Exotica at CMS

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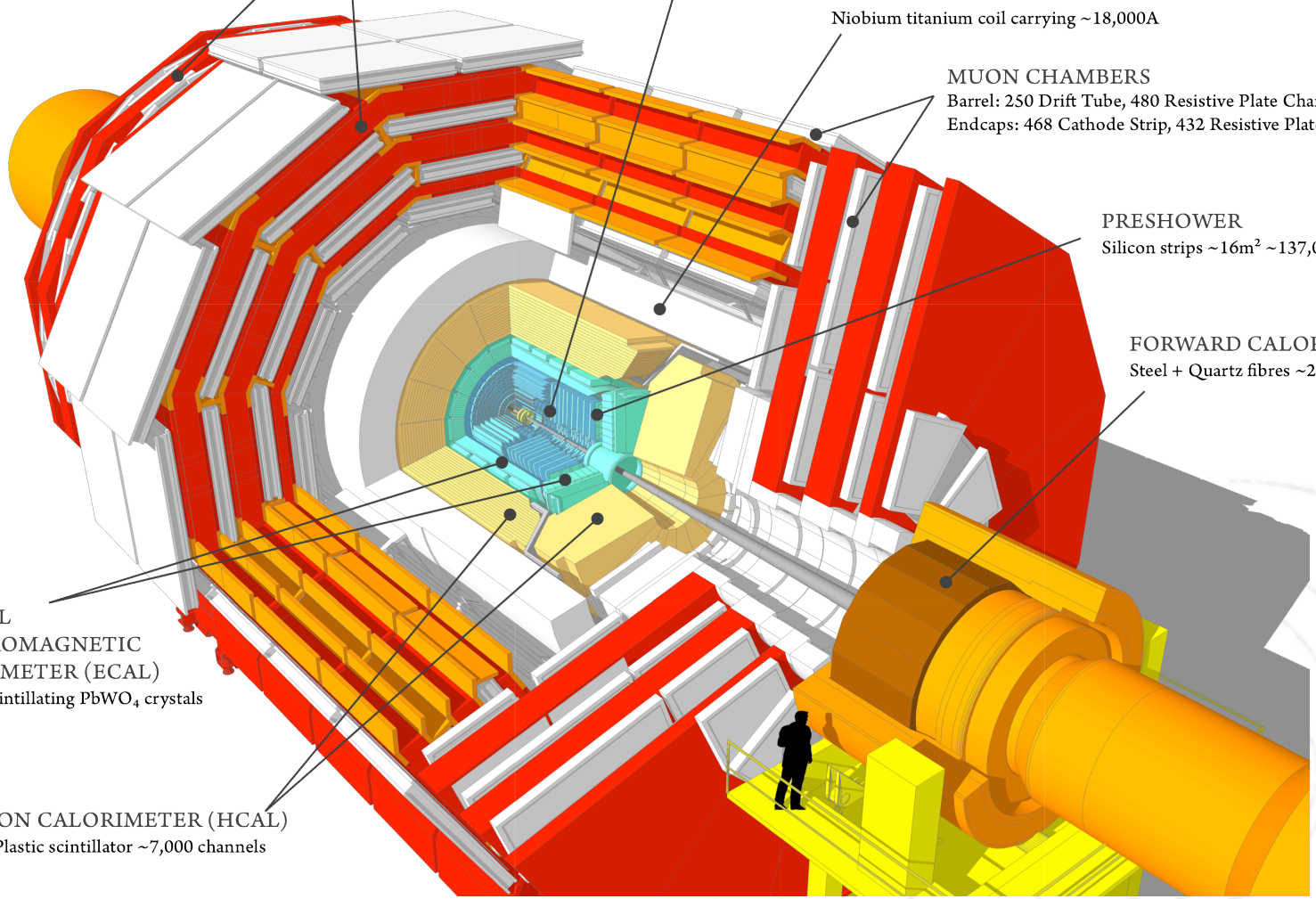
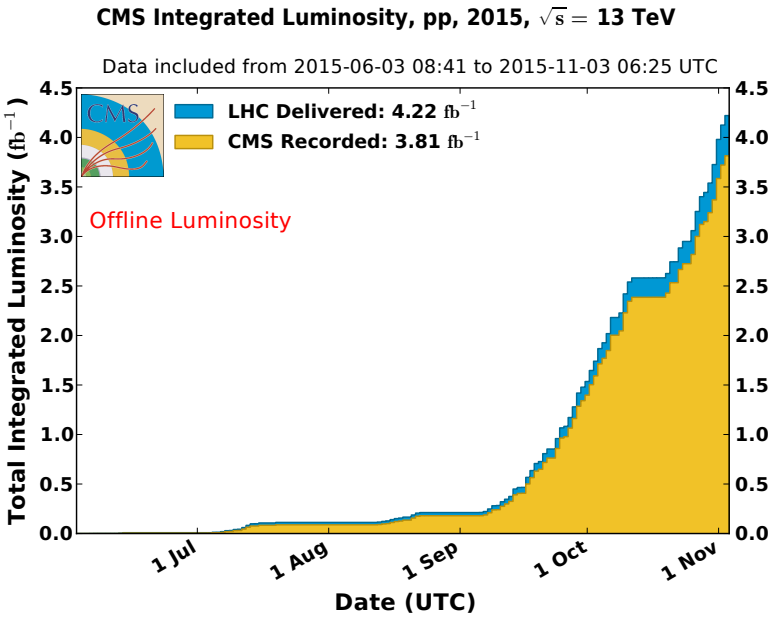
6th International Conference on New Frontiers in Physics

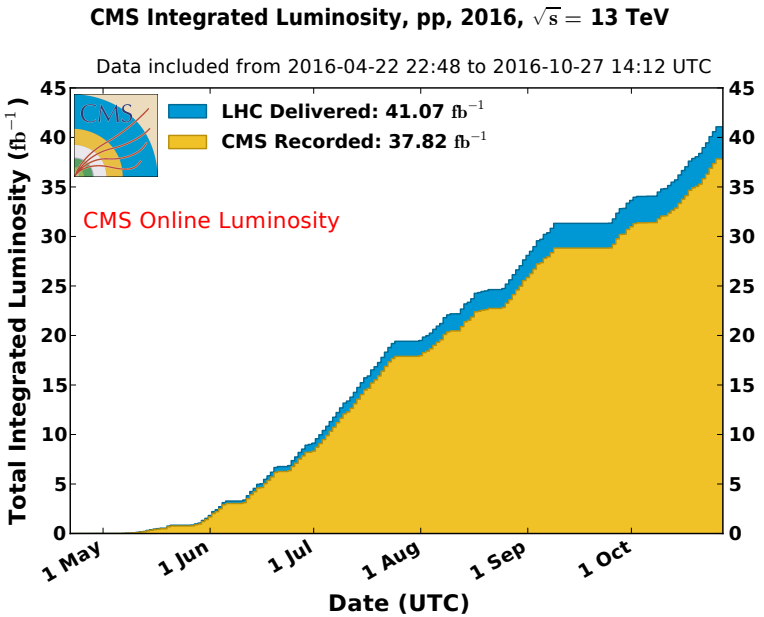
August 23, 2017

Compact Muon Solenoid (CMS)



LHC Run2 @ 13 TeV





- RunII dataset: $\sim$3 fb^{-1} (2015), $\sim$38 fb^{-1}(2016)
- Excellent detector performance
- High data-taking efficiency
- High Energy $\rightarrow$ many searches with boosted topologies

$\Rightarrow$ dedicated algorithms, e.g. jet sub-structure

Beyond the Standart Model searches community at CMS

Exotica group

Generic searches for physics beyond the Standard Model

- Resonances
- Randall–Sundrum Gravitons
- Heavy Gauge Bosons
- Leptoquarks
- Excited Fermions
- Colorons, Axigluons, Diquarks
- ...

Final states:

- Non-hadronic, Jet+X, MET+X, Long-Lived Particles

Beyond-Two-Generations group

New physics featuring the decay to heavy SM objects such as top, W, Z, or Higgs

- Exotic diboson resonances
- Partners of the top quark with vector-like properties (VLQ)
- Heavy resonances, e.g. W' and Z', decaying to final states with top quarks

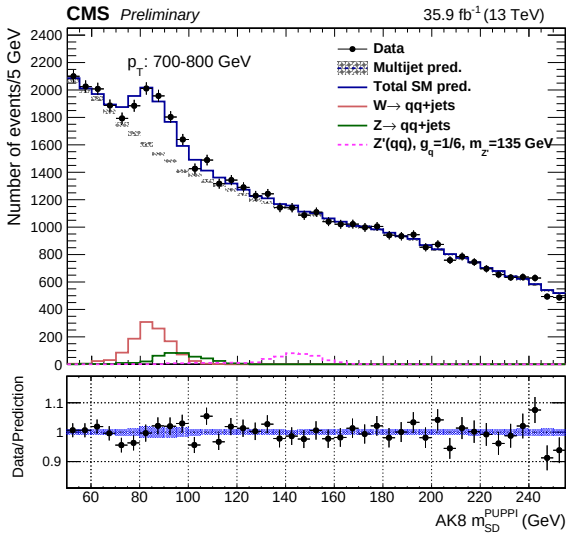
Typical final states signatures involve

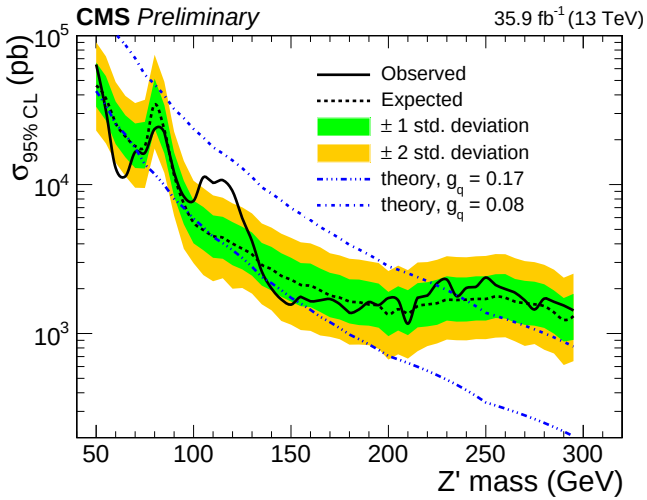
- top quarks, Higgs bosons, vector bosons and/or b quarks

Low mass Di-Jet resonances search

CMS-PAS-EXO-17-001

- Search for leptophobic vector resonances, the mass region 50-300 GeV
- ISR jet with high p_T required to trigger the event
- Resonance reconstructed within single jet:
  - 2-prong substructure (N_2)
  - Groomed (soft drop) mass $\rightarrow$ discriminating variable
  - Transformation employed to decorrelate the soft drop mass from N_2
- Multijet QCD background estimated from data



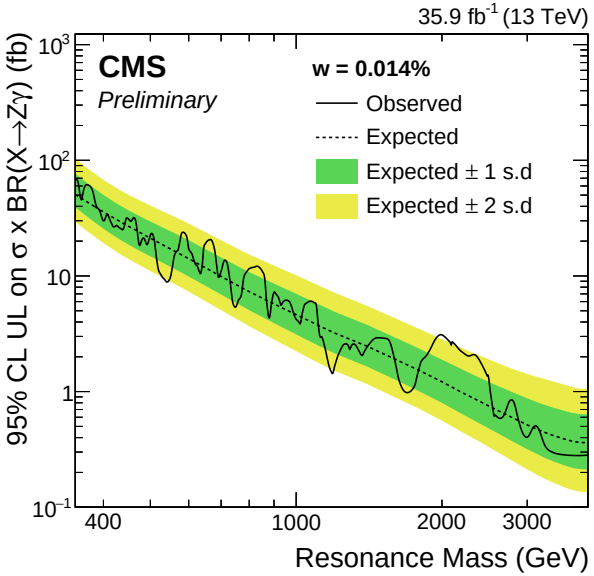


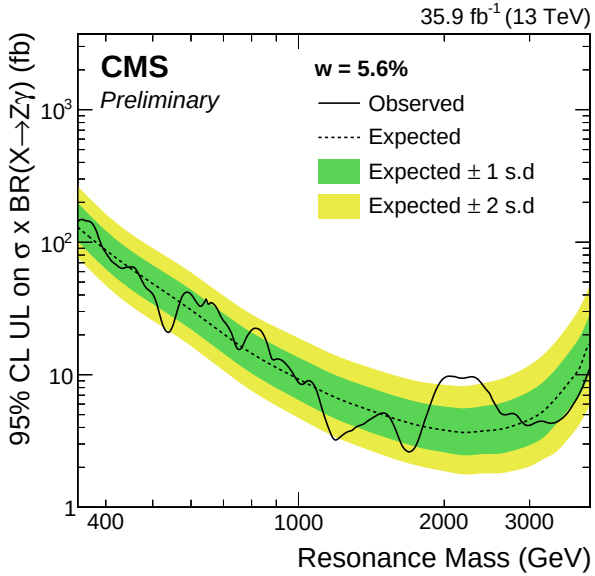
Maximum local p-value (2.9 σ) corresponds to $M_{Z'}$=115 GeV, global p-value 2.2 σ

High-mass resonances in the Z+γ final state

CMS-PAS-EXO-17-005

- Search for spin-0 Z+γ in the leptonic and hadronic decay channels of Z boson
- Z$\rightarrow$ll+γ sensitive for M<$\sim$1 TeV
- Z$\rightarrow$qq dominates the sensitivity for M>2 TeV
  - Merged jet topology $\rightarrow$ cone size R=0.8
  - Pruned with Cambridge-Aachen algorithm jets, sub-jet CSV b-tagging
- Background from direct fit to data



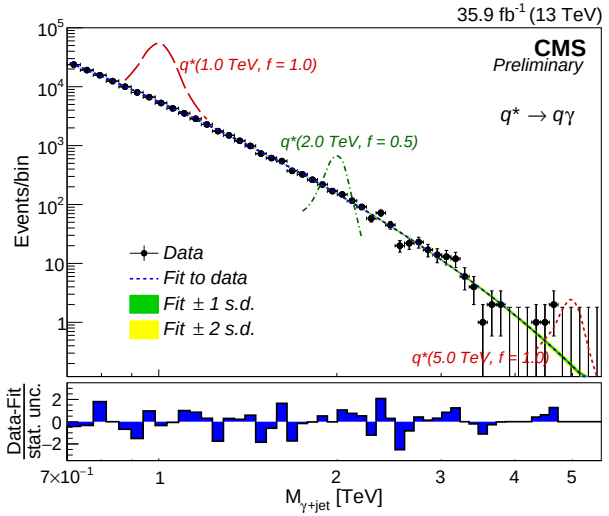


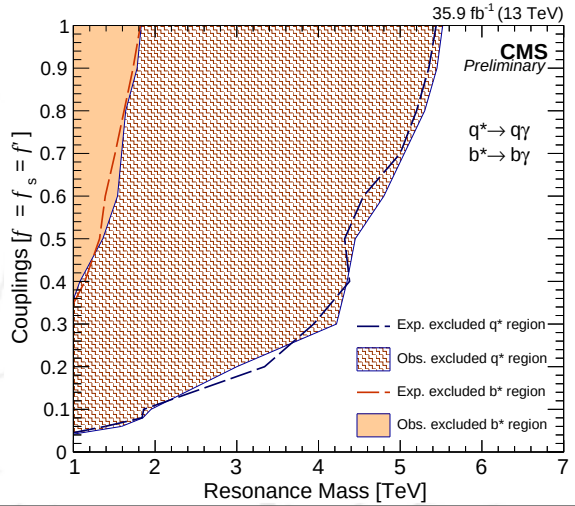
Small ($\sim 2\sigma$) deviation around 2 TeV in jet+γ

Excited states of light and heavy flavor quarks in the γ+jets final state

CMS-PAS-EXO-17-002

- Number of models predict existence of excited states of quarks
- Search for $\mathrm{qg} \to \mathrm{q}^\star \to \mathrm{q}\gamma$, $\mathrm{bg} \to \mathrm{b}^\star \to \mathrm{b}\gamma$ by looking for resonances in γ+jets
- High p_T(>200 GeV) isolated photon, ΔR(jet,γ)>0.5, $\Delta\eta$(jet,γ)<1.5
- Background:
  - QCD multijet
  - The quark-gluon Compton scattering ($\mathrm{qg} \to \mathrm{q}\gamma$)
  - The quark-antiquark annihilation ($\mathrm{qq} \to \mathrm{q}\gamma$)





Observed lower bounds for coupling=1
5.5 TeV ($\mathrm{q}^\star$), 1.8 TeV ($\mathrm{b}^\star$)

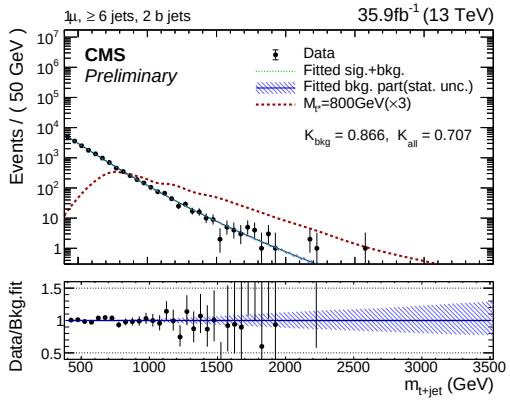
The first result on the search of $\mathrm{b}^\star$ @13 TeV

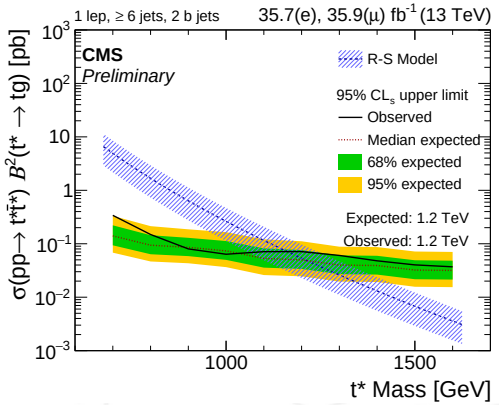
Excited top quarks in the lepton+jets final state

CMS-PAS-B2G-16-025

- Top quark = composite, spin-3/2 particle; dominant decay $t^\star \to tg$
- Search for pair produced $t^\star$:
  $t^\star\bar{t}^\star \to (tg)(\bar{t}g) \to (W^+bg)(W^-\bar{b}g) \to (q_1q_2bg)(l\bar{\nu}\bar{b}g)$
- Finale state: isolated lepton, $\not{E}_T$, at least six jets, two of which must be b-tagged
- Background (mainly SM $t\bar{t}$) estimated with data-driven approach
- Event by event $t^\star$ reconstruction:

$$S = \left(\frac{m_{qq} - M_W}{\sigma_W}\right)^2 + \left(\frac{m_{qqb} - M_t}{\sigma_{t,had}}\right)^2 + \left(\frac{m_{l\nu b} - M_t}{\sigma_{t,lep}}\right)^2 + \left(\frac{m_{l\nu bg} - m_{qqbg}}{\sigma_{t^\star}}\right)^2$$



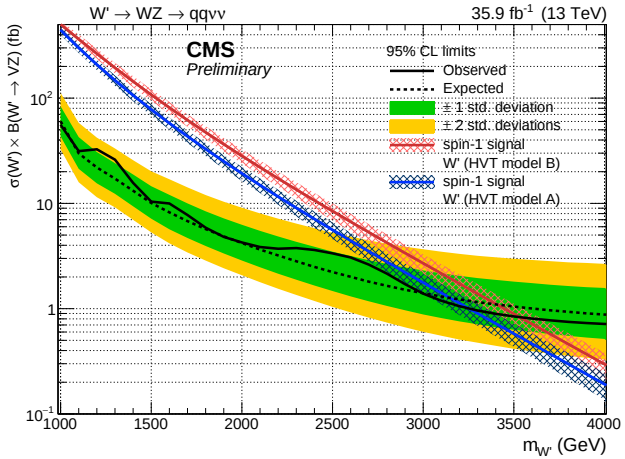


Heavy resonances in the $\nu\nu q\bar{q}$ final state

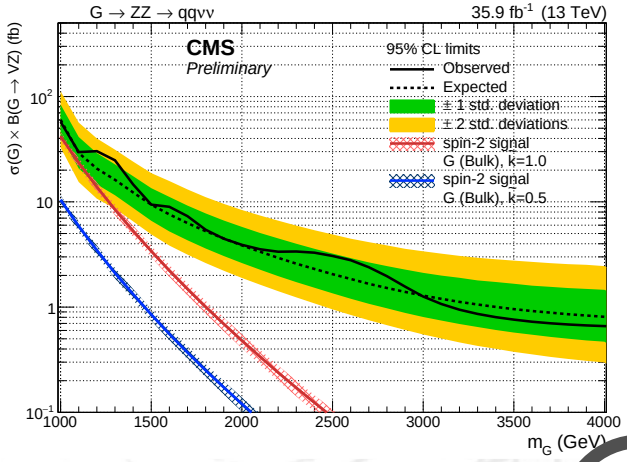
CMS-PAS-B2G-17-005

- Search for heavy resonances decaying into a pair of vector bosons:
  ZZ or ZW $\rightarrow (\nu\nu)(q\bar{q})$
- The vector bosons produced back-to-back with large Lorentz boost
- Selection: $\not{E}_T$ (>200 GeV) + AK8 jet (p_T>200 GeV, $|\eta|$<2.4)
- Jet mass expected to lie withing a window around W and Z mass
- τ_{21} n-subjettiness ratio to distinguish jets with two substructure components
- AK4 jets outside the cone of AK8 jets used for background rejection
  - Top jets with b-tagging
  - Multijet QCD with $\Delta\phi$(AK4 jet,$\not{E}_T$)>0.5 rad
- Data-driven background estimate with α-method

spin-1 HVT



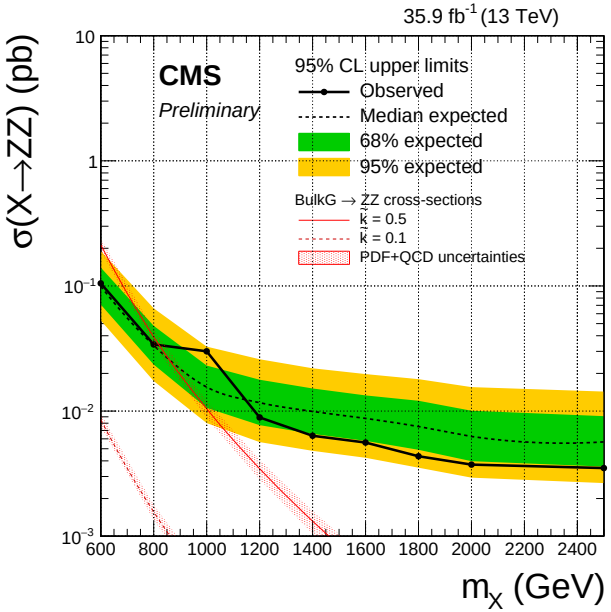
spin-2 bulk graviton

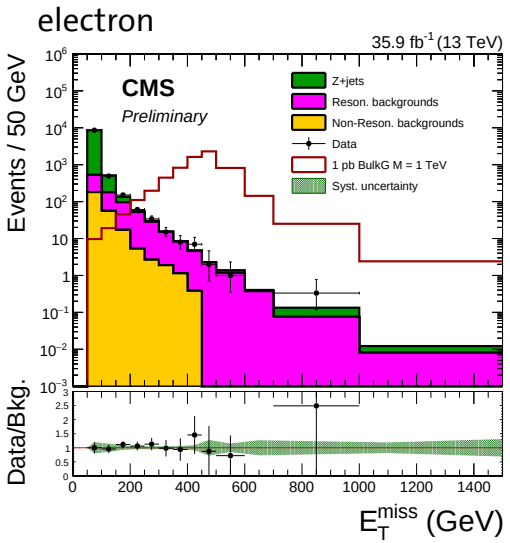


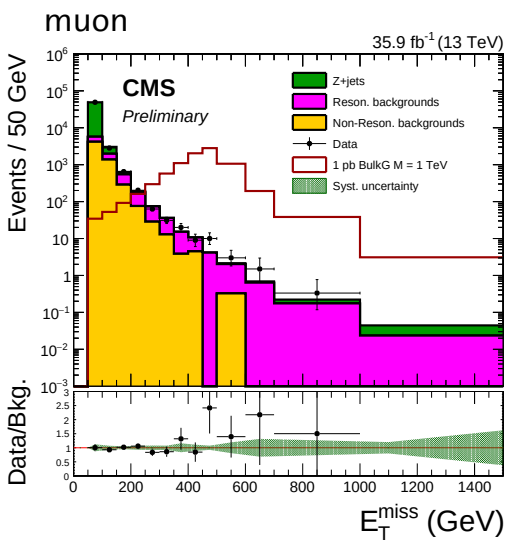
Heavy resonances in the ZZ→(νν)(ll) final state

CMS-PAS-B2G-16-023

- Selection: $\not{E}_T$ and 2 opposite sign leptons with 70 GeV<M_{ll}<110 GeV
- The ZZ produced back-to-back → $|\Delta\phi(Z, \not{E}_T)|$>0.5
- Data-driven background estimate
  - γ+jets to estimate Drell-Yan Z+jets with instrumental $\not{E}_T$
  - Dilepton $e\mu$ to describe non-resonant background



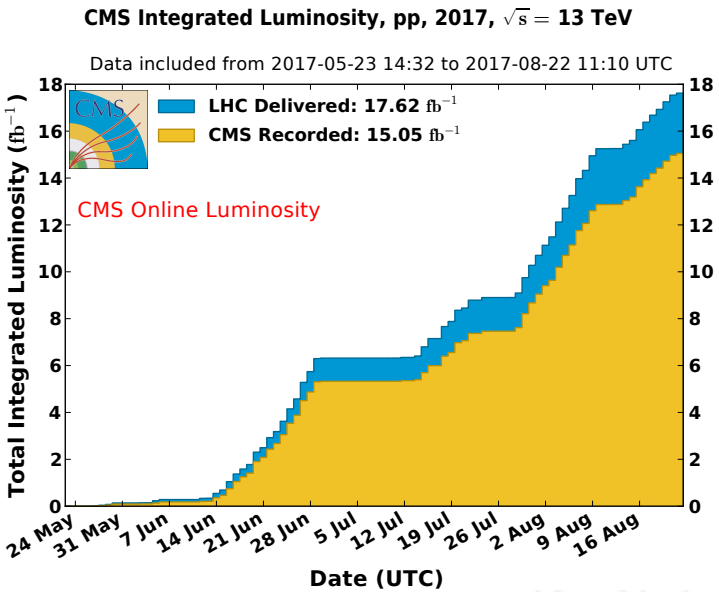




- Higher sensitivity in the low mass region (<1.5 TeV) compare to all hadronic channel

Conclusion

- CMS keep exploring the new energy scale (13 TeV) using $\sim$40 fb^{-1} dataset
- Large number of physics analyses with multiple number of final states
- Data-driven background is useful tool complementary to MC simulation
- No evidence for new physics so far
- LHC continues data taking until the end of 2018
- Expecting $\sim$3 times more data than used in the presented analyses



Stay Tuned!

Back up

Heavy resonances in the ZZ→($\nu\nu$)(ll) final state. Systematic

	Source	Signal	Z+jets	Reson.	Non-Reso
	Luminosity	2.5%	2.5%	2.5%	2.5%
	PDF on cross-section	-	1.7%	1.7%	-
	QCD on cross-section	-	2.3%	3.0%	-
	EW NLO correction	-		3.0%	-
Electron channel	PDF on acceptance	1.0%	3.4%	1.0%	-
	QCD on acceptance	(-)	22.7%	2.9%	-
	Trigger eff.	0.1%	-	(-)	-
	Lepton ID eff.	0.5%	-	(-)	-
	Z p_T reweighting	-	2.1%	-	-
	Non-reson. scale fact.	-	-	-	10.0%
E_T^{miss} modeling uncertainties	Muon scale	0.1%	-	10.1%	-
	Elec. scale	1.8%	-	0.4%	-
	Photon scale	2.9%	-	0.5%	-
	Jet energy scale	1.5%	-	0.4%	-
	Jet energy resolution	1.5%	-	0.5%	-
	Unclustered E	2.3%	-	0.5%	-
	Hadronic recoil	-	0.1%	-	-
Muon channel	PDF on acceptance	1.0%	3.4%	1.0%	-
	QCD on acceptance	(-)	13.1%	2.9%	-
	Trigger eff.	0.2%	-	(-)	-
	Lepton ID eff.	0.9%	-	(-)	-
	Tracking eff.	1.0%	1.0%	1.0%	1.0%
	Z p_T reweighting	-	0.5%	-	-
	Non-reson. scale fact.	-	-	-	2.4%
E_T^{miss} modeling uncertainties	Muon scale	10.9%	-	1.8%	-
	Elec. scale	(-)	-	(-)	-
	Photon scale	0.1%	-	(-)	-
	Jet energy scale	1.2%	-	0.1%	-
	Jet energy resolution	1.9%	-	0.2%	-
	Unclustered E	1.8%	-	0.3%	-
	Hadronic recoil	-	0.1%	-	-