RESULTS OF PARTICIPATION OF NSC KIPT IN THE CERN/CMS MONTE-CARLO EVENT PRODUCTION

L.G.Levchuk, D.V.Soroka, P.V.Sorokin, S.S.Zub

NSC Kharkiv Institute of Physics and Technology, 61108 Kharkiv
e-mail: stah@kipt.kharkov.ua

The hardware configuration and cluster software of the NSC KIPT specialized Linux cluster constructed for carrying out work on CMS physics simulations and data processing are described. The performances and architecture of the cluster are outlined. The results of participation of NSC KIPT in the CERN/CMS Monte-Carlo event production are presented.

Experimental searches for such manifestations of "new physics" as the Standard Model (SM) Higgs boson or supersymmetry (SUSY) partners to already known elementary particles are among the highest-priority problems of the contemporary high-energy physics (HEP). If detected, the corresponding signals, apart from bearing new evidence for the SM, could pave the ways for further development of its extensions. So, great efforts are being undertaken by the world-wide HEP community in order to provide tools for such a discovery. Much hope is associated with the Large Hadron Collider (LHC), which is under construction at CERN and will be put into operation in 2007. Having two colliding proton beams with c.m. energy of 14 TeV, it will be capable of searching the Higgs boson in the whole range of its plausible masses from 100 up to 1000 GeV/c^2 and will possess a significant potential for the SUSY discovery.

For the LHC project luminosity of 1034 $cm^{-2}s^{-1}$, an average of 20 inelastic events occur every 25 ns, while the fraction of this data array that can be selected as candidates for signals of the "new physics" is very small. In case of the CMS detector [I], a two-level trigger system is developed to reduce the input rate of 10^9 events per second to the filtered rate of 10^2, with 1 Mbyte of information per event on average being stored for the further analysis. For the ten-year operational term of the LHC, the total amount of data stored by the CMS collaboration will exceed 10^{16} bytes. Of course, such huge arrays of experimental information are challenging against the data acquisition, processing and storage systems.

To meet the requirements set by the LHC era physics tasks, the concept of the data Grid [2] has been put forward. Its goal is to provide an infrastructure that would allow one a coordinated use and sharing of computational and storage resources. According to this concept, a multi-tier structure of regional centers is being created combining the computing and scientific facilities of many institutes and research centers from more then 30 countries.

The regional centers are expected to be UNIX-like clusters of workstations or personal computers (PC). A cluster can be defined (see Ref. [3]) as a type of a parallel or distributed processing system, which consists of a collection of interconnected stand-alone computers cooperatively working together as a single, integrated computing resource. The last several years have witnessed a considerable world-wide quantitative and qualitative growth of PC-based Linux clusters often also referred to as PC farms. They are used extensively already in the HEP laboratories, and their application area gradually broadens.

Main advantages of Linux clusters compared to other computational systems are due to their ability to have high computing performances at relatively low price. The price-per-performance ratio of a PC cluster-type machine is often estimated [4] as being three to ten times better than that for traditional supercomputers. Certainly, the efficiency of the Linux clusters compared to the supercomputers strongly depends on the character of a computational task. One may expect them being preferable in cases, when the task straightforwardly splits into a certain amount of independent or quasi-independent smaller jobs that can be distributed for execution over different processors of the system. This situation is typical for HEP computing: a needed statistics in a Monte-Carlo simulation can be gained by running several jobs with different initial random seed numbers simultaneously, and large data arrays can be analyzed through their subdivision into relatively small groups of events to be processed independently of each other.

Among other advantages of the cluster architecture, one could mention its flexibility and scalability: cluster capacities can be readily increased by adding new nodes step by step. At last, the fact that a lot of free software is available for the Linux platform results in further improvement of the performance-per-price ratio for the Linux clusters. There exists a variety of cluster configurations from single-image systems with clients booted from the network to heterogeneous parallel systems. One can choose an appropriate hardware and a cluster scheme in accordance with the scientific problem to be solved. What follows is a brief description of the Linux cluster created in the NSC KIPT for computing within the CMS physics program.

NSC KIPT CMS Linux Cluster

The first stage of the NSC KIPT specialized cluster to conduct computing activities on CMS physics including simulations and preparatory work for data processing and analysis has been completed by the end of 2001. Currently, the cluster (see Fig. 1) consists of 10 (one "master" and nine "slave") nodes connected by the 100 Mbit Ethernet. At present, all the nodes are running Linux-2.4-18-27.7.x.cern (Red Hat 7.3). The "master" computer (dual Intel Pentium III 2*800 MHz with random access memory (RAM) of 512 MB). It operates as a file-server that exports the CERNLIB and LHC++ [5] program libraries, CMS-software and users' home directories to the nine other computers via the network file system (NFS). Then, it provides the domain of the network information service (NIS) enabling a joint usage of passwords in the network and acts as a domain name service (DNS) server that establishes the reciprocal compliance between the network computer names and addresses. Also, it works as the portable batch system (PBS) [6] server (see below). One dual Intel Pentium III (2*800 MHz , 512 MB RAM), two dual Pentium III (2*1.0 GHz, 512 MB RAM), five dual Pentium III (2*1.4 GHz, 1024 MB RAM), and one dual Intel Xeon (2*2.0 GHz, 1024 MB RAM) computers have been configured as the "slave" nodes. They are used for calculations in both interactive and batch modes having the hard disk drives (HDD) formatted in a way making it possible to process single files with size of 10 Gbyte. At present, the total cluster HDD storage is 1.1 TB, and the computational capacity is about 50000 bogomips.

The software currently installed on the cluster includes CERNLIB (containing, in particular, the GEANT simulation package, the PAW/PAW++ physics analysis tool and such event generators as PYTHIA [6] and ISAJET) and the LHC++ program library. In addition, we have installed the software developed by the CMS collaboration including CMSIM (a GEANT-based package for simulation of the GMS detector response), ORCA (an object oriented [based on LHC++] tool for CMS event reconstruction and analysis) [8], and IGUANA (a package for CMS interactive data visualization and analysis). Versions of the programs are permanently refreshed according to CMS collaboration current demands.

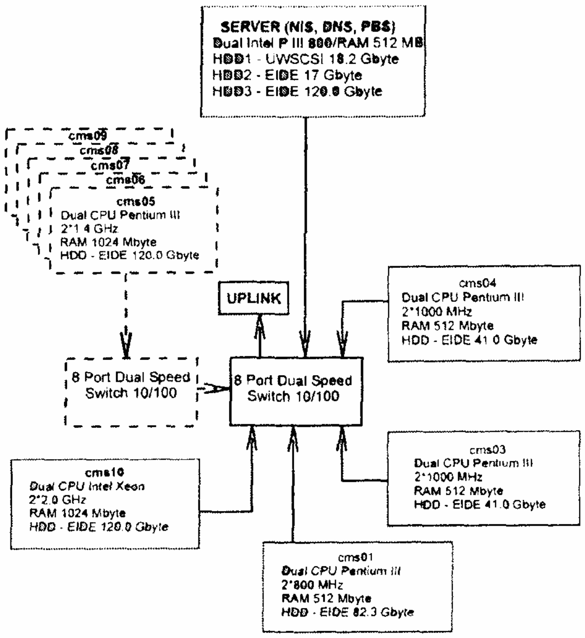

Fig.1. NSC KIPT CMS Linux Cluster.

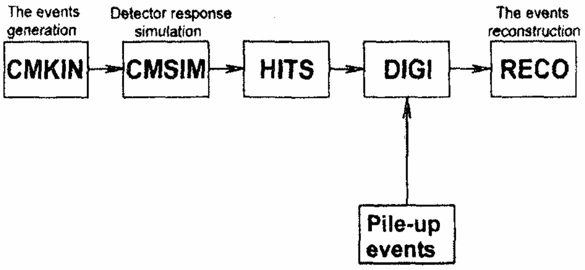

Fig.2. Complete chain of the CMS event generation/reconstruction.

The PBS is used as the cluster batch job and system resource management package. It accepts (see details in Ref. [9]) a batch job preserves and protects the job until running, runs the job and delivers output to the submitter. The PBS allows one to administer flexibly the system resources while carrying on the computing and may be configured to support jobs run on a single system, or many systems grouped together. The cluster in its current configuration possesses performances that already allow us to carry on simulations within the CMS physics program. It was exploited in our Monte-Carlo studies [10] of the possibilities to observe the heavy Higgs boson in decays $H^{\circ} \longrightarrow Z^{\circ}Z^{\circ} \longrightarrow l^+l^-\nu\nu$ at CMS. Also, we took part in the CMS SPRING 02 (generation of high-pT jets in pp collisions at the LHC energy), SUMMER.02 and SUMMER-03 event production runs. The CMS SUMMER_02 event production run included the reconstruction of particles' tracks. The schematic illustration of the generation cycle is shown in Fig.2. It includes the PYTHIA event generation, slow GEANT simulation of CMS detector response performed with CMSIM package, and ORCA track reconstruction with the events pile-up. Creation and submission of the computation jobs as well as the CMS database update have been performed by Impala [11] scripts configured and tuned in accordance with the cluster peculiarities. The jobs were handled by the batch system PBS. A brief statistics of the participation of Kharkiv CMS Group in the CERN/CMS Monte-Carlo Event Production is represented in Table 1.

Table 1

Data Set	Number of events generated	Data type
hi02_photon 100_110	1000	.fz (CMSIM only)
hi02_qcd 100_110	1000	.fz (CMKIN+CMSIM)
hi02_qcd 100_110	5000	.fz (CMKIN+CMSIM)
eg02_BigJets	85250	.ntup(CMKIN+CMSIM+ HITS+DIGI+NtupleMaker)
bt03_qcd 120_170tth	80000	.ntpl (CMSIM)
mu03_tt2mu-M111000	500	.ntpl (CMSIM)
eg03_Wenucalibration	99500	.fz (CMSIM)
jm03_Wjets_20_50	100000	.ntpl (CMKIN)

The detailed information about the activities of Kharkiv CMS Group is presented in [12] and can be also found on CMS Production Web page [13].

Conclusion

The NSC KIPT specialized Linux cluster performances allow us to perform simulations within the CMS physics program and to fulfil the tasks of the SMS event production in the frames of the SMC computing model. Further development of the cluster and its optimization is planned.

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РЕЗУЛЬТАТИ УЧАСТІ ННЦ ХФТІ В CERN/CMS МОНТЕ-КАРЛО ГЕНЕРАЦІЇ

Л.Г.Левчук, Д.В.Сорока, П.В.Сорокін, С.С.Зуб

ННЦ Харківський фізико-технічний інститут,
вул. Академічна, Харків, 161108
e-mail: stah@kipt.kharkov.ua

Описано апаратну конфігурацію та програмне забезпечення спеціалізованого Linux кластера ННЦ ХФТІ, створеного для виконання робіт з моделювання фізики та обробки данних колаборації CMS. Наведено харатеристики та архітектуру кластера. Представлено результати участі ННЦ ХФТІ в CERN/CMS Монте-Карло генерації.