

Searches for New Heavy Resonances in Final States with Leptons and Photons in ATLAS and CMS

Francesco Pandolfi
ETH Zürich



on behalf of the ATLAS and CMS collaborations

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A Powerful Tool for Discovery

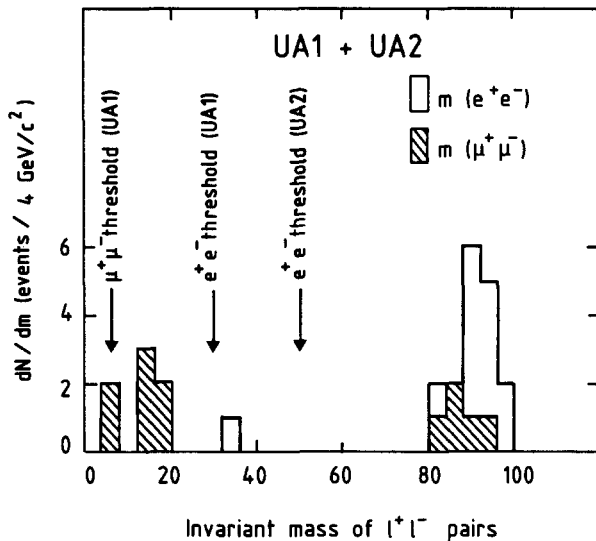


❖ Lepton/photon resonances: a **powerful** discovery tool

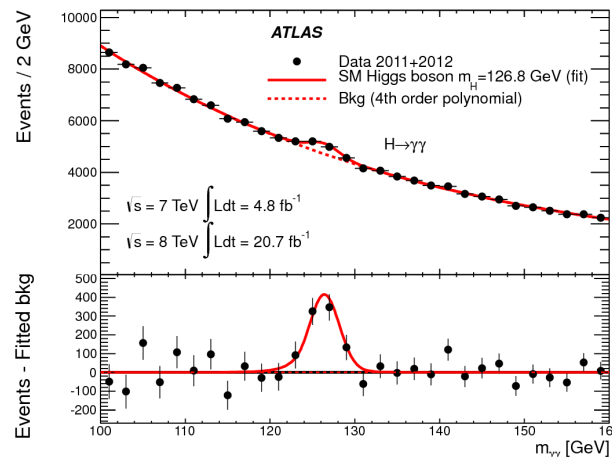
- Discovered Z, W, H bosons

❖ **High** resolution, **low** backgrounds

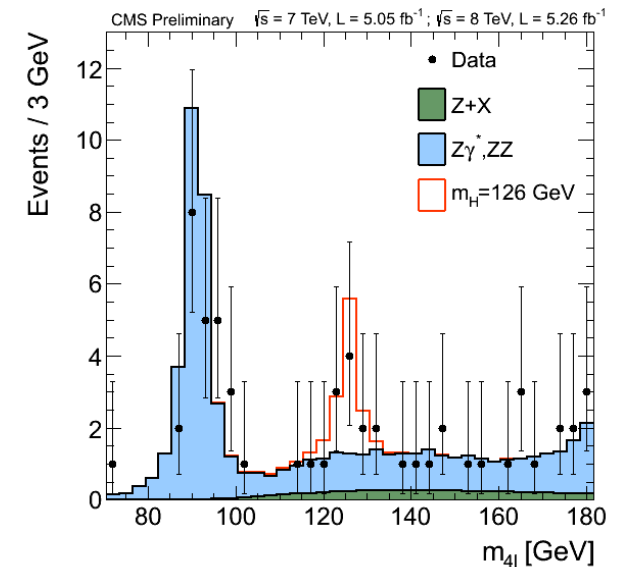
Z → e⁺e⁻



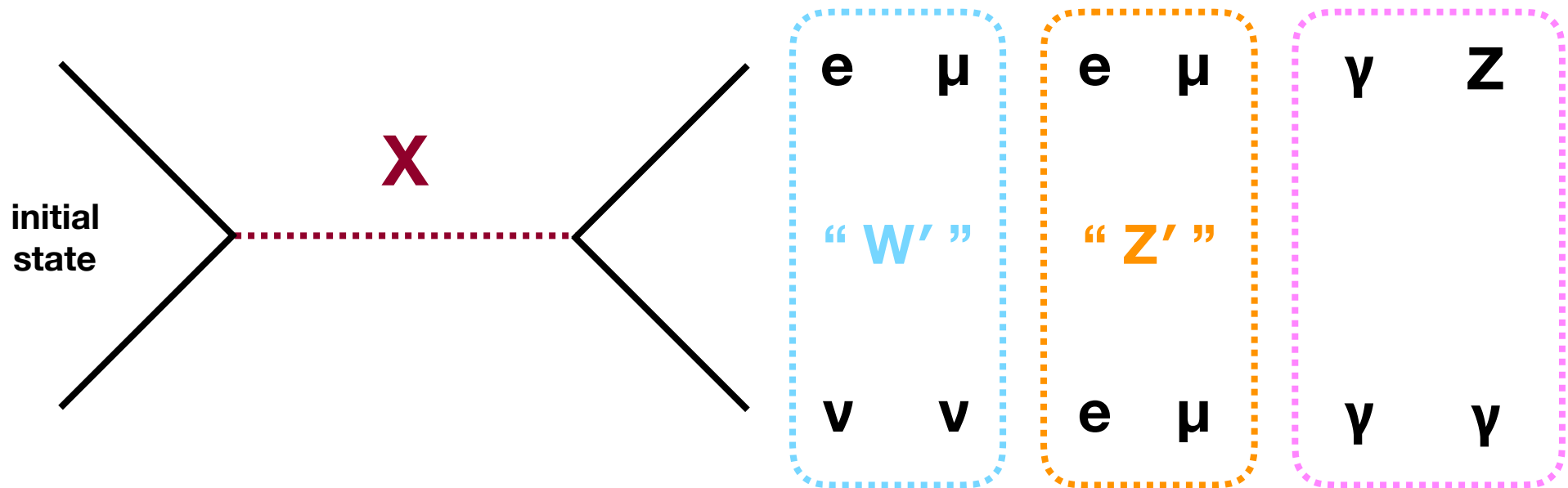
H → γγ



H → ZZ → 4l (e/μ)



What This Talk Will Cover

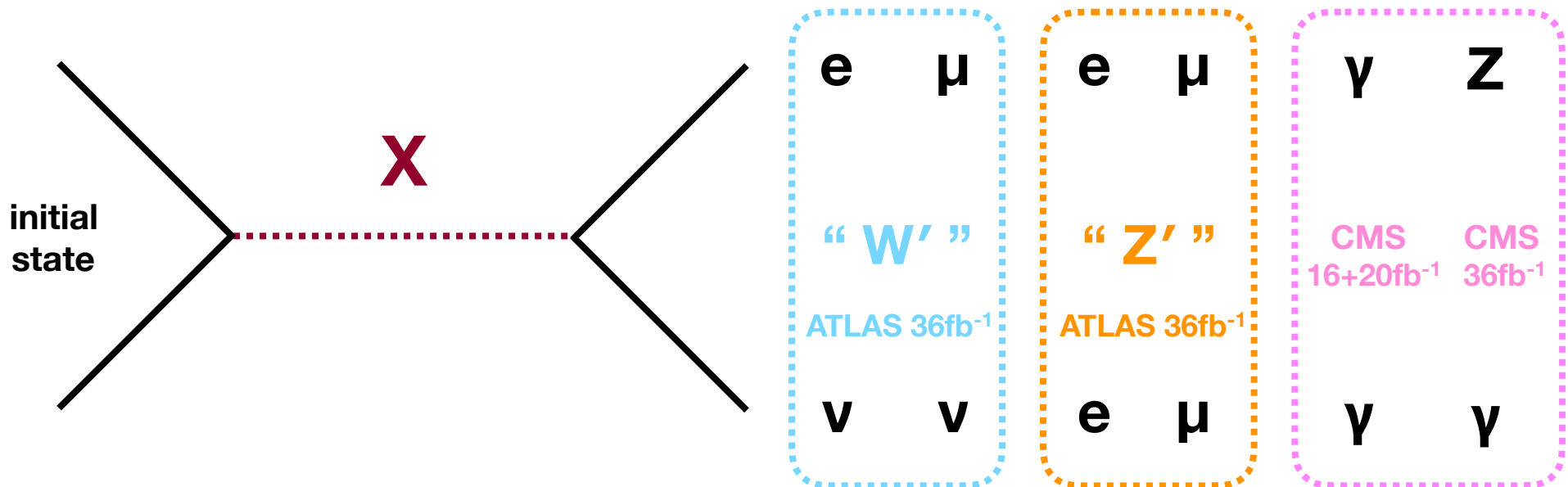


- ❖ ‘Classic’ searches: **similar** techniques/performance in ATLAS and CMS
 - Will show selected results (**personal** choices due to **limited** time)



: results presented here for first time (at a major conference)

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What's Not in This Talk

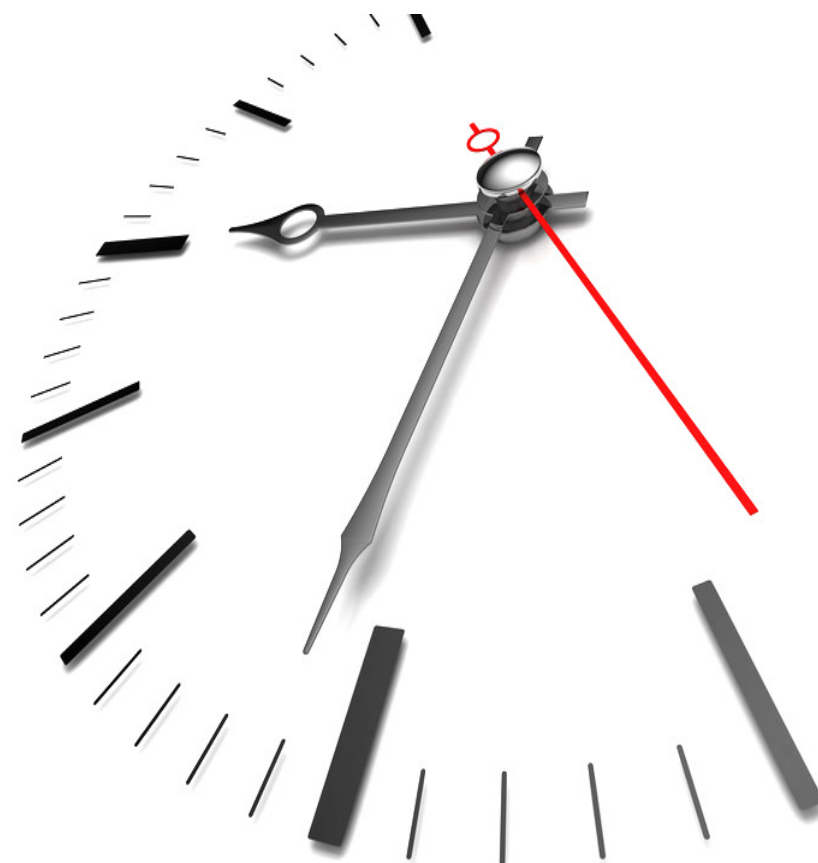


❖ Several searches **not** covered here

- Because of **time** constraints

❖ Some **notable**  results (36 fb^{-1}):

- ATLAS search for $X \rightarrow \gamma + \text{ME}_T$
- CMS search for $X \rightarrow (H \rightarrow \gamma\gamma) + \text{ME}_T$



Single Lepton Search

ATLAS-CONF-2017-016



❖ Events with exactly **one** e/μ and significant ME_T

- **Veto** events with more than one lepton

❖ **Discovery** variable: transverse mass (l, ME_T)

	Electron Channel	Muon Channel
Lepton p _T Cut [GeV]	> 65	> 55
ME _T Cut [GeV]	> 65	> 55

❖ **Main** background: irreducible W → lν, from Powheg NLO MC

- Mass-dependent NLO → NNLO QCD scaling
- Mass-dependent NLO EWK corrections

❖ Fake lepton background (QCD) estimated in **data**

- **Matrix** method: loose → tight ID probability

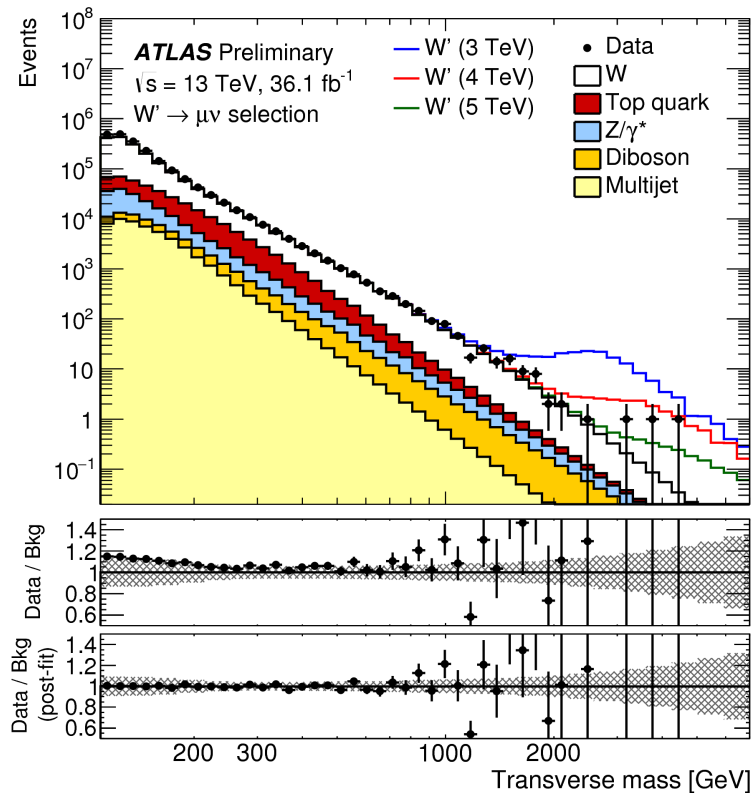
$$\begin{pmatrix} N_T \\ N_L \end{pmatrix} = \mathbf{M} \cdot \begin{pmatrix} N_R \\ N_F \end{pmatrix}$$

T = tight R = real
L = loose F = fake

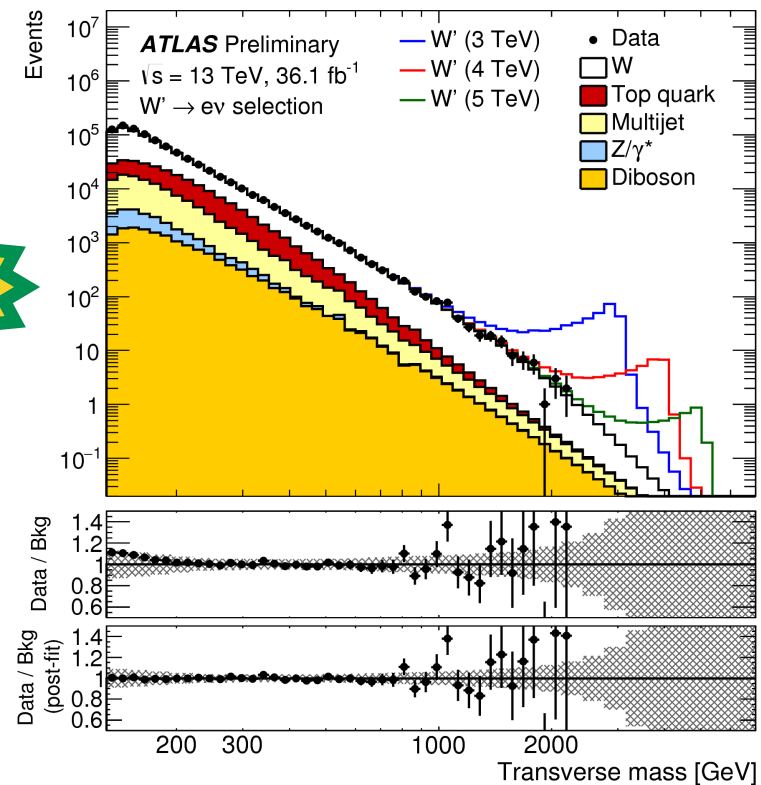
No Excess in Single Lepton Spectra

ATLAS-CONF-2017-016

Muon Channel



Electron Channel

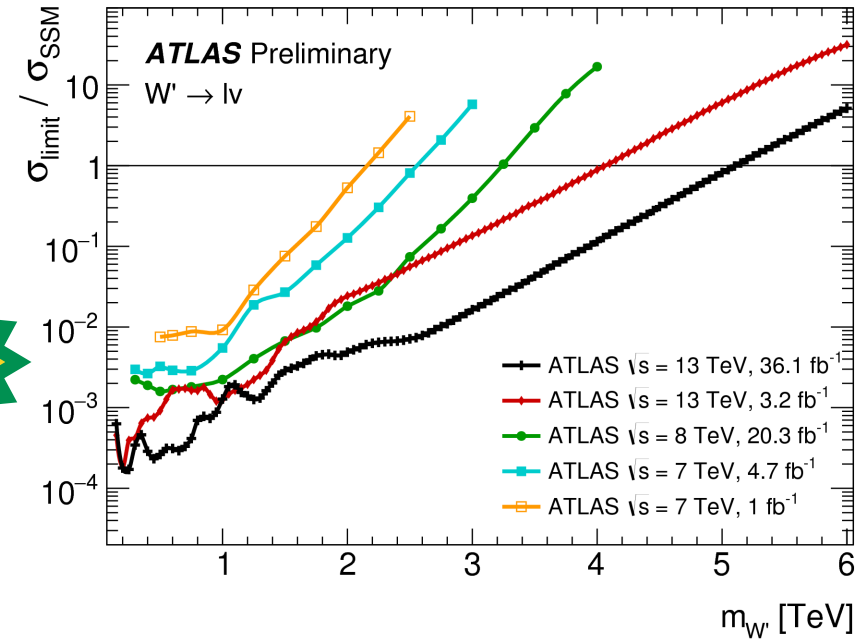
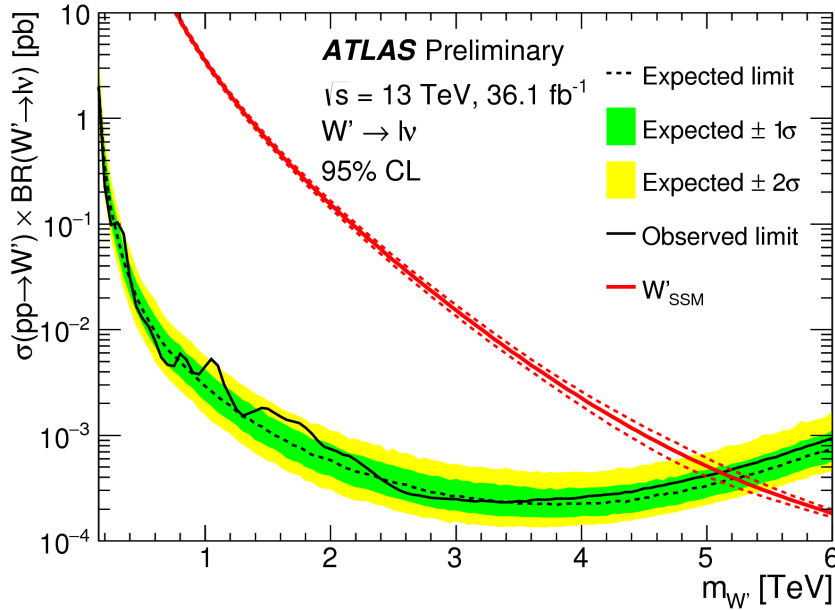


❖ **Consistent with backgrounds**

❖ **Observed excesses all have less than 1σ global significance**

Limits on SSM W' Production

ATLAS-CONF-2017-016



❖ Sequential SM used as **benchmark** model: excluding up to 5.1 TeV

❖ **Significantly** extend limits from previous searches

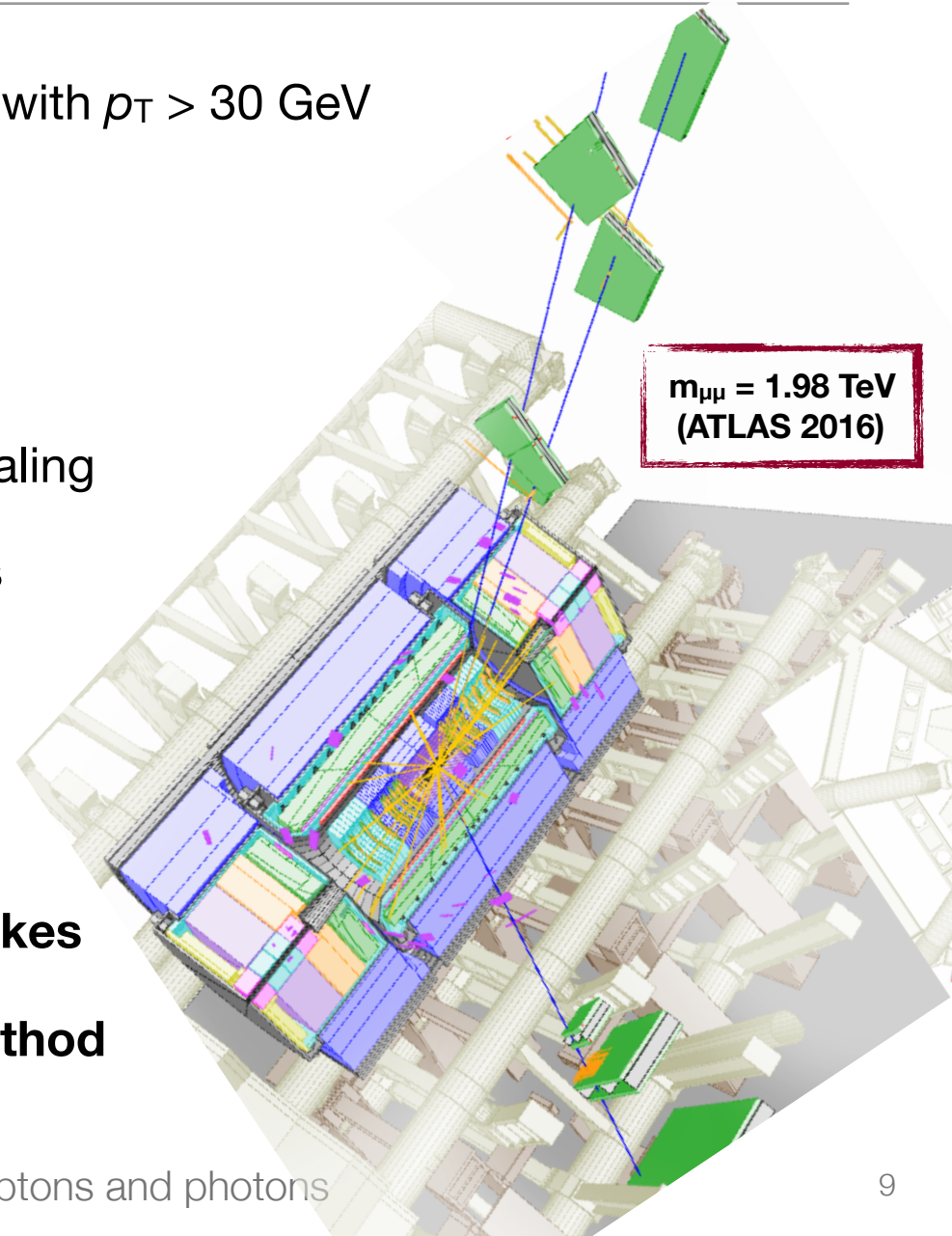
CMS (2.3 fb⁻¹):
M > 4.1 TeV

Dilepton Strategy and Backgrounds

ATLAS-CONF-2017-027



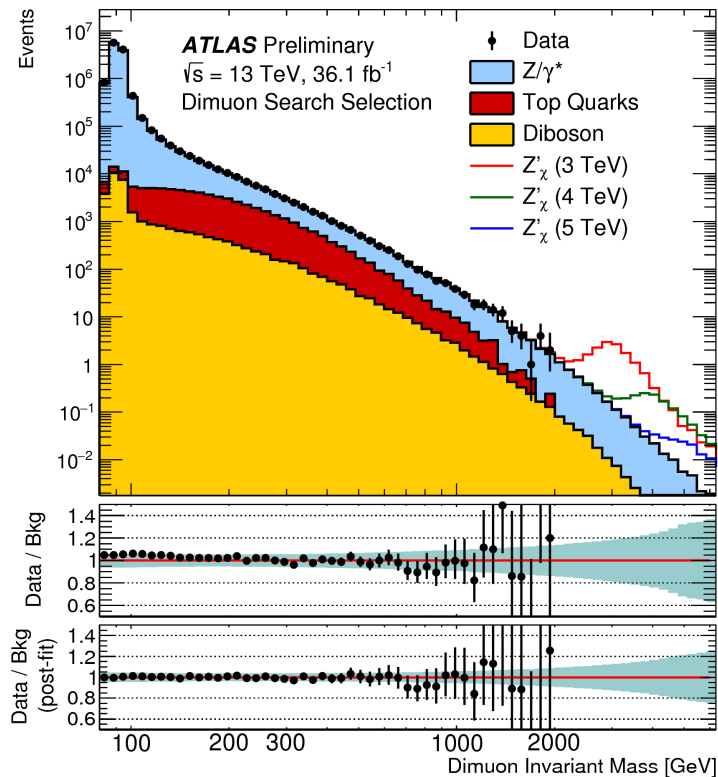
- ❖ Events with **two same-flavor leptons** (e/μ) with $p_T > 30$ GeV
- ❖ **Main** background: DY production
 - Taken from NLO Powheg MC
 - Mass-dependent NLO \rightarrow NNLO QCD scaling
 - Mass-dependent NLO EWK corrections
- ❖ **Small** contributions from other processes with real leptons in final state (top, diboson)
- ❖ Electron channel: small contribution from **fakes**
 - Estimated in data with same **matrix method**



No Excess in Dilepton Searches

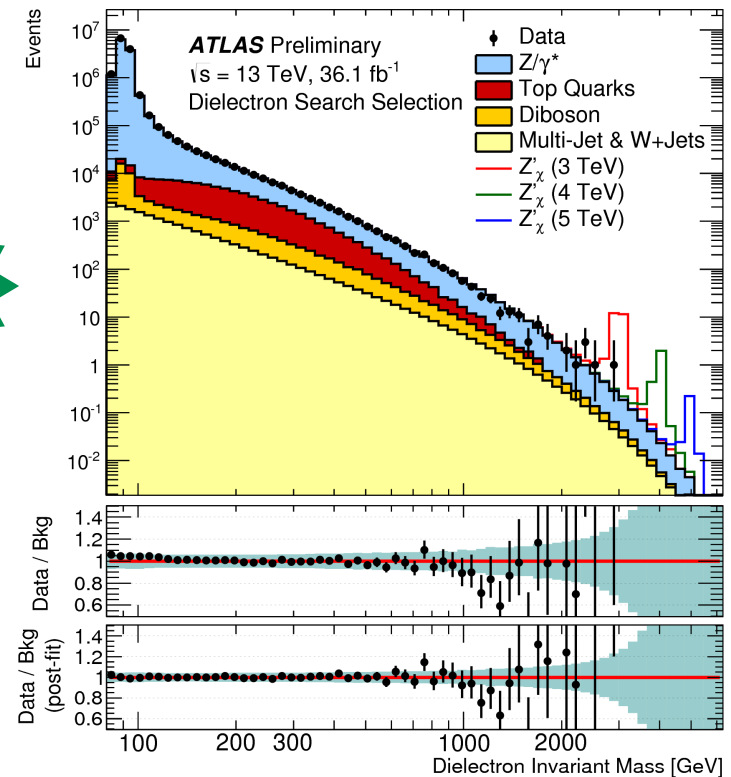
ATLAS-CONF-2017-027

Dimuon Channel



NEW

Dielectron Channel

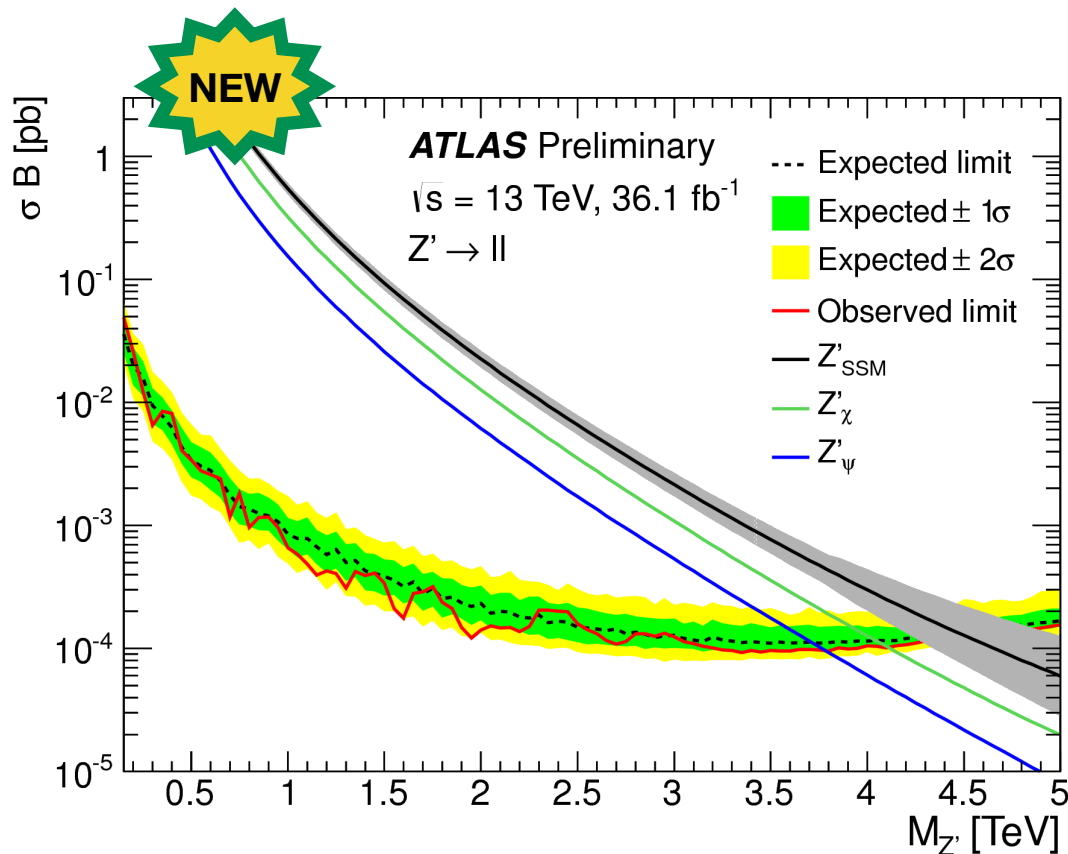


❖ Consistent with backgrounds

❖ Most significant excess at 2.37 TeV in ee channel ($\sim 0.2\sigma$ globally)

Limits on Dilepton Resonances

ATLAS-CONF-2017-027



❖ Setting **limits** on $\sigma \times \text{BR}$

- $M > 4.5$ (3.8) TeV for Z_{SSM} (Z_{ψ})

CMS (13 fb⁻¹):
 $M > 4.0$ (3.5) TeV

❖ Re-interpreted also as search for **non-resonant** production (CI)

- See talk by W. Fedorko

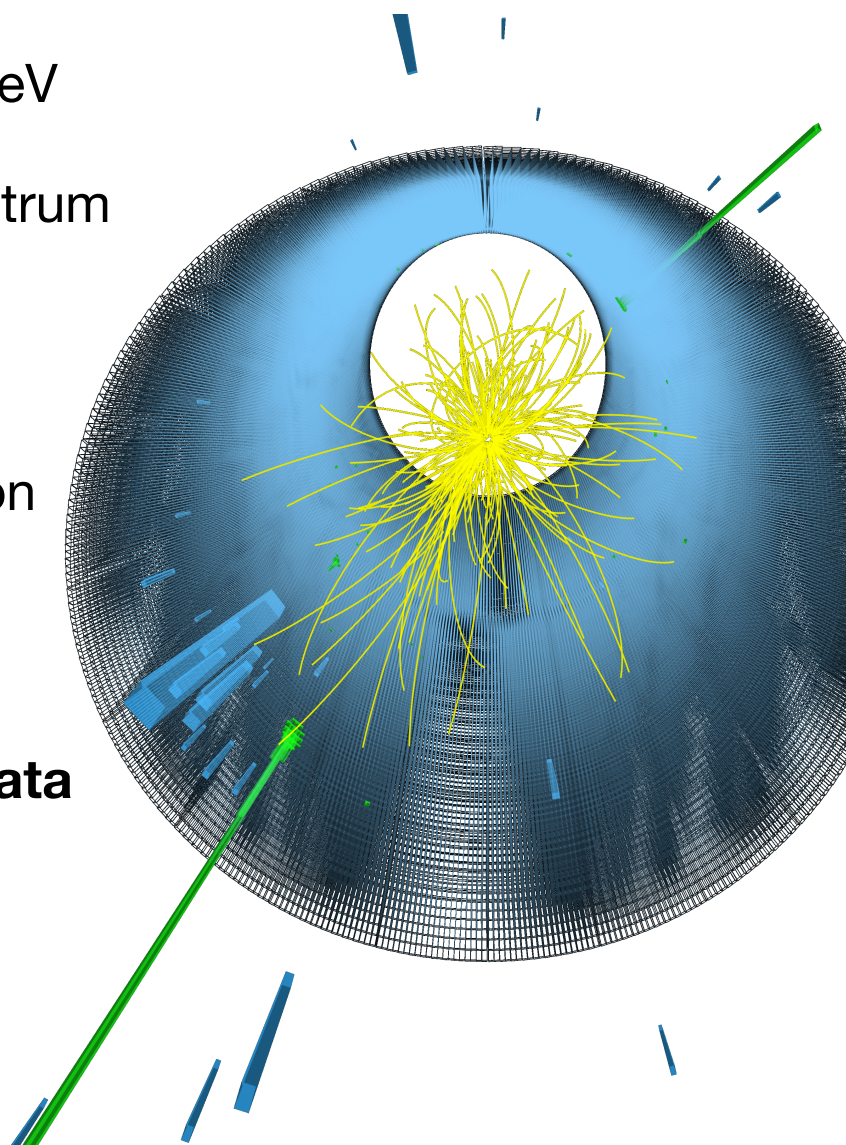
Diphoton Analysis Strategy

Physics Letters B 767 (2017) 147

- ❖ Select events with **two photons** with $p_T > 75$ GeV
 - And look for **bumps** in diphoton mass spectrum

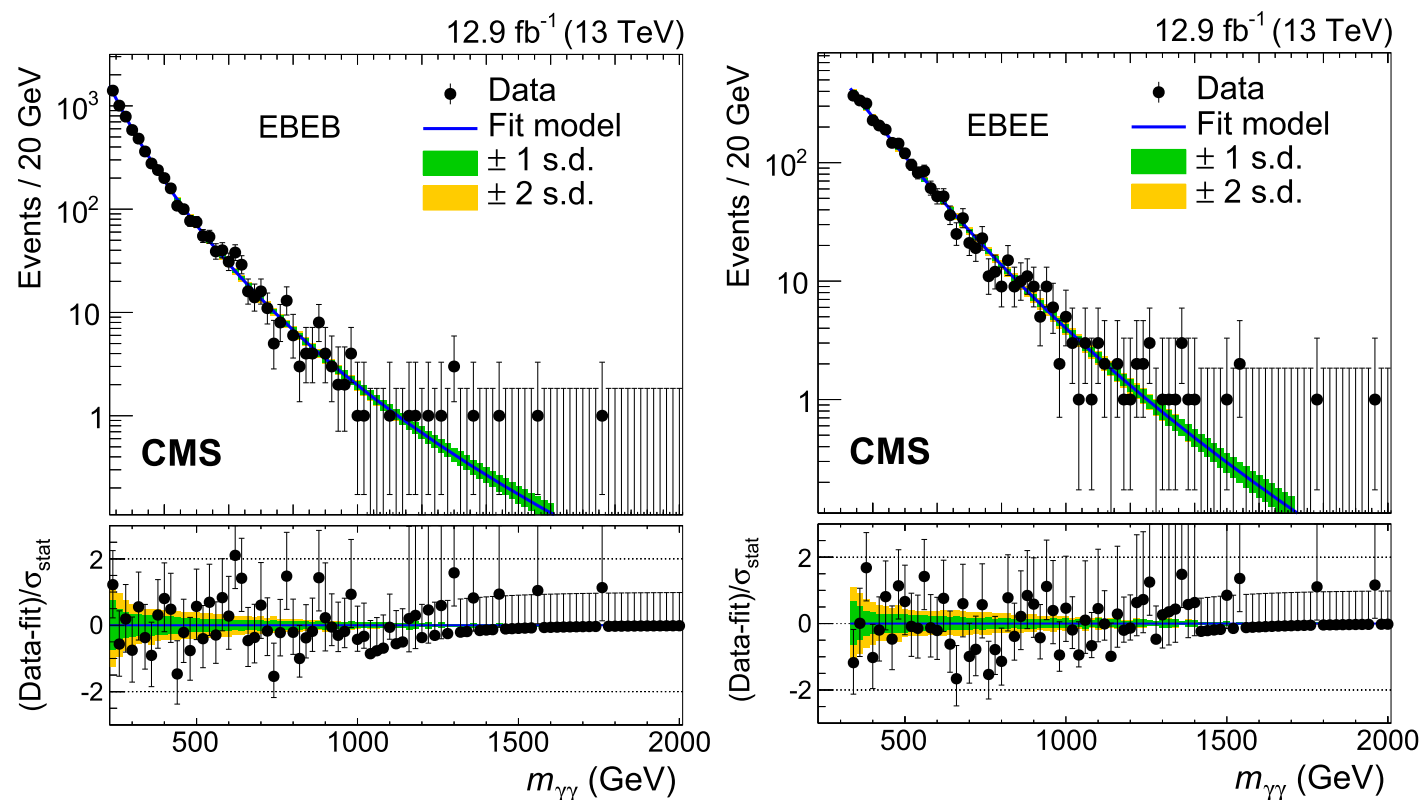
- ❖ Events **classified** based on photon rapidity
 - **EBEB**: both in barrel ($|\eta| < 1.4$), high resolution
 - **EBEE**: one in endcaps ($1.4 < |\eta| < 2.5$)

- ❖ Continuous background measured directly **in data**
 - **Fit** $m_{\gamma\gamma} > 330$ (230) GeV in EBEB (EBEE)



No Excess in Diphoton Spectra

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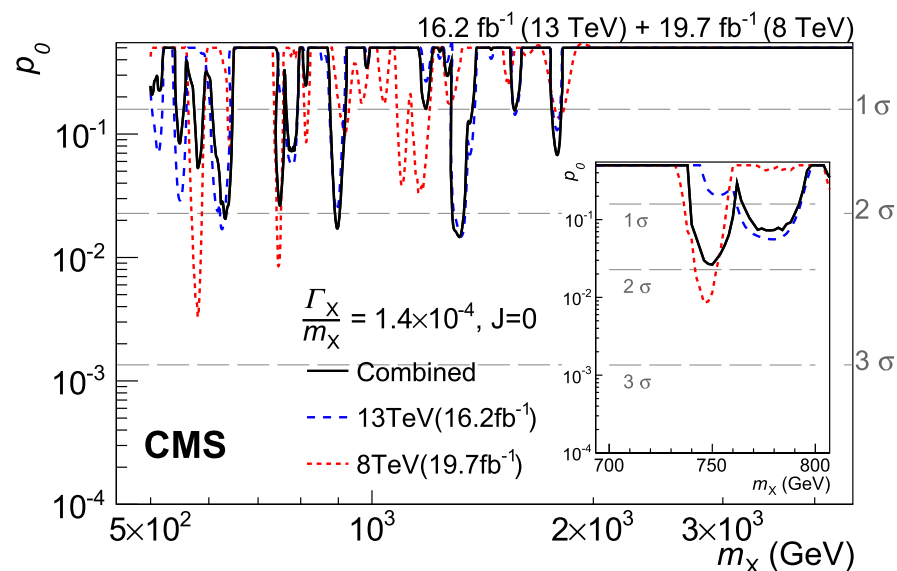


❖ Fit function: $f(x) = x^{a+b \log(x)}$

- **Uncertainty** due to function choice assessed with toys from BG MC

Limits on S=0 and S=2 Resonances

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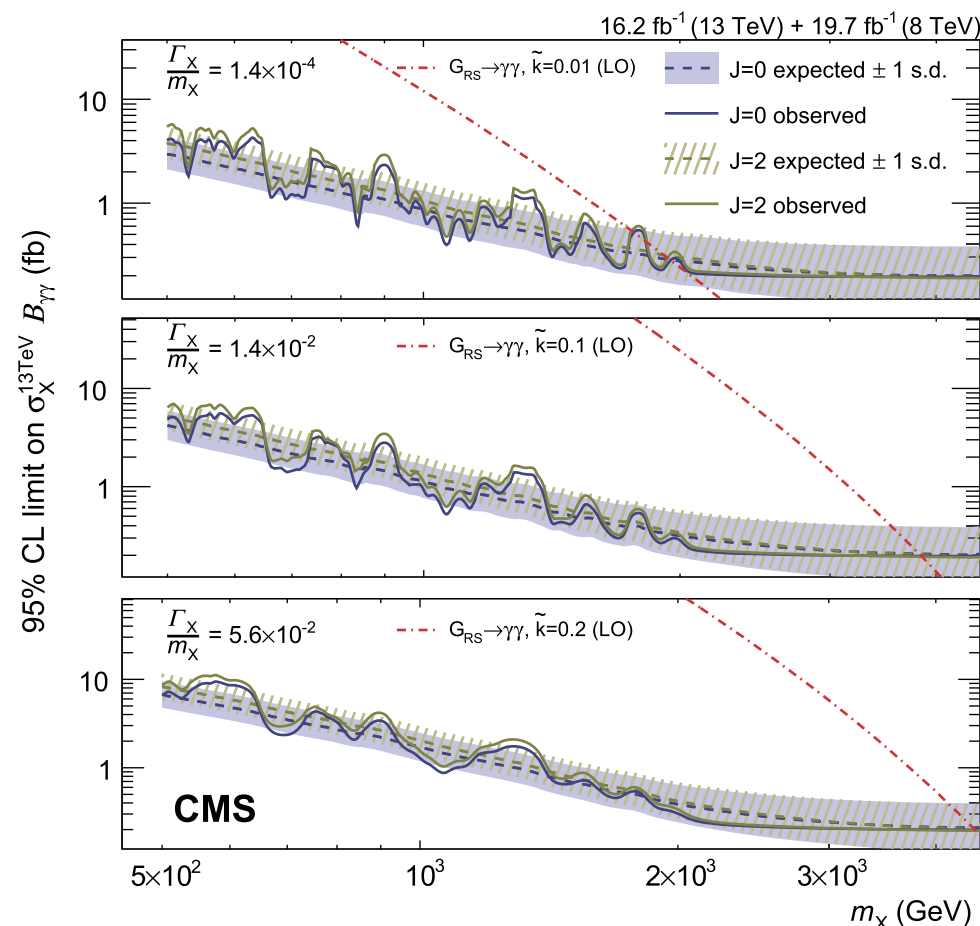


❖ **Combination** of 16.2 fb⁻¹ @ 13 TeV with 19.7 fb⁻¹ @ 8 TeV

- No **significant** excess

❖ **Limits** set on S=0 and S=2 production, for three widths

- $M(G_{RS}) > 1.95/3.85/4.45$ TeV for $\tilde{k} = 0.01/0.1/0.2$



**Similar results
from ATLAS**

Search for ($Z\gamma$) Resonances

CMS-PAS-EXO-17-005

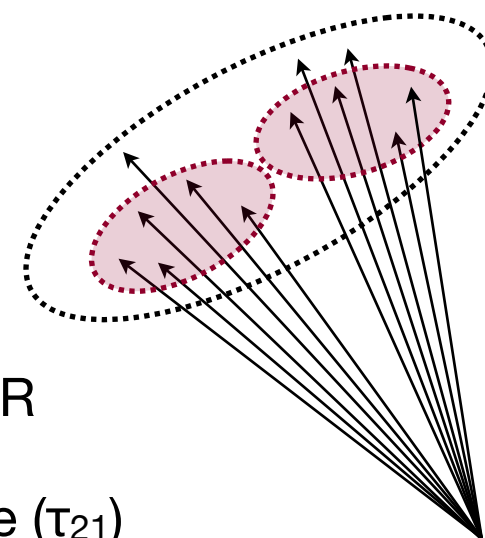
❖ Conceptually **similar** to diphoton search, sensitive also to $S=1$

❖ **Leptonic** channel

- High resolution, low backgrounds, low signal BR
- **Two** categories: $e e \gamma$ and $\mu \mu \gamma$

❖ **Hadronic** channel

- Lower resolution, higher backgrounds, higher signal BR
- **Boosted Z**: large-cone (0.8) jets, pruning, substructure (τ_{21})
- **Three** categories: b-tagged, and 2 bins in τ_{21}



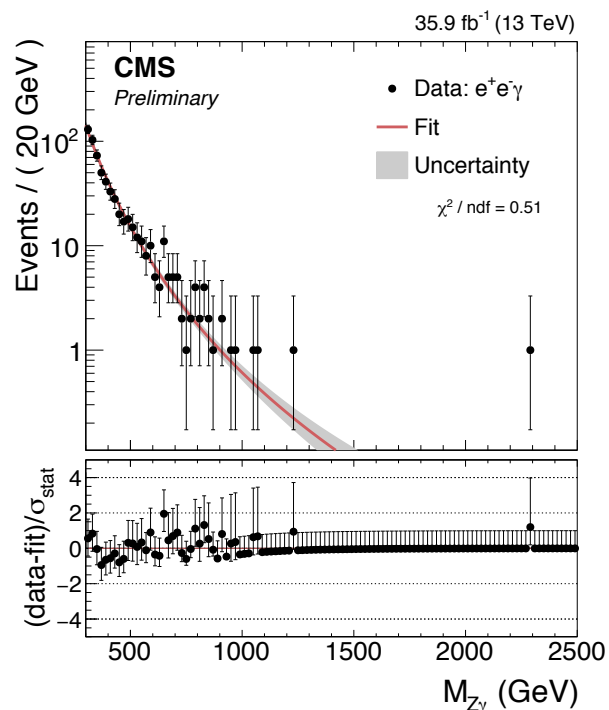
**b-tagging based
on pruned sub-jets**

Z γ Mass Spectra

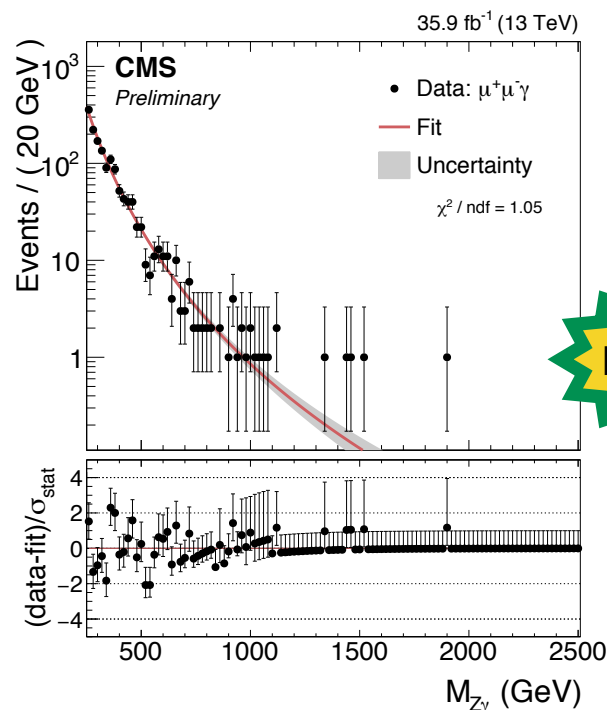
CMS-PAS-EXO-17-005



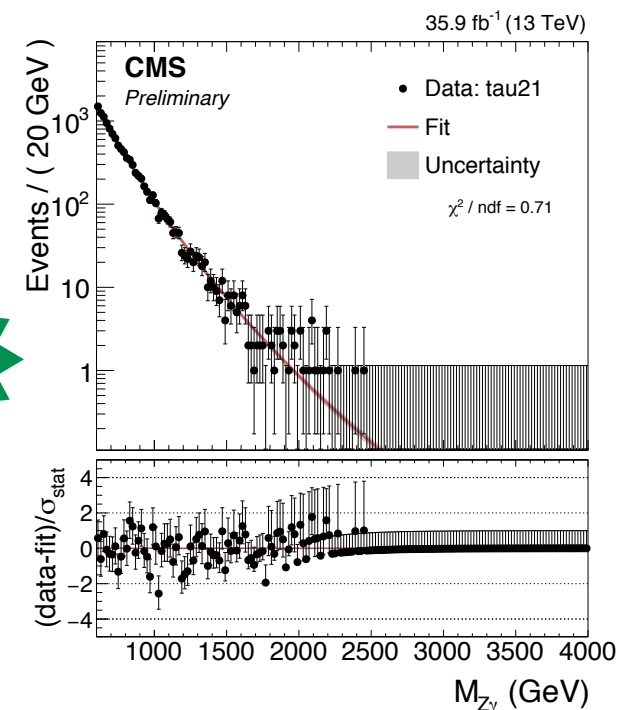
e $e\gamma$ Channel



$\mu\mu\gamma$ Channel



Hadronic τ_{21} Channel



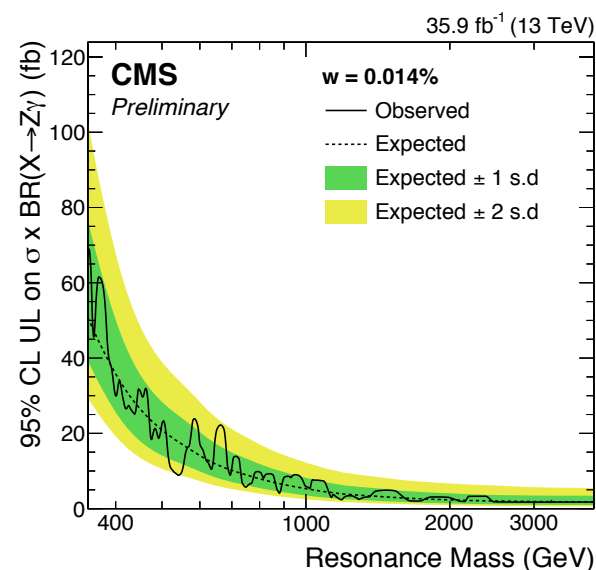
- ❖ **Leptonic** channels dominant at low mass, **hadronic** important at high mass
- ❖ Background shape parametrized with $f(x) = x^{a+b \log(x)}$



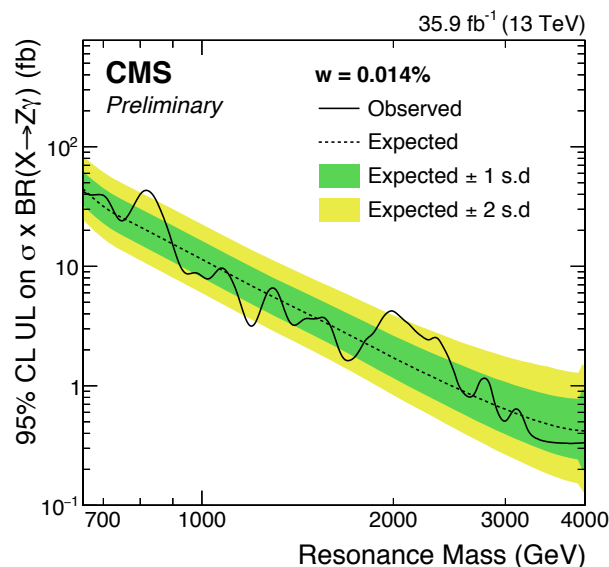
Limits on $Z\gamma$ Resonances

CMS-PAS-EXO-17-005

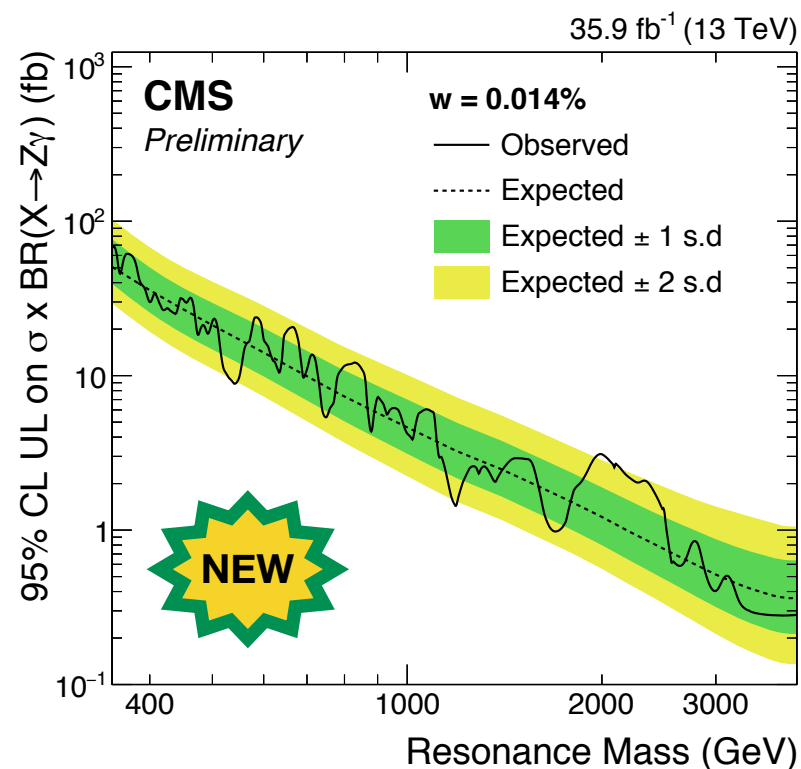
Leptonic Search ($ee+\mu\mu$)



Hadronic Search (3 cat)



Leptonic+Hadronic Combination



❖ Leptonic (hadronic) channel setting limits for $M(X) > 350$ (650) GeV (**narrow** resonance)

• Also limits on **wide** resonances (not shown here)

❖ No **significant** excess up to 4 TeV

ATLAS (3.2 fb⁻¹):
UL = 30 fb @ 900 GeV

Conclusions



- ❖ Resonances in leptons and photons: tools for **discoveries**
 - Discovered W,Z,H bosons
- ❖ ATLAS and CMS pursuing these searches at LHC Run II
 - **Up to 36 fb^{-1}** of data scrutinized
 - Extending reach to the **energy frontier**
- ❖ Presented **latest** searches in lepton+ M_{E_T} , dilepton, diphoton, and Z+photon
 - No **significant** excess yet
 - Significantly **extended** previous limits