EXOTICA IN CMS

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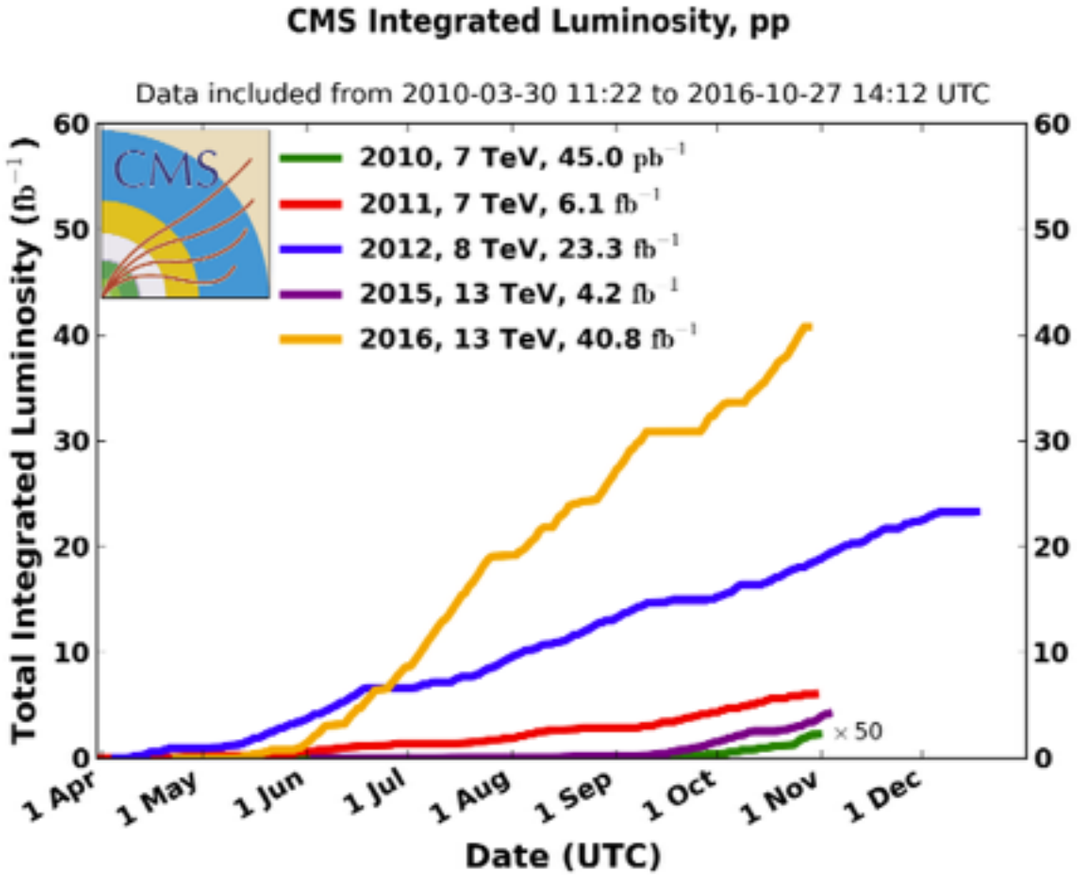
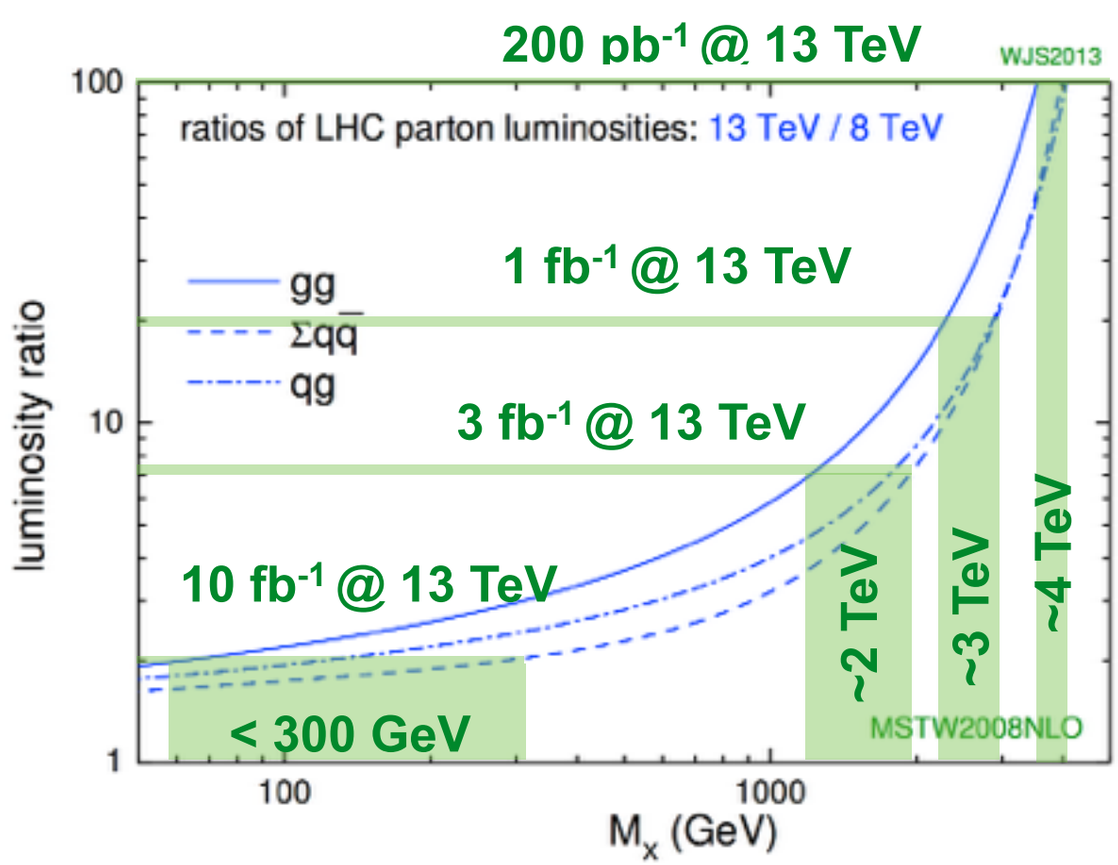
HIGH MASS PARTICLE SEARCHES AT CMS

- **High energy and large integrated luminosity** give sensitivity for searches in **unexplored phase space**
  - particularly important for high mass resonances
- **2016 data crucial for these searches**
  - **large sample (~36 fb^{-1}) at 13 TeV** allows for completion of wide search program and enough to **supersede all 8 TeV results**





SEARCH PROGRAM

Several final states can be investigated

- **di-objects**: dijet, diphoton, dilepton, ...
  - *physics interest*: **new bosons, extra dimensions, excited fermions, gravitons, DM, …**
- **composite objects**: VV, boosted W/Z, boosted top, ...
  - *physics interest*: **new bosons, extra dimensions, VLQ, ...**
- **final states with MET**: lepton, lepton+jet+MET, ...
  - *physics interest*: **new bosons, new heavy neutrinos, …**

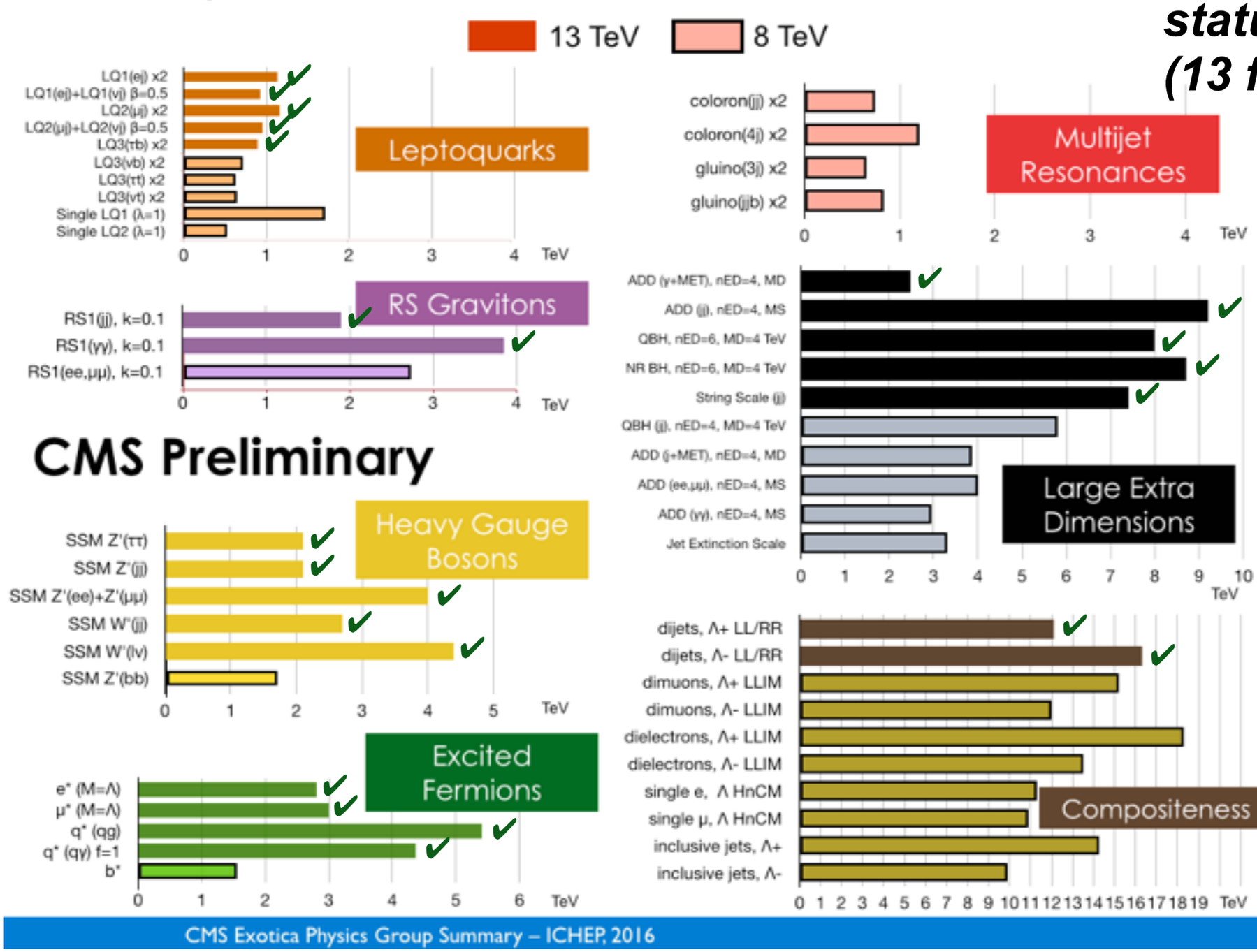
Search technique: reconstruct invariant mass/event energy with as many as possible decay products of the new particle

- possibly use MET if present
- substructures in case of boosted jets, decay of tops or V bosons

STATUS OF SEARCHES

- 13 TeV results **dramatically extend exclusion limits**
- **Still many 8 TeV channels to be updated**

status at ICHEP 16 (13 fb^{-1} at 13 TeV)



similar table for VV, VLQ, T', resonances to heavy quarks in backup

STATUS OF SEARCHES

- 13 TeV results **dramatically extend exclusion limits**
- **S**

CMS strategy:
publication of the preliminary 13 TeV results shown last year (more than 18 new publications, full list in backup)

What I will present today:
only new results based on full 2016 dataset (36 fb^{-1})

- **multileptons for type III See-saw**
- **VLQ in Z(leptonic)t(hadronic)**
- **$X_{5/3}$ in same sign dilepton**
- **W' → tb in lepton+jet**
- **dijet**

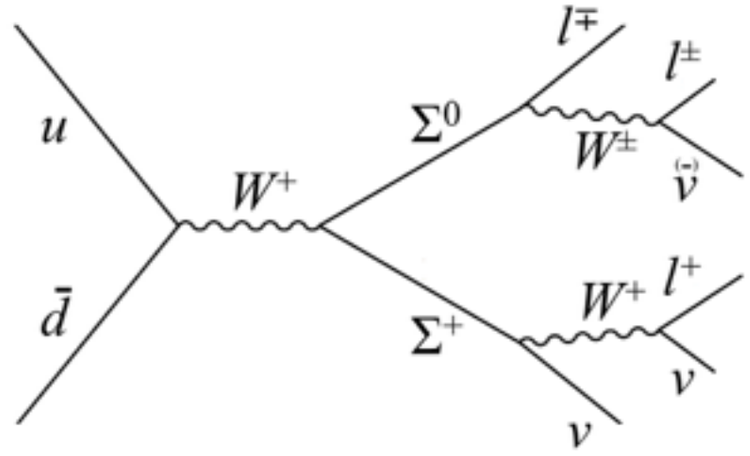
(N.B.) di-boson CMS results have been already presented by Gustaaf B. this morning

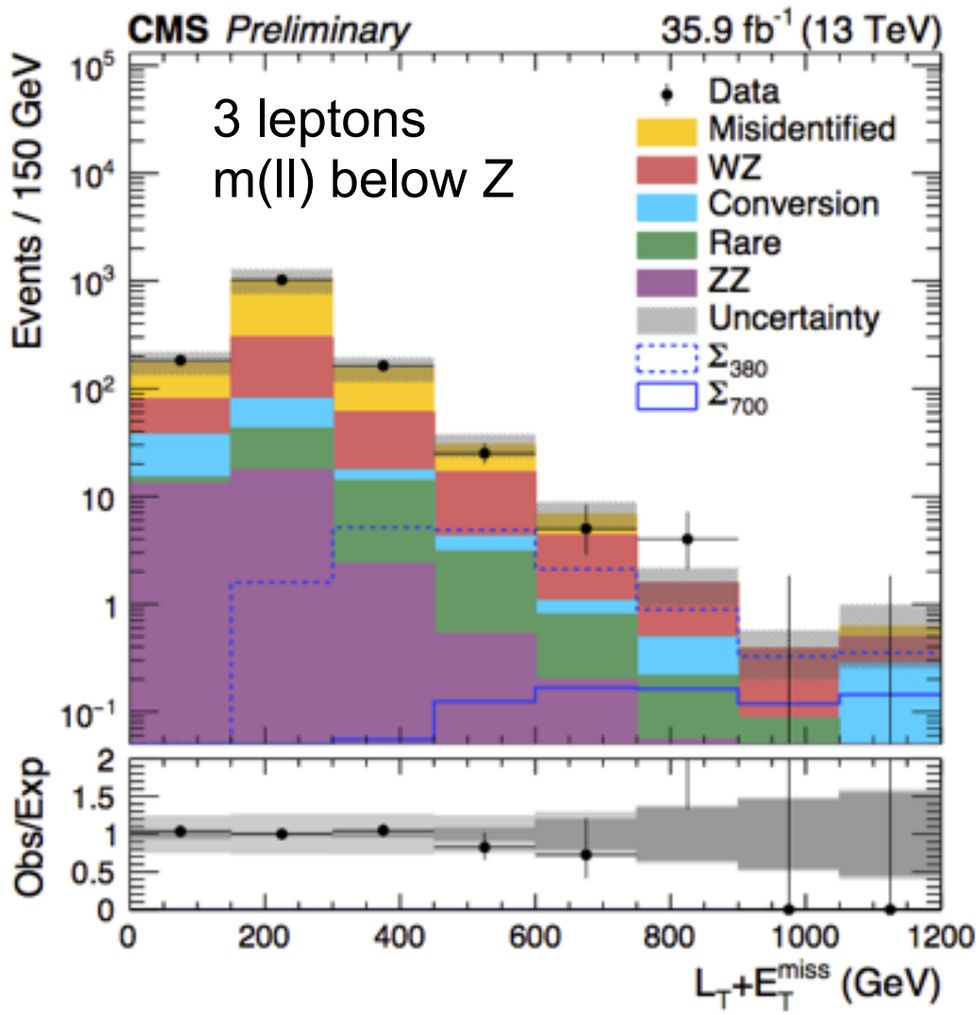
EP 16 TeV)

similar table from B2G (VV, VLQ, T', ...) working group in backup

MULTILEPTONS IN TYPE III SEESAW

- **Type III seesaw introduces new heavy fermions, coupling to leptons, Higgs and V bosons**
  - explains smallness of neutrino mass
- **Final state with at least three leptons and missing energy**
  - example $\Sigma^{\pm}\Sigma^{0} \rightarrow W^{\pm}\nu W^{\pm}\ell^{\mp} \rightarrow \ell^{\pm}\nu\nu\ell^{\pm}\nu\ell^{\mp}$
- **Main discriminating variable**
  - scalar sum of all lepton p_T (L_T)+ MET
- **8 search regions**
  - based on numbers of leptons and dilepton mass (below/on/above Z)
- **Backgrounds mainly from control regions**
  - dibosons and misidentified leptons dominate





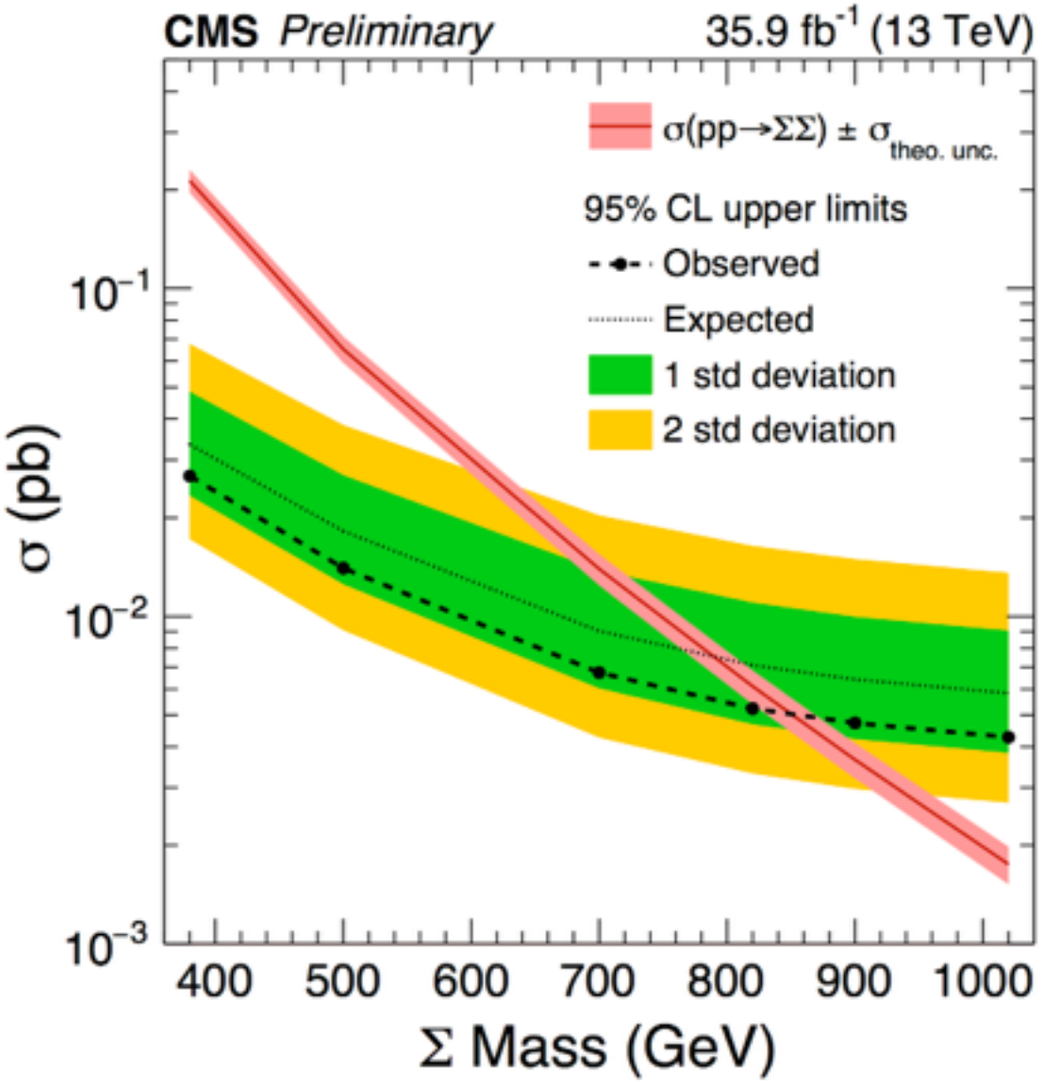
MULTILEPTONS: RESULTS

- **No significant excess in any of the eight regions**

- **Limits set in the democratic scenario:**
  - new charged leptons and heavy neutrino degenerate in mass
  - same couplings and BRs to leptons with different flavors

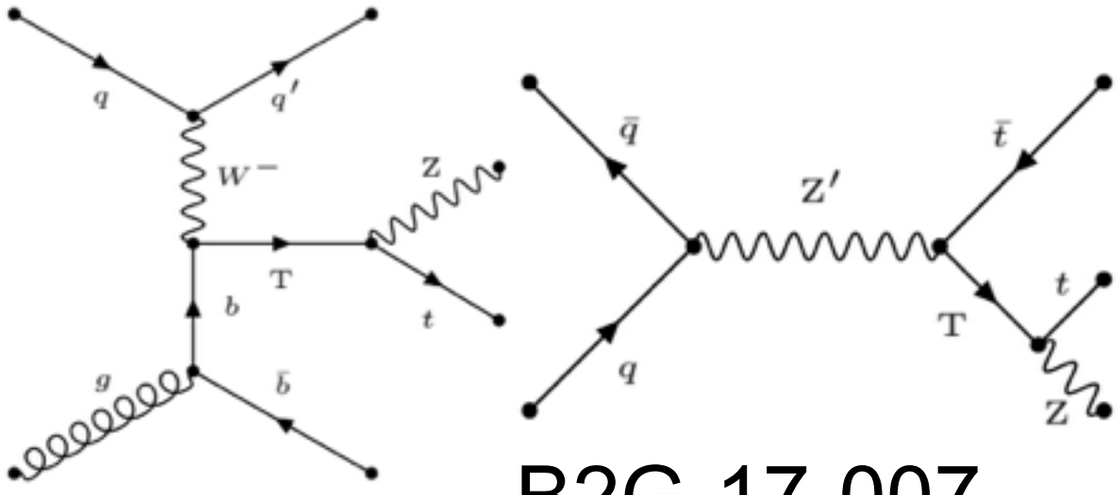
- **Limits on degenerate mass of new heavy fermions is 850 GeV (790 GeV expected)**
  - previous 13 TeV limits improved by 400 GeV!

EXO-17-006



VLQ IN Zt FINAL STATE

- **Vector-like T quark models solve hierarchy problem**
  - new heavy partner of top in loop
- **Search of T VLQ with 2/3 charge, decaying to Zt**
  - **Z is leptonic and top hadronic**
  - possibly require the **presence of extra jet** (association with b or t)
- **10 categories based on**
  - merged/resolved topology of W/t
  - presence of forward jet
- **Limits on m(T) > 1.2-1.45 TeV** depending on production mechanism and width of T
  - large improvement wrt ICHEP



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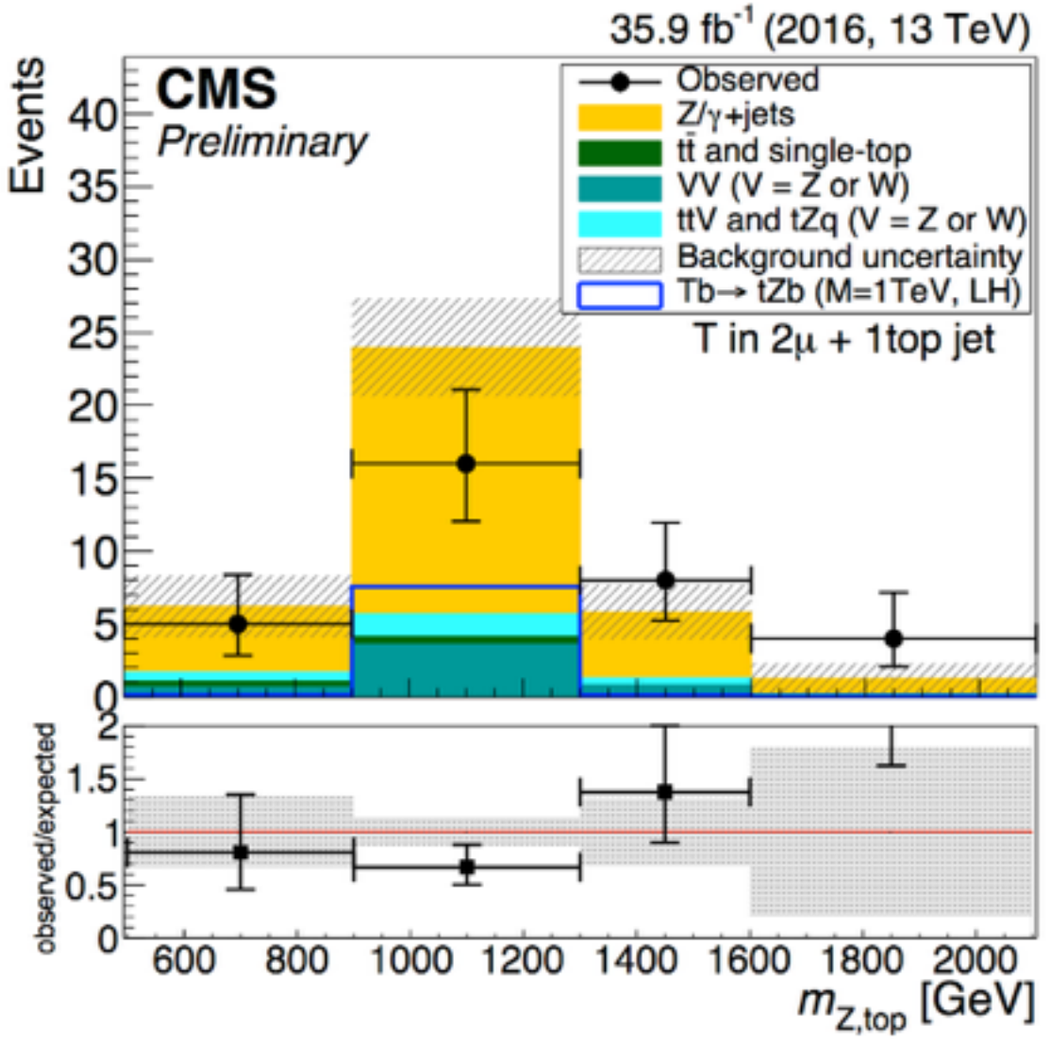
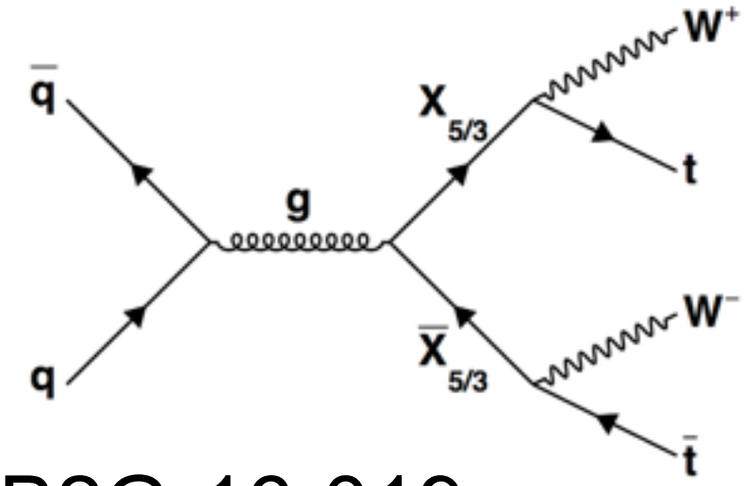


$X_{5/3}$ IN SAME-SIGN DILEPTON

- **Search of top partner with 5/3 charge**
  - not contributing to coupling of Higgs to gluons
- **Final state with both W and top in leptons (being same-sign)**
  - no explicit requirement on the other $X_{5/3}$
- **Requirements**
  - two same-sign e/mu with modified isolation to deal with boosted top
  - large H_T^{lep} (scalar sum of jets and lep)
- **No excess**
  - **limits on mass at 1.16 (1.10) TeV** on right- (left-) handed $X_{5/3}$



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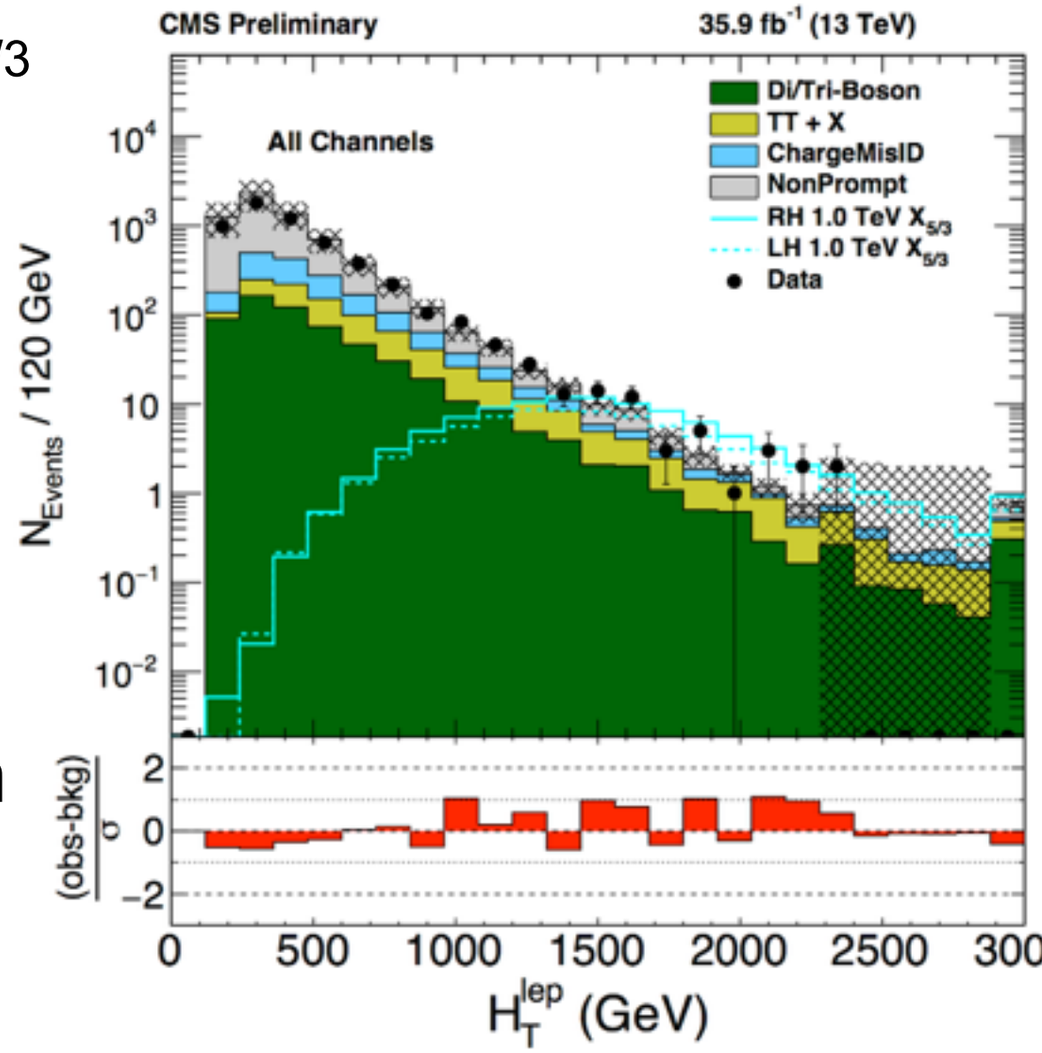
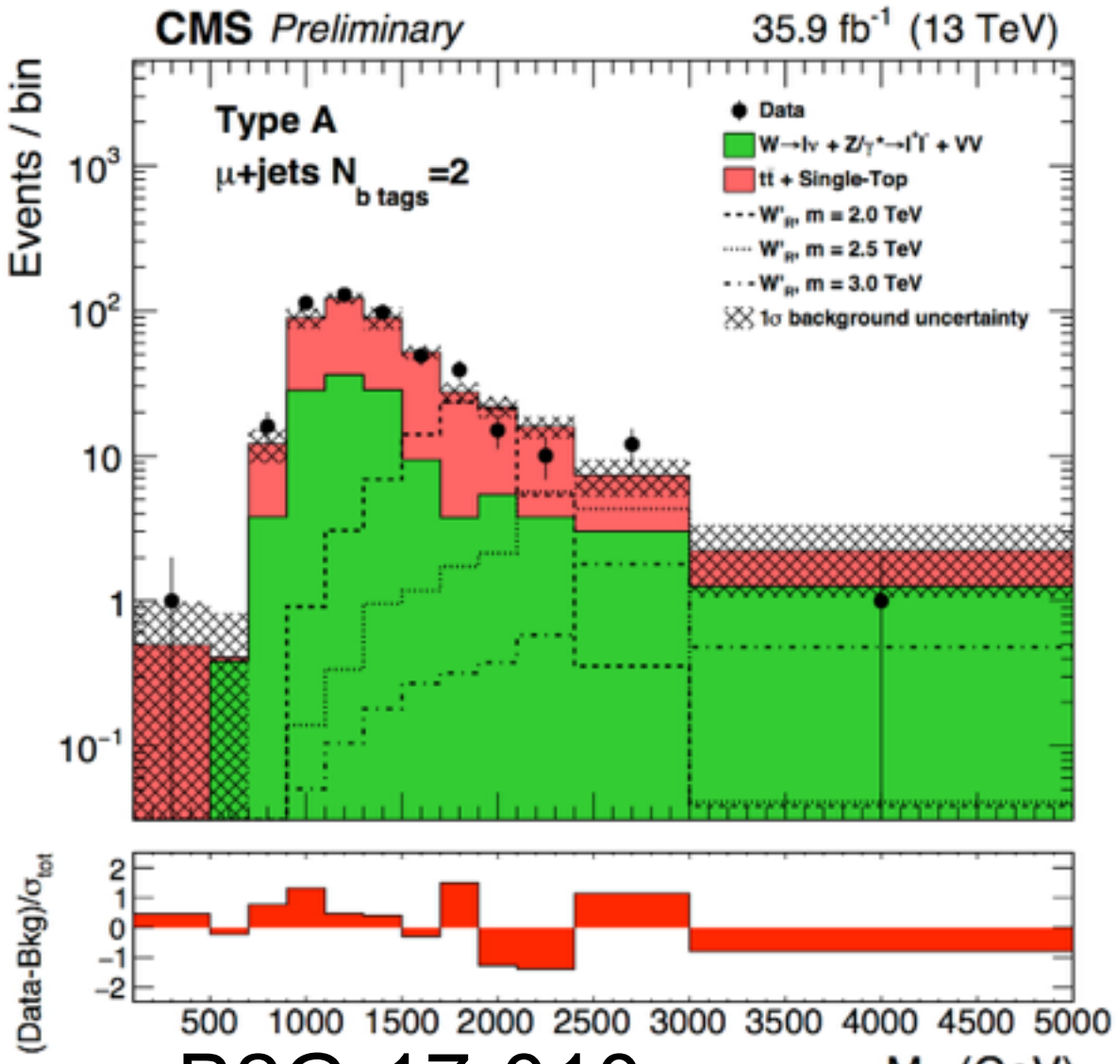


W'→tb IN LEPTON+JET FINAL STATE

- **Many theories** predict existence of **new heavy vector bosons**
- **W'→tb complements other W' searches**
  - in some models tb decay is enhanced
  - allows for full reconstruction of W' mass (up to quadratic ambiguity)
- **Final state:** single lepton, multiple jets, and missing transverse E
- **Mass** reconstructed after **imposing W mass constraint**
  - care in dealing with multiple/ imaginary solution
- **8 categories** based on jet p_T, lepton flavor, and N_{bjet}
- **No excess**
  - mass limits at 3.4-3.6 TeV depending on v_R mass

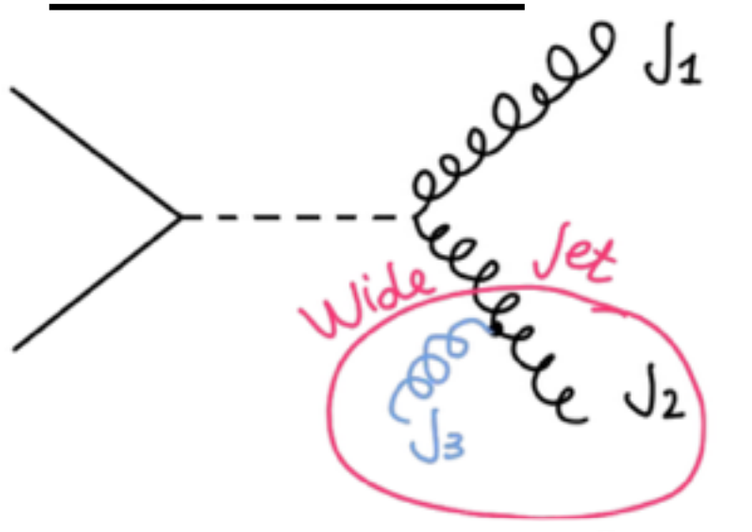


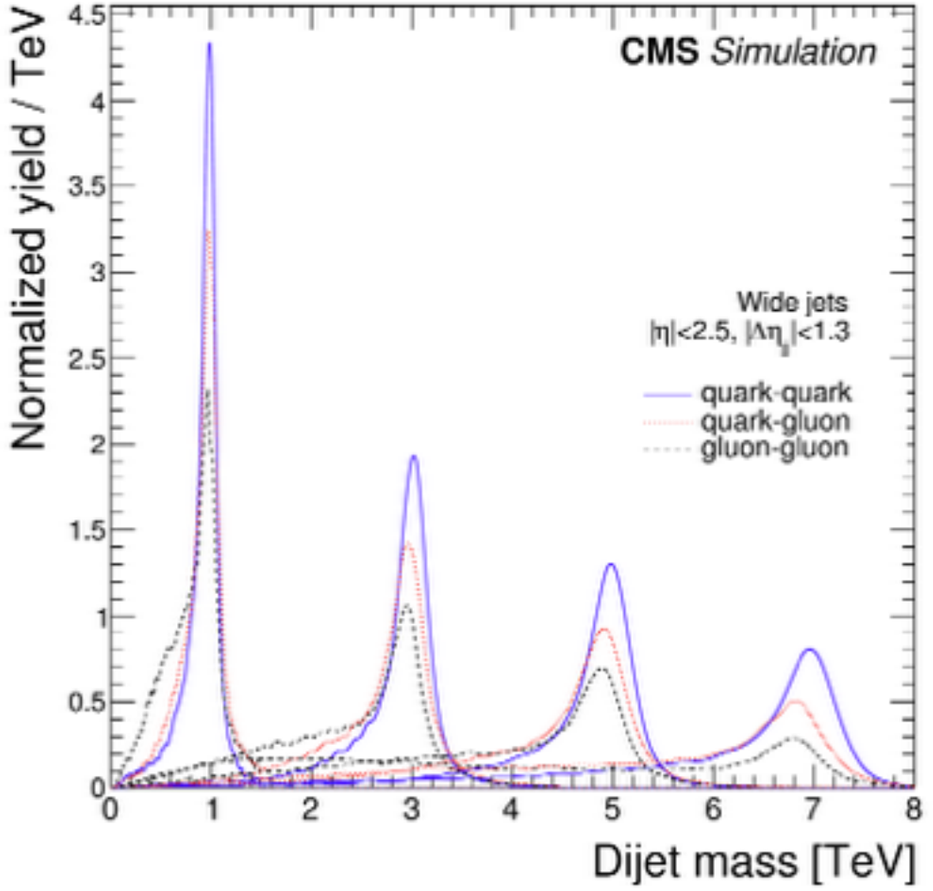
B2G-17-010

DIJET

- **Most powerful search at LHC**
  - largest cross sections involve jets
- **Sensitive to several scenarios**
  - interpreted for excited quarks, strings, new bosons, gravitons, DM
  - valid for qq, gq, gg resonances
- **Simple and robust analysis**
  - background from dijet invariant mass fit
- **Use of wide jets** (ΔR=1.1) to recover radiation
- **At "low" masses (M<1.6 TeV) use of data-scouting**

EXO-16-056



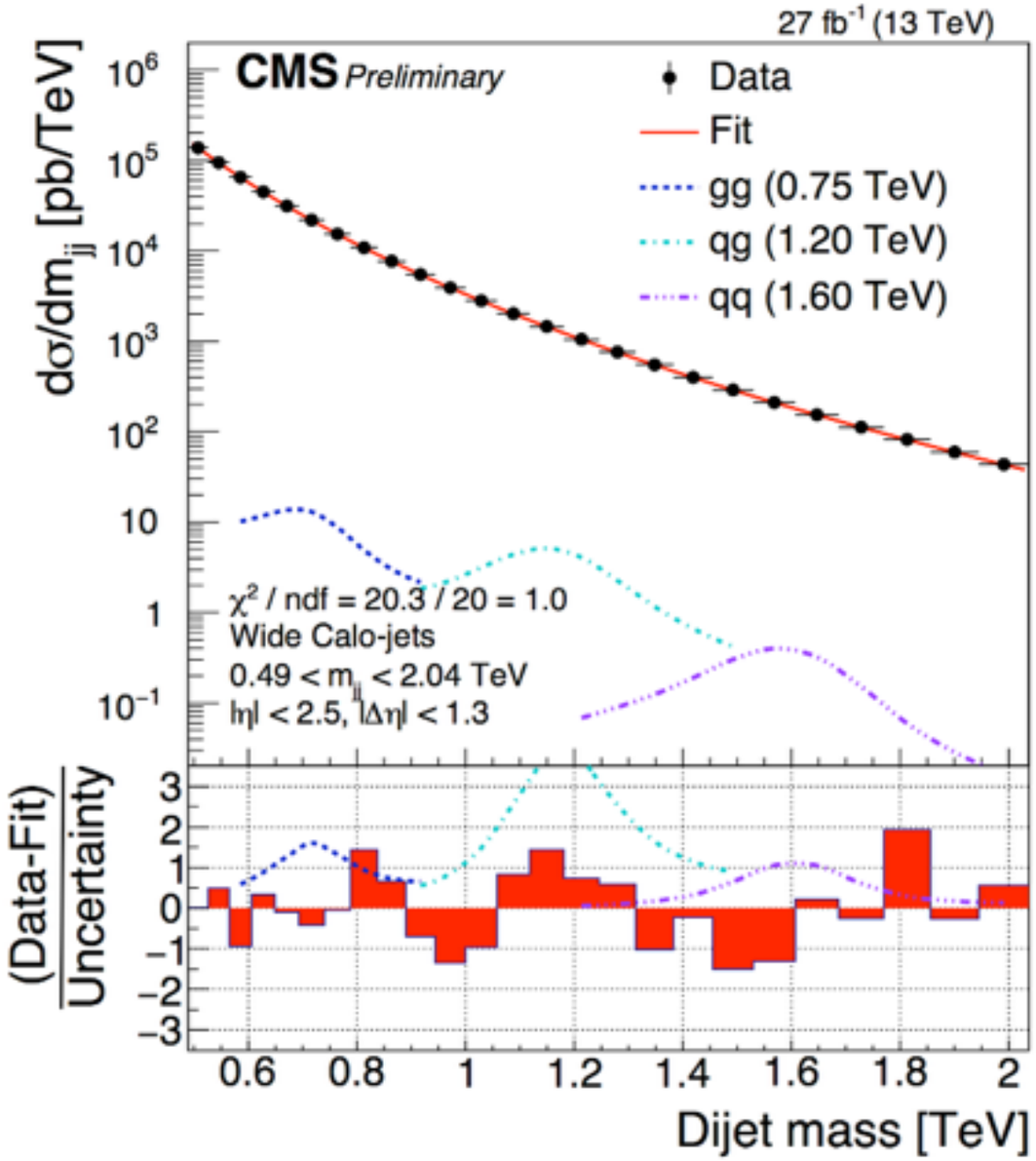


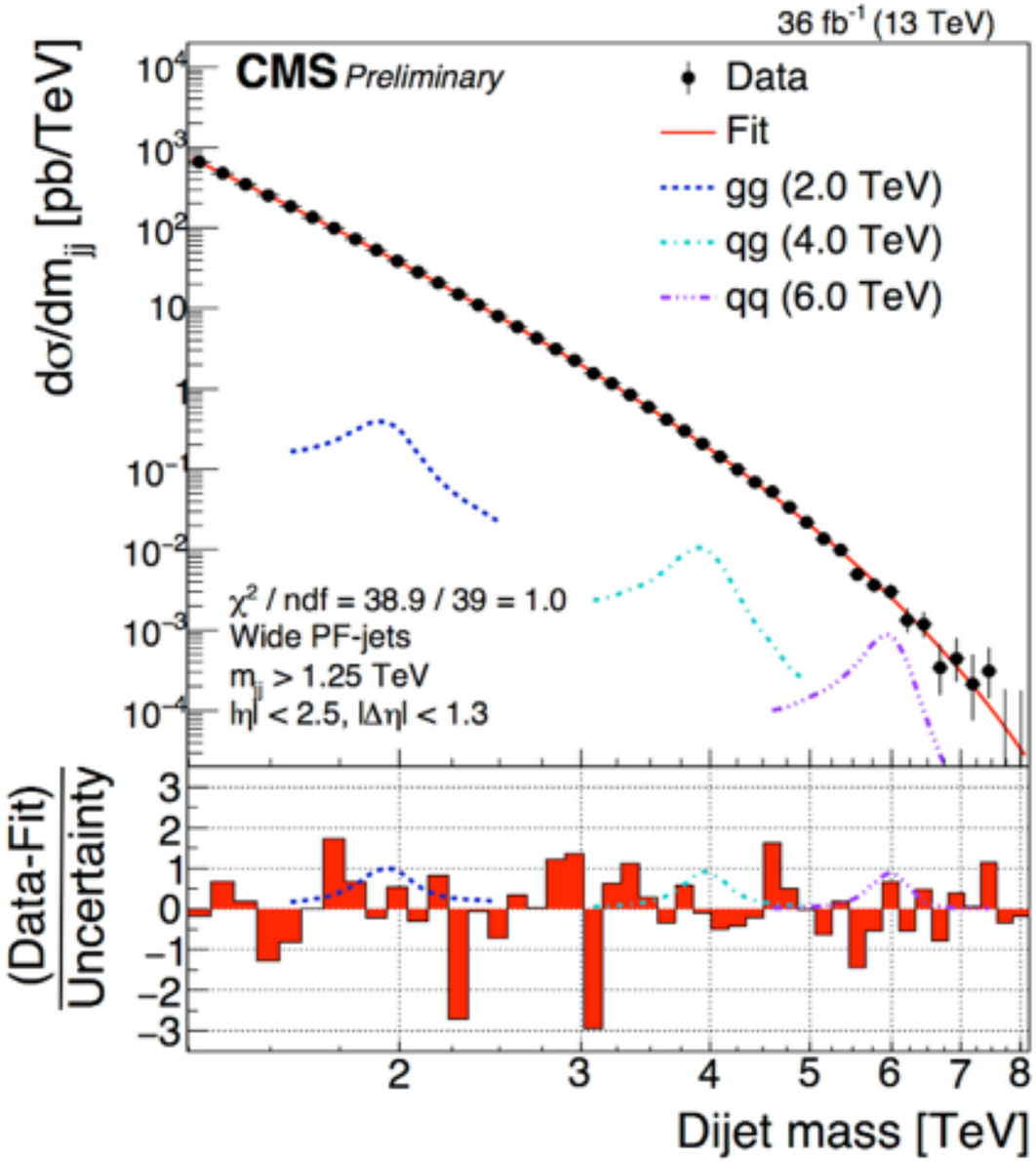
DIJET: SPECTRA

- 5 (4) parameter fit for high (low) mass
- **No excess**

$$\frac{\mathrm{d}\sigma}{\mathrm{d}m_{jj}} = \frac{P_0(1-x)^{P_1}}{x^{P_2+P_3\ln(x)+P_4\ln(x)^2}}$$

$$x = m_{jj}/\sqrt{s}$$

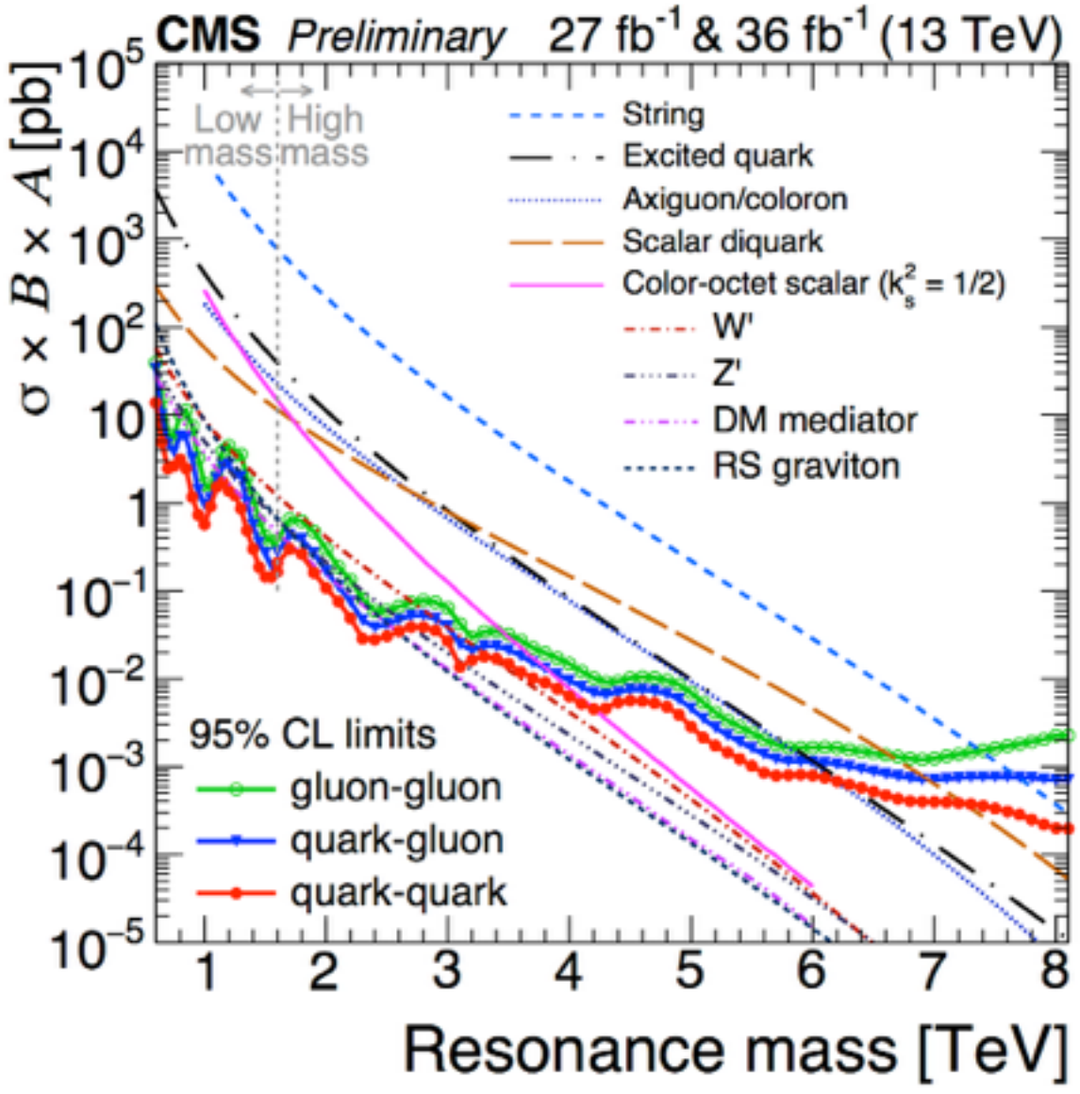




DIJET: INTERPRETATION

- **Interpreted in 9 different models**
  - substantial improvement wrt ICHEP
  - superseding all 8 TeV results
- DM interpretation detailed in talk of Livia S. (this morning)

Model	Final State	Observed (expected) mass limit [TeV] 36 fb^{-1} 13 TeV	12.9 fb^{-1} 13 TeV
String	qg	7.7 (7.7)	7.4 (7.4)
Scalar diquark	qq	7.2 (7.4)	6.9 (6.8)
Axigluon/coloron	$q\bar{q}$	6.1 (6.0)	5.5 (5.6)
Excited quark	qg	6.0 (5.8)	5.4 (5.4)
Color-octet scalar ($k_s^2 = 1/2$)	gg	3.4 (3.6)	3.0 (3.3)
W′	$q\bar{q}$	3.3 (3.6)	2.7 (3.1)
Z′	$q\bar{q}$	2.7 (2.9)	2.1 (2.3)
RS Graviton ($k/M_{PL} = 0.1$)	$q\bar{q}$, gg	1.7 (2.1)	1.9 (1.8)
DM Mediator ($m_{DM} = 1$ GeV)	$q\bar{q}$	2.6 (2.5)	2.0 (2.0)

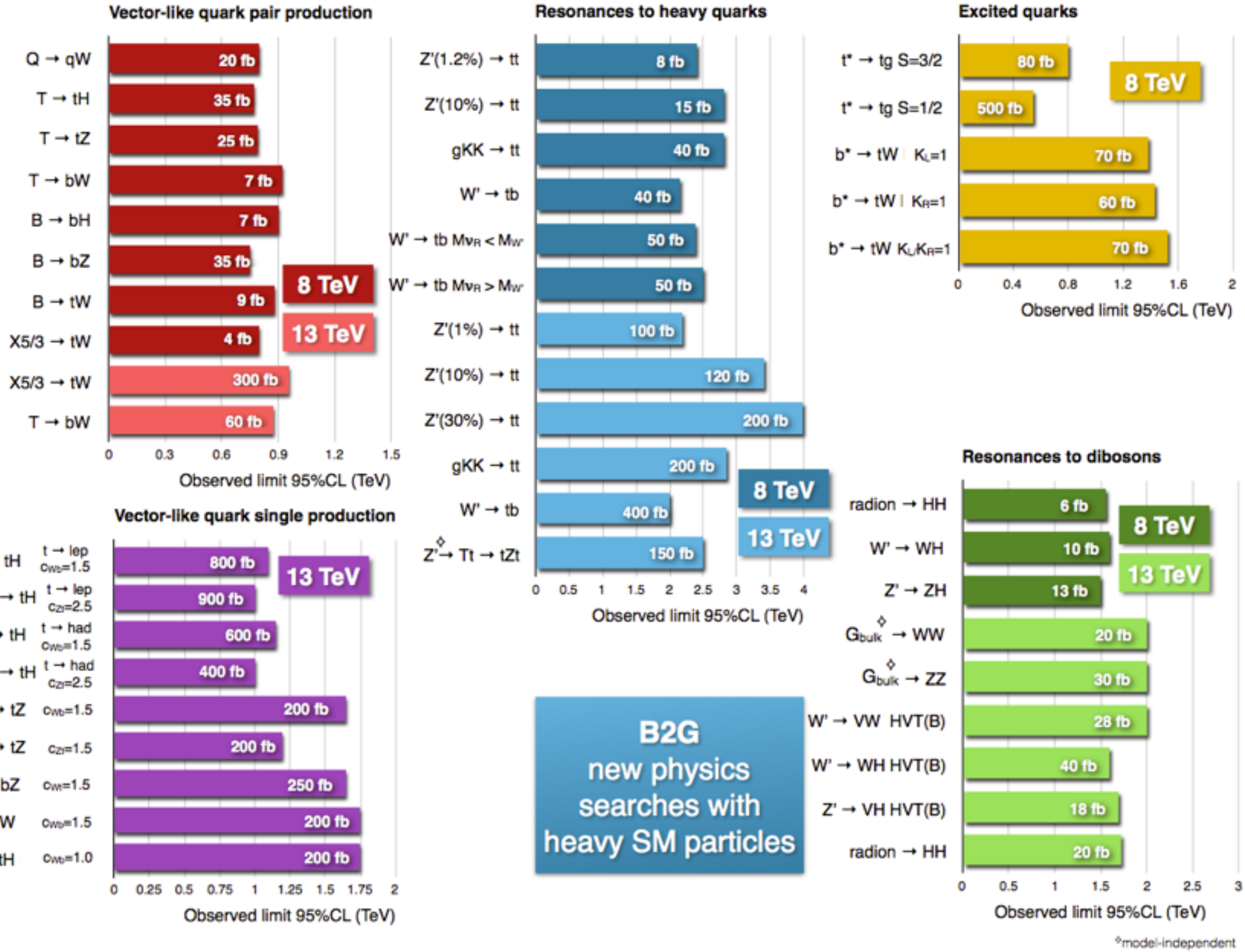


CONCLUSIONS

- **CMS has a wide program for search of new high mass particles**
  - several new published results based on 13 TeV data
- Presented **updates on full 2016 dataset (36 fb^{-1})**
  - multileptons in type III see-saw, VLQ (T and $X_{5/3}$), W'→tb, dijet
- **No new Physics seen yet**
- **Run1 program is being fully repeated**
  - many searches on full 2016 13 TeV dataset still to be finalized
- **Improving analyses**
  - new final states and new analysis techniques
- **Surprises may come** from mass regions already excluded in specific models and benchmarks
  - keep searching in the low/intermediate mass region
- **Next years still crucial for these searches**

BACKUP

B2G TABLE


Vector-like quark pair production
Q → qW 20 fb
T → tH 35 fb
T → tZ 25 fb
T → bW 7 fb
B → bH 7 fb
B → bZ 35 fb
B → tW 9 fb
X5/3 → tW 4 fb
X5/3 → tW 300 fb
T → bW 60 fb
8 TeV
13 TeV
0 0.3 0.6 0.9 1.2 1.5
Observed limit 95%CL (TeV)
Vector-like quark single production
T → tH t → lep cWb=1.5 800 fb
T → tH t → lep cZt=2.5 900 fb
T → tH t → had cWb=1.5 600 fb
T → tH t → had cZt=2.5 400 fb
T → tZ cWb=1.5 200 fb
T → tZ cZt=1.5 200 fb
B → bZ cWt=1.5 250 fb
T → bW cWb=1.5 200 fb
Y → tH cWb=1.0 200 fb
13 TeV
0 0.25 0.5 0.75 1 1.25 1.5 1.75 2
Observed limit 95%CL (TeV)
Resonances to heavy quarks
Z'(1.2%) → tt 8 fb
Z'(10%) → tt 15 fb
gKK → tt 40 fb
W' → tb 40 fb
W' → tb MνR < MW' 50 fb
W' → tb MνR > MW' 50 fb
Z'(1%) → tt 100 fb
Z'(10%) → tt 120 fb
Z'(30%) → tt 200 fb
gKK → tt 200 fb
W' → tb 400 fb
Z'◇ → Tt → tZt 150 fb
8 TeV
13 TeV
0 0.5 1 1.5 2 2.5 3 3.5 4
Observed limit 95%CL (TeV)
Excited quarks
t* → tg S=3/2 80 fb
t* → tg S=1/2 500 fb
b* → tW | KL=1 70 fb
b* → tW | KR=1 60 fb
b* → tW KL/KR=1 70 fb
8 TeV
0 0.4 0.8 1.2 1.6 2
Observed limit 95%CL (TeV)
B2G
new physics
searches with
heavy SM particles
Resonances to dibosons
radion → HH 6 fb
W' → WH 10 fb
Z' → ZH 13 fb
Gbulk◇ → WW 20 fb
Gbulk◇ → ZZ 30 fb
W' → VW HVT(B) 28 fb
W' → WH HVT(B) 40 fb
Z' → VH HVT(B) 18 fb
radion → HH 20 fb
8 TeV
13 TeV
0 0.5 1 1.5 2 2.5 3
Observed limit 95%CL (TeV)
◇model-independent