# Recent results from CMS experiment

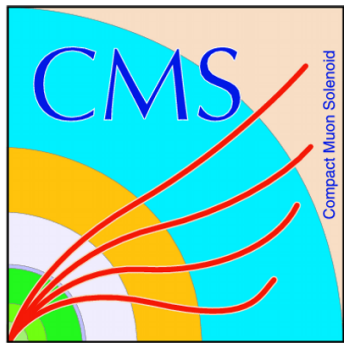
**Javier Murillo** - On Behalf of the CMS collaboration

XXXI Reunión Anual de la División de
Partículas y Campos de la SMF

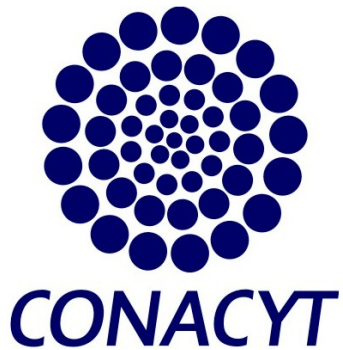
Centro de Investigación y de Estudios Avanzados

Ciudad de México

May 23, 2017



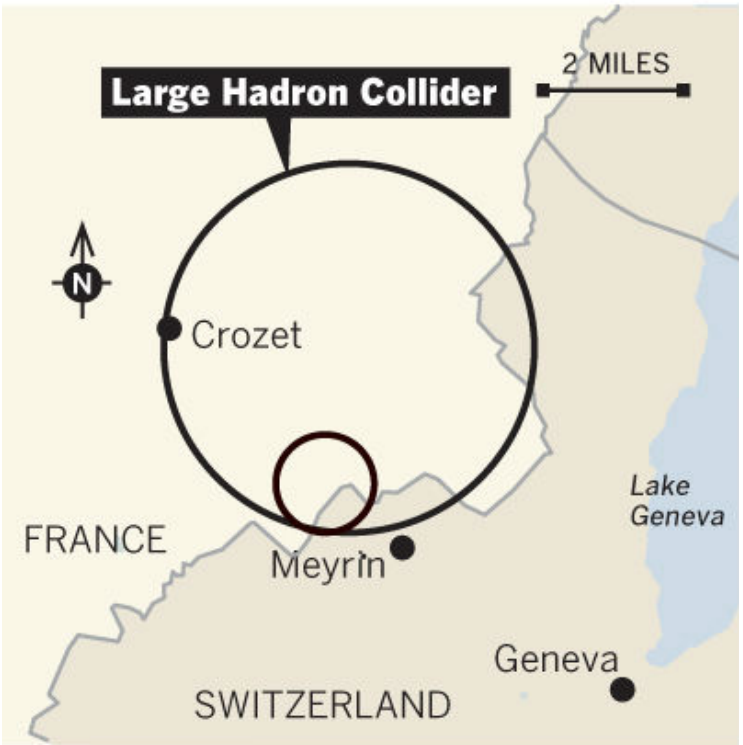


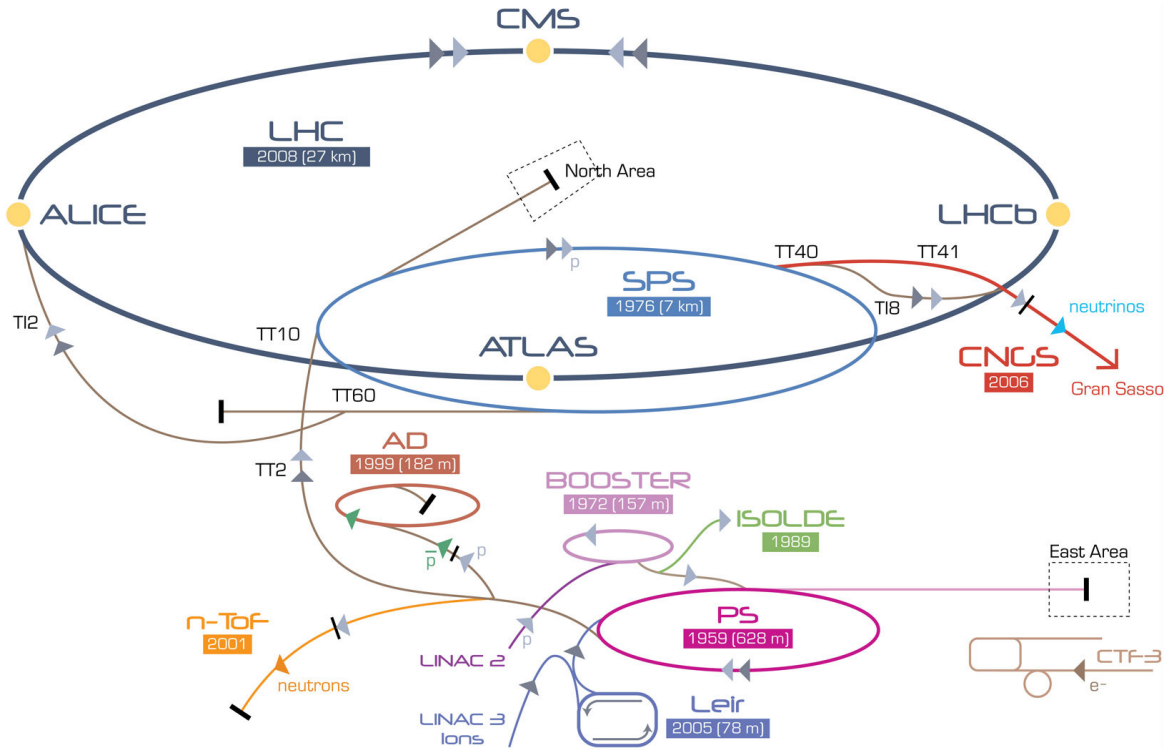
# Overview

# LHC Timeline

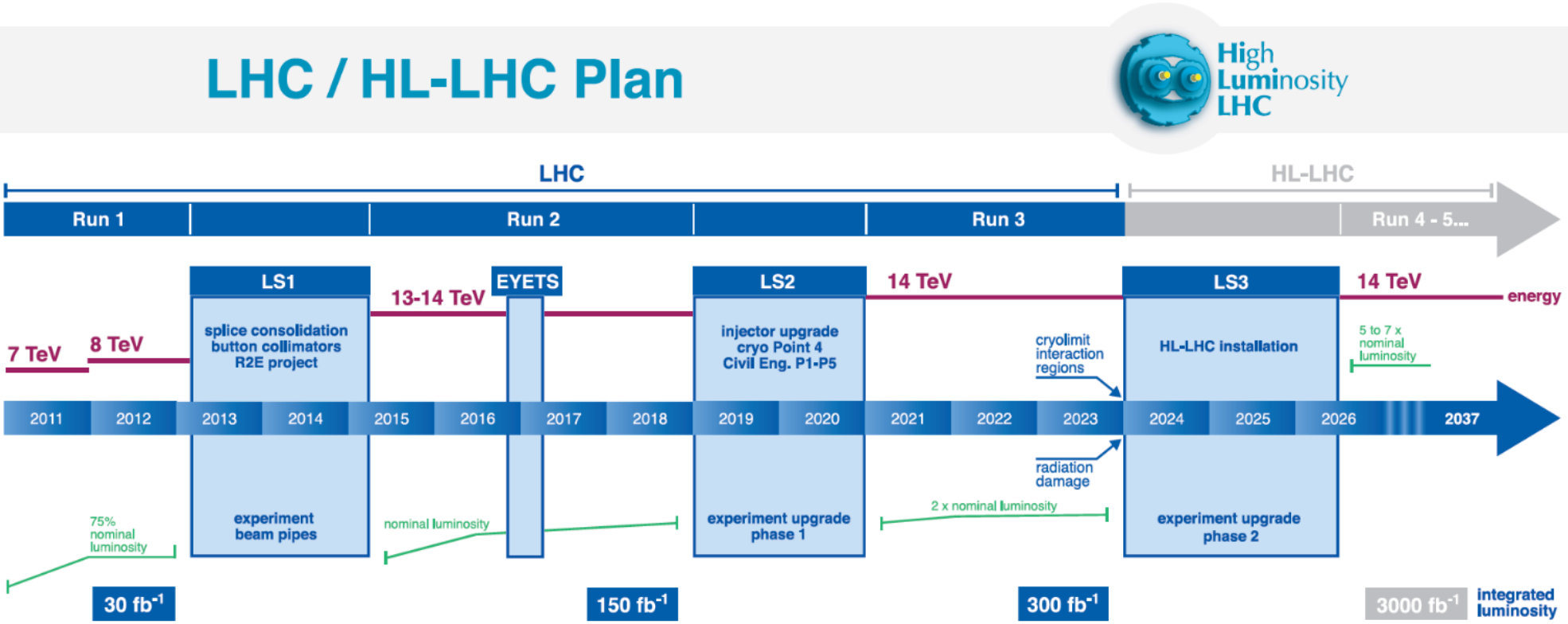
# Acceleration complex at CERN

- The LHC extends to both sides of the border between France and Switzerland
- Proton bunches are produced, split and accelerated sequentially through different accelerators before injection into the LHC
- Ongoing Run 2 at 13 TeV



- Main goal: Identify Physics beyond the Standard Model
- Run-II: 2015 - 2018 / LS2: From July 2018, will last $\sim$ 21 months
- Run-III: 2021 - 2023 / LS3: From 2023, will last $\sim$ 33 months




HL-LHC High Luminosity Large Hadron Collider: The HL-LHC project
`http://hilumilhc.web.cern.ch/about/hl-lhc-project`

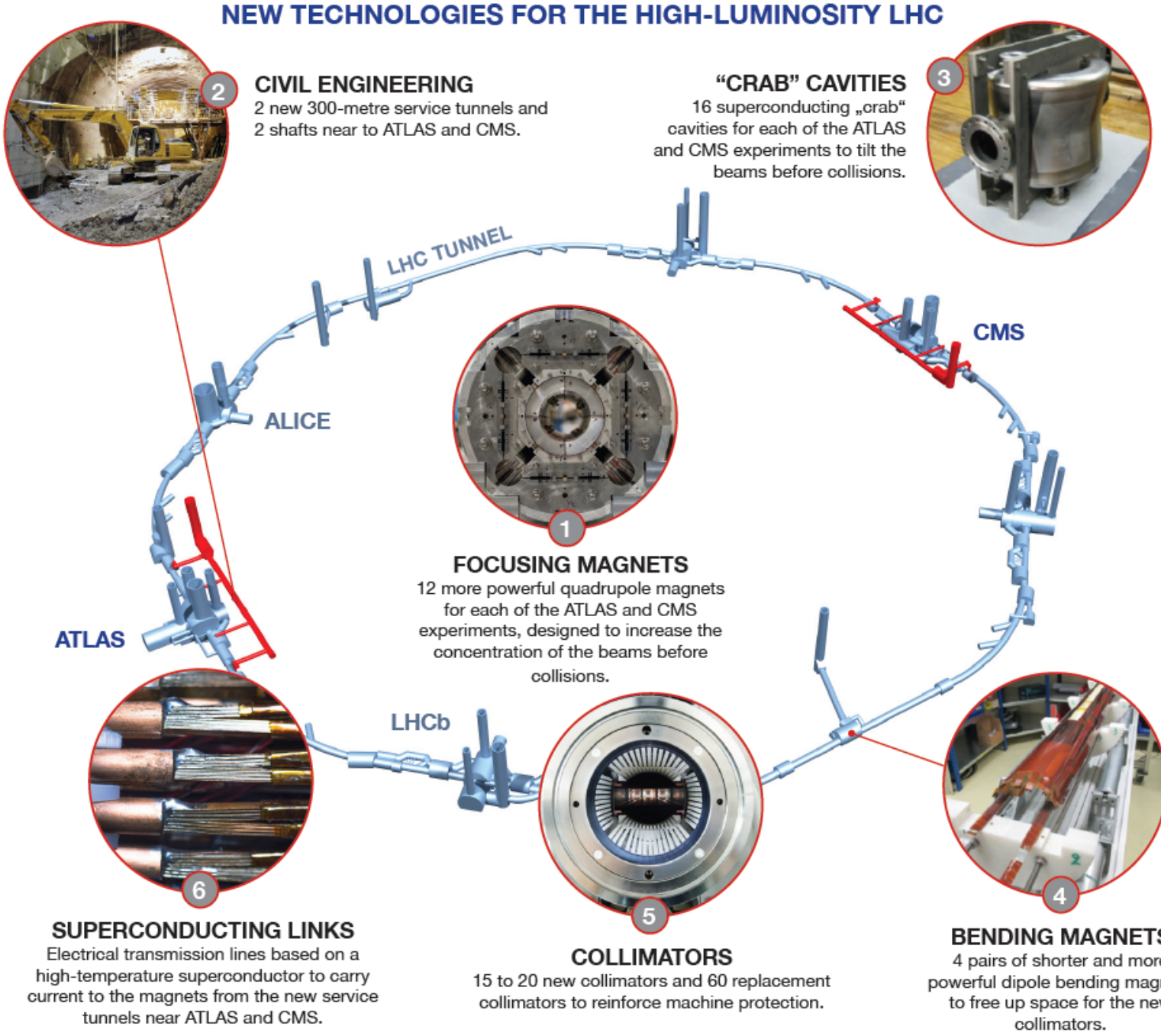
The update of the European strategy for particle physics
`http://iopscience.iop.org/1402-4896/2013/T158/014019`

# LHC and CMS current status and schedule ahead

- **Run-II: 2015 - 2018**
  - 2016: April - November:
    Peak luminosity $\sim 1.4 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$
    $\sim$ 49% of stable beams time
    CMS recorded $\sim 37.82\ \text{fb}^{-1}$ of data from pp collisions at 13 TeV
  - 2017: June - November
  - 2018: April - November
  - Integrated luminosity target for both ATLAS and CMS $\sim 100\ \text{fb}^{-1}$
  - Collision energy 13 TeV, peak luminosity $\sim 1.7 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$

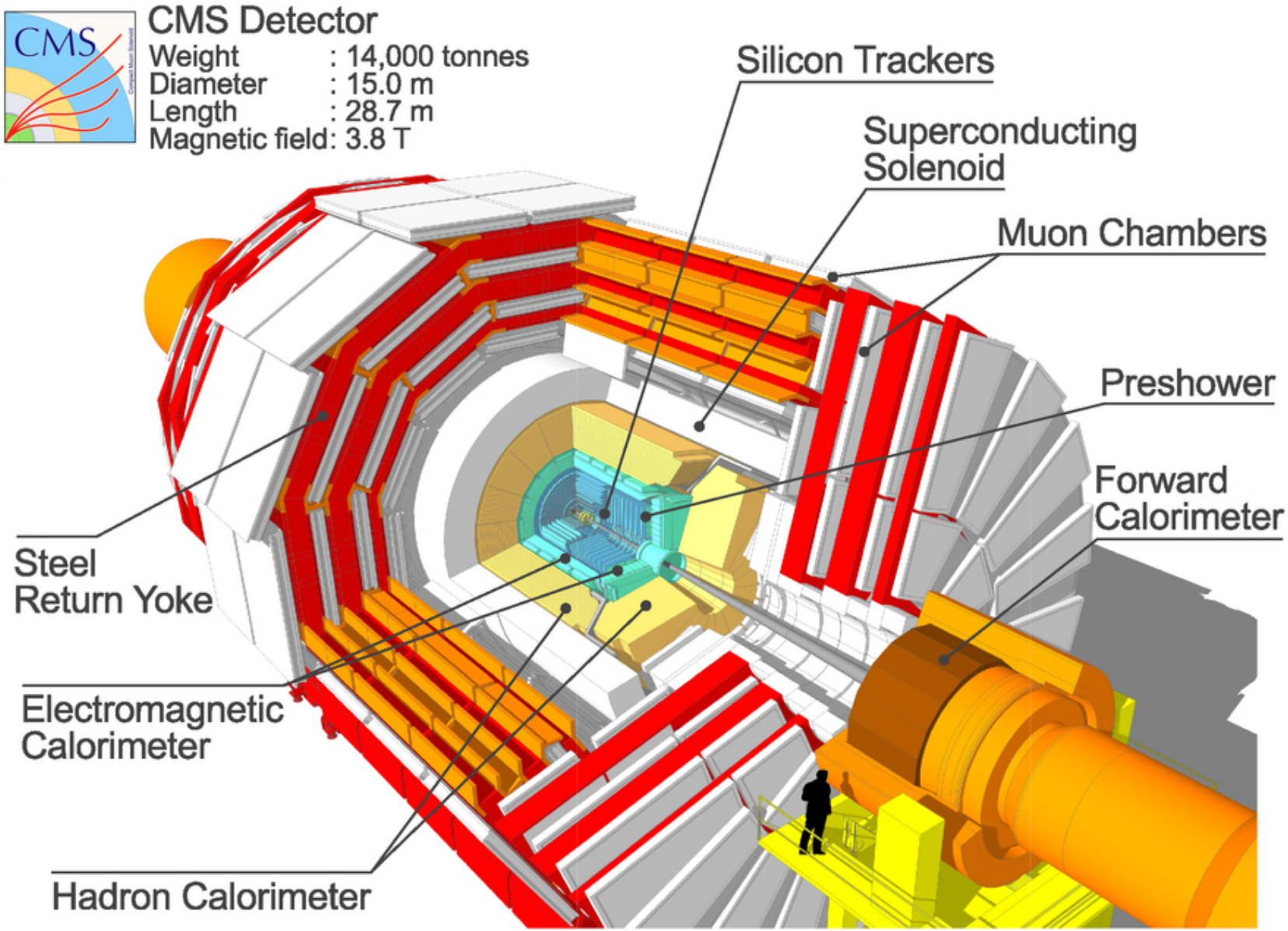
- **Run-III: 2021 - 2023**
  - After the upgrade of the LHC injector chain during the second Long Shutdown (LS2)
  - Integrated luminosity target for both ATLAS and CMS is to complete $\sim 300\ \text{fb}^{-1}$
  - Collision energy 14 (possibly 15) TeV, nominal luminosity $\sim 2.0 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$

- **A high luminosity upgrade** of the LHC interaction regions is foreseen during a third long shutdown (LS3) to further increase the instantaneous luminosity to $5 - 7 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$
  $\rightarrow$ Target integrated luminosity for this period is $\sim 3000\ \text{fb}^{-1}$

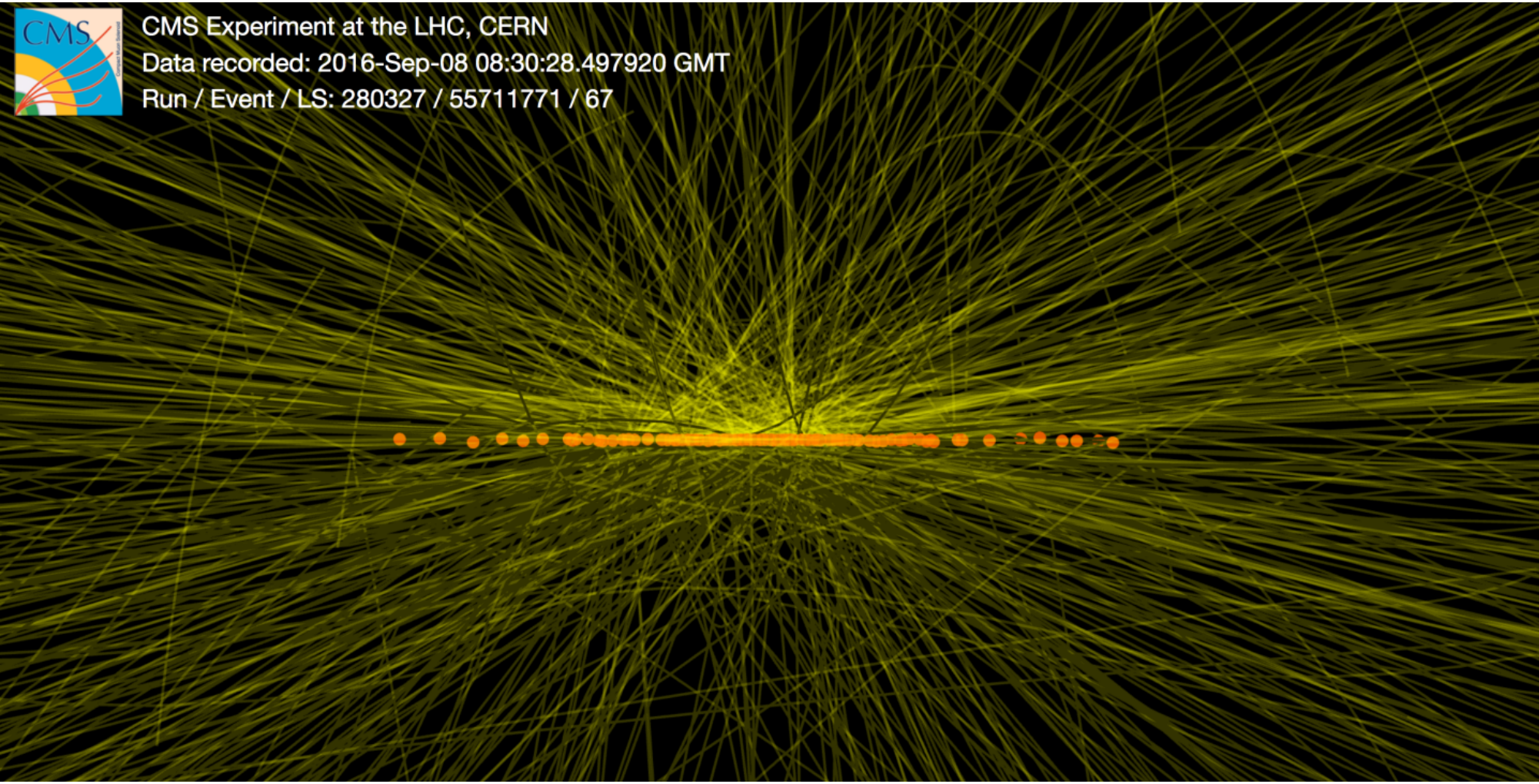

NEW TECHNOLOGIES FOR THE HIGH-LUMINOSITY LHC
2
CIVIL ENGINEERING
2 new 300-metre service tunnels and 2 shafts near to ATLAS and CMS.
3
"CRAB" CAVITIES
16 superconducting „crab" cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.
LHC TUNNEL
CMS
ALICE
1
FOCUSING MAGNETS
12 more powerful quadrupole magnets for each of the ATLAS and CMS experiments, designed to increase the concentration of the beams before collisions.
ATLAS
LHCb
6
SUPERCONDUCTING LINKS
Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service tunnels near ATLAS and CMS.
5
COLLIMATORS
15 to 20 new collimators and 60 replacement collimators to reinforce machine protection.
4
BENDING MAGNETS
4 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators.

# CMS upgrades

- The Compact Muon Solenoid (CMS) is a general-purpose detector at the LHC
- Similar goals as the ATLAS detector, but with different system of magnets

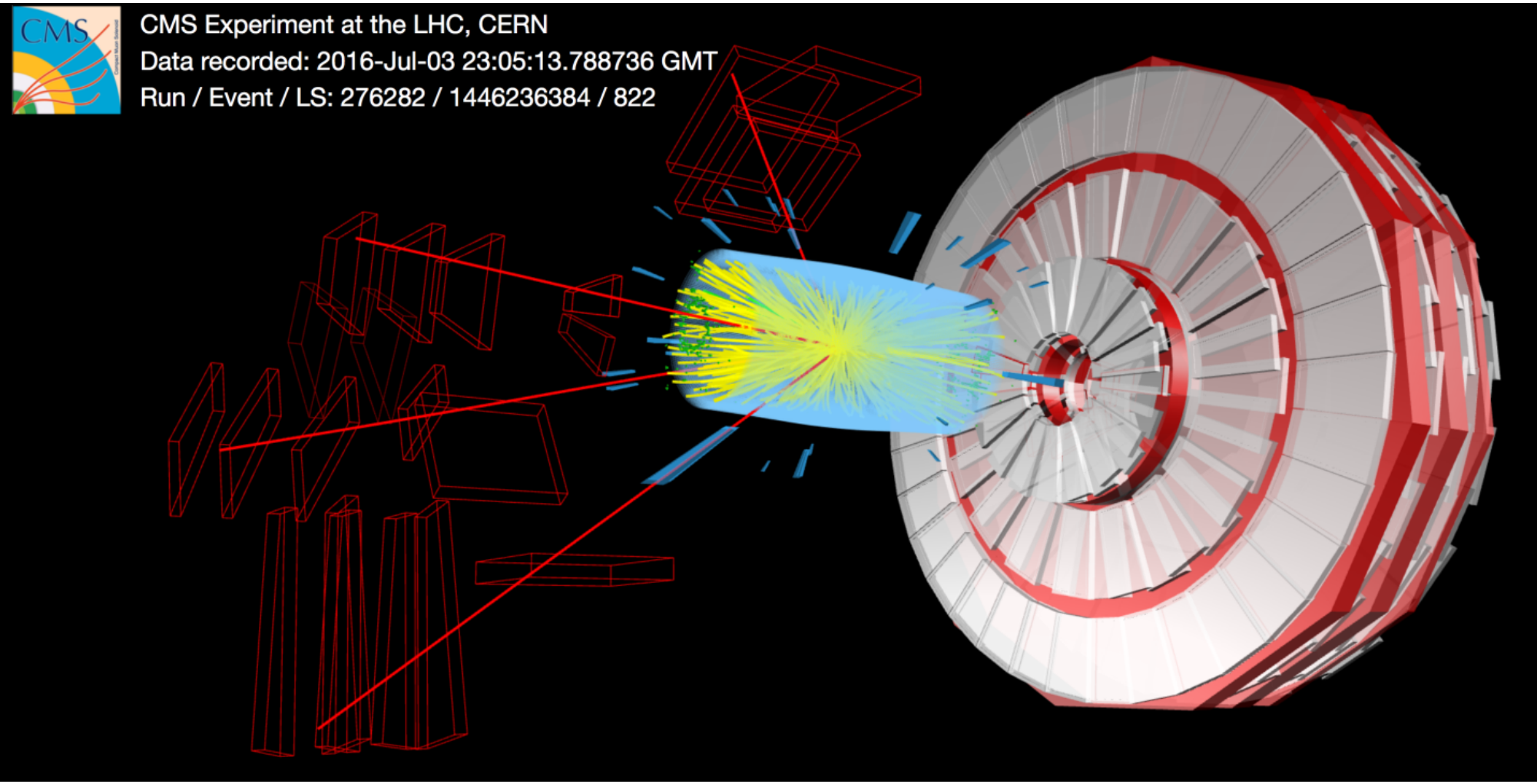


- Multiple proton-proton interactions per bunch crossing
- High pileup event with 86 reconstructed vertices:



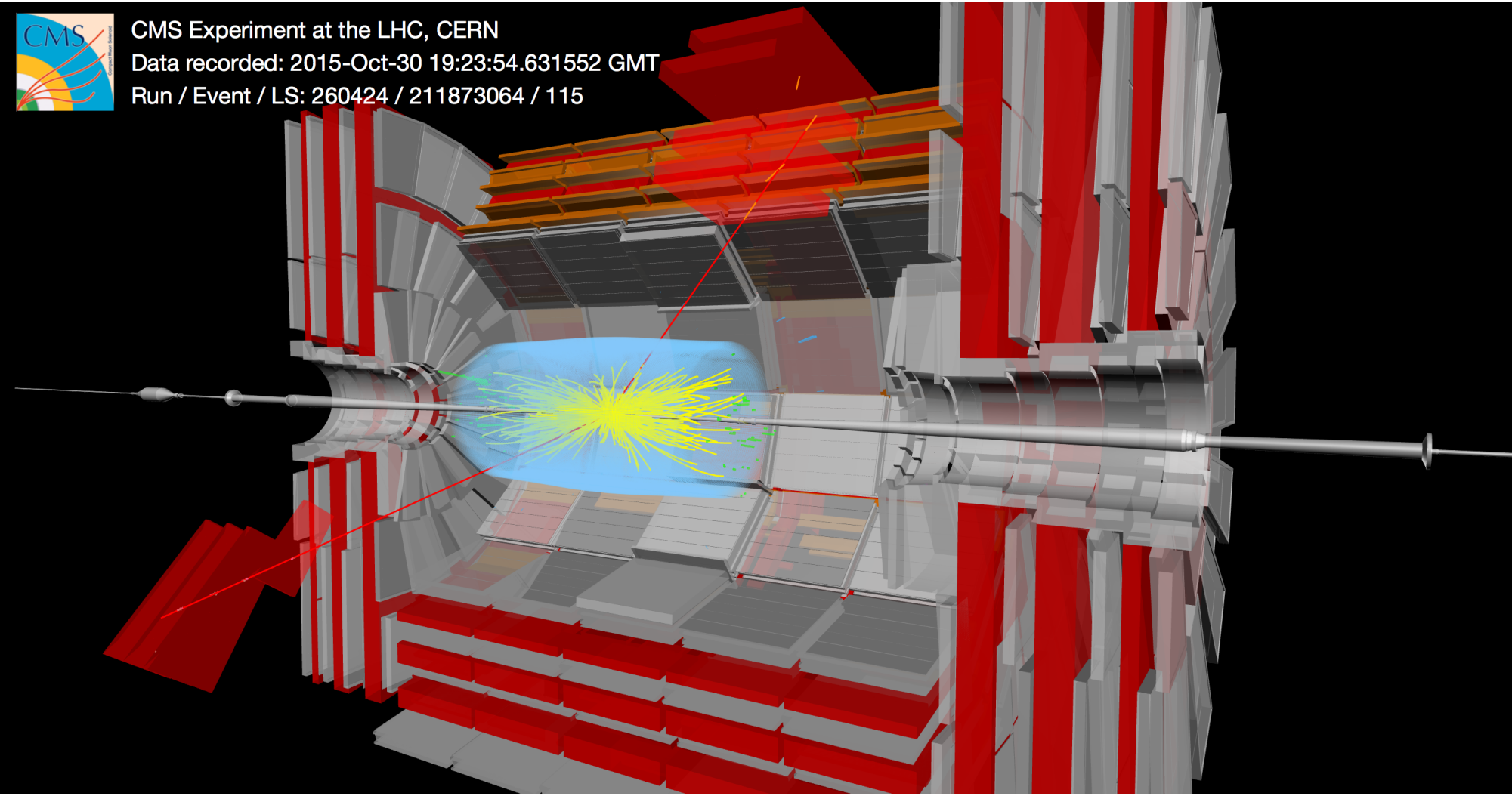

CMS-PHO-EVENTS-2017-001

- An event where two Z candidates are produced and each decay into two muons. This event has 27 reconstructed vertices



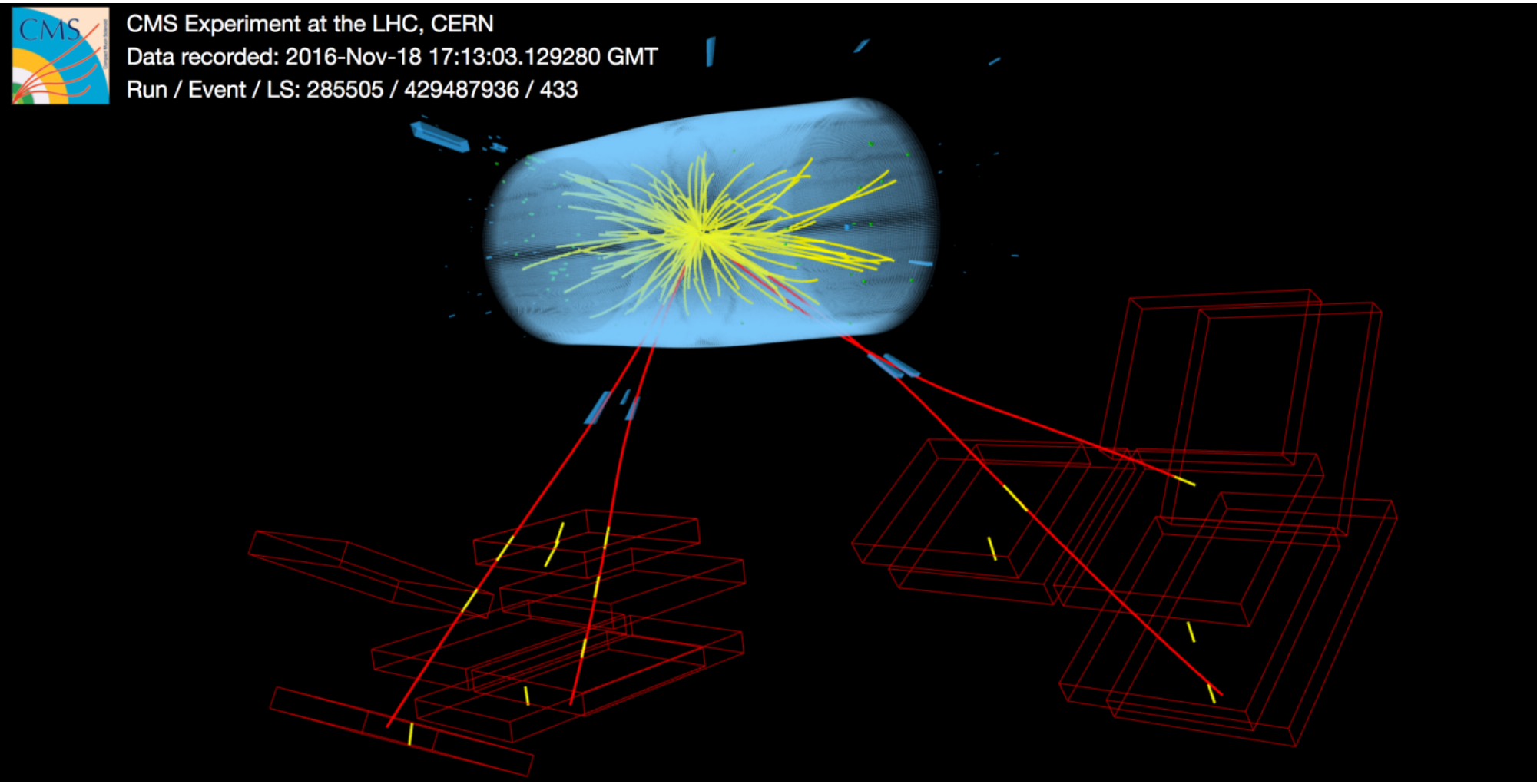

CMS-PHO-EVENTS-2017-001

- Di-muon event candidate




CMS-PHO-EVENTS-2015-005-4

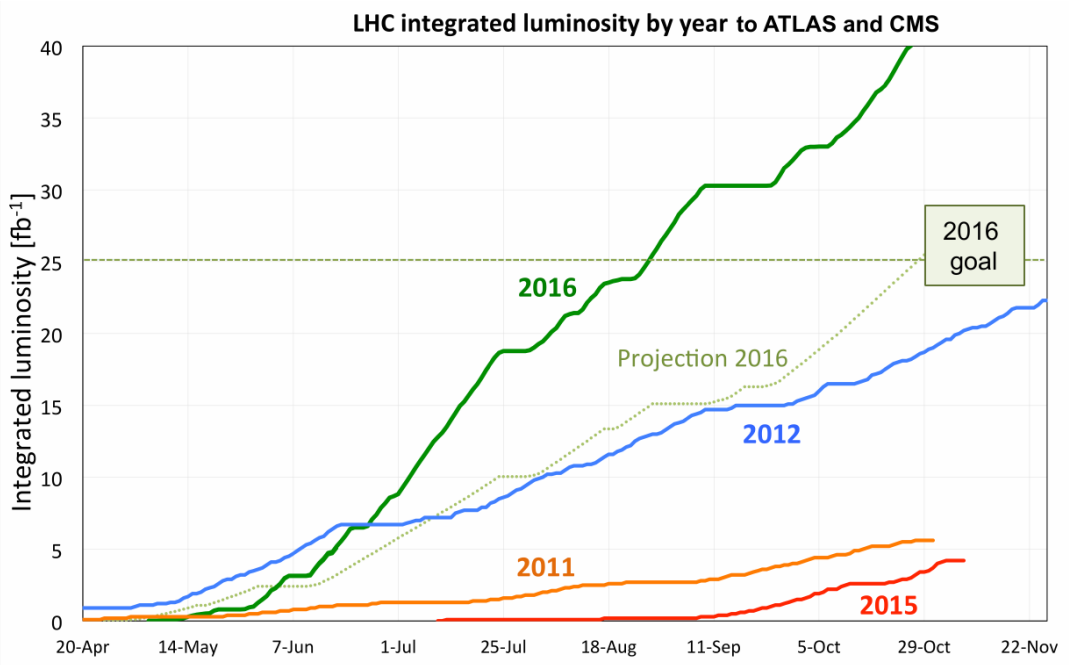
- An event where two candidate J/$\psi$ particles were produced (from the same primary vertex) and each decayed into two muons

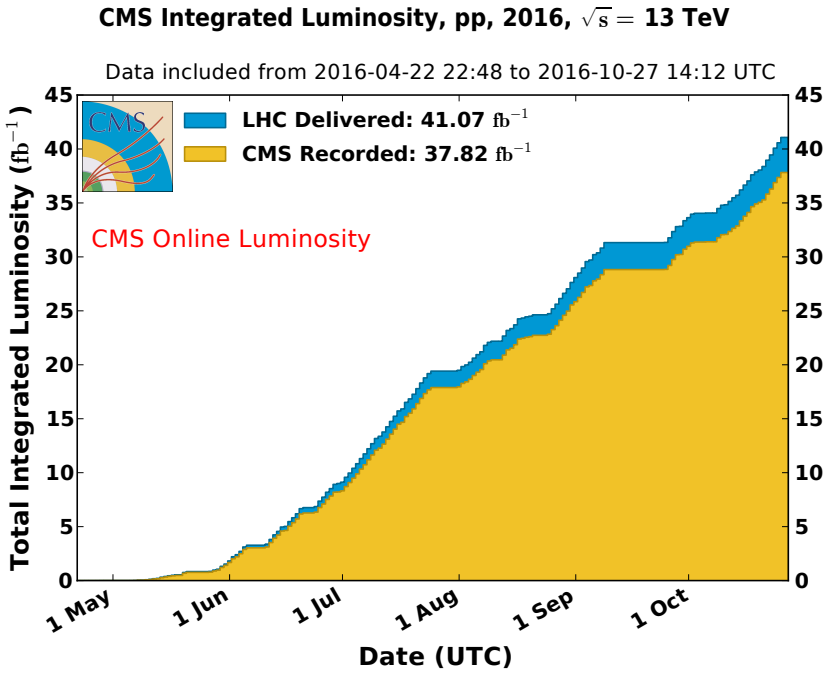



CMS-PHO-EVENTS-2016-009

# CMS integrated luminosity / proton-proton collisions

- Run 2 stretches from 2015 to 2018. The integrated luminosity target over this period for both ATLAS and CMS is around 100 $\text{fb}^{-1}$
- Excedeed design luminosity, initial plan for 2016 was to record $\sim$ 25 $\text{fb}^{-1}$



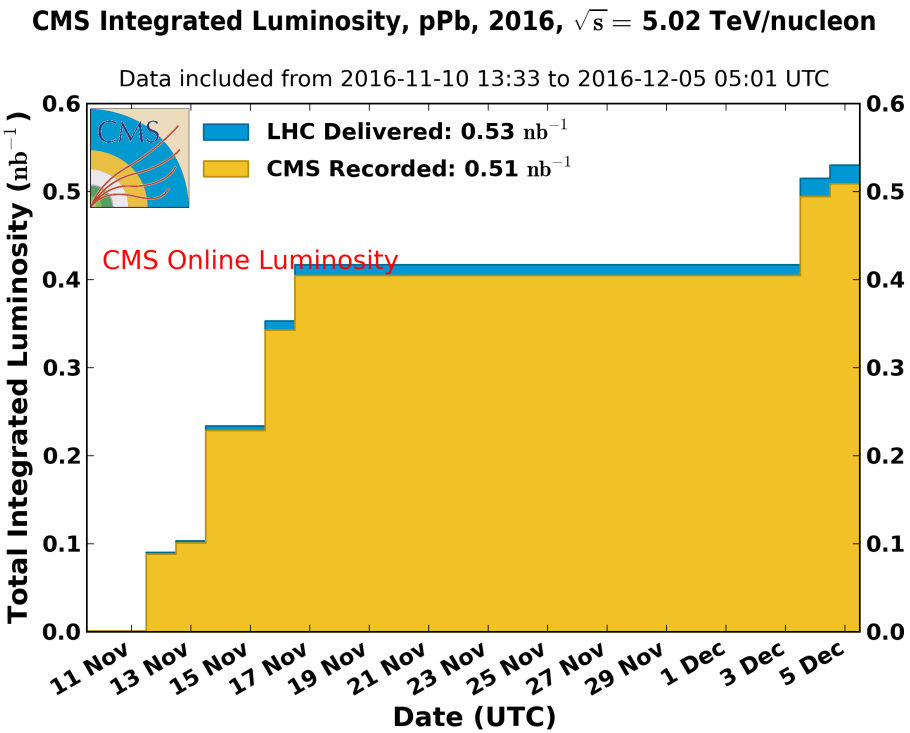



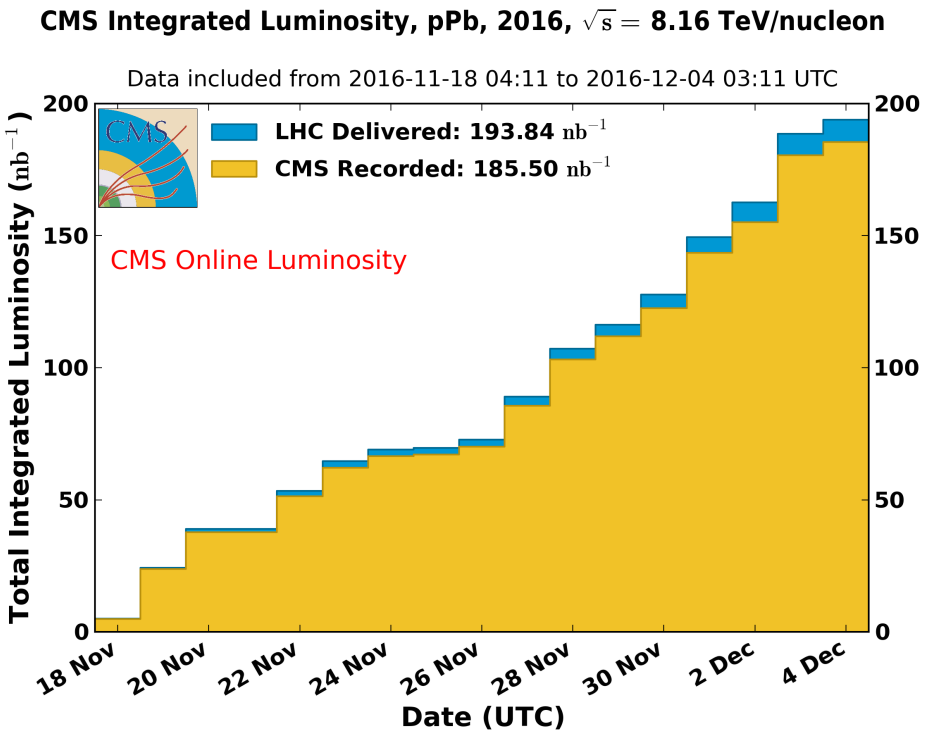

Cumulative luminosity measured online versus day delivered to, and recorded by CMS during stable beams and for p-p collisions at 13 TeV centre-of-mass energy in 2016.

https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults
CMS PAS LUM-13-001

# CMS integrated luminosity / proton-lead collisions

- Run 2 stretches from 2015 to 2018. The integrated luminosity target over this period for both ATLAS and CMS
  - 8 TeV $\rightarrow$ goal: $\sim 50$ nb$^{-1}$, achieved: $\sim 185.5$ nb$^{-1}$




Cumulative luminosity measured online versus day delivered to, and recorded by CMS during stable beams and for p-pb collisions at 5 TeV and 8 TeV centre-of-mass energy in 2016.

https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults
CMS PAS LUM-13-001

# EYETS: Extended Year-End Technical Stop

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Planned to last 22 weeks / part of phase I upgrades

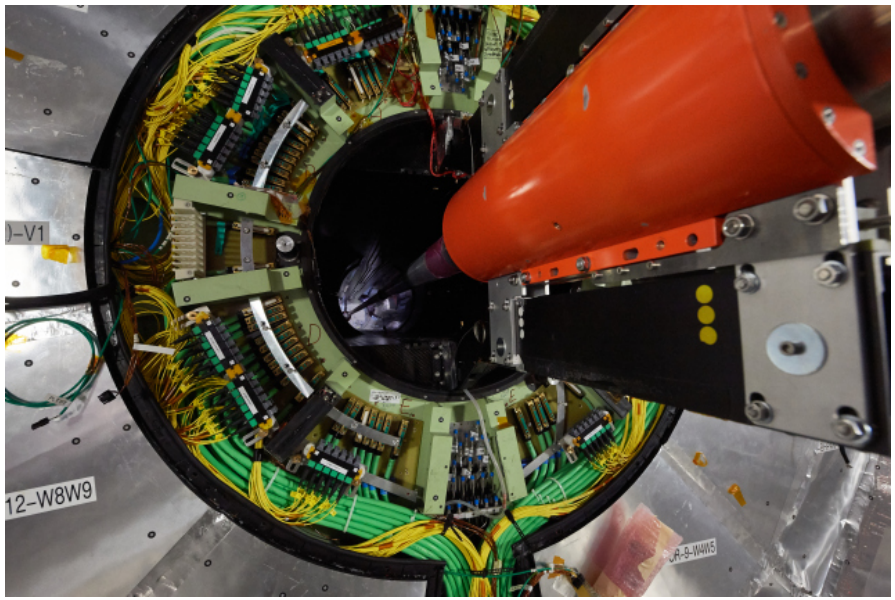
- Upgrades and consolidation of CMS forward detectors
  - Pixel upgrade: FPIX and BFIX
  - HF (consolidation of previously installed PMTs)
  - HE (postponed full upgrade)
  - Muon partial installation of GE1/1 system
  - TOTEM tracker, Pixel luminosity detector

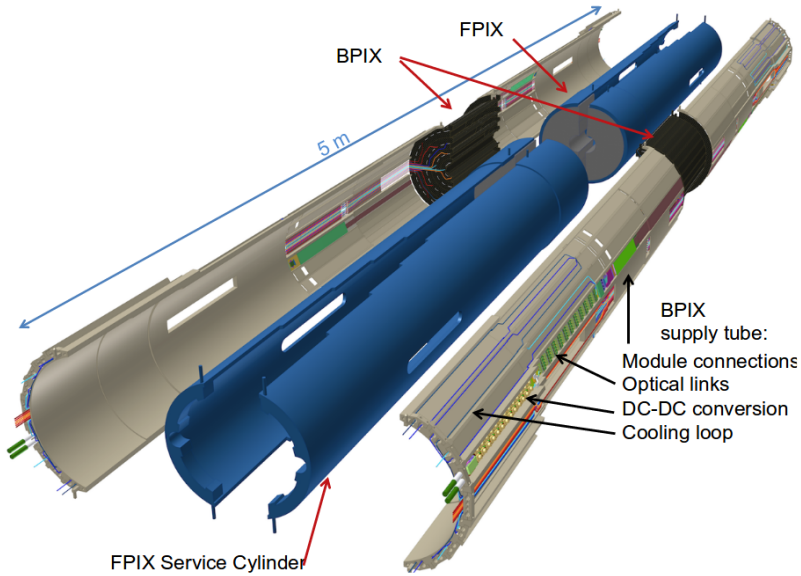
- For the LHC:
  - Maintenance activities of cryogenics, cooling, ventilation, vacuum and other equipment
  - Upgrade of beam instrumentation, kickers, lifts
  - Prototypes and tests in view of the HL-LHC
  - Exchange of one main dipole in the sector 1-2
  - SPS: new internal beam dump
  - Prepare the LHC to run at 14 TeV during Run 3

Frederick Bordry / Recontres de Moriond
http://iopscience.iop.org/1748-0221/3/08/S08001

# CMS Tracking system upgrade / exploiting increased luminosity

- Tracking system: determines trajectories of charged particles
- New pixel detector has been installed (Feb 28 - March 09): Designed to keep high tracking performance at luminosities up to $2\times10^{34}\text{cm}^{-2}\text{s}^{-1}$ and pile-up up to and exceeding 50
  - 4 barrel layers and 3 forward / backward disks: improving pattern recognition capability
    $\rightarrow$ provides four pixel-hit coverage out to pseudorapidities of $\pm$ 2.5 (previously 3)
  - Less material use and minimize radiation damage.
    Necessary services located at high $\eta$ outside tracking volume
  - Substantial improvement in b-tagging efficiency is expected



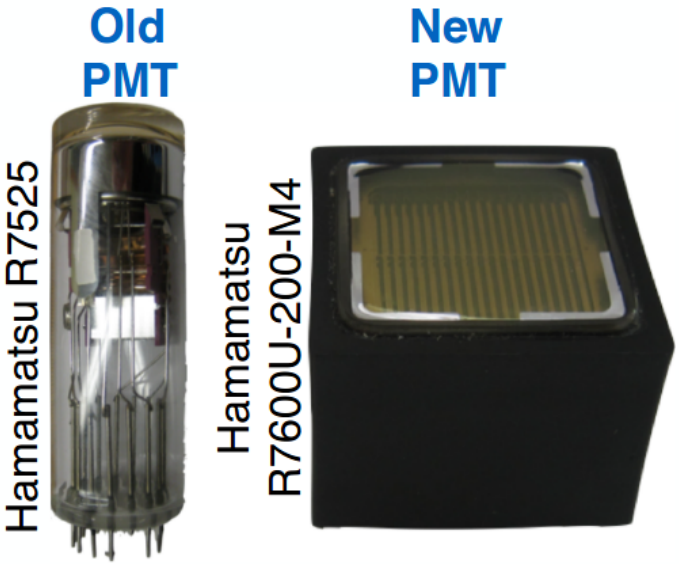


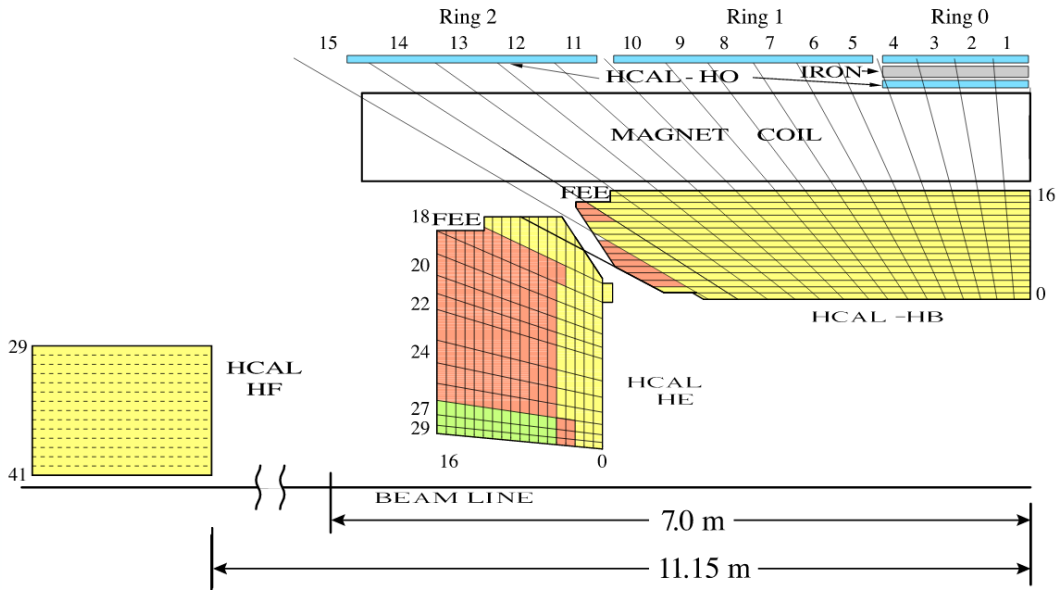

CMS-TDR-011

# CMS Hadronic Calorimeter Forward (HF) and Endcap (HE) systems upgrade

- HF system has been upgraded: to reduce noise from anomalous hits
  Each PMT box adapter board has been split it into two channels
  - Consolidation of PMT boxes installation during LS1 / 36 boxes per side

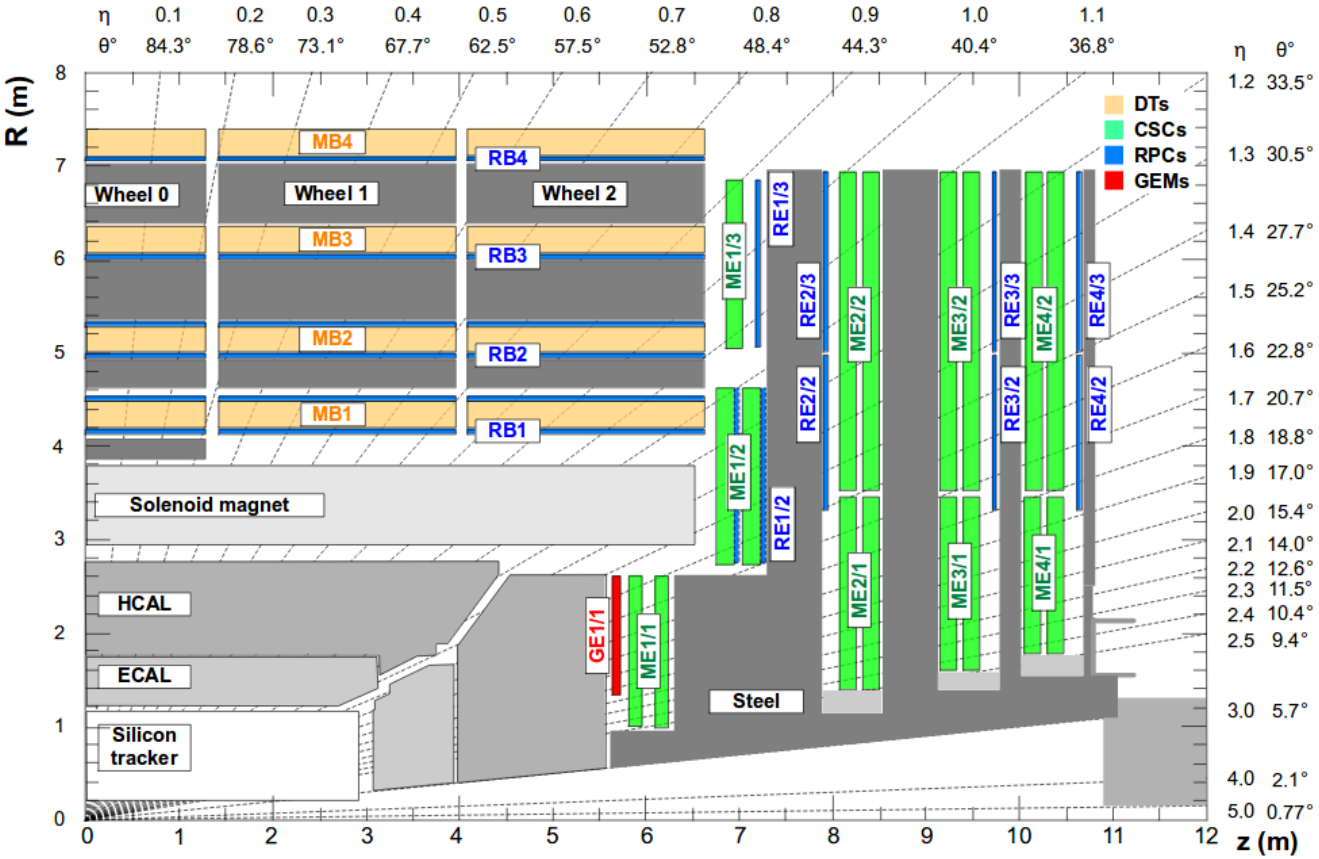
- HE system: efficient upgrade of entire HE in YETS17/18
  - 1 (HE+) out of 36 readout boxes has been replaced
  - Silicon Photo-detectors (SiPMs): replacing Hybrid Photodiodes (HPDs)

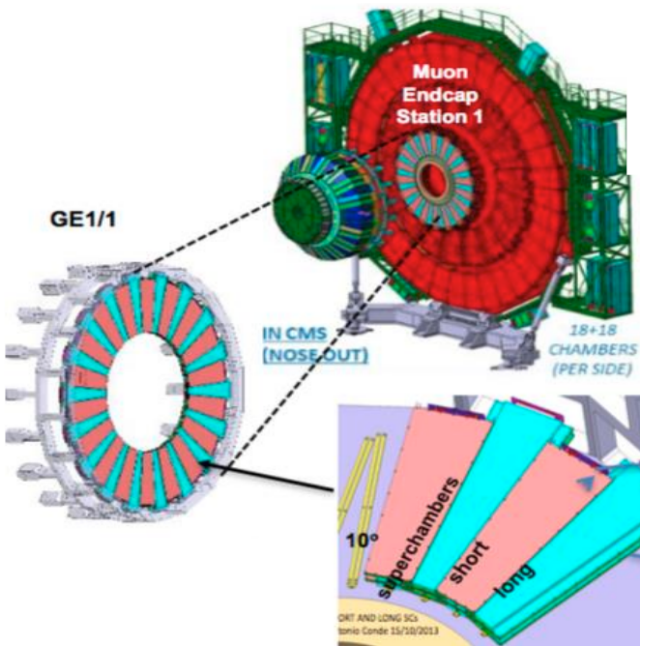



CMS Hadron Forward Calorimeter Phase I Upgrade / 2015 J. Phys. Conf. Ser. 587 012007
The upgrade of the CMS hadron calorimeter with silicon photomultipliers / JINST, Volume 12, January 2017
CERN-LHCC-2012-015 CMS-TDR-10-2012 (Technical Design Report CMS; 10)

- Installation of an additional set of muon detectors GE1/1 that use gas electron multiplier (GEM) technology in the first endcap muon station:
  - To maintain and improve forward muon triggering and reconstruction in the region $1.6 < |\eta| < 2.2$ in the face of high luminosity: where background rates are highest




CMS-TDR-013

# Mexico collaboration with CMS muon detector

Cinvestav

UNIVERSIDAD IBEROAMERICANA CIUDAD DE MÉXICO ®

BUAP

- **(2016-2017)** Current contributions from Mexico to CMS RPCs group

**Benemérita Universidad Autónoma de Puebla**:

In charge of the Upgrade Coordination, the DCS for the RPC system, the Web-DCS for the R&D and Consolidation studies done at GIF++, among others

**Cinvestav**:

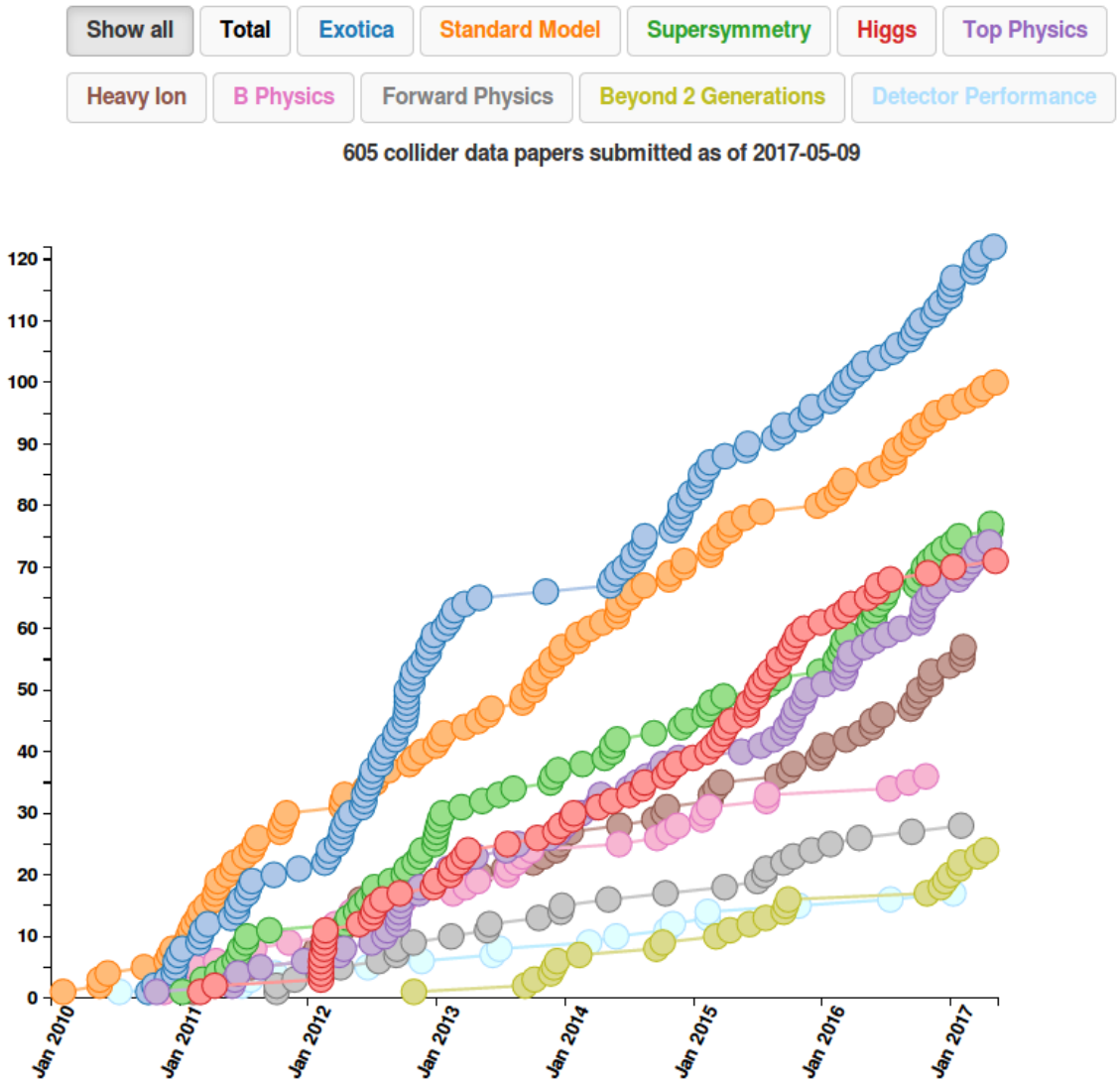
- Substantial contribution in analyses involving RPC detectors currents dependence with luminosity and effect of installation of shielding layers in the muon detector barrel and endcaps
- Analysis on determining optimized working point for High Voltage in the RPC chambers

**Universidad Iberoamericana**:

- Maintenance of software delivering average chambers currents and integrated charge per run
- Analysis on RPCs chambers integrated charge (run 1 and run 2)

# CMS recent results in ongoing Run-II

- 605 physics papers submitted
  ∼ 30 from run-II / several ready for collaboration review
  39 results approved for Moriond

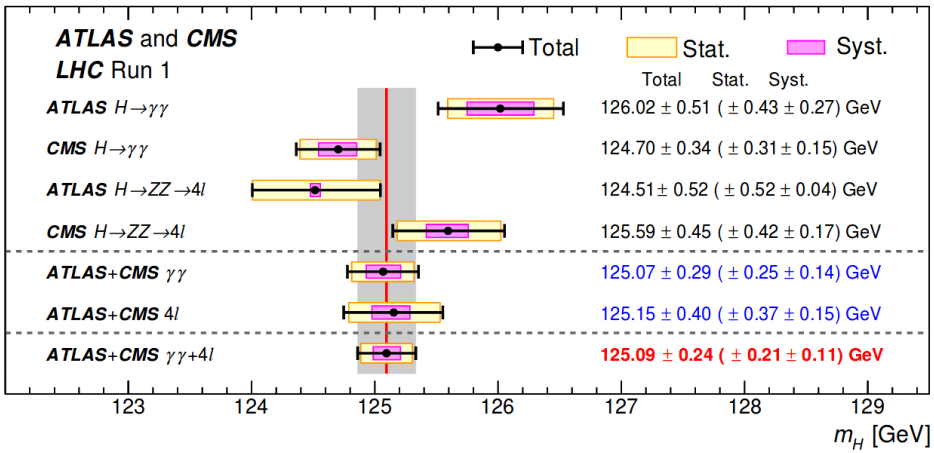


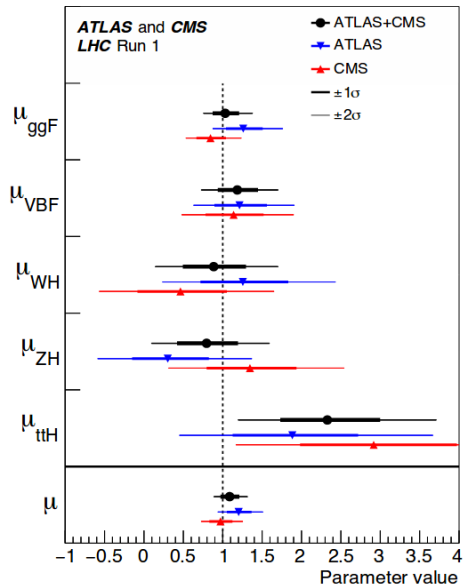

http://cms-results.web.cern.ch/cms-results/public-results/publications-vs-time/

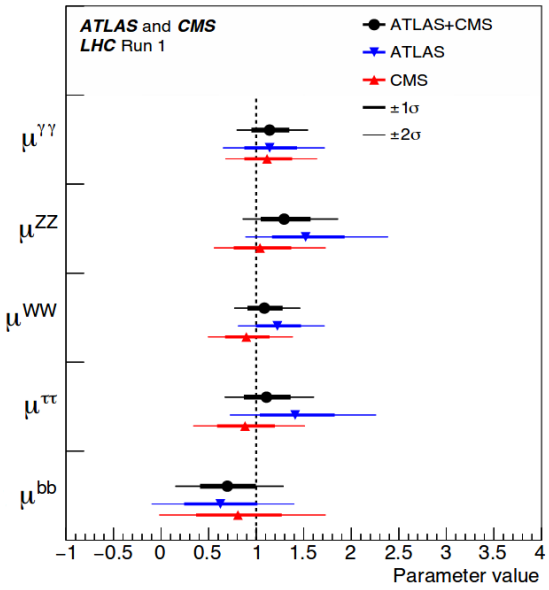
# Combined measurement of the higgs boson mass in p-p collisions at 7 and 8 TeV

- Run-1 legacy:

  Discovery of a new boson in 2012 consistent with the Standard Model (SM) Higgs boson
- Combination of ATLAS and CMS results in the H$\to \gamma\gamma$ and H$\to$ZZ$\to 4\ell$
- $m_H = 125.09 \pm 0.21$ (stat.) $\pm 0.11$ (syst.) GeV
- All couplings are consistent with the SM within $2.5\sigma$



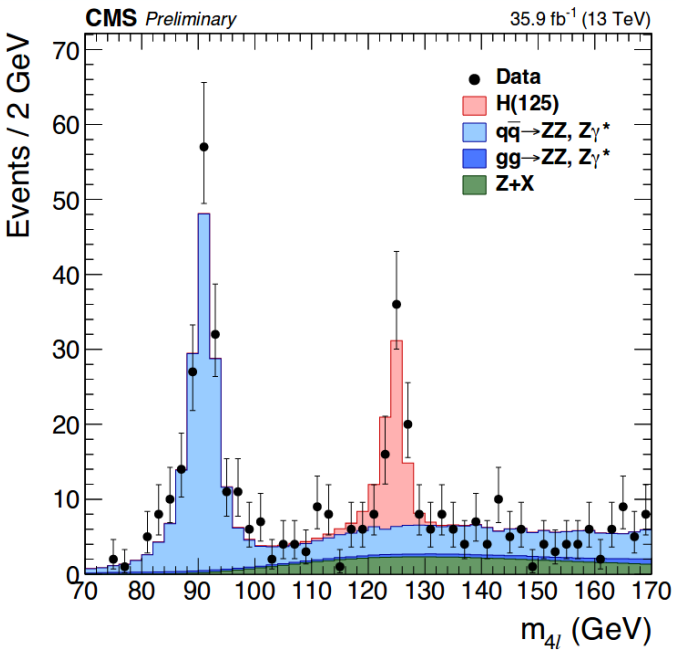



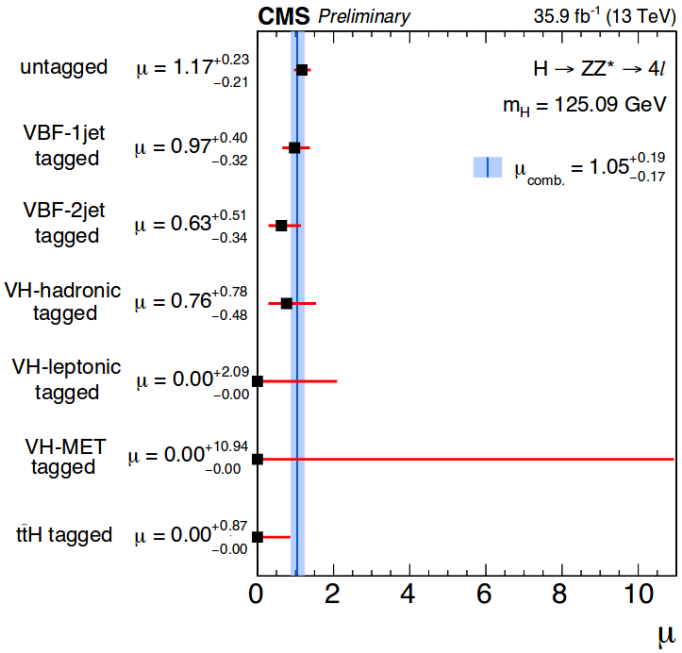



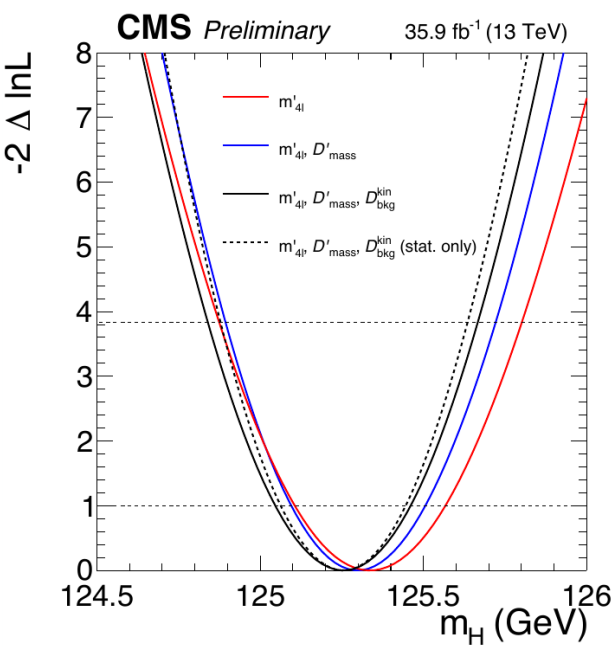

arXiv:1503.07589v1
arXiv:1606.02266

# Observation of 125 GeV Higgs at 13 TeV / H → ZZ → 4ℓ (ℓ = e, μ)

- CMS new mass fit: $m_H = 125.26 \pm 0.20(\text{stat}) \pm 0.08(\text{sys})$ GeV
- Run 1 combination with ATLAS: $m_H = 125.09 \pm 0.21(\text{stat}) \pm 0.11(\text{sys})$ GeV
- One of the most important channels for studies of the Higgs boson properties due to relatively large signal-to-background radio: mass, width and fiducial cross-section
- $\Gamma_H < 1.10$ at 95% C.L. and production $\mu$ comb $= 1.05^{+0.19}_{-0.17}$



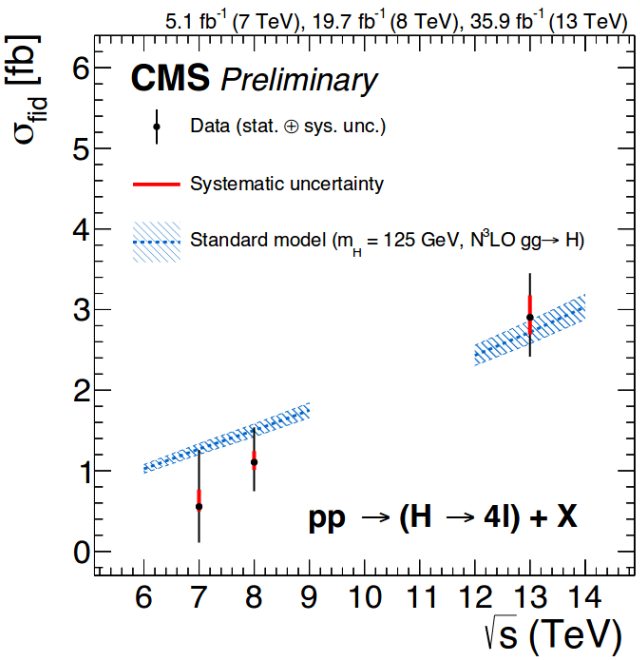



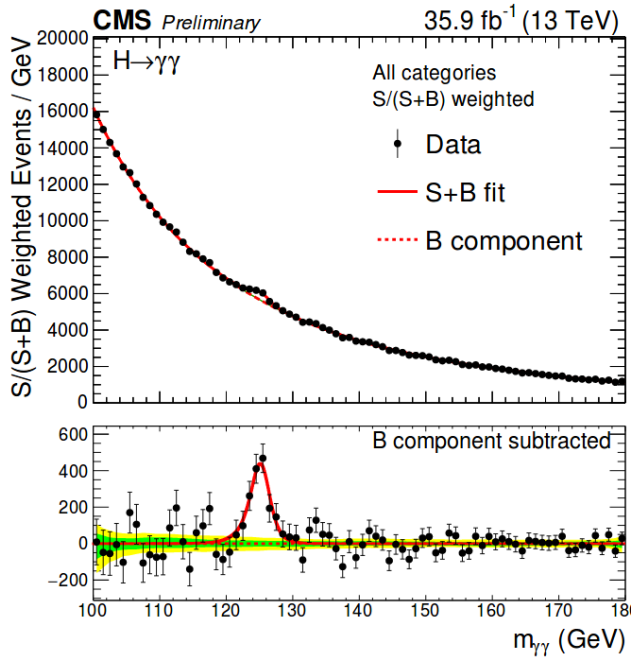



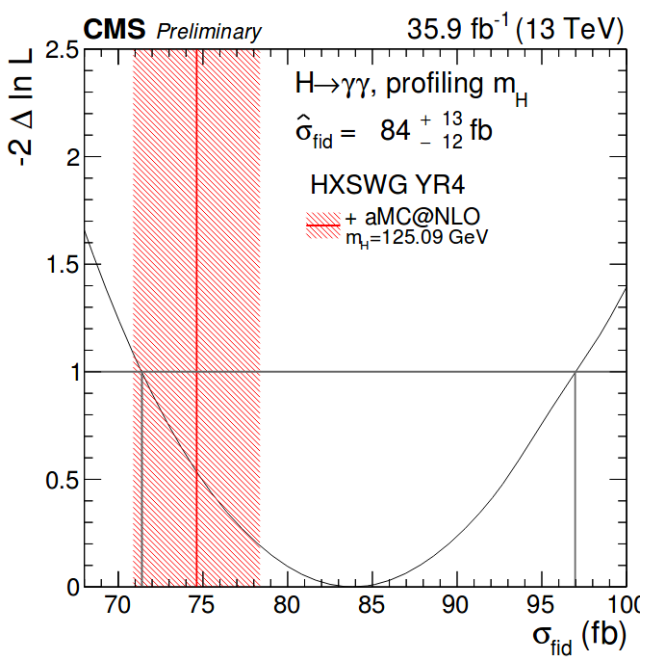

https://cms.cern/news/cms-new-results-Moriond-2017

# Observation of 125 GeV Higgs at 13 TeV / $H \to ZZ \to 4\ell$ ($\ell$ = e, $\mu$) / $H \to \gamma\gamma$

- $H \to 4\ell$: $\sigma_{fid} = 2.90^{+0.48}_{-0.44}(\text{stat.})^{+0.27}_{-0.22}(\text{syst.})\text{fb}$ / $\sigma_{SM} = 2.72 \pm 0.14$ fb
- $H \to \gamma\gamma$: $\sigma_{fid} = 84 \pm 11\ (\text{stat.}) \pm 7\ (\text{syst.})\text{fb}$ / $\sigma_{SM} = 75 \pm 4$ fb
- Anomalous interactions were studied by producing discriminant variables for the different production categories and comparing with the observed data

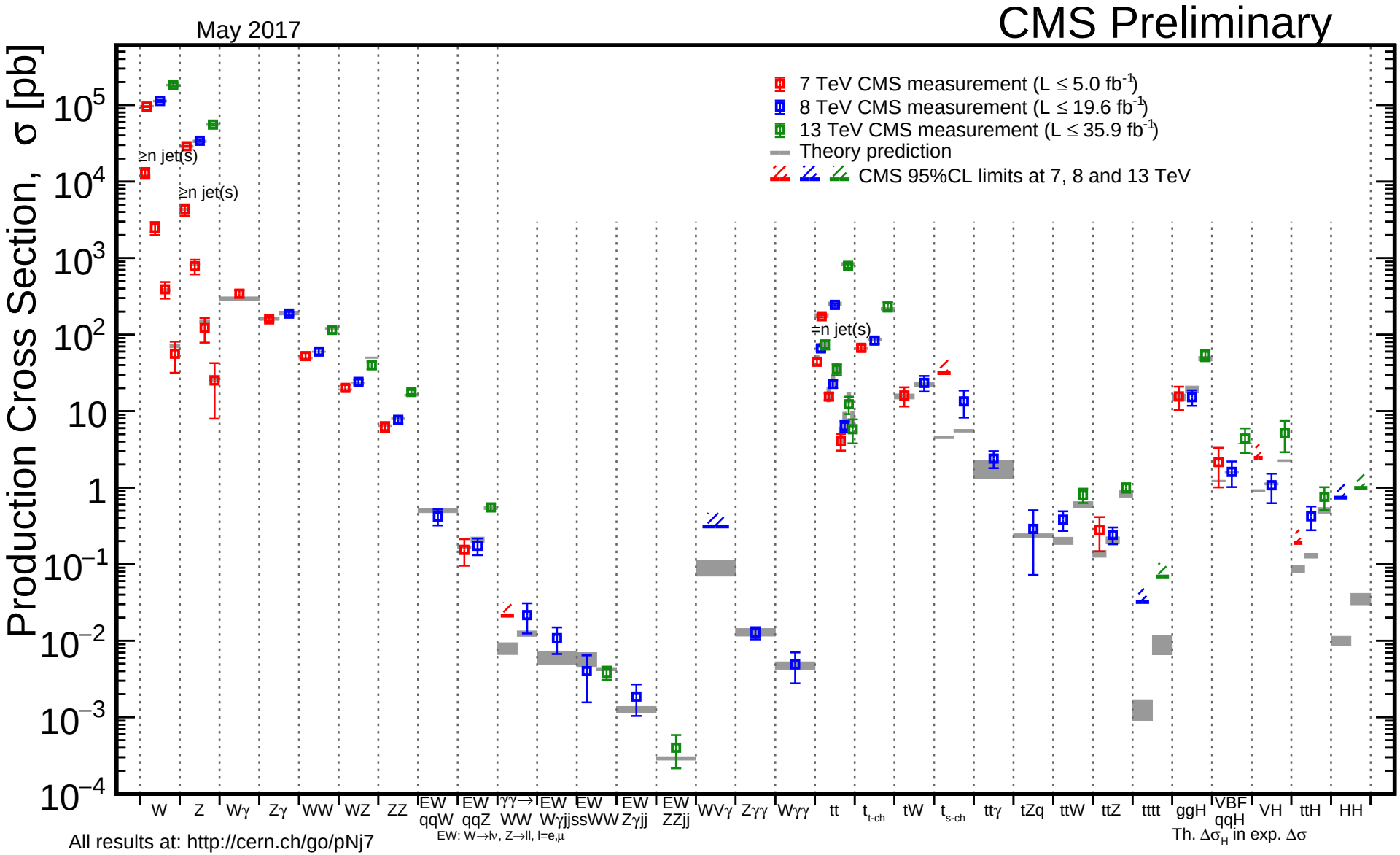



https://cms.cern/news/cms-new-results-Moriond-2017

# CMS Cross Section Measurements

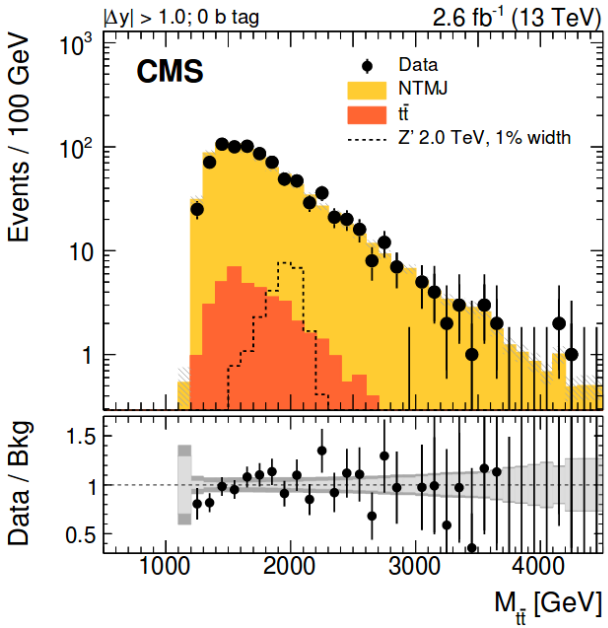


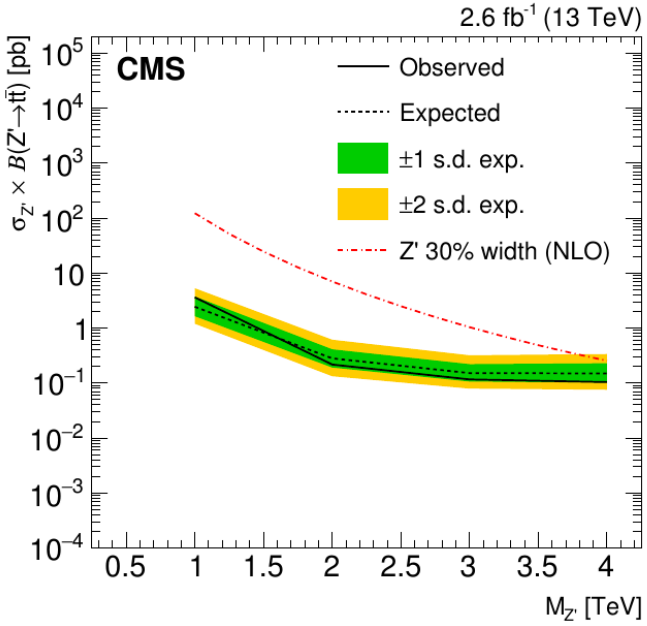

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsCombined

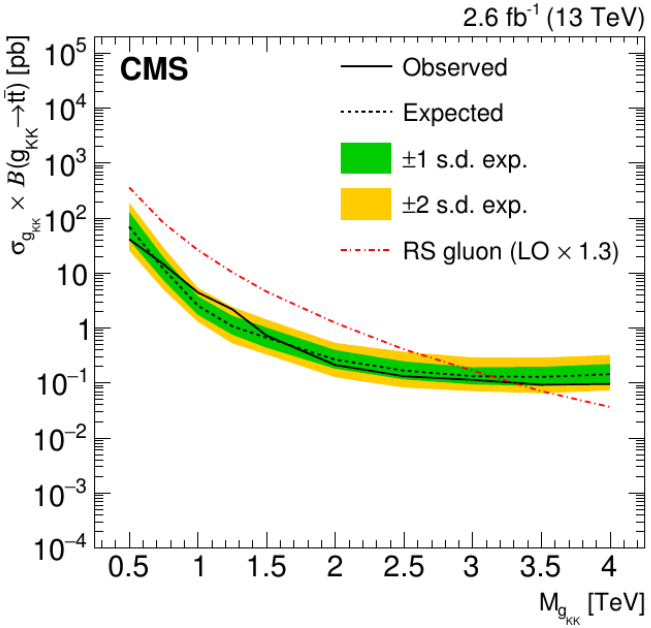
# Search for $t\bar{t}$ resonances in highly-boosted $\ell$+jets and fully hadronic final states

- Massive new particle could be observed as a $t\bar{t}$ resonance at the TeV scale
- Four benchmark models are considered: A Z' boson decaying exclusively to $t\bar{t}$ with relatively decay widths of 1%, 10% and 30% and a KK gluon resonance in the RS model (relative decay width of $\sim$ 17 %)
- Exclusion limits relative to the previous results (at 8 TeV) are improved for all models

  Masses are excluded (at 95% C.L.):
  - up to 4.0 TeV for the 30% width Z' sample
  - up to 3.9 TeV for the 10% width Z' sample (previous: 2.9 TeV)
  - up to 3.3 TeV for the RS KK gluon hypotheses (previous: 2.8 TeV)



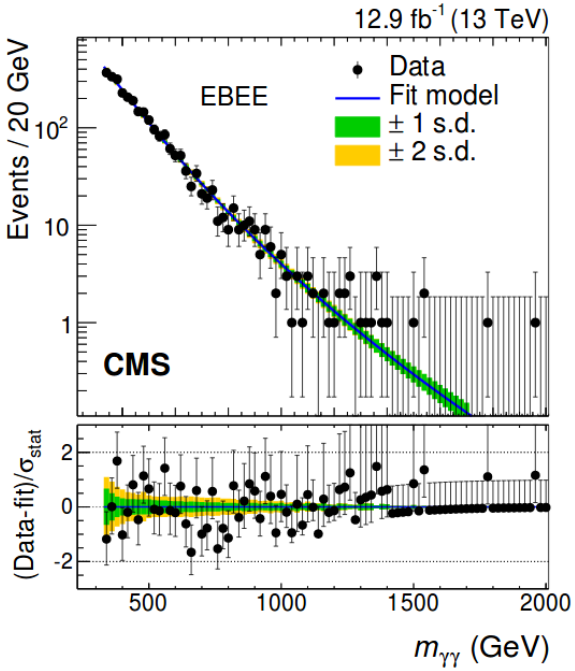



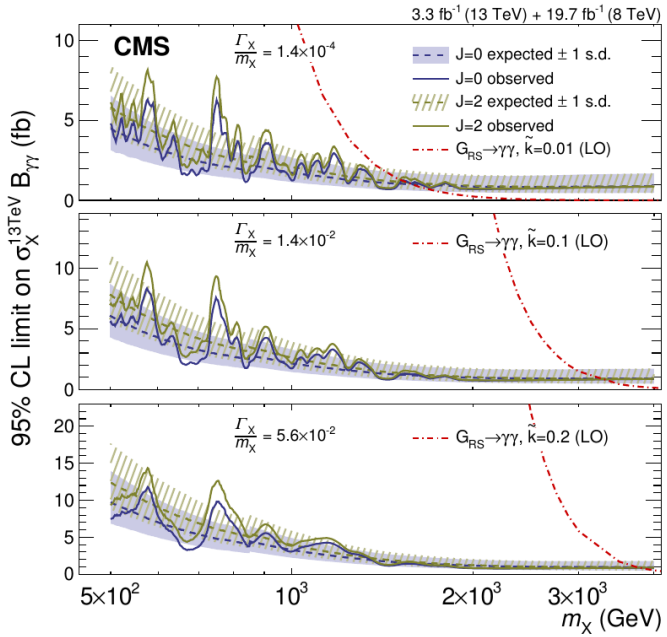



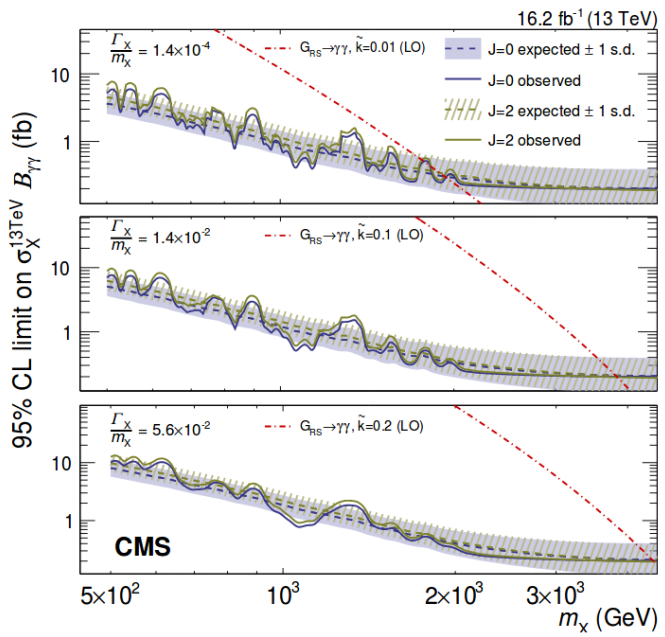

arXiv:1704.03366
arXiv:hep-ph/9805494

# Search for high-mass diphoton resonances in proton-proton collisions

- Extended search of higgs resonance: Using method based on ggF production
- Models with extended Higgs boson sectors: some of these extensions predict new resonances that decay to a diphoton final state such as Randall-Sundrum gravitons
- Masses between 0.5 and 4.5 TeV and widths relative to the mass $1.4\times10^{-4}$ and $5.6\times10^{-2}$

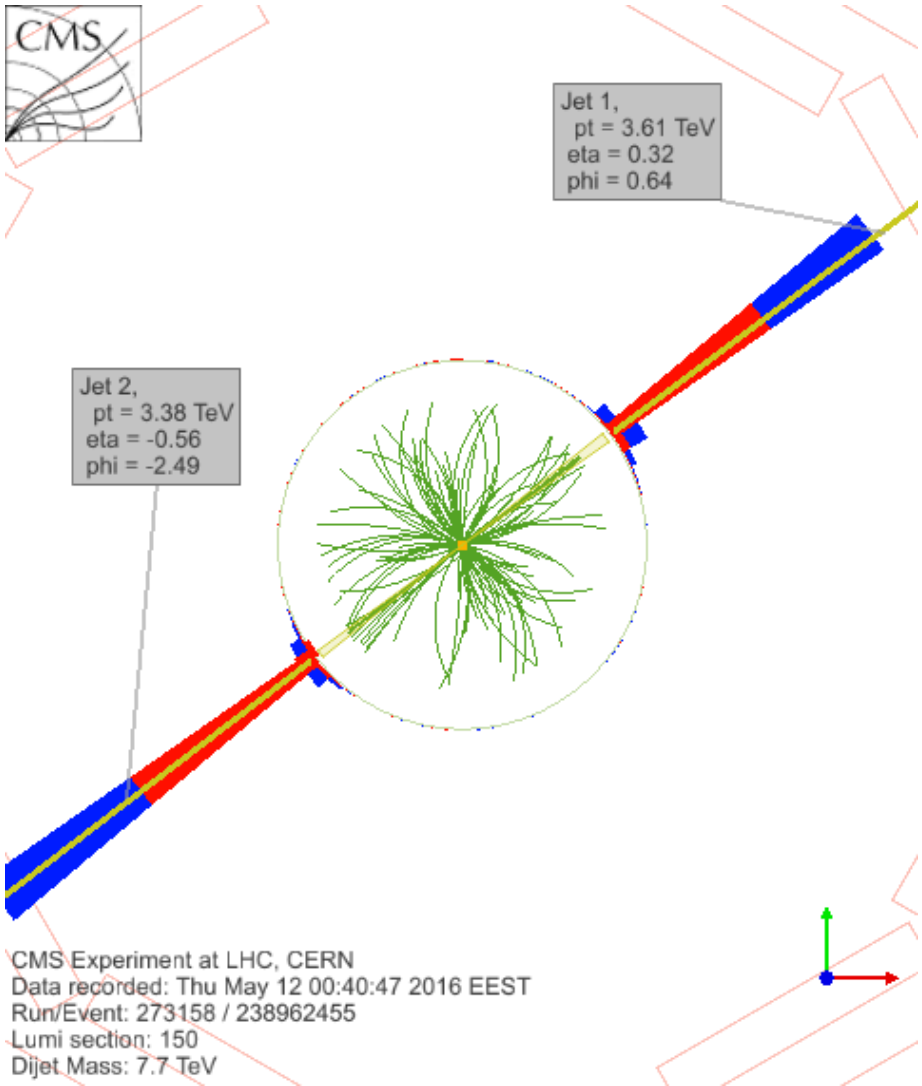



arXiv:1609.02507v2

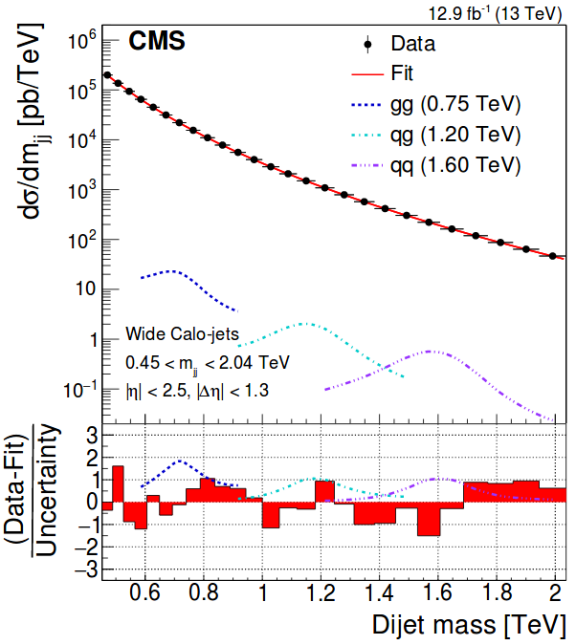
# Search for dijet resonances in proton-proton collisions

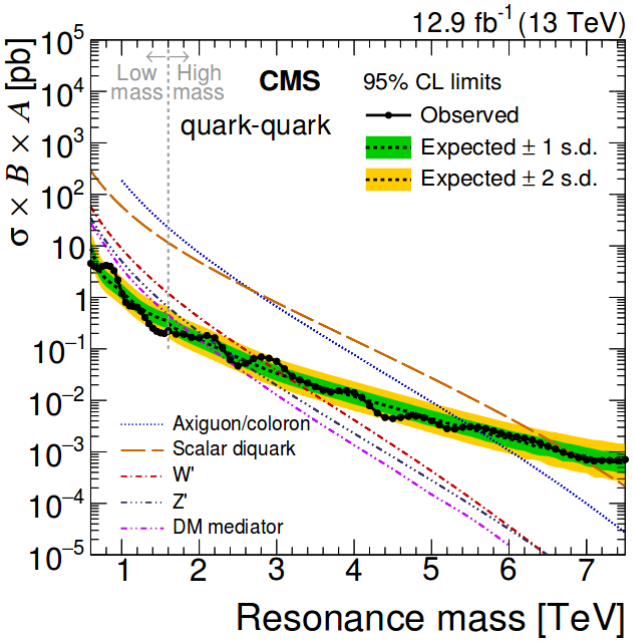


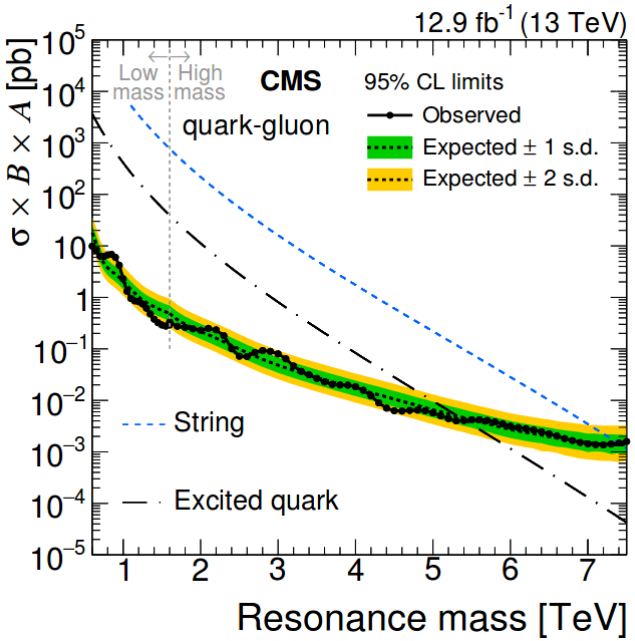

arXiv:1611.03568v1

# Search for dijet resonances in proton-proton collisions / 2016 12.9 fb$^{-1}$, 13 TeV

- No significant evidence for the production of new particles is observed
- Previous limits on production of BSM resonances with the dijet channel are extended
- Updated exclusion limits at 95 % C.L.: string resonances $<$ 7.4 TeV, scalar diquarks $<$ 6.9 TeV, axigluons and colorons $<$ 5.5 TeV, excited quarks $<$ 5.4 TeV, color octect scalars $<$ 3 TeV, W' $<$ 2.7 TeV, Z' bosons $<$ 2.1 TeV, RS gravitons $<$ 1.9 TeV



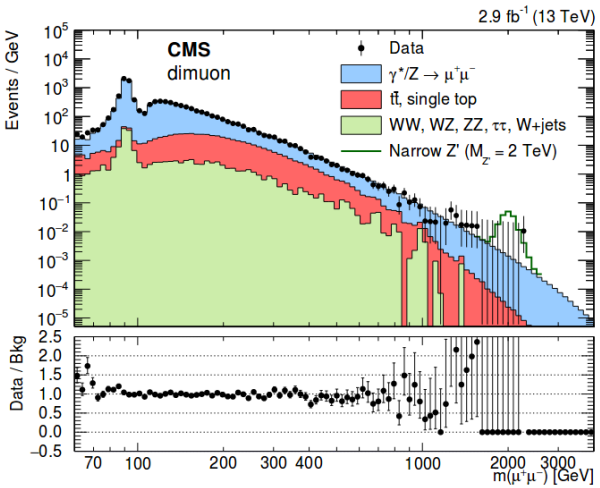



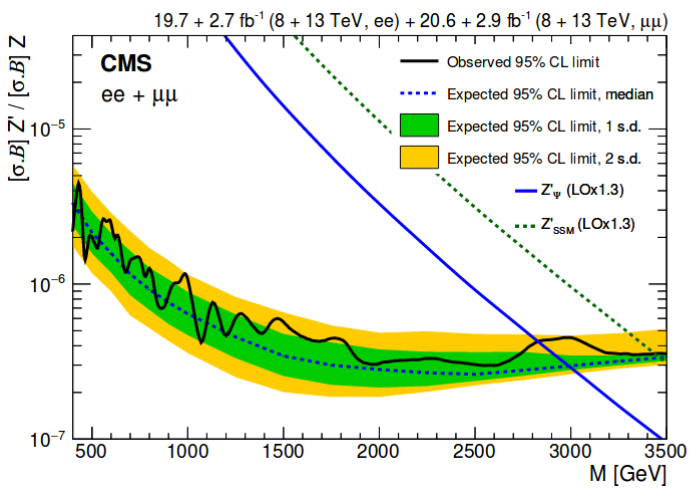



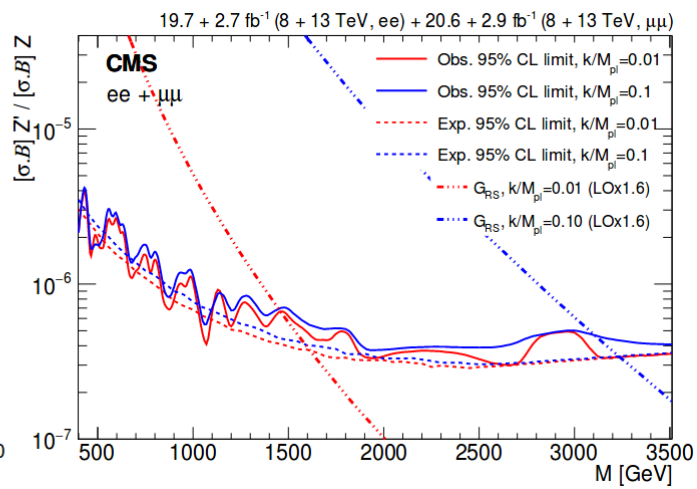

arXiv:1611.03568v1
arXiv:hep-ph/9805494

# Search for resonances in dilepton mass spectra in proton-proton collisions

- A search for narrow resonances in dielectron and dimuon invariant mass spectra
- No evidence for non-standard-model physics is found:
  either in the 13 TeV data set alone or in the combined data set
- These results significantly exceed the limits based on the 8 TeV LHC data
- Exclusion limits:
  - $M(Z'_{SSM}) < 3.87$ TeV (previous 2.90 TeV)
  - $M(Z'_{\psi}) < 2.82$ TeV (previous 2.57 TeV)
  - $M(G_{RS}) < 1.46, 3.11$ TeV



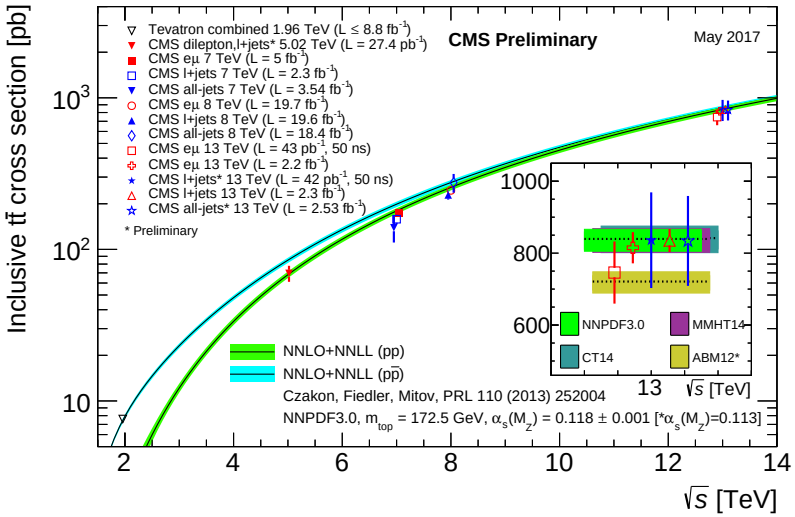



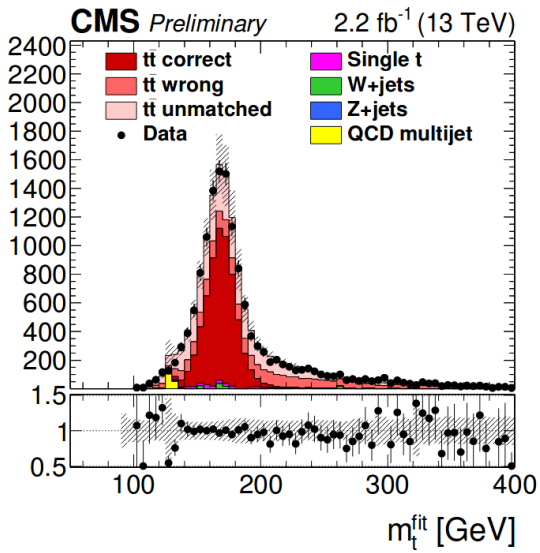



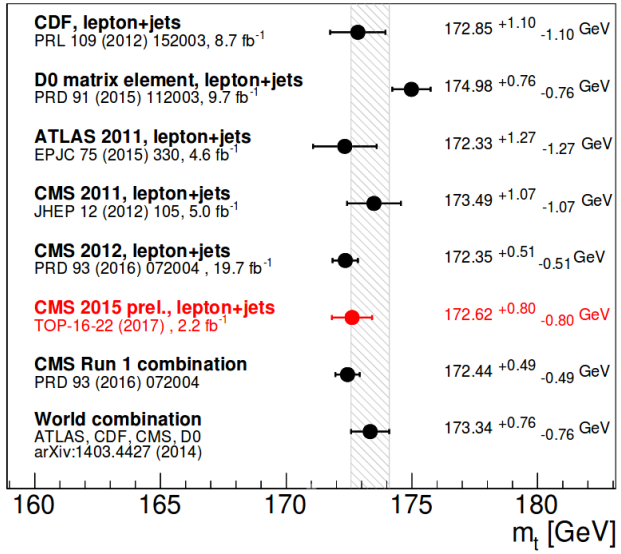

arXiv:1609.05391
arXiv:hep-ph/9805494

# Top quark mass and $t\bar{t}$ cross-section measurements

- $t\bar{t}$ pair cross section most precise CMS measurements in the dilepton and $\ell$+jets channels
- Top mass: Run 1 combination and most recent preliminar measurement with 13 TeV data



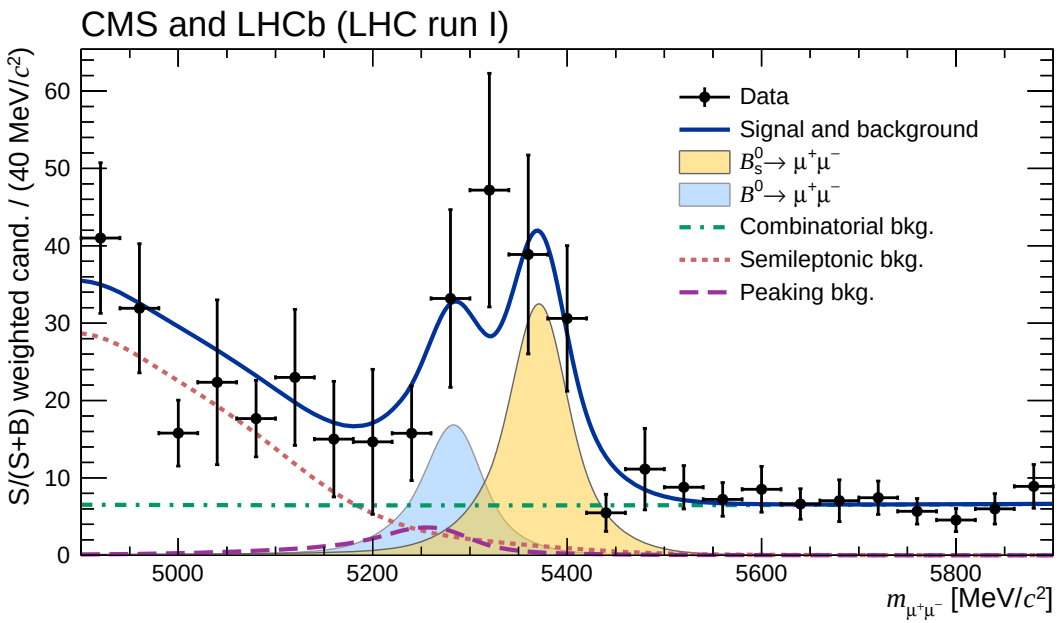



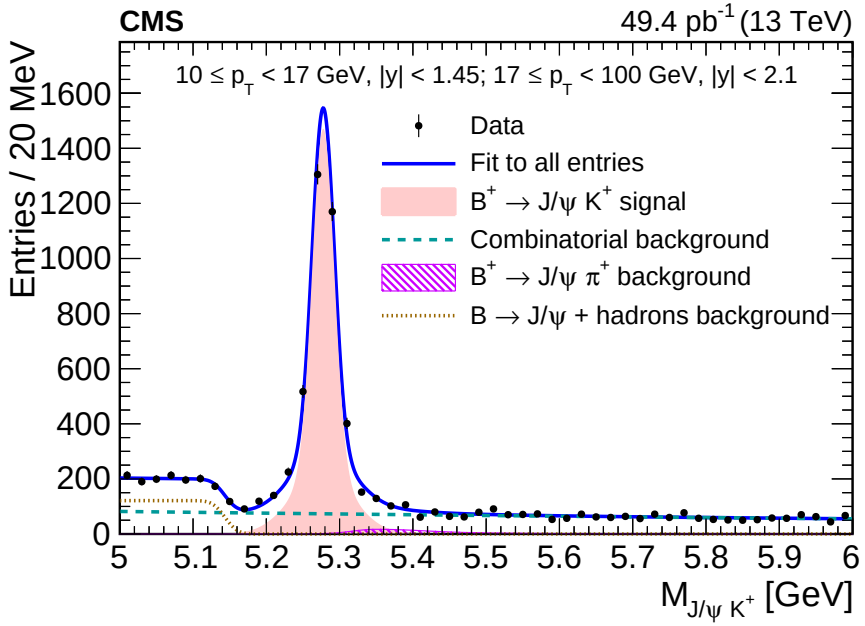




LHCP 2017 / https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOPSummaryFigures
CMS-PAS-TOP-16-022

# Results on B-physics

- $B_s^0 \to \mu\mu$: CMS and LHCb data ($\sqrt{s} = 7$ and 8 TeV)
  - Measurement of $B(B_s^0 \to \mu\mu)$ and $B(B^0 \to \mu\mu)$
  - Initiates a phase of precision measurements of the properties of this decay
  - Production is approximately doubled with 13 TeV pp collisions
- Measurement of the total and differential inclusive $B^+$ hadron cross sections ($\sqrt{s} = 13$ TeV)
  Results show a reasonable agreement with theoretical calculations within the uncertainties

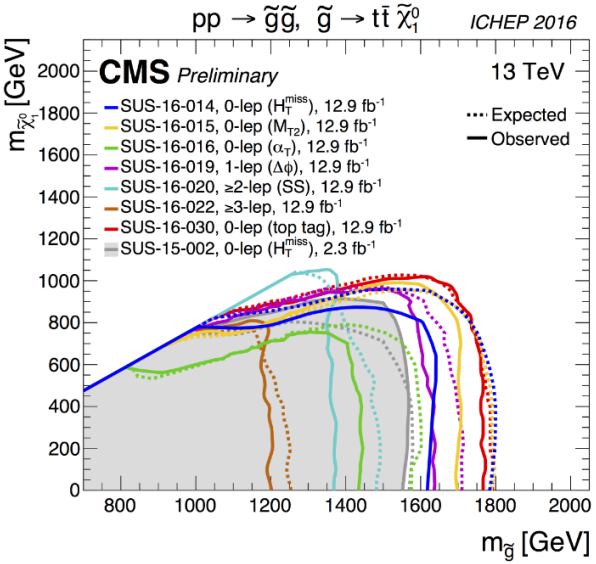


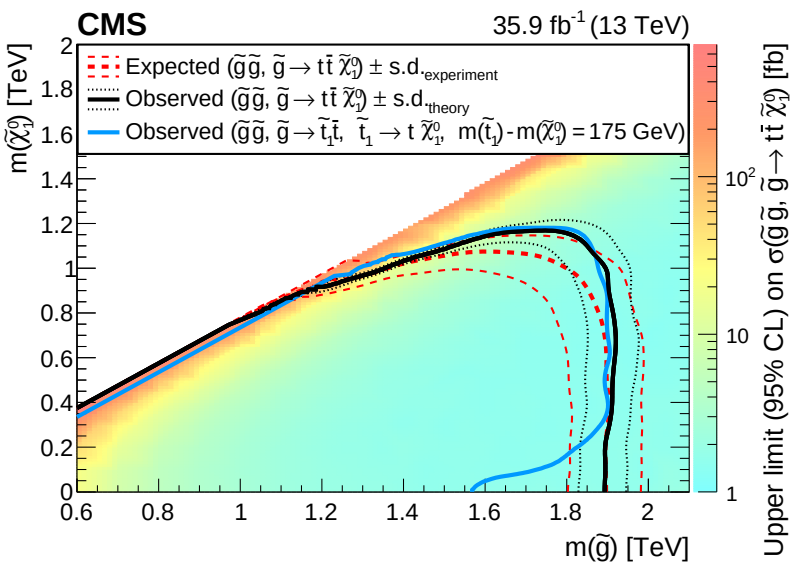



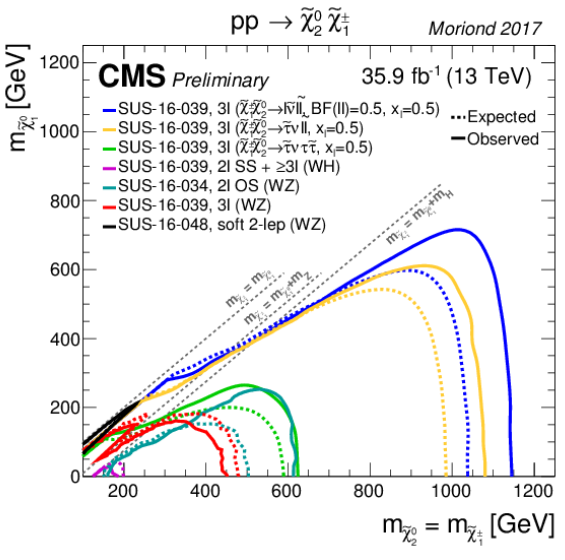

arxiv:1411.4413 [hep-ex]
arxiv:1609.00873 [hep-ex]

# Search for supersymmetry

- Exclusion of gluino and neutralino masses at 95% CL
  higher limits can be set for $\tilde{g}$ using hadronic channel with single lepton and multiple jets
- Limits are also set for $\tilde{\chi}_2^0$, $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$
- Similar searches performed over top squarks




arXiv:1705.04673 [hep-ex]
https://cms.cern/news/cms-new-results-Moriond-2017

# Analysis work in Cinvestav

## Measurement of the $\Lambda_b$ polarization and the angular parameters of the decay $\Lambda_b \to J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$

The CMS Collaboration

**Abstract**

We present a measurement of the $\Lambda_b$ polarization based on an angular analysis of the decay $\Lambda_b \to J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$, using data from pp collisions at $\sqrt{s} = 7$ TeV and 8 TeV collected with the CMS detector. A transverse $\Lambda_b$ polarization of $0.00 \pm 0.06(stat) \pm 0.02(syst)$ is measured.

## Quarkonium production cross sections in pp collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration

**Abstract**

Differential prompt production cross sections of $J/\psi$, $\psi(2S)$, and $\Upsilon(nS)$ ($n = 1, 2, 3$) vector mesons have been measured in $pp$ collisions at 13 TeV, using data collected by the CMS detector in 2015, corresponding to an integrated luminosity of 2.4 $fb^{-1}$ for $J/\psi$, and 2.7 $fb^{-1}$ for the other mesons. The five S-wave quarkonium states were reconstructed in the dimuon decay channel, for dimuon rapidity $|y| < 1.2$. For each state we present double-differential cross sections in several rapidity and transverse momentum ranges.

## Precision lifetime measurements of b hadrons reconstructed in final states with a $J/\psi$ meson

The CMS Collaboration

**Abstract**

We present measurements of the lifetimes of the $B^0$, $B_s^0$, $\Lambda_b^0$, and $B_c^+$ hadrons using the decay channels $B^0 \to J/\psi K^*(892)^0$, $B^0 \to J/\psi K_S$, $B_s^0 \to J/\psi\pi^+\pi^-$, $B_s^0 \to J/\psi\phi(1020)$, $\Lambda_b^0 \to J/\psi\Lambda$, and $B_c^+ \to J/\psi\pi^+$. The data sample, corresponding to 19.7 $fb^{-1}$, was collected from proton-proton collisions at $\sqrt{s} = 8$ TeV using dedicated triggers to select oppositely charged muons in the $J/\psi$ mass region. The lifetimes times the speed of light are measured to be

$$
\begin{aligned}
c\tau_{B^0} &= 453.0 \pm 1.6\,(\text{stat}) \pm 1.5\,(\text{syst})\ \mu\text{m}\ (\text{in } J/\psi K^*(892)^0)\\
c\tau_{B^0} &= 457.8 \pm 2.7\,(\text{stat}) \pm 2.7\,(\text{syst})\ \mu\text{m}\ (\text{in } J/\psi K_S)\\
c\tau_{B_s^0} &= 504.3 \pm 10.5\,(\text{stat}) \pm 3.7\,(\text{syst})\ \mu\text{m}\ (\text{in } J/\psi\pi^+\pi^-)\\
c\tau_{B_s^0} &= 443.9 \pm 2.0\,(\text{stat}) \pm 1.2\,(\text{syst})\ \mu\text{m}\ (\text{in } J/\psi\phi(1020))\\
c\tau_{\Lambda_b^0} &= 443.1 \pm 8.2\,(\text{stat}) \pm 2.7\,(\text{syst})\ \mu\text{m}\\
c\tau_{B_c^+} &= 162.3 \pm 8.2\,(\text{stat}) \pm 4.7\,(\text{syst}) \pm 0.1(\tau_{B^+})\ \mu\text{m}
\end{aligned}
$$

where the first uncertainty is statistical and the other is systematic. All results are in agreement with the current world average values.

## Search for resonance-like structures in the $B_s^0\pi^\pm$ invariant mass spectrum

**Abstract**

A search for resonance-like structures in the $B_s^0\pi^\pm$ invariant mass spectrum is performed using an integrated luminosity of 19.7 $fb^{-1}$ of $pp$ collisions collected by the CMS experiment at $\sqrt{s} = 8$ TeV. The $B_s^0$ candidates are reconstructed in the decay chain $B_s^0 \to J/\psi\phi$, $J/\psi \to \mu^+\mu^-$, $\phi \to K^+K^-$. The $B_s^0\pi^\pm$ invariant mass distributions do not show any unexpected structures for different kinematic requirements imposed to the $\pi^\pm$, $B_s^0$ and $B_s^0\pi^\pm$ candidates. Upper limits on the relative production of the $X(5568)$ state, claimed by the DØ Collaboration, are estimated to be:

$$
\begin{aligned}
\rho_X &< 1.1\%\ @\ 95\%\,\text{CL for } p_T(B_s^0) > 10\,\text{GeV},\\
\rho_X &< 1.0\%\ @\ 95\%\,\text{CL for } p_T(B_s^0) > 15\,\text{GeV},
\end{aligned}
$$

which are in strong disagreement with DØ measurements of $8.6 \pm 2.4\%$ ($8.2 \pm 3.1\%$) for $p_T(B_s^0) > 10(15)$ GeV.



- Observation of $J/\psi$p resonances consistent with pentaquark states in $\Lambda_b^0 \to J/\psi K^- p$ decays
- $J/\psi$ production and pentaquark search in p-Pb collisions at $\sqrt{s} = 8$ TeV

# Analysis work in BUAP

Available on the CERN CDS information server **CMS PAS HIG-16-031**

CMS Physics Analysis Summary

Contact: cms-pag-conveners-higgs@cern.ch 2016/10/12

Search for charged Higgs bosons with the $H^{\pm} \to \tau^{\pm}\nu_{\tau}$ decay channel in the fully hadronic final state at $\sqrt{s} = 13$ TeV

The CMS Collaboration

**POM: CMS PAS AN-16-491** CMS PAS AN-16-491

DRAFT
CMS Physics Analysis Summary

*The content of this note is intended for CMS internal use and distribution only*

2017/05/08
Head Id: 401033
Archive Id: 392599:403025MP
Archive Date: 2017/04/26
Archive Tag: trunk

Search for a charged Higgs boson decaying into a top and a bottom quark in the single lepton and dilepton final state at

Available on CMS information server **CMS DN -2017/005**

The Compact Muon Solenoid Experiment

**Detector Note**

The content of this note is intended for CMS internal use and distribution only

10 January 2017

Estimation of radiation background and impact on muon detectors performance for Phase-2 and Run-2 scenarios

Available on the CMS information server **CMS AN-17-090**

CMS Draft Analysis Note

*The content of this note is intended for CMS internal use and distribution only*

2017/05/10
Head Id: 403705
Archive Id: 403693:403714
Archive Date: 2017/05/09
Archive Tag: trunk

**Common note:**
**CMS AN-17-090**

PAS is currently written

Search for a charged Higgs decaying into a top and a bottom quark in leptonic final states at $\sqrt{s} = 13$ TeV

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-EP/2016-321
2017/01/24

CMS-TOP-16-006

Paper Accepted in JHEP

Measurement of the $t\bar{t}$ production cross section using events with one lepton and at least one jet in pp collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration*

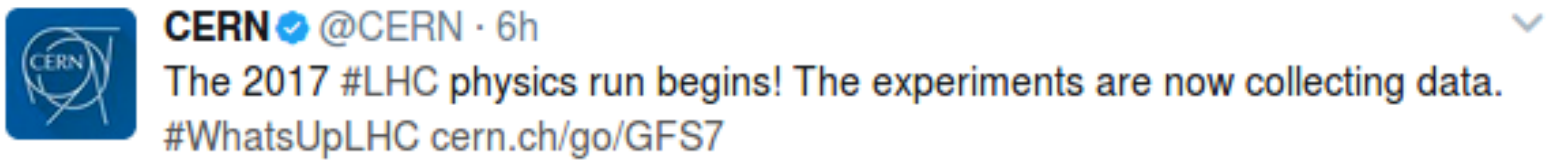
## Summary and conclusions

- Additional analyses from Run 1 and Run 2 under progress or in process to be published
- Successful data collection in 2016 and EYETS upgrade process during 2016/17
- For higgs physics, SUSY and search of heavy resonances: significant improvement compared to Run 1
- Electroweak precision measurements need excellent understanding of the detector performance and thus final detector calibrations:

  - Study of Z + jj production, W + jj, Z forward and backward asymmetry, $Z \rightarrow \mu\mu$ angular analysis, W charge asymmetry, W/Z trasnverse momentum

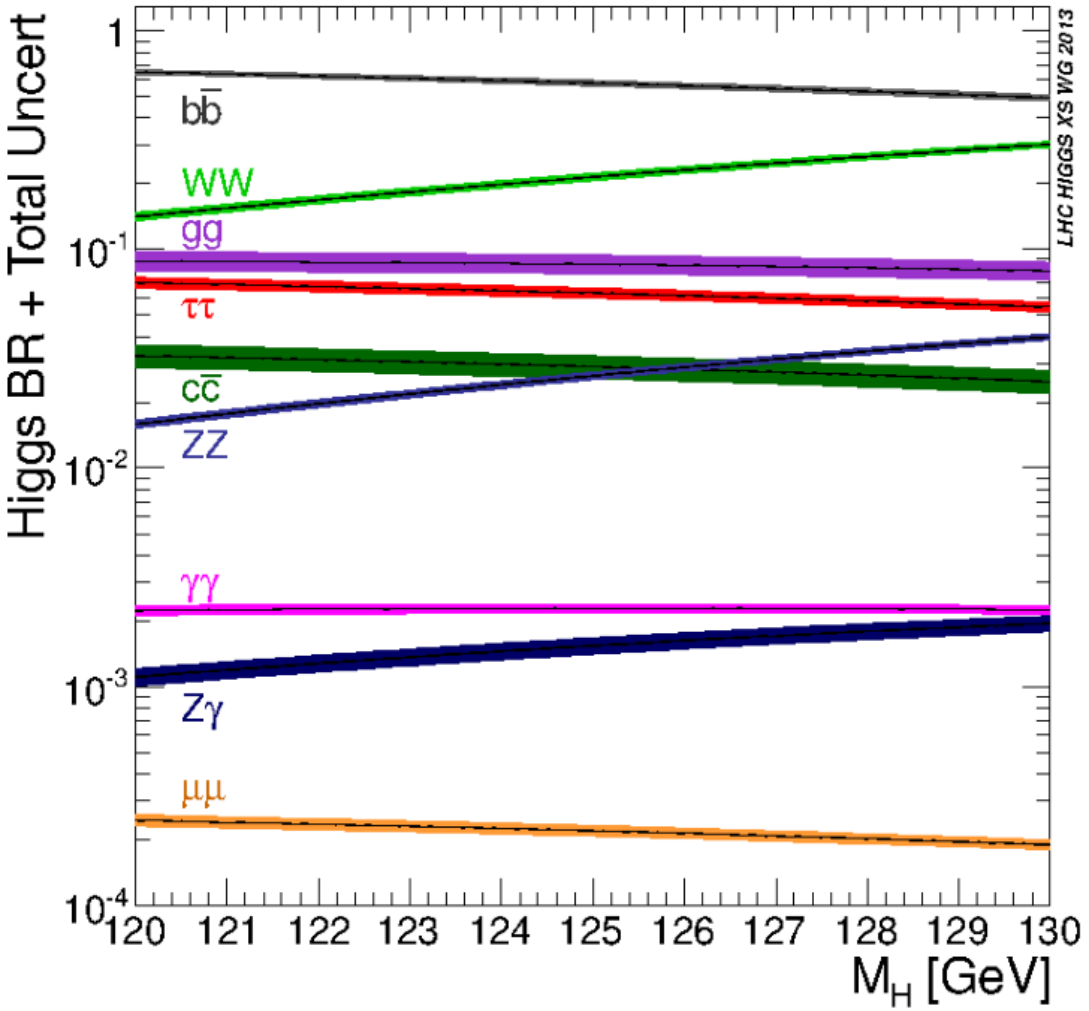
  - Statistics from Run II data will help with precision

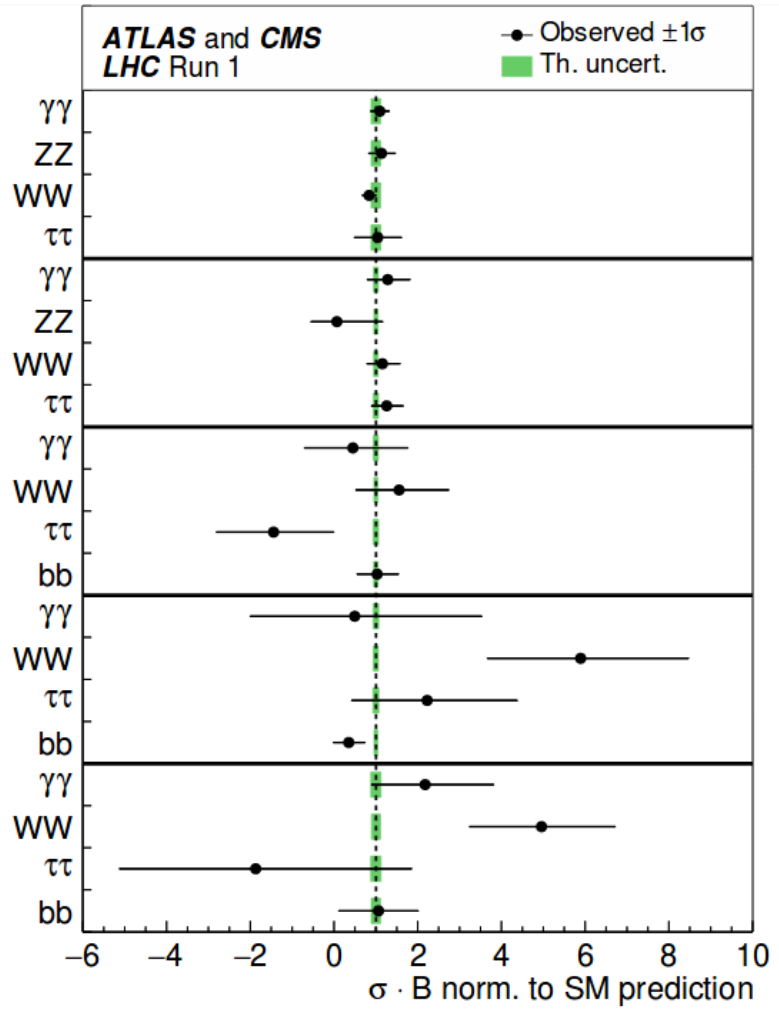
- For recent searches for heavy resonances: no BSM results so far
- The LHC has already started its 2017 run: 'stable beams' have been achieved just yesterday!



# Backup

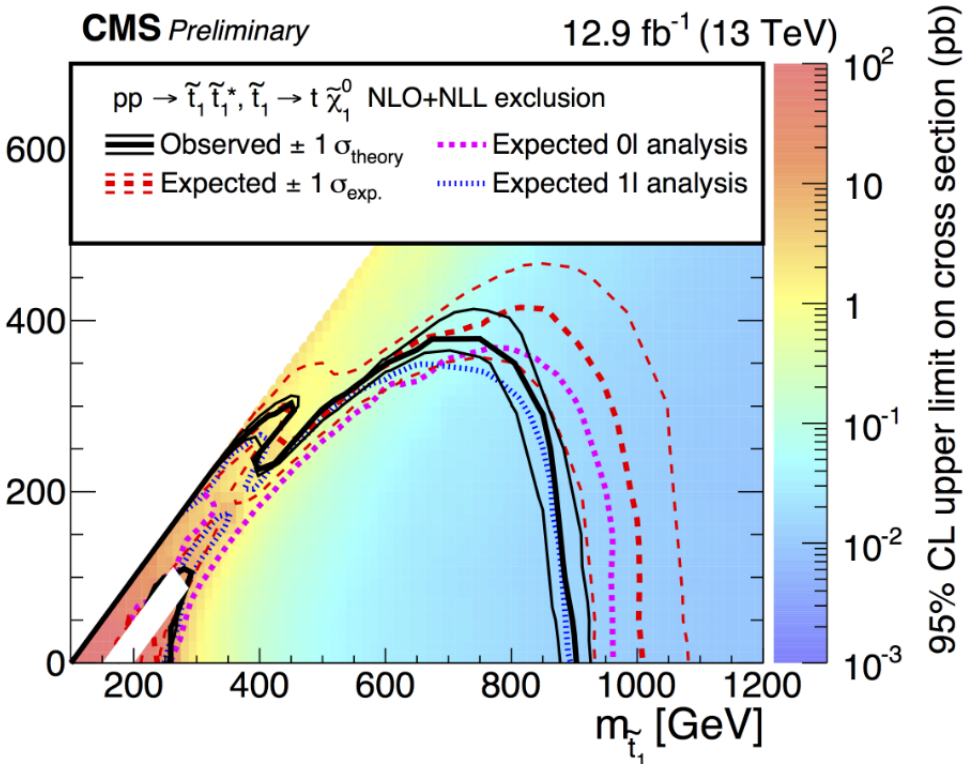
# Observation of 125 GeV Higgs at 13 TeV




arXiv:1606.02266

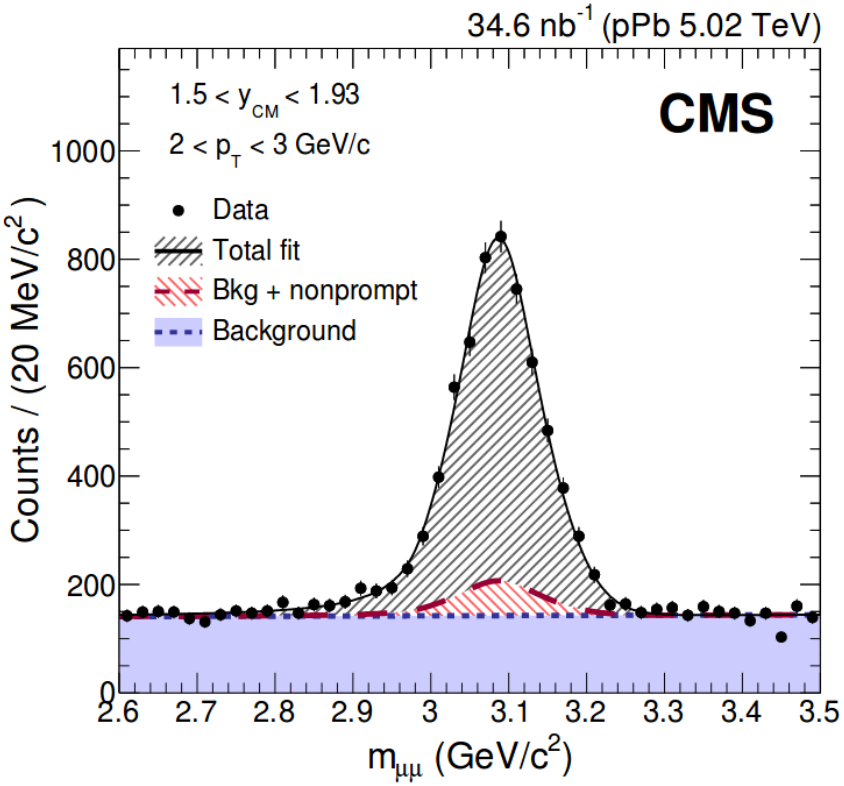
# Search for supersymmetry

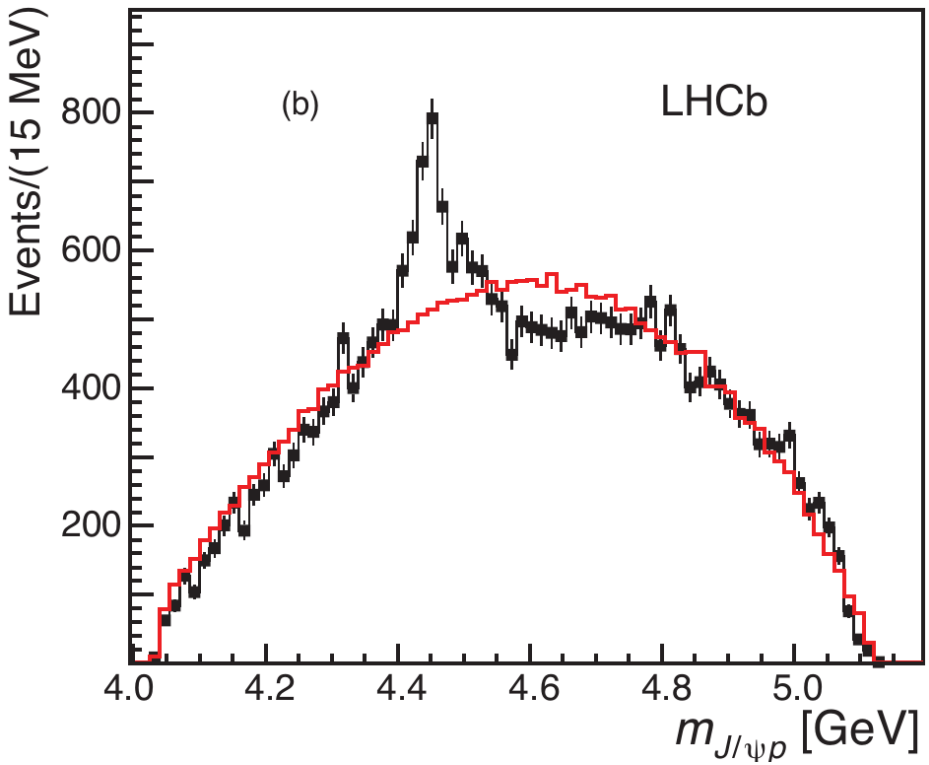



http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/ICHEP-2016.html

# Study of J/$\psi$ and search for pentaquarks

- 2013 data / $\int$Ldt $\sim$ 35 nb$^{-1}$: CMS latest publication on $J/\psi$ in pPb collisions
- 7 and 8 TeV collisions / $\int$Ldt $\sim$ 3 fb$^{-1}$: LHCb observation of J/$\psi$ resonances

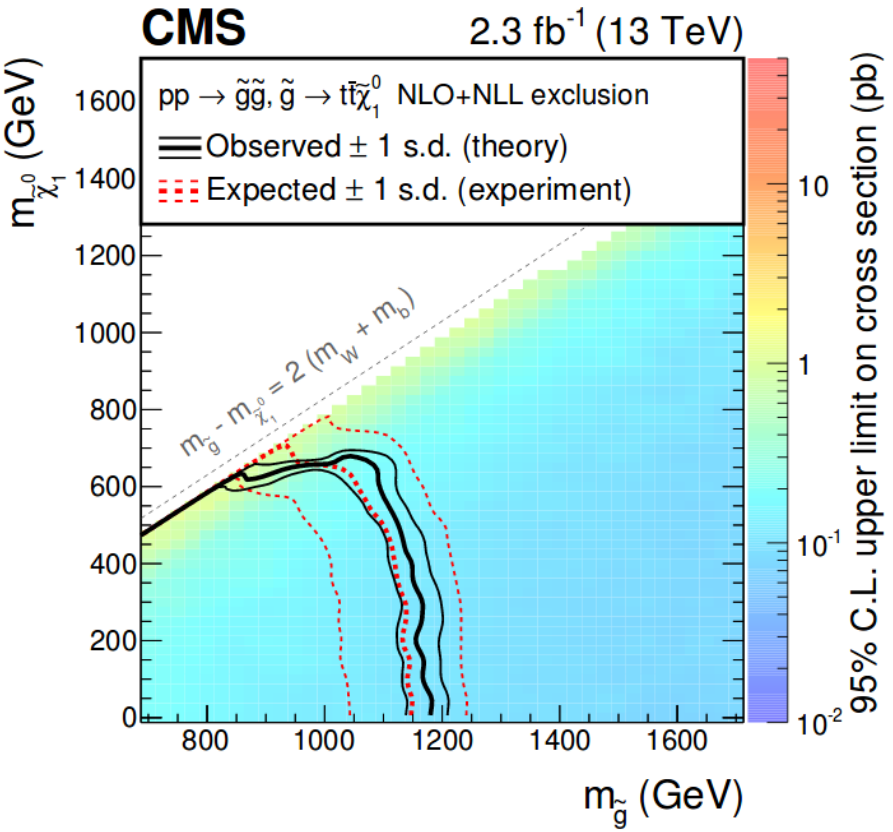


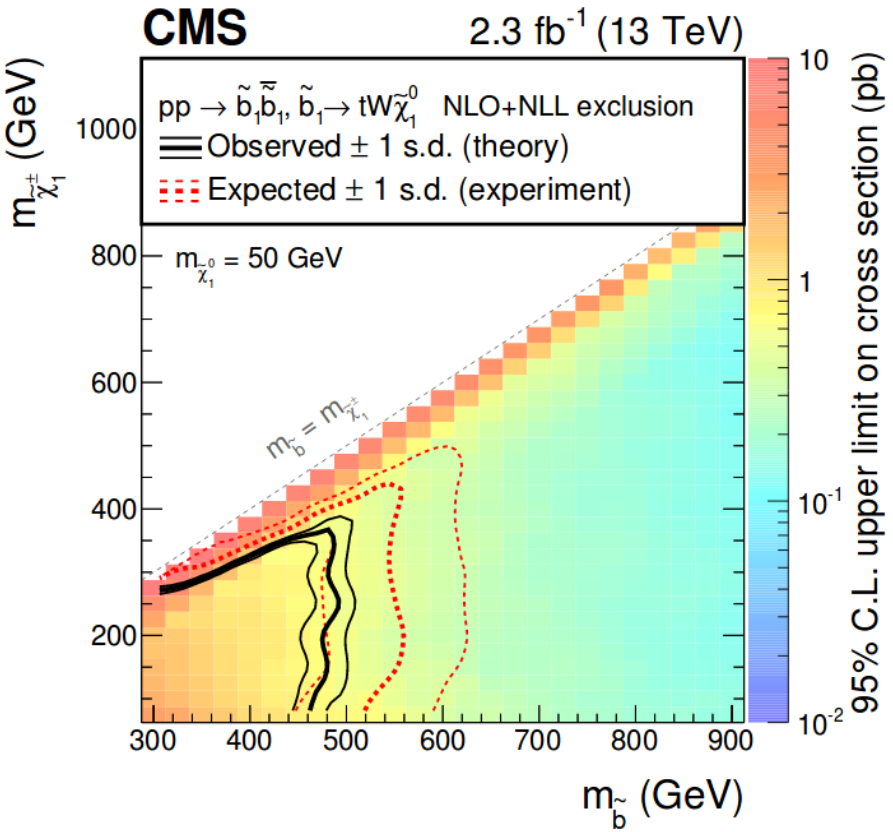




arXiv:1702.01462
arXiv:1507.03414

# Search for supersymmetry with multiple charged leptons in proton-proton collisions

- $\int 2.3\text{dt fb}^{-1}$, $\sqrt{s} = 13$ TeV
- Final states with at least three charged leptons: any combination of muon or electrons
- The event yields observed in data are consistent with the expected background contributions from standard model processes

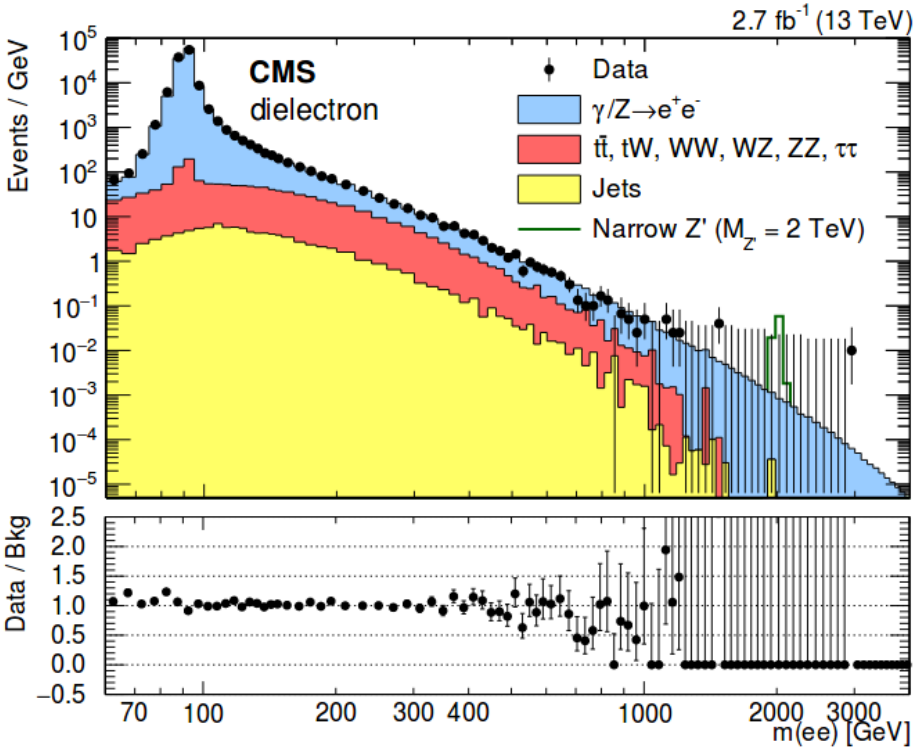


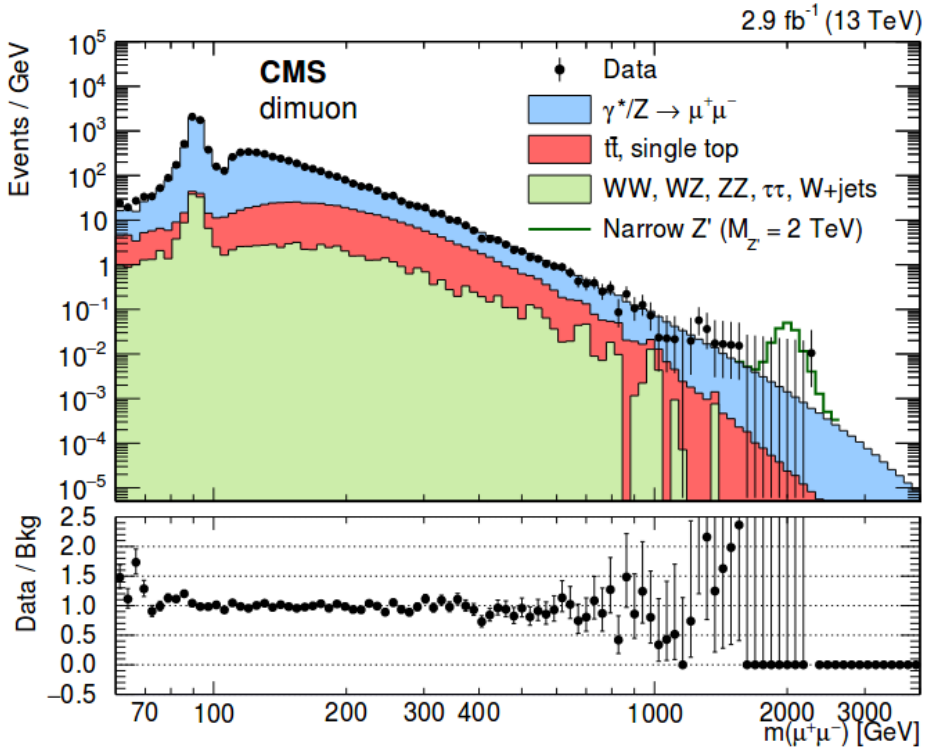




arXiv:1701.06940

# Search for resonances in dilepton mass spectra in proton-proton collisions

- A search for narrow resonances in dielectron and dimuon invariant mass spectra
- No evidence for non-standard-model physics is found: either in the 13 TeV data set alone or in the combined data set
- These results significantly exceed the limits based on the 8 TeV LHC data

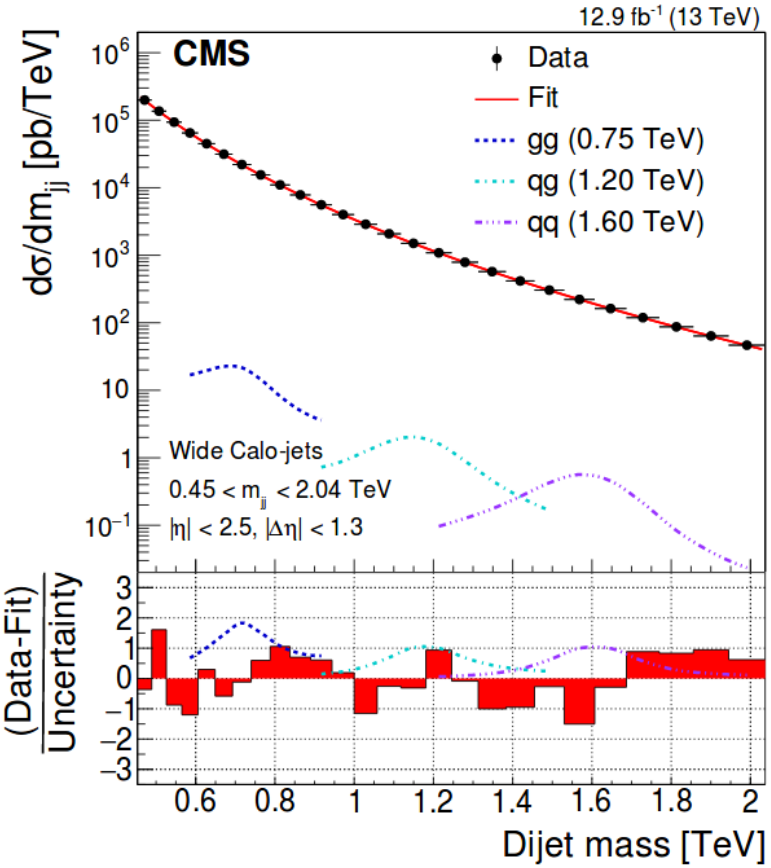


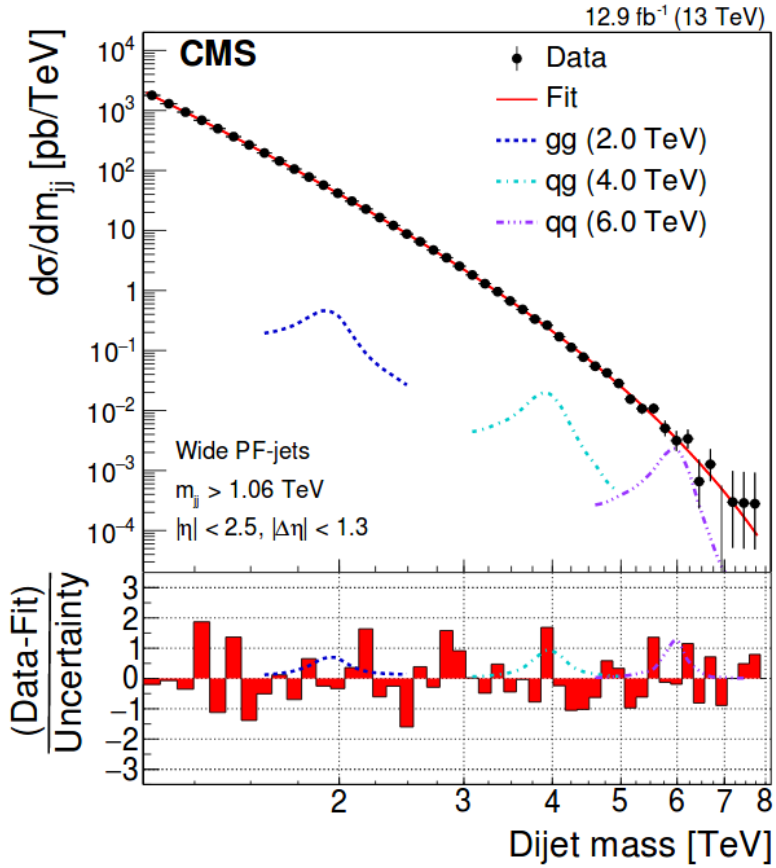




arXiv:1609.05391

# Search for dijet resonances in proton-proton collisions / 2016 12.9 $fb^{-1}$, 13 TeV

- Constraints on dark matter and other models
- No significant evidence for the production of new particles is observed
  - Upper limits (at 95% C.L.) on the producing cross-section for narrow resonances with masses above 0.6 TeV

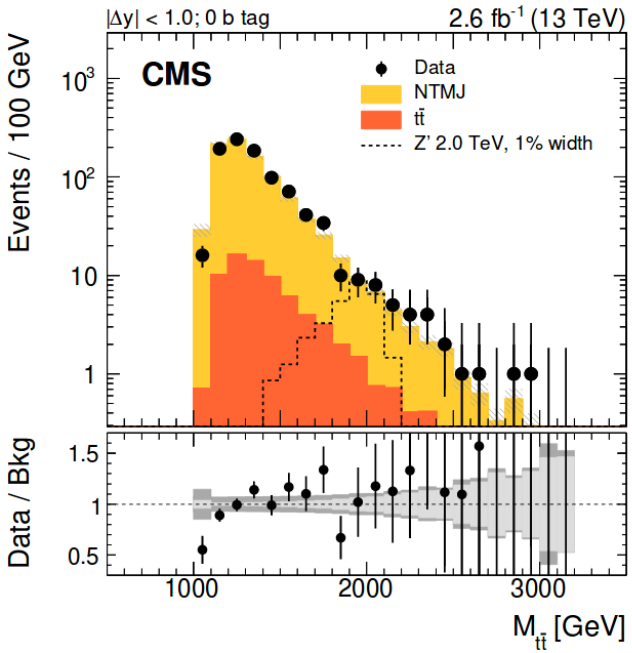


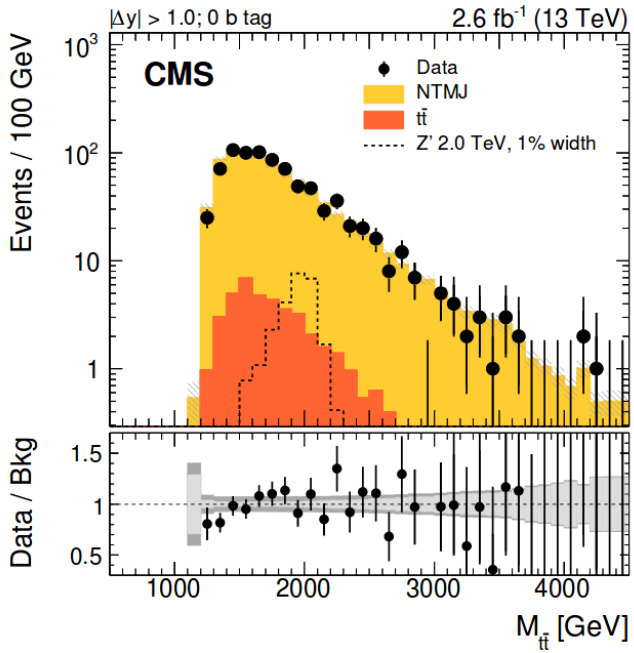




arXiv:1611.03568v1

# Search for $t\bar{t}$ resonances in highly-boosted $\ell$+jets and fully hadronic final states

- Massive new particle could be observed as a $t\bar{t}$ resonance at the TeV scale: upper limits on their production cross section are set
- Four benchmark models are considered: A Z' boson decaying exclusively to $t\bar{t}$ with relatively decay widths of 1%, 10% and 30% and a KK gluon resonance in the RS model (relative decay width of $\sim$ 17 %)




arXiv:1704.03366

# Additional higgs analyses in final stages: ATLAS and CMS

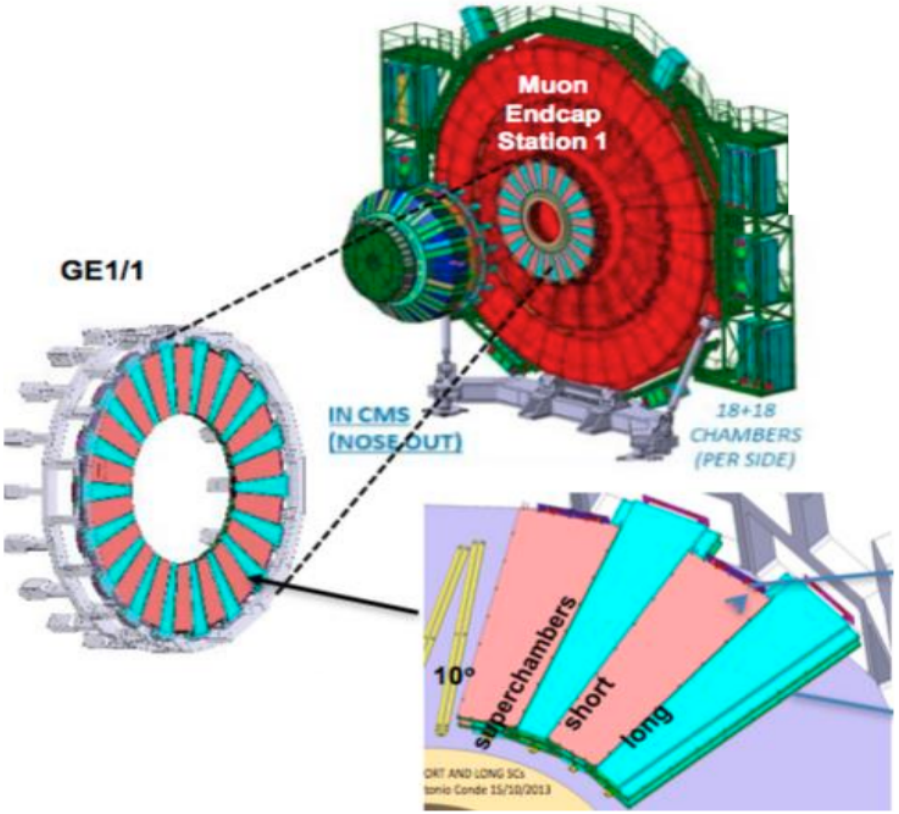
- HH pairs production: Study has been done assuming the pair HH decays to a $\tau\tau$ pair and a $b\bar{b}$
  - Different theories predict resonant Higgs pair production X$\rightarrow$HH
- Events with missing energy + H $\rightarrow \gamma\gamma$ (SM):
  - Three different theoretical benchmark models: BSM physics responsible for producing DM
  - Association of DM particles with $E_T^{miss}$
- H$\rightarrow \mu\mu$: decay of the SM $m_H = 125$ GeV higgs boson.
  - SM branching ratio for this decay $= 2.18\times10^{-4}$
  - Observed / expected upper limits cross sections (at 95% C.L.) still $\sim$ 3.0 times the SM prediction

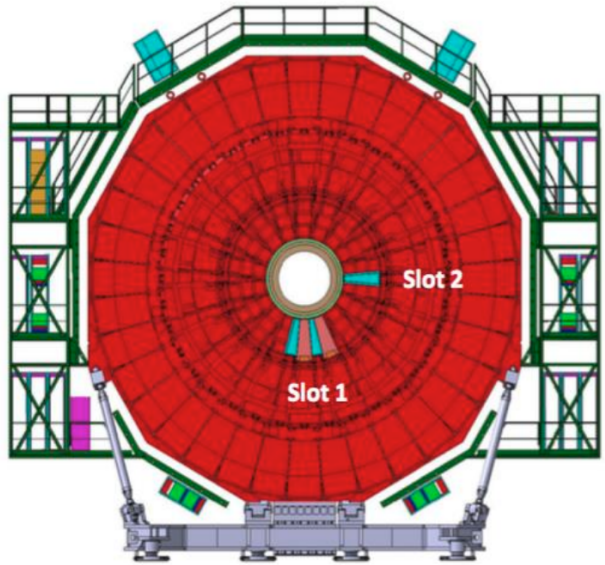
https://cms.cern/news/cms-new-results-Moriond-2017

# CMS muon GE1/1 muon station installation

- 5 GEM chambers covering 40 + 10 degrees were installed on the YE-1 endcap disk

  - GEM detectors have been identified as a suitable technology to operate in the high radiation environtment present in that region
  - Upgrade will help to reduce the GE1/1 commissioning period during LS2
  - Maintaining low muon trigger $p_T$ thresholds is important for a broad spectrum of physics studies ranging from new physics searches to the measurements in the Higgs sector

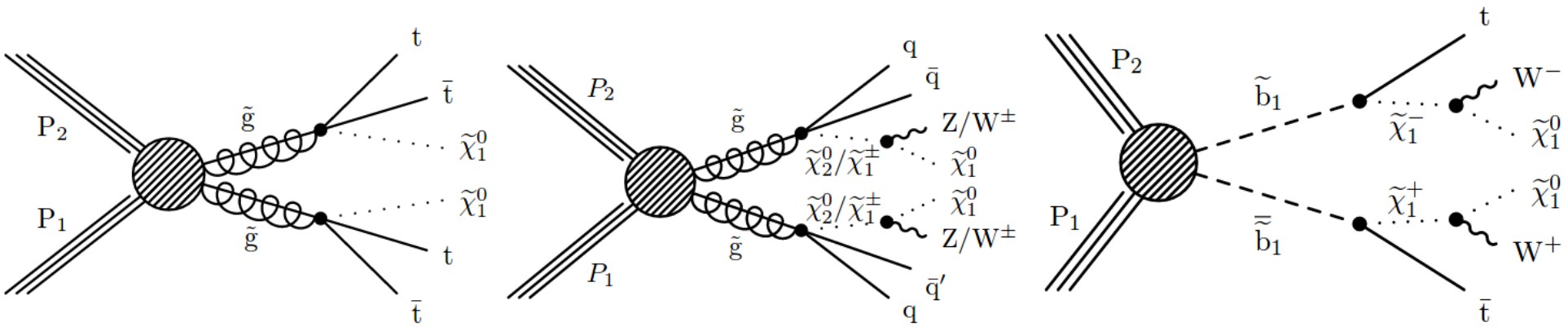



CMS-TDR-013

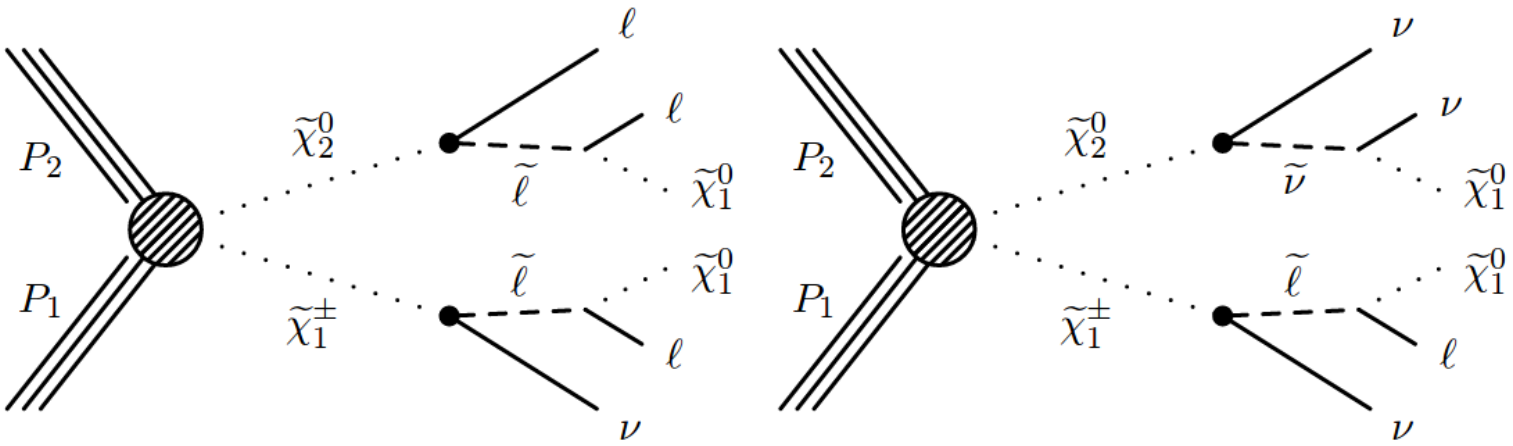
# Search for supersymmetry with multiple charged leptons in proton-proton collisions

- $\int 2.3\text{dt fb}^{-1}$, $\sqrt{s} = 13$ TeV
- Final states with at least three charged leptons: any combination of muon or electrons
- The event yields observed in data are consistent with the expected background contributions from standard model processes
- Diagrams for gluino and bottom squark production:




arXiv:1701.06940

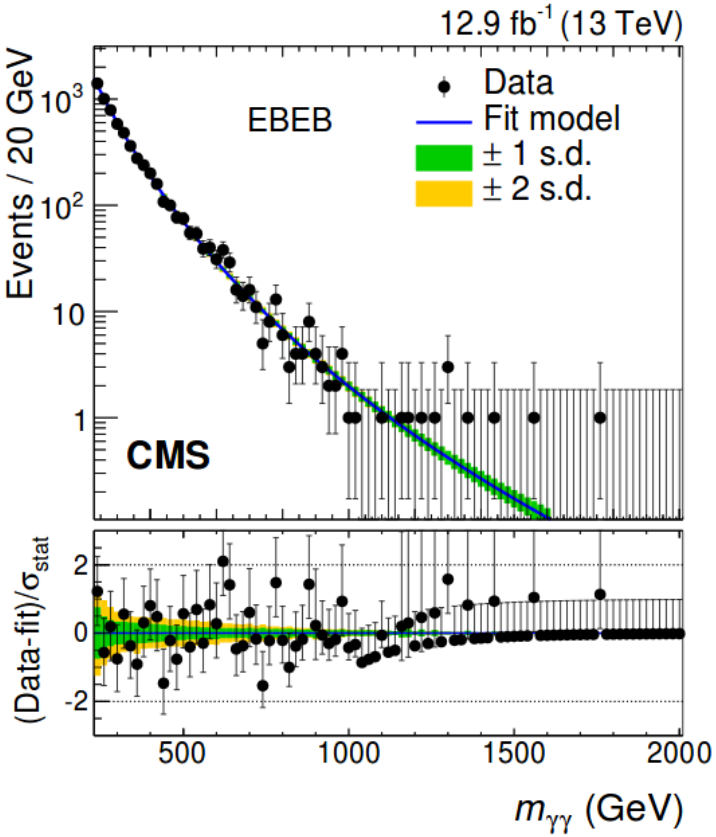
# Search for supersymmetry

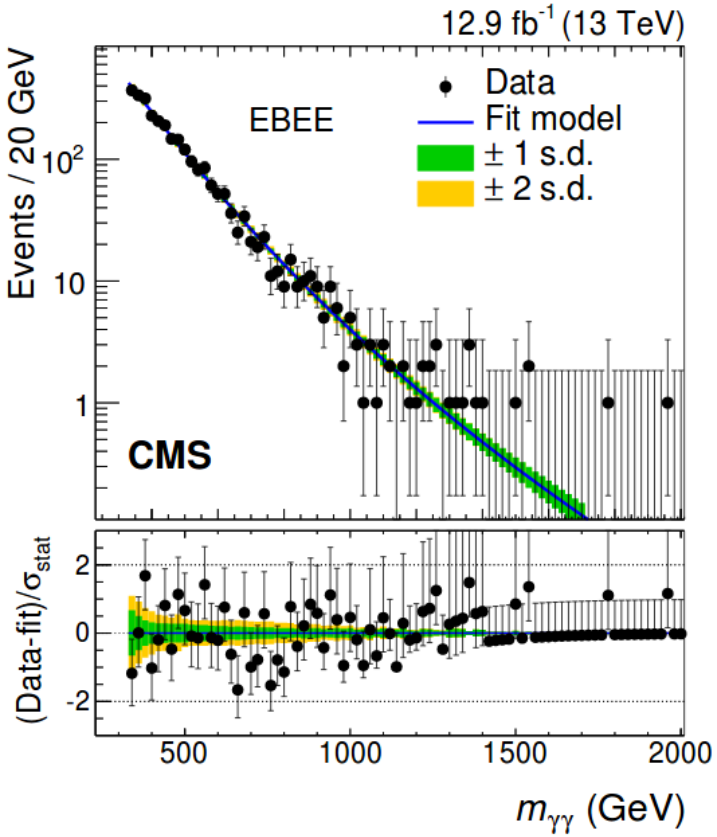



https://cms.cern/news/cms-new-results-Moriond-2017

# Search for high-mass diphoton resonances in proton-proton collisions

- Extended search of higgs resonance: Using method based on ggF production
- Models with extended Higgs boson sectors: some of these extensions predict new resonances that decay to a diphoton final state such as Randall-Sundrum gravitons
- Masses between 0.5 and 4.5 TeV and widths relative to the mass $1.4\times10^{-4}$ and $5.6\times10^{-2}$

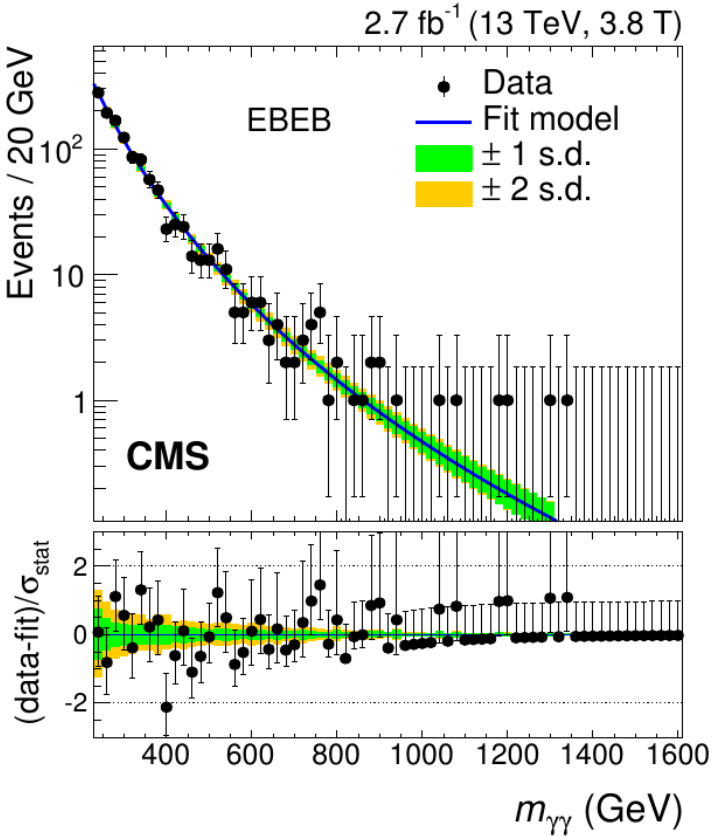


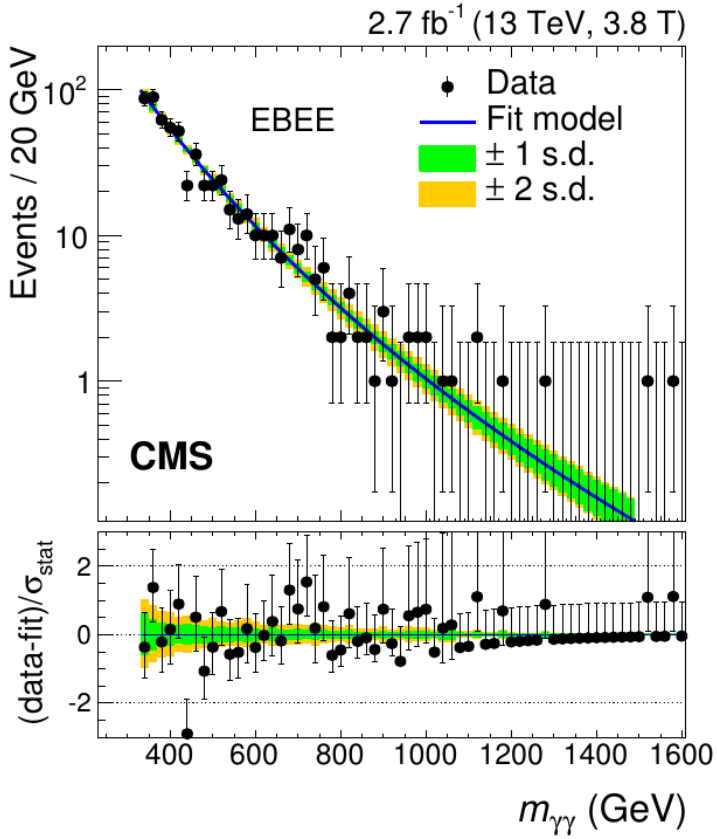




arXiv:1609.02507v2

# Search for high-mass diphoton resonances in proton-proton collisions

- Previous result: "A modest excess of events compatible with a narrow resonance with a mass of about 750 GeV is observed"



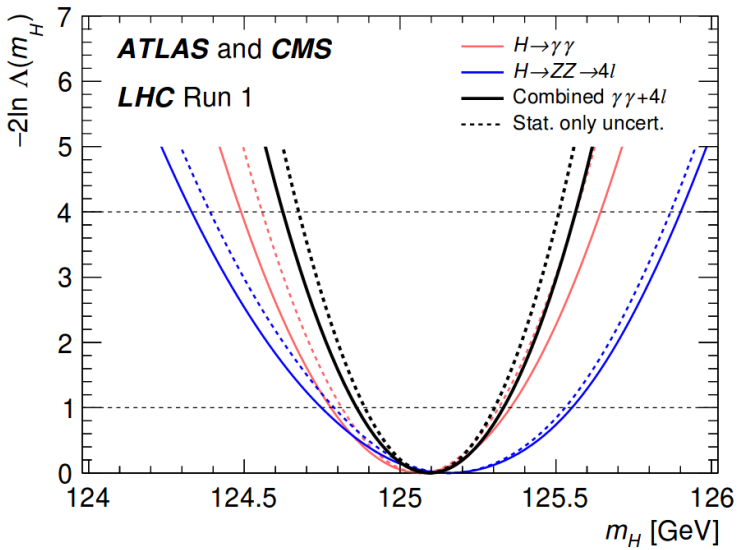



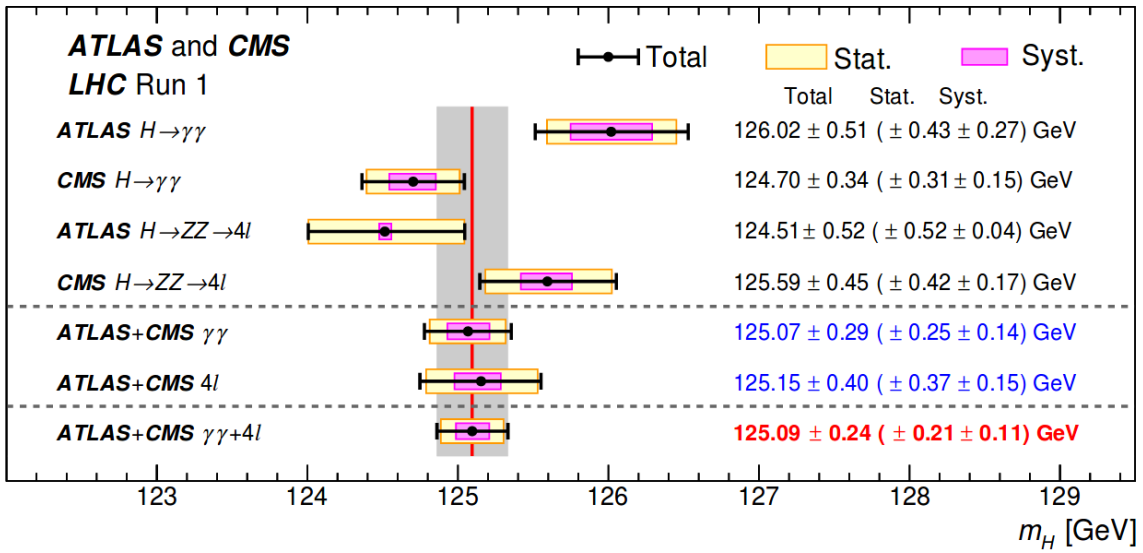

arXiv:1609.04093

# Combined measurement of the higgs boson mass in p-p collisions at 7 and 8 TeV

- Run-1 legacy:

  Discovery of a new boson in 2012 consistent with the Standard Model (SM) Higgs boson
- Combination of ATLAS and CMS results in the H$\to \gamma\gamma$ and H$\to$ZZ$\to 4\ell$
- $m_H = 125.09 \pm 0.21$ (stat.) $\pm 0.11$ (syst.) GeV




arXiv:1503.07589v1

# CMS areas of research

CMS Publications
- Run 2 data
- Run 1 data
- Cosmics data
- The CMS Experiment at the CERN LHC

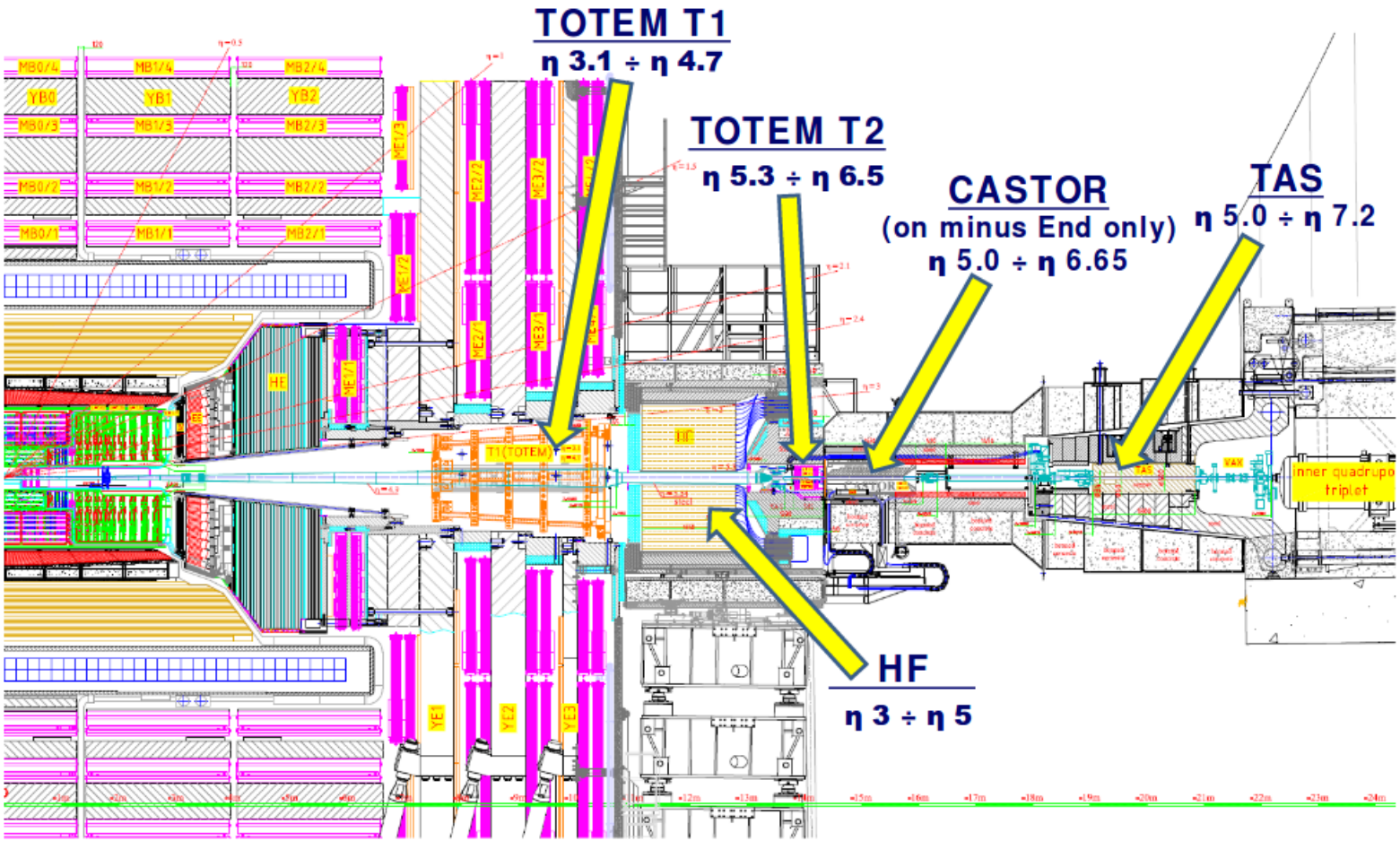
CMS Physics Publications
- Forward and Small-x QCD Physics
- B Physics and Quarkonia
- Standard Model Physics
- Top Physics
- Higgs Physics
- Supersymmetry
- Exotica
- Beyond 2 Generations
- Heavy-Ion Physics

CMS Physics Object Publications
- Tracking
- Vertexing and B Tagging
- Electron Photon
- Muon
- Jet and Missing ET
- Tau

`http://cms-results.web.cern.ch/cms-results/public-results/publications/`

# Much more upgrade work in progress

- TOTEM Forward detectors
  - Upgrade of pixel detector for ROMAN POTs tracker
- Pixel Luminosity Telescope: 1.75m from IP (both ends of CMS, $|\eta| \sim 4.2$)
  - Diamonds sensors upgrade




CMS-CR-2015-121

# CMS muon GE1/1 muon station installation

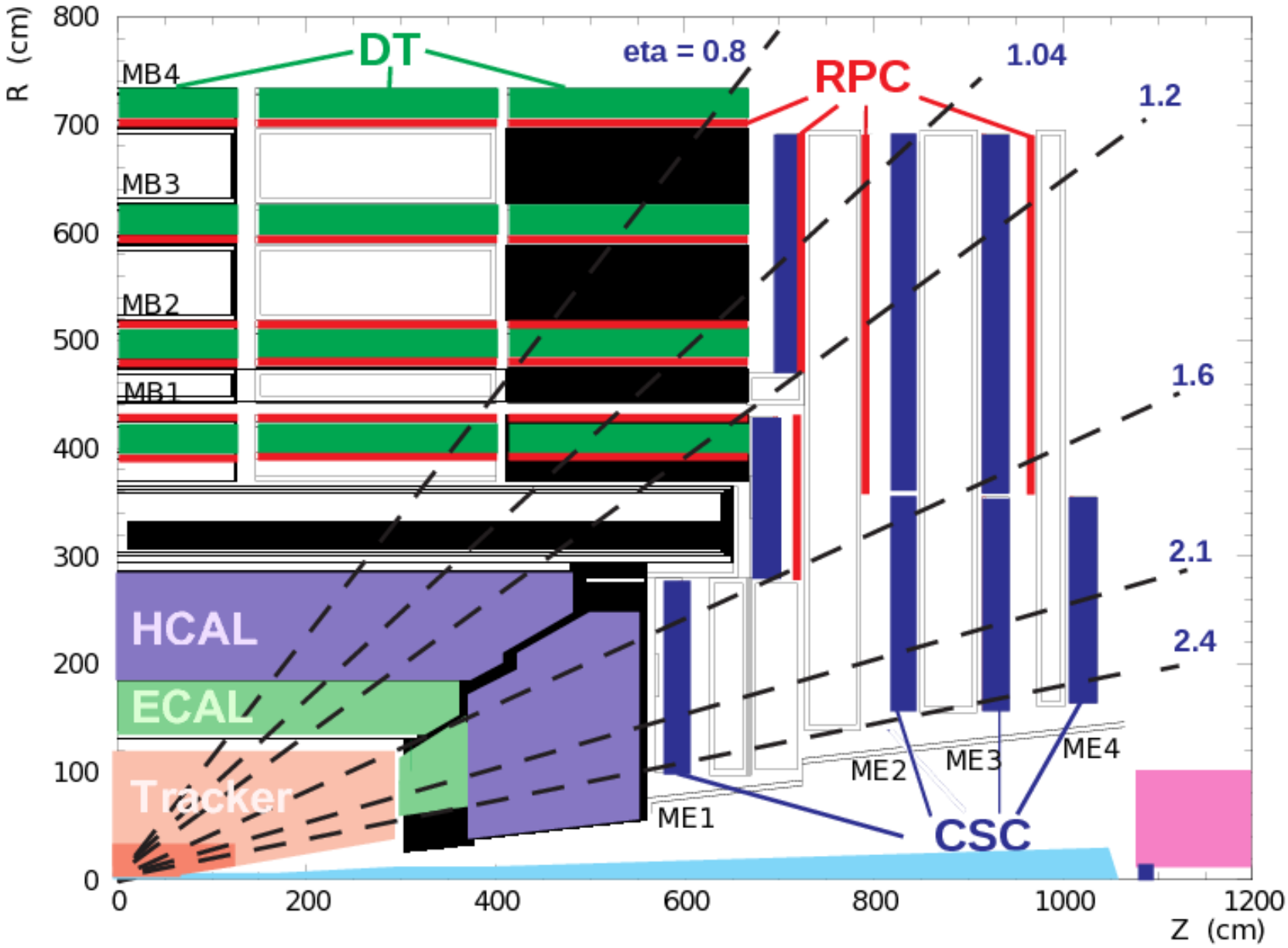
- CMS muon subdetector was originally designed as highly hermetic and redundant system that employs three detection technologies:

  - Drift tubes (DT) in the barrel: covering acceptances up to $|\eta| < 1.2$
  - Cathode strip chambers (CSC) in the endcap: covering $1.0 < |\eta| < 2.4$
  - Resistive plate chambers (RPC) barrel and endcap: provide trigger and coarse position measurement (not beyond $|\eta| < 1.6$)

- Installation of an additional set of muon detectors GE1/1 that use gas electron multiplier (GEM) technology in the first endcap muon station:

  - To maintain and possibly improve forward muon triggering and reconstruction in the region $1.6 < |\eta| < 2.2$ in the face of high luminosity:
  here currently the amount of detection layers is lowest and background rates are highest
  - Located where the bending of muons within the CMS solenoid is small
  - Improves L1 stand-alone muon trigger momentum resolution
  - In general lower rates are expected under previous experienced conditions
  - Low muon trigger $p_T$ thresholds will be maintained: important for broad spectrum of physics studies ranging from new physics searches to measurements in the higgs sector

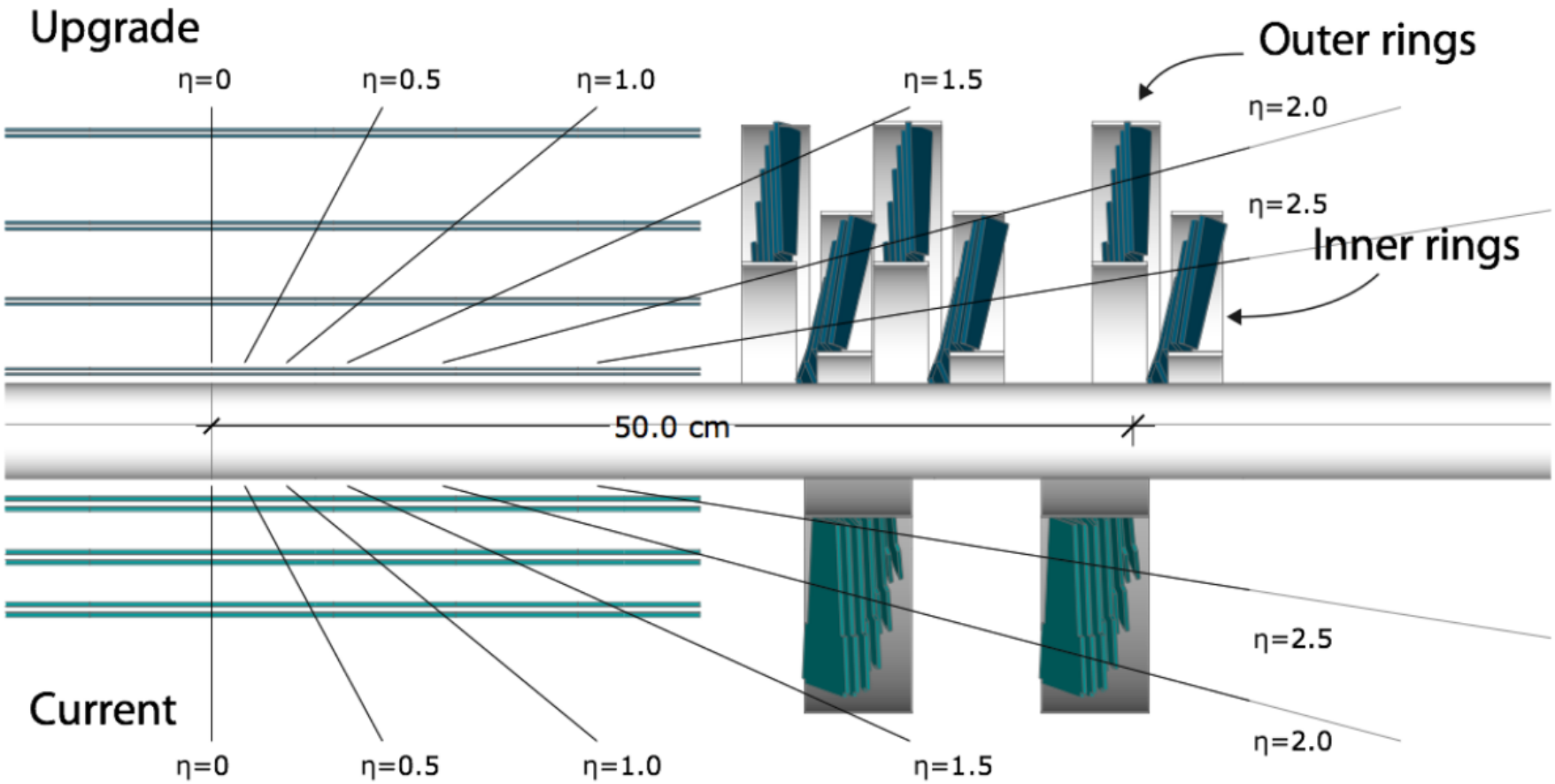
CMS-TDR-013




arXiv:1206.4071

# CMS Tracking system upgrade / exploiting increased luminosity

- Innermost barrel layer at 29 mm from the beam line
- Provides a four-hit coverage for all tracks over the pseudorapidity range up to $\pm$ 2.5




CMS-TDR-011

# CMS Tracking system upgrade / exploiting increased luminosity

- Previous pixel detector (resolution 10 - 20 $\mu$m, designed for data rates expected up to the LHC design luminosity of $1\times10^{34}\text{cm}^{-2}\text{s}^{-1}$):

  - Three barrel layers (BPIX) at radii:
    4.4, 7.3 and 10.2 cm / new: 3.9, 6.8, 10.9, 16.0 cm

  - Two forward / backward disks (FPIX) at:
    $\pm$ 34.5cm and $\pm$ 46.5cm / new: $\pm$ 29.1, $\pm$ 39.6, $\pm$ 51.6 cm
    (extending radius from 6 to 15 cm) / new system expands from 4.5 to 16.1 cm

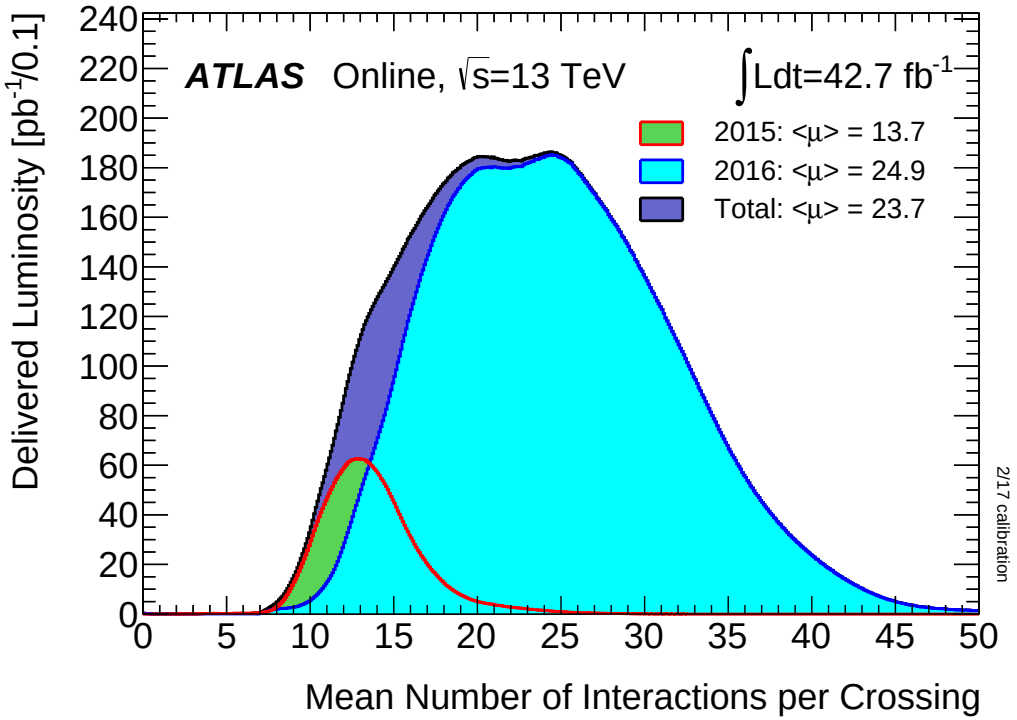
  - Barrel pixel detector: 48 milllion pixels ($0.78\text{m}^2$) / new: 80 million channels
  - Forward pixel detector: 18 million channels ($0.28\text{m}^2$) / new: 45 million channels
  - Substantial data losses due to read out chip material (ROC) / new one has been installed with improved buffering

- Used online for:

  - Primary vertex reconstruction
  - Electron / photon identification
  - Muon reconstruction
  - Tau identification
  - b-tagging
  - Off-line missing energy reconstruction

CMS-TDR-011

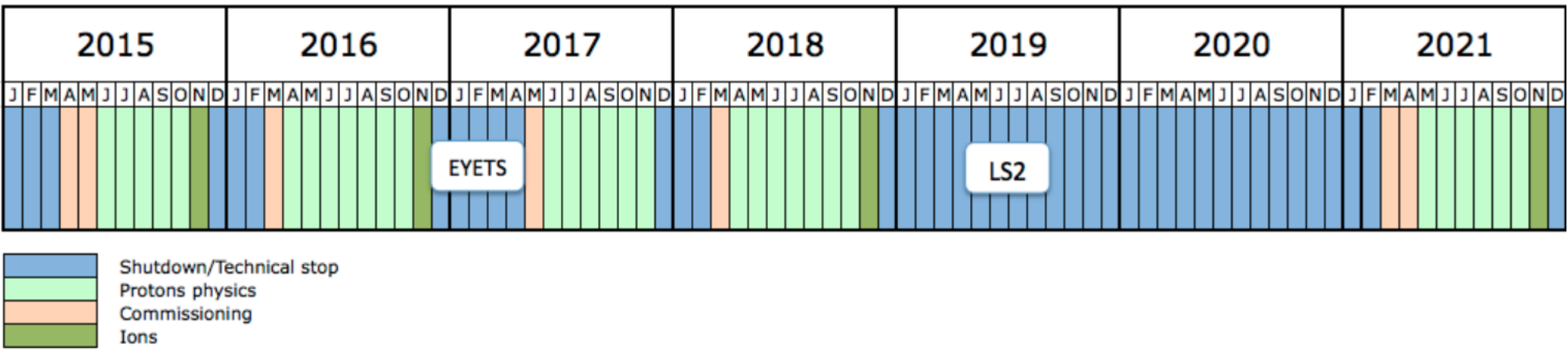
- Pileup in Run 2




https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2

- Run-II: 2015 - 2018
  - 2016: April - November, 2017: June - November / peak luminosity $\sim 1.4 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$
  - The integrated luminosity target over this period for both ATLAS and CMS is $\sim 100\ \text{fb}^{-1}$
  - Collision energy 13 TeV, peak luminosity $\sim 1.7 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$

- Run-III: 2021 - 2023
  - The integrated luminosity target in this run for both ATLAS and CMS is to complete a total of $\sim 300\ \text{fb}^{-1}$
  - Collision energy 14 TeV, nominal luminosity $\sim 2.0 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$



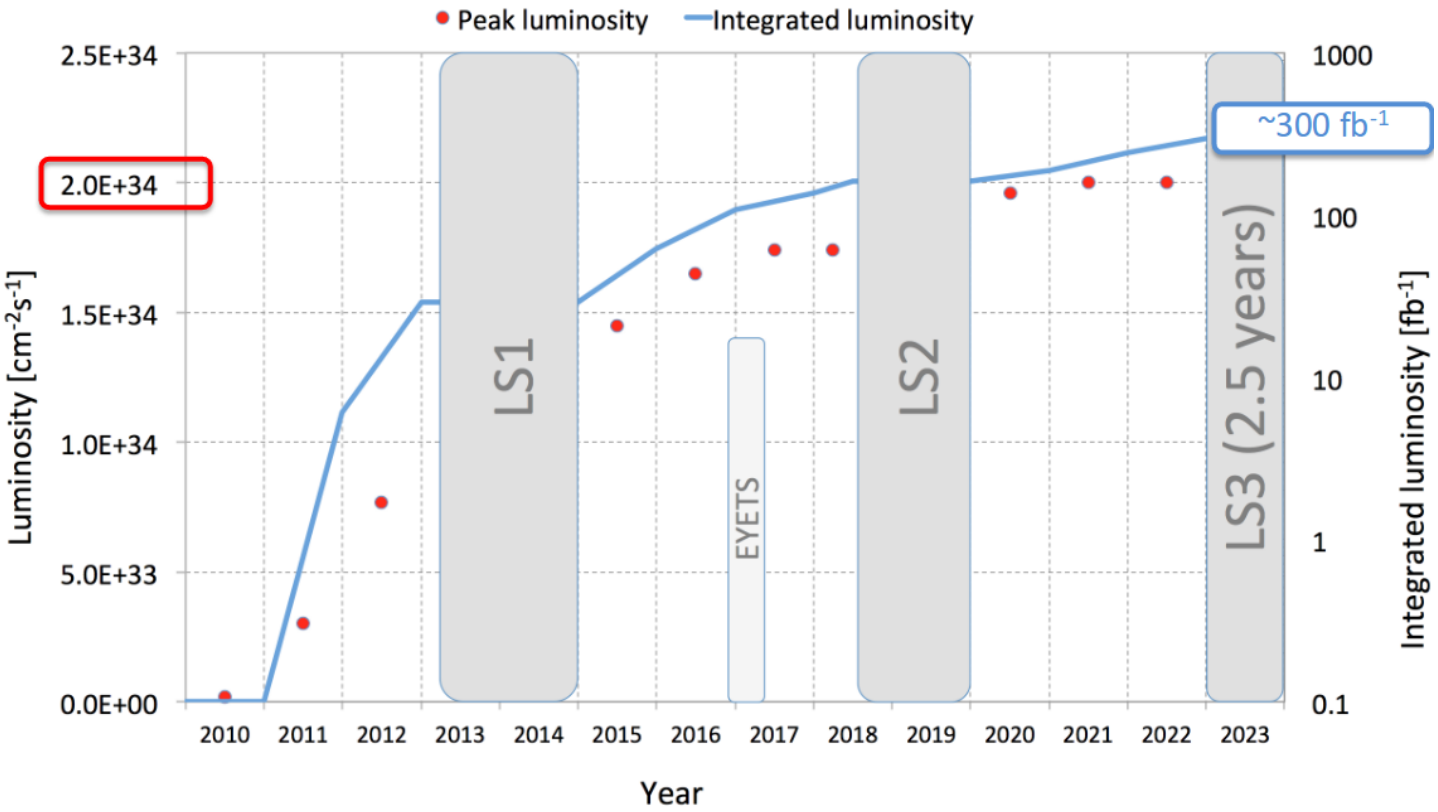

lhc-commissioning
https://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC-long-term.htm
http://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC-schedule-update.pdf
http://iopscience.iop.org/journal/1748-0221/page/extra.lhc

- Run-II: 2015 - 2018

  - The integrated luminosity target over this period for both ATLAS and CMS is $\sim$ 100 fb$^{-1}$

- Run-III: 2021 - 2023

  - The integrated luminosity target in this run for both ATLAS and CMS is to complete a total of $\sim$ 300 fb$^{-1}$




lhc-commissioning

https://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC-long-term.htm

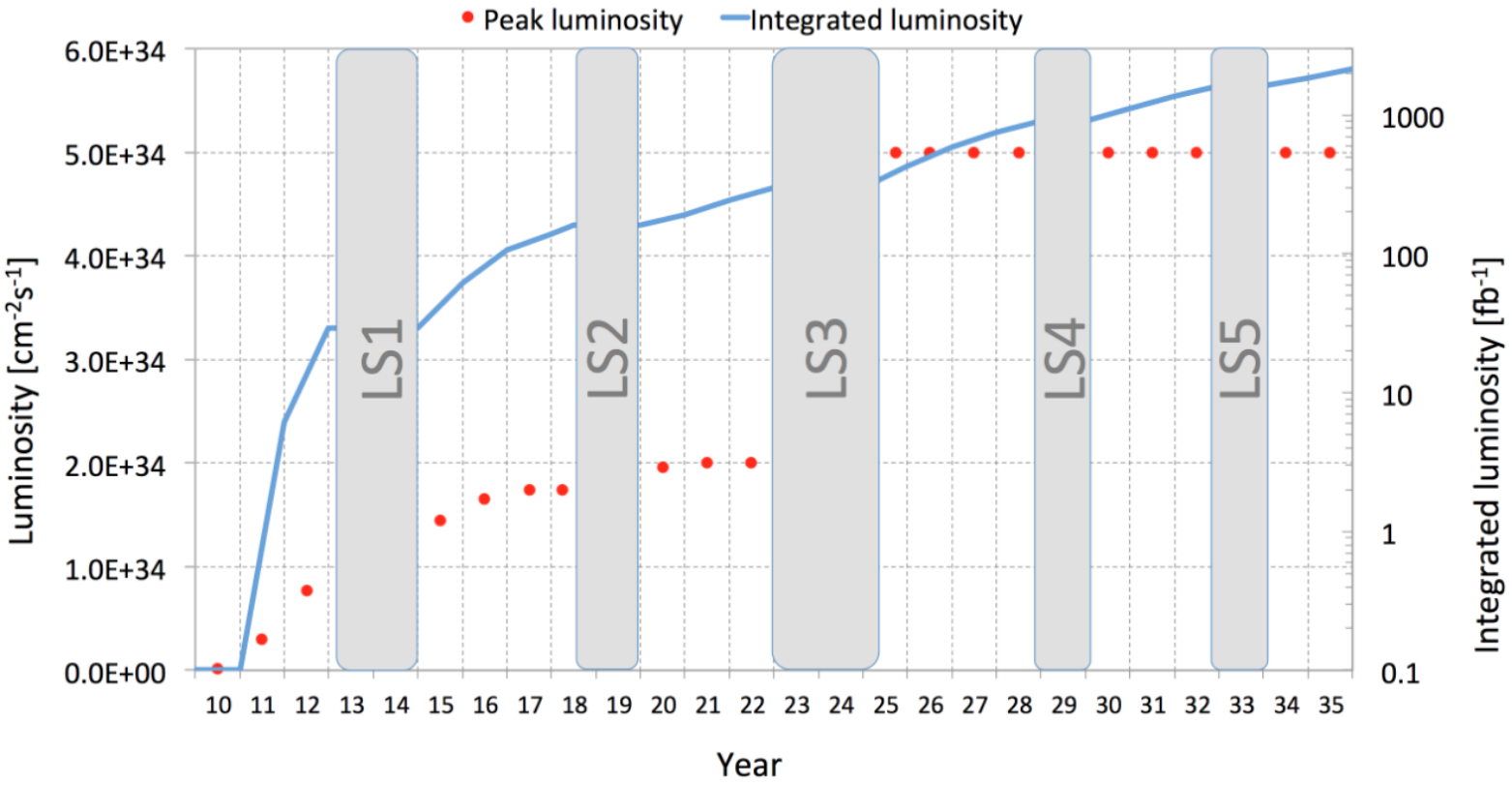
http://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC-schedule-update.pdf

- Run-II: 2015 - 2018

  - The integrated luminosity target over this period for both ATLAS and CMS is $\sim$ 100 fb$^{-1}$

- Run-III: 2021 - 2023

  - The integrated luminosity target in this run for both ATLAS and CMS is to complete a total of $\sim$ 300 fb$^{-1}$

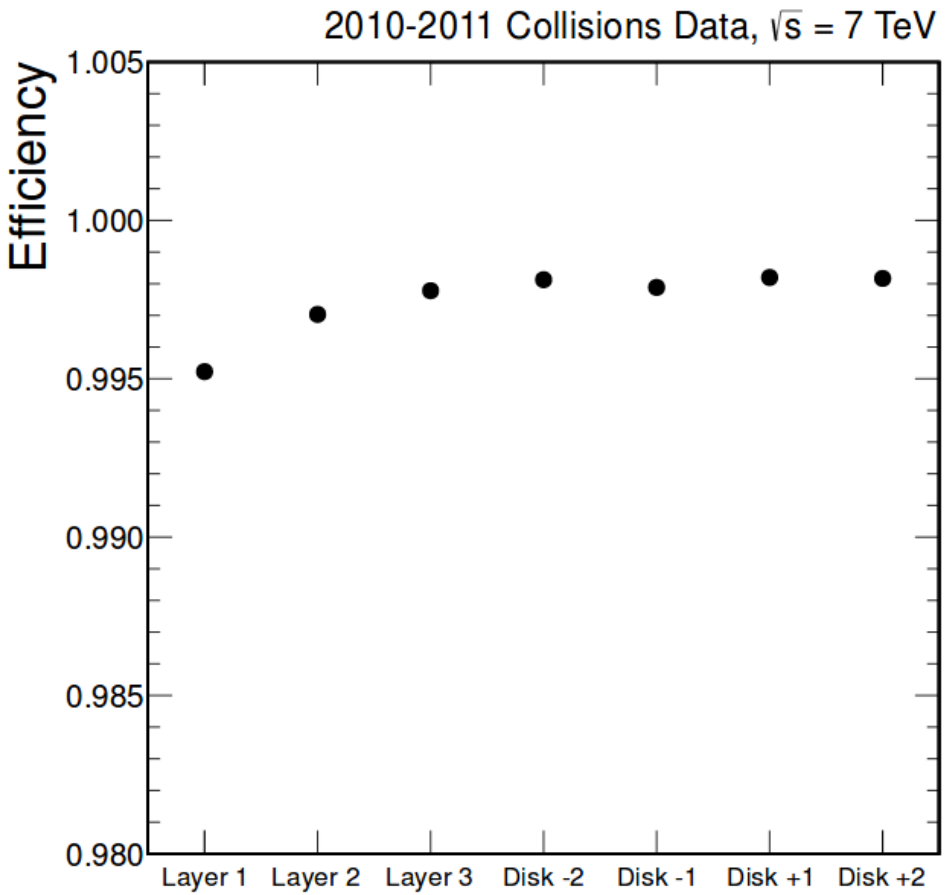


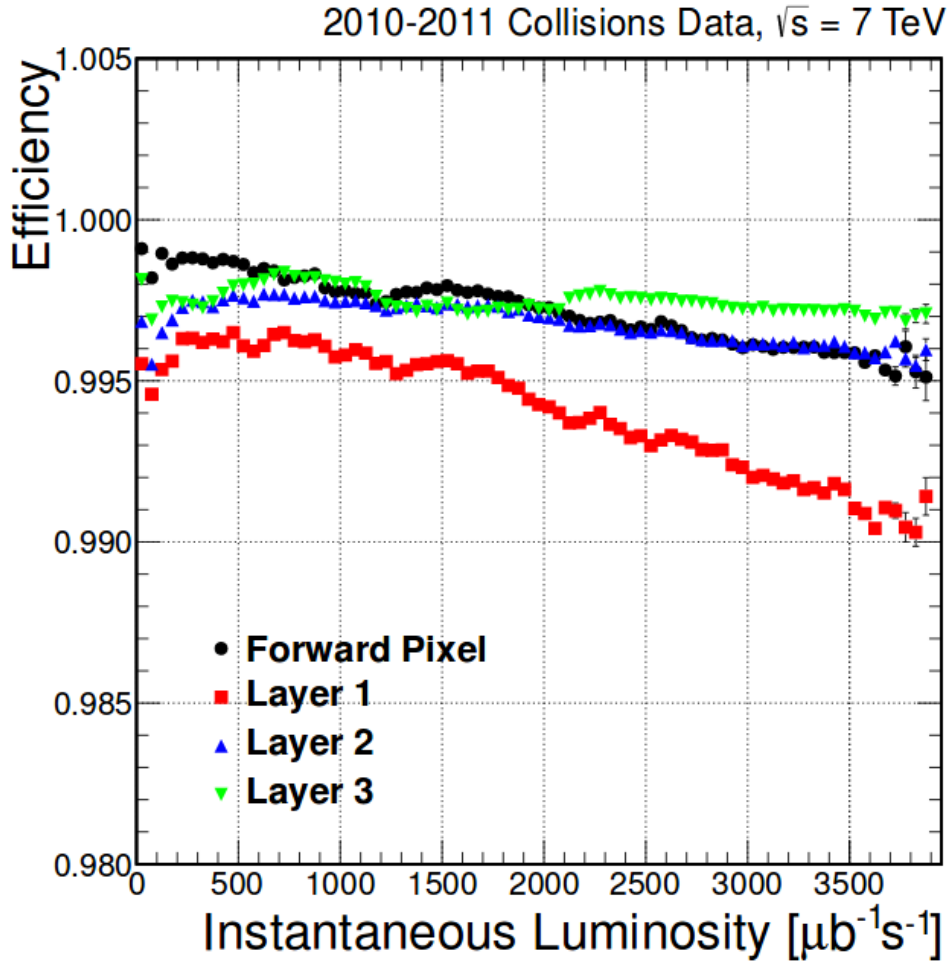

lhc-commissioning

https://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC-long-term.htm

http://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC-schedule-update.pdf

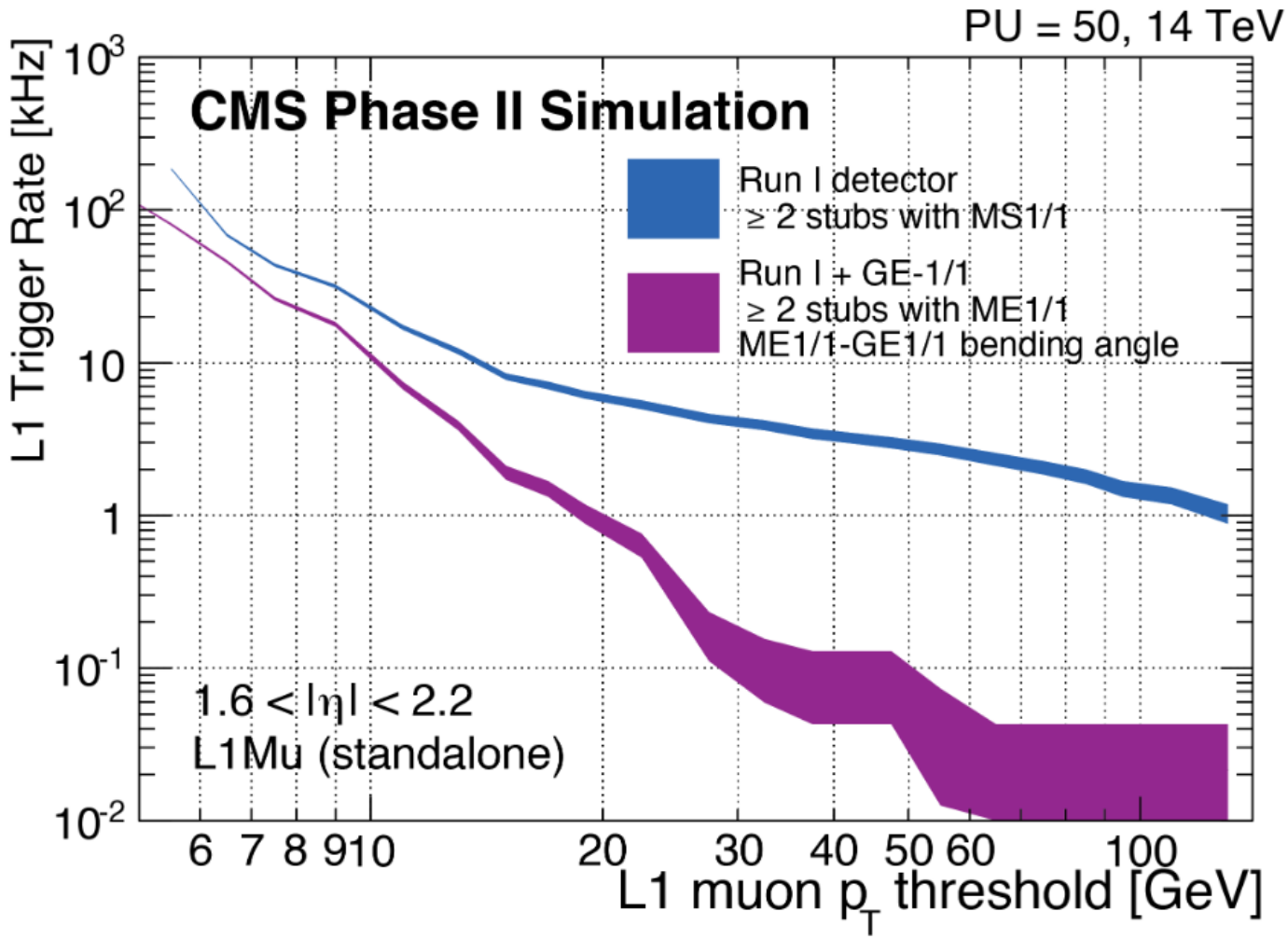
- Inefficiency increases with instantaneous luminosity and trigger ratedue to limits in the internal readout chip buffers
- Also increase in pile-up makes the pixel detector more inefficient
- Events where a Z-boson decays into a pair or muons ($\mu$)



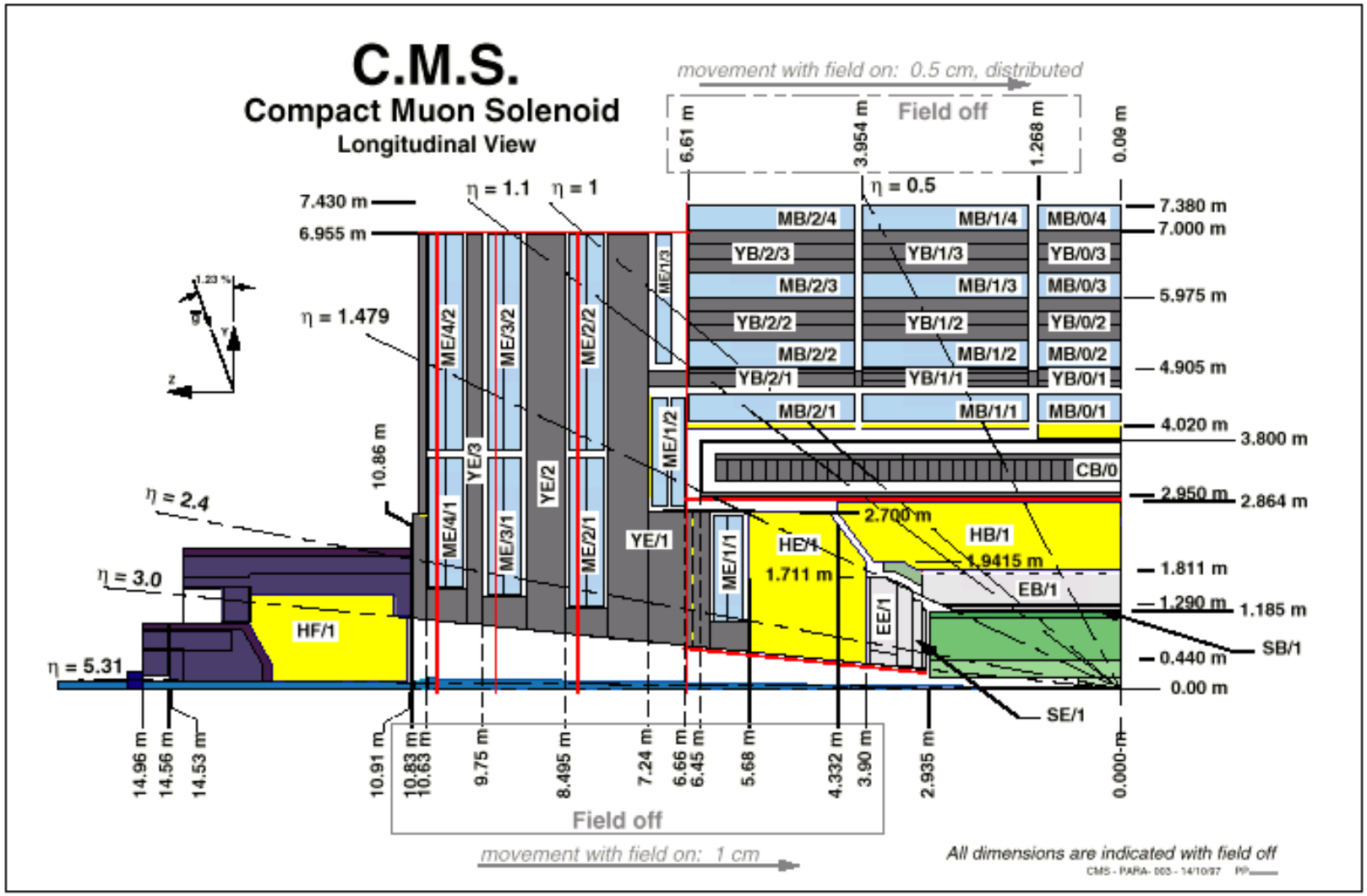

CMS-TDR-011

- I


PU = 50, 14 TeV
CMS Phase II Simulation
Run I detector
≥ 2 stubs with MS1/1
Run I + GE-1/1
≥ 2 stubs with ME1/1
ME1/1-GE1/1 bending angle
1.6 < |η| < 2.2
L1Mu (standalone)
L1 Trigger Rate [kHz]
L1 muon p_T threshold [GeV]

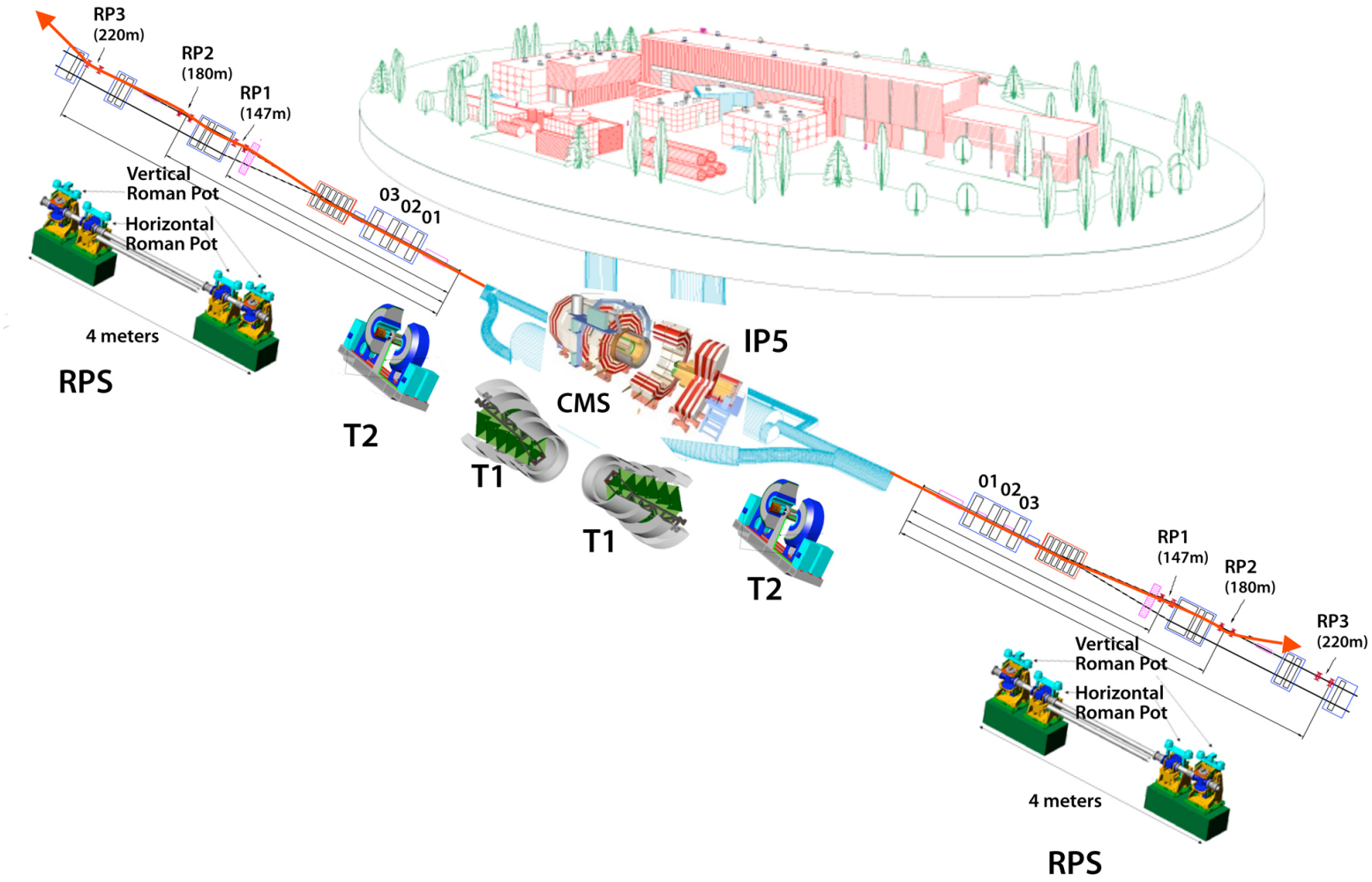
CMS-TDR-013

- CMS detector longitudinal view

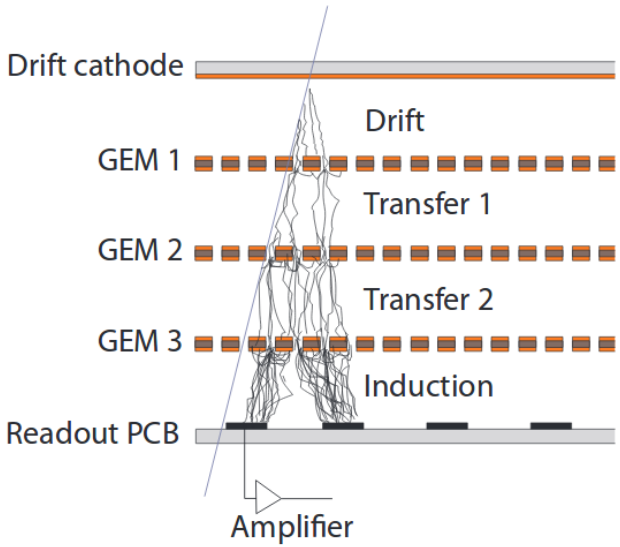


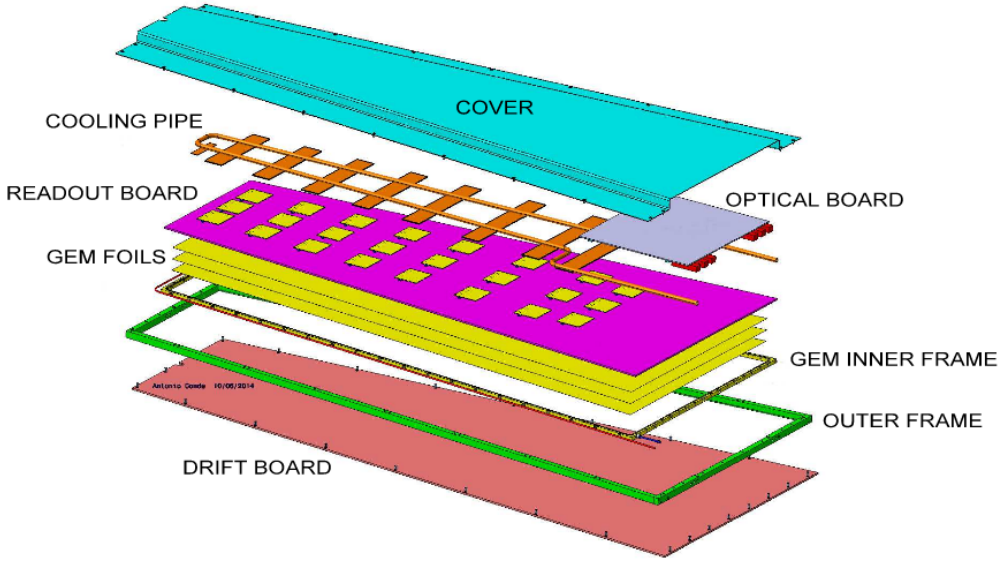

The CMS experiment at the CERN LHC, 2008, JINST 3 S08004

## TOTEM detector longitudinal view

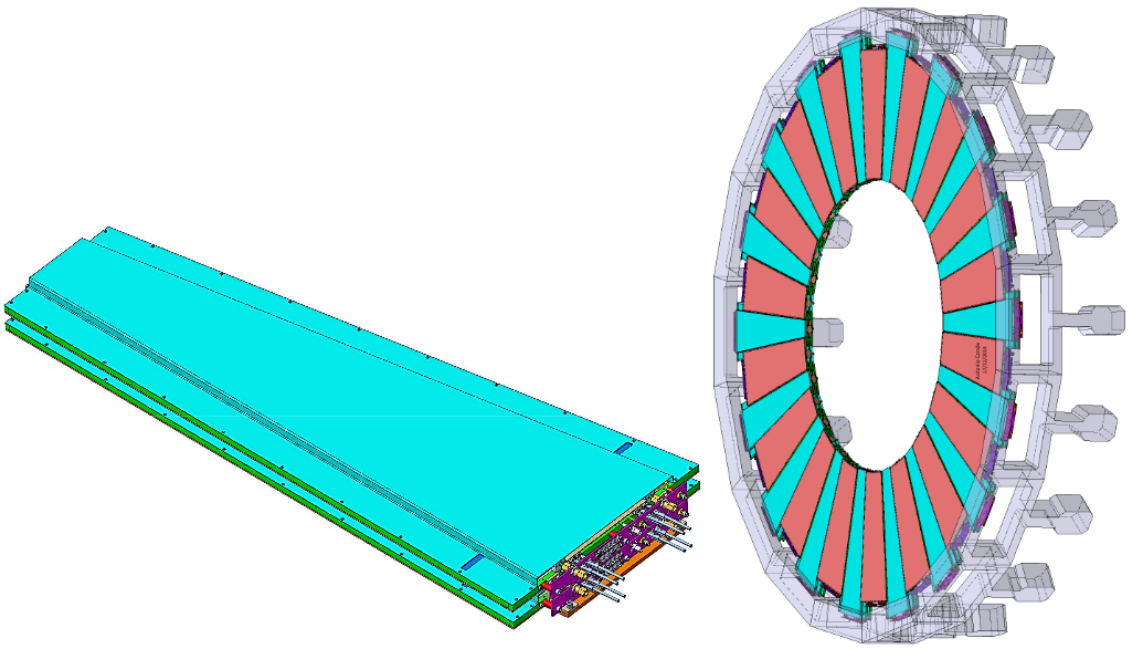



The CMS experiment at the CERN LHC, 2008, JINST 3 S08004


Drift cathode
Drift
GEM 1
Transfer 1
GEM 2
Transfer 2
GEM 3
Induction
Readout PCB
Amplifier


COVER
COOLING PIPE
READOUT BOARD
OPTICAL BOARD
GEM FOILS
GEM INNER FRAME
OUTER FRAME
DRIFT BOARD

CMS-TDR-013



CMS-TDR-013