CMS Computing Resource Request
2015-2017

Feb 16th, 2015

Introduction

The computing facilities for storing, processing, and analyzing the LHC data constitute the final stage in a long series of data-handling steps that are necessary for CMS to fully realize the value of the LHC program. The computing resources available to CMS have been critical to the exciting physics program that was carried out during the first run of the LHC (Run I). In preparation for the second LHC run (Run II), CMS plans to deploy sufficient resources to fully realize the physics potential of the experiment. In parallel, and in order to optimize its usage of worldwide computing resources, CMS is attempting to capitalize on efficiency gains obtained while running the currently deployed systems. This document is an update of the document provided in August 2014. For the purposes of planning, CMS divides the operations period of the second run into resource years as shown in Table 1. The number of live seconds in 2015, 2016 and 2017 is estimated from the experience gained in the corresponding years of Run I. 2015 is the first year with a “new” machine, while 2016 and 2017 are nominal running years. Year 2018 is not considered in this document, since in the most recent schedule, the LHC is expected to provide collisions for only three months.

Year	Start	End	Live Seconds (pp)	Live Seconds (HI)
Resource Year: 2014	April 2014	March 2015	0	0
Resource Year: 2015	April 2015	March 2016	3.0Ms (expected)	0.7Ms (expected)
Resource Year: 2016	April 2016	March 2017	5.0Ms (expected)	0.7Ms (expected)
Resource Year: 2017	April 2017	March 2018	7.0Ms (expected)	0.7Ms (expected)

Table 1: Definitions of LHC Resource Years and the total number of live seconds expected from the accelerator for each year.

The need to study the properties of the light Higgs boson discovered in Run I, and the searches for new physics at the new energy frontier necessitate the increase in the High-Level Trigger (HLT) output rate to 1kHz. As already indicated in the February 2014 document, this results in a significant increase in the computing needs. The total increase in request during 2013-2015 could be accommodated within a flat budget over this period, but due to only modest increases in 2013 and 2014 the accumulated increase in 2015 is large.

Since the original 2015 request was made in April 2013, there have been a few modifications in the plans impacting the resources requested, as well as more studies that have solidified the figures requested. The largest impact is from the decrease in the expected live seconds for 2015 to 3M (from 5M) seconds. Based on the most recent LHC schedule for 2015, and also on the experience with the commissioning and startup in Run 1, CMS does not expect a full nominal year of data in 2015. Additionally, the larger reconstruction times expected with 25ns bunch spacing have been largely mitigated, though this was anticipated in the planning. The anticipated HLT rate has not changed, but has been studied in more detail. After discussions with the physics groups, the RECO data tier for most channels should be treated as transient and will be stored on disk temporarily – or not written at all. Additionally, the disk fill factor, the organized processing efficiency, and the tape filling efficiency have all been changed to reflect our best common understanding of how resources are used.

As an early indication, preliminary numbers for 2016 and 2017 are also included. Using the current model assumptions and planned activities for the second and third years of Run II, these are the best estimates of the resources needed. Nevertheless, the experience from 2015 running will likely cause adjustments in the plans and needs.

Experience from Run I

In 2012 the machine live time exceeded our initial planning by 25%. Part of this was attributed to the extension of the originally planned run of the LHC. The instantaneous luminosity at the end of the run and the CMS HLT rate were both high in the second half of the year reaching 7 10^{33} $cm^{-2}s^{-1}$ and 1 kHz (400 Hz prompt and 600 Hz parked) respectively. The total integrated luminosity recorded was nearly $22fb^{-1}$.

• *The Tier-0 Center*

  • The Tier-0 was capable of using the period between fills more completely than planned. A system for spilling Tier-0 jobs into the public queues at CERN was commissioned and subsequently used heavily. When the machine was able to refill quickly, the Tier-0 would fall behind and CMS would only catch up during longer refilling periods, machine development, or machine downtimes, e.g. due to problems. The infrastructure was sufficiently stable to handle this mode of running.

  • The Tier-0 load was higher also due to the need to repack the "parked" data samples and then transfer them to Tier-1s. The estimate that the Tier-0 could handle the additional throughput as long as it was not promptly reconstructed proved correct.

  • The Tier-0 was also used for data reprocessing during periods when the load was not as high. This added to the offline processing capacity.

- *The CAF*
    - The CAF performed several commissioning activities, including validation, alignment and calibration activities. The overall average utilization of the CAF remained low, and about half of the processing capacity was moved to Tier-0.
- *The Tier-1 Centers*
    - Tier-1 centers accepted the data as divided into primary datasets from the Tier-0.
    - Tier-1 centers served data to requesting Tier-2 facilities.
    - Tier-1 centers reprocessed the entrusted samples with new software versions and updated alignment and calibration constants. During 2012 CMS changed software versions early at the time of ICHEP and then stayed with that release. The quality of the prompt reconstruction was sufficiently good for conference analyses except for some dedicated channels that used small-scale reprocessing samples. Data reprocessing was concentrated in one major reprocessing campaign at the end of the year. Reducing software version changes and extra reprocessing passes have allowed to concentrate on simulation, thus enabling CMS to complete a large simulation sample in time for the 2013 winter conferences.
    - Tier-1 centers performed simulated event production and their digitization including addition of pile-up events and reconstruction.
    - Tier-1 centers accepted simulation data from Tier-2 centers for custodial storage.
- *The Tier-2 Centers*
    - Tier-2 centers provided analysis resources to the physics community.
    - Tier-2 centers performed simulated event production.

The amount of pile-up in the proton-proton crossings increased in September 2012 to a larger value than anticipated in the planning, which led to higher event complexity for the final four months of running. In computing, this manifested itself as longer reconstruction times.

Changes in the operating model for 2014

During 2014 CMS was expected to primarily prepare simulation samples for 2015, and for upgrade studies of the CMS detector. The higher pile-up expected in 2015 is more difficult to simulate and requires more computing resources. CMS has changed the setup of the Tier-0 to be similar to that of the other Tier-1s and now CMS regularly uses Tier-0 for normal offline processing and analysis activities. More requests are submitted through the Tier-0 grid interfaces using pilots, and more network links to and from the Tier-0 to Tier-2s have been activated.

CMS has also commissioned the High Level Trigger (HLT) farm for offline processing activities and expect to have access to the farm for the bulk of the year. This resource augments the Tier-1 data processing capacity by about 40%. This new resource is one of the reasons the requested increase in CPU for 2014 was very modest.

Changes in the operation model for 2015-2017

There are two main factors driving the increase of the CMS computing resources for 2015. The first is the expected increase in the number of pile-up events that, with the current code, would require a factor 2.5 increase in reconstruction time. The second is the expected increase in the average HLT rate to 1 kHz. With no changes in the offline computing operations of the experiment, a factor of six (2.5×2.5) increase in processing resources would be needed in order to maintain the current activities. Such an increase would be impossible in a constrained budget period; hence the operational efficiency of the computing system as a whole has been improved in order to reduce the total resources requested. The changes and the corresponding gains are described in what follows.

First, CMS intends to move a substantial fraction of the prompt reconstruction step from the Tier-0 to Tier-1 centers, a procedure already validated during Run I, in order to speed up the processing of parked samples. The deployment of a sizeable fraction of the prompt reconstruction at Tier-1 centers will clearly reduce the resources available for reprocessing and simulation at these centers; CMS is indeed assuming that the level of organization achieved by CMS in 2012 will be maintained in 2015, and fewer reprocessing passes will be needed. In order to reduce the simulation load, CMS also anticipates a reduction in the fraction of simulated events with respect to the data events collected. The commissioning work during 2013 and 2014 in order to validate the HLT farm for reconstruction during annual shutdowns has been successful and CMS is confident that it will be able to successfully exploit these additional resources; this might augment the Tier-1 data processing capacity by about 10-20%, also reducing the overall reprocessing resources required at Tier-1s. Even with these changes, in 2015 CMS will need an increase by approximately a factor two of the processing resources with respect to the resources in 2012, as already estimated in previous documents submitted to the CSRG.

Overall, CMS expects to be more severely resource constrained in Run II. In order to be in a better position to protect high priority activities, CMS has attempted to migrate to a more flexible model, in which activities can be performed more freely with respect to the initial static Tier hierarchy: examples are prompt reconstruction to Tier-1s, the ability for Tier-1s to share workflows by deploying CPU resources reading from remote storage over the data federation, and the ability of Tier-2s to participate in simulation reprocessing. An aspect of this was to logically separate the Tier-1 disk and tape, such that data could be subscribed to either as an independent resource. This reduces the functional differences between Tier-1 and Tier-2 centers, and improves the disk management at Tier-2s.

The resource increases in 2016 and 2017 scale with the expected increases in LHC live time and thus the data accumulated during Run II. We note that, due to lack of resources, we have eliminated the resources needed for partial reprocessing in 2016-2017. In Run1 these partial reprocessing passes were critical to some calibration sensitive search channels including Higgs to gamma gamma. While every effort will be made to validate all software, calibrations and procedures to the greatest possible extent for the primary data processing, and in addition CMS is introducing new data formats that will allow greater flexibility in applying corrections, depending on the calibration and analysis experience that will be obtained in 2015 CMS, may well need to augment the Tier-1 processing resources to include capacity for partial mid-year reprocessing. In that case the 2016-2017 resources will have to be augmented accordingly.

During the CSA14 challenge, a new, more compact data format for physics analysis (MiniAOD) has been tested. It consists in a reduced version of standard AOD, with a consolidated version of most used Physics Objects. It is not meant as a replacement for the AOD in all analysis cases, like those needing detailed detector level information, and is targeted to be usable in ~80% of the analyses that use the AOD. CSA14 has proven the usability of MiniAOD for a range of analyses, while its current content still needs to be fine-tuned. The primary MiniAOD goal, physics-wise, is not a reduction of disk space occupied at sites (the MiniAOD being a factor ~10 smaller than the AOD), but the possibility to provide physics users with a stable, approved set of physics objects, in an agile format with faster access time. AOD will still be needed for ~20% of the analyses, hence, though their replication at Tier-2s can be decreased, it can nevertheless not be avoided. In addition, the MiniAODs are expected to be updated more often than the AODs and to be distributed in more copies to allow for more options and fast analysis turnaround. For these reasons, a specific disk budget for MiniAOD is not included, assuming instead that they will fit within the AOD budget, In summary, we are not changing for the moment 2016-2017 disk requests due to the introduction of the new data Tier.

Resource Parameters

Most assumptions and resource parameters used in the simulation of the CMS model are unchanged since the last version of this document. The one exception is the size of the RECO format, which is now expected to increase by a factor two when high pile-up is accounted for more precisely. The overall effect is, however, negligible, since CMS will cease saving most of the RECO, as explained later in this document; the increase can therefore be adsorbed in the original request numbers.

The most important input parameters for the calculations of the resources required each year are given in Table 2. The expected average HLT rate for prompt reconstruction in CMS is approximately 1 kHz starting in 2015, with an initial overlap between primary datasets of 25%. The machine live time is expected to increase in 2016 and 2017, but the HLT rate should be the same as in 2015.

The CMS Collaboration has started a process in order to evaluate the possibility to park a fraction of the data in Run II, as was done in the last year of Run I. Since the decision process is not yet complete, the resources needed have been left out of the current Computing Model simulations.

The Tier-0 CPU requests can be reduced via the exploitation of the time between fills. This is quantified via the "keep up factor", which is defined as the ratio between the data taking time and the Tier-0 processing time. During Run I, this factor was very close to 1 (meaning that, for example, an eight–hour fill would be promptly reconstructed in eight hours); in 2015-2017 this factor can be decreased using the inter-fill time to finish processing of the previous fill. The increase in Tier-0 keep up factor in 2016-2017 with respect to 2015 reflects the larger expected live time of the LHC.

Parameter	**Year**							
	2010	2011	2012	2013	2014	2015	2016	2017
HLT(Hz)	200Hz-600Hz	300Hz	300-700Hz	0	0	1000Hz	1000Hz	1000Hz
PDS Overlap Factor	1.30	1.25	1.25	NA	NA	1.25	1.25	1.25
Parked Data	0	0	600Hz Peak (~400Hz Average)	0	0	0	0	0
Tier-0 Keep-Up	0.75	0.75	0.50	NA	NA	0.40	0.50	0.6

Table 2: Parameters driving the yearly computing resources needed by CMS.

Three pile-up scenarios are used for 2015 planning: 20, 25, and 30 interactions per crossing, with an average of 25. These are mean values and the peak values of interactions per crossing are clearly higher, except in some leveling scenarios and lower average planned for the opening months. A ramp up is foreseen, but at both 25ns and 50ns running both pile-up scenarios are possible.

Parameter	**Expected Pile-Up**		
	20	25	30
RAW Event Size Data (MB)	0.55	0.65	0.75

Parameter	Expected Pile-Up		
	20	25	30
RAW Event Size MC (MB)	1.50	1.50	1.50
RECO Event Size Data (MB)	0.70	1.6	1.9
RECO Event Size MC (MB)	0.75	1.8	2.1
AOD Event Size Data (MB)	0.28	0.31	0.37
AOD Event Size MC (MB)	0.33	0.35	0.41
Repacker Time (HS06s)	3	6	6
RECO Time Data (HS06s)	300	525	920
Gen-Sim Time MC (HS06s)	500	500	500
Re-digi/Re-RECO Time MC (HS06s)	300	675	1100

Table 3: Event parameters that depend on the number of pile-up interactions per crossing

The processing times for reconstruction and simulation in HEP-SPEC06 units increase with the mean instantaneous pile-up. At very high numbers of pile-up events the reconstruction time grows non-linearly.

Resources needed for Upgrade Studies are not included in the current projection. A rough estimate shows that these should account for ~10% of the deployed resources, and are thus considered possible to fulfill in the shadow of standard running operations; this will need to be confirmed in the next months.

The public release of Run I data at regular intervals is expected to continue within the context of the data preservation project; this hosting capacity is outside the normal CMS computing capacity, and is not considered in this document.

Tier-0 Request

The Tier-0 computing requests for proton-proton running are shown in Table 4. The request for processing resources for CERN does not increase in 2013 and 2014, though the CPU resources of both the Tier-0 and the CAF are assumed to be available for analysis and simulation. These are included in the Tier-0 table and zeroed in the CAF table. This helps alleviate the expected resource shortages at the Tier-2s by the end of 2013 when the integrated data sample is the largest and in 2014 when there is a need for analysis of old data and simulation and studies for the 2015 run.

The 2015-2017 request is based on reconstructing half or fewer of the events immediately through Prompt Reconstruction at CERN in the Tier-0, before moving the workflow to Tier-1s. In addition, since the live time is expected to be lower in 2015, CMS has anticipated using more time between fills or during periods without beam.

Tier-0					
Year	**2013**	**2014**	**2015**	**2016**	**2017**
CPU (kHS06)					
Express	0	0	17	21	40
Prompt RECO	0	0	210	249	276
Repack	0	0	8	10	10
Alca Workflow	0	0	6	6	7
VOBoxes	12	12	15	16	17
Analysis/Simulation	109	109	0	0	0
Total	121	121	256	302	350
Disk (TB)					
Tier-0 Streamer Pool	0	0	1000	1000	1000
Tier-0 Input Buffer	0	0	500	500	500
Tier-0 Export Buffer	0	0	1500	1500	1500
Tier-0 Production Space	0	0	200	200	200
Analysis Disk	7000 (Repurposed CAF disk)	7000 (Repurposed CAF disk)	0	0	0
Total T0 Disk (TB)	7000	7000	3200	3200	3200
Tape (TB)					
Total Tier-0 Volume of RAW pp on tape	7000	7000	10000	13000	20000
Total Tier-0 Volume of RECO pp on tape	12000	12000	13000	14000	16000

Tier-0					
Year	**2013**	**2014**	**2015**	**2016**	**2017**
Total Tier-0 Volume of AlcaRECO pp on tape	1000	1000	1000	2000	2000
Analysis/Simulation	6000	6000	7000	9000	12000
Total	26000	26000	31000	38000	50000

Table 4: The processing and storage requests for the CERN Tier-0 as a function of year.

CAF Request

In the beginning of Run I the CAF was planned as a resource for calibration, validation, and prompt analysis. Over the first two years of running several elements of low-latency calibration were added to the automated prompt calibration loop, performed during the delay before launching prompt reconstruction. Much of the validation and prompt analysis can now be performed at Tier-2 centers. With the deployment of the Xrootd data federation, CMS expects to have no samples accessible only on the CAF machines. Nevertheless, there is still need for resources that can be used promptly for calibration and validation exercise. As a result of moving some of the originally planned CAF activities to other sites, the CAF proposed for 2015 is smaller in terms of CPU than was deployed in Run I. The CAF disk, however, has increased and is made available via the data federation, which allows for the use of remote CPU resources.

In 2013 and 2014, all processing and storage resources available at the CAF were made available as analysis resources, similarly to the bulk of the Tier-0 processing resources. This has allowed for efficient use of resources during LS1. CMS will encourage the continued use of local CERN resources for analysis with a request for disk space to host data and simulation samples on CAF AOD Disk, and subsequently accessible through the data federation.

In 2015 the CAF is assigned dedicated resources for low-latency work. There is essentially no increase over 2012, which was already a significant reduction with respect to the beginning of Run I. The automation achieved by the end of Run I is anticipated to continue into the beginning of Run II. In years 2016 and 2017, CAF resources are scaling less than the accumulated data, and less than the ramp in the LHC live time.

CAF					
Year	**2013**	**2014**	**2015**	**2016**	**2017**
CPU (kHS06)					
CAF Processing	0	0	14	13	14

CAF					
Year	**2013**	**2014**	**2015**	**2016**	**2017**
CAF Interactive	0	0	1	2	3
Total	0	0	15	15	17
Disk (TB)					
CAF Express Data Volume (TB)	0	0	2500	2500	2500
CAF Prompt RECO Data Volume (TB)	0	0	2000	2000	2000
CAF MC Volume (TB)	0	0	1000	1000	1000
CAF AOD Disk			4000	4000	5000
CAF RelVal Vol-ume (TB)	0	0	300	300	300
CAF Tier-2	0	0	1500	2500	2500
Stager Pool	0	0	800	800	800
Total	0 (Moved to Tier-0 for analysis)	0 (Moved to Tier-0 for analysis)	12100	13100	14100
Tape (TB)					
CAF Tape	0	0	4000	6000	8000

Table 5: Processing and storage requests for the CERN CAF as a function of year.

Tier-1 Request

The requests for Tier-1 resources are shown in Table 6 for 2014 through 2017. Tier-1 processing had previously been driven by reconstruction time, the total volume of data, and the time allocated to complete a processing pass. In 2015-2017, the Tier-1s will perform at least 50% of the prompt reconstruction, which drives the Tier-1 needs along with simulation processing. A complete data reprocessing is planned only during shutdowns, when the HLT resources will be available to complement Tier-1 resources.

Tier-1

Year	2013	2014	2015	2016	2017
CPU (kHS06)					
Processing	165	175	300	400	525
Disk (TB)					
Disk Space RAW Data	3500	3500	2500	3000	4000
Disk Space RECO Data	2000	2000	3000	3000	5000
Disk Space AOD Data	7000	7000	6000	8000	10000
Disk Space RAW MC	1500	1500	1500	1500	2000
Disk Space RECO MC	1500	1500	1500	1500	2000
Disk Space AOD MC	5000	5000	5000	8000	10000
Disk Space Skimming	3000	3000	2000	4000	5000
Tier-1 Temp Disk	2500	2500	5500	6000	7000
Total	26000	26000	27000	35000	45000
Tape (TB)					
Total RAW Data	5000	5000	9000	14000	21000
Total RAW Simulation	14000	16000	18000	20000	25000
Total RECO Data	8000	8000	9000	10000	12000
Total Skimmed Data	2000	2000	3000	5000	6000
Total RECO MC	8000	9000	10000	11000	13000
Total AOD Data	7000	8000	12000	20000	29000
Total AOD MC	6000	7500	12500	20000	29000
Tape Total	50000	55000	73500	100000	135000

Table 6: Processing and storage requests for the total Tier-1 centers as a function of year.

Figure 1 shows the Tier-1 utilization expected during the first three years of Run II. The plot shows the load from prompt reconstruction (called “Punctual RECO” when referring to Tier-1), simulation processing, and the enormous load associated with a single reprocessing pass at the end of the year. This would be impossible without the contribution from the HLT farm that nearly doubles the Tier-1 processing capacity during the annual shutdown, i.e. for a period of three months. This resource is only dedicated to offline processing during LHC shutdown periods, and CMS will need to be prepared with calibrations, releases, and requests to ensure the opportunity window is not missed. Especially in 2016 there is an assumption of growth in the HLT farm to allow a complete processing of the data. The resources of the HLT farm are outside the scope of the WLCG, and the actual growth of this resource will be monitored.

The original version of the CMS computing model assumes that one copy of the current version of the reconstructed data and the current year's raw data are kept on disk, with 10% of two copies of preceding versions of the RECO. Starting from 2015, RECO will be transitioned to a transient format with only a sliding window of six months after processing in 2015 and 2016 (three in 2017) retained on disk and not written to tape at all. This will reduce the growth rate of both disk and tape as new data is collected in Run2.

CMS has implemented a data federation based on XrootD. This allows sites to fall back to wide area distribution if a file is not found locally, and it allows the bulk of the experiment data to be read by remote applications for limited use cases. All seven Tier-1s are serving data from disk throughout the federation. With the strong focus on AOD, the complete copy of the reconstructed data on Tier-1 disk space is expected to be in AOD format and will be accessible through the data federation. This also allows the reduction of the data replication factor used to calculate Tier-2 disk needs. The expected utilization of disk space is shown in Figure 2. The majority of analysis accesses will continue to be served by locally hosted samples though the federation will provide robustness against failures and improve resource balancing.

Simulated events needed for reprocessing or transfer to Tier-2 centers are generally expected to be staged from tape. Since 2013 CMS has worked with the Tier-1 centers in order to separate active disk and archival tape. Data is now subscribed from tape to disk via PhEDEx and remain on disk until the subscription is deleted. Data are explicitly subscribed to archive when determined to be ready. Managing and predicting the contents of the Tier-1 disk should be much more reliable in Run II, and the use of the disk at the Tier-1s would be more efficient. The archival functionality in the mass storage systems remains important to CMS for long-term data storage and is an important contribution of Tier-1s. The expected tape utilization is shown in Figure 3. More active data access is concentrated on disk-based systems and is provided by all sites through data federation.

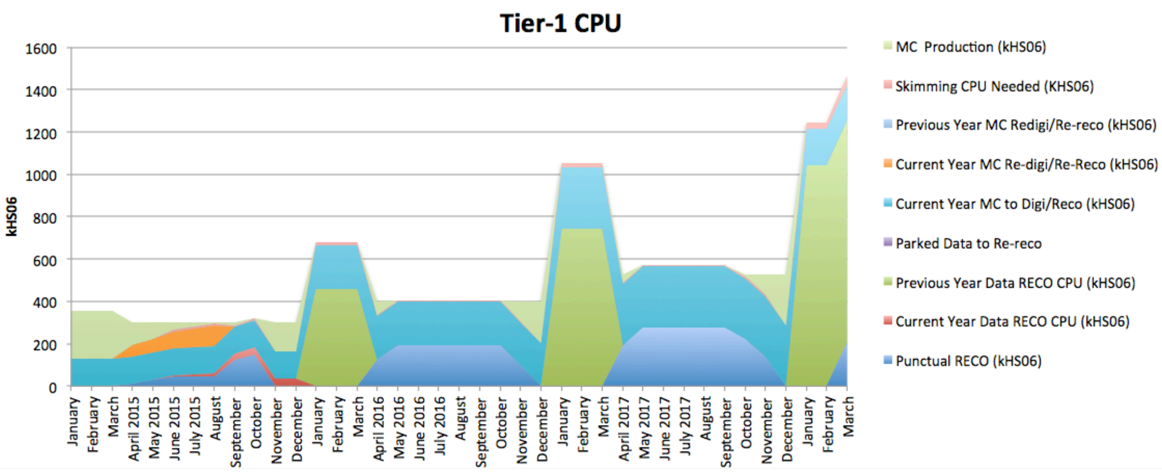

Figure 1: Tier-1 processing activities in 2014-2016 as a function of month. The large peaks include the contribution from the HLT farm.

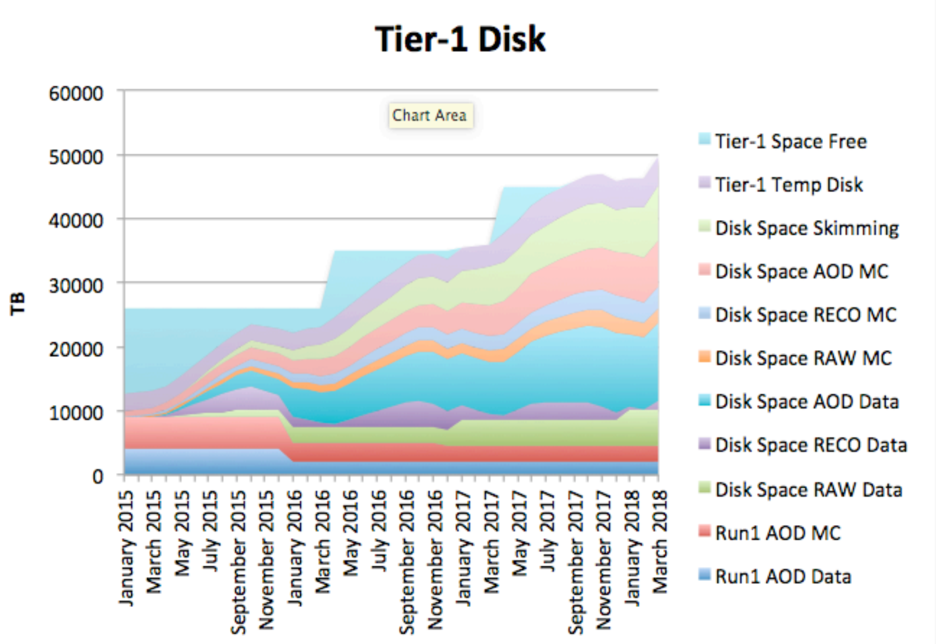

Figure 2: Tier-1 disk usage by data type.

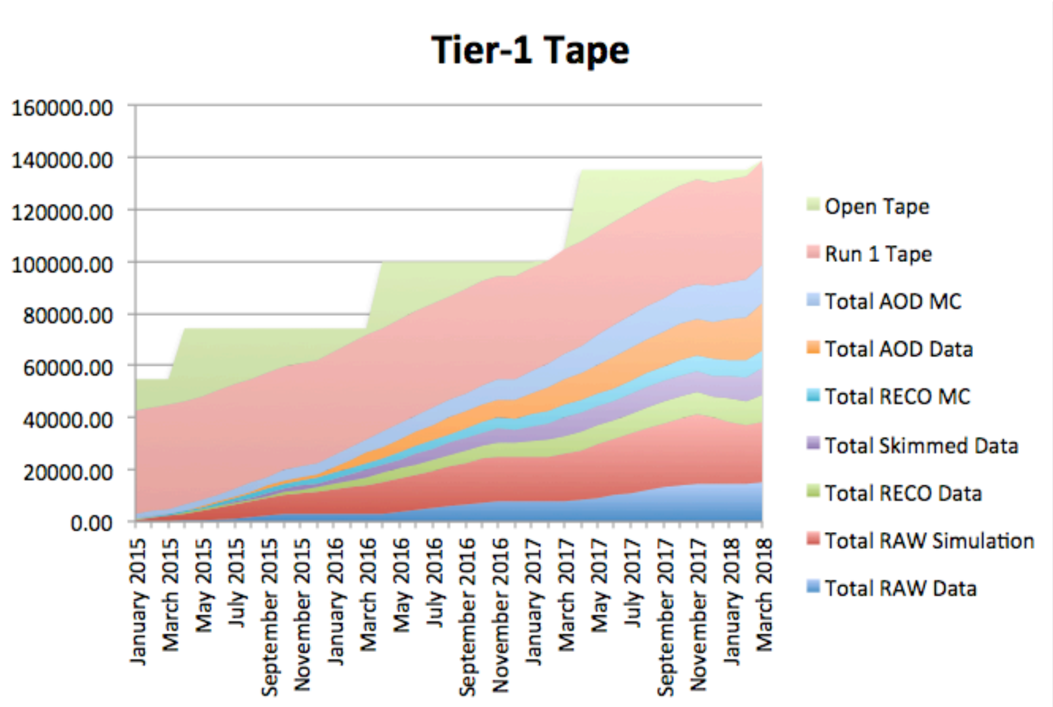

Figure 3: Tier-1 tape usage by data type. The single largest contribution is the persistent storage from Run1.

Tier-2 Request

The Tier-2 resource request can be seen in Table 7. The resource needs for 2015 do not grow as substantially as the Tier-0 or Tier-1 resources, primarily due to the presence of only a single year of data. In this planning CMS assumes that the majority of analyses of Run I data will be completed in 2015 and that only a small number of the datasets from the first three years of data-taking will need to be hosted. The resource needs show a larger growth for 2016 and 2017, with up to three years of data to analyze from Run II.

Tier-2					
Year	**2013**	**2014**	**2015**	**2016**	**2017**
CPU (kHS06)					
Analysis	250	290	400	550	600
MC Production	100	100	100	150	200
Total	350	390	500	700	800
Disk (TB)					
RECO Data on Disk	1000	1000	1000	1000	1000
AOD Data on Disk	8000	8000	8000	11000	16000
RECO MC on Disk	2000	2000	2000	1000	1000
AOD MC on Disk	8000	8000	10000	14000	16000
User Space On Tier-2s	4800	6000	8400	11000	12000
Production Space on Tier-2s	2000	2000	2000	2000	2000
Total	25800	27000	31400	40000	48000

Table 7: The processing and storage requests for the total Tier-2 centers are shown as a function of year.

The total amount of processing and storage resources needed for analysis depends strongly on whether RECO or AOD are used for analysis. During Run I, CMS transitioned slowly to a predominant usage of AOD; for Run II, CMS assumes that this will occur already from the start of data taking in 2015. The total Tier-2 analysis needs also scale with the number of events collected. Figure 4 shows the evolution of storage requirements at the Tier-2s, while Figure 5 shows the evolution of the corresponding processing resources. The XrootD data federation, already operating in the majority of our Tier-2 sites (and in the totality of the major ones), allows for a reduction in the number of copies of AOD stored on Tier-2 disks; the replication factor, which was 3.0 during Run I, is expected to scale down to 1.7 by the end of the Run.

With the current simulation parameters, Tier-2 disk is the most problematic resource for CMS, with the request level (as in Fig. 4) off by a few PBs at the end of 2016 and 2017. The request for this resource is not changed for the moment (already at a

+37% with respect to previous year), waiting to gain some operational experience during the first months of data taking.

Summary

The total processing, disk, and tape requests for the 2015-2017 resource years are listed in Table 8, with 2014 reported for reference. The requests maintain the fundamentals of the computing model and take into account our best and most recent understanding from the operational experience CMS has accumulated with collision data. The requests for 2014 were very small and CMS is requesting a substantial increase for the start of the next run in 2015. The requests are also large for 2016, due to the increased LHC live time, and the accumulation of data to be analyzed. First estimates for 2017 predict a smaller increase with respect to 2016, but they will need to be validated via operational experience. In the table, the column named "2016" lists within parentheses the recommendations resulting from the October 2014 C-RSG scrutiny process (when different from our initial requests).

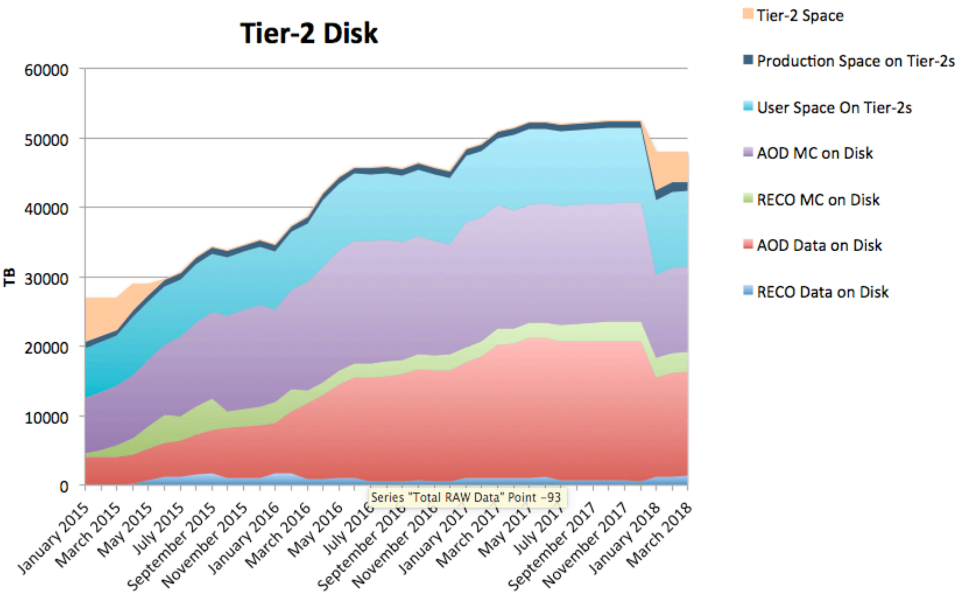

Figure 4: The contributions to the total storage used at the Tier-2 sites are plotted for 2015-2017. The green bars are the contribution from RECO events, the proportion of which is expected to be small for all of Run2.

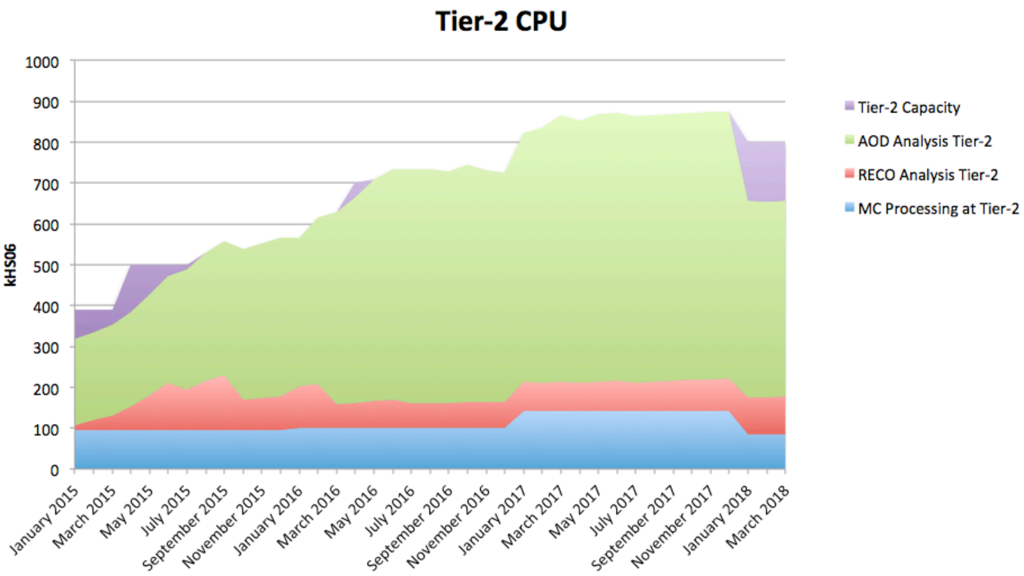

Figure 5: The contributions to the processing used at the Tier-2 sites are plotted for 2015-2017.

	2014	Increase from 2013	2015	Increase from 2014	2016 (C-RSG Oct 14)	Increase from 2015	2017	Increase from 2016
Tier-0 CPU (kHS06)	121	0%	256	111%	302	18%	350	18%
Tier-0 Disk (TB)	7000	0%	3000	Reallocated to CAF	3250	0%	3250	0%
Tier-0 Tape (TB)	26000	0%	31000	31%	38000	23%	50000	31%
CAF CPU (kHS06)	0	0%	15	-	15	17%	17	21%
CAF Disk (TB)	0	0%	12000	-	13100	9%	14000	7%
CAF Tape (TB)	0	0%	4000	-	6000	50%	8000	33%
T1 CPU (kHS06)	175	0%	300	71%	400	33%	525	31%
T1 Disk (TB)	26000	0%	26000	4%	35000 (33000)	30%	45000	28%
T1 Tape (TB)	55000	11%	74000	34%	100000	35%	135000	35%
T2 CPU (kHS06)	390	14%	500	25%	700	40%	800	14%
T2 Disk (TB)	27000	4%	29000	16%	40000 (38000)	37%	48000	20%

Table 8: Processing, disk, and tape resources requested by CMS for all centrally controlled computing tiers. The column named "2016" shows within parentheses the resources as scrutinized by C-RSG in October 2014.