Hunting ϕ Mesons in C + C Collisions at 2 AGeV

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The HADES spectrometer at SIS/GSI, initially designed for investigating the production of vector mesons via their leptonic decay into e^+e^- pairs, is able to detect hadronic probes, too. Here, we study the channel $\phi \to K^+K^-$ in collisions of C + C at a beam energy of $E_{beam} = 2$ AGeV [1].

First, we have to find out whether the number of expected ϕ mesons in the data sample of about $N = 10^8$ events is large enough to justify such an experimental analysis. The number of ϕ mesons decaying into charged kaons can be calculated as $N_{\phi\to K^+K^-} = N_{ev}\cdot\epsilon_{trig}\cdot(P_{\phi\to K^+K^-}/P_{K^-})\cdot(\sigma_{K^-}/\sigma_{tot})\cdot\epsilon_{acc}(\Delta p_K, \Delta\theta_K, n_{sec}, E_{beam}, T_\phi)$. $\epsilon_{trig} \simeq 2.8$ is the 1st level trigger vs. minimum bias enhancement as estimated in ref. [2] aimed at K^+ production. The number of anti kaons arising from ϕ decay, $P_{\phi\to K^+K^-}/P_{K^-} \geq 0.22$, is taken from the system Ni + Ni at 1.9 AGeV investigated by the FOPI collaboration [3]. The K^- production probability, i.e. the ratio of K^- and total geometrical cross sections, $\sigma_{K^-}/\sigma_{tot} = 2\cdot 10^{-4}$, was measured by the KaoS collaboration [4]. Finally, the detector acceptance (including kaon decay) of the decay channel $\phi \to K^+K^-$ is estimated applying Monte Carlo (MC) simulations. For the daughter kaons a momentum range of $\Delta p_K = (100 - 800)$ MeV/c is assumed. Only the outer part of the time-of-flight detector (TOF system) which exhibits much better time resolution than the inner part (TOFino) will be used in the analysis, hence $\Delta\theta_K = 45^o - 85^o$ was set in MC. Since only three out of six sectors could be used for the present analysis, sectors $n_{sec} = 0, 2, 3$ are activated in MC. The essential parameter of the midrapidity fireball modelled in MC is the inverse slope parameter T_ϕ of the Boltzmann-like c.m. kinetic energy distribution. So far, there is no published data on the momentum-space distribution of ϕ mesons in heavy-ion collisions at SIS energies. Thus, this parameter was chosen to be equal to the corresponding proton one, $T_\phi = T_p = 120$ MeV [5], which yields an acceptance factor of $\epsilon_{acc} = 2.5\cdot 10^{-3}$. Having all these numbers at hand, in the above event sample we expect to see $N_{\phi\to K^+K^-} \geq 30$ ϕ mesons via their charged-kaon decay.

For the analysis of the experimental data, "kaon-pair-candidate" N-tuples are filled with the only condition of a ± 150 MeV mass window around the nominal kaon mass, roughly corresponding to a 3σ cut at 10% mass resolution. (For masses we set $c = 1$.) Scanning these N-tuples, the same phase-space-relevant cuts as used in MC, i.e. i) TOF system only, ii) sectors 0, 2, 3, and iii) $100 < p_K/(\mathrm{MeV/c}) < 800$, are applied. To enhance the ratio of a possible signal over background, also quality cuts are investigated and optimized, i.e. iv) upper χ^2 limits on the inner ($\chi^2 < 15$) and outer ($\chi^2 < 30\,(17)$ for sectors 0, 3 (2)) track segments fitted to the hit positions measured with multiwire drift chambers (MDCs) in front and behind the HADES magnet, and v) MDC-TOF matching, $\Delta x < 40$ mm and $\Delta y < 10$ mm. About 400 kaon-pair candidates passed these conditions. Finally, kinematically suppressed opening angles ($> 120^o$) are rejected. Figure 1 displays the corresponding invariant mass distribution. Indeed, a peak is visible at the position of the nominal ϕ mass. Integrating the peak over ± 8 MeV, an excess yield of about 22 entries with a significance of 2.8 is observed. Note, however, that the deduced width is a factor of $2 \div 3$ smaller than expected from MC simulations.

An order of magnitude more ϕ's is expected for the system Ar + KCl at 1.8 AGeV, due to a larger data sample and full azimuthal coverage of the spectrometer with at least three MDCs. This system is presently prepared for data-summary-tape production.

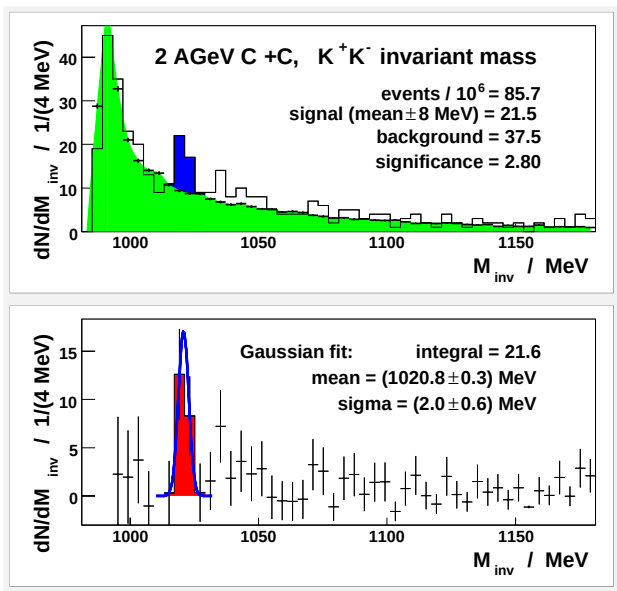

Fig. 1 *Upper panel: The invariant mass distribution of K^+K^- pair candidates (histogram). The light hatched (green) distribution gives the (renormalized at large invariant masses) corresponding uncorrelated background. The dark (blue) histogram is the potential signal within a 8 MeV wide mass window around the peak center. Lower panel: The difference of both distributions. The full line is a Gaussian fit to the yield excess at masses of 1010 MeV - 1030 MeV.*

[1] R. Kotte, HADES collab. meeting, GSI, Oct 2006
[2] A. Sadovsky, Ph.D. thesis, TU Dresden (2007)
[3] A. Mangiarotti et al., Nucl. Phys. A 714 (2003) 89
[4] F. Laue et al., Phys. Ref. Lett. 82 (1999) 1640
[5] P. Tlusty, Proc. XLII Wintermeeting on Nuclear Physics, Bormio 2004, Vol. 120 (2005) 171