2014 Summer Results from CMS

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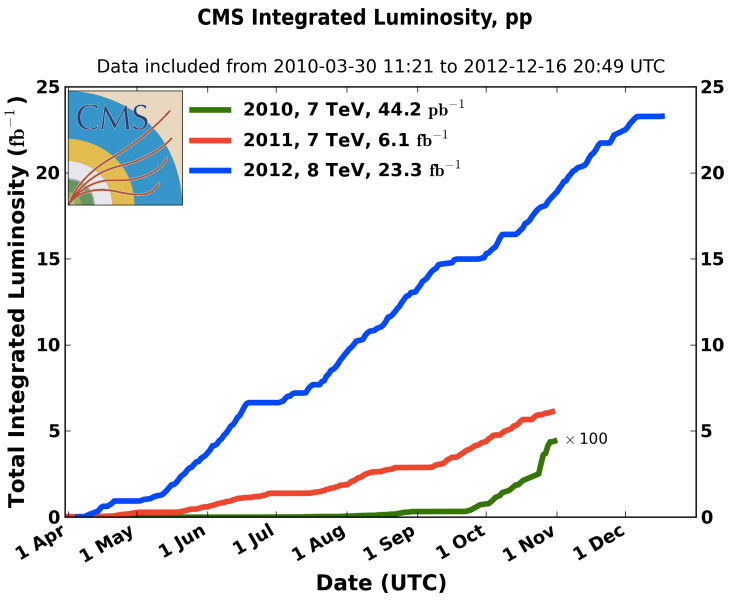
Boston University

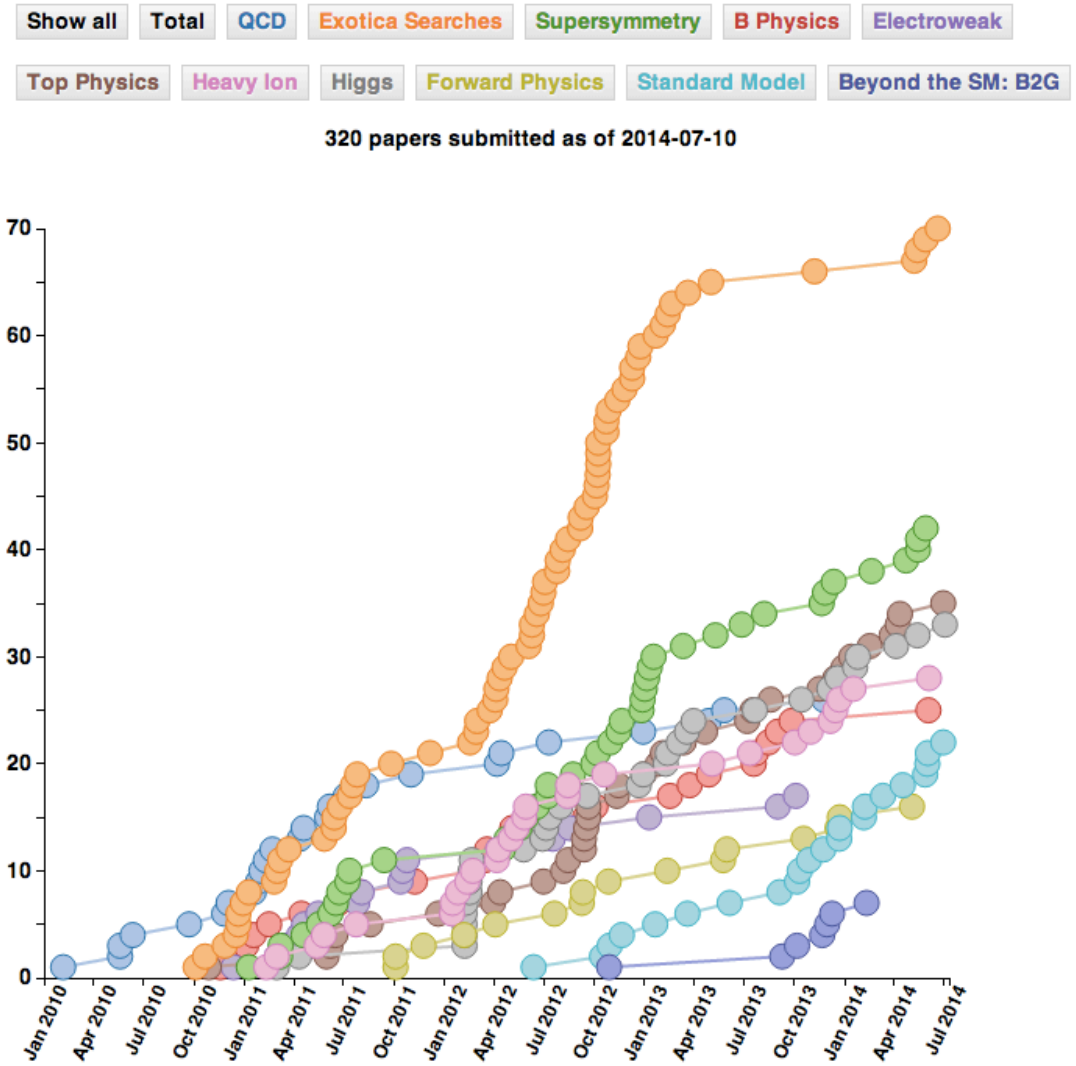
July 11th, 2014

Fermilab Wine & Cheese Seminar

Outline

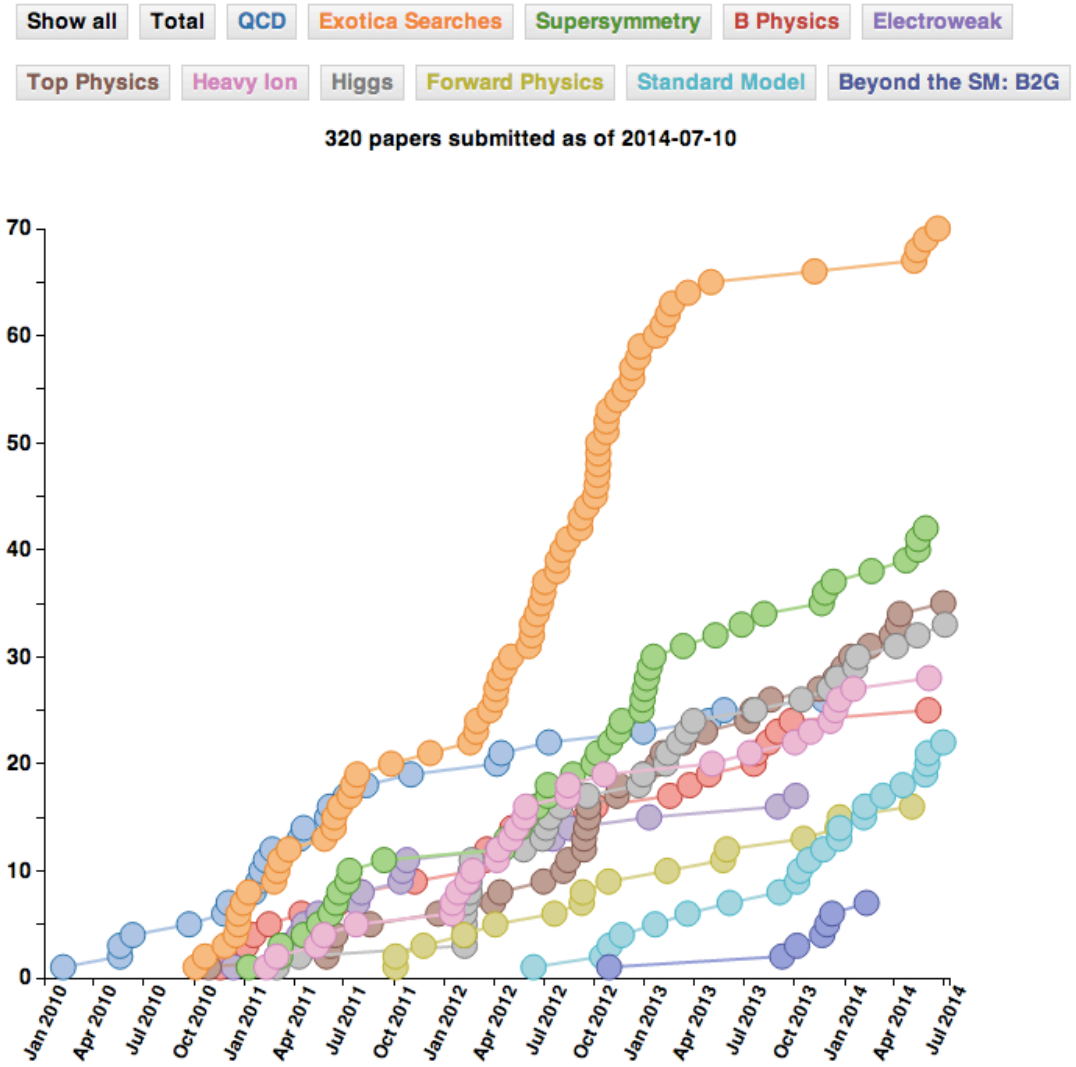
- Comprehensive physics program undertaken by CMS
  - https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults





Outline

- Comprehensive physics program undertaken by CMS
  - https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults
- I will show only a (v. small) subset of recent CMS 8 TeV results
  - Summary of Higgs results*
  - Beyond the SM searches**
    - tb resonances
    - stops



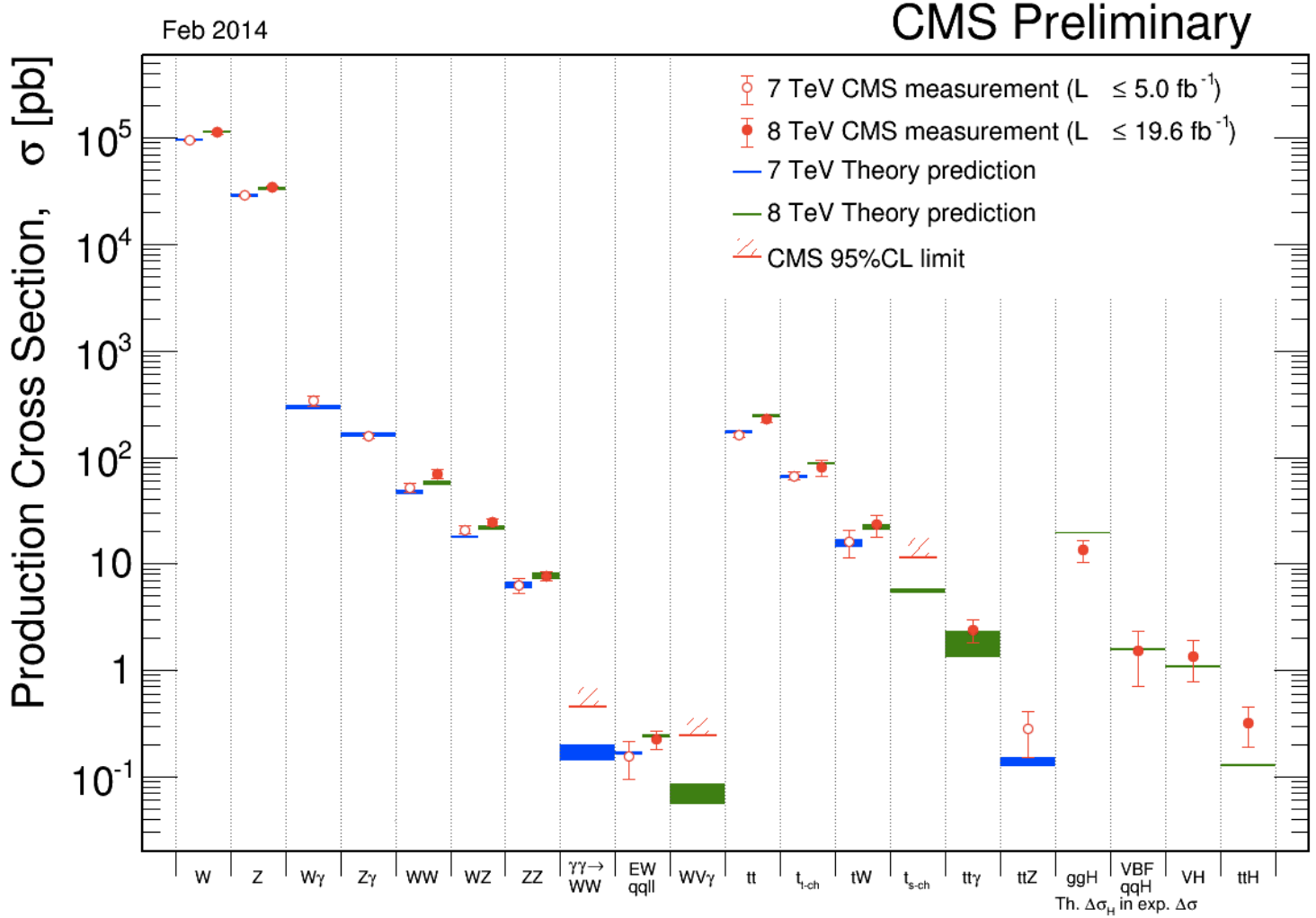
*: "Latest Results on the Higgs Boson" Wine & Cheese Seminar by Chris Neu [September 12]

**: Complementary to nice talks given by Nhan Tran [April 25] & Sal Rappoccio [June 6]

Stairway to heaven…

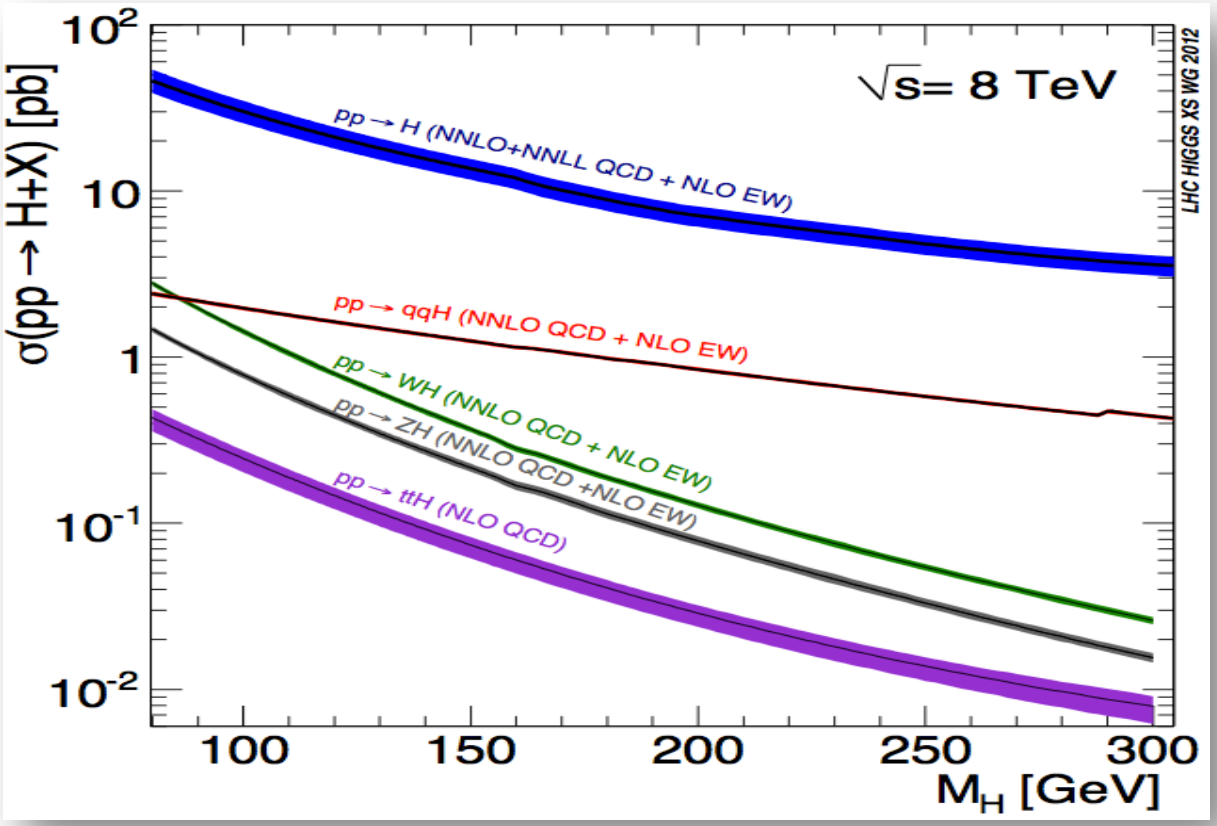
CMS has measured most of the SM processes with amazing precision!

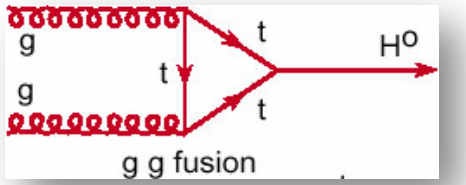
"Yesterday's discovery is today's calibration, and tomorrow's background."
– V. L. Telegdi **[http://cern.ch/go/lf9C]**

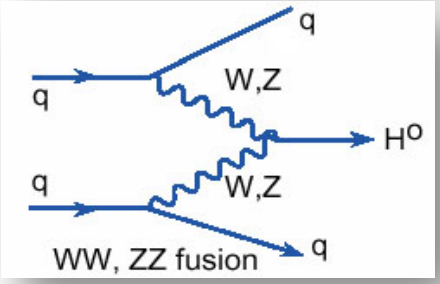


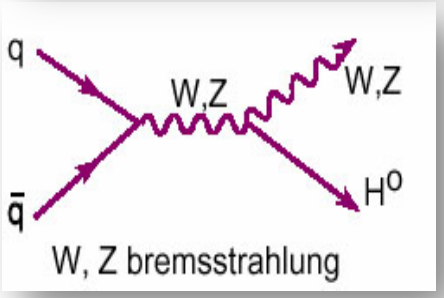
Higgs Boson Production

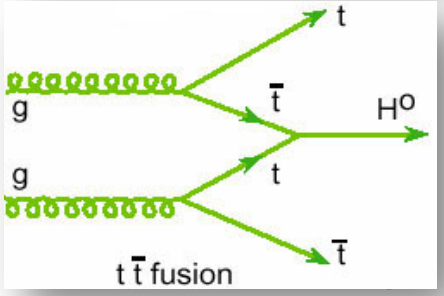
- Dominant production mode: gluon-gluon fusion followed by vector boson fusion (VBF)
- All production modes exploited (gg, VBF, VH, ttH)
  - Latter 3 have smaller σ but better S/B in many cases







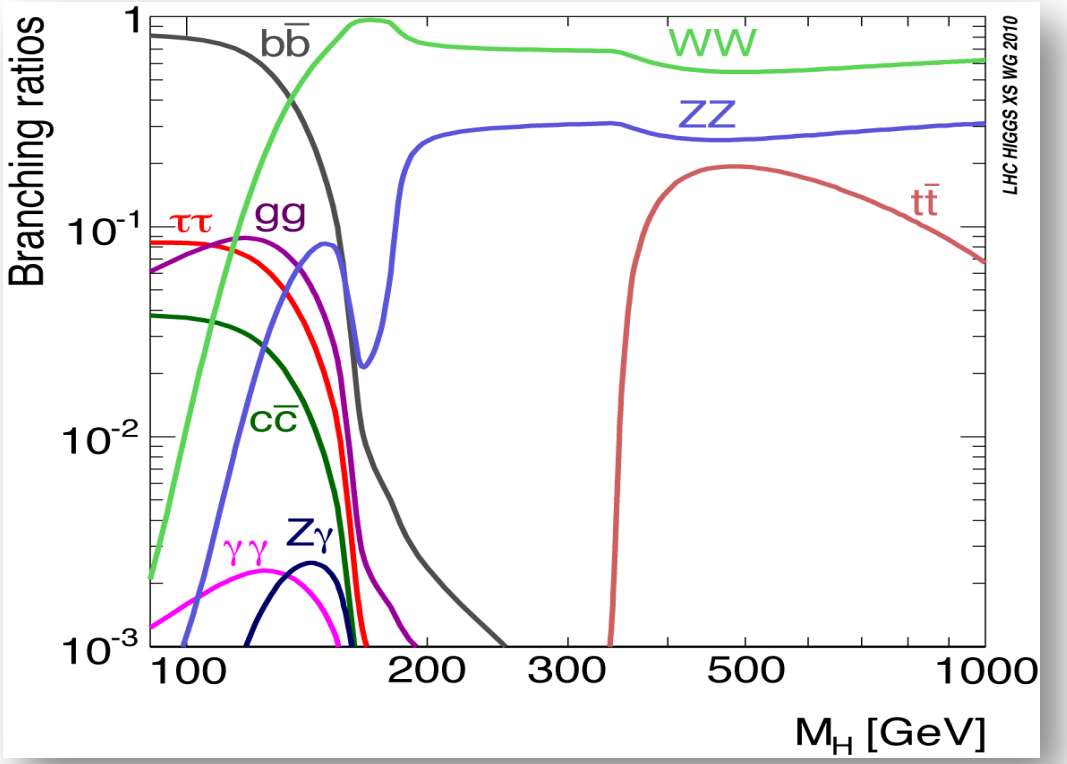




Higgs Boson Decay

5 important decay modes:

- High mass: WW, ZZ
- Low mass: bb, ττ, WW, ZZ, γγ
- Very good mass resolution (1%): H→γγ and H→ZZ→4l
- ZZ(4l) has low background



Oversimplified big picture

★ "seen" ☆ "tried"	$H\to b\bar{b}$	$H\to\tau\tau$	$H\to WW$	$H\to ZZ$	$H\to\gamma\gamma$	$H\to Z^{(*)}\gamma$	$H\to$inv.	$H\to\mu\mu$	$H\to c\bar{c}$ $H\to HH$
ggH		★	★	★	★	☆		☆	
VBF	☆	★	★	☆	★	☆	☆	☆	
VH	★	☆	☆	☆	☆		☆		
ttH	☆	☆	☆		☆				

A. David (ICHEP 2014)

Still much to explore on the rarer ends.
(to the right and to the bottom) (and outside this picture)

Grand Summary

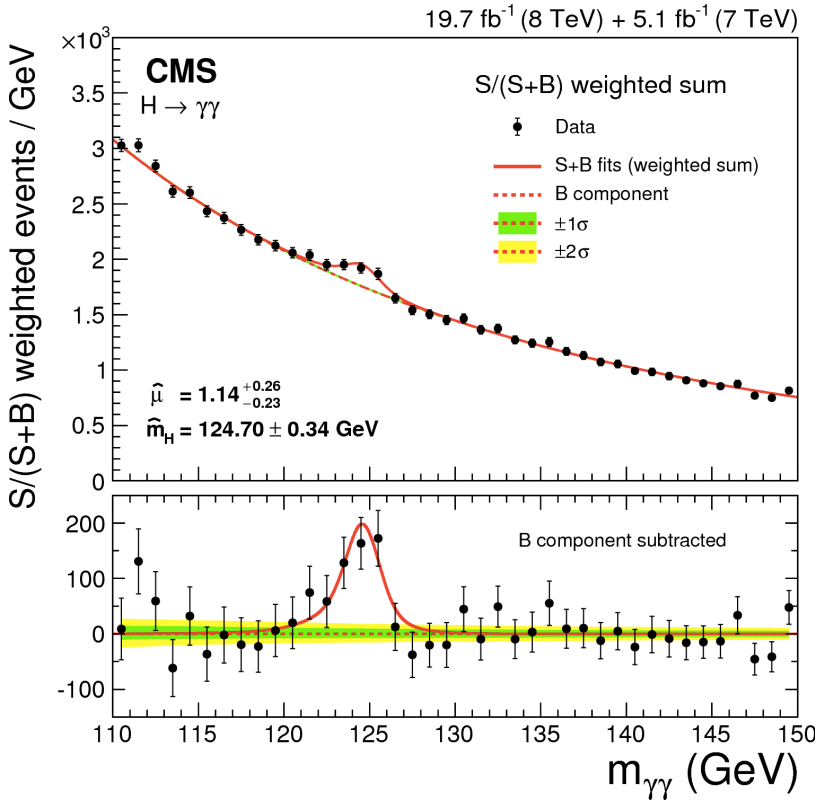
Channel	$H \to WW$	$H \to ZZ \to 4l$	$VH, H \to bb$	$H \to \tau\tau$	$H \to \gamma\gamma$
Mass Resolution	16%	1-2%	10%	10-20%	1-2%
Expected Significance σ	5.8	6.7	2.1	3.7	5.2
Comments	High Yield	Low Bkg		3.2 σ (obs) 1st evidence of fermion coupling	

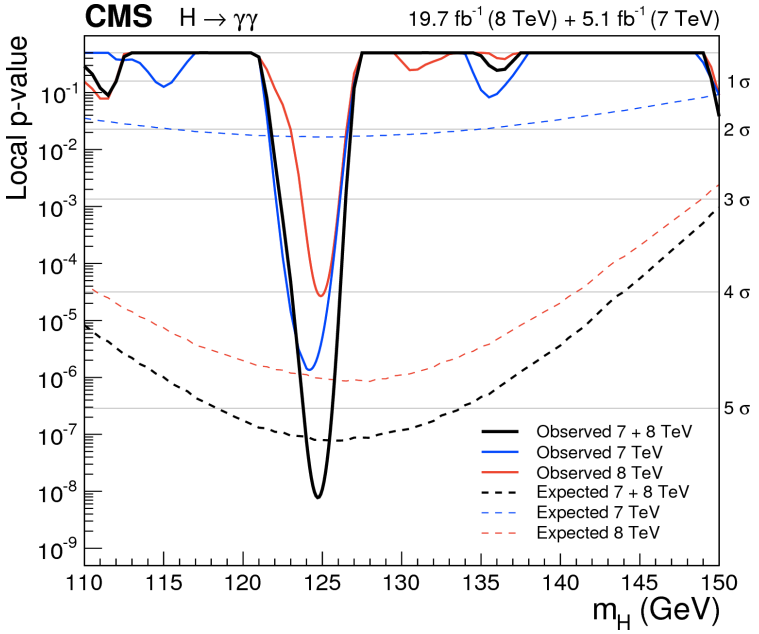
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIG

Final Run I H→ γγ analysis

NEW

- Final calibration of the ECAL for Run 1 data.
- Improved simulation/understanding of:
  - ECAL noise evolution with time.
  - Effect of out-of-time collisions.
  - material in front of ECAL.
- Improved description of energy scale uncertainties.
- 25 event categories (all production modes)…





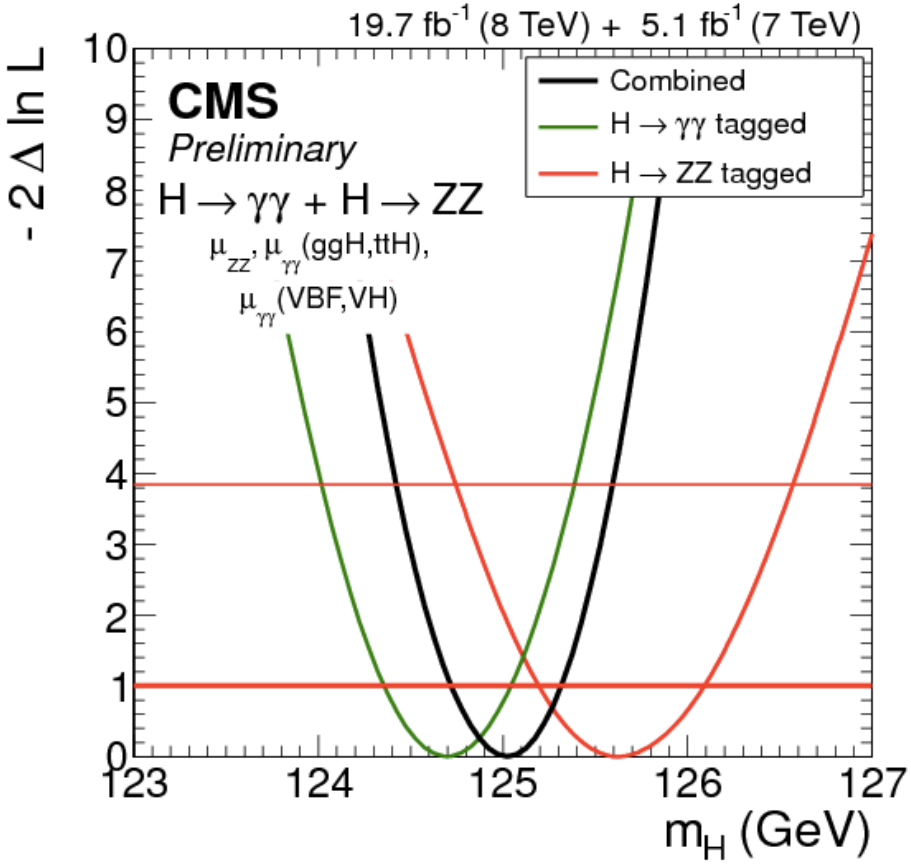
Significance: 5.7σ obs. (5.2σ exp.)

EPJC: arXiv:1407.0558

Combined Mass Measurements

NEW

Combining the high resolution channels



$$m_H = 125.03 \pm 0.30 \left[{}^{+0.26}_{-0.27}(\text{stat.}) {}^{+0.13}_{-0.15}(\text{syst.}) \right] \text{ GeV}$$

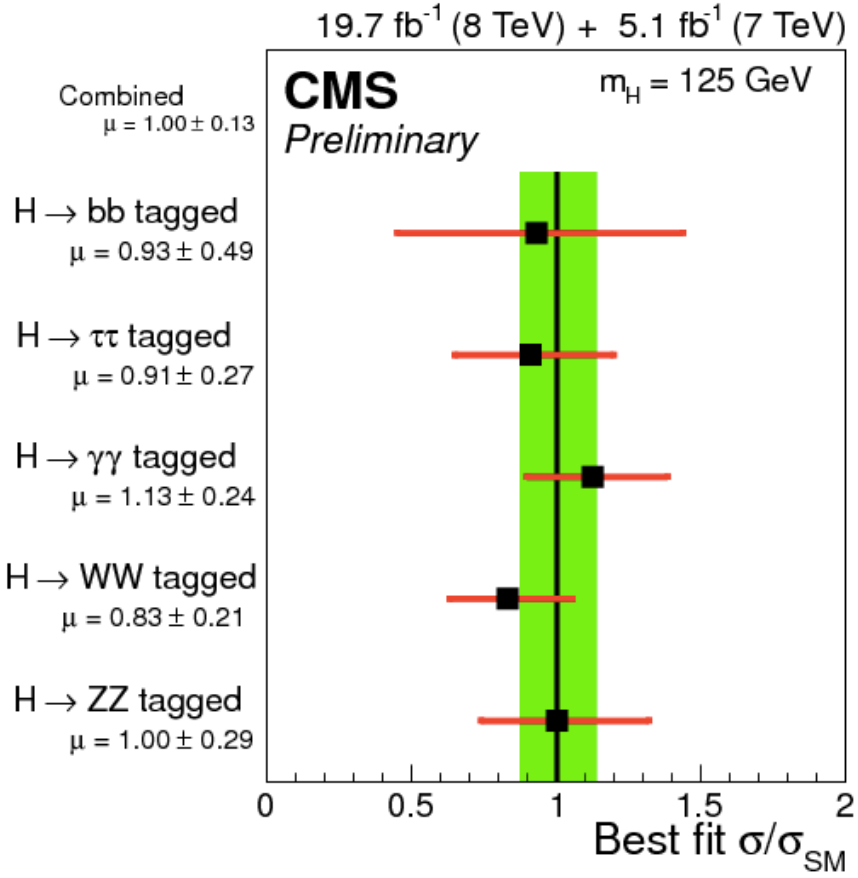
Combination of Final Results

CMS-PAS-HIG-14-009

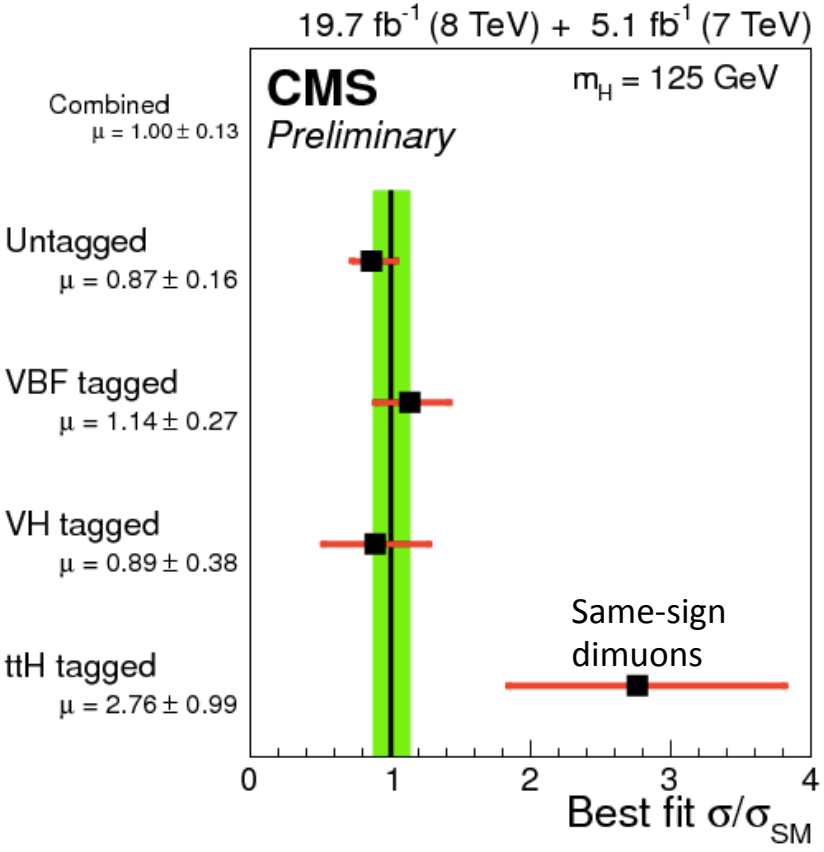
Signal Strength

$$\sigma/\sigma_{\mathrm{SM}} = 1.00 \pm 0.13 \left[\pm 0.09(\mathrm{stat.})^{+0.08}_{-0.07}(\mathrm{theo.}) \pm 0.07(\mathrm{syst.})\right]$$

Grouped by dominant decay

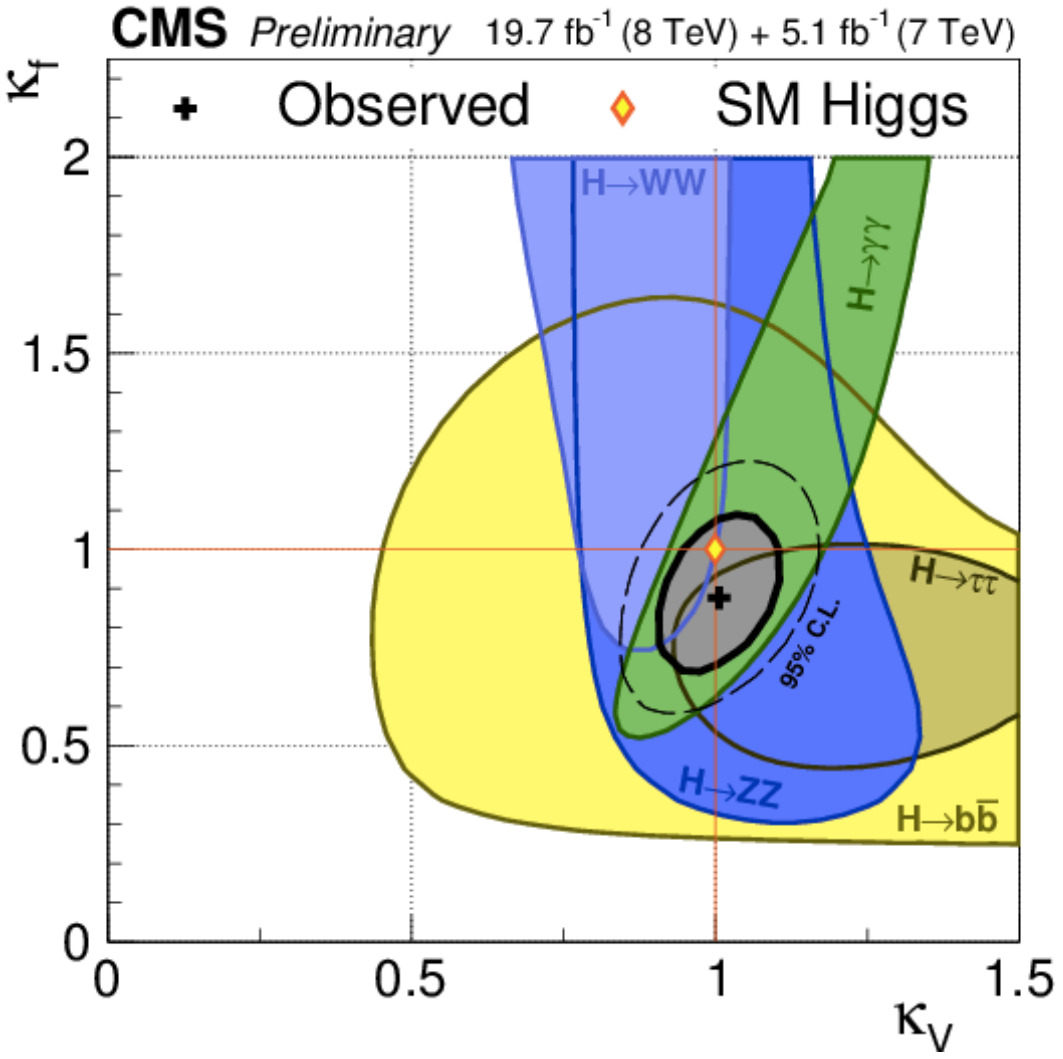


Grouped by production tag



Coupling deviations

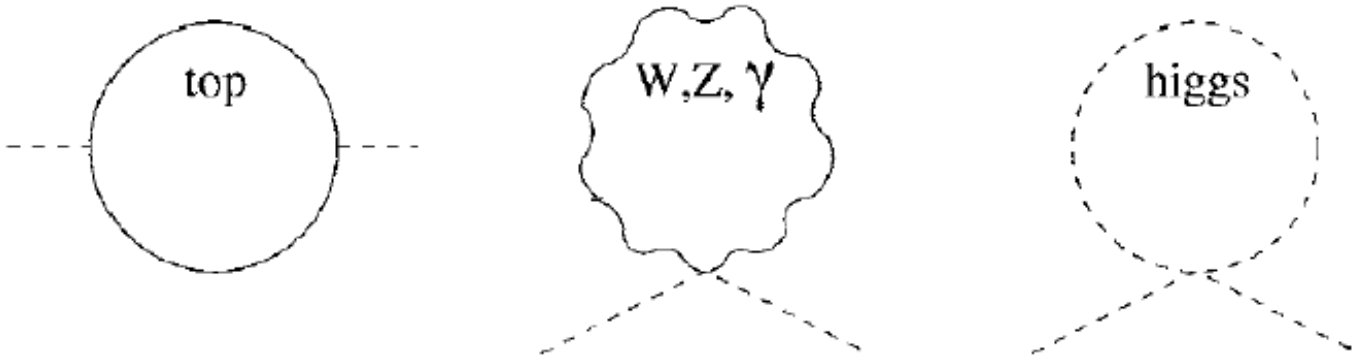
- Scaling the couplings to fermions (κ_f) and vector bosons (κ_V).
- All decay channels converging around SM expectation.



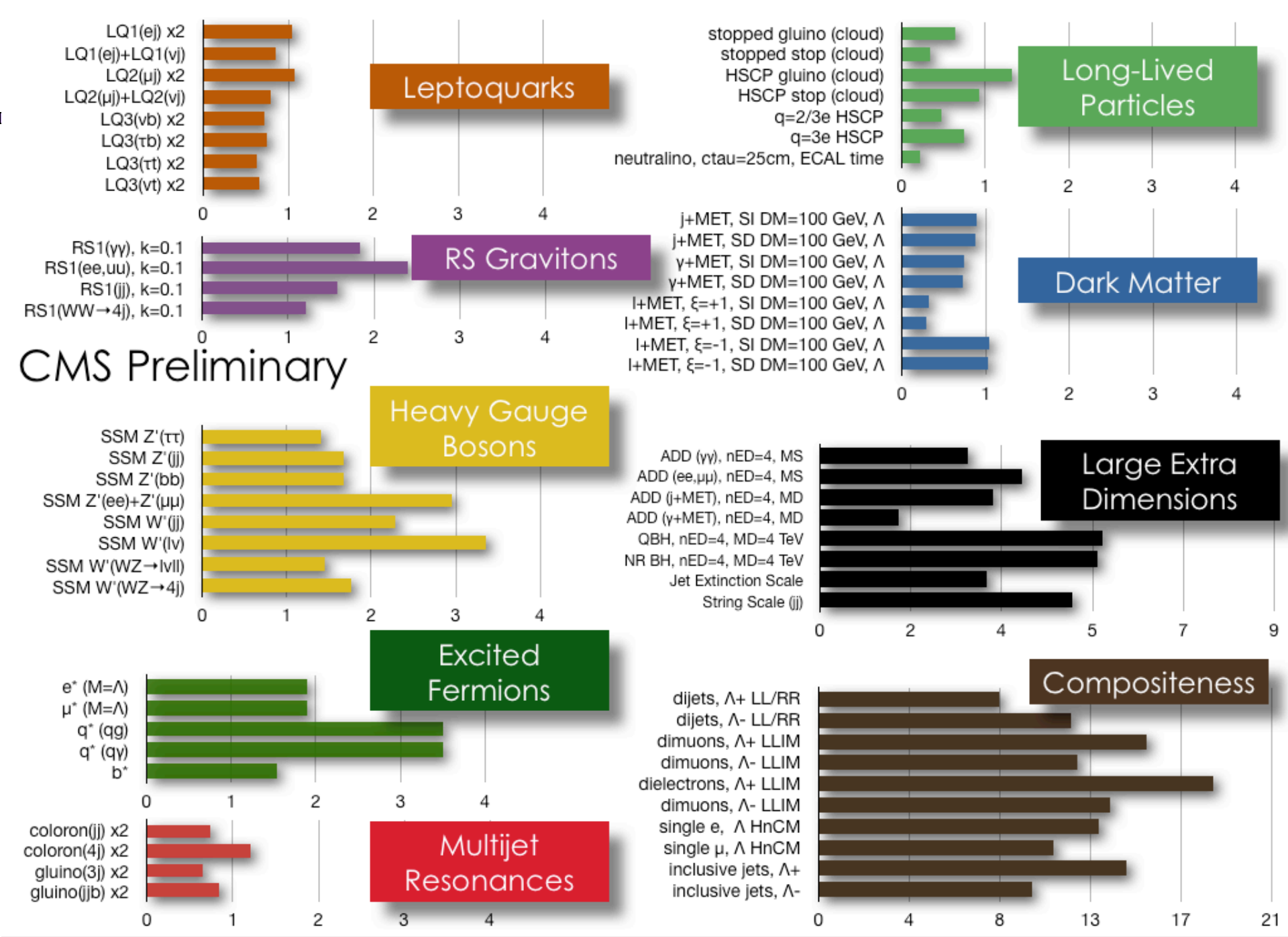
Searches (BSM)

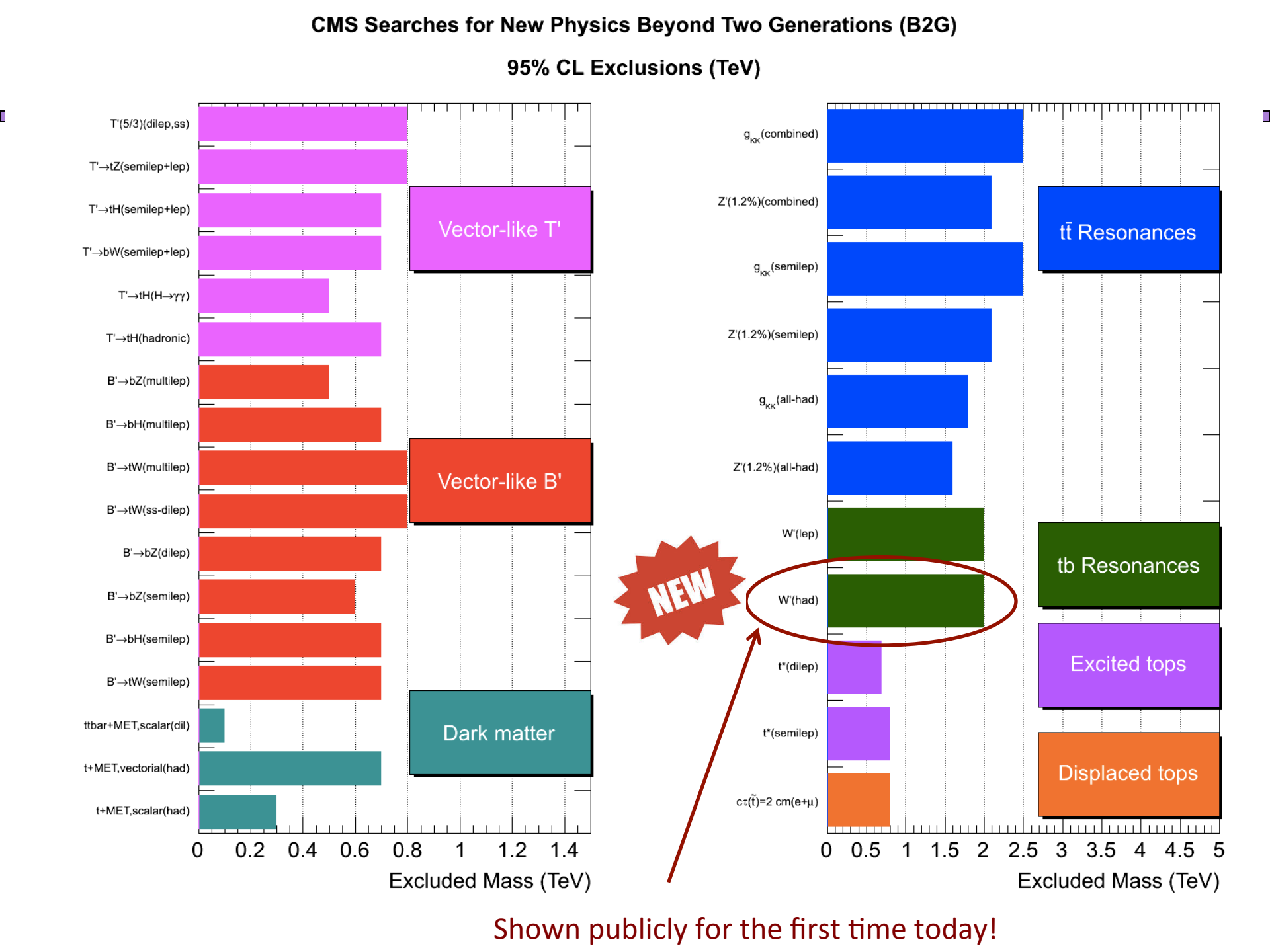
Searches for W' bosons

- With the discovery of the Higgs boson, the problem of the stability of M_h against radiative corrections has become urgent.
  - For m_h = 126 GeV, requires cancellation to *1 part in* 10^{34}*!*



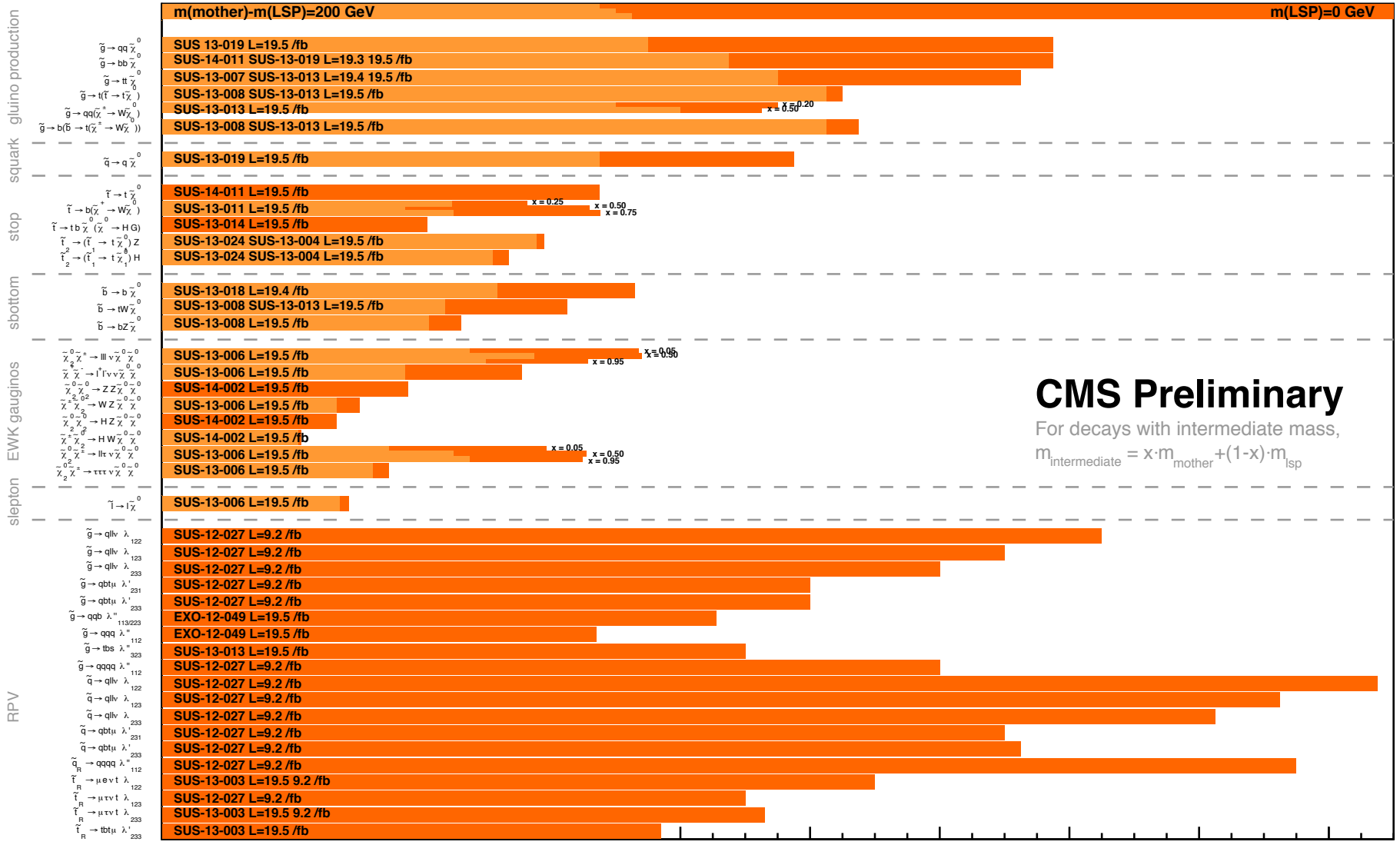
- New heavy gauge bosons (e.g. Z'/W') predicted by many new physics theories with enlarged symmetry:
  - Sequential Standard Model, Little Higgs, Extra Dimensions, Minimal Higgsless Models, Technicolor, etc.
- New physics models introduce new particles which cancel the divergences of the top, gauge, and self-coupling loops


LQ1(ej) x2
LQ1(ej)+LQ1(vj)
LQ2(μj) x2
LQ2(μj)+LQ2(vj)
LQ3(νb) x2
LQ3(τb) x2
LQ3(τt) x2
LQ3(νt) x2
Leptoquarks
stopped gluino (cloud)
stopped stop (cloud)
HSCP gluino (cloud)
HSCP stop (cloud)
q=2/3e HSCP
q=3e HSCP
neutralino, ctau=25cm, ECAL time
Long-Lived Particles
RS1(γγ), k=0.1
RS1(ee,uu), k=0.1
RS1(jj), k=0.1
RS1(WW→4j), k=0.1
RS Gravitons
j+MET, SI DM=100 GeV, Λ
j+MET, SD DM=100 GeV, Λ
γ+MET, SI DM=100 GeV, Λ
γ+MET, SD DM=100 GeV, Λ
l+MET, ξ=+1, SI DM=100 GeV, Λ
l+MET, ξ=+1, SD DM=100 GeV, Λ
l+MET, ξ=-1, SI DM=100 GeV, Λ
l+MET, ξ=-1, SD DM=100 GeV, Λ
Dark Matter
CMS Preliminary
SSM Z'(ττ)
SSM Z'(jj)
SSM Z'(bb)
SSM Z'(ee)+Z'(μμ)
SSM W'(jj)
SSM W'(lν)
SSM W'(WZ→lνll)
SSM W'(WZ→4j)
Heavy Gauge Bosons
ADD (γγ), nED=4, MS
ADD (ee,μμ), nED=4, MS
ADD (j+MET), nED=4, MD
ADD (γ+MET), nED=4, MD
QBH, nED=4, MD=4 TeV
NR BH, nED=4, MD=4 TeV
Jet Extinction Scale
String Scale (jj)
Large Extra Dimensions
e* (M=Λ)
μ* (M=Λ)
q* (qg)
q* (qγ)
b*
Excited Fermions
dijets, Λ+ LL/RR
dijets, Λ- LL/RR
dimuons, Λ+ LLIM
dimuons, Λ- LLIM
dielectrons, Λ+ LLIM
dimuons, Λ- LLIM
single e, Λ HnCM
single μ, Λ HnCM
inclusive jets, Λ+
inclusive jets, Λ-
Compositeness
coloron(jj) x2
coloron(4j) x2
gluino(3j) x2
gluino(jjb) x2
Multijet Resonances


CMS Searches for New Physics Beyond Two Generations (B2G)
95% CL Exclusions (TeV)
T'(5/3)(dilep,ss)
T'→tZ(semilep+lep)
T'→tH(semilep+lep)
T'→bW(semilep+lep)
T'→tH(H→γγ)
T'→tH(hadronic)
B'→bZ(multilep)
B'→bH(multilep)
B'→tW(multilep)
B'→tW(ss-dilep)
B'→bZ(dilep)
B'→bZ(semilep)
B'→bH(semilep)
B'→tW(semilep)
ttbar+MET,scalar(dil)
t+MET,vectorial(had)
t+MET,scalar(had)
Vector-like T'
Vector-like B'
Dark matter
0 0.2 0.4 0.6 0.8 1 1.2 1.4
Excluded Mass (TeV)
g_KK(combined)
Z'(1.2%)(combined)
g_KK(semilep)
Z'(1.2%)(semilep)
g_KK(all-had)
Z'(1.2%)(all-had)
W'(lep)
W'(had)
t*(dilep)
t*(semilep)
cτ(t̃)=2 cm(e+μ)
tt̄ Resonances
tb Resonances
Excited tops
Displaced tops
NEW
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
Excluded Mass (TeV)
Shown publicly for the first time today!

Summary of CMS SUSY Results* in SMS framework

ICHEP 2014



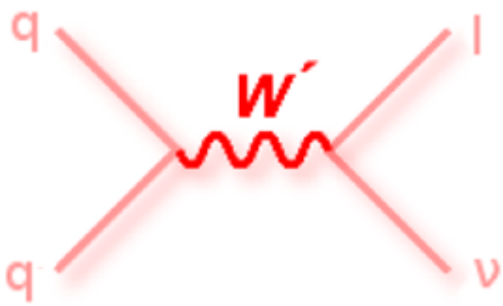
*Observed limits, theory uncertainties not included

Only a selection of available mass limits

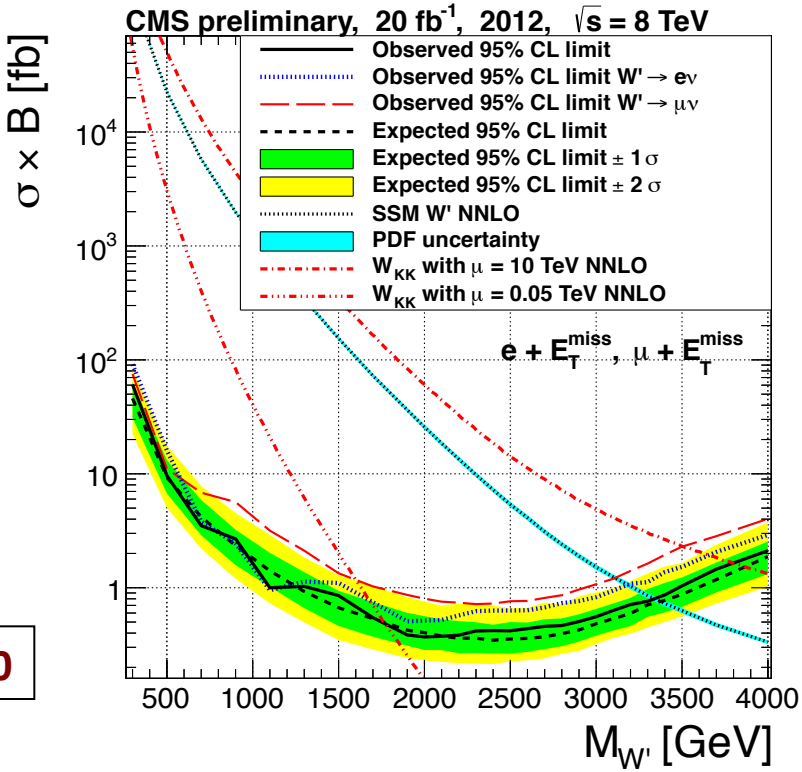
Probe *up to* the quoted mass limit

Searches for W' bosons

- New heavy gauge bosons (e.g. W') predicted by many new physics theories
  - Sequential Standard Model, Little Higgs, Extra Dimensions, Minimal Higgsless Models, Technicolor, etc.



- W' signatures
  - Leptonic: e + ν, μ + ν, τ + ν
  - Bosonic: WZ, Wγ
  - Hadronic: qq', tb



CMS-PAS-EXO-12-060

Searches for W' bosons

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- W' signatures
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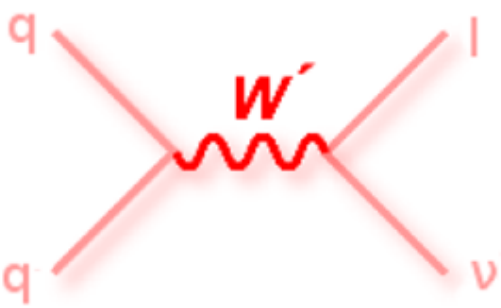
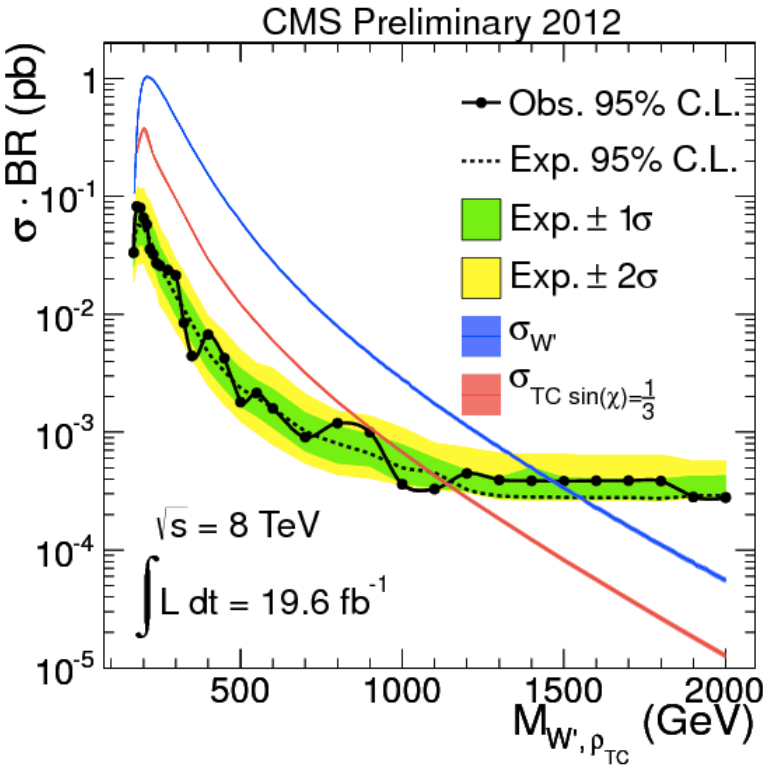
  - Bosonic: WZ, Wγ
  - Hadronic: qq', tb





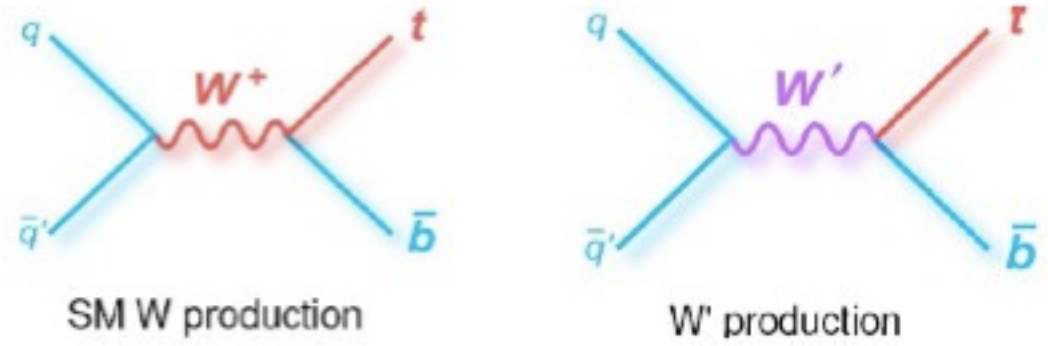
CMS-PAS-EXO-12-025

W'→ tb

- The single top quark decay channel is a promising searching ground for a W' that interacts hadronically
  - Relatively small QCD multijet backgrounds, compared to the decay to light quarks
  - Couplings to third generation fermions may be enhanced in some models
    - Muller, Nandi: Phys. Lett. B 392 383 (1996) 345,
    - Malkawi, Tait, Yuan: Phys. Lett. B 385 (1996) 304
  - No assumptions regarding the mass of the right-handed neutrino
- Three different production channels possible:
  - Only s-channel is interesting (resonance)
  - W' contribution to the other channels is too small
- The effective Lagrangian of W' interactions to quarks can be written in a model independent form as:

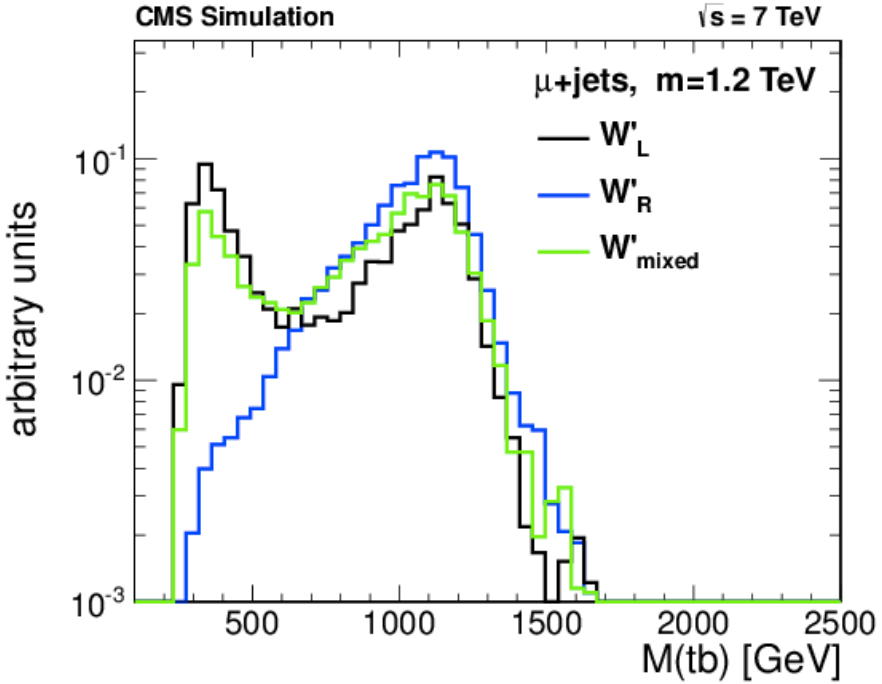
$$\mathcal{L} = \frac{V_{f_i f_j}}{2\sqrt{2}} g_w \bar{f}_i \gamma_\mu \left(a^{\mathrm{R}}_{f_i f_j}(1+\gamma^5) + a^{\mathrm{L}}_{f_i f_j}(1-\gamma^5)\right) \mathrm{W}'^{\mu} f_j + \mathrm{h.c.},$$

W-W’ Interference



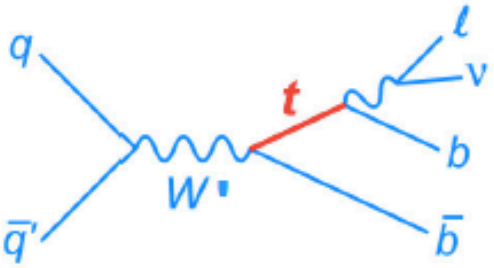
Both left- and right-handed couplings are allowed, and if the left-handed coupling is non-zero, the W' will interfere with the SM W

- Interference effects significantly change the shape of the M(tb) distribution
- The full effect of interference can be taken into account by simulating three different signal samples with left-handed, right-handed, or left- and right-handed fermionic couplings



Event Selection (lepton + jets)

JHEP 05 (2014) 108



Lepton Selection:

- Exactly 1 electron(muon) with pT > 50 GeV, and |η| < 2.5(2.1)

Jet Selection:

- Require at least 2 jets with leading jet pT > 120 and 2nd leading jet pT > 40 GeV

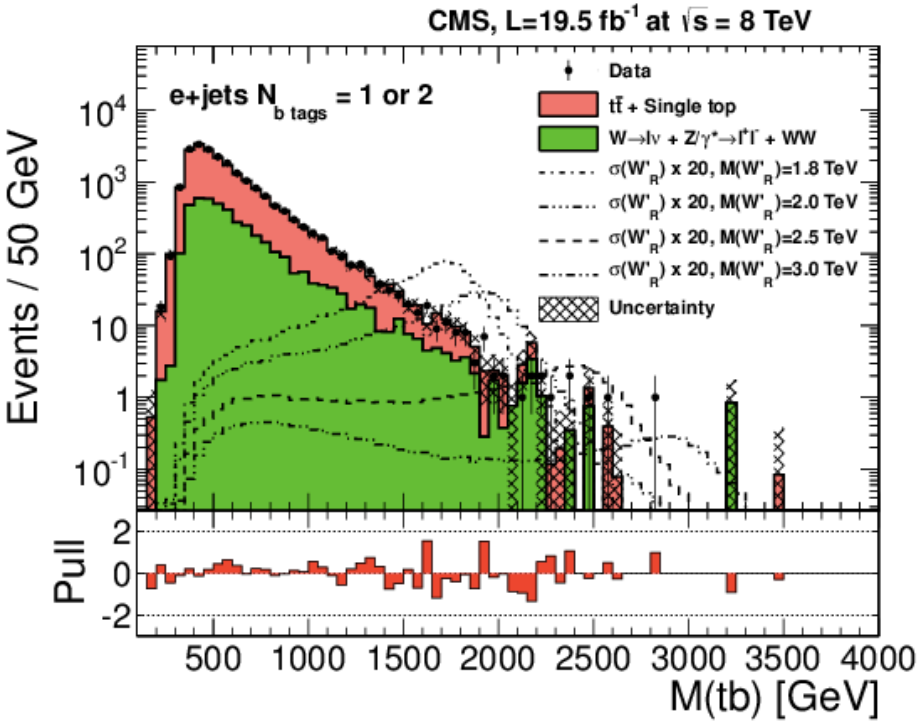
MET Selection:

- Require MET > 20 GeV

B-tagging Selection:

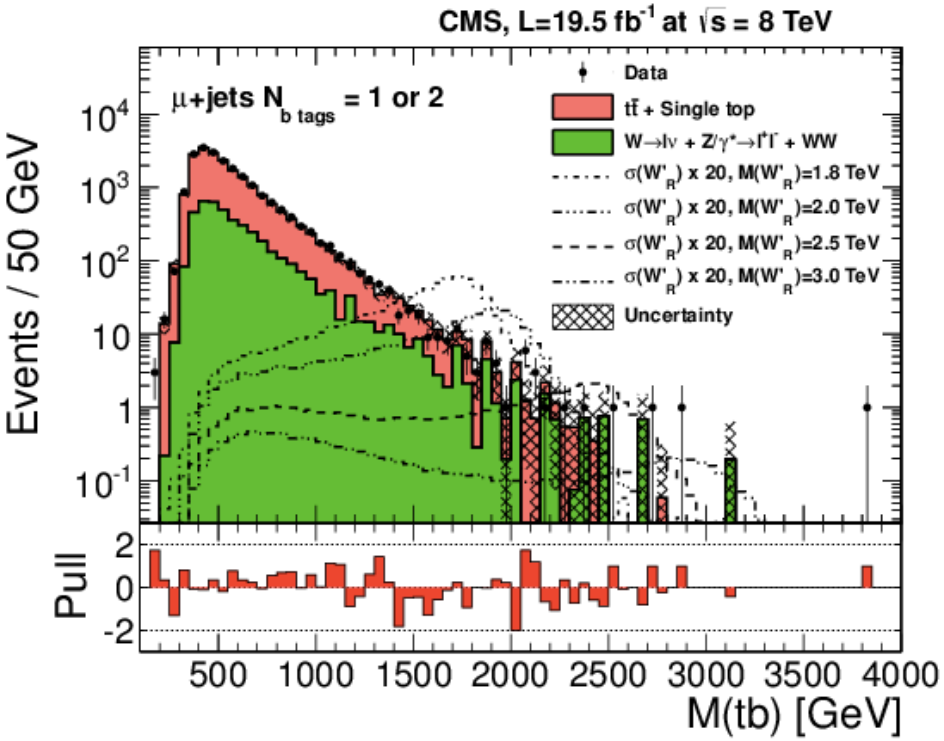
- Require at least one of the leading two jets to be b-tagged

W’ Invariant Mass



Additional cuts for increasing sensitivity

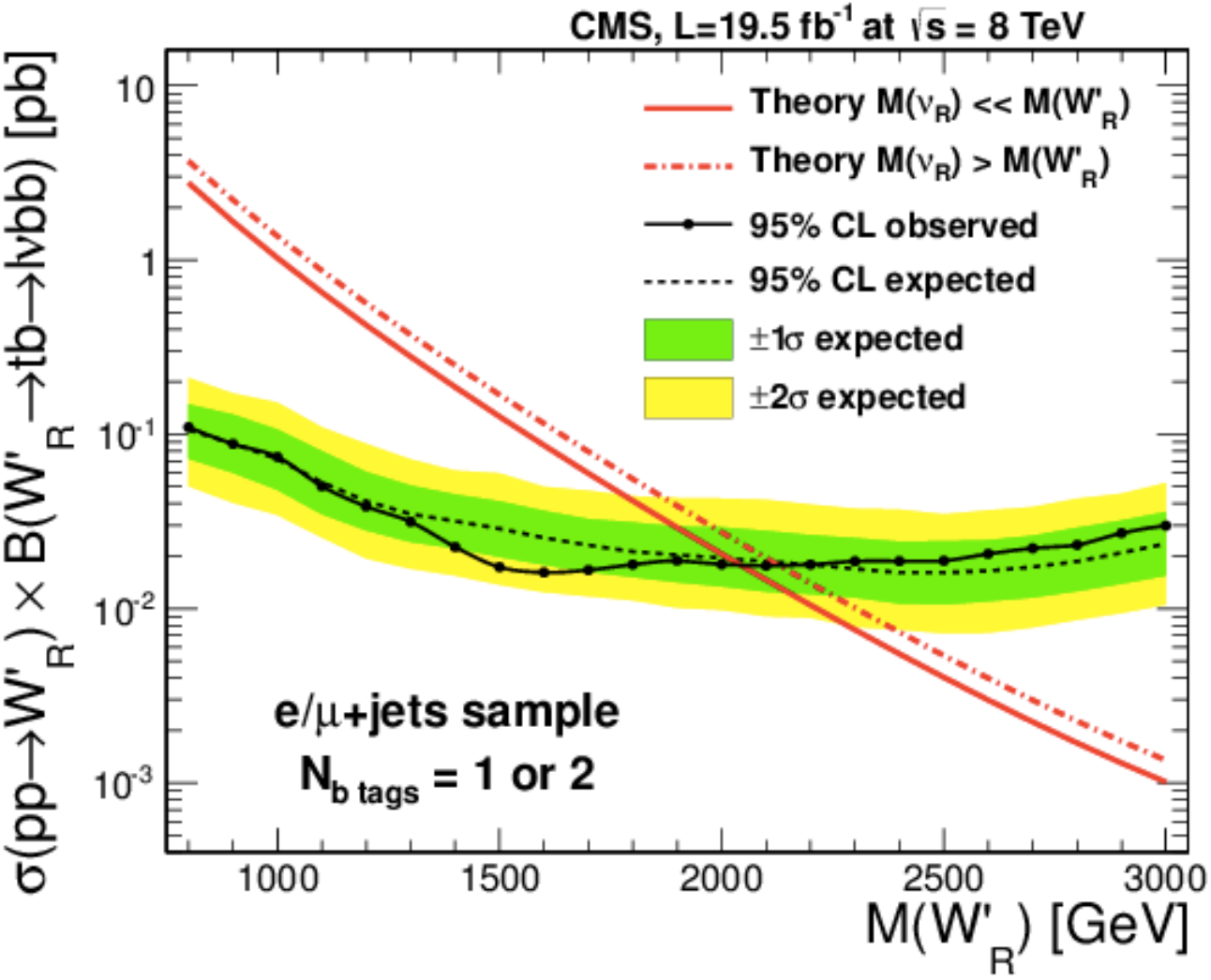
- 130 < m(top) < 210 GeV
- pt(top) > 85 GeV
- pt(j1,j2) > 140 GeV



Top pair + single top: Normalized to (~)NNLO cross section, shape from MC and checked in control region

W+jets: Shape from MC and checked in a control region, normalization derived from the data

Exclusion Limit



Limit @ 95%:
m(W'$_R$) > 2.03 TeV

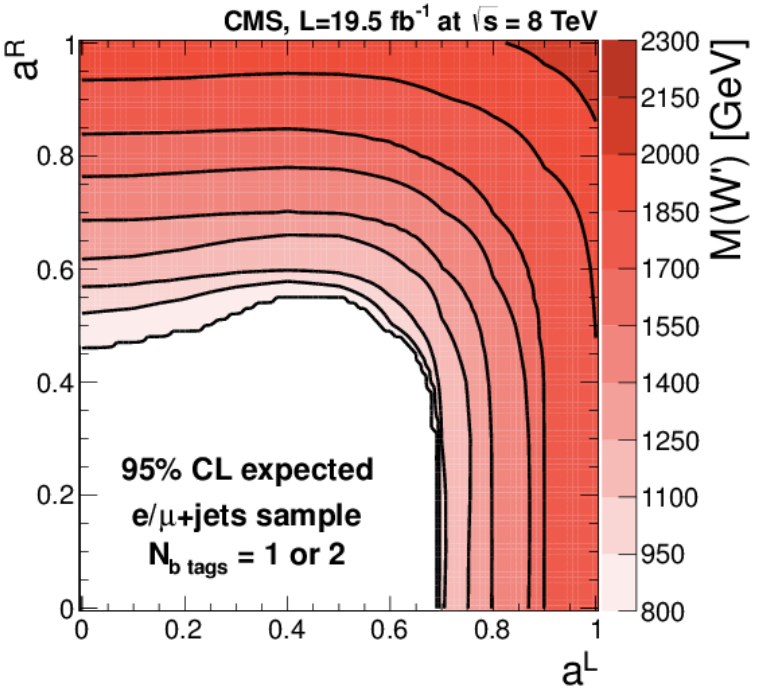
JHEP 05 (2014) 108

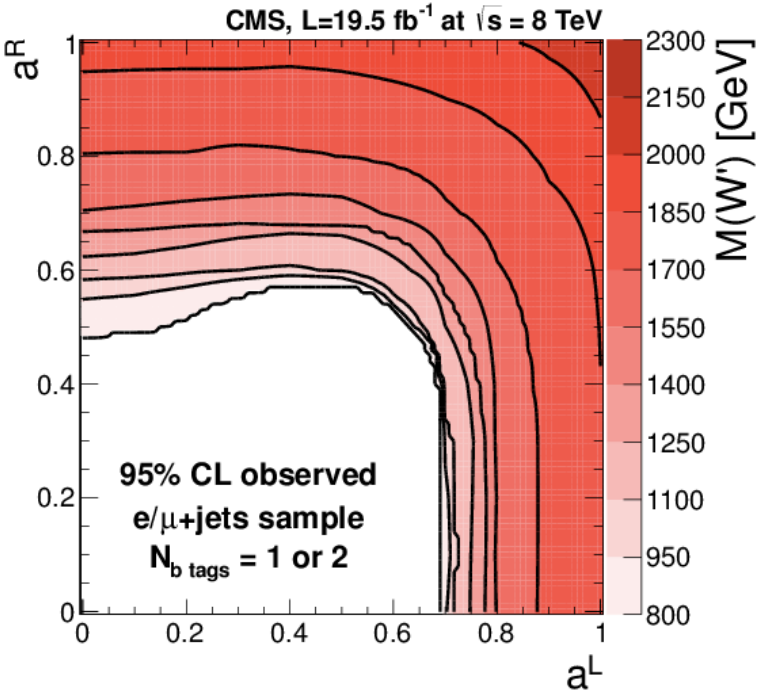
Generalized Couplings

- For any set of the three parameters a_L, a_R, and $M_{W'}$
- The W' invariant mass distribution is determined by adding the distributions from the four samples generated with (a_L, a_R) = (0, 0), (1, 0), (0, 1), and (1, 1) in the proportions given by:

$$\begin{aligned}\sigma &= \sigma_{SM} + a^L_{ud}a^L_{tb}\left(\sigma_L - \sigma_R - \sigma_{SM}\right) \\ &+ \left(\left(a^L_{ud}a^L_{tb}\right)^2 + \left(a^R_{ud}a^R_{tb}\right)^2\right)\sigma_R \\ &+ \frac{1}{2}\left(\left(a^L_{ud}a^R_{tb}\right)^2 + \left(a^R_{ud}a^L_{tb}\right)^2\right)\left(\sigma_{LR} - \sigma_L - \sigma_R\right).\end{aligned}$$

JHEP 05 (2014) 108





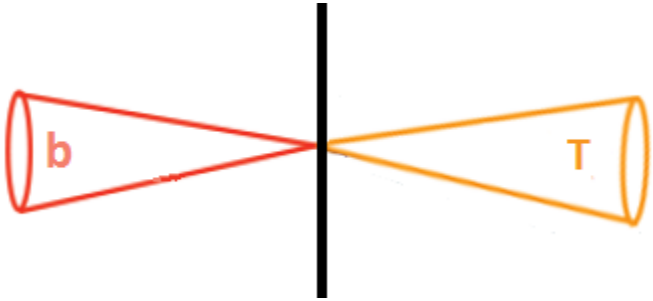
Fully Hadronic Final State

NEW

- Focus on high mass W' (> 1.3 TeV)
- Top daughter jets are highly boosted
  - Merged into a single jet
- B candidate jet in opposite hemisphere
- Interested in high p_T objects
  - p_T > 450 GeV for top candidate
  - p_T > 370 GeV for b candidate

Merged Top Jet

- Analysis Strategy:
  - Boosted top jet identification
  - b-tagging
  - Background estimation

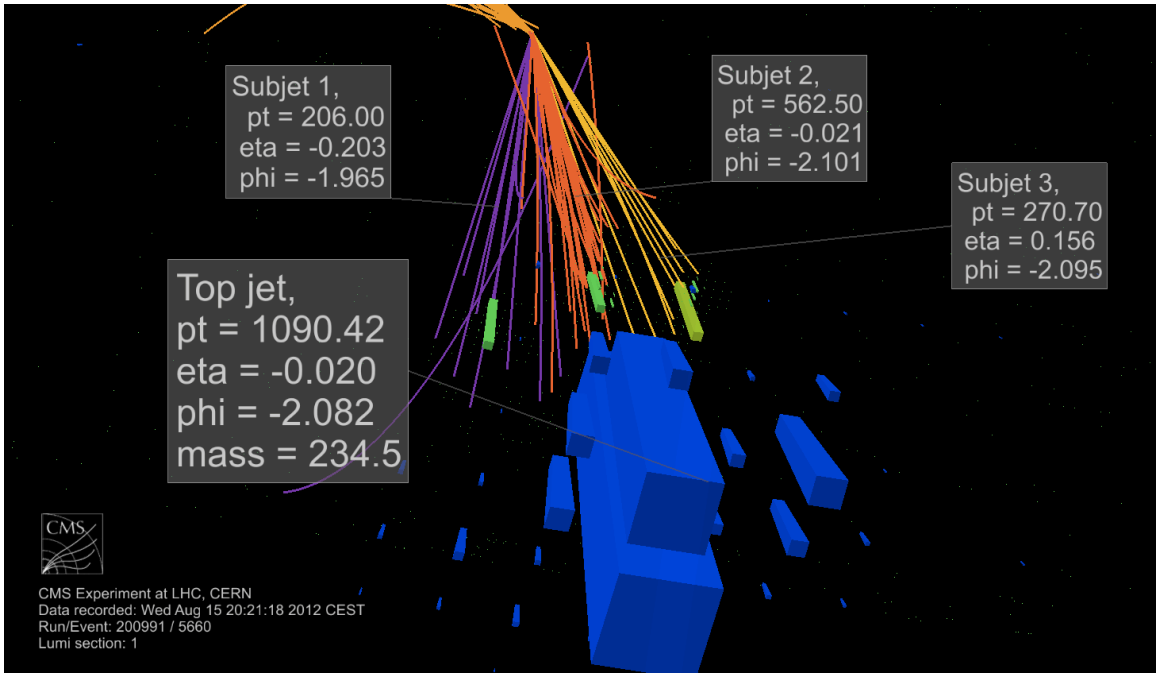


Event Topology

CMS-PAS-B2G-12-009

CMS Top tagging algorithm

- Cambridge-Aachen jet clustering algorithm with R = 0.8
- Try to decompose merged jets into two and then three or four primordial "subjets"
- The top jet should contain three subjets
  - Two subjets from the W decay
  - One from the b-quark hadronization
- Use $N_{subjets}$ >=3



CMS Top-Tagging Algorithm

- Calculate the pairwise mass of subjets

$$m_{ij} = \sqrt{(E_i + E_j)^2 - (\vec{p}_i + \vec{p}_j)^2}$$

- Put a subjet pair within the range of W boson mass
  - Cut on minimum $m_{ij} > 50$ GeV
- Put jet within top mass range
  - 140 GeV < M < 250 GeV

N-subjettiness

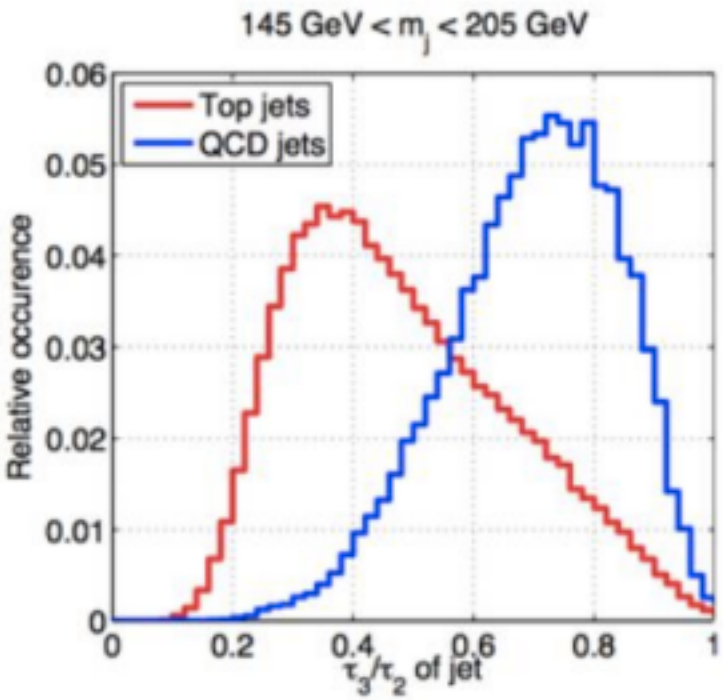
- Variables τ_N describe how consistent the jet energy is with having N subjets

$$\tau_N = \frac{1}{d_0} \sum_k p_{T,k} \min \{\Delta R_{1,k}, \Delta R_{2,k}, \cdots, \Delta R_{N,k}\}$$

  - J. Thaler, K. Van Tilburg, arXiv:1011.2268

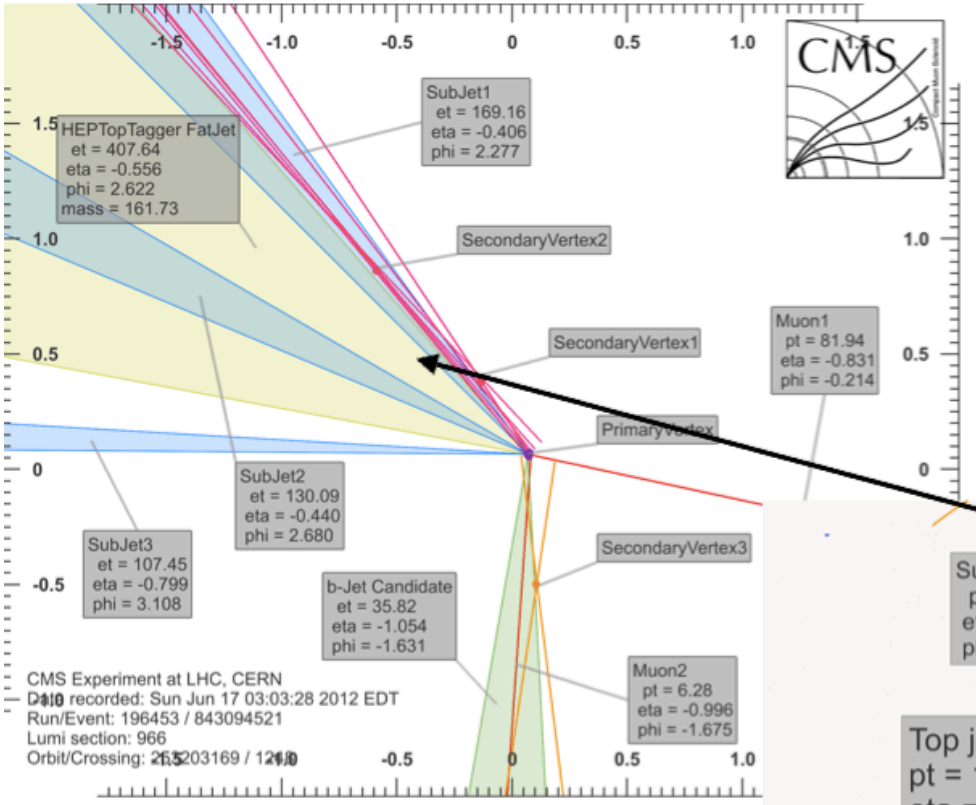
- As $\tau_N \rightarrow 0$, jet is more consistent with having N subjets
  - e.g. as $\tau_3 \rightarrow 0$, more like a top jet
  - e.g. as $\tau_2 \rightarrow 0$, more like a W jet
  - e.g. as $\tau_1 \rightarrow 0$, more like a quark jet

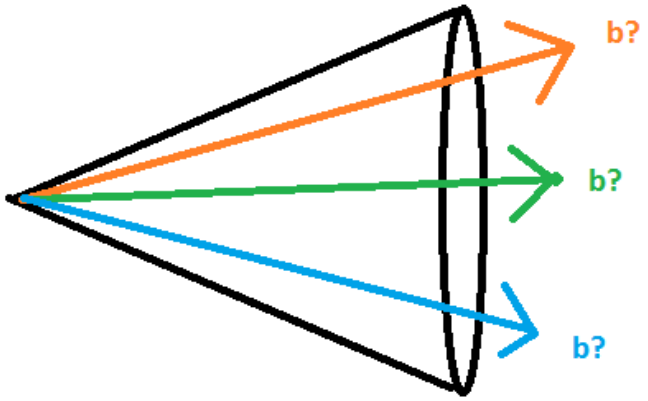
- Ratios are typically used – eg. τ_3/τ_2 to separate top jets from W jets
  - Require $\tau_3/\tau_2 < 0.55$

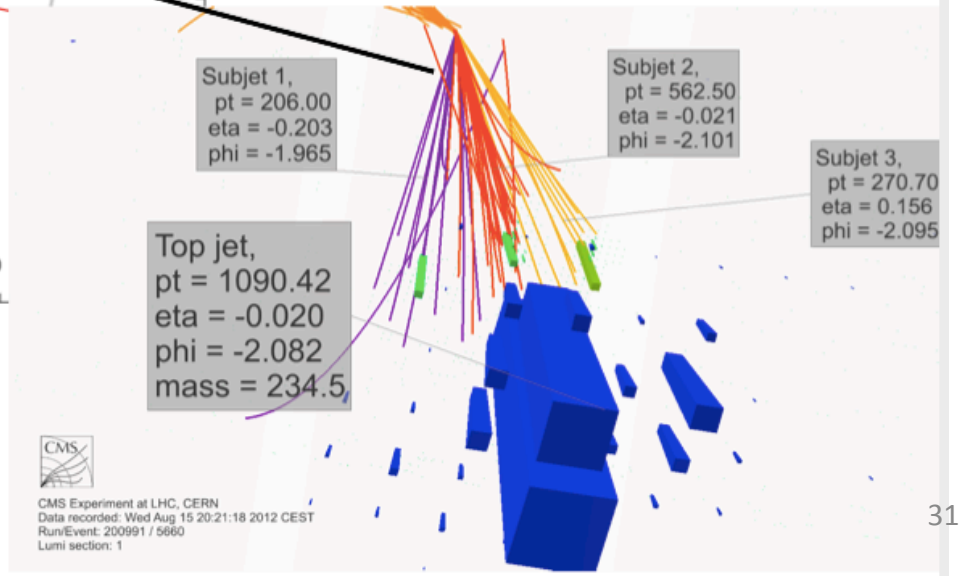


B-tagging subjets

- One of the subjets within the top jet should be a b-jet
- Allow for any of the three subjets to be b-tagged



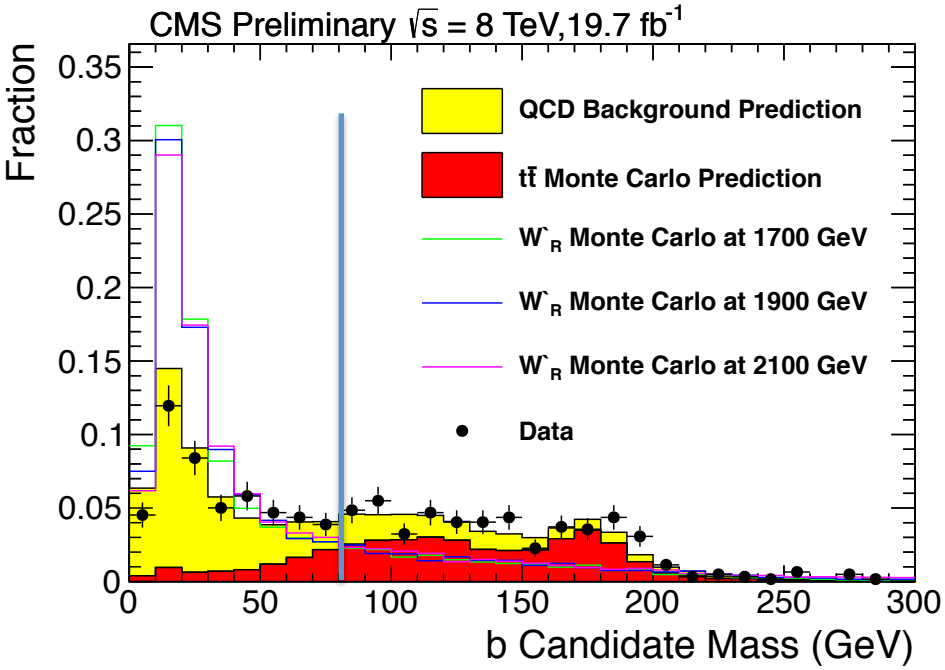




Additional selection

- QCD reduced after top tagging

- Need to reduce ttbar background contribution
  - In W' → tb signal MC, the b candidate jet is usually a true b jet
  - In ttbar, the b candidate jet is commonly a merged top or W boson jet
  - Require b candidate jet mass < 70 GeV
    - ttbar reduction of ~80%



Background estimation

- Extract QCD estimate from data (both shape and normalization)
  - Measure the average b-tagging rate for QCD jets in control region

Control Region

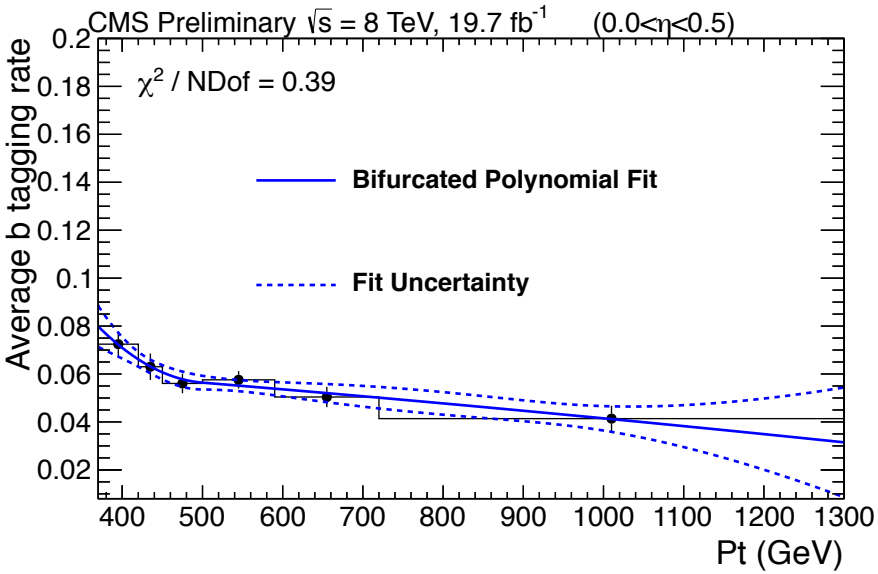
$$\bar{P}_{btag} = \frac{N_{post}}{N_{pre}}$$

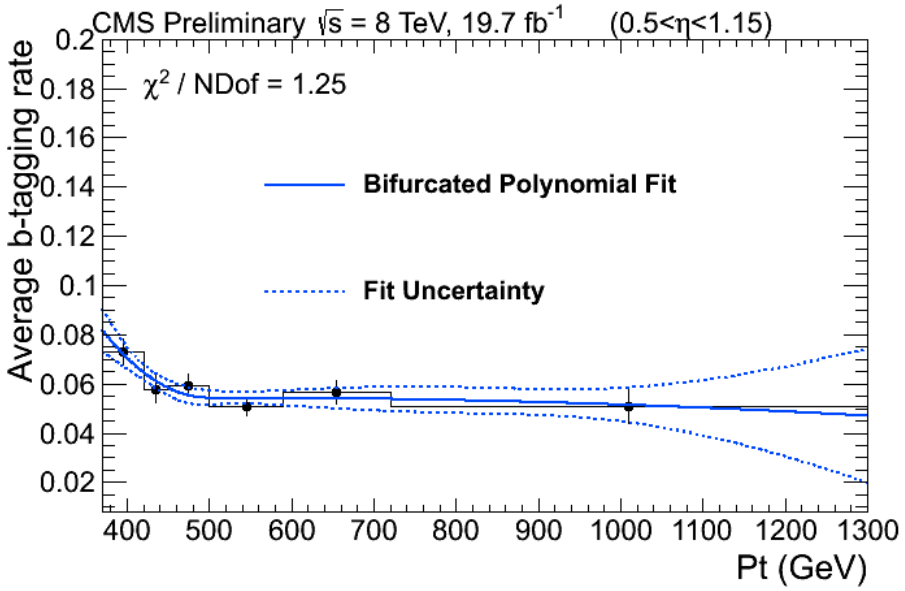
  - Apply this average b-tagging rate to the pre-btagged sample in the signal region

Signal Region

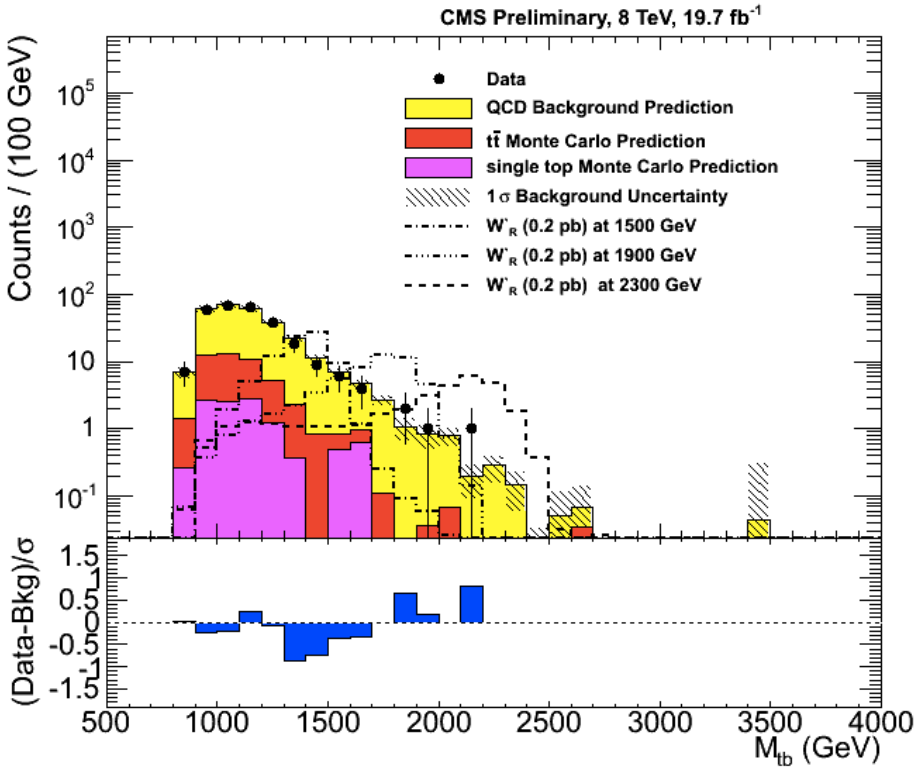
$$N_{post} \cong N_{pre} \times \bar{P}_{btag}$$

- ttbar: extract shape from MC, normalization from data



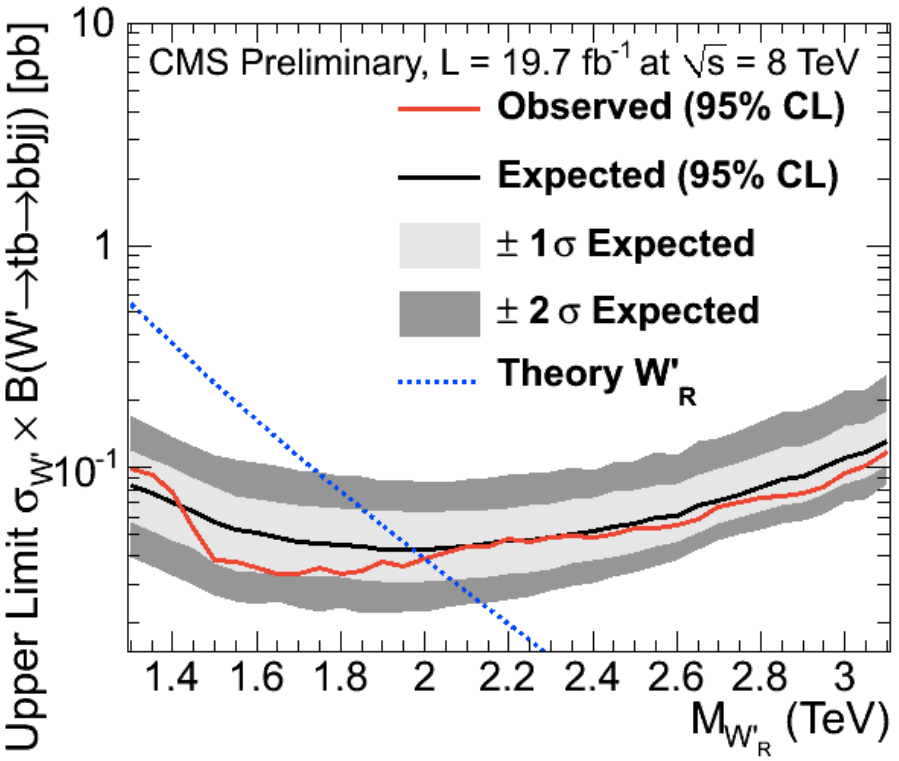


Results

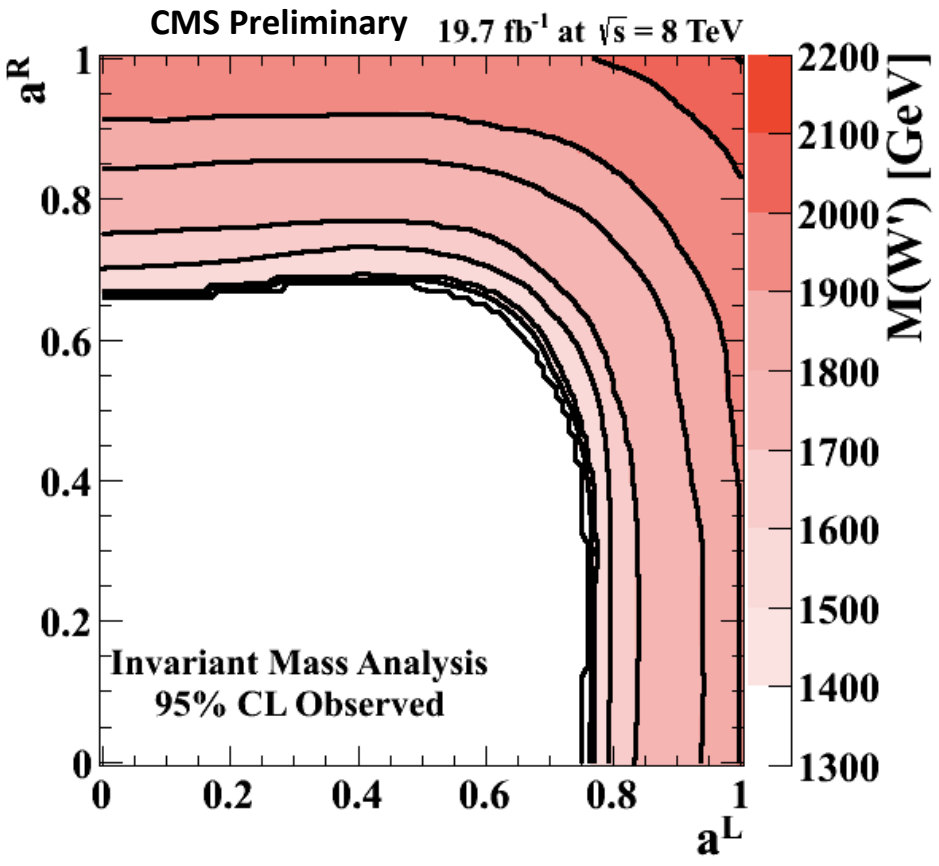


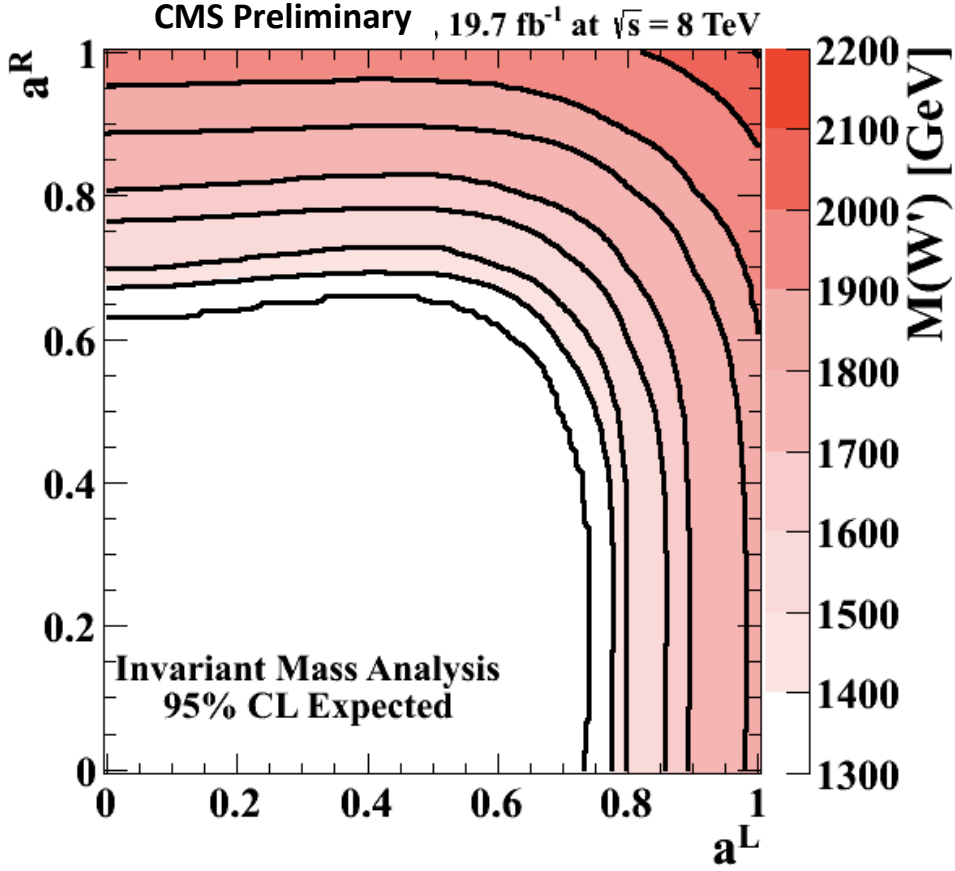
CMS-PAS-B2G-12-009

W': @ 95% CL
Observed: 2.0 TeV
Expected: 1.95 TeV



Generalized Coupling Limits



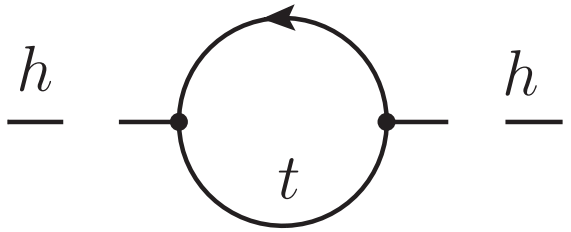


CMS-PAS-B2G-12-009

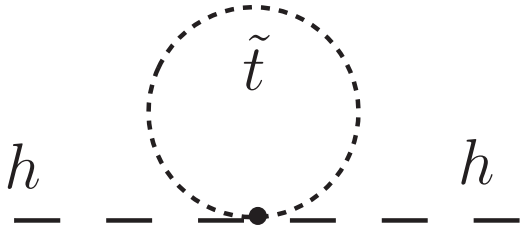
SUSY Searches

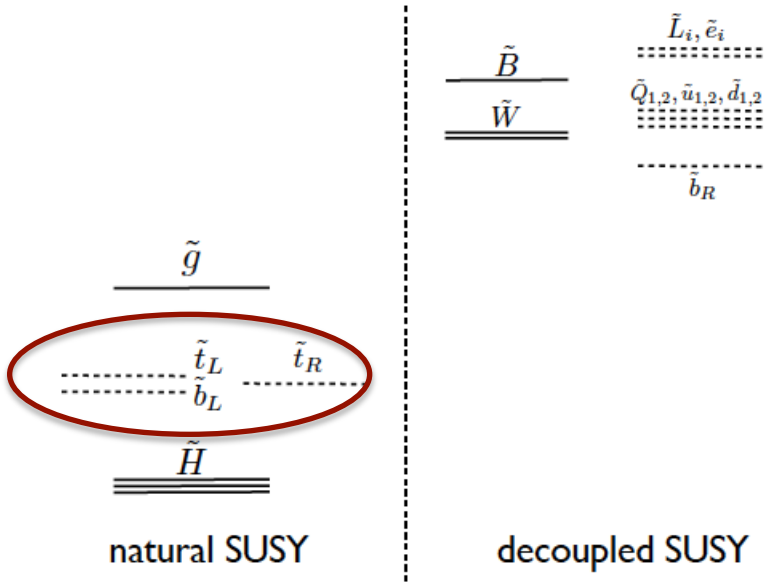
Natural SUSY searches

- Many searches designed for signatures motivated by a "natural" solution to the gauge hierarchy problem.
  - Standard Model fermions get bosonic partners, bosons get fermionic partners



- The lightest Higgs mass is allowed to *naturally* be at the electroweak scale, no fine tuning required.





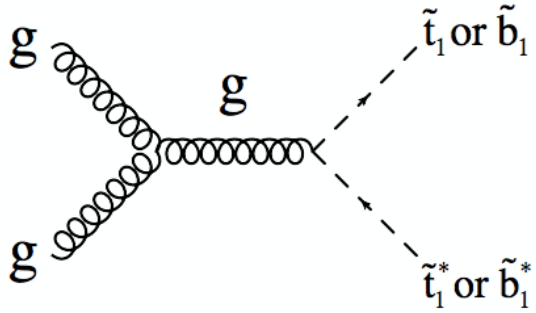
1) N. Arkani-Hamed
2) M. Papucci, J.T. Ruderman, and A. Weiler, http://arxiv.org/abs/1110.6926

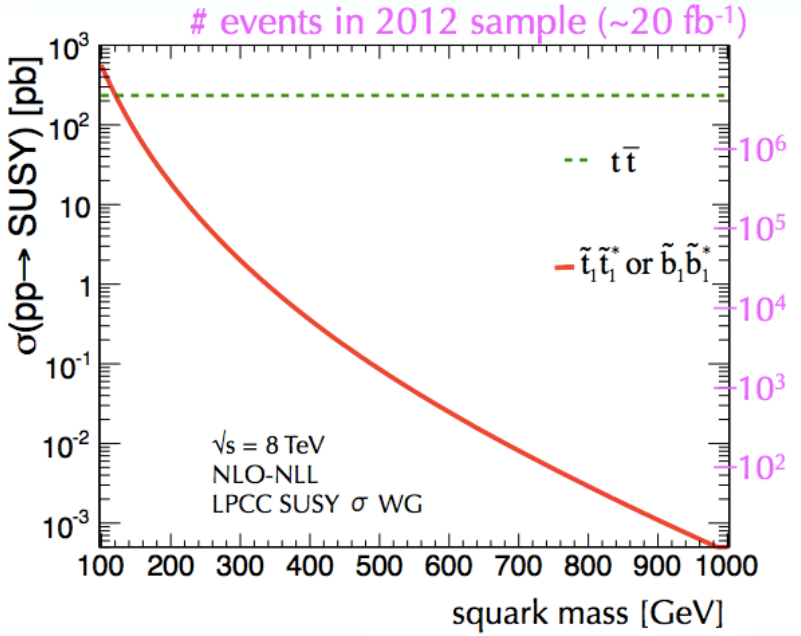
Bosonic top partners

Production and Decay

Production:

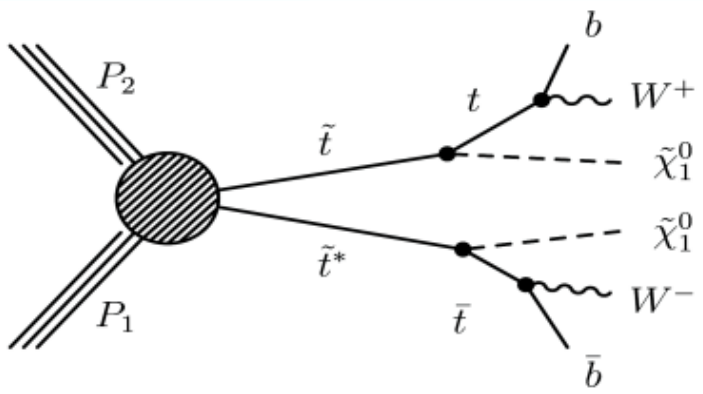
- stop and sbottom pair production via gluon gluon fusion and qqbar annhilation





Decay:

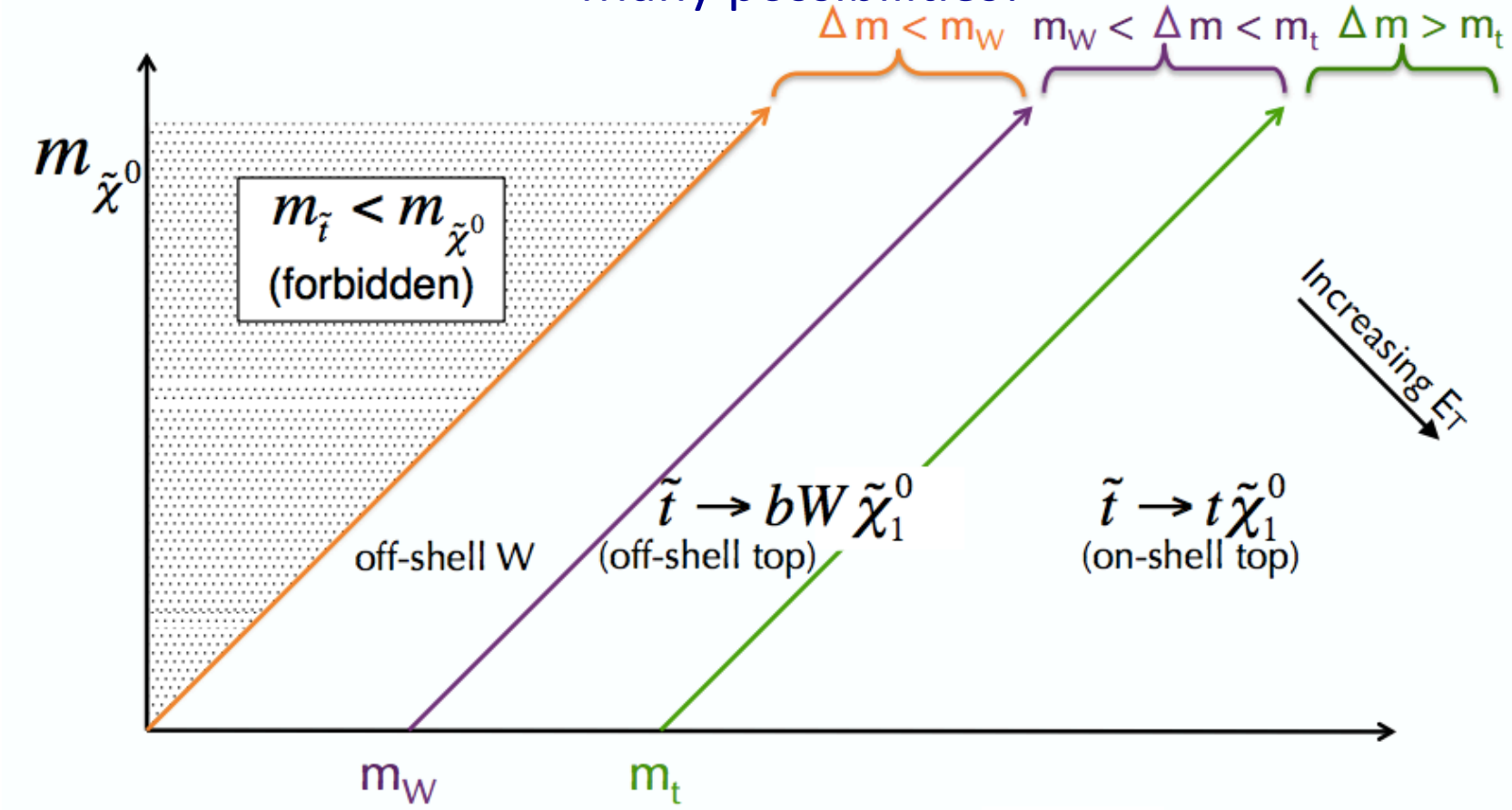
- R-parity conservation - the number of SUSY particles must be preserved in the decay (assumed in this talk)
  - Lightest supersymmetric particle (LSP) cannot decay
    - In this talk, the LSP is ~always the lightest neutralino
  - Dark matter candidate!



Will concentrate on direct production of stops

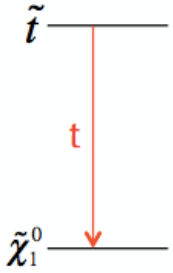
Decay signatures

Many possibilities!



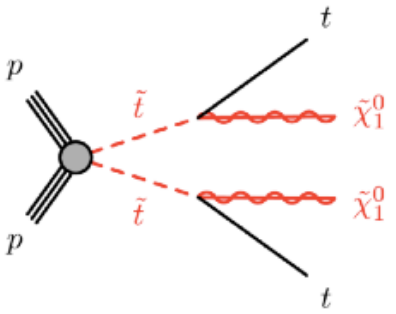
Δm defines different regions of phase space:

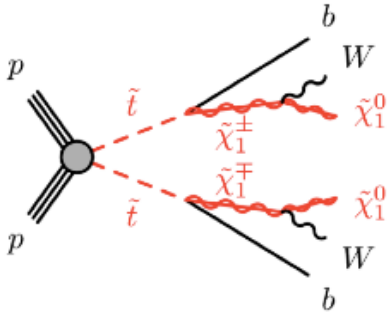
- Different kinematically allowed decays
- Amount of energy for decay products

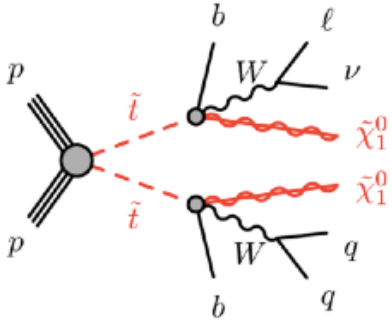


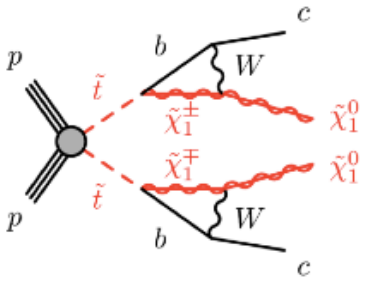
$$\Delta m \equiv m_{\tilde{t}} - m_{\tilde{\chi}^0}$$

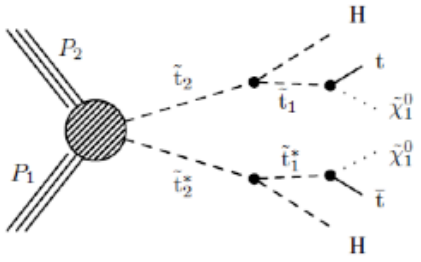
Direct stop searches

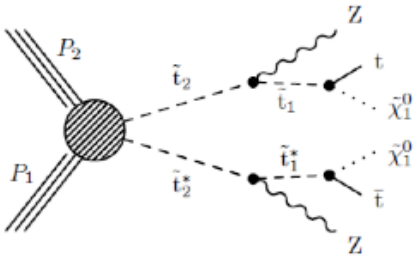


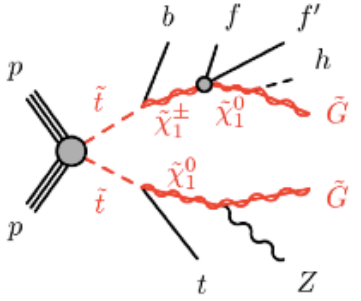


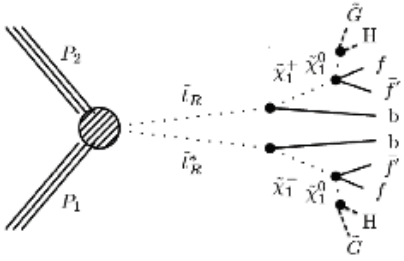












Stop Searches

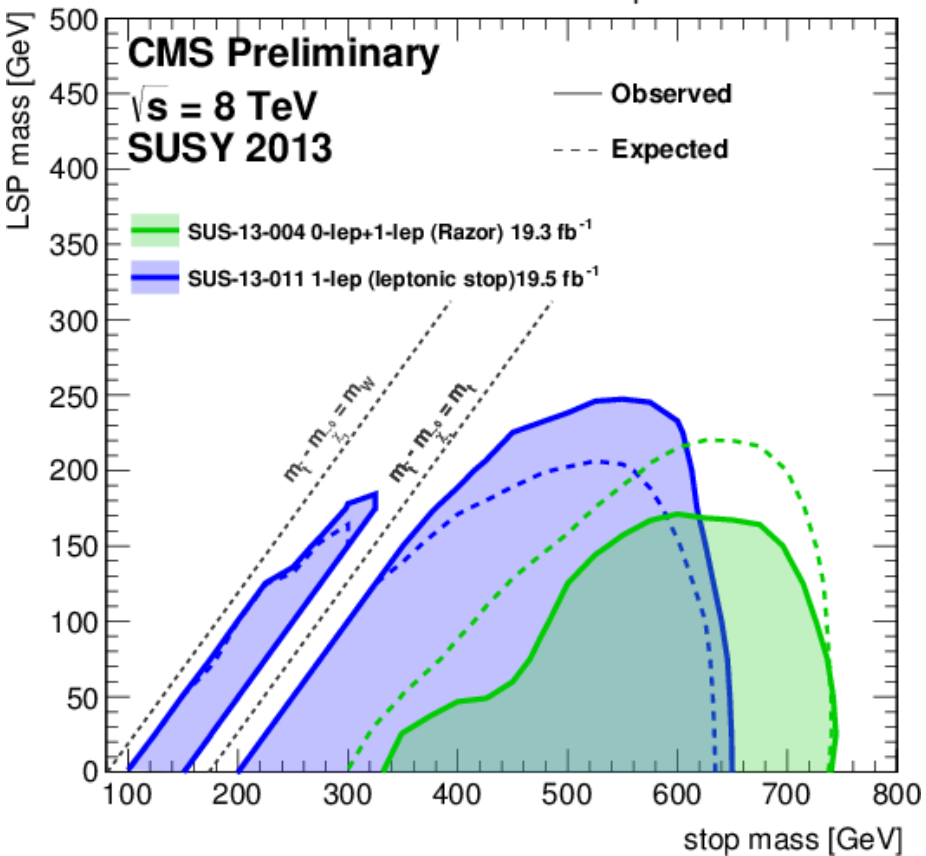
Where we were last year….

m_{stop} < ~700 GeV exclusion for light LSP

Note gap in exclusion for $\Delta m = m_t$ (stop "on top" of top)

No exclusion for $\Delta m < m_W$ from non-targeted searches

$\tilde{t}$-$\tilde{t}$ production, $\tilde{t} \rightarrow t\,\tilde{\chi}_1^0$



1 lepton dedicated search (SUS-13-011) is complementary to hadronic (SUS-13-004) search

Combine the two analyses….

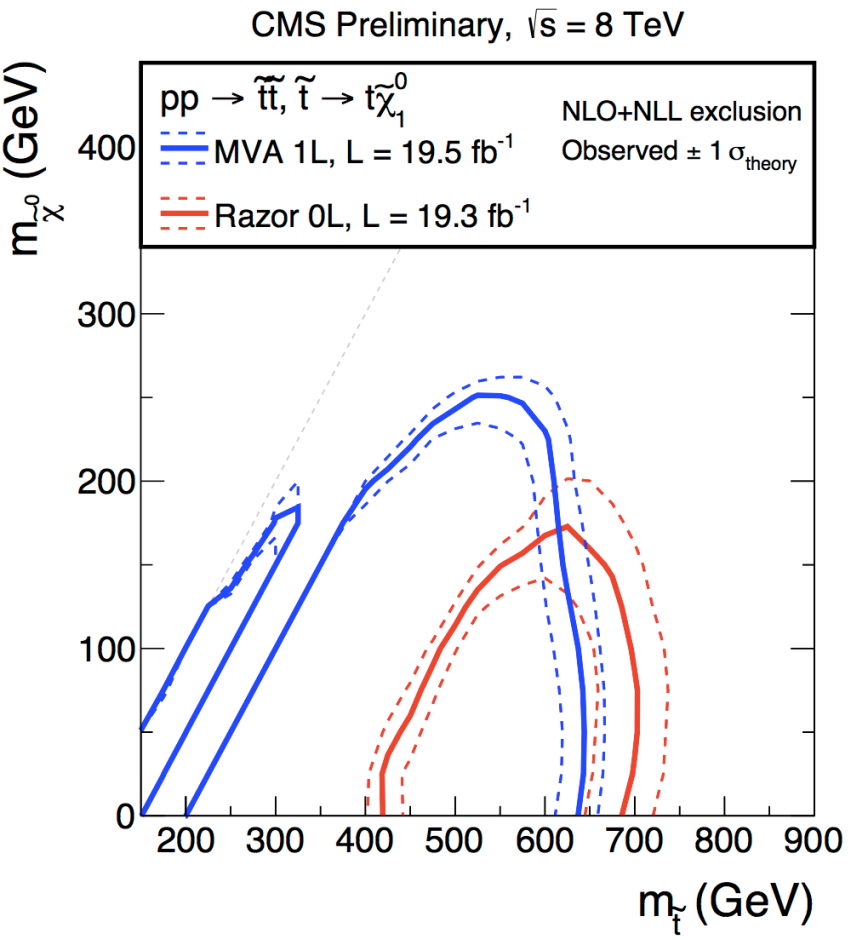
Light Stop Combination

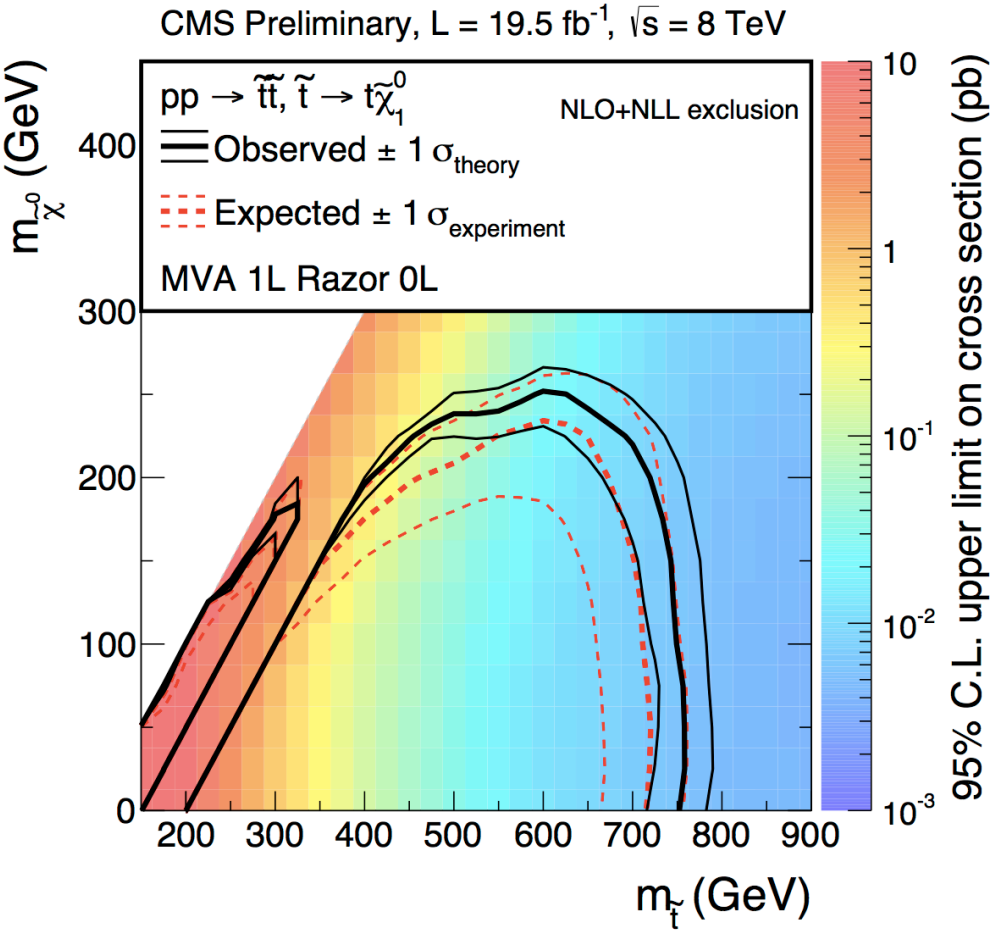
NEW

CMS-PAS-SUS-14-011

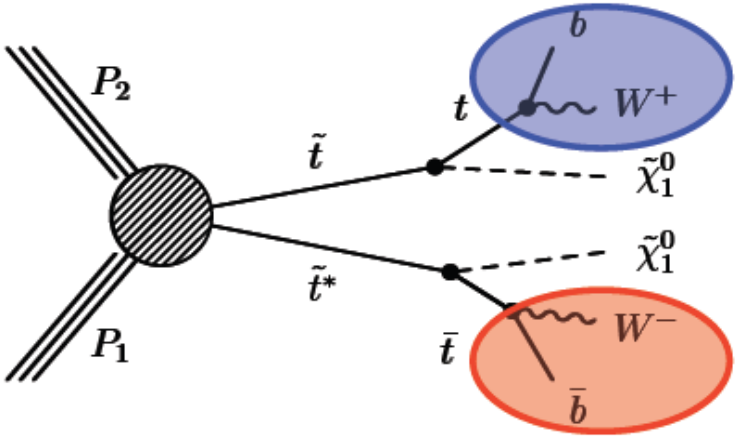
m_{stop} < ~750 GeV exclusion for light LSP

New Combined Result





0 lepton stop search



Fully reconstructed 3-jet system

Partially reconstructed "Remnant"

A targeted search reconstructs both top quarks, one fully and the other partially, and then applies topological cuts

CMS-PAS-SUS-13-015

Selection:

e & μ veto with $p_T > 5$

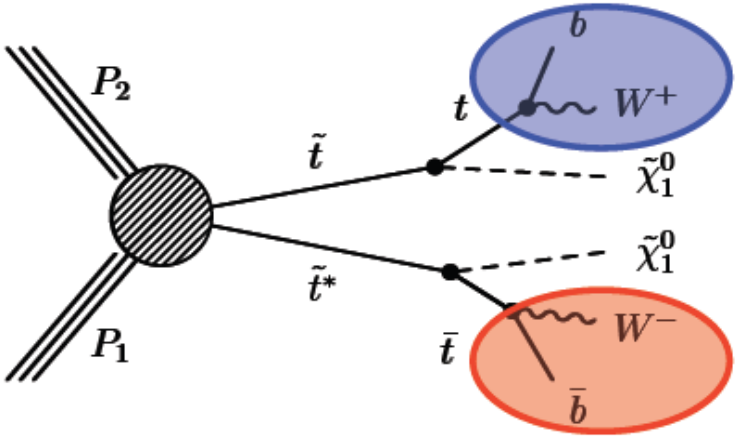
≥ 5 jets with $|n| < 2.4$ and $p_T > 70,70,50,50,30$

$N_b \geq 1$

$p_T^{miss} > 200$

$\Delta\phi(j_{1,2,3}, p_T^{miss}) > 0.5,0.5,0.3$

0 lepton stop search



Fully reconstructed 3-jet system

Partially reconstructed "Remnant"

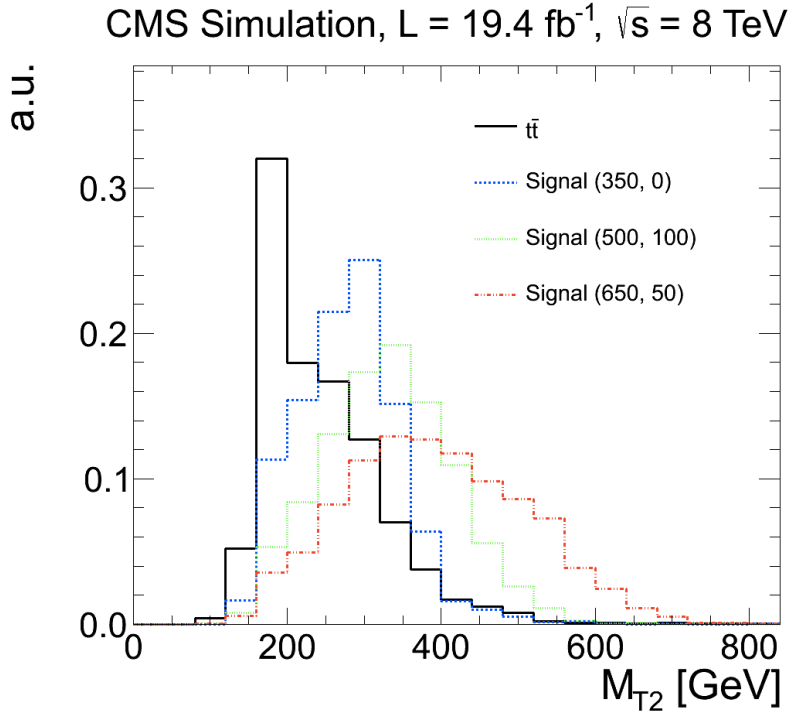
Use p_T of 3-jet, remnant, and MET to calculate:

M_{T2}

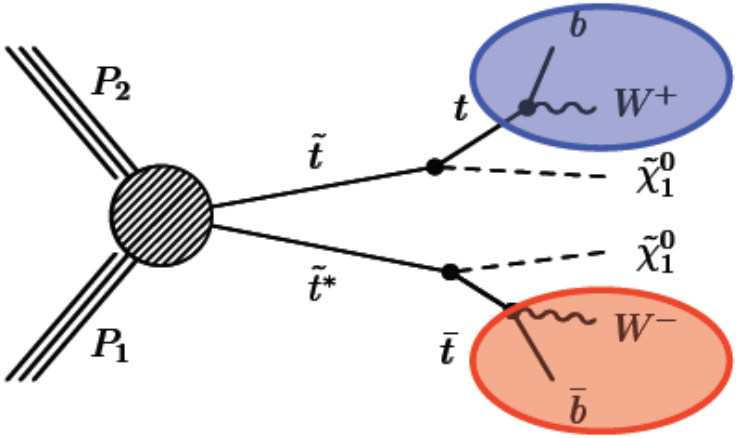
M_T^{Rsys}

M_T^{3jet}

M_{T2} > 300 GeV



0 lepton stop search



Fully reconstructed 3-jet system

Partially reconstructed "Remnant"

Use p_T of 3-jet, remnant, and MET to calculate:

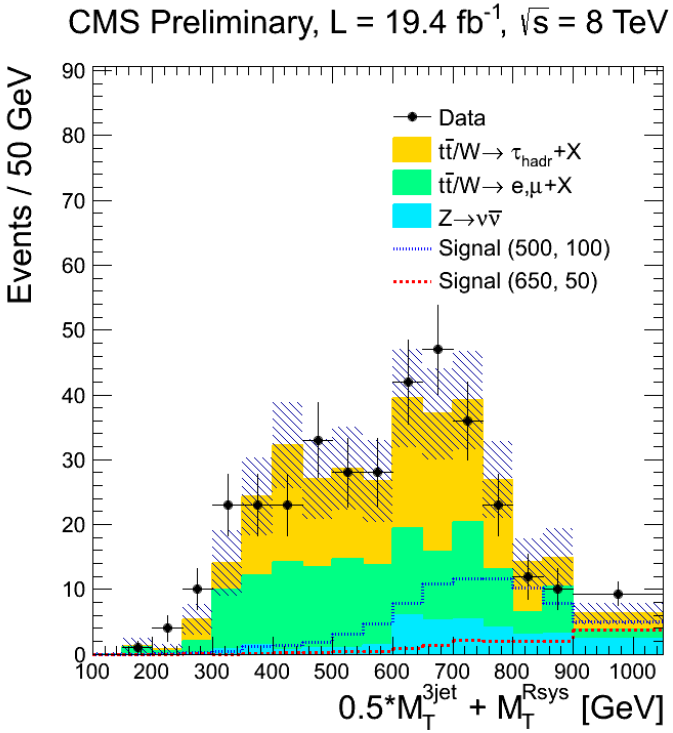
M_{T2}

M_T^{Rsys}

M_T^{3jet}

$M_{T2} > 300$ GeV

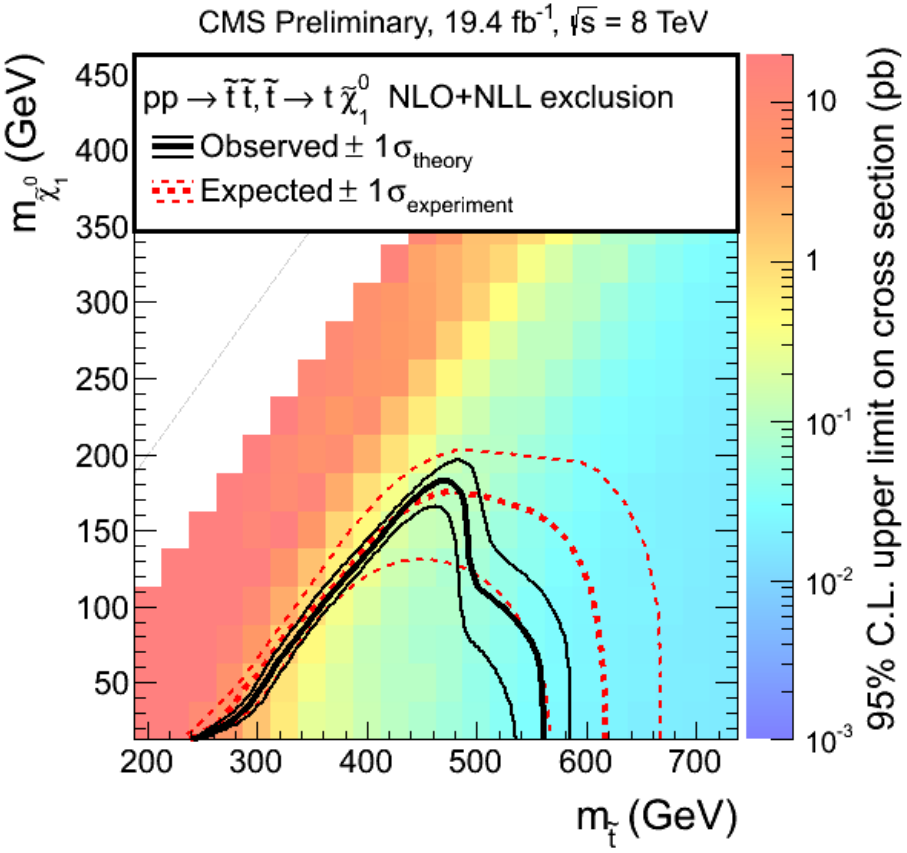
$0.5\ M_T^{3jet} + M_T^{Rsys} >= 500$ GeV



0-lepton stop search

Search region	Total background	Obs. data
$p_T^{miss} > 200$ GeV, $N_{b\text{-jets}} \geq 1$	$254.3\ ^{+35.0}_{-31.0}$	254
$p_T^{miss} > 350$ GeV, $N_{b\text{-jets}} \geq 1$	$40.9\ ^{+8.6}_{-9.6}$	45
$p_T^{miss} > 200$ GeV, $N_{b\text{-jets}} \geq 2$	$88.4\ ^{+19.8}_{-13.5}$	83
$p_T^{miss} > 350$ GeV, $N_{b\text{-jets}} \geq 2$	$8.6\ ^{+7.1}_{-2.7}$	15

Limits set in (m_{stop}, m_{LSP})

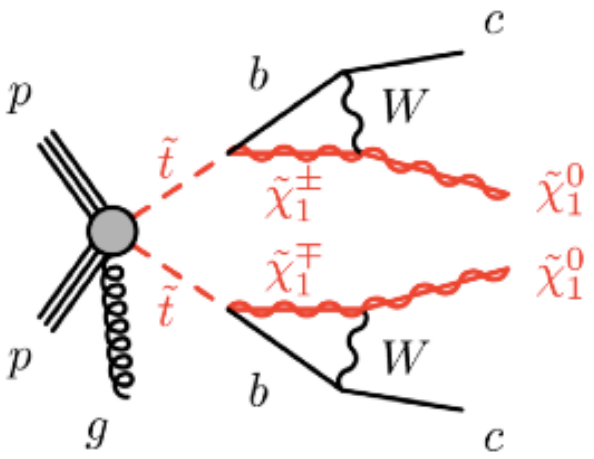


CMS-PAS-SUS-13-015

``Charmed'' search

- For $\Delta m < m_W + m_b$, search for $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$
  - allowed when $\Delta m > m_c$
- Target compressed spectra where decay products are ~ all invisible
- Signature: charm jets very soft and LSPs are ~back-to-back, so require hard ISR jet recoiling against MET from the LSPs

CMS-PAS-SUS-13-009

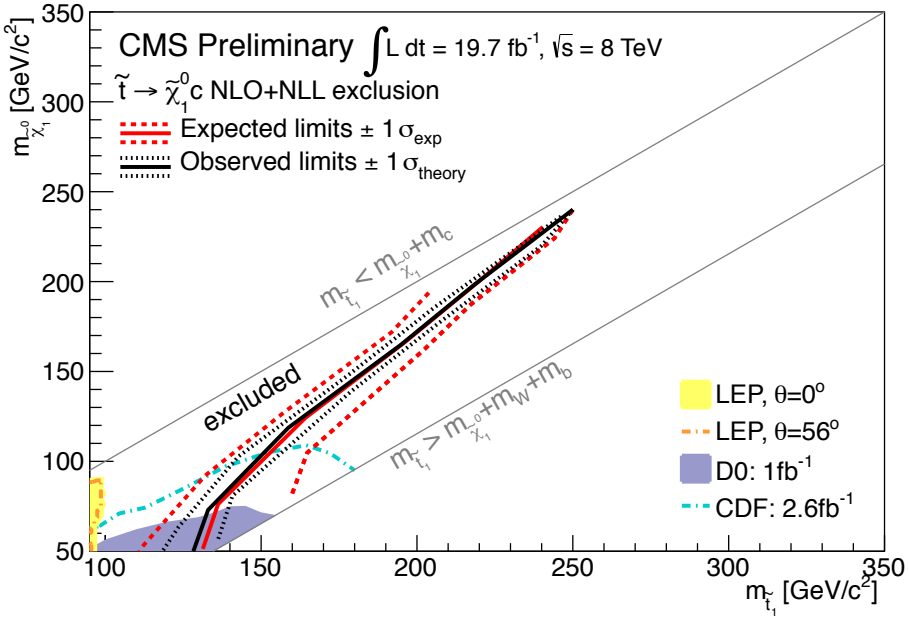


Require:
MET>250
1 or 2 jets, $p_T(j_2)>60$, $|\eta|<4.5$
$\Delta\phi(j_1, j_2)<2.5$
Lepton veto

Search with varying $p_T(j_1)$ thresholds.

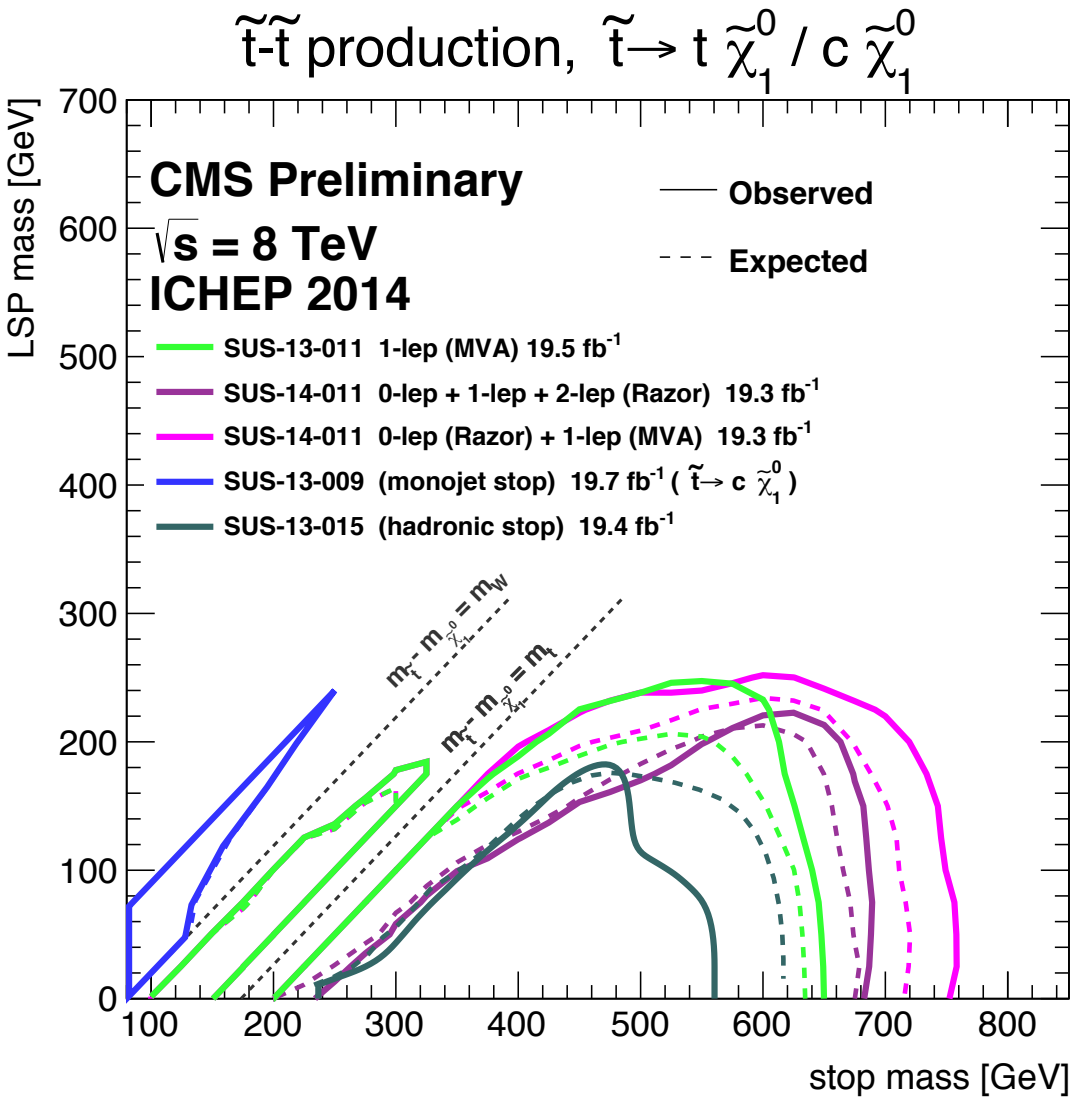
``Charmed'' search

$p_T(j_1)$ (GeV/c)	> 250	> 300	> 350	> 400	> 450	> 500	> 550
$Z \to \nu\nu$+jets	21209±1115	10077±592	4597±324	2250±197	1250±137	663±94	334±65
W+jets	12328±707	5939±366	2690±180	1246±92	627±52	301±29	150±18
$t\bar{t}$	602±301	344±172	178±89	91±46	48±24	27±14	18±9.0
$Z \to \ell\ell$+jets	127±64	75±38	40±20	25±13	17±8.3	11±5.6	7.4±3.7
Single t	172±86	97±49	49±24	21±10	11±5.7	5.2±2.6	3.2±1.6
QCD Multijets	786±473	508±306	304±184	162±99	80±49	52±32	28±18
DiBoson	639±320	369±184	206±103	113±56	64±32	36±18	21±10
Total SM	35862±1474	17409±803	8064±437	3907±250	2098±160	1096±106	563±71
Data	36582	17646	8119	3896	1898	1003	565



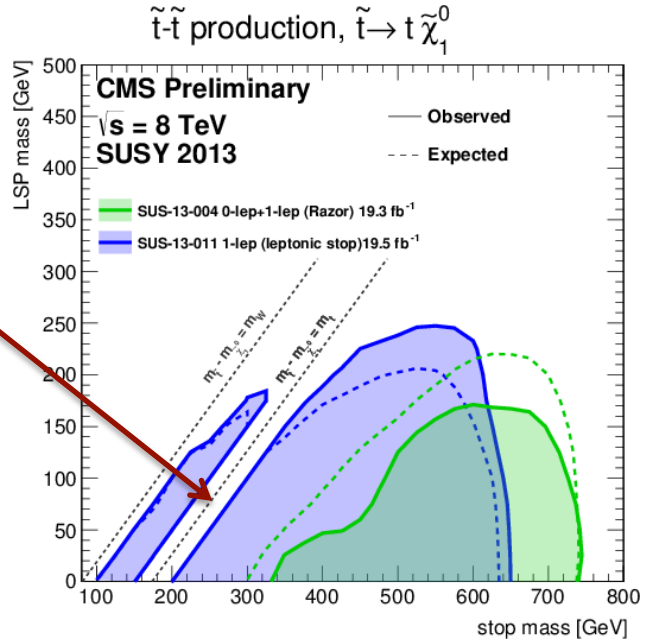
CMS-PAS-SUS-13-009

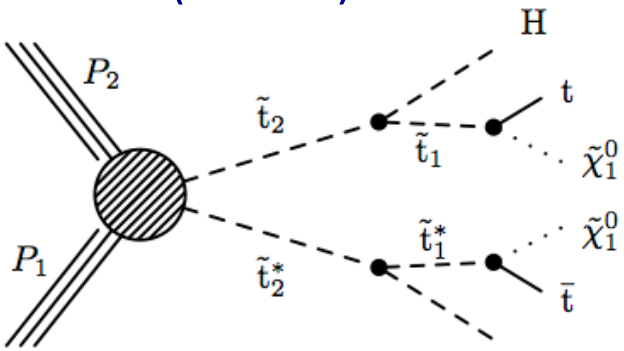
Stop results

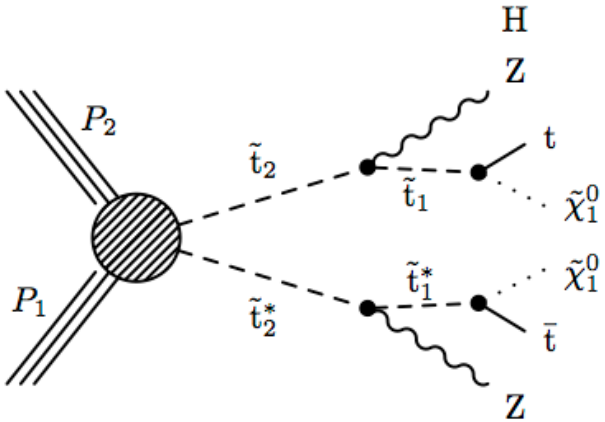


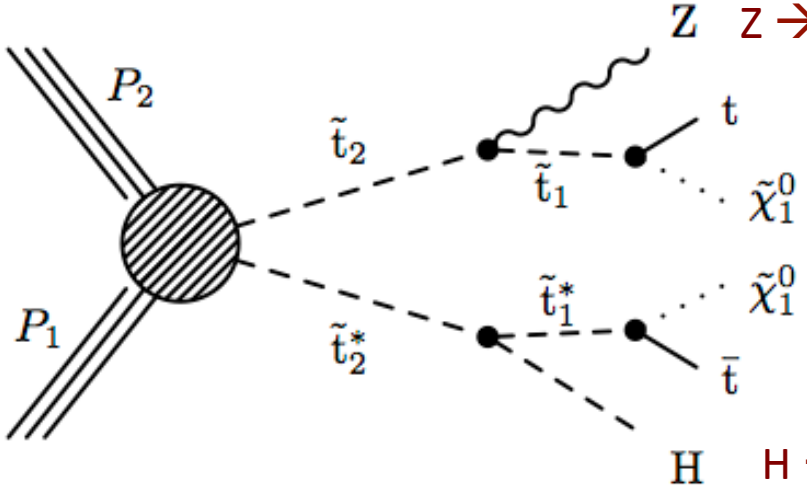
stop$_2$ searches

- If $\Delta m \sim m_{top}$, $\tilde{t}_1$ signal is very similar to SM top pair production and there is little sensitivity with the existing searches.
- Look for relatively light $\tilde{t}_2$ that decays to $\tilde{t}_1$
- Signature: same final state as $\tilde{t}_1 \rightarrow$ t LSP, but with multiple additional leptons (from Z) and/ or b (from H)









Z → dilepton signature

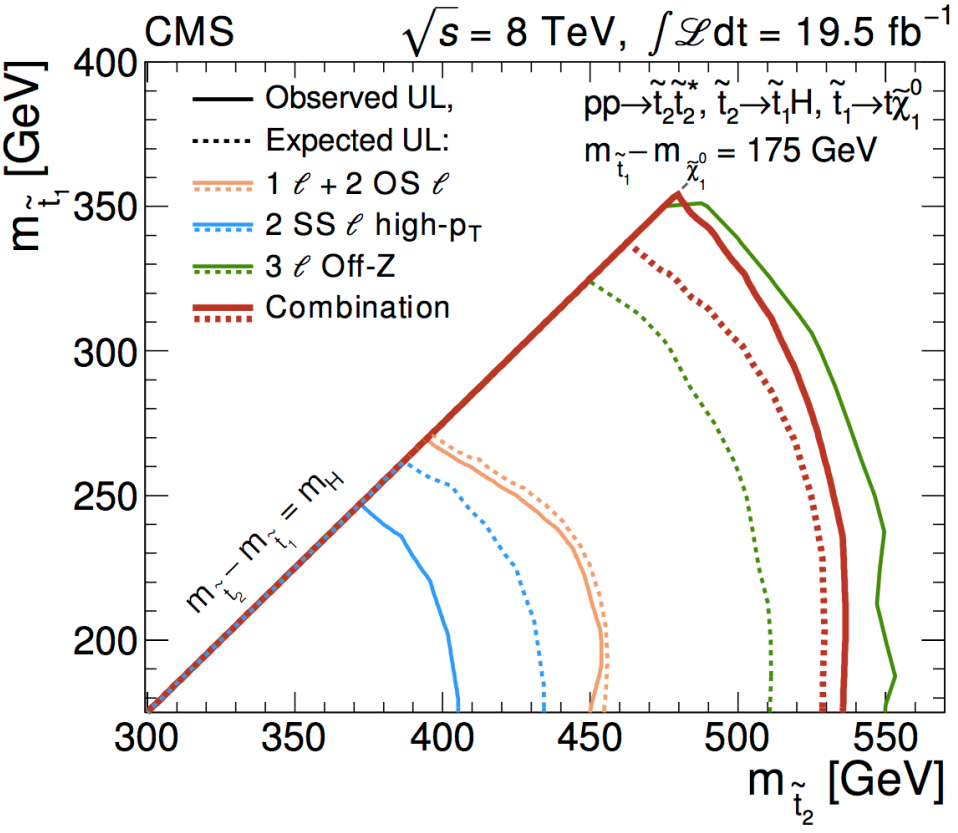
Use Higgs to tag SUSY signatures!

H → bbbar signature

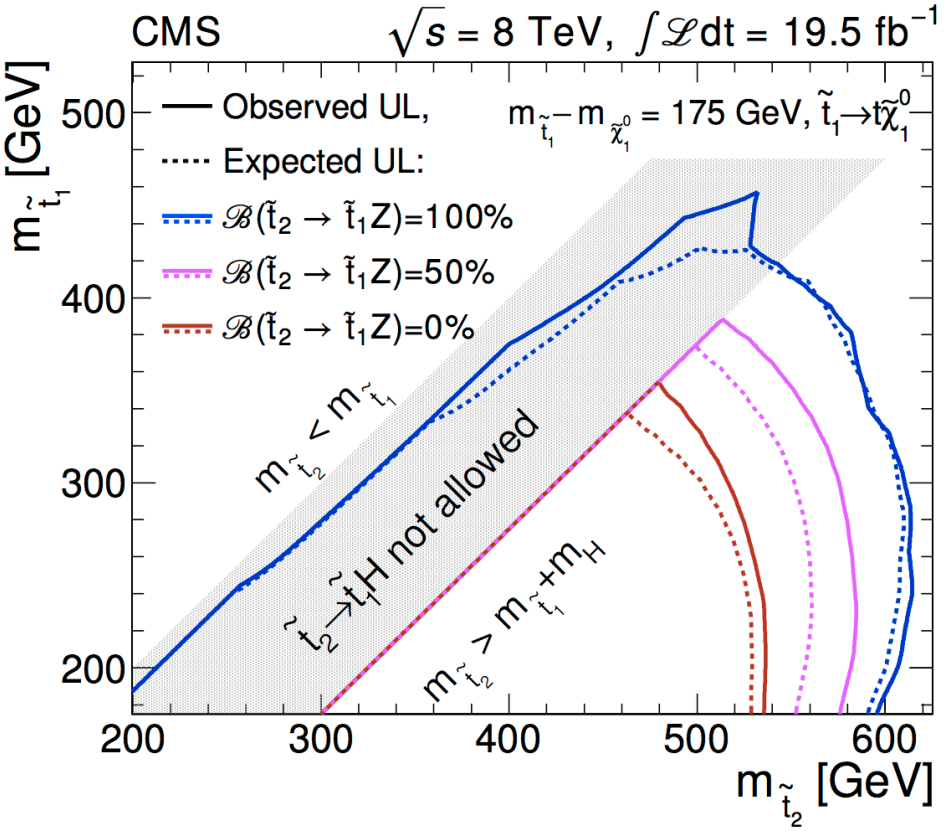
CMS: arXiv:1405.3886

stop$_2$ searches

Combine the results of all three lepton analyses
Exclusivity through lepton counting



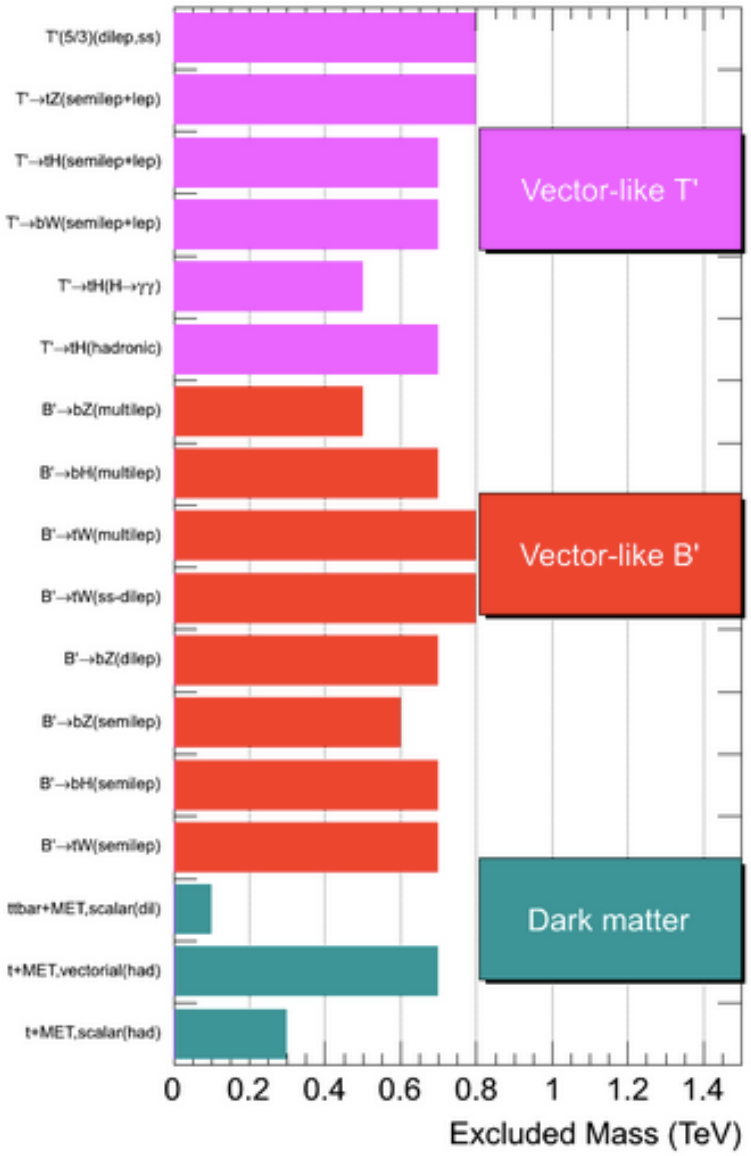
Decay with H



Mixed branching ratio scenario

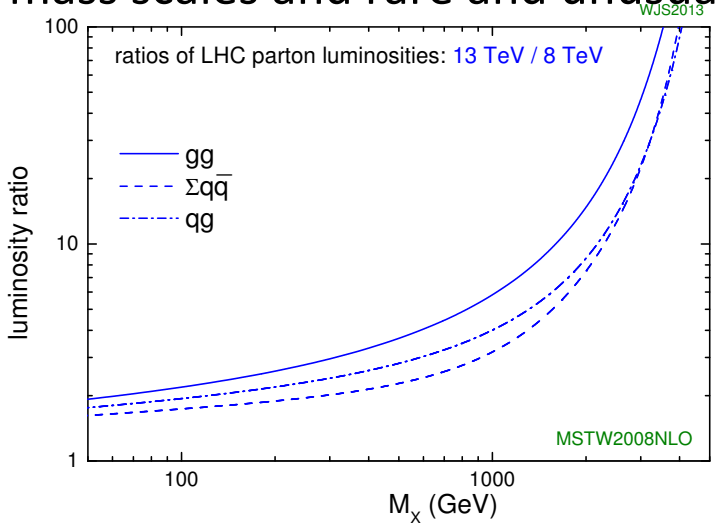
Fermionic top partners

- Fourth generation models
  - Heavy neutrino→ dark matter candidate
  - Large CP violation
- Vector-like quarks (VLQs) [non-chiral fermions]
  - Predicted by a large variety of models
    - Little Higgs models
    - Warped extra dimensions
    - Composite Higgs model
  - Not excluded by Higgs cross sections



Summary & Conclusions

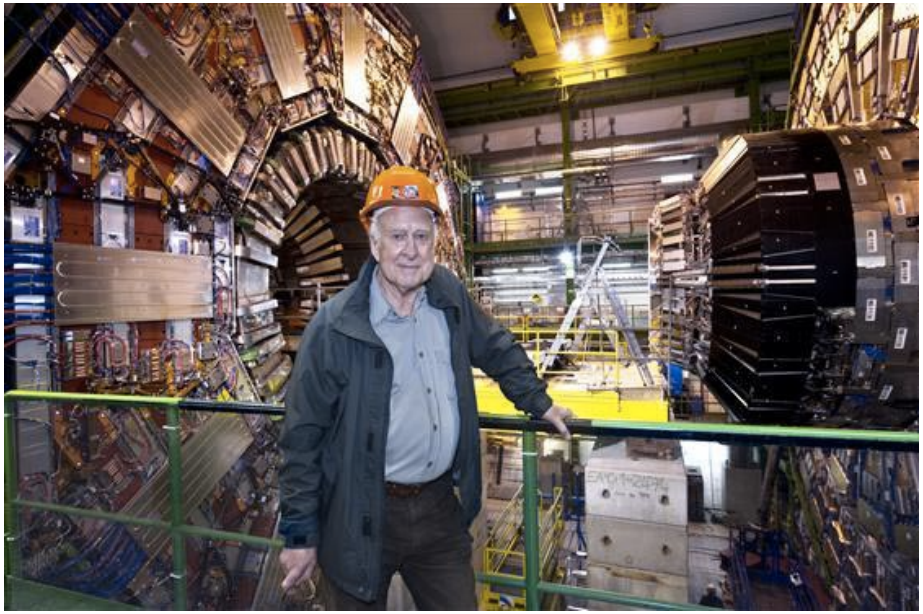
- Wide range of measurements and searches being performed by CMS
  - Precision measurements, studies of the Higgs boson
  - Searches for new physics beyond the Standard Model
- Searches cover comprehensive spectrum of final states
  - Exclude large regions of parameter space
  - Lots of progress in exploring difficult regions of parameter space/ complicated/boosted final states
- The Run II LHC dataset will provide even greater sensitivity to new physics discoveries
  - Explore new mass scales and rare and unusual processes



Summary & Conclusions

2008:

Only Higgs seen at LHC so far!



Summary & Conclusions

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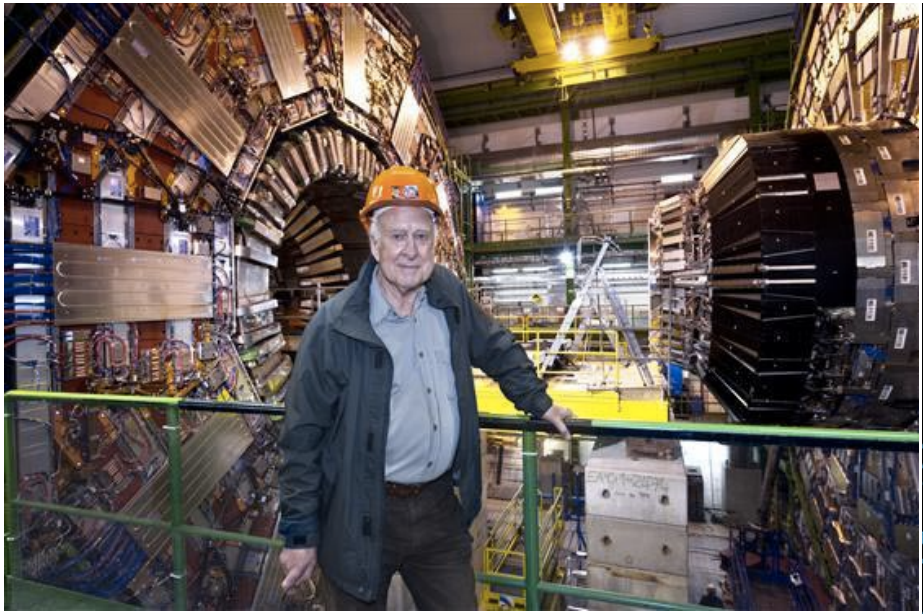

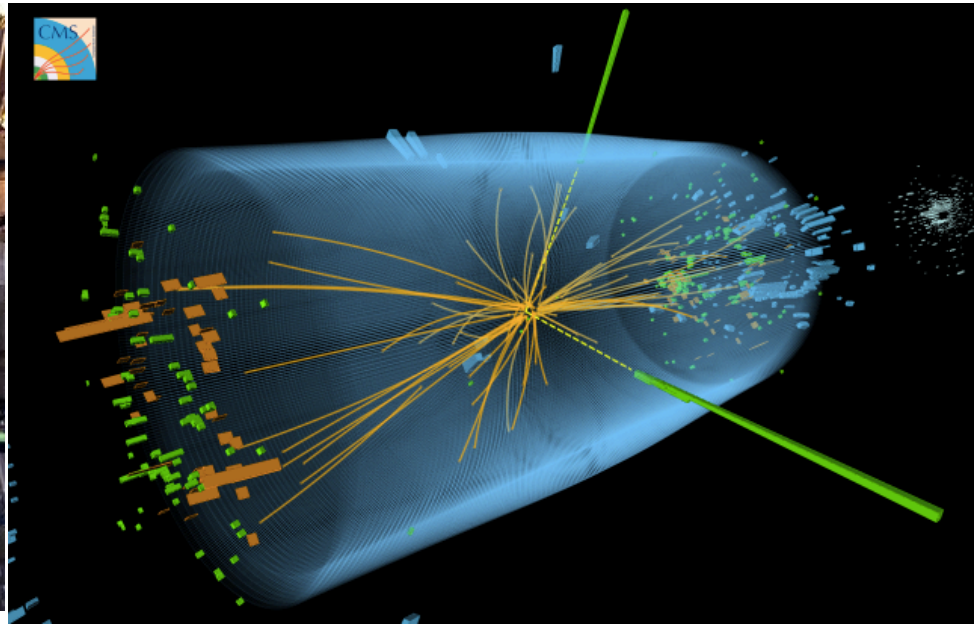

Summary & Conclusions

http://cp3-origins.dk/a/4276

News Flash 2016

all the news that is yet to print

The New York Times

Exotic Top Partner Discovered

By THE FREE ASSOSIATION PRESS**

The scientific community was rocked yesterday when the CMS collaboration announced the discovery of a strange new heavy particle in a press conference at CERN. “This is an historic occasion.”, said the CERN director, congratulating the team that led the effort…

** Credit: Hal Evans