LHCb Computing Resources: 2016 reassessment and 2017 requests

LHCb Public Note

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Abstract

This document presents a reassessment for 2016 and an estimate for 2017 of computing resources needed by LHCb, as resulting from the current LHC data taking and recent changes in the LHCb computing model parameters.
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1. Introduction

This document summarizes the most recent update of the computing resources needed by LHCb in the period 2016-2017 and is based on the latest measurements of the LHCb computing parameters and latest updates of the LHC running plans.

The Computing Resources Scrutiny Group (CRSG) has finalized the scrutiny of 2016 requests in Spring 2015. Since then, the running time of the LHC in 2015 and the expected running time in 2017 have been significantly reduced. LHCb is also going to take part in the heavy ion run at the end of 2015. Moreover, some changes in the input parameters of the LHCb computing model have been implemented, following the comments and recommendations contained in the last CRSG report [CERN-RRB-2015-014]. These changes result in a reassessment of the 2016 and 2017 requests.

The LHCb computing model, its current implementation and recent changes are described in section 2, while processing plans are described in section 3. Resource estimates are given separately for proton-proton and heavy ion physics in sections 4 and 5, respectively. A summary of the requests is given in section 6.

2. The LHCb Computing Model and recent changes

A detailed description of the LHCb Computing Model is given elsewhere [LHCb-PUB-2012-014 and LHCb-PUB-2011-009]. Subsequent reports [LHCb-PUB-2013-002, LHCb-PUB-2013-014 and LHCb-PUB-2014-014] discussed further changes and their impact on the required resources. The most relevant features, summarized in LHCb-PUB-2015-003, are also given below:

- Stripping lines were redesigned and as many lines as possible were migrated to mDST. A new DST stream (MDST.DST) has been introduced out of the stripping, with a single replica, containing all events selected by mDST streams, and which can be used to regenerate mDSTs without rerunning the stripping in case analysts miss some important information that would then force them to wait for the next incremental restripping to regenerate the mDST. We foresee that the migration to mDST will be finished by 2017, so MDST.DST will no longer be needed by then.
- We now have a significant amount of disk storage available at a selection of Tier2 sites (referred to as T2-D). The T2-D sites host part of the most recent version of official datasets for analysis, both for real and simulated data, and are therefore available for running user analysis jobs requiring those data.
- For Run 2 we expect the event sizes (and therefore processing times) to remain roughly the same as in Run 1: although the size of single interaction events will increase due to increased track multiplicity (13 TeV centre of mass compared to 8 TeV), and increased out-of-time pileup (25ns vs. 50ns. bunch spacing), this will be offset by lower in-time pileup as a result of almost doubling the number of colliding bunches (2448 vs 1380).
- We assume that the average simulated event size can be reduced by a further 10% (to 180 kB), as we progressively introduce the use of mDST format also for simulated data. We also assume a 20% reduction in the time spent to simulate and reconstruct a single event. We are currently exploiting fast Monte Carlo simulation in order to obtain further savings in processing time.

Some changes with respect to our last report were implemented, which impact the resources required for 2016 and 2017:

\footnote{For the purpose of this document a given year always refers to the period between April 1\textsuperscript{st} of that year and March 31\textsuperscript{st} of the following year.}
• The LHC schedule for 2015 is now shorter than initially expected, with approximately 50 days for proton physics foreseen from the end of August until the remainder of 2015. In our calculations, we assume a live time of 1.5Ms for the LHC proton running in 2015 (instead of the initial 3.0Ms). This decreased LHC running time reduces the requirements on CPU and storage in 2016 and 2017, for activities related to the 2015 data taking.

• The 2017 running time is also expected to be shorter than anticipated. We assume a live time of 5.1Ms in 2017, according to the latest projections. Due to this decrease of running time, it will not be any longer necessary to “park” part of the stream from the HLT.

• We expect to take heavy ion data in 2015. We estimate that the resources made available to LHCb in 2015 are sufficient to accommodate this additional request. For 2016 and 2017, we have now a much firmer plan for heavy ion running, which results in more accurate estimates of the needed computing resources.

• We follow the recommendation of the CRSG and no longer require a second copy of all derived data for data preservation purposes. In case of tape losses, derived data would be regenerated. This results in a reduction of the tape requests for 2016 and 2017.

• We no longer store the content of the RAW banks in the FULL.DST. This represents approximately a factor two saving on the size of the FULL.DST, resulting in a decrease in storage requests. We refer to this new data format as RDST in the following.

• We will generate approximately 50% of the simulation needs for the analysis of 2016 and 2017 data before the restart of the LHC in spring 2017 and 2018 (i.e. during the 2016 and 2017 WLCG accounting periods, respectively). In previous requests, we scaled this figure down to 25% in order to mitigate the ramp-up in the needed resources. This scaling is not optimal and could have delayed physics analysis until adequate Monte Carlo samples were made available.

3. Processing plans for 2015 and beyond

3.1. Simulation

Most analyses of 2011-2012 data are now in an advanced state, therefore most of their simulation needs have been satisfied. Simulation efforts are now concentrating on further simulations for the LHCb Upgrade studies, on tuning the simulation to the observed 2015 data-taking conditions, and on implementing the latest updates to generators and decay processes.

Since we will not reprocess the 2015 data during the 2015-2016 winter shutdown, we plan to start a massive production of simulated events for the analysis of 2015 data after the end of the LHC 2015 run.

3.2. Fast Monte-Carlo simulation

In our last report, we discussed the possible implementation of fast MC simulation in LHCb, with a parameterized detector response, in order to mitigate the impact on CPU due to the usage of the full GEANT4 detector simulation. The level of approximation ranges from smearing the event high level quantities, like momentum resolution and track efficiency, to parameterizing the response of the subdetectors themselves. In both cases the detector resolutions measured in real data are used. The
integration of the DELPHES package in the LHCb simulation framework is under development in this context.

As an alternative, we implemented the possibility of using a "particle gun" approach, in which only the signal decay is generated, not the entire pp collision. These are then put through the full GEANT detector simulation and the usual event reconstruction. A reduction factor of ~ 20 in both CPU and disk space is estimated with this technique.

Other techniques have been deployed for reducing the disk space usage by running the trigger and stripping steps in so-called "filtering" mode, in which generated MC event which fail the trigger or stripping criteria are thrown away. The definition of a microDST format for MC, where only the signal part of the event would be saved, is also under investigation.

3.3. Data taking

Table 3-1 shows the assumptions made concerning the availability of the LHC for physics running in 2015, 2016 and 2017\(^2\). The 2015 schedule was agreed with the C-RSG and the other LHC experiments in early 2014. The current schedule for 2015\(^3\) has considerably fewer days for physics. As a result, we won’t use up all the pledged storage resources for 2015. We assume that LHCb will collect also heavy ion data (see Section 5). Furthermore we assume that the LHC will run with a bunch spacing of 25ns; this is an important parameter because it will allow the same instantaneous luminosity to be achieved with lower in-time pileup, which has some implications for the trigger efficiency and for the event size (and therefore computing resources requirements).

The LHCb trigger rate for LHC Run 2 is expected to increase to 12.5 kHz and to remain roughly constant throughout the run. In the first part of data taking we have been using a loose trigger to make cross-section measurements, we will introduce luminosity leveling as soon as the machine luminosity allows us to do so at our nominal in-time pileup. Of the 12.5 kHz, 2.5 kHz will be analysed directly in the HLT farm and will not be reconstructed offline (TURBO stream). In order to cope with possible shortages of offline resources, we have implemented the possibility to split the remaining 10 kHz between a “FULL” stream for prompt physics analysis, and a “PARKED” stream to be reconstructed and analysed later. The estimates presented in this document assume that resources will be sufficient to take the full 10 kHz in the FULL stream for the 2016 and 2017 runs; the PARKED stream might be introduced in 2018, if needed. We have used the data taken so far in 2015 to extrapolate the bandwidth division between the TURBO stream and the rest, and find values in agreement with our initial predictions.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton physics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LHC run days</td>
<td></td>
<td>90</td>
<td>213</td>
<td>188</td>
</tr>
<tr>
<td>Fraction of days for physics</td>
<td></td>
<td>0.60</td>
<td>0.70</td>
<td>0.80</td>
</tr>
<tr>
<td>LHC efficiency</td>
<td></td>
<td>0.32</td>
<td>0.39</td>
<td>0.39</td>
</tr>
<tr>
<td>Approx. running seconds</td>
<td></td>
<td>1.5 (10^6)</td>
<td>5.0 (10^6)</td>
<td>5.1 (10^6)</td>
</tr>
<tr>
<td>Heavy Ion physics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approx. running seconds</td>
<td></td>
<td>1.1 (10^6)</td>
<td>1.4 (10^6)</td>
<td>0.1 (10^6)</td>
</tr>
</tbody>
</table>

Table 3-1: Assumed LHC proton-proton and heavy ion running time for 2015, 2016 and 2017. For 2015, the fraction of days for physics and the LHC efficiency are fictitious and only aimed at obtaining a running time of 1.5Ms for proton physics.


3.4. Processing model for 2015 and beyond

Studies during LS1, as well as real data taking in the first months of 2015, make us confident that alignment and calibration procedures running in the HLT farm provide “physics quality” calibrations for the offline reconstruction within hours of data taking. We nevertheless plan up to two weeks of RAW data and stripping buffers, in order to validate any unexpected changes. Any further reprocessing of RAW data will be postponed until after the run, during Long Shutdown 2, outside the time frame of the current requests.

A full restripping of the 2015 data will be performed at the end of the 2015 run, starting from the RDST produced by the prompt reconstruction. This, and another subsequent restripping, to be performed one year later, will also be the occasion to apply improved detector calibrations to the data used for physics analysis. The same model will be applied to data collected in subsequent years: one full restripping at the end of data taking, another one one year later, plus two incremental stripplings in between. A full restripping of all Run 2 data will then take place during Long Shutdown 2, outside the time frame of the current requests.

The available resources would also allow us an incremental stripping of Run 1 data during the 2015 WLCG year, if needed, with negligible impact on the 2016 requests.
4. Resource estimates: proton physics

4.1. CPU resources

Table 4-1 presents, for the different activities, the CPU work estimates when applying the models described in the previous sections. Note that in this table we do not apply any efficiency factors: these are resource requirements assuming 100% efficiency in using the available CPU. The last row shows the power averaged over the year required to provide this work, after applying the standard CPU efficiency factors (85% for organized work, 75% for user analysis).

<table>
<thead>
<tr>
<th>CPU Work in WLCG year (kHS06.years)</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prompt Reconstruction</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>First pass Stripping</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Full Restripping</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>Incremental (Re-)stripping</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Simulation</td>
<td>153</td>
<td>212</td>
</tr>
<tr>
<td>VoBoxes and other services</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>User Analysis</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td><strong>Total Work (kHS06.years)</strong></td>
<td><strong>240</strong></td>
<td><strong>306</strong></td>
</tr>
<tr>
<td><strong>Efficiency corrected average power (kHS06)</strong></td>
<td><strong>285</strong></td>
<td><strong>364</strong></td>
</tr>
</tbody>
</table>

Table 4-1: Estimated CPU work needed for the different activities. Proton physics

4.2. Storage resources

Table 4-2 presents, for the different data classes, the forecast total disk space usage at the end of the years 2016 and 2017 when applying the models described in the previous sections. This corresponds to the estimated disk space requirement if one assumes 100% efficiency in using the available disk. The numbers include the standard 85% tape efficiency correction, which is probably pessimistic for RAW data that is written sequentially to a dedicated tape class, and never deleted.

<table>
<thead>
<tr>
<th>Disk storage usage forecast (PB)</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stripped Real Data</td>
<td>11.1</td>
<td>14.4</td>
</tr>
<tr>
<td>Simulated Data</td>
<td>6.4</td>
<td>10.3</td>
</tr>
<tr>
<td>User Data</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>MDST.DST</td>
<td>1.2</td>
<td>0.0</td>
</tr>
<tr>
<td>RAW and other buffers</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Other</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21.3</strong></td>
<td><strong>27.4</strong></td>
</tr>
</tbody>
</table>

Table 4-2: Break down of estimated Disk Storage usage for the different categories of LHCb data. Proton physics.
### 5. Resource estimates: heavy ion physics

The current LHCb plans for heavy ion runs in Run 2 are as follows. In 2015, we expect to collect 24 days of Pb-Pb collisions. At the same time, a gaseous Neon target (SMOG) installed at IP8 will provide Pb-Ne collisions in a fixed-target configuration. These events can be recorded in parallel to the Pb-Pb events. In addition, we foresee a dedicated run of 7 days of p-Ne collision in the SMOG configuration. We foresee the same running conditions in 2016, where the Neon will be replaced by Argon. No heavy-ion running is foreseen in the LHC schedule for 2017. Nevertheless, we plan to use SMOG to accumulate 7 days of proton-Argon collisions.

The CPU and storage resources corresponding to the above data taking plan have been determined by using the LHCb computing model, where input parameters have been tuned appropriately. The resulting resources are summarized in Table 5-1.

<table>
<thead>
<tr>
<th>Resources for heavy ion running</th>
<th>2016 Request</th>
<th>2017 Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU (kHS06)</td>
<td>10.1</td>
<td>0.8</td>
</tr>
<tr>
<td>Disk (PB)</td>
<td>2.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Tape (PB)</td>
<td>1.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**Table 5-1: Resources needed for heavy ion running**

### 6. Summary of requests

Table 6-1 shows the CPU requests at the various tiers, as well as for the HLT farm and Yandex, after summing the requirements for proton and heavy ion physics. We assume that the HLT and Yandex farms will provide the same level of computing power as in the past, therefore we subtract the contributions from these two sites from our requests to WLCG.

The columns “Guessed pledge” are an estimate of the WLCG pledges which might be available in 2016, by assuming a 20% increase with respect to the previous year. In both sets of columns, the required resources are apportioned between the different Tiers taking into account the capacities that are already installed.

The resources requested to WLCG are covered by the resources that we can reasonably assume to be pledged to LHCb in both years.

The disk and tape estimates shown in previous section have to be broken down into fractions to be provided by the different Tiers using the distribution policies described in LHCb-PUB-2013-002.

The results of this sharing are shown in Table 6-2 and Table 6-3. Requests due to proton and heavy ion physics have been summed up.
Table 6-1: CPU power requested at the different Tier levels. Proton and heavy ion physics

<table>
<thead>
<tr>
<th>Power (kHS06)</th>
<th>Guessed pledge 2016</th>
<th>Guessed pledge 2017</th>
<th>Request 2016</th>
<th>Request 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 0</td>
<td>49</td>
<td>59</td>
<td>48</td>
<td>59</td>
</tr>
<tr>
<td>Tier 1</td>
<td>158</td>
<td>190</td>
<td>146</td>
<td>184</td>
</tr>
<tr>
<td>Tier 2</td>
<td>89</td>
<td>107</td>
<td>81</td>
<td>102</td>
</tr>
<tr>
<td><strong>Total WLCG</strong></td>
<td><strong>297</strong></td>
<td><strong>356</strong></td>
<td><strong>275</strong></td>
<td><strong>345</strong></td>
</tr>
<tr>
<td>HLT farm</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Yandex</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total non-WLCG</strong></td>
<td><strong>20</strong></td>
<td><strong>20</strong></td>
<td><strong>20</strong></td>
<td><strong>20</strong></td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td><strong>317</strong></td>
<td><strong>376</strong></td>
<td><strong>295</strong></td>
<td><strong>365</strong></td>
</tr>
</tbody>
</table>

Table 6-2: LHCb Disk request for each Tier level. Note that for countries hosting a Tier1, the Tier2 contribution could also be provided at the Tier1. Proton and heavy ion physics.

<table>
<thead>
<tr>
<th>Disk (PB)</th>
<th>2016 Request</th>
<th>2017 Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier0</td>
<td>5.8</td>
<td>8.5</td>
</tr>
<tr>
<td>Tier1</td>
<td>14.9</td>
<td>17.4</td>
</tr>
<tr>
<td>Tier2</td>
<td>2.8</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23.5</strong></td>
<td><strong>29.7</strong></td>
</tr>
</tbody>
</table>

Table 6-3: LHCb Tape request for each Tier level. Proton and heavy ion physics.

<table>
<thead>
<tr>
<th>Tape (PB)</th>
<th>2016 Request</th>
<th>2017 Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier0</td>
<td>15.0</td>
<td>21.6</td>
</tr>
<tr>
<td>Tier1</td>
<td>25.8</td>
<td>38.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>40.8</strong></td>
<td><strong>59.6</strong></td>
</tr>
</tbody>
</table>

The disk requests for 2016 and 2017 are 2.8PB and 1PB lower than foreseen in the last scrutiny round. This is due to the amount of 2015 data being lower than anticipated, and to further cleanup made possible by the data popularity algorithms, reported in LHCb-PUB-2015-019.

The large step in tape provision shown in the last scrutiny round is now mitigated by the reduced dataset sizes foreseen in 2015 and 2017 and, most importantly, by the suppression of RAW banks on the reconstruction output (RDST) and the suppression of the second copy of the archive for data preservation purposes. Nevertheless, the slope in the tape requests is still higher than what we can reasonably achieve with a flat-funding scenario, which will likely be overtaken by the 2018 requests.
7. Conclusion

The offline resources needed by LHCb in the 2016 and 2017 WLCG years have been reassessed, following recent changes in the LHC schedule and in the LHCb computing model parameters.

The reduced LHC live times in 2015 and 2017 directly impact the data volume to be stored, and alleviate the pressure on storage resources. The implementation of the CRSG encouragements in reducing the number of replicas for derived data and a sizeable reduction of the size of a fully reconstructed event allow us to reduce the tape needs within a flat budget for both years. However, the slope of the required tape resources exceeds the one expected with a flat budget scenario, meaning that this issue will come back in subsequent years.

Efforts are continuing to make better use of the available disk space. As shown in LHCb-PUB-2015-019, the analysis of data popularity allows us to remove unused datasets. At the moment, the analysis of data popularity and the consequent data management are performed “by hand”. We are continuing the development of a classifier tool, based on the Yandex Reproducible Experiment Platform, which would ultimately predict future dataset usage using the access history of the data storage, and perform data management in an automatic way.
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