Heating Nuclear Matter With Energetic Antiproton And Pion Beams

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Determining the properties of the nuclear equation of state (EOS) as a function of temperature and density is one of the major objectives for the investigation of nuclear reactions. In order to investigate the properties of nuclear matter at low density, the energy deposition of 8 GeV/c antiproton and pion beams on ^{197}Au nuclei, experiment E900a, has been studied at the Brookhaven AGS accelerator using the Indiana Silicon Sphere (ISiS) 4π detector array [1].

Hadron-induced reactions provide many unique advantages in the studies of the thermodynamic properties of hot nuclei [2-6]. Hard nucleon-nucleon scatterings heat the nucleus rapidly ($\tau \leq$ 30-40 fm/c) via Δ excitation, pion rescattering, and multiple-pion reabsorption [2]. In contrast to heavy-ion reactions, the target nucleus is rapidly heated with little compression via collisions induced by GeV light-ion beams [2,5,6]. The annihilation of antiprotons within a nucleus produces several pions which will heat the nucleus to higher excitation. Therefore, heating nuclear matter with antiprotons is an ideal method to study the nuclear properties at low density ($\rho < \rho_0$).

The experiment E900a was performed at the Brookhaven National Laboratory AGS accelerator. The secondary beam of 8 GeV/c negative particles (π^-, K^-, $\bar{p}$) were tagged with a time-of-flight and Cerenkov counter system. The beam which was incident on a 4 cm^2 self-supporting ^{197}Au foil of thickness 2 mg/cm^2 consisted of about 4×10^6 particles/cycle (~4.5s cycle with ~ 2.2s flat top spill). The beam composition at the target was 98% π^-, 1% K^-, and 1% $\bar{p}$. Light charged particles and intermediate-mass fragments from the π^-, $\bar{p}$ + Au reactions were measured with the Indiana Silicon Sphere (ISiS) 4π detector array.

The ISiS detector array consists of 162 triple telescopes covering 74% of 4π in solid angle [1]. There are 90 telescopes in the forward hemisphere and 72 telescopes in the backward hemisphere which cover the angular ranges from 14° to 86.5° and 93.5° to 166° in polar angle. Each telescope is composed of a gas-ionization chamber, a 500 μm silicon detector, and a 2.8 cm CsI(Tl) scintillation crystal with photodiode readout. The telescope dynamic range permits the measurement of charged particles up to $Z \approx 16$ with energies between 0.6 – 96 MeV/nucleon with discrete charge resolution. The Si-CsI telescope provides isotopic resolution for energetic H, He, and Li ($8 \le E/A \le 92$ MeV). Valid signals in at least three silicon detectors in the array were required for event-readout. The final data consist of 25,000 $\bar{p}$ and 2,500,000 π^- events.

Calibration of the ISiS silicon detector was performed using a pulser. The gas ionization detectors were then calibrated at various pressures with ^{241}Am and ^{157}Gd sources. The energy loss of the alpha particles in the gas ionization chamber at each pressure was obtained from the calibrated energy deposited in Si detectors. The CsI detectors were calibrated by choosing points on isotope lines on the particle identification plots. Then the energy deposited in CsI crystal was calculated from the calibrated energy loss in the Si detector.

The analysis of this data set is under way. The caloric curve will be determined from the 8 GeV/c π^-, $\bar{p}$ + Au reactions, using the excitation energies derived from reconstructed events and temperature based on double-isotope ratio method [7]. The results from this experiment will be compared to the 4.8 GeV ^{3}He + Au, Ag reactions.

References.

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