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Memorandum

To: Members of the SPS Committee

From: J. Stachel for the CERES/NA45 Collaboration

Subject: Physics impact of a run with Indium beam in 2003

One of the prime goals of the SPS heavy ion program is to determine with precision evidence for and signals of the QCD phase transition. Indeed the combined data of all experiments give evidence that a new state of matter is created at least in the collisions of the heaviest systems as outlined in the CERN press release from February 2000 and summarized in U. Heinz, M. Jacob, nucl-th/0002042. Along with the deconfinement phase transition it is also expected that an underlying symmetry of the QCD Lagrangian, chiral symmetry, that is spontaneously broken in the normal hadronic world, is restored. This is confirmed by lattice QCD simulations which also show that the two phase transitions occur at the same critical conditions.

It is agreed among the heavy ion physics community that the clearest probe for restoration of chiral symmetry is the modification of vector mesons, chiefly of the ρ meson, as function of temperature and/or baryon density. The NA45 data on the di-lepton mass and transverse momentum spectra in Pb-Au collisions at 160 and 40 A GeV have shown evidence for such a modification of the ρ meson. Indeed, the observed mass spectrum is, for e^+e^- masses larger than 200 MeV/c^2, essentially exponential without any trace of the ρ/ω resonances but with a yield per pion in the mass range above 200 MeV/c^2 enhanced by more than a factor of 2 compared to p-nucleon collisions. This has been explained in terms of models where the ρ spectral function is changed dramatically in the hot and dense medium ('melting of the ρ'). The effect is concentrated at low p_t in accordance with the models.

The aim of the 2000 run was to see the presence and shape of the ω and ϕ resonances on top of the continuum. With the data sample of 32 Million central collisions we expect to double the e^+e^- pair yield as compared to the 1996 run at a simultaneously significantly improved mass resolution and a better signal-to-background ratio (1/8.5 vs. 1/11). This will allow to see whether these resonance structures are present in the spectrum. A definitive physics message comprises a measurement of the lineshape of these resonances.

We expect that the CERES run with Indium beams in 2003 will make a significant physics impact in 3 areas.

1. Statistical significance: we expect an increase in the total number of e^+e^- pairs with mass above 0.2 GeV/c^2 by about a factor of two due to improvements in computing power that have naturally occured over the time and due to the smaller event size as

compared to Pb-Au. Further, the smaller multiplicities are expected to lead to a signal-to-background ratio improved also by about a factor of two. This implies an effective signal increased by a factor of four. The effect of this increased effective signal together with the resolution that we obtain already for the 2000 data were used as input of a Monte-Carlo simulation of the expected e^+e^- data. The result is shown in the Figure. Also shown in the figure are three model calculations. The curve labelled 'vacuum ρ' shows that, without any medium modification of the ρ, we would have for the first time good sensitivity to such an unmodified ρ spectral shape - the much narrower ω peak can be seen in the curve labelled 'cocktail' containing all expected hadronic decays but the ρ contribution. (Of course in this unlikely case another explanation for the enhancement seen in the data would have to be found). The other two curves refer to two possible scenarios of in-medium modifications indicative of ρ melting. One of the two (R/W) was used for simulation of the data. With this anticipated increase in significance the Indium data would be far superior to any data CERES has taken before with a concomitant physics impact due to the demonstration of ρ melting.

2. A-dependence: Several of the physics observables considered important as QGP signatures have been studied as function of the mass number of the colliding nuclei. There are data for strangeness production for p-p, S-S, and Pb-Pb and for J/ψ and $\psi'/(J/\psi)$ production in p-p, p-A, S-U, and Pb-Pb. The data were found not to scale with the number of participating nucleons. Rather, a scaling with the energy density achieved in the collision reproduces these data. For the interpretation of the e^+e^- data it is very important to test whether this same scaling applies in view of the present theoretical weight that is put on e^+e^- production in binary collisions - mostly via $\pi\pi$ collisions and a modified ρ but also via $q\bar{q}$ collisions in a partonic system - and the role of total baryon density in the in-medium modifications.

3. Centrality dependence: With increasing centrality the overall energy density and the size of a region above a given energy density will grow. Beyond that, the centrality dependence for a low-mass enhancement due to changes in the spectral function of the vector mesons is non-trivial due to the interplay of i) number of binary collisions, ii) the centrality dependence of the medium modification itself, iii) the centrality dependence of the duration of the collision and possibly the expansion dynamics. This all makes this an interesting observable. A good measurement of the centrality dependence does not exist for e^+e^- data sofar. The planned Indium run will allow to do better than existing data by about one order of magnitude due to the increased significance of the signal as compared to 1996.

These expected results will be unique. No other experiment at CERN or any other accelerator will provide access to this kinematical regime (the entire enhancement is concentrated at low p_t) and beam energy range.

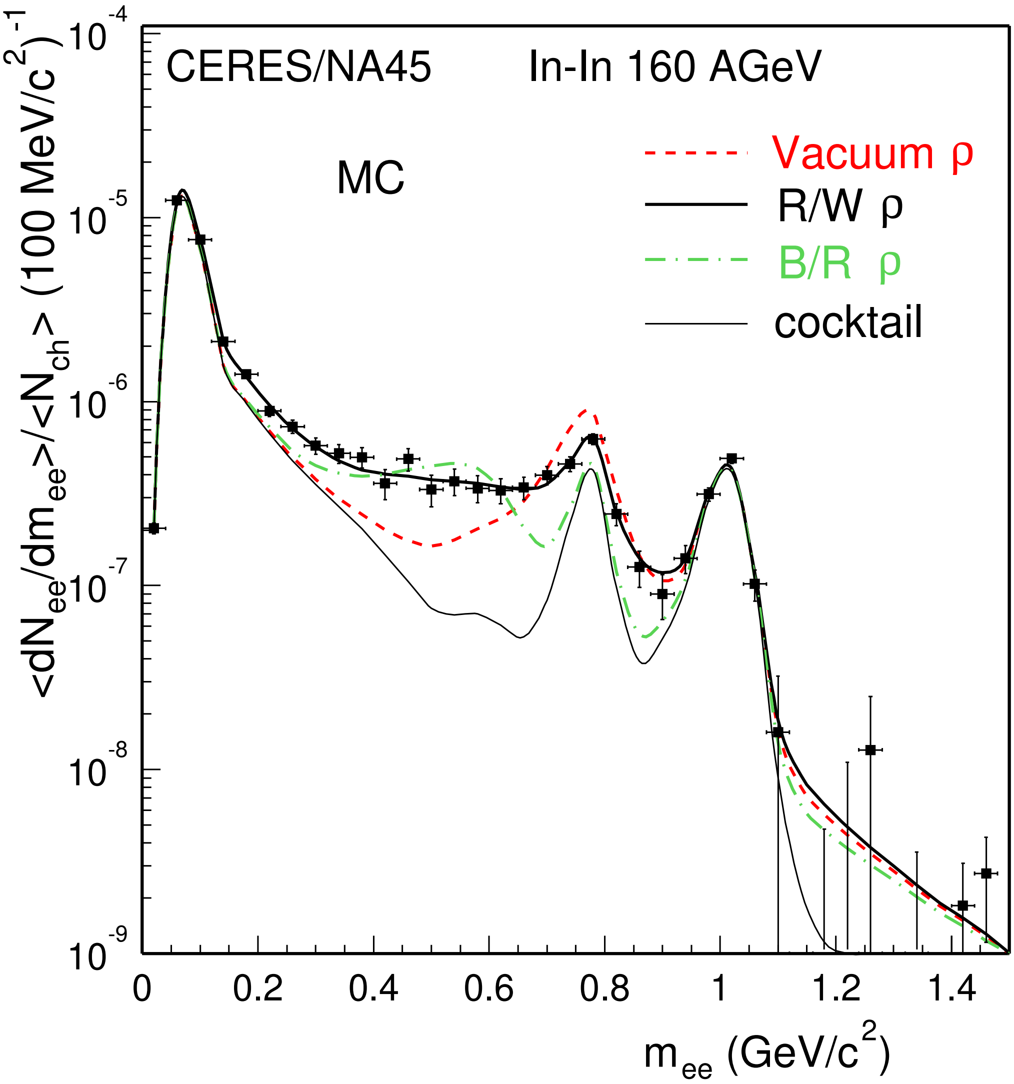

Figure 1: Invariant e^+e^- pair mass spectrum simulated for the statistical significance and resolution expected for the 2003 In-run. The three curves show theoretical predictions (provided to us by R. Rapp) without (vacuum ρ) and with in-medium ρ modification. For the latter, two of the different possible theoretical scenarios have been chosen. The data points are simulated for the Rapp/Wambach (R/W) scenario. To exhibit explicitely the ω line-shape, the hadronic decay cocktail without the ρ is shown as well.