Proc. APS Centennial Meeting
Atlanta, GA
March 21-26, 1999

BNL-66394

THE YEAR-ONE PHYSICS CAPABILITIES OF STAR

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For the STAR COLLABORATION [a]

When the Relativistic Heavy Ion Collider (RHIC) at BNL begins operation in the Fall of 1999, heavy ions will be accelerated in collider mode for the first time, and a new energy regime will be entered for Heavy Ion Physics. The Solenoidal Tracker At RHIC (STAR) detector has a near 4π coverage and is dedicated to taking hadronic measurements. A large volume Time Projection Chamber placed in a solenoidal magnet at 0.5T is used to track and identify the many thousands of produced particles. STAR will measure many observables simultaneously on an event-by-event basis to study signatures of a possible QGP phase transition and the space-time evolution of the collision process. The goal is to obtain a fundamental understanding of the microscopic structure of hadronic interactions, at the level of quarks and gluons, at high energy densities. This paper outlines the physics STAR intends to study during the first year of operation.

1 Introduction

With the advent of the RHIC physics program at energies of $\sqrt{s} \leq 200A - GeV$ in November 1999, a new regime will be entered for relativistic heavy ions collisions. The STAR detector [1] is one of four experiments designed to investigate this new territory.

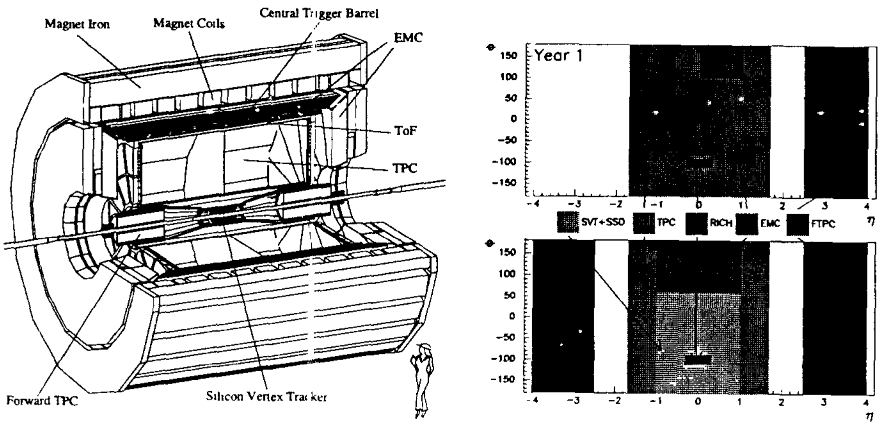
1.1 The STAR detector

The STAR detector configuration and acceptance can be seen in Fig. 1 for year 1 and beyond. The large volume TPC is used to identify charged hadrons around mid-rapidity. The Ring Imaging CHerenkov (RICH) detector identifies high-p_t charged particles over a small rapidity region, and the Electro-Magnetic Calorimeter (EMC) patch compliments the charged particle measurements with that of neutral particles. When both the Forward TPCs are included a near 4π acceptance is achieved for charged particle detection.

1.2 Triggering and data sets

It is expected that the majority of the first year will be dedicated to Au+Au collisions at $\sqrt{s} = 200A - GeV$, with the possibility of a beam species, or

[a] see http://www.star.bnl.gov/STAR/spb/institute.html for collaboration list



a) b)

Figure 1: a) The STAR detector and b) The acceptance in year one and beyond

energy, change for some part of the running. By the end of the first year RHIC is expected to be operating at 10% of design luminosity (200 Au+Au collisions/sec). The STAR DAQ rate is 1 Hz, so STAR will not be luminosity limited.

STAR triggering will be based initially on centrality. The main trigger is from the Central Trigger Barrel (CTB) via charged particle multiplicity measurements at mid-rapidity. The other triggers are from the Zero Degree Calorimeter (ZDC), centrality through missing forward energy, and the EMC which gives transverse energy triggers. STAR also hopes to implement high p_t triggers on specific topologies such as high p_t π^0s in the EMC and high p_t charged particles in the RICH.

We intend to look at three different centrality bins, minimum bias ($\sigma/\sigma_{geom} >$ 95%), mid-central ($<$ 20%) and central ($<$ 3%) with the goal of recording at least 1 million events in each. In addition it is expected that several million peripheral (photon/Pomeron) collisions will be recorded.

2 The Physics Capabilities of STAR

In the first year STAR aims to investigate many aspects of a RHIC collision. These are discussed below.

2.1 *Global event information*

Global event measurements provide information on the reaction dynamics of the collision. An understanding and control of the collision geometry is essential for studying the effects of a de-confined phase, the probability of formation being strongly dependent on centrality and the size of the collision volume. The TPC and FTPC will measure the $d\sigma/dN_{charged}$, the EMC patch will provide the $d\sigma/dE_t$ and the ZDC $d\sigma/dE_0$. All these measurements should, in principle, allow a determination of the impact parameter of the collision, Fig. 2a.

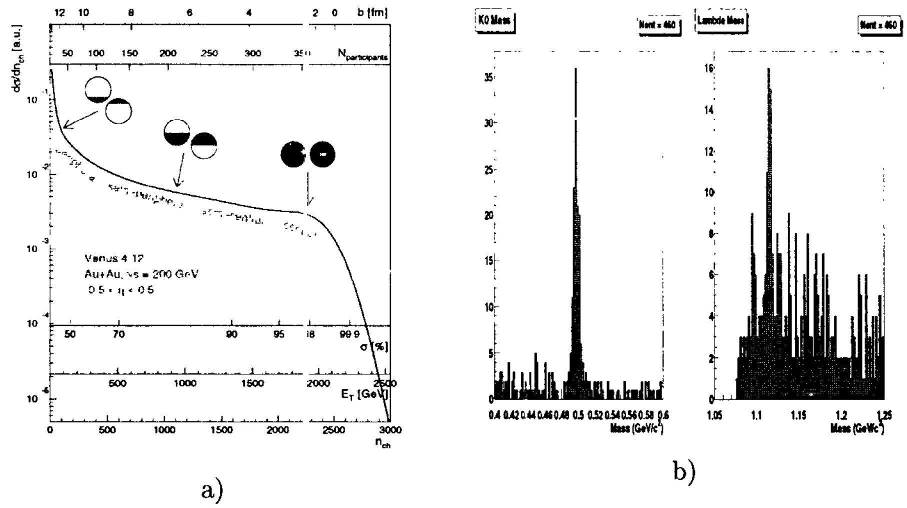


Figure 2: a) The predicted global variable distributions from Venus 4.12 [2] Au-Au collisions at $\sqrt{s} = 200A - GeV$ b) Λ and K_s^0 reconstruction from 100 events in year 1 using STAR TPC

2.2 *Spectra and Strangeness*

Measurements of charged-particle spectra ($\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$, d, $\bar{d}$, t, possibly heavier nuclear and anti-nuclear fragments, $e^{\pm}$, ρ and ϕ mesons) are made possible by the high tracking efficiency and resolution of the TPC. The RICH detector and TPC combined allow particle identification to be made across a wide momentum range Table 1. There is much disagreement among models about particle production rates, and STAR will be able to address these issues very soon after the first RHIC collisions.

Table 1: PID ranges for the TPC and RICH detectors

Detector	$\pi(GeV/c)$	$K(GeV/c)$	$P(GeV/c)$
TPC	0.07-0.6	0.07-0.6	0.07-1.0
RICH	0.6-3.0	1.1-3.0	1.5-5.0

From the rapidity and p_t distributions of identified particles we can extract information about the chemical and thermal freeze-out and flow. The net baryon yield will tell us about the stopping in the collision.

Neutral strange particle reconstruction from 100 events (Fig. 2b) (a few minutes data taking) allow us to identify K_s^0 and estimate the Λ yield. Thus in the first year an extensive exploration of the $\mid S \mid = 1$ particle production will be performed. The FTPC will probe strangeness production at high rapidity. Here again, a first comparison to models will be of great interest.

2.3 High p_t

In contrast to the low-p_t regime the high-p_t region in RHIC collisions will be dominated by products from the hard scattering of partons. The spectral shapes above $p_t \approx 2\ GeV/c$ will provide information on pQCD issues such as jet quenching, shadowing and the initial conditions of the fire ball [3].

Therefore, we want to measure spectra over a wide range of transverse momenta and particle species. The EMC patch will be used to reconstruct high-p_t neutral particles via $\pi^0 \rightarrow \gamma\gamma$ and $\eta \rightarrow \gamma\gamma$. and the RICH will serve similarly for charged particles. About 10 days of RHIC operation should supply statistics for charged particles and about one month of data taking will provide a low background measurement of the π^0 production.

2.4 Particle Correlations

Particle correlations allow us to probe the freeze-out geometry and expansion dynamics of the fire-ball. Within an hour of RHIC running STAR is capable of performing 3-D 2 pion correlation measurements. By the end of the first year STAR will no longer be statistics limited for the two particle proton and charged kaon correlation measurements.

2.5 Event-by-Event analysis

Event-by-Event analysis will be used to search for dynamical fluctuations that are expected near the QCD phase boundary and for alterations in the vacuum symmetries, such as chiral symmetry. Flow measurements will probe the nuclear equation of state. In-medium effects on parton propagation and fragmentation will be examined by measuring high p_t correlations.

Event-wise global variable distributions give us initial information about dynamical fluctuations in chemical and kinetic equilibrium, while scaled topological analysis will provide a more general search for event-wise variations in momentum space.

2.6 Peripheral Collisions

The peripheral-collision program utilizes colliding nuclei as sources of fields. We aim to look at $\gamma\gamma$ interactions with high luminosity, such as $\gamma\gamma \rightarrow e^+e^-$, $\mu^+\mu^-$, $f_2(1270)$,mesons and $\rho^0\rho^0$. It is estimated that $\approx$ 33K f_2 will be recorded in the first year and $\approx$ 600 $\rho^0\rho^0$. This program will also investigate $\gamma - Pomeron \rightarrow \rho, \phi, J/\psi, \eta^*$ and ϕ^*.

3 Year 2 and beyond

During the summer shut down of 2000, STAR will be upgraded by the addition of the second FTPC, the Silicon Vertex Tracker (SVT) and the Silicon Strip Detector (SSD), also more of the EMC will be added.

The improvement in the reconstruction efficiency of the decay particles, due to the inclusion of the SVT and SSD, means that STAR will be able to make $\mid S \mid > 1$ particle measurements and perform K^0_s K^0_s (and possibly $\Lambda\Lambda$) correlation studies.

As well as continuing to study Au-Au collisions, STAR will embark upon a systematic study of relativistic heavy ion collisions over a broad range of collision energies and beam species. The pp collision and spin physics program will also be started in the second year.

Acknowledgements

I would like to give special thanks to Gene Van Buren and Thomas Ullrich for their contributions to this talk and John Harris, Tom Trainor and Tom Humanic for their help in producing it. This work was supported in part by U.S. Department of Energy Contract No. DE-AC02-98CH10886.

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