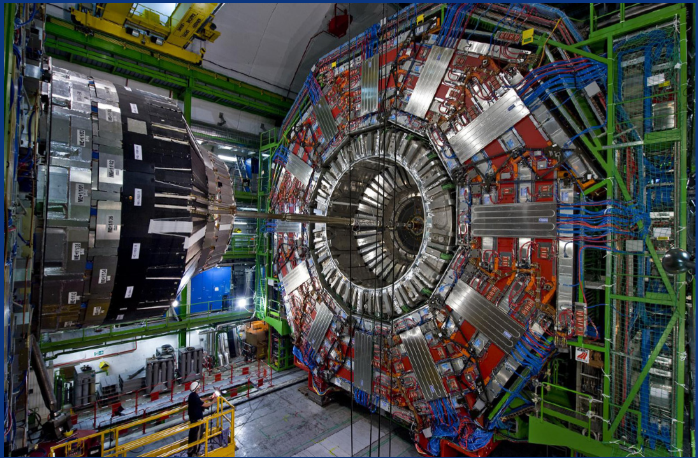
CMS Report 2018

Patricia McBride
US ATLAS Workshop
Univ. of Pittsburgh
July 30, 2018

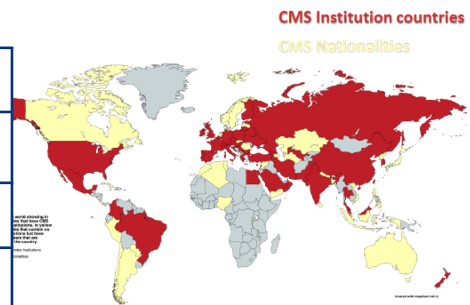


Outline (request from organizers)

- Physics highlights.
- Detector: current status, how it is being reconfigured for the future, new capabilities.
- Projects which are common with ATLAS (combinations, for example)
- How does CMS organize its paper review? How does it's speaker's committee work? Any lessons learned on the managerial side?
- Software: how are you poised to meet software challenges of HL-LHC?
- Any messages for young people who have to jump experiments?
- ..and anything you'd like to address to our community.

The CMS collaboration

Collaboration of People, Institutes, Nations	
47 Countries	207 Institutes
1850 PhD Physicists	928 PhD Students
1021 Under-graduates	930 Engineers

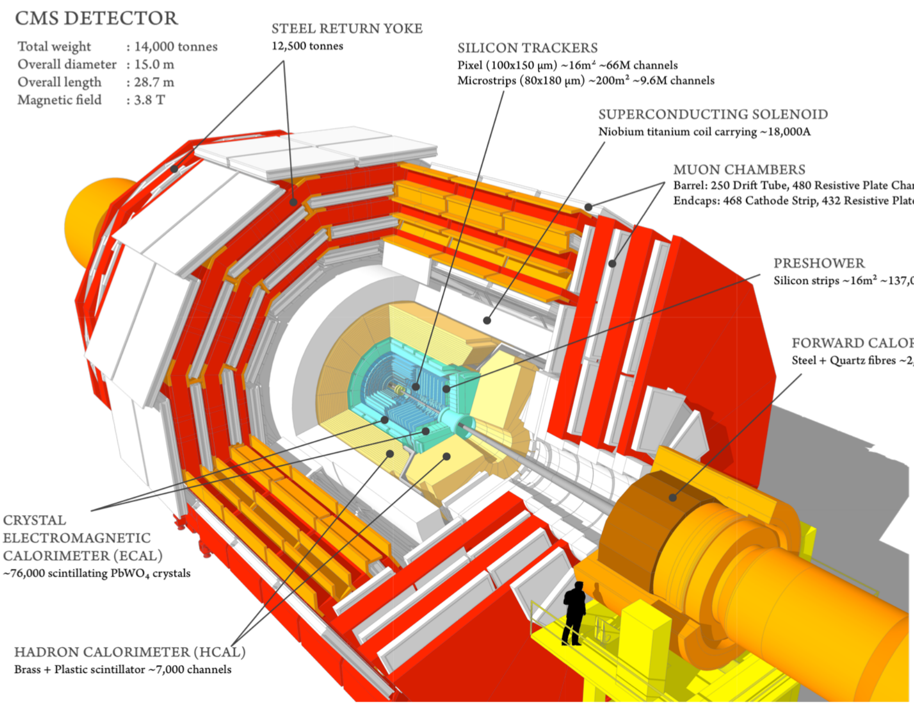


https://cms-users.web.cern.ch/cms-users/cms/Management/Stats/stats.html

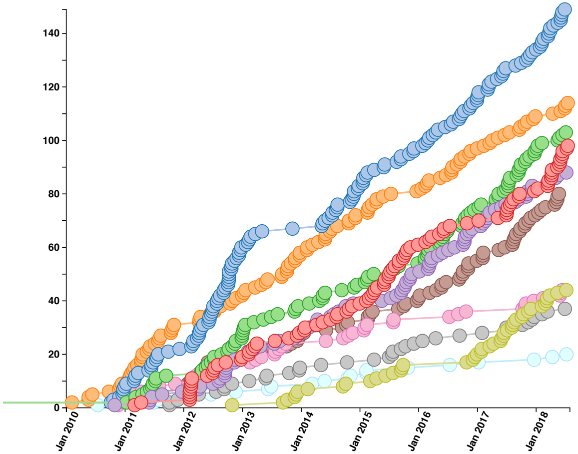
Snapshot of an evolving collaboration

- The U.S. plays a large role in CMS and is nearly 30% of the collaboration (HEP/NP).

The CMS detector



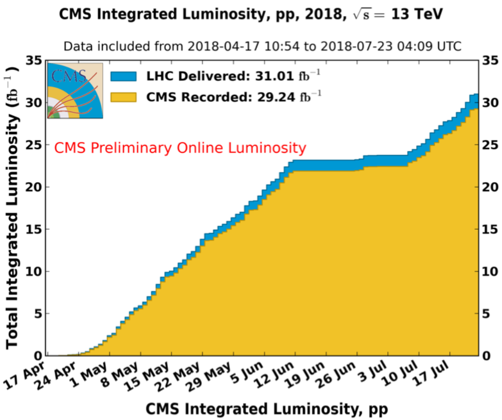
CMS publications



CMS has 800 publications so far in a wide variety of physics (and detector) topics.

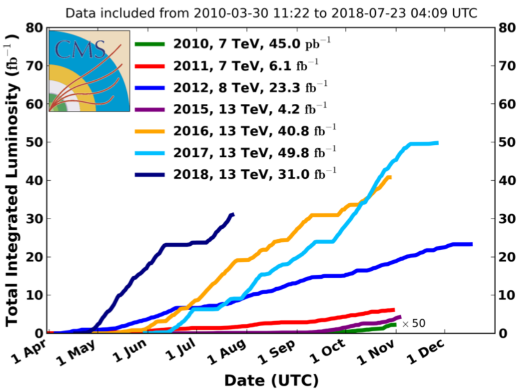
Many Run 2 analysis will be completed during LS2.
- And the time for combinations…

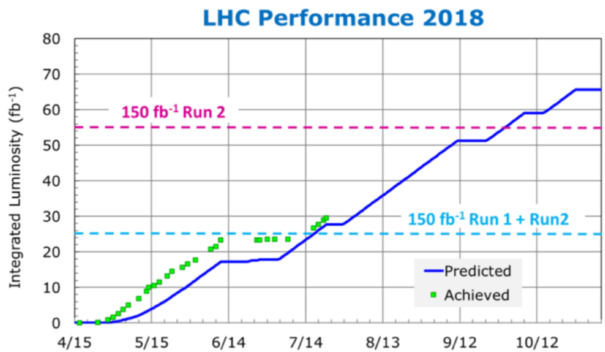
LHC in 2018



Looking forward to a strong finish to LHC Run 2 until the end of 2018.

CMS joins ATLAS in thanking the LHC machine group for their continued stellar performance.





LHC Goals and Schedule

The LHC promises to deliver significant integrated Luminosity for CMS and ATLAS in 2018.

LHC schedule 2018

A production year to complete Run 2

Goal 60 fb^{-1} ATLAS/CMS

2 fb-1 for LHCb

with 131 days of p-p physics

55 fb^{-1} and 1.8 fb^{-1} if 119 days

BCMS 25ns , 13 TeV

keeping the LHC availability close to 50% (stable beams)

Pb-Pb run : 24 days
4 days setting-up

Special runs: 9 days (16 days ?)

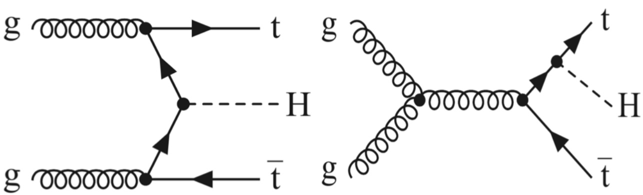
20 days of MD
+ 3-5 days, later during 2018 according integrated luminosity

Week 49: **powering tests to 14 TeV**
(Main dipole circuit ONE sector training to 14 TeV)

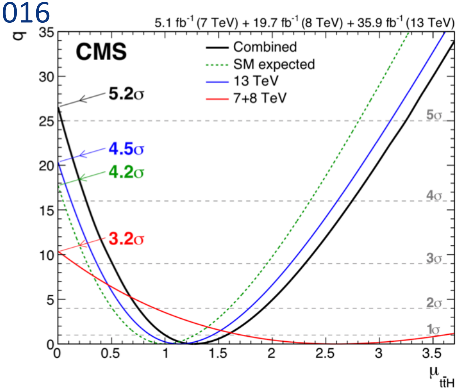
LHC Performance Workshop 2018 – Chamonix'18
Summary
F. Bordry
7th March 2017

We are here

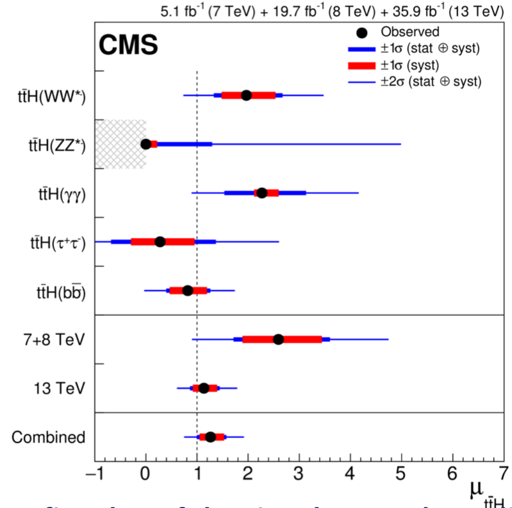
Observation of ttH production: 7, 8 and 13 TeV combined



Run 1+2016



Test statistic vs coupling strength modifier The horizontal dashed lines indicate the *p*-values for the background-only hypothesis obtained from the asymptotic distribution of *q*.

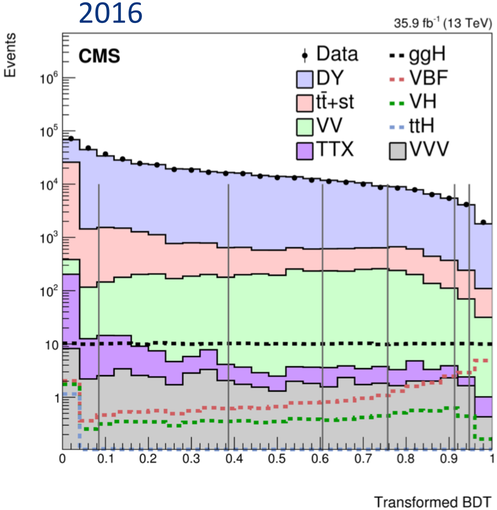


Best fit value of the signal strength modifier for (upper section) the five individual decay channels considered, (middle section) the combined result for 7+8 TeV alone and for 13 TeV alone, and (lower section) the overall combined result.

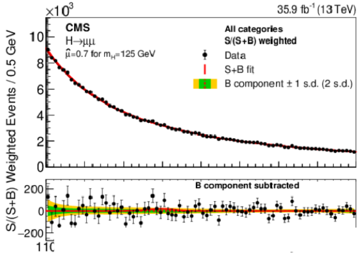
Phys. Rev Lett. 120 (2018) 231801

Higgs to two muons

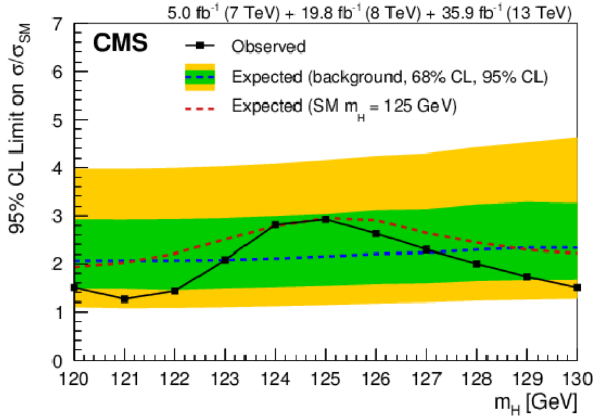
2016



The transformed BDT output distributions in data (solid points) and MC simulation (histograms).



The difference between the data and the background component of the fit.

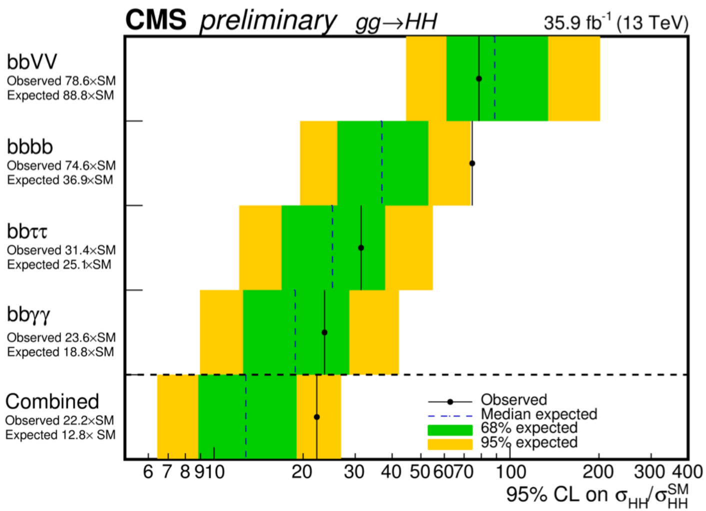


Combination: Upper limit on the SM Higgs branching fraction to muons of 6.4×10^{-4}. UL observed (expected) is 2.92 (2.16) times the SM value.

arXiv:1807.06325

Higgs boson pair production

2016



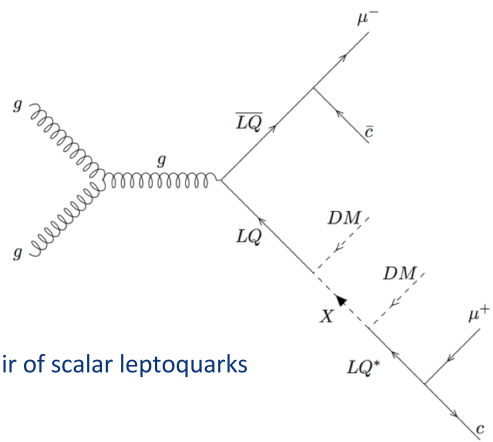
Observed (expected) 95% confidence level upper limit corresponds to 22.2 (12.8) times the prediction for the SM cross section.

HIG-17-030

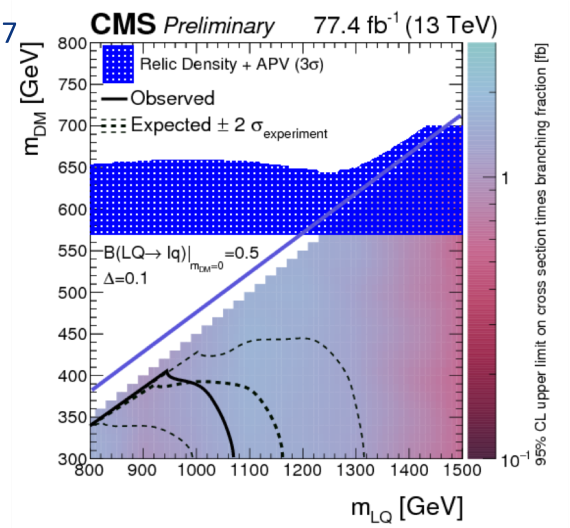
95% confidence level exclusion limits on the SM nonresonant Higgs boson pair production cross section.

Search for LQ + DM

2016/2017



Pair of scalar leptoquarks



The dark matter signature is given by a peak at the leptoquark mass in the invariant mass distribution of the highest p_T muon and jet. The data are observed to agree with the predictions from the standard model. Leptoquarks with masses up to 1160 GeV are excluded.

EXO-17-015

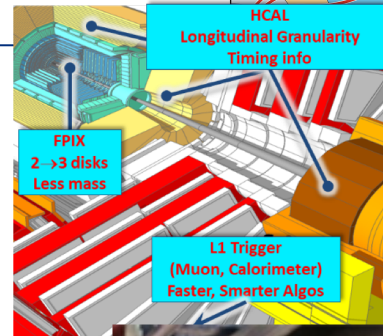
CMS challenges - 2018

- **Operations and Analysis**
  - CMS Phase 1 upgrade nearly complete; commissioning new detectors and electronics
- **Phase I Upgrade**
  - Complete HCAL upgrade – complete production of barrel readout modules for installation in LS2
- **Phase 2 Upgrade Early Construction**
  - Construction of GEM detector GE1/1 for installation in LS2
  - Start production of CSC electronics to be ready to install in LS2
- **Lessons learned from Phase 1 Upgrades**
  - DC-DC converters – mystery solved

Phase 1 Upgrade nearing completion

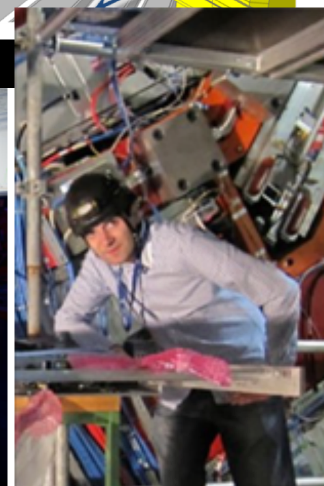
Forward Pixel Detector - Done, in Operations
L1 Trigger - Done, in Operations
Hadron Calorimetry Electronics: includes latest QIE ASIC

- Backend Readout - **Done, in Operations**
- Forward and Endcap Front-end - **Done, in Operations**
- Barrel portion will complete by end of 2018 -install in LS2




Andrew Whitbeck at the HCAL electronics burn-in installation

Lou Del Monte and Nadja Strobbe testing QIE11 ASICs

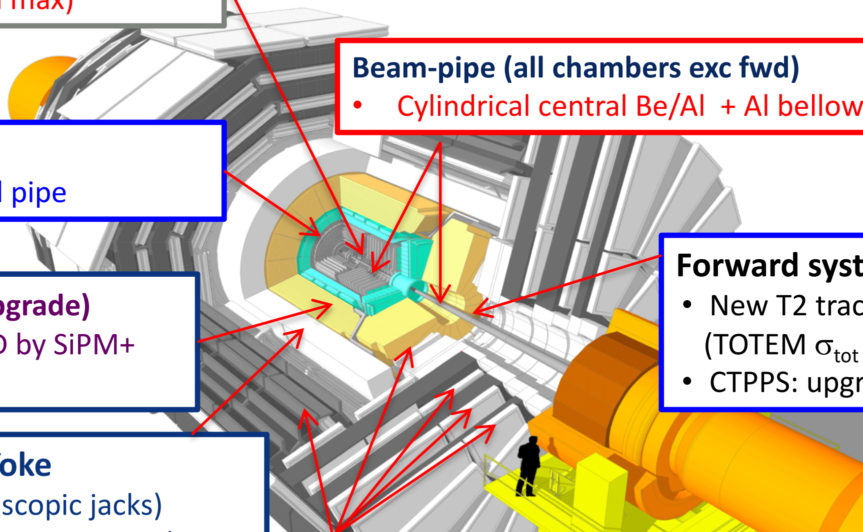


Aram Apyan during installation

LS2 overview: CMS

Pixel Tracker
- Replace L1 (250fb-1 design max)

Beam-pipe (all chambers exc fwd)
- Cylindrical central Be/Al + Al bellows

Barrel ECAL
- New S2U chilled water feed pipe



Forward systems
- New T2 track det (TOTEM σ_{tot} expt)
- CTPPS: upgrade

Barrel HCAL (last Phase1 upgrade)
- Replace rad damaged HPD by SiPM+ depth segmentation

MAGNET (stays cold!) & Yoke
- New opening system (telescopic jacks)
- New YE1 cable gantry (Phase2 services)

Muon System
- **New Cathode Strip Chamber FE electronics for inner rings of endcap (disks 2,3 & 4)**
- New GEM layer in inner ring of 1^{st} endcap disk
- **Leak repair campaign in barrel RPC**

Trigger/DAQ
- DAQ 2 ---> DAQ 3, EVB x 4 faster
- Starpoint update

CMS Phase-II upgrades for HL-LHC

Technical proposal CERN-LHCC-2015-010 https://cds.cern.ch/record/2020886
Scope Document CERN-LHCC-2015-019 https://cds.cern.ch/record/2055167/files/LHCC-G-165.pdf

Trigger/HLT/DAQ

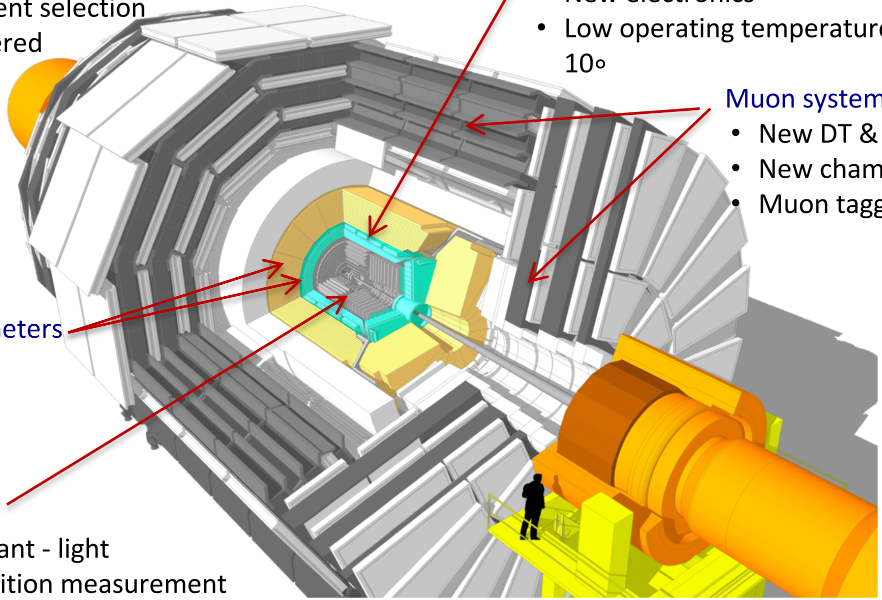
- Track information in hardware event selection
- 750 kHz hardware event selection
- 7.5 kHz events registered

Barrel EM calorimeter

- New electronics
- Low operating temperature ≃ -10∘

Muon systems

- New DT & CSC electronics
- New chambers 1.6 < η < 2.4
- Muon tagging 2.4 < η < 3



New Endcap Calorimeters

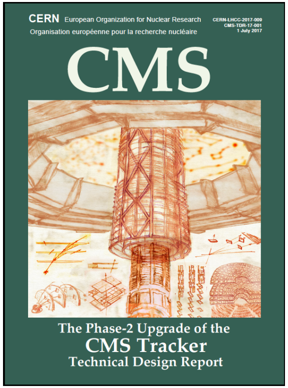
- Rad. Tolerant
- 5D measurement

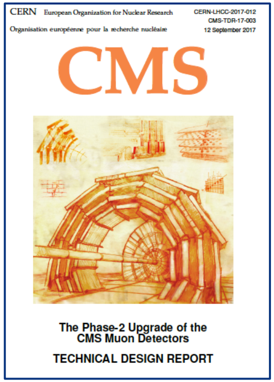
New Tracker

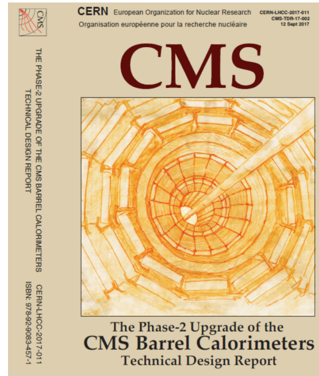
- Rad. Tolerant - light
- High Definition measurement
- 40 MHz selective readout for hardware trigger
- Extended Pixel coverage to η ≃ 3.8

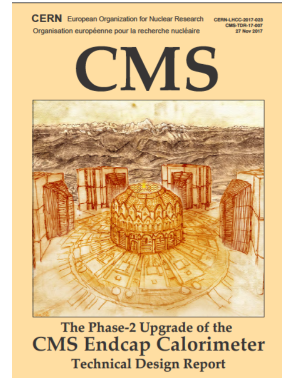
Beam radiation and luminosity
Common systems and infrastructure

HL-LHC TDRs approved so far









Work to do

CERN-LHCC-2017-xxx
CMS-TDR-17-004
September 12, 2017

The Phase-2 Upgrade of the CMS Trigger

Interim Report to the LHCC

CMS Collaboration

DRAFT

2020

CERN-LHCC-2017-xxx
CMS-TDR-xxx
xx Month 2017

Interim Technical Design Report

for the CMS Phase-2 DAQ Upgrade

CMS Collaboration

version 2017-08-08
for CWR
svn revision 420077

DRAFT

2021

CMS-TDR-17-006

TECHNICAL PROPOSAL FOR
A MIP TIMING DETECTOR
IN THE CMS EXPERIMENT
PHASE 2 UPGRADE

DRAFT

2018/19

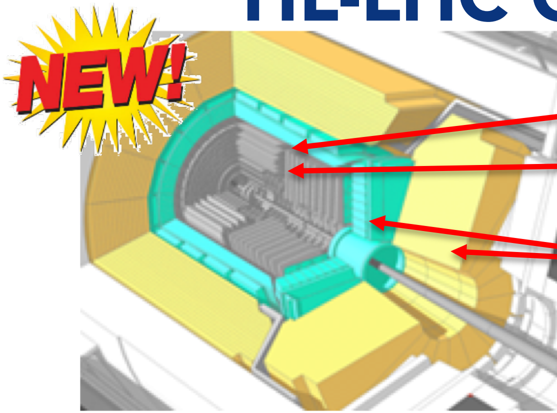
BRIL

2020

Plus

- PPS
- Computing
- Physics

HL-LHC CMS Upgrade

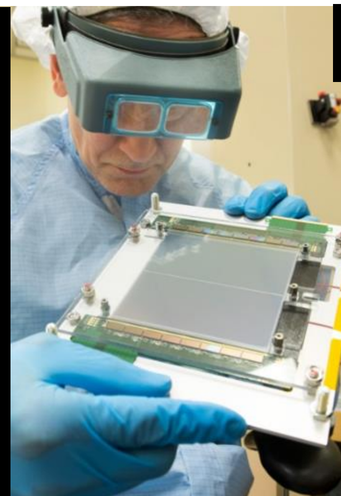


- **Timing Layer** – 4D tracking!
- **Outer and Inner Tracker** – Track Trigger capabilities!
- **Calorimeter Endcap** – Imaging Jets!
- **L1 Trigger** – Track/Calorimetry correlation at L1!

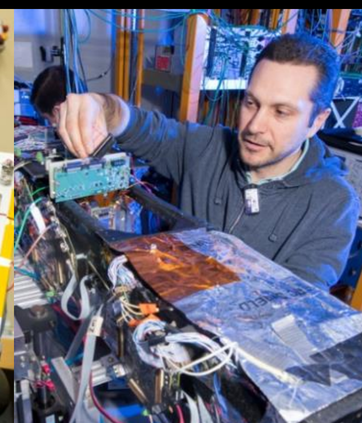
And more…

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

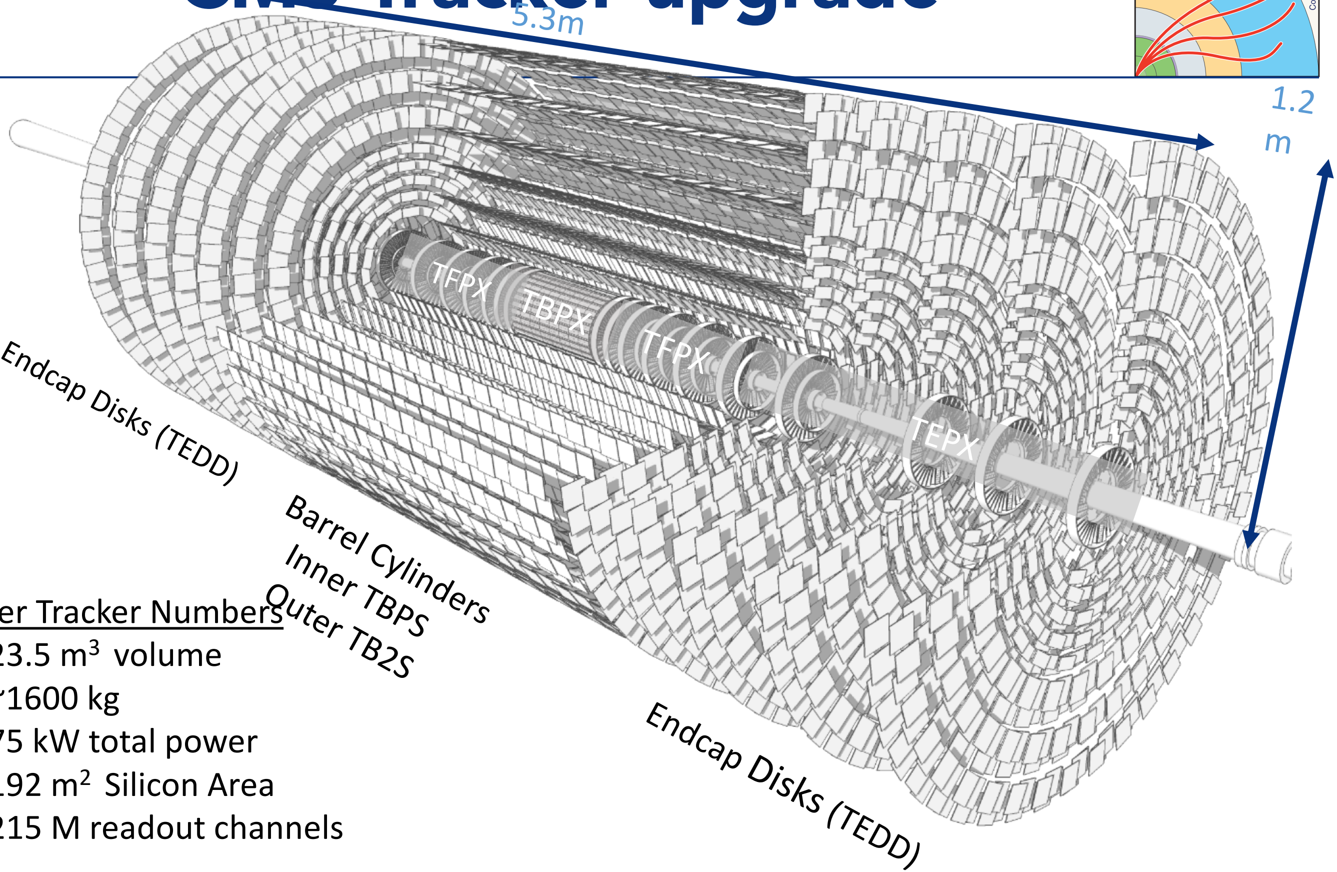
Bert Gonzales with prototype Outer **Tracker** Module at SiDet



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



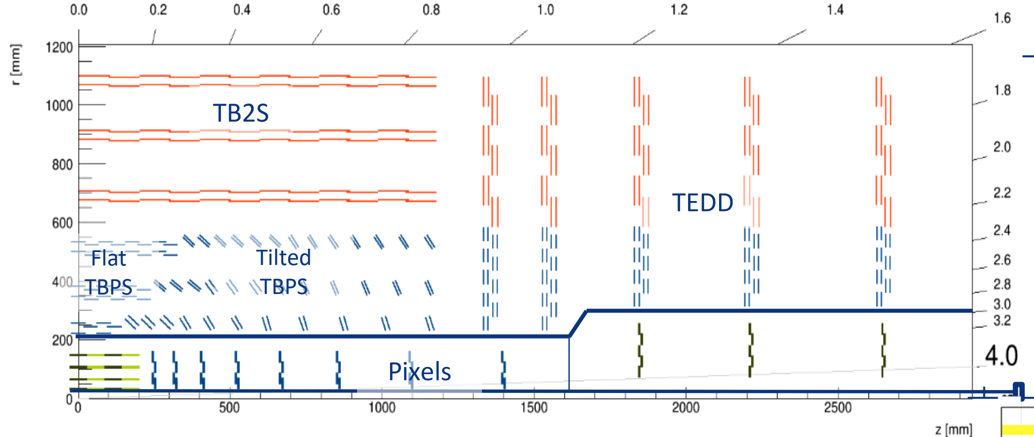
CMS Tracker upgrade



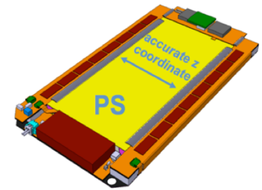
Outer Tracker Numbers

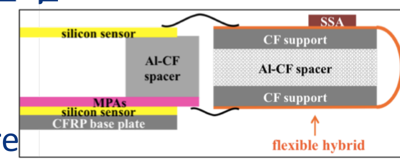
- 23.5 m^3 volume
- ~1600 kg
- 75 kW total power
- 192 m^2 Silicon Area
- 215 M readout channels

Outer Tracker – HL-LHC



Pixel-Strip modules

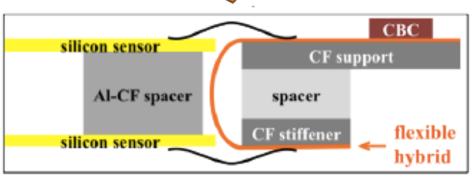


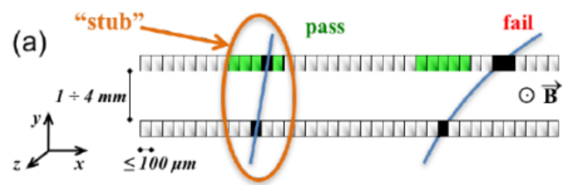


Strip-Strip modules

Sensor "sandwich" provides local curvature information for trigger

Different spacing in sandwich at different radii to match trigger

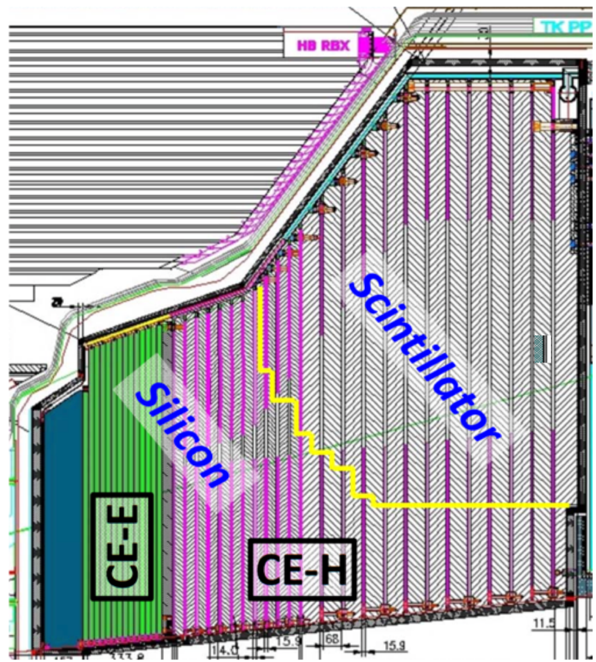




High Granularity Endcap Calorimeter (CE) for HL-LHC

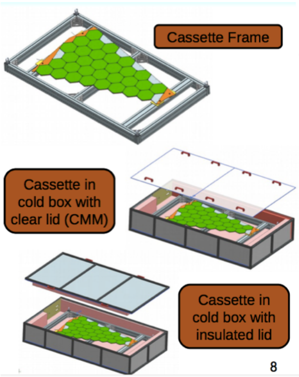
Requirements for new Endcap Calorimeter :

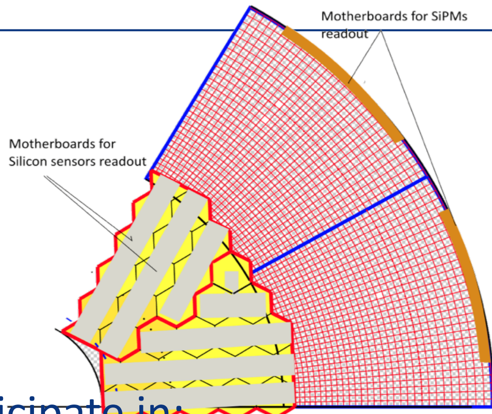
- ***radiation tolerance:*** fully preserve the energy resolution after 3000fb−1
- ***dense calorimeter:*** to preserve lateral compactness of showers,
- ***fine lateral granularity:*** *S/N* for MIP calibration, two shower separation, observation of narrow jets, minimize the inclusion of energy from particles originating in pileup interactions
- ***fine longitudinal granularity:*** good electromagnetic energy resolution, pattern recognition, and discrimination against pileup,
- ***precision measurement of the time of high energy showers:*** aiding rejection of energy from pileup, and the identification of the vertex of the triggering interaction,
- ***ability to contribute to the level-1 trigger decision.***

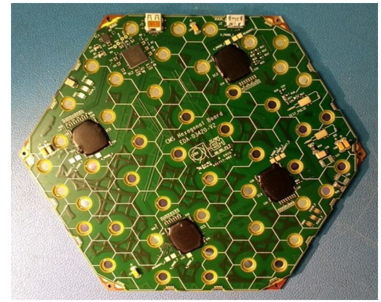


CMS HL-LHC Upgrade Endcap (CE)

HL-LHC Endcap Calorimeter – US

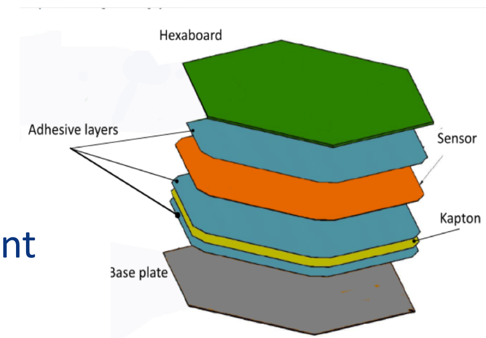






US is planning to participate in:

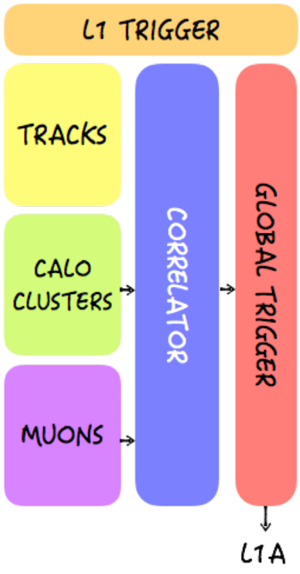
- Module construction: Silicon modules and some modules for CE-E section
- Cassette assembly: 15 layers for the CE-H
- Data concentrator ASIC
- Scintillator tileboards: Silicon PM development and construction of front layers
- Organization/leadership of LV / HV supplies



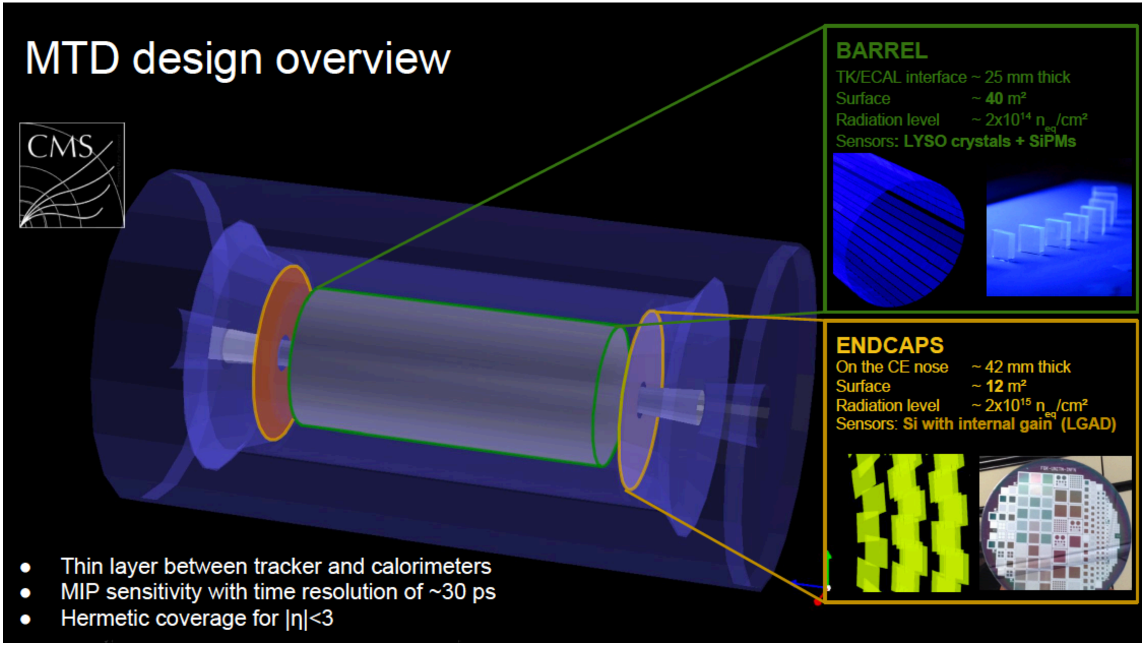
Trigger / DAQ for HL-LHC

- Increased information
  - Increased granularity in the calorimeters
  - Tracking information at L1
- Increased processing implies more complex objects and algorithms

- Conceptual design; R&D underway
- TDRs in 2020/2021



CMS MIP Timing Detector (MTD)



CMS Technical Proposal approved by LHCC in Spring 2018

The is a lot of interest in the collaboration for this project. US physicists are actively contributing to the design. Significant opportunities to collaborate on the R&D.

Layout of MTD system

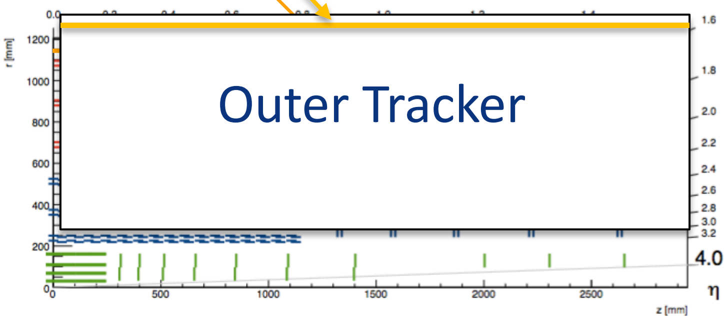
Hermetic MIP Timing: Barrel & Endcap

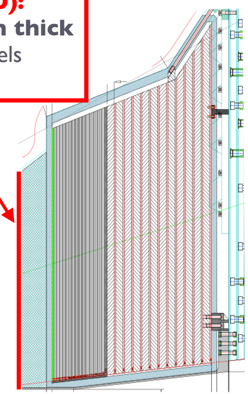
Requirements:

- Hermeticity: barrel ($|\eta| < 1.48$) and endcap ($1.6 < |\eta| < 2.95$)
- Radiation: $2\text{x}10^{14}$ n_{eq}/cm^2 (barrel) and up to $2\text{x}10^{15}$ 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 m², ~250k channels
- Integrate with tracker

Si with internal gain (LGAD):
- On the endcap nose ~ **42 mm thick**
- Area ~12 m² (total), ~4M channels
- Integrate with endcap

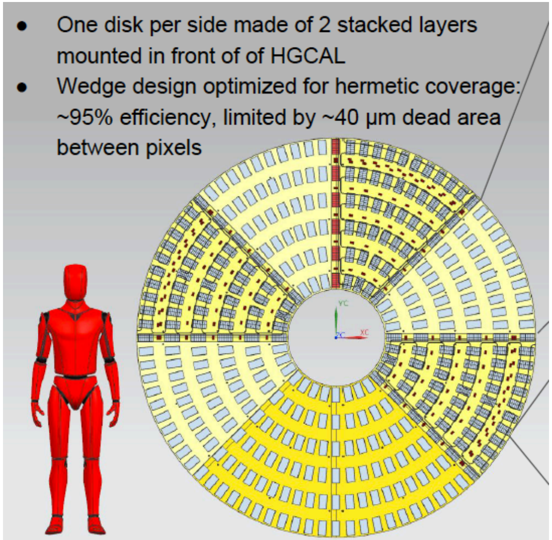


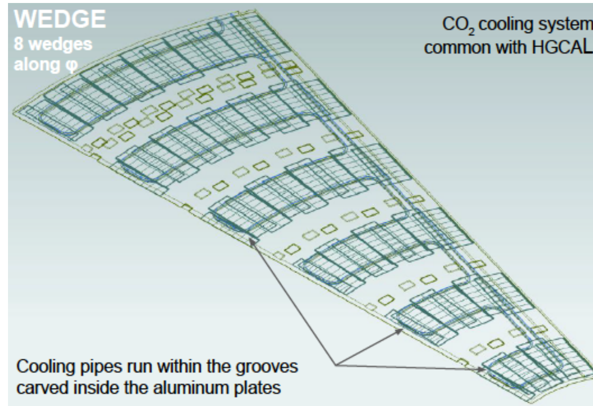


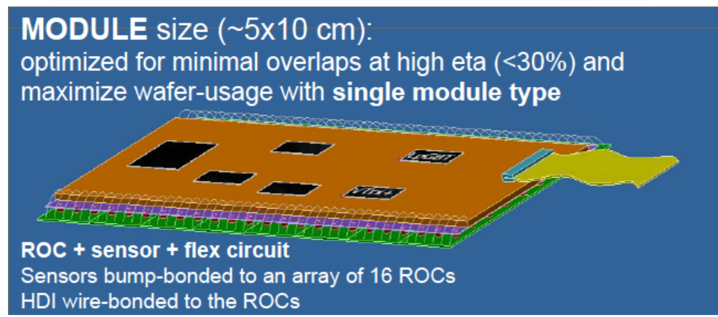
21

Lindsey Gray, FNAL

Endcap Timing layer (ETL) Modules (conceptual design)



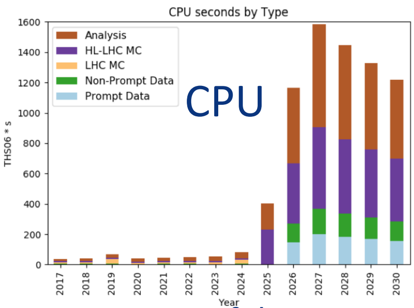


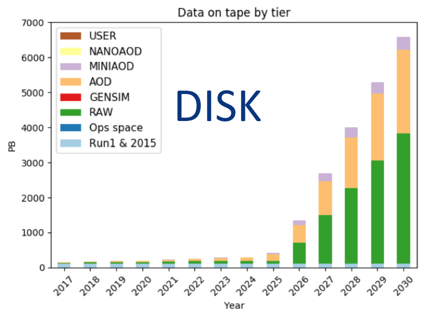


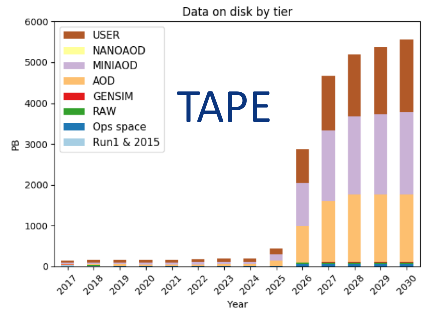
- Accounting:
  - Two layers per disk
  - Two disks on each endcap
  - 8 wedges per disk
  - 2624 system modules
  - ~2M total channels

HL-LHC Computing Challenges

- LHC has had remarkable success with Software and Computing, but the HL-LHC presents significant challenges for the experiments.
  - CMS resource needs for Run4 are staggering.







- HEPAP Portfolio review comments:
  - **“ The panel strongly encourages U.S. ATLAS and U.S. CMS to pursue an aggressive “advanced computing” R&D program. In view of the critical role of data handling and processing to the success of these programs, this challenge should not be underestimated.**
  - **“ We continue to dream of the small university-based group led by a faculty member being able to do a complete analysis. The development of a new analysis paradigm, through some major transformation of the current approach, would be highly desirable.**

- There are ample opportunities to get involved (and to collaborate) on the challenges of HL-LHC software and computing.

LHC Physics Center (LPC)

- LPC = Physics analysis and detector operations and upgrade regional center with about 100 resident scientists at Fermilab.
  - High level software support, excellent computing and the Remote Operations Center
  - Collaboration with the Theory (and ATLAS) community
  - Many social and educational events and tutorials
- Hosts the CMS Data analysis school – annual event
- Distinguished Researcher program: 15 DRs in 2018
- Guest and Visitor program → short/medium term visits to the LPC, focus on upgrades/operations
- Current leadership: Cecilia Gerber and Sergo Jindariani

CMS Diversity and Inclusion

CMS has formed a Diversity Office

to foster a working environment where all members of the Collaboration can thrive and bring in their talents, irrespective of age, career status, employment situation, institutional affiliation, geographical location, nationality, gender, ethnicity, family situation, sexual orientation, or disabilities.

The mandate of the Diversity Office is to:

- advise management and individuals on diversity related matters
- propose actions to promote diversity and create awareness
- monitor and record statistical information related to diversity
- actively listen to Collaboration members' concerns
- report regularly to the Collaboration about status and progress of diversity related issues
- collaborate with relevant bodies outside CMS such as the CERN Diversity Office if required

The Diversity Office is a standing body of the Collaboration Board

CMS Women

- Increased social media presence.
- Regular discussion sessions open to all.

Summary and Conclusion

- CMS Run 2 is going well and we are delighted to have the flood of data to analyze.
  - 800 papers and counting…
- There are many opportunities for physics analysis, detector development and computing innovations within CMS.
- I didn't cover many of the topics requested, so please ask questions.