\sigma_{K^0_s}$= 3.8±0.6 mb, respectively.

The measured Λ/π^+ ratio from pC reaction is equal to $(5.3\pm0.8)*10^{-2}$. The experimental Λ/π^+ ratio in the pC reaction is approximately two times larger than the Λ/π^+ ratio from pp reactions or from simulated pC reactions by FRITIOF model for the same energy. The Λ/π^+ ratio in interaction C+C at momentum 10 Gev/c is four times larger than the Λ/π^+ ratio from p+p reactions at the same energy.

The investigation has been performed at the Veksler and Baldin Laboratory of High Energies, JINR.

. Introduction

;rangeness enhancement has been extensively discussed as a possible signature for the ıark-gluon plasma(QGP)[1, 2]. Strange particle production has also been analyzed reırding such reaction mechanisms as the multinucleon effect[3], or the fireball effect[4], or ; the deconfiment signal, within the context of thermal equilibration models[5]-[8].

In particular, strange particles have been observed extensively on hadron - nucleus ıd nucleus-nucleus collisions 4-15 Gev regions[9]-[14]. The strange hyperon yields[9]-[11] e therefore of great interest as an indicator of strange quark production. The number Λs produced in $\overline{p}$+Ta reaction at 4 GeV/c was 11.3 times larger than that expected ɔm the geometrical cross section [9]. Experiments with Si+Au and Au+AU collisions 11.6[13] and 14.6 A GeV/c [14] measured a K^+/π^+ ratio in heavy-ion reactions that four to five times larger than the K^+/π^+ ratio from p+p reactions at the same energy. ıe thermal model[6] gives an good description of K^+/π^+, Λ/π^+ ratio for data Au+Au, +Au interaction at momenta 10-15 A Gev/c and, showing a broad maximum at the me energies.

However, there have not been sufficient experimental data concerning strange-hyperon ɔduction over 10-40 GeV/c momentum range. In this paper the new results are preıted the measured inclusive cross sections for $\Lambda(K^0_s)$ production and Λ/π^+ ratio in the ıction p+^{12}C.

2. Experimental procedure

2.1. METHOD

Searching for the V^0 on $\approx$ 700000(or 345*2 tapes) photographs of the JINR 2m propane bubble chamber exposed to a 10GeV/c proton beam [16]-[21]. The primary proton beams must be to satisfy of conditions: $\mid tg\alpha \mid < 0.02$ $1.62 < \beta < 1.69$ rad. The magnetic field (B=15.2 kG) measurement error is ΔB/B=1%. The fit GRIND -based program GEOFIT[18] is used to measure the kinematics track parameter p, α, β. Measurements were repeated three times for events which failed in reconstruction by GEOFIT.

The estimate of ionization, the peculiarities of the end track points of stopping particles permitted one to identify them over the following momentum ranges : protons of $0.150 \leq p \leq 0.900$ GeV/c and $K^{\pm} of p \leq 0.6$ GeV/c.

2.2. Identification of Λ and K_s^0

The events with V^0 (Λ and K_s^0) were identified using the following criteria [19, 20]:
1) V^0 stars from the photographs were selected according to $\Lambda \rightarrow \pi^- + p$, neutral $K_s \rightarrow \pi^- + \pi^+$ or $\gamma \rightarrow e^+ + e^-$ hypothesis. A momentum limit of K_s^0 and Λ is greater than 0.1 and 0.2 GeV/c, respectively ; 2) V^0 stars should have the effective mass of K_s^0 and of Λ 3) these V^0 stars are directed to some vertices(complanarity); 4) they should have one vertex, a three constraint fit for the M_K or M_Λ hypothesis and after the fit, $\chi^2_{V^0}$ should be selected over range less than 12; 5)The analysis has shown[20] that the events with undivided ΛK_s^0 were assumed to be events as Λ.

Table 1 presents (70%) the number of experimental V^0 events produced from interactions of: a) primary proton beams, b)secondary charged particles and c)secondary neutral particles.

The V^0s classified into three grades. The first grade comprised V^0s which could be identified with above cuts and bubble densities of the positive track emitted from the V^0s The second grade comprised V^0s which could be undivided ΛK_s^0. For correctly identification the undivided V^0s are used the α(Fig.1a) and the $cos\theta^*_{\pi^-}$(Fig.1b) distributions.

$$\alpha = (P_{\|}^+ - P_{\|}^-)/(P_{\|}^+ - P_{\|}^-)$$

Where $P_{\|}^+$ and $P_{\|}^-$ are the momentum components of positive and negative charged tracks from the V^0s relative direction of the V^0s momentum.The

$cos\theta^*_{\pi^-}$ is the angular distribution of π^- from K_s^0 decay. The α(Fig.1a) and the $cos\theta^*_{\pi^-}$ distributions from K_s^0 decay were isotropic in the K_s^0 rest frame after removing undivided ΛK_s^0. Then these ΛK_s^0 events appropriated events as Λ. After we show in Fig.1c that the $cos\theta^*_{\pi^-}$ distributions for the Λ+ΛK_s^0s have been also isotropic in V^0 rest frame. As a result of above procedure have lost of K_s^0 8.5% and admixture of K_s^0 in Λs events 4.6% The third grade comprised V^0s which could be the invisible V^0s at a large azimuth angl ϕ[20]. The average ϕ weights were $< w_\phi > = 1.06 \pm 0.02$ for K_s^0 and $< w_\phi > = 1.14 \pm$ 0.0 for Λ.

Figures.2a,c and 2b,d show the effective mass distribution of Λ(8657-events),K^0(4122 events) particles and their χ^2 from kinematics fits, respectively, produced from the bean protons interacting with propane targets. The measured masses of these events have th following Gaussian distribution parameters $< M(K_s) >= 497.7\pm3.6$, s.d.= 23.9 MeV/c^2 and $< M(\Lambda) > =1117.0\pm 0.6$, s.d.=10.0 MeV/$c^2$. The masses of the observed Λ, K_s^0 are consistent with their PDG values. The expected functional form for χ^2 is depicted with the dotted histogram(Fig.2).

Each V^0 event weighted by a factor w_{geom} (=1/e_τ), where e_τ is the probability for potentially observing the V^0, it can be expressed as

$$e_\tau = exp(-L_{min}/L) - exp(-L_{max}/L),$$

where L(=cpτ/M) is the flight length of the V^0,L_{max} the path length from the reaction point to the boundary of fiducial volume, and L_{min}(0.5 cm) an observable minimum distance between the reaction point and the V^0 vertex. M,τ, and p are the mass, lifetime, and momentum of the V^0. The average geometrical weights were 1.34±0.02 for Λ and 1.22±0.04 for K^0.

Now, let us examine a possibility from neutron stars of imitating Λ and K_s^0 the using model FRITIOF[22] for the hypotheses reaction p+C→n+X,n+n→ $\pi^-p(or\pi^-\pi^+) + X^0$ with including fermi motion in carbon. Then, these background events were analyzed by using the same experimental condition for the selection V^0s. The 2 vertex analysis have shown the background from neutron stars are equal to 0.1% for Λ and 0.001 for K_s^0 events.

2.3. The selection of interactions on carbon nucleus

The criteria for selection of interaction with carbon has shown[19, 25]. The p+C→ $\Lambda(K_s^0)X$ reaction were selected by the following criteria:

1. $Q = n_+ \ - \ n_- > 2$;
2. $n_p \ + \ n_\Lambda > 1$;
3. $n_p^b \ + \ n_\Lambda^b > 0$;
4. $n_- > 2$;
5. n_{ch}= odd number ;
6. $\frac{E_p(\Lambda) - P_{p(\Lambda)} cos\Theta_{p(\Lambda)}}{m_t} > 1$.

n_+ *and* $n_- >$ are the number of positive and negative particles on the star;n_p *and* n_Λ are the number protons and Λ hyperons with momentum p<0.75 GeV/c on the star.n_p^b n_Λ^p are the number protons and Λ hyperons to emitted in backward direction. $E_{p(\Lambda)}$, $P_{p(\Lambda)}$ and $\Theta_{p(\Lambda)}$ are a energy, a momentum and a emitted angle of protons(or Λs) in the Lab. system. m_t is the mass of target. These criteria were separated $\approx$ 83 % from all inelastic p+C interactions[25]. The p+C events were selected by the above criteria the using FRITIOF model [22]. Results of the simulation have lost 18% and 20% from interactions pC→ Λ X and pC→ K_s^0X, respectively. The contribution from pp→ Λ X and pp→ K_s^0X in pC interactions are equal to 1.0% and 0.3%, respectively.

3. The measured cross sections Λ and K^0

The cross section is defined by the formula:

$$\sigma = \frac{\sigma_0}{e} \prod_i w_i = \frac{\sigma_r * N_r^{V^0} * w_{hyp} * w_{geom} * w\phi * w_{kin} * w_{int}}{N_{int}^r * e_1 * e_2 * e_3}, \quad (3.1)$$

where e_1 is the efficiency of search for V^0 on the photographs, e_2 the efficiency of measurements. The V^0s of 75%(preliminary) could be successfully reconstructed and accepted in the analysis. e_3 the probability of decay via the channel of charged particles ($\Lambda \rightarrow p\pi^-, K^0 \rightarrow \pi^+\pi^-$), $\sigma_0 = \sigma_r/N_r$ the total cross section, where σ_r is the total cross section for registered events, N_r is the total number of registered interactions of beam protons over the range of the chamber. $\sigma_t(p + C_3H_8) = 3\sigma_{pC} + 8\sigma_{pp}$=(1456±88)mb [27], where σ_t, σ_{pC} *and* σ_{pp} are the total cross sections in interactions $p + C_3H_8$,p+C and p+p, respectively. The propane bubble chamber method have been permitted the registration the part of all elastic interactions with the propane [23, 24] therefore the total cross section of registered events is equal to: $\sigma_r(p + C_3H_8) = 3\sigma_{pC}(inelastic) + 8\sigma_{pp}(inelastic) + 8\sigma_{pp}(elastic)0.70 = (1049 \pm 60)$mb.

w_i are weights for the lost events with V^0 for(Table 2): w_{geom} - the V^0 decay outside the chamber; w_ϕ - the required isotropy for V^0 in the azimuthal (XZ) plane; w_{hyp} - the undivided ΛK_s^0 events; w_{int} - the selected as p + ^{12}C from the interaction of p + C_3H_8; w_{kin} - the kinematic conditions(with FRITIOF);w_{int}- the V^0+ propane interactions.

Table 3 show that the experimental cross sections are calculated by formula 3.1 for inclusive Λ hyperons and K_s^0 mesons productions in the interactions of pp and pC at beam momentum 10 GeV/c.

Ratios of average multiplicities Λ hyperons and K_s^0 mesons to multiplicities π^+ mesons in p+C interaction at beam momenta 4.2 GeV/c and 10 GeV/c show in Table 4. Experimental data on multiplicities π^+ mesons in the interactions of pC at momenta 4.2 GeV/c ($< n_{\pi+} >$= 0.71±0.01) and 10 Gev/c ($< n_{\pi+} >$= 1.0±0.05) taken from publications [26] and [25], respectively.

The Λ/π^+ ratio for C+C reaction is shown in Table 5 and on Fig.3. This ratio have been obtained by using the Glauber approach on the experimental cross section for p+C $\rightarrow$ ΛX reaction.

4. Conclusion

The experimental data from the 2 m propane bubble chamber have been analyzed for pC$\rightarrow$ $\Lambda(K_s^0)$X reactions at 10 GeV/c. The estimation of experimental inclusive cross sections for Λ and K_s^0 production in pC collisions is equal to σ_Λ= 13.3±1.7 mb and $\sigma_{K_s^0}$= 3.8±0.6 mb, respectively. The measured Λ/π^+ ratio in pC and pp reactions is equal to (5.3 0.8)*10-2 and (2.7 0.4)*10-2, respectively. The experimental Λ/π^+ ratio in the pC reaction is approximately two times larger than the Λ/π^+ ratio from pp reactions or from simulated pC reactions by FRITIOF model for the same energy.The Λ/π^+ ratio in C+C collisions at 10.0 A GeV/c obtained that is four times larger than the Λ/π^+ ratio from p+p reactions at the same energy.

Table 1: The amount (70 %) of V^0 events from interactions of different types which were registrated on photographs with propane bubble chambers method.

Chanel	The amount events from interactions.: primary beam protons	sec. charged particles	sec. neutral particles	Total events
$\rightarrow \Lambda(only)x$	5276	2814	1063	9387
$\rightarrow K_s^0(only)x$	4122	1795	481	6543
$\rightarrow (\Lambda$ and $K_s^0)$ x	3381	1095	376	4608

Table 2: Weight of the lost experimental events with Λ and K_s^0 for pC and pp interactions.

Type of reaction	$1/e_1$	$1/e_2$	w_{geom}	w_ϕ	w_{int}	w_{kin}	$1/e_3$	W_{sum}
pC$\rightarrow \Lambda X$	1.14	1.25	1.34	1.14	1.11	1.18	1.56	4.37±0.37
pp$\rightarrow \Lambda X$	1.14	1.25	1.36	1.14	1.11	1.37	1.56	5.15±0.44
pC$\rightarrow K_s^0 X$	1.14	1.25	1.22	1.06	1.04	1.04	1.47	2.93±0.25
pp$\rightarrow K_s^0 X$	1.14	1.25	1.36	1.06	1.05	1.06	1.47	3.31±0.28

Table 3: Cross sections Λ hyperons and K_s^0 mesons for pp and pC interactions at beam momentum 10 GeV/c.

Type of reaction	$N_{V^0}^{exp.}$	W_{sum}	$N_{V^0}^t$ Total	$n_{V^0} = N_{V^0}^t / N_{in}$	σ mb
pC$\rightarrow \Lambda X$	6126	4.37±0.37	26770	0.053±0.005	13.3±1.6
pp$\rightarrow \Lambda X$	836	5.15±0.44	4303	0.026±0.003	0.80±0.08
pC$\rightarrow K_s^0 X$	3188	2.93±0.25	9341	0.018±0.002	3.8±0.5
pp$\rightarrow K_s^0 X$	699	3.31±0.28	2313	0.015±0.001	0.43±0.04

Table 4: Ratios of average multiplicities Λ hyperons and K_s^0 mesons to multiplicities π^+ mesons for p+C interaction at beam momenta 4.2 GeV/c and 10 GeV/c.

	pC This experiment (10 GeV/c)	pC FRITIOF (10 GeV/c)	Cp Experiment (4.2 GeV/c)	Cp FRITIOF (4.2 GeV/c)
$< n_\Lambda > / < n_{\pi+} > \times 10^2$	5.3±0.8	2.6	0.7±0.3	0.9
$< n_{K_s^0} > / < n_{\pi+} > \times 10^2$	1.8±0.3	1.8	0.3±0.2	0.3

Table 5: Ratios of average multiplicities Λ hyperons to multiplicities π^+ mesons for C+C interactions at beam momentum 4.2 and 10 GeV/c.

	4.2 Experiment	10 Experiment
$< n_\Lambda > / < n_{\pi+} > \times 10^2$	2.0±0.6	10.9±1.7

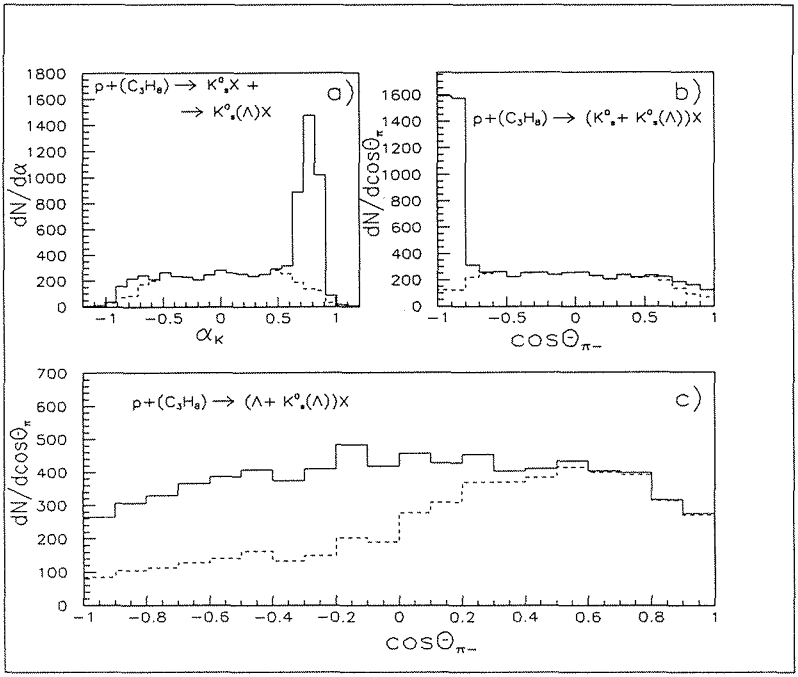

Figure 1: Distributions of α (Armenteros parameter) and cosΘ^*- are used for correctly identification of the undivided V0s. $\alpha = (P_{\parallel}^{+} - P_{\parallel}^{-})/((P_{\parallel}^{+} - P_{\parallel}^{-})$. Where $P_{\parallel}^{+}$ and $P_{\parallel}^{-}$ are the parallel components of momenta positive and negative charged tracks. cosΘ^* - is the angular distribution of π^- from K_s^0 decay. Distributions of α and cosθ- were isotropic in the rest frame of K_s^0 when undivided ΛK_s^0 were assumed to be events as Λ

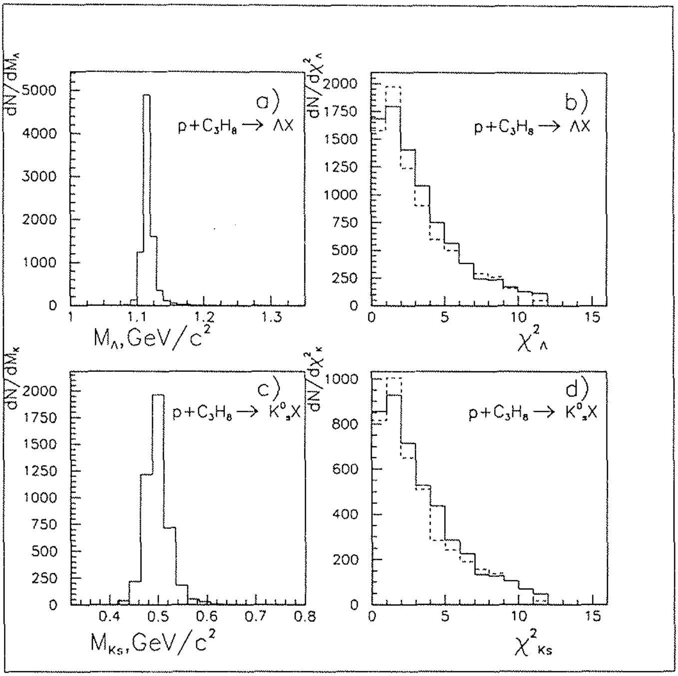

Figure 2: The distribution of experimental V^0 events produced from interactions of beam protons with propane: a) for the effective mass of M_Λ; b)for $\chi^2_\Lambda(1V-3C)$ of the fits via the decay mode $\Lambda \rightarrow \pi^- + p$; c) for the effective mass of $M_{K^0_s}$;d)for $\chi^2_{K^0_s}(1V-3C)$ of the fits via decay mode $K^0_s \rightarrow \pi^- + \pi^+$. The expected functional form for χ^2 is depicted with the dotted histogram

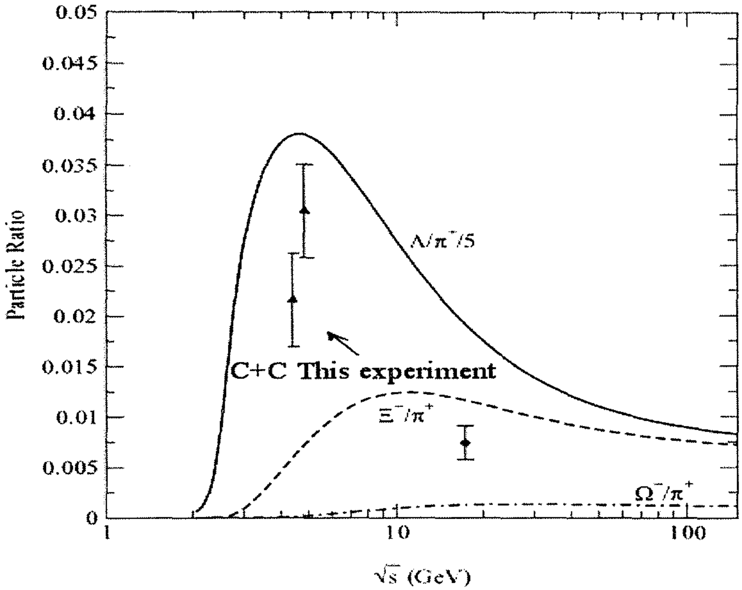

Figure 3: Prediction of the statistical-thermal model[6] for Λ/π^+(note the factor 5), and Ξ^-/π^+ and Ω^-/π^+ ratios a function of $\sqrt{s}$. For compilation of AGS data see [7]. The Λ/π^+ ratio in interaction C+C on figure is obtained by using data from this experiment

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