


# New Physics search at CMS

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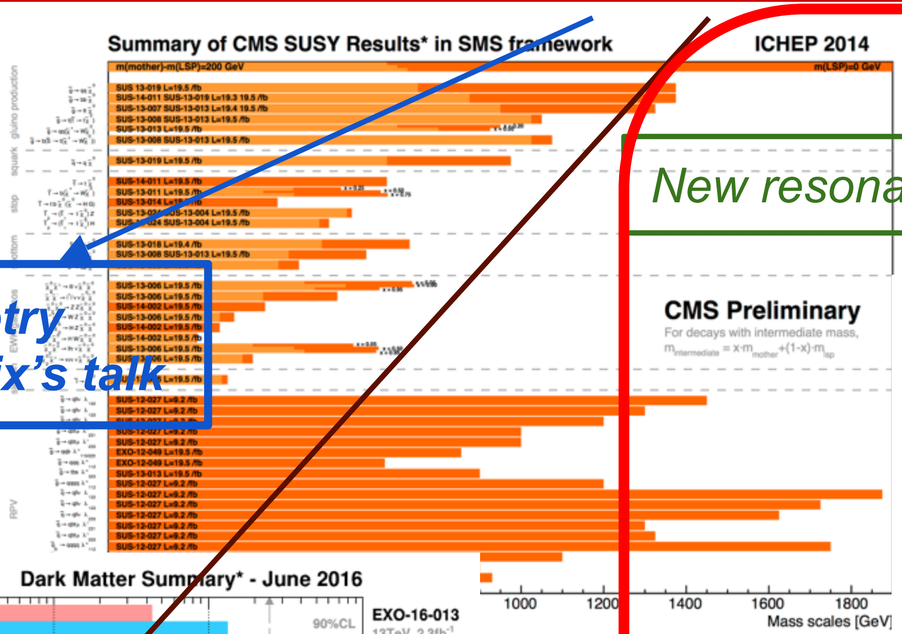
La Thuile-2017

# Overview

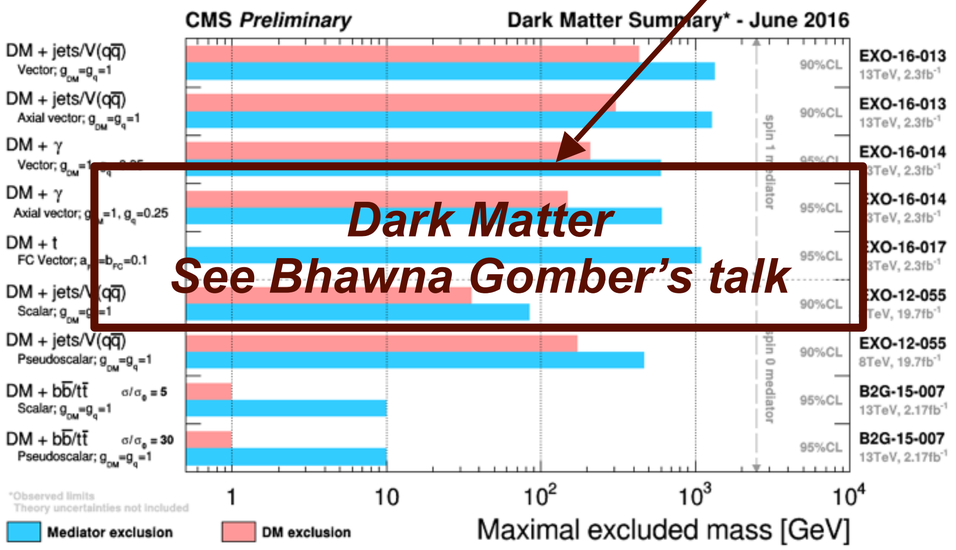
## *What is New Physics?*

Standard Model physics has standard problems: hierarchy, baryon asymmetry, gravity, etc...

**SUperSYmmetry**
**See Florent Lacroix's talk**



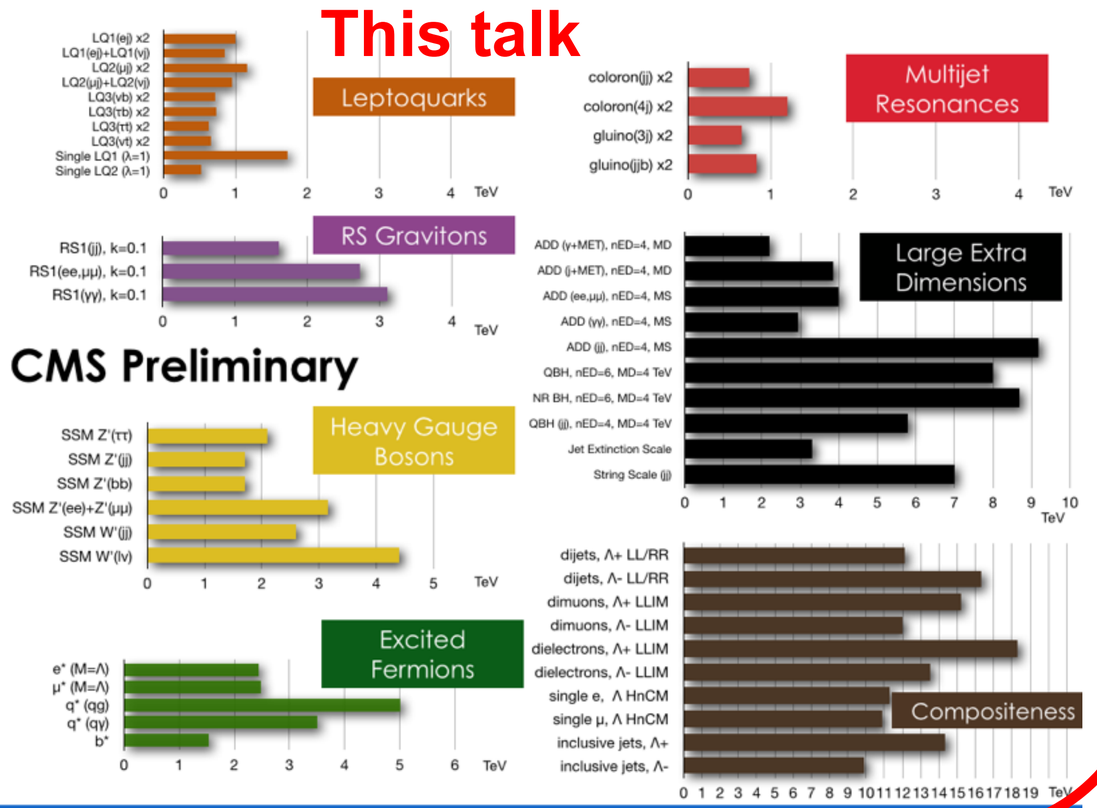

**Dark Matter**
**See Bhawna Gomber's talk**




**Exotica**

- New resonances
- Long-lived particles
- Gravitons
- ...

**This talk**



# Experimental signatures

## Neutral resonances

- dilepton with $\ell = e, \mu$
- ditau with hadronic and leptonic $\tau$ decays
- diphoton
- dijet with light quarks jets
- dijet with heavy quarks jets
- Z+photon

## Charged resonances

- lepton + MET with $\ell = e, \mu$
- $W' \to tb$ with different top quark decays

## Leptoquarks (3rd gen)

- Energetic lepton ($\ell = e, \mu$) plus $LQ \to \tau W(jj)$

## Heavy stable particles

- Disappearing tracks
- Displaced vertices

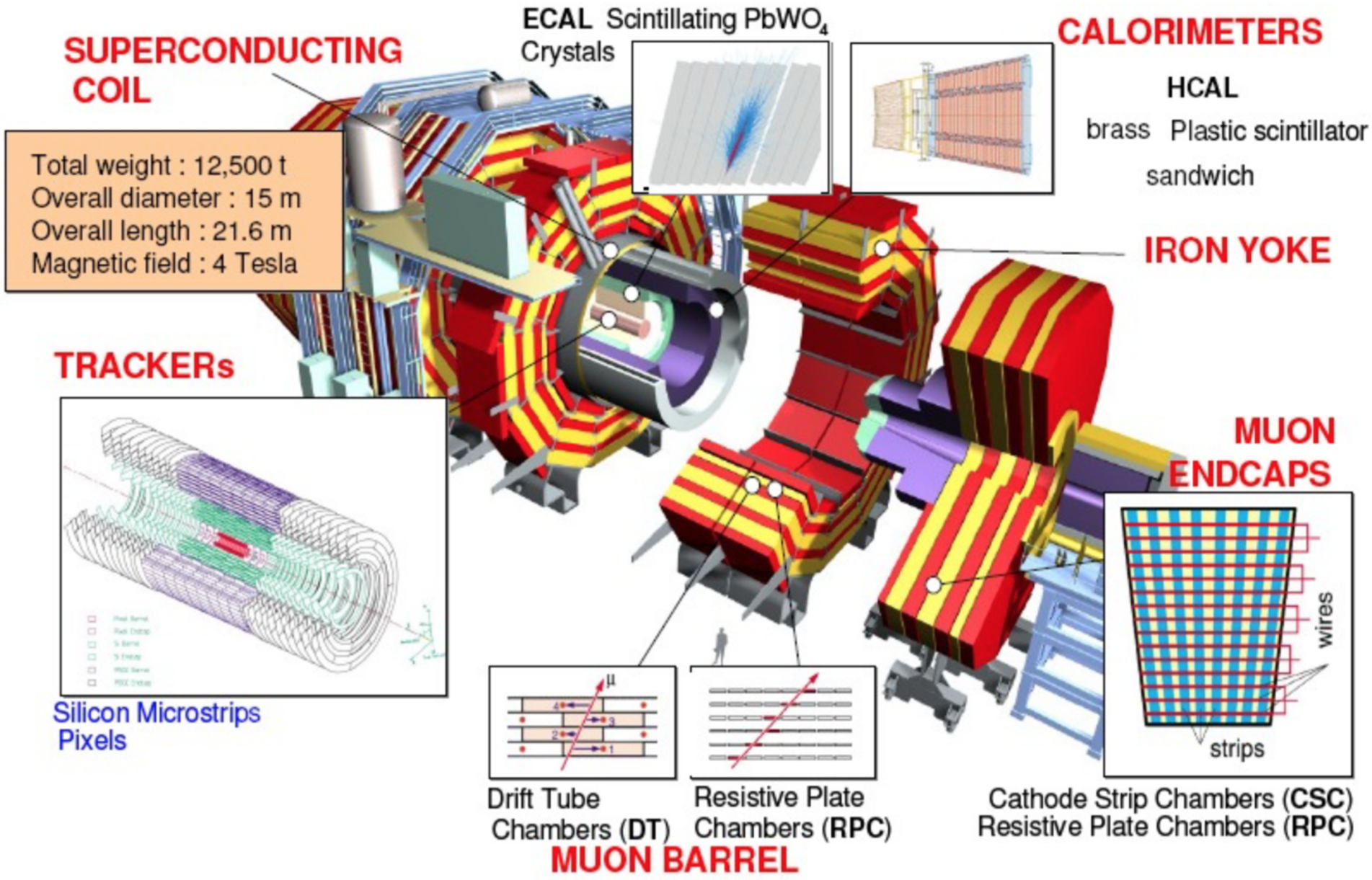
And many more…

# Outline

- ☑ CMS performed very well in the past years
- ☑ Huge amount of results were produced
- ☑ Recent Beyond Standard Model results amounts:
  - ☑ 79 Exotica analyses
  - ☑ 16 Beyond 2nd Generation analyses (relatively new group :))

Not possible to cover everything in 20mn talk!
→ Concentrate on the most recent results

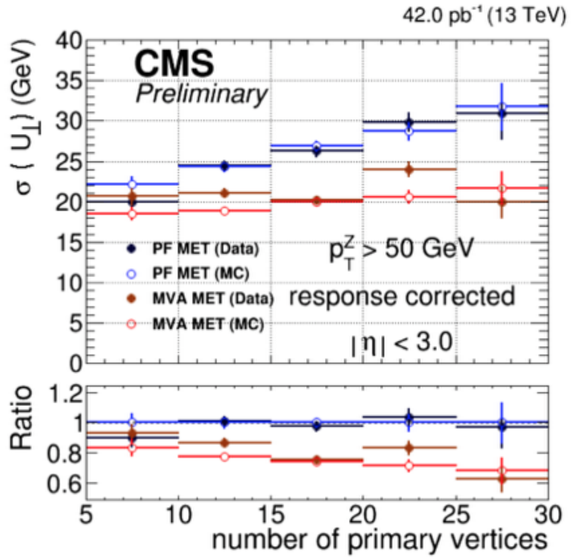
# The CMS detector at the LHC

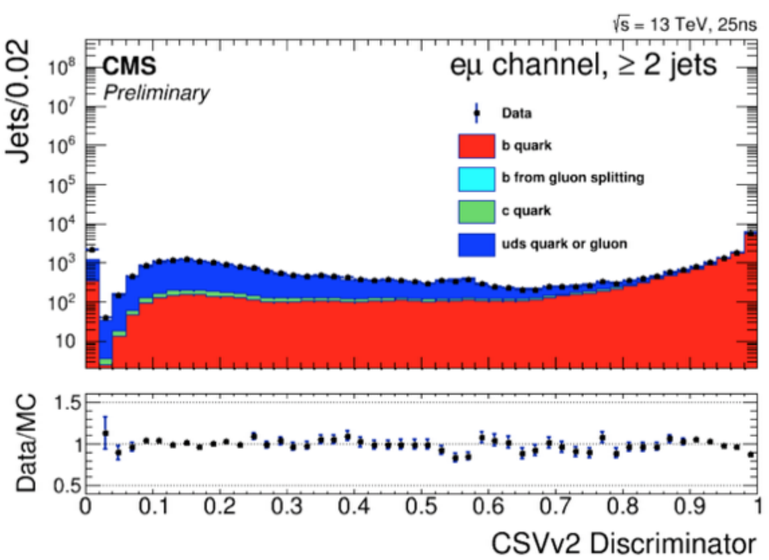


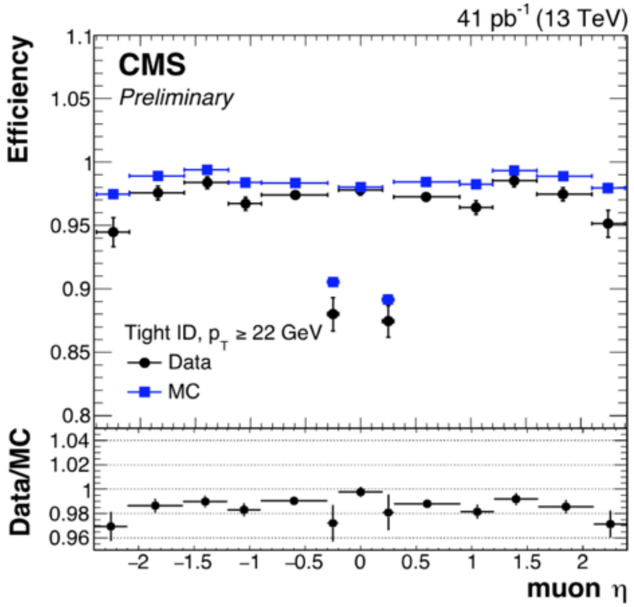
# Objects reconstruction

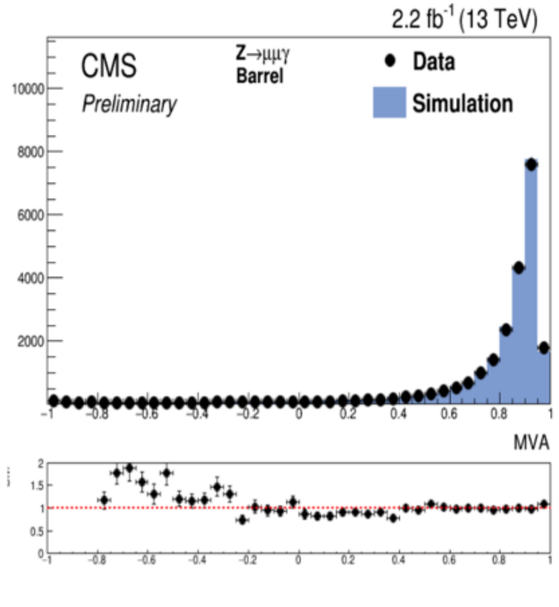
Jets and MET:

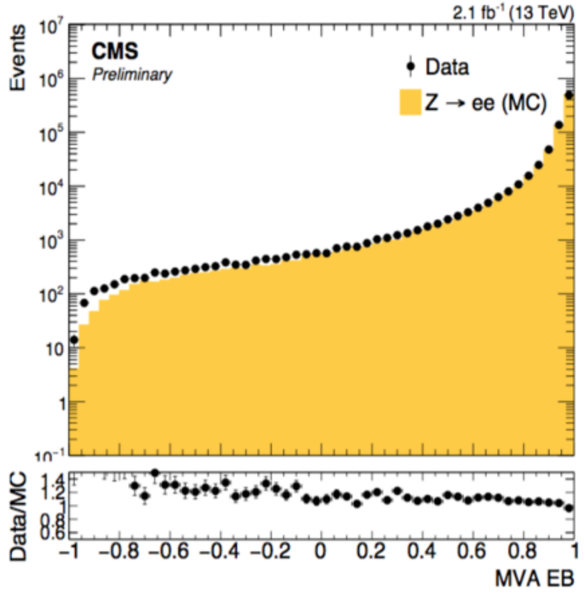
- Good performance for both 25 and 50 ns bunch spacing and w.r.t pileup
- Jet Energy scale corrections derived from data
- Detailed studies of MET/MHT conducted



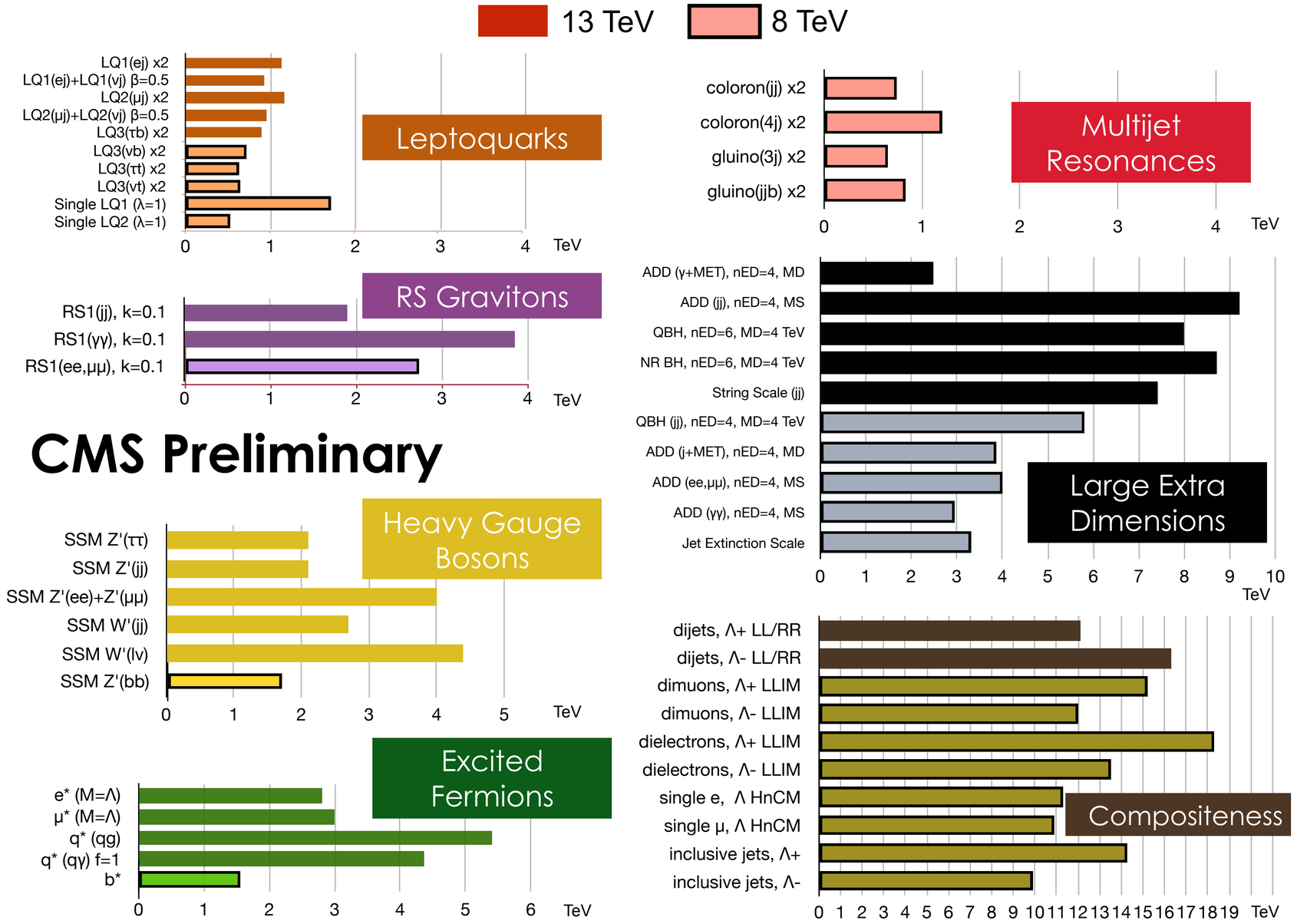




Leptons and photons:

- New isolation algorithm, exploring dependency of isolation cone vs transverse momentum
- New and improved algorithms for leptons and photons identification

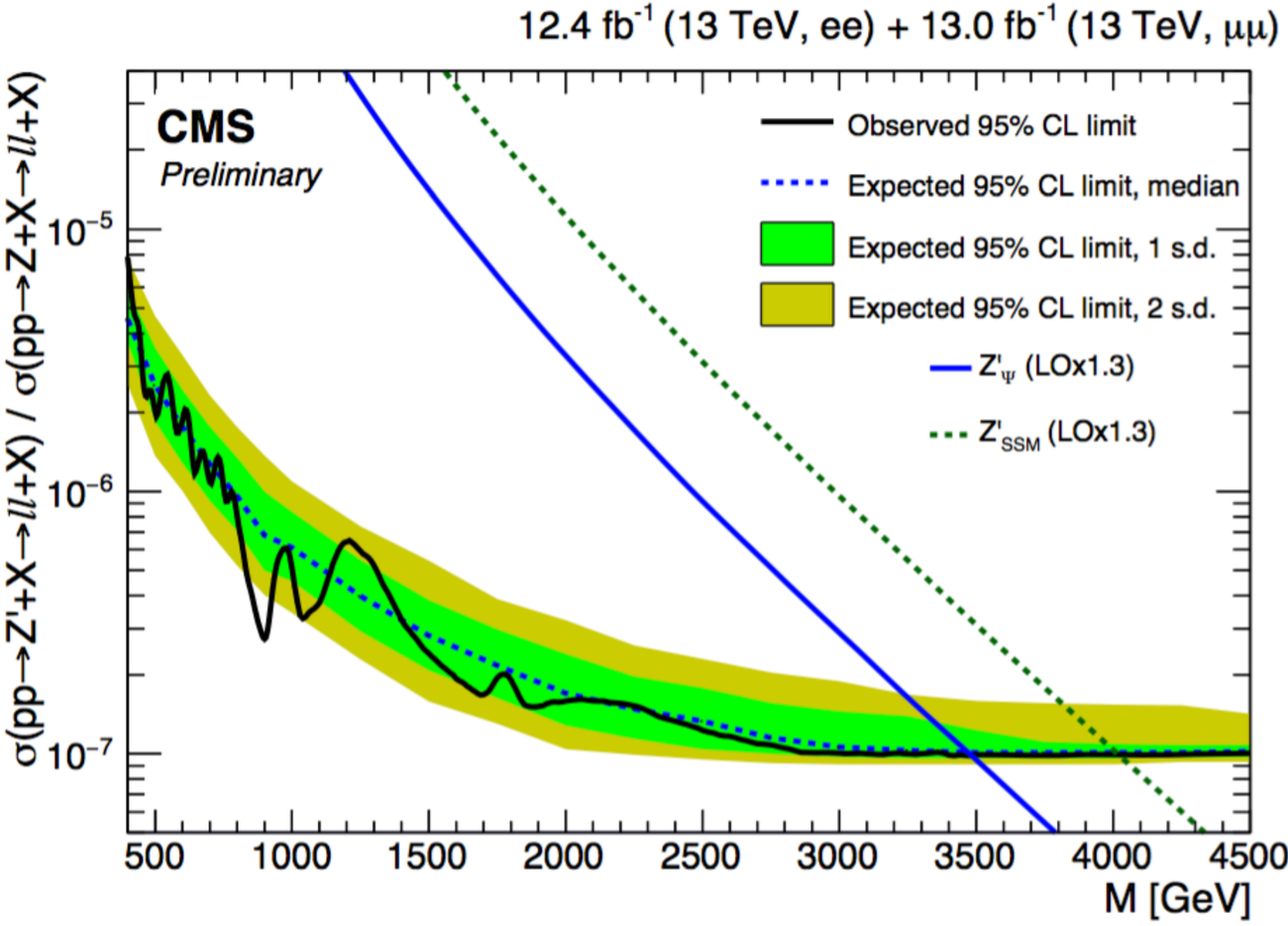
# Exotica searches: brief summary



# Dilepton resonance search

Selection:

- Two isolated opposite sign same flavor leptons
- Relatively high transverse momentum. In case of more than one pair reconstructed, select the highest pT pair




Put constraints on

$$R_\sigma = \frac{\sigma(pp \to Z'(\ell\ell) + X)}{\sigma(pp \to Z(\ell\ell) + X)}$$

CMS-PAS-EXO-16-031

# Di-tau resonance search

JHEP02(2017)048

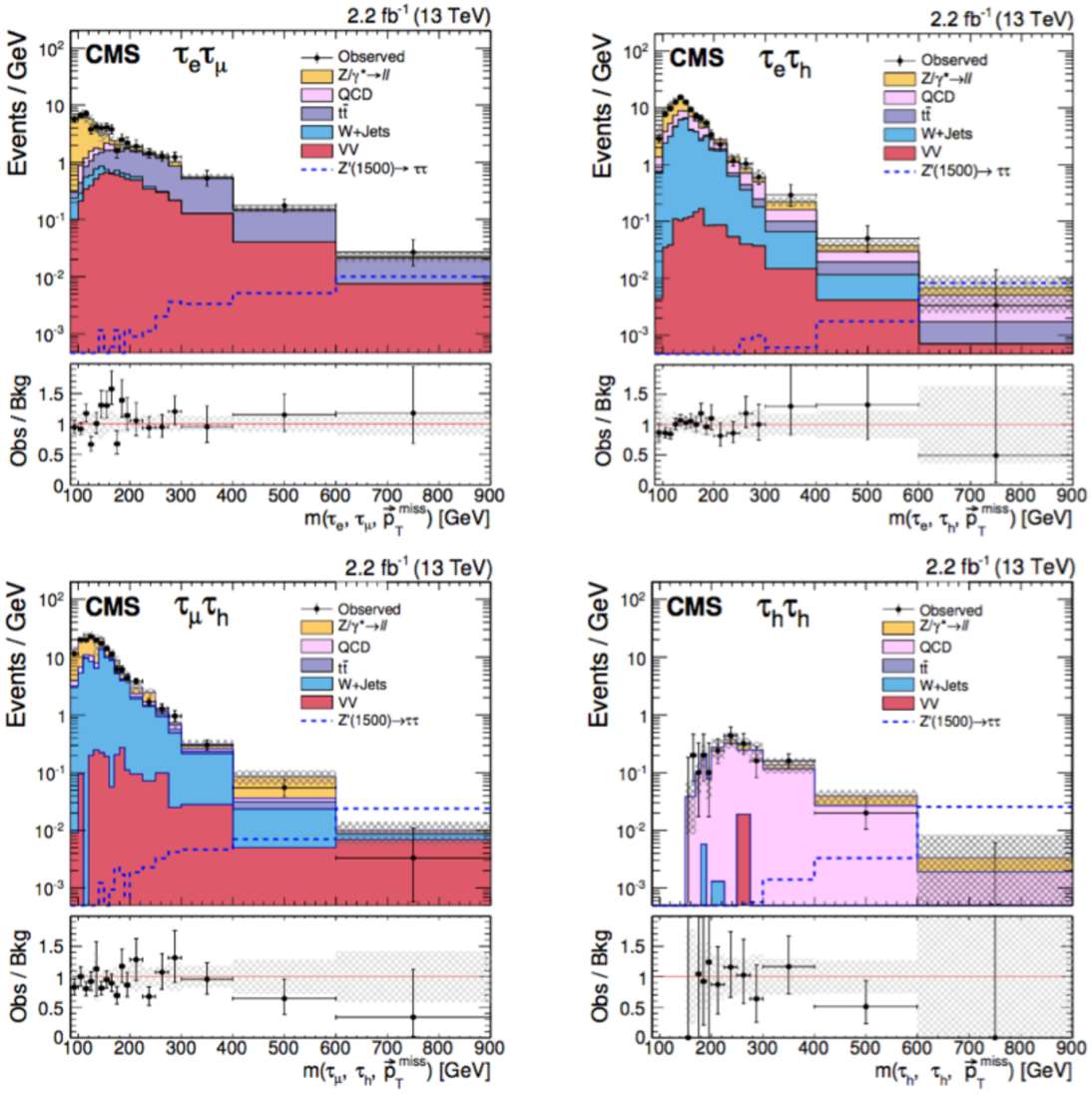
$$m(\tau_1, \tau_2, \not{E}_T) = \sqrt{(E_{\tau_1} + E_{\tau_2} + \not{E}_T)^2 - (\vec{p}_{\tau_1} + \vec{p}_{\tau_2} + \vec{\not{E}}_T)^2}$$

Analysis is performed for various tau decays:

$$\tau_e\tau_\mu, \tau_e\tau_h, \tau_\mu\tau_h, \tau_h\tau_h$$

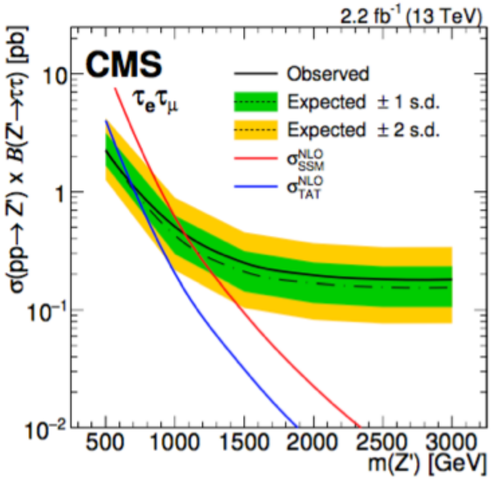
- Search for back-to-back tau pairs with missing energy aligned correspondingly
- For lepton-involved modes use single lepton trigger
- For fully hadronic decay require di-tau hadronic trigger

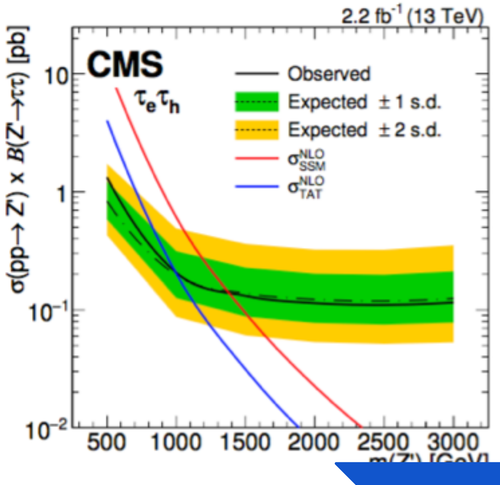
Data driven background estimation technique was used wherever possible

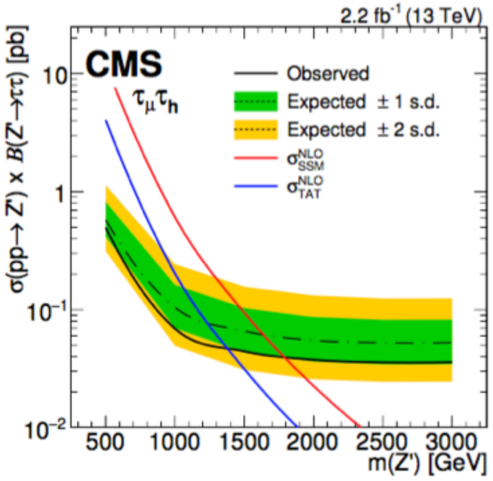


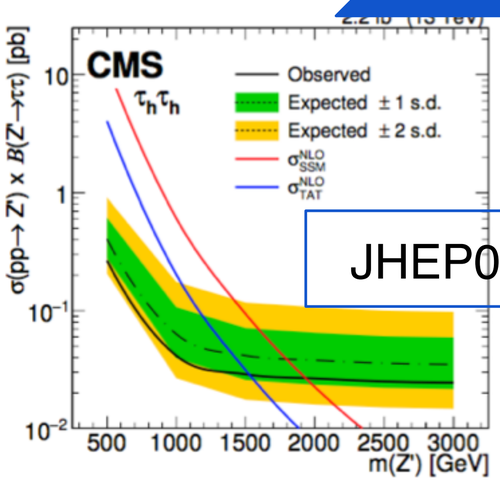
# Di-tau resonance search

No evidence of NP decaying to tau pair is observed

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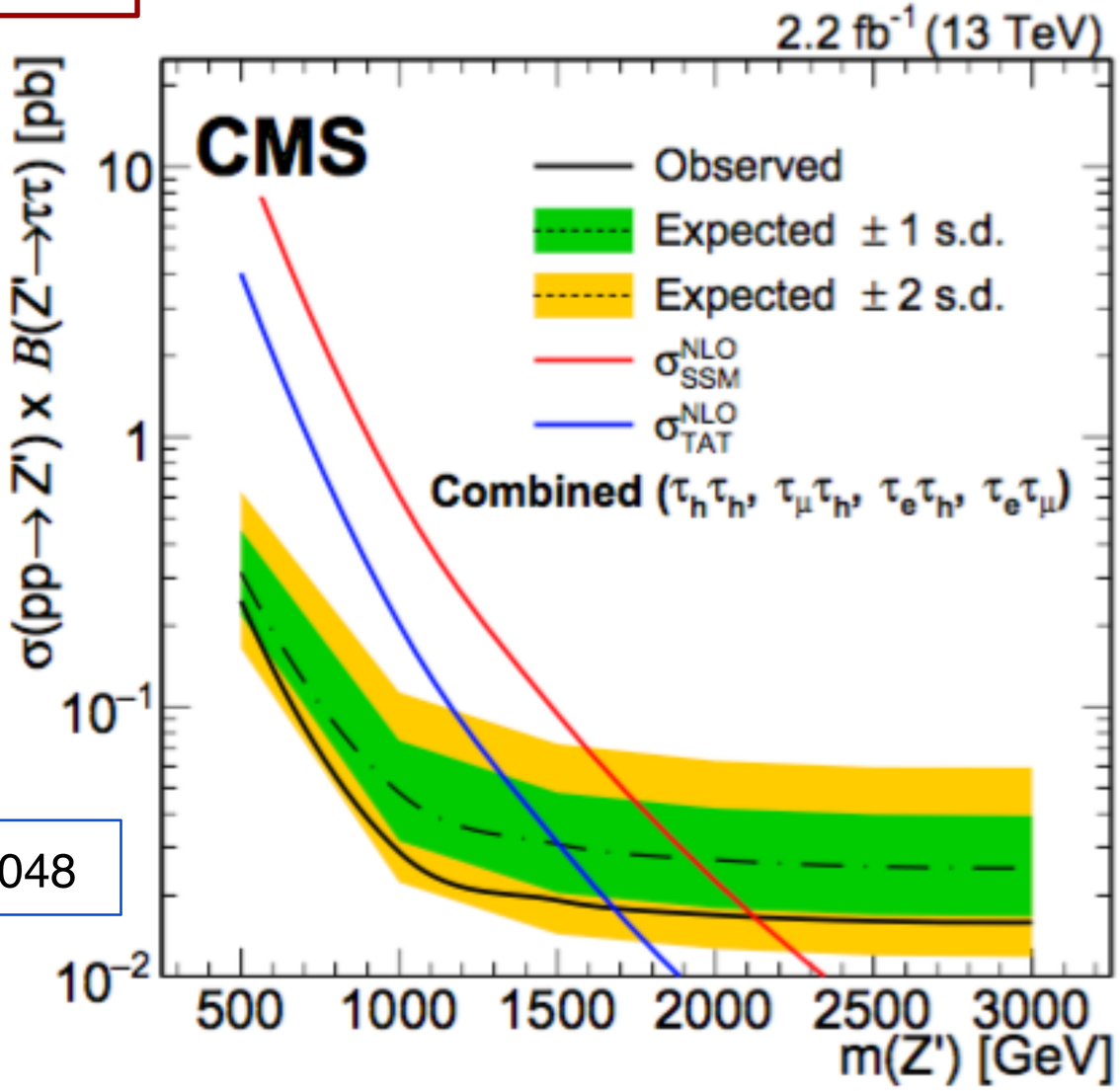
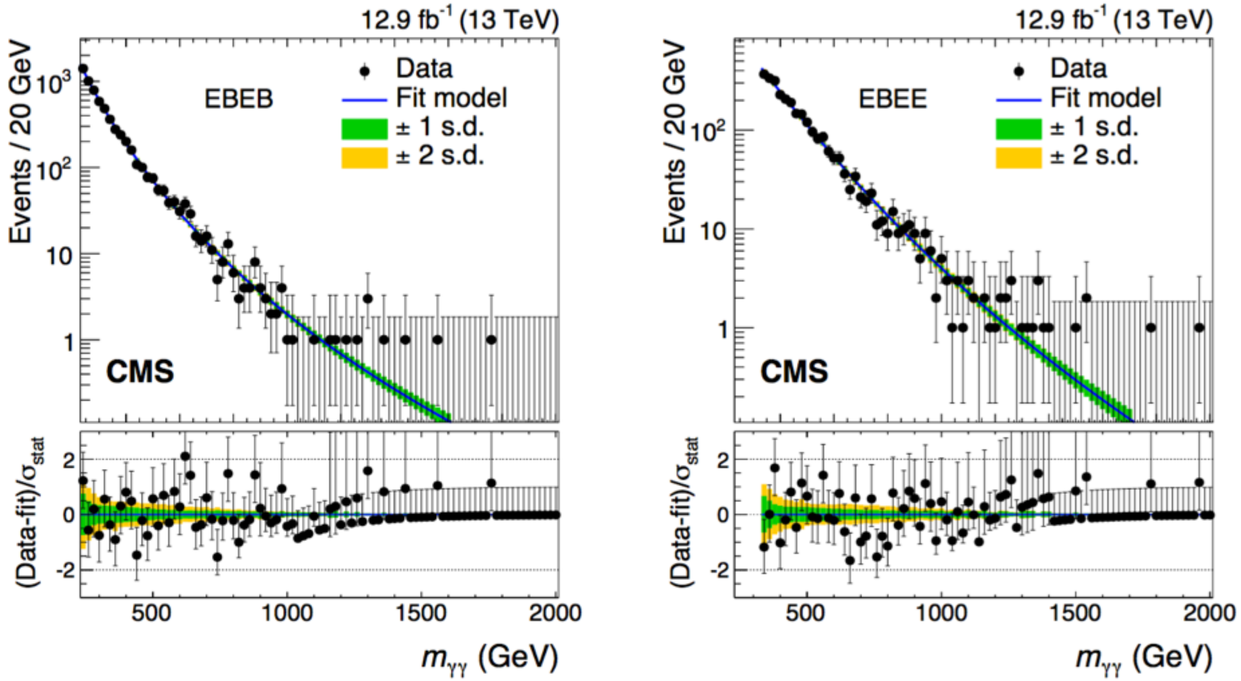


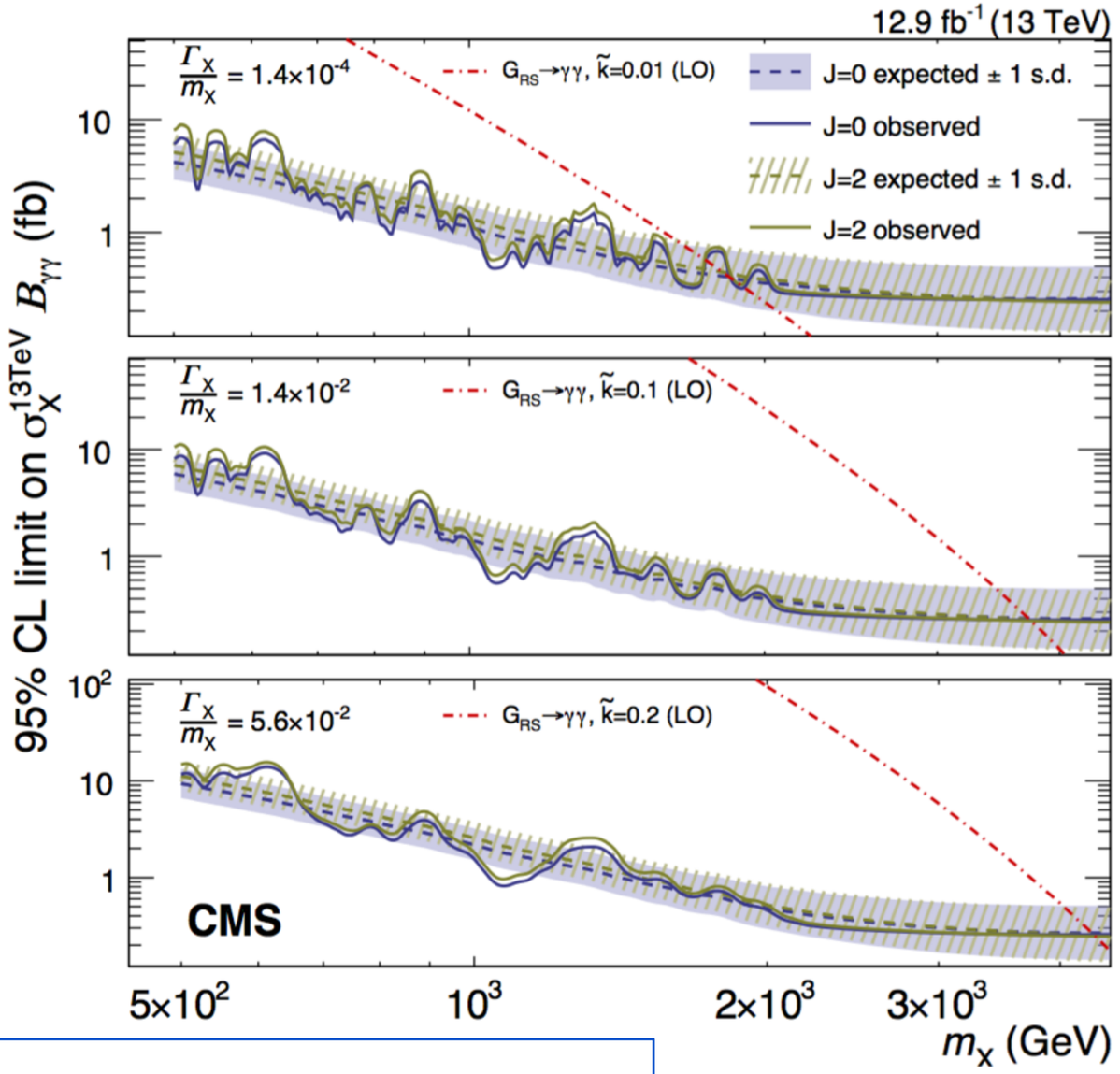
# Diphoton resonance search

Selection:

- Two energetic (>75GeV) photons

Examine spectrum above 500 GeV



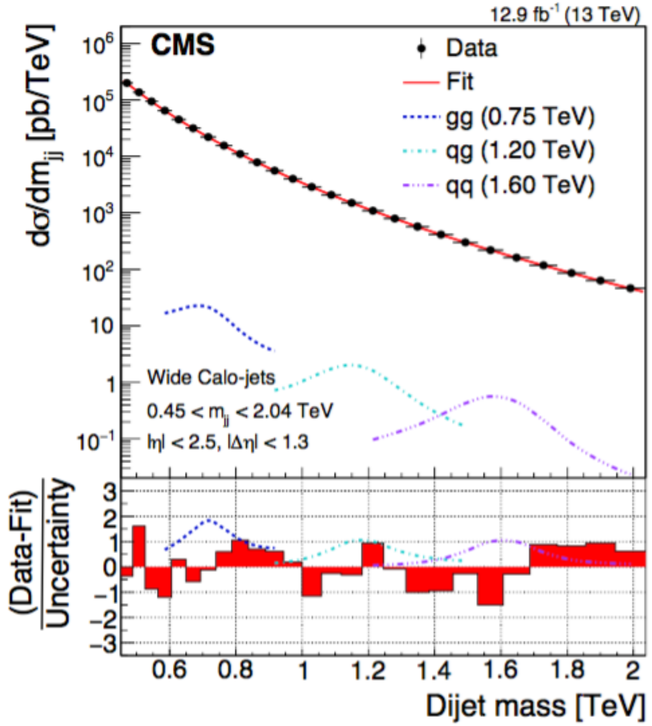

10.1016/j.physletb2017.01.027

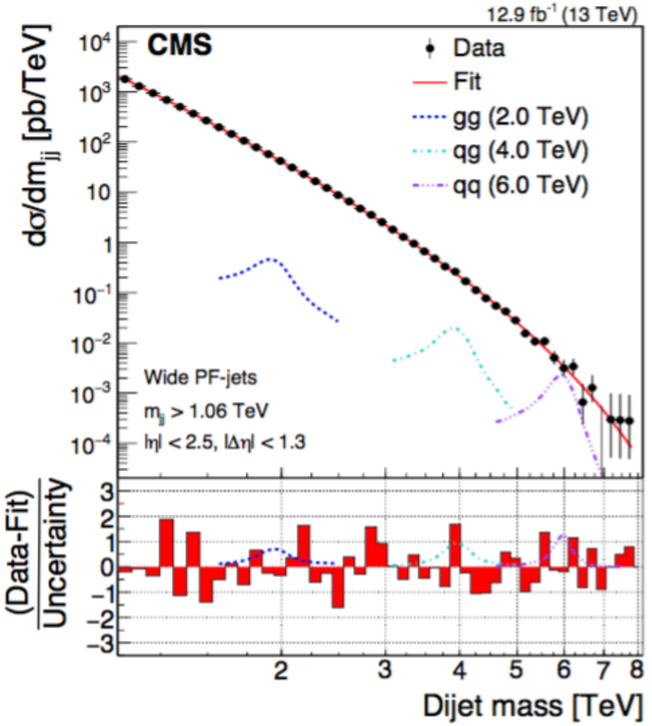
# Dijet resonance search

CMS-EXO-16-032

Selection:

- Dijet back-to-back topology
- High-mass search (PF jets):
  - $H_T > 800\,\text{GeV}$
  - $m_{jj} > 1.06\,\text{TeV}$
- Low-mass search (Calo jets):
  - $H_T > 250\,\text{GeV}$,
    $m_{jj} > 0.45\,\text{TeV}$



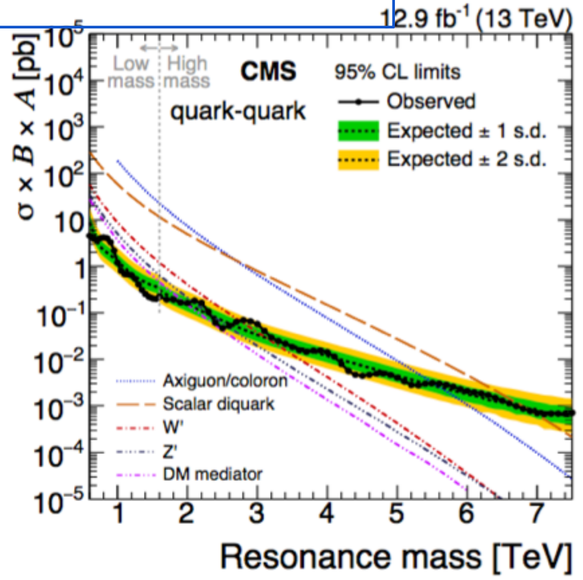

Spatially close jets are merged into “wide jets” to reduce analysis sensitivity to I(F)SR
Dijet invariant mass spectrum can be described with following function:

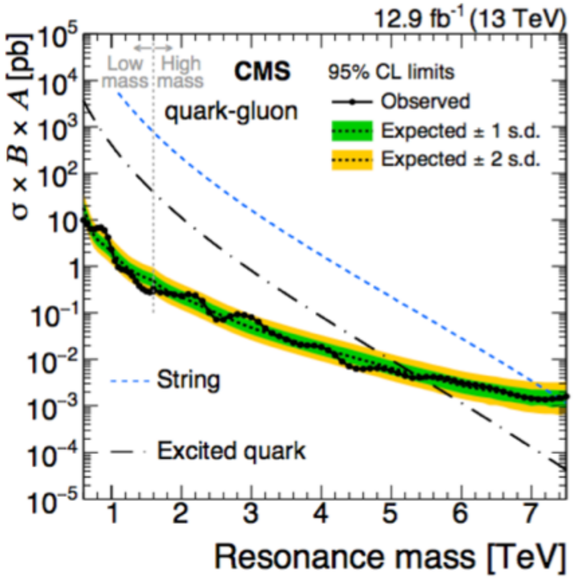
$$\frac{d\sigma}{dm_{jj}} = \frac{P_0(1-x)^{P_1}}{x^{P_2+P_3\ln(x)}}$$

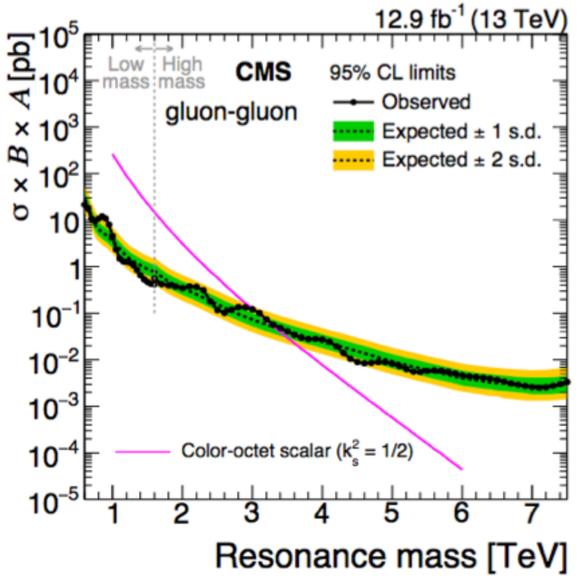
# Dijet resonance search

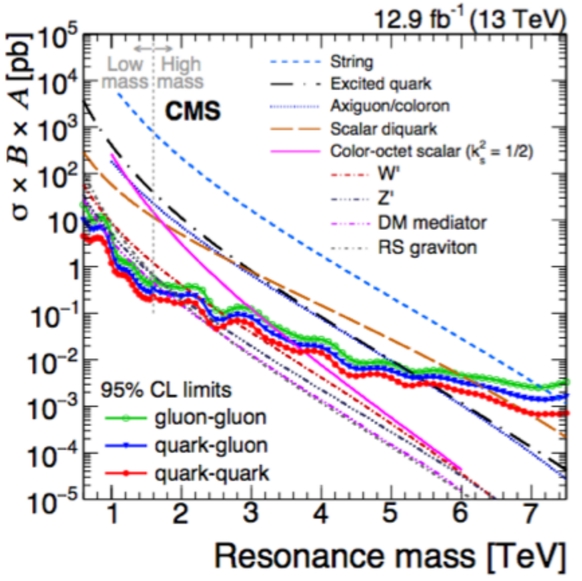
CMS-EXO-16-032

| Model | Final state | Limit [TeV] Obs. | Exp. |
|---|---|---|---|
| String | qg | 7.4 | 7.4 |
| Scalar diquark | qq | 6.9 | 6.8 |
| Axigluon/coloron | $q\bar{q}$ | 5.5 | 5.6 |
| Excited quark | qg | 5.4 | 5.4 |
| Color-octet scalar ($k_s^2 = 1/2$) | gg | 3.0 | 3.3 |
| $W'$ | $q\bar{q}$ | 2.7 | 3.1 |
| $Z'$ | $q\bar{q}$ | 2.1* | 2.3 |
| DM mediator ($m_{DM} = 1$GeV) | $q\bar{q}$ | 2.0 | 2.0 |
| RS graviton | $q\bar{q}$, gg | 1.9 | 1.8 |

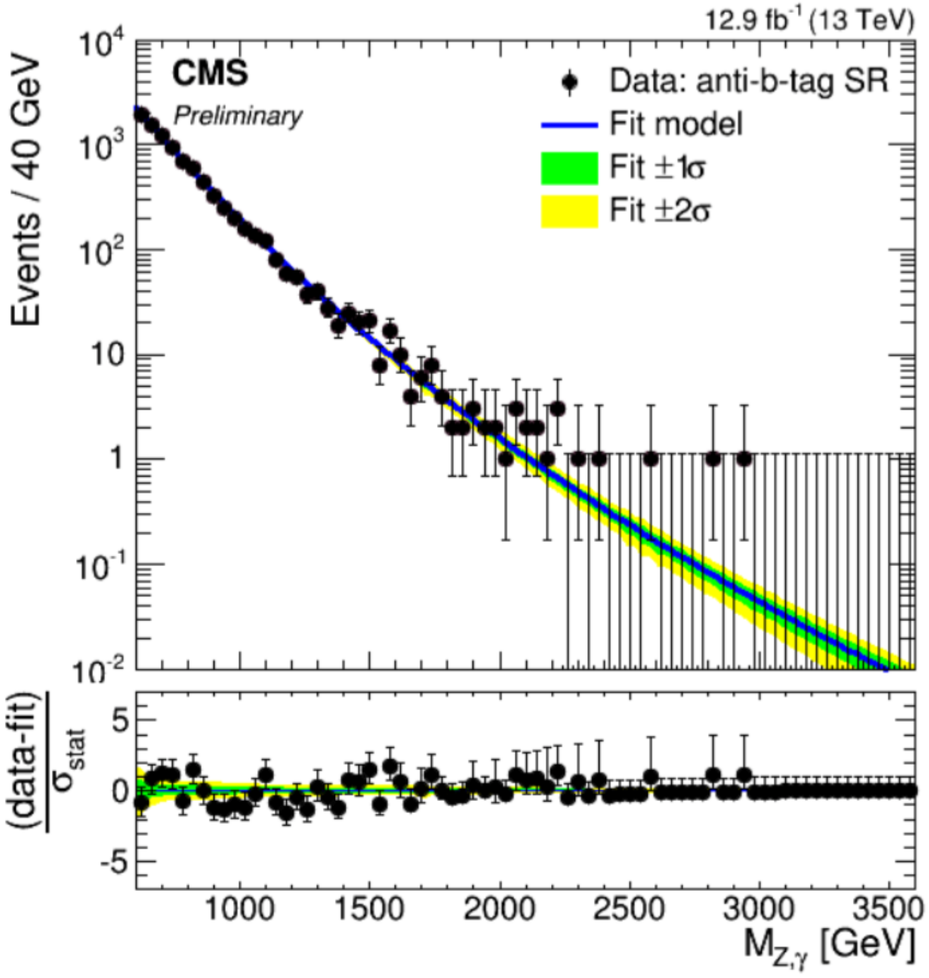


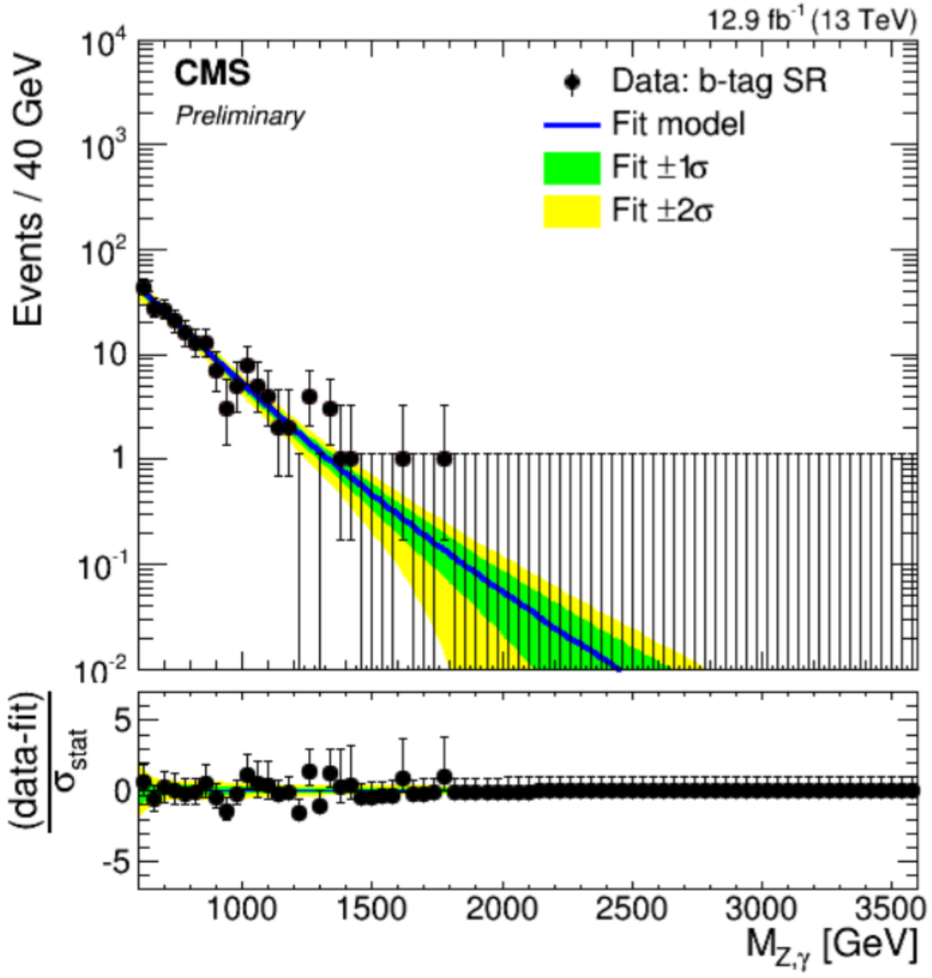



# Boosted topology: Z(qq) + photon



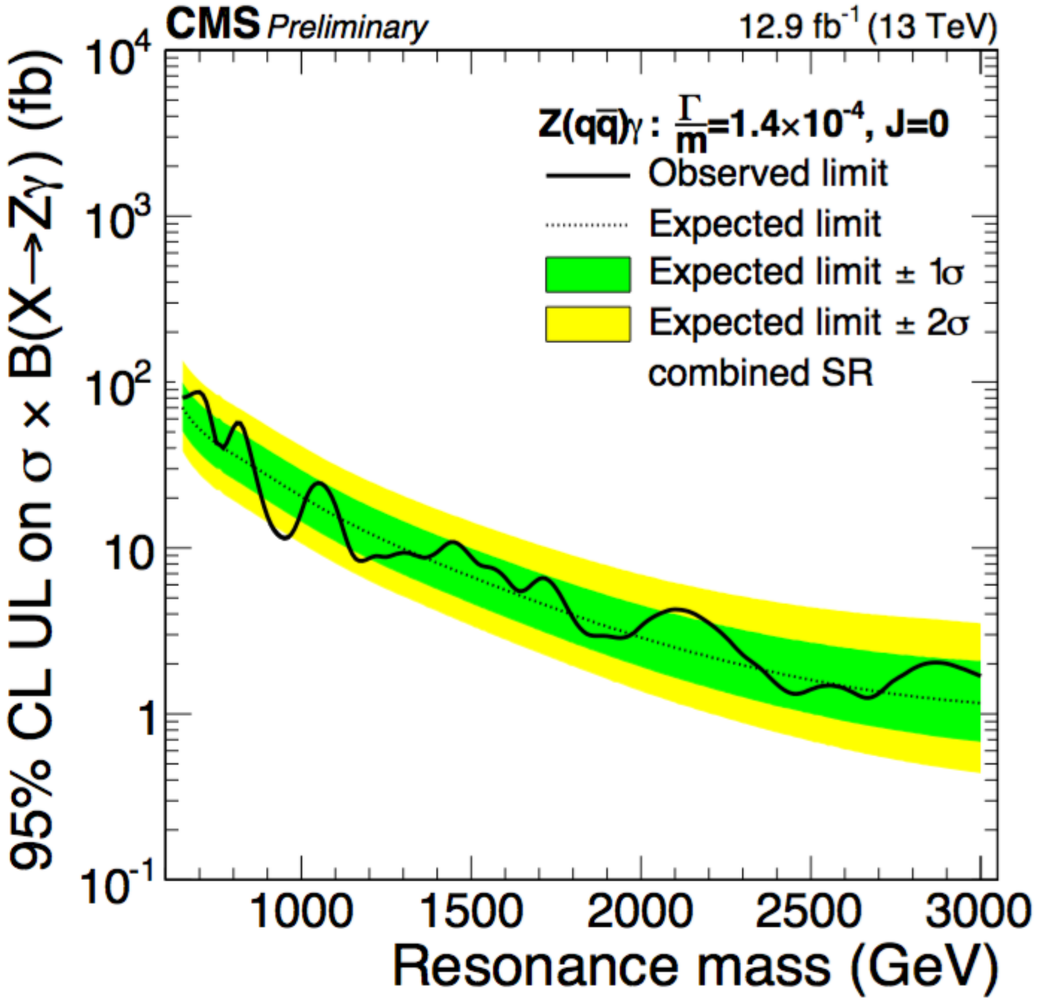

(a) anti-b-tagged SR



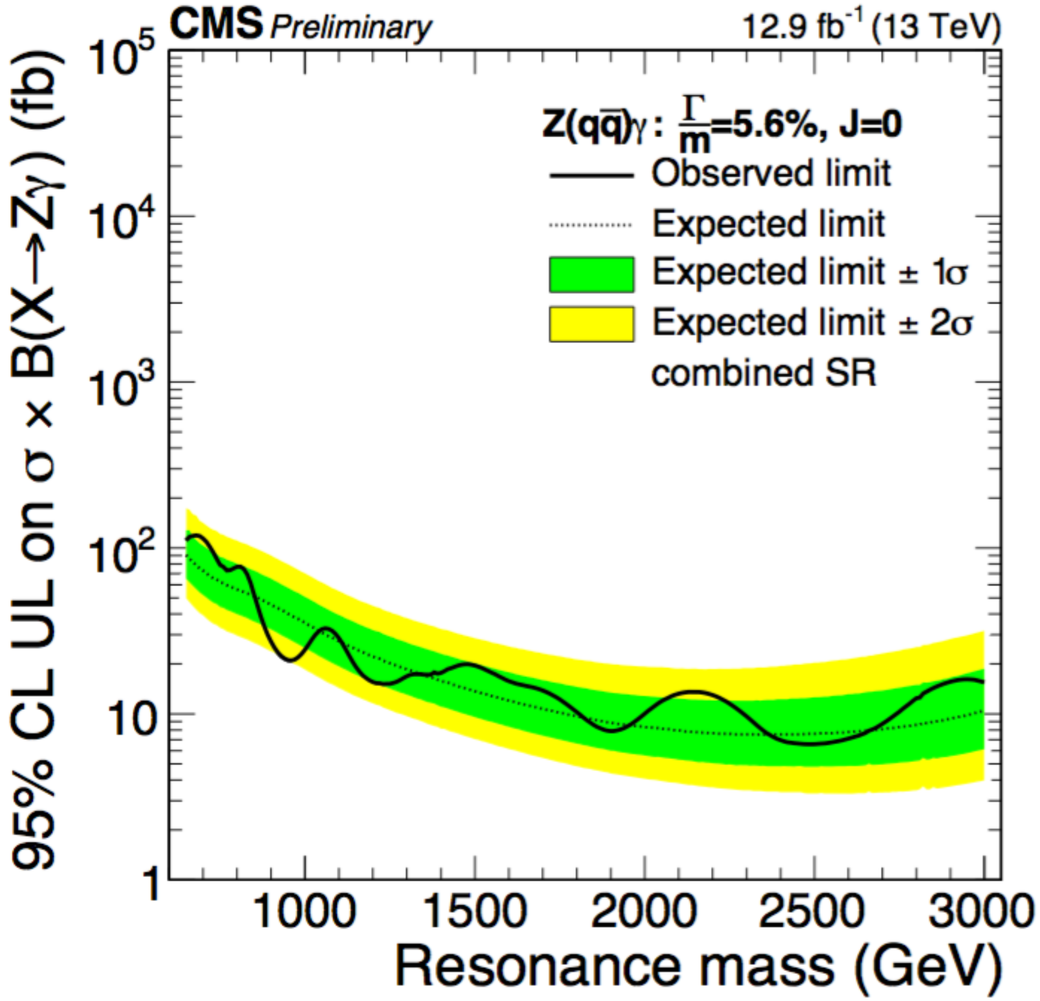

(b) b-tagged SR

CMS-PAS-EXO-16-035

# Boosted topology: Z(qq) + photon




(a) $\frac{\Gamma}{m} = 0.014\%$: combined limit

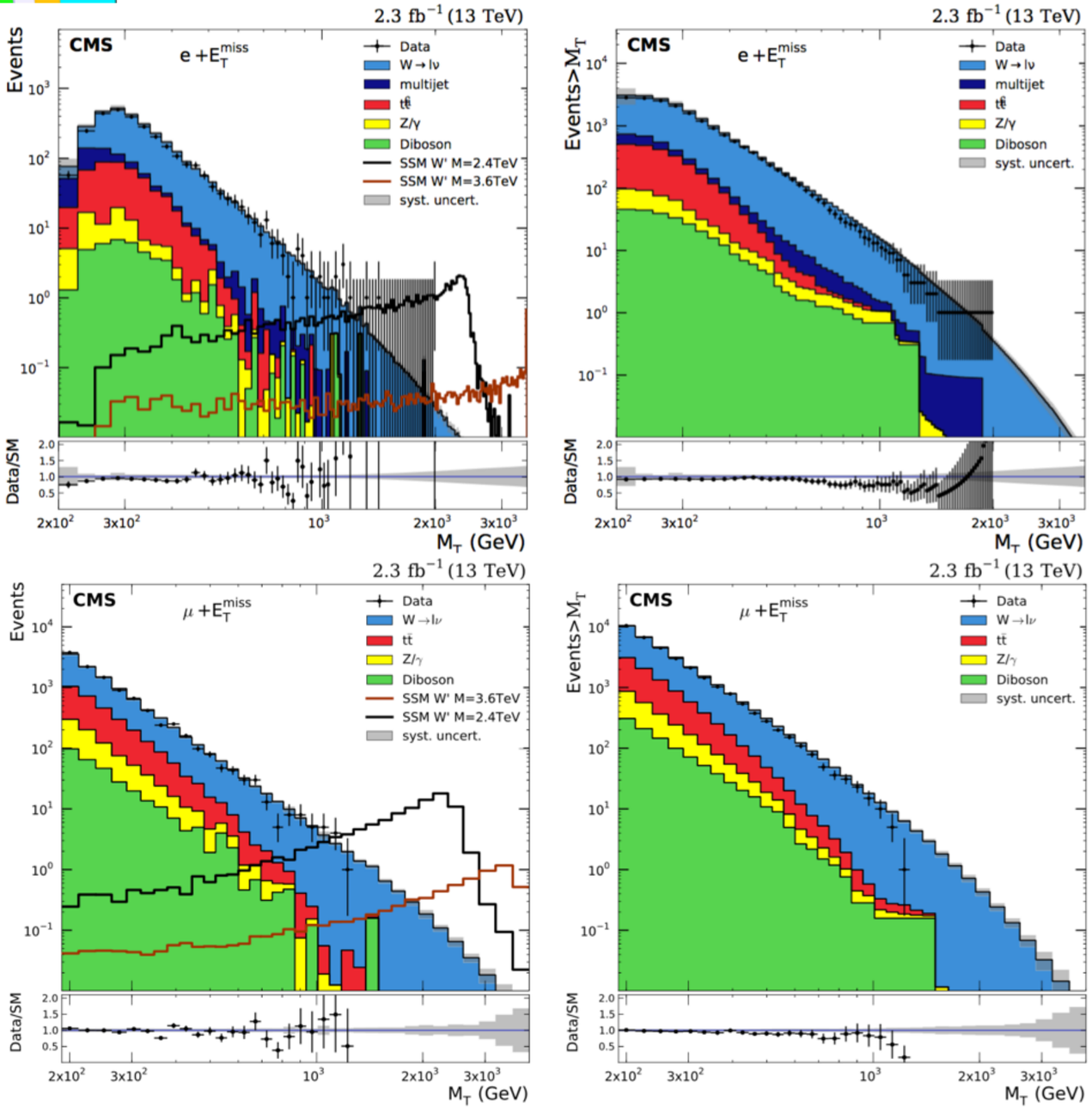


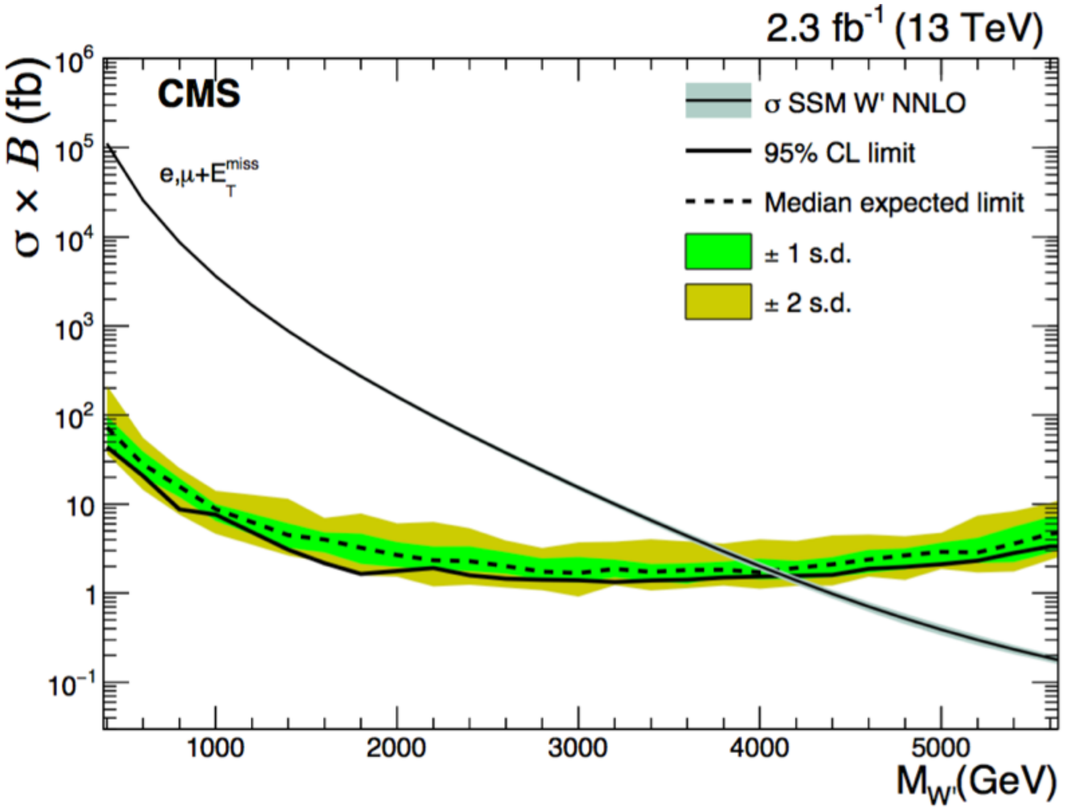

(b) $\frac{\Gamma}{m} = 5.6\%$: combined limit

CMS-PAS-EXO-16-035

# $W' \rightarrow \ell + MET$

CMS-EXO-15-006



# $W' \to \ell + MET$: model-independent limit setting

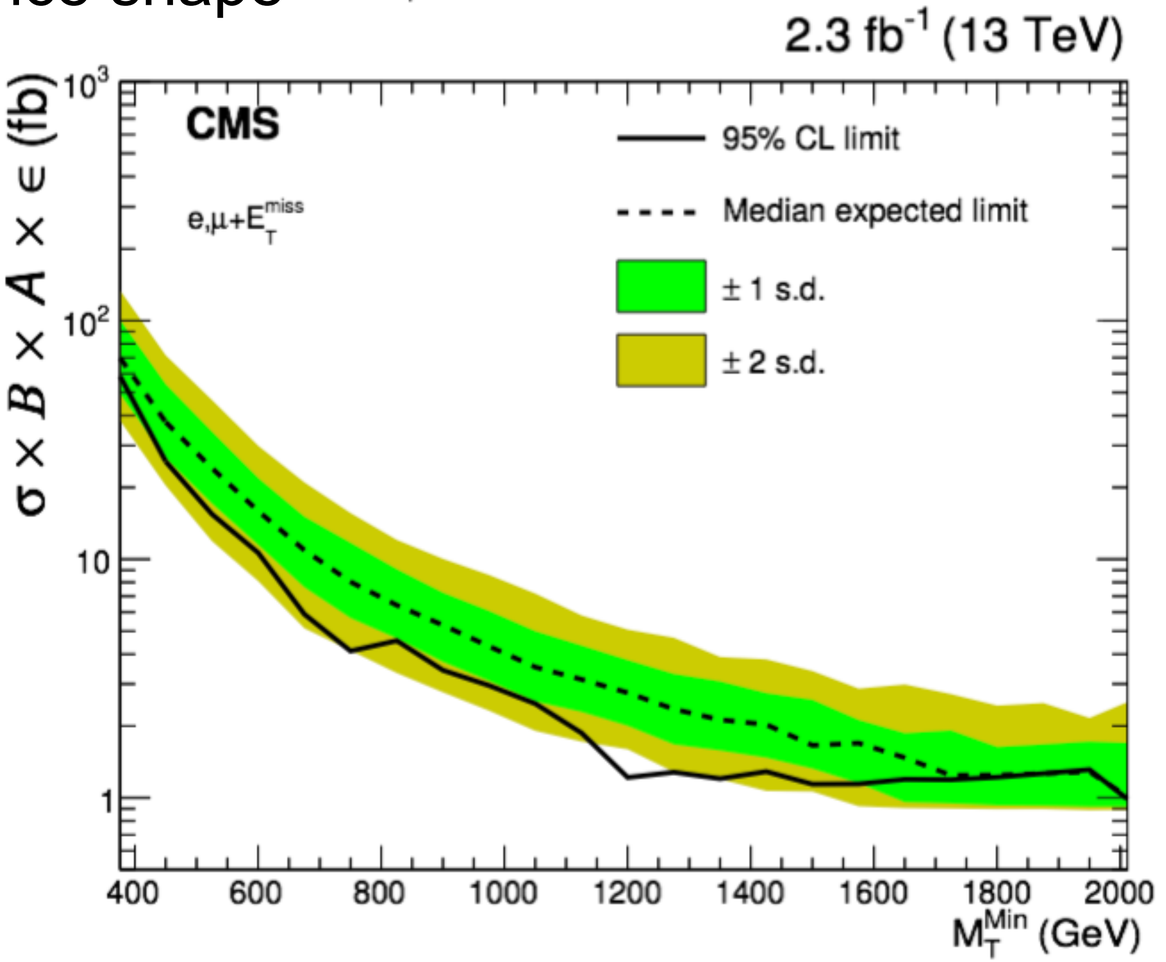
CMS-EXO-15-006

- ☑ Perform a single bin cut-and-count cross-section measurement
- ☑ Such result doesn't depend on the resonance shape

- ☑ If the reconstruction efficiency is uniform (which is the case here for $M_T$>500 GeV), then the limit on a model cross-section can be obtained in a following way:

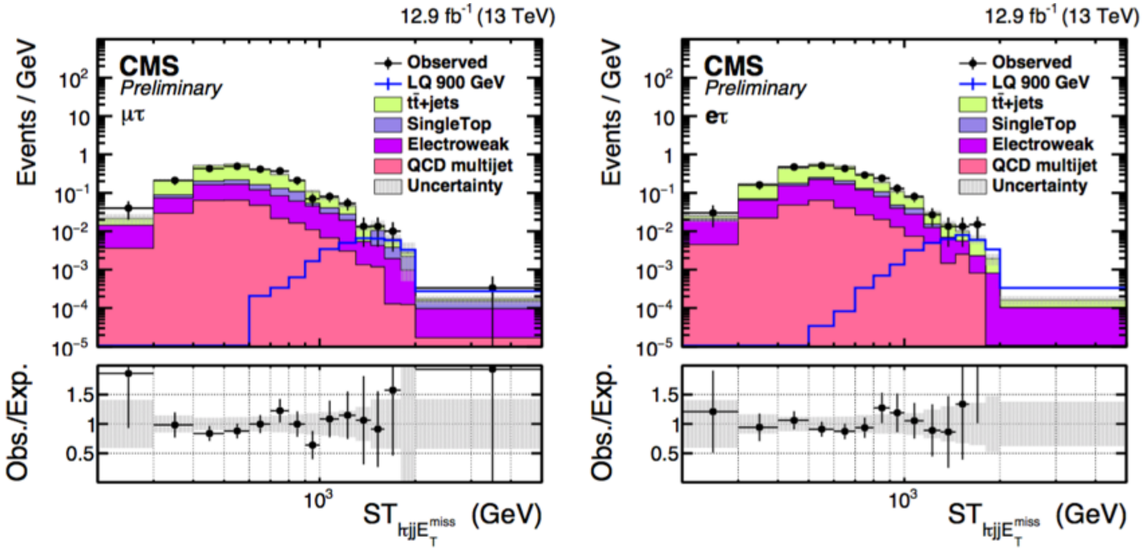
$$(\sigma\,\mathcal{B}\,A\,\epsilon)_{\text{excl}} = \frac{(\sigma\,\mathcal{B}\,A\,\epsilon)_{\text{MI}}(M_{\text{T}}^{\text{min}})}{f_{M_{\text{T}}}(M_{\text{T}}^{\text{min}})}$$

where $f_{M_{\text{T}}}(M_{\text{T}}^{\text{min}})$ is a model-dependent acceptance factor



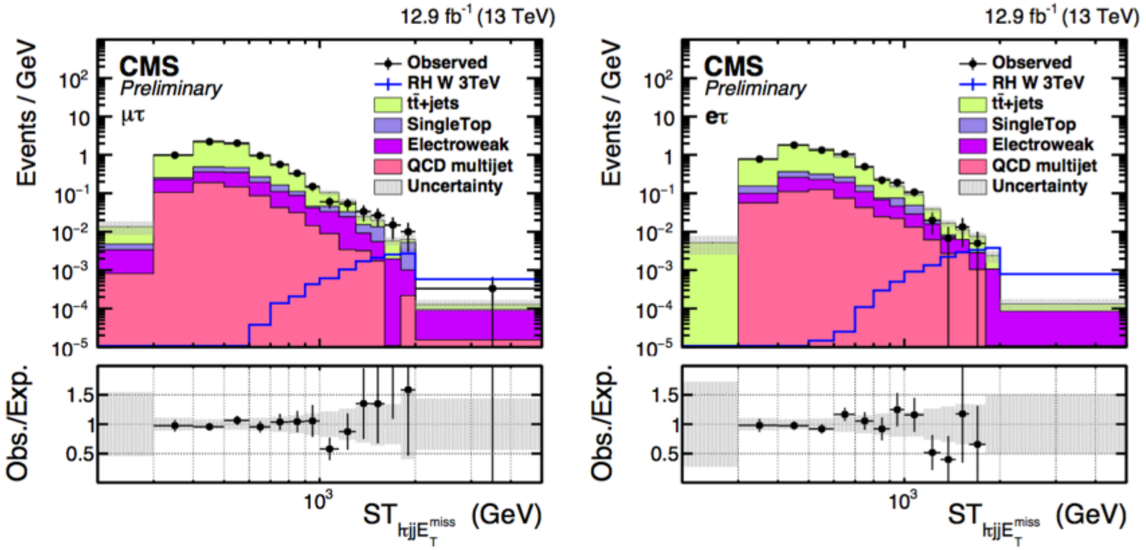
# 3rd generation leptoquarks

$$S_T = p_T(\ell) + p_T(\tau_h) + p_T(jet_1) + p_T(jet_2) + E_T^{miss}$$





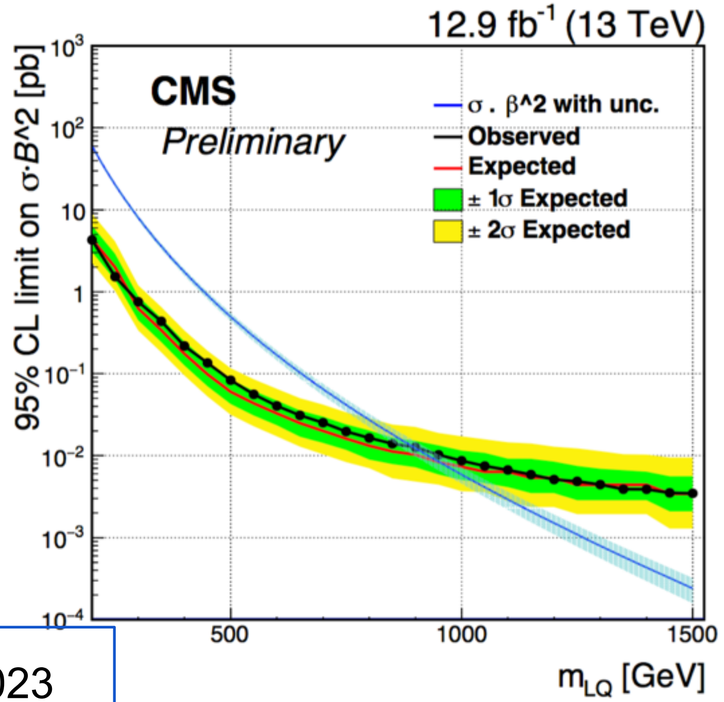


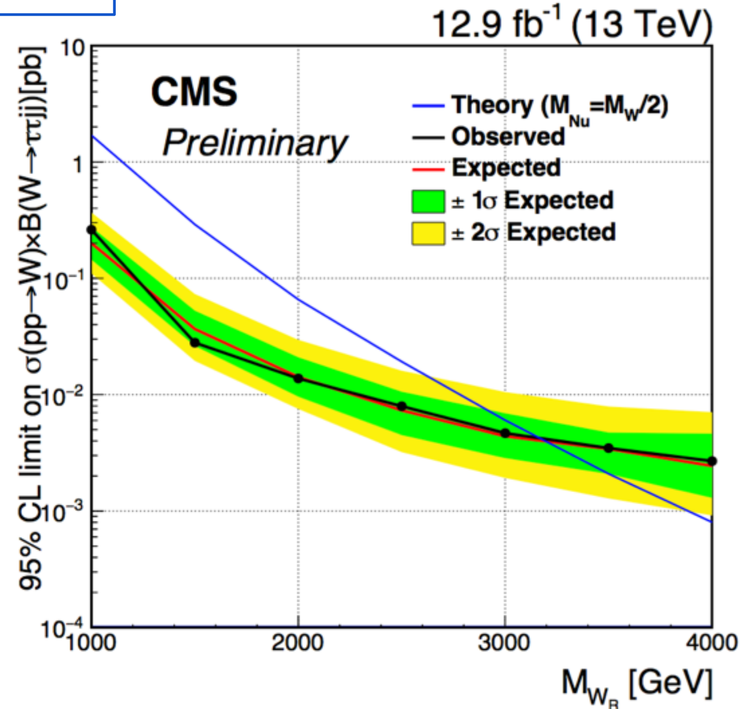




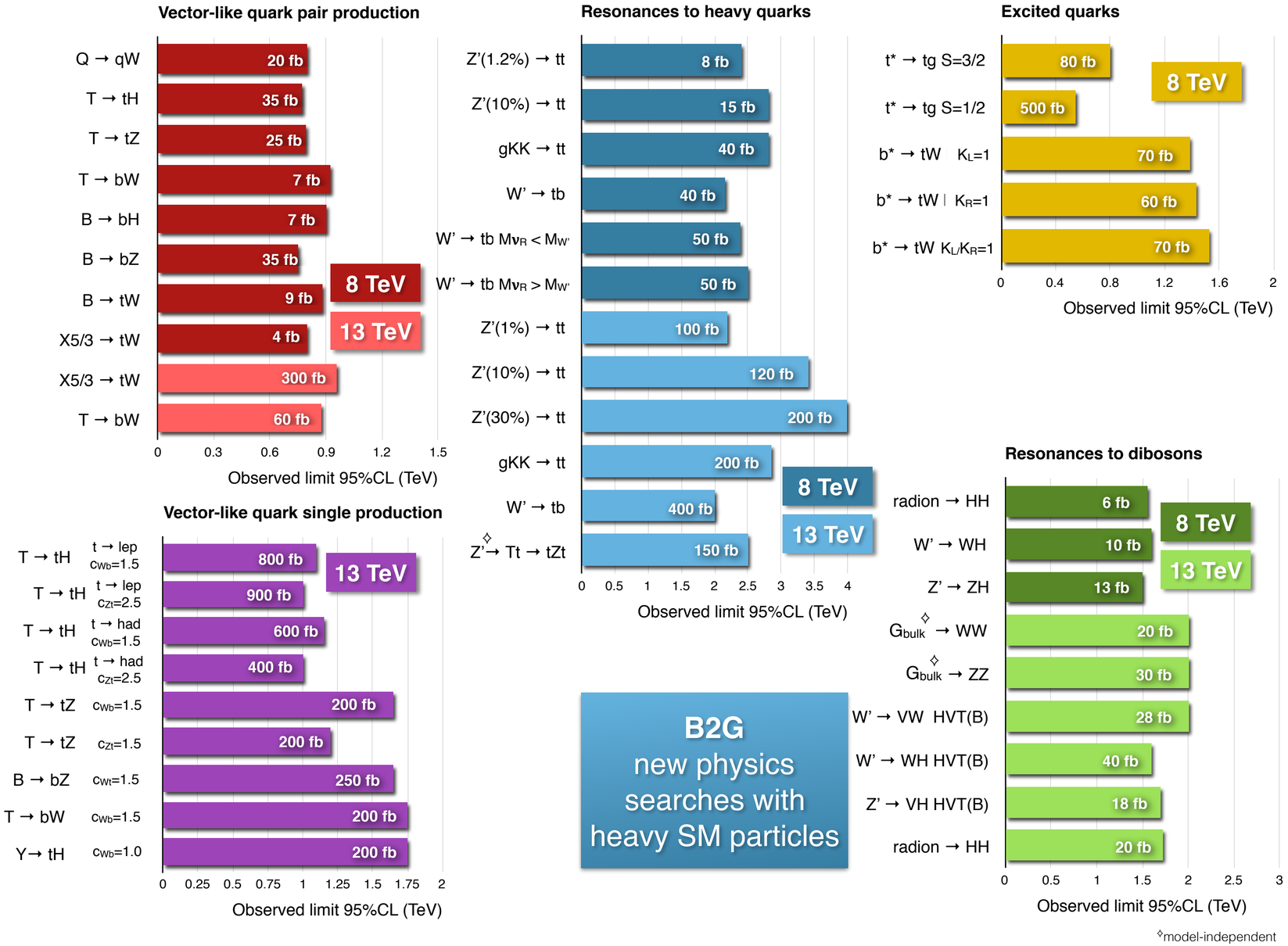


CMS-PAS-EXO-16-023



# Beyond 2 Generations



# Top quark-antiquark all hadronic resonances

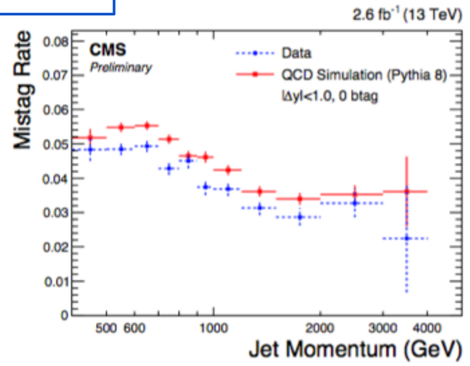
CMS-PAS-B2G-15-003

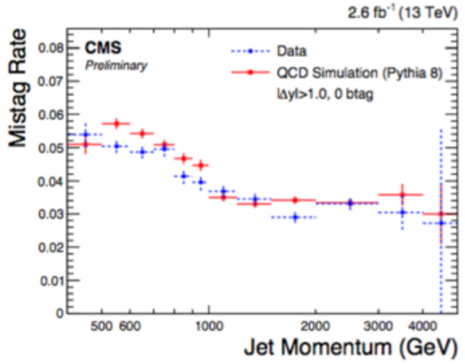
Selection:

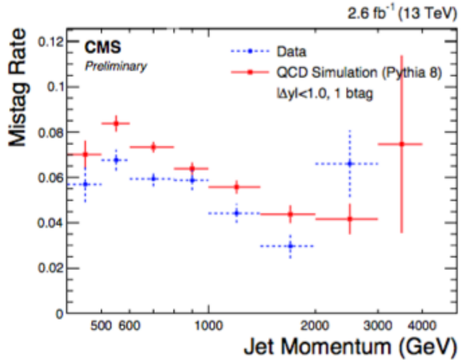
- Dijet back-to-back topology
- pT(jet) > 400 GeV
- Both jets should satisfy top-tagging criteria
- Veto events with leptons

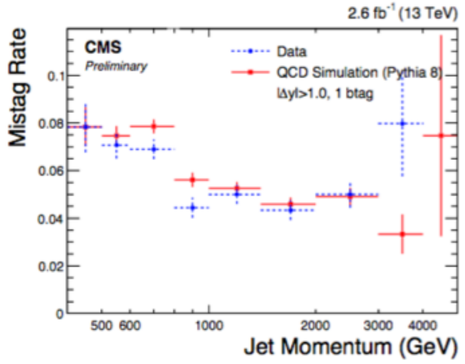
Jet reconstruction and top tagging:

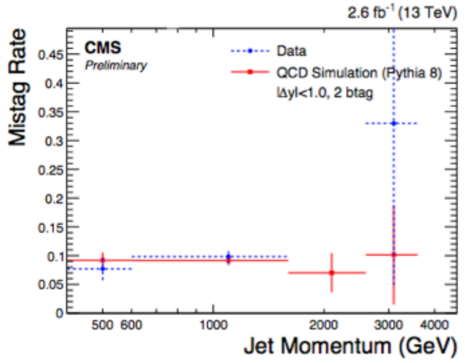
- Anti-Kt algorithm with R=0.8 (AK8 jets)
- Recluster using CA algorithm
- Apply “soft drop” algorithm with angular exponent $\beta = 0$, soft threshold $z_{cut} < 0.1$, and characteristic radius $R_0 = 0.8$
- Identify b quark using combined secondary vertex b-tagging algorithm
- Calculate the N-subjettines for the top quark: $\tau_{32} < 0.69$,
- Apply the mass window $110 < \tilde{M}_{SD} < 210\,\text{GeV}$

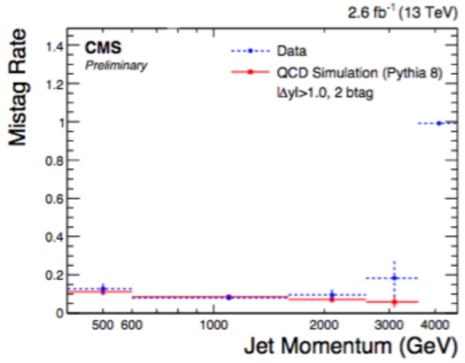


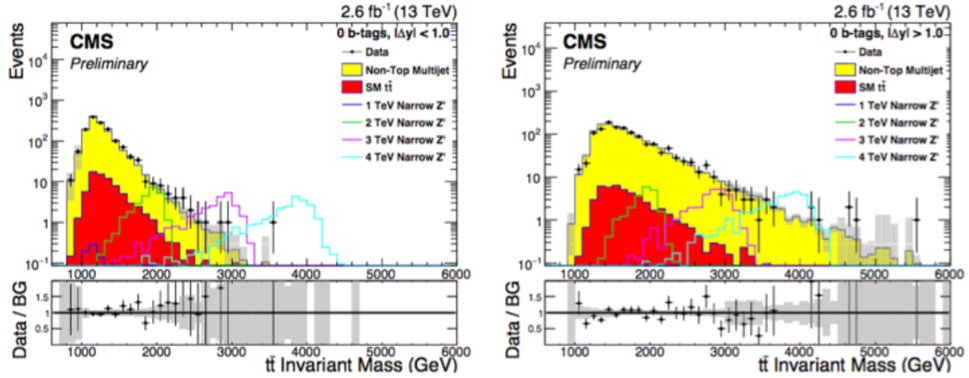



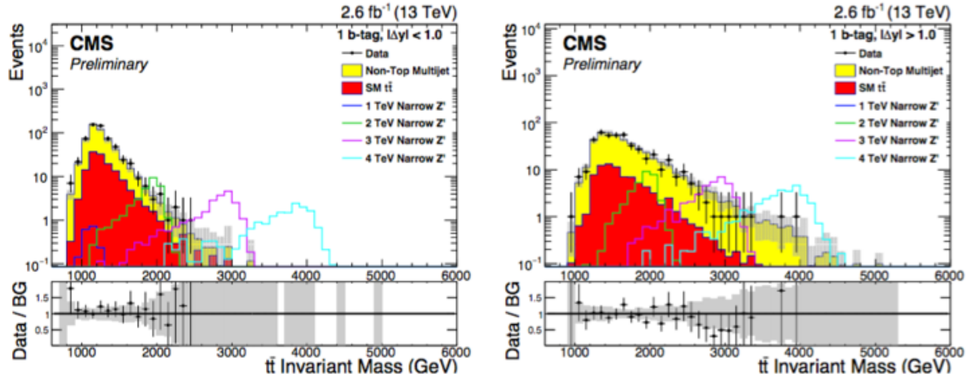
# Top quark-antiquark all hadronic resonances

CMS-PAS-B2G-15-003



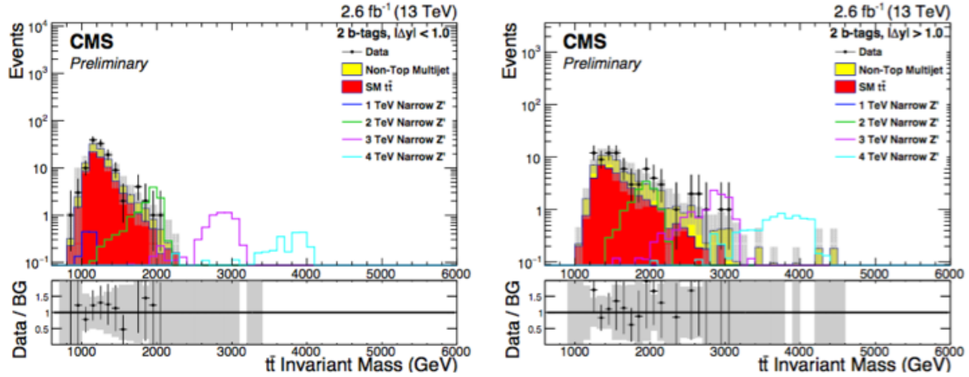






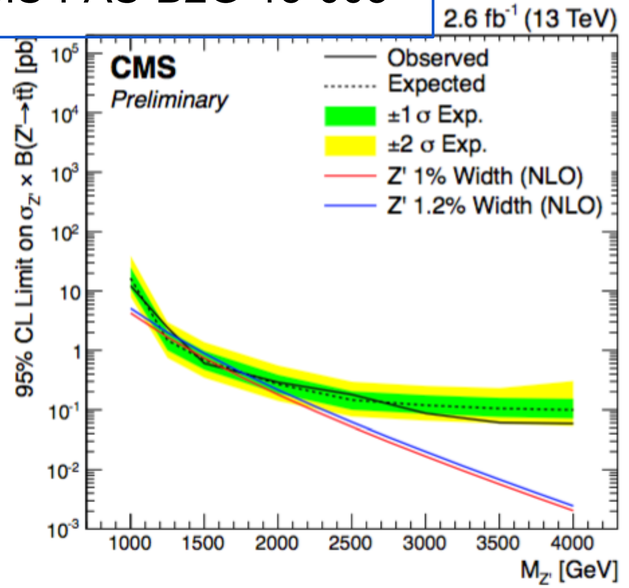


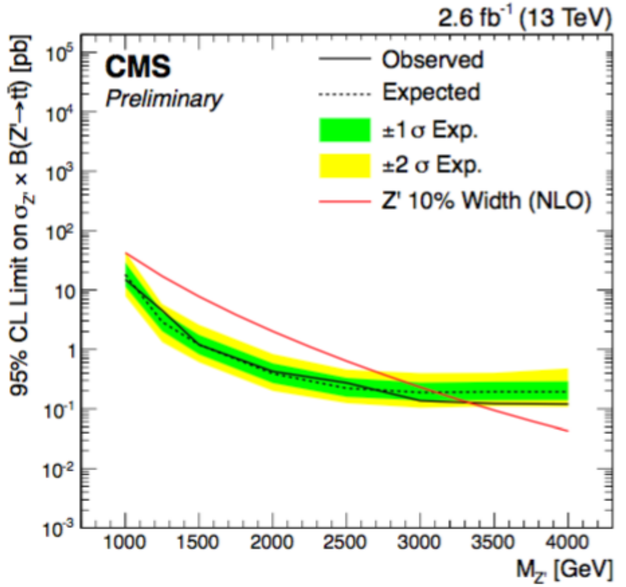


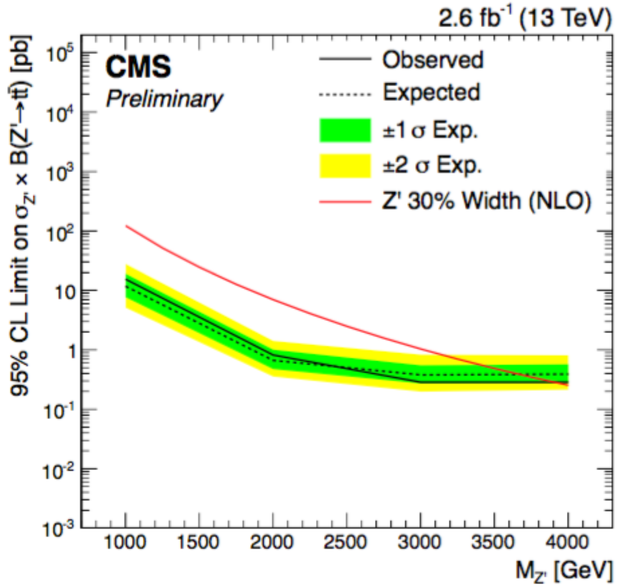


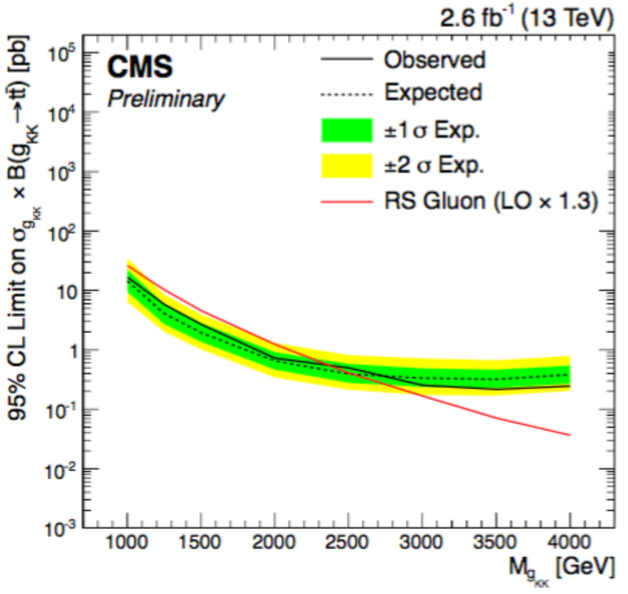






# Conclusions

- ☑ CMS performed very well in 2016
- ☑ A complete set of various EXO analysis covering different topologies have been deployed by CMS
- ☑ Given the current amount of data most of them targeting mainly resonance production in frames of different EFT
- ☑ A good agreement between observation and prediction has been observed in all cases
- ☑ Stay tuned, new data will become public soon!