

Searches for Nonresonant New Phenomena in Final States with Leptons and Photons at the CMS Experiment

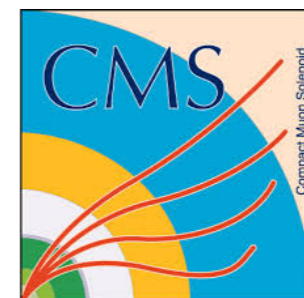
Kyungwook Nam

Seoul National University

on behalf of the CMS Collaboration

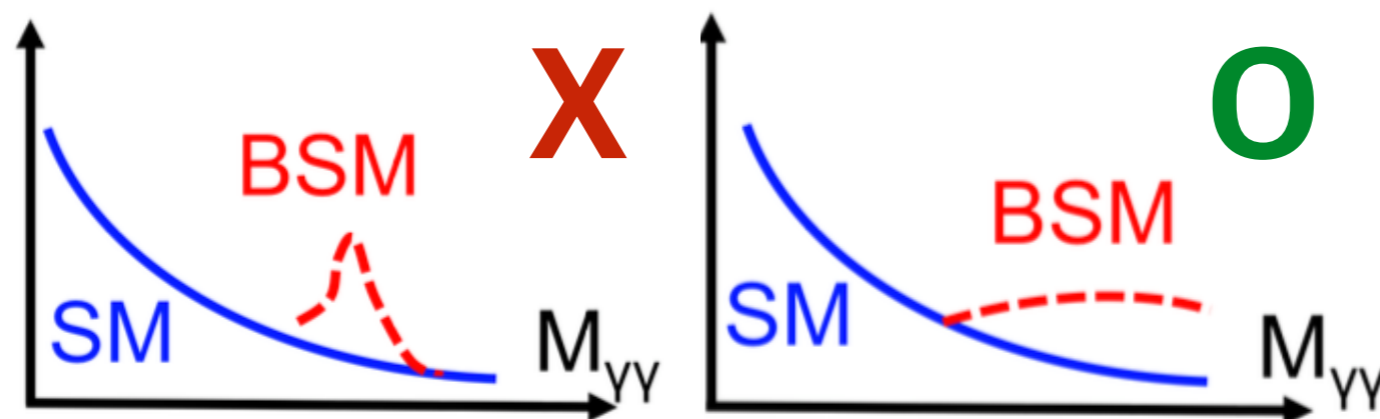
ICHEP 2018

Seoul, 6 July 2018

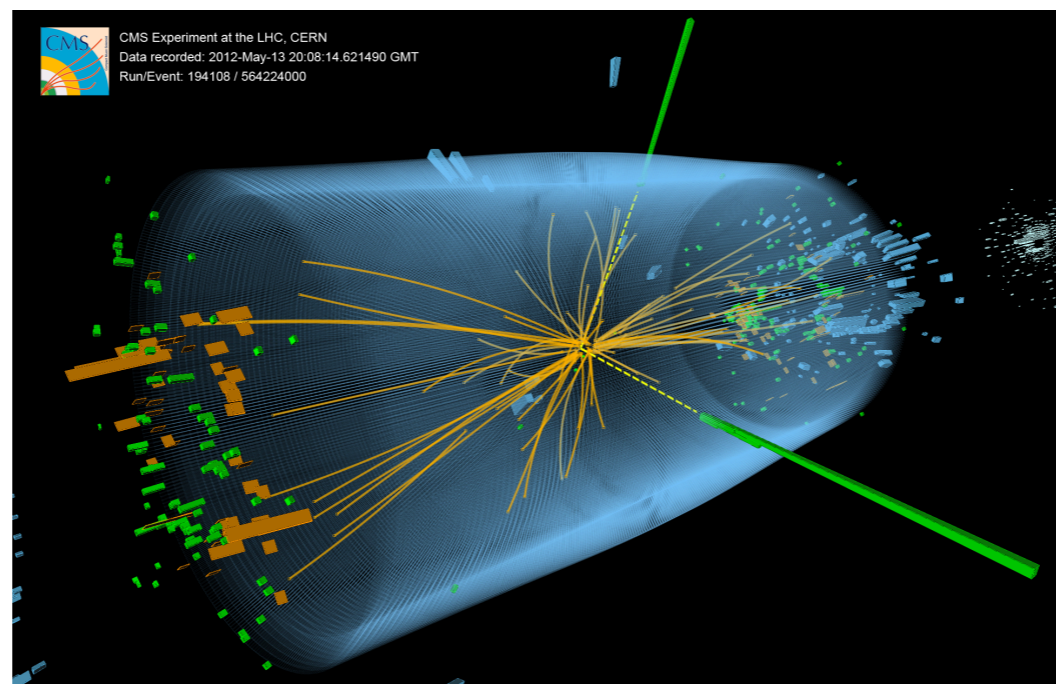


Nonresonant Phenomena in Lepton / Photon Final States

- **Nonresonant signal**
 - **Broad excess** in kinematic distributions



- **Lepton / photon final states**
 - **Clean signatures** in the detector



CMS 8 TeV
 $H \rightarrow \gamma\gamma$ candidate event

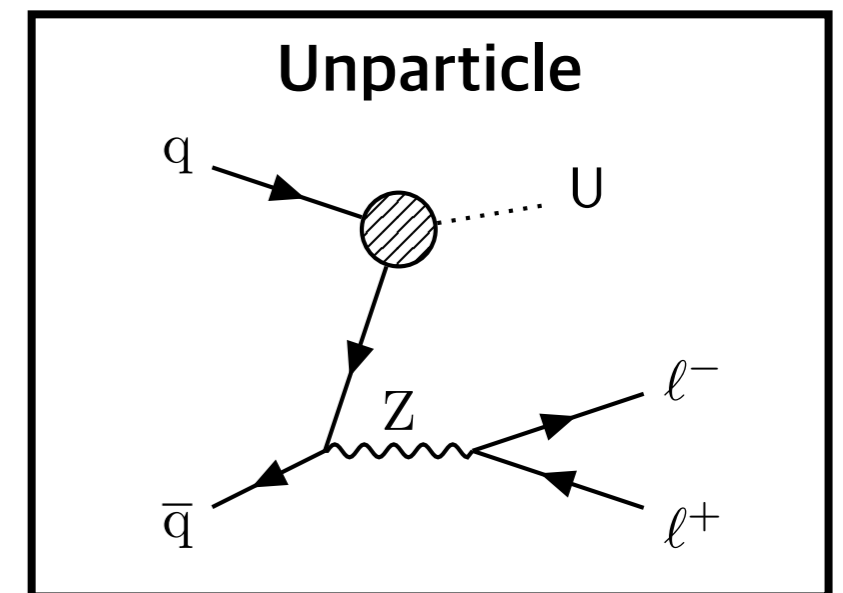
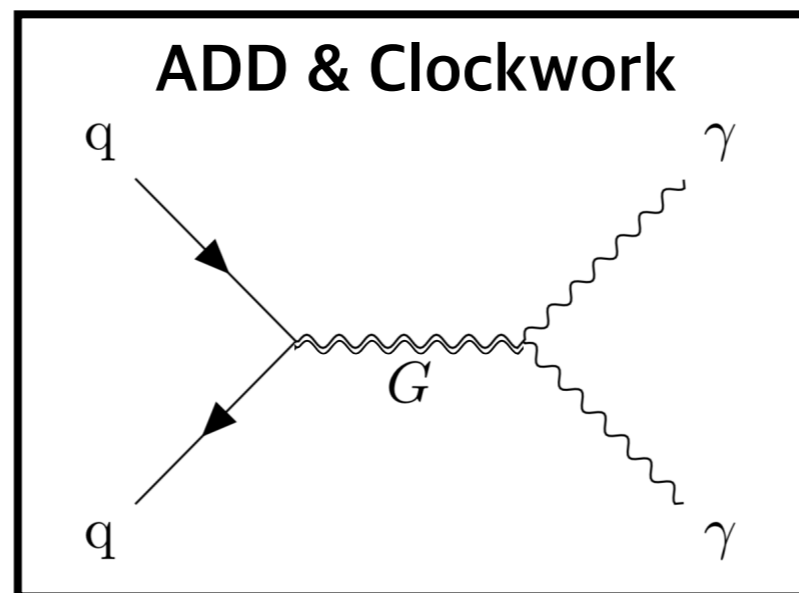
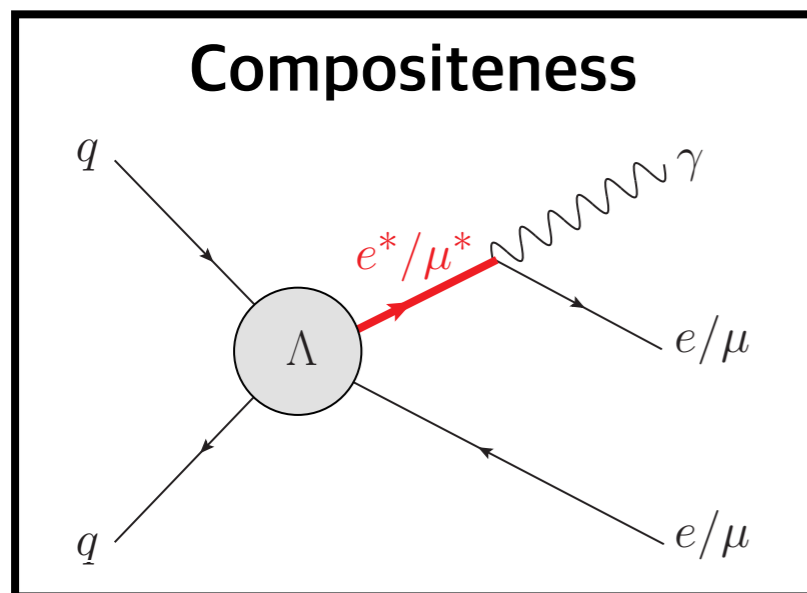
Searches at the CMS Experiment

- CMS searches for nonresonant BSM signatures in lepton / photon final states using 2016 data (35.9 fb⁻¹) are presented

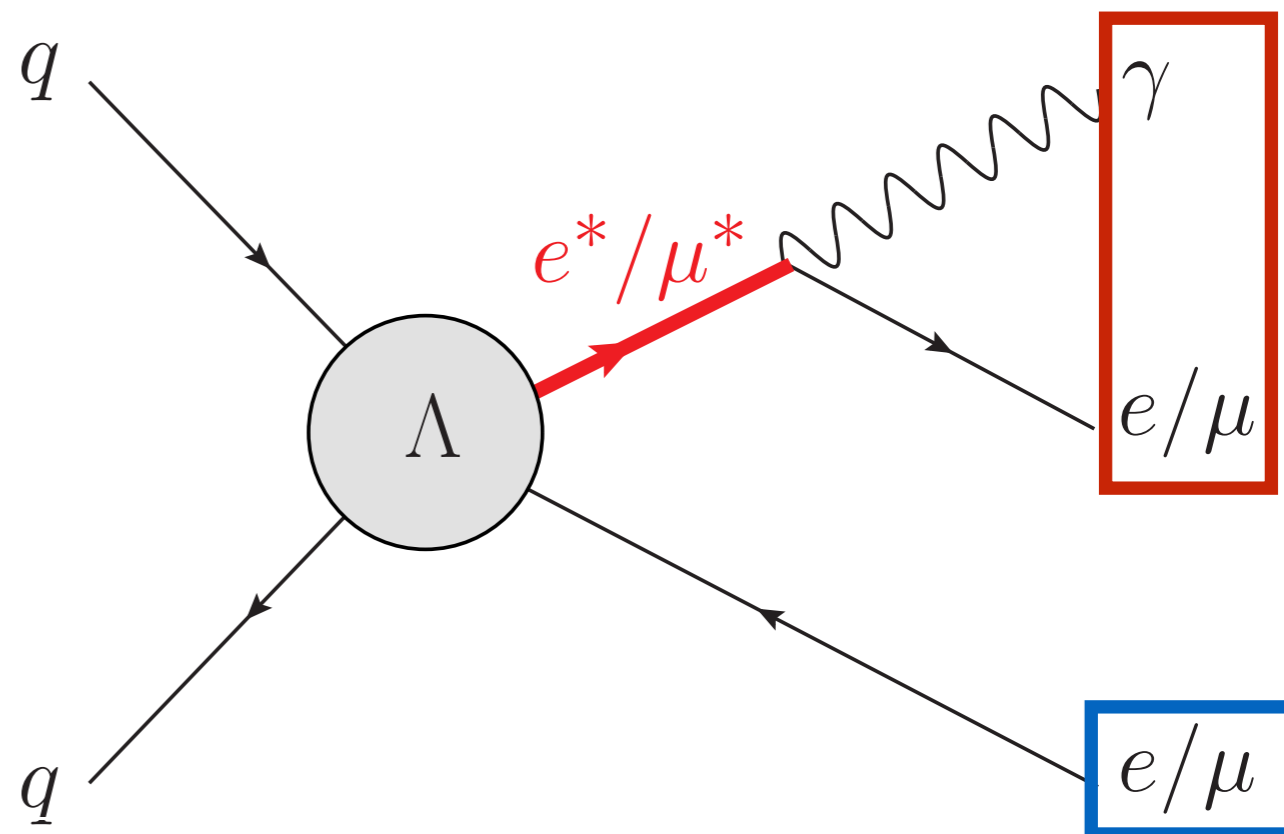
New!
New!

	Document	Motivation
Excited leptons in the $l\gamma$ final state	CMS-PAS-EXO-18-004	Compositeness
Monophoton	CMS-PAS-EXO-16-053	DM, ADD
MonoZ(l)	Eur. Phys. J. C 78 (2018) 291 CMS-EXO-16-052	DM, ADD, unparticle
Nonresonant diphoton	CMS-PAS-EXO-17-017	ADD, clockwork

DM: covered by Andreas Albert, "Searches for dark matter with CMS",



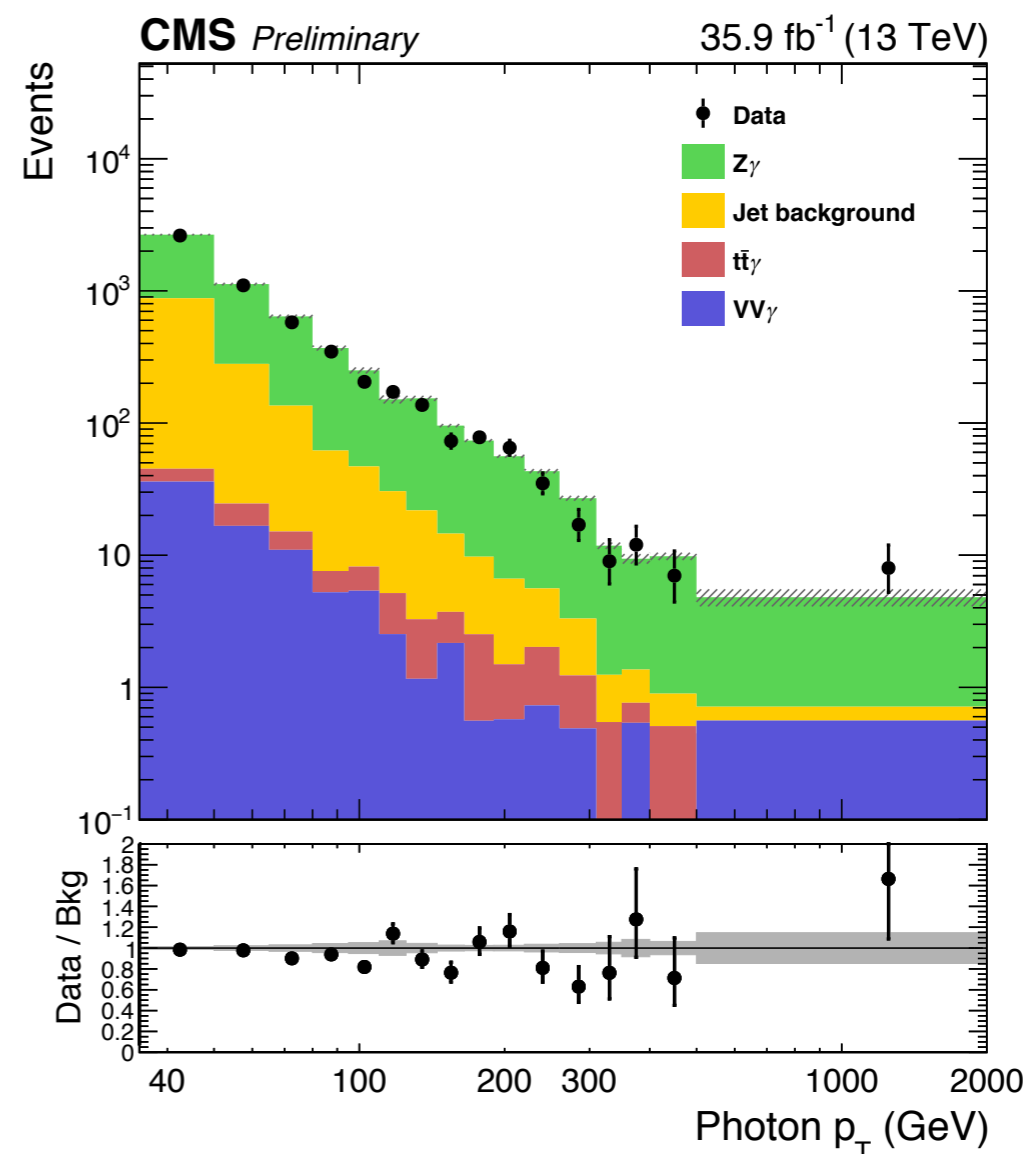
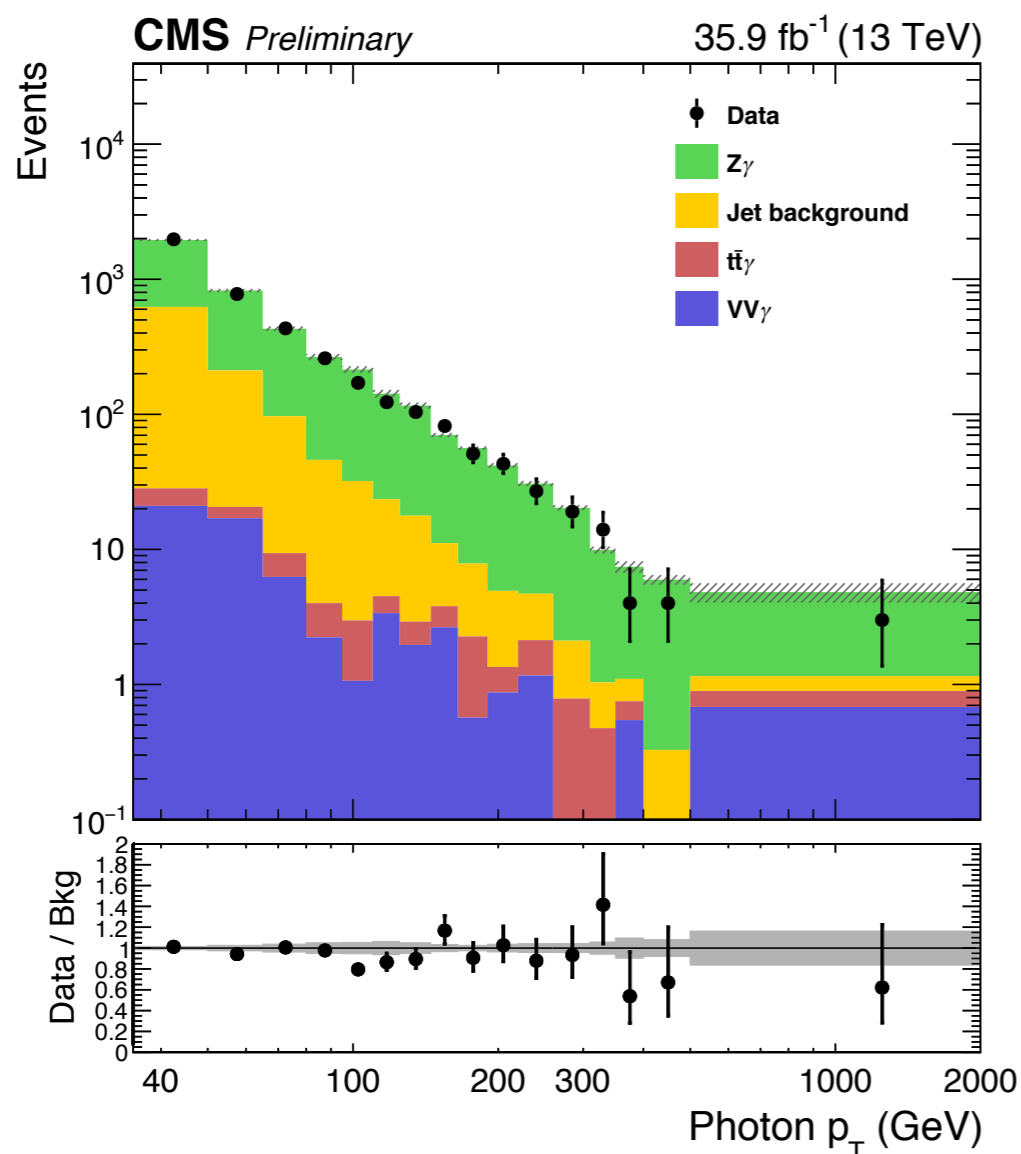
- Look for excited leptons in **the $l\gamma$ final state**
 - Production via a 4-fermion contact interaction associated with **one extra lepton**
 - Excited leptons eventually decay to **$l\gamma$**
- Key features of event selection
 - Two channels: $ee\gamma / \mu\mu\gamma$
 - Using double-electron / single-muon triggers
 - Two same flavor leptons with $p_T > 35$ GeV
 - Photon with $p_T > 35$ GeV
 - $\Delta R(l, \gamma) > 0.7$
 - Z-veto criteria: $M_{ll} > 116$ GeV

New!

Excited Leptons in the $l\gamma$ Final State

CMS-PAS-EXO-18-004

New!

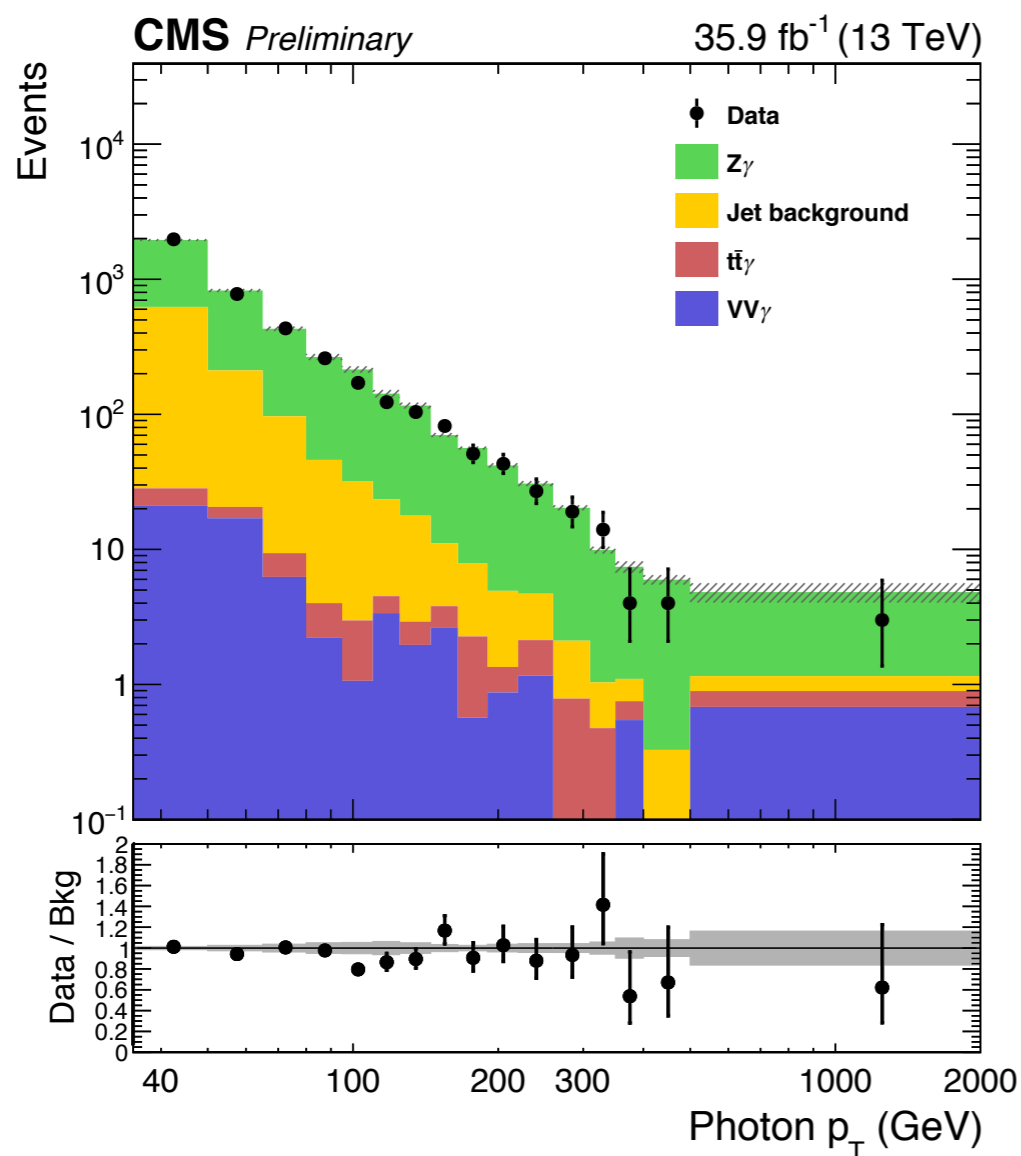


- Major backgrounds from **Z boson production + γ or jets**
 - **Z-veto criteria** is essential for background suppression
 - Background control region: Z-peak

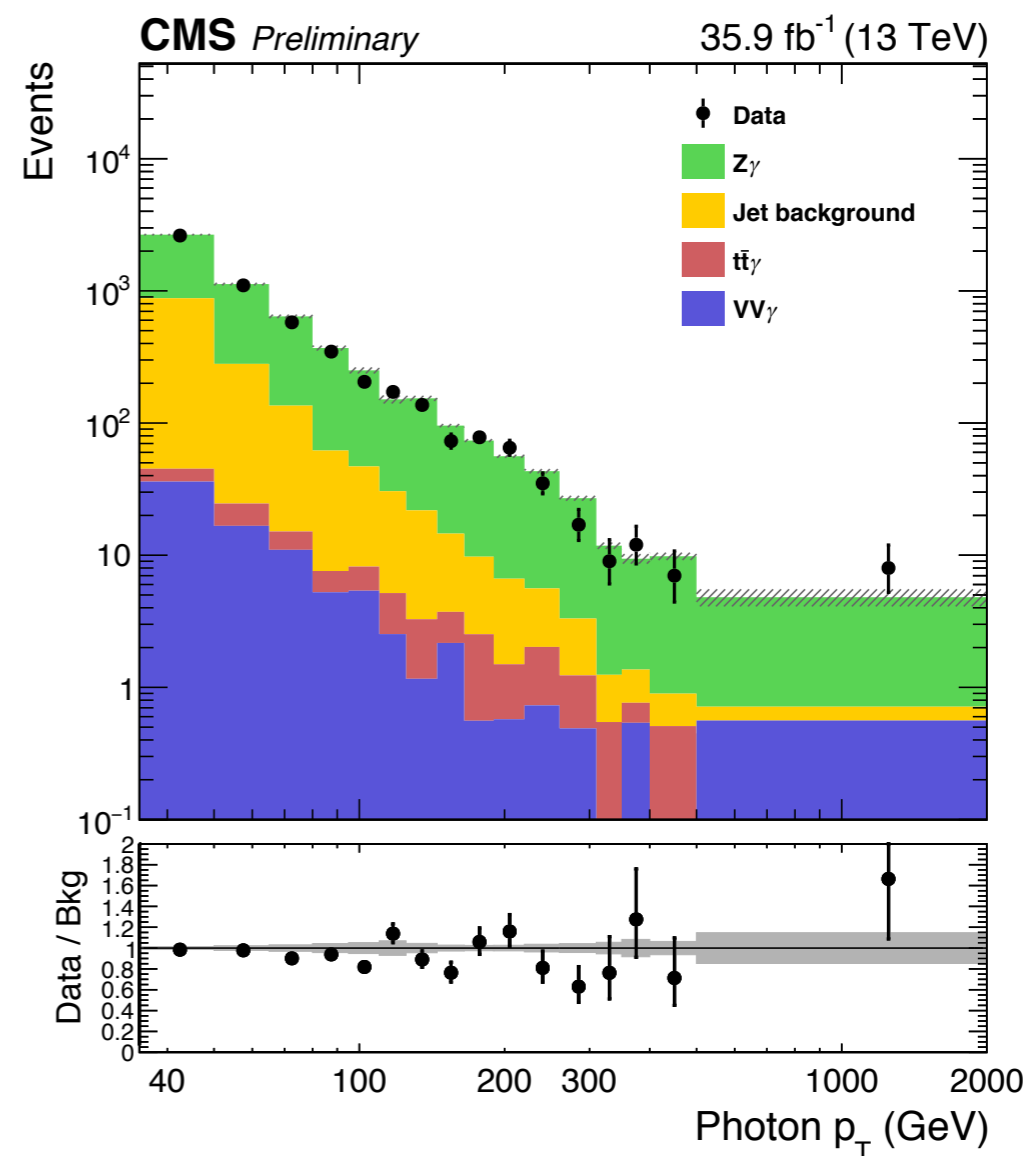
Excited Leptons in the $l\gamma$ Final State

CMS-PAS-EXO-18-004

New!



CR: $Z(ee)\gamma$

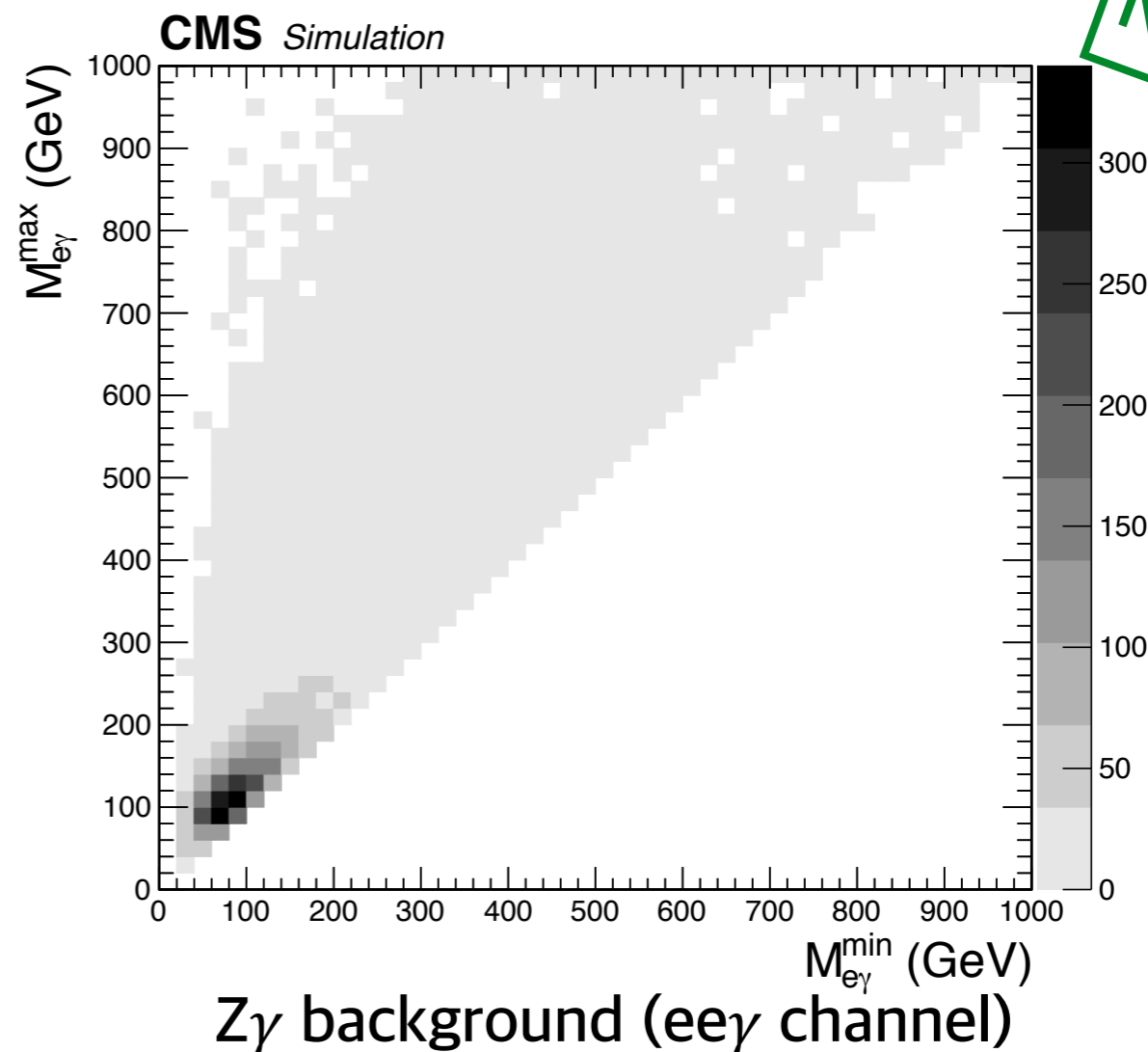
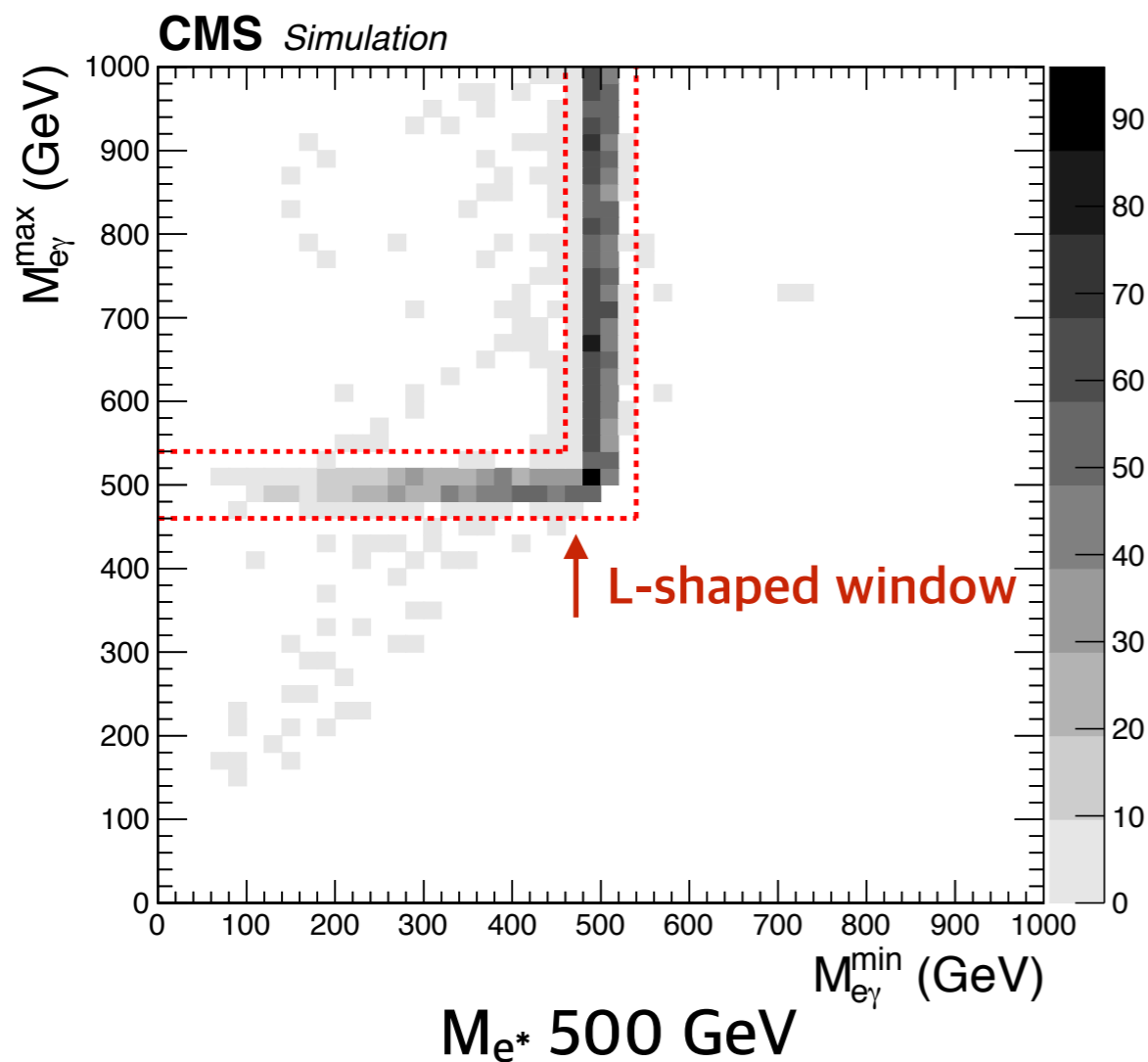


CR: $Z(\mu\mu)\gamma$

- Bkg estimation strategies depending on **the source of the photon**
 - **Prompt photon**: MC
 - **Photon misidentified by a jet**: data-driven

Excited Leptons in the $l\gamma$ Final State

CMS-PAS-EXO-18-004



- **2D M_{\min} - M_{\max} distribution: a key to signal discrimination**
 - Masses of two $l\gamma$ pairings: M_{\min} (smaller), M_{\max} (larger)
 - Signal (L-shape) vs background (scattered): clearly distinguished
 - **L-shaped search window** is set in 2D M_{\min} - M_{\max} distribution

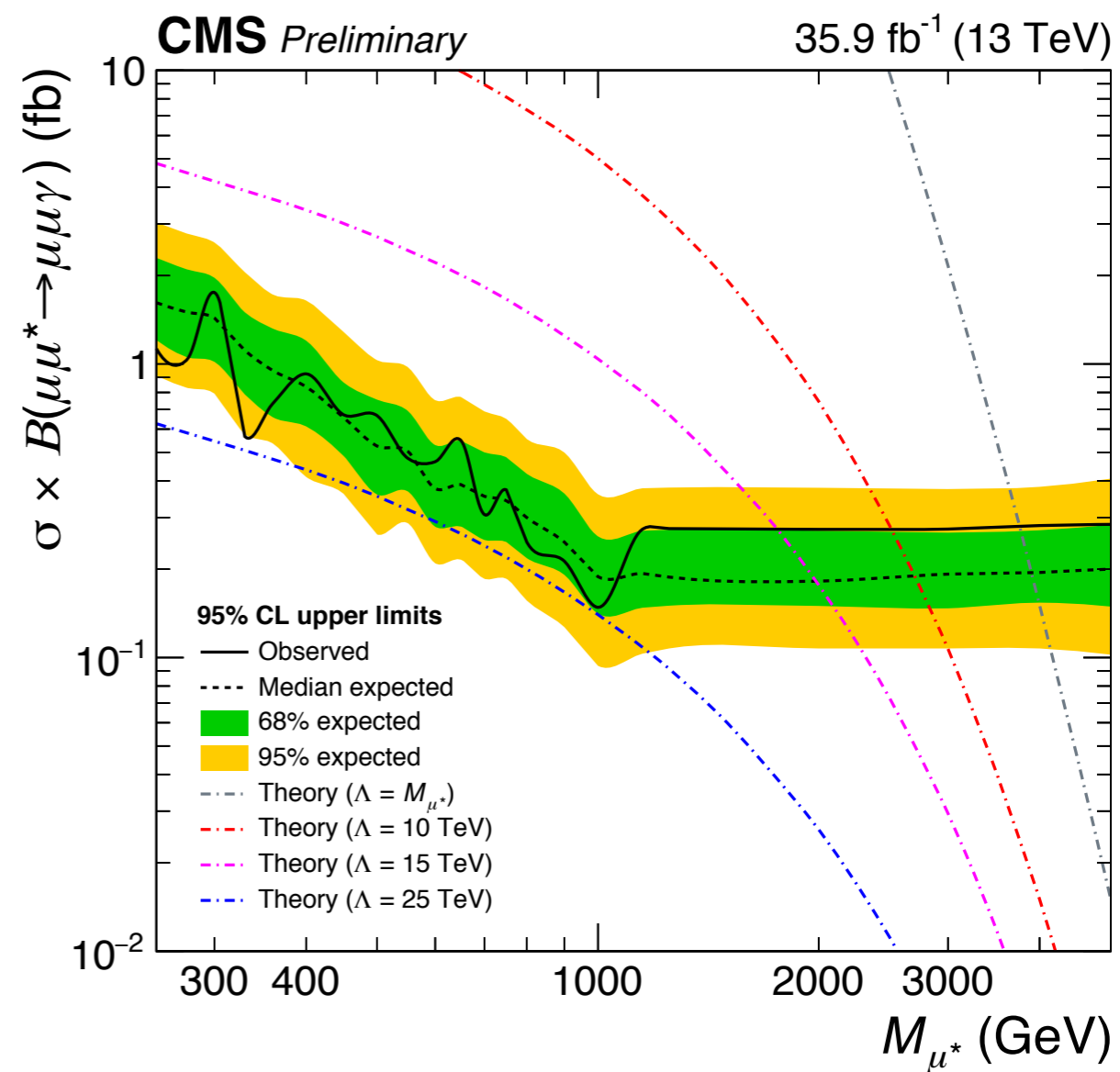
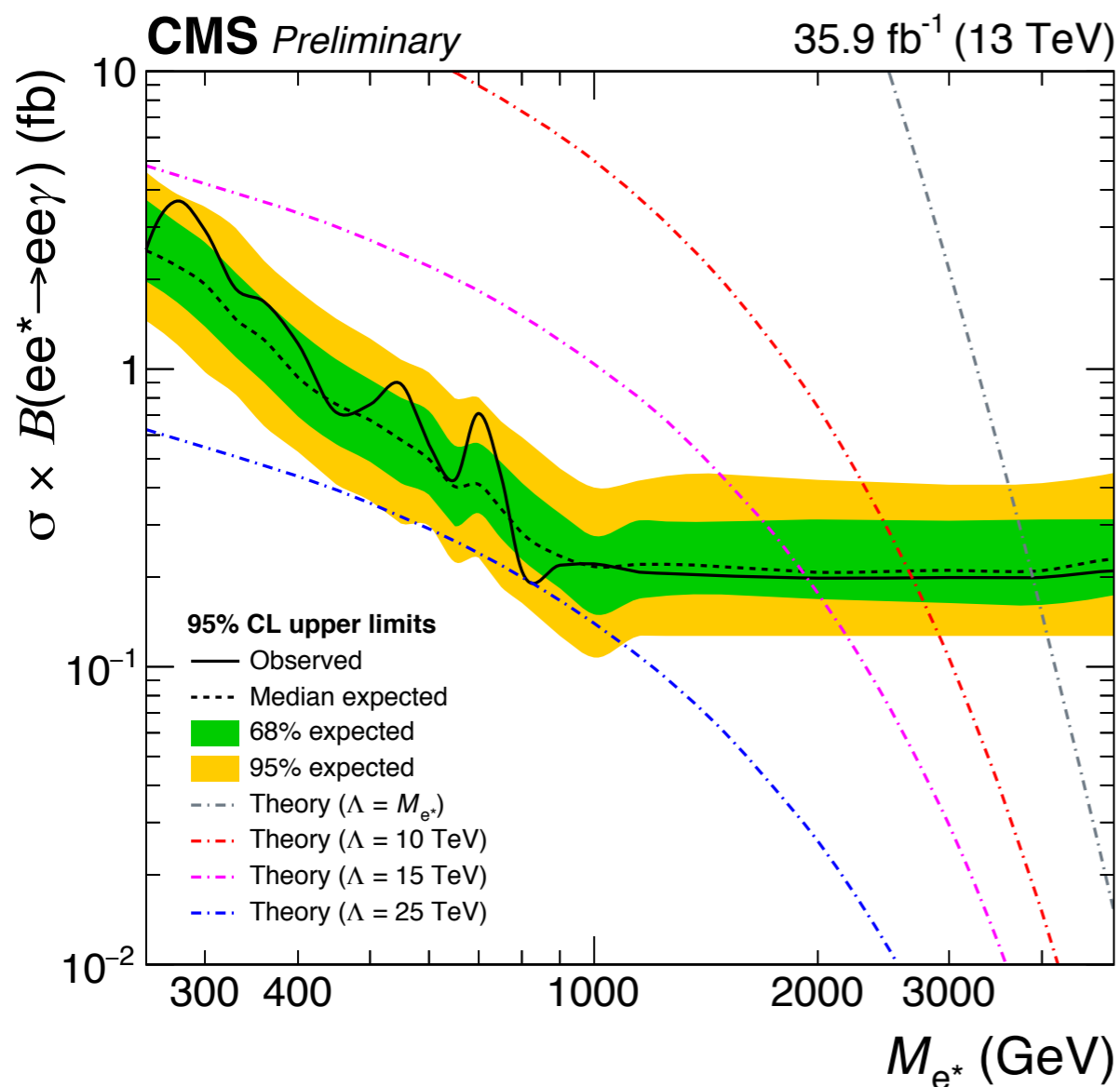
Excited Leptons in the $l\gamma$ Final State

CMS-PAS-EXO-18-004

- M_{e^*} (M_{μ^*}) < 3.9 (3.8) TeV excluded for the case $\Lambda = M_{l^*}$
 - CMS 8 TeV \times : 2.5 (2.5) TeV
- **Most stringent limits to date**

New!

\times JHEP 03 (2016) 125, CMS-EXO-14-015



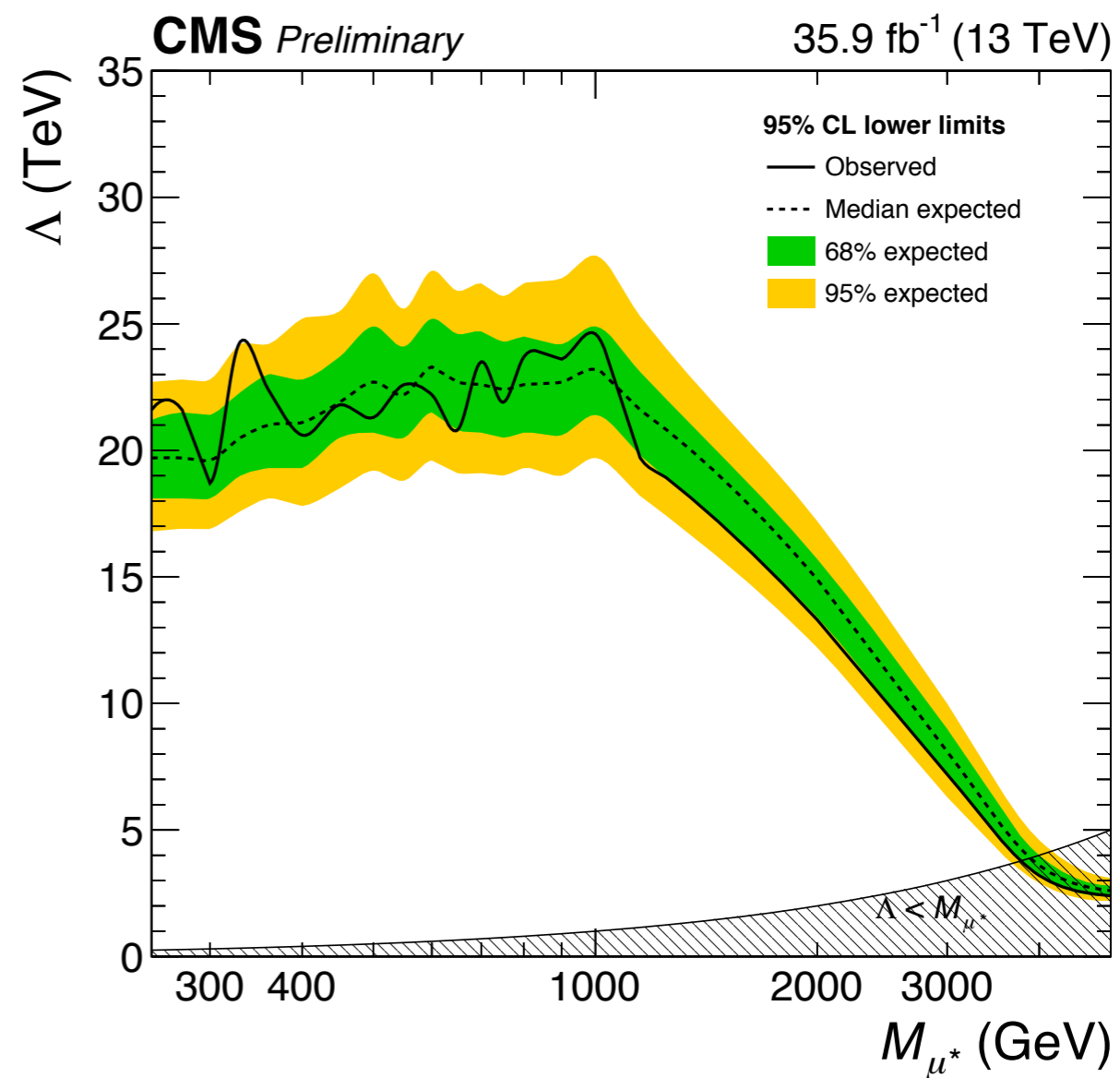
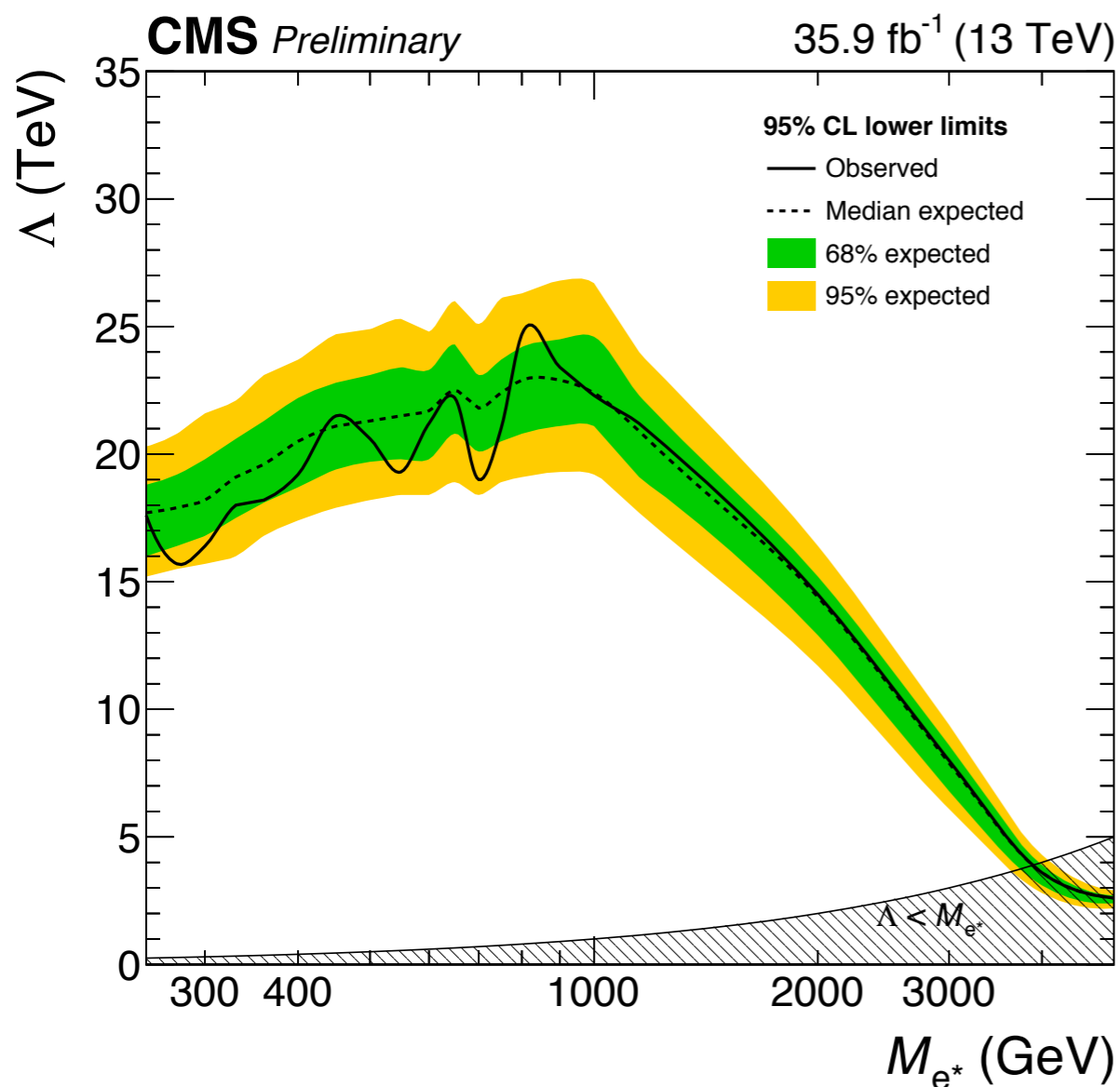
Excited Leptons in the $l\gamma$ Final State

CMS-PAS-EXO-18-004

- Exclusion limits on the compositeness scale Λ up to **25 TeV**
 - CMS 8 TeV ✖: 16 TeV
- **Most stringent limits to date**

New!

✖ JHEP 03 (2016) 125, CMS-EXO-14-015

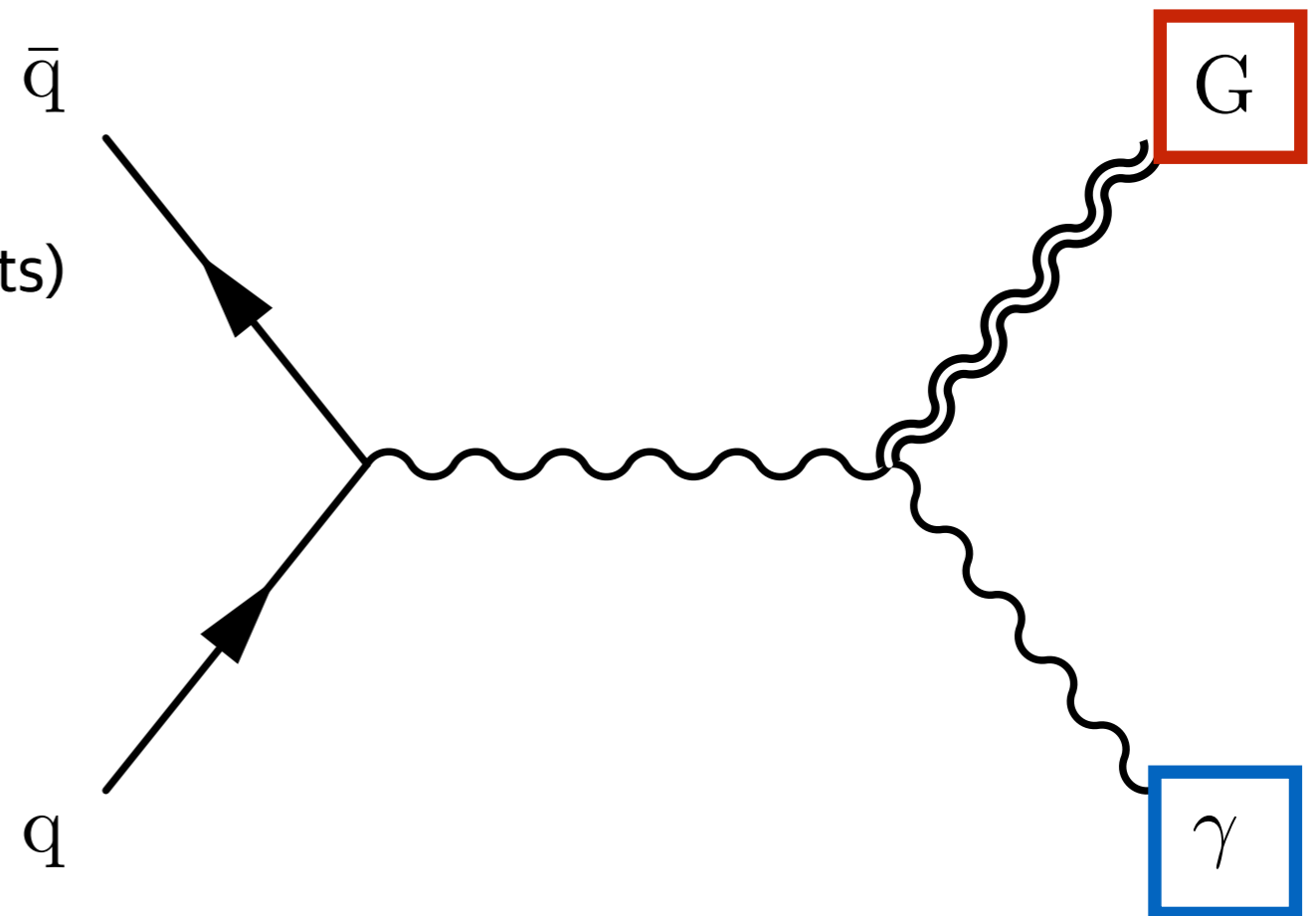


- **A sign of ADD graviton in the monophoton final state**

- Graviton produced via $qq \rightarrow \gamma G$
- Graviton escapes the detector \rightarrow **large missing p_T**
- Back-to-back **high- p_T photon**

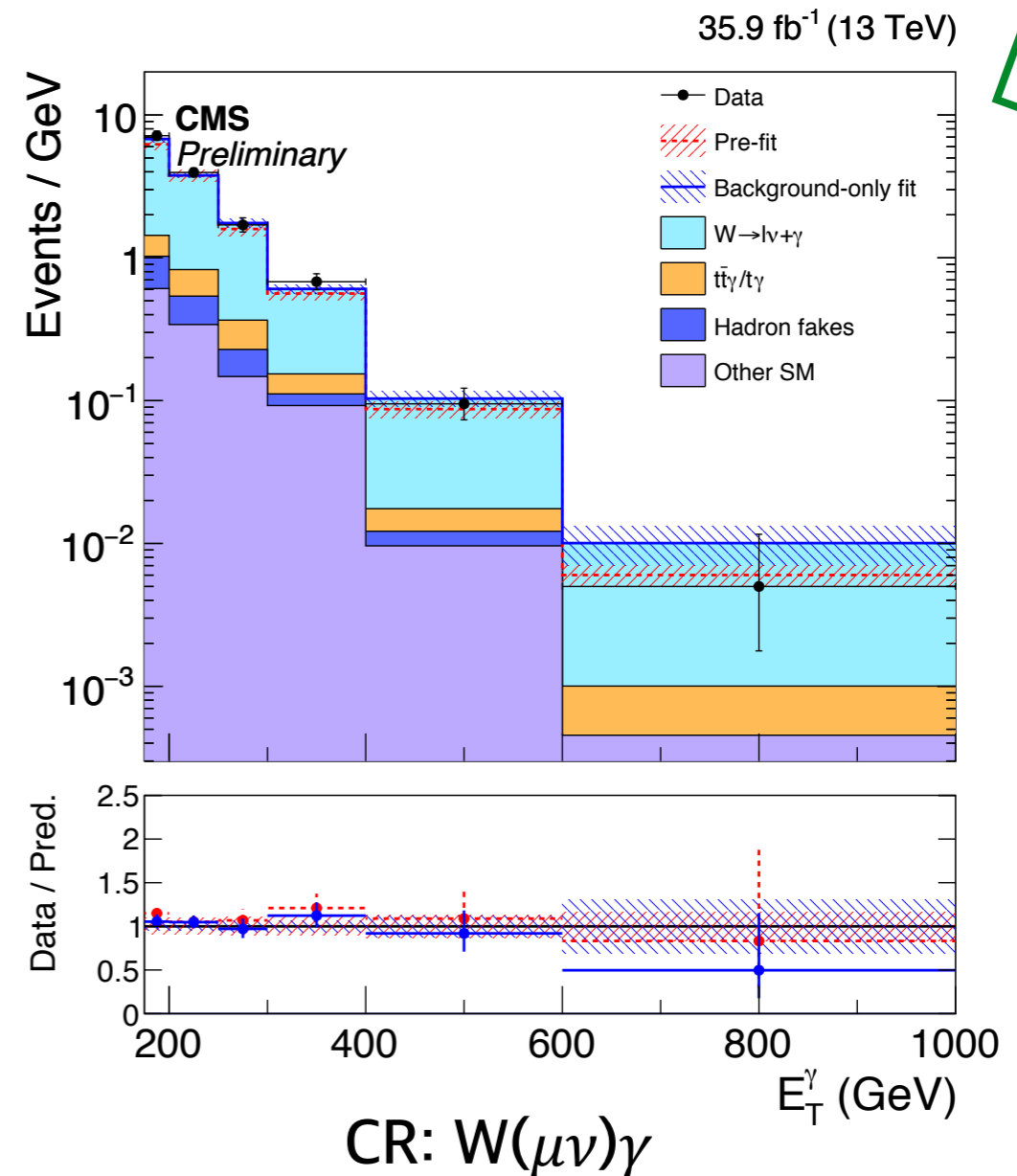
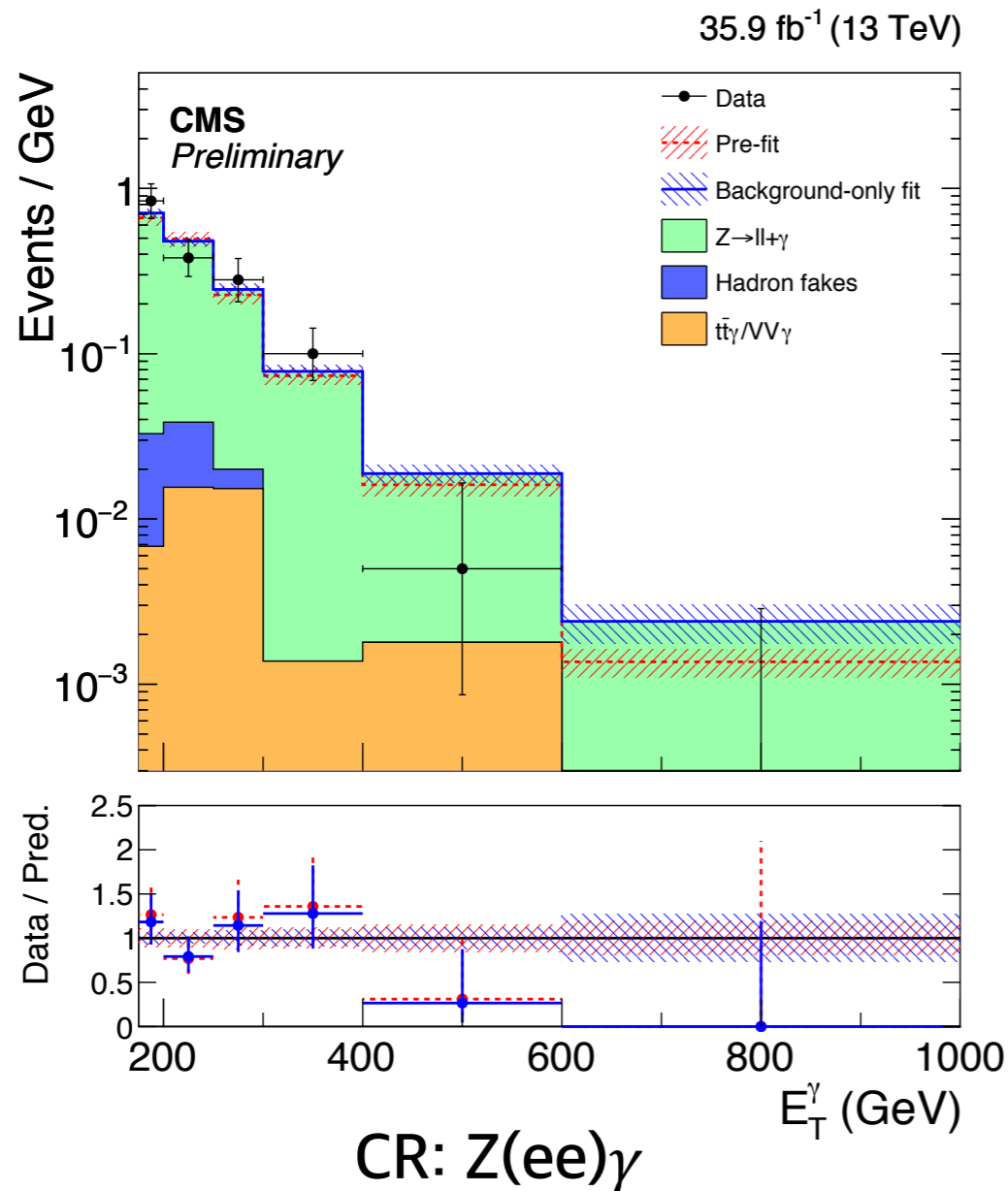
- **Key features of event selection**

- Using a single photon trigger
- Photon with $p_T > 175$ GeV
- Missing $p_T > 170$ GeV
- $\Delta\phi(\gamma, \text{missing } p_T) > 0.5$
- $\Delta\phi(\text{jet}, \text{missing } p_T) > 0.5$ (4 leading jets)
- Lepton veto



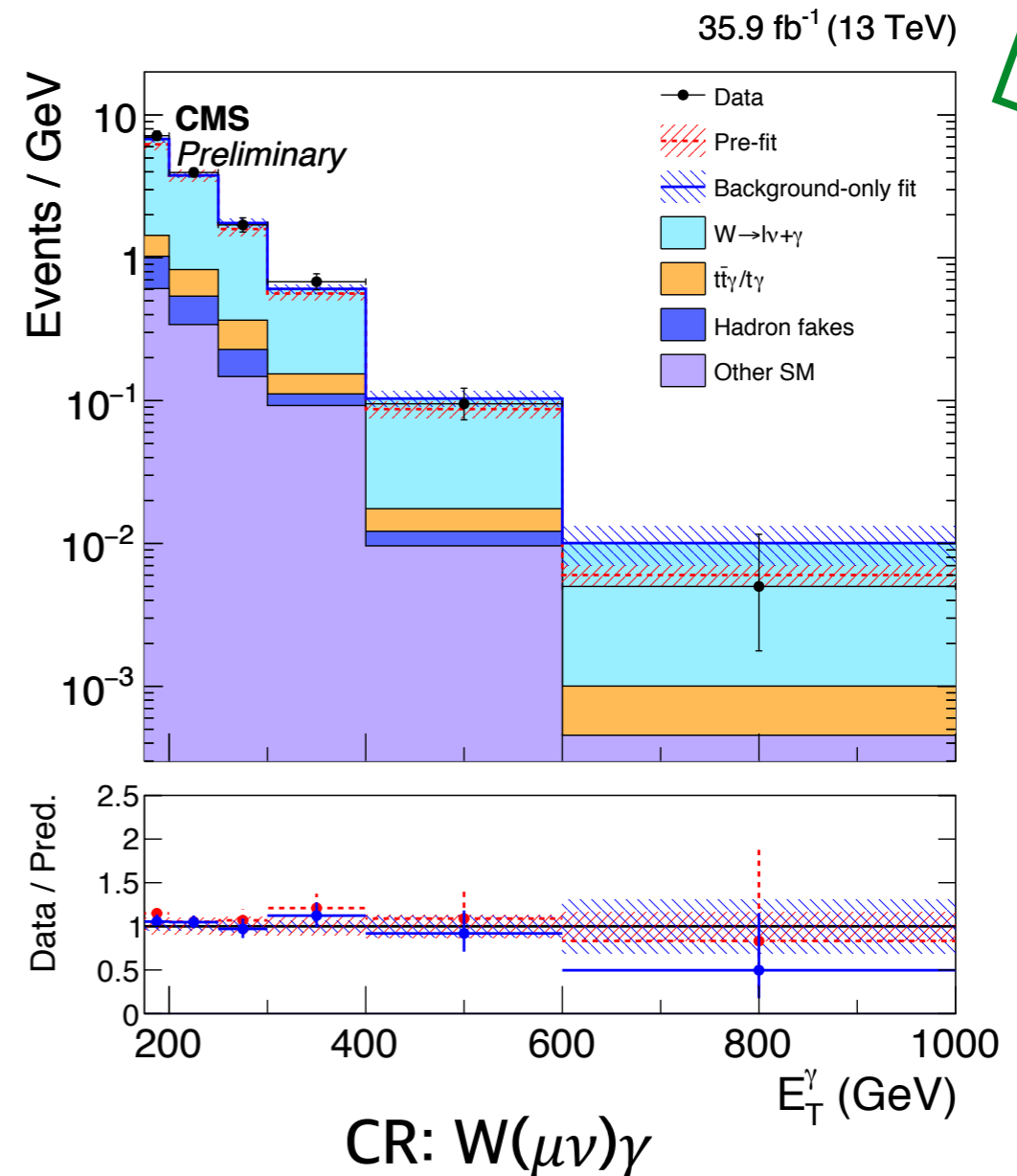
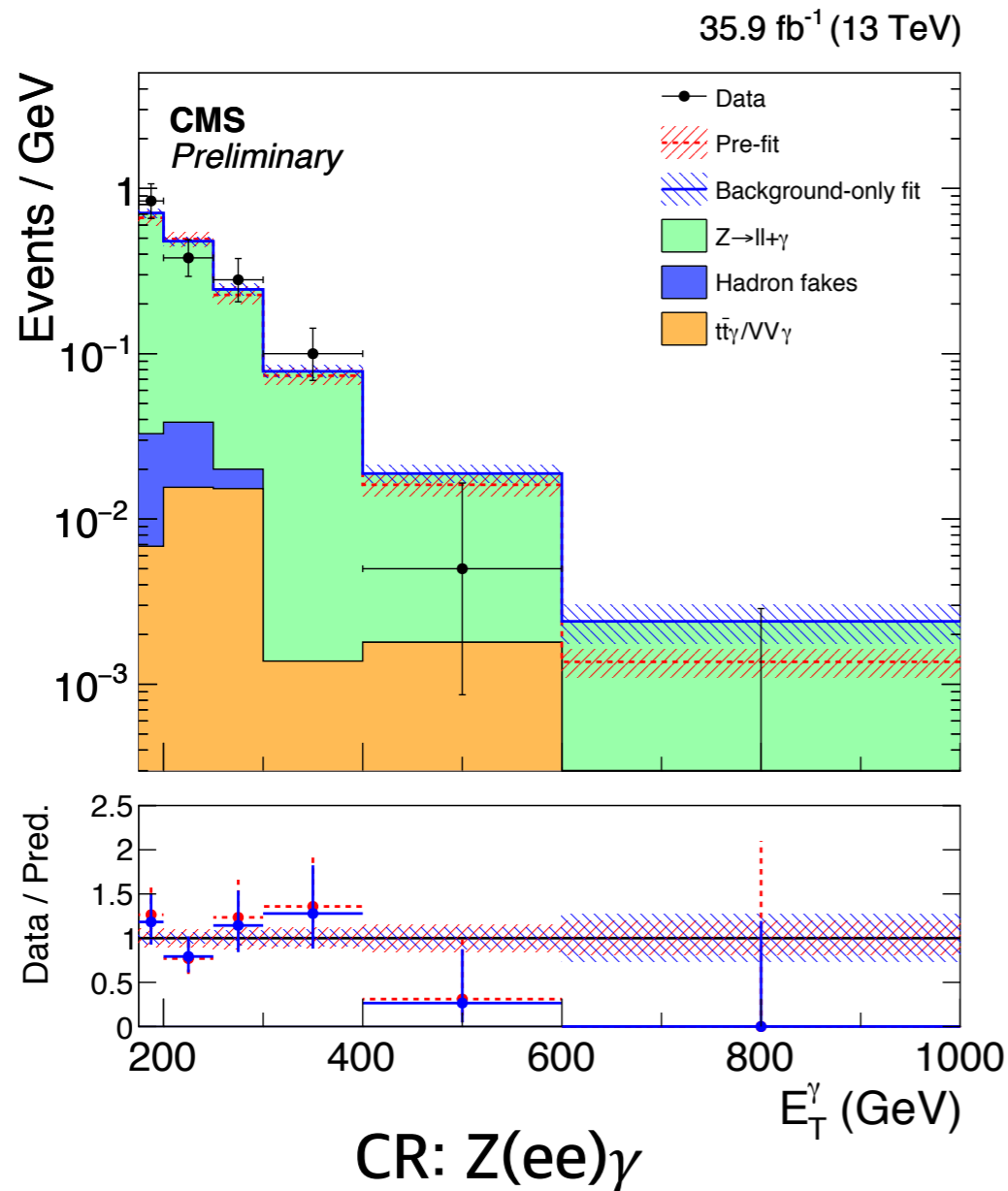
New!

New!



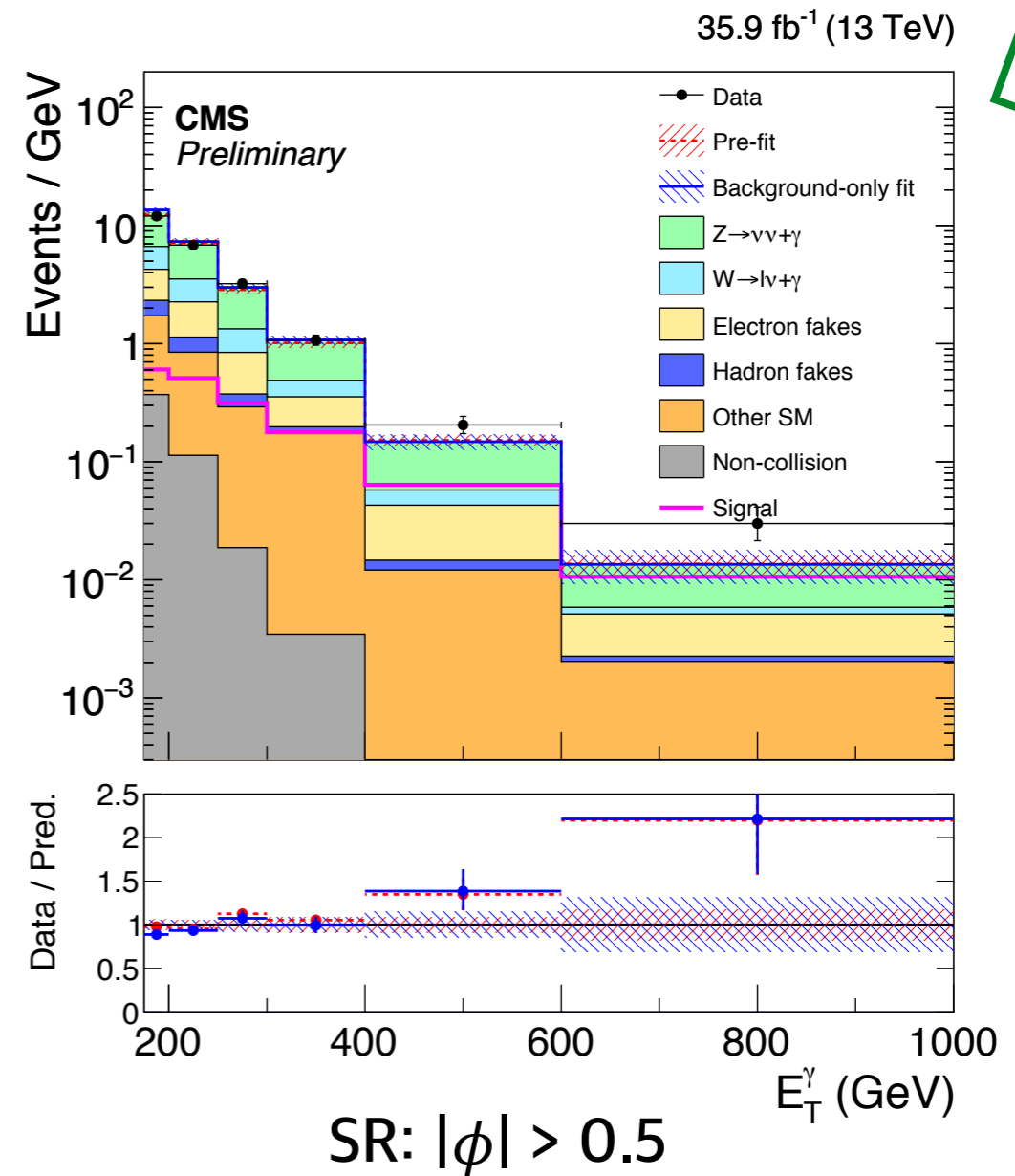
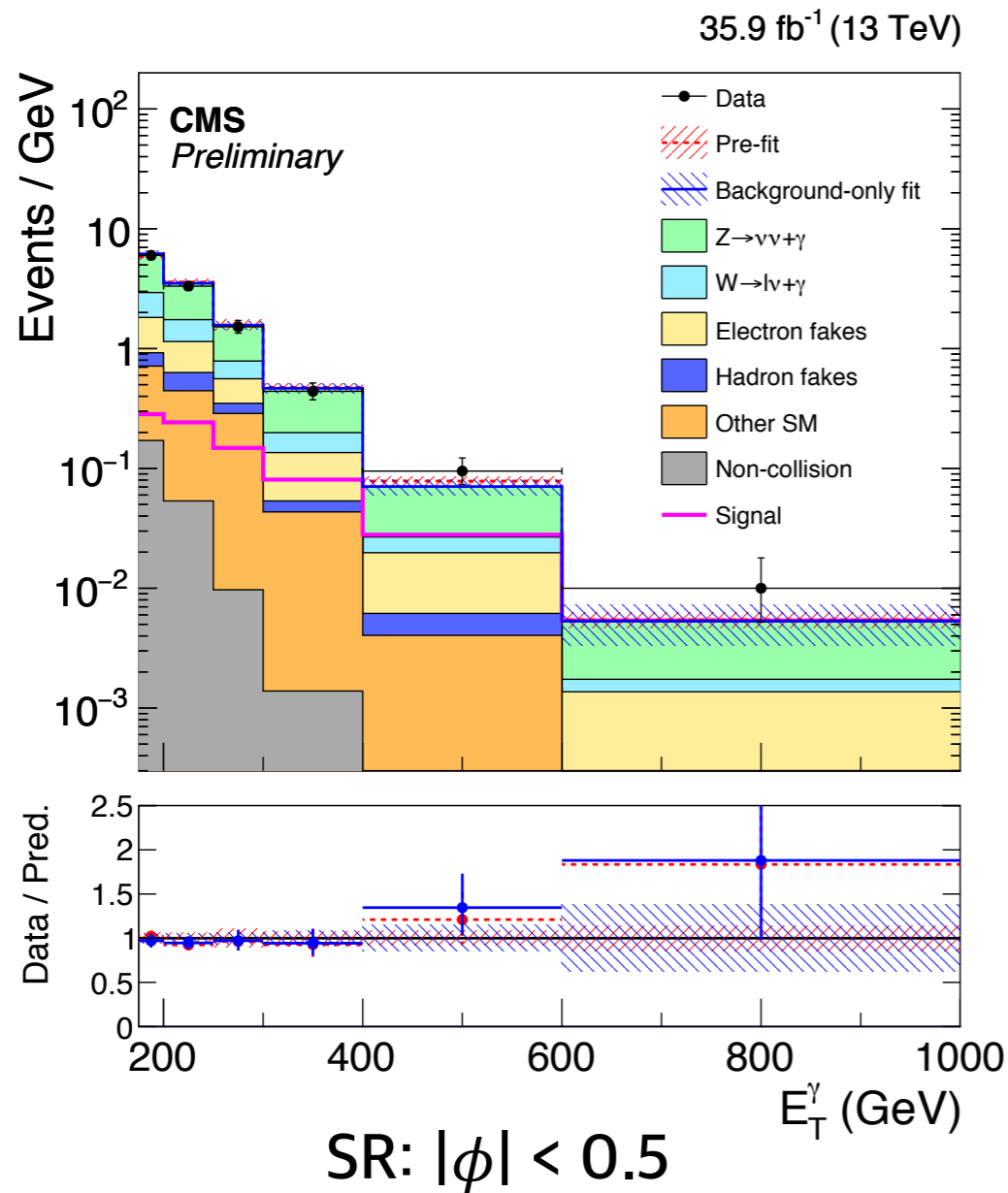
- Dominant $Z(\nu\nu)\gamma$ and $W(l\nu)\gamma$ backgrounds estimated using both data and MC
 - Kinematic distribution shapes: MC
 - Normalization: simultaneous fit to SR and CRs in data

New!



- **Data-driven technique** used to estimate other backgrounds
 - Electron / jet misidentified as a photon
 - Noncollision sources: ECAL spikes, beam halo muons

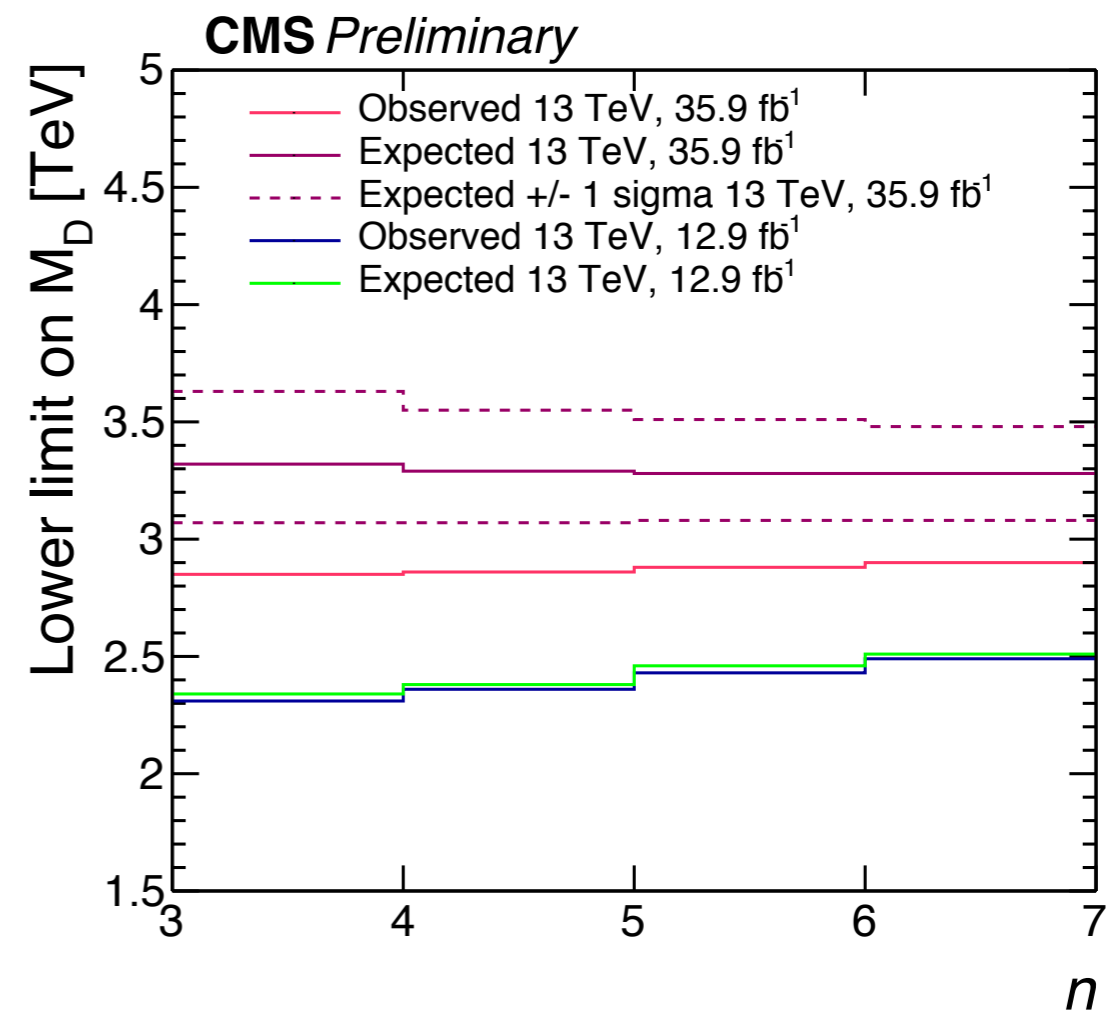
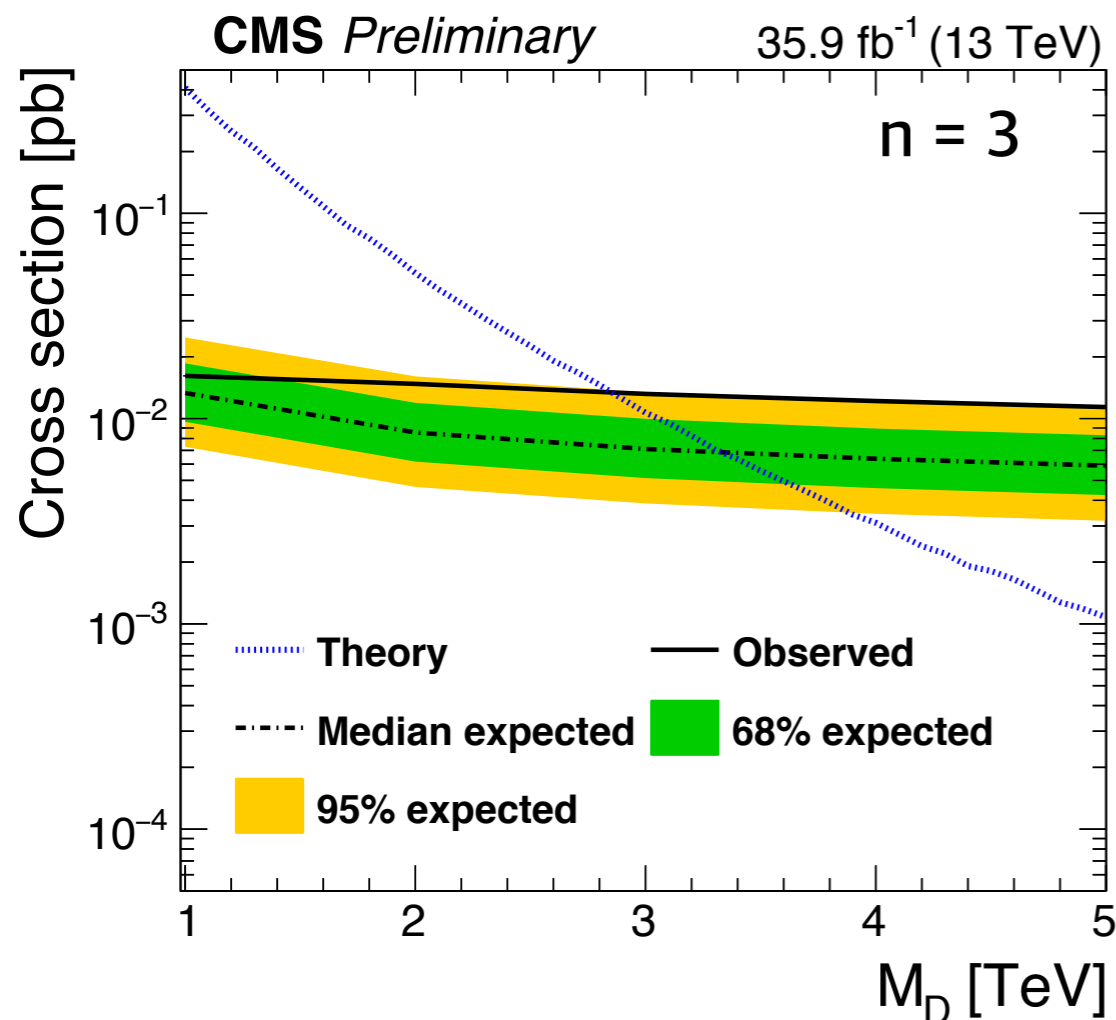
New!



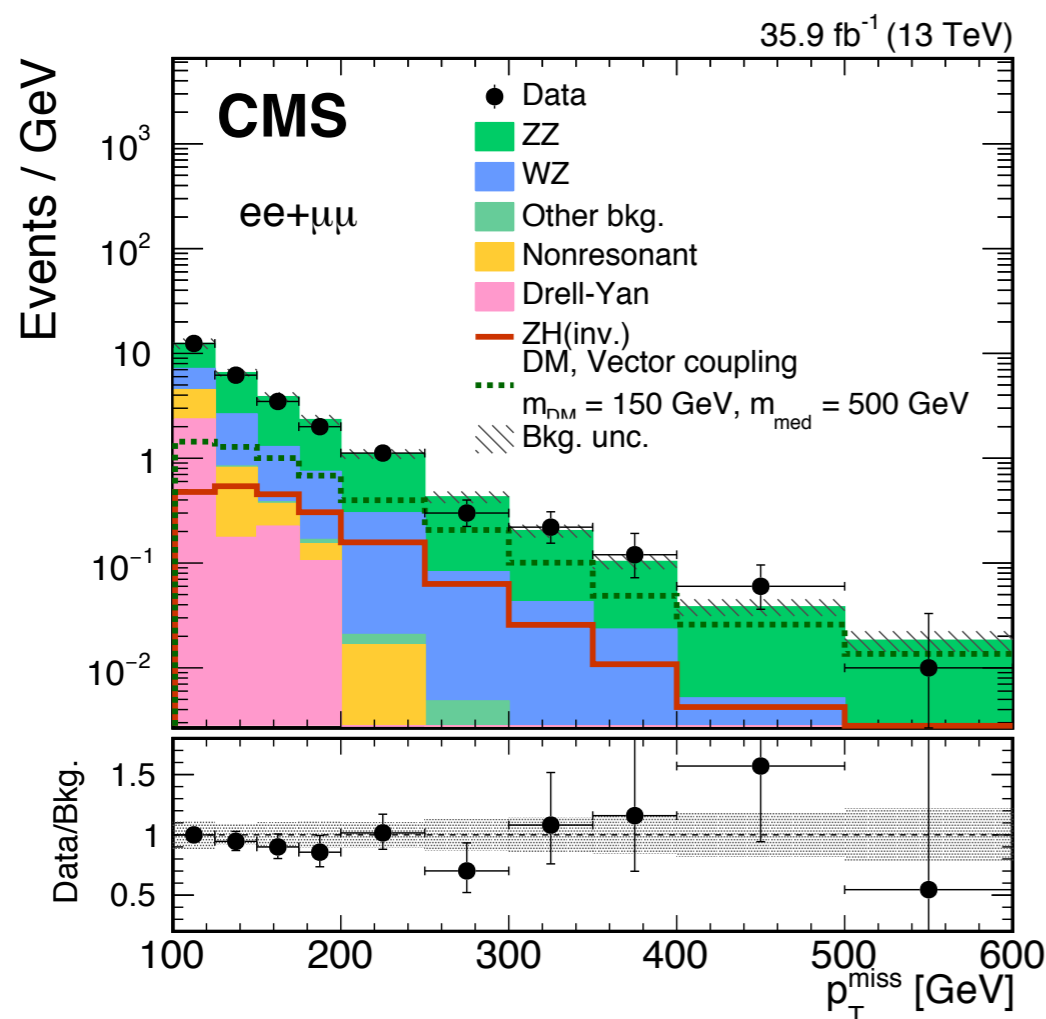
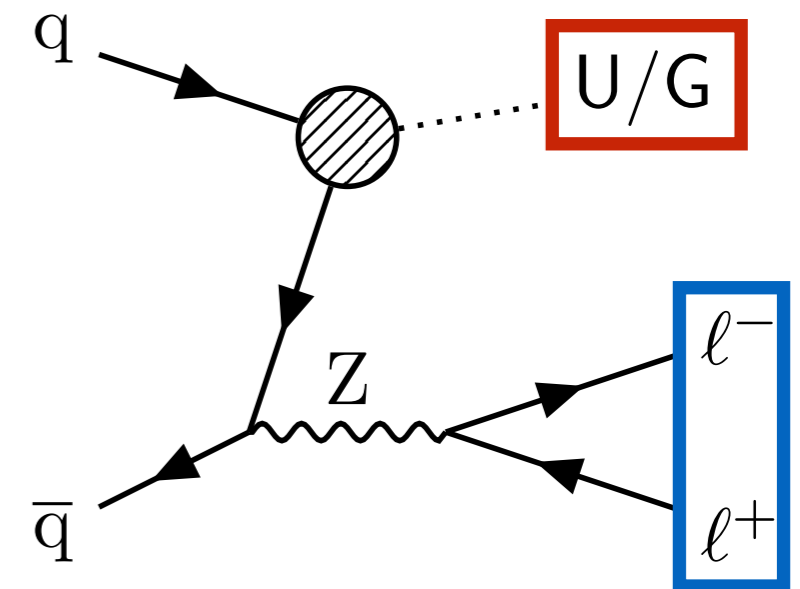
- **Signal extraction using photon p_T spectrum**
 - Better resolution, better control over uncertainties compared to using missing p_T

- The fundamental Planck scale M_D excluded up to **2.9 TeV**
 - As a function of n , # of extra dimensions
- Significantly improved from the previous result using part of 2016 data (12.9 fb^{-1})
 - JHEP 10 (2017) 073, CMS-EXO-16-039

New!



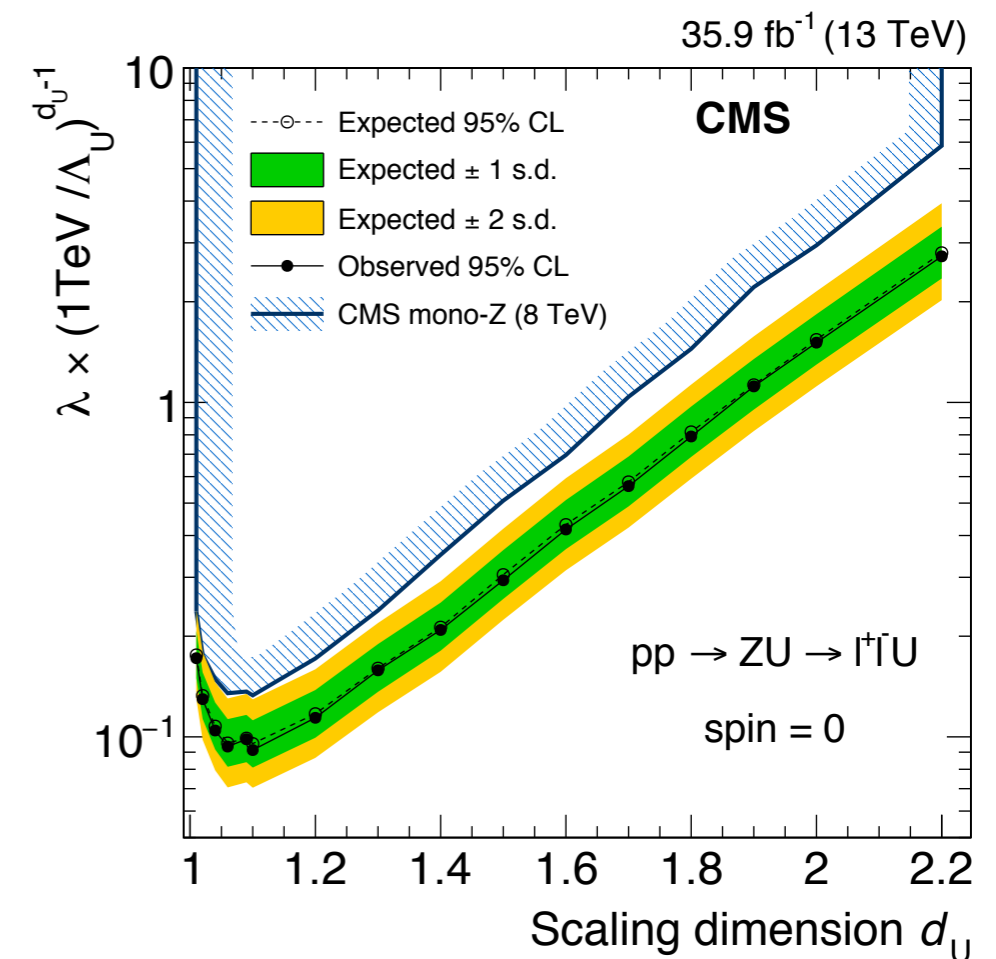
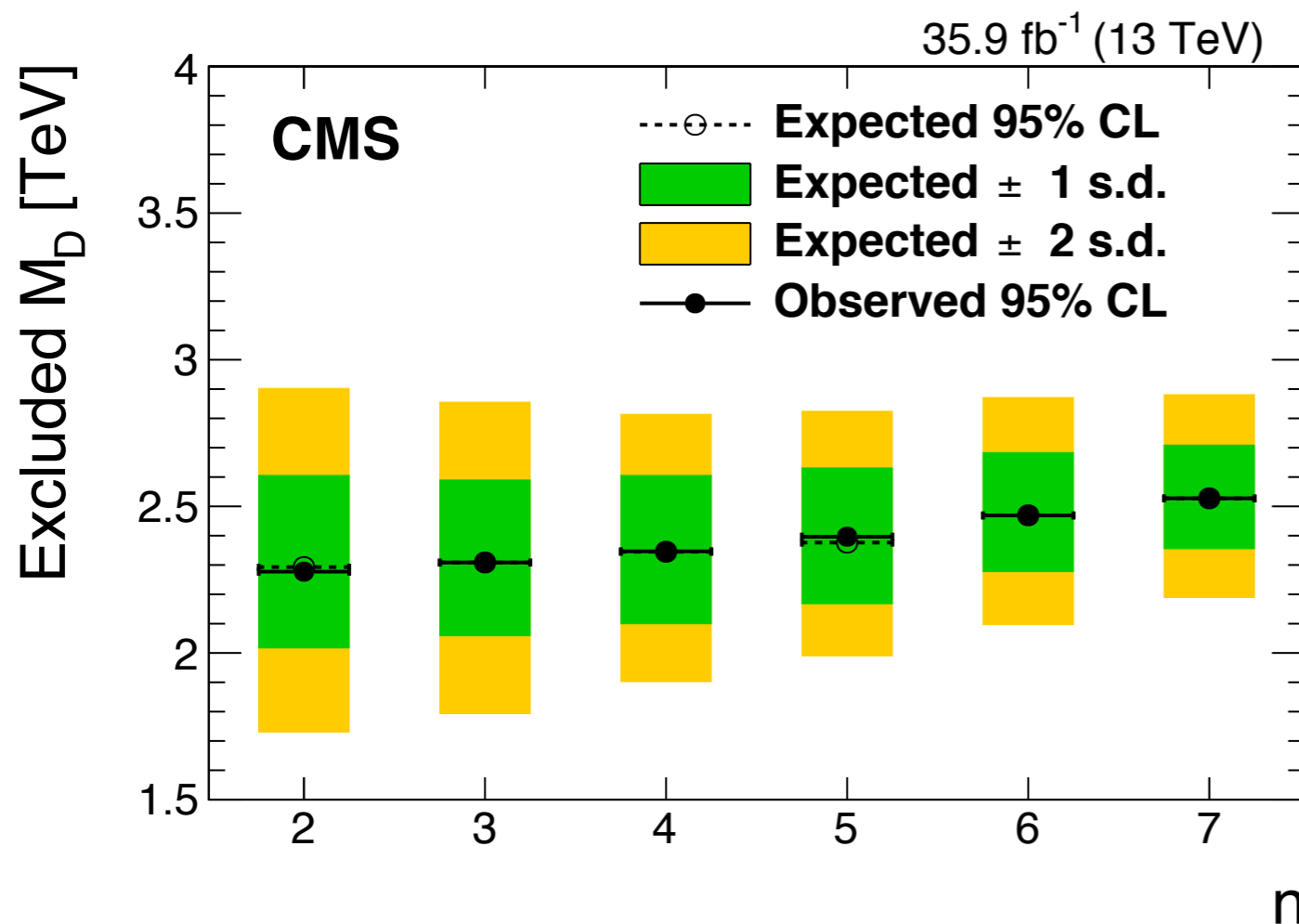
- **New physics hidden in Z(II) + missing p_T**
 - ADD graviton or unparticle leads to **large missing p_T**
 - In association with **Z \rightarrow ll**
 - Evident in the missing p_T distribution



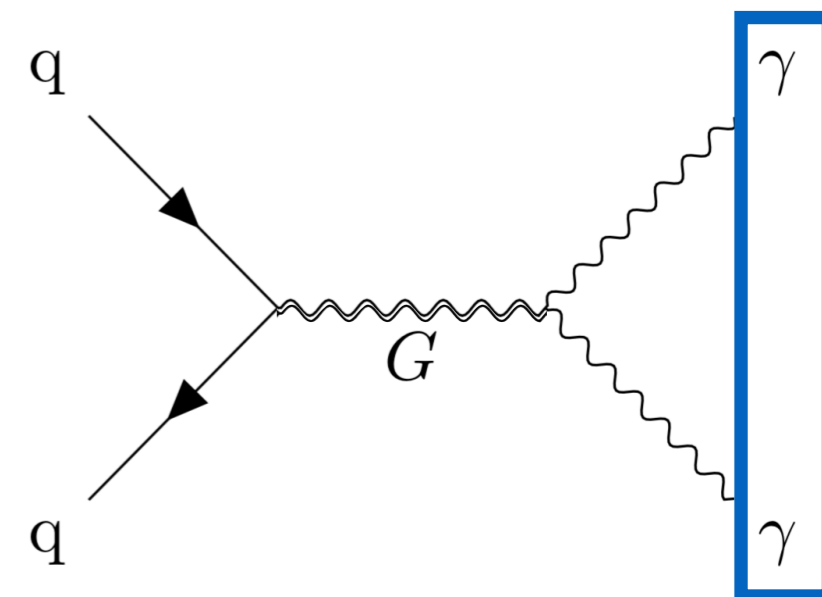
• Search strategies in brief

- Two channels: $ee / \mu\mu$
- Bkg estimation: **similar to monophoton search**
- ➔ ZZ / WZ: simultaneous fit to SR & CRs
- ➔ Nonresonant and DY: data-driven
- ➔ Others: MC
- Signal extraction using **missing p_T shape**

- **ADD:** the fundamental Planck scale M_D up to **2.5 TeV** excluded
- **Unparticle:** limits on the Wilson coefficient of the unparticle-quark coupling operator
 - λ : coupling between quarks and unparticles
 - Λ_U : cutoff scale
 - d_U : characteristic scaling dimension

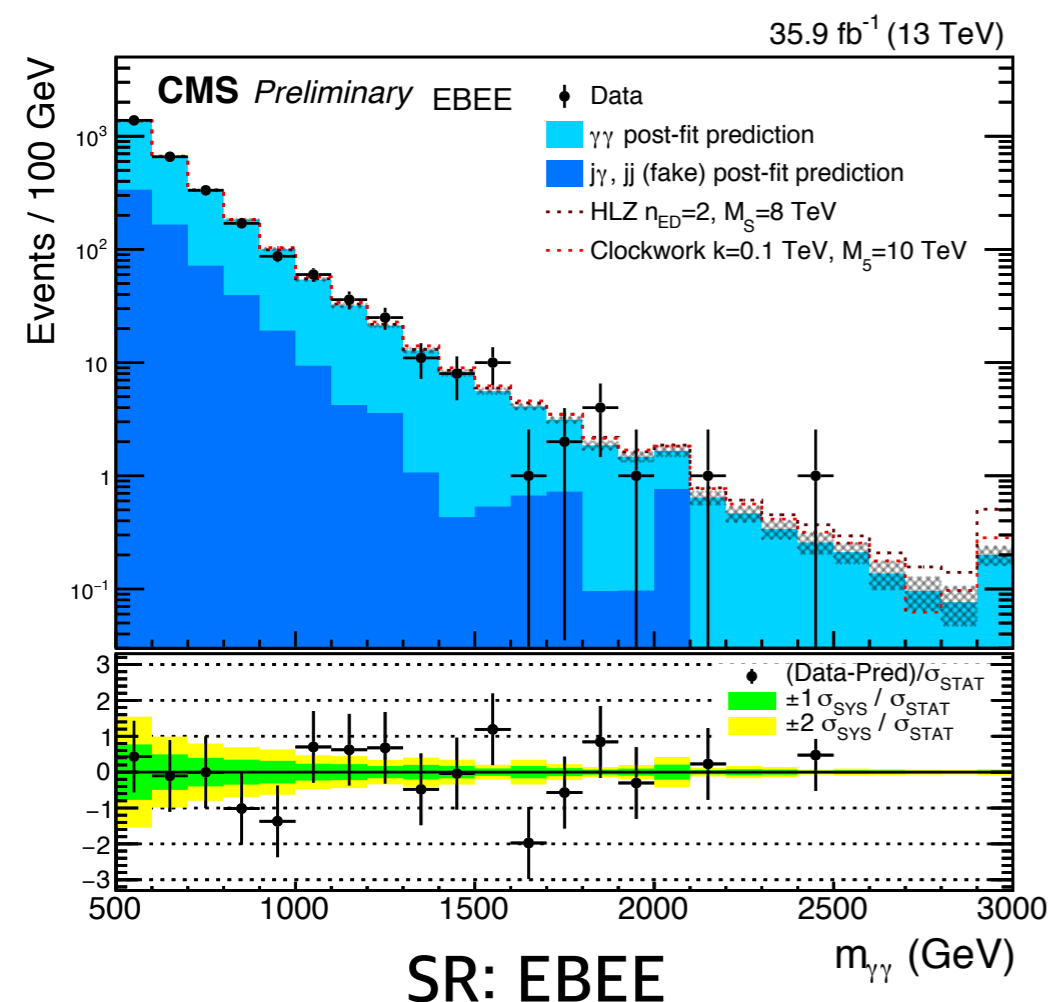


- Motivated by massive graviton production in the diphoton final state
 - ADD, clockwork: **continuous graviton mass spectrum**
 - nonresonant excess in the diphoton mass spectrum



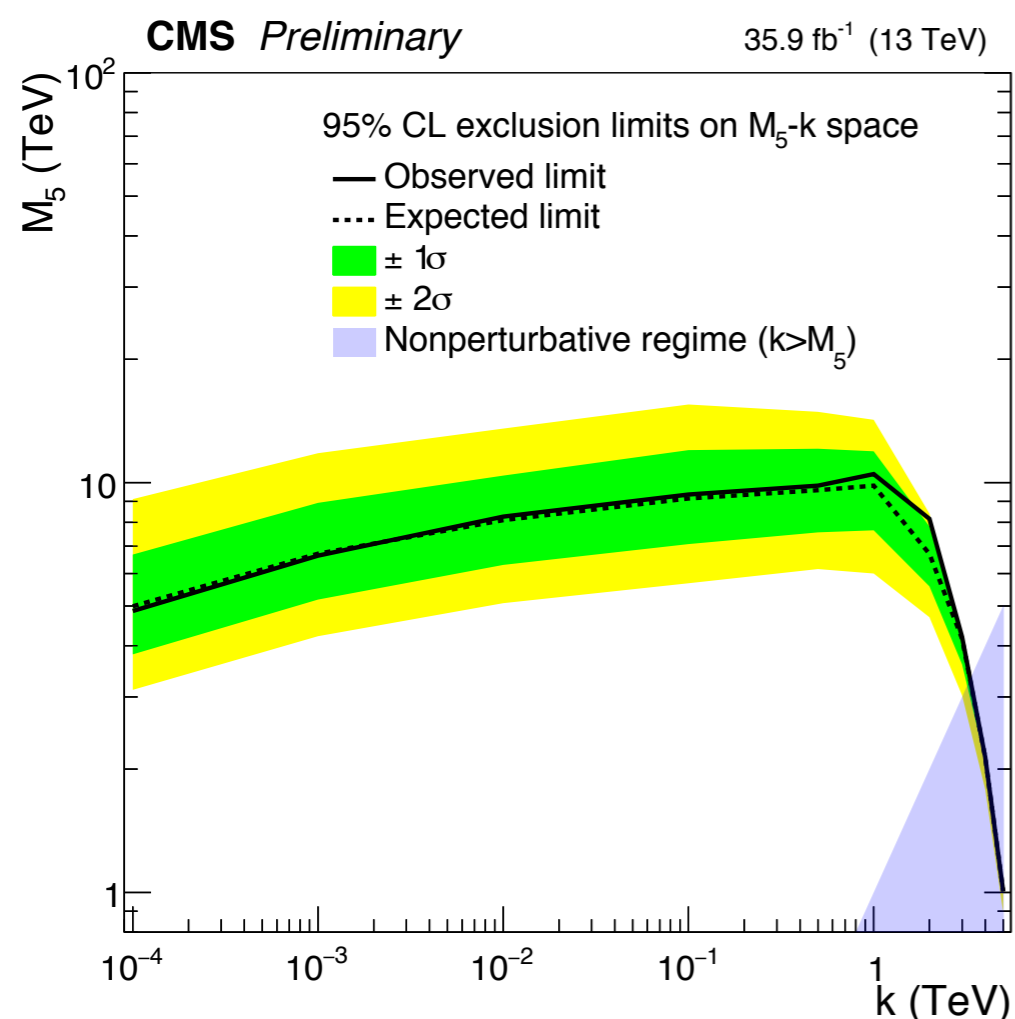
Search strategies in brief

- Two high p_T photons, at least one in the barrel (EB)
 - ➔ Two categories: EBEB / EBEE
- Background estimation
 - ➔ $\gamma\gamma$: MC
 - ➔ $j\gamma, jj$: data-driven
- Signal extraction using **diphoton mass spectrum**



Signal:	GRW	Hewett		HLZ					
		negative	positive	$n_{ED}=2$	$n_{ED}=3$	$n_{ED}=4$	$n_{ED}=5$	$n_{ED}=6$	$n_{ED}=7$
Expected:	$7.1^{+0.7}_{-0.5}$	$5.5^{+0.1}_{-0.3}$	$6.3^{+0.6}_{-0.4}$	$8.4^{+1.3}_{-1.1}$	$8.4^{+0.8}_{-0.6}$	$7.1^{+0.7}_{-0.5}$	$6.4^{+0.6}_{-0.5}$	$6.0^{+0.6}_{-0.4}$	$5.6^{+0.6}_{-0.4}$
Observed:	7.8	5.6	7.0	9.7	9.3	7.8	7.0	6.6	6.2

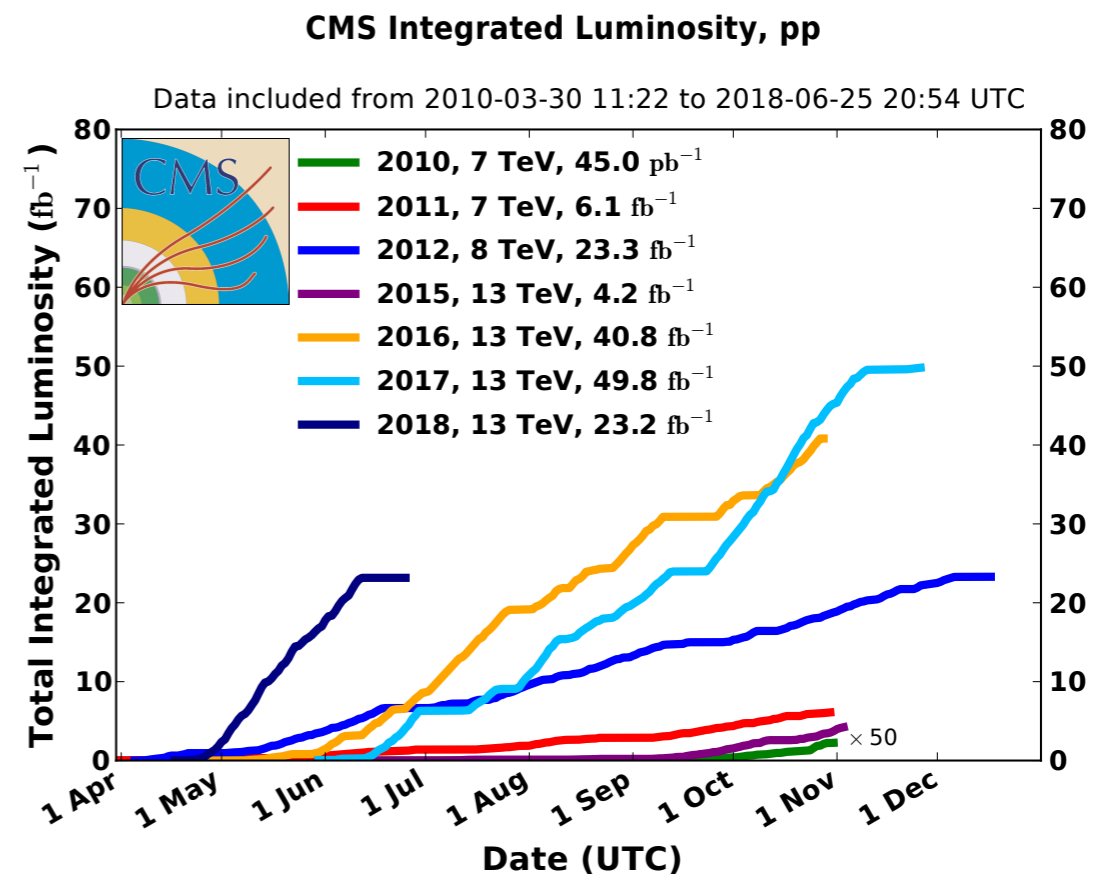
- **ADD:** limits set on the cutoff scale M_s , for **each different convention**



- **Clockwork:** **the first limits set on the parameter space**
 - M_5 : gravity scale
 - k : called clockwork spring, a measure of the effectiveness of the clockwork mechanism

Summary

- **CMS has published a number of new results on searches for nonresonant phenomena in lepton / photon final states**
 - Based on 2016 data (35.9 fb^{-1})
 - No evidence for new physics observed yet
 - Significant improvements w.r.t previous limits
- **Stay tuned**
 - New results are coming out with more data (2017, 2018)



Backup