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SQM2015: Summary of Theory Talks

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Abstract.   A summary of plenary talks presented at the 15th Strangeness in Quark Matter 2015 conference held at the JINR, Dubna July 6-11, 2015.
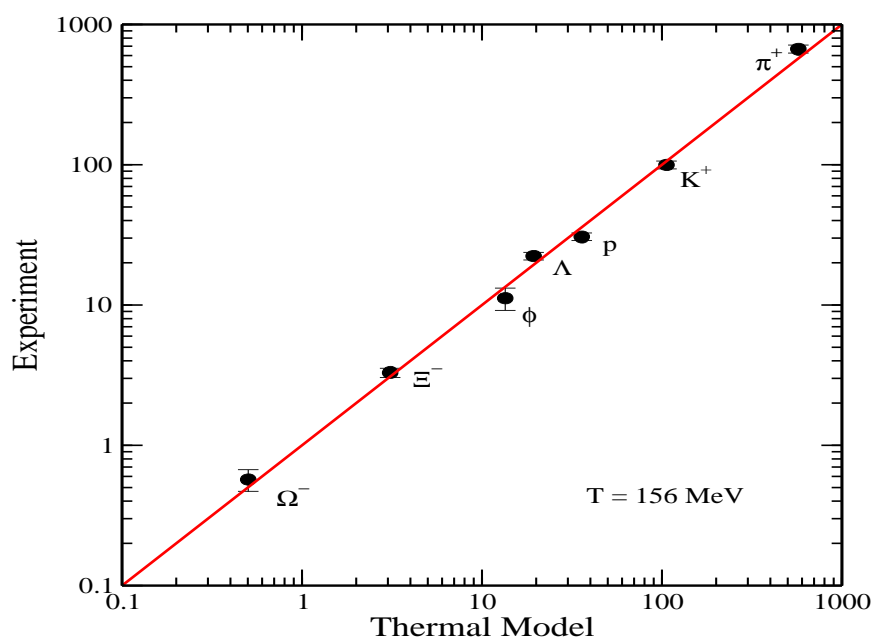
1. Overview
During the "*Strangeness in Quark Matter 2015*" (SQM2015) conference, held at the JINR in Dubna from July 6-11 a total of about 150 talks were presented of which approximately half were theory talks. In preparation for this overview generous use was made of the material submitted to these proceedings. Due to the large number of talks this overview is limited to the submitted plenary talks.

2. Chemical Equilibrium.
One of the important lessons learned from the study of heavy ion collisions in the past few years is how well chemical equilibrium works at all beam energies. At high energies this was shown by results from the ALICE collaboration [1], at low beam energies it was shown by the HADES collaboration [2]. In both cases the agreement with chemical equilibrium is remarkable. At the same time there are also clear deviations, as seen in the yields of Ξ's at low energy and of protons at high energies. The agreement is made more striking by plotting the results in Fig. (1) in a form first suggested about two decades ago by Becattini [3]. It is worth emphasizing that all yields of hadrons are established at a single freeze-out temperature to a very good approximation.

The deviations at lower energies were addressed in the talk of M. Bleicher [4] where it was shown that by adding new decay channels of heavier resonances one can explain the additional yield of Ξ's and ϕ's.

3. Heavy Quarks and Transport Models.

The agreement is generally very good and predictions for higher beam energies were presented. The production of heavy flavors was considered by several speakers [6, 7, 8, 9]. Due to the heavy masses these are mainly produced in the early stages of the collisions when the initial energy has not been degraded and, due to the smaller cross sections, they provide information on the early stages of the collisions.

The behavior of jets moving through the hot and dense medium created in heavy-ion collisions was discussed by Djordjevic [5]. A formalism was presented for calculating the energy loss and the suppression of jets taking into account radiative and collisional energy loss. The calculations were applied to angular averaged values of R_{AA} which are less sensitive to the evolution of the medium. The results were compared to R_{AA} for various particles, including light and heavy hadrons, for a wide range of probes, centralities and beam energies. It was noted [9] that the values of R_{AA} and v_2 are described well by many models and it is necessary to go beyond these observables in heavy-ion collisions. More differential observables like correlations and higher-order flow coefficients of D mesons as well as the elliptic flow of B mesons indicate to have a

larger discriminating power and are good candidates for reaching another level of understanding of the heavy-flavor dynamics and its relation to the bulk medium evolution. As a result they can help us to identify the most dominant features of the heavy-quark-medium interaction in order to connect experimental data to fundamental properties of QCD.

Detailed results were presented based on the Parton-Hadron-String Dynamics approach [6] where it was concluded that collisional energy loss was dominant up to p_T values of 15 GeV/c in relativistic heavy-ion collisions.

The present theoretical understanding of quarkonium production was presented in great detail by Lansberg [8]. It was strongly argued that the study of quarkonium production in proton-nucleus collisions is of fundamental importance if one wishes to not only properly interpret quantitatively but also qualitatively interpret the physics underlying the quarkonium suppression in nucleus-nucleus collisions. The case of the sequential suppression of Υ measured by CMS is a prime example. Just measuring quarkonium production in nucleus-nucleus collisions is not enough. One of the mechanisms which can explain the relative suppression is the scattering with comoving hadrons. This is included in the comover interaction model which was introduced long ago to explain part of the anomalous quarkonium suppression in AA collisions.

The talk of Beraudo [7] considered transport approaches based on the Boltzmann and Langevin equations. The importance of future beauty measurements as well as heavy flavor studies in small systems like p-Pb was emphasized. It was shown that correlations would be helpful to resolve some of the outstanding issues.

A new approach to identify isotopes and hypernuclei in transport models was presented by Le Fèvre [10]. The new algorithm includes pairing and asymmetry energies as well as other effects is able to describe the nuclear binding energy and allow for the calculation of isotope yields. It was shown that the asymmetry and pairing potentials have a strong influence on the yields and on the momentum anisotropies for the (hyper-)isotopes. The fragment formation is sensitive to the density dependence of the asymmetry energy and the pairing energy. However, fragments test this dependence only for densities below the saturation density.

4. Lattice QCD

An investigation was presented by Wittig [12] about the existence of the H-dibaryon using lattice QCD. These are very demanding calculations and a bound H-dibaryon was only found at unphysically large pion masses. There is a need for more and better lattice data.

An important ingredient in understanding heavy-ion experiments is the production of hadronic resonances and their subsequent decays. Information about this is far from complete [14]. Related to this, interesting results about strange resonances were presented by Kaczmarek [11] as obtained from Lattice QCD. A large list of strange baryons and mesons is found in lattice QCD which are not listed by the Particle Data Group [14] . These directly affect calculations done using the thermal model. It would be very helpful to also have information about non-strange baryons and mesons as this has implications for the calculation of the K^+/π^+ ratio using the thermal model. Furthermore, there is no information about decay channels from lattice QCD. Finally and most importantly, one needs experimental confirmation about all these new hadrons!

A report about heavy quarkonia from Lattice QCD was presented by Rothkopf [13]. Combining an effective description for heavy quarks with finite temperature lattice QCD we compute in-medium spectra providing insight in heavy quarkonium melting in a static thermal

medium. On the other hand spectral information was used to extract the complex in-medium potential which provides the basis for a dynamical description of quarkonium real-time evolution via the Schrödinger equation. It was pointed out that bottomonium S-wave and P-wave will survive up to very high temperatures of at least T = 250 MeV.

5. Conclusions

In conclusion, an impressive amount of progress has been made in the theoretical understanding of relativistic heavy ion collisions. Many suggestions were made for future measurements that will be improve our present models. The next series of experiments at various laboratories and different beam energies will contribute greatly to the better understanding.

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