

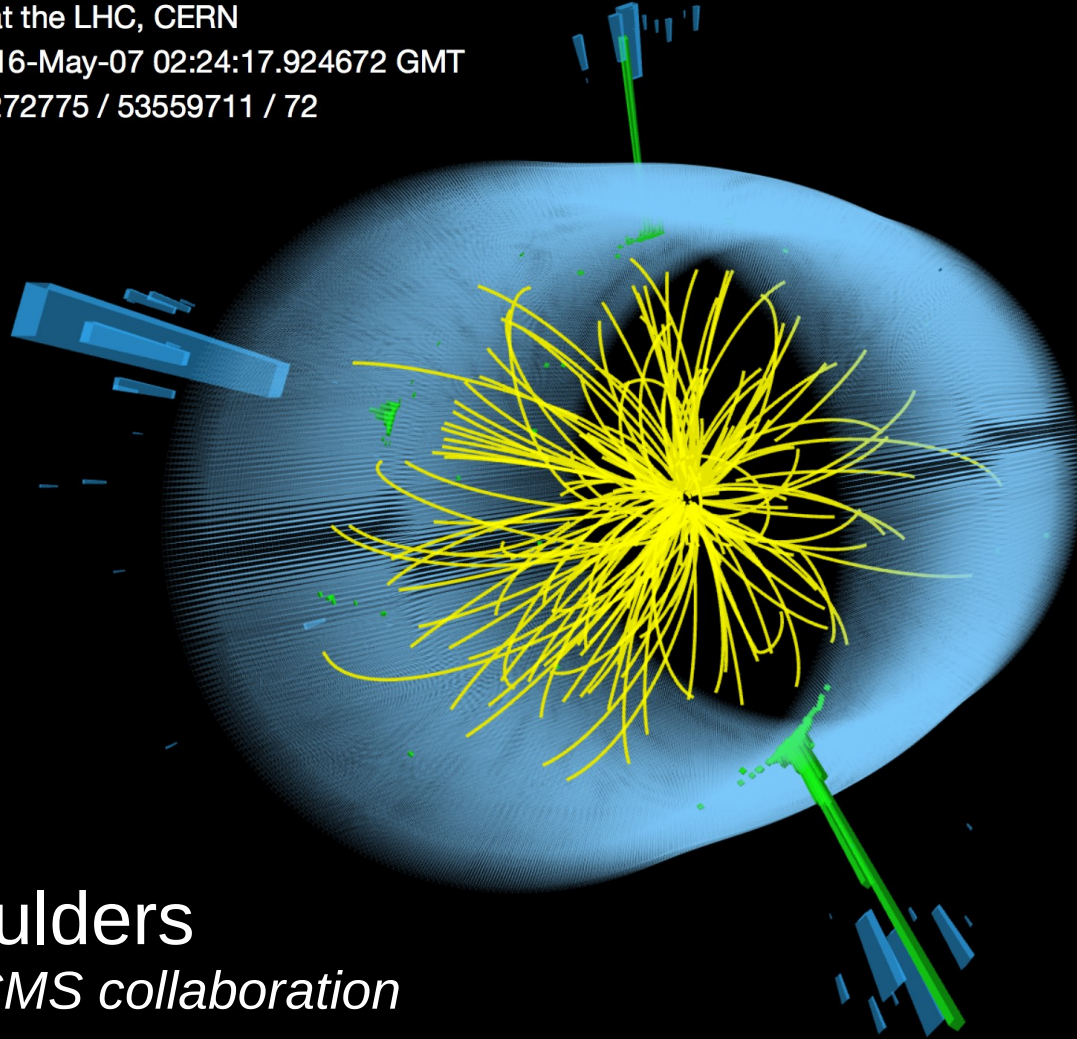
# Status and recent highlights



CMS Experiment at the LHC, CERN

Data recorded: 2016-May-07 02:24:17.924672 GMT

Run / Event / LS: 272775 / 53559711 / 72



Petra Van Mulders  
*on behalf of the CMS collaboration*



Vrije  
Universiteit  
Brussel



Research Foundation  
Flanders  
Opening new horizons



# The CMS collaboration & its activities



4400+ CMS members

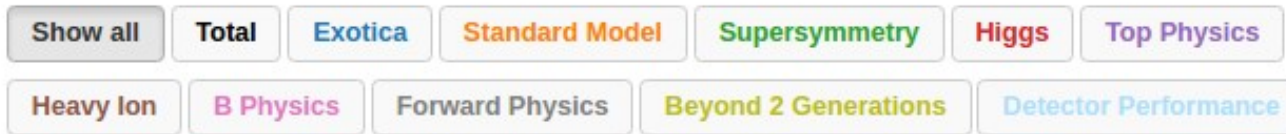
200+ institutes

- Upgrade: Phase I (LHC) & Phase II (HL-LHC)
- Run 1: analyses mainly focused on precision measurements
- Run 2: main focus of this talk

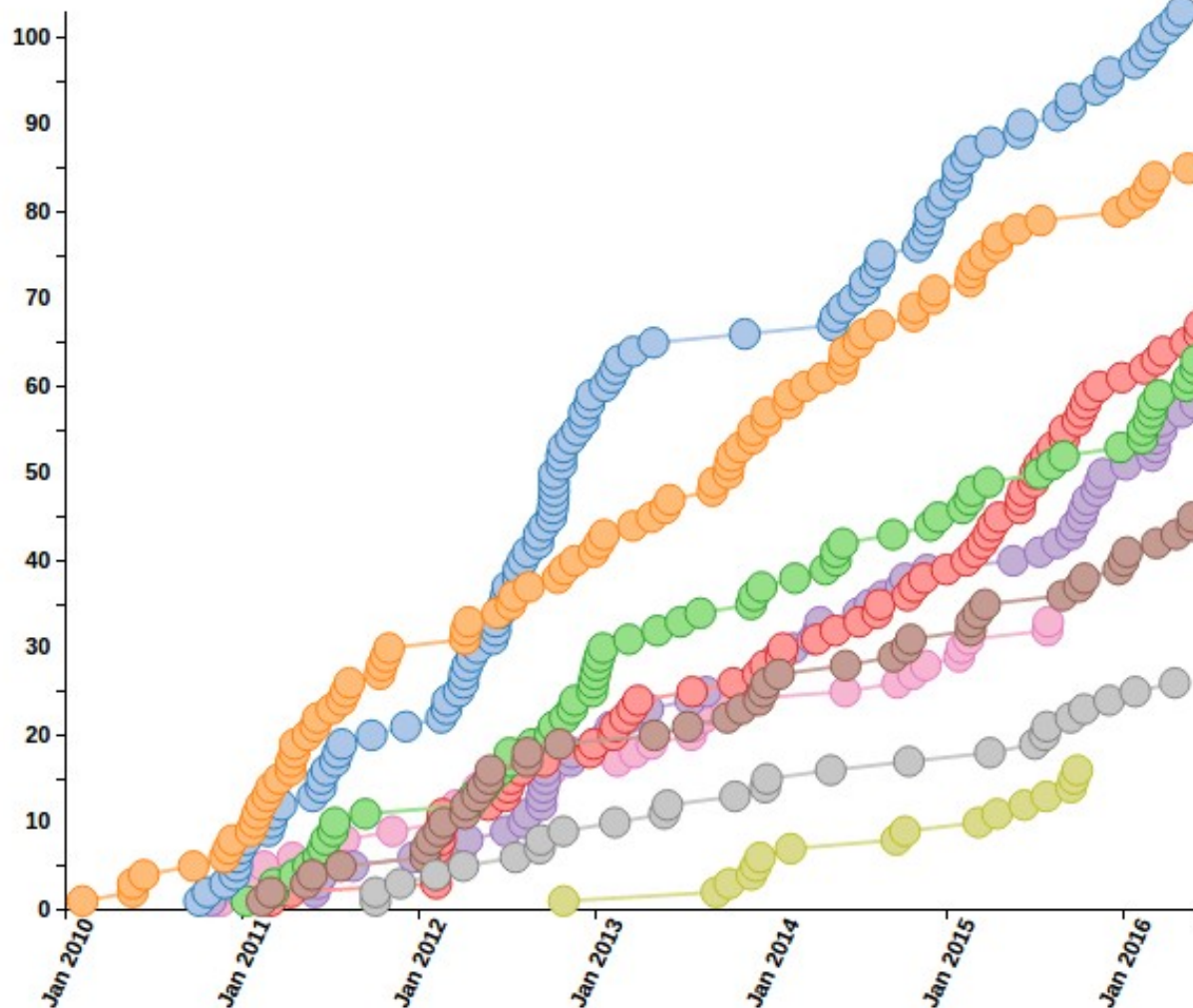
# Content

- Physics highlights based on 2015 data at 13 TeV
- Overall status of the CMS experiment in 2016
- Object performance in 2016

# Physics results



510 collider data papers submitted as of 2016-06-08



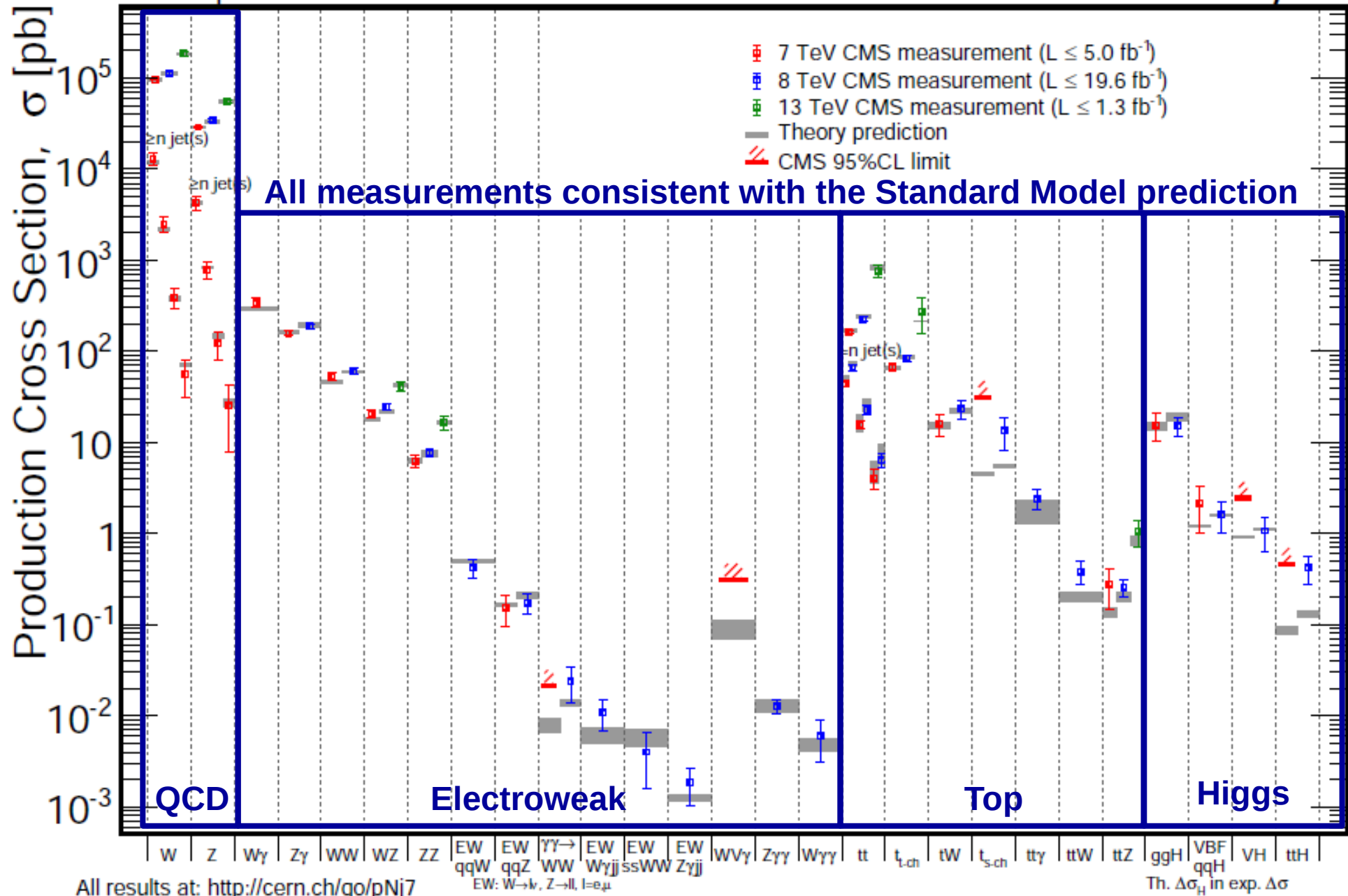
- Already 93 Run 2 public results
- Of which 9 Run 2 papers submitted
- Recent Run 1 legacy papers on precision measurements:  
  
Higgs, Top, Electroweak, QCD, Heavy Flavour
- In total over 500 papers submitted



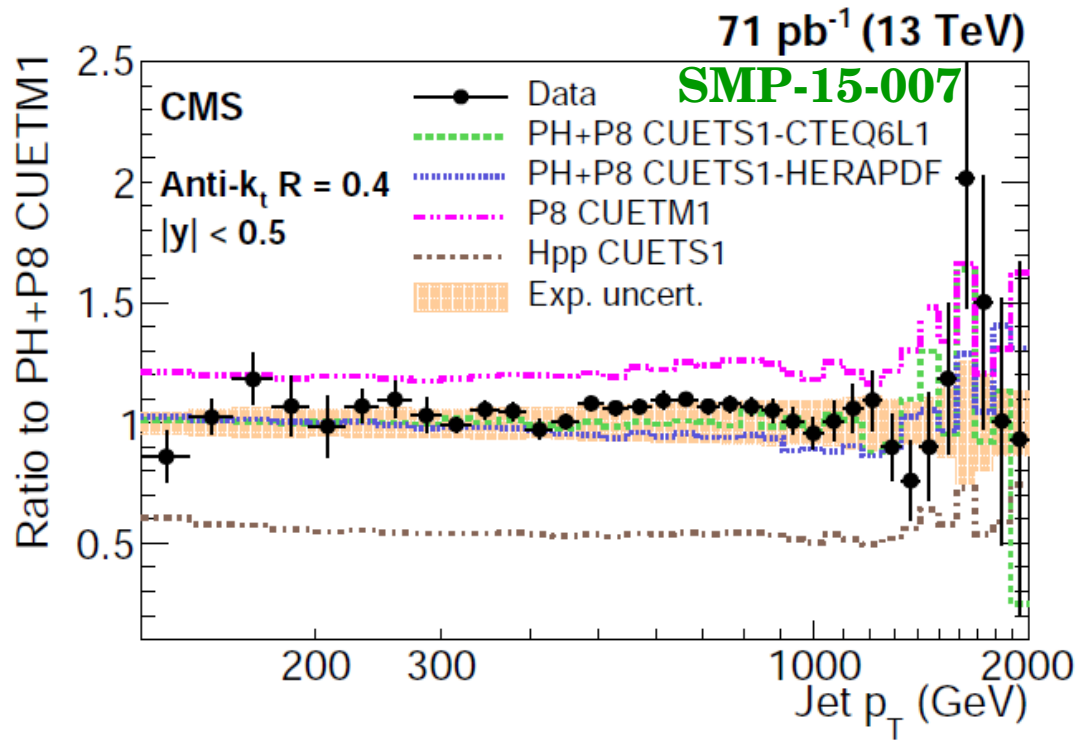
# Cross section measurements

April 2016

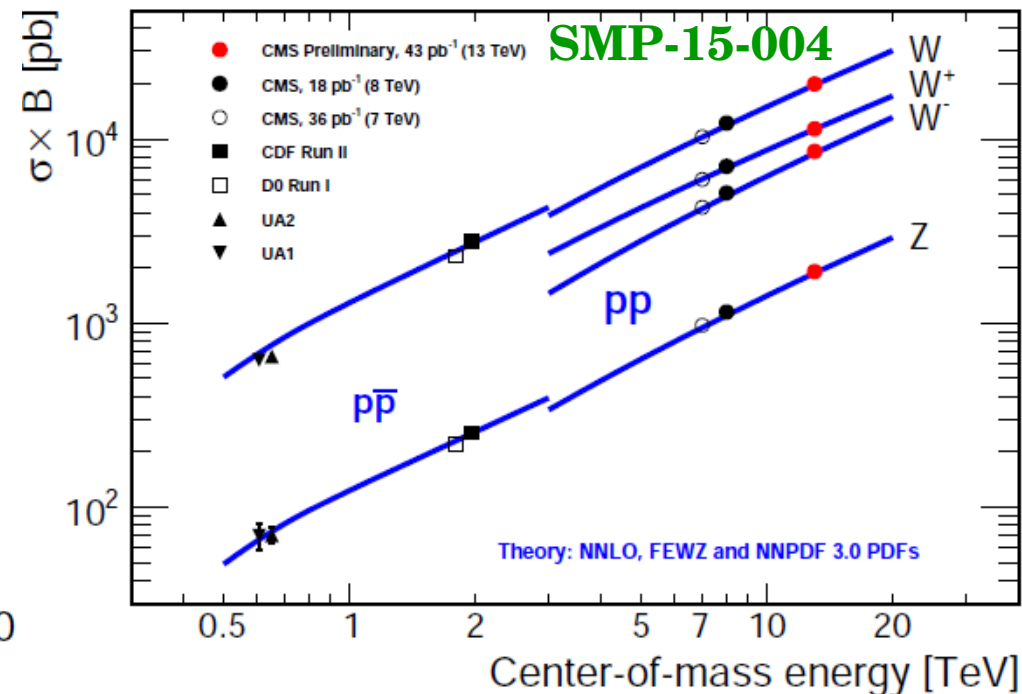
CMS Preliminary



# Measurement of inclusive jet and W/Z production (differential) cross section



Measured inclusive jet cross section agrees well with POWHEG+Pythia8 in the entire kinematic range studied



The measured values agree with the NNLO QCD cross section calculations

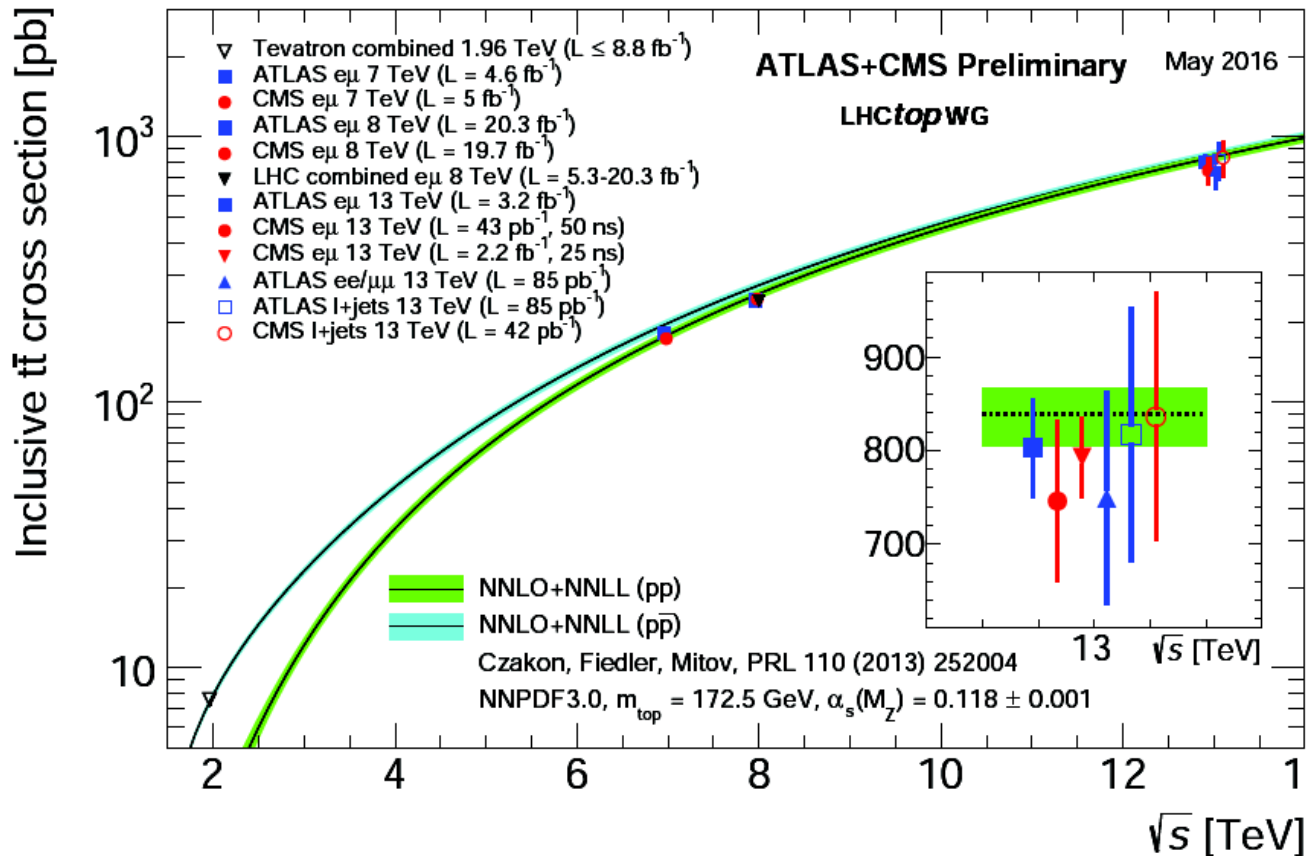
*T. Seva, J. Kuechler, K. Mueller, E. Radermacher, G. Flouris (QCD parallel)*

*O. Villalobos Baillie, V. Ciulli, M. Santana Rangel (QCD plenary)*

*N. Woods, Q. Li, N. Vranjes, A. Apyan, (Electroweak parallel)*

*M. Schott, L. Lloret Iglesias, E. Nurse (Electroweak plenary)*

# Top quark production

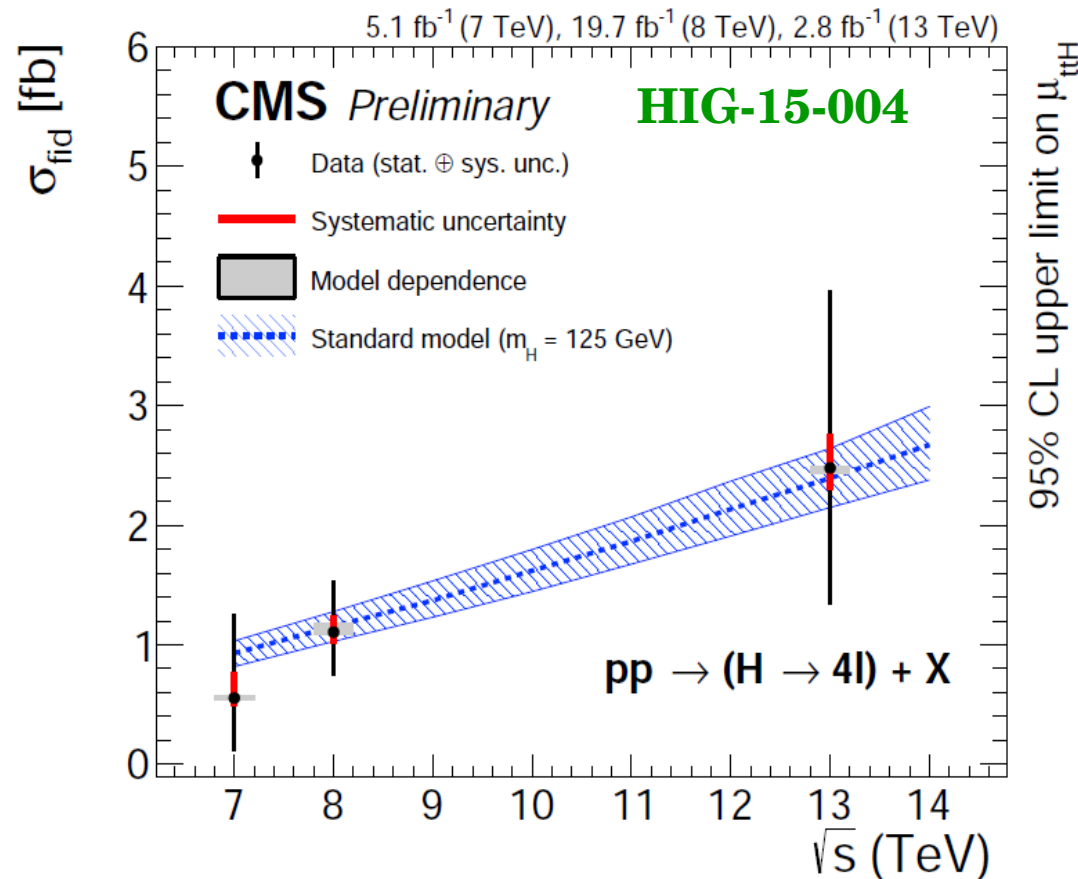


- Cross section at 13 TeV measured with a precision of 5.5% **TOP-16-005**
- Cross section measured at 5 TeV **TOP-16-015**
- Single top t-channel: 15% uncertainty **TOP-16-003**
- Top quark mass measured with a precision of 0.3% (Run 1) **TOP-14-022**
- W boson polarization  
→ most precise measurements of helicity fractions to date (Run 1) **TOP-13-008**

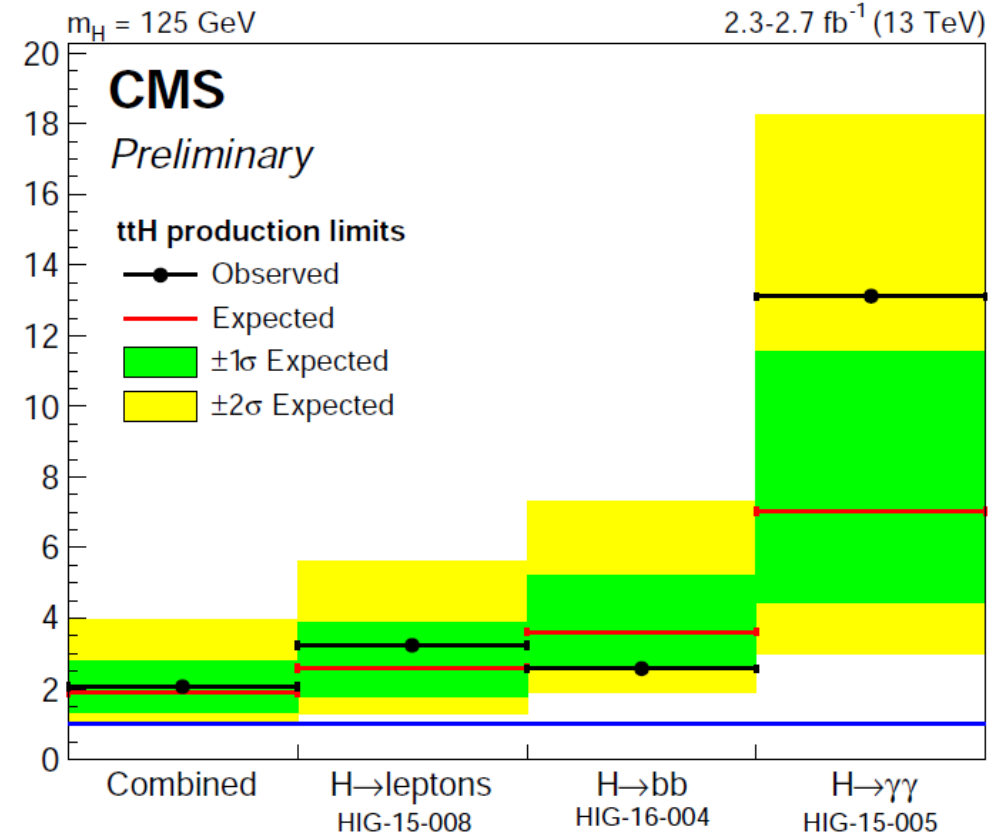
Differential cross section measurements performed in all decay channels for Run 1 and Run 2

S. Tokar, M. Naseri, J. Cifuentes, C. Eckardt, C. Zhou, T. Chwalek, M. Komm (Top parallel)  
A. Knue, J. Fernandez Menendez, K. Skovpen (Top plenary)

# Higgs physics at 13 TeV



Large jump in sensitivity due to larger cross section at 13 TeV



$\mu_{t\bar{t}H}$ :  $0.15^{+0.95}_{-0.81}$  **TTHCombMoriond2016**  
 (Run 1  $\mu_{t\bar{t}H}$ :  $2.9^{+1.0}_{-0.9}$ ) **HIG-15-002**

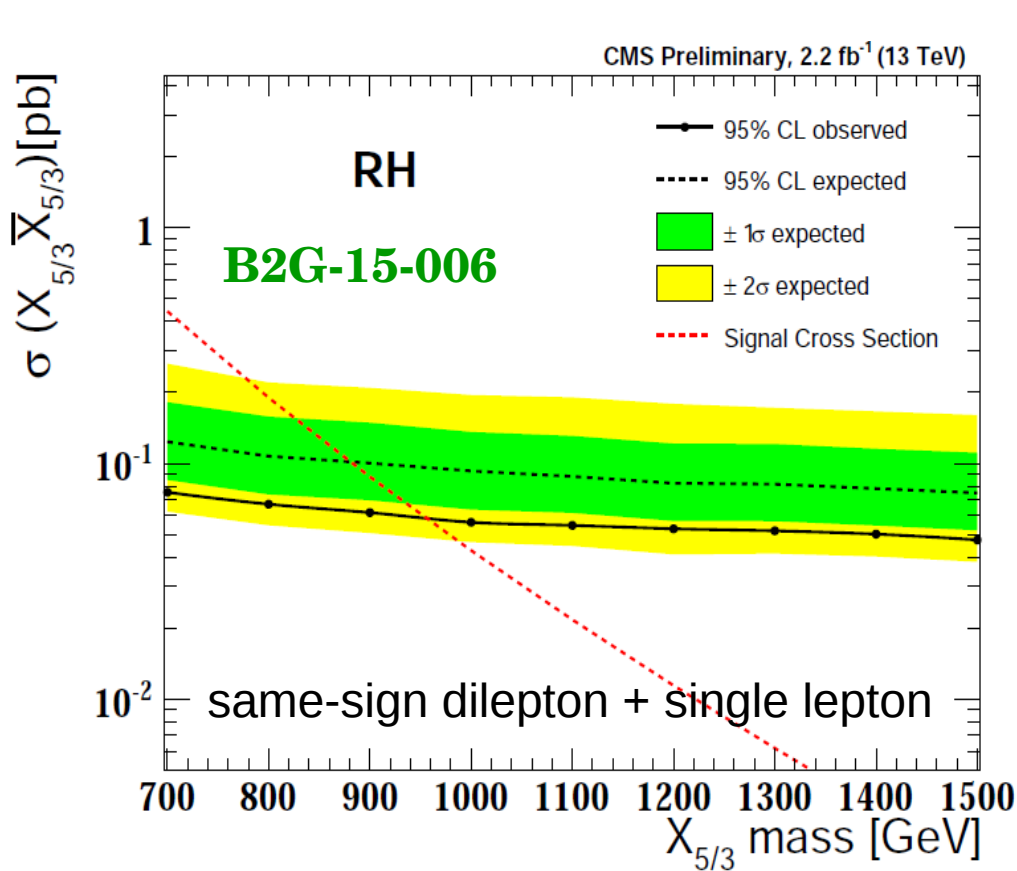
Many searches, e.g H  $\rightarrow$  invisible (Run 1 + Run 2 combination) **HIG-16-009**  
 (non-)resonant HH decays **HIG-16-002** **HIG-16-011** **HIG-16-012** **HIG-16-013**

J. Strandberg, S. Donato, J. Tanaka (Higgs plenary)

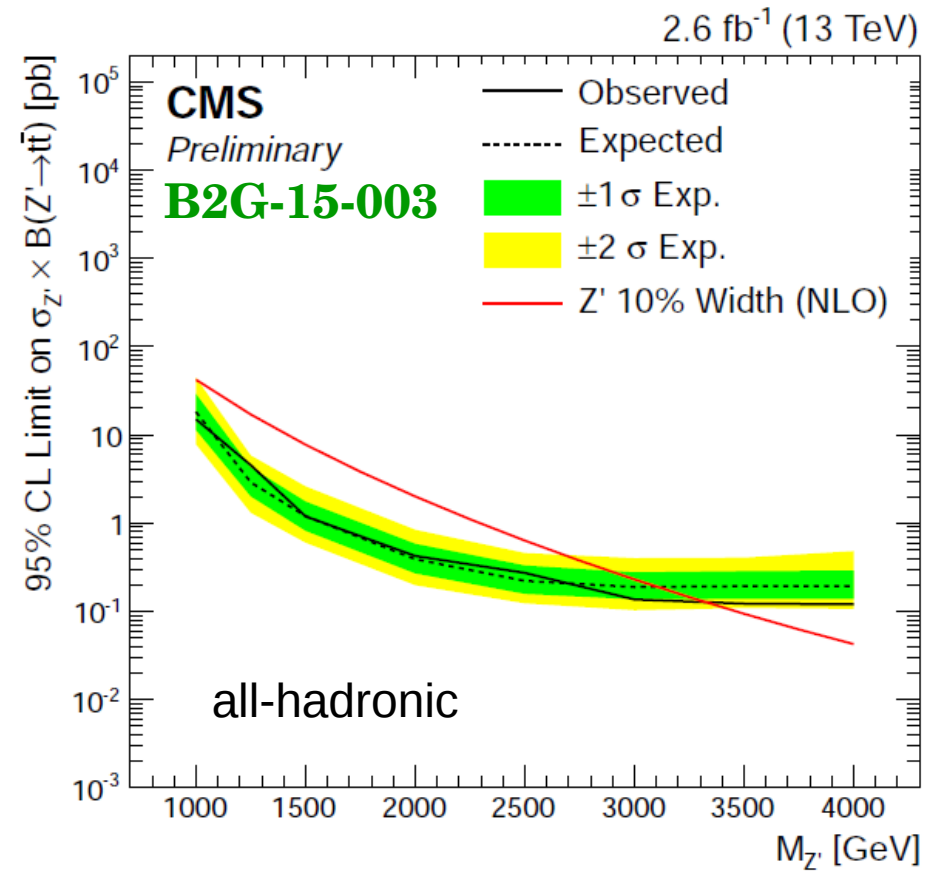
J. Stupak, C. Caillol, E. Ntomari, H. Ohman, A. De Wit, P. Galler (Higgs parallel)



# Searching new “exotic” particles



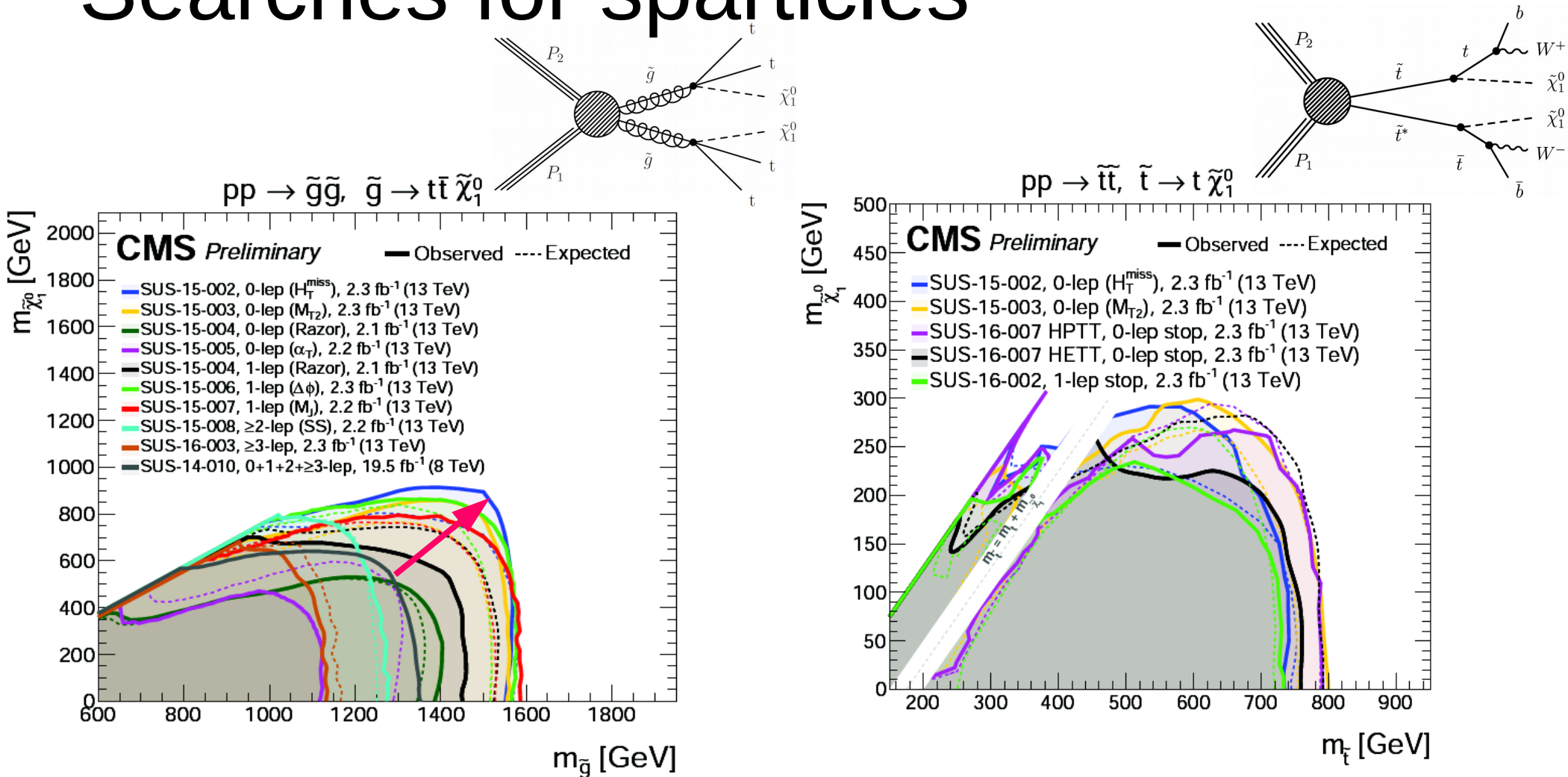
Existence of top quark partner  $X_{5/3}$  is excluded with masses below 0.96 TeV (Run 1 limit: 0.8 TeV)



Existence of  $Z' \rightarrow t\bar{t}$  (10% width) excluded with masses between 1 and 3.3 TeV (Run 1 limit, all decay channels combined: 2.9 TeV)

J. Damgov, D. Marley, C. Mc Lean, T. Lenz, B. Jayatilaka (parallel)  
J. Frost, A. Schmidt, A. Hinzmann (plenary)

# Searches for sparticles

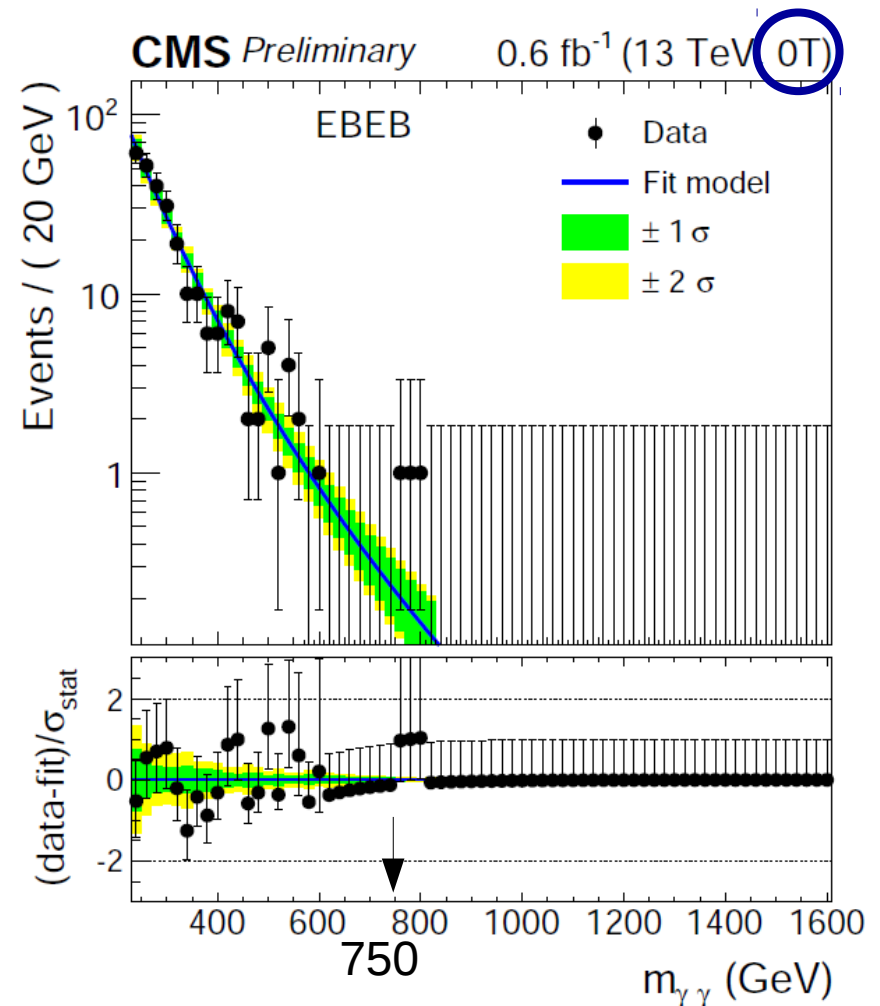
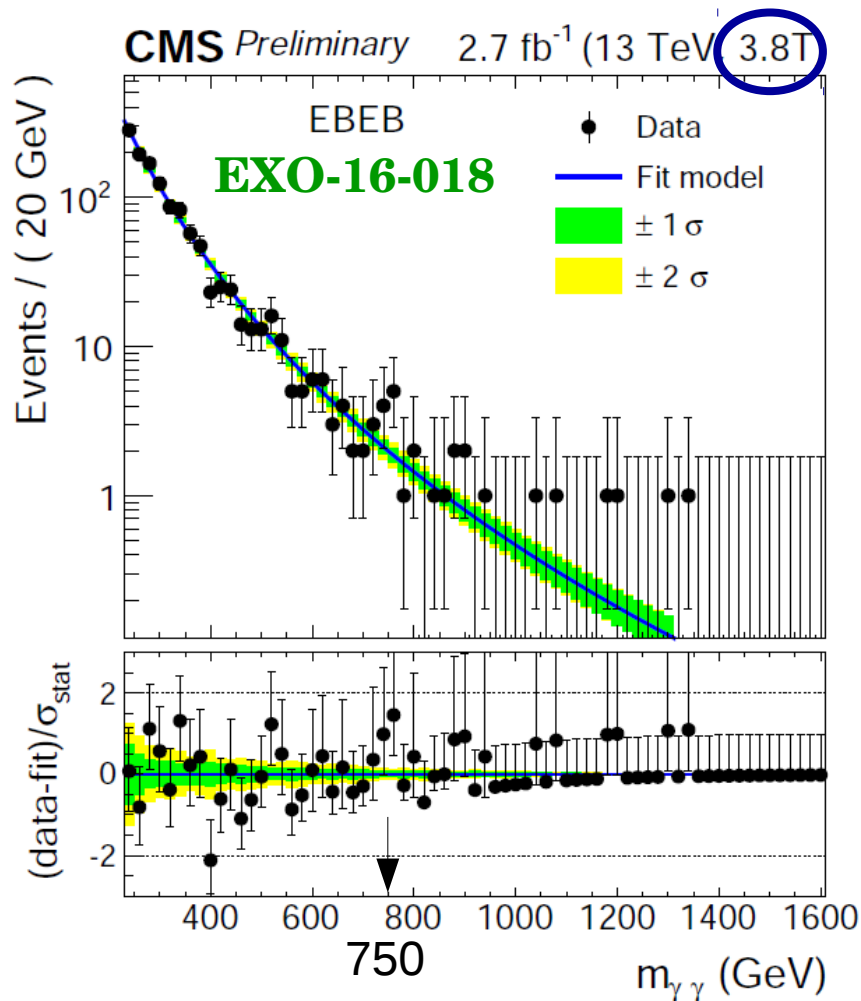


Huge jump in sensitivity, for massless neutralino  $\rightarrow$  limit on the gluino mass at least 200 GeV higher

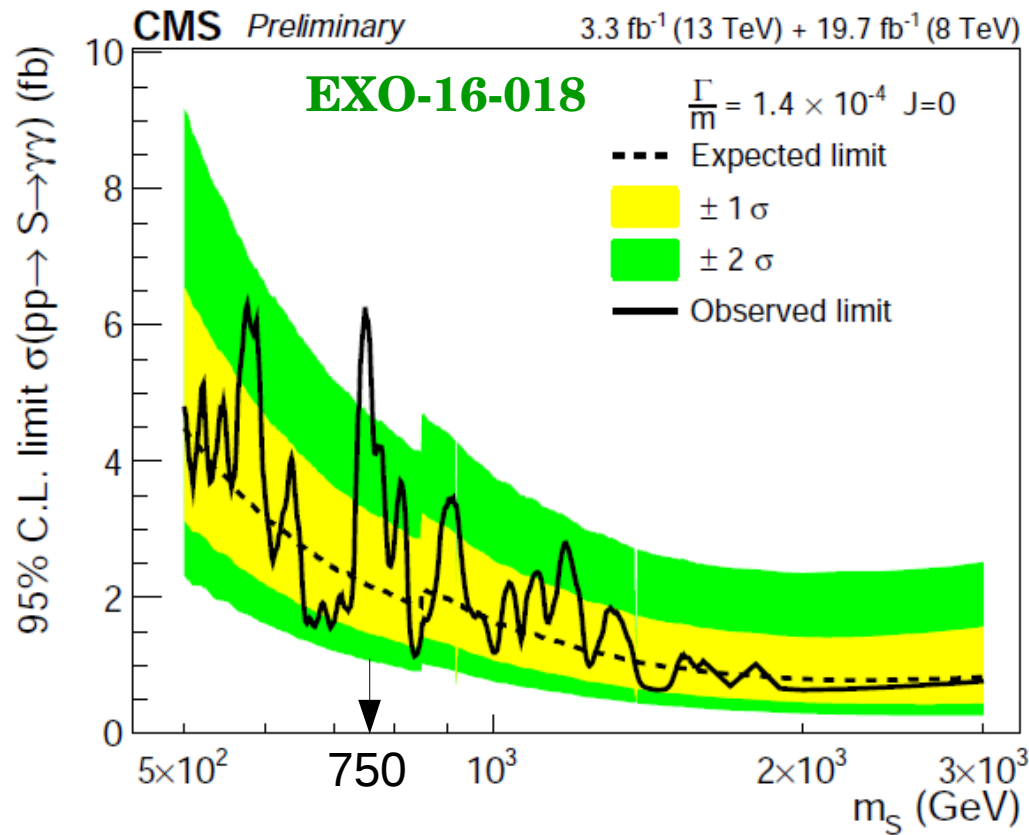
The “stealth” region is probed by precision measurements of top quark pair production

T. Sakuma, W. Fawcett, A. Lobanov, J. Tucker, E. Chabert, G. Della Porta (SUSY parallel)  
M. Hodgkinson, J-F. Schulte, W. Hopkins (SUSY plenary)

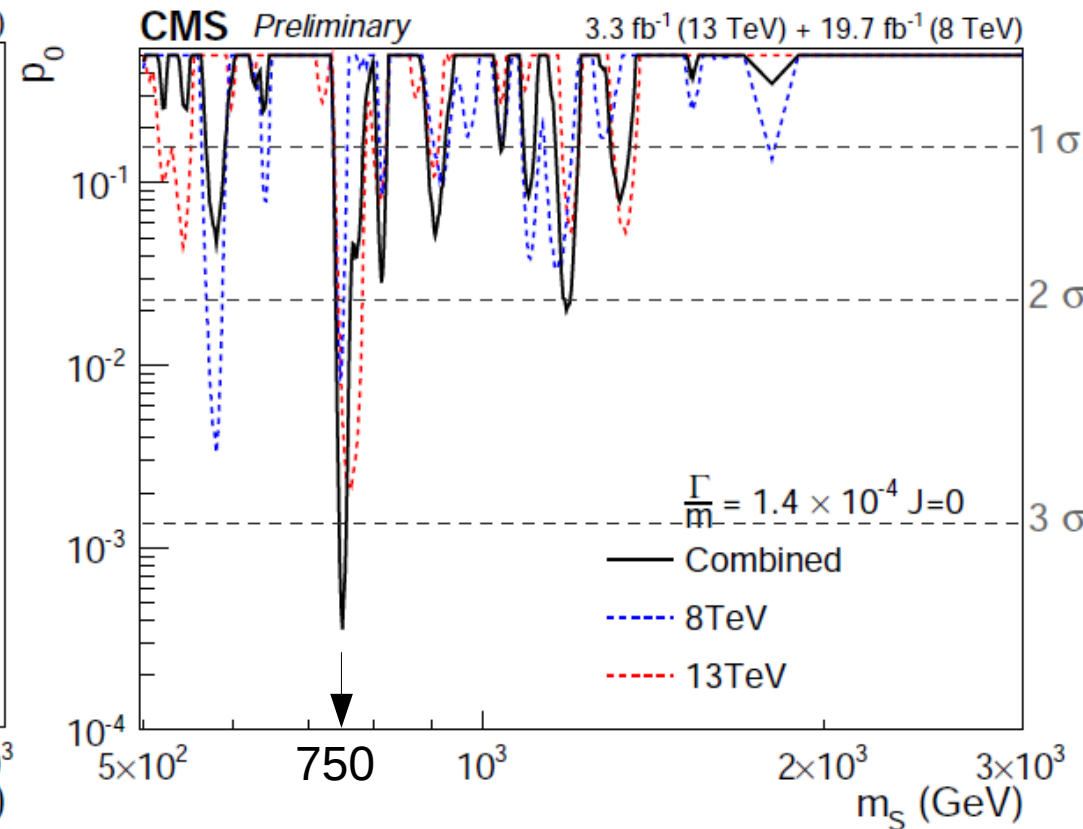
# 2016 should provide an answer to the diphoton@750GeV excitement



# 2016 should provide an answer to the diphoton@750GeV excitement



Combined 8+13TeV cross section limit assuming a narrow width spin-0 resonance decaying to 2 photons

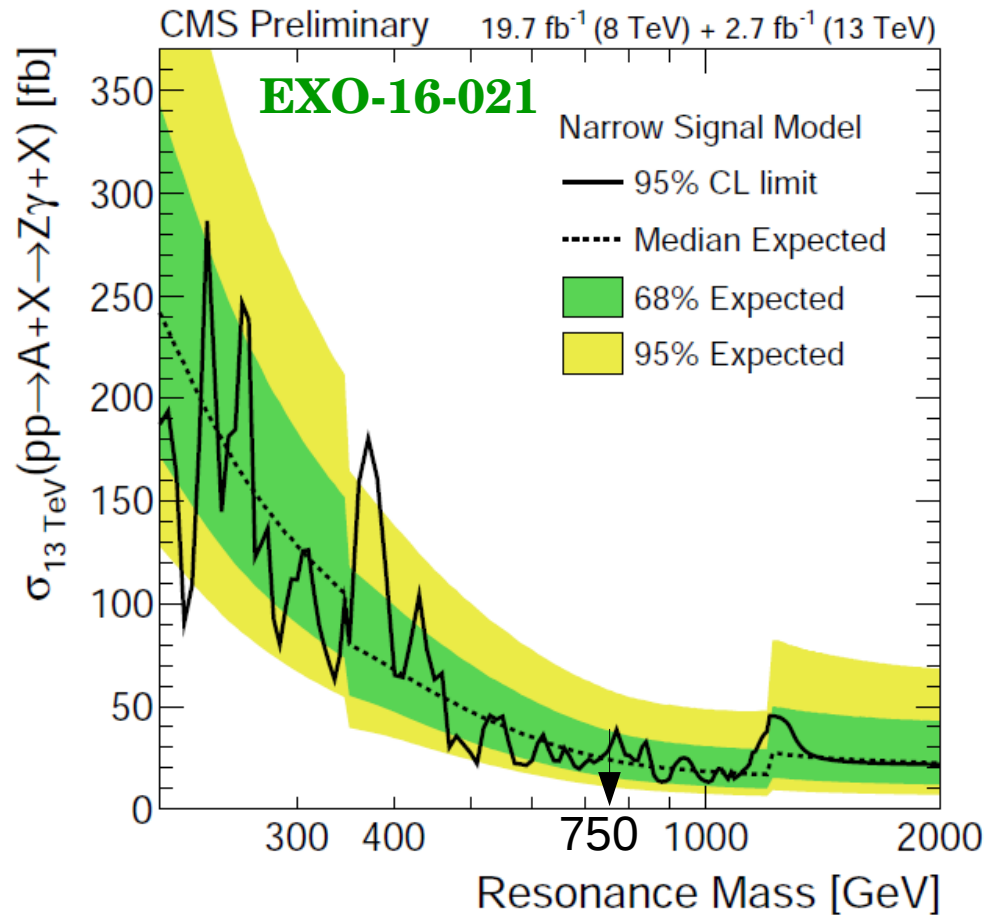


Combined 8+13TeV p-value  
Maximum local significance: 3.4 $\sigma$  at a mass of 750 GeV

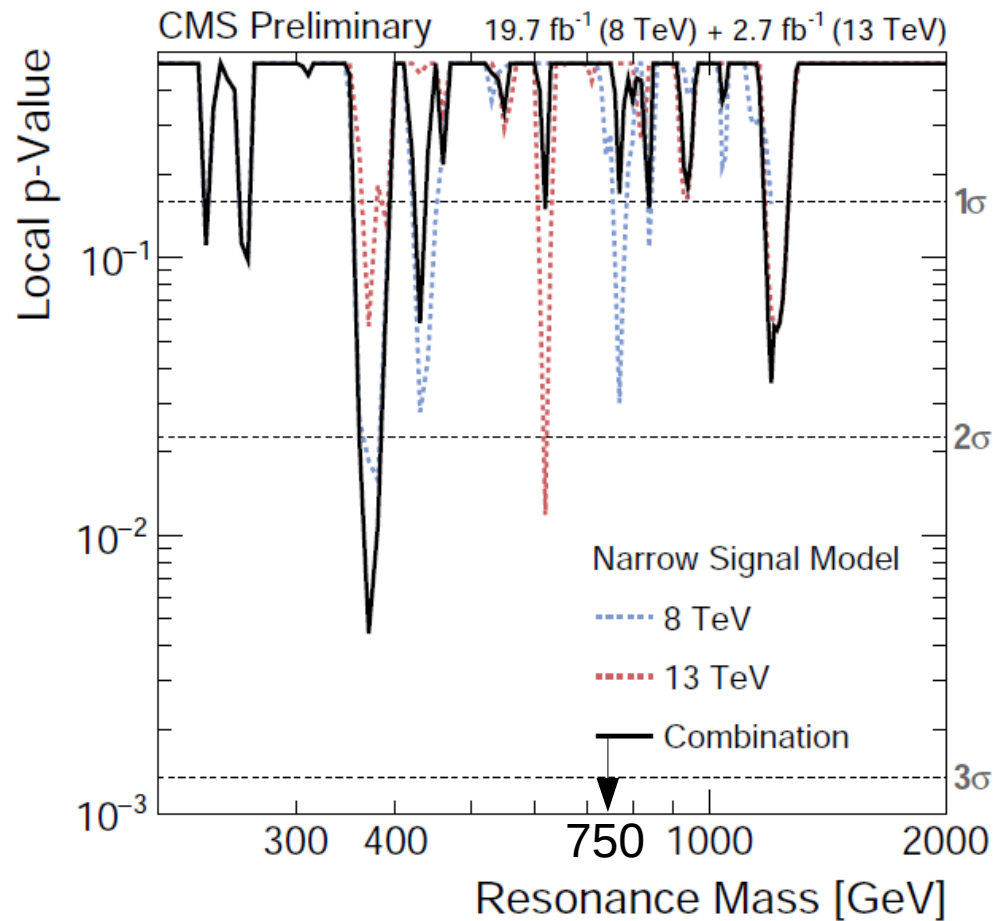
Many searches for X(750) in other final states!



# Combination of 8+13 TeV $Z\gamma$ search

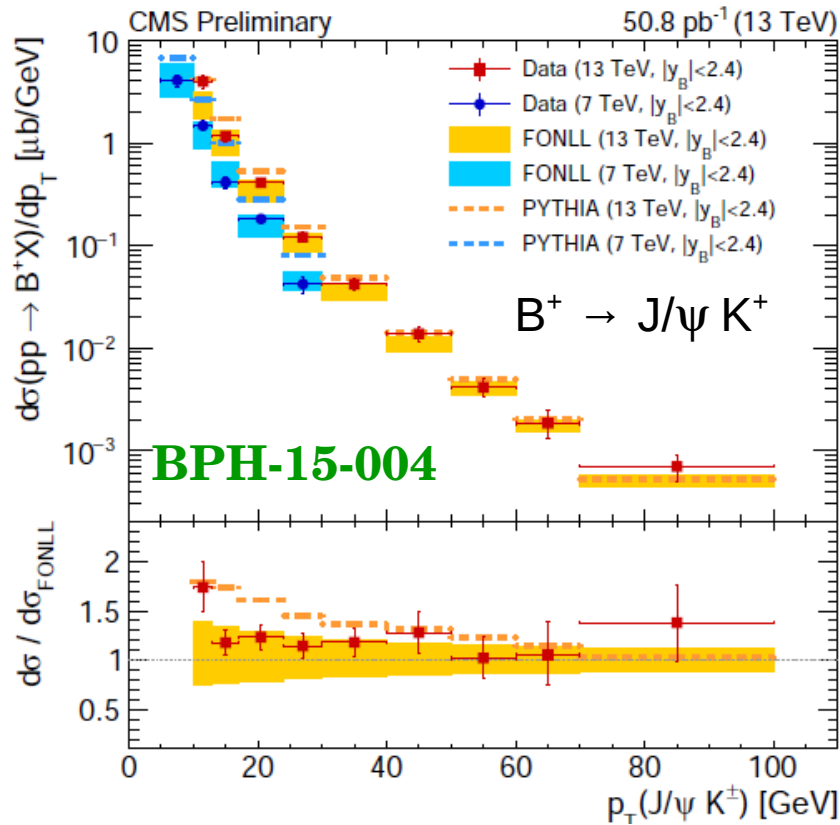


Combined 8+13 TeV cross section limit assuming a narrow width spin-0 resonance decaying to  $Z\gamma$

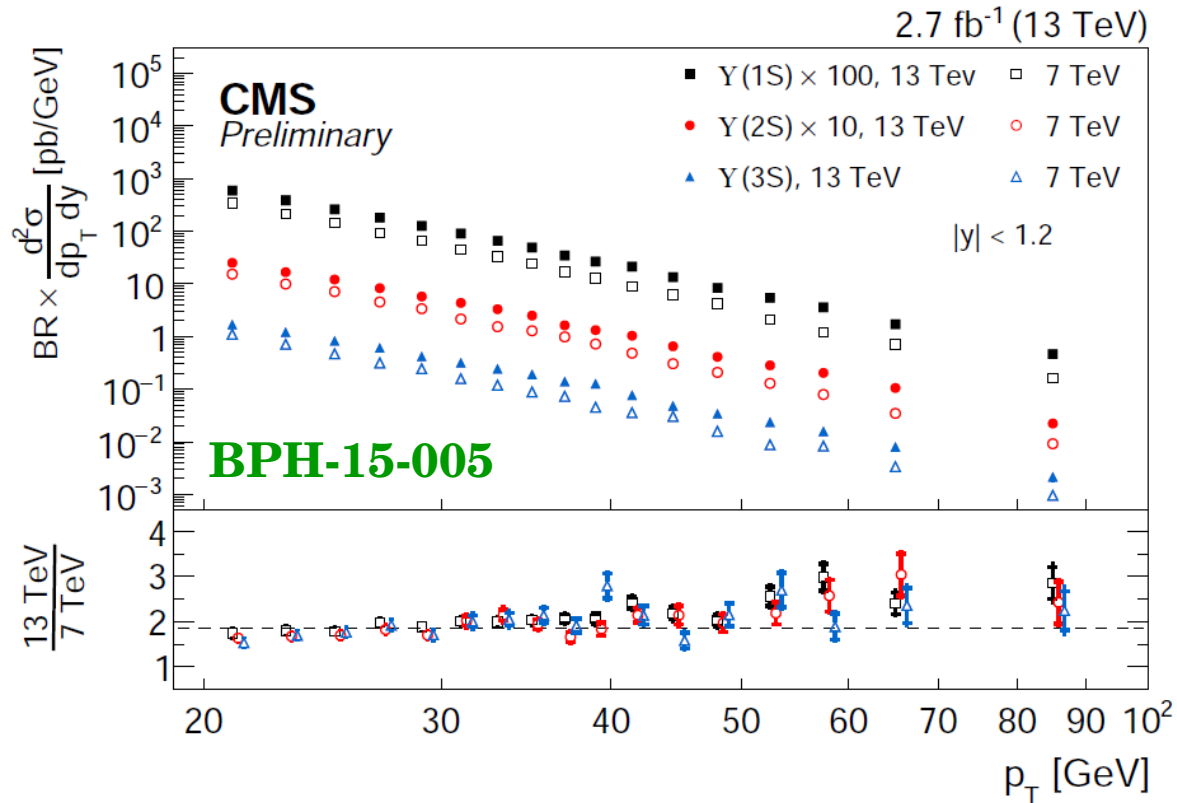


Largest excess (mass around 370 GeV) corresponds to  $2.6\sigma$  local significance ( $<1\sigma$  global)

# Recent heavy flavour production measurements



The differential cross section measurement for  $B^+$  production at 13 TeV is in reasonable agreement with the expectation

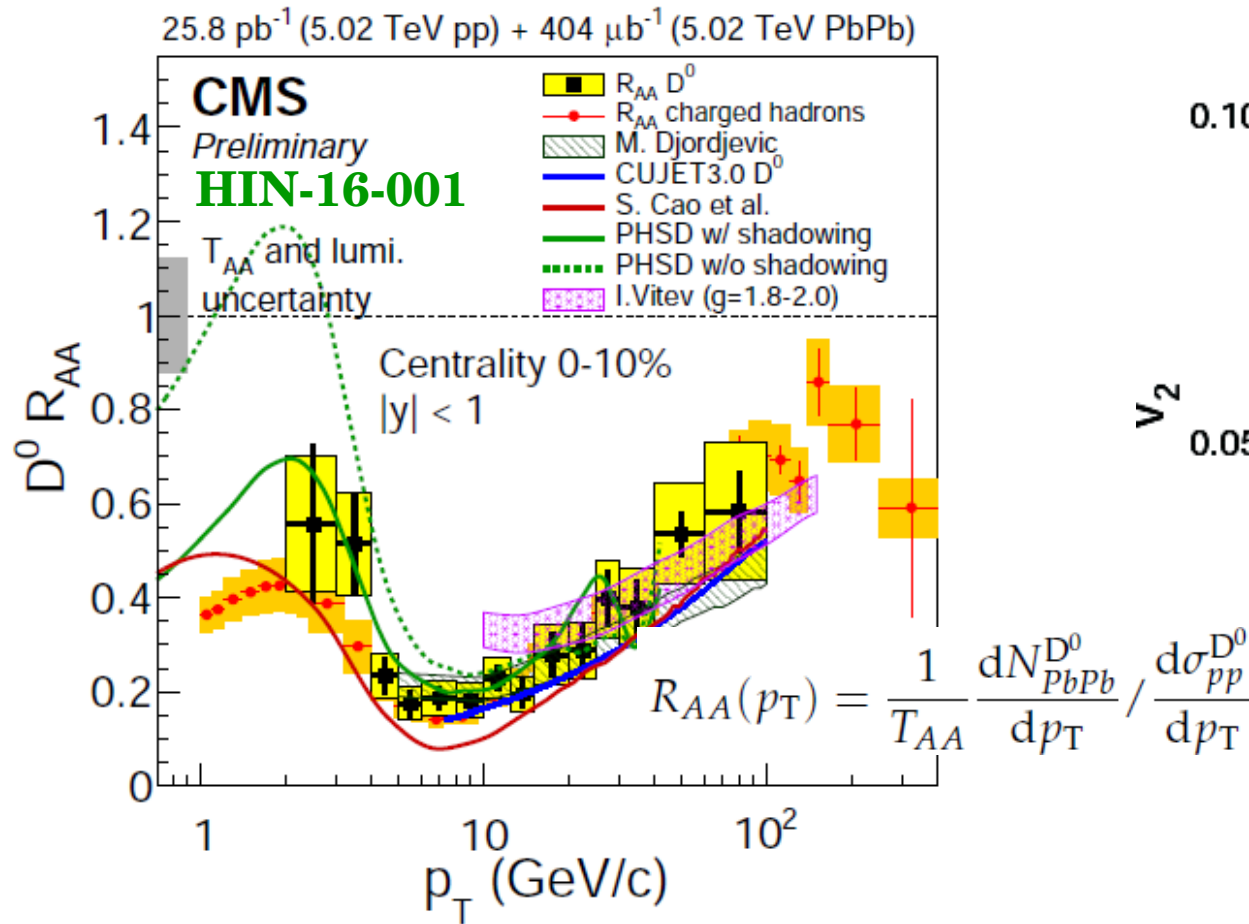


The 13 TeV cross section of the quarkonium states is 2 – 3 times larger than at 7 TeV as expected from the evolution of the parton distribution functions

*N. Bartosik 2x, A. Pompili (Heavy Flavour parallel)*

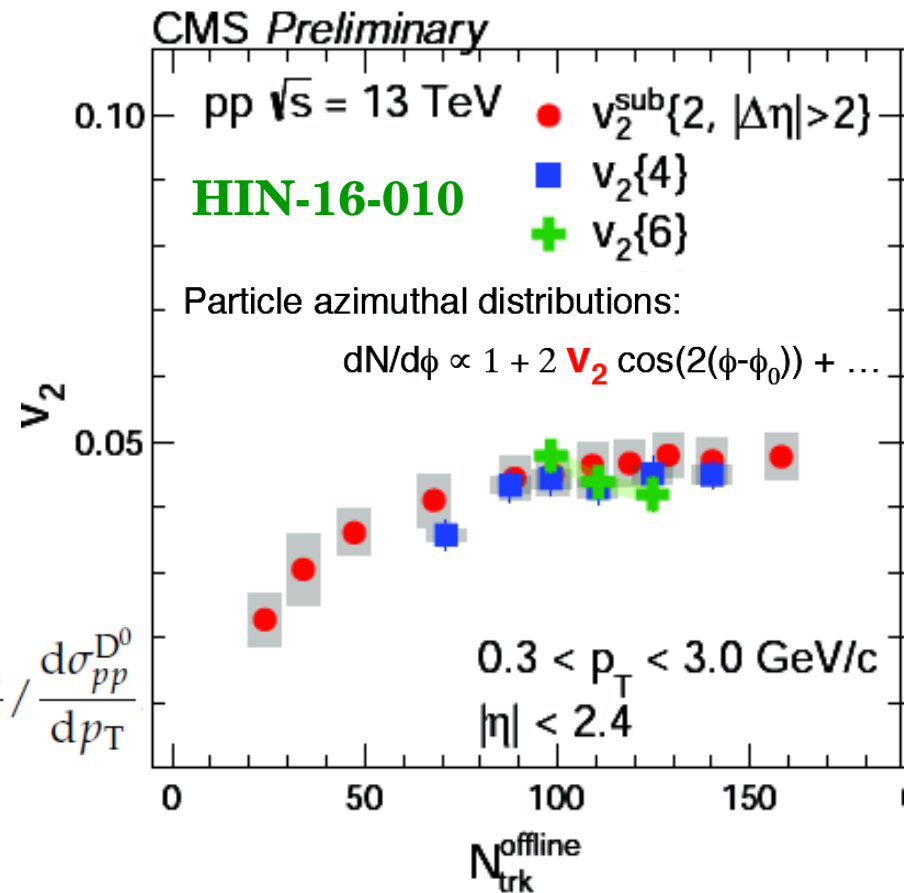
*M. Kreps, M. Needham, A. Navarro (Heavy Flavour plenary)*

# Important advances for heavy ions



$R_{AA}$  (nuclear modification factor) for  $D^0$  mesons is consistent with  $R_{AA}$  for inclusive charged hadrons

Z. Chen, Z. Tu, D. Gulhan (Heavy Ion: parallel)  
S. Bufalino, M. Rybar, A. Mischke (Heavy Ion plenary)

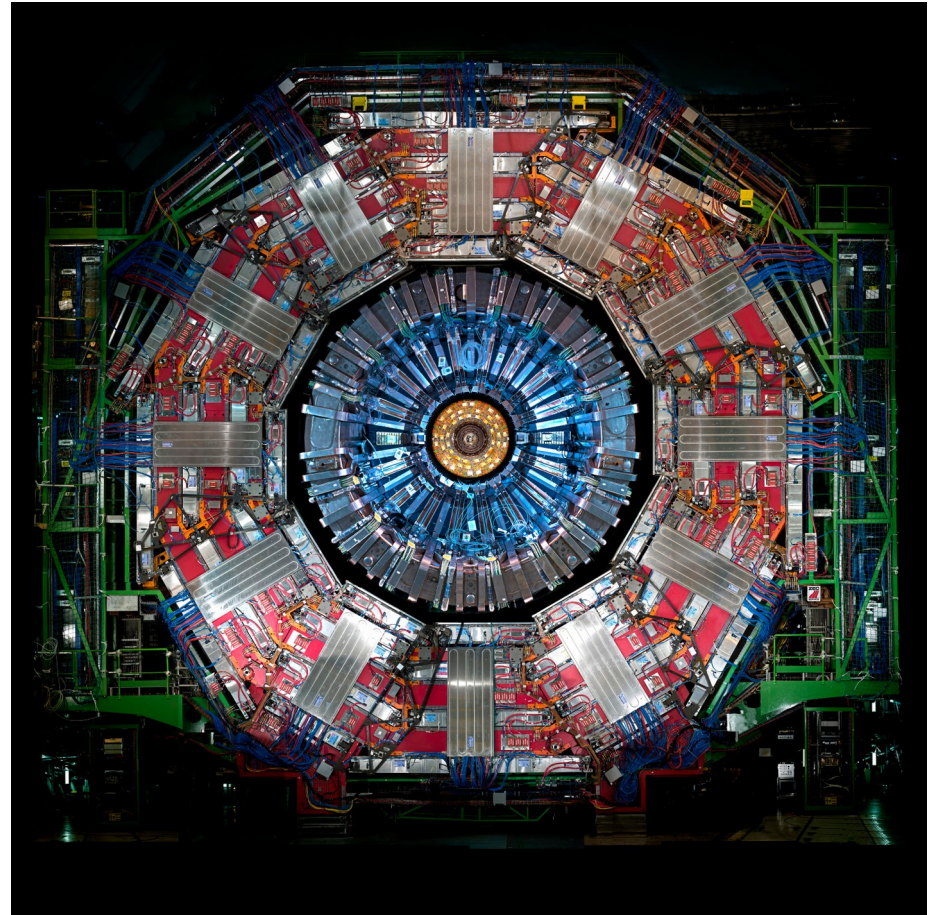


$v_2$  (elliptic flow) for 2, 4 and 6 particle correlations has comparable magnitude

→ indication for the collective nature of the long-range correlations

# Content

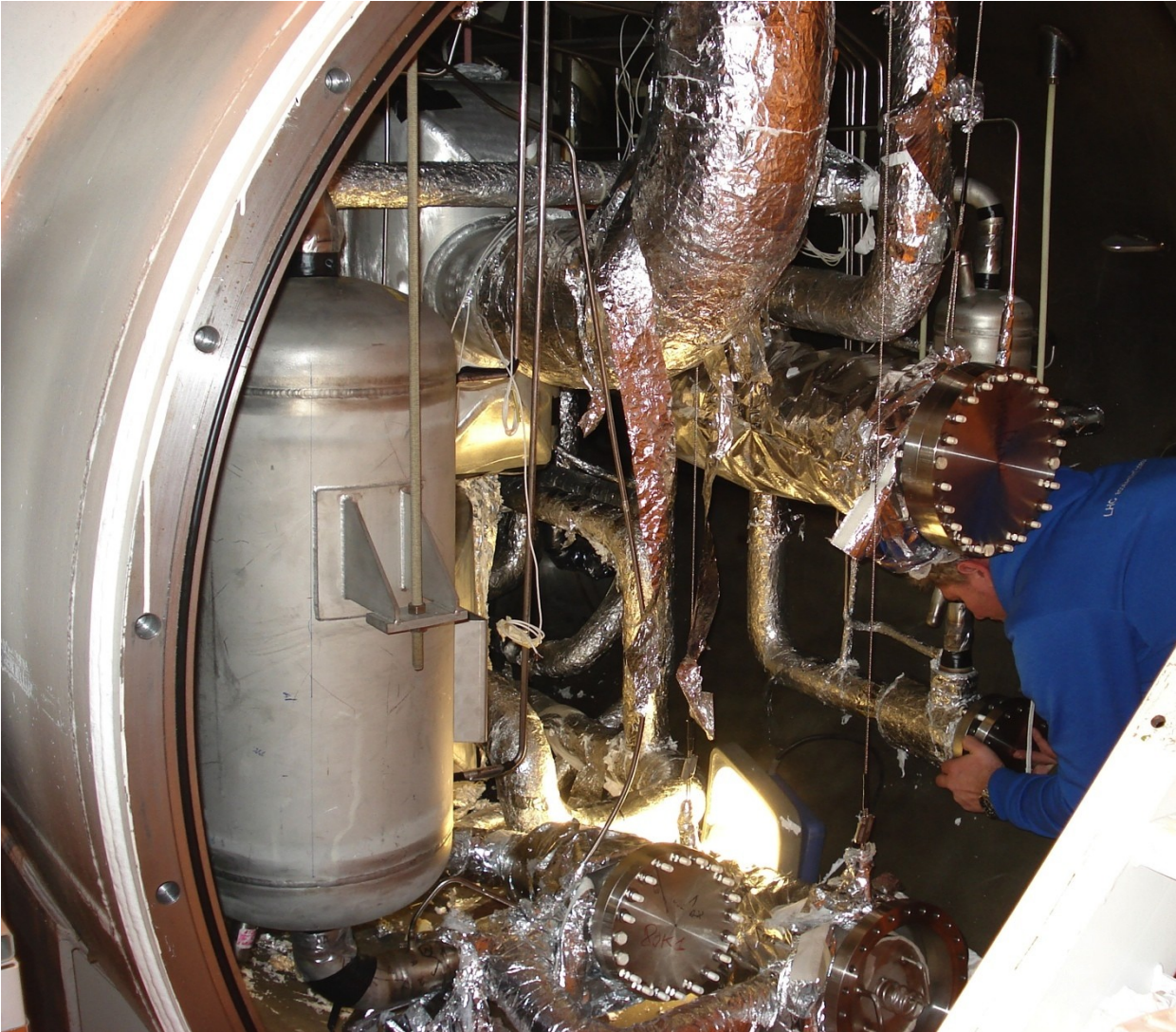
- Physics highlights based on 2015 data at 13 TeV
- Overall status of the CMS experiment in 2016
- Object performance in 2016





# CMS magnet cryogenic system

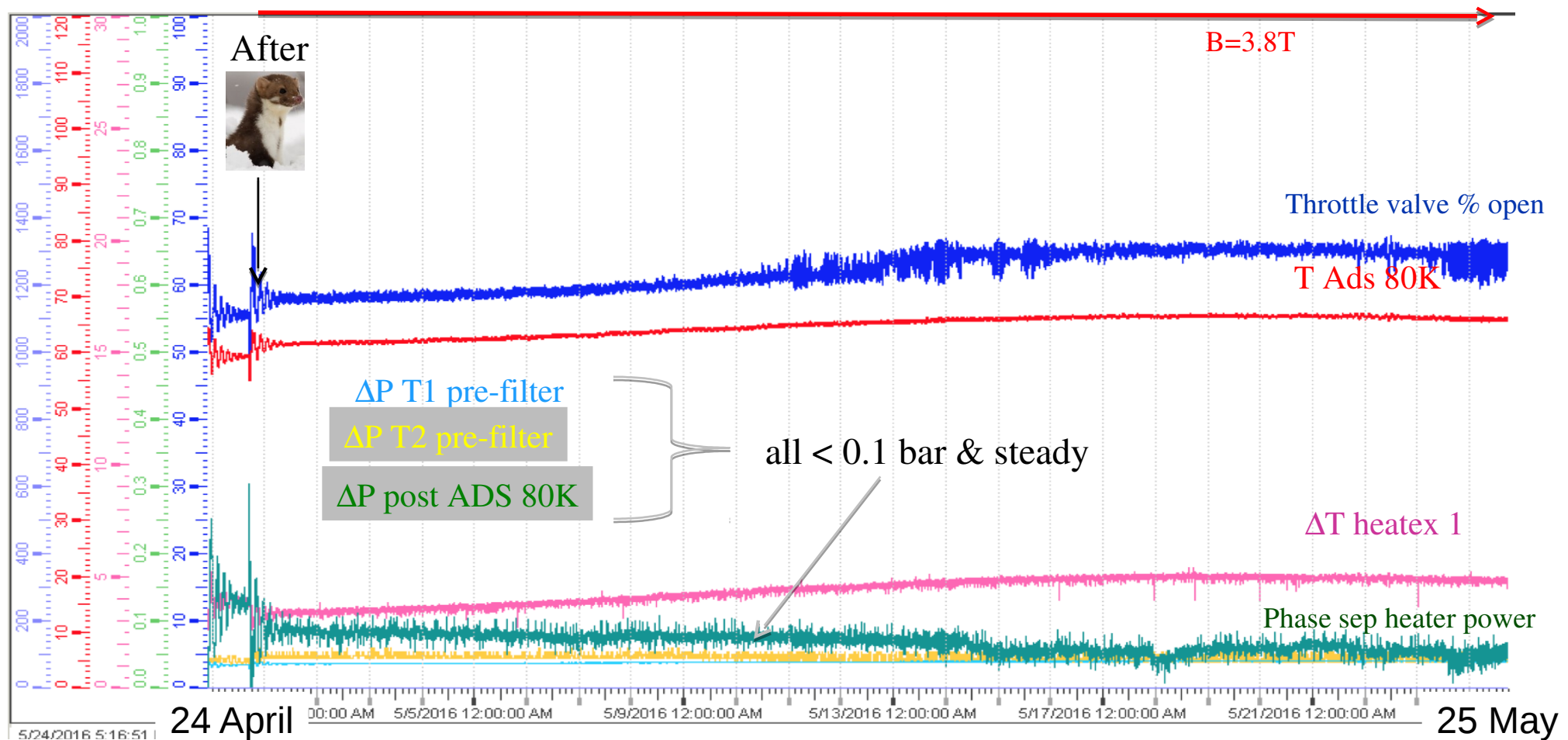
Intense programme to refurbish the cryogenic system for B=3.8T operation in 2016



- Cold box cleaning to remove traces of Breox contaminant
- Replacement of primary oil removal system

# CMS magnet cryogenic system

Reached 3.8T on April 28, operational parameters stable in time

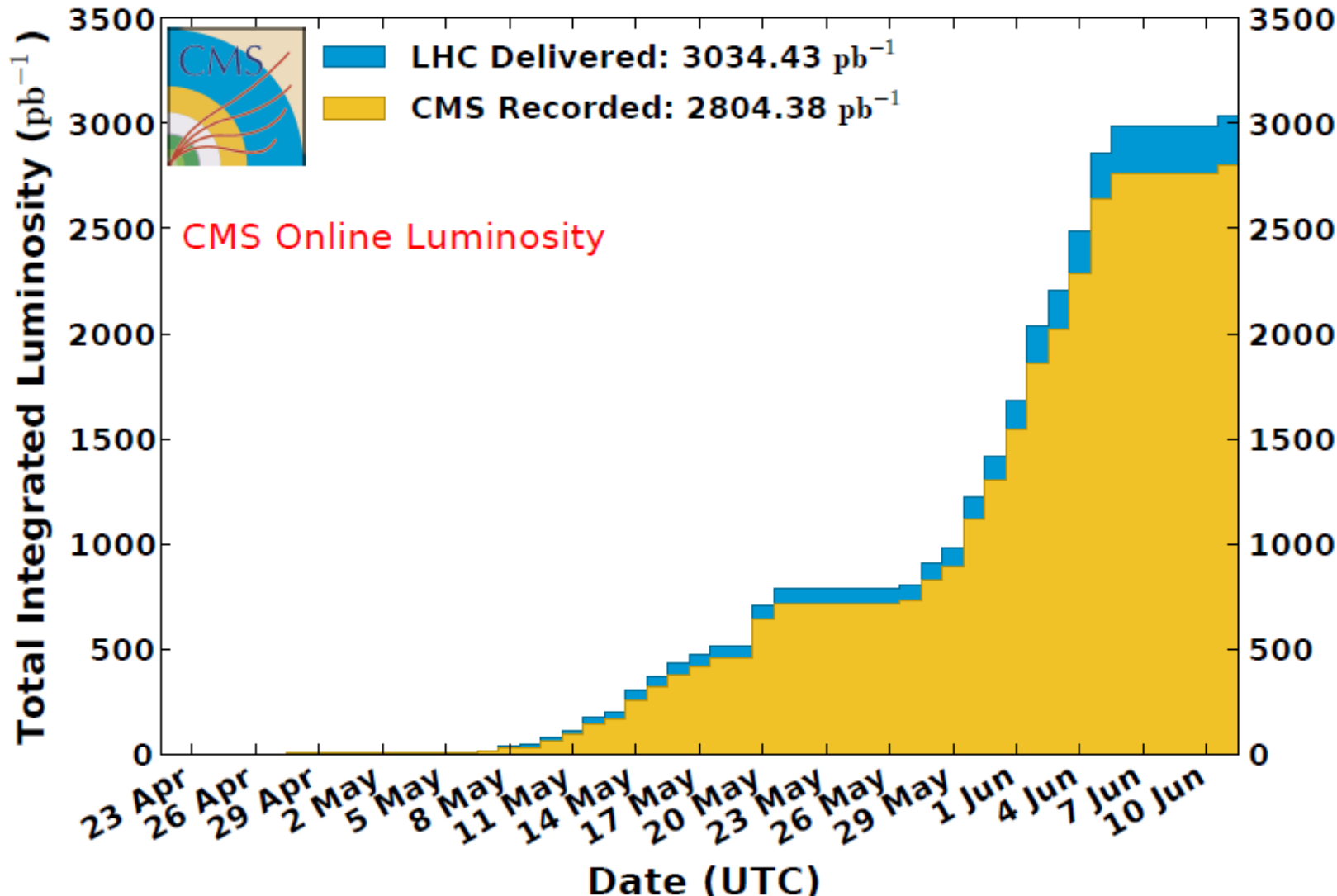


A warm thanks to colleagues from CERN-TE dept, technical support from other CERN depts, CERN-EN,EP, CERN Management, CMS Magnet team and integration office, contractors (particularly Althead, ZEC service), CMS members for support and advice

# CMS is efficiently taking data

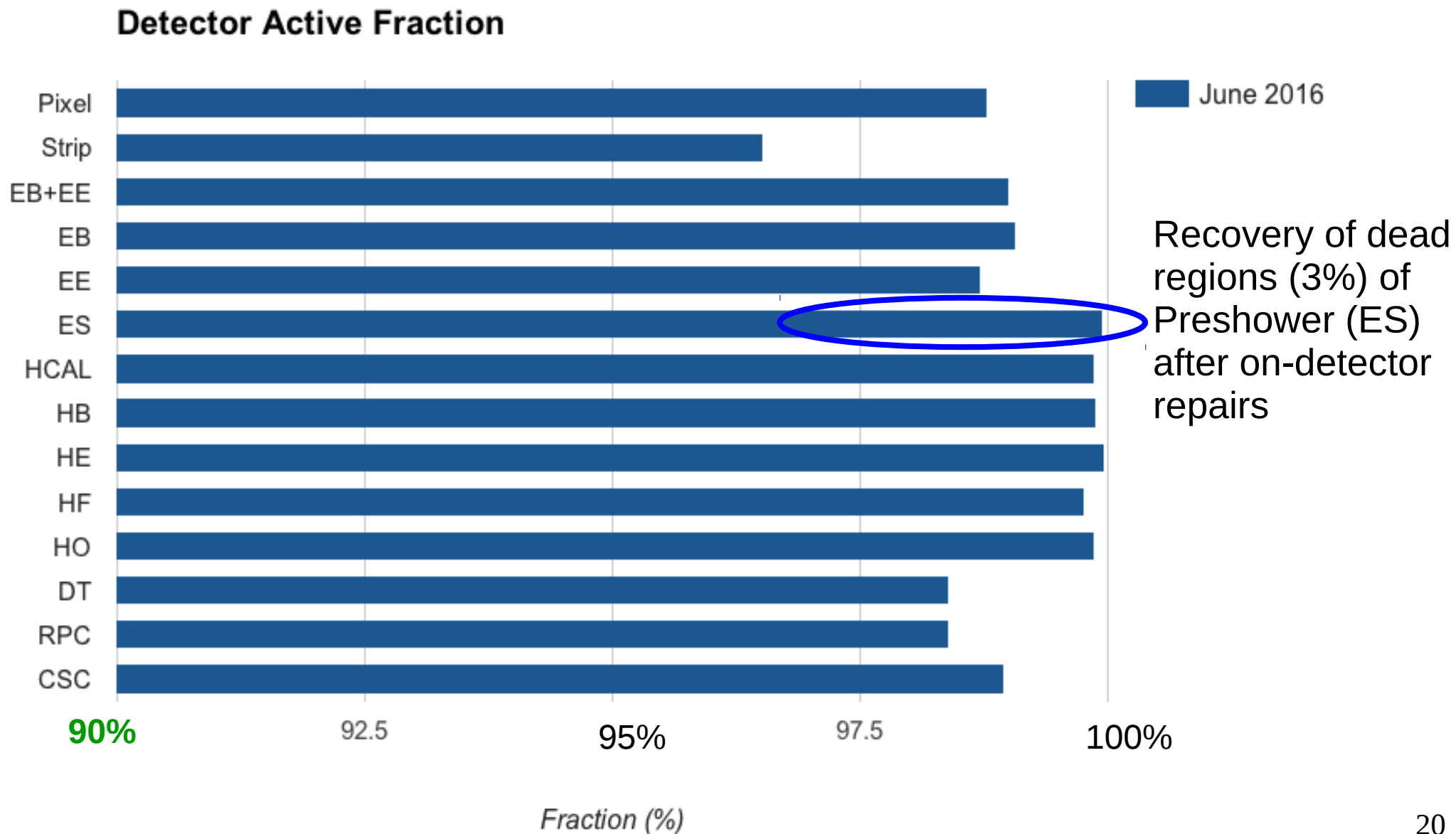
CMS Integrated Luminosity, pp, 2016,  $\sqrt{s} = 13$  TeV

Data included from 2016-04-22 22:48 to 2016-06-11 16:41 UTC



Special thanks to the LHC team!!!

# Overall detector performance looks similar as at the end of 2015



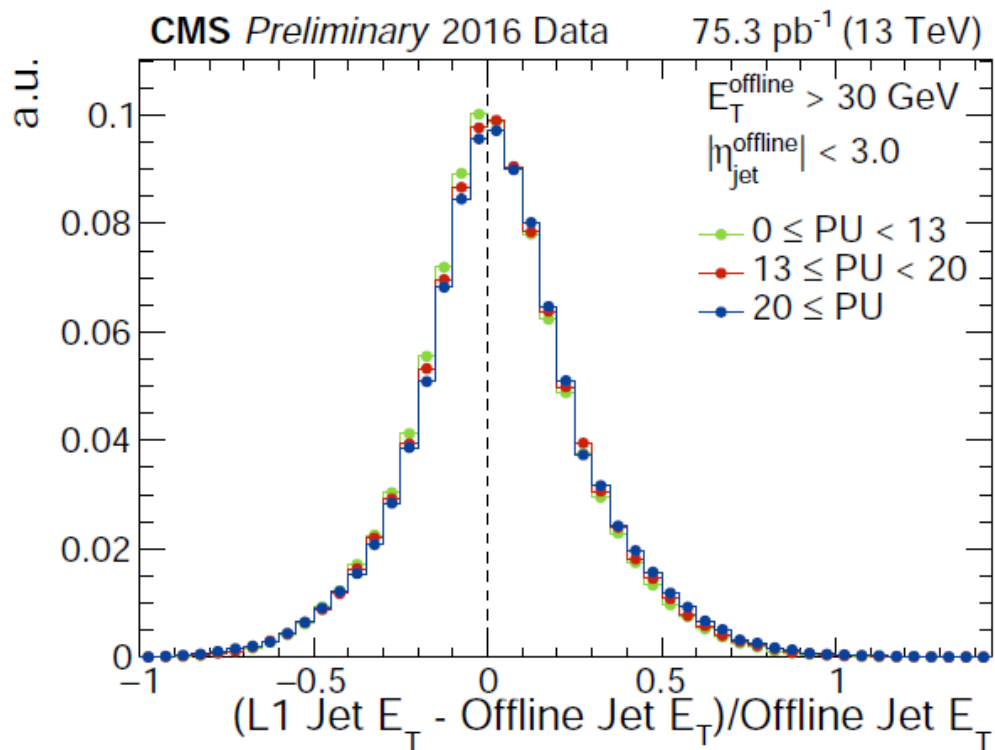


# Content

- Physics highlights based on 2015 data at 13 TeV
- Overall status of the CMS experiment in 2016
- Object readiness and performance:
  - L1 trigger
  - Muons
  - Electrons & photons
  - Jets & missing transverse energy
  - b jet and tau identification

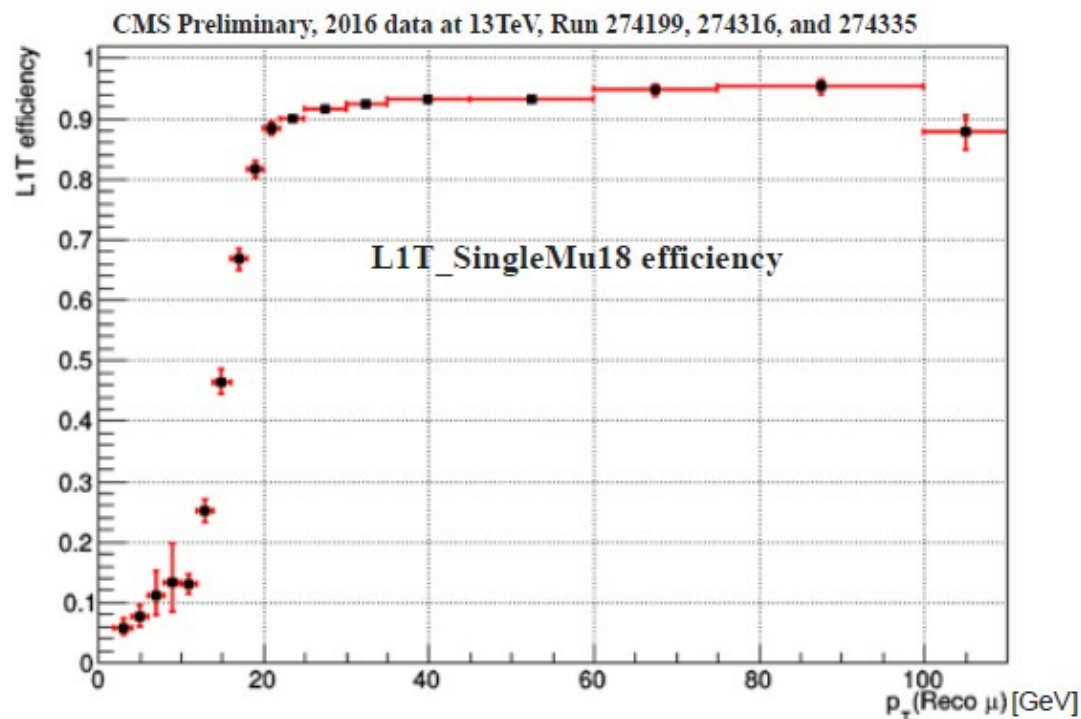
# L1 trigger upgraded for 2016 run

Changes in calorimeter and muon triggers. For muons, exploit detector redundancy already at L1 trigger level using 3 regional track finders followed by a global muon trigger for duplicate merging and removal



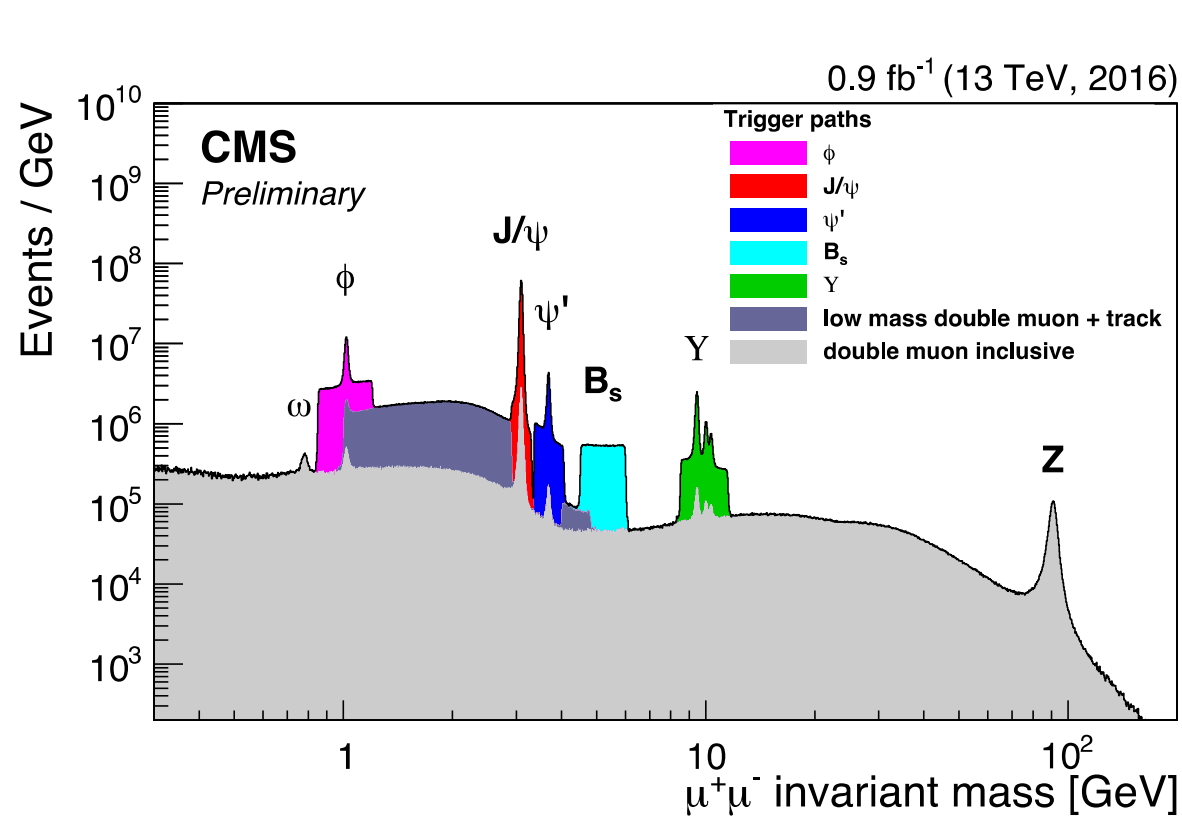
Difference of L1 and offline jet energy shows consistency.

Also robust against pile up collisions

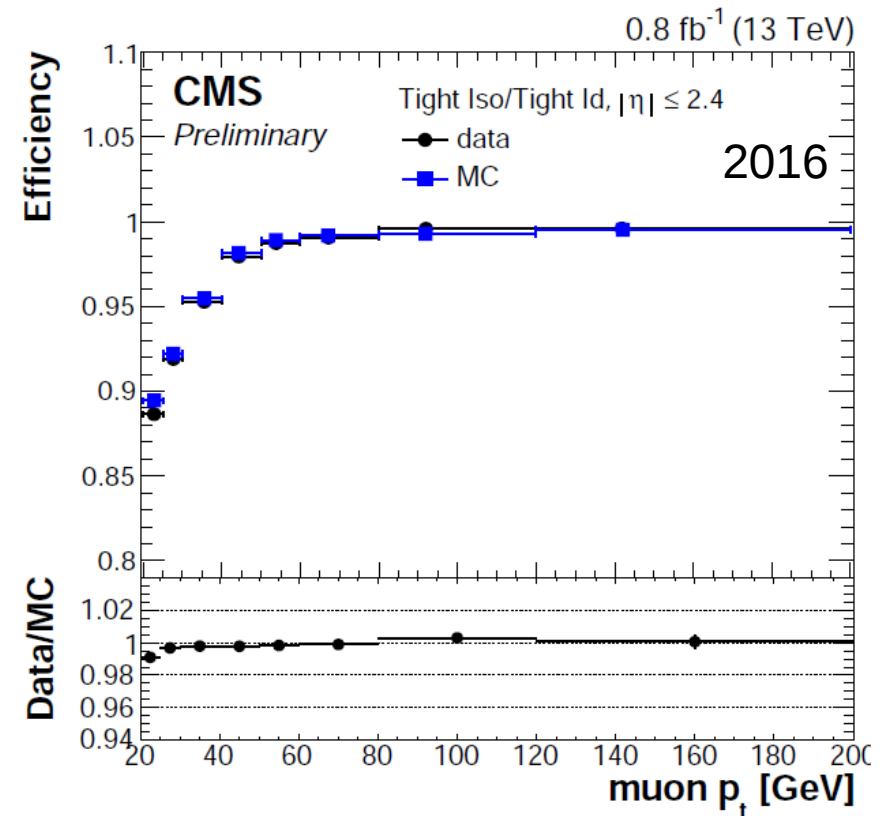


SingleMuon L1 trigger efficiency measured with tag and probe method on  $Z \rightarrow \mu\mu$  events. For muons with  $p_T$  above 20 GeV the efficiency is  $\sim 93\%$

# Muons and dimuon mass resonances

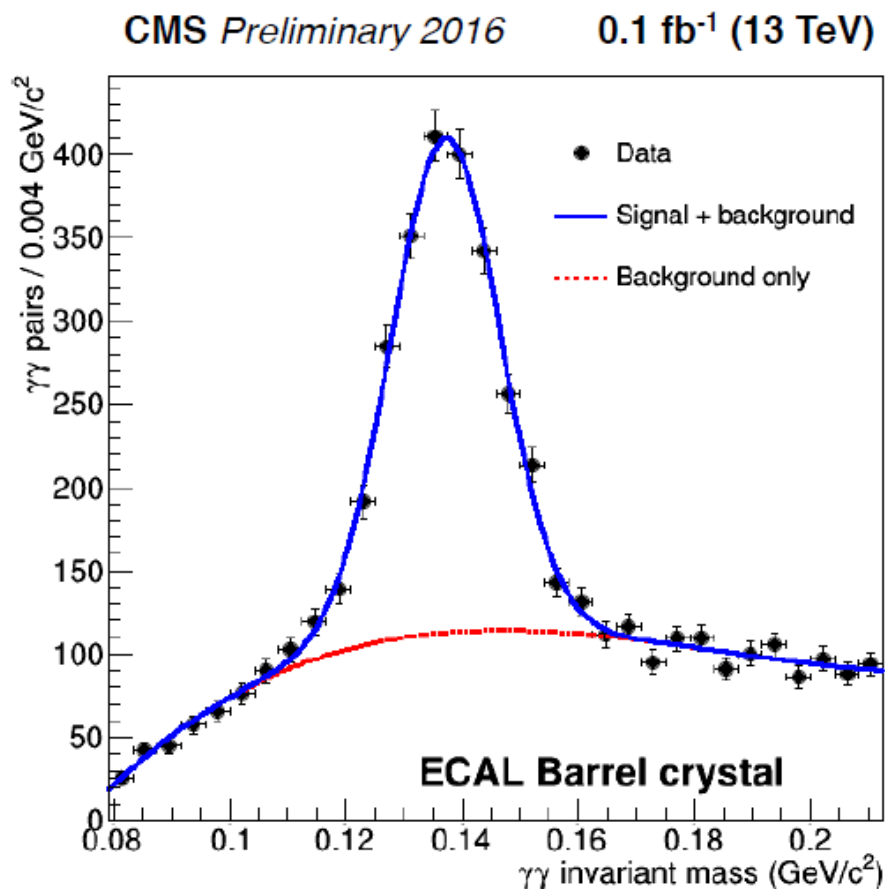


Dimuon mass distribution collected with various dimuon triggers.

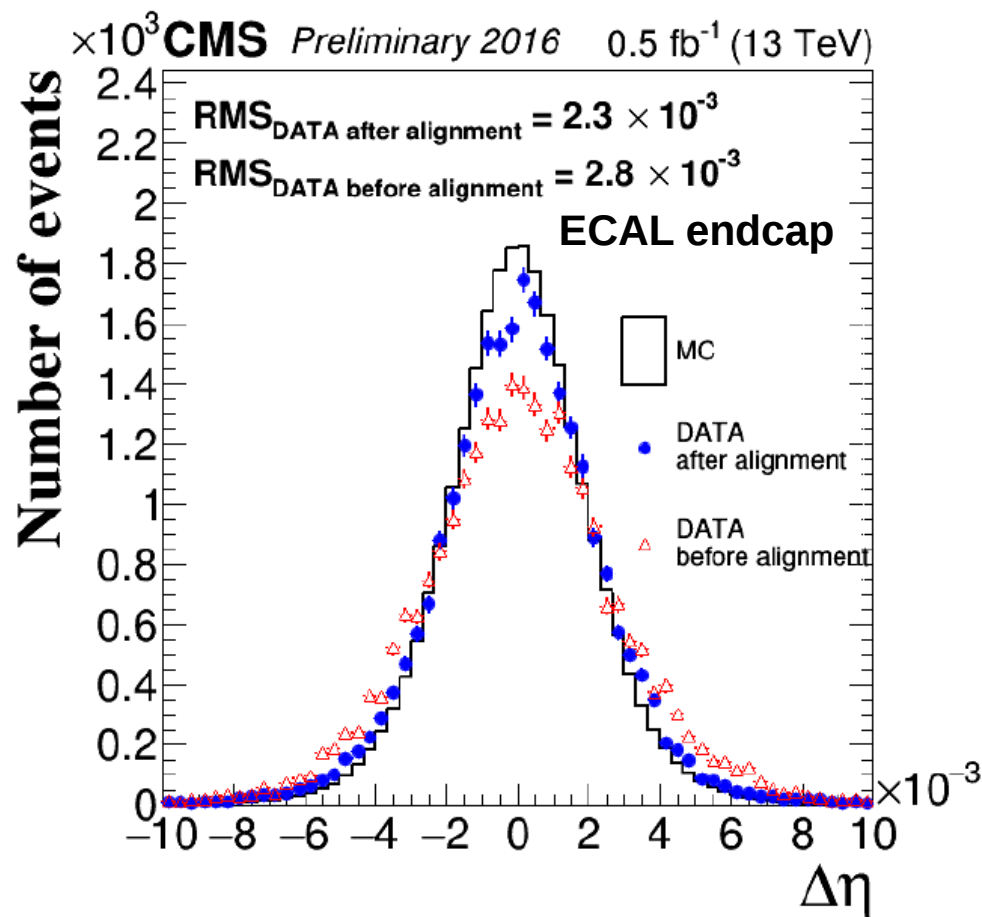


Efficiency for tight muons to pass the isolation cut. Agreement between data and MC is very good.

# Photons and electrons



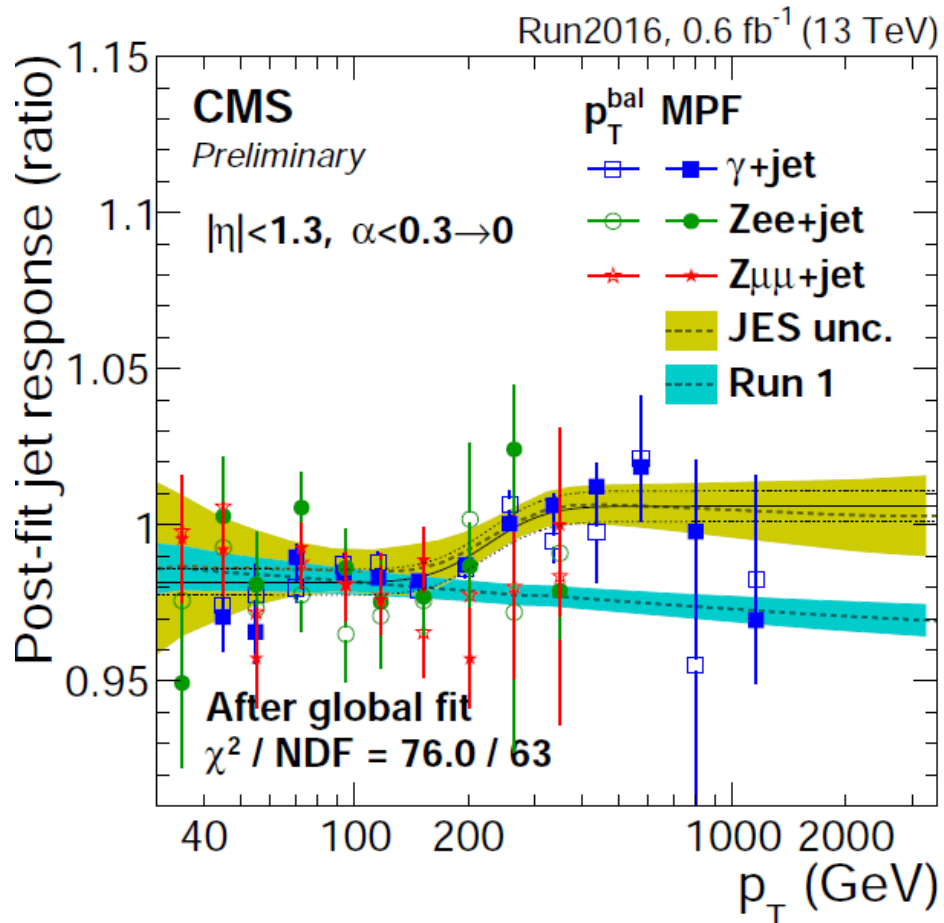
$\pi^0$  mass peak reconstructed from photon pairs in a single ECAL crystal  
→ used for intercalibration of ECAL crystal energies, RMS on relative energy scale during a fill is around 7% when this calibration is applied



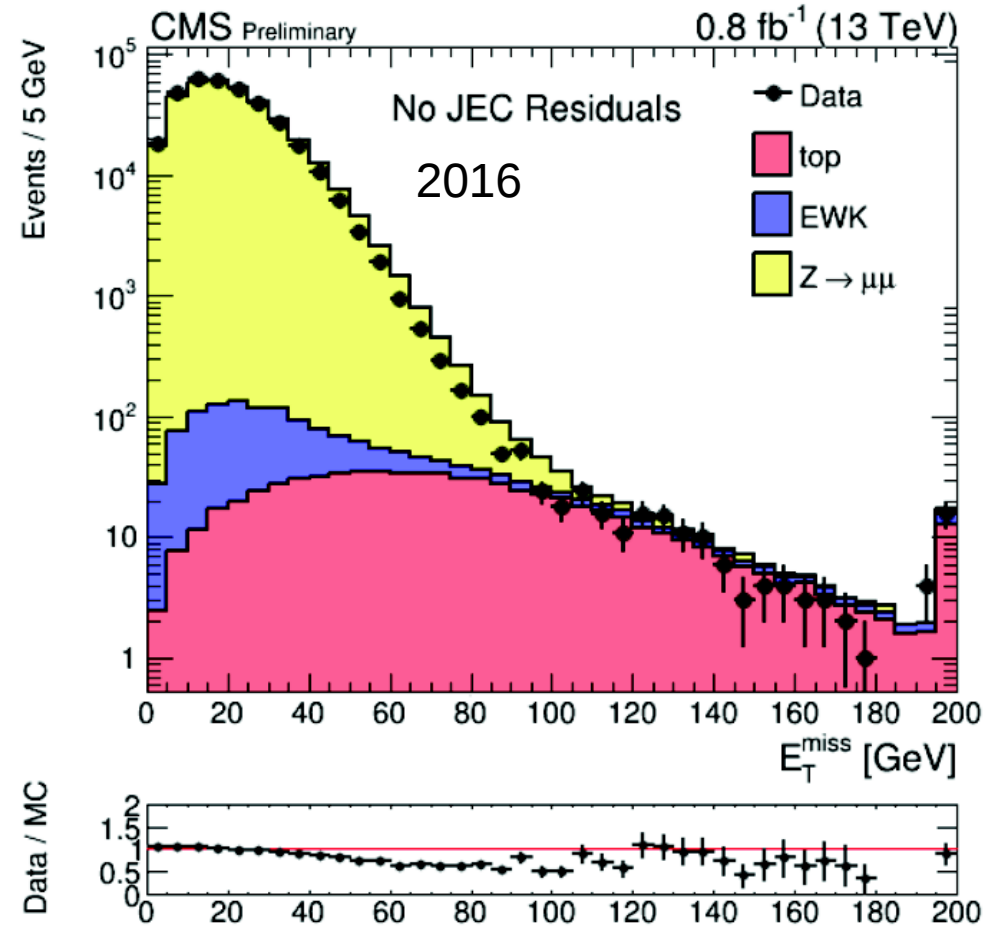
Alignment obtained from  $Z \rightarrow ee$  events  
In the ECAL barrel the RMS is roughly half compared to the endcaps



# Jet and missing transverse energy

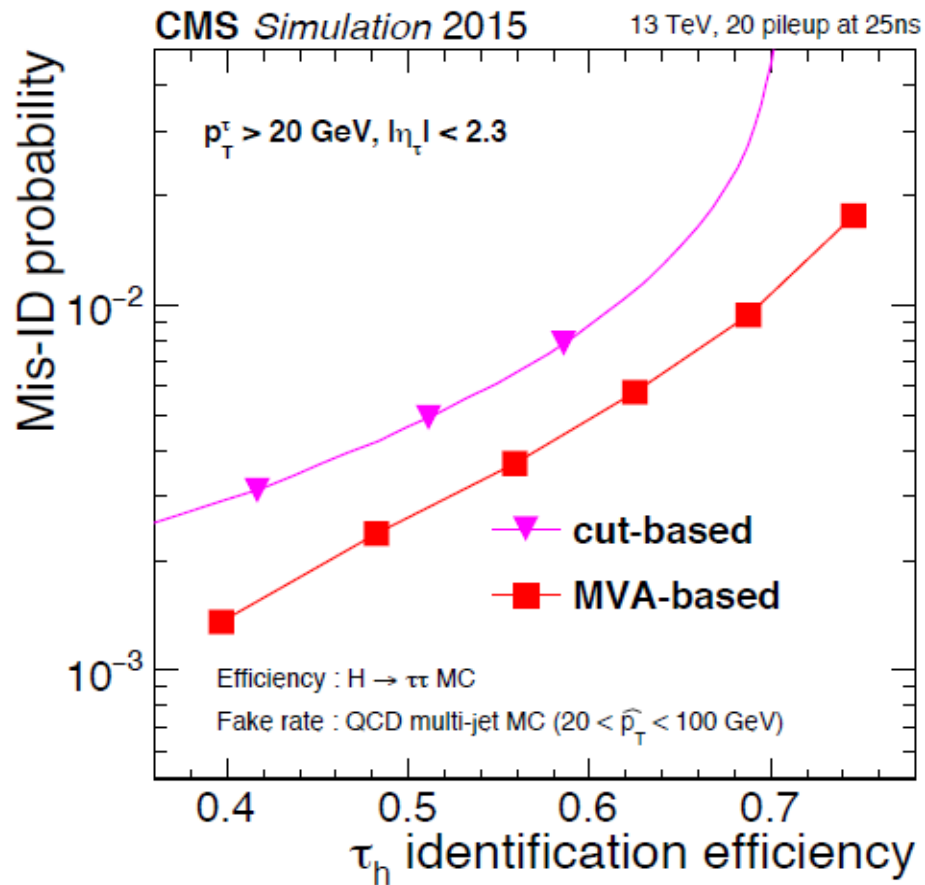


Post-fit jet response as a function of the jet transverse momentum. Same trend observed as in 2015 data, attributed to the change in local reconstruction in the HCAL.

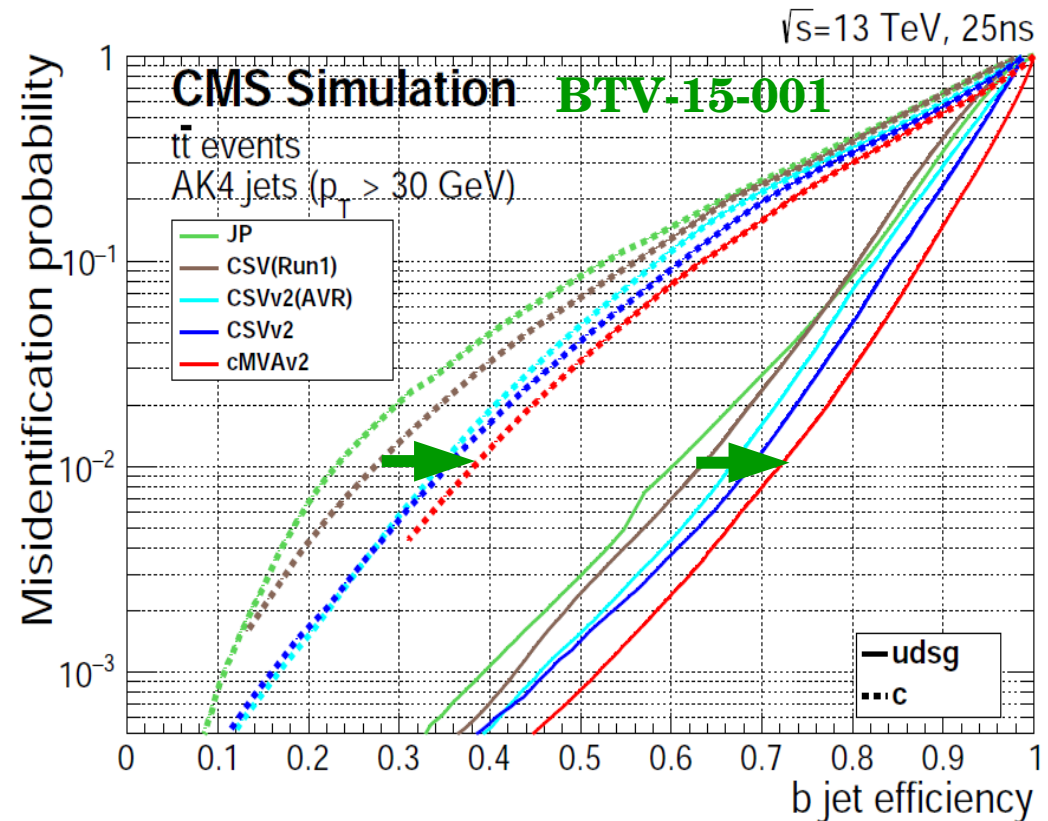


Missing transverse energy quite well modelled taking into account that residual jet energy corrections are not applied

# Tau and b jet identification



Improved MVA-based identification efficiency is performing significantly better than cut-based (~20% relative improvement)

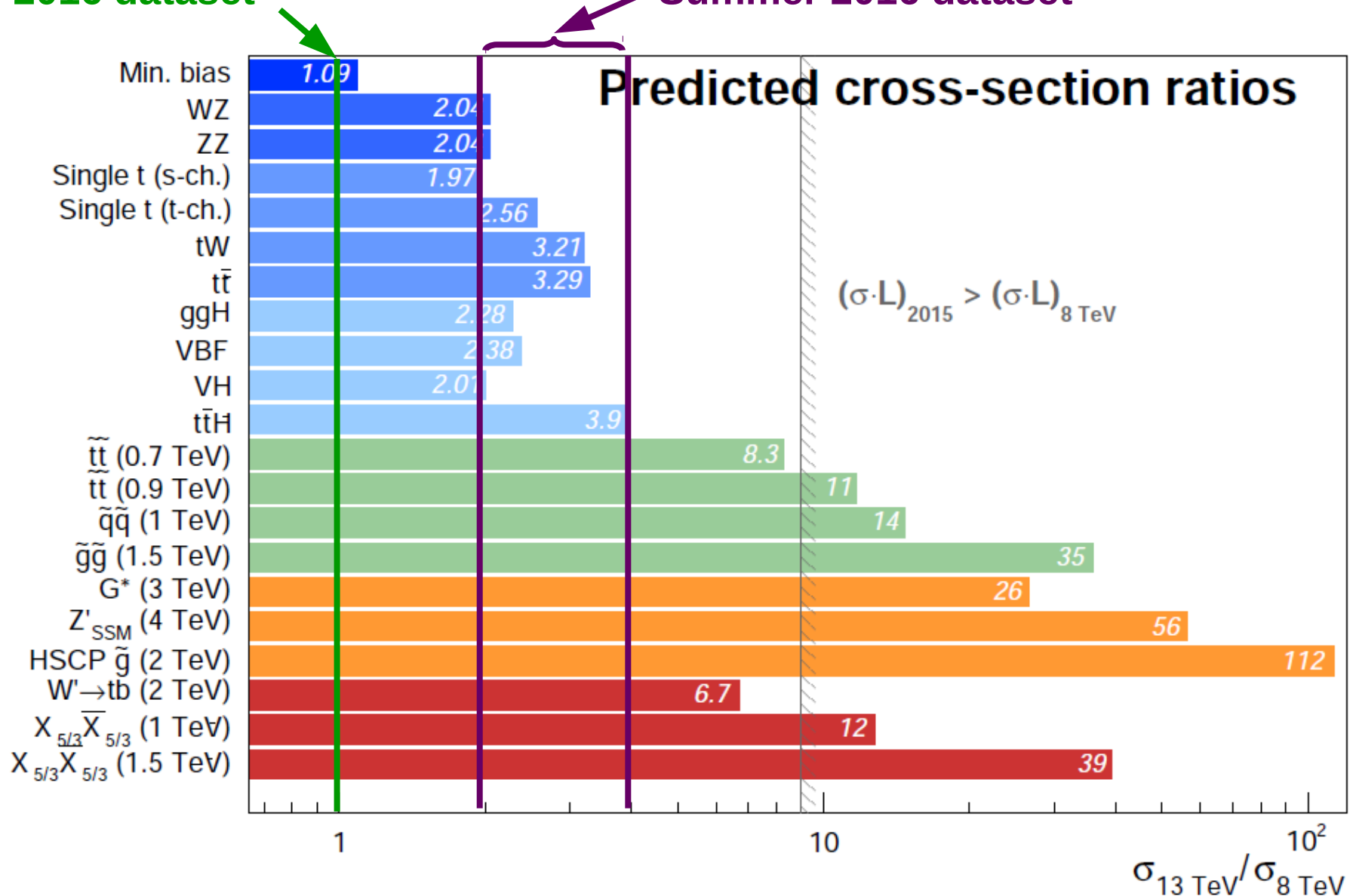


Algorithm performance significantly improved for Run 2 (~10% higher b jet identification efficiency for a misidentification probability of 1%)

# Run 2 has only just begun...

End of 2016 dataset

Summer 2016 dataset



2016 brings unique opportunities for both precision measurements and searches!

# Many other highlights ...

Performance      *W. Kozanecki (Performance parallel)*

Upgrade            *P. Krieger, B. Clerbaux, G. Punzi, A. Uras (parallel)*  
*A. Belloni (plenary)*

## POSTERS:

Trigger            *R. Aggleton, X. Gao*

Tracker            *M. Schroeder*

Muon CSC        *J. Wange*

MET                *M. Vesterbacka*

Phase I            *E. Gulmez*

SUSY               *J.-F. Schulte, E. Tadavani*

Higgs              *N. Chernyavskaya, L. Viliani, T. Cheng, H. Mei, B. Li*

Top                 *C. Mc Lean*

Dark Matter       *D. Vannerom*

Exotica            *W. Fang, C. Gonzalez Hernandez*

Heavy Flavour    *B. Martins Galinhas*

In total, 90 presentations or posters containing CMS results!!!



# Happy CMS faces

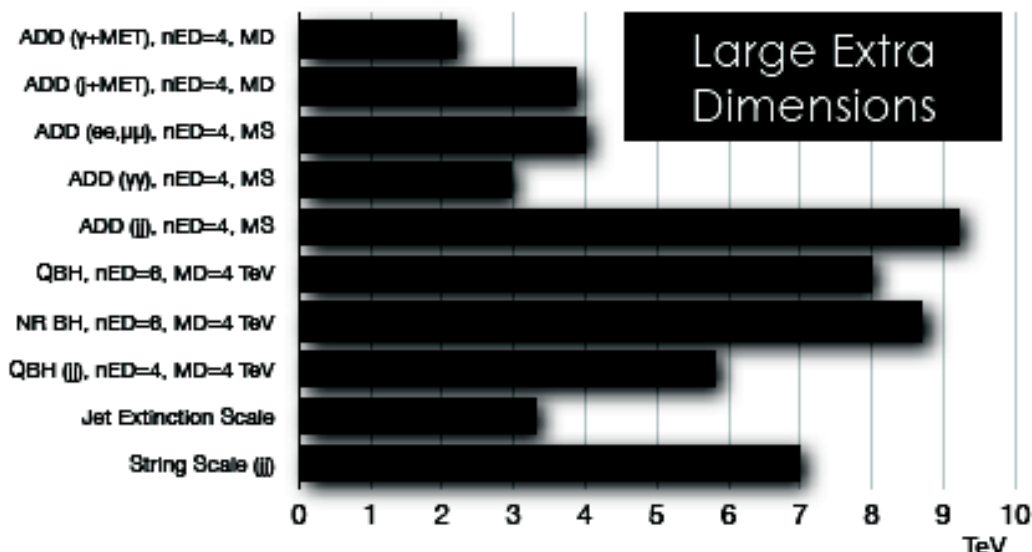
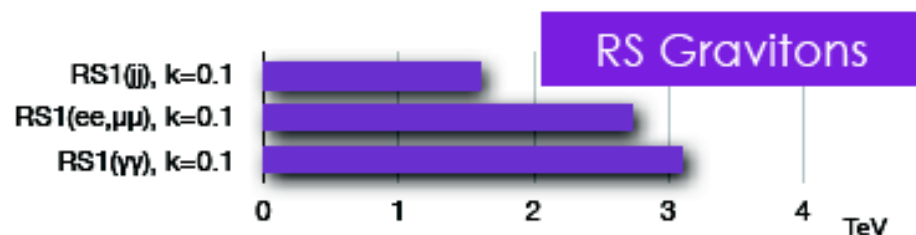
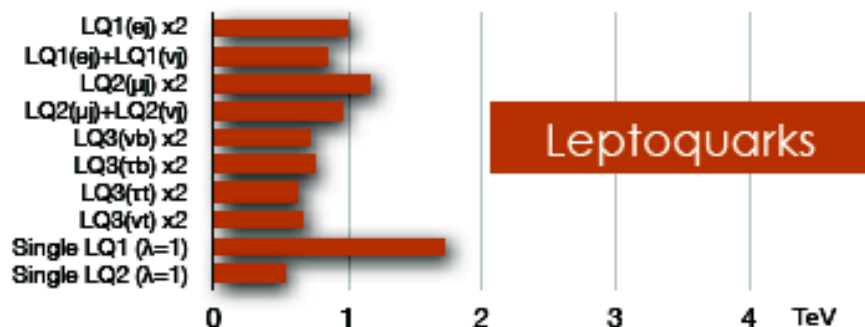
CMS is fully ready for physics analyses with 3.8 T B-field in 2016



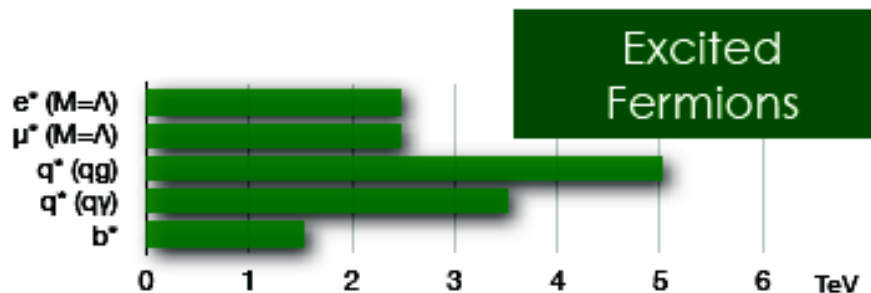
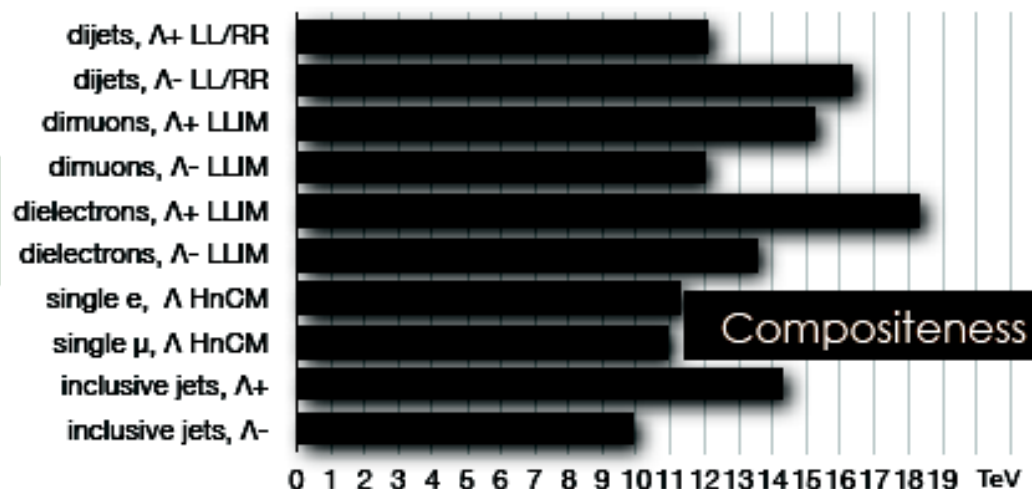
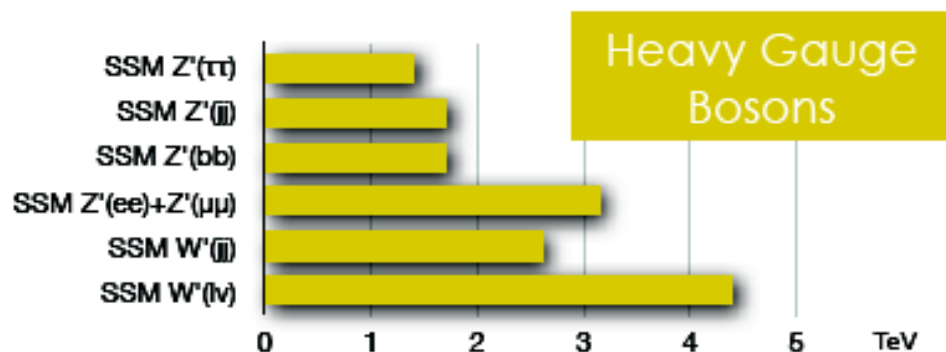
**Many thanks to 4400+ CMS members!**

# Additional material

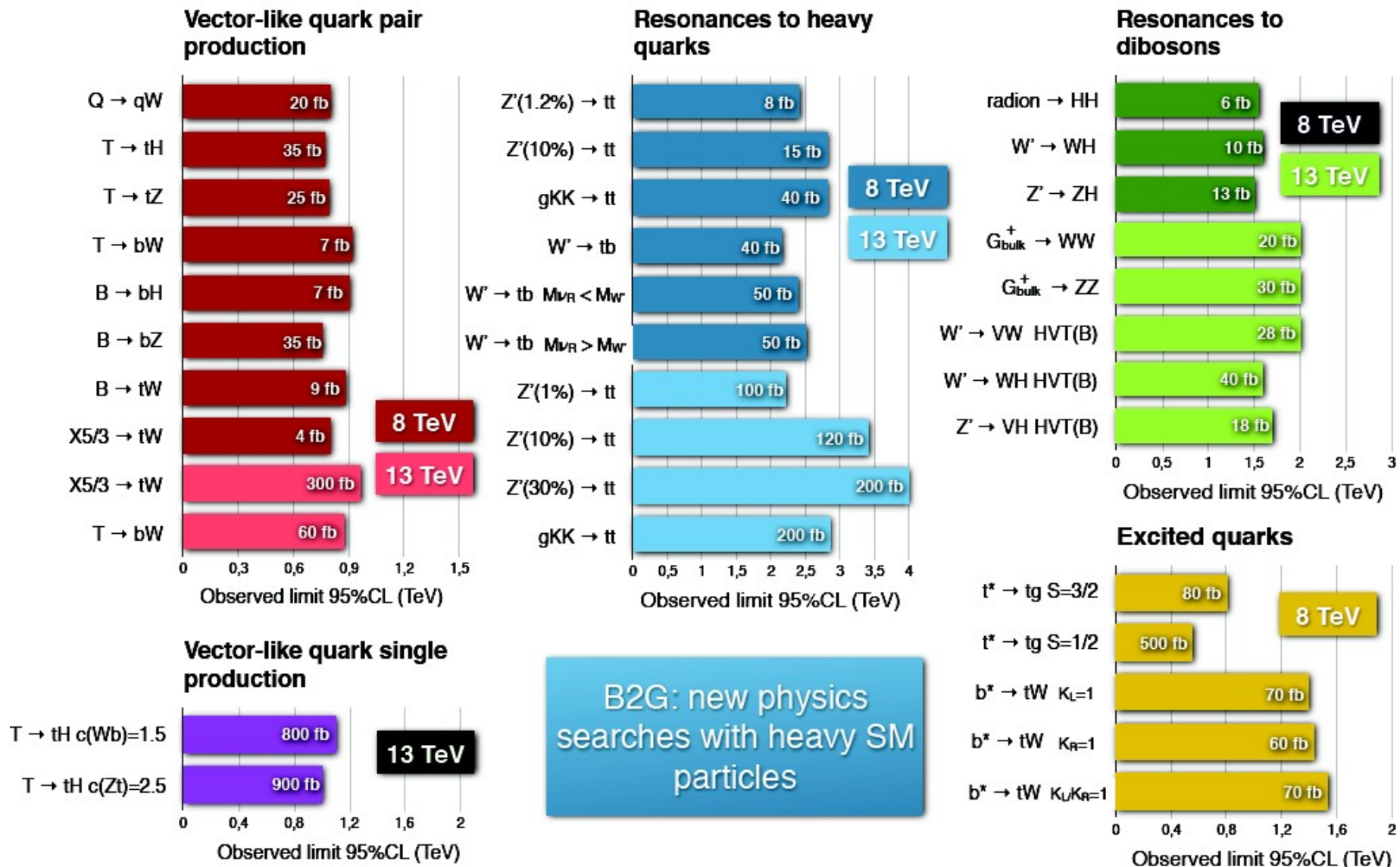
- Link to much more results:  
<http://cms-results.web.cern.ch/cms-results/public-results/publications/>
- EXO summary of searches
- B2G summary of searches
- Single top quark production cross section measurements
- Data/MC comparison for tau and b jet identification variables



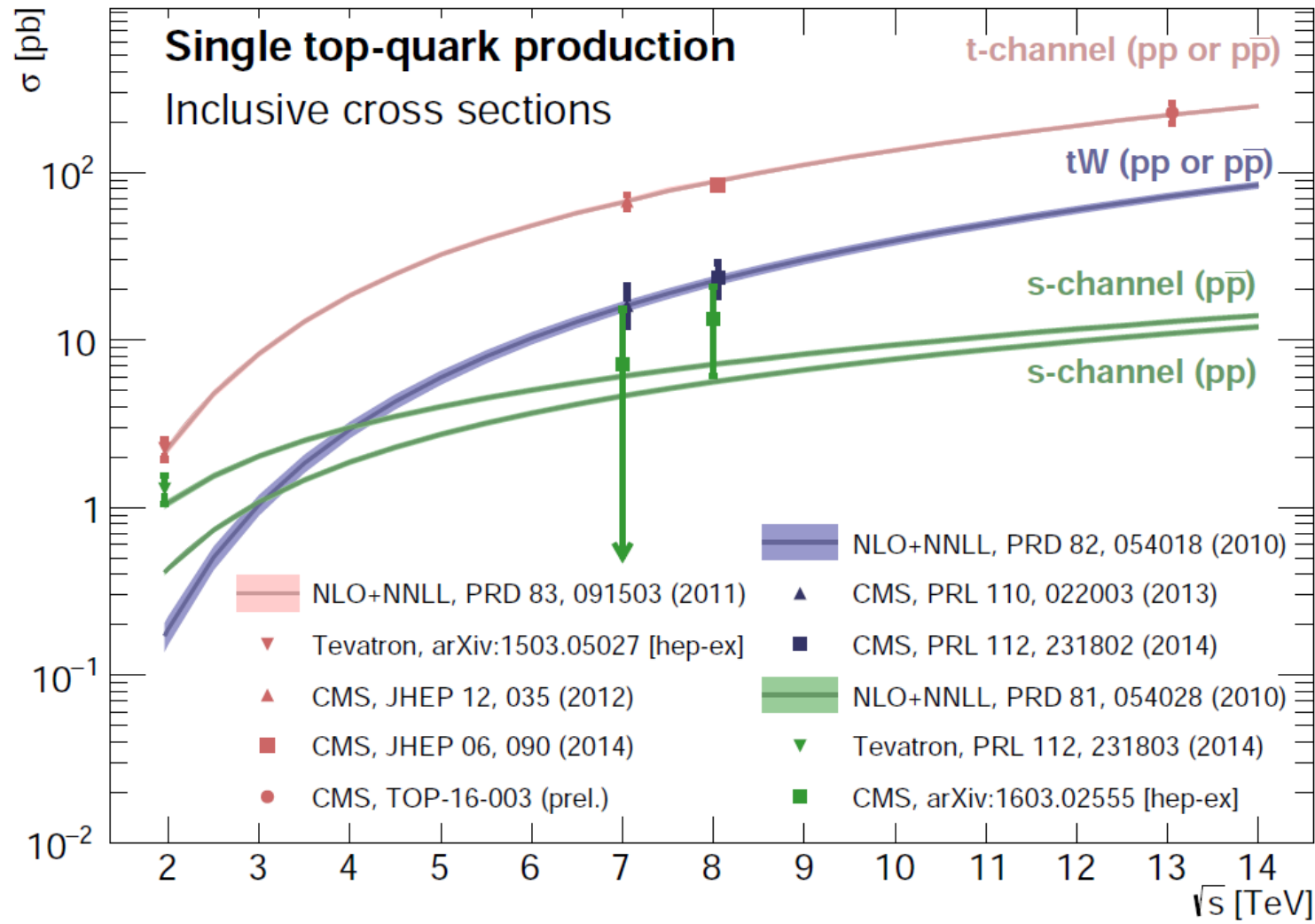
**CMS Preliminary**



# Searches for heavy quarks and diboson resonances

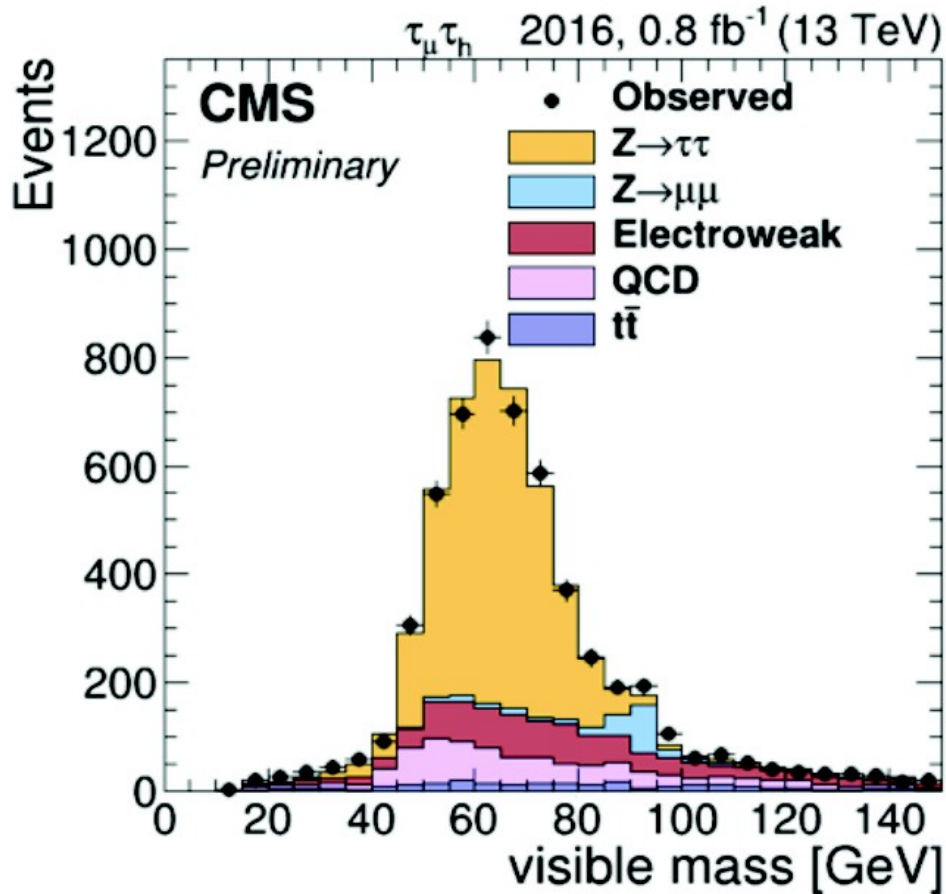


# Single top quark production cross section

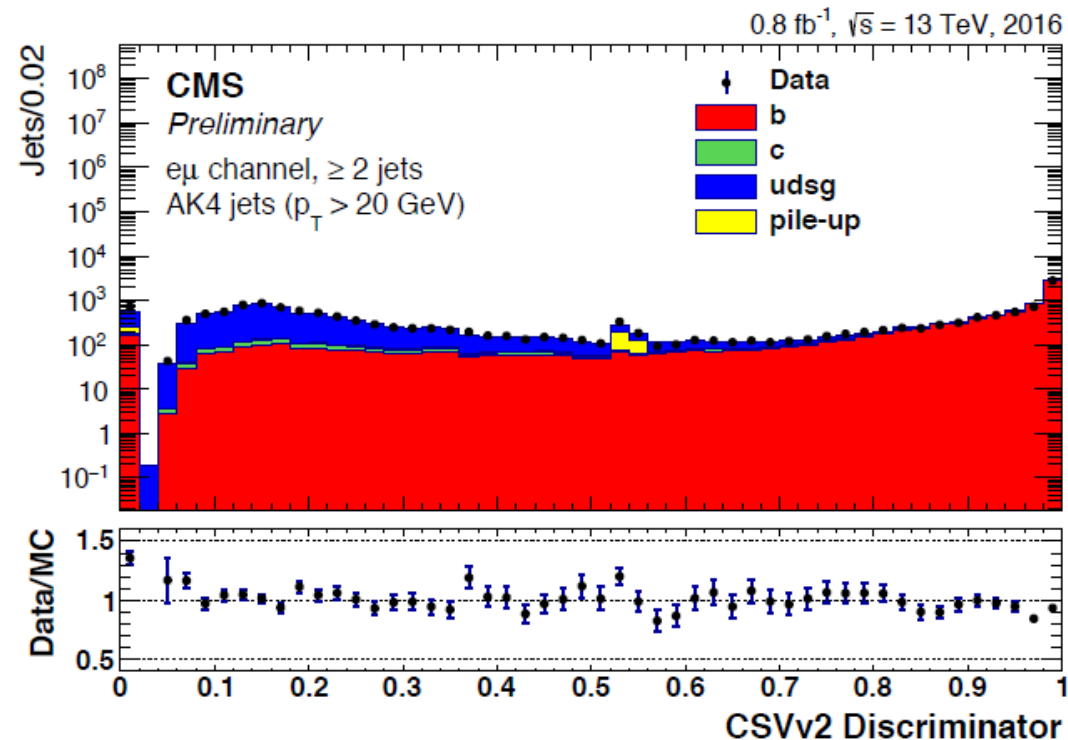




# Tau and b jet identification



Invariant mass of the muon and the visible decay products of the hadronically decaying tau



Reasonable data/MC agreement for the CSVv2 flagship tagger obtained with top quark pair events