Massive numerical simulations for the Cherenkov Telescope Array

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1. Introduction

The Cherenkov Telescope Array is a next generation astronomical observatory to observe very high energy gamma-rays in the energy range from around 20 GeV to beyond 300 TeV. It will consists of two separate sites, located in the Southern and Northern hemispheres to provide all-sky coverage. Over one hundred telescopes have to be build and deployed on sites to provide almost 10 km^2 effective area.. The CTA will offer an order of magnitude better sensitivity over the existing instruments. Scientific goals for the observatory range from the simple observations of known objects, such pulsars, pulsar wind nebula, supernova remnants, binary systems, star clusters and active galactic nuclei with their super massive black holes to very high energy surveys and new objects discoveries. Cosmological studies of intergalactic background field are also possible, as well as astrophysical tests of fundamental theories of physics.

The CTA is currently in its design phase. Beside the development of the specific telescopes the array configuration needs to be determined and optimized. It is also necessary to provide expected performance characteristic to allow for determination of scientific cases, prove the fulfillment of the CTA requirements and optimize the construction costs. This is done through the massive numerical simulations of the array performance of the numerous array configurations and possible locations of the observatory. These simulations require millions of CPU hours and thus the grid approach is the more efficient way of performing the calculations.

2. Description of a problem solution

Massive numerical simulations have been performed to optimize the array layout and determine its expected performance. Such a simulation consist of two stages performed on the grid: 1) the air shower simulation with determination of the Cherenkov light emission – this stage is performed using `CORSIKA` simulation code [1], and 2) simulation of the Cherenkov light detection process by the telescopes of the array using `sim_telarray` [2]. These stages require substantial computing resources since together with gamma-ray events a large number of background events needs to be simulated in order to allow for sensitivity determination. Due to excellent gamma-hadron separation the required number of background events is of the order of one thousand larger than gamma-ray events. The third stage of the computations – determination of the array parameters – is usually done on computer clusters available locally.

Two such massive simulations have been already performed on the grid, so called Prod-1 and Prod-2. During Prod-1 campaign a total number of 275 telescopes of five different kinds have been simulated and analyzed. The detailed description of the results can be found in [3]. More recently a Prod-2 campaign have been performed with a total number of 229 telescope positions and seven different kinds of telescopes. Some of the positions were used by more than one telescope type. The simulation were performed for five different candidate sites. The array layout and brief description of the initial simulation set-up can be found in [4]. During Prod-2 campaign DIRAC (Distributed Infrastructure with Remote Agent Control – diracgrid.org) interware has been used to control job submission and job status.

3. Results

The main part of the Prod-2 campaign lasted from week 53 of 2012 till week 30 of 2013. During the production over 1.8 mln jobs were executed. On average 590 computing cores has been used constantly in 18 computing centers supporting virtual organization `vo.cta.in2p3.fr` with a peak of 8000 concurrent jobs reached during the simulations. From 32 mln HS06 hours used, by far the most part was contributed by the ACK AGH CYFRONET with a total number of over 70 thousand CPU days (over 52% of the total). The data produced during the campaign used over 670TB of disk storage with 420TB contributed by the CYFRONET.

Data from the Prod-2 campaign is currently being analyzed by the various groups within the CTA collaboration. From the plethora of ongoing projects some of the most interesting are the analysis of the sub-arrays devoted to the observations of the most energetic gamma-rays. These arrays consist of around 70 telescopes and thus constitute the most numerous part of the whole array. An example of such a study is presented in [5], where it was shown that a sub-array of 70 4-meter class telescopes is able to fulfill the CTA requirements. Another example include an analysis of a 5-telescope mini-arrays which are considered for deployment before the final construction of the observatory to provide technical and scientific test-beds of various concepts explored within the CTA collaboration.

4. Conclusions and future work

Both Prod-1 and Prod-2 numerical simulations prove that the basic concept of the CTA observatory is correct and allowed for an array layout optimization according to the telescope types and site location. They also provided the data necessary for the determination of the basic array parameters such as sensitivity, angular resolution and energy resolution.

Despite the detailed exploration of the already produced data future studies will include additional massive simulations of the optimized array layout for different observational angles and possibly extended gamma-ray sources. These simulations may starts as soon as the final location of the CTA site is chosen allowing for a significant reduction of required resources.

References

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