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Winter Workshop on Nuclear Dynamics
Key West, FL
January 31 - February 5, 1993

MESON PRODUCTION IN RELATIVISTIC HEAVY-ION COLLISIONS AT AGS ENERGIES

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ABSTRACT

Single particle inclusive spectra are presented for pion and kaon production in Si+Au reactions at an incident momentum of 14.6 A·GeV/c and Au+Au reactions at an incident momentum of 11.6 A·GeV/c. A simple geometric scaling of the pion production for central collisions as $A_{proj}^{1/3}$ and $A_{targ}^{2/3}$ results from the observed production of about one pion per participant. Kaon yields are shown to be proportional to the number of excited participants and consistent with RQMD and ARC calculations.

1. Introduction

Meson production has been an interesting topic of investigation since enhanced strangeness (kaon) production was observed by experiment E802 in Si+Au reactions [1]. Furthermore, it has been a driving force for these investigations that new states of nuclear matter, such as the quark-gluon plasma (QGP), might be formed if baryonic densities exceeded some critical value. A possible signature for such a new process would be the observed deviation in the systematic behavior of particle production as this new state, with increased degrees of freedom, hadronized. The recently developed second-level trigger for experiment E802, allowing "on-line" particle identification (E859), and the newly commissioned gold beams at Brookhaven have produced measurements (E866) with a greatly expanded range of conditions under which we can measure particle production rates. The gold beams may also offer the possibility to reach densities twice as large as the maximum density reached with central Si+Au collisions, and close to what is expected to be necessary for QGP formation. So far, no signatures for a new process have emerged, although a good understanding of pion and kaon production has emerged.

Some tentative understanding obtained from previous work with p, O, and Si beams (E802) is now solidified with the larger range of conditions and improved statistics now available. For example, it was found [2] that pion production scales

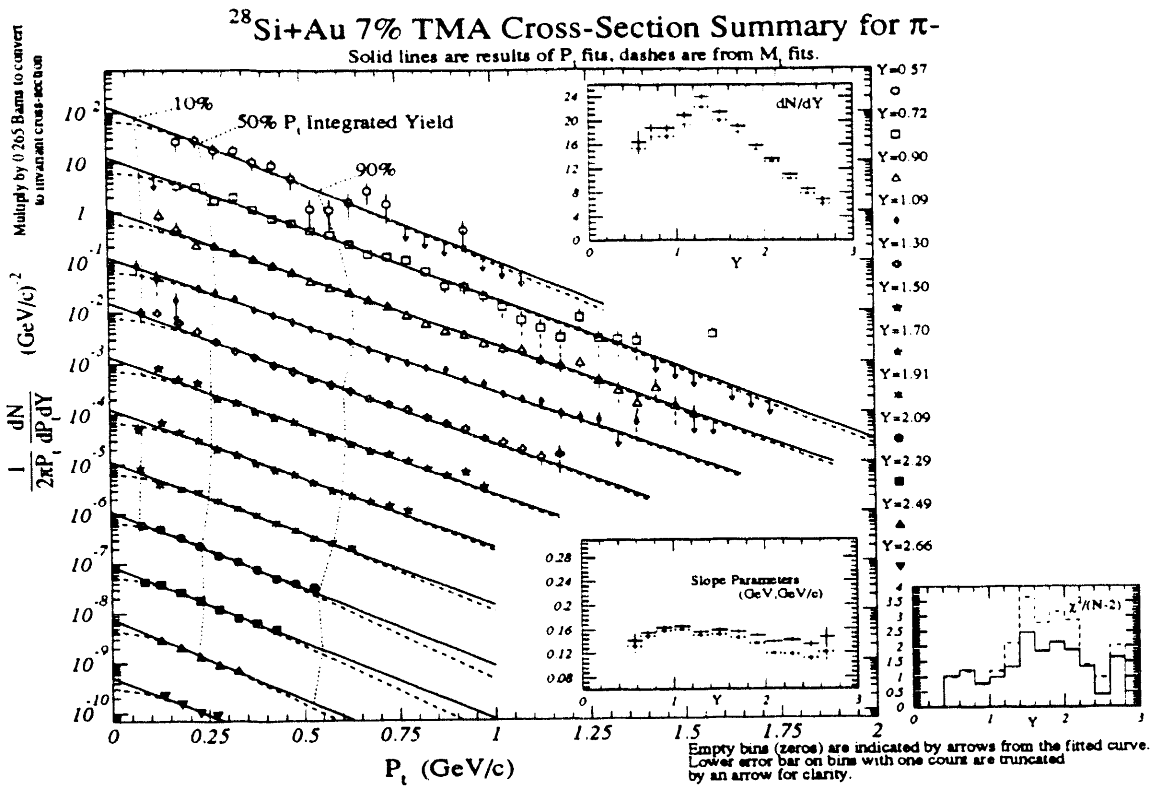

Fig. 1: Invariant cross sections of π^- from central 14.6 A·GeV/c Si+Au collisions for various rapidity slices. Each spectrum is displaced by a power of 10 for clarity. The solid lines show fits to p_t distributions; the dashed curves show fits to m_t distributions. (From Ref. 2)

as the number of participants. Recent work with Au beams confirms this geometric scaling. Kaon production has been found to depend more critically on the number of multiple collisions [2,3]. During this past year, models developed specifically for AGS energies, such as RQMD [4] and ARC [5] now yield detailed results available for comparison. Thus, this confluence of much improved data and new theoretical developments offers an opportune time to analyze how successfully we understand meson production in this energy regime dominated by resonance formation.

2. The Experiment

Experiment E859 was designed to provide enhanced data collection for rare events, such as kaon and anti-baryon production and two-particle correlations, particularly $\pi^-\pi^-$, K^+K^+ and K^+K^- (phi). Using two planes of multi-wire proportional counters together with the TOF hodoscope behind the spectrometer magnet, particle identification within 40 μs is possible for candidate tracks. By then selecting desired events for recording, beam intensities could be raised, and enhancement of data collection rates by a factor of 10 to 40 is possible, depending on event type. Furthermore, a segmented gas Cherenkov counter was installed behind the TOF hodoscope in order to extend particle identification for kaons beyond a momentum of 2.2 GeV/c. As a

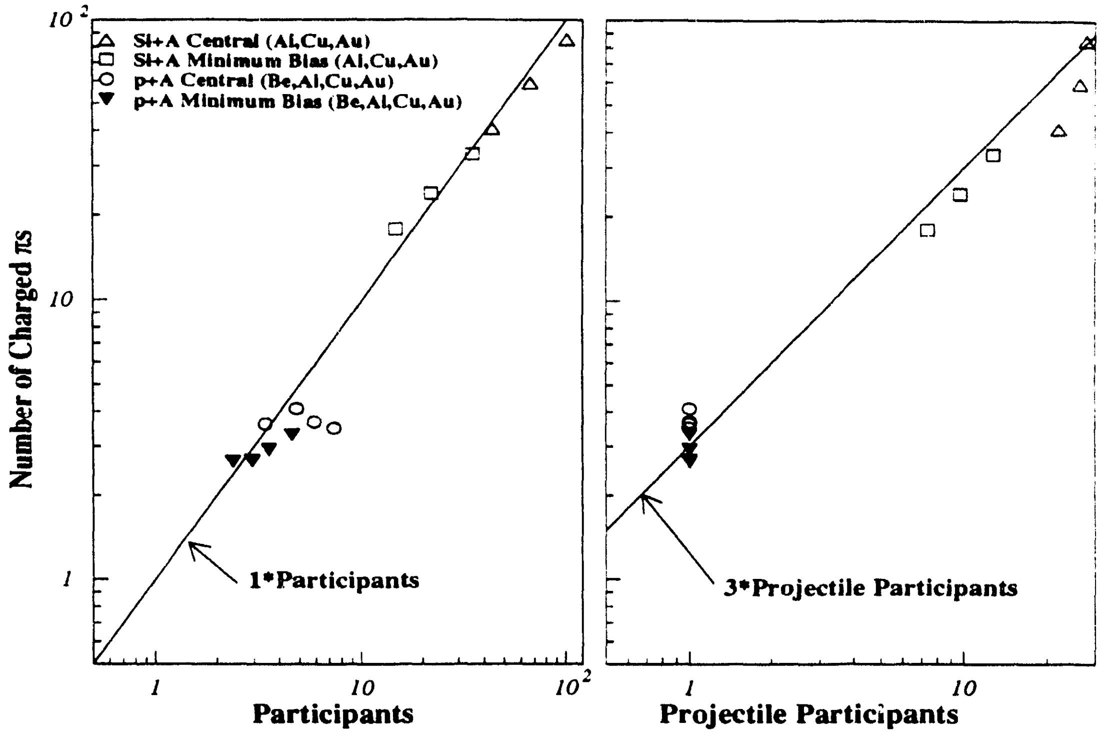

Fig. 2: The number of charged pions for a variety of collision geometries is plotted versus the number of participants, assuming a clean cut geometry, in the left panel. The same data are shown as a function of the number of projectile participants in the right panel. (From Ref. 2)

result, there are now measurements of the kaon slopes and rapidity distributions over a broad y range with good statistics, not just at mid-rapidity. As with E802 there are devices for global event characterization. Central collisions are selected as those which have the largest charged particle multiplicity, which correspond to the upper 7% of the cross section. This is an effective trigger for asymmetric collisions such as Si+Au.

For the study of Au+Au collisions (E866), major modifications are being made to the present spectrometer to increase segmentation. Furthermore, a new smaller solid-angle spectrometer (about 5 msr, compared with the present 25 msr) is being constructed for use at forward angles, with planned completion by August, 1993. Using the partially upgraded present spectrometer, about 5 days of data were collected for Au+Au collisions. For these collisions the present charged-particle multiplicity array is unusable, due to the factor of about 5 increase in occupancy. However, an upgraded forward calorimeter (ZCAL), which subtends a 1.2° cone about 0°, provides an excellent hardware trigger for the geometrical overlap of projectile and target. Within this hardware selection, software cuts were applied to define central collisions as roughly the upper 4% of the inelastic cross section ($E_{proj} \leq 300$ GeV/c).

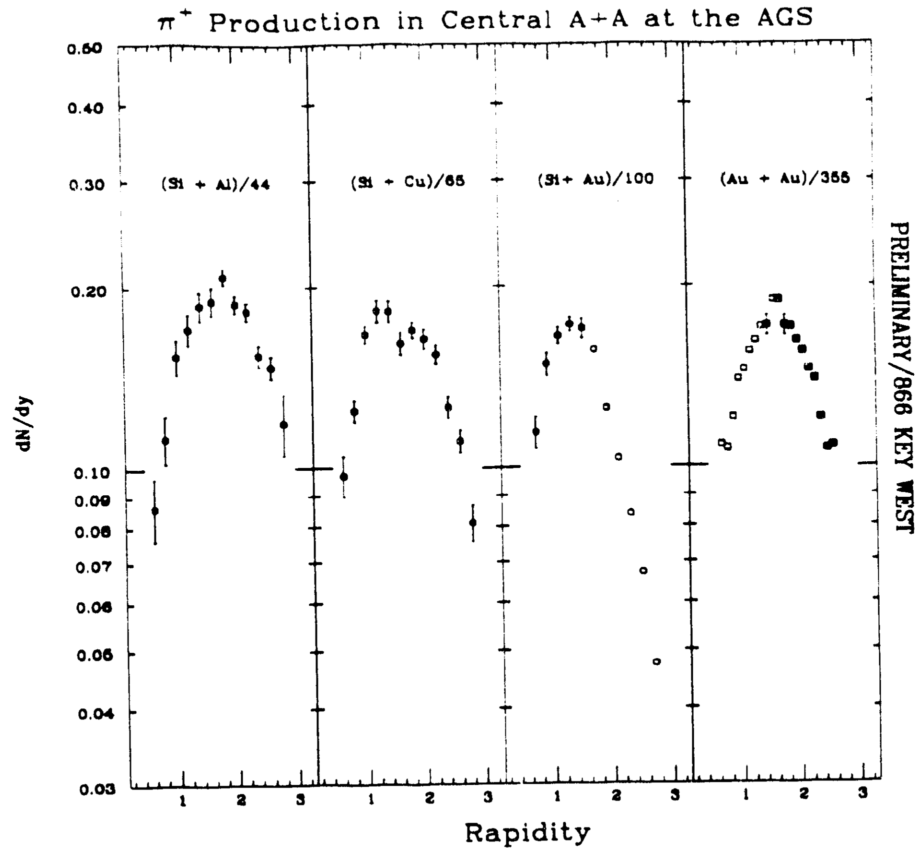

Fig. 3: Rapidity distribution for π^- production for central Si+A and Au+Au collisions.

3. Single particle semi-inclusive spectra

The pion production data from Si+Au collisions from experiment E802 have been reanalyzed [2,6]. Many small corrections have all contributed to increasing the measured yields. The π^- invariant cross-sections from this re-analysis are shown as a function of p_t for central Si+Au collisions in Fig. 1. It is seen that the data are somewhat better described by an exponential dependence in p_t as opposed to m_t. One finds that the yield for π^- somewhat exceeds the yield for π^+, as one might expect given the neutron excess in the participants. Combining the p, O, and Si results, one can plot the total measured yield as a function of the number of participants, assuming a clean-cut geometry. This is shown in Fig. 2, where it is seen that about one pion per participant is produced. Proceeding to a comparison of Si and Au induced reactions with a variety of targets, one is able to directly see this comparison, since for central collisions the participant tube should be proportional to the projectile cross-sectional area and the target diameter. This is demonstrated in Fig. 3, where Si and Au induced reactions are compared.

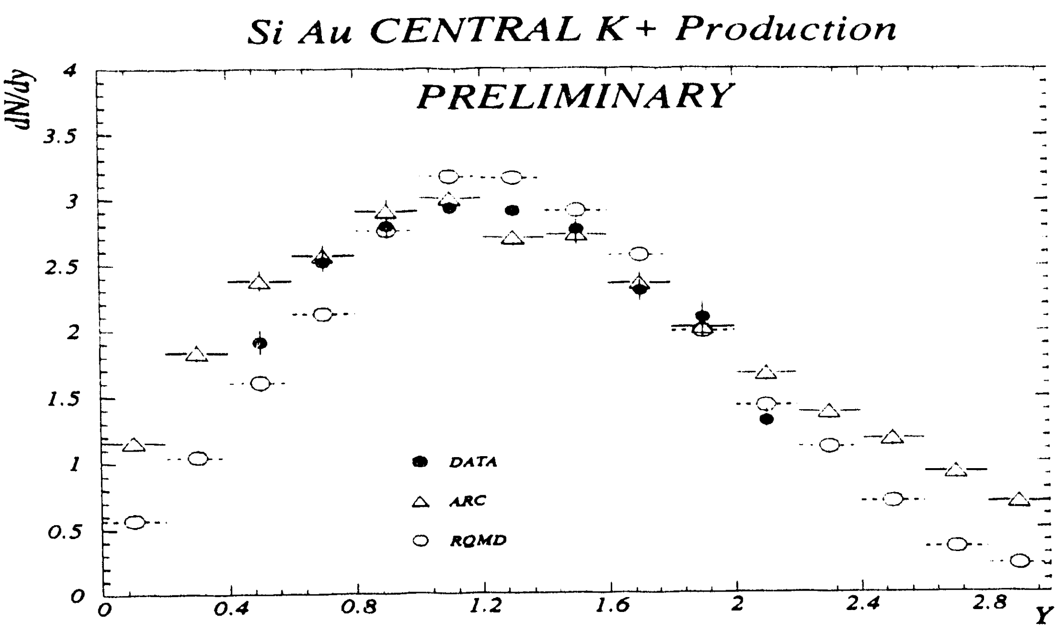

Fig. 4: Rapidity distribution for K^+ for central Si+Au collisions, obtained from exponential m_t fits to the data, with comparisons to model predictions ARC (Version 1.15) and RQMD (Version 1.08).

Kaon production, however, cannot be described with such a simple geometric dependence. The K^+ rapidity distribution, assuming an exponential m_t dependence for the invariant cross sections, is shown in Fig. 4 for central Si+Au collisions [7]. Also shown in Fig. 4 is a comparison to a calculation using the models ARC (Version 1.15) and RQMD (Version 1.08). It is observed [2,8] that the K^+/π^+ particle production ratio is proportional to the number of *excited* collisions per participant, as shown in Fig. 5. This number is found by subtracting the number of projectile participants from the total number of binary collisions (in order to subtract off the first hits) and dividing the difference by the total number of participants. This shows the importance of multiple collisions in the production of strangeness. The collisions of excited resonances with additional projectile and target baryons is uniquely possible with A+A collisions; it is this new feature that can be investigated in this energy region. As the rapidity distribution peaks behind the participant $y_{cm} = 1.25$, it was suggested [9] that rescattering of the produced particles with target spectators might lead to the strange quark enhancement. This no longer seems such an obvious explanation.

Whereas K^+, which contain the $\bar{s}$ quark, are predominantly produced by associated production with lambdas, the K^- are thought to be produced mostly as K^+K^- pairs. Thus, it is interesting to see how the rapidity distributions may differ from K^+. In Fig. 6 one sees the K^- production for central Si+Au collisions. It is observed that the rapidity distribution is peaked at the participant y_{cm}. Finally, we see in Fig. 7 a comparison of the π^+, K^+, and K^- production for Au+Au collisions, where the solid points show the data at higher rapidities, which can be obtained for symmetric collisions by reflection about y_{NN}. The excellent description by the ARC model results,

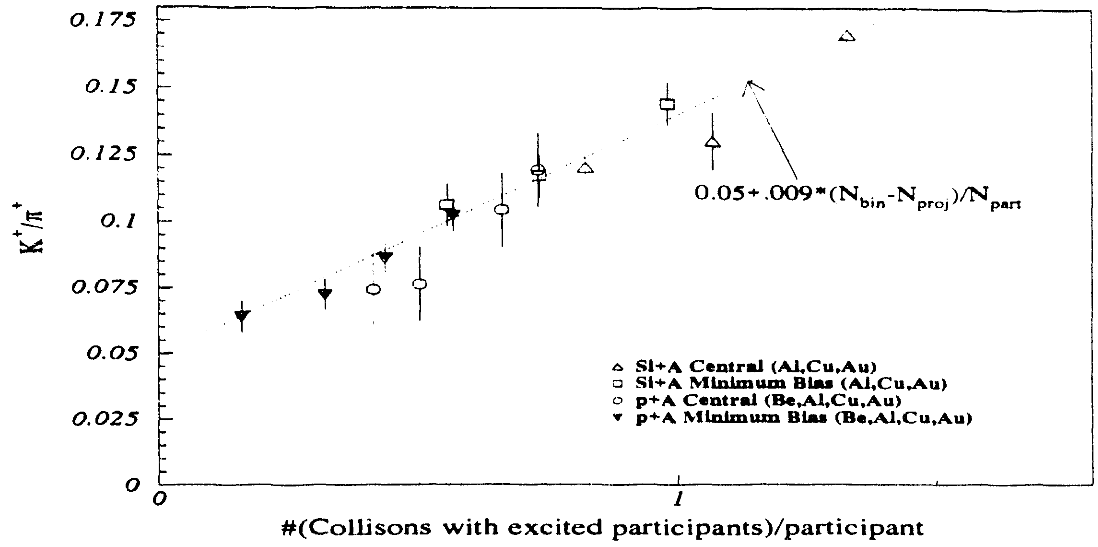

Fig. 5: The K^+/π^+ production ratio for central Si+Au collisions as a function of the number of excited participants per participant, as described in the text. (From Ref. 2)

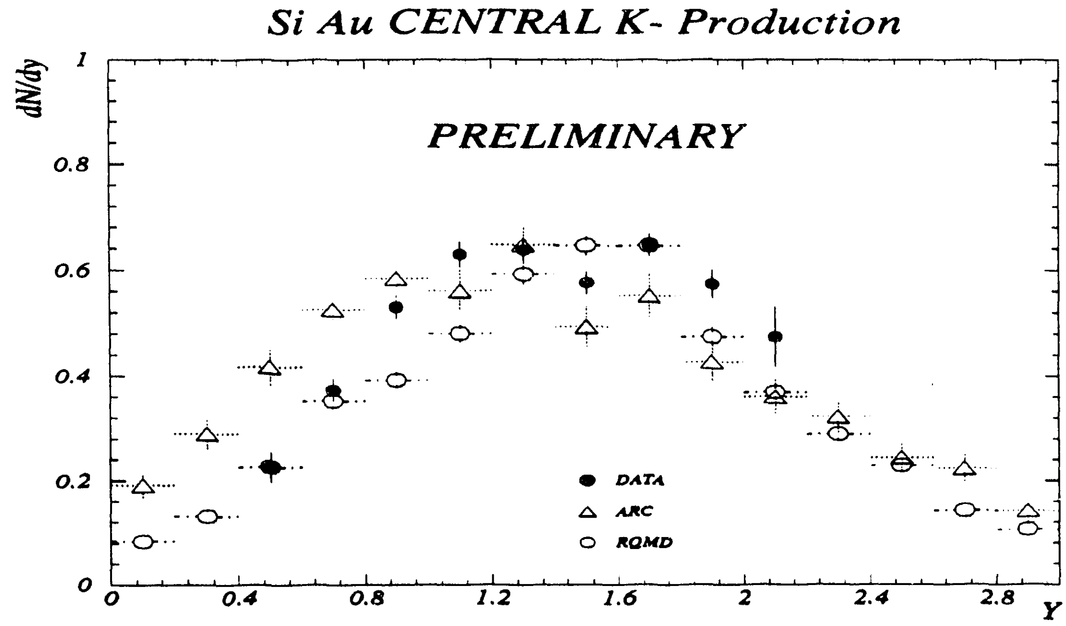

Fig. 6: Rapidity distribution for K^- for central Si+Au collisions, obtained from m_t exponential fits to the invariant cross sections, with comparisons to model predictions ARC (Version 1.15) and RQMD (Version 1.08).

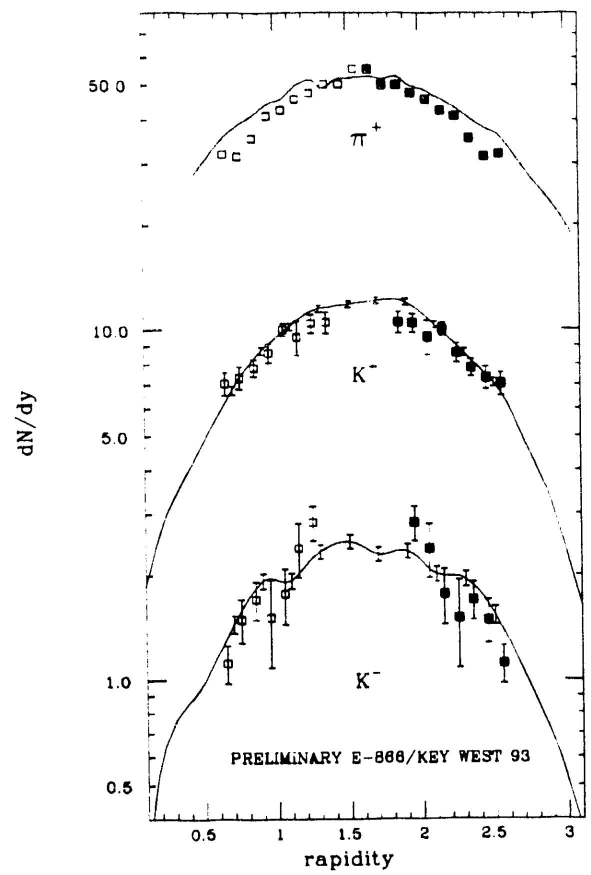

Fig. 7: Rapidity distribution for π^+, K^+, and K^- production for central Au+Au collisions, with comparisons to the model prediction for ARC (Version 1.15).

calculated within the E866 acceptance, is also shown.

4. Conclusions

Meson production at AGS energies is a probe of new physical processes that are possible in A+A collisions, namely the collisions of resonant states with additional baryons in the entrance channel. It is found that the charged pion production scales simply as the number of participants, with about one charged pion per participant produced. The kaon production depends on the number of multiple collisions. It is shown that the K^+/π^+ particle production ratio is proportional to the number of excited collisions per participant. The meson production is well described by both ARC and RQMD model predictions.

5. Acknowledgements

The analysis of the data presented here was mostly carried out by Chuck Parsons (E802), Ted Sung (E859), and Michel Gonin (E866), to whom I am greatly indebted for providing the figures. Thanks are also given to T.J. Schlagel, S.H. Kahana and Y. Pang for allowing the ARC predictions to be shown prior to publication. Also, thanks are given to H. Sorge for allowing use of the RQMD calculations prior to publication.

Experiments 802, 859, and 866 are supported in part by the U.S. Department of Energy contracts and grants with ANL, BNL, UC-Berkeley, UC-Riverside, Columbia, LLNL, and MIT, in part by NASA under contract with UC-Berkeley and by the US-Japan High Energy Physics Collaboration treaty.

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