

Composite Higgs and Naturalness overview - Experiment

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**UNIVERSITÉ
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Signature-Driven Searches

■ Many extensions of the SM have been developed over the past decades:

- Supersymmetry
- Extra-Dimensions
- Technicolor(s)
- Little Higgs
- No Higgs
- GUT
- Hidden Valley
- Leptoquarks
- Compositeness
- 4th generation (t', b')
- LRSM, heavy neutrino
- etc...

- 1 jet + MET
- jets + MET
- 1 lepton + MET
- Same-sign di-lepton
- Dilepton resonance
- Diphoton resonance
- Diphoton + MET
- Multileptons
- Lepton-jet resonance
- Lepton-photon resonance
- Gamma-jet resonance
- Diboson resonance
- Z+MET
- W/Z+Gamma resonance
- Top-antitop resonance
- Slow-moving particles
- Long-lived particles
- Top-antitop production
- Lepton-Jets
- Microscopic blackholes
- Dijet resonance
- etc...

• Not yet thought of



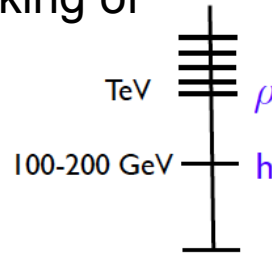
• Uncovered signature

• ...

- Broad mandate, agnostic way of searching: signature-based & model-independent
- Use models as guidance where to look
- Try to cover all possible signatures
- Interpret results using benchmarks

Composite Higgs (CH) Paradigm

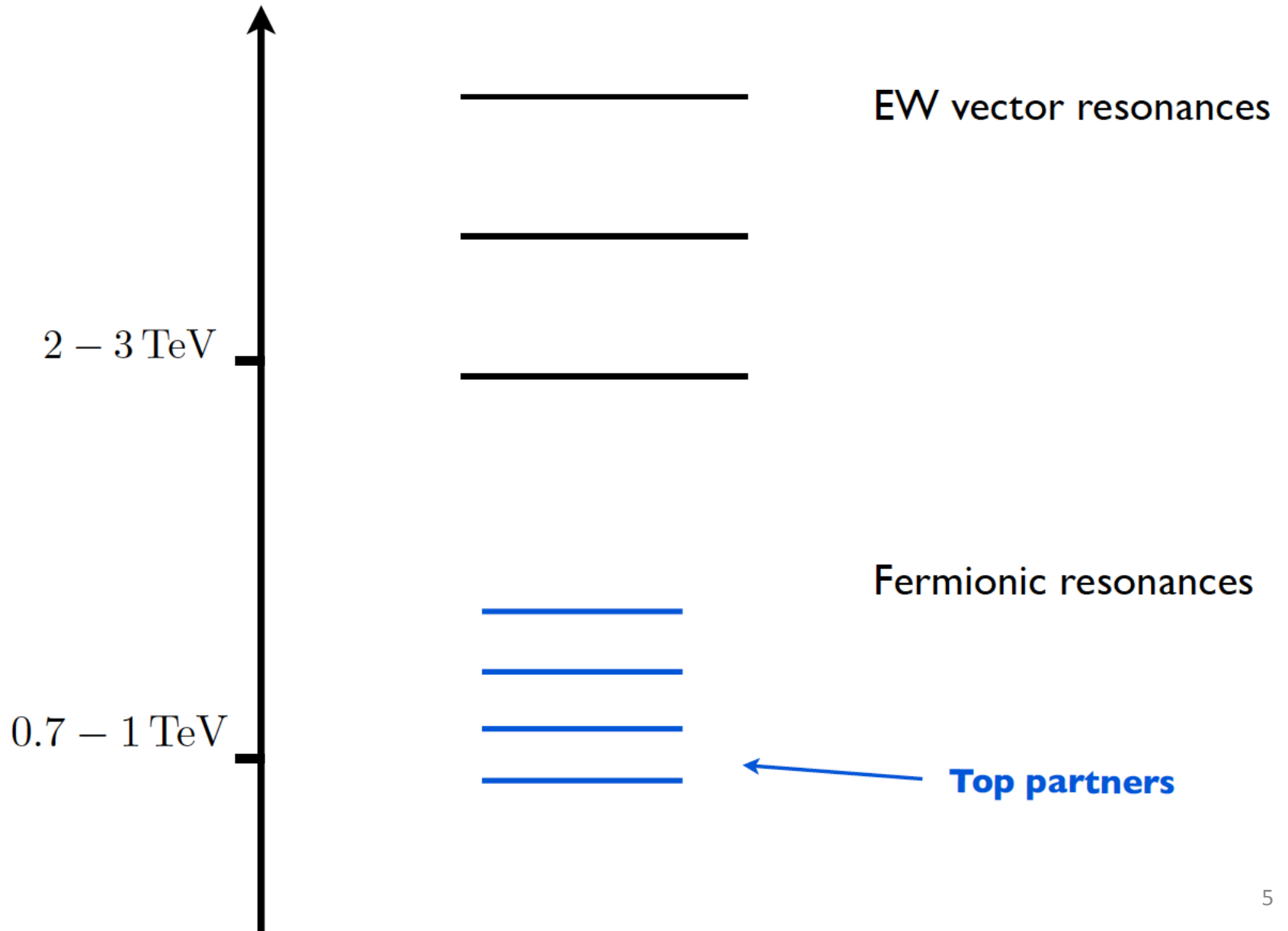
- Models where the Higgs boson is a composite state give a natural solution to the hierarchy problem
- DM can be incorporated naturally in CH models
- The Higgs boson can be light if it is a PNGB emerging from the breaking of a global symmetry (e.g. $SO(5) \rightarrow SO(4)$)
 - Just like π much lighter than ρ (in QCD)
- Partial compositeness:
 - SM fermions mix linearly with composite fermions
 - Fermion mass generation needs separate composite partner for each SM fermion
- Many models exist; CH also *dual* to gravity in higher dimensions / RS (5D field theory is perturbative = calculable)



Basic Phenomenology

- New heavy gauge bosons (to fully unitarize Vector boson scattering) → Drell-Yan produced Z' , W' , KK g
 - Strong coupling limit, mainly decays to WW , WZ , Wh , Zh , $t\bar{t}$, $t\bar{b}$
- New fermionic resonances (usually lighter than gauge bosons, tame radiative corrections to Higgs from top quark) → top/bottom partners
- Not subject of this talk:
 - Twin Higgs: displaced vertex signatures → see Matt Strassler in panel “What have we missed”
 - (Partially) composite top quark can be strongly coupled to the resonances of the EWSB sector → anomalous top-Higgs interactions ($t\bar{t}H$ → more in Run II)
 - Deviations in Higgs couplings to fermions and vector bosons, see e.g. ATLAS-CONF-2014-010
 - EWPTs

Possible Spectrum



Top/Bottom Partners aka VLQs

- Considering four different kinds of Vector-Like Quarks (VLQs) with different charge
- Come in singlets, doublets, triplets

– T (+2/3)

– B (-1/3)

– X (+5/3) – aka $T_{5/3}$

– Y (-4/3)

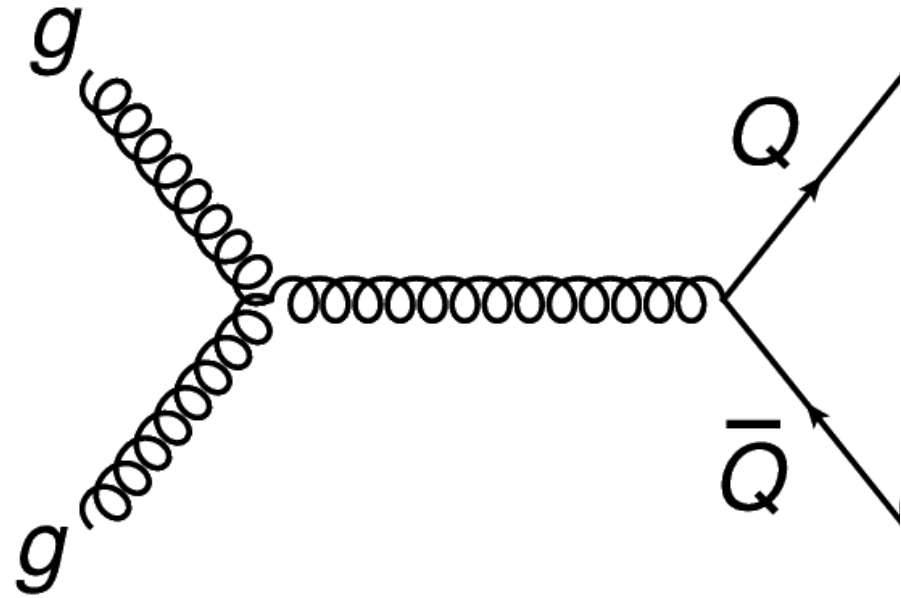
JHEP 11, 030 (2009)

(triplets not included)

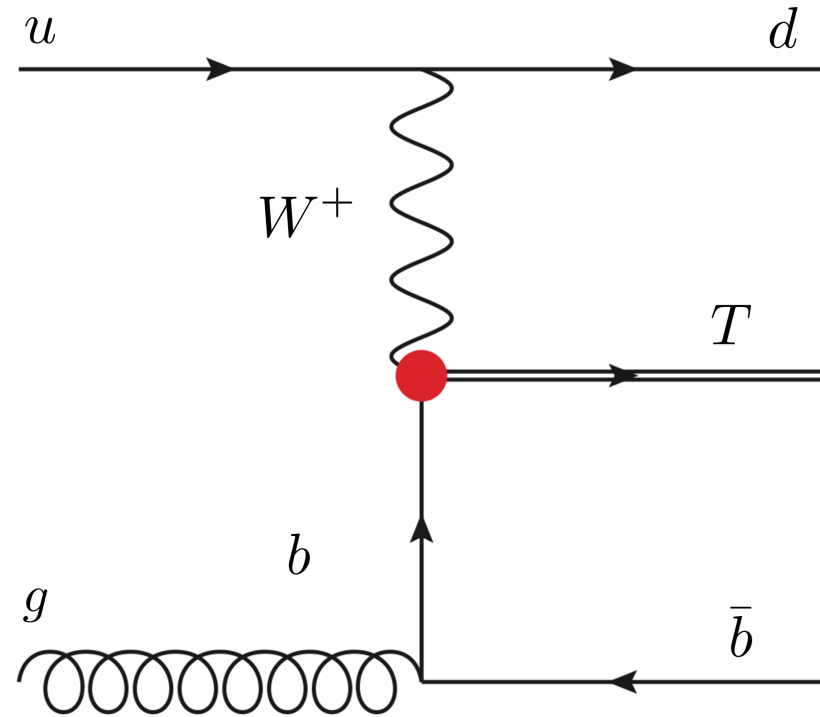
| | Label | Charge | Decay mode |
|---------------|--------------|---------------|--|
| T singlet | T_s | +2/3 | $T \rightarrow W^+b, Zt, ht$ |
| B singlet | B_s | -1/3 | $B \rightarrow Wt, Zb, hb$ |
| (T,B) doublet | TB_d | (+2/3, -1/3) | $T \rightarrow W^+b, Zt, ht$ $B \rightarrow Wt, Zb, hb$ |
| (X,T) doublet | XT_d | (+5/3, +2/3) | $X \rightarrow W^+t$ $T \rightarrow Zt, ht$ |
| (B,Y) doublet | BY_d | (-1/3, -4/3) | $B \rightarrow Zb, hb$ $Y \rightarrow Wb$ |

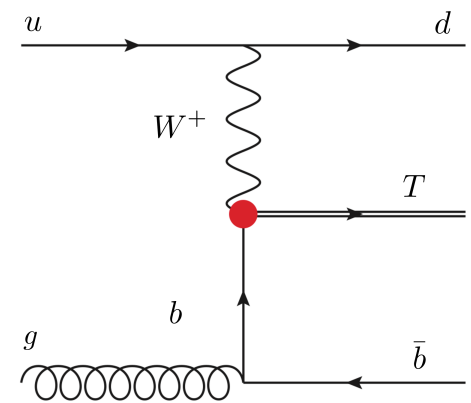
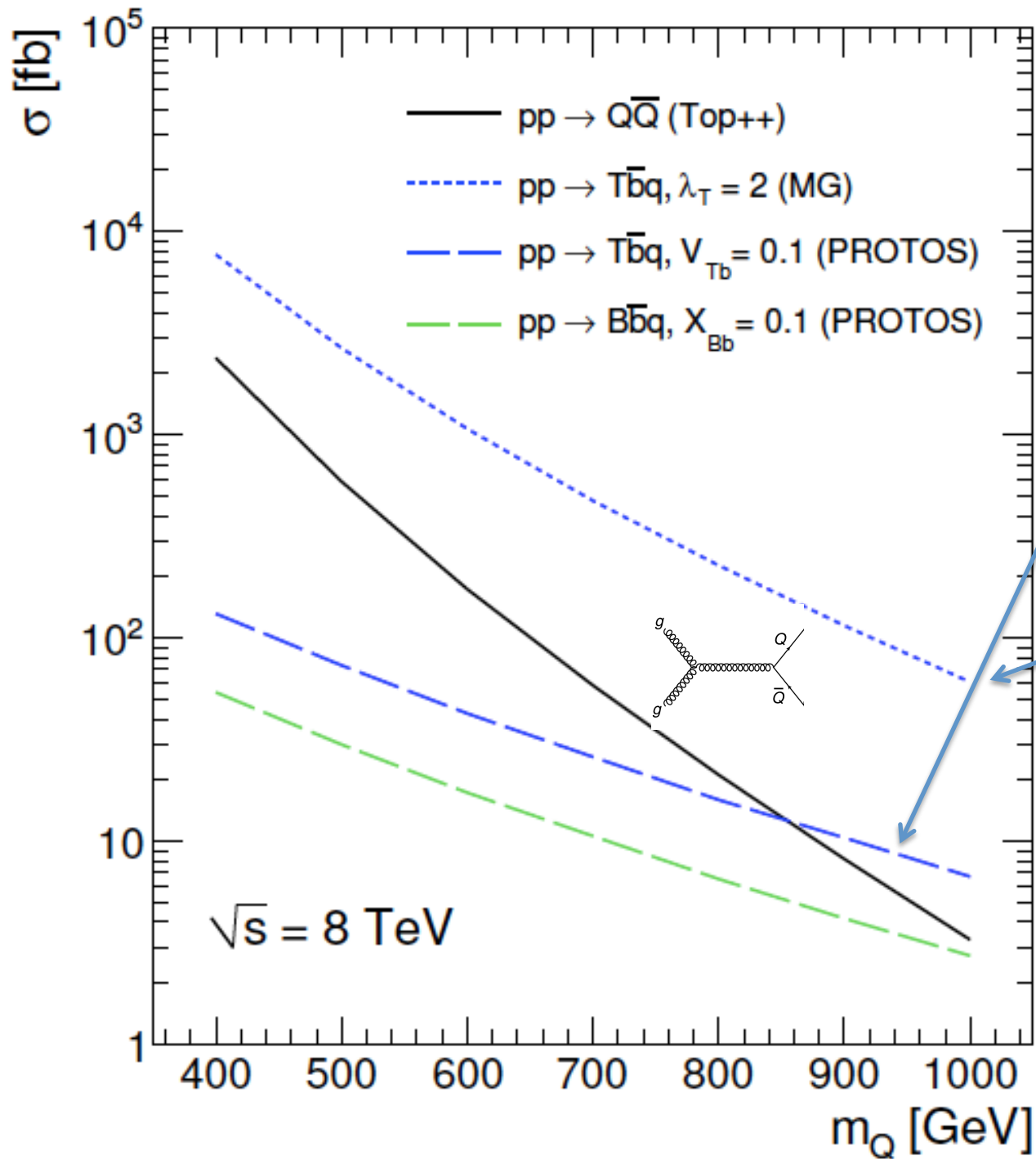
VLQ Production Modes at the LHC

- **Strongly produced in pairs:** large $Q\bar{Q}$ cross-section only dependent on mass (just like $t\bar{t}$)



- **Single production** dependent on mass, charge, coupling (like single top)

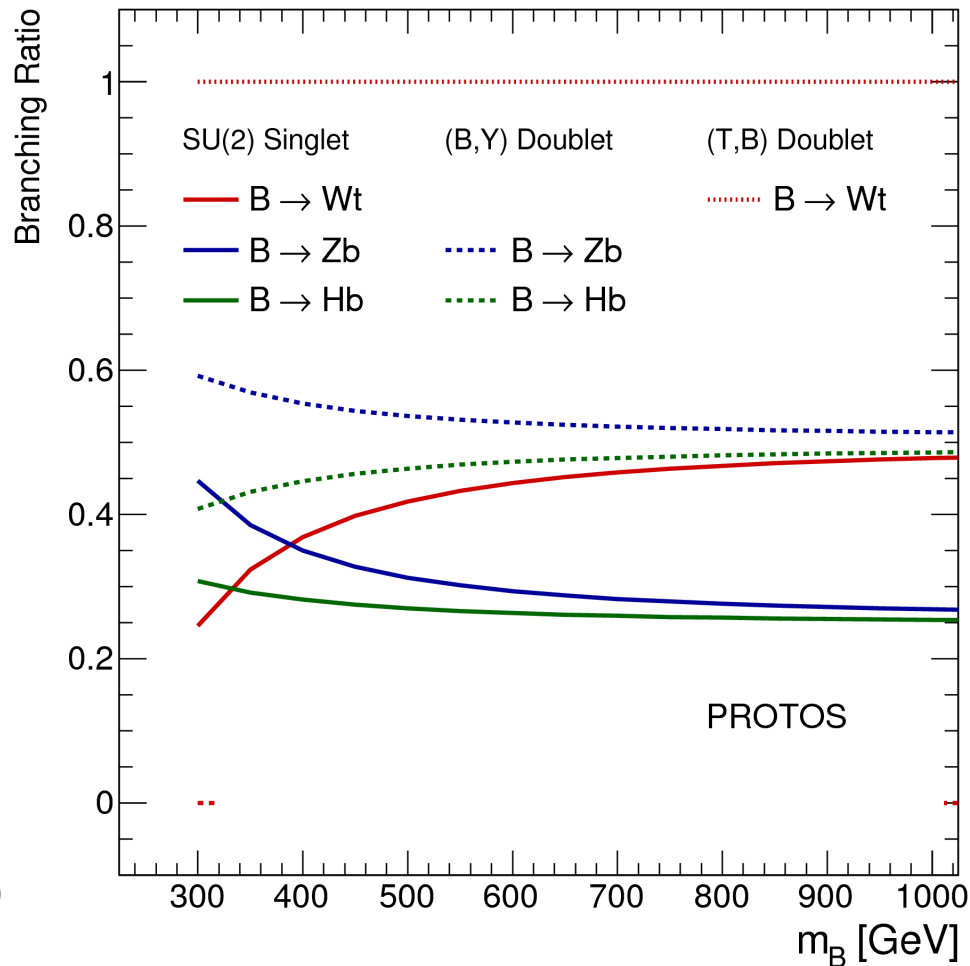
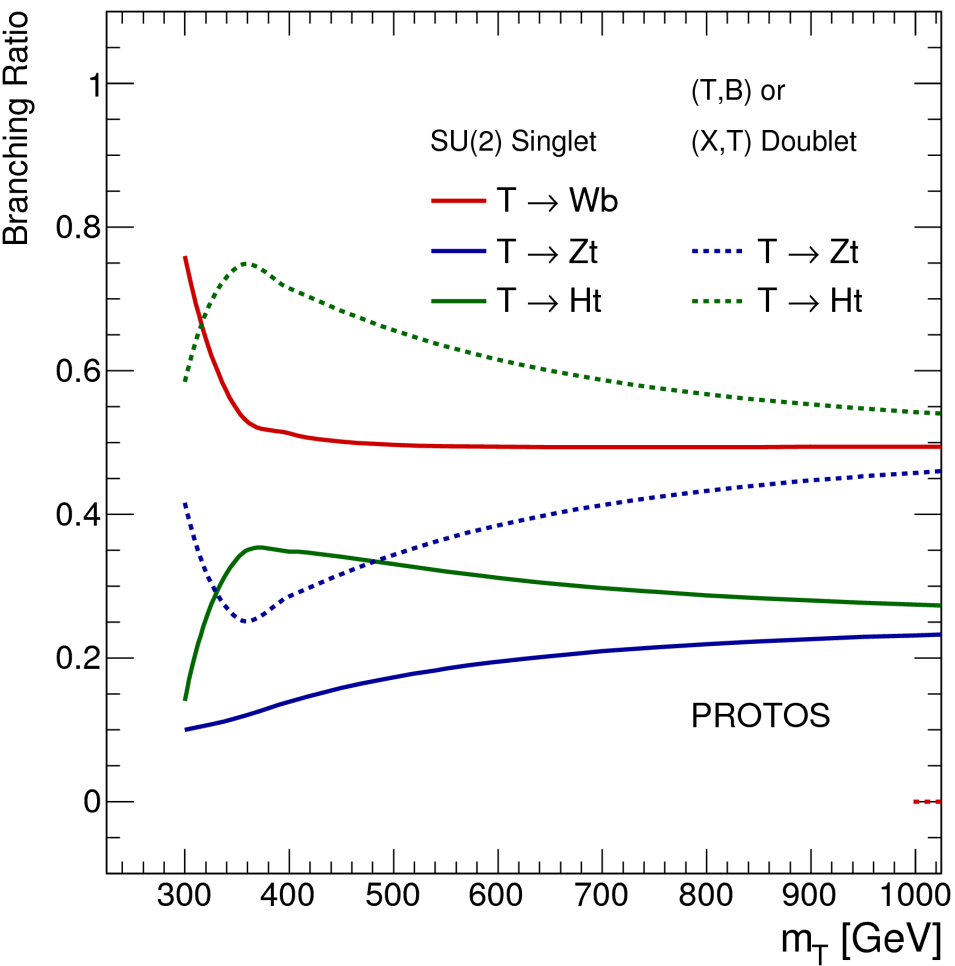




EWPTs:
 $V_{Tb} \leq 0.1$ (applies to single multiplet)
 Relaxed for >1 multiplet (well motivated in CH models)

VLQ Decay Modes

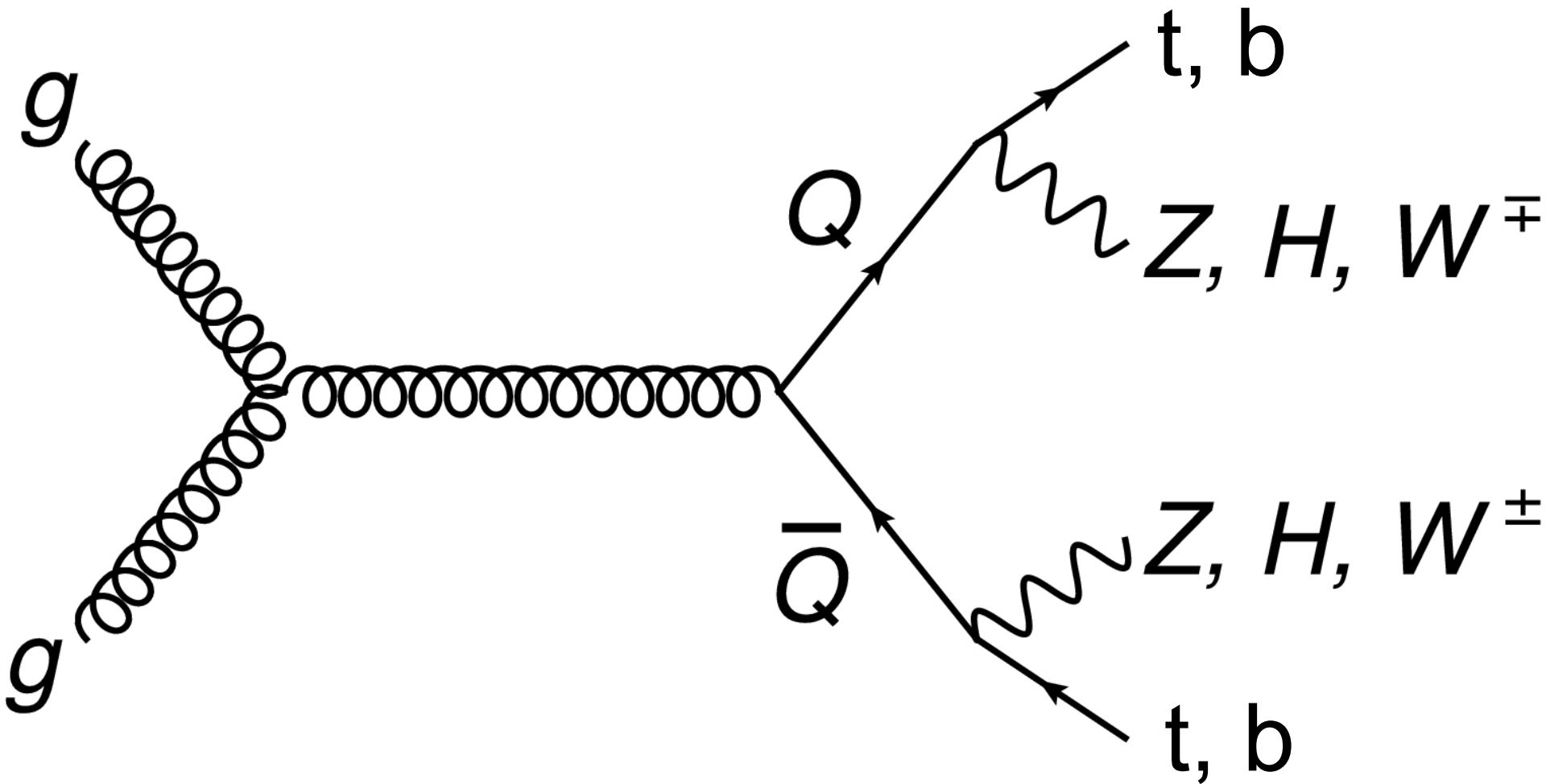
For (T,B) doublet assume $V_{Tb} \ll V_{tB}$



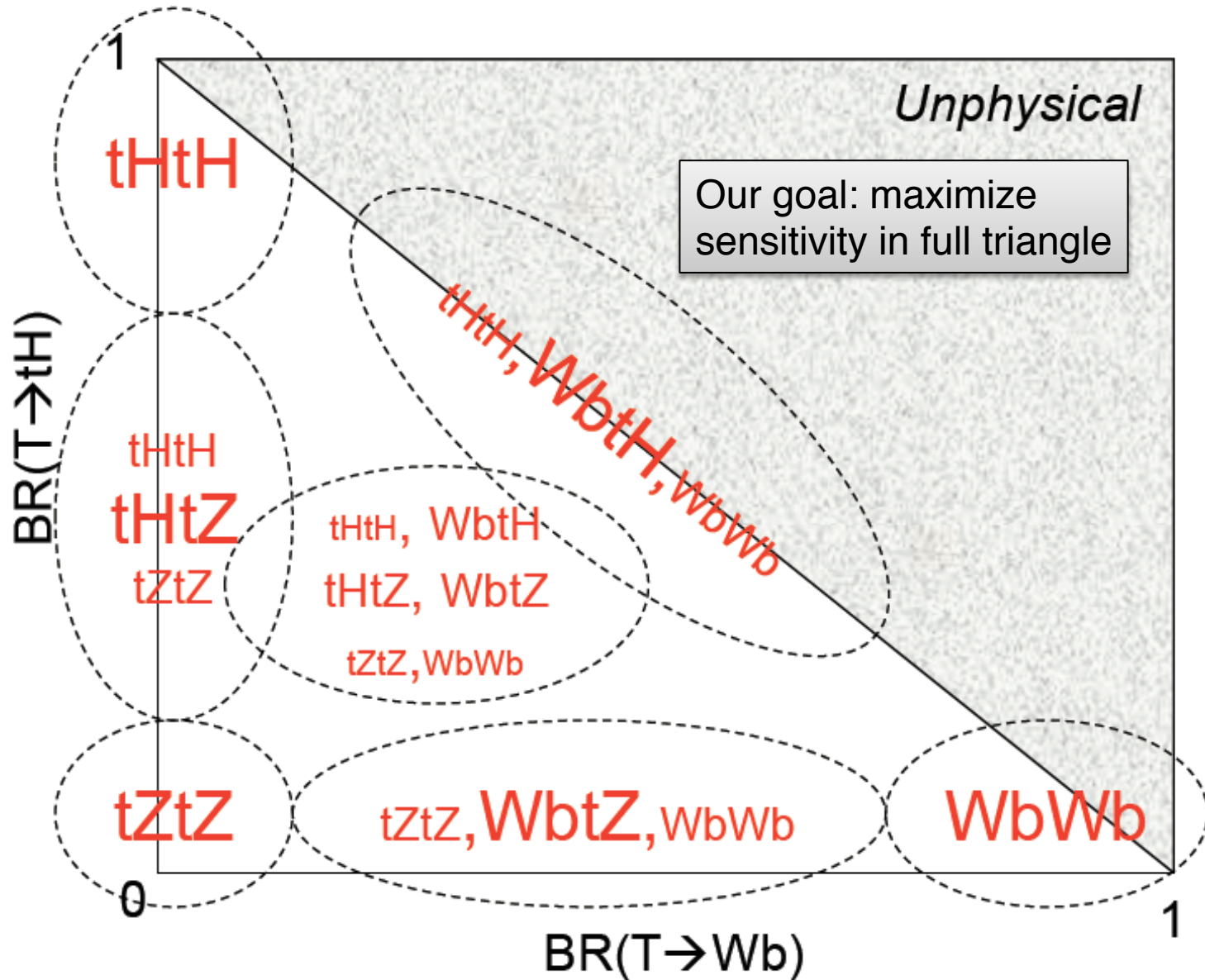
Difference in chirality of singlet and doublet couplings are typically negligible in the presented analyses

VLQ Pair Signature

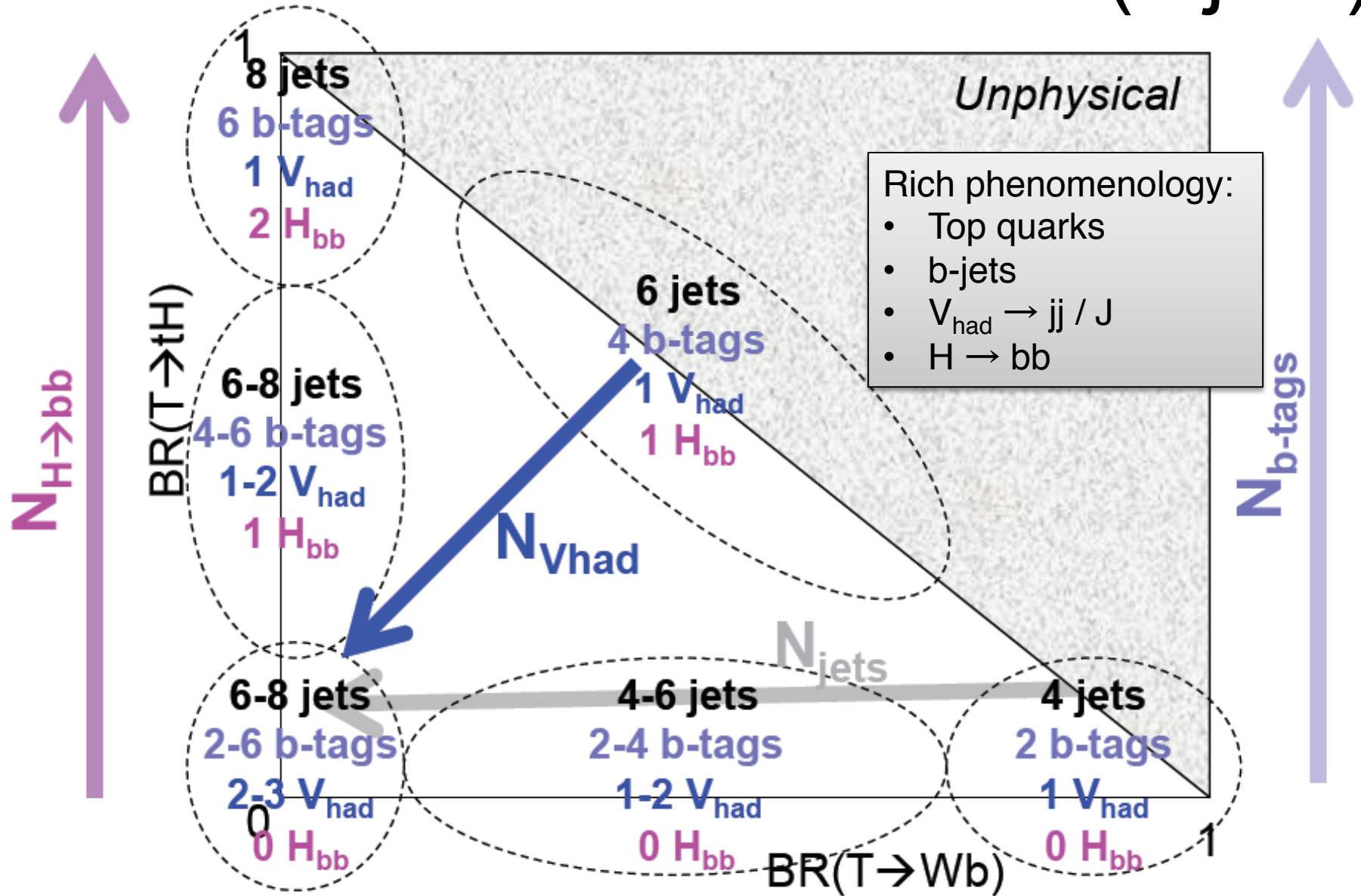
Spectacular signatures: boosted b-jets, tops, W, Z, H bosons



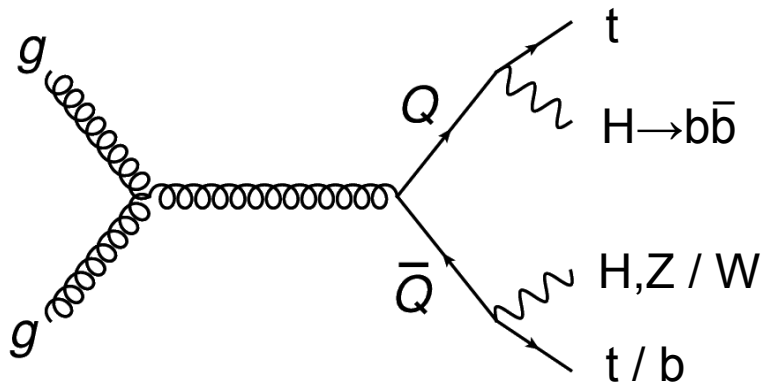
VLQ Pair Production: $T\bar{T}$



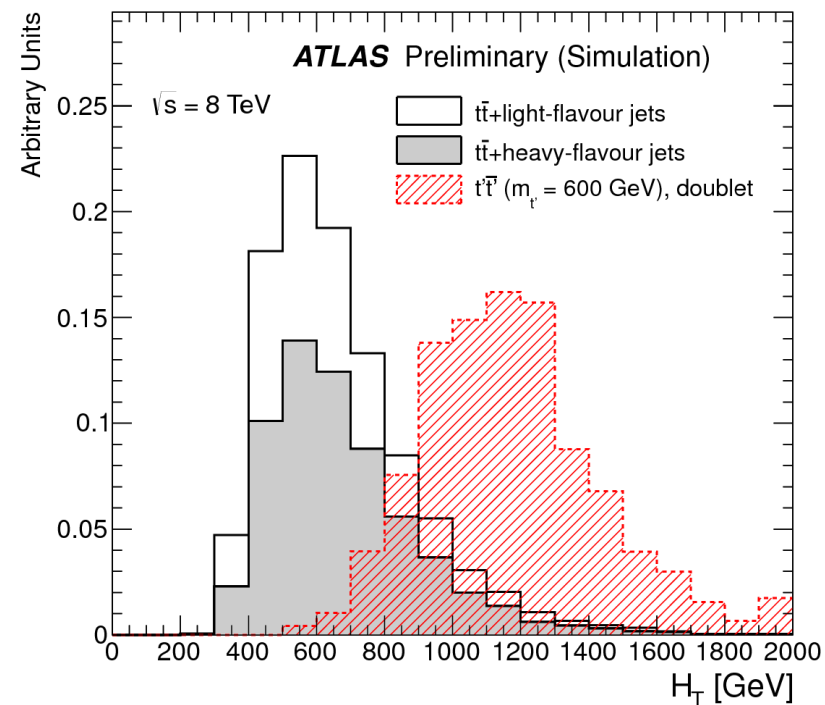
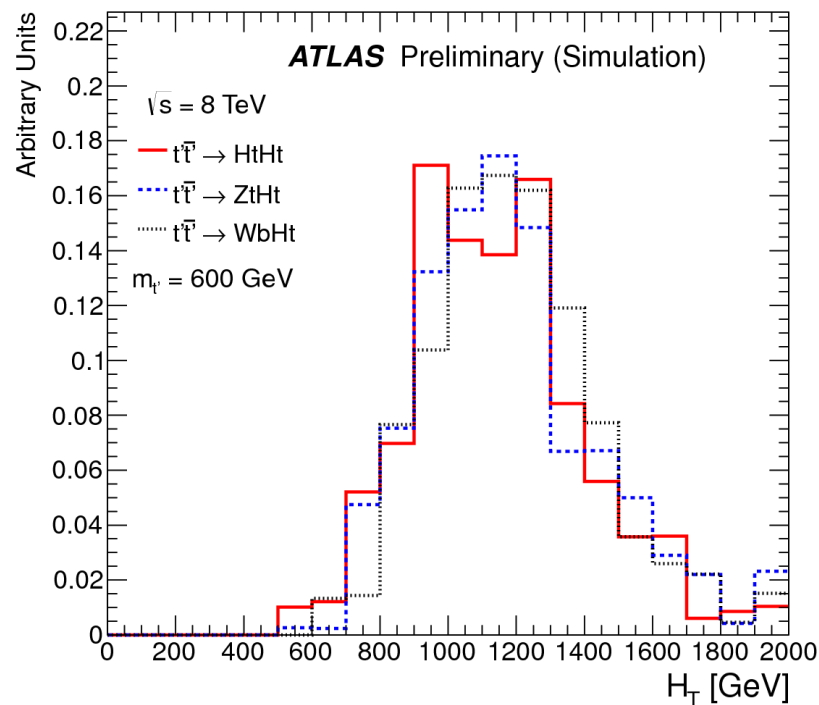
Possible Final States for $T\bar{T}$ (l+jets)



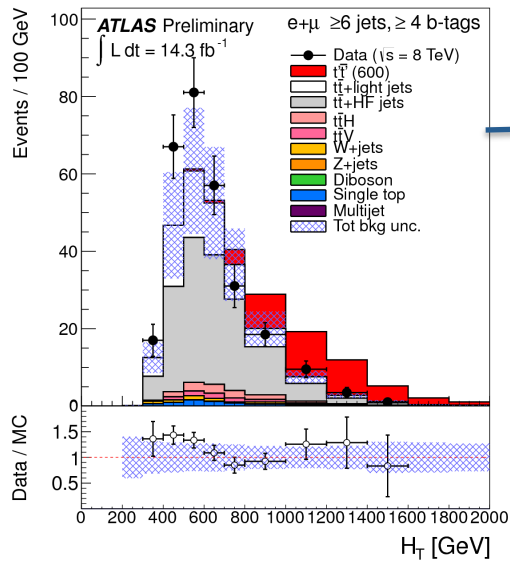
$T\bar{T} \rightarrow Ht+X$ Search Strategy (l+jets)



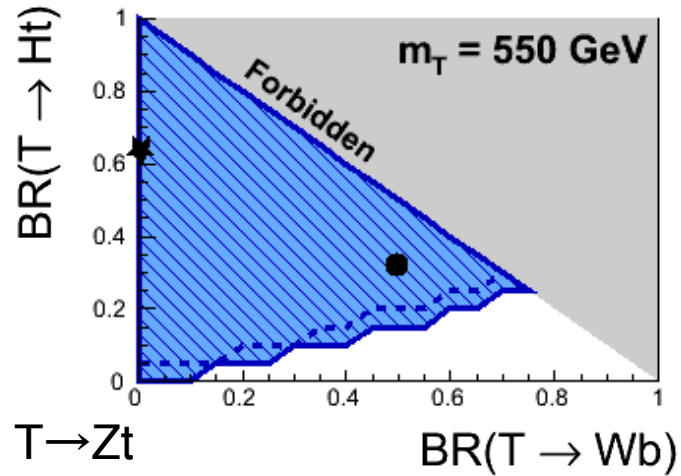
- Require lepton and MET ($W \rightarrow l\nu$)
- ≥ 6 jets
- ≥ 4 b-jets
- Final discriminant: $H_T(l, \nu, \text{jets})$



VLQ $T\bar{T}$ Search Strategy



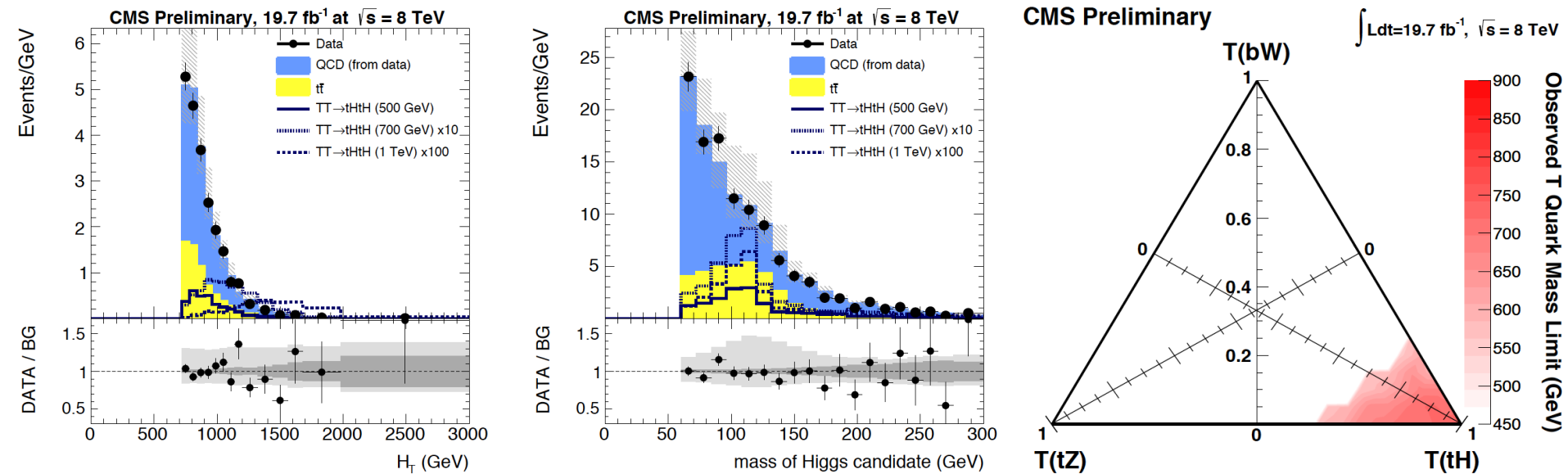
$Ht+X$ (l+jets)



VLQ $T\bar{T} \rightarrow HtH\bar{t}$ (all-hadronic)

- ≥ 2 CA $R=1.5$ jets, $p_T > 150$ GeV
 - ≥ 1 top candidate : HTT-tag + ≥ 1 b-tagged subjet
 - ≥ 1 Higgs candidate: 2 subjet b-tags & $m_{bb} > 60$ GeV

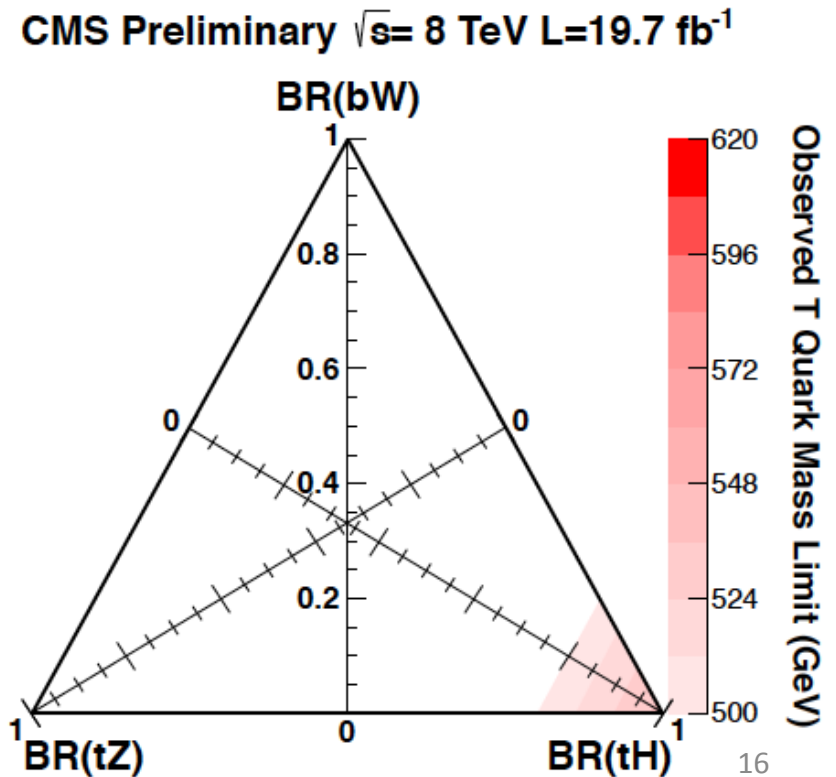
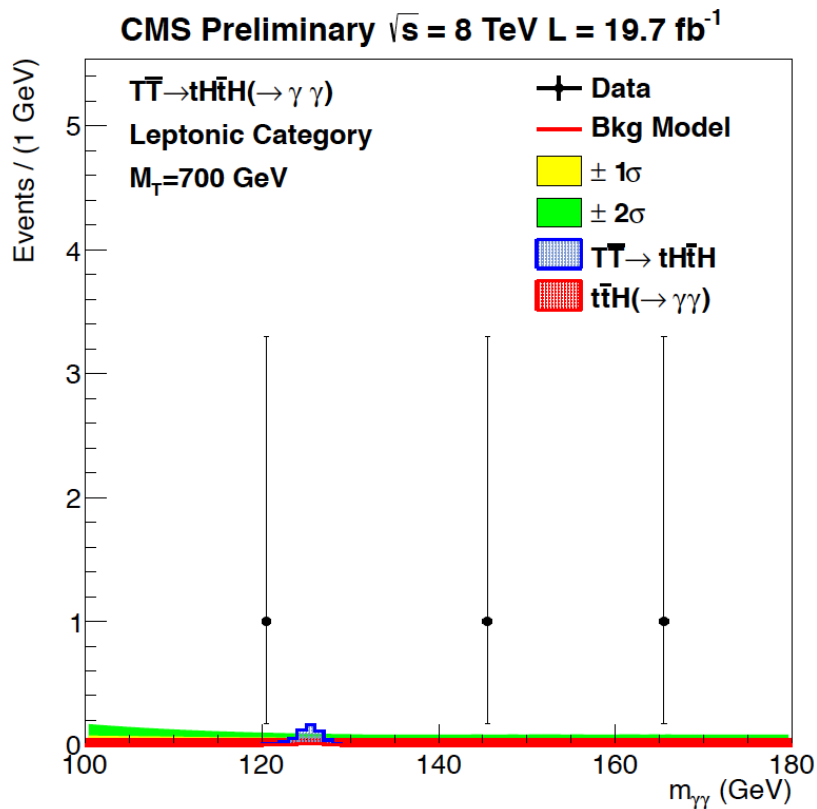
QCD BG estimated from data from sidebands of top- and Higgs-tag



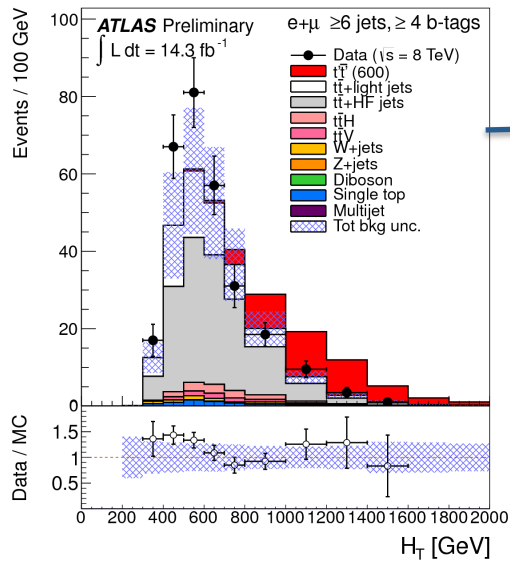
VLQ $Ht+X$, $H \rightarrow \gamma\gamma$

- Very high purity
- Loose kinematic selection (mainly H_T)
- Suffers from low $BR(H \rightarrow \gamma\gamma)$ – factor ~ 300 smaller than $BR(H \rightarrow b\bar{b})$

At high mass scale: kinematic cuts (e.g. H_T) & using dedicated ID for dominant decay modes typically work best (quite different for $t\bar{t}H$)

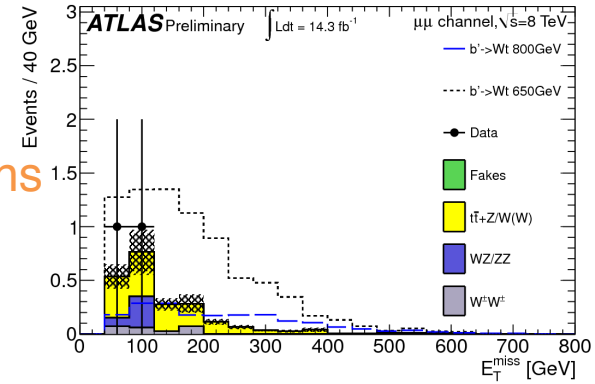
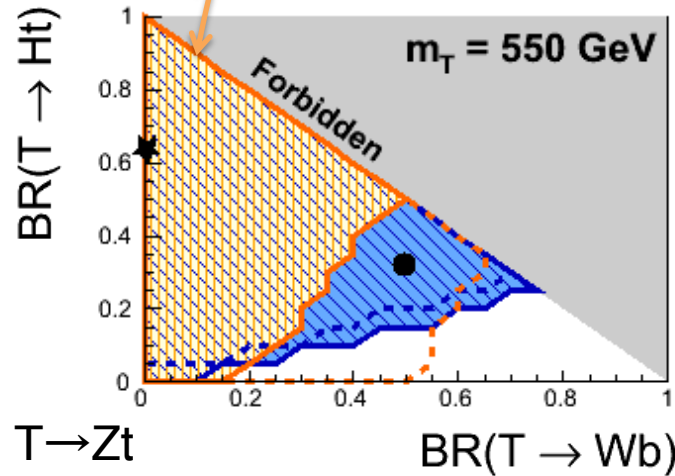


VLQ $T\bar{T}$ Search Strategy



Ht+X (l+jets)

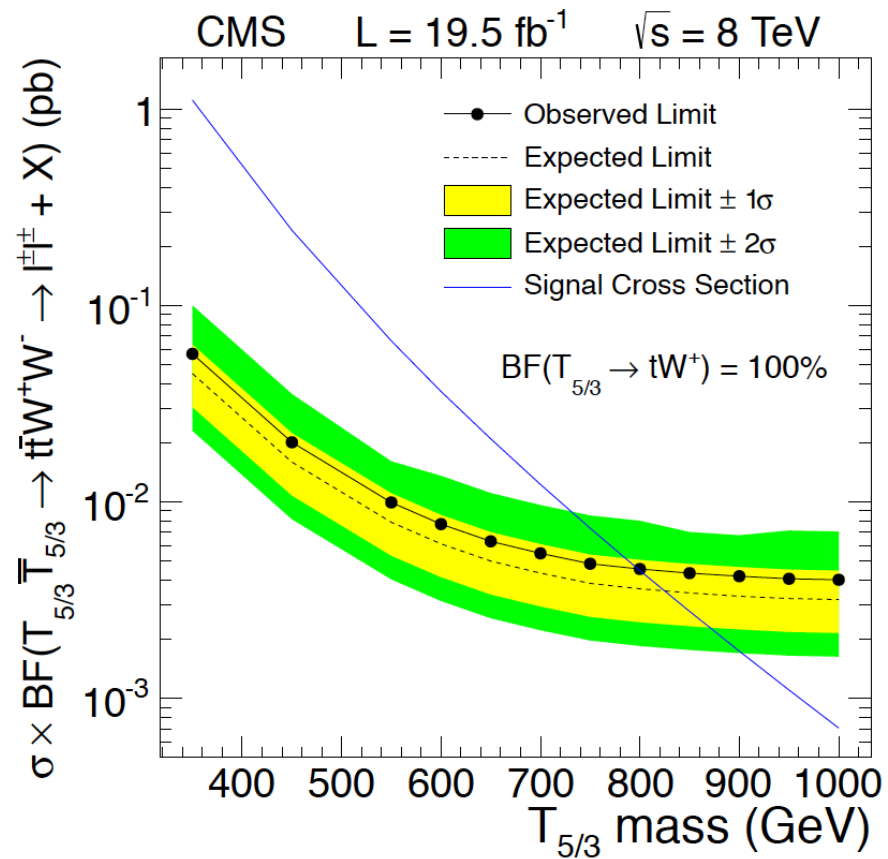
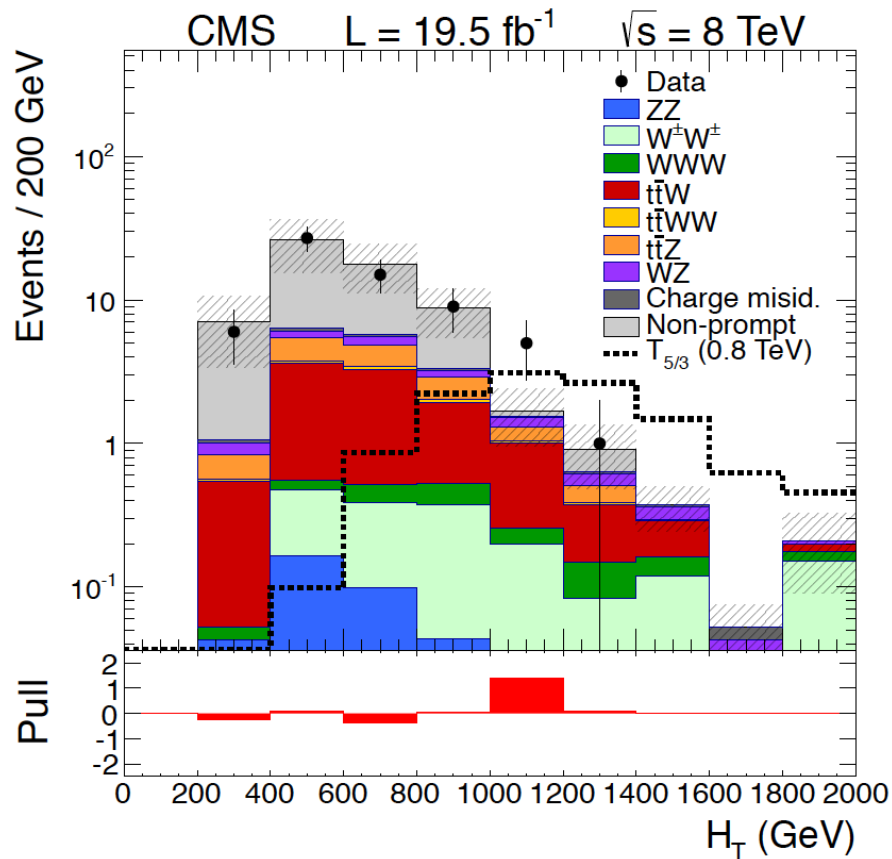
Same-sign leptons



(not a combination, just overlaying results)

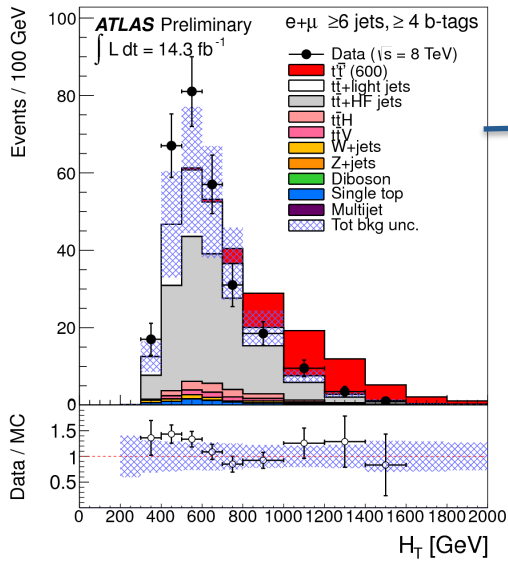
Same-Sign Lepton Search targeting $T_{5/3}$

Using top-tagging, boosted W-jets and H_T to reject the background



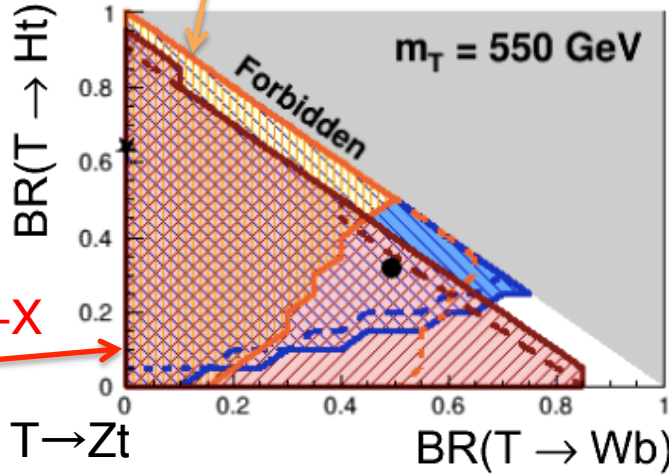
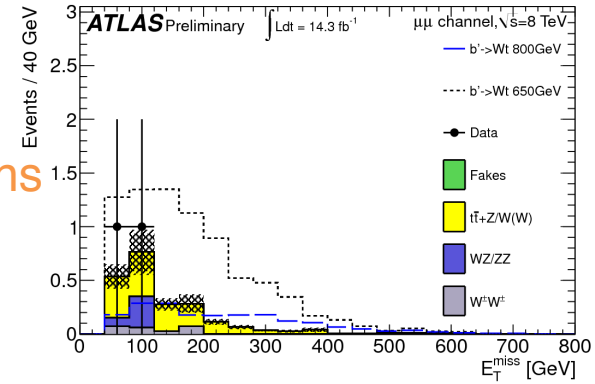
See also ATLAS-CONF-2012-130 for single $T_{5/3}$ production

VLQ $T\bar{T}$ Search Strategy

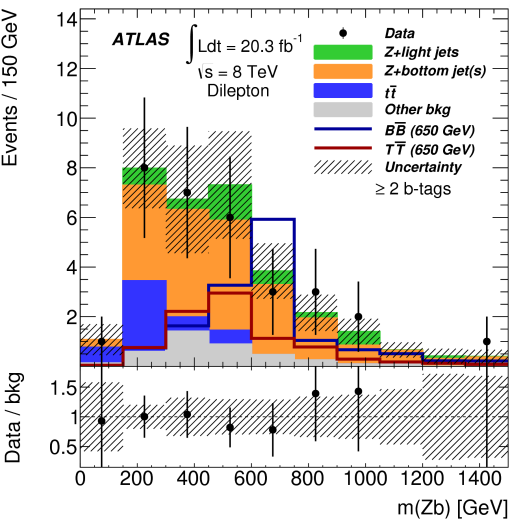


$Ht+X$ (l+jets)

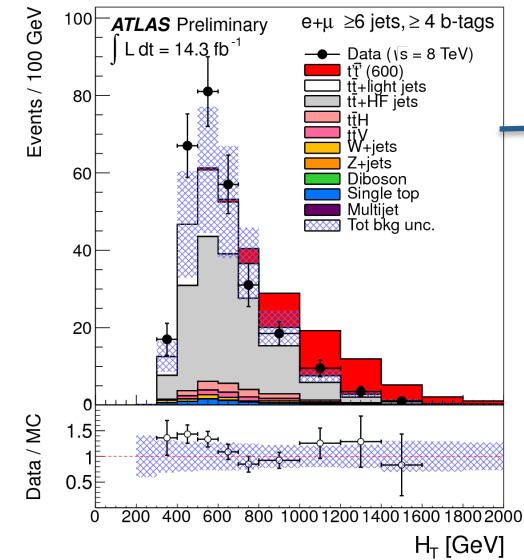
Same-sign leptons



$Z(\rightarrow ll)t+X$

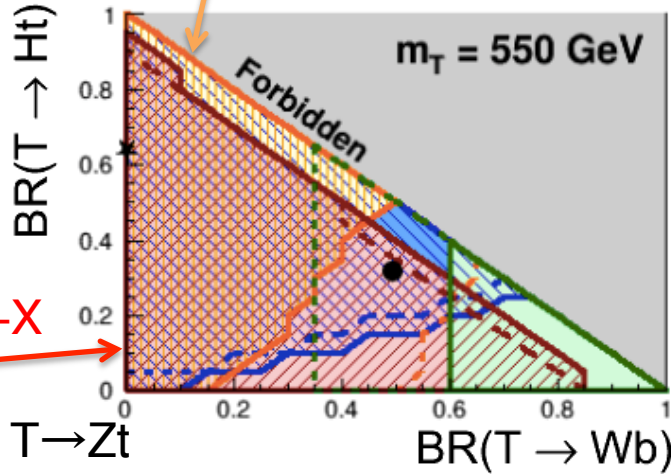
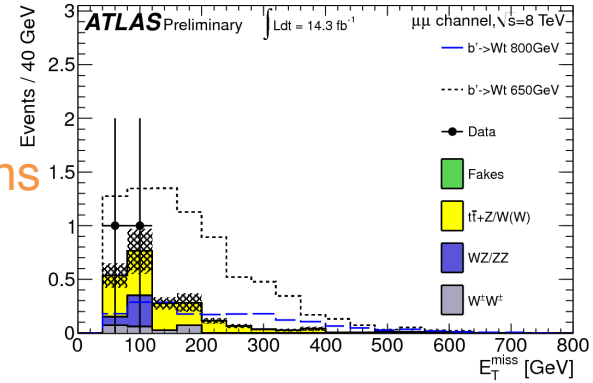


VLQ $T\bar{T}$ Search Strategy

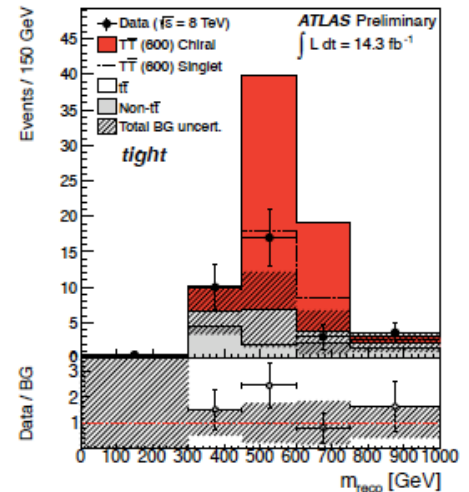
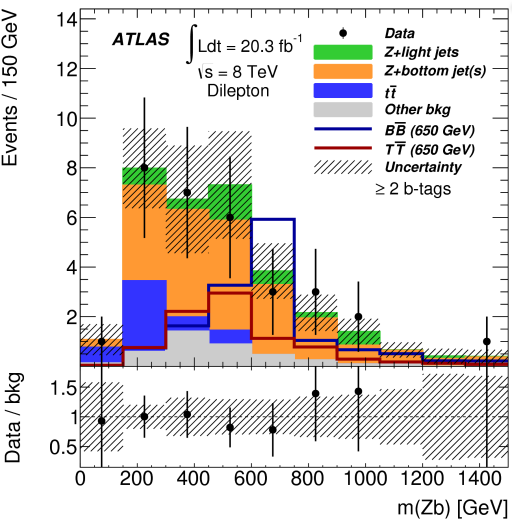


Ht+X (l+jets)

Same-sign leptons

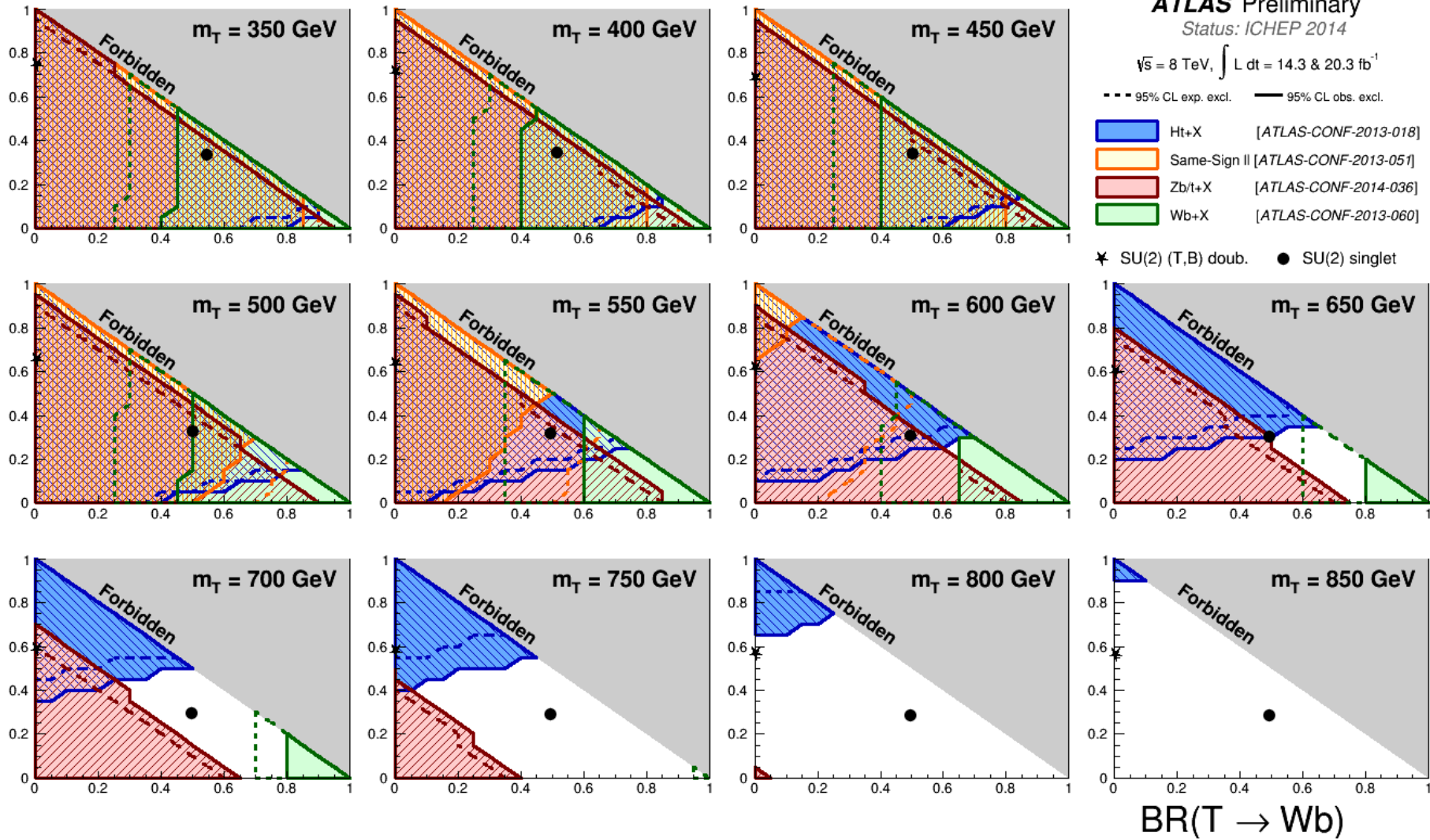


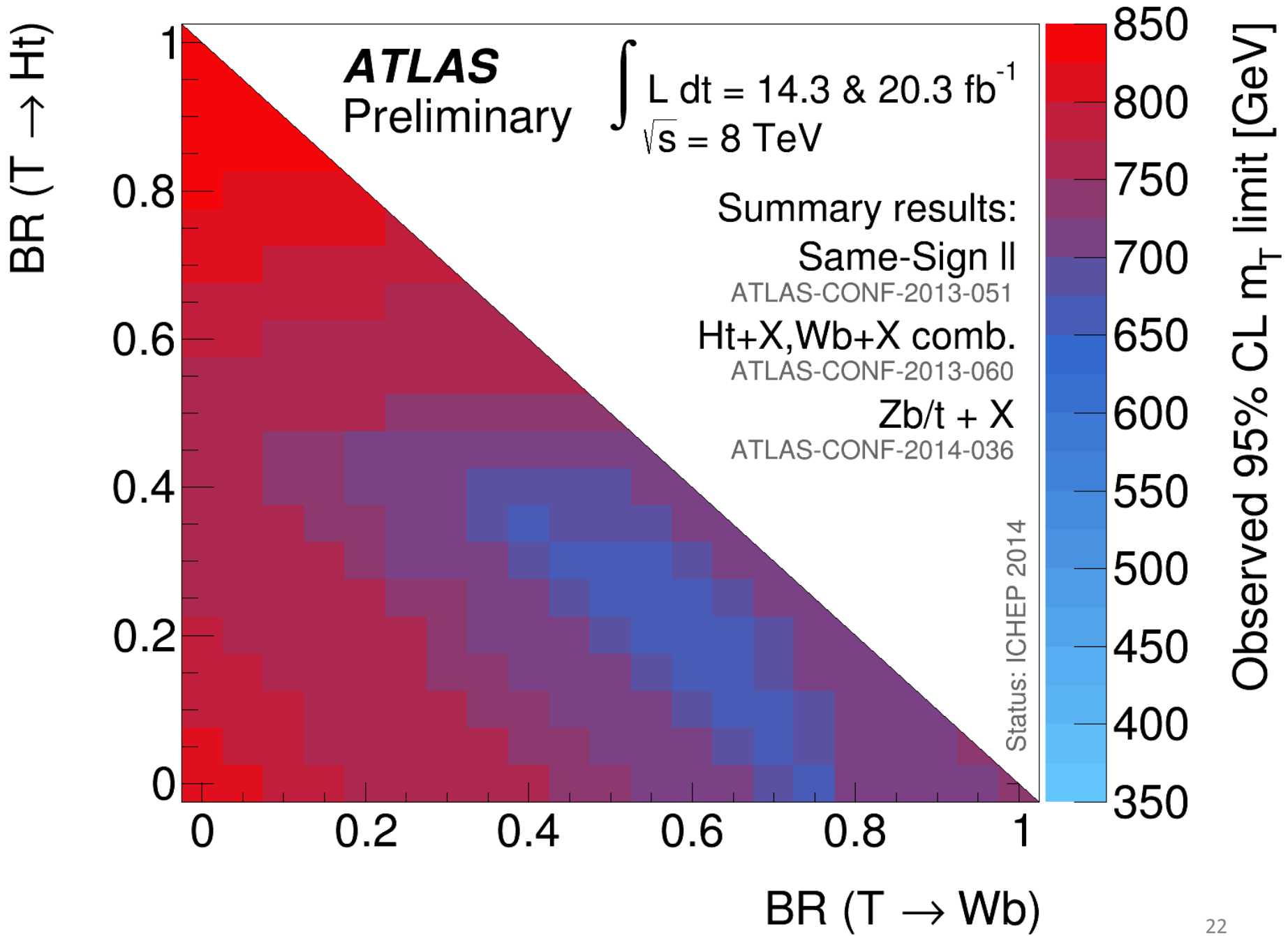
Wb+X (l+jets)



VLT

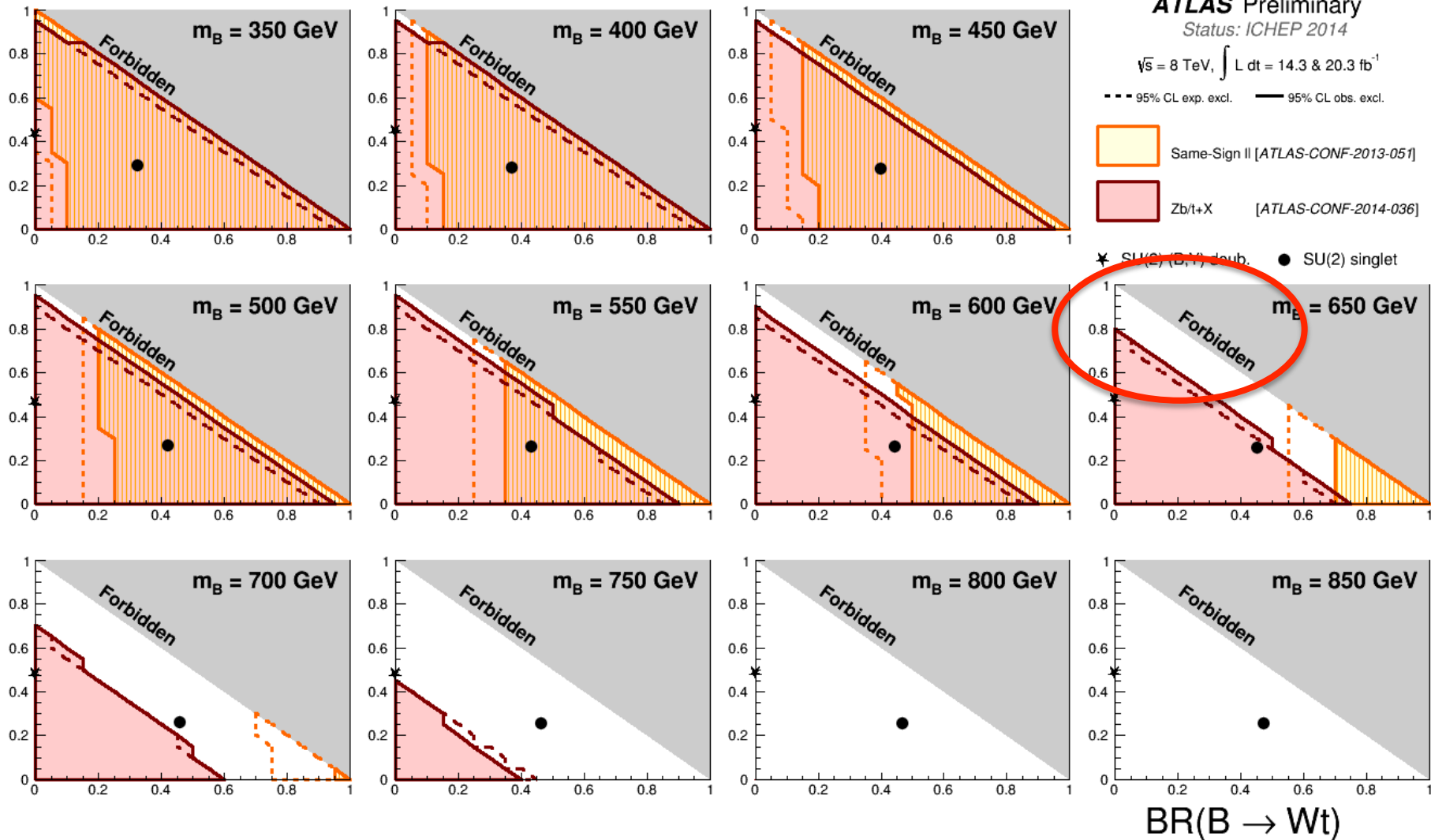
BR($T \rightarrow Ht$)





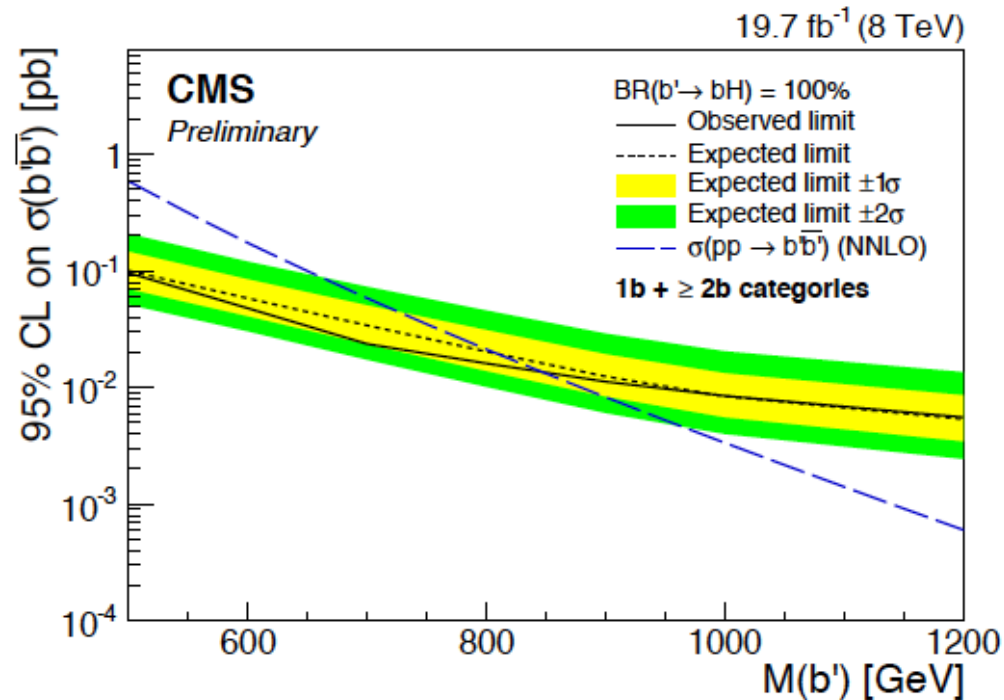
VLB

$BR(B \rightarrow Hb)$



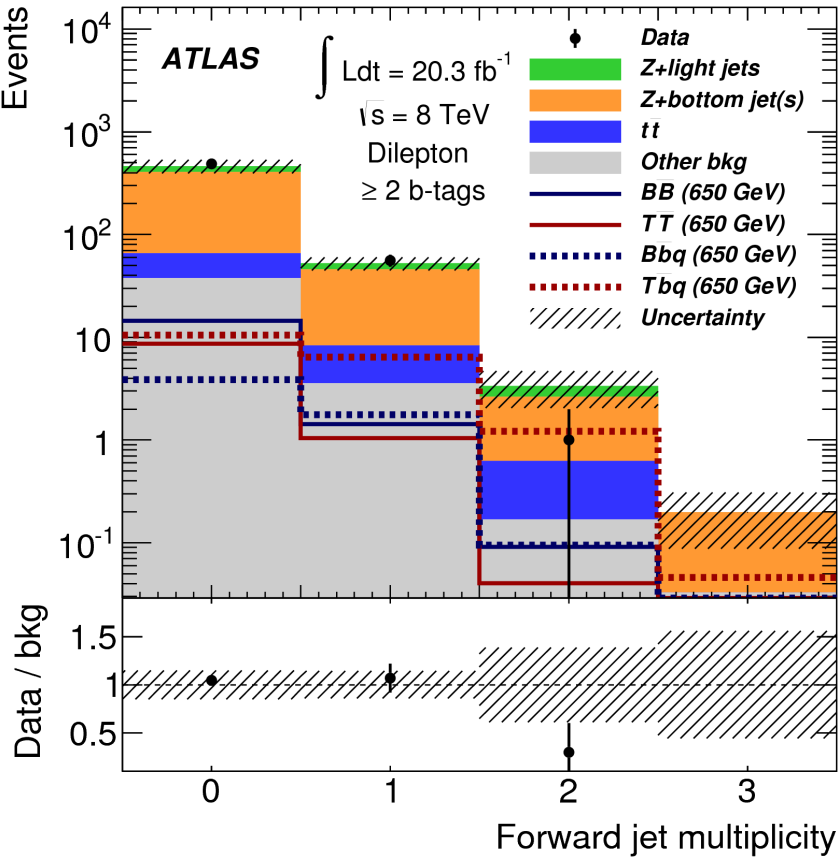
$B\bar{B} \rightarrow HbH\bar{b}, H \rightarrow b\bar{b}$

- Higgs tagging of CA $R=0.8$ jets based on jet substructure (τ_{21}), subjet b-tagging and jet mass
- ≥ 1 Higgs tags, and =1 or ≥ 2 extra b-tags
- Dominant multijets BG from Higgs-mass sideband
- Exp: $m_B > 800$ GeV @ 95% CL for $BR(B \rightarrow Hb) = 1$



Single VLQ (T/B \rightarrow Zt/b)

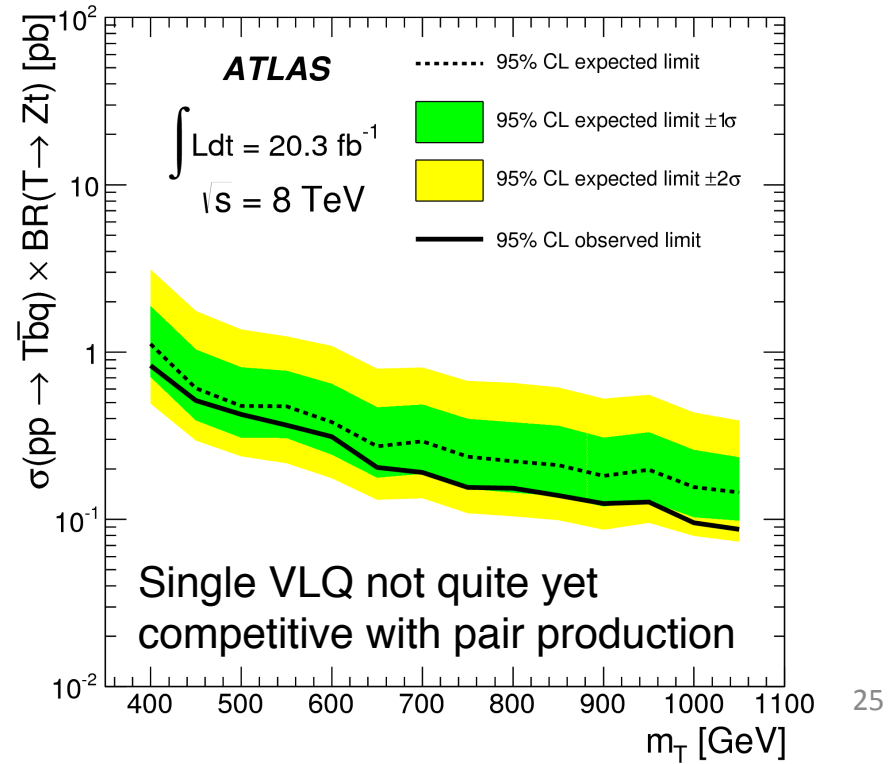
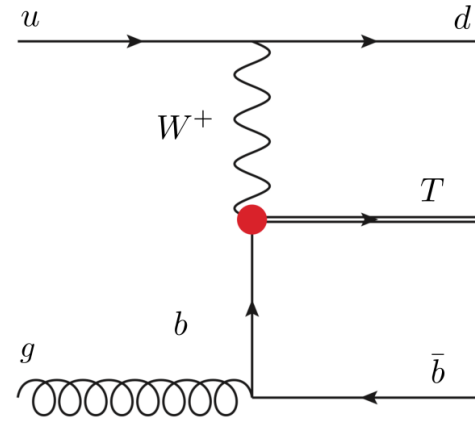
Forward jet tagging:



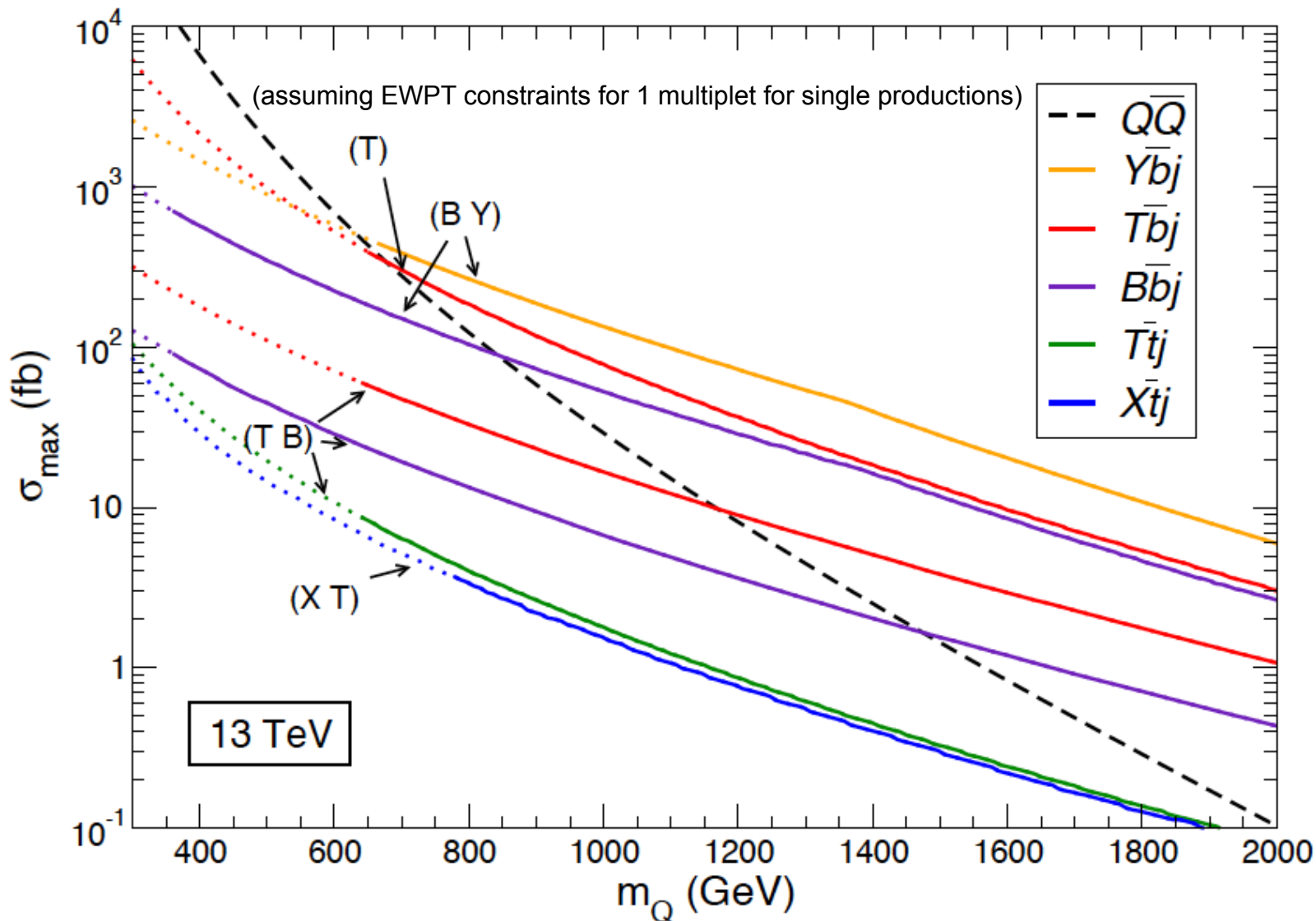
Assuming:

$$\lambda_T = 2 \text{ (Tbq)}$$

$$X_{bB} = 0.5 \text{ (Bbq)}$$



VLQs @ 13 TeV

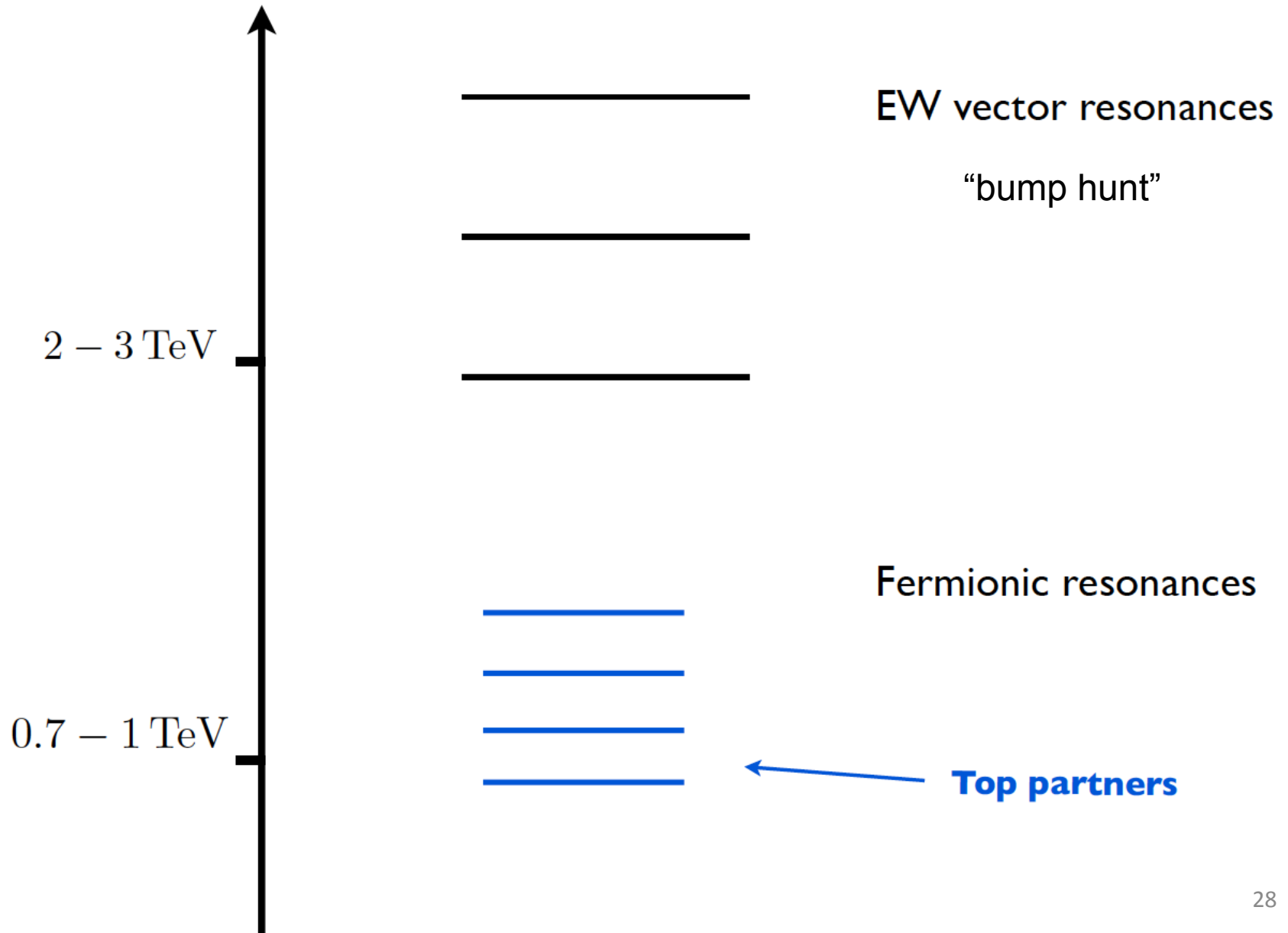


⇒ Single production important for Run II

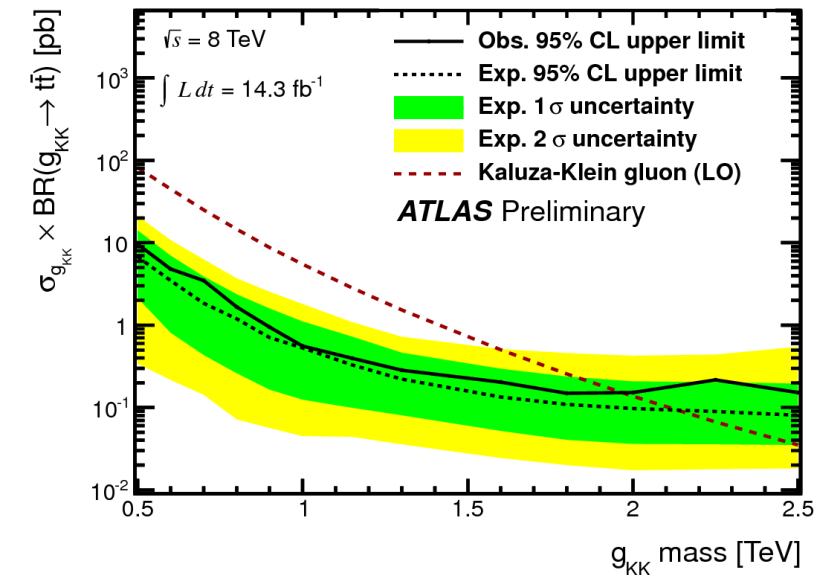
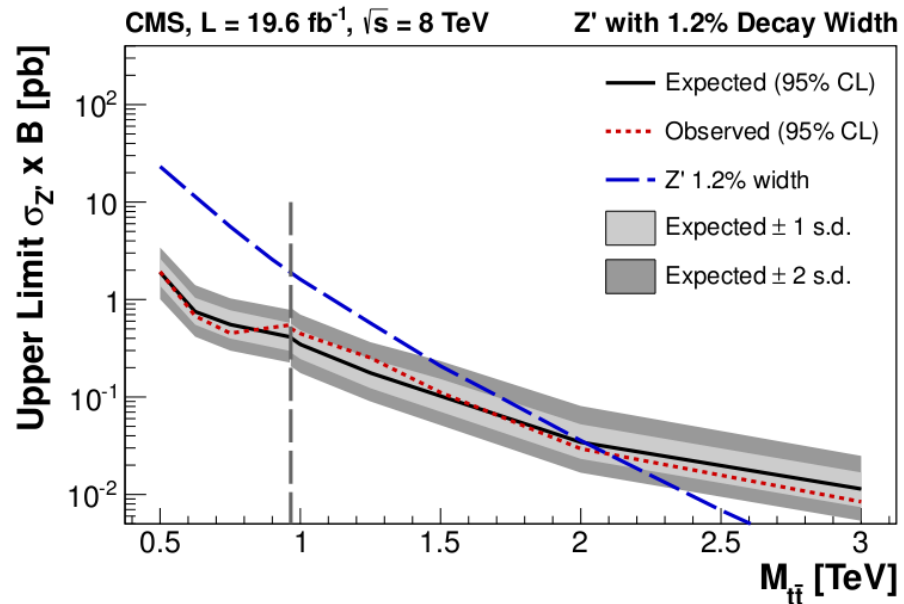
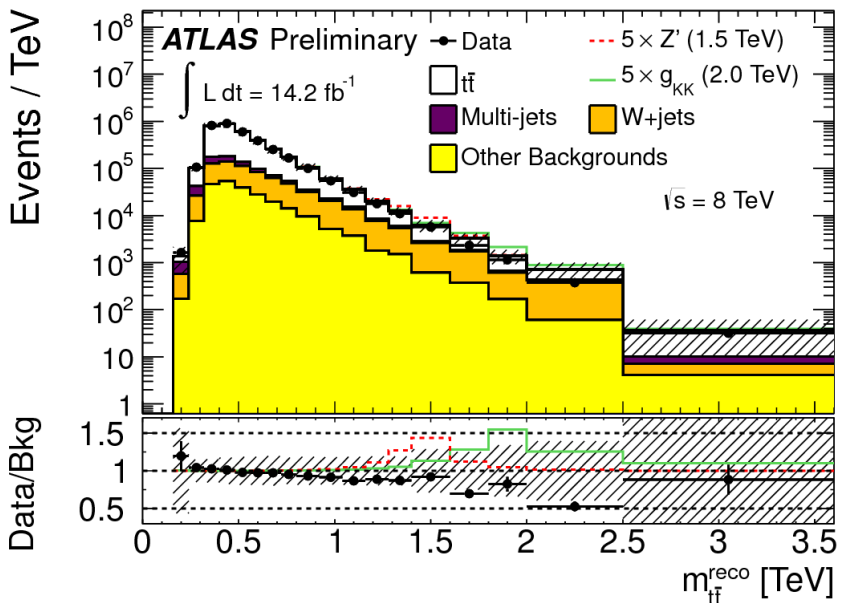
More VLQ searches in backup

- More inclusive VLQ searches
 - PLB 729 (2014) 149
 - CMS PAS B2G-12-019
- Composite light generations
 - ATLAS-CONF-2012-137

Possible Spectrum



KK gluons $\rightarrow t\bar{t}$ (l+jets)

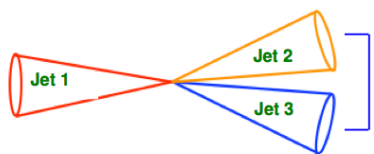


Exclude @ 95% CL:

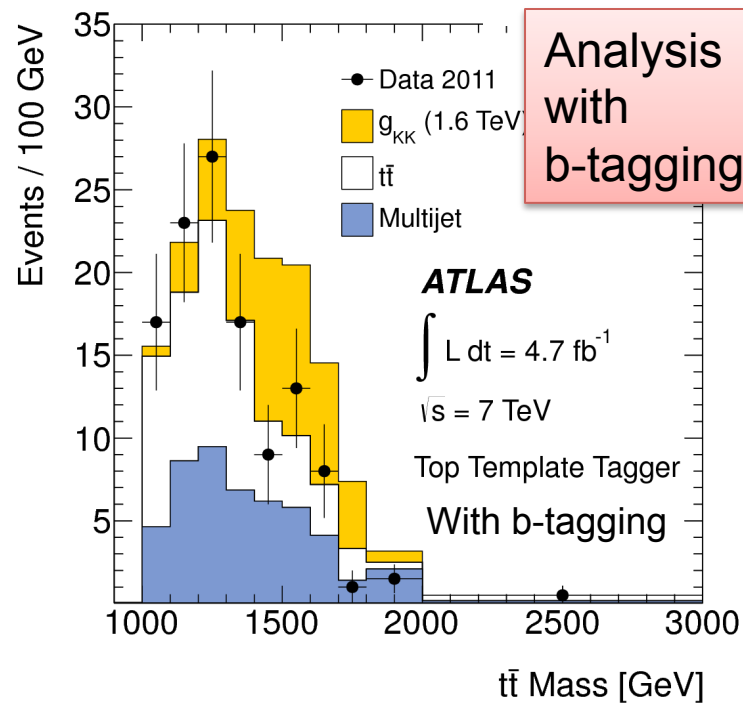
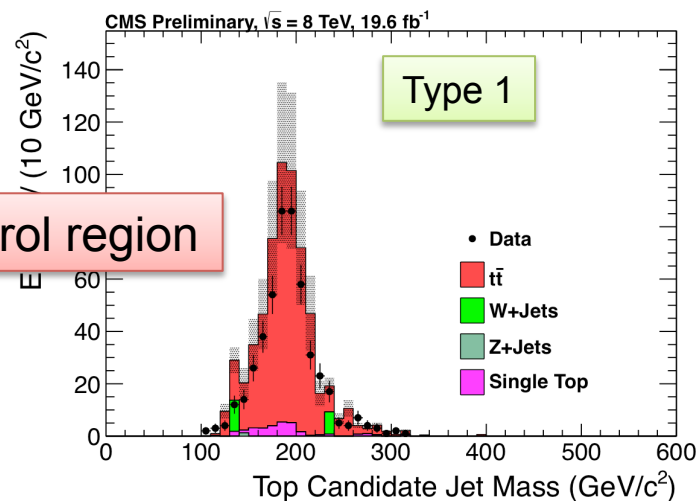
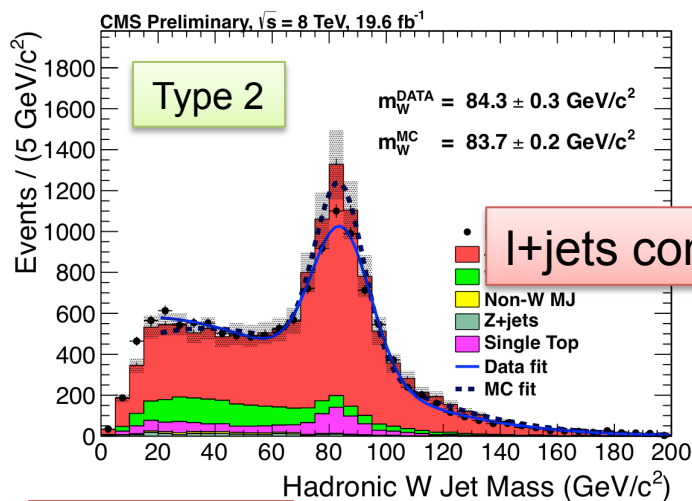
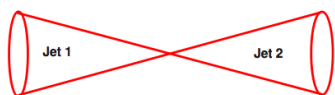
- Leptophobic top color Z'
 - $m < 2.1 \text{ TeV}$ ($\Gamma/m=1.2 \%$)
- RS KK gluon
 - $m < 2.5 \text{ TeV}$ ($\Gamma/m= 15\%$)

$t\bar{t}$ Resonances (all-jets)

Type 1 + Type 2

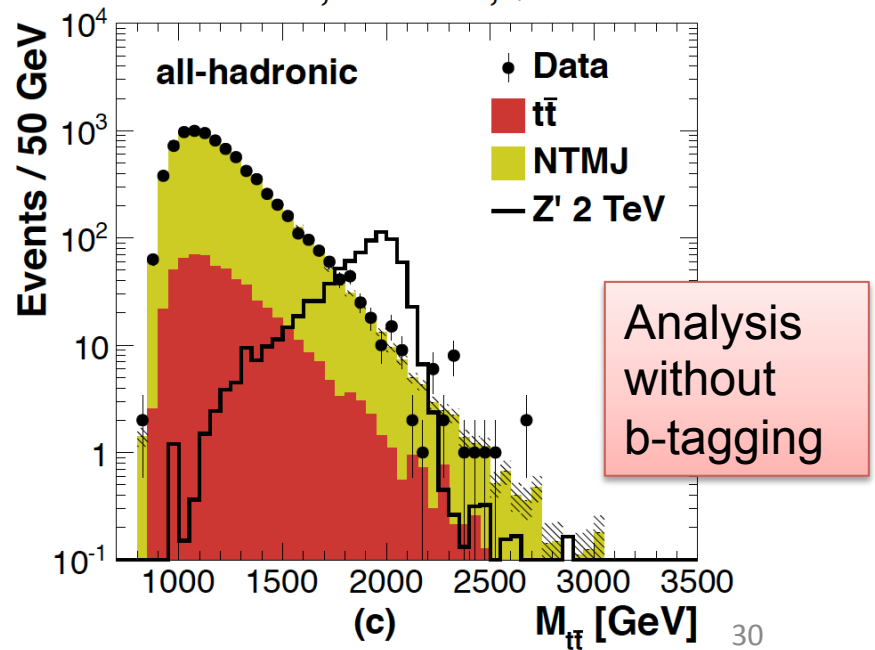


Type 1 + Type 1

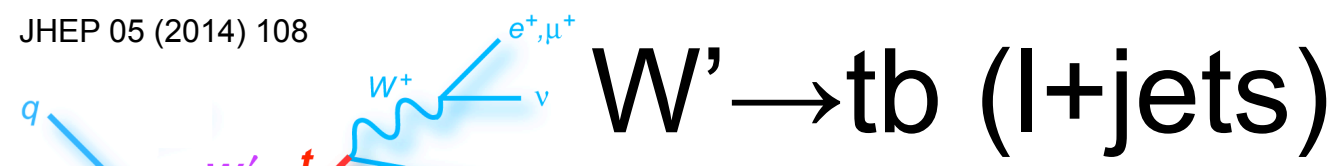


Analysis with b-tagging

CMS, 19.7 fb⁻¹, $\sqrt{s} = 8$ TeV

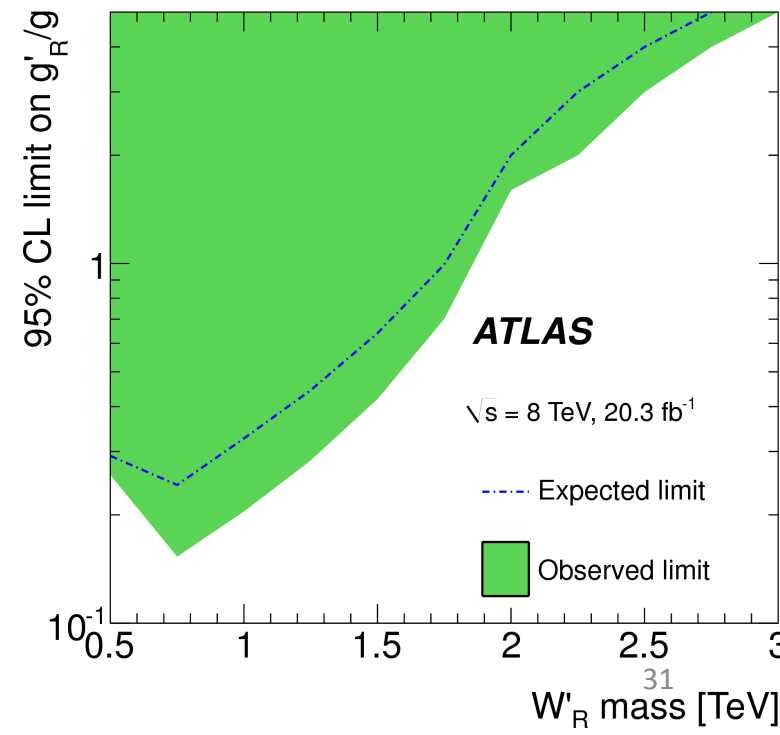
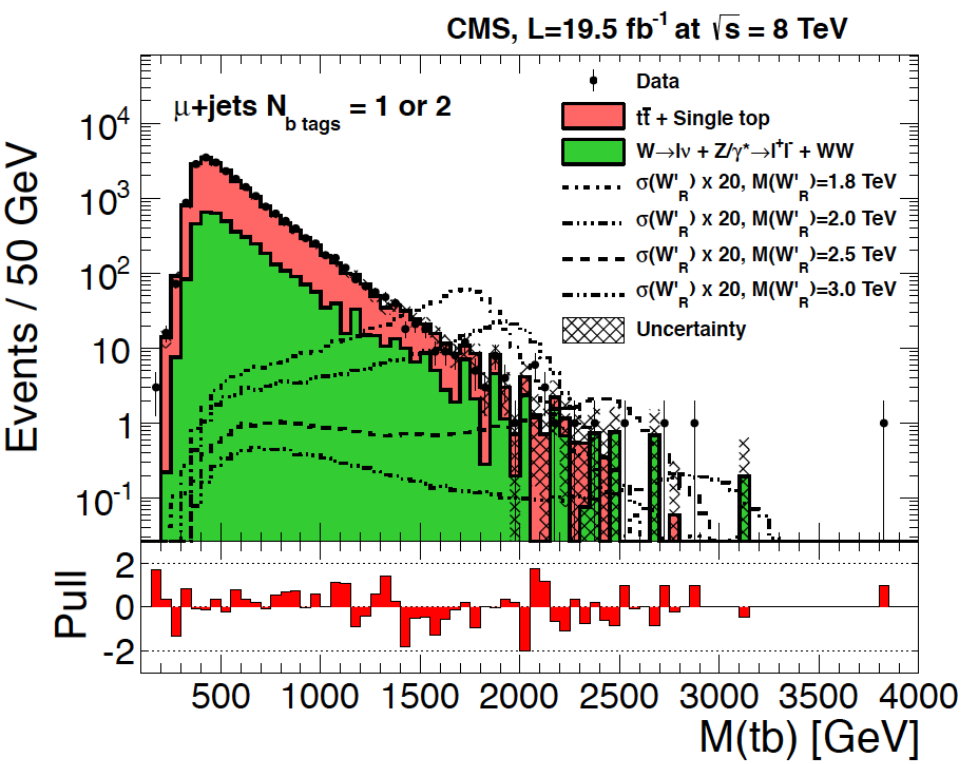
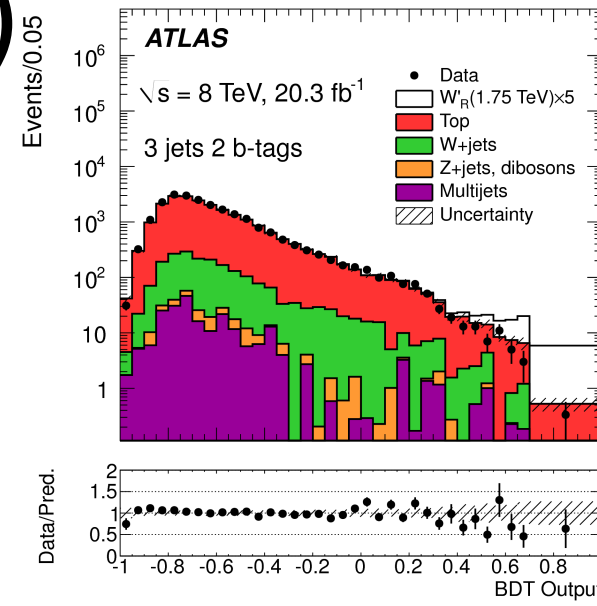


Analysis without b-tagging



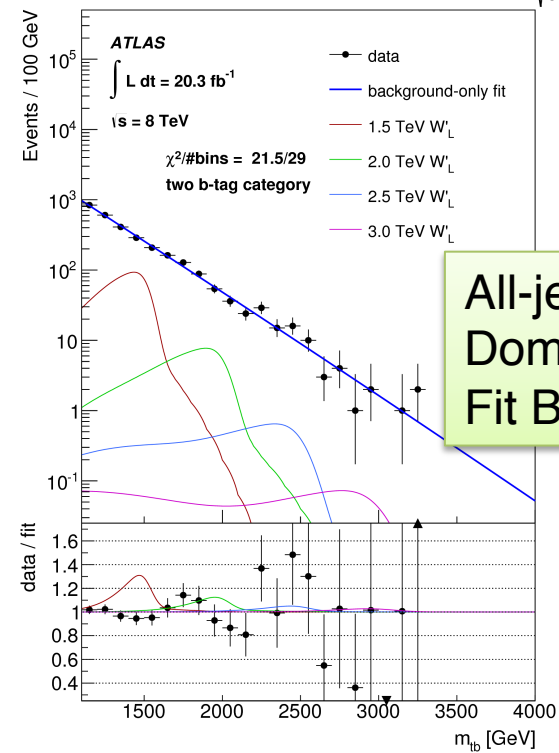
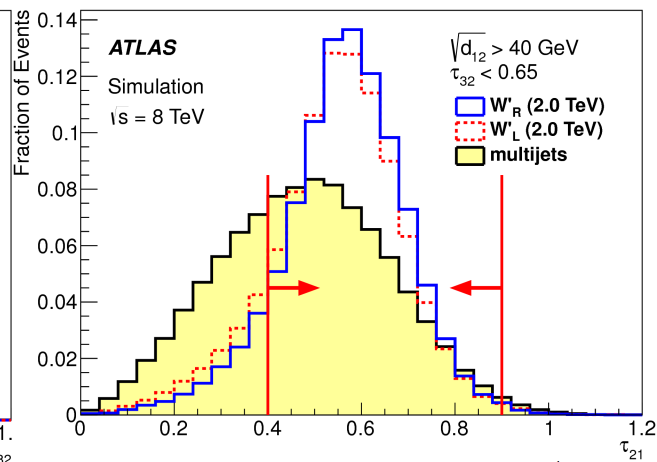
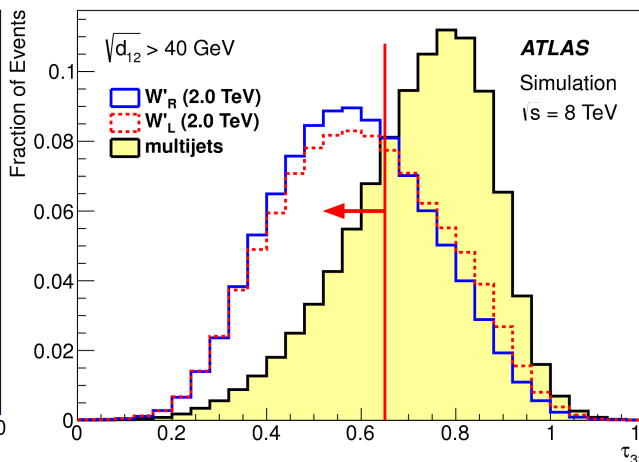
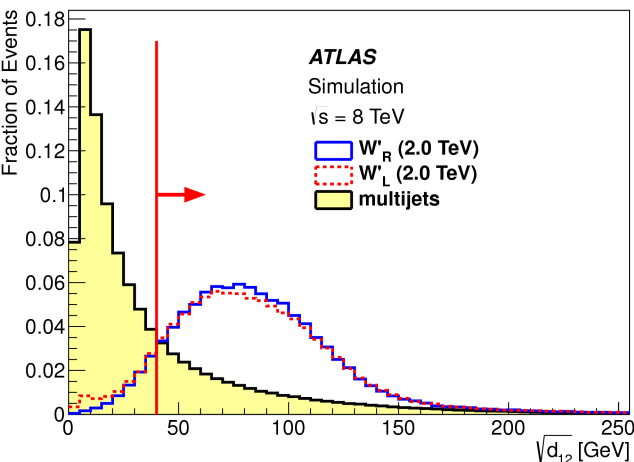
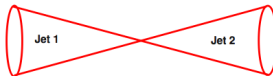
$W' \rightarrow tb$ (l+jets)

- Discriminant: m_{tb} or BDT
- Also present limits vs coupling

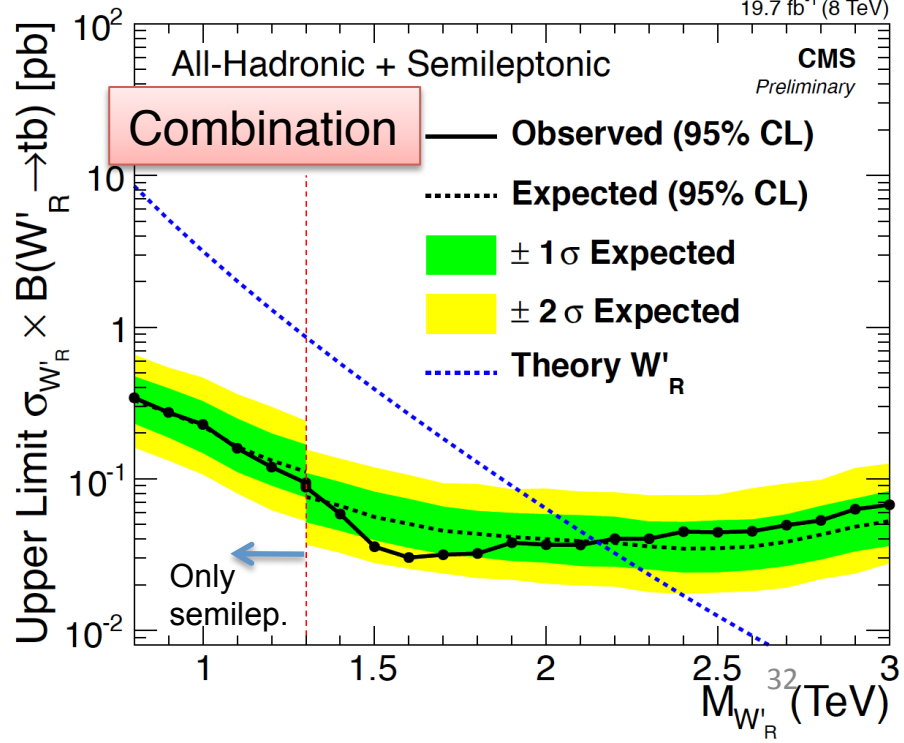


$W' \rightarrow tb$ (all-jets & combination)

All-jets: simple top-tagger + b-tagging:



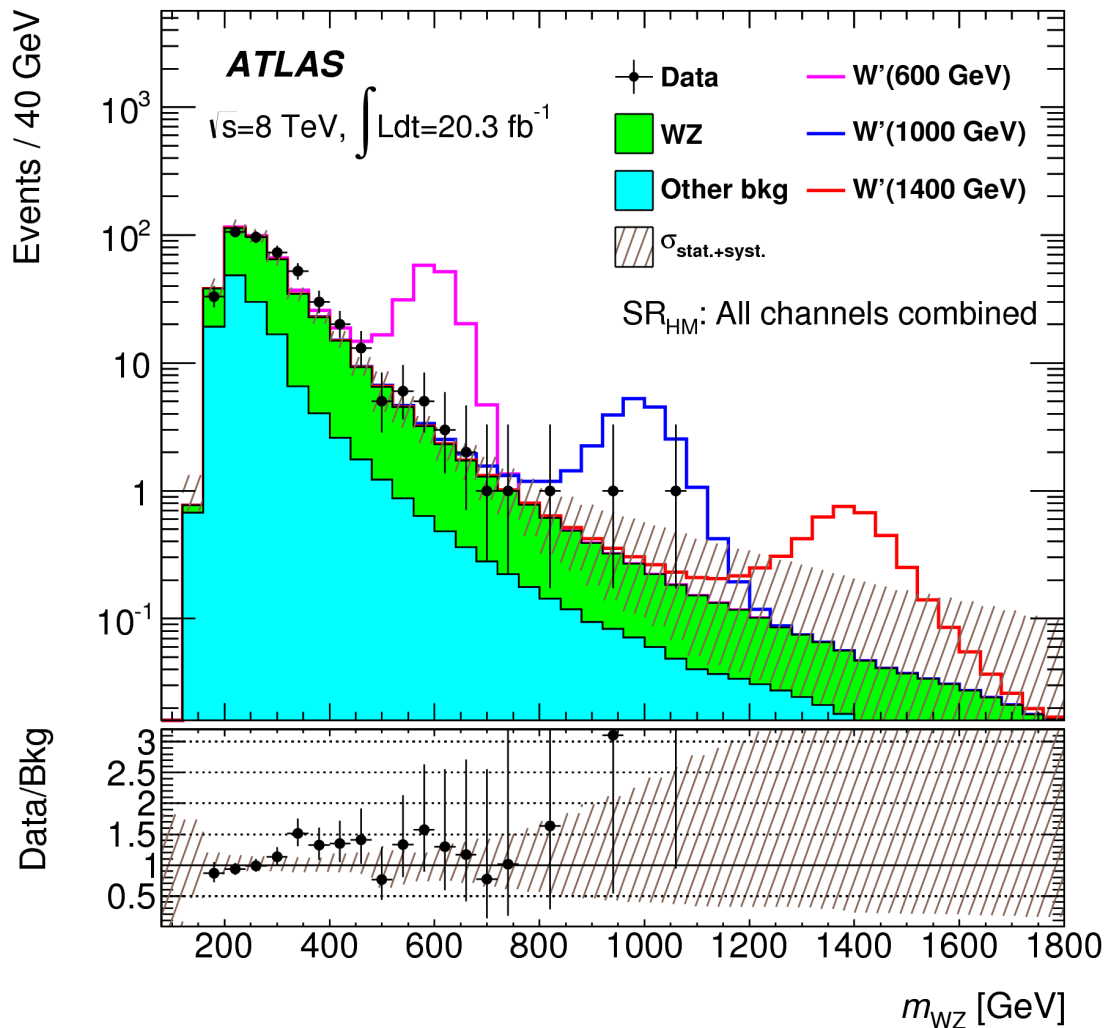
All-jets:
Dominant BG: multijets
Fit BG+signal shapes



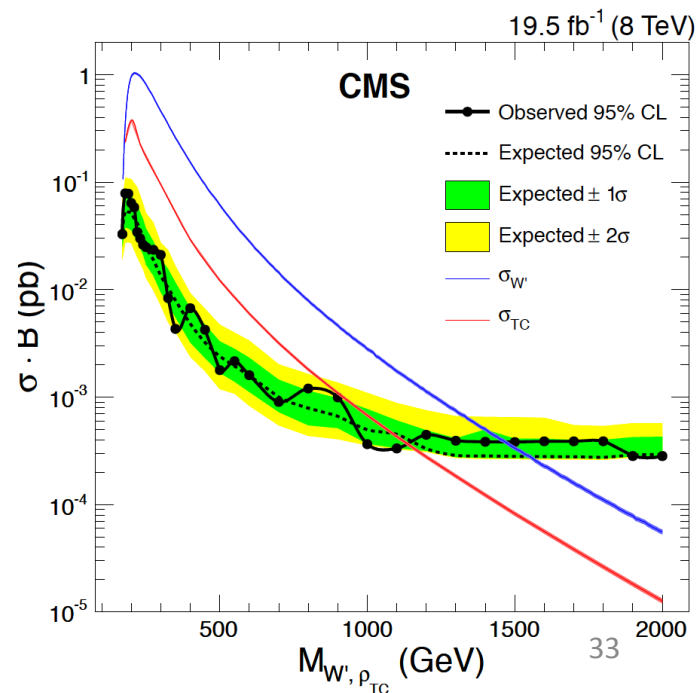
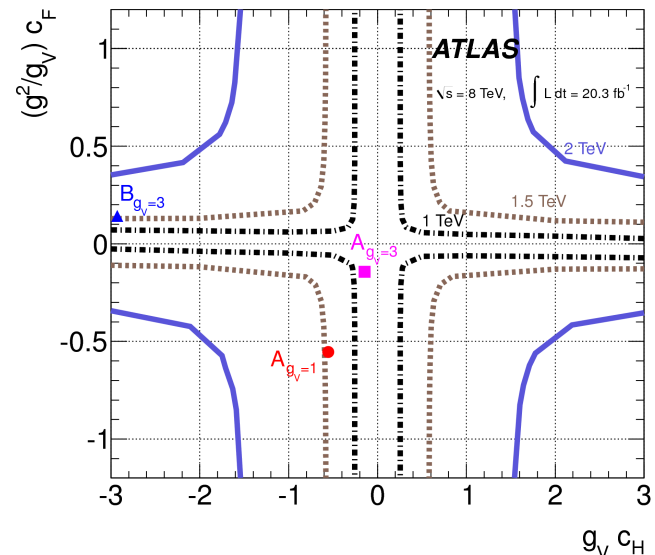
19.7 fb⁻¹ (8 TeV)

WZ → lνl Resonances

A phenomenological Lagrangian for heavy vector triplets (HVT)

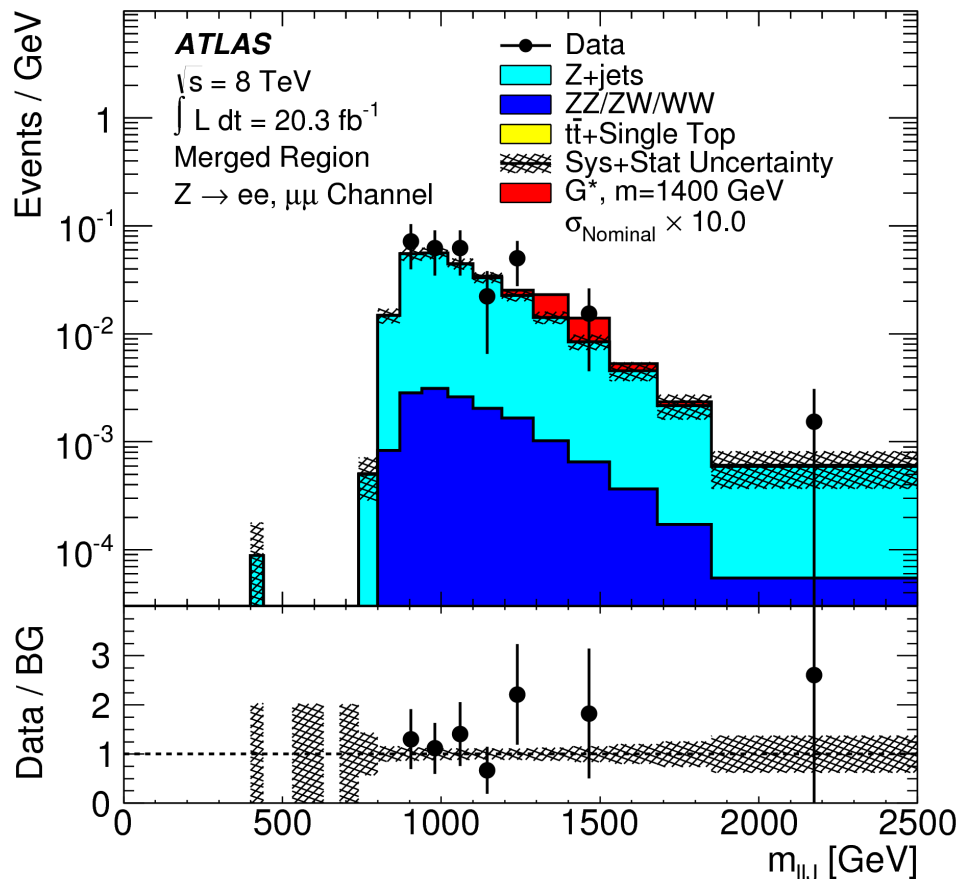


Dominant WZ BG cross-checked in CR

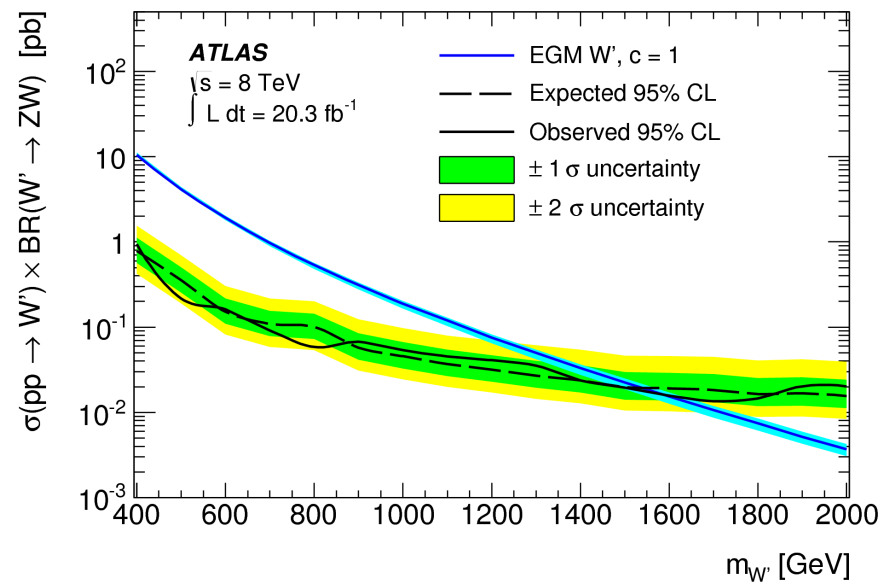
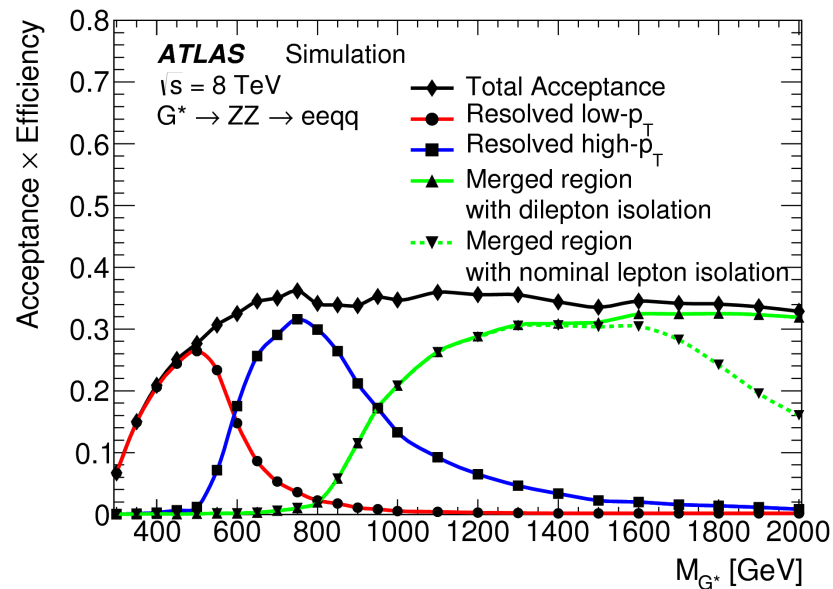


ZV \rightarrow lljj / llJ Resonances

Use BDRS-A splitting & filtering a for CA 1.2 jets to tag V-jets [ATL-PHYS-PUB-2014-004]

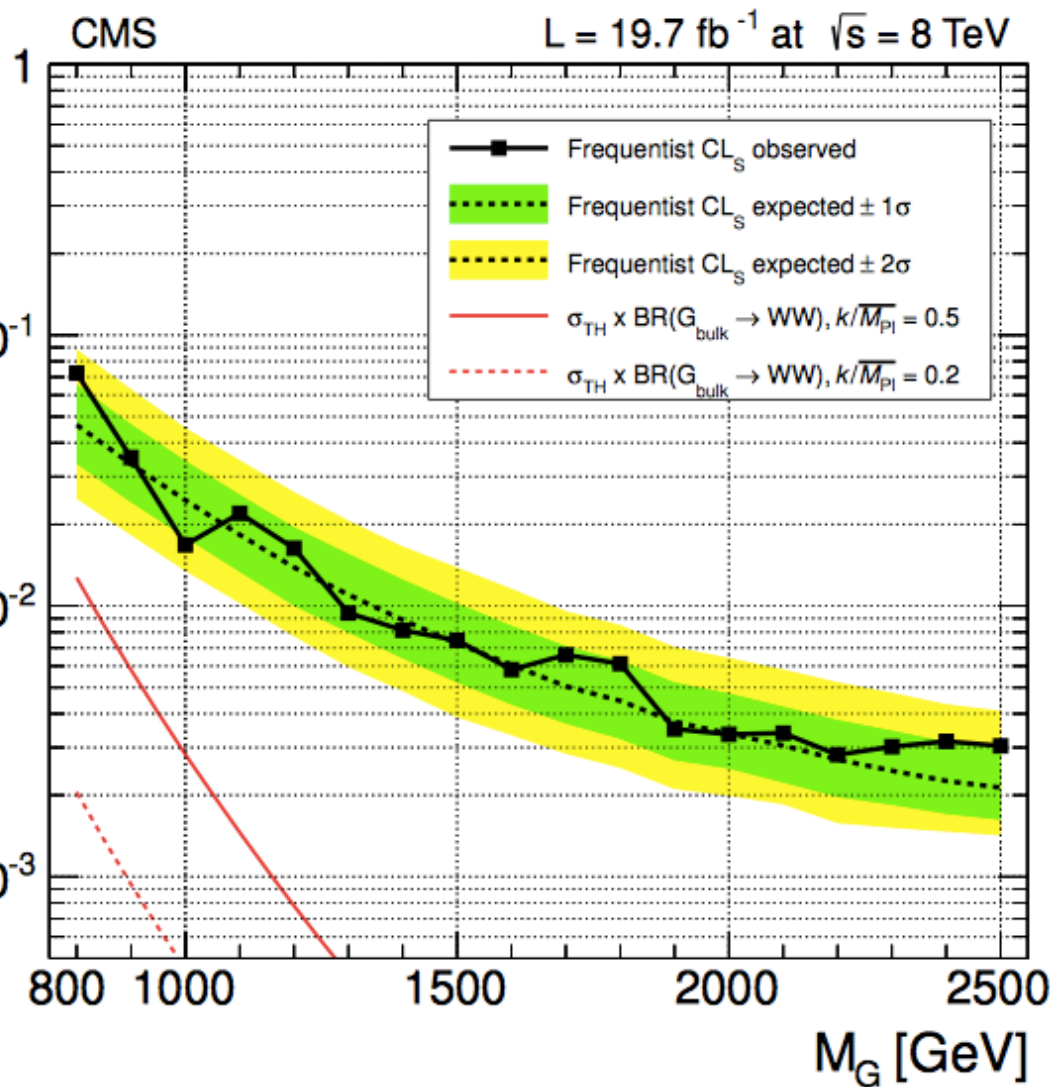
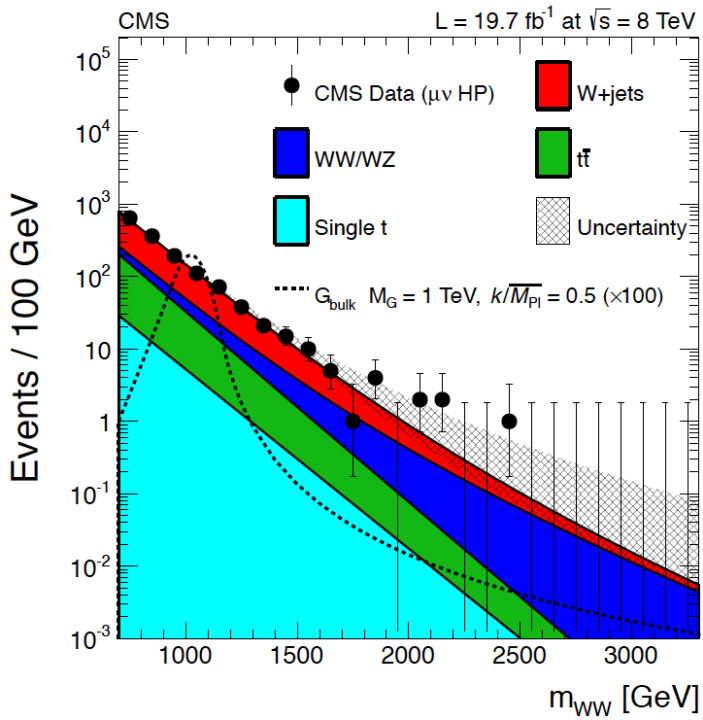
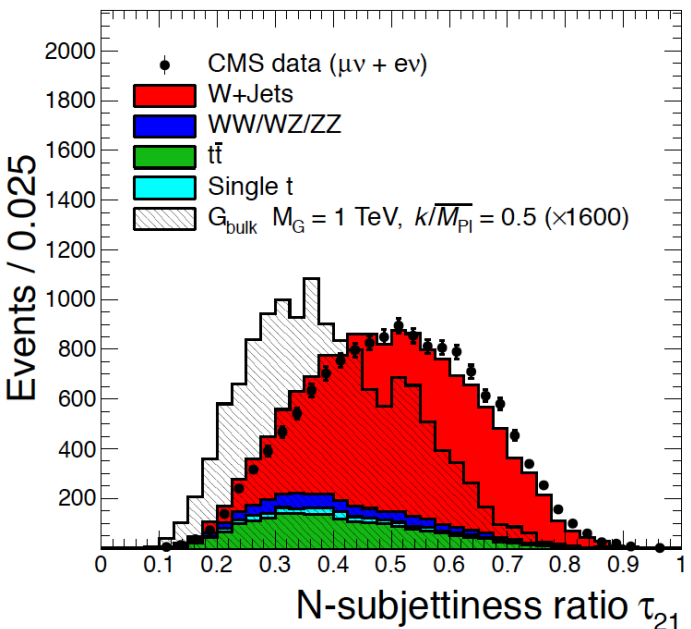


Z+jets BG from V-mass sidebands



WW → lνJ

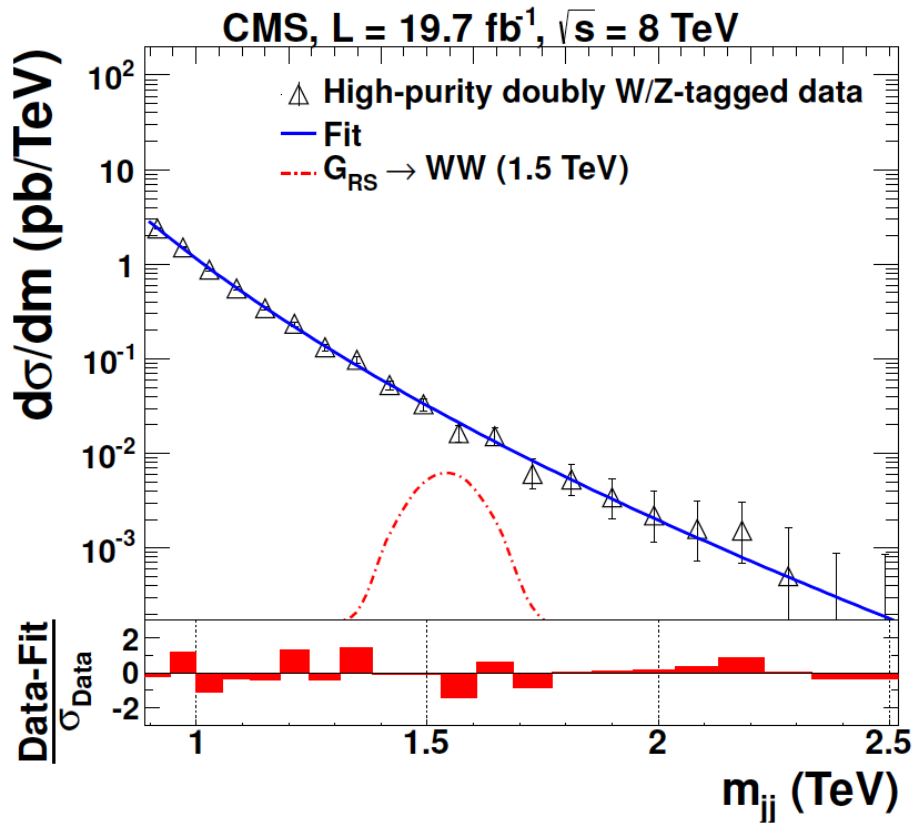
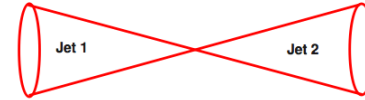
Use N-subjettiness for CA 0.8 jets to tag V-jets



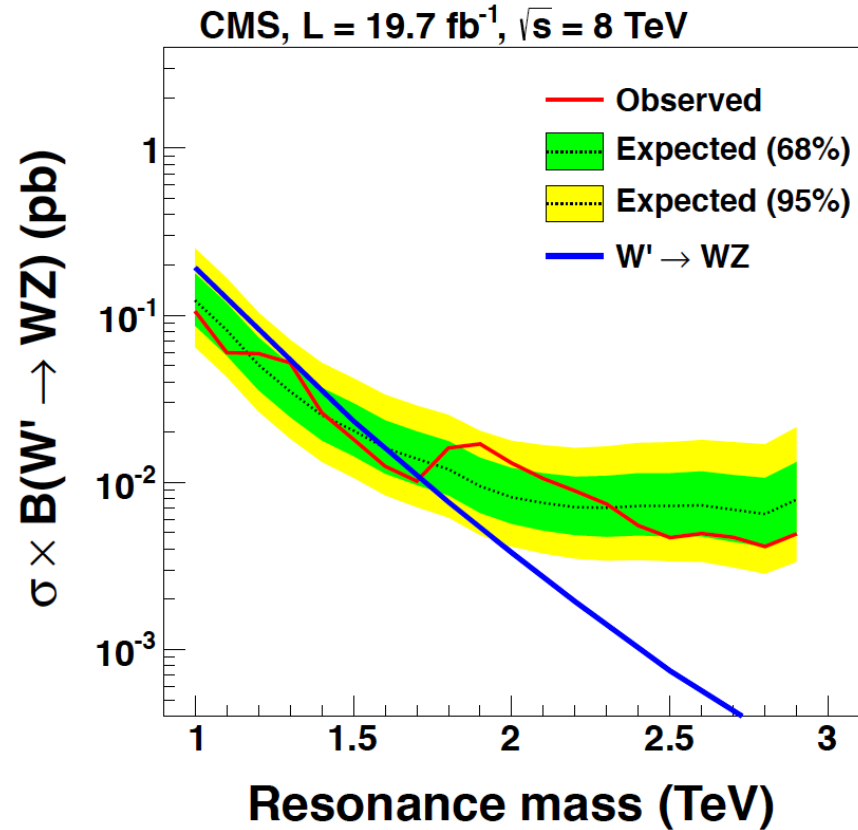
W+jets BG from V-mass sidebands

WW → JJ

Same V-jet tagger as on previous slide

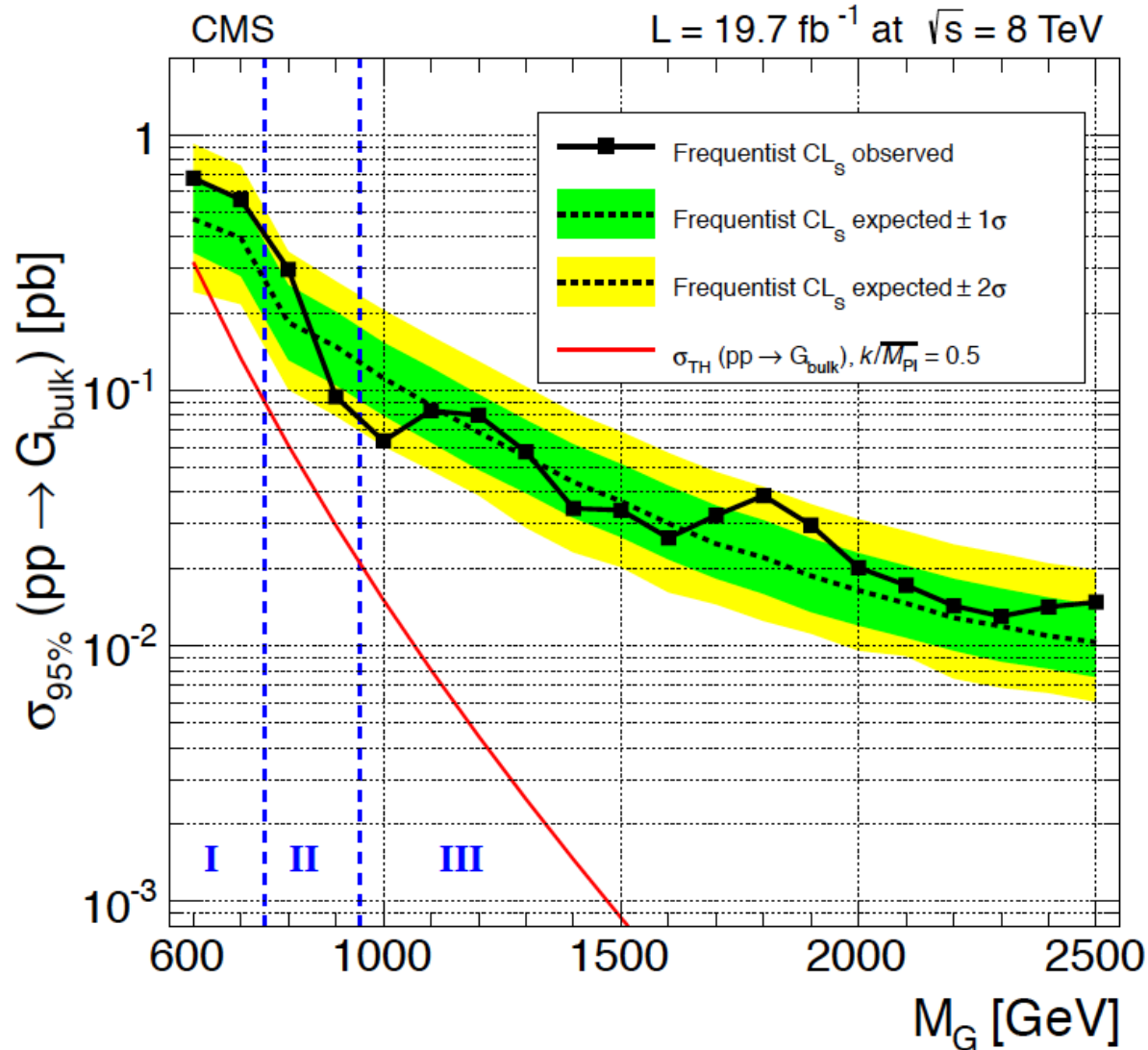


BG described by empirical fit



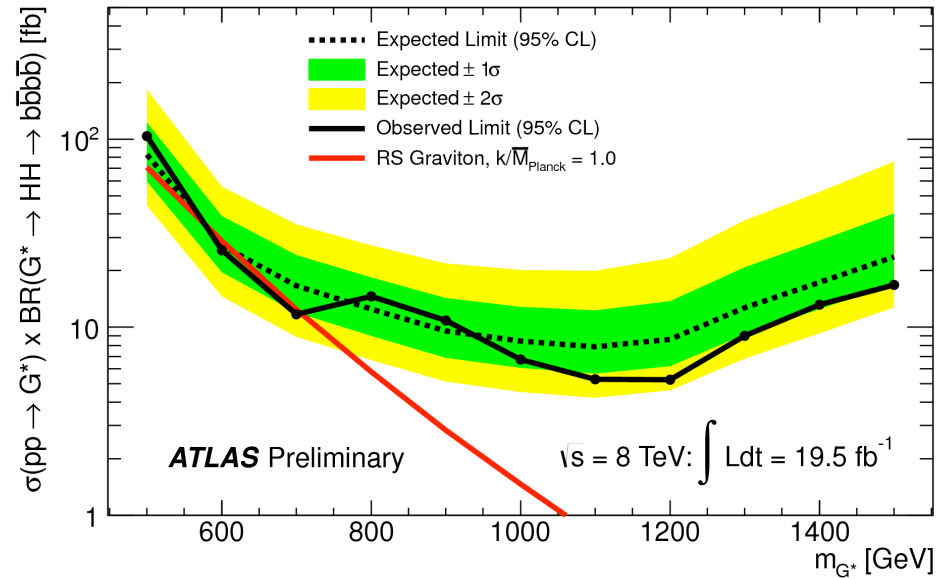
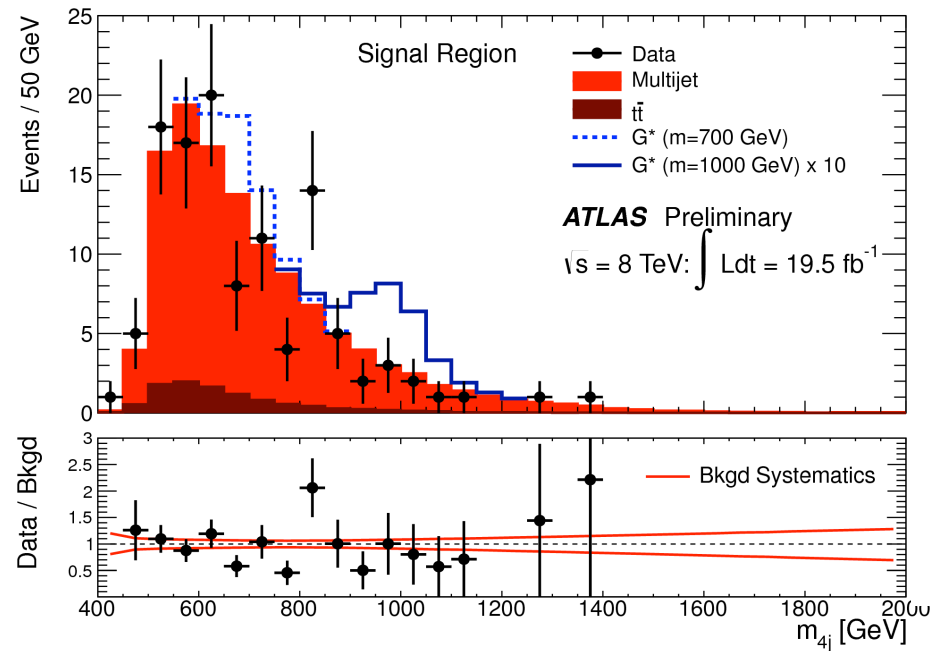
$VV \rightarrow IIJ / I\nu J / JJ$ Combination

Bulk RS graviton benchmark ($k/\bar{M}_{\text{Pl}} = 0.5$)



VV only in III
 $I\nu V$ only in II & III

HH→4b Resonances



Backgrounds:

- Multi-jet (90%): data-driven method
- $t\bar{t}$ (10%): Shape from MC, normalization from data

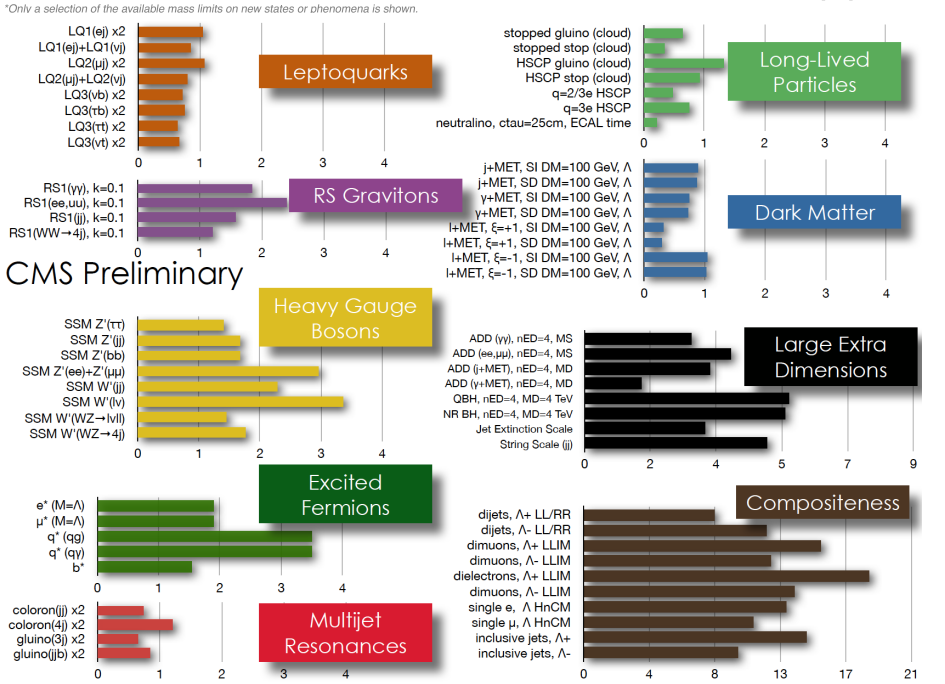
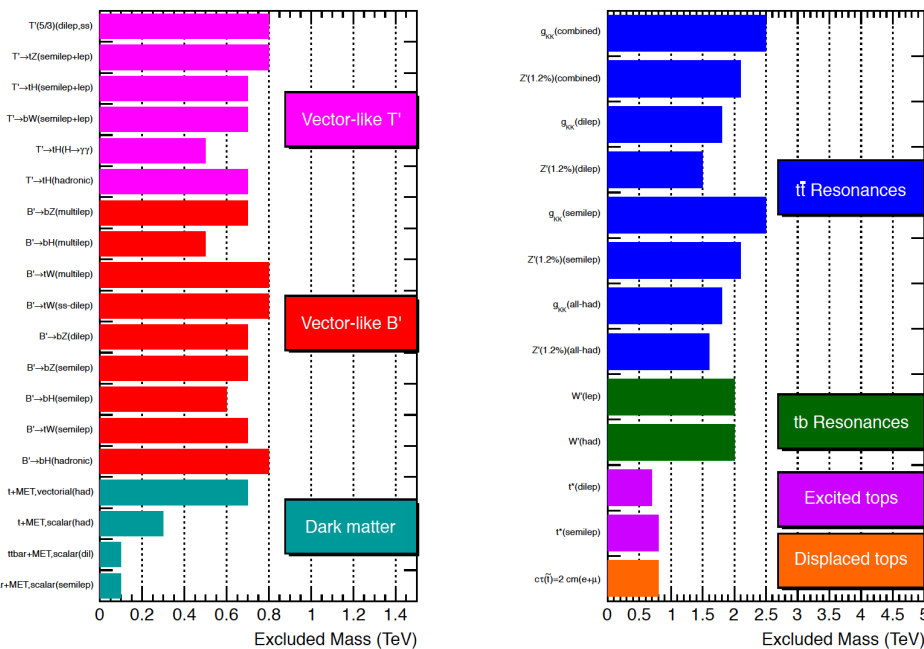
- RS graviton ($k/\bar{M}_{\text{PL}} = 1$) excluded at 95% CL for masses between 590 GeV and 710 GeV
- Theory XS $\sim (k/\bar{M}_{\text{PL}})^2$

Long Summary – not meant to be readable !

| Model | ℓ, γ | Jets | $E_{\text{miss}}^{\text{Tr}}$ | $\int \mathcal{L} dt [\text{fb}^{-1}]$ | Mass limit | Reference |
|--|-----------------------------------|-------|-------------------------------|--|-------------------------------------|------------------------|
| ADD $G_{KK} + g/q$ | - | 1-2j | Yes | 4.7 | M_0 4.37 TeV | a = 2 1210.4481 |
| ADD non-resonant $\ell\ell$ | $2e, \mu$ | - | - | 20.3 | M_0 5.2 TeV | ATLAS-CONF-2014-030 |
| ADD OBH $\rightarrow \ell q$ | $1e, \mu$ | 1j | - | 20.3 | M_0 3.2 TeV | 1311.2056 |
| ADD OBH | - | 2j | - | 20.3 | M_0 5.82 TeV | to be submitted to PRD |
| ADD BH high N_{KK} | 2μ (SS) | - | - | 20.3 | M_0 5.7 TeV | 1308.4075 |
| ADD BH high Σ_{pr} | $\geq 1e, \mu$ $\geq 2j$ | - | - | 20.3 | M_0 5.2 TeV | 1405.4254 |
| RS1 $G_{KK} \rightarrow \ell\ell$ | $2e, \mu$ | - | - | 20.3 | G_{KK} mass 2.64 TeV | 1405.4123 |
| RS1 $G_{KK} \rightarrow W\gamma \rightarrow \ell\nu\bar{\nu}$ | $2e, \mu$ | - | - | 4.7 | G_{KK} mass 1.23 TeV | 1308.3963 |
| Bulk RS $G_{KK} \rightarrow ZZ \rightarrow \ell q q$ | $2e, \mu$ | 2j/1J | - | 20.3 | G_{KK} mass 730 GeV | ATLAS-CONF-2014-039 |
| Bulk RS $G_{KK} \rightarrow HH \rightarrow b\bar{b}\bar{b}\bar{b}$ | $2e, \mu$ | 4j | - | 19.5 | G_{KK} mass 590-710 GeV | ATLAS-CONF-2013-052 |
| Bulk RS $G_{KK} \rightarrow t\bar{t}$ | $1e, \mu$ $\geq 1b, \geq 1J/2j$ | Yes | 14.3 | 14.3 | G_{KK} mass 2.0 TeV | ATLAS-CONF-2013-052 |
| S^1/Z_2 ED | $2e, \mu$ | - | - | 5.0 | $M_{KK} = R^{-1}$ 4.71 TeV | 1209.2555 |
| UED | 2γ | - | Yes | 4.8 | compact, scale R^{-1} 1.41 TeV | ATLAS-CONF-2012-072 |
| SSM $Z' \rightarrow \ell\ell$ | $2e, \mu$ | - | - | 20.3 | Z' mass 2.9 TeV | 1405.4123 |
| SSM $Z' \rightarrow \tau\tau$ | 2τ | - | - | 19.5 | Z' mass 1.9 TeV | ATLAS-CONF-2013-068 |
| SSM $W' \rightarrow e\mu$ | $1e, \mu$ | - | Yes | 20.3 | W' mass 3.24 TeV | ATLAS-CONF-2014-017 |
| EGM $W' \rightarrow WZ \rightarrow \nu\ell\ell'$ | $3e, \mu$ | - | Yes | 20.3 | W' mass 1.52 TeV | 1406.4456 |
| EGM $W' \rightarrow WZ \rightarrow qq\ell\ell$ | $2e, \mu$ 2j/1J | - | - | 20.3 | W' mass 1.59 TeV | ATLAS-CONF-2014-039 |
| LRSM $W'_2 \rightarrow \tau\bar{\nu}$ | $1e, \mu$ 2b, 0-1J | Yes | 14.3 | 14.3 | W' mass 1.84 TeV | ATLAS-CONF-2013-050 |
| LRSM $W'_2 \rightarrow \tau\bar{\nu}$ | $0e, \mu$ $\geq 1b, 1J$ | - | - | 20.3 | W' mass 1.77 TeV | to be submitted to EPJ |
| CI $q\bar{q}q\bar{q}$ | - | 2j | - | 4.8 | A 7.6 TeV | 1210.1718 |
| CI $q\bar{q}\ell\ell$ | $2e, \mu$ | - | - | 20.3 | A 2.9 TeV | ATLAS-CONF-2014-030 |
| CI $q\bar{q}\ell\ell'$ | $2e, \mu$ (SS) $\geq 1b, \geq 1j$ | Yes | 14.3 | 14.3 | A 3.3 TeV | ATLAS-CONF-2013-051 |
| EFT D5 operator (Dirac) | $0e, \mu$ 1-2j | Yes | 10.5 | 10.5 | M_5 731 GeV | ATLAS-CONF-2012-147 |
| EFT D9 operator (Dirac) | $0e, \mu$ 1.4-1.5j | Yes | 20.3 | 20.3 | M_9 2.4 TeV | 1309.4517 |
| Scalar LH^{\pm} gen | $2e, \tau$ $\geq 2j$ | - | - | 10 | LH mass 660 GeV | 1112.8528 |
| Scalar LH^0 gen | $2\mu, \tau$ $\geq 2j$ | - | - | 10 | LH mass 685 GeV | 1333.5172 |
| Scalar LH^{\pm} gen | $1e, \mu, \tau$ 1b, 1j | - | - | 4.7 | LH mass 534 GeV | 1303.9528 |
| Vector-like quark $TT \rightarrow Hc + X$ | $1e, \mu$ $\geq 2b, \geq 4j$ | Yes | 14.3 | 14.3 | T mass 790 GeV | ATLAS-CONF-2013-018 |
| Vector-like quark $TT \rightarrow Wb + X$ | $1e, \mu$ $\geq 1b, \geq 3j$ | Yes | 14.3 | 14.3 | T mass 670 GeV | ATLAS-CONF-2013-060 |
| Vector-like quark $TT \rightarrow Zt + X$ | $2/3e, \mu$ $\geq 2/3b$ | - | - | 20.3 | T mass 735 GeV | ATLAS-CONF-2014-036 |
| Vector-like quark $BB \rightarrow Zb + X$ | $2/3e, \mu$ $\geq 2/3b$ | - | - | 20.3 | B mass 755 GeV | ATLAS-CONF-2014-036 |
| Vector-like quark $BB \rightarrow Wt + X$ | $2e, \mu$ (SS) $\geq 1b, \geq 1j$ | Yes | 14.3 | 14.3 | B mass 720 GeV | ATLAS-CONF-2013-051 |
| Excited quark $q^* \rightarrow q\gamma$ | 1γ | - | - | 20.3 | q^* mass 3.5 TeV | 1309.3230 |
| Excited quark $q^* \rightarrow qg$ | 2j | - | - | 20.3 | q^* mass 4.09 TeV | to be submitted to PRD |
| Excited quark $q^* \rightarrow Wt$ | 1 or $2e, \mu$ 1b, 2j or 1j | Yes | 4.7 | 4.7 | q^* mass 870 GeV | 1301.1563 |
| Excited lepton $\ell^* \rightarrow \ell\gamma$ | $2e, \mu, 1\gamma$ | - | - | 13.0 | ℓ^* mass 2.2 TeV | 1306.1364 |
| LSTC $2\tau \rightarrow W\gamma$ | $1e, \mu, 1\gamma$ | - | Yes | 20.3 | N^{\pm} mass 900 GeV | to be submitted to PLB |
| LRSM Majorana ν | $2e, \mu$ 2j | - | - | 2.1 | N^0 mass 1.5 TeV | 1303.5400 |
| Type III Seesaw | $2e, \mu$ | - | - | 5.8 | N^{\pm} mass 245 GeV | ATLAS-CONF-2013-019 |
| Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$ | $2e, \mu$ (SS) | - | - | 4.7 | $H^{\pm\pm}$ mass 409 GeV | 1210.5070 |
| Multi-charged particles | - | - | - | 4.4 | multi-charged particle mass 490 GeV | 1301.5272 |
| Magnetic monopoles | - | - | - | 2.0 | monopole mass 862 GeV | 1207.6411 |

CMS Searches for New Physics Beyond Two Generations (B2G)

95% CL Exclusions (TeV)



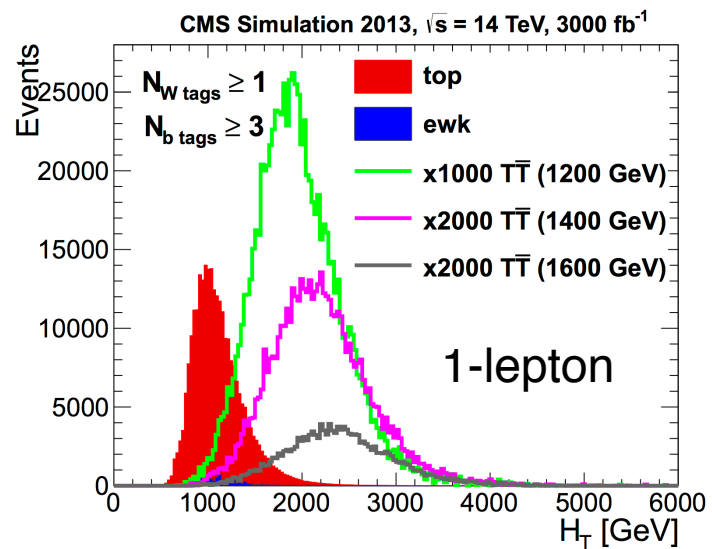
<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO>
<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G>
<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults>

Short Summary

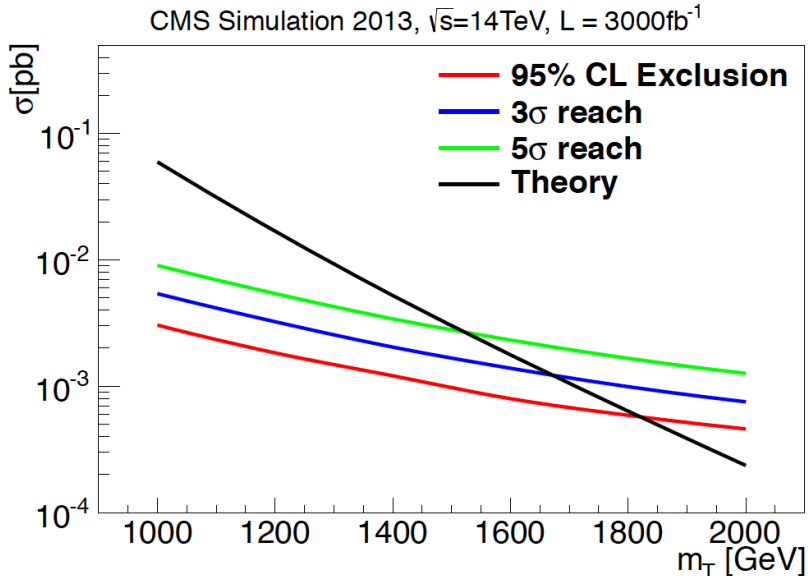
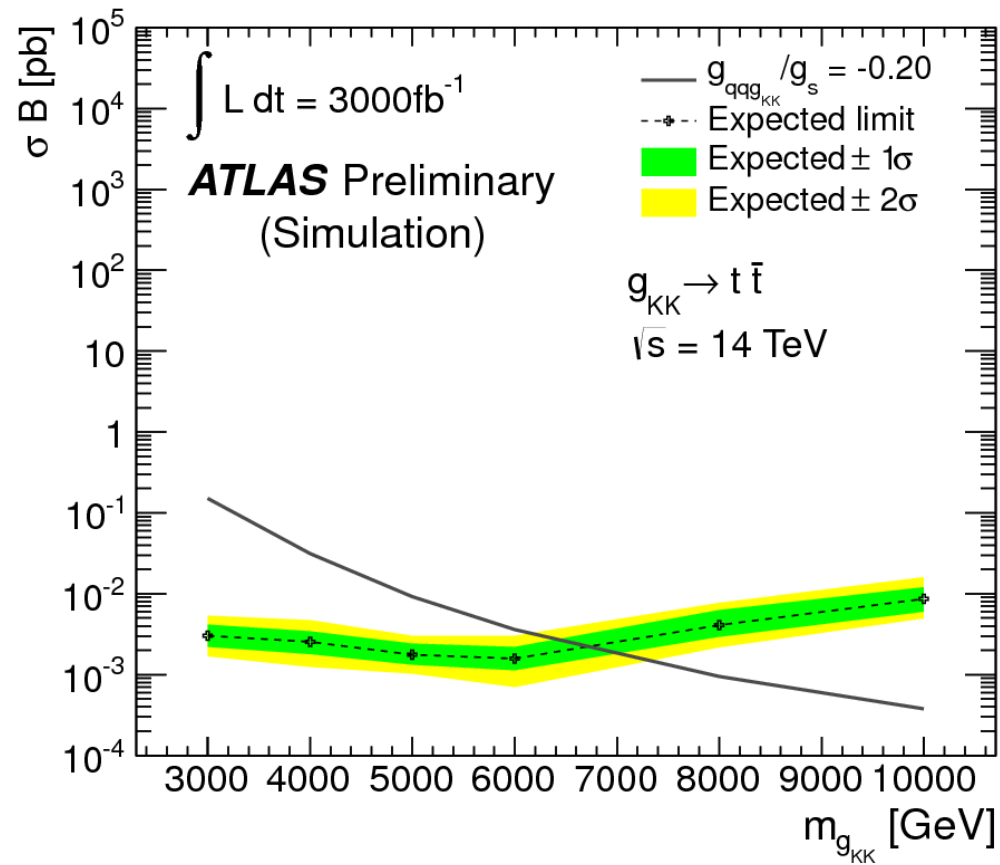
- Mass exclusions @ 95% CL
 - VLQs up to ~ 800 GeV
 - Leptophobic top color Z' with $m < 2.1$ TeV ($\Gamma/m=1.2$ %)
 - RS KK gluon with $m < 2.5$ TeV ($\Gamma/m= 15\%$)
 - $W' \rightarrow tb$ up to ~ 2 TeV
 - Diboson resonances getting close to 2 TeV

Looking deep into the Future

VLQ reach



$g_{KK} \rightarrow t\bar{t}$ reach

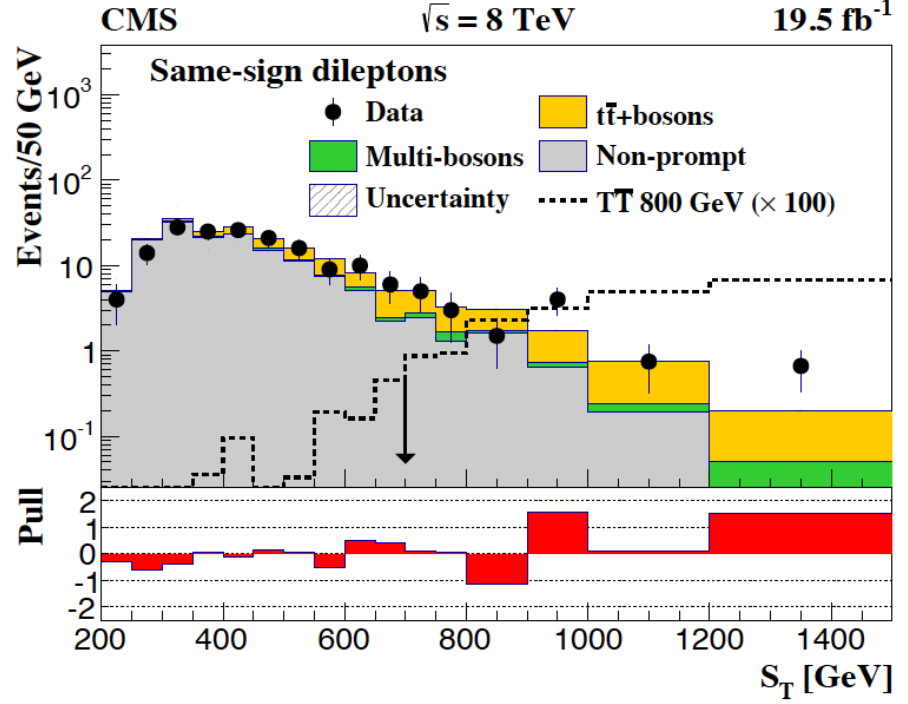
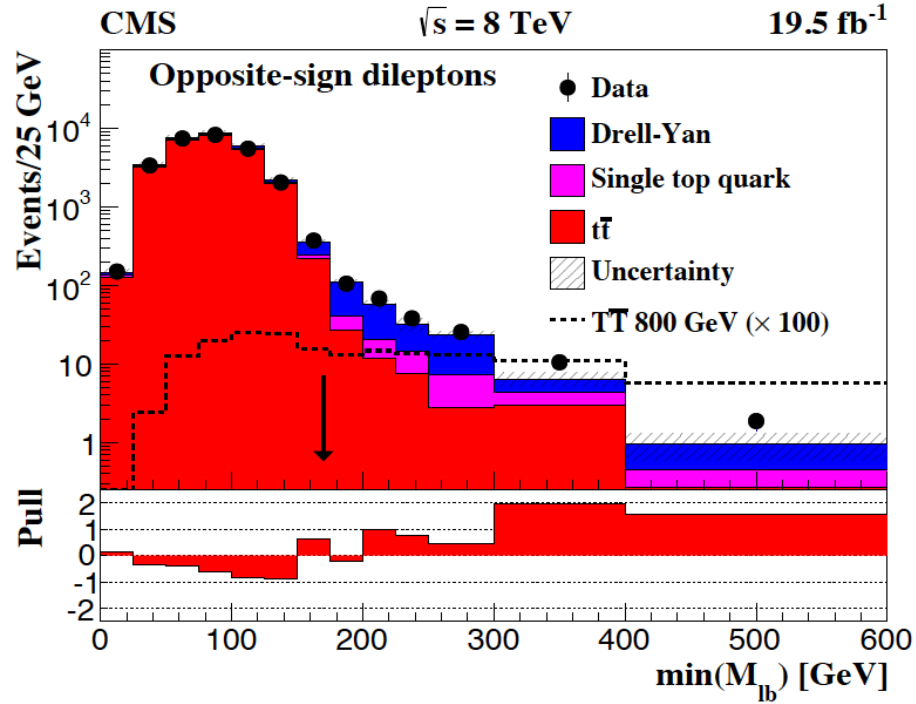


Conclusion & Outlook

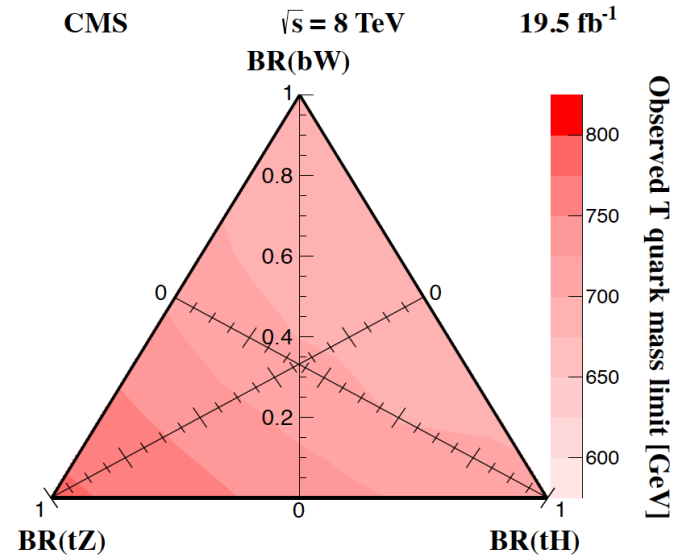
- Many Exotics searches motivated by CH models
 - Signature-based search + interpretation using benchmark
- Run II – entering interesting mass scale for CH
 - Top, W, Z, H decay modes with largest BR most promising at high mass end
 - Identification of boosted top quarks, W, Z, H bosons are essential and will remain a focus
 - Direct searches complemented by Higgs precision measurements
 - Extend searches to single VLQ and light-flavor VLQ
 - And there is more..., e.g. displaced vertices – anything we are missing?

Backup

Inclusive VLT Search

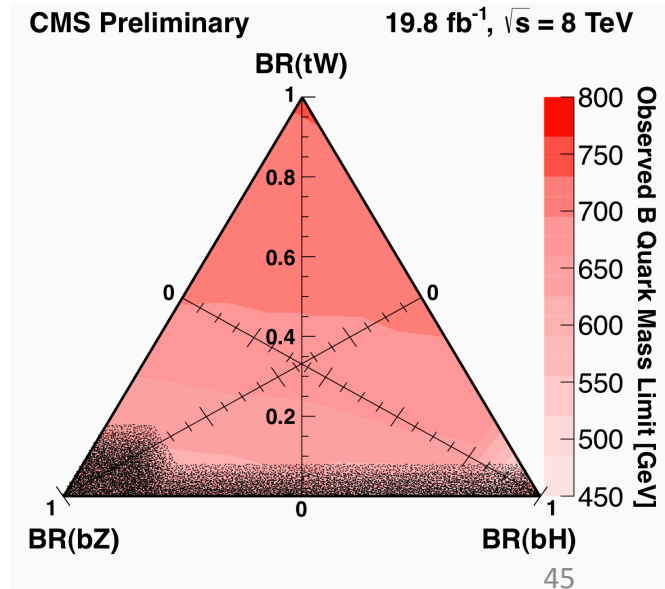
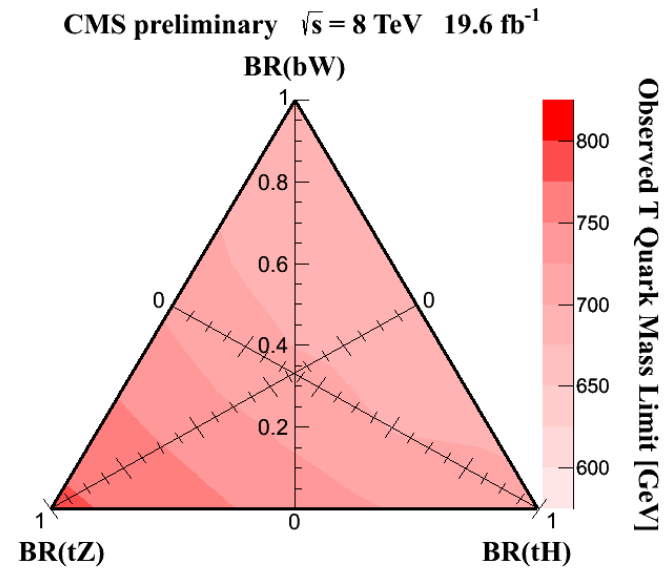
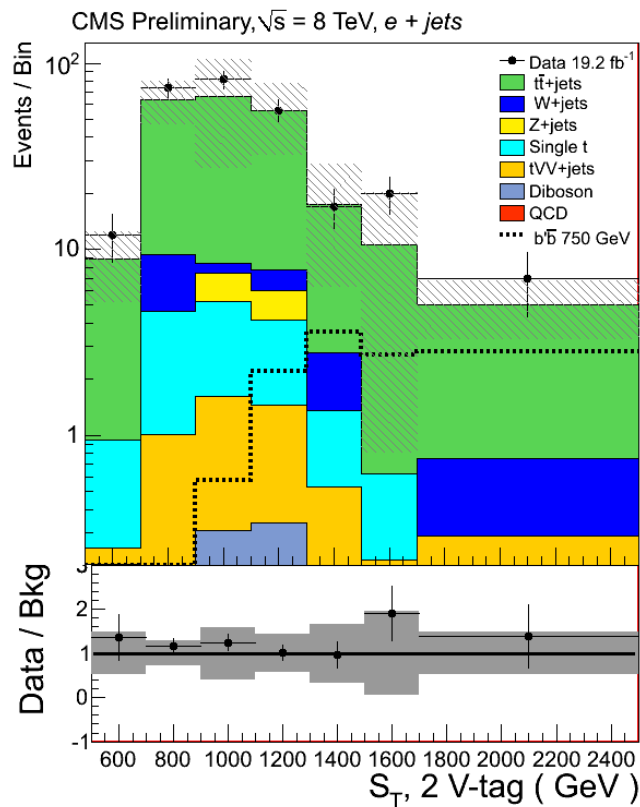


- Single leptons
- Multilepton: OS- (on-/off-Z), SS- and tri-leptons

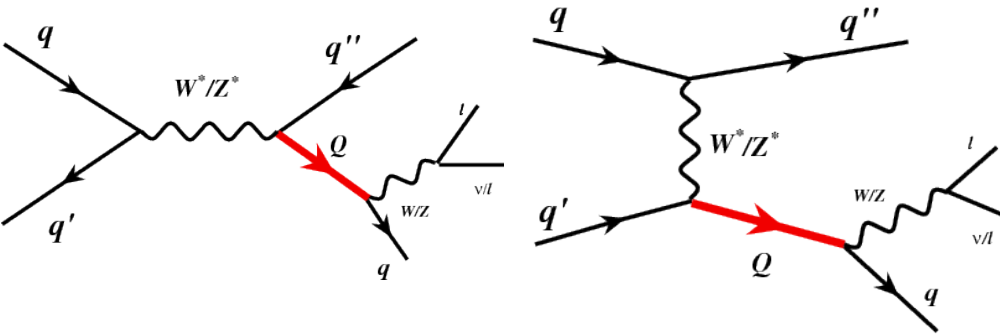


Inclusive VLT & VLB Searches

- Single lepton, ≥ 4 jets, ≥ 1 b-jets
- 0, 1, ≥ 2 V-tags

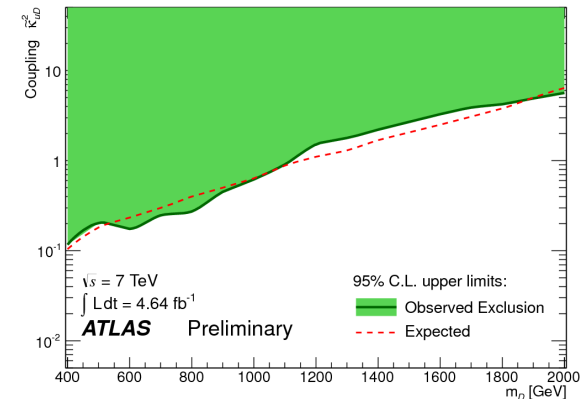
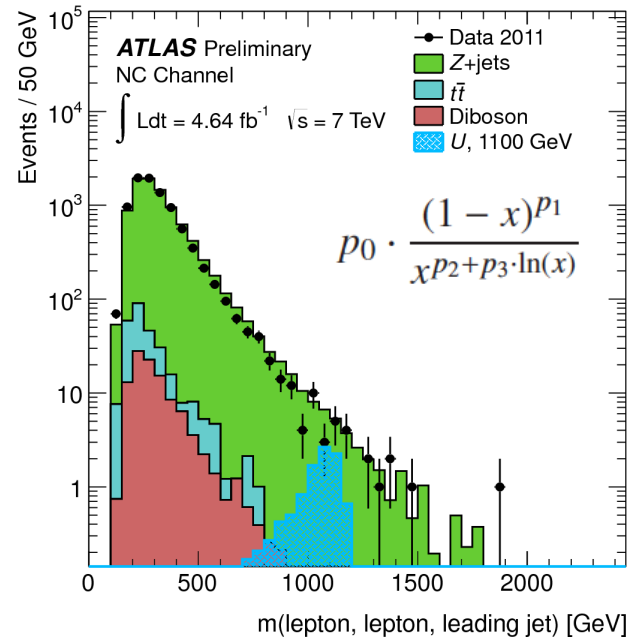
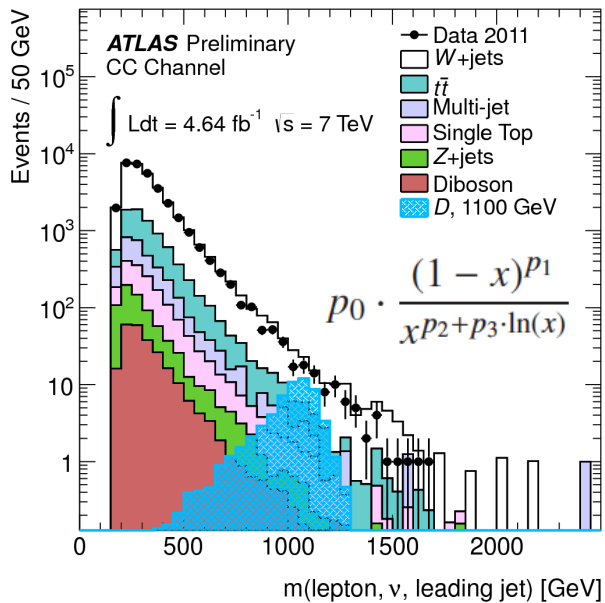


Composite light generations



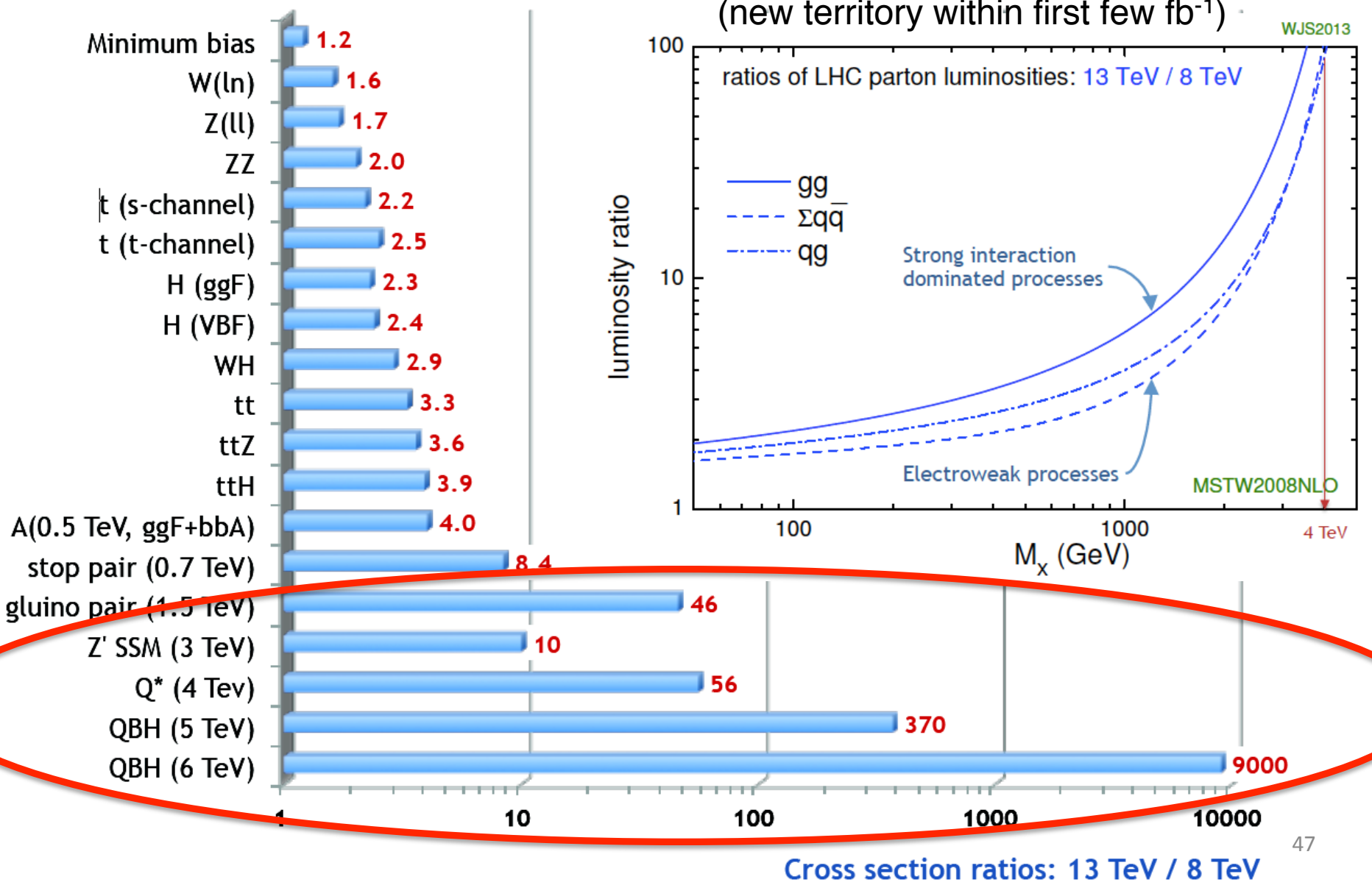
(Large production cross sections)

- Select $W \rightarrow l\nu$ / $Z \rightarrow l\bar{l}$ and 2 jets
- Reconstruct $m(Q) = m(W/Z + \text{jet})$
- Phenomenological fit to $m(Q)$

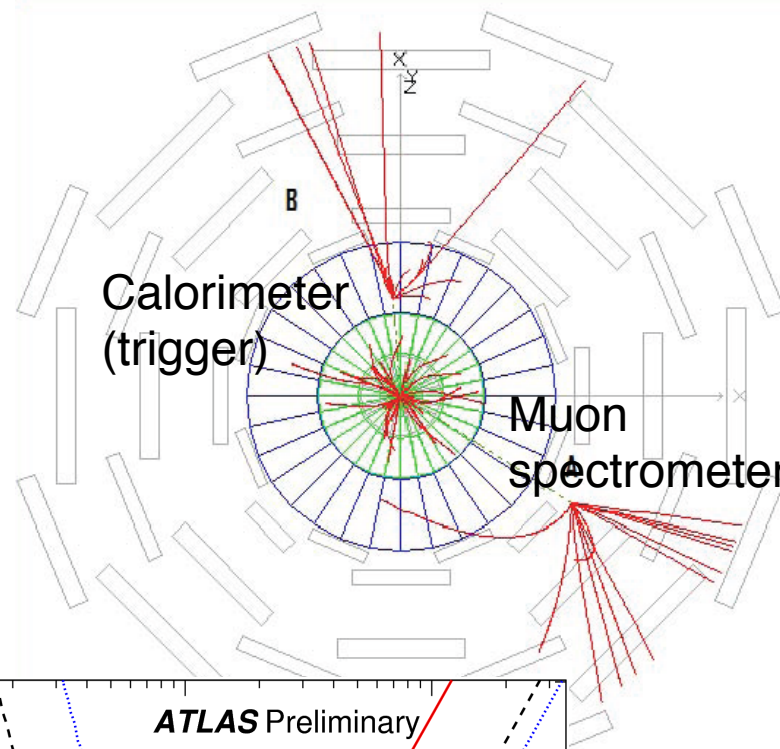
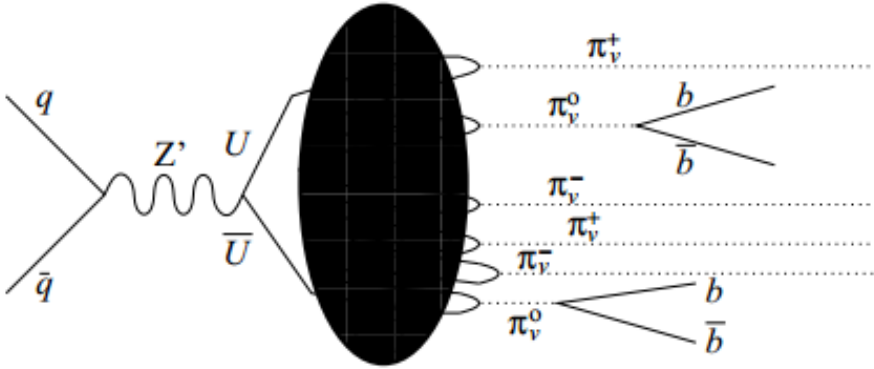


- Exclude @ 95% CL (coupling=1)
 - $m(U_{2/3}) < 1080 \text{ GeV}$
 - $m(D_{1/3}) < 1120 \text{ GeV}$
 - $m(X_{5/3}) < 1420 \text{ GeV}$

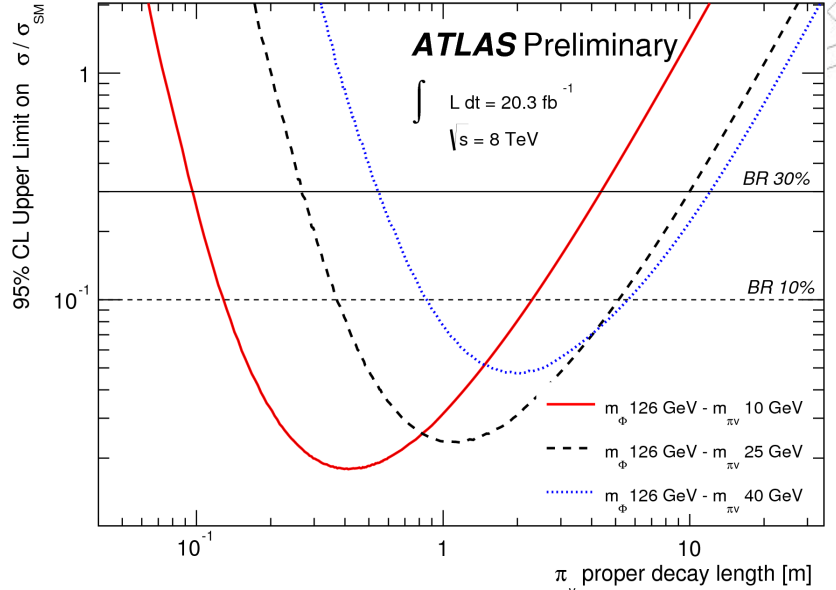
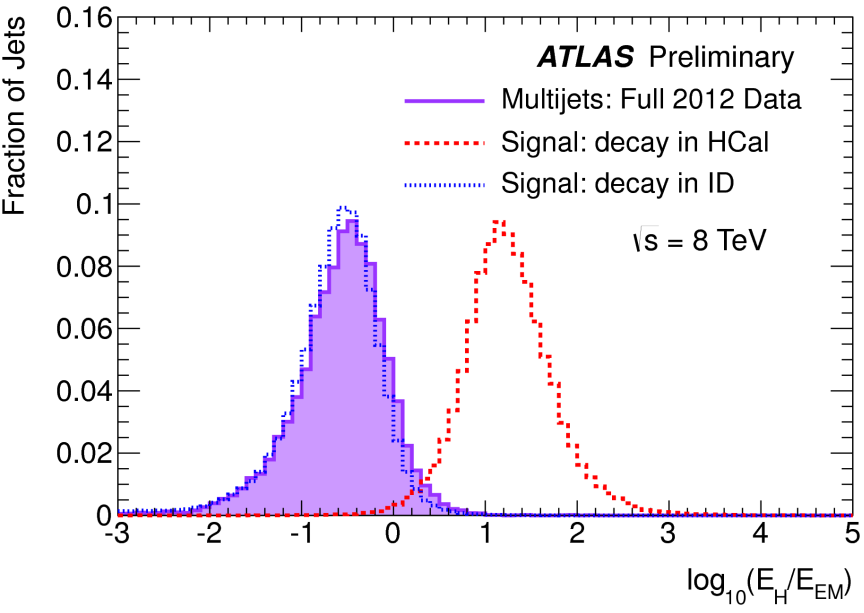
Run II Outlook



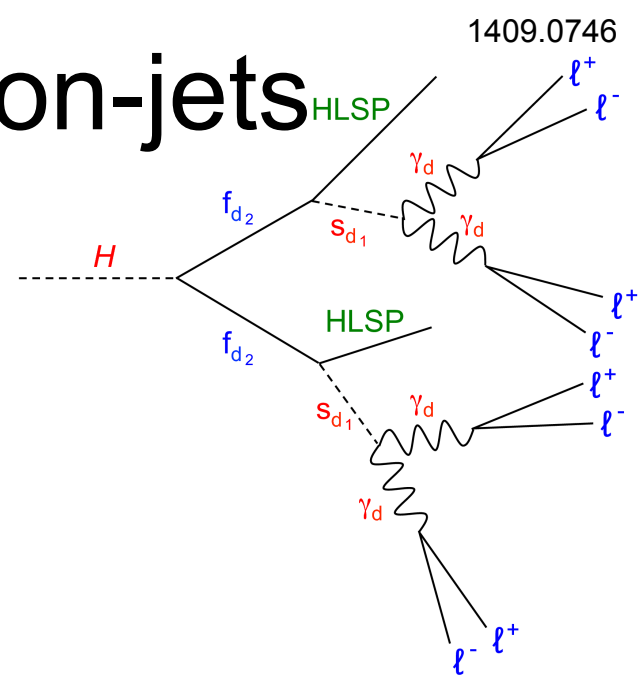
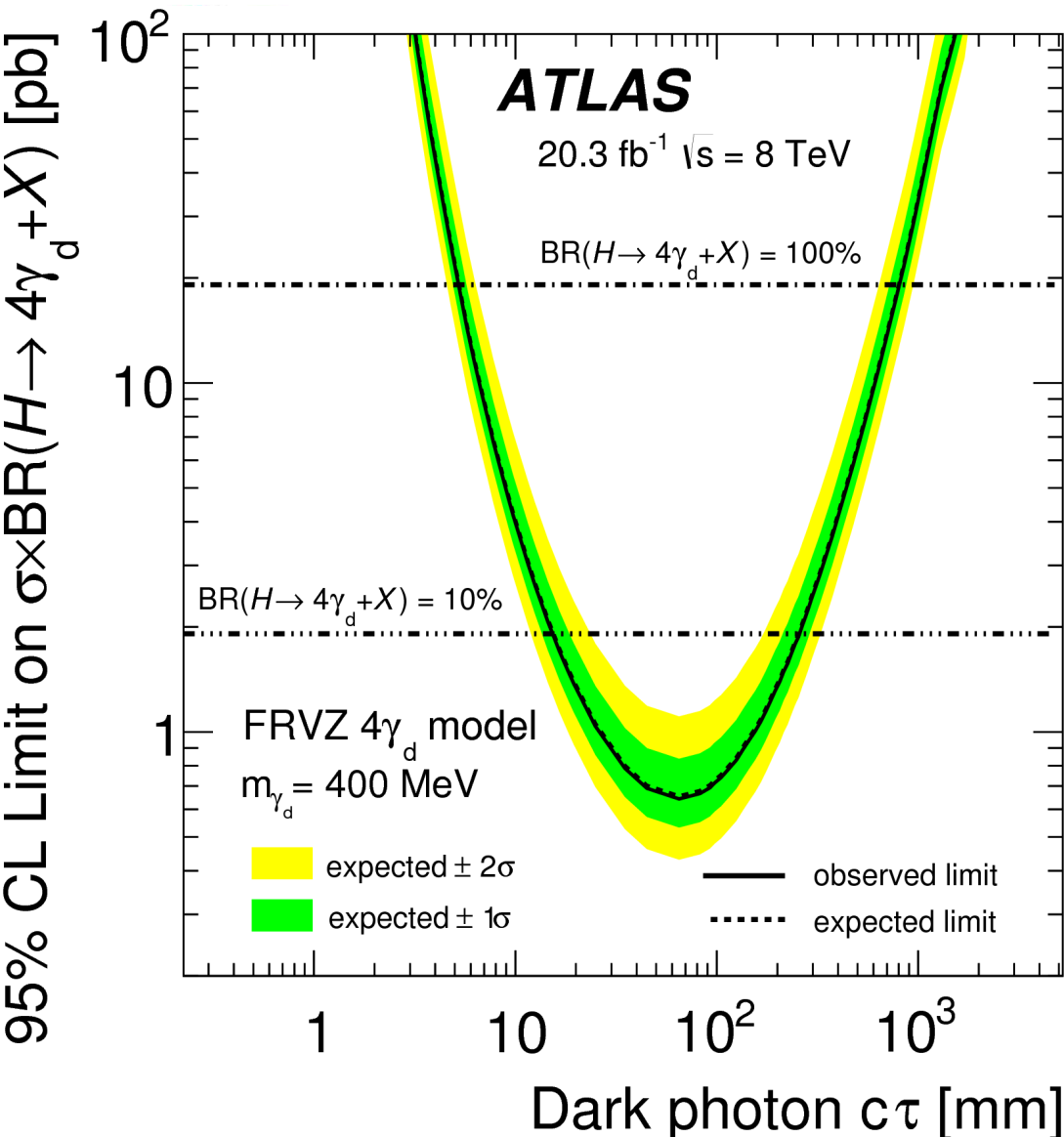
Hidden Valley: Long-Lived Particles



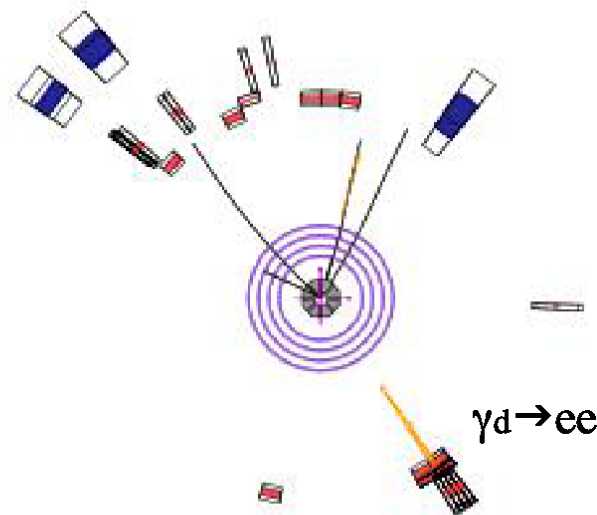
Narrow jets in HCal without tracks



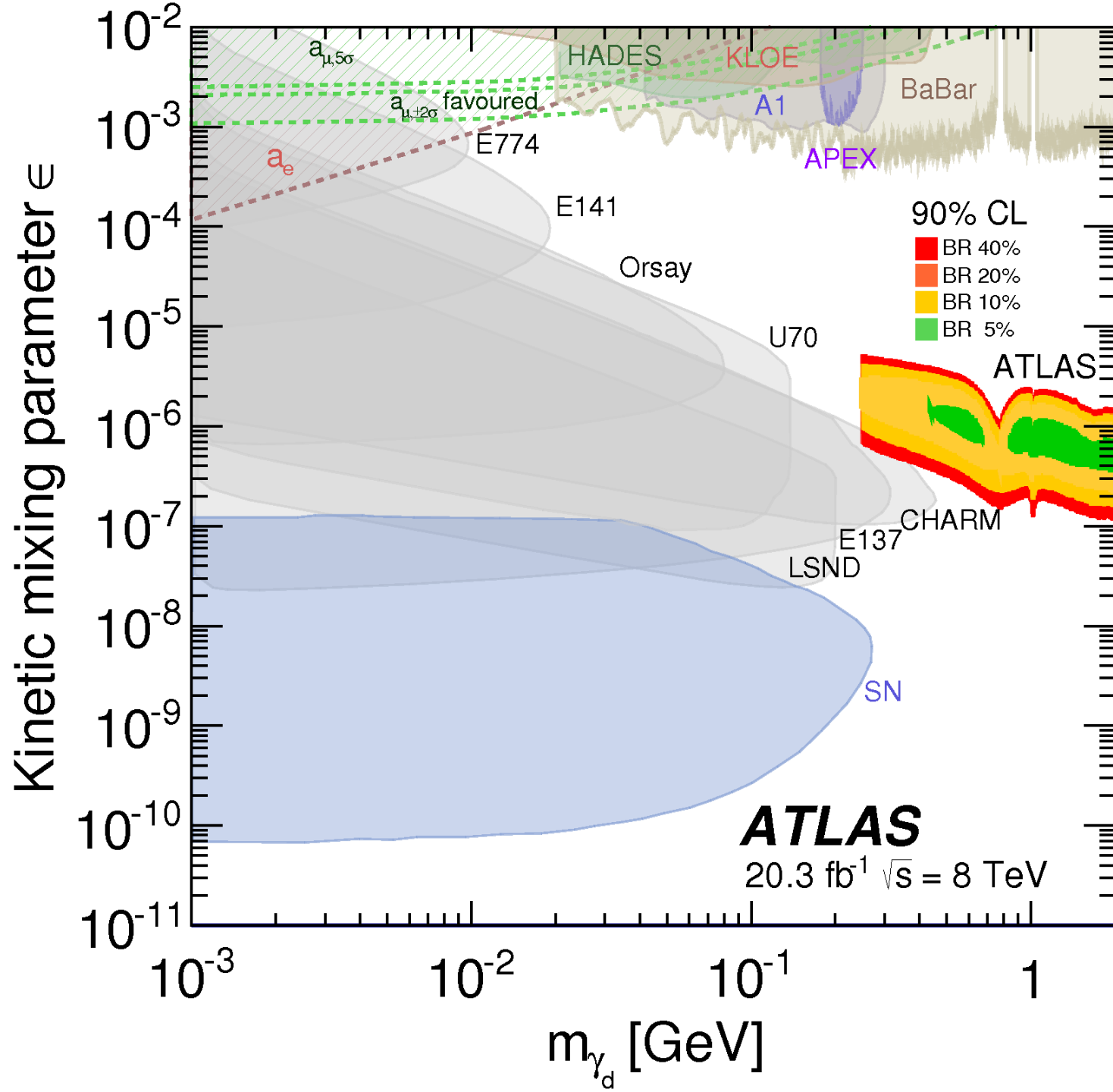
Hidden Sector: Lepton-jets



Falkowski–Ruderman–
Volansky–Zupan



Vector
Portal
Model

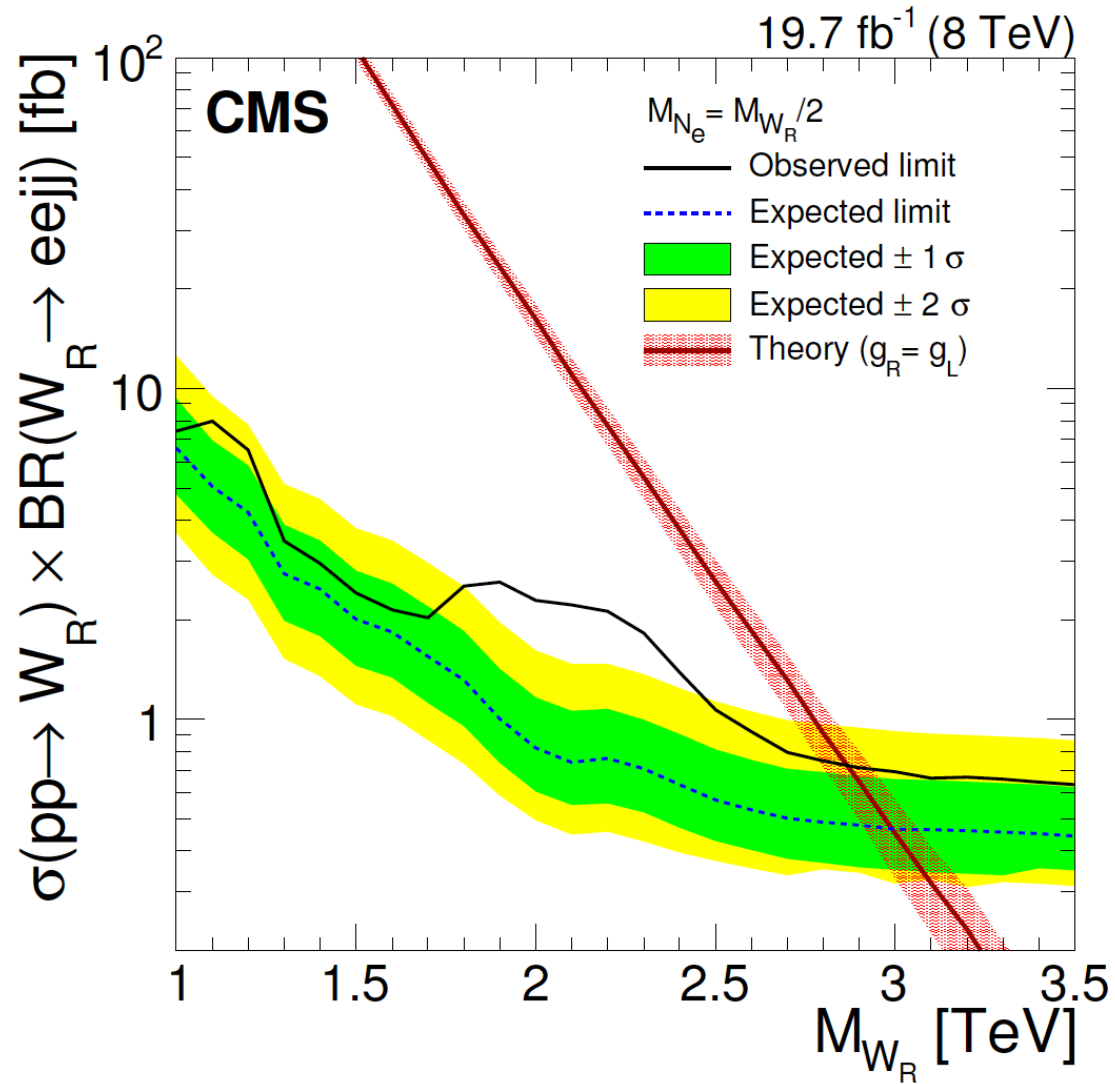
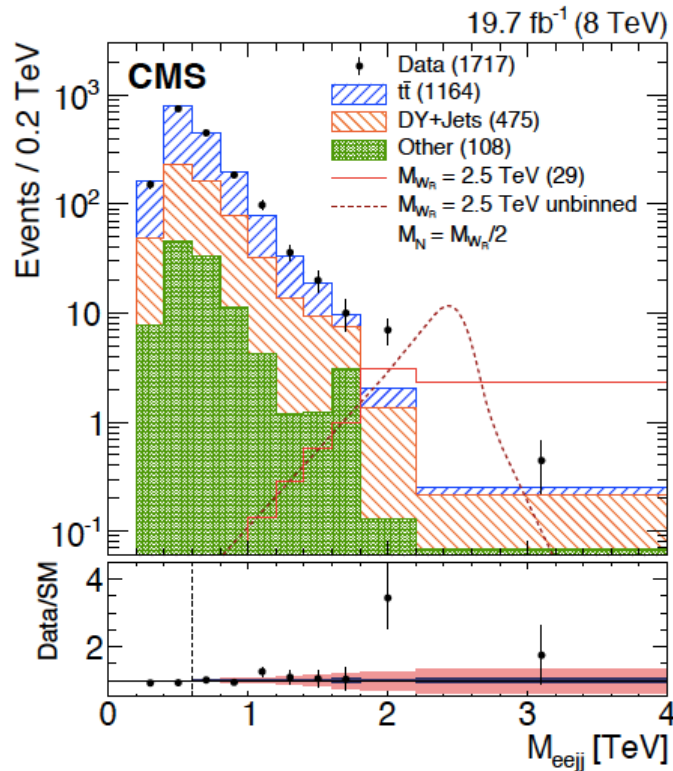


Many More Searches

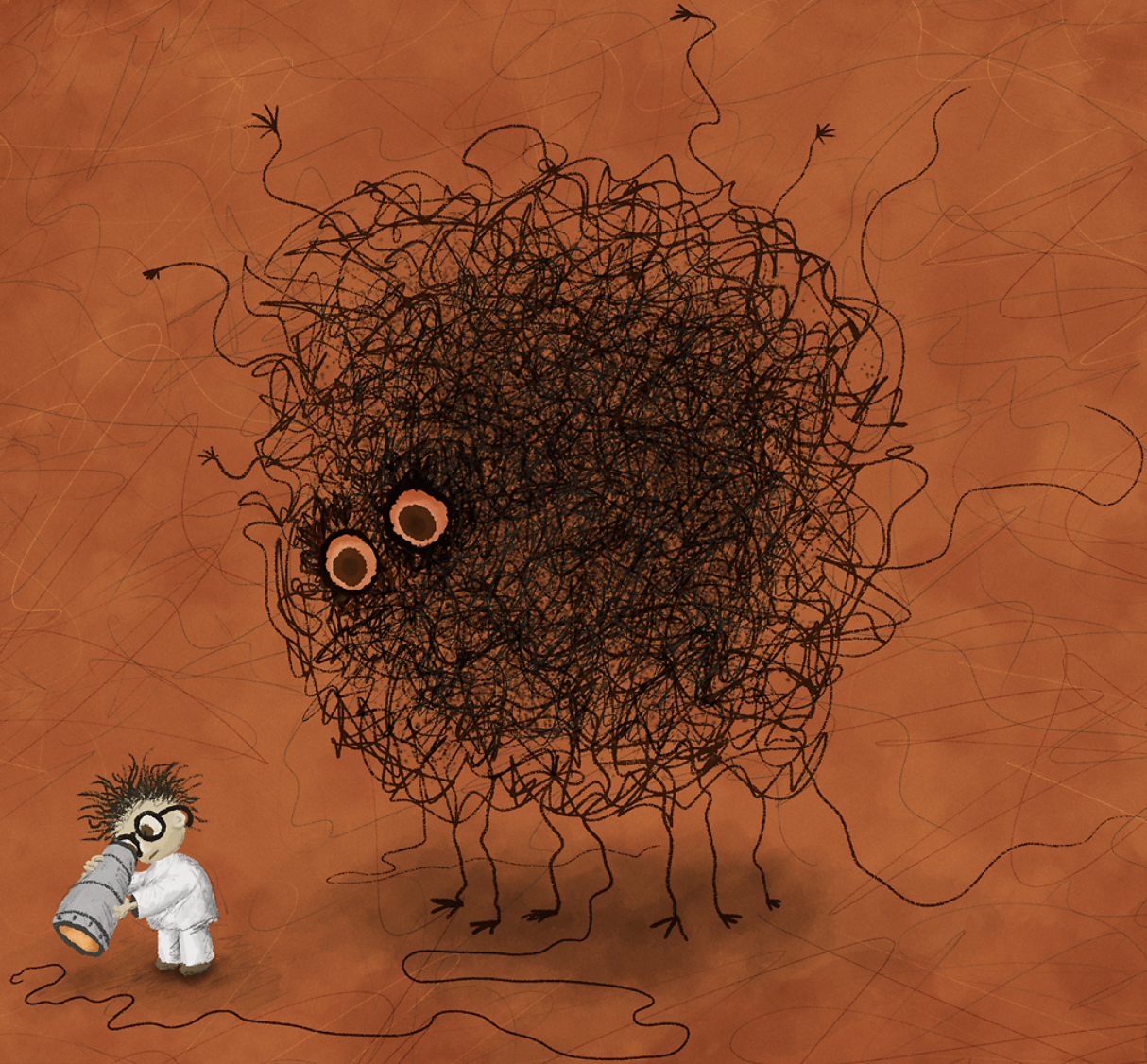
- Lepton Flavor Violation
- Black Hole / TeV gravity / Jet extinction
- Heavy Neutrinos / See-saw / Vector-Like Leptons
- Many other resonance searches: jj , ll , lv , bb , $\tau\tau$, $\gamma\gamma$, γjet , $W\gamma$, $Z\gamma$,...
- Excited leptons
- Contact interactions: jj , ll ,...
- Displaced objects
- Monopoles & multi-charged particles
- Generic multi-lepton and same-sign lepton searches
- ...

First sign of New Physics?

W_R and Heavy Neutrinos



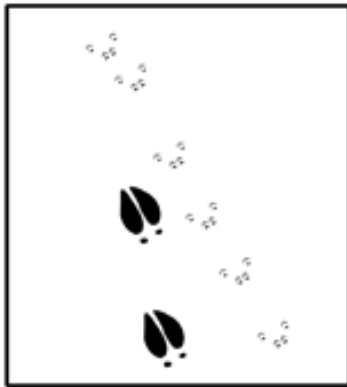
More of these might be coming as we finish up Run I searches...



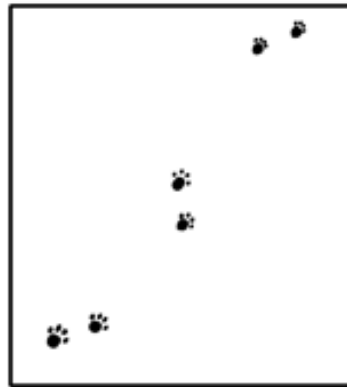
BACKYARD SNOW TRACKING GUIDE



CAT



MOOSE AND SQUIRREL



LONGCAT



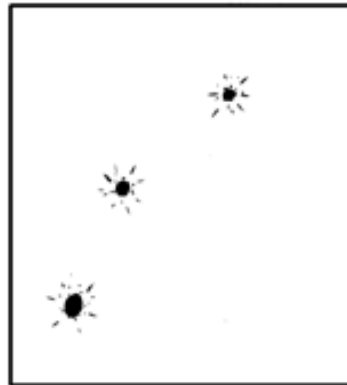
MOUSE RIDING BICYCLE



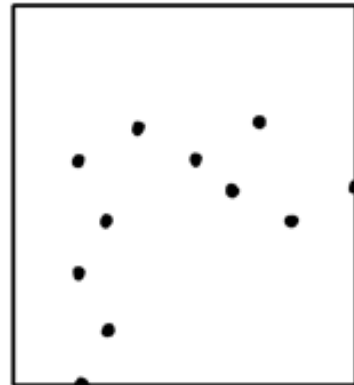
RABBIT STOPPING
TO USE HAIR DRYER



LEGOLAS



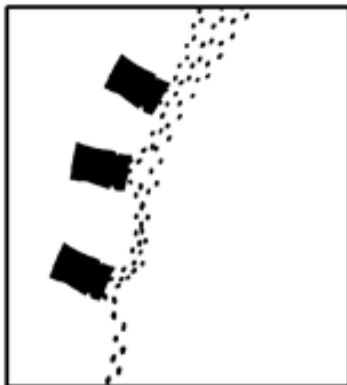
BOBCAT ON POGO STICK



KNIGHT



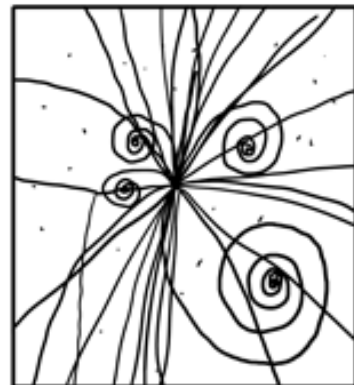
KID WITH
TRANSMOGRIFIER



KID WITH DUPLICATOR



PRIUS



HIGGS BOSON

(Hitoshi Murayama)

