CONF-9206284--3

BNL--48163 BNL-48163

DE93 008056

RECEIVED
FEB 22 1993
OSTI

The BNL Relativistic Heavy Ion Collider (A New Frontier in Nuclear Physics)

Yousef I. Makdisi
RHIC Project, Brookhaven National Laboratory, Upton, NY 11973*

ABSTRACT

The Relativistic Heavy Ion Collider at Brookhaven is in its second year of construction with a target date for completion in late 1997. In this report, I will describe the status of the project, the designated milestones and the capabilities of this collider that set it apart as the premier facility to probe the new frontier of nuclear matter under extreme temperatures and densities.

Two large detectors and a pair of smaller detectors, which are in various stages of approval, form the experimental program at this point. They provide a complementary set of probes to study quark gluon plasma formation through different signatures. The two ring design of this collider allows for collisions between different ion species ranging from protons to gold.

INTRODUCTION

The idea of relativistic heavy ion collisions was first discussed in the long range plans for U.S. nuclear science in 1983 [1]. A proposal from Brookhaven to build RHIC utilizing the ISABELLE/CBA infrastructure was submitted to the Department of Energy in 1984. This was followed by a series of four workshops [2] at BNL and elsewhere to further define the physics program as well as the detectors that will be needed.The first approval for construction was received in fiscal year 1991 with a six year funding plan and a target date for physics in mid 1997.

In what follows, I shall present the accelerator complex [3] and its current construction status, the physics program and topics that will be covered and the associated detectors that have been proposed to carry out this program. Through all of this, I hope to impress upon you the versatility of this collider and the potential that it provides as a link between accelerator based physics and cosmic ray investigations.

*Work performed under the auspices of the U.S. Department of Energy, under contract number DE-AC02-76CH00016.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

THE ACCELERATOR COMPLEX

RHIC [3] will utilize one of two sequences of existing accelerators as injectors to the collider and, depending on whether the beams are protons or heavier ions, the starting points could either be the 200 MeV Linac or the Tandem Van De Graaf. The layout of the complex is shown in Fig. 1.

A gold beam starts in a pulsed sputter ion source and is accelerated to 1 MeV per nucleon and stripped through the tandem to a charge of 14. This is then transferred into the Accumulator/Booster [4] that has been recently commissioned. The Booster's superior vacuum allows the acceleration of heavier ions such as gold at high intensities with little loss due to electron capture. A beam of $6x10^9$ in three bunches is accelerated to 72 MeV and is subsequently stripped to a charge of 77 before injecting into the AGS. As the beam reaches the top AGS energy of 28.3(Z/A) GeV or 10.4 GeV per nucleon it is extracted in a single bunch mode. The beam is again stripped to a charge of 79 and injected into either one of the collider rings. A total of 57 bunches spaced 220 nsec apart in each ring are accelerated to full energy of 100 GeV per nucleon.

The design calls for intensities ranging from $1x10^9$ ions per bunch for gold beams increasing to about $2x10^{11}$ per bunch for protons. The energy reach is variable and its maximum depends on the ion species. The two ring construction provides for the acceleration of different ion species for added flexibility in particular, it is possible to collide beams of ions in one ring with protons in the other. Fig. 2 displays the design luminosities and stored beam lifetimes.

Polarized protons could also be accelerated at the same luminosity as unpolarized protons however this requires the installation of spin preserving siberian snakes in RHIC which are not in the scope of the project [5].

CURRENT STATUS

The Department of Energy gave its Key Decision #3 in January 1992 which provides for full construction authorization. The procurement for the long lead items is underway. The contract for the superconducting cable for the arc dipoles and quadrupoles was awarded to Oxford Superconducting Technologies, and that for the superconducting cable for the insertion magnets has been awarded to OST and Furukawa. The contract for the construction of the 8-cm dipoles for the arcs and insertions was awarded to Grumman Corporation. The contract for the quadrupoles and sextupoles is in preparation.

Most of the injection complex already exists including a good fraction of the magnetic elements that are required for the transfer lines from the AGS to RHIC. These along with most of the tunnel and four experimental areas have been carried over from the ISABELLE/CBA project. The fourteen megawatt liquid helium refrigerator system was also purchased as part of that project.

The superconducting magnet construction follows a fairly conservative design. The required operating field is 3.5 Tesla at 5000A. The short sample current allows a maximum field strength approximately 35% above the operating current. Full cell tests have been carried out to evaluate the performance of the arc magnets as a system. These involved thermal and power cycles, and quench testing including all trim circuits cryogenic and electrical connections similar to that in the final machine.

THE EXPERIMENTAL PROGRAM

The RHIC design calls for six interaction regions where experiments can be installed. The beam crossing angles can vary from 0 to 7 mr. At zero degree crossing angle, the intersection diamond has a sigma of 18 cm for gold-gold beams and less than that for pp . The transverse beam width at the design emittance and beta star is about 170 microns. A planned upgrade calls for a maximum fill of 114 bunches per ring thus reducing the time interval between bunch crossings to 110 nsec. The stored beam life-time is about 10 hours.

A length of approximately 9 meters on either side of the interaction region is available for the detectors before encountering the first magnetic element. Three experimental areas have their enclosures already built; the "narrow angle hall" at 2 o'clock can accommodate a relatively small experiment while the others at 6 and 8 o'clock are designed for large size experiments. A fourth area at 4 o'clock has a floor pad but its enclosure will be built up using movable shielding blocks depending on the particular experiment. The beam height and the available crane coverage vary from one experimental area to another.

The physics program at RHIC is a natural extension to the efforts that are currently underway at heavy ions programs in fixed target experiments [6] at the AGS and the CERN SPS . However, the RHIC collider will extend the available center of mass energies by more than an order of magnitude [3]. Extreme nuclear densities are expected to extend over regions of space and time well over ten fermis. The search for a phase transition and the signatures of the formation of a quark gluon plasma dictate the design of the RHIC detectors.

Several letters of intent were submitted to the Program Advisory Committee all competing for a pot of $80M in FY 1990 dollars that was earmarked for detector construction. Several rounds of discussion resulted in a decision to build two large detectors; STAR and PHENIX for $30 M each, and several smaller detectors the cost of each not to exceed $5 M, the rest to be spent on general upgrade of the experimental areas. Additional funds from sources other than DOE or in kind contributions from some of the international collaborators are expected to enhance the capabilities of the detectors. This was considered the best approach to maximize the physics output.

An LBL/BNL led collaboration [7] was given approval to build the STAR detector. This is a large aperture tracking detector that is based on a time projection chamber imbedded in a 0.5 Tesla solenoidal magnetic field. The detector configuration is shown in Fig. 3. Its large acceptance ($-1 < \eta < 1$ and phi=2pi) allows the correlation of many observables on an event-by-event basis. The design calls for tracking several thousand charged particles per central gold-gold collision with momentum resolution of 2% for momenta as low as 100 MeV/c and particle identification of pions and kaons up to 1 GeV/c. The physics goals comprise; particle production spectra, strangeness production using kaons, lambdas and phi mesons, measurement of energy fluctuations and partonic physics studies via jet production and quenching. In June 1992, the group submitted a conceptual design report and is expected to receive construction funds in FY 1993.

The PHENIX [8] detector, Fig. 4, emphasizes leptons and photons as the primary probes. The central detector comprises an axial magnetic field and two detector arms that cover $|\eta| < 0.35$ and phi=pi. These contain several tracking chambers, a ring imaging cerenkov detector, a set of transition radiation detectors and time expansion chambers for dE/dx measurements, limited time of flight coverage and electromagnetic calorimetry that uses lead glass as well as lead scintillator sandwiches with excellent energy resolution and timing resolution of about 300 psec. One endcap includes a dimuon spectrometer complete with a piston shaped magnet, pion absorbers and tracking. The physics program stresses dilepton production at low and high momentum transfer, vector meson production and direct photon production. The latter will require the addition of a high resolution cesium iodide detector if one is to access the lower pt spectra.

The PHENIX collaboration submitted a preliminary conceptual design report in June 1992 and is scheduled to submit its final CDR by year's end after which they will receive construction funds.

Two small detectors are at various stages of approval. An MIT [9] led collaboration is in the process of writing a conceptual design report on the PHOBOS detector. This table top experiment, Fig. 5, is a two arm spectrometer that uses silicon strip detectors for momentum tracking in a pair of 5 Tesla Helmholtz coils magnets. The experiment focuses on measuring particle production at very low momentum transfer which is not accessible to the large detectors namely 15-600 MeV/c and covers the rapidity region $0<y<1.5$. It will be probe particle production and carry out two particle correlations as well as measure strangeness in lambda and phi meson production.

The second small experiment is proposed by a BNL led group. This Forward Angle and Midrapidity Hadron Spectrometer [10] will use several tracking chambers interspersed among magnetic elements along with ring imaging cerenkov detectors for particle identification in the forward angles. A modified AGS apparatus (experiment E866) covers the mid rapidity range. The forward coverage complements the large detectors and will stress particle production versus rapidity and study the baryon free region that is predicted to prevail should quark gluon plasma develop. This detector is shown in Fig. 6.

The global physics issues along with the expected coverage from the four detectors are shown in Table I. It is worth noting the complementary purpose of these detectors along with the regions of overlap is to assure consistency in the results. A fair fraction of the physics program will be covered on day one with further refinements to follow either with new detectors or upgrades to the existing ones.

The RHIC environment of high luminosities coupled with very high multiplicities (dn/dy =700-1500) put some severe demands on the design of these detectors:

A. High granularity to cope with the combinatorials and reduce the per channel occupancy rate.

1) High numbers of channels,
2) High data rates,
3) Stringent demands on triggering and online filtering and the data acquisition systems,
4) Extensive offline processing power (approx. 40 Gflops [11])

B. Electronics:

1) Deadtimeless pipeline systems,
2) sub 100 nsec ToF resolutions,

3) Shaping times < 100 nsec to cope with bunch crossing times,
4) Low costs per channel,

All of the above require an extensive ongoing R&D program which has evolved from being generic in nature to detector specific.

TABLE I

Physics Measurements*	Detectors**			
	STAR	PHENIX	PHOBOS	FORWARD
1. Global Variables				
ET, dsigma/dn,dn/dy	Y	Y	Y	Y
2. Hadrons				
. dsigma/dpt (pi,K,p,pbar)	Y	Y	Y	Y
. Strangeness production	Y	Y	Y	Y
. HBT Interferometry	Y	Y	Y	
. Open Charm	Y(VTX)	Y		
3. Dileptons				
. Soft Continuum		Y		
. Non-resonant continuum (1-3 GeV)		Y		
. Rho,omega,phi,(mass,width, dsigma)		Y		
. J/psi, psi', upsilon, screening		Y		
4. Photons				
. pi zero, eta, eta'	Y(EMcal)	Y		
. Continuum direct photons				
Very soft	Y(CsI)			
hard (pt>5 GeV/c)	Y(EMcal)	Y		
5. Hard Scattering Processes				
. Jet+Jet	Y(EMcal)			
. Hard Photon+Jet	Y(EMcal)	Y		

* The physics list was compiled from a special meeting at BNL, March 1991.
** In parentheses, are the detectors that are not in the $30M scope, but may be acquired from other resources.

The two large detectors are about to enter the construction phase. It is no secret that an aggressive construction program is called for in order to be ready for physics in late 1997.

CONCLUSION

The construction of the Relativistic Heavy Ion Collider is well underway. This new accelerator will provide an exciting new arena to probe nuclear matter at high temperatures (200 MeV or 10^{12} °K) and extreme nuclear densities. These are conditions that may foster the formation of quark gluon plasma and deconfinement. The systematic studies of pA and AA collisions form a good link between cosmic ray physics and current accelerator based physics.

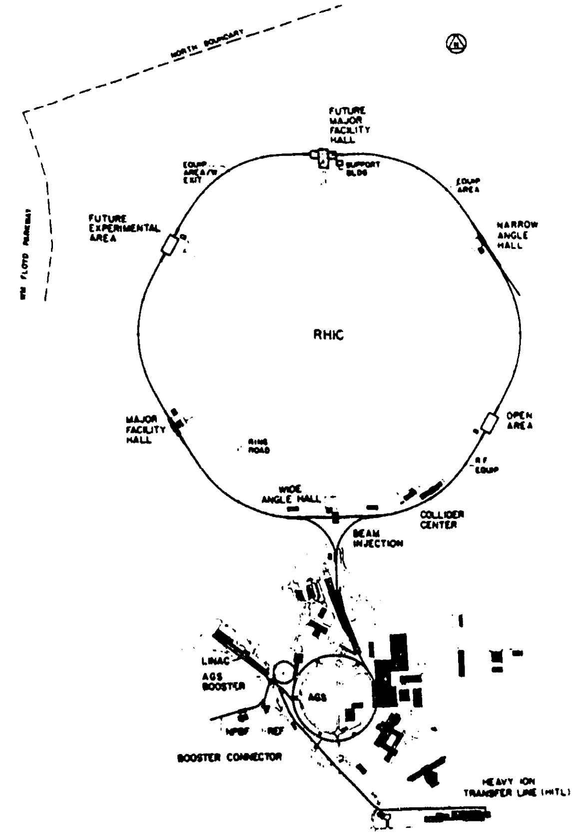
I described the status of the experimental program as of now. This is a dynamic program and not all the intersection regions are occupied. There is additional room and ample time to propose new small and exciting experiments and still be ready for physics in 1997.

REFERENCES

1. "A Long Range Plan for Nuclear Science", a report by the DOE/NSF Nuclear Science Advisory Committee. J. Schiffer, Chairman, Dec. 1983.
2. The last workshop "Proceedings of the Fourth Workshop on Experiments and Detectors for the Relativistic Heavy Ion Collider, M. Fatyga and B. Moskowitz, editors, BNL Report 52262 (1990).
3. Conceptual Design of the Relativistic Heavy Ion Collider RHIC, Brookhaven National Laboratory Report BNL-52195 (1989) and its update (August 1992).
4. W.T. Weng, Progress and Status of the AGS Booster Project, Proc. of 14th International Conference on High Energy Particle Accelerators, Particle Accelerators 27, 259 (1990).
5. M. Beddo et al. Proposal on Spin Physics Using the RHIC Polarized Collider. Submitted to the BNL PAC, August 1992.
6. For the latest reviews, see talks by S. Nagamiya and T. Hatsuda in Quark Matter 91, Proceedings of the Ninth International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions, T. Awes, F. Obenshain, F. Plasil, M. Strayer and C. Wong editors, Nov 11-15, 1991.
7. M. Beddo et al. STAR Conceptual Design Report. LBL PUB-5347, June 1992.
8. J. C. Gregory et al. PHENIX Preliminary Conceptual Design Report, June 1992.
9. A. Carroll et al. PHOBOS Letter of Intent, Jan 1992.
10. D. Beavis et al. Letter of Intent, Forward Angle and a Midrapidity Hadron Spectrometer at RHIC, 1991.
11. W. Love et al. A report of the Offline Computing Committee for RHIC Experiments. Sept. 1992.

Fig. 1

Site map of the RHIC accelerator complex.



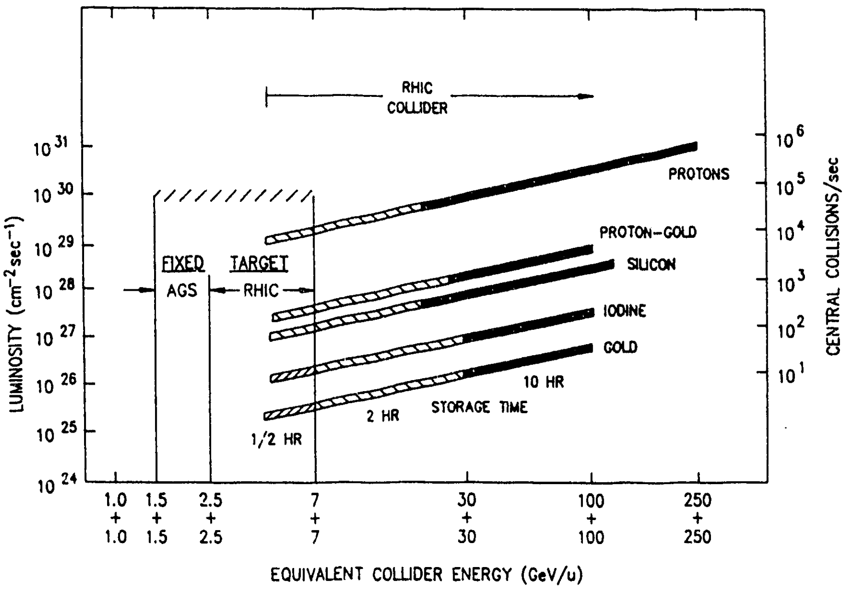


Fig. 2
The design luminosities and frequency of collisions for different colliding ion species and energies.

Fig. 3
Perspective view of the STAR experiment.

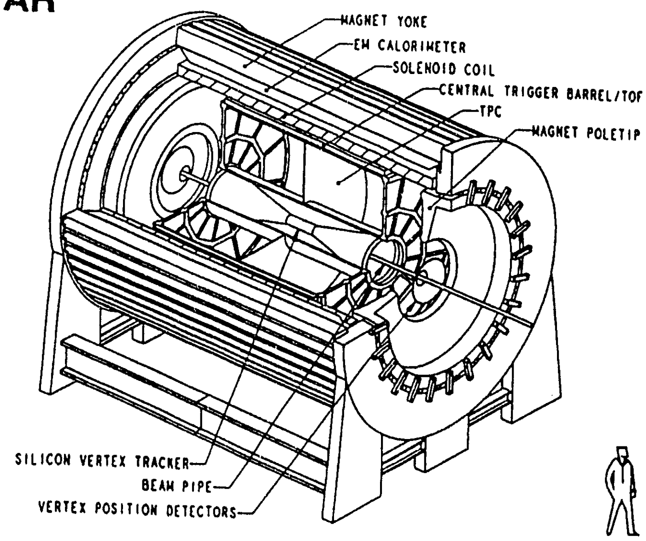
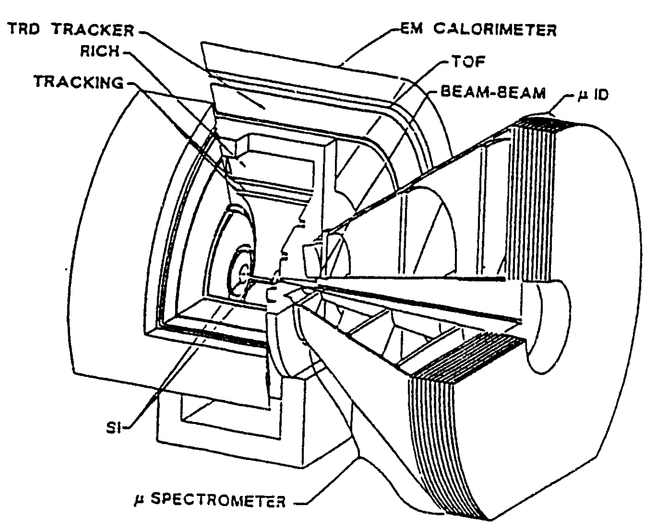


Fig. 4
Perspective view of the PHENIX detector.



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.

Fig. 5

Top view of the PHOBOS detector.

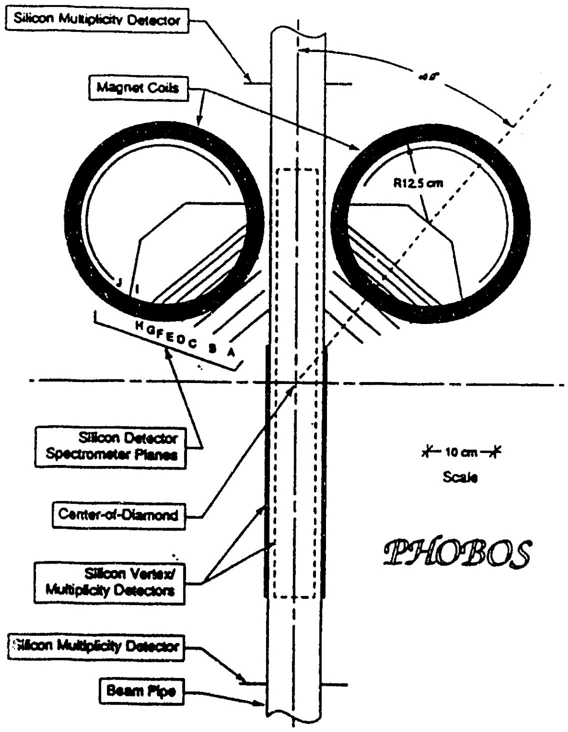
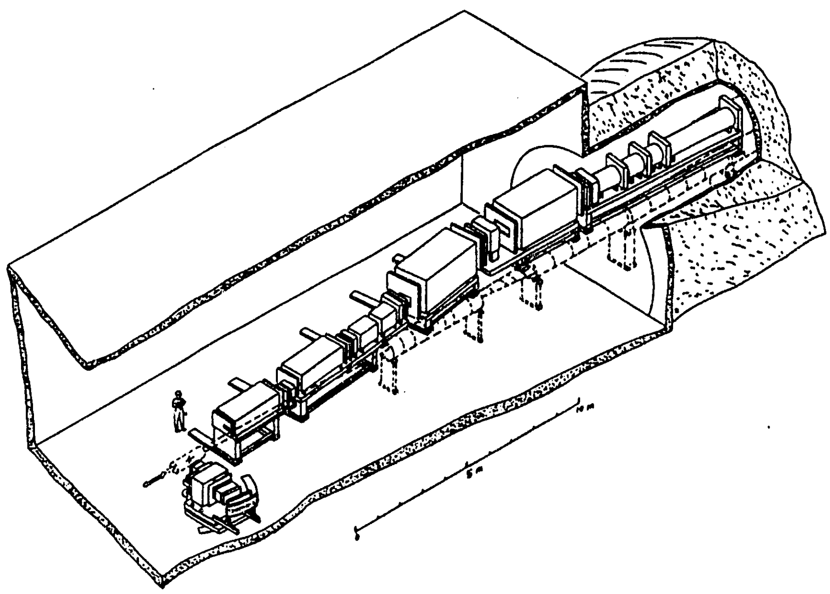


Fig. 6

The Forward Angle and Midrapidity experiment in the narrow angle hall.



END

DATE
FILMED
4 /28/93