ATLAS / CMS First Run-2 Results

Jamie Boyd (incoming LPC!)

Evian Workshop

16/12/15

Overview

- Setting the scene
  - ATLAS / CMS datasets
- Physics Results
  - Standard Model at 13 TeV
  - Re-discovery of the Higgs (?)
  - Searches for new physics

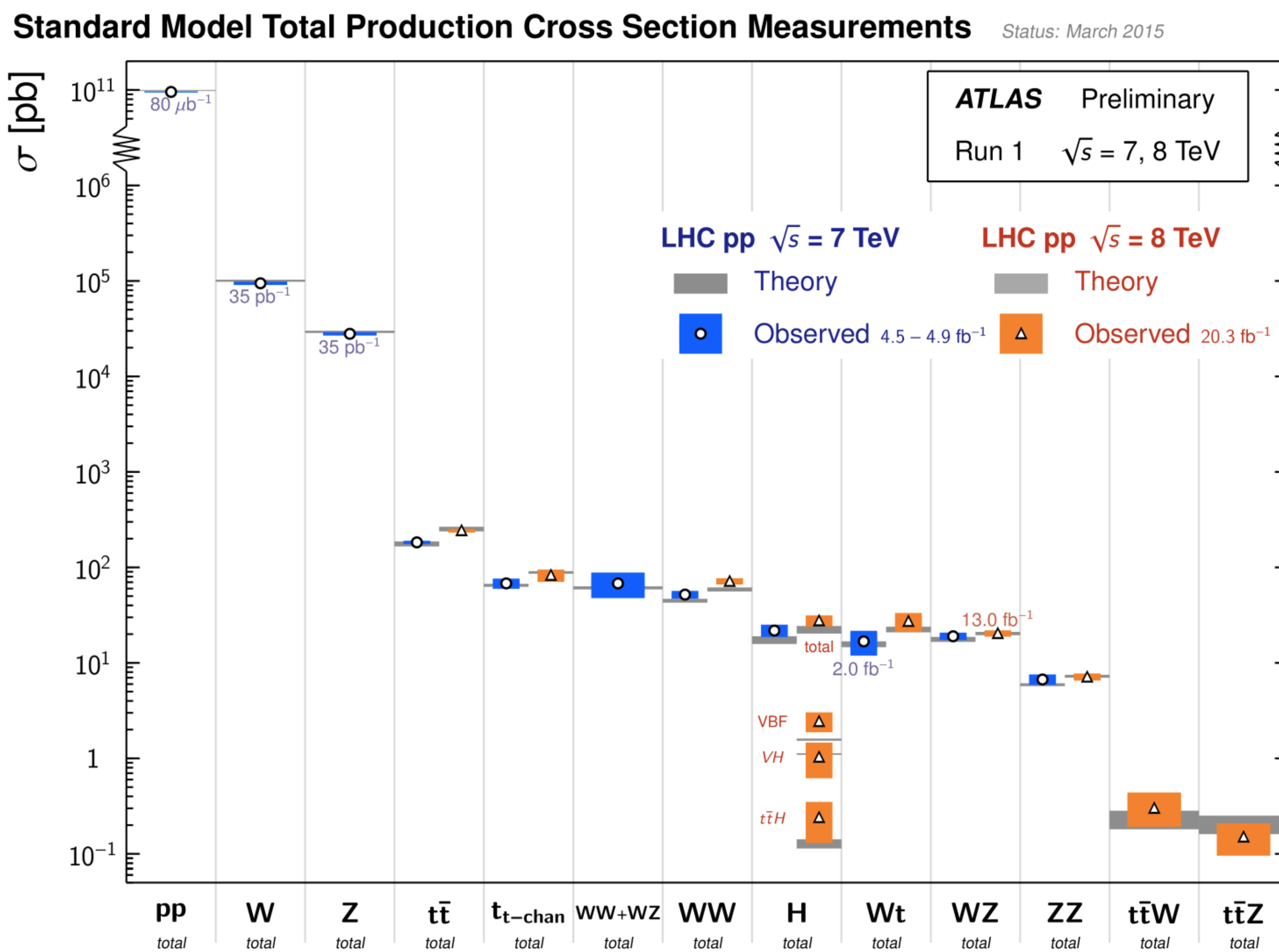
more exciting…

Setting the scene

- As you know LHC delivered 4/fb of pp 13 TeV data to ATLAS/CMS in 2015
  - ***Thank you!***
- First results with 'full dataset' presented at CERN seminar yesterday
  - Results shown here taken from that…
  - These talks were packed with new results (~60 slides for 40min talks!)
  - I present only a taster of this (my choices of the most interesting)
- Dataset for physics:
  - CMS: 2.2 - 2.6/fb (magnet problems, but 75% recorded with magnet on)
  - ATLAS: 3.2 – 3.5/fb

The Standard Model

The Standard Model has been studied in detail with Run-1 – no significant deviations from theory predictions



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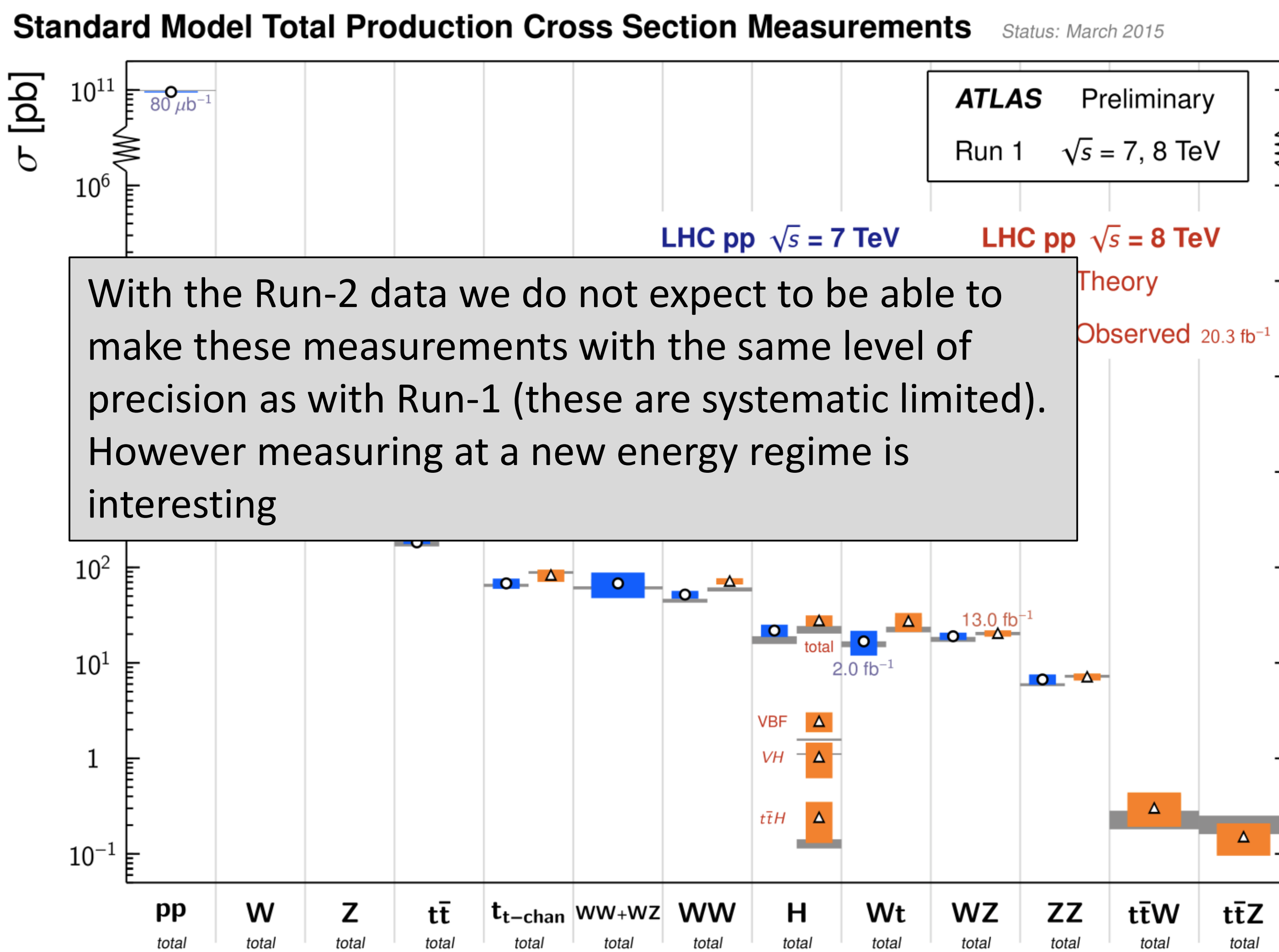
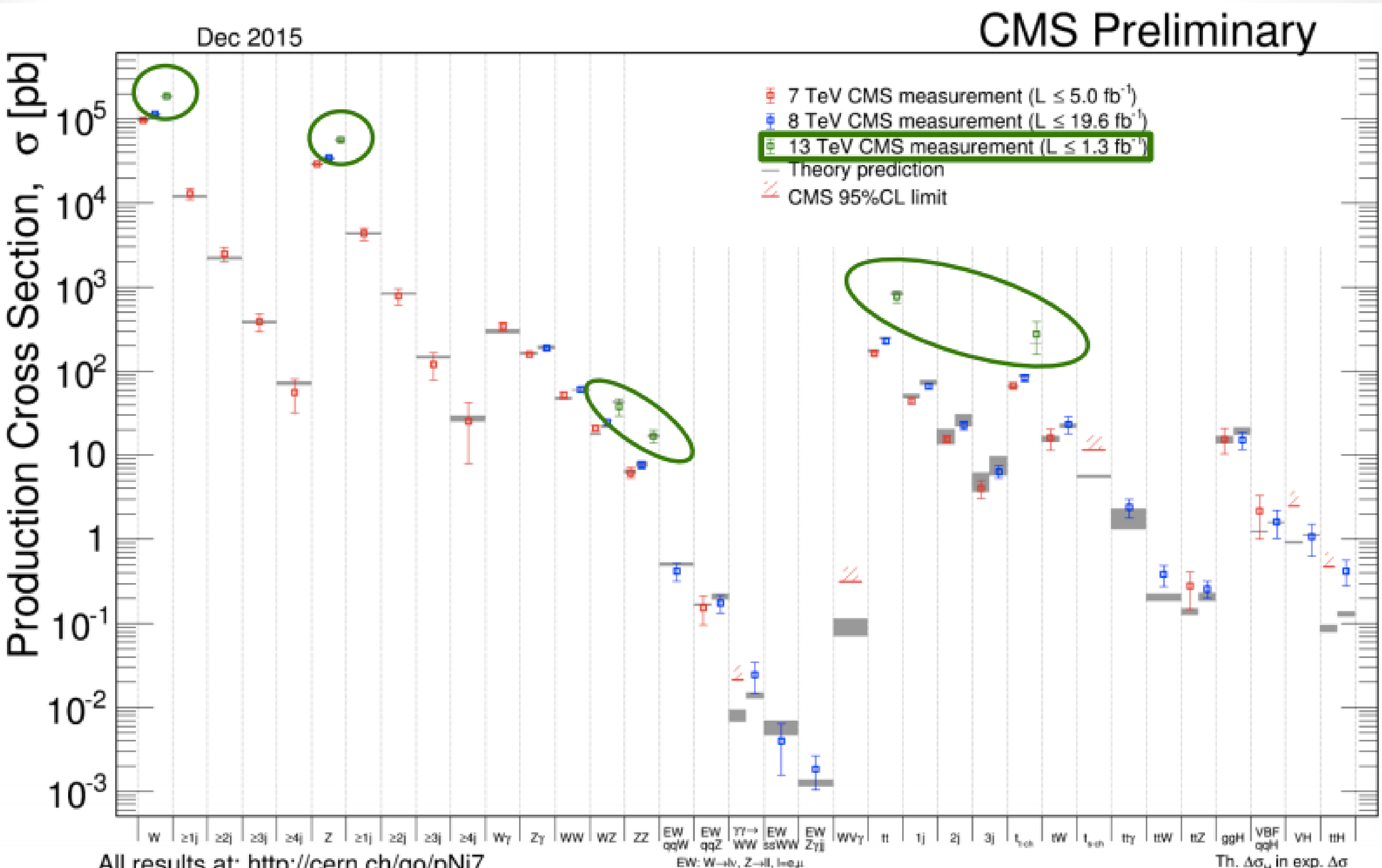


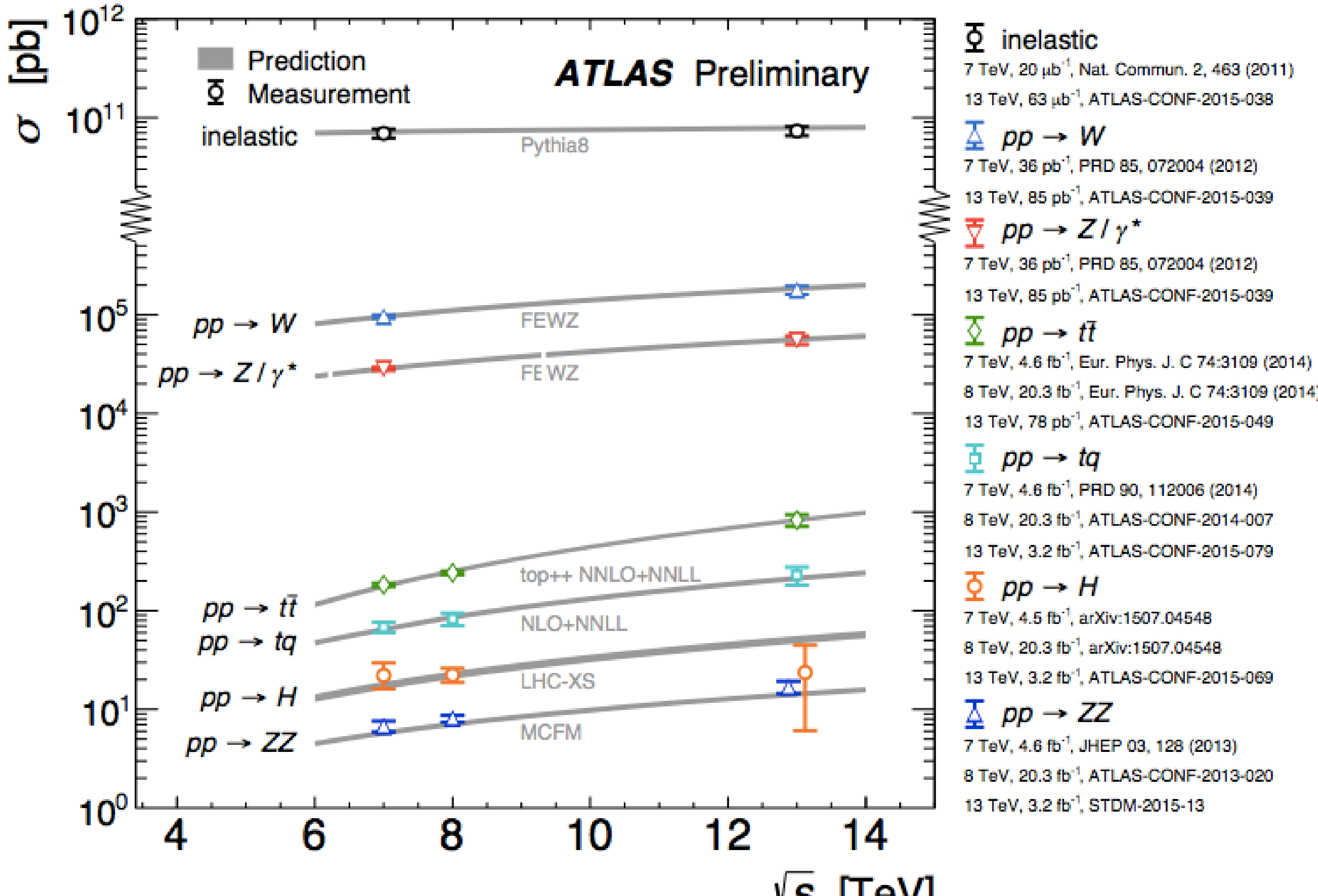
With the Run-2 data we do not expect to be able to make these measurements with the same level of precision as with Run-1 (these are systematic limited). However measuring at a new energy regime is interesting

Standard Model: still going strong



13 TeV measurements agreeing with theory predictions within the measured precision

Summary of Run-2 Total Cross Section Measurements

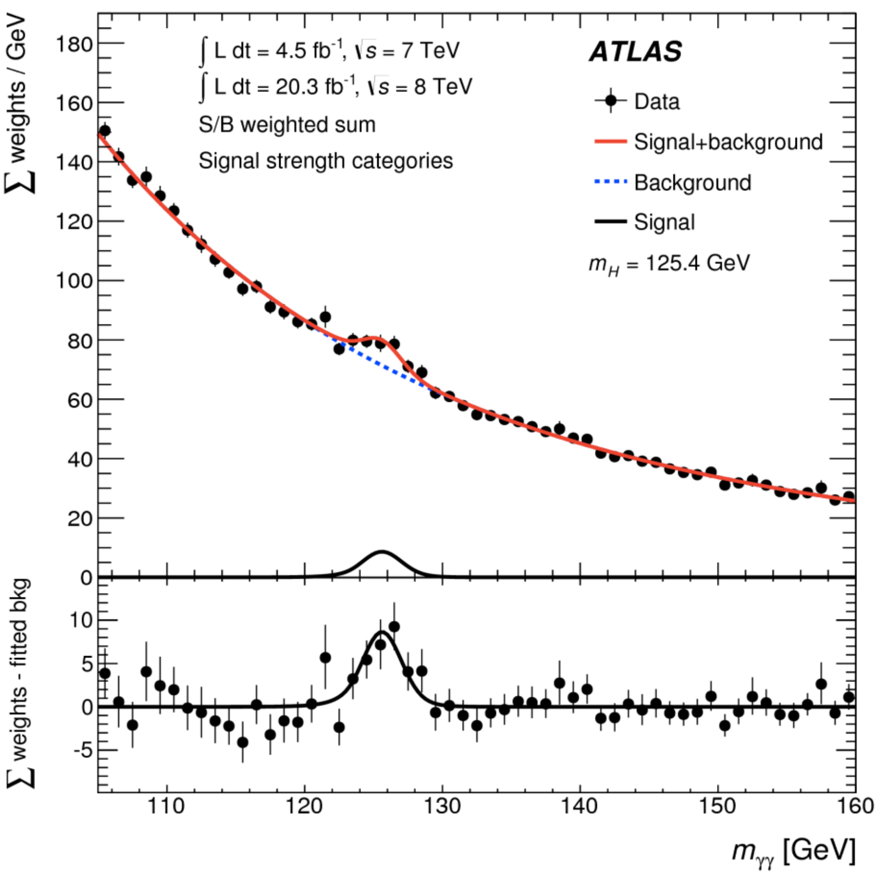


measured predicted x-sec as function of collision energy – agree within errors.

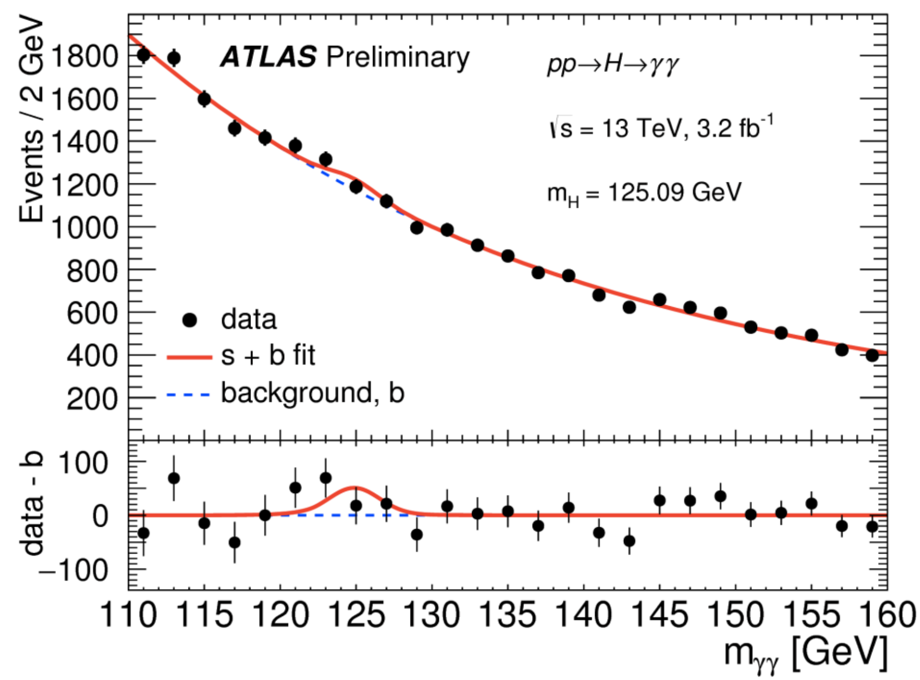
Standard Model Higgs

ATLAS have looked at the Higgs ‘discovery’ decay modes. CMS have not yet unblinded their Higgs searches.

Run-1



Run-2



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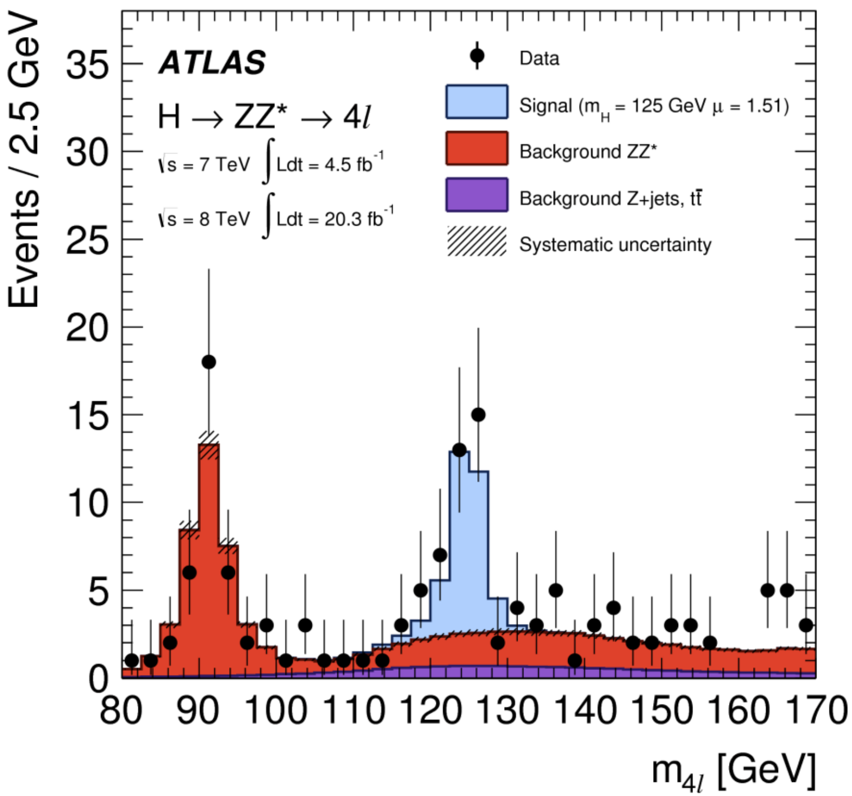
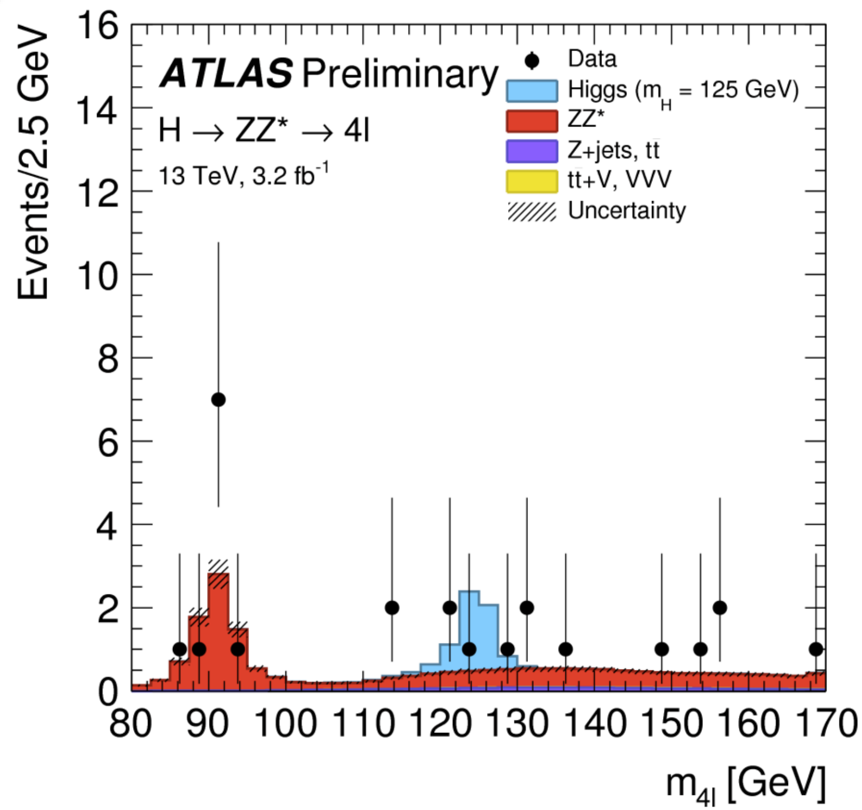
Run-1 → Run-2





Standard Model Higgs

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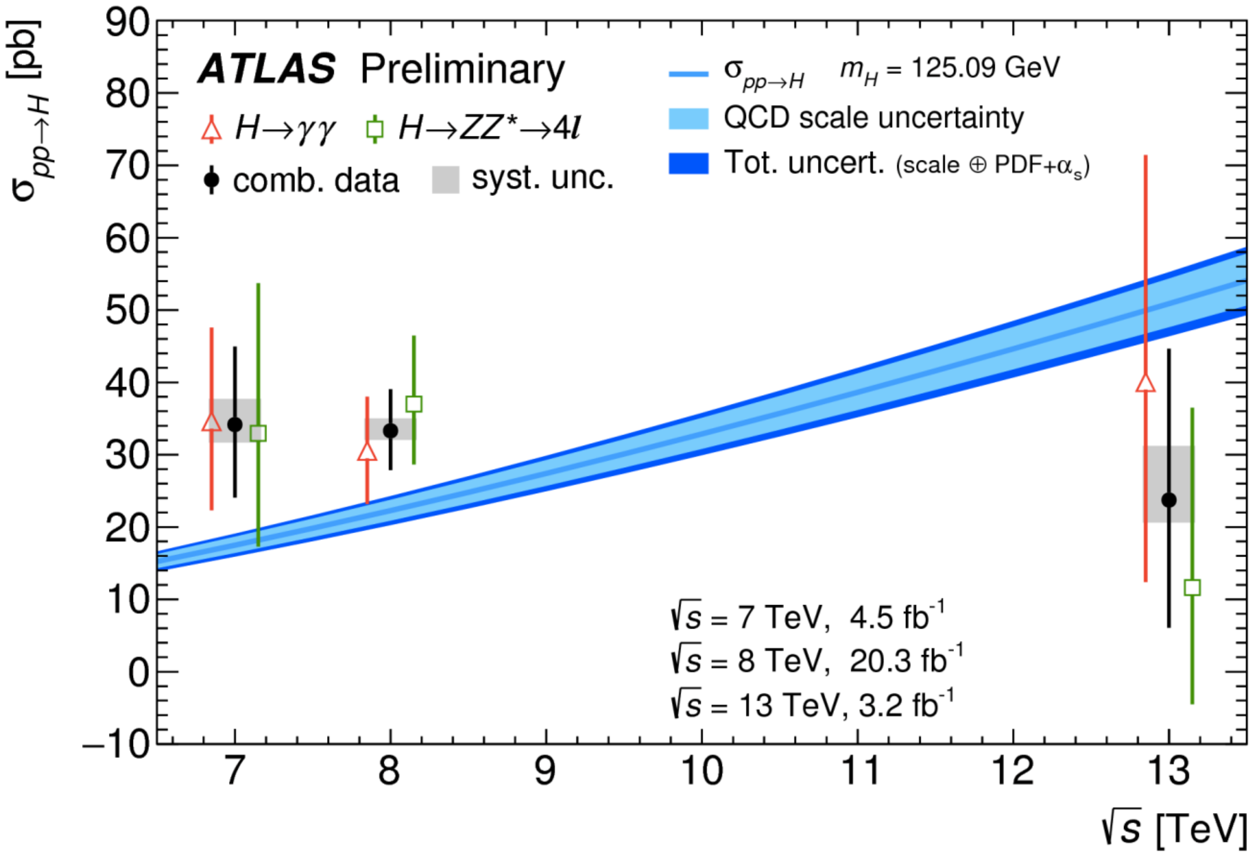
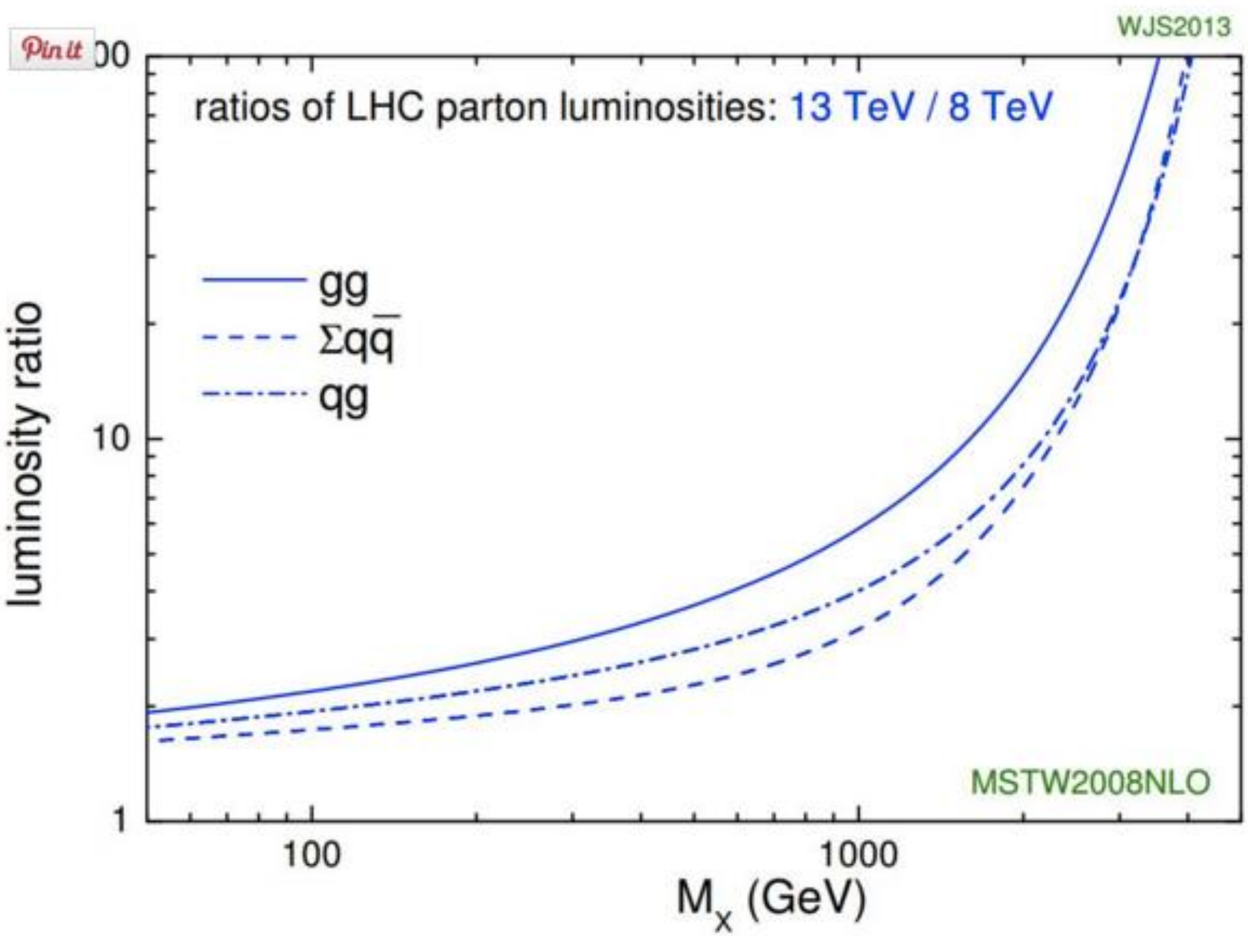


Looks like the Higgs boson has not yet been observed with Run-2 data. 'Under-fluctuation' in ATLAS analysis. But need more data!

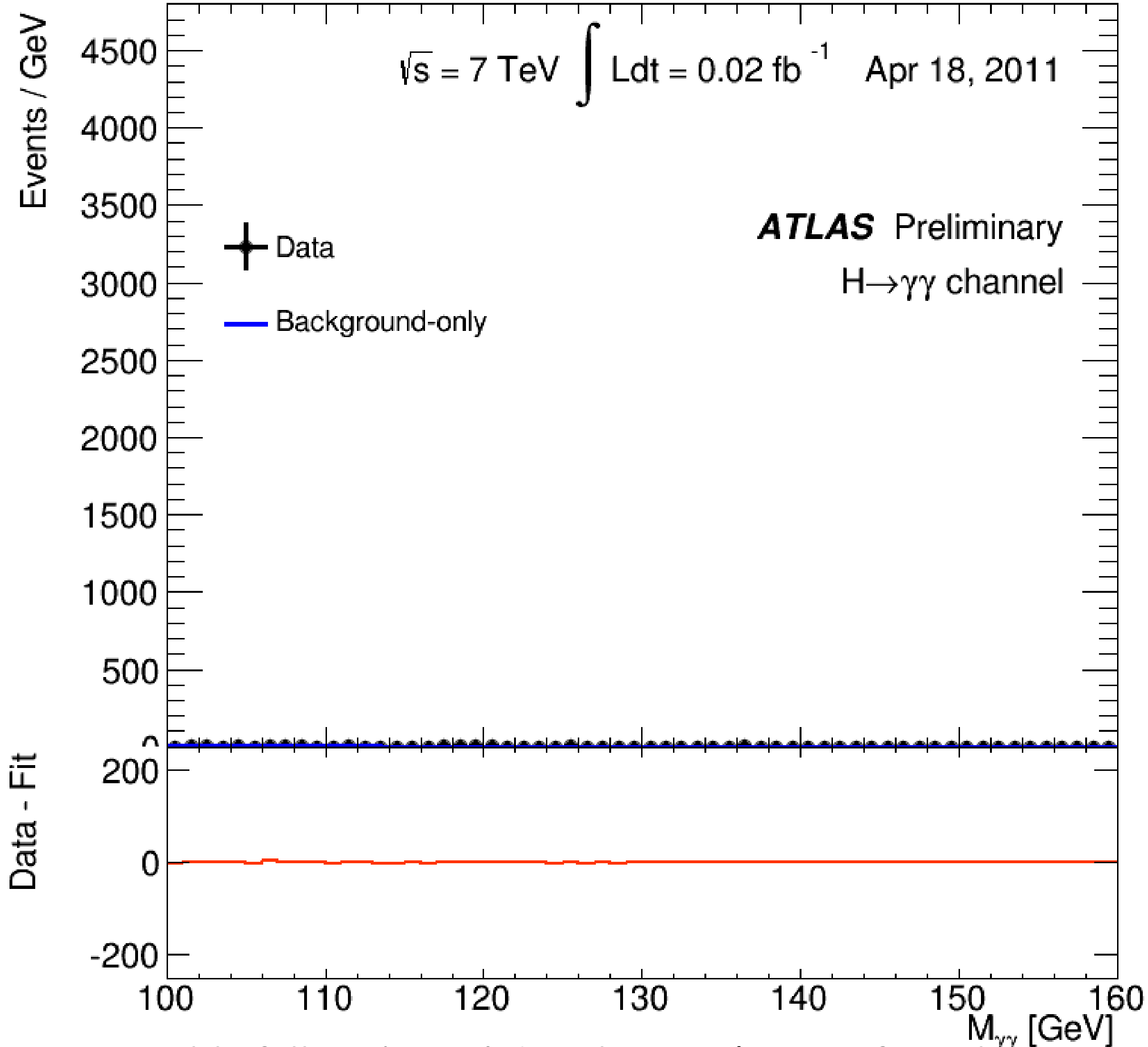
Searches

- The probability (x-sec) for producing new heavy states increases a lot when going from 8 -> 13 TeV
  - Exact increase depends on production and mass of the state



Z' @ 3TeV x20
gluino @ 1.5 TeV x35

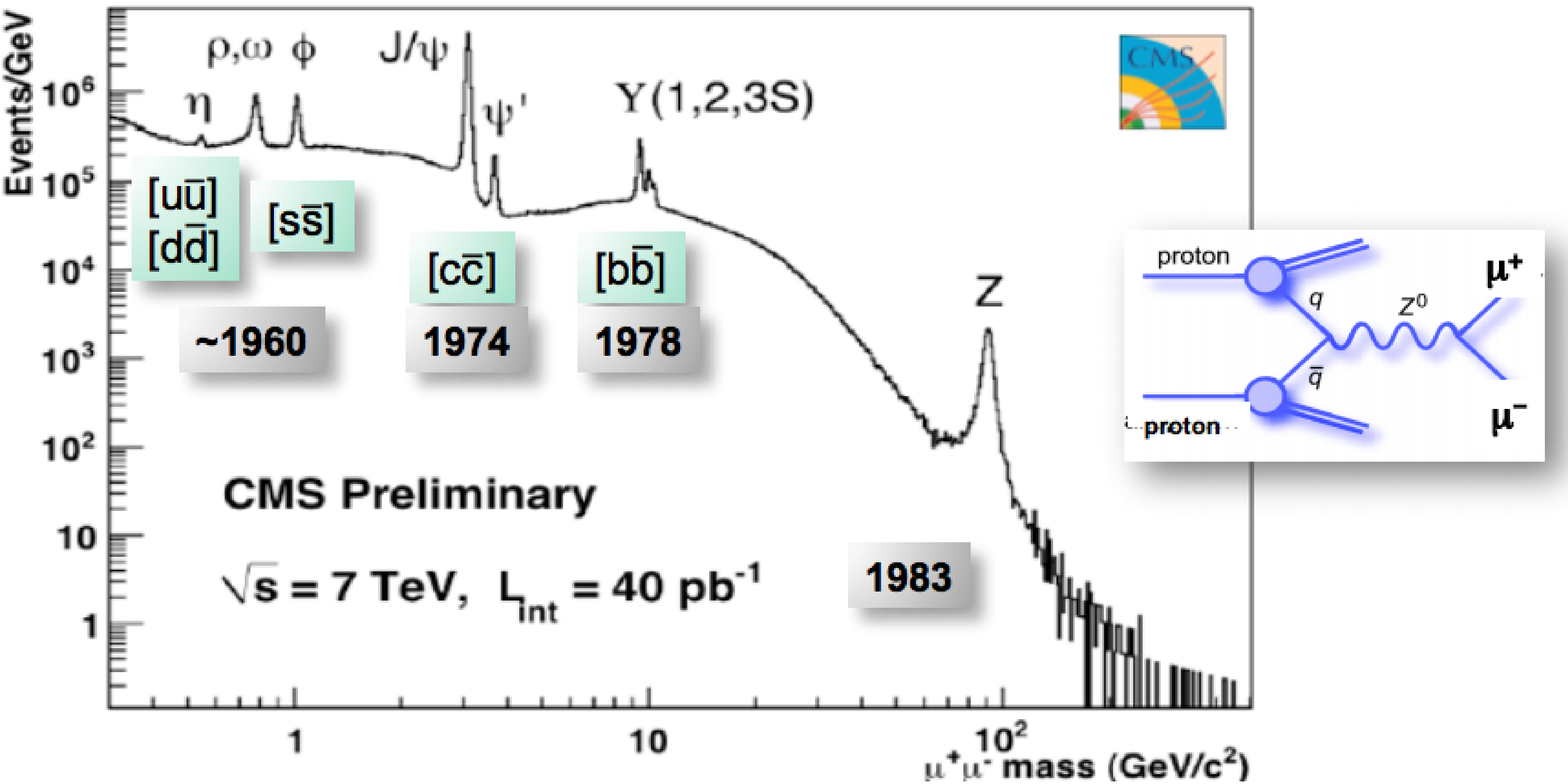
Reminder – how do we discover new particles



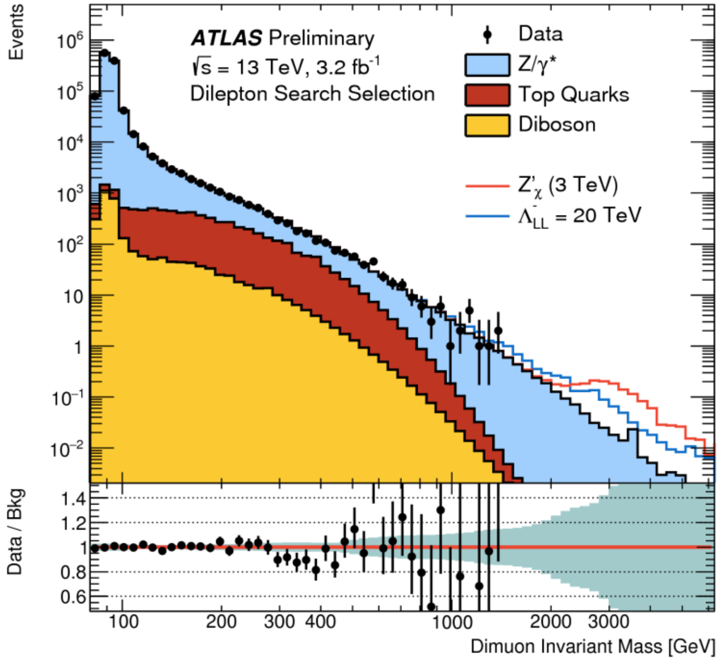
look for a bump on a smoothly falling 'mass' distribution (mass of combination of reconstructed stable particles)

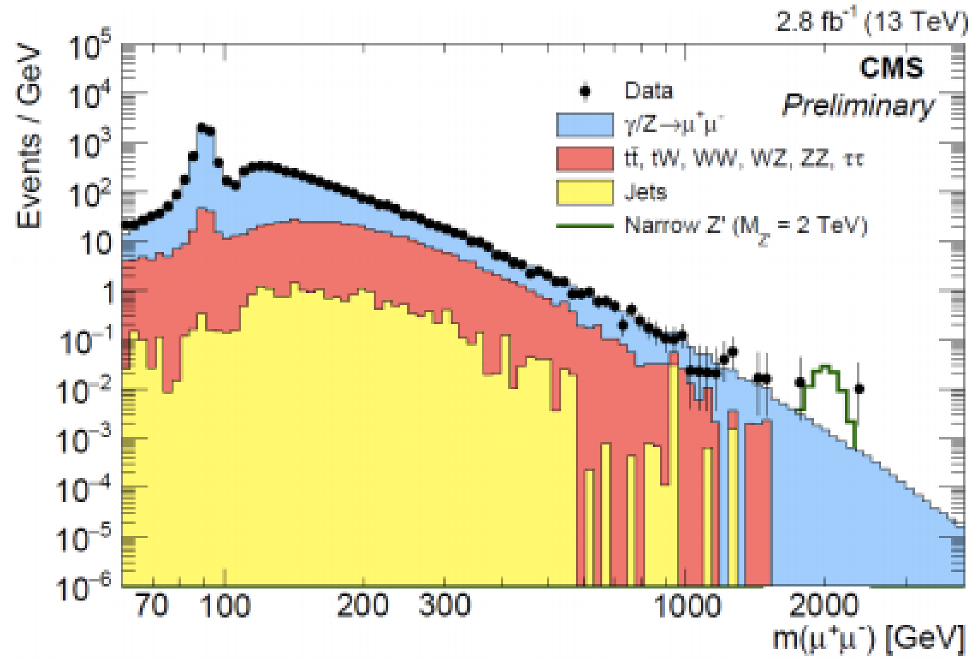
Search for a new heavy Z'

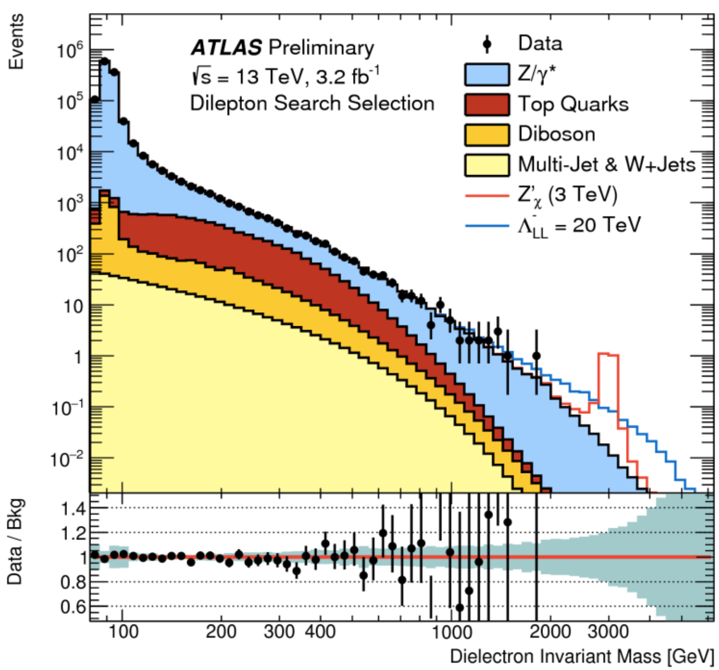
Many new physics models have a new heavy gauge boson which can decay to leptons (el, mu).
Like a Z but heavier - called Z'.
Important to search for such new particles at the LHC.



Historically many important discoveries (Nobel prizes) in di-lepton mass spectrum


ATLAS Preliminary
√s = 13 TeV, 3.2 fb-1
Dilepton Search Selection
Data
Z/γ*
Top Quarks
Diboson
Z'χ (3 TeV)
ΛLL = 20 TeV
Events
Data / Bkg
Dimuon Invariant Mass [GeV]


2.8 fb-1 (13 TeV)
CMS
Preliminary
Data
γ/Z→μ+μ-
tt̄, tW, WW, WZ, ZZ, ττ
Jets
Narrow Z' (MZ' = 2 TeV)
Events / GeV
m(μ+μ-) [GeV]


ATLAS Preliminary
√s = 13 TeV, 3.2 fb-1
Dilepton Search Selection
Data
Z/γ*
Top Quarks
Diboson
Multi-Jet & W+Jets
Z'χ (3 TeV)
ΛLL = 20 TeV
Events
Data / Bkg
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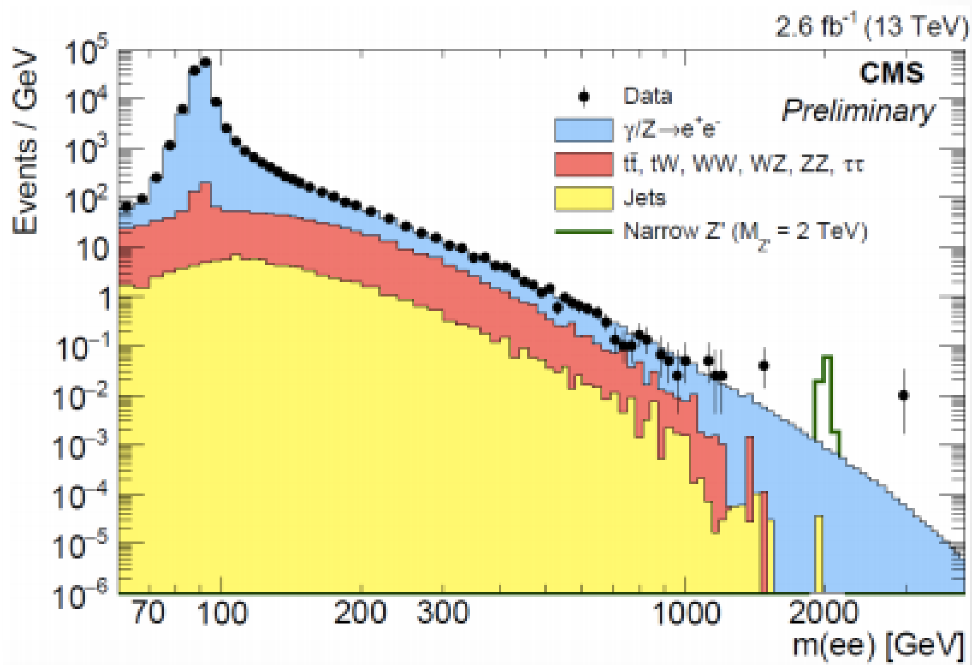
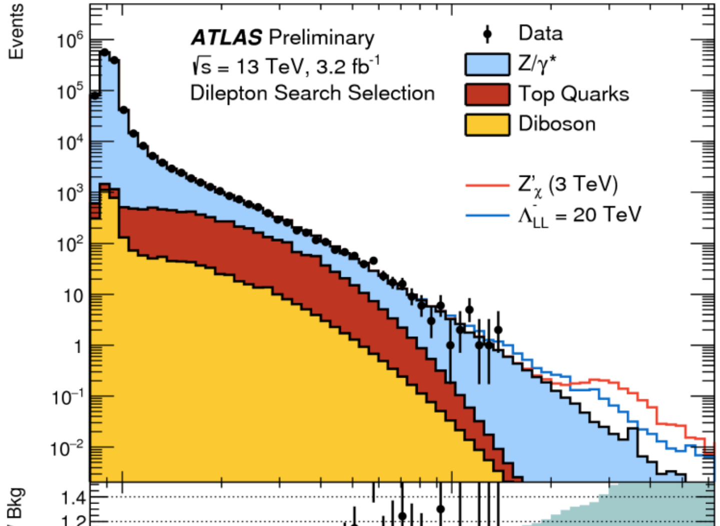
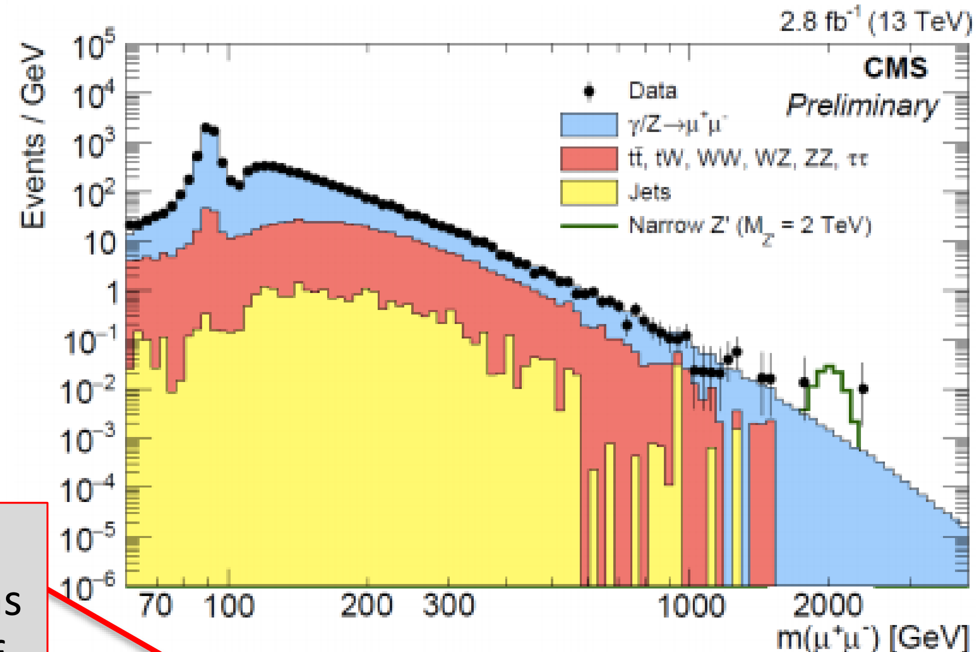
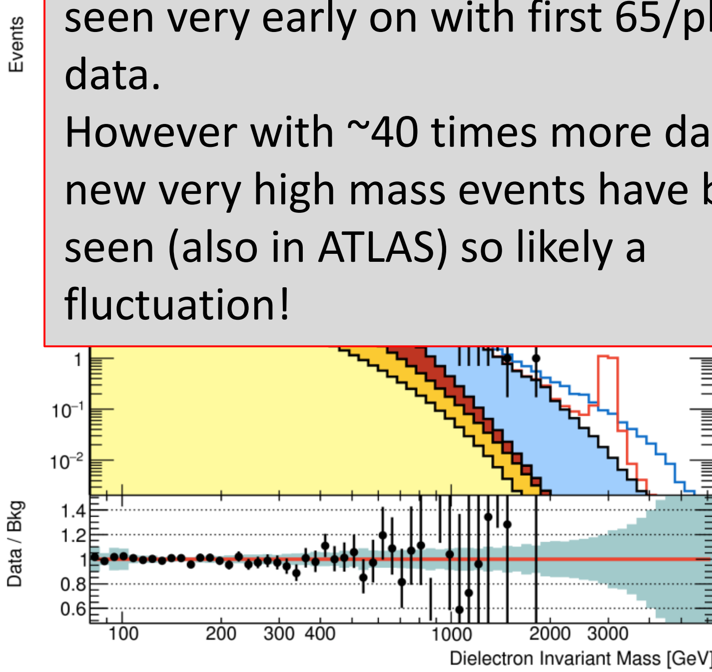

2.6 fb-1 (13 TeV)
CMS
Preliminary
Data
γ/Z→e+e-
tt̄, tW, WW, WZ, ZZ, ττ
Jets
Narrow Z' (MZ' = 2 TeV)
Events / GeV
m(ee) [GeV]

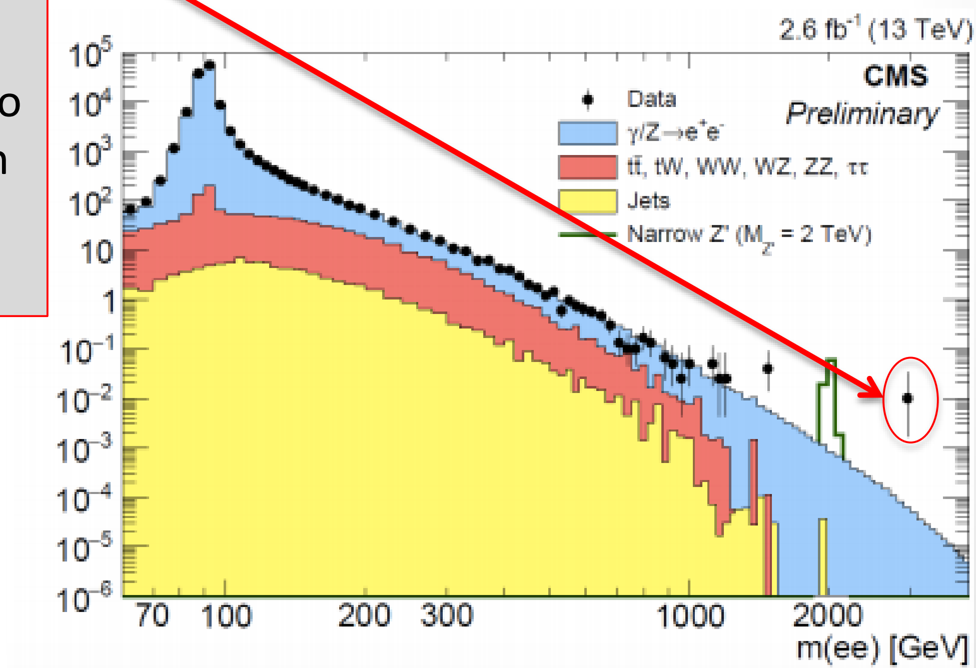


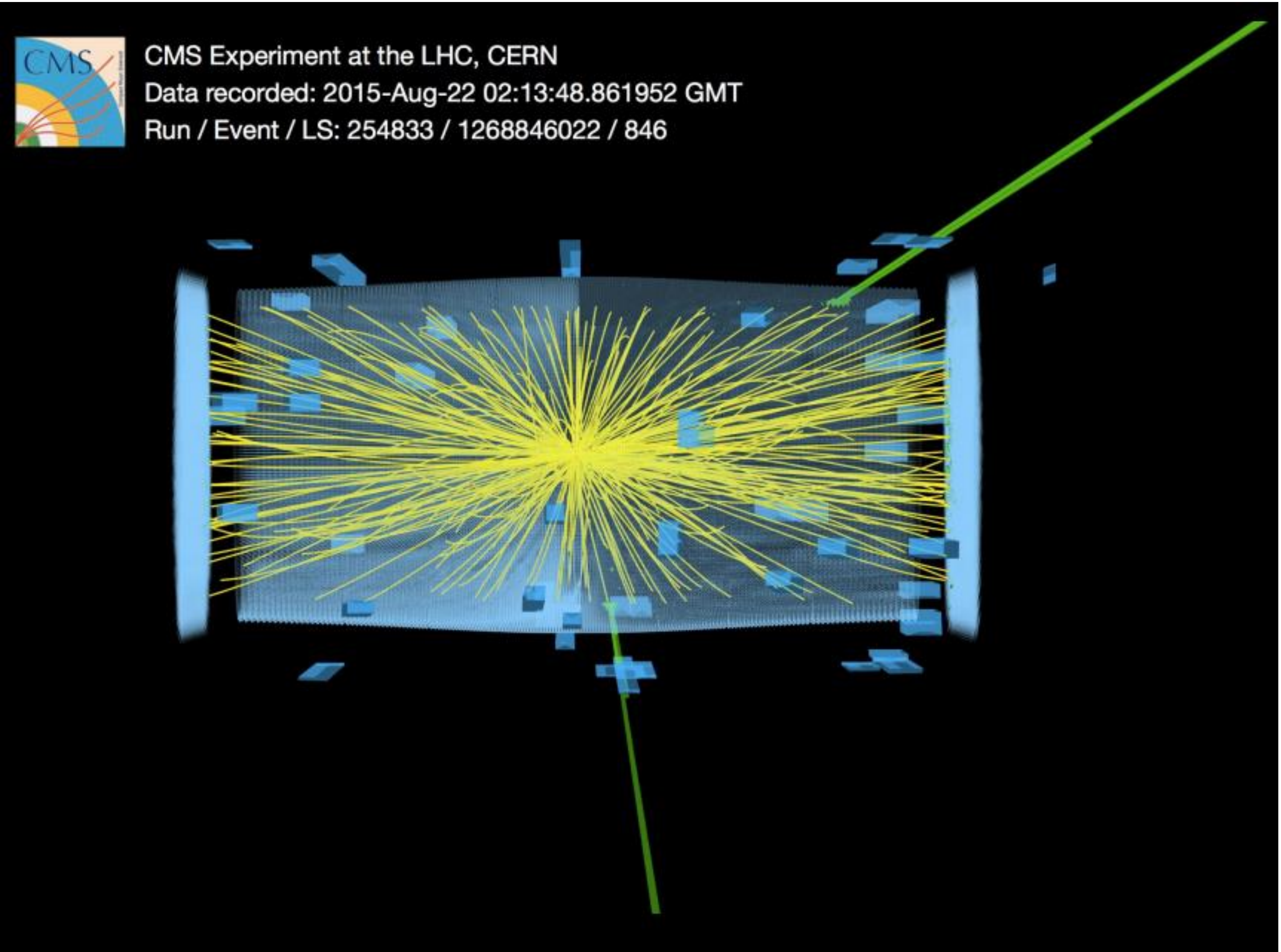


This event (Mee=2.9 TeV) caused lots of excitement in the summer, as it was seen very early on with first 65/pb of data.

However with ~40 times more data no new very high mass events have been seen (also in ATLAS) so likely a fluctuation!

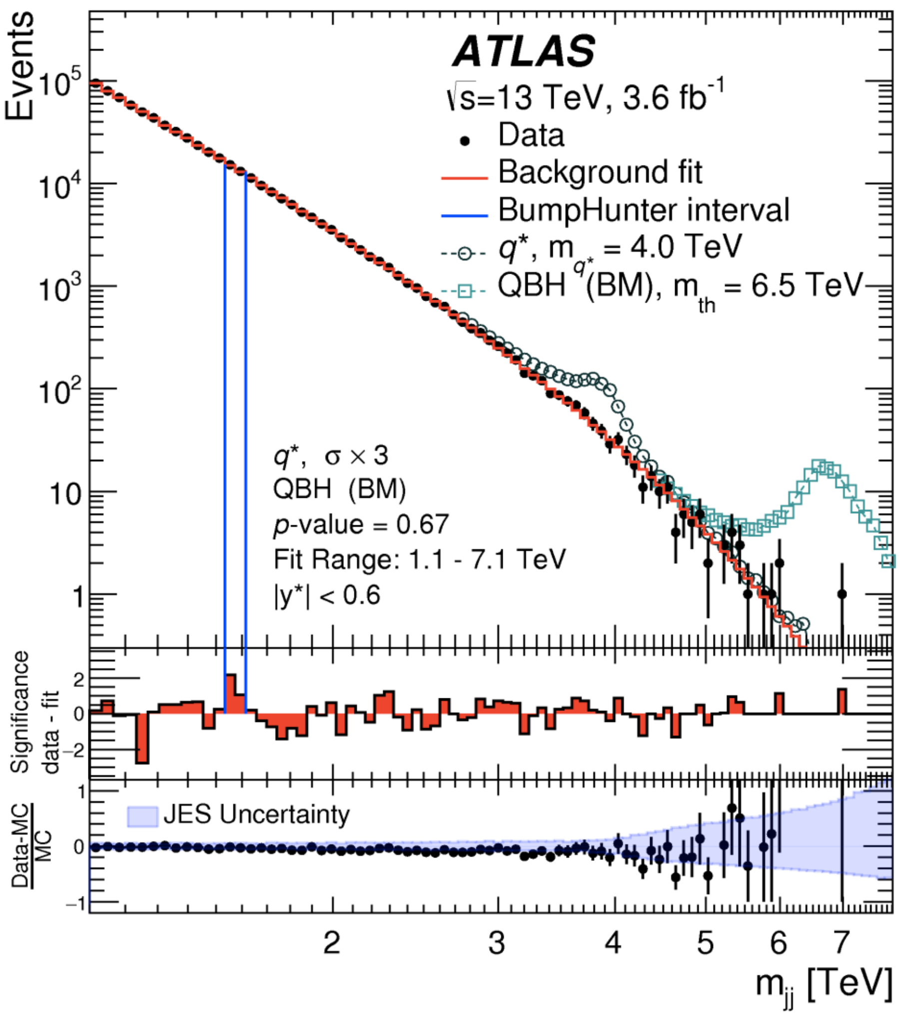


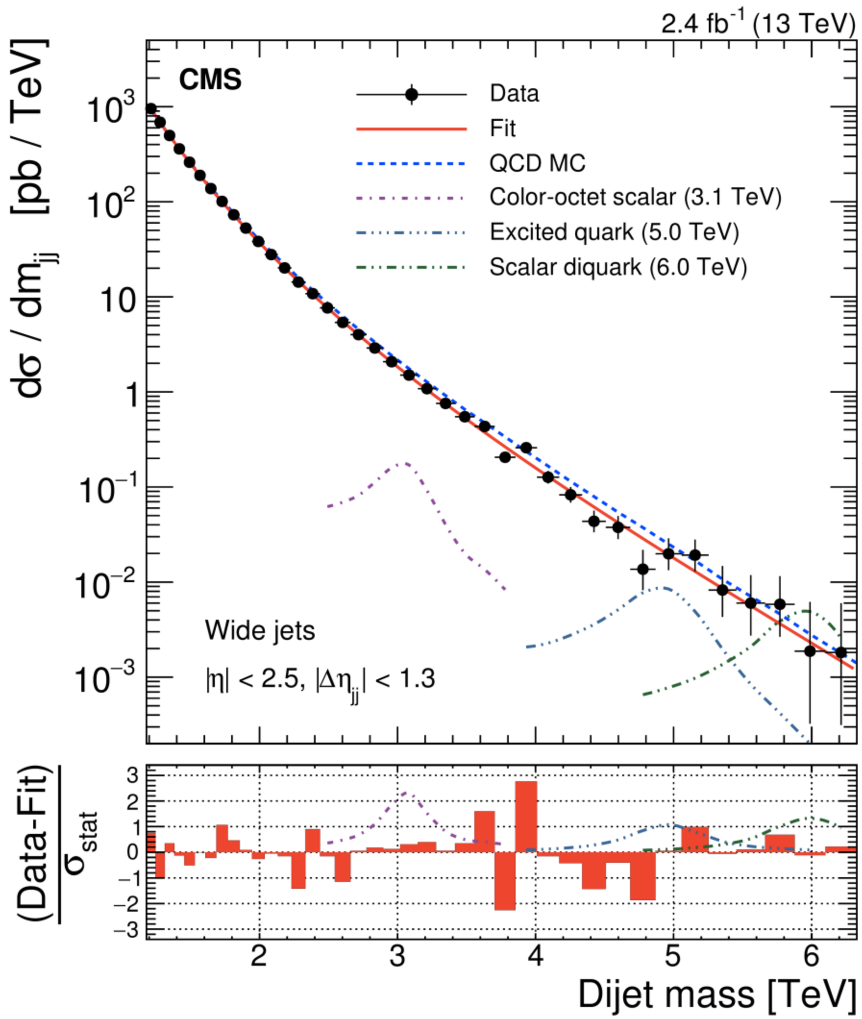


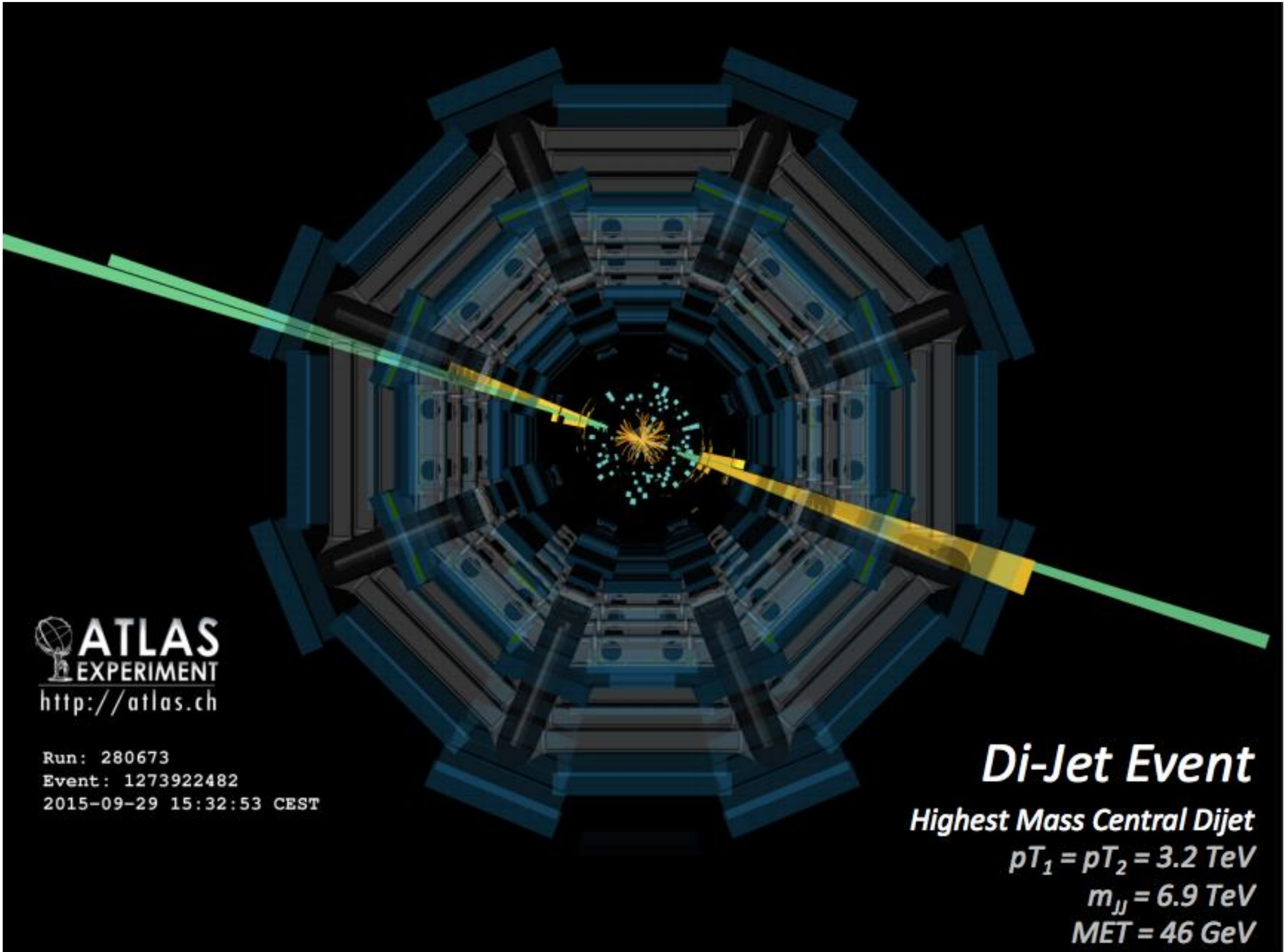

CMS
CMS Experiment at the LHC, CERN
Data recorded: 2015-Aug-22 02:13:48.861952 GMT
Run / Event / LS: 254833 / 1268846022 / 846

di-jet resonances

Similar thing for 2-jet resonances. These distributions are sensitive to potential new phenomena (black holes, excited quarks) not excluded by Run-1 with very little Run-2 data






ATLAS
EXPERIMENT
http://atlas.ch
Run: 280673
Event: 1273922482
2015-09-29 15:32:53 CEST
Di-Jet Event
Highest Mass Central Dijet
$pT_1 = pT_2 = 3.2$ TeV
$m_{JJ} = 6.9$ TeV
MET = 46 GeV

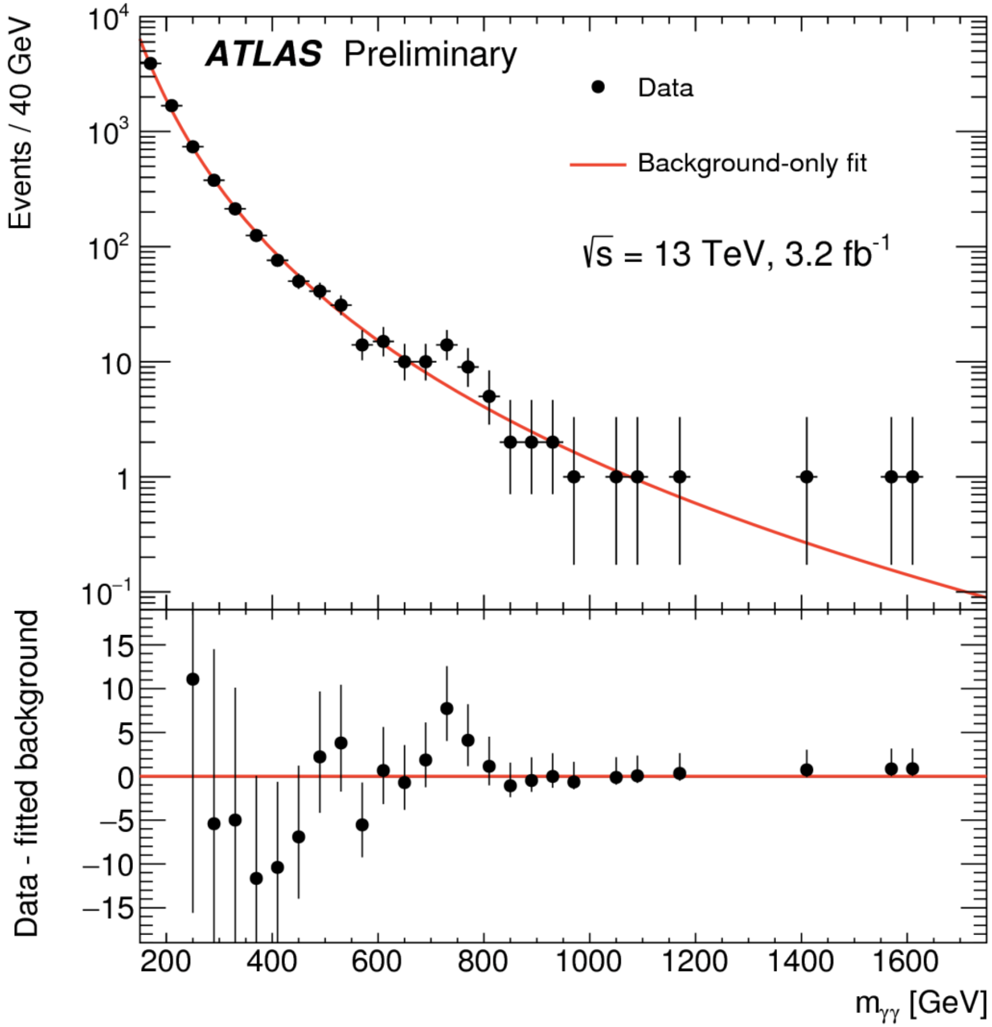
The *excitement* – high mass 2-photon resonances

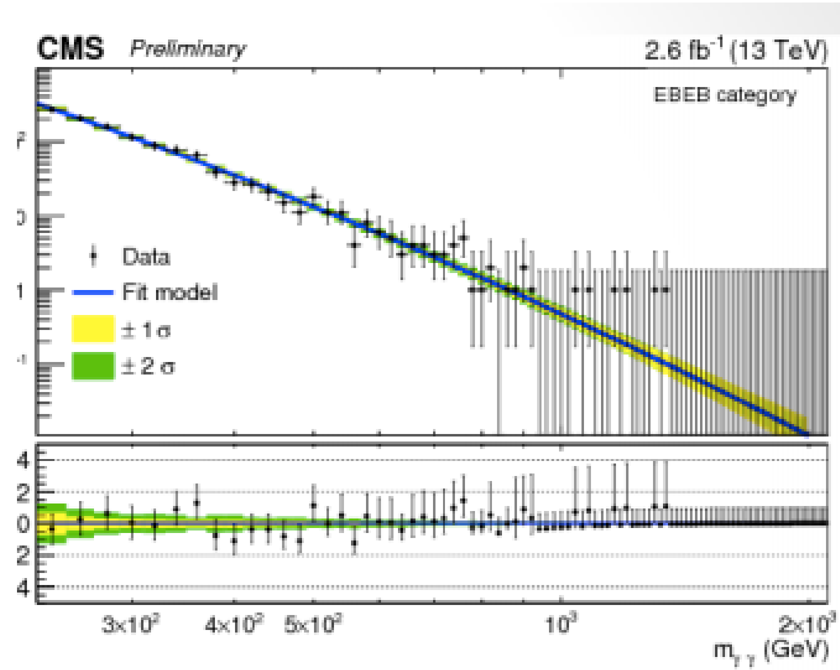
- Why 2photon resonances:
  - Motivated in Beyond-The-Standard-Model theories:
    - Heavy Higgs boson
    - Graviton in extra dimension theories

    (in both cases there are lots of parameters in the theory which can change mass, width, couplings to photons and other particles – quite different from SM Higgs where everything is known for a given mass)
  - 2photon mass resolution 'good' – narrow peak expected
  - photon identification 'good' – main background SM di-photon production
  - (These reasons are why this was one of the 2 discovery Higgs channels)

(because the mass resolution is very good, this means the analysis is sensitive to single bin fluctuations. This is explicitly quantified in the statistical treatment – called the Look-else-where-effect: https://en.wikipedia.org/wiki/Look-elsewhere_effect).

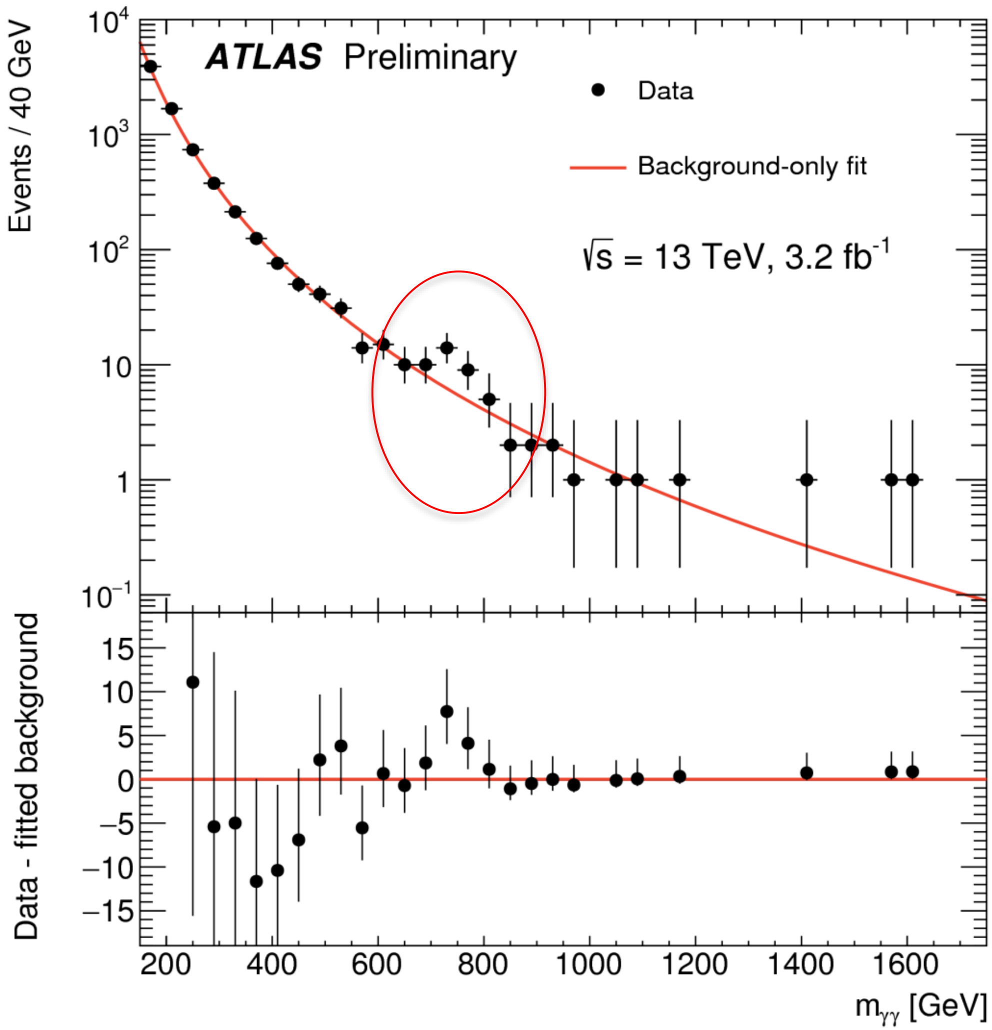
The *excitement* – high mass 2-photon resonances

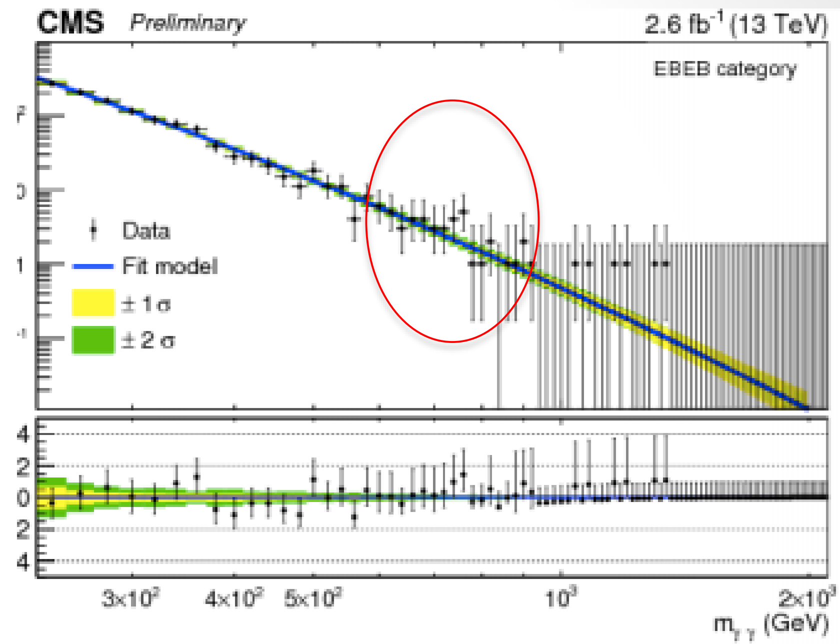




fit smooth background function with narrow signal hypothesis

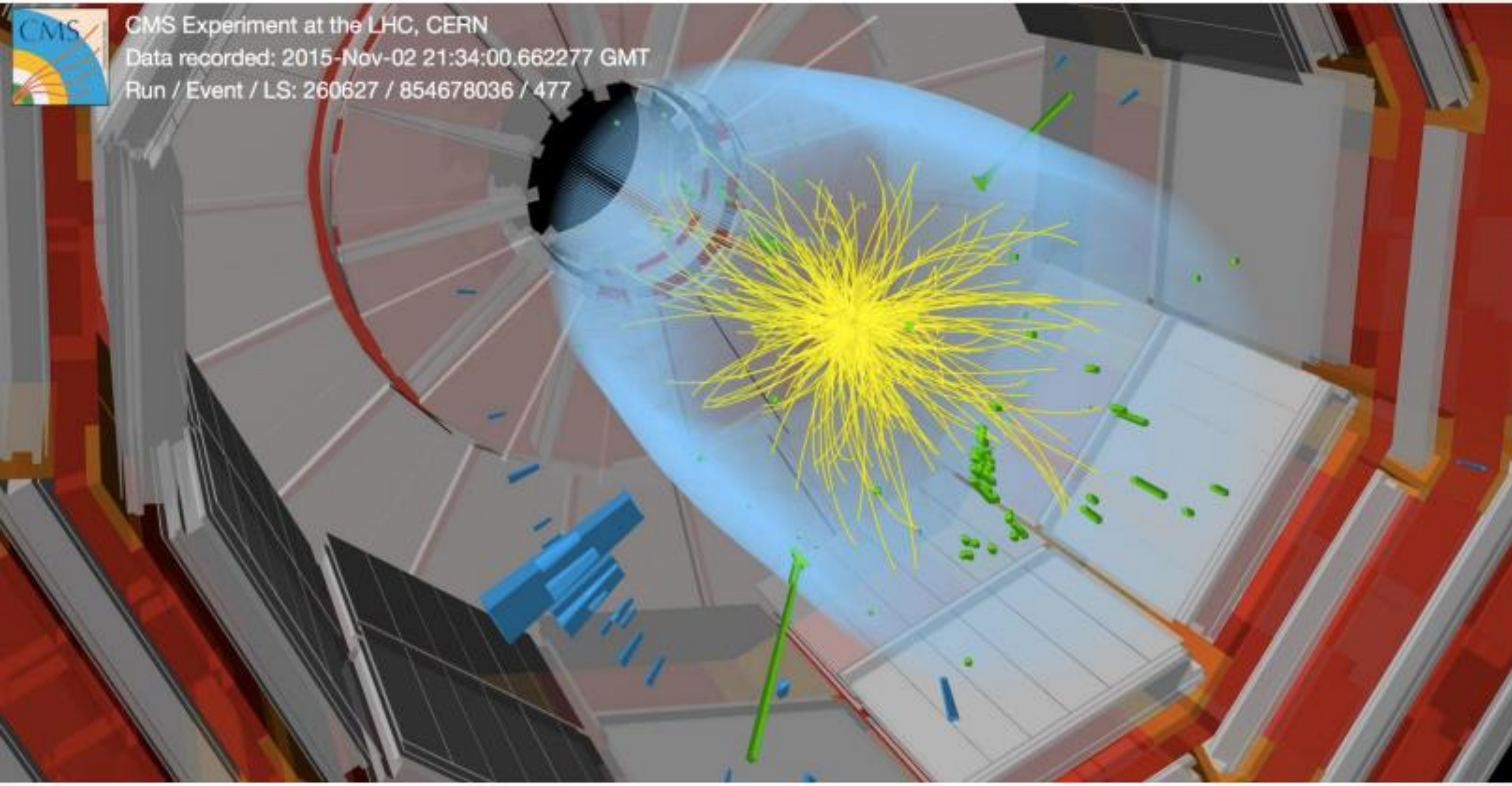
The *excitement* – high mass 2-photon resonances





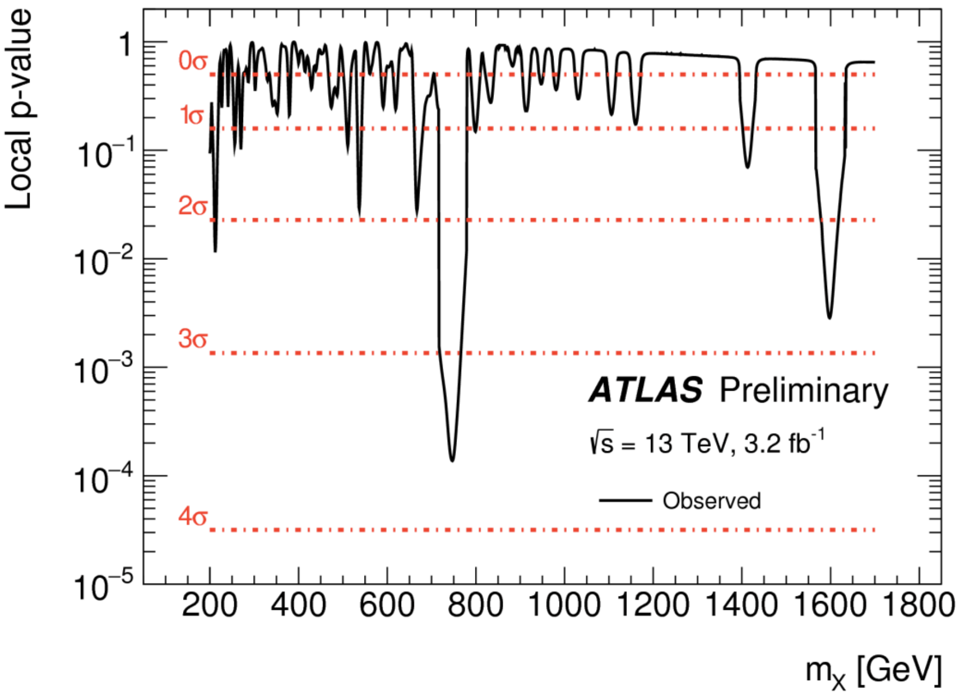
fit smooth background function with narrow signal hypothesis
Excess of events over background observed at ~750 GeV

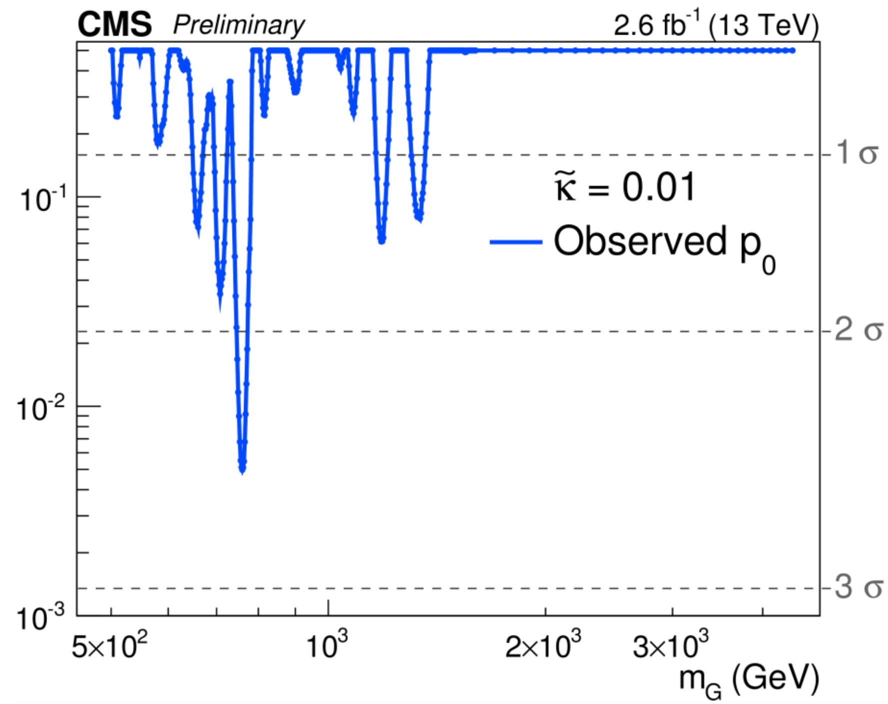
Search for diphoton resonances



Diphoton event with m(γγ) = 745 GeV

The *excitement* – high mass 2-photon resonances – statistical analysis



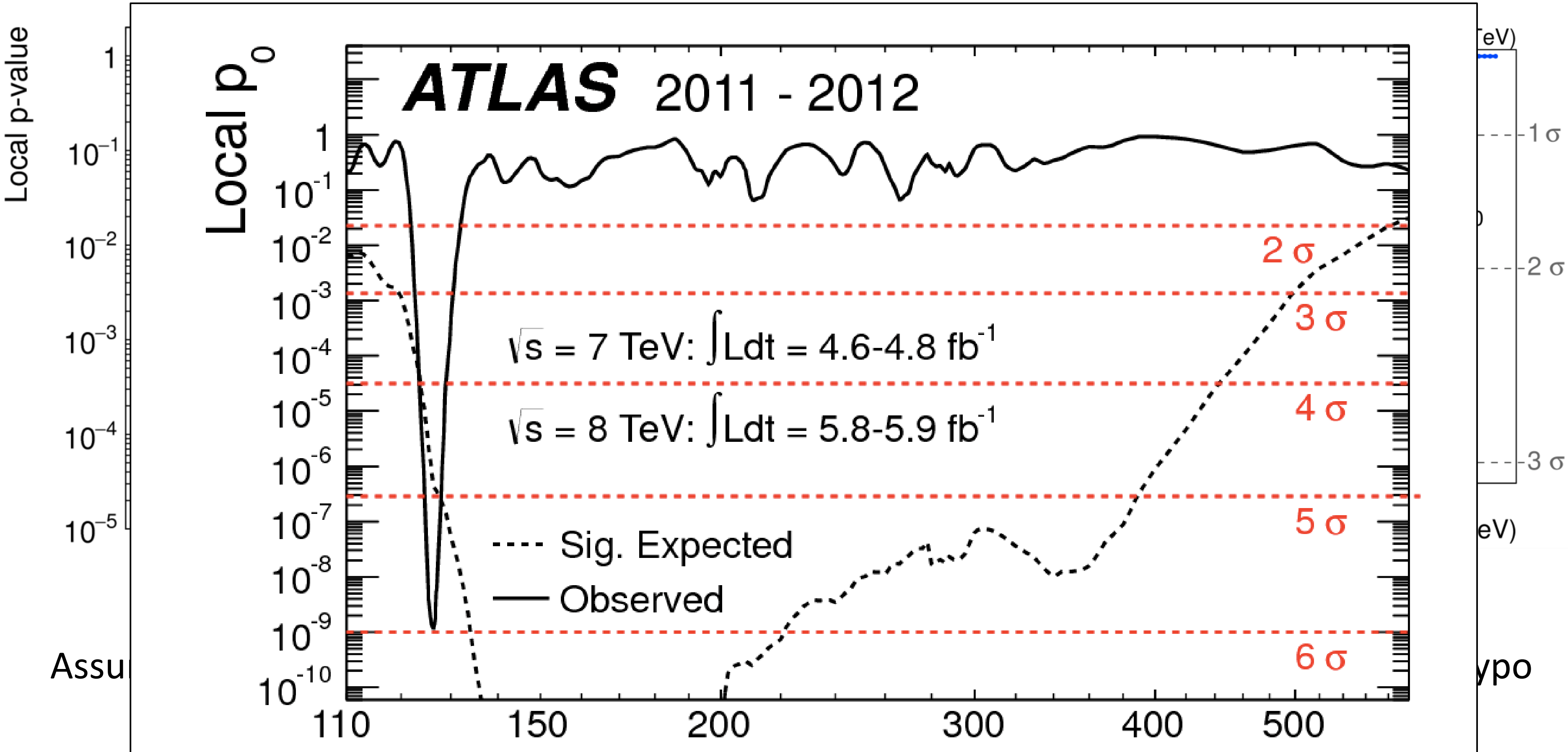


Assuming a narrow signal, plot probability of data being described by the background hypothesis.

The above significances don't take into account the LEE and get substantially reduced when you take that into account.

ATLAS find a slightly better fit with a larger width (6% of mass).

The *excitement* – high mass 2-photon resonances – statistical analysis



reminder – this is what a discovery looks like on these plots!

2photon results

	peak mass	local significance	global significance*
CMS (narrow)	760 GeV	2.6σ	1.2σ
ATLAS (narrow)	750 GeV	3.6σ	2.0σ
ATLAS (best width = 6%)	?	3.9σ	2.3σ

* = global significance depends on range looked in (CMS: 0.5 – 4.5 TeV
ATLAS: 0.2 – 2.0 TeV , width 0 – 10%)

Poor mans combination: use ATLAS excess to say where to look, and then use CMS local significance - ~2.6sigma, but this is only valid if the 2 bumps are at compatible masses (not clear to me yet). Definitely need more data to investigate if this is a real new particle!

Questions i)

- The main question is if the excess was from a real new particle shouldn't we have seen this in Run-1?
- Due to the relatively low mass (~750 GeV) the x-sec increase is only ~x5 (for gluon production, less for others) and we had <5x more data in Run-1 so should have about the-same/slightly-worse sensitivity
- Both ATLAS + CMS have re-checked the Run-1 data and say 'such an excess is compatible with Run-1 data'
  - ATLAS say compatible at the 1.4σ level (assuming gluon production)
  - CMS do a simple combination of Run-1 and Run-2 which slightly increases the signal significance

Questions ii)

- Another popular question is do the events in the ‘excess’ region show any interesting properties compared to background events?
- ATLAS (CMS) have ~40(~10) events in the signal area and compare properties (such as missing energy, number of jets, number of leptons, energy of the photons,…) of these with events in the sidebands – they don’t see any significant differences within the low statistics

(expected) Question

- How much data do we need to discover/study this?
- If it is a real signal, probably 5/fb more would be enough for a ‘discovery’. But much more data would be needed to study the properties (spin, mass, width, decays etc..) of the new particle, and to pin down the theory that is driving this.
- Like the precision studies of the Higgs we need as much data as possible.

This mornings ‘**excess**’ – theory papers on arxiv!

UCB-PTH-15/15

Composite Models for the 750 GeV Diphoton Excess

Keisuke Harigaya and Yasunori Nomura
Berkeley Center for Theoretical Physics, Department of Physics, University of California, Berkeley, CA 94720 and Theoretical Physics Group, Lawrence Berkeley National Laboratory, Berkeley, CA 94720

We present composite models explaining the diphoton excess of mass around 750 GeV rec reported by the LHC experiments.

[hep-ph] 15 Dec 2015

I. INTRODUCTION

Recently, the existence of a diphoton excess of mass around 750 GeV has been reported by both the ATLAS [1] and CMS [2] experiments at the LHC. The signals are still only 3.6 σ and 2.6 σ in the respective experiments, but if confirmed, this would indicate the long awaited discovery of new physics at the TeV scale.

Because of the Landau-Yang theorem [3], a particle decaying into two photons must have either spin 0, 2, or higher. Assuming spin 0, it is natural to postulate that the particle is a composite state of some strong dynamics around the TeV scale, since it would then not introduce any new hierarchy problem beyond that of the standard

TABLE I. Charge assignment of a hidd Here, $a \neq 0$, and Q and $\bar{Q}$ are left-handed

behind the physics generating couplings onance of interest and standard model Motivated by these considerations, present models in which the observed arises from a composite particle of so gauge interactions. We present a scena

Footprints of New Strong Dynamics via Anomaly

Yuichiro Nakai[1], Ryosuke Sato[2,3] and Kohsaku Tobioka[2,3,4]

…rtment of Physics, Harvard University, Cambridge, Massachusetts 02138, USA
[2]Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot 7610001, Israel
…Nuclear Studies, High Energy Accelerator Research Organization (KEK), Tsukuba 305-0801, Japan
…verly Sackler School of Physics and Astronomy, Tel-Aviv University, Tel-Aviv 69978, Israel

…omaly provides a smoking-gun evidence of a new confining gauge theory. Motivated by a …nt excess in diphoton invariant mass distribution at the LHC, we discuss a scenario that …mbu-Goldstone (pNG) boson of a new QCD-like theory is produced by gluon fusion and …pair of the standard model gauge bosons. Despite the strong dynamics, the production …and the decay widths are determined by anomaly matching condition. The excess can …by the pNG boson with mass of around 750 GeV. The model also predicts exotic …as a color octet scalar and baryons which are within the reach of the LHC experiment.

…TRODUCTION

parameters. From the effective interactions of Eq. (1), the widths of ϕ decays into gg and $\gamma\gamma$ are calculated as [11]

$$\Gamma(\phi \to gg) = \frac{\alpha_s^2}{8\pi^3}\frac{k_g^2 m_\phi^3}{\Lambda_g^2},\quad \Gamma(\phi \to \gamma\gamma) = \frac{\alpha^2}{64\pi^3}\frac{k_\gamma^2 m_\phi^3}{\Lambda_\gamma^2}, \qquad (2)$$

where m_ϕ is the mass of ϕ. With a natural assumption $k_\gamma/\Lambda_\gamma \sim k_g/\Lambda_g$, the scalar boson ϕ dominantly decays into two gluons and the total decay width is approximately given by $\Gamma_\phi \simeq \Gamma(\phi \to gg)$. We can also take the branching ratio of diphoton as $\mathrm{Br}(\phi \to \gamma\gamma) \simeq \Gamma(\phi \to \gamma\gamma)/\Gamma(\phi \to gg)$. By using the narrow width approximation [12, 13], the production cross section times branching ratio is then estimated as

$$\sigma(pp \to \phi + X)\mathrm{Br}(\phi \to \gamma\gamma) \simeq \frac{\pi^2}{8m_\phi s}\Gamma(\phi \to \gamma\gamma)\int_0^1 dx_1 \int_0^1 dx_2 \Big[\qquad (3)$$

…e theory is ubiquitous in physics …odel (SM). Most models to solve …such as technicolor [1], (the holo…dall-Sundrum scenarios [2] and a …dels [3], involve new strong dy…ymmetry [4], the breaking scale …given by dimensional transmuta…eory [5]. In addition, the dark …ew pion originating from strong …ore, string theory seems to prefer …h extra gauge groups. Therefore, …ch prevailing nature of strong dy…ot intend to solve the hierarchy …vated to pursue a possibility of a …gauge theory to be explored at

…S and CMS collaboration has re…oton invariant mass distribution …V [10]. If this peak comes from …with mass of around 750 GeV, …mber can be fitted with a rela…

Di-photon excess illuminates Dark Matter

Mihailo Backović*[1], Alberto Mariotti†[2], and Diego Redigolo‡[3,4]

[1]Center for Cosmology, Particle Physics and Phenomenology - CP3, Universite Catholique de Louvain, Louvain-la-neuve, Belgium
[2] Theoretische Natuurkunde and IIHE/ELEM, Vrije Universiteit Brussel, and International Solvay Institutes, Pleinlaan 2, B-1050 Brussels, Belgium
…rsités, UPMC Univ Paris 06, UMR 7589, LPTHE, F-75005, Paris, France
[4]CNRS, UMR 7589, LPTHE, F-75005, Paris, France

December 16, 2015

Abstract

…ose a simplified model of dark matter with a scalar mediator to ac… the di-photon excess recently observed by the … A determination of the total width of the sca…

2015

CERN-PH-TH/2015-302 IFUP-TH/2015

What is the γγ resonance at 750 GeV?

Roberto Franceschini[a], Gian F. Giudice[a], Jernej F. Kamenik[a,b,c], Matthew McC… Riccardo Rattazzi[e], Michele Red… Alessandro Strumia[a,g], Ri…

[a] *CERN, Theory Division, Gene…*
[b] *Jožef Stefan Institute, Jamova 39, 10…*
[c] *Faculty of Mathematics and Physics, Univers… 1000 Ljubljana, Slov…*
[d] *Dept. de Física and IFAE-BIST, Universi… 08193 Bellaterra, Barcelo…*
[e] *Institut de Théorie des Phénomènes Physiques, EP…*
[f] *INFN, Sezione di Firenze, Via G. Sansone, 1,…*
[g] *Dipartimento di Fisica dell’Università…*

Abstract

Run 2 LHC data show hints of a new reso… bution at an invariant mass of 750 GeV. W… of a new boson, extracting information on… theoretical interpretations. Scenarios cov…

arXiv:1512.04933v1 [hep-ph] 15 Dec 2015

Knocking on New Physics’ door with a Scalar Resonance

Dario Buttazzo[a], Admir Greljo[a,b], David Marzocca[a]

(a) Physik-Institut, Universität Zürich, CH-8057 Zürich, Switzerlan…
(b) Faculty of Science, University of Sarajevo, Zmaja od Bosne 33-35, 7100… Bosnia and Herzegovina

Abstract

We speculate about the origin of the recent excess at ∼ 750 GeV in d… ton resonance searches observed by the ATLAS and CMS experiments… 13 TeV data. Its interpretation as a new scalar resonance produced in… fusion and decaying to photons is consistent with all relevant exclusion b… from the 8 TeV LHC run. We provide a simple phenomenological fram… to parametrize the properties of the new resonance and some interpreta… in various concrete setups, such as a singlet (pseudo)scalar, composite… and the MSSM.

…p-ph] 15 Dec 2015

First interpretation of the 750 GeV di-photon resonance at the LHC

Stefano Di Chiara,[1] Luca Marzola,[1,2] and Martti Raidal[1,2]
[1]*National Institute of Chemical Physics and Biophysics, Rävala 10, 10143 Tallinn, Estonia.*
[2]*Institute of Physics, University of Tartu, Ravila 14c, 50411 Tartu, Estonia.*
(Dated: December 16, 2015)

We scrutinise the evidences recently reported by the ATLAS and CMS collaborations for compatible 750 GeV resonances which appear in the di-photon channels of the two experiments in both the 8 TeV and 13 TeV datasets. Similar resonances in di-boson, di-lepton, di-jet and $t\bar{t}$ final states are instead not detected. After discussing the properties and the compatibility of the reported signals, we study the implications on the physics beyond the Standard Model with particular emphasis on possible scalar extension of the theory such as singlet extensions and the two Higgs doublet model. We also analyse the significance of the new experimental indications within the frameworks of the MSSM and of technicolour models, commenting on how these could explain the detected di-photon excess without conflicting with other data.

I. INTRODUCTION

The discovery of the Higgs boson [1, 2], possibly the first spin zero elementary particle observed in Nature, raised the crucial issue concerning the possible existence of several scalar particles with masses much below any supposed cut-off scale of the theory, such as the Planck scale. The detection of a light scalar sector then potentially allows us to discriminate between the theories beyond the Standard Model (SM) which protect the electroweak scale from the influence of the high-energy cut-off, such as supersymmetry or compositeness, and the scenarios supported by selection mechanisms or landscape arguments which disfavour the existence of these particles.

Recently, both the ATLAS [3] and CMS [4] experi…

comment, for completness, on the possibilities offered by a spin-two resonance.

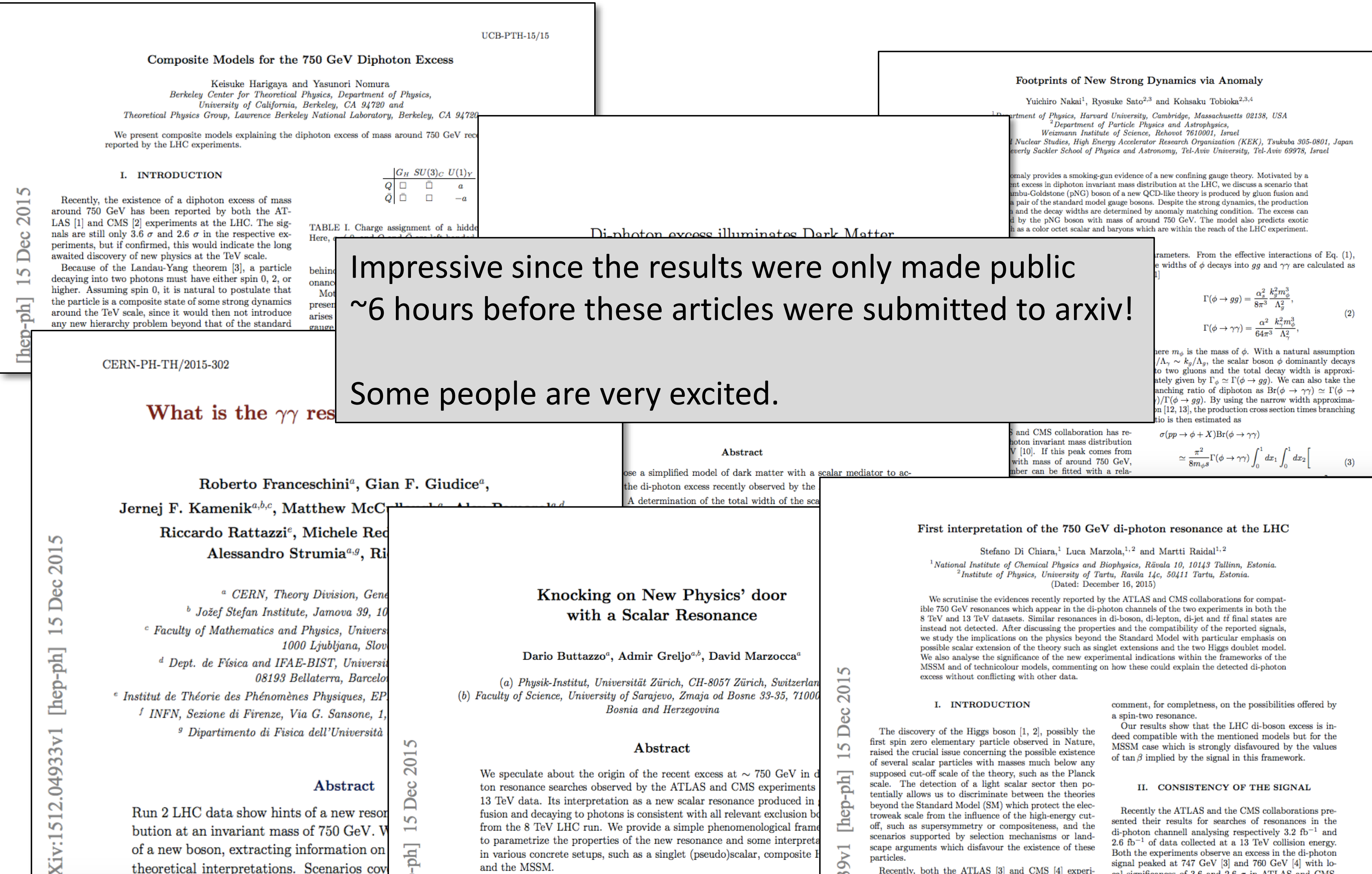
Our results show that the LHC di-boson excess is indeed compatible with the mentioned models but for the MSSM case which is strongly disfavoured by the values of tan β implied by the signal in this framework.

II. CONSISTENCY OF THE SIGNAL

Recently the ATLAS and the CMS collaborations presented their results for searches of resonances in the di-photon channell analysing respectively 3.2 fb^{-1} and 2.6 fb^{-1} of data collected at a 13 TeV collision energy. Both the experiments observe an excess in the di-photon signal peaked at 747 GeV [3] and 760 GeV [4] with local significances of 3.6 and 2.6 σ in ATLAS and CMS,

…39v1 [hep-ph] 15 Dec 2015

This mornings ‘**excess**’ – theory papers on arxiv!



Impressive since the results were only made public ~6 hours before these articles were submitted to arxiv!

Some people are very excited.

and more publicity:

M Sciences

SCIENCES | Vidéos | Archéologie | Astronomie | Biologie | Cerveau | Géophysique | Mathématiques

Au CERN, frémissements autour d'une particule hypothétique

Le Monde.fr | 15.12.2015 à 18h54 • Mis à jour le 16.12.2015 à 10h17 |

The New York Times

Science

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Physicists in Europe Find Tantalizing Hints of a Mysterious New Particle

natu

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News & Comment > News > 2015 > December > Article

NATURE | BREAKING NEWS

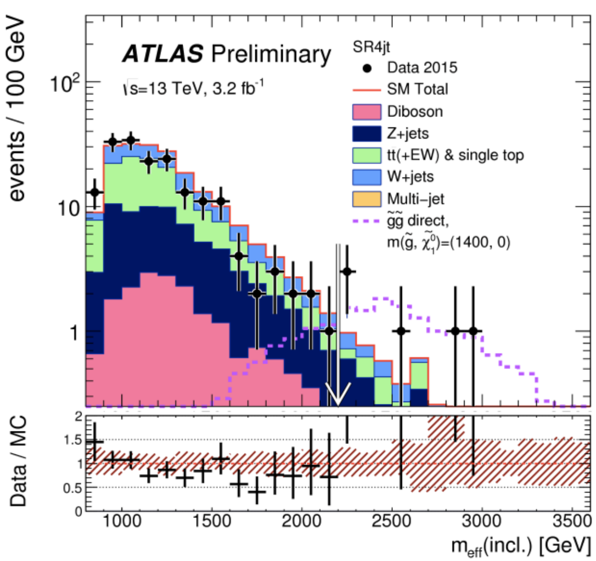
LHC sees hint of boson heavier than Higgs

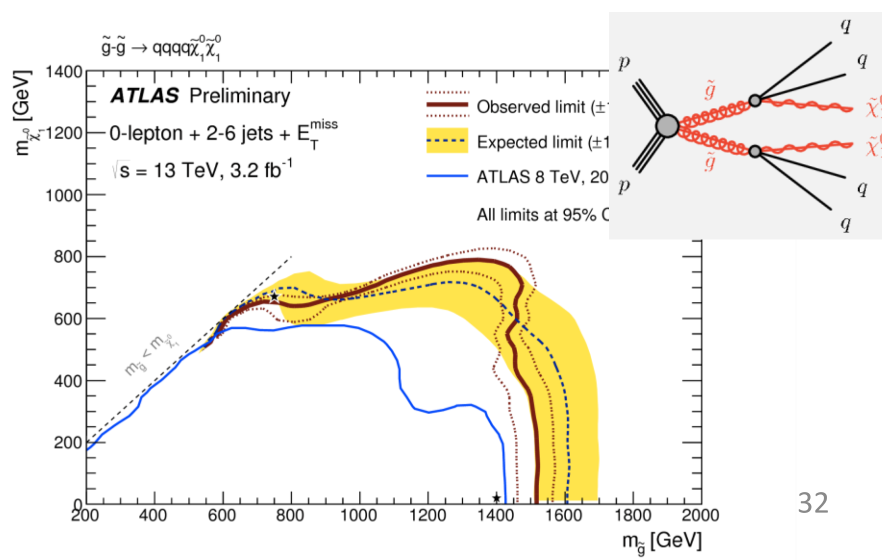
Tantalizing first results from upgraded collider will be followed up within a year.

Davide Castelvecchi

Other searches

- Many other searches were presented but with no exciting results
- In Run-1 there were a few ~2-2.5σ excesses observed in searches for di-boson resonances at ~2 TeV (seen both by ATLAS and CMS)
  - Both experiments presented results for such a search with 2015 data, with no excess. However given the size of the dataset this does not completely rule out the Run-1 excesses
- For SUSY the current Run-2 dataset opens up a well motivated region of parameter space (gluinos with mass of ~1.6 TeV) but unfortunately no sign of a signal yet
  - Next year will also be very interesting for probing SUSY particle masses that can solve the hierarchy problem of the Standard Model





Summary and outlook

- **An extraordinary year for CMS**
  - LS1 work successfully completed
  - Recorded 90% of collisions delivered by LHC, 75% @ 3.8 T
  - Physics object commissioning well advanced
  - New challenge of 25 ns operation has been met
- **33 results on 13 TeV data so far**
  - SM measurements confirming general (and in some cases, precision) agreement at new energy
  - New Physics searches yielding many improved limits beyond Run 1
  - On first look: two interesting excesses in 8 TeV not appearing at 13 TeV
  - New (small) excess in diphoton spectrum, looking forward to more data

More (and updated) results coming for winter conferences!

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

CMS Collaboration - 13 TeV Results 15/12/2015 [54]

“New (small) excess in diphoton spectrum, looking forward to more data”

Summary

- ATLAS made major changes to detector, DAQ, trigger, software and analysis frameworks during LS1, **Including new IBL**
- ATLAS is working very well at 13 TeV with 25ns collisions
- Host of new results presented here with full 2015 data sample
- The ATLAS Collaboration has released a host of new results with the full 2015 13 TeV dataset, *in **24 Conference Notes** and **4 Journal Papers***
  (Available at the following location: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/December2015-13TeV)
  - New measurements of single top and diboson cross sections
  - First look at H(125 GeV) production
  - Many searches for new physics with sensitivity exceeding the Run 1 reach, investigating a vast number of topologies and event characteristics
  - Modest excesses begging for more data

- Eagerly awaiting a much larger haul of data in 2016!

51

“Modest excess begging for more data”

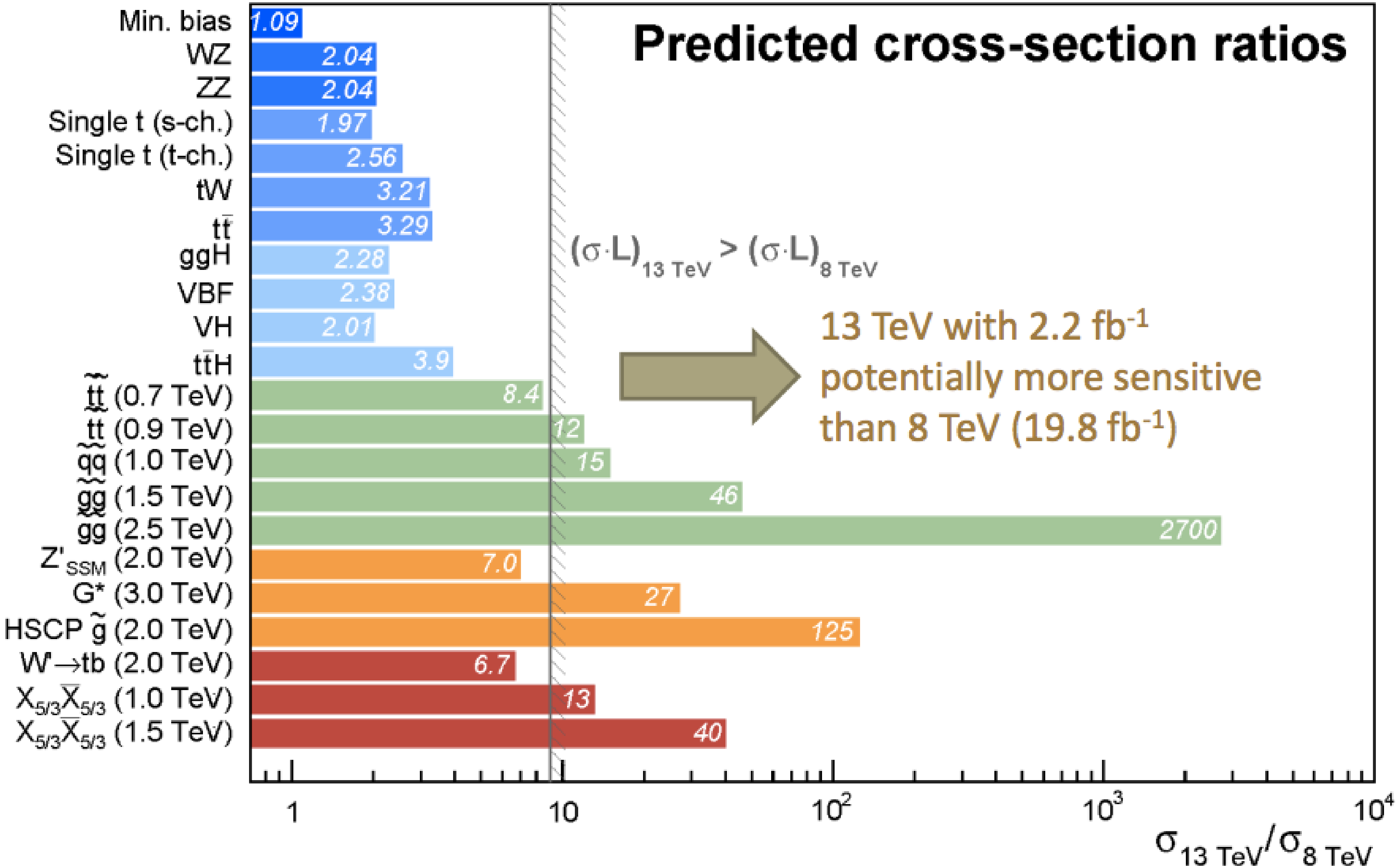
Summary

Huge thanks and Congratulations to the LHC operations team

Looking forward to working with you all as LPC, along with Christoph (as deputy LPC)

Changing of the guard

Backup…


Predicted cross-section ratios
Min. bias 1.09
WZ 2.04
ZZ 2.04
Single t (s-ch.) 1.97
Single t (t-ch.) 2.56
tW 3.21
$t\bar{t}$ 3.29
ggH 2.28
VBF 2.38
VH 2.01
$t\bar{t}H$ 3.9
$\tilde{t}\tilde{t}$ (0.7 TeV) 8.4
$\tilde{t}\tilde{t}$ (0.9 TeV) 12
$\tilde{q}\tilde{q}$ (1.0 TeV) 15
$\tilde{g}\tilde{g}$ (1.5 TeV) 46
$\tilde{g}\tilde{g}$ (2.5 TeV) 2700
Z'_{SSM} (2.0 TeV) 7.0
G* (3.0 TeV) 27
HSCP $\tilde{g}$ (2.0 TeV) 125
$W' \to tb$ (2.0 TeV) 6.7
$X_{5/3}\bar{X}_{5/3}$ (1.0 TeV) 13
$X_{5/3}\bar{X}_{5/3}$ (1.5 TeV) 40
$(\sigma \cdot L)_{13\ TeV} > (\sigma \cdot L)_{8\ TeV}$
13 TeV with 2.2 fb^{-1}
potentially more sensitive
than 8 TeV (19.8 fb^{-1})
1
10
10^2
10^3
10^4
$\sigma_{13\ TeV}/\sigma_{8\ TeV}$

Wed, 16 Dec 2015 (showing first 25 of 37 entries)

[1] **arXiv:1512.04939 [pdf, other]**

First interpretation of the 750 GeV di-photon resonance at the LHC

Stefano Di Chiara, Luca Marzola, Martti Raidal

Comments: 5 pages, 3 figures

Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

[2] **arXiv:1512.04933 [pdf, other]**

What is the γ gamma resonance at 750 GeV?

Roberto Franceschini, Gian F. Giudice, Jernej F. Kamenik, Matthew McCullough, Alex Pomarol, Riccardo

Comments: 32 pages, 7 figures

Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

[3] **arXiv:1512.04931 [pdf, ps, other]**

Diphoton Signatures from Heavy Axion Decays at LHC

Apostolos Pilaftsis

Comments: 6 pages, 1 figure, LaTeX

Subjects: **High Energy Physics - Phenomenology (hep-ph)**

[4] **arXiv:1512.04929 [pdf, other]**

Knocking on New Physics' door with a Scalar Resonance

Dario Buttazzo, Admir Greljo, David Marzocca

Comments: 16 pages, 3 figures, 1 table

Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

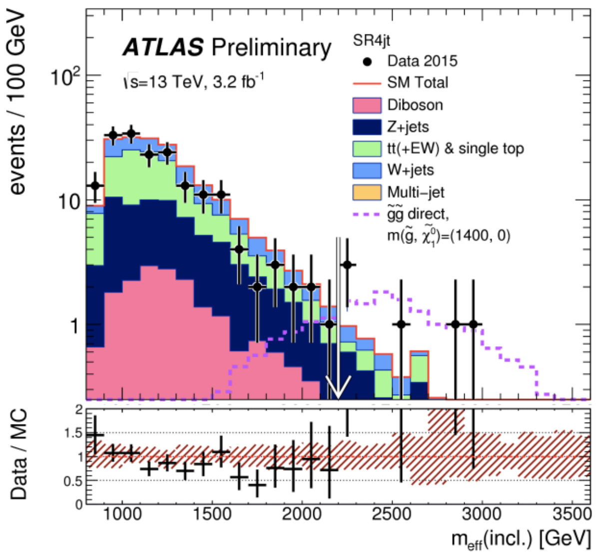
[5] **arXiv:1512.04928 [pdf, other]**

Rays of light from the LHC

Similar results for CMS
Many other SUSY searches from ATLAS/CMS shown…

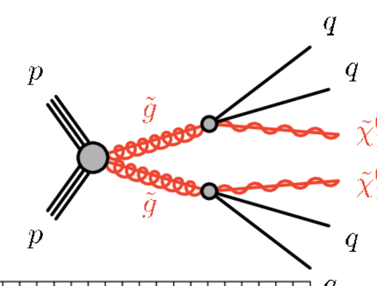
SUSY

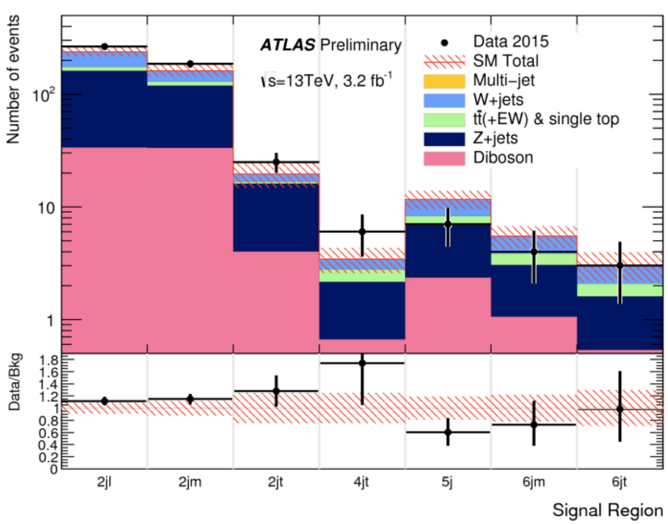
Classic SUSY search looking for high momentum jets and missing transverse energy (from stable weakly interacting lightest SUSY particles (Dark Matter candidate!)).

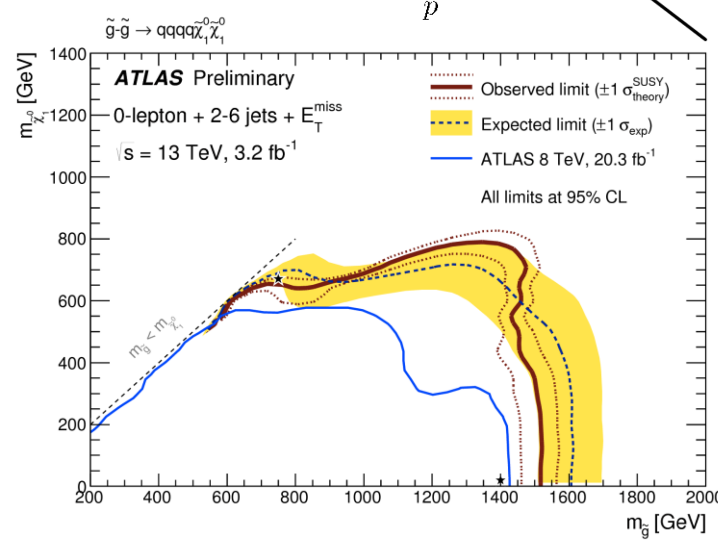


No excess observed.
Set limits (sigh!)

simplified gluino model







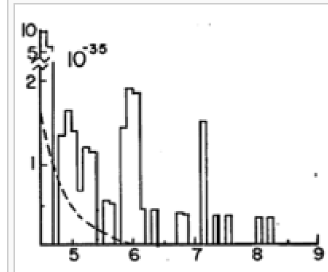
Oops-Leon

From Wikipedia, the free encyclopedia

Oops-Leon is the name given by particle physicists to what was thought to be a new subatomic particle "discovered" at Fermilab in 1976. The E288 collaboration, a group of physicists led by Leon Lederman who worked on the E288 particle detector, announced that a particle with a mass of about 6.0 GeV, which decayed into an electron and a positron, was being produced by the Fermilab particle accelerator.[1] The particle's initial name was the greek letter Upsilon (ϒ). After taking further data, the group discovered that this particle did not actually exist, and the "discovery" was named "Oops-Leon" as a pun on the original name (mispronounced /juːpsɨlɒn/) and the first name of the E288 collaboration leader.[2]

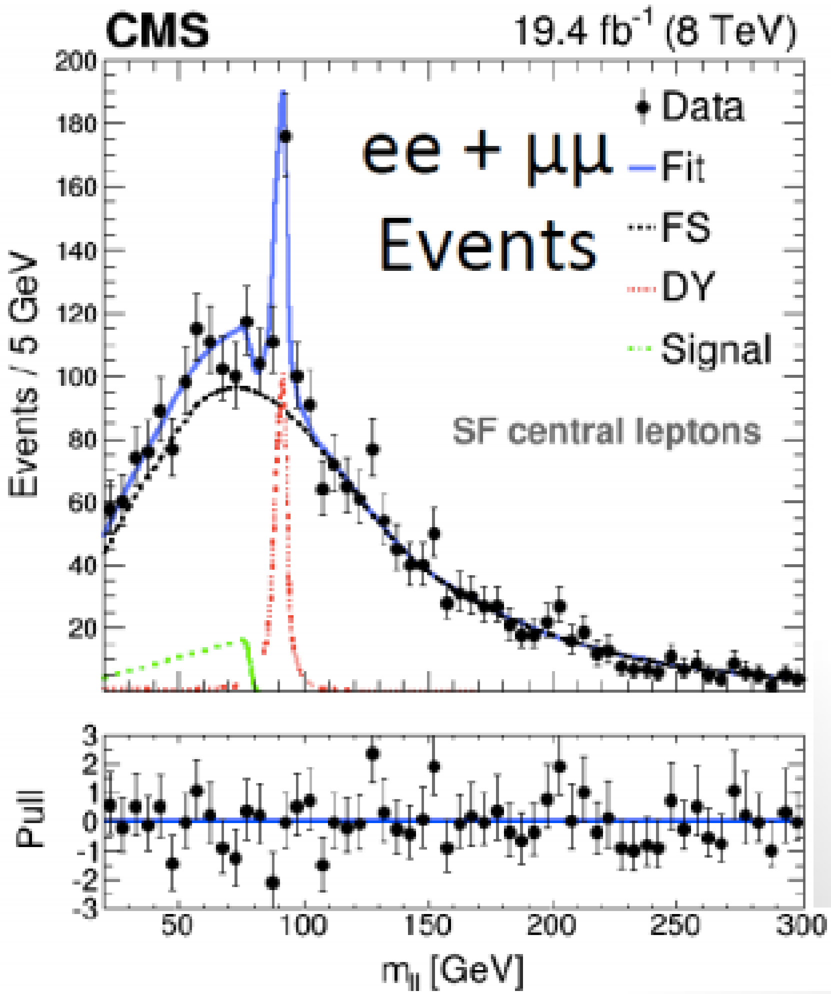
The original publication was based on an apparent peak (resonance) in a histogram of the invariant mass of electron-positron pairs produced by protons colliding with a stationary beryllium target, implying the existence of a particle with a mass of 6 GeV which was being produced and decaying into two leptons. An analysis showed that there was "less than one chance in fifty" that the apparent resonance was simply the result of a coincidence.[1] Subsequent data collected by the same experiment in 1977 revealed that the resonance had been such a coincidence after all.[2] However, a new resonance at 9.5 GeV was discovered using the same basic logic and greater statistical certainty,[3] and the name was reused (see Upsilon particle).

Today's commonly accepted standard for announcing the discovery of a particle is that the number of observed events is 5 standard deviations (σ) above the expected level of the background.[4] Since for a normal distribution of data, the measured number of events will fall within 5σ over 99.9999% of the time, this means a less than one in a million chance that a statistical fluctuation would cause the apparent resonance. Using this standard, the Oops-Leon "discovery" would never have been published.

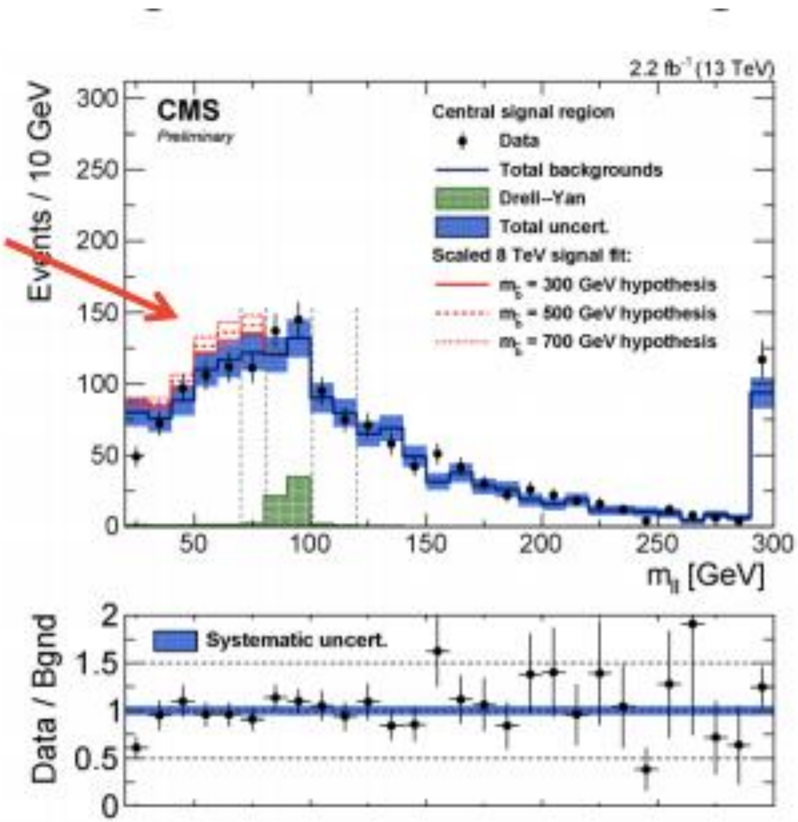


A plot counting the rate of production of electron–positron pairs as a function of invariant mass (in GeV). The apparent peak around 6 GeV was initially identified as a new particle,[1] but named **Oops-Leon** when it turned out not to exist.

https://en.wikipedia.org/wiki/Oops-Leon


CMS
19.4 fb-1 (8 TeV)
ee + μμ
Events
Data
Fit
FS
DY
Signal
SF central leptons
Events / 5 GeV
Pull
m_ll [GeV]

Run 1
excess

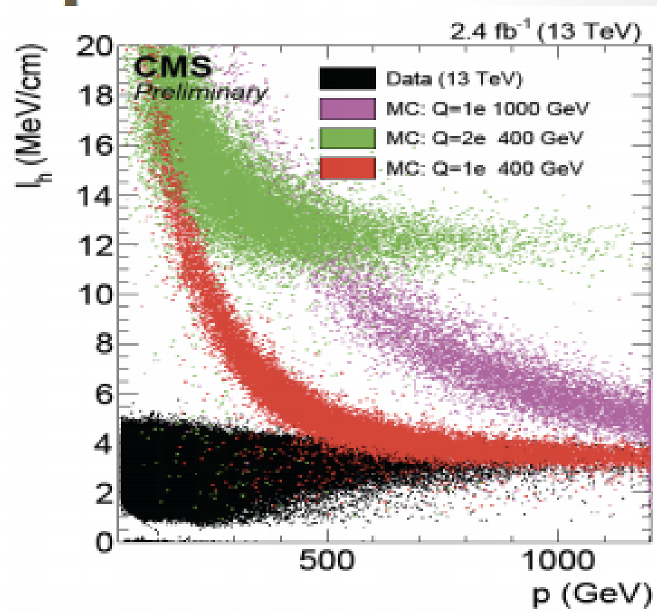

2.2 fb-1 (13 TeV)
CMS
Preliminary
Central signal region
Data
Total backgrounds
Drell–Yan
Total uncert.
Scaled 8 TeV signal fit:
m = 300 GeV hypothesis
m = 500 GeV hypothesis
m = 700 GeV hypothesis
Events / 10 GeV
m_ll [GeV]
Data / Bgnd
Systematic uncert.

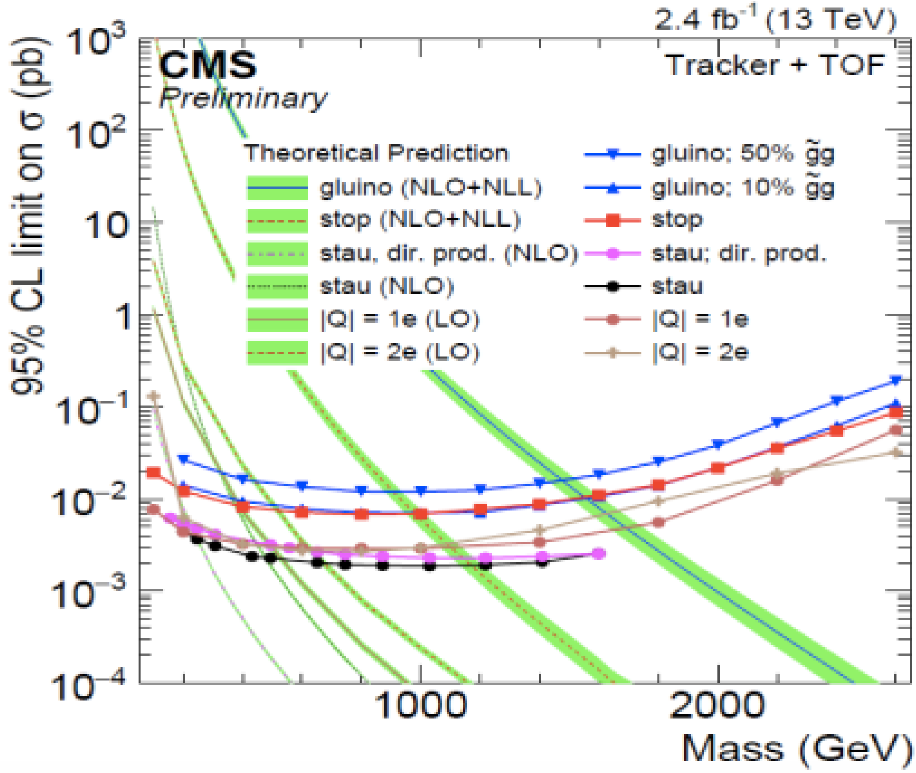
more exotic SUSY:

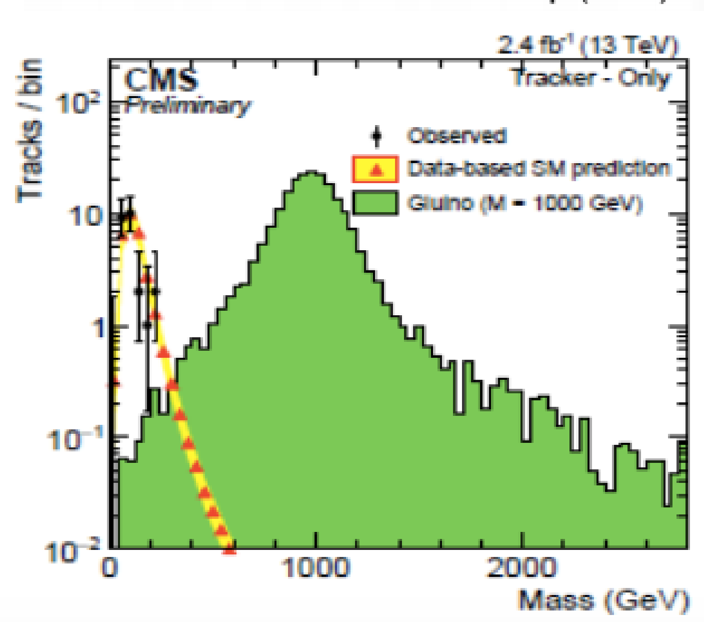
EXO-15-010

Heavy stable charged particles

- **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)**

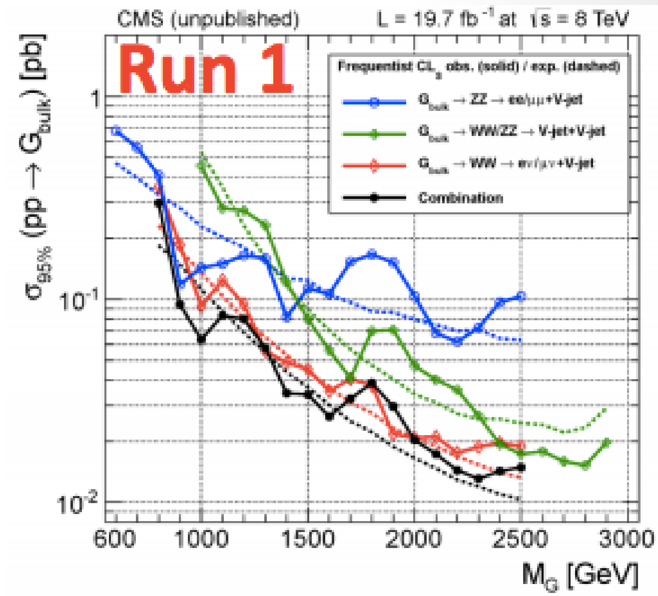




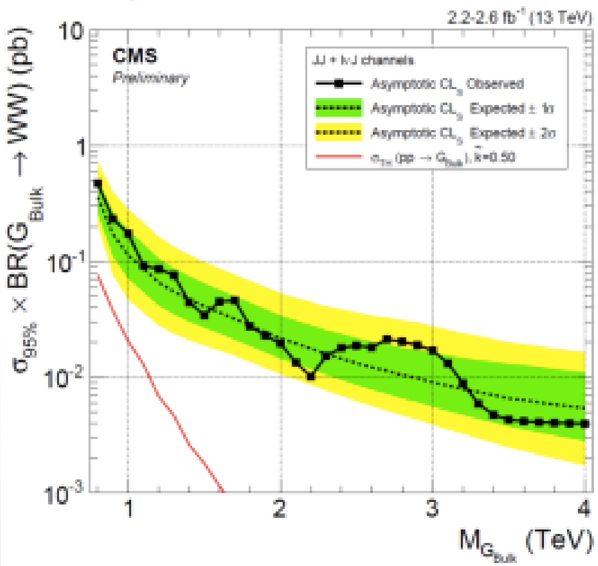


Search for diboson resonances

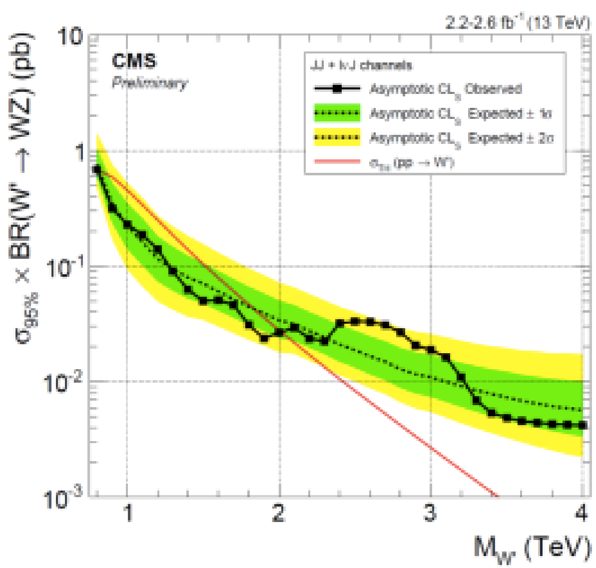
- **Run 1: CMS ~2σ excess near 1.8-2.0 TeV**
- Repeat search at 13 TeV using most sensitive channels: lνJ, JJ
- **Analysis categorized in dijet mass** for optimal sensitivity to WW, WZ, ZZ signals
- **13 TeV: no excess observed in the region of interest near 2 TeV**
  - More data needed to fully exclude Run 1 excess



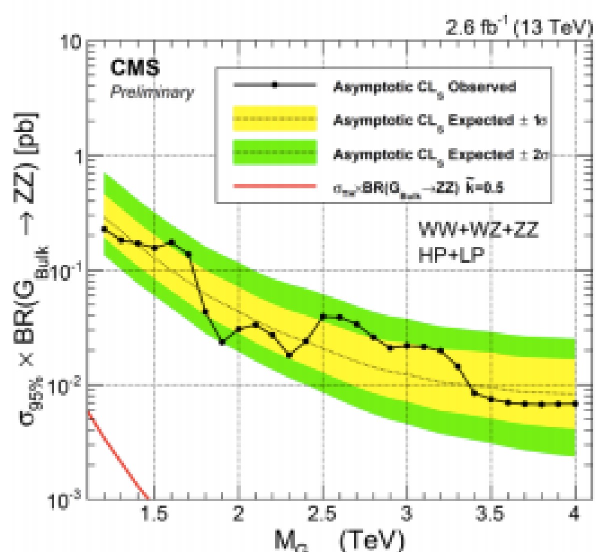
G_{Bulk}→WW (lνJ+JJ)



W'→WZ (lνJ+JJ)

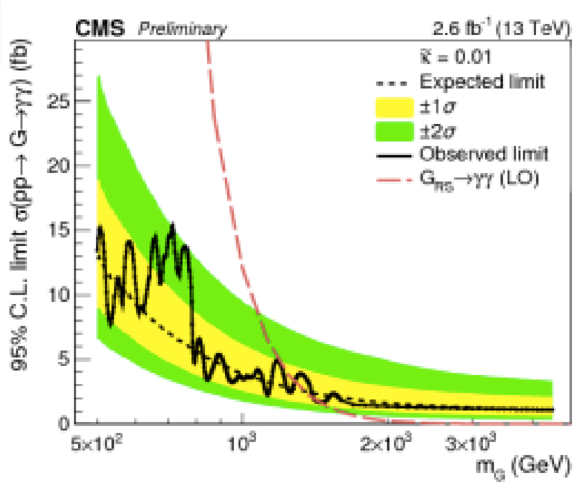


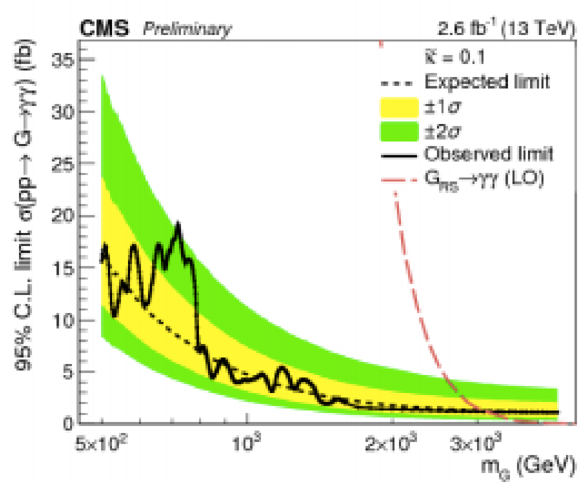
G_{Bulk}→ZZ (JJ)

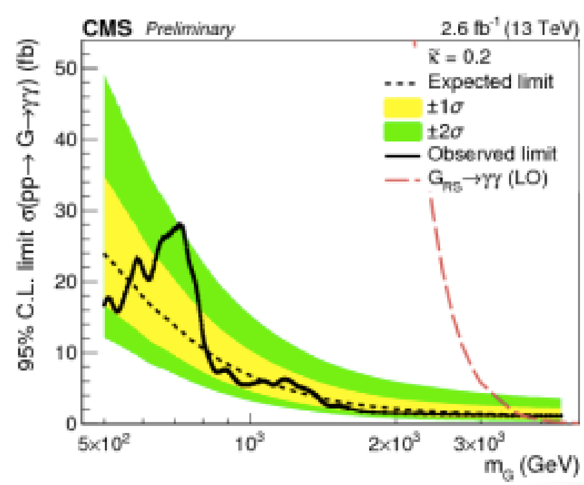


EXO-15-004

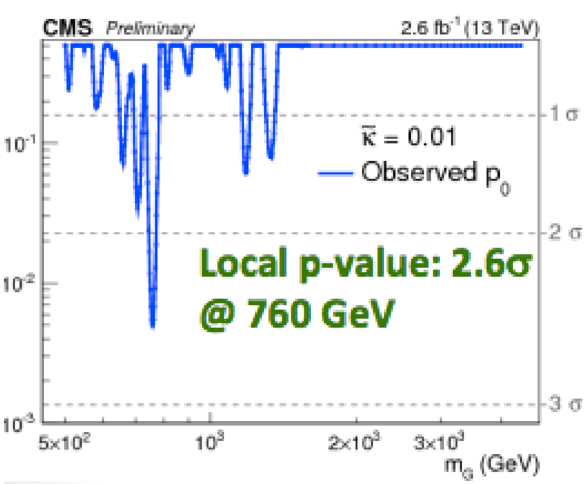
Combined limits and p-values

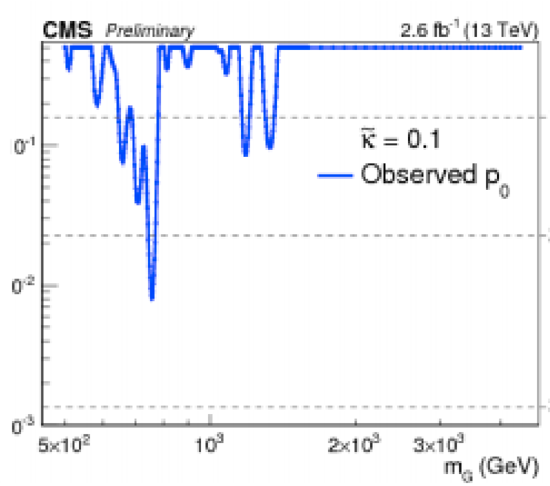


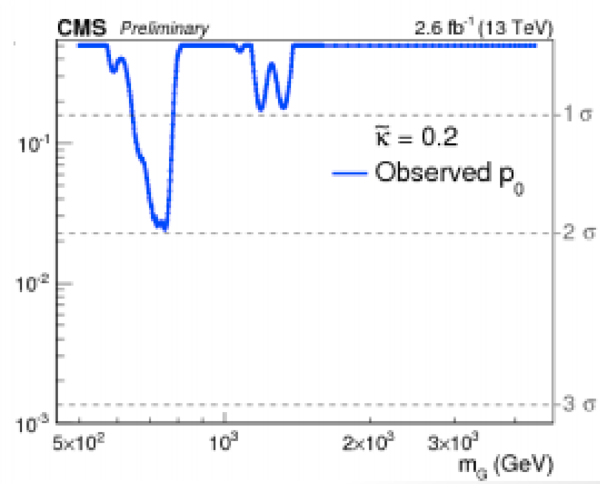




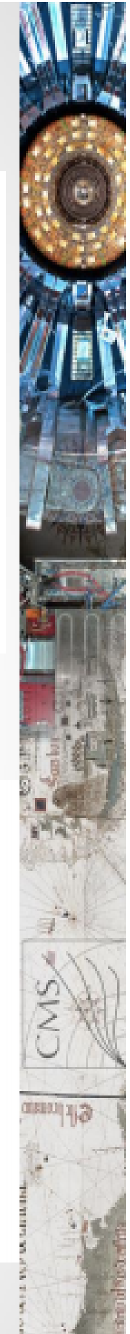
Narrow Width → **Wide (6%) Width**





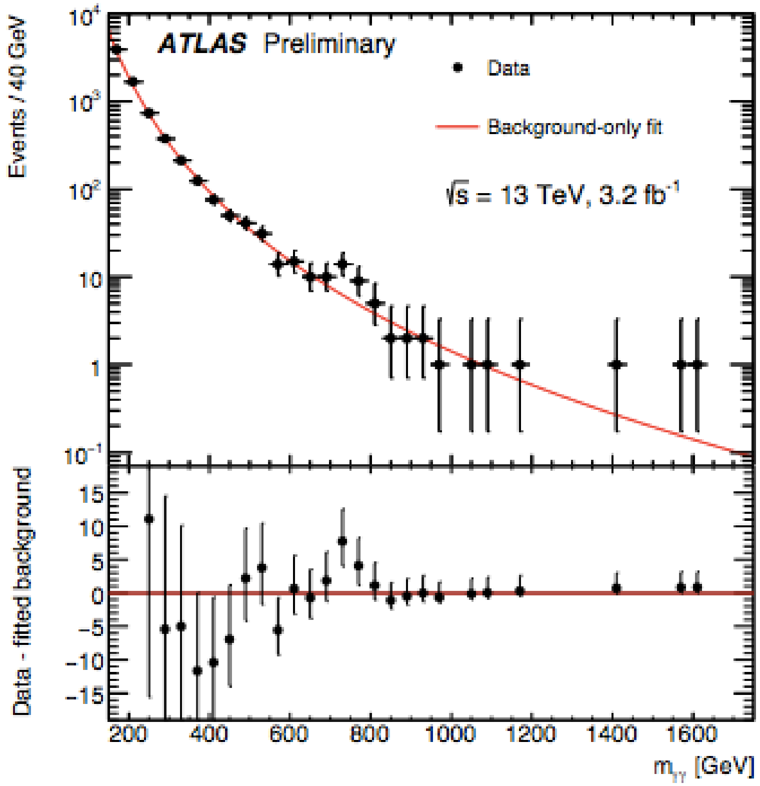


Including LEE (0.5 - 4.5 TeV; narrow width), global p-value < 1.2σ

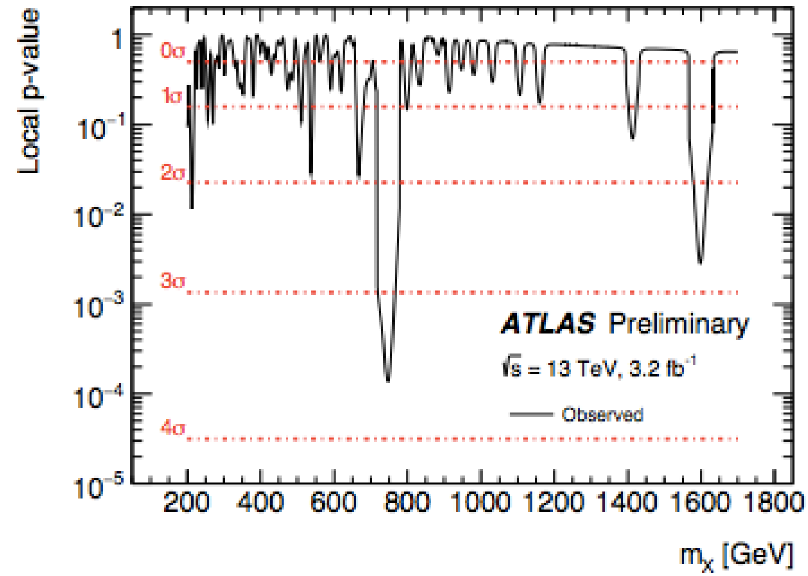


Search for a **Two Photons Resonance** (II)

Results: Events with mass in excess of 200 GeV are included in **unbinned fit**



- **In the NWA search**, an excess of **3.6σ** (local) is observed at a mass hypothesis of minimal p_0 of 750 GeV
- Taking a LEE in a mass range (fixed before unblinding) **of 200 GeV to 2.0 TeV** the global significance of the excess is **2.0σ**

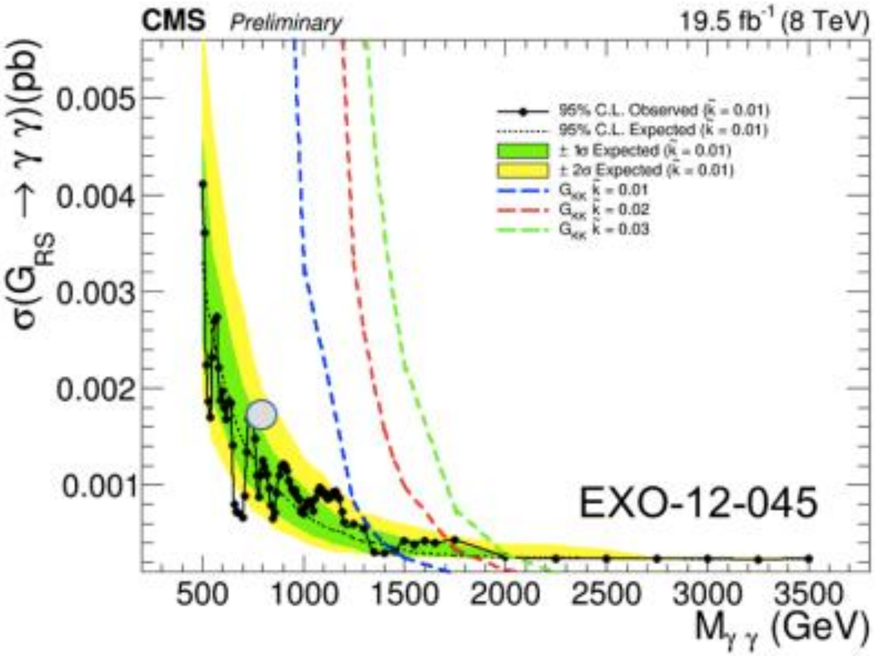


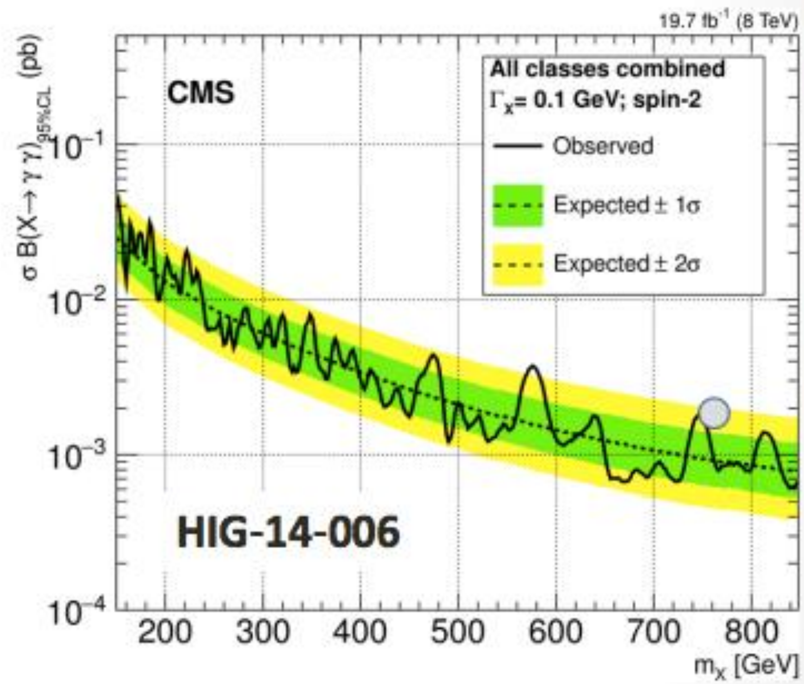
In the NWA fit the resolution uncertainty is profiled in the NWA fit and is pulled by 1.5σ

The data was then fit under a **LW hypothesis** yielding a width of approximately 45 GeV
(Approx. 6% of the best fit mass of approximately 750 GeV)

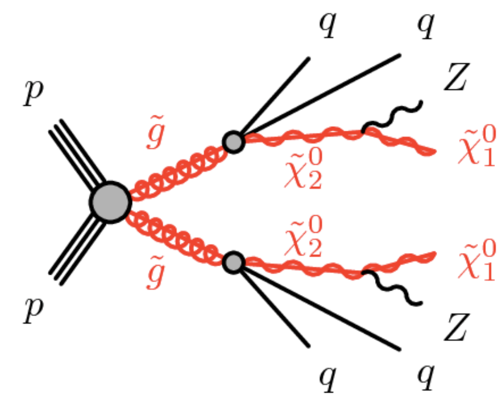
- As expected the local significance increases to **3.9σ**
- Taking into account a LEE in mass and width of up to **10%** of the mass hypothesis of **2.3σ** (Note: upper range in resolution fixed after unblinding)

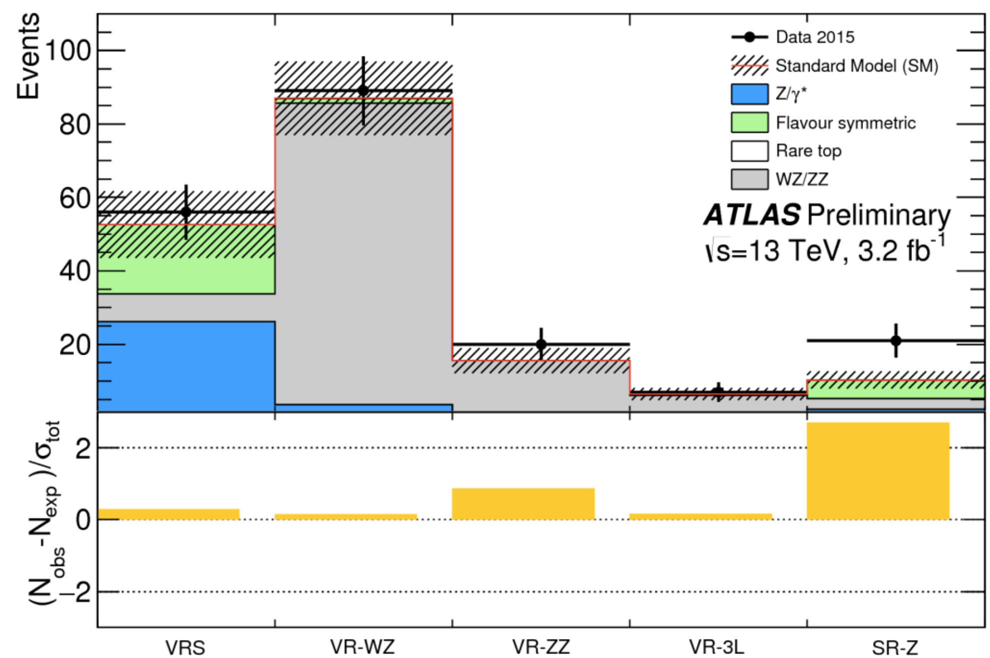
Compatibility with Run 1





Excess not excluded by Run 1searches


p
p
$\tilde{g}$
$\tilde{g}$
q
q
q
q
Z
Z
$\tilde{\chi}_2^0$
$\tilde{\chi}_2^0$
$\tilde{\chi}_1^0$
$\tilde{\chi}_1^0$


Events
Data 2015
Standard Model (SM)
Z/γ*
Flavour symmetric
Rare top
WZ/ZZ
ATLAS Preliminary
√s=13 TeV, 3.2 fb-1
(Nobs-Nexp)/σtot
VRS
VR-WZ
VR-ZZ
VR-3L
SR-Z