PISA: The PHENIX Experiment Simulation Packages

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The PHENIX detector at the RHIC accelerator is a huge, extremely complex experimental device whose physics goals can only be realized with the aid of a sophisticated simulation tool. The PISA (PHENIX Integrated Simulation Application) packages now comprise over 1.7 million lines of software and associated support files, and these are in active use worldwide by scores of detector subsystem programmers among this international collaboration. The simulation software models the ensemble performance of a dozen different detector technologies aimed at unraveling rare signal events in an excruciatingly dense particle background. So far the simulation program has assisted the collaboration physicists in the development of tracking pattern recognition algorithms, multi-level trigger strategies, hardware and software optimizations for background rejection, and Day 1 physics data acquisition planning. On a technical level, the four year software building process has pushed the capabilities of code development, management, and distribution on a multi-national basis. For additional information please access our Web site at http://rhinuc.phy.vanderbilt.edu/siml.html

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1 Introduction to the PHENIX experiment

The PHENIX experiment (Pioneering High Energy Nuclear Interaction eXperiment) is to be carried out on the Relativistic Heavy Ion Collider (RHIC) now being built at Brookhaven National Laboratory and scheduled to be completed in the first quarter of 1999. RHIC is a dedicated heavy ion accelerator producing beams of various ions from proton to gold. It will accelerate counter-circulating beams in two different rings up to 250 (Z/A) GeV energies, crossing each other at six interaction regions. PHENIX is one of two large scale experiments planned at RHIC whose main goal is to detect the formation of a new phase of matter called the *Quark Gluon Plasma* (QGP). This is matter as it existed a few microseconds after the Big Bang, and just before it froze forever into the nucleonic ice crystals which we know today as protons and neutrons.

The PHENIX collaboration [2] currently comprises 396 scientists, engineers, and graduate students from 45 participating institutions in 10 countries: Brazil, Canada, China, Germany, India, Japan, Korea,

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[2] WWW site http://www.rhic.bnl.gov/export1/phenix/WWW/phenix_home.html has complete details regarding the experiment.

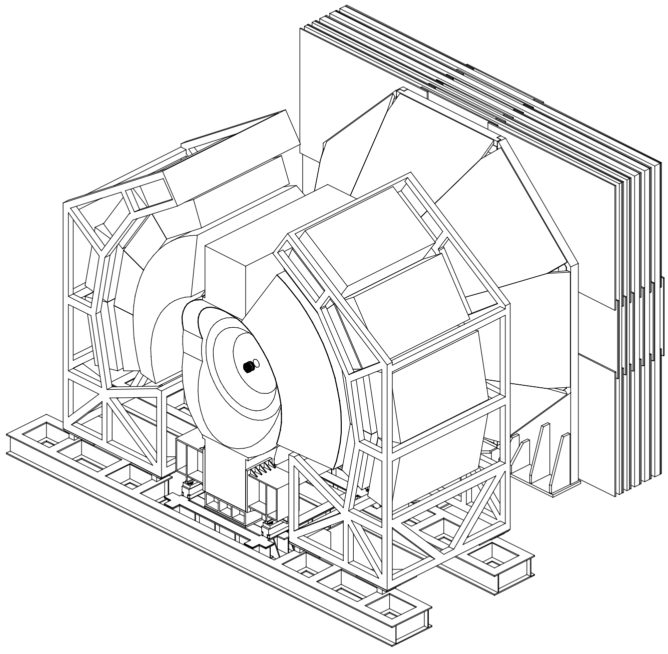

Fig. 1. View of the PHENIX detector including magnet subsystems, Central Arm detector subsystems, and the North Muon Arm. The comparable South Muon Arm is omitted for reasons of figure clarity.

Russia, Sweden, and the U.S. Construction of the PHENIX detector is now about 50% completed and a partial sketch of the apparatus is shown in Figure 1. The whole detector physically spans approximately 12 x 18 x 18 meters.

The detector has been designed to measure as many of the potential QGP signatures as possible and look for simultaneous correlations among them. Two basic properties of the plasma, Debye screening of quantum chromodynamics (QCD) interactions and chiral symmetry restoration, are significant elements of the measurements. To study these QGP signatures electron pairs, muon pairs, photons and charged hadrons must be measured. The detector performance has been optimized to detect the particle pairs and photons with good efficiency over a large momentum range.

Besides being physically impressive in size, the PHENIX detector also encompasses an extremely large number (several hundred thousand) of electronic signal channels. The granularity count in the PHENIX detector is dictated by the prediction that 10,000 to 20,000 particles will be produced in the central collisions of gold nuclei from the RHIC accelerator. Around 90% of these will be the charged and neutral pion particles produced in almost equal abundance. The very short-lived neutral pions will decay immediately at the collision vertex into two photons. This decay mode presents the most serious background problem to the direct photon measurements. There also exists a 1.2% branch of the π^o decaying into an electron-positron pair accompanied by a photon partner (Dalitz decay). This decay branch admits only a very low probability of both the electron and the positron being in the fiducial volume of the Central Arm of the detector. Hence, multiple Dalitz decays in an event induce a combinatoric background for the detection of true electron-positron pairs from the decays of various vector resonances. Correspondingly, the weak decay of the charged pions into muons creates a combinatoric background for the true dimuon signals. One of the major goals of the simulation effort in PHENIX is to establish methods in hardware and software for rejecting these combinatoric backgrounds while retaining a high efficiency for the real signals.

2 View of the PHENIX Simulation Suite and System Development

Collectively the suite of software packages used in PHENIX is popularly called PISA (PHENIX Integrated Simulation Application), although the acronym originally referred to only the GEANT-based geometry and tracking package. Other software packages in the suite are the several event generators written by theorists and interfaced into PISA, a stand-alone geometry verification package called GVERLAP, and the current PHENIX Off-Line analysis shell called PISORP (PISA Output Reconstruction Package).

Approximately 60 PHENIX collaborators worldwide are directly involved in simulation software development and testing which has been proceeding since 1992. A small fraction (10%) of these constitute the simulation core group who are based at Vanderbilt University with remote assistance from staff members of the Bhabha Atomic Research Centre (Bombay). The core group's responsibility is to develop and maintain the software infrastructure which supports all the simulation tools in PHENIX, and to guarantee that the software runs on all the UNIX platforms (IBM/AIX, SGI/IRIX, DEC Alpha/OSF1, HP/HPUX, Sun/SunOS, PC/LINUX, and lately the Pentium Pro running Solaris) approved for use by the collaboration.

The major fraction of the PHENIX simulation group are detector subsystem programmers and users. The PHENIX detector itself consists of a dozen different hardware technologies whose ensemble performance is critical to the success of the experiment. Working within the guidelines specified by the core group members, the detector subsystem programmers have been responsible for creating and maintaining the software geometry models of their individual detectors and coding the response of those detectors to the particle and radiation environment developed within the whole of the PHENIX detector. The subsystem programmers have written and documented the event trigger and the event analysis modules which will optimize the data acquisition and the event reconstruction leading to the extraction of the hoped-for physics signatures of the QGP. The detector subsystem groups also maintain individual WWW pages describing their hardware and software modules in extensive detail, with these pages cross-linked to the main PHENIX Web site.

3 Code Management and Distribution

All the software source code, specialized development tools (*e.g.* GNU-make and GNU-gcc), and support files reside in a central repository at the RHIC Computing Facility (RCF). Developers and users access the software repository by means of the AFS/CVS tools (Andrew File System distribution software from the Transarc Co., and the Concurrent Version System code maintenance software). At present, after nearly five years of development, there are more than 70 MBytes of software source code and support files in the repository, or more than 1.7 million lines assuming 40 Bytes per line. The simulation core group does automatic daily CVS checkouts of the entire PISA/PISORP to insure the integrity of the software across the different supported platforms.

The PHENIX software packages have been imported to large computer farms located at Lawrence Livermore Laboratory (ACISE), Lawrence Berkeley Laboratory (PDSF), and Vanderbilt University itself (VUPAC). The core group is now in the process of generating tens of GBytes of simulated data files on these farms, where the files are being made available to the general collaboration as fake data tapes. By processing these simulated data tapes this year, the collaboration will prepare its readiness for the TBytes torrent of real data which will cascade upon us in 1999.