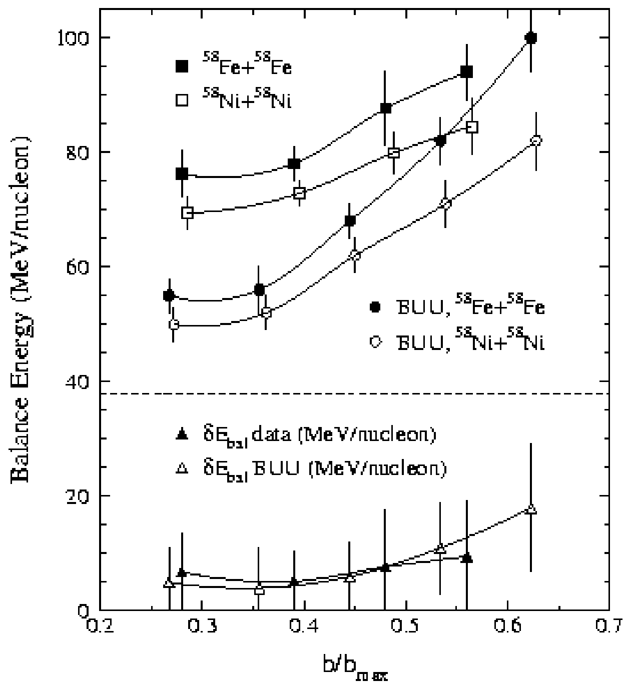
LONGITUDINAL FLOW IN Au+Au COLLISIONS FROM 20 TO 60 AMeV

by Jennifer Seiler

INTRODUCTION AND BACKGROUND

Although we have learned much about behavior of nuclear matter in locations such as supernovas, and their resulting neutron stars and pulsars through observational astronomy, much of what we can learn about properties of such matter is better gotten through the studies of more finite events such as those collisions run at the National Cyclotron. The investigation of longitudinal flow in Au+Au collisions can tell us more about the behavior of nuclear matter in high-energy events such as those seen in Astrophysics. It can also help us to more accurately find the masses of elementary particles, learn more about the creation of neutron rich isotopes, and to gain knowledge of the compressibility of nuclear matter. I studied the flow of particles parallel to the bombarding beam for gold on gold collisions at Fermi energies in the range of 20 to 60 MeV/nucleon. The energies studied, and the resulting temperatures and flow can offer a significant contribution to the futures both nuclear physics and astrophysics.

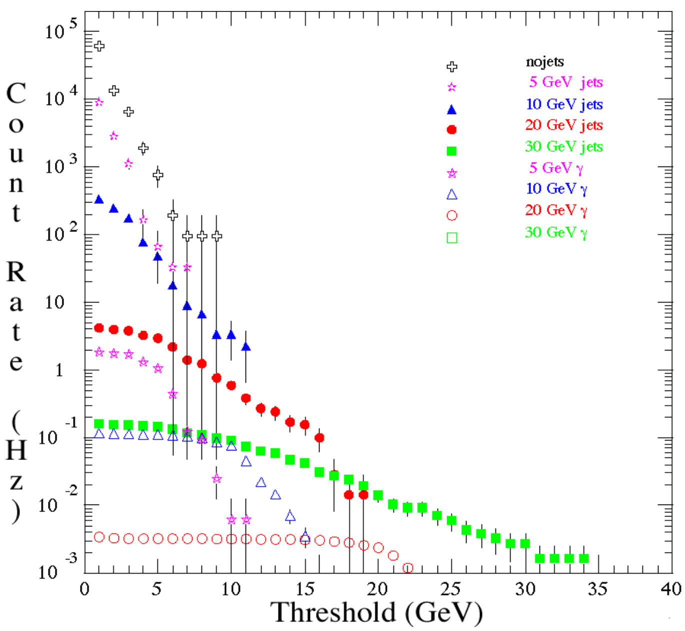
The ground state of nuclear matter is a uniform liquid having equal numbers of protons neutrons with a density of about $2.5*10^{14}$ g/cm^3. In their ground state nucleons behave in a manner similar to fluids that strongly resist attempts at compression, but a compressed state is required to gain information about such things as nucleon interaction, and the nuclear equation of state. The higher the compressibility of the nuclei, the larger the momenta, and therefore, the greater the "flow". Therefore the study of flow in heavy-ion collisions can tell us a lot about the compressibility of nuclear matter. Flow has been studied in the past as a function of nuclear size, beam energy, the beam's neutron/proton ratio, and impact parameter. Four forms of flow (transverse, elliptic, radial, and longitudinal) have been studied in the collision of gold targets with high-energy gold clusters. Transverse, elliptical and radial flows of protons and other nucleons have already been extensively researched for a large range of energies, but very little research has been done on the longitudinal flow of particle following a head-on heavy–ion collision. Studying longitudinal flow can be of assistance in gaining more knowledge about the compressibility and elasticity of heavy-ion reactions. It can therefore help us to predict the outcomes of astrophysical events such as supernovae.



Transverse Flow. Pak, Robert *et al.*, Phys. Rev. Lett. **78**, 1026 (1997).

An equation of state when used in nuclear physics is the relationships between pressure, temperature, density, and the matter itself. If we were to know the equation of state of a collapsing star we could predict its behavior upon collapsing (i.e. if the nuclear matter would 'bounce back' or continue through), therefore predicting the outcome of the supernovae (black hole, pulsar, etc.). Current models, such as the BUU model or the nucleon exchange model, do not account for the dynamics of nuclear collisions at Fermi energies (as seen above). They wrongly predict both the strength of frictional forces and the probability for fusion in collisions at these energies. Therefore it is important that we study collisions at these temperatures and energies thoroughly.

Complex nuclear reactions are induced in the collision of heavy ions such as gold, such that nucleons approach speeds exceeding the nucleonic velocity. Au+Au is the collision of choice in this project because it has a large system size (A = 394). That is, when two nuclei of gold collide with enough energy to overcome the Coulomb repulsion between them, a system of 394 nucleons is formed for a very short time. This is one of the largest systems that can be achieved on earth. At low beam energies (~10 MeV/nucleon), the dominant interaction in the reaction zone is the attractive mean field, which leads to a negative dynamical flow of the final particles. Hot nuclei evaporate individual protons and neutrons at low excitation and are completely vaporized at sufficiently high energy. At intermediate energies disintegration is characterized by several clusters of intermediate size. At high beam energies, the dominant interaction is the nucleon-nucleon repulsive interaction, which leads to a positive flow of the freed nuclei. The energies used for my data were done at intermediate energies. Temperature and energies such as those created in the reactions dealt with in such experiments have not been seen in nature since the earliest moments of the big bang. This rare state allows us to witness interesting reaction phenomena such as the occurrence of very neutron-rich jets of fast particles, and the emission of complex IMFs.



STAR notes, B. Huebner, G.D. Westfall, and A.M. Vander Molen, SN 275 and SN 276, December 1996

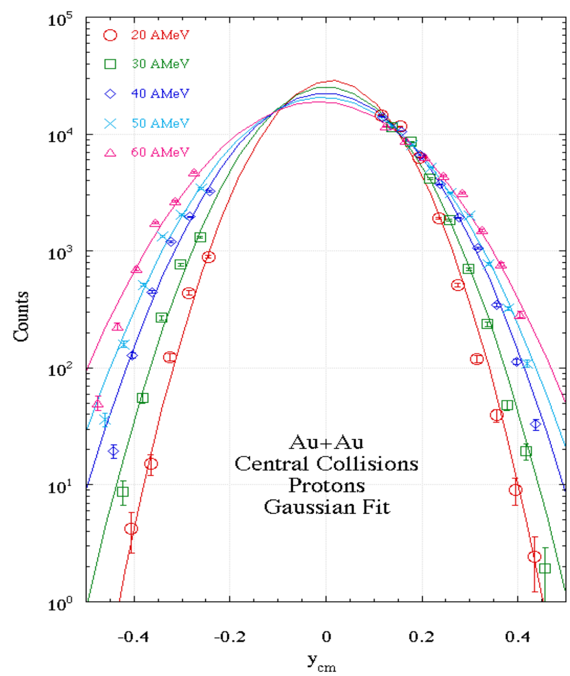
National Superconducting Cyclotron was a marvelous tool to use to measure heavy ion collisions because as it supplies sufficiently energetic and heavy beams to vaporize nuclei in a central collision of two heavy nuclei. The detections for my data were collected by the four-pi array. Using the MSU Four-pi array, the Miniball and the Superball, experiments can be performed with sufficient angular coverage to measure events where up to a few dozen particles may be emitted.

HYPOTHESIS AND PURPOSE

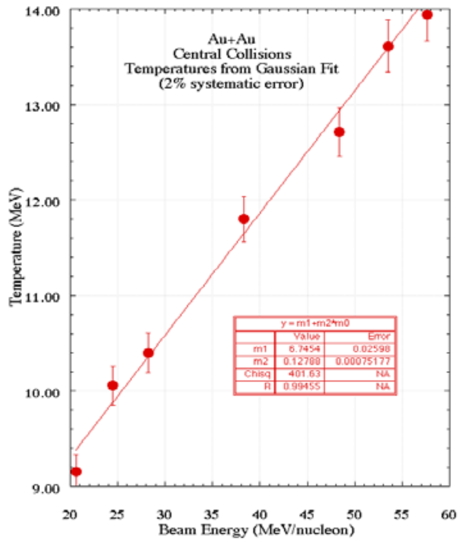
The intention of this Project was to extract information from the thermal model calculations for collisions at beam energies from 20 to 60 AMeV in order to ascertain more knowledge of the nuclear equation of state (EOS). We extracted information about nuclear equation of state because energy gets stored in compression and released, therefore creating longitudinal flow. If we were to assume that longitudinal flow in a central Au-Au collision exists then it can be speculated that two nuclei collide in a perfectly inelastic collision and form a thermal system. We attempted to show that there is a non-uniform thermal model for longitudinal flow in all Au-Au heavy-ion collisions at these intermediate energies, and therefore that the rapidity distributions of the resultant nuclei cannot be described by the model.

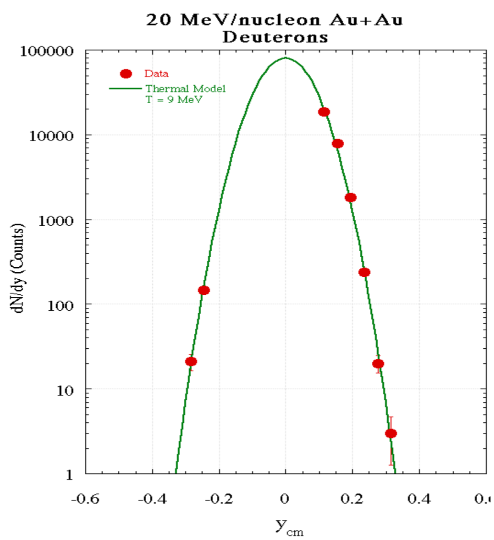
MATERIALS & METHODS

Using thermal model fits to dN/dy of extracted temperatures for protons at all energies, I used thermal model calculation varying the temperature to get the best fit (lowest $\chi 2$).



Using those same temperatures, by taking temperatures for protons at the given energies and using my thermal model code to make dN/dy calculations, I produced thermal model predictions for deuterons, tritons, Z=2, and Z=3.

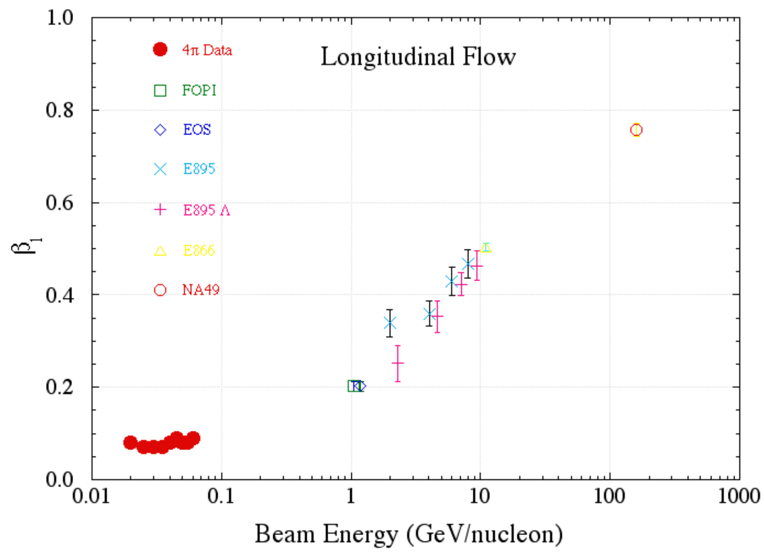




I used the sums of the thermal models to fit data file ($\int_{-y_{max}}^{y_{max}}(dN/dy')dy'$) in order to use longitudinal flow fits to extract longitudinal flow velocities, β_L, for deuterons, tritons, Z=2, and Z=3. I will compare these results with results that have already been calculated for higher energies.

CONCLUSION

When compared with data already calculated for higher energies, my data matched the predictions, and the collision was shown to appear perfectly inelastic.



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