CMS: GENERAL STATUS

129TH MEETING OF THE LHCC, CERN

22ND FEBRUARY 2017

SUDAN PARAMESVARAN (UNIVERSITY OF BRISTOL, UK) ON BEHALF OF THE CMS COLLABORATION
TOPICS TO DISCUSS

- Extended Year-End Technical Stop (EYETS) current status:
  - Pixel upgrade
  - HCAL Forward and HCAL Endcap
  - Muon detectors
  - CT-PPS (CMS-TOTEM Precision Proton Spectrometer)
  - BRIL (Beam Radiation Instrumentation & Luminosity)
- Detector/computing round-up
- Latest Physics results
- Luminosity update
- Looking forward to 2017
WHY UPGRADE THE PIXEL DETECTOR?

- Expect instantaneous luminosities up to $2-2.5 \times 10^{34}$ before LS3, with up to $500 \text{fb}^{-1}$ integrated.

- Exceeds capability of present Readout Chip (ROC) - leads to large hit inefficiency

- Tracking efficiency more robust against higher PU conditions:
  - Improved single Hit efficiency
  - Additional tracking layer

[Graphs showing hit efficiency vs. instantaneous luminosity and correlations between light and c-jet efficiency.]
**PHASE 1 PIXEL DETECTOR UPGRADE**

- 4 layers/3 disks
- $\text{CO}_2$ cooling
- DCDC converters
- Reduced material budget
- New readout ASICs
- New back-end electronics (uTCA)
- Readout inefficiency negligible up to $2-2.5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$, PU $\sim 60-80$

![Diagram of 4 layer barrel and 3 forward disks with supply tubes]
PIXEL DETECTOR CONSTRUCTION

- 1856 modules installed on mechanics with embedded cooling loops
- > 99% fully functional
PIXEL DETECTOR CONSTRUCTION

- 1856 modules installed on mechanics with embedded cooling loops
  - > 99% fully functional
PIXEL DETECTOR IS COMPLETE!

- BPIX AND FPIX are at CERN
  - Fully assembled
  - At final checkout before installation
PIXEL DETECTOR INSTALLATION: DONE SO FAR

- Removed or modified & reinstalled and tested
  - all power supplies
  - the old DAQ VME crates and boards and installed the new uTCA crates (12) and boards (~130).
  - the safety system crates
- Removed the old detector
- Removed the old C\textsubscript{6}F\textsubscript{14} pipes and old optical links
- Installed the new CO\textsubscript{2} pipes and the new optical links
- All preparatory activities completed on schedule!
## PIXEL DETECTOR INSTALLATION/COMMISSIONING

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- Barrel and forward disks will be installed end of February/beginning of March
- Connections (cooling, power, controls, readout) checked before next step
- Environmental sealing established before end of March
- Few days with detector running cold before CMS closure begins
- Detector mostly off during LHC beam commissioning in May
EYETS PROJECTS: HCAL FORWARD (HF)
HF PHASE 1 UPGRADE MOTIVATION

- Beam-induced anomalous **signals** due to particles directly hitting PMT windows.
- Phase-I upgrade in EYETS 16/17:
  - Add **TDC** to improve noise vs physics signal discrimination (spurious signals arise 2-7 ns earlier)
  - **Dual-anode** readout as further discrimination for spurious signals affecting one anode, with the ability to recover energy measurement from the other anode

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**PMT HITS**

iEta=34

(E=500 GeV)
Beam-induced anomalous **signals** due to particles directly hitting PMT windows.

- Phase-I upgrade in EYETS 16/17:
  - Add **TDC** to improve noise vs physics signal discrimination (spurious signals arise 2-7 ns earlier)
  - **Dual-anode** readout as further discrimination for spurious signals affecting one anode, with the ability to recover energy measurement from the other anode

\[
\frac{Q_1 - Q_2}{Q_1 + Q_2}
\]
The HF upgrade consists of:
- PMT Box rework to implement the dual-anode readout
- Front-end electronics replacement

**ALL 72 PMT BOXES REWORKED AND INSTALLED**
### STATUS OF HF FRONT-END INSTALLATION

**ALL WORK FOR HF ON SCHEDULE**

- All 16 front-end crates have been installed in CMS Experimental cavern
- Expect Co-60 calibration campaigns of HF around March 1st

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EYETS PROJECTS: HCAL ENDCAP (HE)
HE PHASE 1 UPGRADE MOTIVATION

- HE: New, improved photo-detectors
  - Hybrid Photo-Detectors (HPD) $\rightarrow$ Silicon Photo-Multipliers (SiPM)
    - To eliminate high amplitude noise and drifting response of HPDs
    - To mitigate effects of radiation damage to scintillators and WLS fibres - SiPMs have 3x the photo-detection efficiency of the HPDs
    - To allow increasing the longitudinal segmentation of readout (pile-up suppression and recalibration of depth-dependent aging) - SiPM (plus new front-end supports up to 7 depth segmentations - fine grained calibration)
HE PHASE 1 UPGRADE

Detector

QIE11

Igloo2 FPGA

SiPMs

FEE Card (12 channels)

FE Module (48 channels)

VTTX

cDAQ

AMC13

uHTR

Calorimeter Trigger
HE PHASE-1 UPGRADE SCHEDULE

Installation Plans

- The Full HE installation was originally planned for LS2 but we accelerated the program based on higher than foreseen radiation damage to the scintillators.
- However, although a huge amount of work has brought this project near ready to be fully installed, the decision has been made not to install the full HE upgrade in this EYETS.
- An analysis of risks vs benefits was undertaken, which included the fact that during 2016 we saw lower than expected radiation damage to the scintillators.
- Alternative installation options are now under evaluation
  - Full HE upgrade during YETS 2017/18
    - Would bring a full year of experience on operating this new detector, also informing the installation of SiPM’s in the Hadron Barrel (HB) Calorimeter planned for LS2
  - Full HE upgrade during LS2 (as originally planned in the TDR)
IN ADDITION A 20-DEGREE PHI SECTOR OF HE+ (HE PLUS #17) HAS BEEN UPGRADED LAST WEEK AS A DEMONSTRATOR.

ALREADY EXTREMELY USEFUL IN INSTALLATION PROCEDURE AND COMMISSIONING.

DECISION TO BE TAKEN IN EARLY MARCH ON WHETHER TO KEEP THIS UPGRADED BOX IN FOR 2017 DATA TAKING
INSTALLATION AND OPERATION OF SINGLE READOUT BOX

high-intensity LED run
large signal seen in all channels

low-intensity LED run
single p.e. peaks clearly visible — great for gain monitoring

laser run
laser light injected into the scintillators — we can see the signal from the detector
EYETS PROJECTS: MUON DETECTORS
Five 10° GE1/1 super-chambers were installed in the +endcap nose (72 to be installed in LS2)

Services being installed, commissioning to start soon

GEM = GAS ELECTRON MULTIPLIER
MUON ENDCAP: CSC COOLING JOINT REPAIR

- Marginal brazing led to a late-2015 water leak
- Repairs done on 36 ME-1/1 chambers so far
- Expect to repair all 72 ME1/1 this EYETS
EYETS PROJECTS: CT-PPS
(CMS-TOTEM PRECISION PROTON SPECTROMETER)
CT-PPS goal is to add precise tracking and timing information to the very forward regions on both sides of CMS.

Physics motivations: New resonances in central exclusive production, two photon Physics, QCD etc.

Major milestone was reached in 2016 with CT-PPS fully integrated in the global CMS DAQ and routinely included in data-taking. 15fb$^{-1}$ collected with CT-PPS.
CT-PPS UPGRADES

- Upgrade of Roman Pots at 220 m for operation of RPIX detectors at High Luminosity
  - Concluded separating vacuum and cooling of the tracking and timing detectors for independent pressure/temperature operation points.
- Installation of new CT-PPS detectors
  - New RPIX pixel detector ready for installation
  - Integration of one additional layer of UFSD timing detectors in Timing RPs being finalized
EYETS PROJECTS: BRIL

BEAM RADIATION INSTRUMENTATION & LUMINOSITY
**BRIL EYETS WORK**

Pixel Luminosity Telescope:
- Detector removed in the P5 lab and minor refurbishment on-going
  - 1 Port card has been replaced to re-establish FASTOR signal in all 16 telescope.
- “Offline” PLT calibration for 2016 data ongoing
- 2017 will have this workflow in prompt calibration to keep online luminosity up-to-date

Fast beam conditions monitor (BCM1F) hardware:
- New sensors (Mix of poly-diamond, single crystal diamond and Si)
- 3 PCBs equipped an complete
- 4th PCB in final preparation

All work in shadow of Pixel replacement
ROUND-UP OF OTHER AREAS
Reminder: this was a Phase 1 upgrade which has already been completed

Data collected during the high pile-up run being used to study evolution of the trigger algorithms in preparation for 2017 run

Improvements in algorithms and calibrations e.g. exploiting RPC data in endcap muon track finder to increase efficiency,

On track to be ready for LHC restart and ready for higher luminosities in 2017
Major achievement: remade 10B MC events over Winter, included improved calibrations, matched PU profile of Run 2 data-taking etc

New taskforce to address CMS computing needs over the next few years, make recommendations, identify new technologies etc. (ECOM =Evolution of the Computing Model)

• CMS is fully engaged in the Community White Paper (CWP) effort. This effort should describe a global vision for software and computing for the HL-LHC era and HEP in the 2020s.
Full 2016 dataset reconstructed in October with improved calibrations w.r.t prompt reconstruction

- Finer grain corrections for radiation damage (Silicon Tracker and HCAL)
- Alignment refinements for Pixel detector
- Improved stability of ECAL calibrations
- Tracking level tuning to improve b tag efficiency for data affected by Silicon Strip dynamic inefficiency
PHYSICS HIGHLIGHTS
587 papers submitted

Run2: 209 public results, 68 papers submitted

All info available here:
Of course a large emphasis currently is on producing results for Winter conferences, and for producing publications with the full 2016 dataset.

Nevertheless have had some interesting results in the last few months:

- Performance on objects: Tau improvements
- Standard Model $t\bar{t}$ production
- Search for Double Charged Higgs
- Search for heavy resonances
- New Heavy ion physics results
Tau Reconstruction uses a Cut-Based Hadron Plus dynamic Strips (HPdS) Algorithm to Reconstruct 1-prong, 1-prong + n^0 and 3-prong Taus.

- This is an improved algorithm to Run 1, which had fixed size strips.
- Improves isolation for high Pt Taus, as well as improving energy scale for all 1 prong + pi0 taus.
- Have now looked at the full 2016 dataset using the new algorithm, excellent data MC agreement.
Precise determinations of the inclusive $tt$ cross sections at all energies

- Latest results at 13 TeV in agreement with NNLO+NNLL predictions
- Final experimental uncertainty at the same level or better than the theory one
- Dileptons (arXiv:1611.04040): $\sigma(tt) = 792 \pm 8 \text{ (stat)} \pm 37 \text{ (syst)} \pm 21 \text{ (lumi)} \text{ pb}$
- Lepton+jets (arXiv:1701.06228): $\sigma(tt) = 835 \pm 3 \text{ (stat)} \pm 23 \text{ (syst)} \pm 23 \text{ (lumi)} \text{ pb}$

SUBMITTED TO JHEP, JAN 2017
ACCEPTED BY EUR. PHYS J. C JAN 2017
Double charged Higgs appearing in BSM with Higgs triplets (e.g. Type II Seesaw models)

4 lepton and 3 lepton final states (including tau), targeting pair production ($\Phi^{++}\Phi^{--}$) and associated production ($\Phi^{\pm}\Phi^{\mp}$)

Cut & count analysis with selection optimised for different mass points

Excluding several benchmarks with masses $\sim$700-800 GeV (extending Run1 limits by $\sim$200 GeV)
Search for a narrow width resonance (spin-0 or spin2) in 2l+2q final state in 550-2000 GeV range

Main improvements: dedicated event categories for boosted hadronically decaying Z (boosted jet with substructure) + MELA discriminator using full kinematics of the reconstructed event

Previous excess found in 2015 dataset @ 650 GeV (3.4 sigma local) is excluded

No significant excess found, most stringent world limits in this sub-channel
Jet substructure selection: using n-subjettiness $\tau_{21}$

4 analysis categories:
- 2e/2$\mu$, high/low $\tau_{21}$ purity selection
- Background estimation using *bump hunt* method with jet mass sideband fit for background normalisation

**Search for $X \rightarrow Z + W \rightarrow 2l2q$**

- Preliminary analysis
- 12.9 fb$^{-1}$ (13 TeV) data
- 95% CL limits
- Observed
- Expected
- ±1 std. deviation
- ±2 std. deviations
- $W'$ (HVT model B, $g_{\gamma}=3$)
- $W'$ (HVT model A, $g_{\gamma}=1$)

**Background estimation using *bump hunt* method with jet mass sideband fit for background normalisation**

**Update with full 2016 stats underway**

**CMS Status**

**LHCC 129**

**22nd February 2017**
QM17 IN CHICAGO, FEB. 6: 1 PLENARY+16 PARALLEL TALKS 7 NEW PRELIM RESULTS

RIDGE IN P-Pb N AT 8.16 TeV

CMS Preliminary
pPb 8.16 TeV, 330 ≤ N_{trk}^{ offline } < 360
1 < p_{T}^{ 9 } < 3 GeV/c
1 < p_{T}^{ assoc } < 3 GeV/c

NEW DATA TAKEN IN NOV. 2016

STUDY OF CORRELATIONS AMONG V_2, V_3 AND V_4 FURTHER SUGGESTS A COMMON ORIGIN OF RIDGE IN PP, P-Pb AND Pb-Pb

CMS (n, m) = \langle v_n^2 v_m^2 \rangle - \langle v_n^2 \rangle \langle v_m^2 \rangle

CMS Preliminary

pp 13 TeV
pPb 8.16 TeV
PbPb 5 TeV
0.3 < \eta < 3 GeV/c

CMS-PAS-HIN-16-022
NUCLEAR MODIFICATION FACTOR OF Y(NS) IN Pb–Pb 5 TEV

- Highest precision data: new constraints to QGP viscosity
- Upsilon states are sequentially suppressed
- No sign of Y(3S) state
LUMINOSITY UPDATE
**LUMINOSITY 2015 & 2016**

- VdM Scan 2016 first analysis gave ~4% difference to 2015 full analysis.
  - While studies continued, we stuck with 2015 calibration for 2016 data
  - Now understood! Vertex constraint in length-scale analysis 2015 biased the Length Scale correction.
- 2015 Luminosity comes down by 2.7% (1 sigma)
- 2016 Luminosity being finalised, but expected to come down by 3-4%
Ratio typically 0.94-0.96 after reduced crossing angle
Will move closer to 1

This table uses updated preliminary 2016 lumi numbers
PREPARING FOR 2017 START UP
CMS is undertaking a large program of work during this EYETS Key to plan early commissioning steps to get to Physics readiness as early as possible

### GLOBAL RUNS
- 8-10 Feb
- 1-3 Mar
- 15-17 Mar

### MAIN GOAL: RE-ESTABLISH GLOBAL RUNNING OPERATIONS AFTER INTERVENTIONS IN EYETS WITH CENTRAL SYSTEM AND AVAILABLE DETECTORS

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### Controls Interventions
- Technical stop (EYETS)
- Machine checkout
- Recommissioning with beam
- Easter Mon
- Ascension
- Special plan

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CMS STATUS

LHCC 129

22nd February 2017
CMS is undertaking a large program of work during this EYETS
Key to plan early commissioning steps to get to Physics readiness as early as possible
CMS is undertaking a large program of work during this EYETS
Key to plan early commissioning steps to get to Physics readiness as early as possible

### Global Runs

- **GLOBAL RUNS:** 8-10 FEB, 1-3 MAR, 15-17 MAR

#### Main Goals:

- **Re-establish Global Running operations with Central System, gradually including all detectors (first strips, then pixels)**
- **Eventually Cosmics data taking with all detectors with high efficiency**
CONCLUSIONS

- CMS has an extensive programme of work going on in EYETS 2016/17
- Flagship EYETS project is the upgrade of the Pixel tracker - progressing well and on schedule
- CMS is preparing well for 2017 data-taking
- Excellent Physics results continuing to come through, expect many more in time for Moriond
CONCLUSIONS

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BIG THANKS TO LHC AND FULL ACCELERATOR CHAIN FOR A GREAT 2016 AND WE LOOK FORWARD TO 2017!
GEARING UP FOR A SUCCESSFUL CONCLUSION TO EYETS AND READY TO ANALYSE LOTS MORE DATA
BACKUP
ECAL STATUS

P5 status
- Refurbishment of LV power supplies (136+ spares) completed
- Regular Barrel HV calibration performed
- Will participate in upcoming global runs to test planned DAQ/trigger updates for 2017 run

DPG status
- 2016 data
  - Provided final optimisations of electron/photon & MET objects for Moriond analyses
  - Working on providing updated calibrations for legacy reconstruction of 2016 data
- 2017 run
  - Retuning of readout thresholds for higher PU conditions in progress
ECAL running at higher luminosity

- No issues foreseen running at higher instantaneous lumi \((2.0 \times 10^{34})\) in 2017
  - no unexpected radiation effects in Front-End electronics and power supplies
  - “SEU-like” recovery procedures in place for ECAL, and will be fully extended to ES for 2017

- Online thresholds will be adjusted accordingly to cope with higher luminosity
  - Zero Suppression, Selective Readout and Level-1 Spike Killer settings being retuned
    - already using high PU data to evaluate these
  - thresholds will increase, but do not expect a significant impact on performance

- Also evaluating effect of integrated luminosity on ECAL performance
  - can already learn from >40fb\(^{-1}\) delivered in 2016
  - no significant ageing effects observed on Front-End electronics
    - number of active channels is stable over six years of operation
  - radiation effects on crystals, photodetectors, sensors are being evaluated in detail
    - results so far appear (to first order) consistent with expectations
Completed Run I publications on searches for anomalous couplings

- Improving limits by combining searches in all production and decay modes
- No sign yet of FCNCs, anomalous Wtb couplings, unexpected asymmetries,...
- Looking ahead for results with full 2016 data!

arXiv:1702.01404