HEP-Chile 2016, Valparaiso Jan 7th

New Results of the CMS Experiment

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The CMS experiment and the 2015 run

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- SUSY searches
- Resonances, resonances, and more resonances
- One much discussed candidate for 2016

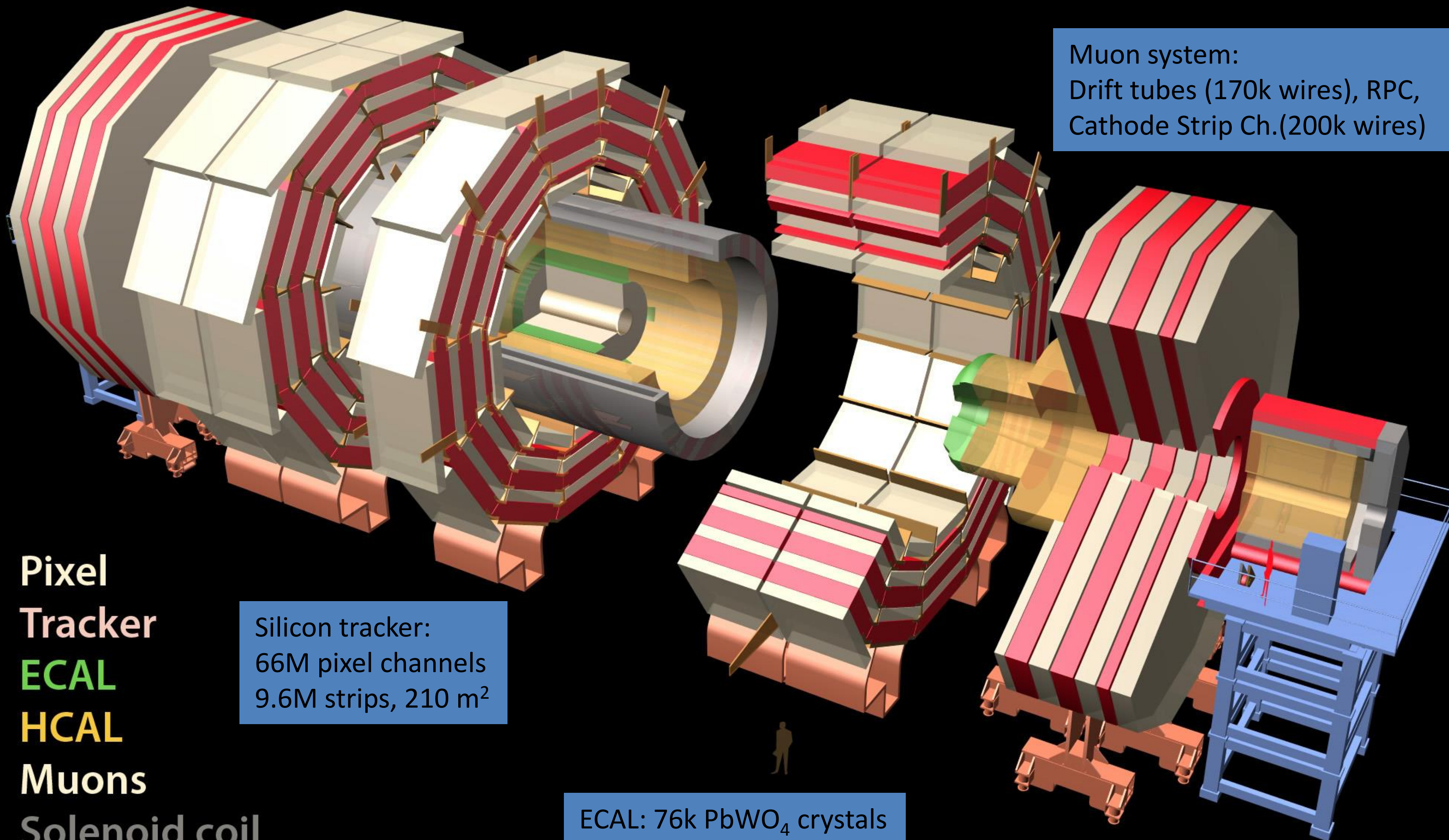
Concluding remarks

The CMS Collaboration

1700 physicists, 700 students, 950 engineers/technicians, 180 institutions from 43 countries

The CMS Detector

10k CPU cores,
2M lines of code



Muon system:
Drift tubes (170k wires), RPC,
Cathode Strip Ch.(200k wires)

Pixel
Tracker
ECAL
HCAL
Muons
Solenoid coil

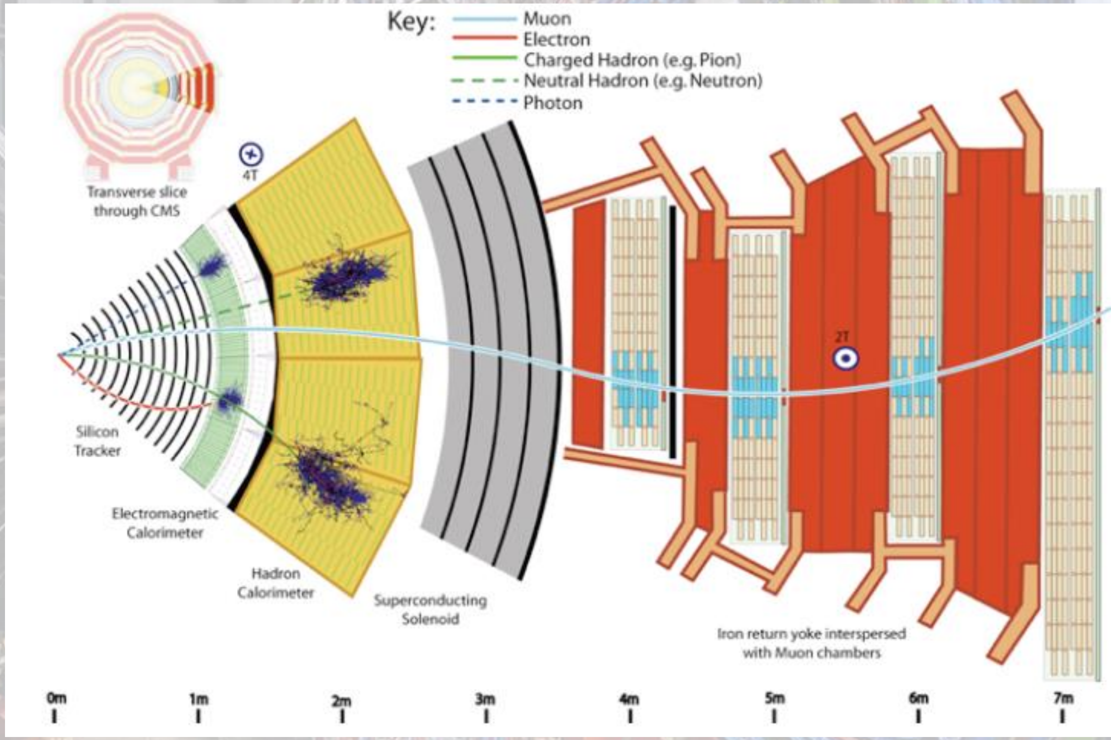
Silicon tracker:
66M pixel channels
9.6M strips, 210 m^2

ECAL: 76k $PbWO_4$ crystals
HCAL: 15k scint/brass ch.

Total weight 12500 t, Overall diameter 15 m, Overall length 21.6 m, Magnetic field 4 Tesla

The CMS Detector

- CMS: A Compact Muon Solenoid
- Actually much more than that:
  - a redundant, all-silicon tracking (210 m^2)
  - a 4-Tesla solenoid for high-resolution momentum measurements
  - a Lead-tungstate crystal calorimeter for high-resolution EM shower measurements
  - hermetic hadron calorimetry
  - redundant muon coverage up to $|\eta|<2.4$

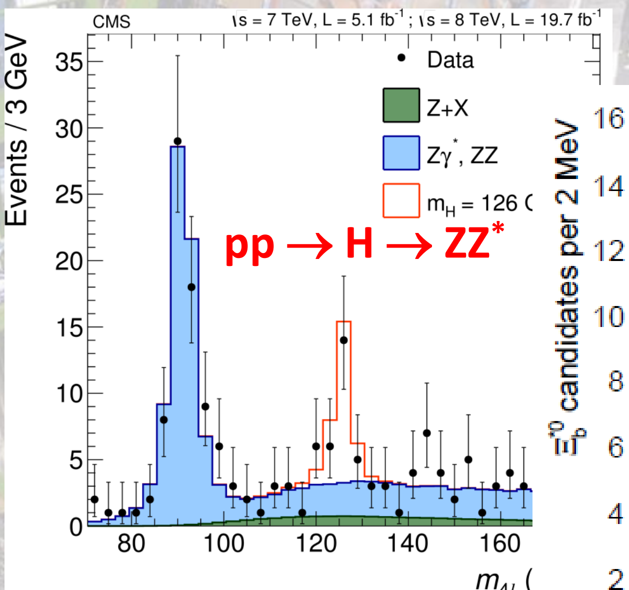


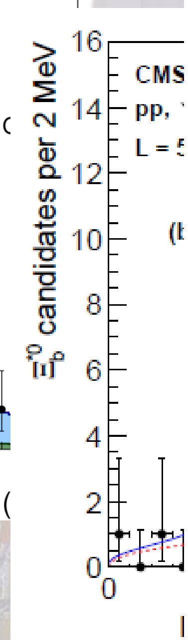
An all-purpose electronic eye for subatomic physics

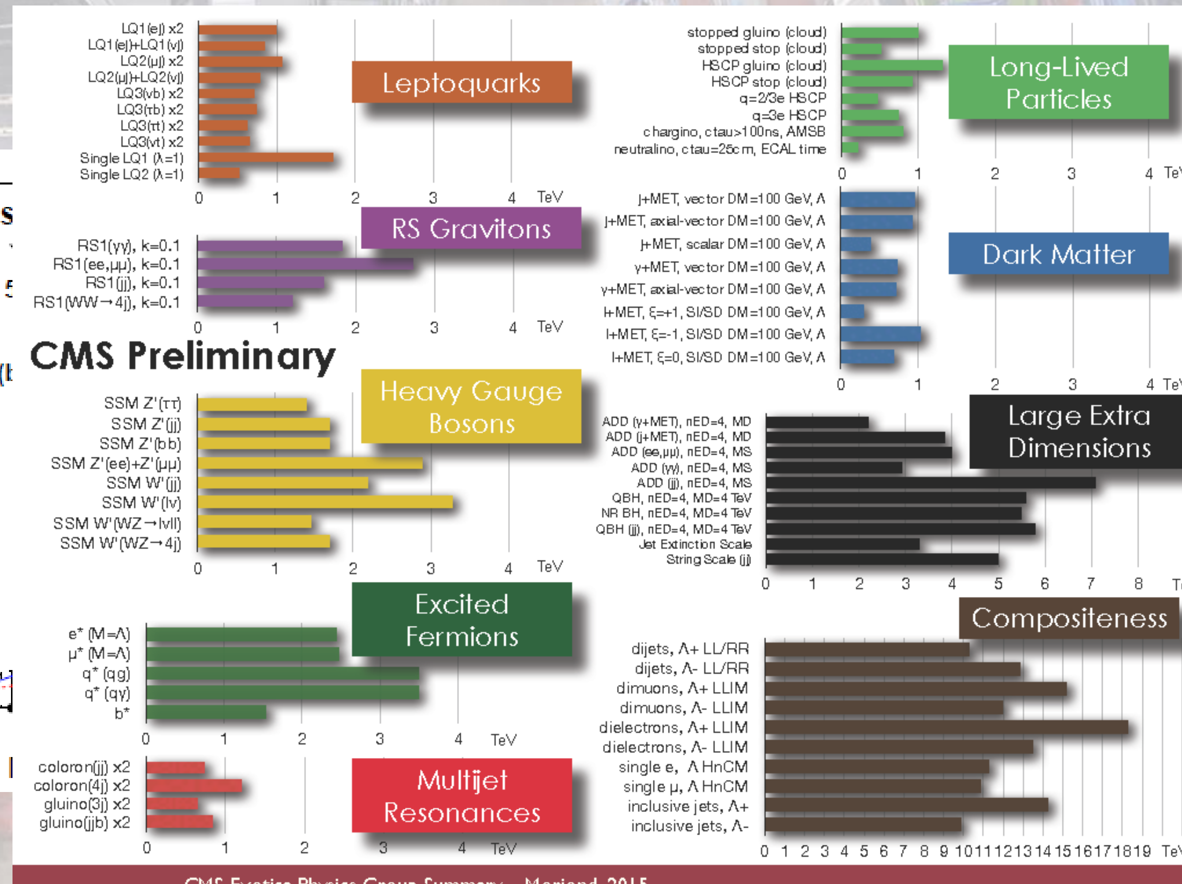
What to remember from Run 1

In Run 1 (2011-2012) the CMS experiment has published **447 articles** based on data from 7- and 8- TeV pp collisions and heavy ion collisions

This has resulted in the **discovery of the Higgs boson, a new baryon, a few Y states,** as well as in scores of other results, and notably the extension of lower limits on the mass of new particles and rate of rare new phenomena

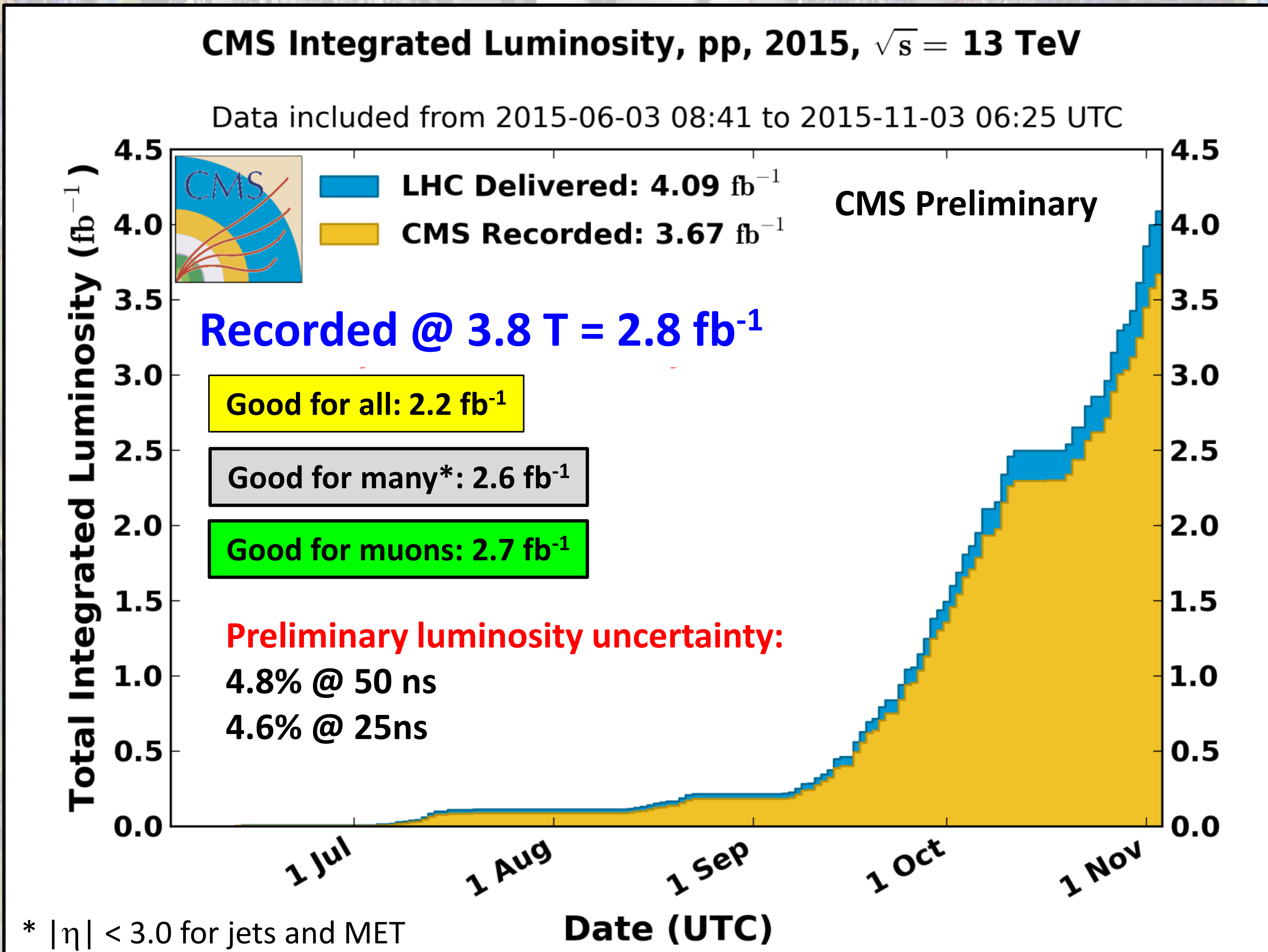




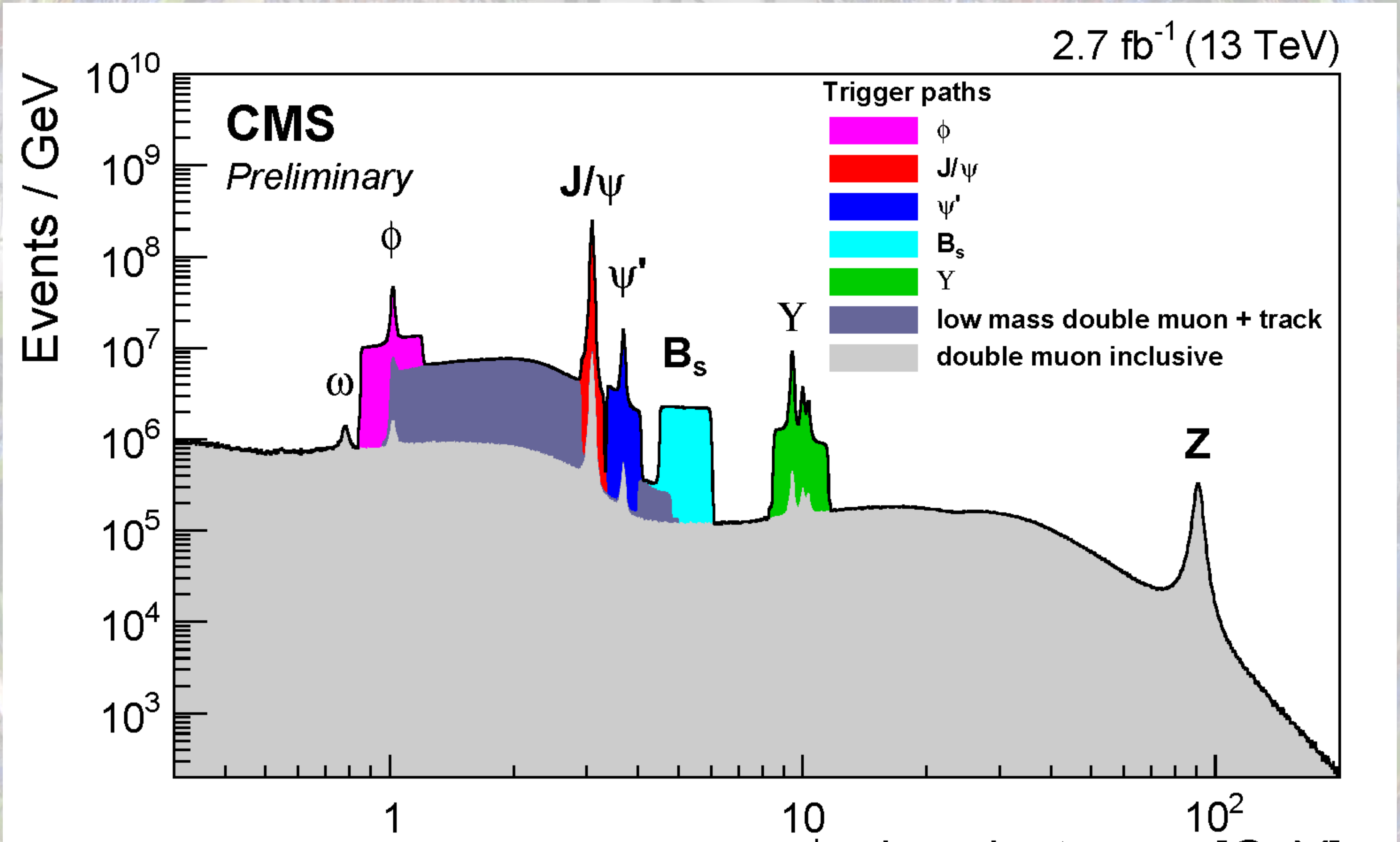


All CMS pubs: http://cms-results.web.cern.ch/cms-results/public-results/publications/

Run 2 data: 13 TeV collisions

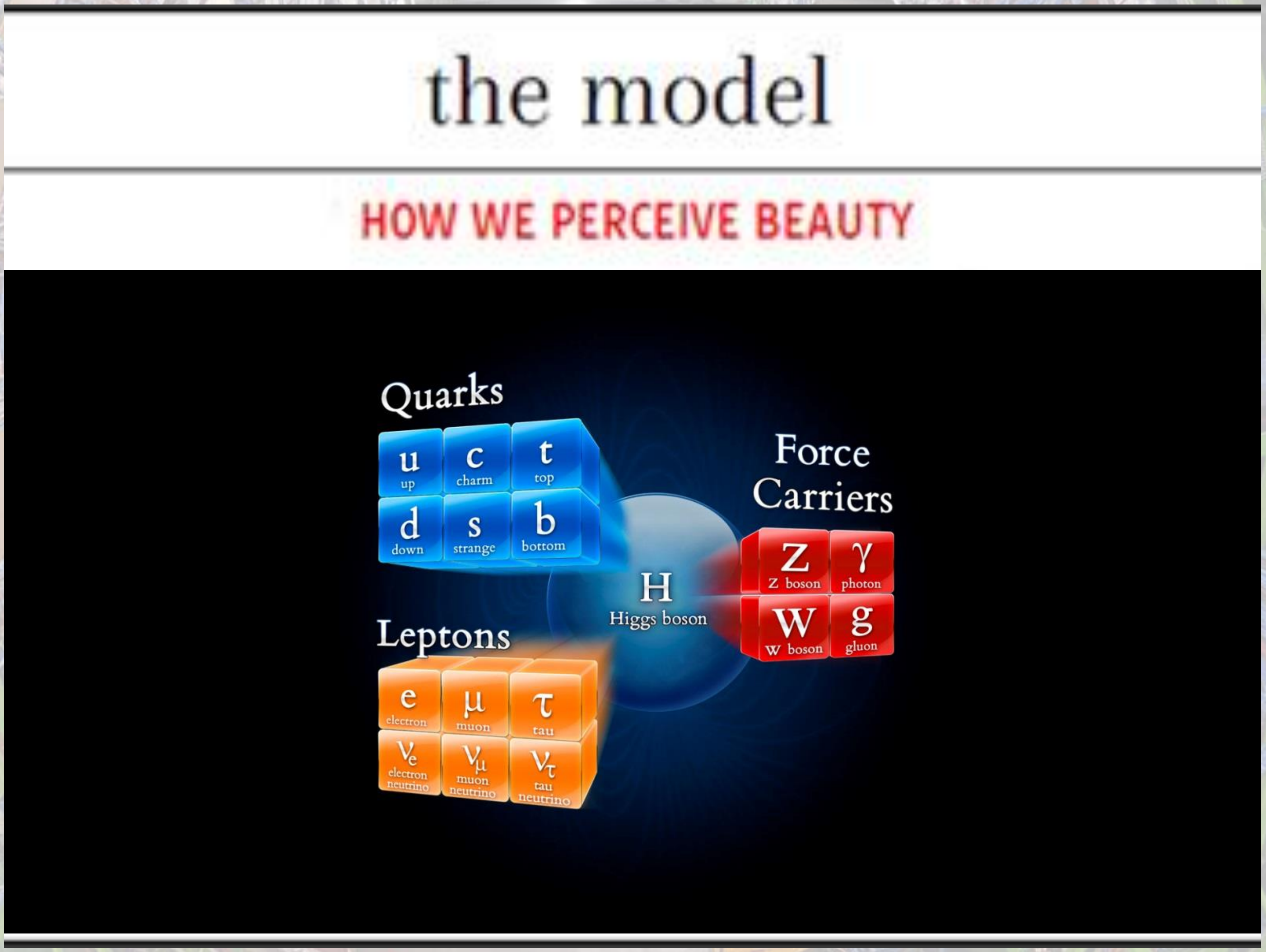


A feel-good graph - dimuon resonances



CMS-DP-2015/055

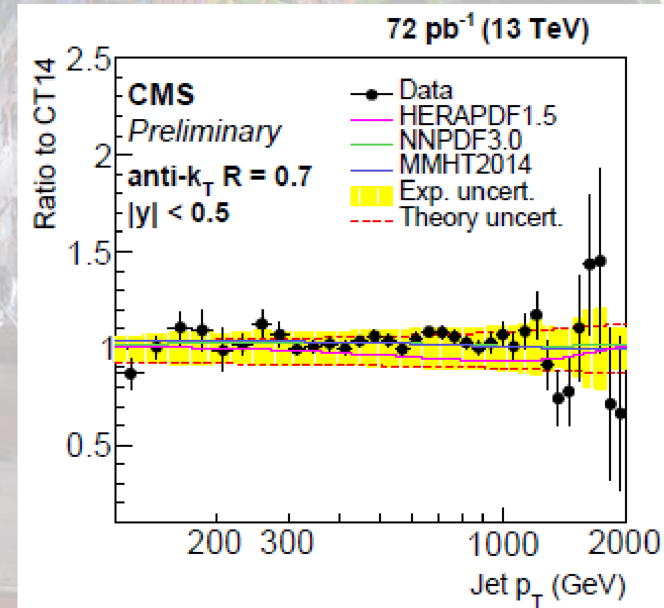
Standard Model measurements at 13 TeV

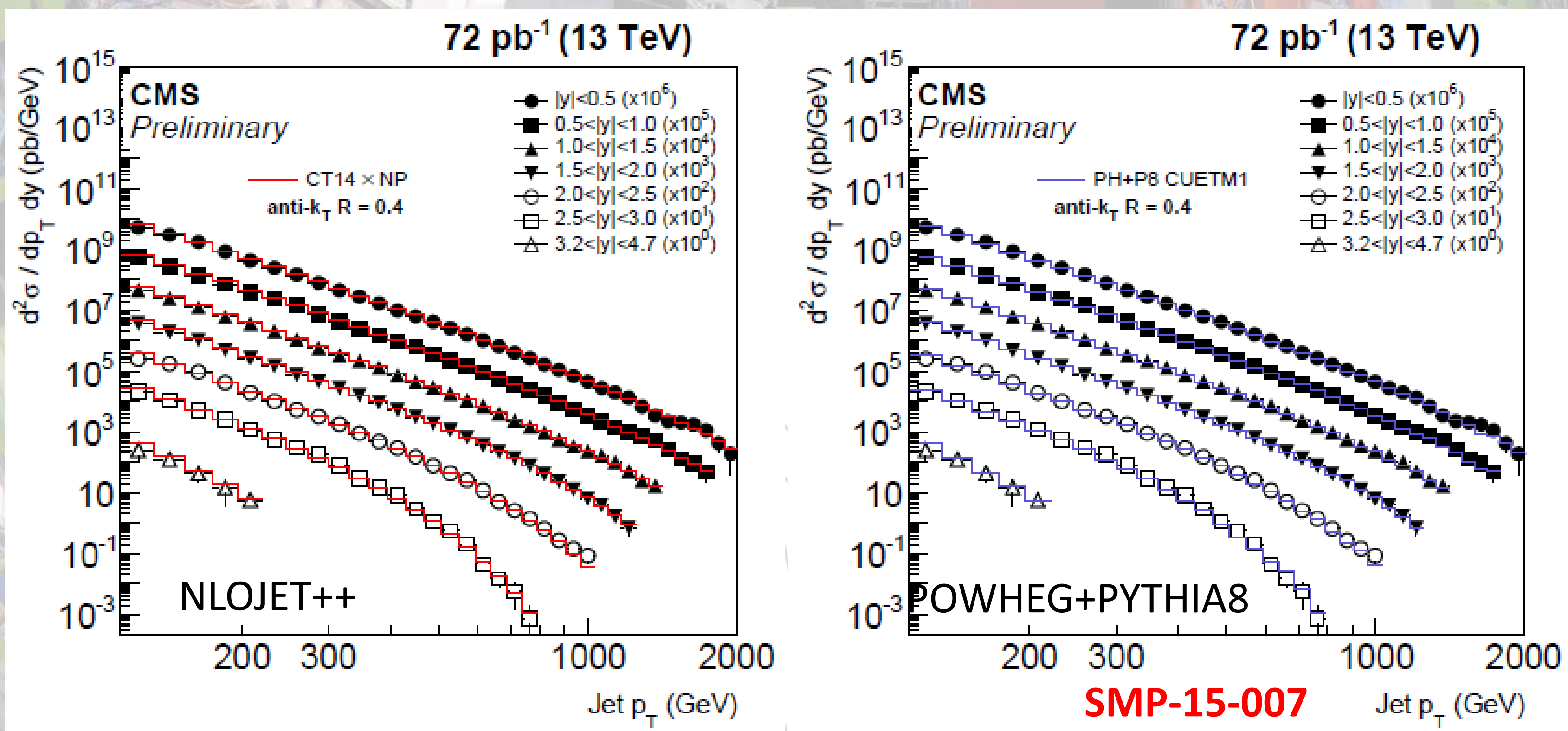


Inclusive jet cross section

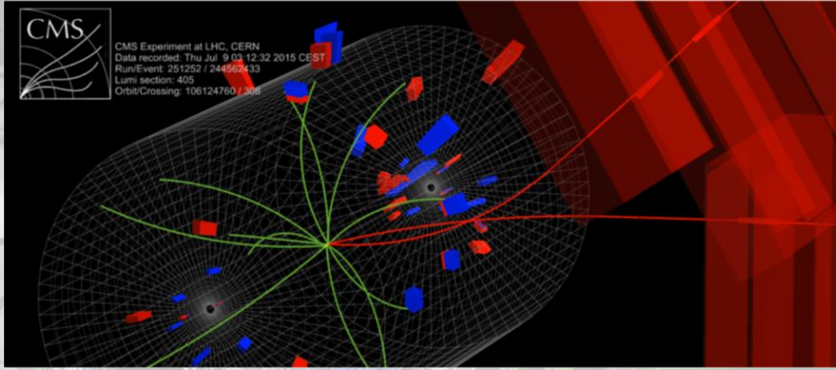
The inclusive jet production cross section has been measured in bins of jet p_T and η using 72/pb of 13 TeV data

A good agreement with QCD predictions using improved tuning of NP and hadronization is observed with both cone radii used (0.4 below, and 0.7, right)



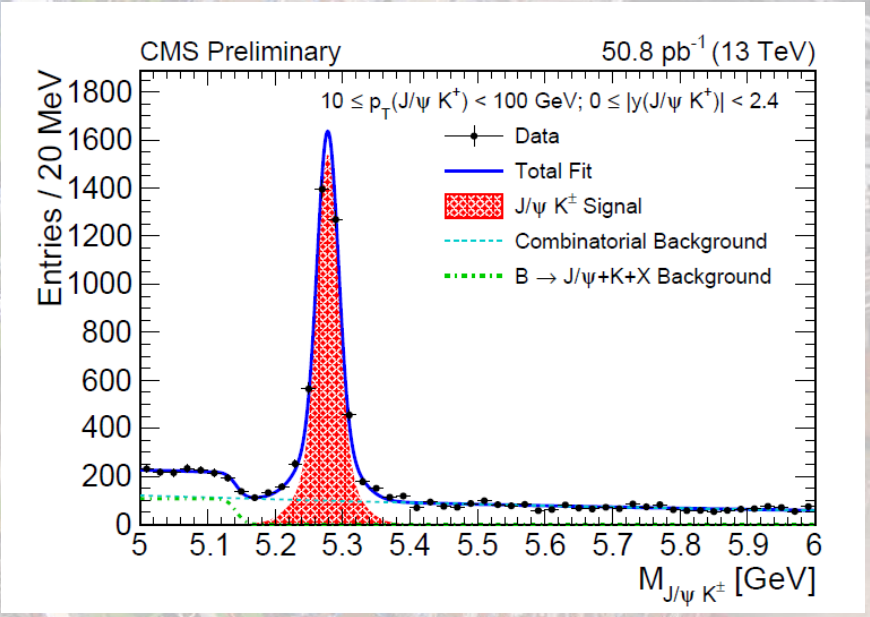


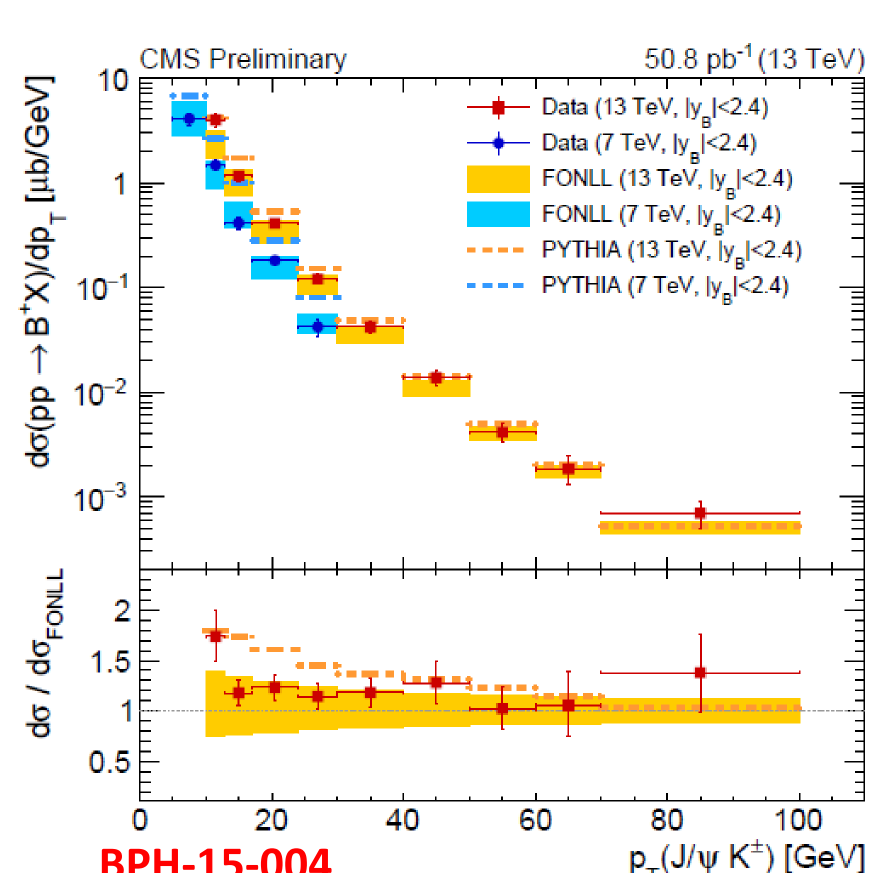
B meson production



B cross sections are studied as a function of p_T and y and compared to FONLL predictions

Use standard $B^+ \rightarrow J/\psi K$ decay from dimuon trigger



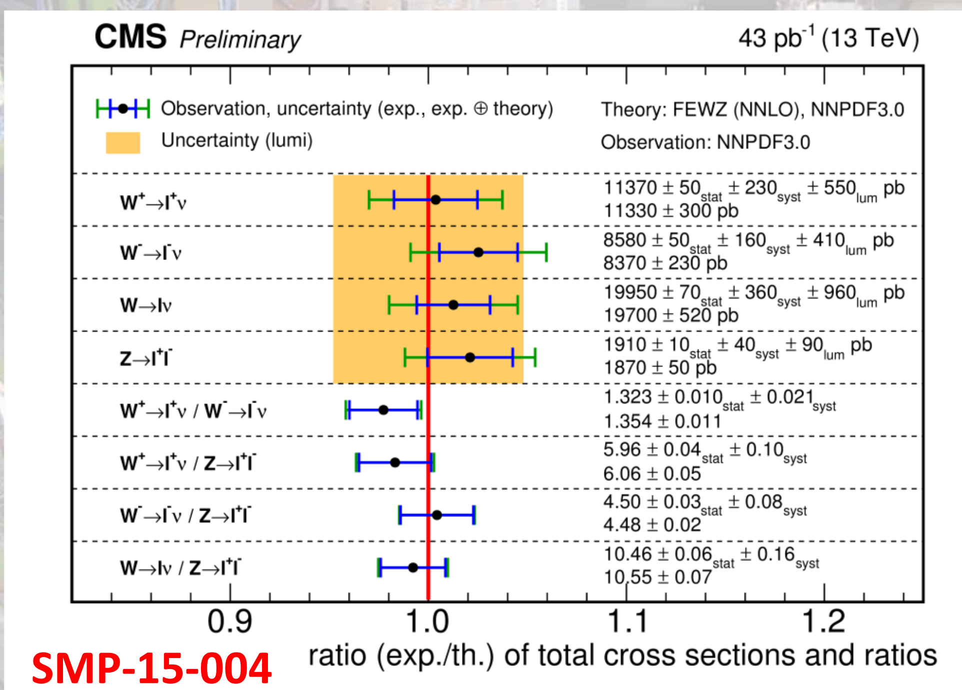


BPH-15-004

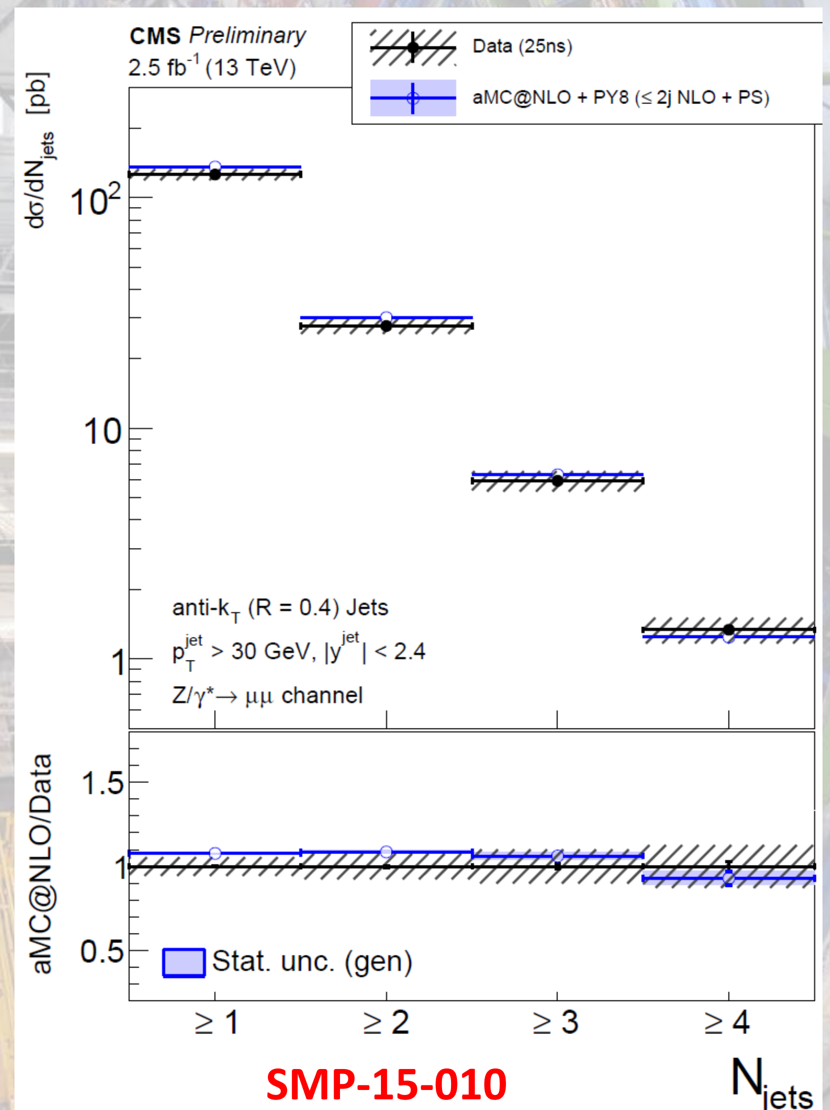
Good agreement with theory is observed in the investigated range up to **$p_T \sim 100$ GeV**

W and Z production

- The first 43/pb of 13 TeV data allowed measurements of inclusive W and Z cross sections and their ratios (W/Z, W^+/W^-)
- A new measurement of $Z(\rightarrow\mu\mu)$ +jets differential cross sections has also been produced with 2.5/fb of Run 2 data



SMP-15-004



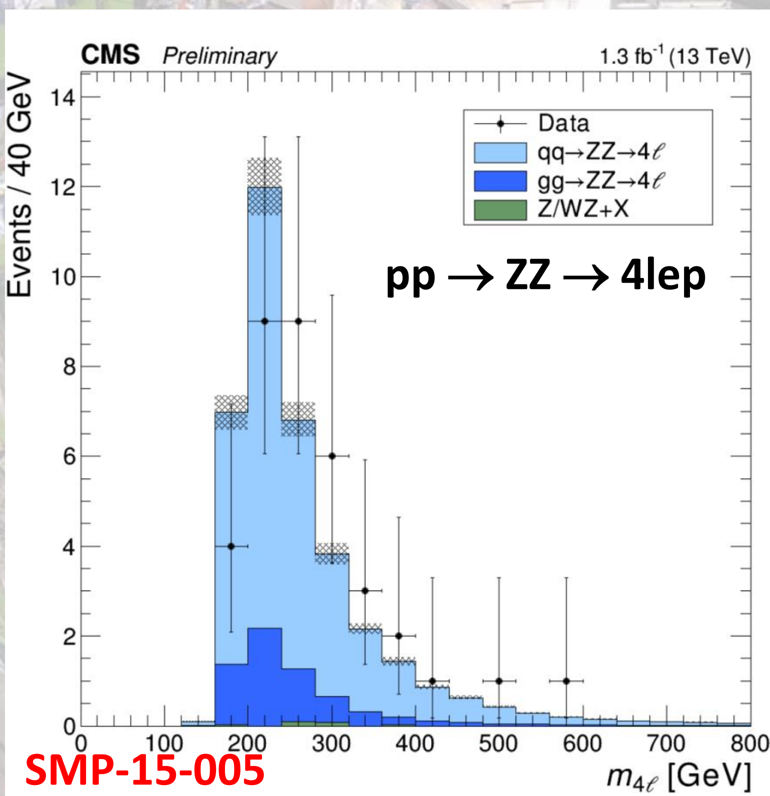
SMP-15-010

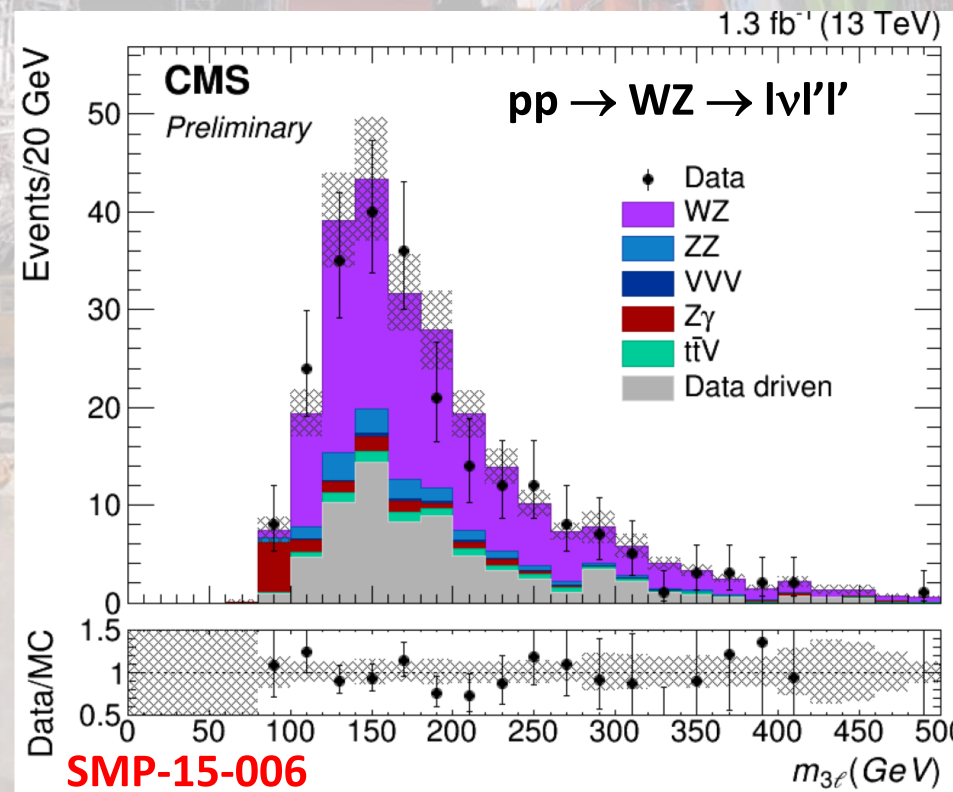
Diboson production: ZZ, WZ

Dibosons provide a further check of the SM at the higher energy of the 2015 run
Boson pairs are a background to many NP searches (including Higgs production)
1.3/fb of Run 2 data were used for these measurements
Data and SM predictions are in very good agreement. The measurements are:

$$\sigma_{\rm fid}(pp \to ZZ \to 4\ell) = 38.0^{+6.7}_{-6.0}\,({\rm stat})^{+1.5}_{-1.2}\,({\rm syst}) \pm 1.8\,({\rm lum.})\,{\rm fb}$$

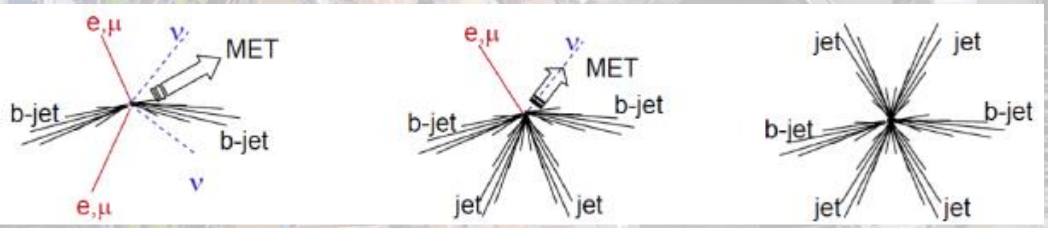
$$\sigma_{\rm fid}(pp \to WZ \to \ell\nu\ell'\ell') = 239 \pm 29\,({\rm stat})^{+52}_{-40}\,({\rm syst}) \pm 11\,({\rm lum})\,{\rm fb}$$





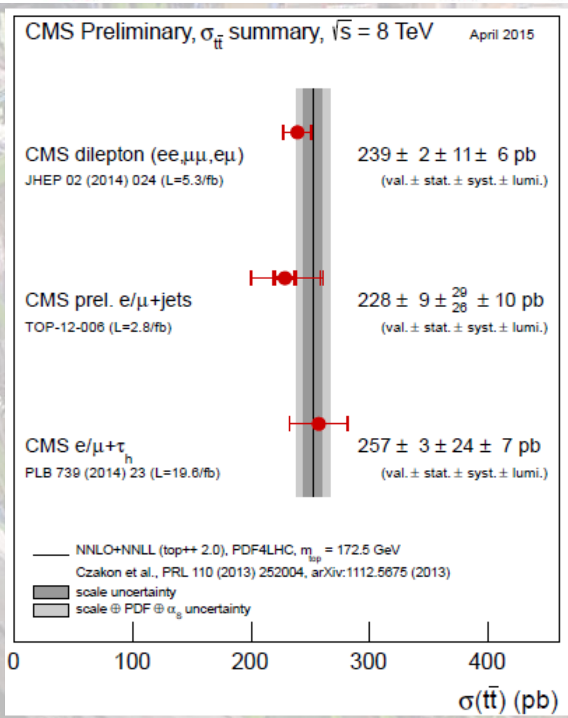
Top quark production cross sections

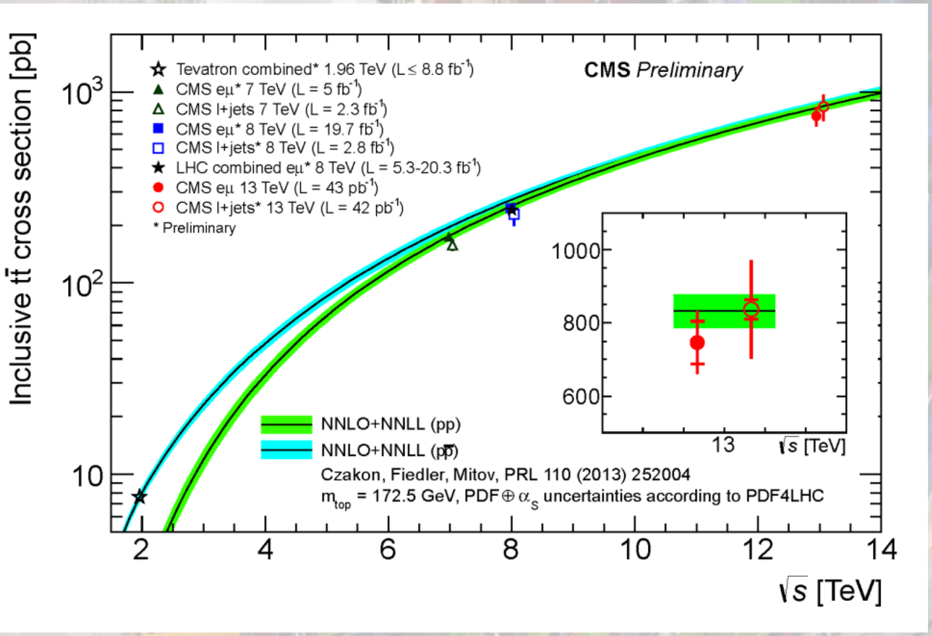
- Top is mainly produced in pairs by gluon-gluon collisions; also produced singly via EW processes (W*→tb, bg→tW, gW→tbq)
- Top pairs mainly undergo three possible decay modes: dileptonic (e,μ: 5%), single lepton (e,μ+jets: 30%), hadronic (all jets: 45%); these have complementary issues and purity
- The precision of CMS results challenges NNLO+NNLL QCD calculations



Bottom line: Great agreement!

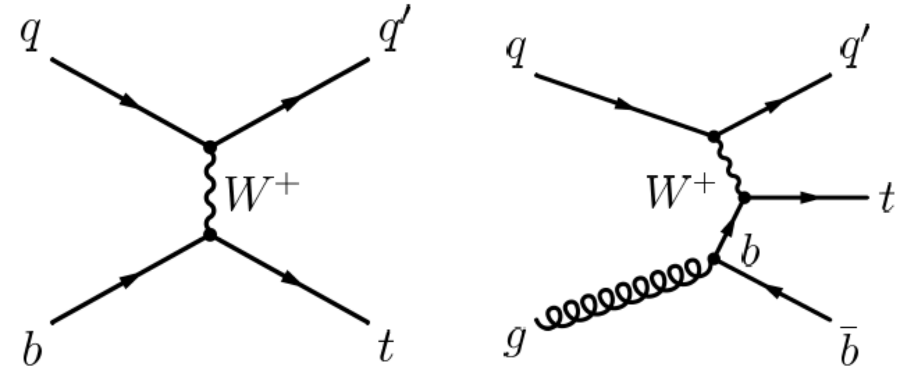
This is a true success of precision calculations of perturbative QCD



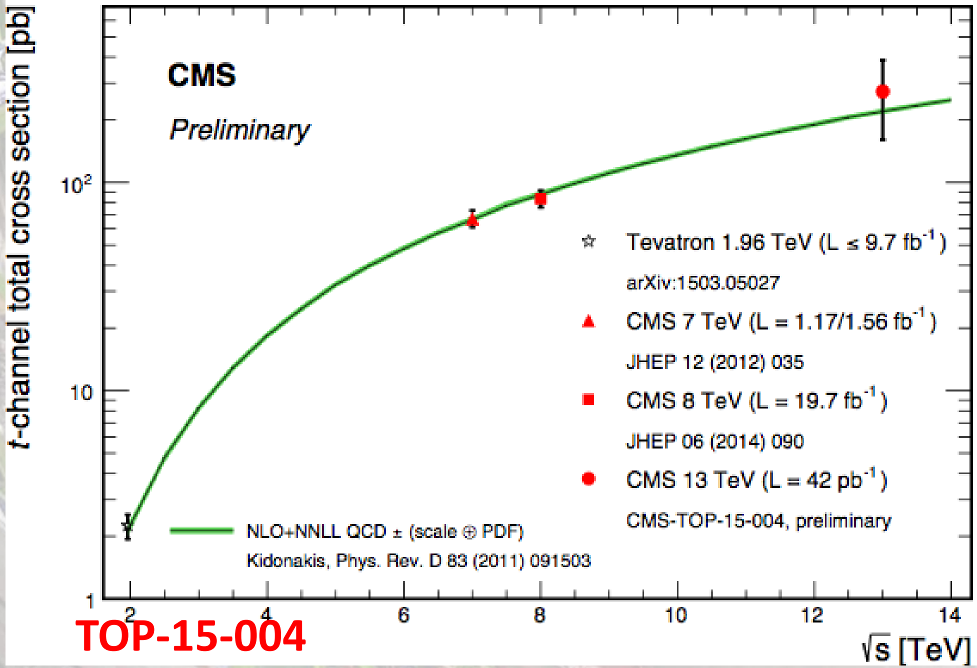


Single top quark production

The t-channel production of single top occurs in pp collisions via two different processes, one of which is sensitive to the b-quark content of the proton



CMS has measured t-channel production in a fiducial PS region, finding good agreement with both aMC & POWHEG



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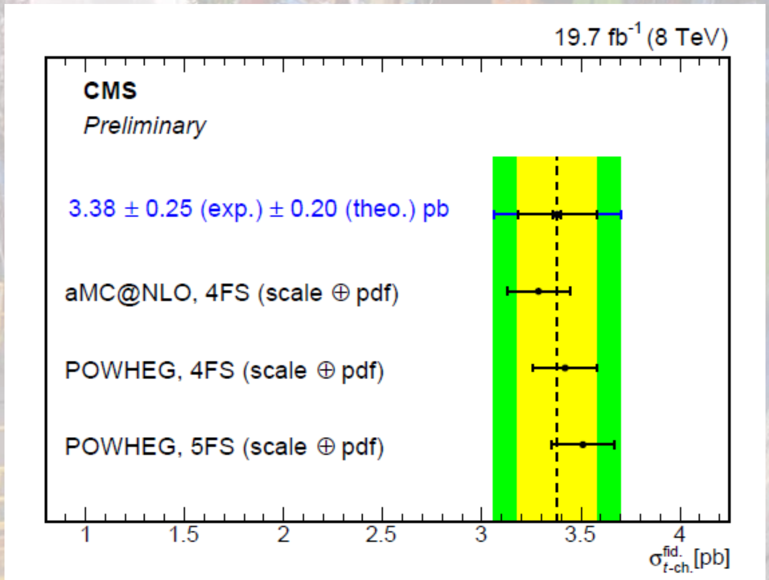
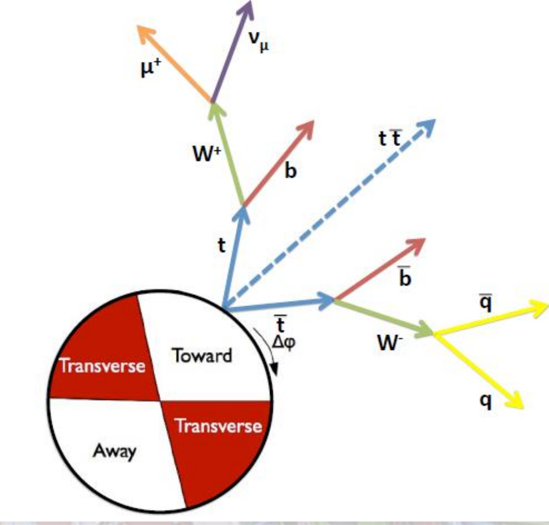
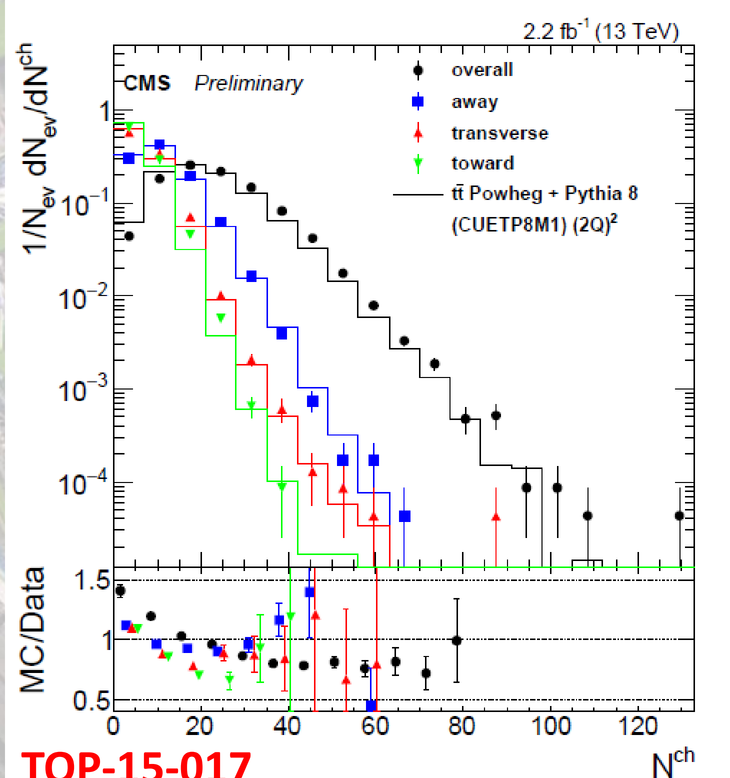


Underlying event: now studied in tt events

The study seeks to improve the event modeling in $t\bar{t}$ production, using fully reconstructed single lepton events

CMS measures charged particle activity (N, Σp_T, $\langle p_T \rangle$) in different regions relative to the momentum of the $t\bar{t}$ system, as a function of $p_T(t\bar{t})$ and for different jet multiplicities



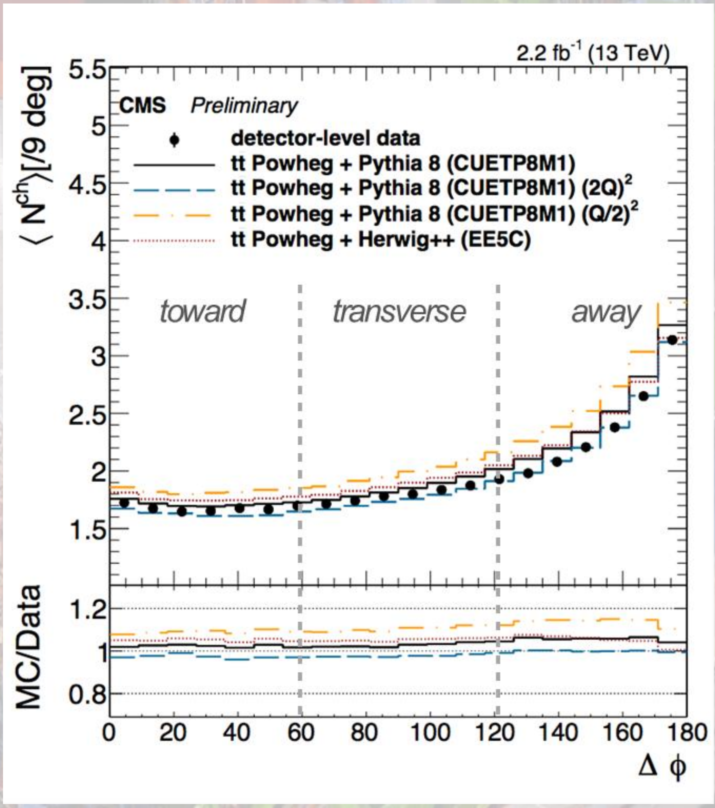


TOP-15-017

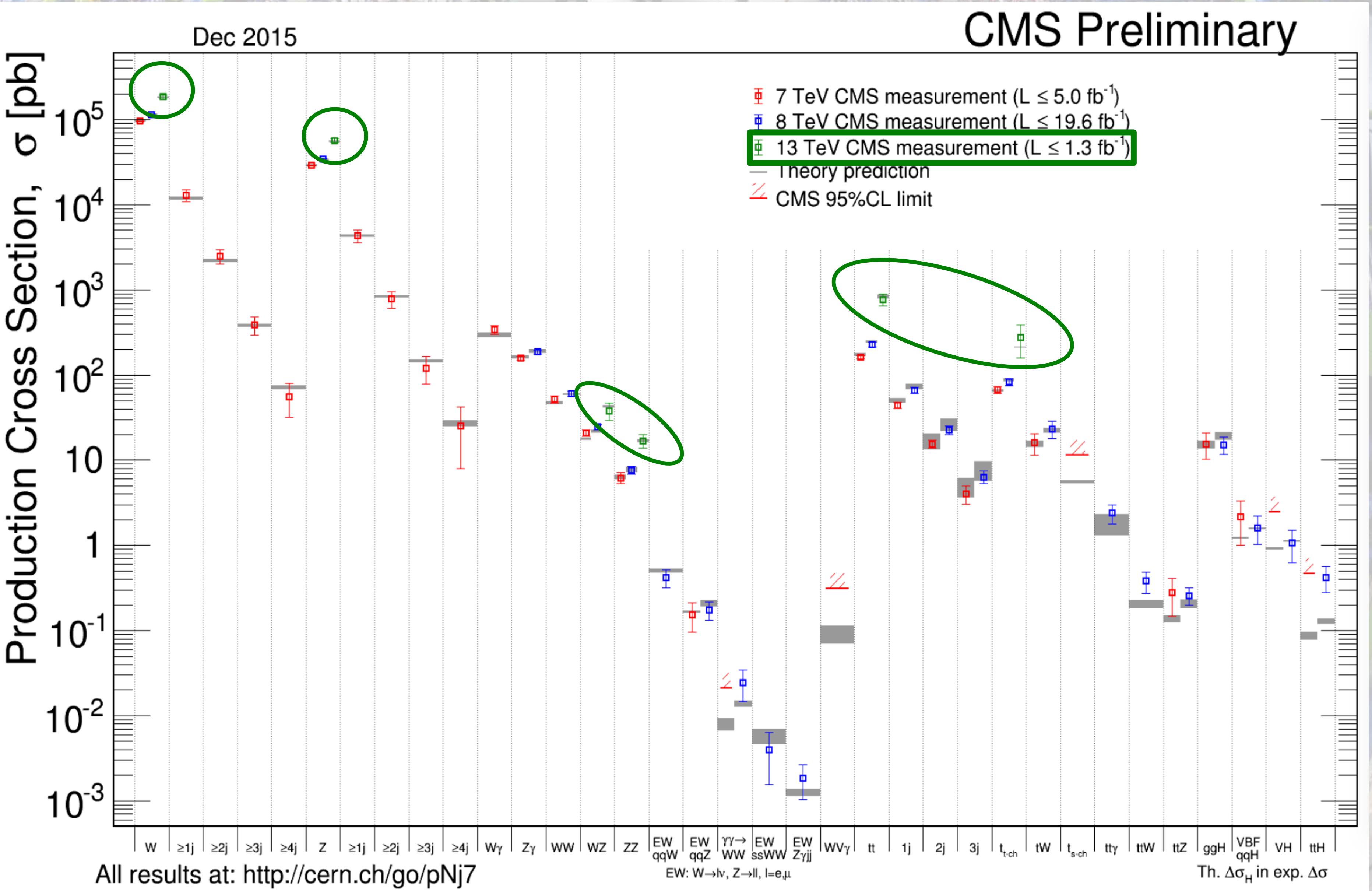
Left: charged multiplicity compared to models with $(2Q)^2$ scale for fragmentation and renormalization

Right: $\Delta\phi$ distributions

The models describe the data reasonably well within model systematics, so it appears not necessary to have a different UE tune to describe heavy flavour production

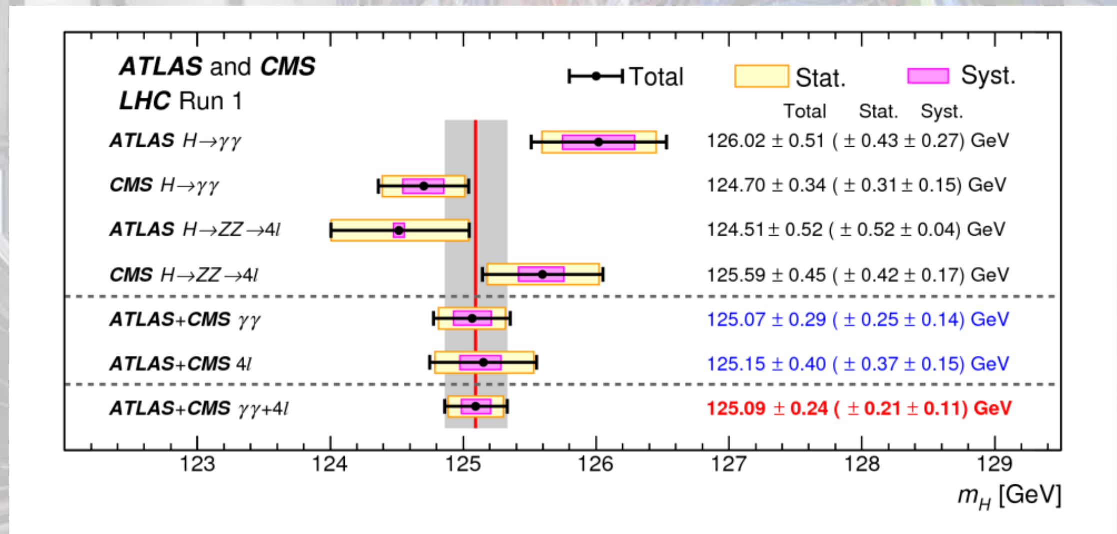


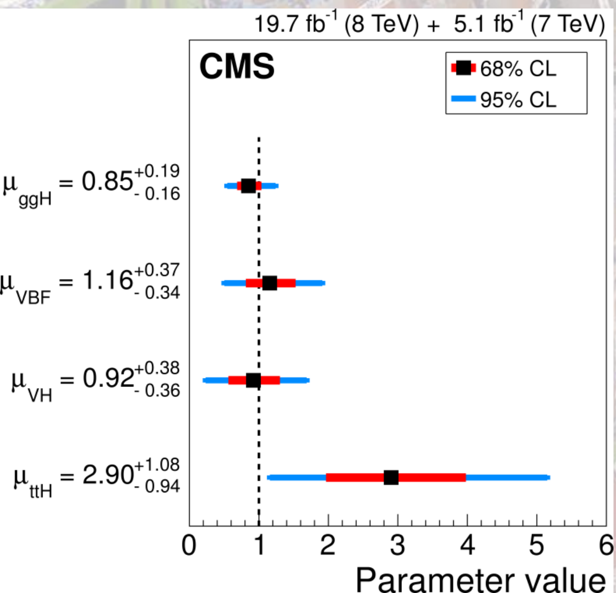
Standard Model Summary



CMS Higgs boson results (Run 1)

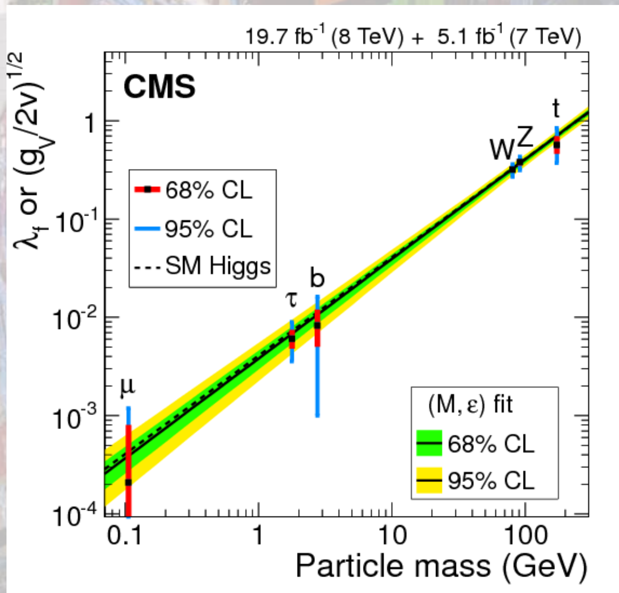
- Mass:
  M_H=125.00 ± 0.27 ± 0.15 GeV
- Cross section:
  $\mu = 1.00 \pm 0.09\ \text{(stat)}\ ^{+0.08}_{-0.07}\ \text{(theo)} \pm 0.07\ \text{(syst)}$
- **J^P: 0^+**
- Couplings: **As the SM predicts!**



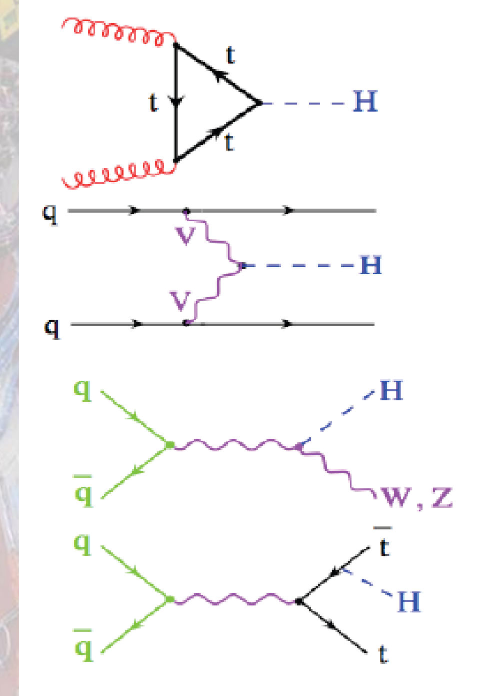


Left: fits to the signal strength μ from measurements in different final states allow to disentangle the contribution of different production modes

Right: coupling of Higgs boson to different particles is compared to SM predictions



Higgs physics at 13 TeV



Higgs production by gluon-gluon fusion and VBF processes increase by a factor of 2.6 with respect to 8 TeV

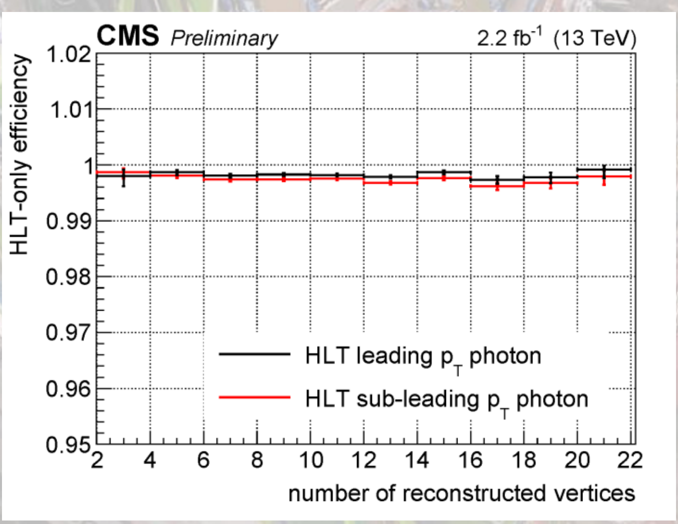
→ Discovery channels visible with ~ 5 fb^{-1}

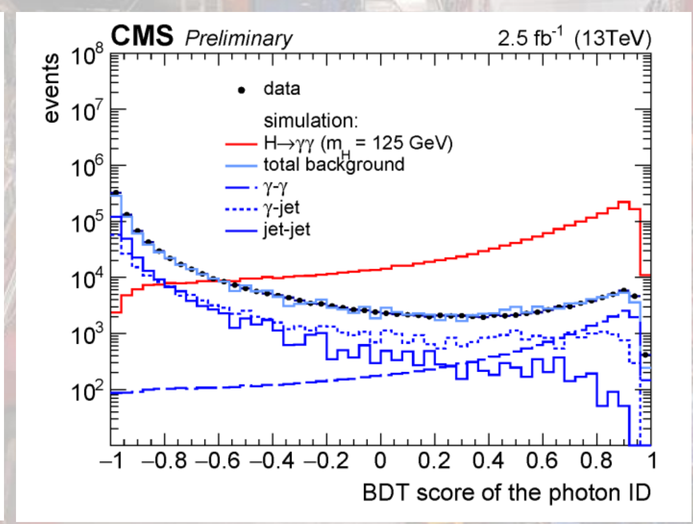
ttH production is boosted by factor x4 →

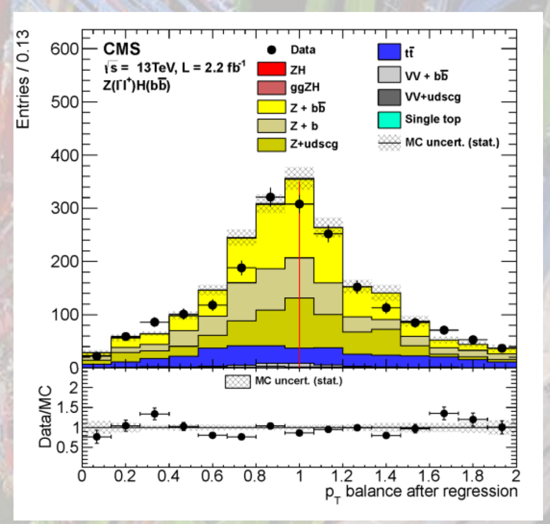
Going after H→bb observation soon

Preliminary studies of analysis-level inputs, control regions, measurements of trigger, ID, selection efficiencies in kinematic regions relevant for Higgs physics

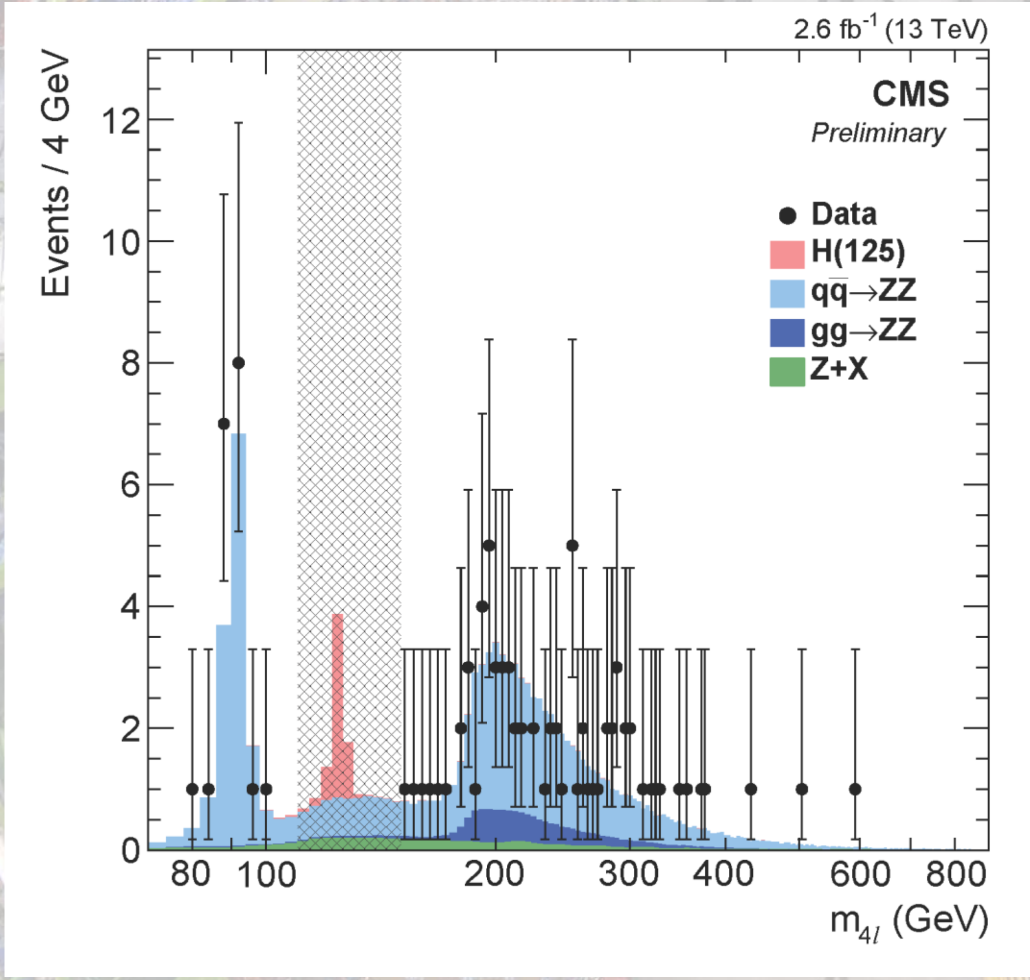
The new energy and running conditions impose reoptimization and retuning → preliminary studies done with few /fb of data, ready for opening the box (so far signal regions kept blinded to avoid biasing ourselves)



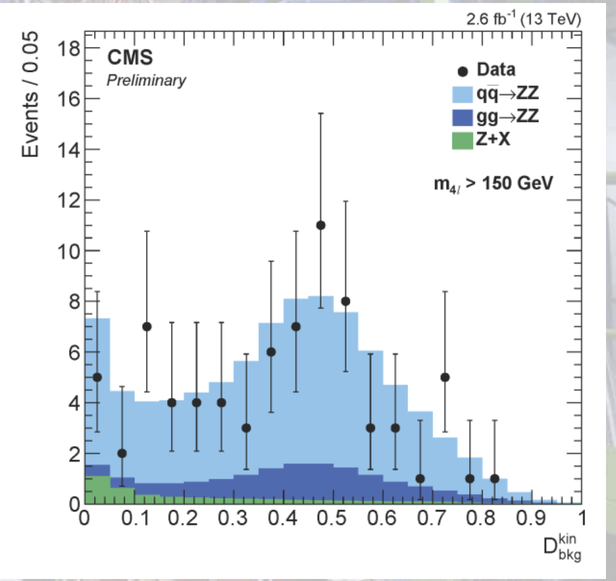




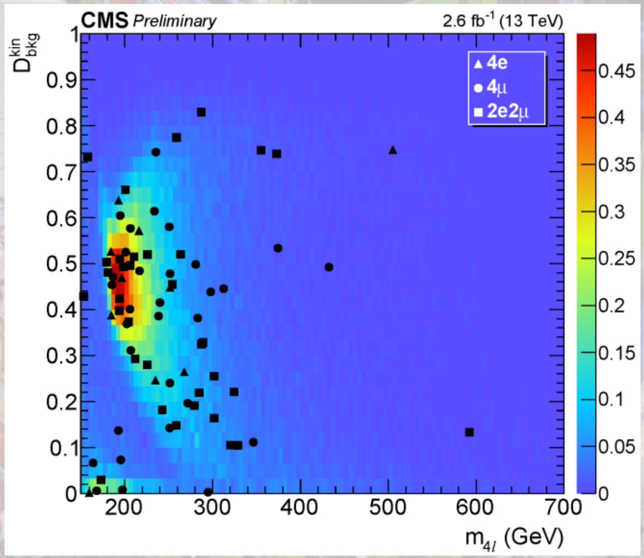
Higgs studies: ZZ(4l)



Kinematic discriminant for m_{4l} > 150 GeV



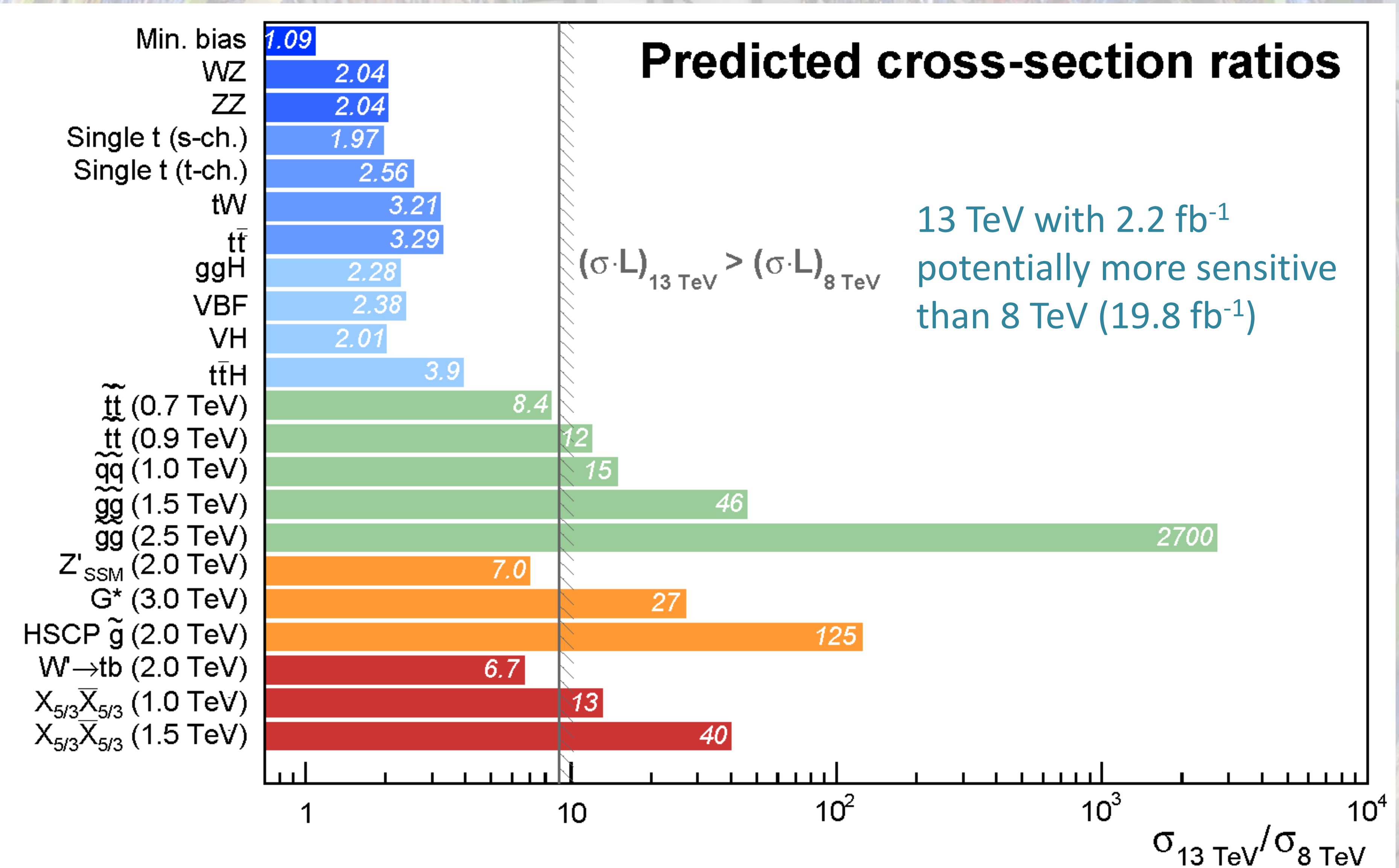
Discriminant vs. m_{4l}



Above: m_{4l} mass with Higgs region blinded, using 2.6/fb of 13 TeV data

New Physics Searches

13 TeV: increased reach for high-mass objects

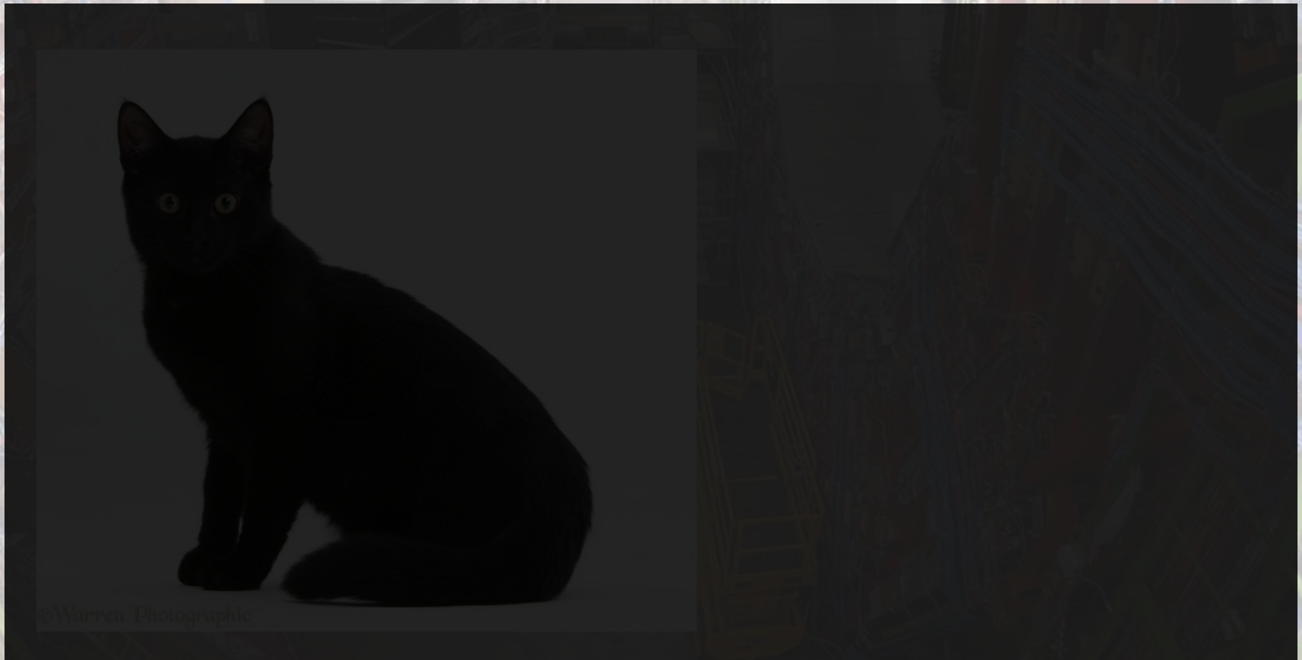


CMS SUSY Searches

CMS is very active in SUSY searches, as we are a bunch of crazy dreamers.
However, we have not found sparticles yet. As a justification I can offer the following:

it is quite hard to find a black cat
in a dark room,
especially if there is no cat

→ We have produced only a string of lower limits on particle masses so far.
Still, it is an exciting business - but there is no time to cover the topic here.
Only flashing a couple of results in the next few slides – a check of an interesting excess of Run 1, and a summary of gluino searches



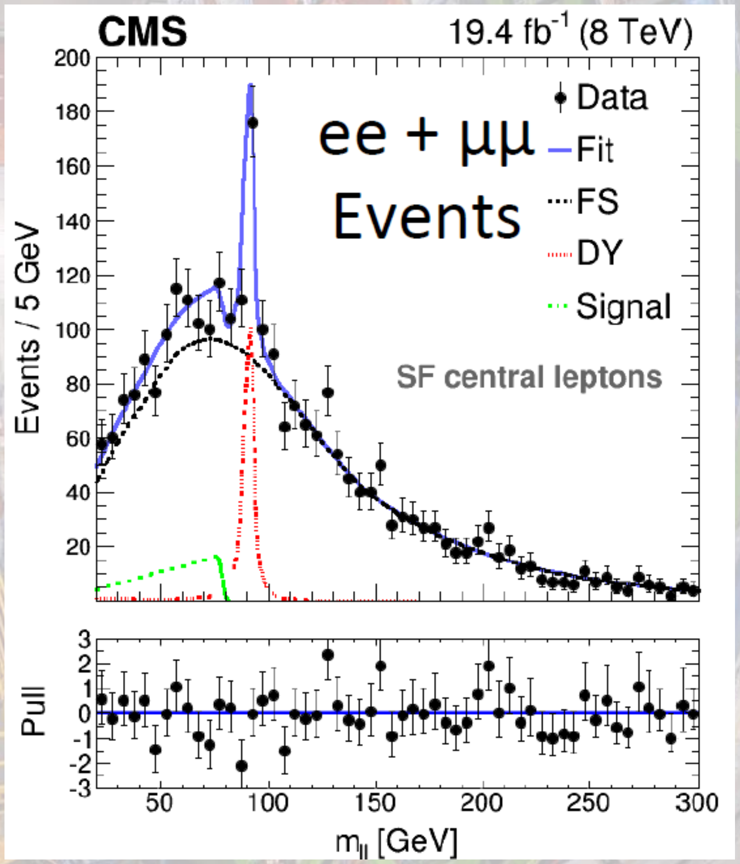
SUSY in opposite-sign dileptons

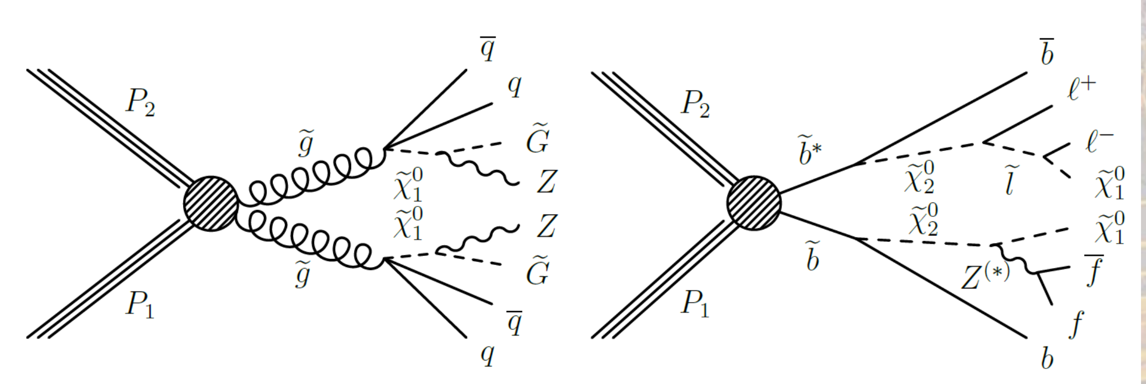
The Run 1 analyses of this channel revealed some deviations from SM backgrounds

With off-Z-peak lepton pairs CMS saw a 2.6σ excess in Run 1, but no similar excess was seen in ATLAS data

OTOH, In Z-like events ATLAS observed a 3.0σ excess in the high-H_T region, while CMS saw no excess

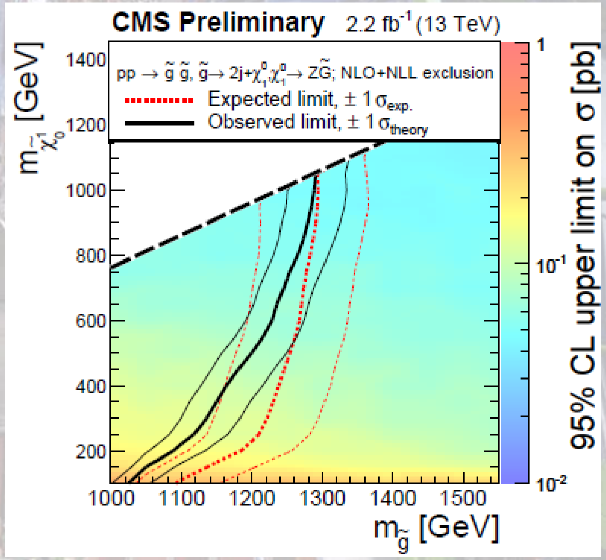
Run 2 data was needed to clarify the situation !

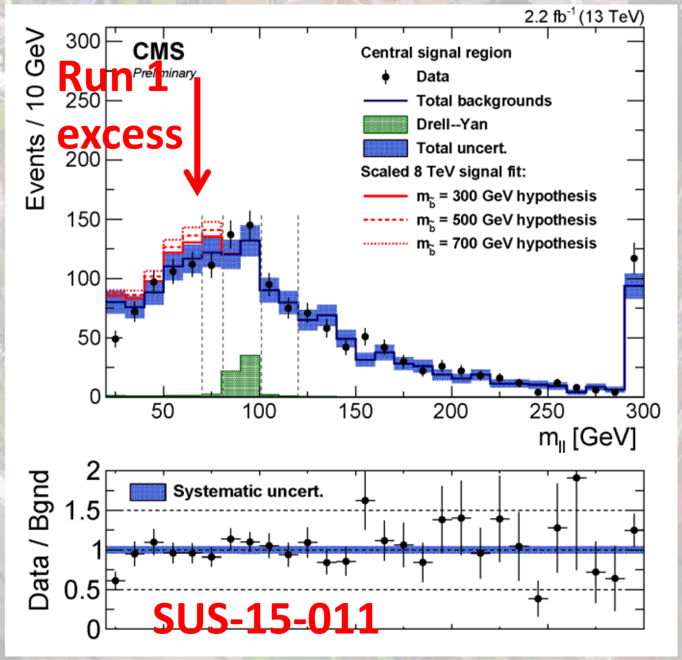




Opposite-sign dileptons at 13 TeV

- The search has been repeated using 2.2/fb of Run 2 data at 13 TeV
- The off-peak selection is similar to Run 1; the on-peak analysis is divided in 12 search regions, and also includes a region targeting the ATLAS excess
- **No significant signals are observed:**
  - Upper limits are below predicted yields scaling from the Run 1 excesses

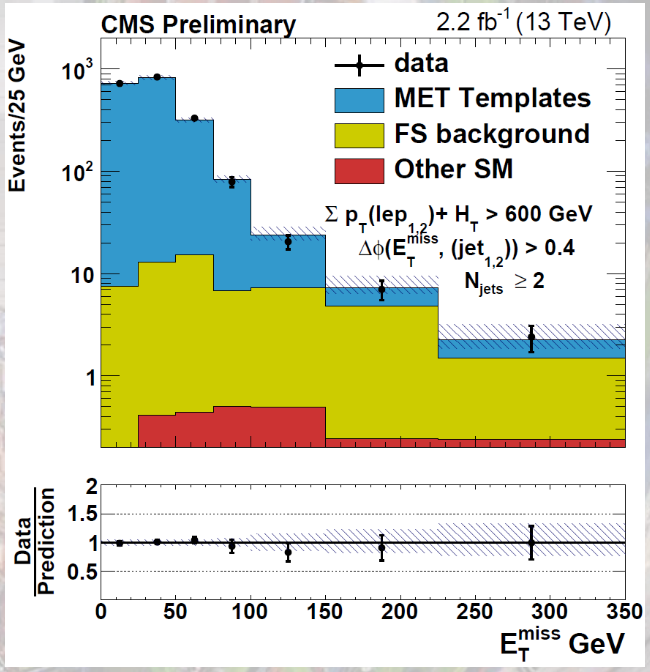




Left: the region where CMS saw an off-peak excess in Run 1

Right: the search region targeting the Run 1 ATLAS excess

→ As ATLAS continues to see it, something is fishy



Gluino searches: overview

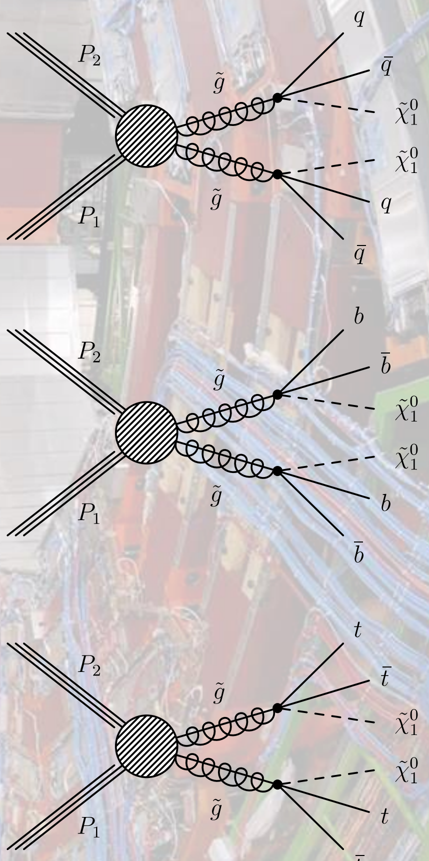
Multiple complementary final states and approaches have been investigated:

- 0 leptons
  - MH$_T$, H$_T$ (SUS-15-002)
  - MT2 (SUS-15-003)
  - Razor (SUS-15-004)
  - α_T (SUS-15-005)
- 1 lepton
  - Sum of jet masses M$_J$ (SUS-15-007)
  - Razor (SUS-15-004)
- Same-sign dilepton (SUS-15-008)
  - Rare SM signature

Run 1: limits range up to ~1.4 TeV

➔Large σ boost at 13 TeV!

- **Inclusive searches benchmarked with simplified models**

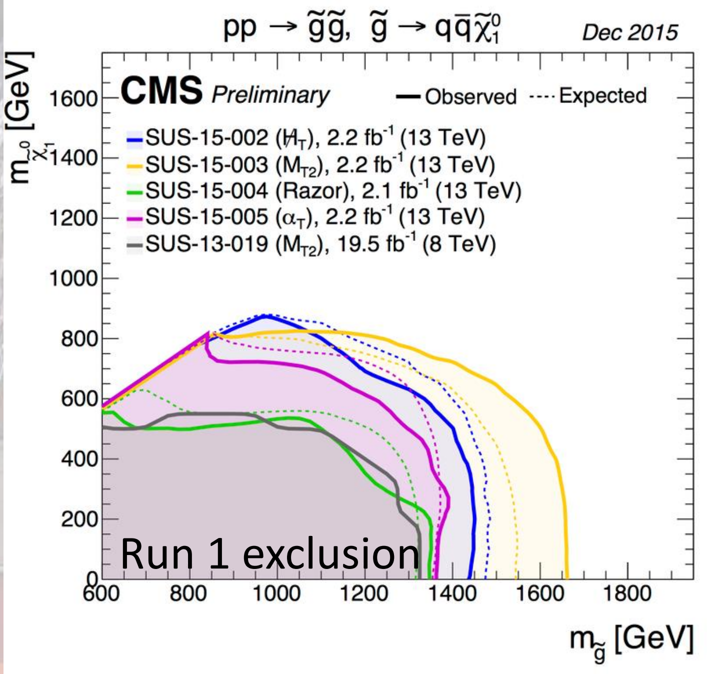


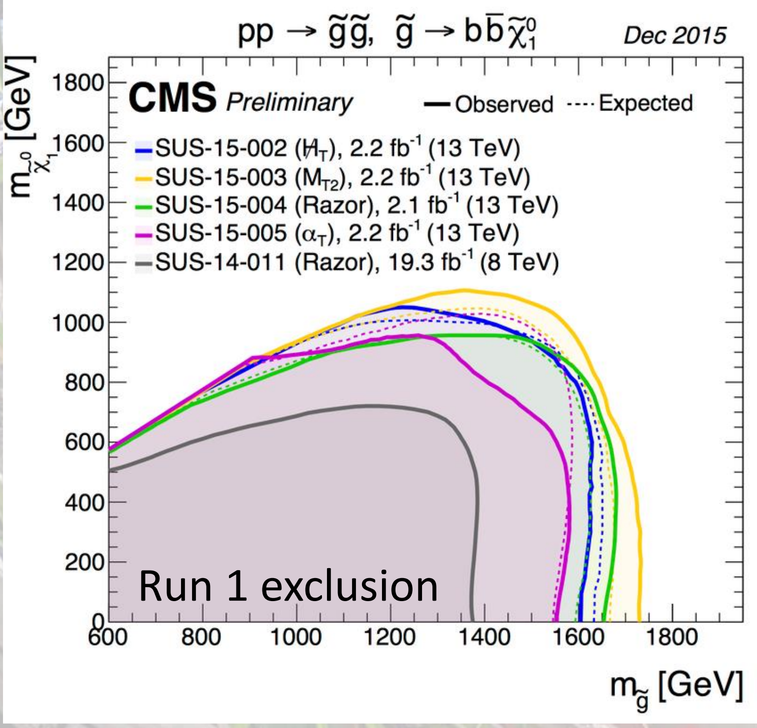
Gluino search results

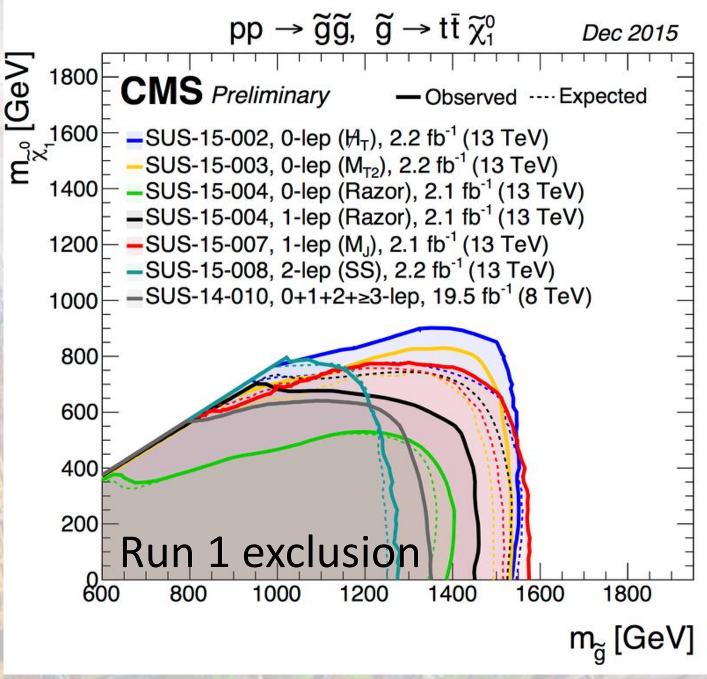
Executive summary: no significant signals observed

Exclusions reach to > 1.7 TeV for simplified models, at low LSP mass

These results significantly exceed Run 1 limits thanks to the sqrt(s) increase







Going deeper into the implausible

If your trust that the LHC *will* find new physics is strong, you certainly approve to casting the net in the open sea even without a real idea of what fish you could be catching, nor a gauge to assess critically the results

The attitude of taking any departure from model predictions as a potential signal of new physics is not dangerous *per se*, but it can divert the attention from more principled searches and studies – one example is given later

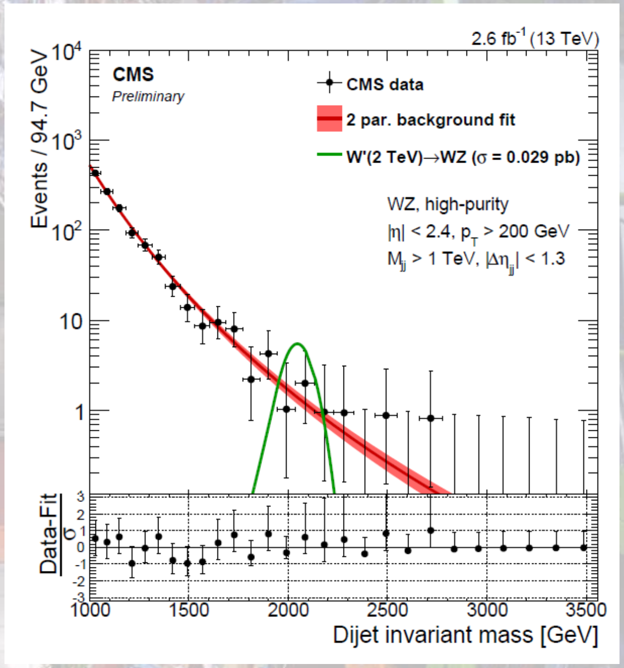
I believe we also need to explain to the users of our physics results that a "global p-value" is still **not a p-value!**

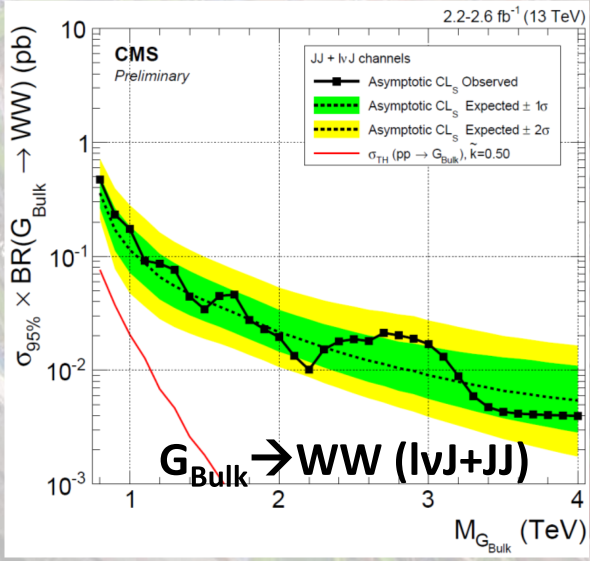
With that in mind, let us give a look at the catch of 2015

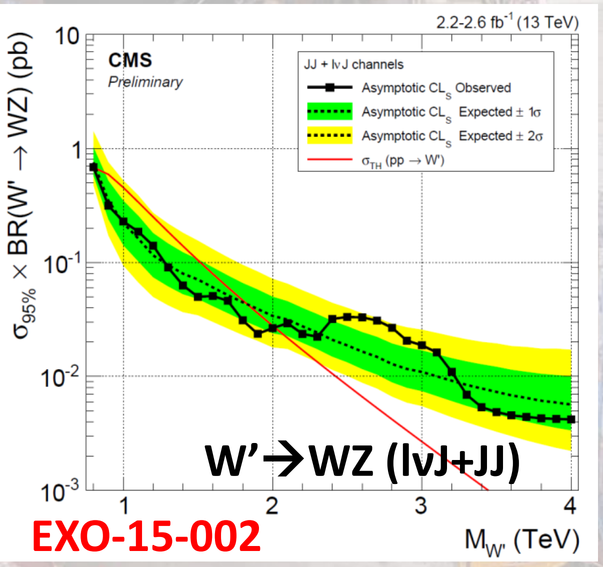
Search for diboson resonances

- In Run 1 CMS saw a ~2σ excess near 1.8-2.0 TeV; ATLAS had a >3 sigma effect in similar mass region
- Repeated search at 13 TeV using most sensitive channels: lνJ, JJ
- Analysis categorized in dijet mass for optimal sensitivity to WW, WZ, ZZ signals
- 13 TeV: *no excess observed in the region of interest* near 2 TeV
  – More data needed to fully exclude Run 1 excess

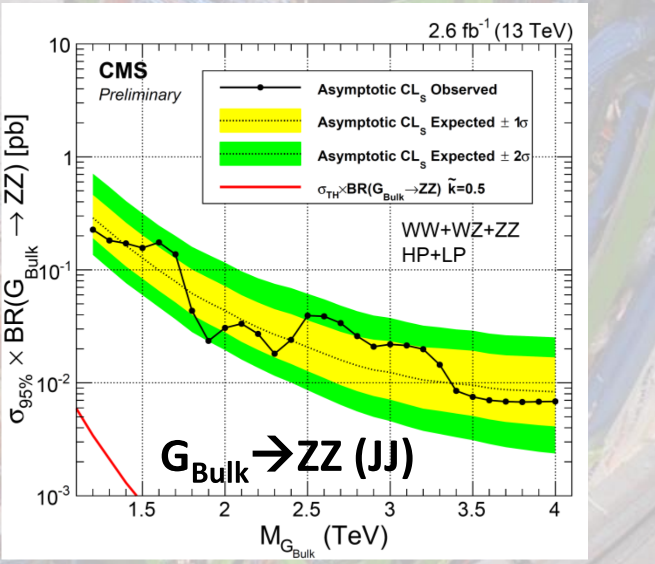
… but of course this is one signal close to be dumped







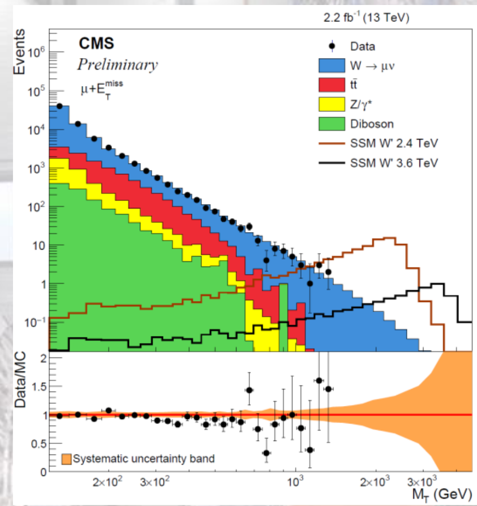
EXO-15-002

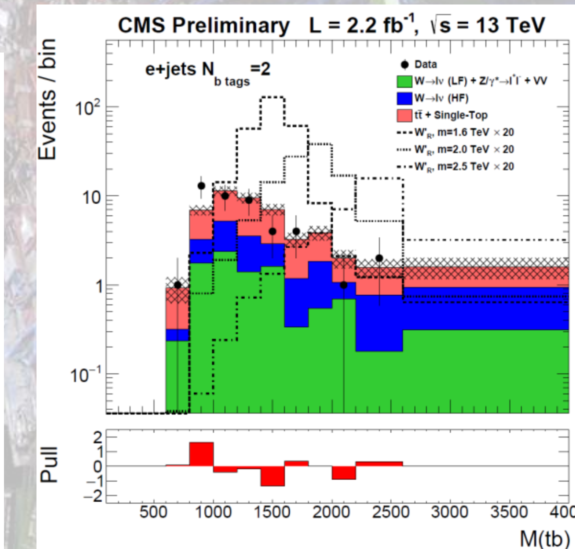


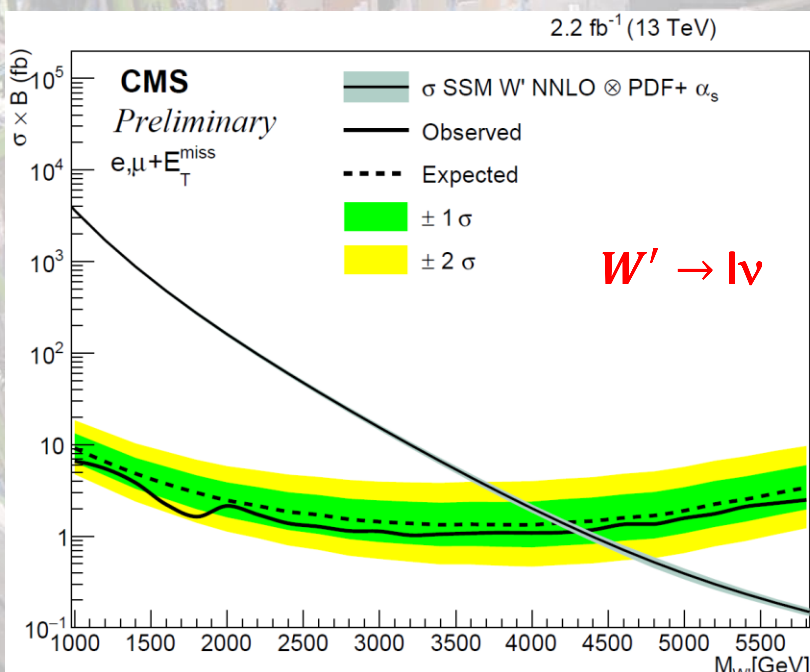
B2G-15-004
EXO-15-006

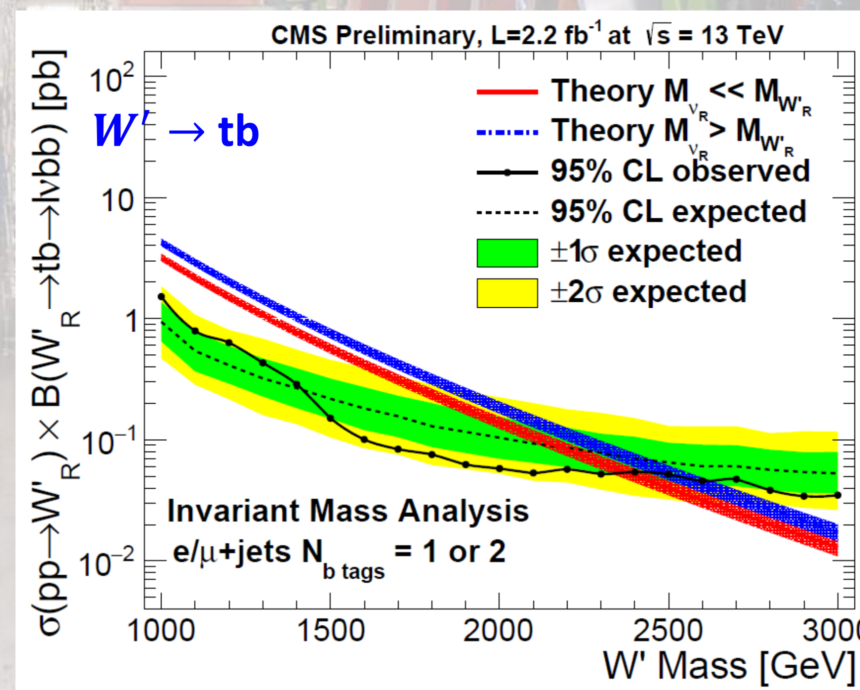
Search for $W' \rightarrow l\nu$ or tb

- A search was done for heavy gauge boson W' decaying to **leptons+missing transverse energy** or **tb** in the lepton+jets channel
- **Mass exclusions: < 4.4 TeV in lep+MET, < 2.38 TeV tb** (Run 1 limits ~2-3 TeV)



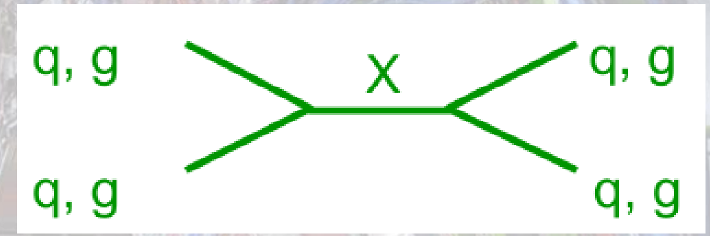


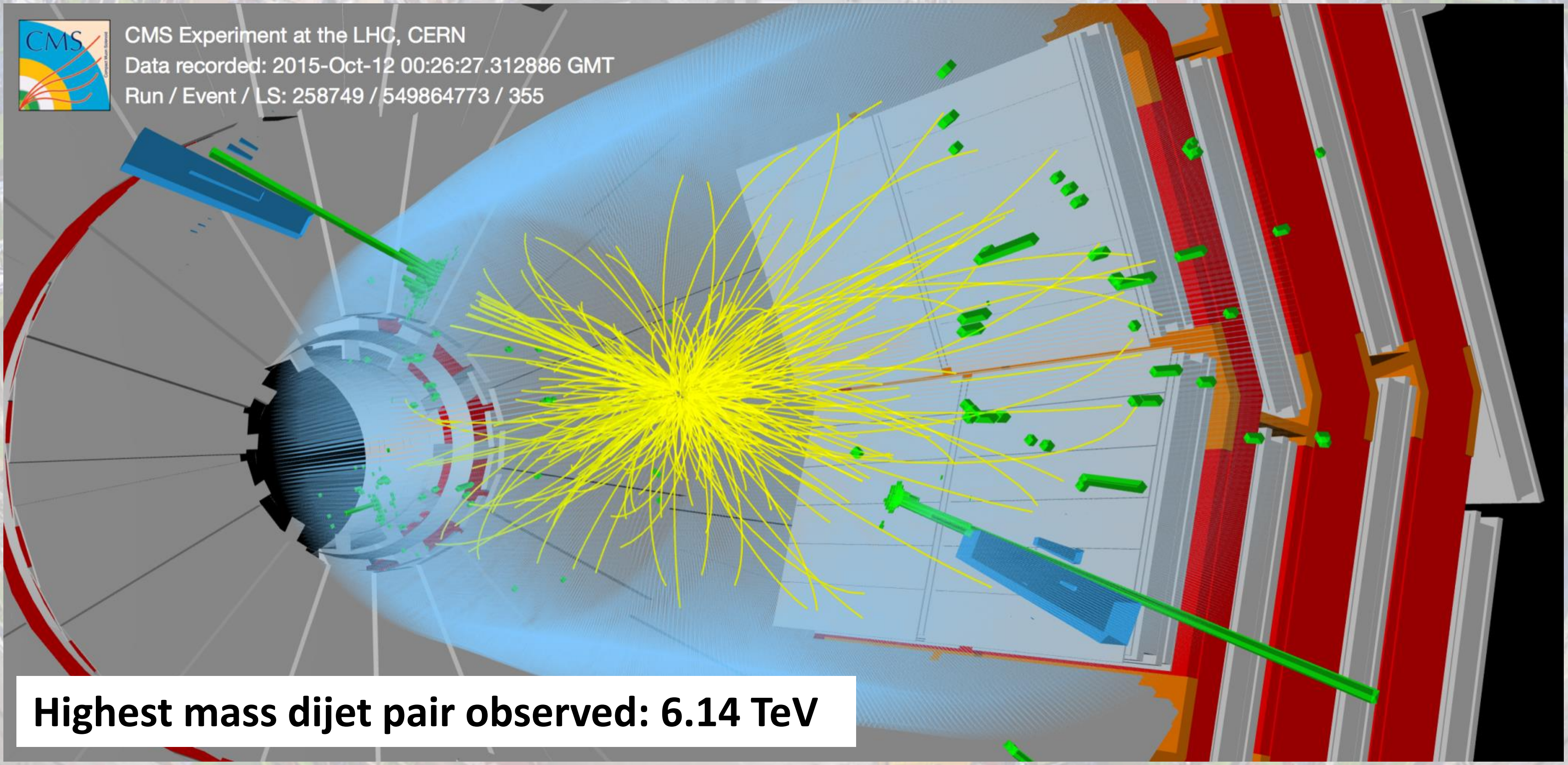




Search for dijet resonances

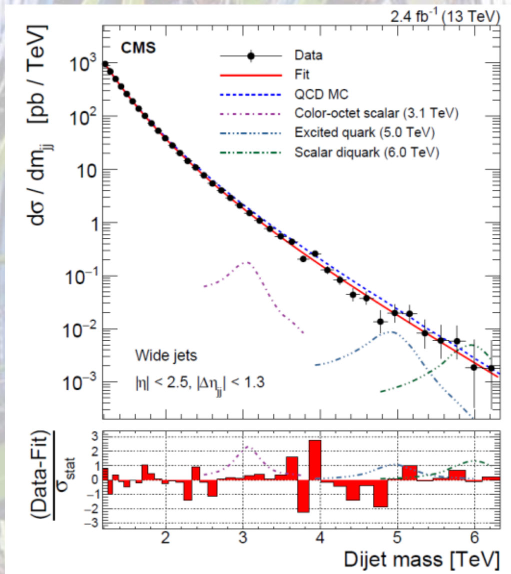
A bump hunt has been carried out on the smoothly falling background of m_{jj}, testing s-channel production of new heavy resonances

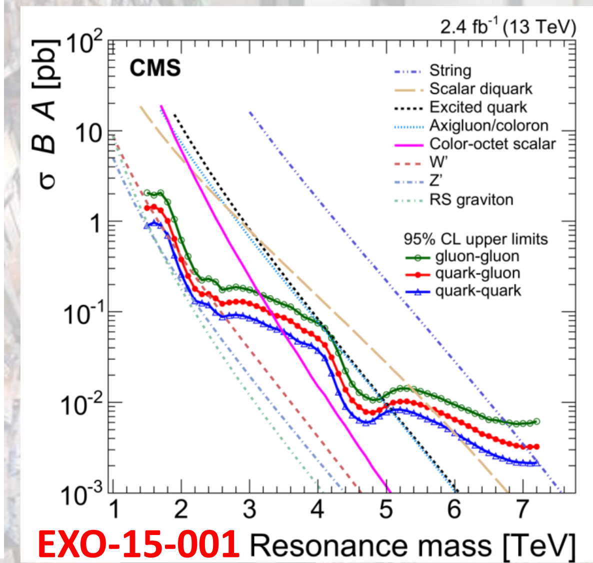




Highest mass dijet pair observed: 6.14 TeV

New physics searches in dijets





CMS searched for new physics in the dijet angular distribution, using

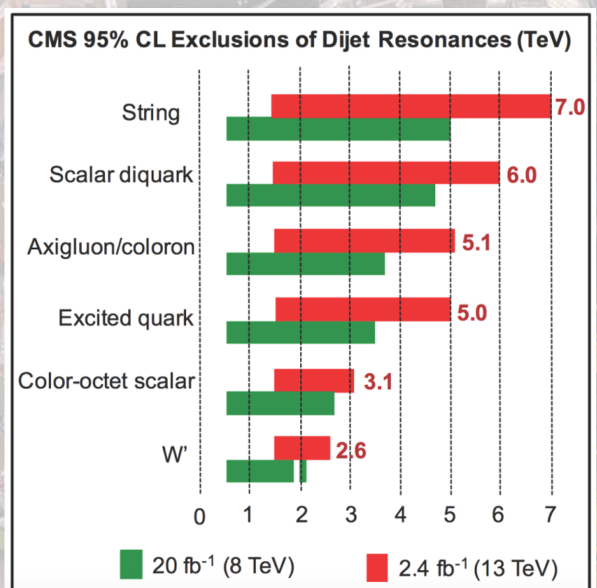
$$\chi_{dijet} = e^{|y_1 - y_2|} \sim \frac{1 + |\cos\theta^*|}{1 - |\cos\theta^*|}$$

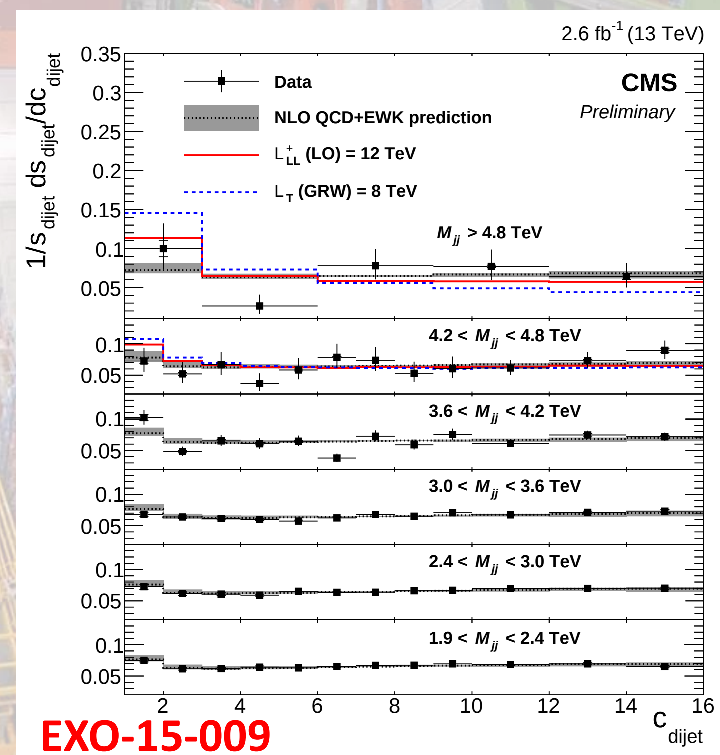
95% CL Limits:

Contact int. Scale Λ: 12.1 – 16.3 TeV

Scale for ADD models: 7.7 – 10.8 TeV

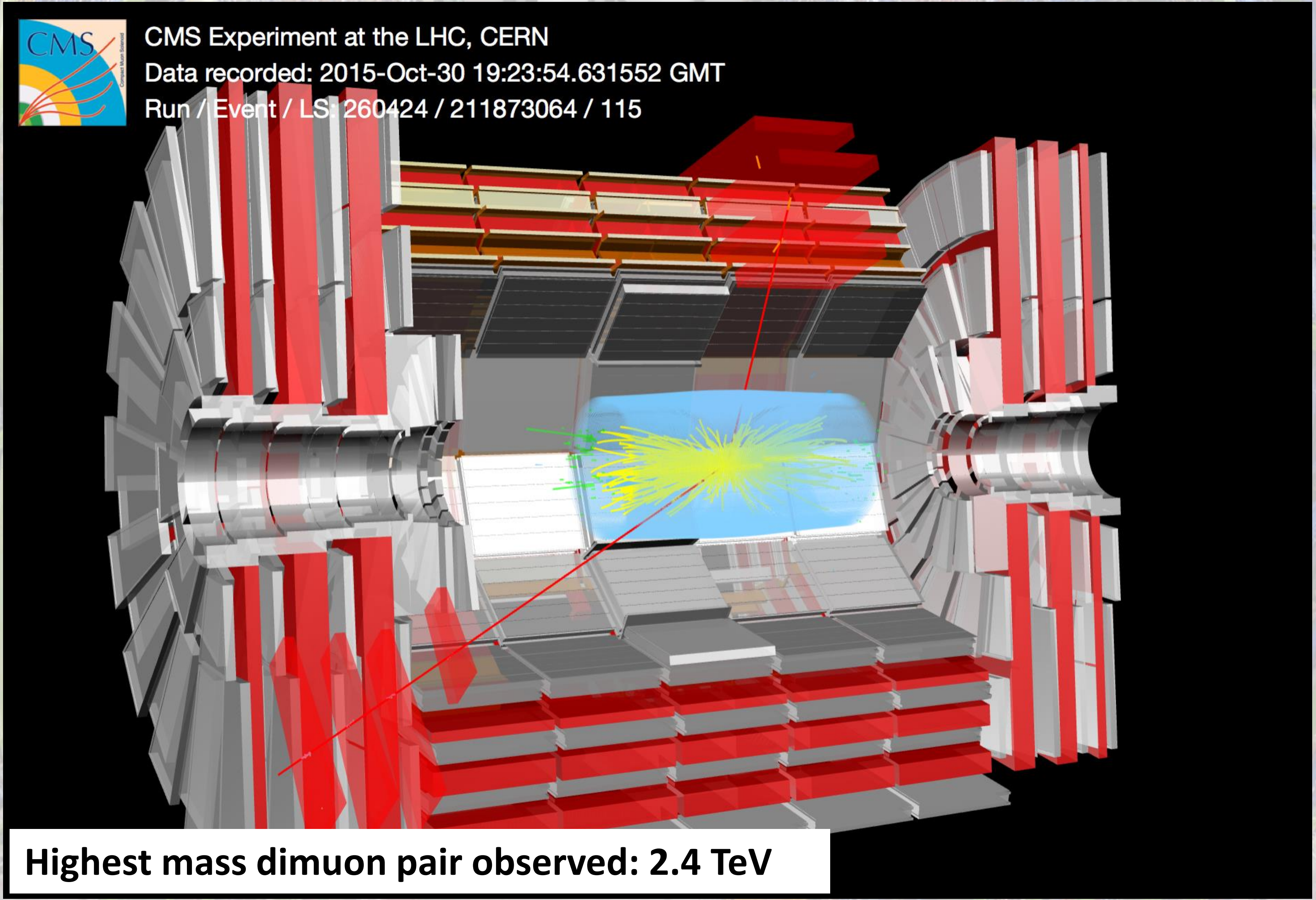
The resonance search finds no significant excess New stringent limits are set on a number of different models





Submitted to PRL, arXiv:1512.01224

Search for dilepton resonances

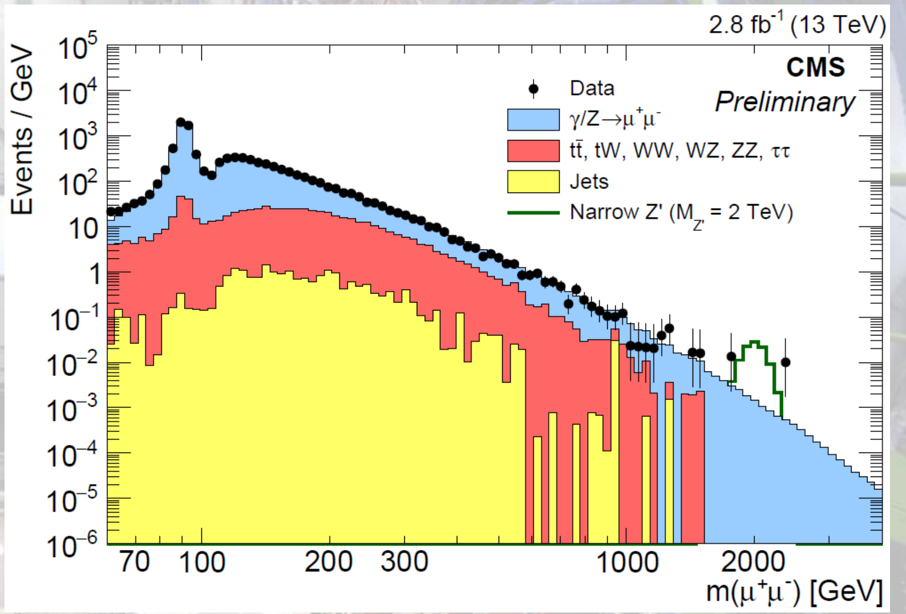


Highest mass dimuon pair observed: 2.4 TeV

Search for dilepton resonances

A search for a localized excess in the mass spectra of muon and electron pairs was carried out

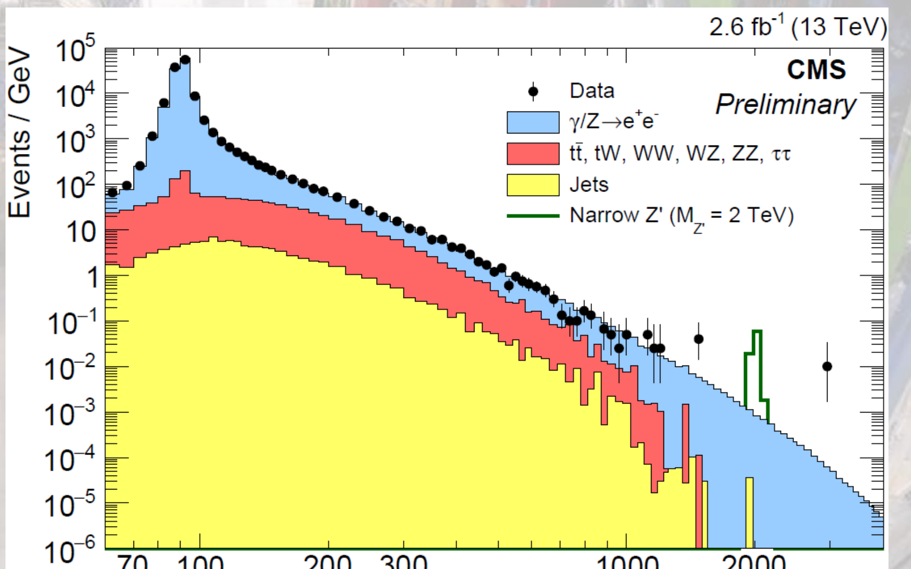
It is a clean signature with very low background at high mass



Highest mass events:

- Muon – 2.4 TeV
- Electron – 2.9 TeV

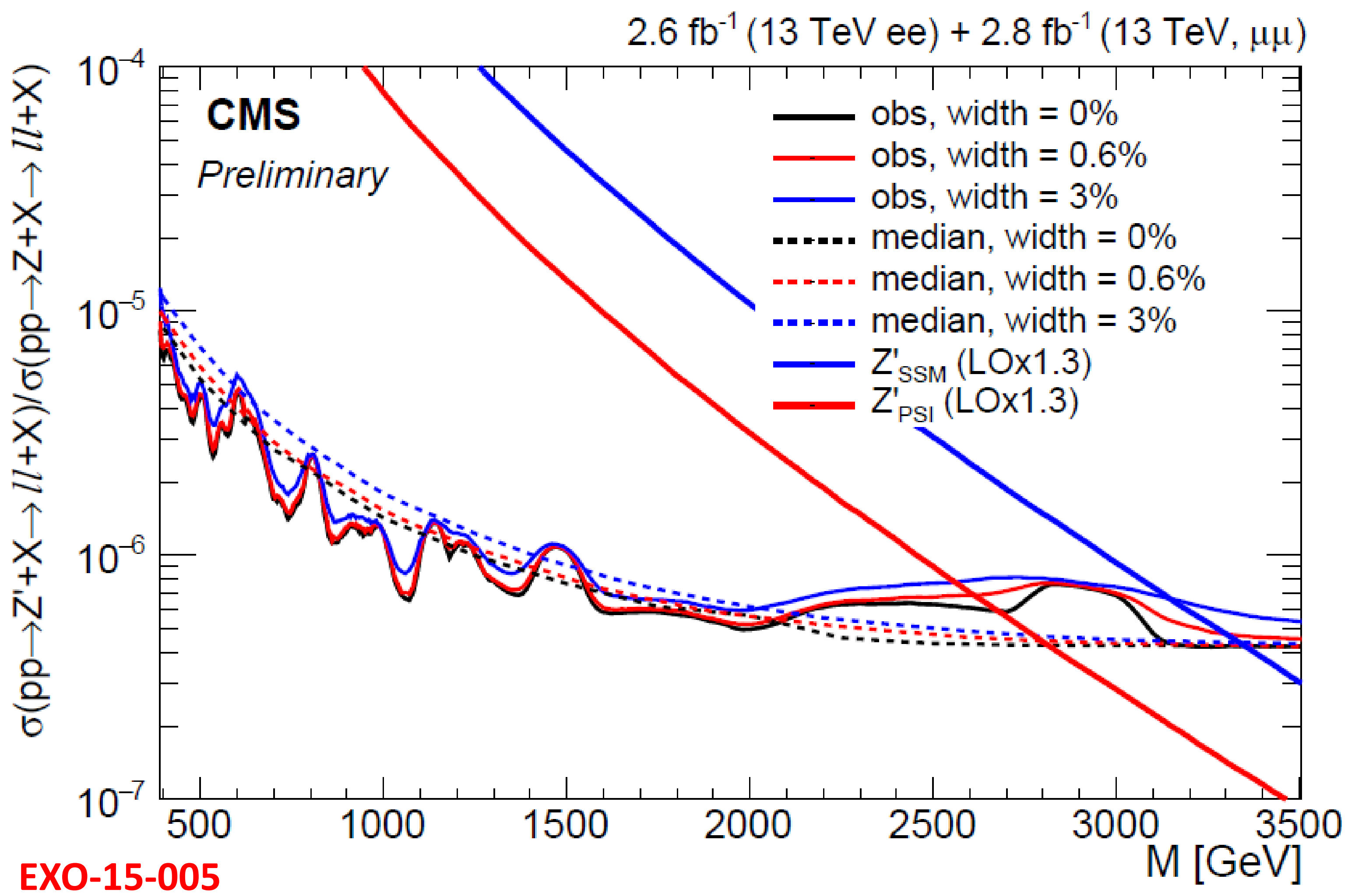
The p-value to observe at least one event with m(ee) > 2.8 TeV is 3.6%



EXO-15-005

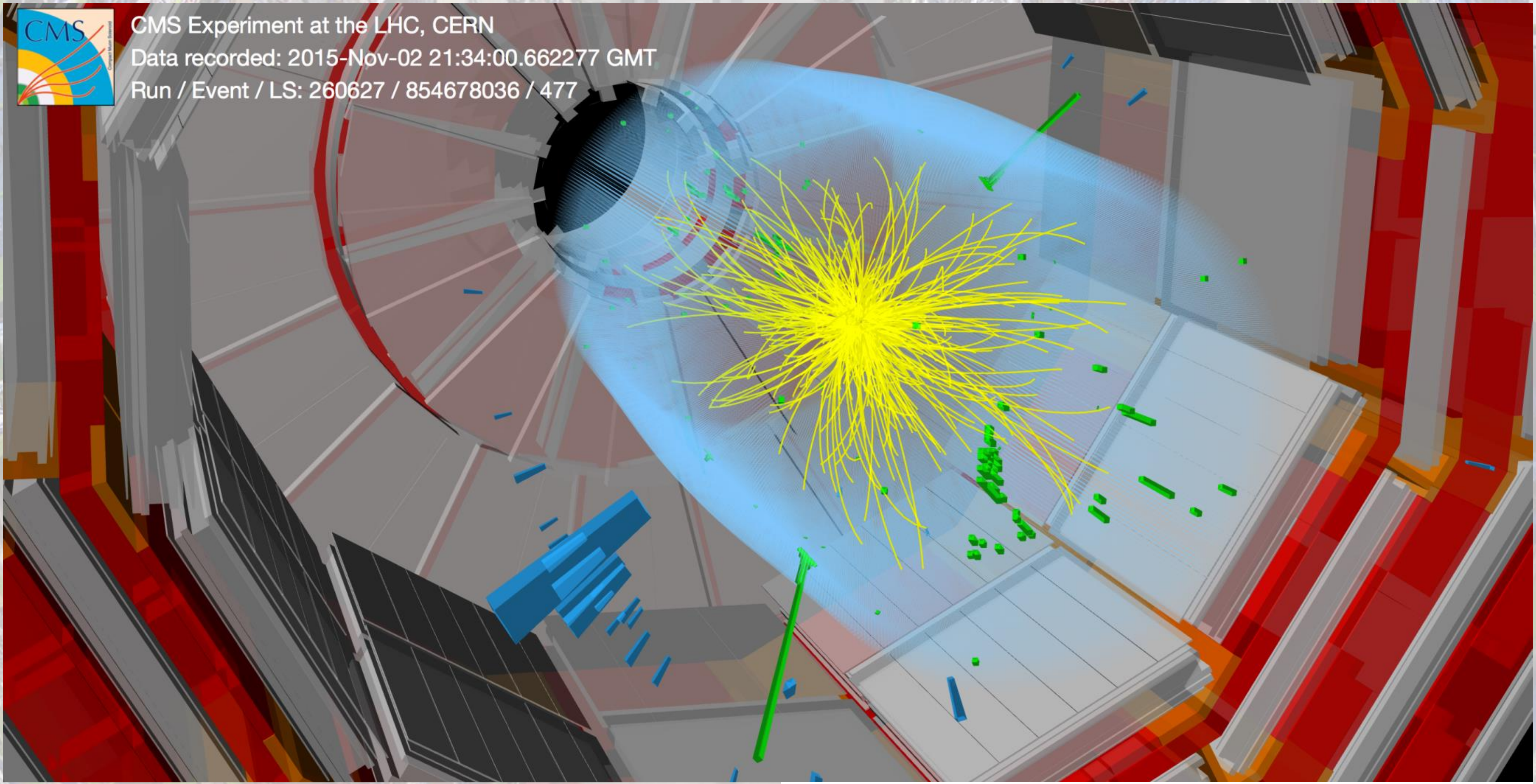
Data are consistent with SM

Limits on dilepton resonances



Combined Mass limits: > 2.60 TeV for Z'(ψ), 3.15 TeV for Z'(SSM)

Search for diphoton resonances



Diphoton event with m(γγ) = 745 GeV

Search for diphoton resonances

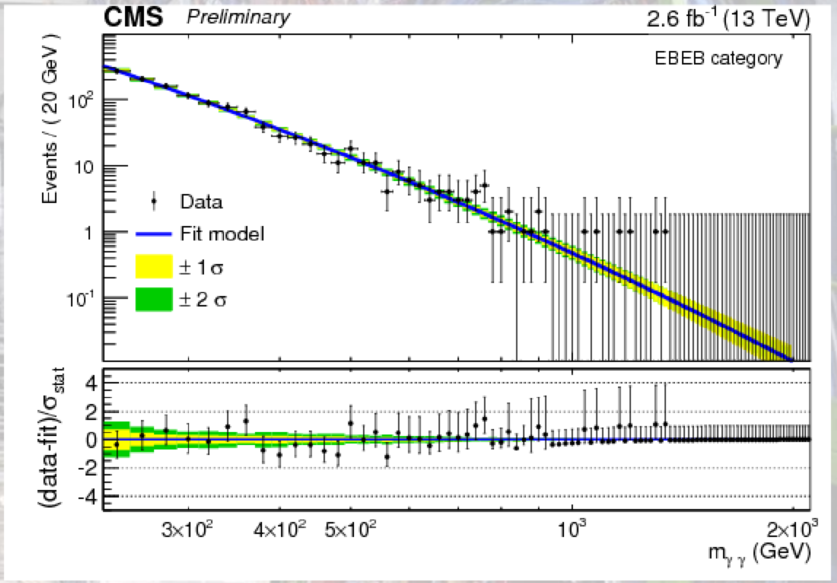
- Two categories: barrel-barrel (EBEB), barrel-endcap (EBEE)
- $p_T^{\gamma} > 75$ GeV, $I_{ch} < 5$ GeV in 0.3 cone around photon direction
- Efficiency, scale and resolution calibrated on $Z \to ee$ and high-mass DY events
- Search for RS graviton with three assumptions on coupling:

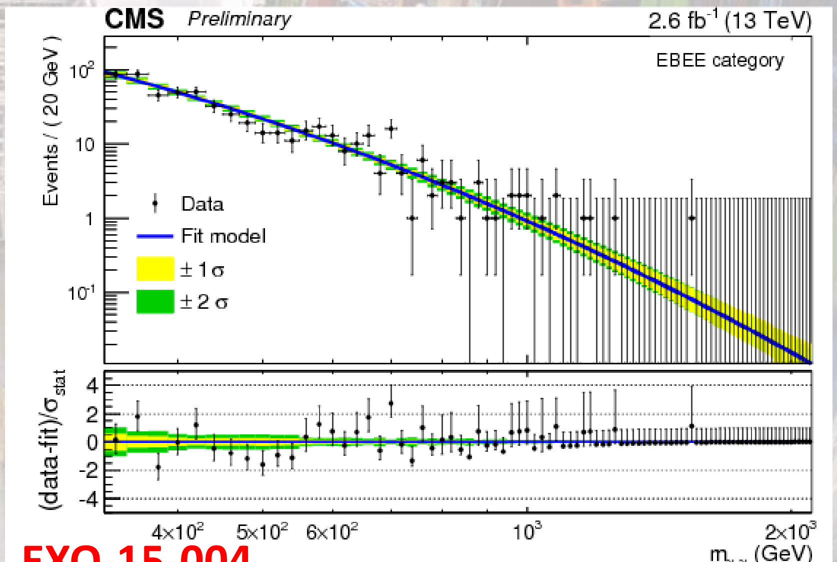
  $\tilde{k} = 0.01$ (narrow), 0.1, 0.2 (wide)

CMS performed this as a blind analysis

No changes have been made since unblinding the data

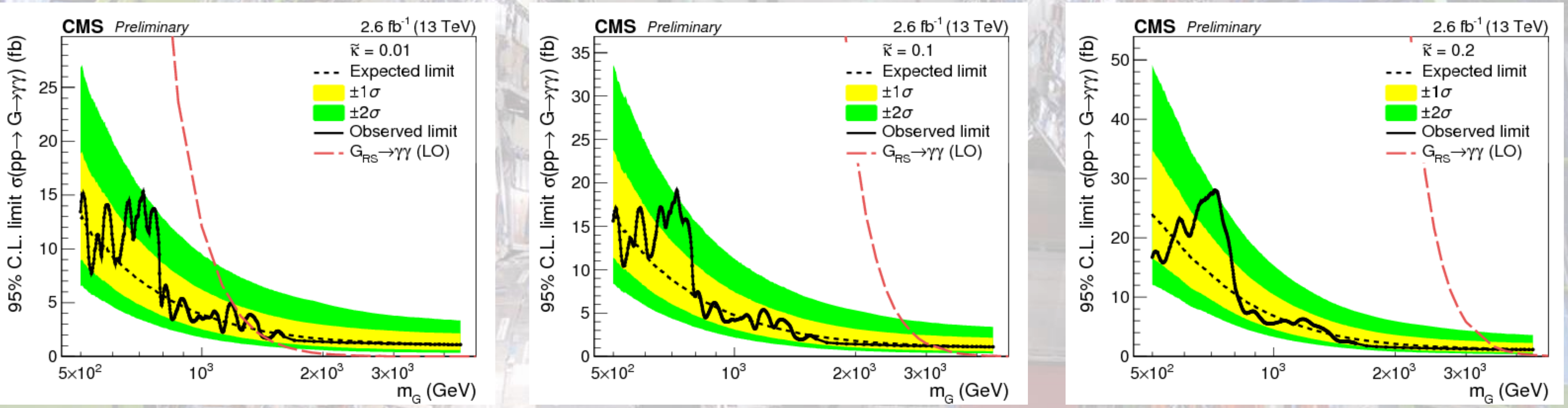
- Beware of post-unblinding procedures…



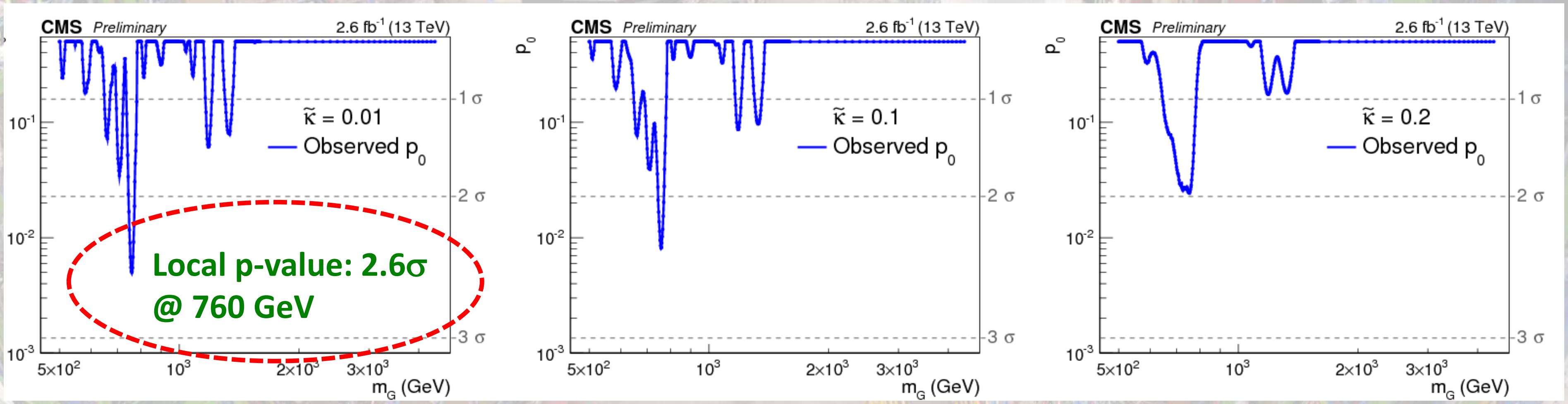


EXO-15-004

Combined limits and p-values



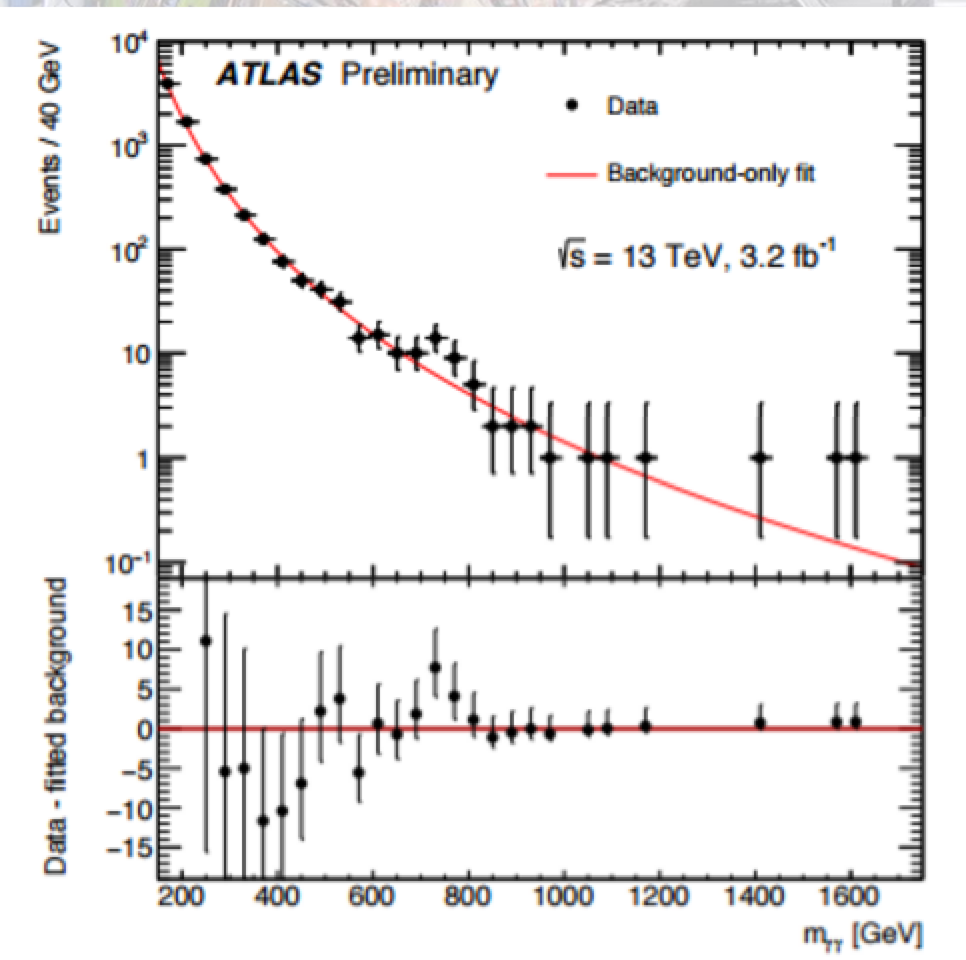
Narrow Width → **Wide (6%) Width**

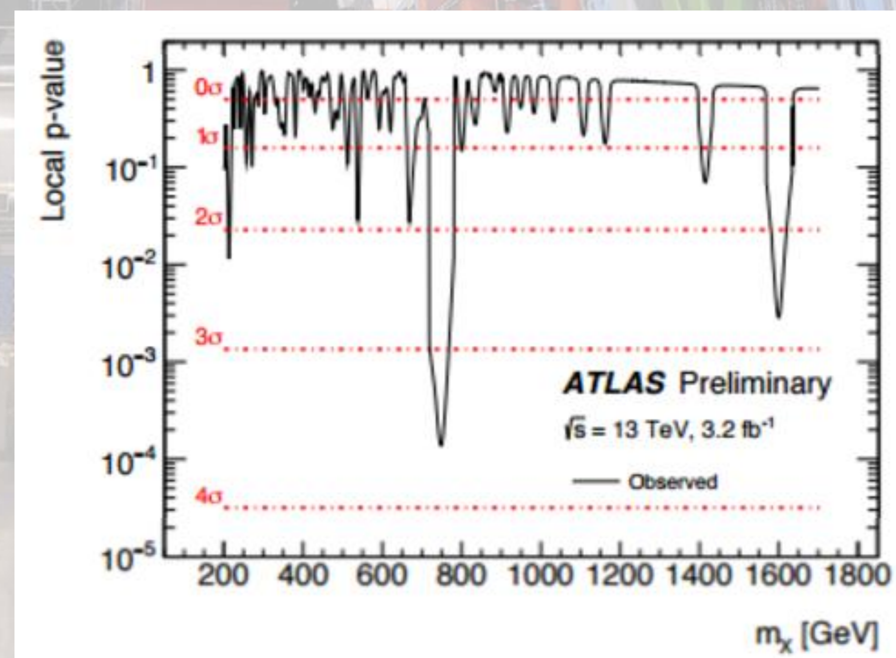


Including LEE (0.5 - 4.5 TeV; narrow width), global p-value < 1.2σ

What does ATLAS see ?

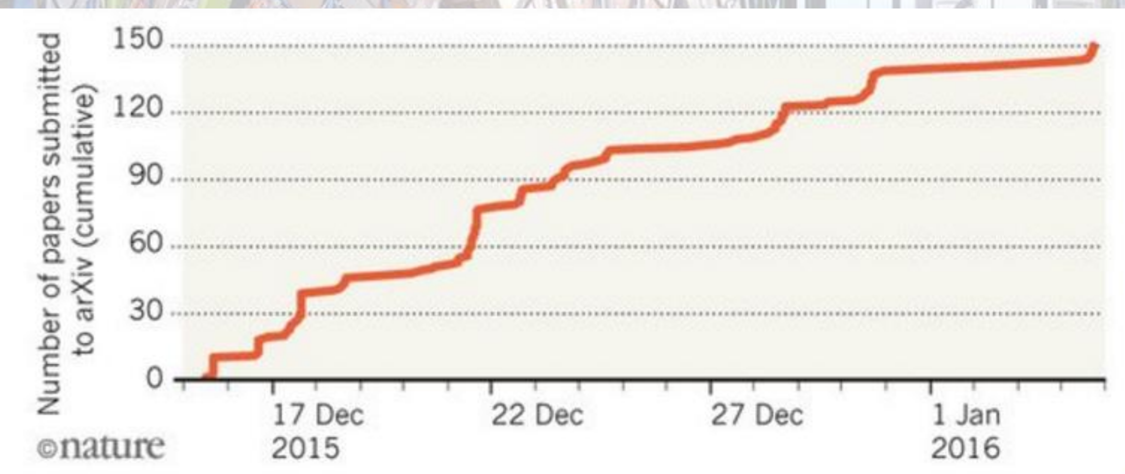
Indeed, the LHC new particle search is a two-player game. The interest of the CMS diphoton excess would be minor, were it not for the fact that ATLAS also sees a significant bump…





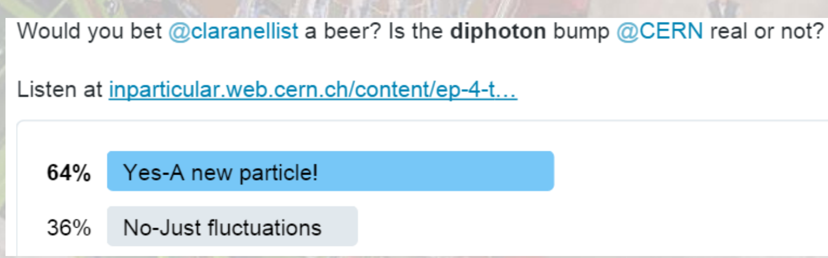
The pheno feeding frenzy

Since December 15th the Cornell arxiv got flooded with **150 new papers** that try to explain the diphoton excesses of ATLAS and CMS



Bets have been offered and accepted on the nature of the new particle, with various odds

Twitter already has its verdict:



Some of the proposed explanations:

Two higgs doublets
Seesaw vectorlike fermions
Closed strings
Neutrino-catalyzed
Indirect signature of DM
Colorful resonances
Resonant sneutrino
SU(5) GUT
Inert scalar multiplet
Trinification
Dark left-right model
Vector leptoquarks
D3-brane
Deflected-anomaly SUSY breaking
Radion candidate
Squarkonium-Diquarkonium
R-parity violating SUSY
Gravitons in multi-warped scenario

750 GeV bump: In summary…

1 - It is quicker to say what the 750 GeV bump cannot be:

Not the Lochness monster, which has an evident 3-bump structure

Not Mickey Mouse, who clearly has a non-Gaussian tail

2 – The signal is clearly inspiring the creativity of theorists.

The three best article titles so far are:

3rd place "**The 750 GeV Diphoton Excess May Not Imply a 750 GeV Resonance**"

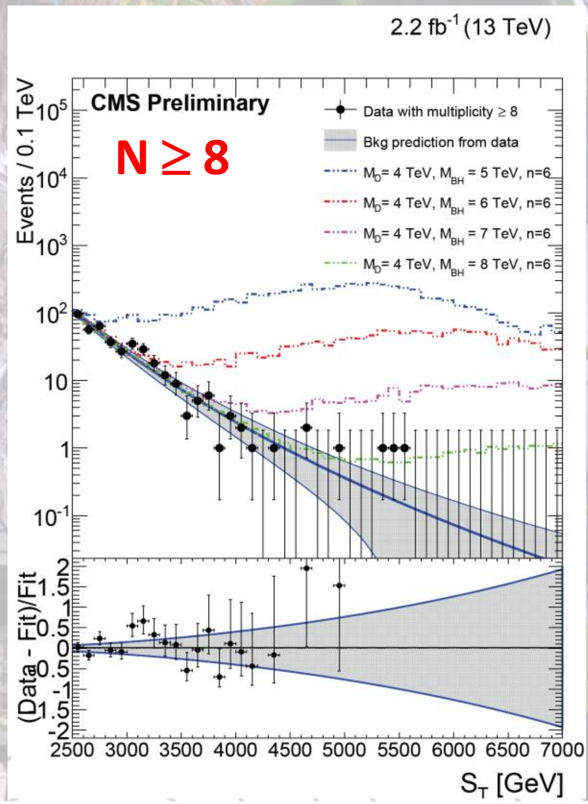
2nd place "**Running After Diphoton**"

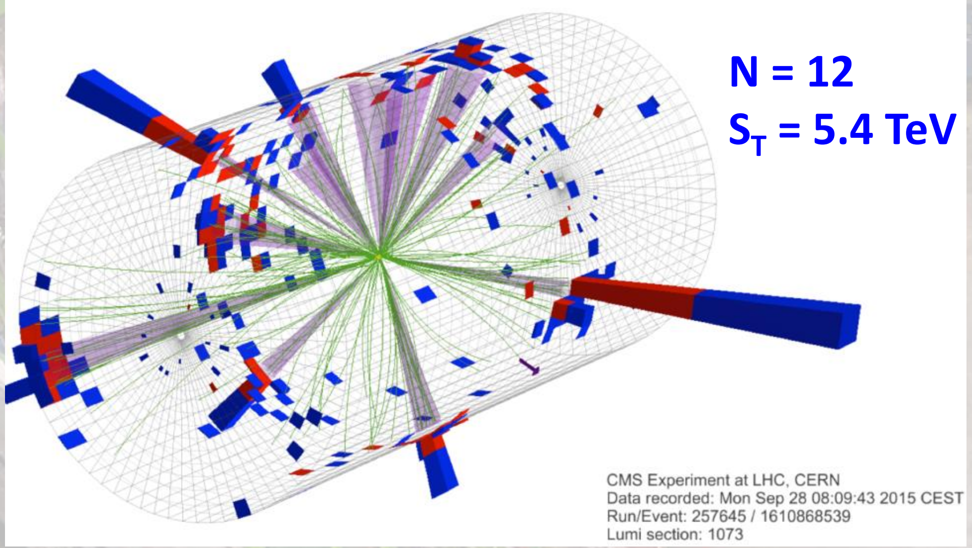
And the winner is … "**How the gamma-gamma Resonance Stole Christmas**"

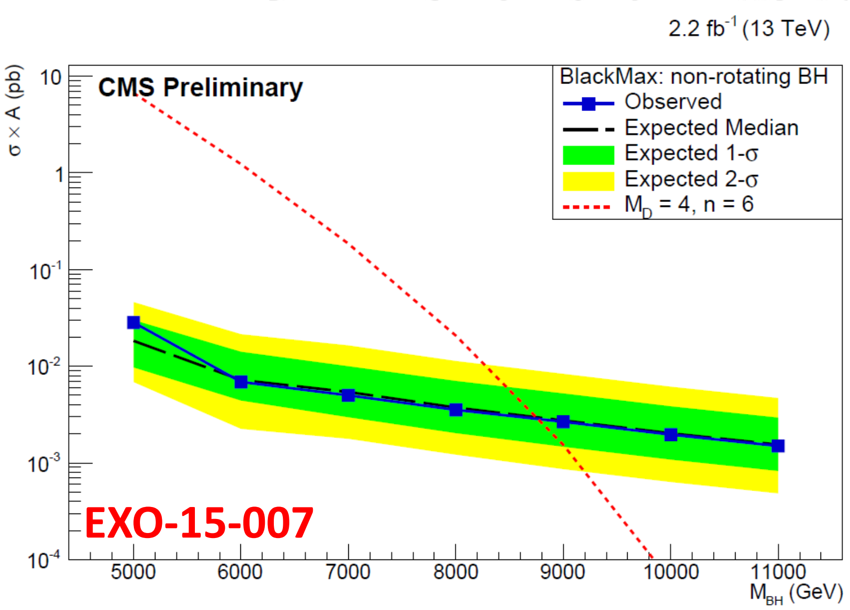
Search for black holes

- Production of microscopic BH is predicted in ADD model when apparent Planck mass in 4D is small. Semi-classical BH (M>MD) produce many objects, quantum BH can decay with LFV and give rise to varying signatures

- Robust analysis binned in number of objects (jets, leptons, photons) and S_T
- Model-independent limits set as function of (N, S_T), **mass limits are 8 TeV for QBH and 8.7 TeV for semi-classical BH** (Run 1: 5.5-6.0 TeV)

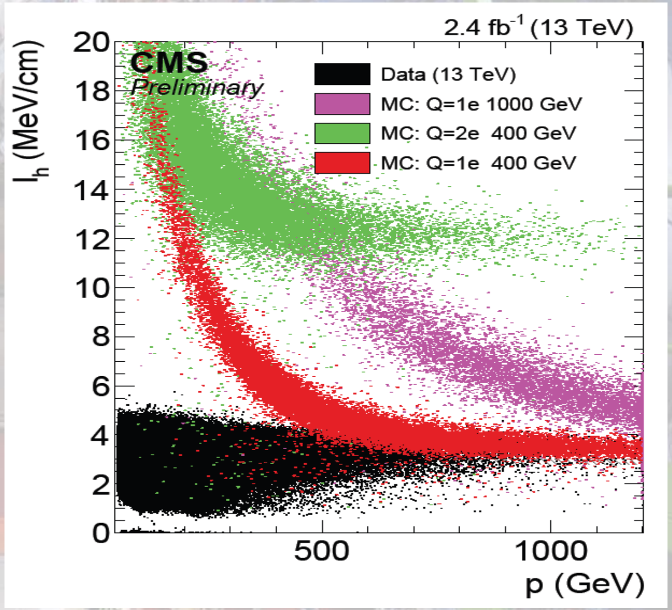


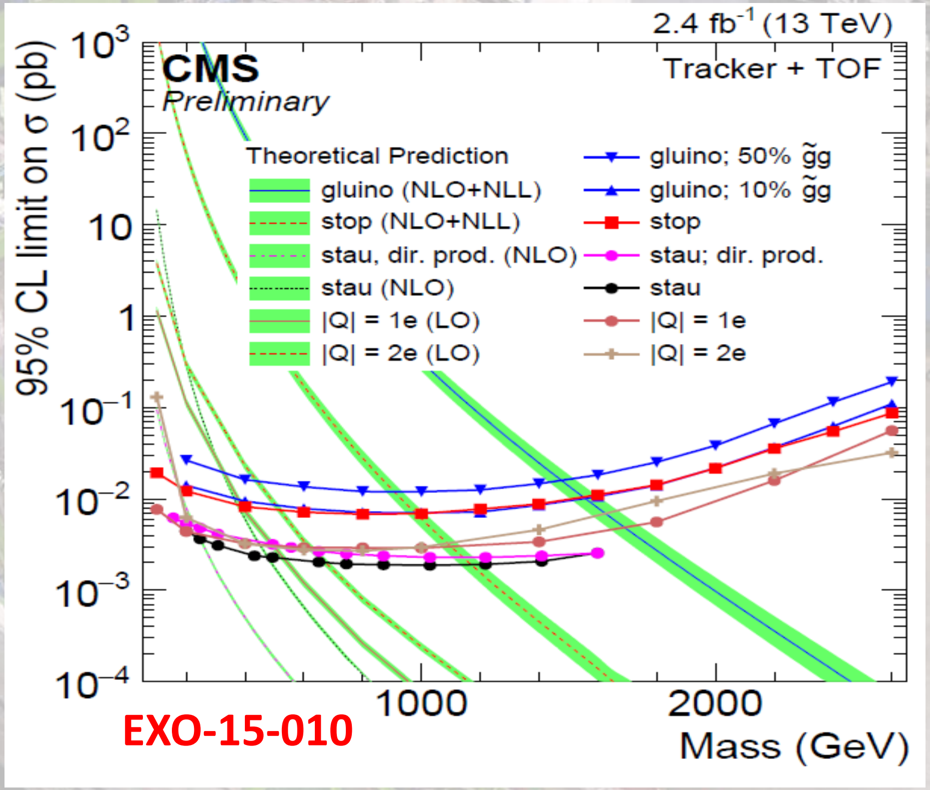


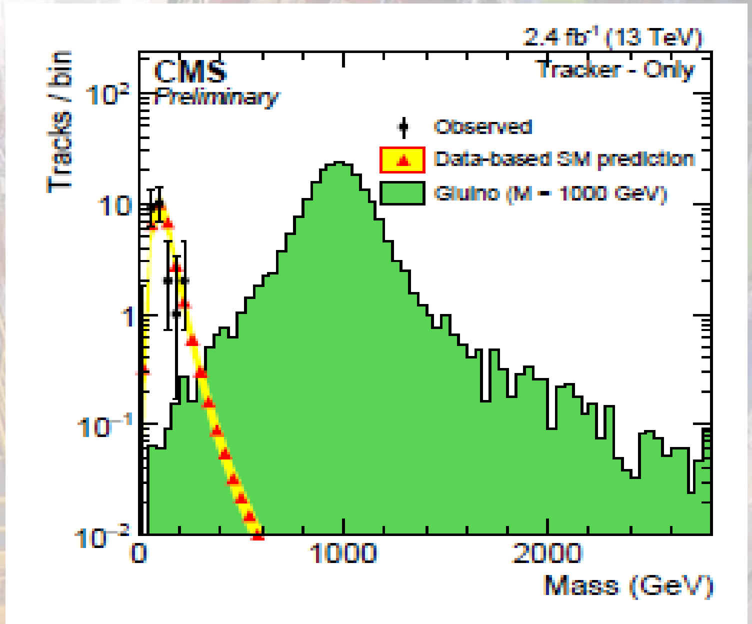


Heavy stable charged particles

- **R-hadrons or stop/stau signals can be sought with a HSCP signature:** tracks with high p_T, high tracker dE/dx, long TOF from IP to muon system
- **Limits on gluino mass > 1.6 TeV (1.3 TeV in Run 1)**



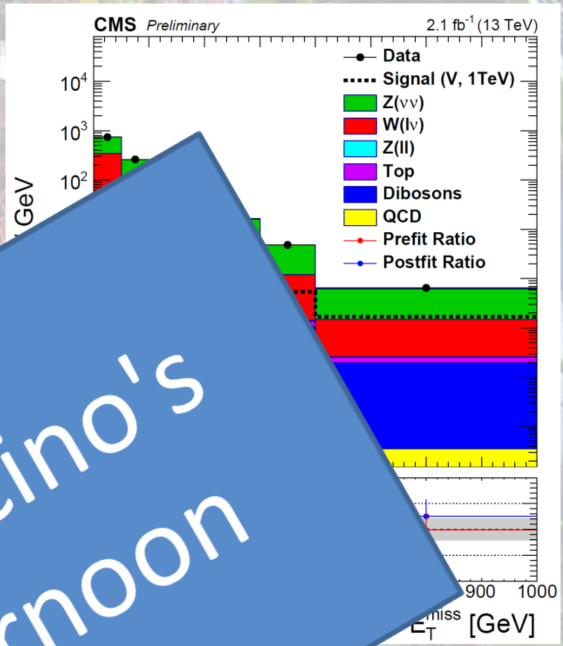


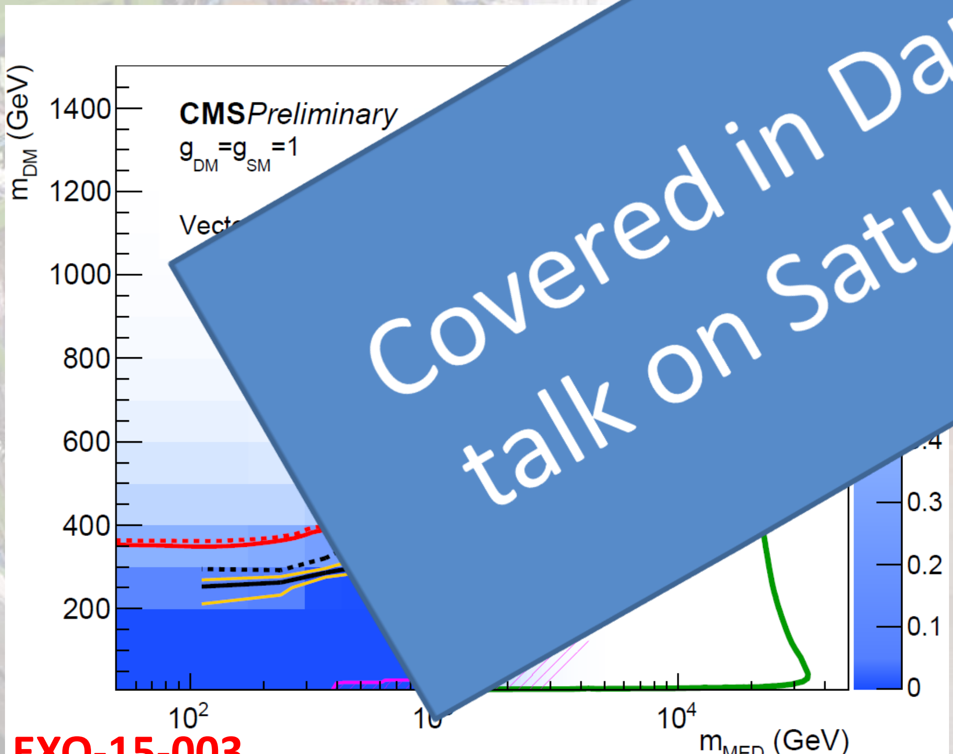


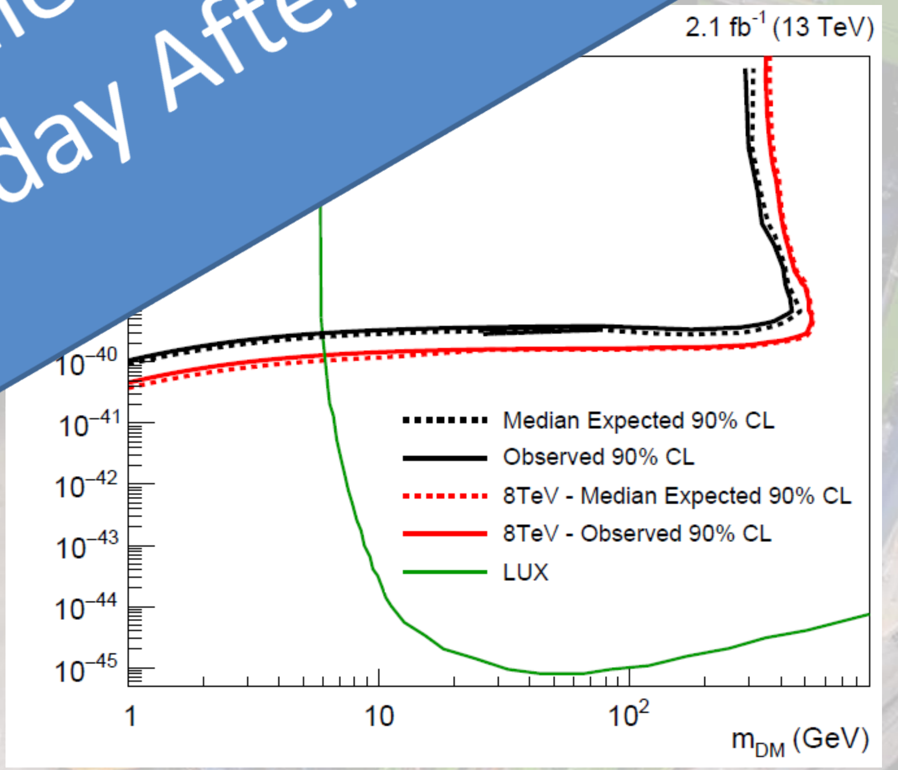
Search for dark matter

- Search for generic dark matter in **final states with jets and large missing transverse energy**
- Traditional monojet search extended to multijet final states, searching for DM pai
produced via a **vector mediator**
- Limits comparable to those set i

Covered in Daniele Trocino's talk on Saturday Afternoon





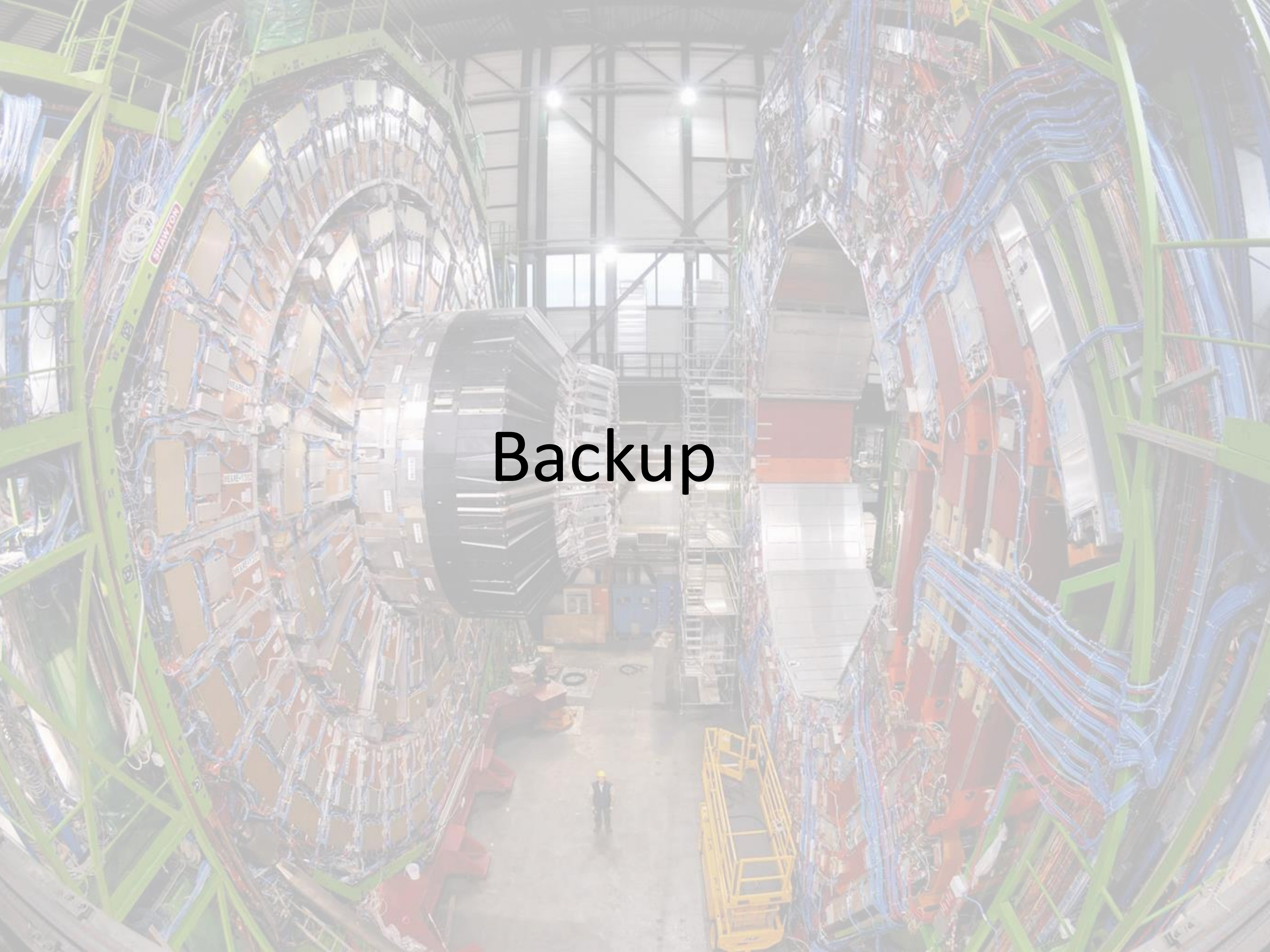


EXO-15-003

Summary and outlook

- Restarted Physics program after long shutdown
  - CMS recorded 90% of delivered pp collisions, 75% @ 3.8 T
  - Physics objects commissioning well advanced to finalized
  - Operation at 25ns and good understanding of data
- CMS has produced 33 results on the analysis of 13 TeV data so far
  - SM measurements confirm theoretical predictions at new energy
  - New Physics searches yielding many improved limits beyond Run 1
    - Disfavoring diboson resonance and dilepton SUSY excesses
  - New not-significant excess in diphoton spectrum
- Looking forward to 2016 for more results and data!

All new results presented here are available at this link:
http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/LHC-Jamboree-2015.html



Backup

How CMS prepared for Run 2

- Main challenge: mitigate the effects of radiation on the performance of the Tracker
  Addressed by equipping it to operate at low temperatures (down to -20°C). Cooling plant and cooling distribution were modified to prevent condensation.

- Planning ahead: Central beampipe was replaced by a narrower one in preparation for the installation in 2016-‘17 of a new Pixel Tracker that will better measure the momenta and points of origin of charged particles.

- Better muon system: A fourth measuring station was added to each muon endcap, in order to maintain discrimination between low-momentum muons and background as the LHC beam intensities increase. This was complemented by two 125-ton shielding at each end of detector, reducing neutron backgrounds.

- Better luminosity measurement: A luminosity-measuring device, the Pixel Luminosity Telescope, was installed on either side of the collision point around the beam-pipe.

- Other improvements:
  - Photo-detectors in the hadron calorimeter were replaced by better-performing designs, moving the muon readout to more accessible locations for maintenance; a first stage of a new hardware triggering system was installed.
  - The software and computing systems underwent a significant overhaul during the shutdown to reduce the time needed to produce analysis datasets.

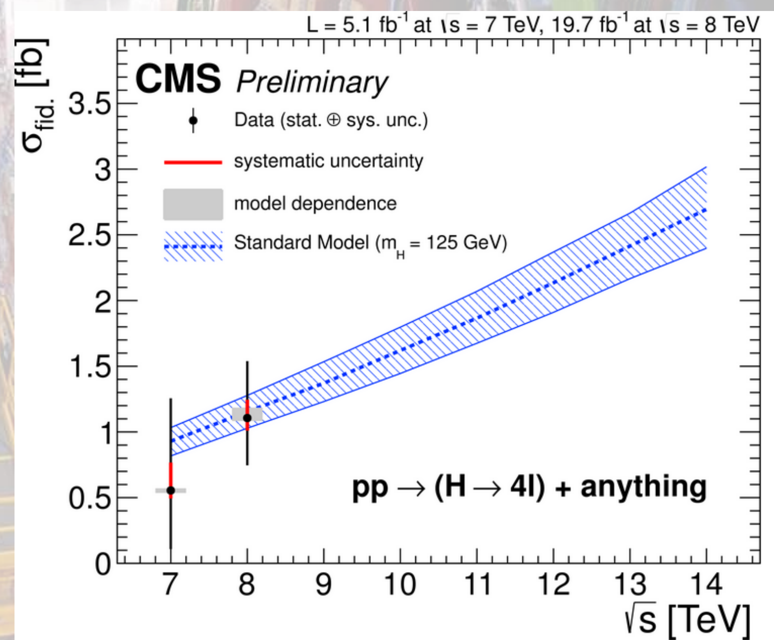
Higgs boson: going differential

In the old days of hadron spectroscopy, people used to say that **with one event you could measure a cross section, and with two you could publish differential distributions...**

CMS collected many Higgs events in the Run 1 data, so it was due time to start studying fiducial differential distributions.

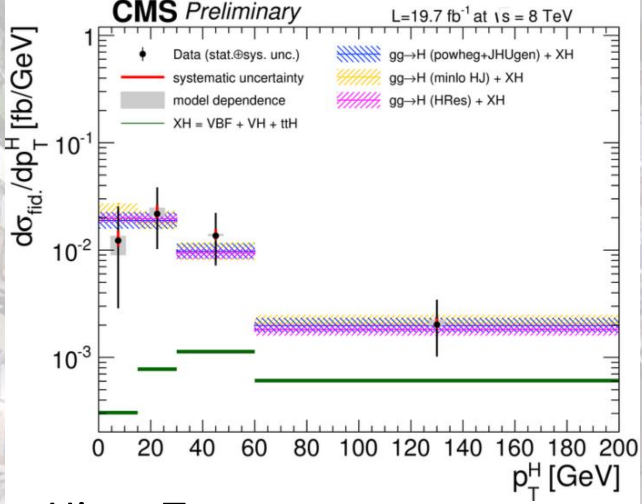
Fiducial == the measurement is performed in a region of phase space matching the detector acceptance. This reduces model systematics

Requirements for the $H \to 4\ell$ fiducial phase space	
Lepton kinematics and isolation	
leading lepton p_T	$p_T > 20$ GeV
next-to-leading lepton p_T	$p_T > 10$ GeV
additional electrons (muons) p_T	$p_T > 7(5)$ GeV
pseudorapidity of electrons (muons)	$\|\eta\| < 2.5(2.4)$
p_T sum of all stable particles within $\Delta R < 0.4$ from lepton	less than $0.4 \cdot p_T$
Event topology	
existence of at least two SFOS lepton pairs, where leptons satisfy criteria above	
inv. mass of the Z_1 candidate	$40\,\text{GeV} < m(Z_1) < 120\,\text{GeV}$
inv. mass of the Z_2 candidate	$12\,\text{GeV} < m(Z_2) < 120\,\text{GeV}$
distance between selected four leptons	$\Delta R(\ell_i \ell_j) > 0.02$ for any $i \neq j$
inv. mass of any opposite sign lepton pair	$m(\ell^+\ell'^-) > 4\,\text{GeV}$
inv. mass of the selected four leptons	$105\,\text{GeV} < m_{4\ell} < 140\,\text{GeV}$
the selected four leptons must originate from the $H \to 4\ell$ decay	

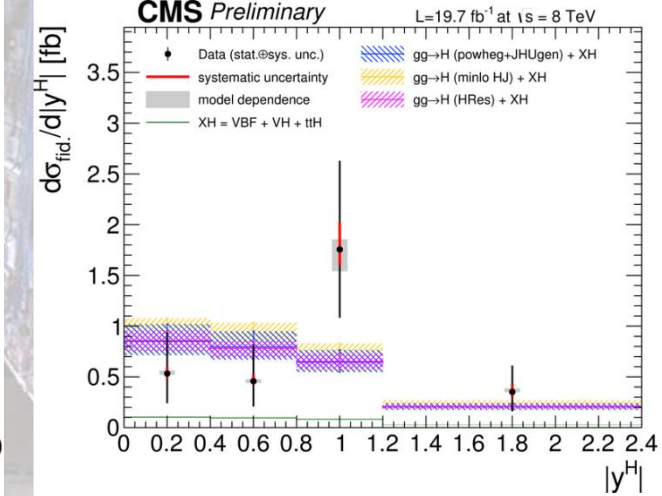


The cross section is derived in the fiducial volume at 7 and 8 TeV independently, by maximum likelihood fits to the data assuming M_h=125 GeV. They are compared to predictions at NNLO+NNLL performed with Hres, MinLOHJ, and POWHEG+JHUGEN.

Besides the cross section at 7 and 8 TeV, the considered variables for differential production cross section studies are the transverse momentum and rapidity of the four leptons in $H \rightarrow ZZ^* \rightarrow 4l$, and its kinematics WRT the leading jet.

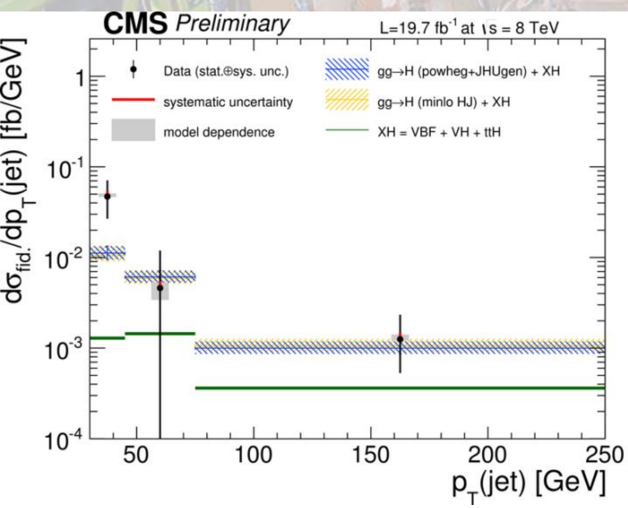


Higgs Transverse momentum

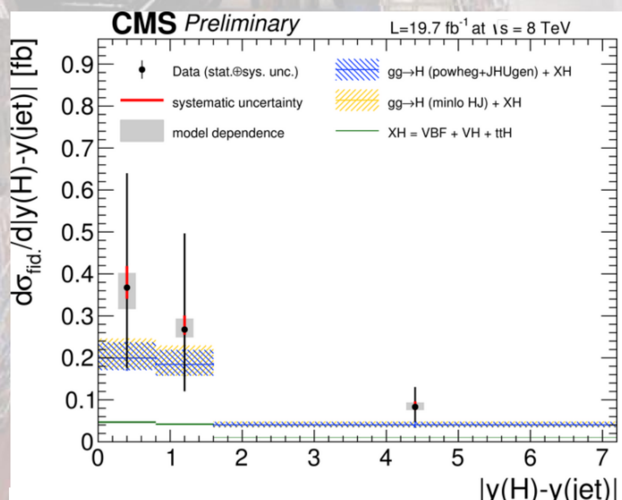


Higgs rapidity

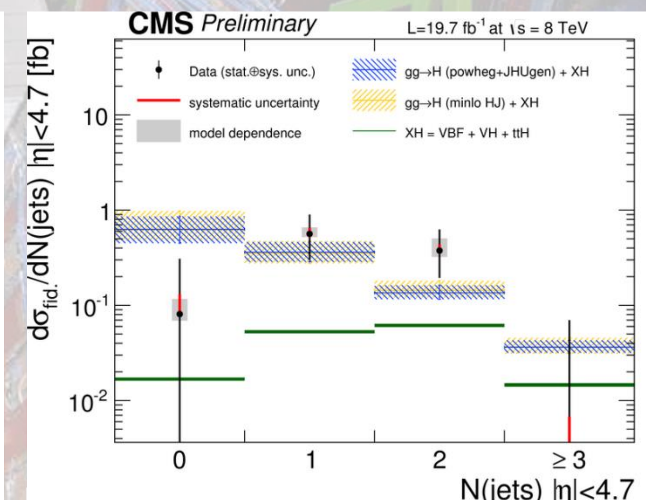
Results match nicely the precise theoretical predictions at NNLO in all considered distributions



Jet transverse momentum



Jet-H rapidity difference



Number of jets in H events

CMS Public Results @ 13 TeV

Standard Model results (15):

BPH-15-004: B production cross section
FSQ-15-001: Pseudorapidity distributions of charged hadrons
FSQ-15-002: Two-particle correlations (the “ridge”)
FSQ-15-007: Underlying event
SMP-15-004: Inclusive W/Z cross section
SMP-15-005: ZZ production cross section
SMP-15-006: WZ production cross section
SMP-15-007: Inclusive jet production
SMP-15-010: Z+jets differential cross sections
TOP-15-003: Inclusive ttbar cross section in the emu channel
TOP-15-004: t-channel single top production
TOP-15-005: Differential tt cross section in the lepton + jets channel
TOP-15-010: Differential tt cross section in the dilepton channel
TOP-15-013: ttbar differential cross sections as function of HT,
TOP-15-017: Underlying Event studies in ttbar events

CMS Public Results @ 13 TeV

New Physics searches (18):

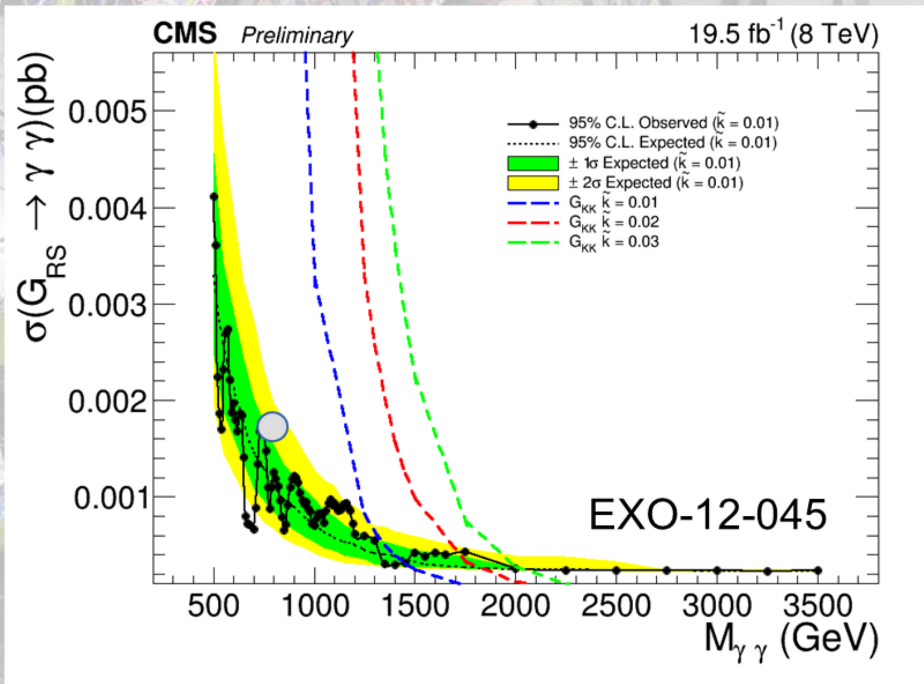
B2G-15-004: Search for W'->tb (semi-leptonic)
B2G-15-006: X53 in SS dilepton and lepton+jets
EXO-15-001: Search for dijet resonances
EXO-15-002: Search for diboson resonances
EXO-15-003: Search for dark matter in monojets
EXO-15-004: Search for diphoton resonances
EXO-15-005: Search for dilepton resonances
EXO-15-006: Search for W’ in lepton + MET final state
EXO-15-007: Search for Black Holes
EXO-15-009: Search for new physics in dijets with chi
EXO-15-010: Search for Heavy Stable Charged Particles

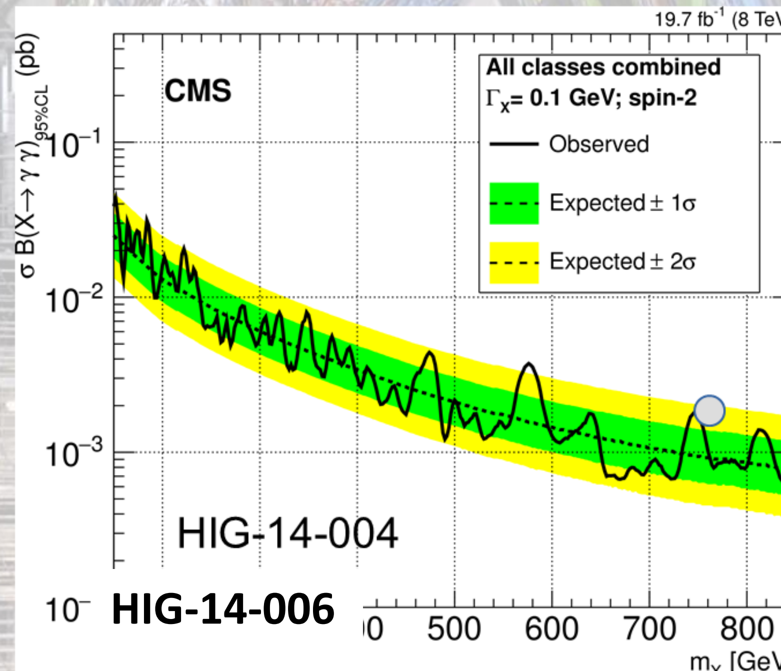
Exotica searches

SUS-15-002: Search for supersymmetry in multijet+MET
SUS-15-003: Search for new physics in the all-hadronic final state with the MT2
SUS-15-004: Inclusive search for supersymmetry using the razor variables
SUS-15-005: Search for supersymmetry using alpha_T
SUS-15-007: Search for supersymmetry in 1-lepton events using large radius jets
SUS-15-008: Search for SUSY in same-sign dilepton events
SUS-15-011: Search for SUSY in final states with opposite-sign dileptons

SUSY searches

Compatibility with Run 1

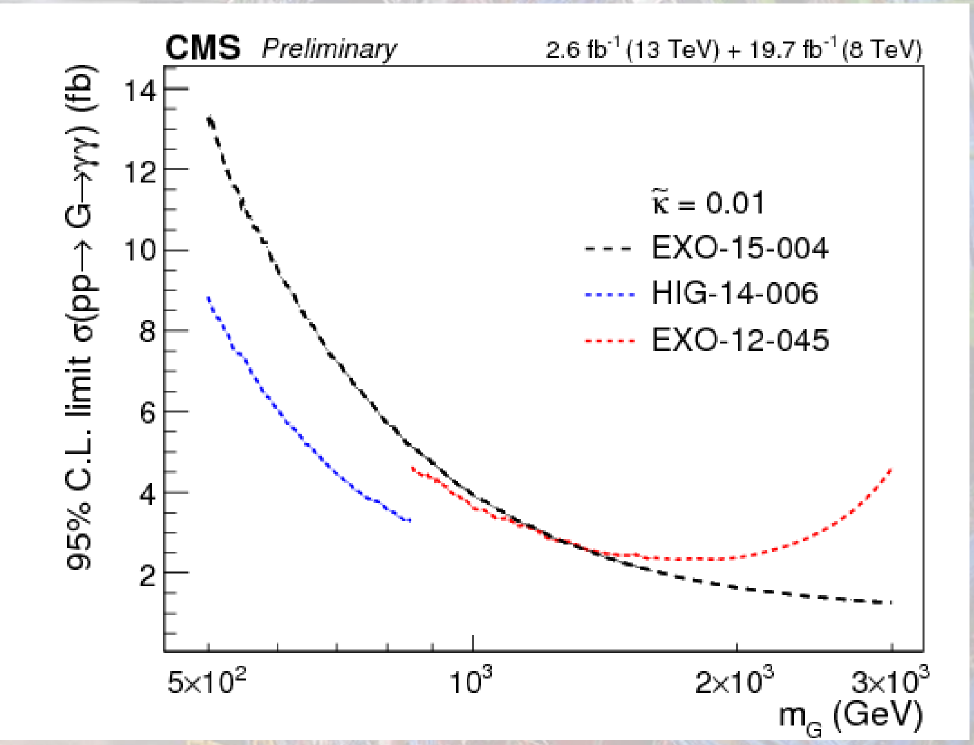




The 750 GeV excess is not excluded by Run 1 searches

Combination of 8TeV and 13TeV results

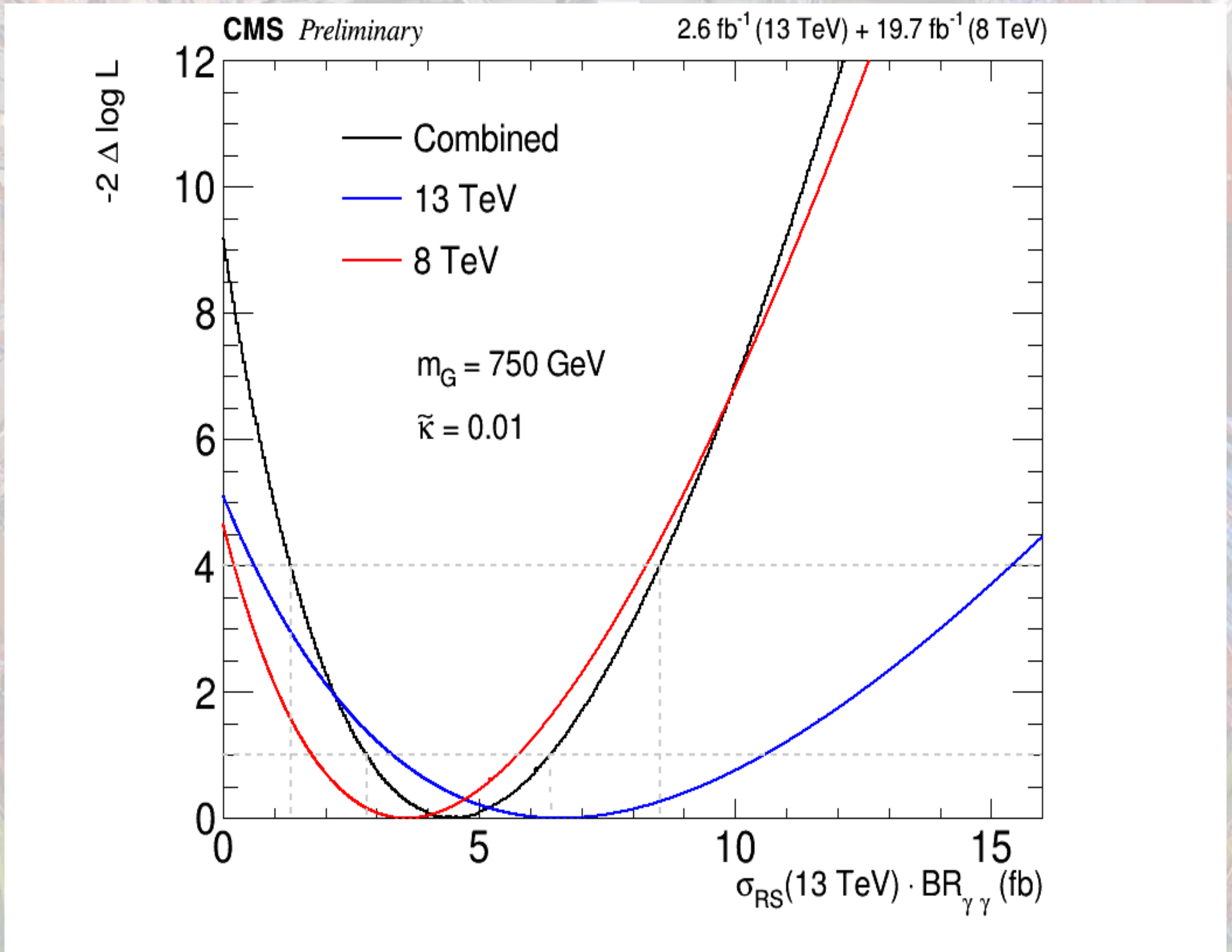
- Combination performed assuming narrow RS graviton hypothesis.
  - Results expressed in terms of equivalent 13TeV cross sections.



- Two analyses at 8TeV.
  - HIG-14-006 and EXO-12-045
  - HIG-14-006 is the most sensitive in the covered range (larger acceptance, plus categorization).

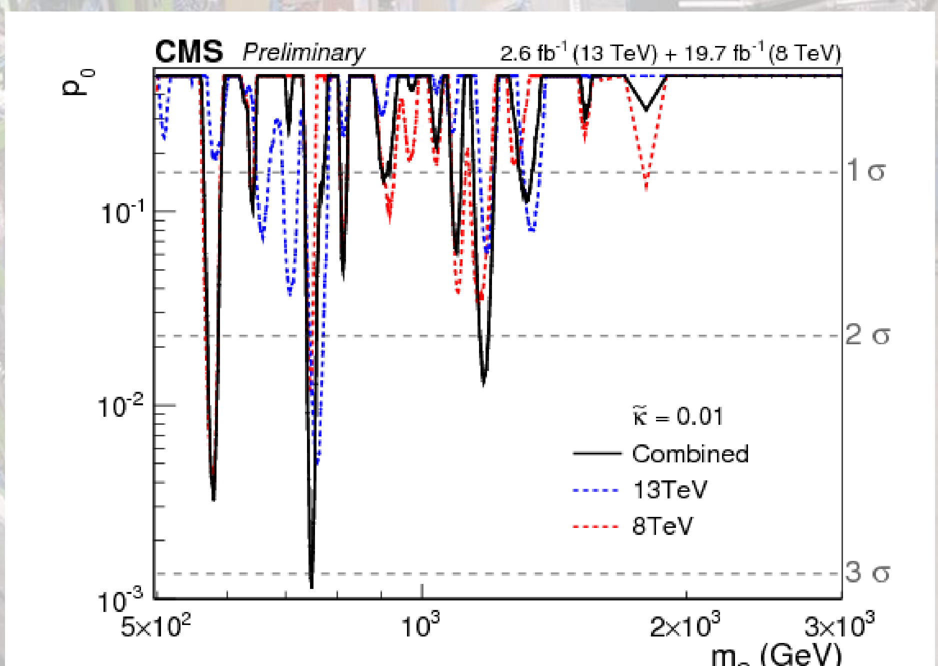
Log-likelihood scan at 750 GeV

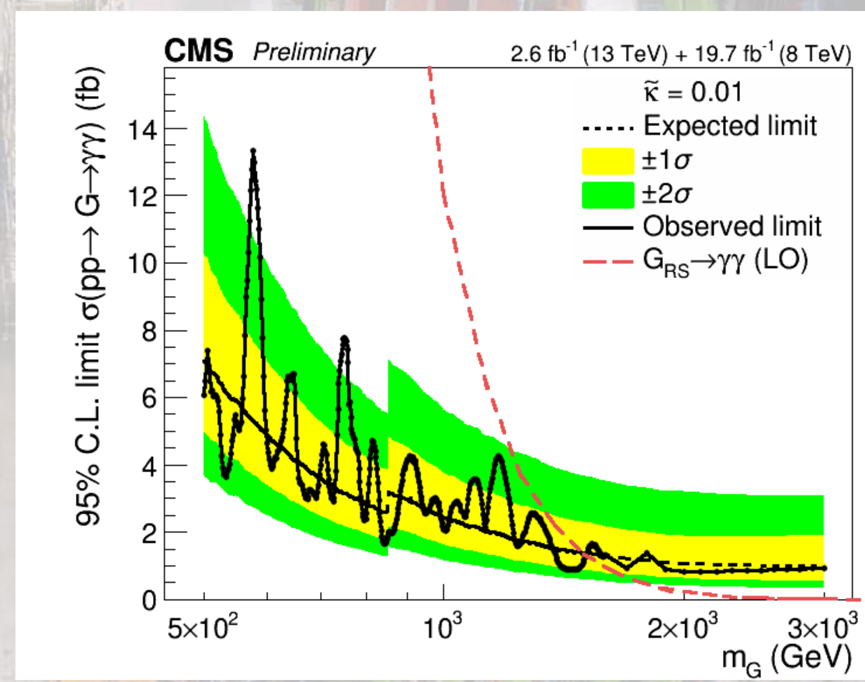
Results of the bump searches in Run 1 and Run 2 data can be expressed in terms of equivalent 13TeV cross sections



Combined limits and p-values

- Combined limit improves single analyses sensitivity by 20-30%.
  - Largest excess: M_G = 750GeV, local significance 3σ
  - global significance < 1.7σ

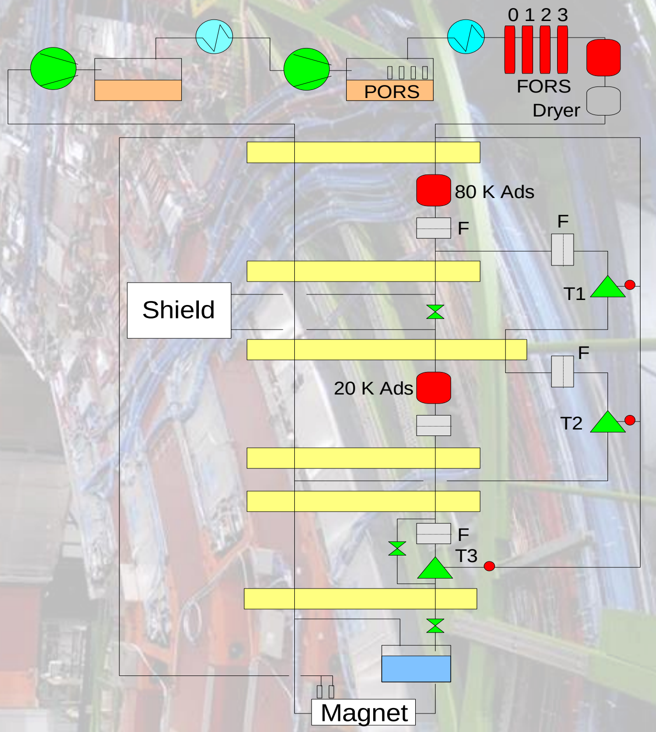




CMS Operation in 2015

- At the end of the Long Shutdown 1 we realized that the **performance of the cryogenic system feeding Liquid He to our Magnet was severely impaired by a contamination of the Cold box**
- This has affected our operation in 2015: a large effort from the **CERN cryogenic and technical departments associated to our Technical Coordination have limited the impact, allowing to collect ~¾ of the delivered luminosity with full magnetic field.**
- The detector and new acquisition system was ready from the start of LHC running at 13 TeV: **we have logged data with efficiency well above 90% with trigger thresholds similar or lower than the ones at Run I**
- **A detailed plan of repair and cleaning of the cryo system, to be executed during the Year End Technical Stop, is ready** and foresees the system to be ready for Physics production by the first week of April, i.e. well ahead of the start of physics production of LHC in 2016

Magnet Cryogenics

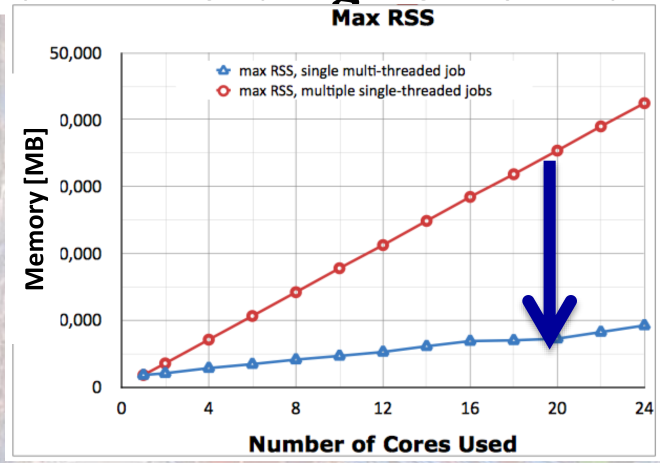


- The restart of the CMS magnet after LS1 was more complicated than anticipated due to problems with the cryogenic system in providing liquid Helium.
- Inefficiencies of the oil separation system of the compressors for the warm Helium required several interventions and delayed the start of routine operation of the cryogenic system.
- The data delivered during the first two weeks of LHC re-commissioning with beams at low luminosity have been collected with B=0
- Currently the magnet can be operated, but the continuous up-time is still limited by the performance of the cryogenic system requiring more frequent maintenance than usual.
- A comprehensive program to re-establish its nominal performance is underway. These recovery activities for the cryogenic system will be synchronized with the accelerator schedule in order to run for adequately long periods.

DAQ & Computing & Offline

- **New DAQ2 concept realized for the online part**
- **Replaced all 500 DAQ Computers, and 1/2 of the High Level Trigger (HLT) CPUs → increase budget to 0.3s/event from 0.2s/event**
- **HLT Farm now also used for production and other offline tasks**

Multi-threading now standard

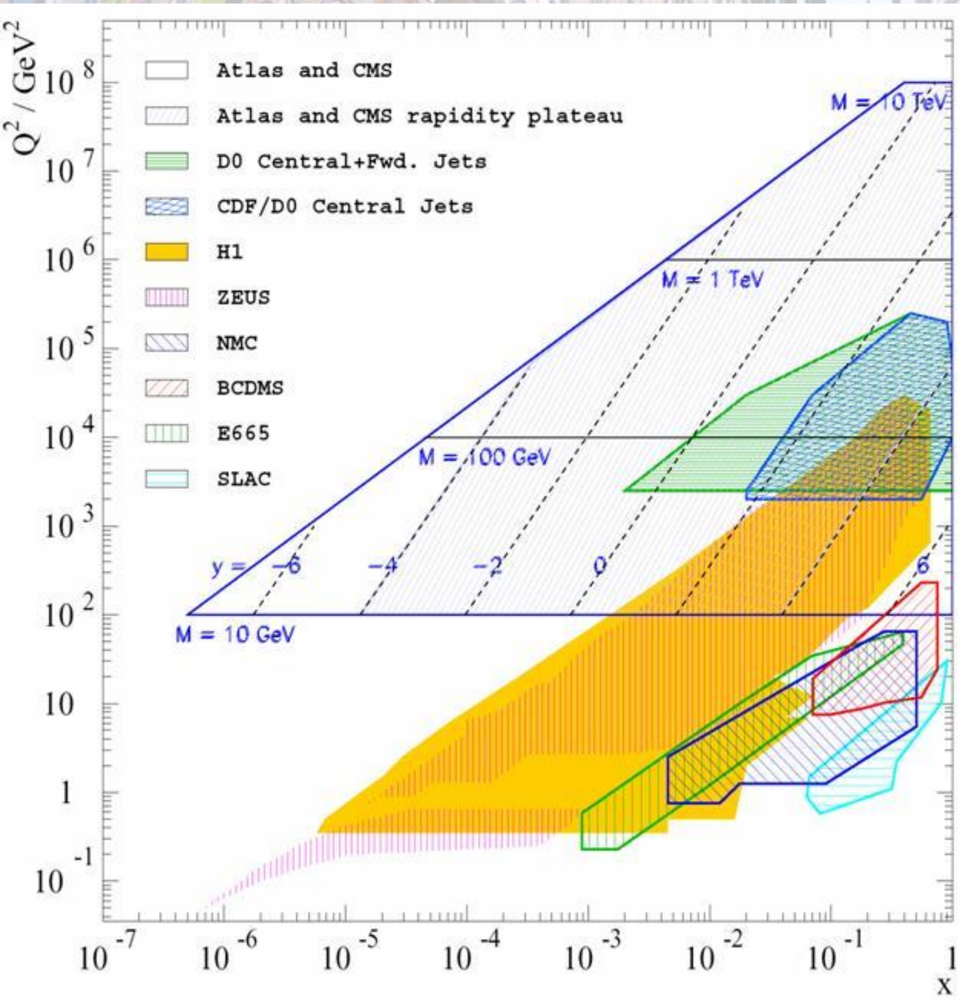


- **Move to multi-threading with multi-core queues at CERN and Tier-1 centers**
- **New, more flexible and efficient workflow and data management systems**

- **Improvements in Distributed Analysis**
- **Faster event reconstruction**
- **New miniAOD data format for many physics object improvements:**
  - **compact high level data objects (30-50 kb/event) → gain factor ~10**
  - **covering needs of mainstream analyses → avoid duplications**

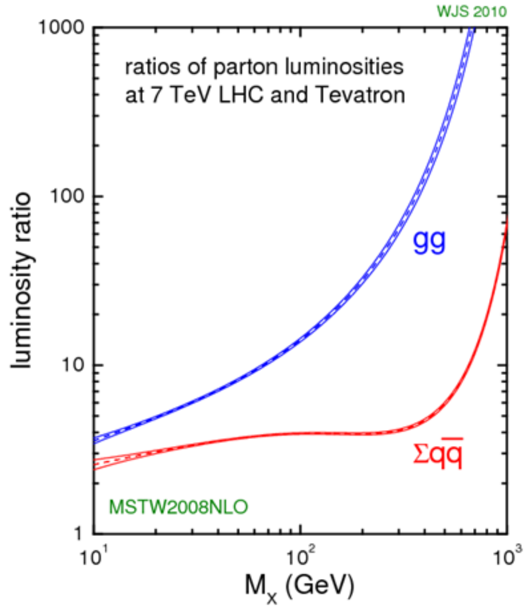
PDF and Parton Luminosities

Kinematical range spans largely unknown regions of (x,Q^2) → PDF uncertainties



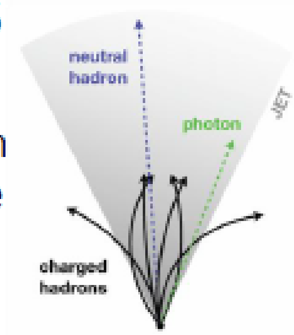
Gluon luminosity grows much faster than quark luminosity below effective masses of 500 GeV

The implication for searches is generally a strong advantage WRT lower-energy machines (TeVatron) in production of massive particles, particularly at high end



Jet Reconstruction & Energy Scale Calibration

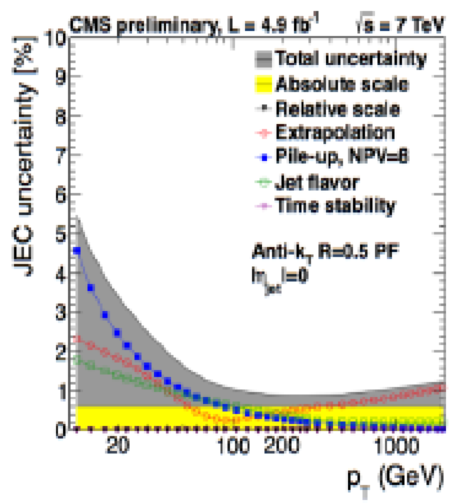
- **Anti-k_T clustering algorithm** : Infrared and collinear safe. Used with R=0.5 and 0.7.
- **Particle Flow Jets (PF Jets)** : The CMS global event reconstruction (PF) is an event reconstruction technique which reconstructs and identifies all stable particles in the event, through the optimal combination of all CMS sub-detectors. PF Jets are the output of anti-k_T on the reconstructed particles.

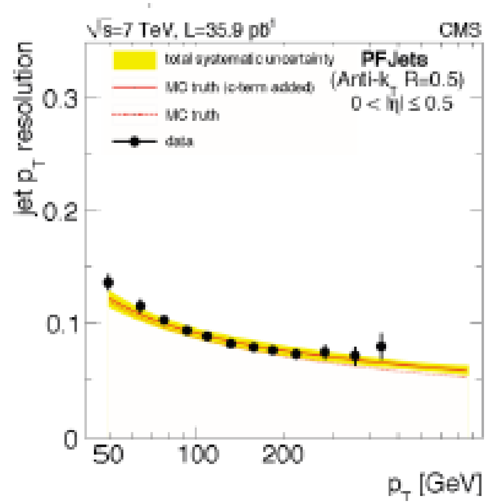


- For the Jet energy scale calibration CMS adopted a Factorized approach.

Calibrated Jet = Raw Jet × Offset Correction (pile-up) × Relative Correction (vs η) × Absolute Correction (vs p_T)

CMS :
JME-10-003
JME-10-010
JINST 6 2011
DP2012-006

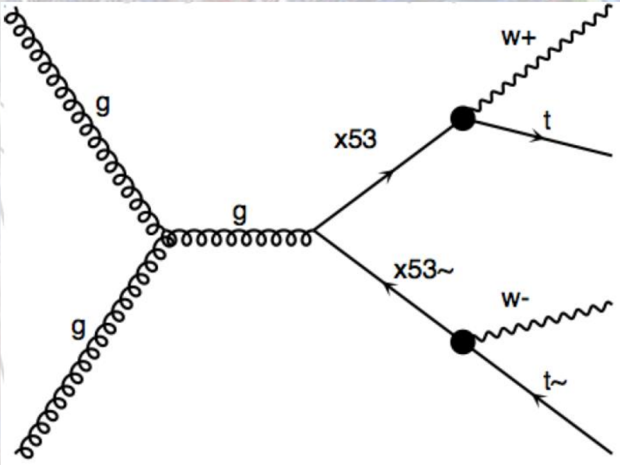


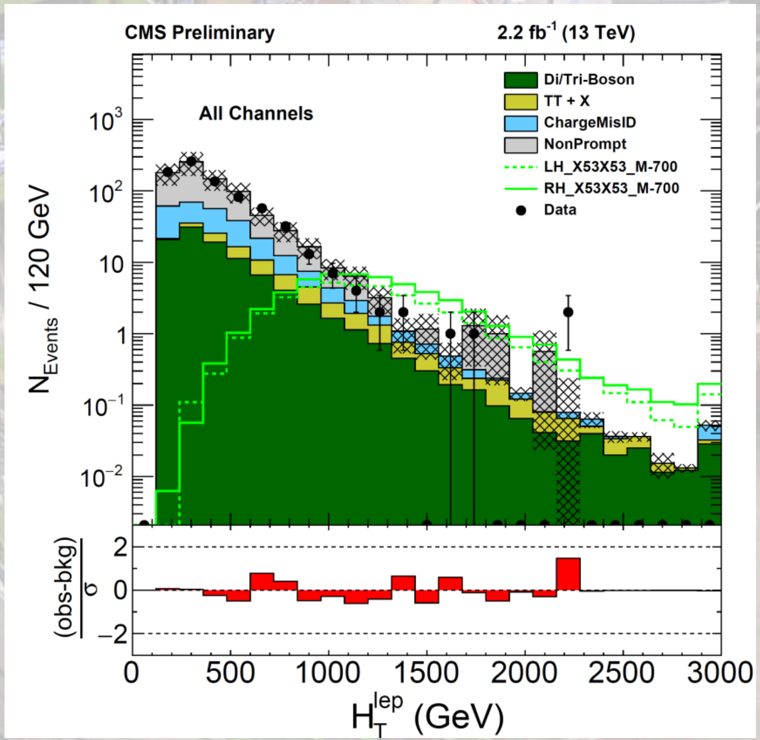


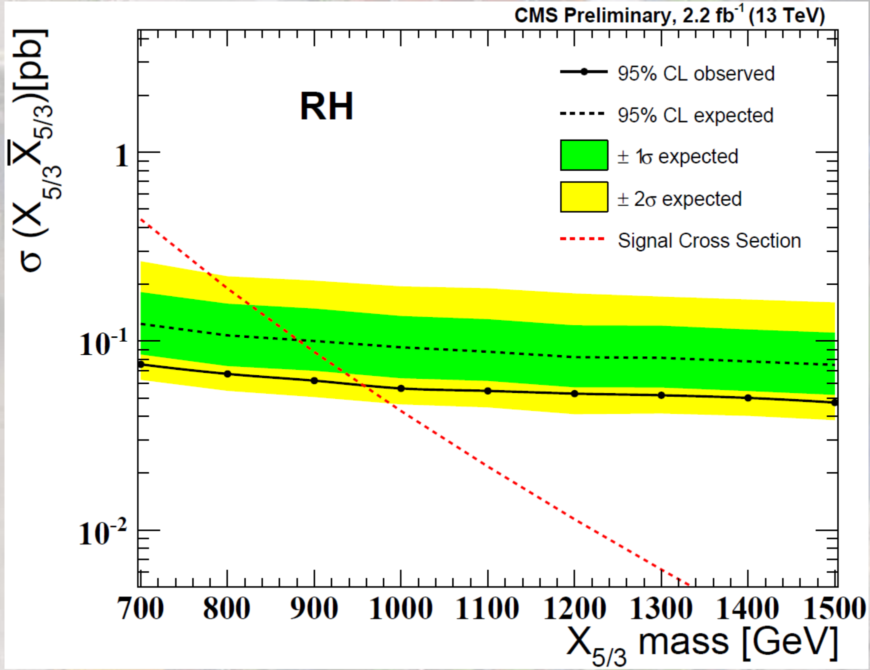
Jet p_T resolution: ≈9% at 100 GeV

Top quark partners with q = 5e/3

- **Search for $X_{5/3} \rightarrow tW$**, predicted in composite Higgs models
- **Same-sign dilepton and lepton+jets** channels used to search for signal
- Limits set on right-handed (960 GeV) and left-handed (940 GeV) top partners





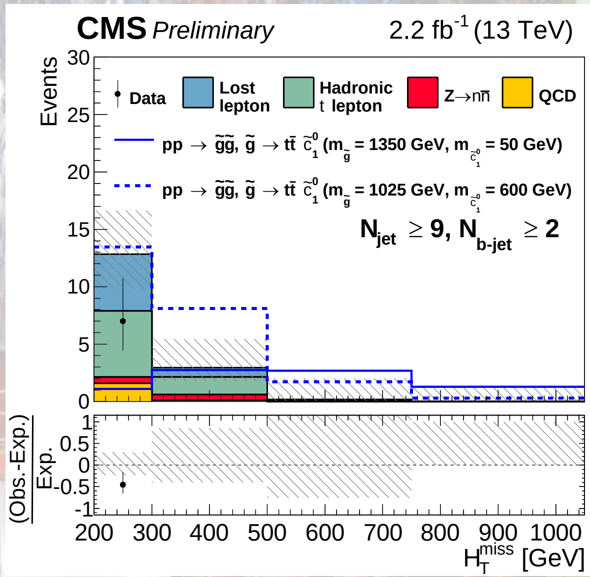


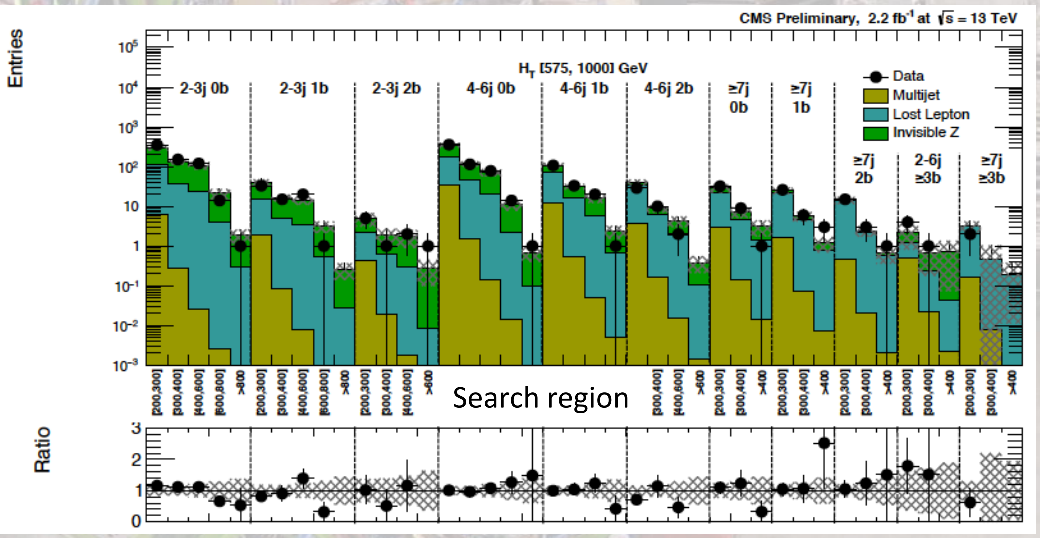
Gluino searches: hadronic

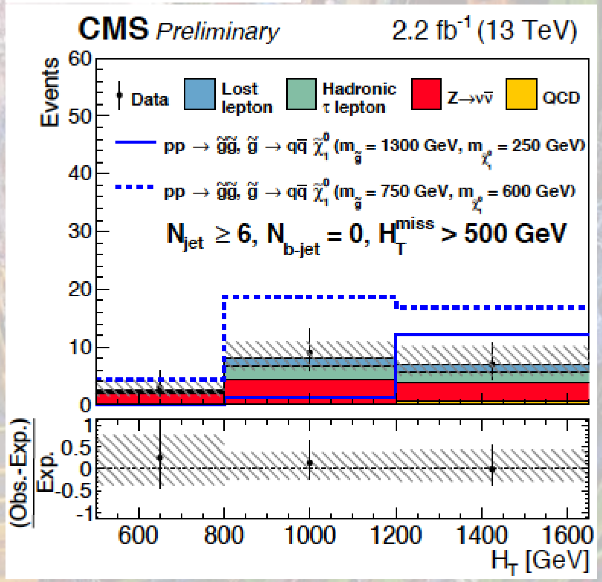
- **Broad Searches** binned in nJet, nB, HT, and MHT/MT2
- **Common features:** SM bkg determined using data-driven techniques:
  - Top and W+jets (“lost lepton”): estimated from single-lepton control samples
  - Z→νν (invisible): from γ + jets and Z→μμ
  - QCD multijet: suppressed with angular and missing energy variables

MH_T, H_T (SUS-15-002):

Extended to include nJet ≥ 9





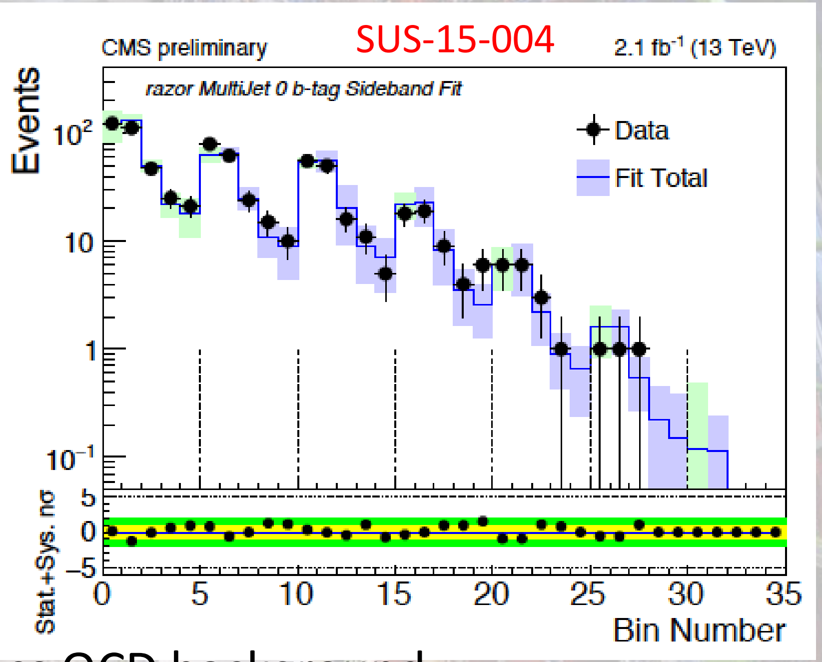


M_{T2} (SUS-15-003):

Extended to include monojet bins

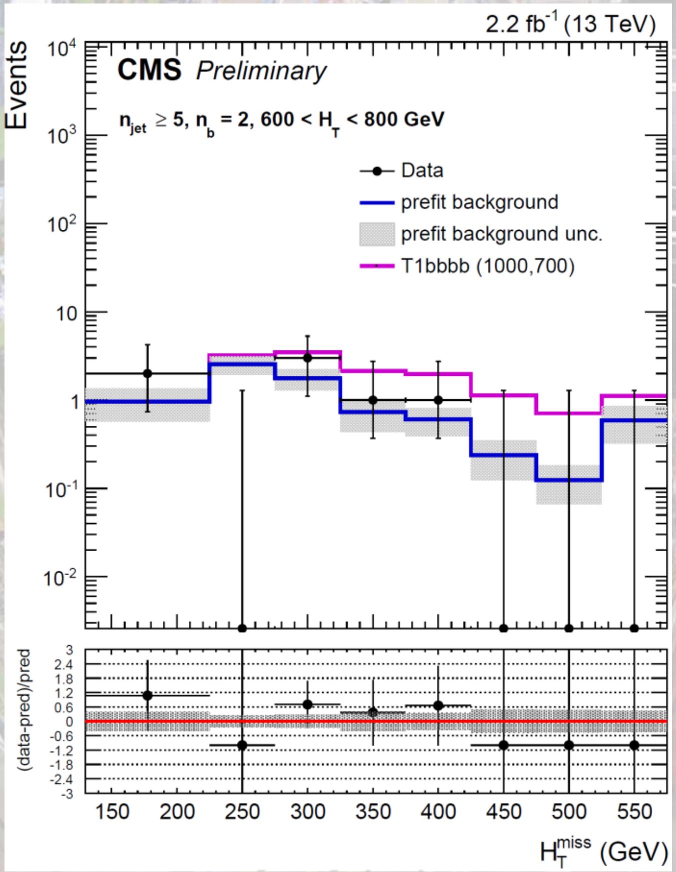
Gluino searches: hadronic

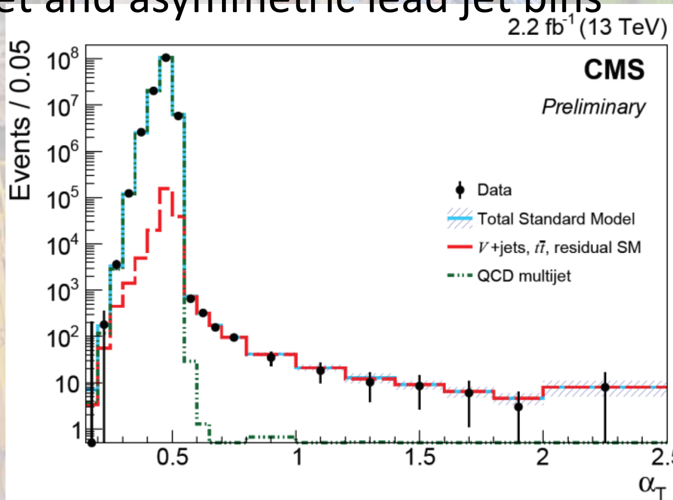
- **Razor Search:** signal bump in MR
- Utilize fits to kinematic variables R^2 and MR in data to characterize backgrounds
- Binned in nB



SUS-15-005

- **α_T:** Suppress QCD background
  - Binned in HT, MHT, nJet, nB
  - New: monojet and asymmetric lead jet bins

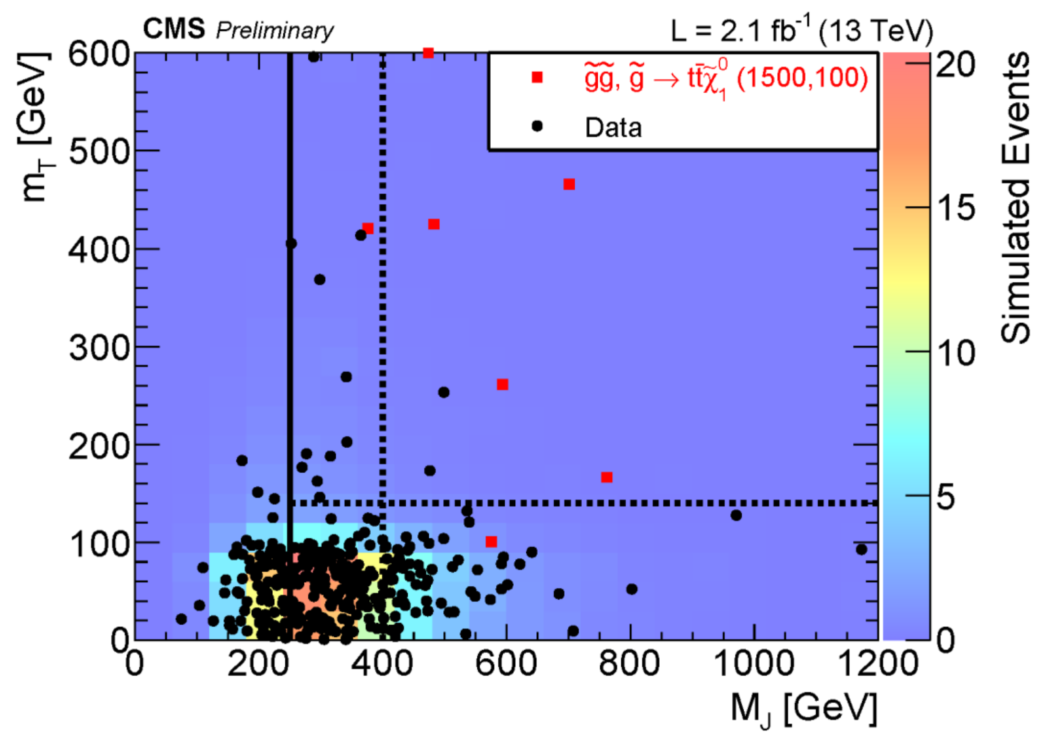


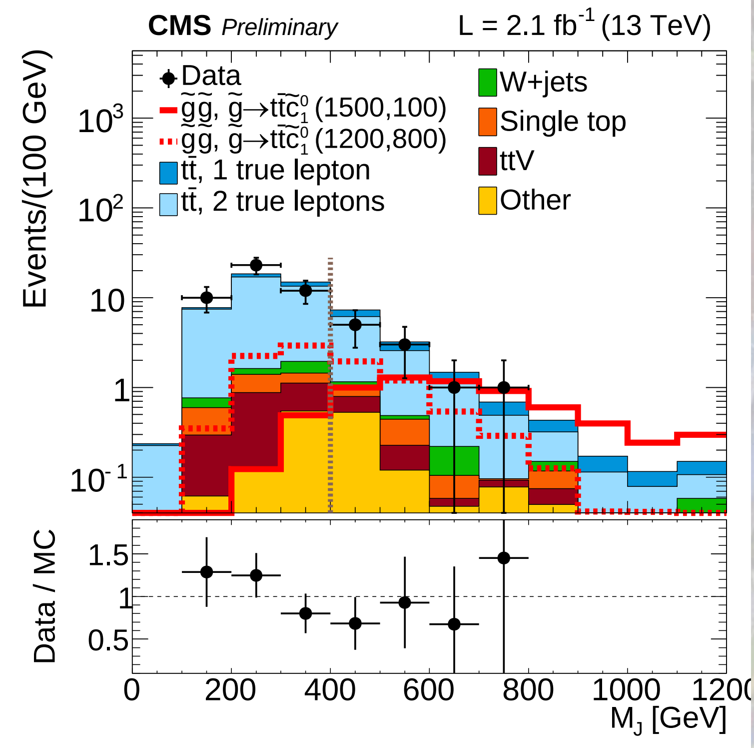


SUS-15-007

Gluino search in 1L + jets (M_J)

- **Signature:** 1 lepton + many jets and b-jets
- Search in events with large Σ(jet mass) = M_J
- Data-driven bkg estimation at high M_J and M_T

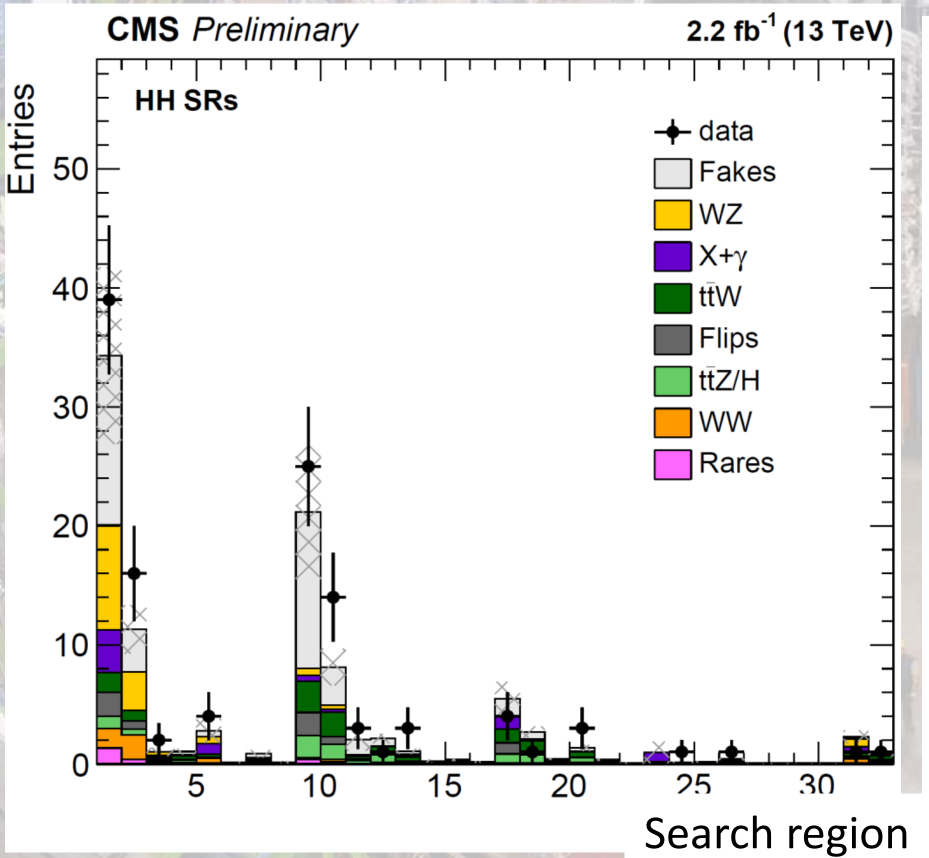


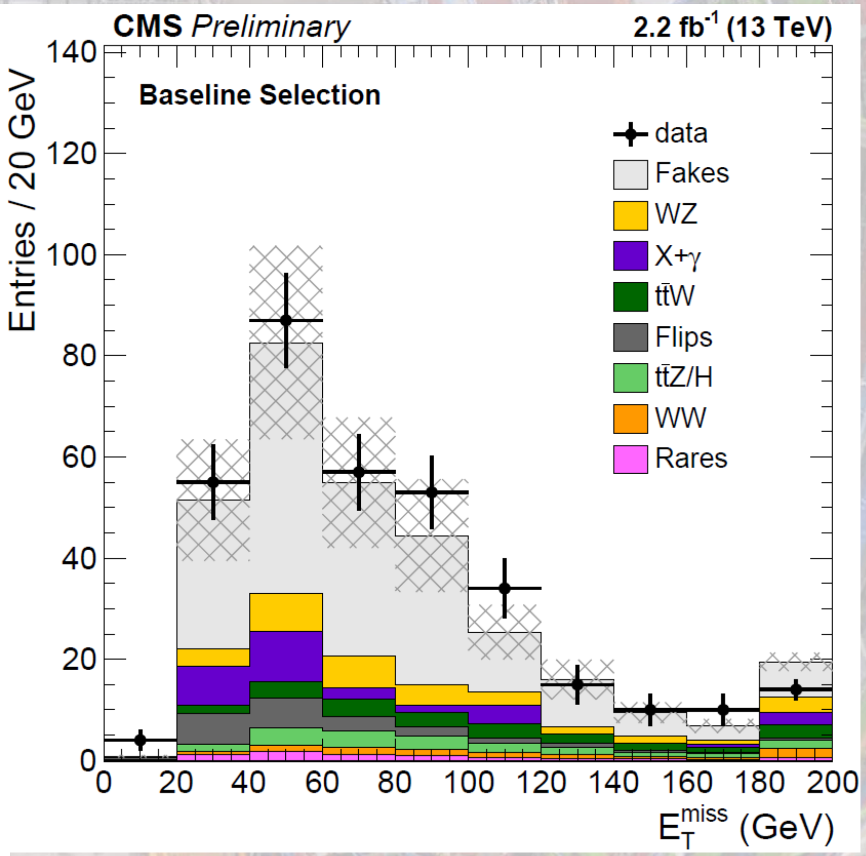


SUS-15-008

Search with same-sign leptons

- **Inclusive Search:** Binned in n-jet, nB, MET, HT, MT
- Main background from non-prompt leptons measured in data
- Di-lepton trigger extends reach to very low MET





Top quark mass

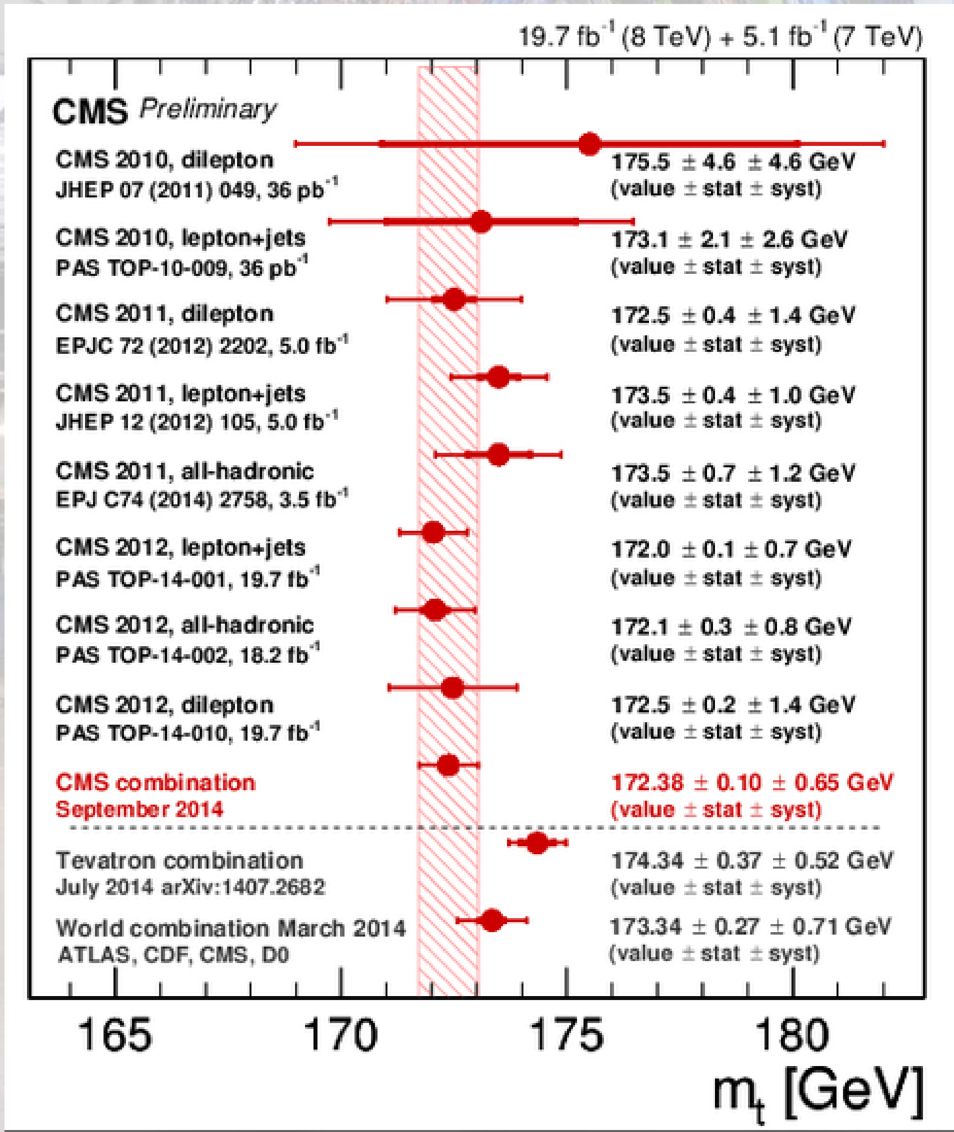
- CMS produced a number of top mass measurements in Run 1.
- A combination of those results yields

  M_t=172.38+-0.10+-0.65 GeV

  → beats all other single-experiment results

  → matches combined precision of Tevatron measurements

- Small tension with TeVatron results, mainly due to high m_t D0 determination



Higgs studies: $\gamma\gamma$

The new energy and running conditions impose reoptimization and retuning → preliminary studies done with few /fb of data, ready for opening the box