General Exotics review of ATLAS and CMS

LHC France – Annecy 2013

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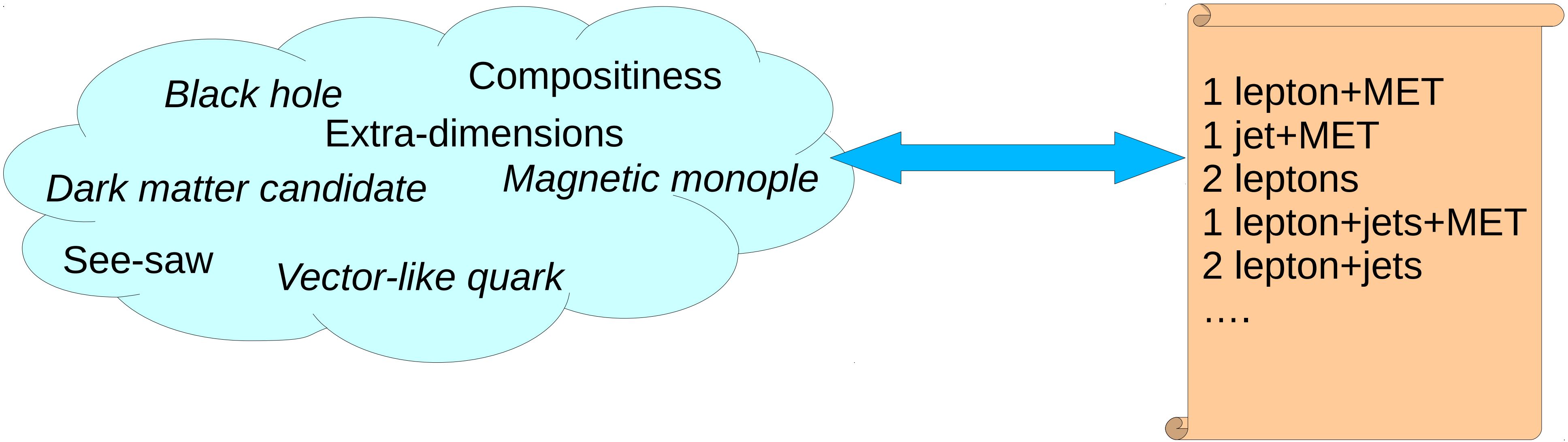
(LPC – Clermont-Ferrand)

Exotic Searches

- Strategy:
  - Mainly: look at signatures and interpret the results within various models
  - Sometime: consider a specific model, and look for it in the data



- This talk will focus on 8TeV results
  - Will talk about 7TeV results when a French team is involved

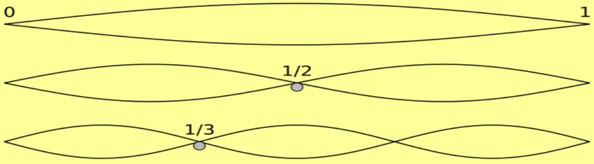
Will include quick reminders on the various exotic models

Leptonic Signatures

- Dilepton resonances
- Non-resonant dileptons
- Lepton + MET
- Dilepton + gamma
- 4 leptons (type III Seesaw Model heavy fermions)

New bosons and extra-dimensions

- The hierarchy problem can be addressed by adding new space dimensions (→Kaluza-Klein resonances)
  - New dimensions compactified
    →excitations of the fields are quantified
  - Excitation modes seen as new heavy particles



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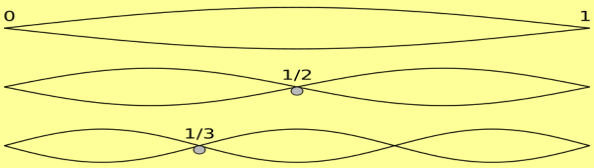
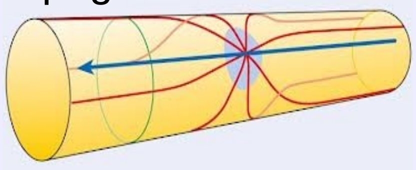


Arkani-Hamed, Dimopoulos and Dvali (ADD):

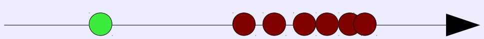
- *n* compactified (radius *R*) flat extra-dimensions
- Only the gravity (G) can propagate in these dimensions
  → dilution of the gravity



- M_D: new Planck Scale in 4+n dimensions

$$M_{Pl}{}^2 \sim M_D{}^{2+n} R^n$$

- New resonances, but small splitting between modes → ~continuum



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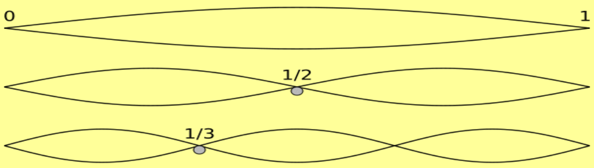

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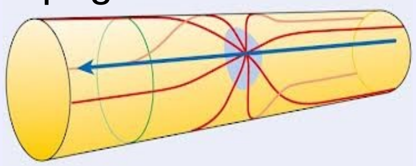

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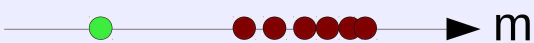
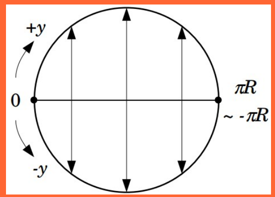
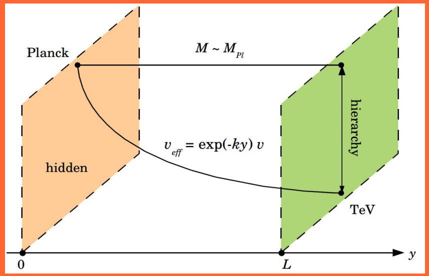


Randall-Sudrum (RS):

- 1 additional compactified extra-dimension with a Z_2 symmetry:

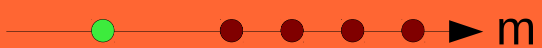


- Equivalent to 2 branes:



- gravity almost constant
- Higgs vev exponentially suppressed

- First resonances are well-defined/separated



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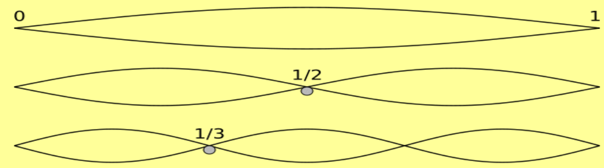

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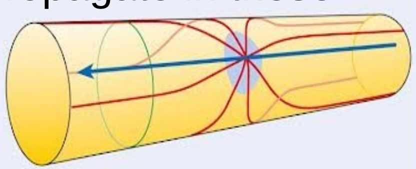

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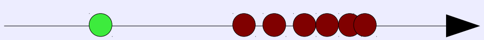

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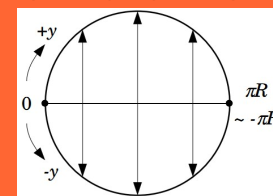

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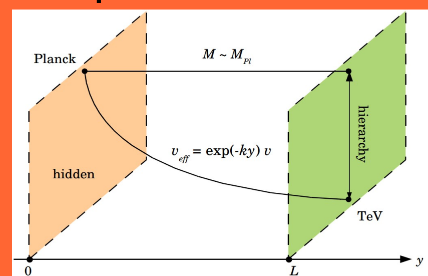

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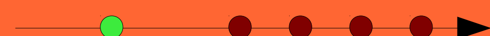

Others models with new bosons

- Universal ExtraDimension (**UED**):
  - SM particles can propagate in the additional dimensions
  - KK-parity
  - KK=1 particle: produced by pair, dark matter candidate
  - KK=2 particle can be produced single

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- Grand Unification Theory (**GUT**):
  - Aim to unify the strong and weak forces into a simple gauge group
  - The simplest group compatible with the experiments is SO(10)
    - Predict one extra neutral boson (Z') and heavy right handed neutrinos
  - Larger groups (E(6),...) predict more Z' and additional fermions

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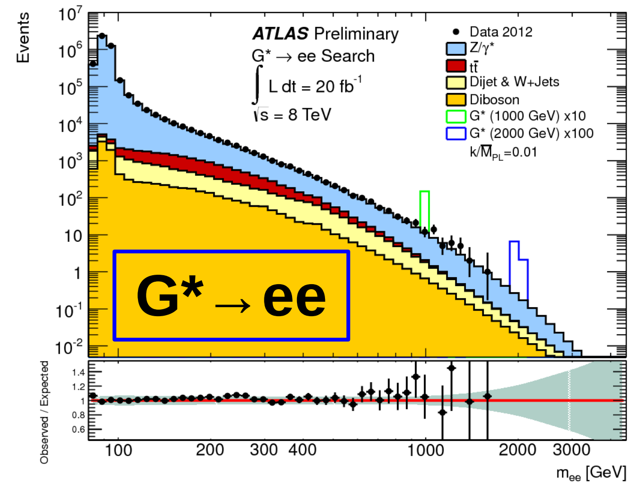
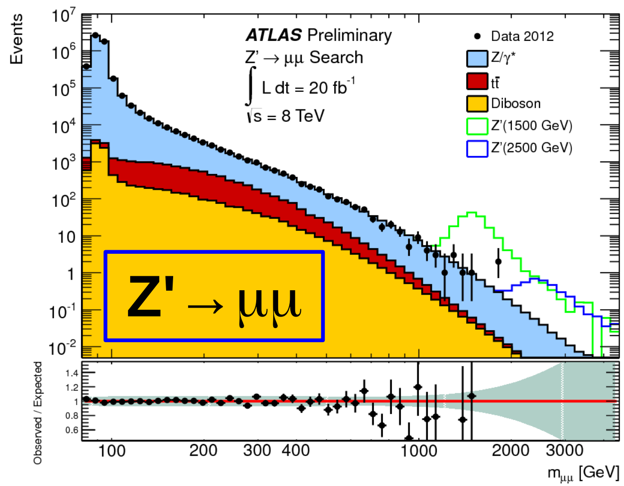
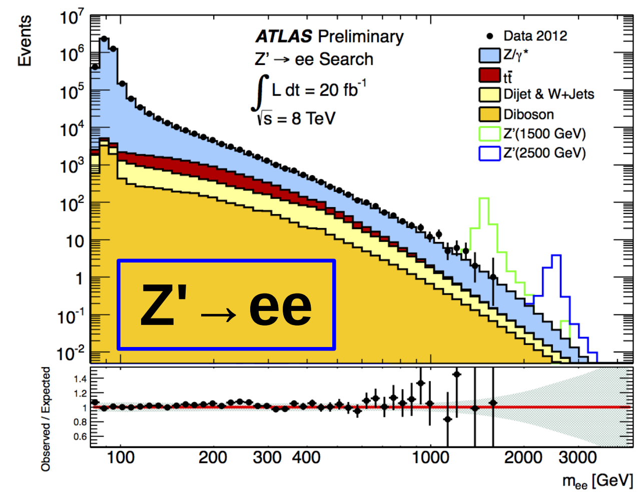
- Sequential Standard Model (**SSM**):
  - Generic model → benchmark
  - Add a boson (Z'/W') with the same coupling than the SM's one (Z/W)
  - Sometime with a slightly modified coupling so the relative width (Γ/m) is constant

Dilepton resonances

- Search for high mass dilepton (e or μ) resonance, using RS Z' or G* as benchmarks
- Select events with 2 high pT leptons
- Backgrounds from MC, apart for fake leptons
  - ee: multijet/W+jets from data
  - $\mu\mu$: multijet/W+jets negligible
  - MC normalized to data in the Z peak region



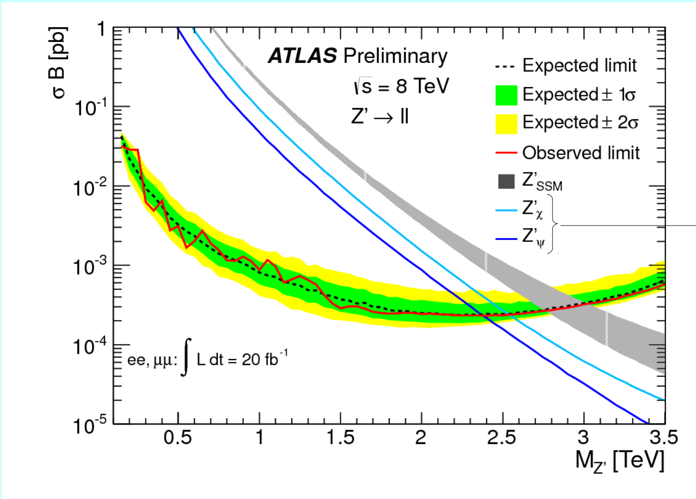




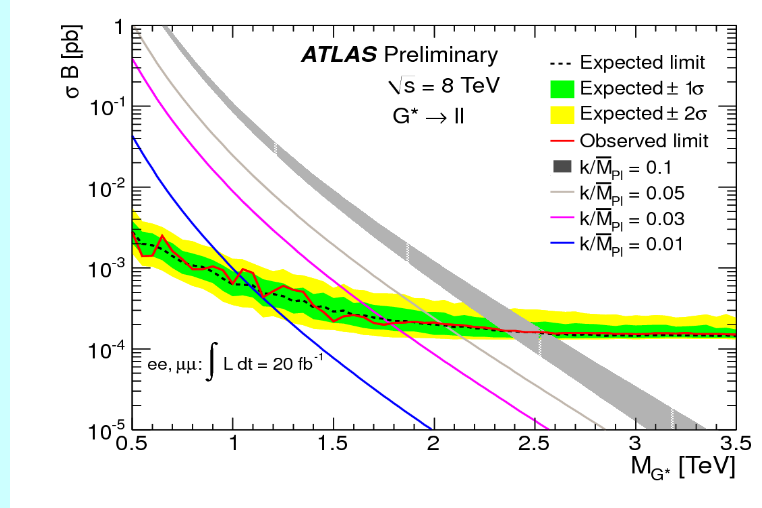
LAPP
Saclay

Dilepton resonances

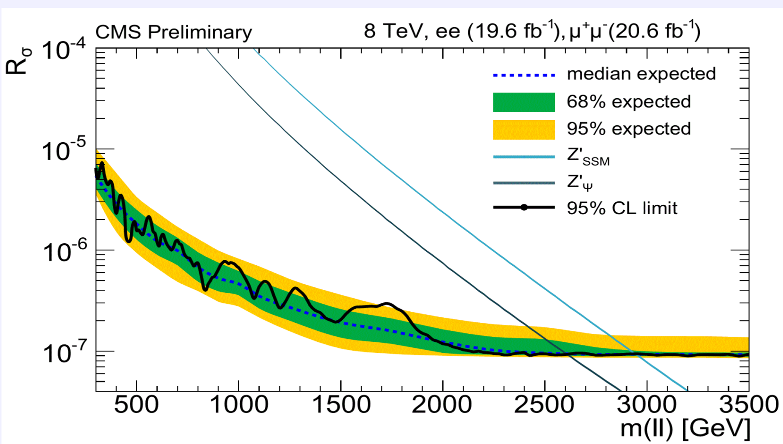
ATLAS-CONF-2013-017
CMS-PAS-EXO-12-061



GUT



$$R_\sigma = \frac{\sigma(\mathrm{pp} \to \mathrm{Z}' + \mathrm{X} \to \ell\ell + \mathrm{X})}{\sigma(\mathrm{pp} \to \mathrm{Z} + \mathrm{X} \to \ell\ell + \mathrm{X})}$$



- SSM Z' mass excluded up to 3TeV
- Limits strongly depend on signal (Z'/G*) and on model's parameters

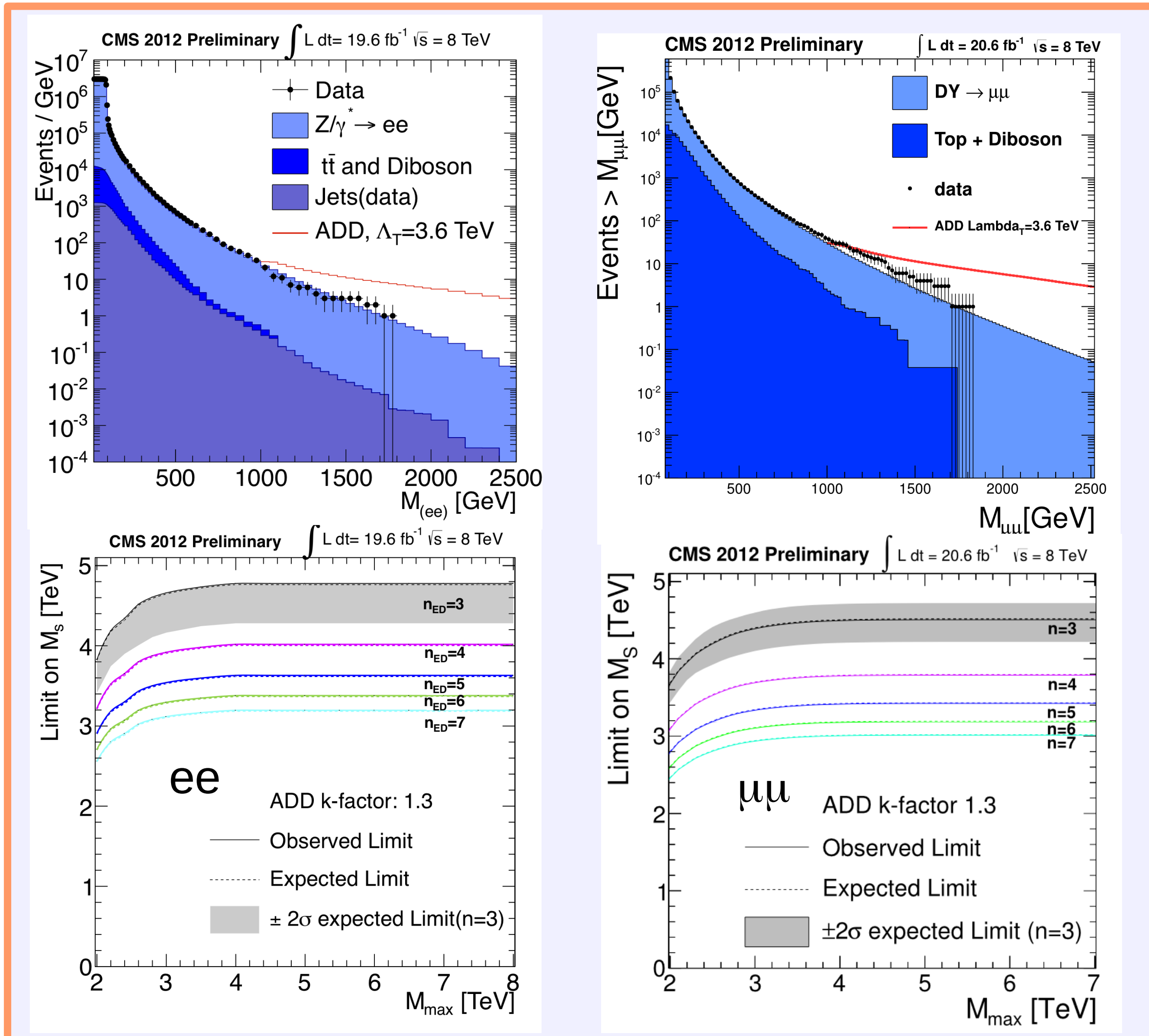
LAPP
Saclay

Non-resonant dileptons

CMS-PAS-EXO-12-027 CMS-PAS-EXO-12-031

ATL: Phys. Rev. D 87, 015010 (2013)

- Similar analysis than for the resonance but search for excess/deficit in the tail



Atlas 7TeV, 4.7 fb^{-1}

Channel	Prior	Exp. limit [TeV]	Obs. limit [TeV]
ee	$1/M_S^4$	2.88	2.73
	$1/M_S^8$	2.72	2.62
$\mu\mu$	$1/M_S^4$	2.83	2.83
	$1/M_S^8$	2.61	2.61
$ee+\mu\mu$	$1/M_S^4$	3.16	3.00
	$1/M_S^8$	2.96	2.85
$ee+\mu\mu+\gamma\gamma$	$1/M_S^4$	3.43	3.22
	$1/M_S^8$	3.27	3.12

Limits on M_S

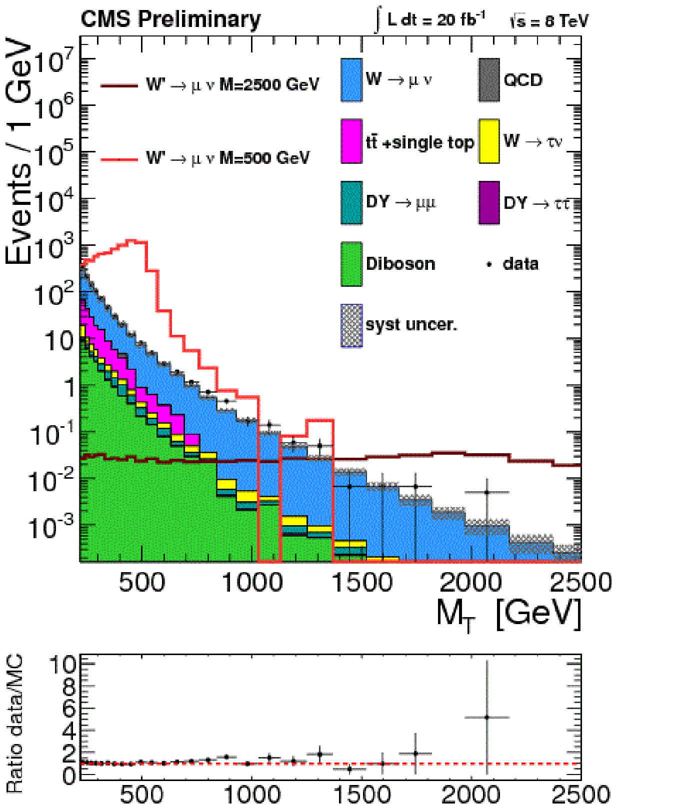
M_S: ultra-violet cut-off of the sum over KK excitations

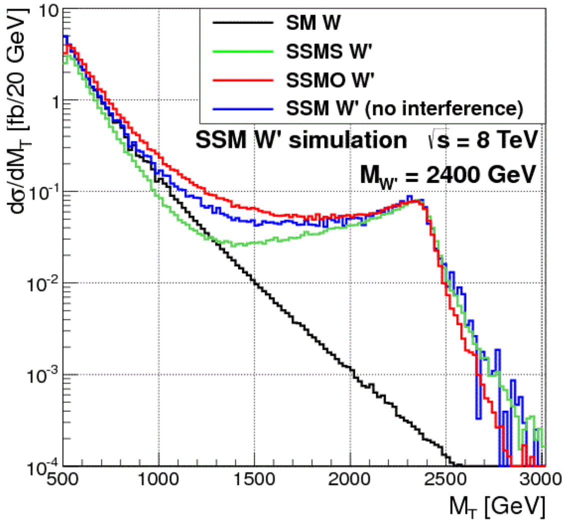
M_{max}: assume no signal above this threshold

Lepton + MET

CMS-PAS-EXO-12-060
ATL: Eur. Phys. J. C (2012) 72: 2241

- Typical selection (CMS):
  - High pT (100/45GeV) e/μ
  - High MET : 0.4<MET/pT<1.5
  - Lepton and MET back-to-back : $\Delta\phi > 0.8\pi$
- Sensitive to W' production
- CMS also looks at impact of interferences





$$M_{\mathrm{T}} = \sqrt{2 \cdot p_{\mathrm{T}}^{\ell} \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot (1 - \cos \Delta\phi_{\ell,\nu})}$$

Lepton + MET

CMS-PAS-EXO-12-060
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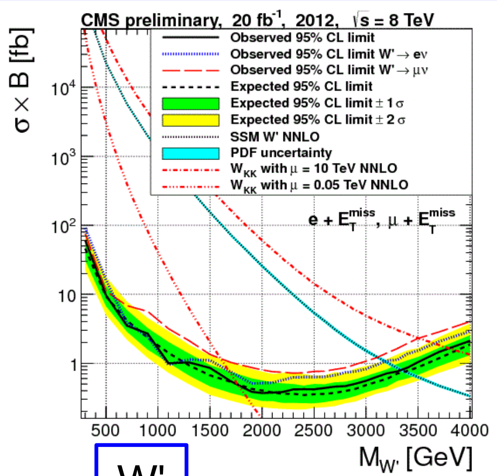
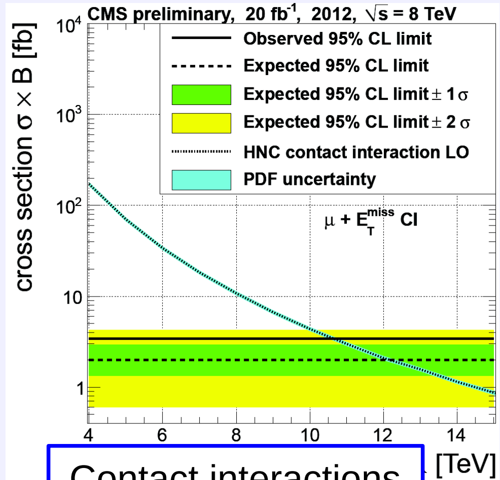
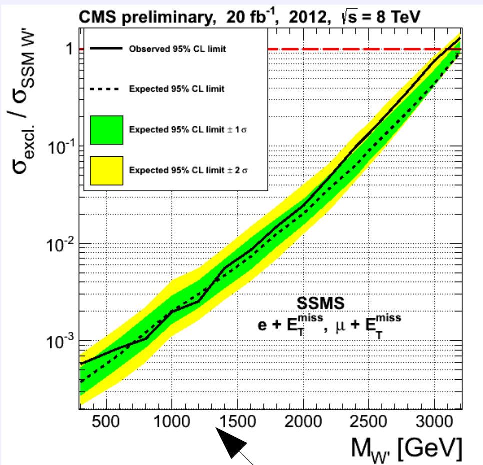
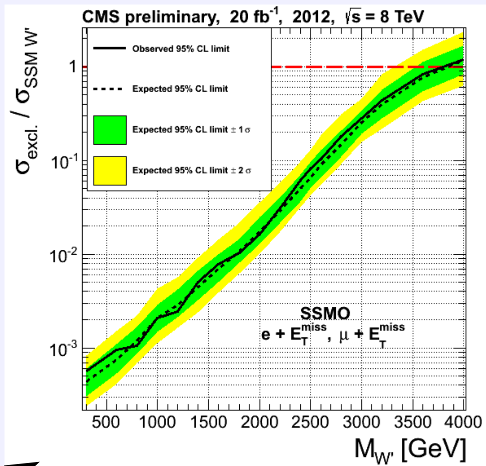


W'

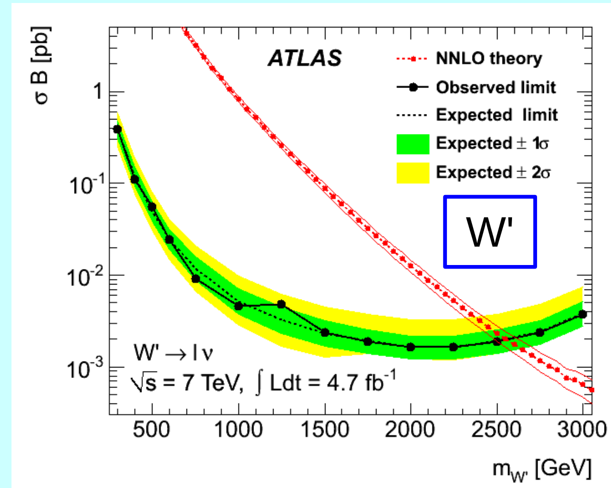


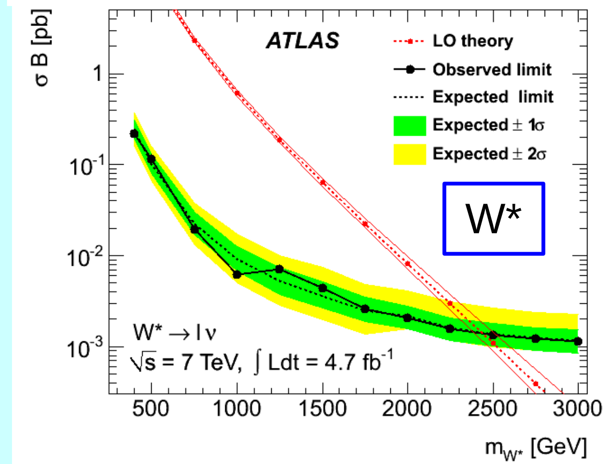
Contact interactions





Destructive/constructive interferences

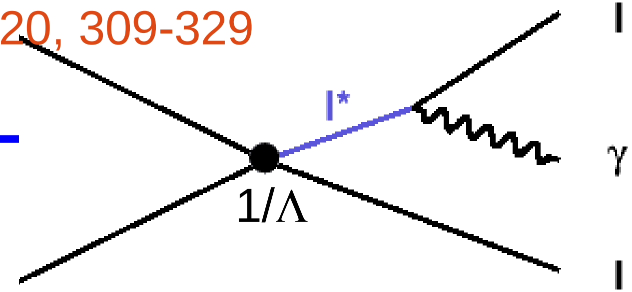




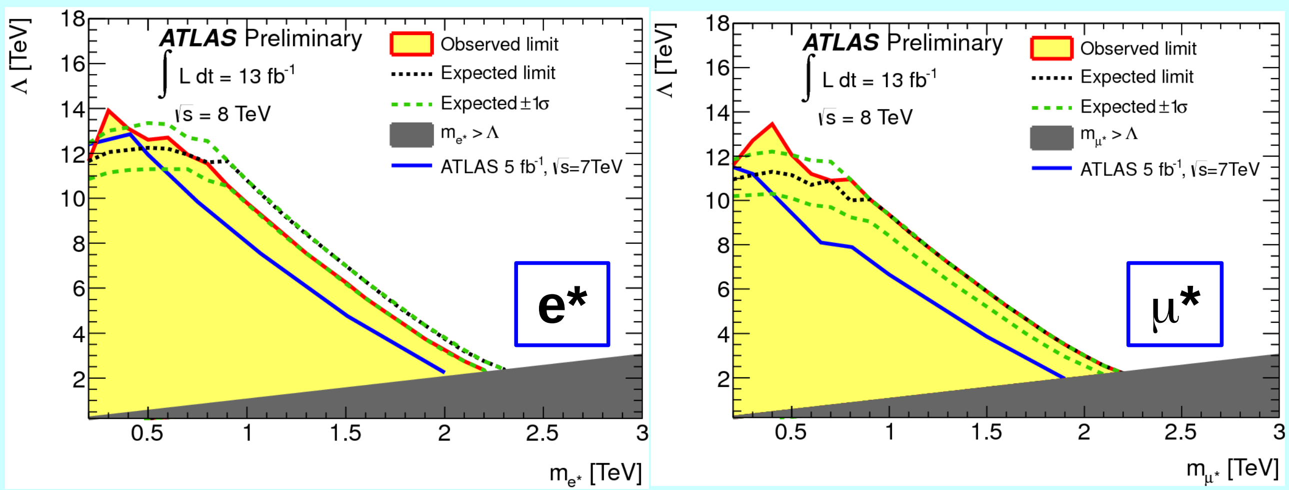
- Many models can be probed

Di-leptons+gamma

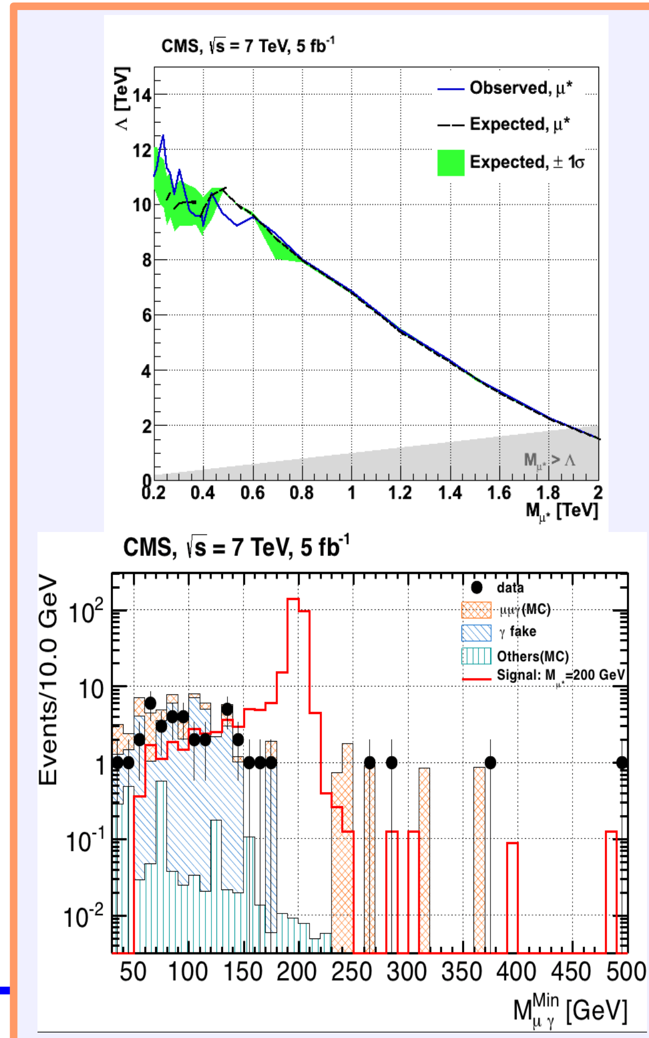
CMS: Phys. Let. B (2013) 720, 309-329
ATLAS-CONF-2012-146



- Assume compositness to address generational structure and mass hierachy of quark/leptons
- 4-lepton contact interaction
- 2 high pT electrons/muons (same flavor)+ isolated γ

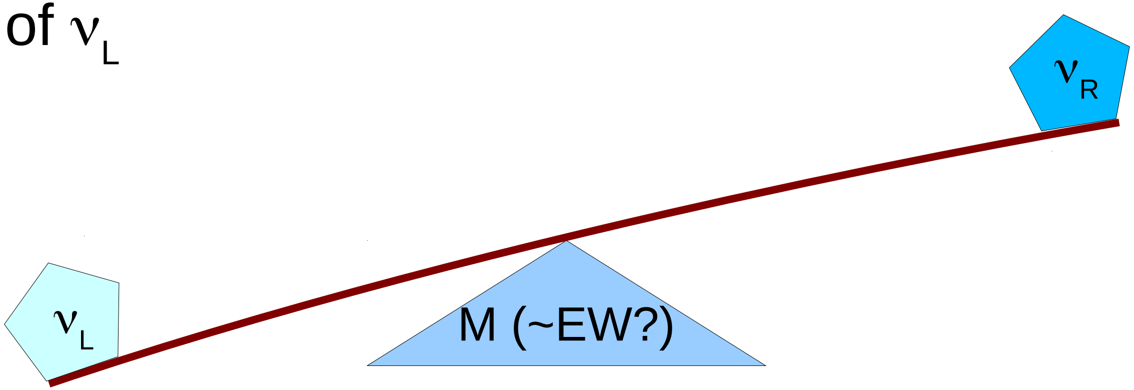


- Limits up to Λ=12TeV
- e* and μ* can not be combined



Seesaws

Explain the very low mass of ν_L

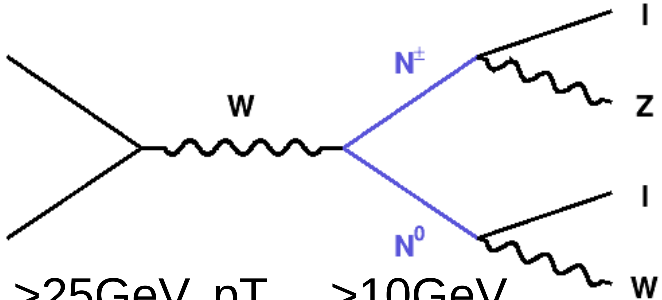


- Type I
  - 2 ν_R, m~10^{14}GeV
  - Inaccessible
- Type II
  - Higgs sector extented to a triplet (H^0, $H^\pm$, $H^{\pm\pm}$)
  - Searches for $H^{\pm\pm}$ done with 7TeV data (see back-up)
- Type III
  - Add a $SU(2)_L$ triplet (N^-, N^0, N^+)
  - $N^0 \sim \nu_R$ of type I

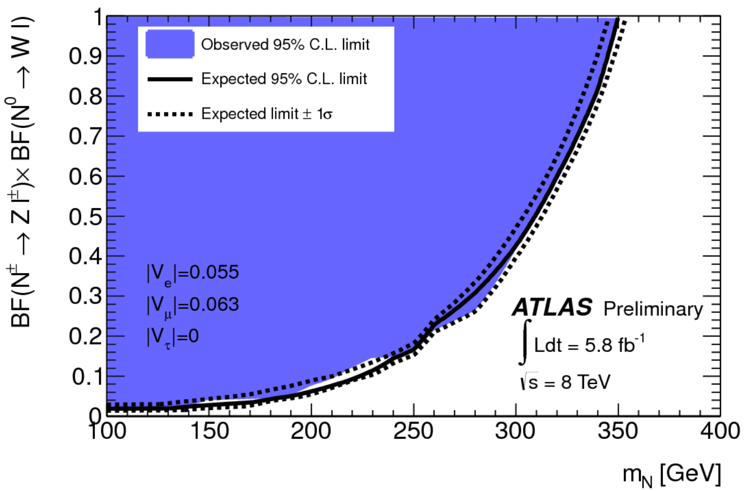
Type III Seesaw Model Heavy Fermions

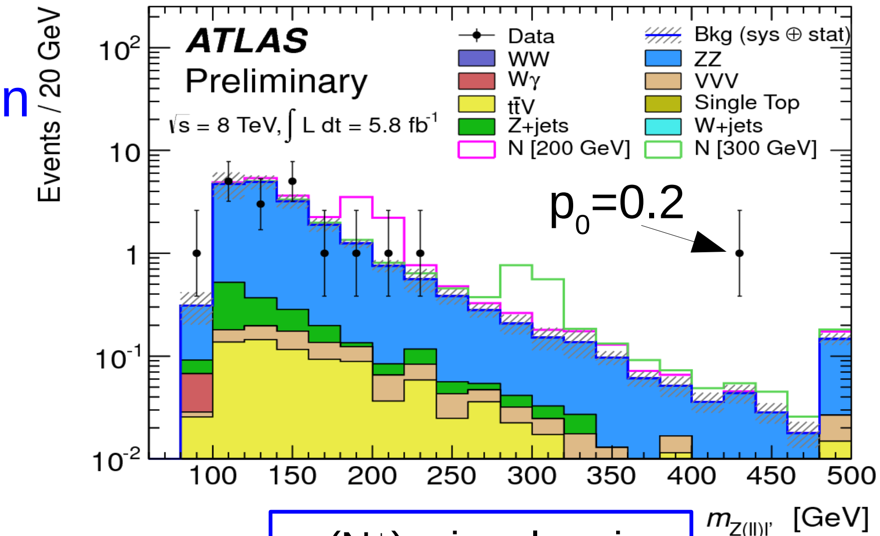
ATLAS-CONF-2013-019

- Search for heavy fermions N^0, $N^\pm$
  - $m(N^0) \sim m(N^\pm)$
  - Search for pair production



- Selection:
  - At least 4 leptons (e or μ), pT_1>25GeV, $pT_{2,3,4}$>10GeV
  - m(ll) within 10GeV of the Z mass.
- $N^\pm$ from the Z candidate + the closest lepton





m(N±), signal region

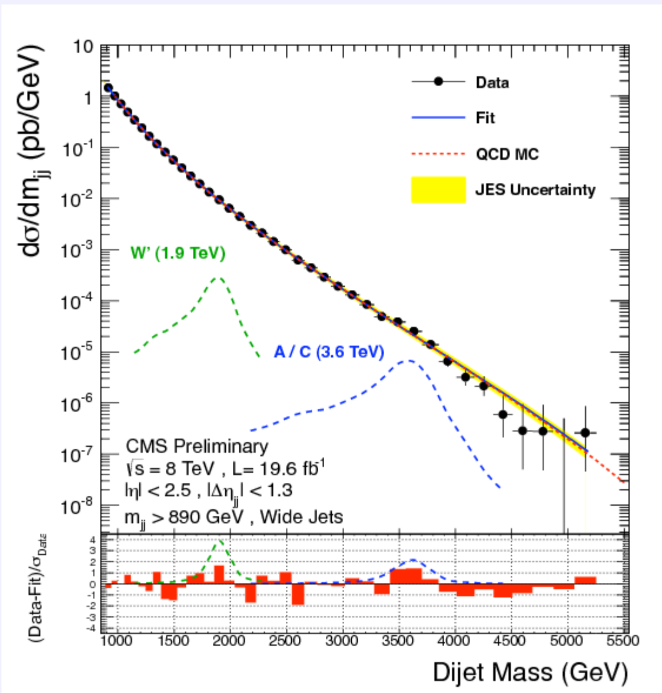
Jet/gamma Signatures

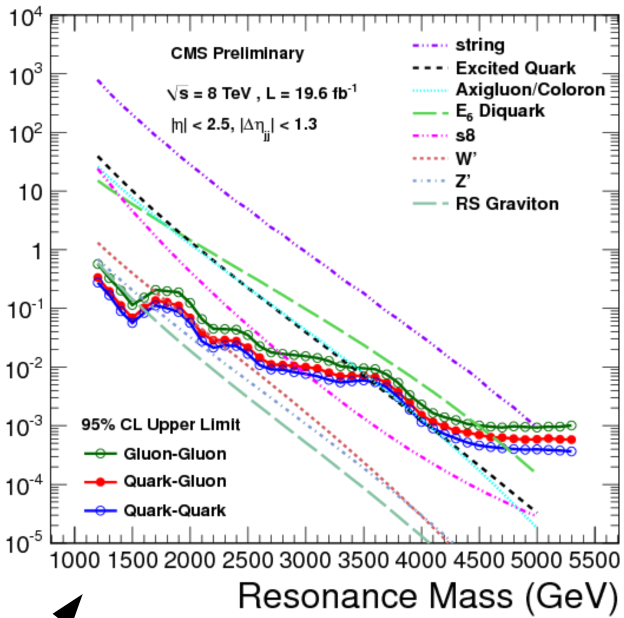
- Dijet resonances
- Diphoton
- Jet + missing E_T
- Monophoton + missing E_T
- Diphoton + missing E_T

Di-jet resonance

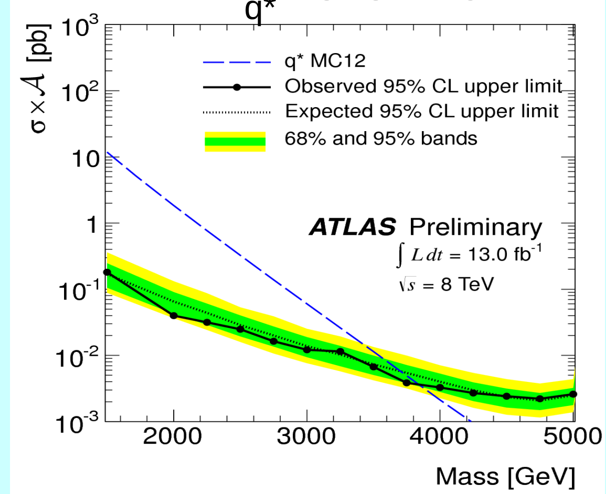
ATLAS-CONF-2012-148
CMS-PAS-EXO-12-059

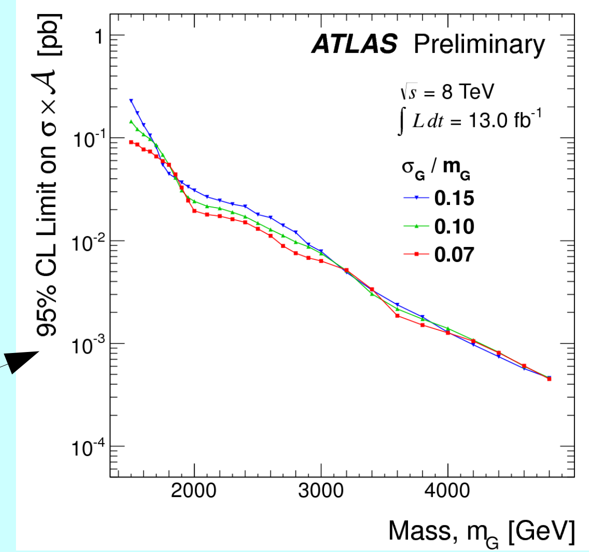
- 2 high pT jets
- Background fitted from data





$m_{q^*} > 3.84$ TeV

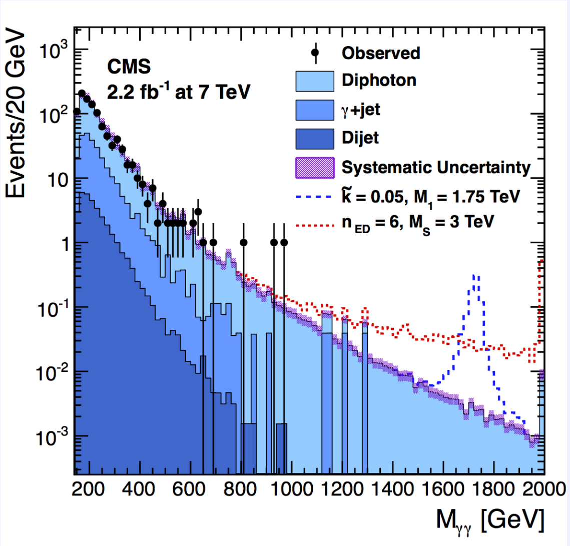


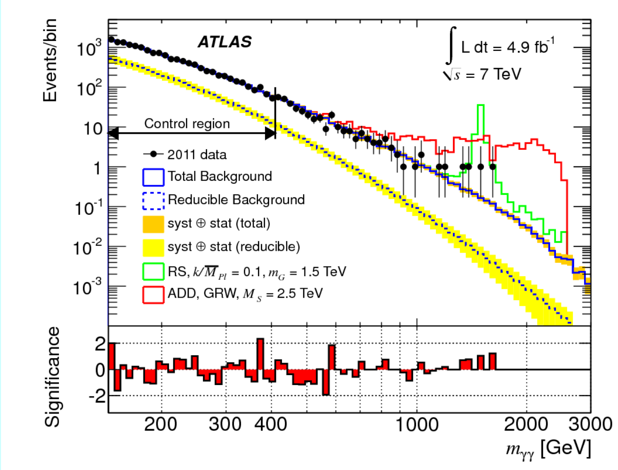


- Result on many models or...
  ... using a generic gaussian parameterization

Diphoton

- 2 high pT photons
- Look for ADD and RS signal
- Complementary to 2-lepton searches





LPSC

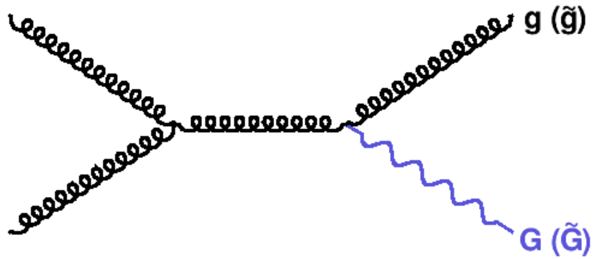
talk by Quentin Buat

Monojet + missing E_T

ATLAS-CONF-2012-147
CMS-PAS-EXO-12-048

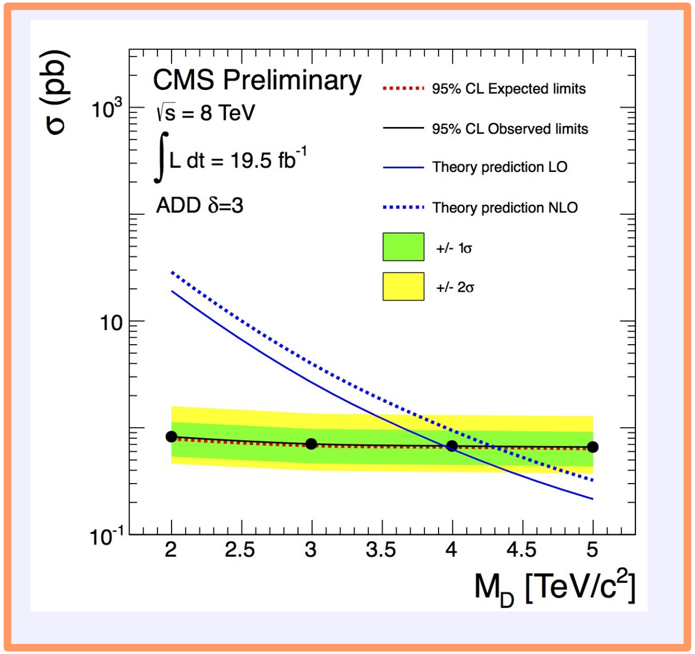
- Predicted by supersymmetry (gravitino), Large Extra Dimension (graviton), …

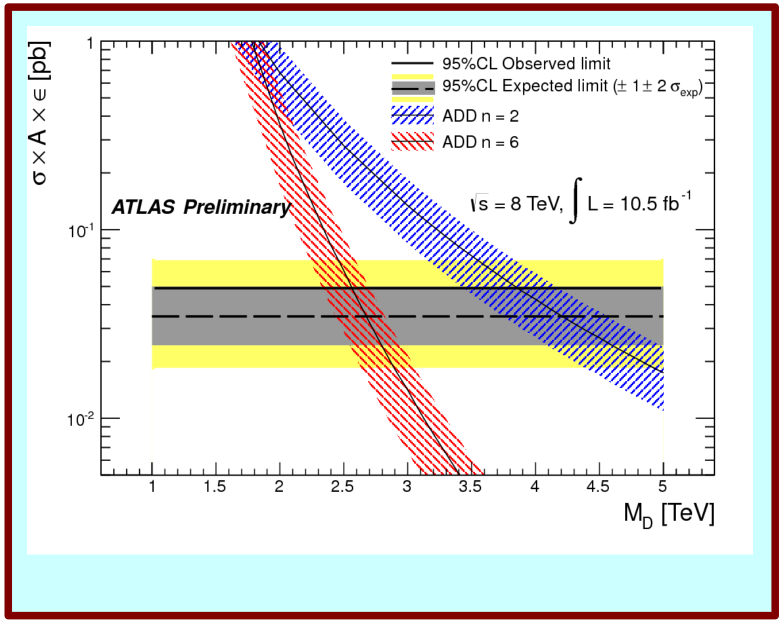
- Missing E_T + high pt jet



Jet(s)

Not detected





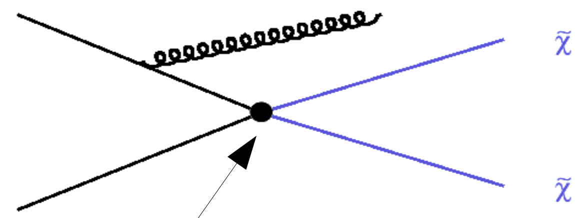
ADD graviton: theoretical cross-sections highly depend on the number of extra-dimensions

M_D: new Planck Scale in 4+n dimensions

Monojet + missing E_T

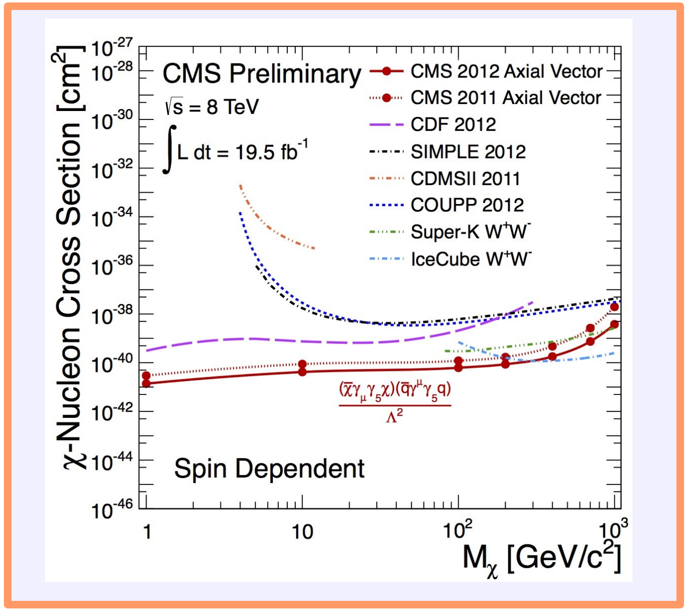
ATLAS-CONF-2012-147
CMS-PAS-EXO-12-048

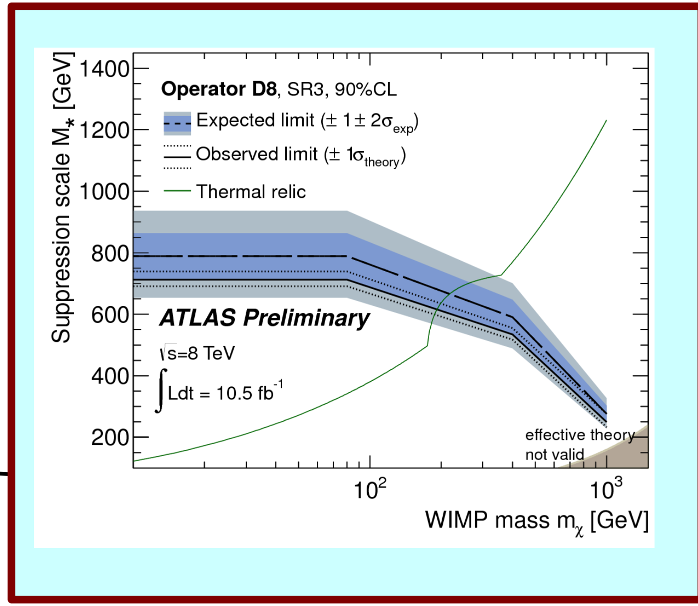
- Can also probe the WIMP pair production
  - Candidate for dark matter
  - Colliders complementary to other experiments, for the low mass regime



$\propto\Lambda$ or M_*: cut-off scale

Various operators tested





Name	Operator	Coefficient
D1	$\bar\chi\chi\bar q q$	m_q/M_*^3
D2	$\bar\chi\gamma^5\chi\bar q q$	im_q/M_*^3
D3	$\bar\chi\chi\bar q\gamma^5 q$	im_q/M_*^3
D4	$\bar\chi\gamma^5\chi\bar q\gamma^5 q$	m_q/M_*^3
D5	$\bar\chi\gamma^\mu\chi\bar q\gamma_\mu q$	$1/M_*^2$
D6	$\bar\chi\gamma^\mu\gamma^5\chi\bar q\gamma_\mu q$	$1/M_*^2$
D7	$\bar\chi\gamma^\mu\chi\bar q\gamma_\mu\gamma^5 q$	$1/M_*^2$
D8	$\bar\chi\gamma^\mu\gamma^5\chi\bar q\gamma_\mu\gamma^5 q$	$1/M_*^2$
D9	$\bar\chi\sigma^{\mu\nu}\chi\bar q\sigma_{\mu\nu}q$	$1/M_*^2$
D10	$\bar\chi\sigma_{\mu\nu}\gamma^5\chi\bar q\sigma_{\alpha\beta}q$	i/M_*^2
D11	$\bar\chi\chi G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/4M_*^3$
D12	$\bar\chi\gamma^5\chi G_{\mu\nu}G^{\mu\nu}$	$i\alpha_s/4M_*^3$
D13	$\bar\chi\chi G_{\mu\nu}\tilde G^{\mu\nu}$	$i\alpha_s/4M_*^3$
D14	$\bar\chi\gamma^5\chi G_{\mu\nu}\tilde G^{\mu\nu}$	$\alpha_s/4M_*^3$

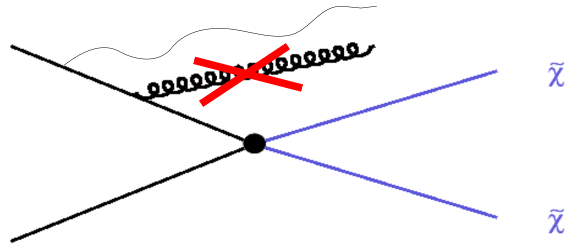
Jet+MET analyses sensitive to an large number of models
→ see more results in backup

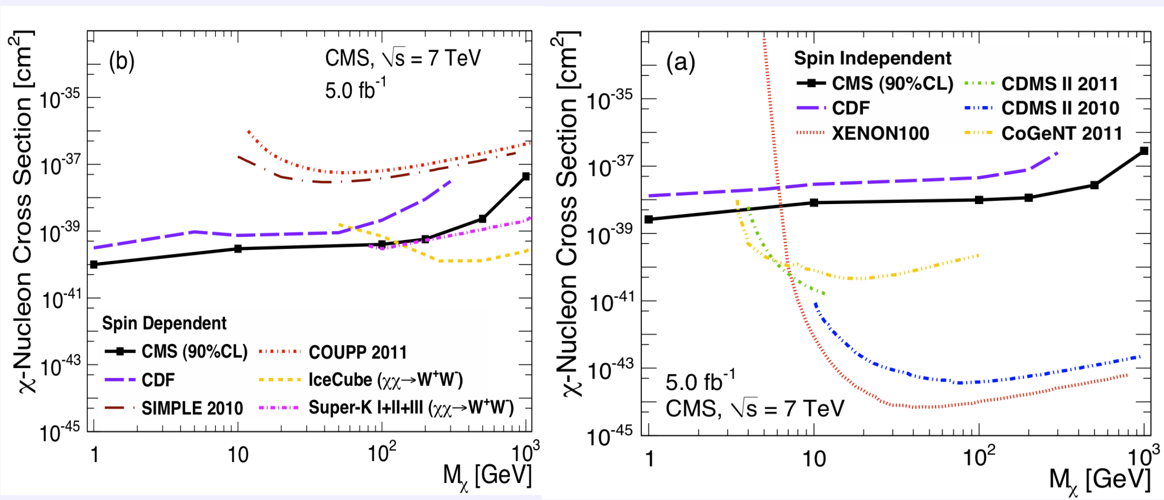
Phys.Rev.D82:116010 (2010)

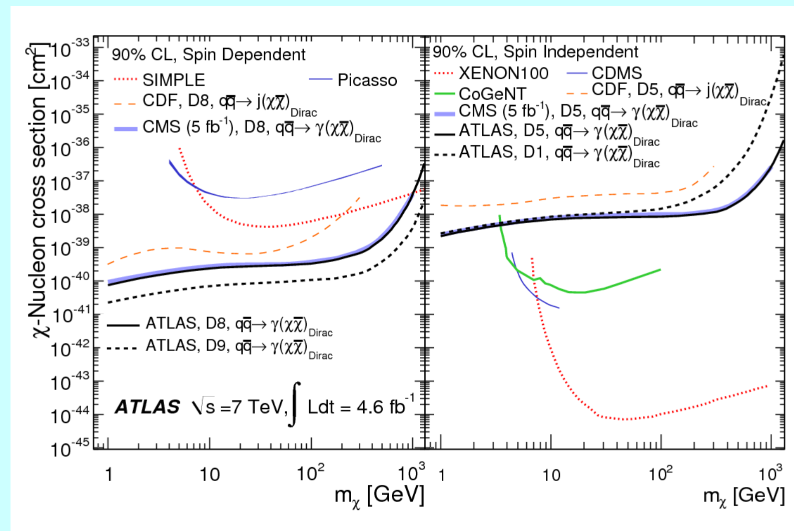
Monophoton + missing E_T

ATL: PRL 110, 011802 (2013)
CMS: PRL 108, 261803 (2012)

- Sensitive to many model, just like mono-jet+MET
  - Extra-dimension
  - WIMPS







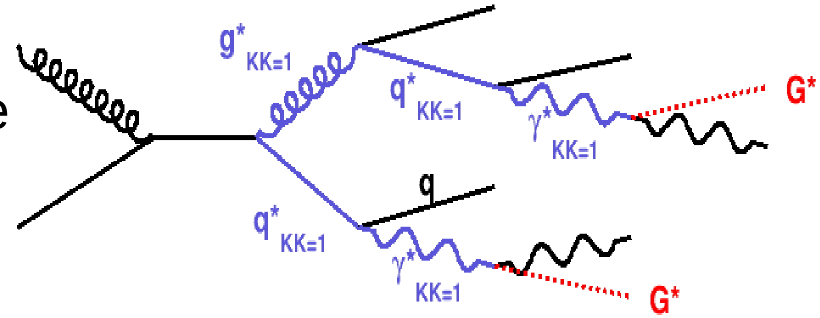
Saclay

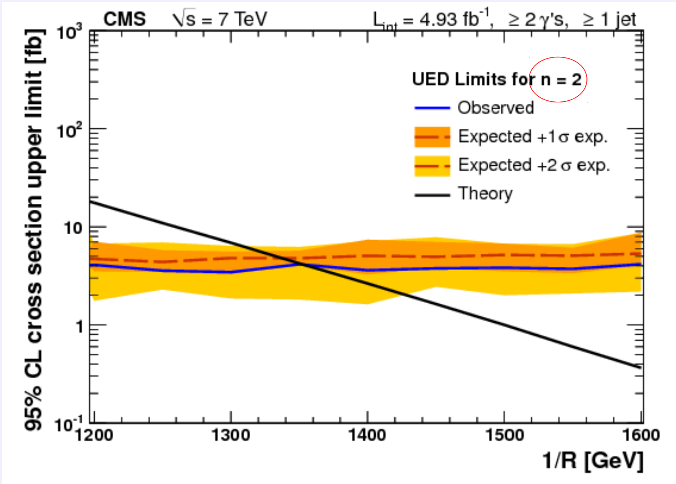
Diphoton + missing E_T

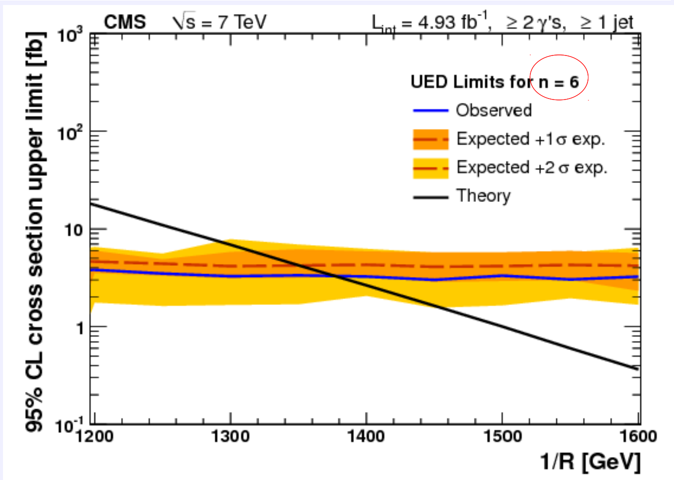
LAPP

ATL: PLB 718 (2012) 411
CMS: JHEP03 (2013) 111

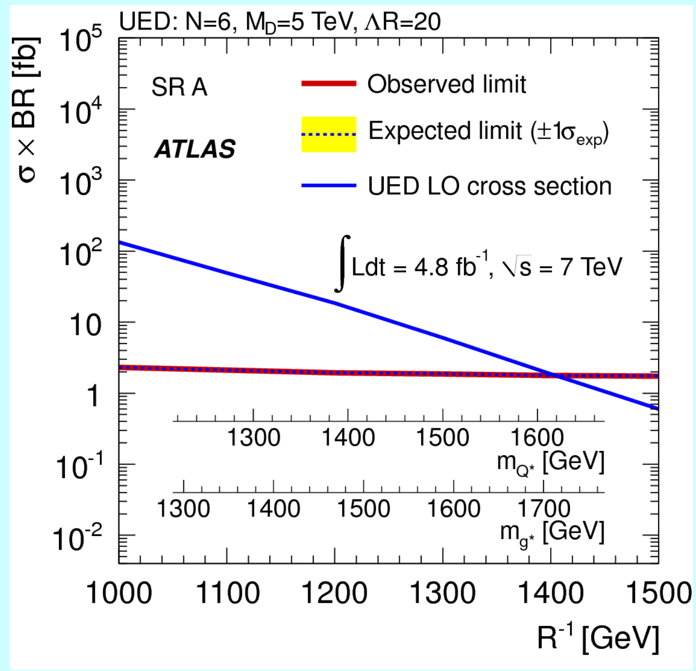
- Probe UED embedded into LED space
  - Lightest KK particle produced in cascade
  - … and then decay into photon+G*







Results do not depend on n

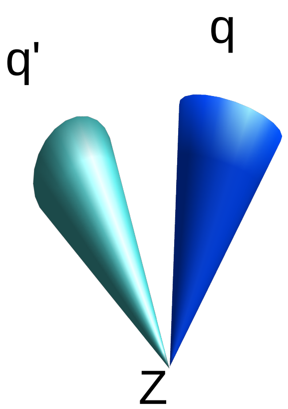


Lepton+jets Signatures

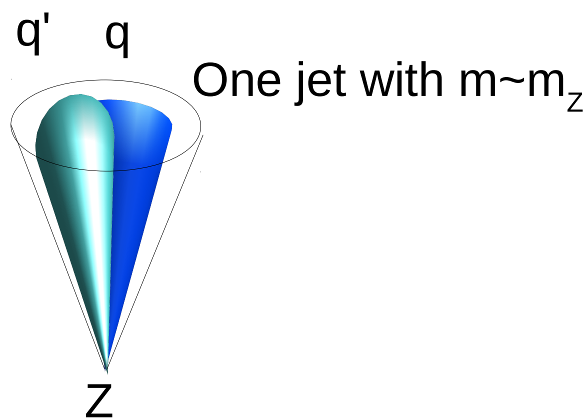
- WZ/ZZ
- $W\gamma/Z\gamma$
- t', b', $t^{5/3}$
- t-jet resonances
- ttbar resonances

Di-boson resonances (WW, WZ, ZZ)

- Interesting signature:
  - Sensitive to heavy bosons (W'), graviton, ...
  - Potentially...
    - many leptons
    - MET
    - high mass jet (for a high mass resonance the bosons are boosted)



Low boost



High boost

Di-boson resonances

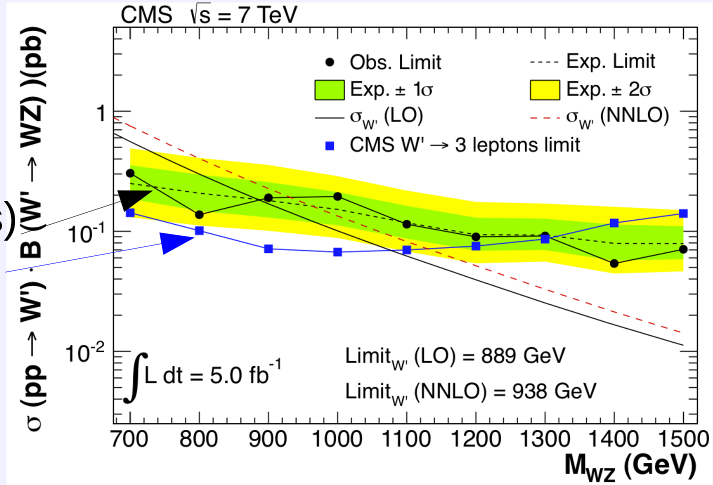
CMS : JHEP02(2013)036

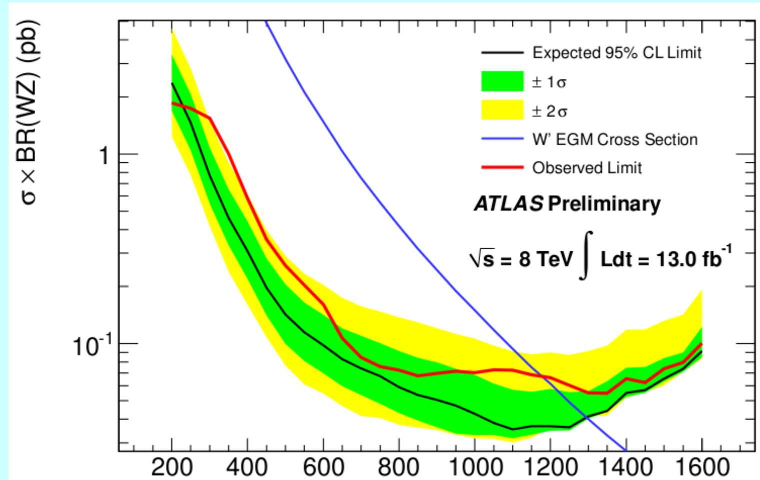
ATLAS-CONF-2013-015
ATLAS-CONF-2012-150

W' → WZ

→ 2l/ν+jet(s)

→ 3l+MET

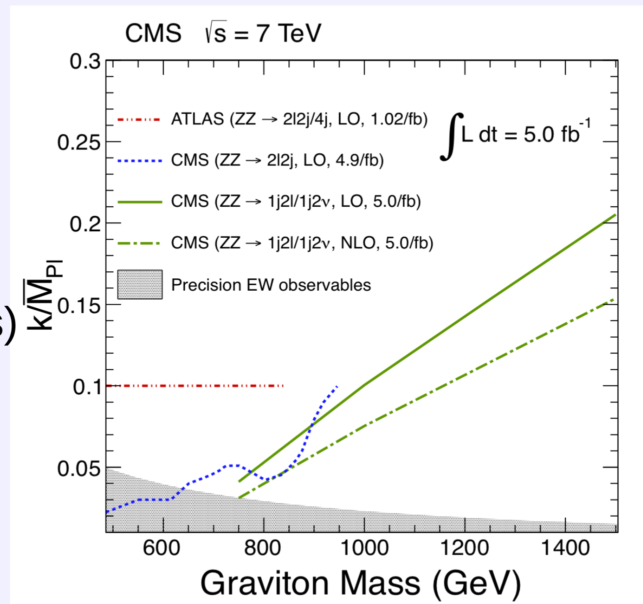


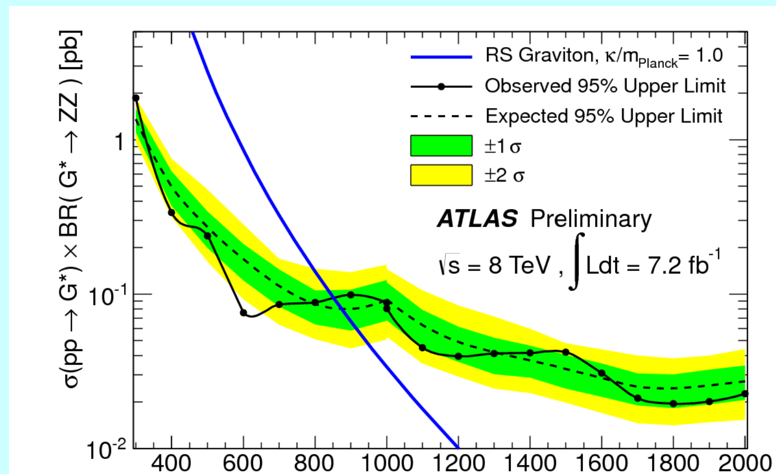


W' → WZ → 3l+MET

G* → ZZ

→ 2l/ν +jet(s)



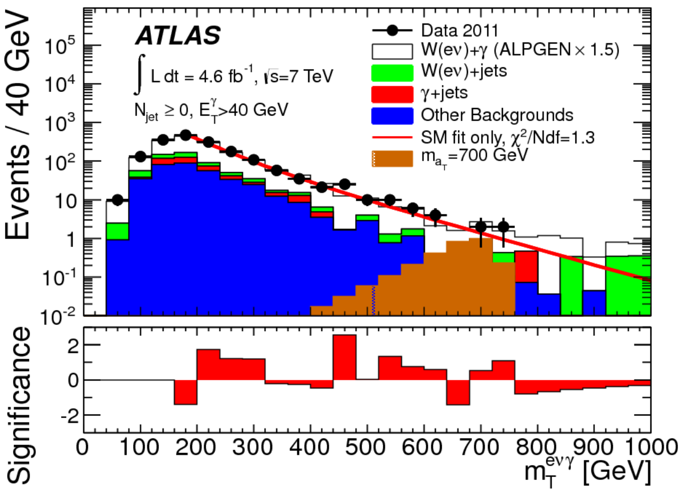


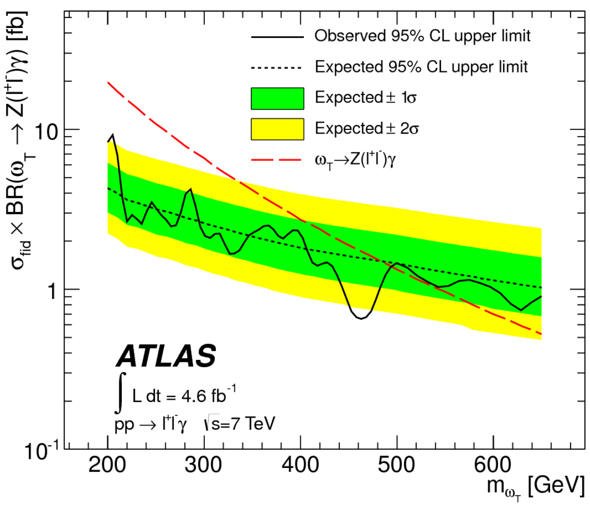
G* → ZZ → 2l +jet(s)

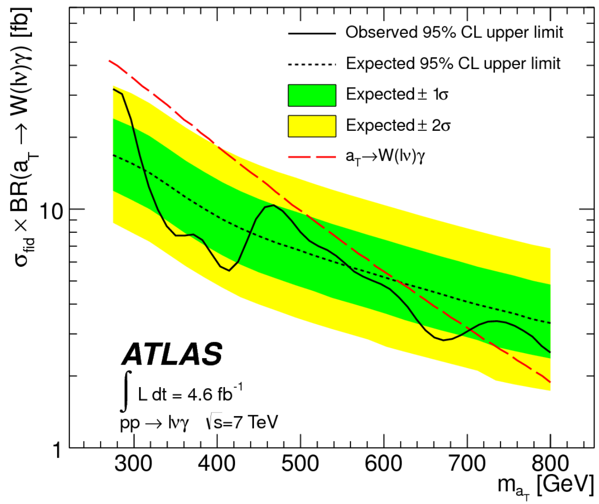
Wγ/Zγ

- Technicolor predict Wγ/Zγ resonances
  - Technicolor disfavored by Higgs-like particle
  - … some technicolor models still alive
- $\omega_T \rightarrow W\gamma$, $a_T \rightarrow Z\gamma$
- Recycling a SM analysis of Wγ/Zγ couplings, with higher γ's pT cut

LAPP
Saclay







Vector-like quarks

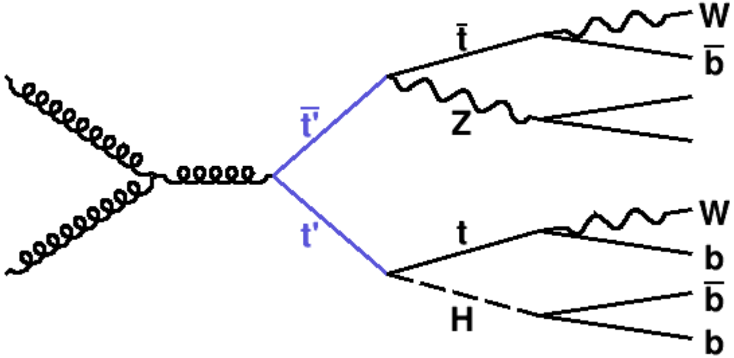
- Add weak-isospin singlets/doublets/triplets $\rightarrow$ top quark partner
  - Cancelation of Higgs divergences (“Little-Higgs”)
  - Heavy top resonance in extra-dimensions
  - …
- Examples of particles/decays:
  - $t' \rightarrow tH, tZ, bW$
  - $T_{5/3} \rightarrow tW$
  - $b' \rightarrow tW, bZ, bH$
  - ...
- They are not 4th generation quarks !

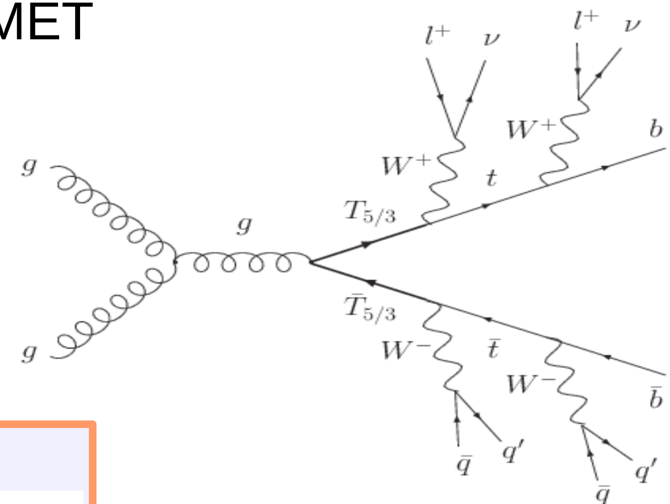
Vector-like quarks

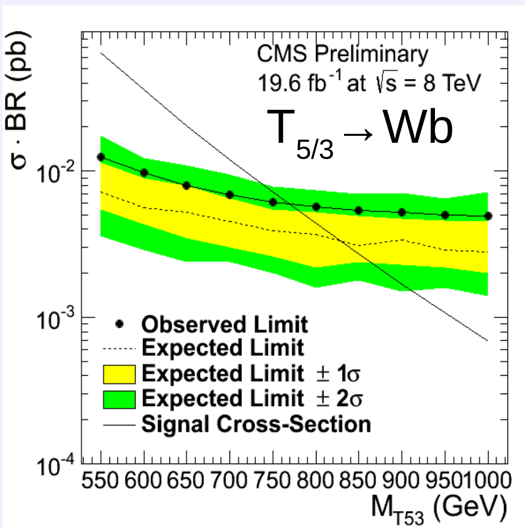
CMS-PAS-B2G-12-012 ATLAS-CONF-2013-018
CMS-PAS-SUS-12-027 ATLAS-CONF-2012-130
Phys. Lett. B 718 (2013)1284-1302

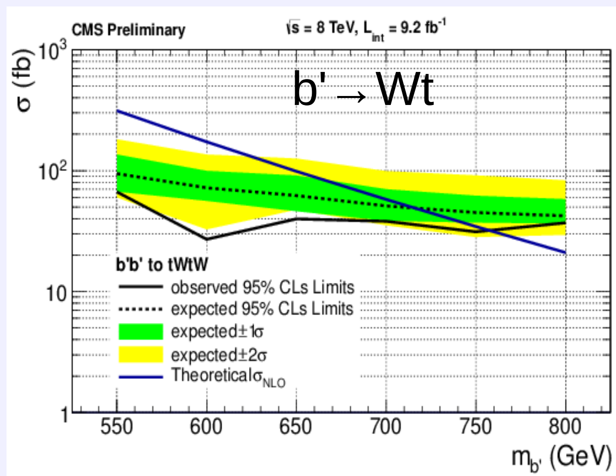
- Search for VLQ using events enriched in top quark, bosons and heavy flavors
  → high usage of b-tagging, leptons, MET

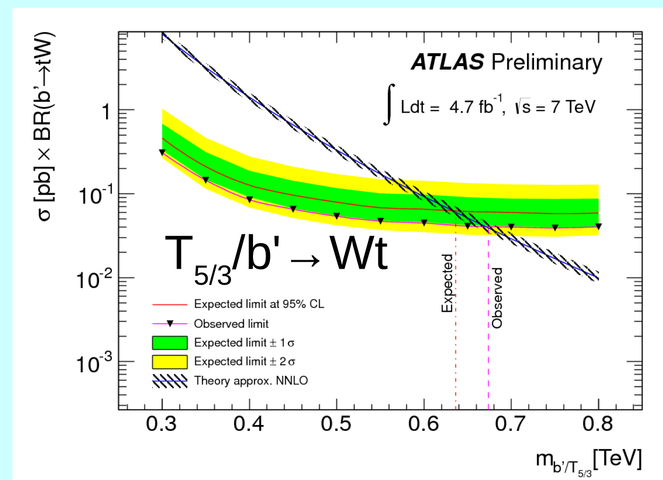
CPPM
IPNL
LAL
LPC-Cl
Saclay









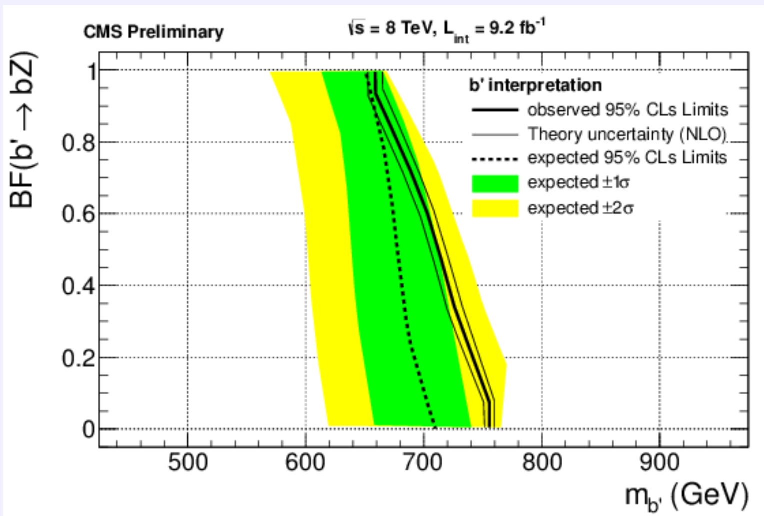


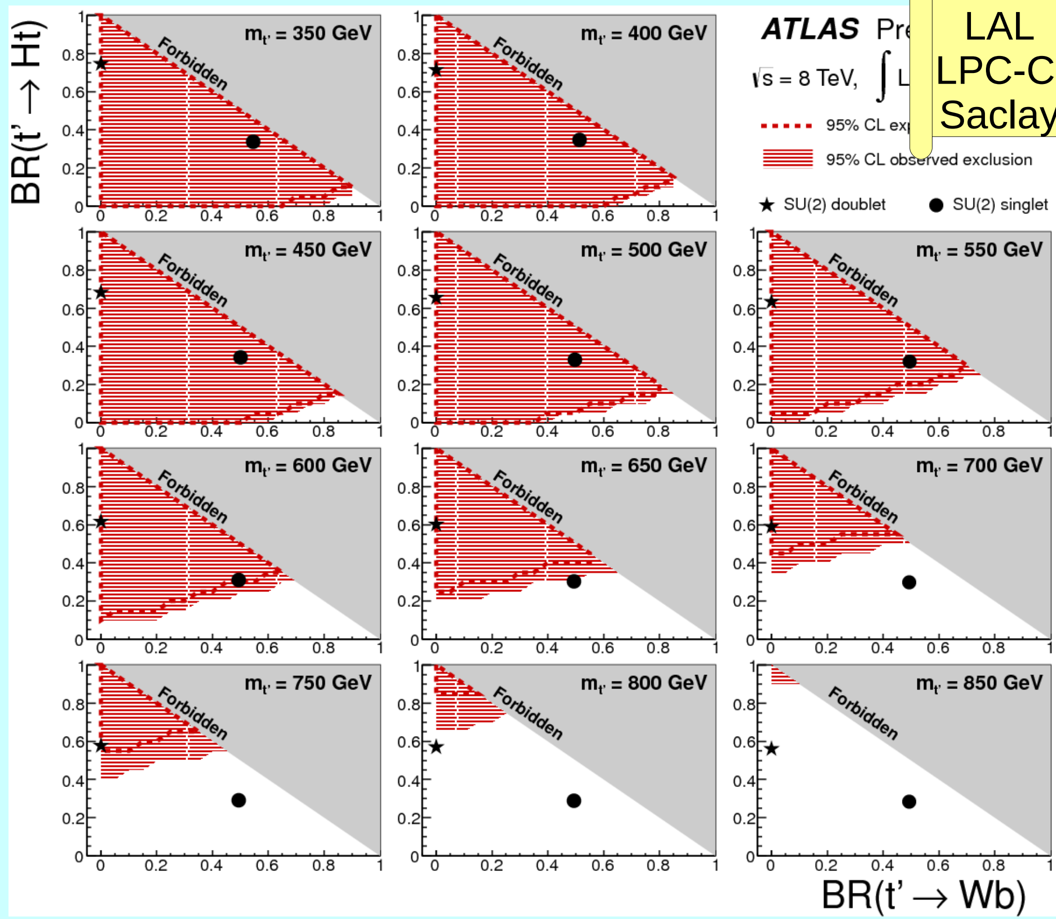
Vector-like quarks

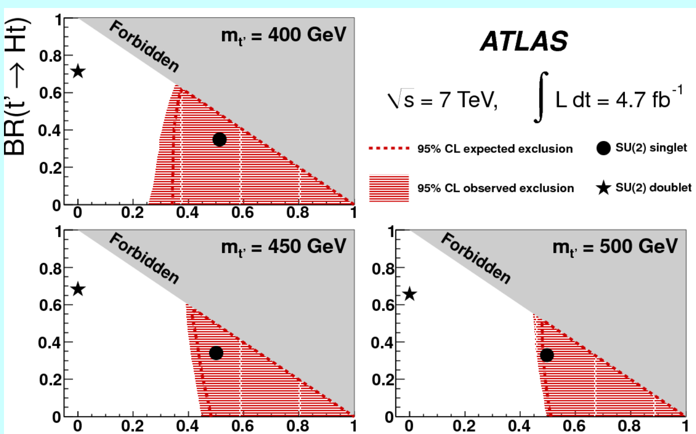
CMS-PAS-B2G-12-012 ATLAS-CONF-2013-018
CMS-PAS-SUS-12-027 ATLAS-CONF-2012-130
Phys. Lett. B 718 (2013)1284-1302

CPPM
IPNL
LAL
LPC-CI
Saclay

- Limits also provided as function of the various BR





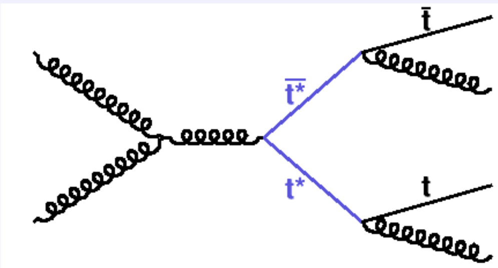


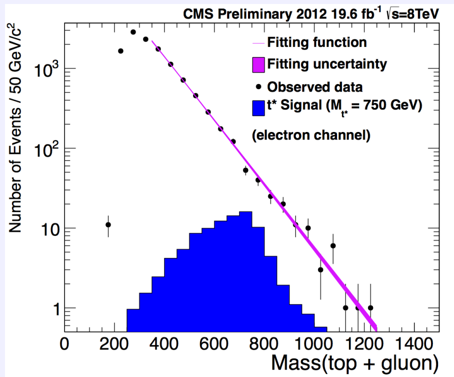
More details in Daniela Paredes' talk

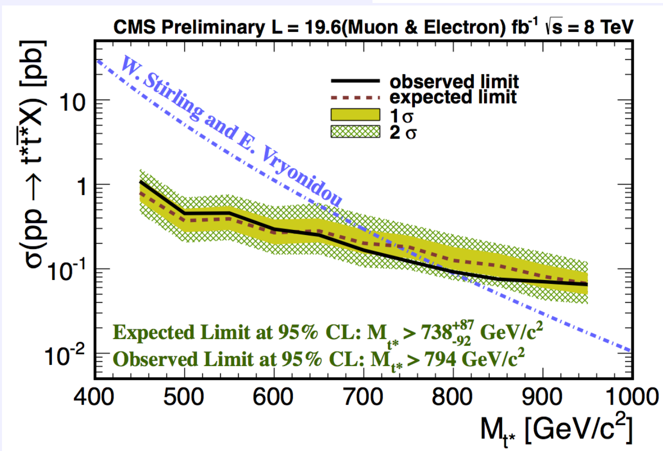
top+jet

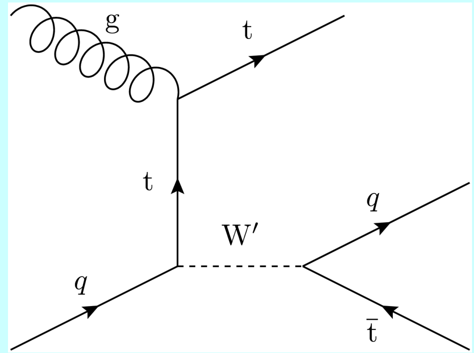
ATL: PRD 86, 091103 (2012)
CMS-PAS-B2G-12-014

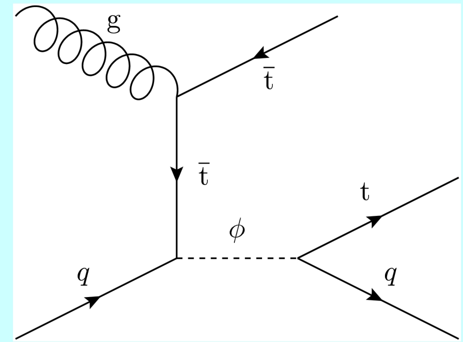
- Use the W and top mass constraints
  → reconstruct the t*, W', ...

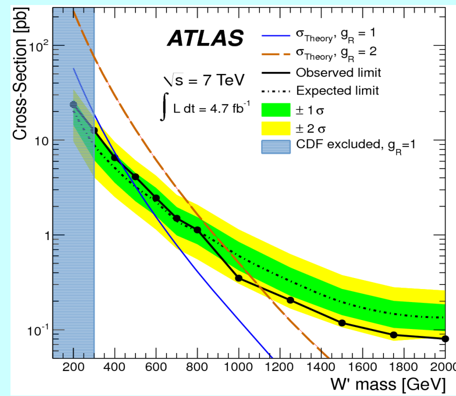


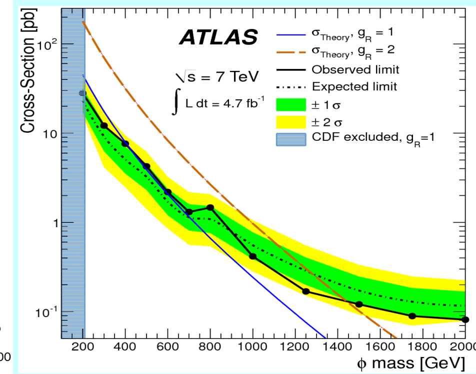










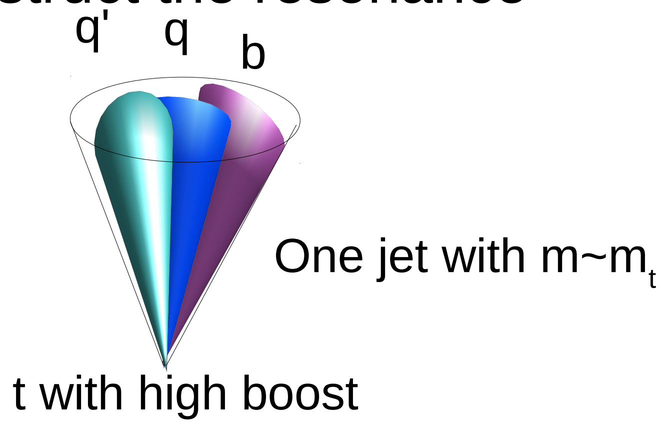


W' → tb presented in Julien Donini's talk

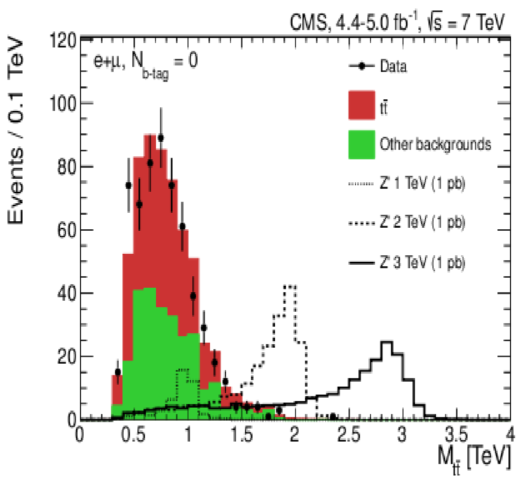
Ttbar resonance

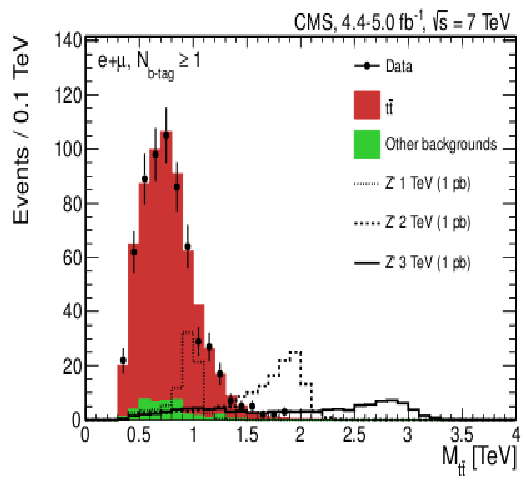
LPSC
LPC-CI

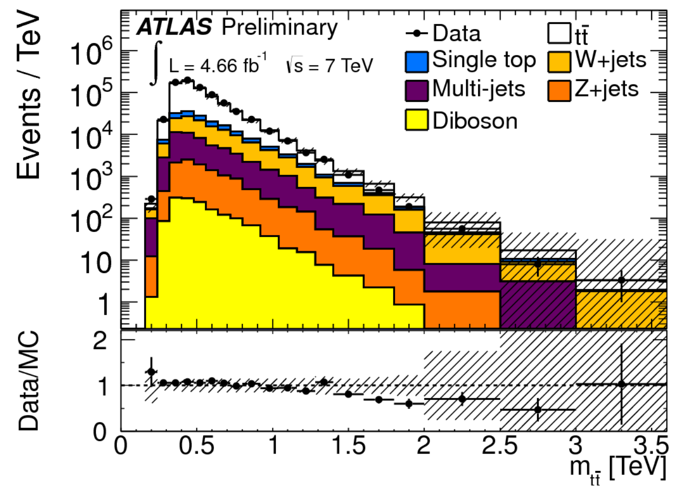
- Sensitive to models with extra-dimensions
- Use the W and top mass constraints to reconstruct the resonance
- Possibility to look at boosted top



talk by Benjamin Dechenaux







Other Signatures

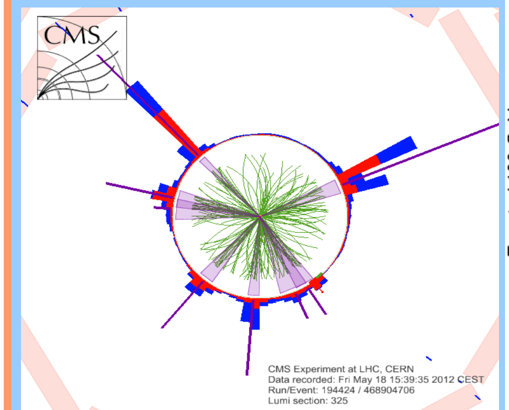
- Black holes
- Long-lived multicharged

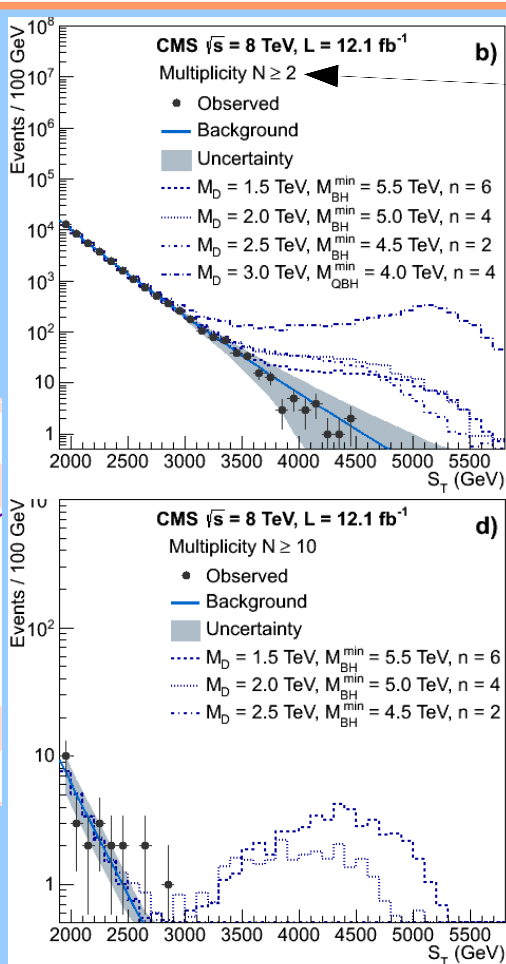
Black holes

- Quantum black holes typically decay into pair of high pT jets
- Semiclassical BH and string balls decay into high number of energetic particles

$S_T = \Sigma p_T$

using jets, electron, muons, MET, photons, with pT>50GeV



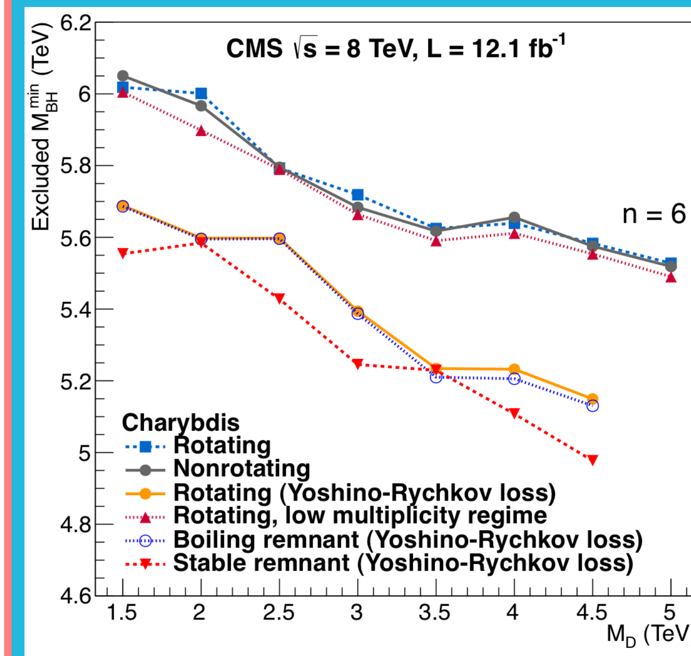


N: number of high pT objects N∈[2,10]

Background fitted on data

Optimize cuts on S_T and N for each signal point

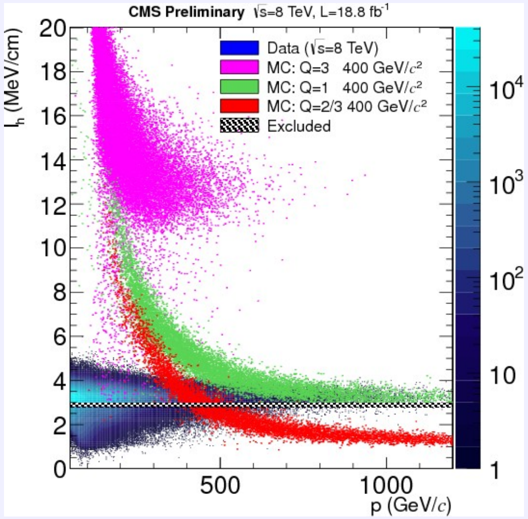
Various limits depending on:
- n: number of extra dimensions
- M^{min}_{BH}: minimal mass of BH
- M_D: Planck scale in 4+n dimensions



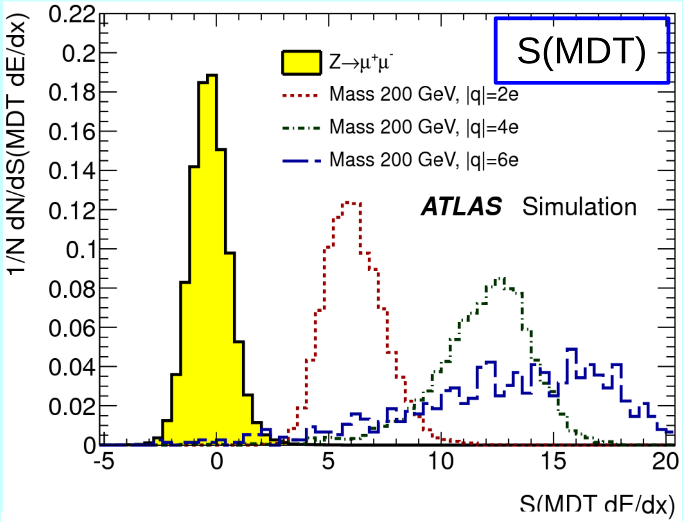
Long-lived, multi-charged particles

ATL: Sub to PLB
CMS-PAS-EXO-12-026

- Particles predicted by many models
  - magnetic monopoles, long-lived micro black holes, Q-balls
- Particles up to Q=6e : highly ionizing → large dE/dx
- Request low momentum or large dE/dX in the various sub-detectors
- Issues:
  - Slow particles → large time window
  - High charge → large track bending → pT=90GeV , Q=6e reconstructed as pT=15GeV Q=e



I_h a measure of the ionization power @CMS vs p

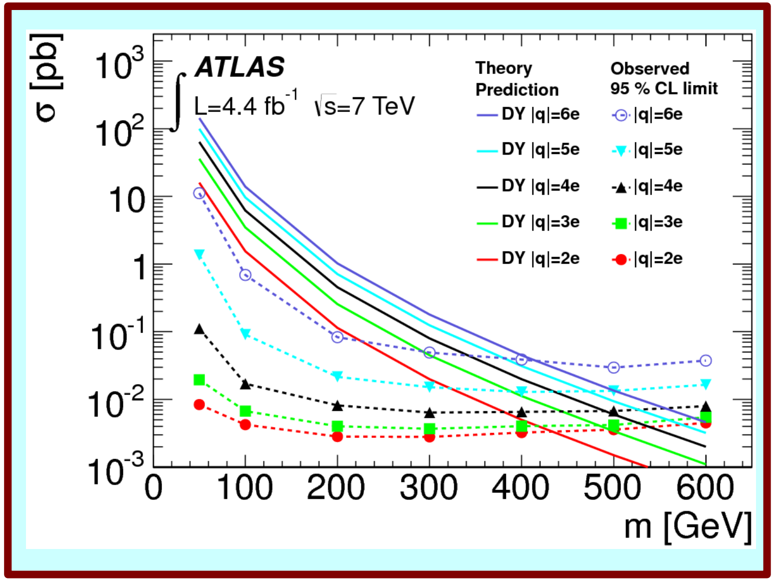


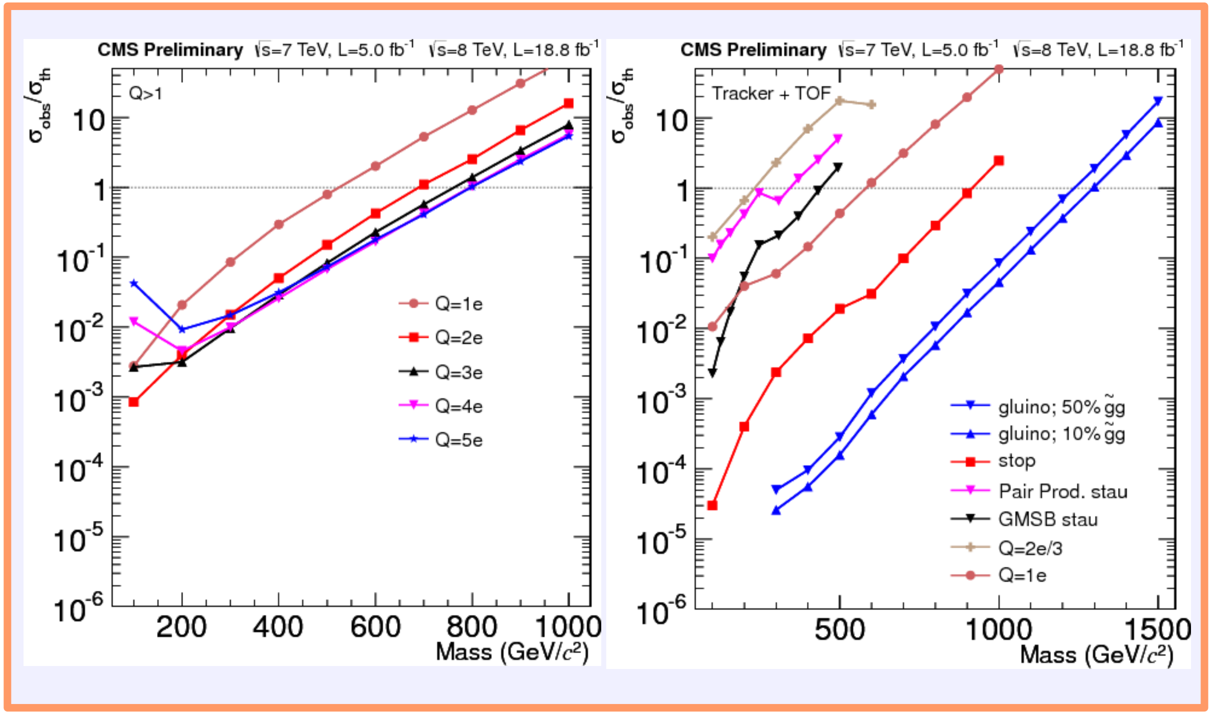
$$S(\mathrm{d}E/\mathrm{d}x) = \frac{\mathrm{d}E/\mathrm{d}x_{\mathrm{track}} - \langle \mathrm{d}E/\mathrm{d}x_{\mu} \rangle}{\sigma(\mathrm{d}E/\mathrm{d}x_{\mu})}$$

Long-lived, multi-charged particles

ATL: Sub to PLB
CMS-PAS-EXO-12-026

- Low background
- Limits dominated by the statistic uncertainty





Conclusion

- Searches with 8TeV dataset are closing in on many models

- Tighter and tighter limits on various models
  - Extra-dimension
  - Compositeness
  - Vector-like quark
  - Black hole
  - Long-lived multi-charge particle
  - …

  - But need to keep in mind we exclude benchmarks, there may be signal with a small mass and small cross-section....

- The funniest part of the data is still to come : 300fb^{-1} @ 13/14TeV !

Backup

Dilepton resonances

NEW

ATLAS-CONF-2013-017

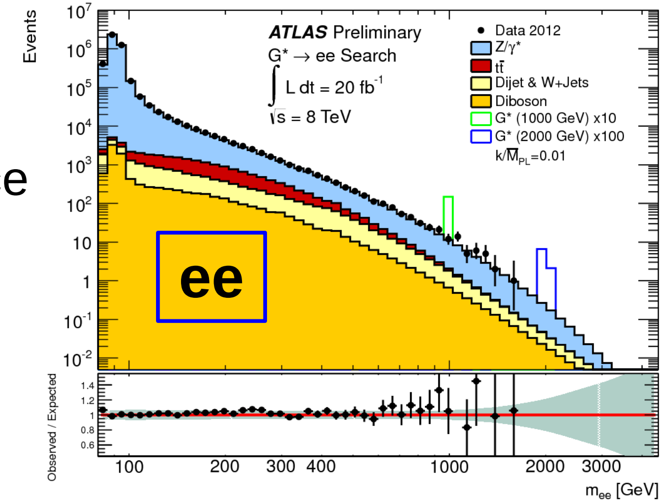
- Search for high mass dilepton resonance, using Z' or G* as benchmarks
- ee:
  - Diphoton trigger (for good background estimation)
  - 2 electrons with E_T>40GeV and 30GeV
  - Acc x eff =73% @ 2TeV
- μμ:
  - Single muon trigger
  - 2 muons with pT>25GeV, opposite charge
  - Acc x eff =46% @ 2TeV
- Backgrounds from MC, apart for fake leptons
  - ee: multijet/W+jets from data
  - μμ: multijet/W+jets negligible
  - MC normalized to data in the Z peak region (80-110GeV)

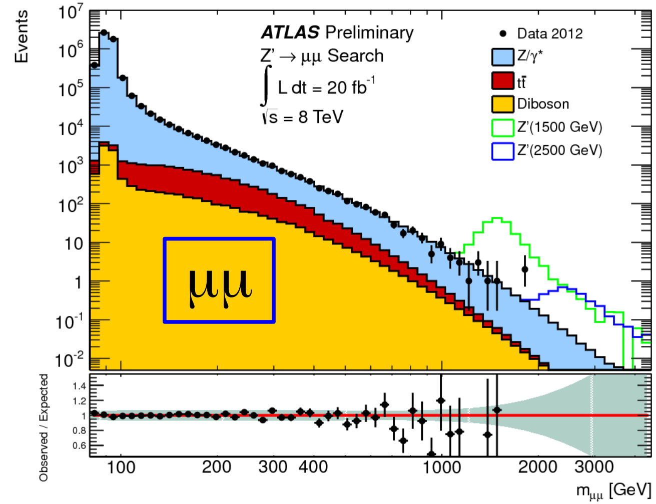
Dilepton resonances

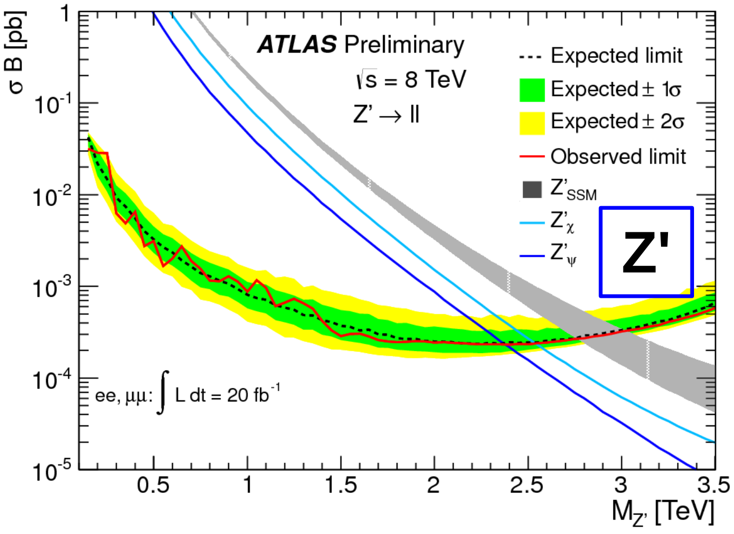
NEW

ATLAS-CONF-2013-017

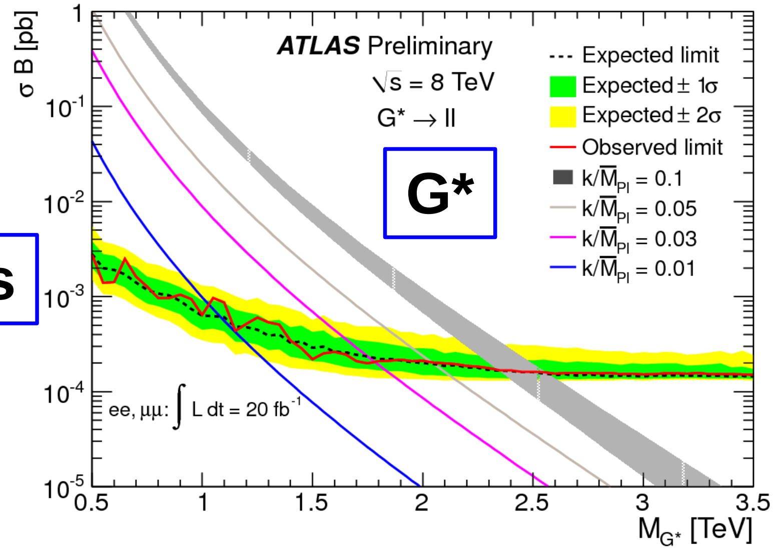
- Main systematic uncertainties:
  - Variation (15%) and choice (17%) of PDF
  - W+jets/multijet (9%)







Combined limits

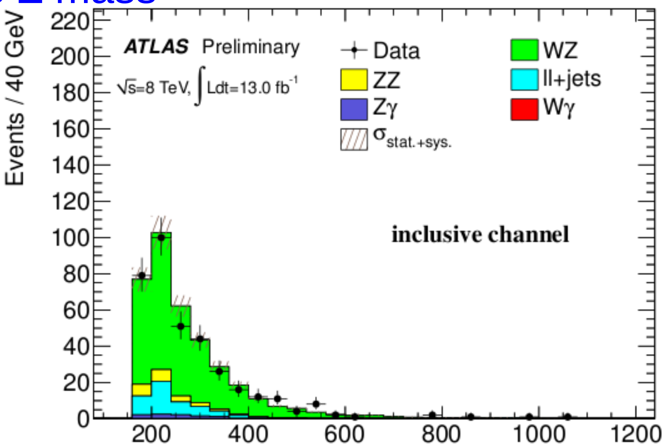


WZ resonances

NEW

ATLAS-CONF-2013-015

- Resonance decaying into WZ(lνl'l') search for with 2 benchmark models:
  - Extended gauge model (EGM), W': $g_{W'WZ}=g_{WWZ}x(m_W m_Z/m^2_{W'})$
  - Low Scale Technicolor (LSTC), $\rho_T \rightarrow WZ$
- Selection:
  - Single lepton trigger
  - Missing E_T (MET)>25GeV, exactly 3 leptons (e or μ), pT>25GeV
    - $e\nu ee$, $e\nu\mu\mu$, $\mu\nu ee$, $\mu\nu\mu\mu$
    - Same flavor leptons: opposite sign, within 20GeV of the Z mass
    - ν' s p_z recovered from W's mass constraint
  - $\Delta y(W,Z)<1.8$, $\Delta\phi(W,Z)>2.6$
- Backgrounds
  - WZ, ZZ, Zγ: from MC
  - Z+jets, ttbar, …: ll+fake lepton → fake rate from data
  - Backgrounds (apart WZ) from a fit for m(WZ)>300GeV
  - WZ from a fit for m(WZ)>500GeV

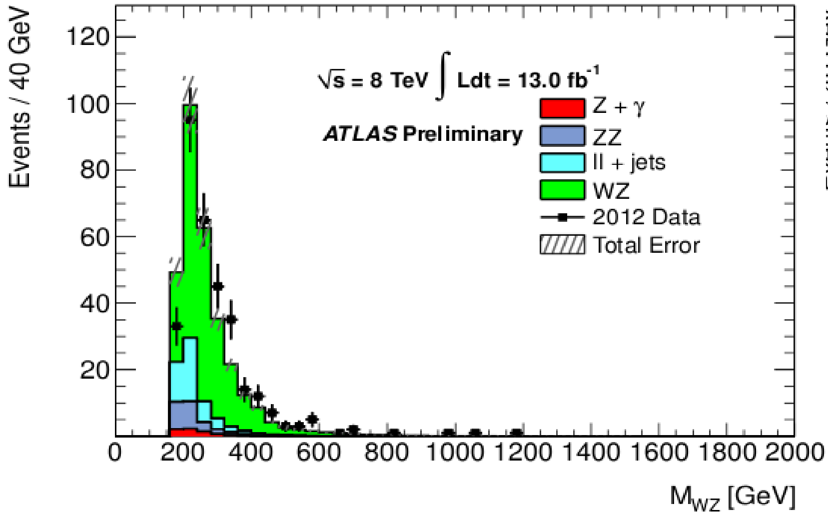


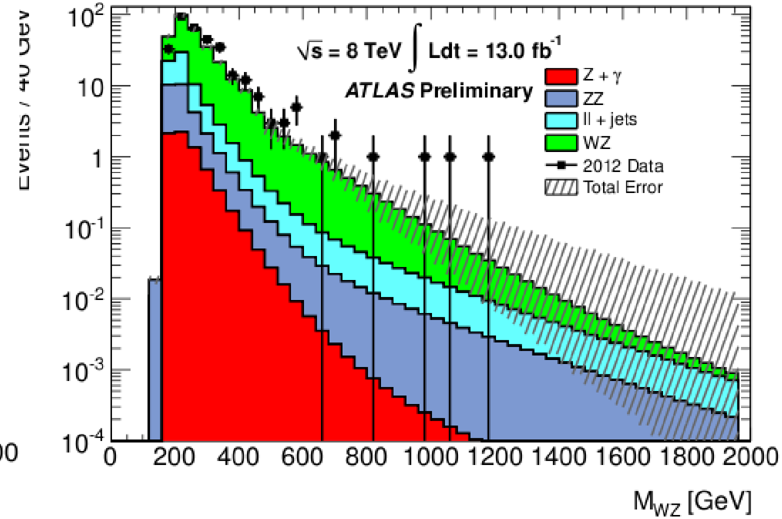
m(WZ), WZ control region

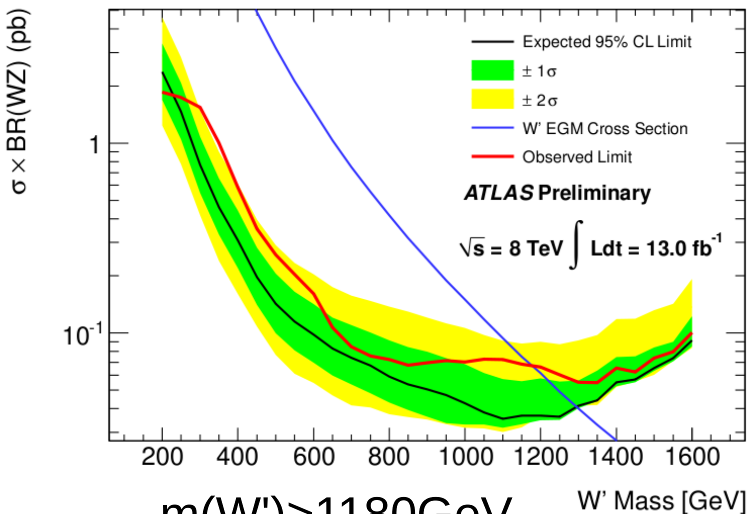
WZ resonances

NEW

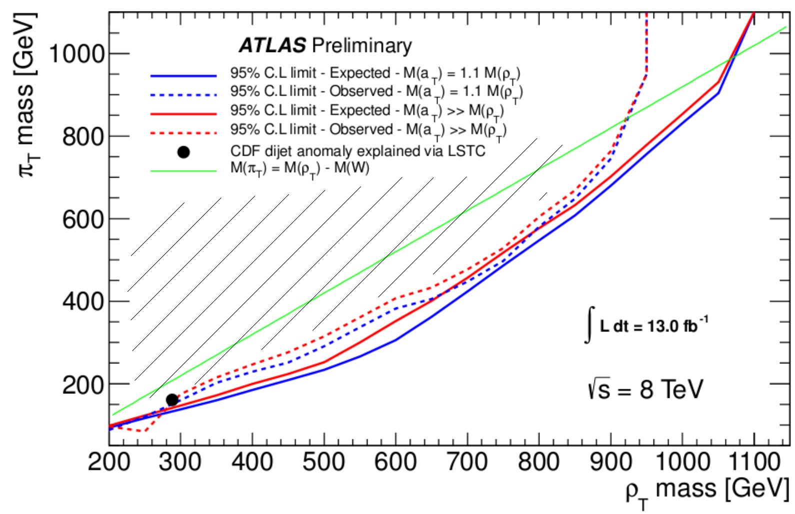
ATLAS-CONF-2013-015







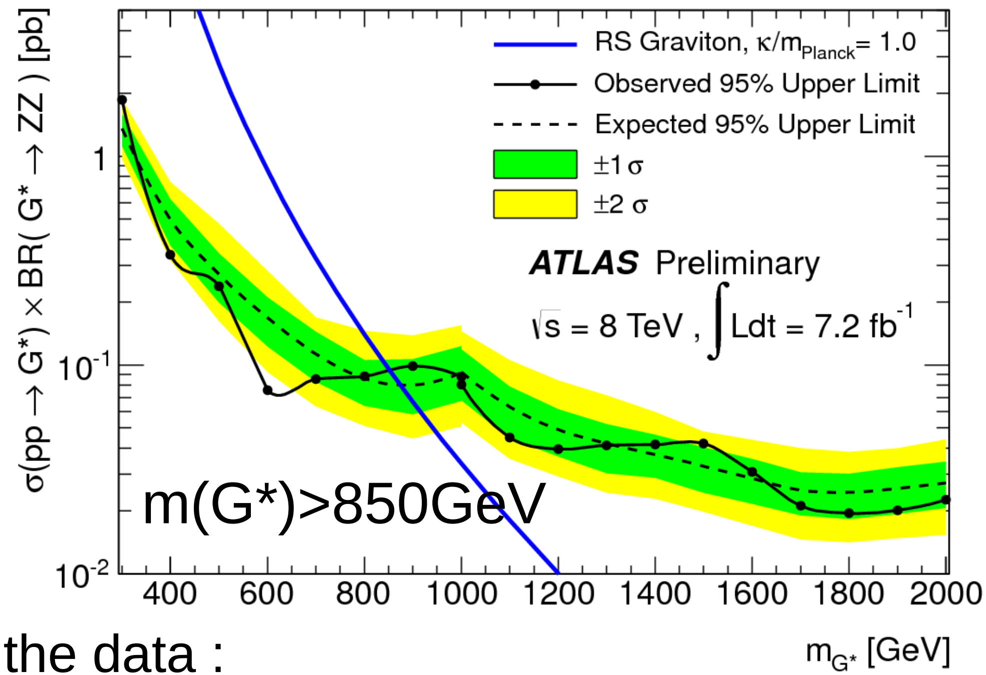
m(W')>1180GeV



ZZ resonances

ATLAS-CONF-2012-150

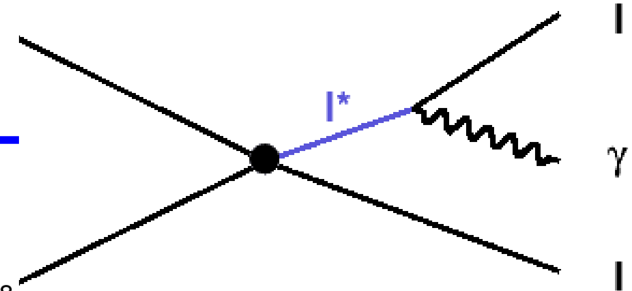
- Use spin-2 Randall-Sundrum Graviton as benchmark model
- Select Z boson in ee/$\mu\mu$ events: $66<m_{ll}<116$GeV.
- Second Z depending on the topology: resolved or merged (2 quarks fall into the same jet)
  - Resolved selection (m<1TeV)
    - $pT_{ll}>50$GeV
    - $65<m_{jj}<115$GeV, $\Delta\varphi_{jj}<1.6$
  - Merged selection (m>1TeV)
    - $pT_{ll}>200$GeV
    - $pT_j>200$GeV, $m_j>40$GeV



- Background estimated from a fit on the data :
  - If fit's χ^2 has probability<1%, exclude the region of disagreement → re-fit
  - Cross-checked with MC

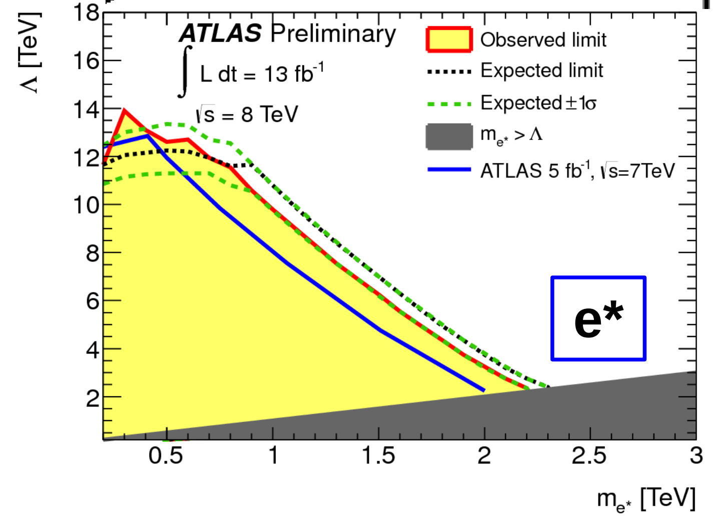
Excited leptons

ATLAS-CONF-2012-146

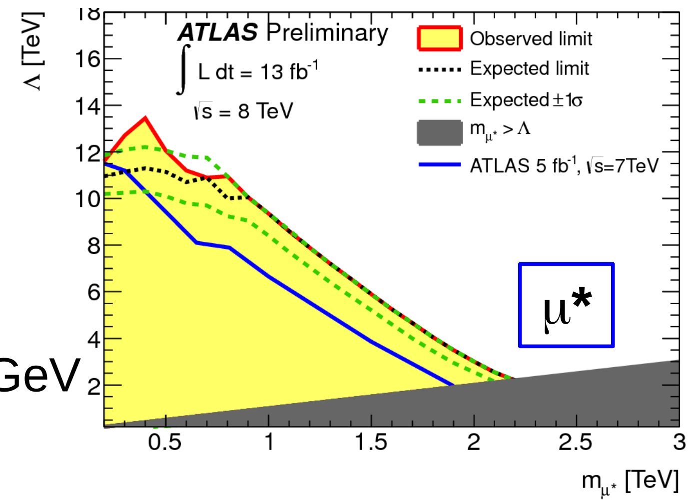


- Benchmark model: contact interaction

- Selection:
  - eeγ: 2 electrons with pT>40GeV and 35GeV
  - μμγ: 2 muons with 25GeV
  - pT_γ>30GeV, isolated from lepton
  - m_{ll}>100GeV



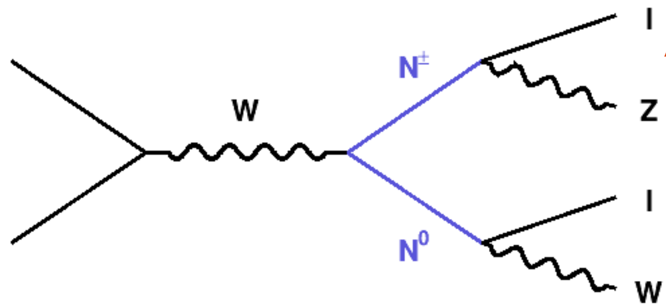
- Background from MC
  - Z+jets scaling from data
    70<m_{ll}<110 (correct fake-γ rate)
  - For $m_{ll\gamma}$>250GeV:
    - Low statistics for Z+X
    - Fits Z+jet and Z+γ in the range 110< $m_{ll\gamma}$<1050GeV



Type III Seesaw Model Heavy Fermions

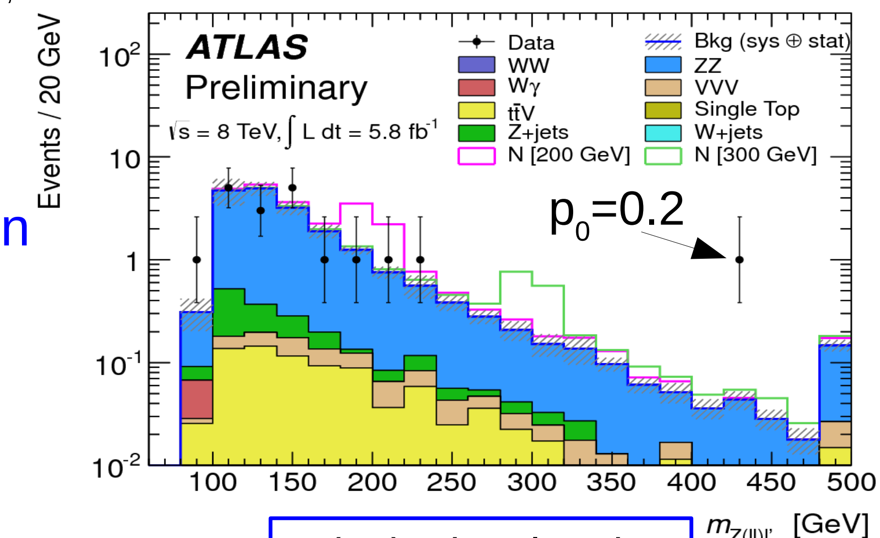
NEW

- Type III seesaw (→ neutrino masses) predicts heavy fermions N^0, $N^\pm$
  - $m(N^0) \sim m(N^\pm)$
  - Search for pair production



ATLAS-CONF-2013-019

- Selection:
  - Single lepton trigger
  - At least 4 leptons (e or μ), pT_1>25GeV, $pT_{2,3,4}$>10GeV
  - m(ll) within 10GeV of the Z mass.
  - Veto events with a second Z
- $N^\pm$ from the Z candidate + the closest lepton
- Backgrounds from MC
  - Z+jets (bb/cc): low statistics → reverse the isolation cut and normalize it in a control region



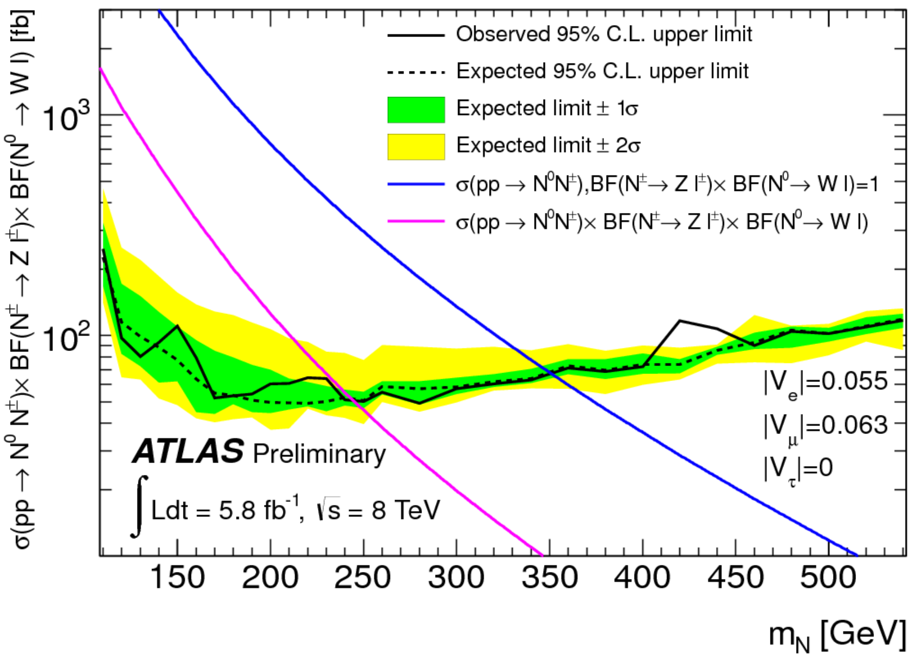
m($N^\pm$), signal region

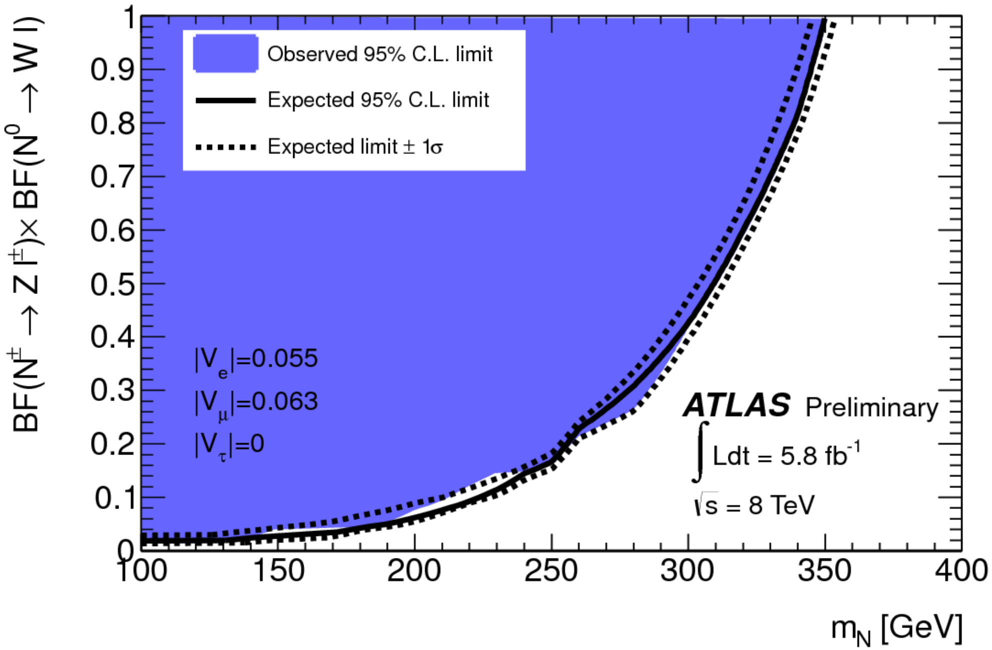
Type III Seesaw Model Heavy Fermions

NEW

- Main systematic uncertainties:
  - Electron identification (2.7%)
  - Fast simulation vs full G4 simulation: 6.8% on signal acceptance
  - Z+jets shape (100%) and normalization (370%)

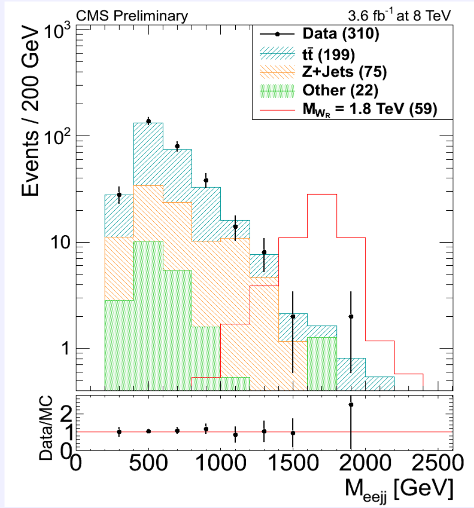
ATLAS-CONF-2013-019

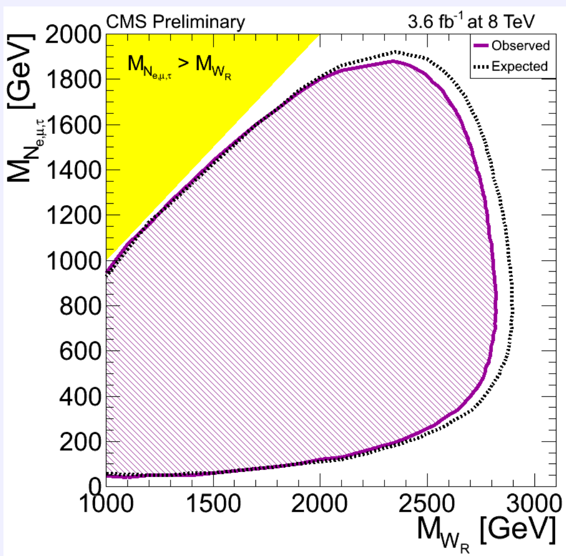




Seesaw, other searches

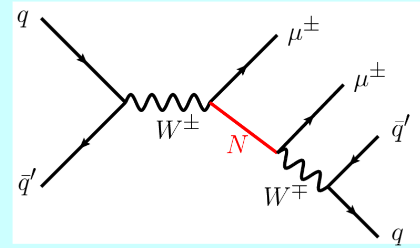
$W_R \rightarrow l\,N \rightarrow l\,l'\,jj$

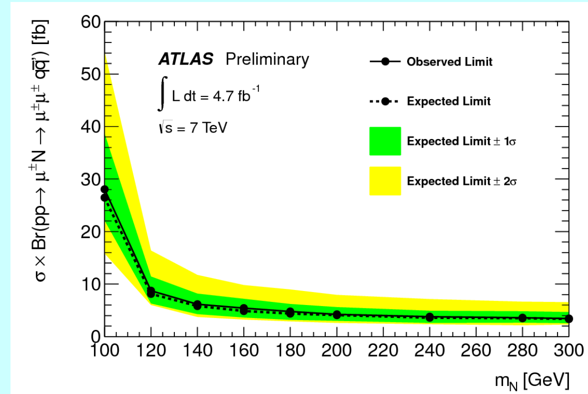


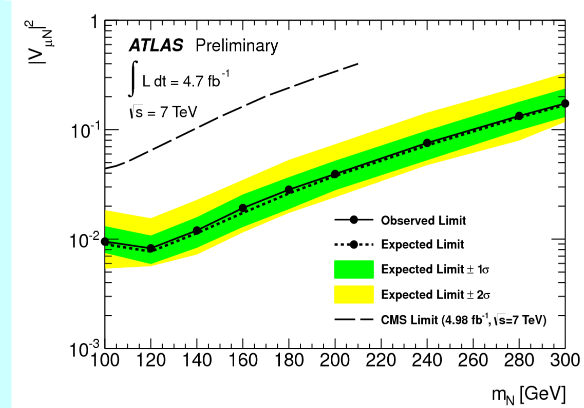


$W \rightarrow l\,N \rightarrow l\,l'\,jj$

Majorana neutrino







Top-like quarks

NEW

ATLAS-CONF-2013-018

- Top quark partner from addition of weak-isospin singlets/doublets/triplets
- 3 possible decay modes: t' → Wb, t' → Zt, t' → Ht
  - Focus on high jet and b-jet multiplicities: t't' → HtHt/ZtHt/WbHt (H → bb)

- Selection
  - Single lepton triggers, exactly one lepton (e or μ)
  - MET>20GeV, MET+ W transerve mass > 60GeV
  - At least 6 jets, then split into 3 channels
    - 2 b-tagged jets and H_T(=sum jet, lepton pT and MET)<700GeV
    - 3 b-tagged jets

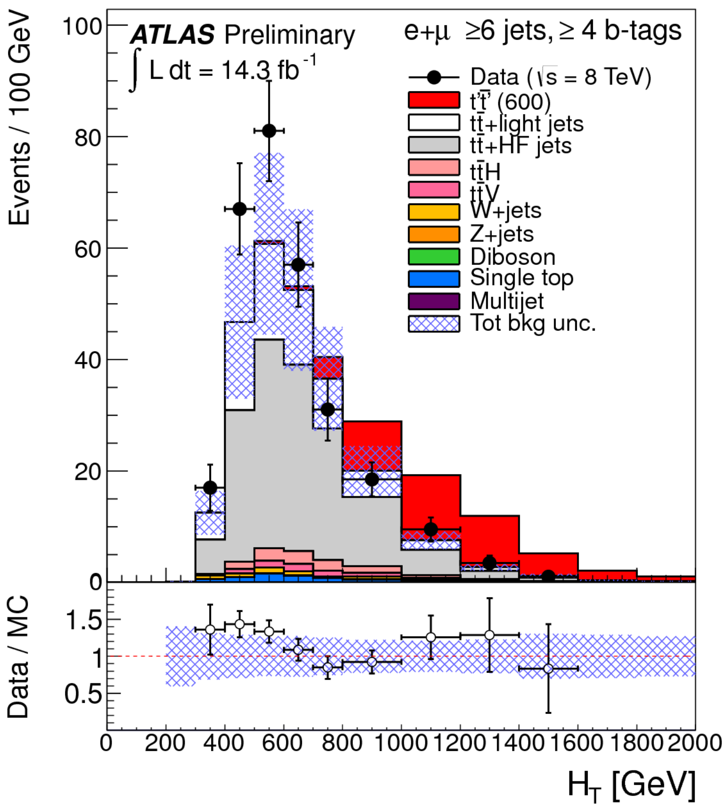
    Constrain the systematic uncertainties
    - At least 4 b-tagged jets : drives the sensitivity
- Backgrounds:
  - tt+jets: MC, light and heavy flavor components of the jets fitted in a control region
  - Other backgrounds (small) MC apart for:
    - W+jets: MC, data-driven normalization
    - Multijet: data-driven

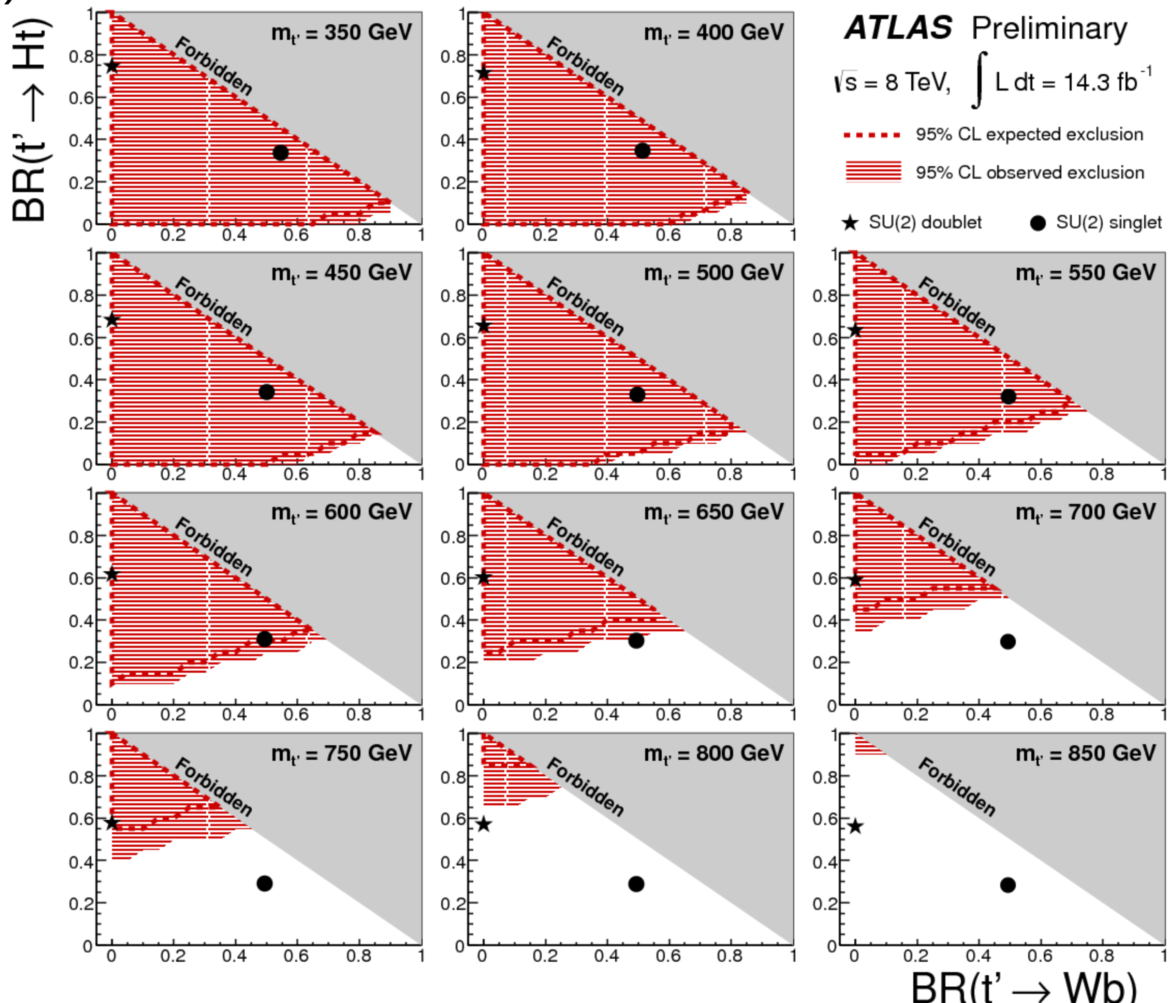
Top-like quarks

NEW

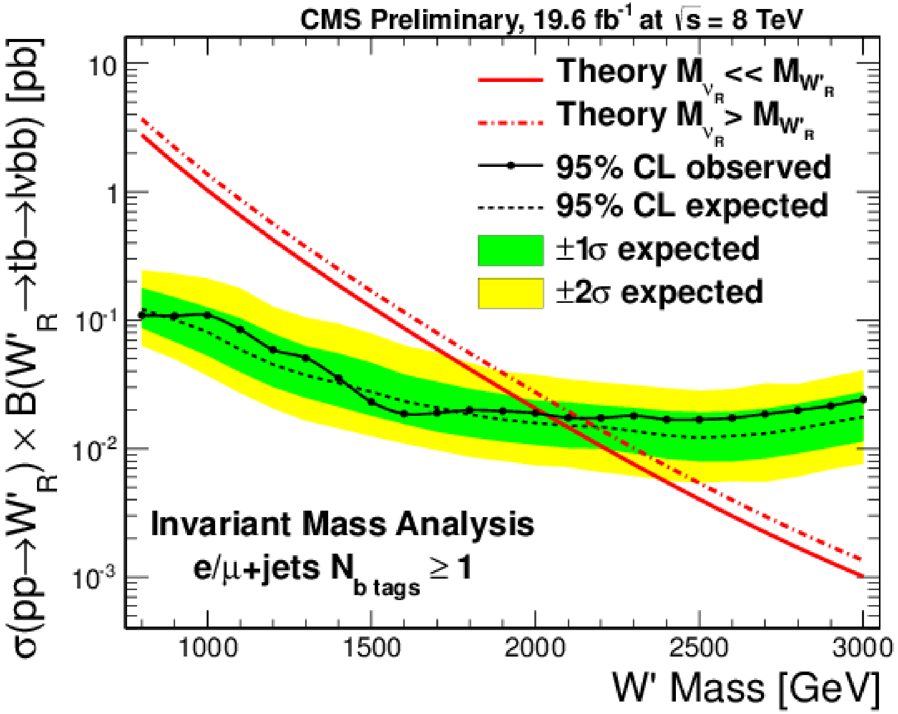
ATLAS-CONF-2013-018

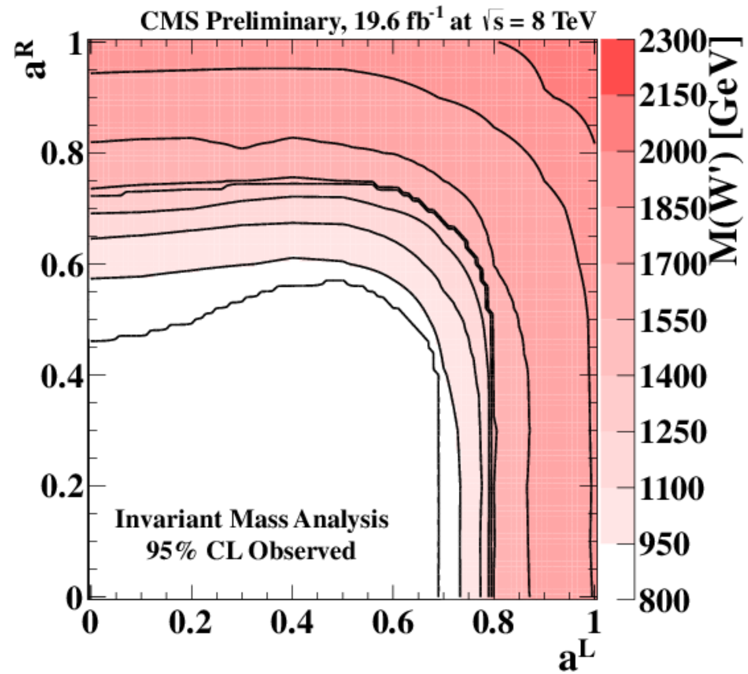
- Dominant systematic uncertainties
  - Normalization of backgrounds (42%)
  - tt+heavy flavor fraction (32%)
  - b-/c-tagging (16%/11%)



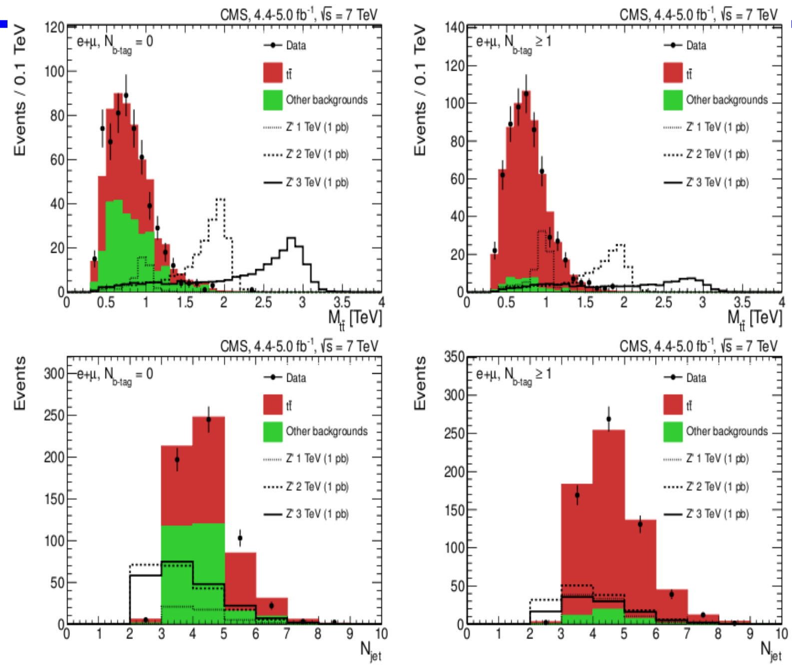


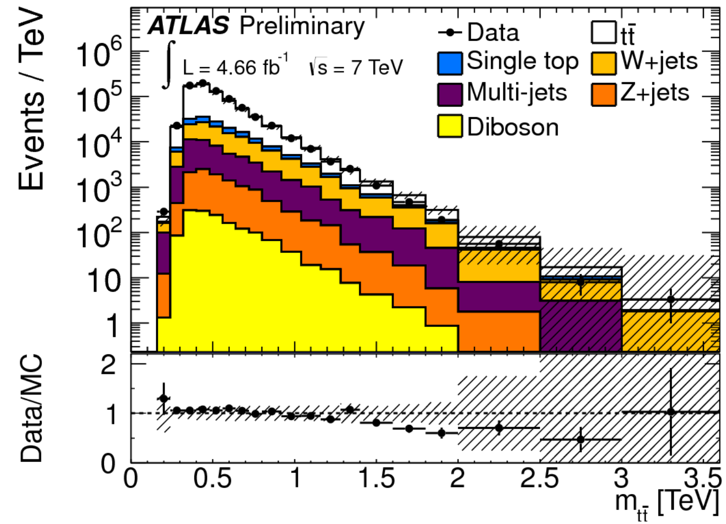
t+b resonance → J. Donini

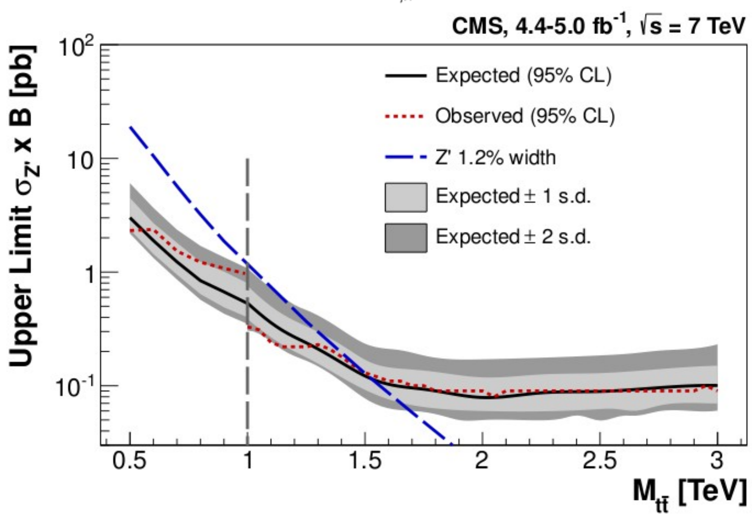


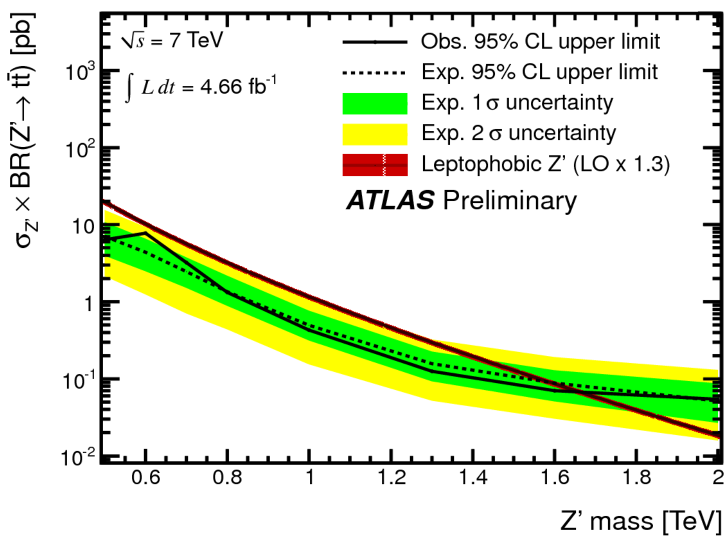


Ttbar resonance





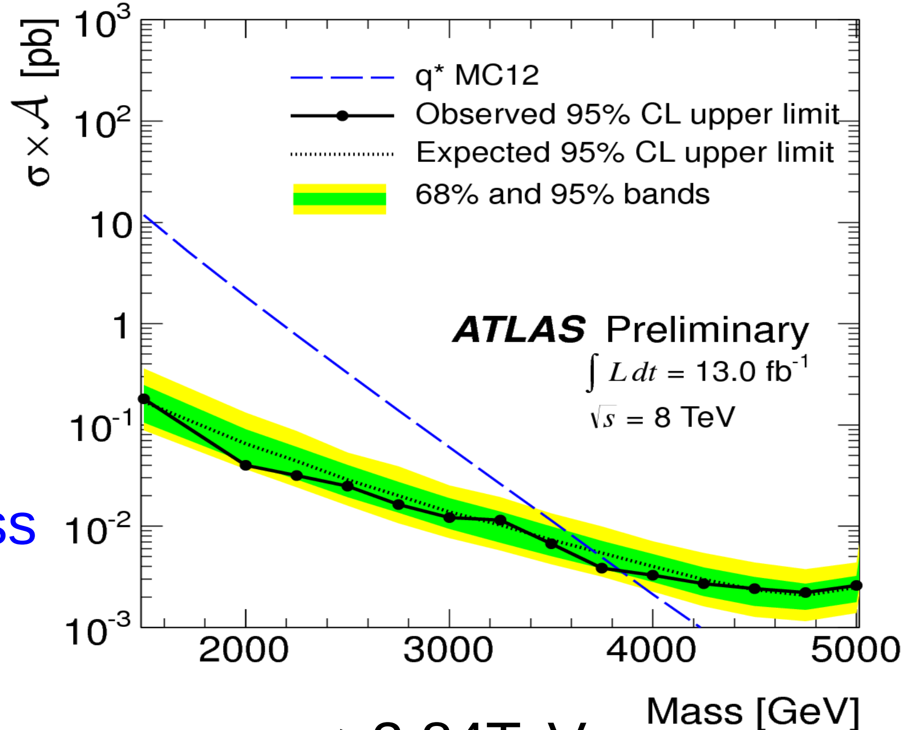




Di-jet resonance

ATLAS-CONF-2012-148

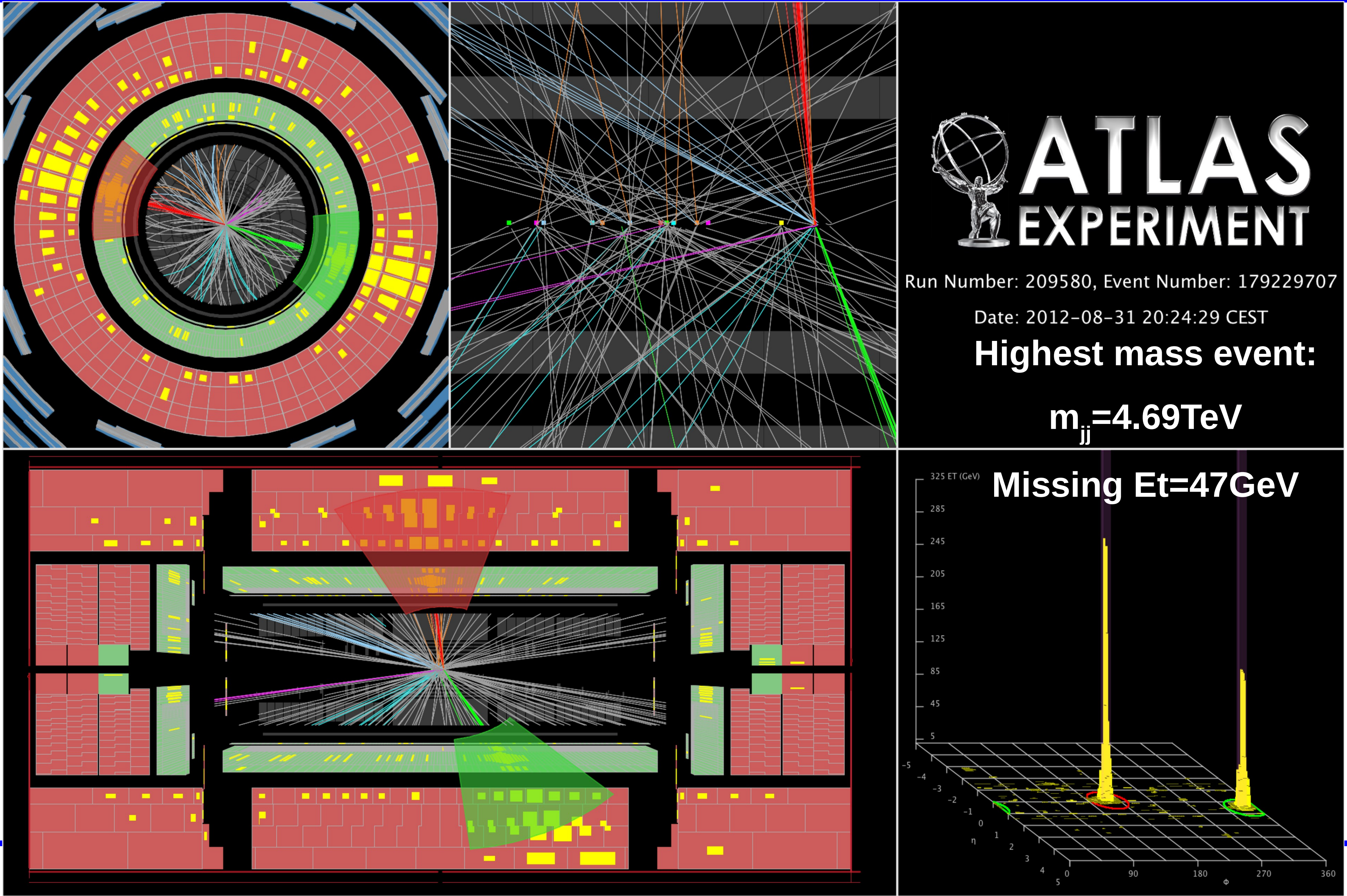
- Di-jet resonances predicted by many models (compositness, extra-dimensions,...)
- Selection
  - High pT jet trigger
  - 2 anti-kt jets with R=0.6, |y|<2.8, pT>150 GeV
  - $|y^*|=|y_1-y_2|/2 < 0.6$, $m_{jj}>1$ TeV
- Background fitted from data
- Search for excesses/deficits
  - Take care of Look-Elsewhere Effect
- Limits expressed as function of q* mass or simplified Gaussian model (backup)



$m_{q^*}>3.84$TeV

Di-jet mass

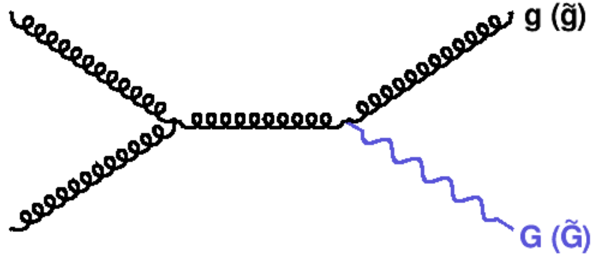
ATLAS-CONF-2012-148

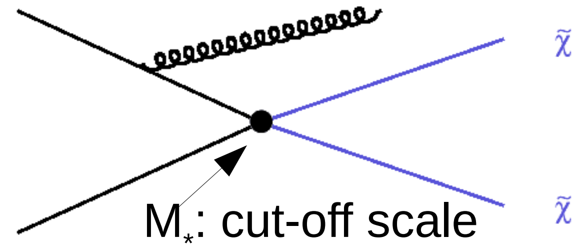


Monojet + missing E_T

ATLAS-CONF-2012-147

- Predicted by supersymmetry (gravitino), Large Extra Dimension (graviton), WIMPS …

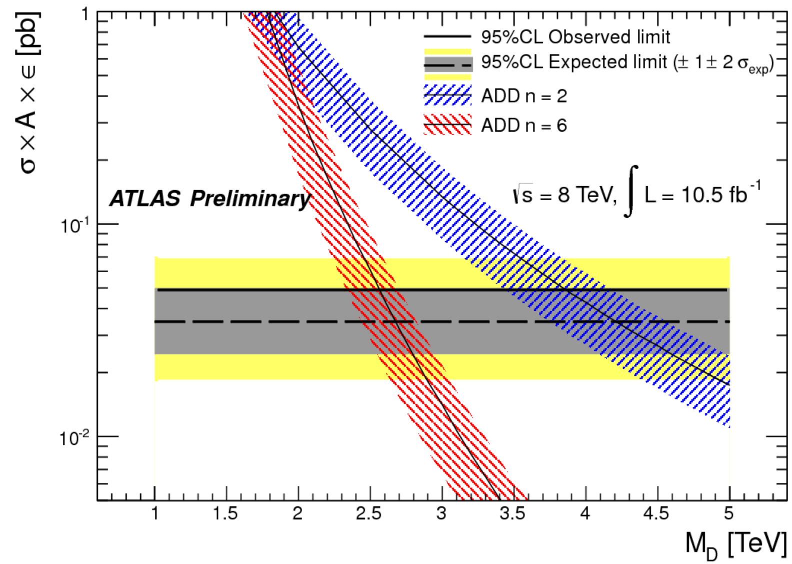


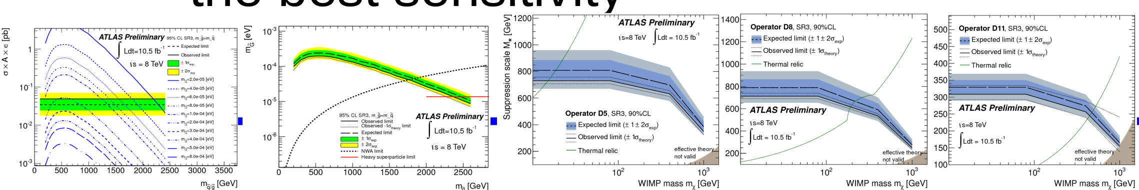


Various operators tested

- Selection:
  - missing E_T trigger,
  - MET>120GeV
  - At most 2 anti-Kt jets (R=0.4), pT>30GeV, $|\eta|<4.5$
  - Leading jet: pT>120GeV, $|\eta|<2$
  - $\Delta\varphi(2^{nd}$ jet, MET$)>0.5$
  - Lepton veto

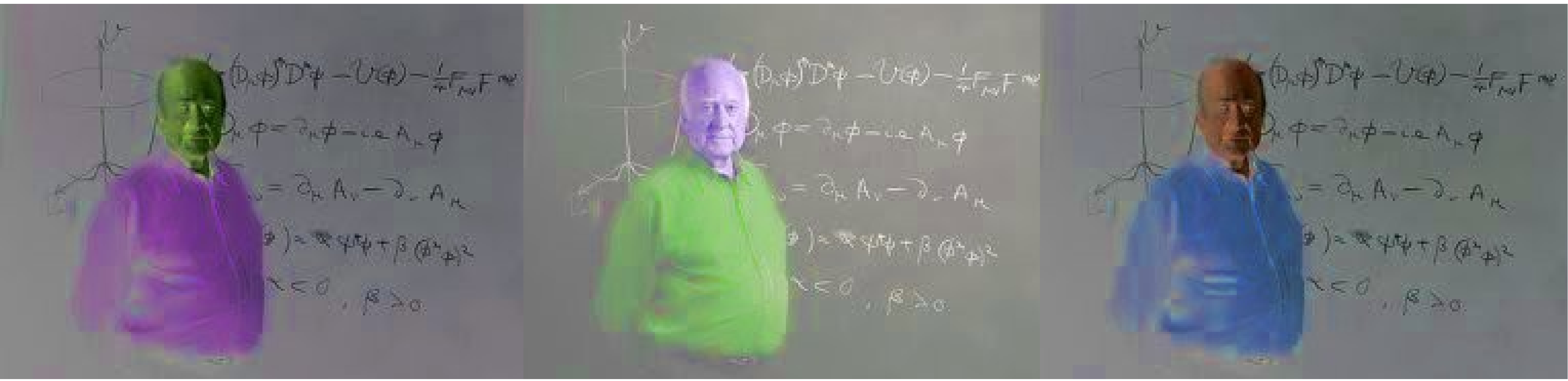
- 4 signal regions: MET and leading jet pT larger than 120, 220, 350, 500 GeV
  - 350 GeV working point gives the best sensitivity





(Much more limits in backup slides)

Exotics Higgs



Higgs → hidden sector / electron jet

Accepted by NJP
EXOT-2011-01

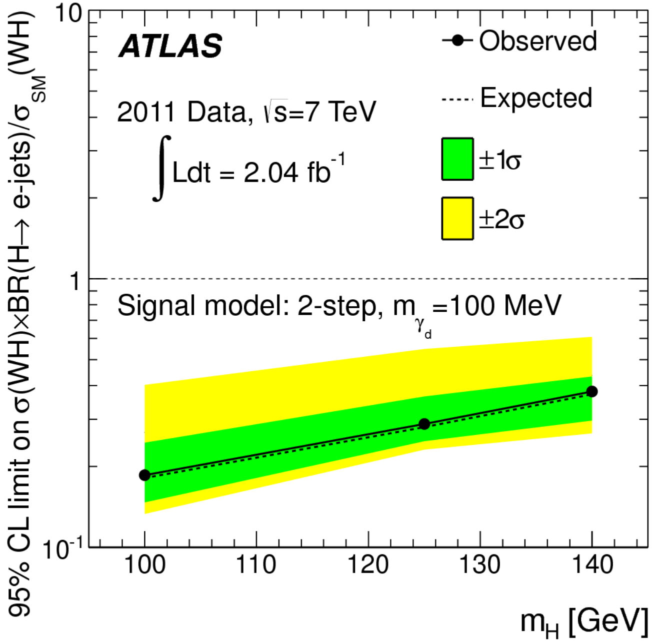
- Search using the **HW(→ e/μ ν)** production

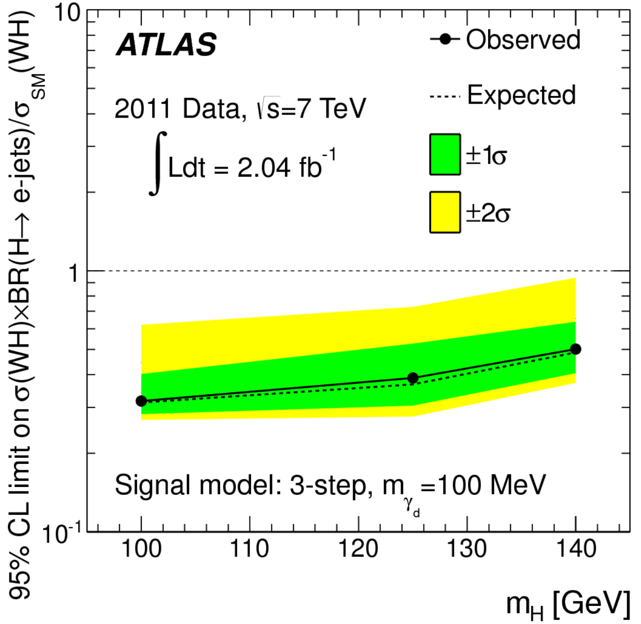
- Single lepton trigger, one isolated lepton, MET>25GeV,
  at least 2 electron-jets (high electromagnetic and charged fractions, ...)

- Backgrounds :
  - Fake electron-jets, from final state photon radiation and π^0 decays
  - Fully data-driven

- Main systematic:
  80% on the background estimation

- Similar results for $m(\gamma_d)$=100 or 200MeV

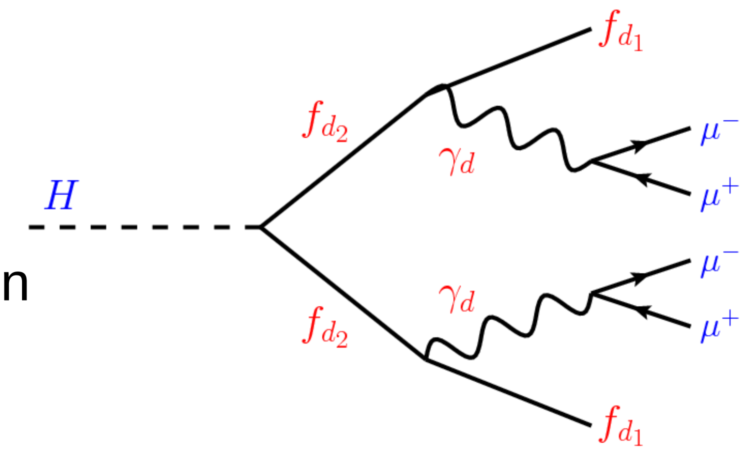




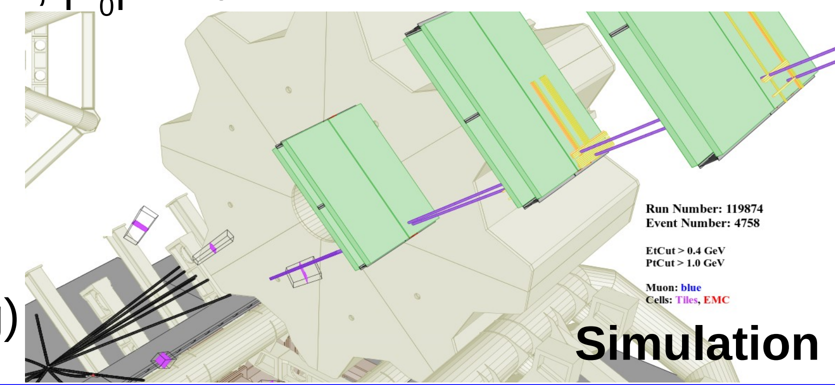
Higgs → hidden sector / muon jet

Accepted by PLB
EXOT-2011-12

- Assume
  - heavier γ_d: 400MeV, with $c\tau$~O(40mm)
  - m(f_{d2})=5GeV, m(f_{d1})=2GeV
    → muon jets, with high impact parameters (IP)
- Single production of H^0, f_{d1} escape to the detection
  - $\gamma_d \rightarrow \mu\mu$: 45%



- Selection:
  - Trigger with the muon spectrometer, large IP prevent the use of inner tracker
  - 2 isolated muon jets, back-to-back ($\Delta\varphi$>2), neutral
  - Not too far from the primary vertex $|d_0|$<200mm, $|z_0|$<270mm
- Backgrounds
  - Prompt muon: negligible
  - Multijet: data-driven
  - Cosmic-ray: from data (empty bunch crossing)

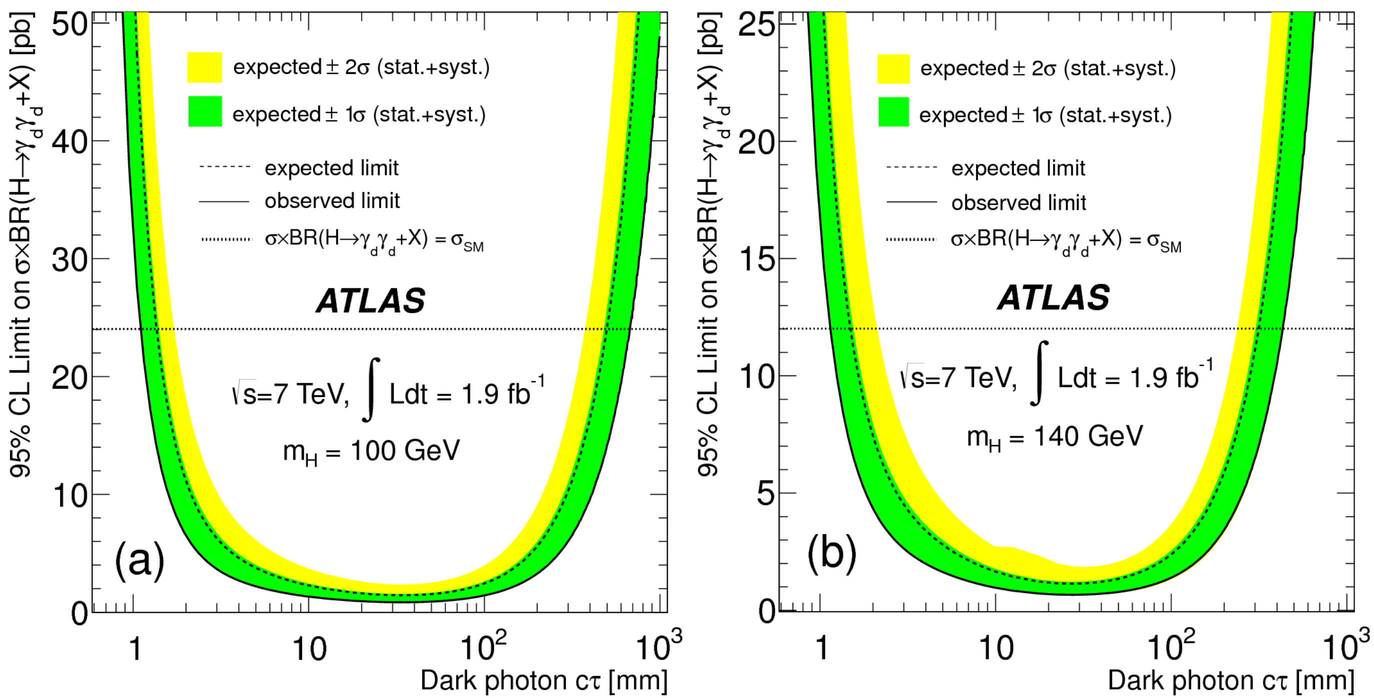


Higgs → hidden sector / muon jet

Accepted by PLB
EXOT-2011-12

- Main systematic uncertainties: trigger (17%), reconstruction of γ_d (13%)
- Almost no background at the end:

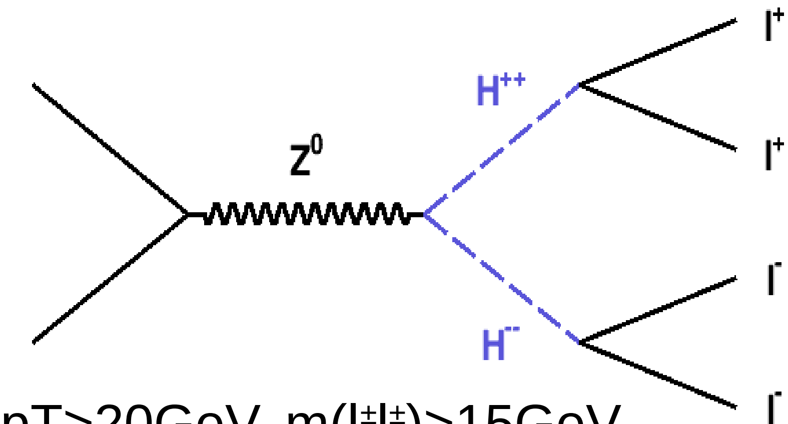
cut	cosmic-rays	multi-jet	total background	m_H = 100 GeV	m_H = 140 GeV	data
$N_{MJ} = 2$	3.0 ± 2.1	N/A	N/A	$135 \pm 11^{+29}_{-21}$	$90 \pm 9^{+17}_{-13}$	871
$E_T^{isol} \leq 5$ GeV	3.0 ± 2.1	N/A	N/A	$132 \pm 11^{+28}_{-21}$	$88 \pm 9^{+17}_{-13}$	219
$\|\Delta\phi\| \geq 2$	1.5 ± 1.5	$153 \pm 18 \pm 9$	$155 \pm 18 \pm 9$	$123 \pm 11^{+26}_{-19}$	$81 \pm 9^{+15}_{-12}$	104
$Q_{MJ} = 0$	1.5 ± 1.5	$57 \pm 15 \pm 22$	$59 \pm 15 \pm 22$	$121 \pm 11^{+26}_{-19}$	$79 \pm 8^{+15}_{-12}$	80
$\|d_0\|, \|z_0\|$	$0^{+1.64}_{-0}$	$111 \pm 39 \pm 63$	$111 \pm 39 \pm 63$	$105 \pm 10^{+22}_{-16}$	$66 \pm 8^{+12}_{-10}$	70
$\Sigma p_T^{ID} < 3$ GeV	$0^{+1.64}_{-0}$	$0.06 \pm 0.02^{+0.66}_{-0.06}$	$0.06^{+1.64+0.66}_{-0.02-0.06}$	$75 \pm 9^{+16}_{-12}$	$48 \pm 7^{+9}_{-7}$	0



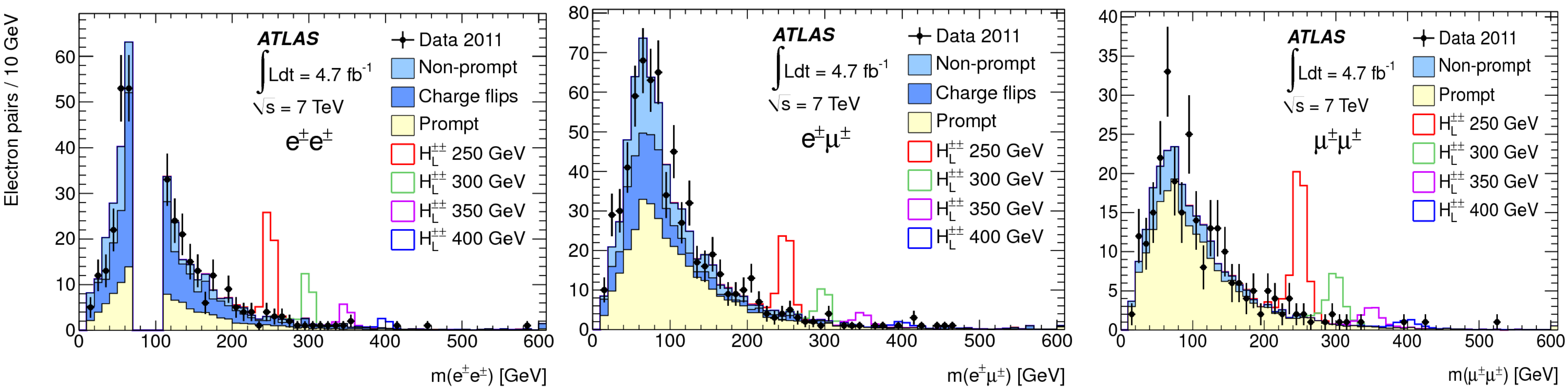
Doubly-charged Higgs boson

EPJC 72 (2012) 2244
EXOT-2012-18

- Extensions (type II seesaw, ...) predict the Higgs sector is extended to a triplet (H^0, $H^\pm$, $H^{\pm\pm}$)
- $H^{\pm\pm}$: **narrow resonance**, pair-produced
  - $H^{\pm\pm}$ couples to left- or right-handed fermions
- Assume $H^{\pm\pm}$ decay only into **ee**, **eμ** or **μμ**



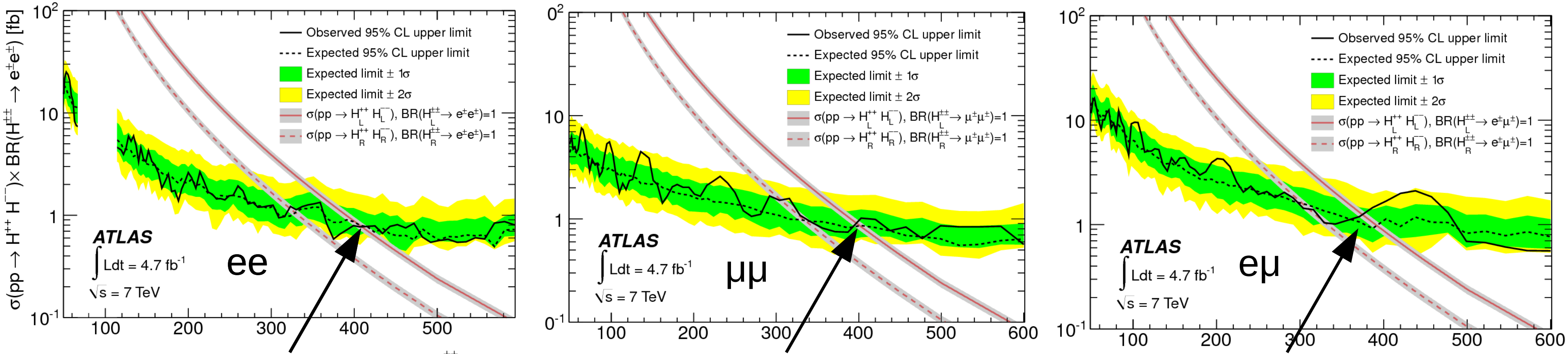
- Single lepton trigger, at least two leptons with pT>20GeV, m($l^\pm l^\pm$)>15GeV
- Search for signals inside windows of ±4% [**ee**] or ±(6+0.007.m_H)% [**eμ**, **μμ**] of the tested m_H



Doubly-charged Higgs boson

EXOT-2012-18

- Limits depend on if the $H^{\pm\pm}$ couples to left- or right-handed fermions

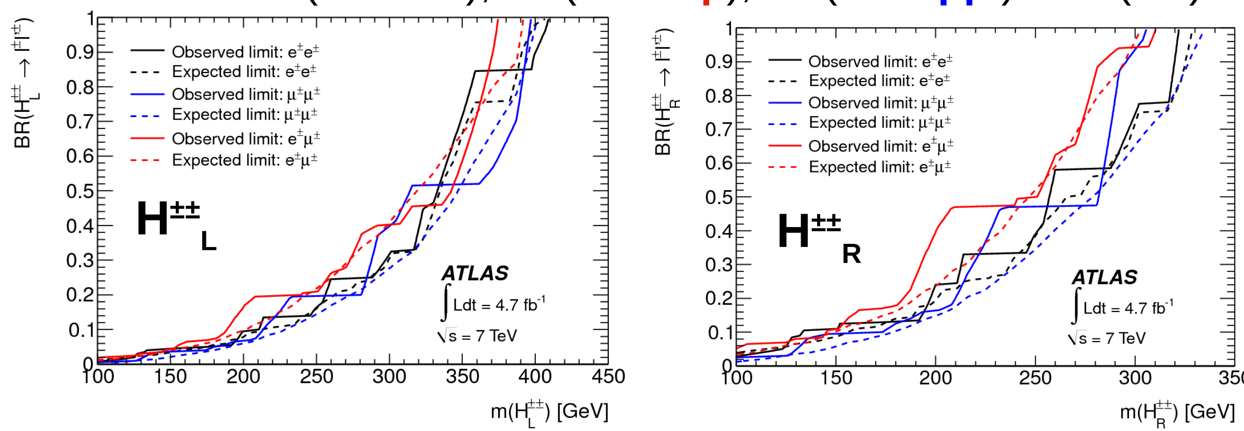


$m(H^{\pm\pm}_L)>409$GeV $m(H^{\pm\pm}_L)>398$GeV $m(H^{\pm\pm}_L)>375$GeV

Dominant uncertainties:

- ±12% for WZ/ZZ cross-sections
- ±40% for non-prompt and charge flips
- Limited by the statistics at high mass

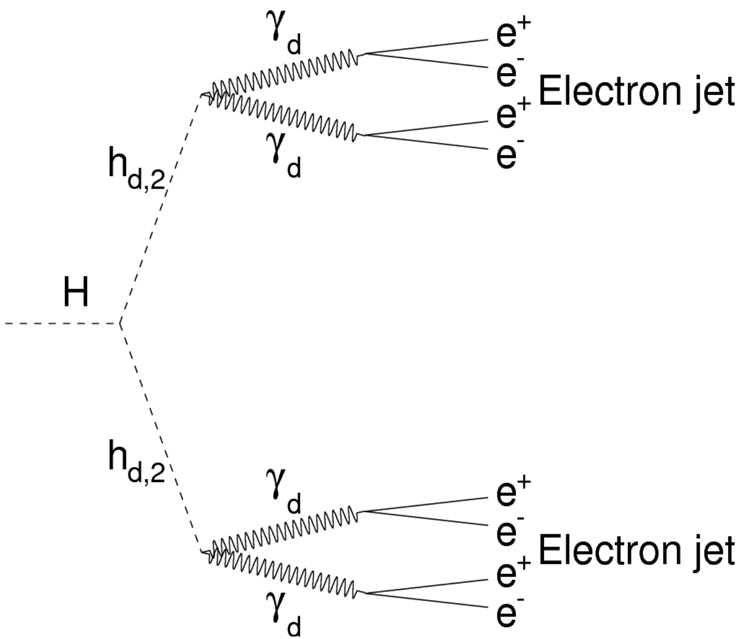
Limits on BR($H^{\pm\pm}\rightarrow$ **ee**), BR($H^{\pm\pm}\rightarrow$ **eμ**), BR($H^{\pm\pm}\rightarrow$ **μμ**) vs m($H^{\pm\pm}$)

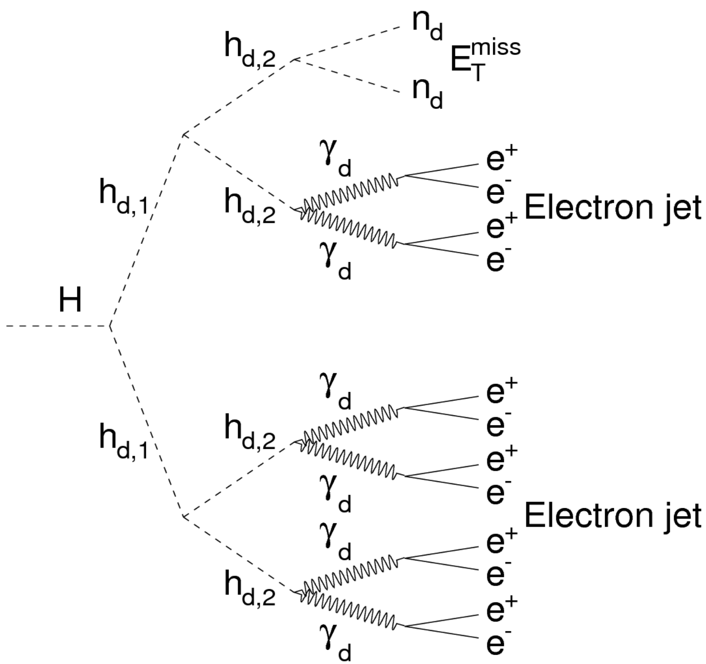


Higgs → hidden sector / electron jet

Accepted by NJP
EXOT-2011-01

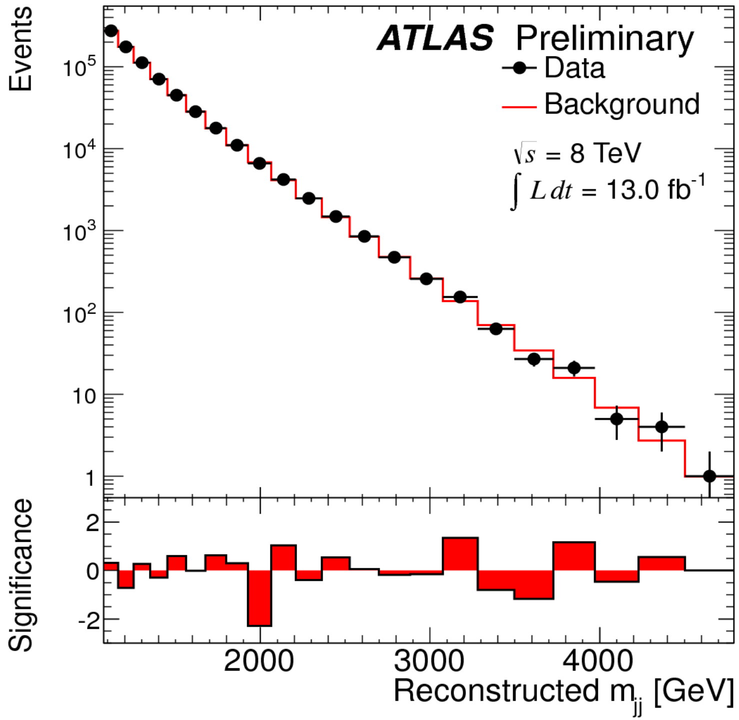
- The Higgs boson could decay into hidden-sector particles (string theory, unparticle model)
- 2 models considered → 2- or 3-step decay chains
  - New particles assumed very light → decays are boosted → jet of electrons
    - $m(h_{d,1})$=10GeV, $m(h_{d,2})$=4GeV, $m(n_d)$=90MeV, $m(\gamma_d)$=100 or 200MeV
    - Results unchanged while $m(h_{d,1/2})$<10GeV and $BR(h_{d,2} \rightarrow n_d n_d)$<0.2





Di-jet mass

- Di-jet resonances predicted by many models (compositness, extra-dimensions,...)
- Selection
  - High pT jet trigger
  - 2 anti-kt jets with R=0.6, |y|<2.8, pT>150 GeV
  - $|y^*|=|y_1-y_2|/2 < 0.6$, $m_{jj}>1$ TeV

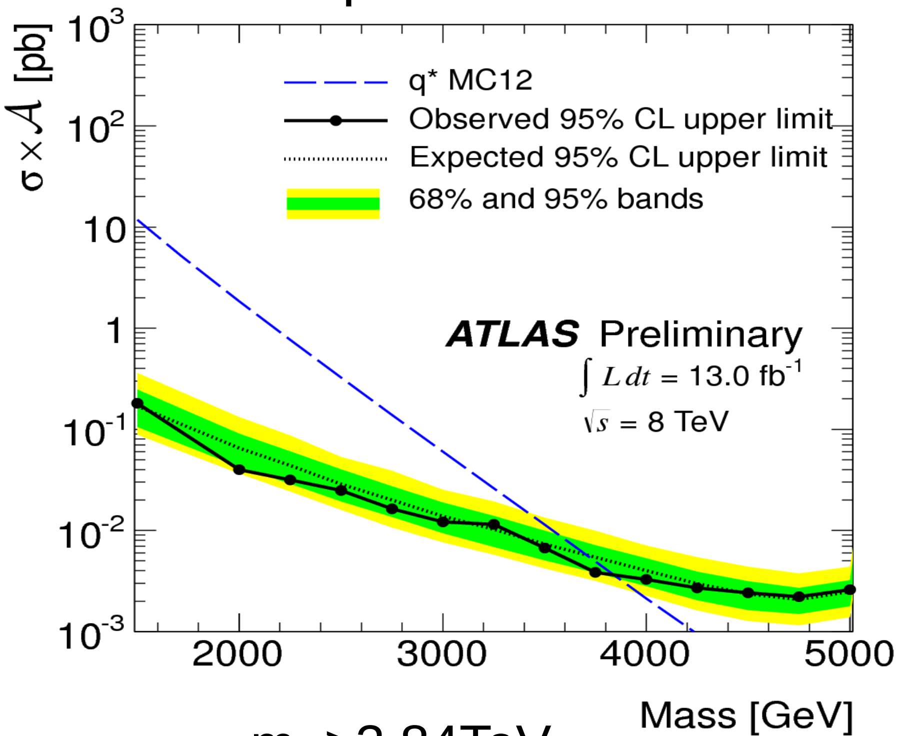


- Background fitted from data:
  - $f(x) = p_1(1-x)^{p_2}x^{p_3+p_4 \ln x}$
  - Assume Poisson statistics
    χ^2/NDF=15.5/18=0.86
- Search for excesses/deficits
  - Take care of Look-Elsewhere Effect

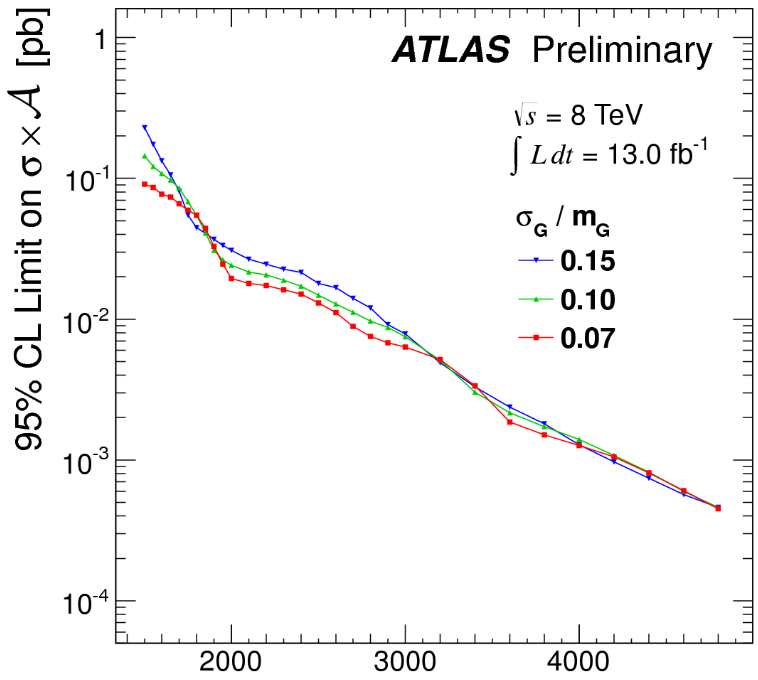
Di-jet mass

ATLAS-CONF-2012-148

- Jet energy scale is the main uncertainty (can be as low as 4%)
- Limits expressed as function of q* mass and simplified Gaussian model



m_{q^*}>3.84TeV



Gaussian distributions with width of 7%, 10% or 15%

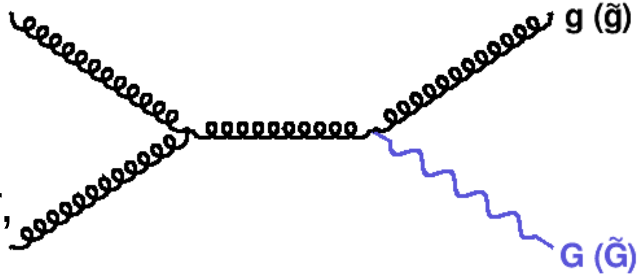
Detector resolution on m_{jj}

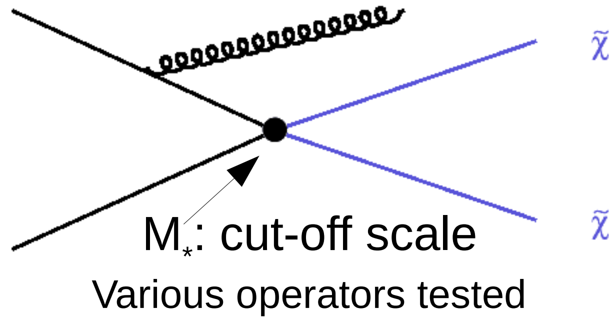
from 7% (1TeV) to 4% (3TeV)

Monojet + missing E_T

ATLAS-CONF-2012-147

- Predicted by supersymmetry (gravitino), Large Extra Dimension (graviton), WIMPS ...





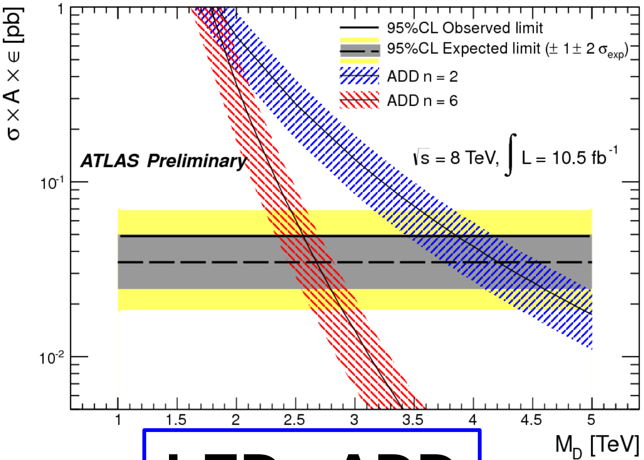
- Selection:
  - missing E_T (MET) trigger,
  - MET>120GeV
  - At most 2 anti-Kt jets (R=0.4), pT>30GeV, $|\eta|<4.5$
  - Leading jet: pT>120GeV, $|\eta|<2$
  - $\Delta\varphi$(2^{nd} jet, MET)>0.5
  - Lepton veto

- Main backgrounds (W/Z+jets, multijet, ...) are data-driven, apart from top and dibosons

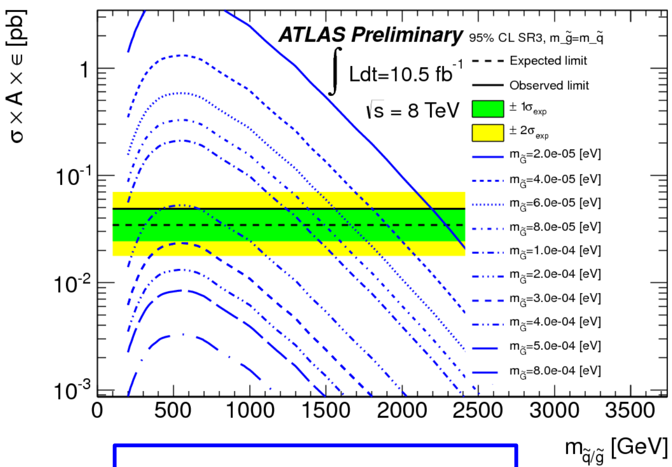
- 4 signal regions: both MET and leading jet pT larger than 120, 220, 350, 500 GeV
  - 350 GeV working point gives the best sensitivity

Monojet + missing E_T

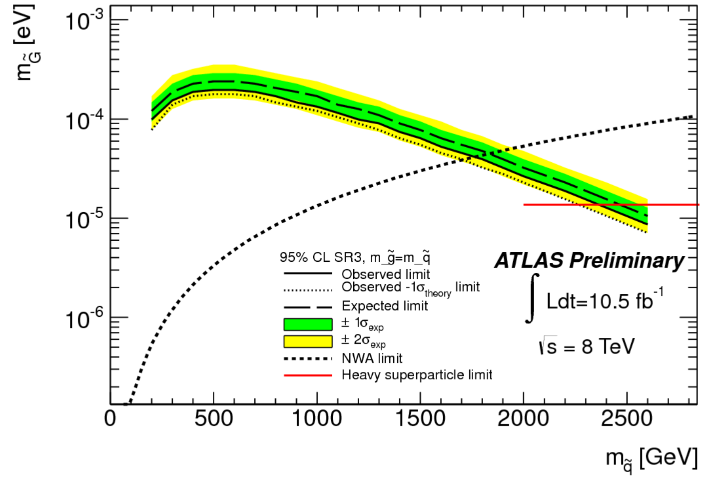
ATLAS-CONF-2012-147

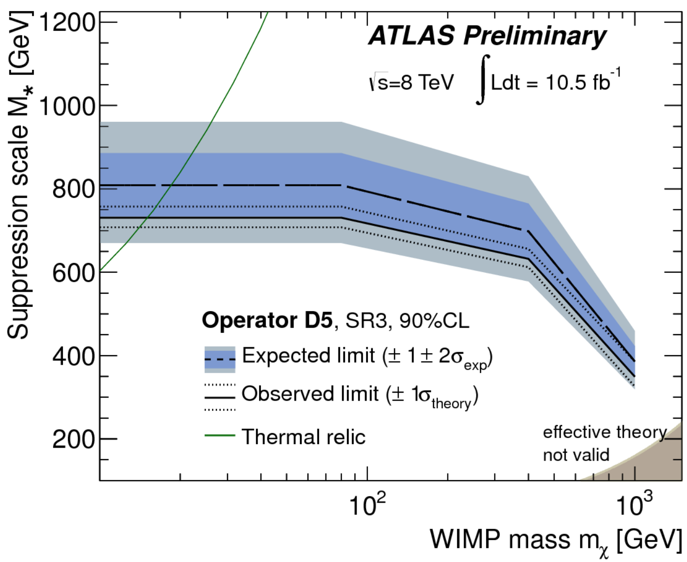


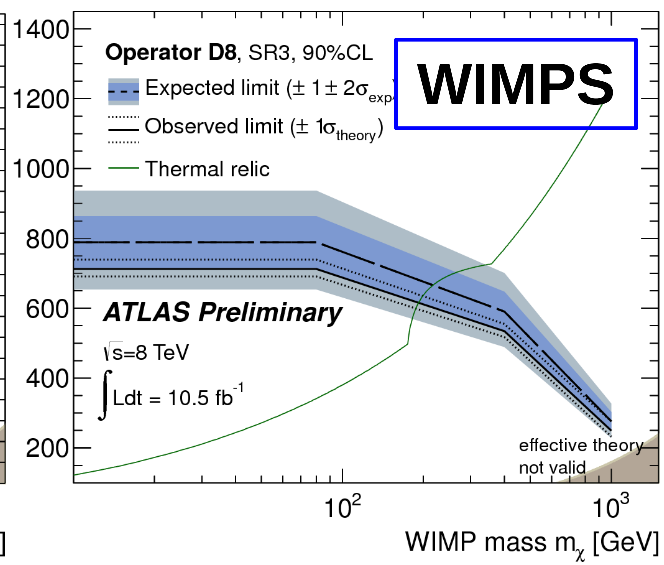
LED - ADD



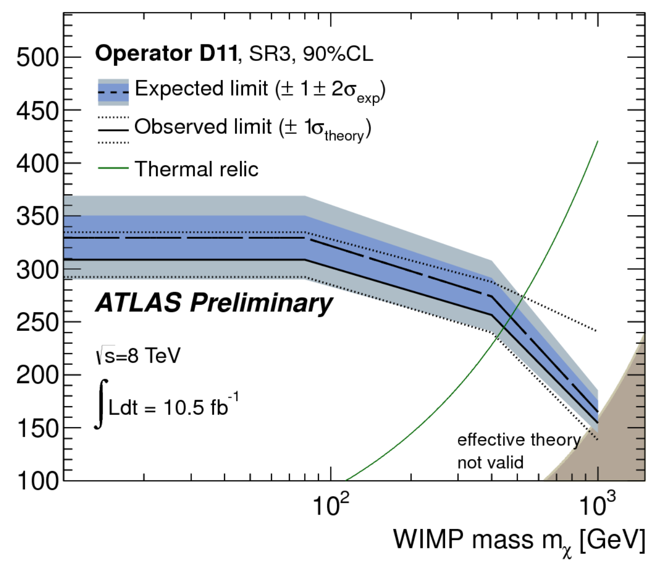
GMSB SUSY







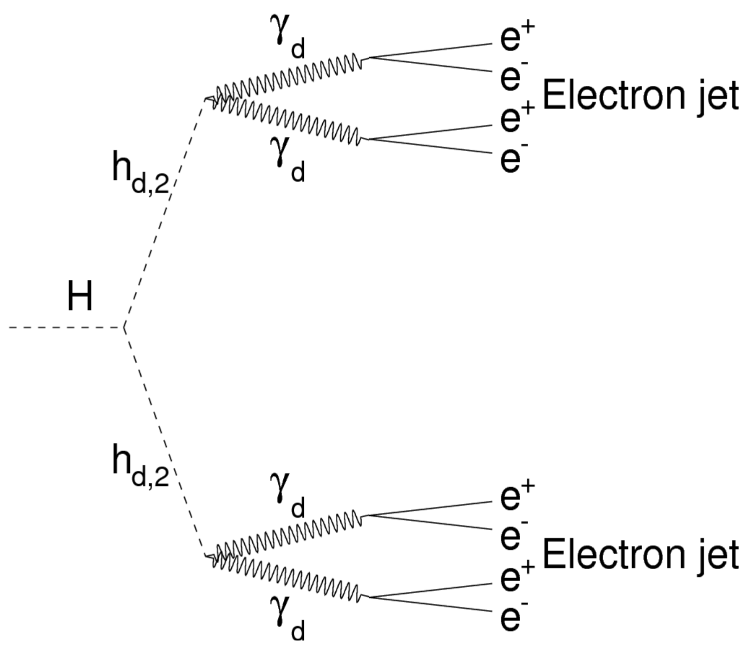
WIMPS

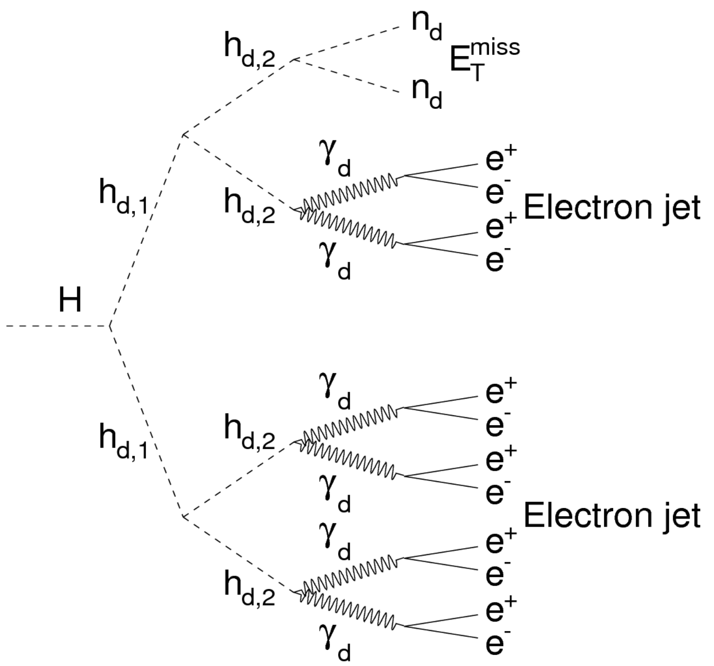


Higgs → hidden sector / electron jet

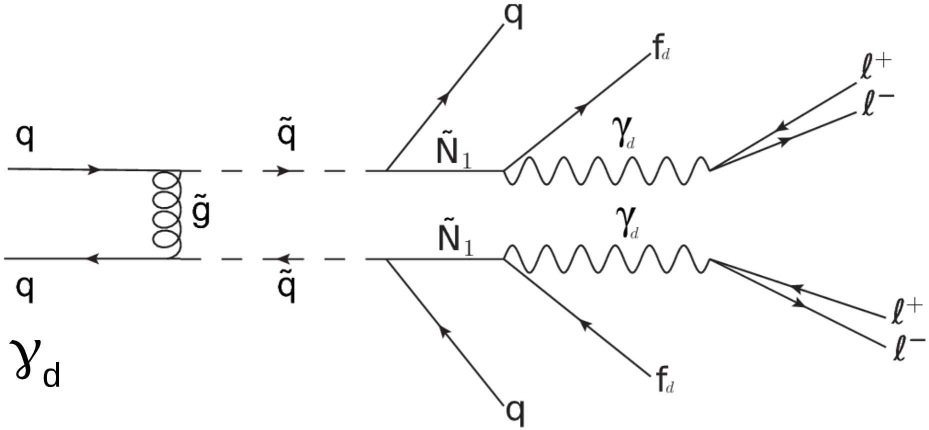
Accepted by NJP
EXOT-2011-01

- The Higgs boson could decay into hidden-sector particles (string theory, unparticle model)
- 2 models considered → 2- or 3-step decay chains
  - New particles assumed very light → decays are boosted → jet of electrons
    - $m(h_{d,1})$=10GeV, $m(h_{d,2})$=4GeV, $m(n_d)$=90MeV, $m(\gamma_d)$=100 or 200MeV
    - Results unchanged while $m(h_{d,1/2})$<10GeV and $BR(h_{d,2} \to n_d n_d)$<0.2





Hidden valley

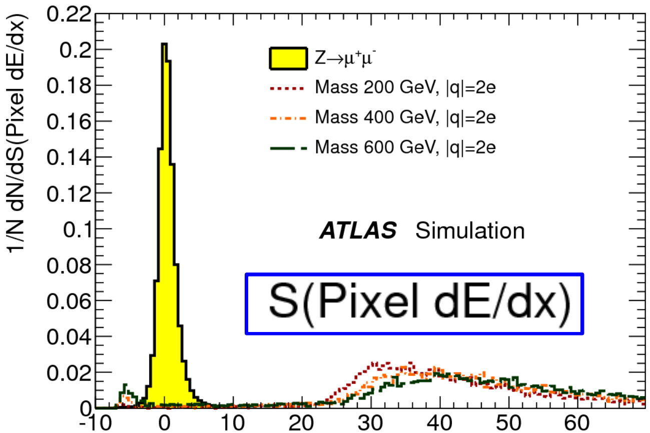


- Squark pair production
- f_d can radiate γ_d, depending on the coupling a_d, increasing the number of γ_d
- Selections
  - Single muon jet with at least 4 muons,
  - Pairs of muon jet, with at least 2 muons,
  - Or pairs of electron jets, with at least 2 electrons
- Background
  - Mainly mulitjets and gamma+jets
  - Data driven

Signal Parameters α_d	m_{γ_D} [MeV]	Electron LJ Obs (Exp) pb	1 Muon LJ Obs (Exp) pb	2 Muon LJ Obs (Exp) pb
0.0	150	0.082 (0.082)	-	-
0.0	300	0.11 (0.11)	0.060 (0.035)	0.017 (0.011)
0.0	500	0.20 (0.21)	0.15 (0.090)	0.019 (0.012)
0.10	150	0.096 (0.10)	-	-
0.10	300	0.37 (0.37)	0.064 (0.036)	0.018 (0.011)
0.10	500	0.39 (0.39)	0.053 (0.035)	0.018 (0.011)
0.30	150	0.11 (0.11)	-	-
0.30	300	0.40 (0.40)	0.099 (0.055)	0.020 (0.012)
0.30	500	1.2 (1.2)	0.066 (0.043)	0.022 (0.015)

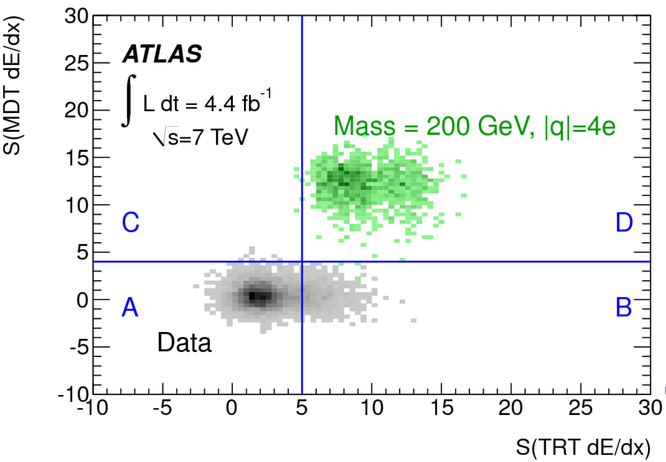
Long-lived, multi-charged particles

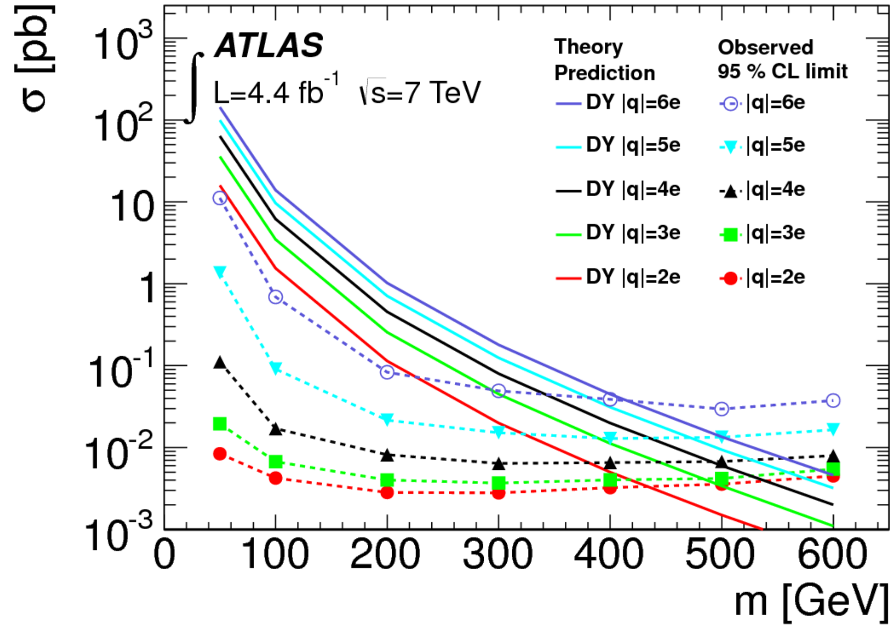
- Particles predicted by many models (magnetic monopoles, long-lived micro black holes, Q-balls)
- Search for 2e≤|q|≤6e particles: highly ionizing → large dE/dx
- Select events with “muon” pairs (assuming Drell-Yan production),
- Request large deviation of dE/dX in the various sub-detectors



$$S(\mathrm{d}E/\mathrm{d}x) = \frac{\mathrm{d}E/\mathrm{d}x_{\mathrm{track}} - \langle \mathrm{d}E/\mathrm{d}x_{\mu} \rangle}{\sigma(\mathrm{d}E/\mathrm{d}x_{\mu})}$$

- Limits dominated by the statistic uncertainty

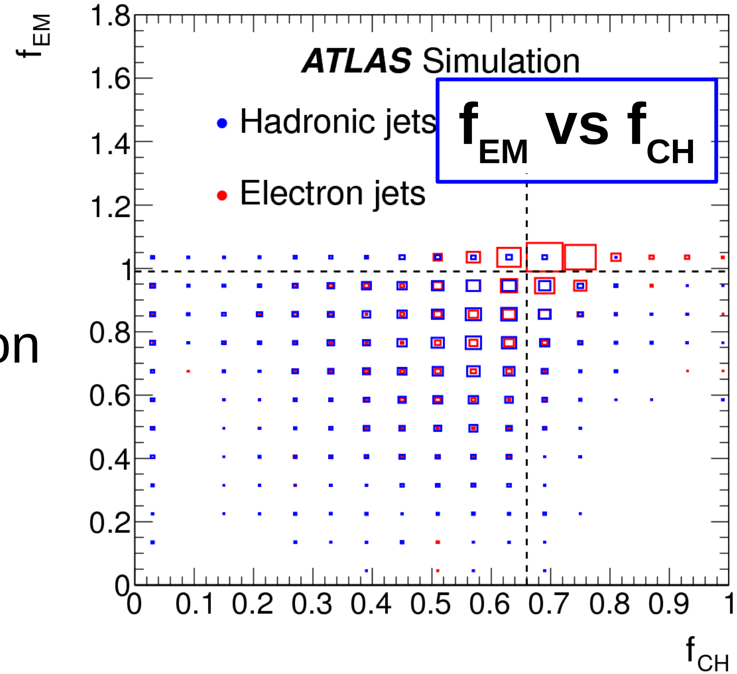




Higgs → hidden sector / electron jet

EXOT-2011-01

- Search using the **HW(→ e/μ ν)** production
- Single lepton trigger, one isolated lepton, MET>25GeV, at least 2 electron-jets:
  - $|\eta|<2$, pT>30GeV
  - High electromagnetic fraction $f_{EM}>0.99$
  - High charged fraction $f_{CH}>0.66$
  - At least 2 tracks, likely to come from electron



- Background :
  - Fake electron-jets, from final state photon radiation and π^0 decays
  - Fully data-driven

Higgs → hidden sector / electron jet

EXOT-2011-01

Signal	three-step model		two-step model	
m_H (GeV)	$m_{\gamma_d} = 100$ MeV	$m_{\gamma_d} = 200$ MeV	$m_{\gamma_d} = 100$ MeV	$m_{\gamma_d} = 200$ MeV
100	$14.3 \pm 1.7 \pm 0.8$	$12.4 \pm 1.6 \pm 0.7$	$22.6 \pm 2.1 \pm 1.2$	$23.5 \pm 2.1 \pm 1.2$
125	$11.3 \pm 1.0 \pm 0.6$	$10.7 \pm 1.1 \pm 0.6$	$16.2 \pm 1.2 \pm 0.9$	$18.1 \pm 1.4 \pm 1.0$
140	$9.6 \pm 0.8 \pm 0.5$	$9.0 \pm 0.8 \pm 0.4$	$13.7 \pm 0.9 \pm 0.8$	$13.9 \pm 0.9 \pm 0.8$
Background	$0.41 \pm 0.29 \pm 0.12$			
Data	1			

- Main systematic:
  80% on the background estimation
- Similar results for $m(\gamma_d)$=100 or 200MeV