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SEARCH FOR STRANGE SIXQUARK STATES
IN PP → K^+X MISSING MASS SPECTRA

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A new interest to study the $S = -1$, $B = 2$ system has recently been raised due to theoretical predictions coming either from both potential [1] and quark bag model calculations [2] about the existence of narrow exotic states. In particular the NIJMEGEN GROUP [3] predicts in the MIT bag model a large number of 6 quark configurations with strangeness $S = 0, -1$ or -2. The stability of these states against quark dissociation or two baryon emission increases with the number of strange quarks involved, the optimum case boeing for the $S = -2$ system (uu dd ss) that could even present a stable di-hyperon state [4] . No experimental evidence for the observation of such $S = -2$ states has yet been found, but the cross section level reached in these different experimental researches [5] does not rule out their existence.

For the $S = -1$ states, among many different candidates proposed in different experiments [6] a likely state has been recently proposed as a result of a $d(K^-, \pi^-)X$ experiment [7] . This state is observed in the mass region close to the ΣN threshold ; in this region two structures are observed : one at 2129 MeV, which was previously observed [8] is associated with a cusp effect due to the opening of the ΣN threshold and the strong coupling of this channel to the Λp channel, while the other at 2139 MeV with a width $\Gamma = 8$ MeV fits very well with the D_T six quark state *of ref. 9.*

There are no reported observations of enhancements in Λp missing mass spectra below ΣN threshold except for the Λp FSI in the $pp \rightarrow K^+X$ experiment of ref. [10] which found a marked deviation in the upper end of the K^+ momentum spectra.

A new $pp \rightarrow K^+X$ experiment has been performed at the Saturn National Laboratory with high resolution to study Λp and ΣN final interactions in a large range of momentum transfer and missing mass. This paper presents the first results obtained at an incident proton energy of 2.3 GeV in the mass region for X : $2055 < M_X < 2180$ GeV and for kaon emission angles $\theta_K = 8°$ and $10°$.

The experiment utilizes the Saturn Synchrotron and the SPES 4 beam line spectrometer [11] . The synchrotron delivers protons with energies ranging from .2 to 2.9 GeV with an intensity of 10^{12}p/s. The SPES 4 beam line is a 32 meter long spectrometer which allows the momentum analysis of particles up to 4 GeV/c. The (p,K^+) experiment is performed with high proton intensity beam. The detection of K^+ has to be done in a very high flux of protons and π^+. The K^+ discrimination is achieved by :

- *Momentum analysis with SPES 4. The solid angle of the spectrometer, defined by a lead collimator is $\Delta\Omega = 2.5\ 10^{-4}$, with momentum acceptance $\Delta p/p = \pm 3.5$ %, and momentum resolution 10^{-4}.*
- *Velocity measurement. Different time of flight (TOF) measurements are performed between the intermediate focal plane (IFP) and the region of the final local plane (FFP) located 16 meters downstream. The "starts" are delivered by 12 scintillator counters, the stops are given either by one plane of 13 scintillator counters, or by 4 different Cerenkov counters or by two thin scintillator strips each one viewed by two photomultipliers at each end and covering the whole focal plane.*
- *Proton and pion rejections. These are obtained by 4 Total Reflection Cerenkov Detectors (TRCD). They are made of perspex strips slightly bent to take into account the dependance of the angle of incidence of the particles on momentum, which is the main angle dependance effect in the SPES 4 tuning version here used, so the particles enter always perpendicular in the TRCD (± .25°). The index of the material is such (n = 1.49) that in the range of velocities for the particles here considered, the total reflection of the Cerenkov light is always assured for*

kaons and pions but never for the protons. The TRCD fast coincidence is entered in the trigger, which is defined by a fast coincidence between the particle coming from the IFP and FFP scintillator and this TRCD fast signal leading to a very high rejection for the protons (99 %) on line keeping a pion and kaon efficiency higher than 95 % [12]. Pion rejection is realised by tilting the TRCD by a few degrees such that an important part of the flux is eliminated by playing on the different opening angle of the light produced by pions and kaons ($\Delta\theta = 4°$) having the same momentum but different velocities. That yields different light amplitudes for different particles. In figure 1 are shown the result of the light collection on each side showing the amplitude separation obtained on one side between the few remaining protons and the K^+ or π^+, and on the other side between the protons or K^+ and the π^+ : the signals coming from this side, with a threshold put as shown on the figure, are sent to the trigger in the veto. This operation is repeated four times and the fast final π rejection is better than 90 % on line leading to about 200 π and 100 p for 1 kaon.

A typical time spectrum is shown in figure 2 after applying more restrictive Cerenkov amplitude windows off line. The final good separation between π^+ and K^+ has a FWHM time resolution of typically 800 ps.

-*Reconstruction of particle trajectories in FFP and missing mass spectrum at the target position.* *Two multidrift counters located close to FFP allow the reconstruction of the trajectories in both horizontal and vertical planes. Using the inverse matrix of SPES 4, one can display the θ-momentum (or θ-missing mass) and ϕ-momentum planes at the target position. This allows the rejection of any particle that does not come from the target. The precision for the localisation of the particles in the FFP is around 1 mm. The total energy resolution is 1.5 MeV.*

Scintillator telescopes viewing either a thin CH_2 film upstream from the target, or the liquid hydrogen target (280 mg/cm^2) itself and a secondary emission monitor are used to monitor the relative proton flux. Absolute calibrations of the monitors were made by activation measurement from $^{12}C(p, pn)^{11}C$.

The results of the present investigation include cross sections for 8° and 10° K emissions at 2.3 GeV proton energy. They are shown directly on Fig. 3 and 4 as missing mass spectra by 2.5 MeV bins. The error bars are *only statistical. The thresholds for the Λ and $\Sigma^{\pm}$ production are shown. The full lines correspond to the phase space calculations of the reactions $pp \to K^{+} \Lambda p$ and $\to K^{+} \Sigma^{+}_{o} N$. The figures show the missing mass spectra for $\theta_{K} = 8°$ (Fig. 3) $\theta_{K} = 10°$ (Fig. 4) and the addition of these two spectra (Fig. 5) which are very similar in shape and absolute value. On Fig. 5 one observes clearly two different regions as compared to the 3-body phase space (3-BPS) calculation :*

- *<u>the Λp threshold mass region</u> where the 3-BPS is distorted by the Λ-p final state interaction (FSI). A calculation [13] done within the one kaon exchange mechanism with Λ-p FSI is shown on this figure (dotted line).*

Technical details of the calculations are based upon an older work on pion production off nuclei [14]. One finds linear relation between the $pp \to K^{+}\Lambda p$ and the $K^{+}p \to K^{+}p$ amplitudes. Due to antisymmetry the $K^{+}p$ elastic scattering amplitude is required both in the forward and backward direction. It is taken here to be the same which is consistent with recent $K^{+}p$ phase shift analysis [15]. The Λ-p final state interaction was parameterized in the s-wave by a separable potential with parameters adjusted to a scattering length a and effective range r_{o}. identical for the singlet and triplet s-state ($a = -1.80$ fm, $r_{o} = 3.42$ fm). No attempt to get an absolute normalisation was done although this is quite possible in this model. In order to simplify the calculations non-relativistic kinematics for the Λ-p pair have been used, which is consistent with the way of treating the final interaction. Our predictions for the missing mass spectra below the ΣN threshold are compared in figure 5 with the data on $pp \to K^{+}X$ reaction at 2.3 GeV. An overall energy resolution of 10 MeV was convoluted with the theoretical calculations. The region of the FSI in the missing mass spectrum is well reproduced. A tiny structure seems to appear in the missing mass spectra at 2090 MeV which is not accounted by this calculation.

- *<u>the ΣN threshold mass region</u> where a strong cusp appears at threshold. This structure seen at both angles $\theta_{K} = 8$ and $10°$ with a 10 MeV width seems to have two components : one at 2130 MeV which corresponds to the strong coupling of the ΣN channel to the Λp channel described before the other one at 2138 MeV could correspond to the structure observed at BNL [7] and in other previous bubble chamber experiments [16] . The width of the observed effect is a few MeV. The analysis of other data taken at $\theta_{K} = 12°$ is in progress and can shed light on it. Calculations of the cross sections around the ΣN thresholds in terms of the meson (π or K) exchange model have to be performed before setting any definite conclusion on the nature of this structure.*

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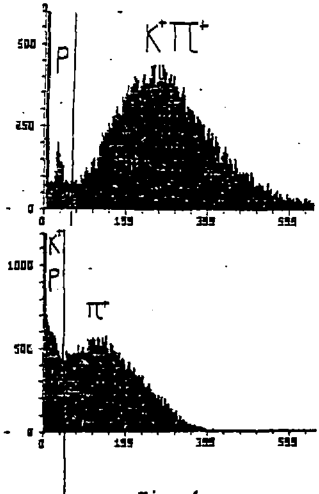

Fig. 1

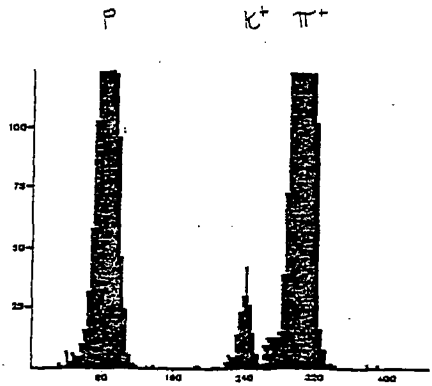

Fig. 2

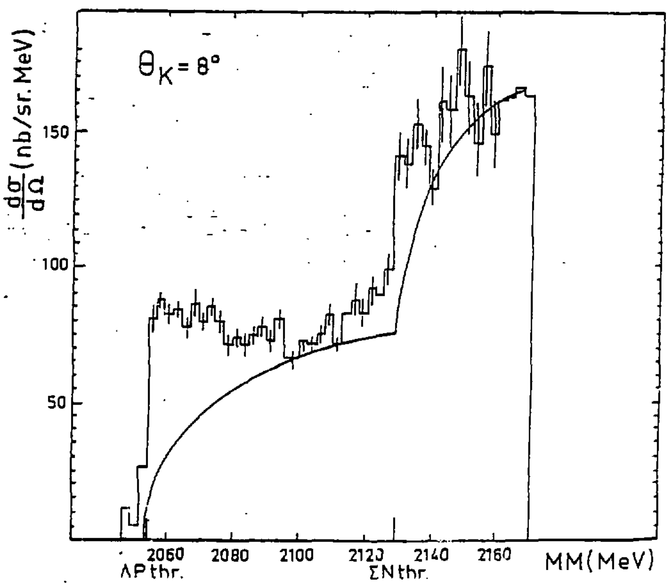

Fig. 3

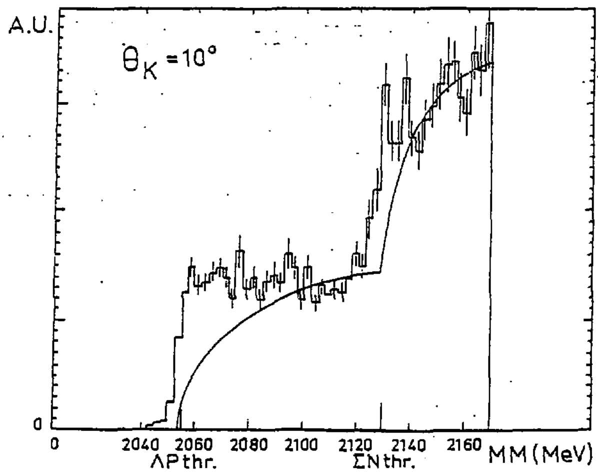
A.U.
$\theta_K = 10°$
0
0
2040 2060 2080 2100 2120 2140 2160
MM (MeV)
ΛP thr.
ΣN thr.

Fig. 4

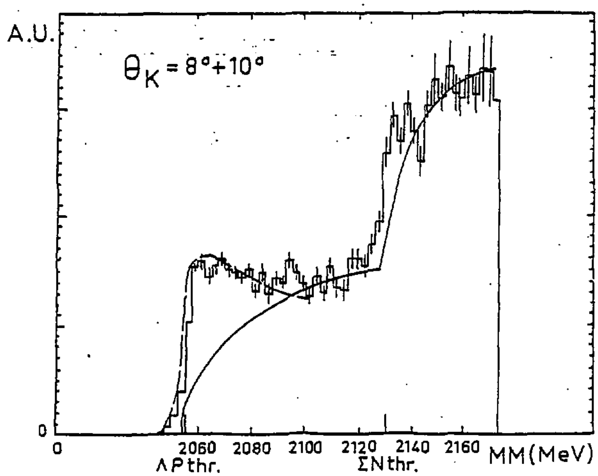
A.U.
$\theta_K = 8° + 10°$
0
0
2060 2080 2100 2120 2140 2160
MM (MeV)
ΛP thr.
ΣN thr.

Fig. 5