A COMPARISON OF RHIC EXPERIMENTS*

C. HALLIWELL

Department of Physics, University of Illinois at Chicago
845 W. Taylor, Chicago, IL 60607-7059, USA

(Received September 9, 1996)

Comparisons are presented of the ability of RHIC experiments to perform hadronic studies at high energy densities. Emphasis is placed on the "common" physics topics that all four experiments will study. As expected, the two "large" experiments at RHIC will provide rich data sets. However, the two "small" RHIC experiments will also contribute significantly to many of the studies.

PACS numbers: 25.75. Dw, 25.75. Gz, 29.40. Gx, 29.40. Ym

1. Introduction

The four experiments being constructed for the Relativistic Heavy-Ion Collider (RHIC) all have the ability to study hadrons to gain insight into the new physics expected at high nuclear energy densities. Although there is some "overlap" between the experiments (as there should be, so that cross-checks can be made), each experiment will make a unique contribution to these studies. In this report direct comparisons will be made between the experiments wherever possible. However, similar physics topics may be studied by using different kinematic regions and with different sensitivities and resolutions. These aspects will also be pointed out where appropriate [1].

First a brief review of each experiment will be presented in Sections 2 and 3. In Section 4 the measurement of particle distributions will be reviewed followed in Section 5 by a discussion of the methods that will be used to measure event "temperature" and energy density. Finally, a comparison of each experiment's ability to study the production of ϕ mesons will be presented.

---

* Presented at the XXXVI Cracow School of Theoretical Physics, Zakopane, Poland, June 1-11, 1996.

2. Acceptance and particle identification

Detailed descriptions of the RHIC experiments are available elsewhere [2, 3] along with an overall summary of their ability to study the "new" physics anticipated at RHIC [4]. All the experiments will study hadronic production and this is the focus of this report; the detection of leptons and photons will not be considered here. A brief description of each experiment's apparatus is given in this section.

BRAHMS: The *B*road *R*ange *HA*dron *M*agnetic *S*pectrometers experiment is designed to study hadronic production *inclusively* over a wide range of rapidity (y) and transverse momentum (p_t). It will do this by using two moveable spectrometers: a "midrapidity" spectrometer (with an acceptance of 0.008 sr) and a "forward" spectrometer. These spectrometers can be moved through the polar angular regions $30° < \theta < 90°$ ($0 < \eta < 1.3$) (where η is the pseudorapidity variable) and $2° < \theta < 30°$ ($1.3 < \eta < 4.0$) respectively. The flexibility of these spectrometers is crucial to BRAHMS's main goal (see Section 4) but it does restrict BRAHMS to having a much smaller acceptance than the other RHIC experiments.

BRAHMS plans to place a silicon device (similar to PHOBOS's vertex detector, see below) in the primary interaction region. It will cover the range $|\eta| < 2.5$ and will primarily function as a charged hadron multiplicity detector.

Hadron identification will be achieved using time of flight (TOF) arrays in each spectrometers. These arrays will be augmented by segmented threshold and ring-imaging Cherenkov (RICH) detectors. The "midrapidity" spectrometer will identify pions with $p_\pi < 3.3$ GeV/c and kaons with $p_K < 5.7$ GeV/c; the "forward" spectrometer (using its RICH counter) will identify pions and kaons with $p_\pi < 25$ GeV/c and $p_K < 35$ GeV/c respectively. These momentum ranges for identifying hadrons are the largest of the four RHIC experiments.

PHENIX: The *P*ioneering *H*igh *E*nergy *N*uclear *I*nteraction e*X*periment will detect hadrons using one of the arms of its two-arm Central Magnet Spectrometer. The kinematic range $|y| < 0.35$ and $\Delta\phi = 30°$ will be covered resulting in a 0.36 sr acceptance. Additional hadron detection will be provided by a two-layer silicon vertex detector which will allow multiplicity measurement in the range $|\eta| < 2.65$. Only minimal tracking will be possible in this detector because of its high occupancy rate. However, it will be able to measure the angular distribution of charged hadrons (without particle identification) on an *event-by-event* basis.

Of the two "large" RHIC experiments, PHENIX's hadron acceptance is smaller than STAR's (see below). However, this is compensated somewhat by its superior particle identification. Using a TOF array placed $\sim 5\ m$ from the primary interaction point, pions with $p_\pi <$ 2.5 GeV/c and kaons with $p_K < 4.0$ GeV/c will be identified.

PHOBOS: Hadron detection in PHOBOS will be achieved using several annular silicon pad arrays placed in the vicinity of the beam pipe. They will all have a granularity of $\Delta\eta = 0.1$ and $\Delta\phi = \pi/16$. They will be augmented in the interaction vertex region by a two-layer highly-segmented silicon device. This set of detectors will allow measurement of η and ϕ distributions of charged secondaries in the same manner as PHENIX's vertex detector but over a larger angular range, $|\eta| < 5.4$.

1% of all charged hadrons will be studied in detail in the mid-rapidity region using a two-arm multi-particle magnetic spectrometer, each arm subtending 0.2 r in ϕ and $0.5 < \eta < 1.5$. Particle identification in this spectrometer will be achieved using TOF arrays which will identify pions and kaons with $p_t < 1.2$ GeV/c and $p_t < 1.9$ GeV/c respectively. Pions and kaons with $p_\pi < 0.6$ GeV/c and $p_K < 1.0$ GeV/c respectively will be identified by their deposition of energy in the spectrometer's silicon detectors. Pions and kaons with lower momenta (down to $p_\pi = 0.06$ GeV/c and $p_K = 0.14$ GeV/c) will be identified through the "ranging out" in the silicon detectors.

STAR: The *S*olenoidal *T*racker *A*t *R*HIC will study hadrons using three detectors: a time projection chamber (TPC), a TOF array and a silicon vertex tracker (SVT).

The TPC will have 2π azimuthal coverage and will track charged particles with $|\eta| < 2$. This tracker will be augmented by additional TPCs in the forward kinematic region ($2 < |\eta| < 4.5$). Secondaries with $p_t < 40$ MeV/c will not be detected in the TPC due to spiralling before entering its inner radius; particles with $40 < p_t < 150$ MeV/c will have their trajectories only partially reconstructed exiting the TPC through its end plate.

The SVT will consist of three layers of silicon drift detectors covering $\Delta\phi = 2\pi$ and $|\eta| < 1$. This detector will have a significant impact on STAR's tracking efficiency at low p_t (for example, increasing it from 30% to 85% at 100 MeV/c [4]). It will also will be essential in the reconstruction of strange particles used in K_s^0-K_s^0 correlation studies (see Section 5.2.2).

STAR's TOF array will be placed $\sim 2.5\ m$ from the primary interaction vertex. dE/dx measurements in the TPC and TOF measurements will allow pions to be identified with $p_\pi < 1.1$ GeV/c and kaons with $p_K < 2.4$ GeV/c.

3. Data collection rates

As can be seen from Section 2, the RHIC experiments differ greatly in their geometrical acceptances (hence the terminology "large" for PHENIX and STAR and "small" for BRAHMS and PHOBOS). The advantages the "large" experiments gain from their acceptances is somewhat offset by restrictions on their data collection rates.

The **maximum** instantaneous data collection rate in all RHIC experiments will be restricted (for hardware reasons) to $\sim 20\ M$bytes/s. This will primarily affect STAR because its event size will be $\sim 16\ M$bytes. This means that its collection rate will be restricted to $\sim 1\ Hz$.

PHENIX's event size will be less than STAR's (300 Kbytes) and, if a data sample of 800 T bytes/year is possible [5], their data collection rate can be as high as 70 Hz.

In contrast to the two "large" experiments, the "small" experiments will be able to collect data at a much higher rate ($\sim 250\ Hz$) because of their small event size ($\sim 10 - 20\ K$bytes). Their data samples, totaled over a year, will be comparable in size to those from the "large" experiments and consequently BRAHMS and PHOBOS should be able to perform competitive physics studies from a statistical point of view.

4. Particle production

The capability of the RHIC experiments to study hadronic physics is estimated using Monte-Carlo simulations. Presently, the simulations differ greatly in their predictions of the physics of a $\sqrt{s} = 200$ GeV/nucleon central Au-Au collision. This leads to large uncertainties in predicting the anticipated performance of a particular experiment.

The predictions of baryon and meson production from VENUS [6], HIJING [7], FRITIOF [8] and RQMD [9] differ because of their fundamental physics assumptions. For example, RQMD assumes that a nucleus-nucleus interaction involves diquarks colliding incoherently within the nucleus and large formation times are ignored. Consequently, it predicts a far higher net baryon density at $y = 0$ then FRITIOF and HIJING which assume that the diquark propagates unscathed through the nucleus and fragments into a baryon and mesons outside it. VENUS, on the other hand, assumes that the diquarks disintegrate and form double strings which shift the baryons away from the fragmentation regions. These different approaches result in an uncertainty of a factor of ~ 10 in the net baryon density at $y = 0$ [10].

Predictions of meson production also vary significantly between these models. For example, HIJING predicts $dN_{ch}/d\eta = 900$ at $\eta = 0$ if no shadowing or quenching within the nucleus is assumed; including these effects lowers $dN_{ch}/d\eta$ to 600. Alternatively, a "naive" Parton Cascade model [11] predicts $dN_{ch}/d\eta = 3800$ at $\eta = 0$ which becomes 1200 when shadowing, parton fusion and gluon interference are included [10]. Again, uncertainty factors of 5 to 10 are present.

Of all the RHIC experiments, BRAHMS will make a unique contribution of constraining the various models by studying baryon production over all the kinematic regions ($|y| < 4$). However, until this measurement is carried out, it is important to bear in mind the large theoretical uncertainties when comparing the ability of the experiments to study *specific* hadronic topics. These topics will be considered in the following sections.

5. Temperature and energy density

Temperature (T, frequently associated with $< p_t >$) and energy density, ε, are two fundamental quantities that characterize the new physics that may occur at RHIC. Both will be measured at RHIC by all experiments.

5.1. Measurement of temperature

BRAHMS will be able to use its multiplicity detector to correlate event samples with *inclusive* measurements of $< p_t >$. PHOBOS will also measure $< p_t >$ *inclusively*; its data sample will be somewhat larger than BRAHMS but it will not span as large a p_t range. PHENIX will measure $< p_t >$ *inclusively* as well; its data set will be similar in size to PHOBOS's. PHENIX's measurements will complement PHOBOS's because it will identify particles with higher p_t than PHOBOS. However, PHOBOS will contribute at the low end of the p_t range in the region of $p_t = 60$ MeV/c.

STAR is the only experiment that will attempt to measure $< p_t >$ on an *event-by-event basis*. An uncertainty of ~ 4 MeV on a temperature of $\sim$ 250 MeV is anticipated. However, a potential problem to this measurement may be track contamination at low values of p_t.

5.2. Measurement of energy density

According to Bjorken [12] an estimate of energy density is given by:

$$\varepsilon = \frac{1}{\pi R_\perp^2 \tau_0} \frac{dE_t}{dy}$$

where $R_\perp$ is the transverse radius of the interaction, τ_0 is estimated to be $\sim$ 1 fm and dE_t/dy is the rapidity density of transverse energy, E_t. The determination of ε therefore requires measurement of dE_t/dy and $R_\perp$. Both will be measured using similar methods in all RHIC experiments.

5.2.1. Measurement of dE_t/dy

BRAHMS will use its multiplicity device to detect charged secondaries in the central region and so obtain a measurement of $dn_{\text{charged}}/d\eta$. In a similar fashion, PHOBOS will use its annular and vertex detectors. Both experiments will then be able to use p_t distributions of identified secondaries detected in their spectrometers to correct their η distributions to form y distributions. These in turn will form the basis of a $dE_{t\,\text{charged}}/dy$ determination.

To illustrate the power of PHOBOS's detectors, an example of a *single* event is shown in Fig. 1.

It is evident from Fig. 1 that PHOBOS will be capable of measuring η distributions on an *event-by-event* basis over the total η range. They may also be able to study correlations (caused, for example by a disoriented chiral condensate [13]) between secondaries on an *event-by-event* basis. The results, which rely on the large acceptance and high degree of granularity of thess detectors, are promising [13, 14].

The silicon vertex detector in PHENIX will measure $dn_{\text{charged}}/d\eta$ in a similar way to PHOBOS (albeit over a smaller angular range) and the data will have to be converted into dE_t/dy in a similar fashion. This measurement will be augmented by a determination of dE_t/dy of photons and electrons in an electromagnetic calorimeter over a range $|y| < 0.5$.

STAR will be able to make a more direct determination of dE_t/dy than any other RHIC experiment by measuring $dE_{t\,\text{charged}}/dy$ directly from tracks detected in its TPC. It will also determine dE_t/dy associated with photons and electrons using a lead-scintillator sampling calorimeter.

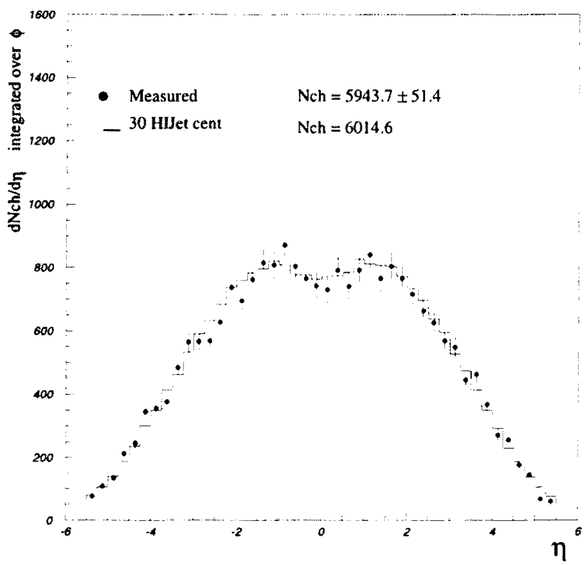

Fig. 1. A simulated $dN_{\text{charged}}/d\eta$ distribution for a single central $\sqrt{s}$ = 200 GeV/nucleon central Au-Au event detected in the PHOBOS experiment. The statistical fluctuations can be estimated by comparing the distribution to a simialr distribution formed from 30 such events (solid histogram).

5.2.2. Measurement of $R_\perp$

Measurements of $R_\perp$ will be obtained by studying correlations between identical bosons; such studies may also be useful in determining whether there is evidence for long hadronization times [15]. The high multiplicties expected at RHIC open up several possibilities which are summarized in this section.

$\pi - \pi$ correlations

Two-particle correlation studies benefit greatly from large acceptances [16] and consequently the STAR experiment will spearhead this effort. However, the other RHIC experiments will also contribute to this study.

Although BRAHMS's apparatus has not been optimized to perform correlation studies, it will be able to reconstruct 10^5 $\pi - \pi$ pairs in an ~ 8 *hr* period [2]. In contrast to this, PHENIX will accept 10^6 events events in 6 *hr* allowing it to resolve 10 fm sources. In fact, PHENIX's momentum resolution should allow resolution of sources $\sim$ 20 fm in radius.

PHOBOS will accept $\sim$ 50 charged tracks in each of its spectrometer arms when a central $Au - Au$ collision occurs which will result in ~ 1200 π^- pairs per event. PHOBOS will then use its excellent momentum resolution at low p_t to resolve sources up to $\sim$ 20 fm in radius [17].

The large acceptance of STAR opens up the possibility of measuring two-particle correlations on an *event-by-event* basis (all the other RHIC experiments will be restricted to *inclusive* measurements). A typical central $Au - Au$ event will produce $\sim$ 1000 – 1500 π^- in STARS's TPC; these will form $750K - 900K$ $\pi^- - \pi^-$ pairs. Assuming a formation size and time of 10 fm and 10 fm/c respectively, the region where the $\pi^- - \pi^-$ correlation function will differ significantly from unity will be restricted to q_l, $q_\perp$, $q_0 < 20$ MeV. This region will be populated by only 40 π^- pairs, and, if 5 MeV bins are used in a 3-dimensional analysis, there will be less than a single π^- pair per bin. Even though such an analysis appears difficult a 1-dimensinal event-by-event analysis should be possible [18].

A comparison of STAR and PHOBOS illustrates the contribution that the "small" RHIC experiments will make. Although STAR accepts $\sim$ 700 times as many pairs *per event* than PHOBOS, the data sets resulting from the two experiments *per year* will be comparable because of PHOBOS's superior data collection rate

In addition to measuring $R_\perp$, two-particle correlations may be useful in detecting the presence of new length scales. For example, the creation of a disoriented chiral condensate [13] or plasma droplets [20] will both tend to affect the correlation function and this may be measurable in the RHIC experiments.

Multi-π correlations

PHENIX, PHOBOS and STAR all will have the capability of studying **multi**-pion correlations. Such studies will not be restricted by statistical errors but the value of such studies has been questioned [16].

Instrumental effects

All two-particle correlation analyses will be affected to some degree by instrumental effects such as detection efficiency, spurious (or "ghost" tracks), and two track resolution.

BRAHMS has studied the effect of two-track resolution on $Q_{\rm inv}$, the invariant momentum difference, and it is significant ($\sim$ 20% for $Q_{\rm inv} <$ 0.02 GeV/c). A sizeable correction in this kinematic region will be required. PHOBOS has studied the resolution effect by reconstructing simulated tracks that traverse its spectrometer. PHOBOS has achieved track reconstruction efficiencies of 80 – 85% for tracks with $p > 0.3$ GeV/c. The fraction of spurious tracks created in the reconstruction process is small ($\sim$ 3% over the entire momentum range) and they will have minimal effect on the correlation function [17]. The effect of two-track resolution on $Q_{\rm inv}$ has also been studied and it is significant in the $Q_{\rm inv} < 0.02$ GeV/c region (see figure 2).

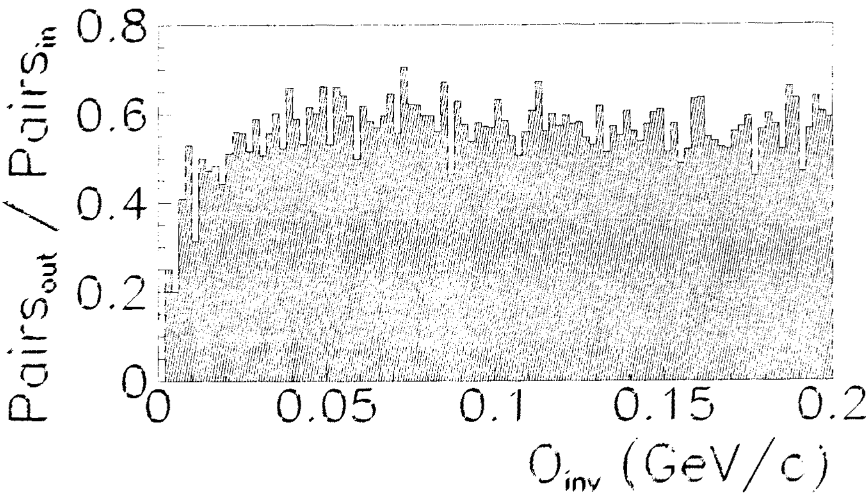

Fig. 2. The effect of two track resolution on Q_{inv} as measured in the PHOBOS experiment.

STAR has achieved similar track reconstruction efficiencies as PHOBOS using data from its TPC and has also studied the effects of spurious tracks. This problem is potentially more serious for STAR than PHOBOS because of the number of tracks in its sensitive volume (3000 compared to 100). When no p_t cut is applied to the STAR data, the two-particle correlation function increases by a factor of 6 above the expected value of 2 at $Q_{\mathrm{inv}} = 0$. If a $p_t > 200$ MeV/c restriction is applied, this increase is lowered to 3.5. Further cuts requiring tracks to traverse the full sensitive volume of the TPC enhance the purity of the track sample [19].

$K - K$ correlations

The study of correlations between pairs of kaons has several advantages over a similar study using pions. Kaons have a smaller interaction cross section than pions as they traverse nuclear matter. There are also fewer higher mass resonances to decay to a kaon and therefore potentially distort the correlation function. However, a disadvantage of using kaons is the larger Coulomb interaction between kaons but this can be corrected for by measuring $K - \pi$ correlations.

STAR has the possibility of not only studying $K^{\pm} - K^{\pm}$ pairs but also performing $K^0_s - K^0_s$ interferometry by reconstructing K^0_s mesons using its SVT. Such a study benefits from no Coulomb repulsion between the two bosons, is not affected by two-track resolution and the K_s^0 mesons have a smaller hadronic interaction cross section than pions. Even though the $K_s^0 - K_s^0$ rate is expected to be approximately $10^{-5} \times \pi - \pi$ rate, $\sim 3K_s^0$ mesons will be reconstructed in STAR in each event. A simulation of the correlation function resulting from 10^4 central events (corresponding to 3 hr data collection [21]) is shown in figure 3.

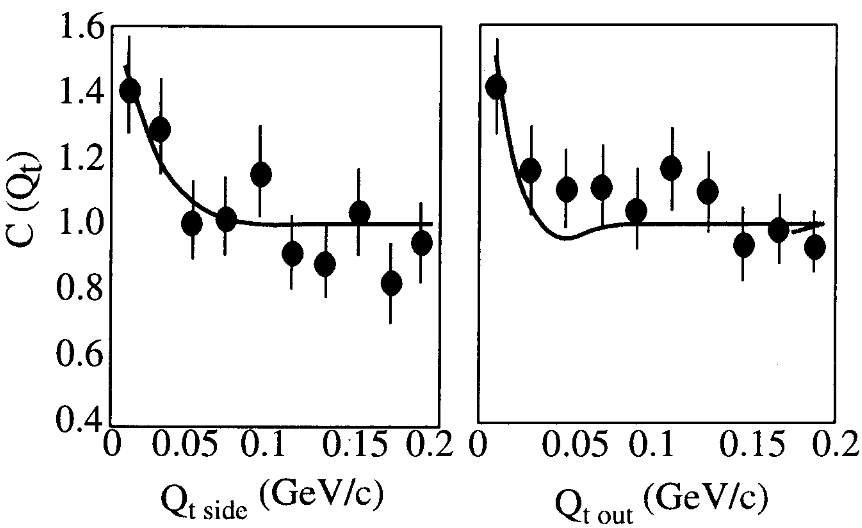

Fig. 3. A simulation of STAR's capability to measure the K_s^0-K_s^0 correlation function. A incoherent spherical source with a radius of 10 fm was assumed. The solid line is "perfect" input. K_s^0 mesons with $|y_{K_s^0}| < 0.5$ were accepted. The points include the effects of detector efficiency, momentum smearing and mutiple scattering of the decay pions.

6. ϕ studies

Study of ϕ meson production may provide a unique probe of a new state of matter. If the ϕ meson is moving slowly through the nuclear matter, its mass and width may change because of chiral symmetry restoration [22]. Of the several ϕ decay modes, $\phi \to K^+K^-$ has several advantages. It has a large branching ratio, a low Q value (resulting in the K momenta being sensitive to changes in the ϕ mass) and the decay kaons are relatively easy to detect. However, this decay mode has the disadvatage (compared to the leptonic mode) that, as the decay products travel through the hardronic medium, they will have a high probability of interaction.

PHENIX will be able to study ϕ mesons with p_t down 0.6 GeV/c (see figure 4). This cutoff is caused by the restriction on the opening angle of the decay kaons.

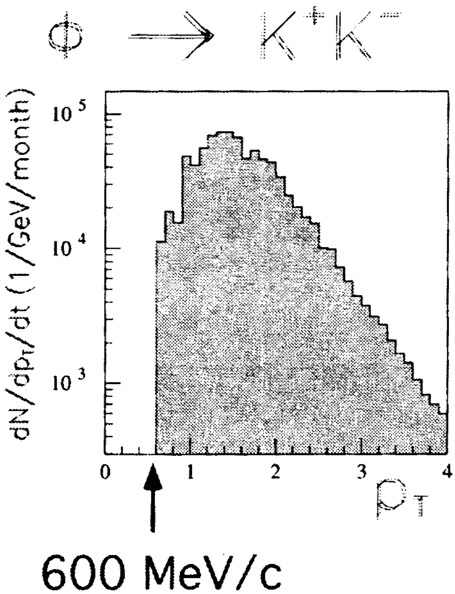

Fig. 4. The acceptance and rate for $\phi \to K^+K^-$ for identified kaons in the PHENIX experiment. 10^8 central collisions/month were assumed.

The rates of ϕ production in PHENIX are shown in figure 5. It can be seen from figures 4 and 5 that statistics will not constrain PHENIX's study of ϕ mesons with $p_t > 1$ GeV/c.

PHENIX will also study ϕ mesons using its lepton decay mode. The mass resolution from this mode will be 5 times worse than the hadronic mode but the leptons will not undergo interactions in the hadronic matter. This study will complement the $\phi \to K^+K^-$ measurement.

PHOBOS has an acceptance that allows it to study ϕ mesons produced with low p_t because of the large opening angle of its two spectrometer arms (a single kaon from the pair will be detected in each arm). Expected ϕ mass and decay width resolutions have been estimated to be 0.2 GeV and 0.5 GeV respectively [14] from 19 hours of data collection. This will be sufficient to detect possible mass shifts and decay widths. The detected ϕ rate in PHOBOS will be similar to PHENIX's but in a different p_t range. The two studies should complement each other well.

Finally, STAR will reconstruct $\sim 6\phi$ mesons in each central Au-Au event and will also be able to make an inclusive study of ϕ mesons with low p_t.

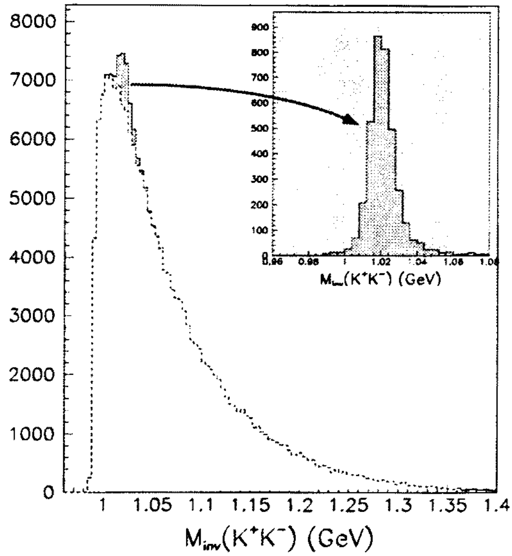

Fig. 5. The invariant mass spectrum of K^+K^- pairs for $200K$ $Au - Au$ events detected in the PHENIX experiment.

7. Summary

The four RHIC experiments will complement each other in their studies of hadronic physics. The "small" experiments will obtain comparable data sets to the "large" experiments because of their superior data collection rate. STAR will be the only experiment that may be able to measure quantities, such as T and ε, on an *event-by-event* basis; other experiments will make *inclusive* measurements.

This work was supported, in part, through U.S. Department of Energy Grant DE-FG02-94ER40865.

REFERENCES

[1] Copies of the transparencies that formed the basis of this document can be found on the World-Wide Web at:
http://sunhehi.phy.uic.edu/~phobos/phobos/public_info
/presentations/1996_06_01/home.html

[2] In-depth descriptions of all four experiments are available in their respective Conceptual Design Reports:

BRAHMS: (Oct. 1994)
PHENIX: (Jan. 1993)
PHOBOS: (Apr. 1994)
STAR: (Jun. 1992)

3] **BRAHMS:** F. Vidabaek, *Nucl. Phys.* **A566**, 299c (1994);
PHENIX: S. Nagamiya, *Nucl. Phys.* **A566**, 287c (1994);
PHOBOS: B. Wyslouch, *Nucl. Phys.* **A566**, 305c (1994);
STAR: J.W. Harris, *Nucl. Phys.* **A566**, 277c (1994).
Further information can be found at the home pages on the World-WIde-Web at:
BRAHMS: http://rsgi01.rhic.bnl.gov/export1/brahms/WWW/brahms.html;
PHENIX: http://rsgi01.rhic.bnl.gov/export1/phenix/WWW/phenix_home.html;
PHOBOS: http://sunhehi.phy.uic.edu/~phobos/phobos/home.html;
STAR: http://rsgi01.rhic.bnl.gov/star/starlib/doc/www/star.html.

4] T.J. Hallman, J. Thomas, *Nucl. Phys.* **A590**, 399c (1995).

5] "RHIC Computing Facility", Brookhaven National Laboratory internal report (1996).

6] K. Werner, *Phys. Rep.* **232**, 87 (1993).

7] X. N. Wang *et al.*, *Phys. Rev.* **D44**, 3501 (1991).
X. N. Wang *et al.*, *Phys. Rev.* D45, 844 (1992).

8] B. Andersson *et al.*, *Nucl. Phys.* **B281**, 289 (1987).

9] H. Sorge *et al.*, *Nucl. Phys.* **A498**, 567c (1989).

0] B. Moskowitz, Proc. of the Pre-Conf. Workshop, 11th Int. Conf. on Ultra-Relativistic Nucleus-Nucleus Collisions, 111 (1995).

1] K. Geiger *et al.*, *Nucl. Phys.* **B369**, 600 (1992).

2] J.D. Bjorken, *Phys. Rev.* **D27**, 140 (1983).

3] S. Gavin, *Nucl. Phys.* **A590**, 163c (1995).

4] M.D. Baker, Proc. of the Pre-Conf. Workshop, 11th Int. Conf. on Ultra-Relativistic Nucleus-Nucleus Collisions, 31 (1995).

5] S. Pratt, *Phys. Rev.* **C33**, 1314 (1986).

6] W.A. Zajc, Proc. of the Pre-Conf. Workshop, 11th Int. Conf. Ultra-Relativistic Nucleus-Nucleus Collisions, 121 (1995).
A version of this report is available on the World-Wide web at:
http://nevis1.columbia.edu/phenix/physics/hadrons/papers/qm95/qm95_hbt/qm 95_hbt.html.

7] G. Roland, Proc. of the Pre-Conf. Workshop, 11th Int. Conf. on Ultra-Relativistic Nucleus-Nucleus Collisions, 111 (1995).

8] A. Dean Chacon, STAR note #92, 1993 (unpublished).

9] D. Cebra *et al.*, STAR note #211, 1995 (unpublished).

0] S. Pratt *et al.*, *Phys. Rev. Lett.* **68**, 1109 (1992).

1] D. Keane, STAR Note #47, 1992 (unpublished).
D. Keane *et al.*, STAR Note #224, 1995 (unpublished).

[22] D. Lissauer *et al.*, *Phys. Lett.* **B253**, 15 (1991).
[23] For acceptance of ϕ mesons in PHENIX see Y. Miake, TOF mini review, July 1995 and on the World-Wide web at:
http://rsgi01.rhic.bnl.gov/~phenix/GIF/p04_sn.gif.