Lessons from the 750 GeV ghost:

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Higgs@LHC

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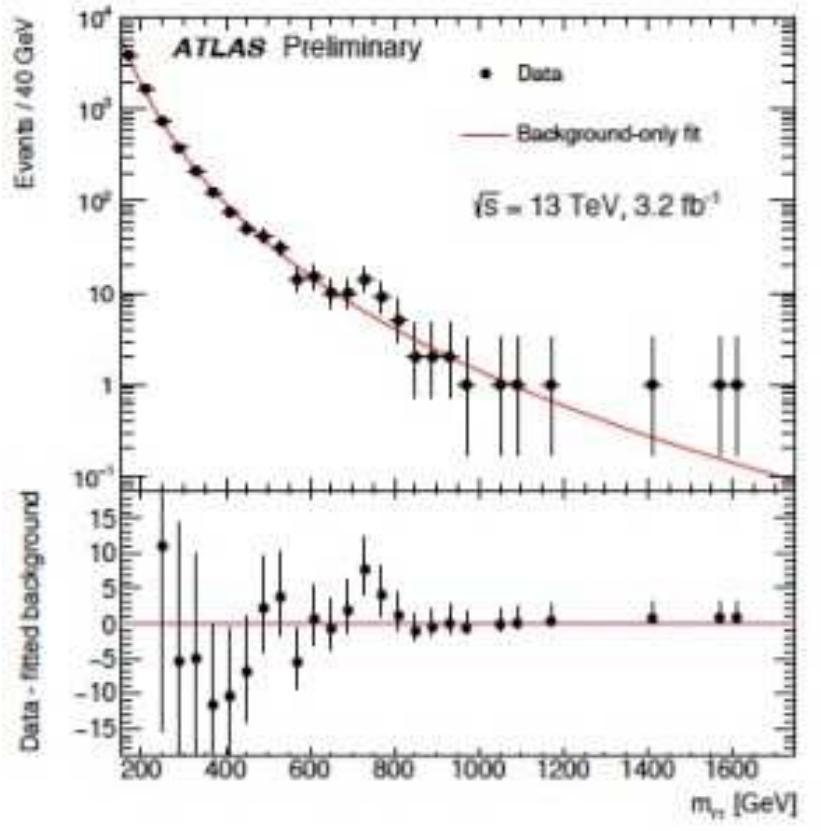
1. The story in short: December 2015 – March 2016

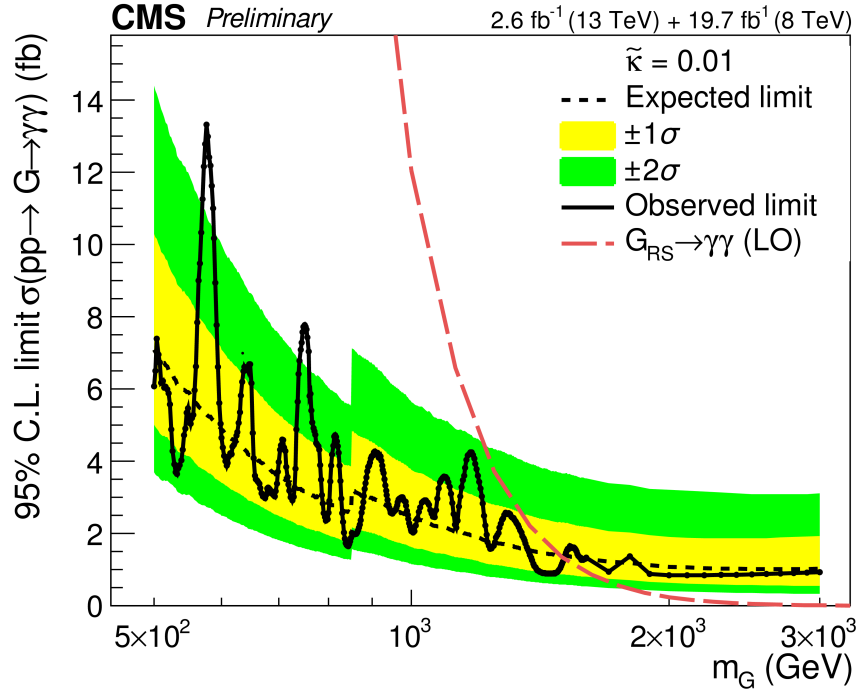
ATLAS di-photon results:

3.9σ local excess at $\sqrt{s}$=13TeV (in March about 2σ from 8 TeV). global significance: 2σ only.



CMS di-photon results:

3.4σ local excess at $\sqrt{s}$=8+13TeV (improvement from Dec. to March) global significance: less than 2σ.

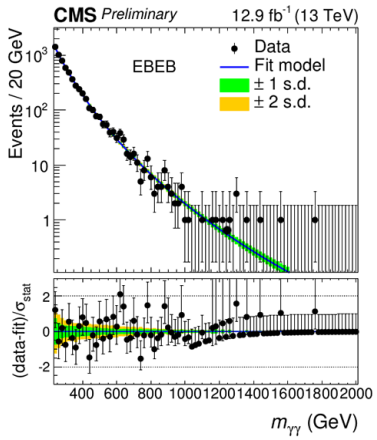


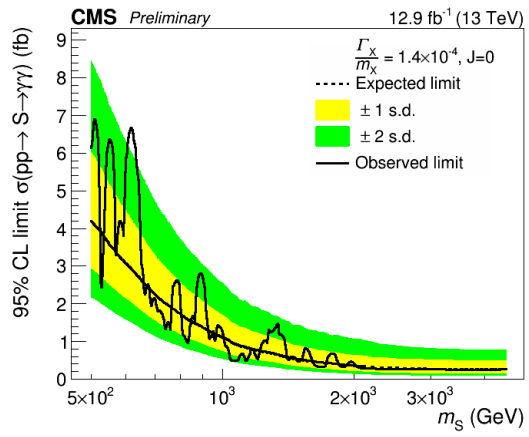
It had a smell of December 2011 the (other?) Higgstorical day....

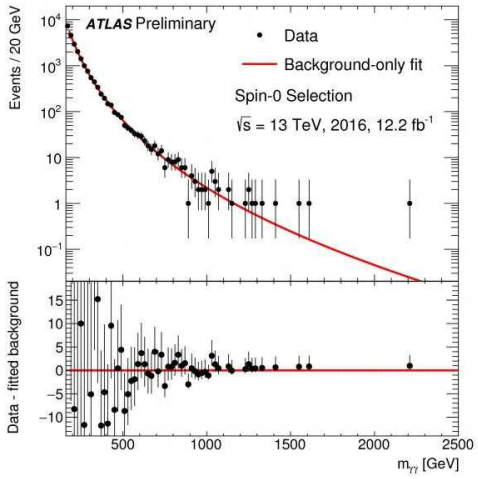
Two possibilities:
the biggest discovery since decades?
the mother of statistical fluctuations?

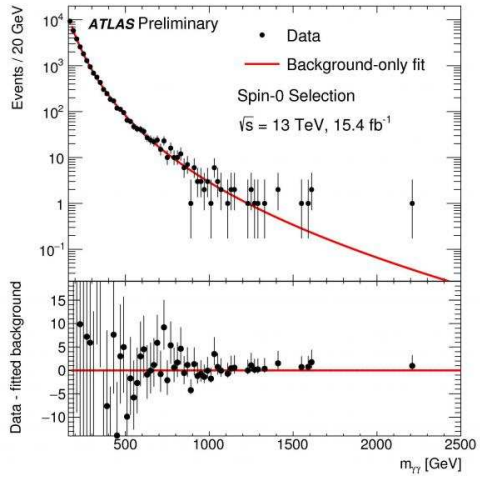
1. The story in short: July–August 2016

ATLAS and CMS results with a luminosity increased to $> 10\ \mathrm{fb}^{-1}$:









no diphoton excess in both cases:
It was only a statistical fluctuation.
Too bad... But this is life..

But before forgetting the entire issue, let's draw some conclusions first.

2. Lessons: the good

Experimentalist's (official) attitude: be cool and collect data...

In public: too early for a claim:
beware of LookElsewhereEffect
... it is only two poor sigmas!
(they were more excited privately)

And if you insist a little bit:

Need more statistics to conclude
Let us wait till summer!

Conclusion: LEE is not a joke

and it is to be taken very seriously!

– 100s of different search channels for new physics in each experiment;

– many invariant masses, topologies for any given search channel,

$\Rightarrow$ only global significance counts.

Well, I have to make a mea culpa:

for me, LEE definition: ATLAS $\Leftrightarrow$ CMS...

I see now that it is not entirely true.

And even counting LEE only once seems to be a wrong attitude too..

Good to wait before saying anything!

(but some worried about the December announcement... no more jamborees?)

All these are little details...

2. Lessons: the good

The main point is that a discovery of a new state did not go to the press.

(I mean an official statement by the ATLAS, CMS or CERN managements; forget about blogs, delirium of journalists, discussions in cafeterias, etc...)

To summarize: the 5sigma (local?) significance before going public was really a wise choice made by the elders; one never knows effect..

Only field with such a strong measure?
If you take a field like biology for instance:
2 sigma significance for a claim is the rule...

– The Lancet's Editor-in-Chief R. Horton: "A lot of what is published is incorrect", "looking around more or less at random, statistical 'significant results' sooner or later will show up". What? Holly cow!

– Bayer pharmaceutical company says: "we fail to replicate two-thirds of published drug studies". Mama mia!

(from G. d'Agostini, arXiv:1609.01668)

Thanks, no more pill/placebo for me....

3. Lessons: the bad??

Theorists attitude: did they jeopardize their careers?

First, what is the job of a theorist

(more precise, phenomenologist..)?

- **make theoretical models to explain physics phenomena;**
- **make predictions of the model to be verified by experiments;**
- **confront the models with all sorts of experimental data...**

So, one main important duty is

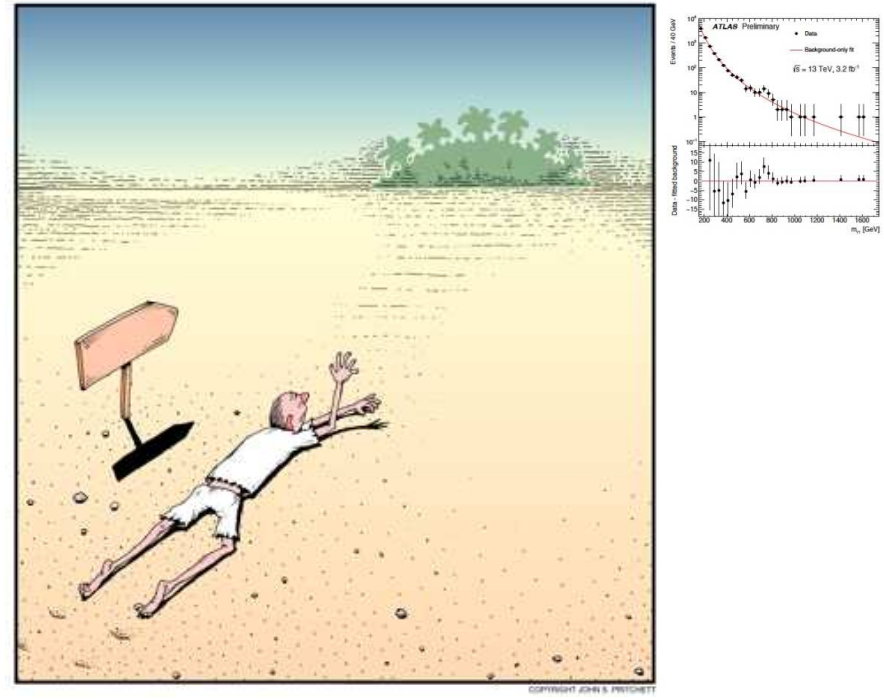
(besides being human, passionate, and hearing noises in corridors...)

to look at experimental data and interpret it in the context of a model...

and this is exactly what happened!

So for the poor theorists:

waiting for new physics for 30 years, and recently started to get desperate; and something interesting appears!



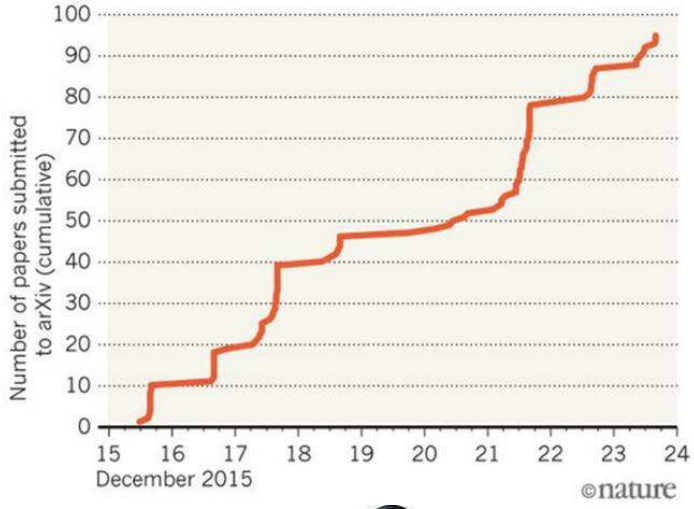
They did their job and interpreted experimental data! And even more: looked at very far implications!?

3. Lessons: the bad??

Tsunami of theory papers trying to interpret the 750 GeV diphotons:

10 papers the very first day,
100 at the end of the year,
about 400 papers as of today..
(and not much more than that..)

Nature article/Dorigo/Jester blogs:



Florilège of explanations:

– cascading heavy quarks,
– collimated 2x2 photons,
– new gauge bosons Z'+X
– sgoldstinos and other SUSY,
– quirks, hidden valleys?
– even statistical fluctuation...

But most papers are talking about a new heavy resonance:

– Dark matter mediators
– Technipions/Goldstones, ..
– Axions,radions/dilatons,..
– Gravitons or any spin 2...
– Higgs bosons...

and other possibilities...

I tried myself some interpretations (in the context of 2HDMs, MSSM,...)

3. Lessons: the bad??

Is there anything wrong with that? According to me, not really...

- **The significance was really strong in a very clean search channel:**

– two different experiments at two different energies at the same place with local significance of 4sigma each (consistent with energy increase).

Anything comparable? Not in my lifetime (except for top and Higgs...):

– not 4jet, $\gamma\gamma$, 115GeV H at LEP; Wjj, eeγ, $\mathrm{A_{FB}^t}$ at Tevatron, HERA μ, ...

– I worked myself on $\lesssim 3\sigma$ from one experiment: $\mathrm{A_{FB}^t}$, $\mathrm{A_{FB}^b}$, μ (g-2),...

– Not the first $\gamma\gamma$ anomaly at the LHC; remember $\mu^{\mathrm{H(125)}\to\gamma\gamma}_{\mathrm{8\,TeV\,LHC}} \approx 2$!!

- **But 400 papers is a bit too much? It was not the first time:**

– Remember, a few hundred papers after discovery of charm in 1973;
– Probably hundred papers on SUSY after its "discovery" in 1980s?
– Not countable on LEP/Tevatron/HERA anomalies and g-2 or AFB...
– At least 400 papers on the 125 GeV $\mathrm{H} \to \gamma\gamma$ anomaly in LHC-RunI..

- **Many "me too!" and empty or low quality phenomenological papers?**

– not more than average in arXiv; how many "not even wrong" papers?
– most papers (about half) not published; refereeing was not so bad...

So nothing new in the world of physics (not to mention other fields..): only difference is the time scale? But we are now in the Internet era!

3. Lessons: the bad??

And the most important thing: we really learned something!

The excess can be viewed as good opportunity to test old and new ideas:

- **full scale "stress test" for the various models of new physics**

as it was complicated to explain large diphoton rate initially "observed" some models failed miserably but some other turned quite flexible...;

- **It (re)opened new options for new physics scenarios beyond SM**

(many NP scenario gained interest after an anomaly: GMSB, RpV, f^*, ...).

– two Higgs doublet models: rich phenomenology and solve problems;
– vector like-fermions are possible (despite of Higgs) and interesting;
– still interesting SUSY scenarios to look for in MSSM and beyond;
– strongly interacting models not completely dead and make surprises...

- **Taking the example of 2HDMs and the MSSM and personal experience:**

– viable Higgs-portal dark matter in 2HDMs with vector-like leptons;
– Coulomb singularities near threshold enhance (diphoton) resonances;
– Light stops with strong Higgs couplings are viable/hidden/natural;
– Interference effects are important in all processes (including $t\bar{t}$);
– You should keep searching for the unexpected (even if it weird)....

All this will stay useful even if the 750 digamma excess has vanished!!
(Maybe it was simply the last repetition before the première/générale?)

4. The ugly: RIP BSM@LHC?

Is the RIP only for the 750 GeV excess or it is for all BSM physics?

The chances that it is true are not slim: if we need a 5σ signal at end of LHC we should already start seeing some 2σ (and this time properly, including LEE and in both ATLAS and CMS teams...).

It was/is not yet the case (eg at ICHEP) but from now on, with 30 fb^{-1} on tape, something should start to show up....

If nothing is seen in December/Moriond I will start to get seriously nervous... Surviving with precision Higgs only? (but it should stay between us...).

As André said, we will still continue doing very good/important Science.

But I can't refrain from thinking that it would be a slightly boring life ahead.

But let us for the time being hope for the best: It is action time!

5. Conclusions

Two possibilities for the 750 excess:
1) the biggest discovery since decades?
2) the mother of statistical fluctuations?
It turned out that option 2) was right; too bad... but this is how life goes...

No one to be blamed in the process
and everybody did his/her job properly:
– experimentalists waited for more data,
– theorists wrote interpretation papers, some had fun, some took vacations,
and nobody got hurt, injured or killed.

That's how it works in Physics/Science:
the main point is to understand nature but we are all waiting signals of the new (especially that we need some clues...). Some "signals" just fade away, but some become established physics.

But, at the end of the day, we always learn something new about Nature!

Alvaro de Rujula (1985)