Search for High-Mass Diphoton Resonances in ATLAS

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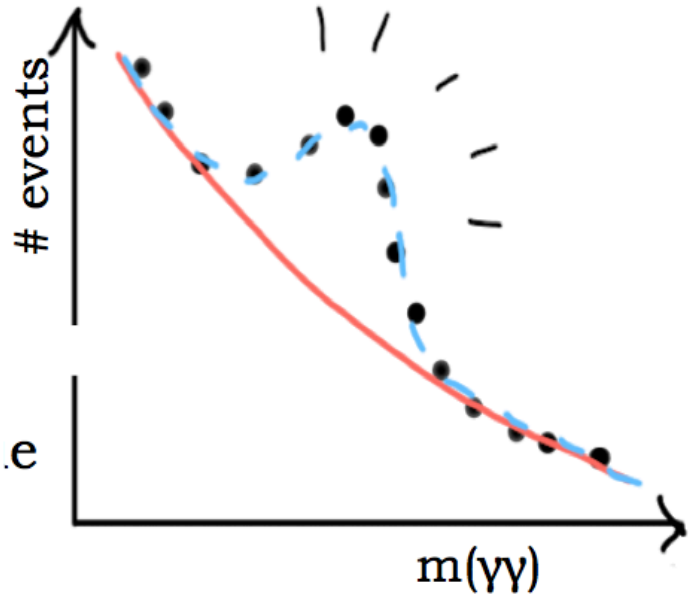
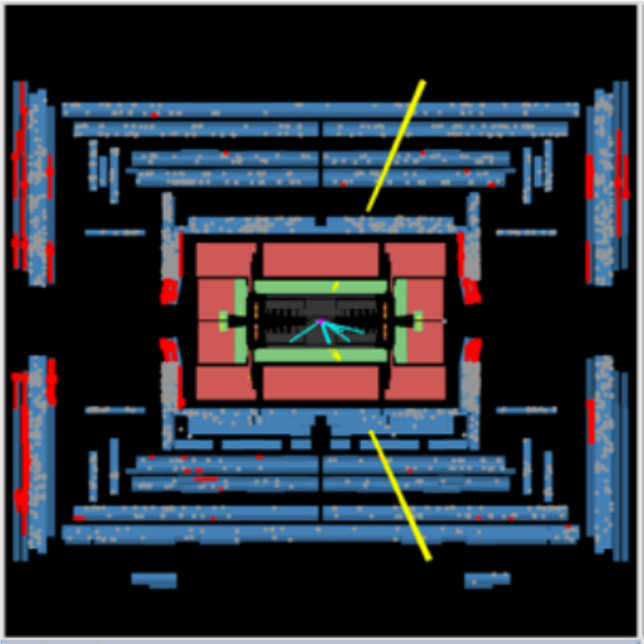
US-LUA 2016, LBNL

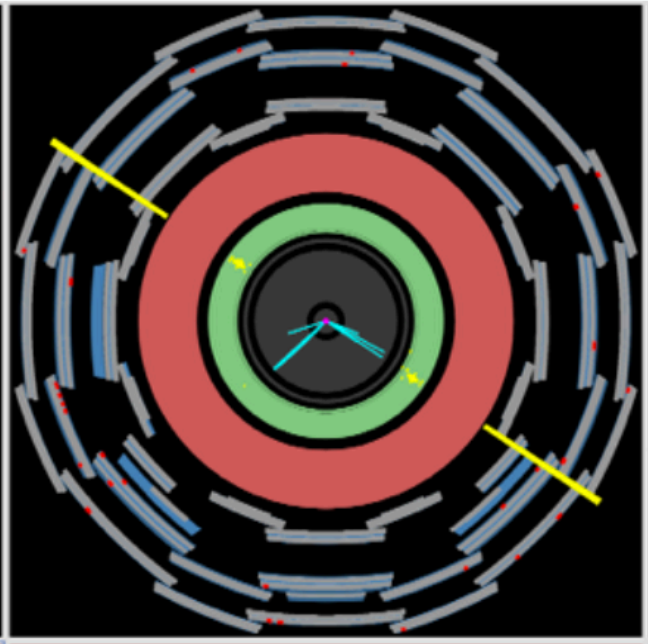
What are we looking for?

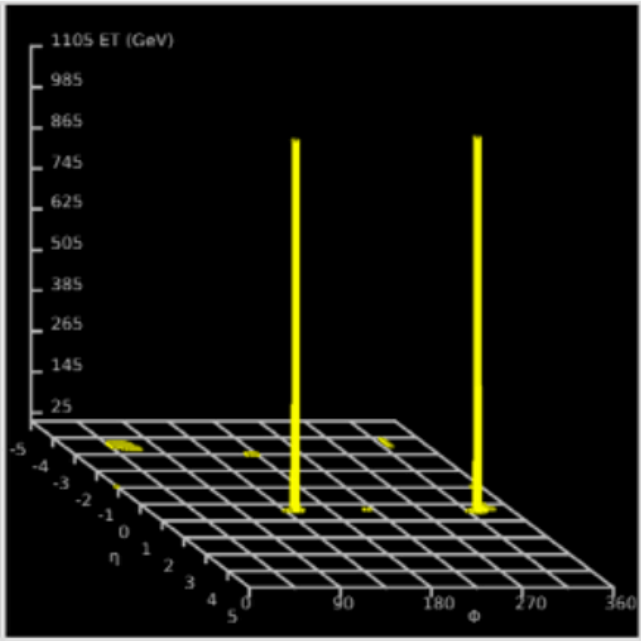
- Searching for two photons with a large invariant mass ($M_{\gamma\gamma}$) – "general" search which is designed to be as model independent as possible
- Two signal models used: scalar and spin-2
  - Scalar signals might be found from an extended Higgs sector
  - Spin-2 signal based on a Randall–Sundrum graviton
  - Looser kinematics cuts for the spin-2 analysis

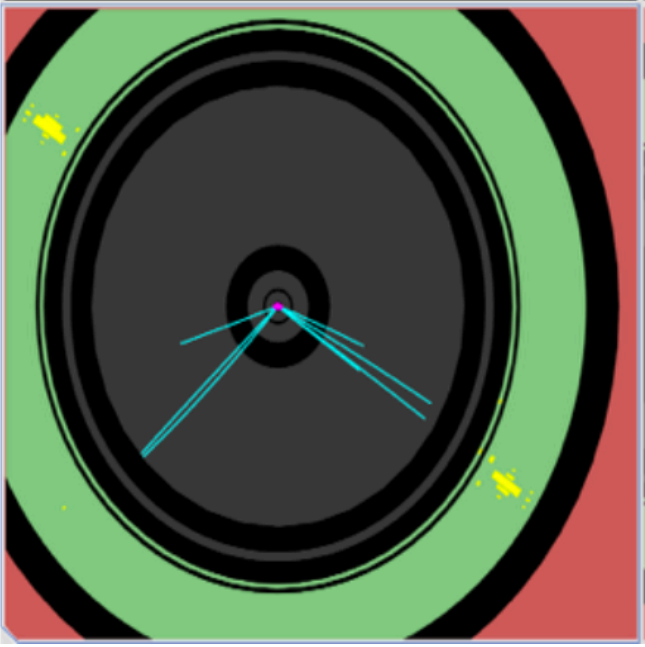


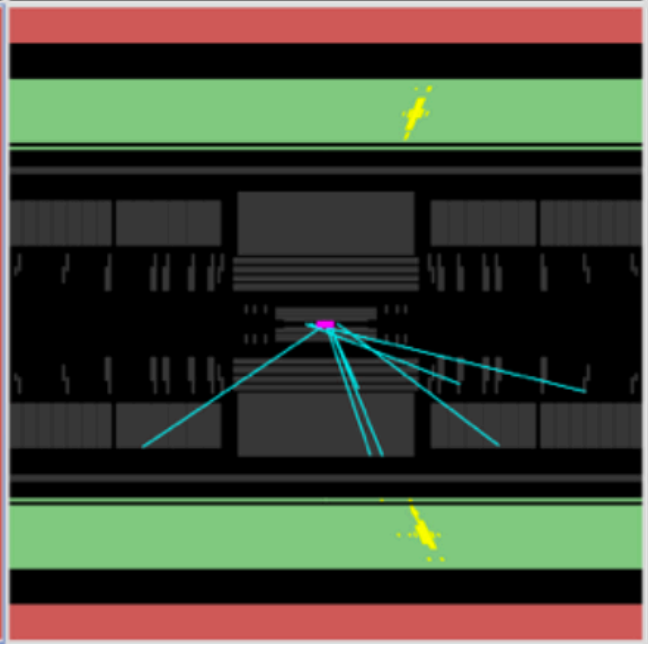
L. Barak (CERN), "The diphoton excess" (NPKI 16/06/16)









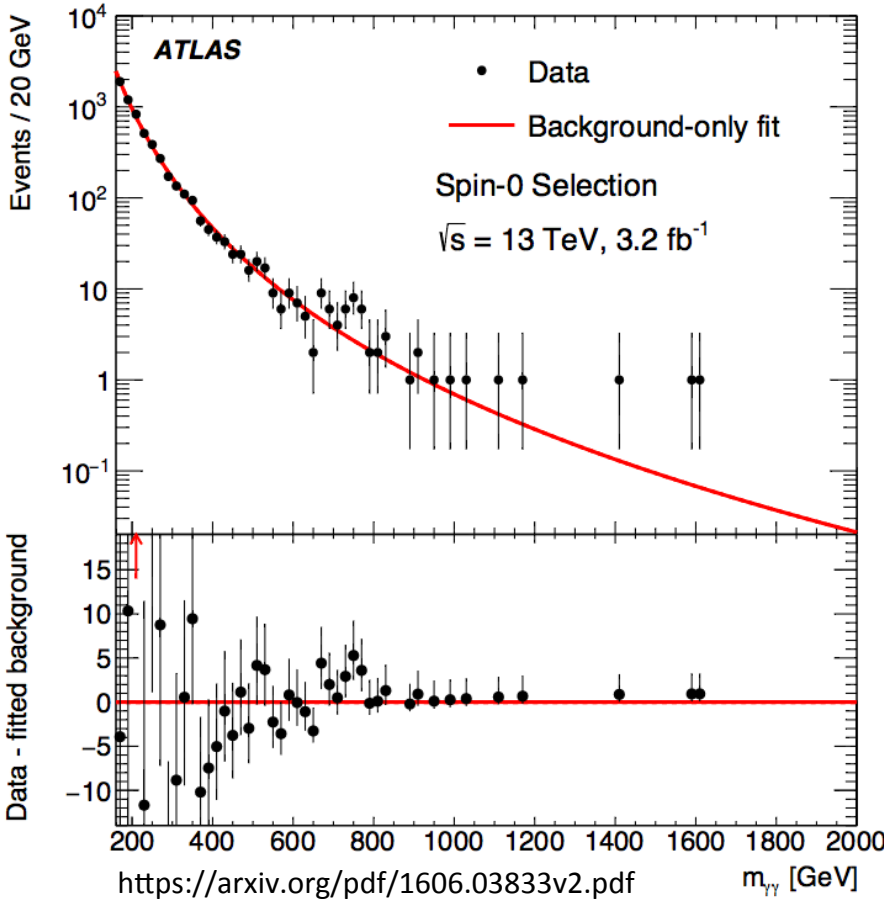


$M_{\gamma\gamma}$ = 2.2 TeV

So, What Was All That Hype About?

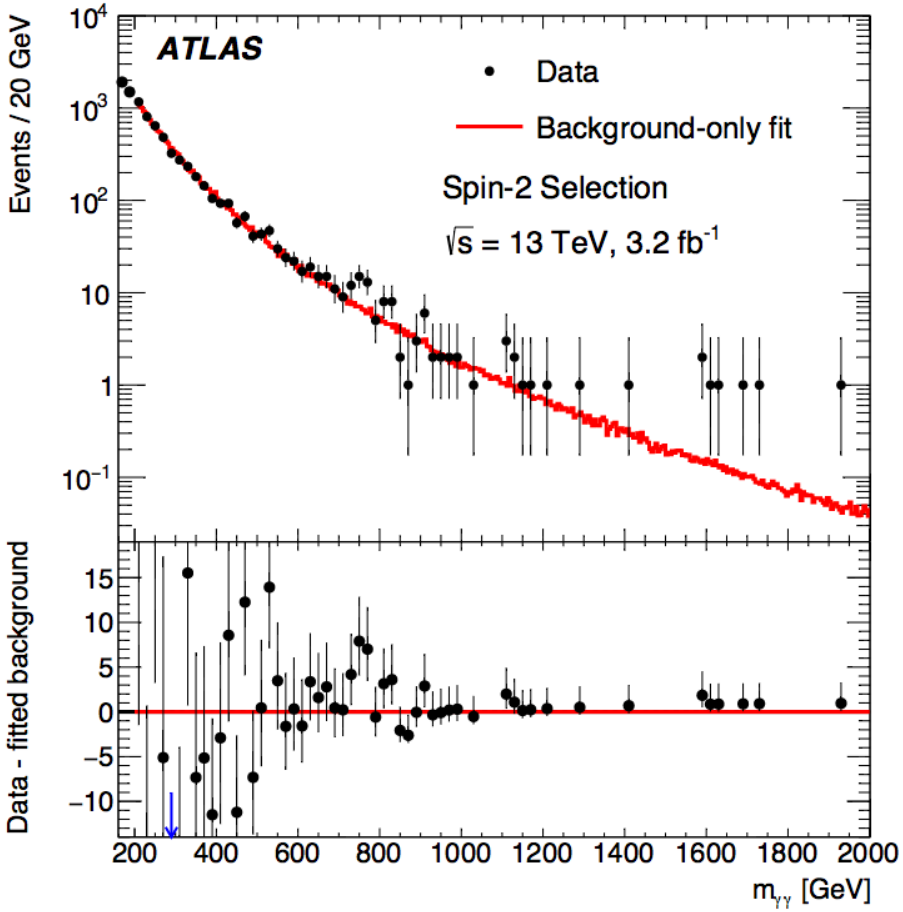
Significant bump seen in the 2015 analysis in ATLAS!

Spin-0 Analysis

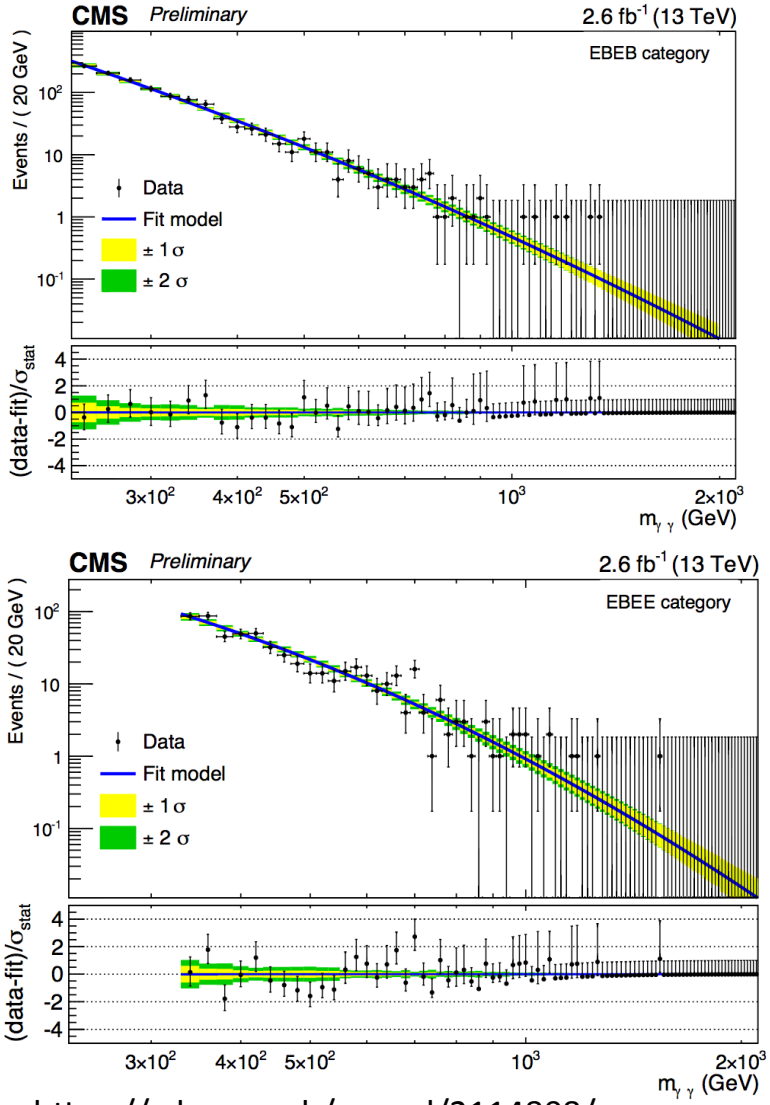


https://arxiv.org/pdf/1606.03833v2.pdf

Spin-2 Analysis



And Even More Hype?



- CMS also observed a (not as) significant excess, at around the same mass range!
- NB: Plots on the left are split by eta-category, not by signal type
- Summary of 2015 Significances:
  - ATLAS -
    - 3.9 sigma local in scalar at 750 GeV
    - 3.8 sigma local in spin-2 at 750 GeV
  - CMS -
    - 2.6 sigma local in spin-2 at 760 GeV

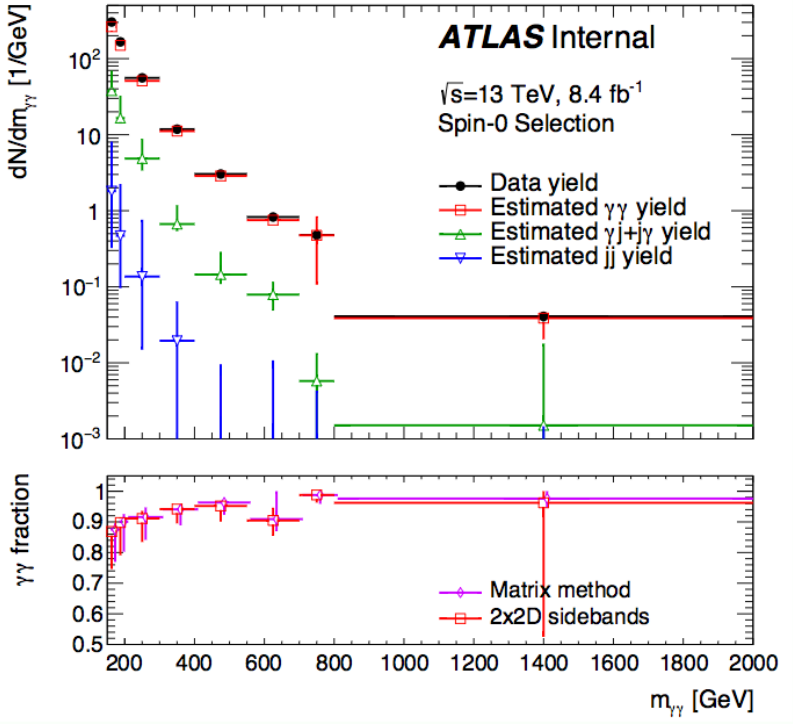
https://cds.cern.ch/record/2114808/files/EXO-15-004-pas.pdf

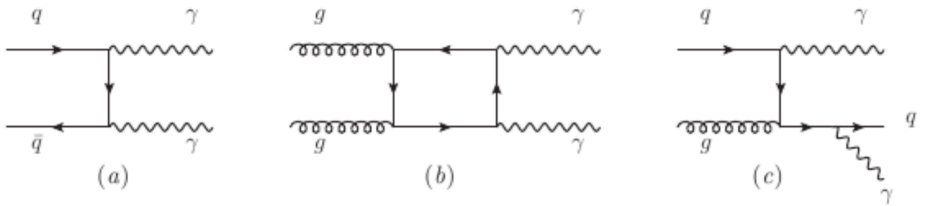
2016 Analysis Summary

- Event Selection:
  1. Diphoton trigger (γ_1>35, γ_2>25 GeV)
  2. $|\eta|$<2.37
     - excluding crack region (1.37<$|\eta|$<1.52)
  3. Tight Isolation
  4. Tight photon ID (both photons)
  5. Kinematic Cuts (depending on analysis)
     - Spin-0: p_T (γ_1) > 0.4*$M_{\gamma\gamma}$, p_T (γ_2) > 0.3*$M_{\gamma\gamma}$
     - Spin-2: pT (γ_1 and γ_2) > 55 GeV
     - Spin-0 relative pT cuts suppress backgrounds with very large $\Delta\eta_{\gamma\gamma}$
- Selection is the same as in 2015
- What changed?
  - Improved energy calibration, isolation and reconstruction
- A lot more data! 12.2 fb-1 more than in 2015

Backgrounds

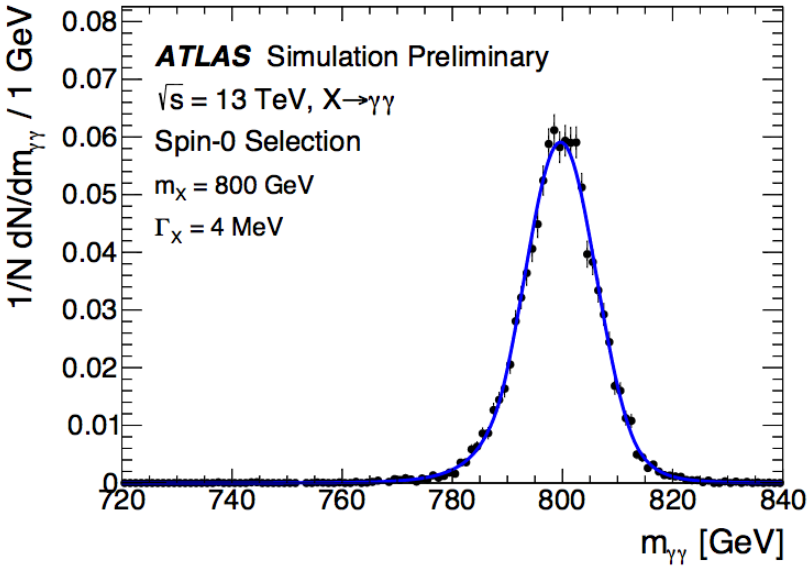
- Split into two categories:
  1. Reducible: γ+jet and jet+jet (with jets faking γ's)
  2. Irreducible: SM γγ events
- Purity esitmated at > 90% in both analyses
- Spin-2 irreducible backgrounds determined using Monte-Carlo (Sherpa+Diphox) template, reducible backgrounds determined using data-driven methods
- Spin-0 backgrounds determined using functional form: $f_{k;d}(x;b,\{a_k\}) = (1-x^d)^b x^{\sum_{j=0}^{k} a_j \log(x)^j}$

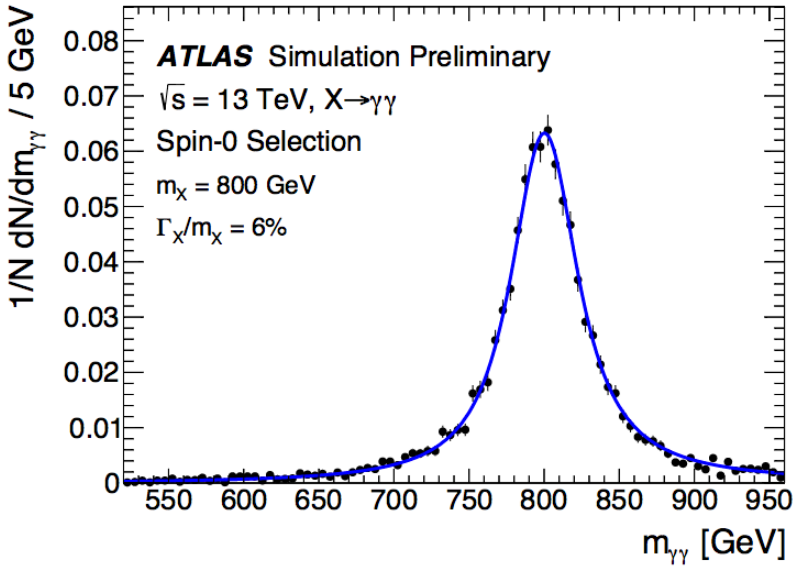




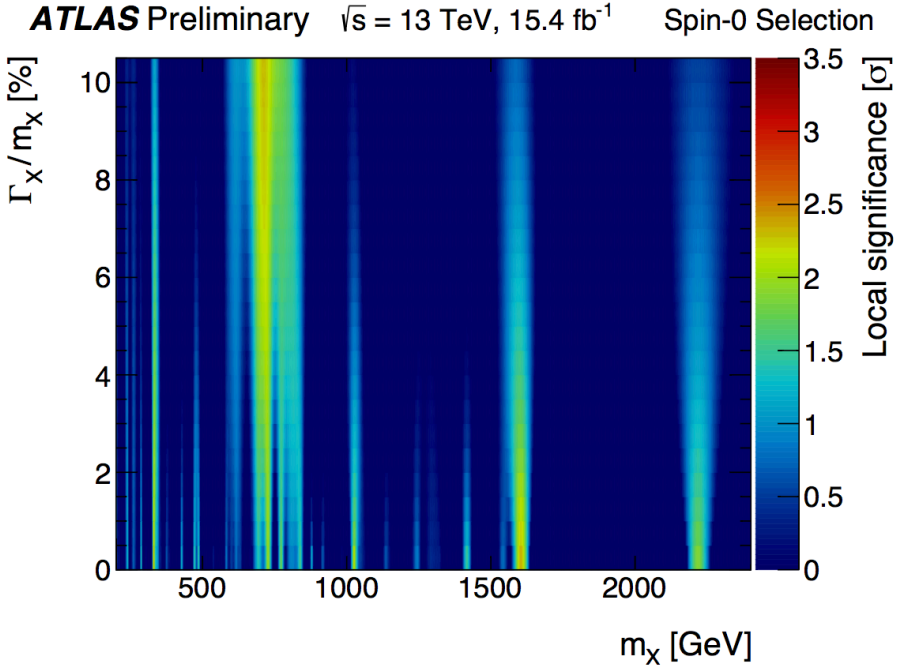
Signal Samples

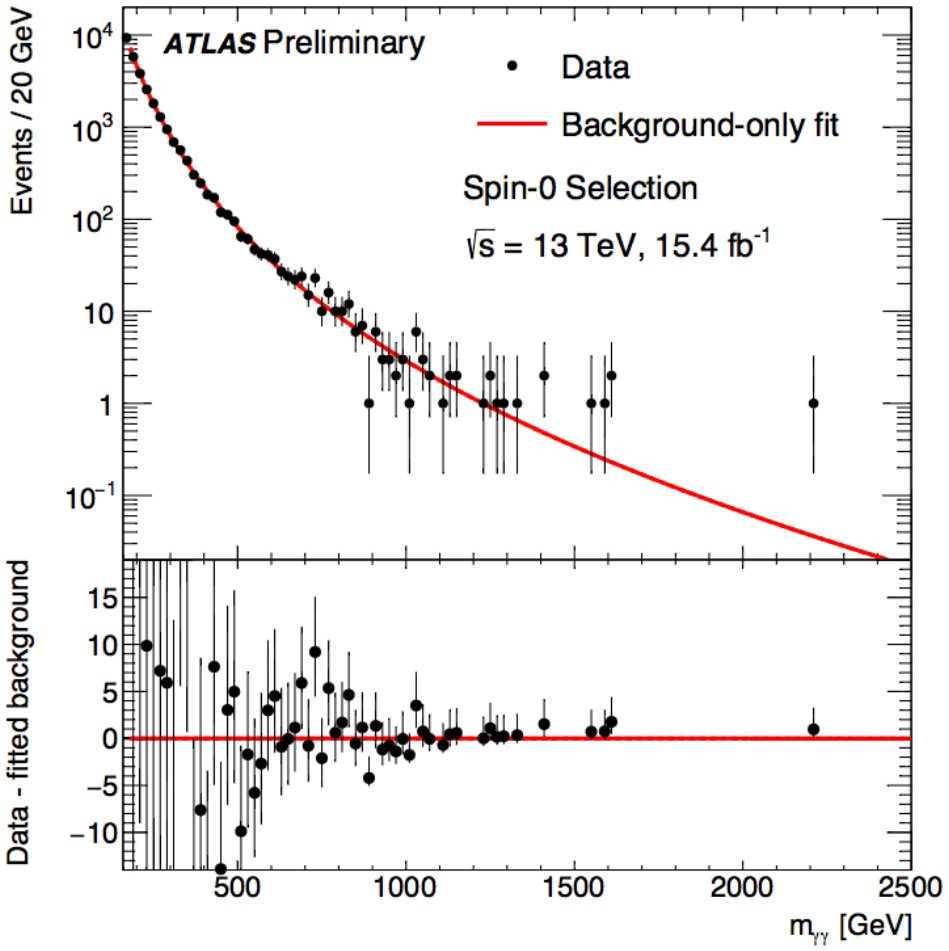
- Monte Carlo signal samples generated with MadGraph5_aMC@NLO for both analyses
- Signal M_{yy} distribution obtained by convoluting MC shape with the detector resolution, modeled by Double-Sided Crystal Ball function
- Range of signal widths produced





2015 + 2016 Data Spin-0 Results





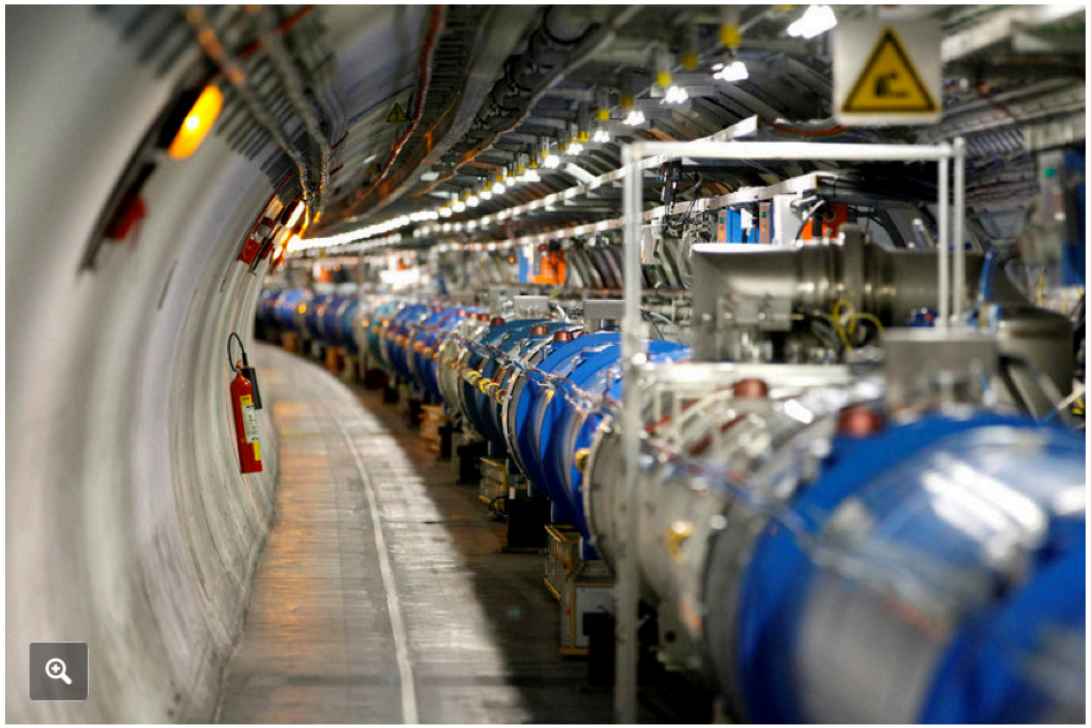
Sadly, no more sign of an excess

Conclusions

The New York Times

The Particle That Wasn't

By DENNIS OVERBYE AUG. 5, 2016



The Large Hadron Collider at CERN in 2014. Pierre Albouy/Reuters

- We didn't discover a new particle…
- New focus is setting limits
- Between more data and continued analysis improvements, there is still much work to be done!

http://www.nytimes.com/2016/08/05/science/cern-large-hadron-collider-particle.html?_r=0

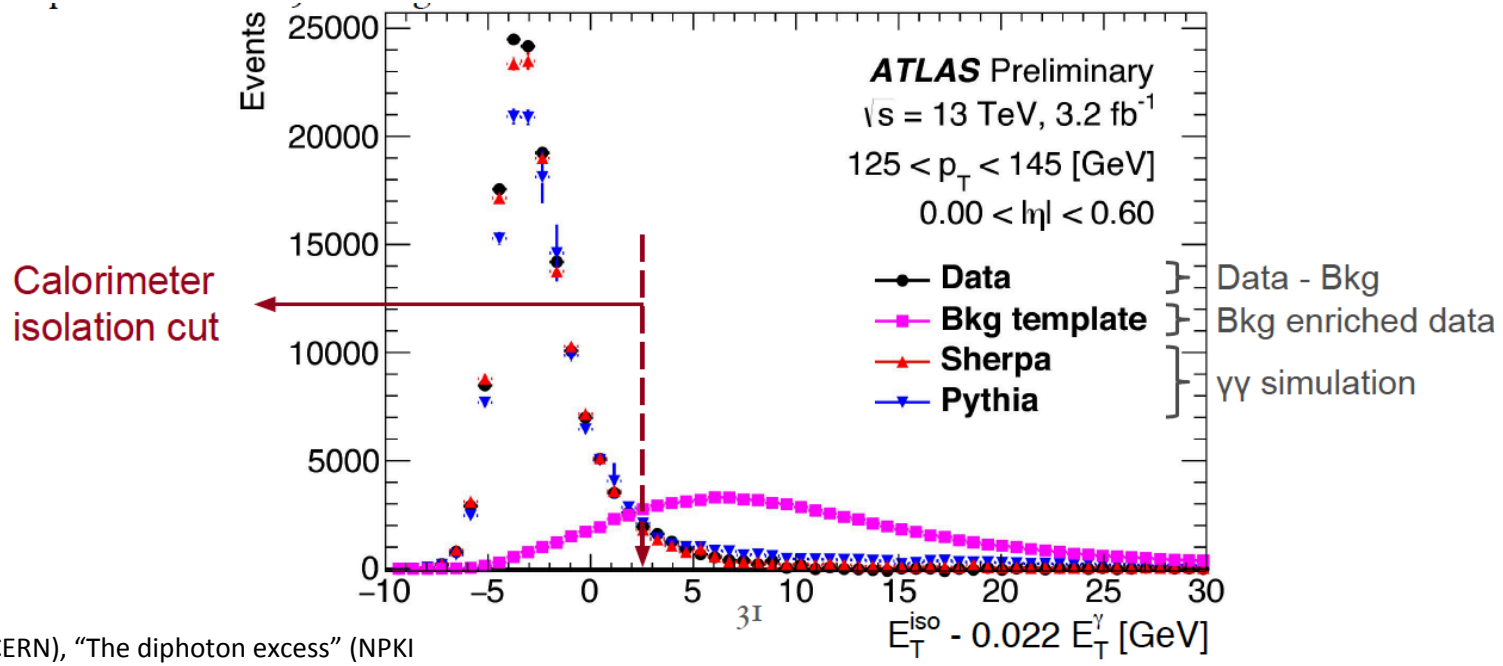
References

- ATLAS 2016 ICHEP Conf Note:
  - https://cds.cern.ch/record/2206154/files/ATLAS-CONF-2016-059.pdf?version=1
- ATLAS 2016 ICHEP Presentation:
  - https://indico.cern.ch/event/432527/contributions/1072336/attachments/1321033/1981068/BL_ATLAS_HighMassDiphotons_ICHEP2016.pdf
- ATLAS 2015 Analysis Paper (arxiv)
  - https://arxiv.org/pdf/1606.03833v2.pdf
- CMS 2015 Physics Analysis Summary:
  - https://cds.cern.ch/record/2114808/files/EXO-15-004-pas.pdf

BACKUP SLIDES

Photon Isolation

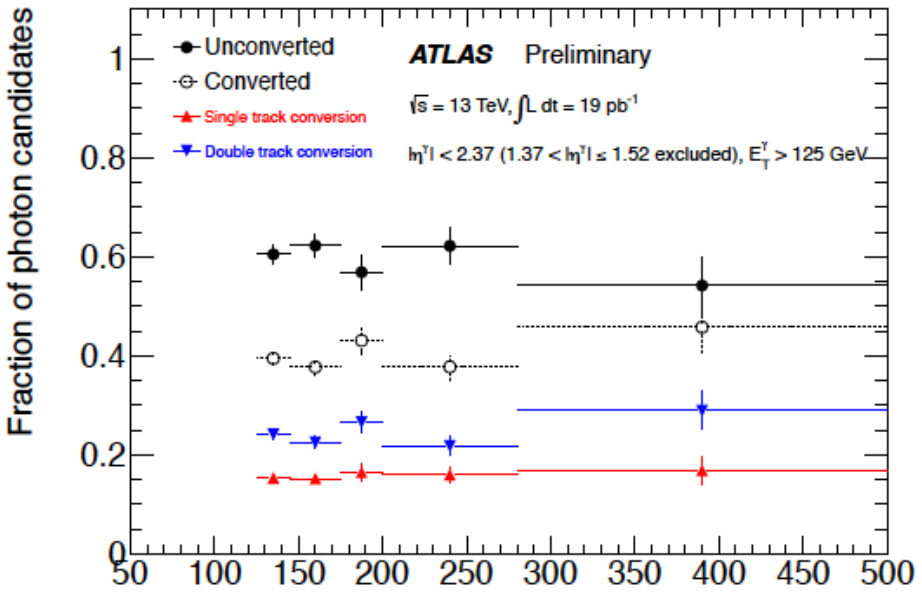
- Two types:
  1. Calo-Iso – topoETcone40
     - Sum(E_T) deposited in cone of ΔR=0.4 around the photon cluster
     - Excludes area of ΔηxΔφ = 0.125 x 0.175 (centered on the cluster
  2. Track-Iso = ptcone20
     - Sum(pT) deposited in cone of ΔR=0.2 around the photon cluster



L. Barak (CERN), "The diphoton excess" (NPKI 16/06/16)

Converted/Unconverted Photons

- Converted Photon = a photon which has interacted with part of the detector before the EM calorimeter and converted into an electron-positron pair
- Converted photons can have either one two tracks



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Photon ID

- Loose/Tight ID categories defined by different cuts on shower shape variables
  - Look at shower in both EM and Hadronic Calorimeters
- Separate criteria for converted/unconverted photons and for different eta regions
- Crack region excluded (too much dead material)