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Chapter 1

Introduction

This document sets out the organisation, cost estimate and time schedule of the ALICE Muon Chambers (MCH) Detector, Muon Identifier Detector (MID), the Fast Interaction Trigger Detector (FIT) Upgrade, the common read-out ASIC SAMPA and the common read-out (CRU) Projects as described in the TDR (CERN-LHCC-2013-019, April 15, 2014).

Within the ALICE upgrade program two common hardware developments are pursued. The SAMPA detector read-out ASIC will be used by the MCH and the Time Projection Chamber (TPC). The common read-out unit (CRU) is a hardware read-out platform which will be used by TPC, MCH, MID, Inner Tracking System (ITS), Zero Degree Calorimeter (ZDC) and Transition radiation detector (TRD).

Chapter 1 describes the MCH, chapter 2 the MID, chapter 3 the SAMPA ASIC, chapter 4 the CRU and chapter 5 the FIT. All chapters are organised in a similar manner where section 1 lists the participating institutes and shows the organisational chart for the management of the corresponding Upgrade Project. Section 2 provides explanations and justifications of cost estimates for the main cost items. The work breakdown structure (WBS) of the Upgrade projects is explained in detail in section 3, starting with an overview of all cost items and a responsibility chart for the allocation of funding. Then, for each level 1 cost item, details of the cost estimates are given in summary tables together with explanations of the underlying basis for estimates. Section 4 describes the resource loaded schedule and section 5 deals with the manpower requirements necessary for the execution of the corresponding upgrade projects. An evaluation of the most relevant project risks is given in section 6.

Chapter 2

Muon Chambers - MCH

2.1 Project Organisation

The Muon Project Leader (PL) heads the MCH Project. He is assisted by the MCH Sub-project Leader (SL) and the MCH Upgrade Coordinator (UC). The PL, SPL and UC are all members of the ALICE Technical Board and thus can assure the coherence of this project within the ALICE experiment in general. Issues of a financial, managerial and organizational nature are discussed and decided by the Muon Institutional Board. This board also endorses technical matters proposed by the PL, SL or UC. The Project Leader, Sub-project leader and Upgrade Coordinator are ex-officio members of the Institutional Board. The Institutes participating in the MCH Upgrade Project, are listed in Tab. 2.1.

As shown in Fig. 2.1, the MCH Upgrade Project is organised into 5 Work Packages.

2.2 Budget Explanation and Justification

This chapter addresses important design choices and their possible impact on the project cost and schedule. In order to minimise the overall upgrade effort on development and cost, the MCH upgrade design reuses the existing chamber design including the infrastructure such as data transmission via printed circuit boards,

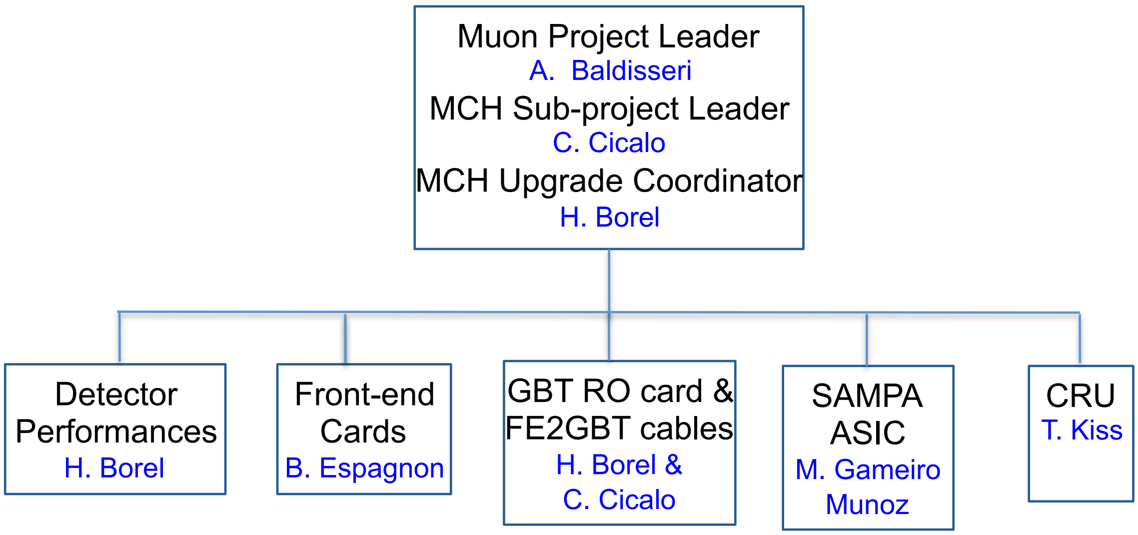


Figure 2.1: The MCH Upgrade Coordination flow chart.

Country	City	Institute
Brazil	São Paulo	UNICAMP, Universidade Estadual de Campinas
Brazil	São Paulo	IFUSP, Instituto de Física, Universidade de São Paulo
Brazil	São Paulo	EPUSP, Escola Politécnica, Universidade de São Paulo
France	Orsay	IPNO, Institut de Physique Nucléaire d'Orsay, IN2P3/CNRS
France	Saclay	SPhN, Service de Physique Nucléaire, CEA-IRFU Saclay
Hungaria	Budapest	Wigner Research Centre for Physics, Institute for Particle Nuclear Physics
India	Kolkata	VECC, Variable Energy Cyclotron Center, Department of Atomic Energy
India	Kolkata	SAHA Institute of Nuclear Physics
India	Kolkata	Bose Institute
India	Aligarh	Aligarh Muslim University
India	Mumbai	Bhabha Atomic Research Centre
Italy	Cagliari	INFN and Università degli Studi di Cagliari

Table 2.1: Institutes participating in the MCH Upgrade Project.

cooling, mechanics and power supply systems. These considerations have been taken into account for the front-end electronics data interface, power consumption and the on-detector read-out architecture. As a result the front-end cards are designed to be compatible with the existing chamber connectors and layout. The MCH read-out architecture follows the ALICE common approach shared with a majority of upgraded detectors.

2.2.1 Front-end cards & SAMPA

The presently used front-end ASIC is inappropriate for the upgrade operation conditions due to the increased interaction rate. The same situation applies for the ALICE TPC front-end electronics. In order to reduce the overall effort, the MCH and TPC projects develop a common read-out ASIC, called SAMPA. The differences in specifications, such as the different signal polarity and dynamic range are taken into account by the implementation of programmable parameters in the ASIC. For the MCH application the SAMPA specifications on noise or data bandwidth provide a comfortable margin. Chapter 3 deals with the SAMPA project in detail.
Each Front-End card (FEC) will host 2 SAMPA ASICS. The FEC design and prototyping will be done in laboratory while the production in industry, including some basic tests.

2.2.2 E-link & GBT Read-out card

The standardised front-end links use the versatile link and GBT components. This electrical and optical, radiation tolerant serial transmission link set is developed by the CERN Electronics Design Group. The design and prototyping of link and GBT cards will be done in laboratory while the production in industry, including some basic tests.

2.2.3 Common Read-out Unit

The MCH detector upgrade design has adopted the ALICE common read-out architecture, which uses standard front-end links and the ALICE common read-out unit

(CRU) to concentrate the data and provide a connection to the ALICE standard link to the online systems (DDL3) and to the standardised timing and trigger distribution link (TTS). The standard front-end links use the versatile link and GBT components. This approach reduces the overall development by benefiting from centralised versatile link component developments and the development of the common read-out unit used by a large number of upgraded ALICE detectors.

2.2.4 System tests

The whole chain of data transmission and components configuration will be tested by MCH upgrade collaboration in laboratory as soon as the different components will be available. These tests will occur in different steps: tests of prototypes of SAMPA ASIC and FEC on a dedicated test bench developed by MCH laboratories, tests of final SAMPA and FEC on final test bench (developed by laboratories), tests from FEC to GBT included, then adding CRU and CTP (Triggers). A complete test with detector and the whole electronic, read-out chain will be then tested.

2.2.5 Installation & commissioning

The final installation in the ALICE cavern will start at the beginning of Long Shutdown 2 (mid-2018). The installation will consist in dismounting the detectors (slats and quadrants), fixing the links, plugging FEC and GBT cards, mounting the detectors and start testing. The commissioning of MCH will be done along with the installation, followed by the commissioning of the complete MCH. Installation and commissioning will be realized by all participating MCH laboratories, as it was already done for the installation, commissioning, repairing of MCH chambers (as an example, the dismounting , repairing in cavern, mounting of the 140 slats was achieved during LS1 in 6 months by succeeding teams of 3 people).

In the overwhole work on MCH upgrade, except for production in industry, no outsourced manpower is foreseen.

Activity	MaterialCost (kCHF)	TotalCost/item (CHF)
1. Front-end cards	**745**	**39**
1.1. Design & Prototyping	*	
1.2. Qualification	10	
1.3. Production	690	36
1.4. Tests	45	
2. SAMPA ASIC	**1178**	**31**
3. GBT Read-out Cards	**271**	**470**
3.1. Design & Prototyping	*	
3.2. Qualification	10	
3.3. Production	241	420
3.3.1 GBTx	35	60
3.3.2 VTRx	115	200
3.3.3 SCA	6	10
3.3.4 PCB	85	150
3.4.Tests	20	
4. FE2GBT cable (E-link)	**285**	**15**
4.1. Design & Prototyping	*	
4.2. Qualification	10	
4.3. Production	265	14
4.4. Tests	10	
5. Optical fibers	**172**	**300**
5.1. Production & installation	172	300
6. CRU inputs	**182**	**316**

Table 2.2: CORE cost breakdown structure of the ALICE MCH upgrade (* R&D not included)

2.3 Cost Chart

Table 2.2 shows the Work Breakdown Structure (WBS) chart for MCH Upgrade Project. The tasks of the WBS have been broken down in 6 level 1 subgroups referring to either main detector subcomponents or to the most essential parts and services foreseen to be installed in the MCH.

Cost estimates are provided for each level 1 task and are understood as to be CORE costs, including detector components and production costs (as well as industrial or outsourced manpower for production if any), but not costs for personnel and basic infrastructures of the participating institutes. All estimates based on offers or quotes in foreign currency have been converted into Swiss francs using the exchange rates of February 2014 (cf. Table 2.3).

Table 2.3: Exchange rates used in the cost estimates.

1 EUR	1.23 CHF
1 USD	0.9 CHF

Year	2014	2015	2016	2017	2018	2019	Total
Spending [kCHF]	24	223	710	704	0	0	1661
Spending [kCHF]	401	397	1338	704	0	0	2839

Table 2.4: Expected spending profile for the ALICE MCH upgrade, without (and with) SAMPA and CRU in the first line (second line).

More detailed information on the cost estimate for the level 1 and 2 items are given in the following sections. The expected spending profile, based on the detailed cost estimates and the project planning, is shown in Tab. 2.4. No explicit contingency has been mentionned. The funding agencies are aware to preserve it. Table 2.5 shows the cost breakdown structure together with the expected funding contributions.

2.3.1 Front-end cards

The price estimation is based on the production price of the present front-end card (MANU)). Table 2.6 shows the required quantities of front-end cards in the different MCH stations.

2.3.2 GBT read-out cards

The price estimation is based on the current prices of the existing components (GBTx: 60 CHF, VTRx: 200 CHF, SCA: 10 CHF) and on the PCB estimated price

Activity	Country/Inst	Financing (kCHF)
1. Front-end cards	France/IPN Orsay	745
2. SAMPA ASIC	Brazil/	1178
3. GBT Read-out Cards	France/CEA Saclay	271
4. FE2GBT cable	Italy/INFN Cagliari	285
5. Optical fibers	[India/SAHA + Aligarh]:[France/CEA Saclay]	[86]:[86]
6. CRU inputs	India/SAHA + Aligarh	182

Table 2.5: Cost breakdown structure of the ALICE MCH upgrade, including expected funding from the different contributors.

	#FEC	x% Spares	Total
Station 1	3600	15	4140
Station 2	3500	15	4025
Station 3	2460	15	2830
Station 4	3400	15	3910
Station 5	3740	15	4300
Total	16500	15	19000

Table 2.6: Quantities of Front-end cards needed for the different detector parts.

	#ROC	x% Spares	Total
Station 1	115	15	132
Station 2	115	15	132
Station 3	80	15	92
Station 4	80	15	92
Station 5	110	15	127
Total	500	15	575

Table 2.7: Quantities of GBT read-out cards needed for the different detector parts.

(150 CHF). Table 2.7 shows the required quantities of GBT cards in the different MCH stations.

2.3.3 Front-end cables (FE2GBT)

The choice of the material of the link between the FEC and the GBT card is not yet fixed; the main option is to use kapton skin in which signal lines are embedded. The price estimation of 15 CHF/piece is based on this option.

2.3.4 SAMPA

Chapter 3 deals in detail with the SAMPA project. The cost estimate for the SAMPA is based on 56000 SAMPA needed for MCH and TPC. Section **??** details this cost estimate for the SAMPA ASIC manufacturing, packaging and testing.
The number of ASICs needed for MCH is 33000 plus 15% spares for a total of 38000 ASICs. Table 2.8 gives an overview of the quantity of chips needed for the MCH stations.

	#SAMPA	x% Spares	Total
Station 1	7200	15	8280
Station 2	7000	15	8050
Station 3	4920	15	5660
Station 4	6800	15	7820
Station 5	7480	15	8600
Total	33000	15	38000

Table 2.8: Quantities of SAMPA ASICs needed for the different detector parts.

2.3.5 Common read-out unit

Each GBT card is linked through an optical fiber to an input of a CRU. The number of CRU inputs is therefore the number of GBT cards, 575 (500 + 15 % spare). Each CRU can have 24 inputs resulting in a total of 25 CRU. The price per CRU input has been evaluated for the baseline solution using AMC40 components and is detailed in chapter 4.

2.3.6 Optical fibers

The cost includes the present price of optical fibers and the installation cost (from present setup). The installation of the optical fibers between the cavern and the upstairs control room will occur during Long Shutdown 2.

2.3.7 Power Distribution and Cooling

The cooling system was designed to dissipate the heat produced by electronics and to keep all the stations in a stable environment. The present heat dissipation of the electronics amounts to 2.5 kW in station 1, 2.5 kW in station 2, 1.6 kW in station 3, 2.4 kW in station 4 and 2.7 kW in station 5, corresponding to a power consumption of the front-end card of less than 15 mW per channel.
Air cooling was chosen with different solutions for stations 1 and 2, with their specific closed environment and quadrant design, for station 3 located in the dipole, and for stations 4 and 5 placed in an open environment. We will keep this cooling

infrastructure.

Concerning the present low voltage power supply, twenty-eight WIENER PL500/F12 power supplies are used to deliver low voltages to the detectors. Each power supply consists in 12 independent channels which are presentely gathered in groups of three voltages (- 2.5, 2.5 and 3.3 V) needed for the electronics. These power supplies will be reused for the upgraded electronics, with a rearrangement of the mapping.

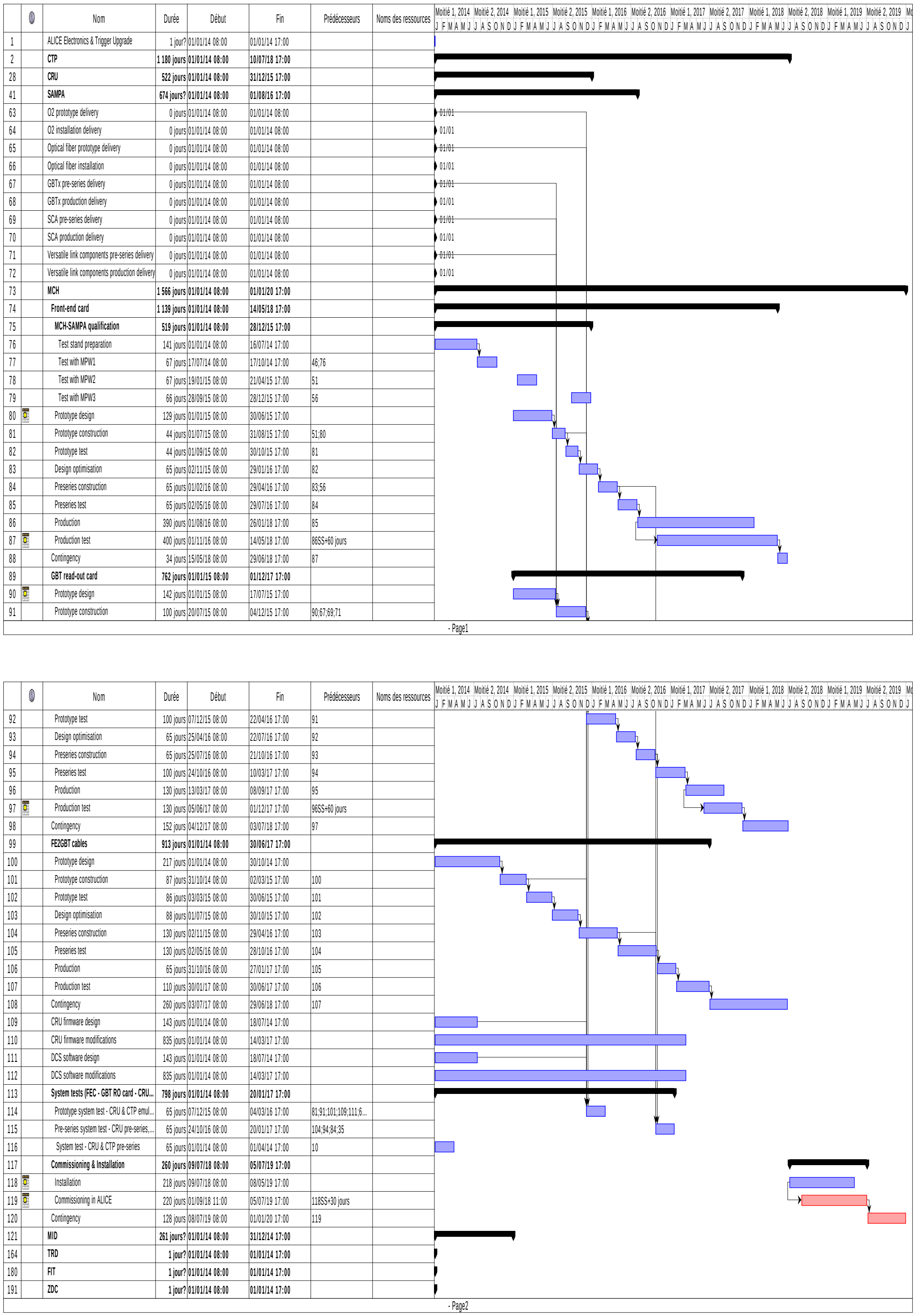
2.3.8 Detector Control System

The Detector Control System (DCS) is used to power and control the low and high voltage power supplies (the latter will be identical and with the same mapping than presentely) and to monitor the gas flow and the temperature sensors, as now. The DCS signals are transmitted optically from the CRU to the GBT card and on dedicated electrical line between the GBT-SCA component to the Front-End Card.

2.4 Schedule

The MCH upgrade schedule is presented in Fig. 2.2.
Few remarks concerning this schedule:

- The effective design of the front-end card prototype needs the knowledge of the SAMPA pin out and the e-link connector choice.
- The GBT card design does not need to start before beginning of 2015.
- There is no need for the whole production of FEC, GBT cards to start with the installation and commisioning during LS2. The installation will be done chamber per chamber, immedialtely followed by a first commissioning.



		Nom	Durée	Début	Fin	Prédécesseurs	Noms des ressources
1		ALICE Electronics & Trigger Upgrade	1 jour?	01/01/14 08:00	01/01/14 17:00		
2		**CTP**	**1 180 jours**	**01/01/14 08:00**	**10/07/18 17:00**		
28		**CRU**	**522 jours**	**01/01/14 08:00**	**31/12/15 17:00**		
41		**SAMPA**	**674 jours?**	**01/01/14 08:00**	**01/08/16 17:00**		
63		O2 prototype delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
64		O2 installation delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
65		Optical fiber prototype delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
66		Optical fiber installation	0 jours	01/01/14 08:00	01/01/14 08:00		
67		GBTx pre-series delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
68		GBTx production delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
69		SCA pre-series delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
70		SCA production delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
71		Versatile link components pre-series delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
72		Versatile link components production delivery	0 jours	01/01/14 08:00	01/01/14 08:00		
73		**MCH**	**1 566 jours**	**01/01/14 08:00**	**01/01/20 17:00**		
74		**Front-end card**	**1 139 jours**	**01/01/14 08:00**	**14/05/18 17:00**		
75		**MCH-SAMPA qualification**	**519 jours**	**01/01/14 08:00**	**28/12/15 17:00**		
76		Test stand preparation	141 jours	01/01/14 08:00	16/07/14 17:00		
77		Test with MPW1	67 jours	17/07/14 08:00	17/10/14 17:00	46;76	
78		Test with MPW2	67 jours	19/01/15 08:00	21/04/15 17:00	51	
79		Test with MPW3	66 jours	28/09/15 08:00	28/12/15 17:00	56	
80		Prototype design	129 jours	01/01/15 08:00	30/06/15 17:00		
81		Prototype construction	44 jours	01/07/15 08:00	31/08/15 17:00	51;80	
82		Prototype test	44 jours	01/09/15 08:00	30/10/15 17:00	81	
83		Design optimisation	65 jours	02/11/15 08:00	29/01/16 17:00	82	
84		Preseries construction	65 jours	01/02/16 08:00	29/04/16 17:00	83;56	
85		Preseries test	65 jours	02/05/16 08:00	29/07/16 17:00	84	
86		Production	390 jours	01/08/16 08:00	26/01/18 17:00	85	
87		Production test	400 jours	01/11/16 08:00	14/05/18 17:00	86SS+60 jours	
88		Contingency	34 jours	15/05/18 08:00	29/06/18 17:00	87	
89		**GBT read-out card**	**762 jours**	**01/01/15 08:00**	**01/12/17 17:00**		
90		Prototype design	142 jours	01/01/15 08:00	17/07/15 17:00		
91		Prototype construction	100 jours	20/07/15 08:00	04/12/15 17:00	90;67;69;71	

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		Nom	Durée	Début	Fin	Prédécesseurs	Noms des ressources
92		Prototype test	100 jours	07/12/15 08:00	22/04/16 17:00	91	
93		Design optimisation	65 jours	25/04/16 08:00	22/07/16 17:00	92	
94		Preseries construction	65 jours	25/07/16 08:00	21/10/16 17:00	93	
95		Preseries test	100 jours	24/10/16 08:00	10/03/17 17:00	94	
96		Production	130 jours	13/03/17 08:00	08/09/17 17:00	95	
97		Production test	130 jours	05/06/17 08:00	01/12/17 17:00	96SS+60 jours	
98		Contingency	152 jours	04/12/17 08:00	03/07/18 17:00	97	
99		**FE2GBT cables**	**913 jours**	**01/01/14 08:00**	**30/06/17 17:00**		
100		Prototype design	217 jours	01/01/14 08:00	30/10/14 17:00		
101		Prototype construction	87 jours	31/10/14 08:00	02/03/15 17:00	100	
102		Prototype test	86 jours	03/03/15 08:00	30/06/15 17:00	101	
103		Design optimisation	88 jours	01/07/15 08:00	30/10/15 17:00	102	
104		Preseries construction	130 jours	02/11/15 08:00	29/04/16 17:00	103	
105		Preseries test	130 jours	02/05/16 08:00	28/10/16 17:00	104	
106		Production	65 jours	31/10/16 08:00	27/01/17 17:00	105	
107		Production test	110 jours	30/01/17 08:00	30/06/17 17:00	106	
108		Contingency	260 jours	03/07/17 08:00	29/06/18 17:00	107	
109		CRU firmware design	143 jours	01/01/14 08:00	18/07/14 17:00		
110		CRU firmware modifications	835 jours	01/01/14 08:00	14/03/17 17:00		
111		DCS software design	143 jours	01/01/14 08:00	18/07/14 17:00		
112		DCS software modifications	835 jours	01/01/14 08:00	14/03/17 17:00		
113		**System tests (FEC - GBT RO card - CRU...**	**798 jours**	**01/01/14 08:00**	**20/01/17 17:00**		
114		Prototype system test - CRU & CTP emul...	65 jours	07/12/15 08:00	04/03/16 17:00	81;91;101;109;111;6...	
115		Pre-series system test - CRU pre-series,...	65 jours	24/10/16 08:00	20/01/17 17:00	104;94;84;35	
116		System test - CRU & CTP pre-series	65 jours	01/01/14 08:00	01/04/14 17:00	10	
117		**Commissioning & Installation**	**260 jours**	**09/07/18 08:00**	**05/07/19 17:00**		
118		Installation	218 jours	09/07/18 08:00	08/05/19 17:00		
119		Commissioning in ALICE	220 jours	01/09/18 11:00	05/07/19 17:00	118SS+30 jours	
120		Contingency	128 jours	08/07/19 08:00	01/01/20 17:00	119	
121		**MID**	**261 jours?**	**01/01/14 08:00**	**31/12/14 17:00**		
164		**TRD**	**1 jour?**	**01/01/14 08:00**	**01/01/14 17:00**		
180		**FIT**	**1 jour?**	**01/01/14 08:00**	**01/01/14 17:00**		
191		**ZDC**	**1 jour?**	**01/01/14 08:00**	**01/01/14 17:00**		

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Figure 2.2: The MCH upgrade schedule.

2.5 Manpower

The estimated manpower available in the collaboration institutes, which is needed for the different activities, is shown in Tab. 2.9. The numbers are divided into physicists (PH), electronics engineers (EE) and technicians (ET) and others (OT).

2.6 Risk Register

The different items do not present technical risks, except for SAMPA which has especially to demonstrate the parallel running of the signal sampling and data transmission. Different prototypes are foreseen.

Funding risks:
Even if not yet officially approved, the financing of each level-1 item has been discussed with the corresponding Funding Agency and the cost was considered reasonable.
In case of the failure of part of the funding, a backup solution would be to ask money from region, Europe or ANR (Agence nationale de la Recherche in France).
The specific SAMPA case is detailed in chapter 3.

General schedule risks

The main possible risk concerning the schedule is related to the long production and test of the Front-End card (19000), which depends partly on the SAMPA chips delivery.

Activity	Institute	Contact person	2014				2015				2016				2017				2018			
			PH	EE	ET	Ot	PH	EE	ET	Ot	PH	EE	ET	Ot	PH	EE	ET	Ot	PH	EE	ET	Ot
1. Front-end cards	**IN2P3/INP Orsay**	B. Espagnon	0.5	1	1.3	0	0.5	1.5	1.7	0	0.5	1.2	1.7	0	0.5	1.2	1.7	0	0.5	1.2	1.7	0
1.1. Design & Prototyping			0.5	1	1.3	0	0.5	1.5	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0
1.2. Qualification			0	0	0	0	0	0	0	0	0.5	1.5	1.7	0	0	0	0	0	0	0	0	0
1.3. Production			0	0	0	0	0	0	0	0	0	0	0	0	0.5	1.2	1.7	0	0	0	0	0
1.4. Tests			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1.2	1.7	0
2. SAMPA ASIC *	**Brazil/Sao Paulo**	xx	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3. GBT Read-out cards	**CEA/Irfu Saclay**	H. Borel	0.5	0	0	0	0.5	1.2	0	0	0.5	1.2	0	0	0.5	1.2	0	0	0.5	1.2	0	0
1.1. Design & Prototyping			0.5	0	0	0	0.5	1.2	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0
1.2. Qualification			0	0	0	0	0	0	0	0	0.5	0.8	0	0	0	0.2	0	0	0	0	0	0
1.3. Production			0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0	0	0	0.2	0	0
1.4. Tests			0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.8	0	0	0.5	1	0	0
4. FE2GBT cable	**INFN/Cagliari**	C. Cicalo	0.5	1.5	0	0	0.5	1.5	0	0	0.5	1.5	0	0	0.5	1.5	0	0	0.5	1.5	0	0
1.1. Design & Prototyping			0.5	1.5	0	0	0.5	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.2. Qualification			0	0	0	0	0	0	0	0	0.5	1.5	0	0	0	0	0	0	0	0	0	0
1.3. Production			0	0	0	0	0	0	0	0	0	0	0	0	0.5	1.5	0	0	0	0	0	0
1.4. Tests			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1.5	0	0
5. CRU **	**Hungary/India**	T. Kiss	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 2.9: Available manpower per institute and year (in FTE). * see chapter 3, ** see chapter 4