Dijet resonances and Quark compositeness at hadron colliders

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Dijet resonance current status: from Bogdan Dobrescu, FY [arXiv:1306.2629]

Dijet resonances sensitivity: FY

UED projection: Kyoungchul Kong, FY

Quark compositeness: Suneet Upadhyay, Daniel Whiteson, FY

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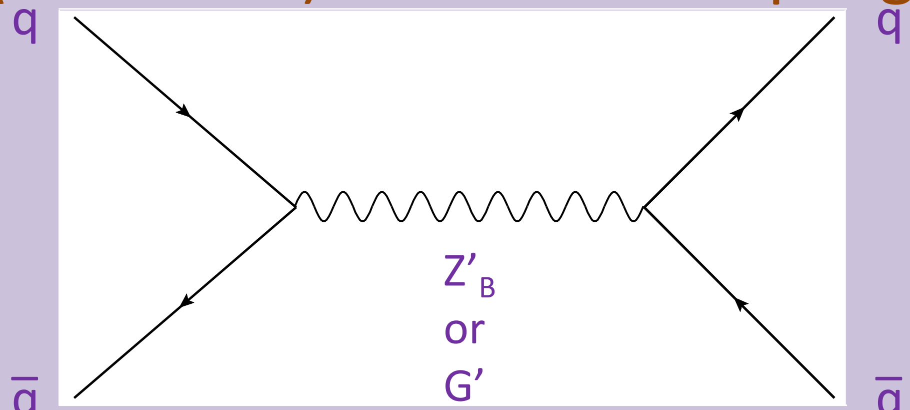
Dijet resonances – barebones theory

- Many BSM models have additional gauge symmetry
  - Generic signature is a new vector resonance
  - An important class of models have leptophobic gauge bosons
    - Z'_B (baryon number)
    - G' (coloron)
- Separately, the simplest *s*-channel resonance at a high energy hadron collider is a dijet resonance
  - $q\bar{q}$ resonance
  - gg resonance: loop-induced (e.g. Higgs)
  - qg resonance: loop-induced
  - qq resonance: flavor constraints

BSM Parameters

- Natural to consider sensitivity for dijet resonances
  - Production and decay vertices use same coupling
  - Two parameters: coupling and mass (other NP heavy)
    - Leptophobic, and no tree-level gluon coupling
    - Universal coupling to quarks – BR to jj (including $b\bar{b}$) only depends on mass
      - Interplay with $t\bar{t}$ resonance searches
  - Map effective rate ($\sigma \times Br \times A$) limits into coupling vs. mass plane



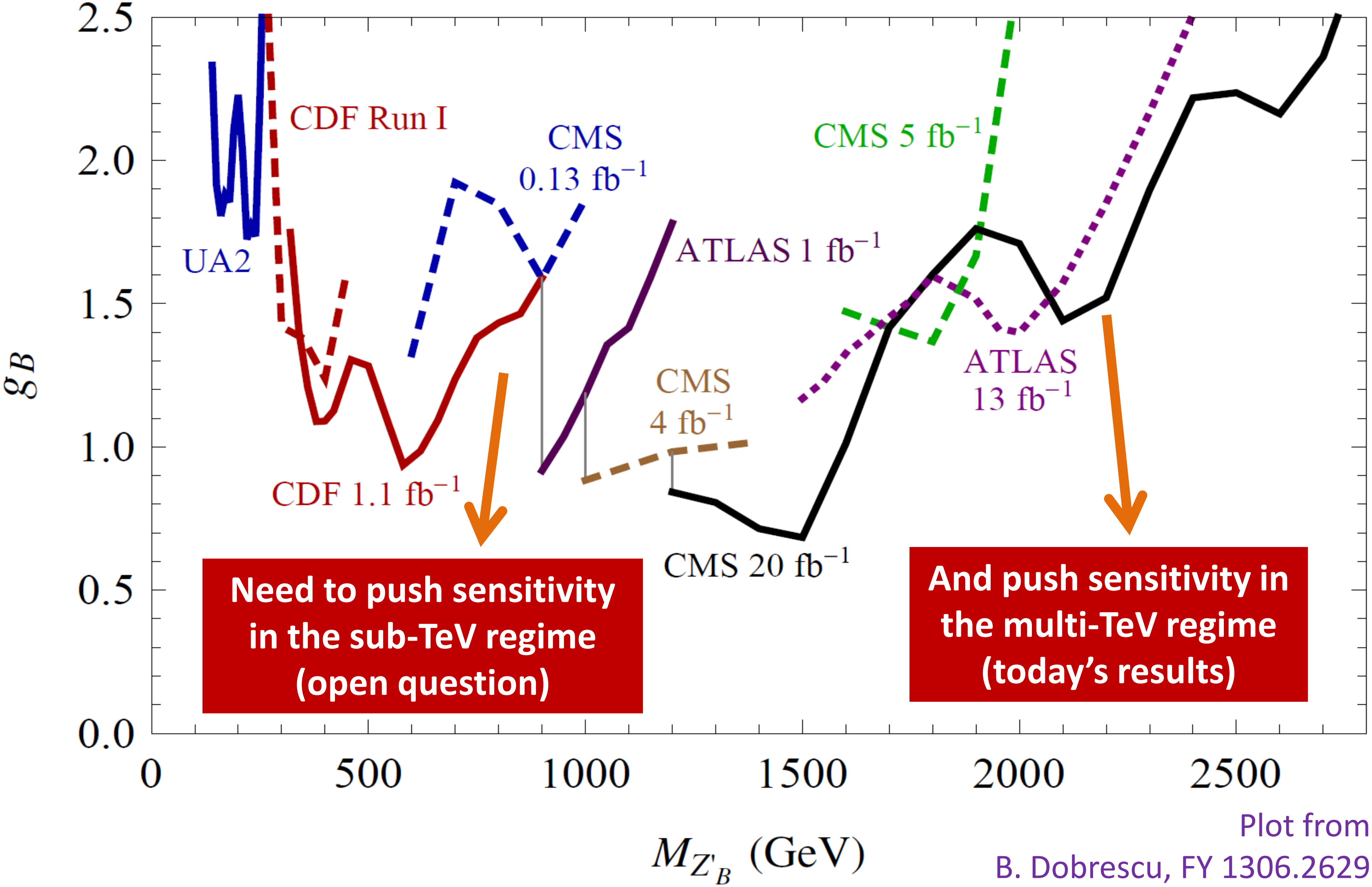
Coupling–mass mapping

- Higher energy colliders probe ever heavier resonances
  - Are still sensitive to more weakly-coupled resonances
  - Low end of resonance search window also moves up
    - More QCD background at low masses competes with finite trigger bandwidth
- As run conditions change (higher instantaneous luminosity), triggers are also adjusted upwards
  - Small luminosity studies may be the final word on low mass dijet resonances for an experiment
- Sensitivity gaps develop at crossover points
- The coupling–mass mapping highlights these gaps
  - Also aids comparisons of different searches with different luminosities and colliders

Past searches

Collider $\sqrt{s}$ (TeV)	Experiment Luminosity (fb^{-1})	Mass Range (GeV)
$p\bar{p}$, 0.63	UA1 [2] 4.9×10^{-4}	150–400
	UA2 [3] 4.7×10^{-3}	80–320
	UA2 [4] 10.9×10^{-3}	140–300
$p\bar{p}$, 1.8	CDF [5] 2.6×10^{-6}	60–500
	CDF [6] 4.2×10^{-3}	200–900
	CDF [7] 1.9×10^{-2}	200–1150
	CDF [8] 0.11	200–1150
	D0 [10] 0.11	200–900
$p\bar{p}$, 1.96	CDF [9] 1.1	260–1400
pp, 7	ATLAS [11] 3.15×10^{-4}	300–1700
	ATLAS [12] 3.6×10^{-2}	600–4000
	ATLAS [13] 0.16	900–4000
	ATLAS [14] 0.81	900–4000
	ATLAS [15] 1.0	900–4000
	ATLAS [16] 4.8	1000–4000
	CMS [19] 2.9×10^{-3}	500–2600
	CMS [20] 1.0	1000–4100
	CMS [21] 5.0	1000–4300
	CMS [22] 0.13	600–1000
pp, 8	CMS [23] 4.0	1000–4800
	ATLAS [17] 5.8	1500–4000
	ATLAS [18] 13	1500–4800
	CMS [24] 20	1200–5300

Coupling vs. mass limits: Z'_B dijet resonance

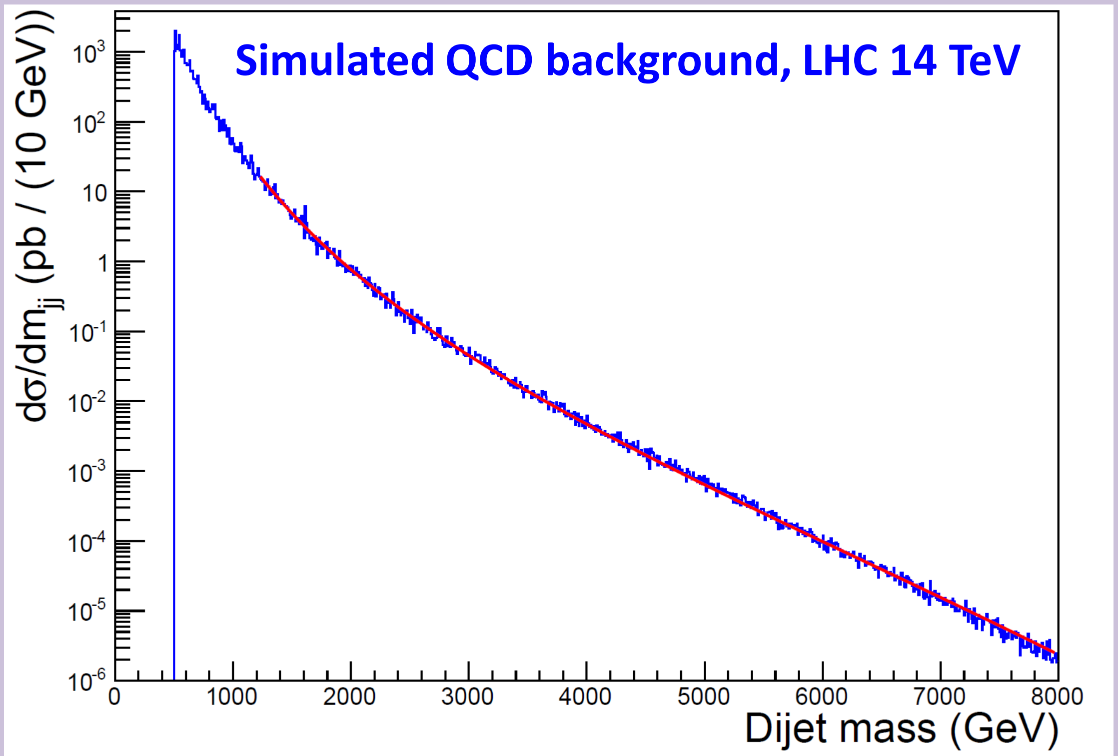


Plot from
B. Dobrescu, FY 1306.2629

Future sensitivity

- Generate QCD background in bins of leading jet p_T using MadGraph 5 + Pythia 6 with MLM matching
  - Cluster with FastJet, anti-kT, R = 0.5
  - Smooth dijet invariant mass spectrum

Follow similar procedure as CMS NOTE 2006/069 and CMS NOTE 2006/070



Flat K-factor of 1.40
No detector simulation
No pile-up
Trigger bandwidth issues

Thanks to C. Williams for helpful discussions

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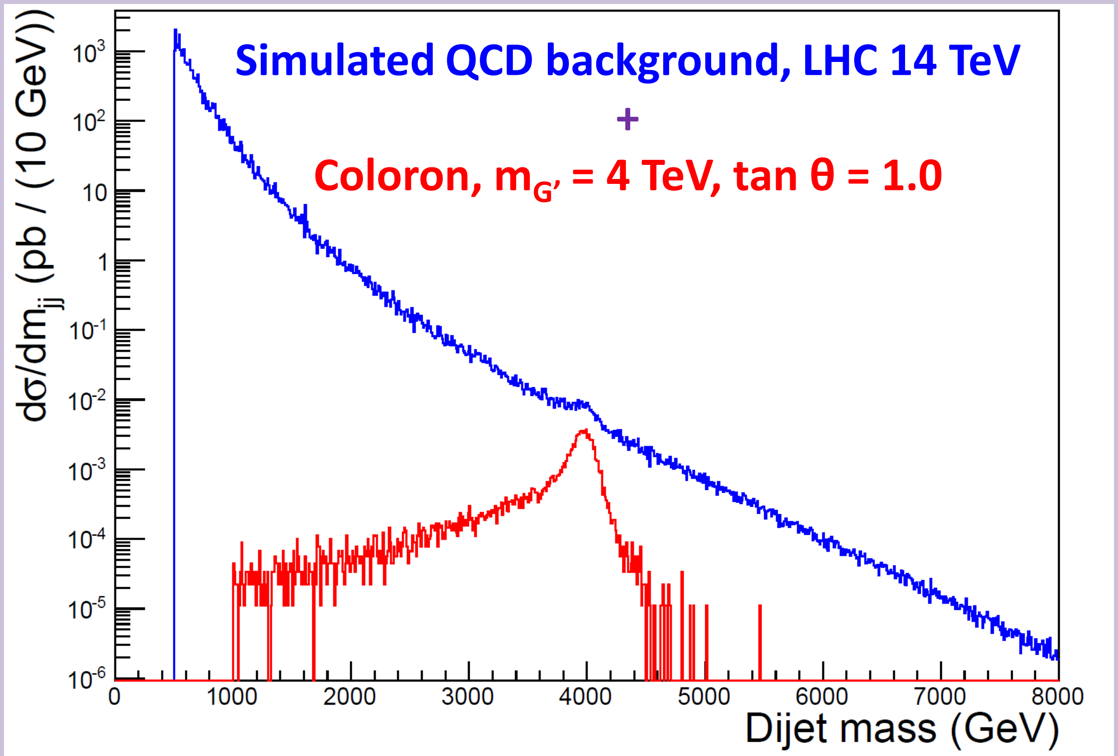
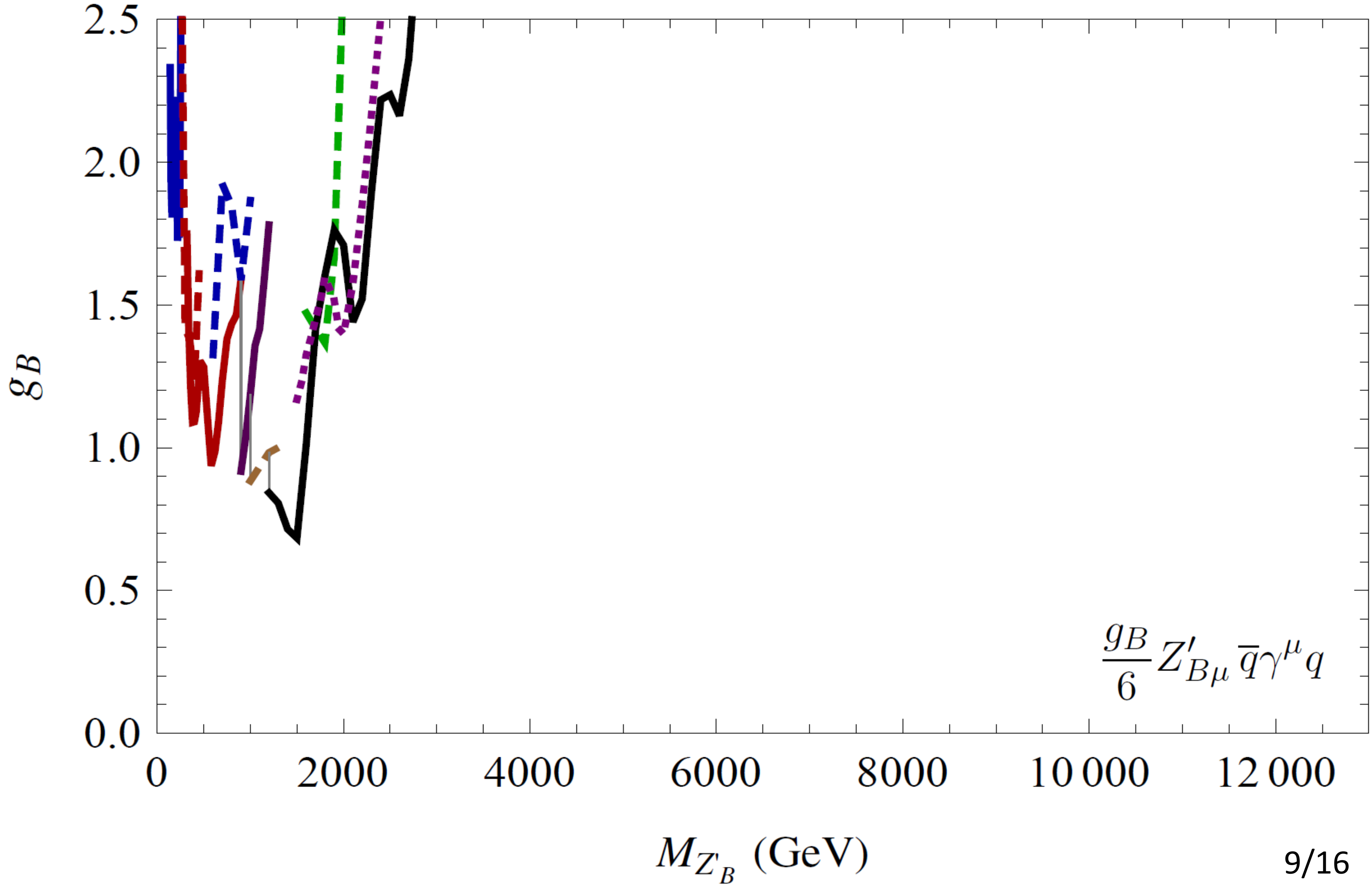


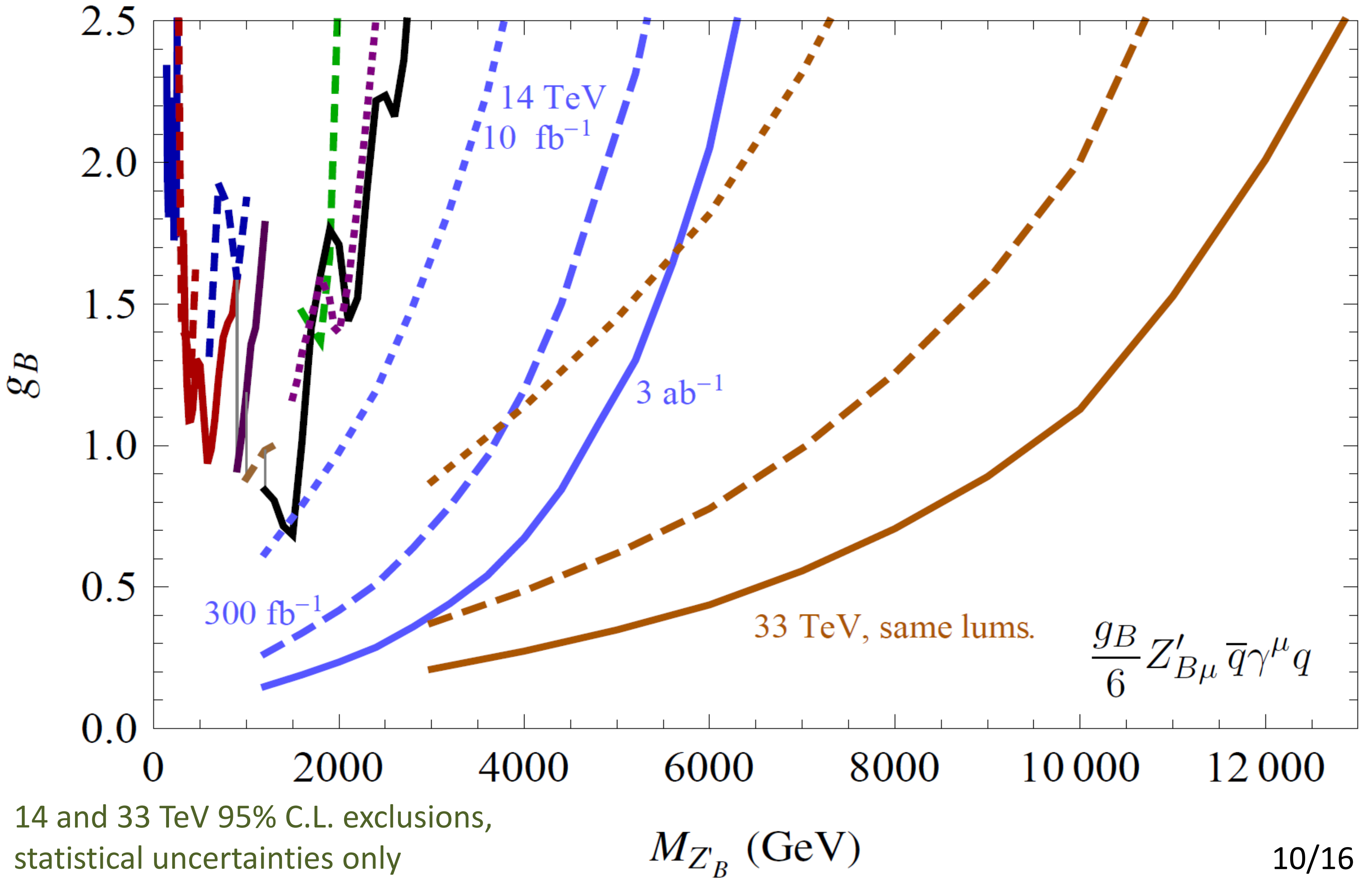
Bump hunting! (Follow cuts in CMS 1302.4794 analysis)

Construct 95% C.L. exclusion projections from statistical uncertainties only

Coupling vs. mass **current limits**: Z'_B

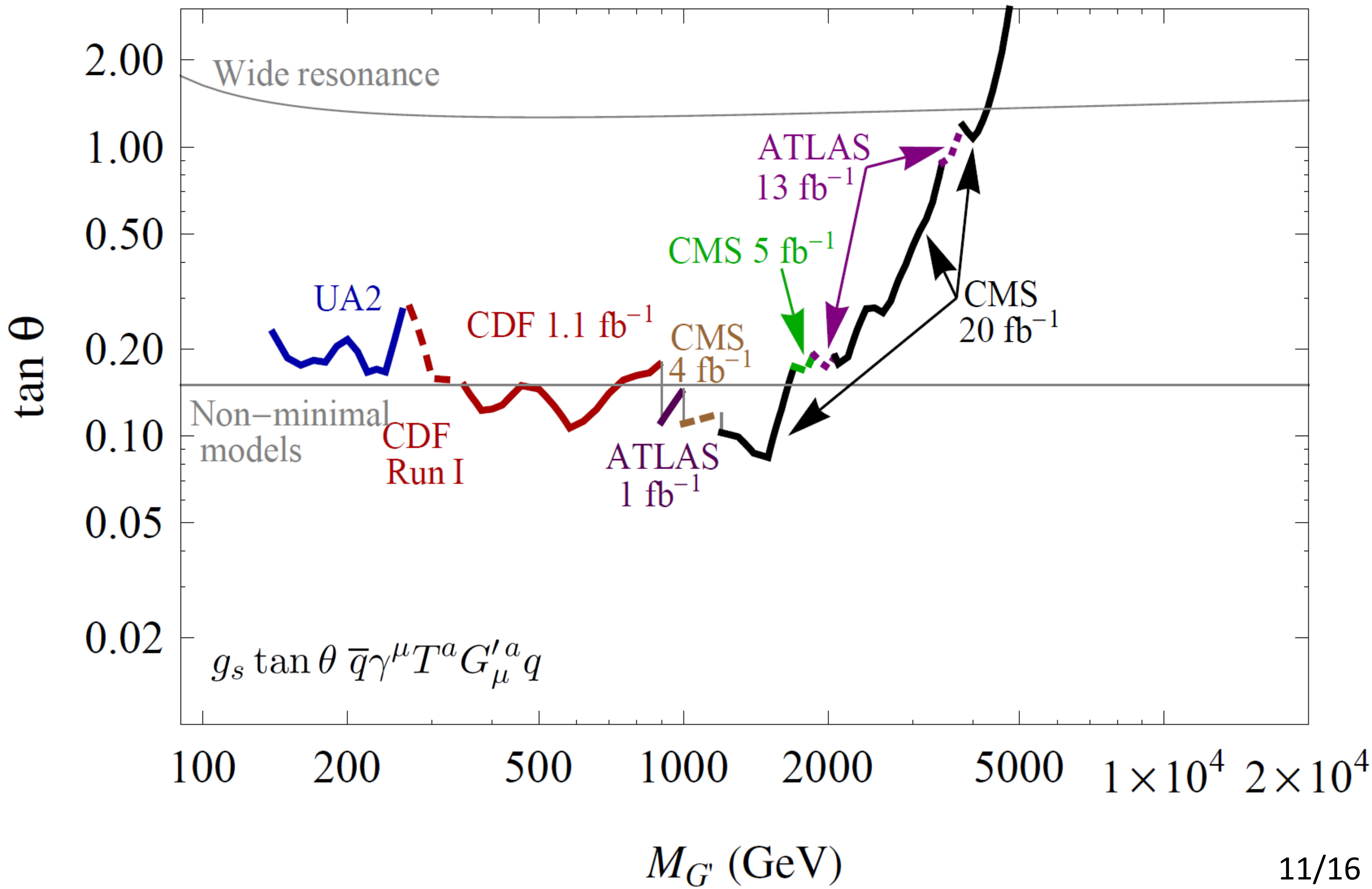


Coupling vs. mass projections: Z'_B

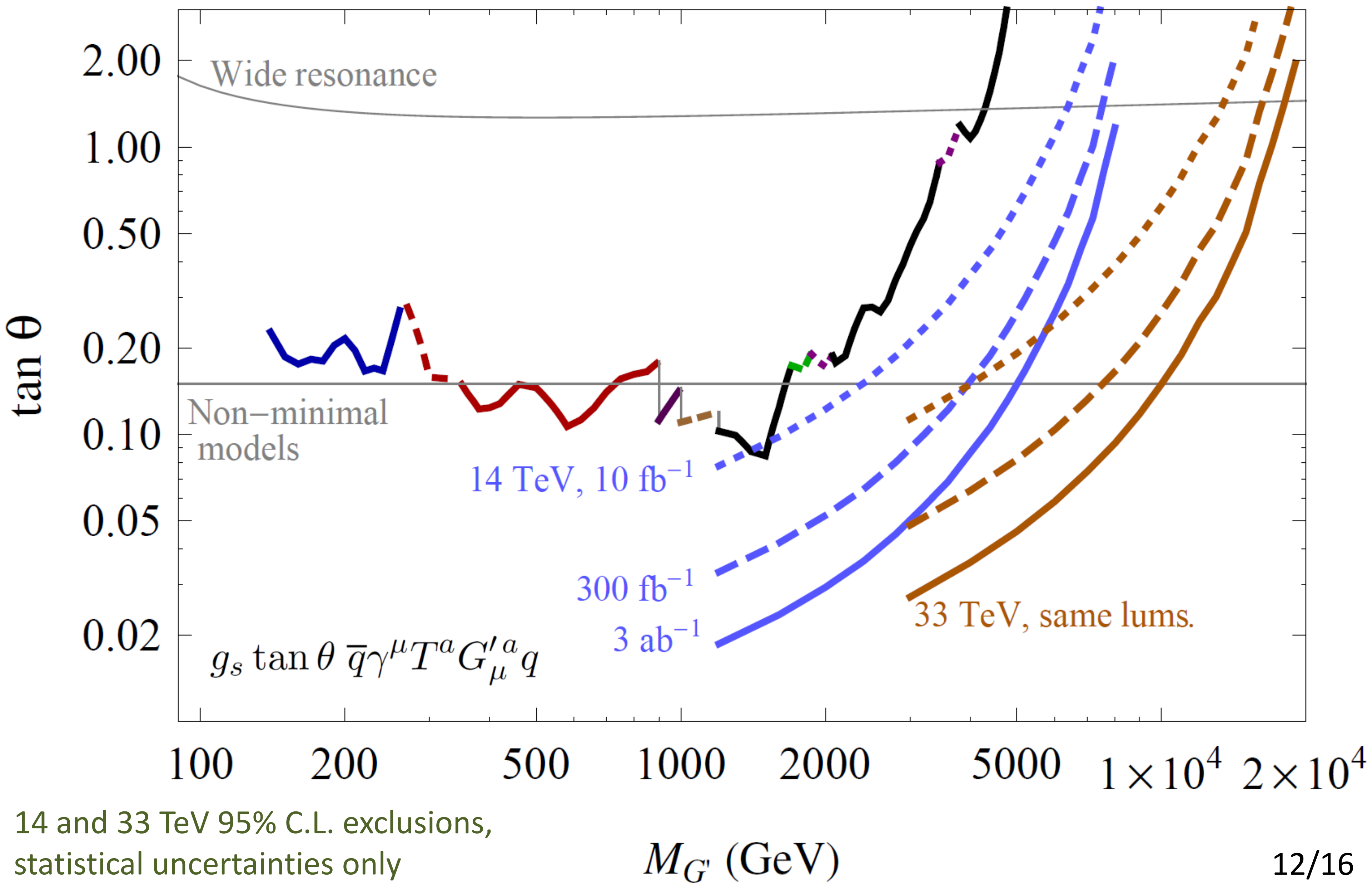


14 and 33 TeV 95% C.L. exclusions, statistical uncertainties only

Coupling vs. mass **current limits**: G'



Coupling vs. mass projections: G'



14 and 33 TeV 95% C.L. exclusions, statistical uncertainties only

Dijet resonances: remaining issues

- Estimate systematic uncertainties
- Add discovery sensitivity curves
- Will also discuss **KK gluons** in this channel
  - Translate to UED model parameters

with KC Kong

- Start of search window is driven by trigger
  - Possibility for parked data at HL LHC?
- Prospects for sub-TeV mass window require alternate triggers
  - Can be studied in current Tevatron and LHC data
- Should be cognizant of possible sensitivity gaps as we transition to new energies and luminosities

Quark compositeness

with S. Upadhyay, D. Whiteson

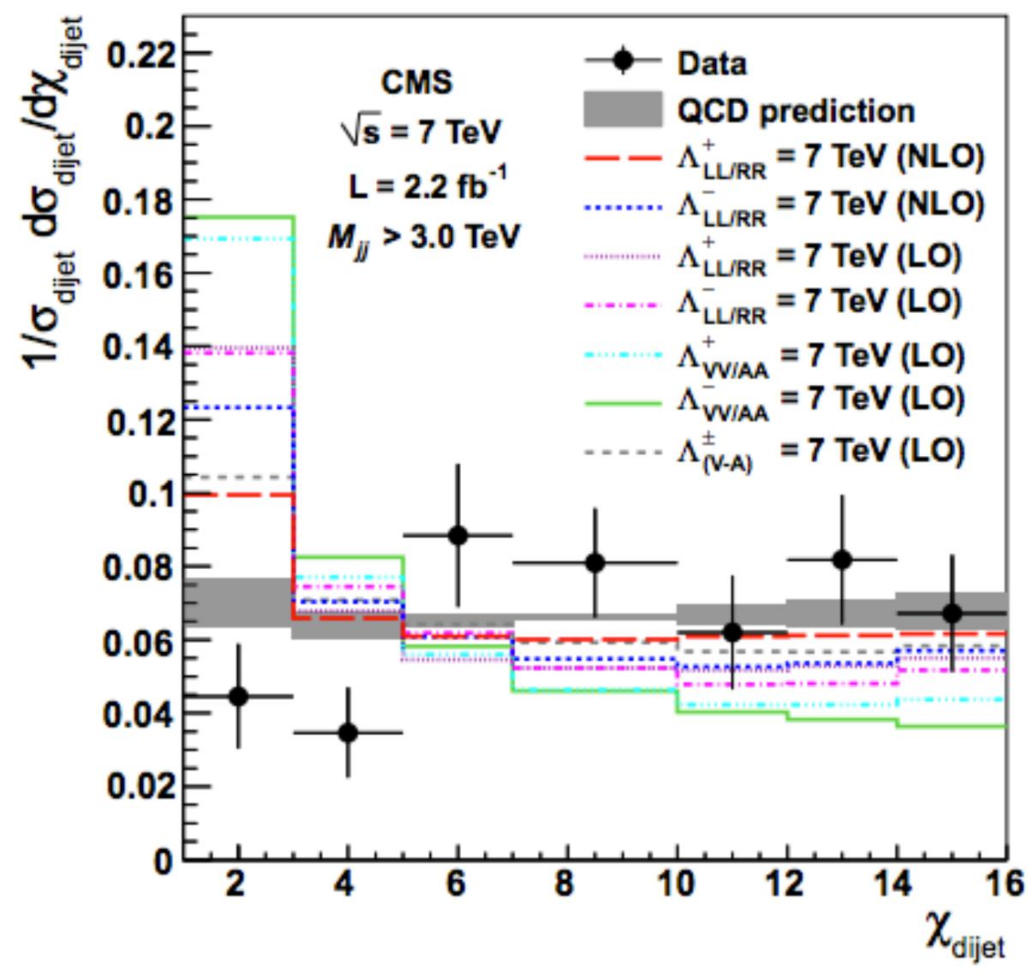
- Instead of a resonance feature, look for deviations in dijet angular distributions at high dijet masses

Follow CMS analysis[1]

Probe Λ scale of 6D, four quark operator

Use LO background and signal from MadGraph 5 + Pythia + Delphes

Focus on highest mass bin

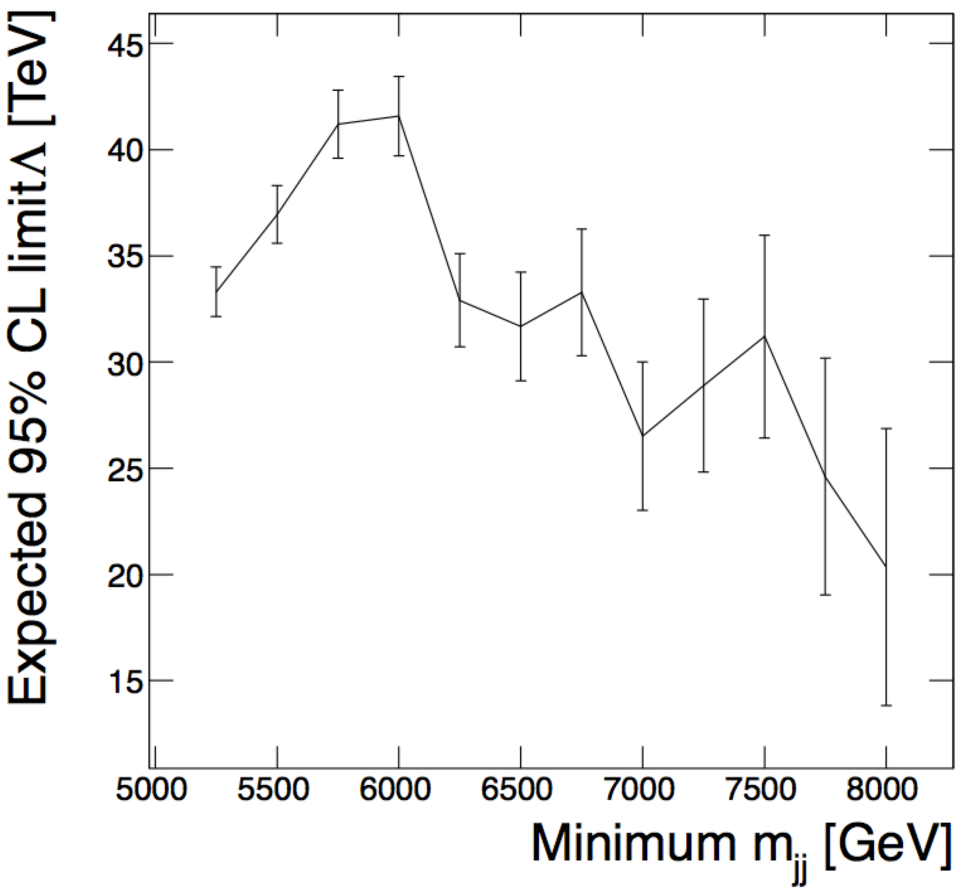


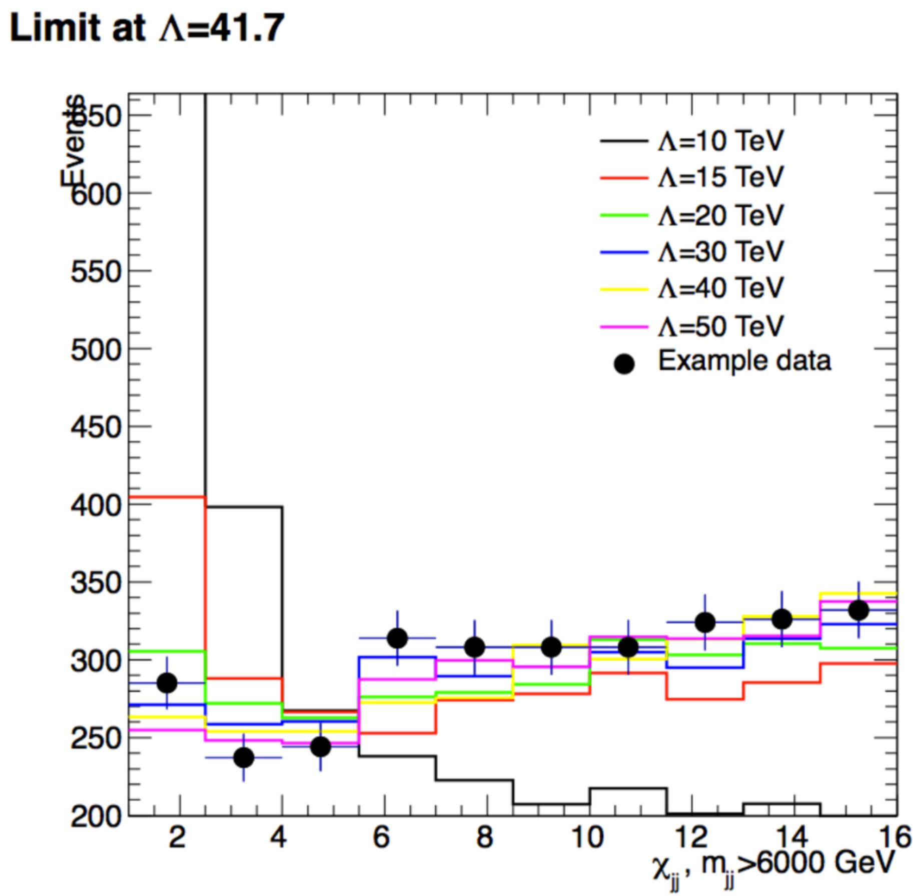
[1]CMS, JHEP **1205**, 055 (2012) [arXiv:1202.5535 [hep-ex]]

Results for 14 TeV, 300 fb^{-1}

- Optimize mass threshold

Example data





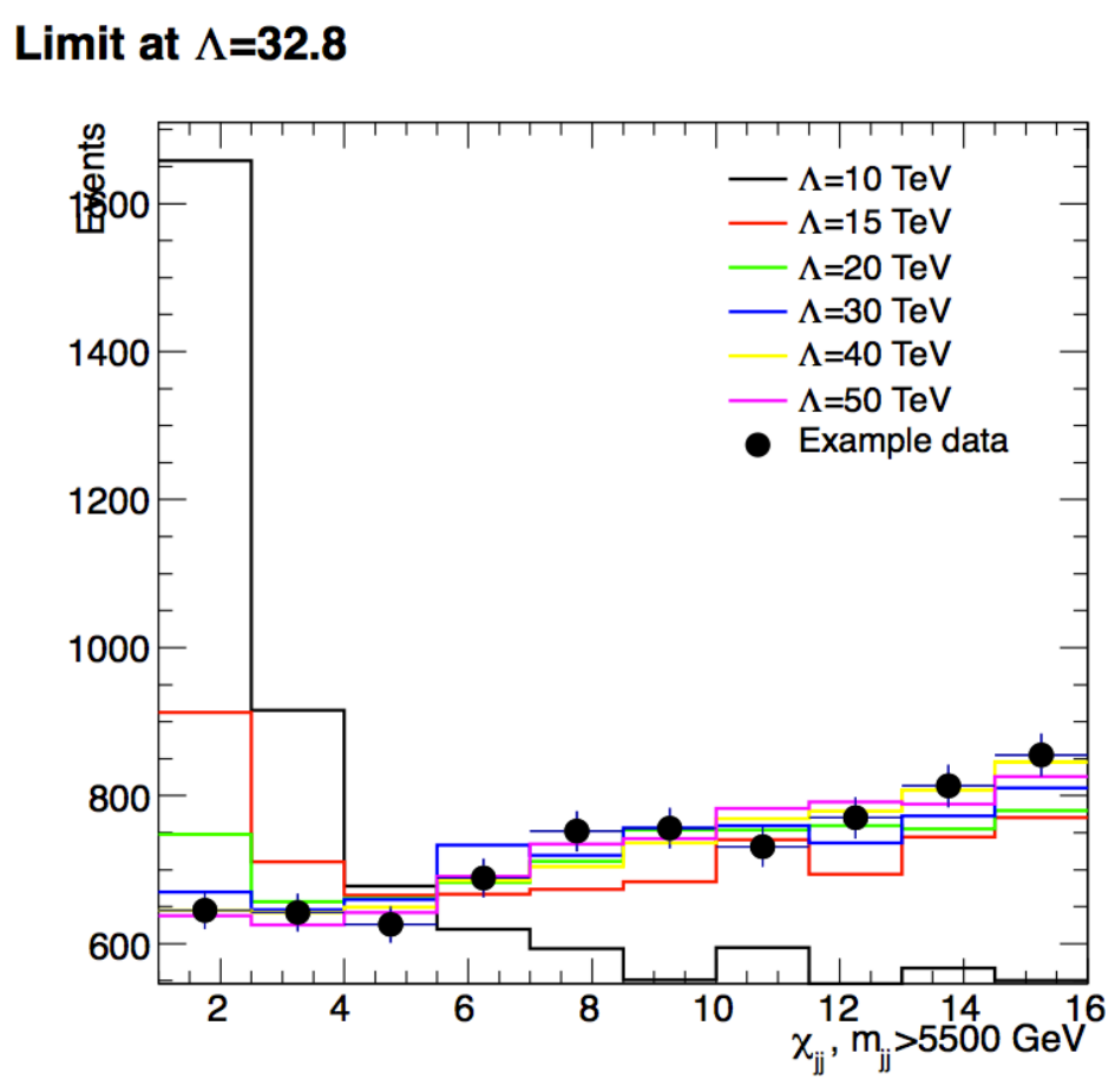
Summary

- The dijet final state is an important benchmark
  - If history holds, a dijet resonance search is likely the first BSM result from any future hadron collider
- Coupling–mass mapping (though model-dependent) provides a useful presentation of current limits and future sensitivities
  - New resonances will trace out contours in this plane
  - Sub-TeV regime can be probed by associated production modes
    - Also, can study ILC production from Z' radiation off final state quarks
  - Need to identify and ameliorate sensitivity gaps
- Quark compositeness searches probe even higher scales for possible new physics

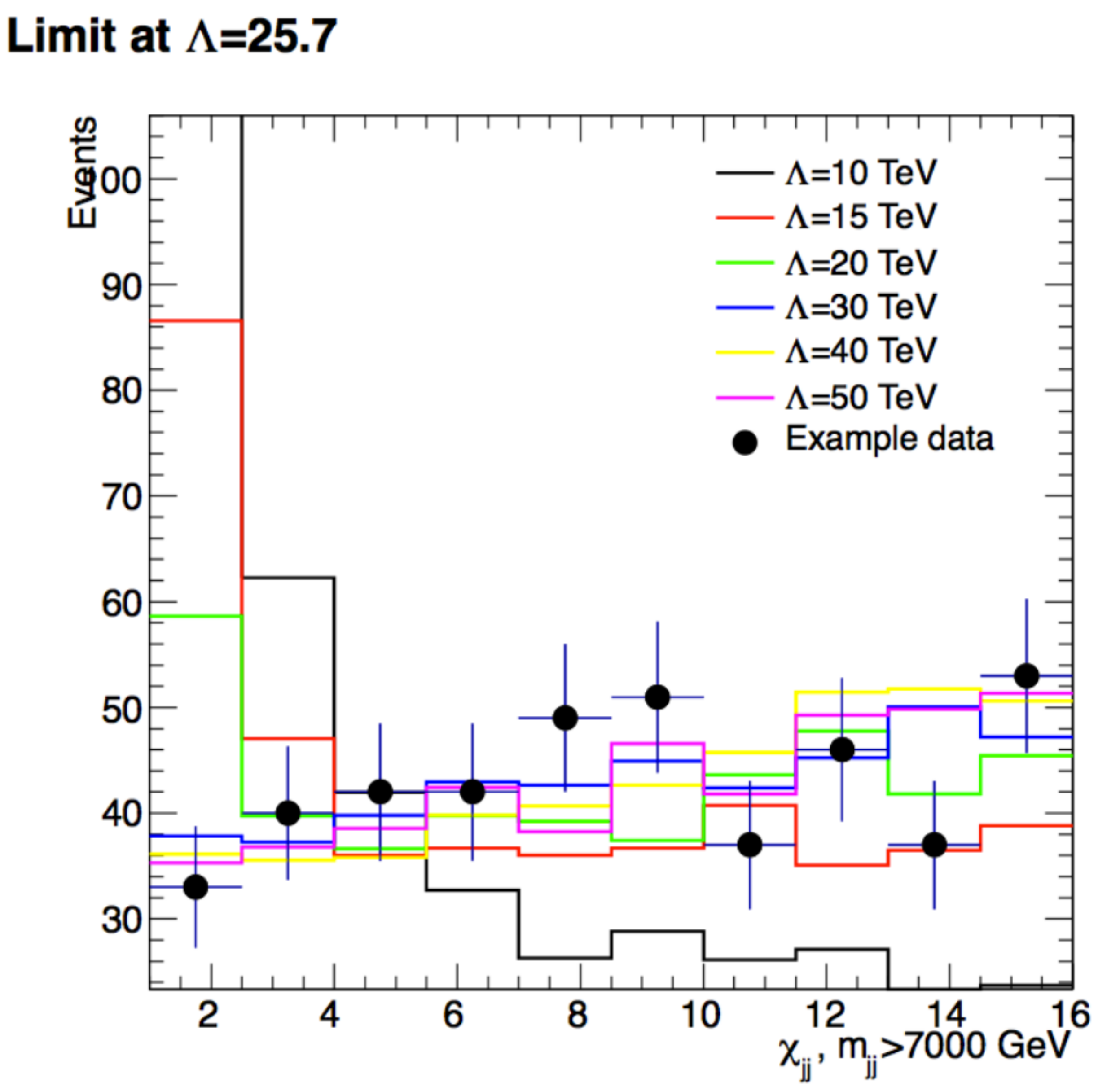
Hadron collider genealogy

- CERN SPS, $p\bar{p}$ machine
  - 630 GeV, 10.9 pb^{-1}
- Tevatron, $p\bar{p}$ machine
  - Run I: 1.8 TeV, 110 pb^{-1}
  - Run II: 1.96 TeV, 10 fb^{-1}
- LHC, pp machine
  - Run I: 7 TeV, 5 fb^{-1}; 8 TeV, 20 fb^{-1}
    - CMS parked data, 13 fb^{-1}
  - Run II: 13 (14) TeV, 300 fb^{-1} (anticipated)

Other thresholds



Other thresholds



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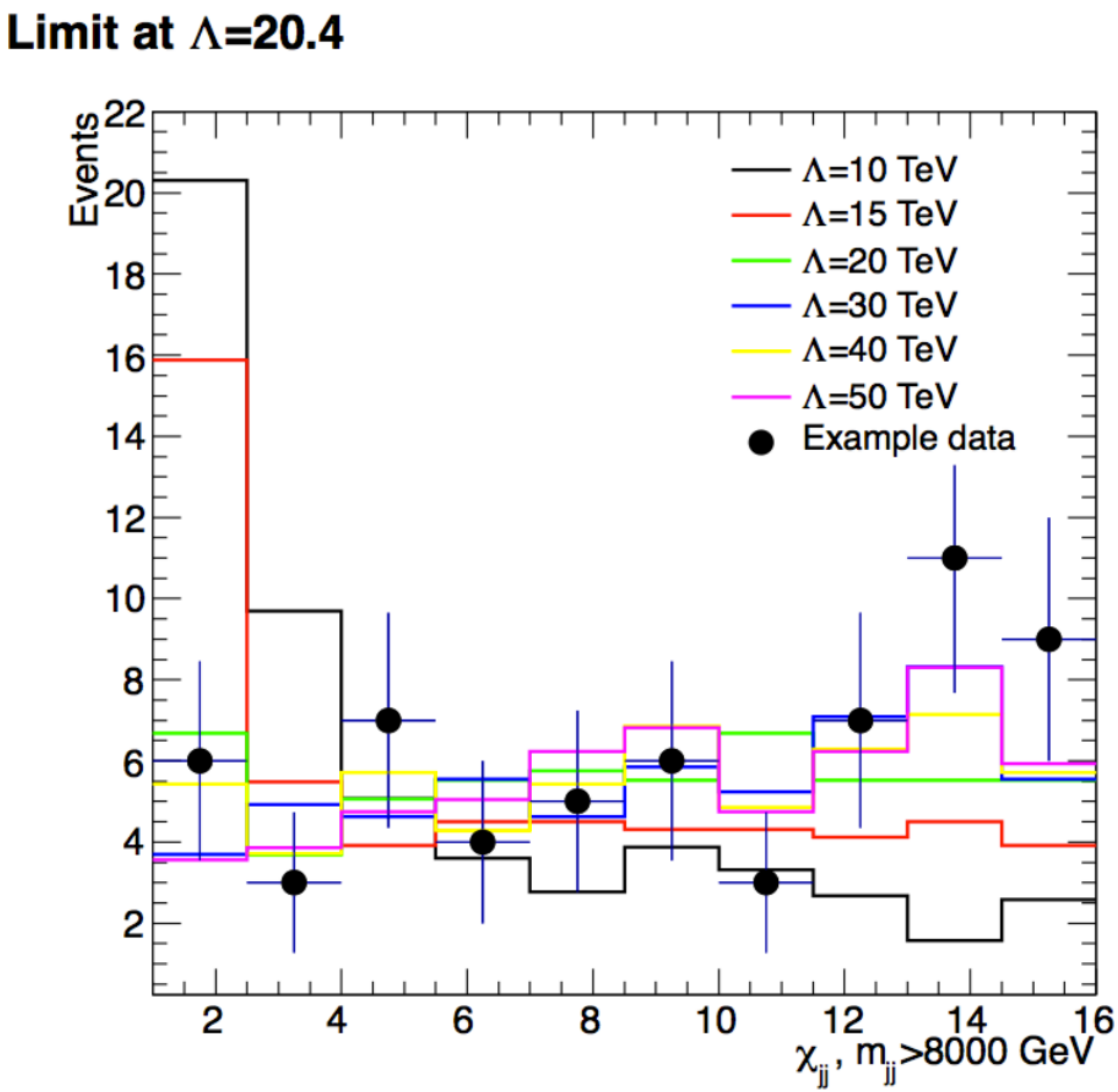

33 TeV study in progress