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NA61/SHINE ion program

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This contribution summarizes the current status and future plans of the NA61/SHINE experiment located at CERN SPS. This experiment is the successor of a former NA49 experiment. The broad physics program includes the investigation of the properties of strongly interacting matter, as well as precision measurements of hadron production for the T2K neutrino experiment and for the Pierre Auger Observatory and KASCADE cosmic-ray projects. The main goal of NA61/SHINE project is to discover the critical point of strongly interacting matter and study properties of the onset of deconfinement. These goals will be reached by measurements of hadron production properties in nucleus + nucleus, proton + proton and proton + Pb collisions at full range of SPS energies.

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The NA61/SHINE (SPS Heavy Ion and Neutrino Experiment) experiment is located at the CERN Super Proton Synchrotron (SPS) facility [1]. This project is the continuation of the NA49 experiment. The NA61/SHINE pursues a rich physics program in various fields. First, precise hadron production measurements are performed to deliver input for the calculations of the neutrino flux in the T2K neutrino oscillation experiment , as well as for more reliable simulations of cosmic-ray air showers in the Pierre Auger and KASCADE experiments [2]. Second, the p + p, p + nucleus, and nucleus + nucleus collisions are studied extensively at SPS energies. The energy and system size scan will be performed with the aim of studying properties of the onset of deconfinement and searching for the critical point of strongly interacting matter.

The NA61/SHINE experiment uses a large acceptance hadron spectrometer located on the H2 beam line in the North Area of CERN. Its main detector components, software, calibration, and analysis methods were inherited from the NA49 experiment [3]. The main tracking devices are four large volume time projection chambers (TPCs), which are capable of detecting up to 70% of all charged particles created in the studied reactions. Two of them, the vertex TPCs, are located in the magnetic field of two super-conducting dipole magnets with maximum bending powers of 9 Tesla meters. Two other tracking devices (MTPC-L and MTPC-R) are positioned downstream of the magnets symmetrically with respect to the beam line. One supplementary small TPC, the gap TPC, is installed on the beam axis between the vertex TPCs. In addition three TOF-walls are positioned behind the TPCs. Two of them (TOF-L/R) were inherited from the NA49 experiment. A forward TOF-wall was added in 2007 to extend the acceptance for particles with $p < 3$ GeV/c. In 2008 a new TPC readout and DAQ system with about 70 Hz readout frequency were installed. These modifications increased the event rate by factor of about 10.

For the ion programme the Projectile Spectator Detector have been assembled and tested. This detector will allow precise measurement of the energy of projectile spectators and will provide a single nucleon resolution necessary for the fluctuation studies essential in search for a critical point. Additionally the He beam pipe was installed in order to reduce δ-electron production by the beam by a factor of 10. Charge identification of secondary fragments delivered to the experimental area will be performed by a new Cherenkov detector (Z-detector). The performance of this detector was tested during the last proton run of the NA61/SHINE experiment.

In the last decades, collisions of heavy ions in the laboratory became an important tool for studying the phase diagram of strongly interacting matter. Depending on the incident energy a highly compressed baryon dominated system or an extremely hot quark-gluon plasma phase is created in these collisions.

Particle yields measured in heavy-ion collisions at SIS, AGS, SPS and RHIC have been successfully described by the statistical model [4]. These results show that at lower baryochemical potential (SPS, RHIC) the curve of temperature versus baryo-chemical potential representing chemical freeze-out tend to merge with the phase boundary between partonic and hadronic media predicted by the lattice QCD calculations [5].

Results on the energy dependence of hadron production in central Pb + Pb collisions coming from the the energy scan at SPS done by NA49 collaboration provide evidence for the onset of a transition to the system of deconfined quarks and gluons [6]. Hadron production properties in central collisions as a function of collision energy exhibit rapid changes at about 30A GeV. The recent RHIC results confirm this observations [7]. The LHC data demonstrate that the energy dependence of hadron production properties shows rapid changes only at the SPS energies [8]. This agrees with the interpretation of the NA49 structures as due to the onset of deconfinement and the expectation of only a smooth evolution of the quark-gluon plasma properties with increasing collision energy above the onset energy. The search for onset of deconfinement signals in particle correlations and event-by-event fluctuations is up to now inconclusive [9].

The lattice QCD calculations indicate that the phase diagram boundary line between hadronic and partonic phases has a critical endpoint. This critical point is predicted to lie in a region of the phase diagram accessible at SPS energies [5]. Enhanced fluctuations in multiplicity and average transverse momentum are expected if hadronization and freeze-out happen near the critical point. The NA49 experiment has already looked for indications of the critical point. The pilot data on collisions of medium and light mass nuclei suggest that signals of the critical point may be visible in C + C and Si + Si collisions at 158 AGeV [10].

These results motivate the NA61/SHINE collaboration to perform a systematic search for the critical point. This goal will be achieved by performing a two dimensional scan in collisions energy (the whole SPS energy range from 13A to 158A GeV) and size of the colliding nuclei (p+p, ^{7}Be + ^{9}Be, ^{40}Ar + ^{40}Ca, ^{129}Xe + ^{139}La). At the same time these measurements will also deliver us the information for a detailed study of properties of the onset of deconfinement. The two dimensional scan already started and a complete set of data should be registered by the end of 2015.

The NA61/SHINE investigates energy and system size dependence of hadron production in nucleus-nucleus, proton-proton collisions with aim to study the properties of the onset of deconfinement. It has a significant discovery potential for the critical point of strongly interacting matter, if it exists.

References

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