Indication of an excited hyperon state in pp collisions with ANKE at COSY-Jülich

I. Zychor[a], V. Koptev[b], M. Büscher[c], A. Dzyuba[c], I. Keshelashvili[c], V. Kleber[d], R. Koch[c], S. Krewald[c], Y. Maeda[c], S. Mikirtichyants[b], M. Nekipelov[bc], H. Ströher[c] and C. Wilkin[e]

[a]The Andrzej Sołtan Institute for Nuclear Studies, 05400 Świerk, Poland

[b]Petersburg Nuclear, Physics Institute, 188350 Gatchina, Russia

[c]Institut für Kernphysik, Forschungszentrum Jülich, 52425 Jülich, Germany

[d]Institut für Kernphysik, Universität zu Köln, 550937 Köln, Germany

[e]University College London, London WC1E 6BT, U.K.

The reaction $pp \to pK^+Y$ has been studied with the ANKE spectrometer at COSY Jülich in order to investigate heavy hyperon production. The missing mass spectra $MM(pK^+)$ have been analyzed and compared with Monte Carlo simulations. Indication of a hyperon resonance $Y^{0*}(1480)$ have been found.

1. Introduction

The production and properties of hyperons have been studied for more than 50 years, mostly in pion and kaon induced reactions. Hyperon production in pp collisions close to the threshold has been studied at SATURNE (Saclay, France) and COSY-Jülich. Reasonably complete information on $\Lambda(1116)$, $\Sigma^0(1192)$, $\Sigma^0(1385)$, $\Lambda(1405)$ and $\Lambda(1520)$ can be found in the literature [1] although for the $\Lambda(1405)$, in spite of rather high statistics achieved (the total world statistics is several thousand events), there are still open questions concerning the nature of this resonance: is it a singlet *qqq* state in the frame of SU(3) or a quark-gluon *(uds-q)* hybrid, or a KN bound state? The $\Sigma(1480)$ hyperon is not well established yet. In the 2004 Review of Particle Physics it is described as a 'bump' with unknown quantum numbers.

We have investigated whether additional information on hyperon production might be obtained from proton-proton interactions at low energies.

2. Experiment and simulations

The experiment has been performed at the Cooler Synchrotron COSY at the Research Center Jülich (Germany) [2]. COSY is a medium energy accelerator and storage ring for both polarized and unpolarized protons and deuterons. The measurements were performed at a proton beam momentum of 3.65 GeV/c incident on a a hydrogen cluster–

jet target. The average luminosity during the measurements was $L = (1.38 \pm 0.15) \times 10^{31}\,\mathrm{s}^{-1}\,\mathrm{cm}^{-2}$. The ANKE magnetic spectrometer [3] used in the experiment consists

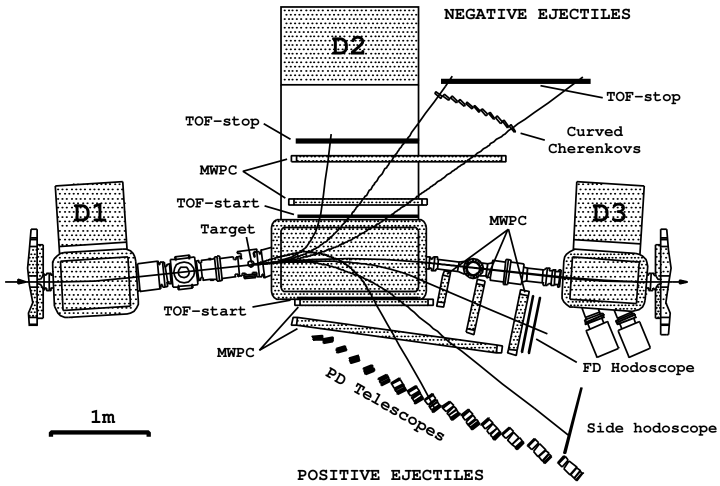

Figure 1. ANKE spectrometer and detectors.

of three dipole magnets. The central C–shaped spectrometer, placed downstream of the target, separates the reaction products from the circulating COSY beam. The ANKE detection system, comprising range telescopes, scintillation counters and multi–wire proportional chambers, simultaneously registers both positively and negatively charged particles and measures their momenta [4].

At a COSY beam momentum of 3.65 GeV/c hyperons Y with masses up to $\sim$ 1540 MeV/c^2 can be produced in the reaction $pp \to pK^+Y$. This is shown in Fig. 2 where the missing mass m_Y spectrum is shown for the case that a K^+-meson in coincidence with a proton is detected with ANKE. While the ground-state hyperons are clearly seen in the spectrum, the heavier ones are on top of a broad background which can mainly be attributed to the production of additional pions. Thus the unambigous identification of these hyperons requires the detection of additional coincident particles from their decays.

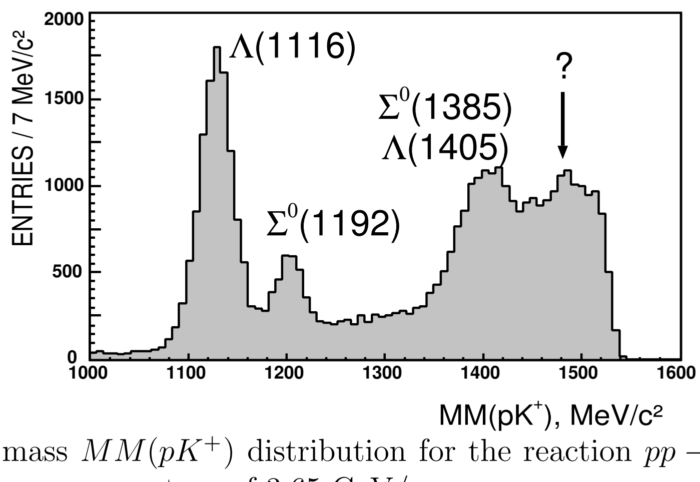

Figure 2. Missing mass $MM(pK^+)$ distribution for the reaction $pp \to pK^+Y$ measured with ANKE at a beam momentum of 3.65 GeV/c

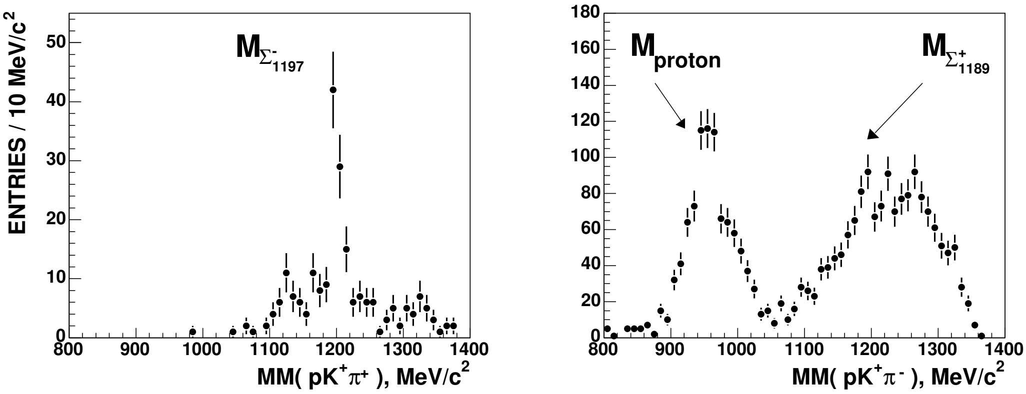

Figure 3. Missing mass spectra for the reaction $pp \to pK^+\pi^+X^-$(left) and $pp \to pK^+\pi^-X^+$(right).

A final state comprising a proton, a positively charged kaon, a pion of either charge and an unidentified residue X was investigated in the reaction $pp \to pK^+Y \to pK^+\pi^\pm X^\mp$. A missing mass spectrum in the reaction $pp \to pK^+\pi^+X^-$ shows a flat background with a peak at approximately 1195 MeV/C^2 (left part in Fig. 3). The peak corresponds to the decay $Y \to \pi^+\Sigma^-(1197)$. In the charge–mirrored $pp \to pK^+\pi^-X^+$ case, the π^- may originate from different sources, *e.g.* a decay with the $\Sigma^+(1189)$ or a secondary decay of $\Lambda \to p\pi^-$, arising from the major background reaction $pp \to pK^+\Lambda \to pK^+\pi^-p$. Protons from this reaction can be easily rejected by cutting $MM(pK^+\pi^-)$ around the proton mass (right part in Fig. 3). Nevertheless the missing mass distribution for the (π^-X^+)-final state is more complicated.

If only events around the Σ mass are selected, then the missing mass spectrum $MM(pK^+)$ in the reaction $pp \to pK^+\pi^+X^-$ shows two peaks, see left part in Fig. 4. One of them corresponds to the contribution of $\Sigma^0(1385)$ and $\Lambda(1405)$ hyperons. The second peak

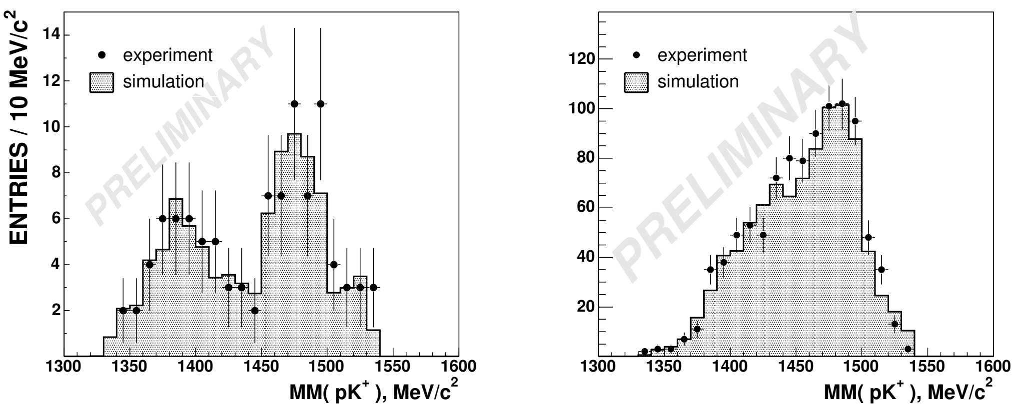

Figure 4. Experimental and simulated missing mass $MM(pK^+)$ spectra for the reaction $pp \to pK^+\pi^+X^-$(left) and $pp \to pK^+\pi^-X^+$(right). The shaded histogram shows the fitted Monte Carlo simulations.

is located at a mass ∼1480 MeV/c^2. In the $\pi^- X^+$ case, the distribution also peaks at 1480 MeV/c^2, see right part in Fig. 4.

We have assumed that the measured missing mass $MM(pK^+)$ spectra can be explained by the production of hyperon resonances and non-resonant contributions. Detailed Monte Carlo simulations have been performed including the production of well established excited hyperons ($\Sigma^0(1385), \Lambda(1405)$ and $\Lambda(1520)$) and non-resonant contributions like $pp \to pK^+\pi X$ and $pp \to pK^+\pi\pi X$, X denotes any hyperon which could be produced in the experiment. From the comparison of measured and simulated missing mass distributions it turned out that it is necessary to include another excited hyperon Y^{0*} with a mass $M(Y^{0*}) = (1480 \pm 15)$ MeV/c^2 and a width $\Gamma(Y^{0*}) = (60 \pm 15)$ MeV/c^2.

3. Conclusions

We have found indication of a neutral hyperon resonance Y^{0*} produced in proton–proton collisions at 3.65 GeV/c and decaying into π^+X^- and π^-X^+ final states. Its parameters are $M(Y^{0*}) = (1480 \pm 15)$ MeV/c^2 and $\Gamma(Y^{0*}) = (60 \pm 15)$ MeV/c^2 though, since it is neutral, it can be either a Λ or Σ hyperon. The production cross section is of the order of few hundred nanobarns. It seems to be difficult to integrate the low mass Y^{0*} hyperon within the existing classification of 3q-baryons [5,6]. On the basis of available data we cannot decide whether it is a 3–quark baryon or an exotic state, although some preference towards its exotic nature may be deduced from theoretical considerations [7–12].

Further studies are required to determine its quantum numbers. At ANKE, using a deuterium cluster target and spectator proton tagging, one can search for the charged Y^{-*} hyperon in the reaction $pn \to pK^+Y^{-*} \to pK^+\pi^-X^0$. The investigation of Y^* decays with photons in the final state is foreseen with the WASA detector at COSY [13].

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REFERENCES

1. S. Eidelman *et al.*, Phys. Lett. B **592**, 1 (2004)
2. R. Maier, Nucl. Instr. Methods Phys. Res., Sect. A **390**, 1 (1997)
3. S. Barsov *et al.*, Nucl. Instr. Methods Phys. Res., Sect. A **462**, 364 (2001)
4. M. Büscher *et al.*, Nucl. Instr. Methods Phys. Res., Sect. A **481**, 378 (2002)
5. U. Loehring *et al.*, Eur. Phys. J. A **10**, 447 (2001)
6. S. Capstick and N. Isgur, Phys. Rev. D **34**, 2809 (1986)
7. H. Högaasen and P. Sorba, Nucl. Phys. B **145**, 119 (1978)
8. Ya.I. Azimov *et al.*, Phys. Rev. C **68**, 045204 (2003)
9. R.A. Arndt *et al.*, Phys. Rev. C **69**, 035208 (2004)
10. R. Jaffe and F. Wilczek, Phys. Rev. D **69**, 114017 (2004)
11. Y. Oh, H. Kim and S.H. Lee, Phys. Rev. D **69**, 094009 (2004)
12. C. Garcia-Recio, M.F.M. Lutz and J. Nieves, Phys. Lett. B **582**, 49 (2004)
13. COSY Proposal 136.1 (2004), http://www.fz-juelich.de/ikp/wasa/