Financial Plan for CMS Upgrade

In the last RRB meeting of April 2012 CMS reported progress on the preparation and execution of work described in the Technical Proposal for the Upgrades submitted to the LHCC [CERN-LHCC-2011-006]. The Technical Proposal describes all projects considered necessary to maintain and optimize the physics potential of the experiment for operation up to $2x10^{34}cm^{-2}s^{-1}$ (Phase I of the Upgrades).

Phase II of the Upgrades will allow CMS to operate at the high luminosity expected after 2023 (with luminosity leveling at $4\text{-}5x10^{34}cm^{-2}s^{-1}$). Preparations for Phase II require R&D to be done in parallel with data-taking and with the construction and installation work for Phase I. This R&D was outlined in the appendix of the Technical Proposal. It entails additional costs, incurred by Funding Agencies, concurrent with the support for Phase I.

Along with the Technical Proposal it was foreseen to prepare Technical Design Reports (TDRs) for the major new projects that were included in the scope. CMS has now prepared TDRs for two projects that will be completed in the period through Long Shutdown 2 (LS2): The Pixel Detector Upgrade [CERN-LHCC-2012-016] and the HCAL Detector Upgrade [CERN-LHCC-2012-015]. These TDRs were reviewed and approved by the CMS collaboration, and presented to the LHCC at their meeting in September.

The LHCC found the physics case for the Pixel and HCAL upgrades extremely compelling and strongly support these projects be funded and carried out as planned. In its preliminary report it makes the following statements: *"The documentation included detailed work plans, credible schedules and budget estimates and well-motivated physics justifications and notes that front-loading of resources would alleviate potential pressure on the schedule. … The TDRs have been vetted through extensive CMS internal processes to review the design, cost estimates and funding considerations. … The LHCC endorses the HCAL and Pixel upgrades without reservations".*

A third TDR is in preparation for the L1-Trigger Upgrade, and will be submitted to the LHCC in early 2013.

Along with the successful R&D and design work described in the TDRs, we have now refined and updated the Pixels and HCAL cost estimates, which have been reviewed by CMS. We have also updated and reviewed the estimates for the Common Items. Table 1 summarizes the new estimates for Phase I. The costs include material and installation only, and do not include R&D, or any contingency. The total cost has risen 3% from 64,447 kCHF [cf. CERN-RRB-2012-031] to 66'620 kCHF, with the change largely attributed to updated estimates arising from a more advanced level of design in the TDRs.

Table 1: Upgrade Phase I Costs (kCHF)

Subsystem/Common Item	Budget (kCHF)	
	Revised	Original
Pixel Tracker	17,100	17,350
HCAL	8,044	5,817
HF - Phototubes	1,990	1,990
Muon CSC	5,570	5,570
Muon DT	2,200	2,200
Muon RPC	4,220	4,220
DAQ	6,700	6,700
Trigger	4,600	4,600
Common Items	16,196	16,000
Magnet power and cryo	1,567	1,330
Beam Instrumentation	1,672	1,540
Infrastructure	5,423	6,315
Test Beam Facilities Upgrade	620	610
Safety systems upgrade	540	964
Electronics Integration	1,780	1,575
Engineering Integration	4,594	3,666
Grand Total	66,620	64,447

In order to meet the schedules presented in the TDRs, driven by the anticipated performance evolution of the LHC, the projects must proceed to procurement and initial fabrication in 2013.

Following the approval of the Pixel and HCAL TDRs, CMS is now ready to proceed with the implementation of these projects. A summary of the financial plan for these is shown in tables 2.1 – 2.4 (for the Pixel Upgrade) and tables 3.1 – 3.4 (for the HCAL Upgrade).

Table 2.1: Cost estimate for the Phase I Pixel Detector Upgrade Project (as presented in the TDR)

Costs are for materials and services only, without contingency

Area	Item	Cost (kCHF)
FPIX	Detectors (incl. Bumpbonding)	2,224
	Module Electronics	276
	Module Mechanics	424
	Service Cylinder	221
	Module Production, Testing, Integration	222
FPIX Total		3,368
BPIX	Detectors (incl. Bumpbonding)	4,892
	Module Electronics	764
	Module Mechanics	314
	Supply Tube	704
	Module Production, Testing, Integration	555
BPIX Total		7,229
CSI	Cooling System	1,030
	Power System	1,110
	Readout Electronics and Data Links	2,415
	DAQ	900
	Interlocks & Monitoring	105
	Commissioning hw @TIF	616
	Installation @P5	147
	Transportation	180
CSI Total		6,503
Grand Total		17,100

Table 2.2: The desired cost profile for the Phase I Pixel Detector Upgrade Project (based on the schedule presented in the TDR)

Year	Annual Funding (kCHF)
2011	355
2012	1,581
2013	4,205
2014	4,996
2015	5,021
2016	942
TOTAL	17,100

Table 2.3: Main cost drivers for the Pixel Detector Upgrade Project in 2013

Item	Cost (kCHF)
FPIX	
Prototypes (bumpbonding qualification)	200
Module Production, Testing, Integration	83
BPIX	
Sensor production	311
Sensor prototypes (bumpbonding qualification)	100
Module Electronics	717
Supply Tube	80
CSI	
Cooling System	819
Power System	201
Readout Electronics and Data Links	1,404
DAQ	92
Interlocks and Monitoring	73
TOTAL	4,080

Table 2.4: Tentative Cost Sharing by Funding Agency for the Pixel Detector Upgrade Project

(Under discussion with the concerned Funding Agencies)

Funding Agency	Share of Cost (kCHF)
Austria	29
CERN	2,821
Finland	413
France - IN2P3	598
Germany-BMBF	1,624
Germany-DESY	1,223
Italy	963
Switzerland	3,638
Taipei	991
United Kingdom	904
USA	3,896
TOTAL	17,100

Table 3.1: Cost estimate for the Phase I HCAL Detector Upgrade Project (as presented in the TDR)

Costs are for materials and services only, without contingency

HF			HB/HE			Subtotals
Back-end		280	Back-end		975	1,255
	uHTR	186		uHTR	557	
	AMC13	41		AMC13	71	
	Crates	53		Crates	148	
				Optical Splitters	198	
Front-end		1,100	Front-end		4,965	6,065
	Cables	320		SiPM	1,548	
	QIE Cards	639		ODU+Control	709	
	Crates	28		QIE Cards	2,017	
	Calibration	17		Calibration	90	
	Low voltage	33		Mechanics	173	
	Fiber cables	65		Low voltage	306	
				Burn-in Station	120	
Controls		59	Controls		301	360
	ngCCM	25		ngCCM	136	
	ngFEC	35		ngFEC	165	
Installation Labor			Installation Labor			
	Front-end	64		Front-end	300	364
Total (all costs in kCHF)						8,044

Table 3.2: The desired cost profile for the Phase I HCAL Detector Upgrade Project (based on the schedule presented in the TDR)

Year	Annual Funding (kCHF)
2013	791
2014	1,851
2015	1,892
2016	2,425
2017	785
2018	300
TOTAL	8,044

Table 3.3: Main cost drivers for the HCAL Detector Upgrade Project in 2013

Item	Cost (kCHF)
HF Front-end: Cables and connectors	410
uTCA Crates	32
HF Back-end: Electronics uHTR	186
HF Back-end: Electronics AMC13	41
Controls Electronics	123
TOTAL	792

Table 3.4: Tentative Cost Sharing by Funding Agency for the HCAL Detector Upgrade Project (Under discussion with the concerned Funding Agencies)

Funding Agency	Share of Cost (kCHF)
Brazil	331
Germany-DESY	80
India	528
RDMS-DMS	468
RDMS-Russia	704
Turkey	307
USA	5,627
TOTAL	8,045

With the urgent need to carry out specific work during Long Shutdown 1 (LS1), due to start in March 2013, and to ramp up the time-critical work described in the Pixel and HCAL TDRs, we expect to initiate critical purchases by early 2013. This includes preparatory work for the L1-Trigger upgrade to provide parallel inputs allowing the new trigger to be developed and commissioned concurrent with operations. This amounts to 500 kCHF. The LHCC has expressed strong support for this as noted earlier and made a specific statement to this effect: *"The LHCC endorses the CMS program of work for Long Shutdown 1 (LS1)."*

As proposed at the April 2012 RRB Meeting, once the Construction MoU is extended, dedicated Addenda would be elaborated for these two projects. These would define in detail the financial obligations of participating Funding Agencies who would be requested to confirm their commitment by signing these Addenda.

Discussions are progressing with Funding Agencies to finalize a global Cost-sharing Matrix for the Phase I Upgrade (Table 4). The target is to obtain commitments from each Funding Agency equal or higher with respect to those corresponding to their fraction of

PhDs in CMS. CMS appreciates the efforts of Funding Agencies to provide information concerning their commitments, thus allowing the completion of the Upgrade Cost-sharing Matrix. We appeal to those who have not yet done so to provide these figures as soon as their national budgetary approval process allows.

The present state of contributions already provided, commitments already declared or strong intentions already expressed by Funding Agencies shows that there is a close matching with the needs for Subsystem-specific Upgrades. The execution of these projects will be the responsibility of the respective Subsystem Management and the participating Funding Agencies.

When the Upgrade Phase I Project was launched its financing was agreed to be a common responsibility of the Funding Agencies comprising the CMS Collaboration with the overall sharing of costs based on the principle of equity as defined by the proportionate PhD share of each Funding Agency. Efforts are made to take into account the interests of each Funding Agency and where it would prefer to allocate its resources.

In parallel, CMS must ensure that all areas of the Project are fully covered and in particular the Common Items. As shown in Table 4, commitments in this area are insufficient. In order to resolve this, discussions are ongoing with Funding Agencies to redistribute funds from areas that already have sufficient funding and to provide targeted contributions where there is a clear need. The equitable sharing of costs described above assures that the full cost of the Phase I project will be covered when all funding agencies have participated.

Only if efforts to allocate resources to underfunded areas prove inadequate would other means of obtaining this funding be proposed to the Collaboration. At present, there is no indication that this will be necessary.

Table 4: Cost-sharing Matrix for Upgrade Phase I

25.10.2012		Subdetector-specific Upgrades						Detector-wide items										
								TDAQ		Common Items								
Institute FA	PhD %	Pixel Tracker	HCAL	HF - Phototubes	Muon CSC	Muon DT	Muon RPC	DAQ	Trigger	Magnet power and Cryo	Beam Instrumentation	Infrastructure	Test Beam Facilities	Safety Systems	Electronics Integration	Engineering Integration	Total expected (projects)	Common Fund (CF)	Total Upgrade Due (incl. CF)
		17,100,000	8,044,000	1,990,000	5,570,000	2,200,000	4,220,000	6,700,000	4,600,000	1,567,000	1,672,000	5,423,000	620,000	540,000	1,780,000	4,594,000			
Common Fund										535,741	620,331	2,543,761	245,716	388,311	634,430	1,476,711		6,445,000	
Austria	1.6%	29,000							1,200,000								1,229,000	102,154	1,055,937
Belgium-FNRS	1.2%						236,000										236,000	74,294	767,954
Belgium-FWO	1.2%						379,000										379,000	74,294	767,954
Brazil	1.2%		331,000														331,000	78,937	815,951
Bulgaria	0.6%																0	37,147	383,977
CERN	5.8%	2,821,000					500,000	3,500,000			500,000	1,500,000		500,000		1,000,000	10,321,000	371,470	3,839,769
China	0.7%				200,000		500,000										700,000	46,434	479,971
Colombia	0.2%						10,000										10,000	13,930	143,991
Croatia	0.5%							200,000									200,000	32,504	335,980
Cyprus	0.4%								11,500								11,500	23,217	239,986
Egypt	0.2%						150,000										150,000	13,930	143,991
Estonia	0.3%					167,153											167,153	18,573	191,988
Finland	1.0%	413,000					130,000						35,000				578,000	65,007	671,960
France-CEA	1.1%																0	69,651	719,957
France-IN2P3	3.8%	598,000						350,000	600,000				100,000		100,000		1,748,000	246,099	2,543,847
Germany-BMBF	4.5%	1,624,000				612,000											2,236,000	287,889	2,975,821
Germany-DESY	2.8%	1,223,000	80,000								240,000						1,543,000	181,091	1,871,888
Greece	1.1%								1,000,000								1,000,000	69,651	719,957
Hungary	0.7%																0	46,434	479,971
India	2.1%		528,000				720,000										1,248,000	134,658	1,391,916
Iran	0.4%																0	27,860	287,983
Ireland	0.0%															16,000	16,000	0	0
Italy	12.5%	963,000				1,000,000	350,000					600,000					2,913,000	803,303	8,303,501
Korea	1.5%						540,000										540,000	97,511	1,007,939
Mexico	0.8%																0	51,077	527,968
New Zealand	0.1%																0	9,287	95,994
Pakistan	0.1%						385,000					800,000					1,185,000	9,287	95,994
Poland	1.1%																0	69,651	719,957
Portugal	0.5%								500,000								500,000	32,504	335,980
RDMS - DMS	1.5%		468,000		500,000												968,000	97,511	1,007,939
RDMS - Russia	4.4%		704,000		1,300,000												2,004,000	283,246	2,927,824
Serbia	0.2%																0	13,930	143,991
Spain	3.5%					400,000											400,000	227,525	2,351,859
Switzerland (ETHZ,PSI,UNIV)*	2.7%	3,638,000															3,638,000	176,448	1,823,889
Taipei	1.1%	991,000															991,000	69,651	719,957
Turkey	1.3%		307,000														307,000	83,581	863,948
United Kingdom	4.0%	904,000						250,000	1,500,000			126,000			126,000		2,906,000	260,029	2,687,839
USA (DOE-HEP, NSF)	31.7%	3,896,000	5,627,000	2,000,000	5,570,000			700,000	3,000,000								20,793,000	2,046,032	21,149,206
USA (DOE-NP)	1.6%																0	102,302	1,057,460
Grand Total	100.0%	17,100,000	8,045,000	2,000,000	7,570,000	2,179,153	3,900,000	5,000,000	7,811,500	535,741	1,360,331	5,569,761	380,716	888,311	860,430	2,492,711	59,248,653	6,445,000	66,620,000

The figures presented in this table are a combination of funding situations ranging from assumed/estimated contributions and requests for funds to firm pledges

Common Upgrade Items, especially those foreseen for implementation in LS1, are critical to the success of the whole of Phase I. These will be financed either by direct contributions from Funding Agencies, or from the Upgrades Common Fund (CF), proposed at the October 2010 RRB Meeting. The Common Fund of 6'445 kCHF was established to cover Common Items for which there are no direct contributions from Funding Agencies. It is composed of cash payments from each Funding Agency according to their fraction of PhDs and covers some 40% of the total costs of Common Items.

Since the April 2011 RRB, about 60% of the Funding Agencies have paid or are in the process of paying their contribution to the Common Fund. CMS expects the process of establishing a schedule for all Funding Agencies to make payments into the Common Fund to be finalized in the course of 2013. This will enable CMS to maintain progress with the LS1 program of work, as many items must be purchased ahead of the LS1 start date. The Cost Profile for the Common Items is defined in Table 5.

Table 5: Cost Profile for Common Items

Draft Common projects cost profile 2010-2018										
23 August 2012 AB	All amounts in kCHF									
ITEM		Upgrade Project Totals	Profile							
			2011	2012	2013	2014	2015	2016	2017	2018
Magnet power and cryo		1,567	247	630	330	65	0	270	0	25
Beam Instrumentation		1,672	0	405	555	329	5	0	205	173
Infrastructure		5,423	975	2,243	780	285	324	373	300	143
Test beam facilities upgrade		620	0	90	300	165	65	0	0	0
Safety systems upgrade		540	0	132	318	90	0	0	0	0
Electronics Integration		1,780	0	55	557	557	15	87	67	442
Engineering Integration		4,594	0	150	1,158	1,159	150	428	275	1,274
		0								
	Totals	16,196	1,222	3,705	3,998	2,650	559	1,158	847	2,057

We greatly appreciate the support of Funding Agencies for the Upgrade Project. Special thanks are extended to those Funding Agencies who have already made cash contributions to the Upgrades Common Fund.