The PHOBOS Detector at RHIC

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PHOBOS is one of four experiments constructed to measure the first Au-Au collisions at RHIC. The performance of this detector system during the intial running period is compared to the original design goals.

1. Introduction

The PHOBOS detector is one of four experiments at the start-up of the Relativistic Heavy Ion Collider. RHIC began operation in the summer of 2000, colliding beams of gold ions at $\sqrt{s_{NN}} = 56$ and 130 GeV to potentially create the highest energy densities ever achieved over an extended volume in the laboratory. Two criteria drove the experimental design: maximum flexibility in the experimental setup in case of unexpected physics, and the assumption that any new phenomena would be rare such that a large number of events would be required in order to find them. A description of the PHOBOS detector follows, along with a report of the performance from the apparatus during the initial running period at RHIC. Additional details of the experimental setup and detector performance can also be found in Refs. [1,2].

2. The PHOBOS detector

The PHOBOS detector is comprised primarily of silicon pad sensors used in two separate detector subsystems, as illustrated in Figure 1. The multiplicity array is a single layer of

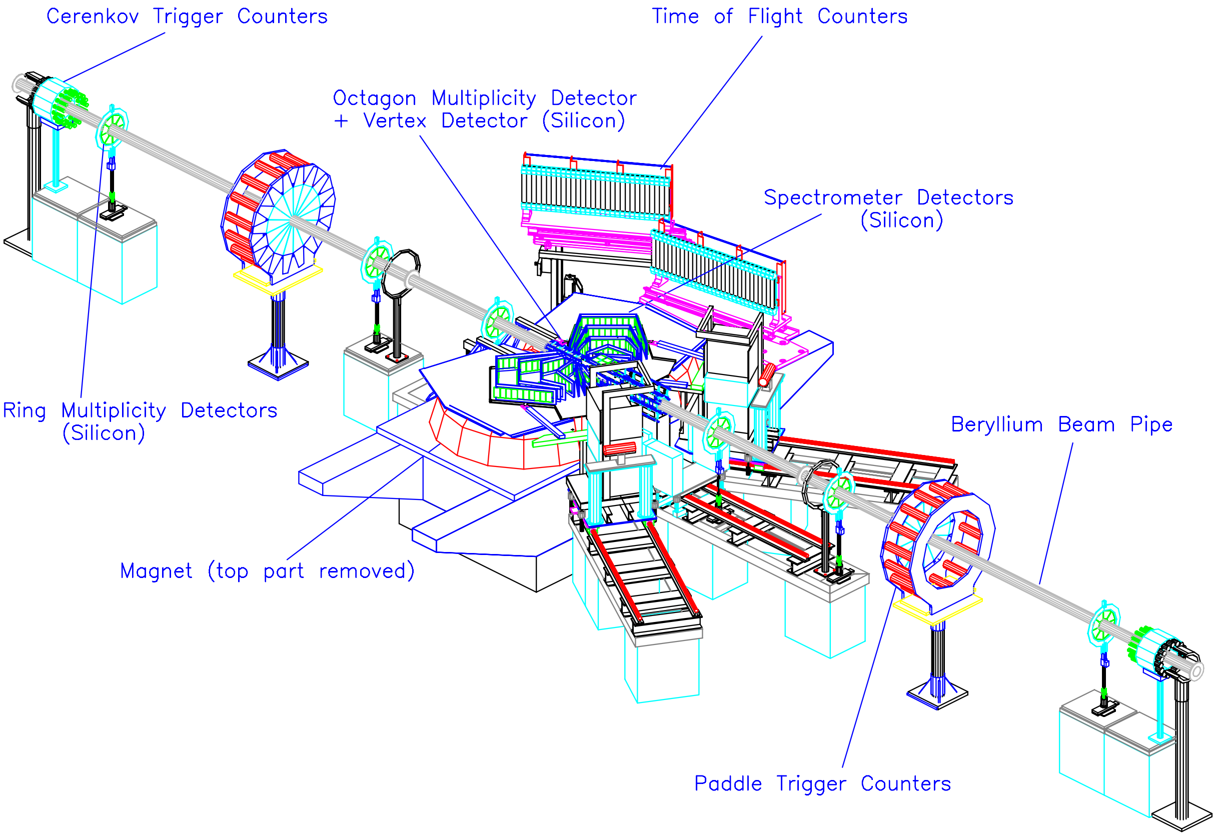

Figure 1. Schematic layout of the PHOBOS detector.

silicon that provides almost 4π coverage. This subsystem is used to measure the number of charged particles emitted from the collisions over a large pseudo-rapidity range $|\eta| \leq 5.4$. Two central double-layered sections of finer granularity Si pads above and below the Be beam pipe serve as a vertex detector. The second subsystem has two spectrometer arms located near mid-rapidity, each consisting of a total of 16 layers of silicon. The spectrometer arms are used to track a fraction ($\sim 2\%$) of the total charged particles emitted in a 2 T magnetic field and to identify these particles by their specific energy loss (dE/dx). Scintillator time-of-flight (TOF) walls extend the particle identification capabilities to higher momenta in one arm.

A minimum-bias event trigger is provided by a coincidence registered between two sets of 16 scintillator paddle counters located at ± 3.21 m from the nominal interaction point along the beam axis (see Fig. 1). The measured time difference is required to be consistent with the primary event vertex occurring between the paddle sets. The paddle counters, which cover $3 < |\eta| < 4.5$, are also used to estimate event centrality, by correlating the sum of their measured signals with the simulated event multiplicity within their acceptance. Each of the four RHIC experiments has zero-degree calorimeters (ZDCs) located ± 18.5 m from the nominal interaction points. The ZDCs provide a common means to measure luminosity and centrality using the beam-velocity neutrons from fragmentation and/or evaporation of the colliding nuclei. The event centrality determined with the paddle counters monotonically correlates with the estimated centrality from the ZDCs (not shown in Fig. 1), providing an independent cross check of both methods.

All the Si sensors in PHOBOS are AC-coupled single-sided, double-metal pad sensors with pad areas varying from 1 to 30 mm^2. Using this technology [3], all signals appear on bonding pads at one or two edges of the sensor, where the read-out chips are connected. The Si sensors are read out with VA-HDR-1 chips [4], providing an analog measurement with large dynamic range (up to 100 MIP) of the ionization charge deposited in each pad. The analog signals are multiplexed out for digitization by 12-bit ADCs. Integrated into the read-out chain is a gain calibration system, which is used to calibrate each individual channel. Latch-up circuitry that interlocks during single-event upset was included to protect against chip radiation damage.

2.1. Multiplicity and Vertex Array

The multiplicity array consists of 23000 channels of large (~ 30 mm^2) Si pads arranged in an octagonal barrel ~ 1 m long, and six Si pad rings at $|z| = 1$, 2, and 5 m along the beam axis (see Fig. 1). The octagon covers $|\eta| < 3.5$ and the six rings extend the coverage up to $|\eta| = 5.4$ over the full azimuth. The charged particle multiplicity is measured using the energy deposition of the particles emitted from the collisions.

The high particle density created in central Au-Au collisions at RHIC produces channel occupancies exceeding 80%. Offline analysis was able to fully correct baseline shifts of the VA-HDR-1 chip up to 100 keV using the information from channels without hits. After the baseline correction, the overall pad-to-pad uniformity was found to be better than 2%, while the signal-to-noise ratio was found to be ~ 13, significantly better than the design specification of 10.

Tracks formed from hit combinations on two successive planes of the vertex detector project back to the beam orbit, resulting in a vertex resolution of $\sigma_x \sim 450$ μm and $\sigma_y \sim \sigma_z \sim 200$ μm. High-η particles originating from this vertex traverse the silicon at a shallow incident angle, depositing a large amount of energy over a long track-length. Secondary particles produced away from the vertex will traverse the silicon at more normal incidence, depositing less energy. Thus a large portion of the secondary contamination at $|\eta| > 1.2$ in the octagon barrel can be suppressed by an energy cut that varied as $\cosh \eta$.

2.2. Spectrometer

Each spectrometer arm (see Fig. 1) consists of 16 layers in total of Si sensors located between the pole tips of a large room-temperature magnet. The double dipole magnet has been optimized to provide a nearly uniform magnetic field up to 2 T over the last eight Si layers and a low field near the beam pipe. Straight tracks in the low field region provide seeds for the pattern recognition necessary in the high field region. For the run in 2000 one spectrometer arm was fully equipped and the second arm had only the first six Si layers installed, resulting in a total of 94000 read-out channels from both arms. Five different pad sizes are used in the spectrometer, optimizing the trade-off between physics requirement and channel count. The typical pad-to-pad signal uniformity in the spectrometer sensors was found to be better than 1% despite the variety of sizes, while the signal-to-noise ratio was ~ 18.

Particle identification of pions, kaons and protons is possible through multiple dE/dx measurements in several Si planes traversed by the particle. To attain good separation of the particle species, it is crucial that the detector response after gain, track angle and detector thickness correction be uniform throughout the spectrometer and only depend on the particle species and momentum. The dE/dx resolution is $\sigma_{dE/dx/\langle dE/dx\rangle} = 7.8\%$, and the momentum resolution achieved at $p = 1$ GeV/c ($p = 10$ GeV/c) is $\delta p/p = 1.5\%$ (2.1%). The thin Be beam pipe and the use of silicon make it possible to extend the low-p_T coverage to ~ 50 MeV/c for pions and ~ 100 MeV/c for protons.

3. Conclusion and Outlook

The PHOBOS detector operated successfully during the initial running period at RHIC, recording ~ 3.5 million collision events on tape. The installed silicon performed well with $\sim 98\%$ of the channels fully functional. The complete baseline design of the PHOBOS detector will be ready for the summer 2001 Physics Run at $\sqrt{s_{NN}} = 200$ GeV including two fully equipped spectrometer arms. Further beyond, the PHOBOS detector will be upgraded to study open charm production through measurement of single electrons at high p_T from displaced vertices. Better vertexing capability will require the addition of a micro-vertex detector, while transition radiation detectors, and electromagnetic calorimetry will provide electron identification.

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