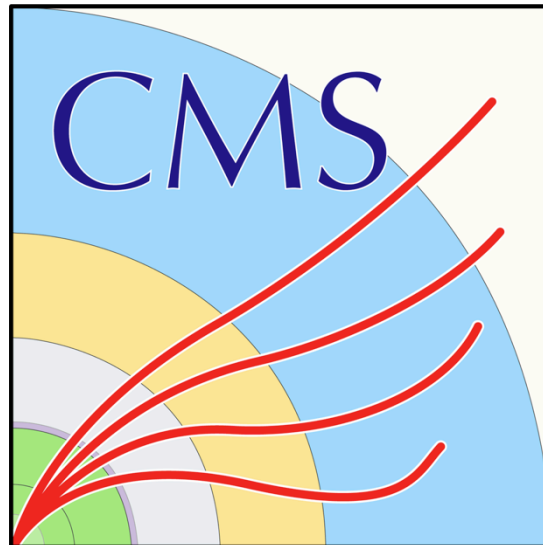


CMS Status Report

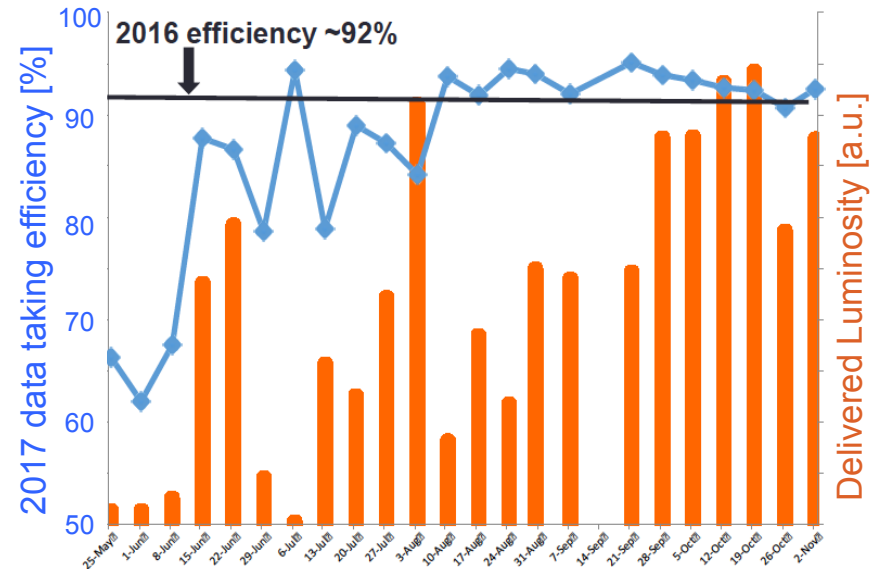
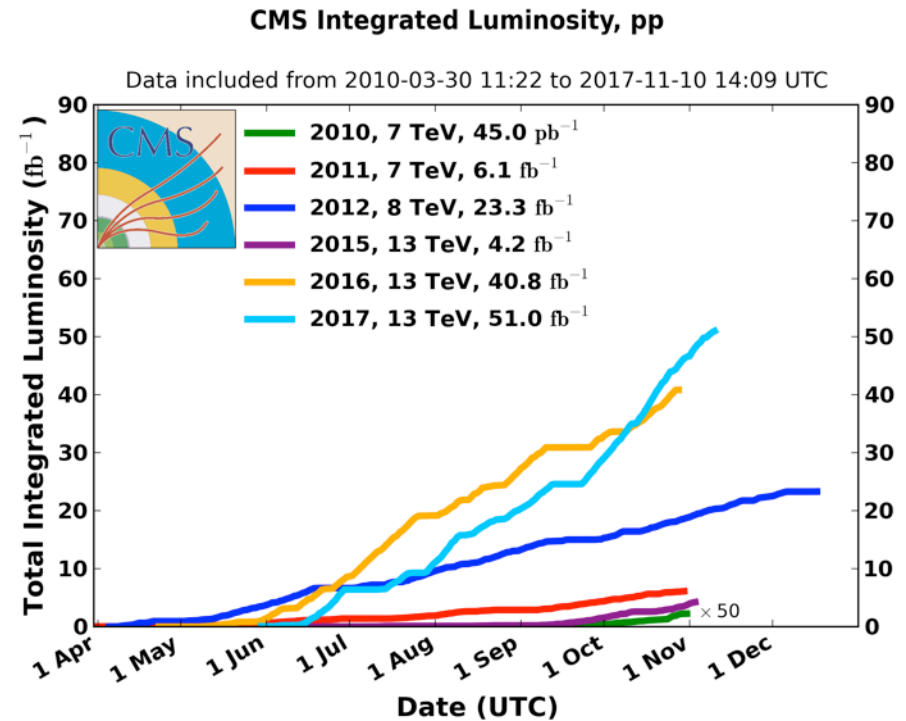
- Looking back at 2017 data taking
- Recent Run 2 physics highlights
- Preparing for 2018 data taking
- Preparing for the future



Lea Caminada (PSI and Universität Zürich)
on behalf of the CMS Collaboration
LHCC Open Session | February 28, 2018

2017 data taking

- LHC showed excellent performance and delivered luminosity of 51 fb^{-1}
 - 20% more than in 2016
- CMS kept up with increasing luminosity and took high quality physics data
 - 46 fb^{-1} recorded
 - 90.3% average data-taking efficiency
 - After challenging start-up phase (accommodating the Phase 1 upgrades) data-taking efficiency improved over the course of the year



CMS detector in 2017

Muon system

- Active channel fraction >98%
- Excellent performance
- Demonstrator GEM detectors for Phase 2 upgrade integrated and successful collision data taking

HCAL

- Active channel fraction >99%
- HF Phase 1 upgrade successful in noise suppression
- HE Phase 1 upgrade for one 20° phi wedge shows promising results, finalized during YETS17/18

ECAL

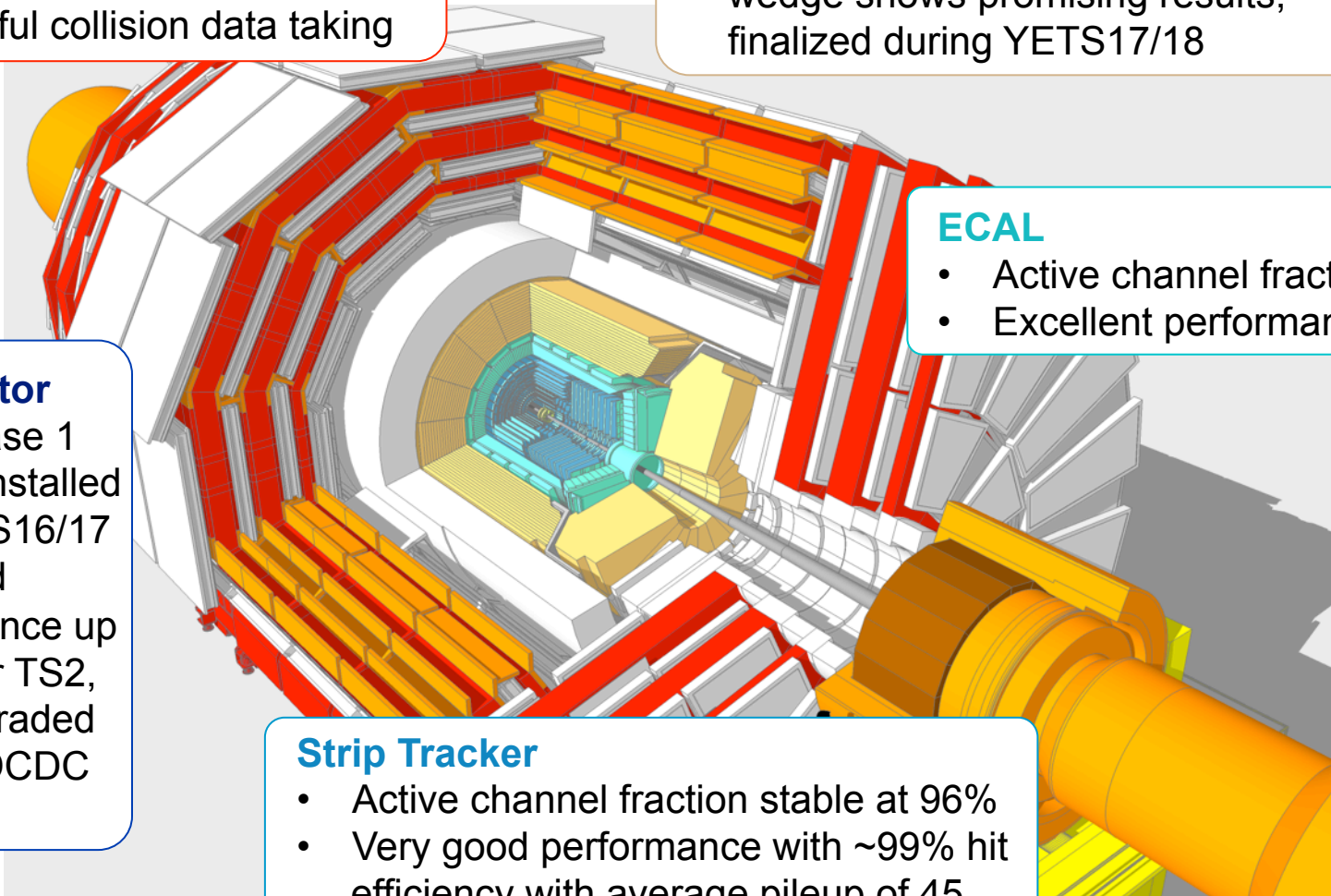
- Active channel fraction 99%
- Excellent performance

Pixel Detector

- New Phase 1 system installed in EYETS16/17
- Improved performance up until after TS2, then degraded due to "DCDC issue"

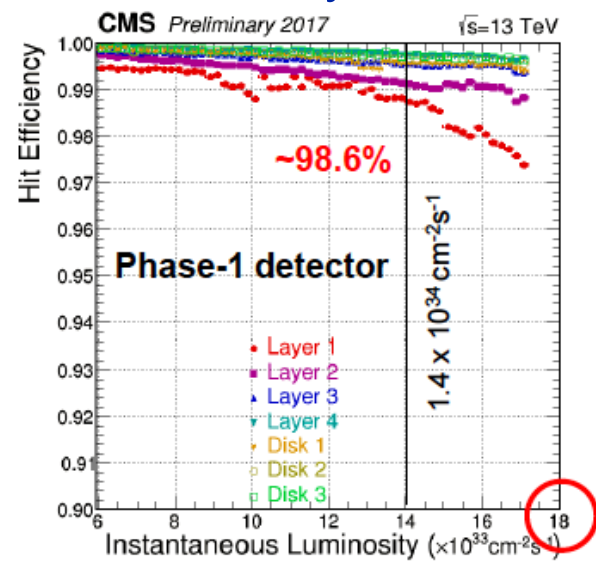
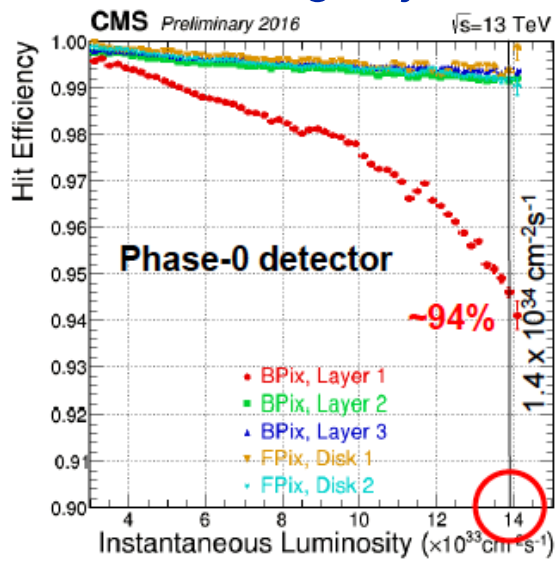
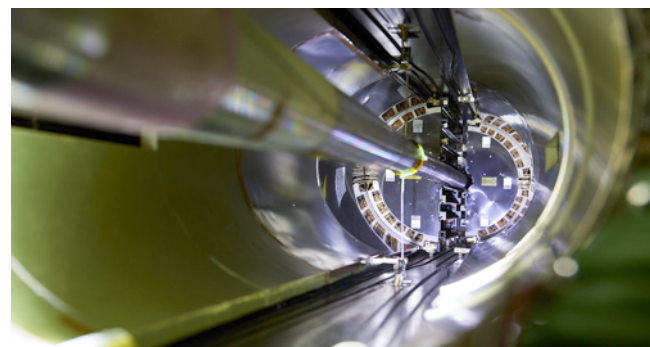
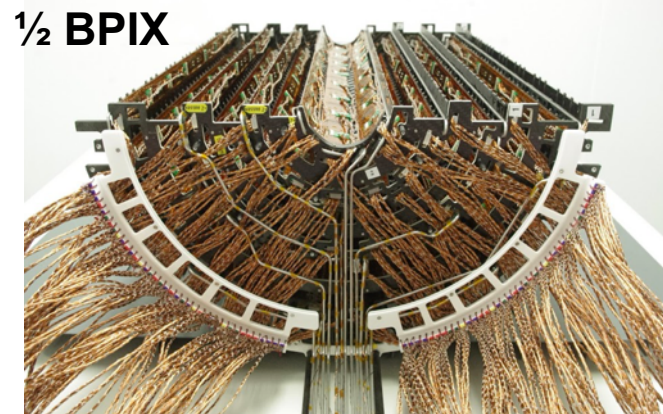
Strip Tracker

- Active channel fraction stable at 96%
- Very good performance with ~99% hit efficiency with average pileup of 45



Phase 1 Pixel Detector Operation

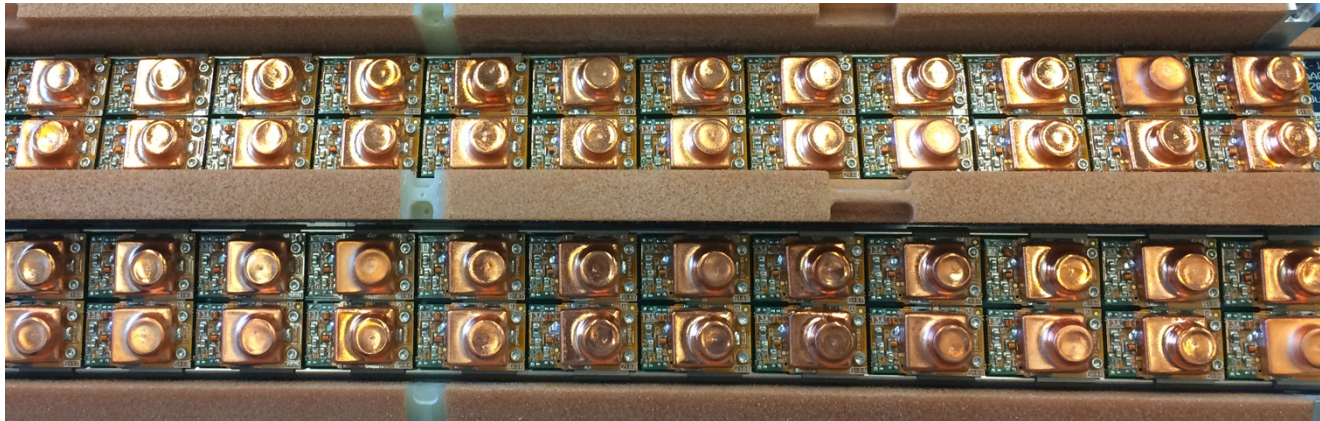
- New 4-layer/2x3-disk pixel system
 - Twice number of channels & active area
 - More tracking layers, but less material
 - New readout chips to reduce dynamic inefficiency at high instantaneous luminosity
- Achieved good performance despite initial challenges in operation
 - Timing adjustment, SEU recovery, reset rate



• Until...

Pixel Detector: DCDC converter issue

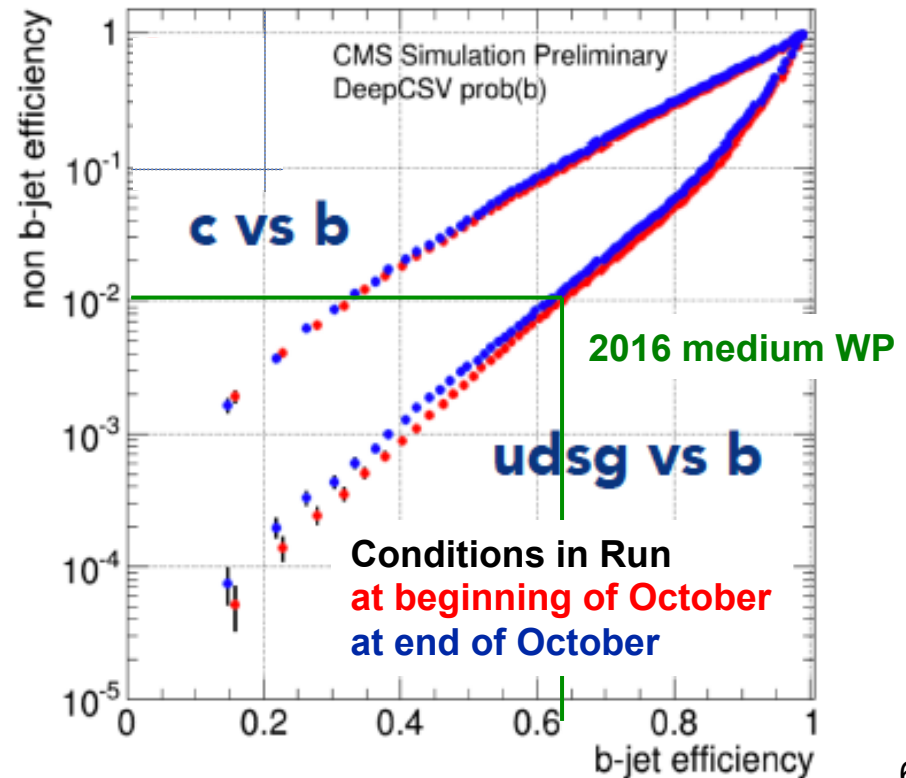
- DCDC converters that provide LV (VA/VD) for pixel detector modules started failing on October 5, 2017
 - damage accumulated, leading to a total of about 50 broken DCDC converters (5% of the detector, BPIX+FPIX)
 - Affected channels during data-taking larger (up to 10%) since power-cycling for module SEU recovery was only done rarely as a precaution
- While impact on 2017 data still bearable, with no action taken, 2018 data-taking would have been endangered
 - asked for extension of YETS (BIG THANKS!!!) to allow for pixel detector intervention
 - Goals: 1) investigate the issue, 2) replace DCDC converters



Impact on tracking and b-tagging in 2017

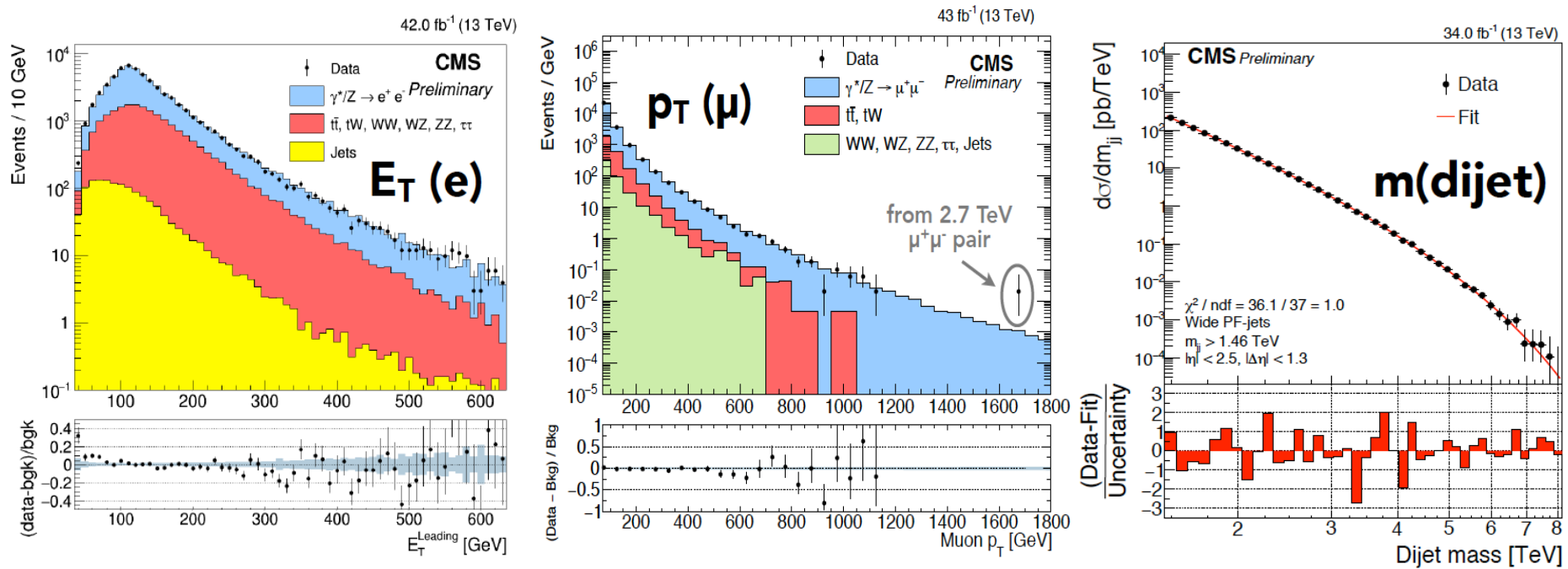
- Many studies performed to assess data quality in last period of the run
- Simulation studies with 2017 detector scenarios based on actual pattern of disabled pixel modules show that tracking efficiency losses are small and data quality is good for physics

- Impact on b-tagging performance is small
 - Achieve performance at least as good as in 2016



Physics with 2017 data

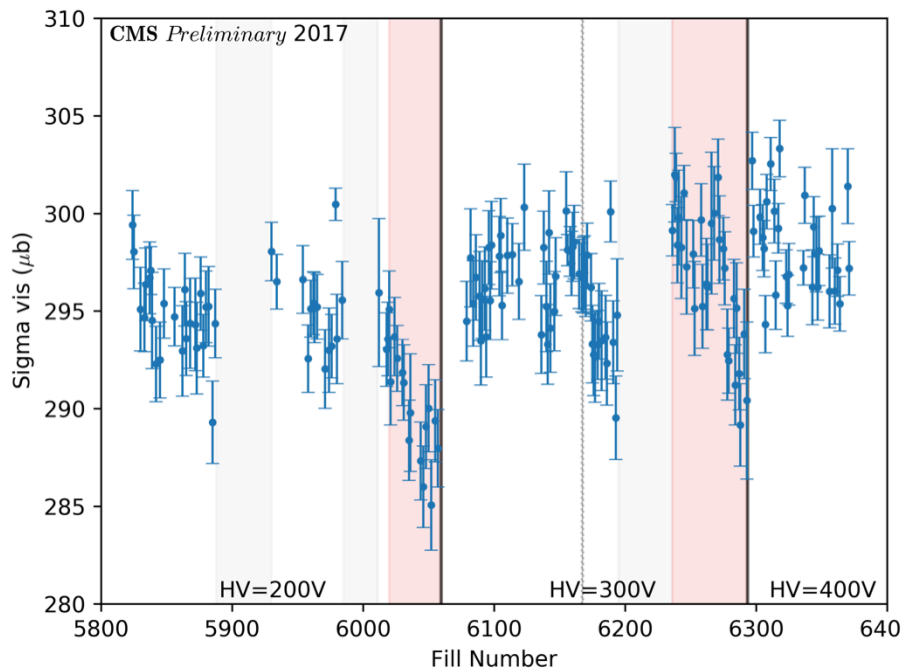
- Data analysis ongoing
- Studies with full data set show that physics object reconstruction performance is good and well-modeled by simulation
- First physics results with 2017 data will be shown at upcoming conferences... stay tuned!



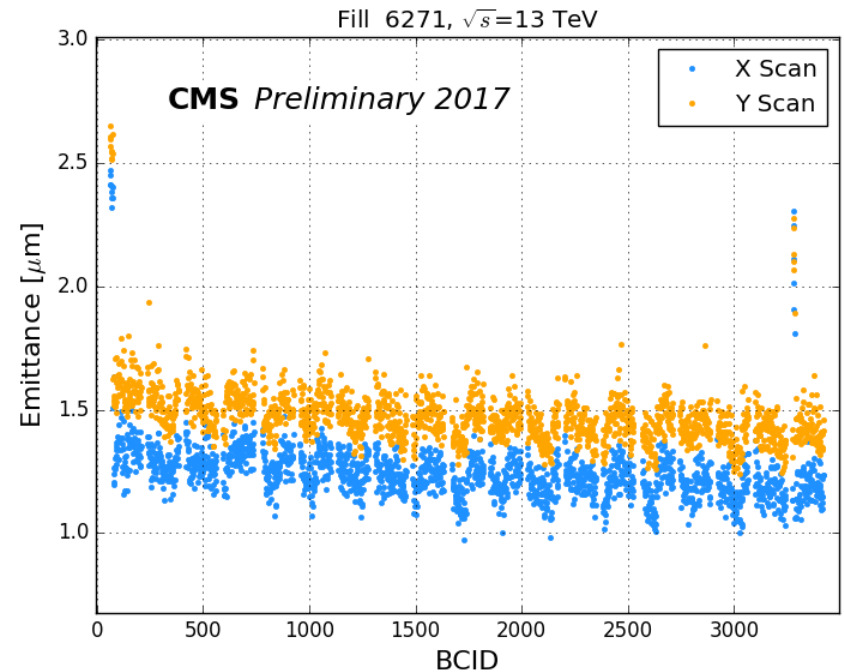
Luminosity Monitoring in 2017 – Fill-by-fill!

- Online measurements of per-bunch visible cross section for each luminometer
- Online measurements of bunch position & emittance

Example uncorrected σ_{vis} measured by PLT fill-by-fill



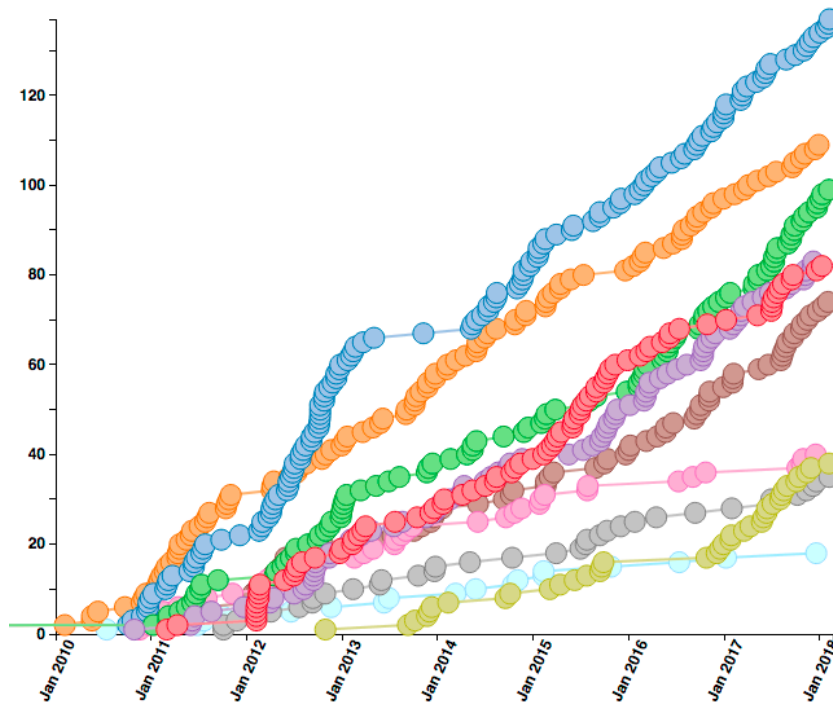
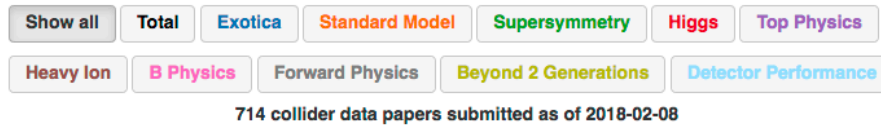
Emittance measured during fill



→ Input to LHC machine performance studies and beam-beam simulations

Run 2 Physics Results

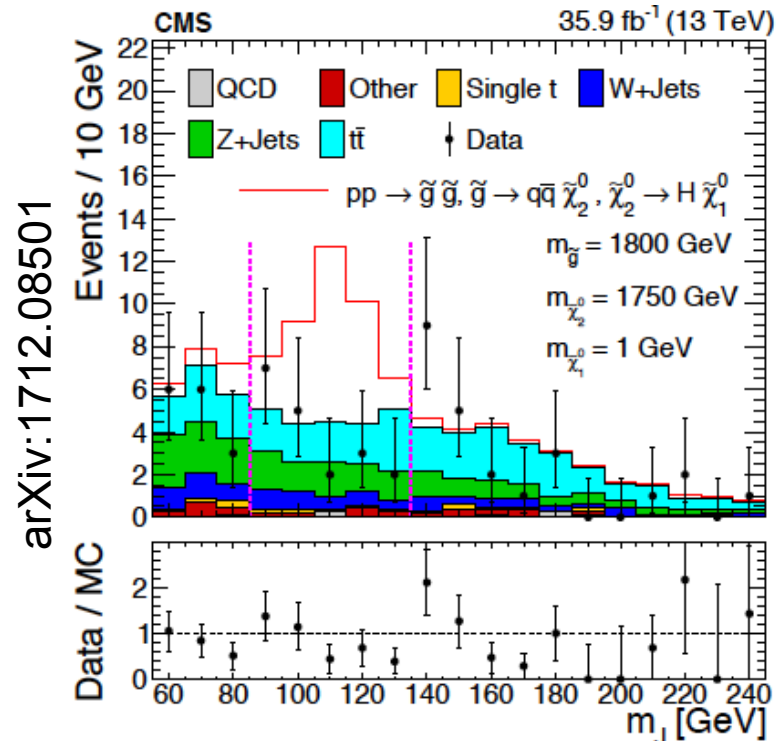
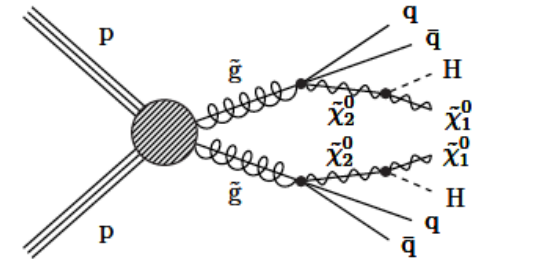
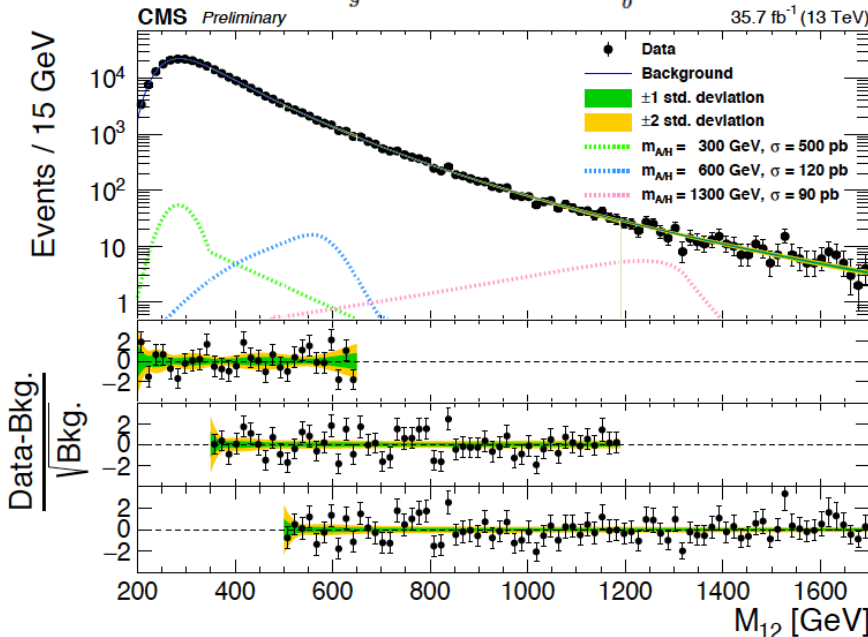
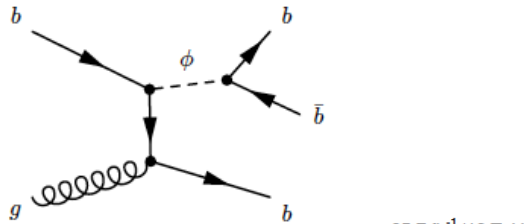
- In 8 years CMS submitted for publication 743 physics papers
 - 714 papers with collision data out of which 156 with Run 2 data
 - 132 papers in 2017 (record year for CMS!)
 - 29 papers since last LHCC (see list in backup)



→ Only a few selected highlights presented in the following

Higgs bosons as probe for new physics

- Exploit complex final states with Higgs boson to probe new physics models (SUSY, extended Higgs sectors, etc)
- Employing advanced experimental techniques as for instance
 - efficient b-tagging at trigger level
 - jet substructure techniques with flavor tagging

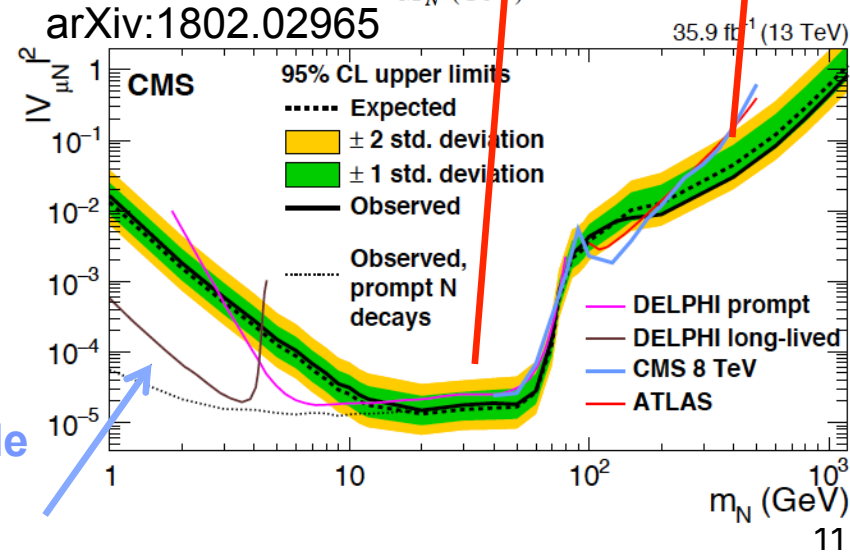
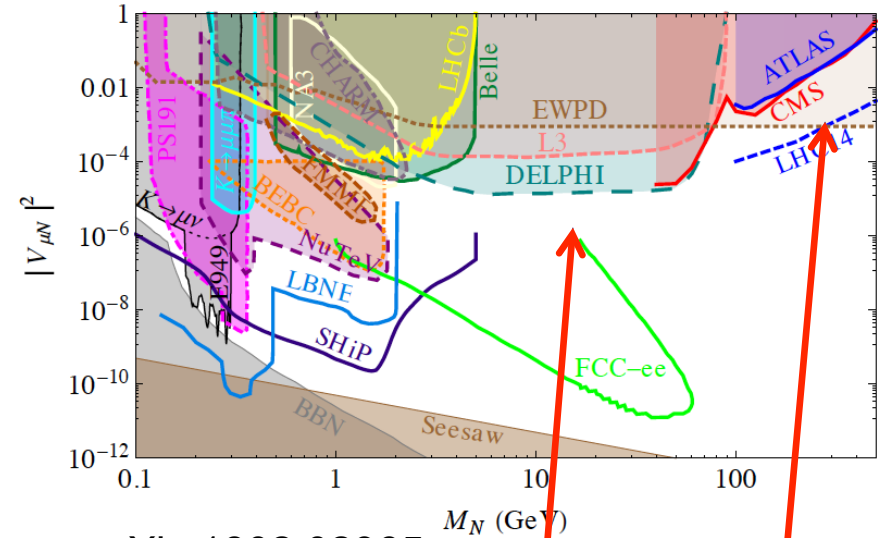


CMS-PAS-HIG-16-018

arXiv:1712.08501

Search for heavy neutral leptons

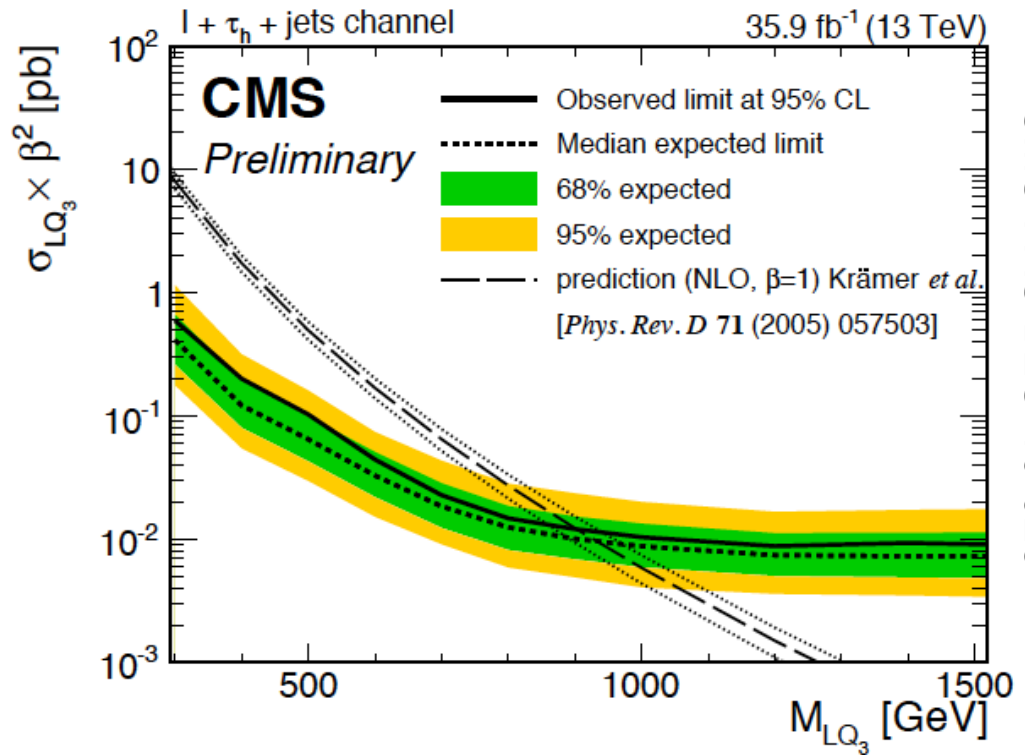
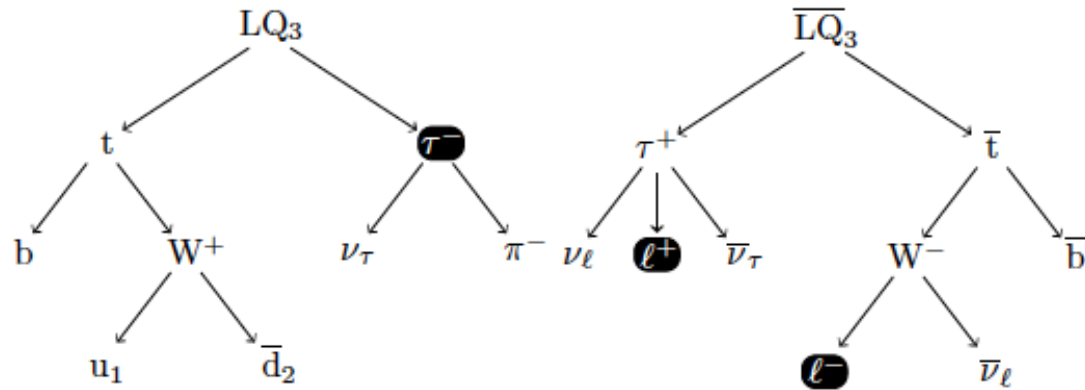
- Adding sterile neutrinos to SM solves a range of questions
 - smallness of neutrino masses
 - baryon asymmetry
 - nature of dark matter
- LHC just started to probe mass range left open by EW precision measurements
- New approach targets leptonic decay of N produced in $W^\pm \rightarrow N e^\pm / N \mu^\pm$
 - first constraints at $m_N > 500$ GeV
 - improved over LEP results at low m_N



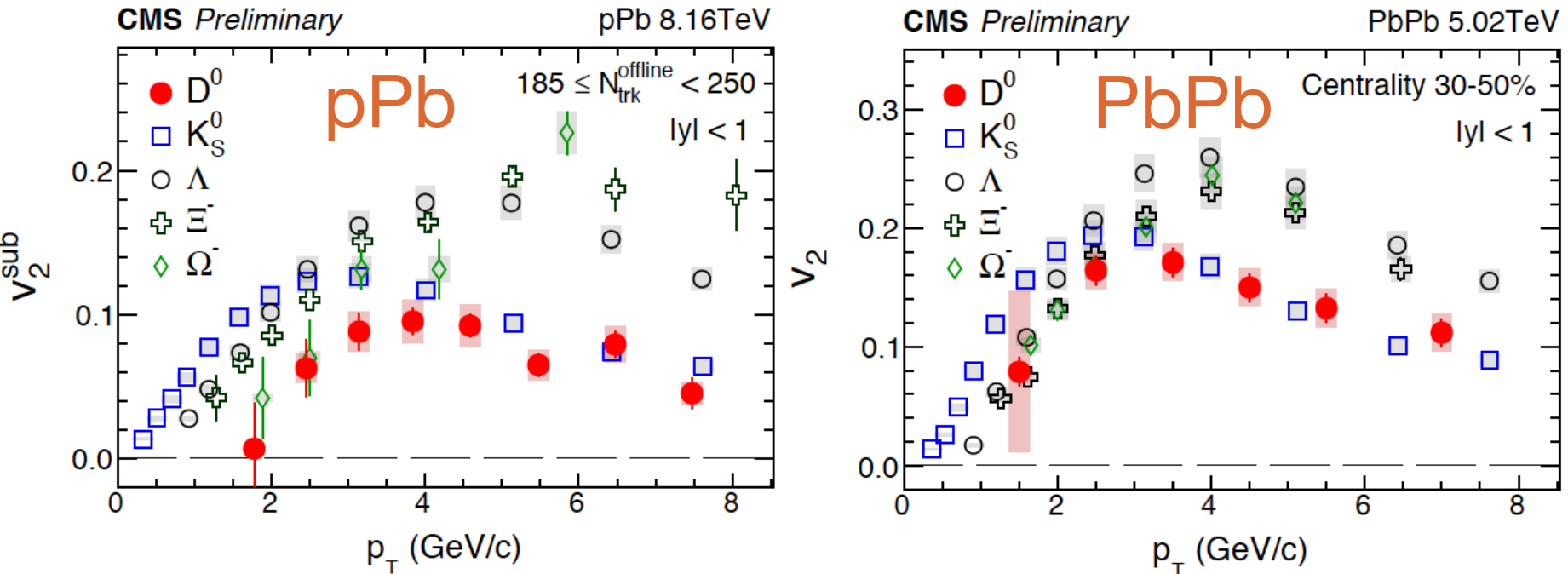
Significantly lower masses will become available when exploiting also displaced signatures!

Search for Leptoquarks (LQ)

- Models with leptoquarks that preferentially couple to 3rd generation can explain R_{D^*} anomaly reported by B-factories and LHCb
- Predict LQ at TeV scale that can be probed at LHC
- Search for decay $LQ \rightarrow \tau \ell$ in LQLQ pair production
 - using final state of $l + \tau + \text{jets}$
 - achieved best limits in this channel excluding masses below 900 GeV



Charm and strange in Heavy Ion collisions

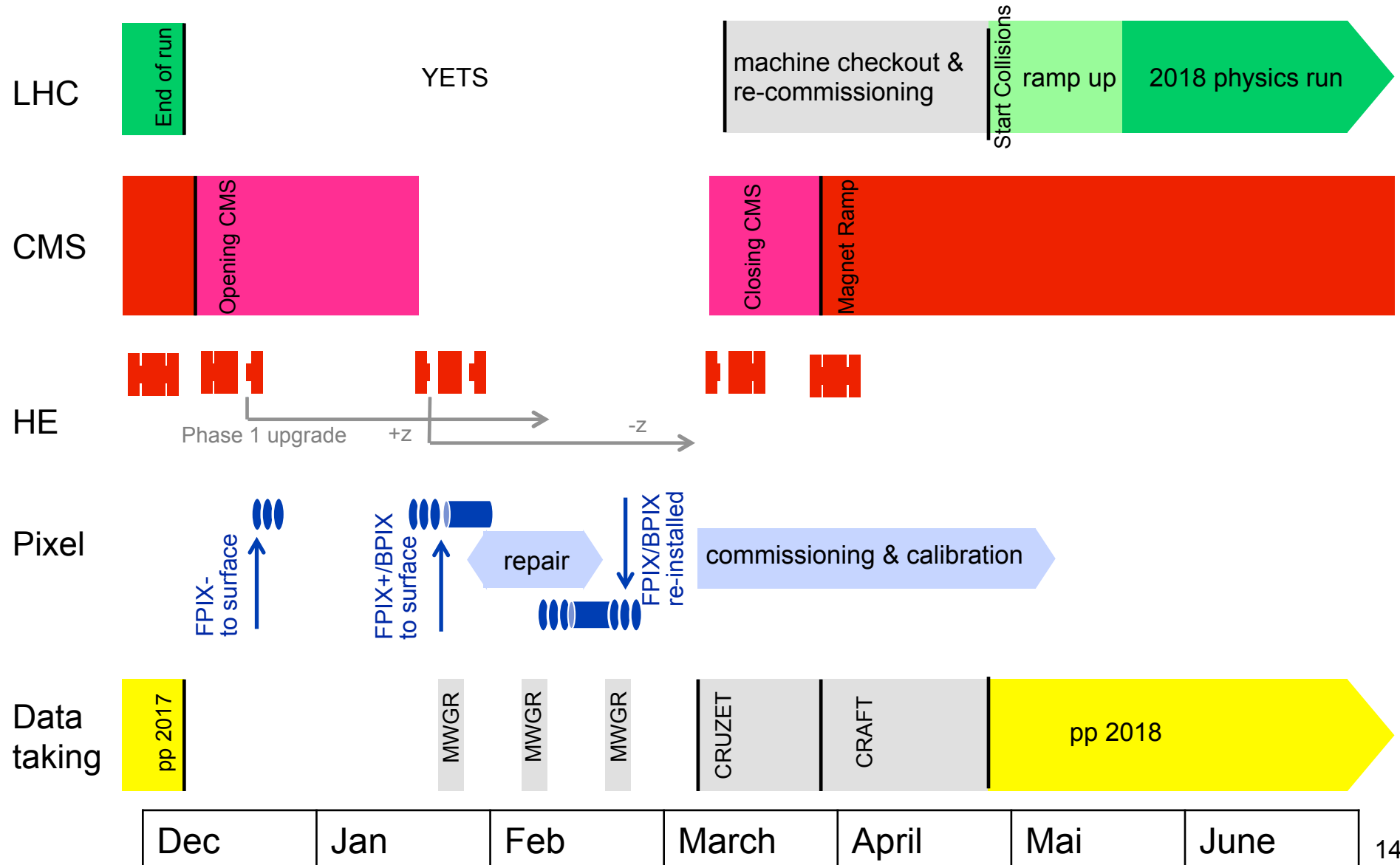


CMS-PAS-HIN-17-003

- Heavy quarks produced in early stages of the collision \rightarrow probe properties of QGP through entire evolution
- Measurement of D mesons compared to strange hadrons
 - mass ordering for strange hadrons similar in pPb and PbPb
 - Smaller elliptic flow for charm in pPb
- May suggest weaker collective behavior for charm quarks in small systems \rightarrow Looking forward to theoretical calculations

Preparing for 2018 data taking

- Started as soon as 2017 run was over...

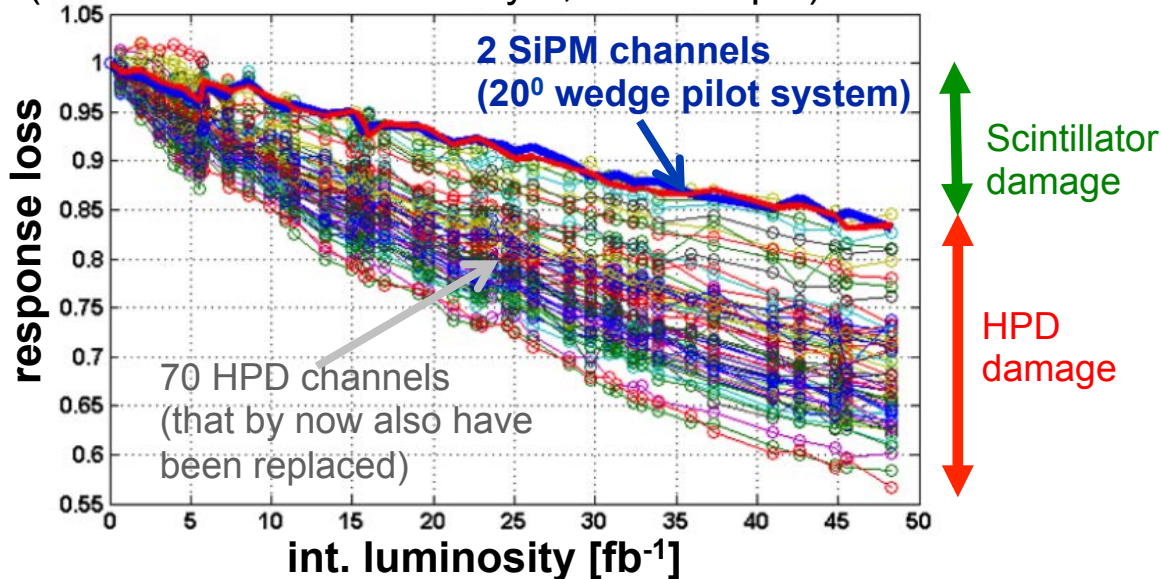


HE Phase 1 Upgrade

- Phase 1 upgrade of HE front-end electronics completed!
 - Intense but smooth operation, confirming excellent experience with pilot system
 - All HE HPDs replaced by SiPMs
 - Eliminated dominant source of HE signal loss
 - Increased longitudinal segmentation and added time information (TDC)



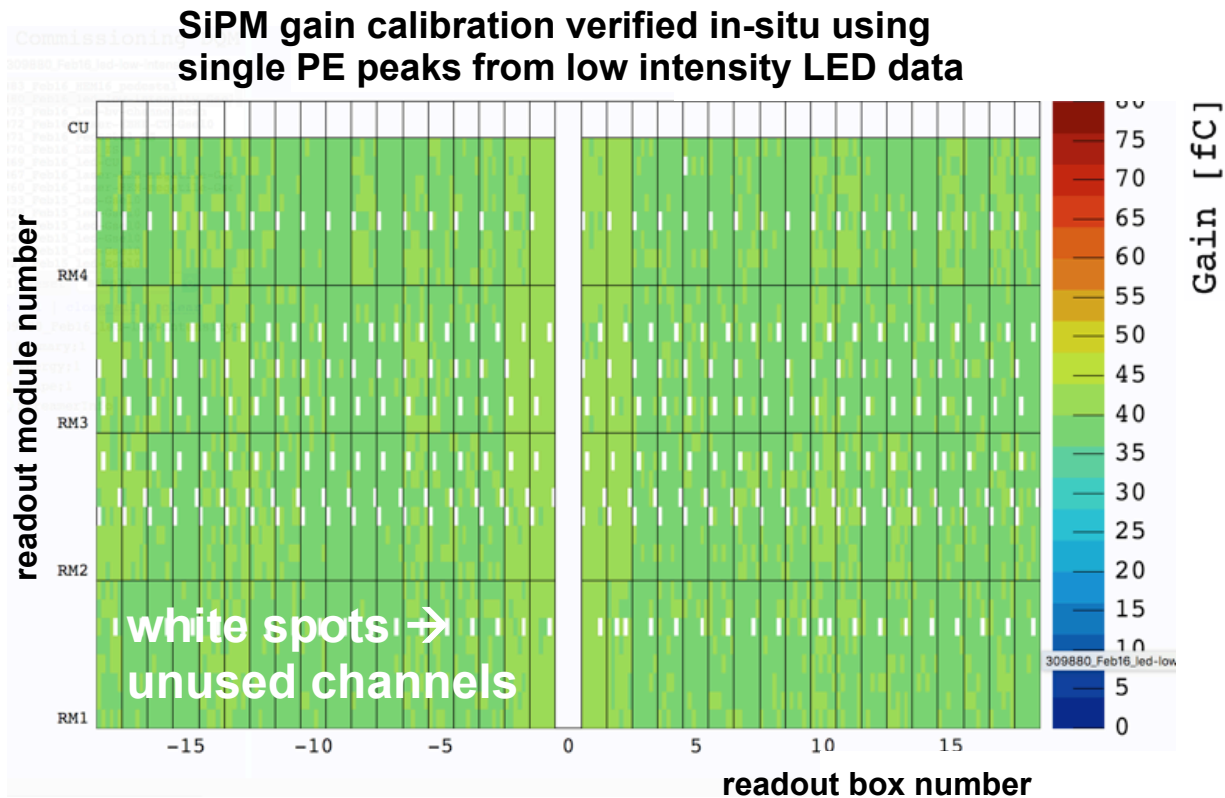
HE **response loss** vs integrated luminosity in 2017
(channels at same eta+layer, different phi):



→ For 2018 we expect a very moderate loss in all HE channels!

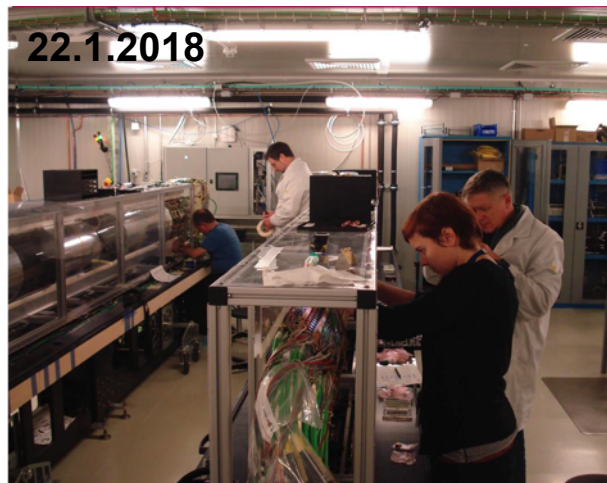
Summary of HE commissioning

- Cobalt-60 calibration campaign completed
- All HE front-end channels are working
 - Pedestals and SiPM bias voltage tuned
 - Commissioning and calibrations well underway
- Already participating in global run!



Pixel detector repair

- FPIX+ extracted before lab closure to get access to problematic converters ASAP
 - work continued every day during holiday season and new year
 - heroic common effort of chip designers, DCDC-, pixel-, DCS- and cooling-experts
- Replaced all DCDC converters on FPIX and BPIX (>1000)
- Huge effort in testing, diagnostic and forensics

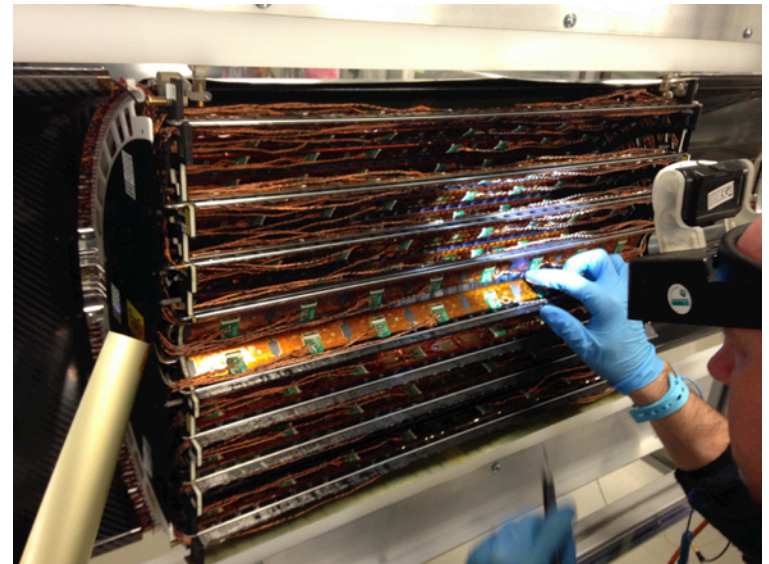
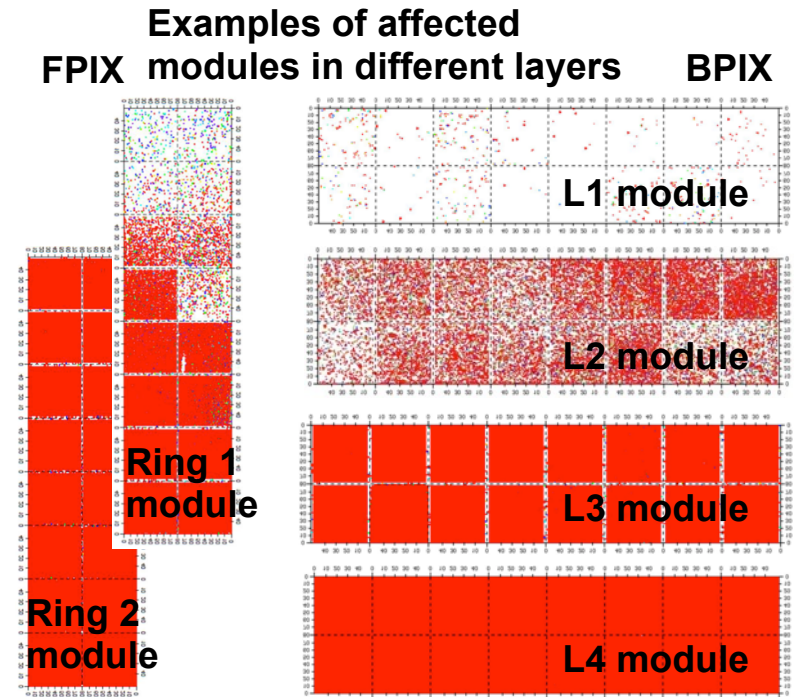


Current understanding of DCDC issue

- Thanks to the effort of the chip designers, we know on transistor-level where the problem in FEAST2 ASIC is located
 - Behavior of broken converters can be reproduced in simulation by drain-gate breakdown in clamp transistors in under voltage protection circuit
 - Additionally found "high-current" converters (early stage of failure?)
 - **what causes this damage is not understood**
 - FEAST2 IV characteristics measured on several samples
 - Phase 1 pixel extracted/spare/new production, pixel pilot system, HCAL, FEAST2 chips on CERN module, irradiated samples, ...
 - Modules with "high-current" found in
 - 30% of Phase 1 pixel detector after 2017 operation
 - 9/33 converters (on CERN module) irradiated in 2014 (tested in 2018)
 - few modules of new production (tested ok in Q&A)
- "High-current" behavior not limited to CMS module/environment
- Large effort in community to investigate and resolve this issue
- Measurement program being set up

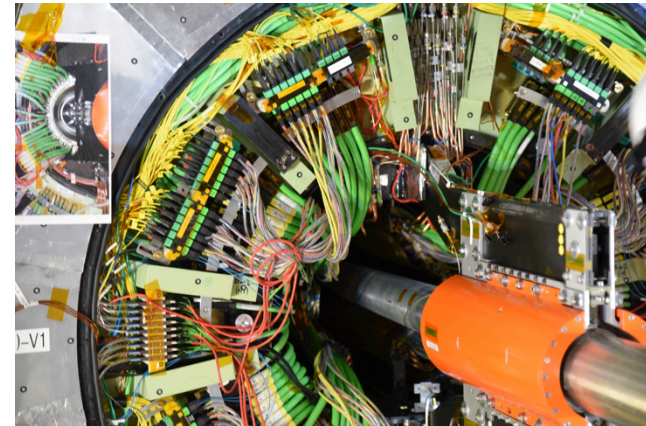
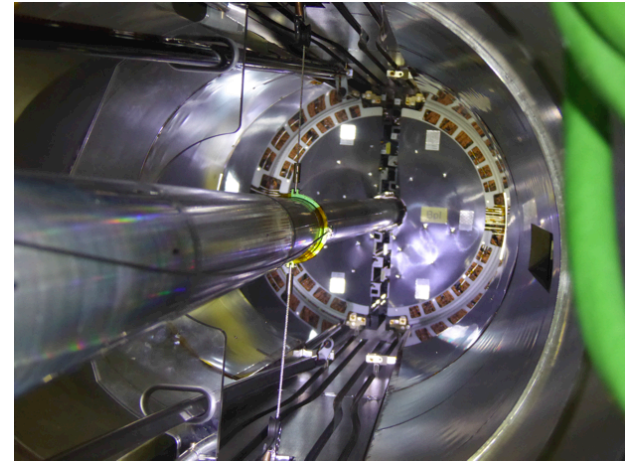
Collateral damage to pixel detector modules

- Since HV granularity is lower than granularity of DCDC converters, modules behind broken DCDC converters were run with LV off, but HV on during 2017 operation
 - This condition caused damage to pixel pre-amplifier
 - Leakage current leads to too high voltage at pre-amp input
 - Amount of damage depends on time and leakage current
 - Damage most severe in BPIX L1
- 6 out of 8 affected modules replaced in L1



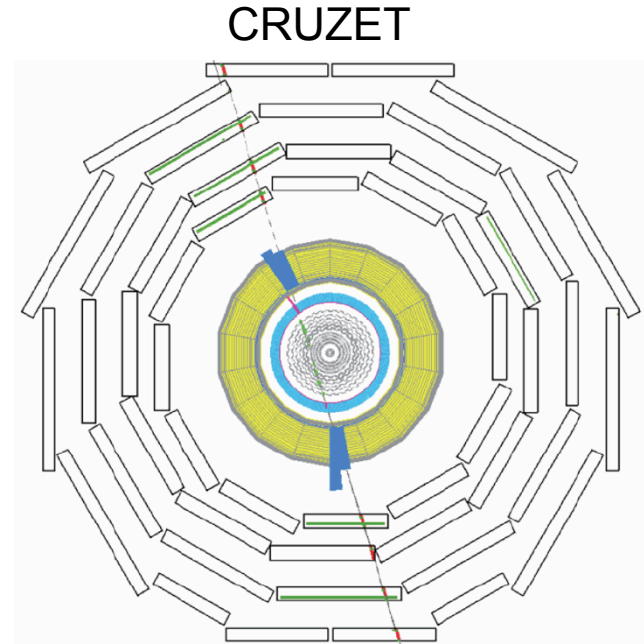
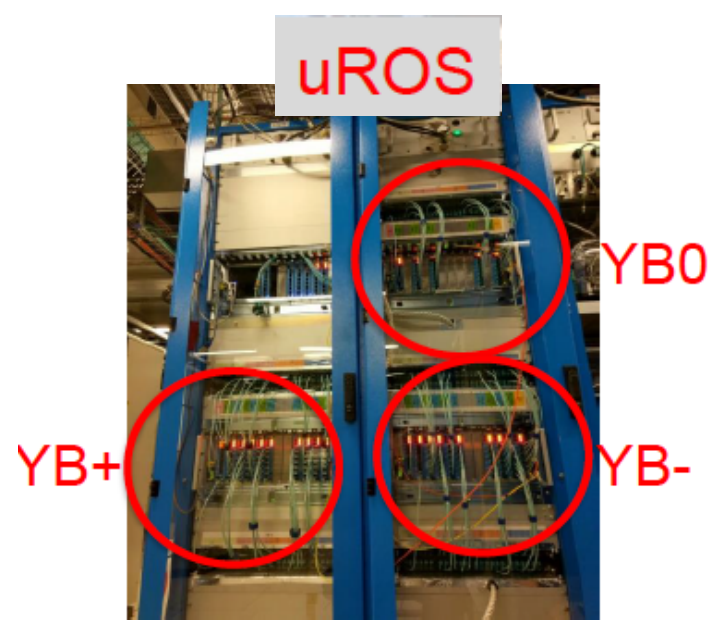
Pixel detector status

- Pixel detector re-installed into CMS mid February
- First checkout successfully completed
 - re-established working fraction of ~97-98%
- Cold operation at -22°C starting this week
 - re-commissioning and calibration
 - participate in CRUZET/CRAFT crucial for alignment
- Operation in 2018 will depend on performance of DCDC converters
 - Learn how to optimize operation procedure to minimize DCDC failures
- Prepare to replace all DCDC converters with new, improved converters in LS2
 - Designers are working on new FEAST version



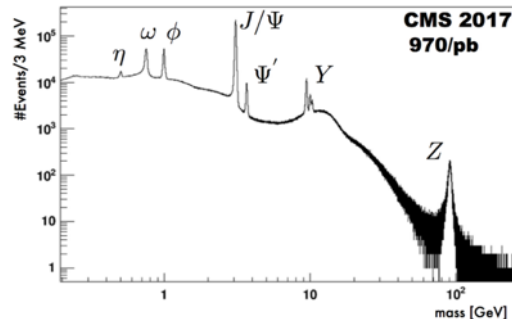
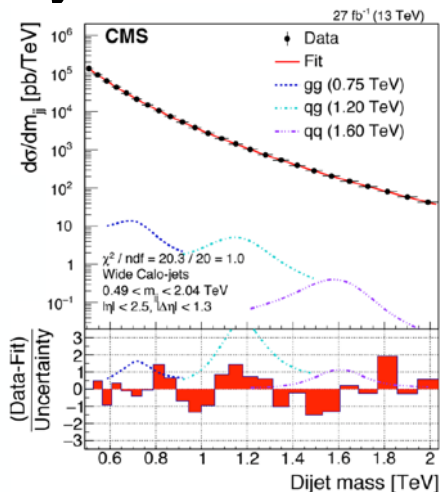
Other YETS activities

- Muon DT Phase 1 upgrade successfully completed
 - Upgrade of DT VME ROS to mTCA ROS (uROS)
 - Comparison with legacy system shows excellent results
- Operation temperature for Si strip tracker and pre-shower detector lowered
 - in order to decrease leakage current
- Detector brought up smoothly for cosmic data-taking starting at the end of January
 - All subsystems (except pixels) run in Mid-Week Global Runs (MWGR)
 - DAQ runs efficient and stable



Trigger development

- Aim is to keep a trigger menu for collision data-taking with the same physics content as at the end of 2017: similar thresholds and rates
 - Target an instantaneous luminosity of $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ with 48b (25ns) bunch trains
 - L1 menu with improvements in object reconstruction and algorithms
 - HLT technical improvements
 - More refined algorithms to mitigate possible pixel detector inefficiencies
 - Adapt to HE upgrade
- Review of scouting and parking strategy to best exploit this last year of Run 2

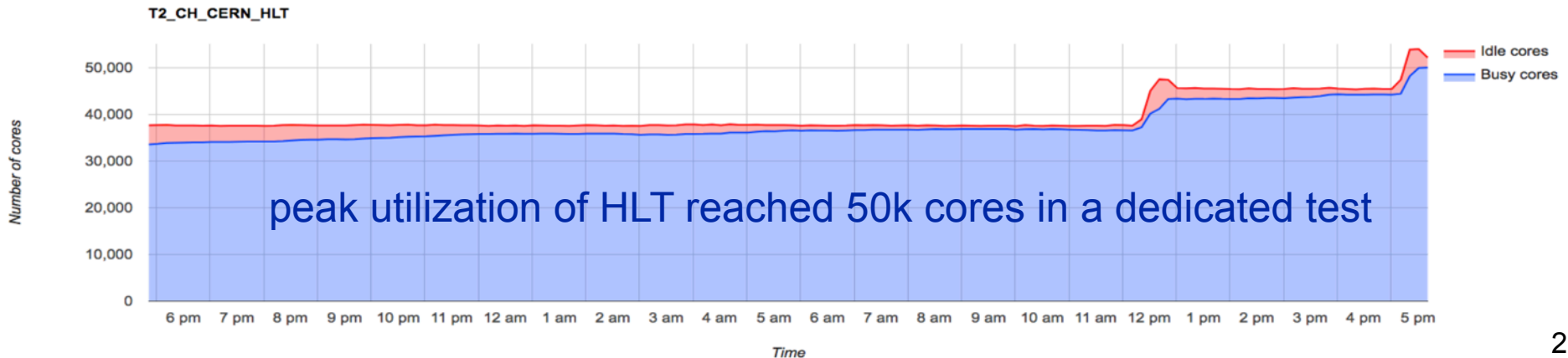


→ Physics case:

- low p_T muons
- complement di-jet mass spectrum at low mass

Software & Computing

- From mid November on, focus on 2017 data and MC re-RECO
 - at the same time preparing for next run
 - Overall, processed almost 50 B events (!) in 2017
- During Christmas break production utilized the full Tier-0 plus a sizeable fraction of HLT cores
 - Important test for 2019, when we plan to do this all year long
 - Test under full load successful, no problems spotted
- Study new data format for event size reduction (NanoAOD)
 - Should enable >50% of analyses, down to 800B/event (factor 50 reduction wrt MINIAOD)



Challenges for 2018 and beyond

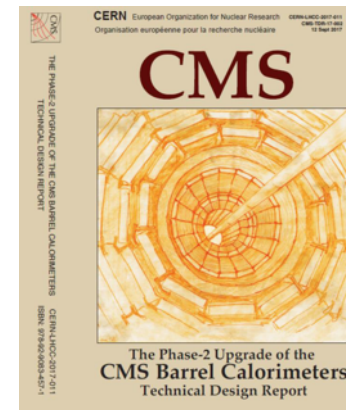
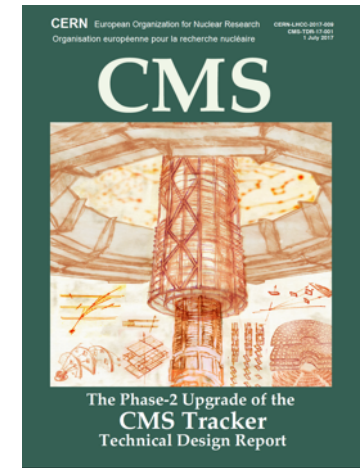
- Take high-quality physics data with increasing luminosity
 - pp and HI
 - Effort in detector operation to keep up performance
- Process and analyze full Run 2 data set
 - Do precision SM physics and search for new physics
- Prepare for various activities scheduled during LS2
 - Muon system upgrade (new CSC FE, new GEM layer GE1/1)
 - HB Phase 1 upgrade
 - Pixel Layer 1 replacement (& DCDC repair)
 - Preparation of infrastructure for LS3 (incl. beampipe replacement)



← GEM chamber production proceeding smoothly

Upgrade for HL-LHC

- Very active time for upgrade preparation producing:
 - 4 TDRs (Tracker, Muons, Barrel and Endcap Calorimeter)
 - <https://cds.cern.ch/record/2293646>
 - <https://cds.cern.ch/record/2272264>
 - <https://cds.cern.ch/record/2283187>
 - <https://cds.cern.ch/record/2283189>
 - 2 Interim Design Reports (Trigger, DAQ/HLT)
 - <https://cds.cern.ch/record/2283192>
 - <https://cds.cern.ch/record/2283193>
 - 1 Technical Proposal (MIP Timing)
 - <https://cds.cern.ch/record/2296612>



The Phase-2 Upgrade of the CMS Level-1 Trigger
Interim Technical Design Report
CMS Collaboration



The Phase-2 Upgrade of the CMS DAQ
Interim Technical Design Report
CMS Collaboration

Summary

- Physics results continue to be excellent in exploring new phase space
- Analysis of 2017 data ongoing, first results to be shown at upcoming conferences
- Used YETS for important repair and upgrade work
 - Pixel detector extracted, major effort in repair (all DCDC converter replaced, 6/8 affected L1 modules replaced), detector re-installed, commissioning in progress
 - Located problem in FEAST2 ASIC, cause not understood yet
→ setting up measurement program
 - HE Phase 1 upgrade completed (HPD → SiPMT)
 - Muon DT Phase 1 upgrade completed (uROS)
- CMS detector preparation on track for 2018 data taking
- Upgrade projects for LS2 and beyond well underway

Backup

CMS Paper submitted since last LHCC meeting (1/3)

CMS Publications

744	B2G-16-029	Search for a heavy resonance decaying to a pair of vector bosons in the lepton plus merged jet final state at $\sqrt{s} = 13$ TeV	Submitted to JHEP	26 February 2018
743	EXO-16-057	Search for narrow resonances in the b-tagged dijet mass spectrum in proton-proton collisions at $\sqrt{s} = 8$ TeV	Submitted to PRL	17 February 2018
742	BPH-15-002	Measurement of the Λ_b polarization and angular parameters in $\Lambda_b \rightarrow J/\psi \Lambda$ decays from pp collisions at $\sqrt{s} = 7$ and 8 TeV	Submitted to PRD	13 February 2018
741	EXO-17-012	Search for heavy neutral leptons in events with three charged leptons in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to PRL	8 February 2018
740	FSQ-15-005	Measurement of the inelastic proton-proton cross section at $\sqrt{s} = 13$ TeV	Submitted to JHEP	7 February 2018
739	SUS-16-038	Search for natural and split supersymmetry in proton-proton collisions at $\sqrt{s} = 13$ TeV in final states with jets and missing transverse momentum	Submitted to JHEP	6 February 2018
738	B2G-17-009	Search for single production of vector-like quarks decaying to a b quark and a Higgs boson	Submitted to JHEP	5 February 2018
737	EXO-16-058	Search for lepton-flavor violating decays of heavy resonances and quantum black holes to $e\mu$ final states in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to JHEP	4 February 2018
736	HIN-16-005	Comparing transverse momentum balance of b jet pairs in pp and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV	Submitted to JHEP	2 February 2018
735	EXO-16-051	Search for dark matter in events with energetic, hadronically decaying top quarks and missing transverse momentum at $\sqrt{s} = 13$ TeV	Submitted to JHEP	25 January 2018
734	HIN-16-014	Observation of medium induced modifications of jet fragmentation in PbPb collisions using isolated-photon-tagged jets	Submitted to PRL	15 January 2018

CMS Paper submitted since last LHCC meeting (2/3)

733	SUS-17-004	Combined search for electroweak production of charginos and neutralinos in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to JHEP	11 January 2018
732	HIG-15-007	Measurement of the $Z\gamma^* \rightarrow \tau\tau$ cross section in pp collisions at $\sqrt{s} = 13$ TeV and validation of τ lepton analysis techniques	Submitted to EPJC	10 January 2018
731	SUS-16-048	Search for new physics in events with two soft oppositely charged leptons and missing transverse momentum in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to PLB	5 January 2018
730	EXO-16-004	Search for decays of stopped exotic long-lived particles produced in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to JHEP	31 December 2017
729	SMP-16-018	Electroweak production of two jets in association with a Z boson in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to EPJC	28 December 2017
728	SUS-16-040	Search for R -parity violating supersymmetry in pp collisions at $\sqrt{s} = 13$ TeV using b jets in a final state with a single lepton, many jets, and high sum of large-radius jet masses	Submitted to PLB	24 December 2017
727	HIN-16-025	Measurement of prompt and nonprompt charmonium suppression in PbPb collisions at 5.02 TeV	Submitted to EPJC	24 December 2017
726	SUS-17-006	Search for physics beyond the standard model in events with high-momentum Higgs bosons and missing transverse momentum in proton-proton collisions at 13 TeV	Submitted to PRL	22 December 2017
725	HIG-17-001	Search for lepton flavour violating decays of the Higgs boson to $\mu\tau$ and $e\tau$ in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to JHEP	20 December 2017
724	FSQ-14-002	Study of Bose-Einstein correlations in pp, pPb, and PbPb collisions at the LHC	Submitted to PRC	20 December 2017

CMS Paper submitted since last LHCC meeting (3/3)

723	BTV-16-002	Identification of heavy-flavour jets with the CMS detector in pp collisions at 13 TeV	Submitted to JINST	19 December 2017
722	BPH-16-002	Search for the X(5568) state decaying into $B_s^0 \pi^\pm$ in proton-proton collisions at $\sqrt{s} = 8$ TeV	Submitted to PRL	17 December 2017
721	SMP-16-014	Azimuthal correlations for inclusive 2-jet, 3-jet, and 4-jet events in pp collisions at $\sqrt{s} = 13$ TeV	Submitted to EPJC	14 December 2017
720	EXO-17-005	Search for $Z\gamma$ resonances using leptonic and hadronic final states in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to JHEP	9 December 2017
719	TOP-16-020	Measurement of the associated production of a single top quark and a Z boson in pp collisions at $\sqrt{s} = 13$ TeV	Accepted by PLB	8 December 2017
718	TOP-17-003	Search for the flavor-changing neutral current interactions of the top quark and the Higgs boson which decays into a pair of b quarks at $\sqrt{s} = 13$ TeV	Submitted to JHEP	6 December 2017
717	FSQ-16-005	Constraints on the double-parton scattering cross section from same-sign W boson pair production in proton-proton collisions at $\sqrt{s} = 8$ TeV	JHEP 02 (2018) 032	6 December 2017
716	EXO-16-048	Search for new physics in final states with an energetic jet or a hadronically decaying W or Z boson and transverse momentum imbalance at $\sqrt{s} = 13$ TeV	Submitted to PRD	6 December 2017

CMS PAS since last LHCC meeting

- **SUS-17-002** Search for supersymmetry in events with tau leptons and missing transverse momentum in proton-proton collisions at $\sqrt{s}=13$ TeV
- **SUS-17-009** Search for selectrons and smuons at $\sqrt{s}= 13$ TeV
- **B2G-16-028** Search for third-generation scalar leptoquarks decaying to a top quark and a tau lepton at $\sqrt{s} = 13$ TeV
- **B2G-17-006** Search for heavy resonances decaying into two Higgs bosons or into a Higgs and a vector boson in proton-proton collisions at 13 TeV
- **B2G-17-013** Search for new heavy resonances decaying into a Z boson and a massive vector boson in the $2\ell 2q$ final state at $\sqrt{s}= 13$ TeV
- **EXO-17-011** Search for a heavy right-handed W boson and a heavy neutrino in events with two same-flavor leptons and two jets
- **HIG-16-018** Search for Higgs bosons produced in association with b quarks and decaying into a b-quark pair with 13 TeV data
- **HIG-17-012** Search for a new scalar resonance decaying to a pair of Z bosons in proton-proton collisions at $\sqrt{s}= 13$ TeV
- **HIG-17-020** Inclusive search for the standard model Higgs boson produced in pp collisions at $\sqrt{s}= 13$ TeV using $H\rightarrow bb$ decays
- **HIN-17-003** Elliptic flow of charm and strange hadrons in high-multiplicity pPb collisions at $\sqrt{s_{NN}}=8.16$ TeV



Hadron Calorimeter performance

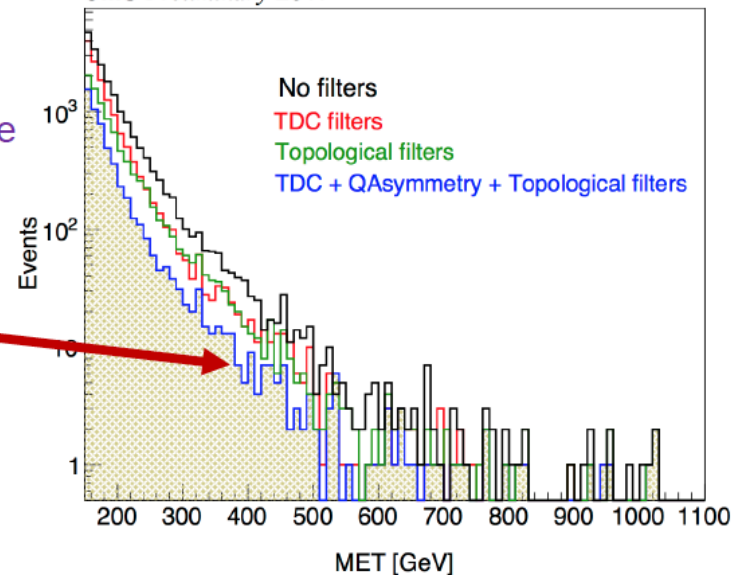
Forward Hadron Calorimeter :

- Steel absorber, quartz fibers, PMT readout

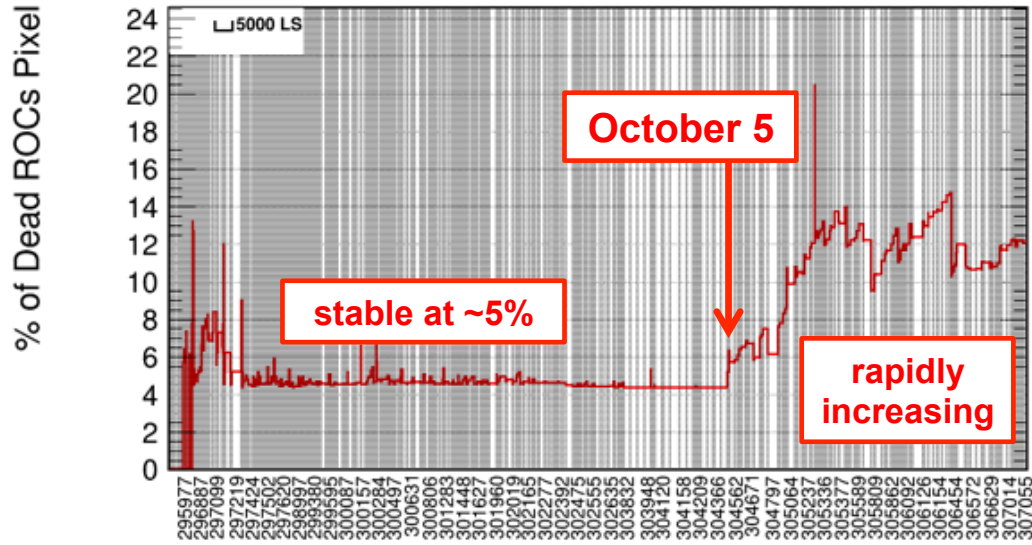
Phase-1 upgrade to address beam-induced PMT anomalous noise

- Upgrade completed in EYETS 2016/17
- All new handles to achieve noise suppression are in use
- **Substantial rate reduction for MET achieved**

CMS Preliminary 2017



Pixel Detector: DCDC converter issue



Strip Tracker and Muon System Status

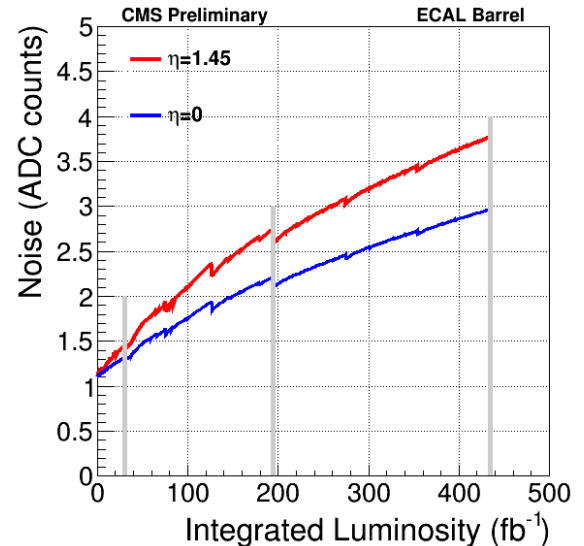
- No major intervention during YETS
- Strip tracker
 - kept cold during whole period
 - Operation temperature lately lowered from -15°C to -20°C to decrease leakage current (needed for individual modules)
- Muon system
 - Fixed water leak in YE1 that appeared in May 2017 and verified that there is no collateral damage
 - Annual system maintenance (gas system, hardware, firmware, software) in progress
 - DAQ upgrade (VME \rightarrow uTCA) successfully completed

Calorimeter Status

- No major intervention during YETS (except for HE)

- ECAL

- Pre-shower operation temperature lowered (-7°C to -15°C)
- Firmware and software upgrades to improve efficiency and reliability, in particular in view of high PU (up to 60)
- Estimation of expected noise and light output until LS3



- HCAL

- HB and HO: fixed one data fiber each that were lost during the year
- HB and HE: faster software algorithm allowed to unify the online and offline local reconstruction
- HF front-end firmware updated to better handle (rare) beam induced low voltage power supply cycles
- MC simulation: an improved description of the front-end electronics time slew was implemented