Analysis of $\mathbf{K^*(892)^0}$ resonance production in proton-proton interactions at the SPS accelerator energy range

The smallest and indivisible parts of matter are called elementary particles and they are included in the Standard Model. This model consists of: six quarks and antiquarks, six leptons and antileptons, Higgs boson (responsible for particle mass) and force carriers such as photon (electromagnetic interactions), gluons (strong interaction), W^+, W^-, and Z^0 bosons (weak interactions). The strong interaction is the strongest one so that quarks are confined in mesons (pairs of quark-antiquark), barions (3 connected quarks) and antibarions (3 connected antiquarks). However, at higher temperatures the Quark-Gluon Plasma (QGP) can be created, in which quarks and gluons are deconfined. Conditions to produce the QGP are achieved during heavy ion collisions. The biggest science centers, where the QGP is examined, are the European Organization of Nuclear Research (CERN, Geneva) and the Brookhaven National Laboratory (BNL, USA).

The NA61/SHINE experiment is located at CERN. Its physics program is focused on searching of the critical point and on the study of the properties of the onset of deconfinement. The scan of the phase diagram of strongly interacting matter is done by changing the energy of colliding ions (from 13A to 150/158A GeV) and by changing the system size (from p+p to Pb+Pb). The main problem with the QGP studies is that it cannot be observed directly because only the particles produced in final state could be measurement by detectors. After the QGP stage, hadronisation, chemical and kinetic freeze-out occure. First phenomena causes confinement of quarks into hadrons and then inelastic interactions between particles are stopped (chemical freeze-out). The particle composition is fixed but kinetic properties of particles could be modified until kinetic freeze-out. So that understanding the phenomena after the QGP is important to measure signatures of the QGP.

Apart from studies of the QGP signatures, there are many interesting phenomena after nucleons collisions. One of the stages, in which properties of particles could be changed, is hadron gas phase. Scale of modifications depends on the time between chemical and kinetic freeze-out. There are two hipotetical possible situations. First one is a single state freeze-out without hadron gas phase occurance. Second one possibility is a gradual freeze-out with hadron gas phase presence during which elastic interactions are possible. Despite many years on studying this process, question about sudden or gradual freeze-out is still open. Single freeze-out model with the chemical and the kinetic freeze-out coincidence was used in describing particle spectra and their yields in measurements at the Relativistic Heavy Ion Collider (RHIC). On the other hand, the latest results from the ALICE experiment at Large Hadron Collider (LHC) show even lower temperature of kinetic freeze-out (T_{kin}) than the one observed at top RHIC energies. One of the simplest explanation is the hadronic phase presence between freeze-outs, which lifetime is increasing with center-of-mass energy. The main objective of this project is the analysis of the short-time resonances, only the $K^*(892)^0$ yield, which will help to check if there is a hadron gas phase between freeze-outs. Due to a shorter lifetime of the $K^*(892)^0$ resonance ($\tau = 3.88 fm/c$) than the expected time between freeze-outs ($\tau \cong 5 fm/c$), the signal will be sensitive to a duration of the freeze-out and presence of the hadron gas phase between them. The unique way of measuring what happens during freeze-out is the analysis of enough short-lived resonance yields to non-resonance yields of particles with similar quark composition ($K^*(892)^0/K^-$) as a function of average number of charged particles per event or center-of-mass energy.

There are also other interesting measurements such as the transverse mass spectra of $K^*(892)^0$ particles which will allow to significantly improve the fits within Blast-Wave models, which are used to obtain kinetic freeze-out parameters: temperature (T) and transverse flow velocity (β_T).

Finally, the hadron gas statistical models use particle yields or ratios of particles yields to obtain chemical freeze-out parameters, such as chemical freeze-out temperature (T), baryochemical potential (μ_B), strangeness undersaturation factor (γ_S), system volume (V), etc. Information about $K^*(892)^0$ production in p+p interaction at SPS energies will allow to perform more precise hadron gas model fits and will significantly contribute to our understanding of the phase diagram of strongly interacting matter.