

## Financial Plan for CMS Upgrade

In the last RRB meeting of October 2012 CMS reported progress on the preparation and execution of work described in the Technical Proposal for the Upgrades approved by 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  $2 \times 10^{34} \text{cm}^{-2} \text{s}^{-1}$  (Phase I of the Upgrades).

CMS also presented the Technical Design Reports (TDRs) for two major Upgrade projects included in the aforementioned Technical Proposal that will be completed in the period from now through the end of Long Shutdown 2 (LS2): the Pixel Detector Upgrade [CERN-LHCC-2012-016] and the HCAL Detector Upgrade [CERN-LHCC-2012-015]. These TDRs were fully endorsed by the LHCC with a clear indication that their physics case is highly compelling. A third TDR is in preparation for the L1-Trigger Upgrade, for which the internal review is in process and the TDR is expected to be submitted to the LHCC by June 2013.

Phase II of the Upgrades will allow CMS to operate at the high luminosity expected after 2023 (with luminosity leveling at  $5 \times 10^{34} \text{cm}^{-2} \text{s}^{-1}$ ). 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 some additional costs, incurred by Funding Agencies, concurrent with support for Phase I.

CMS is currently in the process of carrying out an in-depth study of the eventual costs and likely schedule of the Phase II Upgrade. The cost analysis takes into account the various possible technical and scope scenarios. A full cost estimate will be included in a Technical Proposal for Phase II, anticipated in 2014.

The cost estimates as well as the foreseen spending profiles for the Pixel and HCAL Upgrades, including the main cost drivers in 2013, were presented to the October 2012 RRB. Since then both projects have undergone a thorough internal review. If there are significant updates or revisions of these costs they will be presented to the October 2013 RRB.

The latest cost estimate of the Muon-CSC Upgrade is higher than that of 5'570 kCHF presented previously to the RRB and which was the initial cost estimate from the Technical Proposal of 2010. The current estimate of the total cost of the Muon-CSC Upgrade amounts to 6'844 kCHF.

The additional costs are incurred mainly due to the recuperation of the Cathode Front-End Boards (CFEB) and Low Voltage Distribution Boards (LVDB) electronics from the Muon Endcap ME1/1 and the necessary infrastructure work, which is primarily mechanical work being done by RDMS-DMS. There were also unforeseen expenditures caused by a delay of the chamber production due to panel vendor non-performance in 2011. The additional costs are fully funded by the Funding Agencies involved in the CSC Upgrade (China, RDMS-DMS, RDMS-Russia, USA-DoE and USA-NSF).

The overall CSC Upgrade budget and in particular the cost-change were thoroughly scrutinized via an internal review process. The conclusion was that the expenditure plan is fully justified and that the project is in sound financial shape.

Another change has taken place in the cost of the HCAL Upgrade project, which has increased from 8'044 kCHF (in October 2012) to 8'220 kCHF. This increase is related to the inclusion of the dual-anode boards that were not taken into account in the previous estimate (45 kCHF contribution from the USA) and the addition of pre-production SiPMs (130 kCHF contribution from RDMS-Russia).

As a consequence of the above-mentioned changes the total cost of the Upgrades Phase I Project has risen by 2% from 66'620 kCHF presented to the October 2012 RRB [CERN-RRB-2012-100/Rev.] to 68'070 kCHF. The modified figures are presented in Table 1.

**Table 1: Upgrade Phase I Costs (kCHF)**

Subsystem/Common Item	Budget (kCHF)	
	October 2012 RRB	April 2013 RRB
<b>Pixel Tracker</b>	<b>17,100</b>	<b>17,100</b>
<b>HCAL</b>	<b>8,044</b>	<b>8,219</b>
<b>HF - Phototubes</b>	<b>1,990</b>	<b>1,990</b>
<b>Muon CSC</b>	<b>5,570</b>	<b>6,844</b>
<b>Muon DT</b>	<b>2,200</b>	<b>2,200</b>
<b>Muon RPC</b>	<b>4,220</b>	<b>4,220</b>
<b>DAQ</b>	<b>6,700</b>	<b>6,700</b>
<b>Trigger</b>	<b>4,600</b>	<b>4,600</b>
<b>Common Items</b>	<b>16,196</b>	<b>16,196</b>
Magnet power and cryo	1,567	1,567
Beam Instrumentation	1,672	1,672
Infrastructure	5,423	5,423
Test Beam Facilities Upgrade	620	620
Safety systems upgrade	540	540
Electronics Integration	1,780	1,780
Engineering Integration	4,594	4,594
<b>Grand Total</b>	<b>66,620</b>	<b>68,070</b>
<b>Common Fund</b>	<b>6,445</b>	<b>6,445</b>

Following the approval of the Pixel and HCAL TDRs, both projects are now proceeding with engineering reviews prior to procurements and initial fabrication in order to ensure adherence with defined schedules and carry out necessary work during Long Shutdown 1 (LS1). The expenditures made in 2013 will be reported at the April 2014 RRB.

The Muon Subdetector Upgrade projects are expected to be largely completed during LS1 with the exception of the Muon DTs.

Discussions with Funding Agencies are proceeding in order to finalize the global Cost-sharing Matrix for the Phase I Upgrade (Table 2). The target is to obtain commitments from each Funding Agency at a level that is at least equal to their corresponding fraction of PhDs in CMS (in 2010). CMS appreciates the efforts of Funding Agencies to provide

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information concerning their commitments. We appeal to those who have not yet done so to provide these figures as soon as their national budgetary considerations allow.

The present state of contributions already provided, commitments already declared, or strong intentions already expressed by Funding Agencies give relatively solid assurance of sufficient funding for Subsystem-specific Upgrades. The execution of these projects will be the responsibility of the respective Subsystem Management and the participating Funding Agencies.

However, as signaled at the October 2012 RRB and during previous RRB meetings, there is still a need to ensure the funding to cover upgrade Common Items to ensure conditions for carrying out the Sub-detector Upgrades.

As shown in Table 3, many of the Common Item areas remain unfunded and only a relatively small number of Funding Agencies have made contributions or committed to the financing of specific items in this area. Furthermore, the Upgrades Common Fund (which covers only some 40% of the common costs) is still missing some commitments. Consequently, CMS appeals to the Funding Agencies that have not yet committed contributions in line with the principle of equity defined by the PhD count, to do so or to find ways in which they could provide help in ensuring that Common Items work can proceed on schedule.

As agreed at the October 2012 RRB Meeting, following the extension of the Construction MoU, dedicated Addenda have been elaborated for the Pixel and HCAL projects. These define the financial obligations of participating Funding Agencies, which will be requested to confirm their commitment by signing these Addenda.

A third Addendum has been prepared which defines the responsibility of Funding Agencies for the Upgrade Common Items and specifies in detail the Common Fund contribution. This Addendum is now being transmitted to Funding Agencies for signature.

Table 2: Cost-sharing Matrix for Upgrade Phase I

Total Phase I Upgrade budget 68'070 kCHF

Upgrade Common Fund (CF) 6'445 kCHF

Based on PhD Scientists per Funding Agency

in kCHF

03.04.2013

Funding Agency	Subdetector-specific Upgrades								Detector-wide items								Total expected (without CF)	Common Fund (CF)	Original Total Upgrade FA Target (incl. CF)
	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				
<b>Total Upgrade: 68'070</b>	17,100	8,220	1,990	6,844	2,200	4,220	6,700	4,600	1,567	1,672	5,423	620	540	1,780	4,594				
<b>Common Fund</b>									536	620	2,544	246	388	634	1,477		<b>6,445</b>		
Austria	29							1,200									1,229	102	1,021
Belgium-FNRS						236											236	74	743
Belgium-FWO						379											379	74	743
Brazil		331															331	79	789
Bulgaria																		37	371
CERN	3,000					500	3,500			500	1,500		500		1,000	10,500	371	3,715	
China				200		500										700	46	464	
Colombia						10										10	14	139	
Croatia							200									200	33	325	
Cyprus								12								12	23	232	
Egypt						150										150	14	139	
Estonia					167											167	19	186	
Finland	418					130						35				583	65	650	
France-CEA																	70	696	
France-IN2P3	904						150	500				100		100		1,754	246	2,461	
Germany-BMBF	1,624				612						407					2,643	288	2,879	
Germany-DESY	1,224	80								240						1,544	181	1,811	
Greece								1,000								1,000	70	696	
Hungary	15																46	464	
India		528				720										1,248	135	1,347	
Iran																	28	279	
Ireland														16		16			
Italy	963				1,000	350					600					2,913	803	8,033	
Korea						545										545	98	975	
Mexico																	51	511	
New Zealand																	9	93	
Pakistan						385					800					1,185	9	93	
Poland																	70	696	
Portugal								500								500	33	325	
RDMS - DMS		468		500												968	98	975	
RDMS - Russia		834		690												1,524	283	2,832	
Serbia																	14	139	
Spain					400											400	228	2,275	
Switzerland (ETHZ,PSI,UNIV)*	3,638															3,638	176	1,764	
Taipei	1,000															1,000	70	696	
Turkey		307														307	84	836	
United Kingdom							250	1,500			126			126		2,002	260	2,600	
USA (DOE-HEP, NSF)	3,896	5,672	2,000	5,454			700	3,000								20,722	2,046	20,459	
USA (DOE-NP)																	102	1,023	
<b>Total committed</b>	<b>16,710</b>	<b>8,220</b>	<b>2,000</b>	<b>6,844</b>	<b>2,179</b>	<b>3,905</b>	<b>4,800</b>	<b>7,712</b>	<b>536</b>	<b>1,360</b>	<b>5,977</b>	<b>381</b>	<b>888</b>	<b>860</b>	<b>2,493</b>	<b>58,405</b>	<b>6,445</b>		

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

The vast majority of these common costs will be incurred during LS1 and especially in the course of 2013. They are critical to the success of the Phase I Upgrade program. This is demonstrated in Table 3. The cost profile shown in this table has evolved since it was

presented to October RRB meeting. After full detailed planning for work in LS1 many items foreseen for payments in 2012 are now anticipated for 2013, and some in later years according to our current schedule. The current spending profile for Common Items is expected to remain relatively stable.

Table 3: Cost Profile for Common Items

<b>Common Upgrade Items Cost Profile 2011-2018</b>									
11-Mar-13		All amounts in kCHF							
ITEM	Upgrade Project Totals	Profile							
		2011	2012	2013	2014	2015	2016	2017	2018
Magnet power and cryo	1,567	247	65	895	65	0	270	0	25
Beam Instrumentation	1,672	0	315	555	329	5	0	205	173
Infrastructure	5,423	975	875	1,985	378	394	373	300	143
Test beam facilities upgrade	620	0	90	300	165	65	0	0	0
Safety systems upgrade	540	0	17	458	90	0	0	0	0
Electronics Integration	1,780	0	55	557	587	15	87	67	442
Engineering Integration	4,594	0	150	1,264	1,225	150	428	275	1,274
<b>Totals</b>	<b>16,196</b>	<b>1,222</b>	<b>1,567</b>	<b>6,014</b>	<b>2,839</b>	<b>629</b>	<b>1,158</b>	<b>847</b>	<b>2,057</b>

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