What is hiding at 750 GeV?

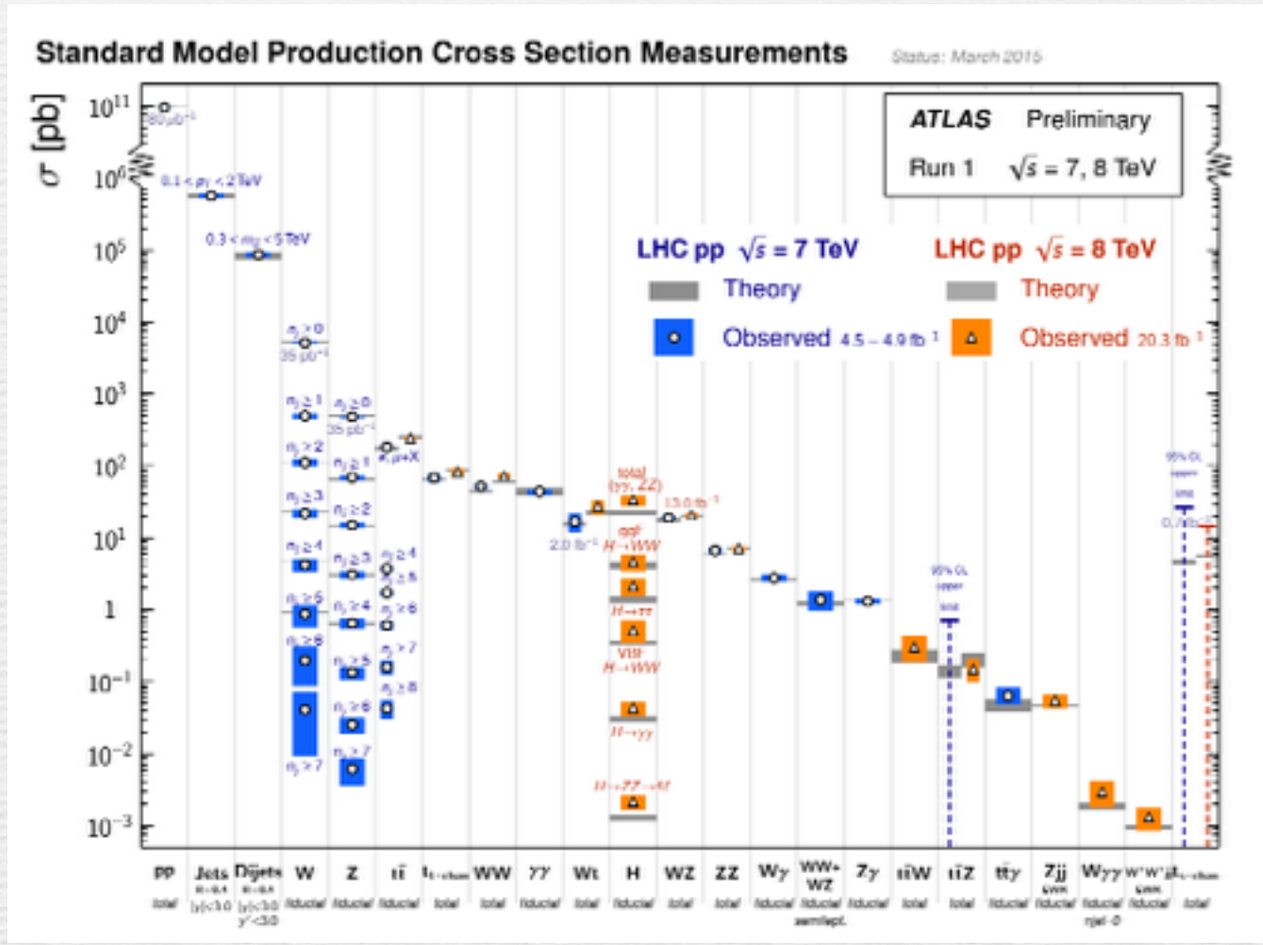
Veronica Sanz (Sussex)

KPS discovery, Daejeon

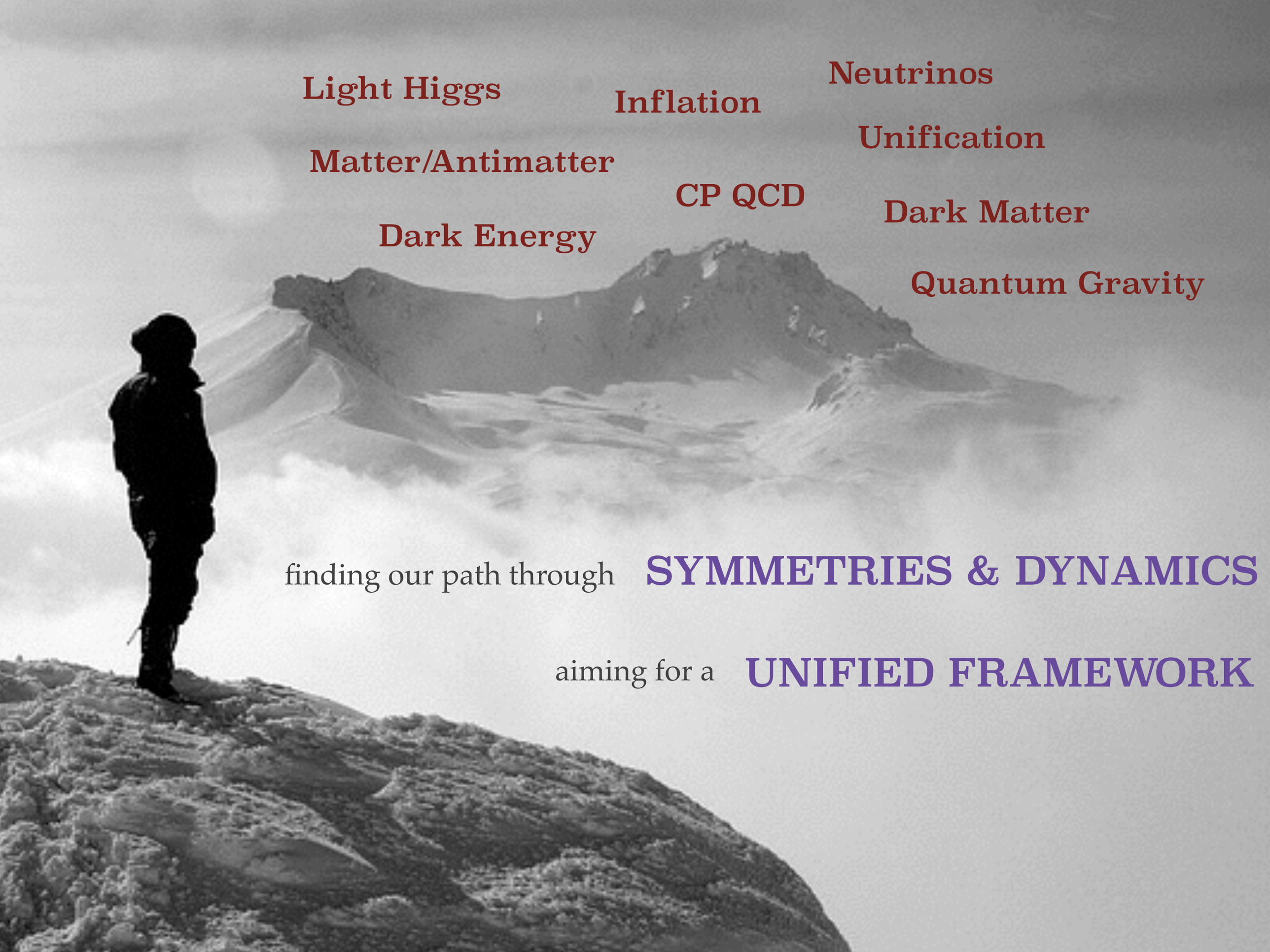
Challenges

Standard Model of Particle Physics

Predictive, successful paradigm being tested to higher and higher precision at the LHC



Based on QFT, symmetries (global/gauge) and consistent ways to break them
Foundation from which we develop theories beyond the SM


Light Higgs
Inflation
Neutrinos
Unification
Matter/Antimatter
CP QCD
Dark Matter
Dark Energy
Quantum Gravity
finding our path through SYMMETRIES & DYNAMICS
aiming for a UNIFIED FRAMEWORK

Example of unified framework: Supersymmetry

Unifies concept of bosons and fermions

Light scalar bosons

Candidates for Dark Matter

Unification of strong/EM/weak forces

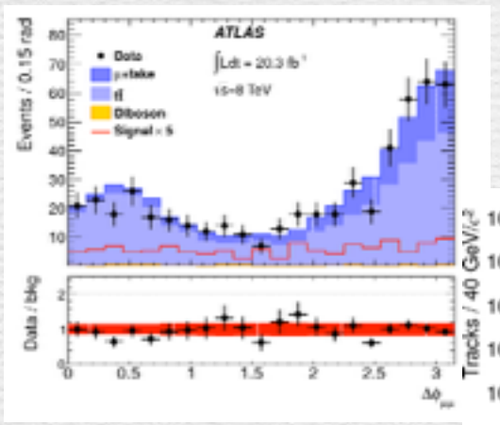
Matter/Antimatter asymmetry

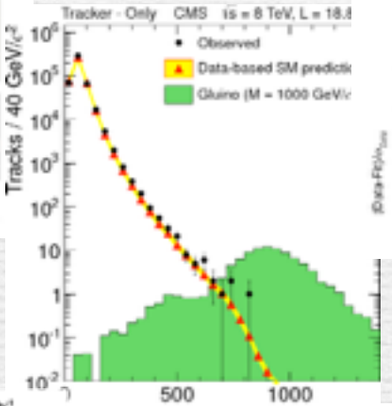
Component of Quantum Gravity

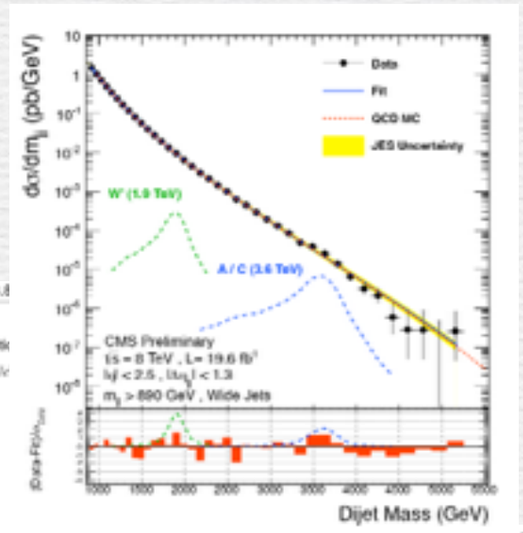
New mechanisms
Inflation, Neutrinos and Dark Energy

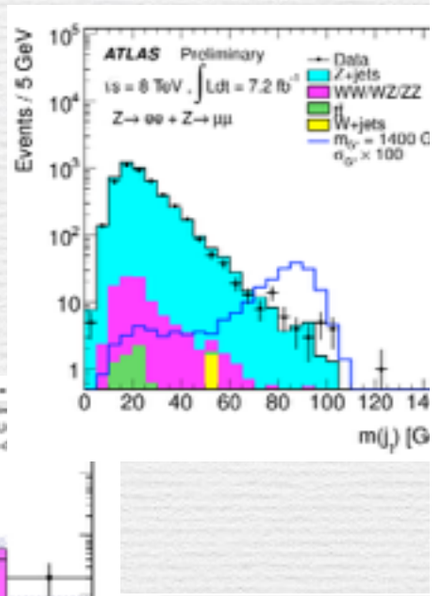
The discovery of SUSY at LHC first step to understand many aspects of Nature

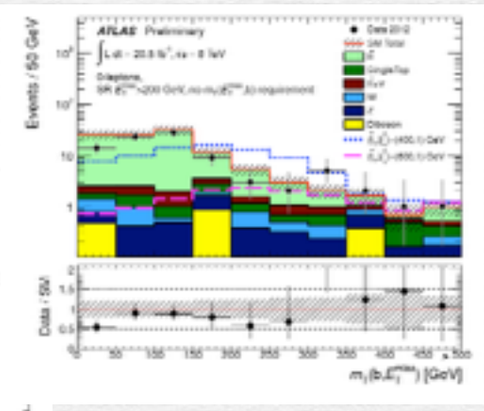
Nature, meanwhile

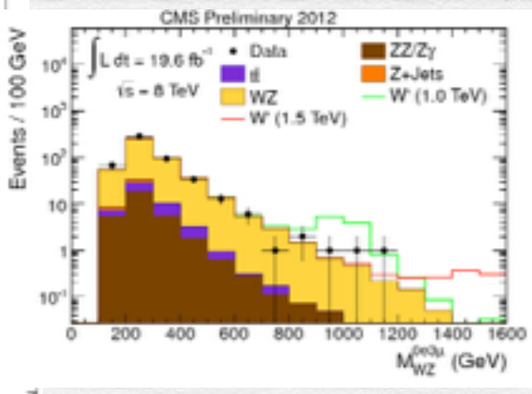


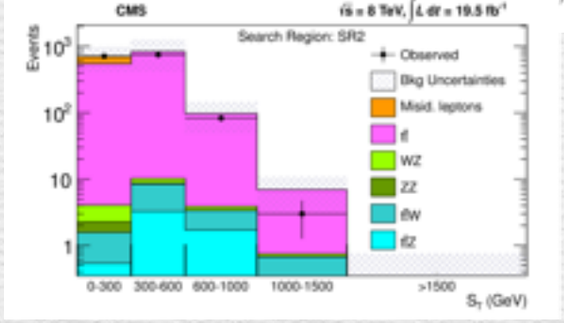


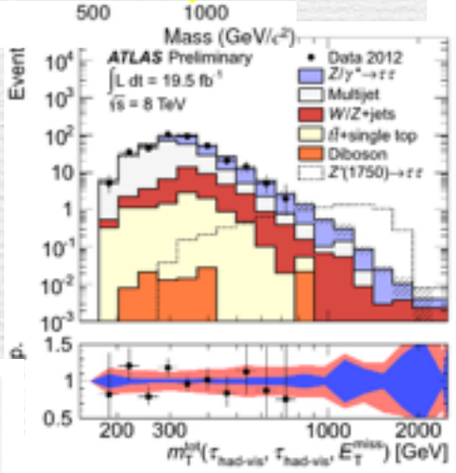


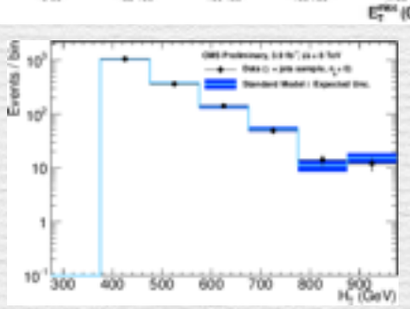


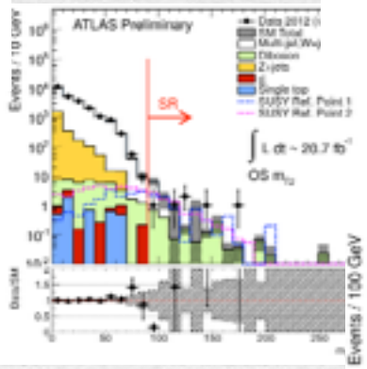


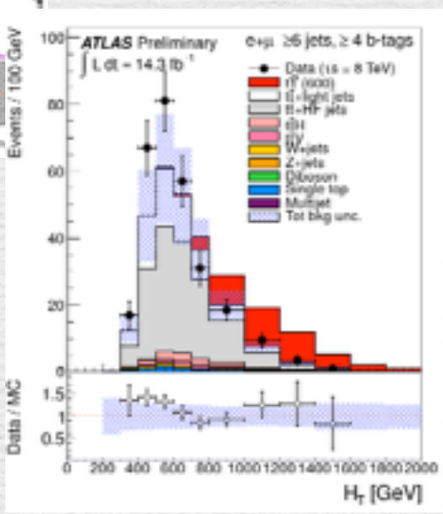


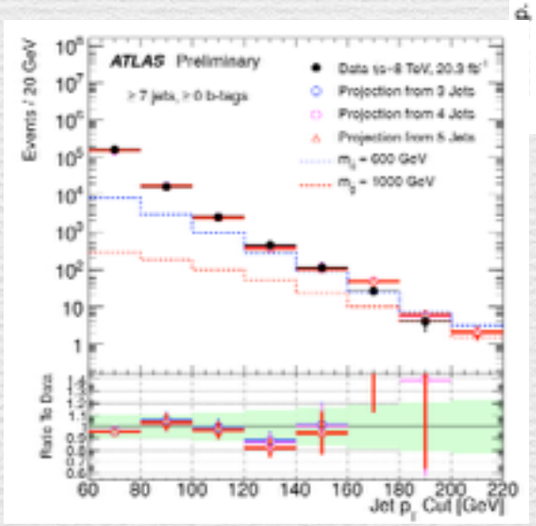


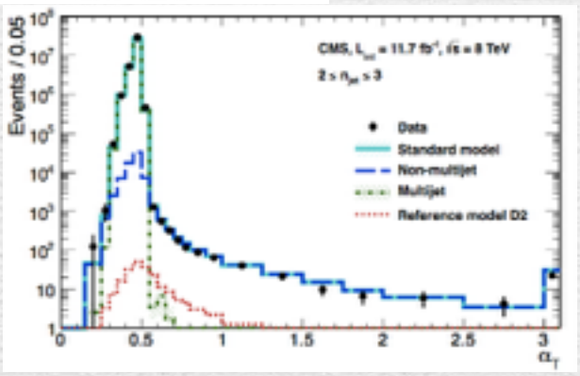


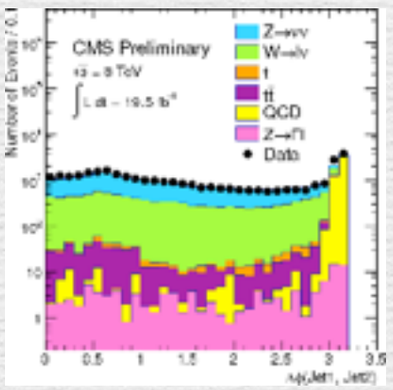




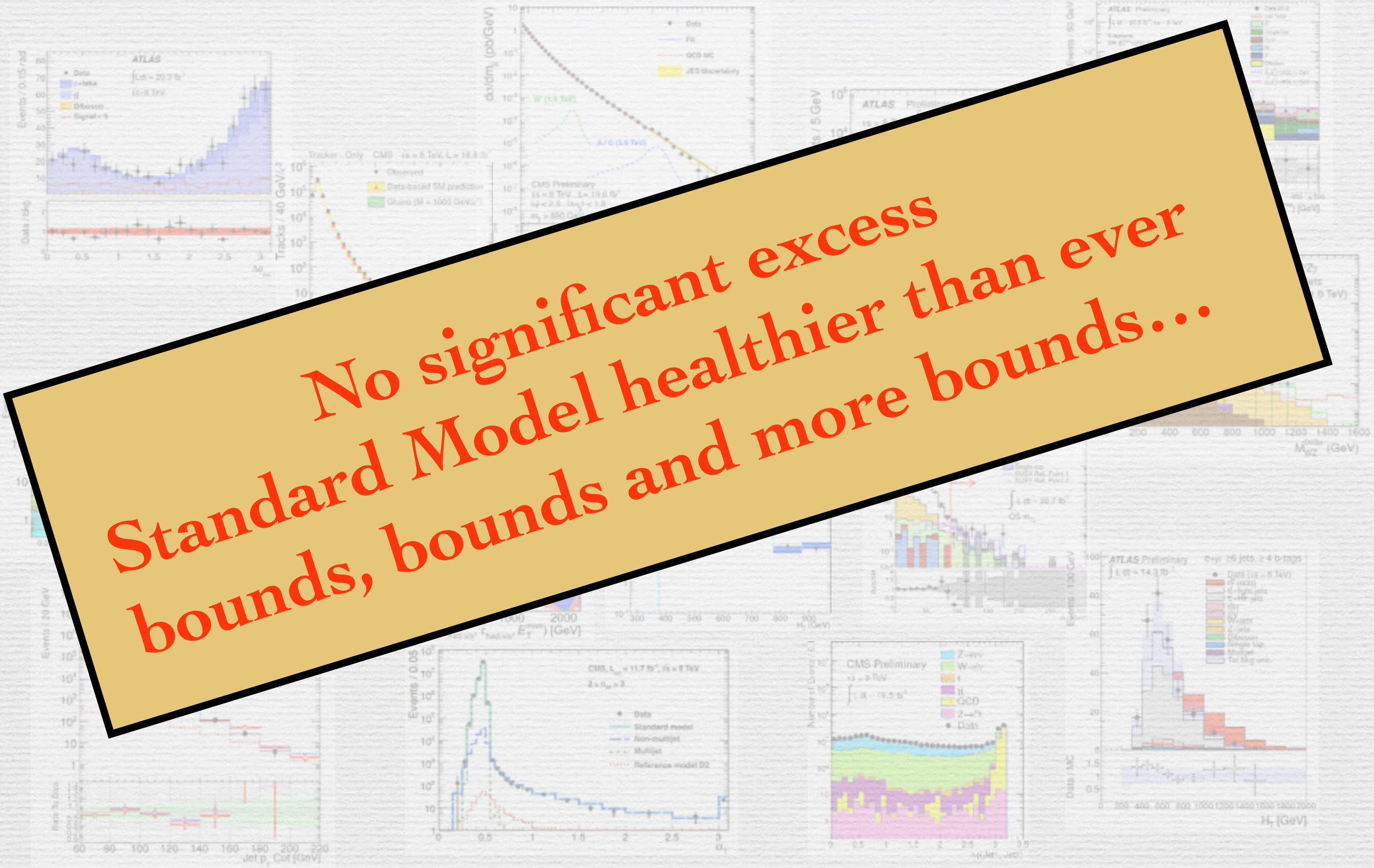








Nature, meanwhile



No significant excess
Standard Model healthier than ever
bounds, bounds and more bounds…

The diphoton excess characteristics

(Theory) Non-trivial
(Experiment) extremely clean

What is it?

An excess in a channel with two photons at
an invariant mass of about 750 GeV

scalar, e.g. more Higgses
tensor, e.g. spin-two graviton
off-shell spin-one? (ask Felix)

What we knew before Dec 2015
Run 1: CMS already a (less significant) excess,
ATLAS did not show above 600 GeV

Dec 2015
excess in both ATLAS and CMS Run2 data

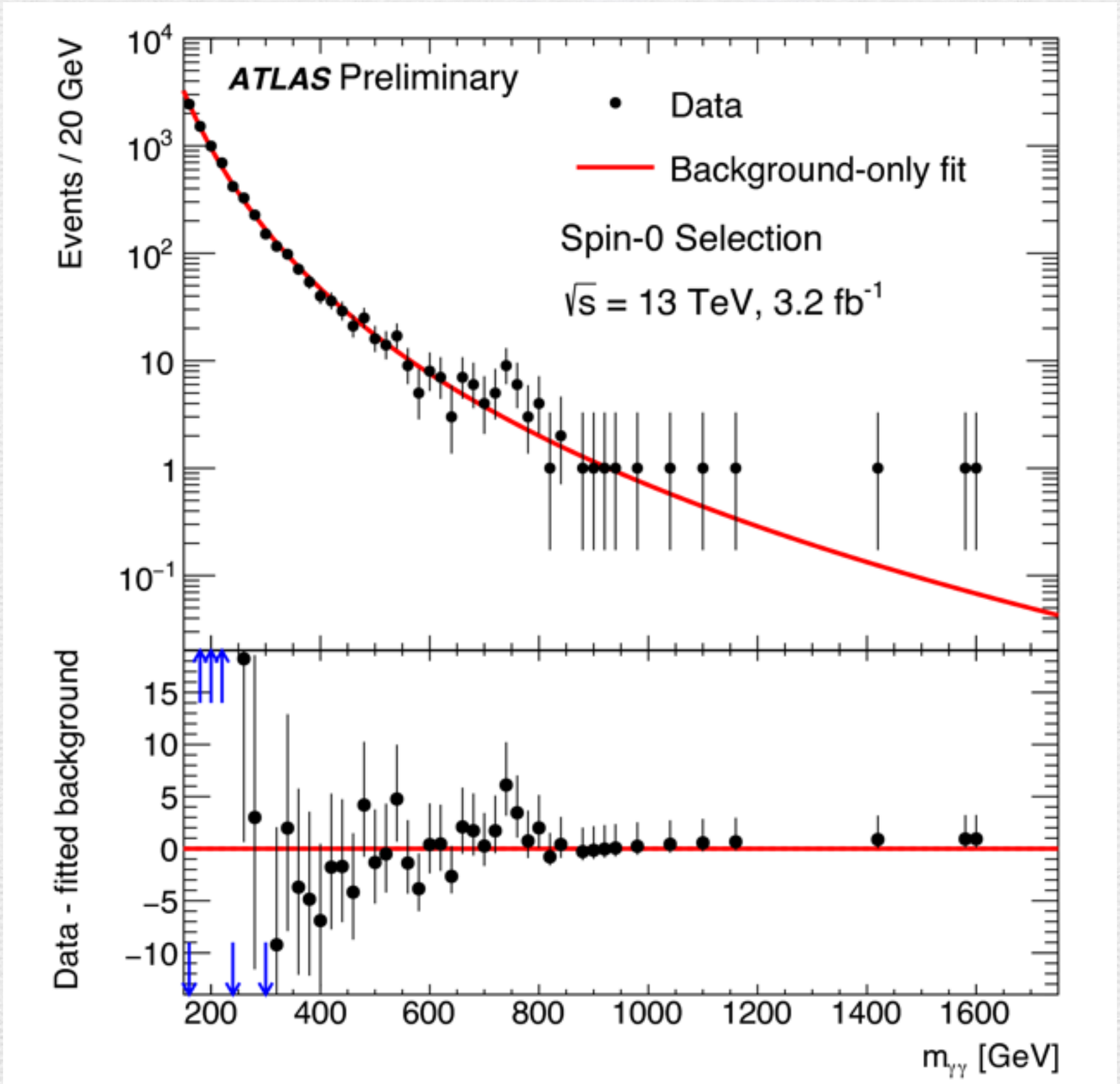
Moriond 2016

ATLAS and CMS results for s=0 & 2
narrow and wide

ATLAS analysis note public

CMS update including improvements in mass resolution and 0T data-set

By eye

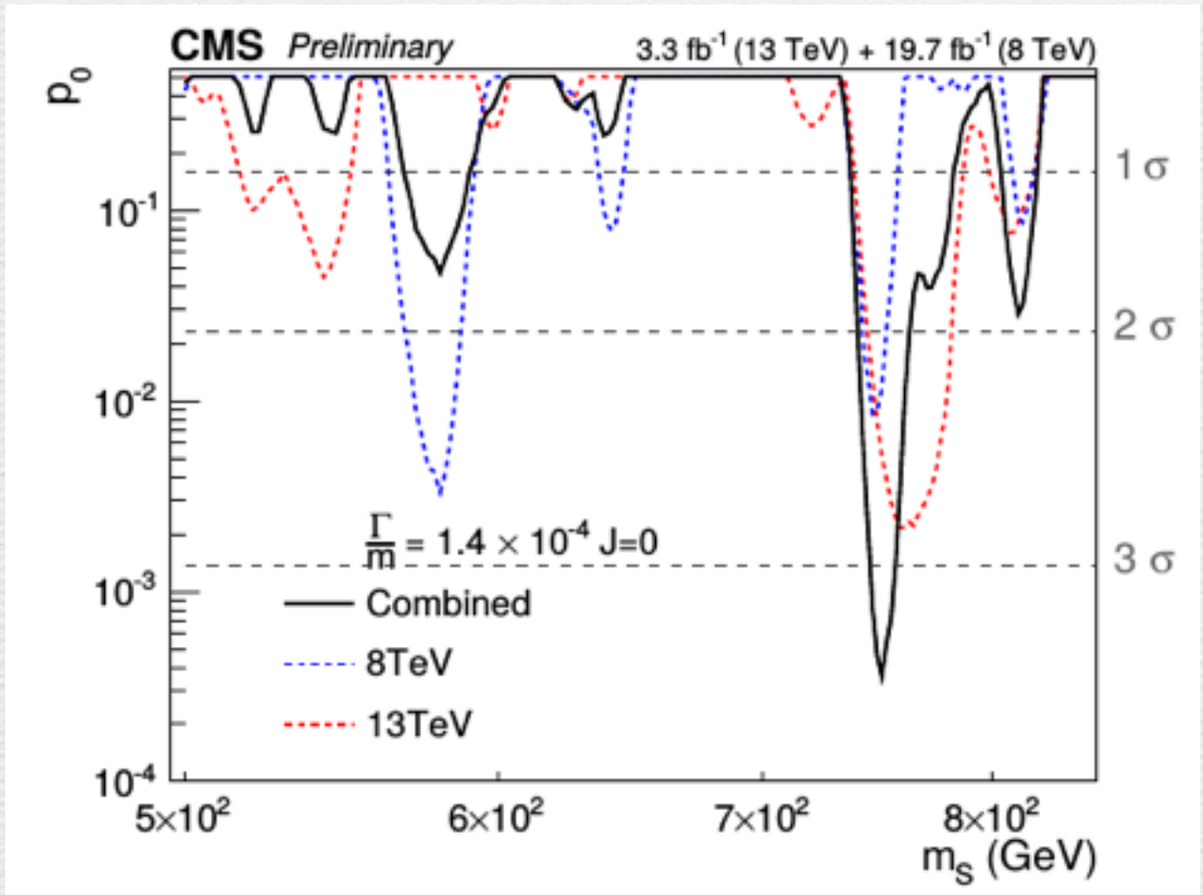

ATLAS Preliminary
Data
Background-only fit
Spin-0 Selection
√s = 13 TeV, 3.2 fb-1
Events / 20 GeV
Data - fitted background
mγγ [GeV]

Significance

ex. interpreted as a gluon-fusion narrow scalar
(similar results for spin-two)

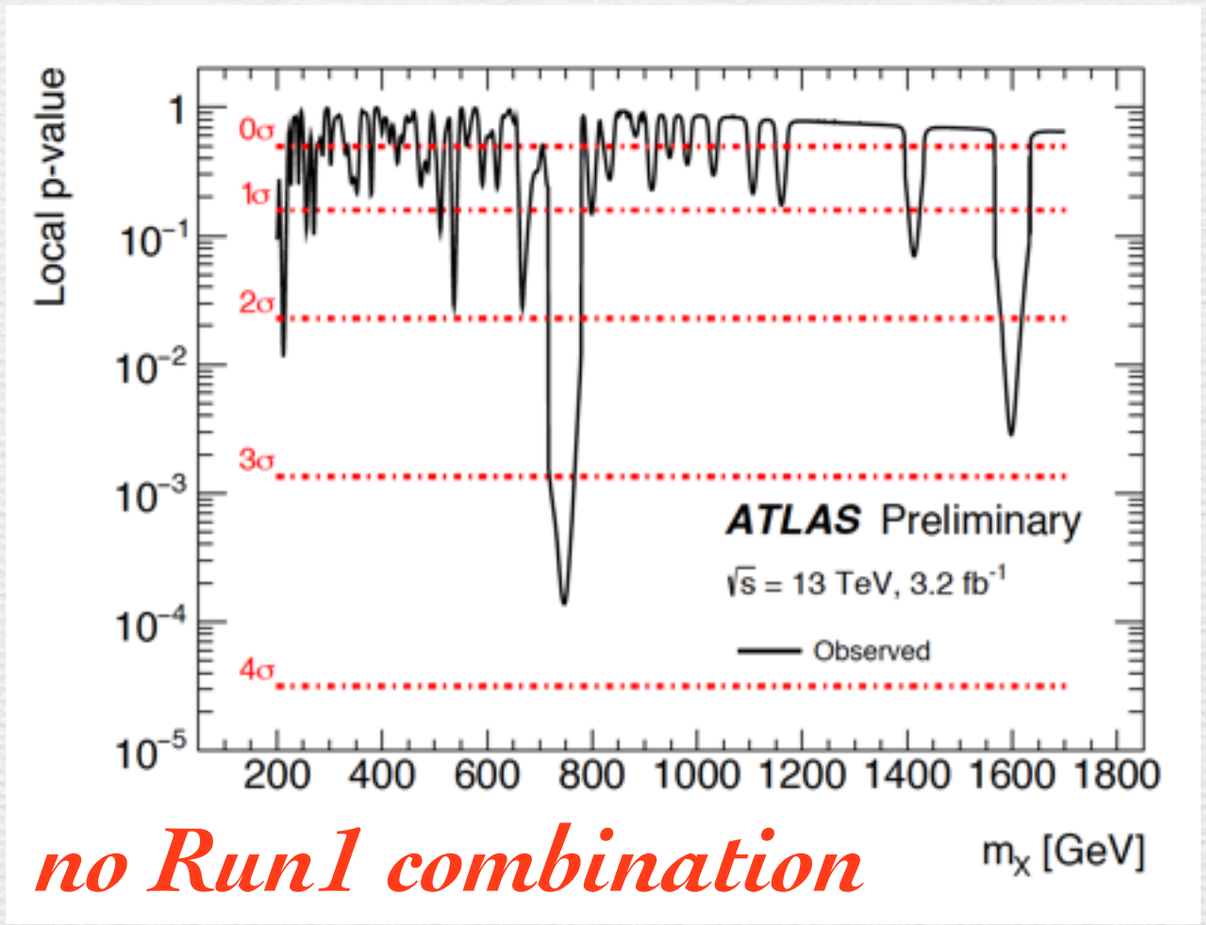
CMS

3.4



ATLAS

3.6

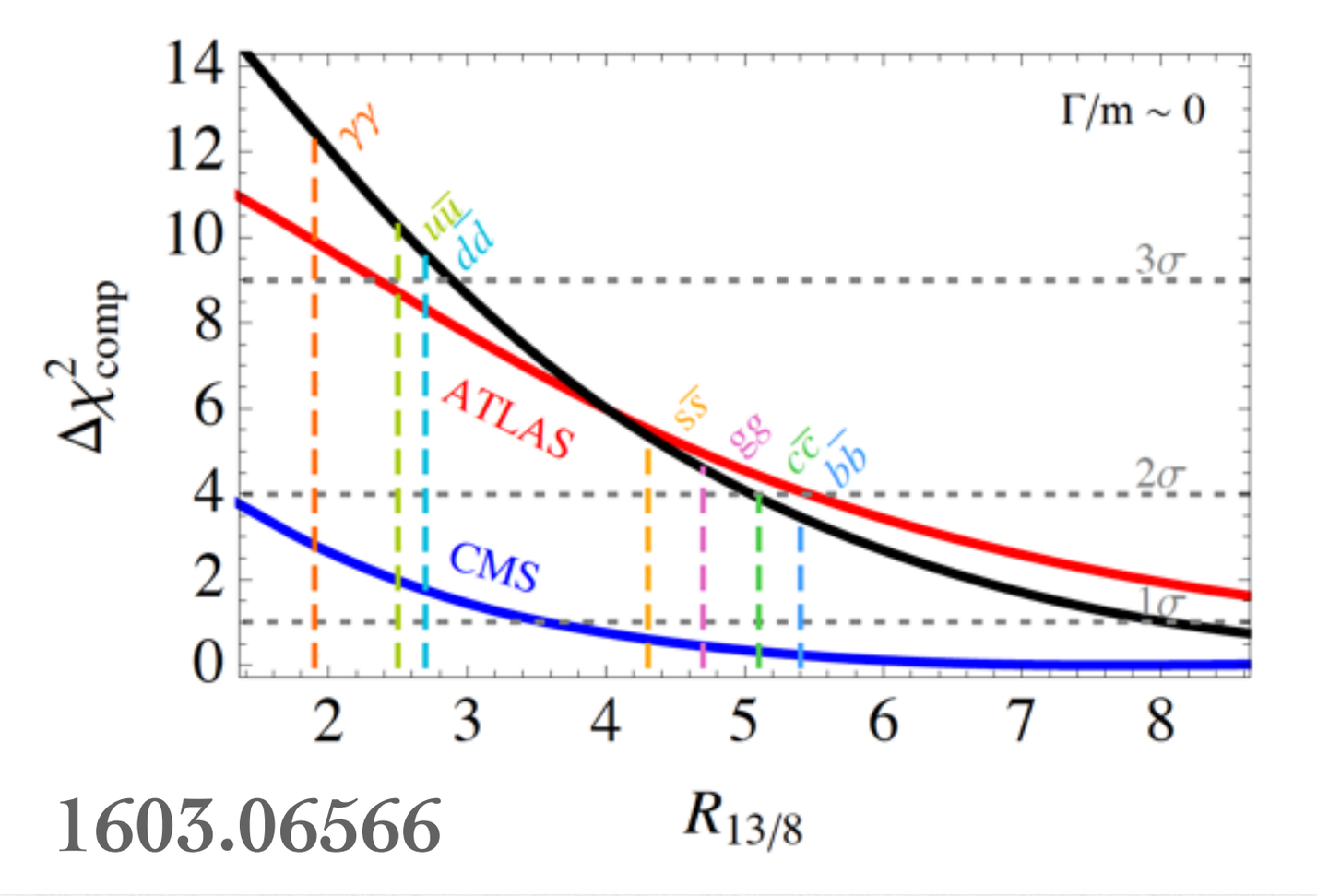


no Run1 combination

(remember LEE should be taken only once)

Production

Kick from 8 to 13 TeV
from non-valence quarks or gluons



1603.06566

sizeable cross section & narrow resonance

indicates gluon-initiated

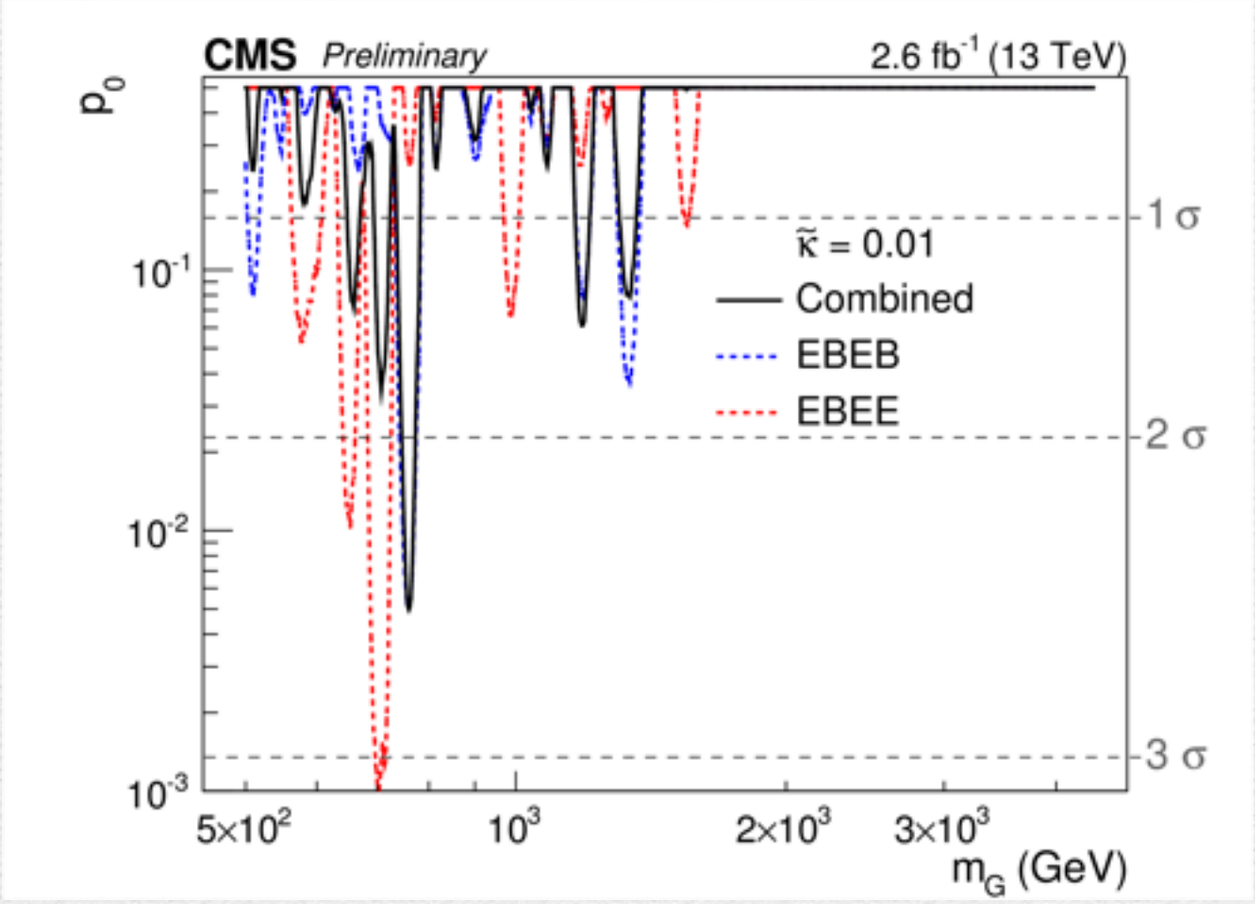
but other productions, incl diphoton still an option

Kinematics

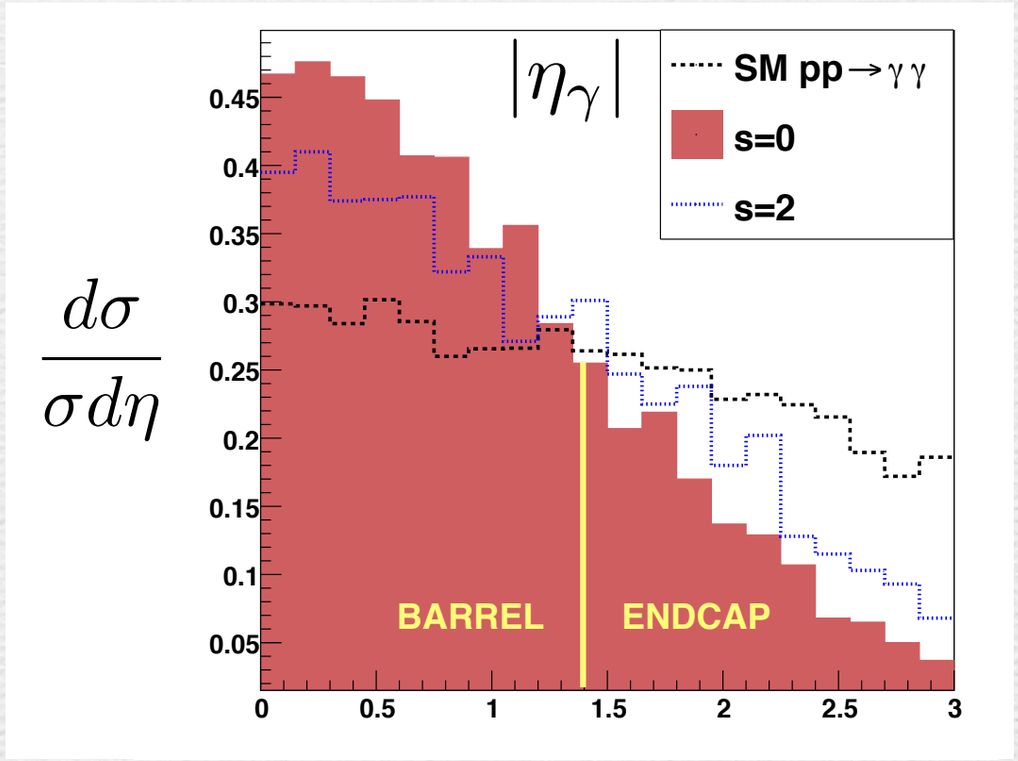
where are the photons? EBEB vs EBEE

Initially (Dec), it looked as if kinematics were funny

CMS



but s=0 and 2 are not so different



Han, Lee, Park, VS.

Kinematics

where are the photons? EBEB vs EBEE

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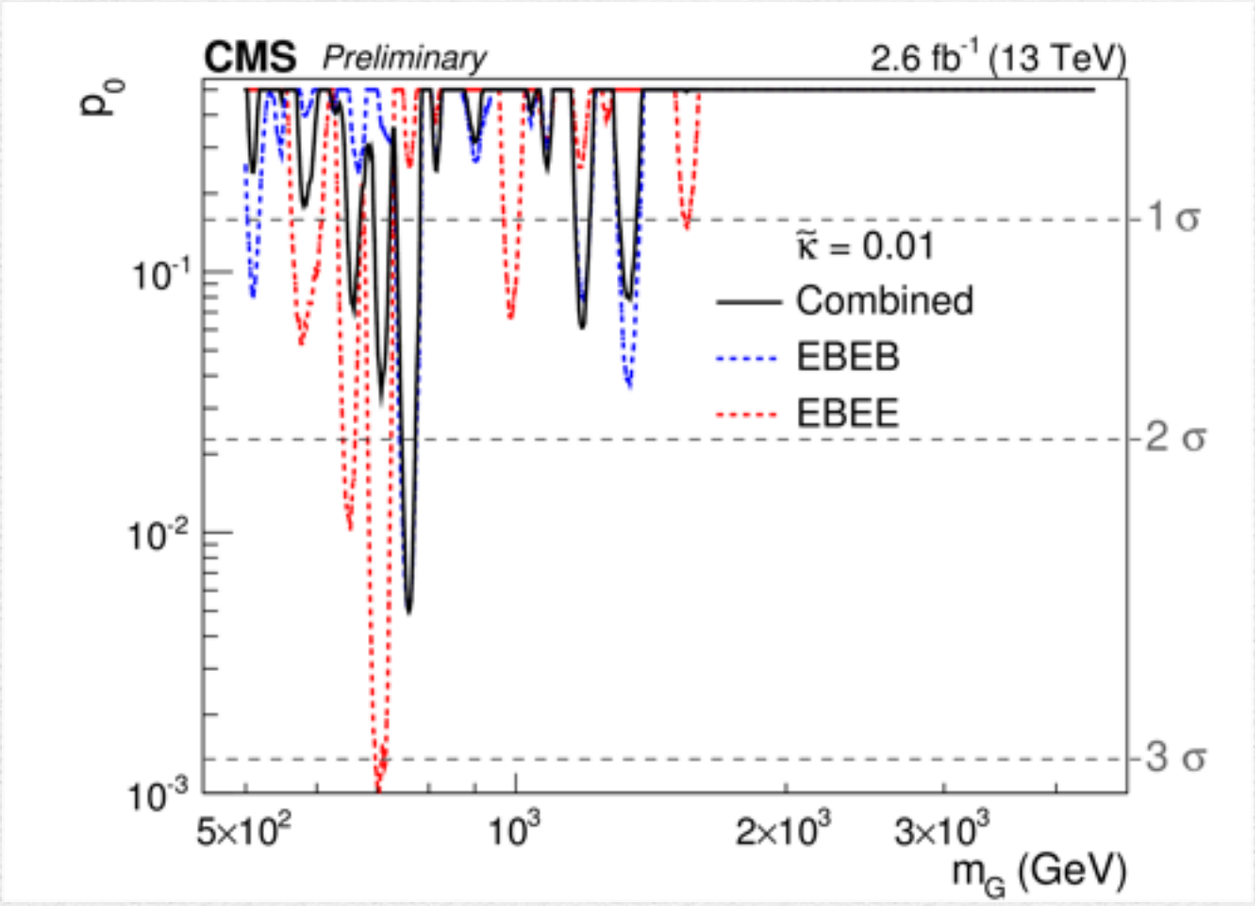
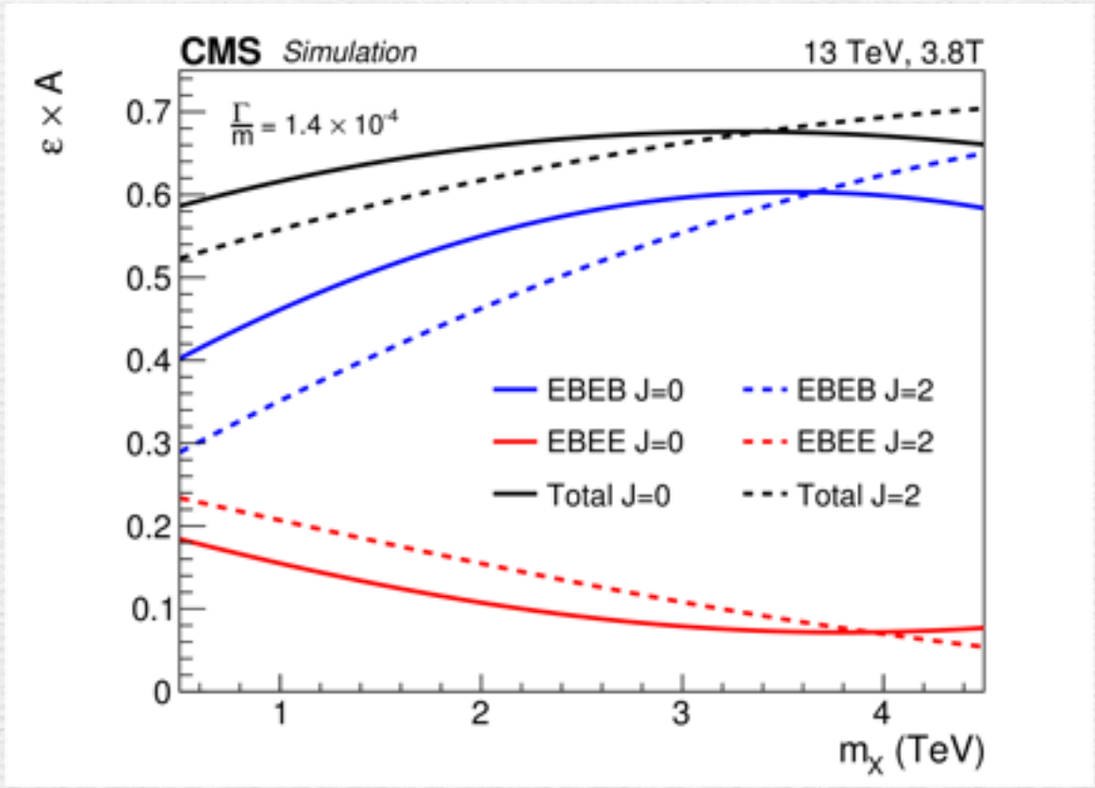
CMS





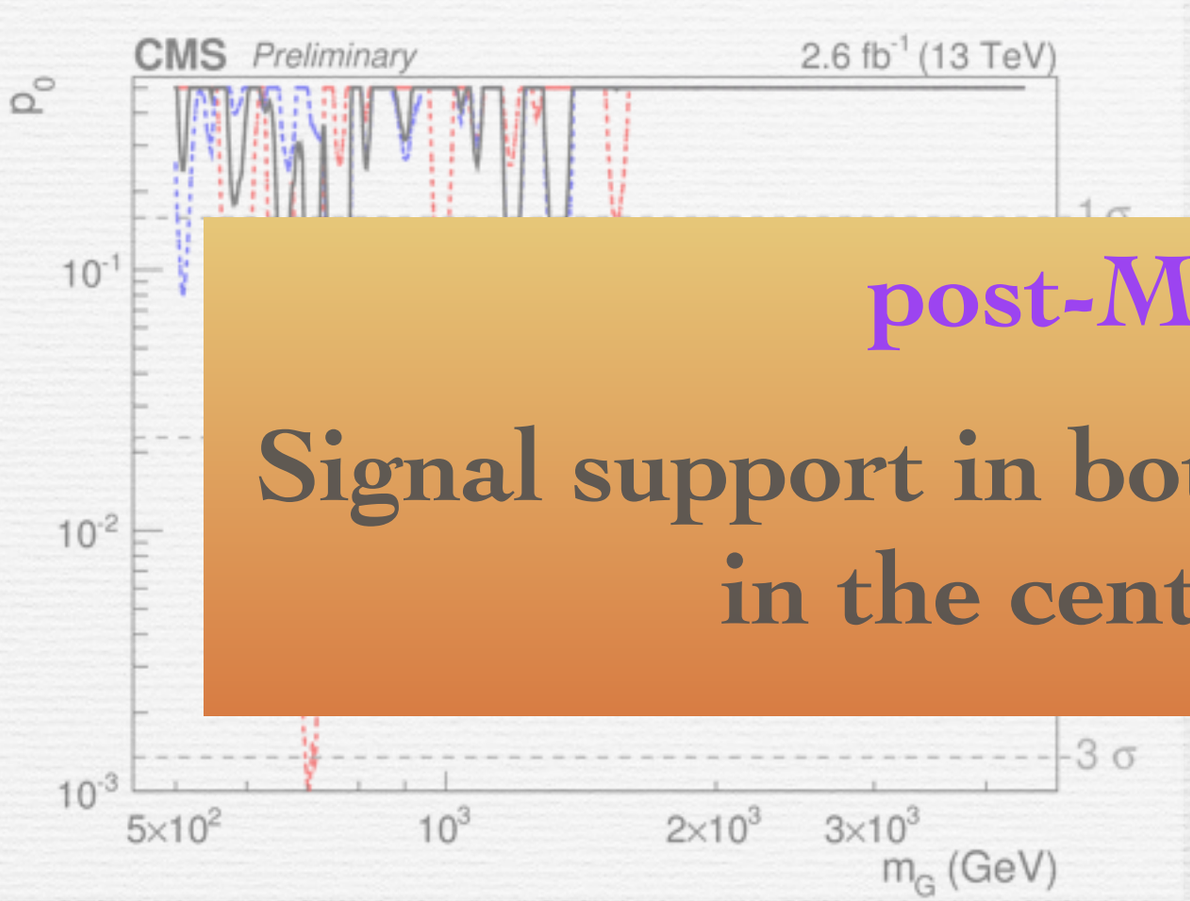
but we didn't have ATLAS to compare with

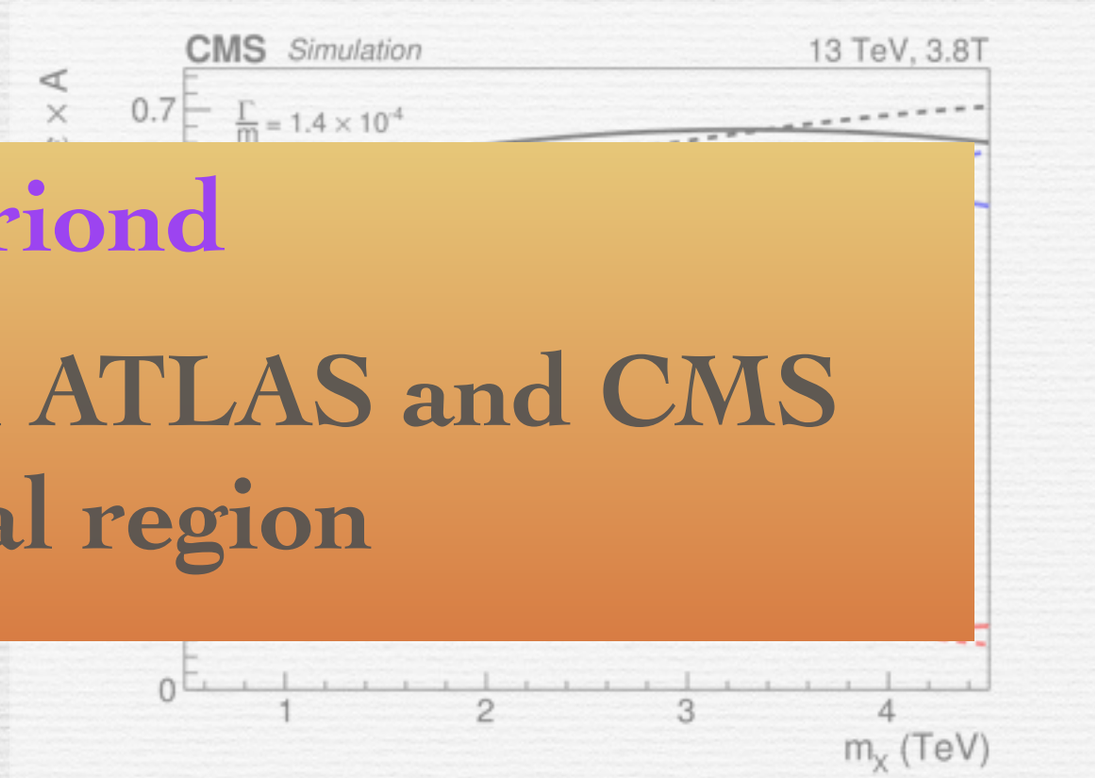
Kinematics

where are the photons? EBEB vs EBEE

Initially (Dec), it looked as if kinematics were funny

CMS





post-Moriond

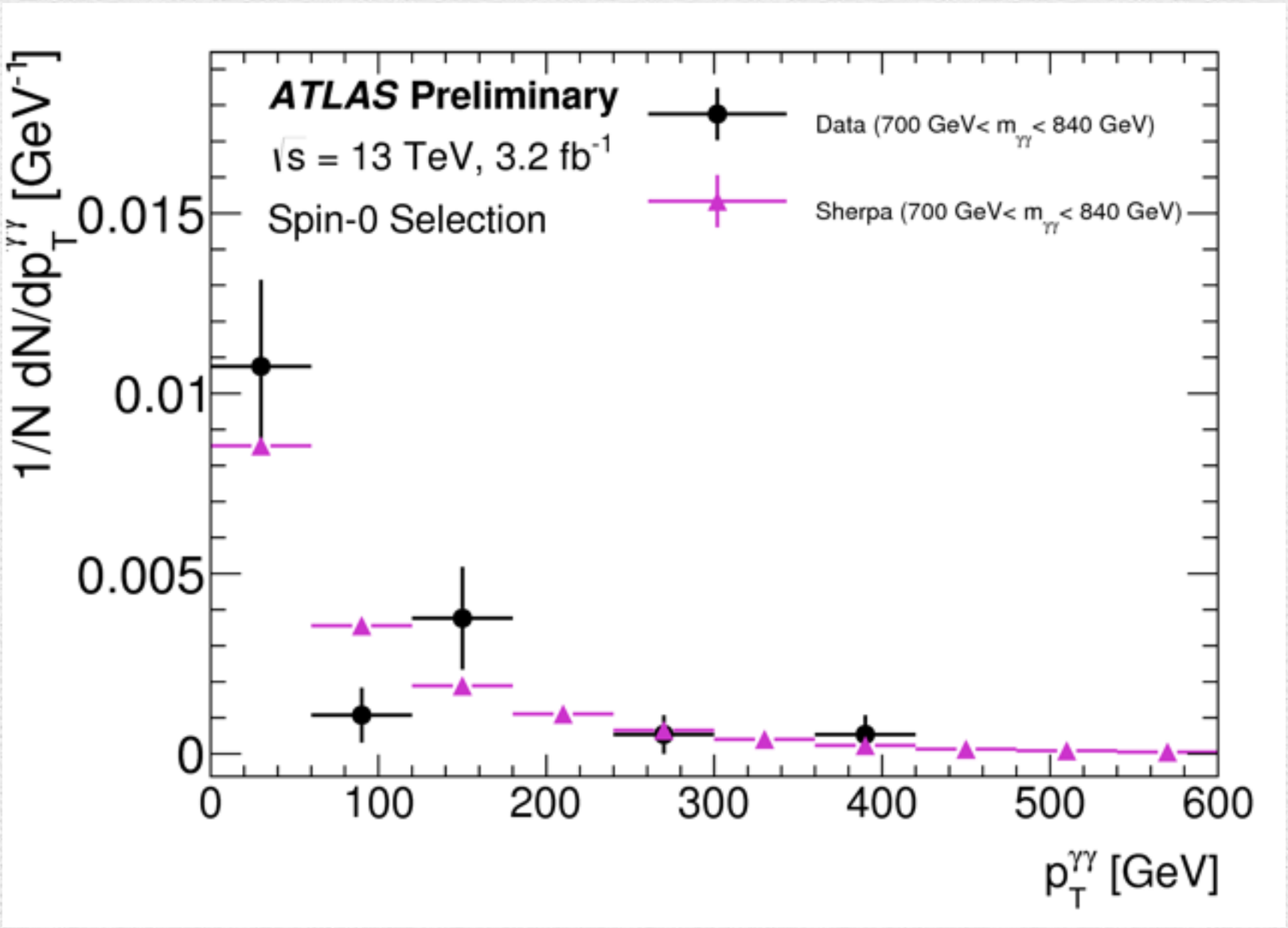
Signal support in both ATLAS and CMS in the central region

but we didn't have ATLAS to compare with

Kinematics

Is this signal coming along other objects?

1. It doesn't recoil (much)



Kinematics

Is this signal coming along other objects?

2. No electrons or muons

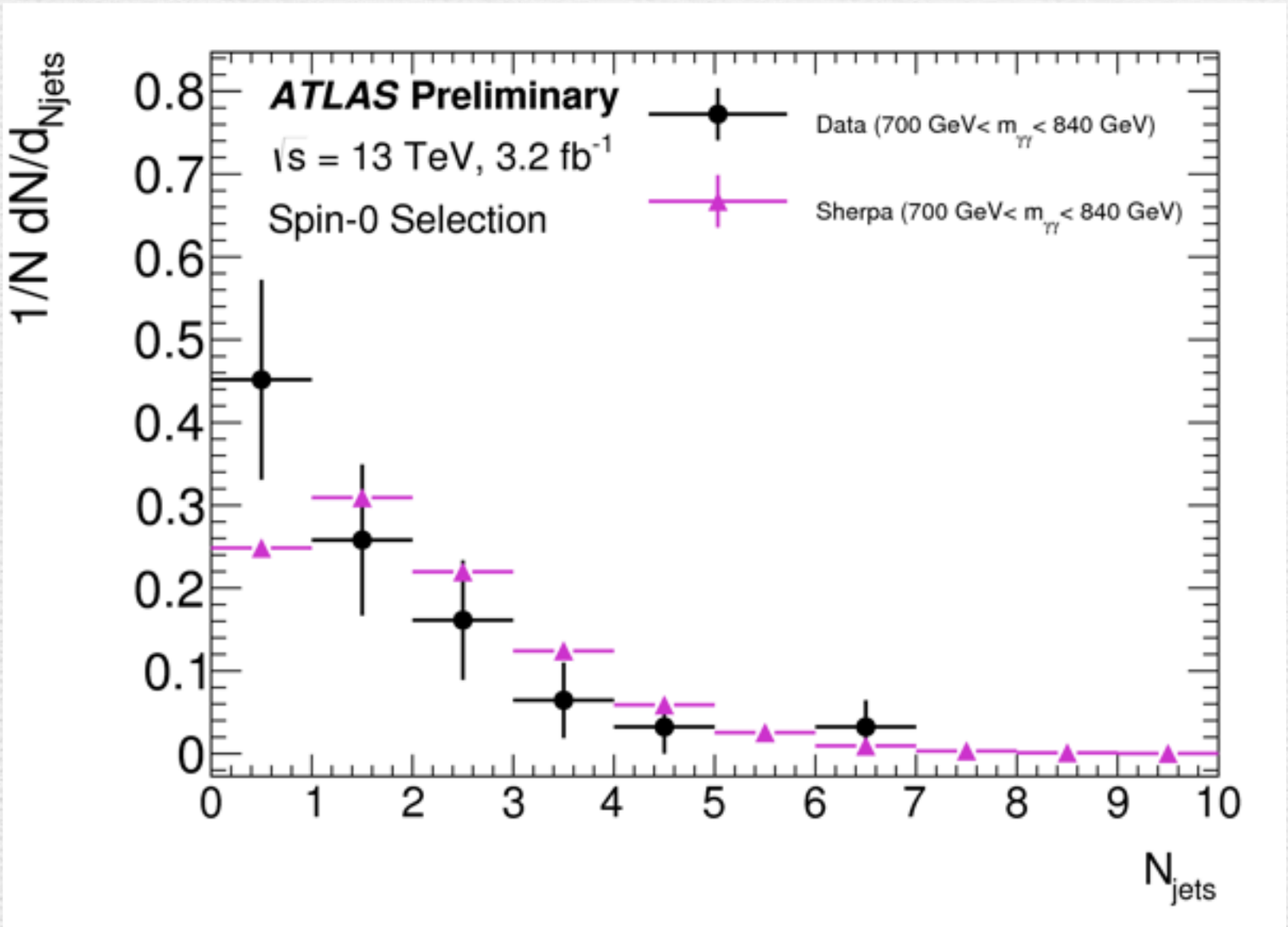
e.g. from ATLAS analysis

"In addition, no electron or muon candidates have been found, with $p_T > 10$ GeV and $|\eta| < 2.$ (electrons) or 2.7 (muons) in the events with invariant masses between 700 GeV and 840 GeV.

Kinematics

Is this signal coming along other objects?

3. No high-pT jets

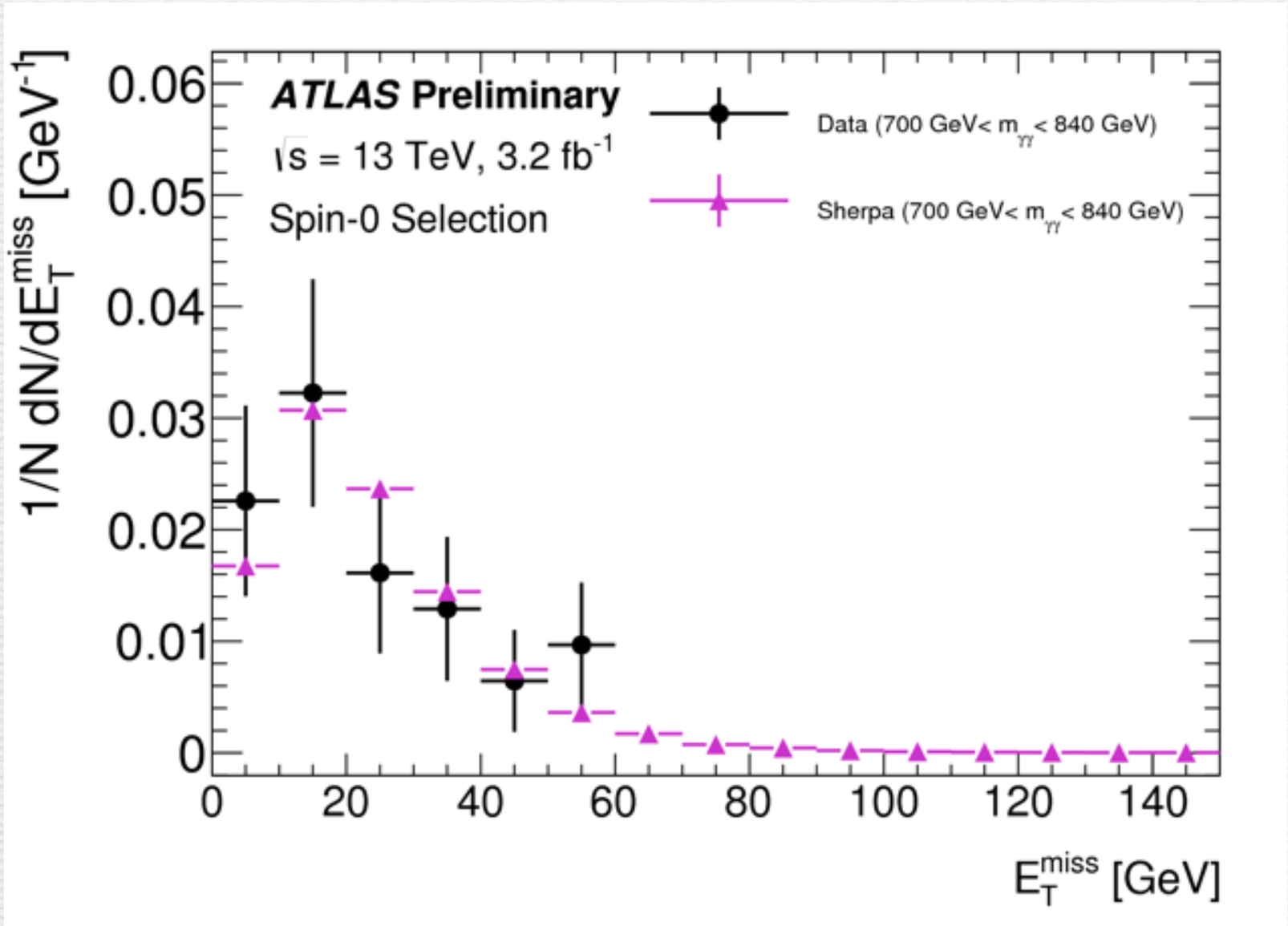


jet anti-kT 0.4
pT> 25, eta< 4.4

Kinematics

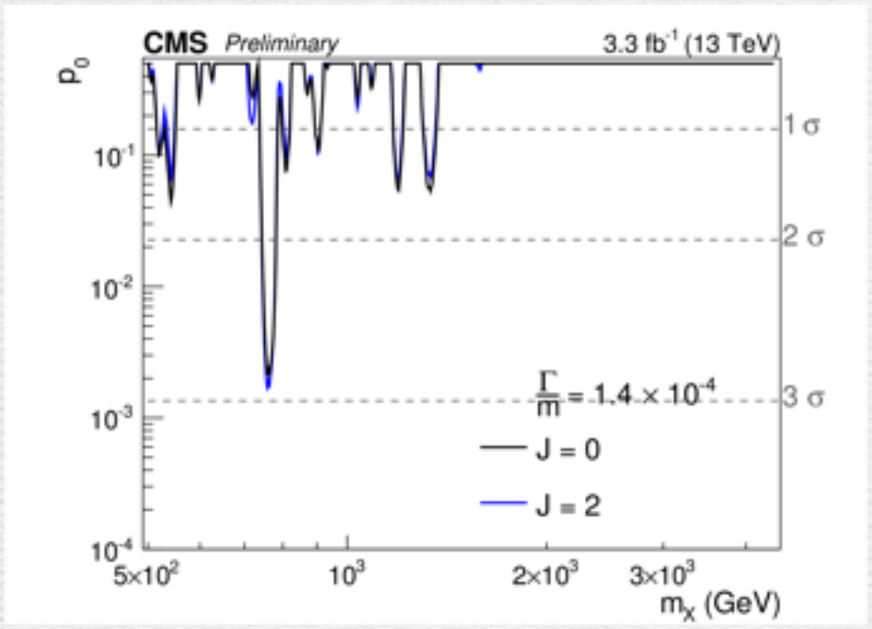
Is this signal coming along other objects?

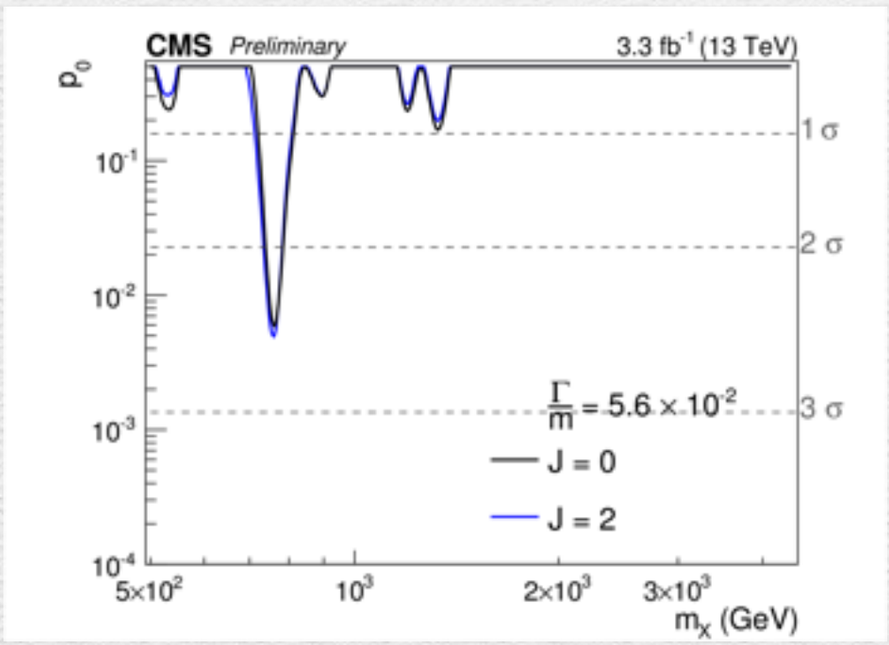
4. No MET



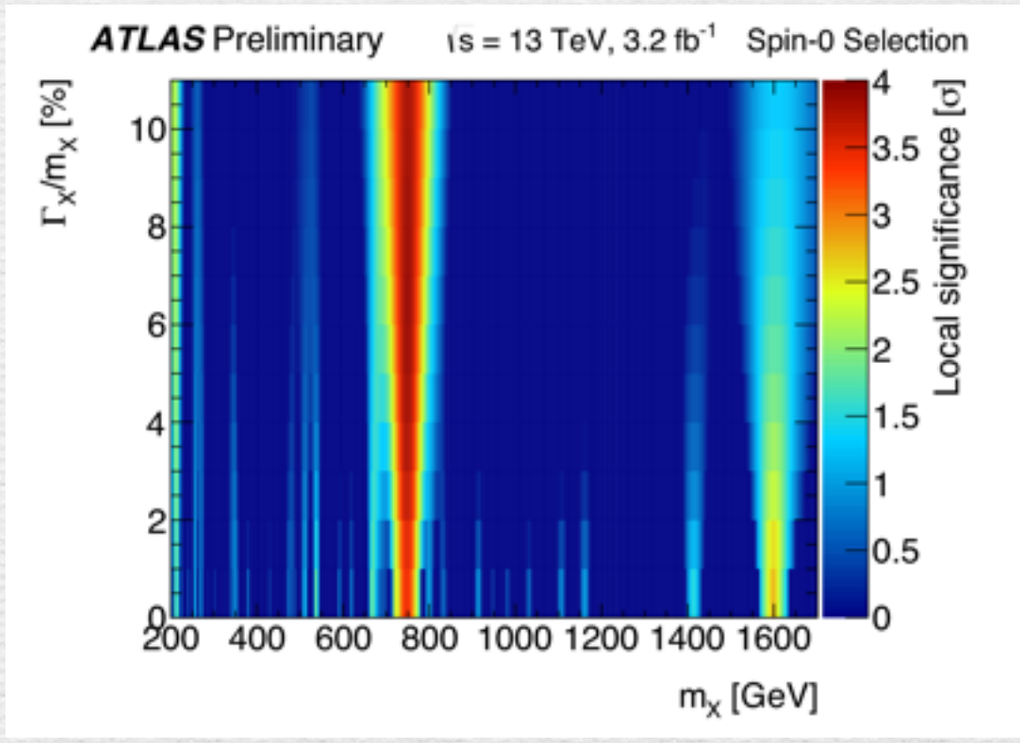
Kinematics
Narrow or wide?

CMS
prefers narrow





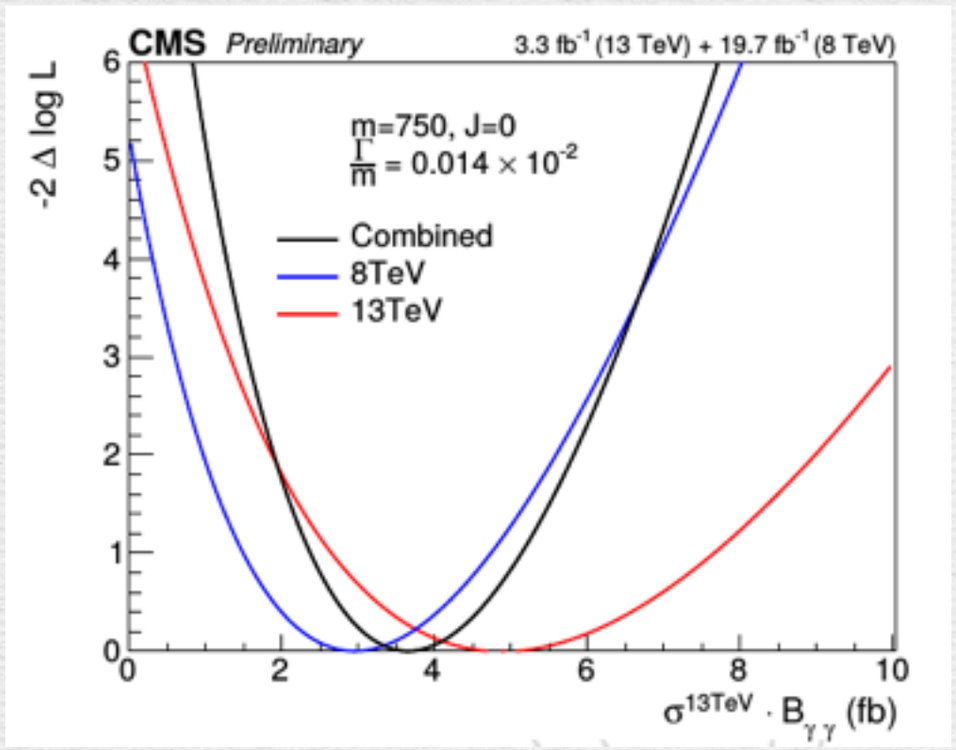
ATLAS
slight preference wide
(0.3 sigma)

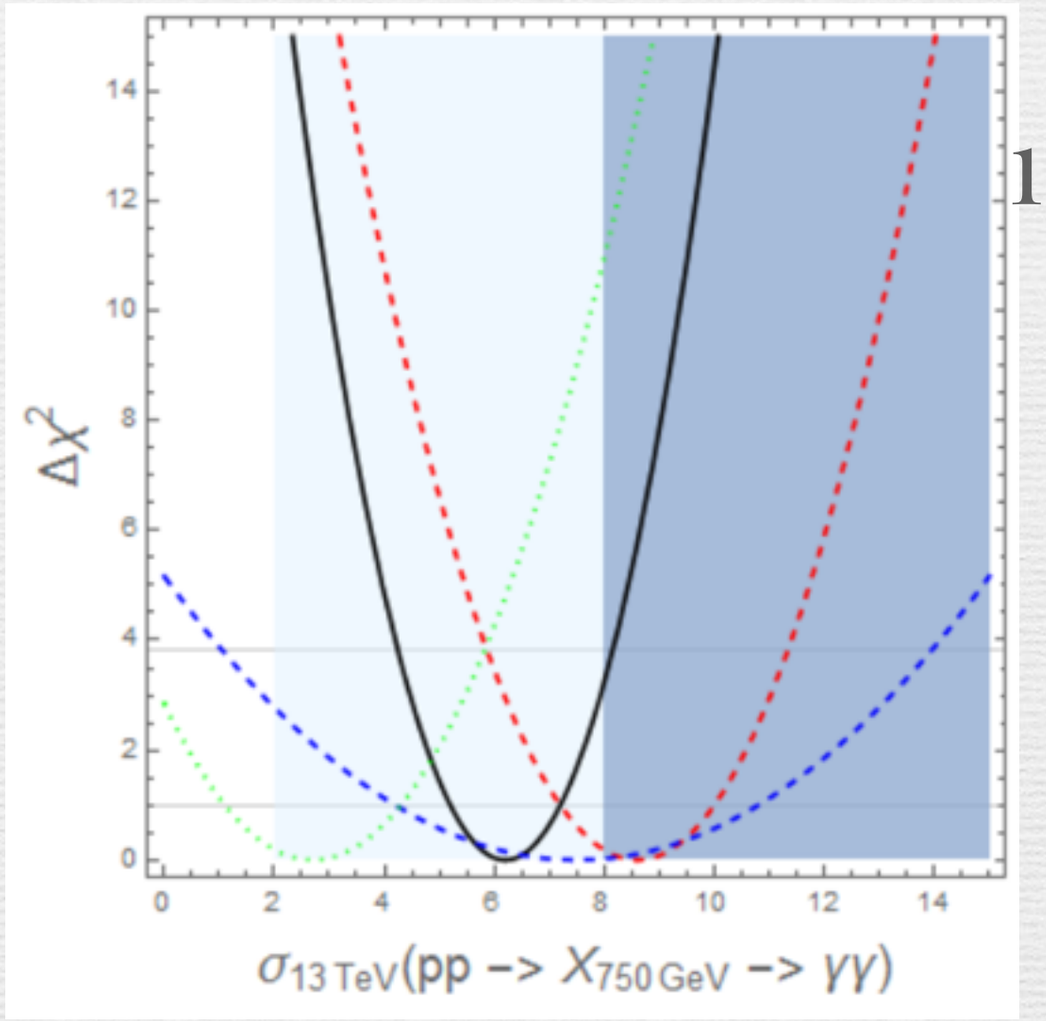


overall
no preference for wide

Signal strength

compatibility? Run1 vs Run 2
and CMS vs ATLAS





1512.05327

CMS1

CMS2

ATLAS2

theorists combination in Dec

6.2 ± 1.0 (fb) (local)

Other final states

light Higgs into diphotons is not like the 750 GeV

Higgs below the threshold of WW, ZZ
suppressed BRs

A heavy resonance in two photons?
it couples to SM gauge interactions we expect
WW, ZZ and Zgamma (and hh)

Model-independent prediction:
diphotons means there must be at least one non-zero BR(Z-gamma) and/or BR(ZZ)

$$g_{\gamma\gamma} = c_1\alpha_1 c_W^2 + c_2\alpha_2 s_W^2$$

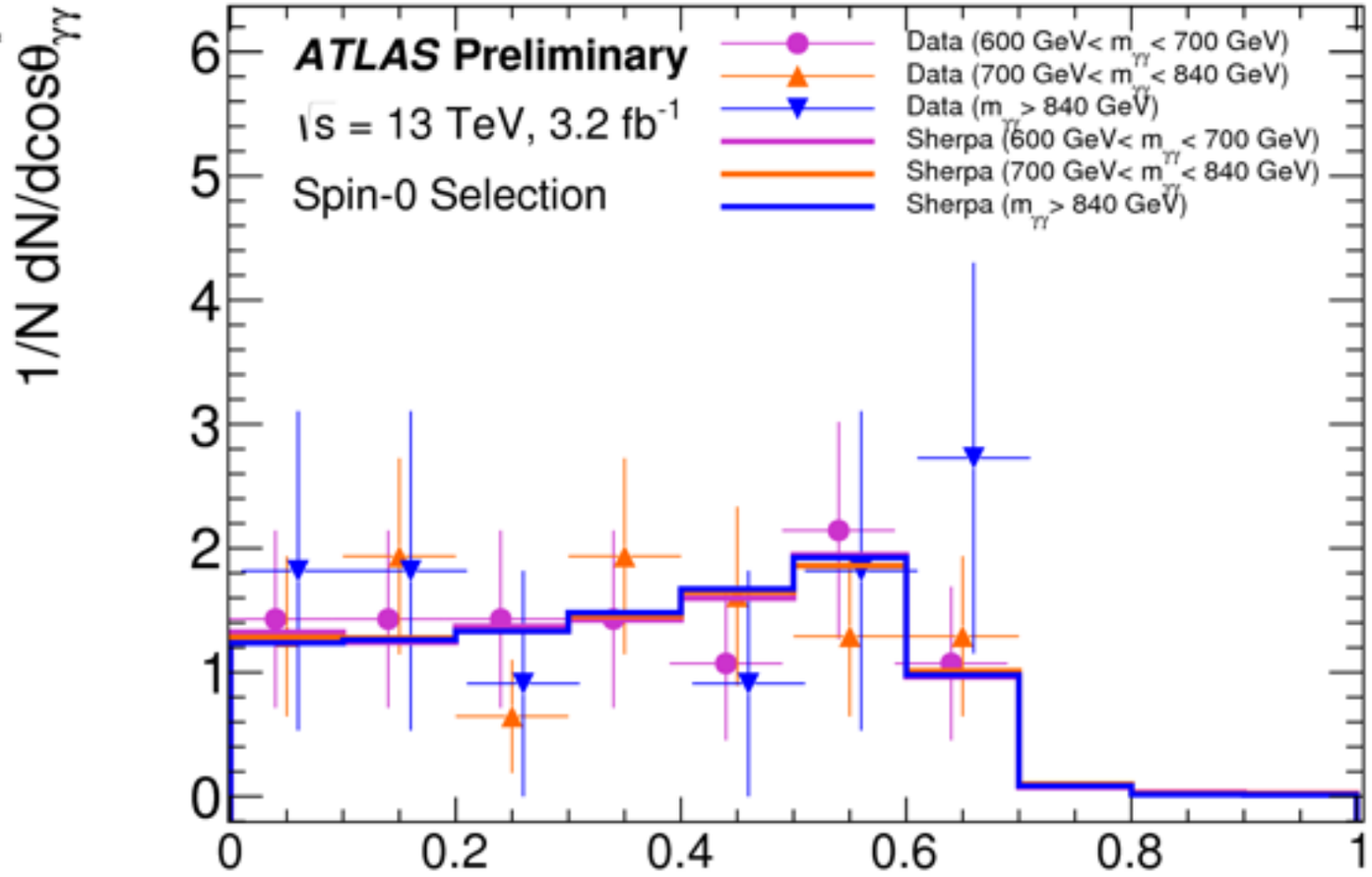
non-zero coupling to photons

$$g_{z\gamma} = (c_1\alpha_1 - c_2\alpha_2)s_{2W}$$
$$g_{zz} = c_1\alpha_1 s_W^2 + c_2\alpha_2 c_W^2$$

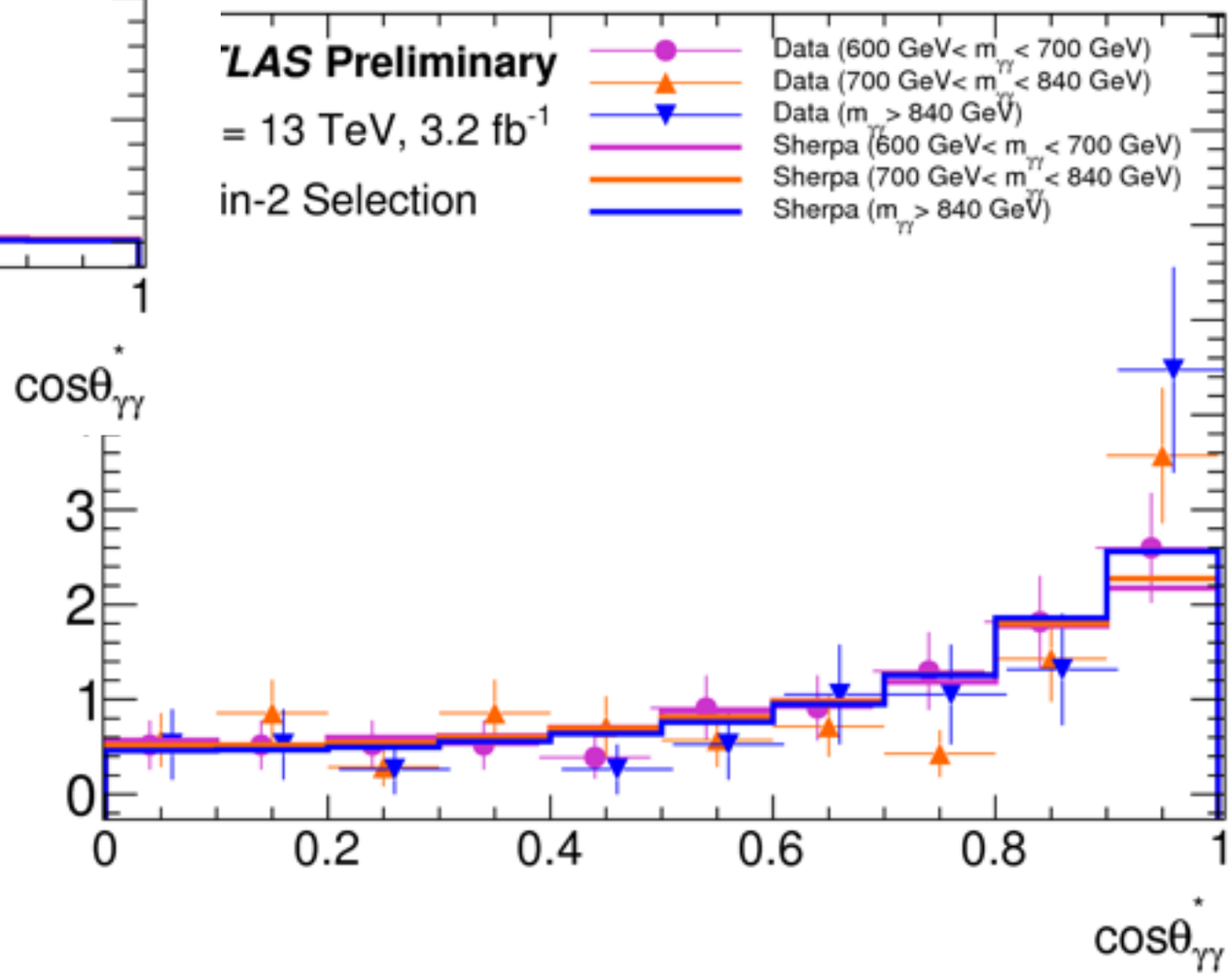
coupling to ZZ and/or Zphoton

No, VS, Setford. 1512.0

Spin



spin-0 vs spin-2
both compatible

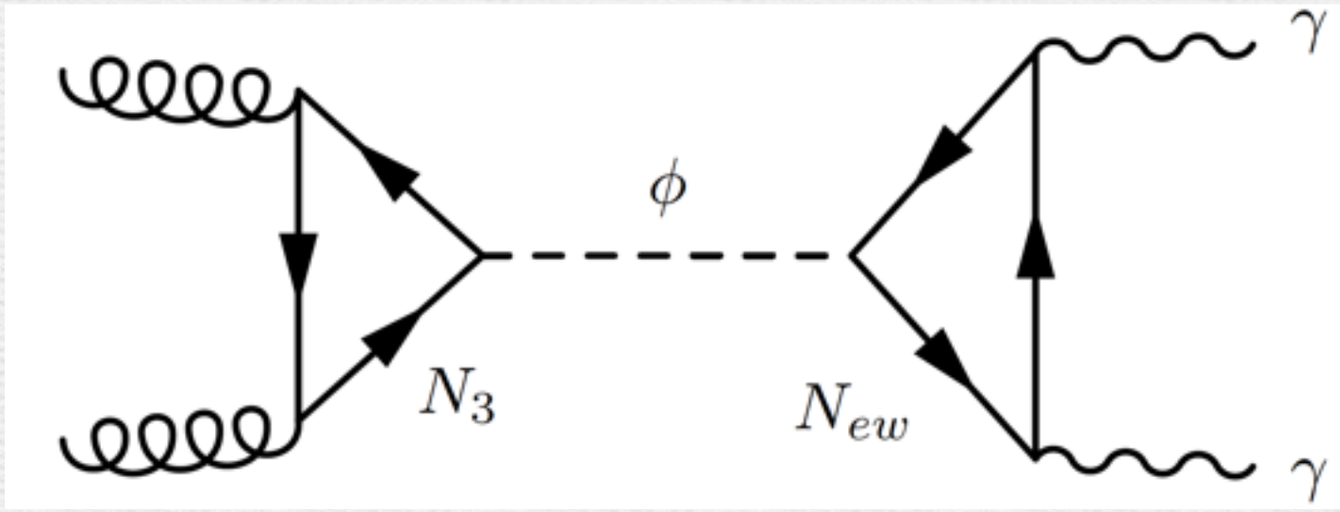


Models for the diphoton

Many papers written (~290 today)
Some model-independent,
most model-building

What is it, if anything?

maybe a scalar coupled to vector-like fermions?



SUSY, Composite scalar?

likely to be seen it in other channels with vector bosons
WW, ZZ, Z-photon
compatible with diphoton first

Spin

J=0

A new scalar

Would this be the end of anthropics?

Spin

J=0

A new scalar

Hooray SUSY!?

MSSM or NMSSM
will not do
compatibility with other
searches, dof,
perturbativity and tuning

non-minimal
or threshold effects

Spin

J=0

A new scalar

Hooray SUSY!?

MSSM or NMSSM
will not do

compatibility with other
searches, dof,
perturbativity and tuning

non-minimal
or threshold effects

Composite dynamics?

glueball of new strong force
or a pseudo-Goldstone boson

link to Composite Higgs

e.g.
see-saw composite Higgs
Dark Matter, Baryogenesis

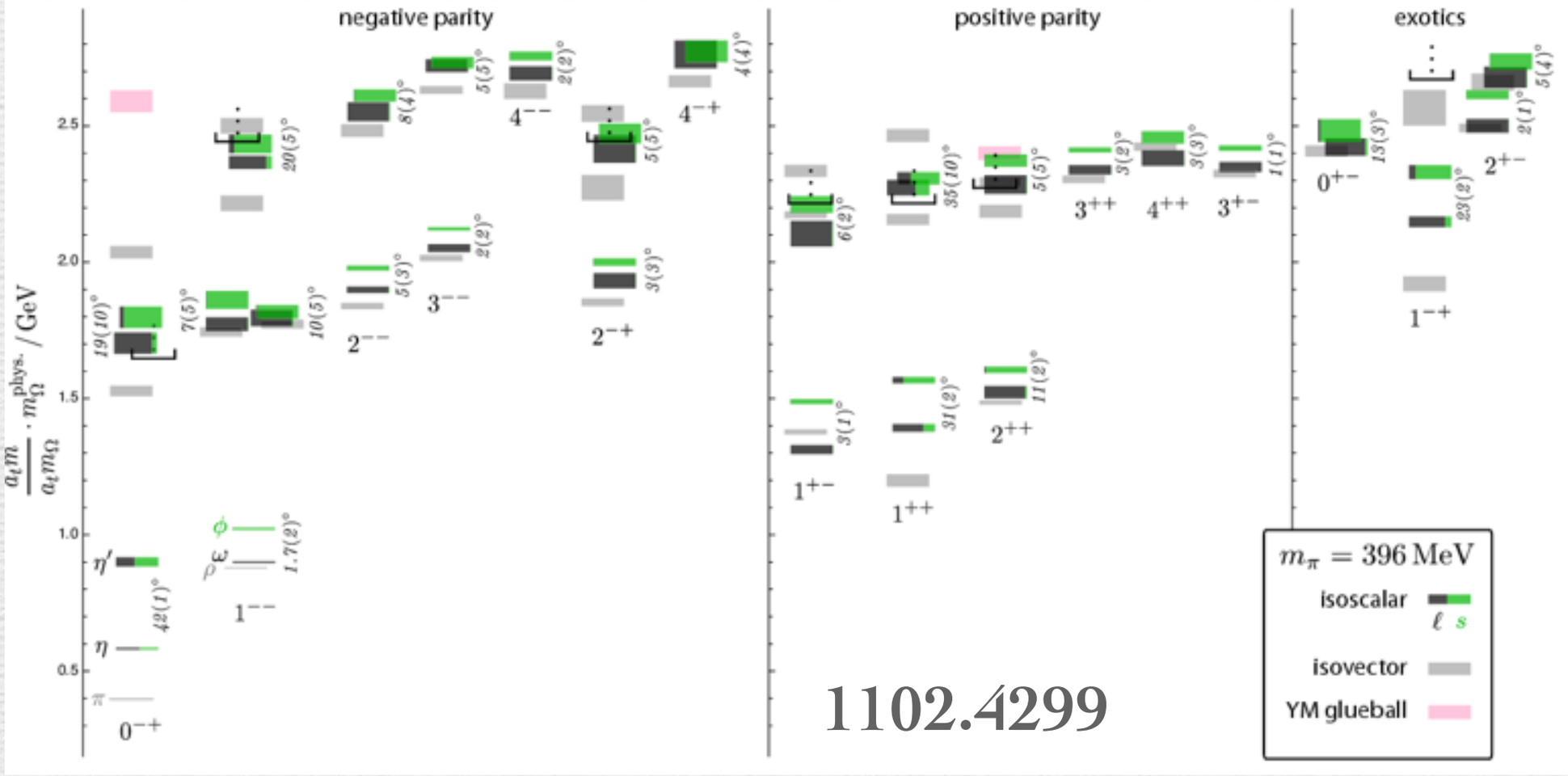
No, VS, Setford.1512.05700

Spin

J=2

A kind of massive graviton or
glueball of new strong force

Important hurdle is EWPTs



1102.4299

Spin

J=2

A kind of massive graviton or
glueball of new strong force

Important hurdle is EWPTs

Experimental interpretations neglect this problem,
theorists use AdS/CFT to find models

recent progress

1603.06980, 1603.08250

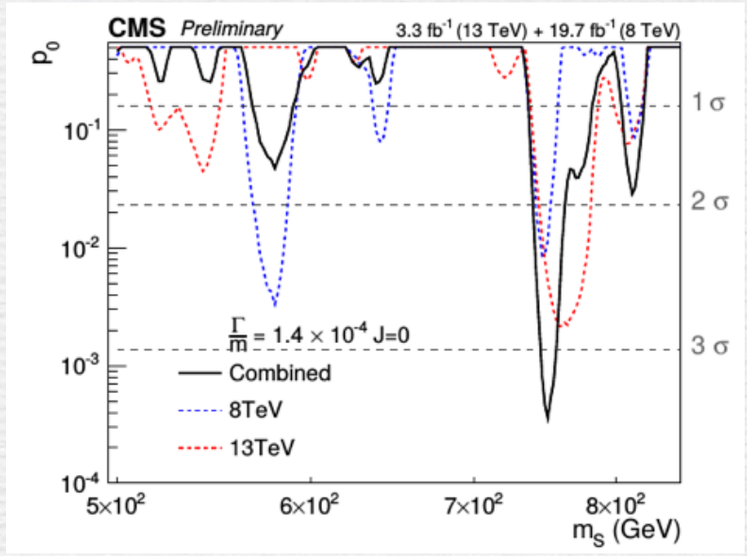
with DM:
talk by HM Lee

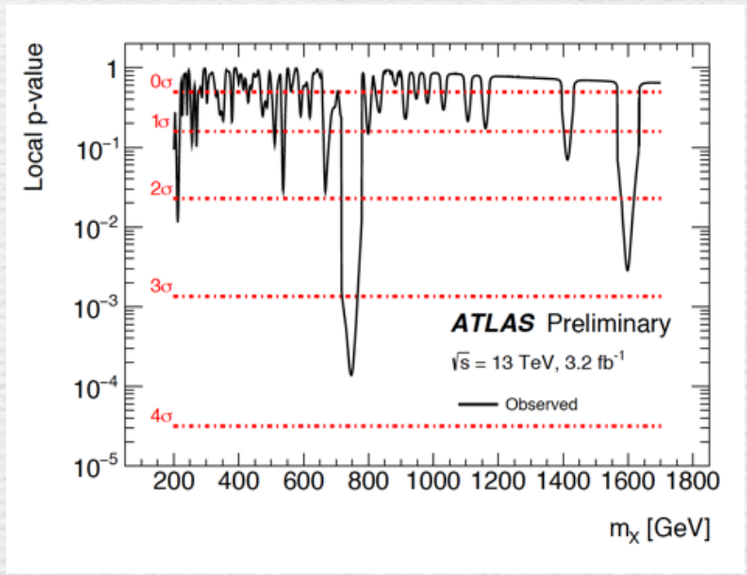
& in composite Higgs

Dillon, VS. 1603.09550

Conclusions

- Two excesses at roughly 3.5 sigma on same location in mass at 750 GeV and cross section 5 fb LEE reduces each to about 2 sigma (double-counting)
- Width and spin still TBD. Excess doesn't come with high-pT objects. Most compatible with gluon-fusion
- Models of spin-zero: composite scalars or non-standard SUSY
- Models of spin-two: non-standard AdS/CFT techniques required





Whatever is hiding, making sense of naturalness, Dark Universe and model-building techniques is a challenge for theorists.
300 papers in ~ 4 months, we are up to it!