Summary of past and present research activities

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Abstract

This short report can be considered as a complement to my CV. It describes the research and teaching activities in which I was involved during my PhD thesis.

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1 $J/\psi \to \mu^+\mu^-$ production in Cu + Cu collisions at $\sqrt{s_{NN}} = 200$ GeV measured by PHENIX at RHIC

PhD at Ecole Polytechnique	2004-2007
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1.1 Motivations to measure the J/ψ production in high energy heavy ion collisions

The J/ψ ($c\bar{c}$) meson, as a heavy quarkonia, is assumed to be produced in the initial stages of the collision only. It is therefore used to probe the subsequent matter formed. When compared to the yield measured in p + p collisions (at the same energy), the J/ψ yield measured in p + A collisions or in heavy-ion (A + A) collisions appears to be modified by several competing effects. Cold nuclear matter (CNM) effects are determined thanks to p + A collisions where no deconfined medium (quark-gluon plasma or QGP) can be produced. In A + A collisions, if sufficient energy density is achieved (more than ten times the nuclear energy density), the QGP should be reached. In this case, it is foreseen that *(i)* the J/ψ will be suppressed due to the colour screening effect, but *(ii)* it can also be enhanced if in-medium formation of the J/ψ (due to the recombination of c and $\bar{c}$ native of two different nuclon-nucleon collisions) is not negligible anymore.

1.2 Benefits from the data collected by PHENIX during the Cu + Cu Run at $\sqrt{s_{NN}} = 200$ GeV

PHENIX, one of the four experiments at RHIC[1], can detect the J/ψ at central rapidity $|\eta| < 0.35$ (*via* the e^+e^- decay mode) and at forward rapidity $1.2 < |\eta| < 2.2$. The latter is carried out *via* $J/\psi \to \mu^+\mu^-$, where the detection is performed with the muon spectrometers, built up from a tracker (MuTr) and an identifier (MuID). Recent PHENIX publications report on the obtained measurements[2] of the J/ψ production in p + p[3] and in Au + Au[4] at $\sqrt{s_{NN}} = 200$ GeV at both rapidities. Two striking features are worth to be noticed: *(i)* at sufficiently high number N_{part} of participant nucleons per collision, the observed suppression is beyond the CNM effects, and *(ii)*, for $N_{part} > 100$, the suppression at forward rapidity is significantly more important than at central rapidity, at variance with the model predictions.

The Cu + Cu data benefits from *important statistics*: the high luminosity achieved during the data taking (about 3.1 nb^{-1} integrated luminosity or 11.9 pb^{-1} if expressed in p + p equivalent luminosity) allows to get more than two times the number of J/ψ obtained in Au + Au. As a lighter system, the measurements done in *Cu + Cu collisions overlap the Au + Au*[5] *ones*

[1] Relativistic Heavy Ion Collider, Brookhaven National Laboratory, New-York, USA
[2] They were also presented at the Quark Matter'06 conference (China).
[3] hep-ex/0611020 (submitted to Phys. Rev. Lett.)
[4] nucl-ex/0611020 (submitted to Phys. Rev. Lett.)
[5] The N_{part} region covered by the Au + Au collisions extends up to $\sim 350 - 400$ participant nucléons per collisions.

up to $N_{part} \sim 100$. Hence, they will allow to increase the precision in this centrality region. This has attracted much interest since *(i)*, it is the N_{part} range where the suppression beyond CNM effects sets in, and *(ii)*, it is also the region where the suppression difference between forward and central rapidity starts.

1.3 Description of my activities

1.3.1 At the data taking time

The Cu + Cu Run (PHENIX Run-5 from January to the end of March 2005) was the first opportunity to use the online level 1 trigger built upon the fast response from the low granularity part of the detector, i.e. the MuID. The MUIDLL1 trigger requires two deep tracks, meaning that each one reached the fourth (out of five) detection plane of the MuID. In addition, each track must have a minimum number of hit planes, four out of five (strict requirement) or three out of five (less severe requirement). My evaluation of the trigger efficiency and rejection power allowed to *motivate the change from the first to the second setting*: indeed, when using the more strict requirement, the J/ψ loss was too high when compared to the second setting (about -19% for the North arm, -6% for the South arm), whereas the gain in rejection power was quite modest (a factor 2 to 4). *About half of the luminosity was taken with the second and less severe requirement.*

1.3.2 During the analysis of the data

In parallel, I was also deeply involved in the analysis of the Cu + Cu data for the dimuon channel, for both the *preliminary results* (presented at Quark Matter'05 conference) and for the *final results*[6].

My work consisted in determining the *correction factors* that combine the impact of the limited *acceptance* of the muon spectrometers, the *efficiencies* of the detection panels, the triggers and the algorithm that reconstructs the path of the particles. These correction factors are needed to evaluate the original number of J/ψ produced in the collision. It has to be underlined that *the two triggers used where employed for the first time* during the Cu + Cu Run, namely the already mentioned MUIDLL1 and the level 2 offline trigger based on the MuTr response. Hence, I am *co-author of the internal analysis note written to support the release of the preliminary results*.

For the final analysis, I managed to bring a significant improvement to the method used to determine the acceptance and efficiency correction factors. The first step was to check that the dominant part of the variation of these correction factors throughout the data taking period was due to the variation of the identity and number of the dead zones in the MuTr (and not to the multiplicity variation that may come, for e.g., from varying beam conditions). Hence, to reproduce the capsule history of the Cu + Cu Run in terms of acceptance and efficiency, one "only" needs to vary these dead zones during the simulation (in particular the identity of the faulty front-end electronics). *This method allows to gain a significant precision on the time-average value of the acceptance and efficiency, namely less than* 2% *systematic errors instead of the* 8% *from the preliminary analysis*. Hence, I am the *main author* of the internal analysis note on acceptance and efficiency that will be submitted to the collaboration in support of the final results. I am also co-author of the internal note recapitulating all the studies and improvements conducted after Quark Matter'05 conference time.

[6] Article in preparation

1.3.3 Regular participation to the internal PHENIX meetings

At several steps of the analysis, I regularly presented the status of my own work and/or reported the status of the whole analysis for the Cu + Cu "muon" team, depending on the kind of internal PHENIX meeting: it can be *(i)* a "muon" group meeting (at which I gave about twenty presentations) where all the topics that involve the use of the muon spectrometers or the related part of the reconstruction/simulation software are debated; or *(ii)* the Cu + Cu paper preparation group meeting (six presentations including the report of the final results for the muon team); or *(iii)* a so-called "heavy/light quarks working group" meeting (three presentations including the report of the final results for the Cu + Cu muon team) where the on-going analysis status on heavy probes (in particular) are regularly reported to PHENIX conveners and to a larger audience, namely any interested person in the collaboration regardless of his own analysis field .

1.3.4 Talks and poster for several conferences

I was given the opportunity to represent the PHENIX collaboration at several international conferences, namely *(i)* a poster presenting my contribution to the analysis and the preliminary Cu + Cu results at Quark Matter'05 conference, and *(ii)* a talk at SQM'06 conference where I presented all the avalaible and preliminary PHENIX results on the J/ψ production in Cu + Cu and Au + Au collisions (the corresponding proceedings are published[7]). I will have this opportunity again at the forthcoming Rencontres de Moriond (QCD and hadronic interactions sessions, March 2007) where the scheduled talk will be on the J/ψ production in Cu + Cu (still preliminary results) and Au + Au collisions (final results).

I was also invited to present a review of RHIC results on quarkonia during the recent ALICE Week (Feb. 2007, Germany), in particular the recently released and final results on the J/ψ production in p + p and Au + Au collisions.

In France, I presented a review of RHIC results on the heavy probes and quarkonia at the first "QGP France" conference (June 2006) which gathers the whole French community working in heavy ion physics.

1.4 JIN: a Monte-Carlo model of cold nuclear effects on the J/ψ production

Determining the part due to CNM effects in the deviation from the p + p behaviour of the J/ψ production in A + A collisions is a key step in any interpretation of this deviation. Of particular importance are the two following CNM effects: *(i)* the change in the parton distribution function within a nucleon bound in a nucleus with respect to a free nucleon (initial state effect) known as "shadowing", and *(ii)* the nuclear absorption (final state effect) where the pre-resonant $c\bar{c}$ pair is broken by interactions with the surrounding nucleons (which come from the projectile or the target nucleus).

The second part of the thesis focuses on the realization of a Monte-Carlo model to investigate the above CNM effects. The goal is first to fit the CNM effects determined in d + Au collisions at $\sqrt{s_{NN}} = 200$ GeV (by PHENIX) then to extrapolate the obtained result in Cu + Cu and Au + Au in order to evaluate the part of the J/ψ suppression that may be due to a deconfinement scenario. This work is being carried out in collaboration with E. G. Ferreiro and F. Fleuret. In our model, named JIN (that stands for J/ψ In Nucleus),

[7] A. Rakotozafindrabe (for the PHENIX collaboration), J/ψ production in Cu + Cu and Au + Au collisions measured by PHENIX at RHIC, J. Phys. G : Nucl. Part. Phys. 32 (2006) S525-S528

the nucleon-nucleon (N-N) interactions are described using the Glauber model, the nucleons being distributed in the nucleus with a Woods-Saxon density profile. A given J/ψ production cross-section is associated to each N-N collision, this cross-section being modulated by a reduction (or enhancement) factor that depends on multiple kinematic variables and that is due to the shadowing. Several models of this factor can be used. JIN's originality lies in the fact that we use a Monte-Carlo approach (instead of the optical approach where one evaluate analytically all the relevant quantities). The noteworthy advantage is that the Monte-Carlo inputs can be chosen to be the experimentally measured rapidity y and transverse momentum p_T distributions of the J/ψ in p + p collisions. Indeed, in the present context, the analytical approach provides predictions at fixed y and p_T only.

2 Additional contributions within the PHENIX collaboration

2.1 During the data taking

As a member of the PHENIX collaboration, I spent a fair amount of time on-site for shift, usually one week per year during the data taking period. Each time, I choose a different role (for e.g., for my next shift scheduled on June, monitor and operate the low and high voltage system; the latter brings the detectors up to operating voltage when the beam is cogged). In addition, I also spent a significant amount of time as the on-site MuTr expert: two weeks per year during the first and the second year as an assistant-expert (in order to learn the needed skills), then two weeks per year during the second year and this year as a full expert. The on-site expert has to be aware of the operation of the MuTr system components. He also has the responsibility to organize and follow through the solution of any MuTr problem for which he is paged. Typical problems are memory addressing errors from the read-out electronics, incorrect calibration, high number of tripping channels due to humidity, etc.

2.2 Analysis of the data collected during the Cu + Cu collisions at $\sqrt{s_{NN}}$ = 62 GeV and the p + p collisions at $\sqrt{s_{NN}}$ = 200 GeV

The insertion of the MUIDLL1 into the acceptance and efficiency determination procedure was used in the subsequent and similar analysis performed with the data taken in Cu + Cu collisions at $\sqrt{s_{NN}} = 62$ GeV and for the recently published p + p data. I contributed to the evaluation of these correction factors for the preliminary Cu + Cu results at $\sqrt{s_{NN}} = 62$ GeV. I also determined the variation of these correction factors throughout the p + p data taking period. Hence, I am co-author of the internal analysis notes written for these two sets of data.

3 Teaching

In parallel to my research activities, I was also a part-time lecturer (in French, "Moniteur") at Ecole Polytechnique. The teaching was practical and represents a charge of about 96 hours per year. The goal was to design a programmable logic circuit. The class can be followed by the students from the last (resp. first) year of the undergraduate (resp. graduate) studies. When they are at the graduate level, their Master major can be either Computer Science or Optics, Matters and Plasmas. The students choose a project, among the ones we offer or a completely new one from their own. Since the project is not specified in advance, this teaching requires a substantial investing of time from the *Moniteur*, in addition to the hours spent with the students, especially during the first year of teaching in order to get familiar with the programmable logic and with the available tools (XilinX software, VHDL language, FPGA, video and audio interface). We often carry out projects such as a basic CPU implementation, a cellular automaton or an audio filter.