1 High Baryon Density Heavy Ion Physics

The regime of heavy ion physics which can be realized at the AGS is that of near maximal density baryonic matter. A rich variety of physics is available with these conditions. This is especially true in the light of the high intensities available with the AGS heavy ion beams. The AGS fixed target physics program will not have achieved even a majority of the interesting studies possible by the time RHIC begins operating.

While the physics of RHIC is clearly of primary interest, there are a number of reasons why it will be scientifically important to continue to explore the physics regimes of the AGS. The fundamental reason is that a full understanding of the behaviour of hadronic matter in the new conditions made possible by high energy heavy ion collisions requires an understanding of the baryon rich regime as well as the hot (presumably) baryon free central regions made available at RHIC.

Along with this basic reason there are possible new "exotic" states of nuclear matter which can only be created at the AGS. These include strangelets and high strangeness hyperfragments involving both Ξ and Λ hyperons. The existence of strangelets is of course not a certainty but if they did exist, they would be very important both for fundamental and practical reasons. The existence of the high strangeness hyperfragments is also not "guaranteed" by our current understanding but is suggested by the present state of knowledge of hyperfragments and low baryon number nuclear physics. Such high strangeness hyperfragments could exist with arbitrarily large strangeness. They would obey a new nuclear physics in which there were four hadrons (Ξ, Λ, p, n) instead of two (p, n).

Some specifics on most of these topics are given below in the section on the "upgrade" of E-864. Many more are possible.

In addition to the primary scientific drive there are technical and educational reasons to pursue a active AGS program. The high marginal productivity of the AGS program (the AGS must be kept in a "warm" operating state to serve as an injector to RHIC) means that fixed target experiments require only incremental resources associated with the beam line and the detector. The experiments are by nature smaller than collider experiments and can turn over faster. They provide flexibility in the program and an invaluable opportunity for younger physicists to gain leadership experience and to see an experiment from inception to analysis.

To date one activity has been undertaken under the auspices of the AGS 2000 workshop and this is listed below.

1.1 Upgrade to E-864

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The present configuration of E-864 includes a number of valuable features:

1. a high rate capability ($> 10^6$ interactions per second)
2. A fast ($\sim 300ns$) flexible, second level trigger based on late energy in the calorimeter.
3. A calorimeter which can accurately measure time ($\sigma = 400ps$) and energy deposited ($\sigma = .5\sqrt{E}/E$), and which covers a large region with good segmentation.
4. A straw tube system which provides accurate measurements of tracks downstream of the analyzing magnets.
5. A three plane segmented hodoscope system which provides excellent particle identification and provides "roads" for the straw tracking analysis.

However, the design of E-864, especially the collimation and the "geometry" of the two analyzing magnets is such as to limit the applicability of the setup (to the topics for which the experiment was proposed). In particular, there are two directions into which it would be desirable to extend the capabilities. These are:

1. The present setup is not sensitive to lifetimes much shorter than 50 ns. It would be very useful to redesign the front end of E-864 so that particles of more typically hyperonic lifetimes could be observed and measured.
2. Because the present design was made for baryon studies, it has essentially no acceptance for particles with magnetic rigidity below $\sim 1.5GeV/c$. there are a number of very interesting topics which could be addressed if acceptance for low rigidity particles could be added to E-864.

The basic idea of the upgrade is to modify the front end of the experiment so that it detects nearly all the particles emitted in the collision and measures their momentum. The downstream part of the experiment would be left essentially as is and would be used to detect and measure the baryonic "fragment" of any N^*, hyperon, strangelet, or "MEMO". The present thought (which needs detailed work!) is to open up the gap of the first magnet and to install a TPC in it. This TPC should have the capability of measuring all (or most) of the tracks entering it from a central Au-Au collision. In addition we would like the TPC to be able to handle an interaction rate of 10^5. The typical drift times are a few μsec so the intrinsic time resolution is there. the problem of course will come from the read out electronics. The central interaction trigger and the E-864 second level trigger are fast enough to use with a gating grid in the TPC and will facilitate reaching the goal.

Some of the physics topics which could be addressed with such a new. upgraded, E-864 are listed below:

- Search for strangelets with hyperonic lifetimes. There is one physics scenario which would predict that all the strangelets made at the AGS would undergo "weak neutron" decay (decay via the weak interaction into a neutron and a baryonic remnant which would in turn decay, etc.). This is the model in which a strangelet production occurs via a QGP and the QGP undergoes "strangeness distillation" and produces a strangeness rich strangelet remnant. As soon as a strangelet charge is reached in the hadronization of the QGP for which the strangelet is stable under the strong interaction, the distillation ends. This could produce all strangelets with strangeness on the high side. It is just these that according to the bag model theory (e.g. Fahri and Jaffe) would decay by the "weak neutron" process. The lifetime associated with the weak neutron decay (since it is a two body process) is of the same order as hyperon lifetimes. As noted above, the downstream part of E-864 can be used to enhance the trigger rate for nuclear isotopes formed after (via) the strangelet decay.

  To establish the existence or non existence of strangelets which could be made at the AGS, this hyperon lifetime "window" must be closed.

- Search for and study of high strangeness hyperfragments. The experimental aspects of this are similar to those for the search for hyperon lifetime strangelets. Indeed, as these particles are more or less expected, discriminating between them and true (strange quark matter) strangelets will be important. Many precise details allow,this to be done (e.g. the charge is expected to be negative for the strangelets and positive for the hyperfragments, etc.). As noted above, these objects open a new nuclear physics. Also as noted above, the downstream part of E-864 can be used to enhance the trigger rate of various nuclear cores, e.g. alpha particle cores of the ${}^{7}_{\Xi^0\Lambda\Lambda}He$.

- Search for the strangeness distillation process itself. The "distillation" process does not require the existence of strangelets to operate. If there are no strangelets, the distillation process will still leave a remnant (after QGP formation) which has unusually high strangeness. In effect, essentially every baryon in the remnant will be a hyperon. Thus studies of the multiplicity of hyperons will show such anomalous events.

- Studies of the $\overline{N^*}$. The anti isobar is very interesting to observe and study for a number of reasons. One of the most exciting is the possibility of large medium induced mass shifts. The potential between nucleons and antinucleons is much larger (and attractive) than that between nucleons. Since the Q value of the isobar is about 150 MeV, there is "room " to observe a considerable mass shift due to the interaction with the isobar and the nuclear medium in which it is created.