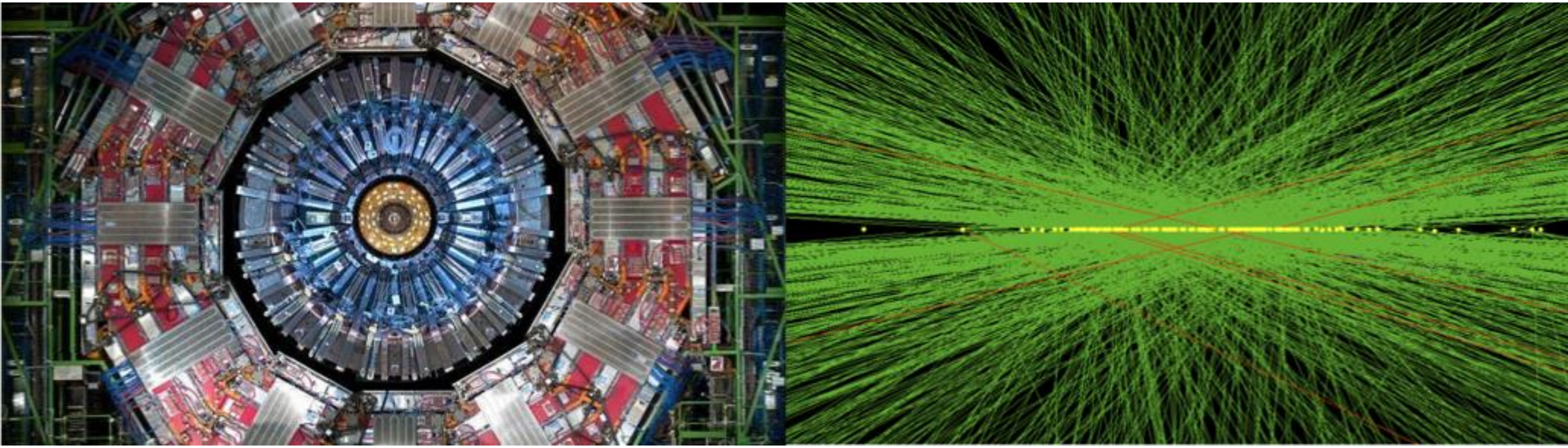
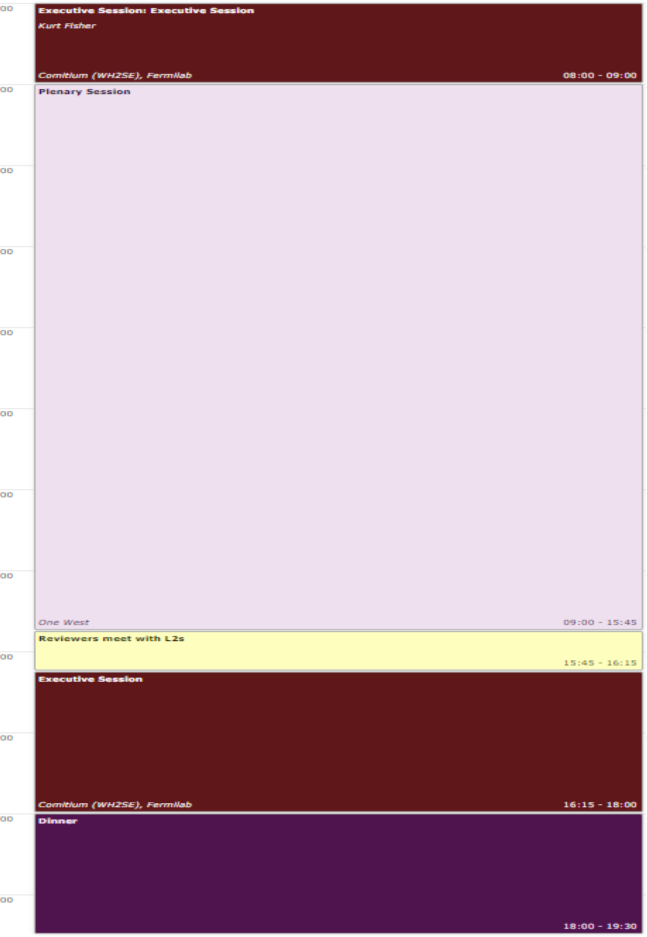
Preliminary logistics

Steve Nahn, Project Manager
CD1 Review
October 22, 2019



Review Agenda



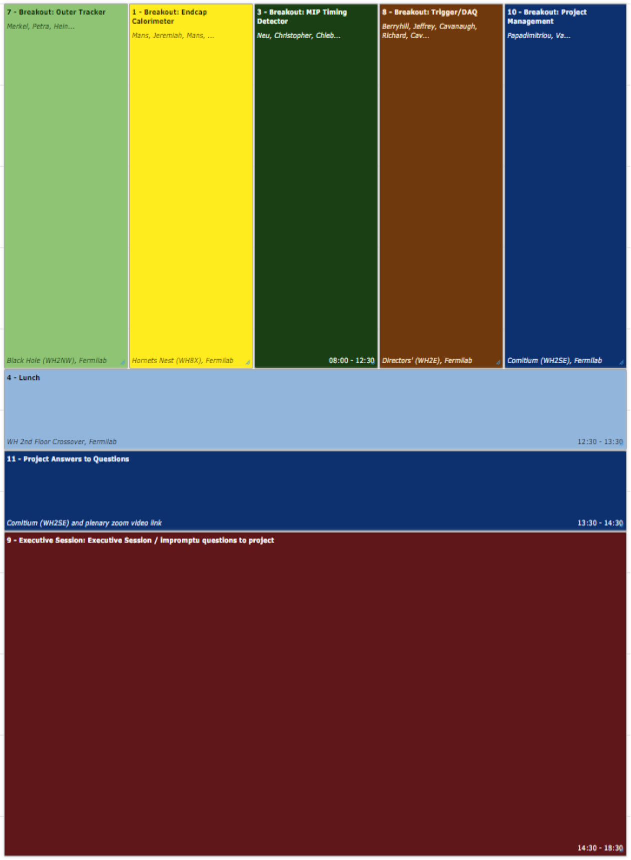
Executive Session: Executive Session
Kurt Fisher
Comitium (WH2SE), Fermilab 08:00 - 09:00

Plenary Session
One West 09:00 - 15:45

Reviewers meet with L2s
15:45 - 16:15

Executive Session
Comitium (WH2SE), Fermilab 16:15 - 18:00

Dinner
18:00 - 19:30



7 - Breakout: Outer Tracker
Merkel, Petra, Hein...
Black Hole (WH2NW), Fermilab

1 - Breakout: Endcap Calorimeter
Mans, Jeremiah, Mans, ...
Hornets Nest (WH8X), Fermilab

3 - Breakout: MIP Timing Detector
Neu, Christopher, Chleb...
08:00 - 12:30

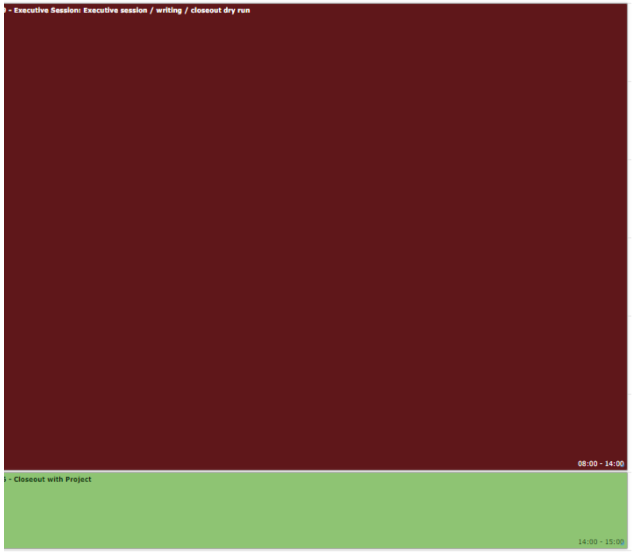
8 - Breakout: Trigger/DAQ
Berryhill, Jeffrey, Cavanaugh, Richard, Cav...
Directors' (WH2E), Fermilab

10 - Breakout: Project Management
Papadimitriou, Va...
Comitium (WH2SE), Fermilab

4 - Lunch
WH 2nd Floor Crossover, Fermilab 12:30 - 13:30

11 - Project Answers to Questions
Comitium (WH2SE) and plenary zoom video link 13:30 - 14:30

9 - Executive Session: Executive Session / impromptu questions to project
14:30 - 18:30



- Executive Session: Executive session / writing / closeout dry run
08:00 - 14:00

- Closeout with Project
14:00 - 15:00

Closeout One East 14:00

<u>Breakout Sessions</u>

Outer Tracker: Black Hole (WH2NW)
Calo Endcap: Snake Pite (WH2NE)
Trigger DAQ: Director's Conference Rm (WH2E)
MTD: Boardroom (WH5SW)
Management: Comitium (WH2SE)

All Executive sessions in Comitium

Plenary Agenda

09:00 - 15:45

Plenary Session

First Day - Plenary overview of L2 areas

Location: One West

09:00 **Lab Intro** *10'*
Speaker: Dr. Joseph Lykken (Fermilab)

09:10 **The CMS HL-LHC Upgrades** *30'*
Speaker: Patricia McBride (Fermilab)

09:40 **Overview of the HL-LHC CMS Detector Upgrade Project** *45'*
Speaker: Steve Nahn (Fermilab)

10:25 **Coffee Break** *15'*

10:40 **Project Overall Cost/Schedule/Risk Evaluation** *45'*
Speakers: Dr. Lucas Taylor (Fermilab), Lucas Taylor

11:25 **L2 Overview: MIP Timing Detector** *50'*
Speaker: Christopher Neu (University of Virginia)

12:15 **Lunch** *1h0'*

13:15 **L2 Overview: Outer Tracker** *50'*
Speaker: Dr. Petra Merkel (Fermi National Accelerator Laboratory)

14:05 **L2 Overview: Endcap Calorimeter** *50'*
Speakers: Jeremiah Mans, Jeremiah Mans (University of Minnesota)

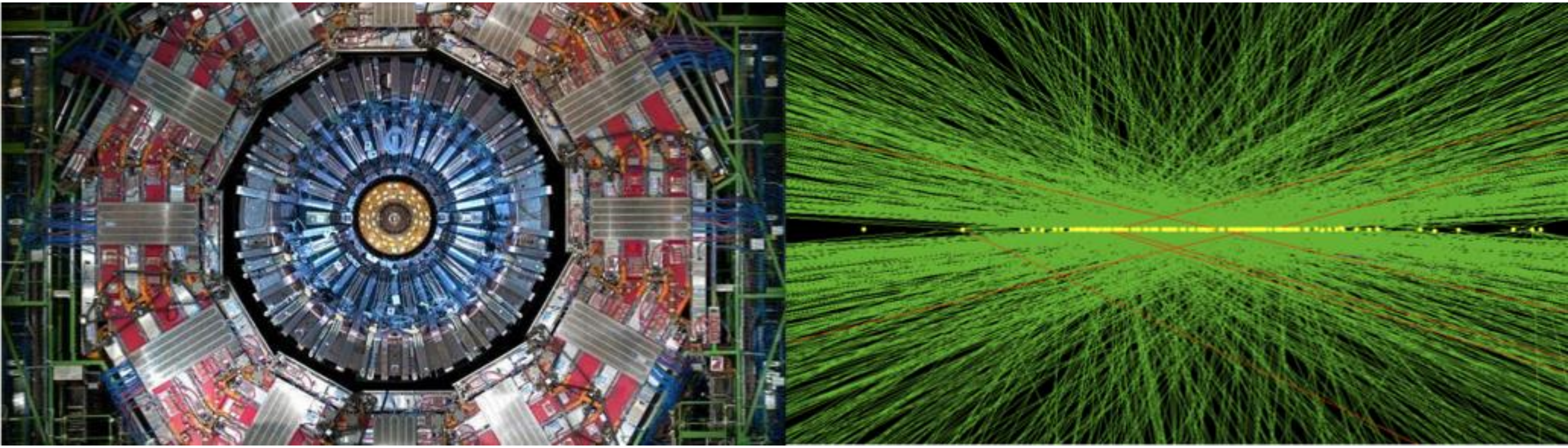
14:55 **L2 Overview: Trigger/DAQ** *50'*
Speaker: Jeffrey Berryhill (Fermilab)

P02: Overview of the HL LHC CMS Detector Upgrade Project

Steve Nahn, Project Manager

CD-1 Review

October 22, 2019



Outline

- Preamble: Charge and Background
- Context of the HL-LHC CMS Detector Upgrade
- Motivation, Project Scope and Organization
- Conceptual Design Development
  - details in L2 and L3 talks
- Summary of Project Cost and Schedule
- ESH&Q
- Response to Previous Reviews
- Closing remarks

Your Charge

Purple boxes labelled "*Charge #n*" demark our response to particular change questions

Because more than a year has elapsed since the last review, I ask that your review committee perform a **full assessment of the project's progress,** current status, and the identification of potential issues, as well as addressing the following specific questions for CD-1:

1. Does the acquisition strategy document a carefully considered analysis of alternatives that supports the preferred alternative?
2. Does the conceptual design satisfy the performance requirements?
3. Does the Conceptual Design Report and supporting documentation adequately justify the stated cost range and project duration?
4. Do the project's plans to execute the work make the most efficient use of the financial, human, and technical resources available to them to meet the mission need? Does the project use the human and technical resources available to them at the participating national labs and universities when they are the most efficient choice? Are qualified vendors being sought out where they are the most cost efficient option?
5. Does the proposed project team have adequate management experience, design skills, and laboratory support to produce a credible technical, cost, and schedule baseline?
6. Are the ES&H aspects of the project being properly addressed and is the ES&H planning currently sufficient for this stage of the project?
7. Is the documentation required by DOE O413.3b for CD-1 approval complete and in good order?
8. Has the project satisfactorily responded to the recommendations from previous reviews?

Update on primary issues from last IPR

- DOE conducted an IPR in June 2018
  - MIP Timing detector deemed not ready for CD-1
  - ESH&Q documentation/process not sufficiently mature
- Since then
  - MTD evolved substantially
    - Domestic Project developed, management team substantially bolstered
      - Independent Conceptual Design Review Nov 15, 2018: (report: CMS-docdb-13698)

      "After two days evaluating the technical design, reading the project documentation, and interviewing the project team, this committee feels that tremendous progress has occurred over the last 6 months and that the MDT is now at or beyond a "CD-1" level of maturity"

      - Director's CD-1 review March 2019:

      "The project team is well-prepared to deliver a credible technical, cost, and schedule baseline. All L2/L3/L4 management positions within the US-MTD organization have been filled and the management team in place has the necessary experience to succeed."

      "US-MTD has made excellent progress in the last 9 months on prototyping, tests and overall design maturity."

    - International project established, TDR written, passed international design and management reviews last month
  - ESH&Q also matured
    - Professional ESH&Q personnel brought into Project Office to help focus L2 efforts on documentation of QA/QC program
    - ESH&Q review Nov 29 2018 (report: CMS-docdb-13709)

    "Are the ESH and QA aspects of the project being properly addressed and is ESH and QA planning sufficient for this stage of the project? a. Yes…."

Charge #5

Biographical Sketches

- Steve Nahn, Project Manager
  - HL-LHC CMS Detector Upgrade Project Manager since June 1 2019
    - HL-LHC CMS Detector L2 Manager: Outer Tracker Sept 2016-June 2019
  - Fermilab senior scientist
  - Management experience
    - LHC CMS Detector Upgrade Project Manager (“Phase 1”) Nov 2014-June 2019
      - $40M Upgrade of Forward Pixel, L1 Trigger, Hadron Calorimeter Photosensors and electronics
    - Reviewer for ATLAS (LHCC, UCG, P2UG), U.S. ATLAS, SuperCDMS, DUNE
    - Previous Apparatus Leadership on Silicon Tracking (CMS, CDF), DAQ (CDF, L3) and Muon Chambers (L3)

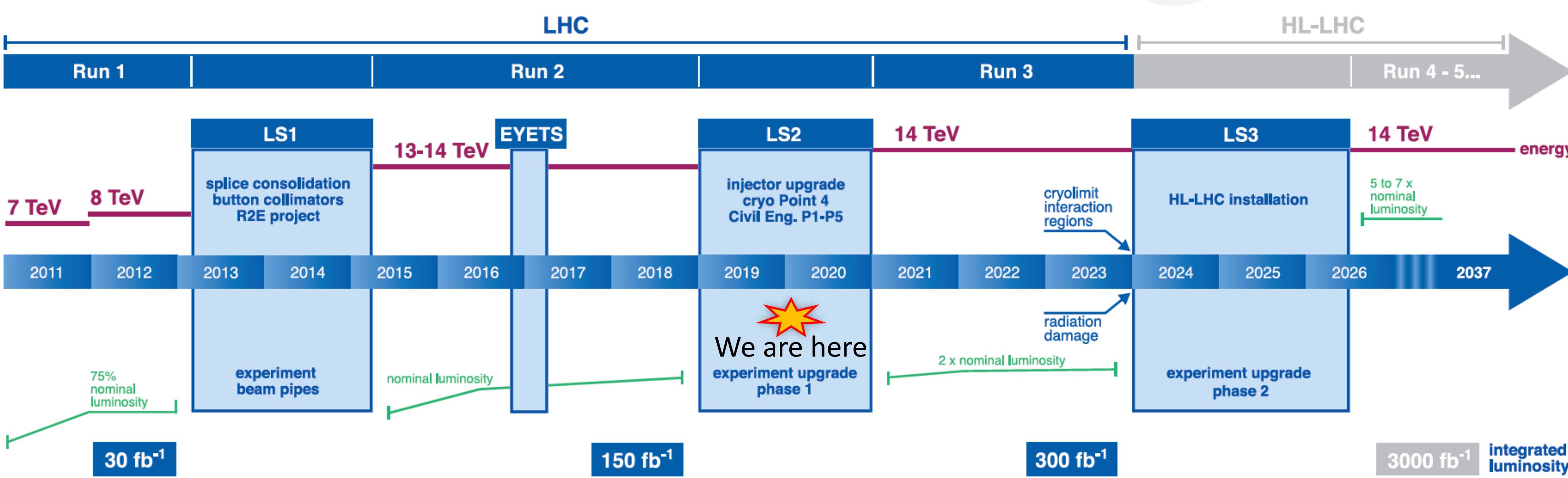
- Vaia Papadimitriou, Deputy Project Manager
  - HL-LHC CMS Detector Upgrade Deputy Project Manager since July, 2018
  - Fermilab senior scientist
  - Management experience
    - LBNE/LBNF Beamline Project Manager (~$200M) (2009-2018) (O413.3b project)
    - Associate Division Head of Accelerator Division – LBNE/LBNF (2009-2018)
    - Assistant Division Head of Accelerator Division - Accelerator Performance (2006-2009)
    - Previous Apparatus Leadership on Calorimetry, Calorimetry Trigger (CDF, E731)

The talk in one slide

- The HL-LHC CMS Detector Upgrade Project is the U.S. (DOE and NSF) participation in the Upgrade of the CMS detector
  - New detectors to operate at higher input/output rate and with increased tolerance to acute and chronic radiation dose
  - Upgraded Electronics to maintain physics capabilities in the face of higher physics and background rates
  - DOE Scope: Outer Tracker, Calorimeter Endcap, L1 Trigger, MIP Timing Layer
  - Design – well beyond “Conceptual Design” required for CD-1
  - Schedule – installed during Long Shutdown 3 of the LHC
  - TPC (AY M$): 162 = 124.6 (BAC) + 27.3 (Estimate Uncertainty) + 10.1 (Risk)
    - Includes 5.1M Scope contingency and 9.7M Installation and Commissioning (I&C)
- We will demonstrate readiness for CD-1 and progress since the June 2018 IPR

Context of the Upgrade

LHC 26 year plan



Run 1
0.75×10^{34} cm^{-2}s^{-1}
50 ns bunch
pileup ~40

Run 2
1.5×10^{34} cm^{-2}s^{-1}
25 ns bunch
pileup ~40

Run 3
$1.7\text{-}2.2 \times 10^{34}$ cm^{-2}s^{-1}
25 ns bunch
pileup ~60

Run 4-6
$\sim 5\text{-}7.5 \times 10^{34}$ cm^{-2}s^{-1}
25 ns bunch
pileup ~140 - 200

- HL-LHC Upgrades to be installed in LS3
  - Currently CY24-26, dates to be discussed at CERN Nov 27
- HL LHC running period continues through 2037 to collect 10-15 times more data (3 ab^{-1} total)

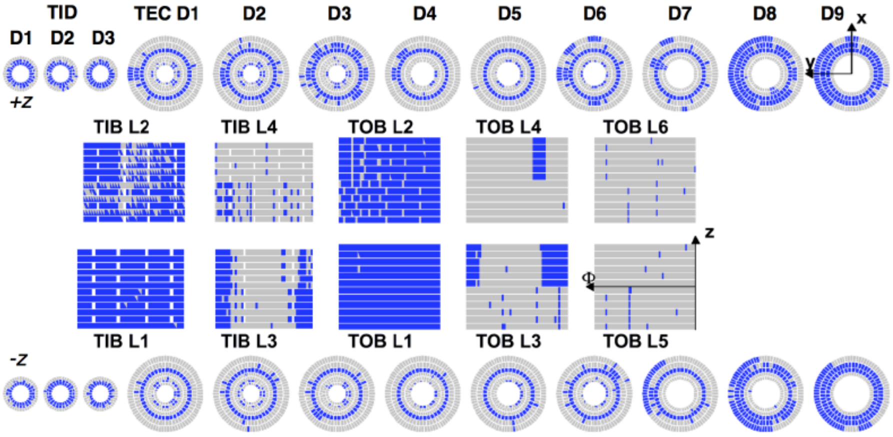
Features of this Project

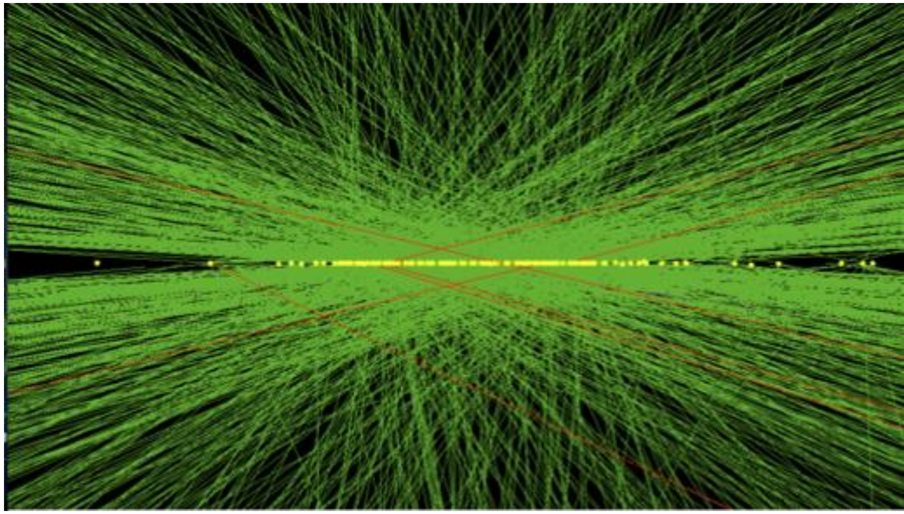
- Upgrade of an existing detector
  - Upgrade must fit geometrically, interface with non-upgraded infrastructure, and be built within the LHC time constraints
- Well established, ~30 year old collaboration
  - Pre-existing and concurrent Operations Program
  - Familiar international context
- Participation in broader international project
  - Ultimate responsibility for producing a working detector lies with the international project
    - International Scrutiny via CERN LHCC/Upgrade Cost Group → Phase 2 Upgrade group
    - Scope divisions negotiated at the subsystem level, during creating of the Technical Design Reports
      - High bar for re-negotiation, but sometimes transpires, with much discussion from all parties
    - All stakeholders consulted on major decisions
      - Nearly constant communication within subsystems
      - Constitution defines a series of reviews (EDR, PRR, IRR) to bring a system to fruition, provides forum for broader input and concurrence
  - Interdependence minimized and controlled
    - U.S. embedded in international organization

Motivation, Scope and Organization

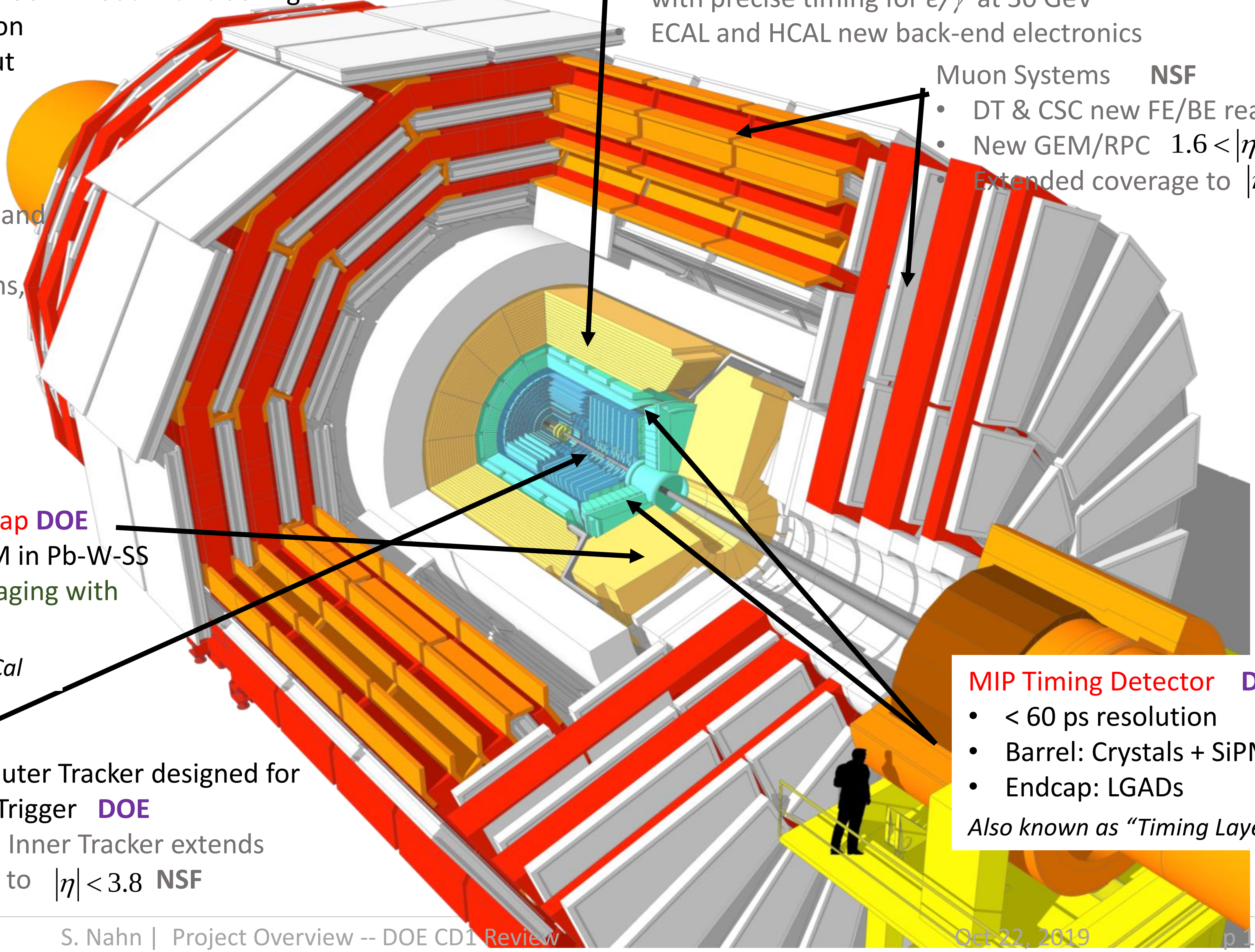
Motivation (synopsis)

- Radiation damage to current detector
  - Current Outer tracker ≈ 40% inoperable after just 1/3 of the HL LHC luminosity
  - Elsewhere, severe degradation in performance
- Instantaneous Luminosity up ×5–7
  - Physics/sec: detector readout rate 100 kHz → 750 kHz
  - Background/sec: trigger latency 4μs → 12 μs
    - Trigger uses more granular input, Tracker information, and more powerful algorithms
- Fighting Pileup
  - Higher granularity Tracker allows spatial discrimination of distinct vertices
  - High resolution timing information dramatically reduces track-vertex mismatches





CMS Upgrade Scope - DOE



L1 Trigger/HLT/DAQ **NSF** and **DOE**
- L1 40 MHz in/750 kHz out with tracking for PF-like selection
- HLT 7.5 kHz out

Barrel Calorimeters **NSF**
- ECAL single crystal granularity in L1 Trigger with precise timing for e/γ at 30 GeV
- ECAL and HCAL new back-end electronics

Muon Systems **NSF**
- DT & CSC new FE/BE readout
- New GEM/RPC $1.6 < |\eta| < 2.4$
- Extended coverage to $|\eta| < 3.0$

Beam Radiation and Luminosity, Common Systems, Infrastructure

Calorimeter Endcap **DOE**
- Si, Scint + SiPM in Pb-W-SS
- 3D shower imaging with precise timing

Also known as HGCal

Tracker
- Si Strip Outer Tracker designed for L1 Track Trigger **DOE**
- Pixelated Inner Tracker extends coverage to $|\eta| < 3.8$ **NSF**

MIP Timing Detector **DOE**
- < 60 ps resolution
- Barrel: Crystals + SiPMs
- Endcap: LGADs

Also known as "Timing Layer" (TL)

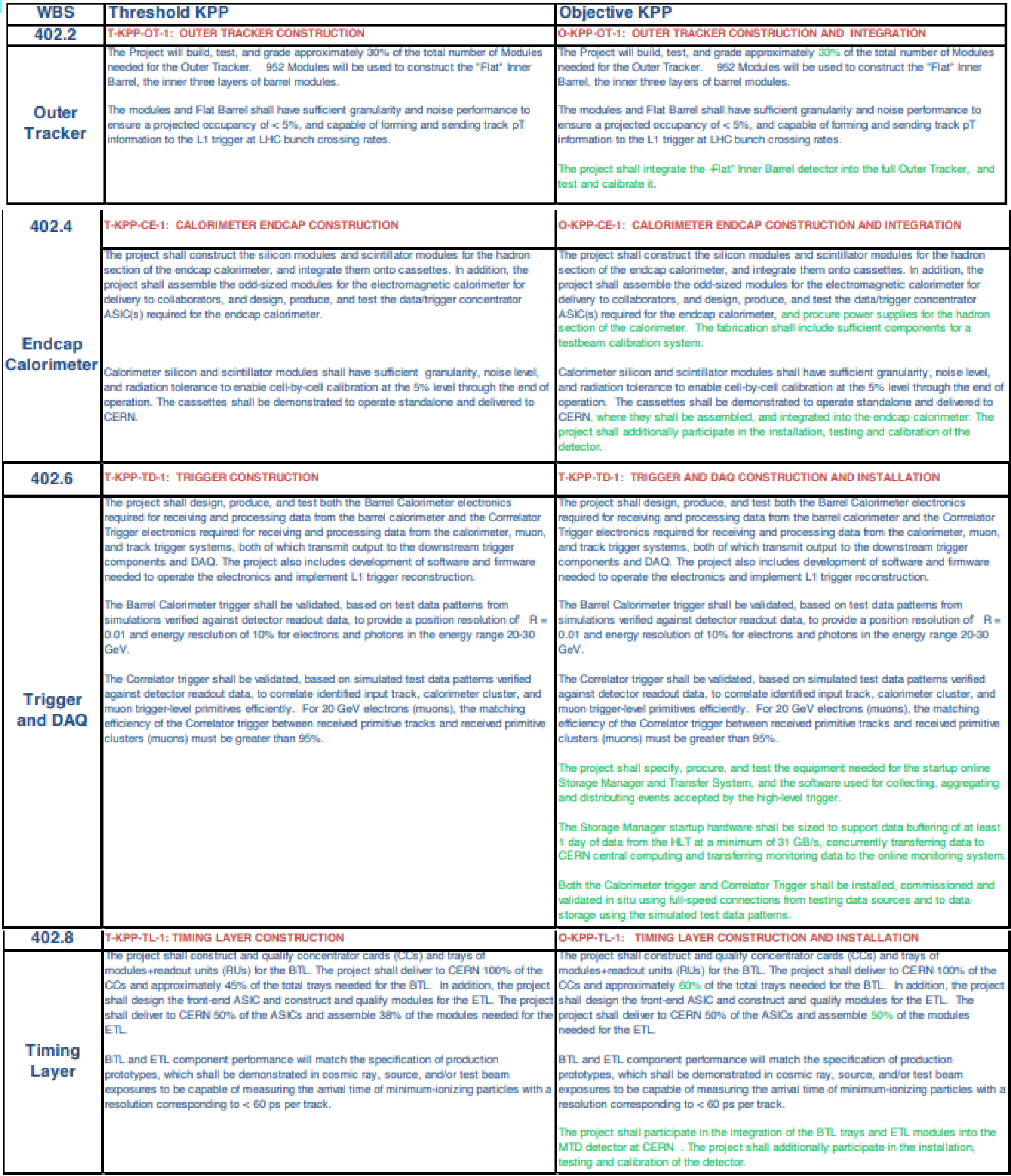
Charge #2,3

DOE Scope overview

- DOE deliverables are described in the Conceptual Design Report (CMS-doc-13151)
- Captured in the preliminary KPPs (CMS-doc-13237)
- Scope Summary by L2 area:
  - 402.2 Outer Tracker (OT) -- modules, inner barrel detector
  - 402.4 Endcap Calorimeter (CE or HGCal) – Active material for Hadronic Section (silicon / scintillator modules / cassettes), concentrator ASIC
  - 402.6 Trigger/DAQ (TD) – calorimeter and correlator trigger systems, Online Data logging/transfer
  - 402.8 MIP Timing Detector (MTD or TL) – Barrel Modules, Trays/ Endcap Modules, Endcap Readout ASIC
- Conceptual Design reviews completed for all L2 areas
  - Reports available to reviewers in Project Documentation

Key Performance Parameter strategy

- Threshold KPP – minimum requirement for completion
  - Decouples from LHC schedule and Integration at CERN to minimize external dependence
  - Includes Quantity and Performance goal
- Objective KPP – project goal given sufficient time and resources
  - Fully costed and scheduled, included in TPC
- Changes since 2018 IPR
  - Reduced from 7 to 4 KPPs per review recommendation
  - Captured Scope contingency of $5.1M in addition to non-fungible $9.7M for I&C



WBS	Threshold KPP	Objective KPP
402.2	T-KPP-OT-1: OUTER TRACKER CONSTRUCTION	O-KPP-OT-1: OUTER TRACKER CONSTRUCTION AND INTEGRATION
Outer Tracker	The Project will build, test, and grade approximately 30% of the total number of Modules needed for the Outer Tracker. 952 Modules will be used to construct the "Flat" Inner Barrel, the inner three layers of barrel modules. The modules and Flat Barrel shall have sufficient granularity and noise performance to ensure a projected occupancy of < 5%, and capable of forming and sending track pT information to the L1 trigger at LHC bunch crossing rates.	The Project will build, test, and grade approximately 33% of the total number of Modules needed for the Outer Tracker. 952 Modules will be used to construct the "Flat" Inner Barrel, the inner three layers of barrel modules. The modules and Flat Barrel shall have sufficient granularity and noise performance to ensure a projected occupancy of < 5%, and capable of forming and sending track pT information to the L1 trigger at LHC bunch crossing rates. The project shall integrate the "Flat" Inner Barrel detector into the full Outer Tracker, and test and calibrate it.
402.4	T-KPP-CE-1: CALORIMETER ENDCAP CONSTRUCTION	O-KPP-CE-1: CALORIMETER ENDCAP CONSTRUCTION AND INTEGRATION
Endcap Calorimeter	The project shall construct the silicon modules and scintillator modules for the hadron section of the endcap calorimeter, and integrate them onto cassettes. In addition, the project shall assemble the odd-sized modules for the electromagnetic calorimeter for delivery to collaborators, and design, produce, and test the data/trigger concentrator ASIC(s) required for the endcap calorimeter. Calorimeter silicon and scintillator modules shall have sufficient granularity, noise level, and radiation tolerance to enable cell-by-cell calibration at the 5% level through the end of operation. The cassettes shall be demonstrated to operate standalone and delivered to CERN.	The project shall construct the silicon modules and scintillator modules for the hadron section of the endcap calorimeter, and integrate them onto cassettes. In addition, the project shall assemble the odd-sized modules for the electromagnetic calorimeter for delivery to collaborators, and design, produce, and test the data/trigger concentrator ASIC(s) required for the endcap calorimeter, and procure power supplies for the hadron section of the calorimeter. The fabrication shall include sufficient components for a testbeam calibration system. Calorimeter silicon and scintillator modules shall have sufficient granularity, noise level, and radiation tolerance to enable cell-by-cell calibration at the 5% level through the end of operation. The cassettes shall be demonstrated to operate standalone and delivered to CERN, where they shall be assembled, and integrated into the endcap calorimeter. The project shall additionally participate in the installation, testing and calibration of the detector.
402.6	T-KPP-TD-1: TRIGGER CONSTRUCTION	T-KPP-TD-1: TRIGGER AND DAQ CONSTRUCTION AND INSTALLATION
Trigger and DAQ	The project shall design, produce, and test both the Barrel Calorimeter electronics required for receiving and processing data from the barrel calorimeter and the Correlator Trigger electronics required for receiving and processing data from the calorimeter, muon, and track trigger systems, both of which transmit output to the downstream trigger components and DAQ. The project also includes development of software and firmware needed to operate the electronics and implement L1 trigger reconstruction. The Barrel Calorimeter trigger shall be validated, based on test data patterns from simulations verified against detector readout data, to provide a position resolution of R = 0.01 and energy resolution of 10% for electrons and photons in the energy range 20-30 GeV. The Correlator trigger shall be validated, based on simulated test data patterns verified against detector readout data, to correlate identified input track, calorimeter cluster, and muon trigger-level primitives efficiently. For 20 GeV electrons (muons), the matching efficiency of the Correlator trigger between received primitive tracks and received primitive clusters (muons) must be greater than 95%.	The project shall design, produce, and test both the Barrel Calorimeter electronics required for receiving and processing data from the barrel calorimeter and the Correlator Trigger electronics required for receiving and processing data from the calorimeter, muon, and track trigger systems, both of which transmit output to the downstream trigger components and DAQ. The project also includes development of software and firmware needed to operate the electronics and implement L1 trigger reconstruction. The Barrel Calorimeter trigger shall be validated, based on test data patterns from simulations verified against detector readout data, to provide a position resolution of R = 0.01 and energy resolution of 10% for electrons and photons in the energy range 20-30 GeV. The Correlator trigger shall be validated, based on simulated test data patterns verified against detector readout data, to correlate identified input track, calorimeter cluster, and muon trigger-level primitives efficiently. For 20 GeV electrons (muons), the matching efficiency of the Correlator trigger between received primitive tracks and received primitive clusters (muons) must be greater than 95%. The project shall specify, procure, and test the equipment needed for the startup online Storage Manager and Transfer System, and the software used for collecting, aggregating and distributing events accepted by the high-level trigger. The Storage Manager startup hardware shall be sized to support data buffering of at least 1 day of data from the HLT at a minimum of 31 GB/s, concurrently transferring data to CERN central computing and transferring monitoring data to the online monitoring system. Both the Calorimeter trigger and Correlator Trigger shall be installed, commissioned and validated in situ using full-speed connections from testing data sources and to data storage using the simulated test data patterns.
402.8	T-KPP-TL-1: TIMING LAYER CONSTRUCTION	O-KPP-TL-1: TIMING LAYER CONSTRUCTION AND INSTALLATION
Timing Layer	The project shall construct and qualify concentrator cards (CCs) and trays of modules+readout units (RUs) for the BTL. The project shall deliver to CERN 100% of the CCs and approximately 45% of the total trays needed for the BTL. In addition, the project shall design the front-end ASIC and construct and qualify modules for the ETL. The project shall deliver to CERN 50% of the ASICs and assemble 38% of the modules needed for the ETL. BTL and ETL component performance will match the specification of production prototypes, which shall be demonstrated in cosmic ray, source, and/or test beam exposures to be capable of measuring the arrival time of minimum-ionizing particles with a resolution corresponding to < 60 ps per track.	The project shall construct and qualify concentrator cards (CCs) and trays of modules+readout units (RUs) for the BTL. The project shall deliver to CERN 100% of the CCs and approximately 60% of the total trays needed for the BTL. In addition, the project shall design the front-end ASIC and construct and qualify modules for the ETL. The project shall deliver to CERN 50% of the ASICs and assemble 50% of the modules needed for the ETL. BTL and ETL component performance will match the specification of production prototypes, which shall be demonstrated in cosmic ray, source, and/or test beam exposures to be capable of measuring the arrival time of minimum-ionizing particles with a resolution corresponding to < 60 ps per track. The project shall participate in the integration of the BTL trays and ETL modules into the MTD detector at CERN . The project shall additionally participate in the installation, testing and calibration of the detector.

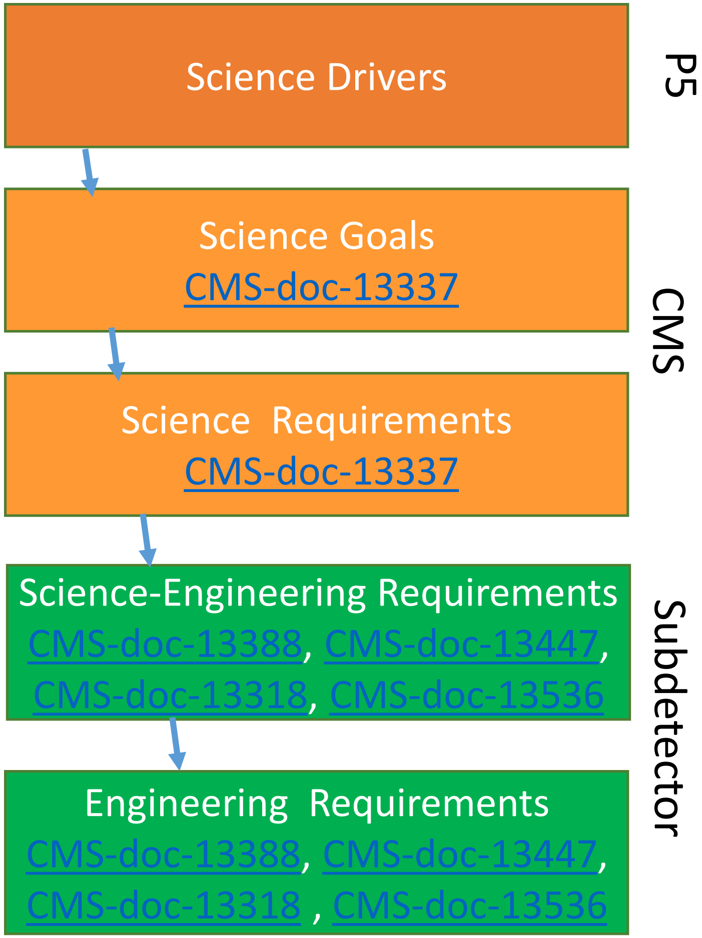
Alternatives analysis

- The project received CD-0 in April, 2016. Three options were enumerated in the "Mission Need" document
  - Option 1: DOE and NSF work together to support the HL-LHC ATLAS + CMS Upgrade projects
  - Option 2: DOE and NSF both act independently in their support of the upgrades
  - Option 3: DOE chooses not to support the HL-LHC upgrades (i.e. do nothing)
- Of the three options, Option 1 has been selected, that the U.S. scope of work is a partnership between DOE and NSF, as the preferred alternative, and the DOE scope assumes this.
  - The Project Office is shared between DOE and NSF. All other scope is independent between DOE and NSF
- More details, including alternate design choices, are in the appendix of the DOE "Acquisition Strategy" CMS-doc-13517
  - This document has been reviewed by DOE. The alternative chosen is agreed to by NSF.

Charge #2

Science Flowdown

- We have formalized our science flowdown to technical requirements
- We recognize the following levels (highest to lowest):
  - Science Drivers - come from the P5 report, captures the U.S. HEP mission
    - Recommendation 10 states LHC Upgrades are highest near-term priority
  - Science Goals - more specific scientific questions that we are addressing with CMS
  - Science Requirements - CMS wide performance requirements
  - Science-Engineering Requirements - sub-detector specific performance requirements that a given L2 area needs to meet in order for the whole of CMS to meet the science requirements
  - Engineering Requirements - technical requirements that a L2 area needs to meet with its designs in order for the science-engineering requirements to be met



P5

Science Drivers

CMS

Science Goals
CMS-doc-13337

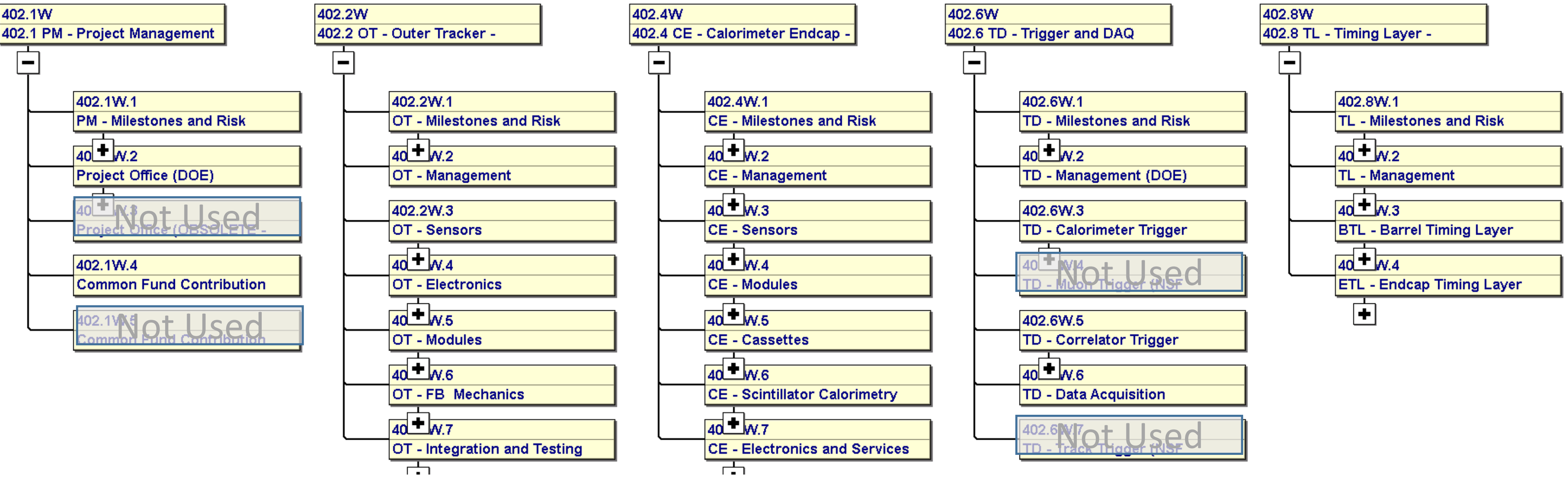
Science Requirements
CMS-doc-13337

Subdetector

Science-Engineering Requirements
CMS-doc-13388, CMS-doc-13447, CMS-doc-13318, CMS-doc-13536

Engineering Requirements
CMS-doc-13388, CMS-doc-13447, CMS-doc-13318 , CMS-doc-13536

Work Breakdown Structure to L3

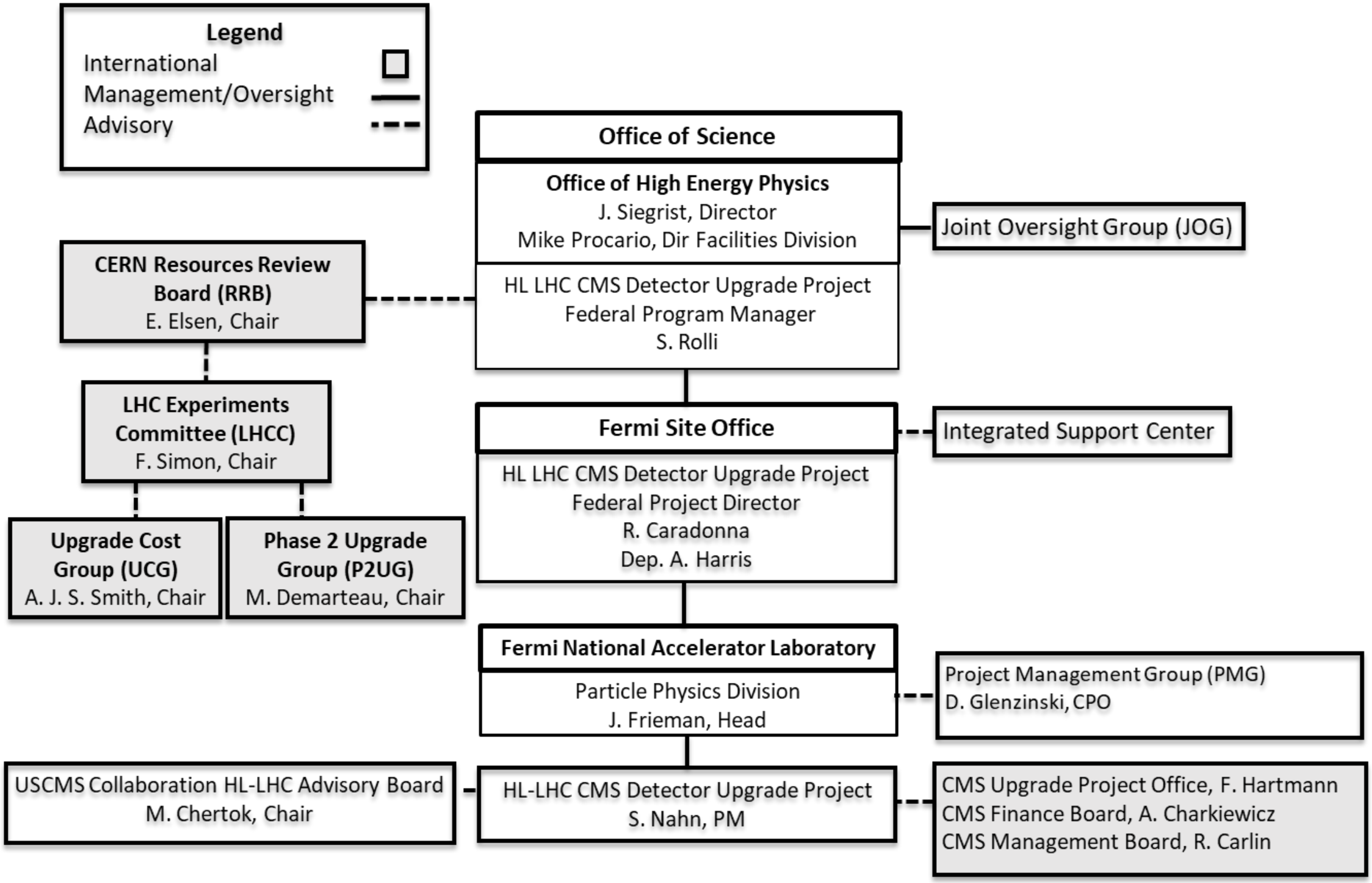


- 402.1W 402.1 PM - Project Management
  - 402.1W.1 PM - Milestones and Risk
  - 40 W.2 Project Office (DOE)
  - Not Used — 40 W.3 Project Office (OBSOLETE -
  - 402.1W.4 Common Fund Contribution
  - Not Used — 402.1W.5 Common Fund Contribution
- 402.2W 402.2 OT - Outer Tracker -
  - 402.2W.1 OT - Milestones and Risk
  - 40 W.2 OT - Management
  - 402.2W.3 OT - Sensors
  - 40 W.4 OT - Electronics
  - 40 W.5 OT - Modules
  - 40 W.6 OT - FB Mechanics
  - 40 W.7 OT - Integration and Testing
- 402.4W 402.4 CE - Calorimeter Endcap -
  - 402.4W.1 CE - Milestones and Risk
  - 40 W.2 CE - Management
  - 40 W.3 CE - Sensors
  - 40 W.4 CE - Modules
  - 40 W.5 CE - Cassettes
  - 40 W.6 CE - Scintillator Calorimetry
  - 40 W.7 CE - Electronics and Services
- 402.6W 402.6 TD - Trigger and DAQ
  - 402.6W.1 TD - Milestones and Risk
  - 40 W.2 TD - Management (DOE)
  - 402.6W.3 TD - Calorimeter Trigger
  - Not Used — 40 W.4 TD - Muon Trigger (NSF
  - 402.6W.5 TD - Correlator Trigger
  - 40 W.6 TD - Data Acquisition
  - Not Used — 402.6W.7 TD - Track Trigger (NSF
- 402.8W 402.8 TL - Timing Layer -
  - 402.8W.1 TL - Milestones and Risk
  - 40 W.2 TL - Management
  - 40 W.3 BTL - Barrel Timing Layer
  - 40 W.4 ETL - Endcap Timing Layer

- Generically breaks down into
  - Management
  - Component Fabrication
  - Assembly Site Preparation, Assembly, Quality Control
  - Integration and Commissioning
- WBS Dictionary [cms-doc 13213]
  - OT, CE, TD mostly unchanged since June 2018 IPR, MTD evolved

Charge #5,7

Project Governance



Legend
International ☐
Management/Oversight ──
Advisory - - -

Office of Science

Office of High Energy Physics
J. Siegrist, Director
Mike Procario, Dir Facilities Division

HL LHC CMS Detector Upgrade Project
Federal Program Manager
S. Rolli

Joint Oversight Group (JOG)

CERN Resources Review Board (RRB)
E. Elsen, Chair

LHC Experiments Committee (LHCC)
F. Simon, Chair

Upgrade Cost Group (UCG)
A. J. S. Smith, Chair

Phase 2 Upgrade Group (P2UG)
M. Demarteau, Chair

Fermi Site Office

HL LHC CMS Detector Upgrade Project
Federal Project Director
R. Caradonna
Dep. A. Harris

Integrated Support Center

Fermi National Accelerator Laboratory

Particle Physics Division
J. Frieman, Head

Project Management Group (PMG)
D. Glenzinski, CPO

USCMS Collaboration HL-LHC Advisory Board
M. Chertok, Chair

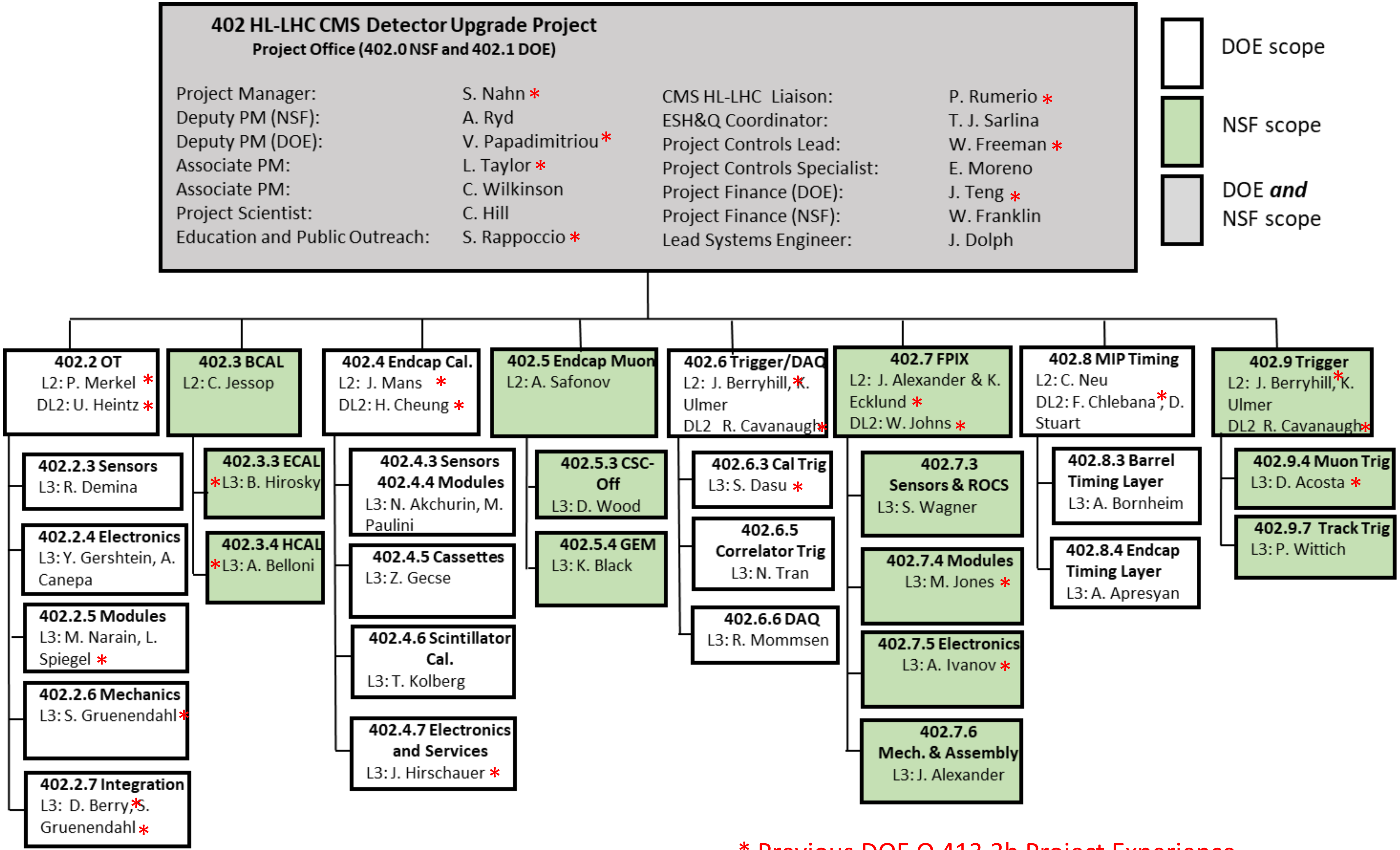
HL-LHC CMS Detector Upgrade Project
S. Nahn, PM

CMS Upgrade Project Office, F. Hartmann
CMS Finance Board, A. Charkiewicz
CMS Management Board, R. Carlin

- Governance documented in preliminary Project Execution Plan (cms-doc 13092)

Charge #5

Project Organization



402 HL-LHC CMS Detector Upgrade Project
Project Office (402.0 NSF and 402.1 DOE)

Project Manager:	S. Nahn *	CMS HL-LHC Liaison:	P. Rumerio *
Deputy PM (NSF):	A. Ryd	ESH&Q Coordinator:	T. J. Sarlina
Deputy PM (DOE):	V. Papadimitriou *	Project Controls Lead:	W. Freeman *
Associate PM:	L. Taylor *	Project Controls Specialist:	E. Moreno
Associate PM:	C. Wilkinson	Project Finance (DOE):	J. Teng *
Project Scientist:	C. Hill	Project Finance (NSF):	W. Franklin
Education and Public Outreach:	S. Rappoccio *	Lead Systems Engineer:	J. Dolph

☐ DOE scope

🟩 NSF scope

▨ DOE *and* NSF scope

402.2 OT
L2: P. Merkel *
DL2: U. Heintz *

- **402.2.3 Sensors** L3: R. Demina
- **402.2.4 Electronics** L3: Y. Gershtein, A. Canepa
- **402.2.5 Modules** L3: M. Narain, L. Spiegel *
- **402.2.6 Mechanics** L3: S. Gruenendahl *
- **402.2.7 Integration** L3: D. Berry, * S. Gruenendahl *

402.3 BCAL
L2: C. Jessop

- **402.3.3 ECAL** * L3: B. Hirosky
- **402.3.4 HCAL** * L3: A. Belloni

402.4 Endcap Cal.
L2: J. Mans *
DL2: H. Cheung *

- **402.4.3 Sensors 402.4.4 Modules** L3: N. Akchurin, M. Paulini
- **402.4.5 Cassettes** L3: Z. Gecse
- **402.4.6 Scintillator Cal.** L3: T. Kolberg
- **402.4.7 Electronics and Services** L3: J. Hirschauer *

402.5 Endcap Muon
L2: A. Safonov

- **402.5.3 CSC-Off** L3: D. Wood
- **402.5.4 GEM** L3: K. Black

402.6 Trigger/DAQ
L2: J. Berryhill, * K. Ulmer
DL2 R. Cavanaugh *

- **402.6.3 Cal Trig** L3: S. Dasu *
- **402.6.5 Correlator Trig** L3: N. Tran
- **402.6.6 DAQ** L3: R. Mommsen

402.7 FPIX
L2: J. Alexander & K. Ecklund *
DL2: W. Johns *

- **402.7.3 Sensors & ROCS** L3: S. Wagner
- **402.7.4 Modules** L3: M. Jones *
- **402.7.5 Electronics** L3: A. Ivanov *
- **402.7.6 Mech. & Assembly** L3: J. Alexander

402.8 MIP Timing
L2: C. Neu
DL2: F. Chlebana *, D. Stuart

- **402.8.3 Barrel Timing Layer** L3: A. Bornheim
- **402.8.4 Endcap Timing Layer** L3: A. Apresyan

402.9 Trigger
L2: J. Berryhill, * K. Ulmer
DL2 R. Cavanaugh *

- **402.9.4 Muon Trig** L3: D. Acosta *
- **402.9.7 Track Trig** L3: P. Wittich

* Previous DOE O 413.3b Project Experience

Institutes on the project

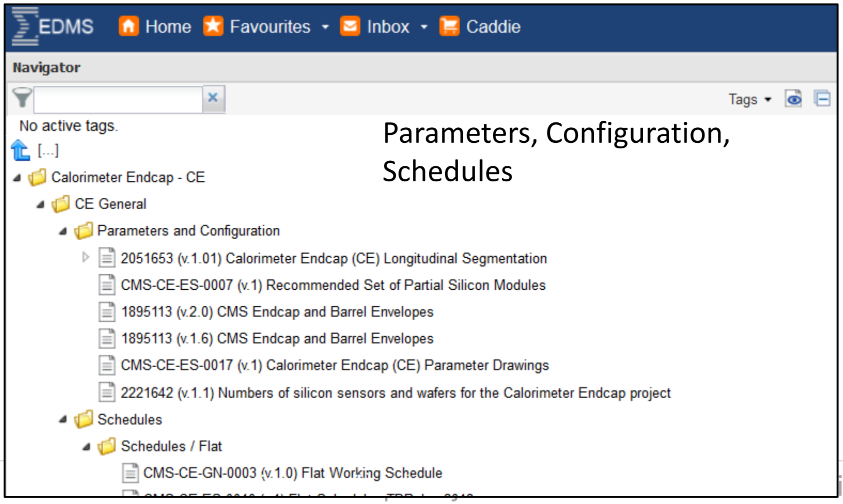
- 38 institutes involved on DOE scope

Institutes	
Bethel College	Northeastern University
Boston University	Northern Illinois University
Brown University	Northwestern University
Carnegie Mellon University	The Ohio State University
University of Colorado	Purdue University
California Institute of Technology	Princeton University
Fairfield University	Rutgers University
University of Florida	Southern Methodist University
Fermilab	Texas A&M
Florida State University	Texas Tech
Florida Institute of Technology	University of Alabama
University of Iowa	University of California Davis
University of Kansas	University of California - Los Angeles
Kansas State University	University of California Santa Barbara
University of Maryland	University of Illinois - Chicago
University of Minnesota	University of Rochester
Massachusetts Institute of Technology	University of Virginia
University of Nebraska	University of Wisconsin
University of Notre Dame	Wayne State University

- Yearly Statements of Work describe agreement between the Project and Institutes for the scope of work and supplied resources
  - SOWs include identification of Institute Safety personnel
  - PO issued when SOW is signed off by all stakeholders

Interfaces

- U.S. CMS Operations
  - Close ties and overlap between Upgrade and Operations
    - Many personnel develop Upgrade while supporting Operations
  - Managers of both are in ~constant contact, with an open door policy
- NSF
  - NSF Principal Investigator for MREFC is Deputy Project Manager, shared project office
    - Leverages synergies in managing large scientific construction projects
- International Upgrade Organization
  - Many management roles covered by U.S. personnel
  - Enhanced effort to implement formal documentation management in EDMS
    - Designs and design change, Interface control, planning documents, etc

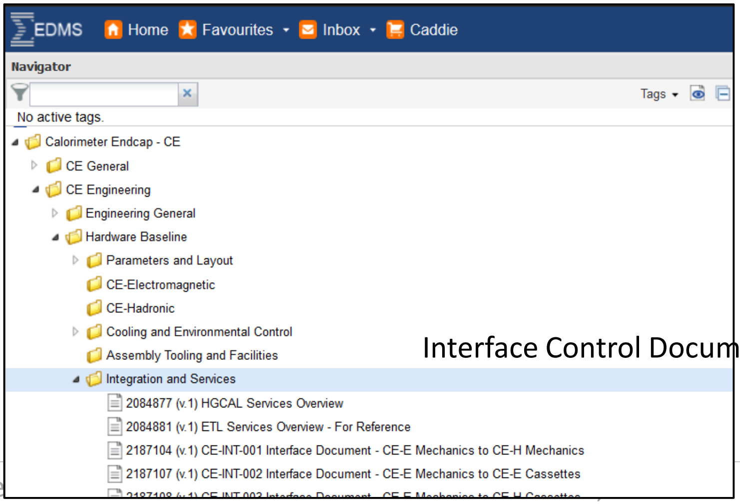


No active tags.

[...]

- Calorimeter Endcap - CE
  - CE General
    - Parameters and Configuration
      - 2051653 (v.1.01) Calorimeter Endcap (CE) Longitudinal Segmentation
      - CMS-CE-ES-0007 (v.1) Recommended Set of Partial Silicon Modules
      - 1895113 (v.2.0) CMS Endcap and Barrel Envelopes
      - 1895113 (v.1.6) CMS Endcap and Barrel Envelopes
      - CMS-CE-ES-0017 (v.1) Calorimeter Endcap (CE) Parameter Drawings
      - 2221642 (v.1.1) Numbers of silicon sensors and wafers for the Calorimeter Endcap project
    - Schedules
      - Schedules / Flat
        - CMS-CE-GN-0003 (v.1.0) Flat Working Schedule

Parameters, Configuration, Schedules



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- Calorimeter Endcap - CE
  - CE General
  - CE Engineering
    - Engineering General
    - Hardware Baseline
      - Parameters and Layout
      - CE-Electromagnetic
      - CE-Hadronic
      - Cooling and Environmental Control
      - Assembly Tooling and Facilities
      - Integration and Services
        - 2084877 (v.1) HGCAL Services Overview
        - 2084881 (v.1) ETL Services Overview - For Reference
        - 2187104 (v.1) CE-INT-001 Interface Document - CE-E Mechanics to CE-H Mechanics
        - 2187107 (v.1) CE-INT-002 Interface Document - CE-E Mechanics to CE-E Cassettes

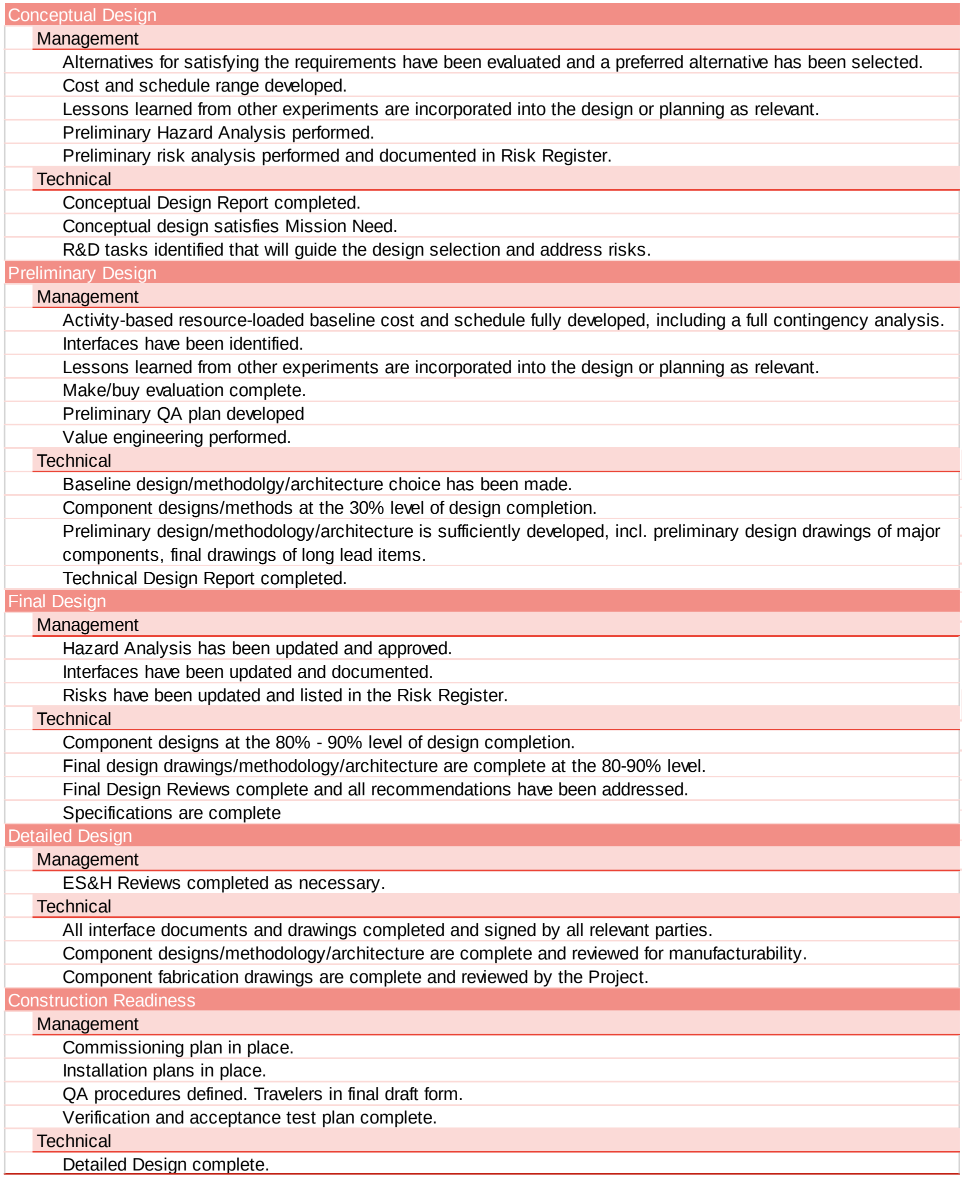
Interface Control Documents

Design Maturity

Evolution of Design

- Conceptual design essentially unchanged since June 2018 IPR for OT, CE, TD
  - Already based on Technical Design Reports in existence at that time, beyond Conceptual level
  - Design changes since then based on moving towards final design and work with prototypes
    - E.g. Revamp readout architecture in CE to relax complexity of Concentrator ASIC
- MTD has matured substantially since June 2018
  - International project established, spearheaded by U.S.
  - Initial design modified to increase robustness, address technical challenges
  - Culminated in TDR approved by LHCC/UCG Sept 2019
    - Progress will be subject to P2UG scrutiny starting Spring 2020

Design Maturity Estimate



Conceptual Design
- Management
  - Alternatives for satisfying the requirements have been evaluated and a preferred alternative has been selected.
  - Cost and schedule range developed.
  - Lessons learned from other experiments are incorporated into the design or planning as relevant.
  - Preliminary Hazard Analysis performed.
  - Preliminary risk analysis performed and documented in Risk Register.
- Technical
  - Conceptual Design Report completed.
  - Conceptual design satisfies Mission Need.
  - R&D tasks identified that will guide the design selection and address risks.

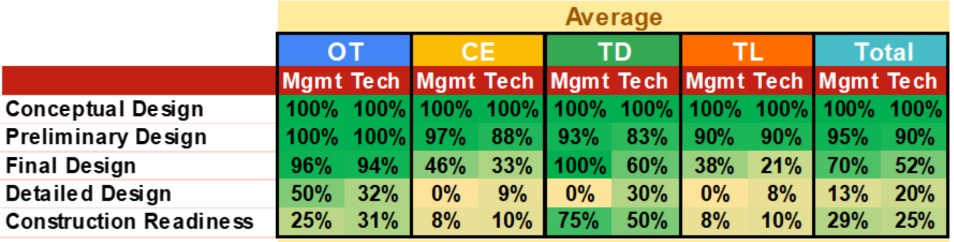
Preliminary Design
- Management
  - Activity-based resource-loaded baseline cost and schedule fully developed, including a full contingency analysis.
  - Interfaces have been identified.
  - Lessons learned from other experiments are incorporated into the design or planning as relevant.
  - Make/buy evaluation complete.
  - Preliminary QA plan developed
  - Value engineering performed.
- Technical
  - Baseline design/methodolgy/architecture choice has been made.
  - Component designs/methods at the 30% level of design completion.
  - Preliminary design/methodology/architecture is sufficiently developed, incl. preliminary design drawings of major components, final drawings of long lead items.
  - Technical Design Report completed.

Final Design
- Management
  - Hazard Analysis has been updated and approved.
  - Interfaces have been updated and documented.
  - Risks have been updated and listed in the Risk Register.
- Technical
  - Component designs at the 80% - 90% level of design completion.
  - Final design drawings/methodology/architecture are complete at the 80-90% level.
  - Final Design Reviews complete and all recommendations have been addressed.
  - Specifications are complete

Detailed Design
- Management
  - ES&H Reviews completed as necessary.
- Technical
  - All interface documents and drawings completed and signed by all relevant parties.
  - Component designs/methodology/architecture are complete and reviewed for manufacturability.
  - Component fabrication drawings are complete and reviewed by the Project.

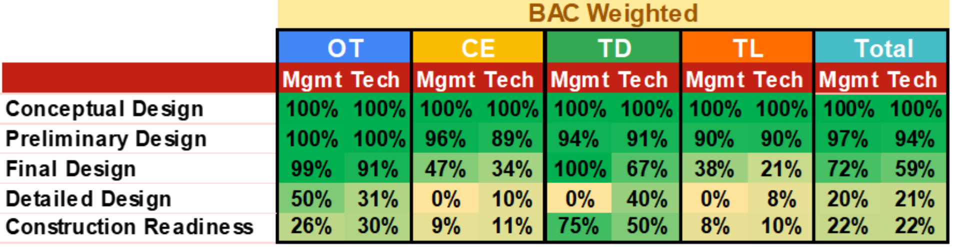
Construction Readiness
- Management
  - Commissioning plan in place.
  - Installation plans in place.
  - QA procedures defined. Travelers in final draft form.
  - Verification and acceptance test plan complete.
- Technical
  - Detailed Design complete.

- Revamped Maturity algorithm
  - Same criteria, but separate “Management” from “Technical” aspects
  - Removed (arbitrary) assignment of absolute completeness
  - Each criteria evaluated at L3, rolled up for full project



Average

	OT		CE		TD		TL		Total	
	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech
Conceptual Design	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Preliminary Design	100%	100%	97%	88%	93%	83%	90%	90%	95%	90%
Final Design	96%	94%	46%	33%	100%	60%	38%	21%	70%	52%
Detailed Design	50%	32%	0%	9%	0%	30%	0%	8%	13%	20%
Construction Readiness	25%	31%	8%	10%	75%	50%	8%	10%	29%	25%



BAC Weighted

	OT		CE		TD		TL		Total	
	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech
Conceptual Design	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Preliminary Design	100%	100%	96%	89%	94%	91%	90%	90%	97%	94%
Final Design	99%	91%	47%	34%	100%	67%	38%	21%	72%	59%
Detailed Design	50%	31%	0%	10%	0%	40%	0%	8%	20%	21%
Construction Readiness	26%	30%	9%	11%	75%	50%	8%	10%	22%	22%

- All subsystems well beyond Conceptual level needed for CD-1, approaching Preliminary design (CD-2)
  - Details of technical progress in L2 talks and breakout

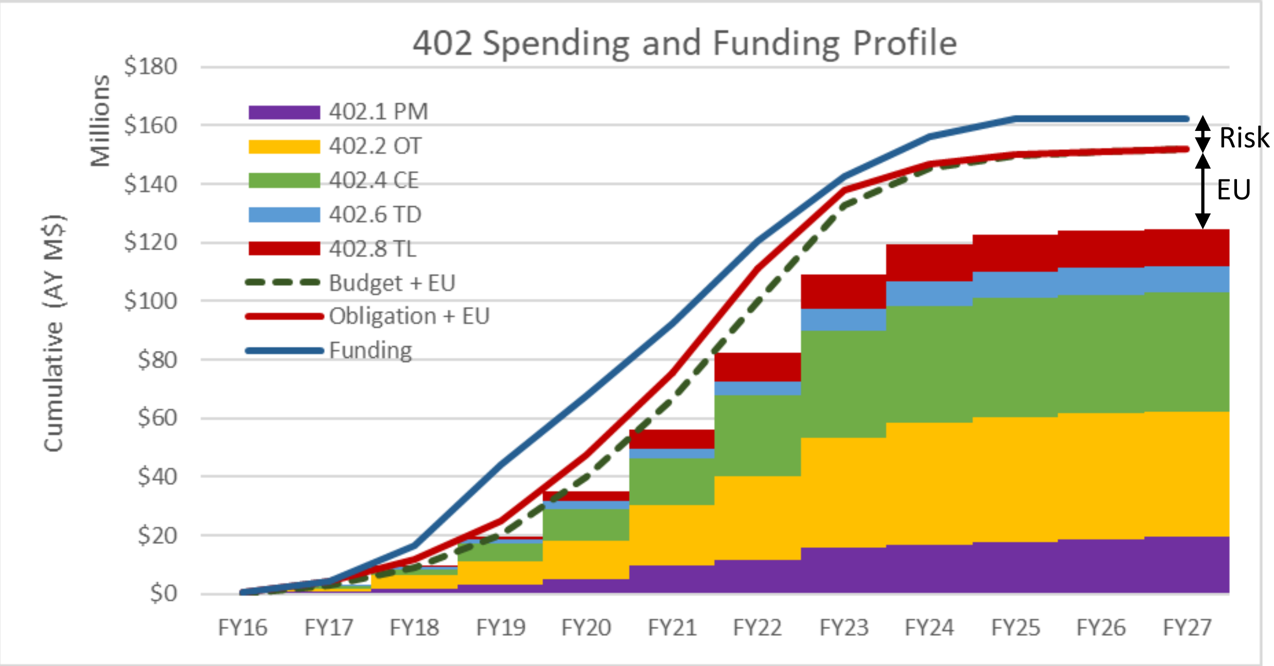
Cost and Schedule Summary

Overview here, more details and methodology in the next talk

Cost Summary

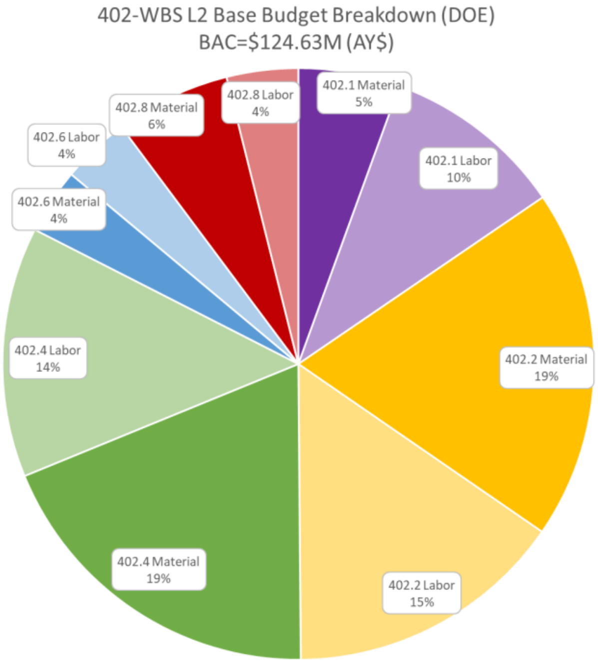
- Three components to the Total Project Cost (TPC)
  1. Budget at Completion (BAC) - the estimated cost of the activity
     - BOE estimates made in direct cost or labor hours, which are then fully loaded with site-specific rates and overheads, and escalated
  2. Estimate Uncertainty (EU) - contingency based on confidence in estimate, scales with BAC
  3. Risk - contingency based on probability of divergence from expected cost range, because of an unlikely event which has cost and schedule impacts
     - Cost and schedule impact determined from Monte Carlo simulation
- TPC = BAC + EU + Risk
  - **Bottom line: Total Project Cost (range) is $144M-$183M**
  - **Point estimate is $162.03M**
  - **Overall cost contingency is 35.1% (CTG),**
    - **Including the scope contingency → 40.2%**
  - **Project is 15% Complete**

Full Project Cost



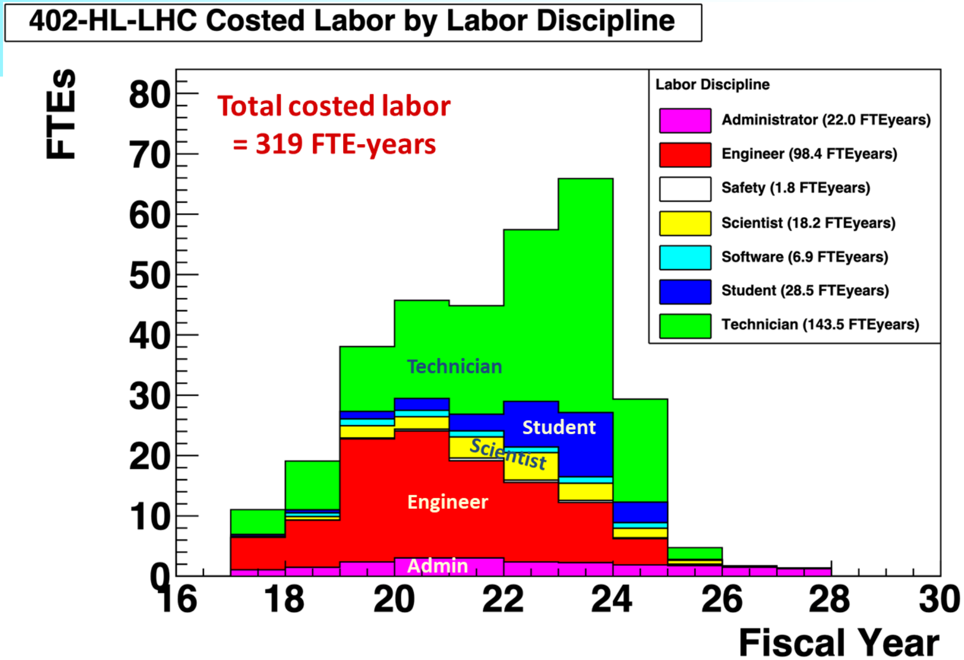
- Ramps from prototyping into production, then tapers
- Funds $162.05 M covers TPC

TPC (AY k$)	Material		Labor		Risk	TPC
	BAC	EU (%)	BAC	EU (%)		
402.1 PM	$6,918	9%	$12,363	8%	$0	$20,897
402.2 OT	$23,841	25%	$19,030	20%	$3,582	$56,344
402.4 CE	$23,617	26%	$17,055	24%	$3,436	$54,252
402.6 TD	$4,455	31%	$4,633	23%	$1,105	$12,631
402.8 TL	$7,855	19%	$4,864	36%	$1,952	$17,901
Grand Total	$66,686	23%	$57,946	20%	$10,075	$162,025

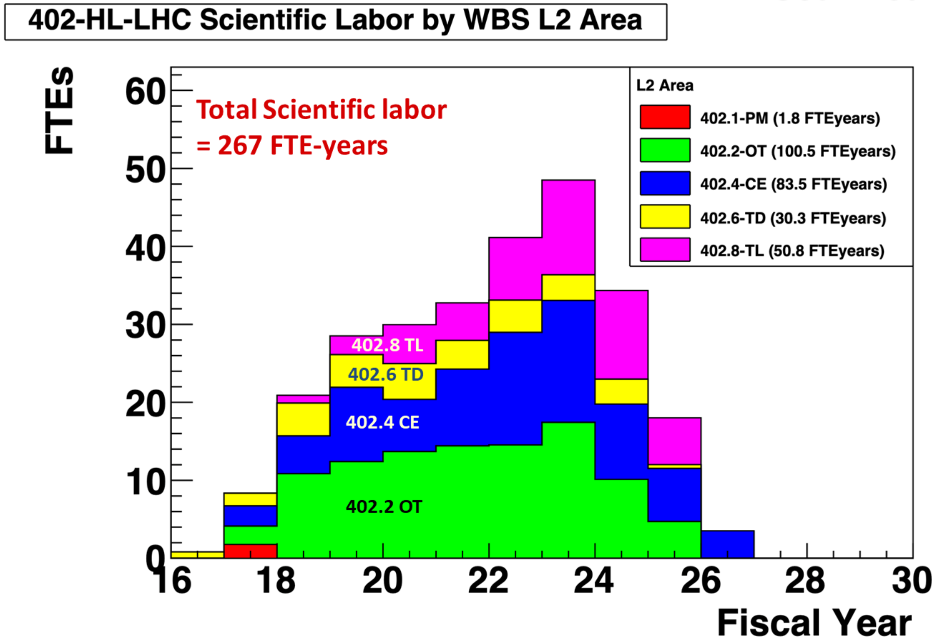


Labor Profile

- Ramp up through prototyping, increase in techs and students as we proceed into production phase
- 45.5% scientific labor
  - 12.6% Management WBSs
    - Not as vulnerable to decrease in Research Budget
  - 32.9% Technical WBSs
    - Each L2 area carries a risk of loss of up to 20% of the scientific labor at 30% probability



402-HL-LHC Costed Labor by Labor Discipline



402-HL-LHC Scientific Labor by WBS L2 Area

Changes since 2018 IPR

- Funding Guidance: 165.0M ⇒ 162.05M
  - Total Cost decreases by 2%
- Mostly modest changes as estimates updated by experience
  - Large percentage changes typically on small numbers
  - MTD maturation shows up as considerable change since 2018 IPR
  - Retirement of Estimate Uncertainty on completed work

All resources

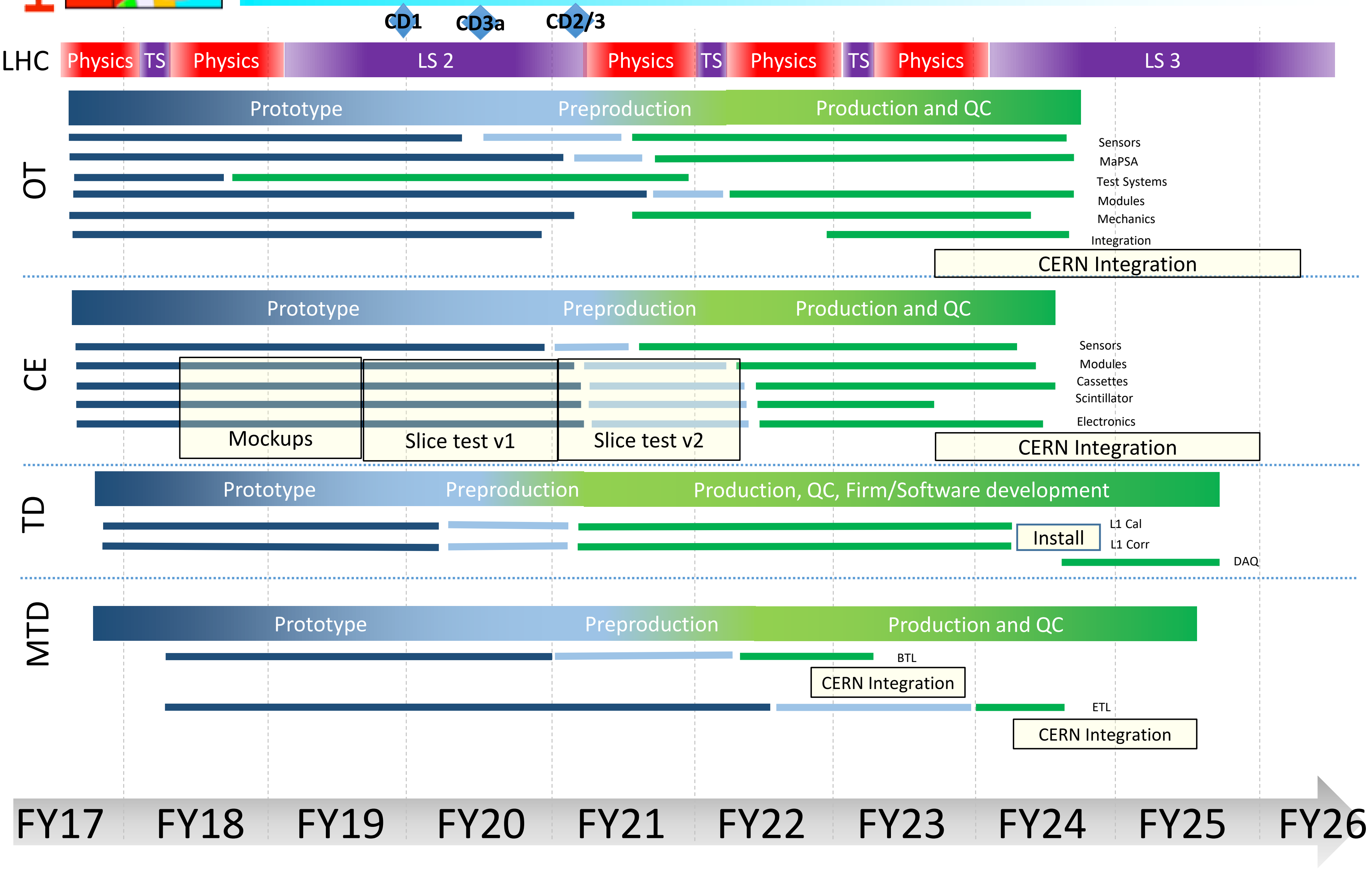
	2019	Change: {Now/Then-1}				
L2/L3 Area	BAC	M&S	Hours	Cost	EU	Total
PM	**19,282**	**10%**	**12%**	**11%**	**-5%**	**10%**
PM - Mgmt	13,468	-15%	12%	8%	-15%	6%
PM - Common Fund	5,814	16%	0%	20%	20%	20%
OT	**42,872**	**-4%**	**11%**	**1%**	**-26%**	**-6%**
OT - Mgmt	1,125	46%	7%	33%	3%	31%
OT - Sensors	7,371	-34%	4%	-24%	-51%	-30%
OT - Electronics	6,222	91%	8%	41%	-9%	29%
OT - Modules	21,786	1%	4%	3%	-23%	-3%
OT - Mechanics	2,380	25%	1%	8%	-26%	-3%
OT - FB Integration	3,987	-2%	160%	-7%	-13%	-9%
CE	**40,672**	**-2%**	**8%**	**-1%**	**-15%**	**-4%**
CE - Mgmt	3,807	0%	-3%	-5%	-17%	-7%
CE - Sensors	8,393	1%	57%	3%	-26%	-3%
CE - Modules	8,406	-13%	0%	-12%	-28%	-15%
CE - Cassettes	9,423	9%	8%	4%	-8%	1%
CE - Scintillator	4,197	0%	36%	10%	-5%	6%
CE - Electronics	6,447	-13%	10%	1%	-6%	-1%
TD	**9,088**	**10%**	**-3%**	**-1%**	**-12%**	**-3%**
TD - Mgmt	215	6%	-3%	1%	-35%	0%
TD - Cal Trig	3,266	-2%	0%	-6%	-16%	-8%
TD - Corr Trig	4,667	28%	-6%	3%	-14%	-1%
TD - DAQ	940	0%	0%	0%	0%	0%
TL	**12,718**	**36%**	**-42%**	**29%**	**-33%**	**9%**
TL - Mgmt	1,246	592%	-88%	524%	1011%	568%
TL - BTL	5,141	17%	111%	9%	-46%	-9%
TL - ETL	6,331	20%	344%	28%	-29%	9%
Grand Total	**124,632**	**3%**	**-5%**	**4%**	**-21%**	**-2%**

Contributed Labor

	2019	Change
L2/L3 Area	Contributed Hours	Hours
PM	**3,157**	**79%**
PM - Mgmt	3,157	79%
OT	**177,843**	**16%**
OT - Mgmt	43,537	7%
OT - Sensors	1,376	5%
OT - Electronics	12,470	9%
OT - Modules	93,736	-2%
OT - Mechanics	496	2%
OT - FB Integration	26,228	627%
CE	**147,664**	**8%**
CE - Mgmt	69,630	-3%
CE - Sensors	4,660	199%
CE - Modules	21,890	7%
CE - Cassettes	4,951	34%
CE - Scintillator	36,589	31%
CE - Electronics	9,944	-9%
TD	**53,497**	**-5%**
TD - Mgmt	25,470	-3%
TD - Cal Trig	8,784	0%
TD - Corr Trig	19,243	-9%
TL	**89,783**	**-61%**
TL - Mgmt	26,520	-88%
TL - BTL	20,216	∞
TL - ETL	43,047	∞
Grand Total	**471,944**	**-18%**

Legend
< -50%
-50%
-25%
0%
25%
50%
> 50%

Cartoon Schedule at L3



Schedule Summary

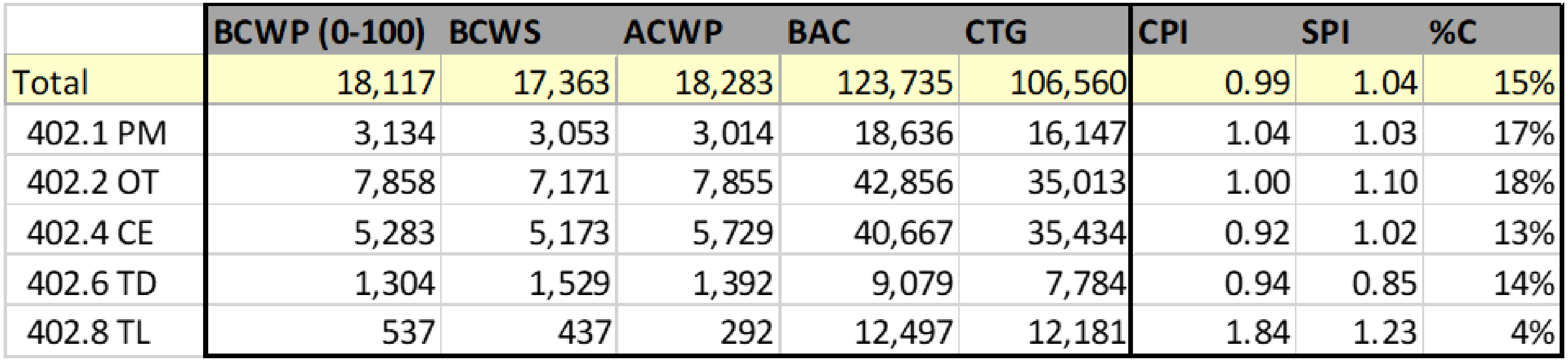
- Activities have been sequenced with logical links to provide a workable and predictive schedule
  - Minimal interdependence between L2 schedules
  - International dependencies, review dates, and expectations imported into synchronization milestones

Subsystem	Float to CMS need-by date (m)	Float to CD-4 (m)
Outer Tracker	5.7 (Modules)/11.4 (Flat Barrel)	37
Calorimeter Endcap	7.2	44
Trigger/DAQ	9.1	44
MTD	11.0 (BTL) / 14.2 (ETL)	54 (BTL)/41 (ETL)

- Finalizing schedule part of moving to a baseline at CD-2
  - LHC schedule discussion will be in the past
  - Component delivery schedules will be updated
  - Duration estimates will be refined from prototyping experience

Coarse Earned Value Assessment

- Before employing EVMS, can make some approximations to calculate EVMS observables
  - BCWP: Estimate Uncertainty retirement is up to date to October, can use “L1/M1” to estimate completed work
    - i.e. using PMT 0-100
  - ACWP: Invoiced costs up to October as proxy for ACWP, without accruals
  - BCWS: Unstatused Resource Loaded Schedule serves as Baseline



	BCWP (0-100)	BCWS	ACWP	BAC	CTG	CPI	SPI	%C
Total	18,117	17,363	18,283	123,735	106,560	0.99	1.04	15%
402.1 PM	3,134	3,053	3,014	18,636	16,147	1.04	1.03	17%
402.2 OT	7,858	7,171	7,855	42,856	35,013	1.00	1.10	18%
402.4 CE	5,283	5,173	5,729	40,667	35,434	0.92	1.02	13%
402.6 TD	1,304	1,529	1,392	9,079	7,784	0.94	0.85	14%
402.8 TL	537	437	292	12,497	12,181	1.84	1.23	4%

- Reasonable results given coarse inputs
  - CPI: Both BCWP and ACWP underestimated, compensate each other
  - SPI: Possibly ahead of schedule, but remains to be seen
- Project starts full EVMS monthly cycle in October
  - 12 months ahead of CD-2 review

ESH&Q

Charge #6

ES&H

Preliminary Hazard Analysis Report: cms-doc-13394

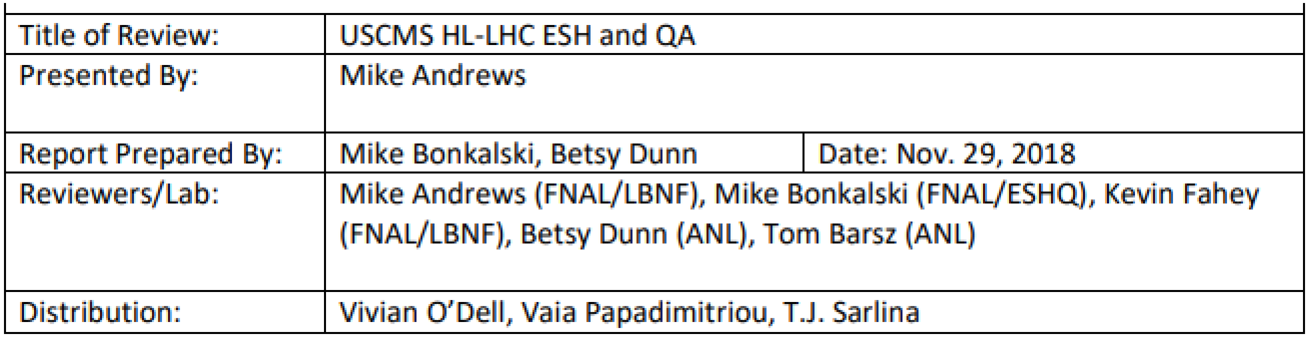
- ES&H aspects are guided by the Fermilab Integrated Safety Management approach, with rules and procedures laid out in the Fermilab ES&H Manual
- In General, Safety is achieved through standard Lab practices
  - Items comply with local safety standards in site of fabrication and operation
  - Radiation campaigns/test beams require appropriate safety training and ORC
  - No construction, accelerator operation, or exotic fabrication
  - No imminent peril situations or unusual hazards
- Phase 1 provides an excellent recent template for ESH issues
  - FPIX + OT fabrication of Silicon + electronics on Carbon composite support structure w/CO2 cooling, much of it done at FNAL
  - CO_2 cooling system at SiDet already has Operational Readiness Clearance
- Project has NEPA exclusion (CMS-doc-13483) and Security Vulnerability Assessment (CMS-doc-13755)

Charge #6

ESH development since last IPR

More in Breakout session

- Added ESH&Q professional to the project office
- Held dedicated ESH&Q review Nov 29, 2018 with PO, L2 participation



Title of Review:	USCMS HL-LHC ESH and QA	
Presented By:	Mike Andrews	
Report Prepared By:	Mike Bonkalski, Betsy Dunn	Date: Nov. 29, 2018
Reviewers/Lab:	Mike Andrews (FNAL/LBNF), Mike Bonkalski (FNAL/ESHQ), Kevin Fahey (FNAL/LBNF), Betsy Dunn (ANL), Tom Barsz (ANL)	
Distribution:	Vivian O'Dell, Vaia Papadimitriou, T.J. Sarlina	

- Recommendations from Report CMS DocDb 13709
  - Develop a clear list of design codes and standards that are applicable to both the U.S. and CERN operations.   *Done* CMS DocDb 13717
  - The QAP needs to address the packaging and shipping requirements for components to be sent to CERN.   ***QAP Updated, reviewed, and signed off***
  - The hazard analysis worksheets within the PHAR need to be reviewed by the ESH&Q Manager.   ***pHAR reviewed, signed off***
  - The ISM Plan needs to be restructured to clarify collaborating institutions ESH requirements.   ***ISM plan updated, reviewed and signed off***
  - Develop a set of ESH review criteria for institutional site visits *Done* CMS DocDb 13668
    - Site visits to UCSB, FNAL, Brown, Princeton, Rutgers in 2019, more planned for 2020

Charge #6

pHAR summary

- Survey of potential hazards in L2 areas carried out using Standard Lab hazard analysis
  - Fermilab QAM 12030

Degree	Pre-Mitigation		Post-Mitigation	
	Severity	Risk	Severity	Risk
Critical		1		
High	2	3		
Medium	6	6	8	7
Low	2		2	2
Minimal				1

WBS Number	WBS Description	Mechanical Hazards	Leak/Spill Hazards	Electrical Hazards	Fire Hazards	CO$_2$ ODH/Cryo Hazards	Laser Hazards	Radiation Hazards	Toxic Material Hazards	Environmental Hazards	ESD Hazards
402.01	Management: Schedule, budget, travel, workshops, integration planning										
402.02.03	Outer Tracker: Sensors			×	×			×			×
402.02.04	Outer Tracker: Electronics			×	×			×			×
402.02.05	Outer Tracker: Modules	×	×	×	×			×	×		×
402.02.06	Outer Tracker: Flat Barrel Mechanics	×		×	×	×			×	×	
402.02.07	Outer Tracker: Integration	×		×	×	×					×
402.04.03	Calorimeter Endcap: Sensors	×	×	×	×		×	×			×
402.04.04	Calorimeter Endcap: Modules	×	×	×	×			×	×		×
402.04.05	Calorimeter Endcap: Cassettes	×		×	×	×		×	×		×
402.04.06	Calorimeter Endcap: Scintillator Callorimetry	×		×	×		×	×		×	×
402.04.07	Calorimeter Endcap: Electronics and Services			×	×			×			×
402.06.03	Trigger / DAQ: Cal Trigger			×	×						×
402.06.05	Trigger / DAQ: Correlator Trigger			×	×						×
402.06.06	Trigger / DAQ: DAQ			×	×						
402.08.03	Timing Layer: Barrel Timing Layer	×		×	×	×	×	×	×		×
402.08.04	Timing Layer: Endcap Timing Layer	×		×	×	×		×	×		×

QA/QC

Quality Assurance Plan: cms-doc-13093

- Quality Assurance – processes to prevent substandard quality
  - Design Reviews, Testing plans, Prototyping iterations
- Quality Control – processes to detect substandard quality
  - Testbeams, Burn-in tests, Sample Irradiations
- Substantial effort to beef up QA/QC formalisms since last review
  - QA/QC summaries per L2 area in the QAP appendices
  - Crosswalk between QA/QC and Requirements validation
  - QA/QC activities are scheduled and resource loaded in the RLS
  - QC Procedures applicable to all fabrication sites are in development as prototyping proceeds

Review Responses

Charge #8

Recent Reviews: June 2018 IPR

- 24 recommendations CMS-doc-13603
  - 15 for CD-1; 6 for CD-2 (not including 3 “proceed to CD-1”)
    - For CD-1 (1: CE, 2 TD, 4 MTD, 8 PM)
  - All CD-1 recommendations closed
    - All others have a response
- OT, CE, TD recommended to proceed to CD-1, MTD was not at a CD-1 level of maturity
  - No reviewed Conceptual Design, immature RLS
- Additional important recommendations to the project office were also made for cost vs. funding profile, documentation, ESH&Q
  - In response to, project management was strengthened:
    - Added a deputy PM with extensive project management experience
    - Added a professional ESH&Q coordinator
    - Fully staffed MTD management

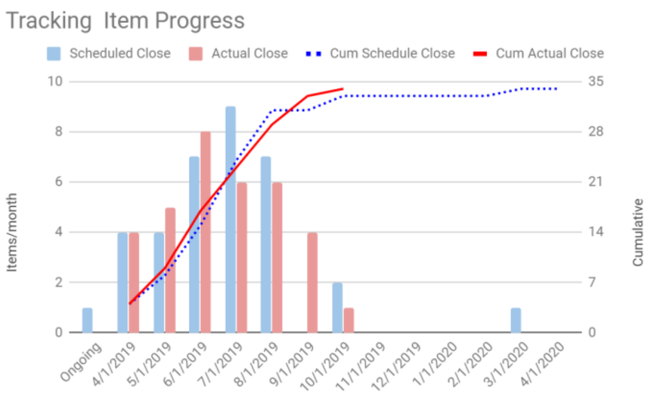
Charge #8

June 2018 IPR Recommendations for PO

- Summary of main Project Office recommendations
  - Project TPC must fit within the DOE funding guidance
  - MIP Timing Detector needs a reviewed Conceptual Design, and all cost and schedule elements developed to CD-1 quality.
  - Revise the Integrated Safety Management Plan and Quality Assurance Plan to accurately document Project process for safety and quality. Document process for identifying relevant codes and standards.
  - Implement document revision control and review
- All these are closed CMS-docdb-13604
  - Details in the breakout sessions

Charge #8

Director’s Review March 2019


Tracking Item Progress

- 14 recommendations and 21 comments tracked
  - R01-R04 technical recs covered by L2s
- Summary of Recommendations
  - ESH (R07,08,09): Update pHAR and ISM, verify SiDet CO_2 plant ORC documentation
  - Planning (R13, R14): Consolidate CD-3a scope, plan for CD-2
  - Scope and Cost (R10,R11, R12): Scrub costs, reassess number of KPPs, add scope contingency that is not I&C
  - Schedule (R05): Incorporate latest international Schedule
  - Presentation (R06): Consistent Rounding in BOEs
- All complete CMS-docdb-13604
  - Including all 21 comments as well

Path forward and Summary

Path Forward beyond CD-1

More in Breakout sessions

- CD-3a March 2020
  - Scope $13,040k (BAC)

Silicon Sensors for OT and CE	$11,941k
LYSO Crystals for MTD	$525k
Carbon Fiber materials for OT	$574k

  - All items will have undergone Production Readiness Reviews
- CD-2 November 2020
  - Technical readiness for CD-2 tracked by milestones in each subsystem
    - currently on track without much float
  - Management readiness requires
    - EVMS Practice with realistic baseline – Fall 2019
    - Revision of DOE documents – Summer 2020
    - Refining of cost and schedule estimates – Summer 2020
  - LS3 schedule change and budget forecast in Nov 2020 may provide impetus to move this later in FY21

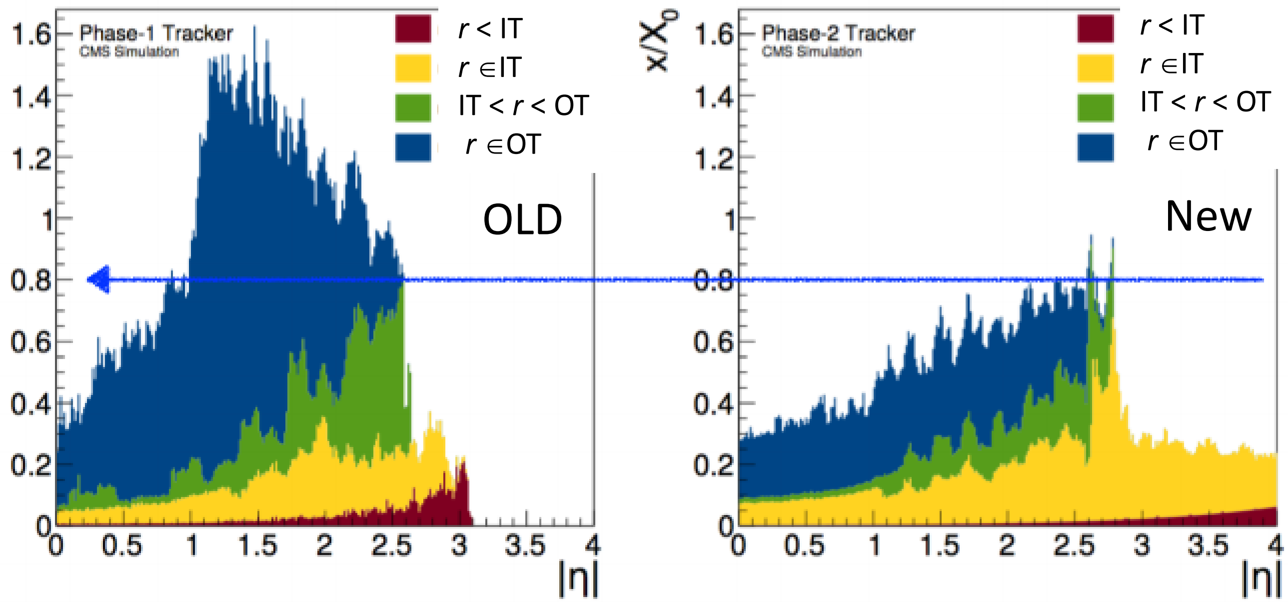
Summary

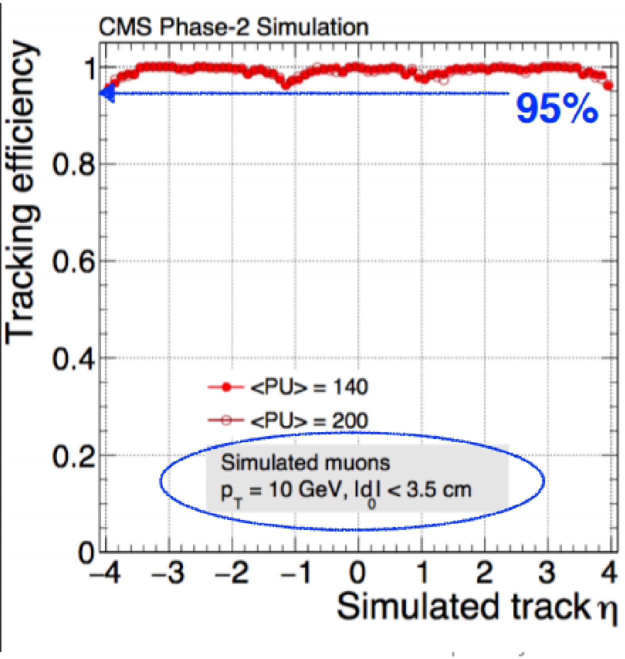
- Project has matured since last review
  - Project Office has increased rigor in documentation and formal procedures
  - MTD is a real project at this point
  - Other L2 Areas have also made substantial progress
- Have addressed all recommendations
- We are ready for CD-1
- We will be ready for CD-3a and CD-2
- We appreciate your thoughtful comments and your time

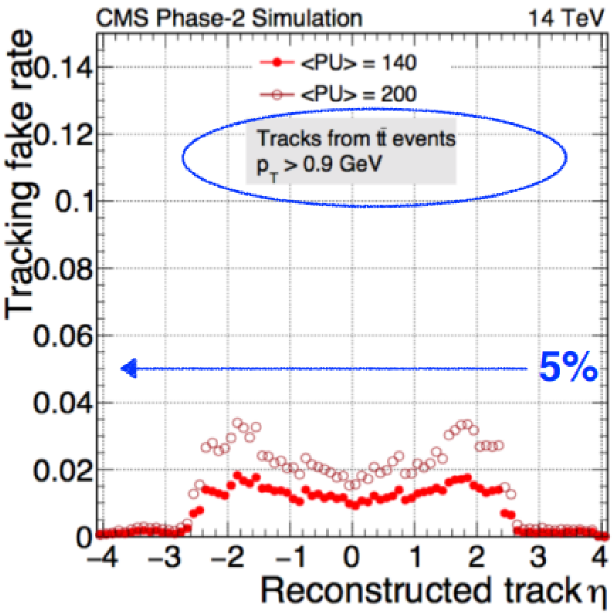
Additional Slides

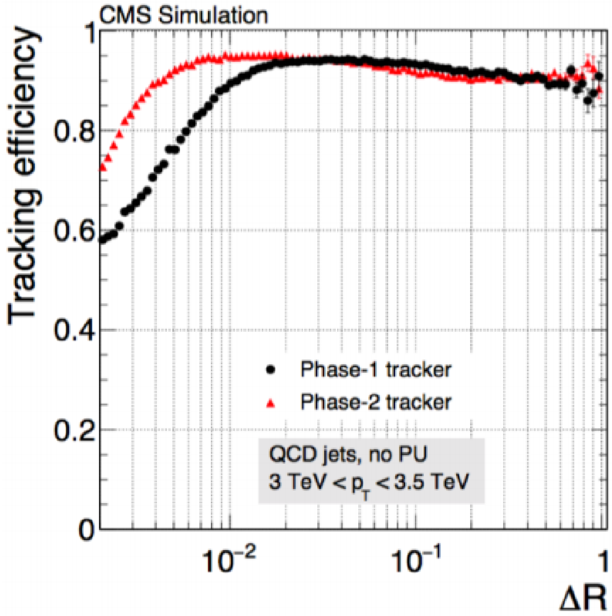
Performance Estimates: Tracking

- Less mass in tracking volume
- High efficiency and low fake rate, better efficiency in jets



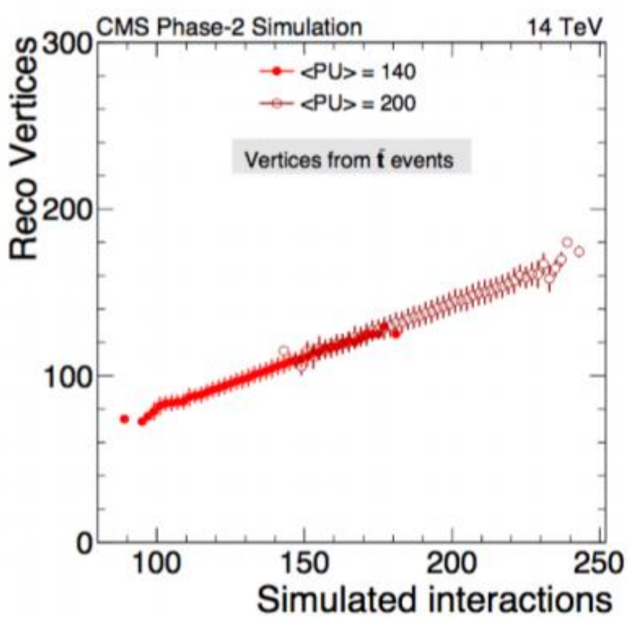


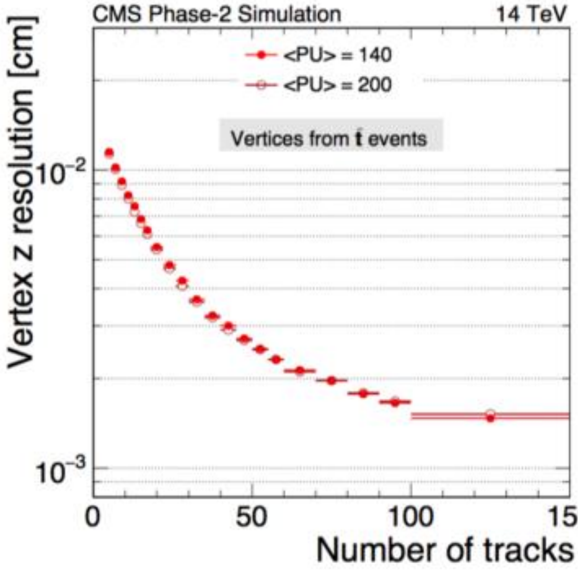


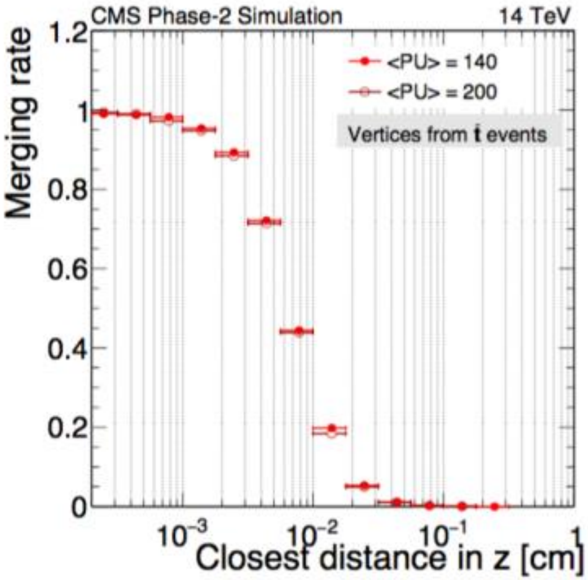


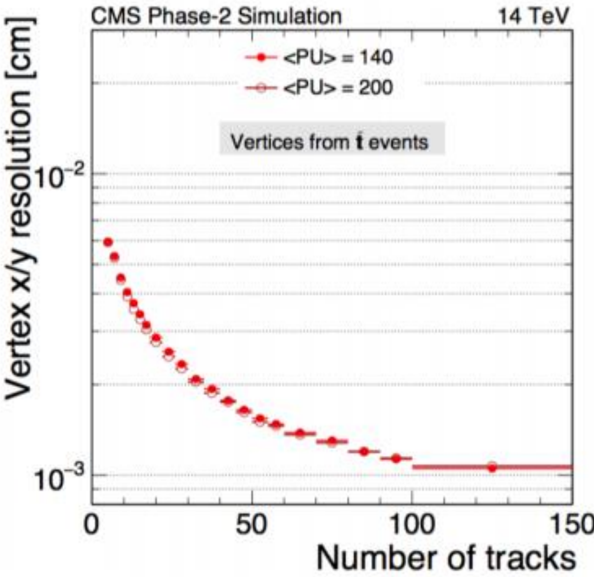
Performance Estimates: Tracking

- Vertexing is robust
  - No saturation of # of vertices
  - Resolution ≤ 100 μm in r and z
  - Minimal merging for Δz ≥ 100 μm
  - Independent of pile-up



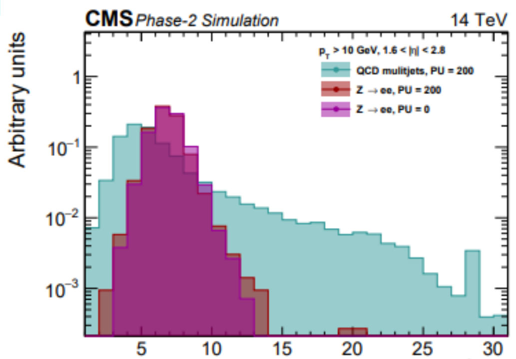


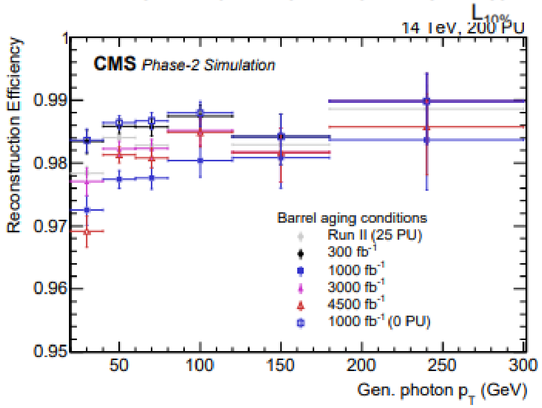


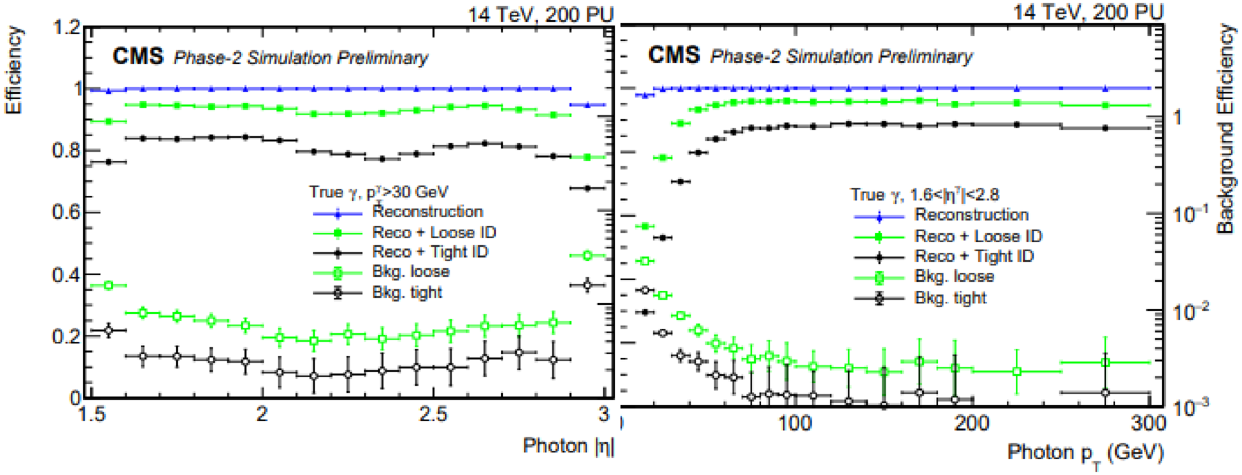


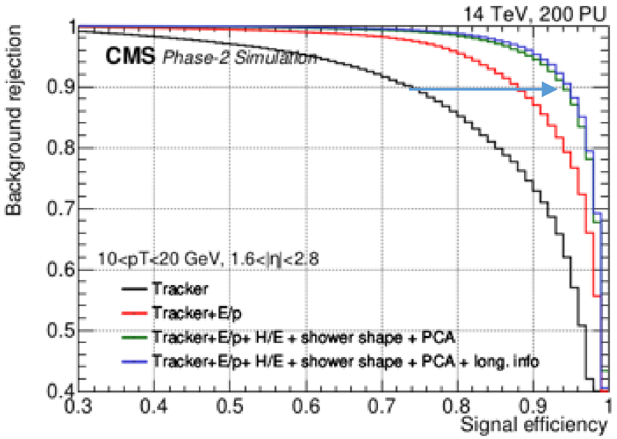
Performance Estimates: Calorimetry

- e/γ Reconstruction
  - Handles on pile-up discrimination
  - Survives to 4.5 ab^{-1}
  - High efficiency/low fake rates across full η, p_T range
    - Clear improvement in ROC curve adding calorimetery
      - ~ 20% signal efficiency at 90% background rejection

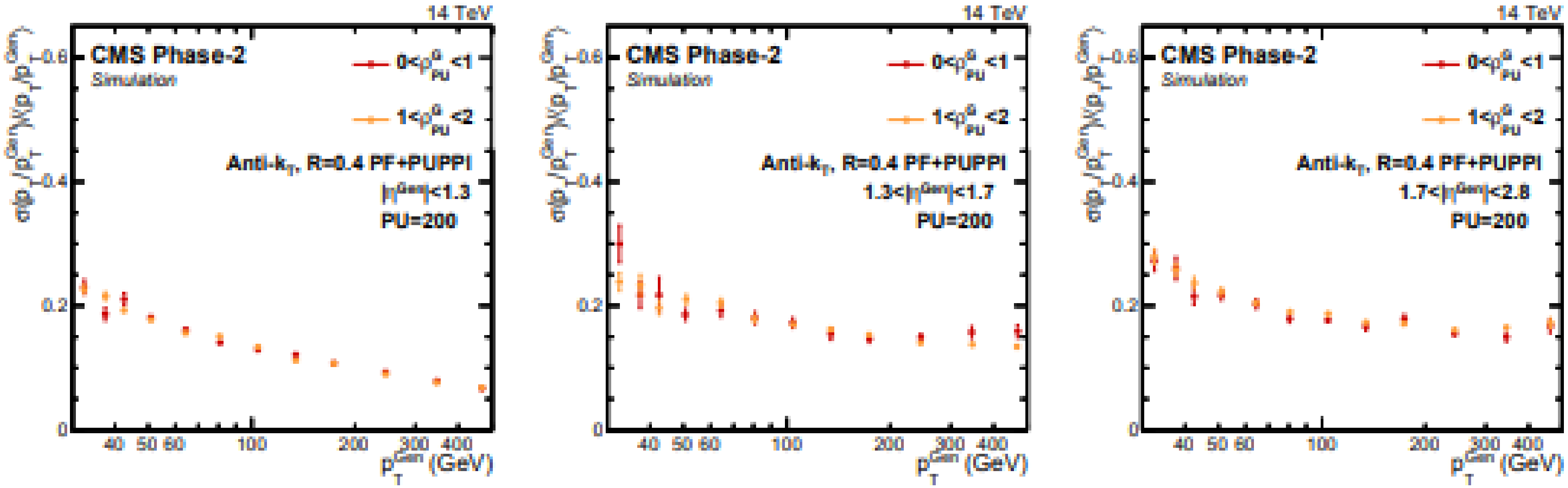




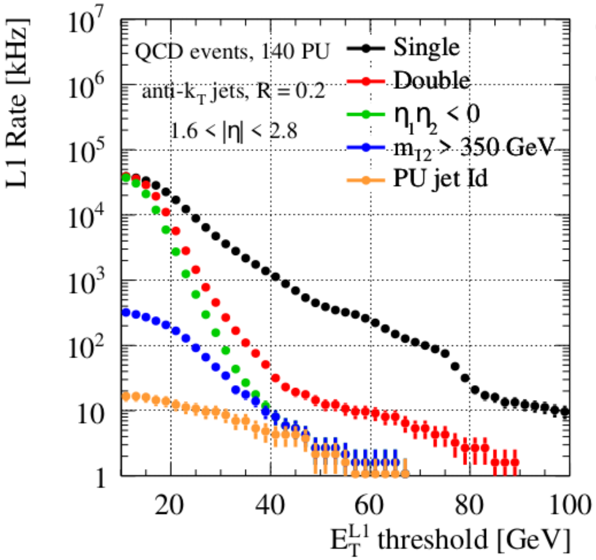


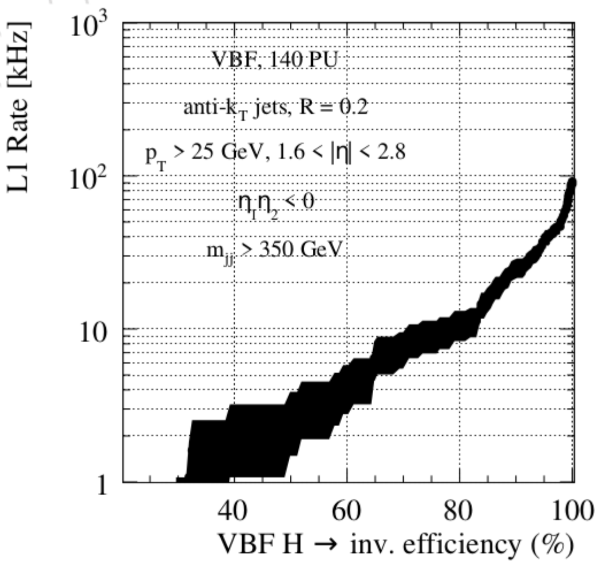


Performance Estimates: Calorimetry



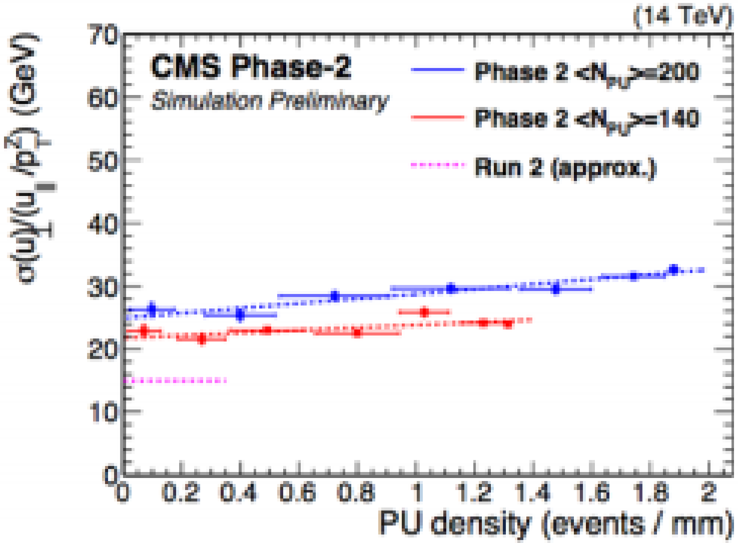
- Hadronic Reconstruction
  - Reasonable Jet energy Resolutions, independent of pile-up
  - Pile-up rejection variables available
    - Can have VBF trigger at reasonable rate



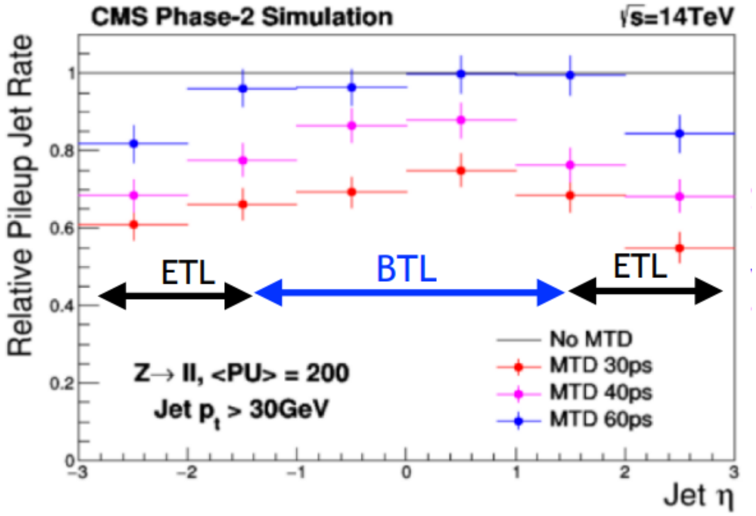


Performance: MET

- MET resolution ~25 GeV in Z→μμ with PU=200
  - Small dependence on line density
  - Not significantly worse than Run 2, with PU 27

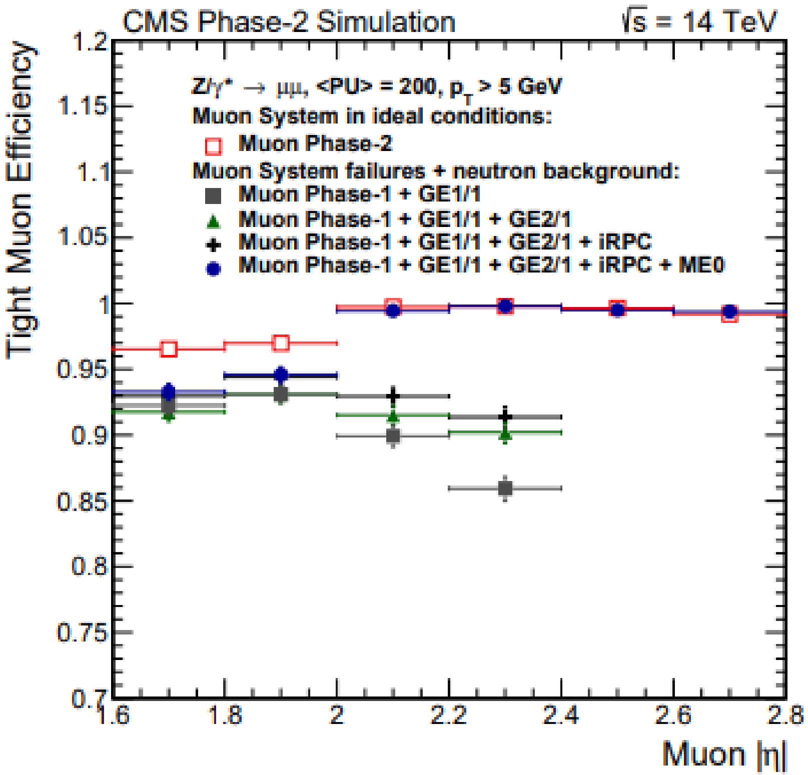


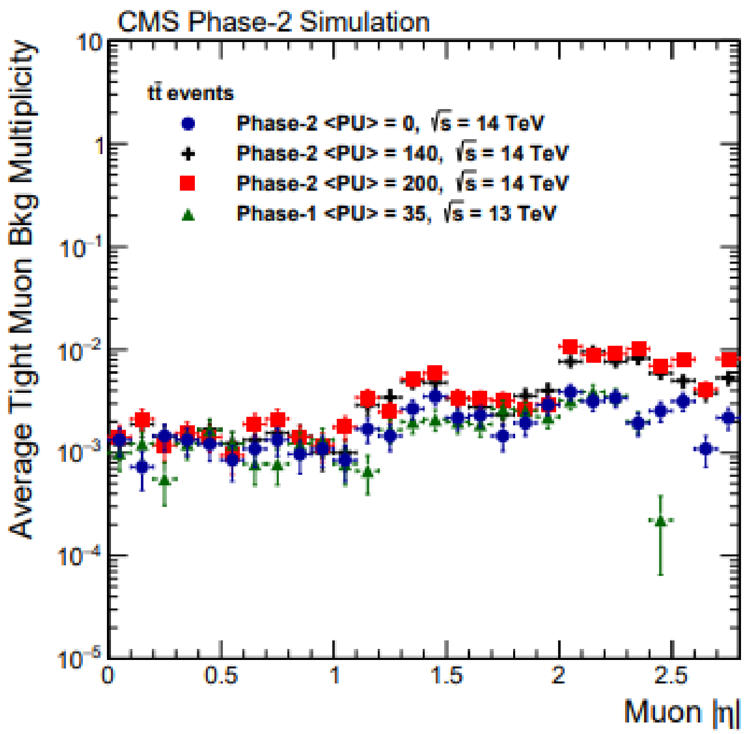
- MTD suppresses pile-up jets from signal jets



Performance Estimates: Muons

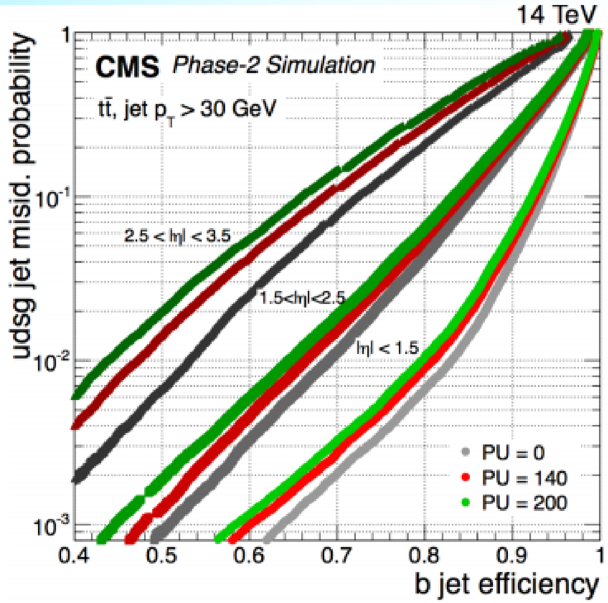
- Increased acceptance across η
- Same fake rate as Phase 1, independent of pile-up

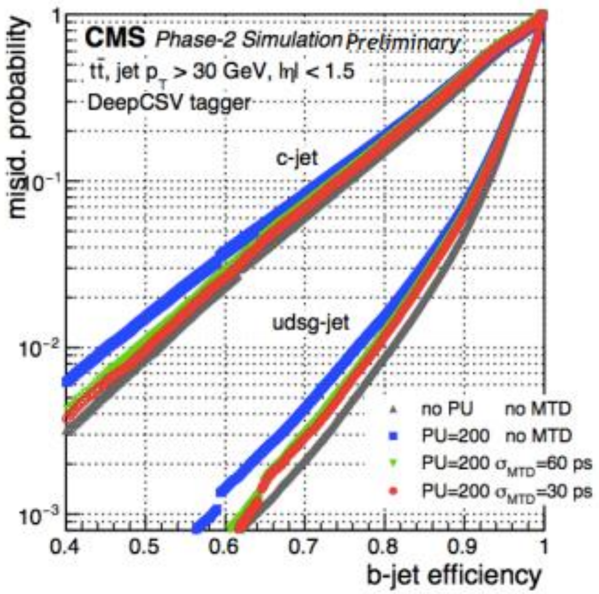


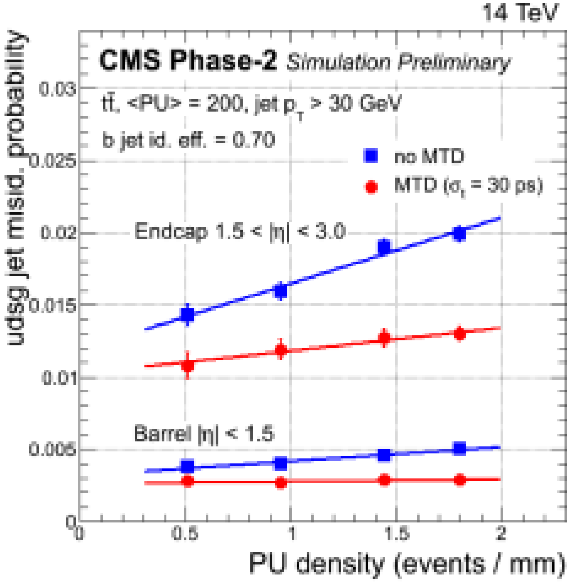


Performance Estimates: b tagging

- Performance at PU 200 similar to PU 0
- MTD improves ROC curves, flattens line density dependence



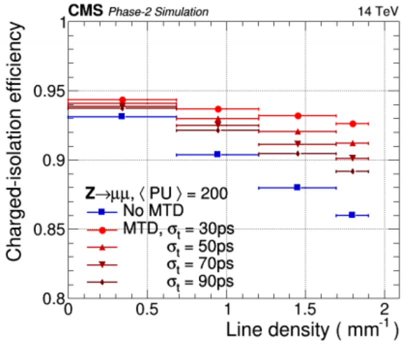


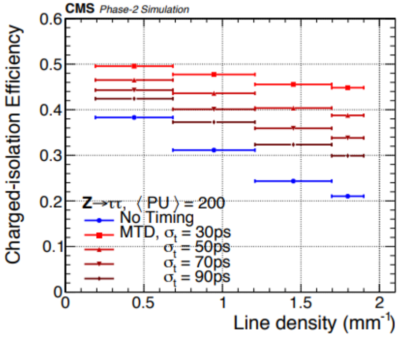


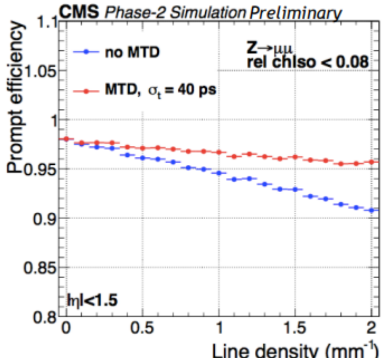
Performance Estimates: Isolation

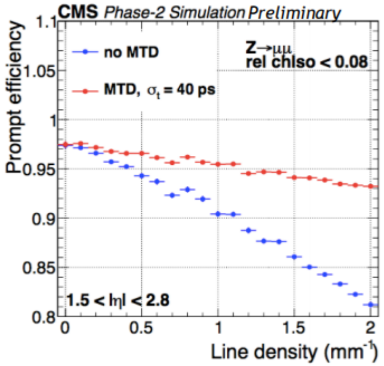
- MTD
  - Improves isolation efficiency
  - flattens isolation dependency on pile-up

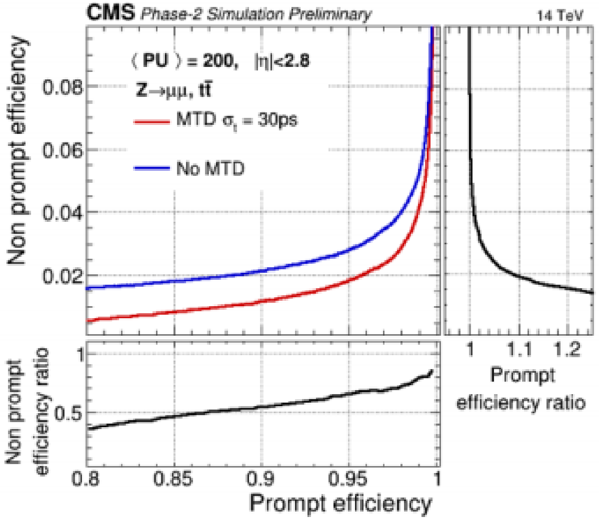
- Overall
  - Detector maintains high isolation efficiency with low background





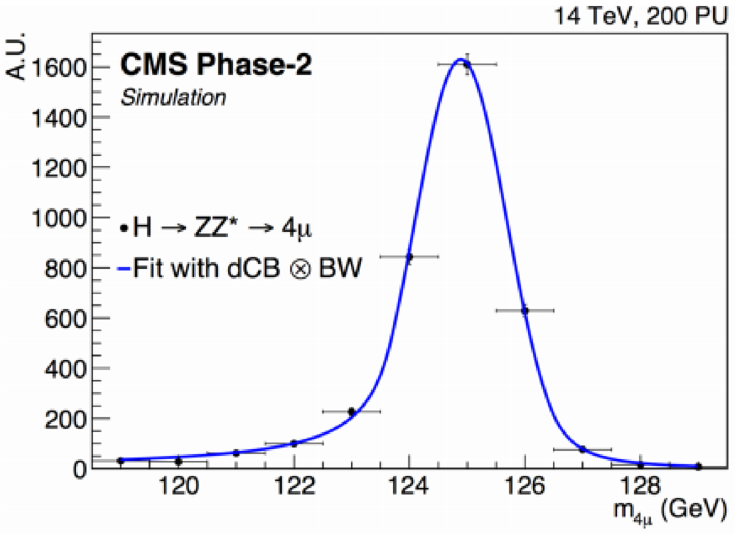


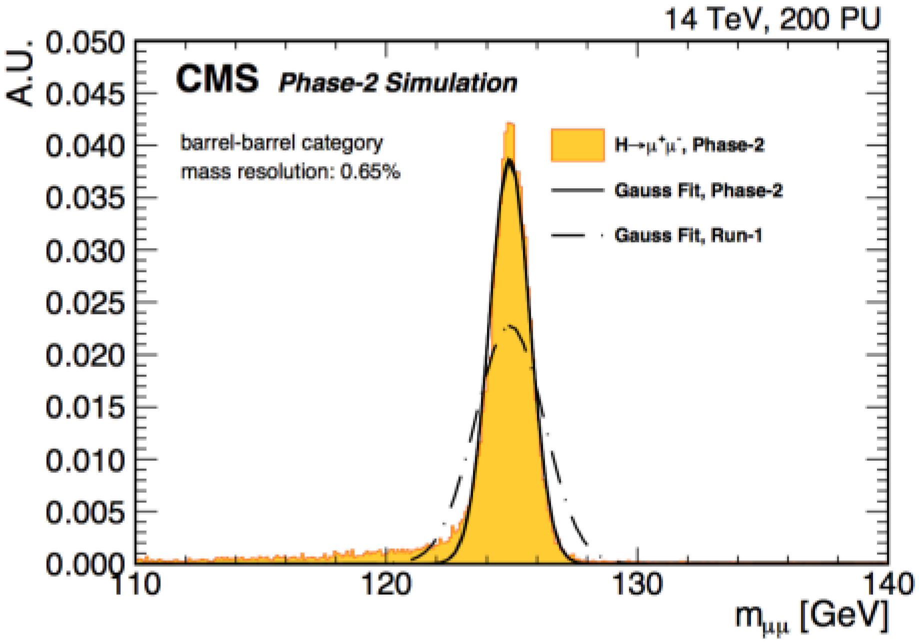


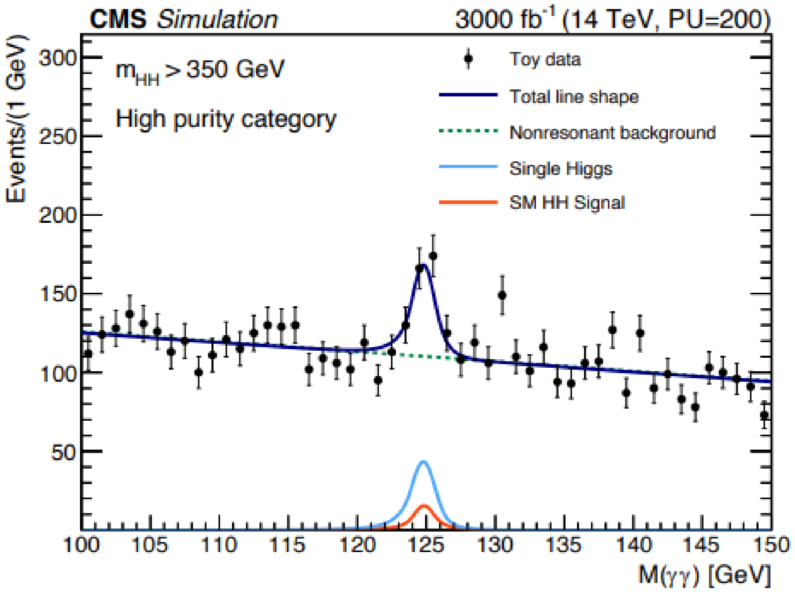


Some prospective Measurements

- Higgs
  - Precision Diboson decays
  - H→μμ
  - diHiggs in γγ channel

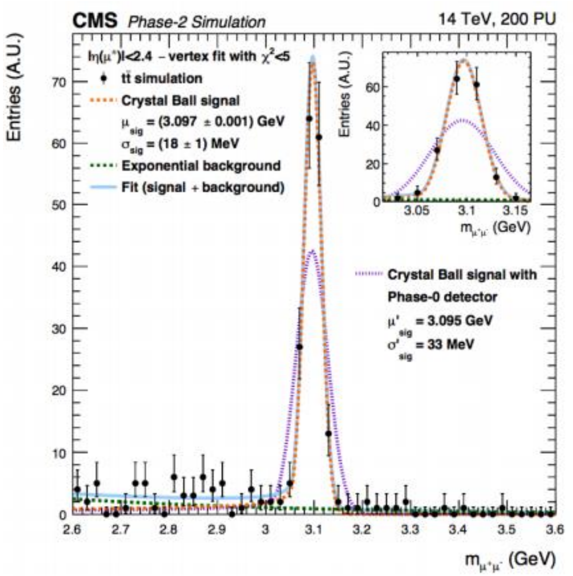


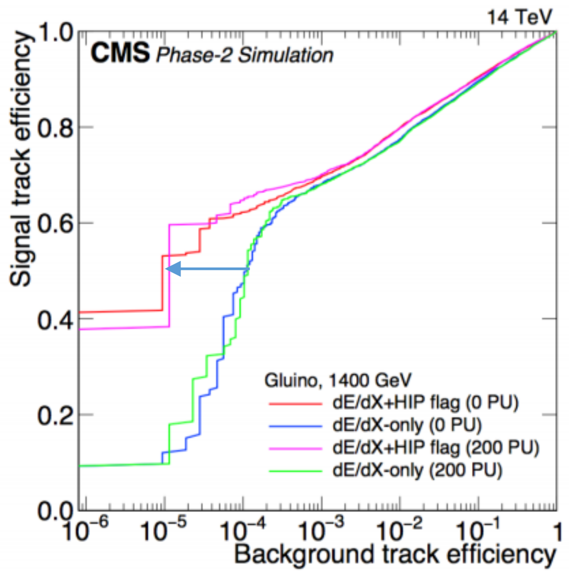


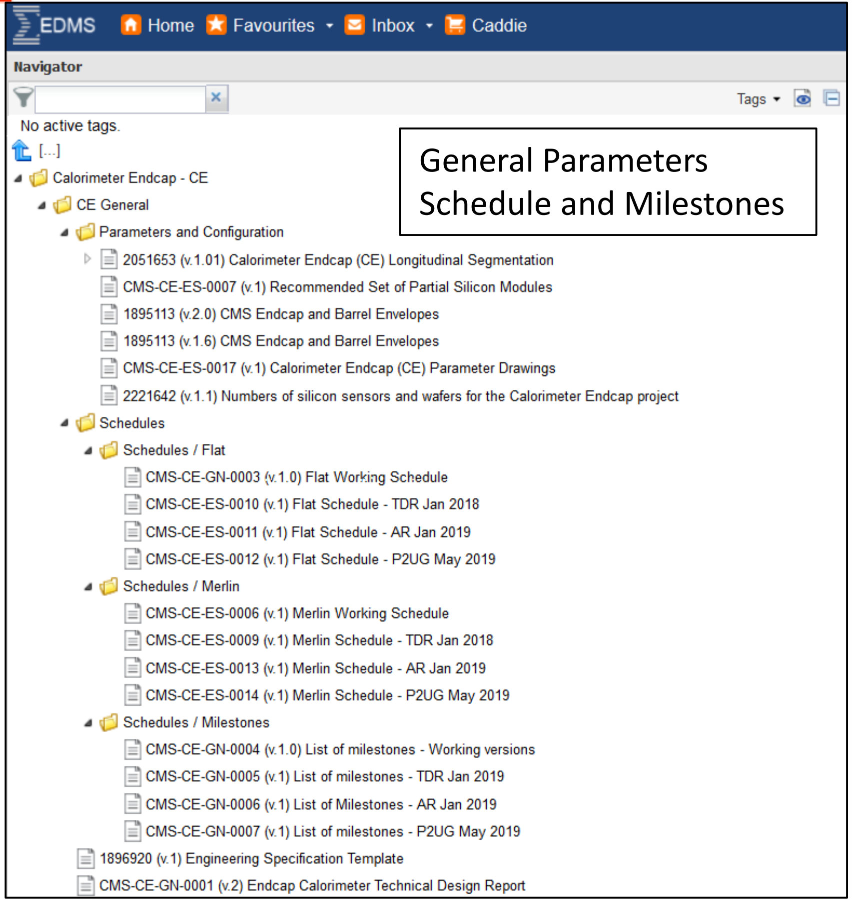


It’s not all about Higgs

- Standard Model
  - Top Mass via $t \rightarrow b \rightarrow J/\psi \rightarrow \mu\mu$
    - 20 MeV resolution, cf. 33 in Phase-0
- New Phenomena
  - Gluino search exploiting Heavy Ionization signal in Tracker allows factor 10 background suppression at similar efficiency

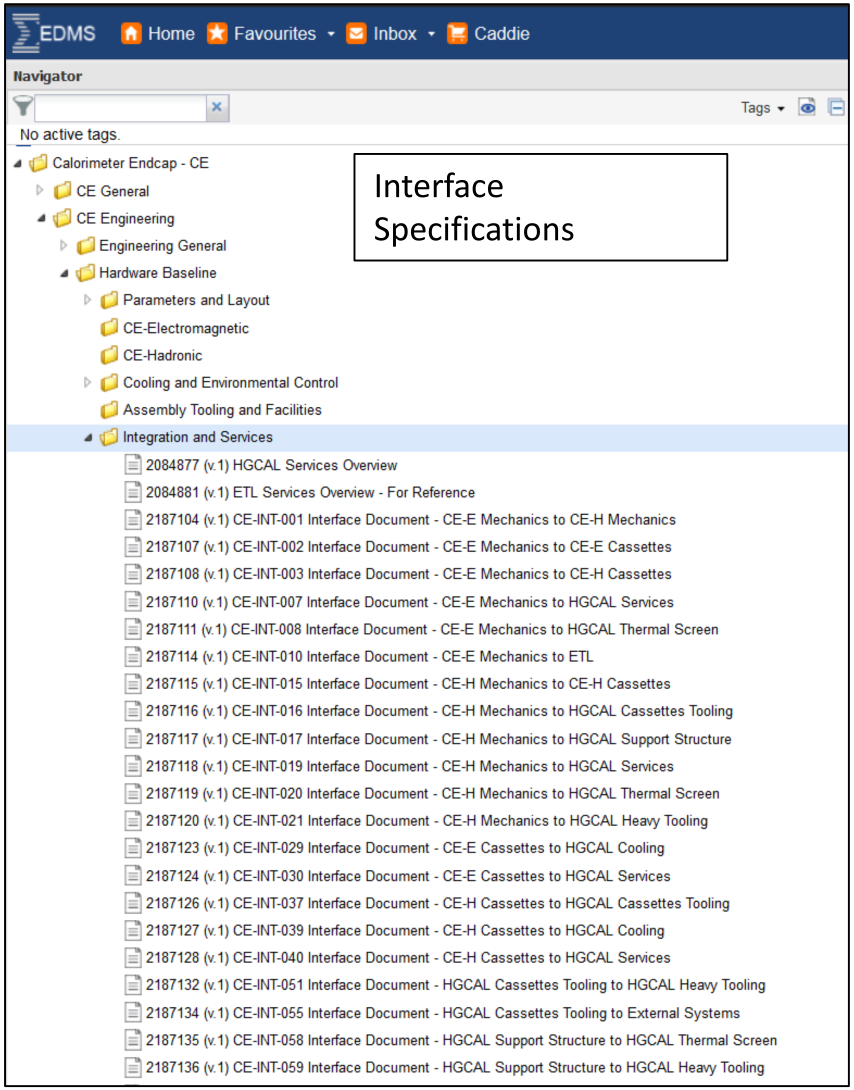






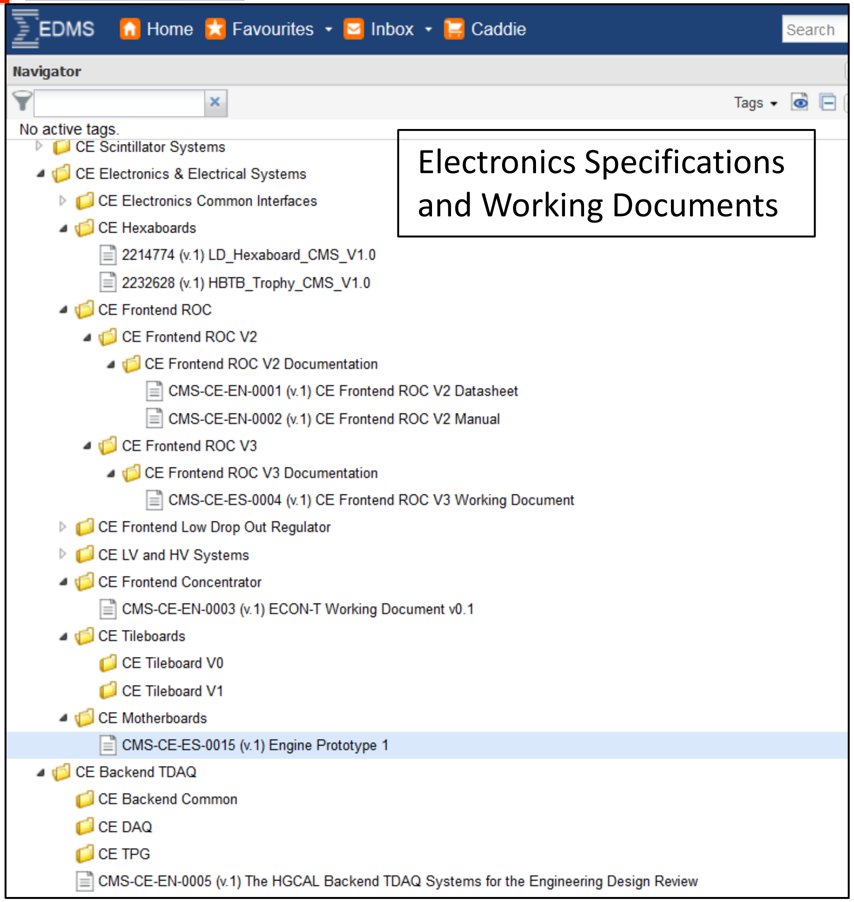
General Parameters
Schedule and Milestones

- Calorimeter Endcap - CE
  - CE General
    - Parameters and Configuration
      - 2051653 (v.1.01) Calorimeter Endcap (CE) Longitudinal Segmentation
      - CMS-CE-ES-0007 (v.1) Recommended Set of Partial Silicon Modules
      - 1895113 (v.2.0) CMS Endcap and Barrel Envelopes
      - 1895113 (v.1.6) CMS Endcap and Barrel Envelopes
      - CMS-CE-ES-0017 (v.1) Calorimeter Endcap (CE) Parameter Drawings
      - 2221642 (v.1.1) Numbers of silicon sensors and wafers for the Calorimeter Endcap project
    - Schedules
      - Schedules / Flat
        - CMS-CE-GN-0003 (v.1.0) Flat Working Schedule
        - CMS-CE-ES-0010 (v.1) Flat Schedule - TDR Jan 2018
        - CMS-CE-ES-0011 (v.1) Flat Schedule - AR Jan 2019
        - CMS-CE-ES-0012 (v.1) Flat Schedule - P2UG May 2019
      - Schedules / Merlin
        - CMS-CE-ES-0006 (v.1) Merlin Working Schedule
        - CMS-CE-ES-0009 (v.1) Merlin Schedule - TDR Jan 2018
        - CMS-CE-ES-0013 (v.1) Merlin Schedule - AR Jan 2019
        - CMS-CE-ES-0014 (v.1) Merlin Schedule - P2UG May 2019
      - Schedules / Milestones
        - CMS-CE-GN-0004 (v.1.0) List of milestones - Working versions
        - CMS-CE-GN-0005 (v.1) List of milestones - TDR Jan 2019
        - CMS-CE-GN-0006 (v.1) List of Milestones - AR Jan 2019
        - CMS-CE-GN-0007 (v.1) List of milestones - P2UG May 2019
    - 1896920 (v.1) Engineering Specification Template
    - CMS-CE-GN-0001 (v.2) Endcap Calorimeter Technical Design Report



Interface
Specifications

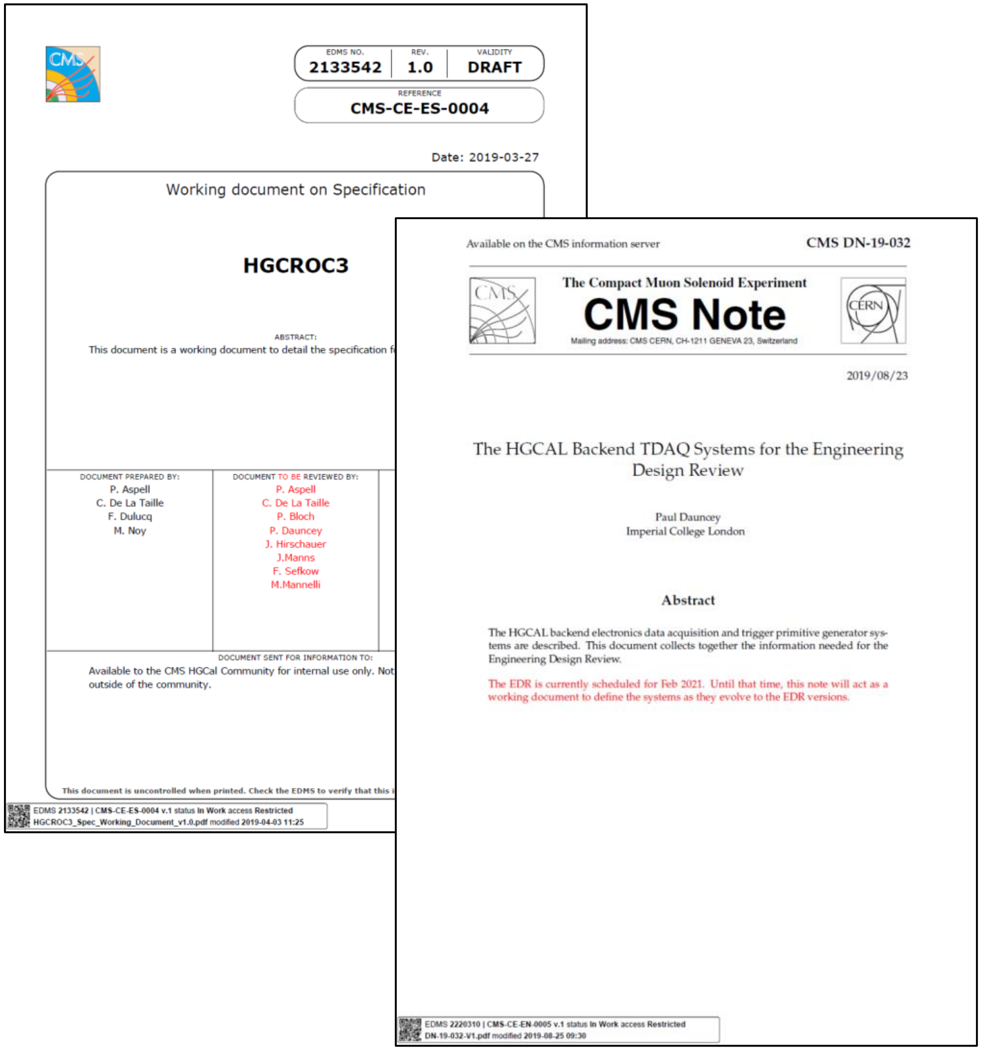
- Calorimeter Endcap - CE
  - CE General
  - CE Engineering
    - Engineering General
    - Hardware Baseline
      - Parameters and Layout
      - CE-Electromagnetic
      - CE-Hadronic
      - Cooling and Environmental Control
      - Assembly Tooling and Facilities
      - Integration and Services
        - 2084877 (v.1) HGCAL Services Overview
        - 2084881 (v.1) ETL Services Overview - For Reference
        - 2187104 (v.1) CE-INT-001 Interface Document - CE-E Mechanics to CE-H Mechanics
        - 2187107 (v.1) CE-INT-002 Interface Document - CE-E Mechanics to CE-E Cassettes
        - 2187108 (v.1) CE-INT-003 Interface Document - CE-E Mechanics to CE-H Cassettes
        - 2187110 (v.1) CE-INT-007 Interface Document - CE-E Mechanics to HGCAL Services
        - 2187111 (v.1) CE-INT-008 Interface Document - CE-E Mechanics to HGCAL Thermal Screen
        - 2187114 (v.1) CE-INT-010 Interface Document - CE-E Mechanics to ETL
        - 2187115 (v.1) CE-INT-015 Interface Document - CE-H Mechanics to CE-H Cassettes
        - 2187116 (v.1) CE-INT-016 Interface Document - CE-H Mechanics to HGCAL Cassettes Tooling
        - 2187117 (v.1) CE-INT-017 Interface Document - CE-H Mechanics to HGCAL Support Structure
        - 2187118 (v.1) CE-INT-019 Interface Document - CE-H Mechanics to HGCAL Services
        - 2187119 (v.1) CE-INT-020 Interface Document - CE-H Mechanics to HGCAL Thermal Screen
        - 2187120 (v.1) CE-INT-021 Interface Document - CE-H Mechanics to HGCAL Heavy Tooling
        - 2187123 (v.1) CE-INT-029 Interface Document - CE-E Cassettes to HGCAL Cooling
        - 2187124 (v.1) CE-INT-030 Interface Document - CE-E Cassettes to HGCAL Services
        - 2187126 (v.1) CE-INT-037 Interface Document - CE-H Cassettes to HGCAL Cassettes Tooling
        - 2187127 (v.1) CE-INT-039 Interface Document - CE-H Cassettes to HGCAL Cooling
        - 2187128 (v.1) CE-INT-040 Interface Document - CE-H Cassettes to HGCAL Services
        - 2187132 (v.1) CE-INT-051 Interface Document - HGCAL Cassettes Tooling to HGCAL Heavy Tooling
        - 2187134 (v.1) CE-INT-055 Interface Document - HGCAL Cassettes Tooling to External Systems
        - 2187135 (v.1) CE-INT-058 Interface Document - HGCAL Support Structure to HGCAL Thermal Screen
        - 2187136 (v.1) CE-INT-059 Interface Document - HGCAL Support Structure to HGCAL Heavy Tooling



No active tags.

- CE Scintillator Systems
- CE Electronics & Electrical Systems
  - CE Electronics Common Interfaces
  - CE Hexaboards
    - 2214774 (v.1) LD_Hexaboard_CMS_V1.0
    - 2232628 (v.1) HBTB_Trophy_CMS_V1.0
  - CE Frontend ROC
    - CE Frontend ROC V2
      - CE Frontend ROC V2 Documentation
        - CMS-CE-EN-0001 (v.1) CE Frontend ROC V2 Datasheet
        - CMS-CE-EN-0002 (v.1) CE Frontend ROC V2 Manual
    - CE Frontend ROC V3
      - CE Frontend ROC V3 Documentation
        - CMS-CE-ES-0004 (v.1) CE Frontend ROC V3 Working Document
  - CE Frontend Low Drop Out Regulator
  - CE LV and HV Systems
  - CE Frontend Concentrator
    - CMS-CE-EN-0003 (v.1) ECON-T Working Document v0.1
  - CE Tileboards
    - CE Tileboard V0
    - CE Tileboard V1
  - CE Motherboards
    - CMS-CE-ES-0015 (v.1) Engine Prototype 1
- CE Backend TDAQ
  - CE Backend Common
  - CE DAQ
  - CE TPG
  - CMS-CE-EN-0005 (v.1) The HGCAL Backend TDAQ Systems for the Engineering Design Review

Electronics Specifications and Working Documents



EDMS NO.	REV.	VALIDITY
2133542	1.0	DRAFT

REFERENCE
CMS-CE-ES-0004

Date: 2019-03-27

Working document on Specification

HGCROC3

ABSTRACT:
This document is a working document to detail the specification f

DOCUMENT PREPARED BY:	DOCUMENT TO BE REVIEWED BY:
P. Aspell C. De La Taille F. Dulucq M. Noy	P. Aspell C. De La Taille P. Bloch P. Dauncey J. Hirschauer J.Manns F. Sefkow M.Mannelli

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The Compact Muon Solenoid Experiment
CMS Note
Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

2019/08/23

The HGCAL Backend TDAQ Systems for the Engineering Design Review

Paul Dauncey
Imperial College London

Abstract

The HGCAL backend electronics data acquisition and trigger primitive generator systems are described. This document collects together the information needed for the Engineering Design Review.

The EDR is currently scheduled for Feb 2021. Until that time, this note will act as a working document to define the systems as they evolve to the EDR versions.

EDMS 2220310 | CMS-CE-EN-0005 v.1 status In Work access Restricted
DN-19-032-V1.pdf modified 2019-08-25 09:30