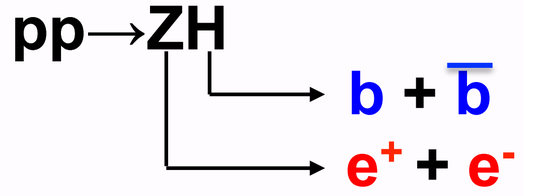
CMS Status Report

Jim Hirschauer

Fermilab

on behalf of the CMS collaboration
LHCC Open Session
12 Sep 2018

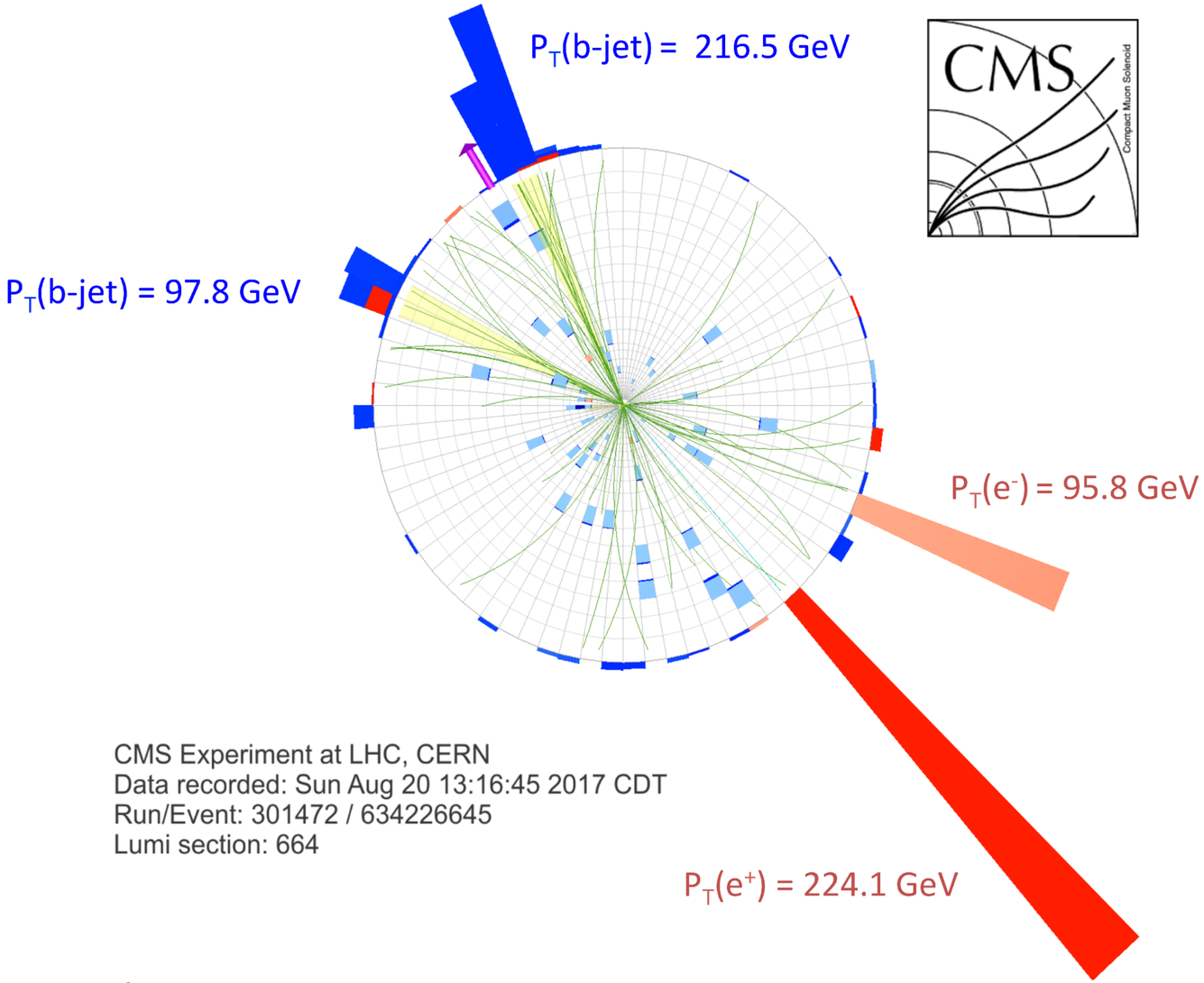
Outline



- Detector performance in 2018.
- Highlights of recent physics results.

  Observation of Higgs boson decay to b quarks!

- Plans for LS2.



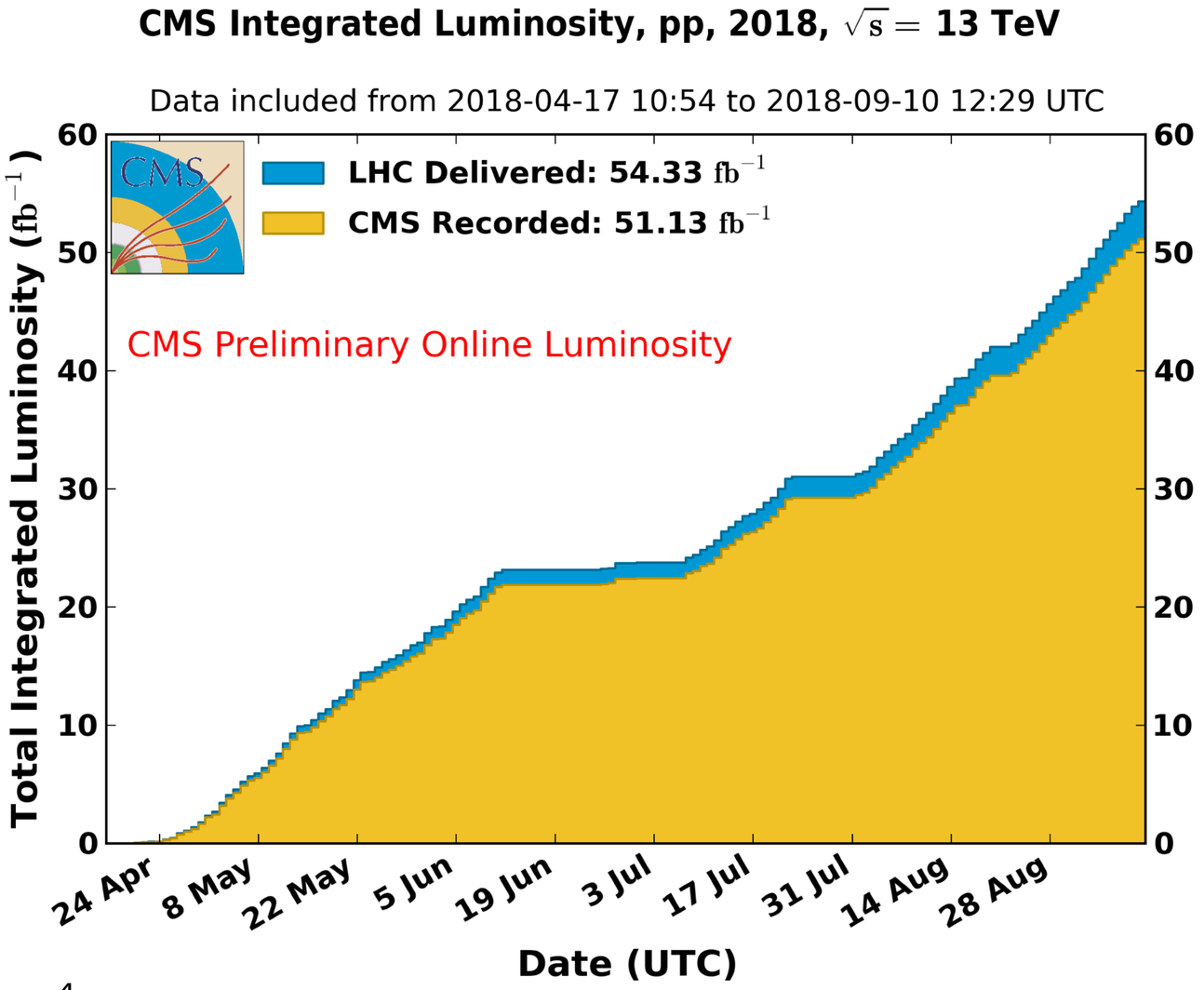
Detector performance

CMS recorded data

- CMS has recorded **>50 fb^{-1}** with almost **95% efficiency** in 2018.
  - record for CMS!
  - 93% efficiency for data certification

Several special runs:

- **Van der Meer scans**
- **β* = 90m** joint with TOTEM collected 5.6 pb^{-1}
- **Low PU runs** collected 28.5 pb^{-1}



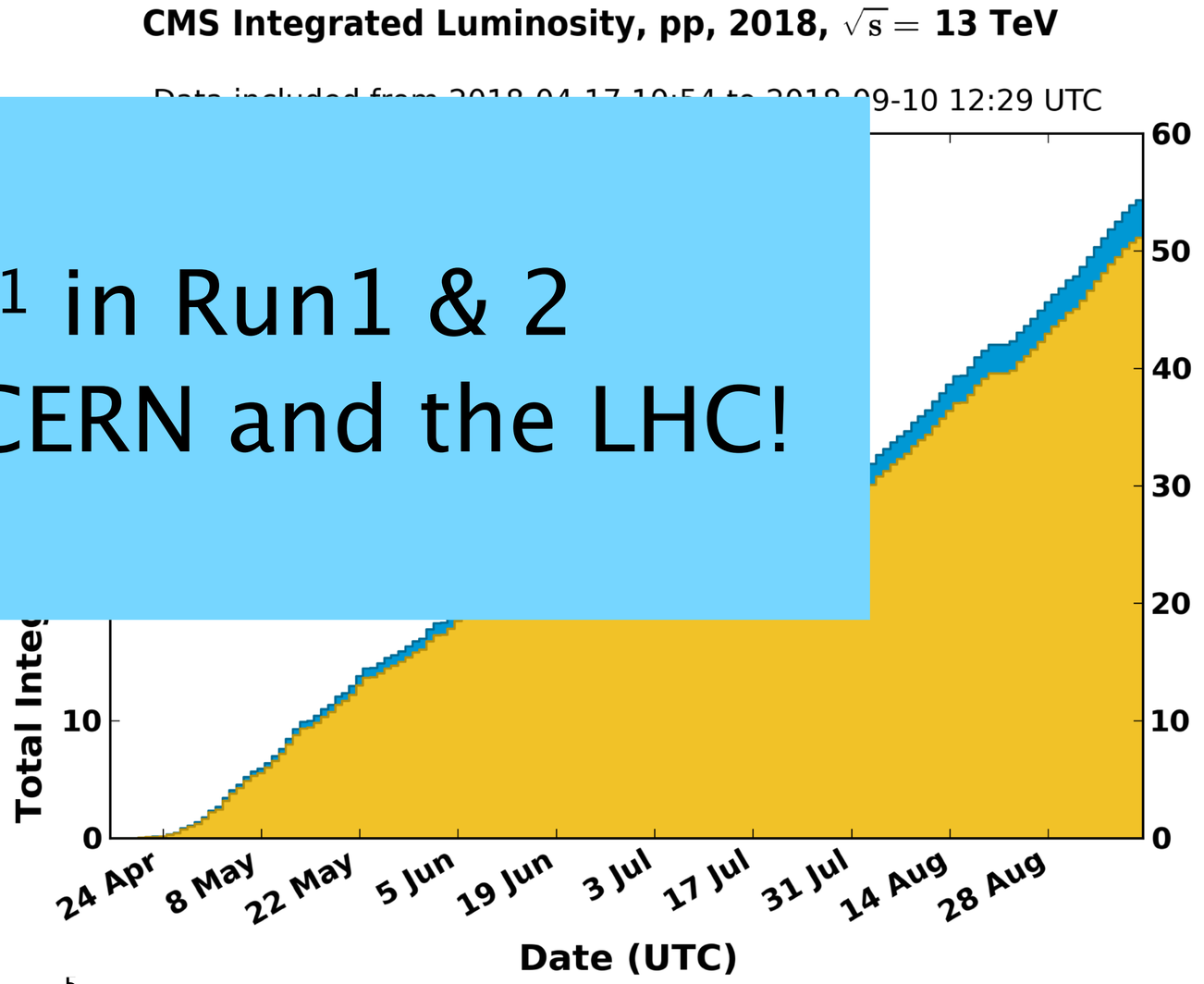
CMS recorded data

- CMS has recorded **>50 fb^{-1}** with almost **95% efficiency** in 2018
  - record f
  - 93% effi

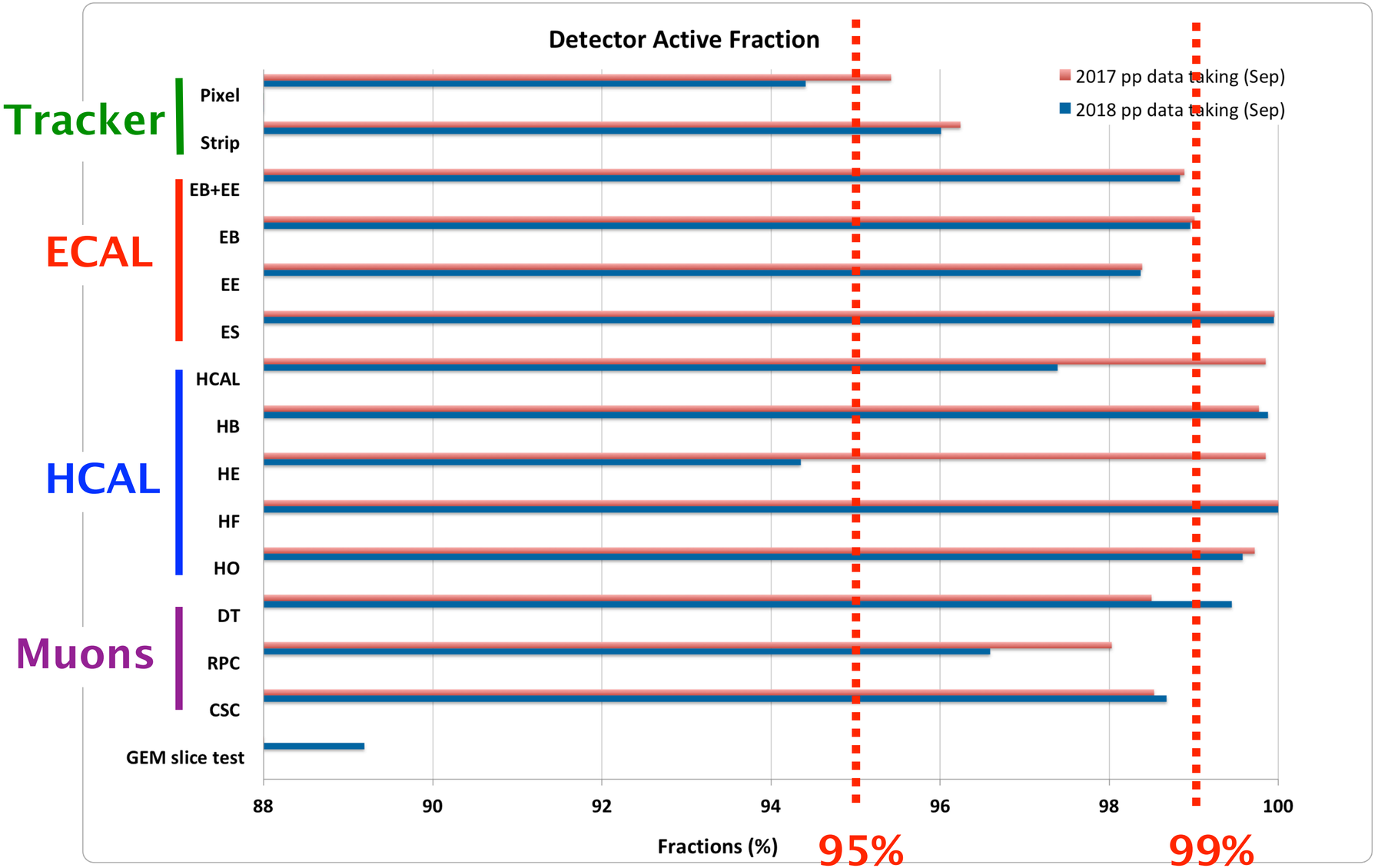
Several speci

- **Van der M**
- **β* = 90m** joint with TOTEM collected 5.6 pb^{-1}
- **Low PU runs** collected 28.5 pb^{-1}

>150 fb^{-1} in Run1 & 2
big thanks to CERN and the LHC!

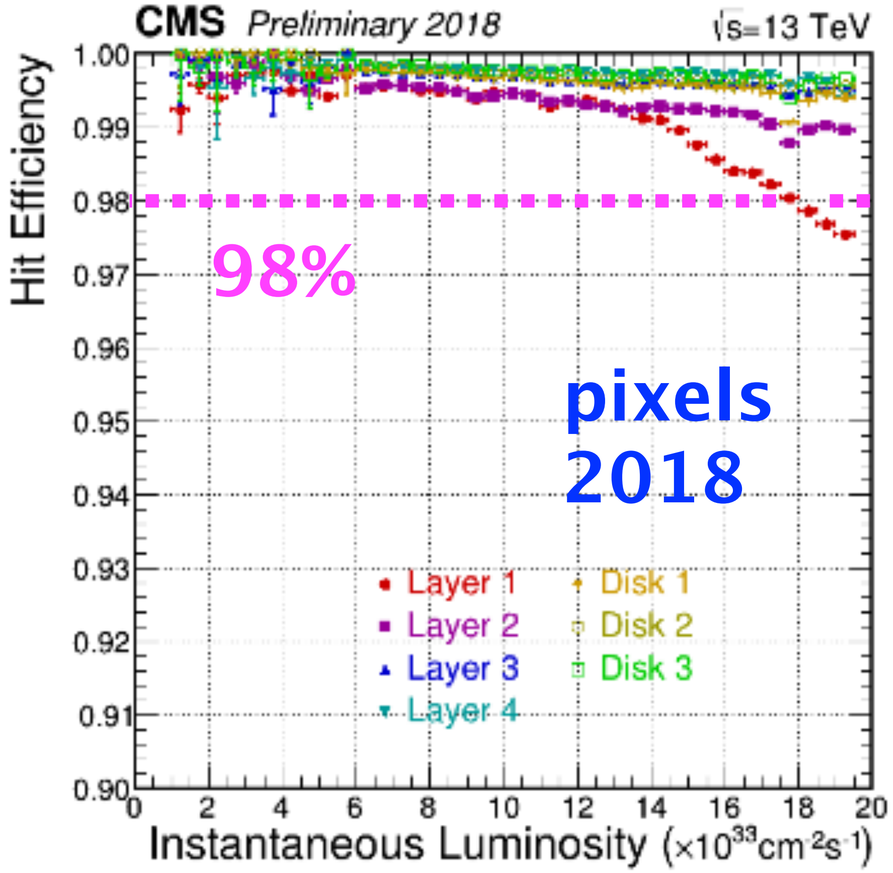


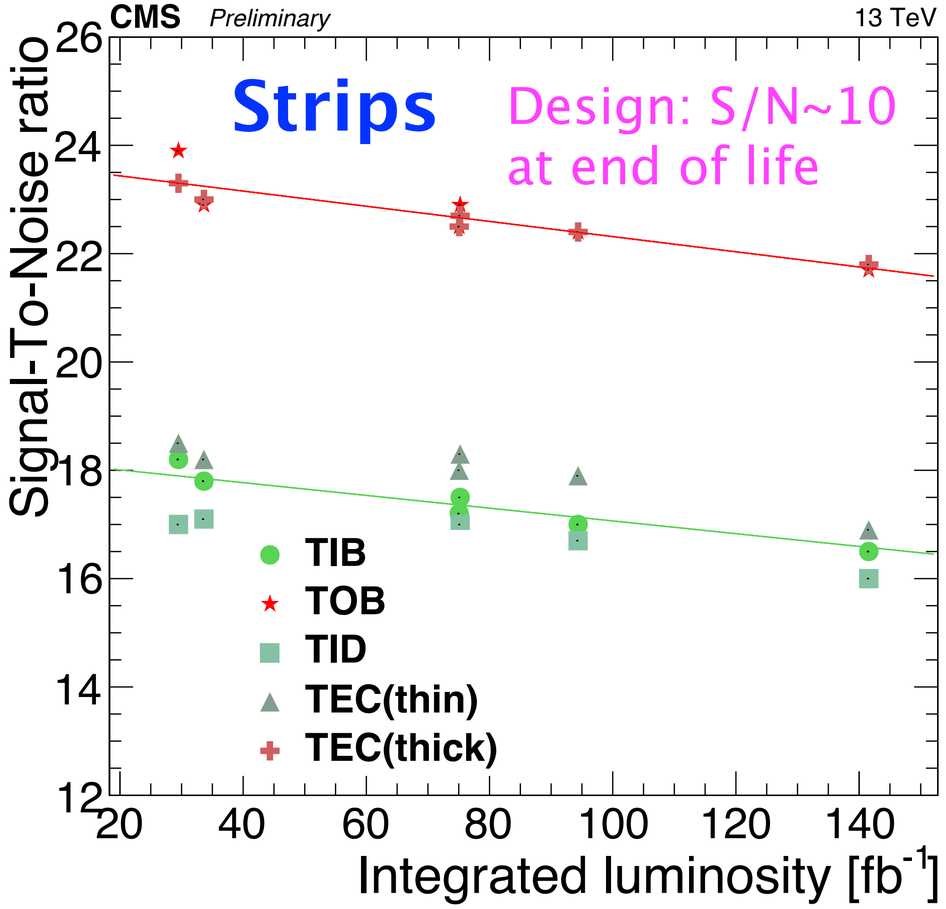
CMS detector summary



Tracker performance

- **High hit efficiency** even at $2 \times 10^{34}\ cm^{-2}\ s^{-1}$ and in innermost layers: strips > ~98.5%, pixels > ~97.5%





- **Strips S/N vs. integrated luminosity** indicates S/N will not be an issue at end of life (around 500/fb).
  - detailed analysis in progress.

Pixel detector DC/DC convertors

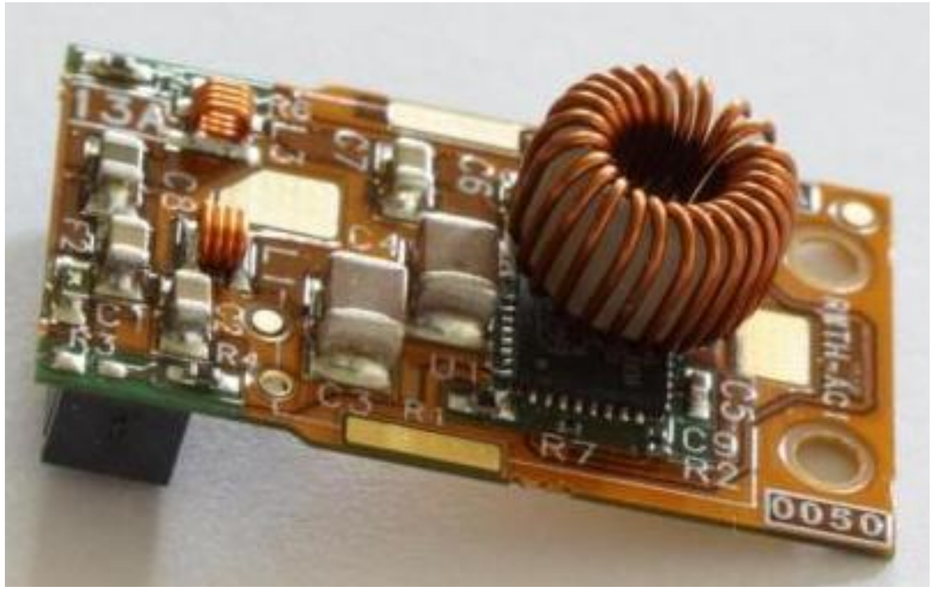
- In late 2017, CMS observed failures of DC/DC convertors in pixel detector.
  - At last LHCC meeting, reported that cause was still not understood.

- **Significant progress** by CERN electronics group to understand issue with FEAST2 ASIC (with help of CMS team).

- Bottom line : damage occurs only for **disabled device** after **high cumulative radiation damage**.

- CMS has ceased disable/re-enable cycles in 2018 :
  - **no FEAST damage** in 2018
  - SEU-affected pixel electronics recovered at end of each fill with supply power cycle.

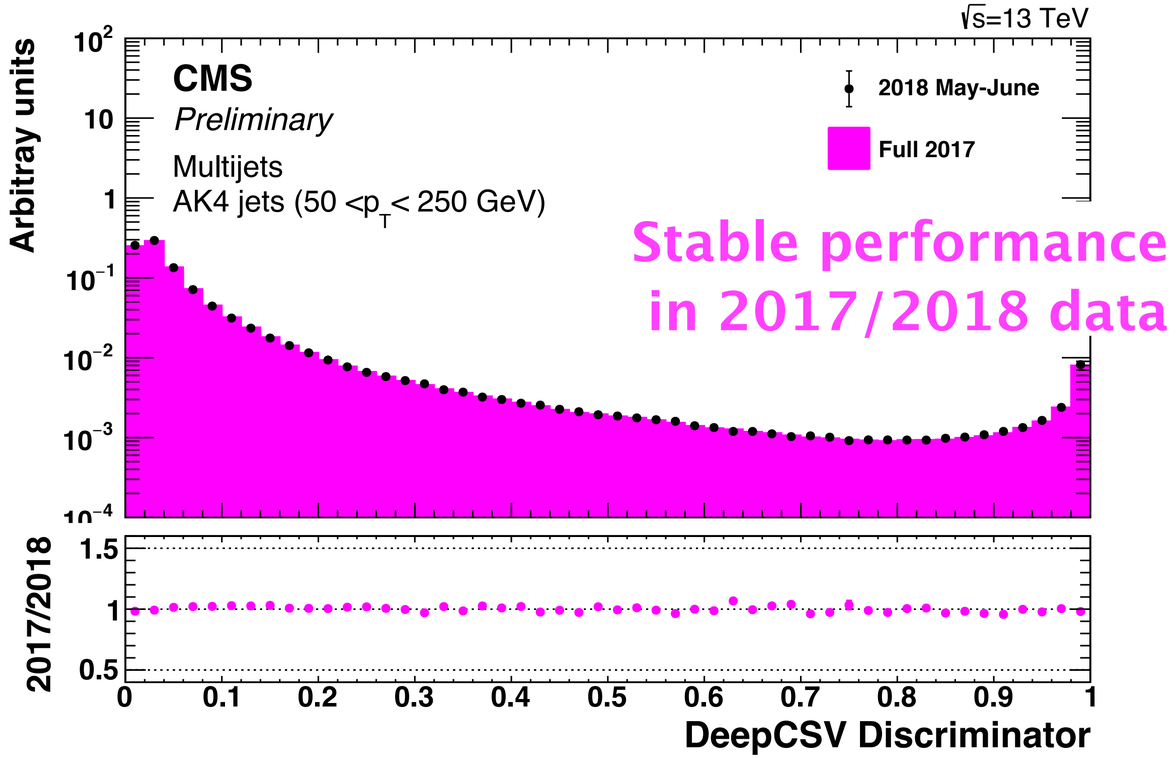
- **Impact on other CMS FEAST users** :
  - HCAL and GEM use FEAST2 but do not reach problematic dose
  - FEAST design is being modified for others.



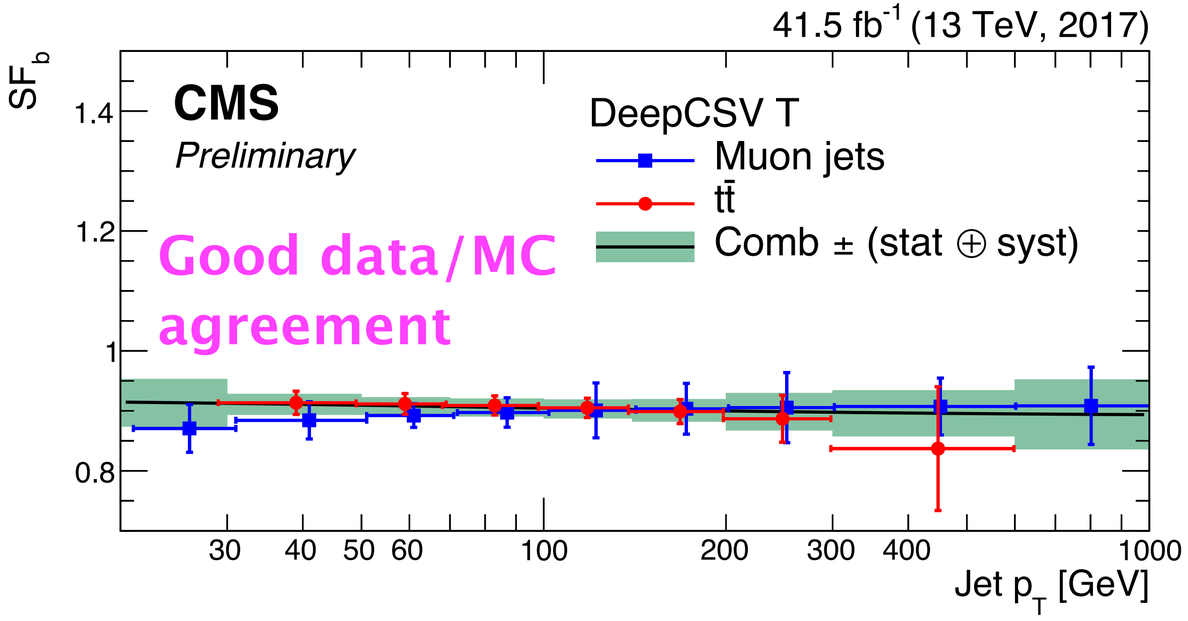
Pixel and b-tagging performance

DP-2018-33

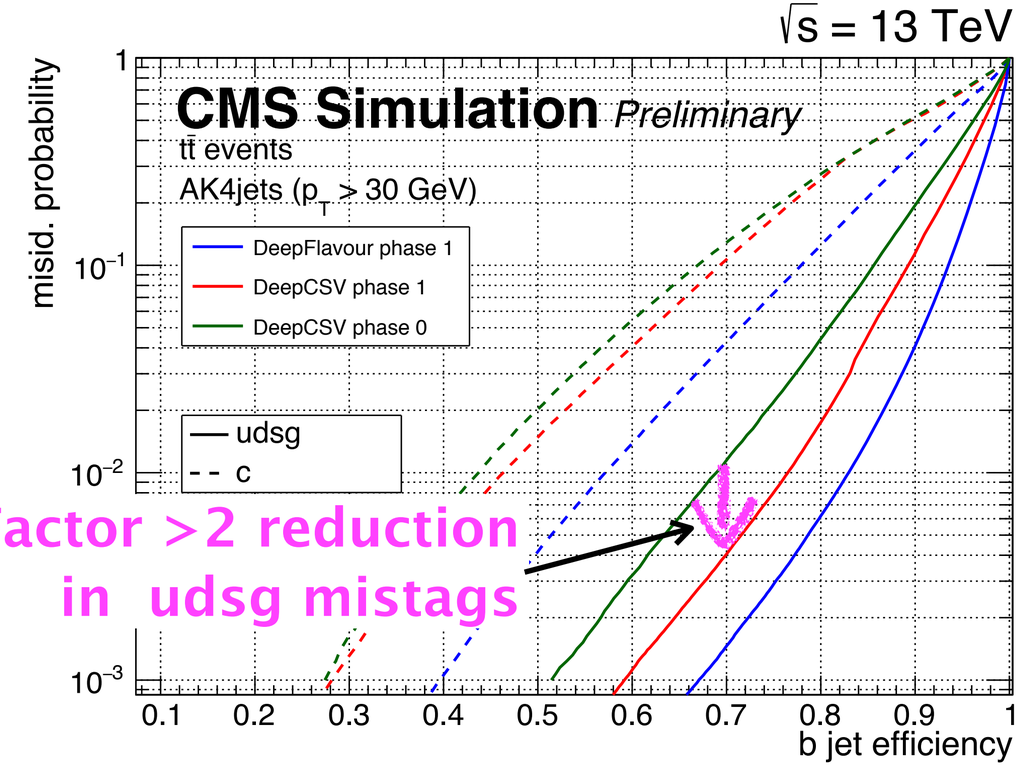
- Despite DC/DC issues, b-tagging performance has been stable and excellent.



Stable performance in 2017/2018 data



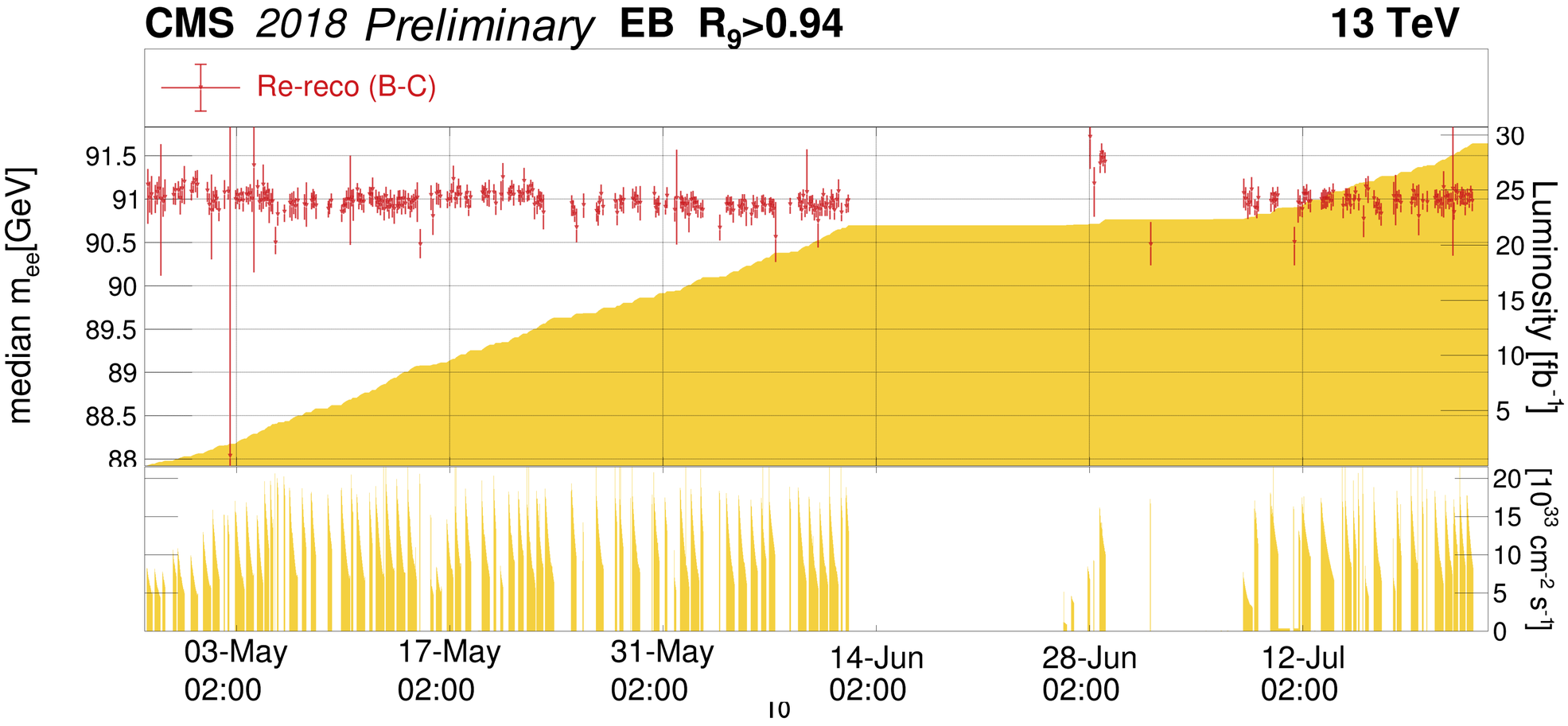
Good data/MC agreement



Factor >2 reduction in udsg mistags

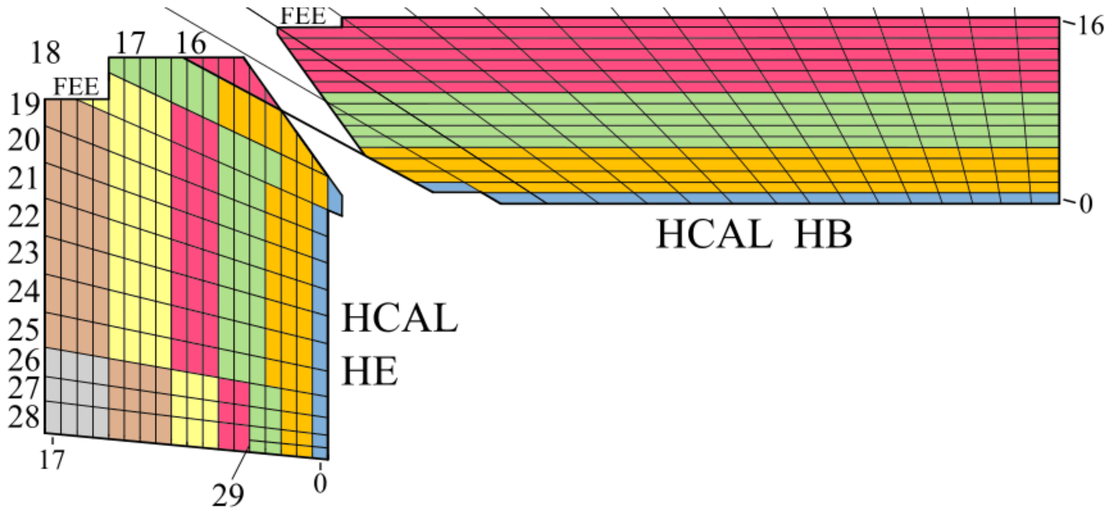
ECAL performance and calibration

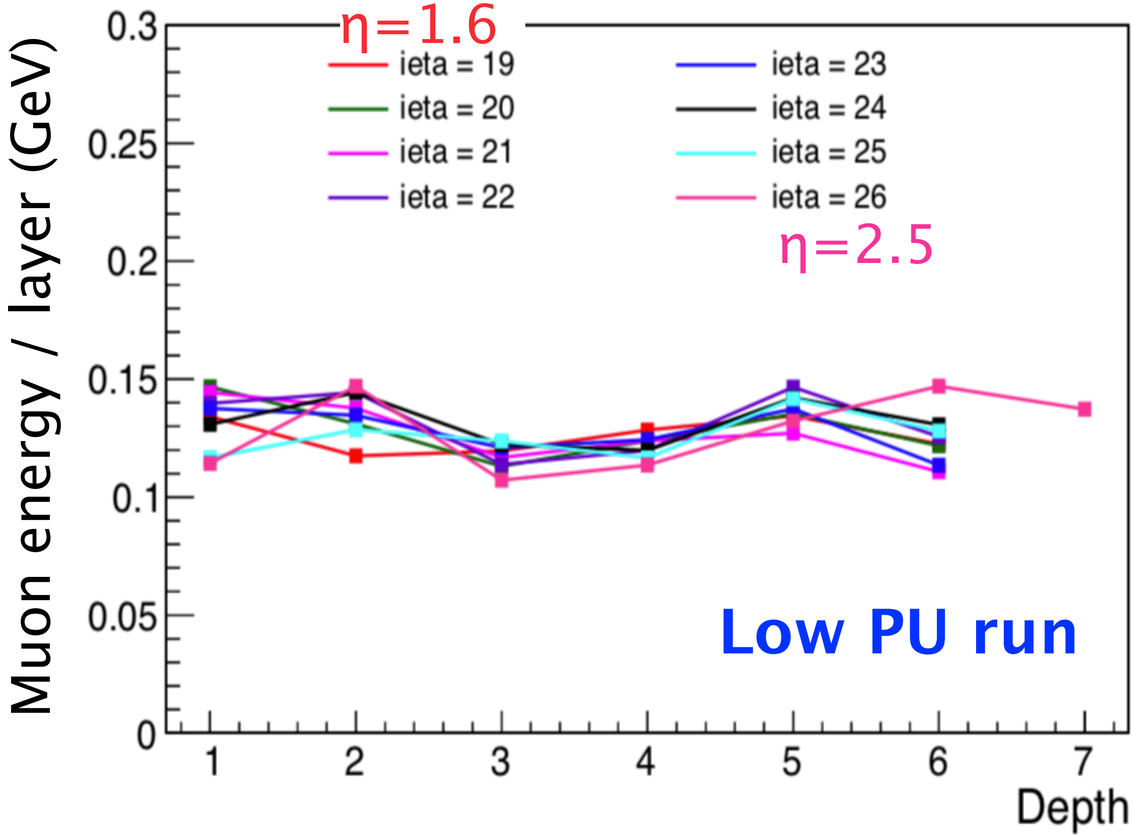
- As presented at last LHCC meeting, early 2018 data will be reprocessed in Fall 2018 with **corrections** based on Z➔ee and W➔ev for use in 2019 winter confs.
- Corrections are ready and yield per mille variations in Z➔ee mass:



HCAL depth segmentation

- HCAL endcap upgraded with **new photosensors and 5 gbps readout** in YETS 2017-18.
    - One benefit is **longitudinal segmentation,** which will allow more precise calibration of radiation damage to scintillator.

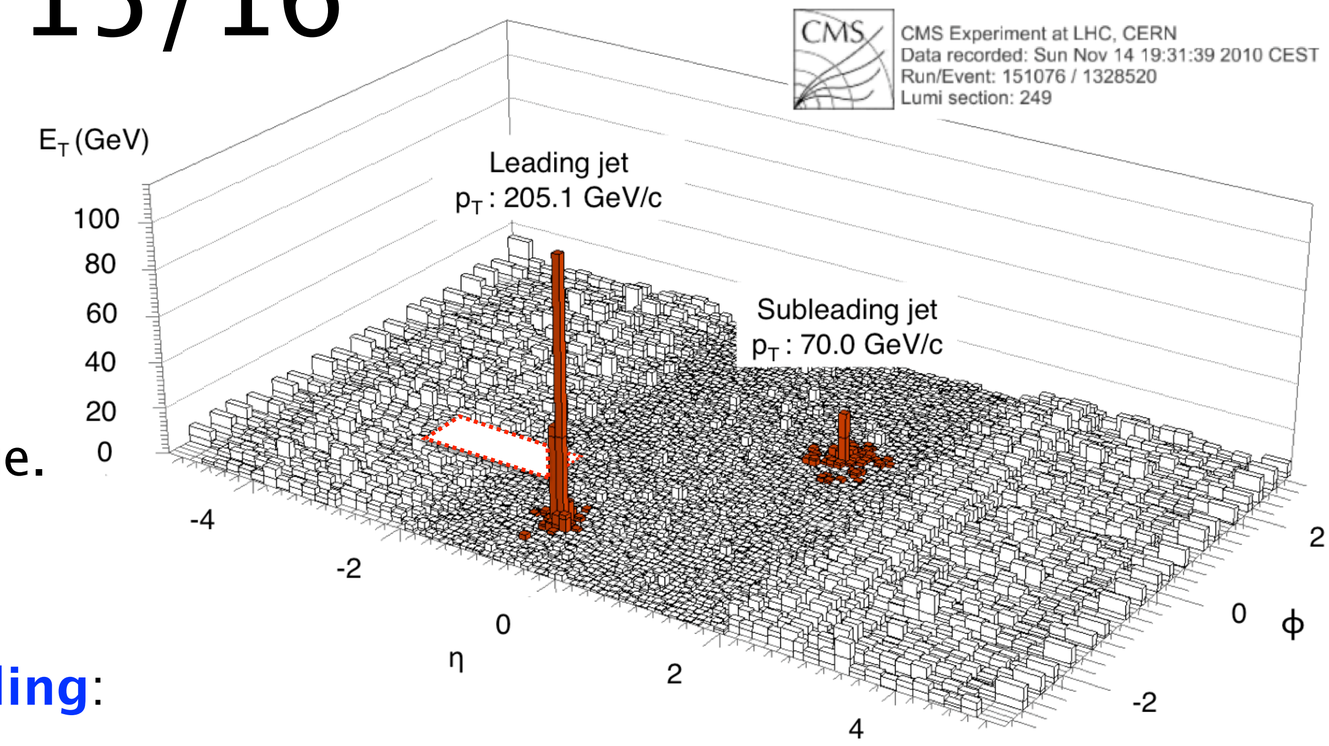




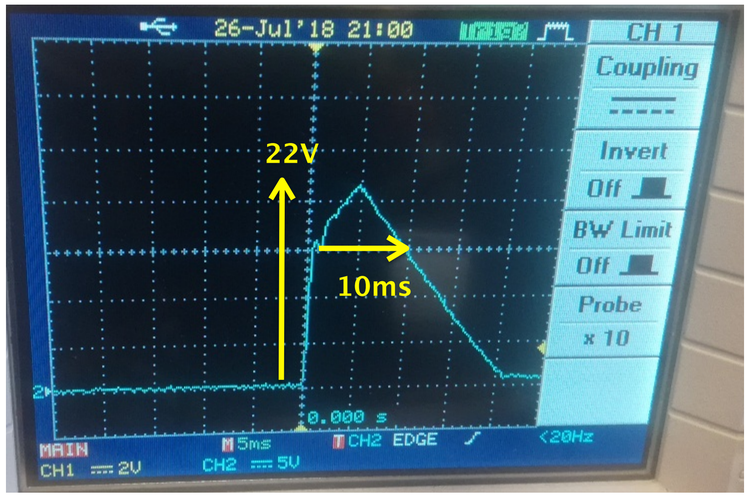
- New **calibration of longitudinal segments** with muons in low PU runs improves understanding of longitudinal calibration.

HCAL endcap sectors 15/16

- Following power interlock on June 30, **two endcap sectors are not functional**.
  - **40° in one endcap, 2% of HCAL** coverage.



- Five-week campaign led to **full understanding**:
  - On power up after interlock, 10V **power supply** (PS) **unable to read internal calibration**.
  - PS sent 22V/10ms pulse to detector
    - exceeded its own 14V max rating
    - **damaged on-detector components** with 12V rating.



HCAL endcap sectors 15/16 (cont'd)

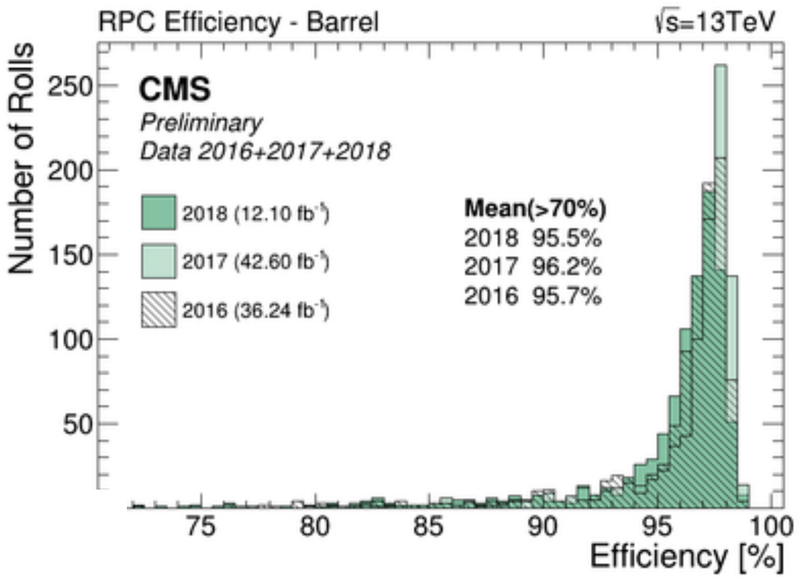
- HCAL **installed secondary safety system** to mitigate risk of damage from potential future transients.

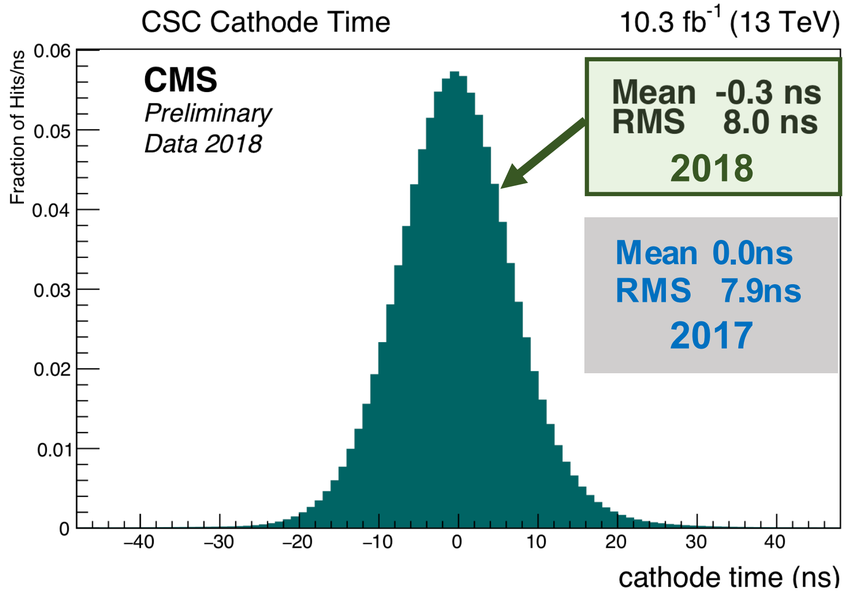
- **PS manufacturer** working to understand and address
  - why the PS fails to read its calibration
  - why the PS sends high voltage when the calibration fails

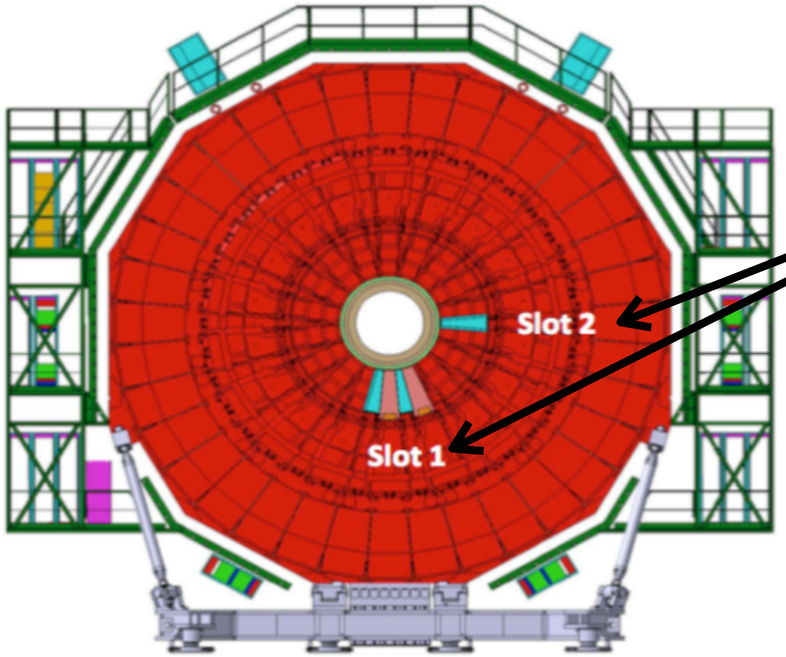
- **Physics impact:**
  - trigger rates are OK
  - effect on MET resolution is small but measureable
  - PF reconstruction reduces impact of loss.
  - Additional modifications of reconstruction in progress to minimize impact.

Muon performance

- Muon performance in 2018 remains stable and excellent.
- **DT DAQ upgraded** in 2018 has run without dead time or data loss.



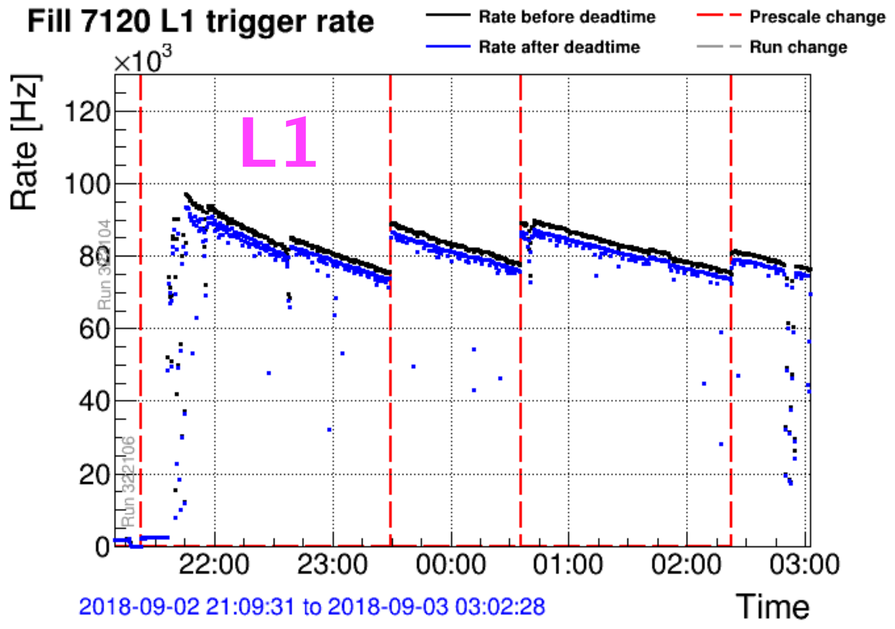


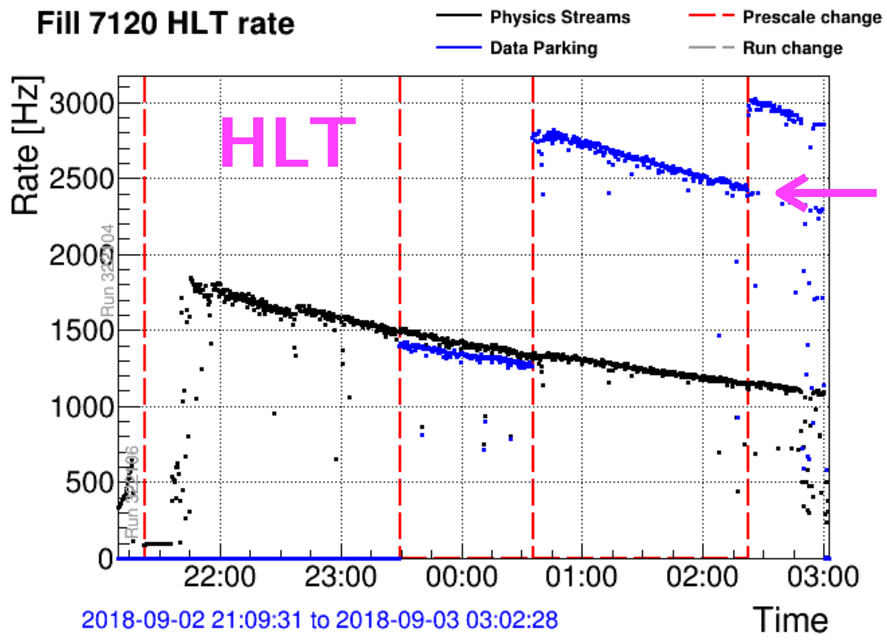


- 10 Triple-GEM detectors installed in negative endcap in EYETS 2016-17
  - commissioned in 2017
  - included in **global CMS DAQ in summer 2018**
  - **Collected 14 fb^{-1}** so far - data are being analyzed

L1+HLT Trigger performance

- Smooth running – only minor updates to trigger have been implemented.
- **L1 trigger** rate reaching **95 kHz** at 2×10^{34} cm^{-2} s^{-1}
  - We been able to lower L1 thresholds for single Egamma, MET, di-tau to improve HLT turn-on curves.
- **HLT** rate reaching **1.8 kHz** at 2×10^{34} cm^{-2} s^{-1} – averaging 1.1 kHz over 12h fill
- We are **"parking" an unbiased sample of B mesons** for future analysis
  - rates reach 5 kHz, so far we have recorded over 9B events.

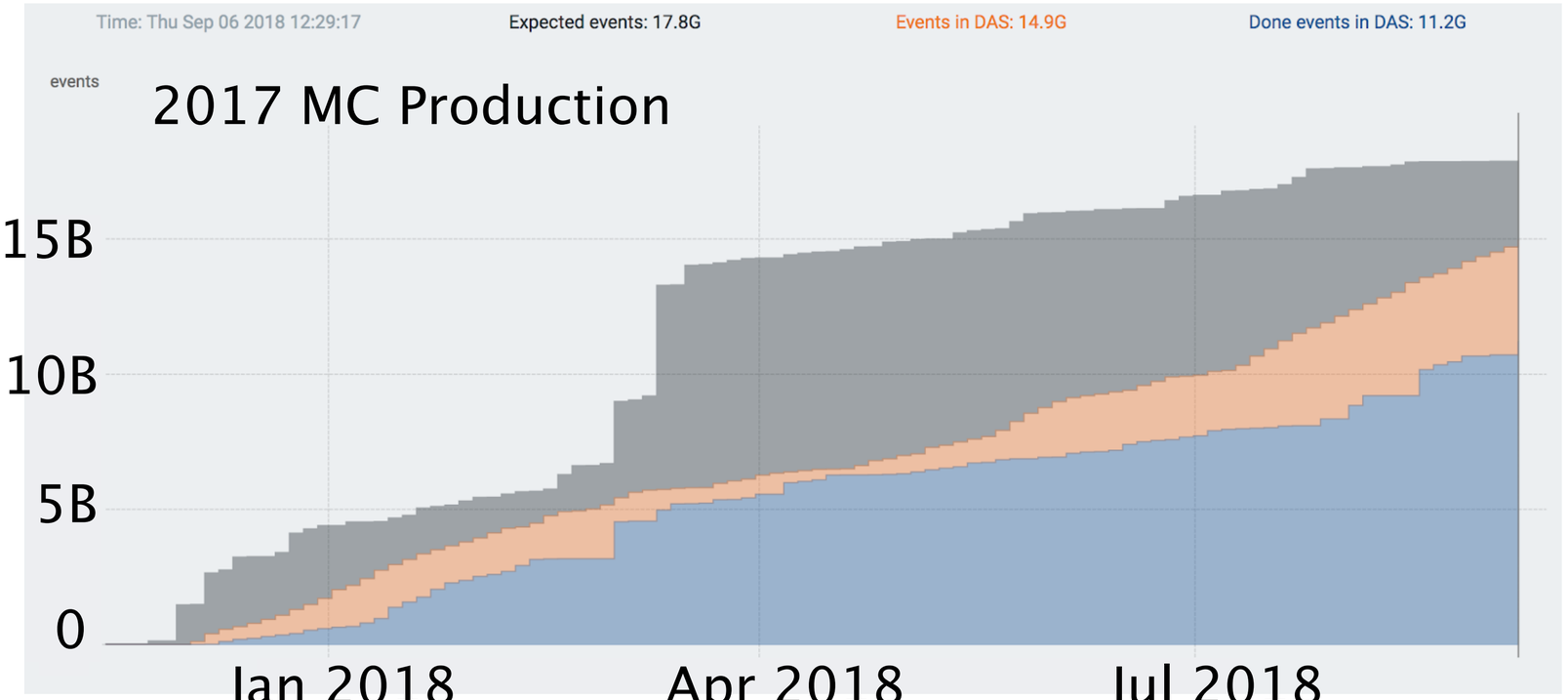


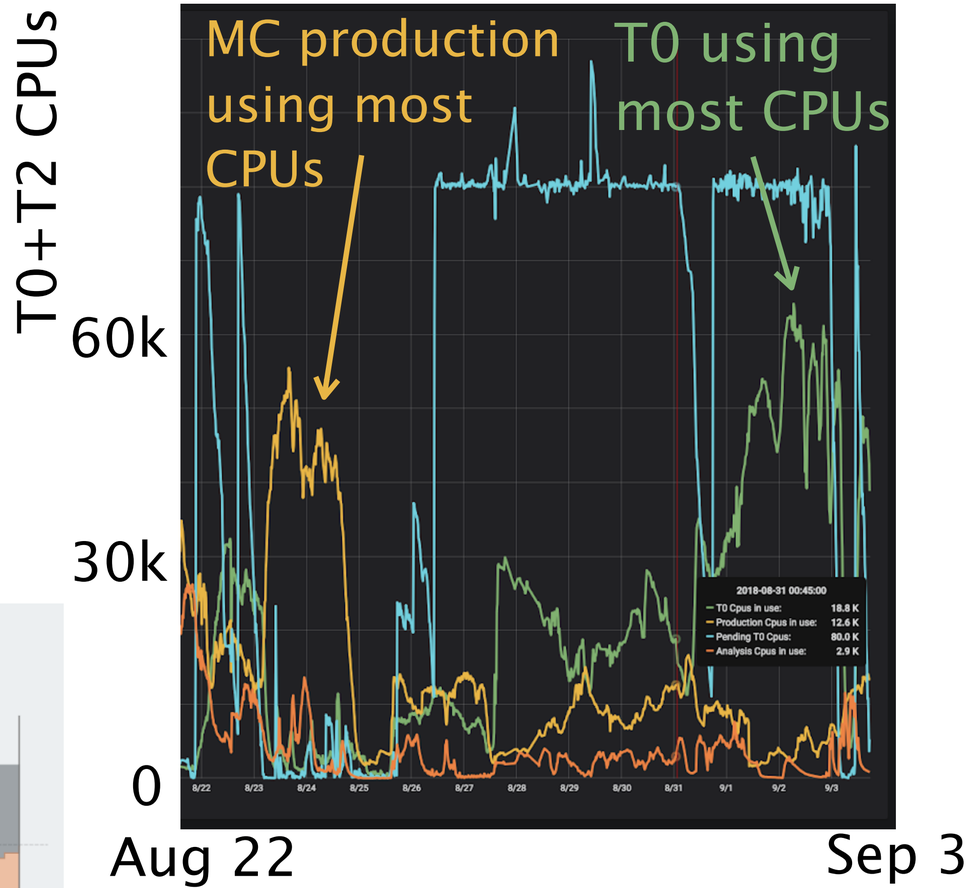


← data parking

Computing

- CMS has gained significant flexibility by **combining CERN T0 and T2 resources**
- Produced **15B 2017 MC** events
  - originally planned 12B + opportunistic additional





- Next step: Massive production of **2018 MC** for Winter conferences 2019.

Physics results

Publications

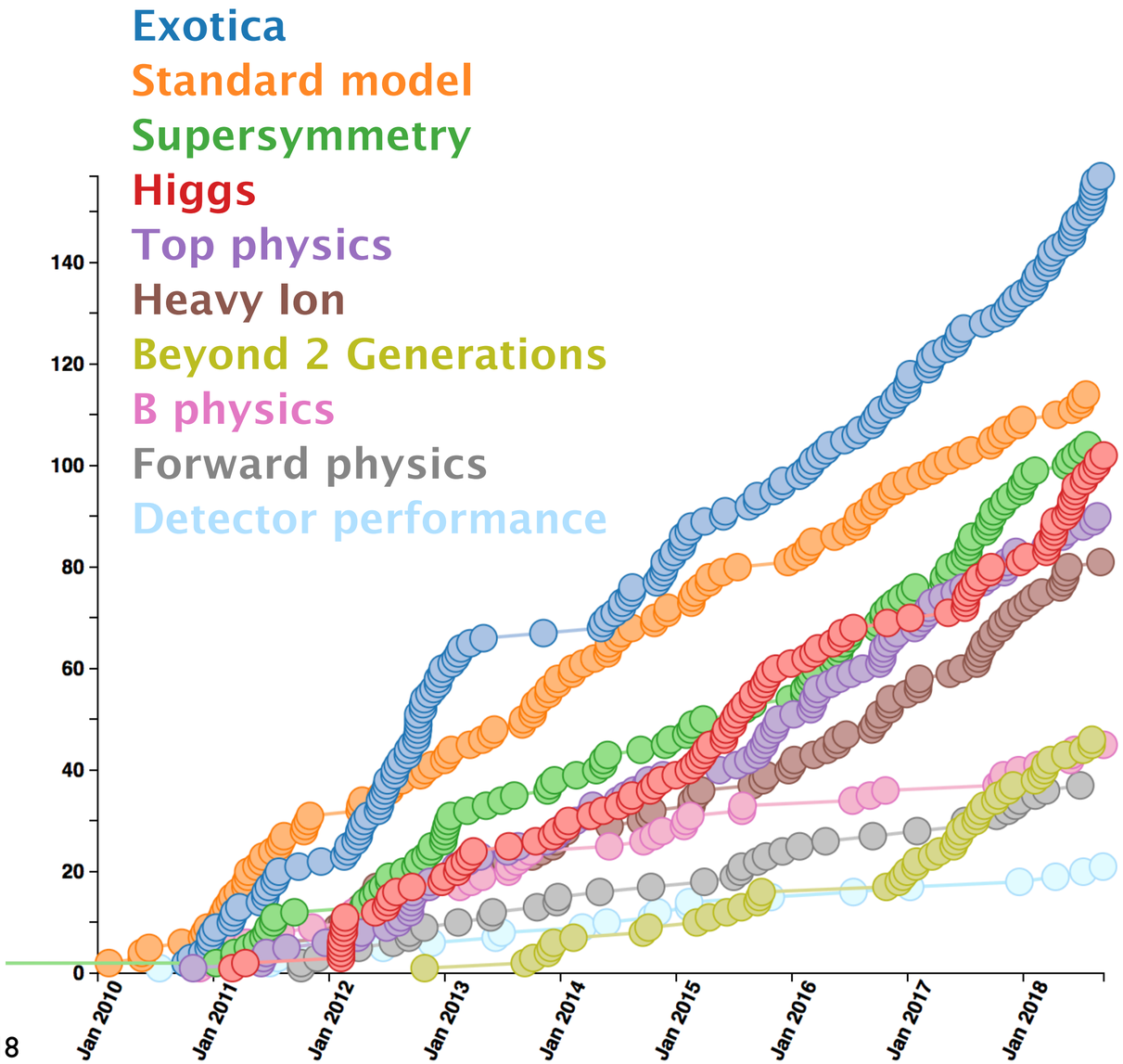
http://cms-results.web.cern.ch/cms-results/public-results/publications/CMS/index.html

- CMS has submitted 796 papers in the past 92 months since Jan 2010.
  8.7/month, 104/year
  - plus additional 25 papers based on non-collision data

No sign of slowing!

- 45 papers since last LHCC
  13.5/month
- 144 papers in past year
  12/month

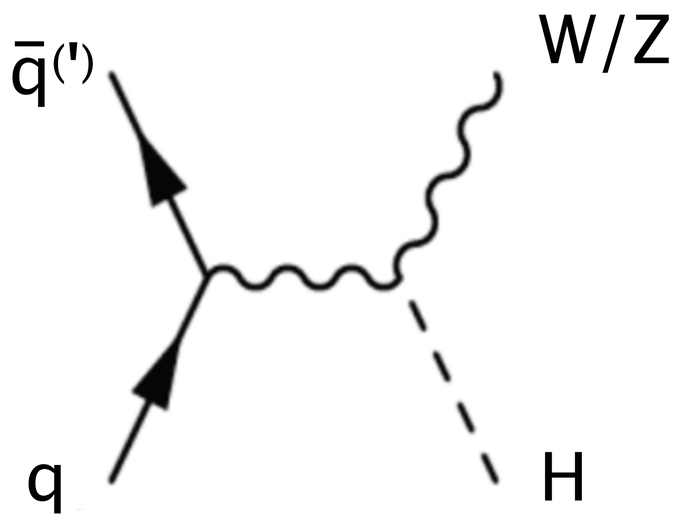
- Recent highlight :
  Observation of Higgs bosons decay to b quarks accepted by PRL

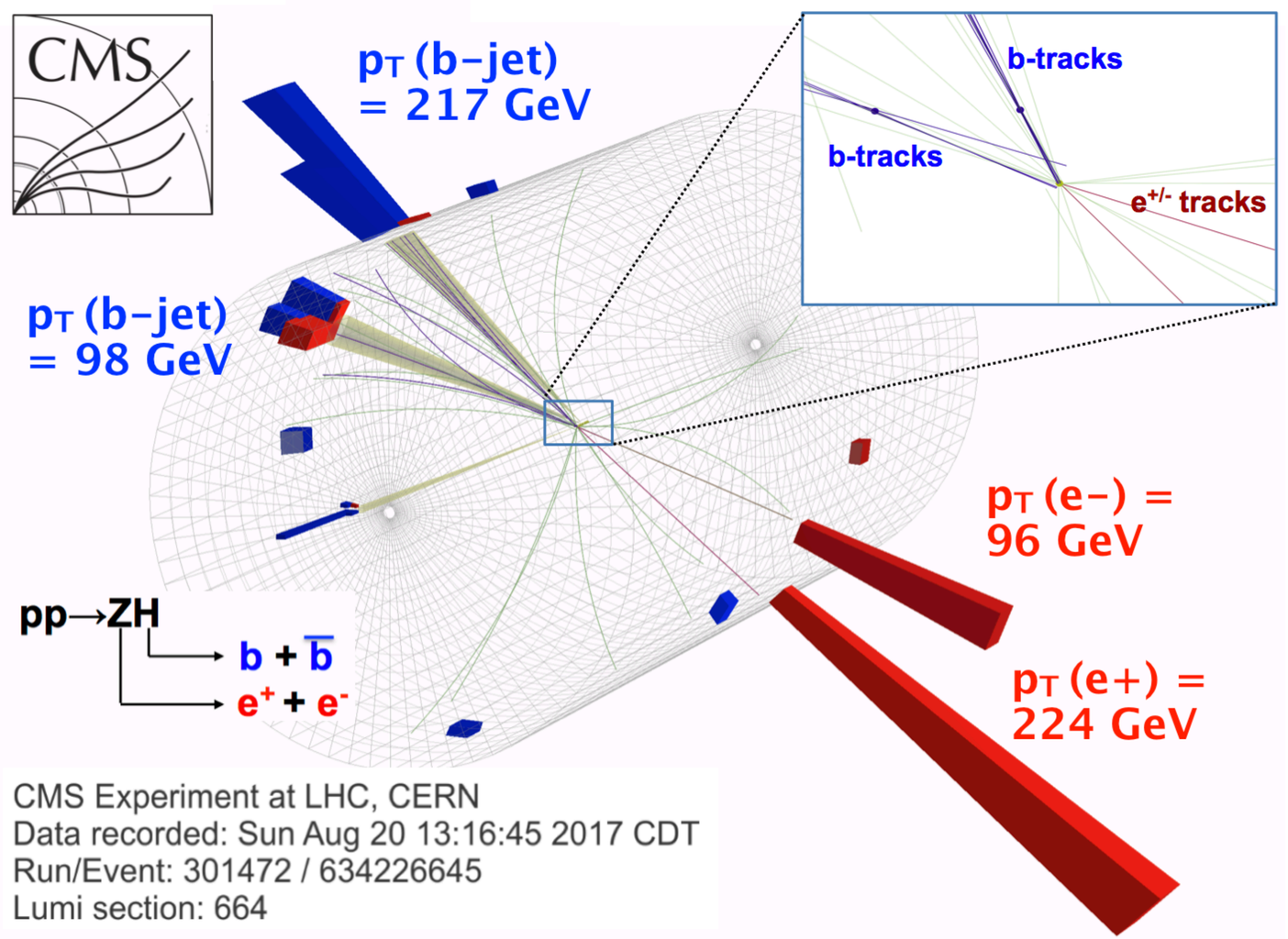


Higgs couplings to heavy fermions

HIG-18-016, arXiv:1808.08242, accepted PRL

Channel	Date
H→ττ	May 2017
pp→ttH	Apr 2018
H→bb, pp→VH	**Aug 2018**





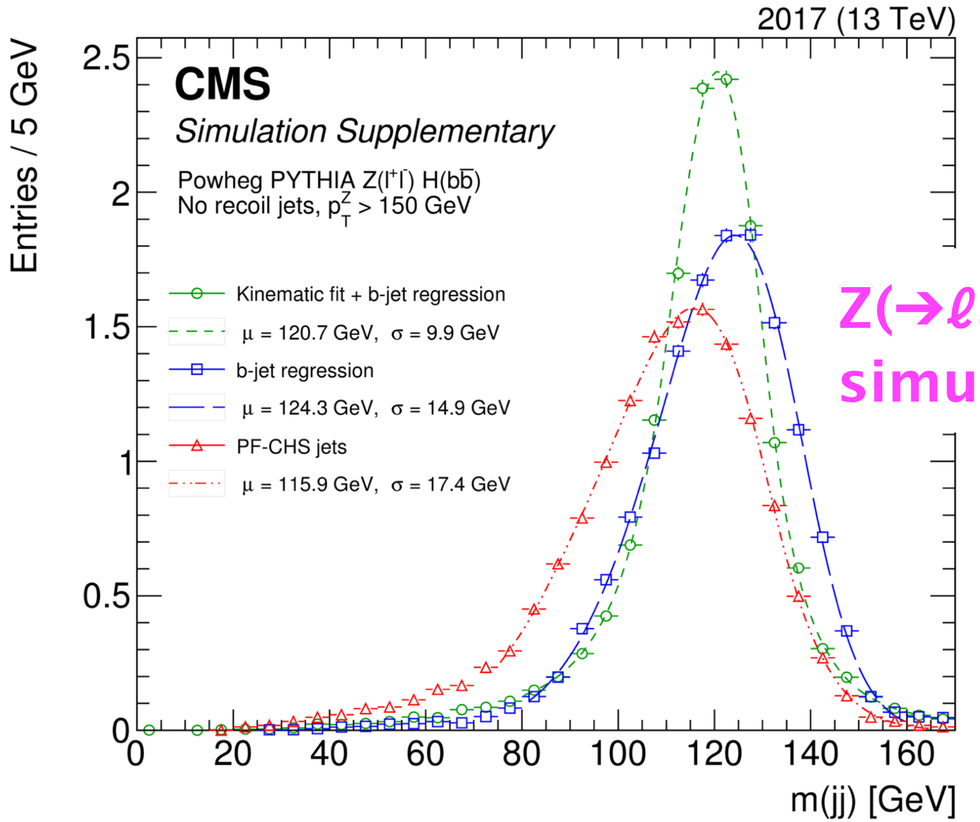
VH→bb in 2017 data

HIG-18-016, arXiv:1808.08242, accepted PRL

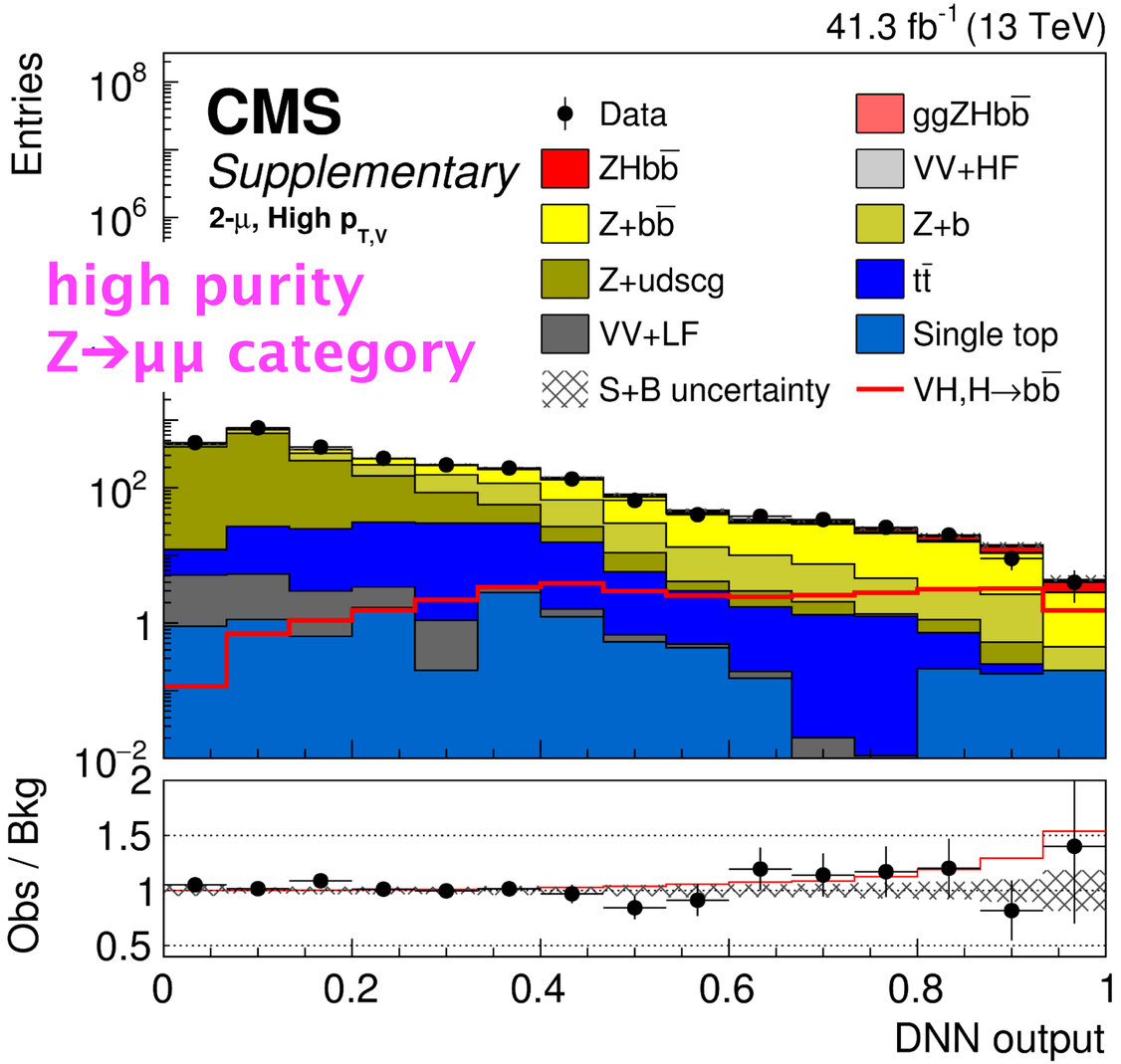
Improved sensitivity by 5-10% w.r.t. 2016 analysis

- new pixel detector, DNN b-tagger, b-jet energy regression, kinematic fit in 2ℓ channel

Signal/background discrimination w/ DNN based on: b-jet properties, jet kinematics, event topology



Z(→$\ell\ell$) H(→bb) simulation

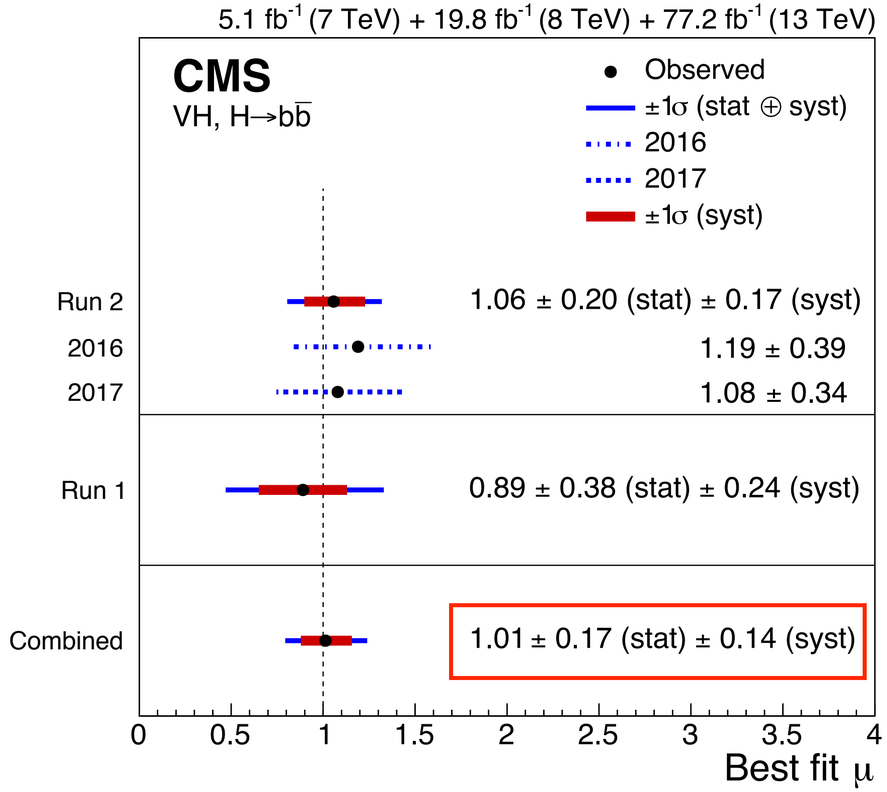


high purity Z→μμ category

Results and combinations

HIG-18-016, arXiv:1808.08242, accepted PRL

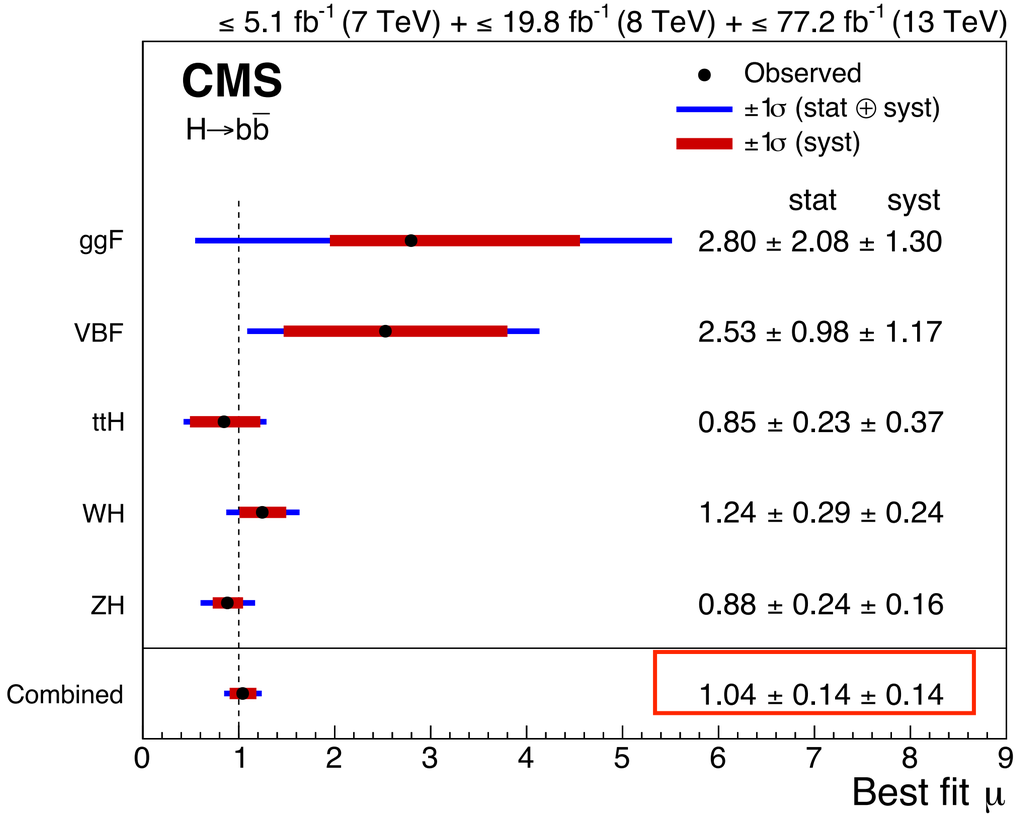
Combine 2017 VH→bb with 2016+Run1



Significance (σ)

Data set	Expected	Observed	Signal strength
2017	3.1	3.3	1.08 ± 0.34
Run 2 (2016+2017)	4.2	4.4	1.06 ± 0.26
Run 1 + Run 2	4.9	4.8	1.01 ± 0.23

Combine VH with other production modes



Significance

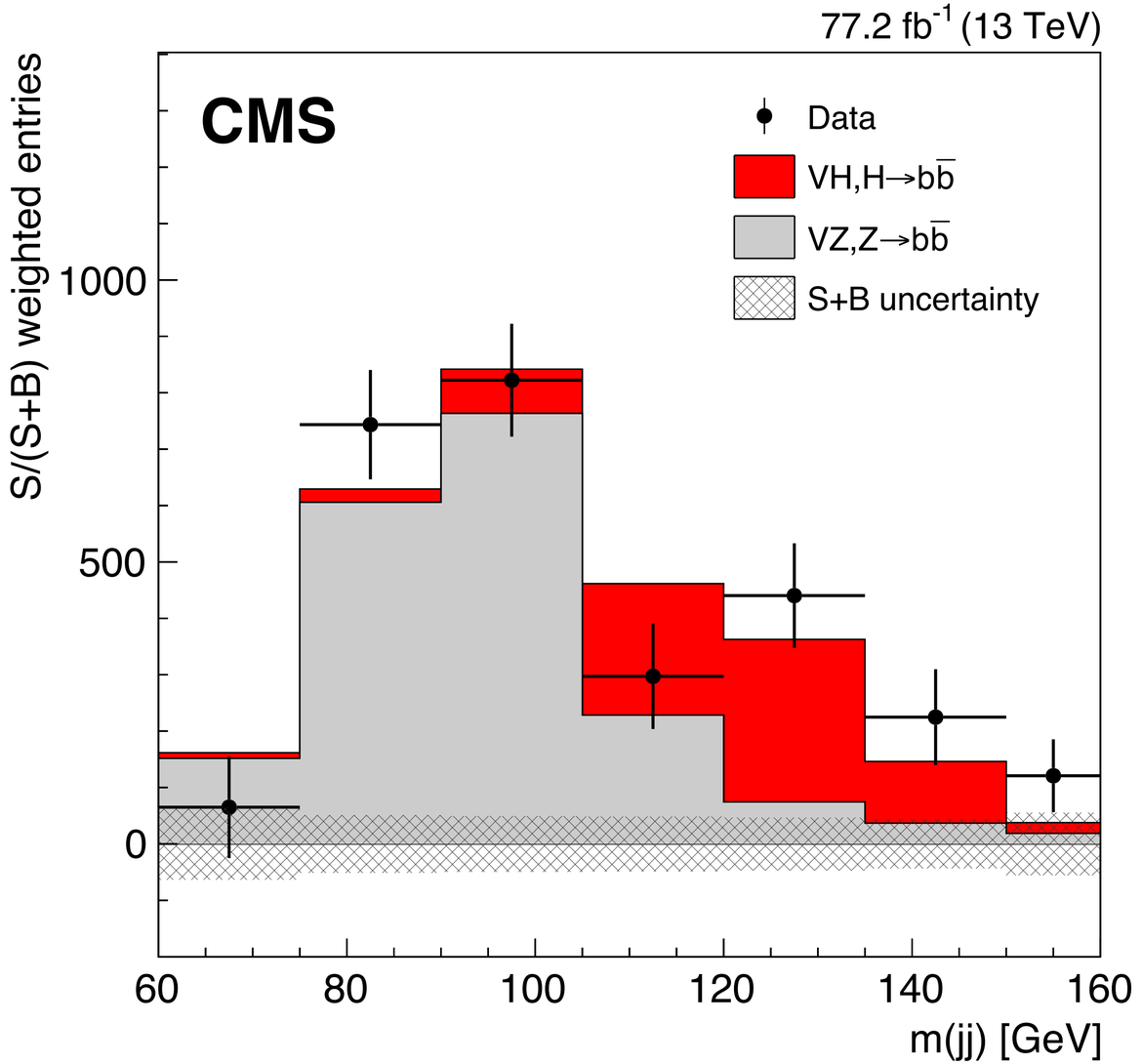
5.5σ expected

5.6σ observed

bb mass distribution

HIG-18-016,
arXiv:1808.08242,
accepted PRL

- Instead of DNN output, analyze M(bb) to visualize signal.
- Signal strengths compatible with main analysis.



Observation of $\chi_{b1}(3P)$ & $\chi_{b2}(3P)$

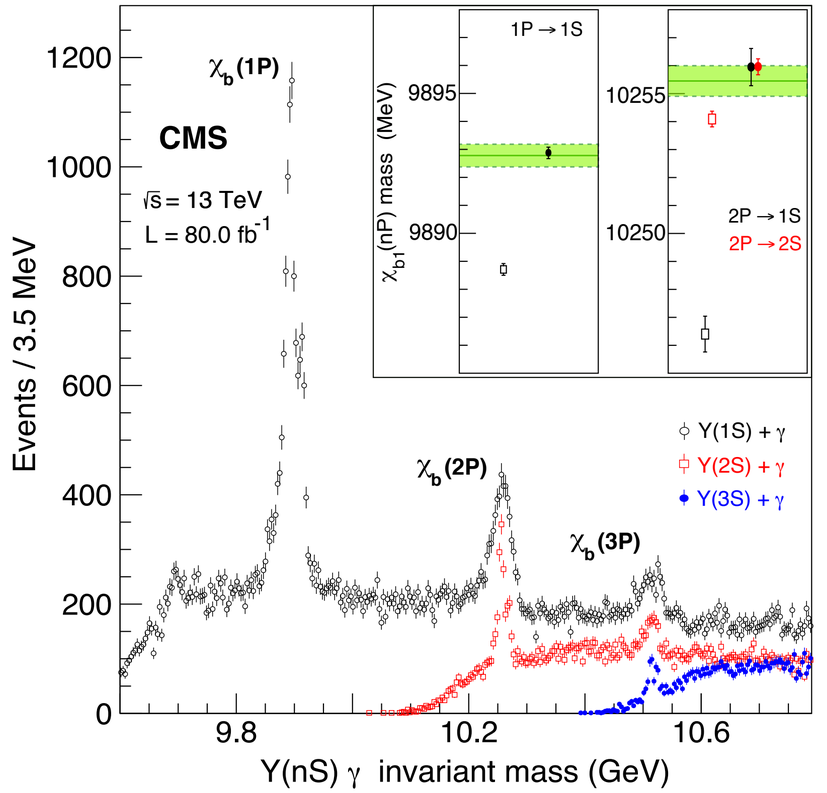
BPH-17-008, arXiv:1805.11192, PRL 121 (2018) 09200

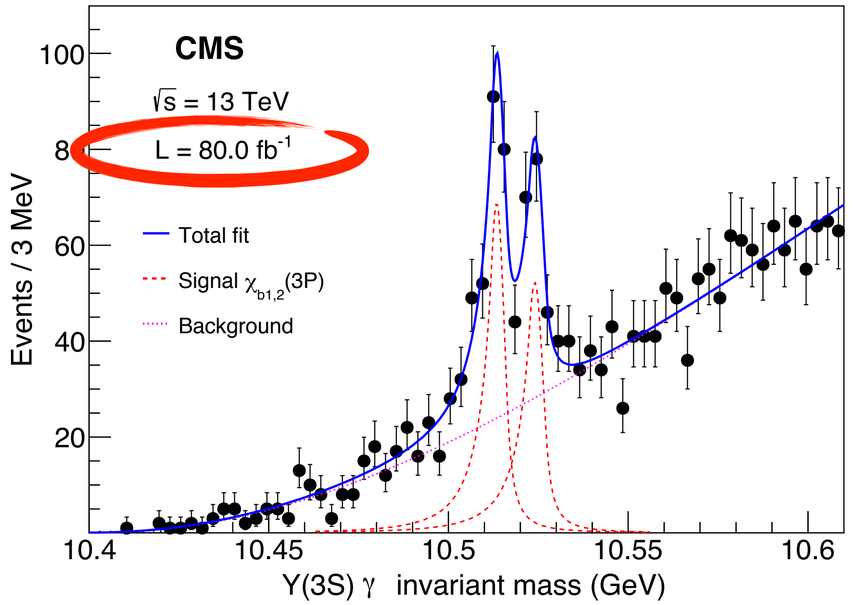
- ATLAS, D0, LHCb observe peak at ~10.5 GeV consistent with $\chi_b(3P)$ in $\Upsilon(nS) + \gamma$
- Must explore structure to understand nature: $\chi_{b1}(3P)$, $\chi_{b2}(3P)$, X_b analog of X(3872), mixture of these [1]?
- Reconstruct mass structure in $\chi_b(3P)$ ➔ ($\Upsilon(3S)$➔μμ)+γ, where γ converts in tracker.
  - **$\Delta M(\chi_{b1}, \chi_{b2})$ expected to be 8–18 MeV**
  - CMS **mass resolution = 2.18 ± 0.32 MeV**

Results:

- ΔM = 10.60 ± 0.64 (stat) ± 0.17 (syst) MeV
- $M(\chi_{b1}(3P))$ = 10513.42± 0.41 ± 0.18 MeV
- $M(\chi_{b2}(3P))$ = 10524.02 ± 0.57 (stat) ± 0.18 (syst) MeV

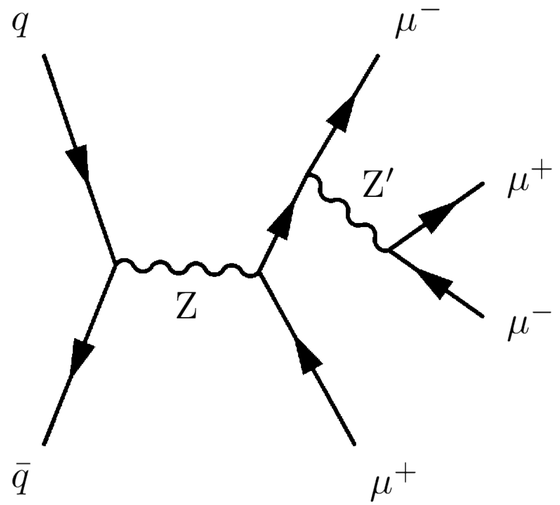
[1] Karliner, Rosner, arXiv:1410.7729





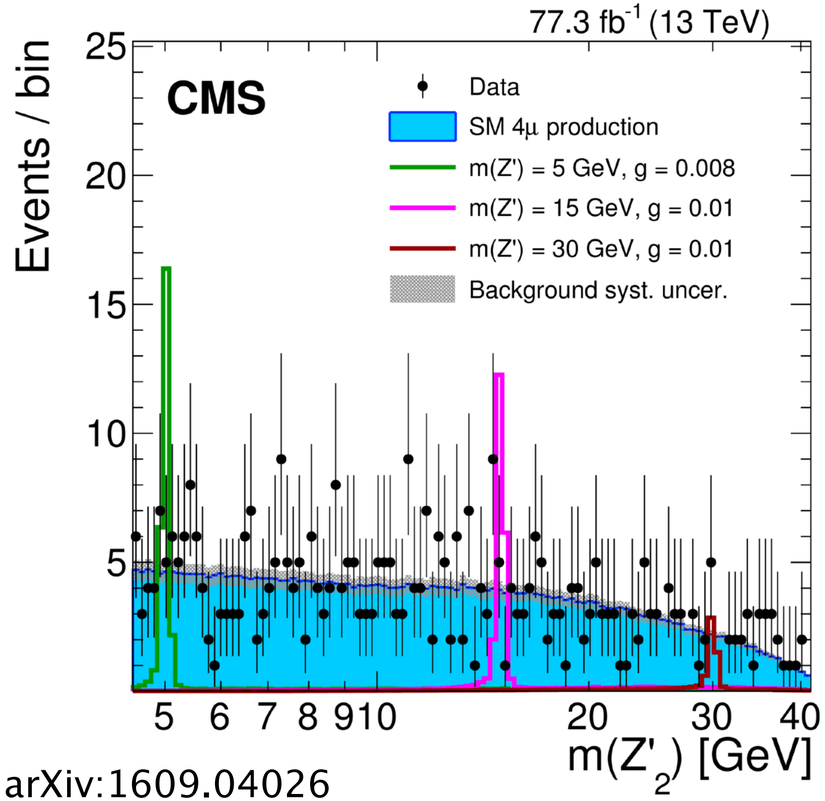
Search for low mass Z' in Z→4ℓ

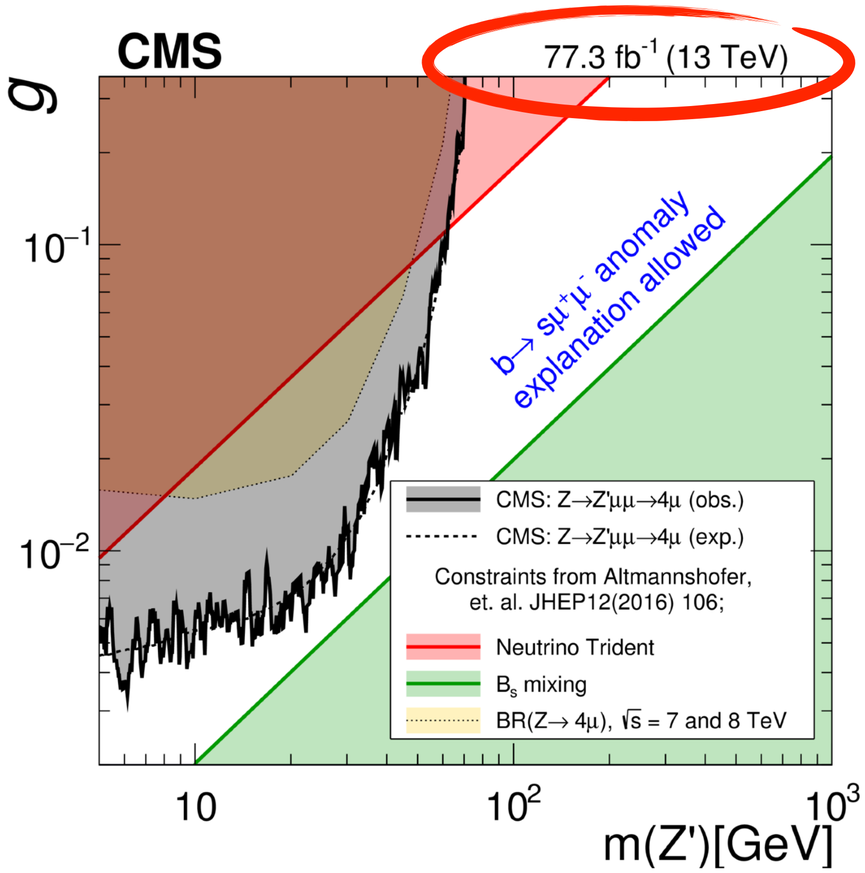
EXO-18-008
arXiv:1808.03684
submitted PLB



- Use incredible LHC luminosity to probe smaller couplings.

- Light Z' associated with $L_\mu - L_\tau$ gauge symmetry could explain R(K*) [1] and muon g-2 [2] anomalies.



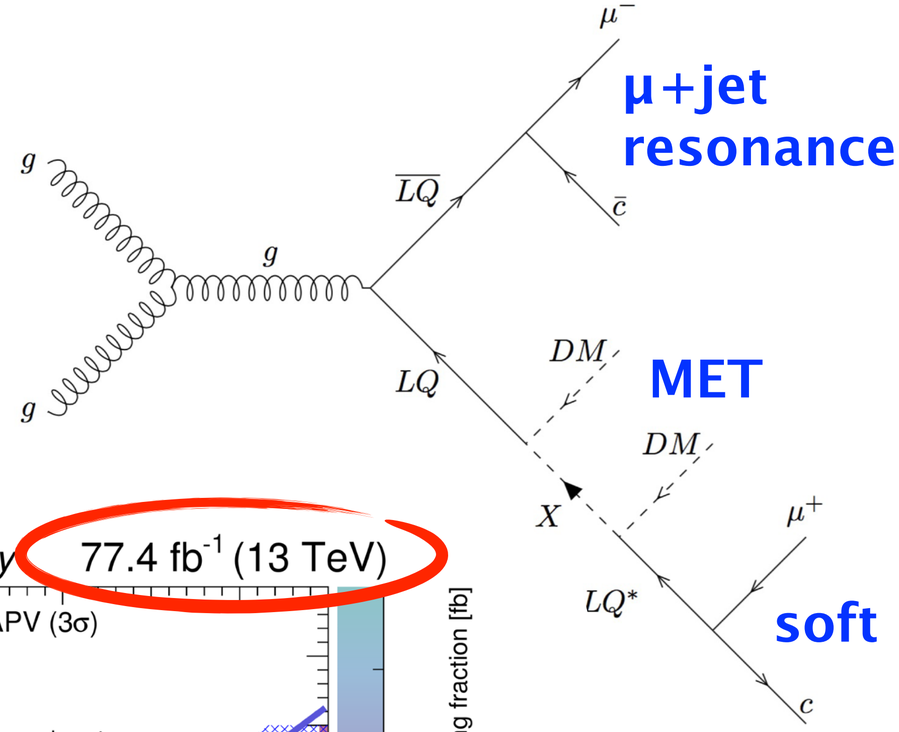


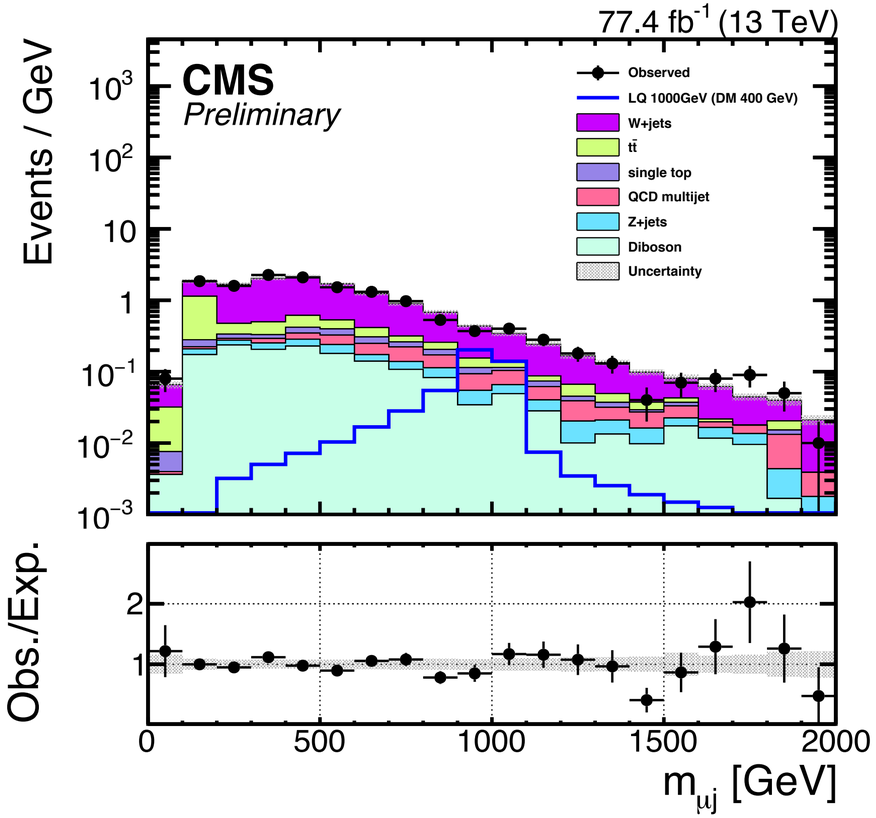
[1] Altmannshofer, Gori, Profumo, Queiroz; arXiv:1609.04026
[2] K. Harigaya et al.; arXiv:1311.0870

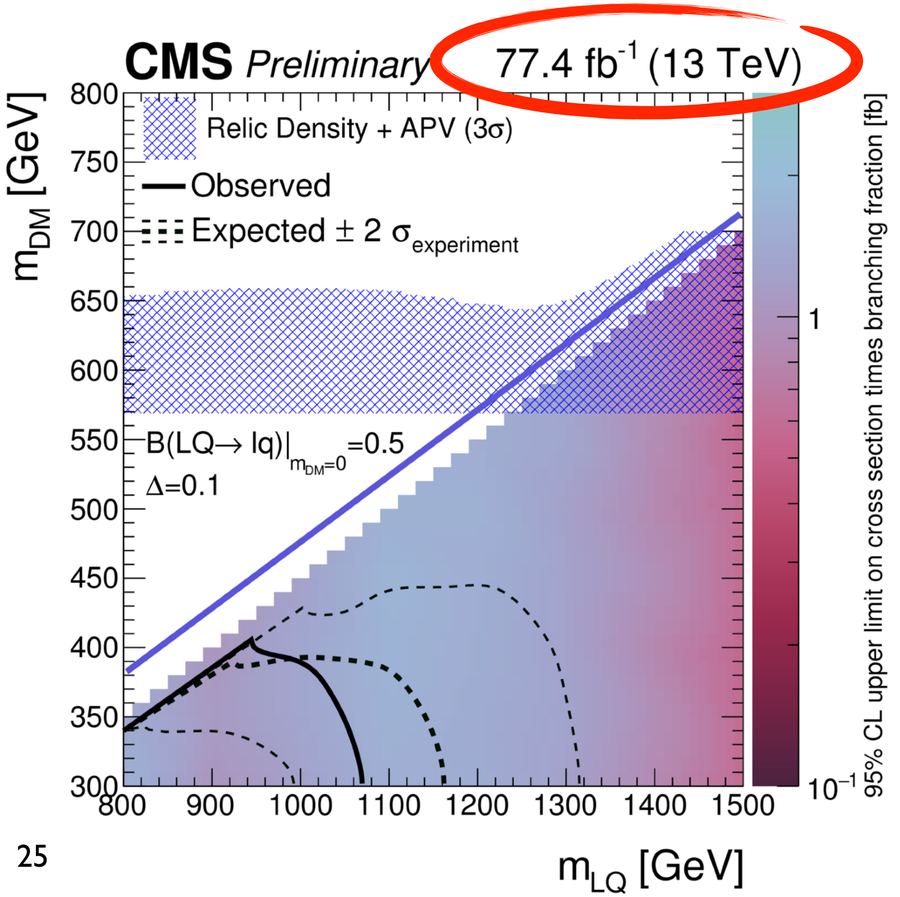
Search for LQ+DM

EXO-17-015

- CMS has extensive program of searches for leptoquarks (LQ).
- Dark matter (DM) co-annihilation with new particles can lead to previously unexplored final states [1].







[1] Coannihilation codex : Baker et al., arXiv:1510.03434

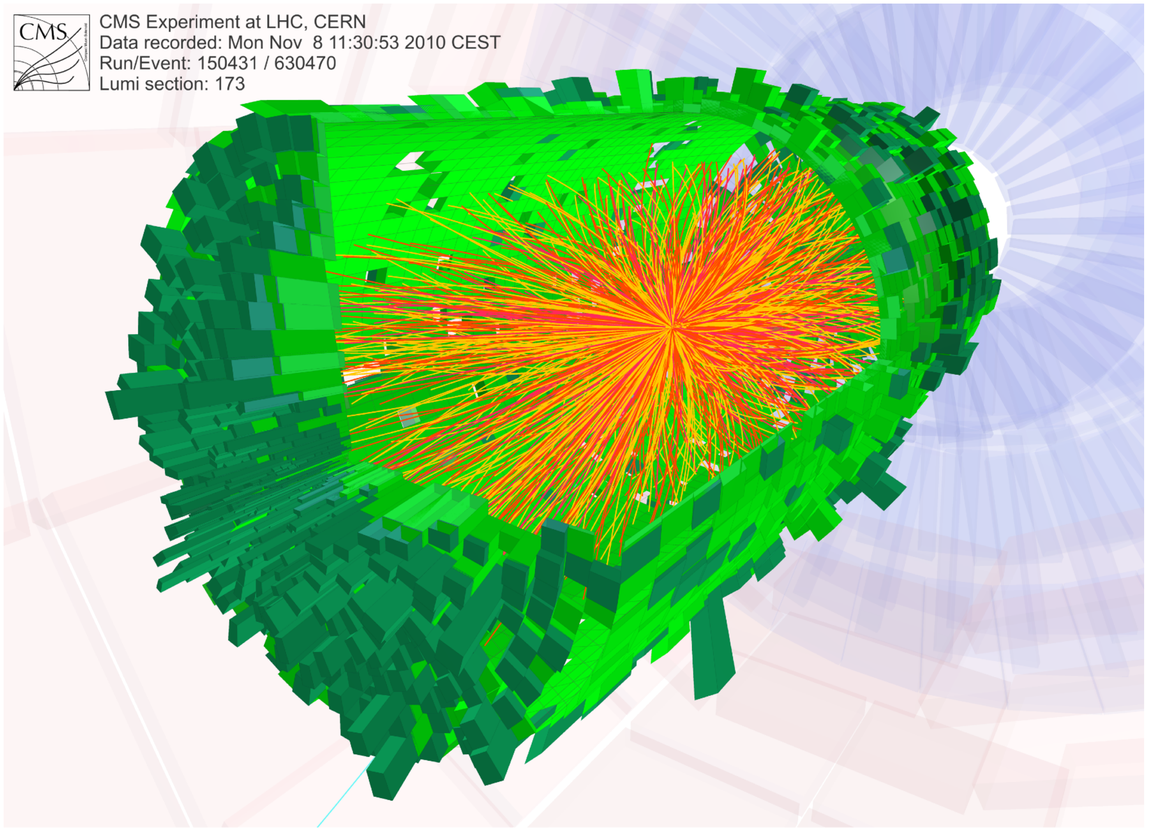
Preparing for 2018 Heavy Ion Run

- At the last LHCC meeting, we showed highlights of extensive results submitted to Quark Matter 2018 conference:

  https://cms.cern/news/quark-matter-2018

- Now **preparing for 2018 Heavy Ion** (HI) run.
  - Goal is 1.2–1.8 nb^{-1} + large minimum bias sample.
  - Study new phase space for energy loss in medium.

- **Next week will perform "dress rehearsal"**:
  - Run with HI-specific firmware for detectors, HI-specific online software, etc.



Plans for LS2

HCAL barrel (last phase 1!): install SiPM + QIE11-based 5 gbps readout

Pixel detector: replace barrel layer 1 and all DCDC convertors

Muon system (already phase 2!):

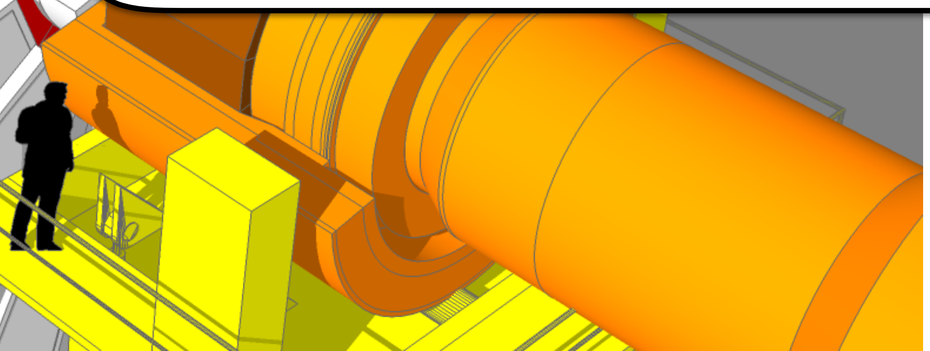
- Install GEMs in high rad region to maintain performance
- Upgrade CSC FEE for HL-LHC trigger rates

Keep **strip tracker** cold to avoid reverse annealing

Install new **beam pipe** for phase 2

Coarse Schedule

- 2019 : Muon & HCAL interleaved
- 2020 : beam pipe installation, then pixel installation



Readiness for LS2

HCAL barrel :

- All 14k SiPMs + 900 readout cards produced and tested.
- ample contingency for installation based on endcap experience in YETS 2017-18

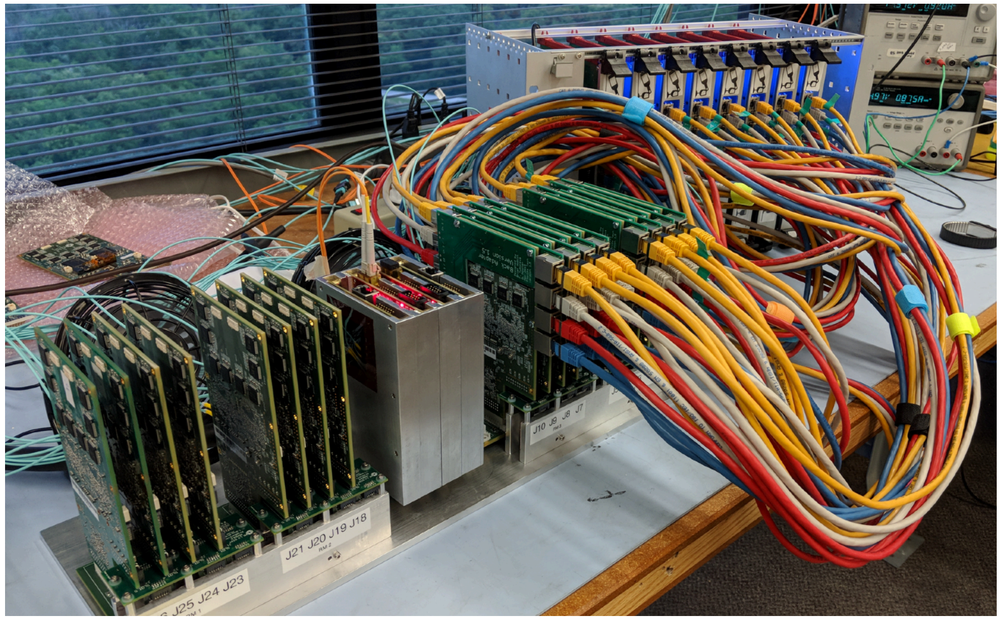
Muon system:

- CSC FEE production on schedule
- GEM production also on schedule with 99% of 144 assembled, 70% validated

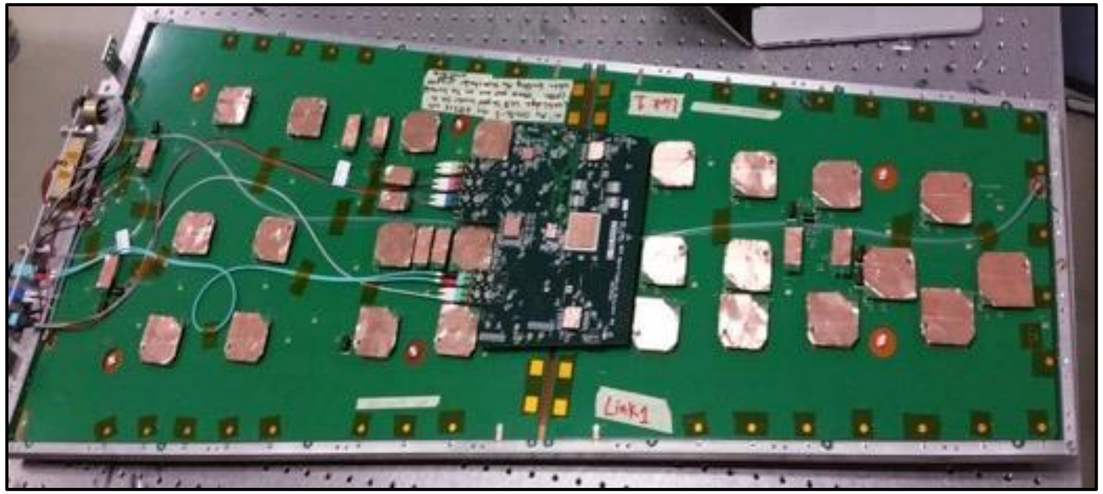
Pixel detector: Preparing final submission of ASIC, which is expected to be ready in mid-2019

Much to be done during LS2, but we have a workable plan!

HCAL readout card calibration at FNAL



GEM chamber with final electronics

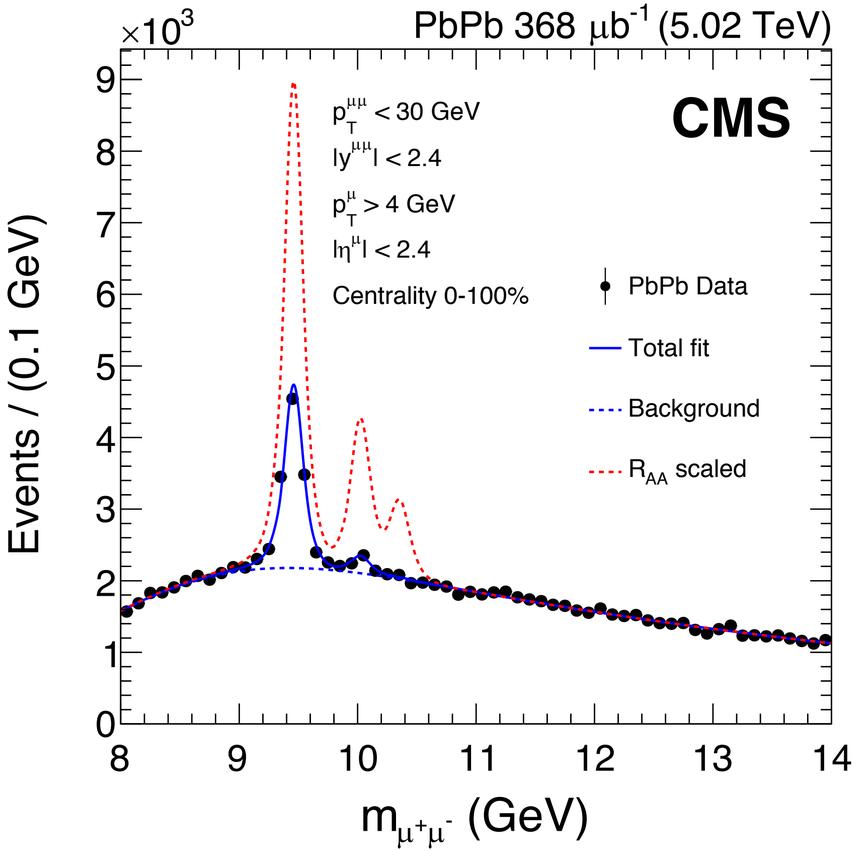
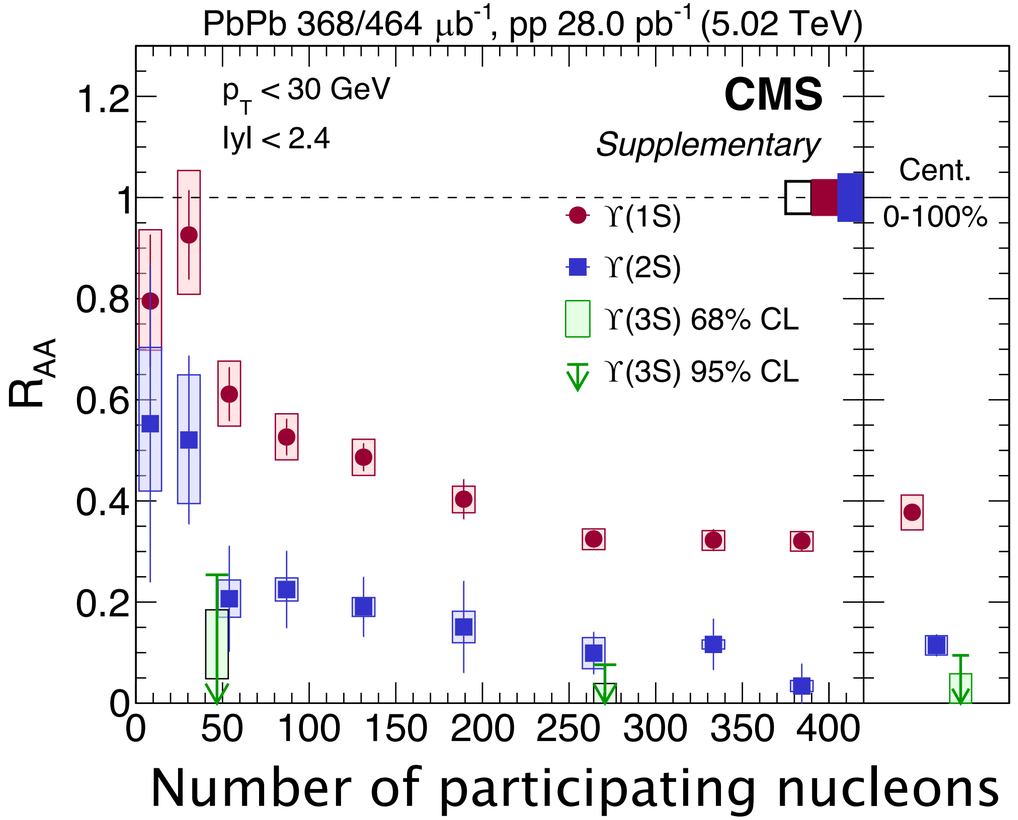


Summary

- **CMS detector** is performing well with **almost 95% efficiency** for data recording.
- High rate of **high quality publications** : **144 in past 12 months**.
- We have **achievable plan for LS2.**
- Preparations for **LS2 upgrades are on schedule.**

Additional material

Bottomonia melting in PbPb collisions

- **Expect $q\bar{q}$ production suppression** in nuclear medium produced in PbPb collisions
  - $b\bar{b}$ less affected by recombination with free quarks than $c\bar{c}$.
- Measure **R_{AA} ~ ratio of $b\bar{b}$ yield measured in PbPb to pp**.
- Expect R_{AA} to follow Y(3S) > Y(2S) > Y(1S) binding energy hierarchy.

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arXiv:1805.09215