



---

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

---

## **CMS recent reviews**

Patricia McBride

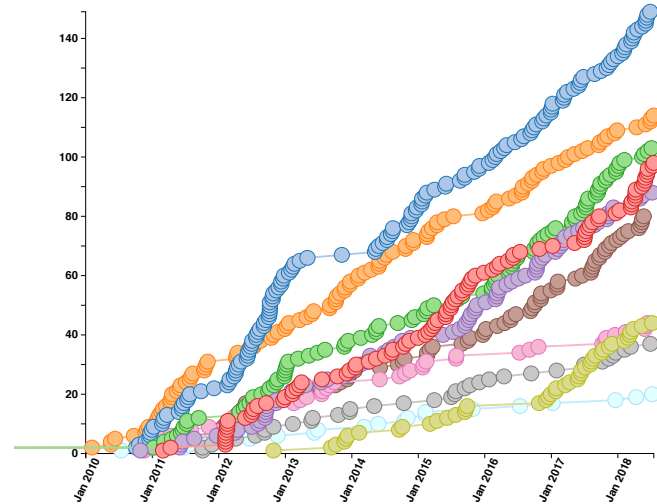
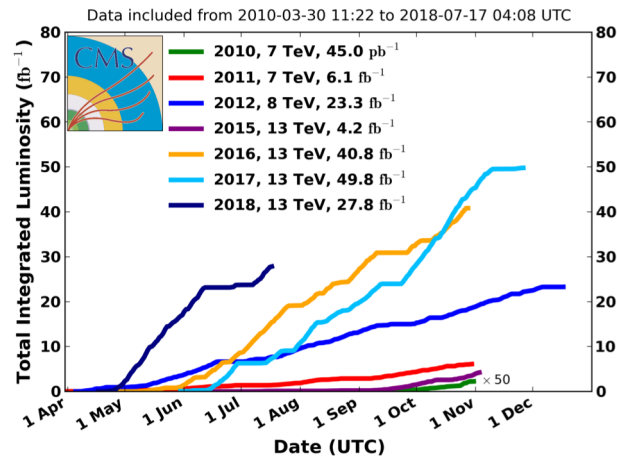
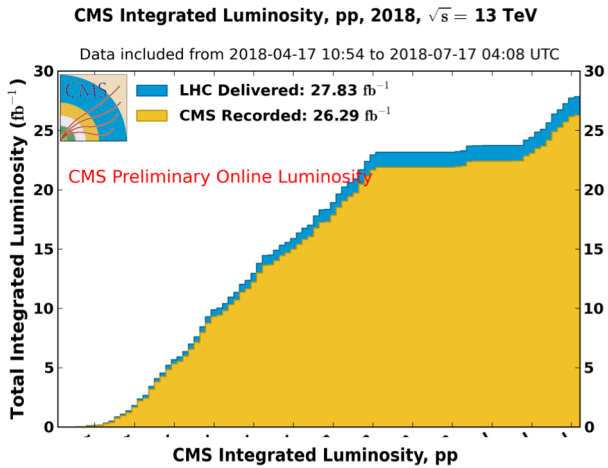
Fermilab PAC

17 July 2018

# CMS in 2018

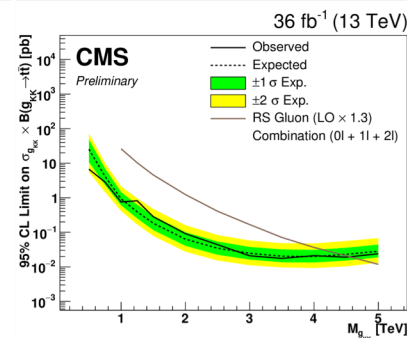
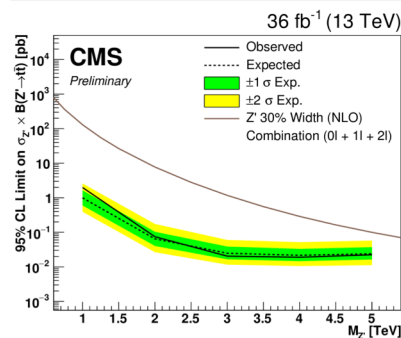
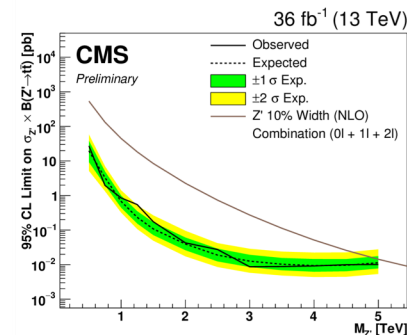
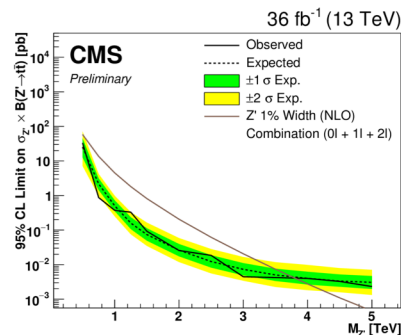
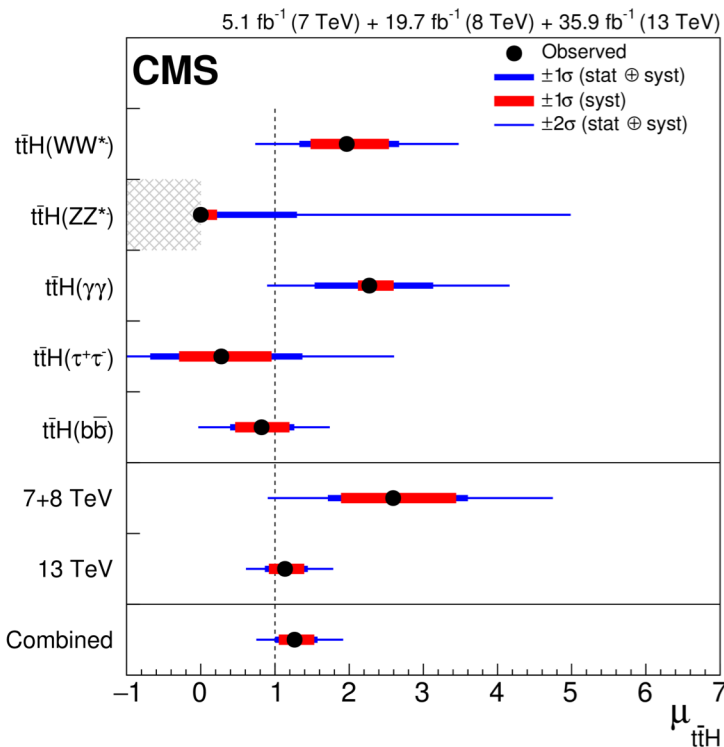
LHC Run 2 will be in full swing until the end of 2018

More than 800 CMS papers have been submitted for publication



During Joel Butler's 2-year term as Spokesperson, CMS has seen many successes.

# Recent CMS physics results highlighting contributions from FNAL and the LPC.



First observation of the **ttH** production process.

Observed significance is 5.2 standard deviations

[Phys. Rev. Lett. 120 \(2018\) 231801](#)

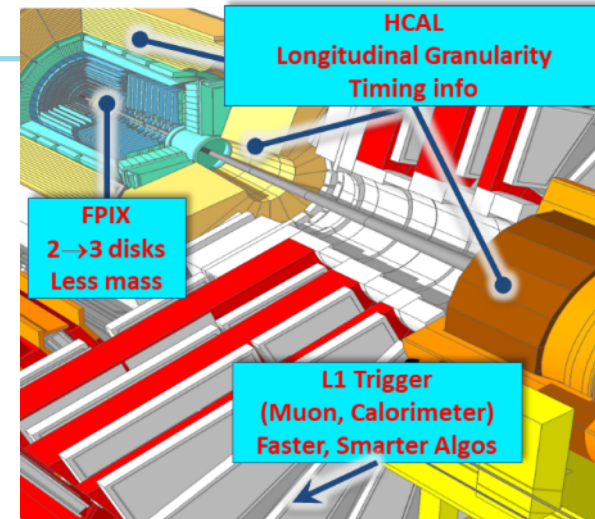
Search for heavy resonance decaying into **tt** pairs.

Sets most stringent limits to date on a **tt** resonance.

[CMS-PAS-B2G-17-017](#)

# Phase 1 Upgrade is nearing completion

- **Forward Pixel Detector - Done, in Operations**
  - After 5 months, experienced issues in low voltage power – issue with DC - DC converters now understood.
- **L1 Trigger - Done, in Operations**
- **Hadron Calorimetry Electronics**, includes latest of the QIE ASIC dynasty
  - Backend Readout - Done, in Operations
  - Forward and Endcap Front-end - Done, in Operations
    - Endcap: Recent power issues under investigation
  - Barrel portion will complete by end of 2018



Happy Andrew Whitbeck at the HCAL electronics burn-in installation



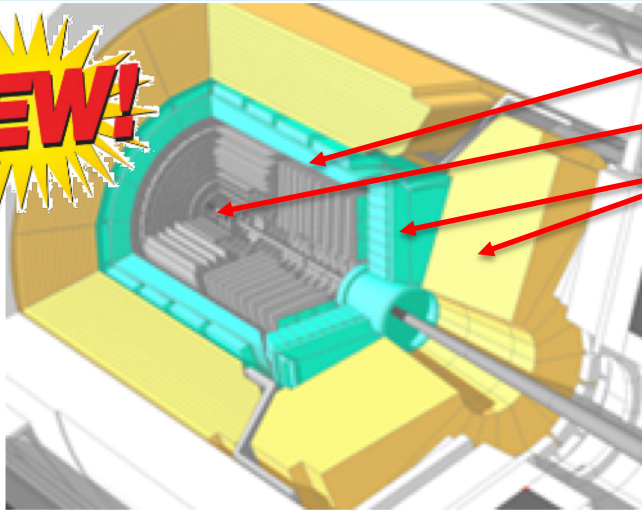
Lou Del Monte and Nadja Strobbe testing QIE11 ASICs



Aram Apyan working on installation

# HL LHC CMS Upgrade: CD-1 review June 5-7, 2018

**NEW!**



**Timing Layer** – 4D tracking!

**Outer Tracker** – Track Trigger capabilities!

**Calorimeter Endcap** – Imaging Jets!

**L1 Trigger** – Track/Calorimetry correlation at L1!

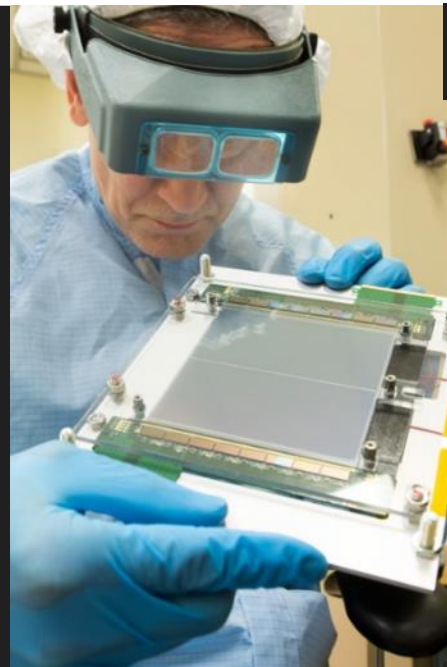
Design and development on-going

- The project draws infrastructure and expertise in the Fermilab detector facilities such as SiDet, Testbeam, proposed **Irradiation facility**, ASIC design, Carbon Fiber fabrication...

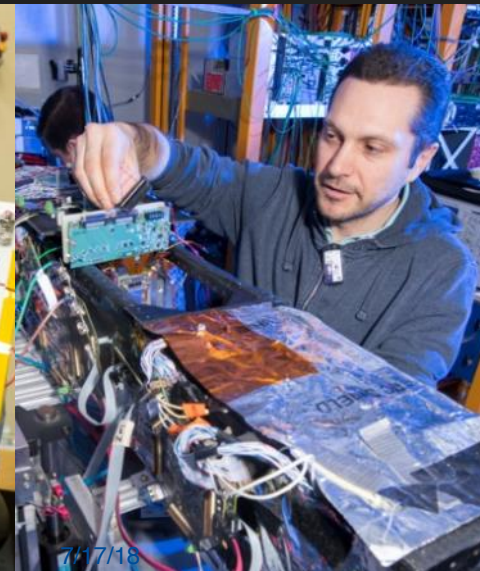


Texas Tech students Sonaina Undleeb and Kamal Lamichhane , with Zoltan Gecse and Maral Alyari testing the prototype **Endcap** cassette at SiDet

Bert Gonzales with prototype Outer Tracker Module at SiDet



Lorenzo Uplegger preparing for **Tracker** Module testing at FTBF



7/17/18

# Overview of the US CMS HL-LHC Upgrades

## Trigger/HLT/DAQ

- Track information in trigger at 40 MHz
- 12.5  $\mu$ s latency
- HLT input/output 750/7.5 kHz

## Barrel Calorimeter

- New FE/BE electronics for full granularity readout at 40 MHz - with improved time resolution
- Lower ECAL operating temperature (8°C)

Upgrade Subdetectors with proposed DOE contributions

## New Endcap Calorimeters

- Rad. tolerant - High granularity transverse and longitudinal
- 4D shower measurement including precise timing capability

## Muon systems

- New DT & CSC FE/BE electronics
- New station to complete CSC at  $1.6 < \eta < 2.4$
- Extended coverage to  $\eta \approx 3$

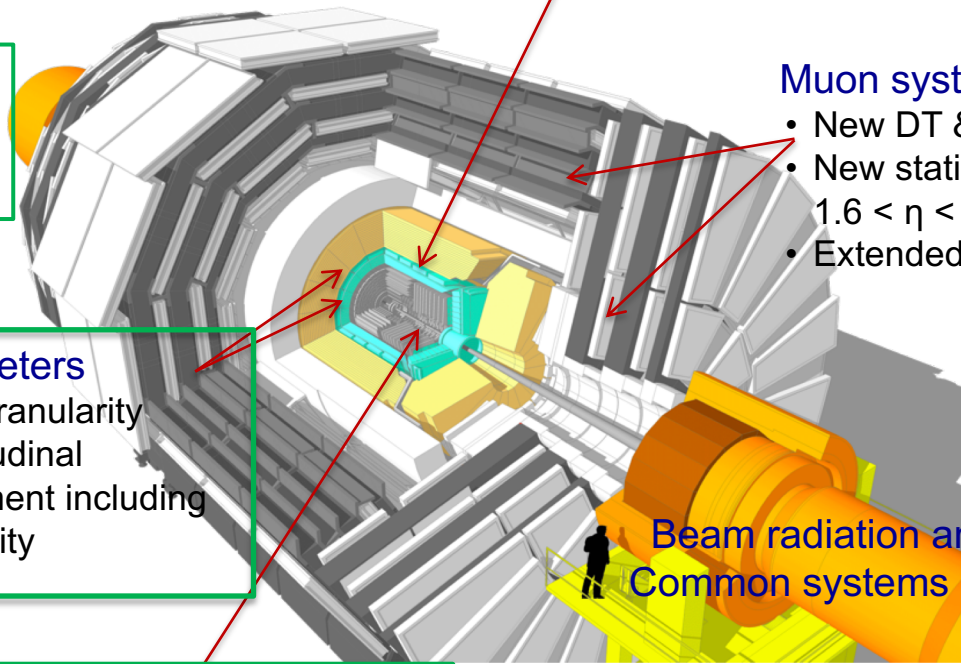
Beam radiation and luminosity  
Common systems and infrastructure

## New Tracker

- Rad. tolerant - increased granularity - lighter
- 40 MHz selective readout (strips) for Trigger
- Extended coverage to  $\eta \approx 3.8$

## MIP precision Timing Detector

- Barrel layer: Crystal + SiPM
- Endcap layer: Low Gain Avalanche Diodes



# CMS HL-LHC Upgrades - International

---

- The scope of the HL-LHC upgrade for CMS was defined in the Technical Proposal in 2015
  - LHCC reviewed the physics case and the proposed detector
  - Stage 1 approval for the CMS (and ATLAS) upgrade projects was granted by the LHC Resource Review Board in Sept 2015
- Technical Design Reports will be prepared for the major subsystem upgrades
  - Completed: Tracker, Barrel Calorimeter, Endcap Calorimeter, Muon Systems
  - Still to do: Trigger, DAQ, MIP Timing Detector, BRIL
  - And: Computing, Physics and PPS
- The individual TDRs are reviewed by the LHCC and the Upgrade Scrutiny Group

# International Review of CMS Upgrade TDRs 2018

[Upgrade Scrutiny Report at the April 2018 RRB](#)

## Comments on the 4 CMS Phase II Upgrade Projects (TDAQ still to come)

Cost: Currently 279 M CHF, an increase of 14M CHF from the Scoping Document.

- ▶ The increase is due to the MIP Timing Detector, which was not in the original scope.
- ▶ Current cost estimates and cost risks look reasonable, with possibilities for small reductions.
- ▶ Most quality flags should converge to 1 or 2 within a year. (They have quotes for Silicon.)
- Resources: Good manpower availability; MM is converging. Enormous Silicon-based activities. Need to be sure that the IT, OT, and EC do not exhaust the supply of appropriately-skilled manpower and facilities, at CERN and throughout the collab.
- Schedule: Credible at this stage, but there are major risks:
  - ▶ IT: Delay in production of FE ASIC; Phase I issues raise short-term potential resource conflicts.
  - ▶ Coping with immensity of Tracker and EC projects. QA/QC/Management must be first rate. Plans are being developed for extra sites to increase throughput if needed.
  - ▶ Schedules for Muon System and Barrel Calorimeter are well-developed and low risk.
- Risks: Mainly to schedule. Also technical risks to IT till FE ASIC is in production.
  - ▶ **Correlated risks are described on a following slide.**

April 23, 2018

RRB Meeting

7

### General

### Recommendation:

[ATLAS and CMS should receive Step 2 approval, so MOU's can be signed, long-term items procured, and resources made available to complete R&D, prototyping, etc.; and proceed toward Step 3 approval \(readiness for construction\).](#)



# Proposed timeline of reviews of the CMS Upgrades

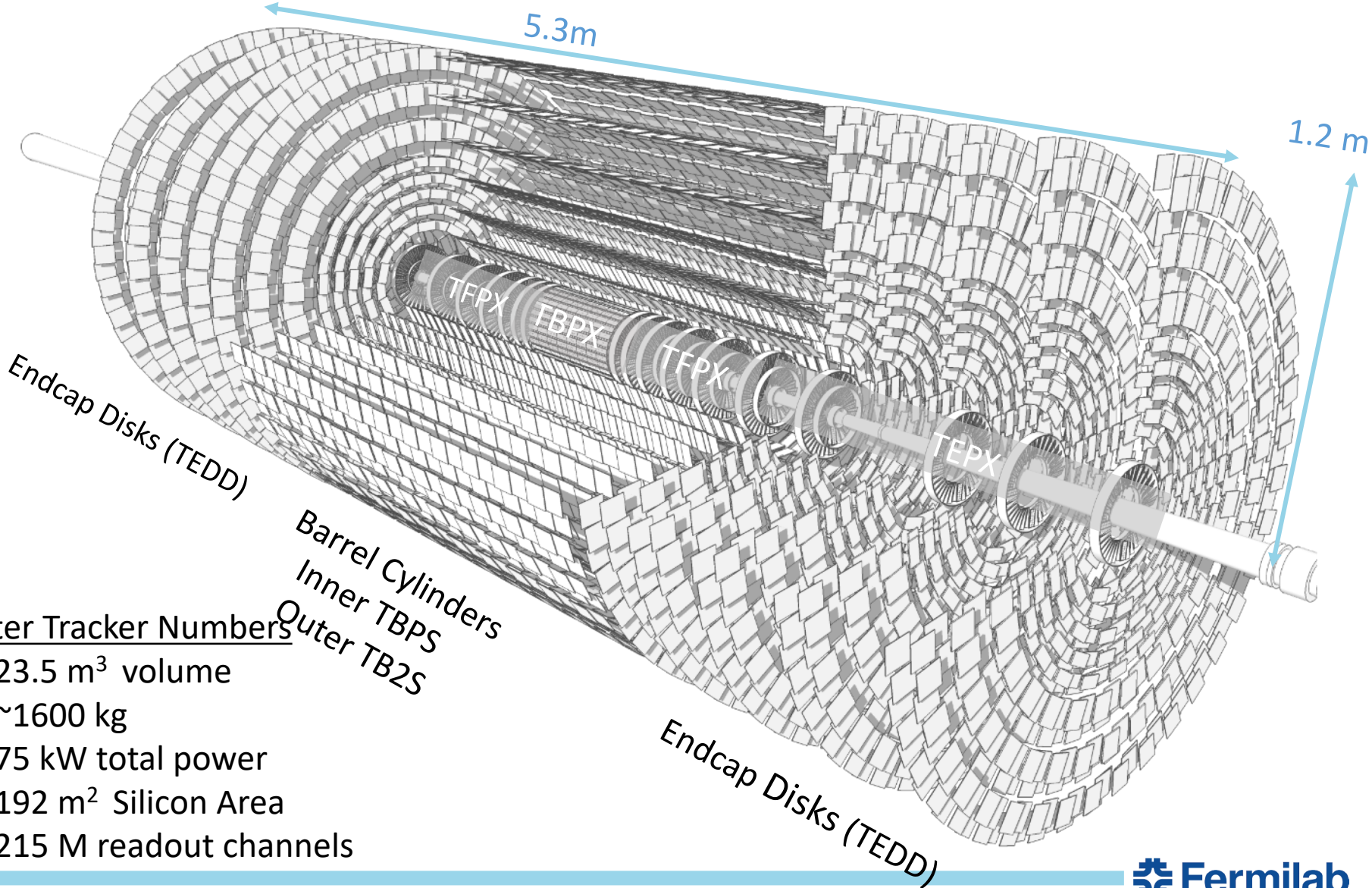
BC - Barrel Calorimeter  
 EC - Endcap Calorimeter  
 MTD - MIP Timing Detector  
 Muon Detector  
 OT - Outer Tracker  
 Trigger/DAQ

	CY16	CY17	CY18	CY19	CY20
NSF	◆ CDR	PDR ◆		FDR ◆	◆ MREFC Starts
DOE	◆ CD0		◆ CD1	◆ CD3a ◆ CD2/3	
iCMS TDRs		◆ OT ◆ BC Muons	◆ EC	◆ MTD	◆ Trigger ◆ DAQ
LHC	Run 2			LS2	

- US CMS (NSF) passed its PDR review in December 2017. The National Science Board presentation is this week.
- DOE CD-1 review was held in early June 2018. Overall the project did very well, but several recommendations required additional work. A follow-up mini-review will be held in the coming months and will focus on these recommendations.

# CMS Tracker upgrade

DOE HEP involvement: ~ 25 %



## Outer Tracker Numbers

- 23.5 m<sup>3</sup> volume
- ~1600 kg
- 75 kW total power
- 192 m<sup>2</sup> Silicon Area
- 215 M readout channels

# HL LHC CMS Detector Upgrade: Outer Tracker (OT)

---

- Basic Design: Module - sensor “sandwich” with variable spacing and on-detector correlation
  - provides local curvature for L1 Track Trigger, crucial component of HL LHC
- U.S. scope: Two-fold goal
  - Build 2500 Pixel-Strip (PS) + 2000 Strip-Strip (2S) Modules
  - Use 952 PS Modules to construct the “flat barrel” = inner 3 layers
- **CD-1 Review outcome - from the committee**
  - **Selected Comments**
    - *The science case for the Outer Tracker is sound.*
    - *The Committee congratulated the team for their excellent presentations. The team is strong and includes several experts with vast experience in their respective areas*
    - *The module design is innovative and advanced.*
  - **Outer Tracker Recommendations**
    - *Based on the assessment above, we recommend finalizing the plan for automation of module construction in close collaboration with international CMS by June 2019. This would allow to gain some experience and collect some statistics about production speed and alignment precision before CD-2.*
    - *Proceed to CD-1*

# HL LHC CMS Detector Upgrade: Endcap Calorimeter (EC)



## US Construction Scope Outline

- **Module Construction**
  - US develops detector-wide standard procedures for silicon module construction, constructs all hadronic silicon modules (11372) and all odd-size/edge modules for the electromagnetic section (1185)
- **Scintillator tileboards**
  - US constructs active material and readout PCBs, procures and mounts SiPM photodetectors, and tests tile modules for the front seven layers of the mixed portion of the hadron calorimeter with surface area 141 m<sup>2</sup> (28% by area)
- **Electronics**
  - US responsible for the design and development of the concentrator ASIC, development of motherboards for silicon and scintillator hadronic sections
  - Specification and procurement of LV/HV power supplies for the hadronic section
- **Cassette Assembly**
  - US develops cassette cooling plate design and assembly procedure, constructs front 15 layers of hadronic calorimeter (360 cassettes)
- **Key Performance Parameters defined encapsulating the project**
  - **Threshold:** Construction of the cassettes and delivery to CERN
  - **Objective:** Integration of the cassettes into the absorber and commissioning of the cassettes

[cms-docdb-13237](#)

Jeremiah Mans

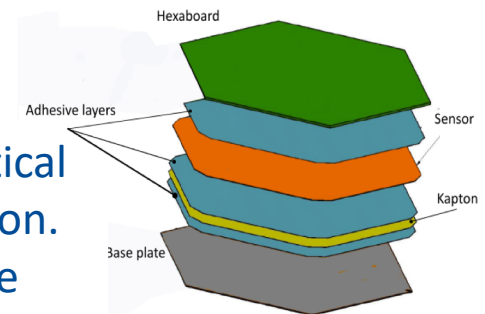
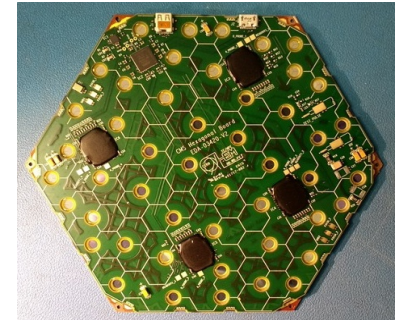
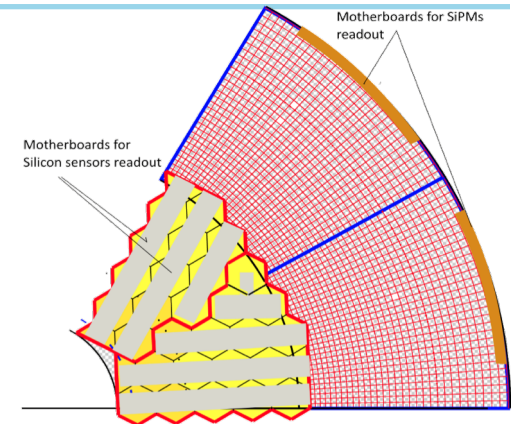
402.4 Endcap Calorimeter

CD1 Review

June 5, 2018

p. 20

Selected recommendation: The aggregator ASIC, the ECON, is a critical US deliverable and a potential schedule driver for cassette production. Maintain close interaction with Fermilab management to ensure the necessary access to ASIC designers and engineers. => Monthly ASIC PMG

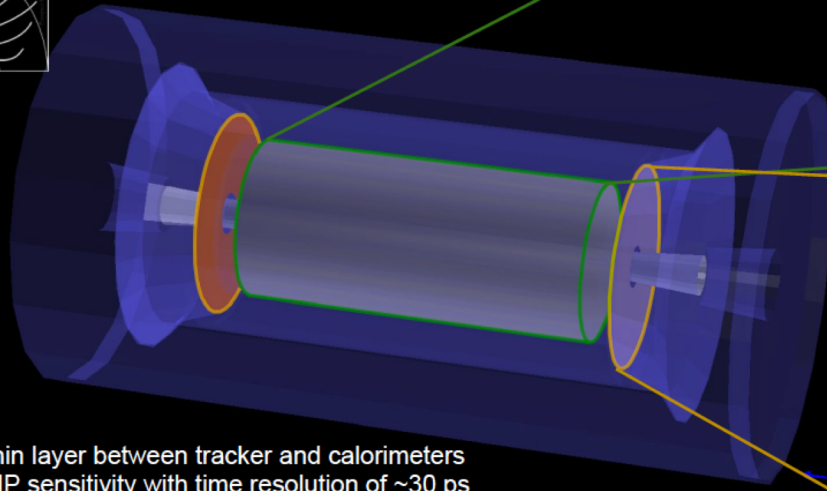


# HL LHC CMS Detector Upgrade: MIP Timing Detector (MTD)



## Conceptual Design

### MTD design overview



**BARREL "BTL"**  
 TK/ECAL interface ~ 25 mm thick  
 Surface ~ 40 m<sup>2</sup>  
 Radiation level ~ 2x10<sup>14</sup> n<sub>eq</sub>/cm<sup>2</sup>  
 Sensors: LYSO crystals + SiPMs

**ENDCAPS "ETL"**  
 On the CE nose ~ 42 mm thick  
 Surface ~ 12 m<sup>2</sup>  
 Radiation level ~ 2x10<sup>15</sup> n<sub>eq</sub>/cm<sup>2</sup>  
 Sensors: Si with internal gain (LGAD)

- Thin layer between tracker and calorimeters
- MIP sensitivity with time resolution of ~30 ps
- Hermetic coverage for  $|\eta| < 3$

- Design** - Timing resolution of 30ps - Cost effective design over large area - Marginal impact on rest of CMS
- constraints:** - Radiation tolerance to 4/ab - Manageable data volume and power - Integration fits within schedule

US-MTD Overview

MTD Technical proposal was submitted to the LHCC in early 2018. Full TDR will be completed early 2019.

Strong US participation in the project: Lindsey Grey was a co-leader of the international effort. Chris Tully is the IB chair. Grey/Apresyan received an LDRD award in 2017. DOE Early Career Award to Artur Apresyan in 2018.

BTL – Barrel Timing Layer  
 ETL – Endcap Timing Layer



# Layout of MTD system



## Hermetic MIP Timing: Barrel & Endcap



Requirements:

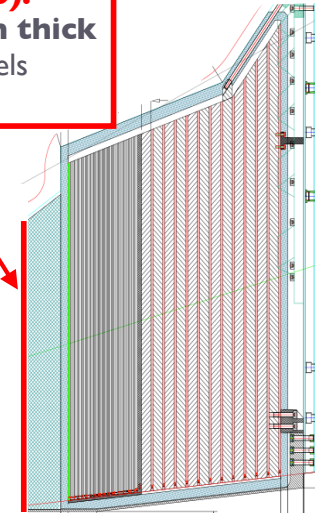
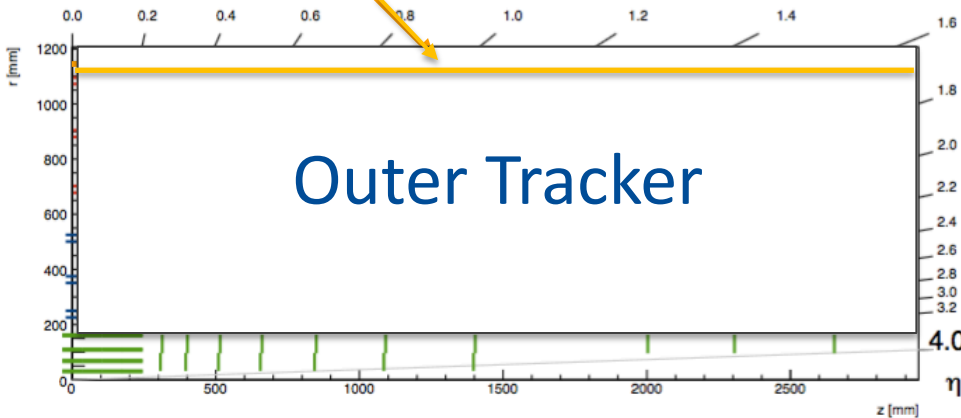
- Hermeticity: barrel ( $|\eta| < 1.48$ ) and endcap ( $1.6 < |\eta| < 2.95$ )
- Radiation:  $2 \times 10^{14}$   $n_{eq}/cm^2$  (barrel) and up to  $2 \times 10^{15}$   $n_{eq}/cm^2$  (endcap)
- Minimal impact on calorimeter performance
- Mechanics and services compatible with existing upgrades

### LYSO:Ce tiles with SiPM readout:

- embedded in TK support ~ **25 mm thick**
- Area ~40 m<sup>2</sup>, ~250k channels
- Integrate with tracker

### Si with internal gain (LGAD):

- On the endcap nose ~ **42 mm thick**
- Area ~12 m<sup>2</sup> (total), ~4M channels
- Integrate with endcap



21

Lindsey Gray, FNAL

# LHCC review of the MTD Technical Proposal

---

The LHCC reviewed the MTD Technical Proposal and gave Stage 1 approval to the international CMS MTD project in early March 2018.

## Timing detectors conclusions

- Technical proposals submitted.
- The committee is convinced that the timing detectors provide a useful tool in the high pile- up regime of the HL-LHC.
- Improvements in jet and electron identification and b- tagging will be obtained.
- The detector concept has been reasonably developed for the maturity of the proposals at this time.

For both experiments optimization and system validation work required to arrive at final configuration.

- Expect TDR submission at the end 2018 / beg 2019, when a full cost review can be carried out.

From F. Forti talk at the RRB April 2018

# DOE Review Recommendations for the MTD project

---

The reviewers concluded the MTD project plan was not yet mature enough to satisfy the DOE CD-1 requirements at the time of the review. They made the following recommendations to achieve CD-1 (from the review closeout report):

- *Recommendations to BTL and ETL:*
  - *As soon as possible, and no later than Q3 CY 2018 develop the managerial part of the project, i.e. nominate L2/3/4 managers, develop milestones, cost uncertainty and risk/mitigation analyses, and planning packages into work packages.*
  - *We recommend to reduce reliance on contributed labor and improve its estimate.*
- *ETL-specific recommendations:*
  - *Allocate sufficient expert ASIC design engineering resources to ensure meeting the requirements on the ASIC design schedule*
- *Remark:*
  - *The reviewers consider the MIP Timing Detector an extremely important and innovative addition to the CMS Phase-II upgrade and to hadron collider physics overall, and highly value the technical capabilities of the group of talented scientists in the MTD subsystem. We hope that these comments and recommendations help guide forward this part of the project.*



# Comments/Recommendations on Management

---

- There were a number of recommendation to management and cost and schedule.
- Recommendations on Management:
  - Project management should work closely with US CMS on a strategy to successfully complete MTD scope with minimal impact to the project. Successful completion of an external review of the MTD conceptual design is required prior to CD-1 approval.
  - Project management should proactively engage in identifying qualified candidates to fill key project positions, in advance of impending changes.
  - Revise the ISM and Quality Assurance Plans to accurately document the process for receipt, review, concurrence, coordination and oversight of project specific plans and activities prior to the issuance of any contract instrument.
  - Develop a clear plan for identification and documentation of codes, standards, requirements and timing for inclusion into project documentation.
  - Review and revise required documentation to comply with the CD-1 minimum requirements ensuring that document control practices and revision control are properly applied throughout with approval or approval process defined and consistency in the project cost and schedule data prior to CD-1 approval.

# Comments/Recommendations on Management

---

- The MTD was seen as valuable part of the physics program, but needed more time to prepare for CD-1. This led to the decision to call a mini-review in a few months.

- **“The committee recognizes the substantial benefit of the MIP timing detector (MTD) to CMS and the commitment of the project to successfully complete this additional scope. However, there is significant concern that project management has not considered strategies for successful completion of this task with minimal impact to the project.**

**While the project meets or exceeds CD-1 requirements in many of the sub projects, and cost and schedule preparation, the external conceptual design review of the MTD has not been completed which is CD-1 Requirement. (See Recommendations)”**

project cost and schedule data prior to CD-1 approval.

## Since the June CD-1 review

---

- The project management office at Fermilab is planning growth to include a new Deputy PM, Vaia Papadimitriou, who has extensive project experience, and a contractor with extensive project experience on LIGO.
- The DOE added a new Federal Project Director to the US CMS project (Robert Caradonna) who has experience with the ATLAS Upgrade project. The previous FBD will stay on as deputy.
- More direct connections between the project office and the experienced team of QA and ES&H professionals at the lab have been established.
- There have been regular workshops with the MTD team to discuss technical issues and prepare an update to the CDR. A strategic approach with a baseline and alternatives has been developed. The team is aiming for a technical review of the US MTD project in September.
- The new management structure for the MTD project has been developed and is nearly finalized. The team is strong and enthusiastic. This new organization will include an advisory group made up of experts with significant project management experience.
- The CMS critical ASIC development (EC and MTD) will be monitored monthly through the new laboratory ASIC PMG.

# Summary and Conclusions

---

- CMS remains convinced of the importance of the MTD to extract HL-LHC physics in the anticipated high pileup conditions. We also appreciate that there is significant work to be done to put this project into good enough shape to pass CD-2 along with the rest of the project.
  - The teams will soon be in place to fully launch this project within the US and within iCMS. There is an overlap between these teams which we see as an advantage.
- The cooperative spirit of CMS has been strengthened through this review process. We are training a new generation to design and build large, complicated detectors, but it is still a work in progress.
- The project office is stronger and populated with experienced managers.

## Upcoming review schedule (tentative)

---

- MTD technical review – Fall 2018
  - This review is needed for CD-1 approval.
- CD-1 mini-review – late 2018
  - Need CD-3a in April 2019 for the silicon purchase.
- The team works closely with iCMS management to make sure all the project schedules stay synchronized.

# Backup

---

# Reviewers' comments on proposed FNAL irradiation facility

---

- Comment from the CMS Outer Tracker Reviewers:
  - We encourage the FNAL plan to establish a proton irradiation facility. This will be of great use for the upgrade program and beyond. For the case, that this facility might not be realized or not available in time, an alternative needs to be found and prepared. An analysis that supports the preferred alternative needs to be carried out.
- Note that a comment/recommendation on the FNAL irradiation facility was made during the ATLAS CD-1 review last week:
  - A key performance requirement for the pixel systems is the reliability after high radiation doses, and the component testing plan relies on the availability of proton, gamma, and neutron irradiation facilities at DOE national labs. Such availability significantly reduces the risk of delays in sensor and material validation. It is also of significant international interest (e.g. CERN will not be available for irradiation campaigns in 2019 and 2020)
- Recommendation to ATLAS
  - Work with DOE to pursue a dedicated proton irradiation facility in the US, e.g. by supporting the proposed irradiation facility at FNAL.

# International CMS review processes [CMS constitution]

---

- Before launching the construction of major parts or upgrades of any Detector System [...] the **Technical Coordinator**, with the agreement of the relevant **Detector System Manager**, organizes reviews [...]. The aim is to minimize risks in cost and schedule.
- An **EDR (Engineering Design Review)** or **ESR (Electronic Systems Review)** is thus held prior the start of construction or upgrade of a large item or important procurement. Adherence to safety requirements is an inherent part of an EDR.
- A **PRR (Procurement Readiness Review)** may be held in anticipation of an EDR or an ESR, to **authorize significant pre-production or pre-procurement**, or where parts of the system are well understood and factorize from the overall design. Such parts can, for schedule reasons, be considered for approval to proceed, providing there is no risk to the satisfactory completion of the overall design needed for the EDR.
- Each Detector System will undergo one or more **MPRs (Manufacturing Progress Reviews)** at strategic moments of the production process. The Technical Coordinator will decide which production processes merit MPRs. The MPR committee will ascertain whether the manufacture is going as planned, whether the milestones are likely to be met and whether the resources (financial and human) required to complete the production are available.
- The written reports of the findings and recommendations from these reviews are sent to the **appropriate System Manager(s)** with copies to **the Spokesperson** and the members of the **CMS Management Board**. Any follow-up is the responsibility of the appropriate System Manager and the Chairperson of the Review Committee.