*МАТЕМАТИКА И МАТЕМАТИЧЕСКО ОБРАЗОВАНИЕ, 2003*
*MATHEMATICS AND EDUCATION IN MATHEMATICS, 2003*
*Proceedings of the Thirty Second Spring Conference of*
*the Union of Bulgarian Mathematicians*
*Sunny Beach, April 5–8, 2003*

# LHC COMPUTING

**Vladimir Dimitrov**

The LHC at CERN is an accelerator which brings protons and ions into head-on collisions at higher energies than ever achieved before. This will allow scientists to penetrate still further into the structure of matter and recreate the conditions prevailing in the early universe, just after the "Big Bang". In this project Bulgaria is participating as CERN member. Computing support for LHC is a challenge not only for us. In this paper state of the art on the topic in Bulgaria is presented.

**Introduction.** CERN is at present building a new accelerator, the Large Hadron Collider (LHC) that will be the most powerful particle physics accelerator ever constructed when it starts operation in 2005. The computing challenges for LHC are:

- the massive computational capacity required for analysis of the data and
- the volume of data to be processed.

The experiments that will be carried out using the LHC are organized as very large collaborations of research physicists and engineers (1,500-2,000 people on an experiment) employed by hundreds of institutes spread across the 20 European member states and the rest of the world. The computing requirements for LHC will be fulfilled using a large facility at CERN and a number of large regional centers spread across the world in various European countries, North America, and Japan. The Data Grid project will provide a prototype system that could be used as the basis for the initial operation of this distributed computing environment. LHC data analysis will begin as the first data is generated in 2005 and continue for at least ten years, offering opportunities for the deployment of commercial tools based on the work of the project.

LHC Computing is intended to support full access to LHC data for all participating institutes and physicists. This means to be created world-wide distributed computing system by participants in LHC experimental program. Steering Group at CERN is responsible for coordination efforts.

**LHC Computing Model.** LHC Computing Model is multi-Tier hierarchical model based on Grid technology.

The heart of the centers of this multi-Tier hierarchical model is Computing Fabric. It contains ten of thousand components (processors, disks, tape drives and network switches) optimized for data intensive operations. A particularly large Computing Fabric installed at CERN will serve as a common Tier 0 center for all experiments and handle the raw data reconstruction and storage. Multi-Tier hierarchies see on Fig.1 and below:

- Tier 0. Organizing Software: Fabric Management

• Tier 1. Organizing Software: Grid Middleware
• Tier 2. Organizing Software: Transparent access to data
• Tier 3 – 4. Application Infrastructure by user applications

Grid technology will be used to interconnect distributed computing fabric in an attempt to contribute solutions to this model that provide a combination of efficient resource utilization and rapid turnaround time.

“Enable communities (“virtual organizations”) to share geographically distributed resources as they pursue common goals – in the absence of central control, omniscience, trust relationships.” – Ian Foster

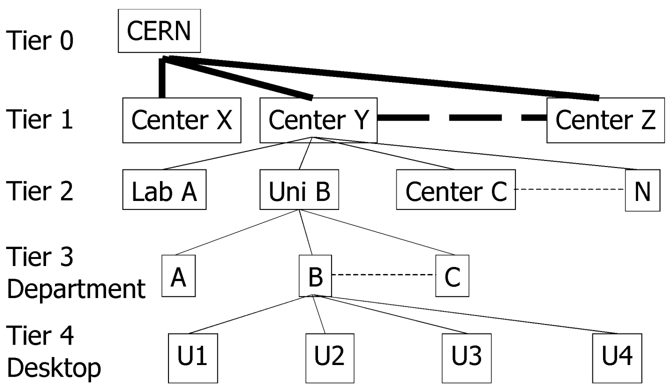


Fig. 1. LHC Computing Model – Multi-Tier achitecture

In order to provide the required bandwidth of the wide area network between nodes in the distributed computing fabric, it will be vital to ensure a good, high-performance Research Networking infrastructure is in place.

Many human resources are needed to write the Core Software for collaborations: ALICE, ATLAS, CMS, LHCb.

**Approximate numbers to remember (per experiment).** General parameters:

• 1 MB = size of a recorded p-p event (up to 40 MB for a Pc-Pb event in ALICE).

• 102 Data taking rate (Hz), down from 109 Hz p-p collisions, after several trigger levels.

• 107 data taking second/y, or ∼116 days (except Ion runs for ALICE ∼15 days/y). To ease comparisons, this number has been fixed equal for all experiments (p-p colisions).

• 109 recorded p-p events per year.

Storage per experiment:

• 3 to 10 PB on tape, total ∼28 PB (with 2/3 more per year beyond). Raw Data storage ∼1/3 of this total.

• 1 to 6 PB of disk. Total ∼11 PB (with 1/3 more per year beyond).

CPU (off-line) per experiment:

• Best guesses today range from ∼1 M SI-95 in LHCb to ∼2 M SI-95 for each of ALICE, ATLAS and CMS. Uncertainties are at least a factor 2. Estimates are in fact the sum of Tier 0, Tier 1 and Tier 2.

Networking:
• 1.5 – 3.0 Gbps between main centers.

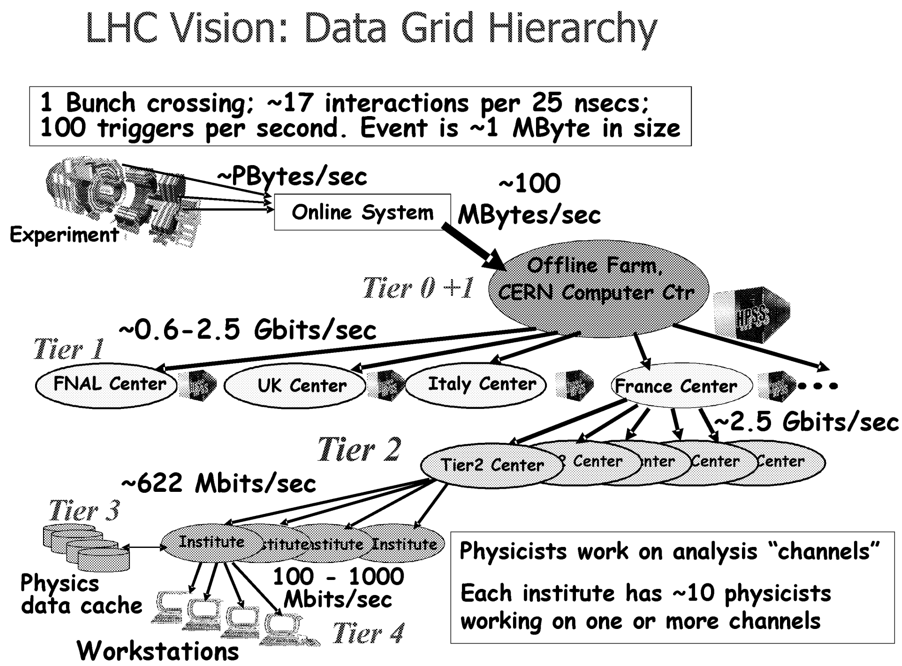


Fig. 2

**Tier 0 & Tier 1 Centers.** There exists one "central site" (CERN): the central site is able to provide all the services. The following steps happen at the central site only:
• Online data acquisition and storage
• Possible data pre processing before first reconstruction
• First data reconstruction
Other production steps (calibration data storage, creation of ESD/AOD/tags) are shared between CERN and the RCs. The central site holds:
• a complete archive of all raw data
• a master copy of the calibration data (including geometry, gains etc...)
• a complete copy of all ESD, AOD, tags possibly online
Data taking estimate is:
• 1 PB raw data per year per experiment
• 10**9 events (1 MB each) per year per experiment
• 100 days of data taking (i.e. 10**7 events per day per experiment)
Current estimates for a single LHC experiment capacity to be installed by 2006 at CERN are (see Robertson):
• 520,000 SI95 for CPU, covering data recording, first-pass reconstruction, some reprocessing, basic analysis of the ESD, support for 4 analysis groups
• about 1400 boxes to be managed

- 540 TBs of disk capacity
- 3 PBs of automated tape capacity
- 46 GB/s LAN throughput

One can assume that 10 to 100 TB of disk space is allocated to AOD/ESD/tags at the central site. In the following, resources for the RC will be expressed in terms of percentage of the CERN ones.

**What a kind of Tier center is suitable for Bulgaria?** How we see from the previous text Tier 1 center is impossible for Bulgaria at this time. For it is needed an enormous investment and advanced telecommunication infrastructure.

Then Tier 2 remains and even such a center is very big for Bulgaria. We have initial talks to create two Tier 2 centers for the Balkan countries – one in Greece and one in Bulgaria.

**What we have for Tier 2 center?**

**Communications.** *External communications:* BTC offers very expensive 2 MB lines. There is a line to France with bigger bandwidth, but still far way from Tier 1 – Tier 2 bandwidth 2.5 GB/sec. Good news is that till the end of this year or at the start of next year BAS will be connected to GEANT with 6 Mbps line (Regional Research and Education Network for South Eastern Europe). This line in Bulgaria will be part of Administration Network.

*Internal communications:* At this time, Sofia University has more than 3 campuses and BAS – more than 2 campuses. Internally they are connected with optics, but between the campuses are used lines from BTC. Sofia University, for example, is using 32 KB line to connect with BAS main campus. BTC offers 2 MB lines – very expensive. Good news here is that there is a possibility to connect all campuses with the Administrative Network. In such a case all Universities and Research Institutes will be optically connected. Administrative Network is using BTC optical lines – it is relatively easy to increase their bandwidth to 622 Mbps (Tier 2 – Tier 3 center).

**Computing Fabric.** In INRNE – BAS first computing fabric is installed with the help of CERN. Linux based software is installed on it and some Globus middleware.

At Sofia University we are planning to create another computing farm.

On these farms will be installed Globus and Datagrid middleware. The idea is to create testbed for Datagrid in Bulgaria, to register Bulgarian segment of Globus and Datagrid, and not at last to prepare computer scientists able to work with these advanced technologies.

**Human Resources.** At this time people involved in LHC computing are 2 Assoc. Prof., 4 Assist. Prof., 2 PhD students, and ∼10 students from Master and Bachelor programs in our Faculty. One Assist. Prof. is now in IT Dept. at CERN. Three students are working in CERN at different experiments as IT specialists.

We will start a new course from the beginning of this educational year on the Grid technologies. We hope to have our exercises on real computing farm.

In the near future we will establish new master program on LHC computing with Faculty of physics.

**Conclusion.** The ideas mentioned in this presentation are result of joint efforts of many people.

Never mind that some people have been pessimistic a year before, we succeeded in many directions.

I think that it is realistic to create Tier 2 center in Bulgaria in the next 2-3 years.

Vladimir Dimitrov
P.O.B 1829, Sofia 1000
e-mail: cht@fmi.uni-sofia.bg

## LHC КОМПЮТИНГ

**Владимир Димитров**

LHC е нов ускорител разработван в CERN. Неговото назначение е да ускорява и сблъсква протони и йони с много високи енергии – такива, каквито досега не са достигани. Това ще позволи на физиците да навлезат още по-дълбоко в структурата на материята и да моделират условия близки до ранните времена от създаването на света – непосредствено след "големия взрив". В този проект участва и България като член на CERN. Обработката на данните, генерирани от LHC, е предизвикателство не само за нас. В този материал са представени усилията на участниците от страната за осигуряване на експеримента.

Решаването на изчислителните проблеми, свързани с LHC, ще отвори нова страница в архитектурата на разпределените системи.