Status of CMS Exotica Results

Mitchell Workshop on Collider and Dark Matter Physics

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Rutgers University

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OF NEW JERSEY

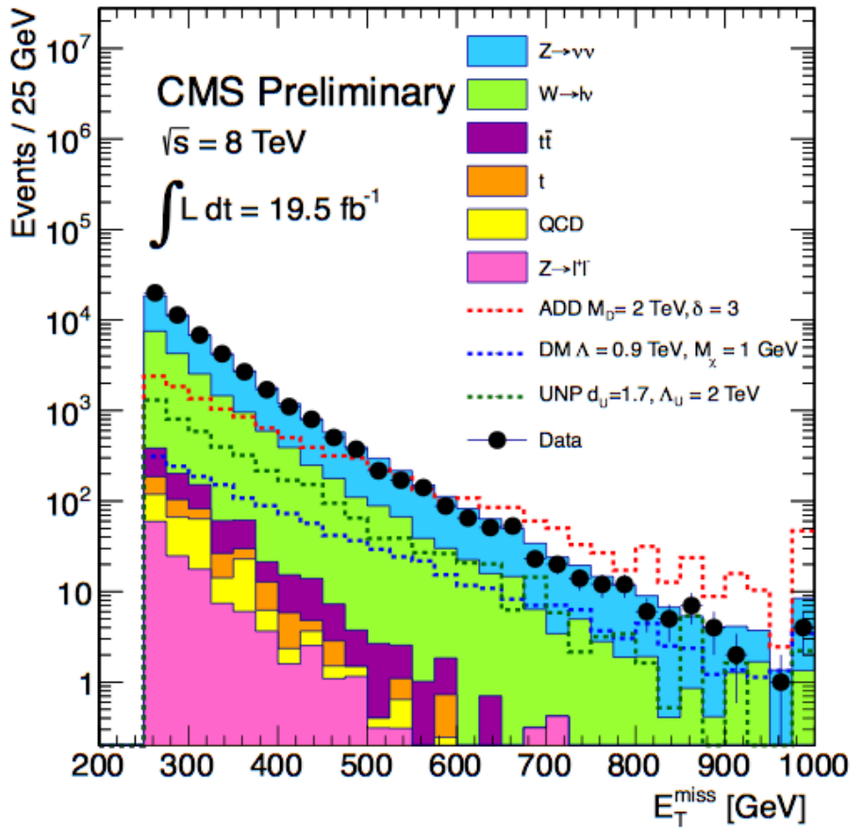
OUTLINE

- The space of New Physics searches is vast
  - Nevertheless, I assume most everyone is familiar with the gist of the LHC search program (SUSY, resonances, vector-like quarks, etc.)
  - This is really a talk about what we **haven't done** rather than what we **have done**
    - Think about where new physics could lie hidden
    - Concentrate on **topologies** rather than **models**

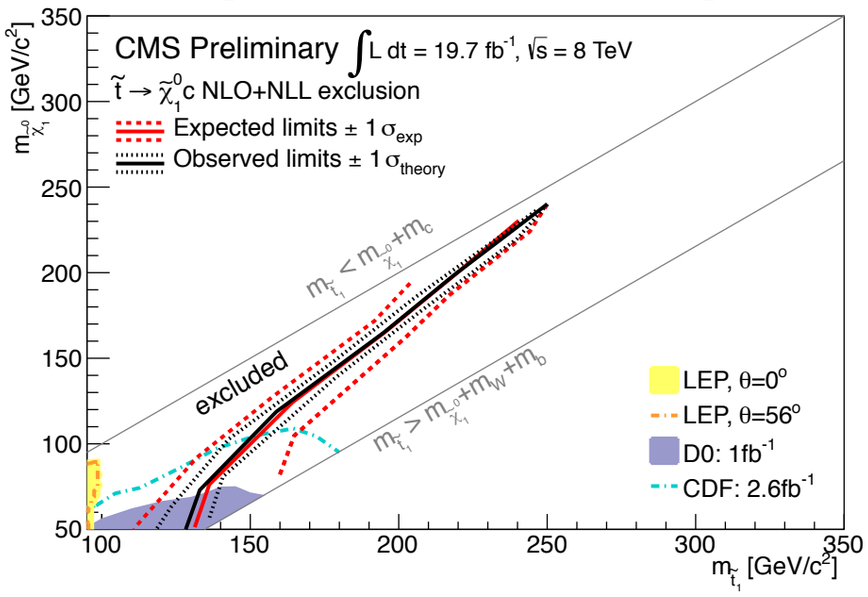
Inclusive Searches

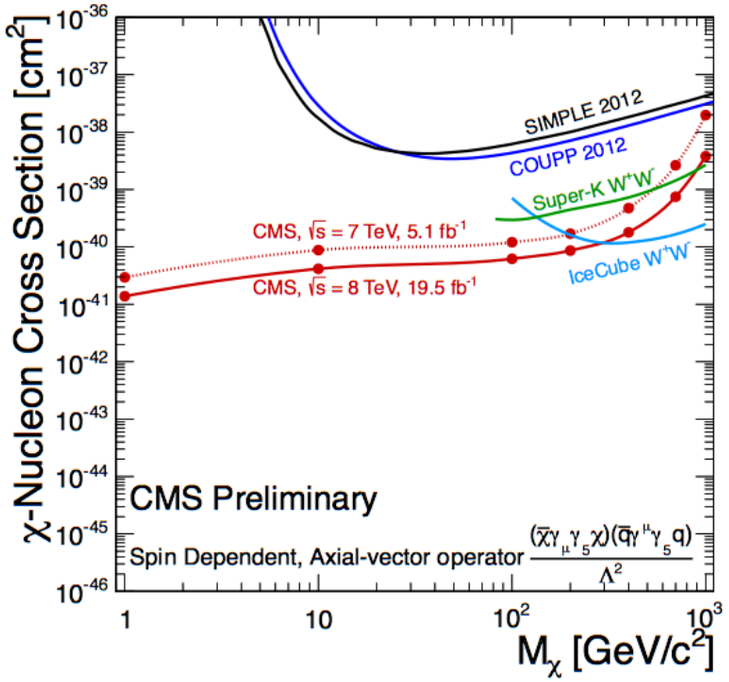
1–2 JETS + MET>250 GEV

- Search for **1-2 jets** recoiling against MET
  - Leading jet has p_T>110 GeV and $|\eta|$<2.4
    - allow second jet with p_T>30 GeV
  - **MET threshold determined by trigger**
- Re-optimized cuts to look for stop→c+LSP
  - no charm tagging; just require harder 2nd jet

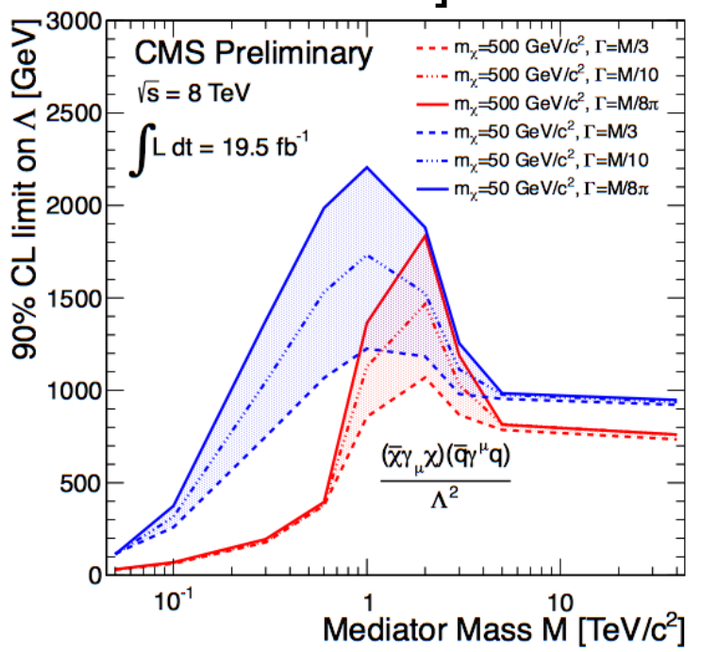


[CMS-SUS-13-009]





[CMS-EXO-12-048]



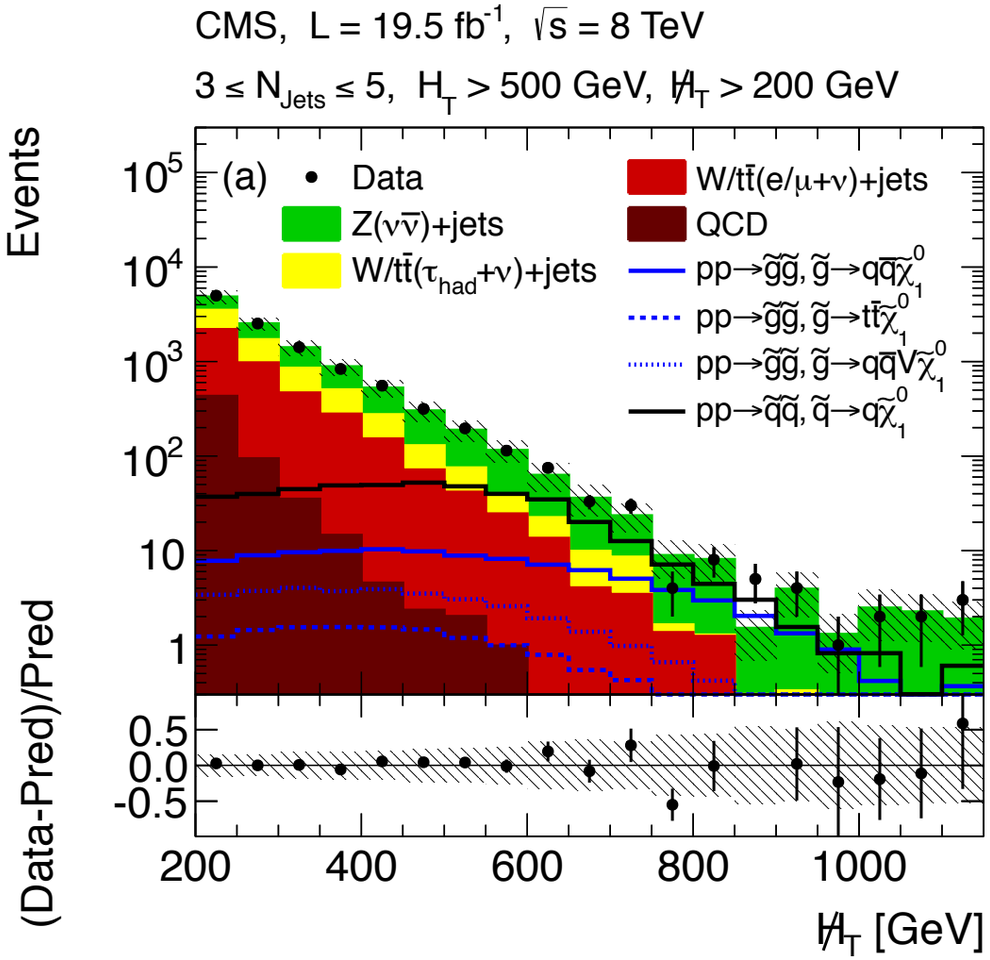
Much more than Just Dark Matter

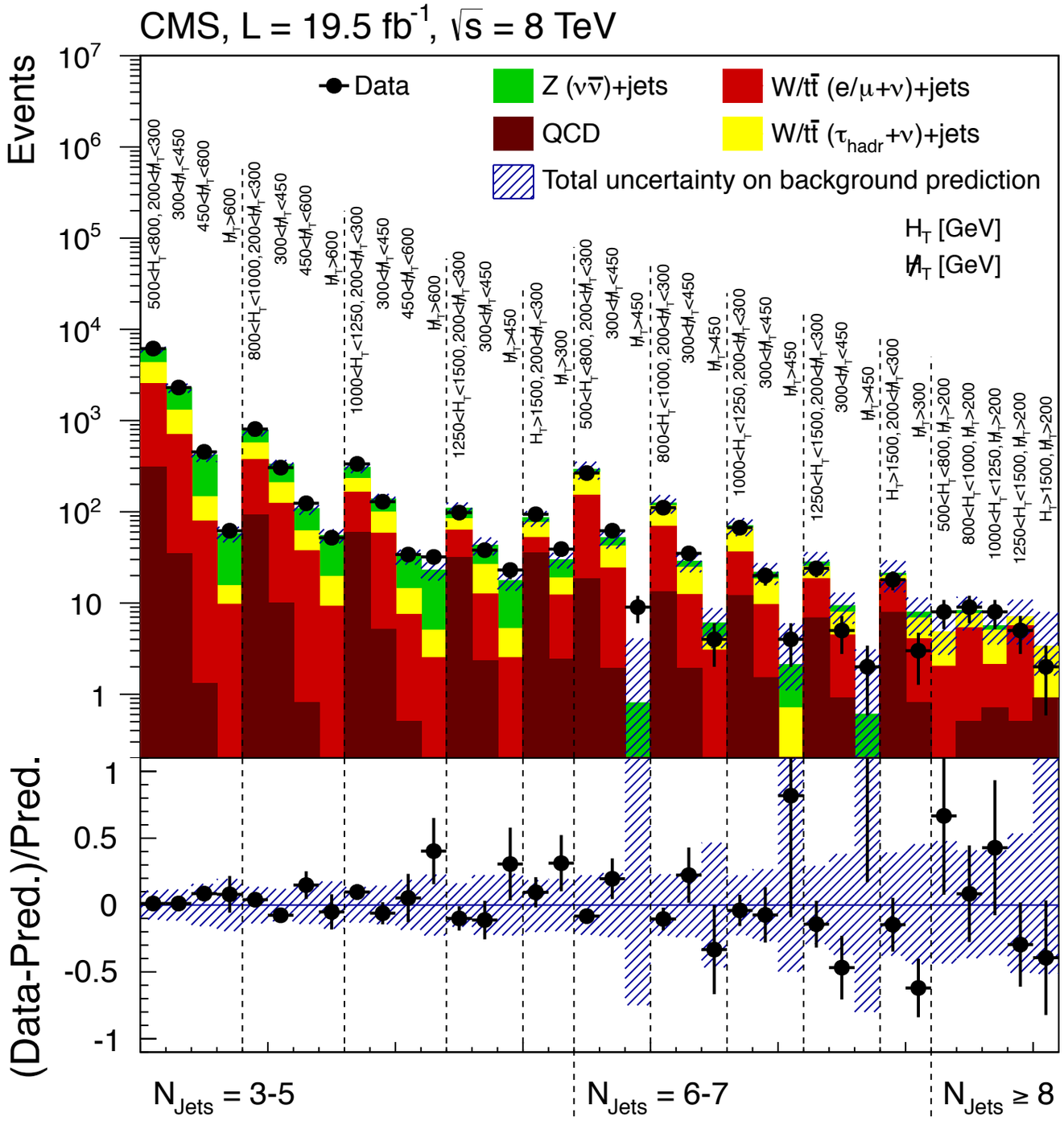
- Monojet searches are really a strategy for new physics searches where we can't trigger on the underlying physics
  - Fundamentally an ISR jet trigger + invisible/unknown/poorly understood/badly reconstructed new physics
  - An entire physics program awaits where we have only scratched the surface
    - Monojet where the jet is b/W/Z/H tagged
    - Monojet + soft lepton(s)
    - Monojet + highly ionizing track(s)
    - Monojet + disappearing track(s)
    - Monojet + displaced track(s)/jet(s)/lepton(s)
    - …
- Don't forget that the EWK-scale is only ~200 GeV
  - i.e. why it's important to keep the trigger thresholds as low as possible

≥3 JETS + H_T>500 GEV + MH_T>200 GEV

[SUS-13-012]

- Search in exclusive bins of N_{Jets}, H_T, and missing H_T

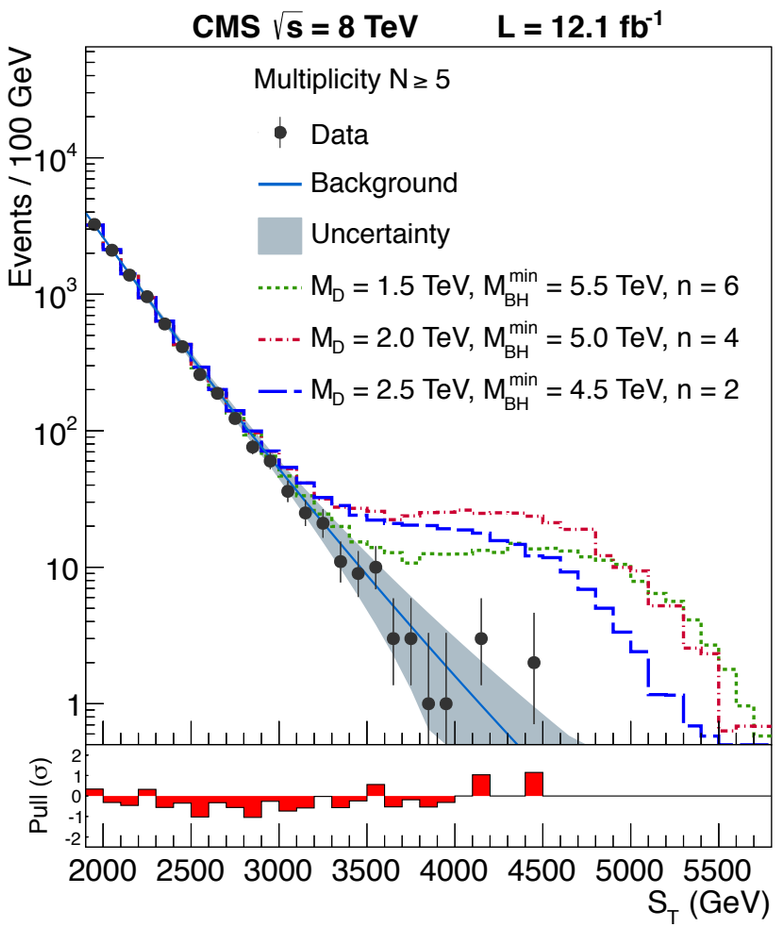


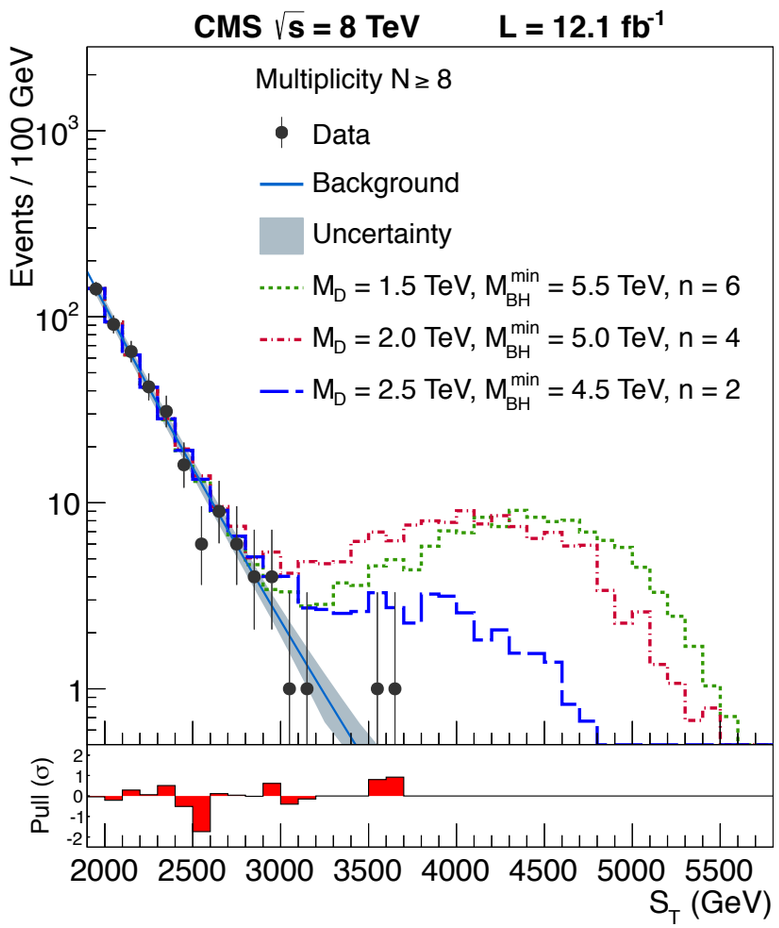


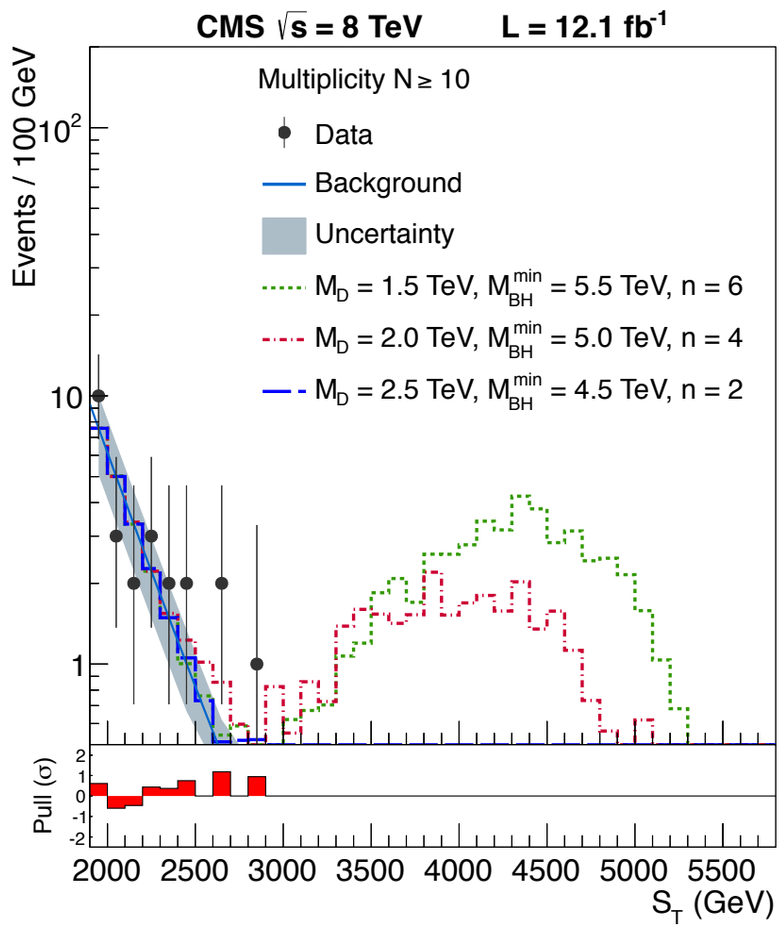
MULTIJETS WITHOUT MET

- Search inclusively for in S_T (=H_T+L_T+MET) distribution
  - count all objects with p_T>50 GeV
  - scale S_T from low multiplicity to project into high multiplicity
    - ongoing effort to lower S_T range by reducing p_T thresholds

[EXO-12-009]

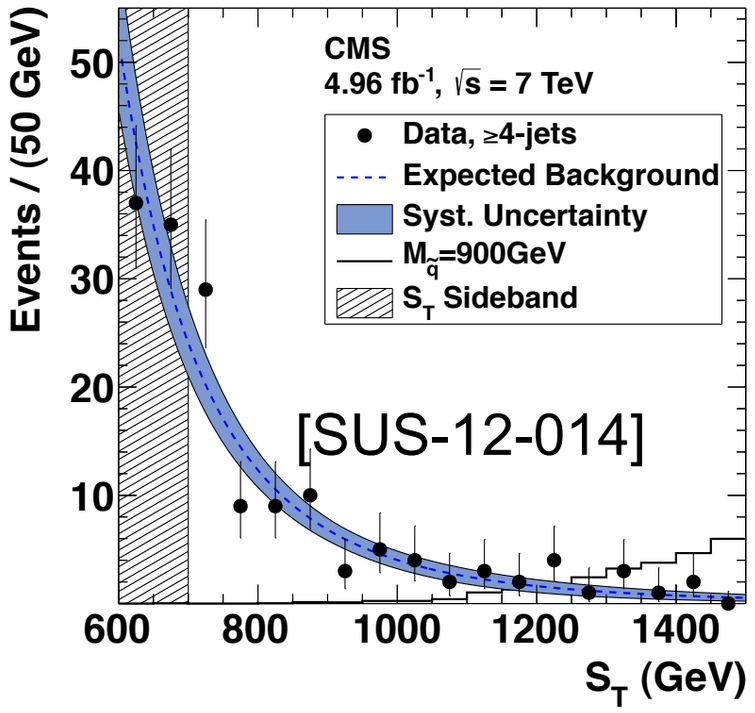




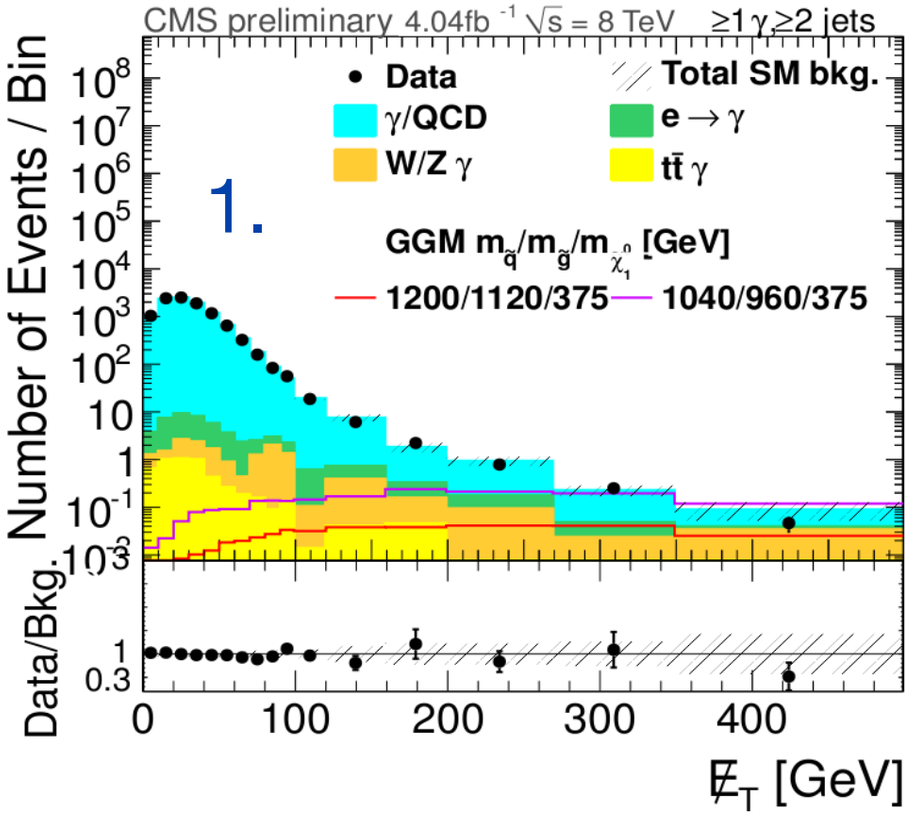


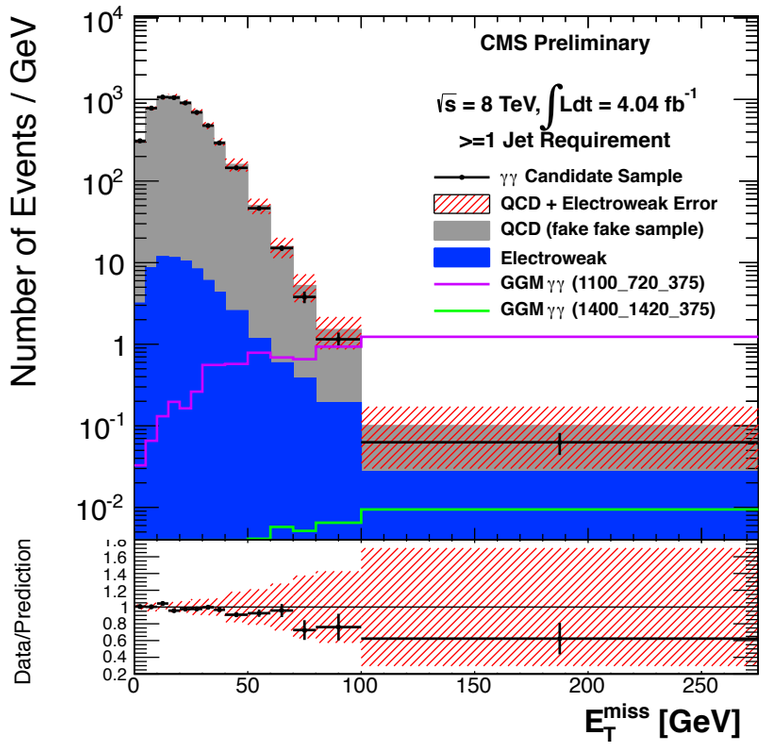
PHOTONS + MET OR JETS

1. 1γ (p_T>80 GeV) + ≥2 jets + MET>100 GeV
2. 2γ (p_T>40 GeV, 25 GeV) + ≥1 jet + MET>100 GeV
3. 2γ (p_T>40 GeV, 25 GeV) + ≥4 jets + S_T>700 GeV



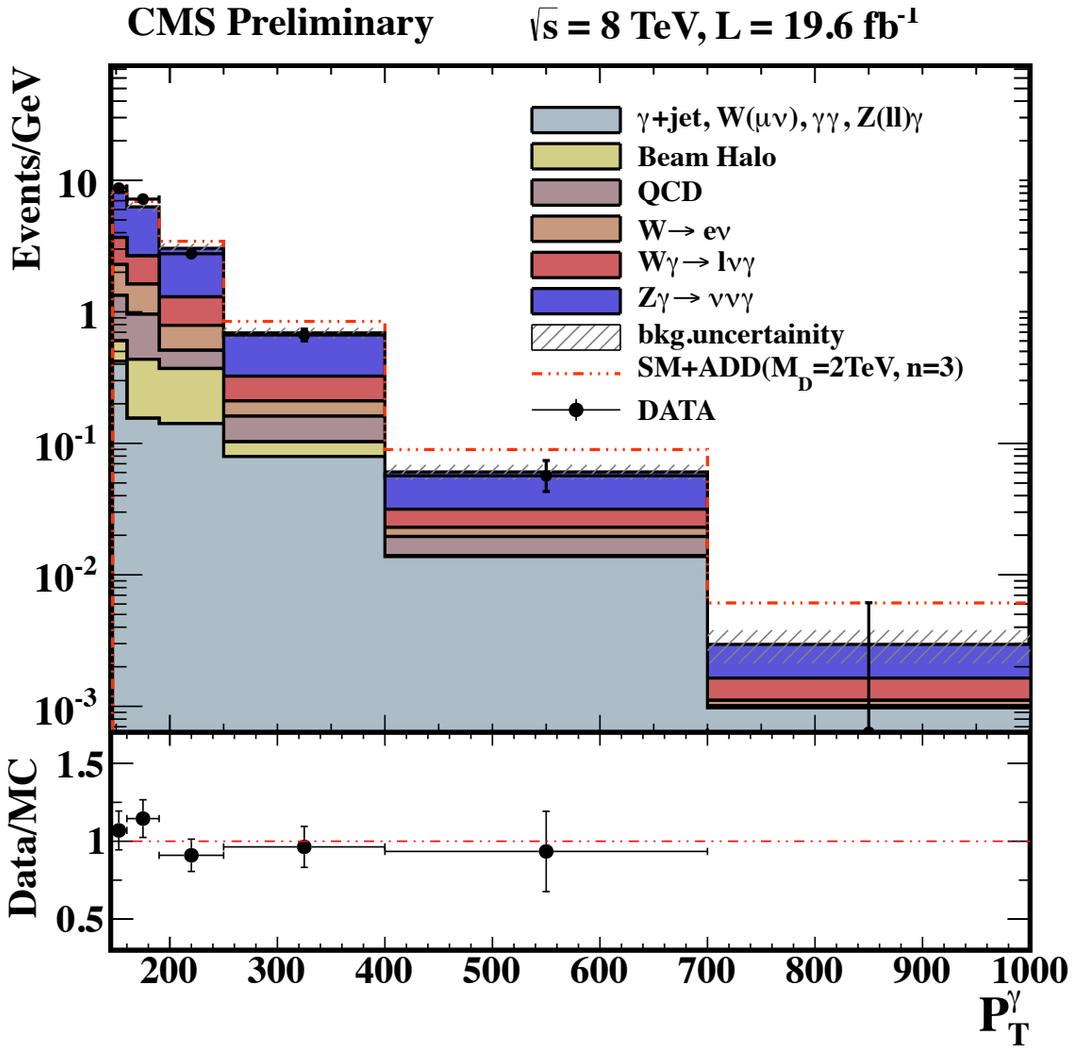
[SUS-12-018]

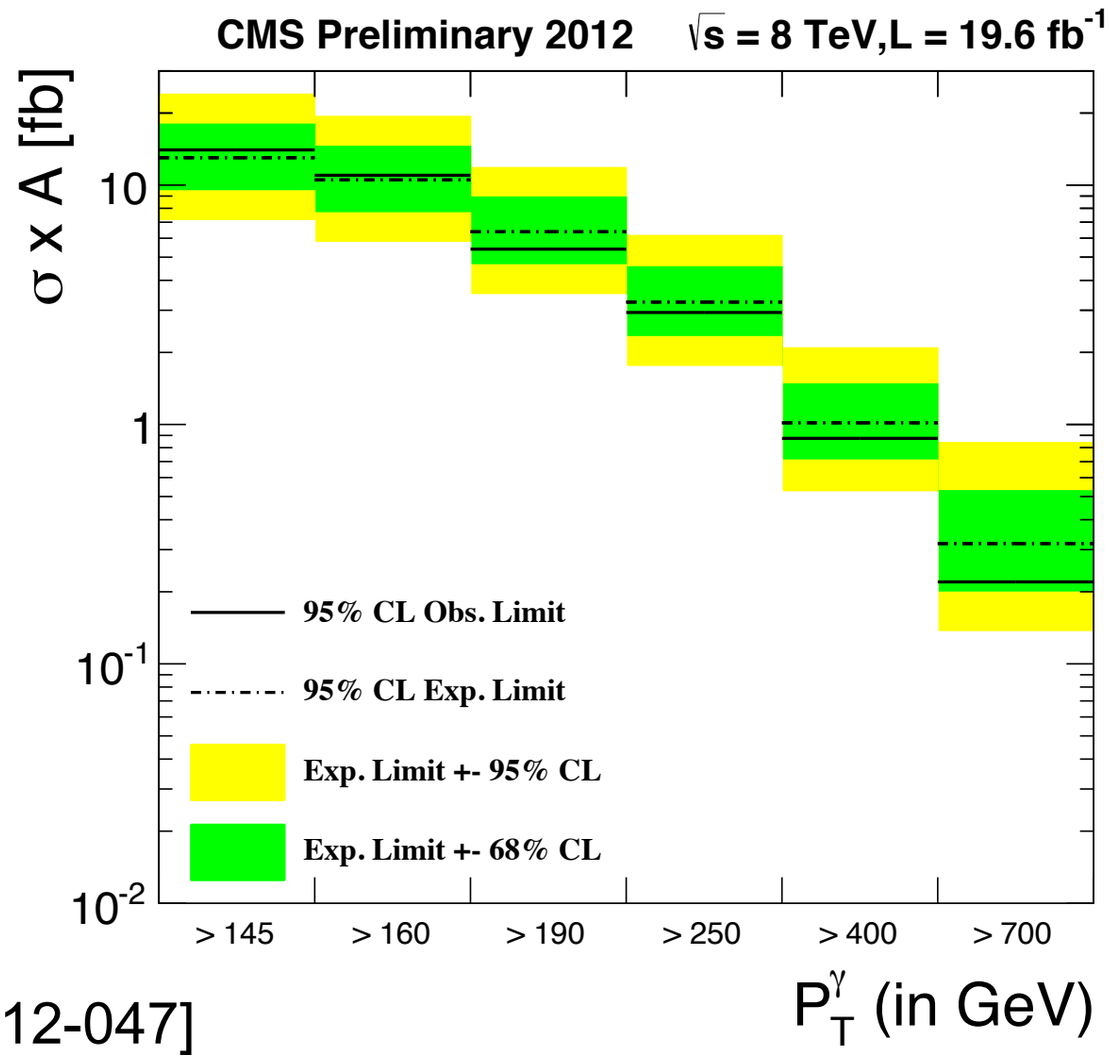




MONOPHOTONS

- 1γ (p_T>145 GeV) + MET>140 GeV
  - plus jet veto (p_T>30 GeV) and lepton veto (p_T>10 GeV)
  - use **photon p_T shape** to extract constraints on new physics



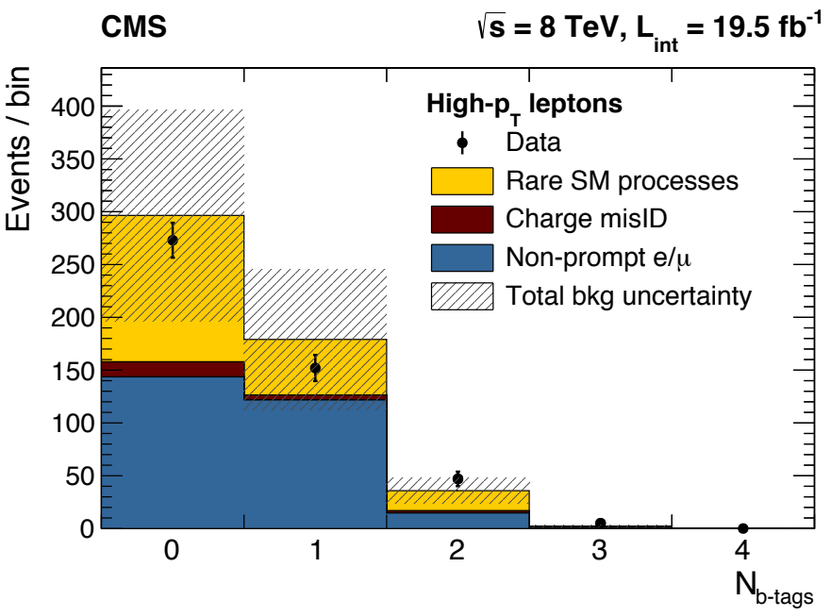


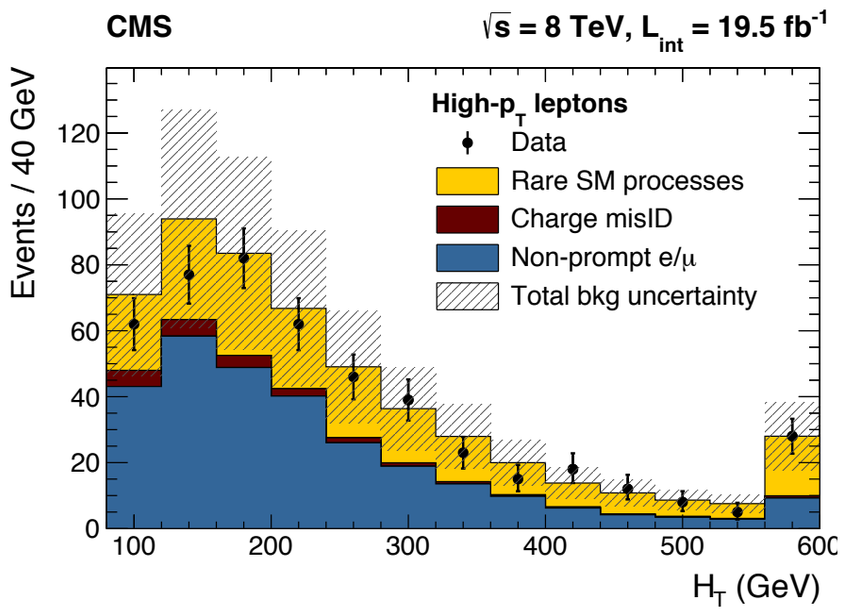
[EXO-12-047]

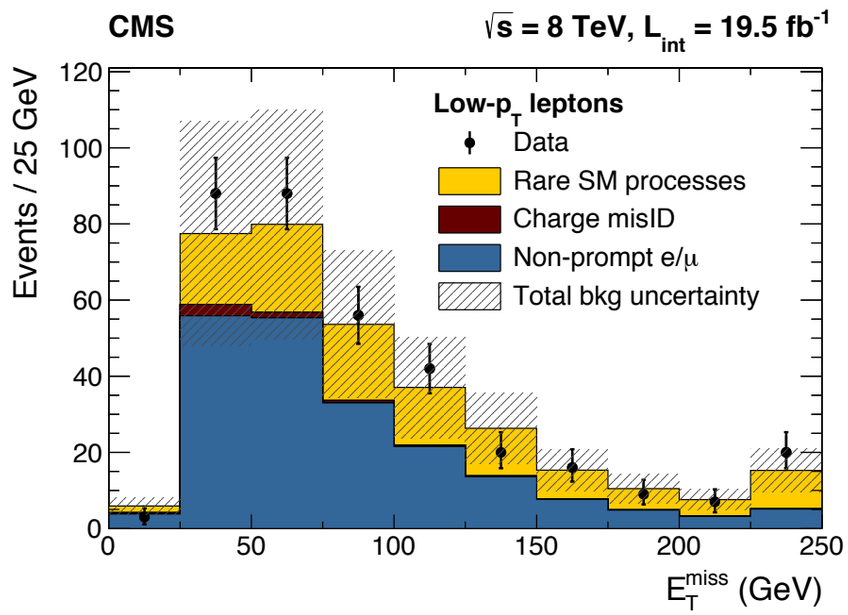
SAME-SIGN DILEPTON BACKGROUNDS

- Two same-sign leptons and ≥2 jets
  - low p_T selection: lepton p_T>10 GeV, H_T>250 GeV
  - high p_T selection: lepton p_T>20 GeV, H_T>80 GeV
    - dominant background uncertainty from **"non-prompt" rate and rare background rate (both assessed at 50%!)**

[SUS-13-013]

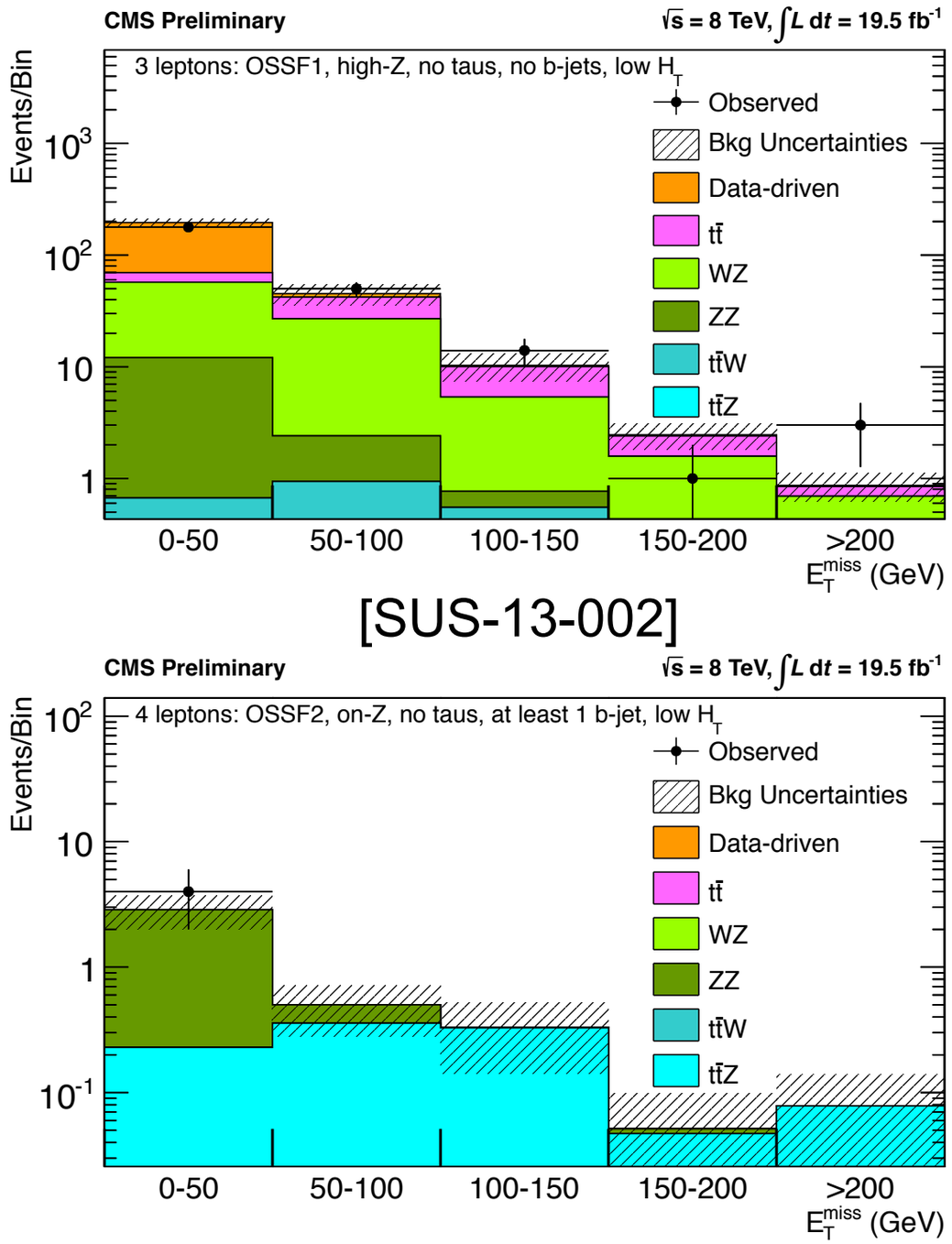






MULTILEPTON SEARCHES

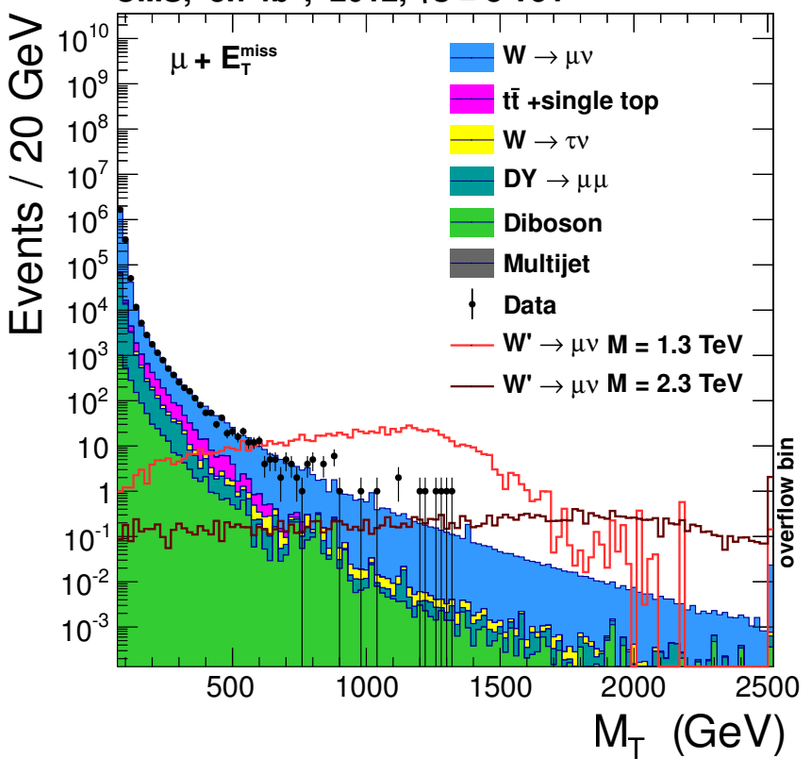
- Search for anomalous multilepton production establishes paradigm of "high resolution" searches at CMS
  - Emphasized **binning** rather than cutting on events with **≥3 leptons**
    - ME_T and H_T
    - number of leptons
      - pT thresholds are 20,10, & 10 GeV
    - number of taus
    - number of b tags
    - # of opposite-sign same flavor (OSSF) lepton pairs
    - on/off shell Z
- Be careful: nearby leptons can spoil each others' isolation



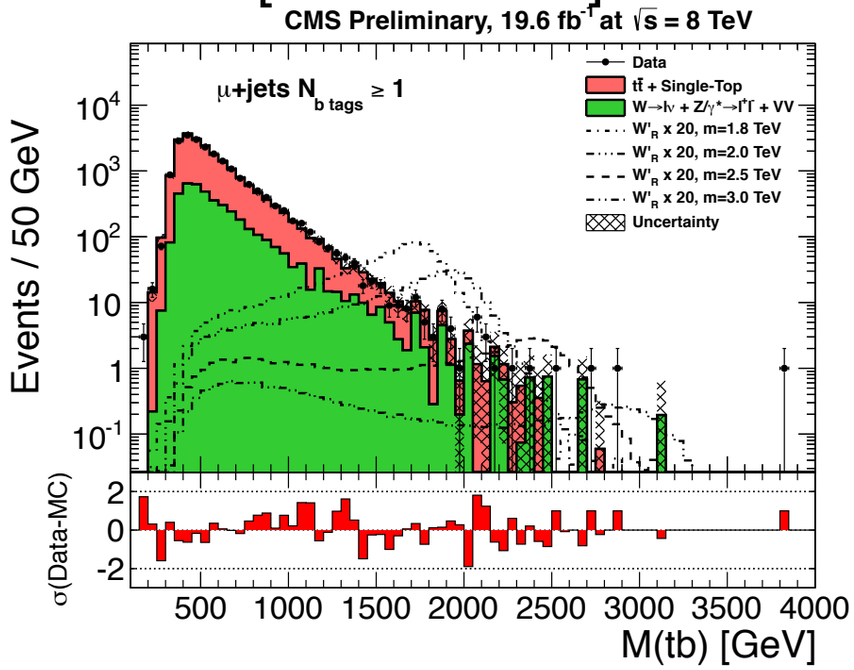
Resonance Searches

RESONANCES

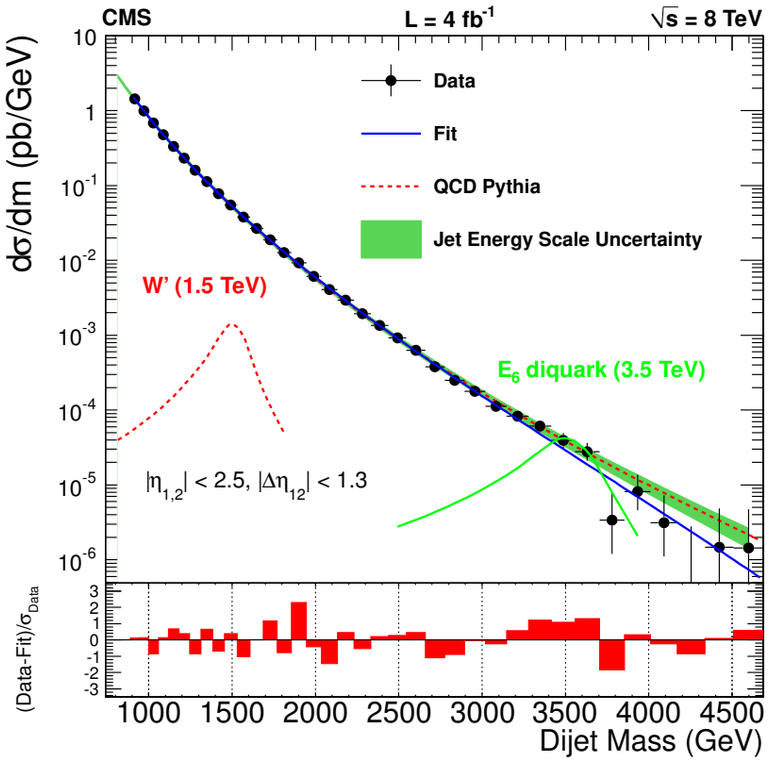
[EXO-12-010]



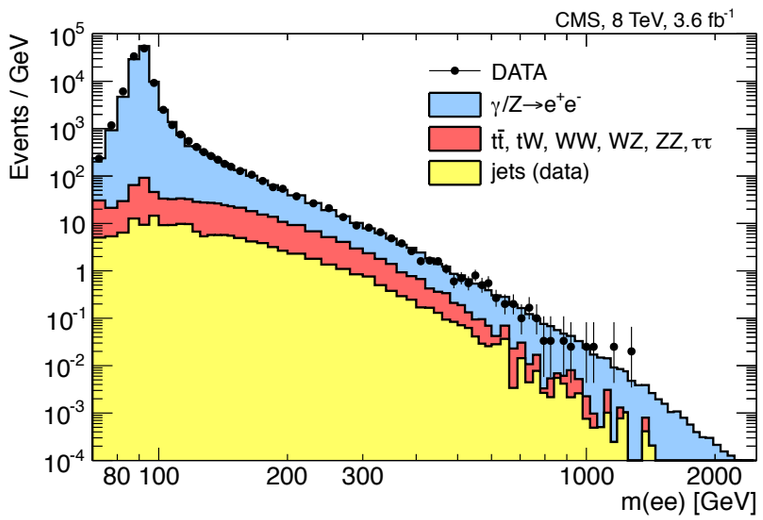
[B2G-12-010]



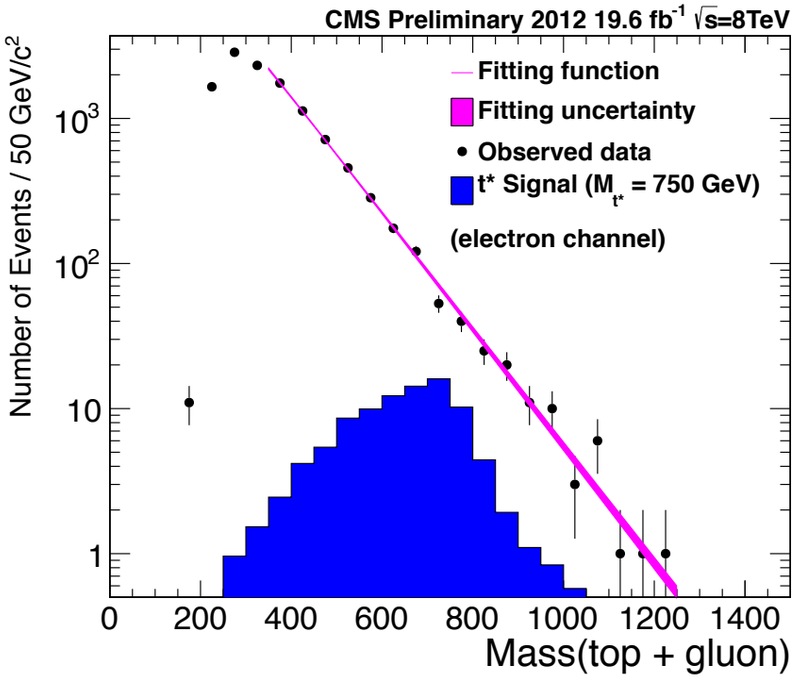
[EXO-12-016]



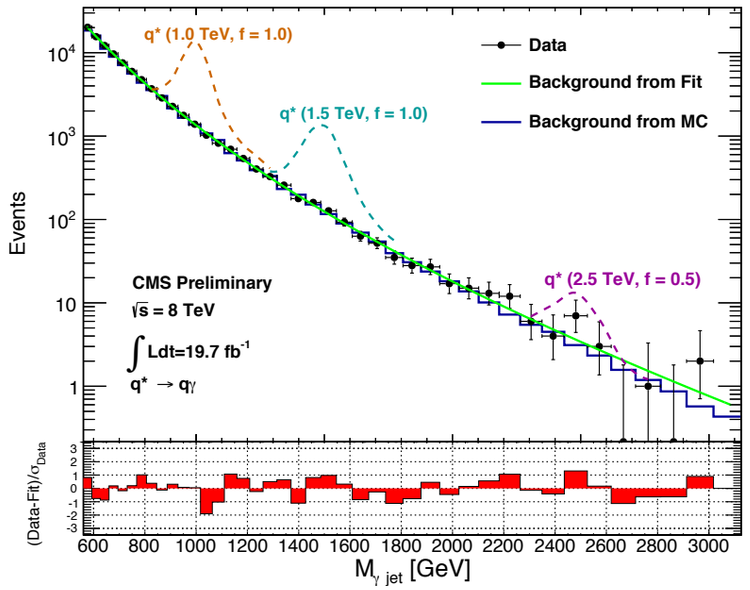
[EXO-12-015]



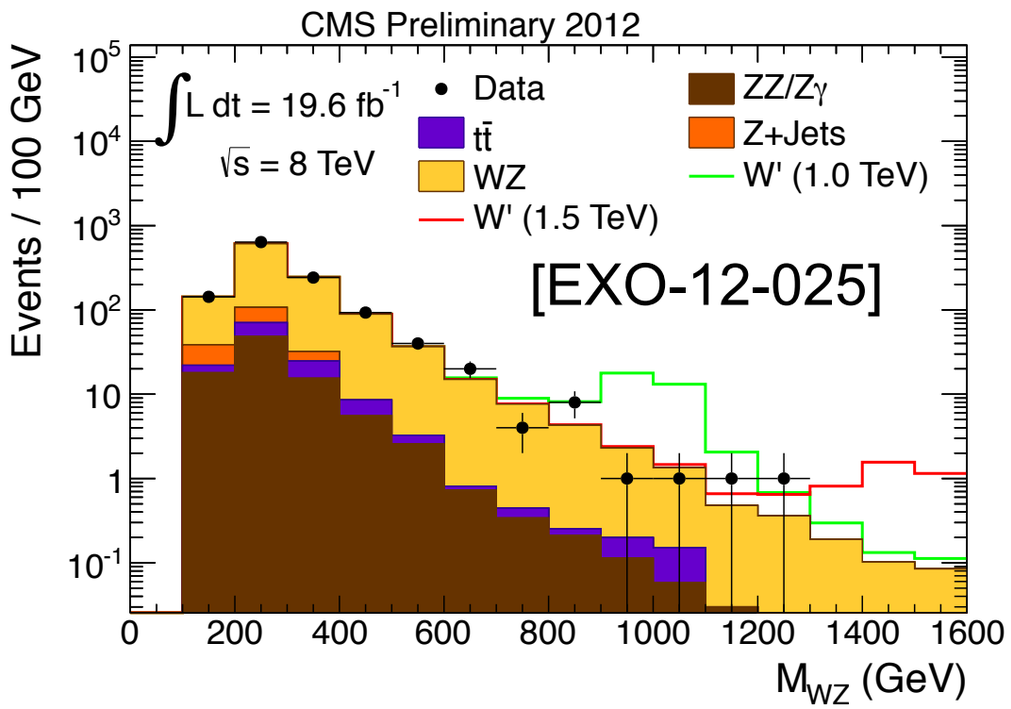
[B2G-12-014]

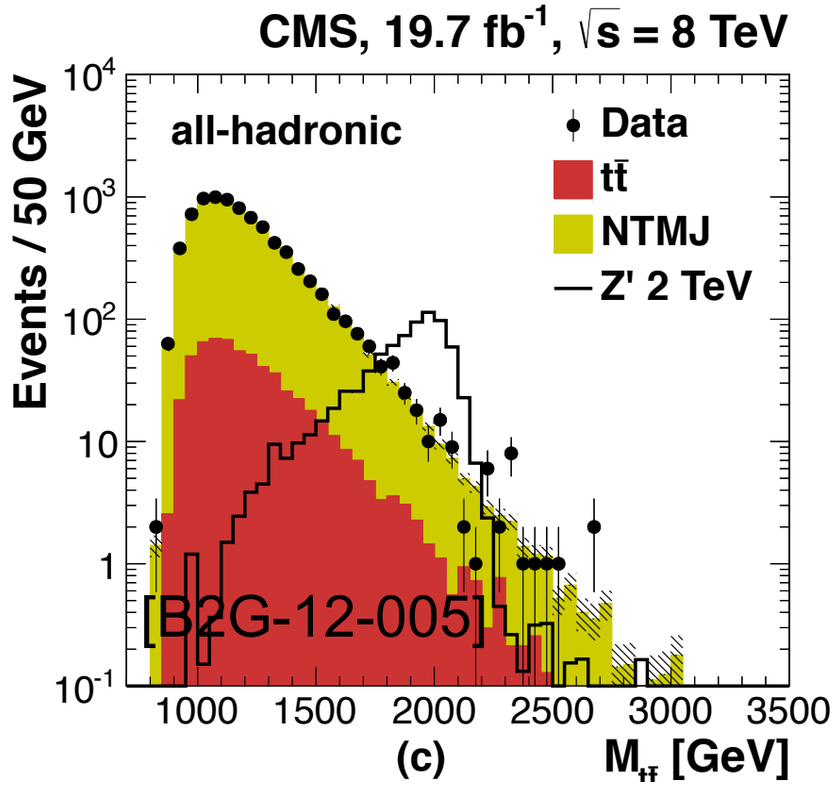


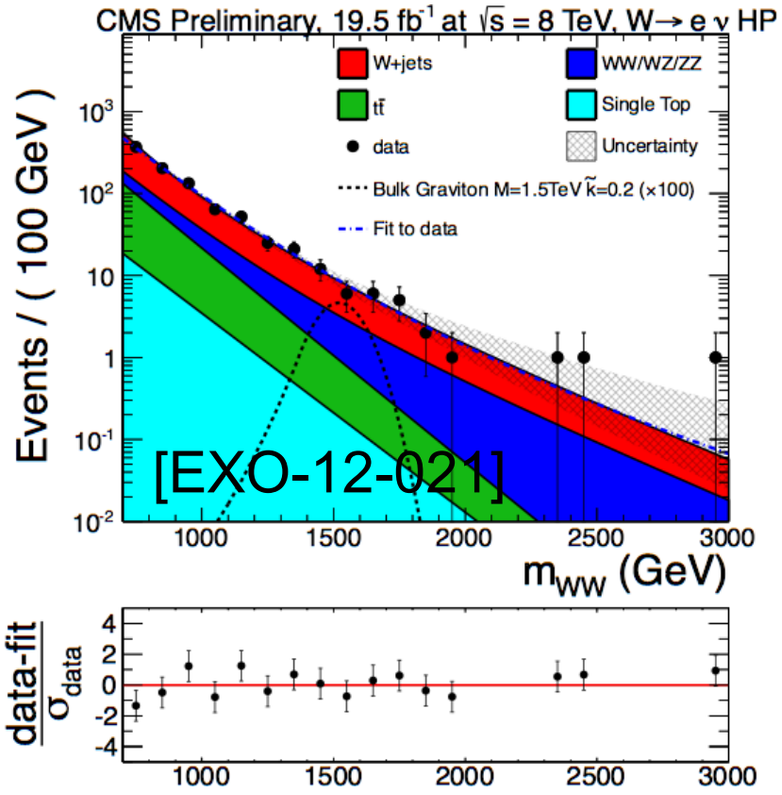
[EXO-13-003]

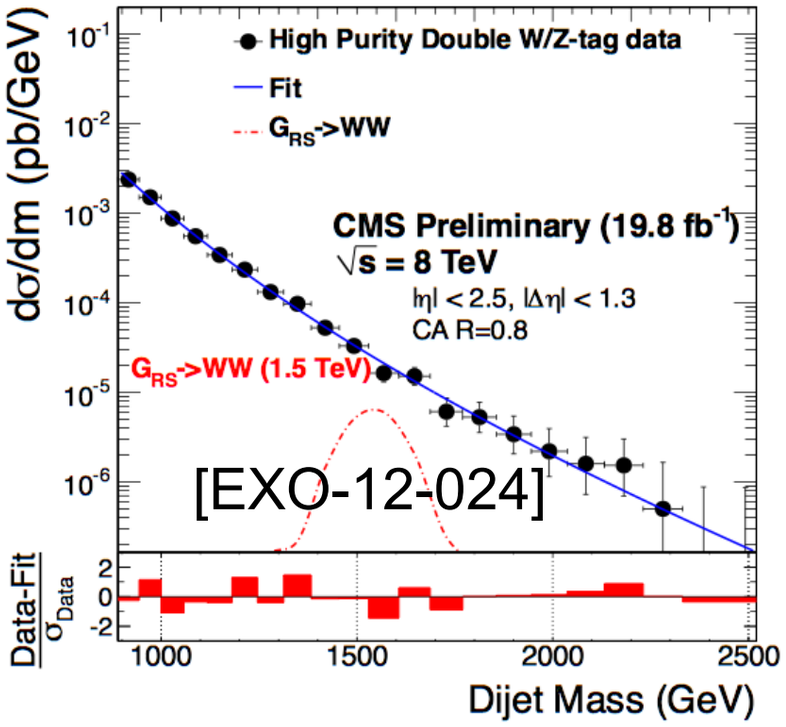


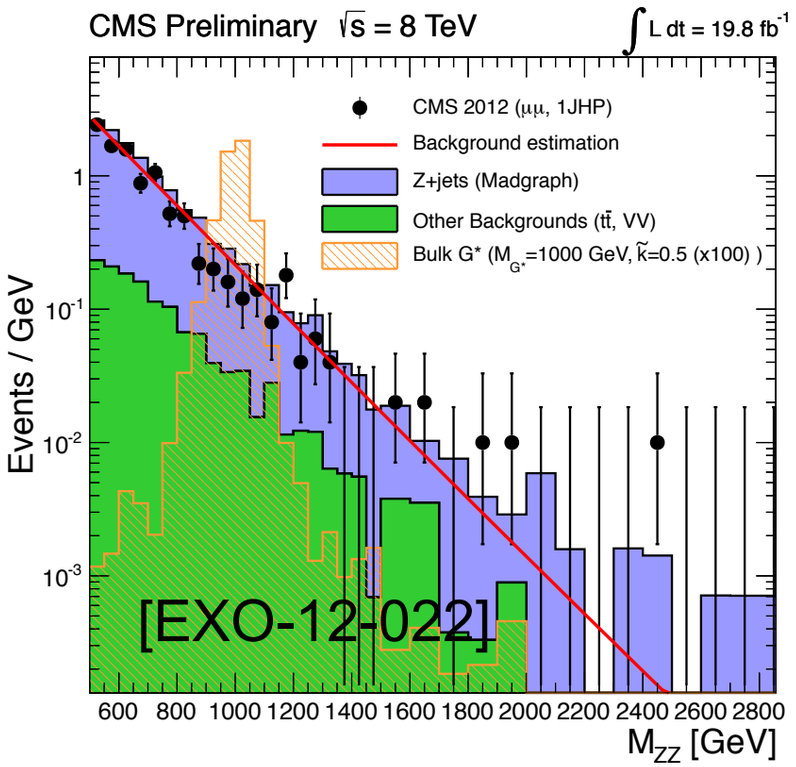
And Even More Resonances!





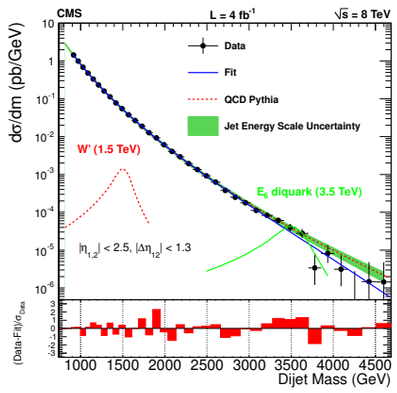






A DIFFERENT KIND OF BUMP HUNT

- One approach that has not been exploited so far is to convolute the bump hunt with the multibin approach



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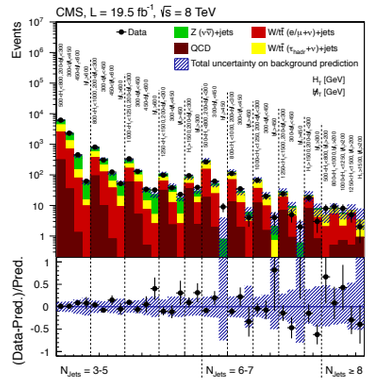
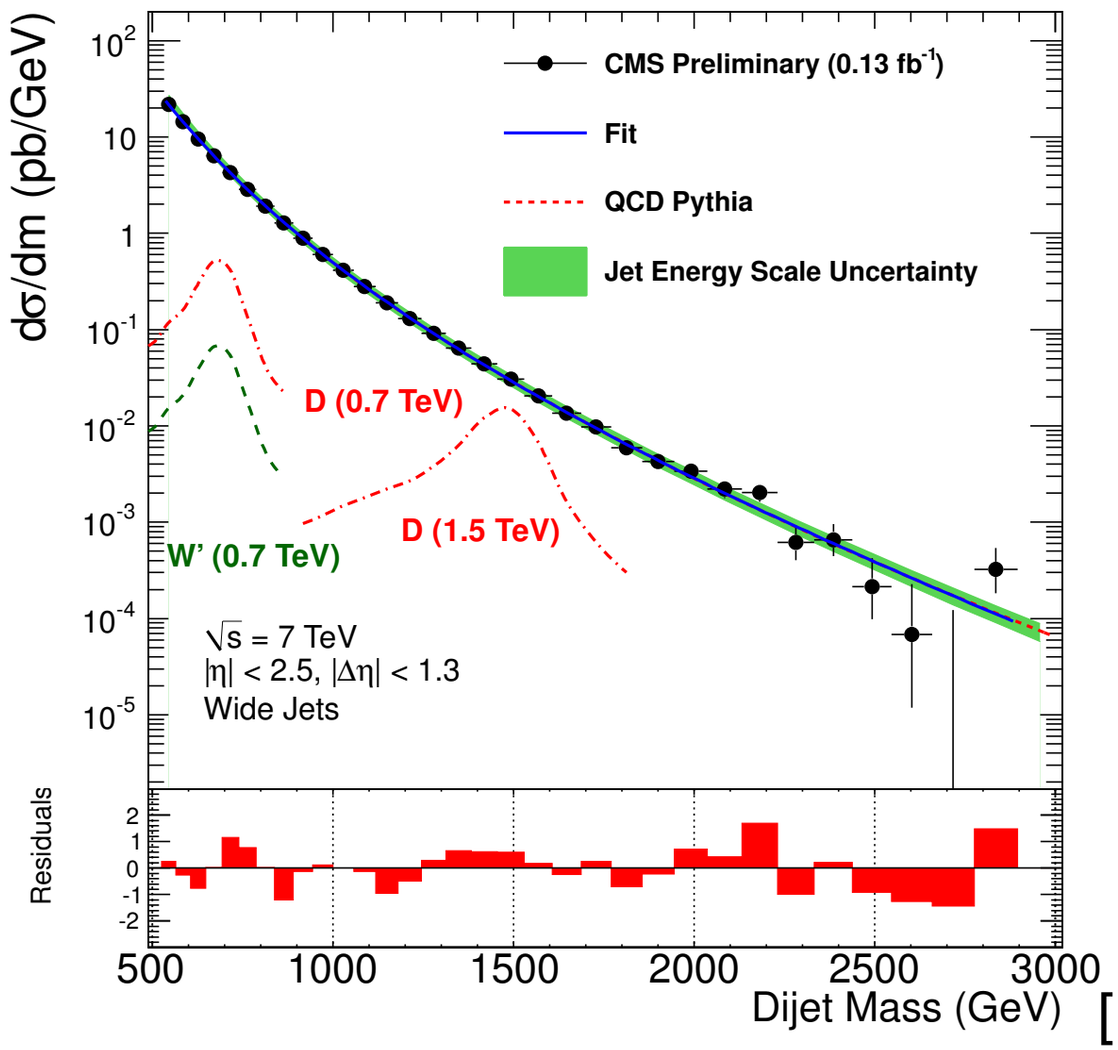
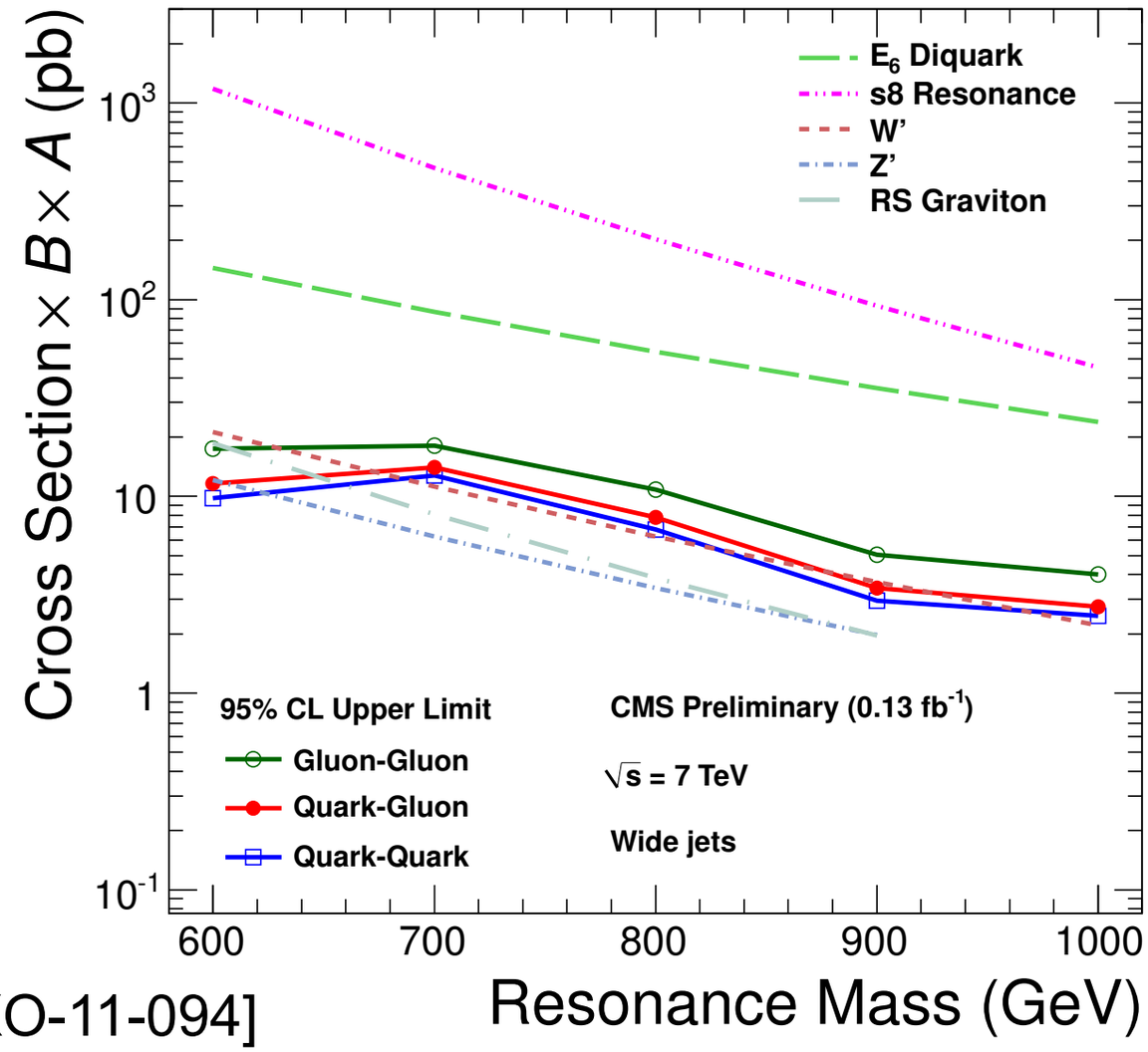


- Often the bump hunt searches fit for the background **in situ**
- Don’t worry about fake rates!

Data Scouting

- Novel trigger, DAQ, and analysis strategy to search below 1 TeV
  - Low jet-trigger thresholds means high event rate (~KHz)
  - Store reduced data format (i.e. jets reconstructed at trigger level)



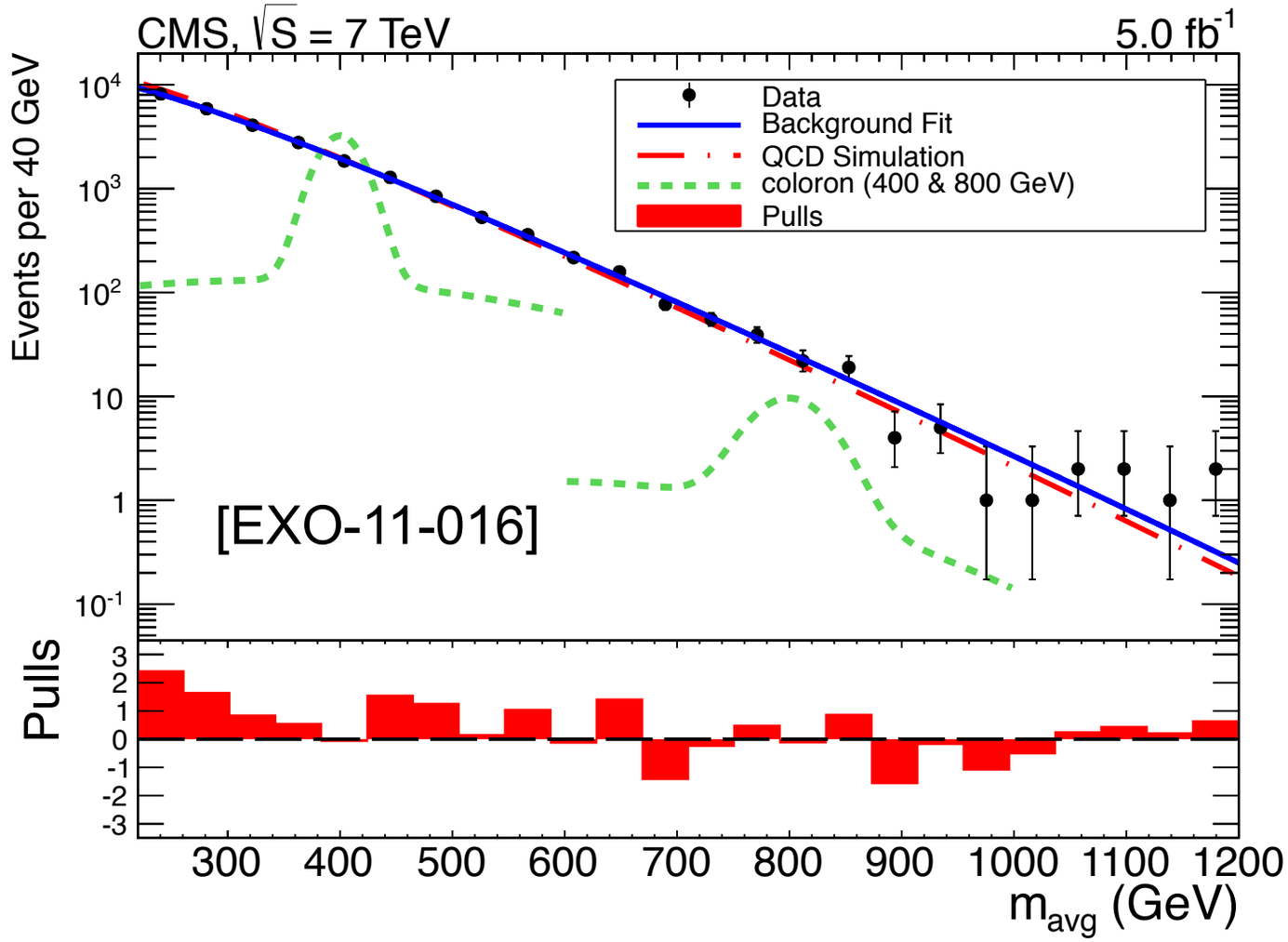


[EXO-11-094]

Data Parking

- In 2012, we "parked" an additional ~300 Hz of data and waited until 2013 to process the datasets
  - Quad jet triggers, inclusive VBF, low-pT monophoton triggers, etc.

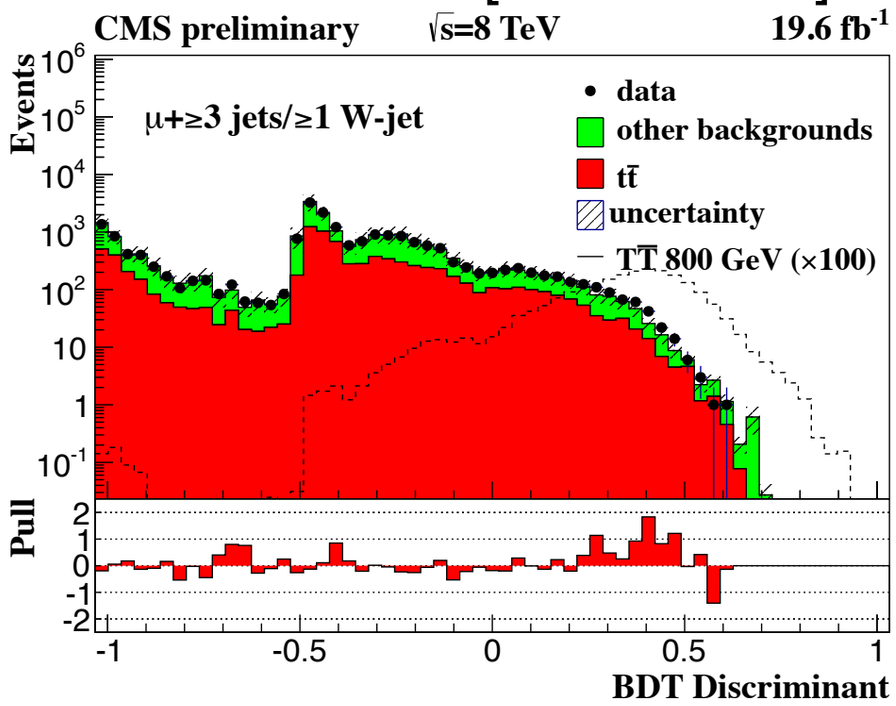
Intent is to tackle important signals that require high-rate triggers (e.g. low-mass stop→jj)



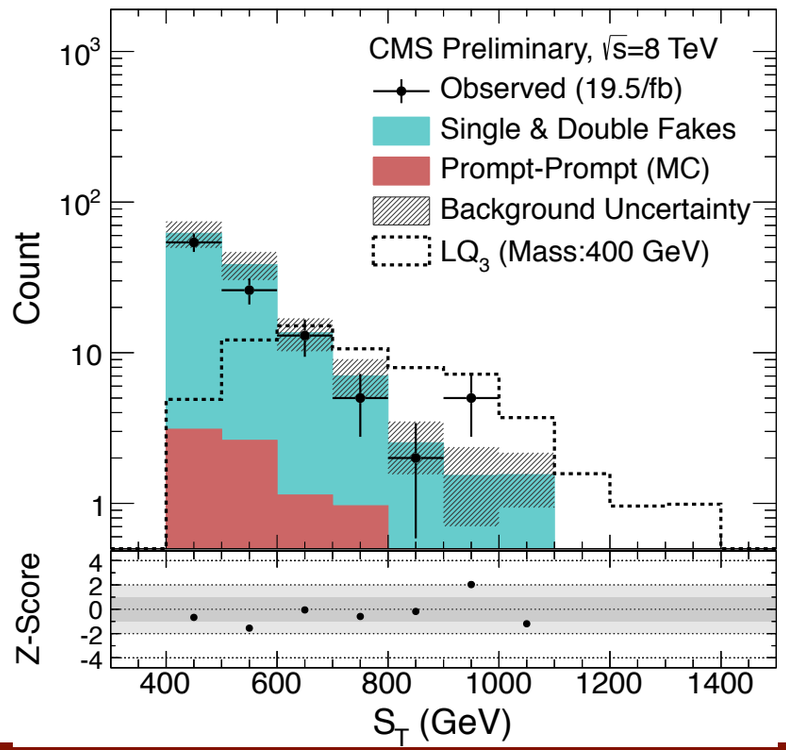
PAIR-PRODUCED RESONANCES

- Significant program dedicated to pair-produced…
  - VLQs (tq, Wq, Zq)
  - LQs (lepton-jet and v-jet in 3 generations)
    - missing many other combinations…

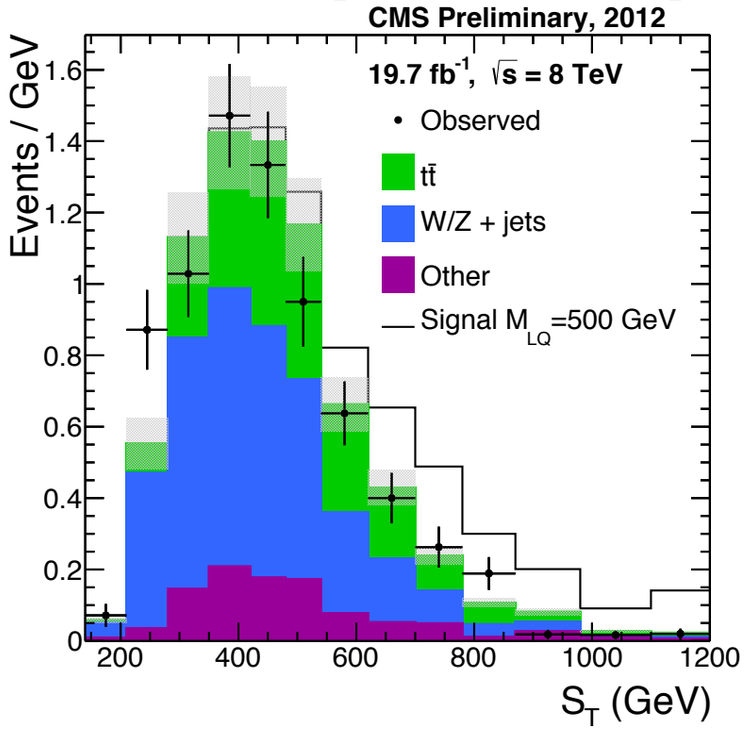
inclusive T'T' [B2G-12-015]



LQ3→t+τ [EXO-12-030]



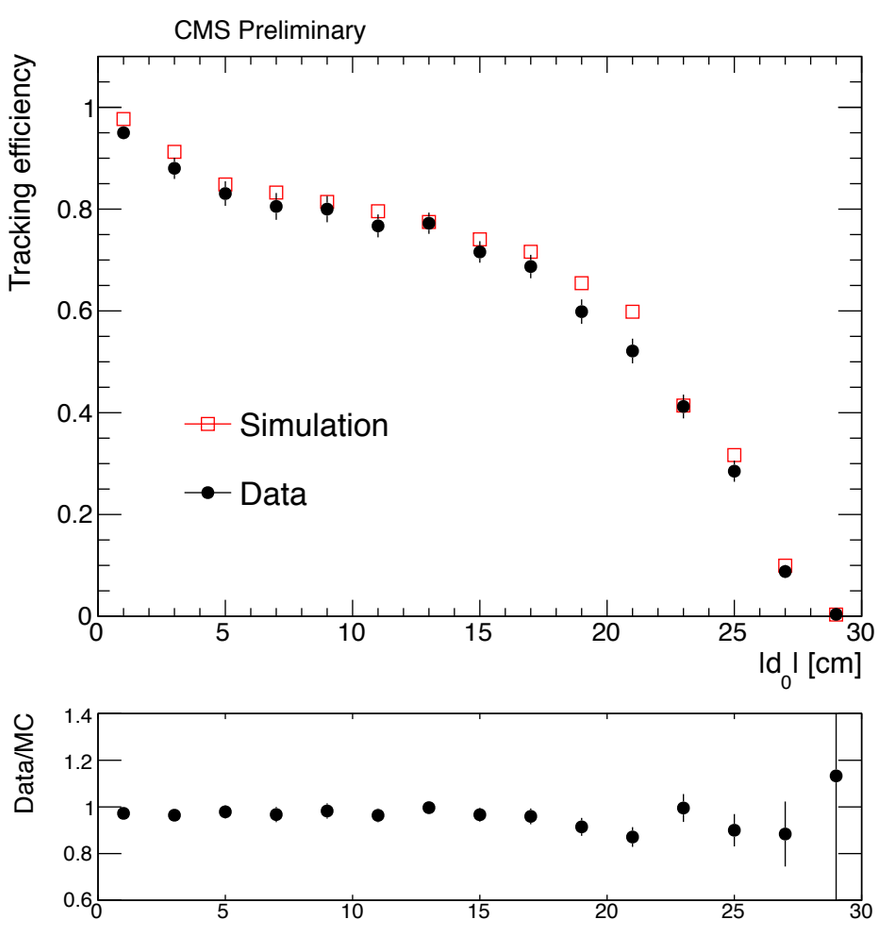
LQ3→b+τ [EXO-12-032]

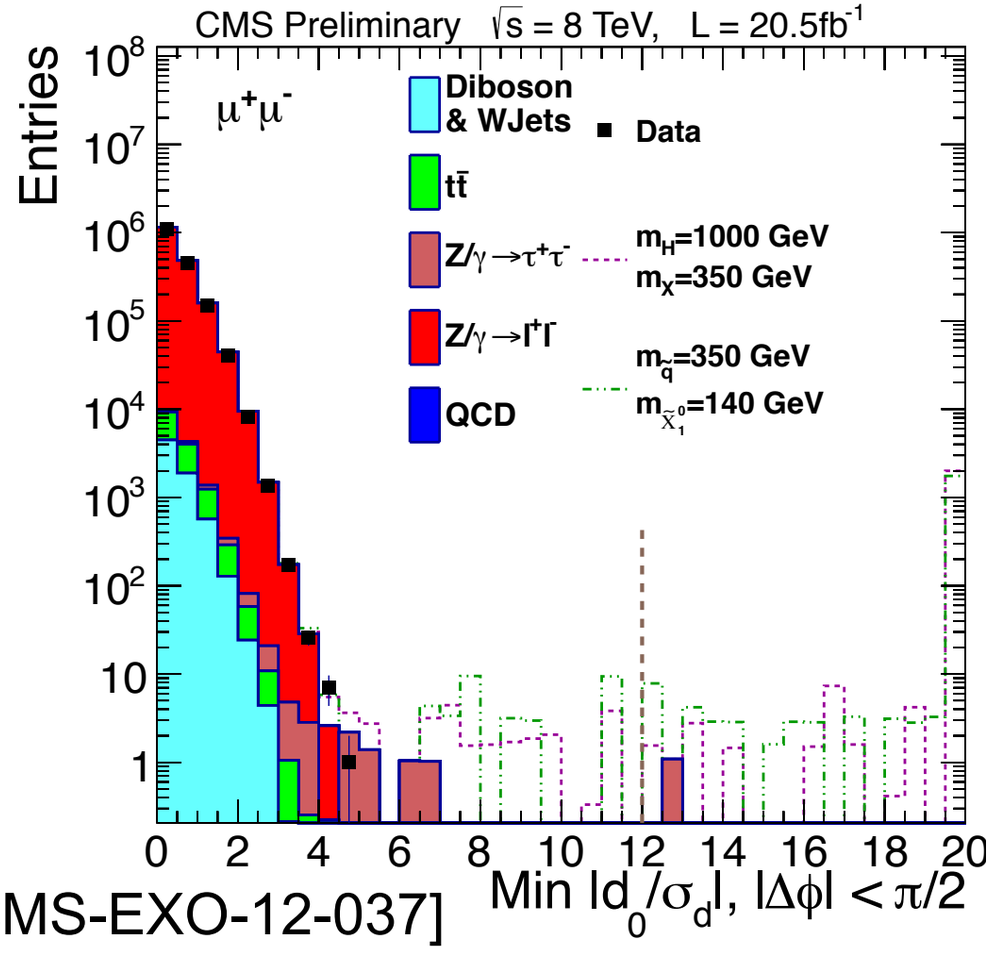


Long-Lived Searches

DISPLACED LEPTONS

- Search for two displaced **isolated** leptons (e^+e^- or $\mu^+\mu^-$) originating from a **common vertex**
  - trigger on “photons” or “L2 muon tracks” and match tracks to these objects
    - avoids d0 bias of dedicated electron/muon reconstruction
  - achieve sub-mm sensitivity

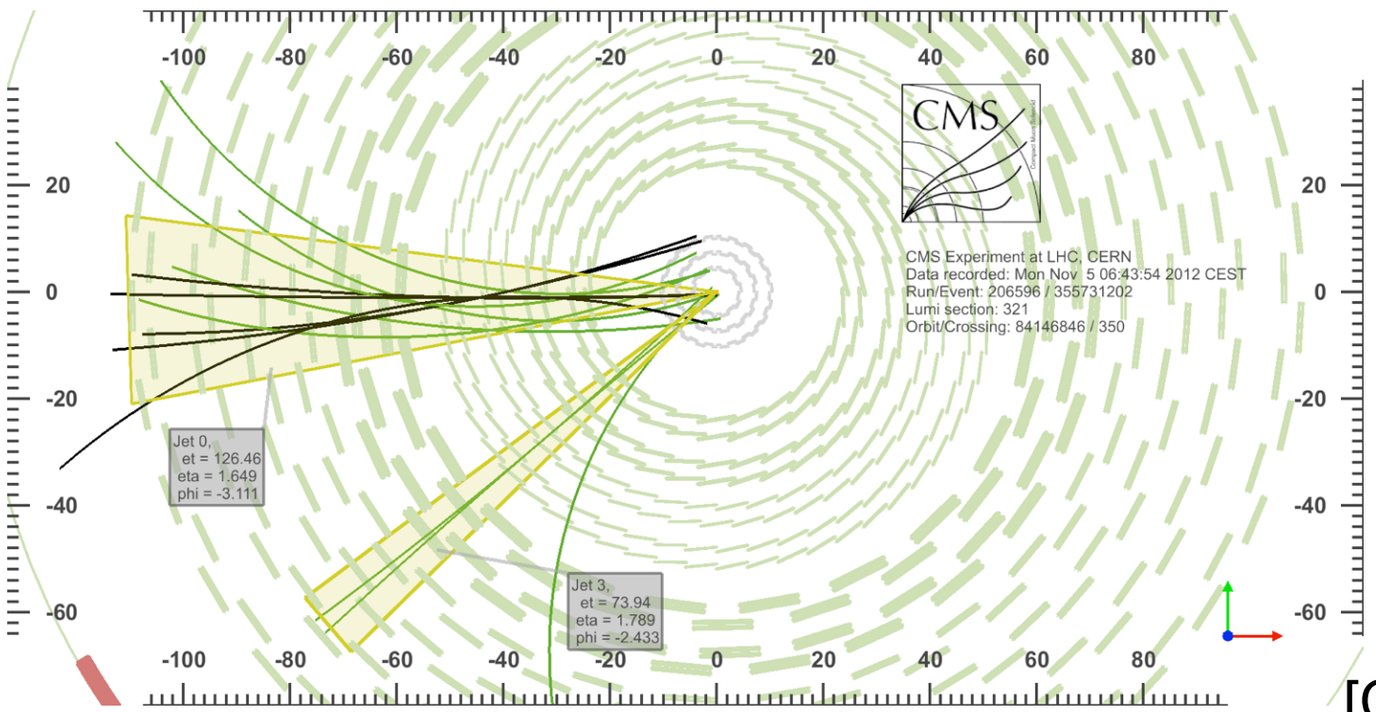


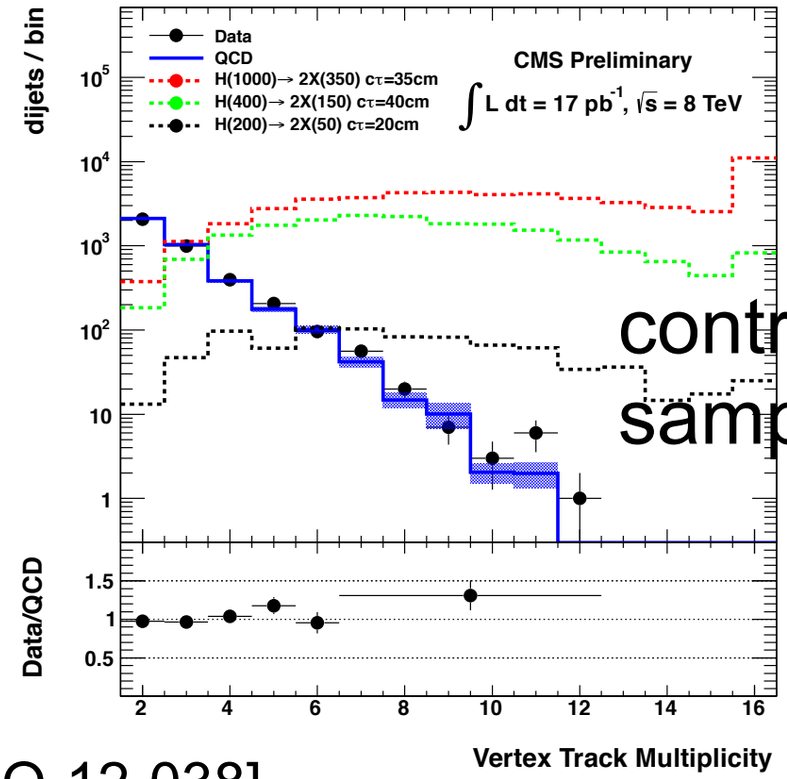


[CMS-EXO-12-037]

DISPLACED DIJETS

- Massive long-lived particles can decay to jets
  - Split SUSY, RPV SUSY, Gauge Mediated SUSY, Hidden Valley models, etc.
- Search for events with **dijets from a common, displaced vertex**
  - Trigger on events with H_T>300 GeV and **≥2 jets with small fraction of prompt tracks**
    - Offline: form multivariate discriminant based on vertex track multiplicity, fraction of tracks with positive d0, and variables from a **dedicated track clustering algorithm**





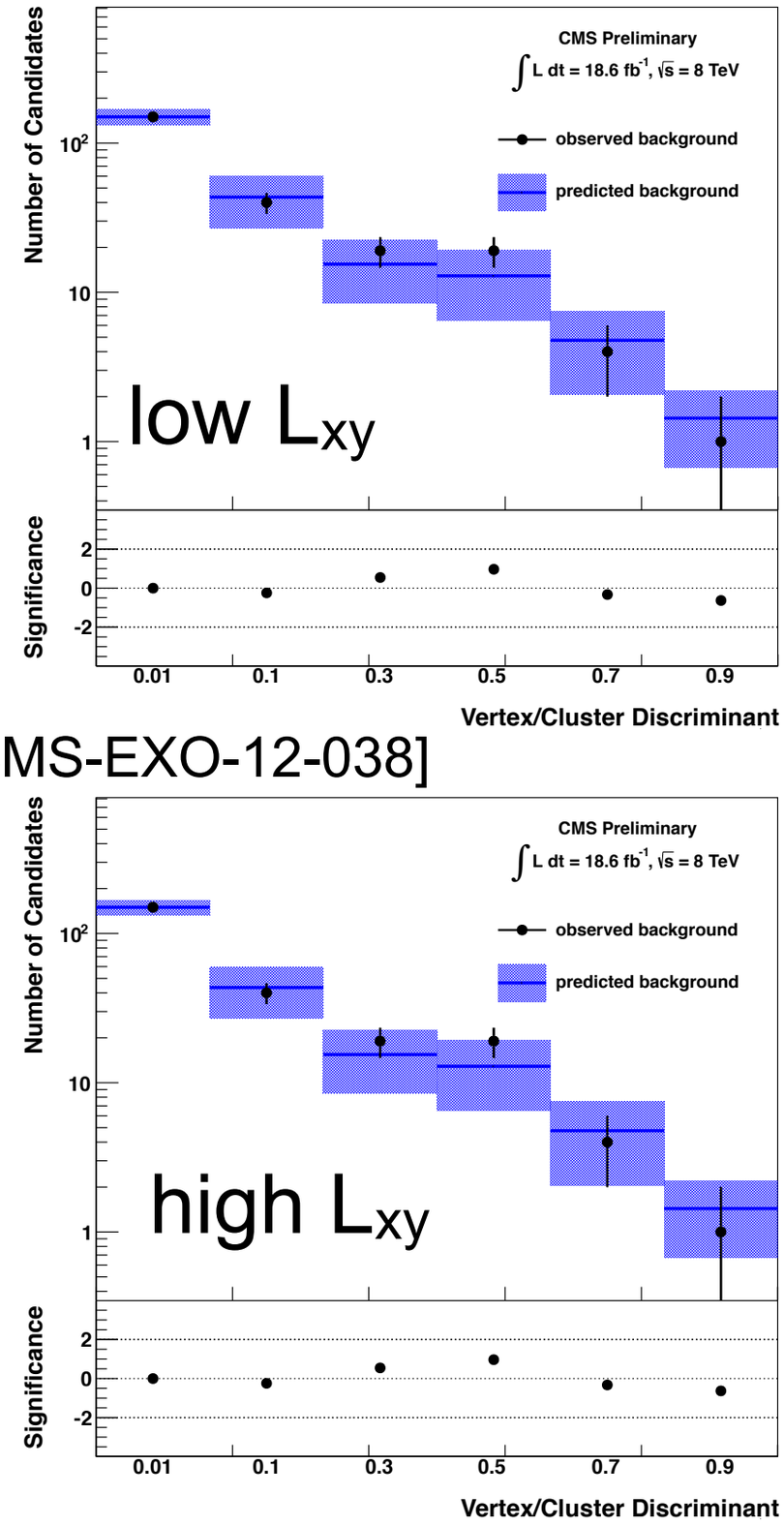
[CMS-EXO-12-038]

Displaced Dijets

- Search strategy: Identify two (overlapping) search regions targeting signals with low and high L_{xy}

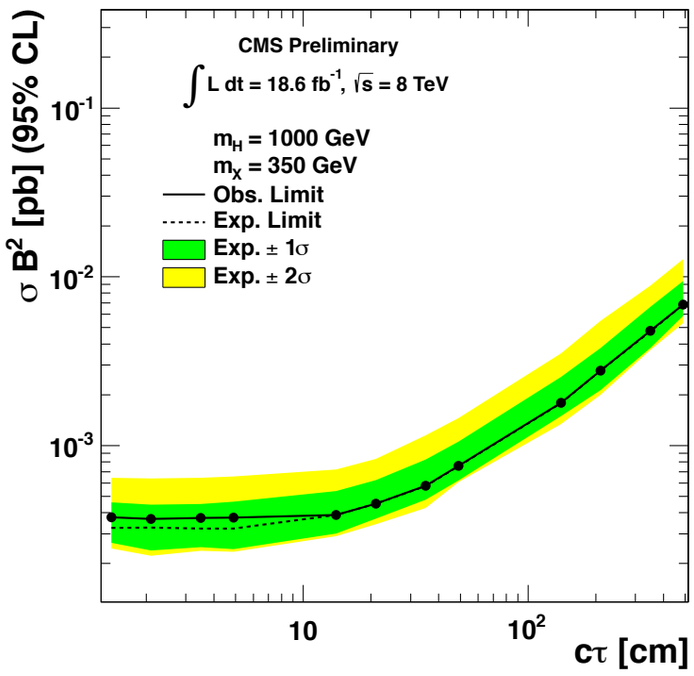
$\mathbf{L_{xy}}$	$< \mathbf{20\ cm (low)}$	$> \mathbf{20\ cm (high)}$
prompt tracks	≤ 1	≤ 1
prompt energy fraction	< 0.15	< 0.09
vertex/cluster disc.	> 0.9	> 0.8
expected background	$1.60 \pm 0.26(stat.) \pm 0.51(syst.)$	$1.14 \pm 0.15(stat.) \pm 0.52(syst.)$
observed	**2**	**1**

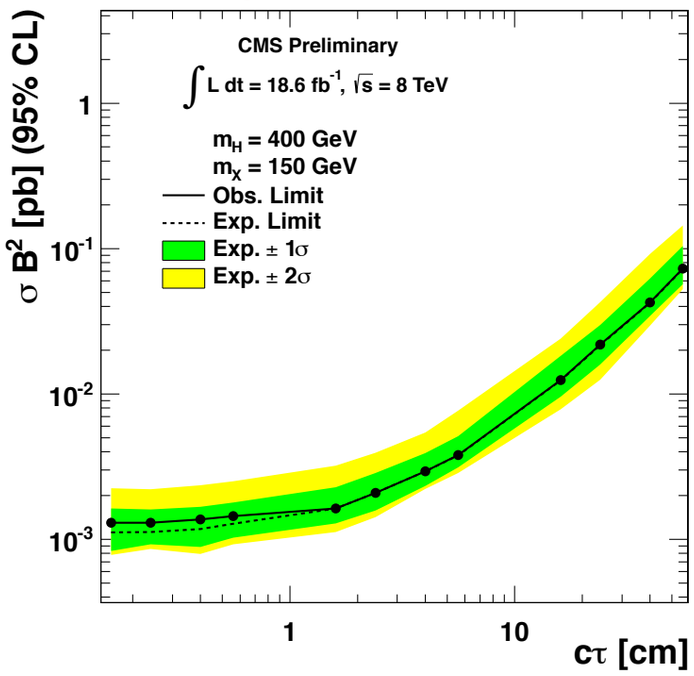
Table 1: Predicted background and the number of observed candidates for optimised selections.



[CMS-EXO-12-038]

- Use data-driven techniques (generalized ABCD method) to estimate backgrounds





Set limits on H→XX→(jj)(jj)

What's Missing from displaced dijets?

- The analysis requires **two** displaced jets from the same vertex
  - Note that some models have two displaced jets from the same vertex, but because of the boost, the jets merge
- Trigger requires **H_T>300 GeV**
  - Can't go after H(125) because of this
  - Should look in other channels: inclusive VBF, lepton+X, etc.
- Analysis has prompt energy fraction requirement
  - If the long-lived particle has electric charge, then sensitivity could be suppressed
- Insensitive to lifetimes $\lesssim$1 mm and $\gtrsim$1 m

Conclusions

- Searches for new physics is covering a very large space
  - Still, gaps remain, even as we are trying to close them
    - often driven by trigger constraints, or sometimes lack of time, or even lack of imagination
    - Some gaps arise implicitly from isolation criteria
    - Be wary of systematically limited searches or those too tuned to a specific model
      - not all searches are not constructed to make a discovery

- Electro-weak scale physics will only get more difficult as we increase the sqrt(s)
  - Should be thinking now about trigger strategies, etc.