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Dimuon production in p-A and In-In collisions

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Abstract. The NA60 experiment studies open charm and prompt dimuon production in proton-nucleus and nucleus-nucleus collisions at the CERN SPS. From June 2002 to November 2004 we collected data on dimuon production from proton-nucleus and Indium-Indium collisions. These data samples allow us to study low mass dimuon production (resonances and continuum), J/ψ suppression and open-charm production. We will also search for thermal dileptons, through the yield of "intermediate mass dimuons". In this paper we briefly overview some of the results obtained up to now, after shortly describing the detector.

Since twenty years many experiments studied proton-nucleus and nucleus-nucleus interations at high energies with the aim of finding signs of a transition from normal hadronic matter to a deconfined state composed of free quarks and gluons [1]. The existence of such a state, known as Quark-Gluon Plasma (QGP), is predicted by QCD, the theory of strong interactions [2]. However, high-energy central nucleus-nucleus collisions are very complex systems to study, and the hot and dense medium they produce is affected both by initial and final state effects. The early stages of the collision are expected to be dominated by hard QCD interactions among the deconfined partons. Hard and electromagnetic probes play a fundamental role in the understanding of the formed state since they are produced in the earliest stages of the interaction, while the soft hadronic physics is determined by the hadronization stage.

The suppression of J/ψ production was predicted as a signature of the deconfinement

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transition [3] and existing results clearly indicate that the produced medium undergoes a major change as the number of nucleons intervenient in the collisions is increased [4]. However, the variable which governs this behaviour is not known unambiguously and, thus, the exact mechanism responsible for the suppression is as yet not clear. Furthermore, a significant fraction ($\sim 30\,\%$) of the produced J/ψ's come from χ_c decays and, therefore, a proper understanding of the J/ψ suppression mechanism requires studying the production or suppression of the χ_c. Up to now, such experimental information is missing.

Building on previous studies by NA38 [5] and HELIOS-3 [6], NA50 has also shown [7] a significant enhancement of intermediate mass dimuons in heavy-ion collisions, a result which might be a manifestation of thermal dilepton production [8]. It is very important to perform a direct measurement in order to clarify this observation. D production should also be measured, to complement the J/ψ picture.

The deconfinement transition must be accompanied by the restoration of chiral symmetry. These two transitions could, in principle, occur for different values of temperature and/or baryon potential. However, lattice QCD results for zero baryon chemical potential have shown that both transitions happen at the same temperature [9] and that they are related to one another. CERES results [10] have shown that the low mass dilepton spectrum is strongly modified when going from p-Be collisions at 450 GeV to S-Au at 200 GeV or Pb-Au at 158 GeV. This observation has been attributed to a decrease of the ρ mass when the produced medium approaches chiral symmetry restoration [11] and to a broadening of the resonance due to in-medium interactions [12]. These results are very interesting and deserve to be studied in detail with improved experimental capabilities, in terms of statistics, mass resolution, etc.

NA60 was built to provide answers to the questions just mentioned. In order to fulfill these goals, NA60 complemented the muon spectrometer previously used by NA50 with a new target area, comprising a silicon beam tracker and silicon tracking vertex telescope, placed inside a 2.5 T dipole field. The beam tracker, operated at 130 K for increased radiation tolerance, is composed of two stations of back-to-back micro-strip sensors with 24 strips of 50 μm pitch, giving a 20 μm resolution on the transverse coordinates of the interaction point, at the target. During the 2003 Indium run the silicon tracking telescope was made of pixel detectors based on the ALICE1LHCb readout chips. The 2002 proton data sample was collected using micro-strip detectors, while in 2004 we complemented the previously used detectors with two new planes of ATLAS pixels, operated at 40 MHz, and some new strip planes.

The improvement achieved by the inclusion of the vertex telescope can be seen in Fig. 1, where the dimuon invariant mass spectrum for the p-A run in 2002 is represented before and after matching the muon spectrometer tracks with the corresponding vertex telescope tracks. During this running period, a 400 GeV proton beam (at intensities around $1\text{–}3{\cdot}10^8$ protons/burst) interacted on Be, In and Pb targets, yielding 600 000 dimuons. After full reconstruction, vertex selection, phase space cuts and matching, 15 000 oposite-sign dimuons were kept. The mass resolution at the ϕ peak is $\sim$30 MeV. The z-vertex resolution is $\sim$600–900 μm, depending on the target position, which allows a clear separation of the individual targets, as shown in Fig. 1-right. The use of the different target materials simultaneously present in the target system allows the extraction of the nuclear dependence of the particle production cross-sections, using a fit of the form $\sigma_{pA} = \sigma_0 A^{\alpha}$. For the ω and ϕ mesons, in particular, we obtain $\alpha^{\omega} = 0.82 \pm 0.01$ and $\alpha^{\phi} = 0.91 \pm 0.02$ (statistical errors only), for the rapidity range $3.3 < y_{lab} < 4.2$ [13].

In the 2003 In-In run we collected $\sim 2.3 \times 10^8$ dimuon trigers with a beam intensity of $\sim 5{\times}10^7$ ions per 5-second burst. The resolution on the determination of the z coordinate of the interaction vertex is ~ 200 μm. This allows a precise selection of events having the primary vertex in one of the seven targets. After matching and combinatorial background subtraction we get the signal dimuon spectrum shown in Fig. 2 where, apart from the ϕ and ω peaks, the $\eta \rightarrow \mu\mu$ channel is also visible, for the first time in heavy ion collisions. The mass resolution at the ϕ

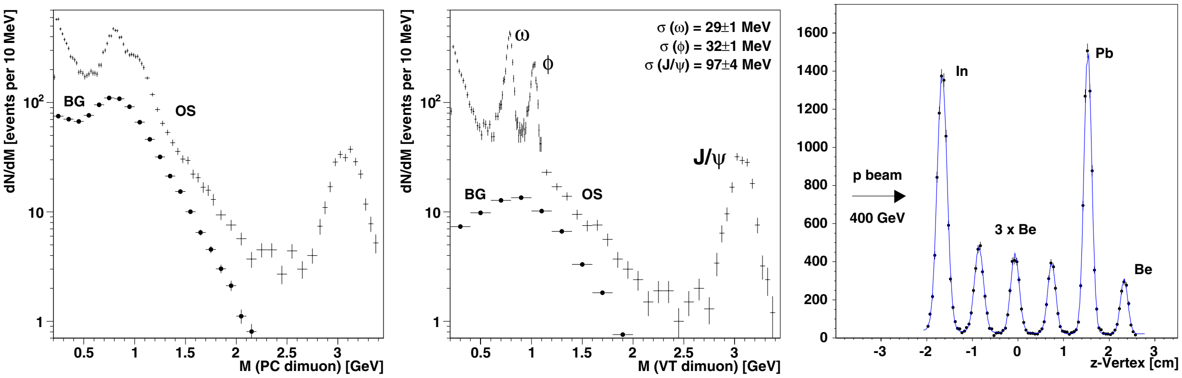

Figure 1. Opposite-sign (OS) and combinatorial background (BG) dimuon mass distributions before (left) and after (centre) muon track matching, integrating events from all the targets seen on the z-vertex distribution (right).

is 23 MeV. The ϕ transverse momentum distribution was studied by selecting signal dimuons in a narrow window around the ϕ mass. The background under the ϕ peak was evaluated and subtracted using two side windows symmetrically located around the peak. The probability that the detector accepts a ϕ meson with a certain p_{T} value depends on the corresponding dimuon rapidity. Therefore, we calculated the ϕ acceptance and pixel efficiency maps in y versus p_{T} cells, and made a 2-dimensional correction of the measured data. The analysis was done in four centrality bins [14]. The corrected 2-dimensional distributions were then projected on the p_{T} axis and fitted to the expression $1/p_{\mathrm{T}}\,\mathrm{d}N/\mathrm{d}p_{\mathrm{T}} \sim \exp(-m_{\mathrm{T}}/T)$, in order to determine the inverse slope parameter T. The result is shown in Fig. 2-right where the measured T is plotted as a function of the number of participants. There is a clear increase of the inverse slope parameter between peripheral and central Indium-Indium collisions, from ~ 218 to ~ 255 MeV. Integrating over all collision centralities we obtain $T = 252 \pm 3$ MeV. In order to check the stability of the results, we have changed the position and width of the side bins used to subtract the background. The results are quite insensitive to such changes. Also the acceptance correction plays a minor

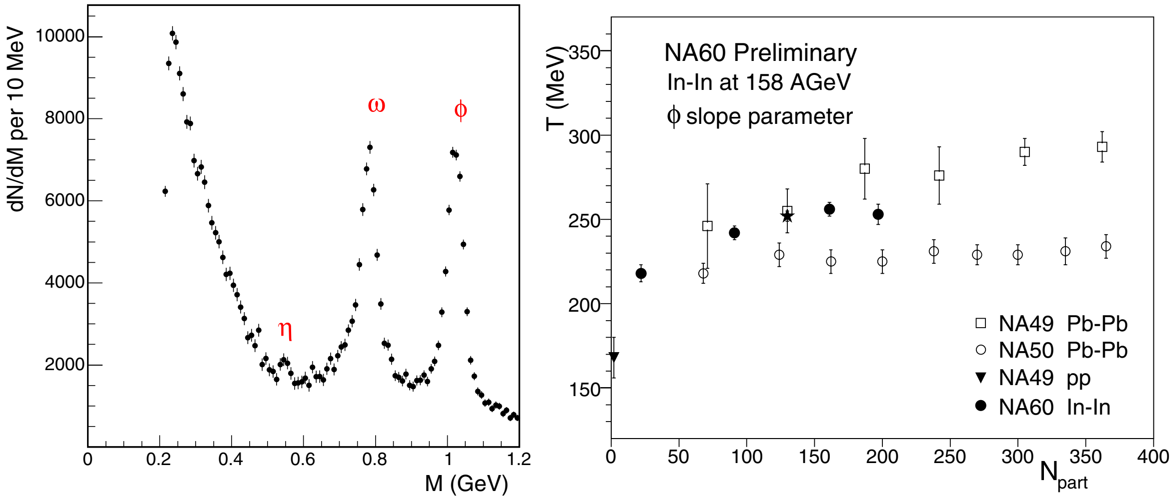

Figure 2. Left: Dimuon mass spectrum after matching and background subtraction. Right: ϕ inverse slope parameter, T, as a function of the number of participants.

role since, at the ϕ mass, it does not change by more than a factor of 2 over the full p_T range.

Using the information from the vertex telescope we are able to separate prompt and displaced muon pairs [15]. The dimuon mass distributions for the displaced and prompt selections are shown in Fig. 3-left. Their ratio, Fig. 3-right, shows clear minima in the regions dominated by the ω, ϕ and J/ψ resonances. The displaced sample dominates in the mass region where open charm is expected to contribute the most.

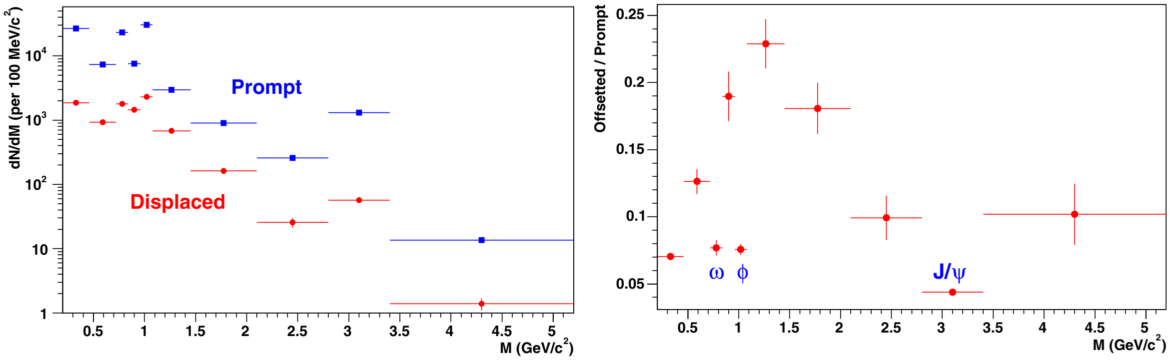

Figure 3. Mass spectra corresponding to "displaced" and "prompt" selections (left) and their ratio (right).

The results presented in this paper will be improved and extended in the near future, thanks to the much higher statistics collected by NA60 in 2004, with 400 GeV protons incident on an expanded target system. Our efforts are also concentrated on the determination and subtraction of the fake matches component, so that we can also address the physics of the dilepton continuum.

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