CERN-RRB-2009-058
28 April 2009

The Status of TOTEM
Progress Summary Report for the April 2009 RRB

The TOTEM Collaboration

1. Introduction

During the year 2008 all the sub-detectors almost completed their production and were tested in a test beam with the final electronics. Before the start of the LHC last September two Roman Pot detector assemblies were installed in the tunnel and one quarter of the T2 telescope in the CMS shielding.

The aim is to install the complete TOTEM experiment before the start of the LHC in autumn 2009. The 220 m stations of the Roman Pots will be complete. The 147 m stations will be partially equipped in order to gain preliminary experience with the radiation and therefore avoid radiation damage in the first LHC run.

The T1 detector will be installed in September after having mounted a new support in the CMS end-cap. The T2 telescope is now being mounted in the CMS shielding, and this installation should be finished mid May.

After a commissioning phase with the first pp-interactions TOTEM will operate continuously during the 2009/2010 run. We envisage that in 2010 TOTEM can take data with the specialised 90 m optics for a first total cross-section measurement.

2. The Roman Pots

After the first two detector assemblies had been installed in the LHC tunnel last summer, a first phase of system commissioning started. A provisional DCS enabling to control the two detector assemblies (LV, HV and environmental monitors) allowed testing the cooling system which serves the four Roman Pot stations with four independent loops. With the cooling station in operation, the detectors in the pots reached the temperature of -35°C which satisfied well the requirements. The proper performance of the cooling system allowed starting the first tests of the control and the readout of the frontend electronics. These tests performed as expected; the data retrieved from the VFAT frontend chips showed the correct format.

The temperature evolution of the pot 2 in sector 5-6 during this test (Fig. 1) evidences the expected slight change in temperature when switching between the run mode and the sleep mode of the VFAT chips in the detector assembly.

These tests were stopped at the end of the year with the start of the maintenance operation on the demineralised water circuits, which is serving the cooling system in Point 5, and will restart with the next installations of detector assemblies.

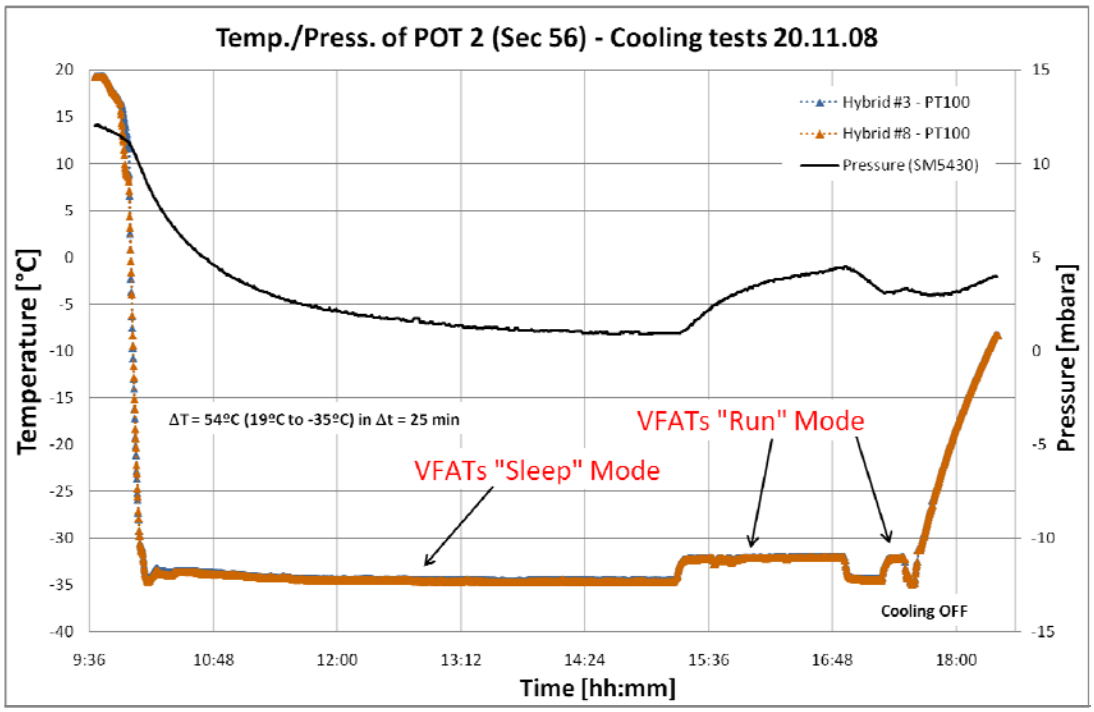


Fig. 1: Temperature evolution as read on two planes of the detector package installed in sector 5-6.

The Roman Pot detector production is ongoing. Due to the absence of beam, the detector commissioning on the surface is performed now with cosmic rays, still exploiting the test setup in the SPS beamline H8. An example of a cosmic track in the two sets of five planes of a recently assembled detector package is shown in Fig. 2.

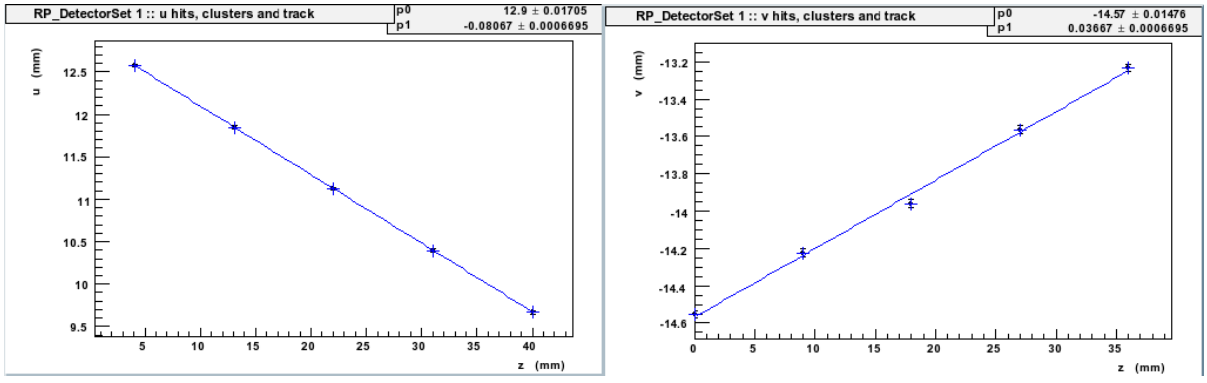


Fig. 2: Cosmic track as registered in the two sets of five planes with strips oriented respectively along the "u" direction (left) and the orthogonal "v" direction (right).

Respecting the foreseen production schedule, there are now five new pots being installed. The picture of the five pots which will complete the detector installation in the station at 220m of the sector 5-6 is shown in Fig. 3.

Fig. 3: Five Roman Pot detector assemblies fully tested and ready for installation in the tunnel to complete the station at 220 m in sector 5-6.

The planning of the Roman Pot detector production is shown in Fig. 4.

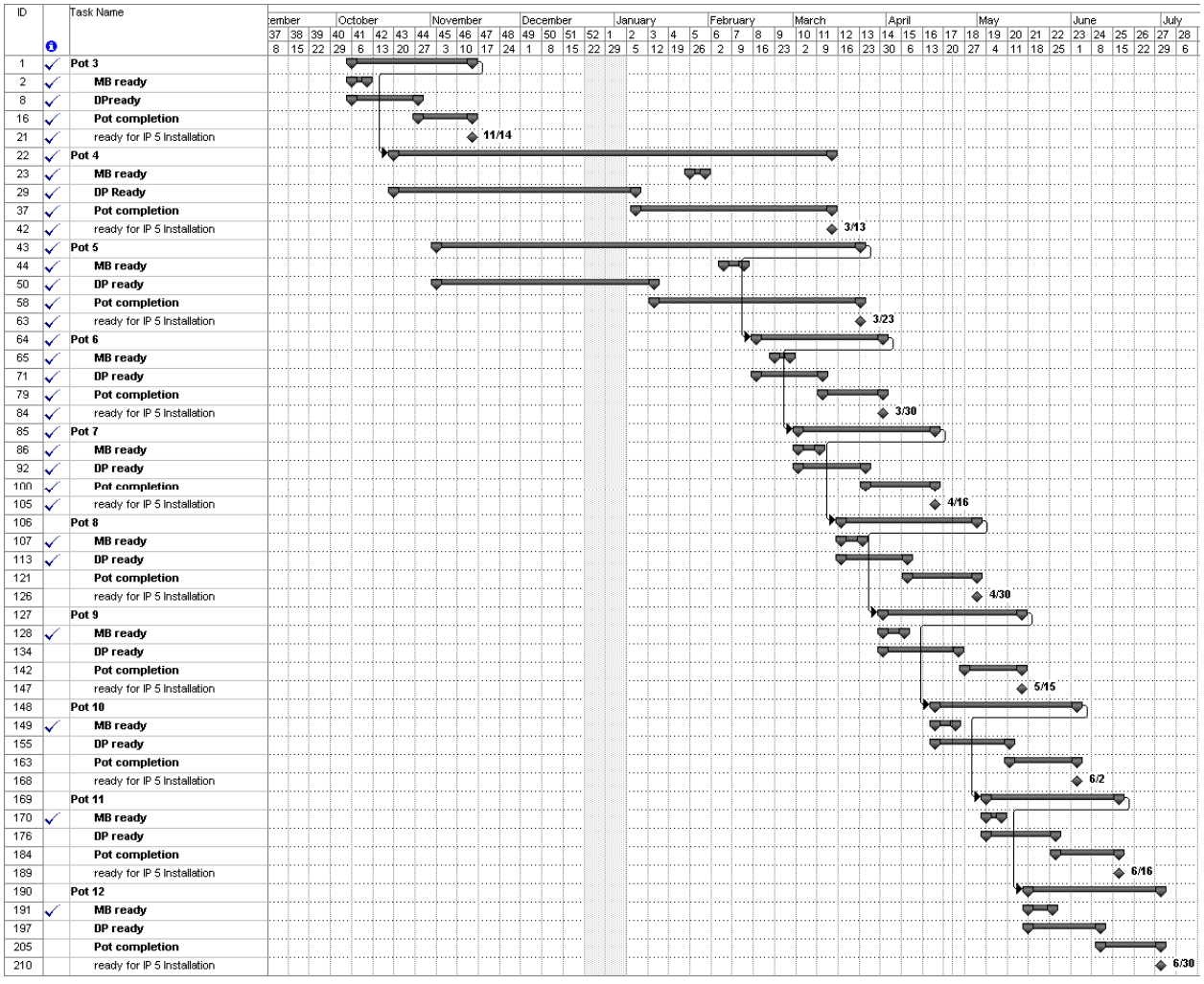


Fig. 4: Planning of the production of the Roman Pot detectors.

3. The T1 CSC Telescope

The T1 telescope will be installed inside the endcaps of CMS, in the region between the beam pipe and the inner envelope of the flux return yoke, between 7.5 m and 10.5 m on either side of the interaction point, thus covering the pseudo-rapidity range $3.1 \leq \eta \leq 4.7$. Each arm of the telescope consists of five planes of trapezoidal Cathode Strip Chambers (CSC): six CSC per plane cover the full azimuthal range. Read-out of the anode wires and of the cathode strips, oriented at $\pm 60^{o}$ with respect to the wires on both sides of the CSC, provides a 3-coordinate measurement for each particle traversing the chamber.

The CSC have been assembled and tested for HV, gas tightness and gain uniformity at PNPI in Russia. The same tests are repeated once the chambers arrive at CERN. Due to the bad quality of some of the panels from the latest productions, the CSC assembly process has experienced significant delays; however, all but one of the chambers needed for the full detector are currently ready: most of the missing ones are spare chambers. Their production is expected to be completed in early June.

The front-end electronics include three types of custom boards for anode and cathode read-out (AFEC and CFEC, respectively) and data concentration/transmission (ROC). At the time of writing, all AFEC and CFEC needed to equip the detector have been produced, while delivery of the final production of the ROC is expected for the first week of May.

The CSC are currently being tested with electronics and the TOTEM DAQ system with cosmic rays in Genova (pre-production chambers and boards had previously been tested with beam in the TOTEMINO set-up at H8). A satisfactory configuration for the grounding scheme and for the shielding has been established in this set-up.

The mechanical supports for the four half-arms have been assembled at CERN: two of them are complete with internal gas and cooling system (one with internal cabling as well). Completion of all four support structures is expected by the end of June. Starting from mid-May, chambers will be mounted as the supports get ready and tested with cosmic rays with the full DAQ chain.

Part of the services for the detector are fixed to the YE3 disk: gas and cooling lines have been installed on YE3-, while appropriate time slots in May and June are being reserved for installation of the remaining pipes and cables on both sides.

Measurements made in the UX5 cavern during 2008 CMS tests have led to the decision, in September 2008, to abandon the previously built and tested support structures to be fixed to the CMS endcaps, and to proceed to a re-design. This involves different fixation points (on the YE2 disk rather than YE3), a new truss structure and different installation procedures. Construction of the new trusses will start on April 27, the first two elements being expected to be ready by the end of May. The new design of the fixation system should be frozen by the end of April, after which fabrication will start. A new installation procedure has also been envisaged, such that a test insertion of the trusses, with alignment, can be foreseen at the beginning of June. Final insertion and installation of the two T1 telescopes is planned for August / September, depending on the CMS schedule.

4. The T2 GEM telescope

The T2 telescopes are installed in the forward shielding of CMS between the vacuum chamber and the inner shielding of the HF calorimeter. In each arm, 20 semi-circular GEM planes are interleaved on both sides of the vacuum chamber to form 10 detector planes with full azimuthal coverage. The gaseous electron multipliers (GEM) detectors were chosen because of their high-rate capability, good spatial resolution, robust mechanical structure and their excellent ageing characteristics.

The individual chambers have been assembled and tested in the clean rooms of the Helsinki Detector Laboratory where a dedicated assembly line was set up. The production of the readout electronics has been completed in summer 2008. Each quarter has been then fully assembled and equipped with electronics at CERN to be systematically tested in the SPS beam line H8, where also cabling and shielding were optimised with respect to noise reduction. These extensive tests were a common effort of the Pisa/Siena, Helsinki and CERN groups. After some optimisation, the operation of the GEM chambers was fully satisfactory and according to expectations. The tests at the TOTEMINO facility on the H8 line are presently performed with cosmic rays due to the absence of beam.

At the time of writing, three out of the four foreseen T2 quarters have already been installed in their final positions in IP5, in compliance with the CMS schedule. The installation of the last quarter is planned for mid May. Two of the three quarters have the services connected and tested, the last one is underway. The cabling is almost done and the commissioning phase is starting these days.

5. The Electronics System

Several production problems occurred for the printed circuit boards. This has caused considerable delays, but overall we have managed to produce in sufficient quantities for installation. This is the case for the Roman Pot hybrids, where we have enough available for the pots at 220 m, and also for T1 and T2 we should have enough for installation. We will need to produce more spares, but this is less urgent.

Despite functional boards from the first series it was mandatory to relaunch the production of the Host Board (the main board in the counting room), because of a severe reliability issue. Component mounting will start in May. For the moment the functional boards from the first series can be used.

The trigger signals from the Roman Pots at 220m have to be propagated electrically to the counting room to meet latency requirements for joint operation with CMS. (Optical transmission can be used for TOTEM standalone operation.) This requires a number of boards (repeater and optocoupler card). The repeater card needed a design correction, which was developed and fine tuned experimentally. After final verification the production will be relaunched. For the moment the optical trigger transmission can be used.

The interlock card, generating the machine interlock signals from TOTEM, is now finally in production. Multiple design iterations were necessary to satisfy machine requirements with a significant increase in complexity.

Cabling in the tunnel will be final in the coming weeks. In the counting-room the DCS and DSS connectivity is underway.
An overview of the electronics production status is given in Fig. 5.

W. S. 24.04.2009	Quantity													
	RP	T1	T2	Test setups + spare	Total	who	design	proto	test	Start Prod	End Prod	Start Test	End of Test	
RP Cards														
RP Hybrid	240			40	280	CERN					Nov-08	Jan-08	Dec-09	final batch in rework, available for 220m
RP Motherboard	24			4	28	CERN					Nov-08	Feb-08	Jun-09	final batch in rework, prod&test ok for 220 m
T1 Cards														
T1 anode hybrid (*)		120		20	140	Genova					Apr-09	Jan-08	May-09	remaining 5 % for installation in production
T1 cathode hybrid (*)		360		30	390	Genova					Apr-09	Jan-08	May-09	remaining 5 % for installation in production
Anode FrontEnd Card (AFEC)		60		10	70	Genova							May-09	final batch just delivered
Cathode FrontEnd Card (CFEC1)		120		20	180	Genova							May-09	final batch just delivered
T1 Readout Card (ROC)		40		5	45	Genova					Apr-08	Jan-08	May-09	Production to be delivered this wk
T2 Cards														
GEM strip hybrid (*)			160	20	180	Pisa								installation quantity delivered
GEM Pad hybrid (*)			520	60	580	Pisa					Apr-09	Jan-08	May-09	remaining 5 % for installation in mounting
Horseshoe Card			40	5	45	Pisa								
11th Card			4	1	5	Pisa								
Kaptons between Horseshoe & 11th			40	7	47	Pisa								
			40	7	47									
			40	7	47									
H,P,T card (sensor carrier)			4	2	6	Pisa							Jul-09	postponed, not essential
Opto TX			8	2	10	Pisa								
Trigger cards														
TriggerTimingControl Card (TTCci)	1			4	5	CMS								
Local Trigger Control Card (LTC)	1			1	2	CMS								not yet delivered
Optical splitter	1			1	2	CMS								not yet delivered
Coincidence Chip hybrid	48		52	20	120	Hungary					Apr-09	Mar-08	May-09	final 25 % in rework, ok for 220m
VFAT Trigger mezzanine	24	40	8	6	78	CERN						Mar-08	Jun-09	90% delivered, last 10 % in test after rework
Repeater Card	124			12	136	CERN							Jul-09	produced, tested, fix developed, in verif
Optocoupler card	2			1	3	CERN							Jul-09	
Trigger output card	1			1	2	Pisa							Jul-09	
T1 Trigger Merger Mezzanine		2		1	3	Genova							Dec-09	Postponed not needed for early operation
DAQ Cards														
Gigabit Opto Hybrid (GOH)	120	100	72	53	345	CMS								
OptoRX	12	10	10	9	41	Preshower								
VME64x Host Board	6	4	4	8	22	CERN							Jun-09	Naked card reproduced, mounting starts May
VME Back Plane	4			1	5	Bari								
Slink64 card	8	6	4		18	CMS								
Interlock Cards														
Interlock card				2	2	CERN							May-09	In production after new iteration with machine
(*) The GEM strip hybrid and T1 hybrids are identical, for the cathodes the wire bonding is different if only the digital part of the VFAT is used. The GEM pad hybrid is only slightly different to match the channel to trigger sector correspondence.														

Fig. 5: Electronics production status.

6. Data Acquisition

Procurement of the full set of event-builder computers and storage for LOCAL DAQ is complete. The cluster has been configured and studied during the last months. A redundant configuration for the storage system has been implemented, and its performance and reliability have been verified to comply with our needs (100 MB/s sustained data rate, fail safe against hard disk and storage unit failures).

New software has been developed to cope with several needs in the experiment (hybrid, detector and front-end electronics testing). In particular, the debugging tools needed for the development of the TOTFED board have been completed.

During the last months, a procedure has been set up in TOTEM to coordinate activities on electronics and DAQ in such a way that firmware and software are released together, in order to minimise the chance of incompatibilities and fake bug reports. To optimise future compatibility, the software is always based on libraries and tools inherited from the CMS DAQ environment.

7. Offline Software and Computing

The TOTEM Offline Software, which includes simulation, reconstruction, calibration, alignment and analysis, is based on the CMSSW Framework. Due to the modular structure of the CMS software, the TOTEM related packages can be incorporated in it, allowing in the future a combined TOTEM/CMS detector simulation and analysis.

The current release (2.0) includes the simulation (Geant4 + digitisation) and the reconstruction in all TOTEM detectors, the simulation of the Coincidence Chip, and the simulation of the L1 Trigger response. A special package which is needed for simulating the proton transportation in the accelerator is also included.
In March 2009, a first bunch of simulated data has been produced, based on the optics at the LHC start-up. Several other scenarios are foreseen in the next months. These data are currently used to develop analysis tools to facilitate data and physics analysis, to define the trigger strategy for the early TOTEM runs and to optimise the software performances.
The development of the alignment procedures for all detectors has started but it is not yet included in the official release.
The Offline Database construction has started: the characterisation of the data has been performed and a list of requirements has been issued. The technology which it will be based on is Oracle.
The Mapping and Calibration chain is under development, following commissioning and installation of the detectors in the tunnel.

8. Physics

The early LHC runs will be performed at low β^* with beams having reduced energy (4 to 5 TeV), reduced number of bunches and a lower number of protons per bunch, giving TOTEM ample opportunities to make its first physics studies: large-$|t|$ elastic scattering, high-mass central and single diffraction and forward charged particle production in inelastic events. In addition, TOTEM will request several runs of a few days at $\beta^* = 90$ m, aiming at an early total cross-section measurement with 4-5 % relative precision as well as studies of soft diffraction at any diffractive mass value.

The physics group is preparing for analysis of TOTEM data from these runs in close collaboration with the offline software group. The time up to the LHC start will be mainly devoted to developing a trigger strategy for the early runs as well as preparing the analysis framework and different analysis tools for the physics analysis of the first data. In parallel, the group will continue to pursue systematic comparisons of different event generators and models in view of preparing the interpretation of the first data.

9. Installation and Commissioning

At present, the 220 m Roman Pot station in sector 5-6 is being completely equipped with silicon detector assemblies. The commissioning will start immediately with cabling, vacuum and cooling tests, survey and Roman Pot motor control before powering the detectors and starting stability tests. The silicon detectors for sector 4-5 will be installed end of June.

For the installation of T1 a new support structure was designed by TOTEM and CMS in order to guarantee a safer installation. This structure is now in production. In

view of minimising the required access time for the T1 installation, the plan is to pre-mount the different parts in early June before CMS is closing for the CRAFT test. This test prevents the installation of T1 during summer. The planning foresees to install the complete T1 telescope in August/September depending on the CMS schedule.

Three quarters of the T2 telescope are now already installed; the fourth will follow mid May. Tests of the gas system and cabling are already in progress. The commissioning of the complete T2 telescope including powering of the detectors and injection of test pulses with start soon.

The TOTEM readout and trigger system, in stand-alone mode, will be installed in IP5 soon to allow extensive commissioning of all detector parts. This includes also the important Detector Control Systems (DCS) and general counting-room infrastructure. The current commissioning planning is shown in appendix A.

10. Construction Budget

- The construction budget does not show variations with respect to the situation presented to the RRB in November 2008.

- The construction Common Fund expenditures were completed in 2008, and the relative account was balanced: now it will be closed as agreed by the FI department.

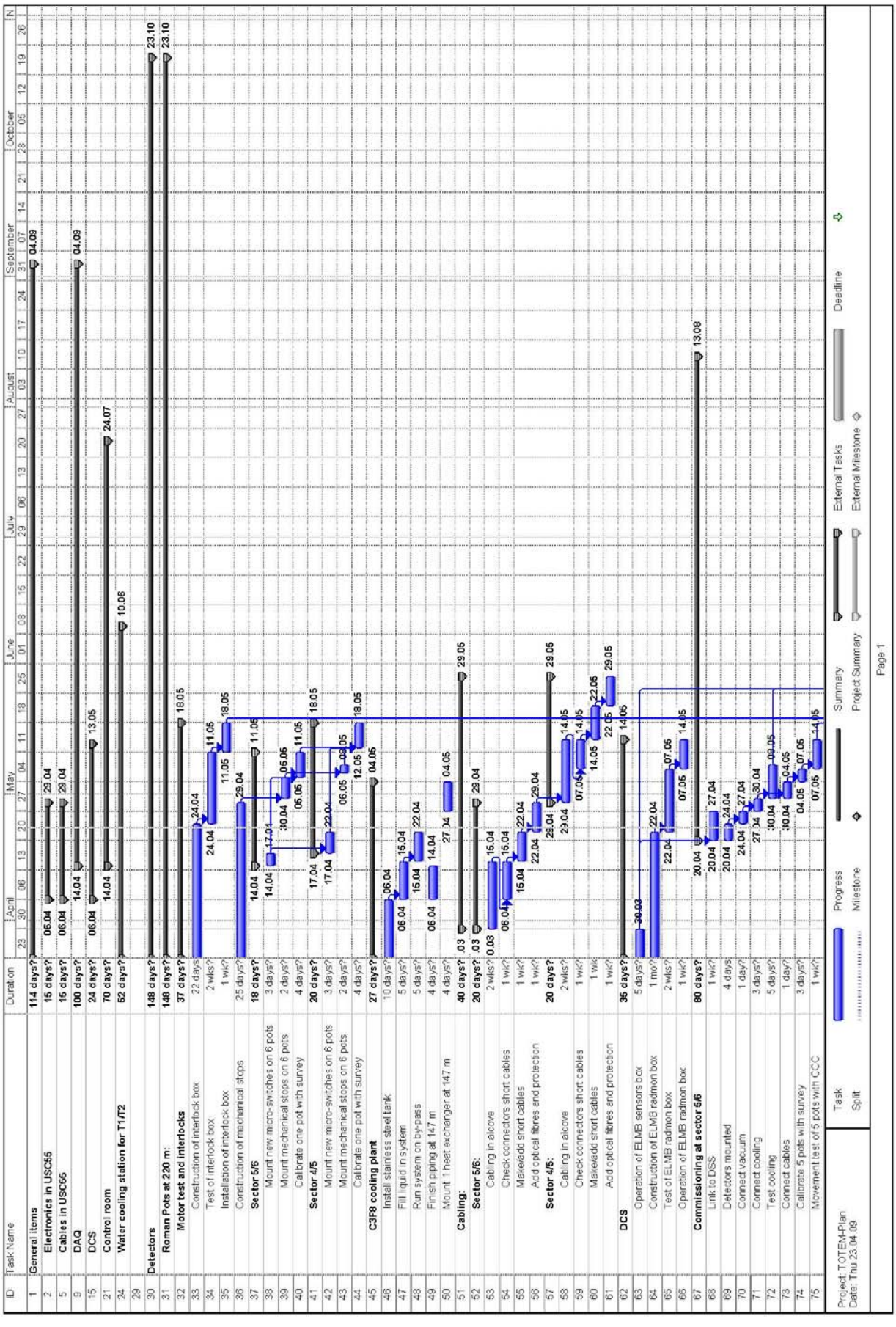
- The commitments to complete the construction “project” expenditures are being paid via the Transit account, according to the projections and figures shown at the RRB November ’08 meeting.

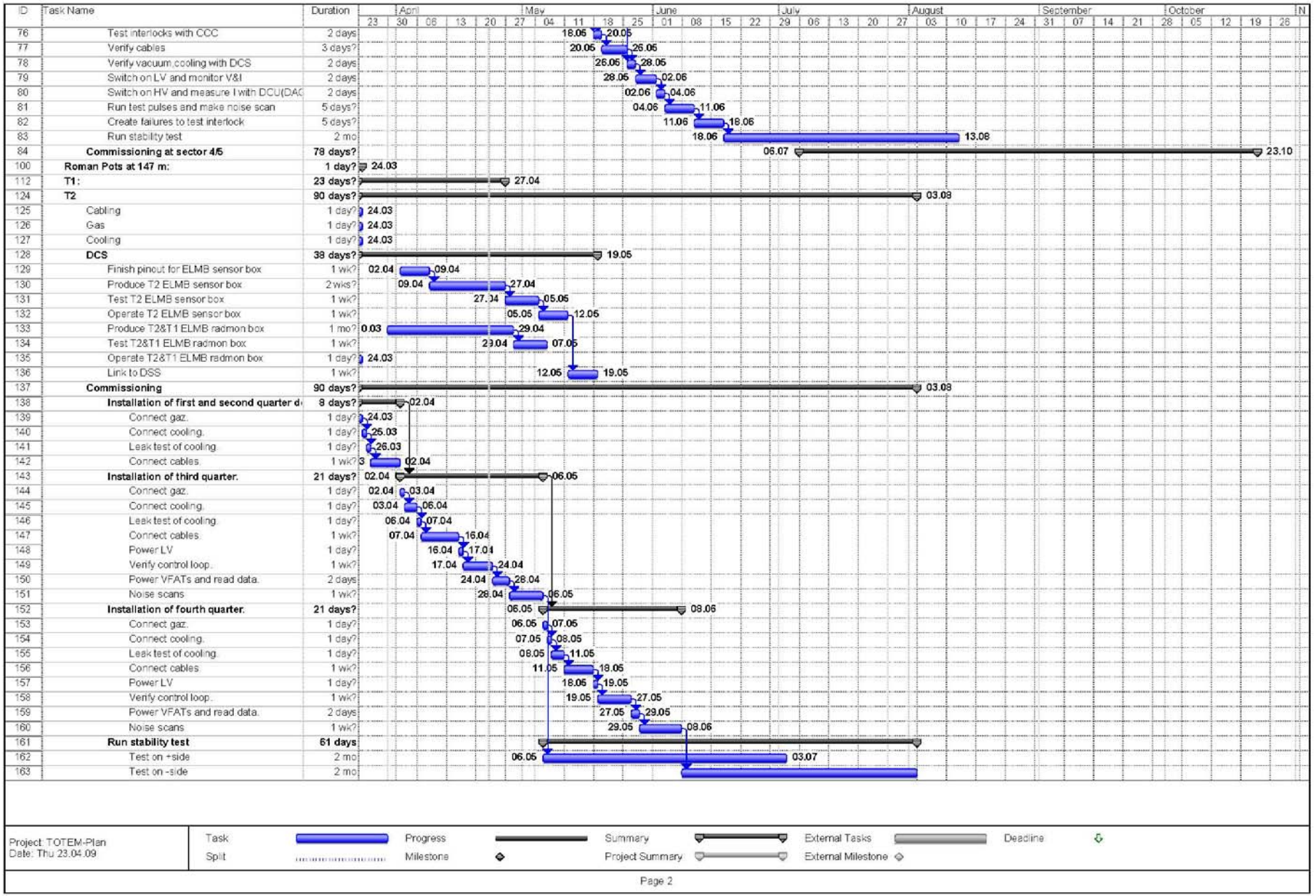
- We are grateful to the Czech Republic funding agency for the additional contribution received for the Roman Pots construction and electronics.

- TOTEM is looking forward to finalising with CERN the income related to the memoranda dated 10 November, which were discussed since the previous RRB meeting: the availability of the corresponding money plays a crucial role vis-à-vis to the cost-to-completion of the project.

- TOTEM also looks forward to presenting to the RRB in autumn the final financial figures upon completion of the experiment construction, which still includes some final commitments of the TOTEM collaborators.

A. Commissioning Planning




ID
Task Name
Duration
April
May
June
July
August
September
October
76 Test interlocks with CCC 2 days 18.05 20.05
77 Verify cables 3 days? 20.05 26.05
78 Verify vacuum,cooling with DCS 2 days 26.05 28.05
79 Switch on LV and monitor V&I 2 days 28.05 02.06
80 Switch on HV and measure I with DCU(DAC 2 days 02.06 04.06
81 Run test pulses and make noise scan 5 days? 04.06 11.06
82 Create failures to test interlock 5 days? 11.06 18.06
83 Run stability test 2 mo 18.06 13.08
84 Commissioning at sector 4/5 78 days? 06.07 23.10
100 Roman Pots at 147 m: 1 day? 24.03
112 T1: 23 days? 27.04
124 T2 90 days? 03.08
125 Cabling 1 day? 24.03
126 Gas 1 day? 24.03
127 Cooling 1 day? 24.03
128 DCS 38 days? 19.05
129 Finish pinout for ELMB sensor box 1 wk? 02.04 09.04
130 Produce T2 ELMB sensor box 2 wks? 09.04 27.04
131 Test T2 ELMB sensor box 1 wk? 27.04 05.05
132 Operate T2 ELMB sensor box 1 wk? 05.05 12.05
133 Produce T2&T1 ELMB radmon box 1 mo? 0.03 29.04
134 Test T2&T1 ELMB radmon box 1 wk? 23.04 07.05
135 Operate T2&T1 ELMB radmon box 1 day? 24.03
136 Link to DSS 1 wk? 12.05 19.05
137 Commissioning 90 days? 03.08
138 Installation of first and second quarter d 8 days? 02.04
139 Connect gaz. 1 day? 24.03
140 Connect cooling. 1 day? 25.03
141 Leak test of cooling. 1 day? 26.03
142 Connect cables. 1 wk? 3 02.04
143 Installation of third quarter. 21 days? 02.04 06.05
144 Connect gaz. 1 day? 02.04 03.04
145 Connect cooling. 1 day? 03.04 06.04
146 Leak test of cooling. 1 day? 06.04 07.04
147 Connect cables. 1 wk? 07.04 16.04
148 Power LV 1 day? 16.04 17.04
149 Verify control loop. 1 wk? 17.04 24.04
150 Power VFATs and read data. 2 days 24.04 28.04
151 Noise scans 1 wk? 28.04 06.05
152 Installation of fourth quarter. 21 days? 06.05 08.06
153 Connect gaz. 1 day? 06.05 07.05
154 Connect cooling. 1 day? 07.05 08.05
155 Leak test of cooling. 1 day? 08.05 11.05
156 Connect cables. 1 wk? 11.05 18.05
157 Power LV 1 day? 18.05 19.05
158 Verify control loop. 1 wk? 19.05 27.05
159 Power VFATs and read data. 2 days 27.05 29.05
160 Noise scans 1 wk? 29.05 08.06
161 Run stability test 61 days
162 Test on +side 2 mo 06.05 03.07
163 Test on -side 2 mo
Project: TOTEM-Plan
Date: Thu 23.04.09
Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline