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RECENT RESULTS ON MESON PRODUCTION FROM SAPHIR* **

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The SAPHIR detector is a magnetic spectrometer for multiparticle final states attached to the 3.5 GeV electron accelerator ELSA. The experiments focus on the photoproduction of associated strangeness in $\gamma \mathrm{p} \rightarrow K^+\Lambda$, $K^+\Sigma^0$ and $K^0\Sigma^+$ final states and the production of the lightest vector mesons ρ, ω and ϕ. In the $K^+\Lambda$ cross section a steep threshold behaviour is observed which is different in the case of $K^+\Sigma^0$ which is reflected in the differential cross section. Contrary, Λ and Σ polarizations show little variation with energy. A bump in the t-distribution for ω-production for $E_\gamma \simeq 1.5$ GeV could be an indication for a resonance while the production of ϕ-mesons appears fully diffractive down to energies below 2 GeV.

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1. Introduction

With a tunable electron energy of up to 3.5 GeV the ELectron Stretcher Accelerator ELSA at the University of Bonn covers the domain of nucleon resonances and exceeds the thresholds of the lowest lying nonets of pseudoscalar and vector mesons. ELSA delivers a beam current of $I = 80$ nA in the stretcher mode and up to $I = 20$ nA in the postaccelerator mode. The duty factor of up to 90% allows to perform coincidence experiments in electron scattering and photoproduction with tagged photon beams. The electron scattering facility ELAN had been used to study elastic and transition form factors for the proton as well as for the neutron. It has now been replaced by a set-up for photoproduction experiments of which the measurement of the Gerasimov–Drell–Hearn sum rule will be the first. Thereafter the crystal barrel detector will take over its place giving access to the detection and spectroscopy of photonic final states. Complementary, SAPHIR is a magnetic spectrometer specialized on charged multiparticle final states. The experiments here focus on the production of η, η' and associated strangeness in $K\Lambda$, $K\Sigma$ as well as vectormeson-production and nucleon resonances. This is the subject of the present paper.

2. The SAPHIR-detector

The SAPHIR-detector [1] is schematically shown in Fig. 1. The ELSA electron beam impinges on a radiator target in front of a magnet giving

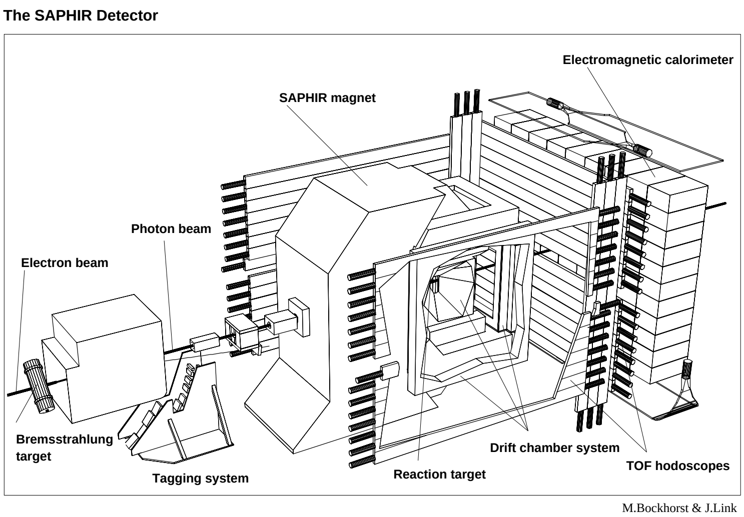

Fig. 1. The SAPHIR-Detector at ELSA

rise to a bremsstrahlungs beam of photons which are tagged with respect to their energy in a range of (0.3–0.95)*E_0. The target (liquid hydrogen or deuterium) is sitting in the gap of a large magnet and is fully enclosed by a drift chamber. Three plastic scintillator hodoscopes serve as trigger devices for charged particles as well as a time-of-flight (TOF) spectrometer. Additional planar drift chambers immediately in front of the TOF-hodoscope will support the track association and reconstruction and improve the momentum resolution. The detector system is thus capable of tracking multiparticle charged final states over the full solid angle. An electromagnetic calorimeter based on shower generation in brass converters and sampling of the ionisation of electrons and positrons in proportional gas chambers is prepared to provide some spatial and energy resolution for forward going photons.

3. Production of Kaon–Hyperon-pairs

Pion photoproduction is mediated through a set of s-channel resonances along with a strong background following Born production mechanisms. Contrary, on the grounds of available data the production of Kaons appears to be more uniform in the photon energy. The data on $\gamma p \rightarrow K^+\Lambda$ and $\gamma p \rightarrow K^+\Sigma^0$ presented here have been taken with the SAPHIR detector [1] using a trigger on 2 charged particles in the final state. They include the reanalysed data of [2], together with additional new data to improve the statistics [3].

Starting from 3 reconstructed tracks a $p\pi^-$ combination was preselected by requiring that the invariant mass of a track pair with one positive and one negative charge be different to the Λ mass by no more than 15 MeV. From these p and π^- tracks the secondary vertex of the Λ decay was determined whereafter the remaining (K^+) track was included to identify the primary vertex.

Fig. 2 shows the reconstructed delay time between the first and second vertex along with a fit to an exponential. The good agreement to the PDG-value proves the clean selection of Λ-Hyperons in the final state. The separation between the $K^+\Lambda$- and $K^+\Sigma^0$-channels was done by a kinematical fit. Fig. 3 shows the missing mass distributions obtained from the measured momenta for events passing this fit.

Fig. 4 shows the total cross section data for either reaction in the energy range between threshold and 2 GeV. For $\gamma p \rightarrow K^+\Lambda$ it shows a steep rise from threshold up to $E_\gamma \approx 1.1$ GeV. This photon energy corresponds to a total energy of 1.7 GeV which coincides with the masses of some N^* resonances ($S_{11}(1650)$, $P_{11}(1700)$, $P_{13}(1720)$) that are known to decay into $K^+\Lambda$ [10]. The decrease immediately behind the $K^+\Sigma^0$ threshold indicates a cusp due to the opening of this channel as has been anticipated in a coupled-

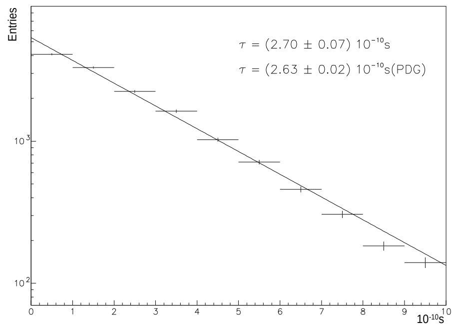

Fig. 2. Lifetime of reconstructed Λs

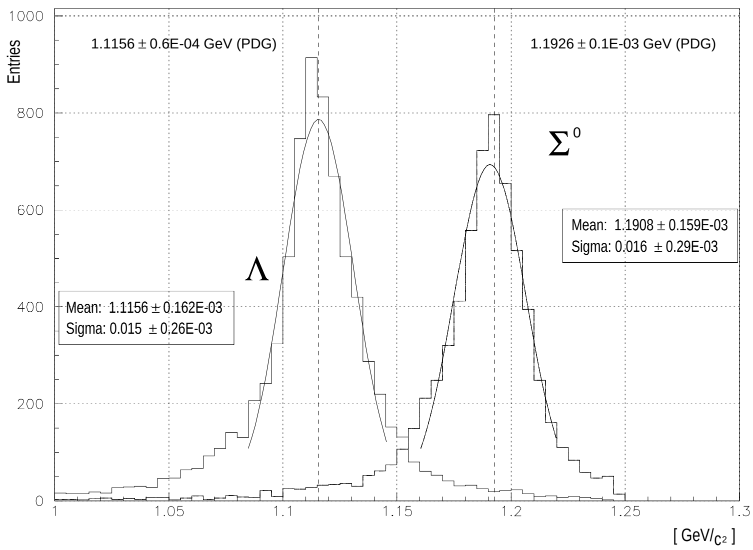

Fig. 3. Distributions of γK^+-missing mass for Λ and Σ^0 candidates.

channel analysis [4], constrained to s-wave amplitudes so far. Contrary, the total cross section of $\gamma p \rightarrow K^+\Sigma^0$ rises smoothly from threshold up to its peak at about 1.45 GeV which corresponds to a γp invariant mass of 1.9 GeV. At this energy a series of Δ states exists, but for none of those a decay fraction into $K^+\Sigma^0$ is experimentally known [10].

Differential cross sections (not shown here, see [11]) exhibit an energy dependent admixture of higher partial waves thus also suggesting resonance contributions. Contrary, the observed Λ and Σ^0 polarizations remain without significant variation with energy throughout the measured range keeping their forward/backward asymmetry and opposite sign relative to each other (see also [11]).

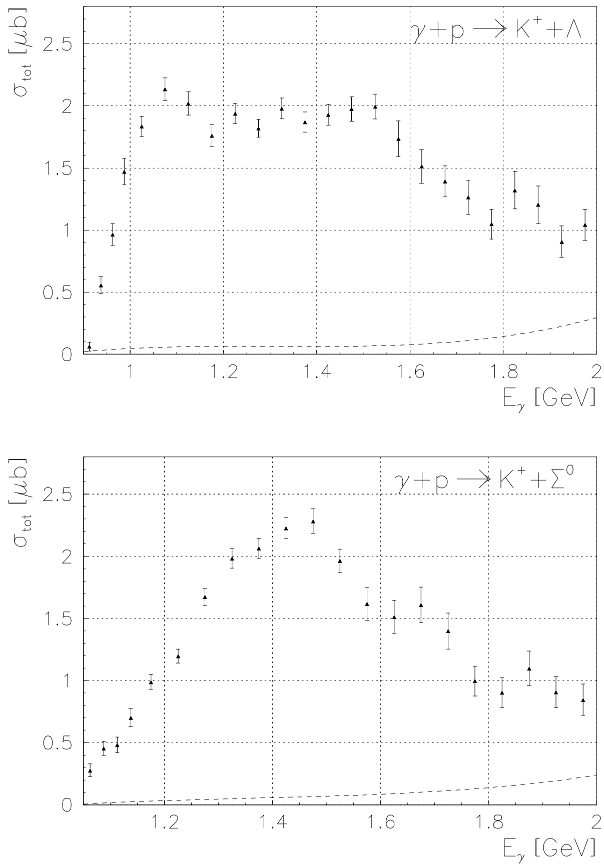

Fig. 4. Cross section $K^+\Lambda$ and $K^+\Sigma^0$. Total cross sections for $\gamma p \rightarrow K^+\Lambda$ (top) and $\gamma p \rightarrow K^+\Sigma^0$ (bottom) from [3]. The error bars denote the quadratic sum of the statistical combined with the systematic errors from the normalization by the photon flux.

$K^0\Sigma^+$-photoproduction proceeds through a different superposition of isospin amplitudes. This reaction is identified via the specific decays $K_S^0 \rightarrow \pi^+\pi^-$ and $\Sigma^+ \rightarrow n\pi^+, p\pi^0$. First results on total cross sections [5] are shown in Fig. 5 along with the only previously existing data point in the plotted energy range of [6].

η and η' mesons complete the basic nonet of pseudoscalar mesons. Contrary to Kaons, their flavour content is less clear. In the final state $p\pi^+\pi^-\eta$, $\eta \rightarrow \pi^+\pi^-\pi^0$ the worlds largest sample of photoproduced η'-particles has been reconstructed. The cross section rises steeply at threshold with a similarly steep fall off beyond 2.1 GeV hinting at a resonance production mechanism. The angular distribution exhibits a pronounced forward/backward

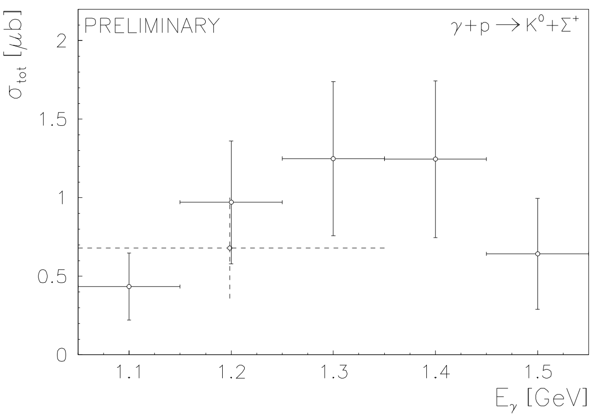

Fig. 5. Total cross section for $K^0\Sigma^+$-photoproduction from SAPHIR (circle) [5] and [6] (triangle). Error bars include statistical and systematic errors.

asymmetry depending on energy. A more complete account of this subject is given elsewhere in these proceedings [9].

4. Vector meson production

The photoproduction of the lightest vector mesons ρ, ω and ϕ at photon energies above 10 GeV is dominated by diffractive production with a small energy dependence and exponential fall off with respect to the four momentum transfer t to the proton. At energies below 3 GeV the production mechanisms are less clear. In a model of Friman and Soyeur [8] the production of ρ-mesons mainly proceeds through σ-exchange while for the ω-meson π-exchange is more relevant. Observables to decide on the production mechanisms like the energy dependence of the total cross section, the shape of the differential cross section $d\sigma/dt$ and the angular distribution of their decays can be measured at SAPHIR. Fig. 6 shows the distribution of the invariant mass of the $\pi^+\pi^-\pi^0$-final state where the π^0-four momentum has been reconstructed from the observed proton and charged pion tracks.

In Fig. 7 the t-distributions are plotted for different bins in E_γ and show a clear deviation from the exponential fall off at $-t \geq 0.5$ GeV^2 for $E_\gamma \simeq 1.5$ GeV. This could be the indication of an N^*-resonance at $\sqrt{s} \simeq$ 1.9 MeV as predicted by Isgur and Koniuk ($F_{15}(1955)$?) [7]. In the meantime more data have been taken to allow for an unbiased fit in terms of Legendre polynomials to check whether the peak is manifestly due to such a resonance.

The distribution of the polar angle of the ω decay in Fig. 8 shows a dominance of diffractive production for $E_\gamma > 2$ GeV which is seen as a $\sin^2$-shape in the helicity system. At lower energies the $\sin^2$-shape changes into

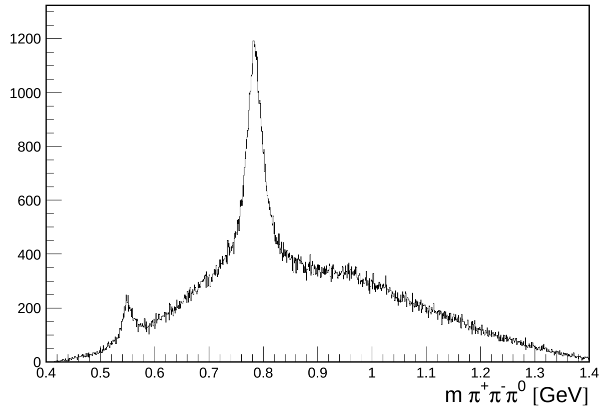

Fig. 6. Invariant mass distribution of $\pi^+\pi^-\pi^0$ showing an ω-peak at 782 MeV and an η-peak at 547 MeV. The photon energy ranges from 0.9 to 2.6 GeV.

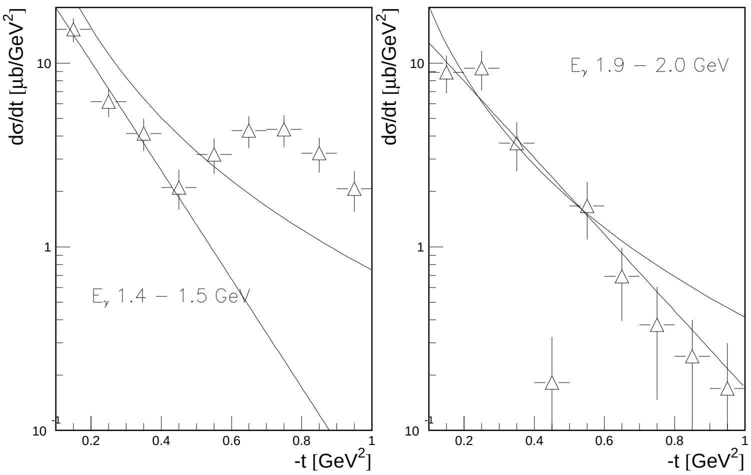

Fig. 7. t-distribution of the ω-mesons for different photon energies, together with an exponential fit (straight line) and a calculation without resonance contribution from Friman and Soyeur [8] (curved line).

a $\cos^2$-shape implying a dominant spin flip behaviour as it is expected for one pion exchange.

The ϕ is identified through its peak in the K^+K^- invariant mass distribution (not shown). Our data have been collected in a photon energy range between threshold and 500 MeV above and constitute the set closest to threshold. Apparently, the obtained t-distribution and, in particular, the decay angular distribution in the helicity system is still consistent with diffractive production (Fig. 9).

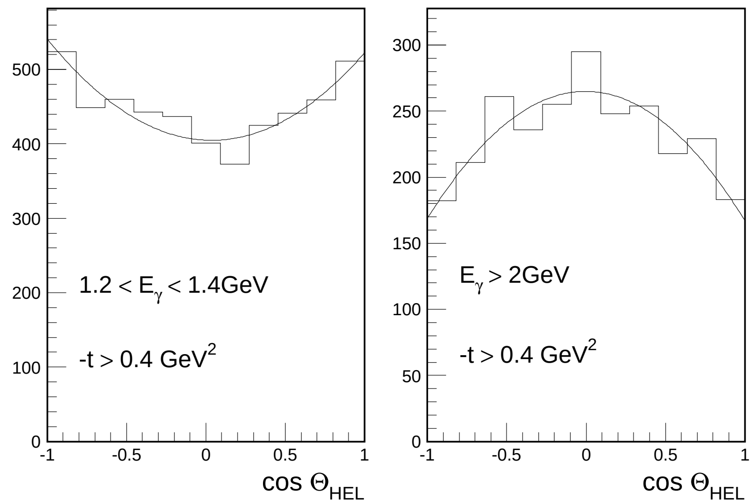

Fig. 8. Decay angular distribution of ω-mesons for different photon energies. The distribution is shown in the helicity system.

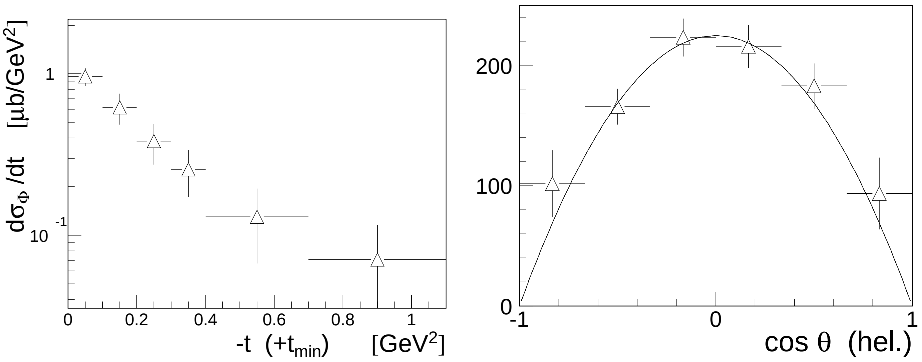

Fig. 9. t-distribution for ϕ-production (left) and decay angular distribution in the helicity system (right), $E_\gamma \leq 2.1$ GeV.

REFERENCES

[1] W.J. Schwille *et al.*, SAPHIR collaboration, *Nucl. Instrum. Methods* **A344**, 470 (1994).

[2] M. Bockhorst *et al.*, SAPHIR collaboration, *Z. Phys.* **C63**, 37 (1994); L. Lindemann, Ph.D. Thesis, Bonn preprint, BONN-IR-93-26 (1993); H. Jüngst, Ph.D. Thesis, Bonn preprint, BONN-IR-95-19 (1995).

[3] M.Q. Tran, doctorate thesis, Bonn preprint, BONN-IR-97-11(1997).

[4] N. Kaiser *et al.*, *Nucl. Phys.* **A612**, 297 (1997).

[5] S. Goers, doctorate thesis, University of Bonn, in preparation.

[6] Aachen-Berlin-Bonn-Hamburg-Heidelberg-München Collaboration, *Phys. Rev.* **188**, 2060 (1969).

[7] R. Koniuk, N. Isgur, *Phys. Rev.* **D12**, 1866 (1980); R. Koniuk, *Nucl. Phys.* **B195**, 452 (1982).

[8] B. Friman, M. Soyeur, LNS/PH/95-16CnRS(1995).

[9] R. Ploetzke, SAPHIR collaboration, Photoproduction of η' mesons at SAPHIR, *Acta Phys. Pol.* **B29**, 3349 (1998) and doctorate thesis, University Bonn, 1998.

[10] Particle Data Group, *Phys. Rev.* **D54** (1996).

[11] M.Q. Tran *et al.*, SAPHIR collaboration, Measurement of $\gamma p \to K^+\Lambda$ and $\gamma p \to K^+\Sigma^0$ at photon energies up to 2 GeV, submitted for publication to *Phys. Lett.* **B**.