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ядерных
исследований
дубна

E1-84-444

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ANALYSIS OF V°-EVENTS REGISTERED IN THE STREAMER SPECTROMETER SKM-200

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1984

In this paper we describe scanning, measurement, identification procedures and corrections which allowed us to obtain data on Λ's and K^0_s's produced in nucleus-nucleus collisions at a momentum of 4.5 GeV/c per incident nucleon [1,2,3].

I. EXPERIMENTAL PART

The 2 m streamer chamber used as a detector was filled with pure neon at atmospheric pressure and placed in a magnetic field of 0.8 T. The fiducial volume (200x100x60 cm^3) of the chamber was divided into two parts 30 cm in width each by a transparent copper wire electrode [4] and was photographed with three 56 mm lenses, OKS1-56-5. The distances between the centres of the lenses were equal to 400 mm, and the distance to the focusing plane (chosen as a beam plane) was 2400 mm. The average demagnification of the pictures was $M \approx 1/40$.

Fiducial marks were located under the chamber. The accuracy in measuring the fiducial marks was 0.03-0.05 mm at a distance of 1800 mm.

To determine optical constants, a test-object with 287 crosses (uniformly distributed on a 2700x1100 mm^2 area) was photographed. The coordinates of the crosses were determined with the accuracy of 0.02-0.03 mm.

The analysis was carried out for events obtained with two types of triggering systems:

i) a trigger for inelastic projectile-target nucleus collisions [5] and

ii) a trigger for central $A_p - A_T$ collisions [6].

The inelastic trigger, consisting of upstream and downstream scintillation dE/dx counters, selected inelastic interactions of required projectile nuclei inside the chamber.

The central trigger consisted of upstream inelastic trigger counters and, in addition, downstream veto-counters registering beam, charged fragments and, in some exposures, neutron spectators of incident nuclei. The cut-off registration angle was 2°-3° for charged fragments and spectator neutrons.

Solid nuclear targets in the form of thin discs (0.2-0.3g/cm^2) were mounted within the chamber; the gaseous neon filling the chamber was also used as a nuclear target.

The experimental set-up (fig.1) was described in detail in Ref. [4].

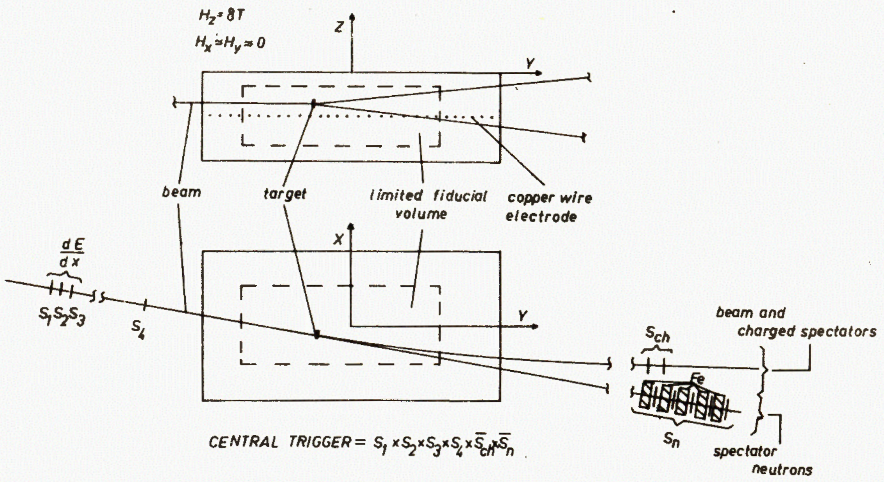


Fig.1. Experimental set-up SKM-200. The triggers and trigger distances are not up to scale.

II. SCANNING AND MEASUREMENTS

About 27000 inelastic ^{4}He-Li and 18000 central nuclear (C-C, C-Ne, O-Ne, C-Cu, C-Zr, C-Pb and O-Pb) interactions were registered on films from the streamer chamber, and the corresponding pictures were double-scanned for V° -events. Out of 980 V° - events thus found 920 were twice measured with the use of semi-automatic measuring devices. The remaining 60 events were unmeasurable for random reasons. The measured V° -events were reconstructed, and the obtained V° -geometry was visually compared with the corresponding pictures of the streamer chamber and, if necessary, remeasured. The measurements containing obvious errors were excluded from the total set of the data, and a final DST was completed by random choice of one measurement for each V° -event. Average measurement errors, obtained after the correction procedure described in Sect.III, are shown in Table 1.

Table 1

	Average measurement errors
$\Delta p/p$	6.5%
$\Delta\lambda$	40 mr
$\Delta\phi$	15 mr

III. IDENTIFICATION

The events were fitted to fulfil kinematical equations of the V° -pointing fit (3C-fit) corresponding to Λ , $\bar{\Lambda}$, K^0_S decays and γ conversion hypotheses. The Böck code [7] was used for fitting. The efficiency of the fitting program was estimated to be about 99%. The Λ and K^0_S decays generated from the nucleon-nucleon (N-N) phase space (including measurement errors in event generation) were used for this estimation.

χ^2 and pull [8] distributions were used to correct values of "point" measurement errors in the reconstruction program.

The shape of the χ^2 and pull distributions are in good agreement with the expected ones see, for example, Fig.2.

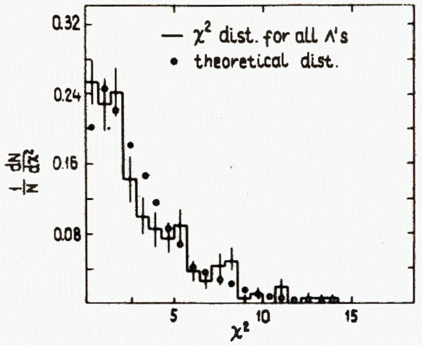


Fig.2. The χ^2 distribution for the total Λ sample (solid-line histogram) and theoretical χ^2 distribution for 3 degrees of freedom (dotted line).

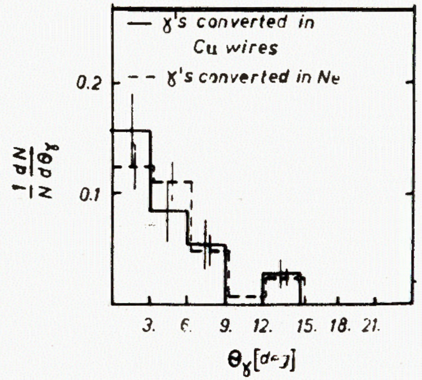


Fig.3. The γ opening angle distribution for γ's converted in the gaseous Ne filling the chamber (dashed line) and in the copper wire electrode (solid line).

The following criteria were required for accepting hadronic hypotheses:

i) the χ^2 value is smaller than 11.3 (the confidence level is 1%);

ii) the proper life time, τ, is lower than 5.5 in mean life time units, τ_0 (only 0.4% of Λ's and K^0_S's survive this limit value).

The analysis of electron pairs from γ conversion in the copper wire electrode, mounted within the chamber [9], yielded a cut-off value of 15° for an opening angle of γ's in this experiment.

The opening angle distributions for γ's converted in the copper wire electrode and gaseous neon are shown in Fig.3.

Table 2

No.	Possible interpretations	Number of events	Final interpretation
1	Λ	159	} Λ
2	ΛK^o_s	201	
3	$\Lambda\gamma$	58	
4	K^o_s	94	} K^o_s
5	$K^o_s\bar{\Lambda}$	7	
6	γ	228	} γ
7	$\gamma\bar{\Lambda}$	3	
8	$\bar{\Lambda}$	0	
9	no fit	91	

Since the precision of measurements and, consequently, the reliability of V° identification were much lower for events occuring close to the chamber walls, a cut on the fiducial volume was applied, see Fig.1. The resulting rejection of 8% of V° -events concerns mainly no-fit events.

Table 2 presents results of the kinematical fit for V°-events within this limited volume.

The final identification was based on:

i) Analysis of kinematical plots, namely, $a-p_t$ plots, where $a=(p_+^2-p_-^2)/p^2$, p_+, p_-, and p are the momenta of positive, negative decay products and V°, respectively, and p_t is the transverse component of momentum of either decay product /10/. The fraction of K^o_s mesons and Λ's thus uniquely identified is about 92% and about 50%, respectively (only Λ and K^o_s hypotheses were considered in this case).

ii) Symmetry considerations which lead to the conclusion that the abundances of K^o_s's (γ's) in the group $\Lambda K^o_s(\Lambda\gamma)$ (mixed identification groups) (see Table 2) and in the group are the same. The validity of this procedure is based on the fact that in this experiment we have observed no uniquely identified $\bar{\Lambda}$ decays and, consequently, the groups $K^o_s\bar{\Lambda}$ and $\gamma\bar{\Lambda}$ may be treated as K^o_s's and γ's, respectively.

Results of the above two procedures are the same and lead us to the conclusion that the groups Λ, ΛK^o_s and $\Lambda\gamma$ may be treated as Λ's; the groups K^o_s and $K^o_s\bar{\Lambda}$, as K^o_s's and the groups γ and $\gamma\bar{\Lambda}$, as γ's.

The estimated contamination of the final Λ sample with other (K^o_s,γ) events is approximately 3%, whereas the final K^o_s sample

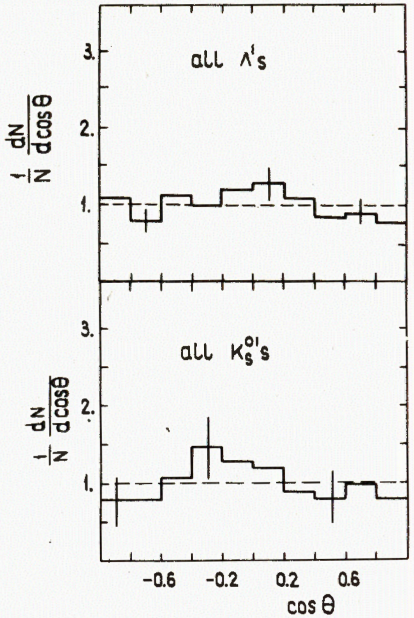
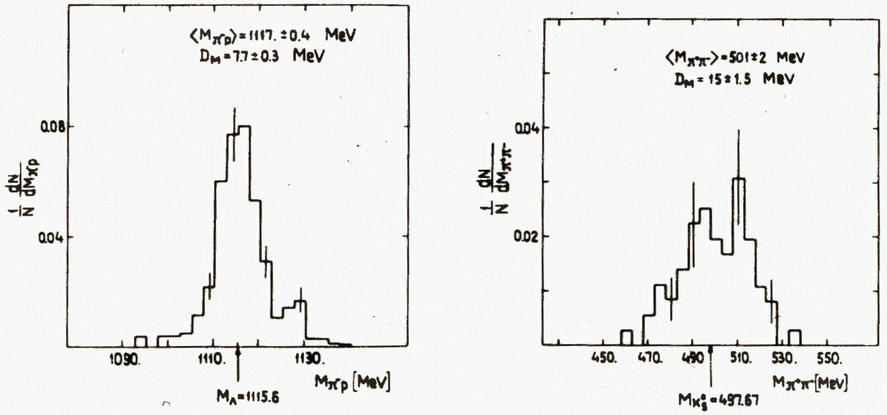


Fig.4. The $\cos\theta^*$ distribution for the total Λ and K^o_s samples separately; θ^* is an angle in the $\Lambda(K^o_s)$ CM system between a positive decay product momentum and $\Lambda(K^o_s)$ momentum. The values corresponding to a uniform distribution (χ^2/NDF=1.6 for Λ's and χ^2/NDF=0.6 for K^o_s's) are shown as a horizontal broken lines.

Fig.5. The invariant mass distributions for the total Λ and K^o_s samples.



is depleted by ~7%. These biases were corrected for in the analysis of strange particle yields. Similar results were obtained when considering events generated from the phase space for reactions NN-NΛK and NN-NΛKπ used to test the fitting program.

CM angular distributions of the decay products for the final samples of Λ's and K^o_s's are shown in Fig.4 as an example.

No uniquely identified $\bar{\Lambda}$ decay was found. Simple geometry considerations and the analysis of kinematic and angular characteristics of events in mixed-identification groups (groups (5) and (7) in Table 2) yielded the upper limit of the number $\bar{\Lambda}$'s in our sample $N_{\bar{\Lambda}} \leq 1$.

Invariant mass distributions for the final Λ and K^0_s samples are shown in Fig.5.

IV. CORRECTIONS

The procedures described in Sect.III selected 418 Λ and 101 K^0_s decays inside the limited fiducial volume.

The samples were depleted due to random losses of events and biased due to selective losses of V^0's with configurations and/or positions which reduce V^0 detectability.

Main selective losses were due to a poor visual resolution in the regions of high track density in the vicinity of interaction vertices. The region radius increases with the multiplicity of charged secondaries and, consequently, with the mass number of colliding nuclei.

In order to estimate the radius, the Λ sample was splitted into 4 subsamples consisting of Λ's emitted from (He-Li), (C-C, C-Ne, O-Ne), (C-Cu, C-Zr) and (C-Pb, O-Pb) collisions. The emission-decay distance, L_Λ, projected on the picture plane was determined for each event. The Bartlett method [11] was used to obtain the calculated mean life time, $\langle\tau\rangle$, as a function of the lower cut, L_{CUT}, on L in each subsample of Λ-events. The limited fiducial volume or the cut on lifetime equal to $5.5\tau_0$ were taken into account. The procedure proved to be insensitive to the imposed upper cut. In Figs.6 and 7 are shown the $\langle\tau\rangle/\tau_0$ ratios as a function of the L_{CUT} value for Λ's subdivided into four subsamples and for all K^0_s's, respectively. The L_{CUT} values, for which $\langle\tau\rangle/\tau_0 = 1$, increasing from ~12 cm for inelastic He-Li collisions to ~18 cm for central C-Pb and O-Pb collisions, led to a decision of using $L_{CUT} = 18$ cm for all Λ and K^0_s events, when Λ's and K^0_s's characteristics produced in various interactions are compared. It should be noted that the lower cuts lead to a removal from the samples of Λ's and K^0_s's with momenta, p, lower than $p = (L_{CUT} M_{\Lambda,K^0})/5.5\tau_0$, e.g., for $L_{CUT} = 18$ cm Λ's with $p < 0.46$ GeV/c and K^0_s's with $p < 0.61$ GeV/c are removed. Figures 8 and 9 show the total samples of Λ's and K^0_s's (points), the removed regions of phase space calculated for $L_{CUT} = 18$ cm (hatched areas) and the phase space limits for $NN \to N\Lambda K$ (solid lines) and $NN \to N\Lambda K\pi$ (dashed lines) on $Y-P_T$ (rapidity-transverse momentum) plots.

Losses due to a particular configuration of V^0-events were studied for Λ sample. Losses in the K^0_s sample were assumed to be the same as in the Λ sample.

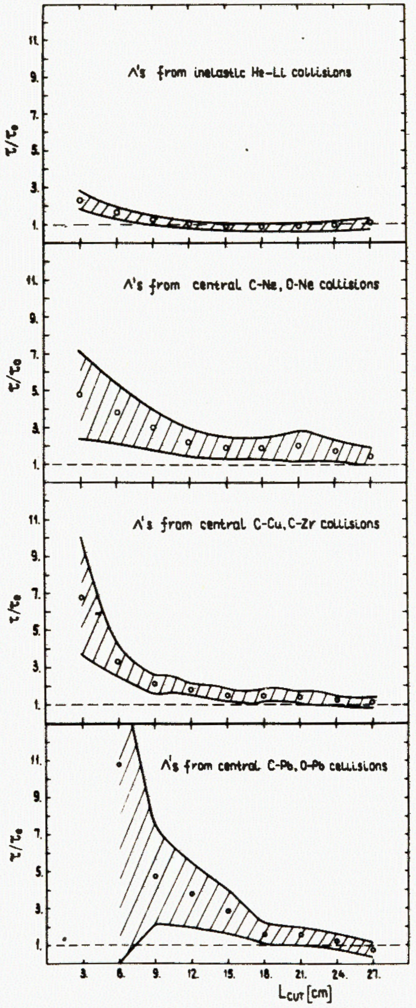


Fig.6. The ratio of the calculated [11] to the proper lifetime for Λ's divided into four subsamples versus lower cut on the projected Λ range, L_{CUT}.

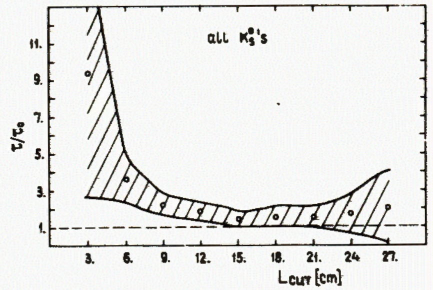


Fig.7. The ratio of the calculated [11] to the proper lifetime for K^0_s's versus lower cut on the projected K^0_s range L_{CUT}.

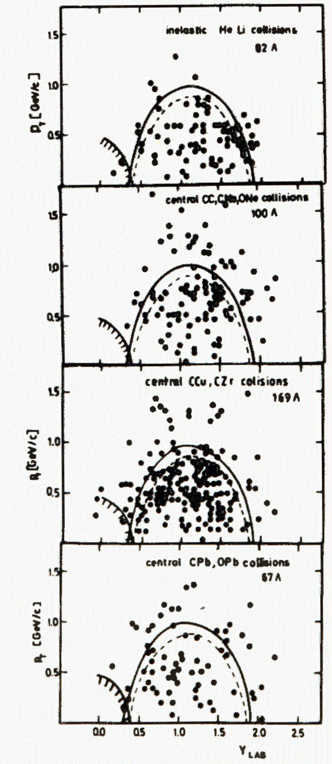


Fig.8. Transverse momentum versus rapidity (lab.system) for the total Λ sample. Solid and dashed lines correspond to the phase-space limits for $NN \to N\Lambda K$ and $NN \to N\Lambda K\pi$ channels, respectively. Hatched areas are the Λ rejection regions ($p_\Lambda < 0.46$ GeV/c) calculated for $L_{CUT} = 18$ cm.

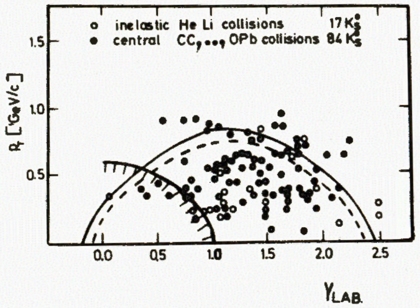


Fig.9. Transverse momentum versus rapidity (lab.system) for the total K_s^0 sample. Solid and dashed lines correspond to the phase limits for $NN \to N\Lambda K$ and $NN \to N\Lambda K\pi$ channels, respectively. A hatched area is the K_s^0 rejection region ($p_{K_s^0} < 0.61$ GeV/c) calculated for $L_{CUT} = 18$ cm.

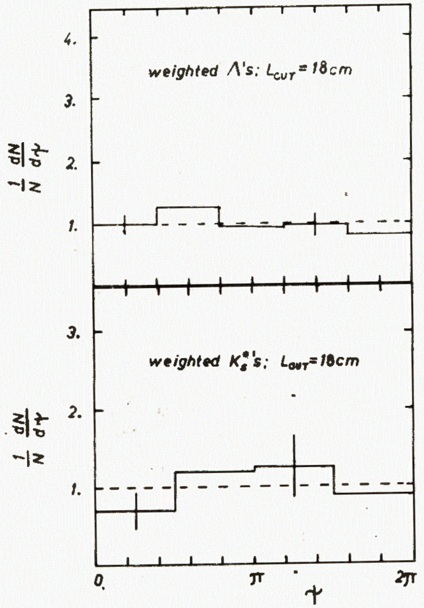


Fig.10. The azimuthal angle distributions for Λ's and K_s^0's with L > 18 cm. The weights corrected for decay outside the limited fiducial volume were used. The values corresponding to a uniform distribution (χ^2/NDF = 1.2 for Λ's and χ^2/NDF = 1.0 for K_s^0's) are shown as horizontal broken lines.

The following checks were performed:

- angular distributions of Λ decay planes (Fig.10) and Λ decay products in the Λ CM system for Λ's decaying in various regions of the fiducial volume; possible losses of events with a too step V° production plane and/or one of the decay products too steep to be easily detected in scanning or reliably measured;
- opening angle distributions and correlations of the opening angle with charged particle multiplicities in parent events;
- possible scanning losses of "narrow" events.

The analysis showed that all observed irregularities are consistent with statistical fluctuations.

Weighting factor, w , was calculated for each V°-event (with $L < L_{CUT}$). The weighting factors thus correct the sample for unregistered (or rejected) decays occuring:

i) at distances $L < L_{CUT}$,
ii) after the particle has survived $5.5\tau_0$,
iii) beyond the limited fiducial volume.

Weights, w , were the only corrections introduced individually for each V° -event. The final numbers of Λ's and K_s^0's,

Table 3

A_p-A_T	Λ	Λ (L>18 cm)	$\langle w \rangle_\Lambda$	K_s^0	K_s^0 (L>18 cm)	$\langle w \rangle_{K_s^0}$
He-Li	82	51	3.8	17	4	17.5
C - C	26	20	4.2	11	11	9.3
C - Ne	60	39		13		
O - Ne	14	10		4		
C - Cu	115	67	4.8	35	18	10.4
C - Zr	54	35		8		
C - Pb	27	21	7.4	9	7	6.3
O - Pb	40	34		4		

the numbers of Λ's and K_s^0's with L > 18 cm and average weights, <w>, obtained for L_{CUT} = 18 cm, are presented in Table 3.

Most of no-fit events (70% of group (9) in Table 2) turned out to occur at a distance less than L_{CUT} = 18 cm. The remaining no-fit events (33 events) underwent a scrutinized check. All of them were found to fail the fitting procedure for random reasons (mostly a bad quality of the pictures), and they were added to the Λ, K_s^0 and γ samples proportionally to the abundances of the samples.

The above correction, the scanning efficiency (85%) and the "measurability" of events (93%) (both values refer to the V° decays with L > 18 cm) were taken into account in yield estimations.

The authors would like to express their sincere thanks to Prof. E.Skrzypczak for fruitful discussions.

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Received by Publishing Department
on June 26, 1984.

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Газдзицки М. и др. E1-84-444

Анализ V^0-событий, регистрируемых на стримерном спектрометре СКМ-200

Рассмотрены методы просмотра, измерений, идентификации и внесения поправок, которые были использованы для получения данных о свойствах Λ- и K^0_s-частиц, рожденных в неупругих и центральных взаимодействиях, которые были зарегистрированы в стримерном спектрометре СКМ-200. Центральные соударения ядер отбирались с помощью специальной триггерной системы. Идентификация была проведена с использованием метода фитирования /3С- фит /, причем вид χ^2-распределения оказался в хорошем согласии с ожидаемым. Использование дополнительных критериев идентификации позволило уменьшить примесь фоновых V^0-событий в группе Λ - до 3% и в группе K^0_s - до 7%, что было учтено при оценке выхода этих частиц.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1984

Gaździcki M. et al. E1-84-444

Analysis of V^0-Events Registered in the Streamer Spectrometer SKM-200

Methods of scanning, measurement, identification and correction are described. They were used to obtain results on the Λ- and K^0_s-particles produced in nucleus-nucleus inelastic and central interactions detected with the SKM-200 streamer spectrometer. The central nuclear collisions were selected using the special triggering system. The identification has been made by fitting the kinematic equations (3C- fit) and the shape χ^2-distributions appeared to be in good agreement with the expected ones. The additional criteria for the identification has diminished the background V^0-admixture up to 3% for Λ- sample and up to 7% for the K^0_s- samples. That has been taken into account to estimate the yields of these particles.

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

Communication of the Joint Institute for Nuclear Research. Dubna 1984