Universität Bielefeld
Department of Physics
Theoretical Physics

Bielefeld University | P.O. Box 10 01 31 | 33501 Bielefeld | GERMANY

Prof. Dr. Helmut Satz

Telephone: +49 (521) 106-6208
Secretariat: +49 (521) 106-6223
Facsimile: +49 (521) 106-2961
satz@physik.uni-bielefeld.de
www.physik.uni-bielefeld.de

Bielefeld, September 1, 2017

Prof. Jordan Nash
Chairperson of the SPS and PS Experiments Commitee (SPSC)
Imperial College London, UK

Prof. Eckard Elsen
Director for Research and Computing
CERN, Geneva, Switzerland

Dear Colleagues,

I am writing you to point out a very promising physics opportunity for the CERN SPS after the coming shut-down, in the context of the heavy ion program and specifically addressed to the continuation of the present experiment NA61/SHINE.
Over the years, charmonium production has proven to be one of the crucial probes for quark-gluon plasma (QGP) production in high energy nuclear collisions. It was noted some twenty years ago [Matsui and HS, PL B 178 (1986) 416] that color screening in the plasma would reduce and eventually prevent the binding of charm quarks and antiquarks to produce charmonia, thus suppressing charmonium production in nuclear collisions as evidence for deconfinement.
The $c\bar{c}$ pairs produced in energetic proton-proton collisions are converted into open charm (D mesons) and charmonia; below LHC energies, one finds about 90 % open charm production, with the remaining 10 % giving charmonia (J/ψ and excited charmonium states). Color screening reduces charm production, so that at a given collision energy, the relative fraction going into charmonia should in nuclear collisions be less than it is in proton-proton collisions at the same energy.
Due to shadowing, parton energy loss etc., the overall scaled number of $c\bar{c}$ produced in nuclear collisons may well be less than it is proton-proton interactions, and this of course will reduce the charmonium production rate in AA relative to pp collisions, even if there is no medium effect on $c\bar{c}$ binding. Hence the effect of the medium on $c\bar{c}$ binding can only be determined by comparing the ratio charmonium production / open charm production in nuclear collisions to that in proton-proton collisions.
To illustrate: if the overall scaled $c\bar{c}$ production in nuclear collisions is reduced by a factor two relative to that in pp collisions, the charmonium production rate is expected to be reduced by the same factor if the medium has no effect whatsoever on the binding process. Hence a simple comparison of only J/ψ production in Pb-Pb collisions to that in pp interactions is completely inconclusive. To see if the production of a hot, deconfining medium has, as predicted, an effect on J/ψ production, it is essential to compare the ratio of J/ψ rates/open charm rates in AA to that in pp collisions.
Up to now, such a comparison has not been possible at the SPS, since the measurement of open charm production requires that of low transverse momentum charmed

mesons, which has so far encountered severe difficulties. Preliminary measurements are only available from RHIC, where it is indeed found that in Au-Au collisions, the rates of J/ψ production at low transverse momenta drop up to 80 % with centrality, compared to the D production rates. In pp collisions, the relative rates are those found at low centrality in nuclear collisions.
At the LHC, such a comparison is not yet possible, again due to difficulties in measuring low momentum D mesons. It may, moreover, be hindered in principle by the possibility of J/ψ production through regeneration. At extreme energies, there is an oversaturation of charm in the produced medium, and this may lead to secondary J/ψ production at hadronisation, preventing a study of medium effects on direct J/ψ formation.
For this reason, the ideal energy range for a precision study of medium effects on J/ψ production is that of the SPS. Here regeneration effects are excluded, since charm production is on the whole too small. Thus $c\bar{c}$ production is essentially due to direct parton interactions, so that any modifications of charmonium/open charm in going from pp to AA interactions is the result of in-medium binding modifications. From this point of view, the ideal experiment would measure at top SPS energy as function of centrality and down to low transverse momenta

- charmonium production (J/ψ, χ_c, ψ')
- open charm production (D mesons)

both in nuclear collisions and in pp interactions at the same energy.
This data should provide a detailed study of charmonium survival in the medium produced in nuclear collisions and hence specify the onset of deconfinement for the different charmonium states, allowing a quantitative study of sequential charmonium suppression [F. Karsch et al., B 637 (2006) 75].
The preliminary results on charmonium production at the SPS formed a significant basis for the CERN conclusions presented in the year 2000, claiming the observation of a new state of matter. As we have shown, such conclusions remain preliminary, as long as the correspond ding open charm data are not available. The proposed measurements of open charm production in nuclear collisions at the SPS energies would allow NA61/SHINE to fill the missing gap and thus to complete an absolutely crucial part of the CERN heavy ion program. I hope that these remarks are of use to you and that the proposed NA61/SHINE program can be realized.

With best regards, sincerely yours,

Prof. Helmut Satz
Fakultät für Physik, Universität Bielefeld
Bielefeld, Germany