CONF-930636--12

Transverse Energy Production with Si and Au Beams at AGS Energy: 7.2 & 13.8 GeV Towards Hot and Dense Hadronic Matter

Jean Barrette

Foster Radiation Laboratory, McGill Univ., Montreal, Canada H3A 2B2

For the E814/E877 Collaboration: BNL, GSI, LANL, McGill Univ., Univ of New Mexico,
Univ. of Pittsburg, Univ. of Sao Paulo, SUNY-Stony Brook, Texas A&M Univ., Wayne
State Univ., Yale Univ.

1. Introduction

One of the main goals of the present heavy-ion reaction studies at the AGS and CERN is the understanding of the space-time evolution of the particle and energy density produced in such collisions. These are necessary ingredients if one wants to understand quantitatively the properties of matter at high temperature and density. In that respect, the study of inclusive global variables such as the transverse energy distribution gives valuable information on the reaction dynamics and, albeit indirectly, on the energy and baryon density reached in nucleus-nucleus collisions.

In the spring of 1992, the AGS produced the first beam of very heavy ions, more specifically a beam of 11.4 GeV/c per nucleon ^{197}Au . This is an important step for our field since it gives a first glimpse as to how the reaction dynamics evolves as the mass and volume of colliding systems reach the largest value that will be available in the future. We have used part of the E814 experimental set-up to study the transverse energy distribution produced in Au induced collisions. These data can be compared to similar data obtained with lighter beams and thus provide for the first time information on how the E_T distribution evolves with the mass of the system as one reaches very large systems. Part of these data has recently appeared in print [1].

2. Experimental set-up

The E814/E877 experimental set-up is described in refs. [2-4]. It is characterized by it nearly 4π calorimetric coverage. The target calorimeter (TCAL) covers the backward hemisphere ($-0.5 < \eta < 0.8$) while the participant calorimeter (PCAL) measures the energy flow in the forward hemisphere ($0.83 < \eta < 4.7$). The target calorimeter is made of 992 NaI crystals, 5.3 radiation length deep. The participant calorimeter is a scintillator tile calorimeter with lead/iron absorber, 4 absorption length deep. The analysis procedures for TCAL are described in refs. [2,3]. The correction for the response of the detectors and for leakage is obtained by tracking through the calorimeter events generated using

MASTER

the code GEANT. For data from PCAL, the transverse energy distribution corrected for leakage are obtained using a Monte-Carlo generated response matrix method described in more details in refs [1,5].

3. Results and Discussion

The measured distributions $d\sigma/dE_T$ for Au+Au and Si+Au are shown in fig. 1 where they are compared to the predictions of various models. For the comparison with TCAL data, model calculations are filtered with the detector response. Good agreement is observed with the predictions of the ARC model [6] (open squares). The Lund string fragmentation model FRITIOF [7] (dashed lines) with parameters tuned to pp collisions at AGS energies also reproduces relatively well the Au+Au data but overpredicts the maximum E_T for Si+Al system. Finally the RQMD model [8] (close circles) overpredicts considerably the data for both systems in the PCAL acceptance while it underpredicts TCAL data by the roughly the same fraction.

FIG. 1. Comparison of the measured total E_T distributions (histograms) with the predictions of various models (see text).

FIG. 2. Experimental $d\sigma/dE_T$ distributions in the PCAL acceptance. The dashed lines are the calculated contributions from collisions with $b < 0.5$ fm. The dotted line corresponds to the Si+Al data scale up by a factor $E_T^0(\text{Au})/E_T^0(\text{Si})$.

The abrupt fall-off at large E_T in the Au+Au data shows that the fluctuations in heavier systems are considerably reduced. This is shown by the dotted histogram in Fig. 2 which was obtained by scaling up by a factor 7.9 the Si+Al PCAL data. Because of this large difference in shape, the comparison of E_T production for the two systems should not be done at a fixed cross section level or a fixed fraction of the geometrical cross section. To compare the two systems we followed the procedure described in ref. [9]. We determine the mean transverse energy, E_T^m , for collisions with $b < 0.5$ fm using different models and then calculate the fraction of the geometrical cross section leading to $E_T > E_T^m$. Although predicting different values of E_T^m , all models give similar fractions of the cross section with

an average value of σ/σ_{geom} of 1.5% for Si+Al and 0.22% for Au+Au. When applied to our data, these fractions (which determine E_T^0 , the E_T for an average collision with $b < 0.5$ fm) give $E_T^0(\text{Si})=40.2$ GeV and $E_T^0(\text{Au})=318.5$ GeV (dashed lines in Fig.2).

FIG. 3. Parameters of the Gaussian functions describing the PCAL $dE_T/d\eta$ distributions as function of E_T/E_T^0 . Results from ARC model calculations are also included: Si+Al (solid lines), Au+Au (dashed lines).

Fig.3 gives a comprehensive picture of the evolution of the E_T distributions as a function of centrality for four systems of different size. It shows the evolution of the parameters (amplitude B , width σ_η , and centroid η_0) of the Gaussian that best described the $dE_T/d\eta$ distribution vs E_T/E_T^0 . One observes first that, for all systems, the peak value B of the $dE_T/d\eta$ distribution increases linearly with the produced total transverse energy. This increase is correlated with a sizable decrease in the width of the E_T distribution by roughly 0.4 unit of rapidity (or $\approx 30\%$) between peripheral and the more central collisions. A similar effect has been observed in the charged particle multiplicity distributions measured with Si projectiles [4]. As stated above, one observes also that the width gets narrower as the mass of the system increases. Finally, for light projectiles on heavy targets the distributions move backward in η as function of centrality while the inverse is observed for reactions of heavy projectiles on light targets. This effect can be understood as being due to the evolution with centrality of the rapidity of the center of mass of the participant region. Both the ARC and RQMD models reproduce well the decrease of the width with the mass of the system and with centrality. However, for symmetric systems both models give centroids which are shifted forward by roughly 0.3 unit of pseudorapidity relative to the data.

These results allow to characterize the evolution with the mass number of the E_T production. E_T^0 increases by a factor of 7.9 when going from Si to Au projectiles (see fig. 2). At mid-rapidity E_T increases even more, by a factor of 8.8, because of the narrowing of the $dE_T/d\eta$ distribution for heavier beams. Many aspects of heavy-ion data obtained with light projectiles are explained qualitatively within a geometrical picture based on the number of nucleons in the overlap volume of the target and projectile [9]. In this picture, E_T production is expected to be proportional to the available energy in the center-of-mass, E^* . For symmetric A+A collisions at impact parameter $b=0$, E^* reaches a maximum given by $E^* = m_N A (\sqrt{2 + 2E_{lab}/Am_N} - 2)$ which, at the present beam energies, results in a ratio of available energy for central collisions of $E^*(Au)/E^*(Si)=5.9$. To describe the evolution of E_T with the mass of the system we introduced the parametrization $E_T \propto E^* A^\alpha$ where a nonzero value of α would indicate a departure from this simple picture. The observed increase of a factor 8.8 in E_T^0 at midrapidity corresponds to a value $\alpha = 0.20 \pm 0.02$. This large value of α implies an increase in E_T production of a factor of ≈ 1.5 (i.e. $(197/27)^\alpha$) for the Au+Au system relative to the Si+Al system as compared to what is expected for independent nucleon-nucleon collisions. Such a relative increase is in agreement with the prediction of models where it can be associated to an increase in the energy and baryon density achieved in Au+Au collisions. For example the ARC model, which reproduces our data, predicts for that system a maximum baryon density ≈ 10.5 times normal nuclear matter density. This model also predicts that a large density ($\rho/\rho_0 > 5$) is reached over a volume of $\approx 40 \text{ fm}^3$, much larger than the volume of maximum baryon density in Si+Al collisions ($\approx 5 \text{ fm}^3$).

4. Conclusion

In conclusion, the first results obtained with very heavy beams are very encouraging and give all indications that with these beams one reaches new and indeed extreme values of energy and baryon density. Furthermore the larger volume and longer period over which these are produced should facilitate the characterization of this hot nuclear matter and thus allow to evidence more easily possible new phenomena like partial deconfinement.

References

1. J.Barrette *et al.*, E814 Collaboration, Phys. Rev. Lett. 70, 2996 (1993).
2. J.Barrette *et al.*, E814 Collaboration, Phys. Rev. Lett. 64, 1219 (1990).
3. J.Barrette *et al.*, E814 Collaboration, Phys. Rev. C 45, 819 (1992).
4. J.Barrette *et al.*, E814 Collaboration, Phys. Rev. C 46, 312 (1992).
5. Z. Zhang, Ph.D. thesis, Univ. of Pittsburg, 1993 (to be published)
6. Y. Pang, T.J. Schlagel, and S.H. Kahana, Phys. Rev. Lett. 68, 2743 (1992).
7. B. Anderson, G. Gustafson, and B. Nilsson-Almqvist, Nucl.Phys. B281, 289 (1987).
8. H. Sorge *et al.*, Nucl. Phys. A525, 95c (1991).
9. J. Stachel and G.R. Young, Ann. Rev. Nucl. Part. Sci. 42, 237 (1992).

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

END

DATE

FILMED

3 / 30 / 94