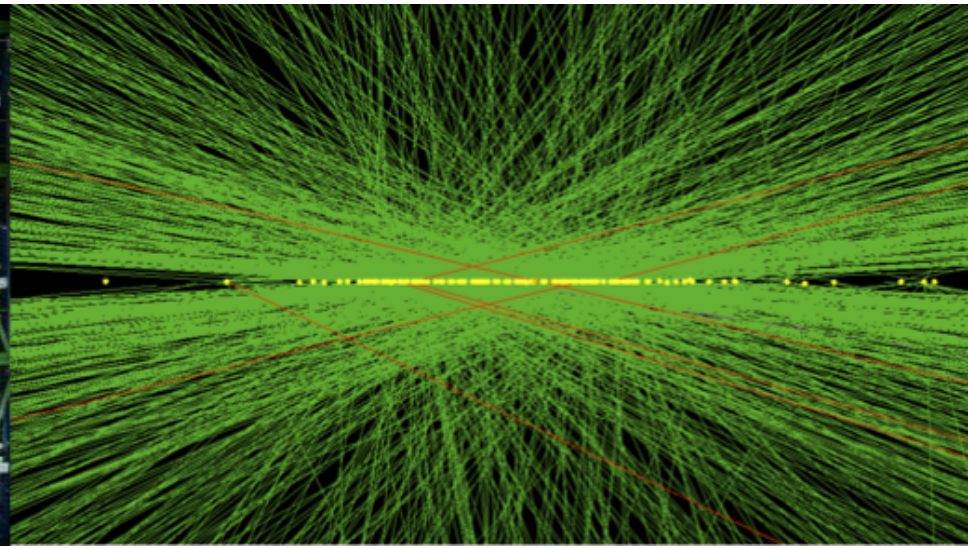
Endcap Muons

Charge is in DocDB-14259

Alexei N. Safonov, Level-2 Manager

MREFC Annual Review

August 25, 2021



Outline

- Overview/Scope
- Completion of R&D
- Progress Overview – Technical
- EVM Status
  - Milestones/Schedule
  - Earned Value Summary
  - Summary of Change Control Actions
- Plans for 2022 and iCMS updates
- QA/QC Implementation
- Summary of Covid Impacts and Plans
  - Cost/Schedule/Forecast
- Supplementary information requested by the reviewers

Key Biographical Sketches

- L2 Manager– Alexei Safonov
  - Professor of Physics, Texas A&M University
  - Current: CMS GEM Deputy PM, CMS GEM Upgrade Coordinator, CSC OTMB electronics improvements campaign (under M&O/DOE), R&D for HL-LHC GEM/CSC backend systems
  - Past: CMS CSC GEM-CSC Trigger Coordinator, CMS Forward Upgrade Project Office, CMS GEM DPG convener, CMS Tau convener, CMS Phase-2 Muon Upgrade TDR chapter co-editor, GE1/1 TDR co-editor, CMS Phase-1 TP Chapter co-editor, CSC ME1/1 OTMB mezzanine & base boards, GEM GE11 OH board design, USCMS LS1 radiation hardness studies, CDF experiment at FNAL
- L3 CSC Upgrade – Darien Wood
  - Professor of Physics, Northeastern University
  - Current: USCMS M&O Endcap Muon PM (L2), CMS Muon Deputy System Manager, US CMS CSC MEX/1 LS2 Electronics Replacement Program (under Ops) Manager
  - Past: CMS CSC Upgrade Coordinator, CMS CSC ME1/1 Electronics Replacement Program, CMS Phase-2 Muon Upgrade TDR chapter co-editor, Spokesperson of the DZero collaboration at FNAL; PM of DZero trigger upgrade, UA2 experiment at CERN, Mark II experiment at SLAC
- L3 GEM Upgrade – Kevin Black
  - Professor, University of Wisconsin – Madison
  - Current: CMS GEM Run Deputy Coordinator, FNAL LPC Coordinator
  - Past: US ATLAS L0 MDT Trigger Project L3 Manager, US ATLAS L1 Physics Support Deputy Manager, ATLAS Muon Trigger Signature Group convenor, ATLAS Reprocessing Coordinator, Operations Leader for the D0 Silicon Track Trigger

HL-LHC Upgrade Overview

DOE and NSF

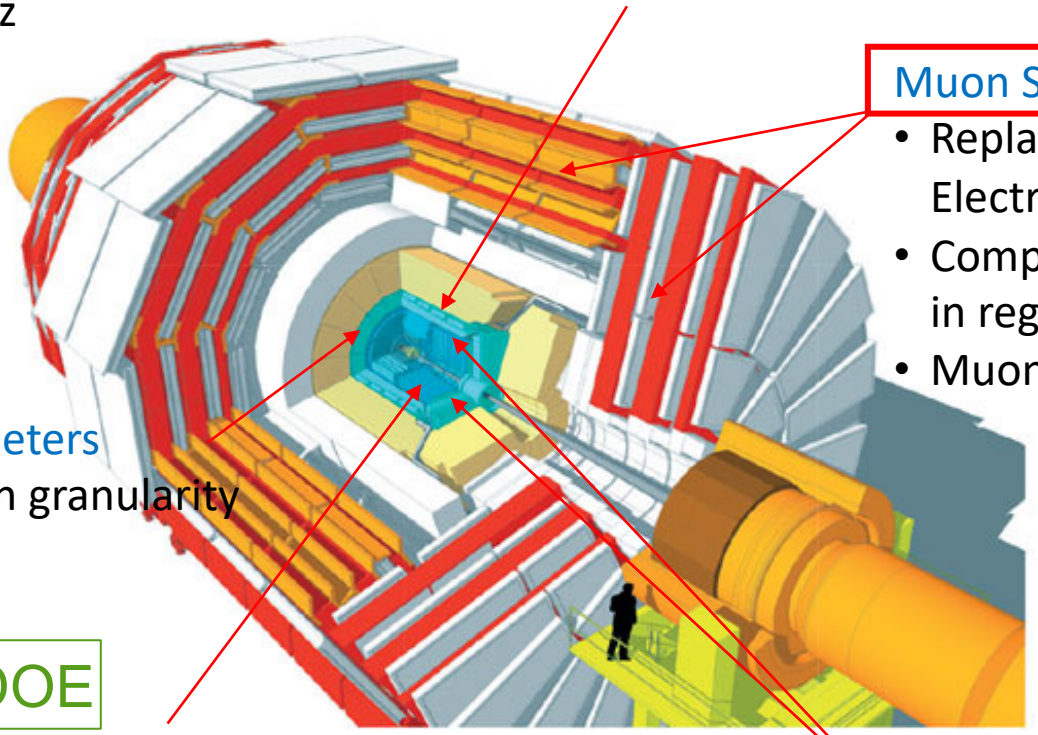
Trigger/HLT/DAQ
- Track information in L1-Trigger
- L1-Trigger: 12.5 μs latency – output 750 kHz
- HLT output 7.5 kHz

NSF

Barrel ECAL/HCAL
- Replace FE/BE electronics
- Lower ECAL operating temp. (8 °C)

NSF

Muon Systems
- Replace DT & CSC FE/BE Electronics
- Complete muon coverage in region $1.5<\eta<2.4$
- Muon tagging $2.4<\eta<3$



DOE

New Endcap Calorimeters
- Rad. tolerant – high granularity
- 3D capable

DOE

New Tracker
- Rad. tolerant – high granularity – significant less material
- 40 MHz selective readout (p_T>2 GeV) in Outer Tracker for L1 -Trigger
- Extended coverage to η=4

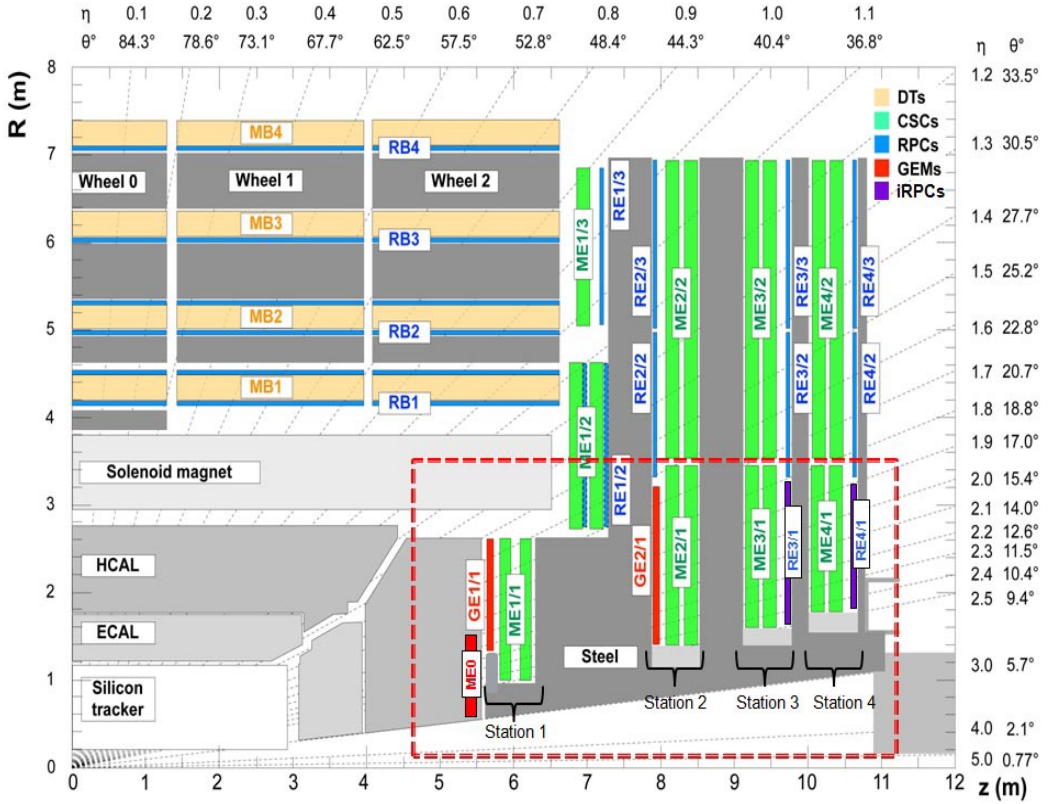
NSF

DOE

MIP Precision Timing Detector
- Barrel: Crystal +SiPM
- Endcap: Low Gain Avalanche Diodes

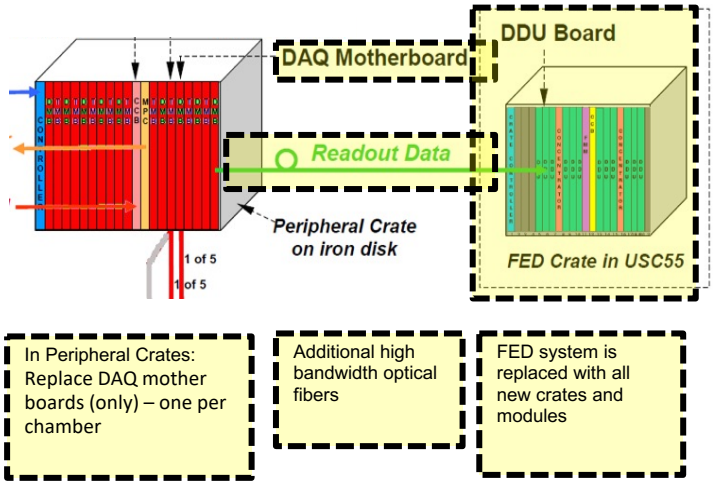
CMS Muon Upgrade Scope

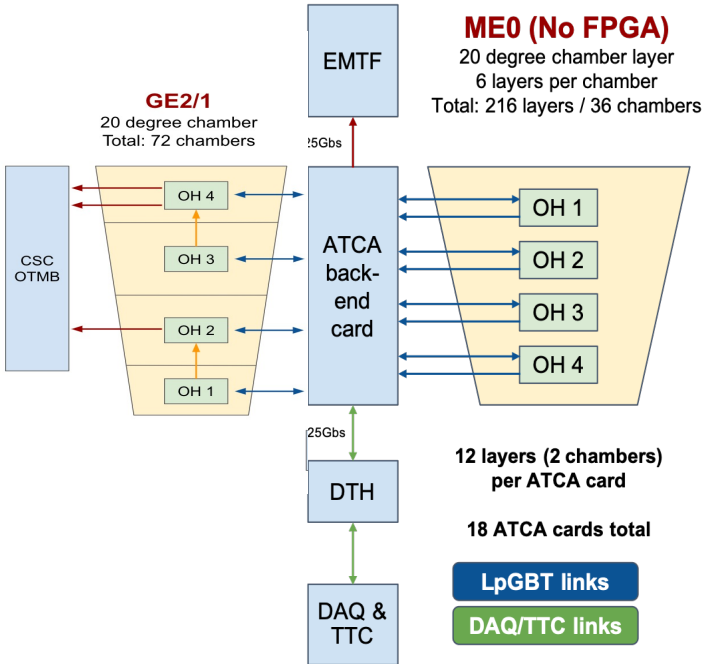
- CMS HL-LHC upgrade scope:
  - Barrel electronics upgrade (no US involvement)
  - Forward muon upgrades: maintain trigger, increase offline coverage
- Endcap Muon Cathode Strip Chambers (CSC):
  - Upgrade ME1-4/1 electronics to cope with data volume/bandwidth
- New Gas Electron Multiplier (GEM) detectors:
  - GE1/1 and 2/1 work with CSC ME1/1 and ME2/1 to maintain muon trigger
  - ME0 works with ME1/1 to maintain trigger and extends offline coverage η=2.4 ➔2.9



NSF Scope in CMS Muon Upgrades

- Focus on maintaining good performance of the CSCs and forward muon trigger
  - Strong US expertise and historical area of US leadership in CMS
  - Scope remains stable since CDR
    - We released one specific link to our international collaborators
- Upgrade of the off-chamber electronics for muon CSC stations ME1/1-ME4/1:
  - Address bandwidth limitations, add capabilities for internal re-synchronization necessary in high rate environment
    - Upgrade optical link and electronics connected to it
- Design and build Trigger/DAQ electronics system for GEM detectors GE2/1 and ME0:
  - Maintain forward muon trigger performance and expand muon coverage
    - Electronics system performing reconstruction and triggering algorithms
    - Data concentration, processing and routing to the CSC Optical Trigger Motherboard (OTMB) and CSC Track Finder (TF)
    - Matching CSC system updates to implement new reconstruction algorithms in firmware





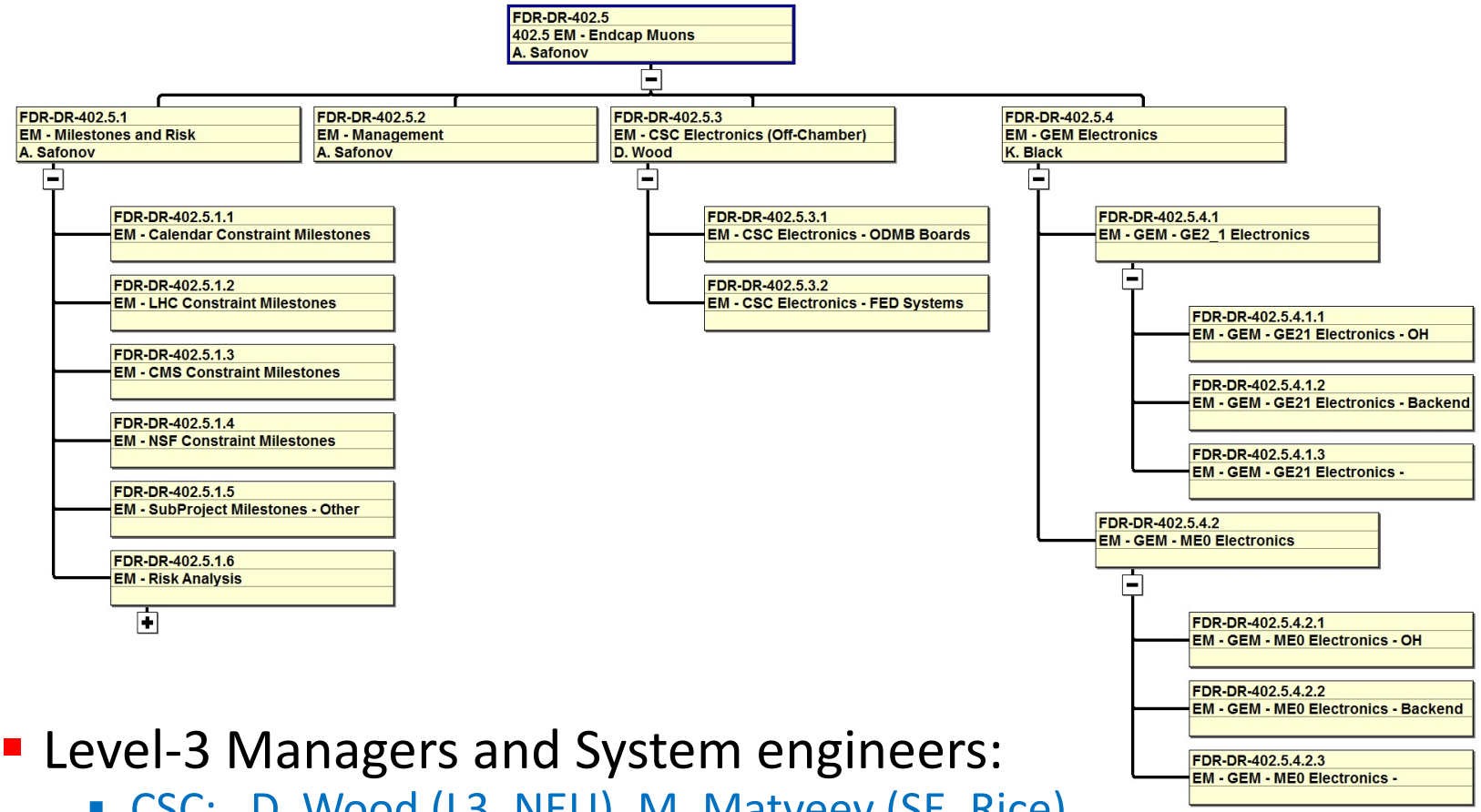
Upgrade Scope Summary

- The NSF scope in CMS Muon upgrades is focused on electronics complete with required firmware/software:
  - Upgrade of elements of the existing CSC electronics system
  - Construction of a part of the electronics readout system for two new GEM detectors
- Technically well understood, includes several types of custom electronics boards plus backend based on ATCA standard
  - Custom boards well understood, similar to boards built in recent past, based on standard technologies (FPGA, optical links), recent prototypes in most cases
  - Backend will use a commonly developed CMS processor card
- Modest number of interfaces and dependences
  - Interfaces are identified, continuously tracked, work in progress towards documenting agreements and placing under control
- While there are challenges routinely expected from projects of this type, there are few technical risks
  - Those that exist are well understood and constantly monitored, mitigation in progress, response plans are well developed

Management Structure

Charge: 2a

- OBS (Organizational Breakdown Structure) mirrors the WBS
  - Remains the same for construction



- Level-3 Managers and System engineers:
  - CSC: D. Wood (L3, NEU), M. Matveev (SE, Rice)
  - GEM: K. Black (L3, Wisconsin) S. Goadhouse (SE, Virginia)

CSC Upgrade: Deliverables

- Key project deliverables for the CSC Off-chamber electronics upgrade:
  - ODMBv2 Boards receiving optical data from CSC on-chamber electronics:
    - 180 Optical DAQ Boards (ODMBv2) for the CSC chambers, capable of transmitting data at >10 Gbps each, complete with firmware and control software, tested and delivered to CERN
  - Backend (FED = Front End Driver) system receiving data from DMB/ODMB boards, processing, concentrating and transmitting event data to CMS central DAQ and optical links
    - 2 ATCA crates with power supplies and control cards, tested and delivered to CERN
    - 12 high power/bandwidth standard CMS ATCA processing cards complete with firmware and control software, tested and delivered to CERN
    - 2 standard CMS ATCA clock/interface cards (one per crate) complete with firmware and control software, tested and delivered to CERN
    - 120 12-fiber bundles of optical fibers connecting original DMB & new ODMBv2 boards to the backend, tested and delivered to CERN
  - Operational spares and a test-stand at CERN

GEM Upgrade: Deliverables

- Key project deliverables for the GE2/1 and ME0 Trigger/DAQ Electronics Upgrade
  - Optohybrid (OH) boards receiving data from front-end chips for processing and concentration:
    - 288 GE2/1 OH boards, 864 ME0 OH boards complete with firmware and control software, tested and delivered to CERN
  - Backend system(s):
    - 1 ATCA crates for GE2/1 and 2 ATCA crates for ME0 with power supplies and control cards, tested and delivered to CERN
    - 4 high power/bandwidth standard CMS ATCA processing cards for GE2/1 and 18 cards for ME0 complete with firmware and control software, tested and delivered to CERN
    - 3 standard CMS ATCA clock/interface cards (one per crate) complete with firmware and control software tested and delivered to CERN
  - Optical Links:
    - GE2/1: a dedicated fiber plant (provides 792 optical fiber links) connecting OH to backend, tested and delivered to CERN
    - ME0: a dedicated fiber plant (incudes 2610 optical fibers links) connecting OH to backend, tested and delivered to CERN
  - Operational spares and components for a test-stand at CERN

Budget Summary

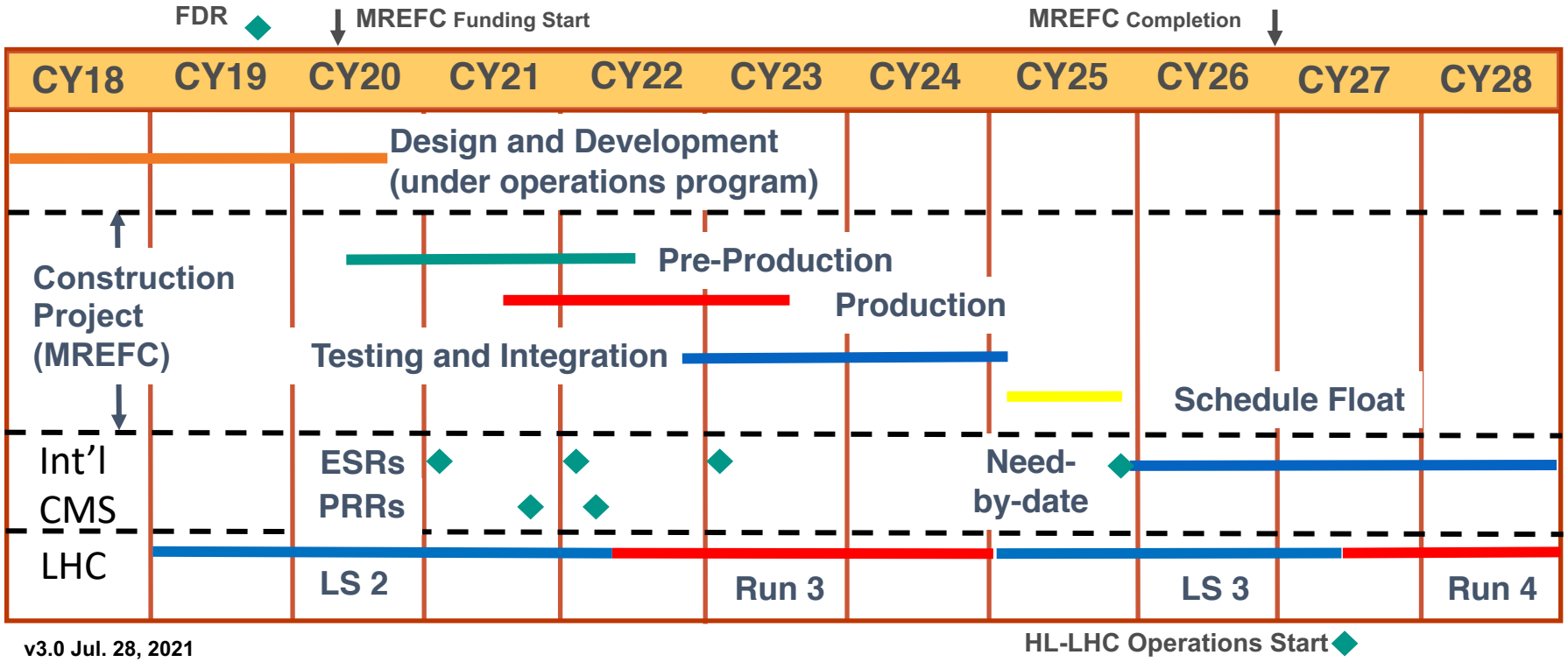
402.5 EM - Endcap Muons

	Labor (Hours)	Direct Labor (FY19 $)	Labor (AY $)	Direct M&S (FY19 $)	M&S (AY $)	Total (AY $)
Total	597910.0	11,798,133	21,768,883	32,378,801	36,148,208	57,917,092
402.0 PM - Project Management (NSF)	37749.0	867,177	2,154,927	3,343,111	4,285,324	6,440,251
402.3 BC - Barrel Calorimeter	70095.0	2,088,313	3,494,596	5,882,759	6,281,510	9,776,106
402.5 EM - Endcap Muons	75369.0	1,187,075	2,338,102	3,920,959	4,390,061	6,728,163
402.5.2 EM - Management	**7710.0**	**104,304**	**183,595**	**459,300**	**621,994**	**805,589**
402.5.3 EM - CSC Electronics (Off-Chamber)	**15711.0**	**303,332**	**637,948**	**1,308,848**	**1,408,668**	**2,046,616**
402.5.3.1 EM - CSC Electronics - ODMB Boards	8170.0	147,191	297,939	833,200	900,438	1,198,377
402.5.3.2 EM - CSC Electronics - FED Systems	7541.0	156,142	340,009	475,648	508,230	848,239
402.5.4 EM - GEM Electronics	**51948.0**	**779,439**	**1,516,559**	**2,152,811**	**2,359,399**	**3,875,958**
402.5.4.1 EM - GEM - GE2_1 Electronics	23094.0	353,251	664,756	826,591	894,890	1,559,646
402.5.4.2 EM - GEM - ME0 Electronics	28854.0	426,188	851,803	1,326,220	1,464,509	2,316,312
402.7 FP - Forward Pixels	293651.0	4,863,506	8,800,552	15,322,525	17,017,457	25,818,009
402.9 TD - Trigger and DAQ (NSF)	121046.0	2,792,062	4,980,706	3,909,447	4,173,856	9,154,562

- Budget nearly unchanged since the FDR (above)
  - As of last month, we are at about 19% to completion

WP_WBS3	Budget	Earned	Actuals	SV	SPI	CV	CPI	BAC	EAC
	$1,885,388.91	$1,337,274.09	$1,162,731.52	($548,114.82)	0.71	$174,542.57	1.15	$7,077,529.17	$6,933,892.56
⊞ M402.5.2 EM - Management	$288,332.30	$237,944.24	$162,034.56	($50,388.06)	0.83	$75,909.68	1.47	$773,302.22	$698,064.37
⊞ M402.5.3 EM - CSC Electronics (Off-Chamber)	$316,275.13	$277,043.28	$226,519.29	($39,231.85)	0.88	$50,523.99	1.22	$2,127,963.02	$2,079,674.57
⊞ M402.5.4 EM - GEM Electronics	$1,280,781.48	$822,286.57	$774,177.67	($458,494.91)	0.64	$48,108.90	1.06	$4,176,263.93	$4,156,153.62
	$1,885,388.91	$1,337,274.09	$1,162,731.52	($548,114.82)	0.71	$174,542.57	1.15	$7,077,529.17	$6,933,892.56

Muon Summary Schedule



- Phases of MREFC schedule:
  - Preproduction – qualify using final parts and design
  - Construction – production of full quantity
  - Testing & Integration – QA/QC all levels, ready for CMS installation

Muon R&D Spending

Charge: 1a, 1b

MUON 402.5.4	Preliminary design of GE2/1 backend system	Mar-18	Mar-18	Completed Mar-18
MUON 402.5.3	Design of FE2.1 OH board prototype complete	Sep-18	Sep-18	Completed Sep-18
MUON 402.5.3	Complete GE2/1 OH board prototype ready for GE2/1 demonstrator	Dec-18	Dec-18	Completed Dec-18
MUON 402.5.4	Backend processor board selected for CSC, GE2/1, ME0	Dec-18	Dec-18	Completed Dec-18
MUON 402.5.4	Pre-production prototype of the GE2/1 OH board	Jul-19	Nov-19	Completed Nov-19
MUON 402.5.4	Pre-Production Prototype of the GE2/1 OH Board Ready for the GE2/1 Demonstrator	Oct-19	Jan-20	Completed Jan-20
MUON 402.5.4	First Fully Functional Prototype of the ME0 OH Board Ready for the ME0 Demonstrator	Nov-19	Nov-19	Completed Nov-19
MUON 402.5.3	CSC ODMB: Pre-Production Prototype Received	Dec-19	Mar-20	Jun-20

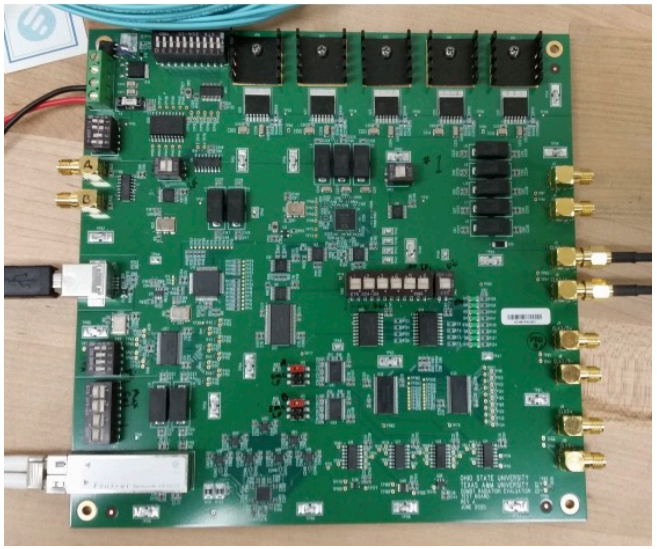
- Some R&D tasks continued past April 1, 2020 (start of the MREFC):
  - Tracked and billed separately, no overlap
  - Variety of reasons for delay (technical, dependences on other sub-projects, international partners delays, COVID induced impacts)

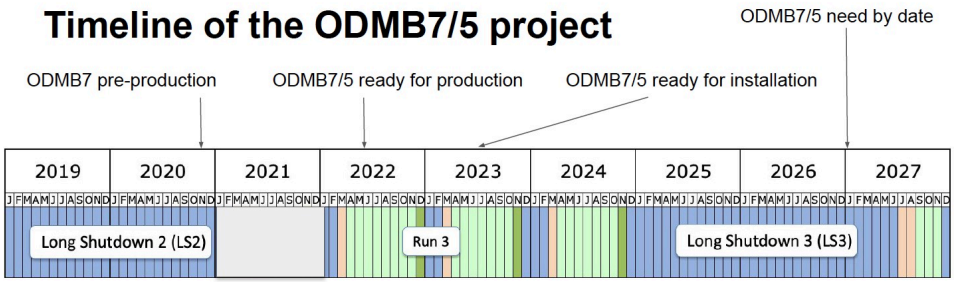
Institution	Spending ($)
FIT	33,396
Northeastern	3,177
Ohio State	88,956
Rice	180,359
TAMU	281,158
UCLA	187,839
Virginia	26,162
Wisconsin	27,818
Total	**828,868**

Progress Summary: CSC ODMB

Charge: 4a

- CSC ODMB pre-production board (OSU + UCSB)
  - Pre-production ODMB7 manufactured in 2020
    - Passed comprehensive testing, only small tweaks for production
    - Firmware development and testing the interfaces with new and legacy CSC components
    - Radiation qualification completed in April'21
  - Procurement to manufacture the pre-production ODMB5 (the second flavor of ODMB) has been green lighted
    - Some delay due to the FPGAs long lead time
  - Testing and integration
    - Production testing setup at UCSB
    - Full ATCA test stand at CERN for integration
  - 4-6 months behind the original baseline
    - Still a comfortably large float



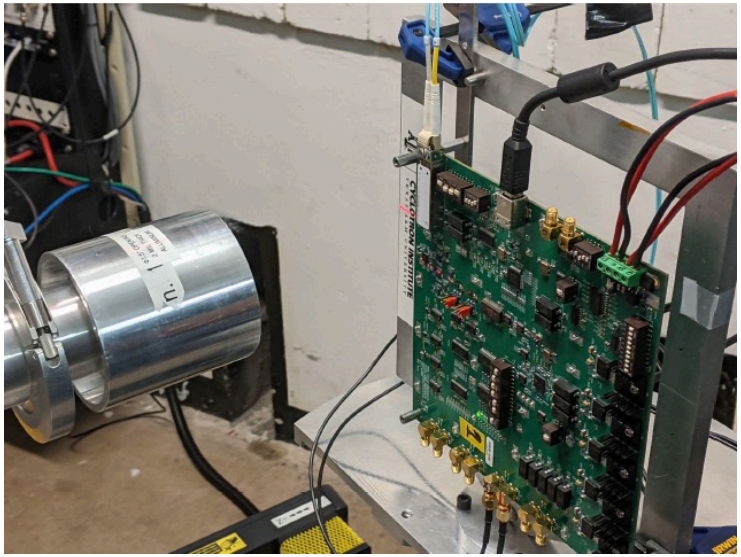


CSC ODMB7: Radiation Testing

Charge: 4a

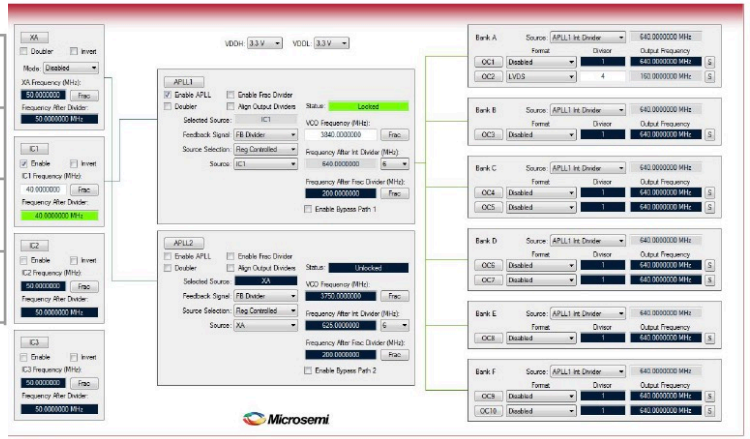
ODMB7/5 components are expected to tolerate HL-LHC radiation levels

- All new components tested with TID test of 5 kRad at the TAMU reactor (September 2020) and are observed to still work
- Fanout chip, high speed multiplexer, and clock synthesizer chip tested in SEU test at TAMU cyclotron (April 2021) with up to 25 kRad and no SEUs observed. Also TID limit likely above 30 kRad



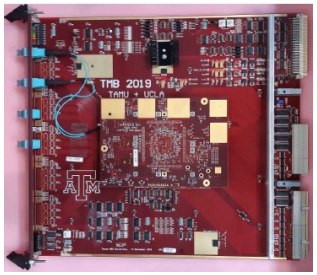
Huge thanks to TAMU colleagues and Ben without whom we would not have been possible!

Component	Total Fluence (cm^{-2})	SEUs
SY58031UMG (Fanout)	2.5×10^{11}	0
SY58017UMGTR (Mux)	2.5×10^{11}	0
ZL30267LDF1 (Clock)	2.5×10^{11}	0

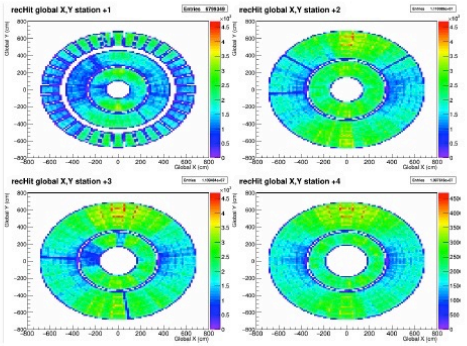


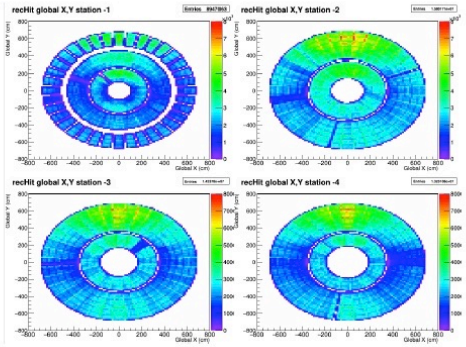
CSC LS-2 Upgrades

- Not in MREFC scope, but an important pre-requisite for the success of LS-3 upgrades: new xDCFEB boards and OTMB boards become interfaces for the LS-3 deliverables
- CSC LS-2 upgrades installation have been completed, testing and commissioning progressing very well



A healthy system after 2 years of upgrade



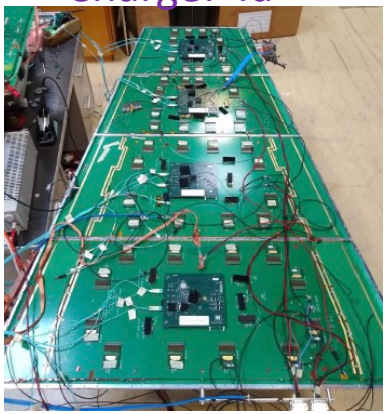


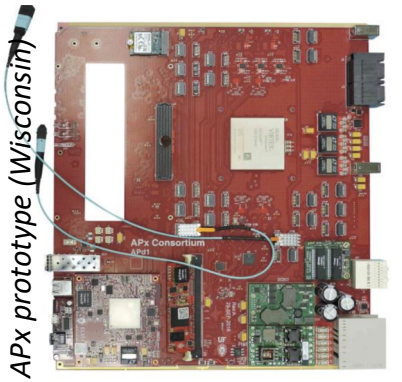
- Various isolated issues typical for re-commissioning are being identified and resolved
  - E.g. fuseholders inside junction boxes for LV in station 1 heating up due to increased resistance (and also increased currents with new electronics) – replaced with unused spares solved the problem indicating aging – looking for an alternative part
- Firmware and software updates and upgrades
  - DCS, GEM-CSC interface development etc.

Progress Summary: GEM GE21

Charge: 4a

- "Early" Phase-2 project
  - System installation in late 2023, a demonstrator chamber to be installed in Fall'21
- In CMS, GE21 is now nearly completely in construction phase:
  - Infrastructure and services released by a PRR in 2018
  - Chamber production released in EDR in 2019
  - Electronics production released in ESR in Jan.2021
    - US scope elements approved in Jul.2020 in a special PRR to allow acquisition of
      - Long lead items (FPGAs mainly) for the Optohybrid (OH) Board
      - The on-chamber and on-disc parts of the optical fiber plant to install the on-disc fibers ahead of schedule in LS-2 to shorten the time required for installation in 2024)
  - The only item left is the backend that has been kicked into a separate PRR in the future:
    - We have been planning to use one of the existing CMS ATCA boards from the trigger project, but the pre-production boards are behind schedule
    - CMS ESR review agreed with us that the interface with the backend is not a concern for the rest of the system
    - Schedule delay is not a concern as it is all off-detector and there is a very substantial float
- Construction schedule is behind but is picking up steam:
  - After initial delays due to COVID and funding availability (India, in particular has been a concern), chamber components production is ramping up
  - Electronics production: the VFAT3 (front end ASIC) manufacturing schedule slipped due to availability reductions at TSMC, but the delay is not as large as originally expected
  - Chamber assembly to start in Dec.2021 (need-by date for the US-built OH board)



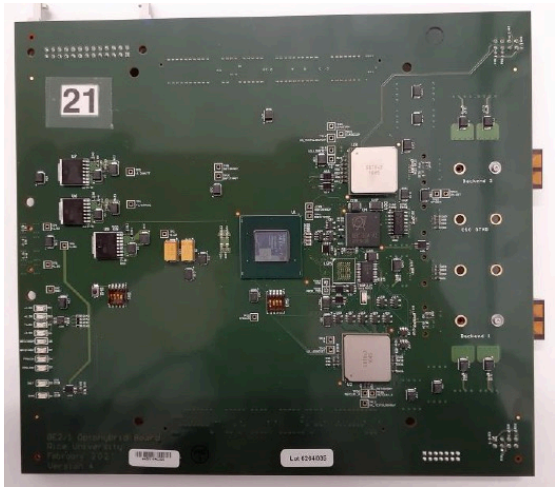


APx prototype (Wisconsin)

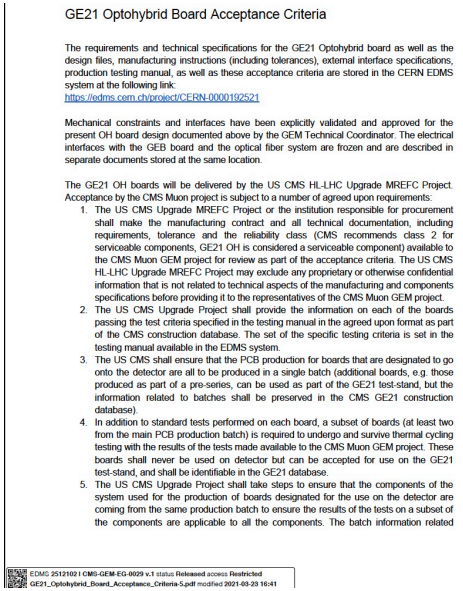
X20 Prototype (UF/UCLA)

GEM GE21: Optohybrid Board

Charge: 4a



- Technically, CMS reviewed the OH design and approved production back in July.2020
  - Purchased all long lead items but been waiting with starting the board manufacturing until the CMS ESR to minimize risks that other non-US electronics may undergo a design change
- Following the ESR review in Jan'21, we released the pre-series boards production, which have been fully tested and certified in April 2021
  - The pre-series validated the halogen-free material required by CERN ES&H (not expecting surprises, just due diligence), also temperature cycling tests to validate the quality of manufacturing and assembly
- Been artificially holding sending boards for full production
  - Pluggable CERN-built VTRX optical transceivers may need repairs for a potential technical issue discovered in calorimeter operations
  - Official CERN recommendation is expected at the end of May, expected to include a proposed fix, in which case we start production
  - A potential backup option with the CERN VTRX+ and a special adapter PCB is in place
    - Not a preferred solution as while it has been validated from the electronics stand point, it remains unclear if the cooling system can be modified to accommodate for these changes or we would need to update the OH design (which likely implies a 3-6 months delay)
  - With the CMS GE21 schedule updates, OHs will arrive well ahead of the actual need-by-date determined by the start of the chamber assembly
- Final green light for production at the very beginning of July following a series of successful reviews (including QA/QC, acceptance and handover to CMS documentation)
  - Updates to the planning to accommodate for the re-testing with "cured" VTRX devices at CERN via BCR (approved in June)



GE21 Optohybrid Board Acceptance Criteria

The requirements and technical specifications for the GE21 Optohybrid board as well as the design files, manufacturing instructions (including tolerances), external interface specifications, production testing manual, as well as these acceptance criteria are stored in the CERN EDMS system at the following link:
https://edms.cern.ch/project/CERN-0000192521

Mechanical constraints and interfaces have been explicitly validated and approved for the present OH board design documented above by the GEM Technical Coordinator. The electrical interfaces with the GEB board and the optical fiber system are frozen and are described in separate documents stored at the same location.

The GE21 OH boards will be delivered by the US CMS HL-LHC Upgrade MREFC Project. Acceptance by the CMS Muon project is subject to a number of agreed upon requirements:

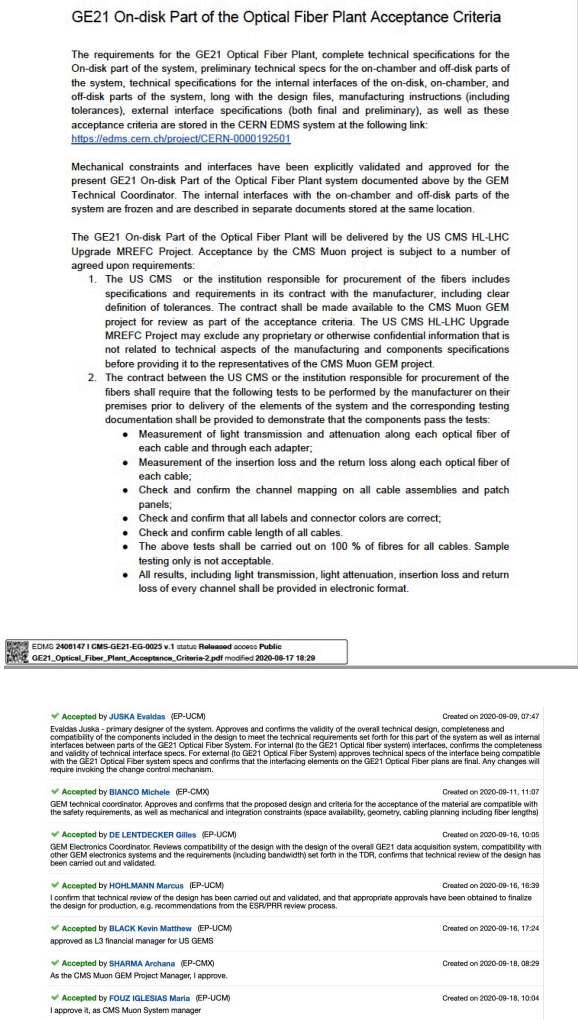
1. The US CMS Upgrade MREFC Project or the institution responsible for procurement shall make the manufacturing contract and all technical documentation, including requirements, tolerance and the reliability class (CMS recommends class 2 for serviceable components, GE21 OH is considered a serviceable component) available to the CMS Muon GEM project for review as part of the acceptance criteria. The US CMS HL-LHC Upgrade MREFC Project may exclude any proprietary or otherwise confidential information that is not related to technical aspects of the manufacturing and components specifications before providing it to the representatives of the CMS Muon GEM project.
2. The US CMS Upgrade Project shall provide the information on each of the boards passing the test criteria specified in the testing manual in the agreed upon format as part of the CMS construction database. The set of the specific testing criteria is set in the testing manual available in the EDMS system.
3. The US CMS shall ensure that the PCB production for boards that are designated to go onto the detector are all to be produced in a single batch (additional boards, e.g. those produced as part of a pre-series, can be used as part of the GE21 test-stand, but the information related to batches shall be preserved in the CMS GE21 construction database).
4. In addition to standard tests performed on each board, a subset of boards (at least two from the main PCB production batch) is required to undergo and survive thermal cycling testing with the results of the tests made available to the CMS Muon GEM project. These boards shall never be used on detector but can be accepted for use on the GE21 test-stand, and shall be identifiable in the GE21 database.
5. The US CMS Upgrade Project shall take steps to ensure that the components of the system used for the production of boards designated for the use on the detector are coming from the same production batch to ensure the results of the tests on a subset of the components are applicable to all the components. The batch information related

EDMS 2512102 | CMS-GEM-EG-0029 v.1 status Released access Restricted
GE21_Optohybrid_Board_Acceptance_Criteria-5.pdf modified 2021-03-23 16:41

GE21 Optical Fiber System

Charge: 4a

- Three parts:
  - On-chamber, on-disk, and off-detector (the sign off on the latter will happen together with the backend sign-off in a dedicated CMS PRR)
- On-disk part installed at the end of 2020
  - Connects GE21 OH boards with the backend and the CSC OTMB board for integrated GEM-CSC triggering
  - Approved by CMS PRR on July 30, 2020 along with the GE21 OH to allow early installation
    - Mitigates risks associated with the short window available for GE21 installation
  - One of our engineers traveled to CERN to lead testing and oversee installation in November of 2020
- On-chamber part fully approved in EDR/ESR in Jan'21:
  - We are holding off the procurement in case we do need to change the OH design to use VTRX+ (if no reliable solution for fixing VTRX is available)
- All documentation in CERN EDMS
  - Requirements, system specs, interfaces, manufacturing files, acceptance criteria etc.
  - Electronic approvals and full document versioning control
  - Set a standard for the new documentation (GE21 and ME0)



GE21 On-disk Part of the Optical Fiber Plant Acceptance Criteria

The requirements for the GE21 Optical Fiber Plant, complete technical specifications for the On-disk part of the system, preliminary technical specs for the on-chamber and off-disk parts of the system, technical specifications for the internal interfaces of the on-disk, on-chamber, and off-disk parts of the system, long with the design files, manufacturing instructions (including tolerances), external interface specifications (both final and preliminary), as well as these acceptance criteria are stored in the CERN EDMS system at the following link:
https://edms.cern.ch/project/CERN-0000192501

Mechanical constraints and interfaces have been explicitly validated and approved for the present GE21 On-disk Part of the Optical Fiber Plant system documented above by the GEM Technical Coordinator. The internal interfaces with the on-chamber and off-disk parts of the system are frozen and are described in separate documents stored at the same location.

The GE21 On-disk Part of the Optical Fiber Plant will be delivered by the US CMS HL-LHC Upgrade MREFC Project. Acceptance by the CMS Muon project is subject to a number of agreed upon requirements:

1. The US CMS or the institution responsible for procurement of the fibers includes specifications and requirements in its contract with the manufacturer, including clear definition of tolerances. The contract shall be made available to the CMS Muon GEM project for review as part of the acceptance criteria. The US CMS HL-LHC Upgrade MREFC Project may exclude any proprietary or otherwise confidential information that is not related to technical aspects of the manufacturing and components specifications before providing it to the representatives of the CMS Muon GEM project.
2. The contract between the US CMS or the institution responsible for procurement of the fibers shall require that the following tests to be performed by the manufacturer on their premises prior to delivery of the elements of the system and the corresponding testing documentation shall be provided to demonstrate that the components pass the tests:
   - Measurement of light transmission and attenuation along each optical fiber of each cable and through each adapter;
   - Measurement of the insertion loss and the return loss along each optical fiber of each cable;
   - Check and confirm the channel mapping on all cable assemblies and patch panels;
   - Check and confirm that all labels and connector colors are correct;
   - Check and confirm cable length of all cables.
   - The above tests shall be carried out on 100 % of fibres for all cables. Sample testing only is not acceptable.
   - All results, including light transmission, light attenuation, insertion loss and return loss of every channel shall be provided in electronic format.

EDMS **2406147 / CMS-GE21-EG-0025 v.1** status **Released** access **Public**
GE21_Optical_Fiber_Plant_Acceptance_Criteria-2.pdf modified **2020-09-17 18:29**

✔ **Accepted** by **JUSKA Evaldas** (EP-UCM) Created on 2020-09-09, 07:47
Evaldas Juska - primary designer of the system. Approves and confirms the validity of the overall technical design, completeness and compatibility of the components included in the design to meet the technical requirements set forth for this part of the system as well as internal interfaces between parts of the GE21 Optical Fiber System. For internal (to the GE21 Optical fiber system) interfaces, confirms the completeness and validity of technical interface specs. For external (to GE21 Optical Fiber System) approves technical specs of the interface being compatible with the GE21 Optical Fiber system specs and confirms that the interfacing elements on the GE21 Optical Fiber plans are final. Any changes will require invoking the change control mechanism.

✔ **Accepted** by **BIANCO Michele** (EP-CMX) Created on 2020-09-11, 11:07
GEM technical coordinator. Approves and confirms that the proposed design and criteria for the acceptance of the material are compatible with the safety requirements, as well as mechanical and integration constraints (space availability, geometry, cabling planning including fiber lengths)

✔ **Accepted** by **DE LENTDECKER Gilles** (EP-UCM) Created on 2020-09-16, 10:05
GEM Electronics Coordinator. Reviews compatibility of the design with the design of the overall GE21 data acquisition system, compatibility with other GEM electronics systems and the requirements (including bandwidth) set forth in the TDR, confirms that technical review of the design has been carried out and validated.

✔ **Accepted** by **HOHLMANN Marcus** (EP-UCM) Created on 2020-09-16, 16:39
I confirm that technical review of the design has been carried out and validated, and that appropriate approvals have been obtained to finalize the design for production, e.g. recommendations from the ESR/PRR review process.

✔ **Accepted** by **BLACK Kevin Matthew** (EP-UCM) Created on 2020-09-16, 17:24
approved as L3 financial manager for US GEMS

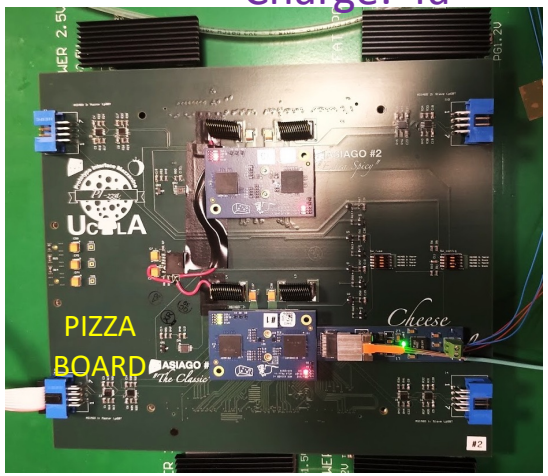
✔ **Accepted** by **SHARMA Archana** (EP-CMX) Created on 2020-09-18, 08:29
As the CMS Muon GEM Project Manager, I approve.

✔ **Accepted** by **FOUZ IGLESIAS Maria** (EP-UCM) Created on 2020-09-18, 10:04
I approve it, as CMS Muon System manager

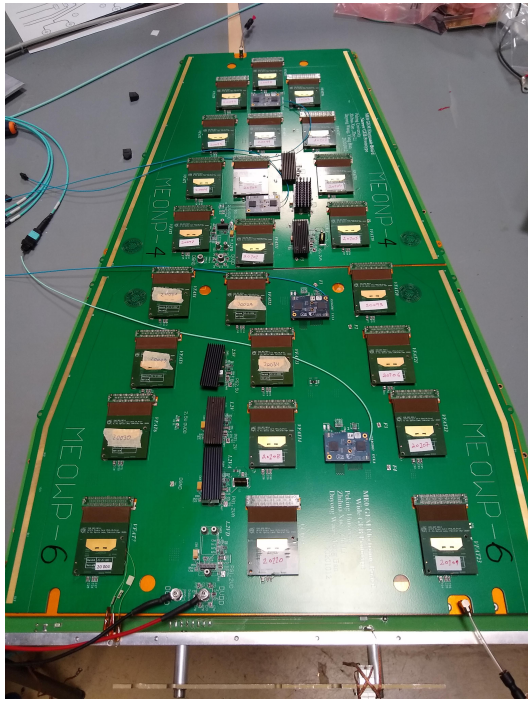
Progress Summary: GEM ME0

Charge: 4a

- A good quality ASIAGO prototype in hand since Fall of 2019
  - Support/adaptor boards (CACIO, PIZZA) allowed full validation (except mechanics/cooling) with the GE21 demonstrator
- Electrical design validation in Fall of 2020:
  - Test compatibility with the new VFAT3 and LpGBT, ATCA backend, CERN VL+ ransceivers, communications using new multi-VFAT3 addressing schema, internal control (IC) path validation
- Full set of pre-production electronics integrated at CERN in Spring'21
  - Pre-production prototypes for full ME0 design integration unavailable (planned for early 2020, but the delay with LpGBT until September made it impossible), but good quality of the previous generation of prototypes allowed integration and validation of the full module with electronics to proceed
    - Integrates OH (US), GEB (PKU), plug-in cards (INFN), and the detector module (CERN et al.)
  - LpGBT delay forced ME0 ESR to be shifted by 3 month to February 2022
    - ME0 electronics schedule has comfortably large floats, so this is not a concern



PIZZA & ASIAGO & CACIO on GE2/1 GEB



Full ME0 On-Chamber Electronics System (Spring'21)

EVM Summary

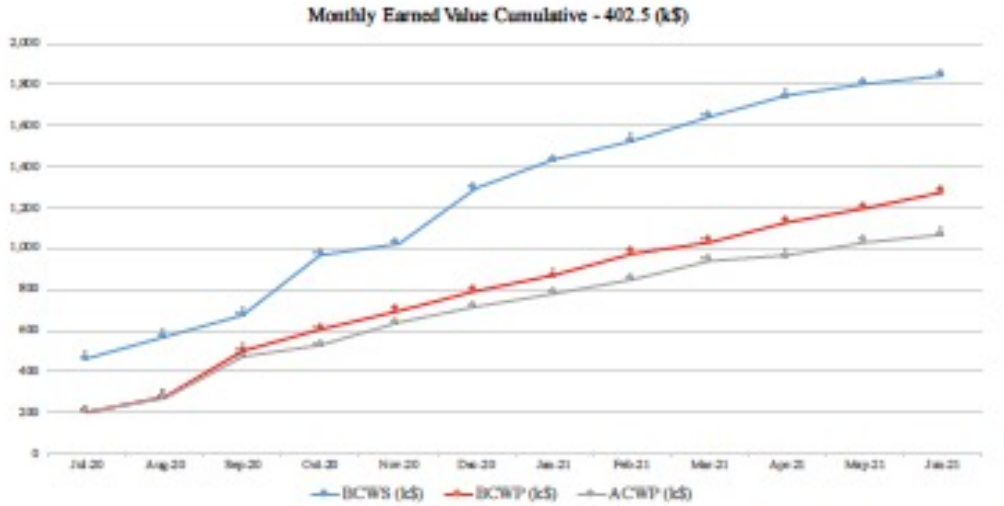
Charge: 2a

- Established a regular monthly routine
  - A joint meeting of L2, L3s, systems engineers + invitees (PIs, and technical experts)
    - Review past month technical progress and consistency of the un-invoiced accruals reported by institutions with the expectations based on the previous month planning and the progress made
    - Review and approve plans for the coming month, including planned hours on various tasks
      - PIs can use it as a reference when they provide personnel salary payment allocation and time & effort to their university accounting
    - Been able to catch a lot of common mistakes in reporting (and PI's understanding of what we are asking of them)
    - Discuss project wide issues (risks, personnel, documentation, BCR planning)
  - Specialized technical meetings
    - Typically once a month by GEM and CSC (separate meetings unless some common issues are discussed)
  - L2/L3 managers well versed in using project management tools
    - Many less comments or correction requests from the PO as they review variance reports
  - Established reporting flows and link people at institutions
    - Most PIs are familiar with the un-invoiced accruals protocols
    - Fast resolution of various funding and sub-award issues
      - Thanks to Brenda and other people at Cornell who have been there to help

EVM Summary: Cost/Schedule

Charge: 2a

- BCWP lags behind BCWS: sub-projects schedule delays
  - Typically 3-6 months, various reasons, including COVID impact
  - More details later
- Costs are generally within the original envelope
  - CPI is somewhat skewed upwards due to unspent travel/COLA
  - Zeros in Actuals are due to COLA for postdocs and students who we could not place at CERN due to COVID



Institution	Budget	Earned	Actual	CPI	SPI
BU	48,290	31,129	19,499	1.60	0.64
CL	183,677	128,446	120,815	1.06	0.70
FT	36,911	25,326	18,231	1.39	0.69
NEU	12,905	12,905	0	-	1.00
OS	192,883	155,963	129,540	1.20	0.81
RI	620,406	382,782	370,532	1.03	0.62
TAM	510,946	342,523	284,699	1.20	0.67
UCD	8,532	9,413	0	-	1.10
UCSB	41,488	41,489	37,237	1.11	1.00
UV	53,701	53,702	34,985	1.53	1.00
UW	120,831	76,917	51,881	1.48	0.64
WSU	12,798	14,119	0	-	1.10
Total	**1,843,372**	**1,274,714**	**1,067,420**	**1.19**	**0.69**

EVM Summary: Milestones

Charge: 2a

- Not many reportable (T3) milestones yet
- Projected delays for early milestones are not negligible
  - Significant impact of external factors: LpGBT delays, ASIC and FPGA shortages, international partners progress delaying major reviews
  - In some cases, schedule variances are artificial
    - E.g. of the "delayed" GE21 optical links, all the important ones are actually already installed at P5, but it looks like we are 9 months behind
- But impact on the project is so far limited
  - Later milestones delays are only ~3 months due to substantial internal floats

Milestone	Baseline	Projection
T4- CMS - Start of ME0 Demonstrator Chamber Assembly	7-Oct-20	01-Jul-21A
T4 -CMS - PRR for GE2/1 Backend	29-Sep-21	26-May-22*
E4 - CMS - GE 2/1 OH Design Review (ESR) - CMS planned date	21-Aug-20	21-Jan-22A
E4- CMS - NBD: ME0 OH prototype ready for demo chamber	11-Jan-21	Fall'21
T3 - EM - GE21 - OH Batch 1/2 ready for chamber assembly	15-Mar-21	27-Jan-22*
E4 - CMS - lpGBT PreProduction Chips Available	30-Sep-21	30-Sep-21
T3 - EM - GE2/1 - Optical Links are ready for installation at P5	19-Apr-21	5-Jan-22
T3 - EM - GE2/1 - Optical Links On-chamber Ready for Inst. at P5	10-Oct-21	1-Sep-21
T3 - EM - CSC - ODMB Board Ready for PRR	21-Jan-22	19-Aug-22
T3 - EM - ME0 - CMS ME0 Electronics ESR Complete	02-Feb-22	02-Feb-22
T3 - EM - ME0 - OH Batch 1/2 Ready for Chamber Assemb	16-Nov-22	16-Nov-22
T3 - EM - ESR for CSC FED system complete	01-Feb-23	01-Feb-23
T3 - EM - Testing Begins of ODMB5 Production Boards	02-Mar-23	29-Sep-23
T3 - EM - GE2/1 - Backend electronics is ready for inst. at P5	05-May-23	23-Aug-23
T3 - EM - CSC - All ODMB Boards Ready for Installation	27-Sep-23	01-May-24
T3 - EM - GE2/1 - Full Integration of OH & Backend Complete	11-Jan-24	28-Mar-24
T3 - EM - ME0 - Backend Electronics and Links Ready for Installation	19-Nov-24	12-Feb-22
T3 - EM - CSC - FED - Integration Completed ready for Installation at P5	03-Jan-25	03-Jan-25
T3 - EM - ME0 - Full Integration of OH & Backend Complete	22-Jan-25	08-Apr-25
T2 - EM - Endcap Muons Upgrades Complete	22-Jan-25	08-Apr-25

Covid Impacts

Charge: 2a

- Main Covid impacts
  - Relatively modest delays associated with labs/facilities closures in Spring-Summer 2020 slowing down testing
  - Significant delays with interface testing due to closures and restrictions at CERN in Summer-Fall 2020
  - Significant delays with manufacturing and shipping due to COVID impact on vendors
    - Most impacted the GE21 pre-production electronics
  - Significant delays from Fall'20 to now due to FPGA shortages and new ASIC manufacturing capacity limitations
    - Impacted all projects (CSC, GE21, ME0) and common backend
  - Significant delays due to ongoing difficulties placing personnel at CERN for integration testing and validation as well as acceptance testing
    - GEM GE21 affected the most, but others are affected due to slower progress with the backend
  - Inability to travel reduces efficiency of management and flexibility to provide expert technical manpower at CERN at the time when it is needed there
- Most of these factors impact the efficiency of technical work (higher labor costs than originally planned) and introduce schedule delays
  - Most M&S costs are well within the projected envelopes

Plans for FY2022 and iCMS Updates

Charge: 2b, 2d

- Plans for 2022
  - CSC: complete ODMB5 and ODMB7 testing and pass CMS ESR/PRR for production boards manufacturing
  - GE21: complete delivery of the Optohybrid boards, provide temporary maintenance and support for hardware until installation (handover to the Operations Program), shift main focus to software/firmware deliverables
  - ME0: complete testing of the pre-production Optohybrid boards, pass CMS ESR review to allow full production to commence
  - Backend: expect major progress (GE21 PRR, development of software/firmware for GEMs and CSCs)
- Schedule updates to realign with significant iCMS schedule changes, reflect changes in planning or resource availability
  - Several BCRs implemented in 2020 and 2021

More details in backup

BCR Number	Title	WBS Number	Owner	Status	Final		Implemented Date
					Cost Impact	Sched. Impact	
HL-LHC CMS-NSF_0130	Muon Upgrade Schedule Realignment (non-COVID)	402.05	Safonov, Alexei	Implemented	$67,685.00		7/7/2021
HL-LHC CMS-NSF_0127	Muon COVID 2021 Schedule Realignment	402.05	Safonov, Alexei	Implemented	$13,733.00	-16 days	6/4/2021
HL-LHC CMS-NSF_0115	Muon FY21 Baseline Planning Updates for SOWs	402.05	Safonov, Alexei	Implemented	$45,018.00		12/9/2020
HL-LHC CMS-NSF_0101	Forward Muons: Corrections of Minor Resource Type and Code Assignment Mistakes	402.05	Safonov, Alexei	Implemented	$2,472.41		9/1/2020

QA/QC Implementation

Charge: 2d

- Of the sub-projects, GE21 is the most advanced as it is an "early LS-3" project
  - Some of the deliverables handed over to CMS (on-disk part of the fiber plant installed at the end of 2020), others are in production (GE21 Optohybrid)
- QA/QC planning documentation underwent a significant expansion of the details for the items in the original list (requirements leading to specs and verification methods)
  - A series of reviews to establish robust QA planning for prevention and early detection of potential problems
  - Detailed specs documents, interface documents and versioning control of the design documentation using the CERN EDMS system
    - We insisted on non-US collaborators following this commonly agreed schema
  - A detailed manual for the GE21 Optohybrid (OH) establishing a full QC protocol to validate and verify specs listed in the original documentation (also in CERN EDMS)
  - Acceptance agreement co-signed by CMS and US CMS management establishing handover protocols and acceptance criteria (arising from specs), an agreement for warranty/service of the OH hardware for about ~1.5 year period until handed over to the Operations program
- Sets the precedent to follow for other sub-projects
  - CSC, ME0, common backend

QA/QC Implementation

Charge: 2d

- Specific links to documents filled in the QA/QC document for the GE21 OH QA/QC procedures as they become better understood and detailed documentation becomes available

CMS Document 13281

Document No.: CMS-FM-QAQC-doc-13281	Revision Level: A v1	Revision Date: 9 Dec 2019																
L2 WBS: 402.05	Subsystem title: Forward Muon	L2 Lead: Safonov																
WBS	WBS Title	L2, L3, L4 Lead	QA/QC Activity Name	Responsible Institution	QA/QC Coordinator/ Contact	QA/QC Activity ID	Quality Control or Assurance Activity/ Parameter	(QA) Validation Activities	(QC) Inspection / Acceptance Tests	Specification(s)	Requirement ID	Requirement Title	Measurement/ Method	Associated Hardware/ Software	Standard / Procedure / Process Doc	Calibration Planning		
402.05.04.01.01	GE2/1 OH	K. Black	Production Testing Database	Rice	L3s	FMU-QA-101	Process Control	Create a database to record test information/data for the production GE21 OH boards to ensure uniform quality control process. The database will include results of tests both at local institutions sites as well as at CERN Acceptance/Certification test site.	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 060	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, GE2/1 Optohybrid Electronics	Perform simulated data entry and read-back, review the results	Database Interface software, local DB implementation	https://edms.cern.ch/ui/#!master/navigator/document?D:100806937:100806937:subDocs	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	Local Test Stand with Software and Firmware and Validation	Rice	L3s	FMU-QA-102	Process Control	Develop hardware tools (test stand) along with software and firmware to enable testing of the production boards	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 006, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, Firmware/Software, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	Use one of the prototype boards to validate the test stand abilities to perform and record required measurements, including electrical connectivity, correct signal routing, connector pinout, FPGA and optical components.	Test-stand consisting of a GEB board with front-end chips and capabilities for readount (backend electronics setup), control computer with appropriate software	https://edms.cern.ch/ui/#!master/navigator/document?D:100806937:100806937:subDocs	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	CERN Acceptance and Certification Test Stand with Software and Firmware and Validation	Rice	L3s	FMU-QA-103	Process Control	Develop hardware fixtures (test stand) along with software and firmware to enable testing of the production boards, including electrical connectivity, routing, FPGA and optical components. Perform testing of the hardware/software/firmware	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 010, 011, 015, 016, 060, 061, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Optohybrid Firmware, GE2/1 Backend Electronics Subsystem	Develop hardware fixtures (test stand) along with software and firmware to enable testing of the production boards in the CERN environment	Production testing Test-Stand	https://edms.cern.ch/ui/#!master/navigator/document?D:100806937:100806937:subDocs	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	Develop test procedures of the boards, including final certification protocol	Rice	L3s	FMU-QA-104	Process Control	Develop a manual to document production testing procedures for the OH cards, including testing steps, software use, database format information	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	Use one of the prototype boards to validate the procedures for testing	Production testing Test-Stand	https://edms.cern.ch/ui/#!master/navigator/document?D:100806937:100806937:subDocs	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	Produce pre-production boards to validate the design meeting specs (heat, power)	Rice	L3s	FMU-QA-105	Design Verification	Perform testing of the pre-production boards to validate the design meets specifications	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 005, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, Magnetic Field Tolerance, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	test voltages, power usage, and cooling and record measurements in database	Production testing Test-Stand	https://edms.cern.ch/ui/#!master/navigator/document?D:100806937:100806937:subDocs	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	Use pre-production boards to validate the design meets specs for radiation tolerance	Rice	L3s	FMU-QA-106	Design Verification	Perform testing of the pre-production boards with the appropriate radiation source	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 004, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, Radiation Tolerance, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	Expose pre-production boards components to exceed the pre-set threshold (3 times the maximum expected HL-LHC exposure for this type of boards), measure performance as a function of TID and flux (for SEU)	Reactor, Cyclotron, specialized facilities (CHARM, GIF++)	https://edms.cern.ch/ui/#!master/navigator/document?D:100806942:100806942:subDocs	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	Produce pre-series boards to qualify vendor and the production flow	Rice	L3s	FMU-QA-107	Process Control	Perform testing of the pre-series boards to identify potential problems with the manufacturer's production setup	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	Verify correct positioning of the parts, electrical connectivity, resistance/impedance measurements, soldering quality, and all standard QC tests	Production testing Test-Stand	https://edms.cern.ch/ui/#!master/navigator/document?D:100806937:100806937:subDocs	N/A		
402.05.04.01.01	GE2/1 OH	A. Safonov	Procurement Readiness Review	CERN	L2	FMU-QA-108	Process Control	Procurement Readiness Review (partial system review for early procurements)	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	Reviewers examine design documentation, results of pre-production and prototype testing, safety, manufacturing and QC planning	N/A	CMS DocDB #13392	N/A		
402.05.04.01.01	GE2/1 OH	A. Safonov	Electronics Systems Review	CERN	L2	FMU-QA-109	Process Control	CMS Electronics Systems Review (full system review)	NA	CMS Constitution - CMS DocDB Ref # 3035	FMu-engr-002, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	Reviewers examine design documentation, results of pre-production and prototype testing, safety, manufacturing and QC planning	N/A	CMS DocDB #13392	N/A		
402.05.04.01.01	GE2/1 OH	A. Safonov	US CMS Production Readiness Review	US CMS	L2	FMU-QA-110	Process Control	US CMS Production Readiness Review	NA	CMS Constitution - CMS DocDB Ref # 3035	FMu-engr-002, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	All designs will go through formal design review under US CMS Coordination before production is launched	N/A	CMS DocDB #13093	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	Packaging for Shipment of Electronics	Rice	L3s	FMU-QA-111	Process Control	Revew packaging and shipping specifications	NA	N/A	FMu-engr-002, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	N/A	N/A	CMS DocDB #13093	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	US CMS review of production sites for testing including QC Readiness (review procedures)	US CMS	L3s	FMU-QA-112	Process Control	Review test equipment, testing manual, training of testing personnel (perform site visit as needed)	NA	NA	FMu-engr-002, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	Reviewers examine test stand, testing documentation, training procedures, QC planning, DHS. Include site visit as needed.	N/A	N/A	N/A		
402.05.04.01.01	GE2/1 OH	K. Black	Testing Documentation Control	US CMS	L3s	FMU-QA-113	Process Control	Cumulative records and documentation of components and boards, including full testing documentation	NA	https://edms.cern.ch/ui/#!master/navigator/document?P:100201970:100807084:subDocs	FMu-engr-002, 010, 011, 015, 016, 060, 070	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE2/1 Optohybrid Electronics, GE2/1 Backend Electronics Subsystem	Compile all relevant records and documentation to pass to the Operations Program	N/A	N/A	N/A		
402.05.04.01.02	GE2/1 Backend	K. Black	Production Testing Database	TAMU	L3s	FMUGEM-QA-114	Process Control	Create a database to record test information/data for the production GE21 optical fibers	NA	N/A [somewhere these database location(s) need to be identified across the project, these QAQC sheets seem as good a place as any to identify them]	FMu-engr-002, 010, 011, 015, 016, 080, 082, 083	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE21 Bi-directional Links, GE21 Uni-directional Link pair, GE21 Uni-directional Links	Perform simulated data entry and read-back, review the results	Database Interface software	Optical Fiber Testing Manual (being drafted) [need doc number]	N/A		
402.05.04.01.02	GE2/1 Backend	K. Black	CERN Test Stand with Software, Firmware, and Validation	TAMU	L3s	FMUGEM-QA-115	Process Control	Develop test stand along with software and firmware to test optical fibers and connectors to ensure uniform control process.	NA	GEM ATCA Technical Specifications Document (in CMS EDMS) [need doc number(s)]	FMu-engr-002, 010, 011, 015, 016, 080, 082, 083, 085	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE21 Bi-directional Links, GE21 Uni-directional Link pair, GE21 Uni-directional Links, GE2/1 Integrated Software	Use one of the optical fibers to validate the test stand abilities and test stand abilities to perform and record required measurements for connection and optical loss	Test-stand consising of optical transmitter and reciever, control computer, and appropriate software	Optical Fiber Testing Manual (being drafted) [need doc number]	N/A		
402.05.04.01.02	GE2/1 Backend	K. Black	Use sample fibers to validate the design meets specs for radiation tolerance	TAMU	L3s	FMUGEM-QA-116	Design Verification	Perform testing of the sample fibers with the appropriate radiation source	NA	Muon TDR [identifies radiation dose but all components must meet specs after dose. Need to	FMu-engr-002, 004, 010, 011, 015, 016, 080, 082, 083	HL Forward Muon System Gas Electron Multiplier (GEM) GE2/1 Detector Addition, Radiation Tolerance, ES&H Personnel Injury and Equipment Damage, ES&H Electrical Hazards, Logistics - Transport, Logistics - Facility, GE21 Bi-directional Links, GE21 Uni-directional Link pair, GE21 Uni-directional Links	Expose sample of fibers to exceed the pre-set threshold (3 times the maximum expected HL-LHC exposure for this type of boards), measure performance as a function of TID and flux (for	Reactor, Cyclotron, specialized facilities (CHARM, GIF++)	Technical Design Report for the threshold exposure	N/A		

QA/QC Implementation

Charge: 2d

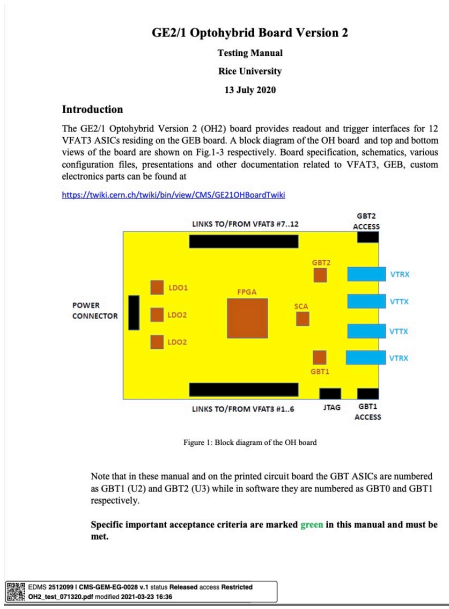
- CERN EDMS documentation for GE21 Optohybrid Board

Documents | Structure | Used in | Access rights | History

Create new document | Attach document | Detach | Auto Link | Export to Excel | Request access | Add all to Caddie | Edit Tags | Download files | Hide Obsolete

#	Id	Title	Fi…	Status	Created on	Author	Document t…	Tags
…	CMS-GEM-EG-0026 v.1	GE 2/1 OH Fiber Interface	2	Released	2021-03-23	KEVIN MATTHEW BLACK	Engineerin…	
…	CMS-GEM-EG-0028 v.1	GE 2/1 OH Testing Manual	2	Released	2021-03-23	KEVIN MATTHEW BLACK	Engineerin…	
…	CMS-GEM-EG-0029 v.1	GE 2/1 OH Acceptance Criteria	2	Released	2021-03-23	KEVIN MATTHEW BLACK	Engineerin…	
…	CMS-GEM-EG-0030 v.1	GE 2/1 OH Mechanics and Cooling Interface	2	Released	2021-03-23	KEVIN MATTHEW BLACK	Engineerin…	
…	CMS-GEM-EG-0031 v.1	GE 2/1 OH/GEB interface document	1	Released	2021-03-23	KEVIN MATTHEW BLACK	Engineerin…	
…	CMS-GEM-EG-0032 v.1	GE 2/1 OH Specifications	1	Released	2021-03-23	KEVIN MATTHEW BLACK	Engineerin…	
…	CMS-GEM-EG-0033 v.1	GE 2/1 OH Design Files	4	Released	2021-03-25	KEVIN MATTHEW BLACK	Engineerin…	
…	CMS-CMS-MR-0007 v.1	GE 2/1 OH Manufacturing Review Recommendati…	1	In Work	2021-07-01	KEVIN MATTHEW BLACK	Report (_R)	

Page 1 of 1 | Total: 17, after filter: 8 (displaying 1 - 8)



GE2/1 Optohybrid Board Version 2

Testing Manual

Rice University

13 July 2020

Introduction

The GE2/1 Optohybrid Version 2 (OH2) board provides readout and trigger interfaces for 12 VFAT3 ASICs residing on the GEB board. A block diagram of the OH board and top and bottom views of the board are shown on Fig.1-3 respectively. Board specification, schematics, various configuration files, presentations and other documentation related to VFAT3, GEB, custom electronics parts can be found at

https://twiki.cern.ch/twiki/bin/view/CMS/GE21OHBoardTwiki

Figure 1: Block diagram of the OH board

Note that in these manual and on the printed circuit board the GBT ASICs are numbered as GBT1 (U2) and GBT2 (U3) while in software they are numbered as GBT0 and GBT1 respectively.

Specific important acceptance criteria are marked green in this manual and must be met.

EDMS 2512099 | CMS-GEM-EG-0028 v.1 status Released access Restricted
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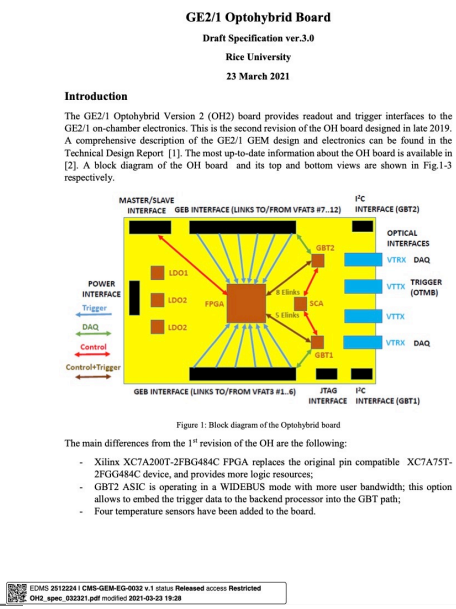


GE2/1 Optohybrid Board

Draft Specification ver.3.0

Rice University

23 March 2021

Introduction

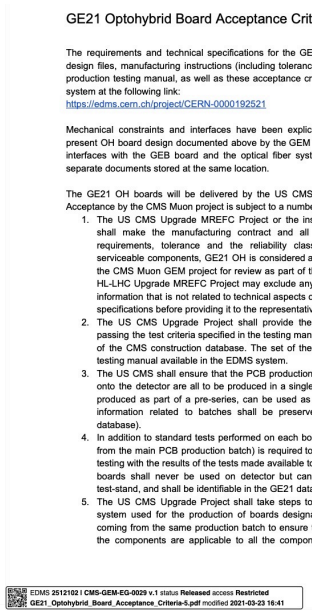
The GE2/1 Optohybrid Version 2 (OH2) board provides readout and trigger interfaces to the GE2/1 on-chamber electronics. This is the second revision of the OH board designed in late 2019. A comprehensive description of the GE2/1 GEM design and electronics can be found in the Technical Design Report [1]. The most up-to-date information about the OH board is available in [2]. A block diagram of the OH board and its top and bottom views are shown in Fig.1-3 respectively.

Figure 1: Block diagram of the Optohybrid board

The main differences from the 1st revision of the OH are the following:

- Xilinx XC7A200T-2FBG484C FPGA replaces the original pin compatible XC7A75T-2FGG484C device, and provides more logic resources;
- GBT2 ASIC is operating in a WIDEBUS mode with more user bandwidth; this option allows to embed the trigger data to the backend processor into the GBT path;
- Four temperature sensors have been added to the board.

EDMS 2512224 | CMS-GEM-EG-0032 v.1 status Released access Restricted
OH2_spec_032321.pdf modified 2021-03-23 19:28



GE21 Optohybrid Board Acceptance Criteria

The requirements and technical specifications for the GE21 Optohybrid board as well as the design files, manufacturing instructions (including tolerances), external interface specifications, production testing manual, as well as these acceptance criteria are stored in the CERN EDMS system at the following link:
https://edms.cern.ch/project/CERN-0000192521

Mechanical constraints and interfaces have been explicitly validated and approved for the present OH board design documented above by the GEM Technical Coordinator. The electrical interfaces with the GEB board and the optical fiber system are frozen and are described in separate documents stored at the same location.

The GE21 OH boards will be delivered by the US CMS HL-LHC Upgrade MREFC Project. Acceptance by the CMS Muon project is subject to a number of agreed upon requirements:

1. The US CMS Upgrade MREFC Project or the institution responsible for procurement shall make the manufacturing contract and all technical documentation, including requirements, tolerance and the reliability class (CMS recommends class 2 for serviceable components, GE21 OH is considered a serviceable component) available to the CMS Muon GEM project for review as part of the acceptance criteria. The US CMS HL-LHC Upgrade MREFC Project may exclude any proprietary or otherwise confidential information that is not related to technical aspects of the manufacturing and components specifications before providing it to the representatives of the CMS Muon GEM project.
2. The US CMS Upgrade Project shall provide the information on each of the boards passing the test criteria specified in the testing manual in the agreed upon format as part of the CMS construction database. The set of the specific testing criteria is set in the testing manual available in the EDMS system.
3. The US CMS shall ensure that the PCB production for boards that are designated to go onto the detector are all to be produced in a single batch (additional boards, e.g. those produced as part of a pre-series, can be used as part of the GE21 test-stand, but the information related to batches shall be preserved in the CMS GE21 construction database).
4. In addition to standard tests performed on each board, a subset of boards (at least two from the main PCB production batch) is required to undergo and survive thermal cycling testing with the results of the tests made available to the CMS Muon GEM project. These boards shall never be used on detector but can be accepted for use on the GE21 test-stand, and shall be identifiable in the GE21 database.
5. The US CMS Upgrade Project shall take steps to ensure that the components of the system used for the production of boards designated for the use on the detector are coming from the same production batch to ensure the results of the tests on a subset of the components are applicable to all the components. The batch information related

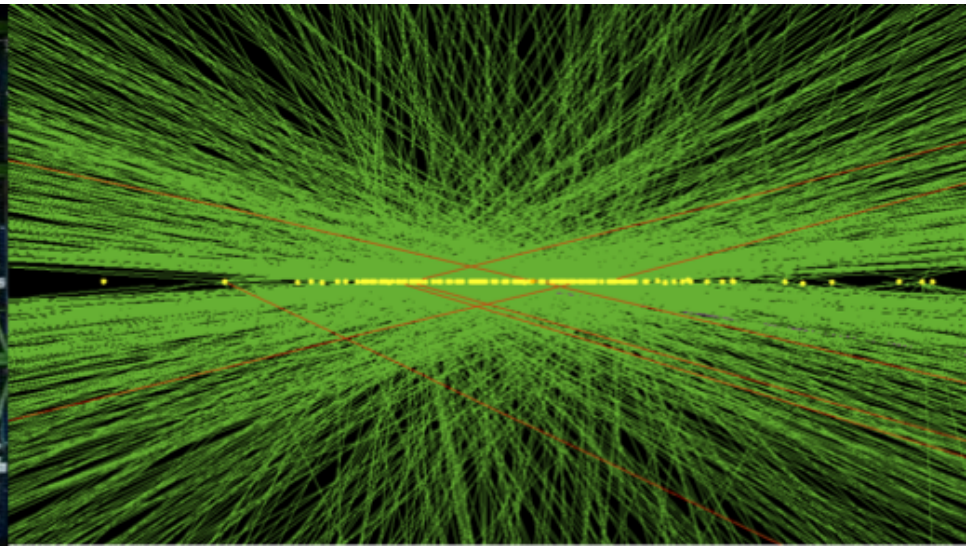
EDMS 2512102 | CMS-GEM-EG-0029 v.1 status Released access Restricted
GE21_Optohybrid_Board_Acceptance_Criteria-5.pdf modified 2021-03-23 16:41

Summary

- All sub-projects are progressing well despite many expected (and unexpected) challenges
  - All US deliverables are meeting the CMS need-by dates
- We have been able to respond to changes in a timely fashion to minimize delays and extra costs:
  - Redistributing work among institutions, pro-actively mitigating risks (GBTX for GE21), early limited scope CMS reviews to allow procurement of US deliverables, redistributing work to avoid standing army costs due to external factors (ASIC/FPGA/LpGBT delays)
- Using project management tools to plan, monitor and anticipate
  - Monthly meetings to review overall progress and in each L3 area, accruals and turnaround reporting, several BCRs processed and implemented, planning of funding (SOWs)

Additional Information

Requested at the pre-meeting n Aug. 20



GE21 and MREFC Risk Evolution

RI-ID	Title	Probability	Schedule Impact	Cost Impact
RT-402-5-01-N	EM - Pre-production electronics boards do not meet requirements	25 %	1 -- 3 -- 5 months	38 -- 74 -- 120 k$
RT-402-5-02-N	EM - Firmware release does not meet specifications	30 %	1 -- 2 -- 3 months	18 -- 72 k$
RT-402-5-04-N	EM - Problem in pre-production or production of GE21 OH boards	10 %	2 -- 4 -- 6 months	56 -- 92 -- 373 k$
RT-402-5-07-N	EM - Delay in board (pre-)production testing due to interfaces	15 %	1 -- 2 -- 6 months	5 -- 50 -- 160 k$
RT-402-5-08-N	EM - Change to scope or interface to CMS	20 %	3 -- 6 -- 12 months	25 -- 500 -- 1000 k$
RT-402-5-09-N	EM - Backend electronics board delay or a major design change	30 %	1 -- 6 -- 12 months	0.5 -- 120 -- 225 k$
RT-402-5-10-N	EM - Electronics boards design needs additional testing or integration	20 %	1 -- 3 -- 6 months	10 -- 36 -- 108 k$
RT-402-5-05-N	EM - ME0 OH board - FPGA is insufficiently radiation hard	15 %	3 -- 4.5 -- 6 months	99 -- 231 -- 363 k$
RT-402-5-06-N	EM - lpGBT chip or VL+ components delays GE2/1 electronics design	75 %	0 -- 4 months	211 -- 236 -- 291 k$
RT-402-3-10-N	BC/EM/FP - lpGBT chip is delayed	50 %	6 -- 12 months	0 k$

added in 2020

added in 2020

retired in 2019

retired in 2020

added in 2020

- GE21 is one of the earliest projects in MREFC: installation in the Fall of 2023
- Active risk management/mitigation been an integral part of our planning
  - Optohybrid boards: first boards needed for the start of assembly
    - CMS forecast for chamber installation: late December
  - Optical Fiber-plant (partially installed):
  - Backend electronics: the (soft) need-by-date agreed upon with CMS is March 2024

GE21 OH: Risk Evolution

- GE21 Optohybrid boards:
  - We insisted on modifying the design to remove the LpGBT chip from the design
    - CMS eventually agreed with us and we retired the corresponding risk at the end of February of 2020
  - Approved by CMS for procurement in August of 2020 in a special PRR review by CMS (we requested it so we could buy the long lead items on time)
    - To finalize the validation of external interfaces, we built our own GE21 plug-in cards (a non-US scope) that have been designed by our collaborators but not produced due to funding issues
  - Remaining GE21 electronics approved by CMS for construction in Jan'21
    - At that time the likelihood of interface changes has been vastly reduced, but new concerns emerged about the CERN VTRX optical transceivers losing performance (a part of the CERN rad hard versatile link system that includes GBTX+VTRX)
    - Finally sent into production in July'21 once a fix for the VTRXs has been identified by CERN (we also have identified a backup solution while waiting)
    - Some modification to the production testing plan (extended the testing program at CERN as the VTRXs will be installed onto the OHs at CERN now)
  - Extensive preparation for production board testing in the US and at CERN
    - Detailed QA/QC planning, documentation, testing manuals, setting up a new test stand at CERN
  - Handing over the boards to CMS in late Fall'21 (first boards) – Winter'22 (last ones)
    - A number of risks will be updated as GE21 will no longer be subject to those risks
- Backend electronics: the need-by-date agreed upon with CMS is March 2024
  - We agreed with CMS to separate the approval of the backend and the off-disk part of the optical fiber plant from the rest, planned for the Fall of 2021
  - Tracked under RT-402-5-09

GE21: iCMS Risk Register

- X

Merlin WBS Number	Activity	Risk ID	Risk Description	Impact Description	Likelihood (L/M/H)	CORE cost impact (L/M/H)	Schedule Impact (L/M/H)
2.5.2.1	GE2/1 Detectors	4.1	Sub-standard quality of the GEM foils delivered by external vendors or delays in manufacturing	If quality of GEM foils is inadequate, foils will need to be re-made leading to delays in the schedule and potentially lead to cost increases. If the impact on schedule is severe enough, it can impact readiness of the detector for installation	M	L	M
		4.2	Delay in detailed designs of 8 different module types	Delay in completion of the detailed engineering drawings/designs can delay the start of production of GEM modules and impact the schedule.	RETIRED	L	M
		4.3	Delay in production of other module and chamber components	If components required for module or chamber construction arrive late, that can potentially delay production of GEM modules.	H	L	L
		4.4	Insufficient module assembly rate at certain production sites	Lower than expected rate of module produciton at one or more pmodule production sites has the potential of delaying completion of GEM modules and the overall schedule of production and manufacturing.	L	L	M
		4.5	GE1/1 production schedule delays impacting GE2/1 schedule	As GE2/1 production relies on the same resources (manpower, module production sites, chamber assembly sites, storage and cosmis stand facilities at CERN) as GE1/1 production, delays in GE1/1 construction project can reduce the available manpower and access to facilities involved in production of GE2/1 detectors. The risk can realize independently of whether GE1/1 is installed on time and the severity is determined by how much of the delay is accumulated. Up to 6 month delay (max schedule impact associated to this risk) can be absorbed by the available float in the schedule.	L	L	M

GE21: iCMS Risk Register 1/2

- GE21 project wise, most significant risks are in detector production
  - Driven by funding delays and COVID

Merlin WBS Number	Activity	Risk ID	Risk Description	Impact Description	Likelihood (L/M/H)	CORE cost impact (L/M/H)	Schedule Impact (L/M/H)
2.5.2.1	GE2/1 Detectors	4.1	Sub-standard quality of the GEM foils delivered by external vendors or delays in manufacturing	If quality of GEM foils is inadequate, foils will need to be re-made leading to delays in the schedule and potentially lead to cost increases. If the impact on schedule is severe enough, it can impact readiness of the detector for installation	M	L	M
		4.2	Delay in detailed designs of 8 different module types	Delay in completion of the detailed engineering drawings/designs can delay the start of production of GEM modules and impact the schedule.	RETIRED	L	M
		4.3	Delay in production of other module and chamber components	If components required for module or chamber construction arrive late, that can potentially delay production of GEM modules.	H	L	L
		4.4	Insufficient module assembly rate at certain production sites	Lower than expected rate of module produciton at one or more pmodule production sites has the potential of delaying completion of GEM modules and the overall schedule of production and manufacturing.	L	L	M
		4.5	GE1/1 production schedule delays impacting GE2/1 schedule	As GE2/1 production relies on the same resources (manpower, module production sites, chamber assembly sites, storage and cosmis stand facilities at CERN) as GE1/1 production, delays in GE1/1 construction project can reduce the available manpower and access to facilities involved in production of GE2/1 detectors. The risk can realize independently of whether GE1/1 is installed on time and the severity is determined by how much of the delay is accumulated. Up to 6 month delay (max schedule impact associated to this risk) can be absorbed by the available float in the schedule.	L	L	M

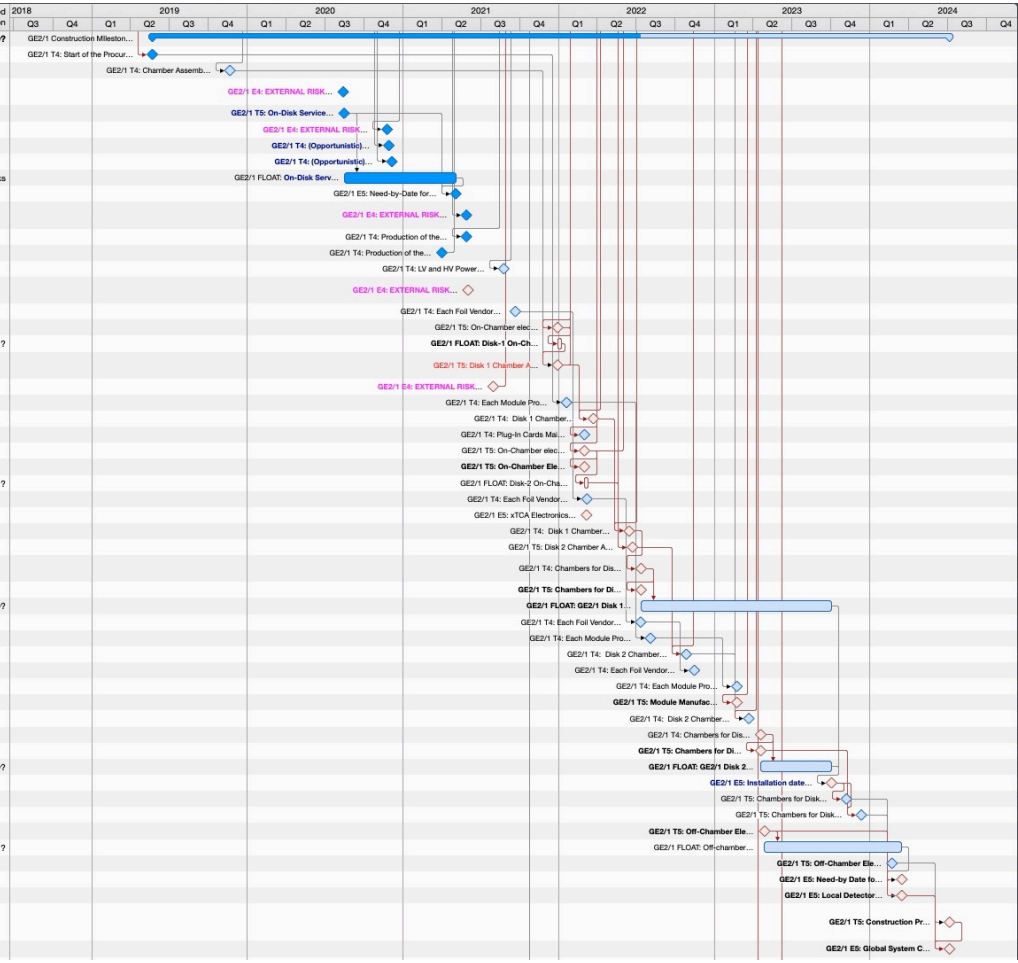
GE21: iCMS Risk Register – 2/2

- Likelihood of significant electronics related risks realizing is quickly diminishing, given extensive integration and maturity of the designs
  - Multiple cycles of prototyping, extensive integration, qualified vendors, funding in place

Merlin WBS Number	Activity	Risk ID	Risk Description	Impact Description	Likelihood (L/M/H)	CORE cost impact (L/M/H)	Schedule Impact (L/M/H)
2.5.2.2	GE2/1 DAQ System	4.6	delay of the design completion for one of the boards (except on-chamber boards) due to unforeseen circumstances, e.g. repitative failure of alternate components to pass radiation requirements, or due to external factors	Completion of board design leading to board production affecting the schedule and potentially leading to a late delivery of the board.	M	L	L
		4.7	Problem in design or production yield of GE21 on-chamber electronics boards	If a problem occurs in design or production, then the schedule can be significantly delayed, which in the worst case can result in a late delivery to CMS, which in turn will not allow CMS to install GE21 chambers early and require re-scheduling its installation. The severity depends on the lateness of the time a problem is dicovered, so while the schedule impact would increase as afunction of time, the likelihood of such event decreases if appropriate mitigation measures are in place.	L	M	H
		4.8	lpGBT chip delay impact on GE2/1 construction	The risk addresses the situation, in which the LpGBT chip is not available in time for the GE2/1 Optohybrid board final design validation and start of production. GE2/1 is one of earliest sub-projects of the forward muon sub-projects with the target installation prior to LS3. Because of its early installation, the GE2/1 detector assembly takes place substantially earlier than most Phase-2 CMS Upgrade projects, and with the updates on the LpGBT schedule reported, the expected delivery date for LpGBT is getting closer to the time when these chips would be necessary for the OH board assembly that preceeds the full chamber assembly.	RETIRED (GE21-003 CC)	M	L
		4.9	VFAT3 ASIC performance significantly substandard due to mismatch in capacitance wth the detector	The risk addresses the situation, in which the VFAT3 chip's operational characteristics (noise) are found to be substantially substandard given mismatch in strip capacitance. The VFAT3 chip being produced and qualified for GE11 has been optimized for the GE11 detector's capacitances, which are not the same as those of GE21 detector. If the difference in capacitane turns out to be sufficient to impact chip performance in a substantive way, that would require a partial design update to the chip, submission for an engineering run yielding increased cost and additional testing that would impact the schedule	RETIRED (GE21-001 CC)	L	H
		4.10	Loss of key engineer on the Project	Completion of the electronics design, testing of the electronics, completion of the design of firmware or software components, completion of electronics integration activities	L	L	M
2.5.2.3	GE2/1 Power System	4.11	One of the components does not meet requirements in terms of performance, longevity, or reliability	Examples include high performance connectors candidates and similar passive components. If the currently considered candidate components are found to not be reliable or performant enough, these components will need to be replaced with a different connector type, likely leading to non negligible cost increases and schedule delays	L	L	L
2.5.2.5	GE2/1 Integration	4.12	Failure to complete detector installation at P5 within the allocated time window	As the time allocated for detetcor installation during YETS2022 and YETS2023 is verly limited, there is a risk that the installation may not be completed within the set time frame.	M	L	H

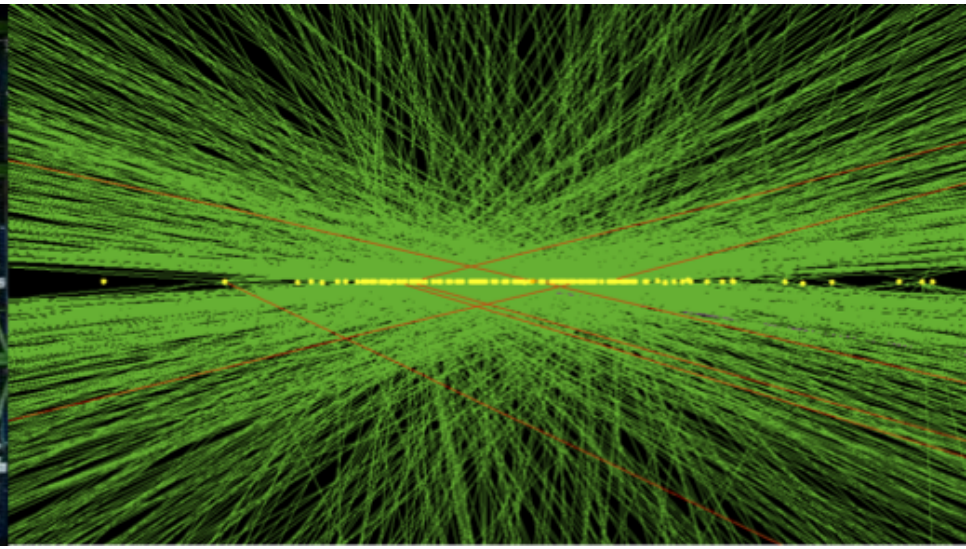
GE21 iCMS Schedule

#	WBS Code	Title	Master Schedule reference	Expected Start	Expected End	Expected Duration
1,642	2.5.2.10.421	**GE2/1 Construction Milestones**		**May 23, 2019**	**July 5, 2024**	**267.4w?**
1,643	2.5.2.10.421.438	GE2/1 T4: Start of the Procurements for Module Production		May 23, 2019	May 23, 2019	
1,644	2.5.2.10.421.463	GE2/1 T4: Chamber Assembly Components and Setup are Ready to Start Chamber Assembly		Nov 20, 2019	Nov 20, 2019	
1,645	2.5.2.10.421.454	GE2/1 E4: EXTERNAL RISK THREAD: GE21 (At Least Partial) Funding Available for GE21 Module PCBs Used in GE21 Module Assembly		Aug 12, 2020	Aug 12, 2020	
1,646	2.5.2.10.421.450	**GE2/1 T5: On-Disk Services Installation (excludes fibers) at P5 is Complete**	GE21.PR.DET.1	Aug 14, 2020	Aug 14, 2020	
1,647	2.5.2.10.421.420	GE2/1 E4: EXTERNAL RISK THREAD: GE21 Foil Production at CERN Can Re-Start (following cross-talk R&D)		Nov 23, 2020	Nov 23, 2020	
1,648	2.5.2.10.421.450	**GE2/1 T4: (Opportunistic) On-Disk Fibers Installation at P5 is Complete for Endcap-1**		Nov 27, 2020	Nov 27, 2020	
1,649	2.5.2.10.421.450	**GE2/1 T4: (Opportunistic) On-Disk Fibers Installation at P5 is Complete for Endcap-2**		Dec 4, 2020	Dec 4, 2020	
1,650	2.5.2.10.421.468	GE2/1 FLOAT: **On-Disk Services Installation to NEED-BY-DATE**		Aug 14, 2020	May 3, 2021	37.2 weeks
1,651	2.5.2.10.421.467	GE2/1 E5: Need-by-Date for Services Installation Completion (Assume end of LS2)		May 3, 2021	May 3, 2021	
1,652	2.5.2.10.421.420	GE2/1 E4: EXTERNAL RISK THREAD: Mecaro GE21 Foil Production Start Delayed (date that procurements can start)		May 28, 2021	May 28, 2021	
1,653	2.5.2.10.421.464	GE2/1 T4: Production of the First GE2/1 Module Has Started		May 28, 2021	May 28, 2021	
1,654	2.5.2.10.421.464	GE2/1 T4: Production of the Cooling Circles Has Started (Work on getting Funding in Place is still proceeding)		April 1, 2021	April 1, 2021	
1,655	2.5.2.10.421.429	GE2/1 T4: LV and HV Power Supply Pre-Series modules tested and validated		Aug 24, 2021	Aug 24, 2021	
1,656	2.5.2.10.421.454	GE2/1 E4: EXTERNAL RISK THREAD: Re-start production of PCBs used in module asssembly beyond the initial batch (depends on funding availability)		June 1, 2021	June 1, 2021	
1,657	2.5.2.10.421.441	GE2/1 T4: Each Foil Vendor Delivers 25% of Foils Assigned		Sep 20, 2021	Sep 20, 2021	
1,658	2.5.2.10.421.451	GE2/1 T5: On-Chamber electronics components ready for Disk-1 Chamber Assembly		Dec 28, 2021	Dec 28, 2021	
1,659	2.5.2.10.421.445	**GE2/1 FLOAT: Disk-1 On-Chamber Electronics Components Ready for Installation to NEED-BY date**		Dec 28, 2021	Dec 28, 2021	0 weeks ?
1,660	2.5.2.10.421.443	GE2/1 T5: Disk 1 Chamber Assembly Starts (DRIVEN BY AVAILABILITY OF ELECTRONICS AND COMPONENTS, CONSTRAINED BY RESOURCE AVAILABILITY DUE TO GE11 Commissioning)		Dec 28, 2021	Dec 28, 2021	
1,661	2.5.2.10.421.454	GE2/1 E4: EXTERNAL RISK THREAD: Availability of VFAT3 ASIC wafers (main production batch)		July 30, 2021	July 30, 2021	
1,662	2.5.2.10.421.448	GE2/1 T4: Each Module Production Site Delivers 33% of Modules Assigned		Jan 18, 2022	Jan 18, 2022	
1,663	2.5.2.10.421.452	GE2/1 T4: Disk 1 Chamber Assembly 50% Completed		Mar 22, 2022	Mar 22, 2022	
1,664	2.5.2.10.421.7	GE2/1 T4: Plug-In Cards Main production batch ready for Chamber assembly		Mar 1, 2022	March 1, 2022	
1,665	2.5.2.10.421.435	GE2/1 T5: On-Chamber electronics components ready for Disk-2 Chamber Assembly		Mar 1, 2022	March 1, 2022	
1,666	2.5.2.10.421.447	**GE2/1 T5: On-Chamber Electronics Manufacturing and Testing is Completed**	GE21.PR.FE.1	Mar 1, 2022	March 1, 2022	
1,667	2.5.2.10.421.459	GE2/1 FLOAT: Disk-2 On-Chamber Electronics Components Ready for Installation to NEED-BY date		Mar 1, 2022	March 1, 2022	0 weeks ?
1,668	2.5.2.10.421.456	GE2/1 T4: Each Foil Vendor Delivers 50% of Foils Assigned		Mar 7, 2022	March 7, 2022	
1,669	2.5.2.10.421.444	GE2/1 E5: xTCA Electronics Available for Ordering (External Constraint)		Mar 7, 2022	March 7, 2022	
1,670	2.5.2.10.421.436	GE2/1 T4: Disk 1 Chamber Assembly 100% Completed		June 14, 2022	June 14, 2022	
1,671	2.5.2.10.421.425	GE2/1 T5: Disk 2 Chamber Assembly Starts		June 23, 2022	June 23, 2022	
1,672	2.5.2.10.421.442	GE2/1 T4: Chambers for Disk 1 Produced, Tested and Certified, ready for installation. Ready to start testing and certification of chambers for Disk-2.		July 12, 2022	July 12, 2022	
1,673	2.5.2.10.421.426	**GE2/1 T5: Chambers for Disk-1 are Assembled, Tested, and Ready for Installation**	GE21.PR.DET.2	July 12, 2022	July 12, 2022	
1,674	2.5.2.10.421.445	**GE2/1 FLOAT: GE2/1 Disk 1 Ready for Installation to TC Installation Start Date**		July 12, 2022	Oct 2, 2023	63.8w?
1,675	2.5.2.10.421.428	GE2/1 T4: Each Foil Vendor Delivers 75% of Foils Assigned		July 11, 2022	July 11, 2022	
1,676	2.5.2.10.421.434	GE2/1 T4: Each Module Production Site Delivers 66% of Modules Assigned		Aug 3, 2022	August 3, 2022	
1,677	2.5.2.10.421.457	GE2/1 T4: Disk 2 Chamber Assembly 50% Completed		Oct 26, 2022	Oct 26, 2022	
1,678	2.5.2.10.421.439	GE2/1 T4: Each Foil Vendor Delivers 100% of Foils Assigned		Nov 14, 2022	Nov 14, 2022	
1,679	2.5.2.10.421.432	GE2/1 T4: Each Module Production Site Delivers 100% of Modules Assigned		Feb 22, 2023	Feb 22, 2023	
1,680	2.5.2.10.421.460	**GE2/1 T5: Module Manufacturing and Testing is Complete**	GE21.PR.DET.3	Feb 22, 2023	Feb 22, 2023	
1,681	2.5.2.10.421.433	GE2/1 T4: Disk 2 Chamber Assembly 100% Completed		Mar 22, 2023	Mar 22, 2023	
1,682	2.5.2.10.421.423	GE2/1 T4: Chambers for Disk 2 Produced, Tested and Certified, ready for installation		April 19, 2023	April 19, 2023	
1,683	2.5.2.10.421.427	**GE2/1 T5: Chambers for Disk-2 are Assembled, tested, and Ready for Installation**	GE21.PR.DET.4	April 19, 2023	April 19, 2023	
1,684	2.5.2.10.421.446	**GE2/1 FLOAT: GE2/1 Disk 2 Ready for Installation to TC Installation Start Date**		April 19, 2023	Oct 2, 2023	23.6w?
1,685	2.5.2.10.421.449	**GE2/1 E5: Installation date agreed upon with TC (2020 schedule update)**		Oct 2, 2023	Oct 2, 2023	
1,686	2.5.2.10.421.437	GE2/1 T5: Chambers for Disk-1 Installed and Tested		Nov 6, 2023	Nov 6, 2023	
1,687	2.5.2.10.421.430	GE2/1 T5: Chambers for Disk-2 Installed and Tested		Dec 11, 2023	Dec 11, 2023	
1,688	2.5.2.10.421.421	**GE2/1 T5: Off-Chamber Electronics Manufacturing and Testing Completed and Ready for Installation**	GE21.PR.BE.1	April 28, 2023	April 28, 2023	
1,689	2.5.2.10.421.466	GE2/1 FLOAT: Off-chamber electronics ready for installation to need-by date		April 28, 2023	Mar 15, 2024	46 weeks ?
1,690	2.5.2.10.421.453	**GE2/1 T5: Off-Chamber Electronics Integration Complete**	GE21.PR.BE.2	Feb 21, 2024	Feb 21, 2024	
1,691	2.5.2.10.421.455	**GE2/1 E5: Need-by Date for Off-Chamber Electronics (Local Detector Commissionning Starts)**		Mar 15, 2024	Mar 15, 2024	
1,692	2.5.2.10.421.455	**GE2/1 E5: Local Detector Commissionning Starts (External Constraint)**		Mar 15, 2024	Mar 15, 2024	
1,693	2.5.2.10.421.431	**GE2/1 T5: Construction Project Complete. Ready for Global System Commissionning.**	GE21.PR.DET5 GE21.PR.FE.2 GE21.PR.BE.3	July 5, 2024	July 5, 2024	
1,694	2.5.2.10.421.424	**GE2/1 E5: Global System Commissionning Starts (External Constraint)**		July 5, 2024	July 5, 2024	



- The schedule is driven by the module/chamber assembly that starts once all the electronics is in place
  - Expect last pieces to be the plug-in cards that require ASICs
  - Current float is 24 weeks

References



R&D Milestones

WBS	Milestone	Planned Finish Date	Last Month's Finish Date	Forecast Finish Date
TFPX 402.7.3	RD53A received for physical testing	Dec-17	Jan-18	Completed Jan-18
TFPX 402.7.6	Demonstrate structural characteristics of step section	Apr-18	Apr-18	Completed May-18
TFPX 402.7.4	Demonstrage HDI handling in module assembly	Oct-18	Oct-18	Completed Oct-18
TFPX 402.7.6	Demonstrate services mounting on mockup service cylinder	Oct-18	Jan-20	Completed Jan-19
TFPX 402.7.6	Demonstrate thermal properties of prototype dee	Nov-18	Aug-19	Completed Jul-19
TFPX 402.7.5	Demonstrate RD53A readout capability	Nov-18	Nov-18	Completed Sep-18
TFPX 402.7.3	Evaluate irradiated prototype sensor in beam test	Dec-18	Dec-18	Completed Nov-18
TFPX 402.7.3	Complete production of thermal mockup modules	Jan-19	Jan-19	Completed Jan-19
TFPX 402.7.6	Fabricate installation hardware and conduct mock insertion studies	Jun-19	Dec-19	Completed Jan-20
TFPX 402.7.5	Module readout and prototype evaluation system developed	Jun-19	Jun-19	Completed Jun-19
TFPX 402.7.3	Complete irradiation studies of planar sensors to full fluence	Jul-19	Jul-19	Completed Jun-19
TFPX 402.7.5	DTC prototype evaluated	Jul-19	Jul-19	Completed Jul-19
TFPX 402.7.3	Establish that radiation damage gradient in inner rings can be accomodated without efficiency loss	Sep-19	Dec-19	Completed Jan-20
TFPX 402.7.4	Demonstrate functionality of prototype tooling for module assembly	Sep-19	Dec-19	Completed Jan-20
TFPX 402.7.5	Prototype portcard with first version of the LpGBT, Versalink, and DCDC chips fabricated	Sep-19	Sep-19	Completed Sep-19
TFPX 402.7.6	Fabricate first prototype service half-cylinder	Oct-19	Oct-19	Completed Jul-19
TFPX 402.7.3	Submit first version of the CPC ROC for production (external)	Dec-19	Apr-20	Jun-20
TFPX 402.7.4	Establish capabilities of at least one additional module factory	Dec-19	Feb-20	Completed Feb-20
TFPX 402.7.5	Prototype e-link and connector design evaluated	Dec-19	Dec-19	Completed Dec-19
TFPX 402.7.6	Complete initial thermal and mechanical studies for dee	Dec-19	Mar-20	Dec-20
TFPX 402.7.4	Complete selection of materials for preproduction modules based on thermal performance, radiation hardness, and assembly studies	Apr-20	Apr-20	Dec-20
TFPX 402.7.3	3D sensors (or inner ring sensor) irradiated to full fluence	Apr-20	Apr-20	Apr-21
BCAL 402.3.3	Demonstration of readout chain using CTP7 with ECAL barrel front-end electronics	Sep-17	Sep-17	Completed Aug-17
BCAL 402.3.3	Define the off-detector architecture	Sep-17	Sep-17	Completed Sep-17
BCAL 402.3.4	HCAL demonstrator chain tests	Dec-18	Dec-18	Completed Dec-18
BCAL 402.3.3	FE Prototype 1 tests	Dec-18	Dec-18	Completed Dec-18
BCAL 402.3.3	FE Prototype 2 tested	Dec-19	Mar-20	Apr-20
BCAL 402.3.3	BCP Prototype tested	Dec-19	Apr-20	Jun-20
MUON 402.5.4	Preliminary design of GE2/1 backend system	Mar-18	Mar-18	Completed Mar-18
MUON 402.5.3	Design of FE2.1 OH board prototype complete	Sep-18	Sep-18	Completed Sep-18
MUON 402.5.3	Complete GE2/1 OH board prototype ready for GE2/1 demonstrator	Dec-18	Dec-18	Completed Dec-18
MUON 402.5.4	Backend processor board selected for CSC, GE2/1, ME0	Dec-18	Dec-18	Completed Dec-18
MUON 402.5.4	Pre-production prototype of the GE2/1 OH board	Jul-19	Nov-19	Completed Nov-19
MUON 402.5.4	Pre-Production Prototype of the GE2/1 OH Board Ready for the GE2/1 Demonstrator	Oct-19	Jan-20	Completed Jan-20
MUON 402.5.4	First Fully Functional Prototype of the ME0 OH Board Ready for the ME0 Demonstrator	Nov-19	Nov-19	Completed Nov-19
MUON 402.5.3	CSC ODMB : Prototype Received	Dec-19	Mar-20	Jun-20
TRIG 402.9.7	µTCA 25 Gbps demonstrator board testing complete	Apr-18	Apr-18	Completed Apr-18
TRIG 402.9.4	Barrel and endcap muon trigger initial algorithm and performance	Mar-18	Mar-18	Completed Mar-18
TRIG 402.9.4	Barrel muon trigger initial algorithm firmware	Jun-18	Jun-18	Completed May-18
TRIG 402.9.4	PTLUT1 memory mezzanine design	Jun-18	Jun-18	Completed May-18
TRIG 402.9.4	PTLUT1 first mezzanines	Sep-18	Sep-18	Completed May-18
TRIG 402.9.4	PTLUT1 card tested	Dec-18	Dec-18	Completed Dec-18
TRIG 402.9.7	Complete track trigger ATCA daughter board design	Dec-18	Feb-19	Completed Feb-19
TRIG 402.9.4	Muon trigger prototype board + memory card tested	Mar-19	May-19	Completed May-19
TRIG 402.9.7	First testing of track trigger ATCA prototype complete	Apr-19	Jun-19	Completed May-19
TRIG 402.9.7	Reference algorithm for track trigger defined	Apr-19	Apr-19	Completed Apr-19
TRIG 402.9.4	Demonstration of muon trigger physics requirements with pro	Dec-19	Dec-19	Completed Dec-19
TRIG 402.9.7	Track trigger preproduction design begins	Jan-20	Jan-20	Completed Feb-20

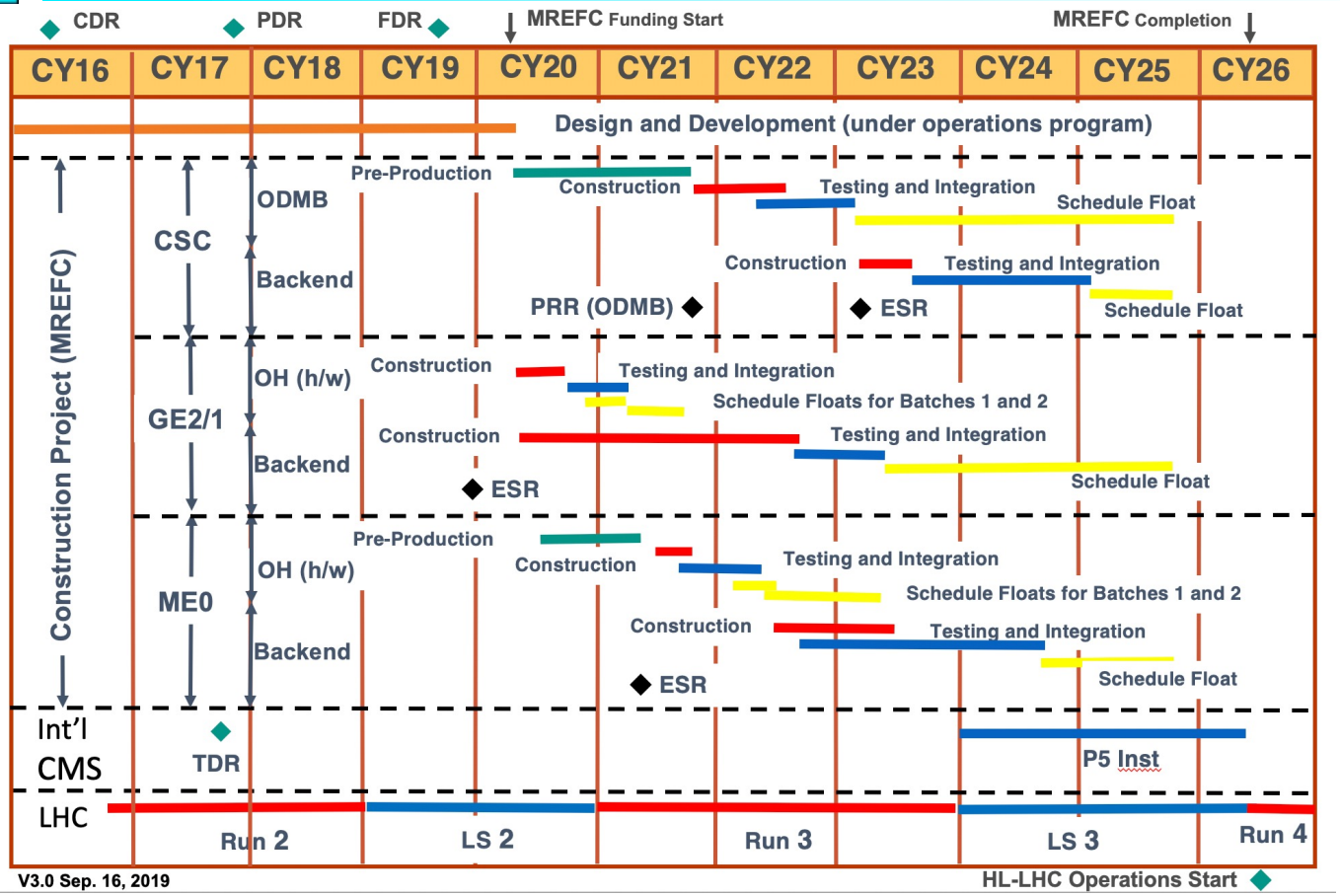
No formal recommendations at the FDR closing for the R&D completion stage

- Longest delay in the R&D stage driven by waiting for validating interfaces in GEM GE21 project:
  - Ended up manufacturing a small electronics board designed by an international collaborator using their blueprints and separated US deliverables into a separate CMS PRR review for approval to proceed with the long lead items procurement and not wait for a delayed GE21 ESR review, which saved at least 6 months of schedule delay
  - Other delays: (i) the backend system test stand setup at CERN, been waiting for the backend driver board prototypes (use boards from another US CMS project to save on development and future maintenance costs, (ii) testing CSC ODMB components for radiation hardness

Muon Dates (Cartoon Schedule)

Milestone	Date	Comment
NSF CDR	2016-03-15	Actual date
NSF PDR	2017-12-12	Actual date for review
NSF FDR	2019-09-18	Actual date for review
NSF MREFC start	2020-04-01	Actual MREFC start
NSF MREFC end	2026-12-31	Target end. (6th year of project ends)
R&D end	2020-04-01	End R&D when we have MREFC funds
Pre-Prod. start	2020-04-01	Start pre-prod. when we have MREFC funds
Pre-Prod. end	2022-06-07	Scheduled pre-prod end
Production start	2021-07-03	Actual Production start
Production end	2023-07-31	Scheduled Production end
Int. start	2022-11-22	Scheduled Integration start
Int. end	2025-01-22	Scheduled Integration end
TDR available	2017-09-12	Actual date
PRR	2021-09-29	Schedule PRR
PRR	2022-03-30	Scheduled PRR
ESR	2021-01-20	Schedule ESR
ESR	2022-02-02	Schedule ESR
ESR	2023-02-01	Schedule ESR
CMS need-by-date	2025-12-01	Planned need by date

Schedule Summary (at FDR)



- Phases of MREFC schedule:
  - Preproduction – qualify using final parts and design
  - Construction – production of full quantity
  - Testing & Integration – QA/QC all levels, ready for CMS installation

Budget Summary (at FDR)

HL-LHC CMS Upgrades NSF MREFC scope			402.0 PM - Project Management	402.3 BC - Barrel Calorimeter	402.5 EM - Endcap Muons	402.7 FP - Forward Pixels	402.9 TD - Trigger and DAQ	Total	
								FTE-yrs	k$
Base Cost = Direct + Indirect + Escalation	Scientific Labor	FTE-yrs	10	17	26	75	31	160	
	Costed Labor	FTE-yrs	11	22	16	91	37	179	
	Total Labor	**FTE-yrs**	**21**	**40**	**43**	**166**	**68**	**338**	
	Total Labor	**k$**	**2,155**	**3,495**	**2,338**	**8,801**	**4,981**		**21,769**
	COLA	k$	383	51	343	146	251		**1,173**
	Common Fund	k$	1,407						**1,407**
	Consultant Services	k$	1,416						**1,416**
	Domestic Travel	k$	273	194	130	636	141		**1,374**
	International travel	k$	258	385	243	528	167		**1,581**
	Materials & Supplies	k$	59	5,652	3,226	15,022	3,615		**27,575**
	Teaching Buyout	k$			446	685			**1,131**
	Other	k$	490		2				**492**
	No M&S category	k$							**0**
	Total M&S	**k$**	**4,285**	**6,282**	**4,390**	**17,017**	**4,174**		**36,148**
Total Base Cost		**k$**	**6,440**	**9,776**	**6,728**	**25,818**	**9,155**		**57,917**
Total Contingency		**k$**	**3,183**	**2,540**	**1,515**	**7,438**	**2,386**		**17,062**
Total Project Cost		**k$**	**9,624**	**12,316**	**8,244**	**33,256**	**11,540**		**74,979**
Total Contingency		(% base)	49.4%	26.0%	22.5%	28.8%	26.1%		29.5%
Total Project Cost		(% total)	12.8%	16.4%	11.0%	44.4%	15.4%		100%

BCR 130: Non-COVID

HL-LHC CMS-NSF_0130: BCR - View

BCR Number: HL-LHC CMS-NSF_0130 | **Title: Muon Upgrade Schedule Realignment (non-COVID)** | **Status: Implemented** | **Owner: Safonov, Alexei**

Details | Baseline Cost/Sched. Changes | Supporting Docs./Risks | Workflow | Change Log

WBS Number: 402.05
Owner: Safonov, Alexei
Type of change: Cost: (YES)
Schedule: (NO)
Technical: (NO)
Other: (NO)
Affect Freeze Period: (NO)
Spans Subprojects: (NO)
Categories: Plan Refinement;Cost;Schedule

Detailed Description

This BCR includes updates to the schedule and technical activities to re-align the MREFC muon upgrade schedule with the international CMS schedule, including adjustments to the plan in response to certain risks realizing (technical issues found with certain electronics components that require additional specialized testing, delays with the delivery of components etc.), changing the order of some of the existing activities to minimize the standing army costs, introducing additional tasks to provide funds for expendable materials and supplies to support and maintain the electronics test stands.

Impact / Justification

If these changes are not performed, the MREFC schedule will remain misaligned with the updated CMS schedule, greatly reducing the effectiveness of the tools to monitor project's progress. Additional activities (and costs) introduced to mitigate risks that have realized, if not performed, are likely to increase the cost and impact the overall schedule.

Status Comments / Notes

[safonov 6/30/21 15:09] updated and corrected based on Sean's feedback, added cost update for ODMB5 pre-production boards; note activities under management WBS are uncosted, which is why we used L1 (no uncertainty on the cost) instead of L2 (LOE 10%).

HL-LHC CMS-NSF_0130: BCR - View

BCR Number: HL-LHC CMS-NSF_0130 | **Title: Muon Upgrade Schedule Realignment (non-COVID)** | **Status: Implemented** | **Owner: Safonov, Alexei**

Details | Baseline Cost/Sched. Changes | **Supporting Docs./Risks** | Workflow | Change Log

These are the BCR's supporting documents

- HL-LHC CMS-NSF_0130_HL-LHC CMS-NSF_0130_HL-LHC CMS-NSF_0130_Description_CSC_GEM-2.rtf
- SCH - PMB - Before vs After BCR130 - By CA.pdf
- SCH - PMB - Before vs After BCR130 - By WBS.pdf
- SCH - Working - Before vs After BCR130 - By CA.pdf
- SCH - Working - Before vs After BCR130 - By WBS.pdf
- SCS Time-phased BCR130 before reclass.xlsx
- SCS Time-phased BCR130 after reclass.xlsx

Risks

- RT-402-5-04-N:EM - Problem in pre-production or production of GE21 OH boards
  The problem associated with the CERN VTRX devices requires additional testing step of the OH boards at CERN with repaired VTRXs.
- RT-402-5-10-N:EM - Electronics boards design needs additional testing or integration
  Delay with the delivery of the CERN LpGBT_v1 (pre-production LpGBT) chip does not allow the completion of the ME0 pre-production board layout.
- RT-402-5-09-N:EM - Backend electronics board delay or a major design change
  Delay with the delivery of the pre-production backend boards requires additional boards to allow parallel development and integration in order to avoid a significant schedule delay.

- As COVID BCR only allowed moving activities, some COVID impact is difficult to disentangle
  - If not COVID, CERN electronics experts would have likely found a fix for VTRX devices sooner

BCR 127: COVID Impact

HL-LHC CMS-NSF_0127: BCR - View

BCR Number: HL-LHC CMS-NSF_0127 | **Title: Muon COVID 2021 Schedule Realignment** | **Status: Implemented** | **Owner: Safonov, Alexei**

Details | Baseline Cost/Sched. Changes | Supporting Docs./Risks | Workflow | Change Log

WBS Number: 402.05
Owner: Safonov, Alexei
Type of change: Cost: (YES)
Schedule: (YES)
Technical: (NO)
Other: (YES)
Affect Freeze Period: (NO)
Spans Subprojects: (NO)
Categories: Plan Refinement;COVID-19;Schedule

Detailed Description

This BCR includes schedule updates that reflect changes in the project execution plan induced by the impacts of the COVID-19 pandemic. Majority of these changes resulted in certain tasks taking longer than expected due to restrictions on the use of lab space, travel, extended delivery times for manufactured items etc. In many cases, the project schedule has been affected by external factors, e.g. changes in CMS schedule due to COVID impact on non-US parts of the projects, which affect the need-by-dates for the US deliverables. The updated baseline schedule captures the impact of these changes and delays accumulated since the project start in April of 2020.

Impact / Justification

The changes reflect impact of COVID, which led to delays in completion of a large number of activities as well as changes in external constraints (need-by dates for deliverables) arising from the updates to the international CMS planning schedule due to impact on the non-US parts of the project, which delayed the onset of activities that require the US project deliverables. As all changes included run this BCR only reschedule tasks, any cost impact is due to projected escalation of costs of the delayed tasks.

Status Comments / Notes

[sscott 6/4/21 13:39] Cost impact of $13,733.39

HL-LHC CMS-NSF_0127: BCR - View

BCR Number: HL-LHC CMS-NSF_0127 | **Title: Muon COVID 2021 Schedule Realignment** | **Status: Implemented** | **Owner: Safonov, Alexei**

Details | Baseline Cost/Sched. Changes | Supporting Docs./Risks | Workflow | Change Log

Cost Baseline Changes

#	Description	CA #	Title	CAM	Preliminary Cost	Final Cost
		402.05.03	CSC Electronics	Wood, Darien	$0.00	$8,206.27
		402.05.04	GEM Electronics	Black, Kevin	$0.00	$5,527.12

Preliminary Cost Impact: $0.00
Final Cost Impact: $13,733.00

Export to Excel

Schedule Baseline Changes

Preliminary

#	Description	CA #	Title	CAM	Start Date Original	Start Date New	Start Date Delta	Completion Date Original	Completion Date New	Completion Date Delta
	Endcap Muons Upgrade Complete (activity EM423275) - delay of 16 working days.	402.05.02	Endcap Muon Management	Safonov, Alexei	1/6/2025	1/22/2025	-16	1/6/2025	1/22/2025	-16

Preliminary Schedule Impact (days): -16

Final

#	Description	CA #	Title	CAM	Start Date Original	Start Date New	Start Date Delta	Completion Date Original	Completion Date New	Completion Date Delta
	Endcap Muons Upgrade Complete (activity EM423275) - delay of 16 working days.	402.05.02	Endcap Muon Management	Safonov, Alexei	1/6/2025	1/22/2025	-16	1/6/2025	1/22/2025	-16

Final Schedule Impact (days): -16

- Agreed to only move future activities (in the baseline), so SPI did not jump to 1.0
- No added M&S costs or labor, only moving future delayed activities to better align with the schedule

BCR 115: FY21 Realignment

HL-LHC CMS-NSF_0115: BCR - View

BCR Number: HL-LHC CMS-NSF_0115 | Title: Muon FY21 Baseline Planning Updates for SOWs | Status: Implemented | Owner: Safonov, Alexei

Details | Baseline Cost/Sched. Changes | Supporting Docs./Risks | Workflow | Change Log

WBS Number: 402.5
Owner: Safonov, Alexei
Type of change: Cost: (YES)
Schedule: (NO)
Technical: (YES)
Other: (NO)
Affect Freeze Period: (NO)
Spans Subprojects: (NO)
Categories: Plan Refinement;Cost

Detailed Description

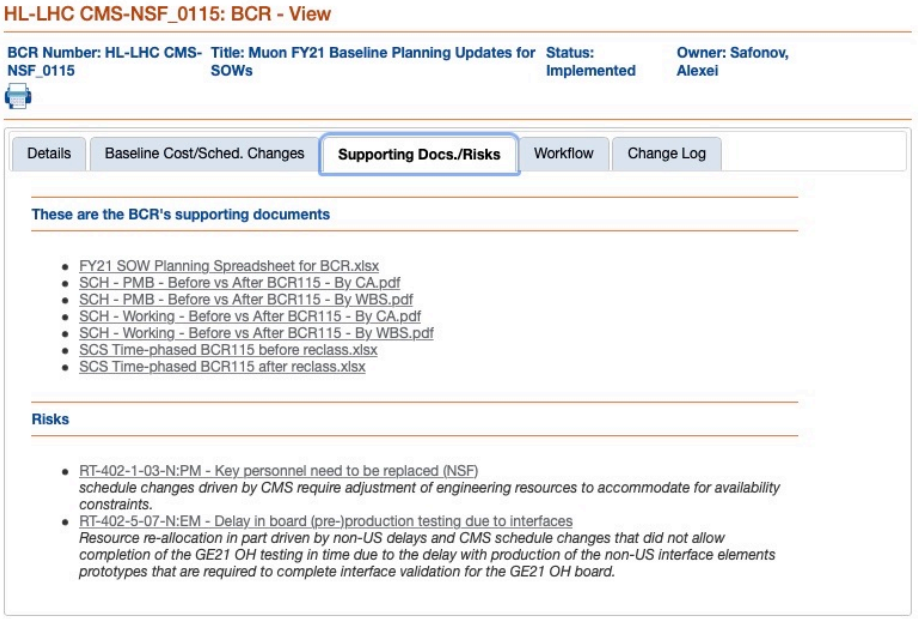
Changes that are primarily addressing assignment of existing tasks to institutions and specific resources, which has been required to optimize resource leveling and expertise availability. As a result of this BCR implementation, a number of tasks will be reallocated to other performing/responsible institutions and resources, several tasks will be postponed due to resource availability. When appropriate, the number of hours assigned to tasks is changed to take into account differences in seniority and experience of the new and previously assigned resources. Because of the variations in labor rates and adjustment of the number of hours assigned, these modifications also affect cost. Finally, additional milestones have been added to mark the start/end for the upscope/descope options, which result in no cost or schedule changes, but are needed to improve efficiency of managing the project.

Impact / Justification

Due to changes in the availability of resources at participating institutions, some resources are no longer available to work on specific tasks and these tasks need to re re-assigned to other resources/institutions. If these tasks are not reassigned, the impact will be a significant schedule delay as a number of planned tasks will not be completed in FY21.

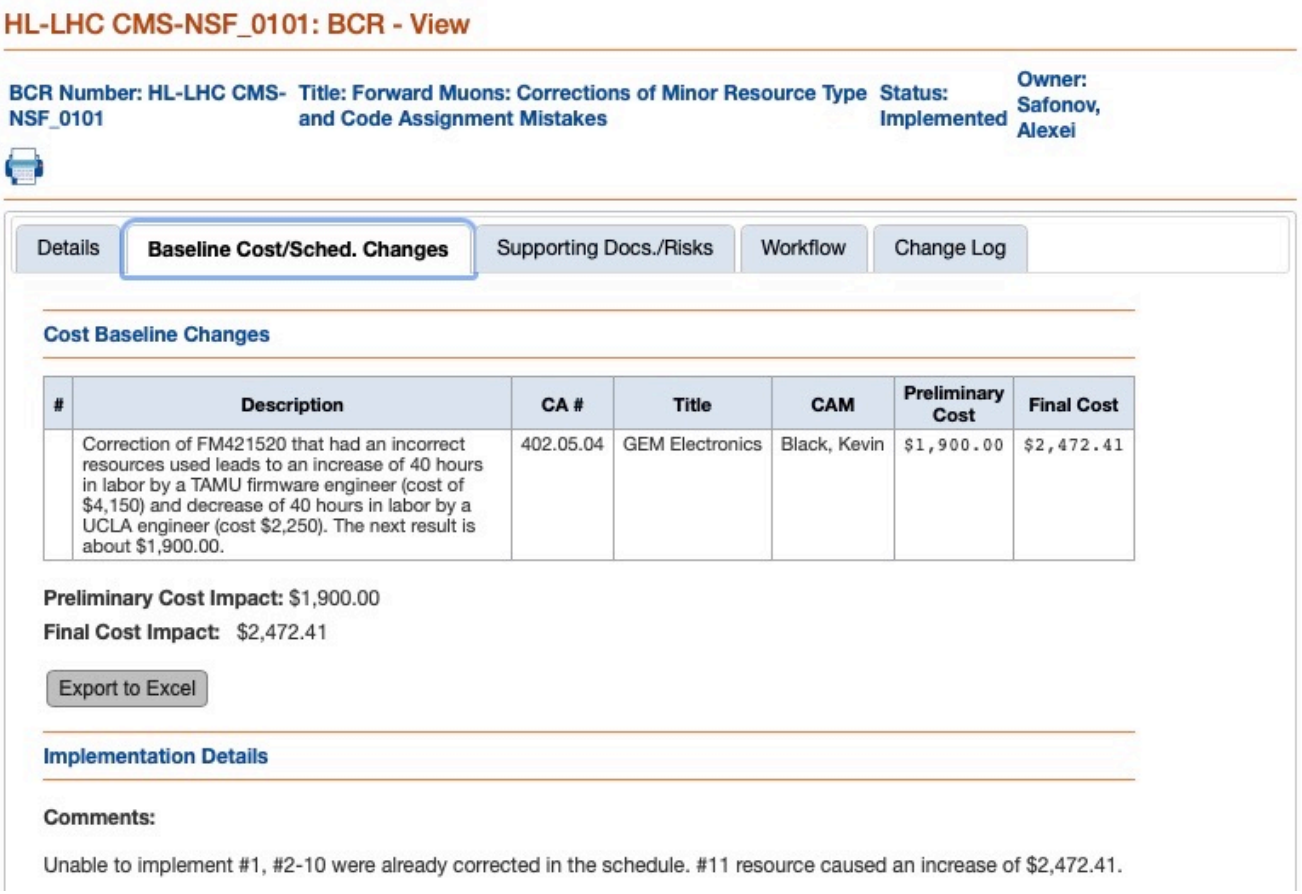
Status Comments / Notes

Created On: 11/4/2020 **By:** Safonov, Alexei
Needed By: 11/12/2020
Last Edited On: 12/9/2020 **By:** sscott
Requested Review On: **By:** safonov
Reviewed On: 12/8/2020 **By:** safonov
Approved On: 12/8/2020
Implemented On: 12/9/2020
Watchlist: (edit)



- Addressed engineers moving between institutions (which added a new institution), updated time sharing of the engineering time in cases where engineers shared with Operations or other projects

BCR 101: Clerical Fixes



HL-LHC CMS-NSF_0101: BCR - View

BCR Number: HL-LHC CMS-NSF_0101 | Title: Forward Muons: Corrections of Minor Resource Type and Code Assignment Mistakes | Status: Implemented | Owner: Safonov, Alexei

Details | **Baseline Cost/Sched. Changes** | Supporting Docs./Risks | Workflow | Change Log

Cost Baseline Changes

#	Description	CA #	Title	CAM	Preliminary Cost	Final Cost
	Correction of FM421520 that had an incorrect resources used leads to an increase of 40 hours in labor by a TAMU firmware engineer (cost of $4,150) and decrease of 40 hours in labor by a UCLA engineer (cost $2,250). The next result is about $1,900.00.	402.05.04	GEM Electronics	Black, Kevin	$1,900.00	$2,472.41

Preliminary Cost Impact: $1,900.00

Final Cost Impact: $2,472.41

Export to Excel

Implementation Details

Comments:

Unable to implement #1, #2-10 were already corrected in the schedule. #11 resource caused an increase of $2,472.41.

- Corrected mistakes in P6 coding that sneaked into the MREFC planning documents