CERN - EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Submitted to
Physics Letters

CERN/EP/PHYS 77-6
14 February 1977

INCLUSIVE ϕ PRODUCTION IN π^-p INTERACTIONS AT 16 GeV/c

Bari-Bonn-CERN-Daresbury-Glasgow-Liverpool-Milano-Vienna Collaboration

B. GHIDINI, F. NAVACH, A. PALANO and V. PICCIARELLI
Istituto di Fisica dell'Università and Sezione INFN, Bari, Italy.

J. BRÖRING, P. MÄTTIG, K. MÜLLER, E. PAUL and W. RÜHMER
Physikalisches Institut der Universität Bonn, Bonn, Germany.

B.R. FRENCH, D.H. MILLER^(*), W.A. MITAROFF, C. PALAZZI-CERRINA, R. STRUB,
A.S. THOMPSON and P.L. WOODWORTH
CERN, European Organization for Nuclear Research, Geneva, Switzerland.

M. EDWARDS
Daresbury Physics Laboratory, Daresbury.

T. ARMSTRONG^(**), J. GORDON, R. KUMAR, G.M. LEWIS, J. SLEEMAN, D.T. STEWART
and R.M. TURNBULL
University of Glasgow, Glasgow, U.K.

C. BEST, R. DONALD, D.N. EDWARDS and M.A. HOULDEN
Oliver Lodge Laboratory, University of Liverpool, Liverpool, U.K.

G. COSTA, L. LIOTTA, L. MANDELLI and S. PENSOTTI
Istituto di Fisica dell'Università and Sezione INFN, Milano, Italy.

H.D. LAMBACHER^(**)
Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften,
Vienna, Austria.

(*) Supported in part by the Energy Research and Development Administration of the U.S.A. The initial work on this experiment was accomplished while the author was a John Simon Guggenheim Fellow and a Visiting Scientist at CERN on sabbatical leave from Purdue University, West Lafayette, Indiana, U.S.A.

(**) Now at CERN.

ABSTRACT

Inclusive ϕ production is studied in π^-p collisions at 16 GeV/c. The ϕ cross section for Feynmann variable $x_\phi > 0.2$ is found to be $(15.5 \pm 3.6)\mu\text{b}$. This leads to an extrapolated cross section of $(29.9 \pm 7.0)\mu\text{b}$ for $x_\phi > 0.0$. Fitting the momentum transfer squared distribution of the ϕ to the form $e^{-bp_T^2}$ gives an average slope of $b = (2.4 \pm 0.3) (\text{GeV}/c)^{-2}$ for $x_\phi > 0.5$.

The discovery in hadronic collisions of leptons of high transverse momentum [1] and of the J/ψ [2] has stimulated interest in the study of vector meson production. While ρ , K^* and J/ψ have been studied inclusively [3-5] and ω semi-inclusively [6-7] with proton and pion beams at several energies, there are few comparable data for inclusive ϕ production. In pp interactions it is known that the inclusive ϕ total cross section rises by a factor 4 between 24 GeV/c [8] and 150 GeV/c [9]. In π Be interactions, the ϕ has been studied at 40 GeV/c [10] and 150 GeV/c [9] and upper limits of the ϕ total cross section have been obtained at medium energies [7, 11].

In this experiment we have observed ϕ production in the inclusive reaction

$$\pi^- p \rightarrow \phi + \text{anything}$$

$$\quad \quad \quad \downarrow$$

$$\quad \quad \quad K^+ K^-$$

at 16 GeV/c beam momentum with the ϕ produced at the Feynman variable $x_\phi \gtrsim 0.2$ ($x_\phi = p^*/p_{\text{max}}^*$ where p^* is the centre of mass longitudinal momentum of the ϕ).

The experiment was performed with the Omega spectrometer at the CERN PS. A general description of the apparatus has been given elsewhere [12] and is shown schematically in fig. 1. The large aperture 1.8 T magnet was filled with optical spark chambers arranged about a 30 cm liquid hydrogen target. These chambers were viewed by television cameras of the plumbicon type producing spark images which were digitized and recorded on-line onto magnetic tape.

The trigger was designed to select a forward $K^-/\bar{p}$ produced with any number of charged tracks at the primary vertex. The triggering track was identified by a large multi-cell Cerenkov counter filled with isobutane at atmospheric pressure and equipped with scintillator hodoscopes front and back. A hodoscope correlation with the Cerenkov counter in anti-coincidence selected events having a K^- with a momentum between 2.8 and 9.8 GeV/c or a $\bar{p}$ with momentum above 2.8 GeV/c.

The 16 GeV/c negative beam had a small (0.27%) fraction of K^- which was vetoed by Cerenkov counters during 75% of the run. For the remainder, it was not possible to distinguish between incident π^- and K^- and the

rate of ϕ production has been found to be 10% larger. On this basis, we estimate the total contribution to ϕ production in our data from incident K^- to be approximately 2,5%. The inclusive ϕ data has the same characteristics for both parts and has been combined in this analysis. During the five days of production run, a total of 1.2 million triggers was recorded. The effective flux was equivalent to 2.4 events/nb.

All events were processed by a modified version of the Omega off-line pattern-recognition and geometry program ROMEO [13]. For this analysis we use 540 000 events of all topologies having good triggering track reconstruction and a vertex in the hydrogen target.

The inclusive ϕ production has been found by taking mass combinations of the triggering track, assumed to be a K^- , with each positive track in the event, assumed to be a K^+ . The events have been weighted for geometric acceptance and kaon decays. Fig. 2 shows the K^+K^- mass spectrum for all events after ROMEO processing, weighted and unweighted. A clear ϕ signal is seen. Both spectra are well fitted by a Gaussian of 9.0 MeV FWHM and central value 1.0196 GeV together with a third order polynomial.

The differential cross sections for ϕ production have been found by dividing the data into suitable bins in each variable and then making a Gaussian plus background fit to the weighted K^+K^- mass spectrum. The Gaussian parameters have been fixed to the above values.

The geometrical acceptance of the K^- trigger from the ϕ is a function of x_ϕ , the transverse momentum (p_T) of the ϕ , and its decay angles in the Gottfried-Jackson frame. For ϕ 's produced with $x_\phi \gtrsim 0.75$ ($p^* \gtrsim 2$ GeV/c) the acceptance is non-zero for all variables. However, as x_ϕ decreases, zero acceptance regions are present in the Gottfried-Jackson plane and, for $x_\phi < 0.42$, also in the $x_\phi - p_T$ planes at low p_T .

The decay angular distribution for the ϕ for that part of the data, where there is no zero acceptance region, is consistent with isotropy. We have corrected the remainder of the data on the basis that the ϕ also decays isotropically at lower x_ϕ . This assumption is consistent with results for inclusive ρ^0 - ω and K^* production in pp interactions [6].

The p_T^2 distributions for two different x_ϕ intervals ($0.615 < x_\phi < 1$ and $0.5 < x_\phi < 0.615$) are shown in figs 3(a) and (b). Both distributions are well fitted by the exponential function $e^{-bp_T^2}$ with $b = (2.43 \pm 0.48)$ and $(2.38 \pm 0.34) \text{ (GeV/c)}^{-2}$ respectively. This value of b is comparable to those of other mesons at this energy [4]. The distributions are equally well fitted to an exponential in transverse energy e^{-cE_T} , ($E_T = \sqrt{p_T^2 + m_\phi^2}$) with $c = (5.79 \pm 1.10)$ and $(6.26 \pm 0.73) \text{ GeV}^{-1}$ respectively.

To obtain the $(d\sigma/dx_\phi)$ for ϕ production for $0.2 < x_\phi < 0.5$, which includes zero acceptance regions in the $x_\phi - p_T$ plane, we introduce the additional assumption that the slope b remains constant at $(2.4 \pm 0.3) \text{ (GeV/c)}^{-2}$. Fig. 4(a) shows the (dN/dx_ϕ) distribution for events weighted for the geometrical acceptance and decay losses together with the corresponding points corrected assuming isotropy and a constant slope b . The smaller errors indicated are statistical only while the larger errors include the uncertainty in the slope b .

The differential cross section $(d\sigma/dx_\phi)$ for ϕ production is shown in fig. 4(b) using the data of fig. 4(a) corrected for reconstruction losses, trigger inefficiencies and for the ϕ branching ratio. The integrated cross section for $x_\phi > 0.2$ is $(15.5 \pm 1.8) \mu\text{b}$ where the error is statistical only. Including normalisation error and errors due to the uncertainty in b described above results in a cross section of $(15.5 \pm 3.6) \mu\text{b}$ for $x_\phi > 0.2$. Fitting this $d\sigma/dx_\phi$ distribution to the form $(1 - |x_\phi|)^n$, we obtain a value of $n = (2.0 \pm 0.2)$. This yields an extrapolated cross section of $(29.9 \pm 7.0) \mu\text{b}$ for $x_\phi > 0.0$.

As a comparison, we include in fig. 4(b) data for backward ρ^0 production [14] also at 16 GeV/c scaled down by a factor 0.025. Backward ρ^0 production in $\pi^- p$ interactions at this energy is known to be predominantly central [14]. The two distributions have a similar shape. We obtain a ratio of ϕ to backward ρ^0 production of (0.028 ± 0.007) for $|x| > 0.2$. This compares to the ratio (0.045 ± 0.012) for the total cross sections $\sigma(pp \rightarrow \phi X)/\sigma(pp \rightarrow \rho^0 X)$ at 24 GeV/c [15] where the ρ^0 , and presumably also the ϕ , are centrally produced.

Our measurement of the ϕ cross section verifies the conclusion of several authors [16] that in medium energy pion or nucleon interactions the ϕ , in spite of its relatively large branching ratio to leptons, is of far less importance than ρ/ω as a contributor to direct lepton production.

ACKNOWLEDGEMENTS

We would like to thank Professor K. Böckmann for interesting discussions.

REFERENCES

- [1] L.M. Lederman, Physics Reports 26C (1976) 149-181.
- [2] J.J. Aubert et al., Phys. Rev. Letters 33 (1974) 1404.
J.E. Augustin et al., Phys. Rev. Letters 33 (1974) 1406.
- [3] K. Böckmann, Rapporteur's Talk at the Int. Conf. on High Energy Physics, Palermo, Sicily, June 1975 and Invited Talk at the Meeting on Multiparticle Production Processes and Inclusive Reactions at High Energies, Serpukov, November 1976 (BONN-HE-76-25). See also references in these two reports.
- [4] H. Bohr et al., Inclusive Yields and Transverse Spectra of the Mesons, CERN/EP/PHYS 76-30 Rev, to be submitted to Nucl. Physics B.
- [5] J.J. Aubert, IMS Symposium on Electron and Photon Interactions in the Resonance Region and on Related Topics, Tokyo, November 1975.
- [6] V. Blobel et al., Phys. Letters 48B (1974) 73.
- [7] J. Bartke et al., Eta and Omega Production in Medium Energy π^+p and K^+p Interactions, CERN/EP/PHYS 76-28 Rev, submitted to Nucl. Phys. B.
- [8] V. Blobel et al., Phys. Letters 59B (1975) 88.
- [9] K.J. Anderson et al., Phys. Rev. Letters 37 (1976) 799.
- [10] Yu.M. Antipov et al., Dimuon Production by 43 GeV/c Negative Particles, Tbilisi-Moscow preprint.
- [11] H.A. Gordon et al., Phys. Rev. Letters 34 (1975) 284.
- [12] O. Gildemeister, Int. Conf. on Instrumentation for High Energy Physics, Frascati, 1973.
- [13] F. Bourgeois, H. Grote and J.C. Lassalle, Pattern Recognition Methods for Omega and SFM Spark Chamber Experiments, CERN DD/DH/70-13.

H. Grote, M. Hansroul, J.C. Lassalle and P. Zanella, Identification of Digitized Particle Trajectories, Intern. Computing Symposium 1973 (North-Holland, 1974).
- [14] J. Bartke et al., Nucl. Phys. B107 (1976) 93.
- [15] K. Böckmann in ref. [3] using data from refs [6] and [8].
- [16] See, for example, K. Raychaudhuri and H. Weisberg, Phys. Rev. D13 (1976) 153.

FIGURE CAPTIONS

Fig. 1 Schematic layout for the 16 GeV/c π^-p experiment. The forward $K^-/\bar{p}$ trigger required:

(a) Either a hit in the scintillation counter (TS) around the target or at least two hits in the multiwire proportional chamber I in front of the target.

(b) A hit in MWPC.II.

(c) A hodoscope (H1/H2) correlation with the Cerenkov counter in anti-coincidence.

MWPC IV was not used in this analysis.

Fig. 2 Effective mass spectrum K^+K^- combinations for all events after ROMEO processing (lower distribution) together with the resulting spectrum after weighting for geometric acceptance and kaon decays (upper distribution). The triggering track is assumed to be a K^- and each positive track taken to be a K^+ in turn. The curves are Gaussians of 9.0 MeV FWHM and central value 1.0196 GeV together with third order polynomials.

Fig. 3 Distributions of transverse momentum squared for the ϕ : (a) for $x_\phi > 0.615$ with a fit to the first five data points only and (b) for $0.5 < x_\phi < 0.615$ after Monte-Carlo corrections described in the text. The fit is to all seven data points.

Fig. 4 (a) (dN/dx_ϕ) distribution for ϕ events. The lower points are from Gaussian plus background fits to the data weighted for geometrical acceptance and decay losses. The upper points are the resulting distribution after Monte-Carlo corrections. The smaller errors on the upper points are statistical only while the larger errors include the uncertainty in the slope b.

(b) Differential cross section $(d\sigma/dx_\phi)$ for forward ϕ production at 16 GeV/c (this experiment) compared to data for backward ρ^0 production in π^-p interactions at the same energy [14]. The curve is a fit to the ϕ data of the form $(1 - |x_\phi|)^n$ where $n = (2.0 \pm 0.2)$. The errors are statistical only.

Fig 1

FIG 2

FIG 3a

Fig 4a

Fig 46