CSCS Proposal: DAMPE

S. Zimmer[1]

[1] University of Geneva, Departement de physique nuclaire et corpusculaire (DPNC), CH-1211, Genève 4, Switzerland

E-mail: `zimmer@cern.ch`

Abstract. DAMPE (DArk Matter Particle Explorer) is one of the five satellite missions in the framework of the Strategic Pioneer Research Program in Space Science of the Chinese Academy of Sciences (CAS). DAMPE has been launched the 17 December 2015 at 08:12 Beijing time into a sun-synchronous orbit at the altitude of 500 km. The satellite is equipped with a powerful space telescope for high energy gamma-ray, electron and cosmic ray detection. The main scientific objective of DAMPE is to measure electrons and photons with much higher energy resolution and energy reach than achievable with existing space experiments in order to identify possible Dark Matter signatures. It has also great potential in advancing the understanding of the origin and propagation mechanism of high energy cosmic rays, as well as may enable new discoveries in high energy gamma-ray astronomy.

1. Introduction

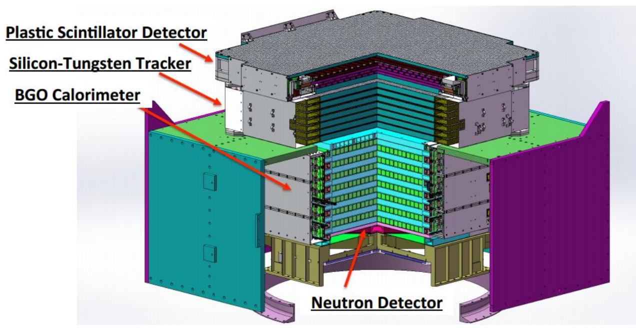

Figure 1. DAMPE telescope scheme:a double layer of the plastic scintillator strip detector (PSD); the silicon-tungsten tracker-converter (STK) made of 6 tracking double layers; the imaging calorimeter with about 31 radiation lengths thickness, made of 14 layers of Bismuth Germanium Oxide (BGO) bars in a hodoscopic arrangement and finally the neutron detector (NUD) placed just below the calorimeter.

DAMPE is a powerful space telescope for high energy gamma-ray, electron and cosmic ray detection. In Fig. 1 a scheme of the DAMPE telescope is shown. The top, the plastic scintillator strip detector (Psd) consists of two layers of scintillating plastic strips that serve as anti-coincidence detector, followed by a silicon-tungsten tracker-converter (STK), which is made of 6 tracking layers. Each tracking layer consists of two layers of single-sided silicon strip detectors measuring the two orthogonal views perpendicular to the pointing direction of the apparatus. Three layers of Tungsten plates with thickness of 1 mm are inserted in front of tracking layer 2, 3 and 4 to promote photon conversion into electron-positron pairs. The STK is followed by an imaging calorimeter of about 31 radiation lengths thickness, made up of 14 layers of Bismuth Germanium Oxide (BGO) bars which are placed in a hodoscopic arrangement. The total thickness of the BGO and the STK correspond to about 33 radiation lengths, making it the deepest calorimeter ever used in space. Finally, in order to detect delayed neutron resulting from hadron showers and to improve the electron/proton separation power, a neutron detector (NUD) is placed just below the calorimeter. The NUD consists of 16, 1 cm thick, boron-doped plastic scintillator plates of 19.5×19.5 cm^2 large, each read out by a photomultiplier.

The primary scientific goal of DAMPE is to measure electrons and photons with much higher energy resolution and energy reach than achievable with existing space experiments. This will help to identify possible Dark Matter signatures but also may advance our understanding of the origin and propagation mechanisms of high energy cosmic rays and possibly lead to new discoveries in high energy gamma-ray astronomy.

DAMPE was designed to have an unprecedented sensitivity and energy reach for electrons, photons and cosmic rays (proton and heavy ions). For electrons and photons, the detection range is 2 GeV-10 TeV, with an energy resolution of about 1.5% at 100 GeV. For cosmic rays, the detection range is 100 GeV-100 TeV, with an energy resolution better than 40% at 800 GeV. The geometrical factor is about 0.3 m^2 sr for electrons and photons, and about 0.2 m^2 sr for cosmic rays. The expected angular resolution is 0.1° at 100 GeV.

2. DAMPE Computing Model and Computing Facilities

As Chinese satellite, DAMPE data are collected via the Chinese space communication system and transmitted to the China National Space Administration (CNSA) center in Beijing. From Beijing data are then transmitted to the Purple Mountain Observatory (PMO) in Nanjing, where they are processed and reconstructed. The processing pipeline of science data is designed to run on cluster of batch processors, currently consisting of more than 1400 computing cores, which can reprocess 3 years DAMPE data within one month.

2.1. Available Computing Resources

The European part of the DAMPE collaboration consists of teams from the department of nuclear and particle physics at the University of Geneva (DPNC) and participating sections of the Italian agency for nuclear and space physics: INFN-Perugia, Lecce and Bari. DAMPE uses the LHC tier 1 computing center at CNAF as main resource for Italian users as well as for a large fraction of MC production. In addition DAMPE makes use of the local computing cluster at INFN-Bari. The computing cluster at DPNC is used in addition, but mostly for user jobs, with a cluster sharing policy between the different research groups (LHC ATLAS taking the largest share). Fig. 2 shows the average number of HS06 units that have been accounted both at CNAF and INFN-Bari over the past half year.[1]

At CNAF we currently have a 3k HS06 CPU allocation along with 100 TB (74% used) of available storage. At DPNC, DAMPE uses 3 file servers, with 175 TB of installed disk space (55% used). In addition, mass storage at DPNC is provided through an older variant of the LHC disk pool manager (DPM), providing O(100) PB of storage access for all groups at DPNC, distributed over 28 linux file servers. The DPM is accessed through a world-accessible redirector at DPNC using the XRootD protocol [9].

[1] Note that for simplicity we assume that 10 HS06 units correspond to 1 CPU.

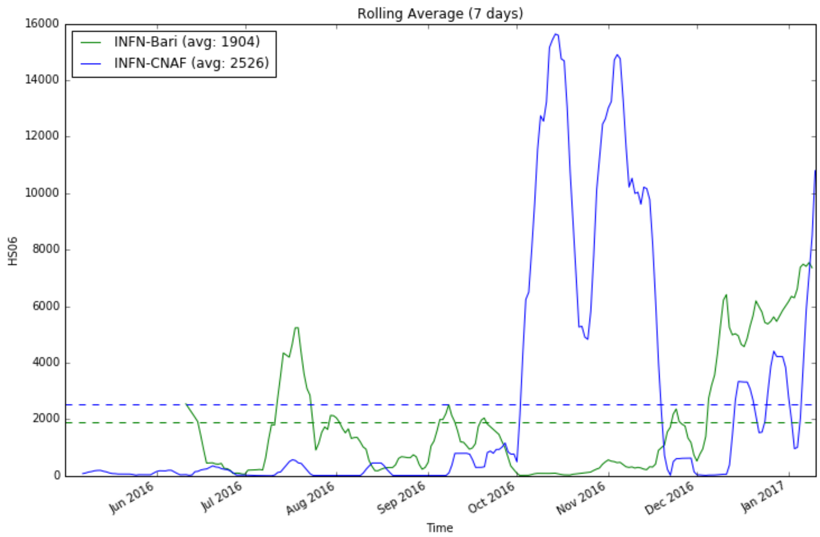

Figure 2. HS06 accounting at contributing INFN sites (CNAF-T1 and INFN-Bari); Note that numbers are approximated by calculating the running mean over a period of 7 days, ignoring episodes of no activity. The global average for the past half year at CNAF corresponds to more than 80% of resources granted for 2017.

2.2. Data production

PMO is the deputed center for DAMPE data production. Data are collected 4 times per day, each time the DAMPE satellite is passing over Chinese ground stations (almost every 6 hours). Once transferred to PMO, binary data, downloaded from the satellite, are processed to produce a stream of raw data in ROOT [1] format (1B data stream, $\sim$ 15 GB/day), and a second stream that include the orbital and slow control information (1F data stream, $\sim$ 15GB/day). The 1B and 1F streams are used to derive calibration files for the different subdetectors ($\sim$ 400MB/day). Finally, data are reconstructed using the DAMPE official reconstruction code, and the so-called 2A data stream (ROOT files, $\sim$ 70 GB/day) is produced. The total amount of data volume produced per day is $\sim$ 100 GB. This data is copied via rsync to a host in Geneva from where it is distributed to the local storage area using a world-accessible XrootD redirector.

2.3. Monte Carlo Production

Analysis of DAMPE data requires large amounts of Monte Carlo (MC) simulation, to fully understand detector capabilities, measurement limits and systematics. In order to facilitate easy workflow handling and management and also enable efficient monitoring of a large number of batch jobs in various states, a NoSQL metadata database using MongoDB [2] has been developed with a prototype currently running at the Physics Department of Geneva University. Database access is provided through a web-frontend and command tools based on the flask-web toolkit [3] with a client-backend of cron scripts that will run on the selected computing farm. The design and implementation of this workflow system is heavily influenced by the implementation of the Fermi-LAT data processing pipeline [4] and the DIRAC computing framework [5].

Once submitted, each batch job continuously reports its status to the database through outgoing http requests. To that end, computing nodes need to allow for outgoing internet access. Each batch job implements a workflow where in- and output data transfers are being performed (and their return codes are reported) as well as the actual running of the payload of a job (which is defined in the metadata description of the job). Dependencies on productions are implemented at the framework level and jobs are only submitted once dependencies are satisfied.

Once generated, a secondary job is initiated which performs digitization and reconstruction of existing MC data with a given release for large amounts of MC data in bulk. This process is set-up via a cron-job at DPNC and occupies up to 200 slots in a 6-hour limited computing queue.

MC production appears as spikes of very high activity over a period of few weeks followed by a phase of verification and setup for follow-up productions.

2.4. Data sharing

Every time a new 1B, 1F or 2A data files are available at PMO, they are copied to a server at CNAF, to the DAMPE storage area. The connection to China is passing through the Orientplus [7] link of the Géant Consortium [8]. The data transfer rate is currently limited by the connection of the PMO to the China Education and Research Network (CERNET), that has a bandwidth of 100 Mb/s.

Currently Geneva acts as master archive for MC data, whereas data is replicated twice, once at CNAF (accessible through gpfs) and once in Geneva. Generated MC from INFN-Bari is copied on a per-job basis as part of the run process to the Geneva storage element, whereas MC from CNAF remains on-site and is synchronized in parallel using a series of rsync and remote XRootD copy operations. If possible, we implement parallel queries to maximize the network throughput. Currently this computing model has few safeguards against failures (other than md5 checksum verification for incoming flight data). To remedy this a data catalog was prototyped but abandoned due to time constraints. To enable experiment-wide access to data and MC from all participating institutes and in order to simplify the current synchronization scheme we are setting up a (world-accessible) redirector, which provides unified access and local site-caching via the XRootD protocol. This process is however dependent on being able to connect the storage system at Geneva university, a work that is currently in progress.

To share MC generated in Europe, a DAMPE server has been placed at the institute for high energy physics, Beijing which is connected to the faster Orientplus network. Data synchronization between this server and PMO is done by manually induced hard-drive exchange.

3. Needs for CSCS

We pursue establishing a collaboration with CSCS for their abilities of long term storage and addressing potential data processing needs in the future. We do not anticipate regular user access but envision that CSCS access will be limited to around 1-3 individuals which are currently employed at DPNC, University of Geneva. Table 1 summarizes the annual needs for DAMPE considering CSCS to be used as long term storage facility. Ideally, data access would be provided though the XrootD redirector, the latter which could be installed on a user interface at CSCS which provides a mount point to the data storage location (GPFS, Lustre). For the computing needs we estimate the usage to 10 cores throughout the year, corresponding to about 90k CPU hours. Note that part of the processing allocation will be used for prototyping and exploring the potential of using CSCS for large scale MC campaigns not covered in this proposal. For the latter, we intend to apply for additional CPU resources through the CSCS HPC proposal program. In total we would like to request annually 65 TB of disk space (accounting for a growth of up to 10% with respect to the descriptions in the previous sections) and 90k CPU hours. DAMPEs nominal mission lifetime will be 3-5 years.

@ROLAND: I tried to be as cost-effective as possible and focus mainly on data storage over CPU needs (as per our discussion). I hope that the approx. 10 CPUs as total "allocation" are

Type	Value	Comments
Raw Data Volume	12 TB	1B and 1F data, desaster recovery from CNAF-T1
Flight Data	40 TB	2A (reconstructed data), assume current data set size
Data processing needs	90k	CPU hours, corresponds to approx. 100 HS06 units
Simulation Data	13 TB	archival of legacy MC datasets
Interactive Work	1	number of user interfaces, see text
Number of users at CSC	1-3	see text

Table 1. Annual projected needs for DAMPE at CSCS

easy to accommodate in the larger proposal.

References

[1] Antcheva I. *et al.* 2009 *Computer Physics Communications* **180** 12, 2499 - 2512, https://root.cern.ch/guides/reference-guide.

[2] https://www.mongodb.org

[3] http://flask.pocoo.org

[4] Dubois R. 2009 *ASP Conference Series* **411** 189

[5] Tsaregorodtsev A. et al. 2008 *Journal of Physics: Conference Series* **119** 062048

[6] Allcock, W.; Bresnahan, J.; Kettimuthu, R.; Link, M. (2005). "The Globus Striped GridFTP Framework and Server". ACM/IEEE SC 2005 Conference (SC'05). p. 54. doi:10.1109/SC.2005.72. ISBN 1-59593-061-2. http://www.globus.org/toolkit/docs/latest-stable/gridftp/

[7] http://www.orientplus.eu

[8] http://www.geant.org

[9] http://xrootd.org