J/ψ suppression in indium-indium collisions at SPS energies

C. Lourenço, R. Averbeck, K. Banicz, J. Castor, B. Chaurand, C. Cicalo, A. Colla, P. Cortese, S. Damjanovic, A. David, et al.

▶ To cite this version:

C. Lourenço, R. Averbeck, K. Banicz, J. Castor, B. Chaurand, et al.. J/ψ suppression in indium-indium collisions at SPS energies. International Europhysics Conference on High Energy Physics HEP2005, Jul 2005, Lisboa, Portugal. pp.PoS(HEP2005)133. in2p3-00025242

HAL Id: in2p3-00025242

https://hal.in2p3.fr/in2p3-00025242

Submitted on 9 Mar 2007

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

PROCEEDINGS OF SCIENCE

J/ψ suppression in indium-indium collisions at SPS energies

Carlos Lourenço* **for the NA60 Collaboration**
CERN-PH, Geneva, Switzerland
E-mail: Carlos.Lourenco@cern.ch

R. Arnaldi [10], R. Averbeck [9], K. Banicz [2,4], J. Castor [3], B. Chaurand [7], C. Cicalò [1], A. Colla [10], P. Cortese [10], S. Damjanovic [4], A. David [2,5], A. De Falco [1], A. Devaux [3], A. Drees [9], L. Ducroux [6], H. En'yo [8], A. Ferretti [10], M. Floris [1], P. Force [3], A. Förster [2], N. Guettet [2,3], A. Guichard [6], H. Gulkanian [11], J. Heuser [8], M. Keil [2,5], L. Kluberg [2,7], J. Lozano [5], F. Manso [3], A. Masoni [1], P. Martins [2,5], A. Neves [5], H. Ohnishi [8], C. Oppedisano [10], P. Parracho [2], P. Pillot [6], G. Puddu [1], E. Radermacher [2], P. Ramalhete [2], P. Rosinsky [2], E. Scomparin [10], J. Seixas [2,5], S. Serci [1], R. Shahoyan [2,5], P. Sonderegger [5], H.J. Specht [4], R. Tieulent [6], G. Usai [1], R. Veenhof [2,5], H.K. Wöhri [2,5]

[1]*Univ. di Cagliari and INFN, Cagliari, Italy;* [2]*CERN, Geneva, Switzerland;* [3]*LPC, Univ. Blaise Pascal and CNRS-IN2P3, Clermont-Ferrand, France;* [4]*Univ. Heidelberg, Heidelberg, Germany;* [5]*Instituto Superior Técnico, Lisbon, Portugal;* [6]*IPN-Lyon, Univ. Claude Bernard Lyon-I and CNRS-IN2P3, Lyon, France;* [7]*LLR, Ecole Polytechnique and CNRS-IN2P3, Palaiseau, France;* [8]*RIKEN, Wako, Saitama, Japan;* [9]*SUNY Stony Brook, New York, USA;* [10]*Univ. di Torino and INFN, Italy;* [11]*YerPhI, Yerevan, Armenia*

In 2003, NA60 collected data on dimuon production in indium-indium collisions at 158 GeV per incident nucleon, to study several anomalies previously observed in high-energy heavy-ion collisions at the CERN SPS. Among these anomalies stands the observation, by NA50, that the production yield of J/ψ mesons is suppressed in central Pb-Pb collisions beyond the normal nuclear absorption defined by proton-nucleus data. This behaviour was predicted to occur if the matter produced in these extreme collisions goes through a phase of deconfined partonic matter, where the charmonium states would be dissolved either due to the screening of their binding potential when the medium temperature exceeds certain critical thresholds (thermal transition, QGP) or when the density of interacting partons exceeds certain thresholds (geometrical transition, percolation). Thanks to its exceptionally good vertexing capabilities, NA60 is able to accurately study the centrality dependence of J/ψ production without using the Drell-Yan sample as reference. Our data shows that the J/ψ is anomalously suppressed for In-In collisions with more than ~ 90 participant nucleons. The comparison with three theoretical *predictions* shows that none of them properly describes the observed suppression pattern.

International Europhysics Conference on High Energy Physics
July 21st – 27th 2005
Lisboa, Portugal

*Speaker.

© Copyright owned by the author(s) under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike Licence.

PoS(HEP2005)133

J/ψ suppression is generally considered one of the most direct signatures of quark-gluon plasma formation [1] and has been studied since 1986 at the CERN SPS, by the NA38 and NA50 experiments [2], through several colliding systems, including p-A, S-U and Pb-Pb. The study of the centrality suppression pattern observed in Pb-Pb collisions indicates that, above a certain centrality threshold, the J/ψ yield is significantly lower than expected from the "nuclear absorption" curve, derived from p-A data. These observations, while being very interesting, left some questions unanswered. Most importantly, it is not clear what exactly is the physics mechanism responsible for the observed suppression pattern. Since there is no anomaly between the p-A and S-U measurements (unlike what happens in the case of the ψ' state), it seems that the mechanism leading to the suppression of the J/ψ yield requires relatively high energy densities, only reached in Pb-Pb collisions above a certain centrality. Having similar suppression patterns in other collision systems, such as In-In, or at other energies, should allow us to determine the physics ("scaling") variable driving the J/ψ suppression (energy density, density of participants, etc.) and, thereby, identify the physics mechanism behind the observations. This is the reason why NA60 chose the In-In collision system, at 158 GeV per incident nucleon, to collect dimuon data in year 2003.

The NA60 experimental apparatus complements the muon spectrometer and the zero-degree calorimeter (ZDC) inherited from NA50 with a completely new target region, composed of a beam tracker and a vertex tracker. The beam tracker is made of two stations of silicon micro-strips, operated at cryogenic temperatures for improved radiation hardness. The vertex tracker, placed in a 2.5 T dipole magnet, is composed of 12 tracking stations, made of newly developed radiation-tolerant silicon pixel detector assemblies, with almost 800 000 pixel cells of 50×425 μm^2 area. Thanks to the vertex tracker, NA60 could reconstruct the hundreds of charged particles produced in a high-energy nuclear collision and select, among them, those that match the two muons seen in the muon spectrometer. Contrary to all previous heavy-ion experiments, NA60 is therefore able to measure the properties of the dimuons at their production point, overcoming the effects of the multiple scattering and energy loss fluctuations induced on the muons by the crossing of the long hadron absorber. Besides the obvious improvement in dimuon mass resolution (from ~ 105 to ~ 70 MeV at the J/ψ), this matching procedure [3] allows us to clearly identify in which of the seven 1.5 mm thick targets (placed in vacuum) the high mass dimuons were produced, even in the most peripheral collisions. The combinatorial background from π and K decays under the J/ψ peak is reduced in the matching step from ~ 3 % to ~ 1 %. However, the matching rate of ~ 70 % (per dimuon) reduces the available statistics. The J/ψ yield was extracted from dimuons in the phase space window $0 < y_{\rm cms} < 1$ and $-0.5 < \cos\theta_{\rm CS} < 0.5$, where $\theta_{\rm CS}$ is the polar decay angle of the muons in the Collins-Soper reference frame. After a detailed event selection procedure, to ensure the quality of the data kept in the final analysis event sample, we are left with $\sim 43\,000$ J/ψ and ~ 300 Drell-Yan events with mass above 4.2 GeV/c^2, before requiring dimuon matching.

Two different analyses have been performed to investigate how the J/ψ production in indium-indium collisions depends on the collision centrality, estimated through the energy released in the ZDC by the projectile nucleons which did not interact in the target. The "standard analysis" uses the ratio between the J/ψ and the Drell-Yan yields, extracted for each centrality bin by fitting the opposite-sign dimuon mass spectrum to the superposition of expected contributions: the J/ψ and the ψ' resonances sitting on a continuum composed of DY dimuons and muon pairs from the simultaneous semi-muonic decay of D and $\overline{\rm D}$ mesons. These "signal" contributions are

PoS(HEP2005)133

evaluated through Monte Carlo simulation, using Pythia as event generator, with "GRV94LO" parton distribution functions. Besides giving the mass shapes of the processes contributing to the J/ψ mass region, these simulations also provide the J/ψ and DY acceptances, $A_{J/\psi} = 12.4\,\%$ and $A_{DY(2.9-4.5)} = 13.2\,\%$ for the data collected with a current of 6500 A in the toroidal magnet of the muon spectrometer. The combinatorial background from π and K decays is estimated from the measured like-sign pairs. Drell-Yan is an interesting reference since it is a hard process, its production cross section scales with the number of binary collisions, and does not suffer final state effects. However, the use of these rare high-mass DY events limits the number of feasible centrality bins. Besides the lack of statistics, the use of DY as a reference introduces extra sources of systematical uncertainties, related to the way the DY yield is determined (sensitive to isospin corrections, to the set of parton densities used in the calculations, to the exact mass window where the yield is integrated, to the line shape of the J/ψ, etc). This method was used by NA50 because the J/ψ / DY ratio benefits from the cancelation of the target identification efficiency, which was somewhat uncertain and depended on the centrality of the collision. The results of this first analysis, limited to only three centrality bins, are compared to previous results in Fig. 1(a).

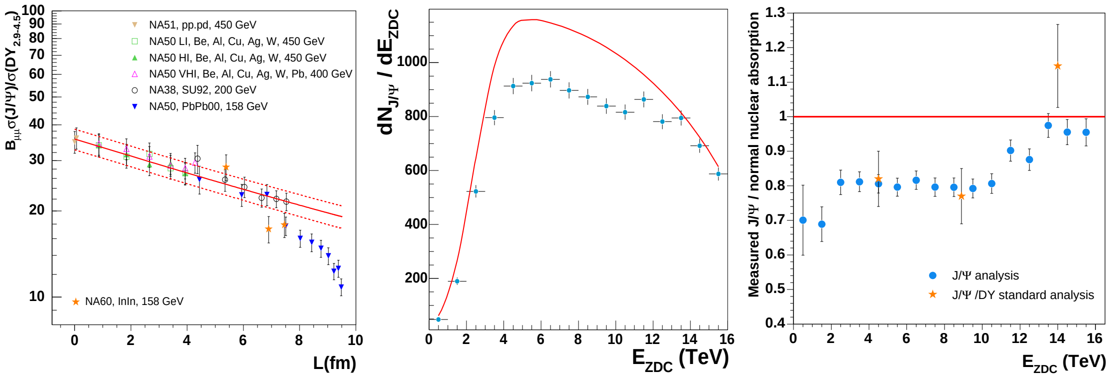

Figure 1: (a) J/ψ / DY standard analysis vs. L, compared with the NA50 and NA38 results; (b) measured J/ψ compared to the normal nuclear absorption curve, vs. $E_{\rm ZDC}$; (c) ratio between the J/ψ points and the absorption curve (stars: standard analysis).

The second analysis procedure directly compares the shape of the distribution of measured J/ψ events with the function describing the centrality dependence of the normal nuclear absorption, obtained within the Glauber model. Since the statistics in this analysis is no longer limited by the DY yield, the muon track matching can be used to have the best possible data quality. Since this shape analysis has no intrinsic absolute normalization, we use the standard analysis values as norm. The direct J/ψ centrality dependence as a function of $E_{\rm ZDC}$ is shown in Fig. 1, together with the expected absorption curve (b), and divided by it (c). This method provides a much more detailed centrality dependence of the J/ψ suppression: the anomalous suppression starts at ~ 12 TeV (corresponding to $N_{\rm part} \sim 90$), followed by a flat survival probability in the more central collisions.

The J/ψ survival probability pattern measured in In-In collisions is compared with the results previously obtained by the NA38 and NA50 experiments in Fig. 2, as a function of three centrality variables: L, $N_{\rm part}$ and the Bjorken energy density, estimated using the event generator VENUS. These variables were obtained from $E_{\rm ZDC}$ using the Glauber model and taking into account the detector resolution. We confirm that L, a variable related to the *normal* nuclear absorption, is

PoS(HEP2005)133

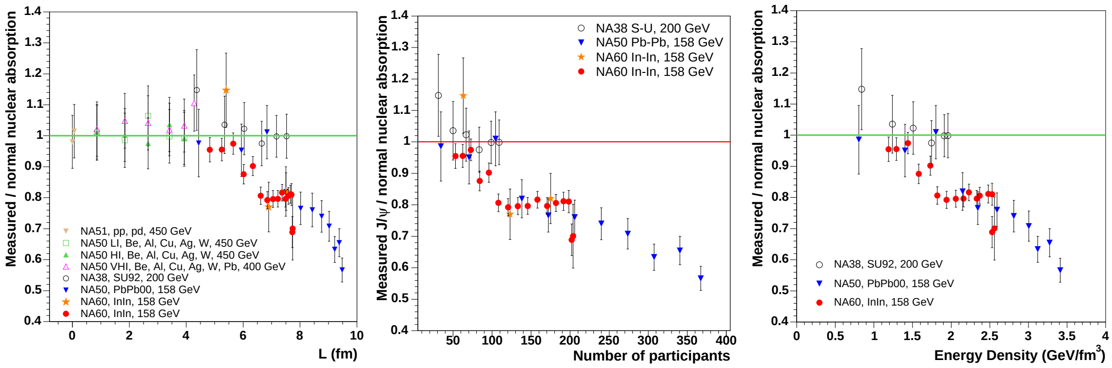

Figure 2: J/ψ survival probability as a function of (a) L, (b) N_{part} and (c) energy density.

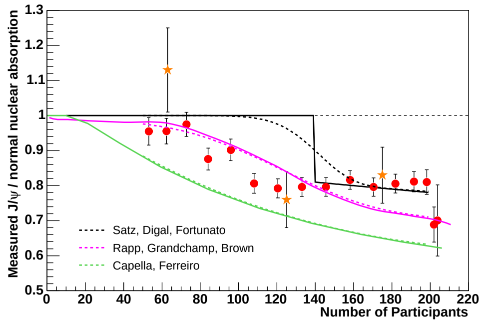

Figure 3: Comparison between the theoretical predictions and the measured J/ψ suppression pattern. The dashed curves include the smearing due to the ZDC experimental resolution.

not a good scaling variable between the S-U, Pb-Pb and In-In colliding systems. The comparison between the In-In and Pb-Pb suppression patterns as a function of the energy density, in particular, would significantly gain from Pb-Pb data points with smaller error bars.

The good quality of the Indium data allows a quantitative comparison with the available theoretical *predictions*. These models predict a J/ψ suppression based on the nuclear absorption and comovers interactions [4], dissociation and regeneration in both quark-gluon plasma and hadron gas [5], and suppression of the χ_c (and therefore of the J/ψ's coming from χ_c decays) in a percolation scenario [6]. They were tuned on the p-A, S-U and Pb-Pb results previously available. The smearing induced by the ZDC experimental resolution on the centrality estimator is taken into account when comparing the calculated curves with the data. Figure 3 shows that none of these predictions properly describes the observed suppression pattern.

References

[1] T. Matsui and H. Satz, Phys. Lett. B178 (1986) 416.

[2] M. Abreu *et al.* (NA50 Coll.), Eur. Phys. J. C39 (2005) 335.

[3] R. Shahoyan *et al.* (NA60 Coll.), these proceedings.

[4] A. Capella and E. Ferreiro, hep-ph/0505032.

[5] L. Grandchamp *et al.*, Phys. Rev. Lett. 92 (2004) 212301; hep-ph/0403204.

[6] S. Digal, A. Fortunato, H. Satz, Eur. Phys. J. C32 (2004) 547.

PoS(HEP2005)133