Searches for resonant and non-resonant new phenomena in CMS

EPS-HEP Conference, Vienna, 22-29 July 2015

This talk will not cover:

- Search for NP in **multilepton final states** (see Shilpi jain's talk)
- Search for NP in **diboson final states** (see Viviana Cavaliere's talk)
- Search for top/bottom partners and top/bottom pair signatures (see Ivan Marchesini's talk)

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Overview

1) RUN1 results from CMS

Results based on 2012 datasets, luminosity about 20 fb^{-1}

Focus on new preliminary results or newly published final results

Searches for narrow or broad resonances and searches for an excess in the tail of mass or transverse momentum distributions in final states :

- Di-jets and mutijet mass spectra
- Di-lepton (ee, μμ, ττ) mass spectra
- Di-photon mass spectrum
- lepton+MET final states

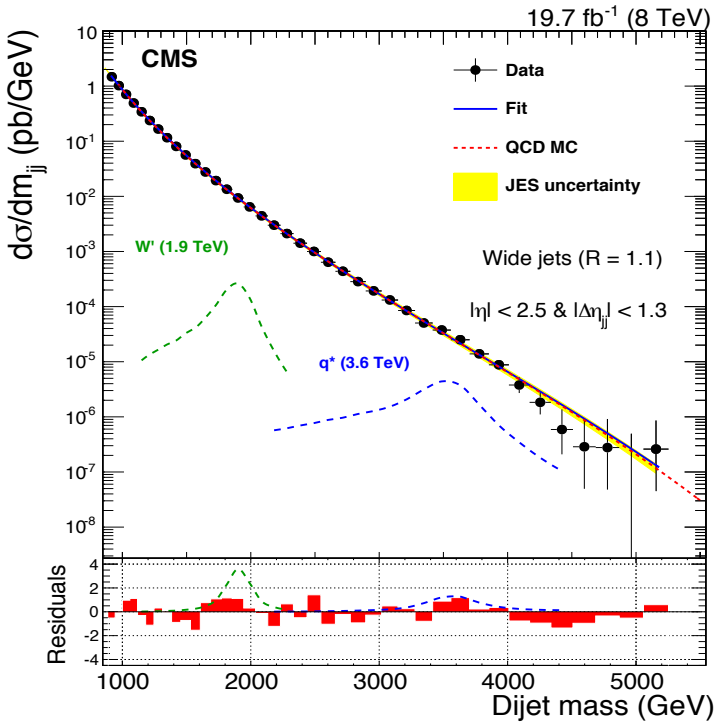
2) First look at the CMS RUN2 data – PRELIMINARY results

- Di-jet invariant mass spectrum
- Displays of the highest di-lepton and (lepton+MET) mass events

Di-jet mass spectrum

PRD 91, 052009, arXiv:1501.05603

- Search for hint of new physics in the di-jet mass spectra / narrow and wide resonances
- Provide a model independent upper limits on sigmaxBR



CMS

$p_T(j) > 30$ GeV
$|\eta(j)| < 2.5$ and $|\Delta\eta_{jj}| < 1.3$
$m(jj) > 890$ GeV to remove trigger bias

- The Particle Flow candidates clustered into jets using the anti-kT algorithm with DR = 0.5
- Geometrically close jets (DR<1.1) combined into "wide jets", which are used to measure m_{jj}
- Also : spectrum divided in categories : 0, 1, 2-btag jets

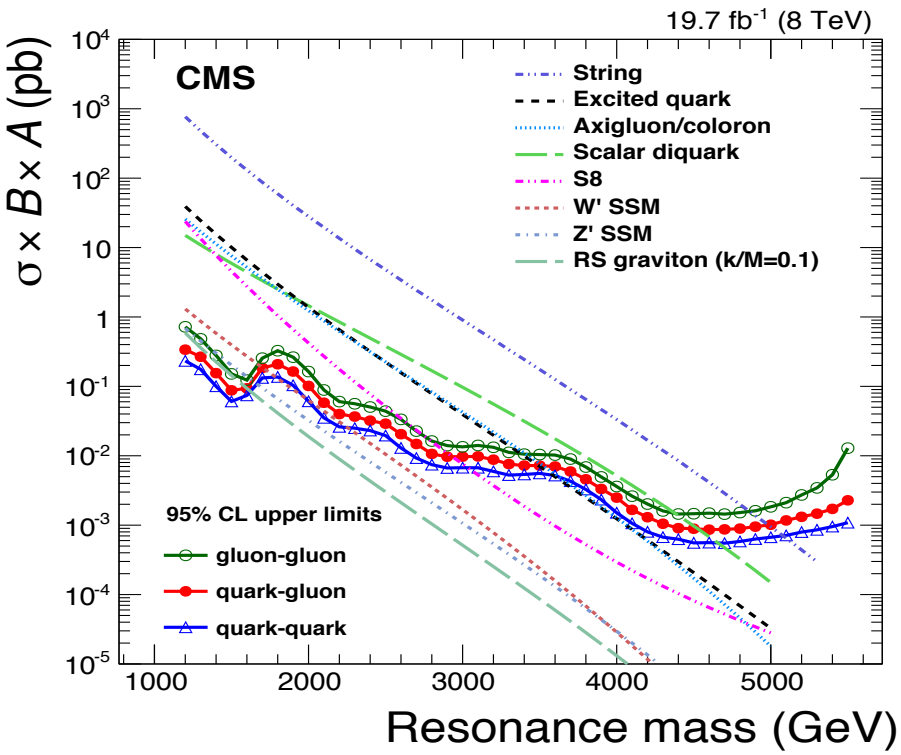
- Highest di-jet mass event at 5.15 TeV
- Dominant systematic uncertainties: jet energy scale, jet energy resolution, luminosity

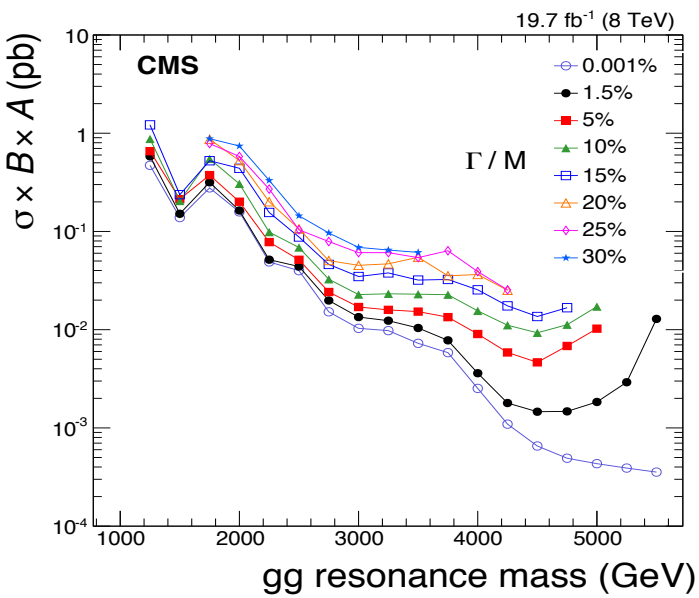
Di-jet resonances

Observed limits on gg, qg and qq narrow resonances compared to LO predictions for several models.

Mass exclusion results for narrow resonances :

- String resonances < 5.0 TeV,
- Excited quarks < 3.5 TeV,
- Scalar di-quarks < 4.7 TeV
- W' (SSM) bosons < 2.2 TeV
- Z' (SSM) bosons < 1.7 TeV
- RS Gravitons (c=0.1) < 1.6 TeV





Wide resonances : width to mass ratio up to 30%

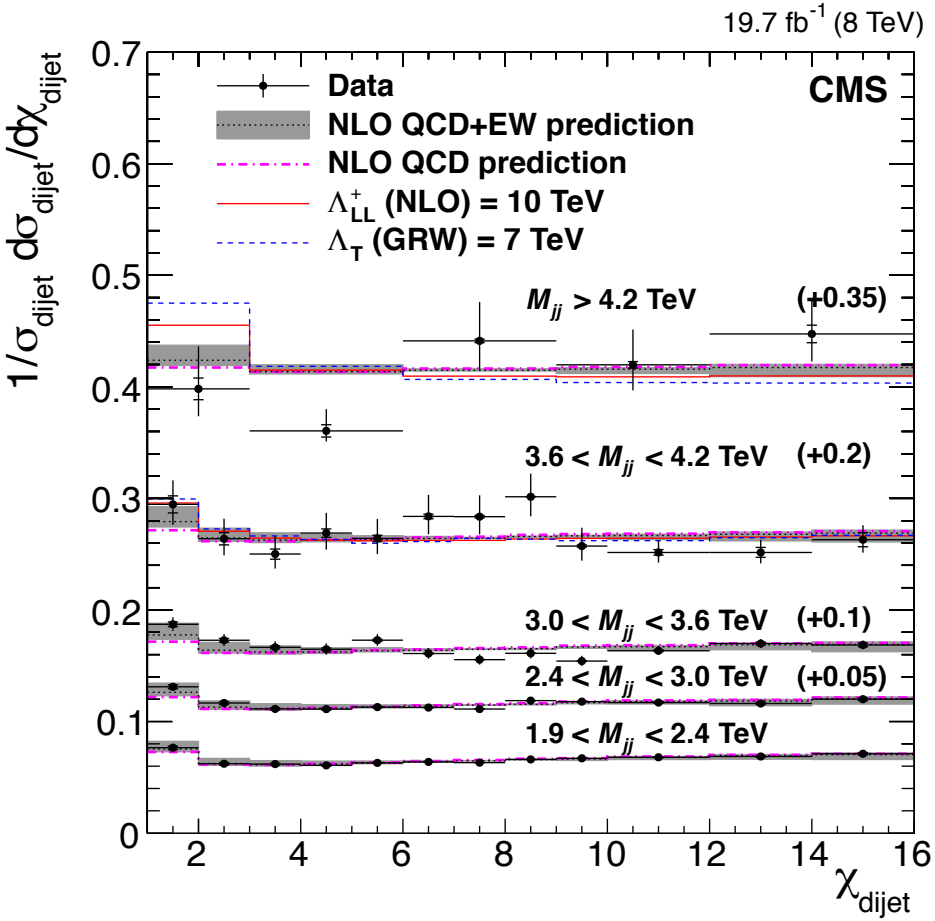
- Axigluons and colorons < 3.6 TeV
- Color-octets scalars < 2.5 TeV

Mass of quantum black holes :

- Lower bounds between 5.0 and 6.3 TeV

Di-jet angular distributions

Phys. Lett. 04 (2015) 042, arXiv:1411.2646



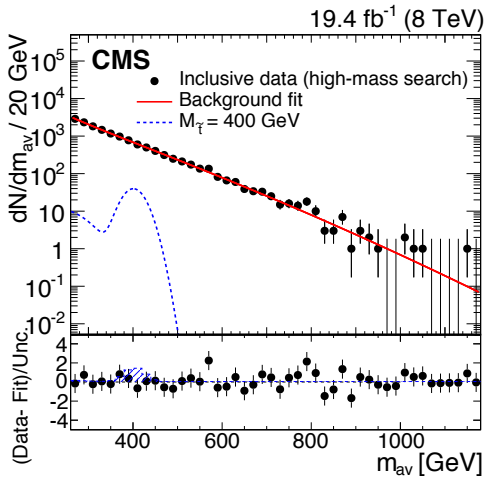
Search for quark contact interactions and extra spatial dimensions in di-jet angular distributions

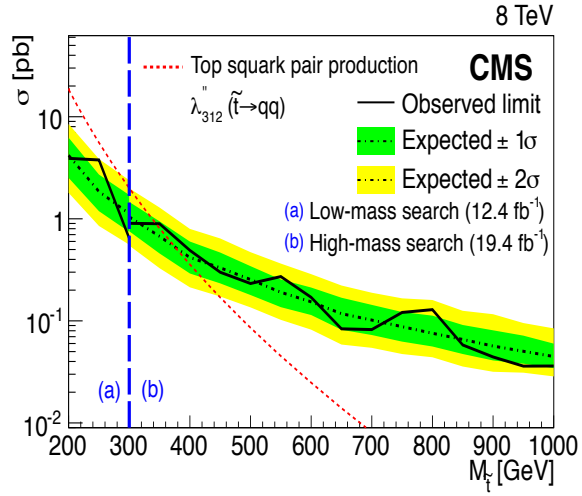
- Red line : prediction for SM+CI with Λ_{LL}^{+} (NLO)=10 TeV
- Blue dashed line : prediction for SM +ADD with Λ_T(GRW)=7 TeV
- SM prediction : perturbative NLO QCD prediction + EWK NLO corrections

X(dijet) = exp(|y1 − y2|); y1,y2=rapidities of the jets
For the scattering of massless partons, χ(dijet) is related to the polar scattering angle θ∗ in the partonic CMF by χ(dijet) = (1 + |cos θ∗|)/(1 − |cos θ∗|)

Muti-jet resonances

- **Pair produced resonances decaying to jets: X→YY, Y→ jj**

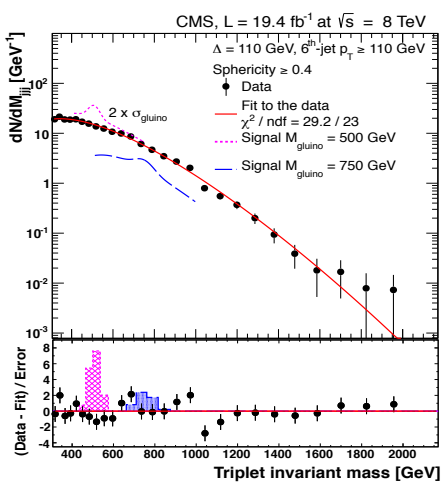


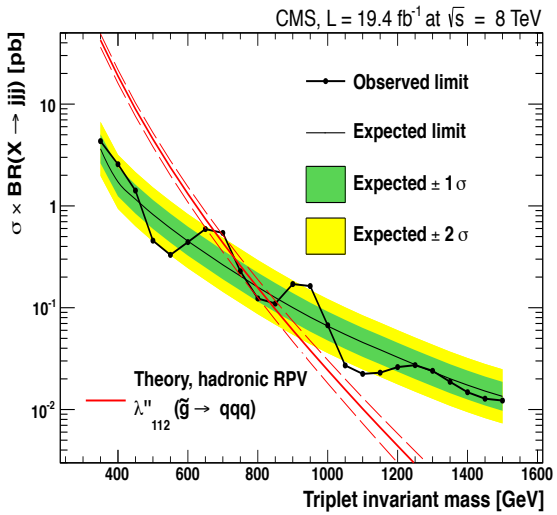


Phys. Lett. 04 (2015) 045, arXiv:1412.7706

Exclude top squark masses for RPV decays to light (heavy) jets in range: 200 < m(jj) < 350 (385) GeV

- **Resonances with three-jet final states: X→ZZ, Z →jjj**





Exclude gluino masses for RPV decays to light (heavy) jets in range: 0 (200) < m(jjj) < 350 (835) GeV

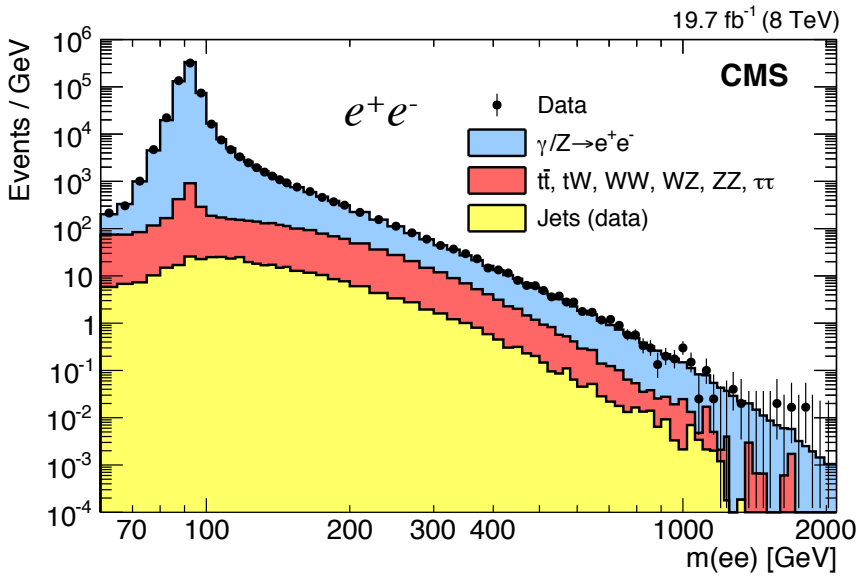
Phys. Lett. B 730 (2014) 193, arXiv:1311.1799

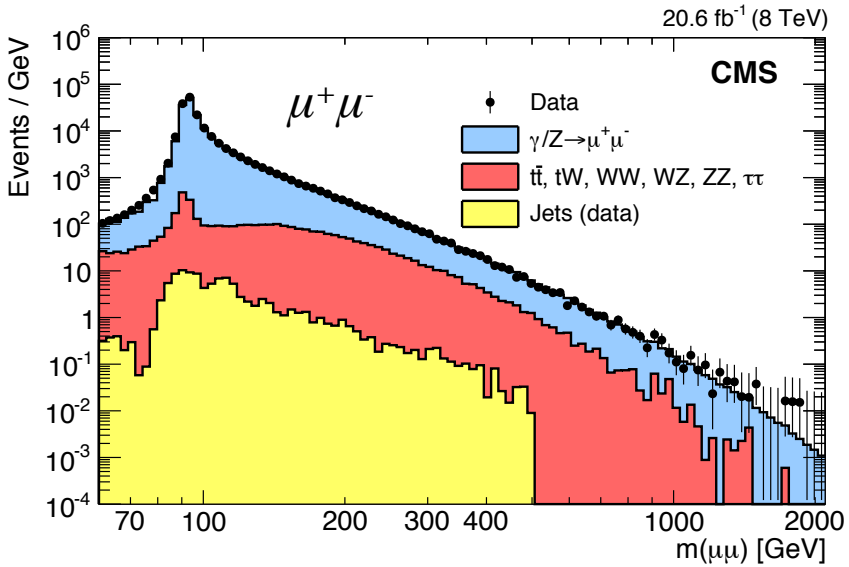
Di-lepton (ee and μμ) mass spectrum

JHEP04 (2015) 025, arXiv:1412.6302

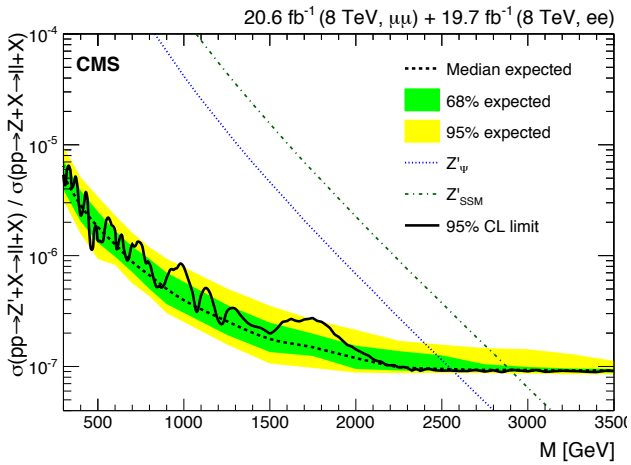
- Simple final states, low backgrounds
- Main backgrounds : Drell-Yan, top-antitop, WW, and multijet from QCD processes (for the electron channel)
- Highest mass event : 1.79 TeV (ee channel) and 1.87 TeV (μμ channel)

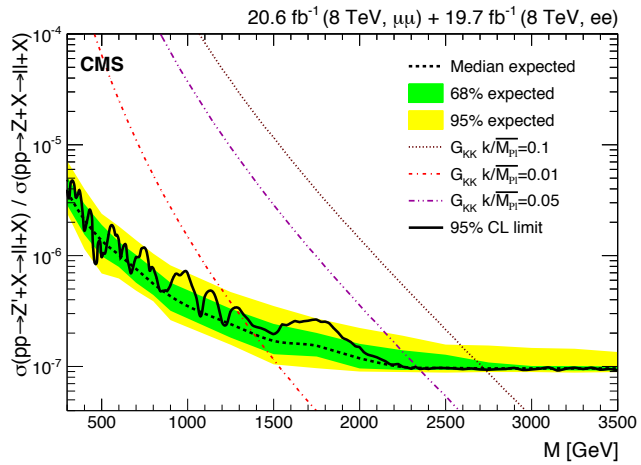
	Selection
ee	$E_T > 35, 35$ GeV $\lvert\eta\rvert < 1.442$ or $1.56 < \lvert\eta\rvert < 2.5$ ID and isolation criteria
$\mu\mu$	$p_T > 45, 45$ GeV $\lvert\eta\rvert < 2.4$ ($\lvert\eta\rvert < 2.1$ for triggering muon) ID and isolation criteria



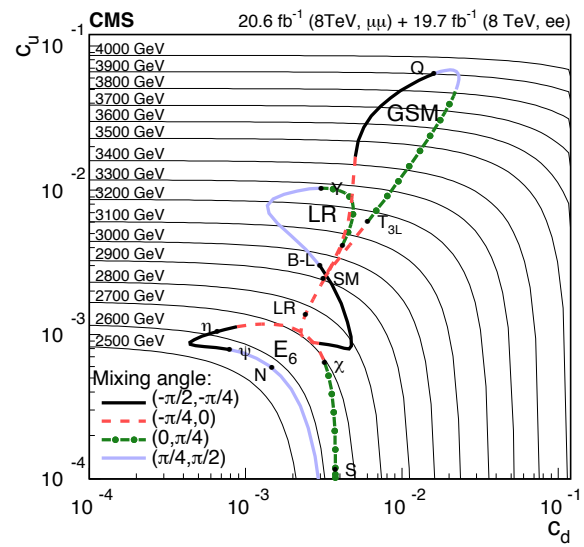


Di-lepton (ee and μμ) resonances



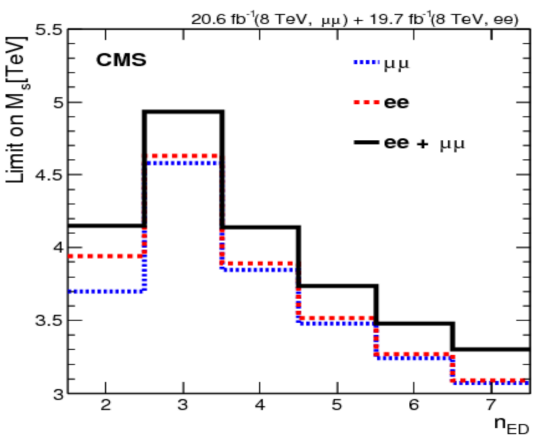


Z' limits in the (c_u, c_d) plane:



$m(Z'_{SSM})$ > 2.90 TeV
$m(Z'_\psi)$ > 2.57 TeV

$m(G\_RS)$ > 2.73, 2.35, and 1.27 TeV for coupling c = 0.1, 0.05, and 0.01



Interpretation in 2 non-resonant analyses : large extra dimension model (ADD) and compositeness model (CI)

Observed limits on M_S scale as a function of the number of extra spatial dimensions n_{ED}

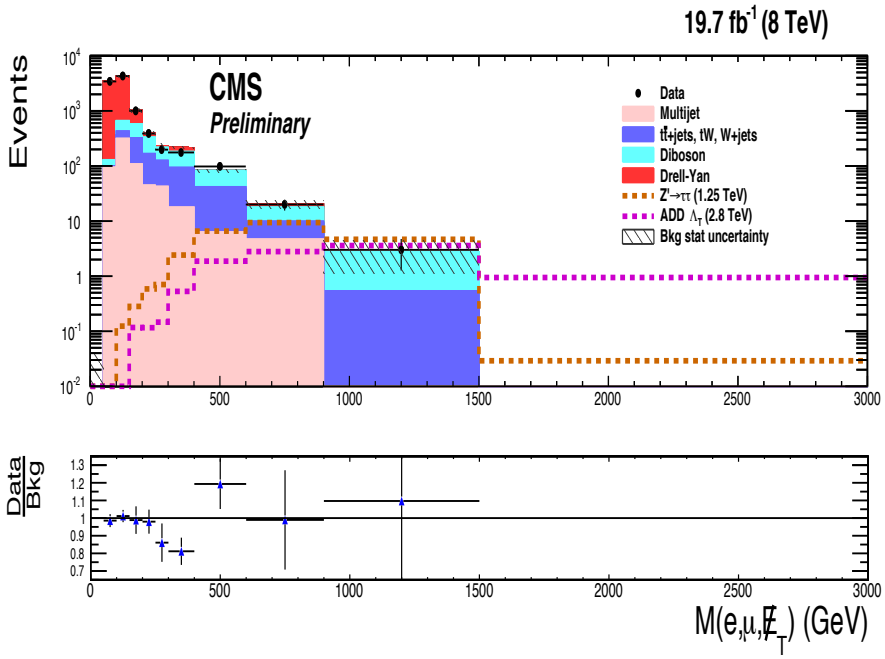
Di-tau resonances

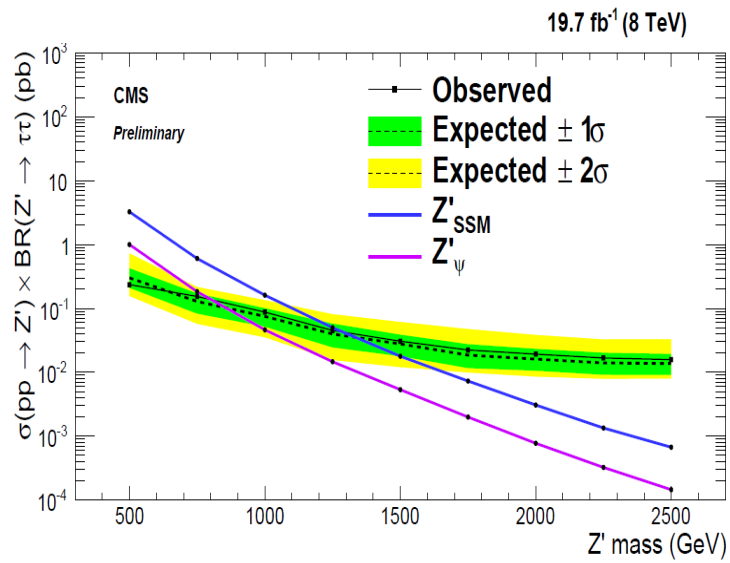
NEW

CMS-PAS-EXO-12-046

- CMS consider τ_e-τ_μ final states (eμ channel)
- Test a possible non-universal coupling
- Main backgrounds: top-antitop, diboson production, Drell-Yan, multijet from QCD

	Kinematics cuts
e	$E_T(e) > 20$ GeV $\lvert\eta(e)\rvert < 1.442$ or $1.56 < \lvert\eta(e)\rvert < 2.5$
μ	$p_T(\mu) > 20$ GeV $\lvert\eta(\mu)\rvert < 2.1$





$m(Z'_{SSM}) > 1300$ GeV
$m(Z'_\psi) > 810$ GeV

- Limits on ADD model: parameter Λ up to 2800 GeV

Di-photon resonances

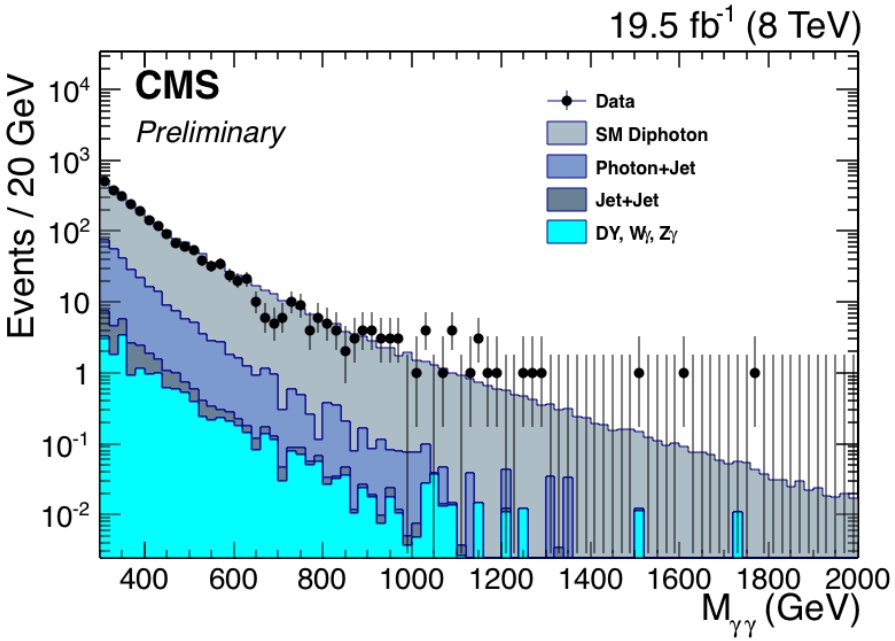
NEW

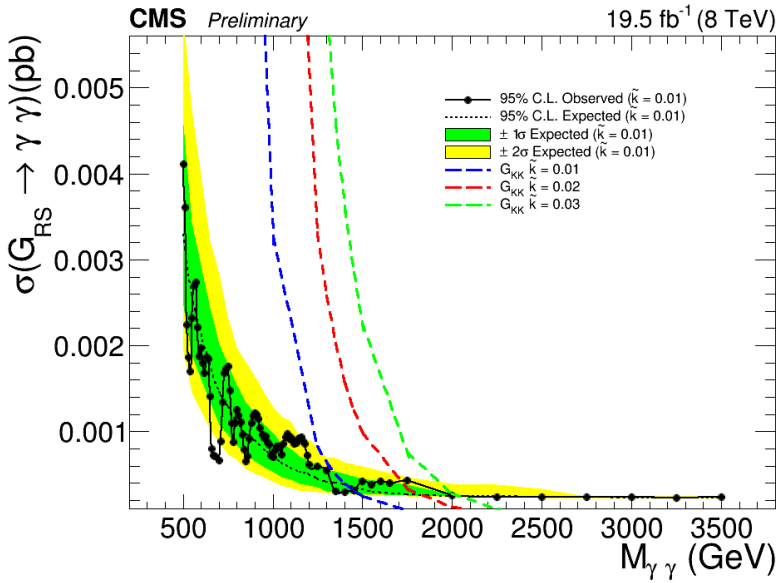
CMS-PAS-EXO-12-045

- Simple final state, large background
- Background from SM processes (box and born diagrams), and from photon + jet or di-jet processes where one or two jets produce a fake photon signature

Kinematics selection

$p_T > 80$ GeV
$|\eta| < 1.4442$
$m(\gamma\gamma) > 300$ GeV





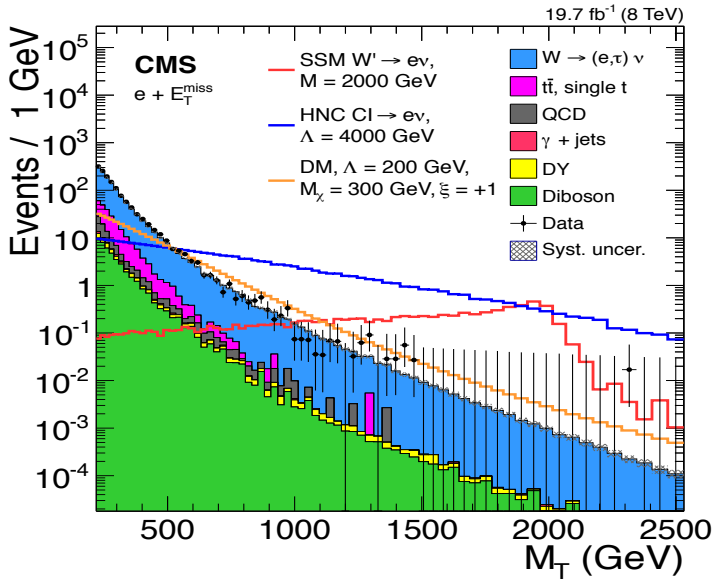
Limits for $k/M_{Pl} = 0.1$: $m(G_{RS}) > 2.78$ TeV

Searches for W'→lν

NEW

Search for W' →eν and W' →μν

M_T distribution for the eν channel:



Interpretation in various models:
heavy W', split universal extra dimension,
W'(KK) as well as dark matter and compositness

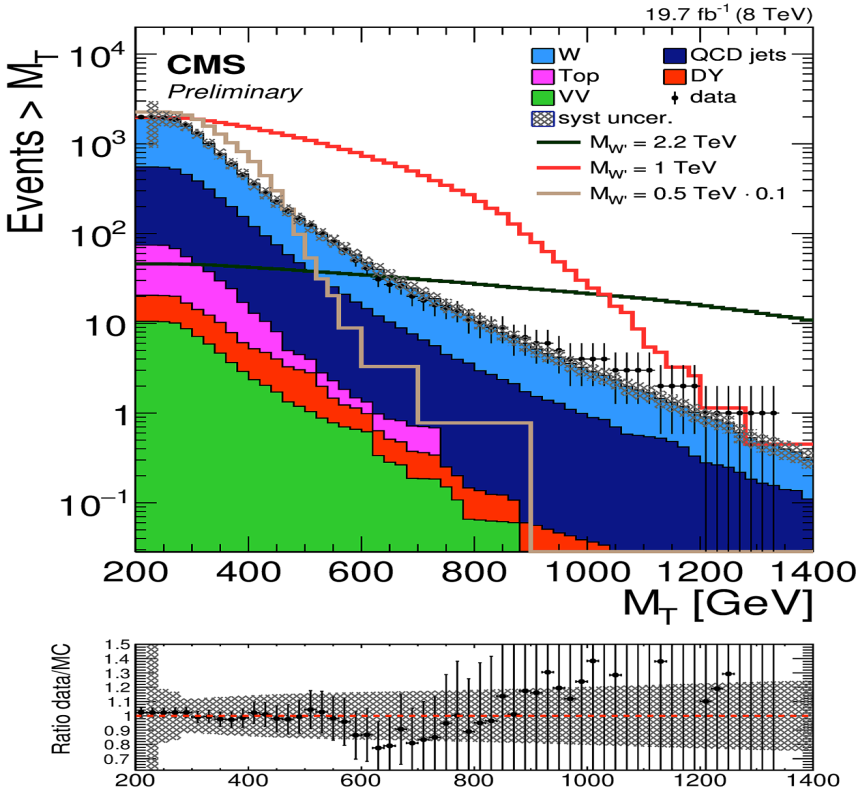
Mass limits of W'(SSM) > 3.28 TeV

PRD 91 (2015) 092005, arXiv:1408.2745

Search for W' →τν

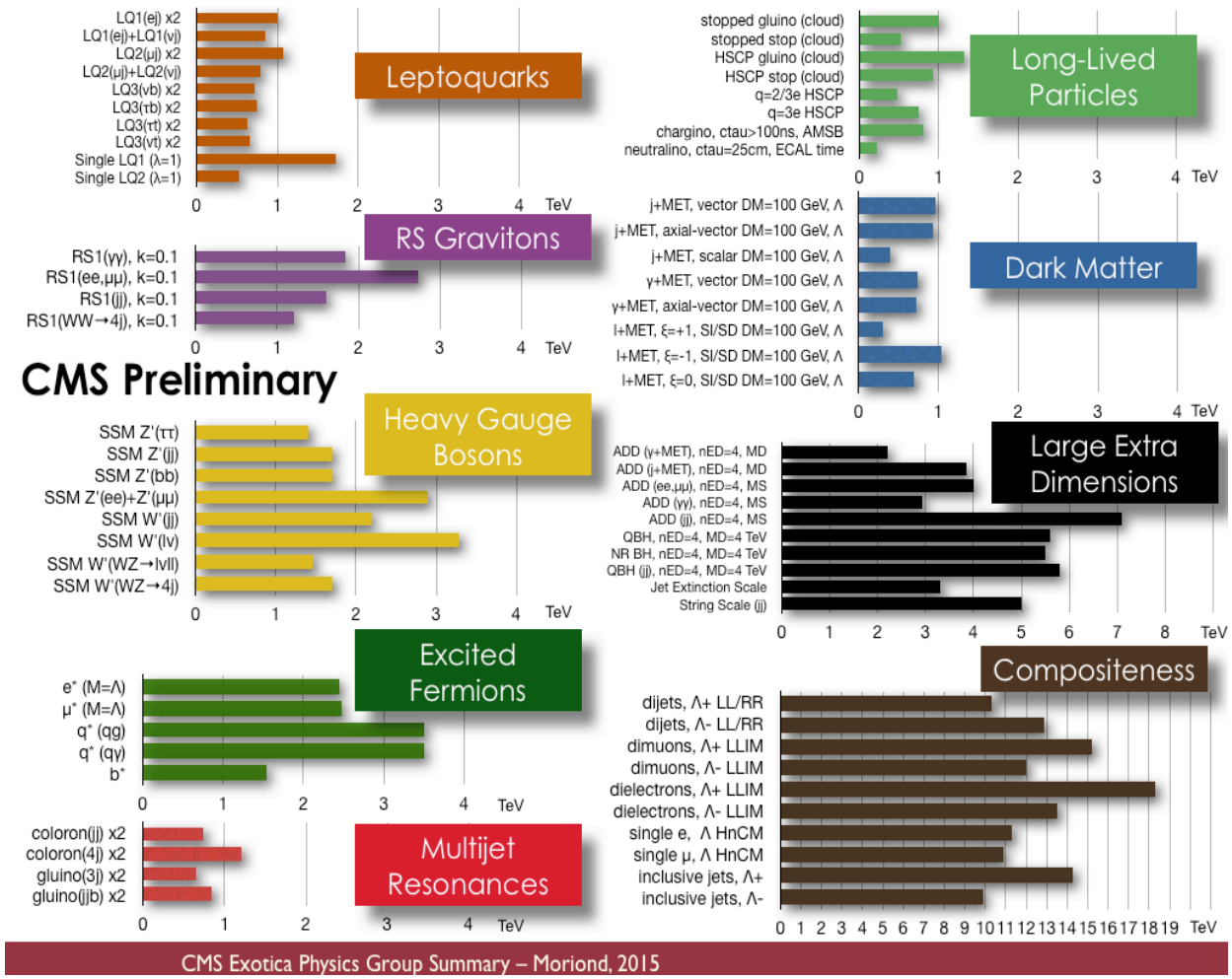
CMS-PAS-EXO-12-011

Test a possible non-universal coupling
Consider hadronic decay of the τ-lepton
Distribution of the cumulative M_T variable:



Mass limits of W' (SSM)> 2.7 TeV

Summary: Run 1 results

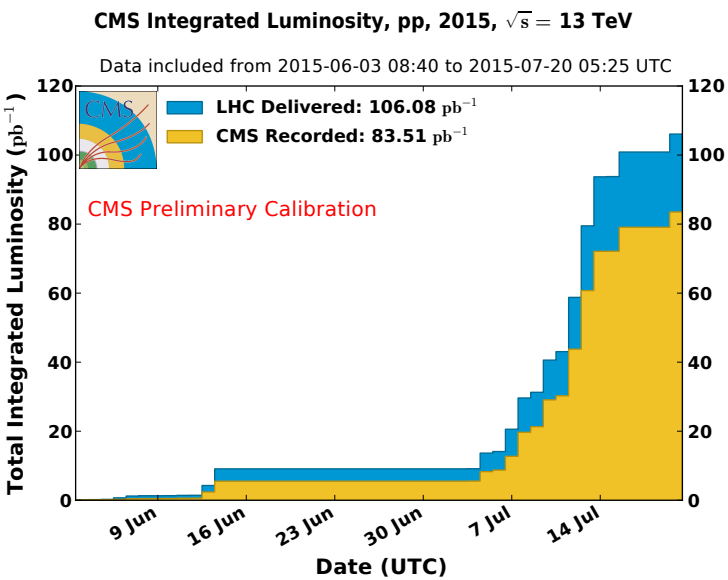


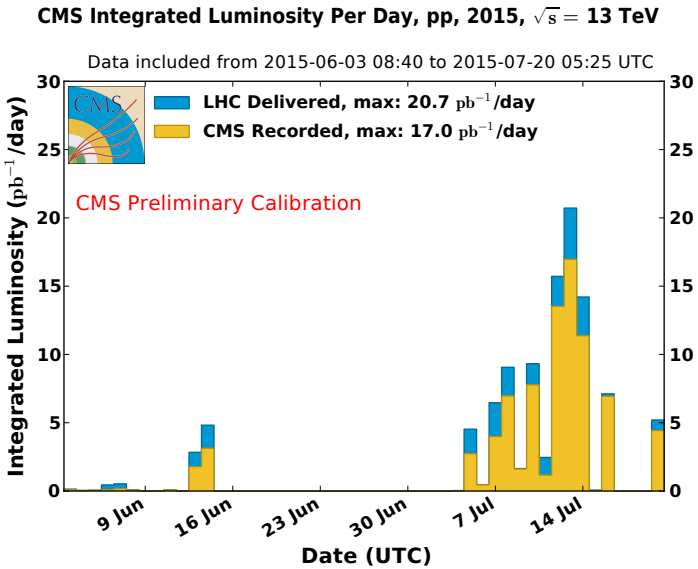
- A large number of analyses
- Mix of simple and complex final states
- Run1 legacy papers with a wide range of model interpretation

All CMS EXOTICA public results at:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G

CMS Run 2 dataset

- Run2 started in June 3, 2015, pp collision at 13 TeV! - 50 ns bunch crossing spacing
- Cumulative luminosity delivered by LHC and recorded by CMS during stable beam
- Integrated luminosity delivered and recorded per day
- CMS B = 3.8 T from 06/07
- Date : June 3, up to July 20
  Total delivered: 106 pb^{-1}
  Total recorded: 83.5 pb^{-1}
  Total recorded at 3.8 T: 61.8 pb^{-1}
  Results @EPS presented up to 43 pb^{-1}
- **More information/control plots in the Kerstin Borras's plenary talk next Monday**





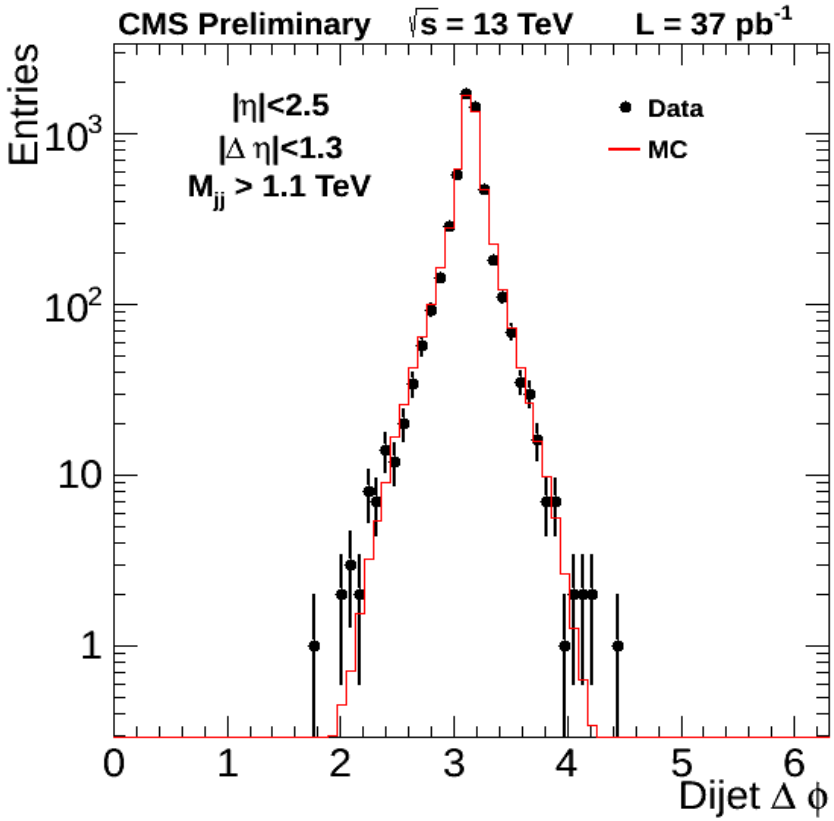
CMS Run 2 – dijet analysis

- Dataset L = 37 pb^{-1}
- Similar selection as for 2012 data analysis for the wide jets reconstruction

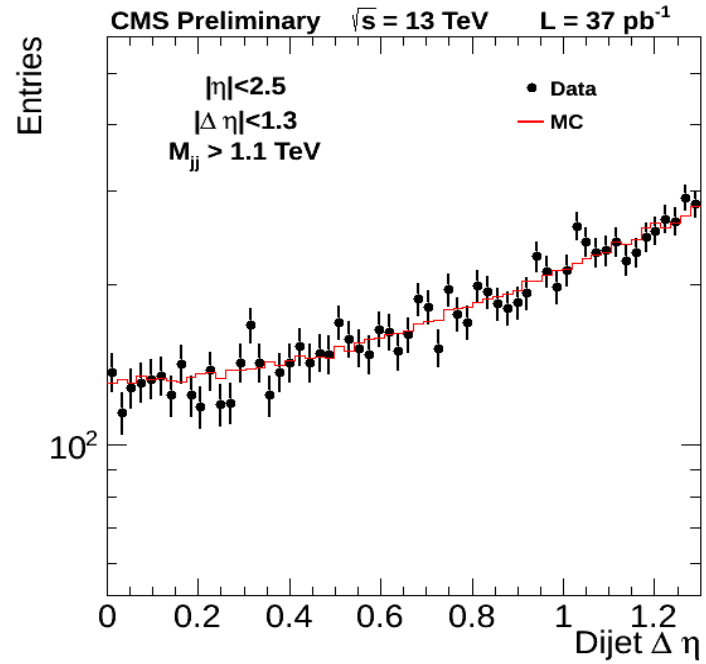
Dijet selection using wide jets

Jet 1: $p_T > 60$ GeV, $|\eta| < 2.5$
Jet 2: $p_T > 30$ GeV, $|\eta| < 2.5$
$|\Delta\eta_{jj}| < 1.3$ $M(jj) > 1.1$ TeV

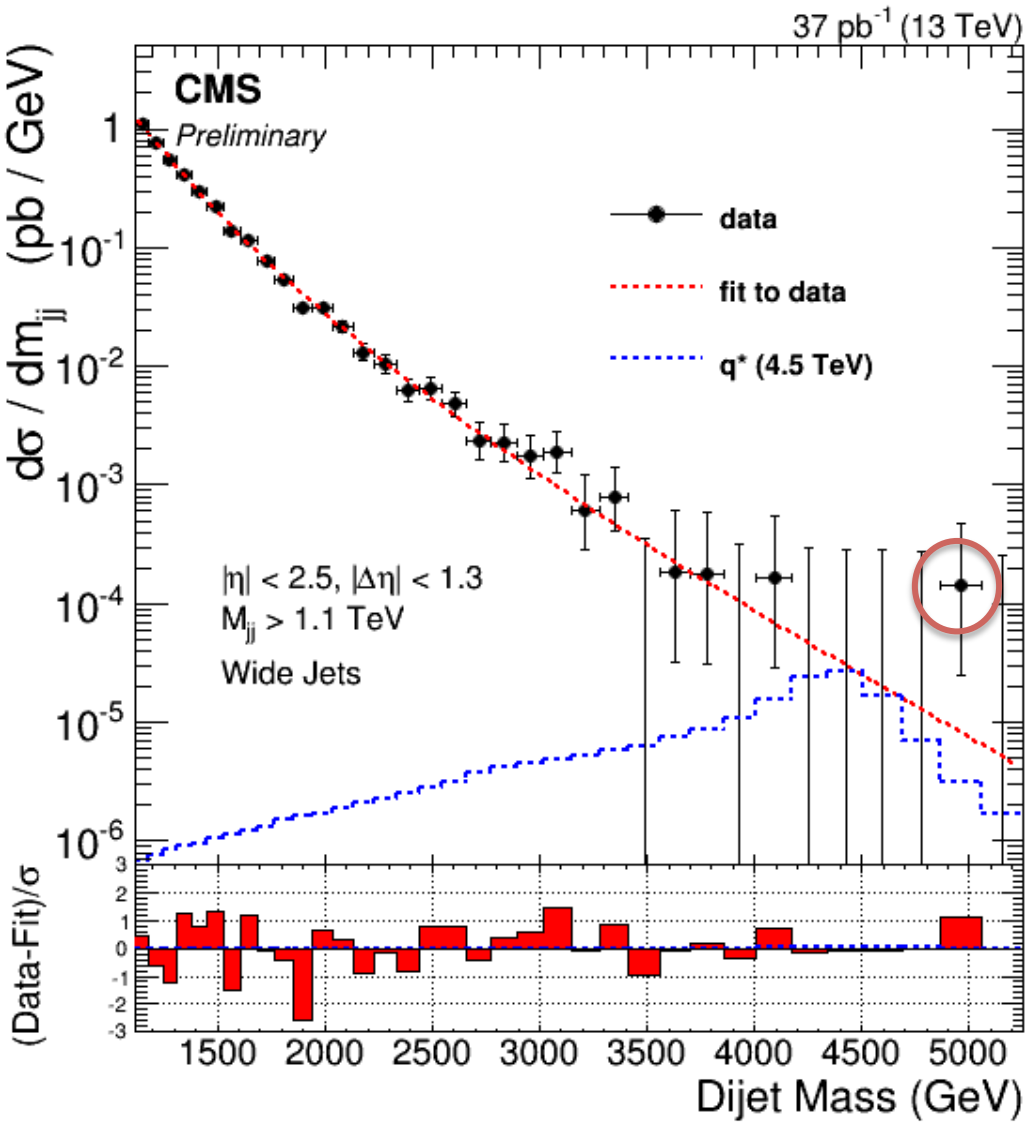
Di-jet ΔΦ distribution



Di-jet Δη distribution



CMS Run 2 – dijet mass spectrum



L = 37 pb^{-1}

- Mass spectrum fitted using a 4 parameter function :

$$\frac{p_0\left(1-\frac{m}{13000}\right)^{p_1}}{\left(\frac{m}{13000}\right)^{p_2+p_3\log\left(\frac{m}{13000}\right)}}$$

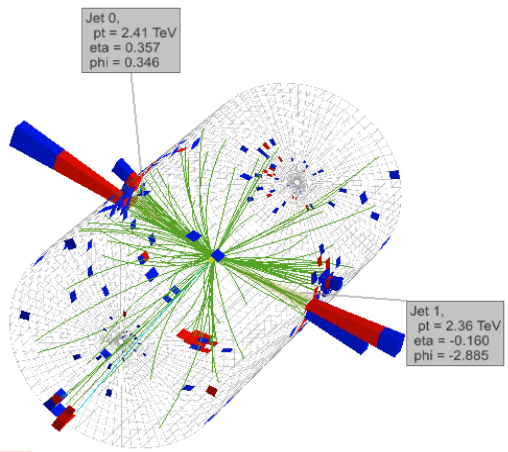
- For illustration purposes: In blue : signal of a q*➔qg resonance at M = 4.5 TeV

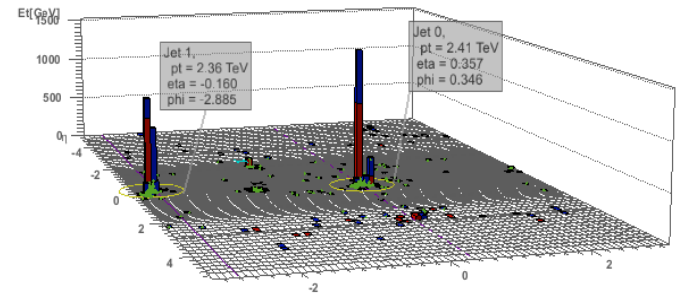
- Highest dijet mass event : M=5 TeV

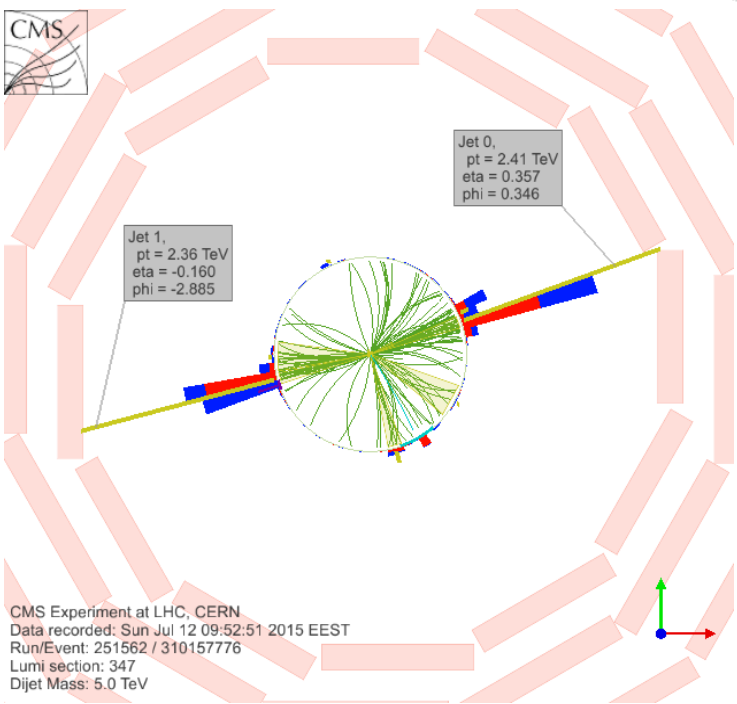
CMS Run 2 – highest dijet mass event

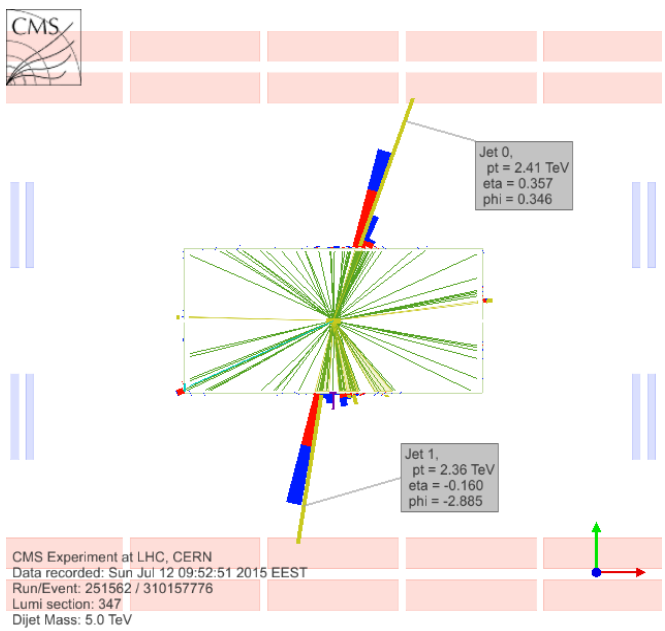
Di-jet event M=5 TeV

Pt(1)= 2.41 TeV
pt(2)= 2.36 TeV









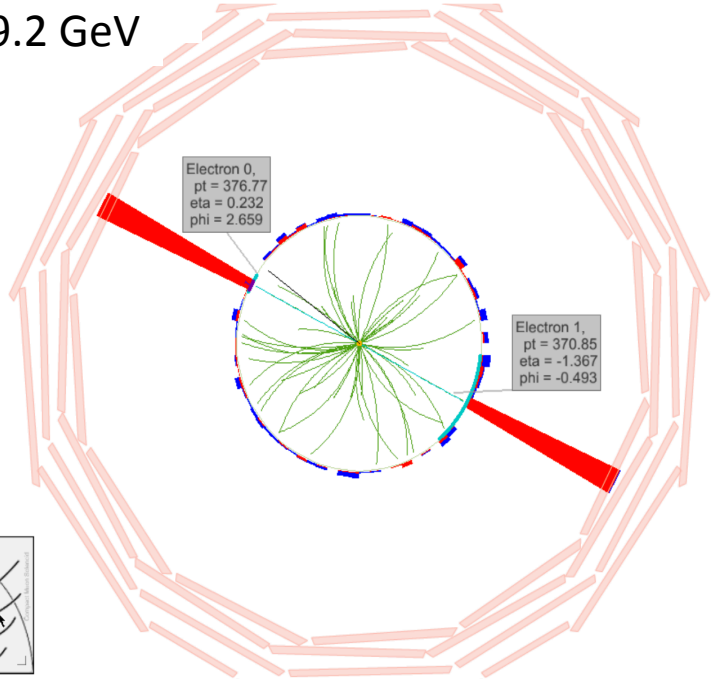
CMS 2015 data
Run = 251562,
date=12Jul 09:52

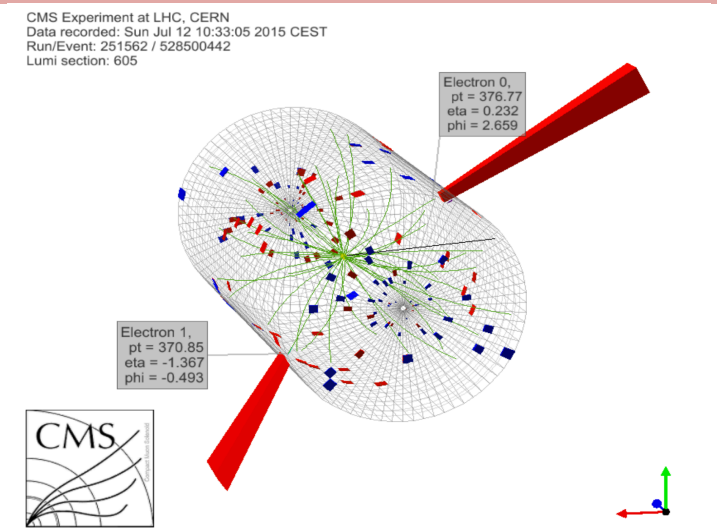
CMS Run 2 – highest ll mass event

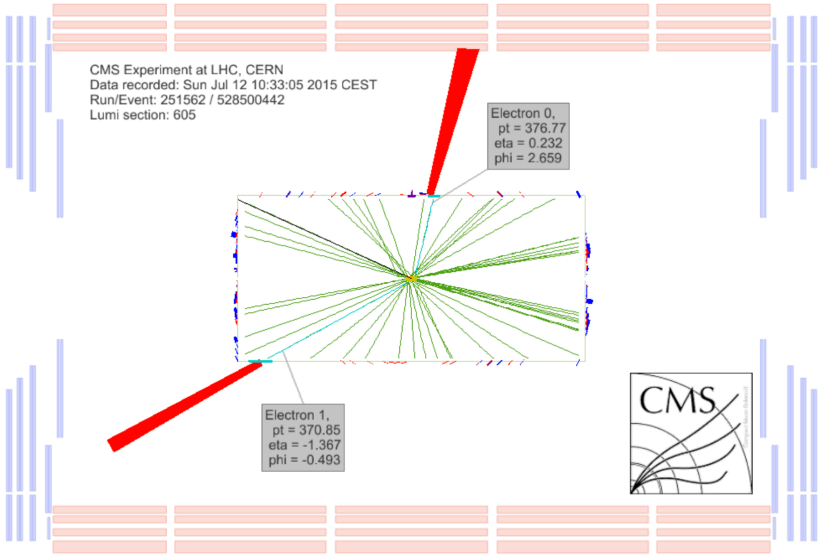
Di-electron event : M = 999 GeV

CMS 2015 data
Run = 251562, date=12Jul 10:33
Pt(1)= 377 GeV, pt(2)= 371 GeV

MET=9.2 GeV

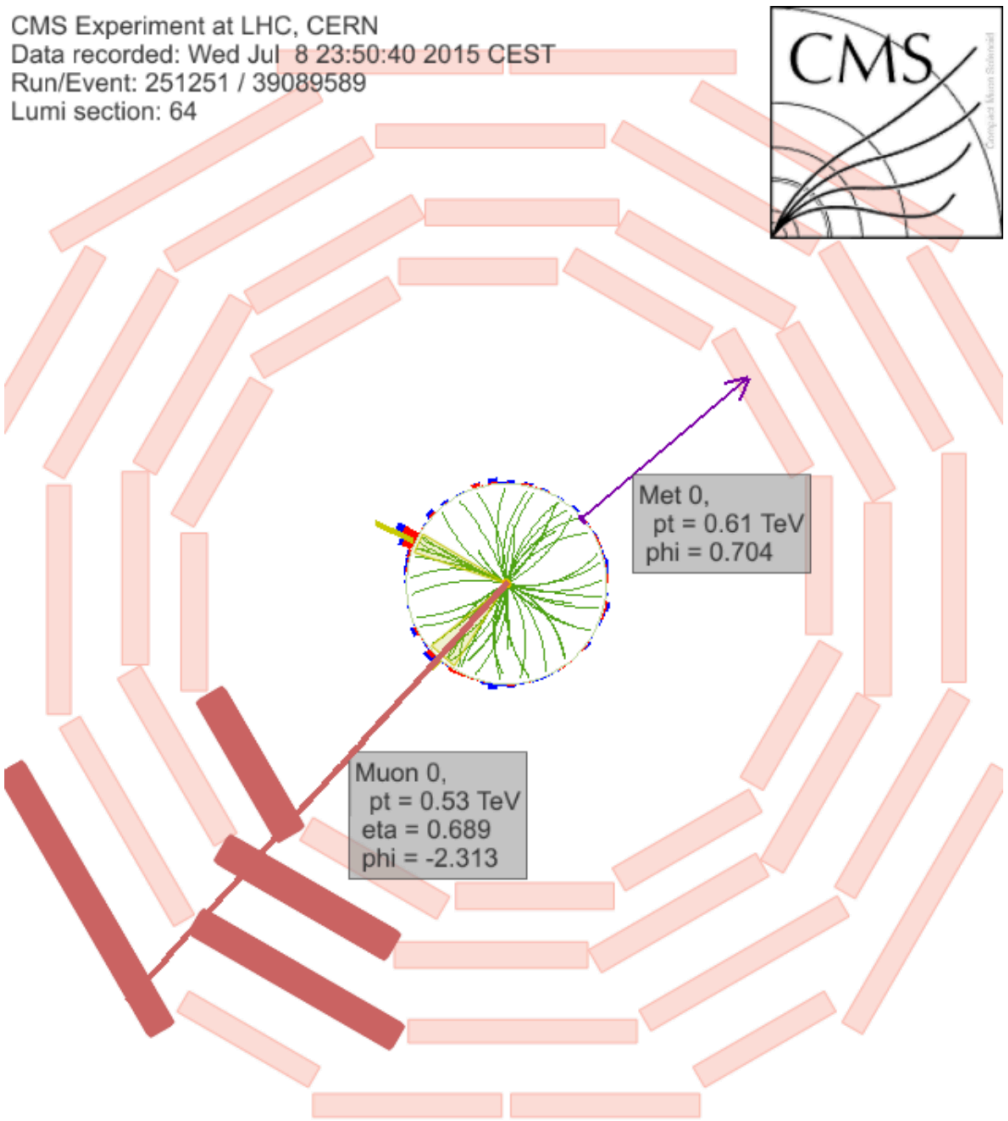






3.5 events expected with m> 500 GeV
for the luminosity analyzed, and 3 events observed

CMS Run 2 – highest (l+MET) mass events



(single μ + MET) event :
M_T = 1.1 TeV

Run = 251251, date=8Jul 23:50
pt(μ)= 0.53 TeV, MET= 0.61 TeV
ΔΦ (μ, MET)=3.0

1 event expected
with m_T > 700 GeV for the
luminosity analyzed

Summary – Run 2

- **LHC Run 2 has just started** - at the highest energy ever!
- First results are shown on di-jet final state analysis
- Highest dilepton and lepton+MET mass events shown
- Number of high mass events compatible with SM expectation

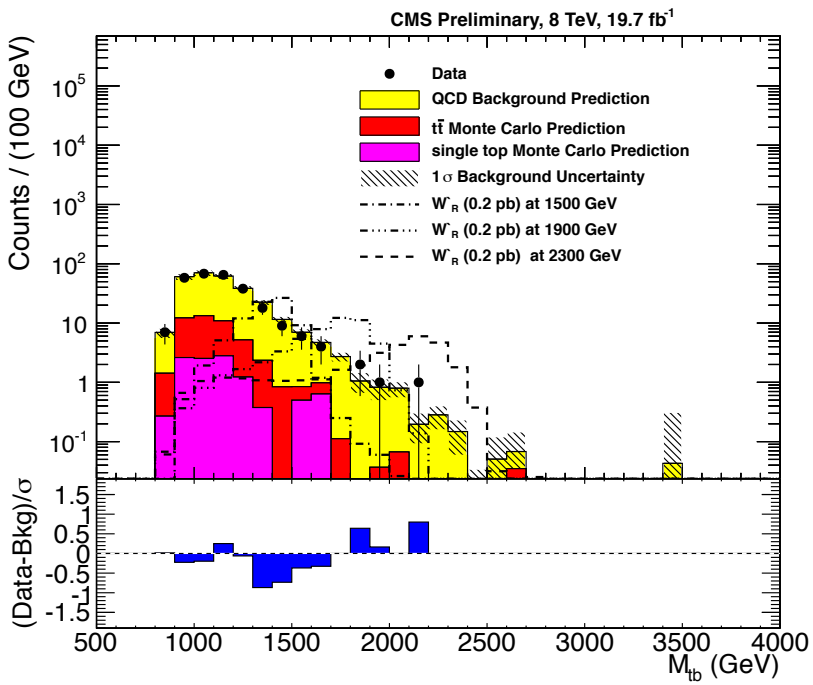
- Much more to come in the near future
- Fingers crossed for seeing hints for new physics at LHC Run 2 soon!

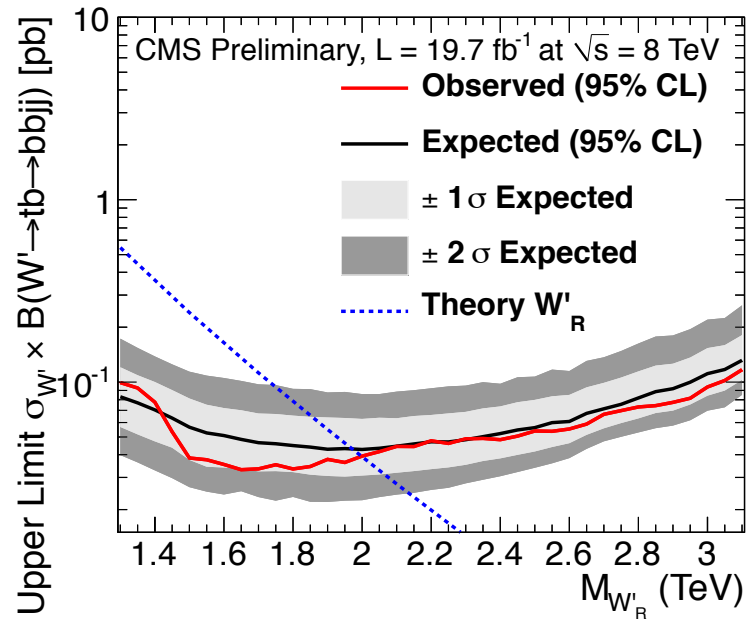
Backups

Searches for W'→tb

CMS-PAS-B2G-12-009

- CMS investigated *W'* boson decaying to *tb* final state
- Dedicated algorithms for top-tagged jets and W' candidates





- Dominant systematic uncertainties: t-tbar production, top-tagging
- Limits: $m(W')_{\text{right handed}} > 2.15$ TeV

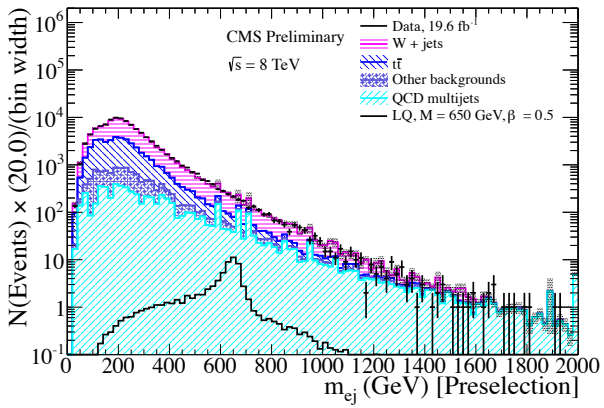
Searches for Leptoquarks: Gen 1 and 2

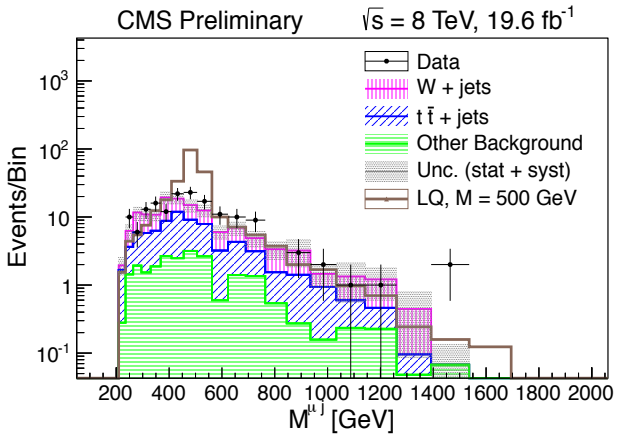
Consider both lvjj and lljj fnal states

CMS-PAS-EXO-12-041

CMS-PAS-EXO-12-042

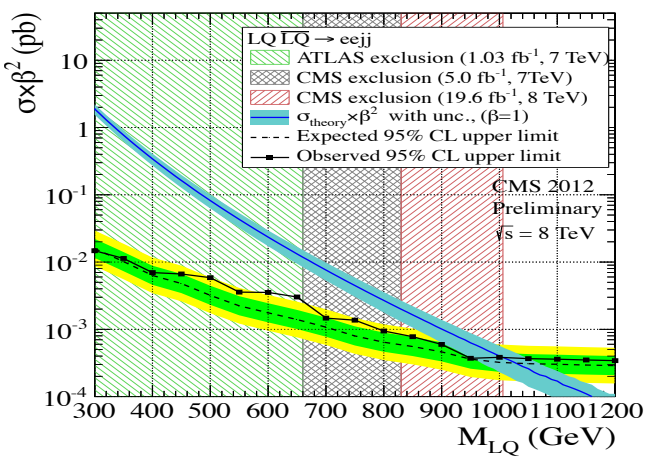
The m(e-jet) distribution for evjj preselection

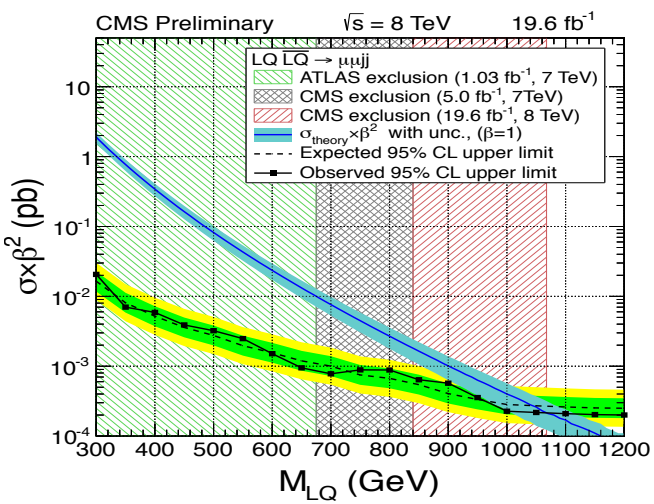




The m(μ-jet) distribution for final μvjj selection

β = BF of a LQ to a charged lepton and a quark





M (LQ) > 1005 (845) GeV for β=1(0.5)

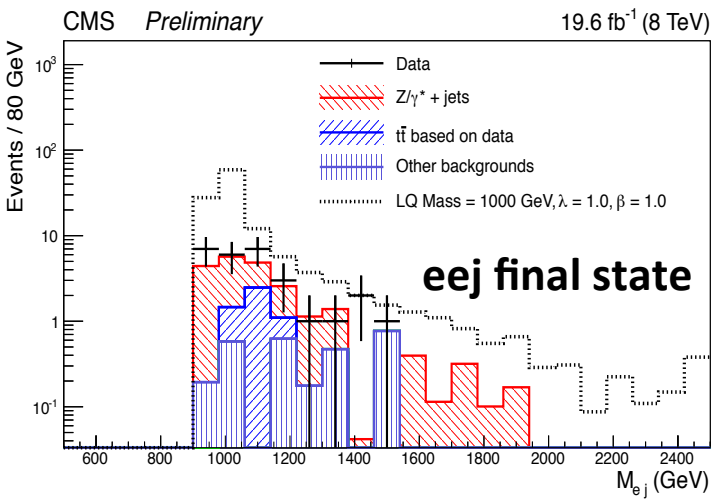
M (LQ) > 1070 (785) GeV for β=1(0.5)

Searches for single production of scalar leptoquarks

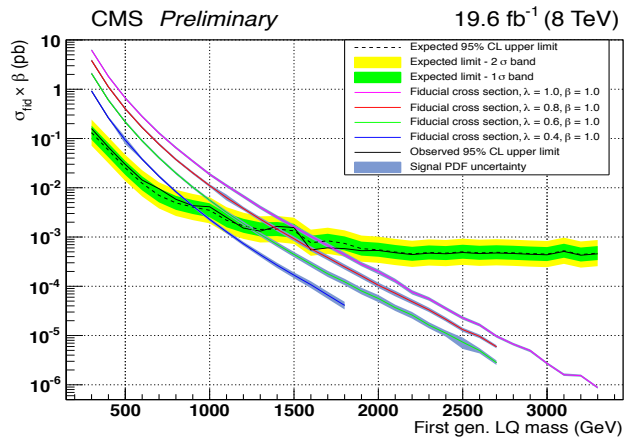
NEW

CMS-PAS-EXO-12-043

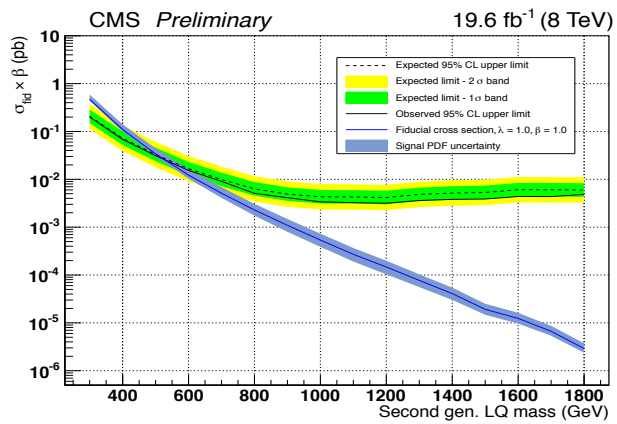
Single production of first and second generation scalar LQ :
In both eejet and μμjet final states



Lepton-jet invariant mass with eej final selection for a LQ of 1 TeV



eej channel



μμj channel

M (LQ1) > 1730 GeV for λ,β=1

M (LQ2) > 530 GeV for λ,β=1

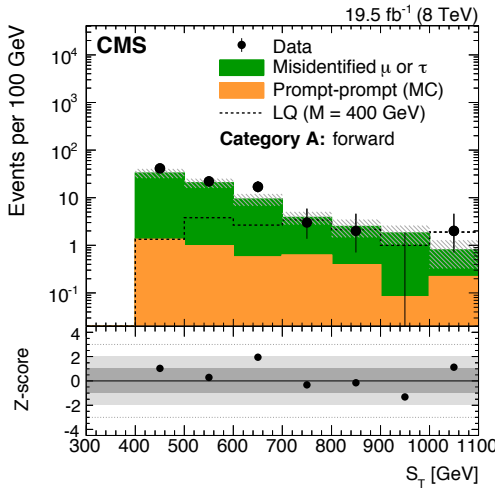
λ = Yukawa coupling at the LQ-lepton-quark vertex

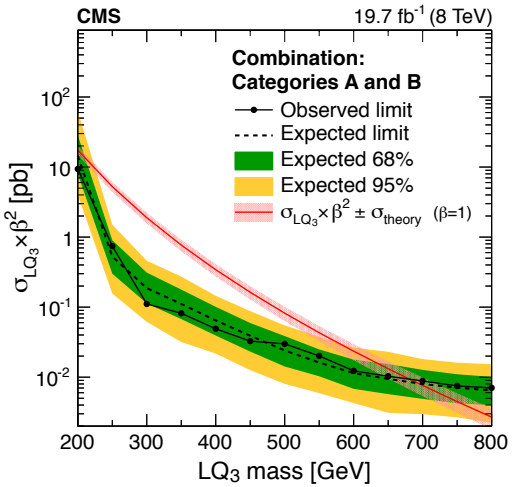
Because the initial state possesses quark flavor, single LQ prod. beyond the first GEN is suppressed

Searches for Leptoquarks in ττ

NEW

- CMS investigate leptoquarks decaying to a *tτ* final state
- Two categories A (B) on right:
- S_T is scalar sum of p_T in the event





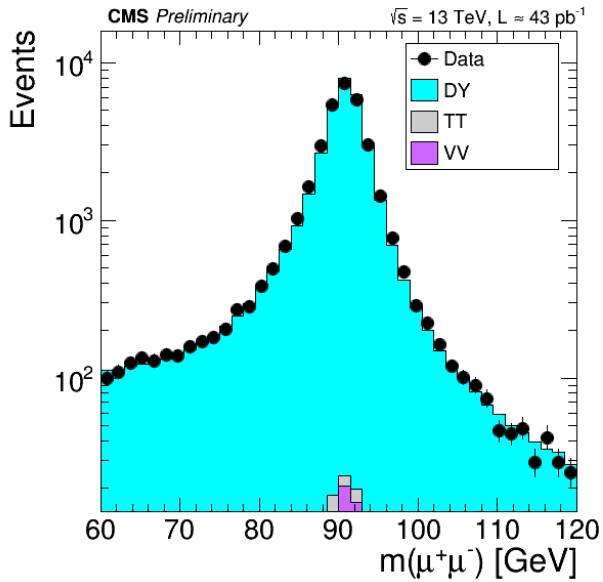
- Limits: $m(LQ \rightarrow t\tau) > 685$ GeV
- Dominant systematic : *t* reco, pileup, background estimation

PAS-EXO-14-008, arXiV: 1503.09049, submitted to JHEP

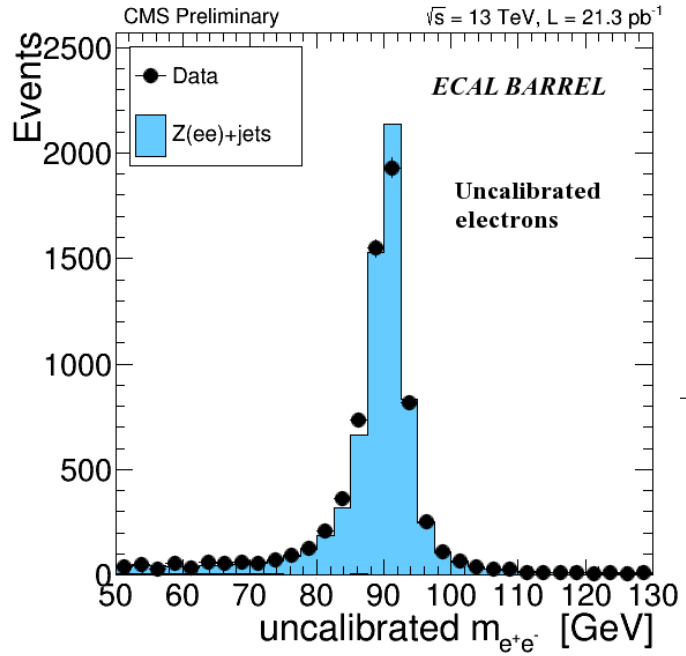
	Category A (B)
τ_{had}	$p_T(\tau_{had}) > 20\ (35)$ GeV $\lvert\eta(\tau_{had})\rvert < 2.1\ (2.1)$
e	$E_T(e) > 15\ (35)$ GeV $\lvert\eta(e)\rvert < 2.5\ (2.1)$
μ	$p_T(\mu) > 25\ (30)$ GeV $\lvert\eta(\mu)\rvert < 2.1\ (2.1)$
jet	$p_T(j) > 40\ (30)$ GeV $\lvert\eta(\mu)\rvert < 3.0\ (2.5)$
E_T^{Miss}	No selection (>50 GeV)
S_T	Optimised by mass (S_T>1000 GeV)
$p_T(\tau_{had})$	Optimised by mass ($p_T(\tau_{had})$>20 GeV)
Leptons	Same sign $\mu\tau_{had}$ ($\mu\tau_{had}$ or $e\tau_{had}$)

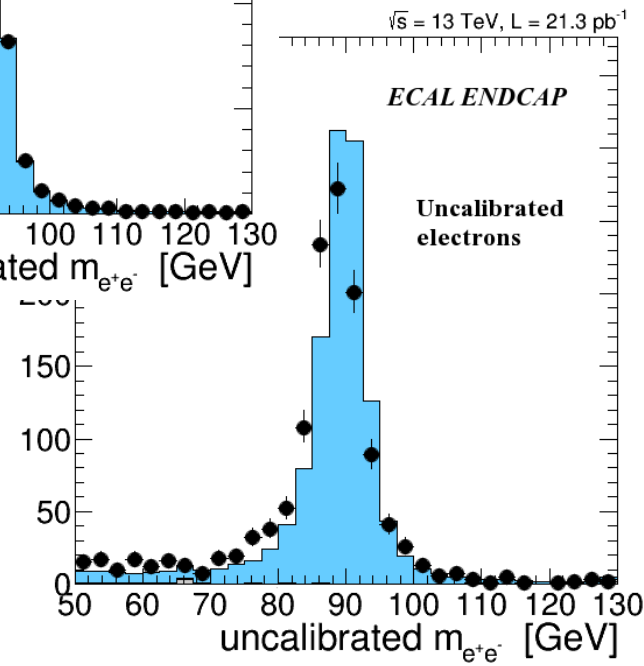
CMS Run 2 – performance plots – Z peak

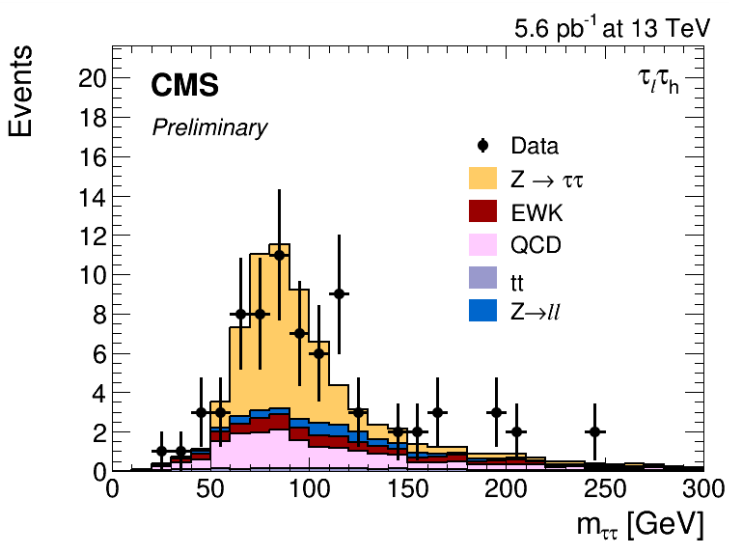
Di-muon mass spectrum L=43 pb^{-1}



Di-electron mass spectra L=21.3 pb^{-1}







Di-tau mass spectrum L=5.6 pb^{-1}