



Status of the CMS experiment

Frank Chlebana (for the Fermilab CMS Group)

2020 July Public PAC Meeting

30 June 2020

Outline

- The Fermilab CMS Department
- Physics Analysis
- CMS Schedule and COVID-19 Planning
- Operations
- Software and Computing
- HL-LHC Upgrades
- Facilities
- LPC Status
- Summary

The Fermilab CMS Department

FNAL CMS Department

- The Fermilab CMS Department is composed of **37 Scientists** and **12 Research Associates**
- In FY20, Fermilab continued to hold leadership roles in the international collaboration with P. McBride as the CMS **deputy spokesperson**, B. Klima as the **chair of the Publication Committee** and **18 of the lab's scientists serving as managers or conveners** of CMS projects and working groups.
- Fermilab led, managed, and supported the national programs with **25** scientists serving as **managers of the HL-LHC CMS Upgrade** and of the **U.S. CMS Operations Program**.
- The group continued to lead in **computing operations**, development of simulation and reconstruction software, as well as **R&D** for data storage, distribution, frameworks, facilities, and access in preparation for the increased data volume expected in Run 3 and HL-LHC.

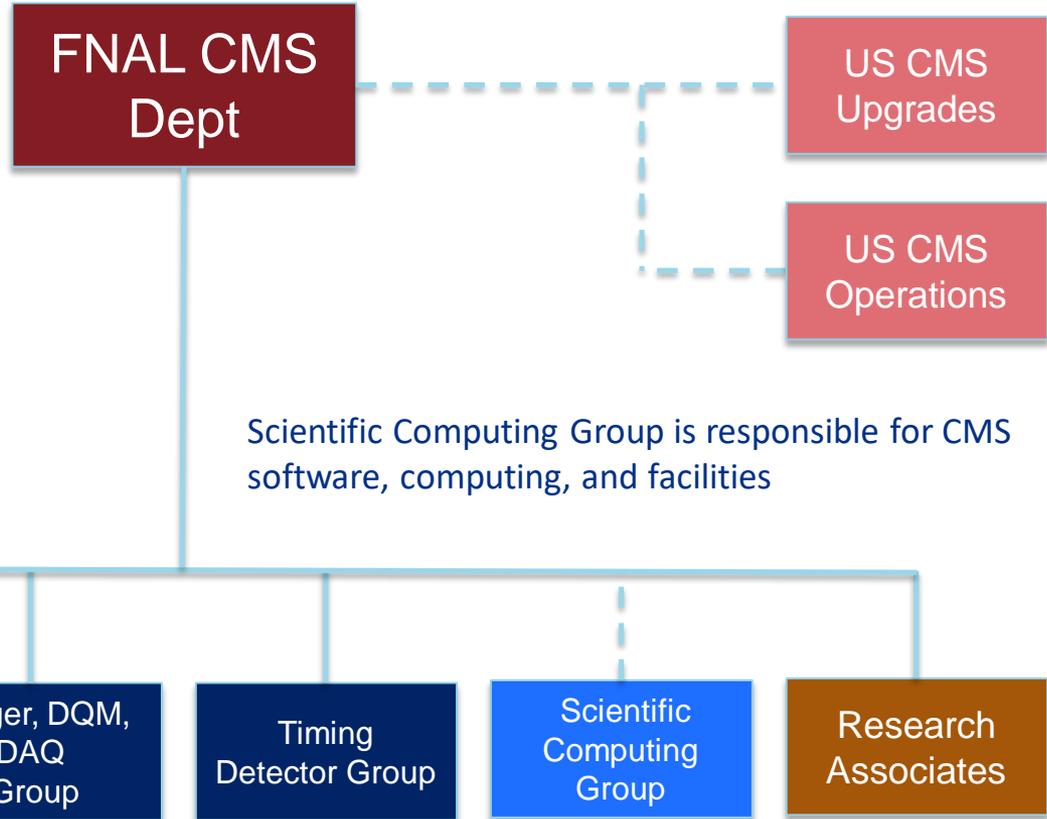
FNAL CMS Department Organization

The FNAL CMS Dept organization is aligned with the technical interests of the group

The FNAL CMS Dept hosts the LPC

Physics focus on high impact areas

- Comprehensive program for Standard Model measurements
- Searches for new physics: Dark matter, SUSY, LLP, Bew resonances



Fermilab's Participation in Community Planning

In FY20, Fermilab scientists were **highly recognized within the community** for their contributions to cutting edge science and technology.

- Joel Butler was elected as **vice-chair of DPF**
- P. Merkel was selected as both **co-chair of CPAD** and **member of the ICFA** Instrumentation Innovation and Development Panel.
- Fermilab scientists were also chosen to be the **leaders of the Snowmass process**: O. Gutsche as co-convenor of the Computational Frontier, P. Merkel of the Instrumentation Frontier, A. Apresyan of the Solid State Detectors and Tracking topical group, and J. Hirschauer of the BSM topical group, D. Elvira as topical convenor for Theoretical Calculations and Simulations in the Computing Frontier.
- O. Gutsche was also selected as the technical lead of the Portable Parallelization Solutions project of the **DOE Center for Computational Excellence**.
- Fermilab group played a major role in the **DOE-OHEP BRN (Basic Research Needs) Study on HEP Detector R&D**.
- Fermilab scientists (P. Bhat, A. Canepa) continued to be asked to write perspective and review papers (“Particle Physics Accelerators in the US and in Asia”, “Search for EWK-inos”)

Recent Awards and Recognition



Ryan Heller: 2019 CMS Detector Award *“For critical contributions to the MTD detector design and prototype development, in particular developments for the characterization of LGAD sensors in lab tests and test beams”*

Maral Alyari: 2019 CMS Detector Award *“For her excellent contributions to the engineering of HGCal, including the critical work on designing, prototyping and testing the mockup cassette”*



Reward and Recognition



Fabio Ravera: *“For outstanding contributions to the R&D and prototyping of the CMS Outer Tracker while developing an innovative search for new physics.”*

Jim Freeman: *“For outstanding work on scintillator R&D, for the development of a new method for building a HGCal tile module, and for the development and commissioning of a pick-and-place machine for demonstrating this new method.”*



New Initiatives in detector R&D – 2020 awardees



Artur Apresyan



Karri DiPetrillo



Ryan Heller

“Study of two novel technologies that extend the LGAD concept to include precise spatial resolution: trench-isolated LGADs and AC-coupled LGADs.”

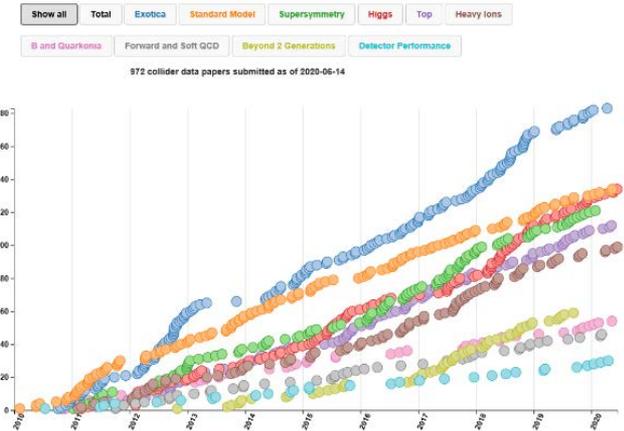
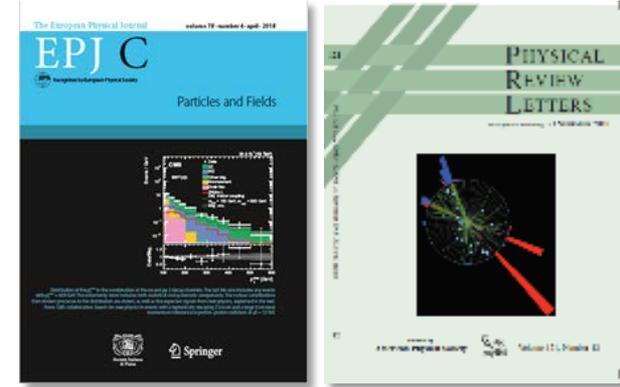
CMS Physics Analysis

CMS Publications (Quality, Diversity, Quantity)

- CMS continues to publish a large number of exciting new physics results. As of June 19, 2020 CMS published **1000** papers in peer-reviewed journals

<http://cms-results.web.cern.ch/cms-results/public-results/publications/CMS/index.html>

- About one third of the papers were published as Letters in PRL or PLB
- To-date CMS published **975** papers based on LHC-collisions data
 - Covering 3/5 of the P5 drivers (BSM, Higgs, DM)
 - Many topics, which were originated in the past by three different accelerators and their corresponding experiments, e.g. Tevatron (energy frontier), B factories (intensity frontier) and RHIC (heavy ion physics), are now covered extensively by CMS



FNAL CMS Physics Program

- **Comprehensive program of SM measurements**
 - Characterization of the Higgs boson
 - Searches for rare SM processes
 - Precision measurement

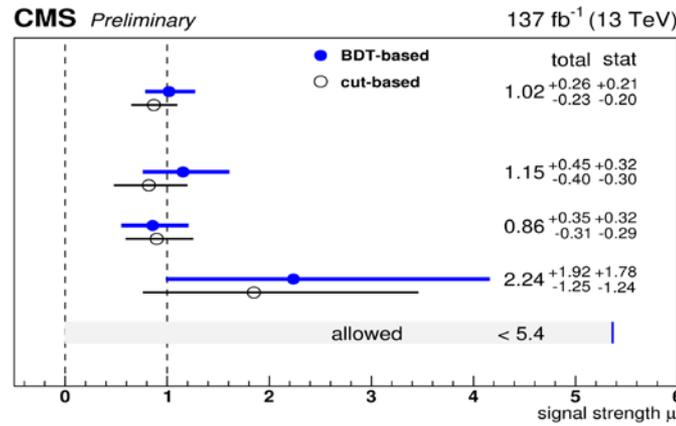
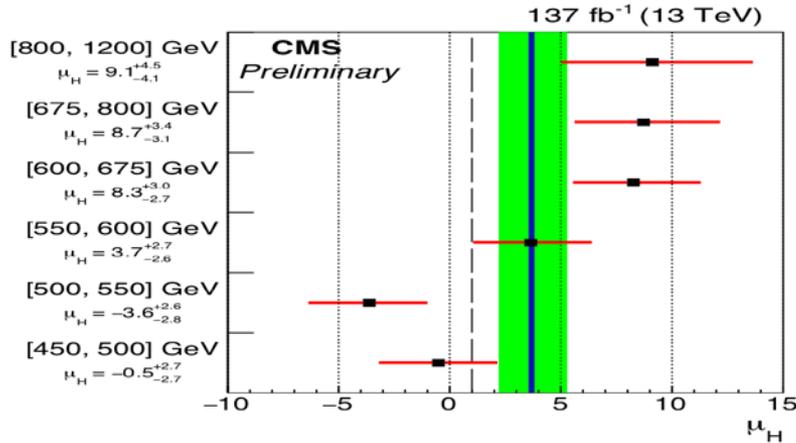
Measurements of production cross sections of WZ and same-sign WW boson pairs in association with two jets
2005.01173
 Search for anomalous electroweak production of vector boson pairs in association with two jets
1905.07445
 Measurement of the Z boson production cross section
1909.04133

Inclusive search for a highly boosted H(bb)
CMS PAS HIG-19-003



3 DRs and 1 Graduate Scholar among the leading contributors

Observation of heavy triboson production
CMS PAS SMP-19-14



FNAL CMS Physics Program

- Includes both “classical” and innovative analyses maximizing the potential for discovery
- Development of advanced tools to enhance sensitivity in challenging corners of phase space
 - Tagging of bosons and identification of leptons, deployment of machine learning, new triggers
- In FY20 we led the analysis for 11 publications/public notes and two review papers

DARK SECTOR

Dark Higgs, Self Interacting Dark Matter, Inelastic Dark Matter, Dark QCD

5 papers by end of Summer + 1 novel search for soft un-clustered energy patterns

LONG LIVED PARTICLES

Signature with displaced jets
Signature with displaced b-jets
Signature with showers in the muon chambers

3 papers by end of Summer

SUPERSYMMETRY

Searches for Higgsinos
Searches for Winos
Searches for RPV-Stealth

3 papers by end of Summer

NEW RESONANCES

Searches in final state with 3j, 4j
Searches in final states with one Higgs boson and one scalar

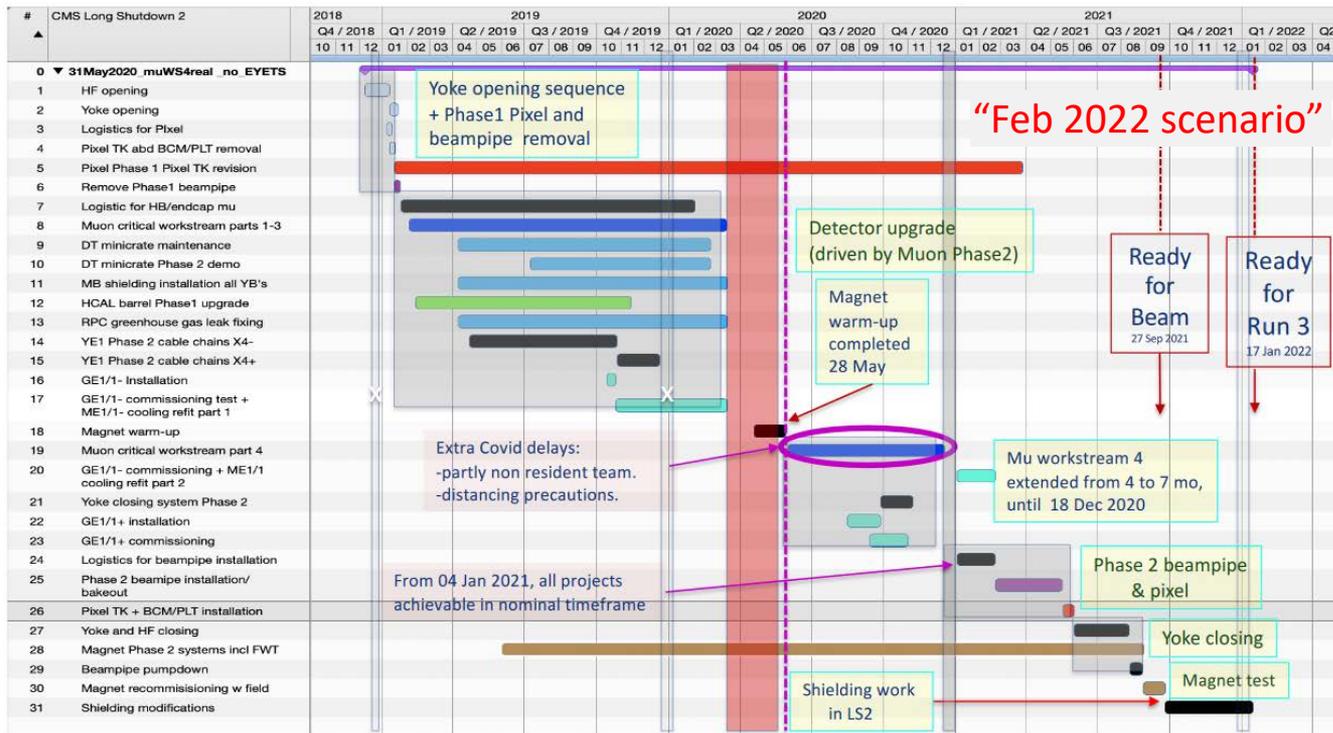
2 papers by end of Summer

CMS Restart with COVID-19 Precautions

- CERN re-opening is being proactively planned, with a staged restart of activities
 - Prior to May 18th CERN conducted safety tours and started the critical activity of the **magnet warm-up**
 - 18 May – present: CERN and CMS is gradually restarting key activities
 - Evaluate the difficulties and efficiency in working with Covid-19 precautions
 - CMS is restarting activities with the locally available team (mostly Institute personnel)
- US CMS management team is working with the CERN teams to help making the restart as safe as possible
- Currently, about 180 US CMS people remain based at CERN
 - They are vital for continuing safe (remote) operations, safety walk-throughs and interventions, and are the essential for a safe re-start of LS2 and operations activities, while travel from the US will still be severely limited
 - US involved in on-site work in many areas, including HCAL, BRIL, Tracker, Trigger, DAQ, EMU,... also some of the upgrade areas
 - We ask for volunteers (with approval by PIs, consistent with institutions' policies) and only for work packages approved by CMS Technical Coordination
 - Most work is still done from home, and all “office work” will continue to be home-based to maximize social distancing

CMS Schedule

Updated CMS schedule resulting from LHC accelerator and Experiments (June 8th, 2020)



No change to LS3 (starting beginning of 2025)

Review of LS2 schedule at end of Oct 2020

Run 3 luminosity depends on how efficient 2022 running will be (*with only a pilot run in 2021*)

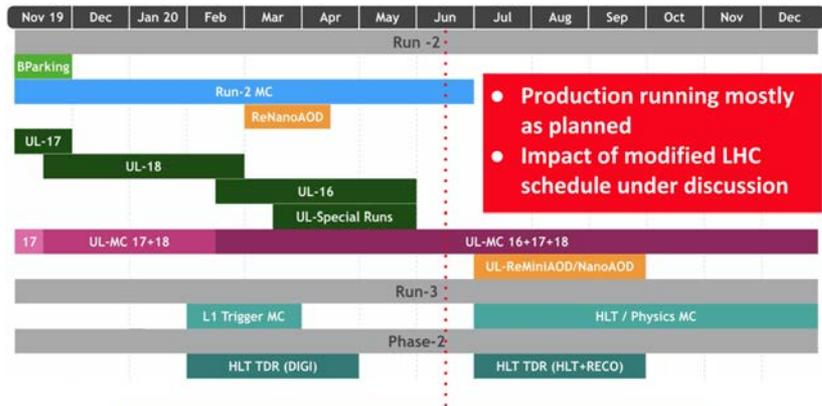
Pre-COVID: 208 fb⁻¹
 60% efficiency: 189 fb⁻¹
 40% efficiency: 173 fb⁻¹

Operations & Software and Computing

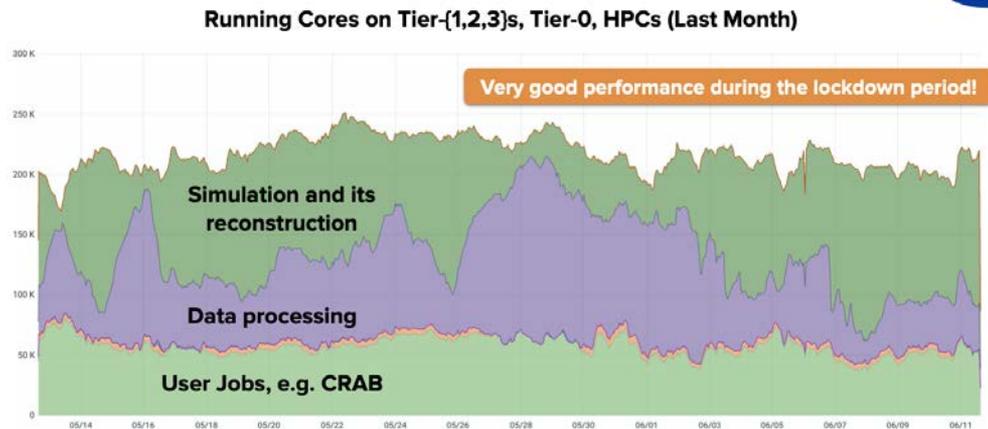
CMS Operations and HL-LHC Computing R&D

- All U.S. Tier-1 and Tier-2 facilities remain fully supported during site closures
 - Impact of site closures on computing availability is so far $< \sim 10\%$
 - Able to meet CMS readiness and reliability requirements

Production Plan



30-Day Production Overview



- Legacy re-reconstruction pass of Run 2 data and new MC
- TDR and Phase 2 upgrade simulation

CMS Operations and HL-LHC Computing R&D

- **Computing Facilities:** Tier-1 is hugely important for CMS, performing excellently and enabling physics data analysis.
 - In FY21/22 we plan for the necessary refurbishments of equipment (CPU, disk systems) and capacity upgrades needed for Run3
- **Software Modernization and HL-LHC Computing R&D:**
 - HL-LHC computing requires modernized physics software
 - Need to focus on innovative algorithms and data structures, including ML / AI, and Fermilab expertise in core s/w frameworks.
 - Storage is a cost driver, and data storage cannot be done “opportunistically”
→ needs R&D in Data Management etc.
 - Work on prototyping of cost-effective facilities, making use of HPC, networking, etc
- **Program Management:** managing the program and sub-contracting with some 45 US universities and CERN

Fermilab CMS group - Software & Computing

International CMS Software & Computing Project

Coordinators
M. Klute, D. Piparo

Core Software
S. Muzaffar, M. Kortelainen

Simulation
V. Ivantchenko, S. Bein

Monitoring & Analytics
V. Kuznetsov, F. Legger

Analysis Infra & Support
S. Belforte, S. Malik, M. Tonjes

Generators *
A. Grosjean, Q. Li

Computing Resources Board
J. Hernandez, K. Bloom

Computing Ops
C. Paus, N. Smith

Workload/Data Mgmt Devel
K. Lannon, K. Ellis

Dyn. Res. Provisioning
D. Spiga, C. Wissing

Facility Services
G. Bagliesi, S. Lammel

Reconstruction
A. Perrotta, S. Krutelyov

Resource Management
J. Flix, D. Lange

Upgrade Software
[K. Pedro]

Submission Infra
J. Letts, A. Perez-Calero

Upgrade R&D and TDR
M. Girone, D. Elvira

Web Services & Security
A. Pfeiffer, TBD

DPOA ***
K. Lassila-Perini E. Carrera

Release Planning Ops
S. Donato, [Pending CB Approval]

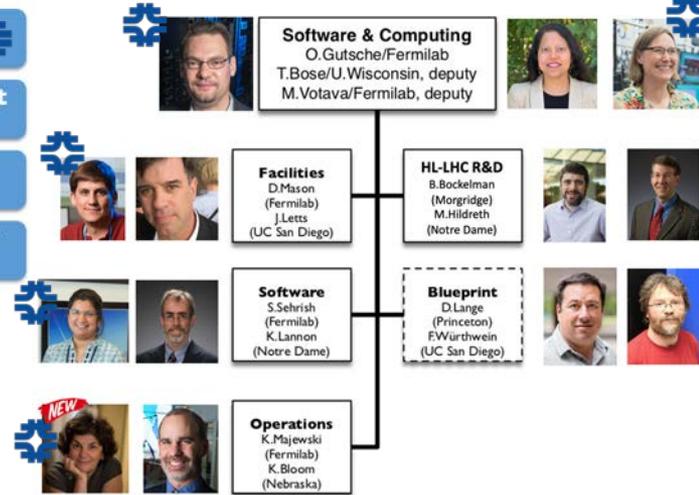
Machine Learning *
J. Vlimant, G. Kasieczka

LI Software **
V. Rekovic

A very broad set of expertises

* Joint with Physics
** Joint with TSG
*** Joint with CB
Mandates [here](#)

U.S. CMS Software & Computing Operations Program



- International CMS Software & Computing and the U.S. CMS Software & Computing Operations program are very interconnected, shown are areas where Fermilab CMS scientists are involved in the management
 - Fermilab scientists (and computing professionals with guidance from scientists) are involved in leadership and execution of almost all aspects of CMS Software & Computing
- New group on **Machine Learning**
 - L. Gray subgroup leader for “Innovation”
 - M. Liu, subgroup leader for “Production”

Fermilab CMS Group - Software & Computing Activities

- **CMS facilities and computing operations (Lammel, Smith)**
 - Workflow operations, data management, facility operations
- **Software development (Elvira, Mrenna, Pedro, Gray, Hall)**
 - Core software (framework), Simulation software (Geant), Generators (Pythia), Reconstruction software (tracking, HGAL) → new architectures (GPUs, FPGAs, ...)
- **Analysis frameworks and facilities R&D (Pedro, Gray, Gutsche, Smith, Cremonesi, Hall, Jayatilaka)**
 - Columnar analysis, Coffea, Spark and analysis facility concepts
- **Machine Learning R&D (Tran, Gray, Pedro, Liu, Cremonesi, Klijnsma, Herwig)**
 - Development of deep learning applications for reconstruction and analysis optimization, Fast inference on FPGAs
 - Fully aligned with Fermilab AI efforts
- **Facilities R&D (Gutsche, Jayatilaka)**
 - HPC leadership class facility access R&D
 - Data management, organization and access R&D
- **Computing model evolution (everyone!)**
 - Evolution of the CMS computing model
- **Management of International CMS and U.S. CMS (Elvira, Lammel, Gutsche, Pedro, Smith)**
 - R&D, Facilities Management, Operations Program Management, Upgrade, Operations

HL-LHC Upgrades

HL LHC 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

Beam Radiation and Luminosity, Common Systems, Infrastructure

Tracker

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

Calorimeter Endcap DOE

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

Also known as HGCaI

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

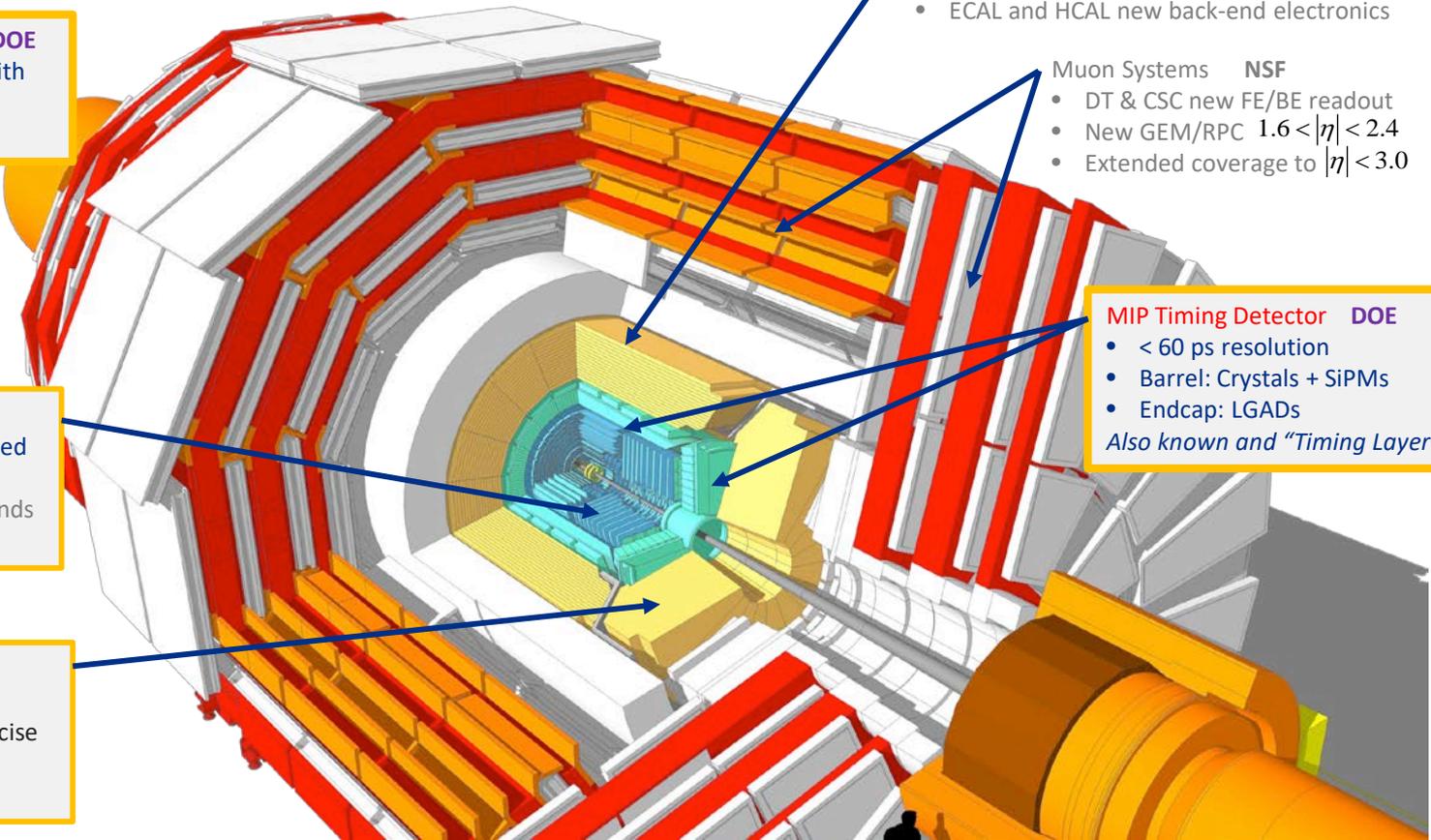
Muon Systems NSF

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

MIP Timing Detector DOE

- < 60 ps resolution
- Barrel: Crystals + SiPMs
- Endcap: LGADs

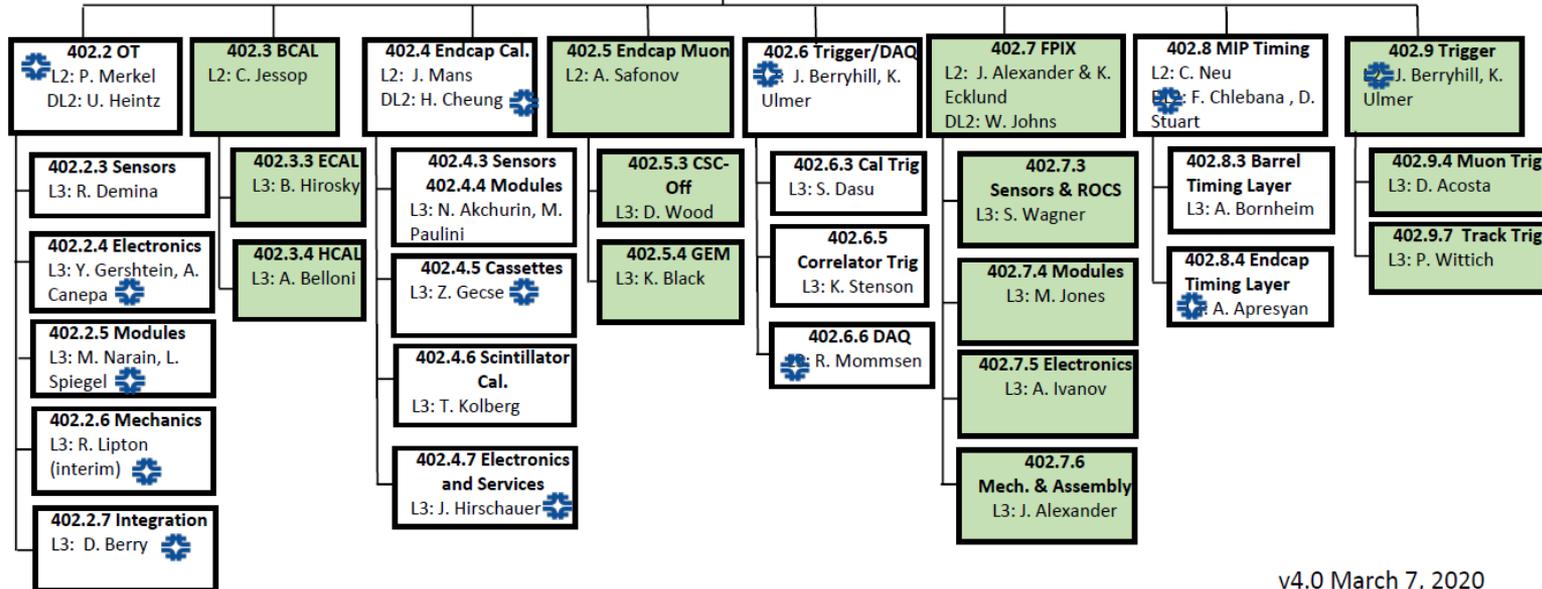
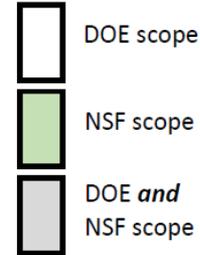
Also known as "Timing Layer (TL)"



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):	B. Smith
Education and Public Outreach:	S. Rappoccio	Lead Systems Engineer:	K. Smolenski



v4.0 March 7, 2020

Outer Tracker

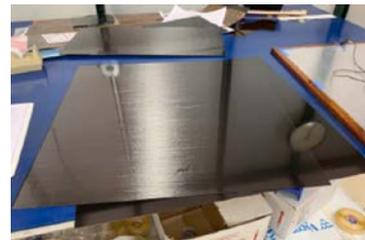
Nahn, Berry, Canepa, Lipton, Merkel, Mills, Murat, Spiegel, Uplegger
(RAs: *Ravera, Weber*)

- Deliverables (Fermilab deliverables)
 - Assemble 4500 Silicon Modules, ½ done at Fermilab
 - Mount 1000 Modules onto Carbon Fiber Structure which comprises central section of inner 3 layers of CMS Tracker
- Key FNAL Resources
 - Labor: Microfabrication and Specialized material expertise, Scientific oversight and QC
 - Facilities: SiDet, Irradiation Test Area, Testbeam, Carbon-Fiber fabrication
- Ongoing Work / Recent Accomplishment
 - Prototype Macro-Pixel Sub-Assemblies (MaPSA) testing
 - Module assembly gantry programming
 - First optical readout setup for 2S modules
 - Burn-in system with cold box
 - DAQ development accommodating all chip and hybrid varieties nearly done
 - Fabrication of carbon fiber layups

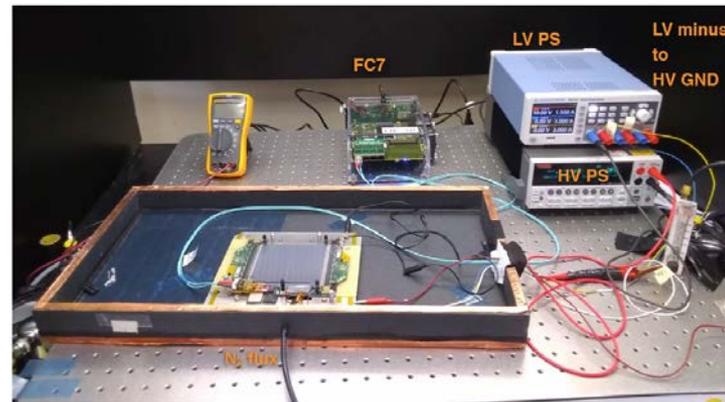
MaPSA test stand



Carbon fiber panel



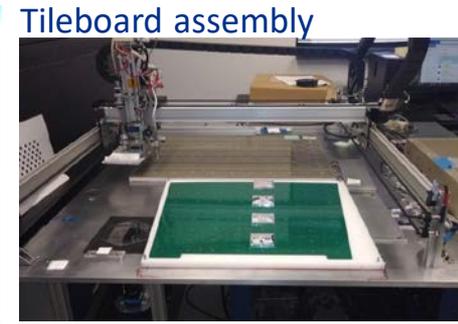
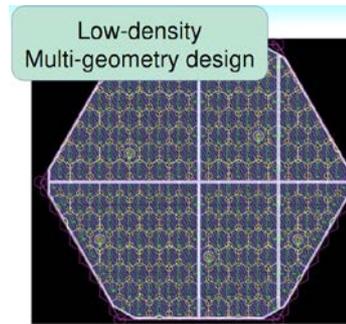
Optical readout



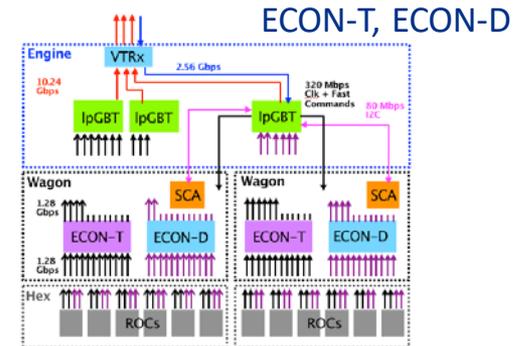
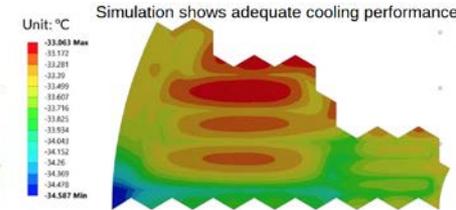
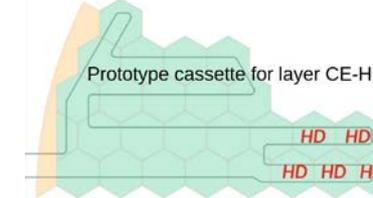
Calorimeter Endcap

Cheung, Alyari, Banerjee, Freeman, Gecse, Hirschauer, Joshi, Lincoln, Strait (RAs: none)

- Deliverables (Fermilab deliverables)
 - Assemble 13,500 Silicon modules and 1404 Tile Modules
 - Assemble 550 Cassettes
 - Design/Fabricate Concentrator ASIC for on-detector data handling (so called ECON)
- Key FNAL Resources
 - Labor: **ASIC Engineering**, Scientific oversight and QC
 - Facilities: SiDet, Lab 6, **Irradiation Test Area**
- Ongoing Work / Recent Accomplishments
 - Silicon sensor design
 - Submission of low density multi-geometry wafer design
 - Cooling plate design and simulation
 - Cassette tooling development
 - Setup of automated tileboard assembly
 - ECON development / design review in progress



Cassette cooling plate



Trigger/DAQ/DQM

Berryhill, Cavanaugh, Jindariani, Maeshima, Mommsen, Tran
(RAs: Herwig)

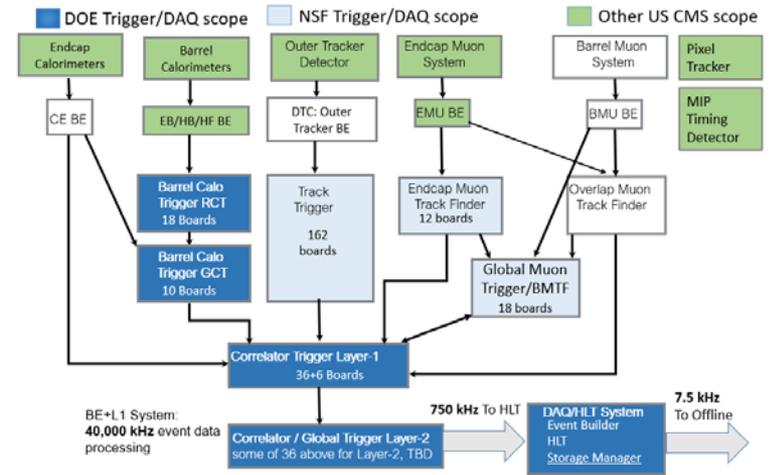
- Deliverables (Fermilab deliverables)
 - Develop hard/firm/soft -ware algorithms for Calorimeter Trigger and Correlator Trigger
 - ATCA platform, latest 25 Gbps architecture and FPGAs
 - Procure and Deploy Data Logger
 - Commodity procurement at the end of the project

Key FNAL Resources

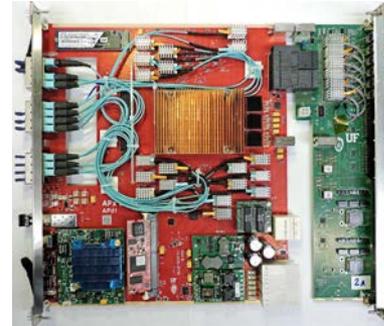
- Labor: **FPGA engineering**, Scientific oversight and algorithm development/testing

Ongoing Work / Recent Accomplishments

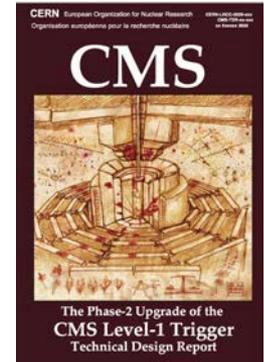
- Approval of Trigger TDR (June 10, 2020)
- Deployment of Particle Flow on prototype trigger boards
- Development of ML algorithms for muon triggers
- Development of new DQM and ML tools for Run 3
- Data certification of legacy Run 2 data



2nd generation APD prototype



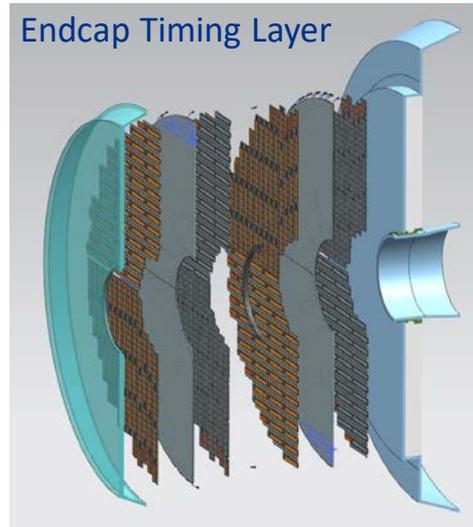
Fastest TDR & UCG review ever



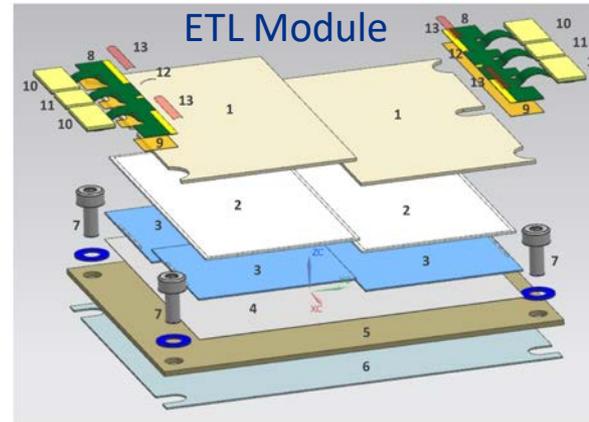
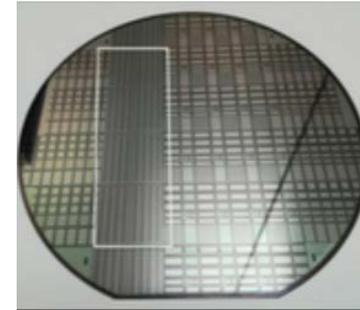
MIP Timing Detector

*Bauerdick, Apresyan, Butler, Chlebana, Gray, Liu, Ristori, Tkaczyk
(RAs: DiPetrillo, Heller)*

- Deliverables (Fermilab deliverables)
 - Barrel Timing Layer (BTL)
 - Assemble all 432 Concentrator Cards
 - Data i/o, power for 4 Readout cards
 - Assemble 6000 Readout Modules to populate 45 trays
 - Endcap Timing Layer (ETL)
 - Assemble 4700 Endcap Modules, $\frac{1}{2}$ at Fermilab
 - Develop and Fabricate Endcap Readout ASIC
- Key FNAL Resources
 - Labor: **ASIC engineering**, Microfabrication expertise, Scientific oversight and QC
 - Facilities: SiDet, **Test Beam**, **Irradiation Test Area**
- Ongoing Work / Recent Accomplishments
 - Large area LGAD sensor testing
 - Establish remote testing capabilities for ETROC1
 - 8x8 mini-ASIC
 - ETROC2 interface emulator development
 - ETROC2 design progress



Low Gain Avalanche Detector (LGAD)



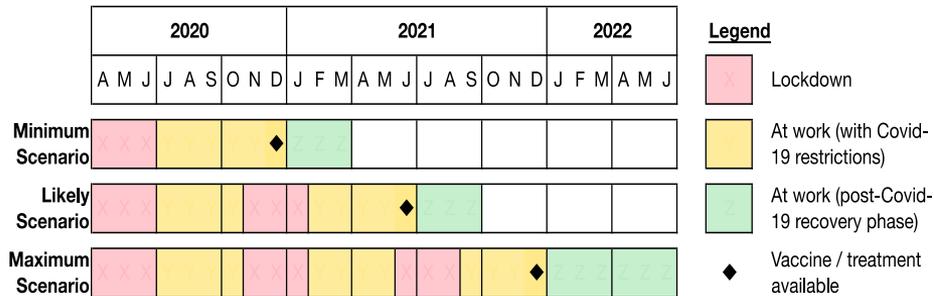
- 1: AIN module cover
- 2: LGAD sensor
- 3: ETL ASIC
- 4: Mounting film
- 5: AIN carrier
- 6: Mounting film
- 7: Mounting screw
- 8: Front-end hybrid
- 9: Adhesive film
- 10: Readout connector
- 11: High voltage connector
- 12: LGAD bias voltage wirebond
- 13: ETROC wirebonds

HL-LHC Upgrade - Current Status

- Received DOE CD-1 approval on Dec 15, 2019
 - Oct 22-24 Review went very well
- Received DOE CD-3a approval on June 8
 - Long lead procurement of OT Silicon, Carbon Fiber, and MTD LYSO crystals
 - *First DOE Critical Decision Review done completely remotely on April 7-8*
- Next step CD-2, aimed at Spring 2021
 - Still assessing influence of CERN LHC LS3 shift in late 2019

HL-LHC CMS Detector Upgrade is pioneering development of the DOE COVID impact paradigm

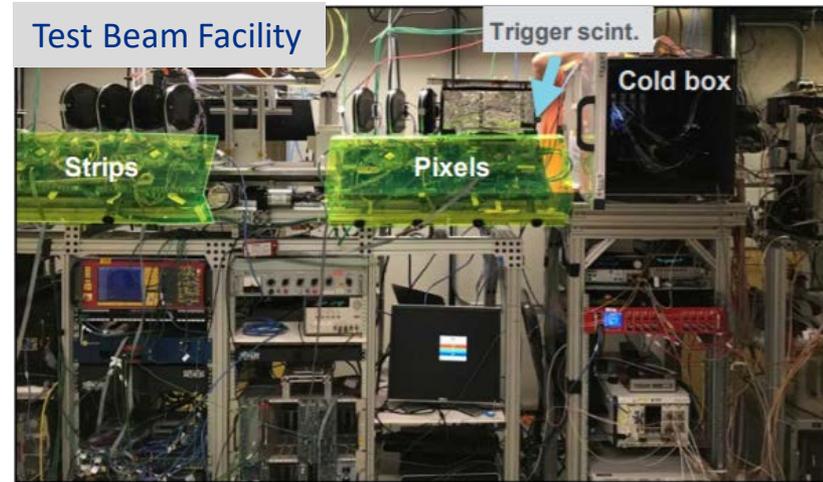
Developed by Deputy PM Lucas Taylor, adopted lab-wide and in other DOE projects as well



- Methodology: Impose inefficiencies on the Project Schedule (P6) based on Work Category for three scenarios (minimum, medium, maximum) to bracket potential schedule impact → **3,6,10 months**
 - **Schedule delays can then be projected into cost impacts**
- Once set up, easy to vary input parameters as knowledge of Pandemic evolves
- Consulting with DOE on the modelling and impact

Fermilab Facilities and Resources

- Heavy Reliance on **irradiation** and **test beam** facilities
 - Irradiation Test Area reaches LHC final dosages in ~day, critical for validation of radiation robustness designs
 - Good progress with ITA setup
 - Commissioning deferred until of accelerator complex restart
 - Fermilab Test Beam Facility
 - Essential for post-irradiation evaluations of final designs, will be in high demand once complex restarts
- Other FNAL Facilities / Resources
 - CO2 cooling plant
 - Upgrading/replacing the condenser units in the system to increase the cooling capacity from 7KW to 12KW
 - Unique facility needed by OT, HGCal, and MTD during prototyping *and* production
 - ASIC Group
 - New hires to replace recent departures allow us to continue ECON development



Succession Planning and Resource Needs

- In the past year, there has been a significant change in the composition of the FNAL CMS group impacting mainly, but not limited to, the Tracking Group's where we have significant near term deliverables
 - Retirements, promotion within the laboratory
- The impact was partially mitigated by the hire of an AS with silicon detector expertise and an AS with computing background
- However, with additional departures anticipated over next 2-3 years, succession planning remains vital in order to maintain our core capabilities and deliver on our commitments
 - Planning to hire an Associate Scientist (FY21)
 - Senior scientist (SiDet) needed as we approach the production phase of the HL-LHC
- Will require a sufficient number of RAs to help with analysis, operations during Run 3, and the HL-LHC upgrade activates
 - RAs typically spend 50% on analysis and 50% on technical contributions
- We depend on continued Engineering and Technical support from the ASIC group and SiDet

LPC Status

LHC Physics Center (LPC)

The LPC continues to operate most of its regular events over video Topic of the Week, Physics Forum, Physics Discussion Groups, Journal Club and DR Office Hours now take place over Vidyo/Zoom with very good attendance (regularly 50+ participants).

The center is hosting 18 Summer HATS (all remote)

Completed six HATS : ~60 registrants in each (compared to ~30 last year). All upcoming HATS already have 20+ registrants (numbers typically increase as we approach the dates). All HATS are being recorded and will be posted online.



The LPC Distinguished Researchers (DR) play a **central role** building the LPC success: they spearhead new ideas, generate critical mass, and actively participate in creating a vibrant community at the LPC.

Fermilab RAs and scientists work in close collaboration with the DRs and critically contribute to the organization of all LPC events.

Summary and Outlook (1/2)

- As of June 19, 2020 CMS **published 1000 papers** in peer-reviewed journals
 - Leading key physics analyses (searches for new physics and standard model precision)
 - The Fermilab CMS Dept has major roles in the HL-LHC upgrade, Operations, and Software and Computing and we are well integrated into CMS at all levels
 - Have major leadership roles in CMS and leading community planning (Snowmass, BRN, DPF, CPAD...)
- Succession planning is vital to maintain expertise and to deliver on our commitments
 - Requires new Associate Scientist FY21 (Tracker), and Senior Scientist (SiDet)
 - Requires sufficient number of RAs to help with Run 3 operations and HL-LHC upgrades
 - Requires availability of resources from the ASIC group and from Engineers / Technicians at SiDet
- Software and Computing
 - Critical computing facilities remained operational, satisfying CMS readiness and reliability requirements
 - Planning for the needs of Run 3 and HL-LHC
 - Pioneering advanced computing techniques and software adaption to new hardware architectures
 - Will be essential to replace aging hardware

Summary and Outlook (2/2)

- Schedule adjustments to accommodate the LS3 shift + COVID slowdown are well advanced
 - CMS ready for beam: Sept 2021, ready for Run 3: Feb 2022 (baseline), no change to LS3 (beginning of 2025)
 - US-CMS HL-LHC developed approach to quantify COVID impact (3/6/10 month delay for HL-LHC upgrade)
 - **COVID impact will lead to a cost increase**
- We have been adapted to teleworking and have started a gradual and safe restart
 - Part of planning CERN reopening
 - Successful CD-3a review (first CD review that was fully remote)
 - Fully engaged in physics analysis and attending e-conferences
- LPC continues to be center of excellence in physics, upgrades, and detector/computing operations.
 - Fermilab scientists and RAs are an integral part and major contributors to the LPC activities
 - **Support for the DR program is essential for the LPC's success**
- There is a broad and growing interest for ITA and test beam availability
 - Good progress on setting up the ITA
 - **ITA and test beam availability will be crucial for the HL-LHC upgrades**

Backup Slides

LPC role in Operations and Upgrades

- **Shifts at the LPC Remote Operations Center**
 - Approximately 250 shifts per year in 2017 and 2018. Taken by 16 institutions
 - 60% of all remote tracker shifts, more than any other remote site
 - Evolving – started new Tracker DQM Expert shift in 2018. First location to secure this kind of remote shift
- **Facilitate broader involvement in DPG/POGs:**
 - Tracker DQM workshop in 2018, CMS. 23 participants and established a new team of LPC TRK DQM developers.
 - Similarly themed Jet/MET workshop and HCAL days followed in 2019
- **New Ideas/Developments:**
 - New effort at the LPC pursuing Machine Learning in FPGAs. Putting Neural Networks into FPGAs for better performance of the Level-1 muon trigger
 - Exploring Machine Learning based solutions for HL-LHC computing
 - Also new dedicated Triggers for Long-Lived particles (e.g. muon shower)
 - Synergy with EIC?
- **The efforts are enabled by the LPC support staff, Distinguished Researchers and Guests & Visitors**

LPC role in Operations and Upgrades

- LPC Distinguished Researchers are involved in almost every major piece of CMS Phase-1 and Phase-2 upgrades
 - Pixels, Outer Tracker, HCAL/HGCal, L1 Trigger, Software and Computing
 - Successful proposals are typically 50% physics and 50% technical work (upgrade or computing)
 - Easy access to unique Fermilab facilities: SiDet, test-beam, engineering, etc
- Graduate Scholar program supports exceptional Graduate Students, from USCMS institutions, by allowing them to spend a year at Fermilab to pursue thesis research opportunities at the LPC
 - Explicitly requires a balanced proposal consisting of physics and technical work
 - In 2020: Chin Lung Tan (Rochester) is working on HGCal and Zhicai Zhang (Caltech) on MTD. In 2019: Martin Kwok (Brown) on HCAL and Cristina Manilla Suarez (JHU) on pixels.
- All successful G&V applications are required to have a major operations or upgrade components. Physics synergies are encouraged but this is not a primary consideration.

Impact of the LPC DR Program

- The LPC Distinguished Researchers (DR) play a central role building the LPC success: they spearhead new ideas, generate critical mass, and actively participate in creating a vibrant community at the center.
 - DRs are leading or supporting the development of every exercise for the annual CMS Data Analysis School and the Summer Hands-on-Tutorial (HATs) series. Record number of attendees in recent years.
 - DRs are instrumental in building community: 50-75% of awarded Guests and Visitors listed DRs as one of their collaborators, DRs encompass 65% of the members of the organizing committees for the LPC seminar series, and all of the workshops were initiated by DRs and had at least one DR in their organizing committee. These events serve 800 people each year.
 - DRs are instrumental in the physics contributions at the LPC, with DRs regularly acting as contact persons for the analyses. In fact, recent metrics show that more than a quarter of CMS Run 2 publications have a majority (more than 50%) of primary analysts associated with the LPC.
 - Junior DRs are regarded as highly prestigious with more than 30% of them accepting tenure track faculty positions within 3 years of the start of their DR appointment.

“Successfully Functioning” Funding Level for the LPC

- The ideal budget for the DR program would provide support for 20+ DRs (junior and senior)
 - We want to maintain a strong USCMS participation in CMS physics, upgrades and operation, and support the level of training for junior members of the collaboration that has proven to be so effective
- In FY20, the center was able to support 3 senior DRs (travel only), 14 junior DRs, and two Graduate Scholars
- The request in the FY21 from Research includes:
 - Funding to maintain the FY20 level of activities
 - Additional funds to allow us to award 3 full senior DRs (salary and travel) to help facilitate the participation of the USCMS community in the Snowmass process.
 - Support to establish an LPC AI fellowship (similar conditions as the junior DR) with a paired dedicated Graduate Scholar - a senior graduate student interested in pursuing ML
 - *Assumes Ops contributions similar to ~FY20*

LPC and COVID: what is working

- The LPC continues to operate most of its regular events in the virtual mode:
 - Topic of the Week, Physics Forum, Physics Discussion Groups, Journal Club and DR Office Hours now take place over Vidyio/Zoom with very good attendance (regularly 50+ participants).
 - In FY20: 7 workshops, 13 TOTW, 13 Physics Forums, 3 Coffee Hours.
- The center is hosting 18 Summer HATS (all remote)
 - Completed six HATS : ~60 registrants in each (compared to ~30 last year).
 - All upcoming HATS already have 20+ registrants (numbers will go up as we approach the dates).
 - All HATS are being recorded and will be posted online. Offline help offered.
- Many CMS results released in Spring'2020 or in preparation for Summer'2020 are led by the LPC users (VVV observation, boosted Higgs, LLPs, etc)
 - LPC computing resources (both CPU and storage) continue to be in high demand
- Discussions have started about how to host the LPC CMSDAS remotely. Maintain close contact with CERN, who will host its first DAS in the video-only regime

LPC and COVID: some concerns

- Due to Fermilab access restrictions most users are unable to access hardware labs, test-beam facilities etc
- Some potential concerns:
 - Do junior scientists (students, young postdocs) receive adequate support and training to continue being effective?
 - While some workshops are being hosted as video-only events, others decided to postpone until next year
 - G&V work requiring on-site presence delayed until the restrictions are eased or lifted
- The full impact on Physics and Operations/Upgrade still need to be quantified.
 - Initiated a survey to better understand effectiveness of LPC programs and challenges faced by the community during this period
 - and to adjust the programs (if needed) to better serve their needs
 - Deadline is June 30th

Fermilab and LPC

- **Fermilab group is an integral part and a major contributor to the LPC activities**
 - Approximately 20-25% of junior DR's are Fermilab postdocs. Selected on competitive basis from the same applicant pool as everybody else.
 - Fermilab scientists serve on the LPC Management Board, G&V committee
 - Co-chair Events, TOTW, Physics Forum, Journal Club committees
- **Fermilab scientists and DRs are often catalysts of new ideas that grow into larger LPC efforts and lead to impactful results, e.g.:**
 - Fast Machine Learning
 - Substructure and boosted Higgs program
 - Triboson observation
 - SUSY Hadronic
 - Searches for Long-Lived signatures
- **Contributions to training programs:**
 - CMSDAS: 7/11 short and 7/8 long exercises have facilitators from Fermilab
 - HATS: 9/18 have a facilitator from Fermilab. 2 of them are lead facilitators.
- **Management (one of the coordinators is from Fermilab)**