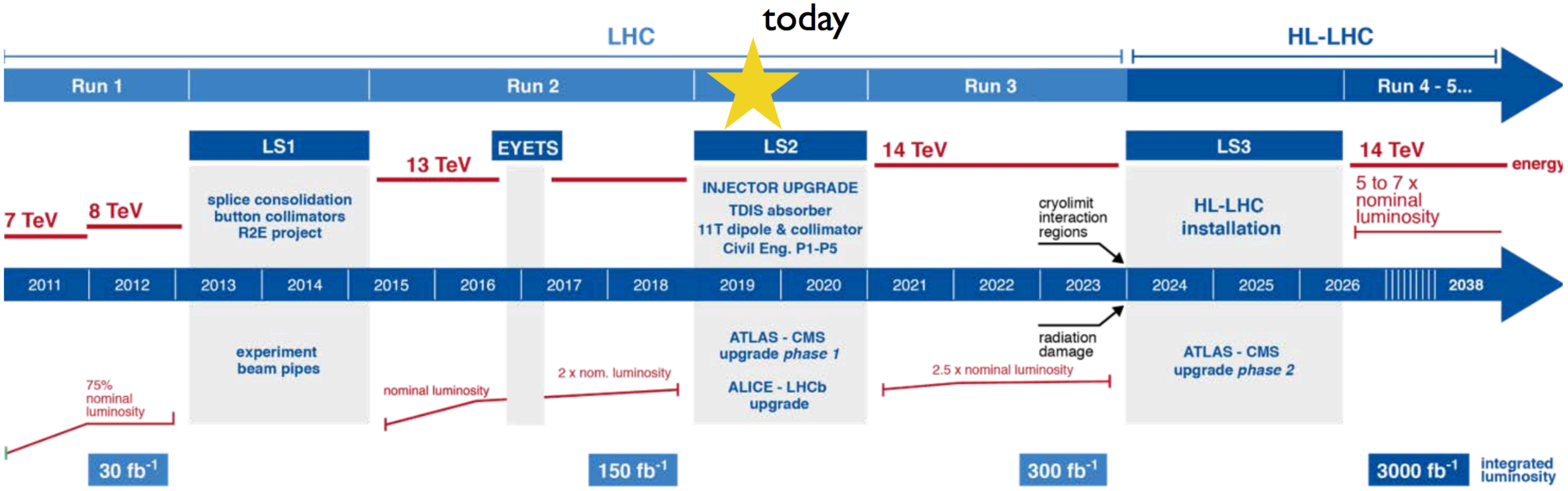
CMS STATUS

PATRICIA MCBRIDE

FERMILAB

LEPTON PHOTON 2019

LHC TIMELINE

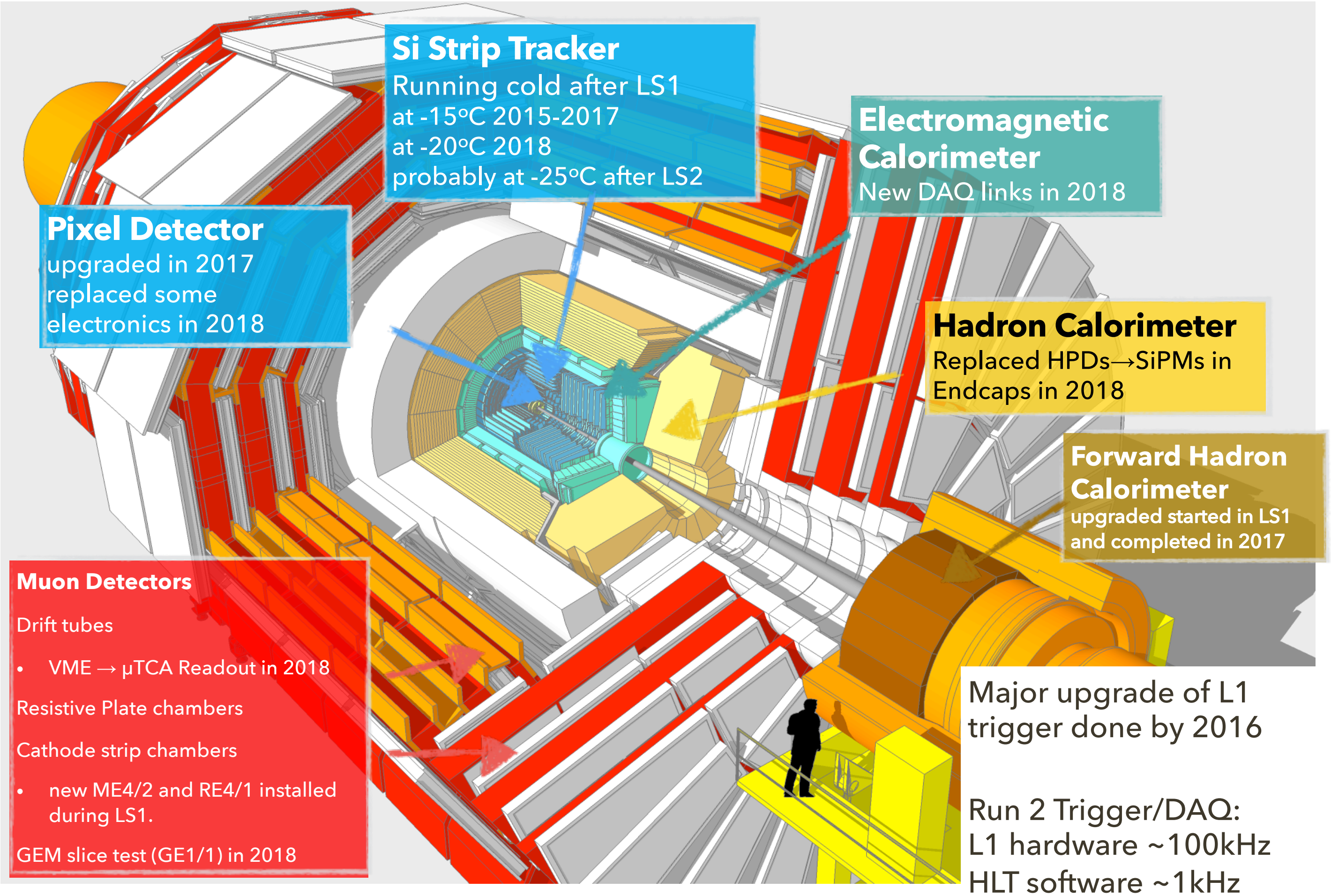


CMS DETECTOR EVOLUTION IN RUN 2

The CMS detector Phase-1 upgrades started during the first Long Shutdown and continued during the Run 2 end of the year technical stops.

The Phase-1 upgrades are nearly complete.

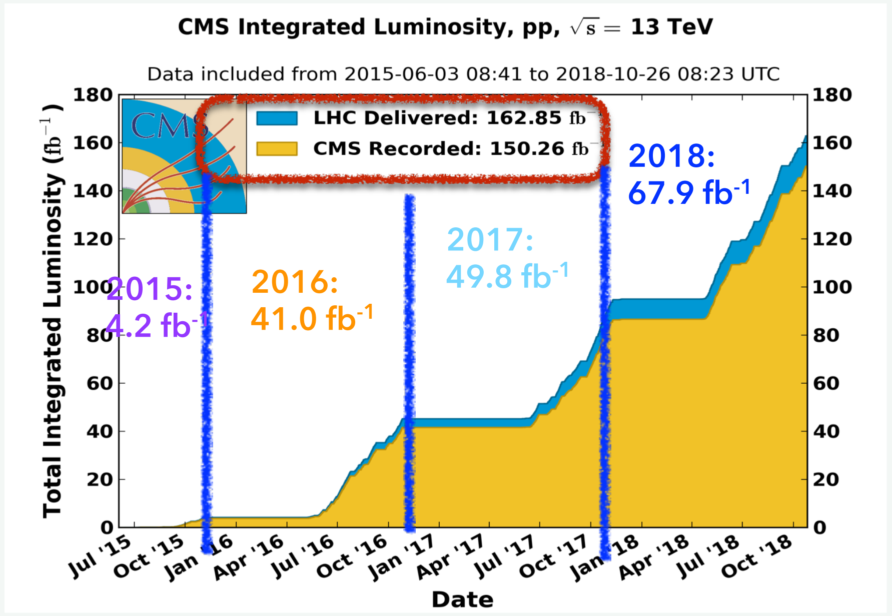
Installation of the HCAL Barrel readout (HPDs→ SiPMs) is the last step. CMS will complete the installation by the end of 2019.

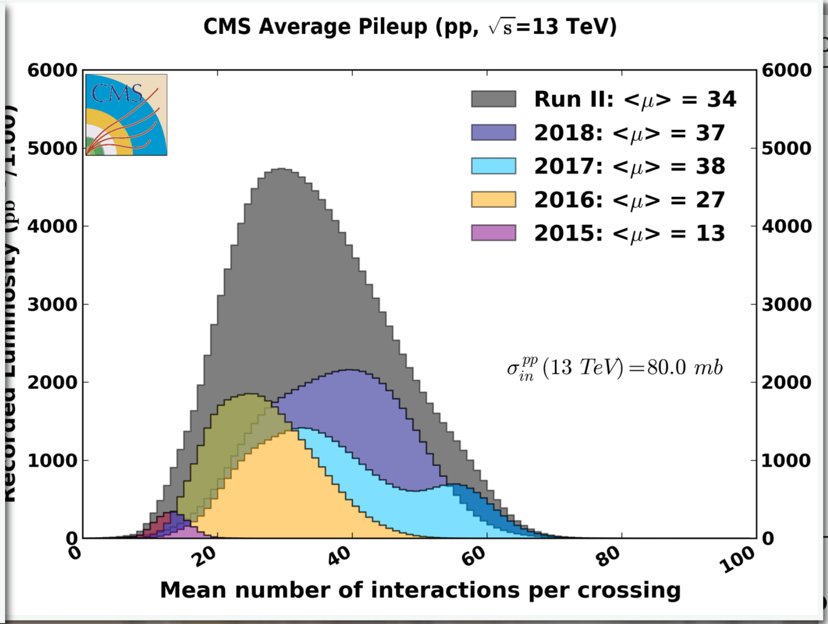


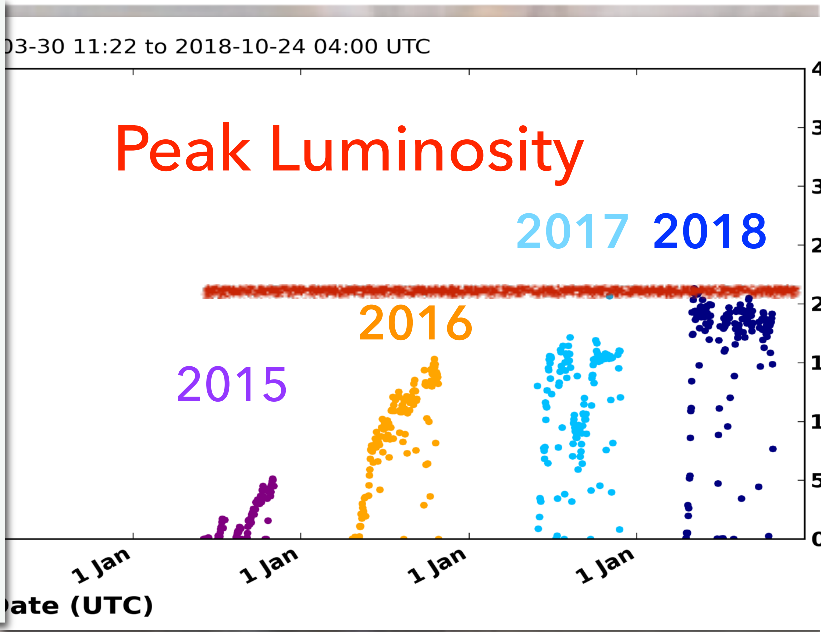
Major upgrade of L1 trigger done by 2016

Run 2 Trigger/DAQ:
L1 hardware ~100kHz
HLT software ~1kHz

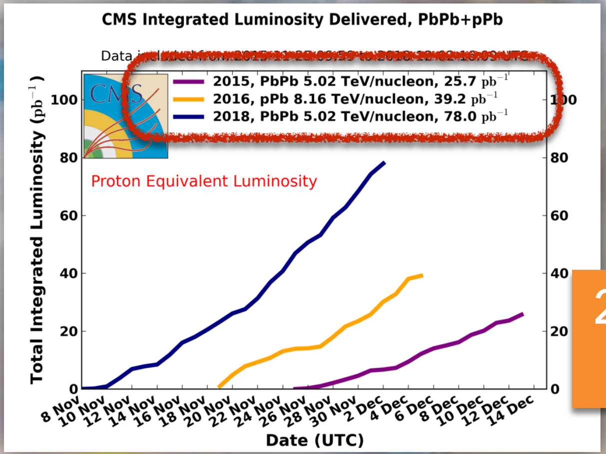
CMS SUMMARY RUN 2

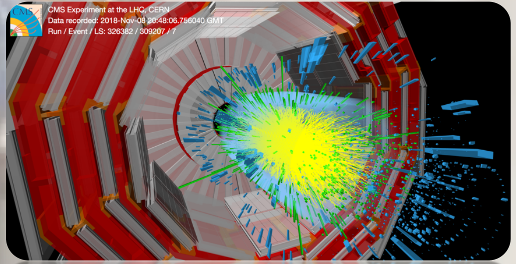






Run 2 pp data taking efficiency 92.3% with 2018 data taking efficiency 94%

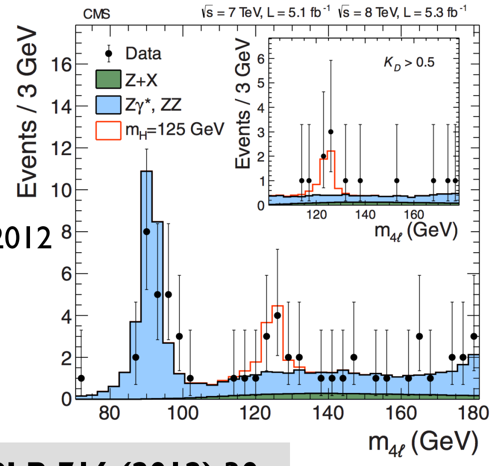




2018 Pb Pb data taking efficiency 95%

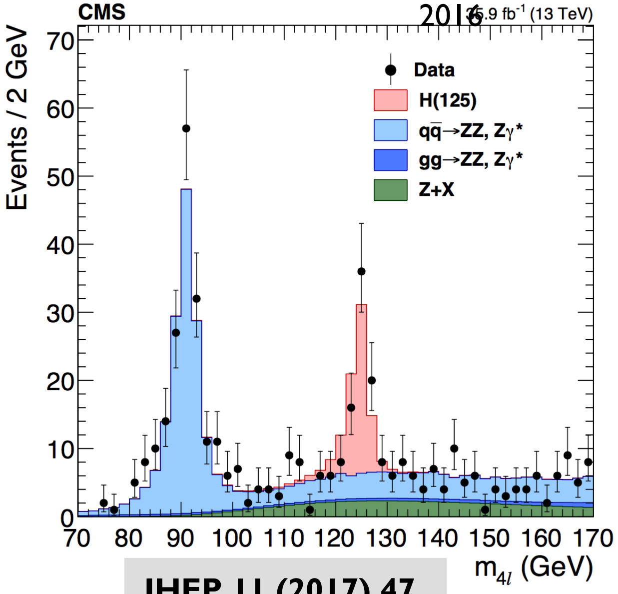
PROGRESS SINCE DISCOVERY: H→ZZ

2012

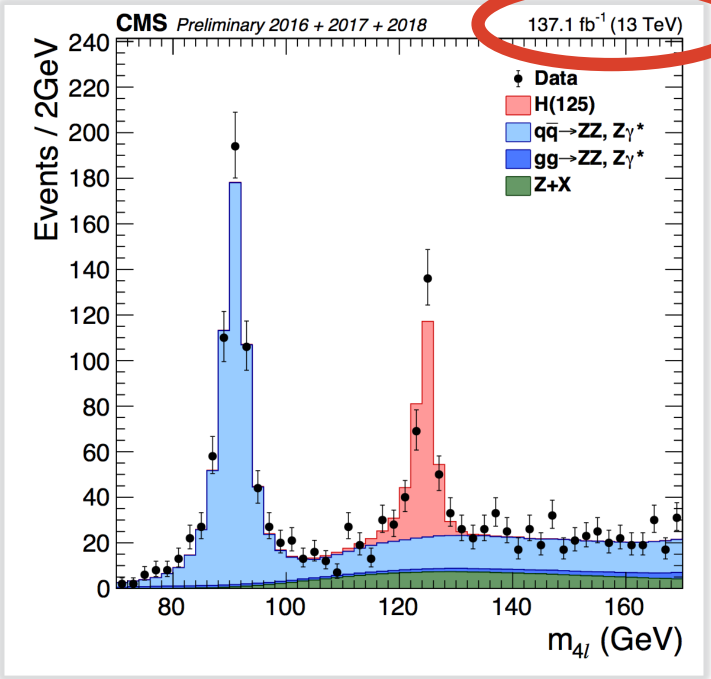


PLB 716 (2012) 30

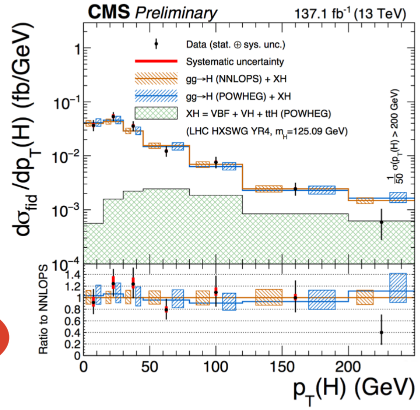
Run 1



JHEP 11 (2017) 47

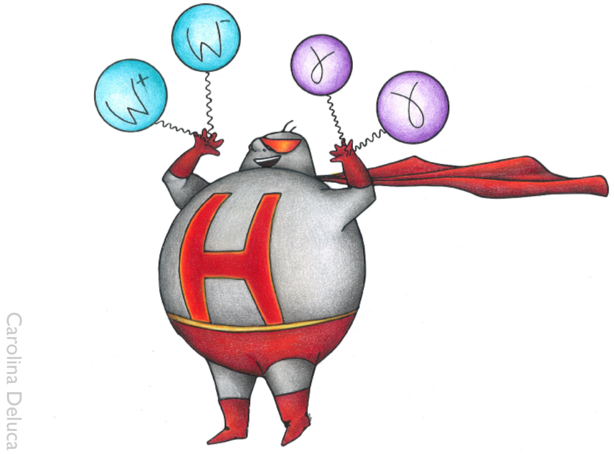


HIG-19-001



Run 2

137 fb^{-1}



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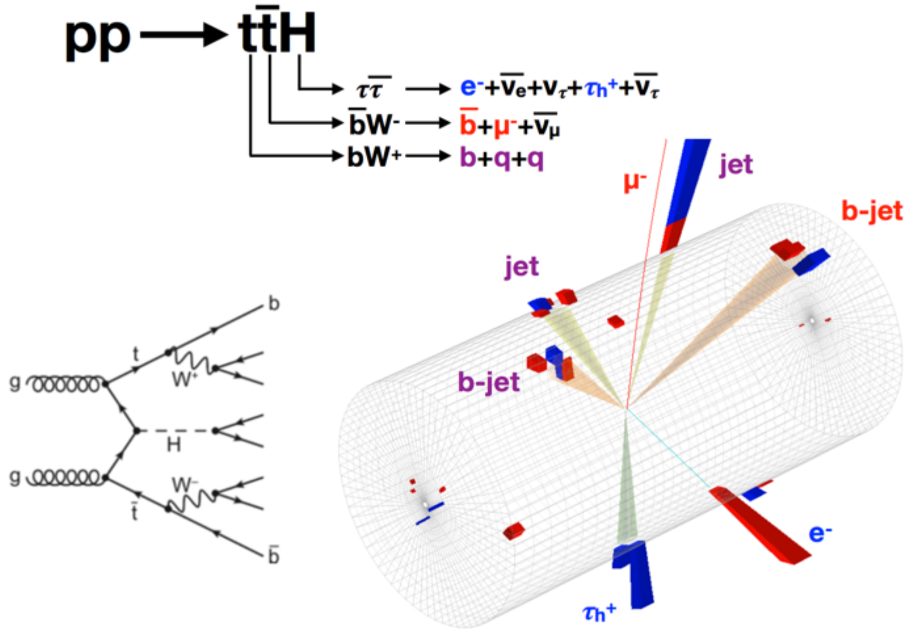
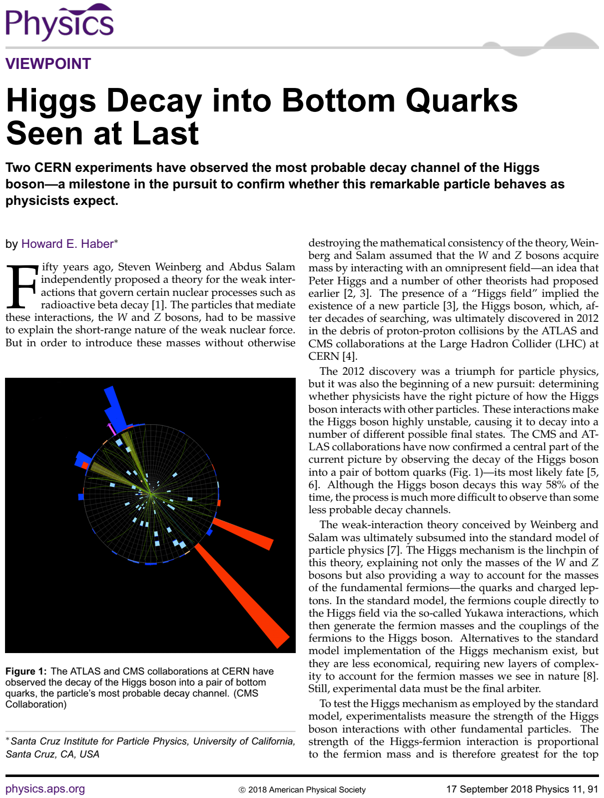
EXPLORING THE HIGGS





Physics

VIEWPOINT

Higgs Decay into Bottom Quarks Seen at Last

Two CERN experiments have observed the most probable decay channel of the Higgs boson—a milestone in the pursuit to confirm whether this remarkable particle behaves as physicists expect.

by Howard E. Haber*

Fifty years ago, Steven Weinberg and Abdus Salam independently proposed a theory for the weak interactions that govern certain nuclear processes such as radioactive beta decay [1]. The particles that mediate these interactions, the *W* and *Z* bosons, had to be massive to explain the short-range nature of the weak nuclear force. But in order to introduce these masses without otherwise destroying the mathematical consistency of the theory, Weinberg and Salam assumed that the *W* and *Z* bosons acquire mass by interacting with an omnipresent field—an idea that Peter Higgs and a number of other theorists had proposed earlier [2, 3]. The presence of a "Higgs field" implied the existence of a new particle [3], the Higgs boson, which, after decades of searching, was ultimately discovered in 2012 in the debris of proton-proton collisions by the ATLAS and CMS collaborations at the Large Hadron Collider (LHC) at CERN [4].

The 2012 discovery was a triumph for particle physics, but it was also the beginning of a new pursuit: determining whether physicists have the right picture of how the Higgs boson interacts with other particles. These interactions make the Higgs boson highly unstable, causing it to decay into a number of different possible final states. The CMS and ATLAS collaborations have now confirmed a central part of the current picture by observing the decay of the Higgs boson into a pair of bottom quarks (Fig. 1)—its most likely fate [5, 6]. Although the Higgs boson decays this way 58% of the time, the process is much more difficult to observe than some less probable decay channels.

The weak-interaction theory conceived by Weinberg and Salam was ultimately subsumed into the standard model of particle physics [7]. The Higgs mechanism is the linchpin of this theory, explaining not only the masses of the *W* and *Z* bosons but also providing a way to account for the masses of the fundamental fermions—the quarks and charged leptons. In the standard model, the fermions couple directly to the Higgs field via the so-called Yukawa interactions, which then generate the fermion masses and the couplings of the fermions to the Higgs boson. Alternatives to the standard model implementation of the Higgs mechanism exist, but they are less economical, requiring new layers of complexity to account for the fermion masses we see in nature [8]. Still, experimental data must be the final arbiter.

To test the Higgs mechanism as employed by the standard model, experimentalists measure the strength of the Higgs boson interactions with other fundamental particles. The strength of the Higgs-fermion interaction is proportional to the fermion mass and is therefore greatest for the top

Figure 1: The ATLAS and CMS collaborations at CERN have observed the decay of the Higgs boson into a pair of bottom quarks, the particle's most probable decay channel. (CMS Collaboration)

Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA, USA

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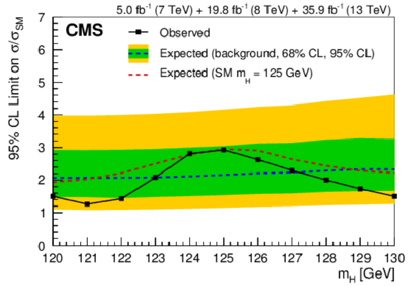
Over the past 2 years, CMS observed H→bb, H→ττ, and ttH production.

Full run 2 results available for a number of analyses; precision takes time.

Now, we are moving towards the second generation: H→μμ, H→cc,.

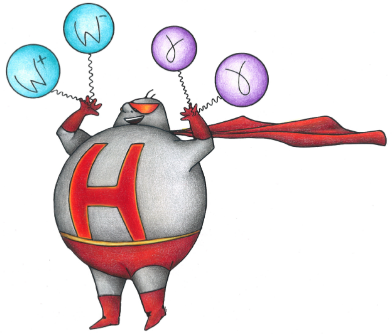
H→μμ



μ_{CMS}=1.0 ± 1.0(stat) ± 0.1(syst) (RunI+2016)

Obs.(exp.): 0.9 σ (1.0σ)

PhysRevLett.122.021801



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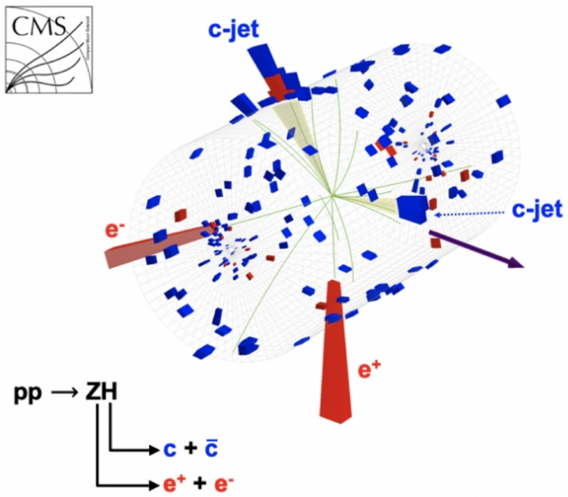
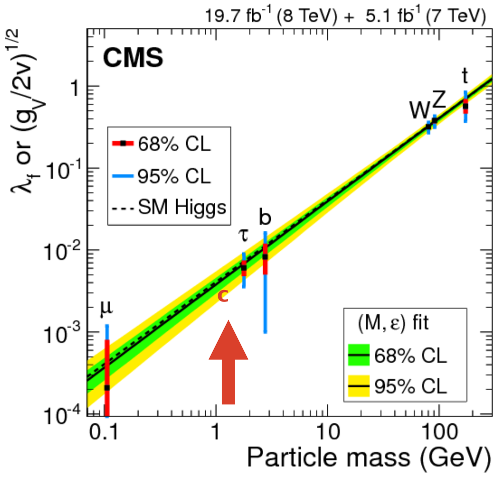
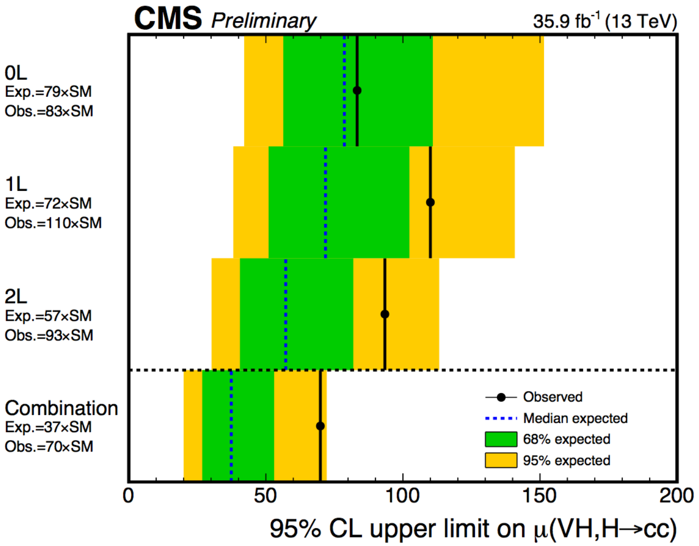
HIGGS MOVING TO THE 2ND GENERATION

HIG-18-031

- First CMS result on VH, **H→cc**
  - Challenging due to low cross section and need for c-tagging
    - Categorization is done according to lepton multiplicity of V decays
    - Analysis used both resolved (2 c jets) and merged (1 cc jet) cases
    - Use of ML and jet substructure for tagging and classification
  - final results from the combination of resolved & merged jet analyses







Combined results for the signal strength:

Obs (exp) Upper Limit: 70 (37) @ 95% C.L.

$$\mu(\mathrm{VH, H} \rightarrow c\bar{c}) = 36^{+20}_{-19}$$

Validate method using VZ production:

$$\mu(\mathrm{VZ, Z} \rightarrow c\bar{c}) = 0.55^{+0.86}_{-0.84}$$

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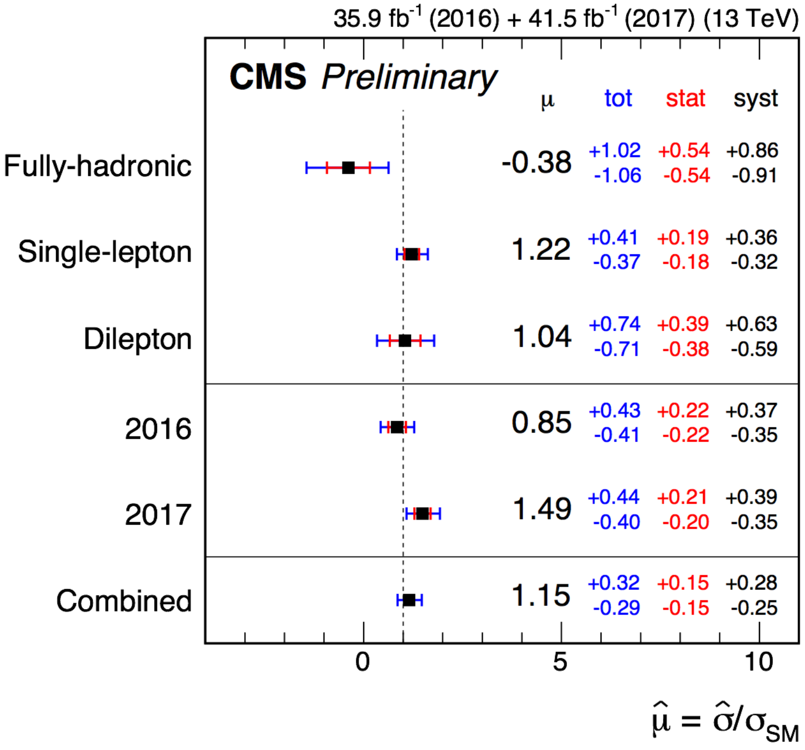
HIGGS DECAYS TO 3RD GENERATION FERMIONS

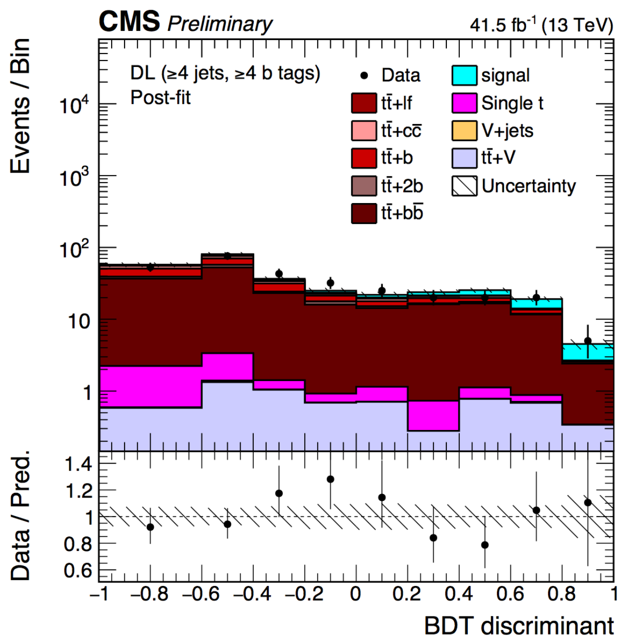
HIG-18-030

- ttH (H→bb)
  - 0, 1, and 2 lepton decay modes
  - Improvements coming from MVA techniques and b-jet identification

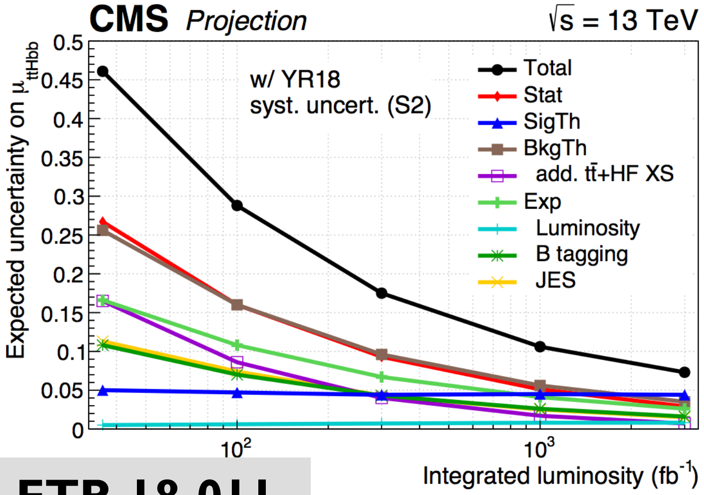


Evidence for H->bb decays based on ttH production only:
obs (exp) significance = 3.9 (3.5) s.d.

$$\mu_{\mathrm{comb}} = 1.15^{+0.32}_{-0.29}$$



Looking ahead:
HL-LHC projections



FTR-18-011

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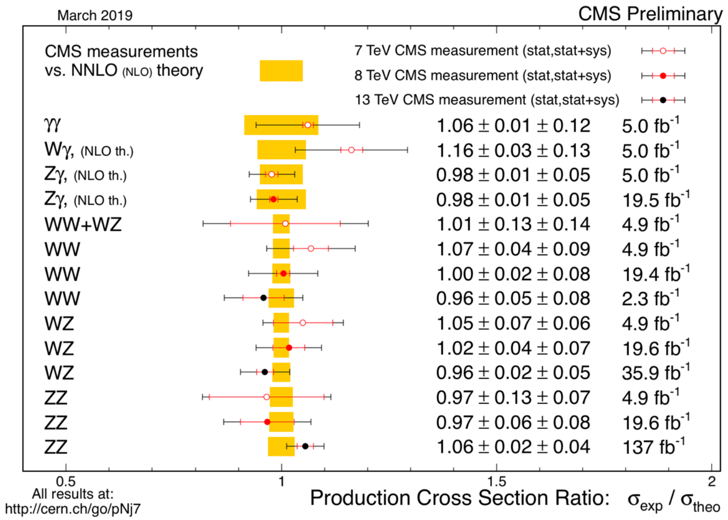
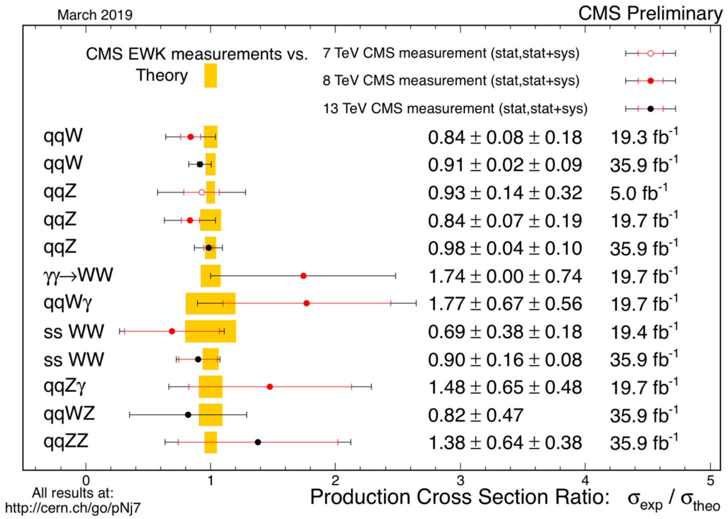
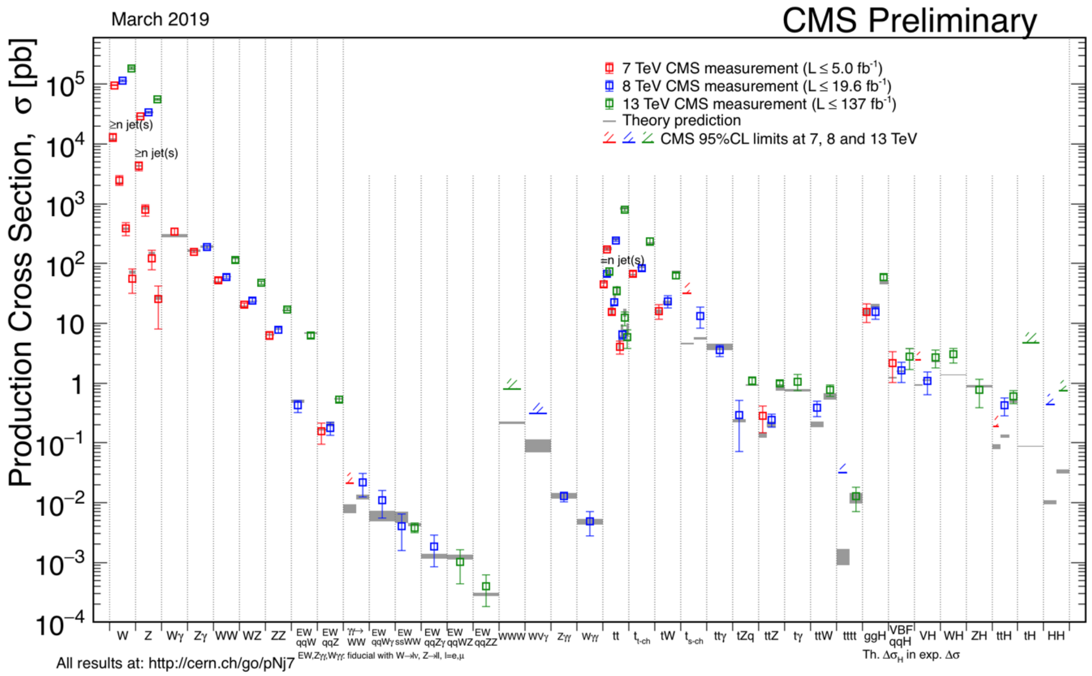
STANDARD MODEL – MEASURING CROSS SECTIONS

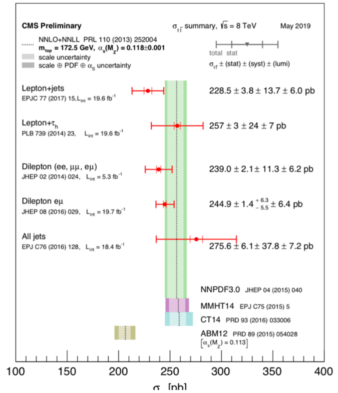


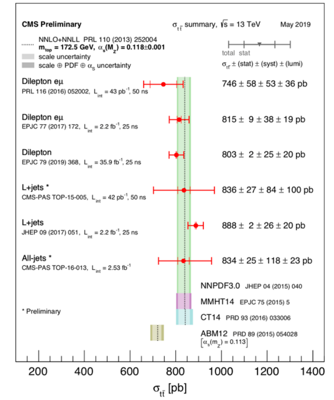


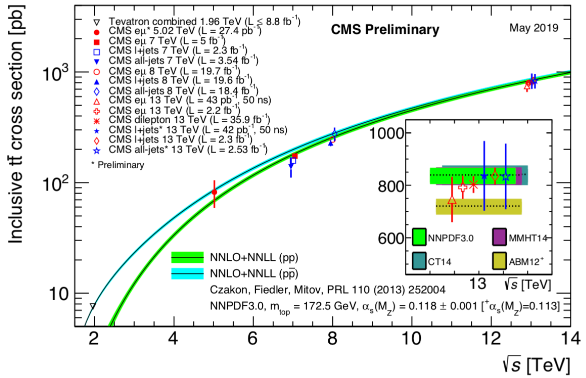


Cross section measurements: Probing the standard model through precision measurements and uncovering rare processes

EWK







TOP

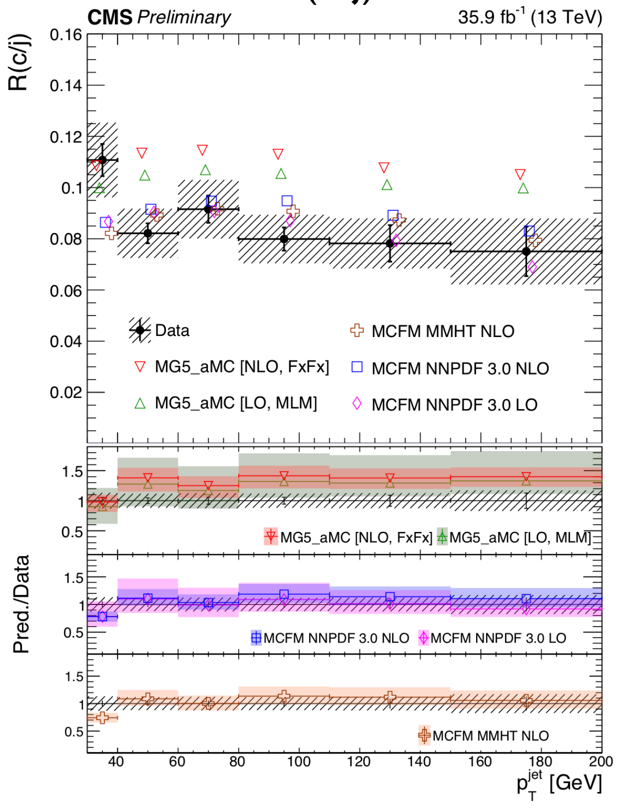
Z BOSONS WITH CHARM OR BOTTOM JETS

SMP-19-004

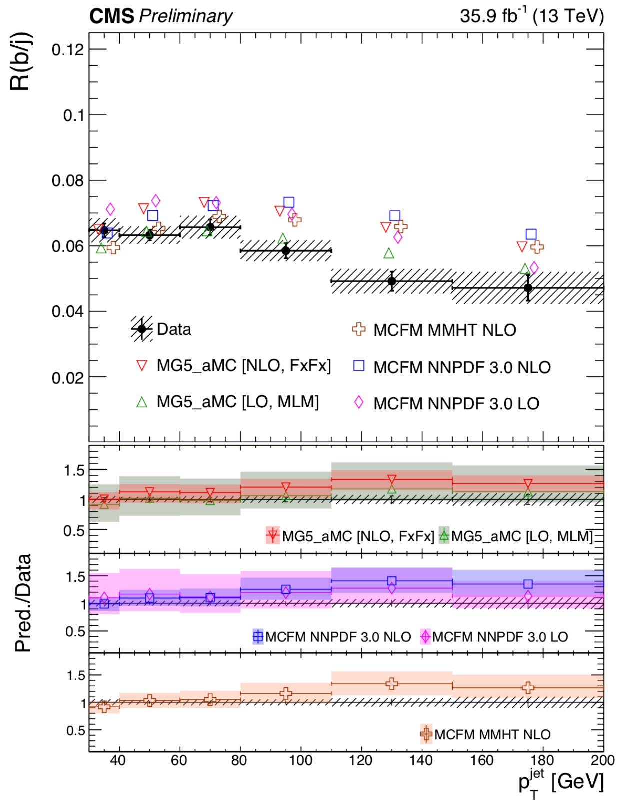
NEW

- Measure ratios of cross sections @ 13 TeV:
  - $\frac{\sigma(\mathrm{Z+c\ jets})}{\sigma(\mathrm{Z+jets})}$ $\frac{\sigma(\mathrm{Z+b\ jets})}{\sigma(\mathrm{Z+jets})}$ $\frac{\sigma(\mathrm{Z+c\ jets})}{\sigma(\mathrm{Z+b\ jets})}$ in the associated production of a Z with a charm or bottom quark jet
  - Event selection (Z + jets)
    - Jet p_t > 30 GeV and IηI < 2.4.
    - Z boson into leptons (e or μ); p_t > 25 GeV
  - b, c and light jets are distinguished using the secondary vertex invariant mass
  - Results are compared with predictions from leading and next-to-leading order perturbative QCD calculations.
  - First measurements at 13 TeV; the measurement precision exceeds that of the current theoretical predictions.

R(c/j)



R(b/j)



Jet p_t

Fermilab

RUNNING OF THE TOP QUARK MASS

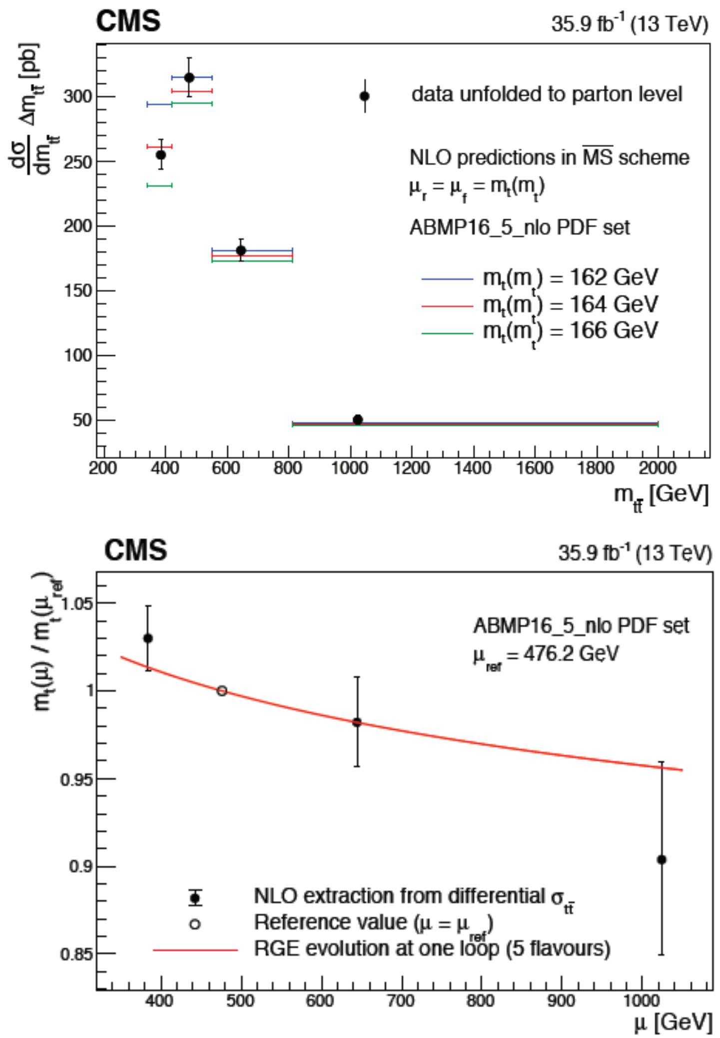
TOP-19-007

NEW

- The running mass m_t of the top quark mass is extracted from the differential $t\bar{t}$ cross section as a function of the invariant mass of the $t\bar{t}$ system
  - in the modified minimal subtraction ($\overline{\mathrm{MS}}$) renormalization scheme

$$\mu^2 \frac{dm(\mu)}{d\mu^2} = -\gamma(\alpha_S(\mu))\, m(\mu)$$

- $t\bar{t}$ candidate events with the $e^{\pm}\mu^{\mp}$ final state
- The differential cross section is measured using a maximum likelihood fit
- χ^2 fit to next-to-leading-order differential theory predictions
- The observed running is compatible with scale dependence predicted by the renormalization group equation.
  - Agreement with RGE prediction at one-loop precision: 1.3 s.d.
  - 2.6 s.d. from a no-running hypothesis



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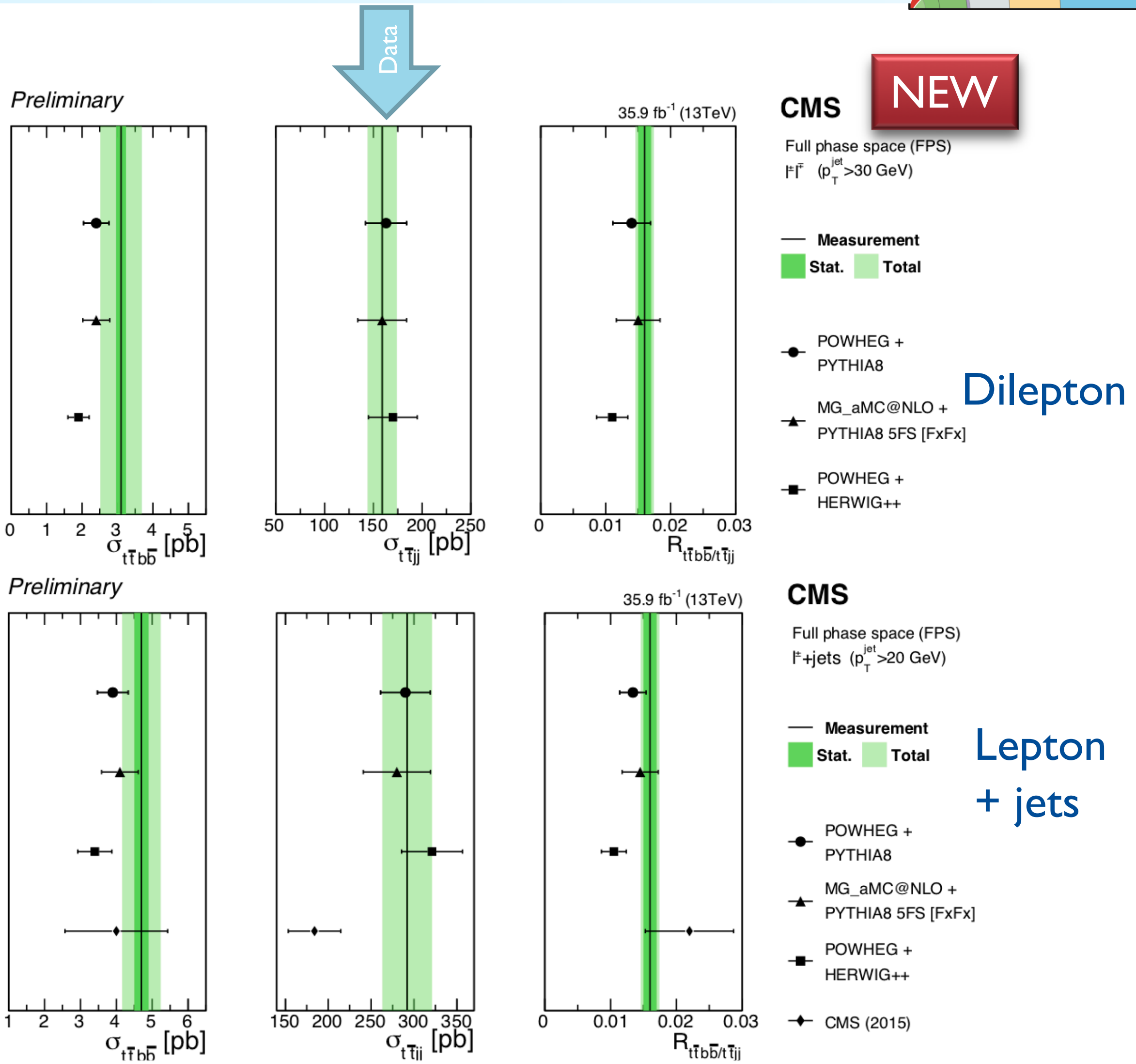
TOP QUARK PAIR PRODUCTION WITH JETS

TOP-18-002

- tt pair production in association with a bb pair (ttbb) is an important background for ttH(H->bb) and tttt
- The measurements of tt̄jj and tt̄bb cross sections provide an important test of NLO QCD calculations
- Performed a binned max. likelihood fit to the b tagging discriminant distribution of the jets to obtain $R_{t\bar{t}bb/t\bar{t}jj}$ and $\sigma_{t\bar{t}jj}$
  - Used dilepton and lepton + jets channels
- These results are extrapolated to full phase space and compared to SM expectations.
  - The measured inclusive tt̄bb cross sections and the cross section ratios are higher than several MC predictions.



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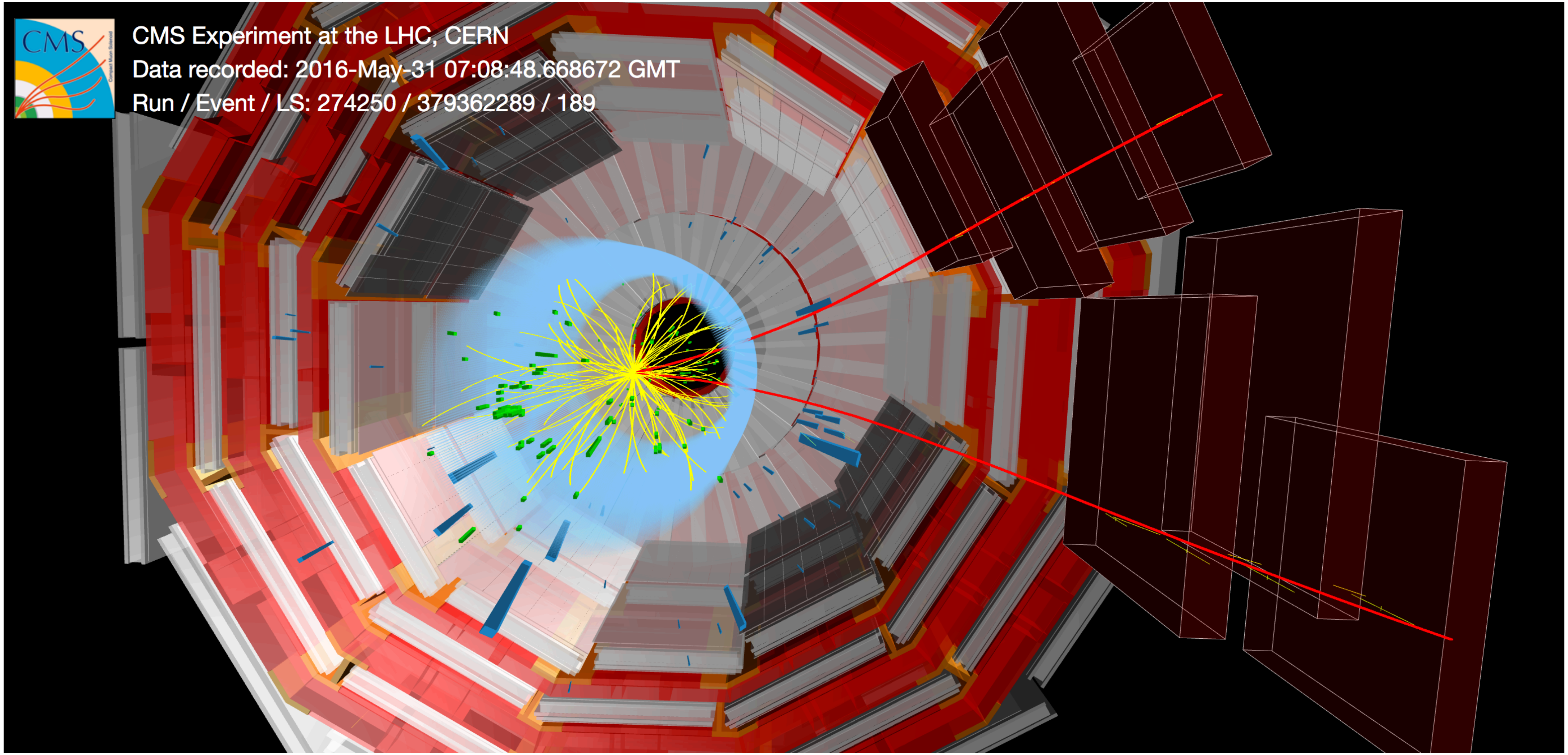
$B_s^0 \rightarrow \mu^+\mu^-$



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PROPERTIES OF $B_s^0 \to \mu^+\mu^-$ DECAYS

BPH-16-004

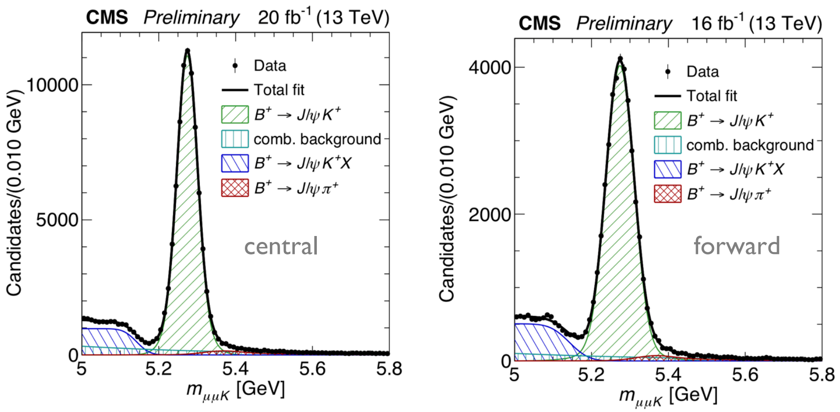
- Previous results from LHCb, ATLAS, CMS
- The $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ branching fractions: measure relative to $B^+ \to J/\psi\, K^+$ decays (with $J/\psi \to \mu^+\mu^-$)
  - Cancellation of many systematic uncertainties
  - Depends on the ratio of the fragmentation functions f_u/f_s
    - Use PDG value: f_s/f_u = 0.252 ± 0.012 (exp) ± 0.015 (additional uncertainty assigned for p_t and energy dependence)

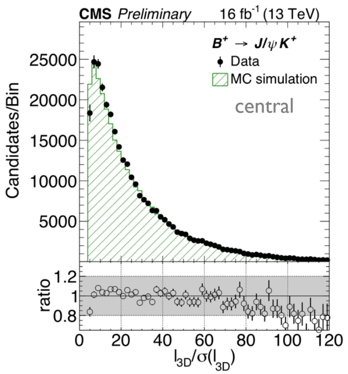
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \frac{N_S}{N_{obs}^{B+}} \frac{f_u}{f_s} \frac{\epsilon_{tot}^{B+}}{\epsilon_{tot}} \mathcal{B}(B^+ \to J/\psi K^+)\, \mathcal{B}(J/\psi \to \mu^+\mu^-)$$

- Dataset: Run 1 (7, 8 TeV) + Run 2 (2016 13 TeV)
- Dimuon selection optimized to reduce fake rates
- $B_s^0 \to J/\psi\, \phi$ used in systematic studies

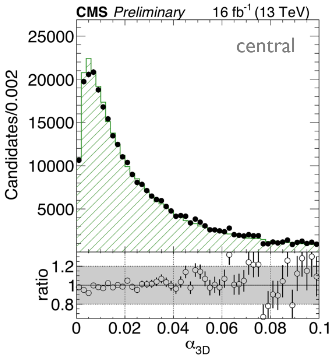
$B^+ \to J/\psi\, K^+$ Data / MC comparisons

Invariant-mass distributions for the μμK system (2016B)

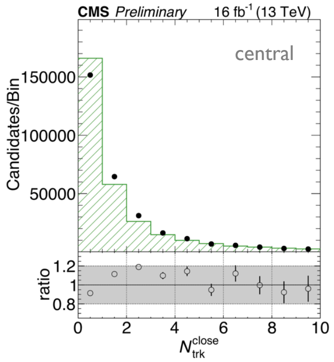




Flight length significance



Pointing angle



# of tracks near secondary vertex

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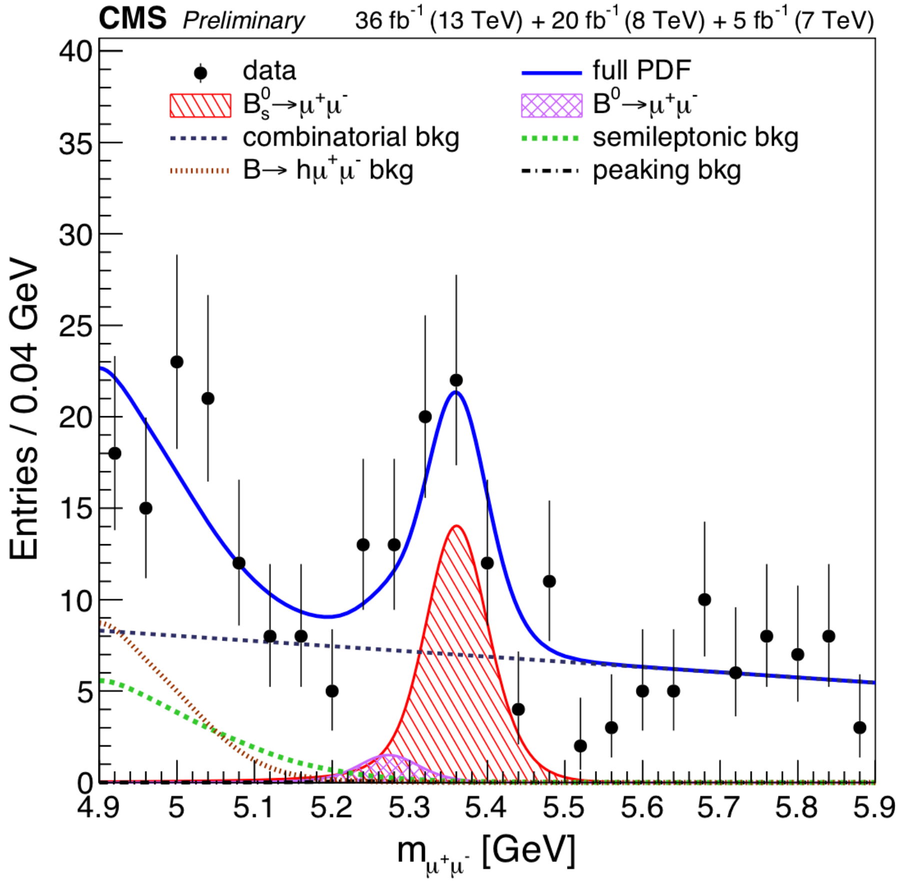
$B_s^0 \to \mu^+\mu^-$ AND $B^0 \to \mu^+\mu^-$

BPH-16-004

NEW

- The decay $B_s^0 \to \mu^+\mu^-$ is observed with a branching fraction of
  - $\mathcal{B}(B_s^0 \to \mu^+\mu^-) = [2.9^{+0.7}_{-0.6}\,(\text{exp}) \pm 0.2(f_s/f_u)] \times 10^{-9}$
    - Significance $B_s^0 \to \mu^+\mu^-$: 5.6 (6.5) s.d. obs (exp)
  - No significant excess is observed for the decay $B^0 \to \mu^+\mu^-$,
    - Upper limit $\mathcal{B}(B^0 \to \mu^+\mu^-) < 3.6 \times 10^{-10}$ at 95% confidence level
    - Previous CMS result: $\mathcal{B}(B^0 \to \mu^+\mu^-) < 1.1 \times 10^{-9}$ Phys. Rev. Lett. **111**, 101804
  - These results are consistent with standard model predictions



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$B_s^0 \rightarrow \mu^+\mu^-$ AND $B^0 \rightarrow \mu^+\mu^-$

NEW

- The decay $B_s^0 \rightarrow \mu^+\mu^-$ is observed with a branching fraction of
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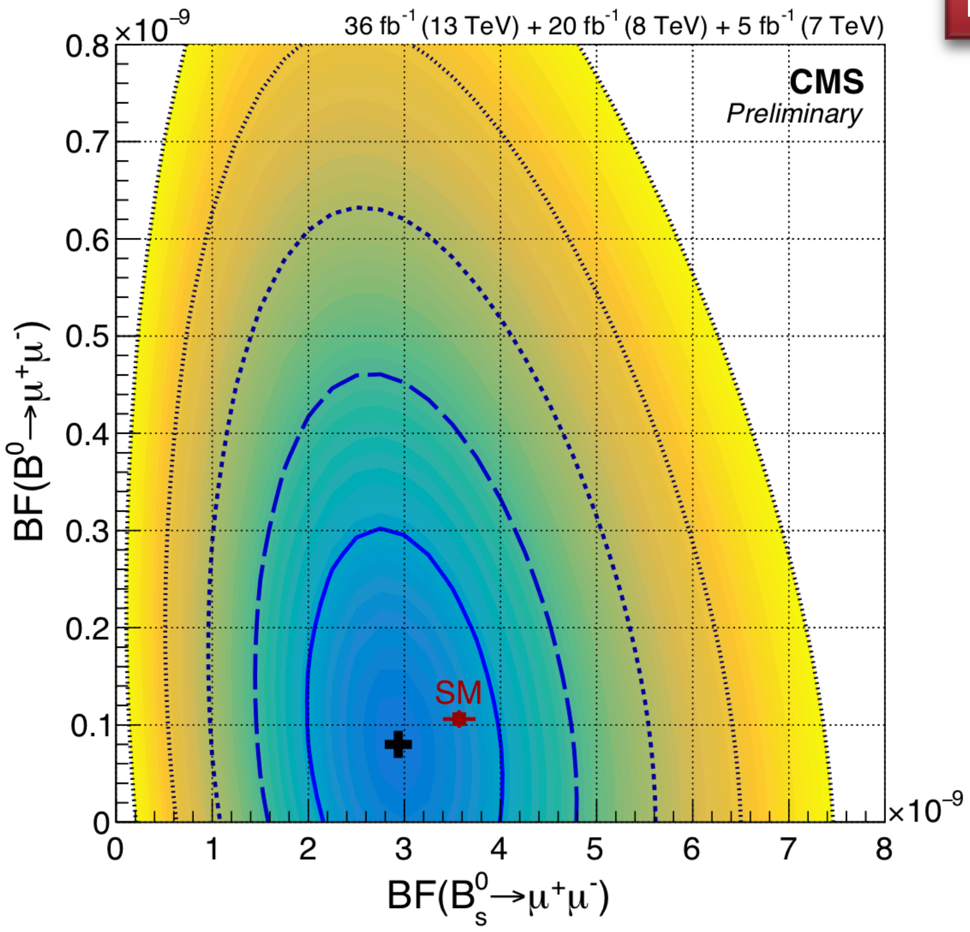

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$B_s^0 \to \mu^+\mu^-$ EFFECTIVE LIFETIME

BPH-16-004

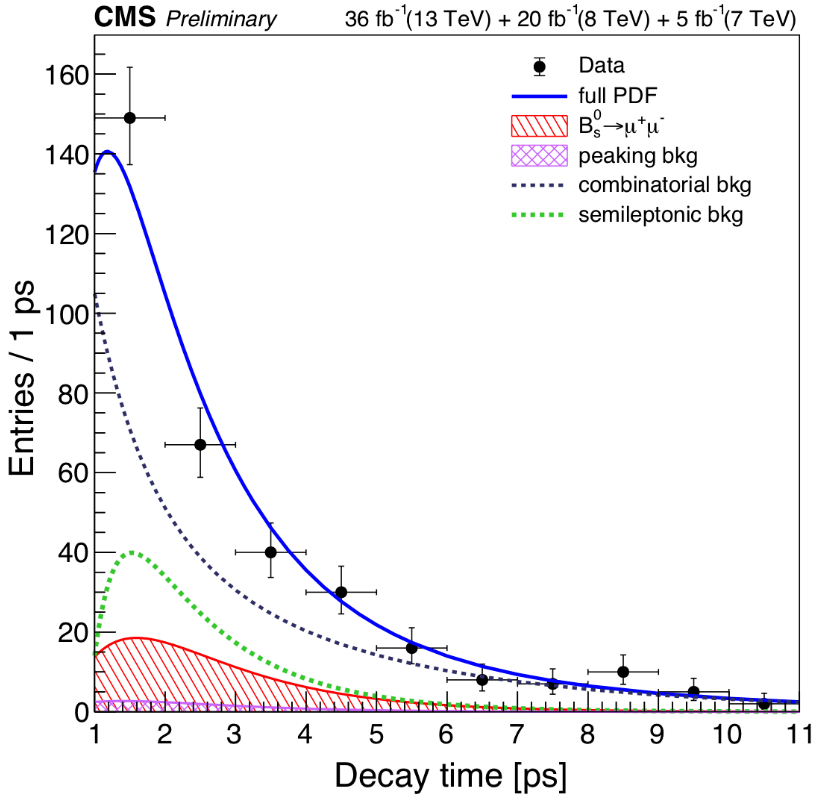
NEW

- $B_s^0 \to \mu^+\mu^-$ effective lifetime is determined using an 2D unbinned maximum likelihood fit to the dimuon invariant **mass** and proper **decay time** distributions:

$$\tau_{\mu+\mu-} = 1.70^{+0.61}_{-0.44}\ \text{ps}$$

The result is consistent with the SM expectations and with an earlier measurement from LHCb.

- Prospects for full Run 2 dataset:
  - Resolve B^0 and enable precision comparisons to the SM for B_s^0
  - New physics could show up in the lifetime with improved precision.



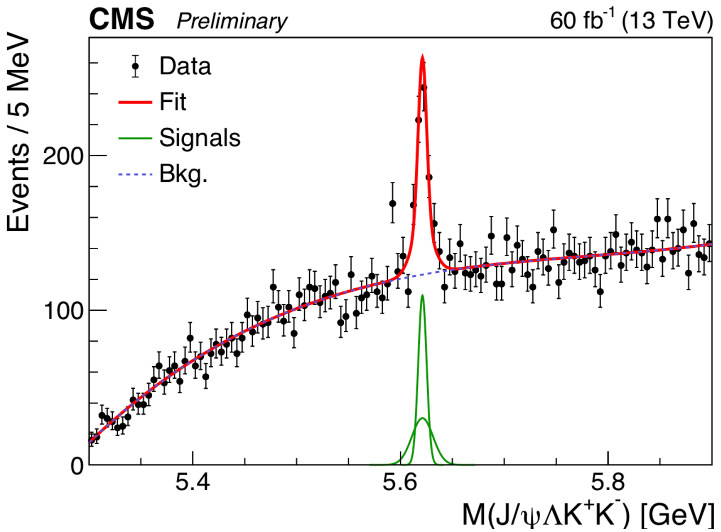
Fermilab

OBSERVATION OF $\Lambda_b^0 \rightarrow J/\psi\,\Lambda\,\phi$

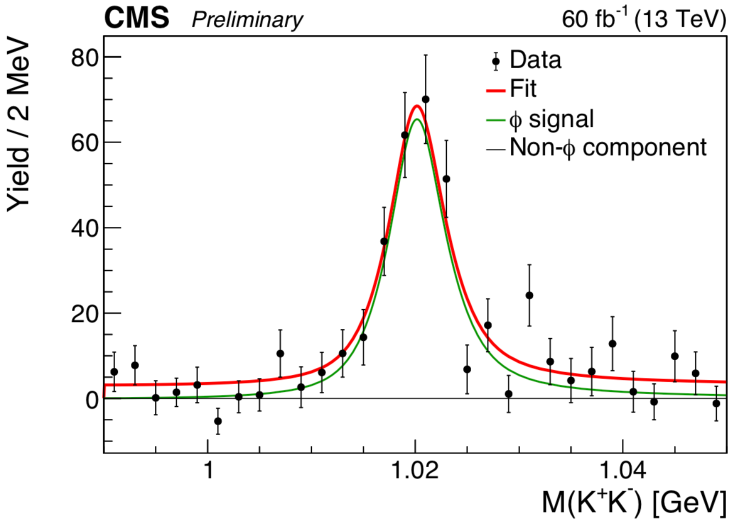
BPH-19-002

NEW

- 1st observation of the decay $\Lambda_b^0 \rightarrow J/\psi\,\Lambda\,\phi$
  - Decay expected to proceed via the b → $c\bar{c}s$ process (similar to $\Lambda_b^0 \rightarrow J/\psi\,\Lambda$ but requires an additional $s\bar{s}$ pair)
- Measure the branching fraction relative to the decay mode $\Lambda_b^0 \rightarrow \psi(2S)\,\Lambda$ which has a similar topology
- $$\frac{N(\Lambda_b^0 \rightarrow J/\psi\,\Lambda\phi)\,\mathcal{B}(\psi(2S)\rightarrow J/\psi\pi^-\pi^+)\,\epsilon(\Lambda_b^0\rightarrow \psi(2S)\Lambda)}{N(\Lambda_b^0\rightarrow \psi(2S)\Lambda)\,\epsilon(\Lambda_b^0\rightarrow J/\psi\,\Lambda\phi)\mathcal{B}(\phi\rightarrow K^+K^-)}$$
- Potential baryonic channel for access to exotic resonances in the $J/\psi\phi$ system



$\Lambda_b^0\rightarrow J/\psi\,\Lambda K^+K^-$: 380 ± 32 events



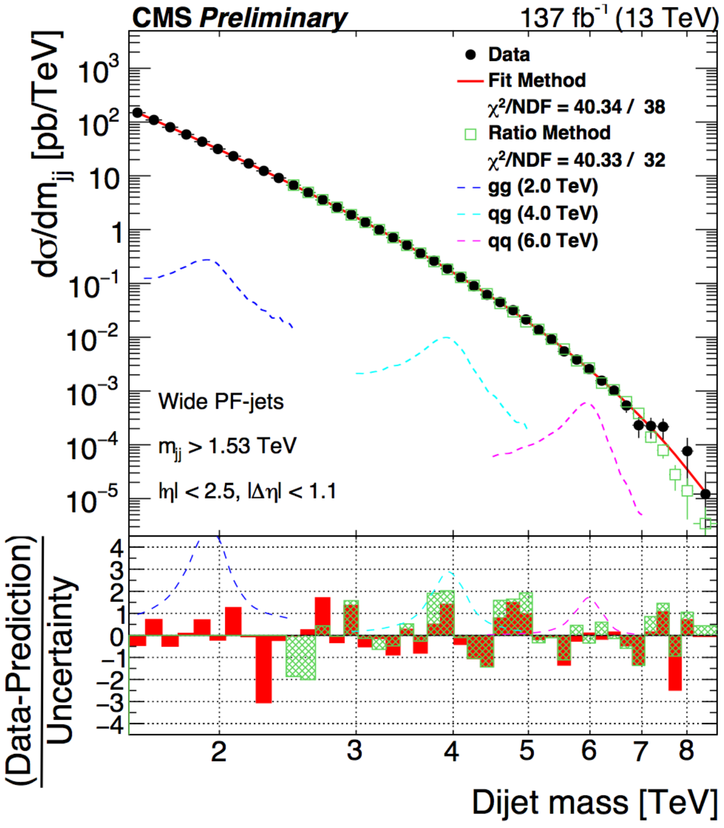
$\Lambda_b^0\rightarrow J/\psi\,\Lambda\phi$: 286 ± 29 events

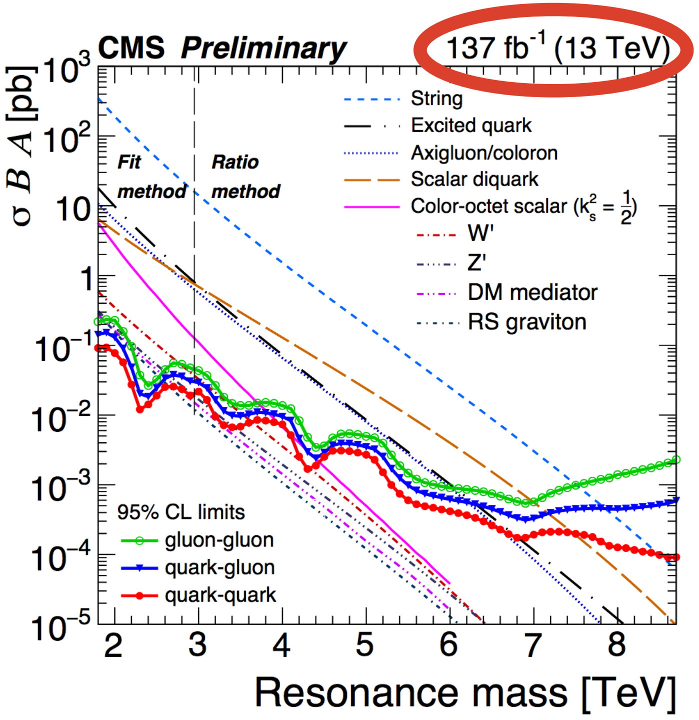
$$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi\,\Lambda\,\varphi)}{\mathcal{B}(\Lambda_b^0 \rightarrow \psi(2S)\,\Lambda)} = (8.26 \pm 0.90\text{ (stat)} \pm 0.68\text{ (syst)} \pm 0.11(\mathcal{B})) \times 10^{-2}$$

RESONANT DECAYS TO TWO JETS

EXO-19-012

- Classical high-mass resonance search
  - Can be interpreted in a wide range of BSM models predicting particles decaying to gg, gq, or qq
  - Continue to improve analysis with new techniques:
    - replace parametric background shape by measurement in data sideband region
    - Robust method and more sensitive for wide resonances
- Results consistent with background





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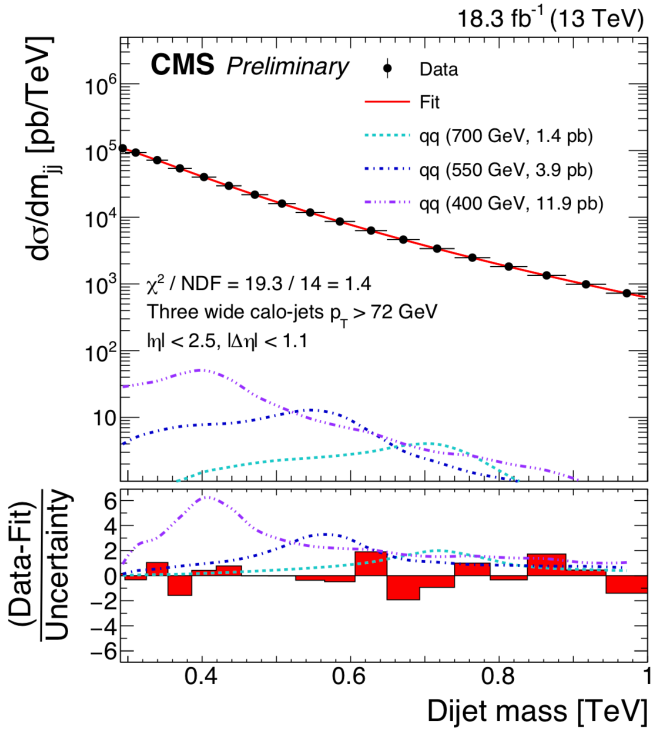
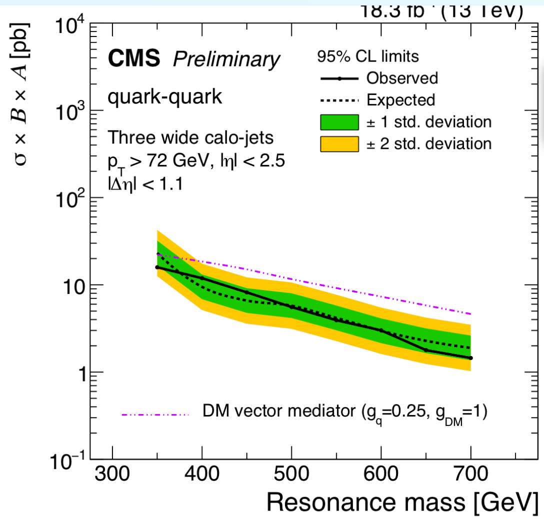
SEARCH FOR DIJET RESONANCES IN EVENTS WITH 3 JETS

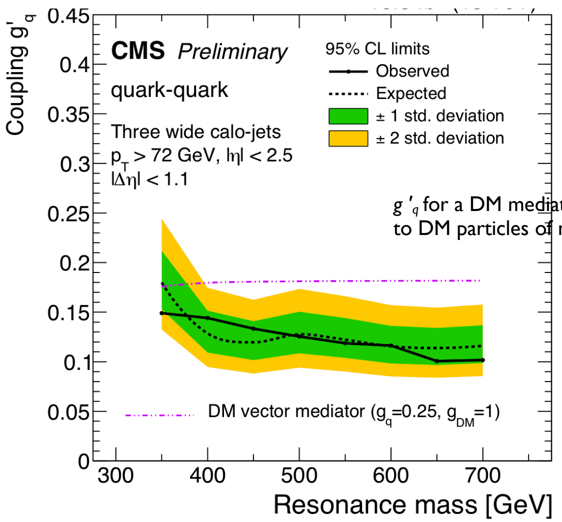
EXO-19-004

NEW



- Search for vector resonances decaying into two jets in the mass range 350 – 700 GeV
  - Look for resonances recoiling against a 3rd jet
  - 2016 data scouting with low H_T trigger thresholds
  - Event selection: Require 3 wide jets p_T > 72 GeV
- No significant excess is found.
- Most stringent limits on resonances decaying to light jets in the **350-450 GeV** mass range
- Set 95 % CL upper limits on the coupling to quarks $g_{q'}$ in the range 0.10 – 0.15 for a vector resonance interacting only with quarks.





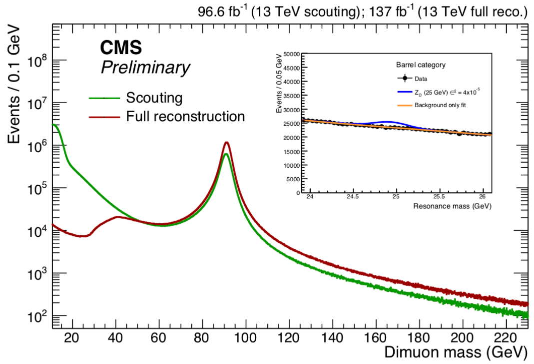
g'_q for a DM mediator that decays to DM particles of mass 1GeV

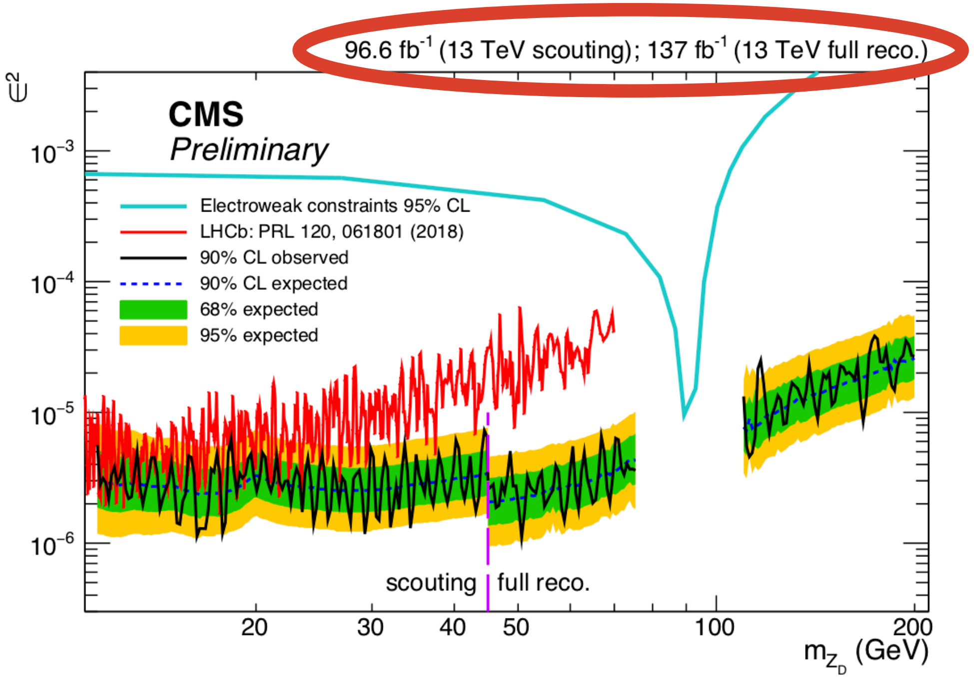
SEARCH FOR DIMUON RESONANCES

EXO-19-018

NEW

- Search for **low-mass** dimuon resonances in the range **11.5-200 GeV** (excluding the Z resonance range)
  - For masses < 45 GeV the search uses high rate dimuon data scouting triggers (muon $p_T > 4.5$ GeV)
    - First CMS analysis using non-hadronic scouting
    - Scouting enables higher rates by recording reduced size events which only contain information reconstructed online
  - Signal: pair of muons (for mass range > 45 GeV search, muon $p_T > 20$ and 10 GeV)
- The results can be interpreted as a **dark photon (Z_D)** that could couple the standard model particles to a hidden, dark sector of particles.
- The strength of the coupling with SM fermions is determined by the kinetic mixing coefficient ϵ.
- Data are found to be consistent with background expectations.





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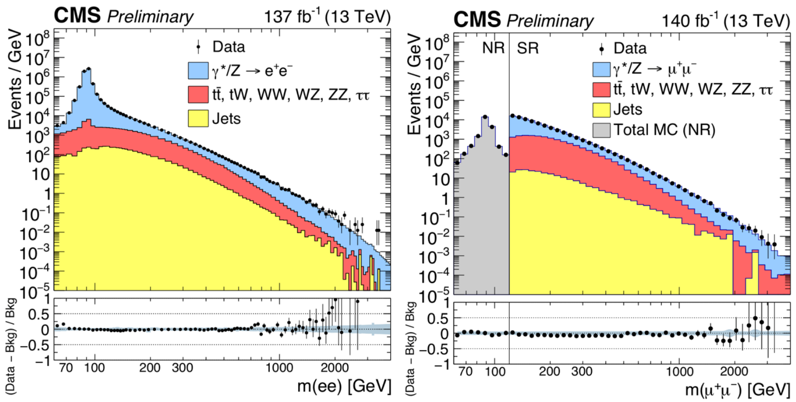
HIGH MASS DILEPTON RESONANCE SEARCH

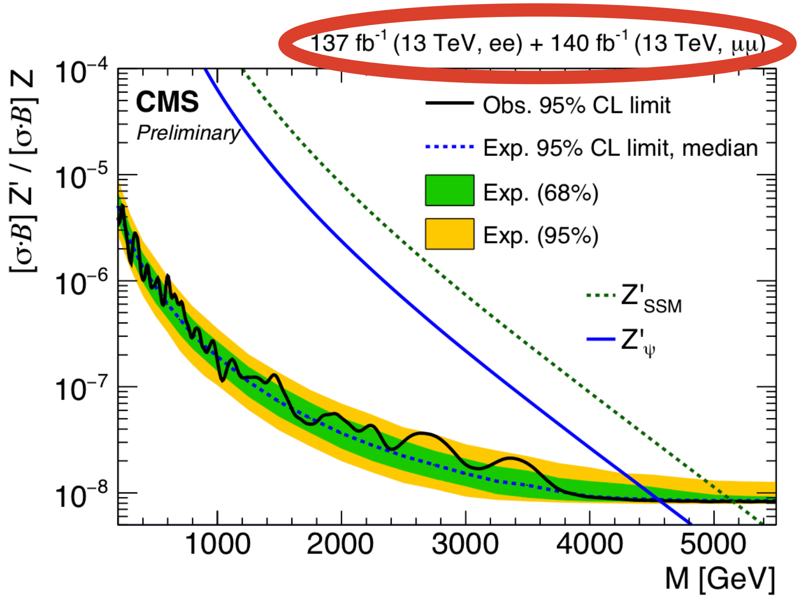
EXO-19-019

NEW

- High-mass dielectron and dimuon events are selected through methods optimized for high-p_T electrons and muons.
- SM backgrounds are estimated from simulation, with corrections to the Drell Yan background and includes the contribution from photon induced processes.
- No significant deviation from SM expectation is observed
- As a result, a Z'_{SSM} (Z'_{ψ}) particle, arising in the superstring-inspired sequential standard model, is excluded below a mass of 5.15 (4.55) TeV at 95% confidence level.

These two searches for narrow resonances decaying to muons cover the mass range **11.5 GeV – 5.5 TeV** (except the Z peak).





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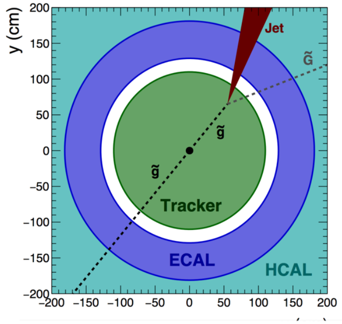
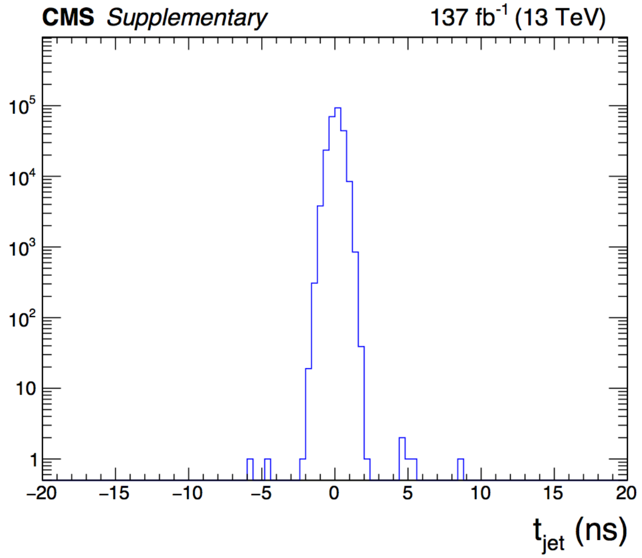
DELAYED JETS

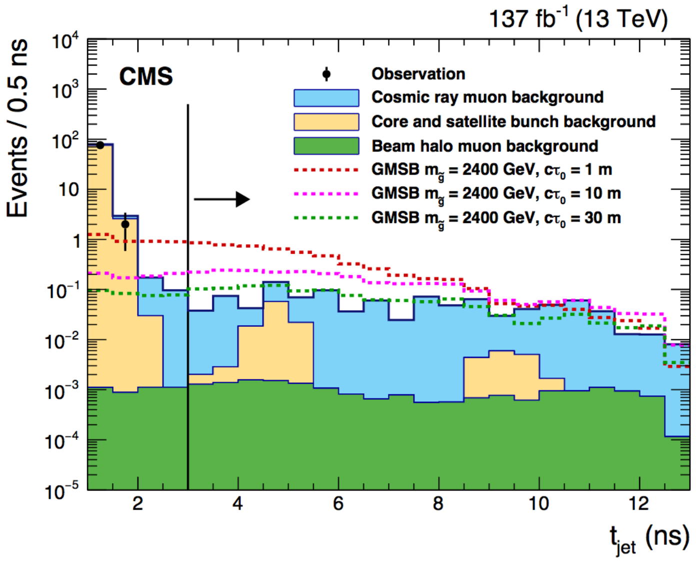
arXiv:1906.06441

- Jet timing from ECAL ($PbWO_4$ Xtals)
  - Long-lived gluinos give rise to jets from displaced vertex
    - Delay due to differences in the velocity and path length
  - uses median time of all ECAL cells in the jet cone

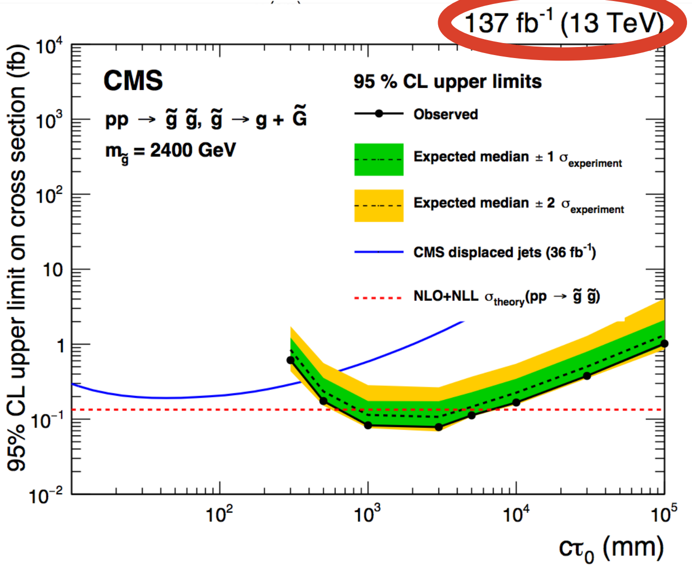




median time of ECAL cells in cone - background jets



main backgrounds from cosmics & satellite bunches



significant extension of sensitivity w.r.t. tracker-based searches

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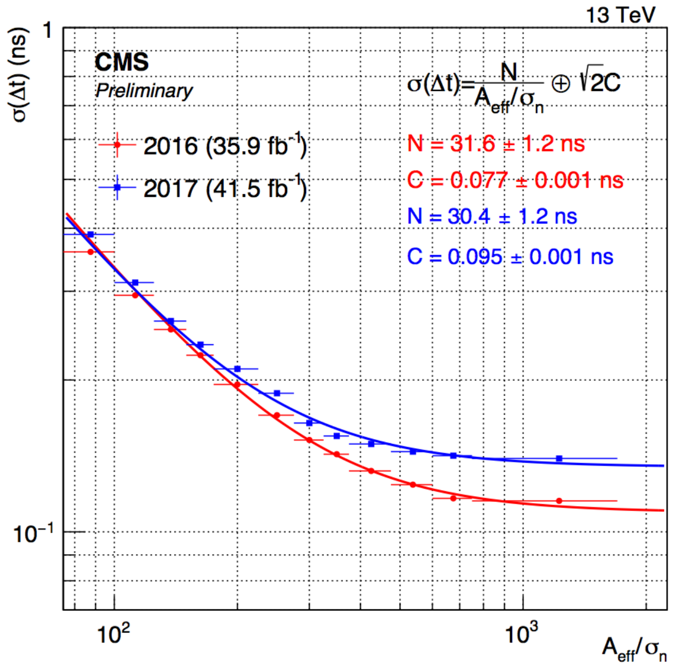
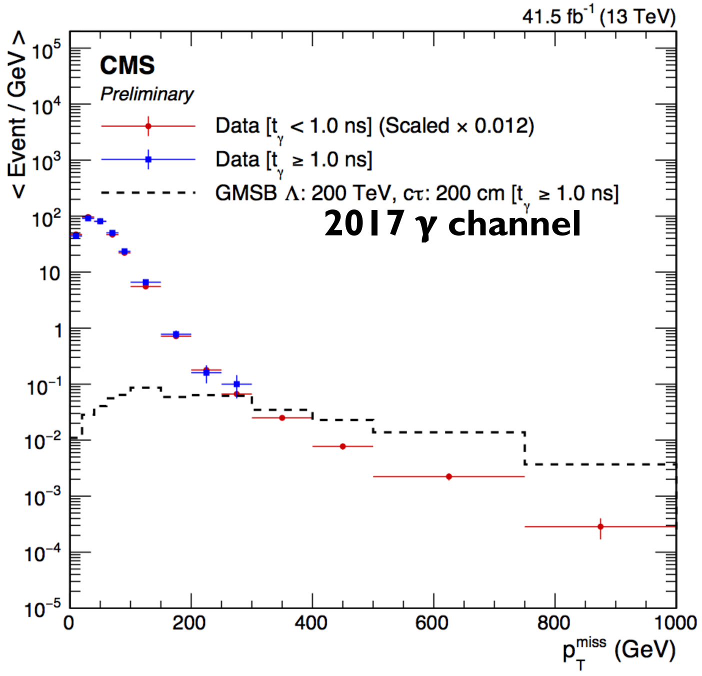
DELAYED PHOTONS

EXO-19-005

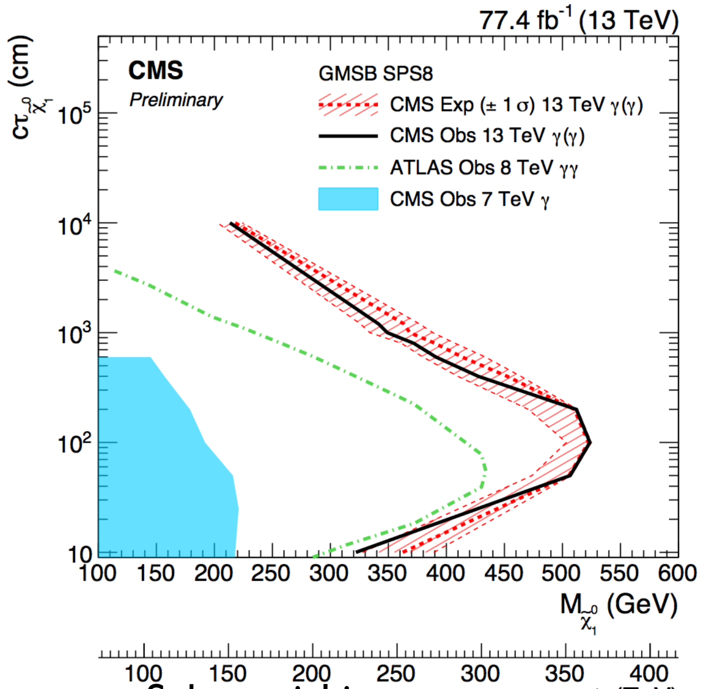
- Photon timing using ECAL
  - Long-lived neutralinos decay to a photon and a gravitino
  - requires precise calibration of ECAL timing and resolution



Time resolution for photons



Spectra for prompt and delayed selections, and signal



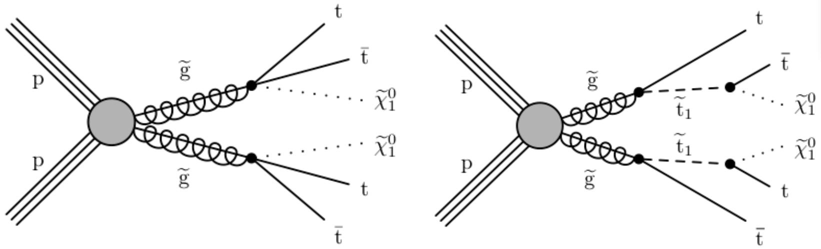
Substantial improvement w.r.t. early Run 1 search

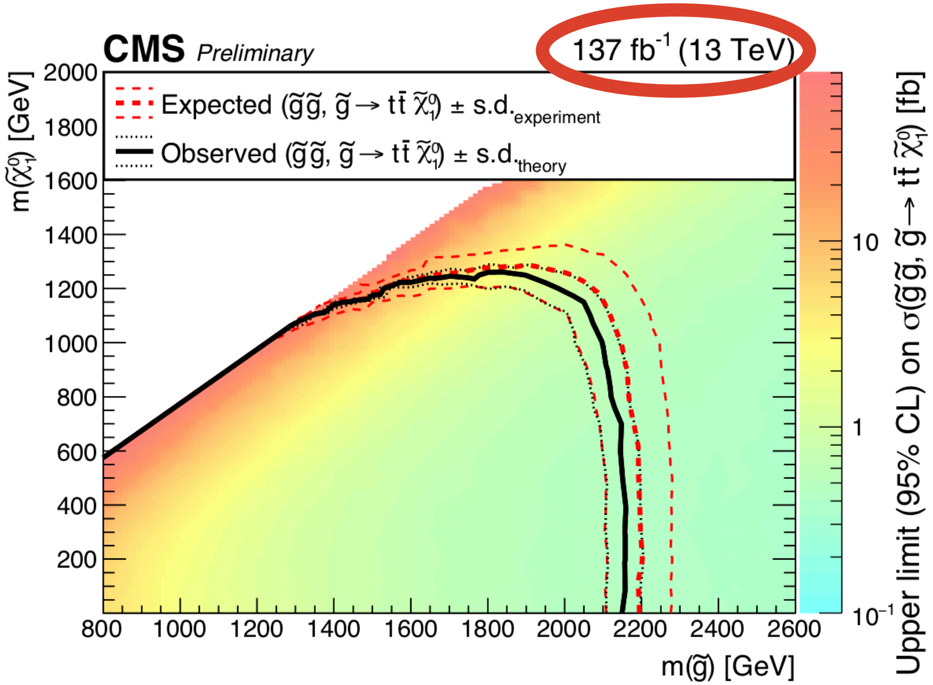
SEARCH FOR SUSY IN 1L FINAL STATES

SUS-19-007

NEW

- Inclusive search for strong SUSY production in final states with MET, b-jets, and a lepton
- Signature: single lepton, multiple jets (with b-tagged jet), and large p_T^{miss}
- Characterization: total number of jets, the #b-tagged jets, p_T^{miss}, and the sum of the masses of large-radius jets.
- Based on the comparison to event yields in control regions, no significant excess compared to SM was observed.
- The results are interpreted as gluino pair production in which each gluino decays into a tt pair and a neutralino.
- Scenarios with gluino masses up to about 2150 GeV are excluded at 95% confidence level for neutralino masses up to 700 GeV.





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CMS PLANS FOR LS2 SHUTDOWN

HCAL barrel (last Phase-1):
install SiPM+QIE11-based 5Gbps readout
Increase longitudinal segmentation

Keep strip tracker cold to avoid reverse annealing

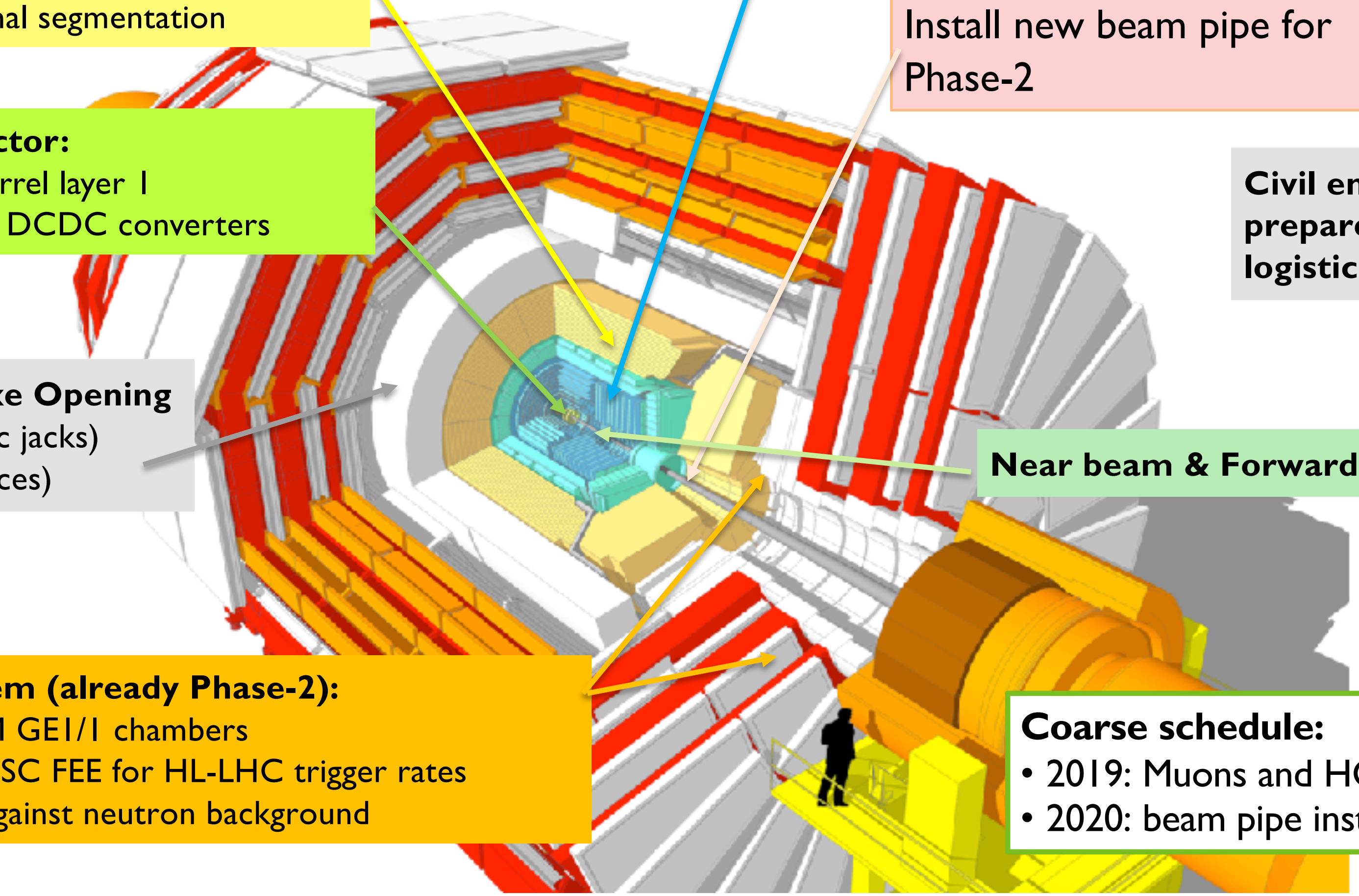
Install new beam pipe for Phase-2

Pixel detector:
- replace barrel layer 1
- replace all DCDC converters

Civil engineering on P5 surface to prepare for Phase-2 assembly and logistics

MAGNET (stays cold!) & Yoke Opening
- New opening system (telescopic jacks)
- New cable gantry (Phase2 services)

Near beam & Forward Systems



Muon system (already Phase-2):
- install GEM GE1/1 chambers
- Upgrade CSC FEE for HL-LHC trigger rates
- Shielding against neutron background

Coarse schedule:
- 2019: Muons and HCAL interleaved
- 2020: beam pipe installation, then pixel re-installation

LS2 – IN PROGRESS

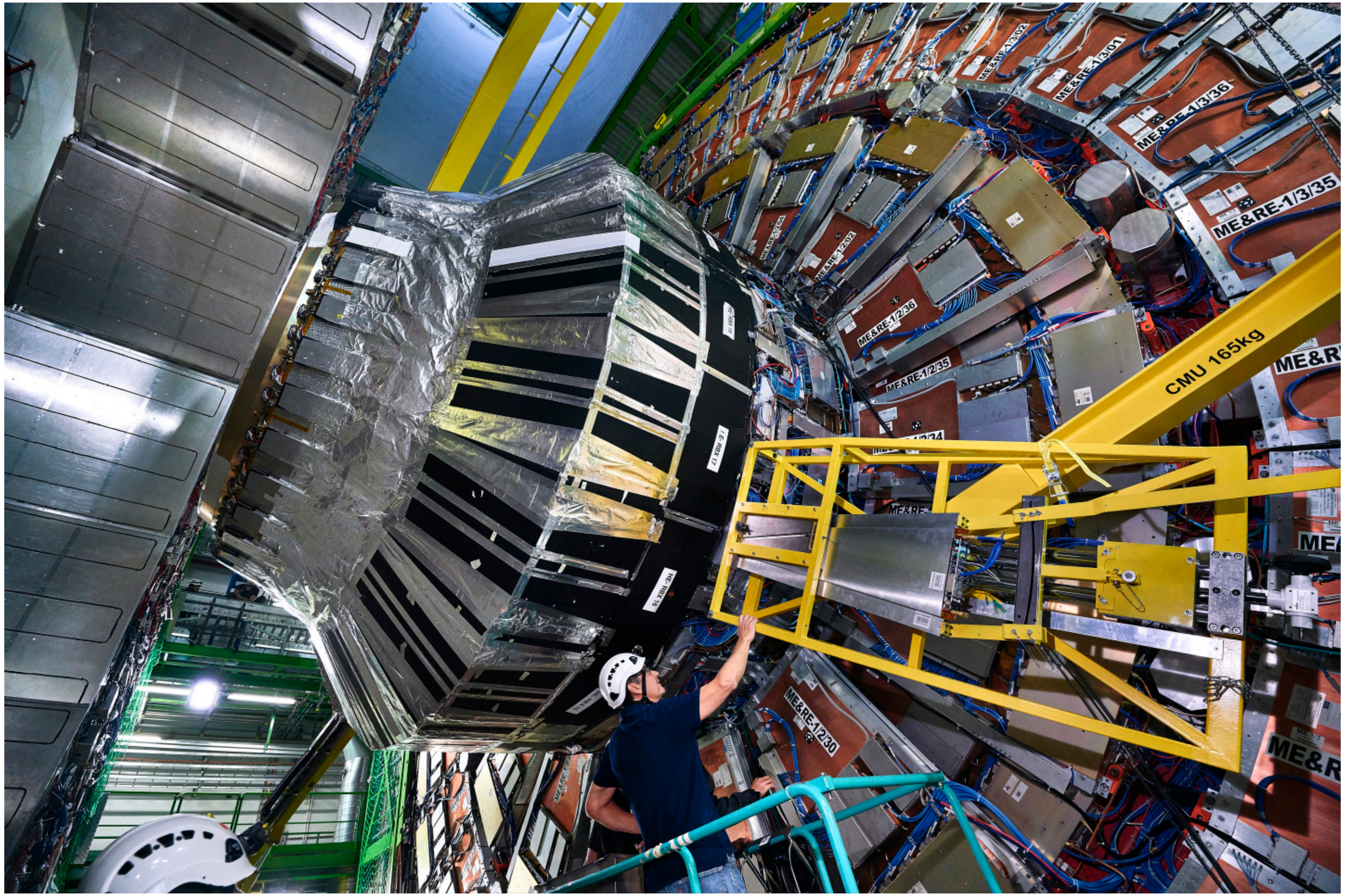
CMS is performing maintenance of the detector, completing the installation of the Phase-1 upgrades and installing infrastructure for the Phase-2 upgrades for the HL-LHC.

- Installation of the 1st CMS Phase-2 detectors (GEM SuperChambers) starting.
- The Phase-2 upgrade of the Muon Detector CSC electronics is also well underway.

Preparing for Run 3

- Exploring trigger options to enhance physics opportunities
- Implementing new techniques such as machine learning in the Level 1 trigger.

Preparing for HL-LHC



CMS PHASE-2 UPGRADE FOR THE HL-LHC

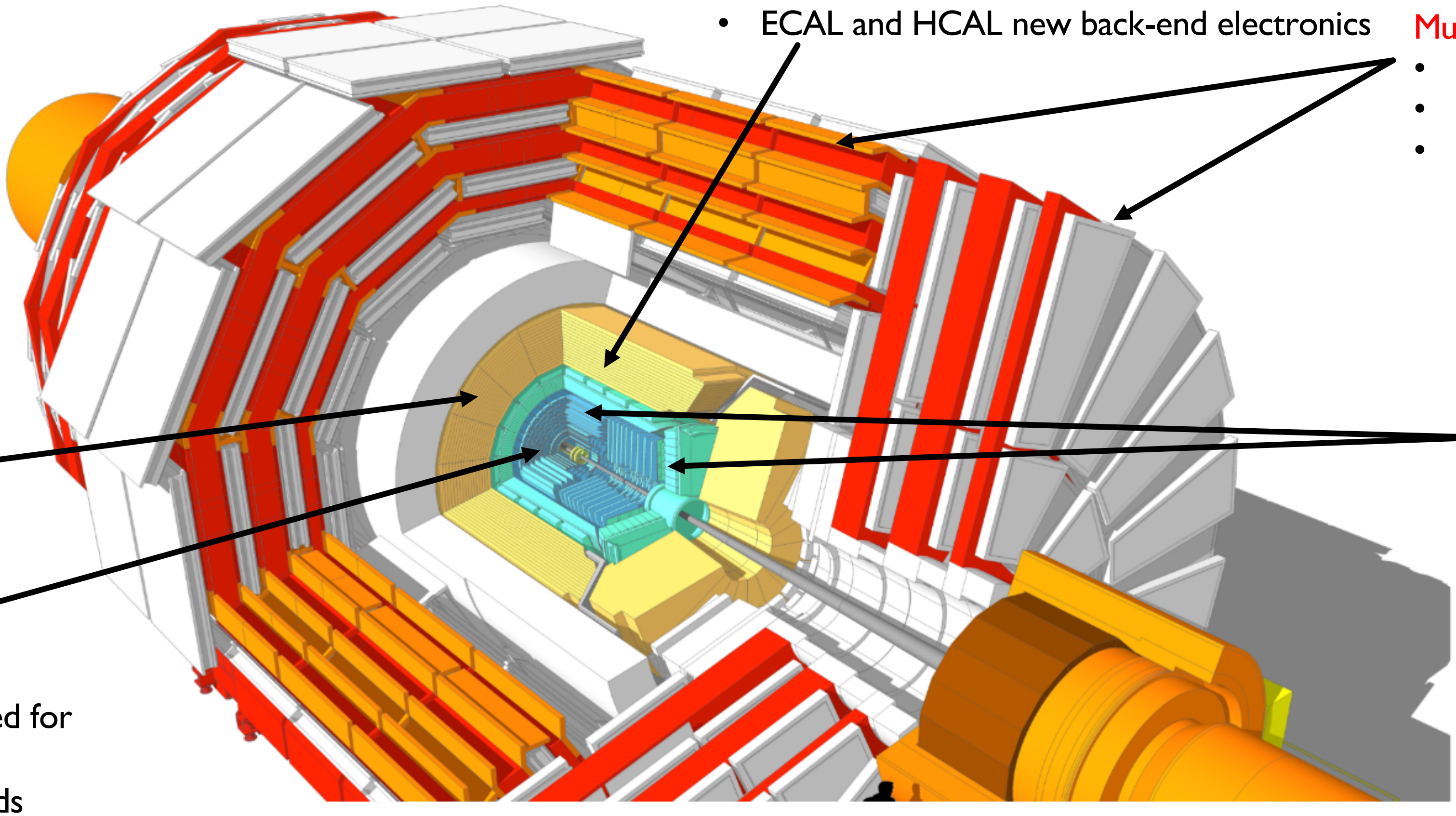
L1 Trigger/HLT/DAQ
- L1 40 MHz in/750 kHz out with tracking for PF-like
- HLT 7.5 kHz out

Beam Radiation and Luminosity, Common Systems, Infrastructure

Barrel Calorimeters
- ECAL single crystal granularity in L1 Trigger with precise timing for e/γ at 30 GeV
- ECAL and HCAL new back-end electronics

Muon Systems
- DT & CSC new FE/BE readout
- New GEM/RPC $1.6 < |\eta| < 2.4$
- Extended coverage to $|\eta| < 2.8$

$|\eta| < 3.0$



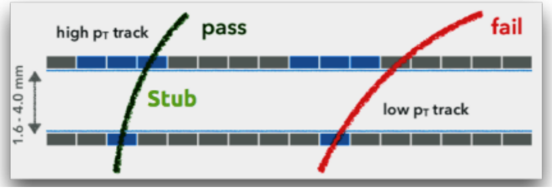
MIP Timing Detector
- 30 ps resolution
- Barrel: Crystals + SiPMs
- Endcap: LGADs

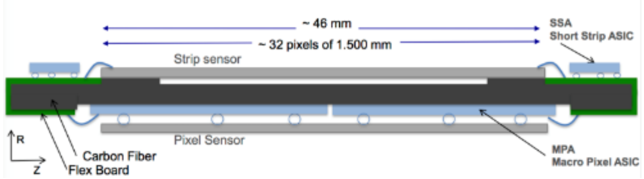
Calorimeter Endcap
- Si, Scint + SiPM in Pb-W-SS
- 3D shower imaging with precise timing

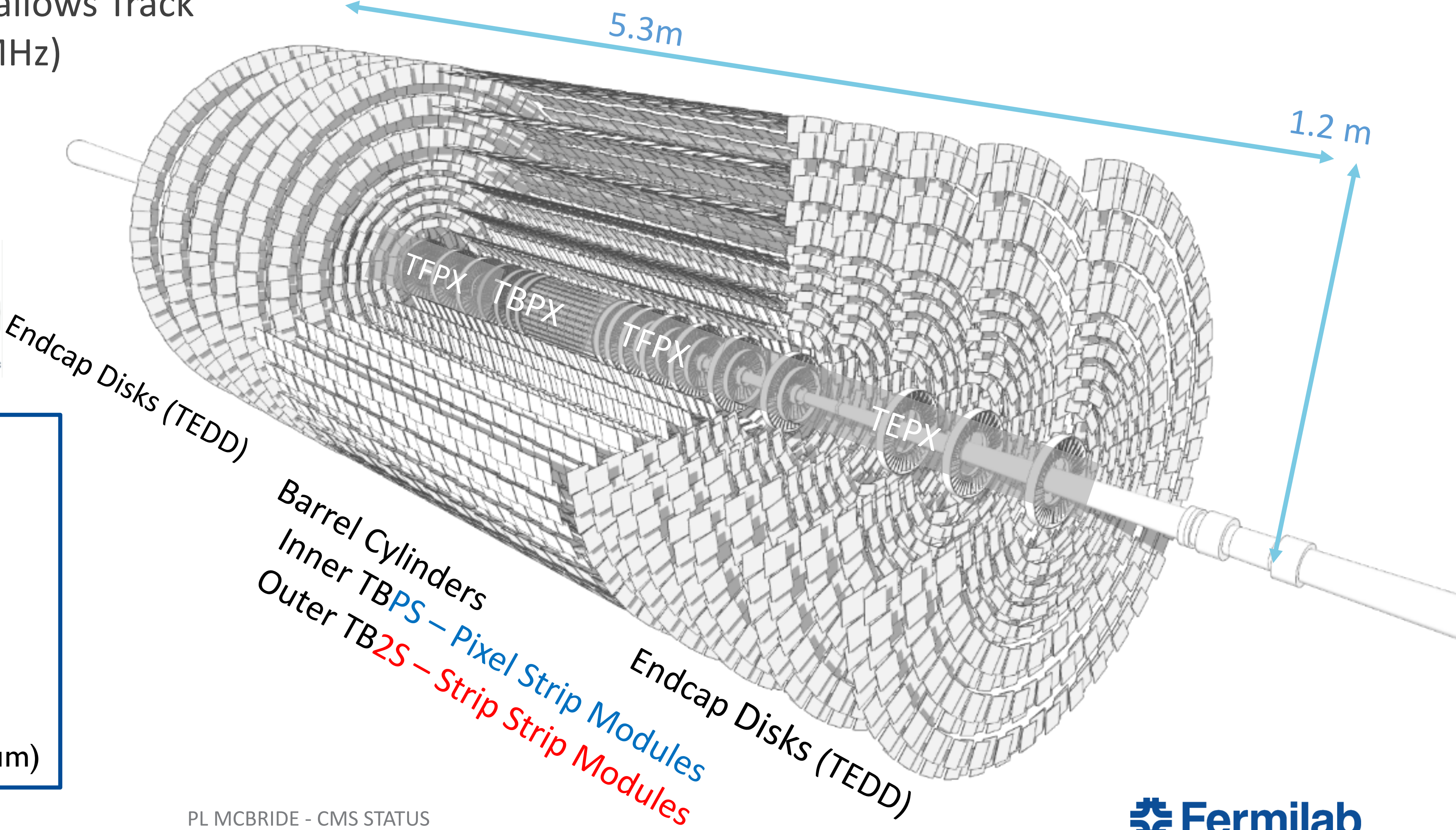
Tracker
- Si Strip Outer Tracker designed for L1 Track Trigger
- Pixelated Inner Tracker extends coverage to $|\eta| < 3.8$

CMS TRACKER UPGRADE FOR HL-LHC

- Module “sandwich” allows Track Triggering at L1 (40 MHz)



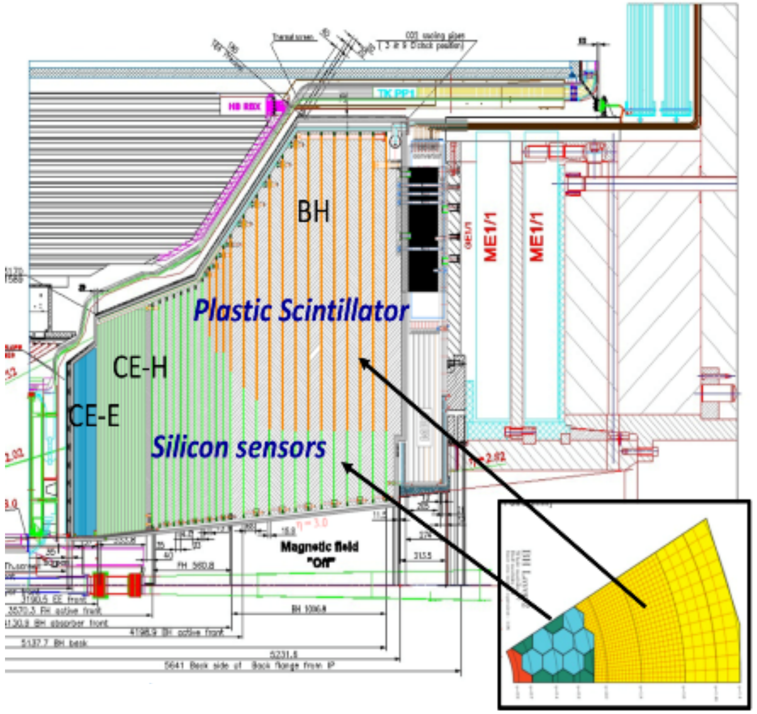




Numbers

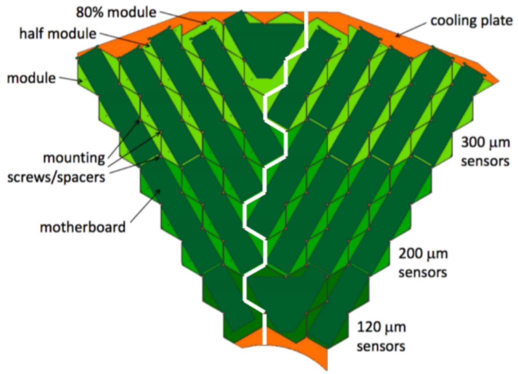
- 23.5 m^3 volume
- ~1600 kg
- 75 kW total power
- 192 m^2 Silicon Area
- 215 M readout channels
- ~2 Billion Pixels (2500 sq. μm)

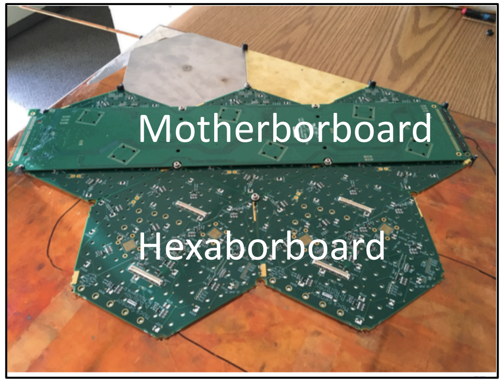
CMS UPGRADE: ENDCAP CALORIMETER



- The high granularity, both in transverse and longitudinal directions, gives powerful handles for pileup mitigation and detailed shower reconstructions.
- The low readout thresholds (below MIP threshold) enables in-situ calibration/monitoring as well as stand-alone muon-ID capabilities.
- Electronics will ensure a 30ps timing capabilities for electromagnetic and hadronic showers of sufficiently high energy.

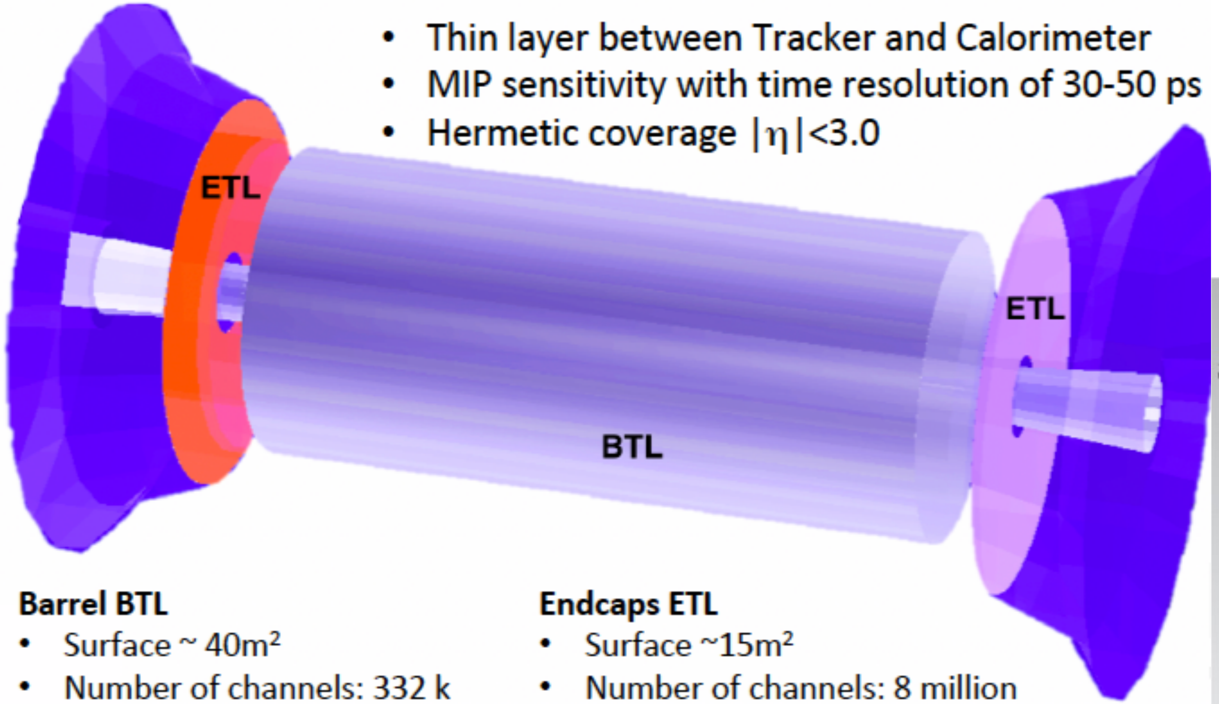
Novel Imaging Calorimeter with highly segmented 4-D image of jet
Electromagnetic: Si and W/Pb 25 X_0,1.7λ
Hadronic: Si-only and mixed Si/Scint, 8λ
~6 Million channels; 8" silicon wafers





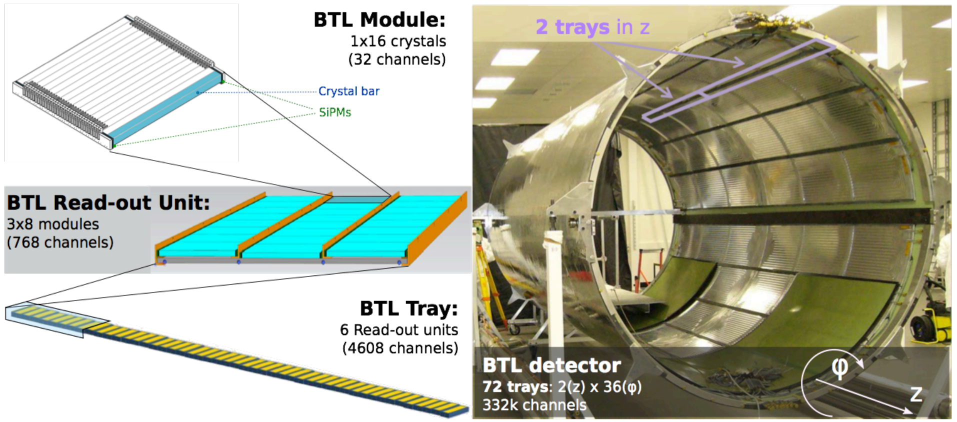
MIP TIMING DETECTOR (MTD)

- Thin layer between Tracker and Calorimeter
- MIP sensitivity with time resolution of 30-50 ps
- Hermetic coverage |η|<3.0

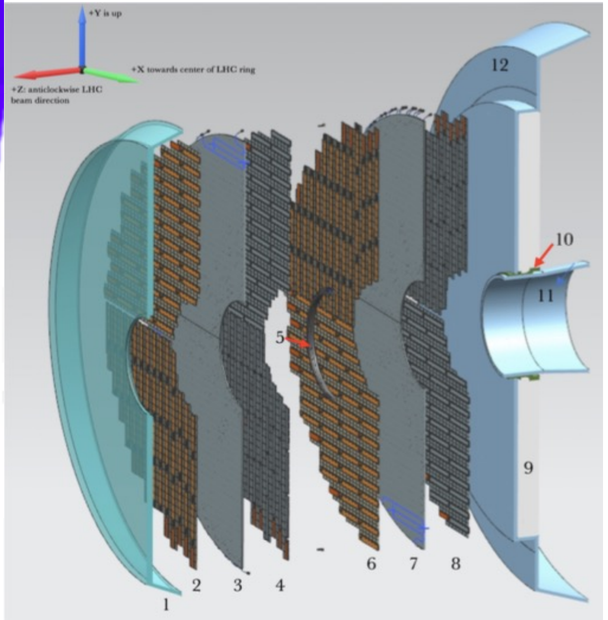


Barrel BTL
- Surface ~ 40m²
- Number of channels: 332 k
- Sensors: LYSO crystals + SiPMS
- pi-K separation up o 2.5 GeV at 3 σ

Endcaps ETL
- Surface ~15m²
- Number of channels: 8 million
- Sensors: Low Gain Avalanche Diodes



Barrel (BTL)



Endcap (ETL)

- A reduction of 2-4 times effective pile-up
- a significant improvement in lepton isolation and missing E_T is expected
- Provides particle ID for Heavy Ion, QCD, B and charm studies

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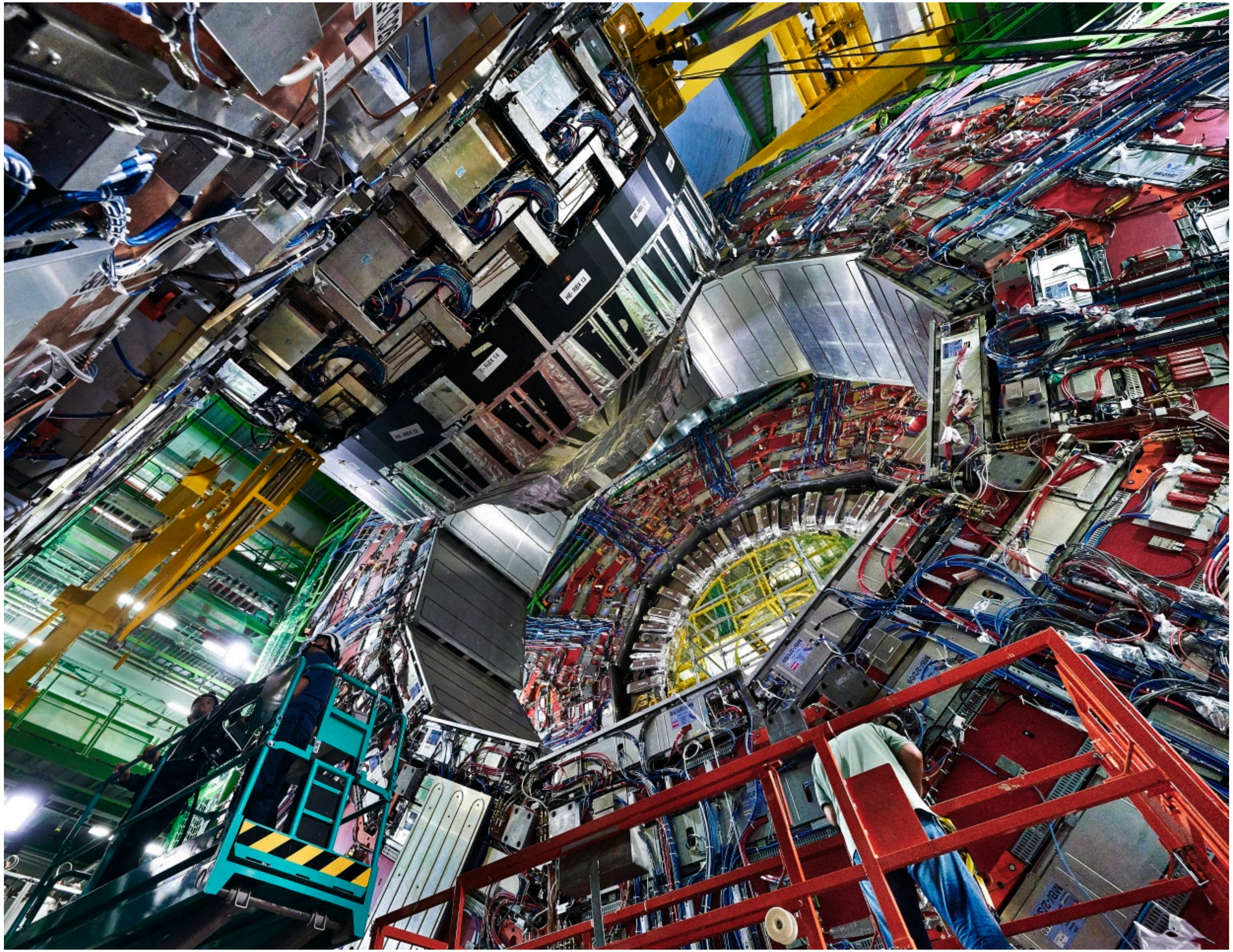
SUMMARY

- **CMS** is very busy during LS2!
  - Vibrant **physics research** program exploiting Run 2 data
  - **Efficient technical program** completing Phase-1 upgrades, preparing for Run 3 (and HL-LHC)
  - Exciting, cutting edge slate of **upgrades** for HL-LHC are underway.
- CMS recently submitted its 900th scientific publication on results using LHC collision data.
- Many results exploiting the full Run 2 dataset are in preparation.



BACKUP

TOP QUARK TO DILEPTONS (INCLUDING τ)

TOP-18-005

- Probing lepton universality in the top sector
- cross section $\sigma_{t\bar{t}}$ = 781 ± 7 (stat) ± 62 (syst) ± 20 (lumi) pb.
- background: $t\bar{t}$ lepton+jet events where one jet is misidentified as the τ_h.
- $R_{\ell\tau_h/\ell\ell}$ = 0.973 ± 0.009 (stat) ± 0.066 (syst) consistent with lepton universality
- $\Gamma(t \rightarrow \tau\nu_\tau b)/\ \Gamma_{total}$ = 0.1050 ± 0.0009 (stat) ± 0.0071 (syst)