New Physics Ideas for Run 2

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Caltech

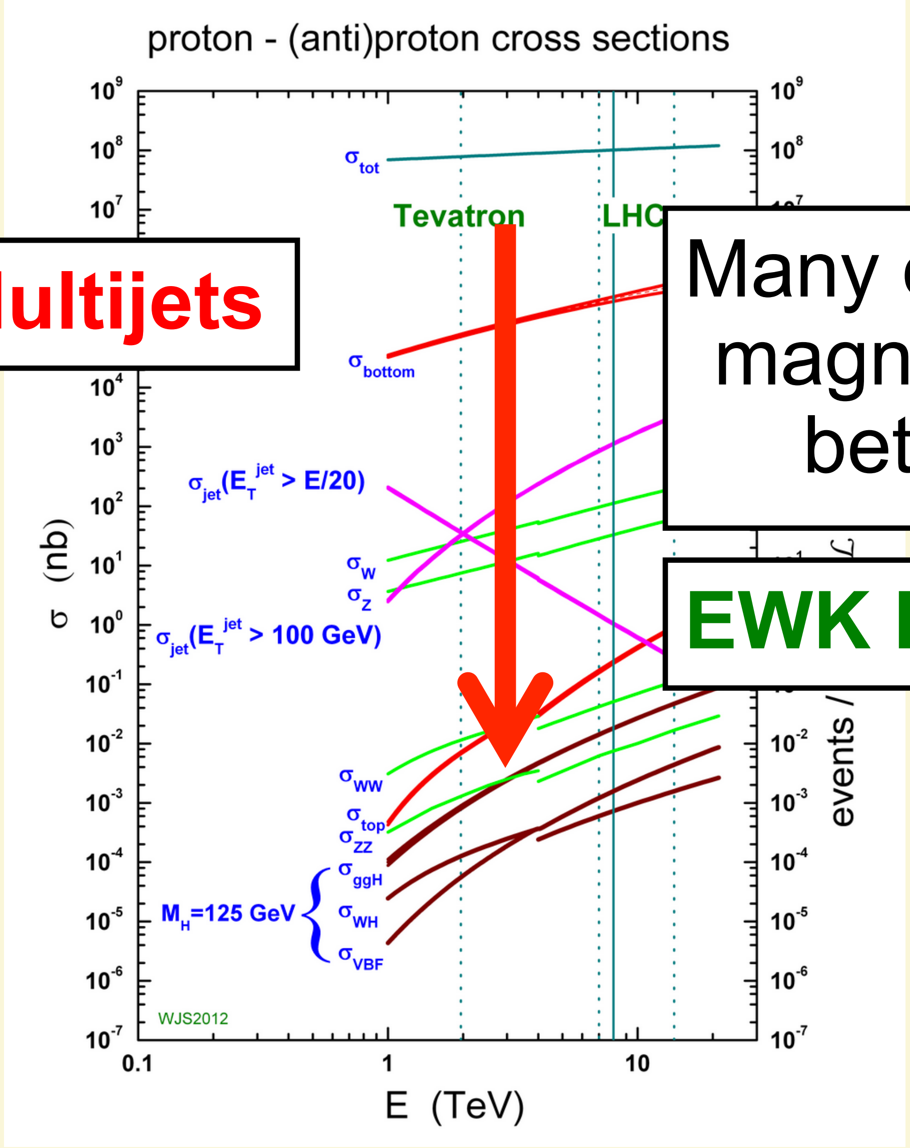
Introduction

- We are in anticipation of some TeV-scale new physics at the LHC : give your favorite reasons
- Nothing definitive found so far…
  … but community remains hopeful
- Higgs story demonstrates the crucial importance of theoretical guidance
- Absent such guidance, I will give an experimental (practical) view of how to search for new physics in Run 2

Standard Model Background
How to search for new physics?

OLD Physics!

QCD Multijets



Many orders of magnitude in between

EWK Processes

Maybe New Physics

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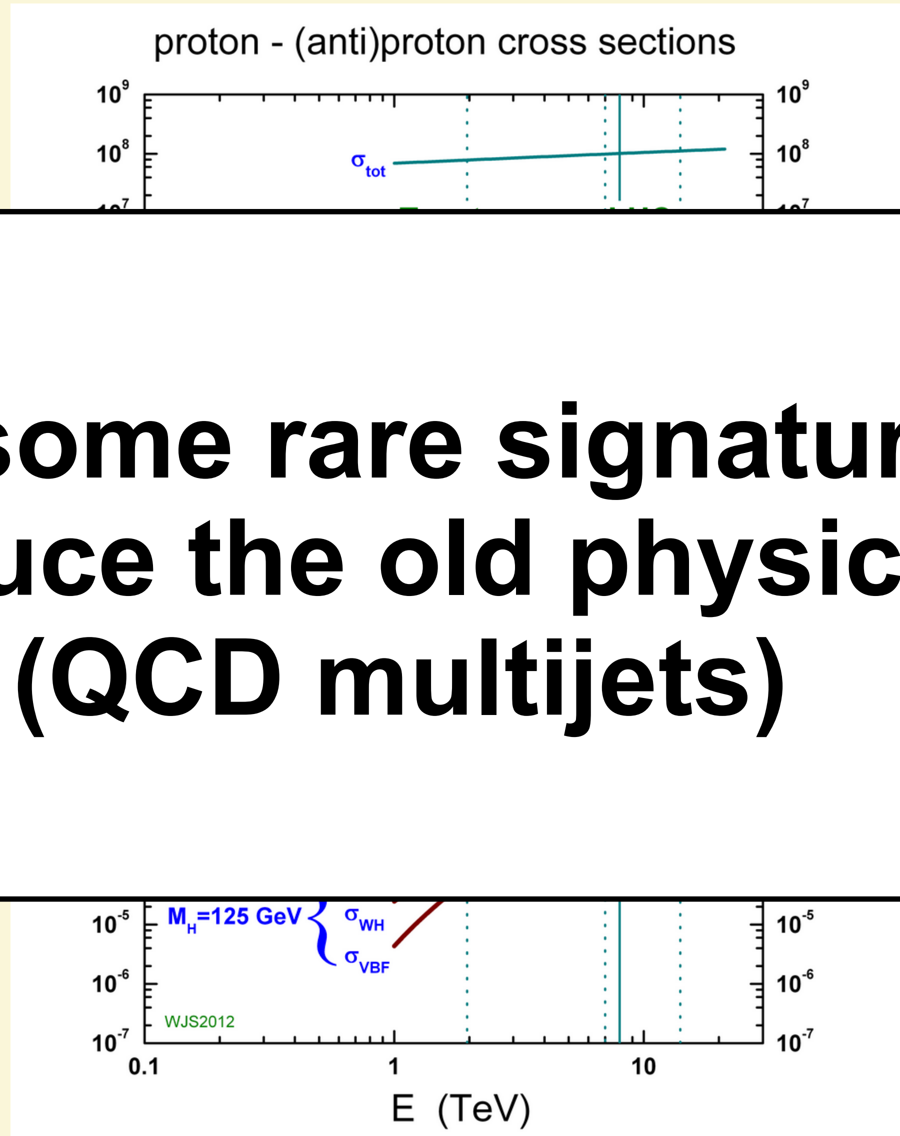
Standard Model Background
How to search for new physics?

OLD Physics!



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New

sics

Need some rare signature to reduce the old physics (QCD multijets)

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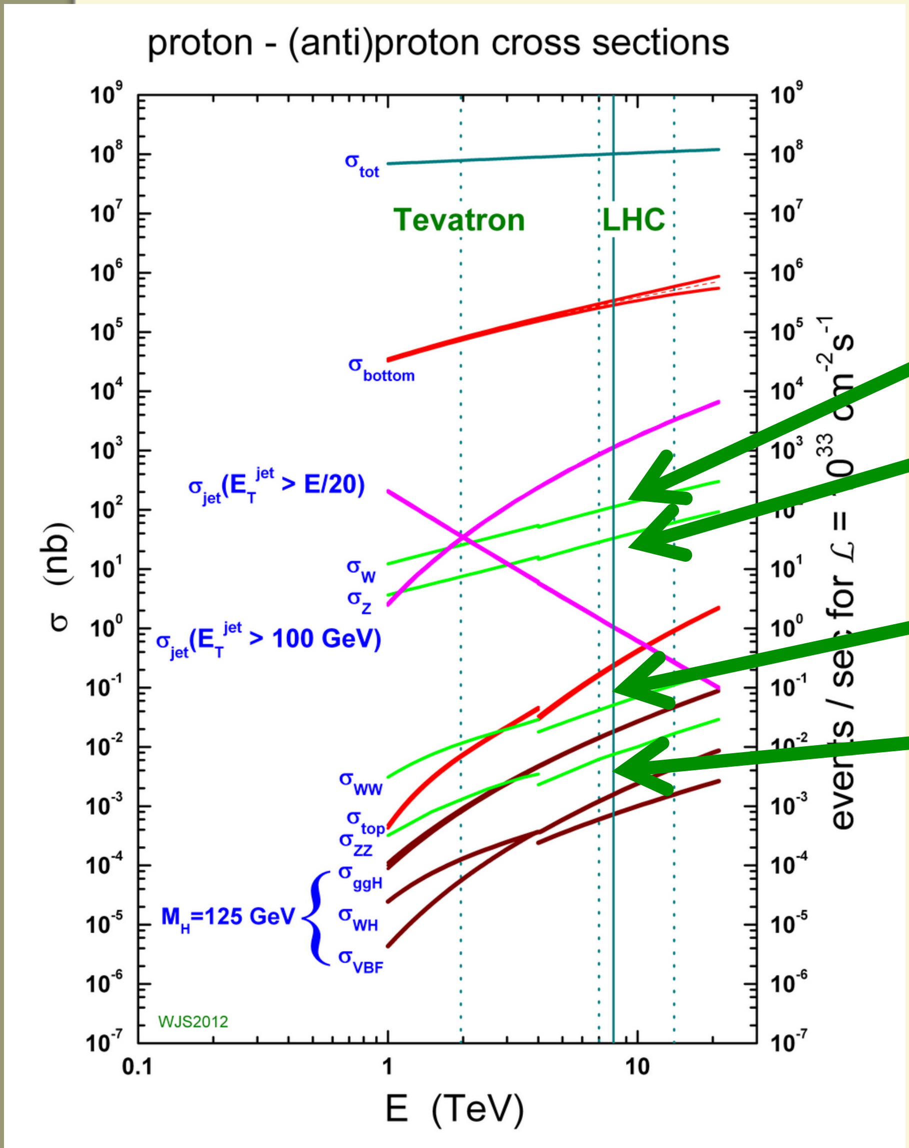
Rare signatures at the LHC : Leptons



- **Leptons**
- **Di-leptons**
- **Di-lepton + MET**
- **3, 4 Leptons**

Bkg suppression ~ $O(10^3)$ per lepton

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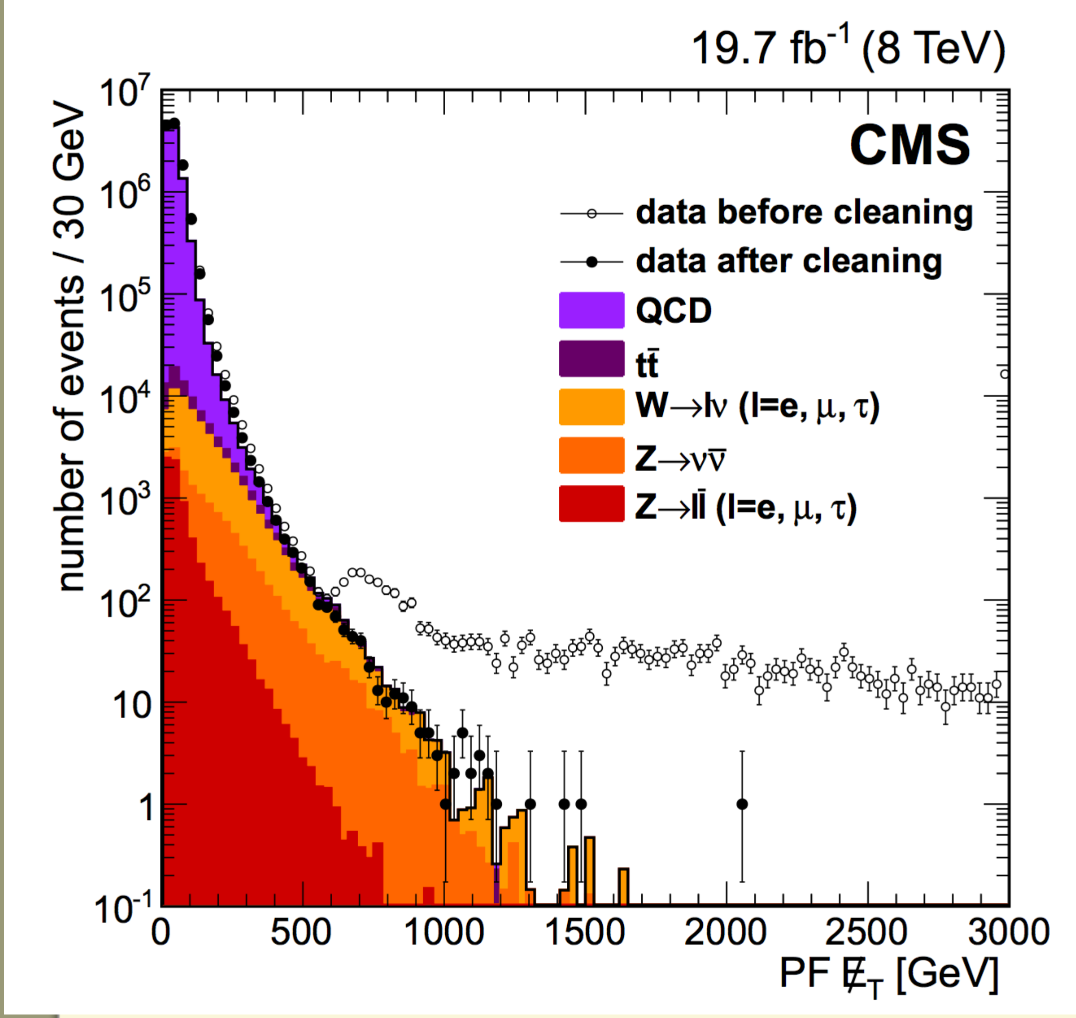
Rare signatures at the LHC : MET



Bkg Suppression : $O(10^3)$ @ ~150-200 GeV

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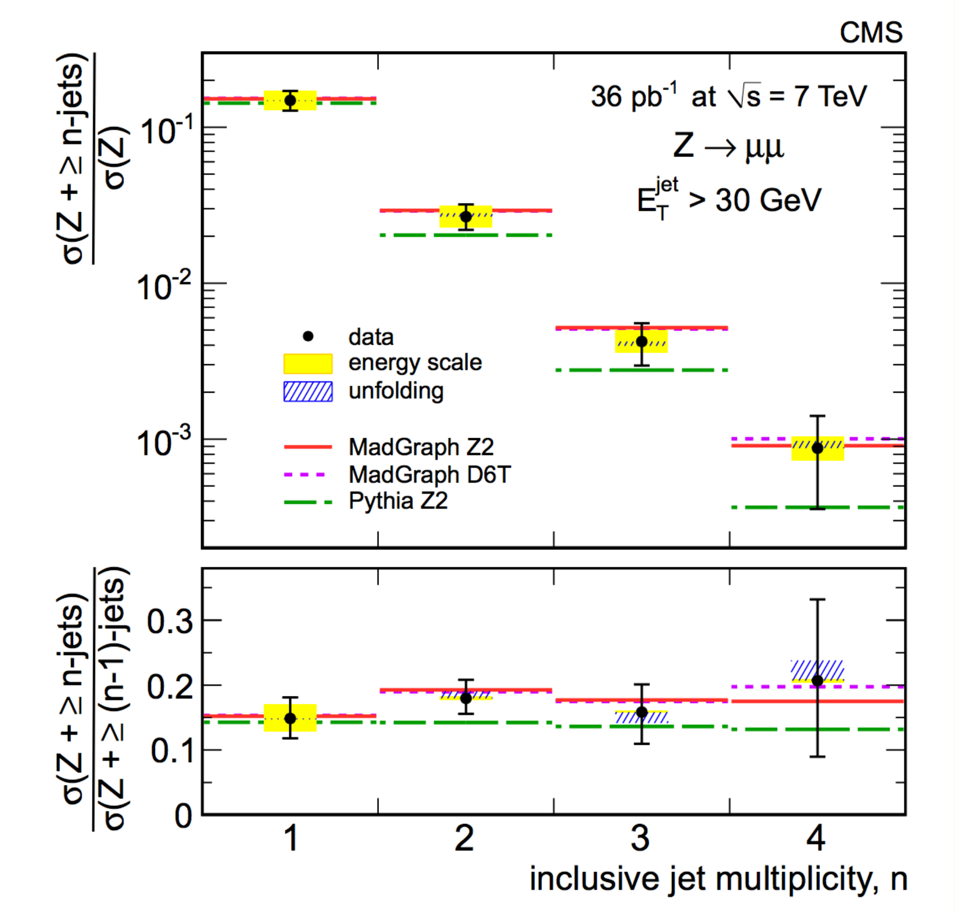
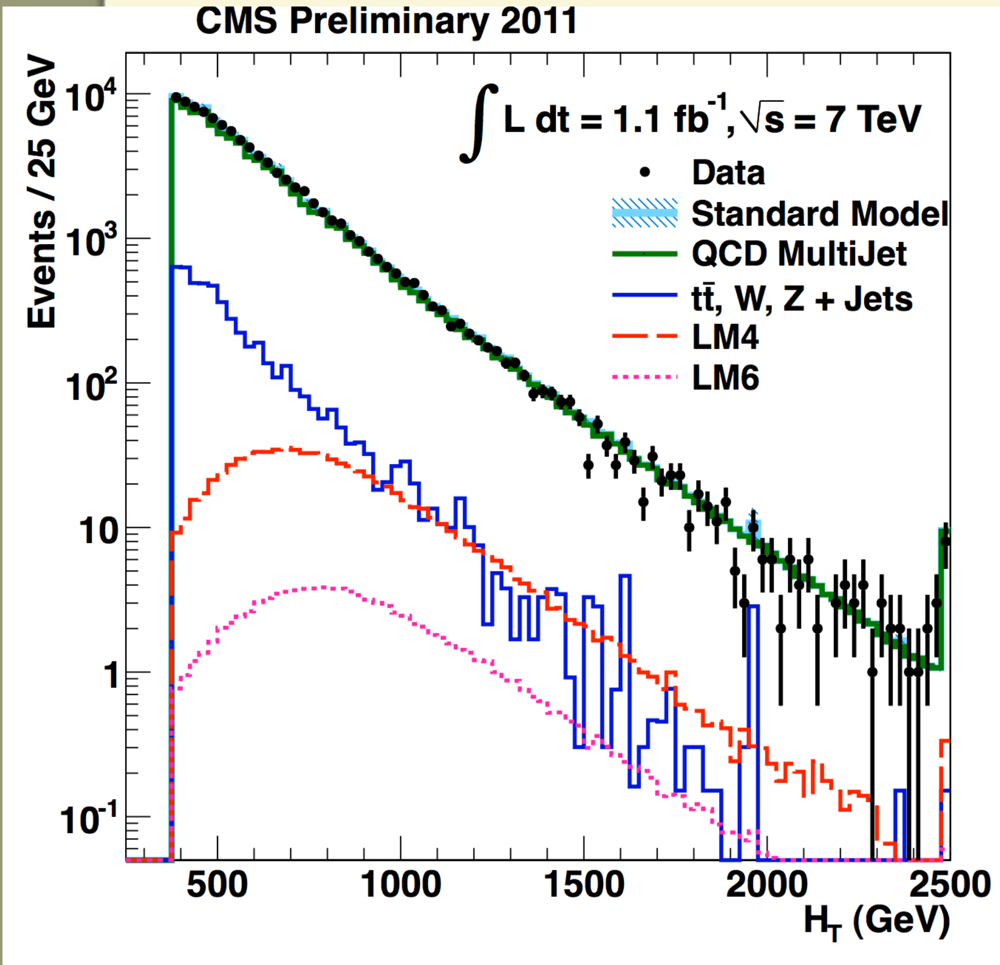
Rare signatures at the LHC : Many Jets

Berends–Giele scaling



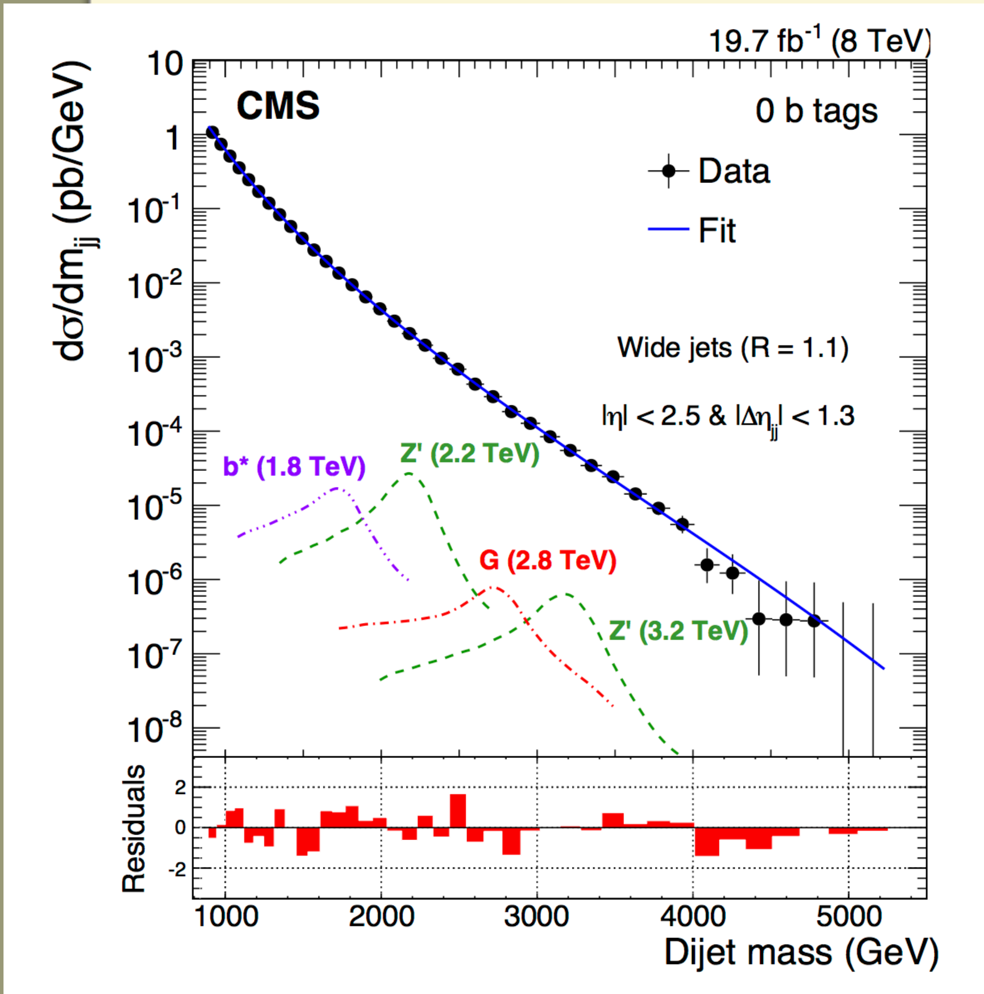
- Factor of ~5 suppression per extra jet

Rare signatures at the LHC : Many Jets



- Factor of ~5 suppression per extra jet
- Factor of 10 suppression per ~500 GeV in HT

Rare signatures at the LHC : Resonances



- Suppression scales with width x resolution

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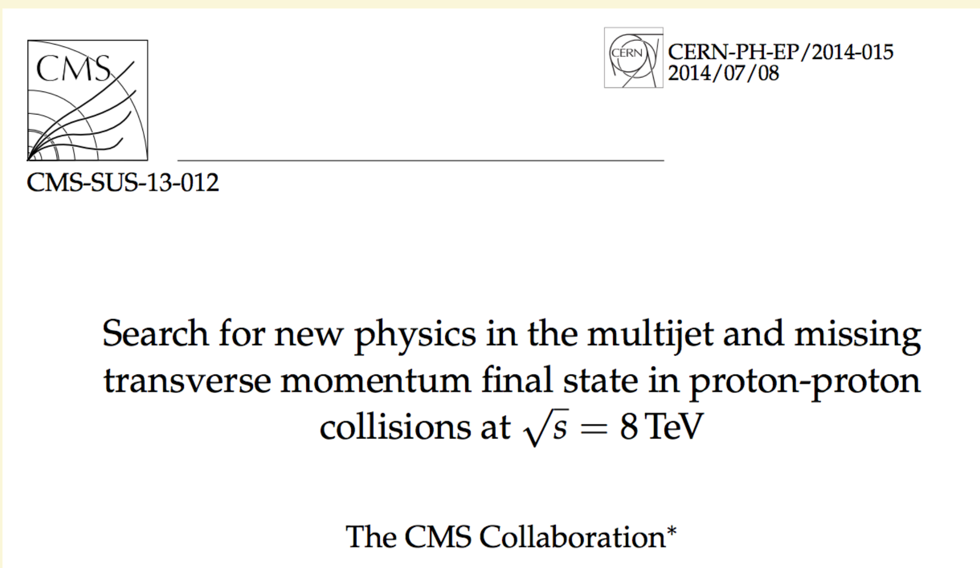
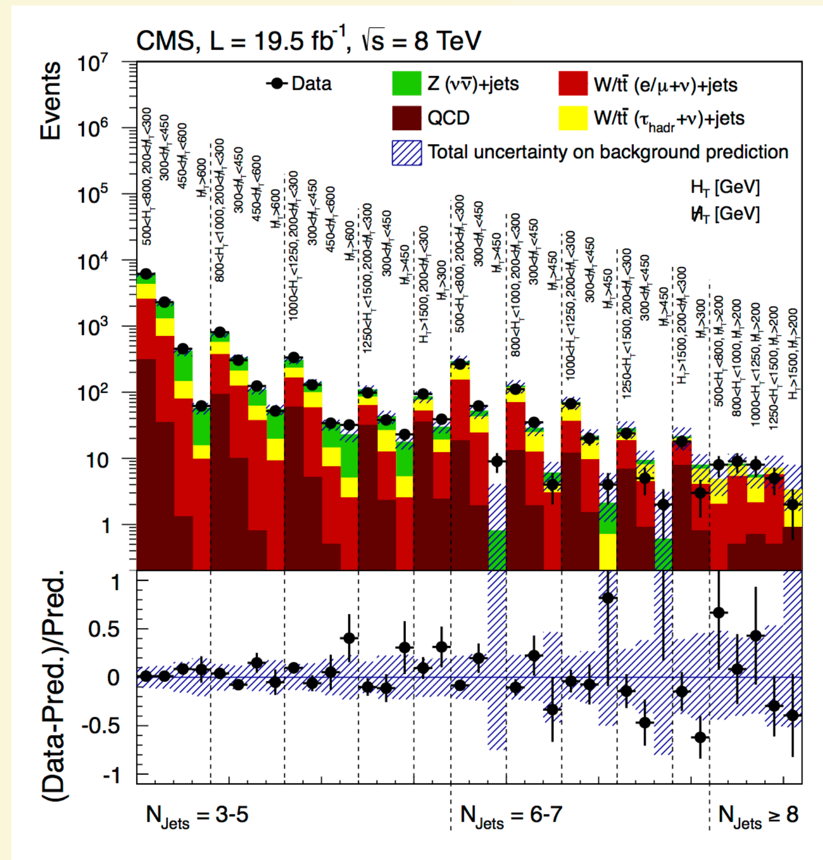
Typical SUSY Searches at the LHC

- Vanilla SUSY searches look for combinations of such signatures:
  - Leptons, large MET, large HT, resonances


CMS
CMS-SUS-13-012
CERN-PH-EP/2014-015
2014/07/08

Search for new physics in the multijet and missing transverse momentum final state in proton-proton collisions at $\sqrt{s} = 8$ TeV

The CMS Collaboration*



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- Generically sensitive to strongly produced TeV scale new physics

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- Vanilla SUSY searches look for combinations of such signatures:
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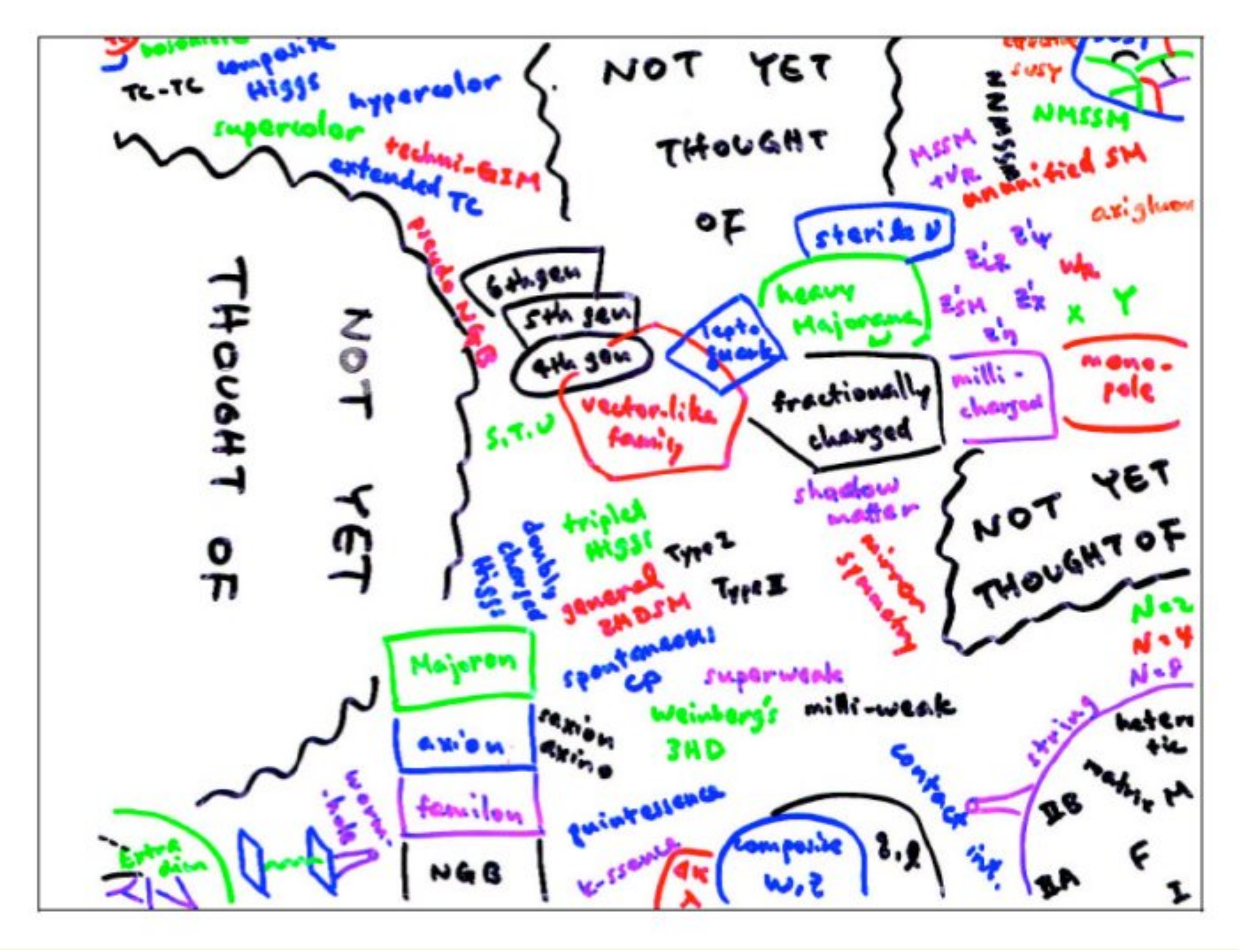
- Generically sensitive to strongly produced TeV scale new physics

- Signatures are sometimes well motivated…
  …but sometimes just convenient

What is the new physics?

- Honestly…we have no clue



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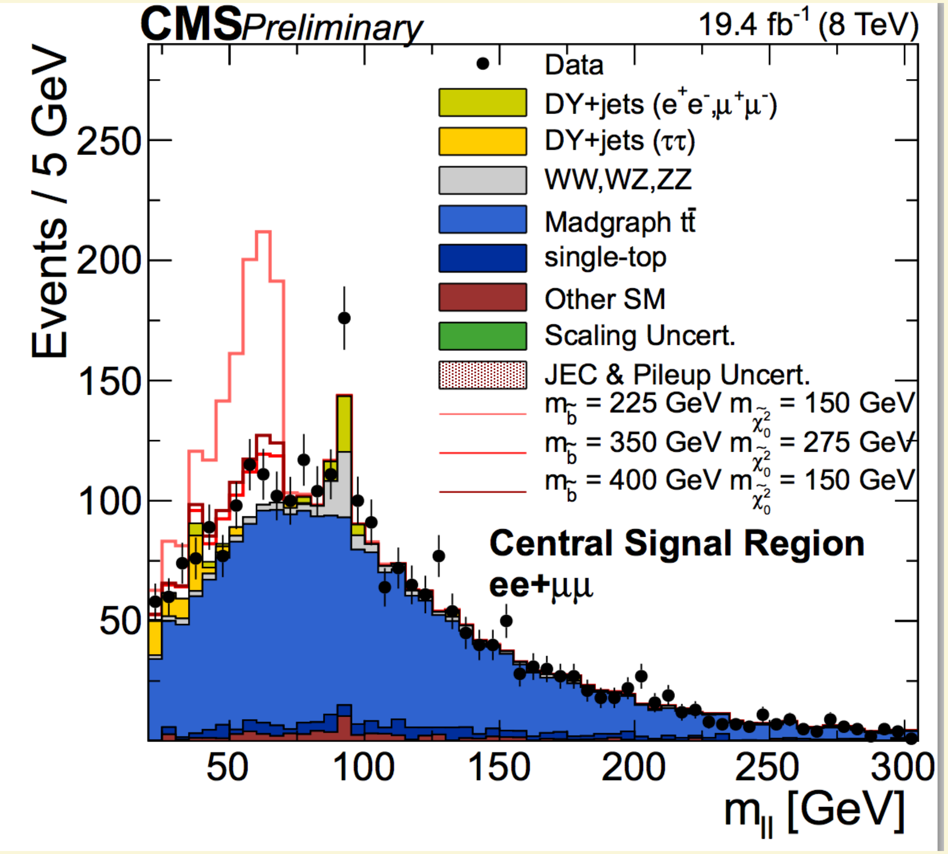
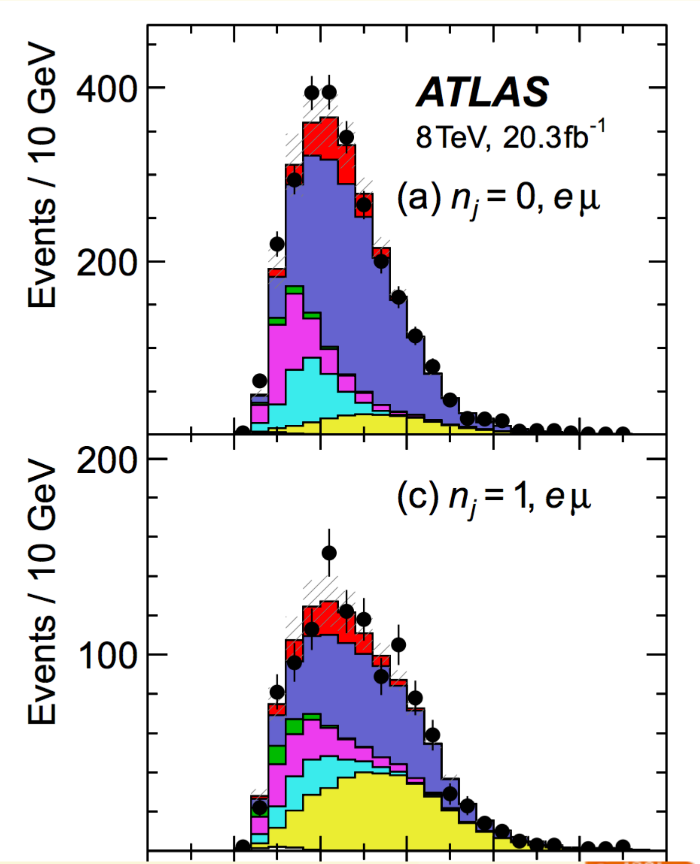
What is the new physics?

- Had it appeared…would we even know that we have found it?





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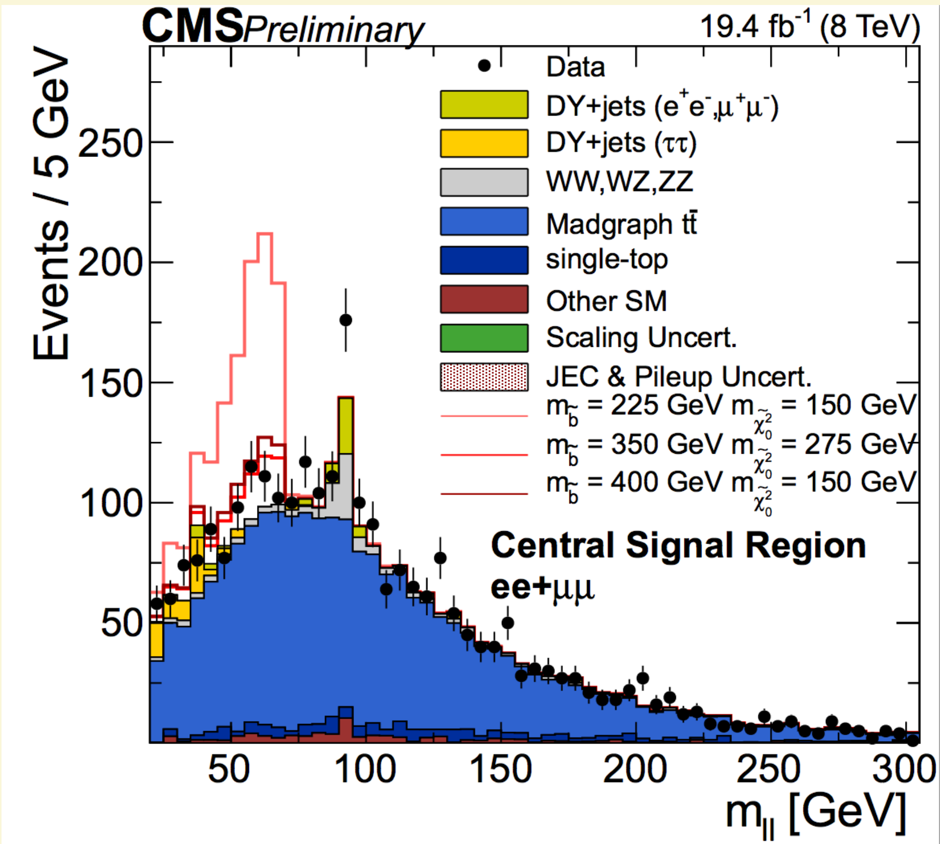
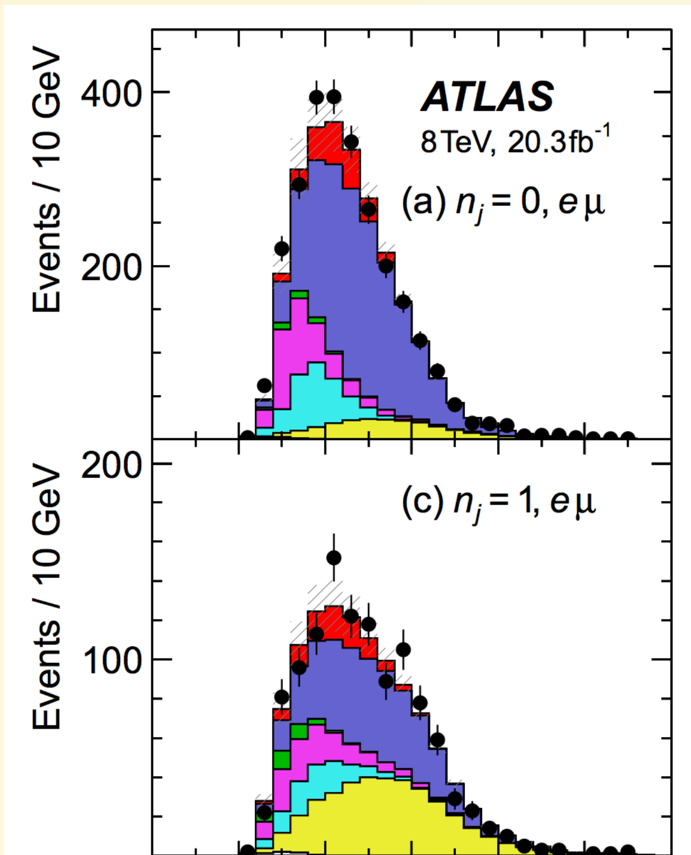
Having a theoretical model for interpretation makes a HUGE difference





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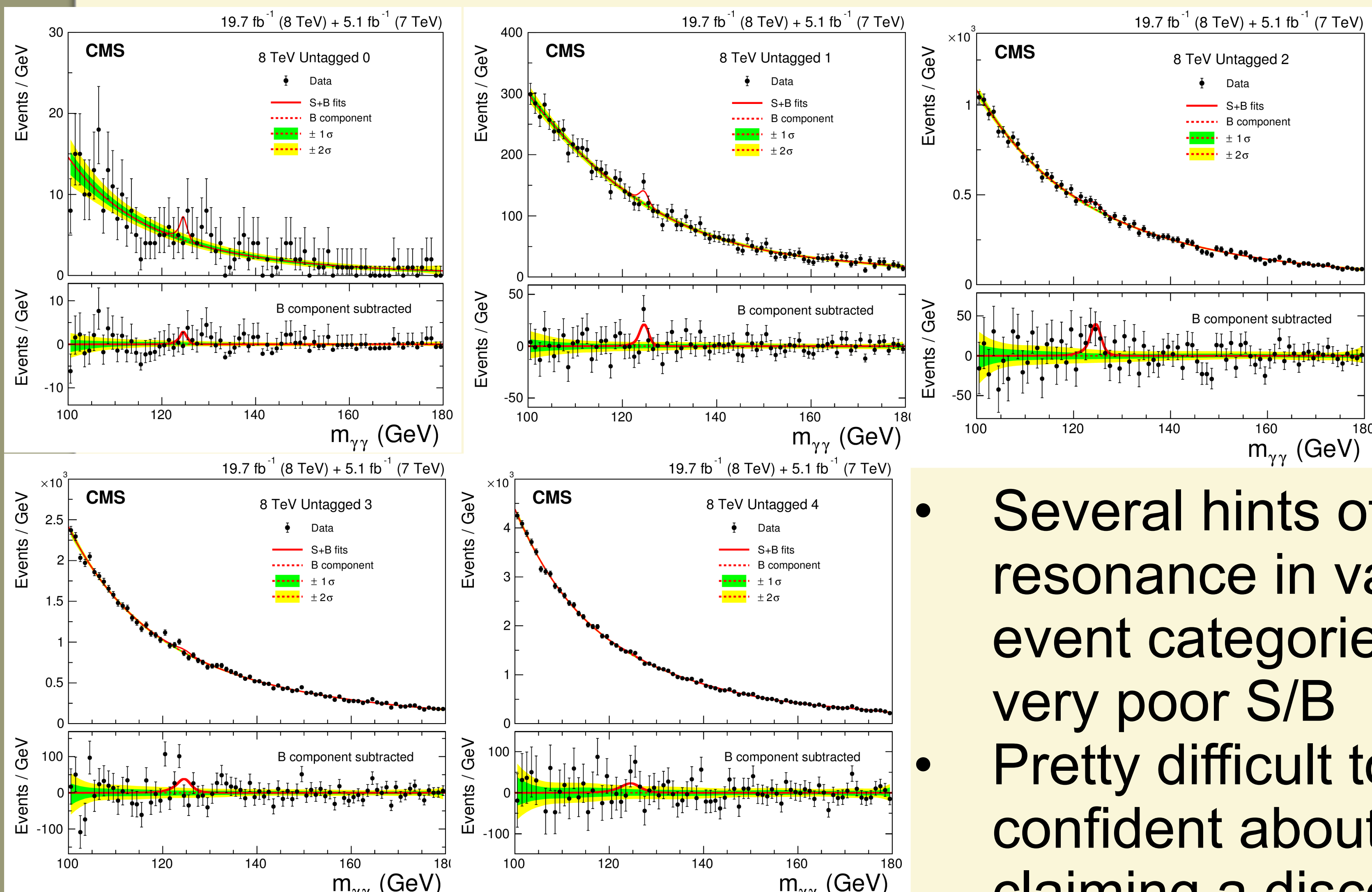
A thought experiment on Higgs

- To gain appreciation of the importance of a theoretical model : imagine the following scenario

  No prior theoretical understanding about the Higgs boson before LHC
  - Didn't know about decay channels and branching ratios
  - Didn't know about different production mechanisms
  - Didn't know about its spin & CP

What would the Higgs discovery look like?

H→γγ



- Several hints of a resonance in various event categories with very poor S/B
- Pretty difficult to be confident about claiming a discovery

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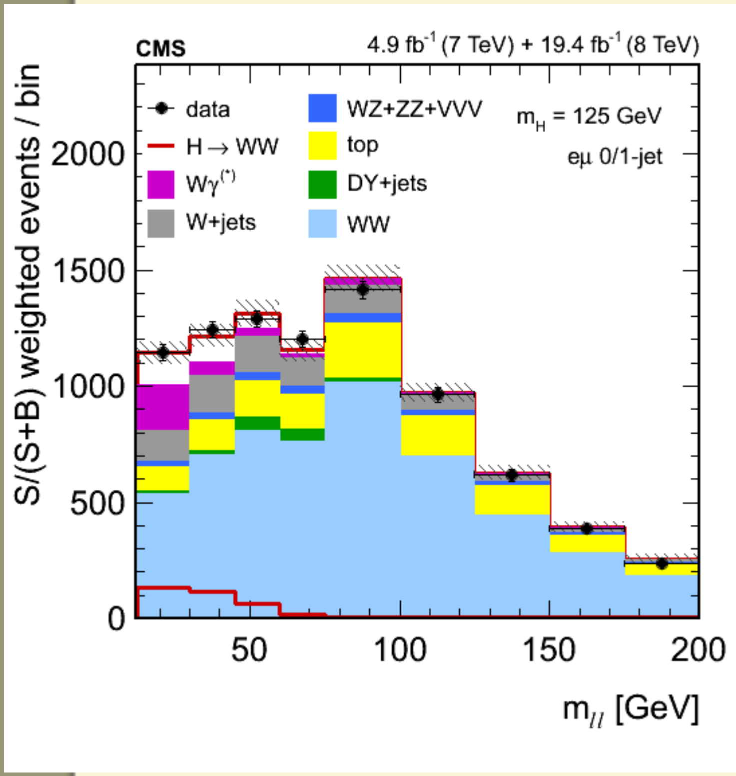
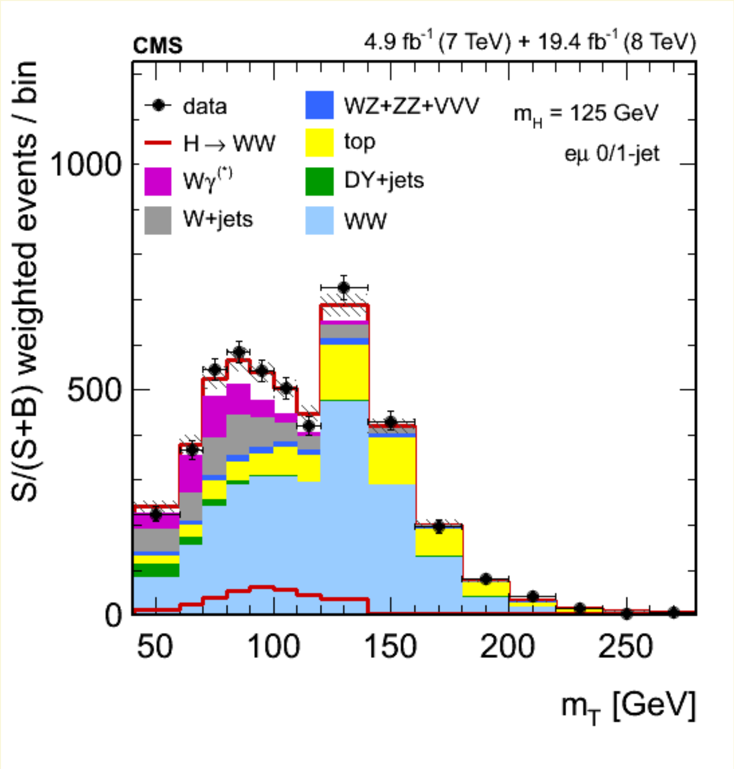
What would the Higgs discovery look like?

H→WW





- A small excess at low m_{ll} & low m_T
- Likely doubts about proper background modeling, a Wγ* bkg that's very difficult to control
- A confident "discovery" would be quite a stretch…

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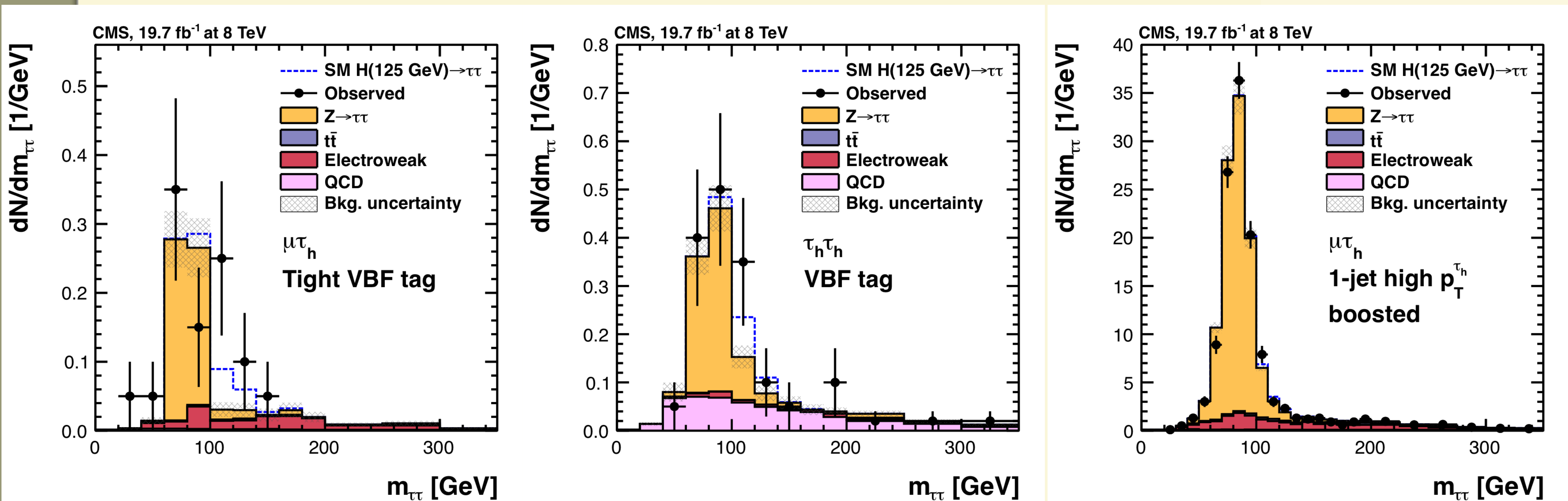
What would the Higgs discovery look like?

H→ττ



- Minor excesses in 2-jet VBF category
- Small excess in 1-jet high boost category, poor S/B
- Total significance ~ 3.5 – 4 σ , but scattered and relies on coherent combination of unusual event categories
- At best, can say there's a hint of something weird…

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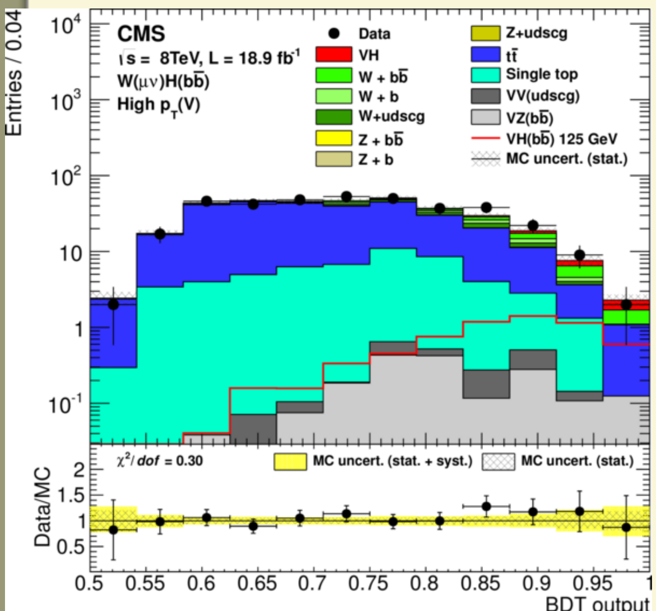
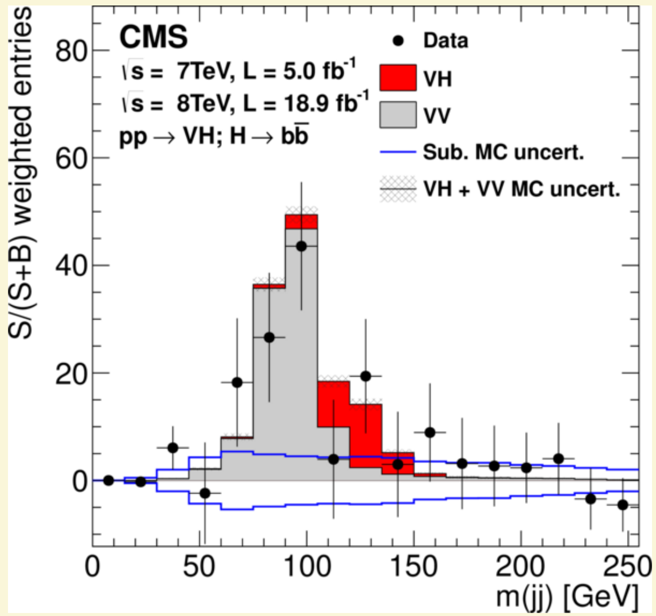
What would the Higgs discovery look like?

H→bb





- Relies a lot on MVA discriminators → would need to know the signal model
- Even then, only a very minor excess. ~ 1–2 σ
- Basically, there's nothing here…

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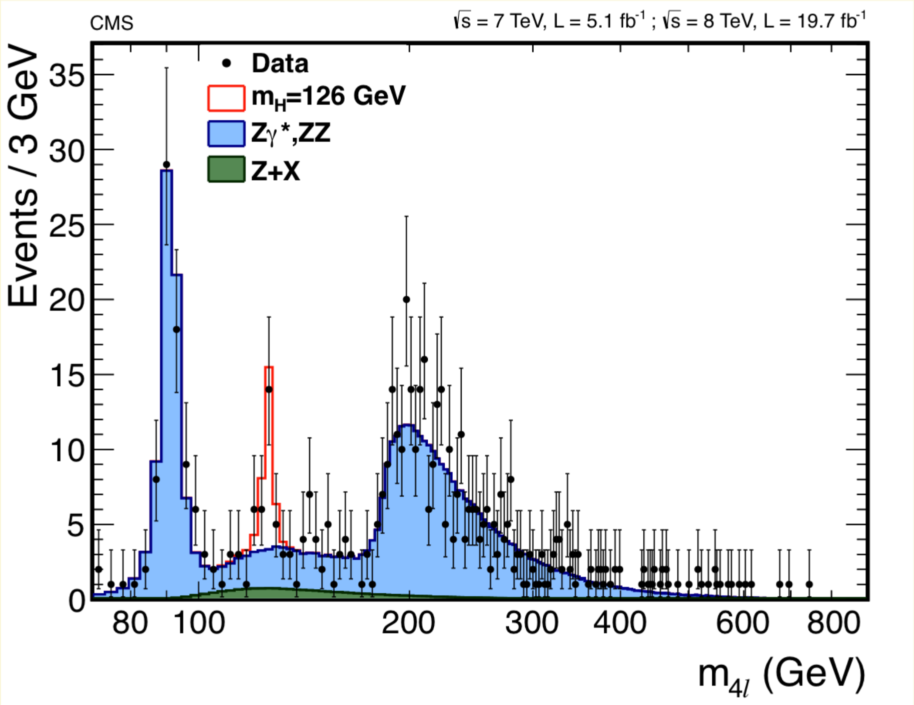
What would the Higgs discovery look like?

H→ 4 lepton



- The only unambiguous signature of a resonance is here
- S/B is good enough to study some kinematic distributions, but not enough events to know much about what this thing is…

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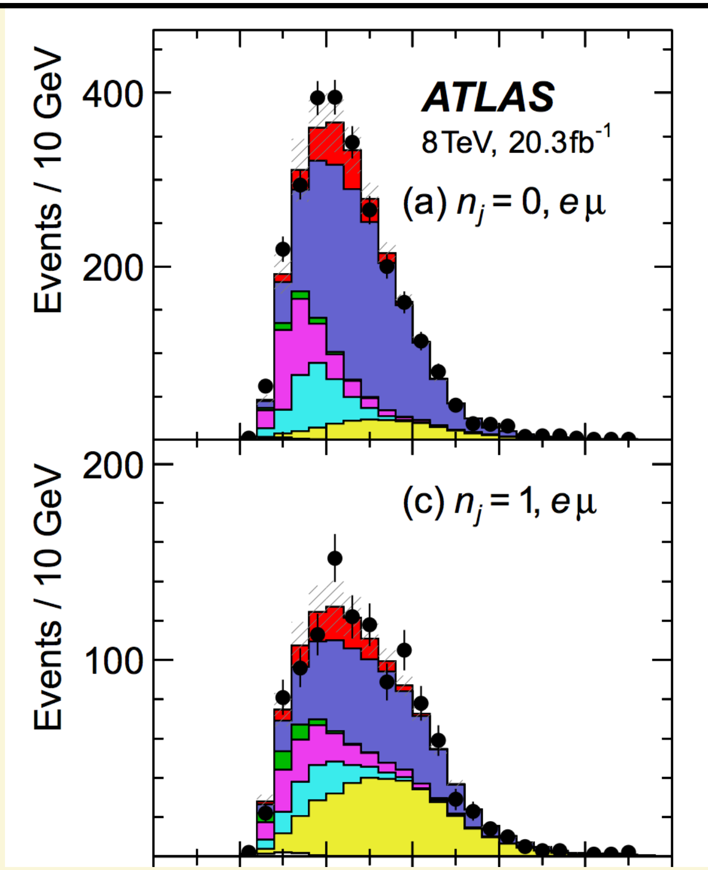
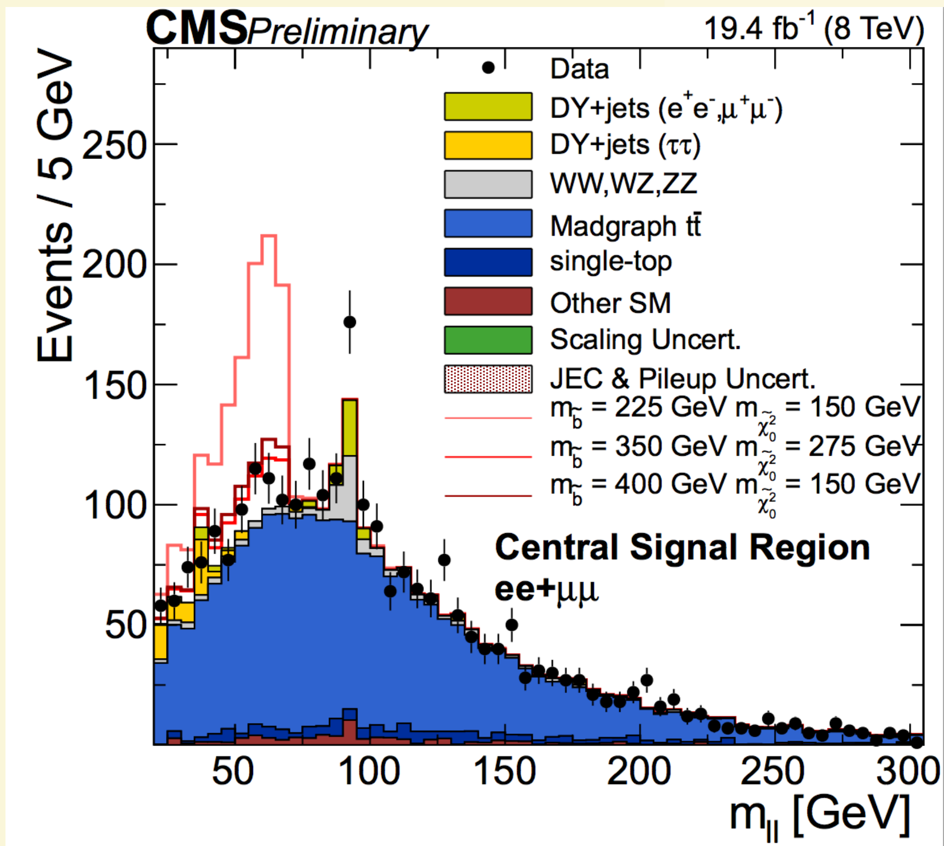
What would the Higgs discovery look like?

- Without knowing the theory, it would be much more difficult to discover the Higgs
- Much more difficult to understand what we have observed
- A lot more doubts about excesses in various channels and the relation between them

- Also a lot of excitement about the opportunity to understand the new physics

Having a theoretical model for interpretation makes a **HUGE** difference





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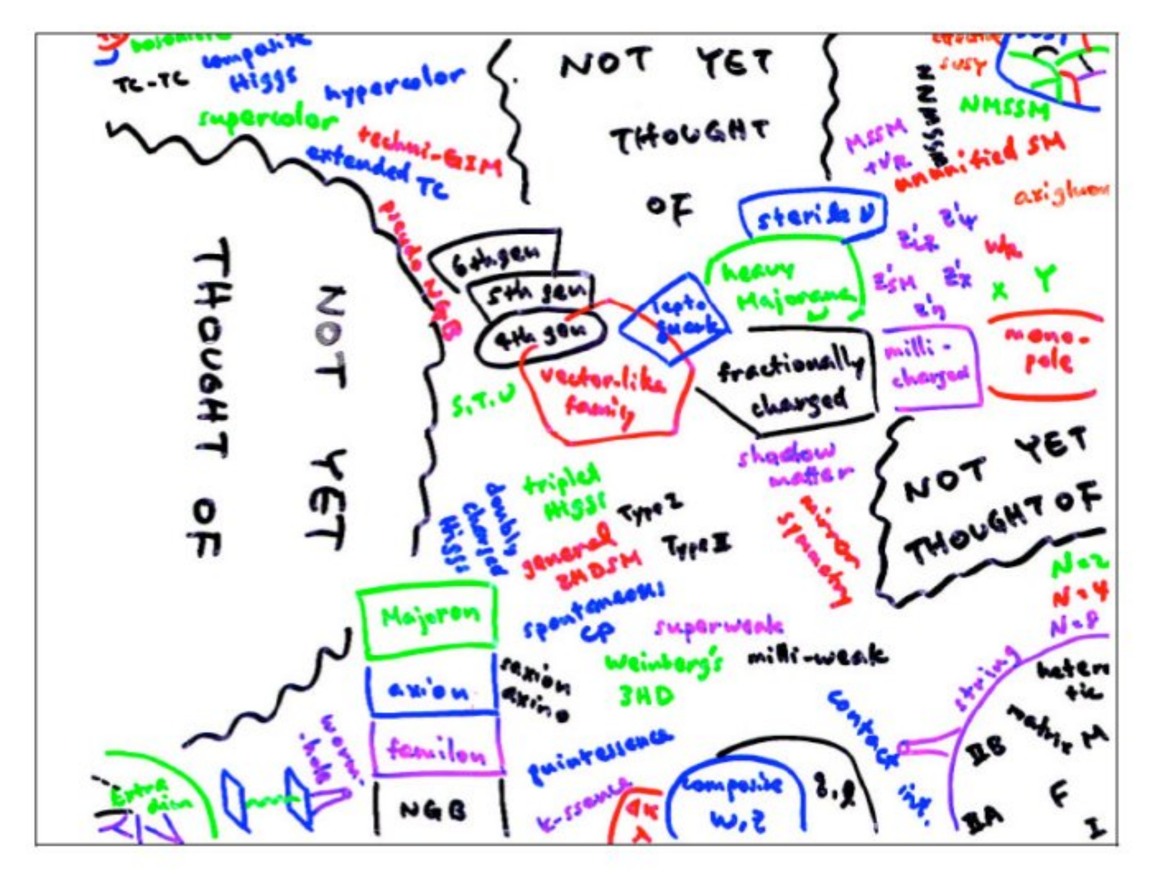
Lack of a leading model forces us to change strategy

- Absent a concrete model
  → need to cover all the bases



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Lack of a leading model forces us to change strategy

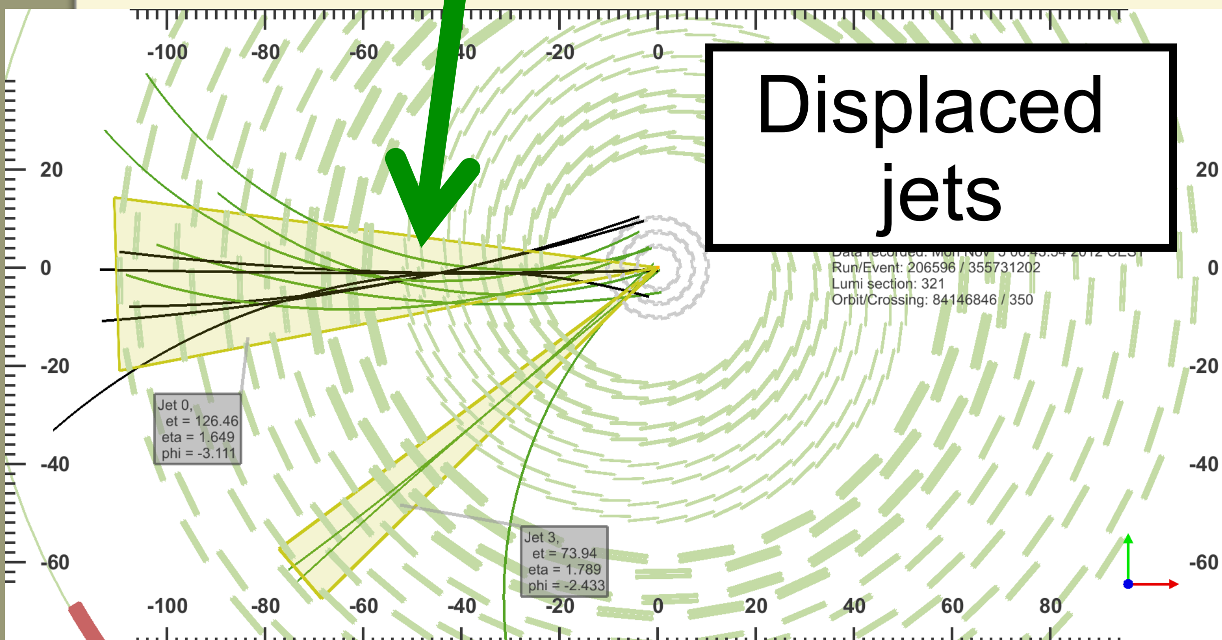
- Absent a concrete model
  → need to cover all the bases

- From the experimental point of view:
  - Make (an exhaustive) list of (interesting) signatures that are sufficiently rare to suppress backgrounds

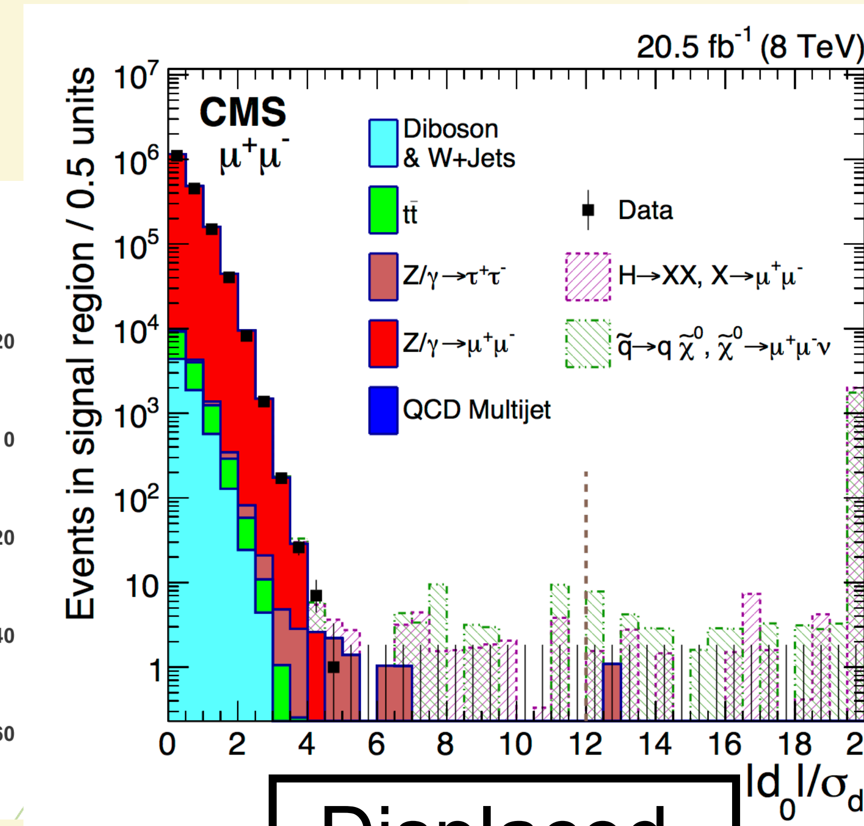
More rare signatures :

Displaced Vertices

A secondary vertex at
44cm away from IP



Displaced
jets



Displaced
dilepton

- Sensitivity to long-lived new particles

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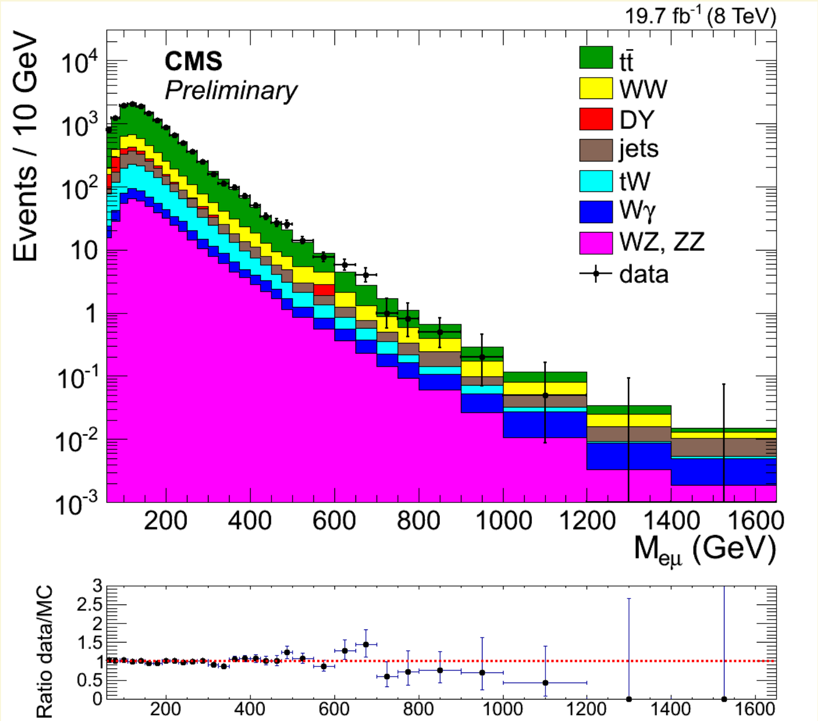
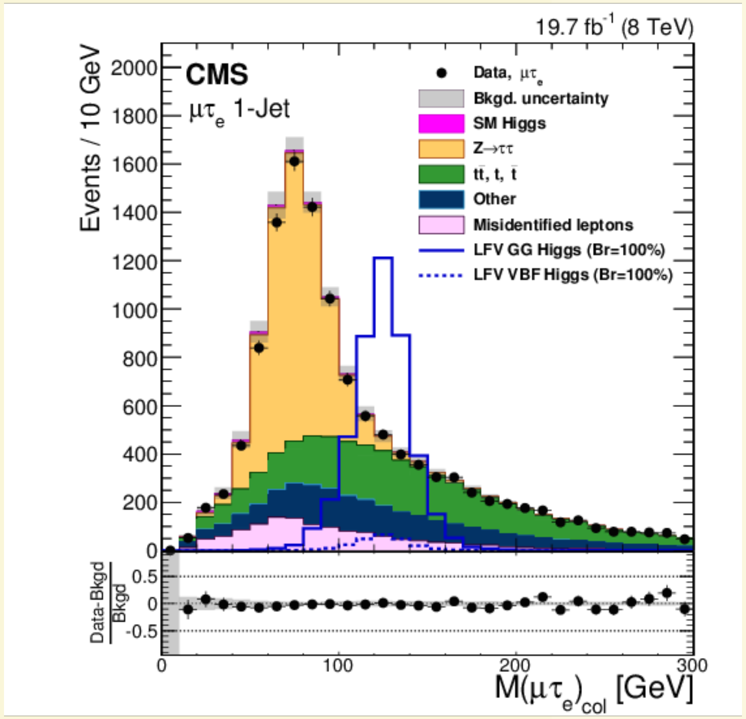
More rare signatures :

Lepton Flavor - Violation

X→eμ



H→μτ



- Lepton flavor violating processes highly suppressed in SM

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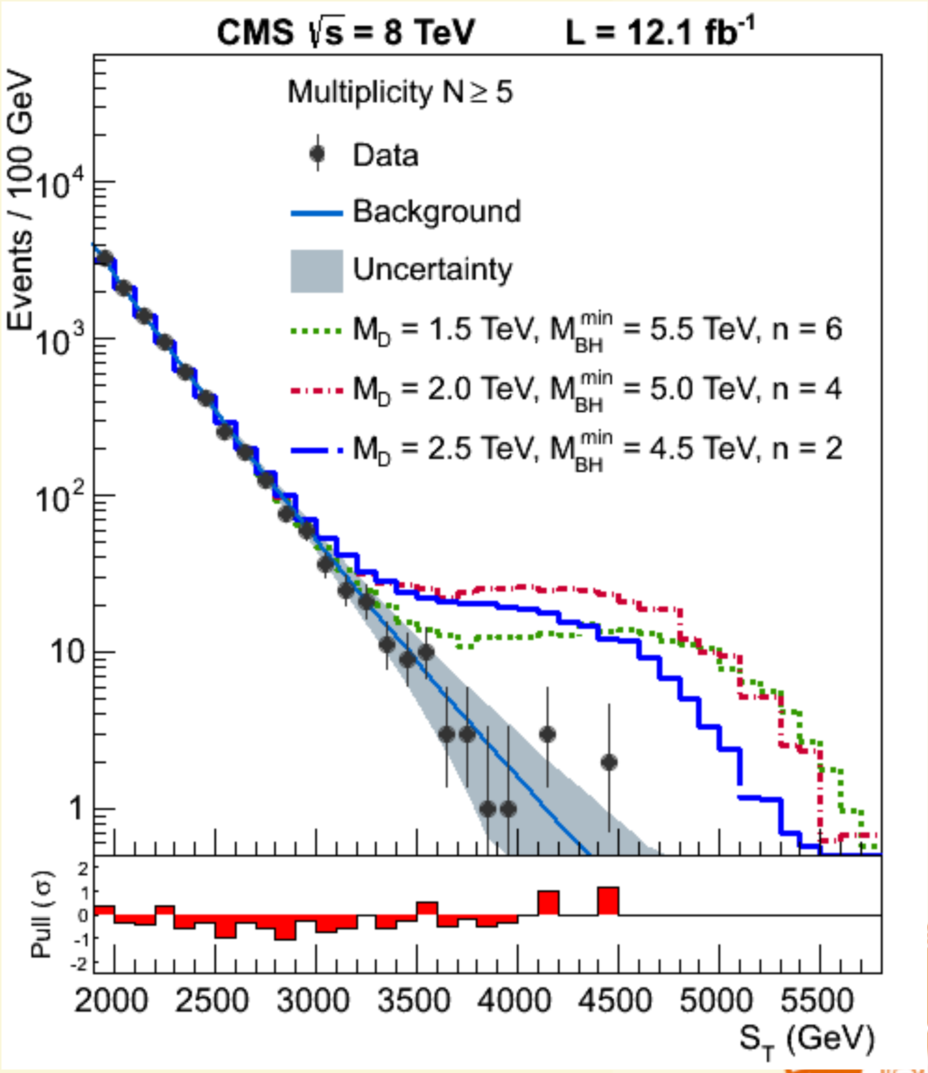
More rare signatures :

Extreme Multiplicity

- ST (sumE$_T$) : ΣE_T
- Factor ~10 suppression for each ~500 GeV of E_T



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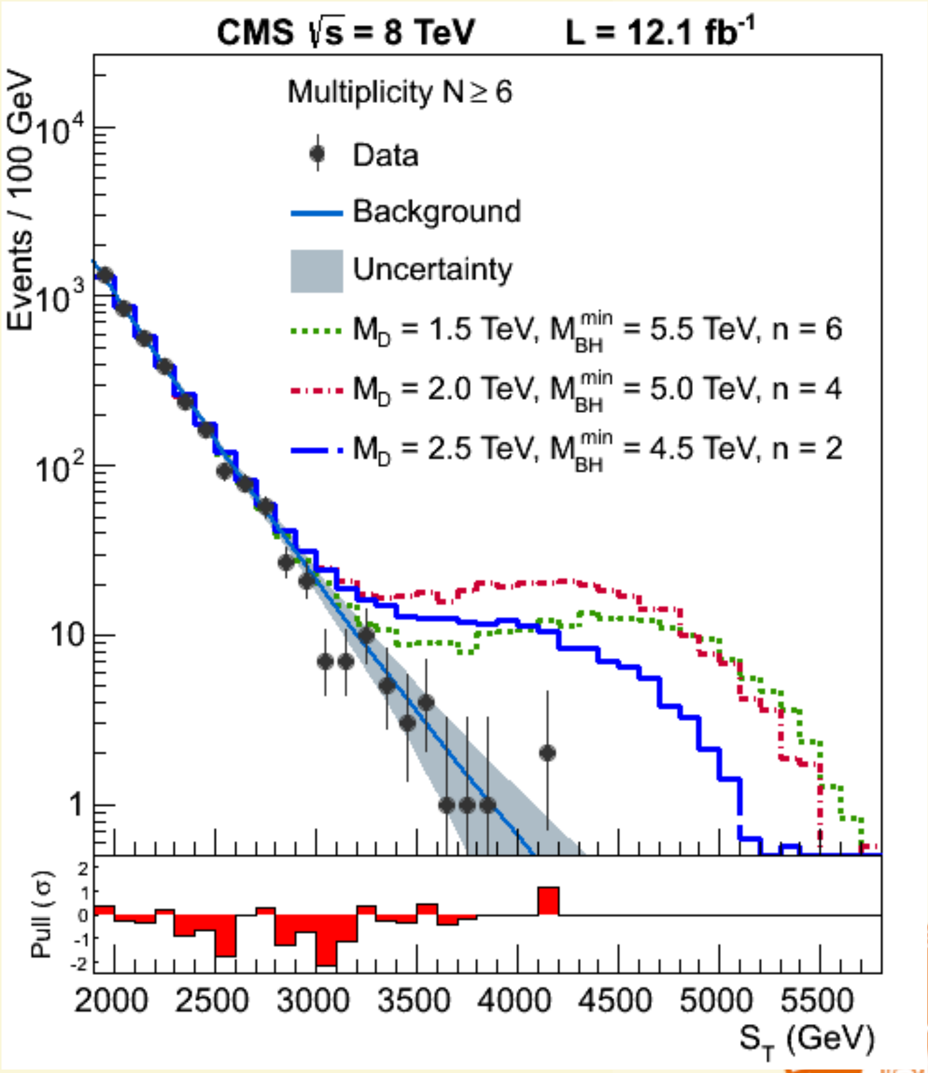

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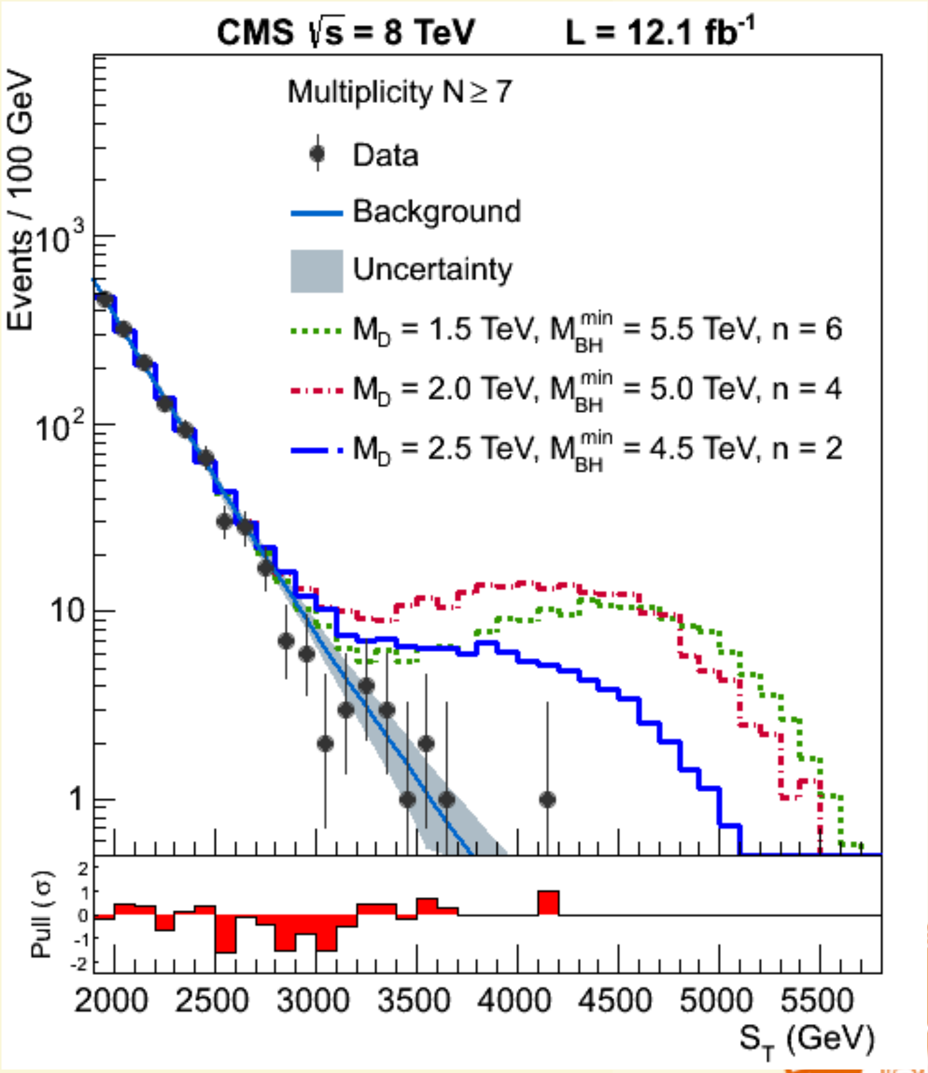

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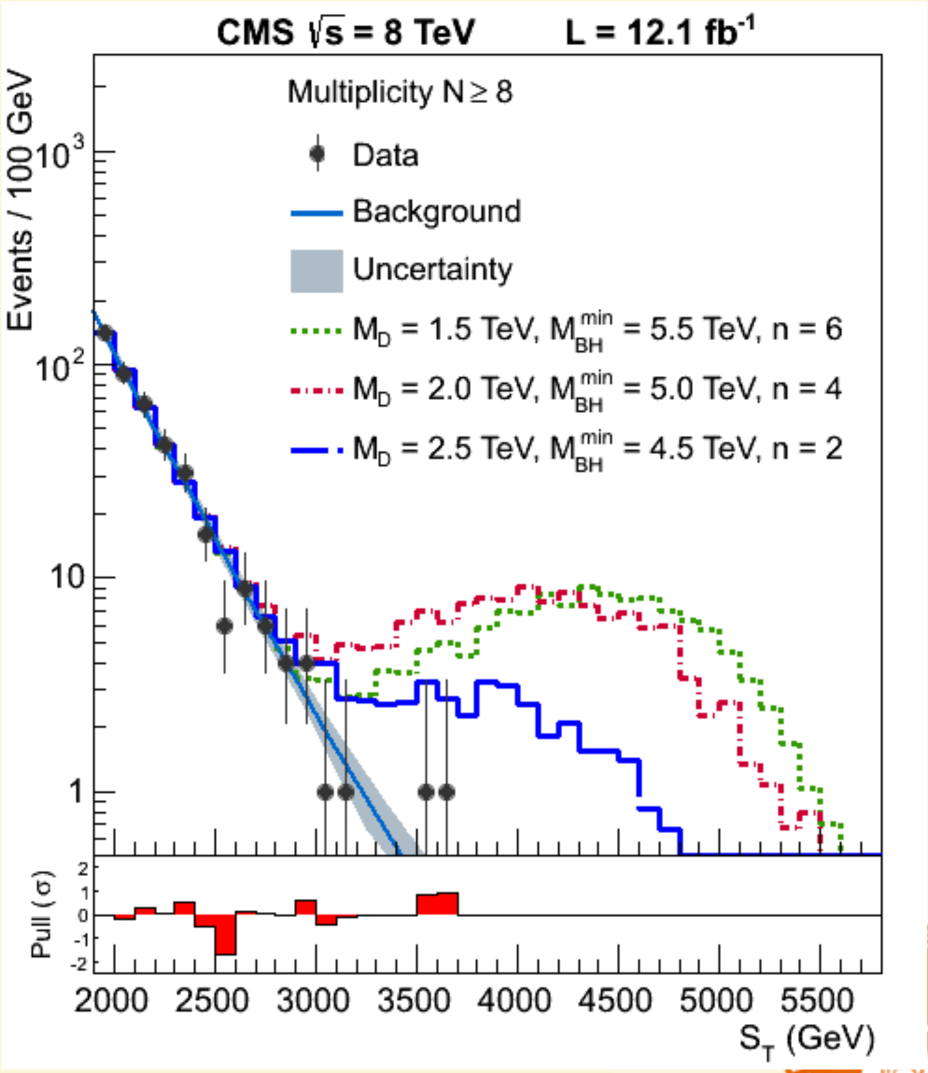

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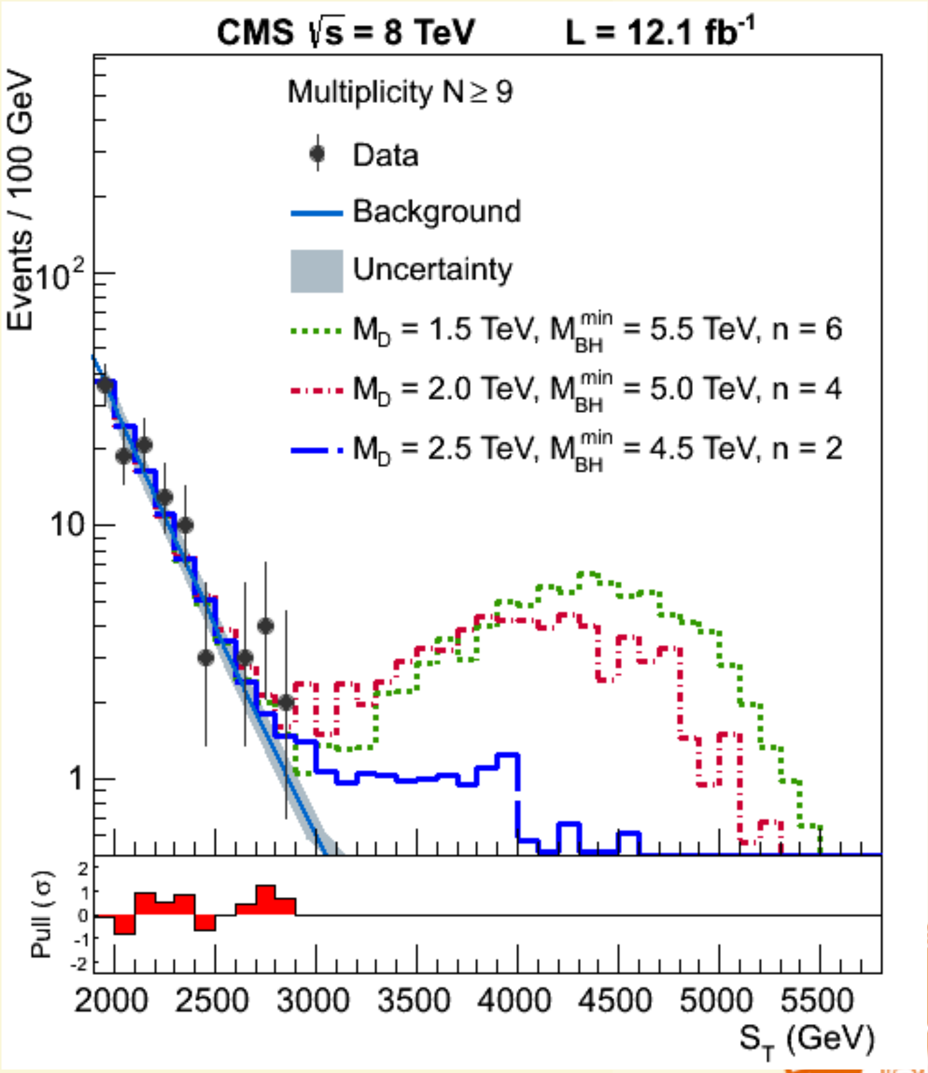

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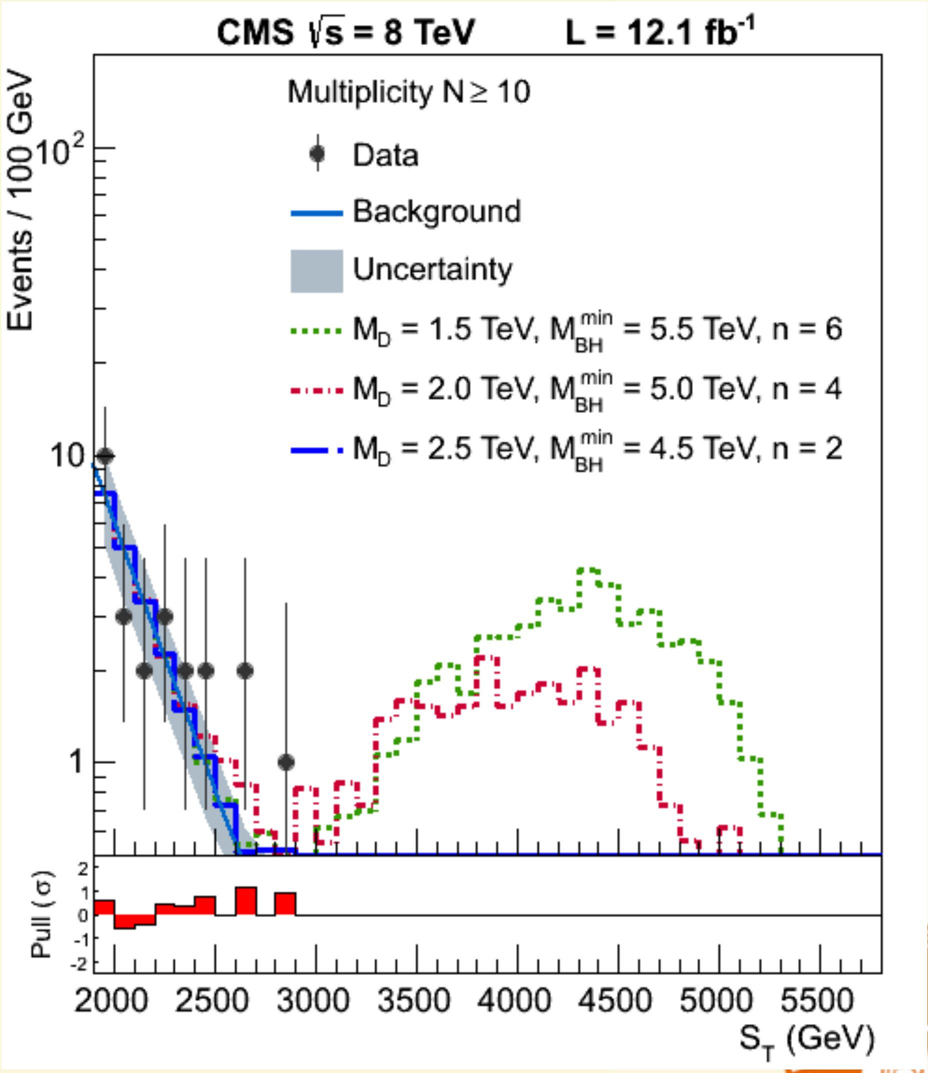
More rare signatures :

Extreme Multiplicity

Generically searching in events with large multiplicity of particles leads to potential sensitivity to:

black holes, hidden-valley scenarios, even vanilla SUSY (eg. ĝĝ→tttt)



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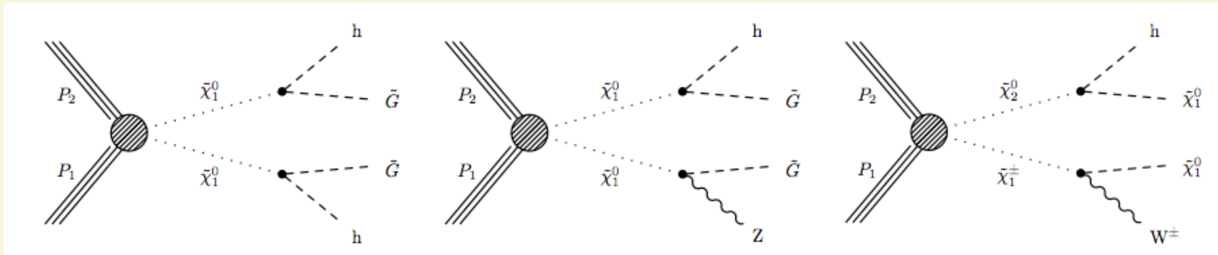
Multiple Coincident Rare Signatures

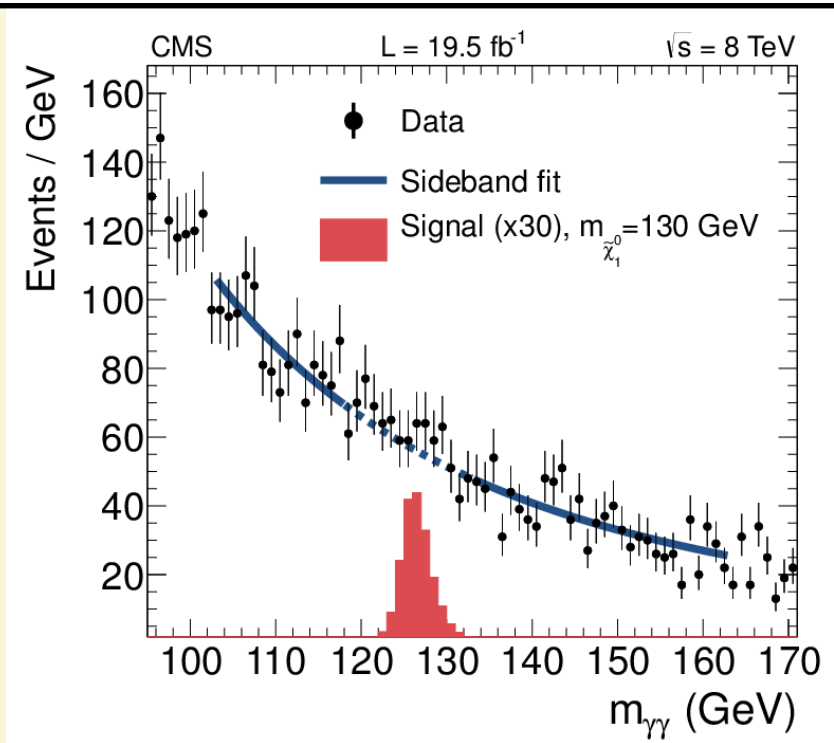
- Typically new physics searches focus on a single **VERY** rare signature
- But backgrounds can also be suppressed by multiple coincident rare signatures, examples:
    - Dilepton (same charge) & moderate HT
    - moderate HT & moderate MET & resonance
    - Higgs & MET
    - Displaced track & MET
    - Displaced track & Higgs
- Many possible combinations not yet studied

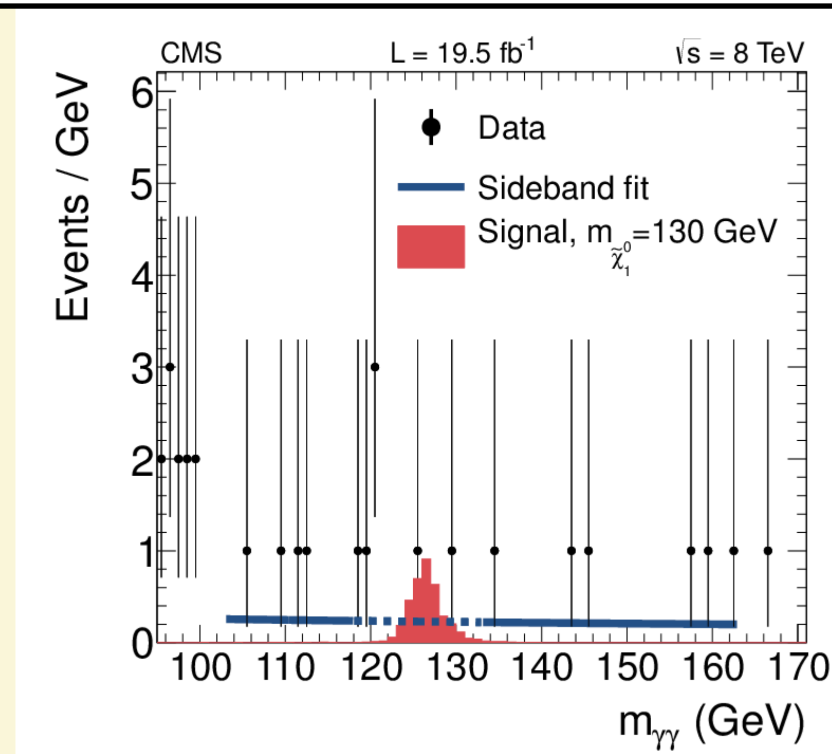
An example: Higgs (Higgs) + MET



W/Z H → jjγγ & MET (LSP)

HH → bbγγ & MET (LSP)





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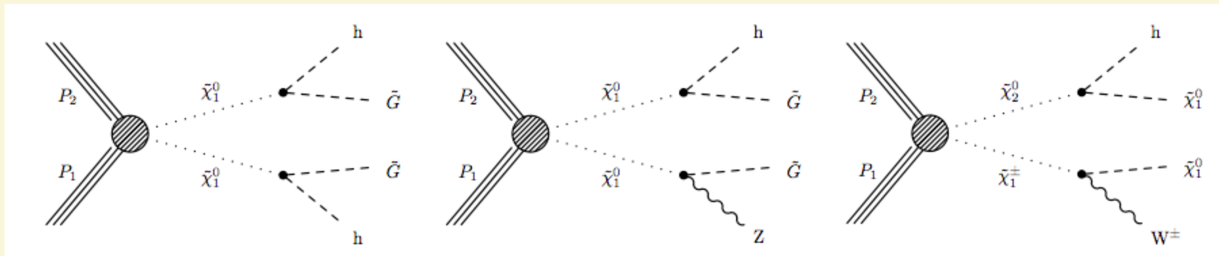
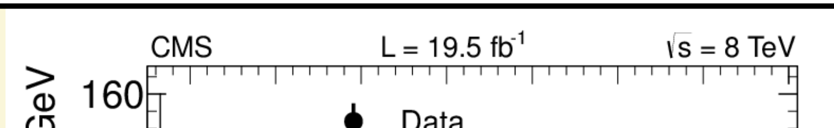
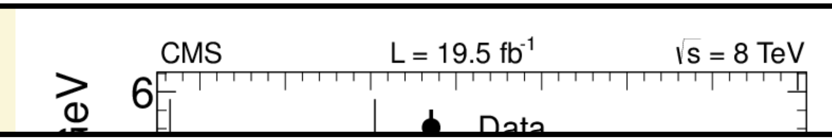
An example: Higgs (Higgs) + MET



W/Z H → jjγγ & MET (LSP)	HH → bbγγ & MET (LSP)





Mix & Match multiple rare signatures allows to extend sensitivity to processes with smaller cross section → weaker couplings or higher mass scales

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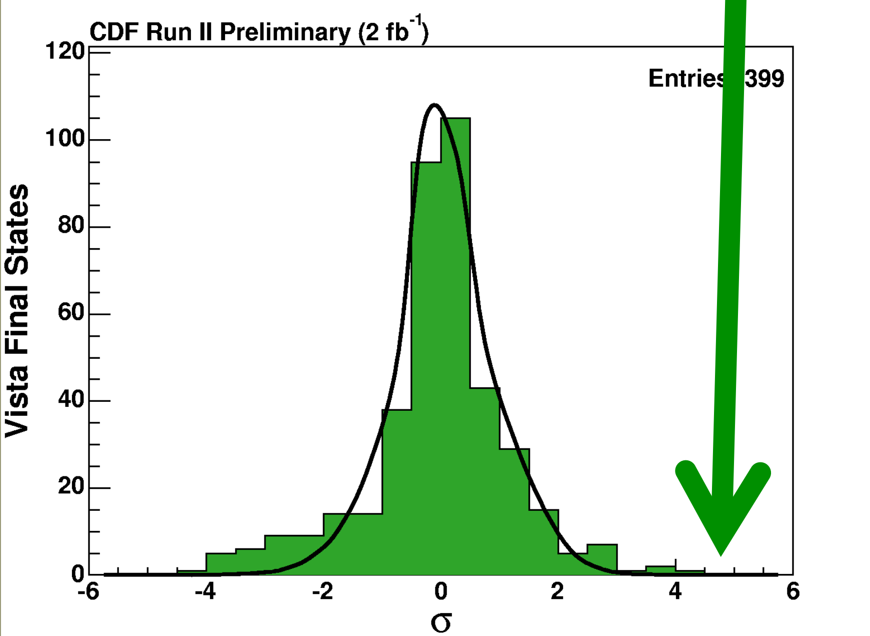
Let's search globally in all signatures

CDF Global Search for New Physics In 399 Final States

Look for Outliers Here



CDF Run II Preliminary (2.0 fb^{-1})
The calculation of σ accounts for the trials factor

Final State	Data	Background	σ
$be^{\pm}\not{p}$	690	817.7 ± 9.2	−2.7
$\gamma\tau^{\pm}$	1371	1217.6 ± 13.3	+2.2
$\mu^{\pm}\tau^{\pm}$	63	35.2 ± 2.8	+1.7
$b2j\not{p}$ high-Σp_T	255	327.2 ± 8.9	−1.7
$2j\tau^{\pm}$ low-Σp_T	574	670.3 ± 8.6	−1.5
$3j\tau^{\pm}$ low-Σp_T	148	199.8 ± 5.2	−1.4
$e^{\pm}\not{p}\tau^{\pm}$	36	17.2 ± 1.7	+1.4
$2j\tau^{\pm}\tau^{\mp}$	33	62.1 ± 4.3	−1.3
$e^{\pm}j$	741710	764832 ± 6447.2	−1.3
$j2\tau^{\pm}$	105	150.8 ± 6.3	−1.2
$e^{\pm}2j$	256946	249148 ± 2201.5	+1.2
$2bj$ low-Σp_T	279	352.5 ± 11.9	−1.1
$j\tau^{\pm}$ low-Σp_T	1385	1525.8 ± 15	−1.1
$2b2j$ low-Σp_T	108	153.5 ± 6.8	−1
$b\mu^{\pm}\not{p}$	528	613.5 ± 8.7	−0.9
$\mu^{\pm}\gamma\not{p}$	523	611 ± 12.1	−0.8
$2b\gamma$	108	70.5 ± 7.9	+0.1
$8j$	14	13.1 ± 4.4	0
$7j$	103	97.8 ± 12.2	0
$6j$	653	659.7 ± 37.3	0
$5j$	3157	3178.7 ± 67.1	0
$4j$ high-Σp_T	88546	89096.6 ± 935.2	0
$4j$ low-Σp_T	14872	14809.6 ± 186.3	0
$4j2\gamma$	46	46.4 ± 3.9	0
$4j\tau^{\pm}$ high-Σp_T	29	26.6 ± 1.7	0
$4j\tau^{\pm}$ low-Σp_T	43	63.1 ± 3.3	0
$4j\not{p}$ high-Σp_T	1064	1012 ± 62.9	0
$4j\gamma\tau^{\pm}$	19	10.8 ± 2	0
$4j\gamma\not{p}$	62	104.2 ± 22.4	0
$4j\gamma$	7962	8271.2 ± 245.1	0
$4j\mu^{\pm}\not{p}$	574	590.5 ± 13.6	0
$4j\mu^{\pm}\mu^{\mp}$	38	48.4 ± 6.2	0
$4j\mu^{\pm}$	1363	1350.1 ± 37.7	0
$3j$ high-Σp_T	159926	159143 ± 1061.9	0
$3j$ low-Σp_T	62681	64213.1 ± 496	0
$3j2\gamma$	151	177.5 ± 7.1	0
$3j\tau^{\pm}$ high-Σp_T	68	76.9 ± 3	0
$3j\not{p}$ high-Σp_T	1706	1899.4 ± 77.6	0
$3j\not{p}$ low-Σp_T	42	36.2 ± 5.7	0
$3j\gamma\tau^{\pm}$	39	37.8 ± 3.6	0
$3j\gamma\not{p}$	204	249.8 ± 24.4	0
$3j\gamma$	24639	24899.4 ± 372.4	0
$3j\mu^{\pm}\not{p}$	2884	2971.5 ± 52.1	0
$3j\mu^{\pm}\gamma\not{p}$	10	3.6 ± 1.9	0
$3j\mu^{\pm}\gamma$	15	7.9 ± 2.9	0
$3j\mu^{\pm}\mu^{\mp}$	175	177.8 ± 16.2	0
$3j\mu^{\pm}$	5032	4989.5 ± 108.9	0
$3b2j$	23	28.9 ± 4.7	0
$3bj$	82	82.6 ± 5.7	0
$3b$	67	85.6 ± 7.7	0
$2\tau^{\pm}$	498	512.7 ± 14.2	0
$2\gamma\not{p}$	128	107.2 ± 6.9	0
2γ	5548	5562.8 ± 40.5	0
$2j$ high-Σp_T	190773	190842 ± 781.2	0
$2j$ low-Σp_T	165984	162530 ± 1581	0
$2j2\tau^{\pm}$	22	40.6 ± 3.2	0
$2j2\gamma\not{p}$	11	8 ± 2.4	0
$2j2\gamma$	580	581 ± 13.7	0
$2j\tau^{\pm}$ high-Σp_T	96	114.6 ± 3.3	0
$2j\not{p}$ high-Σp_T	87	80.9 ± 6.8	0
$2j\not{p}$ low-Σp_T	114	79.5 ± 100.8	0
$2j\not{p}\tau^{\pm}$	18	13.2 ± 2.2	0
$2j\gamma\tau^{\pm}$	142	144.6 ± 5.7	0
$2j\gamma\not{p}$	908	980.3 ± 63.7	0
$2j\gamma$	71364	73021.4 ± 595.9	0
$2j\mu^{\pm}\tau^{\mp}$	16	19.3 ± 2.2	0
$2j\mu^{\pm}\not{p}$	17927	18340.6 ± 201.9	0
$2j\mu^{\pm}\gamma\not{p}$	31	27.7 ± 7.7	0
$2j\mu^{\pm}\gamma$	57	58.2 ± 13	0
$2j\mu^{\pm}\mu^{\mp}\not{p}$	11	7.8 ± 2.7	0
$2j\mu^{\pm}\mu^{\mp}$	956	924.9 ± 61.2	0
$2j\mu^{\pm}$	22461	23111.4 ± 366.6	0
$2e^{\pm}j$	14	13.8 ± 2.3	0
$2e^{\pm}e^{\mp}$	20	17.5 ± 1.7	0
$2e^{\pm}$	32	49.2 ± 3.4	0
$2b$ high-Σp_T	666	689 ± 9.4	0
$2b$ low-Σp_T	323	313.2 ± 10.3	0
$2b3j$ low-Σp_T	53	57.4 ± 6.5	0
$2b2j$ high-Σp_T	718	803.3 ± 12.7	0
$2b2j\not{p}$ high-Σp_T	15	21.8 ± 2.8	0
$2b2j\gamma$	32	39.7 ± 6.2	0
$2b2j\mu^{\pm}\not{p}$	14	17.3 ± 1.9	0
$2b2j\mu^{\pm}$	22	21.8 ± 2	0
$2b\mu^{\pm}\not{p}$	11	14.4 ± 2.1	0
$2bj$ high-Σp_T	891	967.1 ± 13.2	0
$2bj\not{p}$ high-Σp_T	25	31.3 ± 3.1	0
$2bj\gamma$	71	54.5 ± 7.1	0
$2bj\mu^{\pm}\not{p}$	12	10.7 ± 1.9	0
$2be^{\pm}2j\not{p}$	30	27.3 ± 2.2	0
$2be^{\pm}2j$	72	66.5 ± 2.9	0
$2be^{\pm}\not{p}$	22	19.1 ± 2.2	0
$2be^{\pm}j\not{p}$	19	19.4 ± 2.2	0
$2be^{\pm}j$	63	63 ± 3.4	0
$2be^{\pm}$	96	92.1 ± 4.1	0
$\tau^{\pm}\tau^{\mp}$	856	872.5 ± 19	0
$\gamma\not{p}$	3793	3770.7 ± 127.3	0
$\mu^{\pm}\tau^{\mp}$	381	440.9 ± 7.3	0
$\mu^{\pm}\not{p}\tau^{\mp}$	60	75.7 ± 3.4	0
$\mu^{\pm}\not{p}\tau^{\pm}$	15	12 ± 2	0
$\mu^{\pm}\not{p}$	734290	734296 ± 4897.8	0
$\mu^{\pm}\gamma$	475	469.8 ± 12.5	0
$\mu^{\pm}\mu^{\mp}\not{p}$	169	198.5 ± 8.2	0
$\mu^{\pm}\mu^{\mp}\gamma$	83	60 ± 3.1	0
$\mu^{\pm}\mu^{\mp}$	25283	25178.5 ± 86.5	0
$j2\gamma\not{p}$	36	30.4 ± 4.2	0
$j2\gamma$	1822	1813.2 ± 27.4	0
$j\tau^{\pm}$ high-Σp_T	52	56.2 ± 2.5	0
$j\tau^{\pm}\tau^{\mp}$	203	252.2 ± 8.7	0
$j\not{p}$ high-Σp_T	4432	4431.7 ± 45.2	0
$j\gamma\tau^{\pm}$	526	476 ± 9.3	0
$j\gamma\not{p}$	1882	1791.9 ± 72.3	0
$j\gamma$	103319	102124 ± 570.6	0
$j\mu^{\pm}\tau^{\mp}$	71	98 ± 3.9	0
$j\mu^{\pm}\tau^{\pm}$	15	12 ± 2	0
$j\mu^{\pm}\not{p}\tau^{\mp}$	26	30.8 ± 2.6	0
$j\mu^{\pm}\not{p}$	108081	108323 ± 707.7	0
$j\mu^{\pm}\gamma\not{p}$	171	171.1 ± 31	0
$j\mu^{\pm}\gamma$	152	190 ± 39.3	0
$j\mu^{\pm}\mu^{\mp}\not{p}$	32	32.2 ± 10.9	0
$j\mu^{\pm}\mu^{\mp}\gamma$	14	11.5 ± 2.6	0
$j\mu^{\pm}\mu^{\mp}$	4852	4271.2 ± 185.4	0
$j\mu^{\pm}$	77689	76987.5 ± 930.2	0
$e^{\pm}4j\not{p}$	903	830.6 ± 13.2	0
$e^{\pm}4j\gamma$	25	29.2 ± 3.6	0
$e^{\pm}4j$	15750	16740.4 ± 390.5	0
$e^{\pm}3j\tau^{\mp}$	15	21.1 ± 2.2	0
$e^{\pm}3j\not{p}$	4054	4077.2 ± 63.6	0
$e^{\pm}3j\gamma$	108	79.3 ± 5	0
$e^{\pm}3j$	60725	60409.3 ± 723.3	0
$e^{\pm}2\gamma$	41	34.2 ± 2.6	0
$e^{\pm}2j\tau^{\pm}$	37	47.2 ± 2.2	0
$e^{\pm}2j\tau^{\mp}$	109	95.9 ± 6.8	0
$e^{\pm}2j\not{p}$	25725	25403.1 ± 209.4	0
$e^{\pm}2j\gamma\not{p}$	30	31.8 ± 4.8	0
$e^{\pm}2j\gamma$	398	342.8 ± 15.7	0
$e^{\pm}2j\mu^{\mp}\not{p}$	22	14.8 ± 1.9	0
$e^{\pm}2j\mu^{\mp}$	23	15.8 ± 2	0
$e^{\pm}\tau^{\pm}$	437	387 ± 5.3	0
$e^{\pm}\tau^{\mp}$	1333	1266 ± 12.3	0
$e^{\pm}\not{p}\tau^{\mp}$	109	106.1 ± 2.7	0
$e^{\pm}\not{p}$	960826	956579 ± 3077.7	0
$e^{\pm}\gamma\not{p}$	497	496.8 ± 10.3	0
$e^{\pm}\gamma$	3578	3589.9 ± 24.1	0
$e^{\pm}\mu^{\pm}\not{p}$	31	29.9 ± 1.6	0
$e^{\pm}\mu^{\mp}\not{p}$	109	99.4 ± 2.4	0
$e^{\pm}\mu^{\pm}$	45	28.5 ± 1.8	0
$e^{\pm}\mu^{\mp}$	350	313 ± 5.4	0
$e^{\pm}j2\gamma$	13	16.1 ± 3.9	0
$e^{\pm}j\tau^{\mp}$	386	418 ± 18.9	0
$e^{\pm}j\tau^{\pm}$	160	162.8 ± 3.5	0
$e^{\pm}j\not{p}\tau^{\mp}$	48	44.6 ± 3.3	0
$e^{\pm}j\not{p}\tau^{\pm}$	11	8.3 ± 1.5	0
$e^{\pm}j\not{p}$	121431	121023 ± 747.6	0
$e^{\pm}j\gamma\not{p}$	159	192.6 ± 10.9	0
$e^{\pm}j\gamma$	1389	1368.9 ± 38.9	0
$e^{\pm}j\mu^{\mp}\not{p}$	42	33 ± 2.9	0
$e^{\pm}j\mu^{\pm}\not{p}$	16	9.2 ± 1.9	0
$e^{\pm}j\mu^{\mp}$	62	63.8 ± 3.2	0
$e^{\pm}j\mu^{\pm}$	13	8.2 ± 2	0
$e^{\pm}e^{\mp}4j$	148	159.1 ± 7	0
$e^{\pm}e^{\mp}3j$	717	743.6 ± 24.4	0
$e^{\pm}e^{\mp}2j\not{p}$	32	41.4 ± 5.6	0
$e^{\pm}e^{\mp}2j\gamma$	10	11.4 ± 2.9	0
$e^{\pm}e^{\mp}2j$	3638	3566.8 ± 72	0
$e^{\pm}e^{\mp}\tau^{\pm}$	18	16.1 ± 1.7	0
$e^{\pm}e^{\mp}\not{p}$	822	831.8 ± 13.6	0
$e^{\pm}e^{\mp}\gamma$	191	221.9 ± 5.1	0
$e^{\pm}e^{\mp}j\not{p}$	155	170.8 ± 12.4	0
$e^{\pm}e^{\mp}j\gamma$	48	45 ± 3.9	0
$e^{\pm}e^{\mp}j$	17903	18258.2 ± 204.4	0
$e^{\pm}e^{\mp}$	98901	99086.9 ± 147.8	0
$b6j$	51	42.3 ± 3.8	0
$b5j$	237	192.5 ± 7.1	0
$b4j$ high-Σp_T	26	23.4 ± 2.6	0
$b4j$ low-Σp_T	836	821.7 ± 15.9	0
$b3j$ high-Σp_T	12081	12071 ± 84.1	0
$b3j$ low-Σp_T	2974	2873 ± 31	0

Si Xie

Let’s search globally in all signatures

Advantages:

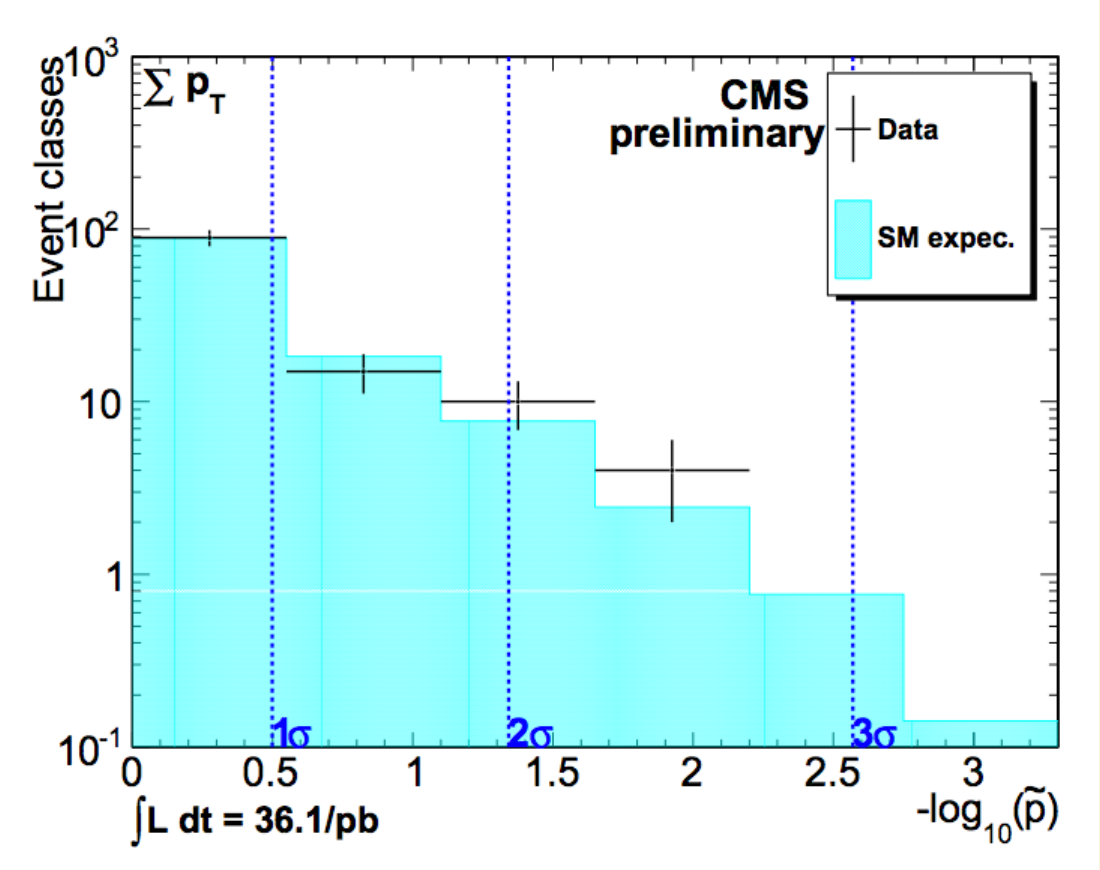
- Broad coverage (exhaustive ?)
- Model independent
- A global understanding of the data, eg:
  - Object selection efficiencies, fake rates, jet energy scales, MET resolution, higher order k-factors
  - Burdened by the requirement to achieve agreement EVERYWHERE → forces you to understand all Monte Carlo discrepancies

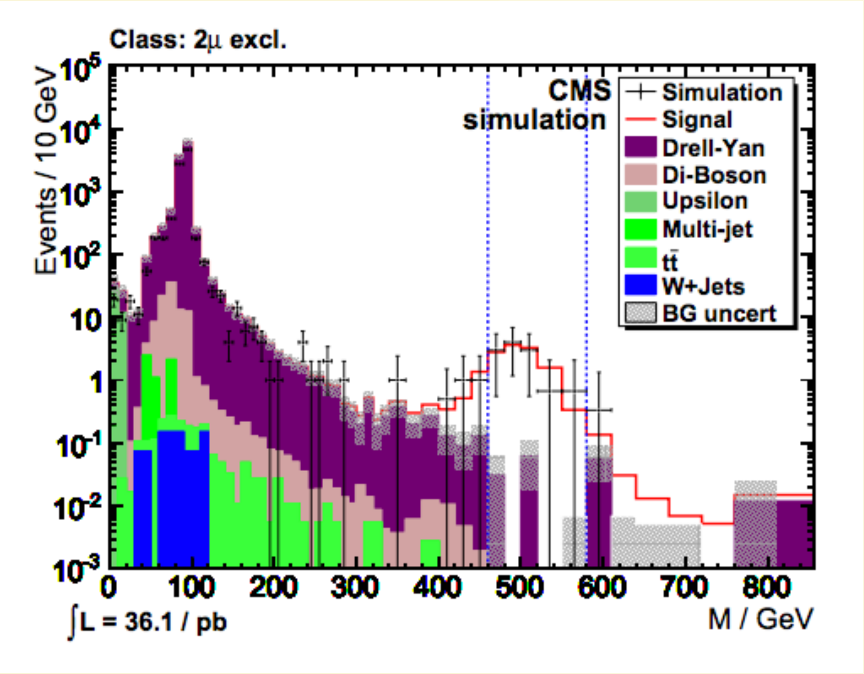
Disadvantages:

- Very difficult & time consuming!

CMS: MUSIC

Public result on Global search @ CMS with 2010 data : 36 pb^{-1}





CMS: MUSIC

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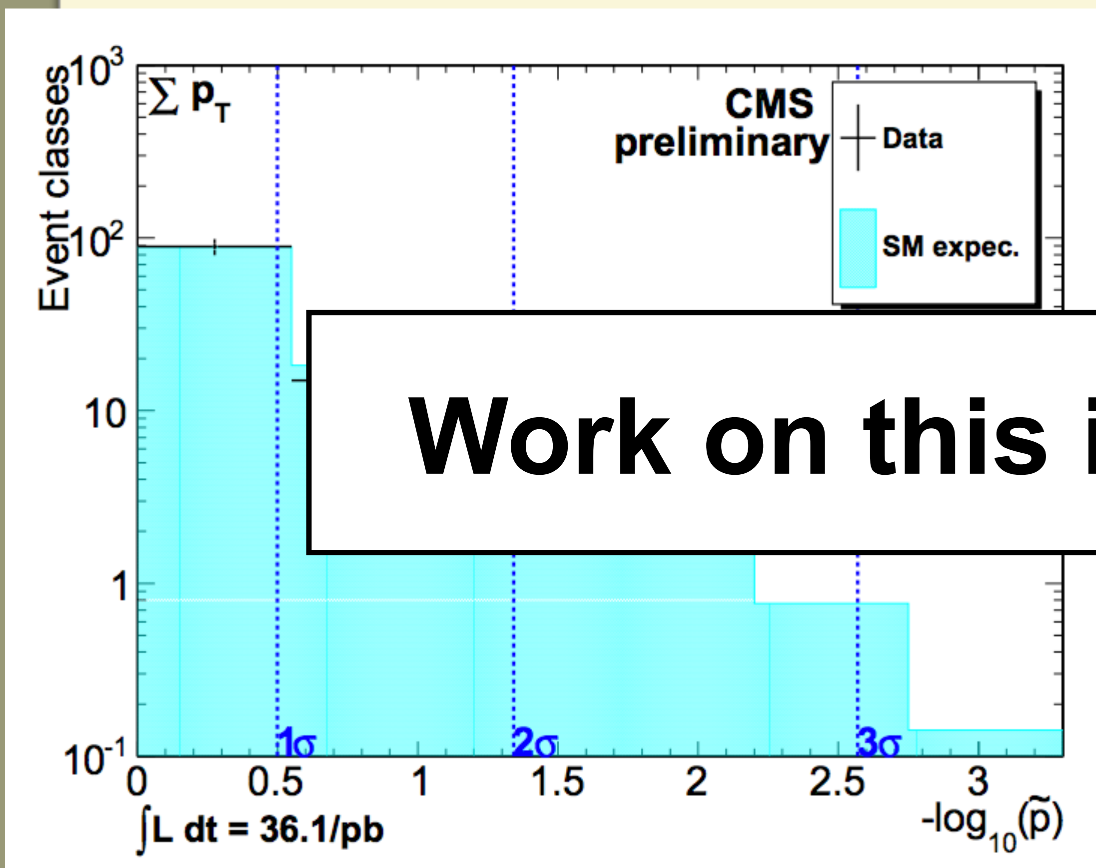
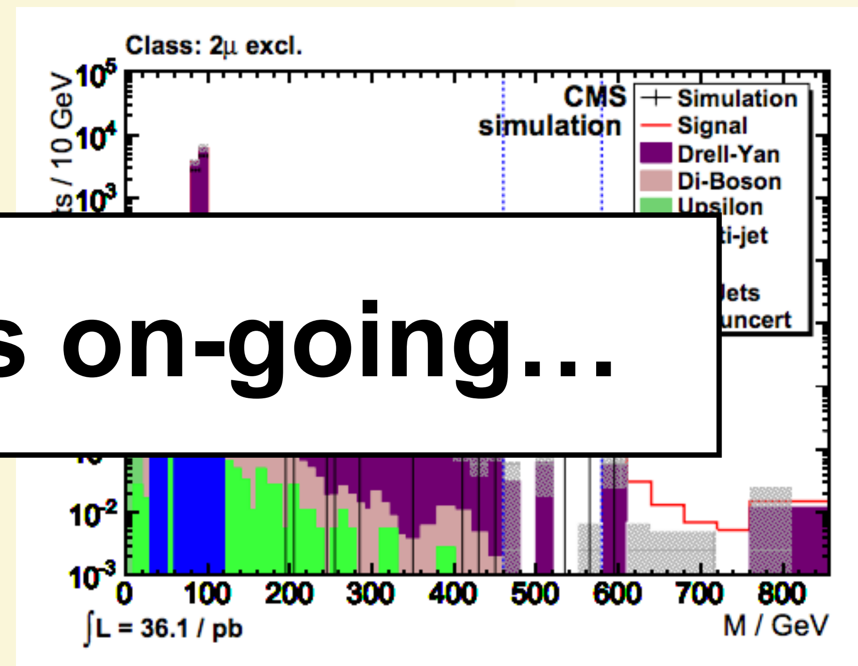




Work on this is on-going…

Best New Physics Ideas for Run 2

↓

New Physics from Run 1

Si Xie

Best New Physics Ideas for Run 2

↓

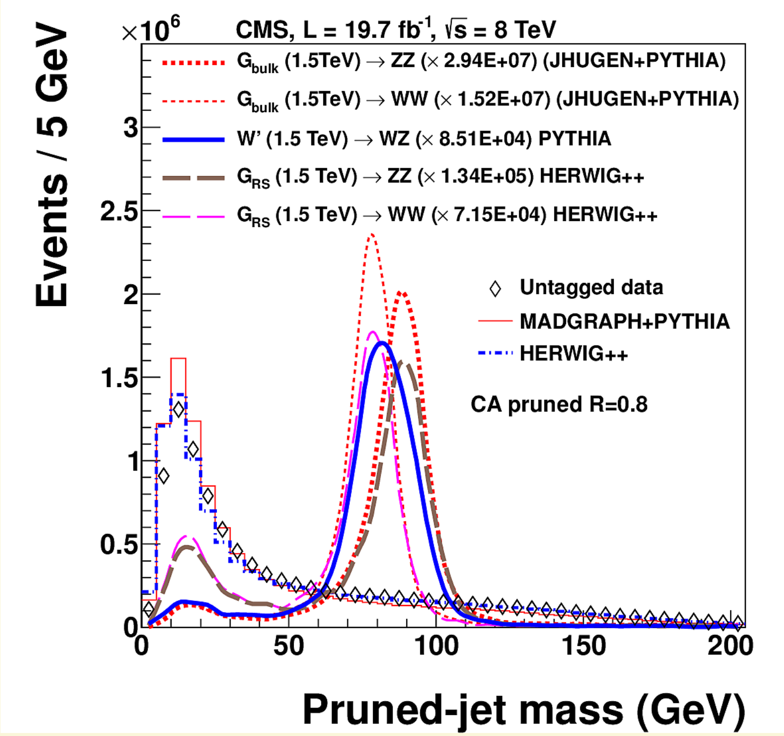
New Physics from Run 1

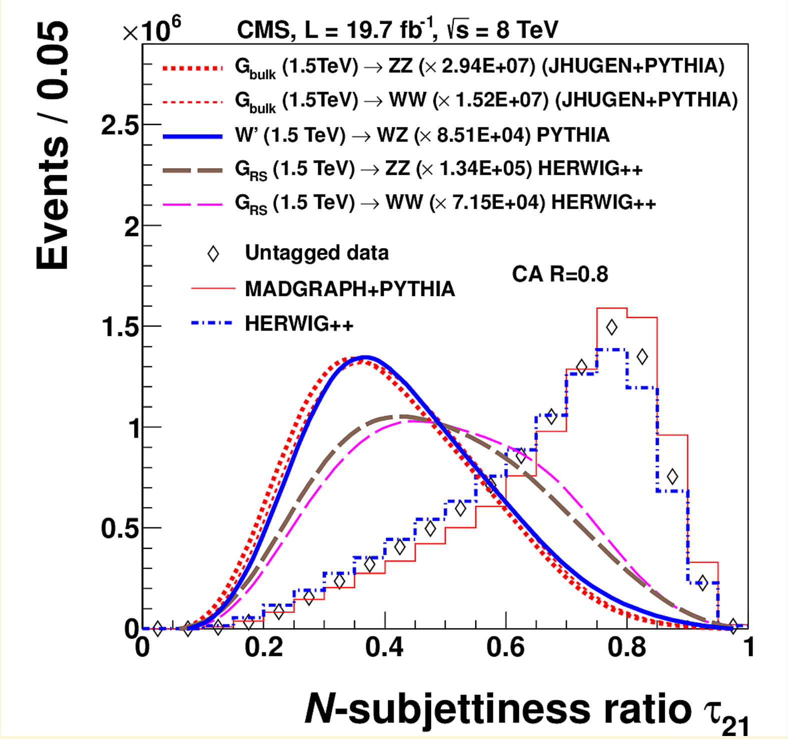
Following slides: A selection of new physics ideas from Run 1

Si Xie

Boosted Dijet Resonance

- $X \rightarrow WW / WZ / ZZ$, W or Z decays to fat jet





- Mass window in jet mass (70 – 100 GeV)
- N-subjettiness regions further enhances S/B

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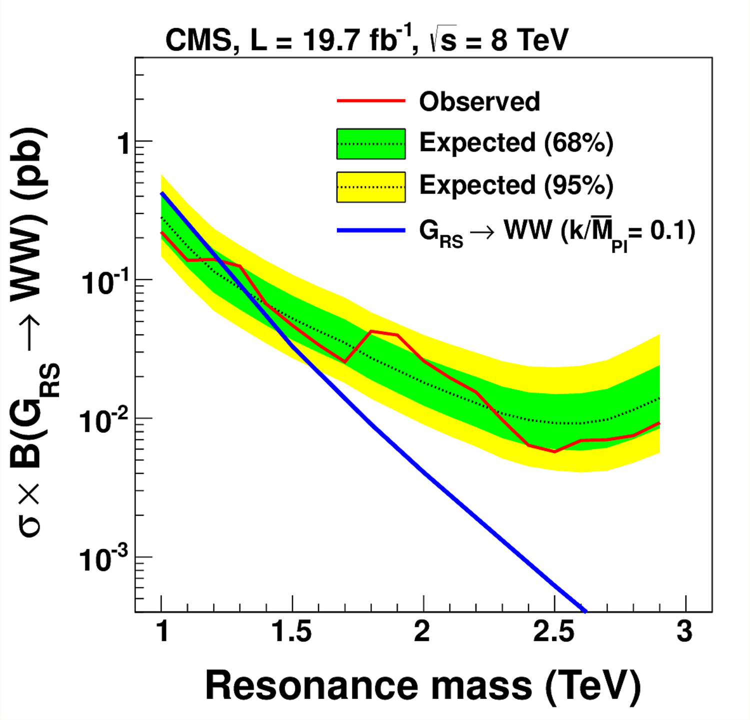
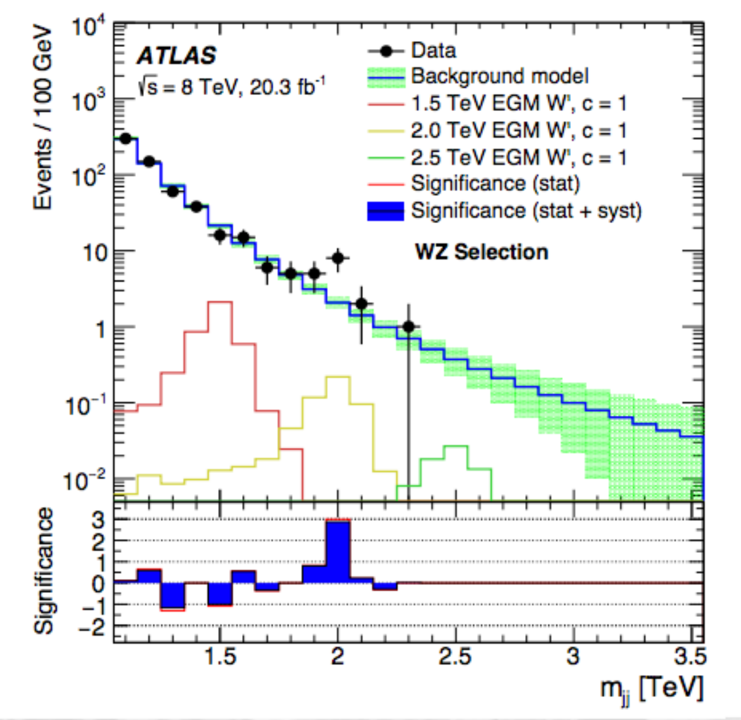
Boosted Dijet Resonance

- X → WW / WZ / ZZ , W or Z decays to fat jet

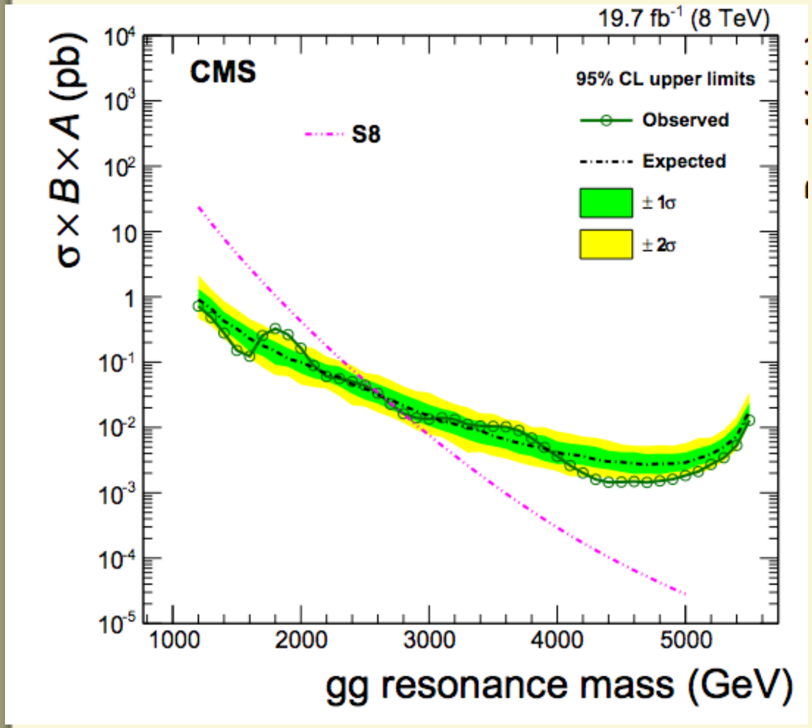


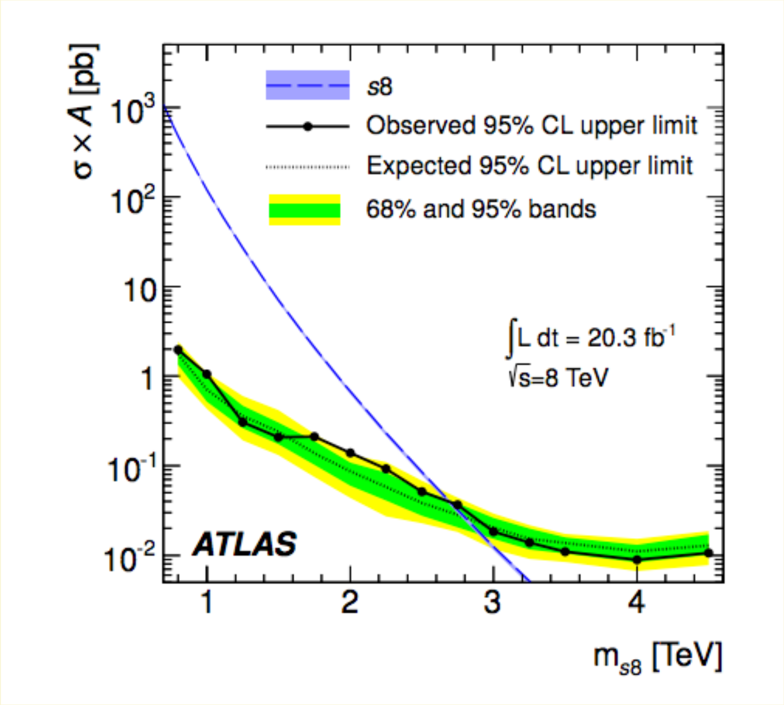


- CMS 1.8σ local significance
- ATLAS: 2.5σ global significance (3.4σ local)

Si Xie

Standard Dijet Resonance Search





- Both CMS and ATLAS exhibit small excesses at the same mass (1.8-2 TeV)

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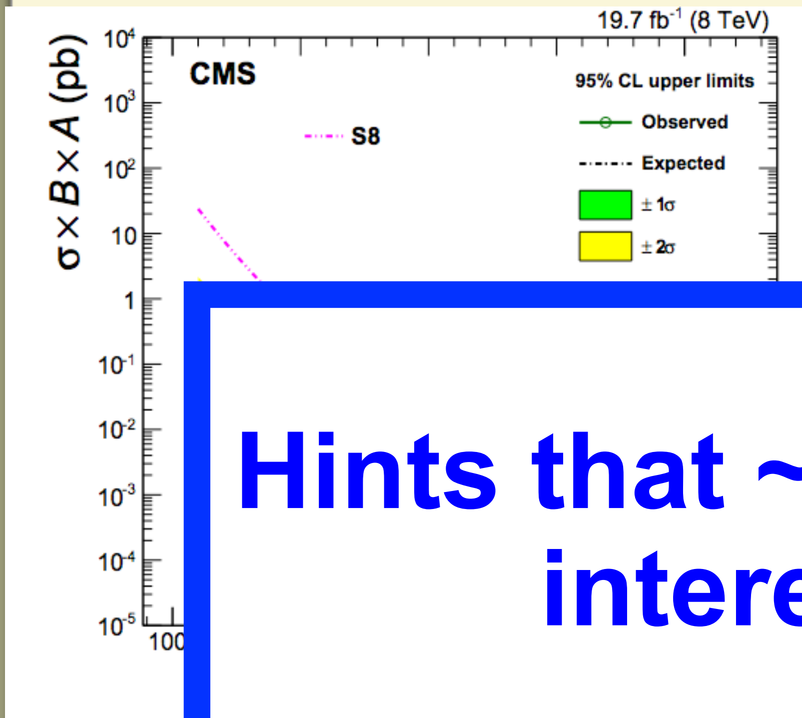
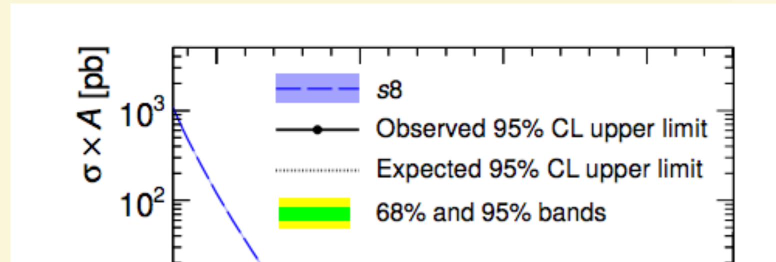
Standard Dijet Resonance Search





Hints that ~2 TeV region is of interest for Run 2

- Both CMS and ATLAS exhibit small excesses at the same mass (1.8-2 TeV)

Si Xie

ttH Production

- Motivated by understanding of Higgs sector and top yukawa

3 Categories of Higgs Decays

$H \rightarrow$ Hadrons
- $H \rightarrow bb$
- $H \rightarrow \tau_h \tau_h$
- $H \rightarrow WW$

$H \rightarrow \gamma\gamma$

$H \rightarrow$ leptons
- $H \rightarrow WW$
- $H \rightarrow ZZ$
- $H \rightarrow \tau\tau$

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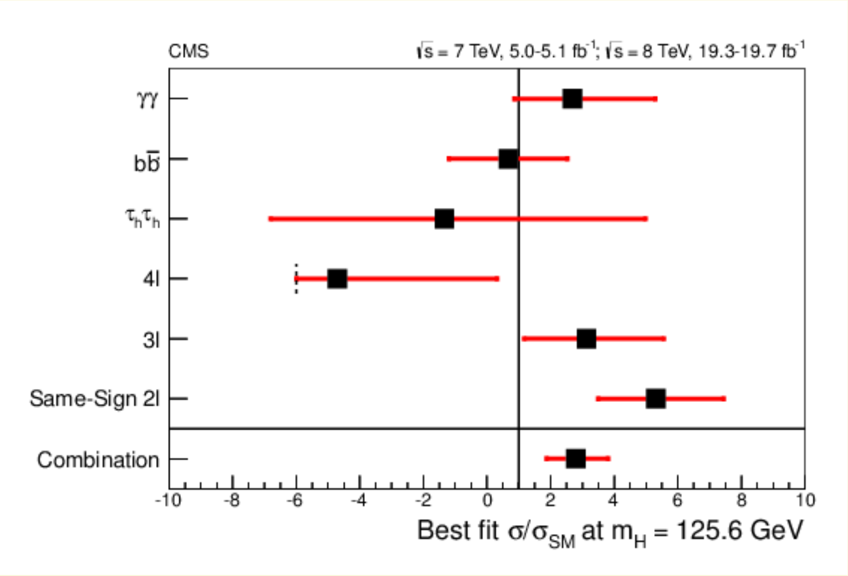
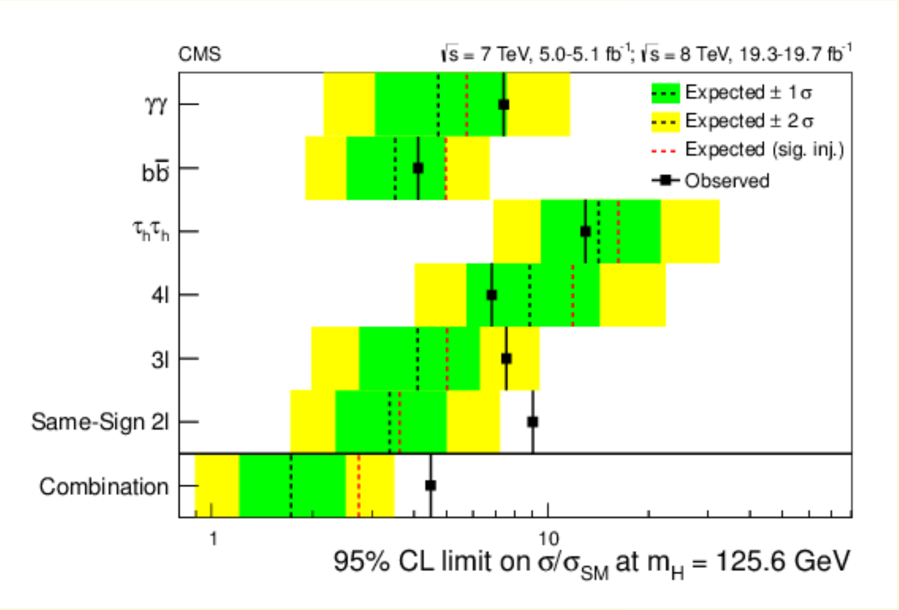
ttH Production : CMS





Best Fit $\mu = 2.8 \pm 1.0$

- CMS Run 1 sees an excess above SM ~ 2σ
  - Led mostly by leptonic decay channels

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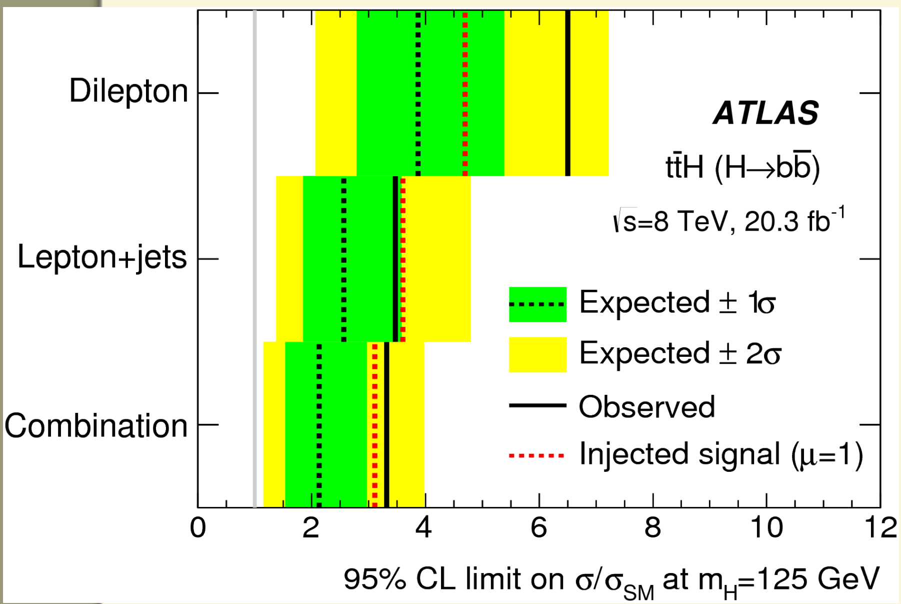
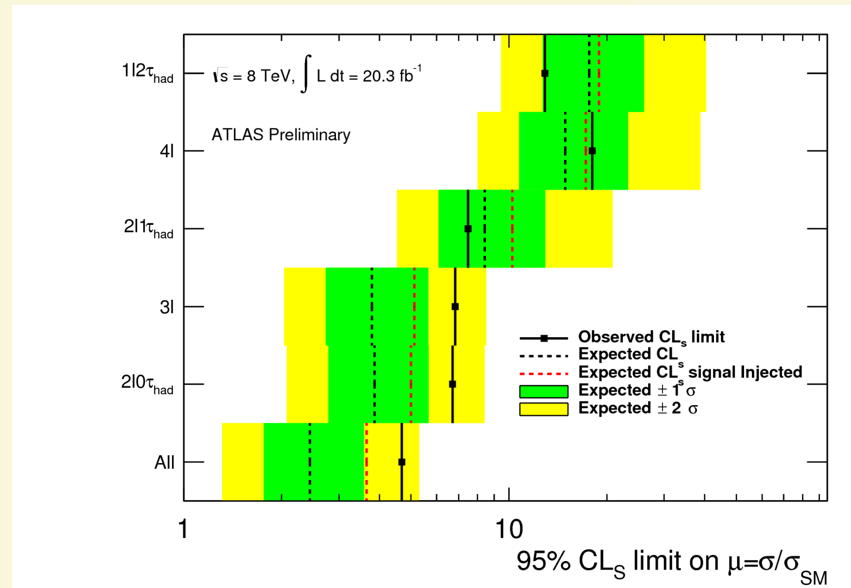
ttH Production : ATLAS

H→bb



Best Fit μ = 1.5 ± 1.1

H→lepton decays



Best Fit μ = 2.1 ± 1.3

- ATLAS Run 1 sees an excess above SM ~ 1σ

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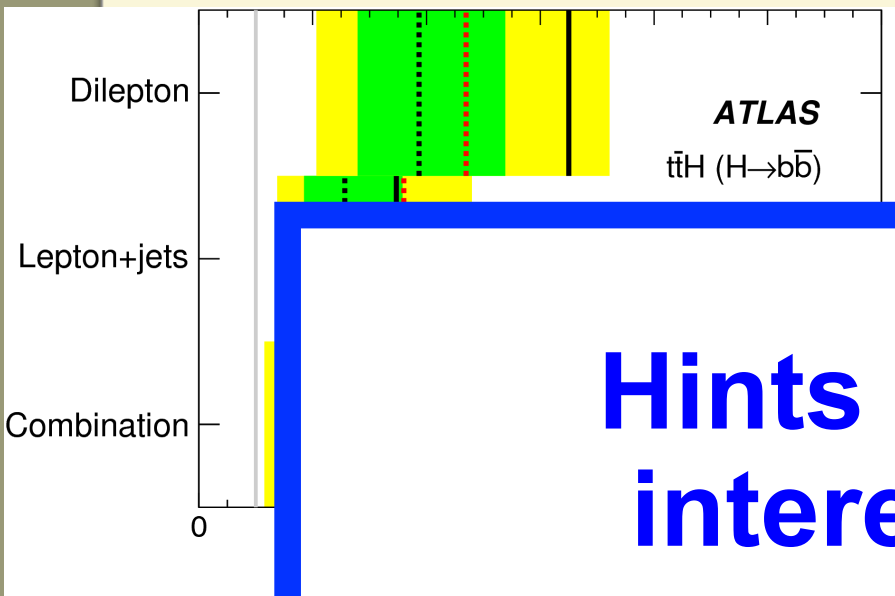
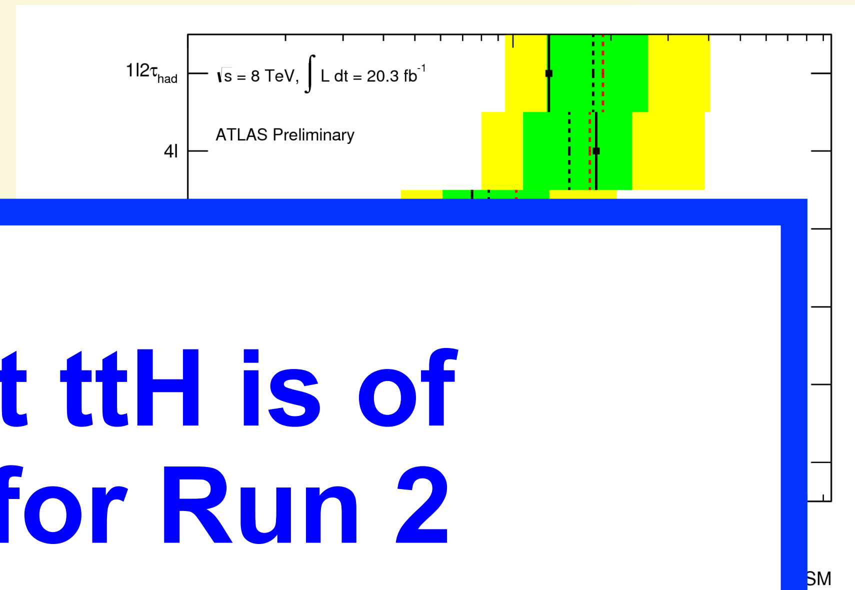
ttH Production : ATLAS

H→bb



Best Fit μ = 1.5 ± 1.1

H→lepton decays



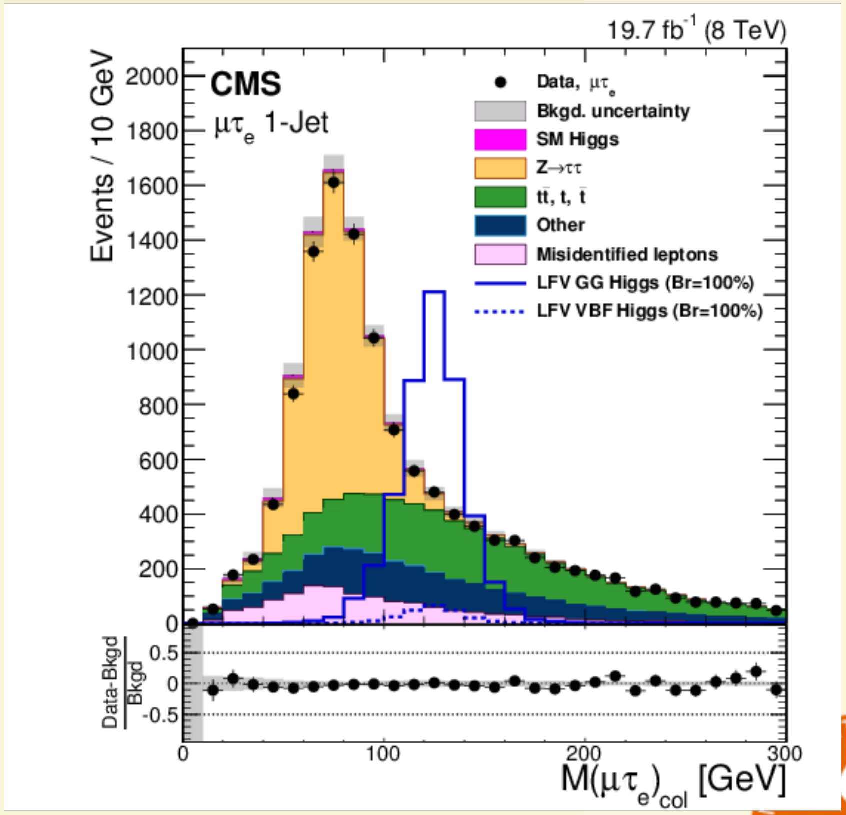
Best Fit μ = 2.1 ± 1.3

Hints that ttH is of interest for Run 2

- ATLAS Run 1 sees an excess above SM ~ 1σ

Higgs → μτ

- Lepton Flavor Violation of generic interest in the Higgs sector. Existing limits are weak (~10%)
  - Muon from direct Higgs decay → larger momentum
  - Only 1 tau decay → neutrinos are collinear to visibles
  - Final discriminant is Higgs mass from collinear approximation



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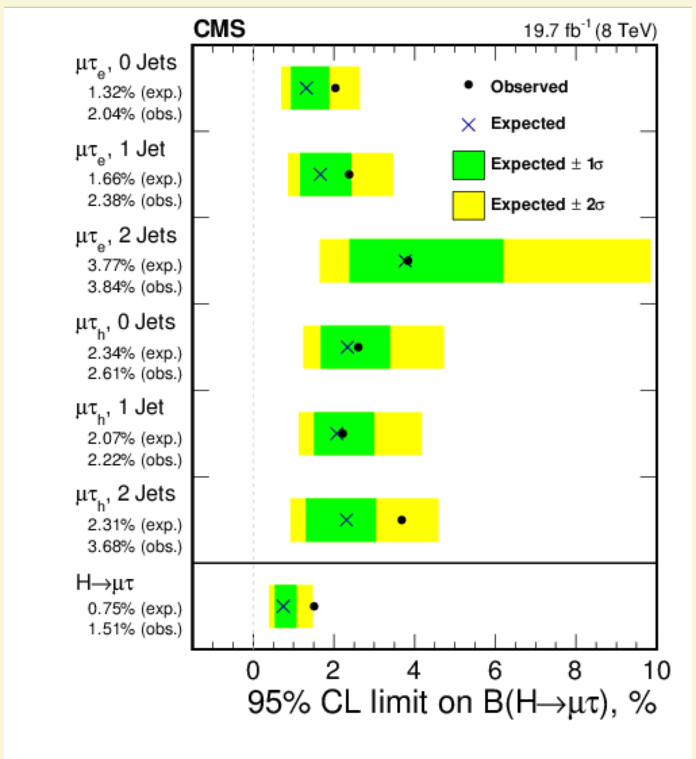
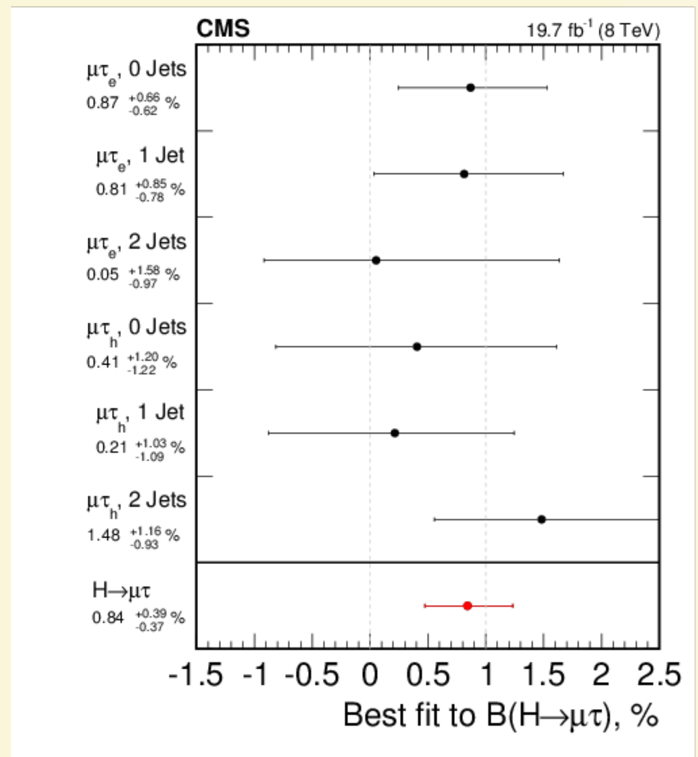
Higgs →μτ

- Observe small excesses in a few categories
- Best fit BR at 0.84% ± 0.4%
- Significance is 2.4 σ





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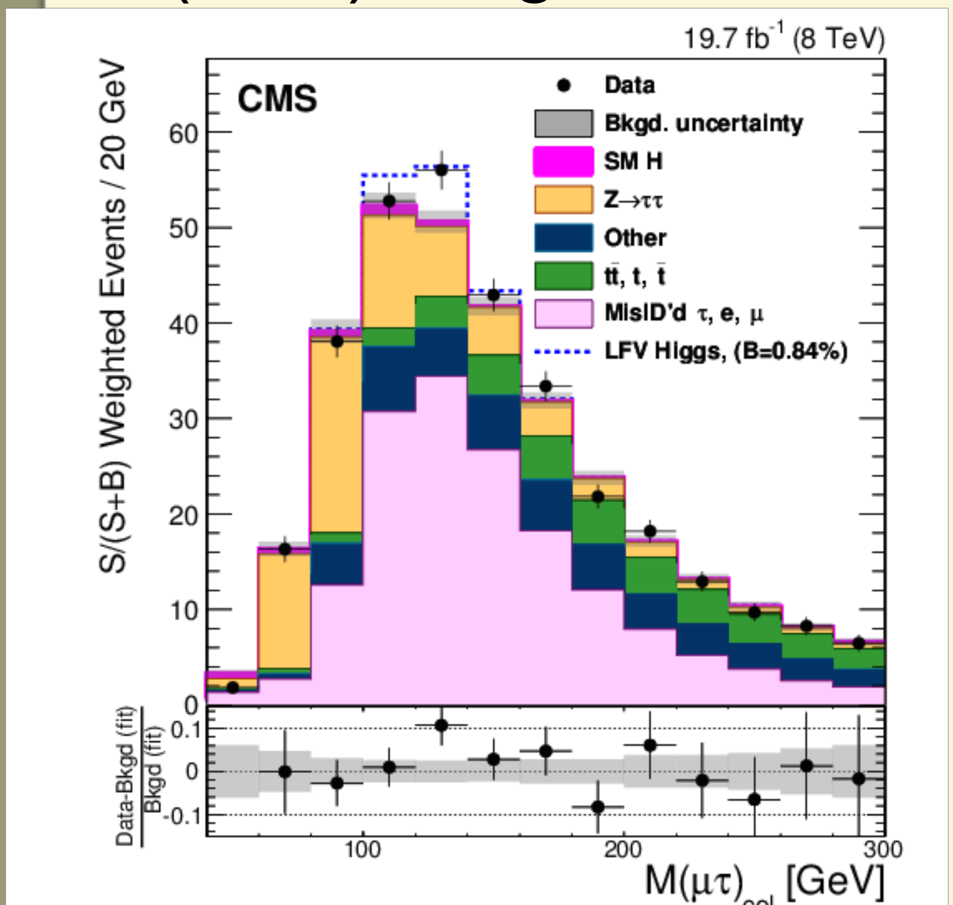
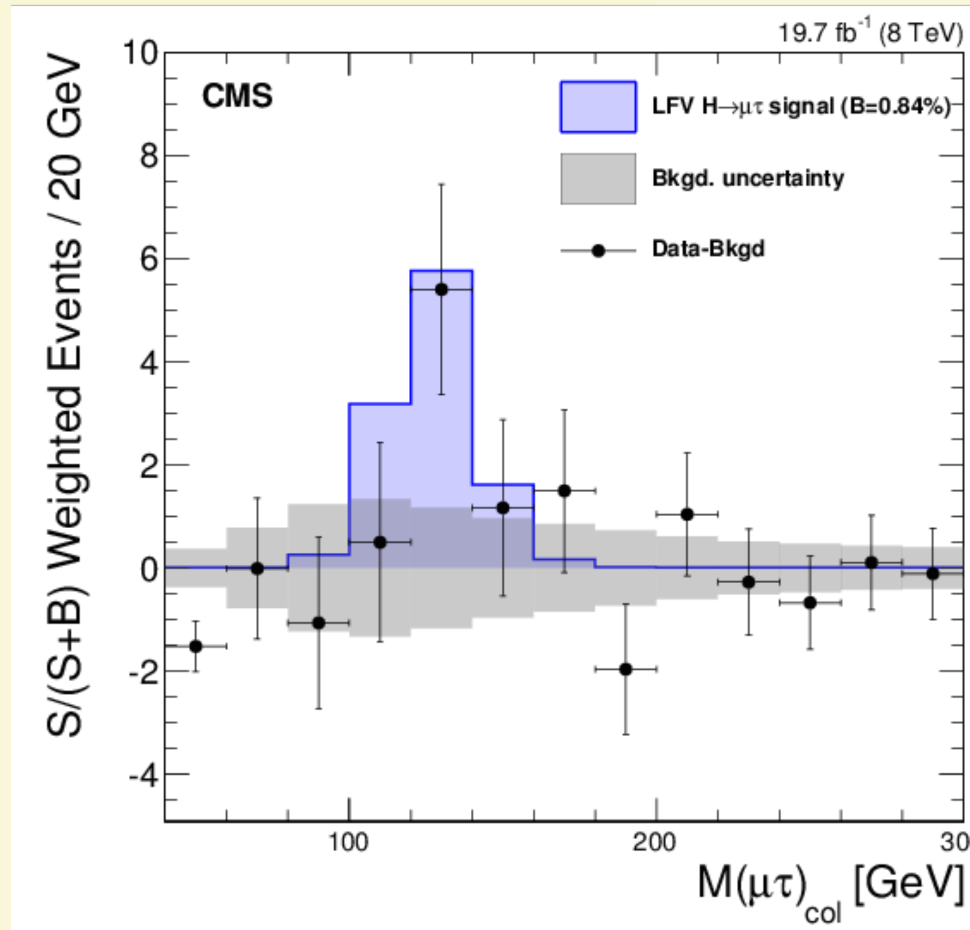
Higgs →μτ

All Channels Combined
S/(S+B) weighted



Background subtracted



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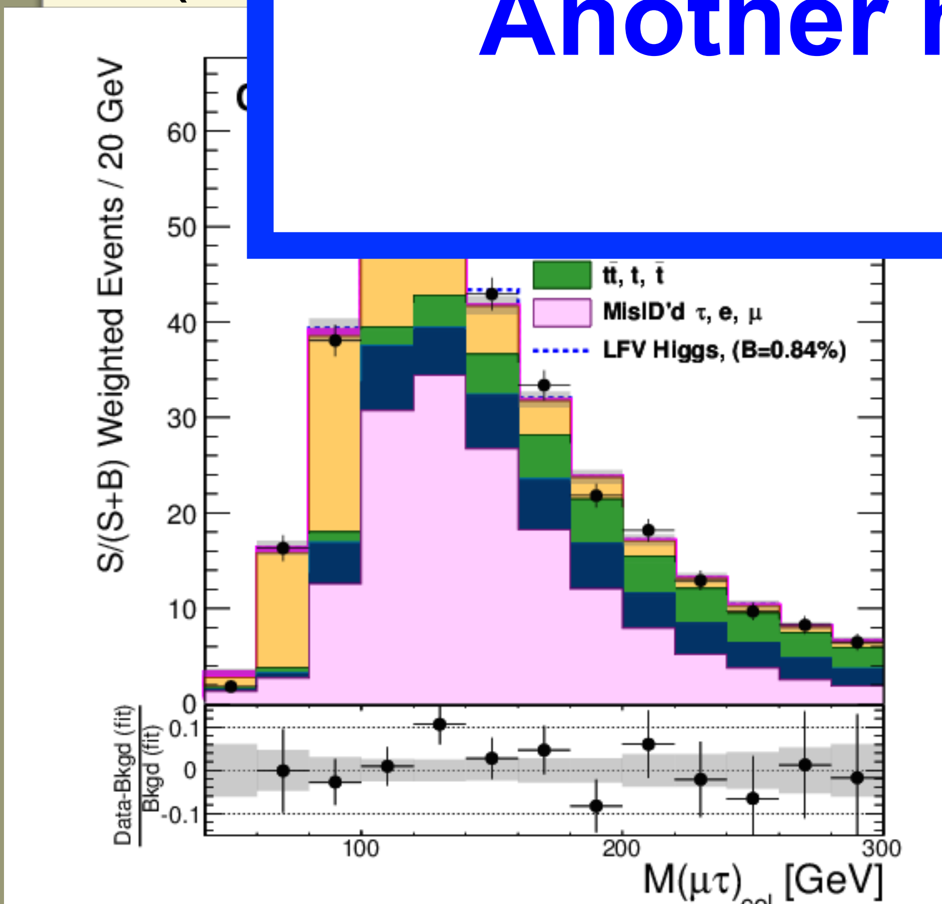
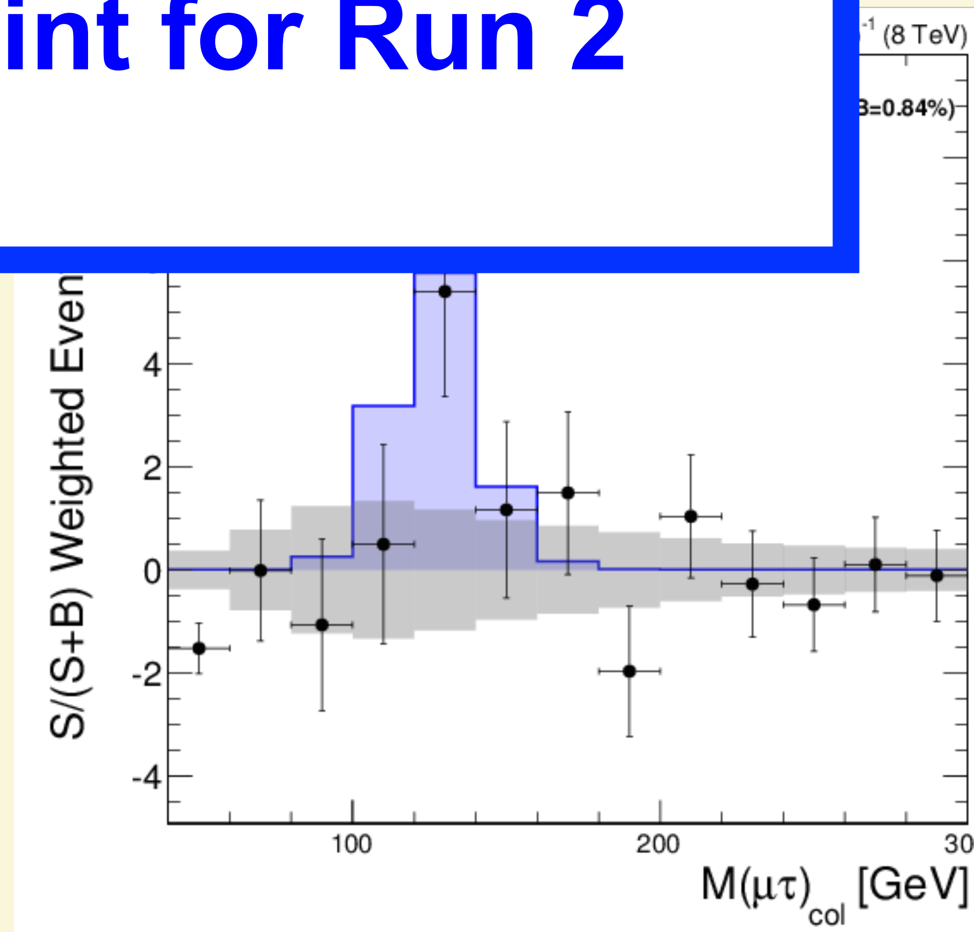
Higgs →μτ

All C
S/(S

ed

Another hint for Run 2





Si Xie

Summary

- Searching for new physics without theoretical guidance is difficult !
- Empirical approaches historically fall into two camps

Isolate rare signatures	Precision Measurement

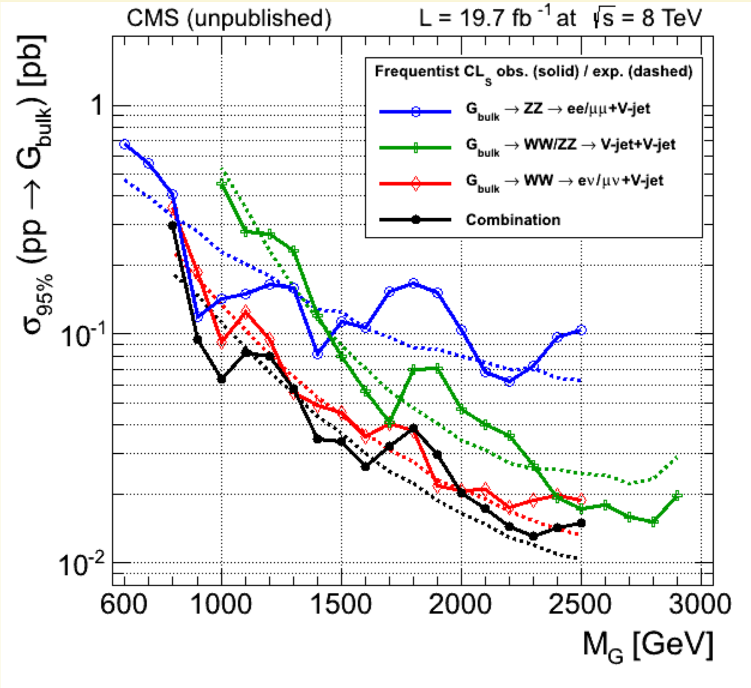
Try to search exhaustively

- The best new physics ideas for Run 2…
  … are hints of new physics from Run 1

Backup

Semileptonic VV Resonance

- X → WW/WZ/ZZ : one boson decays leptonically, other decays to fat jet



- CMS 2σ excess

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