Threshold Measurements at the Experiment COSY–11

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ABSTRACT

Threshold meson production will be studied within the framework of the COSY–11 installation, which is scheduled to be installed in autumn '94. The internal experiment uses a regular COSY dipole, following a cluster target, to separate reaction products from the beam and to analyze their momenta, thus allowing the observation of reaction products at small angles. The structure of resonances, especially in the 1 GeV/c^2 mass range, is to be derived from missing mass reconstructions with both outgoing protons in the predominantly studied $pp \to ppX$ reaction. The identification of mesons or mesonic systems X is supported by the detection of charged decay products. Due to vanishing relative momenta of the ejectiles in threshold production, final state interactions should be observable.

1. Experimental Setup

A three-dimensional display of the experimental setup [1] setup is shown in fig. 1, including particle tracks for the reaction $pp \to ppK^+K^-$ at a beam momentum

1 MeV/c above threshold ($p_{beam}^{thresh} = 3.302$ GeV/c). A hydrogen cluster target will be installed in front of a regular COSY dipole at the internal target location TP 3 of the cooler synchrotron COSY.

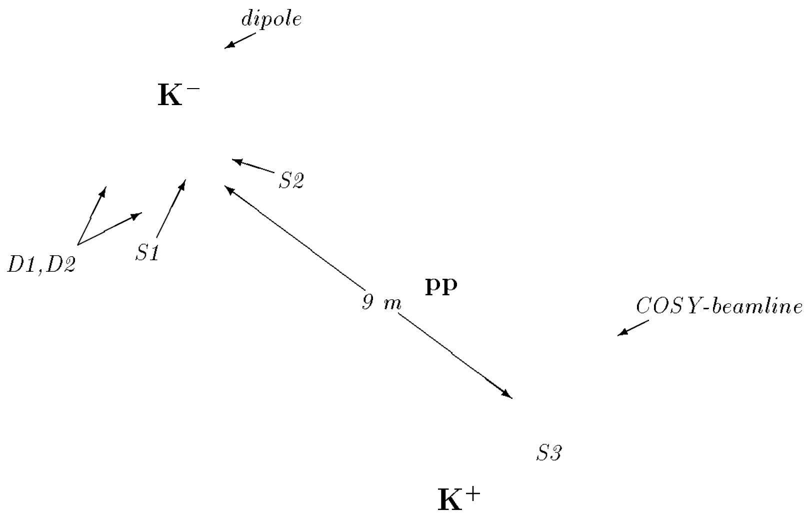

Figure 1: Three dimensional display of the COSY–11 installation.

Besides hydrogen with densities of up to $10^{14}\,\frac{\mathrm{atoms}}{\mathrm{cm}^3}$, the target allows the preparation of cluster beams of gases with higher atomic number (e.g. N_2, CO_2 or Ar), thus facilitating measurements with heavier targets. By mounting different skimmers an alteration of the target beam diameter between 1 and 10 mm is possible. Therefore experimental conditions can be varied between measuring with high resolution or with high luminosity.
In consequence of their smaller momenta, positively charged reaction products are separated from the circulating beam by the magnet and their trajectories are bent towards the centre of the storage ring, as indicated in fig 1. A vacuum chamber, mounted inside the dipole gap, links the COSY vacuum and the detection system, which operates in normal atmosphere, via specially developed exit foils: 30μm aluminium foil glued with carbon tissue of $\sim$ 300μm which reduces the straggling to $\sim$ 0.8mrad for typical proton momenta of 1 GeV/c.
Two stacks of six and eight drift chamber planes respectively (marked D1, D2 in fig. 1) are used to measure the direction of positively charged ejectiles with a position resolution of 200 μm in the horizontal and 500 μm (FWHM) in the vertical direction

in each plane. Similar drift chambers already operate successfully at the Big Karl magnetic spectrometer. Thus, including the knowledge of the dipole field, a complete determination of the particles' four–momentum vector is possible.
An arrangement of sixteen scintillation counters (S1, each 100 mm wide and 4 mm thick) is used to detect two separate protons in the exit channel. Closer proton tracks will be resolved by a second, movable scintillation counter setup (S2, with a width of 12 mm). Furthermore, the multiplicity in the scintillator elements is measured via signal amplitude.
An initial value for the momentum reconstruction of the two outgoing baryons in the $pp \to ppX$ reaction is derived from a time–of–flight measurement, started by the S1 scintillation counters. The stop signal will be provided at a distance of $\sim$9 m by a large area scintillation wall (S3), based on the principle of the Amadeus detector developed at the University of Bonn [2].
Negatively charged mesons, with their tracks being bent towards the inside of the dipole gap, will be detected by a silicon pad detector (with a grid of 5×20 mm^2) and an additional scintillation counter, both of them mounted inside the gap.
A further silicon pad detector will be employed for measuring recoil protons originating from pp elastic scattering, which is used to calibrate the detector system.
Monte Carlo calculations lead to a missing mass resolution of about 1 MeV/c^2 for a 1 GeV/c^2 meson or mesonic system X in the $pp \to ppX$ reaction. This high resolution measurement should contribute to solve physics cases as those exemplified in the following section.

2. Physical Motivation

The production of single mesons and mesonic states with and without strangeness, though of quite fundamental nature, offers a broad field of unsolved questions, especially in the mass range between 950 MeV/c^2 and 1020 MeV/c^2:
The $\Phi(1020)$ meson at the upper limit is believed to be of rather pure s$\overline{\text{s}}$ nature, whereas the structure of the η'(958) at the lower limit of this range is still being discussed. In the case of the scalar mesons $f_0(975)$ and $a_0(980)$ different interpretations are given:
Colour hyperfine interaction leads to a nonet of two–quark two–antiquark states, and both the f_0 and a_0 have been suggested to be described by this structure [3].
An analysis of data on $pp \to pp\pi\pi$ has shown two separate states in the f_0 region [4]. One signal, S(988), is interpreted to be of s$\overline{\text{s}}$ content, whereas S(993) couples to $\pi\pi$ and $K\overline{K}$ with similar strengths, thus indicating a possible glueball candidate.
A $K\overline{K}$ molecule like nature also has been favoured, e.g. in consequence of variational considerations of the two–quark two–antiquark structure in connection with a mapping onto coupled channel meson meson scattering [5], a result which is in agreement with calculations performed using the scattering length formalism [6]. This $K\overline{K}$ interpretation, however, is disfavoured concerning both the results of the ISR data

on central π production [7] or DM2 and MARKII results on $J/\Psi(1S) \rightarrow \Phi\pi\pi, \Phi K\overline{K}$ decays [8].
Finally, recent measurements of γp, $\pi^{\pm}p$ and $K^{\pm}p$ reactions at high momenta suggest a simple $s\bar{s}$ interpretation of the $f_0(975)$ [9].
With the possibility of not only the $f_0(975)$ concealing an overlay of close and narrow states still being discussed, COSY–11 should be able to contribute data of high precision and statistics to the understanding of mesons in the 1 GeV/c^2 mass region.
Threshold measurements on meson production necessarily imply vanishing relative momenta of the reaction products leading to extended interaction times. Consequently, meson–baryon, baryon–baryon and, with mesonic systems X of at least two mesons being produced, meson–meson final state interactions should be observable. Special emphasis should be put on the last-named combination, as two meson systems represent the simplest objects to study the interaction between hadrons.
Eventually turning towards the lower part of the $pp \rightarrow ppX$ production mass range, studies on $pp \rightarrow pp\pi^0$ at IUCF [10], starting at 5 MeV above threshold, revealed significant deviations from the theoretical description of a direct π^0 production. Due to the capability of measuring down to the threshold, data taken at COSY–11 could well supplement IUCF data towards scattering angles of 0°.
The COSY–11 installation might be used for other physics cases as well, and in fact it has been proposed to study the production of a possible πNN dibaryon resonance *d*' (at 2.065 GeV/c^2 with a width of $\sim$0.5 MeV/c^2) via $pp \rightarrow d'\pi^+ \rightarrow pp\pi^-\pi^+$ in an inclusive measurement at threshold using the presented detector arrangement [11].

References

1. W.Oelert, *Proceedings of the* 105^{th} *WE–Heraeus–Seminar, Bad Honnef*, Konferenzen des Forschungszentrums Jülich **12/93** (1993) 127.
2. G.Anton et al., *Nucl. Instr. & Meth.* **A 310** (1991) 631.
3. R.Jaffe, *Phys. Rev. D* **15** (1977) 267.
4. K.Au et al., *Phys. Lett.* **167 B** (1986) 229.
5. J.Weinstein, N.Isgur, *Phys. Rev. D* **41** (1990) 2236.
6. D.Lohse, J.W.Durso, K.Holinde, J.Speth, *Phys. Lett.* **234 B** (1990) 235.
7. D.Morgan, M.R.Pennington, *Phys. Lett.* **258 B** (1991) 444.
8. A.Falvard et al., *Phys. Rev. D* **38** (1988) 2706.
9. R.J.Apsimon et al., OMEGA Photon Collaboration, CERN–PPE/92–135.
10. H.O.Meyer et al., *Nucl. Phys. A* **539** (1992) 633.
11. H.Clement et al., *COSY Proposal No. 30*, IKP KFA Jülich.