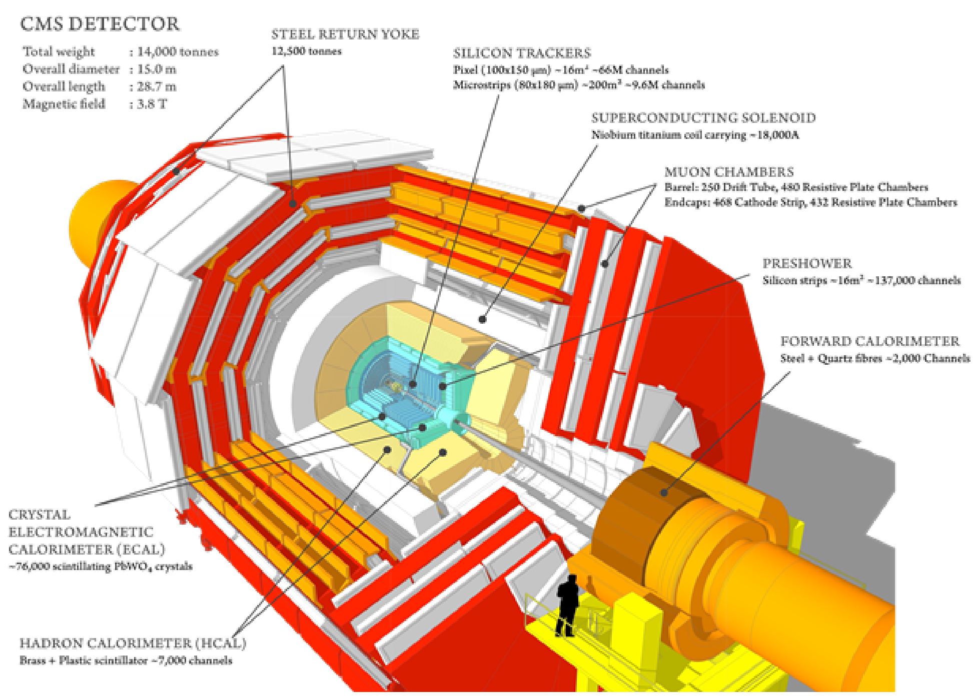
U.S. CMS Compact Muon Solenoid Operations Program
Quarterly Report for the Period Ending September 30, 2015

U.S. CMS Operations Program



Program Manager's Summary

Resource Allocation Advisory Board The Operations Program (OP) managers and the Phase2 upgrade manager are creating a Resource Allocation Advisory Board (RAAB) and charging it to provide advice on questions regarding the allocation of funds between the different activity areas of the OP, and on the interplay between the planned Phase2 upgrade projects, including enabling R&D and pre-construction planning, and the OP. The RAAB is asked to review the longer-term needs and cost estimates, the impact of the cuts in computing upgrades, and the tight management reserve and carry-over allocations in the current plan. It should provide a recommendation for the balance of OP vs. Phase2 upgrade allocations, in particular for 2016, in view of the longer term needs and spending plan for the years beyond, and based on the current understanding of scope and costs, institutional roles and responsibilities, and time lines. The RAAB should get organized immediately and work with the OP and the upgrade project management teams to provide a recommendation in time for the 2016 budget process, that is at the end of July 2015

Jeff Berryhill/Fermilab Pushpa Bhat/Fermilab Joel Butler/Fermilab (chair) Sridhara Dasu/Wisconsin (USCMS CB chair, observer) Sarah Eno/U.Maryland Cecilia Gerber/UIC Kristian Hahn/Northwestern U. Avi Yagil/UC San Diego

Report of the U.S. CMS Resource Manager

The funding provided by DOE and NSF to the U.S. CMS Operations Program for 2002 through 2015, as well as the funding guidance for 2016 through 2019, is shown in Figure~1.

Resources are distributed and tracked across the three areas through which the Operations Program is implemented: Detector Operations (DetOps), Software and Computing (S&C), and Common Operations (ComOps). ComOps is a category for items that would otherwise belong in both, or neither, of the other two categories.

Internal budget reviews for calendar year 2015 took place in August and September of 2014. Through this process, U.S. CMS Management developed a detailed spending plan. This plan was further refined through the March 2015 joint NSF/DOE Operations Program review.

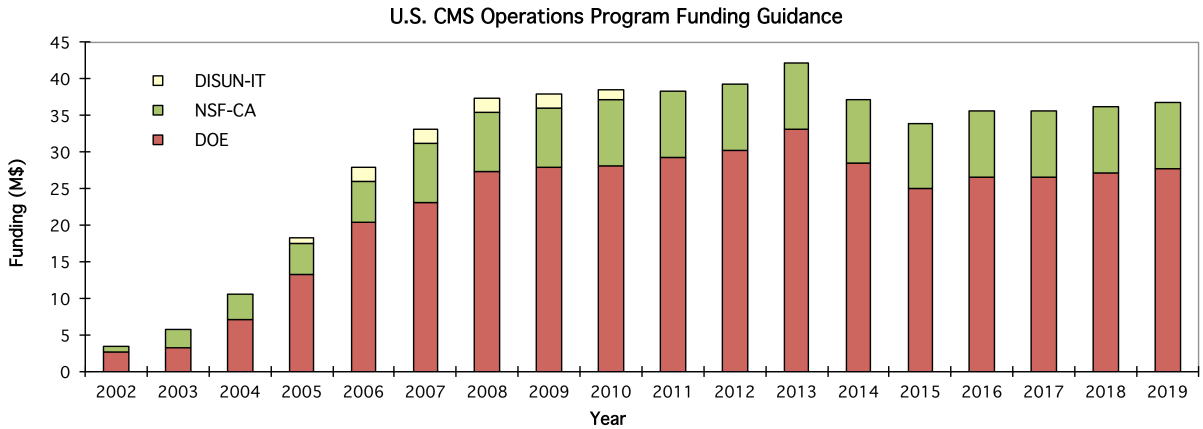


Figure 1: The annual U.S. CMS Operations Program funding provided by DOE and NSF. For 2002 through 2015 the chart shows the actual funding, while for 2016 onward the current funding guidance is shown.

Primarily during the first quarter of the calendar year, Statement of Work (SOW) agreements were established with each institution that is providing a deliverable in exchange for Operations Program funding. The SOWs specify the tasks to be carried out, as well as any portions of salaries, materials and services (M&S), travel funding, or cost of living adjustments (COLA) to be paid from the Operations Program budget. The SOWs must be approved by U.S. CMS Operations Program management, by the Fermilab Director Designee, and by representatives of the collaborating group and institution. Through September of 2015, a total of 109 SOWs (71 DOE and 38 NSF) were produced and approved. After a SOW is approved, any additional changes are considered and, if approved, enacted through a Change Request procedure.

Table~1 shows the Spending Plan Change Log which captures revisions that were made prior to SOW approvals, as well as modifications implemented through Change Requests. The information is reported here down to the level-2 subsystem categories within DetOps, S&C, and ComOps. There was a relatively large number of Change Requests relating to Phase 2 (HL-LHC) Upgrade R&D this quarter. These are summarized separately in Table~2. The CY15 spending plan, as of the end of Q3, is shown for DOE and NSF funds in Table~3. The plan will continue to evolve slightly as Change Requests are executed.

Once funds have been committed through purchase orders, in the case of DOE, and sub-awards, in the case of NSF, they are considered obligated. Figure~2 shows the obligations in the areas of DetOps, S&C, and ComOps, as compared to the spending plan, for DOE funds. The spending plan is plotted as if expenditures are carried out in even allocations each month, but this is intentionally not the case due to equipment purchases and the larger of the transfers to CERN-based Team Accounts, the latter of which are targeted for when exchange rates are favorable.

Spending through Universities and CERN Team Accounts is budgeted and tracked according to the calendar year, while spending at Fermilab has historically been budgeted according to the fiscal year. Of special note is that this year we have transitioned to reporting based on calendar year rather than based on fiscal year. There are two features of Figure~2 related to this transition. First,

Table 1: Spending Plan Change Log for CY15 Q3

WBS	Subsystem	Change Request Number	Description of Change	CY15Q3 Plan	Change $	CY15Q4 Plan
U.S. CMS Detector Operations Change Control Activity						
11	Endcap Muon		Insurance rate change	$1,836,040	$456	$1,836,496
12	Hardon Calorimeter	CR-030, CR-031	Contractor time reduction; CR-030: Engineering labor at Iowa; CR-031: COLA decrease and Maryland SWF increase	$1,598,163	$5,495	$1,603,658
13	Trigger	CR-015	U Florida TA COLA Adjustment	$919,475	$6,666	$926,141
14	Data Acquisition			$780,208	$0	$780,208
15	Electromagnetic Calorimeter			$841,815	$0	$841,815
16/17	Tracker (Fpix&SiTrk)			$732,798	$0	$732,798
18	Detector Support			$258,262	$0	$258,262
19	BRIL	CR-002	TA M&S and COLA reduction; Princeton SWF increase	$388,180	$0	$388,180
30	Phase 2 Upgrade R&D	CR-031 to CR-044	See table of Phase 2 Upgrade R&D Change Requests	$3,237,253	$777,702	$4,014,955
11-18,30	**Detector Operations**			**$10,592,194**	**$790,319**	**$11,382,513**
U.S. CMS Common Operations Change Control Activity						
21.2	Common Costs (M&OA, LS1, Loan)	CR-085, CR-086, CR-087, CR-088, CR-089	CR-085: NSF M&O-A and LS1 actual exchange rate, CR-086: DOE LS1 actual exch. rate and early payment, CR-087: DOE M&O-A payment 1 actual excahnge rate, CR-088: DOE M&O-A payment 2 actual excahnge rate, CR-089: DOE M&O-A payment 3 actual excahnge rate	$5,415,822	($513,049)	$4,902,773
21.3	RCMS			$554,413	$0	$554,413
21.4	LHC Physics Center	CR-082	Brown SWF support	$635,637	$38,542	$674,179
21.5	Operations Support	CR-078, CR-079, CR-081, CR-084, CR-090	CR-078: Fairfield EndCap Calorimeter activities; CR-079 UCLA CSC Project Manager; CR-081: Cornell HL-LHC deputy project manager; CR-084: Boston SWF support; SOWs for Wisconsin and Nebraska SWF; CR-090: Caltech SWF support	$1,455,591	$329,080	$1,784,671
21.6	Program Office		Pre-SOW adjustment	$1,029,394	$20,000	$1,049,394
21.7	E&O	CR-083	Notre Dame outreach professional	$286,480	$59,000	$345,480
21.8	Collaboration Support			$10,000	($7,500)	$2,500
21	**Common Operations**			**$9,387,337**	**($73,927)**	**$9,313,410**
U.S. CMS Software and Computing Change Control Activity						
22.1	Fermilab Facilities		None this quarter	$6,556,269	$0	$6,556,269
22.2	University Facilities			$4,142,508	$0	$4,142,508
22.3	Computing Operations			$1,129,031	$0	$1,129,031
22.4	Computing Infrastructure and Services			$2,106,931	$0	$2,106,931
22.5	Software and Support			$1,951,086	$0	$1,951,086
22.6	Technologies & Upgrade R&D			$899,330	$0	$899,330
22.7	S&C Program Management & CMS Coordination			$694,276	$0	$694,276
22	**Software and Computing**			**$17,479,431**	**$0**	**$17,479,431**
U.S. CMS Operations Program Total				**$37,458,962**	**$716,392**	**$38,175,354**

Table 2: Phase 2 (HL-LHC) Upgrade R&D Change Requests in CY15 Q3

Phase 2 Upgrade R&D Change Requests in CY15 Q3			
Change Request Number	**Institution**	**Description**	**Change $**
CR-031	CERN	Purchase of HGC prototype sensors	$60,000
CR-032	UCSB	Engineering design of front-end ASIC, HGC module	$190,000
CR-033	Minnesota	Technical labor & M&S for cassette for test beam	$40,000
CR-034	Maryland	Qualification and testing of rad tolerant scintillator	$35,000
CR-035	FNAL	HGCAL R&D labor	$30,000
CR-036	Minnesota	M&S funds for HGCAL test cassettes	$10,000
	UCSB	M&S funds for HGCAL test cassettes	($10,000)
CR-037	Cornell	Engineer for fwd pixel mechanical modeling	$29,343
CR-038	CERN	HGCAL R&D labor	$10,000
	FNAL	HGCAL R&D labor & adjustment	$10,000
	Minnesota	HGCAL labor, M&S, and travel	$30,000
CR-039	Ohio State	HL-LHC tracker upgrade L2 manager support	$46,123
CR-040	Iowa	Shashlik R&D completion	$50,000
CR-041	Caltech	Shashlik R&D completion	$60,000
CR-042	Virginia	Shashlik R&D completion	$85,000
CR-043	Notre Dame	Shashlik R&D completion	$85,000
CR-044	Brown	Outer tracker test beam labor & travel	$10,584

obligations for DOE spending at Fermilab in the last three months of calendar year 2014 have been included in the plotted obligations for 2015. Second, to accommodate the three month offset between fiscal year and calendar year, a buffer of $3M has been allocated this year, drawing from carry over from previous years. This is indicated by the difference between the solid and dashed blue lines. Figure~3 shows the total obligations and the spending plan, for NSF funds. Of the $9M in NSF funding, $2.5M in subawards went out this quarter, in addition to spending directly at Princeton.

Resources deployed at CERN, and paid directly in Swiss francs, account for approximately 28% of the 2015 spending plan. This carries considerable exposure to the exchange rate. A rate of 0.9 CHF/USD has been used for planning, while the actual rate in CY15 Q3 averaged 0.96 CHF/USD. Figure~4 shows the allocated budgets and year-to-date spending through the Team Accounts that are used for expenditures at CERN. Spending for labor and cost of living adjustments occurs at a fairly constant rate. Figure~4 does not include the last 823K CHF of the Upgrade Common Fund payments and the 3,827K CHF M&O-A payments, as these are each made through multiple payments to a separate Team Account. % Source for exchange rate average: % http://www.oanda.com/currency/historical-rates/

Table 3: Spending plan at the end of CY15 Q3, for funds from DOE, NSF, and the total.

WBS	Subsystem	DOE Funds	NSF Funds	Total
11	Endcap Muon	$1,501,776	$334,720	$1,836,496
12	Hadron Calorimeter	$1,530,247	$73,411	$1,603,658
13	Trigger	$778,331	$147,810	$926,141
14	Data Acquisition	$780,208	$0	$780,208
15	Electromagnetic Calorimeter	$841,815	$0	$841,815
16/17	Tracker (Fpix-SiTrk)	$703,520	$29,278	$732,798
18	Detector Support	$258,262	$0	$258,262
19	BRIL	$115,300	$272,880	$388,180
30	Phase 2 Upgrade R&D	$3,263,171	$751,785	$4,014,955
11-19,30	**Detector Operations**	**$9,772,630**	**$1,609,884**	**$11,382,513**
21.2	Common Costs (M&OA,LS1,UpgrdLoan)	$3,894,968	$1,007,805	$4,902,773
21.3	Run Coordination and Monintoring	$554,413	$0	$554,413
21.4	LHC Physics Center	$674,179	$0	$674,179
21.5	Operations Support	$1,595,945	$188,726	$1,784,671
21.6	Program Office	$931,844	$117,550	$1,049,394
21.7	Education and Outreach	$229,000	$116,480	$345,480
21.8	Collaboration Support	$2,500	$0	$2,500
21	**Common Operations**	**$7,882,849**	**$1,430,561**	**$9,313,410**
22.1	Fermilab Facilities	$6,556,269	$0	$6,556,269
22.2	University Facilities	$111,217	$4,031,291	$4,142,508
22.3	Computing Operations	$713,568	$415,463	$1,129,031
22.4	Software and Support	$1,677,995	$428,936	$2,106,931
22.5	Computing Infrastucture and Services	$1,694,841	$256,245	$1,951,086
22.6	Technologies & Upgrade R&D	$206,191	$693,139	$899,330
22.7	S&C Program Management and CMS Coordination	$464,016	$230,260	$694,276
22	**Software and Computing**	**$11,424,097**	**$6,055,334**	**$17,479,431**
U.S. CMS Operations Program Total		**$29,079,575**	**$9,095,779**	**$38,175,354**

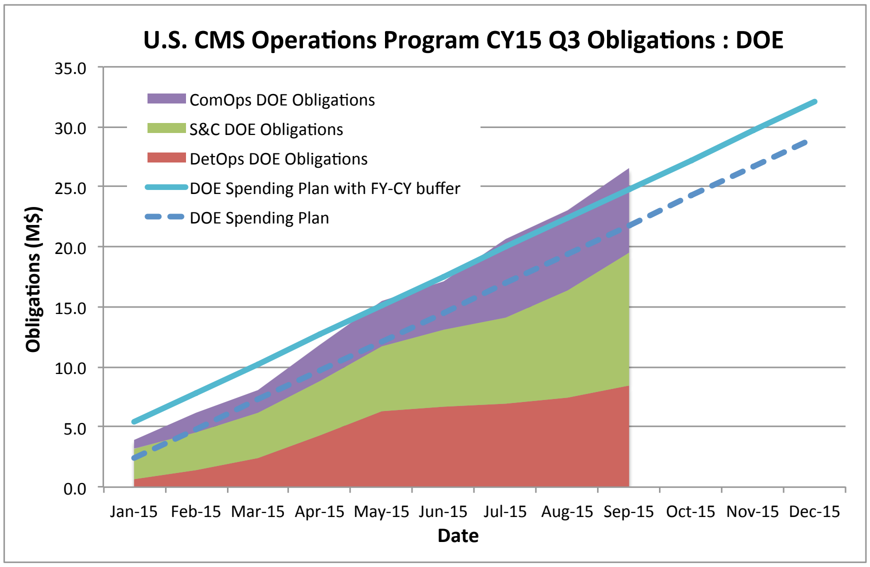


Figure 2: Obligations and spending plan for DOE funds. The spending plan is indicated with the assumption of equal monthly increments just as a rough guide. The lines show the spending plan with (solid) and without (dashed) a required buffer to bridge the difference between fiscal year and calendar year for funds spent at Fermilab, as described in the text.

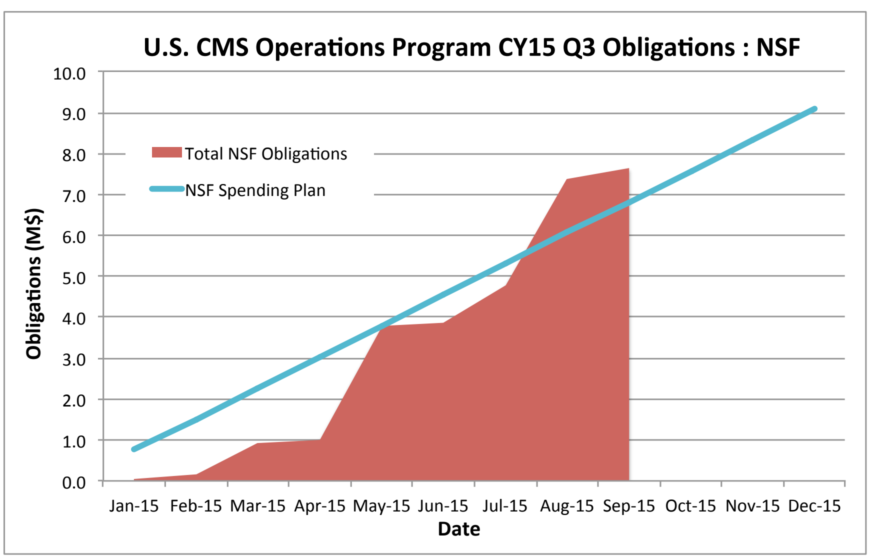


Figure 3: Obligations and spending plan for NSF funds. The spending plan is indicated with the assumption of equal monthly increments as a rough guide.

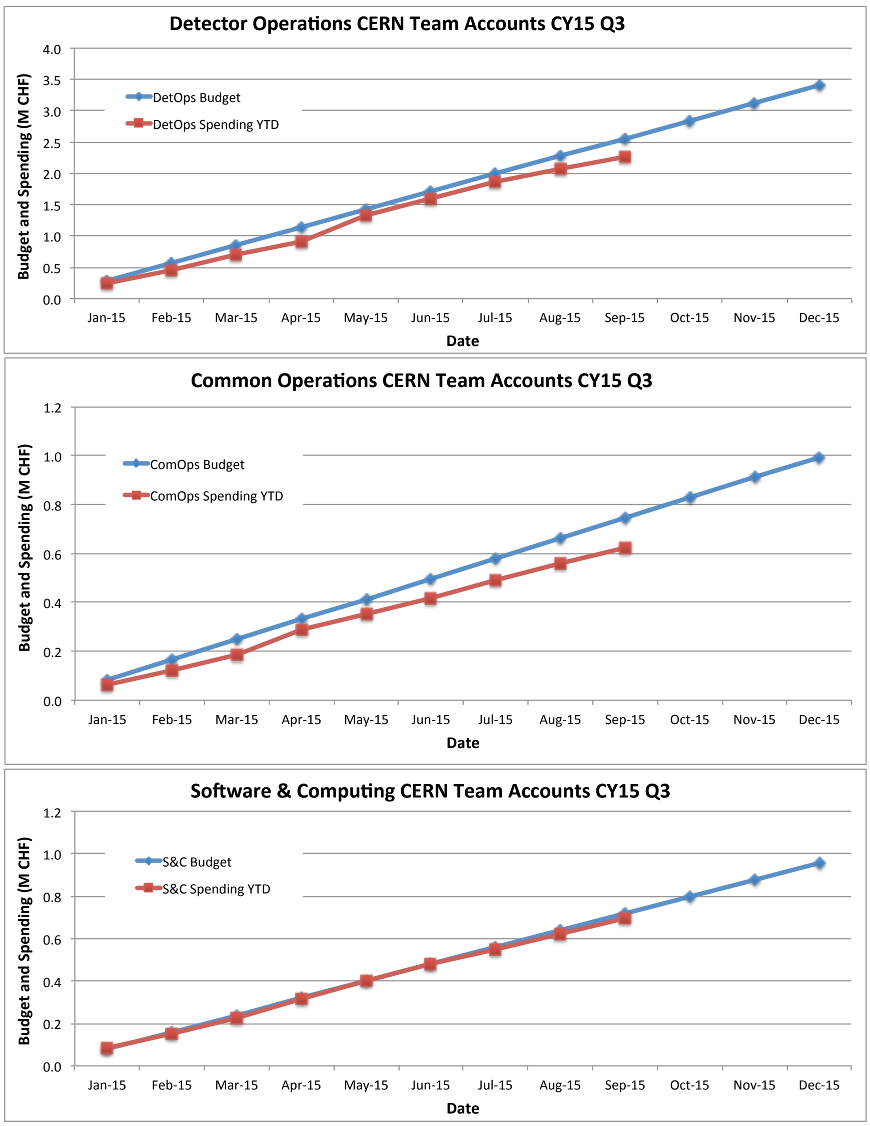


Figure 4: Budget plan and year-to-date spending, in Swiss francs, through DetOps (top), ComOps (middle), and S&C (bottom) Team Accounts.

Detector Operations

Problems with the CMS magnet continued through the quarter. Since March the "Cold Box" (CB) that produces Liquid He for the operation of the CMS magnet has shown problems, after an incident where compressor oil contaminated the CB circuit. For definitive recovery, the system requires an overall cleanup which takes several months. Meanwhile, the CERN cryo group, in collaboration with the CMS Technical Coordination, has been trying to find a way to operate the CB with a reasonable Duty Cycle ($\geq$ 70%) that would allow operation of the magnet synchronized with physics operation of the LHC until the Year end technical stop. After a number of corrective actions, performance of the magnet has improved and it appears this goal is being met.

Figure 5 shows the total luminosity delivered and recorded by CMS during 2015. Of this data, approximately 0.40 fb^{-1} is with the magnetic field off or below nominal value.

With this quarterly report we begin to give metric performance results. These are presented in each sub-detector section below.

BRIL

The highlight of this quarter was the successful calibration of the PLT and other luminosity detectors using a full VdM scan. Due to readiness of the detector and the software the PLT provided the fastest turnaround of all LHC detectors in reporting luminosity to LHC. Furthermore, the calibration agrees within 1% with preliminary calibrations from previous beam scans. The CMS detector is in the position to publish the luminosity online with 99% uptime.

In addition to the trigger based on triple coincidences, PLT has implemented a second trigger to randomly select the bunch crossings for saving full particle track information. This trigger mode is in the commissioning phase. It allows comparative systematic studies and potentially improves the luminosity uncertainty.

Table 4: BRIL Milestones.

Subsystem	Description	Scheduled	Achieved
BRIL	Hardware installed	Jan	Jan
BRIL	Ready to deliver Lum	March	March
BRIL	Ready to deliver bkg nums	May	May

Table 5: BRIL Metrics.

Metric	Performance
Fraction of telescopes operational	14/16
Efficiency of delivery of lumi histograms	100 %
Uptime of lumi histogram production	100 %

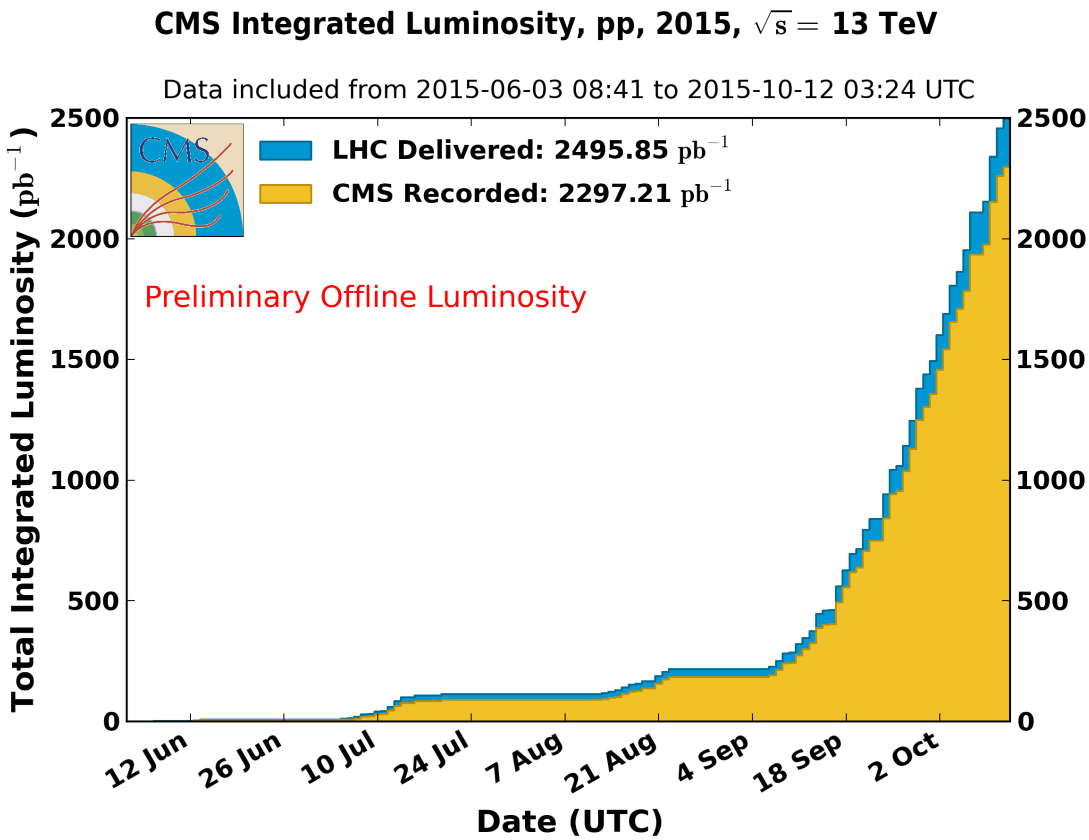


Figure 5: Cumulative offline luminosity versus day delivered to (blue), and recorded by CMS (orange) during stable beams and for p-p collisions at 13 TeV centre-of-mass energy in 2015. The delivered luminosity accounts for the luminosity delivered from the start of stable beams until the LHC requests CMS to turn off the sensitive detectors to allow a beam dump or beam studies. Given is the luminosity as determined from counting rates measured by the luminosity detectors after offline validation. This preliminary calibration is based on short van-der-Meer scans performed routinely by LHC in every fill.

Tracker

The tracker system has been performing well and has met its milestones. There had been an ongoing problem with condensation in the pneumatic control lines for the cooling system which has been traced to short sections of plastic tubing in the system. The plan is to replace these short sections with aluminum jacketed pipe in the year end technical stop and to mitigate the problem with bleed valves in the meantime.

Tracker - Strips

Strips have accounted for 4% of the lost lumi since the start of the high intensity running. We continue to try and recover problematic FEDs (less than 1% of the Strips), but the emphasis is now on smooth data taking rather than detailed channel recovery.

Tracker - Pixels

Major downtime from the pixels has come from the testing of Heavy Ion firmware for the pixel fed. As the request for firmware that could run at a much higher rate for heavy ion collisions was made in May 2015, the opportunity to develop with beam in 2012-2013 was lost, and we did not fully develop an alternative testing method during Long Shutdown 1 (LS1). The firmware passes all tests outside of collisions, and we are left with using collisions to fully map out the areas of problems with the heavy ion firmware. The pixels accounted for 21% of the lost lumi since the start of the high intensity running. 98.6% of the pixel tracker channels are working. 99.8% of the FPiX channels are working.

Table 6: Tracker Milestones.

Subsystem	Description	Scheduled	Achieved
Tracker	Installation and checkout		Achieved
Tracker	Tracker operate -15C		Achieved
Tracker	Pixel operate -10C		Achieved
Tracker	Ready for proton beams	March	March

Table 7: Tracker Metrics.

Metric	Pixels	Strips
% Working channels	98.6%	97.5%
Fraction of deadtime attributed	21%	4%

ECAL

All parts of ECAL (EB/EE/ES) are taking data normally. Substantial effort has been devoted to improving the data-taking efficiency of ECAL by simulating higher than normal data acquisition rates and solving the rare errors that occurred. The ECAL optical links to the legacy and upgraded calorimeter triggers have been successfully validated and the detector has been synchronized with the rest of CMS using beam splash events and proton-proton collisions data.

In addition, the laser used for calibrating the crystals has been operating well. At the end of Run 1 there was a laser power stability issue that was traced to a flawed humidity sensor, which has since been replaced. With that replacement the operation has been stable with no power loss in the system.

A successful test beam campaign was conducted in Sep 2015 using electrons provided by the H4 beamline at the CERN-SPS. Measurements of highly irradiated $PbWO_4$ crystals were recorded, with special two-sided readout, to study the changes in light collection efficiency as a function of the radiation-induced crystal transparency change.

Table 8: ECAL Milestones.

Subsystem	Description	Scheduled	Achieved
ECAL	Finish HV Install	Feb	May

Subsystem	Description	Scheduled	Achieved
ECAL	Baseline levels zero suppression	March	March
ECAL	Complete install HV calib system	April	May
ECAL	Selective readout	June	First pass completed
ECAL	Trigger thresholds	June	First pass completed
ECAL	Zero suppression thresholds	June	First pass completed

Table 9: ECAL Metrics.

Metric	Performance
Fraction of channels operational: EB	99.1%
Fraction of channels operational: EE	98.9%
Fraction of channels operational: ES	98.4%
Fraction of deadtime attributed	14%
Resolution performance	TBD

HCAL

In this quarter, the HCAL project has focused on two tasks:
the operation of the HCAL detector for LHC collisions at 13 TeV in Run II, and the development and installation of the Phase I upgrades.

With Run II underway, a major emphasis has been the collection of high quality data from all HCAL subsystems (HBHE, HF, and HO). To accommodate collisions with 25 ns bunch spacing, new local reconstruction code has been developed and commissioned; the improved algorithm has substantially improved the mitigation of out-of-time pileup. Using data taken early in Run II, the calibration of the HBHE and HF sub-detectors has been adjusted, and corresponding corrections to the Level-1 trigger look-up tables have been implemented.

The long-term stability of the response of HCAL photo-detectors in Run II is being monitored using the LED calibration system. The average gain of the legacy HBHE hybrid photodiodes (HPDs) has been nearly stable over the last six months at the level of 1%, although a slow drift, either up or down, of the individual HPD gains with time is observed, comparable to effects seen in Run I. The gains of the new PMTs for the HF are stable within 1%, with no evidence of gain loss as a function of integrated luminosity. Similarly, the gain of the HO Silicon PhotoMultipliers (SiPMs) is very stable, with no sign of dependence on the magnetic field.

Table 10: HCAL Milestones.

Subsystem	Description	Scheduled	Achieved
HCAL	Fully functional HCAL in CRAFT runs	March	March
HCAL	prepared to do HF Phase scan and ϕ symmetry calibration analysis	May	May
HCAL	New HBHE backend operating in parallel with legacy system	July	July

The status of the HCAL metrics is as follows:

- Fraction of channels working
  in HF, 1 channel out of 1728 dead
  in HBHE, 7 channels out of 5184 dead
  in HO all 2150 channels work.
  In total $>$ 99.9% working channels
- Fraction of downtime attributable to HCAL since LS1, 0.5%
  2.7pb-1 lost of 562 pb-1
- Intercalibration uniformity between individual HCAL towers
  HB: depth 1: 3-4%
  HE: depth 1: $\approx$ 1-2%, depth 2,3: 3-4%
  HF: depth 1: 1-1.5%, depth 2: ~3% (still some outliers)

Unfortunately, there have been issues that led to a significant loss of data during data certification. There were issues with the loss of synchronization between the HF backends and fronts ends that cost 75~pb^{-1} of bad data and an issue with a low voltage power supply for HF that cost 10~pb^{-1} of bad data. These issues have been resolved. There is also an issue with μHTR registers being occasionally corrupted when a detector re-configuration is issued. This problem is still under study, but a temporary work-around has been implemented.

EMU

The transition to 25 ns LHC beam bunch spacing went smoothly for the CSC system. Figure 6 shows the track segment times in the CSC readout window displaying the 25 ns beam structure clearly.

The spatial resolution for reconstructed hits on CSC chambers was measured from collision data. The resolution varies by chamber type, with a median value of 128 μm. The resolutions are very close to the values from Run 1, aside from the ME1/1 chambers, where the resolution on the inner region (ME1/1a) has gone from 64 μm to 51 μm. This improvement is largely due to the removal of the 3-to-1 cathode strip ganging in this region performed during the LS1.

A sample of $Z \to \mu\mu$ events from Run 2 collision data were used to make the first measurement of the efficiencies for CSC segments and trigger primitives (LCT). The average for all 540 chambers is greater than 96% with a few outliers from known outstanding chamber issues and low statistical accuracy. The efficiencies are more uniform than in Run 1 due to the high fraction of operational system channels.

Table 11: EMU Milestones.

Subsystem	Description	Scheduled	Achieved
EMU	CSC ready for collisions	May	April
EMU	Calibration for HLT and Offline included in DB	July	delayed
EMU	Fine timing adjustments with collision data completed	July	July

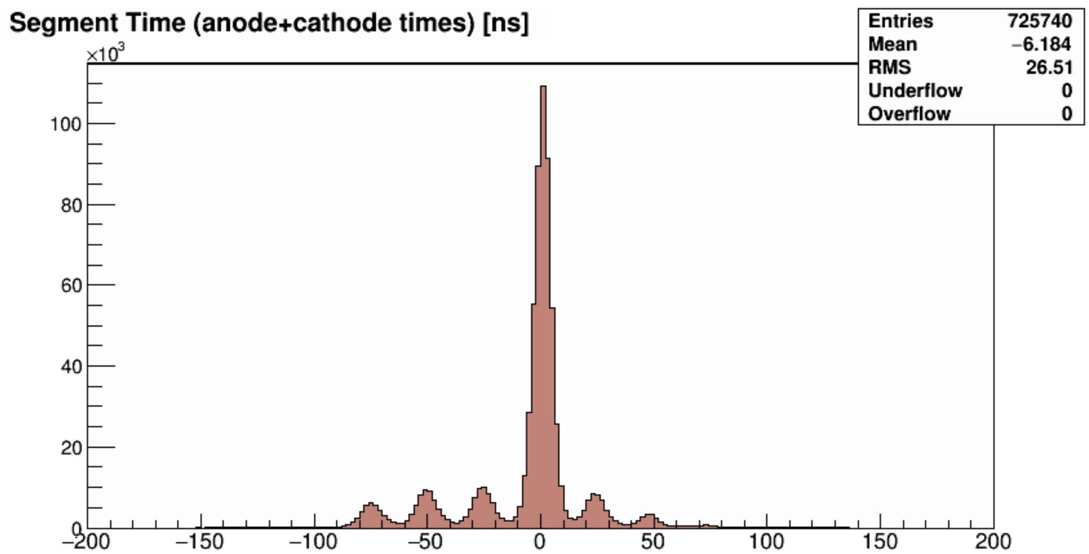


Figure 6: The timing of CSC Segments relative to the triggered beam crossing in 25 ns collision data.

The milestone "Calibration for HLT and Offline included in DB" has been delayed. It is now expected that it will be completed in December. There are technical problems with taking calibration data at Point 5. These have been worked on since July, but they can only be done when CMS is not taking data. Operational issues that affect physics running are given higher priority. We are using a set of calibration constants from Run 1, except for ME1/1 and ME4/2 chambers where these constants are not available. For these, we use typical values for each chamber. The impact of this delay is low, the reconstruction is quite insensitive to the calibration. The main motivations for the calibration are to represent the cross talk correctly in the simulation and to allow more precise tracking of gas gain.

Table 12: CSC Metrics.

Metric	Performance
% Working channels	99.3%
Fraction of deadtime attributed	8%
Median spatial resolution	128 μm

DAQ

DAQ met all its milestones and performing with negligible down time during physics data taking. LHC has not completed the Luminosity ramp up and presently CMS is taking data with 80 kHz Level 1 trigger rate and average event size of 650 kB which is below the design throughput of the DAQ2.

Event Building performance demonstrated in emulation runs that it could sustain event building at 100 kHz L1 accept rate with a margin of 1.5 times the run 1 event size of 750kB. (DAQ I design performance was 100 kHz L1 accept rate for 1 MB Events) with full DAQ chain - event building, High Level Trigger (HLT) processing (actually emulated as sleep) and collecting HLT selected event in to single files per stream ready to be send to tier 0. Actual demonstration, of course, will be with real detector data with full HLT menu but for that we need to wait LHC luminosity to increase.

Metric	Performance
Downtime due to DAQ	negligible
Median spatial resolution	128 μm

Trigger

During this quarter the US groups continued their work on the regional calorimeter (RCT) and the endcap muon triggers.

Regional Calorimeter Trigger

During the last three months, the CMS RCT has participated in the 25 ns LHC proton-proton collisions. CMS has switched from calorimeter triggers with the RCT and GCT to triggers with the the RCT and Stage-1 MP7. Accordingly, the configuration and hardware monitoring were added to the Trigger Supervisor, and the histograms in the online Data Quality Monitoring (DQM) were updated to use the readout from the MP7. Previously it was reported that the RCT output could be readout via CDAQ using the CTP7. Using this data, a second set of online DQM (emulator and occupancy) histograms were added to the Online DQM of the RCT.

The new HF uHTR links to RCT have been commissioned. There were still some issues with links going into error and with the HF link synchronization. This caused effects in the Jet rates which were similar to the ECAL issues. It was mitigated in the same way, using the same firmware as for the ECAL oRMS, but will need further dedicated study outside of physics running.

Endcap Muon Trigger

The Rice University, Northeastern, and University of Florida groups have maintained on-call coverage of the CSC Track-Finder during the reporting period, with only a few instances needing intervention. We eventually had to replace a QPLL module on one sector processor that had occasionally lost synchronization during operations.

The CSC Track-Finder group also participates in the CMS TimeX group, which is part of Run Operations. In that context, the CSC Track-Finder delay buffer depths are being monitored to flag any shifts in the TCDS clock timing, which has been observed by several CMS subsystems. Moreover, we have participated in system tests of the new reset procedure in order to avoid these TCDS timing shifts.

Table 15: Trigger Milestones.

Subsystem	Description	Scheduled	Achieved
TRIG	Legacy RCT ready for physics	June	June
TRIG	MPC ready for physics	June	June
TRIG	CSCTF Ready for physics	June	June
TRIG	Stage-1 Layer-1 calorimeter trigger ready for physics	Sept.	Sept.

Table 16: Trigger Metrics.

Metric	Performance
Frac legacy RCT channels	100%
Frac of deadtime attributed legacy RCT	0.18%
Frac of MPC Channels	100%
Frac of EMUTF Channels	100%
Frac of deadtime attributed to legacy EMUTF	0.13%
Frac of Stage-1 Layer-1 Channels	100%
Frac of deadtime attributed to Stage 1 Layer 1	0%

Software and Computing

As the LHC has settled into stable operations in the last quarter of FY15, the U.S. CMS Software and Computing Operations Program has also entered a very operational mode. Various aspects of operations, both of the central processing and data management systems, have become routine, with adjustments as necessary as experience is gained. This has been facilitated by the various development efforts carried out during the shutdown. While development continues on many products and services, the top priority is supporting current operations, with an eye towards the use of new resources such as the Amazon cloud or clusters at supercomputing centers. CMS software has seen the benefits of the multi-threaded framework, and development has continued to expand the scope of those gains. As a result of all of this, facilities at both Fermilab and the universities have seen increasing amounts of activity, both centrally- and user-controlled. The facilities have been much more full than in recent previous quarters, but site performance has remained just as good. End-of-year hardware purchases, both completed and planned, will help to keep up with the demand.

Table 17: Major milestones achieved this quarter

Date	Milestone
July 2015	Production release CMSSW_7_5_0 made available
August 2015	Implement continuous integration for WMAgent
September 2015	FY15 Tier 1 purchases completed

Fermilab Facilities

LHC Run 2 continued through the 4th quarter of the 2015 fiscal year, with the FNAL facility accepting over a petabyte of LHC collision data so far. As the run continues in earnest, utilization of the Tier 1 has also increased from shutdown levels, with the FNAL facility being full to capacity becoming the norm rather than the exception. Site readiness improved over the previous quarter, with FNAL passing CMS site tests 98% of the time for the quarter as shown in Figure 7.

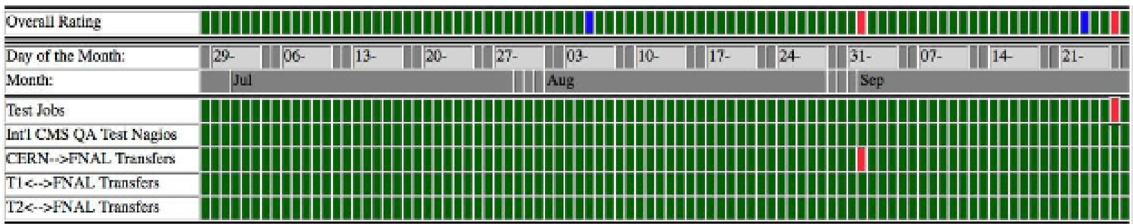


Figure 7: Fermilab readiness metrics for 2015Q3. Green indicates a passing metric, red a failed metric. Blue indicates a scheduled downtime. Fermilab was 98% available during the quarter.

The FY15 hardware purchase cycle was completed this quarter, with hardware beginning to arrive and be installed late September. We were able to take advantage of very good market pricing this year both for disk and CPU, and used this to buy ahead for the next two years, when significant budget pressure is expected from the Phase 2 upgrade program. FNAL purchased 168 nodes of 48 core Intel CPU based batch nodes, and approximately 8 PB of disk storage toward the 2016, and to some extent 2017, CMS pledges. The increase in size of the batch farm requires upgrades in network connectivity to the storage pools, and management reserve funds were used to facilitate this. Almost 6 PB of tape media was also purchased and installed to hold incoming Run 2 data.

University Facilities

This quarter saw a continuing increase in the usage of the U.S. CMS Tier-2 facilities as LHC Run 2 continued, as seen in Figure 8. This increase was largely due to running the CMS data reconstruction at the U.S. Tier-2 sites. This workflow has been possible at Tier-2 sites since May, thanks in part to development work undertaken during the shutdown. These workflows place a heavy strain on the internal networking capabilities of the sites, but our sites are all able to handle the increased load. Physics analysis with CRAB3 is also increasing.

The seven U.S. sites are planning or are in the process of finalizing their hardware purchases for 2015. The connection of the Tier-2 sites to the LHCONE VPN by ESNet is proceeding in an orderly manner and should be completed this quarter. All sites have deployed the HTCondor-CE computing element, and have either retired or are planning to retire their GRAM CEs very soon.

All of the U.S. CMS Tier-2 sites have operated successfully this quarter. On our two official performance metrics based on CMS test jobs, all sites were at least 92.4% available (a 4.4% improvement over the third quarter 2015) and 95% ready, 1% better than last quarter. The CMS goal for each of these metrics is 80%. The U.S. CMS Tier-2 centers delivered 44% of all computing time by Tier-2 sites in CMS (goal is >25%), being 7 of the 8 top most-used Tier-2 sites in all of global CMS.

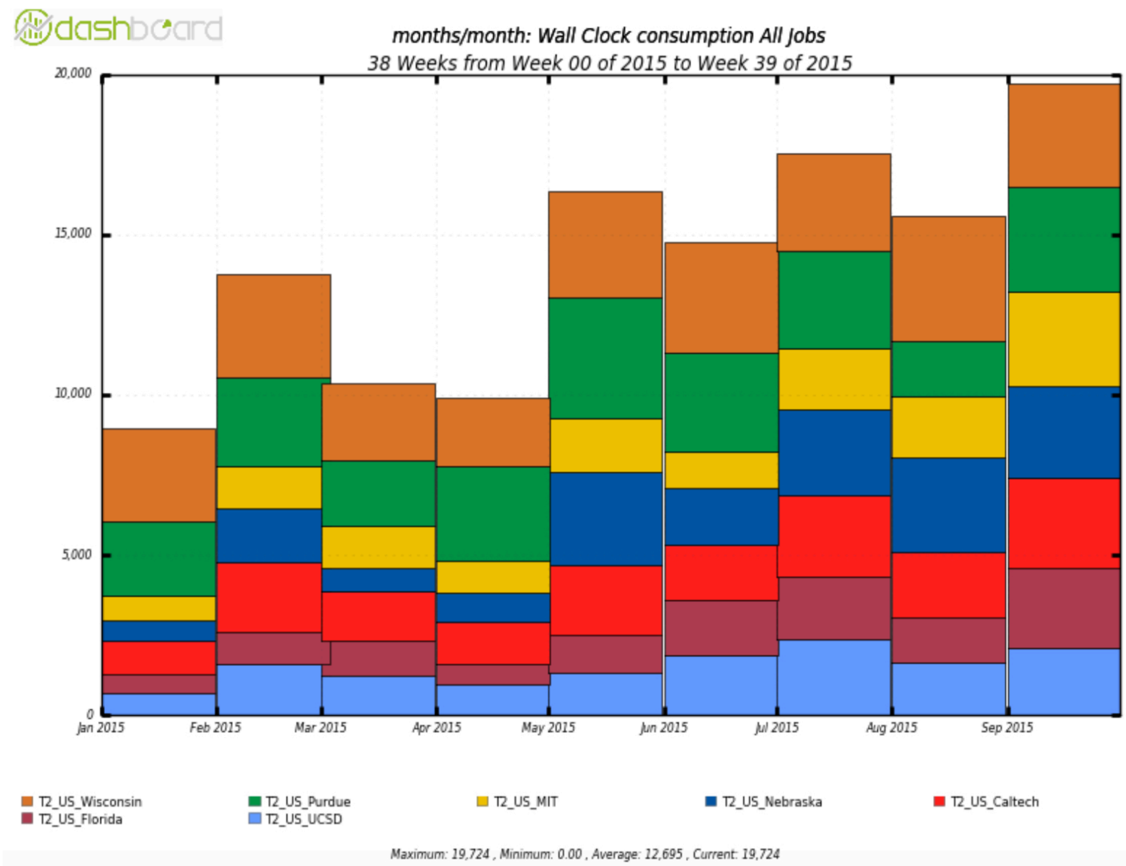


Figure 8: Wall clock time consumption of CMS workflows at the U.S. CMS Tier-2 sites by month.

Fourteen Tier-3 sites required assistance from the Tier-3 support team this past quarter. These support activities include helping sites complete the transition from OSG 3.1 to 3.2, including a critical security patch for GUMS that could only be applied to sites that have already upgraded. In addition, the site support team continues to assist several sites in rebuilding their site in preparation for Run 2. In particular, there is an ongoing effort to implement a modern cluster configuration and provisioning system at the University of Maryland, as well as new efforts to rebuild clusters at Rice and FSU. Efforts continue to refresh documentation for site configuration and administration.

Progress on CMS Connect has focused on connecting the CMS Connect infrastructure to CMS monitoring, which has required significant software development. Documentation is nearly complete and beta testing should begin during the next quarter.

Operations

In this quarter, the Tier-0 was operating in data-taking mode to process data from global data taking. The prompt processing of the freshly recorded data was successful and proceeded without any remarkable problems. Smaller issues and newly appearing software were quickly resolved and adapted easily enough that one could call it "operations as usual." We are preparing to change our present co-team leader for the Tier-0 operations (Dirk Hufnagel). He is a very valuable resource as he is also the core developer for the Tier-0 software we are now entering an operations-dominated period.

The activities in Monte Carlo production and Monte Carlo and data reprocessing have been rather limited and it was easy to keep up with the incoming requests. The streamlining of the production and processing activities has continued and the operations team was very well prepared to deal with the campaigns which started in the beginning of October. In particular, the integration of the dynamic data management tool for the space occupied by production data samples will be very valuable to reduce the worry about overstepping quotas. In the 4th quarter of FY2015 we have completed 2.44B DIGI-RECO events, 3.38B GEN-SIM events and redone 50M MINIAOD. The last number is expected to increase dramatically in the next quarter as we are have just started the re-reconstruction campaign. During this quarter we have not made significant progress to run production requests on the opportunistic HLT resource as data taking has been the priority. We hope to pick up this topic in the next quarter.

In the area of data transfers and data management substantial progress has been made. We have continued the integration of AAA operations and while there are still issues reported regularly the operations team is getting more comfortable with solving problems. The Dynamic Data Management has finally been deployed to carry out automatic deletions in the production data space. The strategy does not require a last copy but instead protects data from deletion by a simple locking mechanism. Any data (dataset or block level) that is in use by production at a given site has to be explicitly locked at the specific site. Thus any production activity that requires data will have to set its locks and release them once done. Many of those locks are extracted automatically from the production tools while others are entered explicitly by existing tools or by hand. The seamless integration of the dynamic data management into all production activities is expected to continue for a while before it can be considered complete. In the next quarter we expect to review the dynamic data management policies and continue development towards further optimizing space usage. Tape pledges at the Tier-1 centers have been reviewed and we are continuing our deletion campaigns to free up space on the existing tapes. The dynamic data management tools are a good candidate to to help reduce the effort used on the deletion campaigns.

Computing Infrastructure and Services

This was the first quarter of Run 2 data taking. The work within U.S. CMS Computing Infrastructure and Services centered around supporting the data taking Run 2. We also continue to lay the groundwork for future improvements to come during and after Run 2. All projects have made progress on modernizing their Python code.

During the quarter, work on the WMAgent concentrated on continued small improvements for Run 2 and the addition of new workflow types and features to support running on Amazon Web Services (AWS), including a new chained workflow type. WMAgent completed a campaign to modernize its Python code and restored automated testing of proposed changes in continuous integration. A gradual transition to Request Manager v2 continues and will be complete by FY16Q2.

With development effectively finished for the Tier-0, the aim for FY16Q1 and beyond is to reliably operate the system during Run 2 data taking. During Q4, the Tier-0 began to produce the MINIAOD data tier. The Tier-0 was also updated to support automatic data management.

Development responsibilities for CRAB3, begun by the U.S., have been almost completely shifted to international CMS. CRAB3 usage continues to show strong growth in at the expense of CRAB2 usage.

DAS and DBS, the CMS metadata services, served larger and larger numbers of requests as the run began. A couple of changes enable this larger load. On the DAS side, horizontal scaling to additional servers has been implemented. DBS struggled with memory consumption issues that are being solved with Python generators. This will be moved into production in FY16Q1.

There was one major GlideinWMS release during the quarter and two patch releases. The major release provides an important improvement for CMS: the ability to schedule an additional high-IO job in a multicore pilot. This is crucial for the Tier-0 to avoid scheduling many high-IO jobs on a single physical machine or leaving resources unallocated. This will be put into production in FY16Q1. In the future, GlideinWMS will improve the monitoring related to completed multicore glideins. Coupled with the AWS pilot project, the GlideinWMS team will add native configuration support for EC2 spot pricing and availability zones in the glidein factory.

Efforts continue to increase the operational robustness of the "Any Data, Anytime, Anywhere" infrastructure. A number of issues in the stability of the regional redirectors were identified and fixed; along the way, many sites were pushed to upgrade to newer versions of Xrootd, which had a number of improvements. Further improvements to monitoring and testing are being considered, and the transitional federation for less-performant sites will be fully populated in the coming quarter.

We are continuing to make progress on cloud and opportunistic resource usage. We completed our Gordon allocation, using 1.8M core hours on Gordon, roughly equivalent to 4M core hours at CMS T2 centers. This allocation was used for GEN-SIM as well as DIGI-RECO. For the latter, the pileup samples were read via XRootd from UCSD-T2, and the GEN-SIM input for DIGI-RECO were read via Xrootd from FNAL. Output was staged out directly to FNAL. Merging was run at FNAL, i.e. contrary to the previous use of Gordon in 2013, no significant disk space at Gordon was used, simplifying operations on Gordon significantly.

For cloud we rely on the HEPCloud project at FNAL to execute our AWS project. For our future use of NERSC and Comet, we are relying on OSG to work through the issues of using these resources. In both cases we collaborate with FNAL and OSG as needed to make progress. The goal in both cases is to establish our capability to elastically grow resources to meet deadlines.

Software and Support

The U.S. CMS Software and Support group continues to contribute to the production of improved software releases to support the development of the major fronts of CMS. The CMSSW_7_4_X series is being maintained as the main production release for operating the HLT trigger and prompt reconstruction for the 2015 run. The introduction of the multi-threaded reconstruction has resulted in large memory savings and reduced processing latency enabling the handling of the large Run 2 trigger rates. As part of the commissioning and deployment of the reconstruction application, it was discovered that the special configuration used in the Tier-0, which requires many output modules and just-in-time compilation within ROOT, triggered larger concurrency inefficiencies compared to the testing configurations that had been used during the development of the threaded application. These problems were fixed in the development release series CMSSW_7_6_X, which will be used for the end-of-year reprocessing. Maintenance work was also done on the 7_4 release to allow it to be used in the HLT, which is currently running in single threaded mode. Due to a lack of sufficient memory per core it cannot sustain the required trigger rate during the last two weeks of data taking without moving to multi-threaded processing. In Figure 9, the point circled in black marks the current limit of the single-threaded HLT application, and the green circle marks the rate that the multi-threaded application allows. This welcomed capability comes just in time to maximize physics data taking efficiency for CMS.

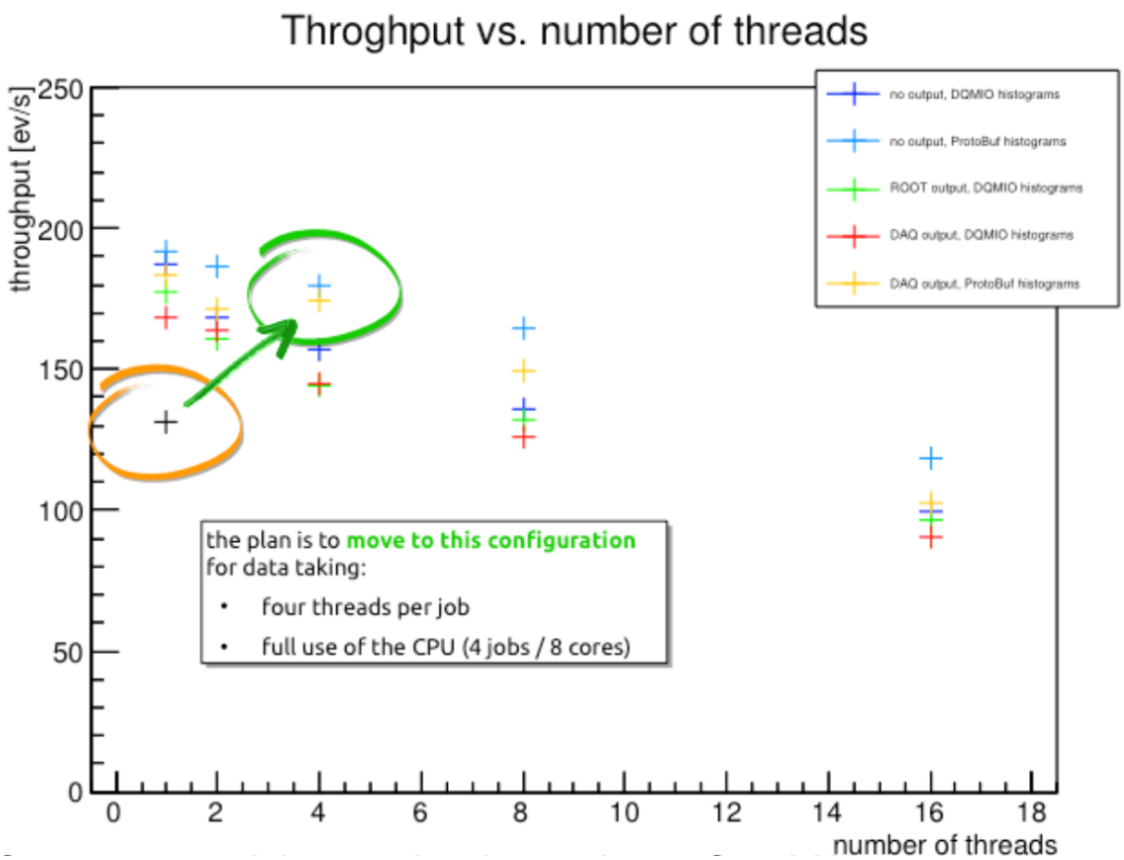


Figure 9: Event throughput rates as a function of the number of threads for single- and multi-threaded applications.

Meanwhile the 7_5_X release series is being prepared to operate during the heavy-ion run. In this release the GEN-SIM application has been validated to run in multi-threaded mode.