Recherche directe de nouvelle physique au LHC

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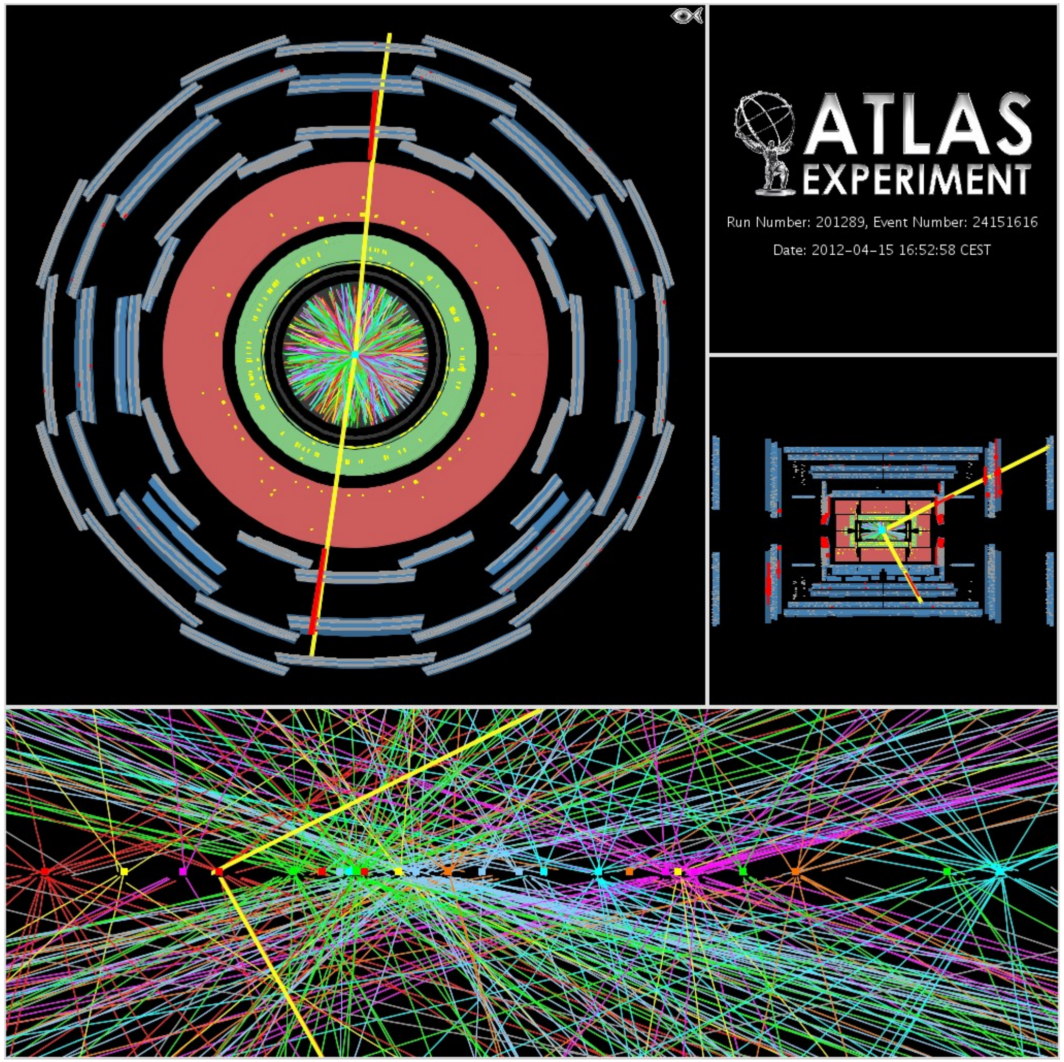


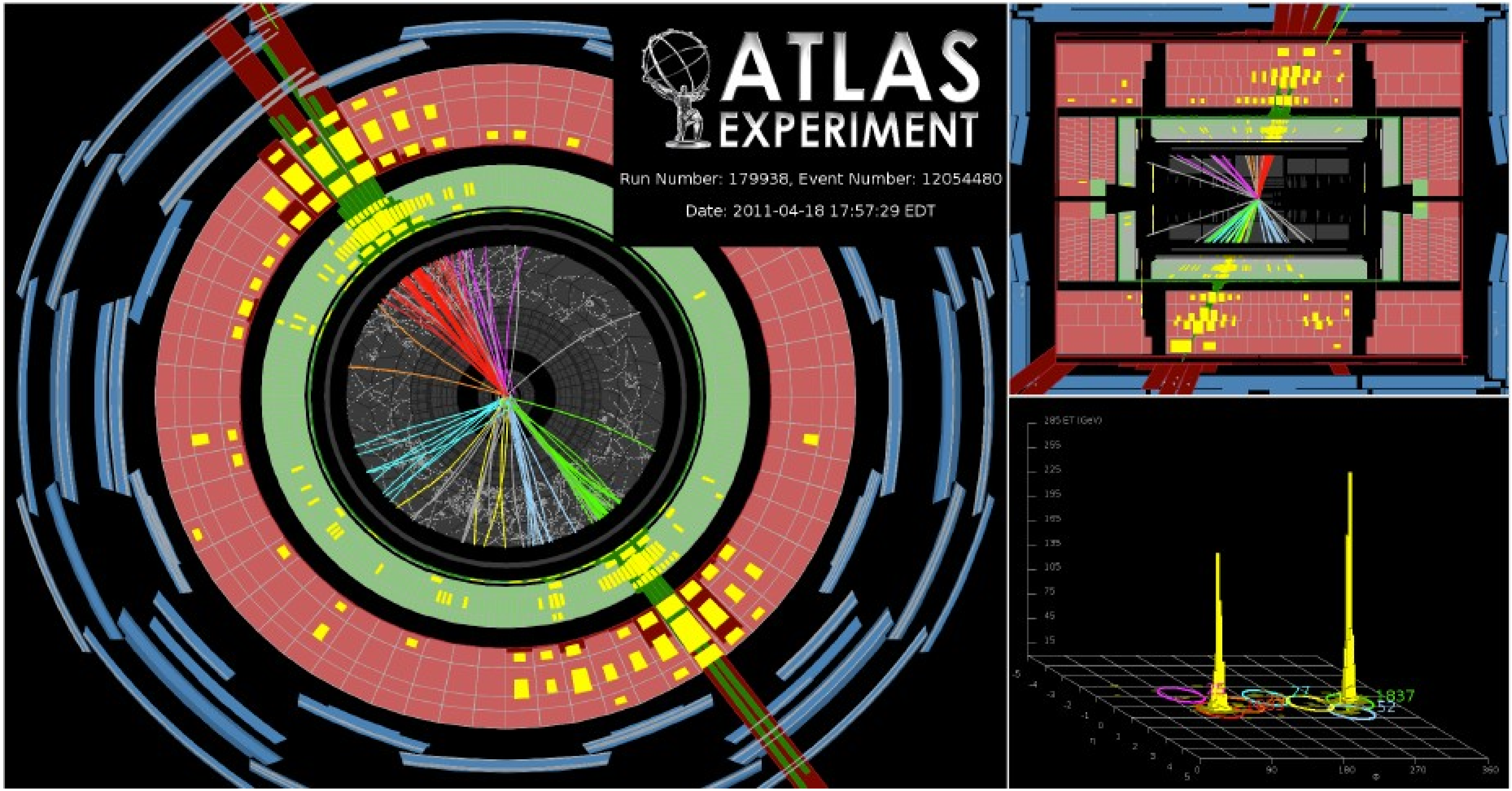
Outline

- Introduction
- Supersymmetry
- Long-lived particles
- Extra-dimensions and heavy resonances
  - → Large Extra-dimensions. Monojet, monophoton, BH
  - → Warped Extra-dimensions. Dilepton, t-tbar resonances.
- 4^{th} generation and heavy quarks
  - → t', b', vector-like quarks
- Model-independent searches
  - → Same-sign dilepton
  - → Generic searches
- Outlook and conclusions

yesterday (Introduction, Supersymmetry, Long-lived particles)

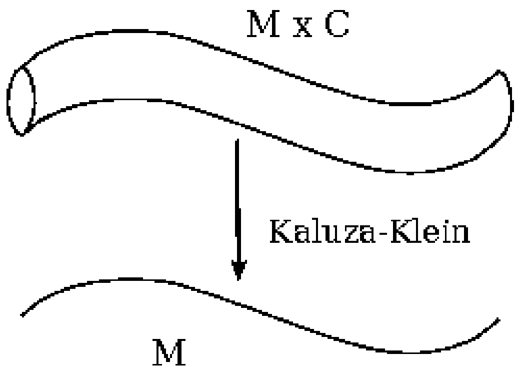
today (Extra-dimensions and heavy resonances through Outlook and conclusions)

Extra-Dimensions and Heavy Resonances



A Short History of Extra-Dimensions

- *1921-26* : Kaluza & Klein attempt to unify EM and relativity by adding a dimension to general relativity
  - → Compactification → Kaluza-Klein towers
  - → **E = nhc / R** (R = ED radius, n integer)



- *1998* : Large ED (Arkani-Hamed, Dimopoulos, Dvali)

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

- *1999* : Warped ED Warped Randall-Sundrum

$$ds^2 = e^{-2kr_c|\phi|}\eta_{\mu\nu}dx^\mu dx^\nu + r_c d\phi^2$$

$$\phi \approx -\phi, \quad |\phi| \le \pi$$

- Since then: many more...

Large Extra-Dimensions (ADD)

- Basic idea: In fact, gravity becomes strong at the TeV-scale → Hierarchy Problem is gone.
- Apply Gauss' Law at 3+n dimensions:

  for r<<R: $V(r) \sim 1/r^{(n+1)}$

  Gravity gets stronger at small distances!
- for r>>R: V(r) = 1/r (ED not visible at large distances)
- n = 1 and 2: excluded from macroscopic gravity observation

$$V(r) \sim \frac{m_1 m_2}{M_{Pl(4+n)}^{n+2}} \frac{1}{r^{n+1}}, \quad (r \ll R)$$

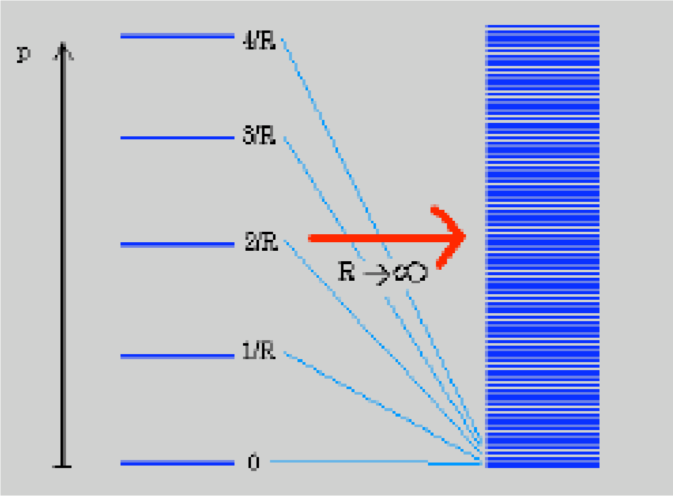
$$M_{Pl}{}^2 \sim M_D{}^{2+n} R^n$$

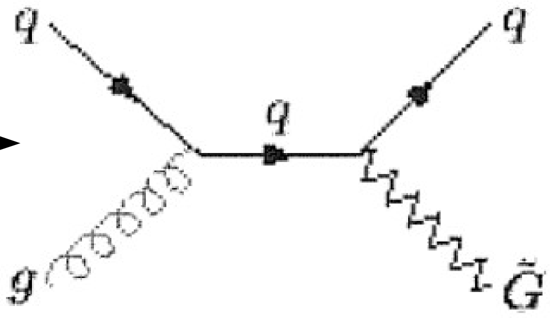
Typical size of ED
For M_D ~ TeV:

n	R
1	~ 1 mpc
2	~ 1 mm
4	~ 1 pm
6	~ 1 fm

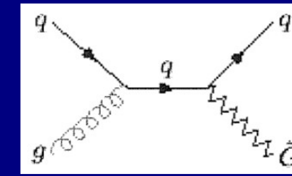
Large Extra-Dimensions (ADD)

- KK tower of excited gravitons: large ED means small ΔE between states: ΔE ~ 1/R
  - → Experimentally: continuum
- At the LHC, three ways to look for it:
  - → Deviation in DY or dijet spectrum caused by continuum
  - → Monojet/monophoton: graviton production recoiling against quark or photon
  - → Black-hole

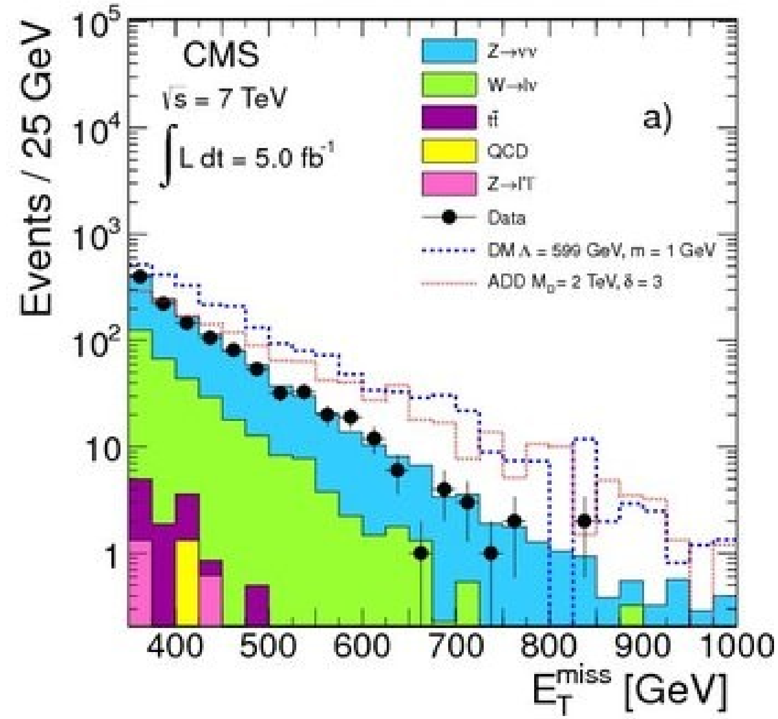


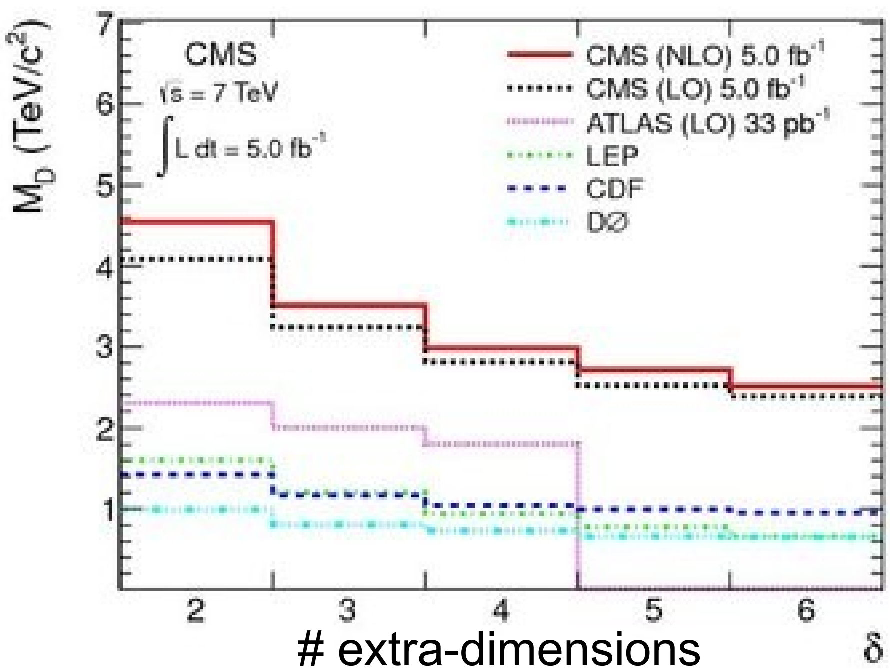


ADD: Search for Monojets



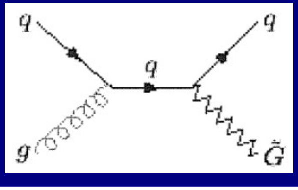
- Look for a jet and ~ nothing else
- Challenge:
  - → Instrumental background
  - → Understanding Z(→ νν) + jets



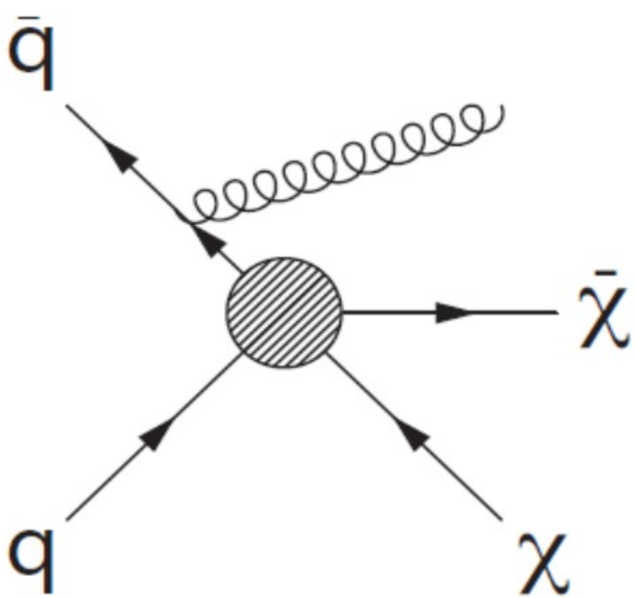


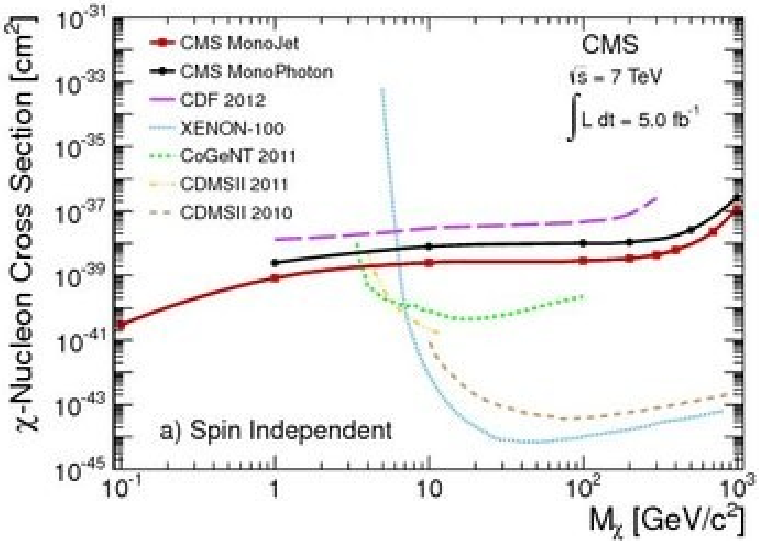
- Stringent limits on ADD

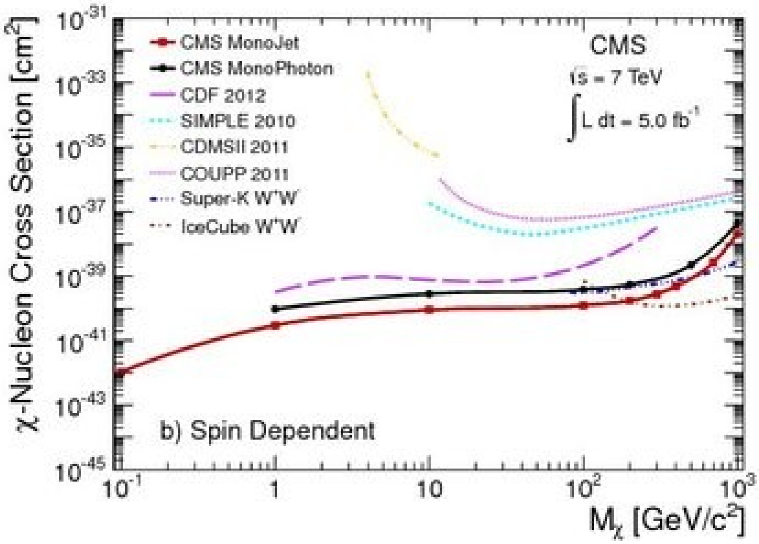
ADD: Search for Monojets



- Look for a jet and ~ nothing else
- Challenge:
  - → Instrumental background
  - → Understanding Z(→ νν) + jets
- Also sensitive to WIMP production:

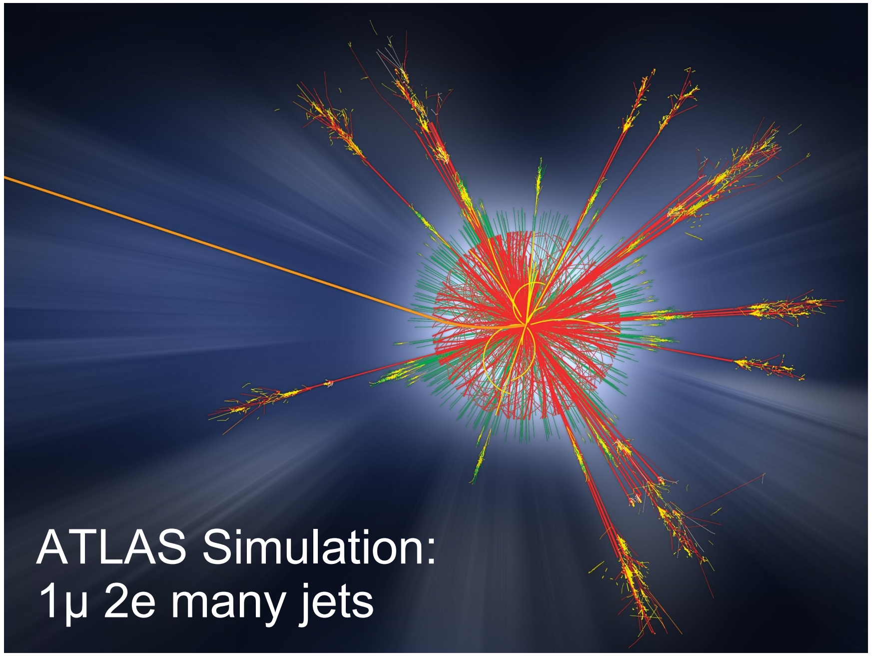






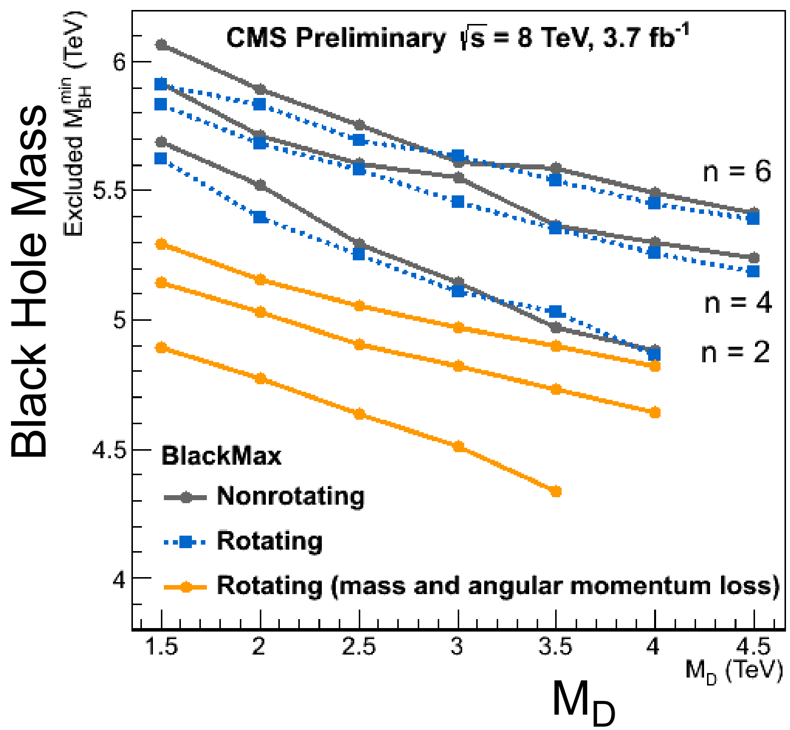
Microscopic Black Holes

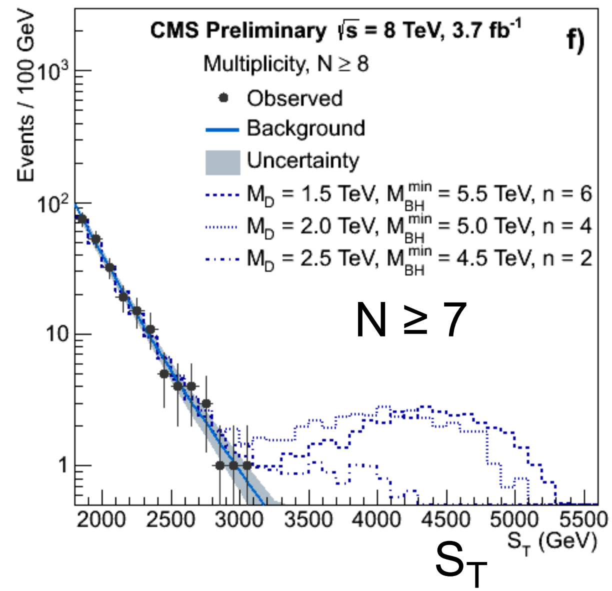
- If Gravity becomes strong at TeV → strong enough to produce Microscopic black-holes decaying through Hawking radiation
- Large uncertainty on models due to our ignorance of quantum gravity
- Semi-classical models only for m(B.H.) >> m(threshold)
- A safe bet: decay is democratic and isotropic → **Look for (many) jets (and leptons) at high mass**

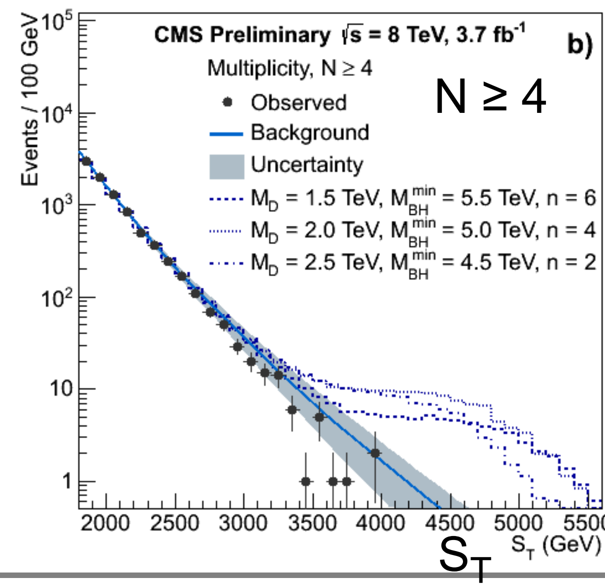


Microscopic Black Holes
“multi-object” CMS analysis with 8 TeV data:

- Cut on total number of objects (jets, photons, electrons, muons) in event
- Look for deviation in total transverse energy S_T (a.k.a. H_T at ATLAS)

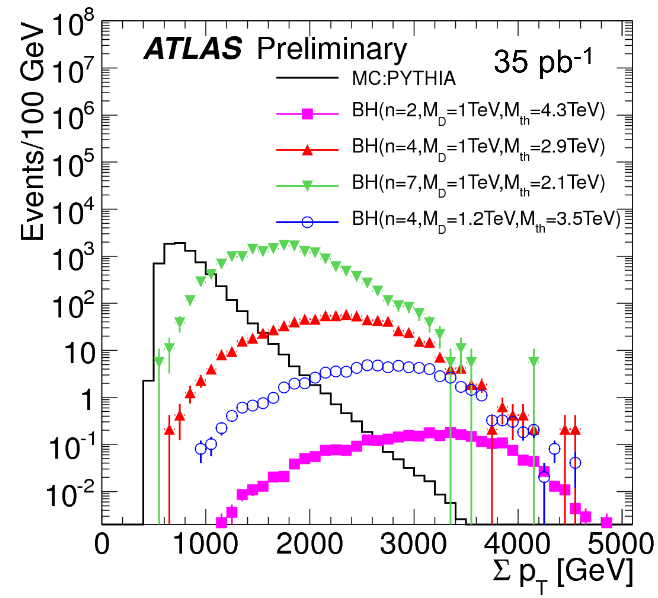


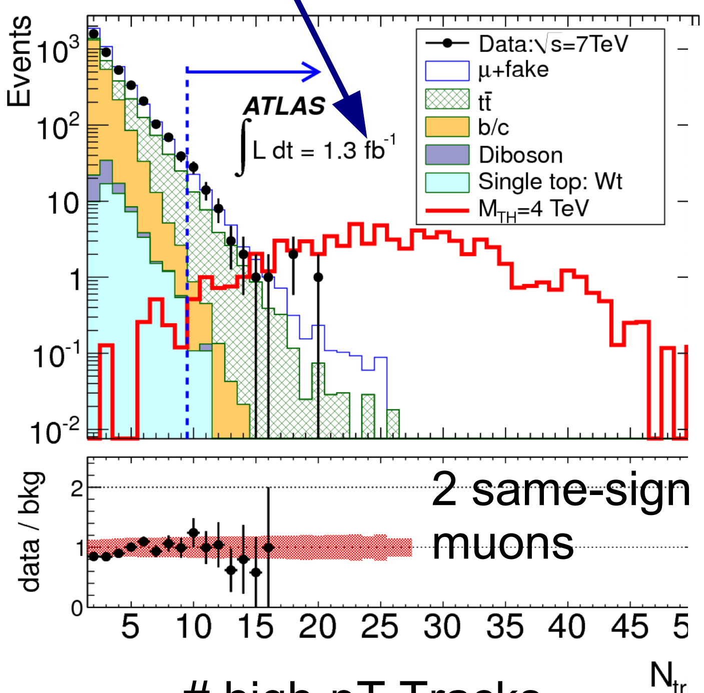




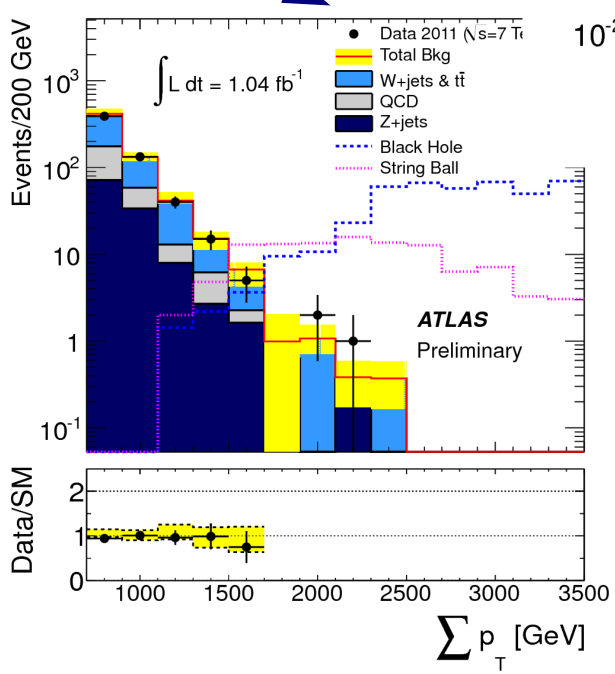
Black Holes: Multi-Jets, Lepton+Jets, Same-Sign

- Multijet
- L+Jets
- Same-sign Dimuon



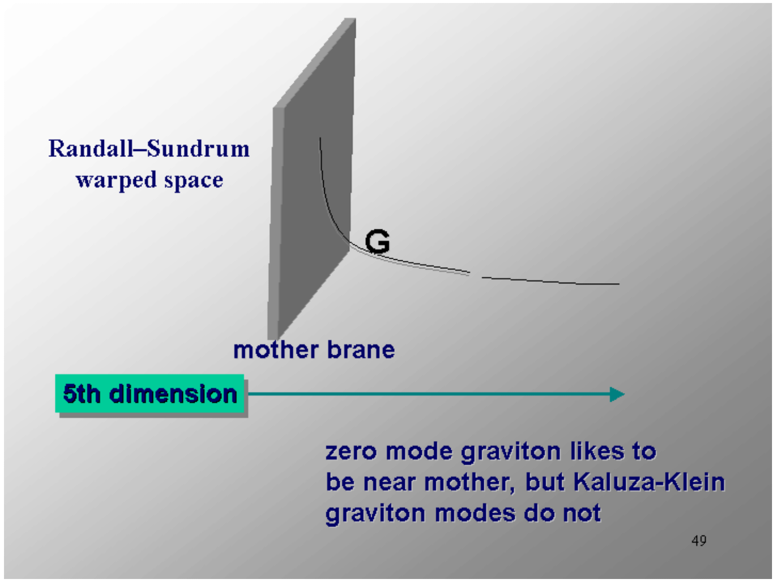


high-pT Tracks



Warped Extra-Dimensions (RS)

- One extra-dimension with negative curvature i.e. anti de Sitter metrix
- RS1: Planck brane and TeV brane at the boundaries of the ED
  - → KK graviton tower with ΔE ~ 1 TeV
  - → Signature: KK graviton to dilepton or diphoton
- Bulk-RS: all fields propagate in ED and create KK tower.
  - → KK graviton couples to massive particles → large BR to WW, ZZ
  - → KK gluon → ttbar

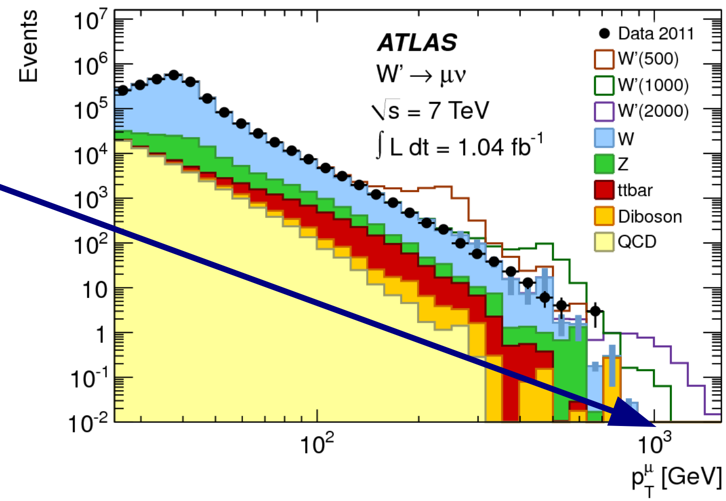


$$ds^2 = e^{-2kr_c|\phi|}\eta_{\mu\nu}dx^\mu dx^\nu + r_c d\phi^2$$

$$\phi \approx -\phi, \quad |\phi| \leq \pi$$

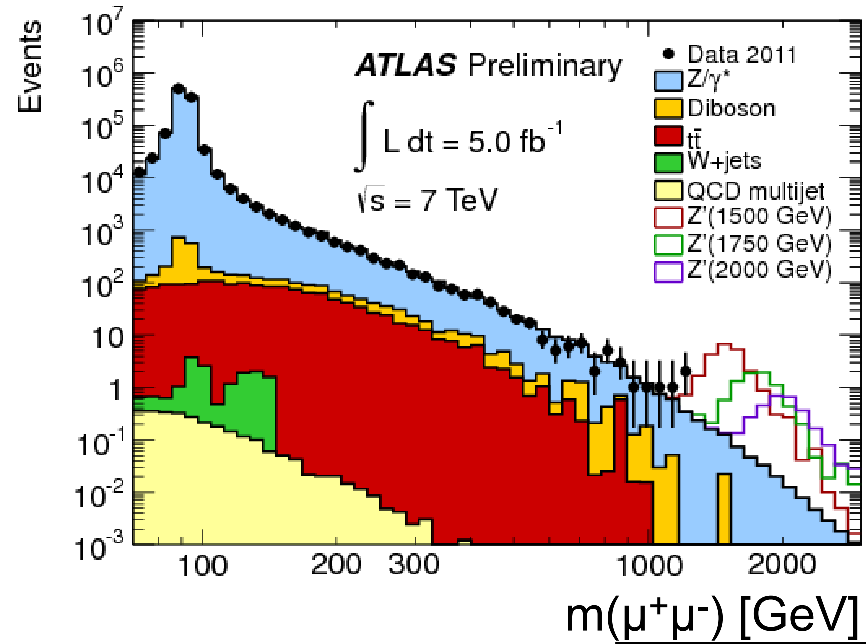
Search for Heavy Resonances: Dilepton Channel

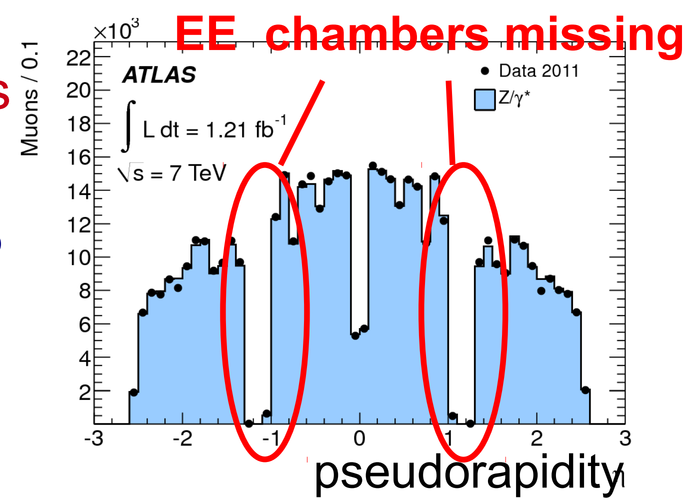
- Predicted by numerous extensions of the Standard Model:
  - → Randall-Sundrum ED → Kaluza-Klein graviton
  - → GUT-inspired theories, Little Higgs → heavy gauge boson(s) Z' (W')
  - → Technicolor → narrow technihadrons
- Experimental challenge: understand detector performance (resolution, efficiency) for a signal with (almost) no control sample at very high momentum → confidence in alignment, simulation, etc...
- Electrons and muons: reaching pT ~ 1 TeV!

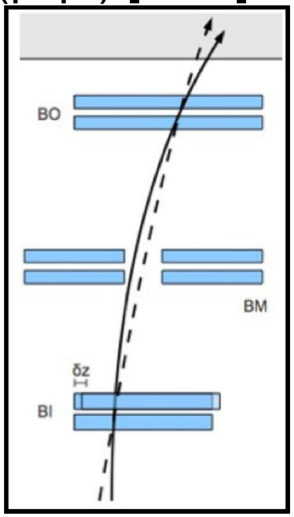


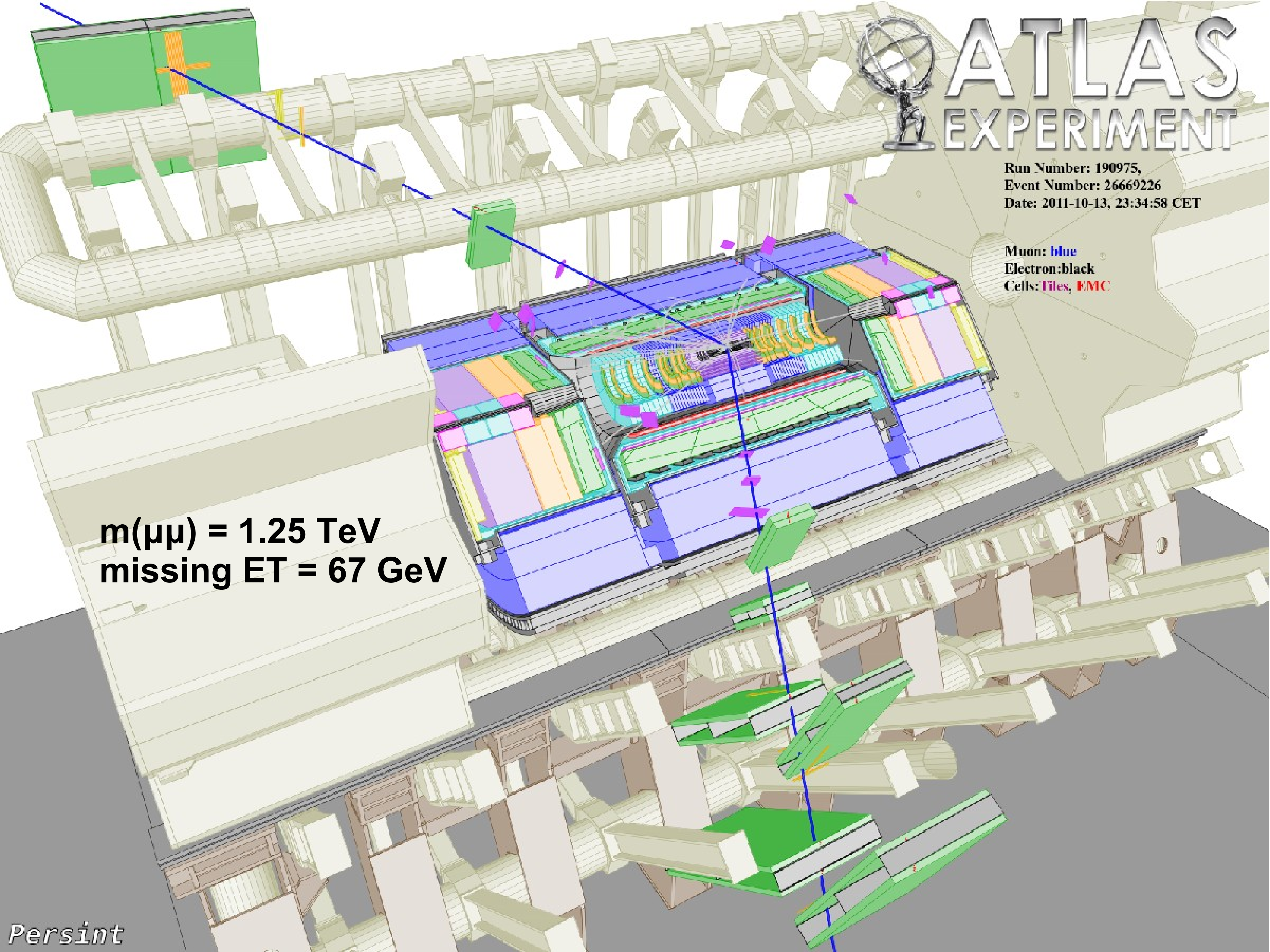
Search for Heavy Resonance: dilepton channel

- Dimuon channel
- Alignment critical
  - → Now close to nominal (30 μm) in most of the detector
  - → Resolution 13% at p_T = 1 TeV
- Require 3-station tracks for good resolution → loss of acceptance
  - → Now also using 2-station tracks in well-understood regions
  - → This Winter: installation of 75% of missing EEL's completed → half recovered in 2012 data





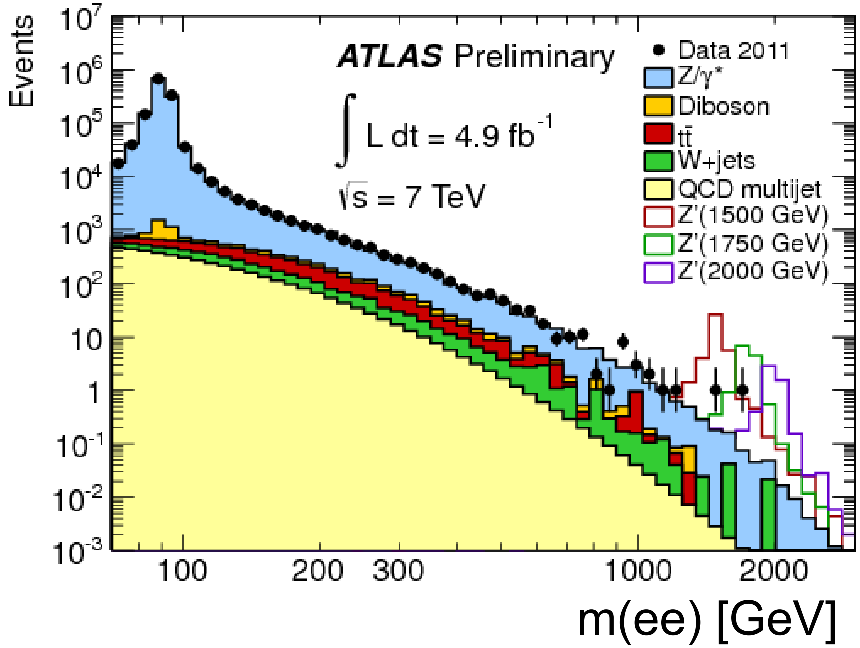




ATLAS EXPERIMENT
Run Number: 190975,
Event Number: 26669226
Date: 2011-10-13, 23:34:58 CET
Muon: blue
Electron:black
Cells:Tiles, EMC
m(μμ) = 1.25 TeV
missing ET = 67 GeV
Persint

Search for Heavy Resonance: dilepton channel

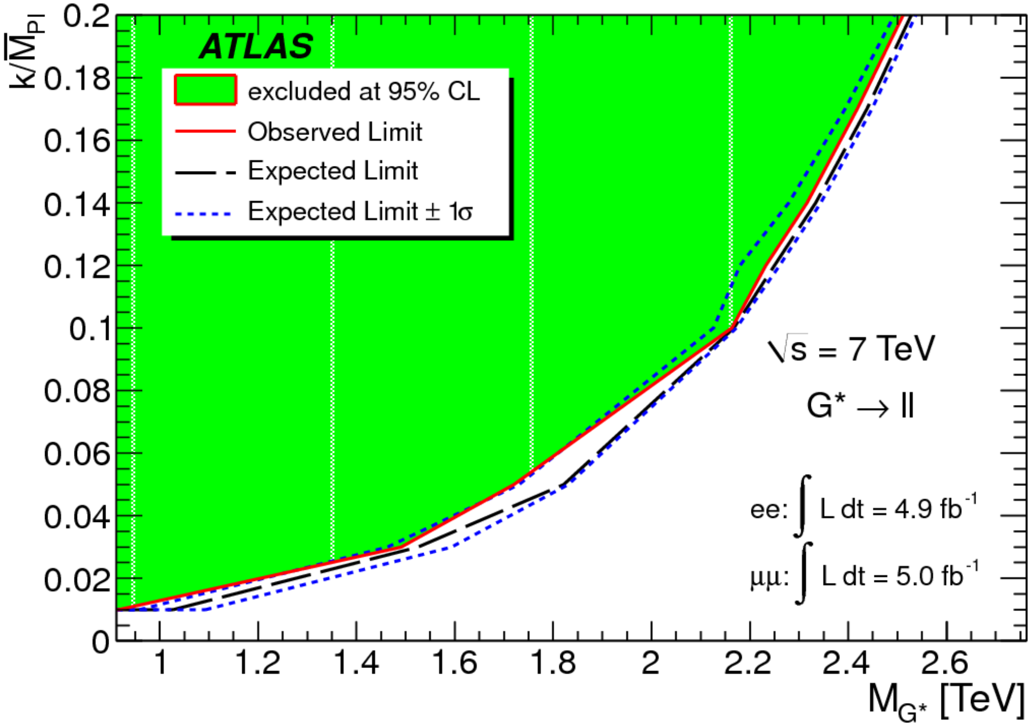
- Dielectron channel
- Excellent resolution: < 2% at high momentum
- Poor charge measurement → no charge requirement in the dielectron channel



Search for Heavy Resonance: dilepton channel

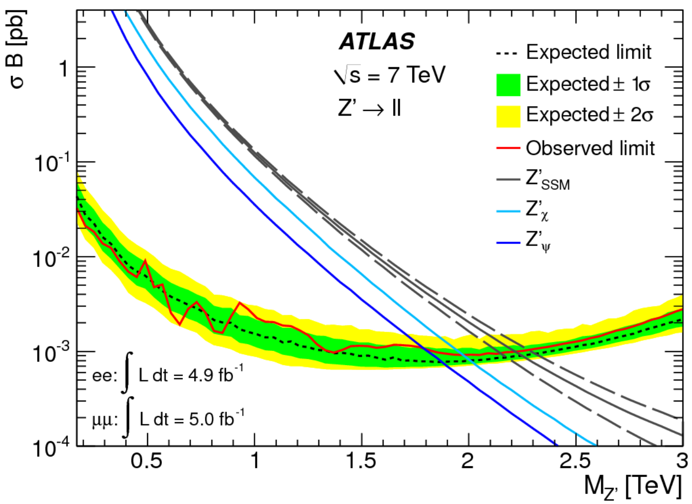
- No deviation from SM is observed. Limits as a function of RS graviton mass and coupling

  m(RS graviton, k/M_{Pl} = 0.1) > 2.16 TeV at 95% CL



Search for Heavy Resonance: dilepton channel

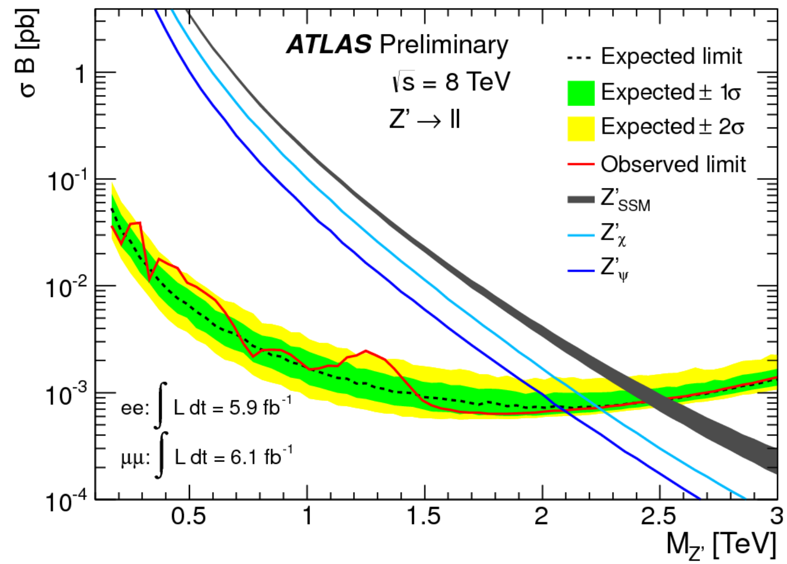
- Sequential SM: assume Z' with same couplings as SM Z



5 fb^{-1} at 7 TeV:

m(SSM Z') > 2.21 TeV

(95% CL)



6 fb^{-1} at 8 TeV:

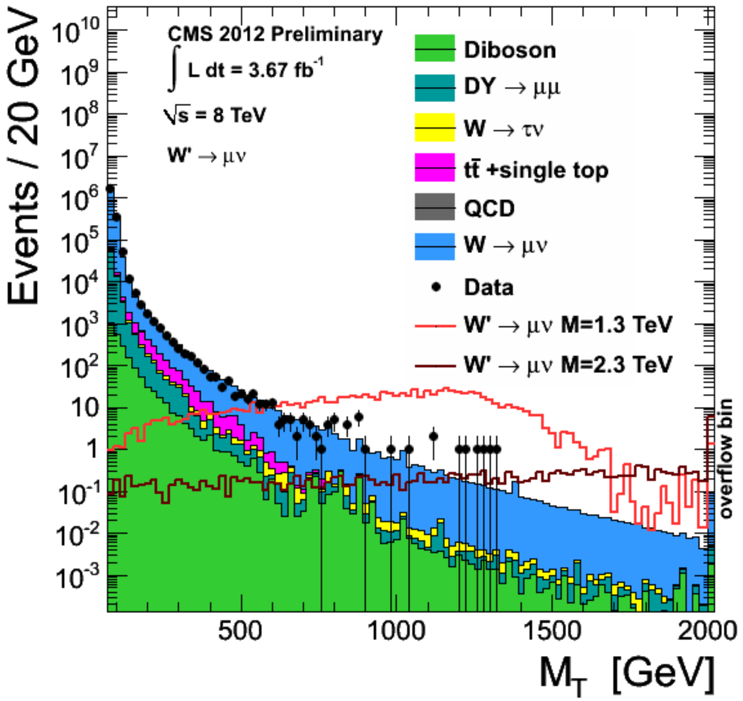
m(SSM Z') > 2.49 TeV

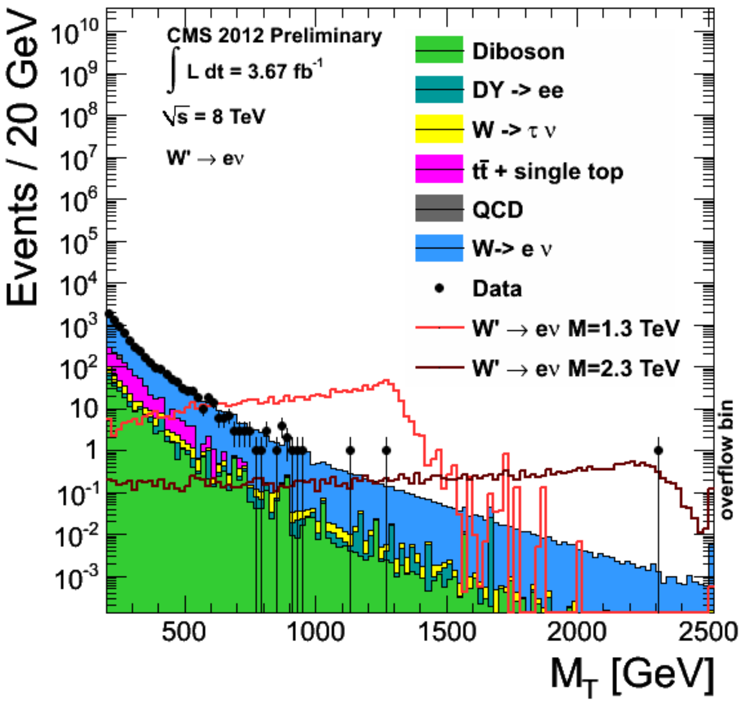
(95% CL)

Search for Heavy Resonance: W' → lν

- W': the charged equivalent of the Z'
- Bulk-RS: excited KK W
- Final state: 1 lepton + Missing E_T
- Look for Jacobian peak in transverse mass

$$m_T = \sqrt{2 p_T \not{E}_T (1 - cos\Delta\phi_{\ell,\not{E}_T})}$$



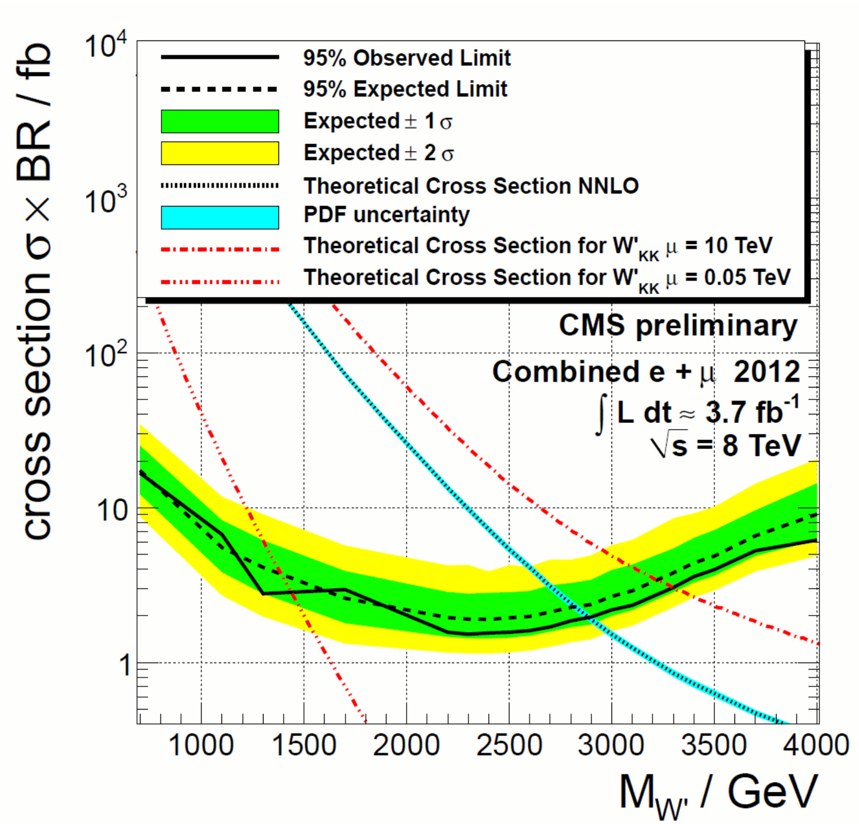


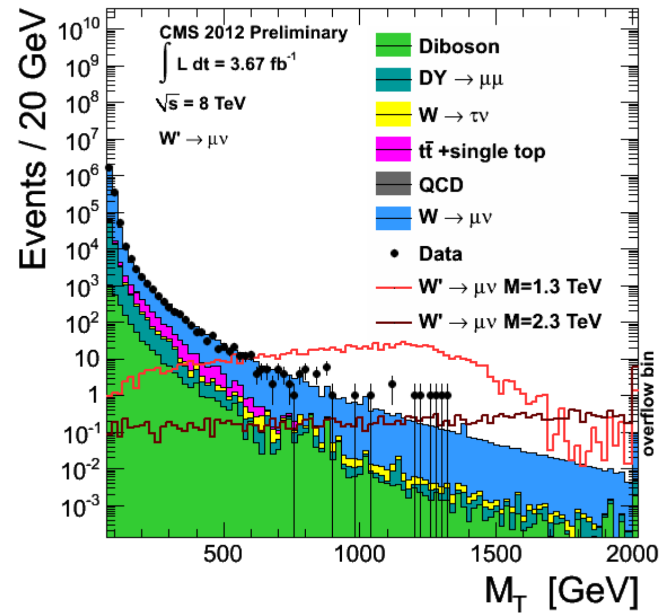
Search for Heavy Resonance: W' → lν

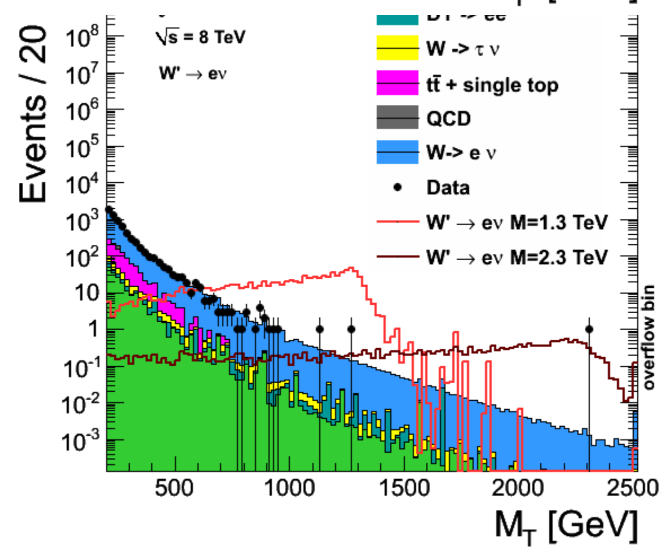
Sequential SM:

m(W') > 2.85 TeV at 95% C.L.

Also set limits on W_KK







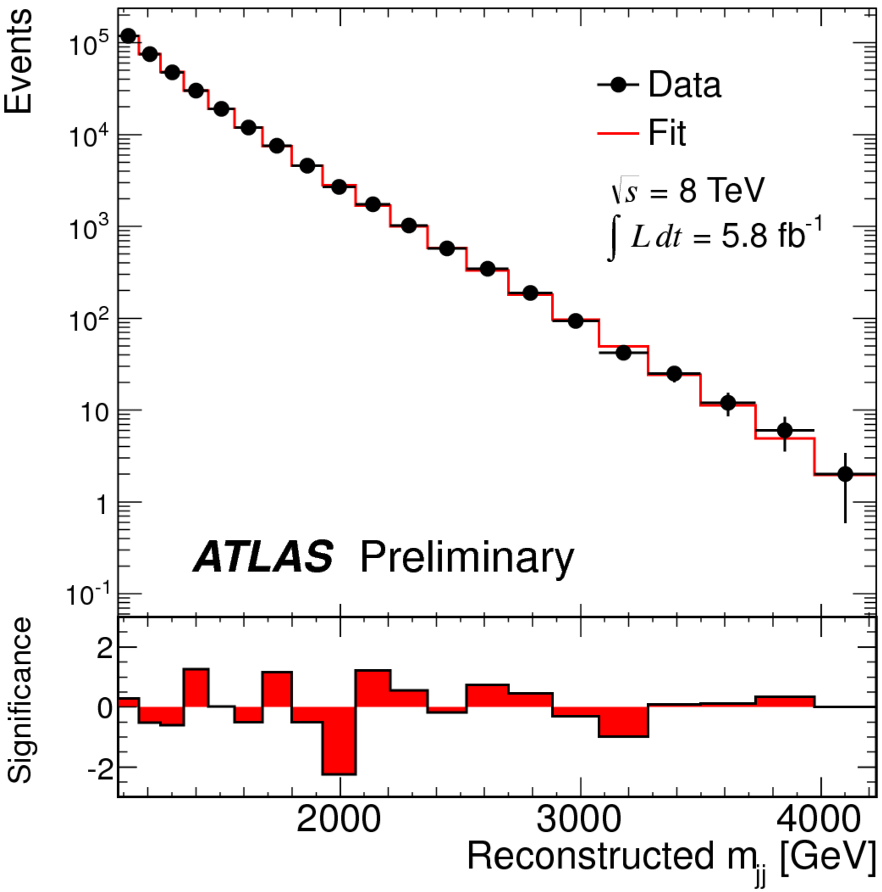
Search for Heavy Resonance: Dijet Resonance

- Strong gravity, excited quarks, contact interaction
- Look for resonance above phenomenological fit of the data:

$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x}$$

$$x \equiv m_{jj}/\sqrt{s}$$

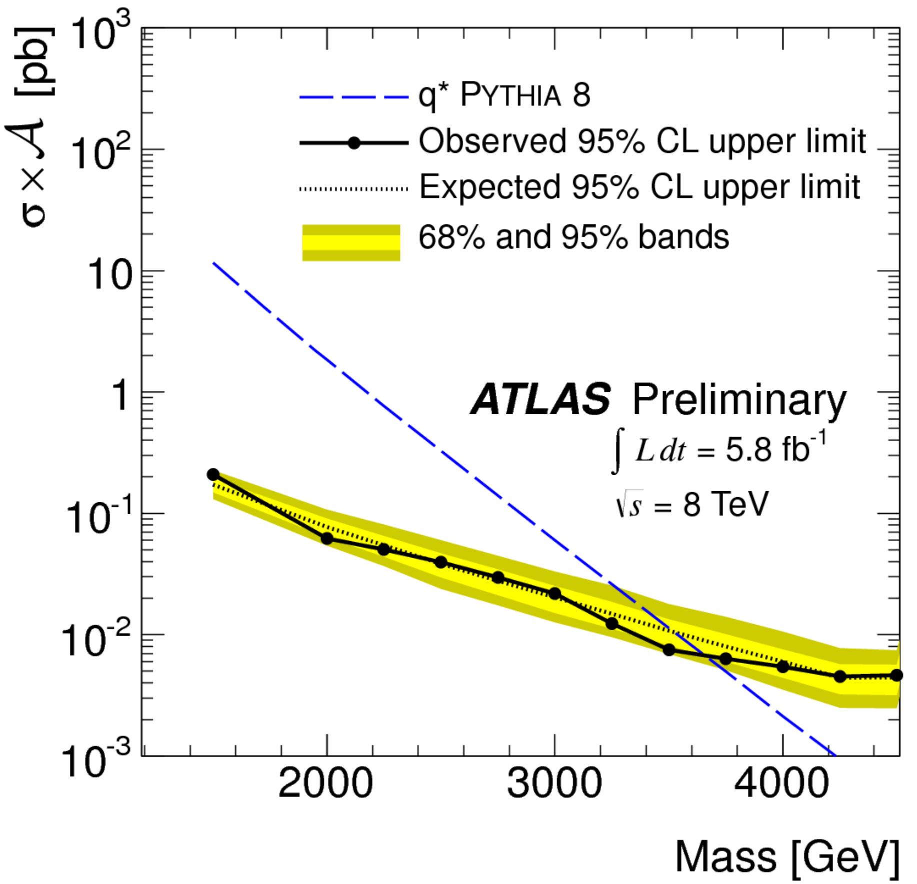
Probing the quark structure beyond 4 TeV



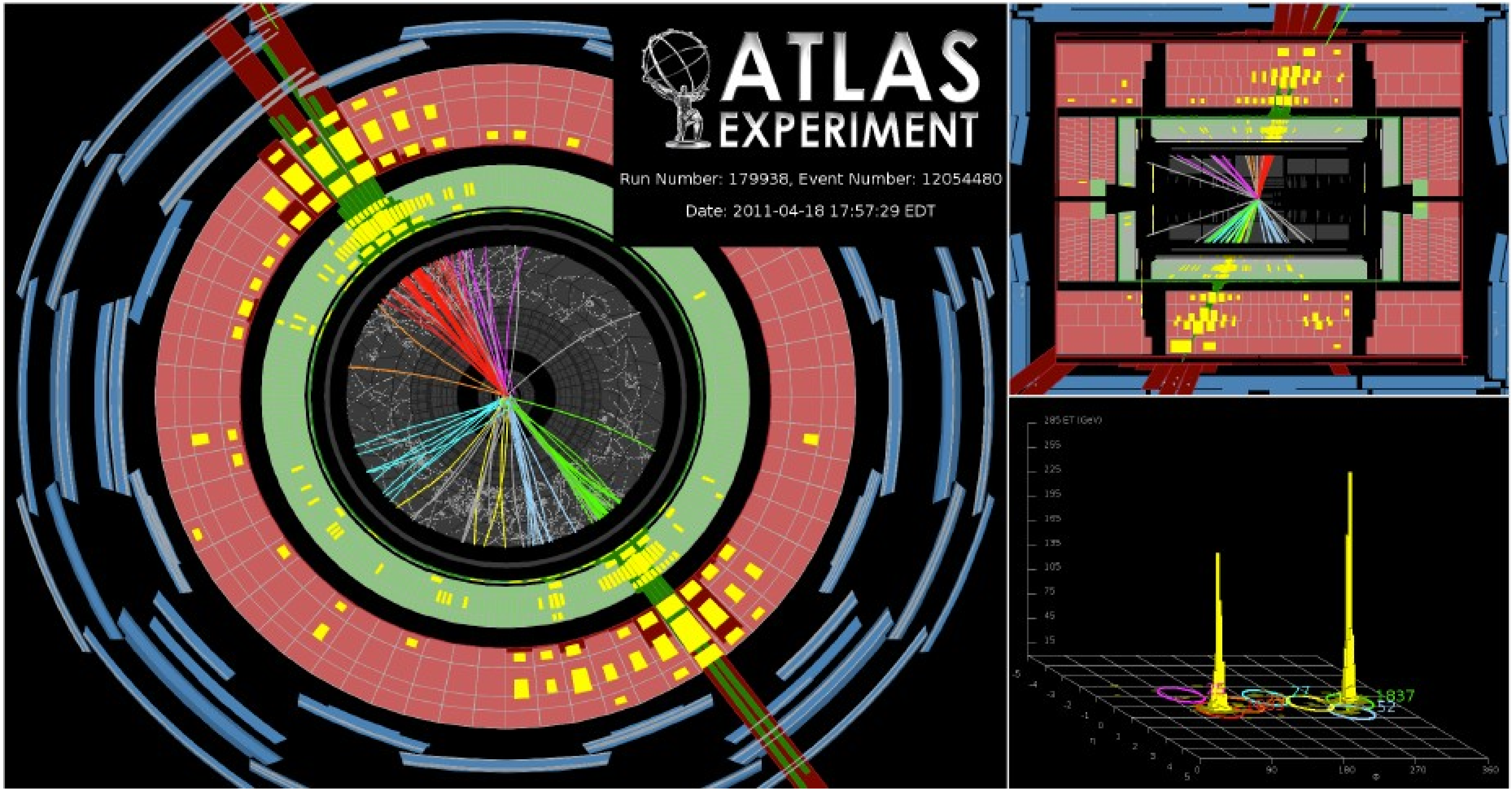
Search for Heavy Resonance: Dijet Resonance

- "Search phase": frequentist approach
  - → Binned likelihood (goodness of fit)
  - → "BumpHunter" looking for an excess of any width over the entire spectrum
- "Limit phase": Bayesian approach (flat cross-section prior)
- Excited quark:

  m > 3.66 TeV at 95% CL



Search for Heavy Resonance: Dijet

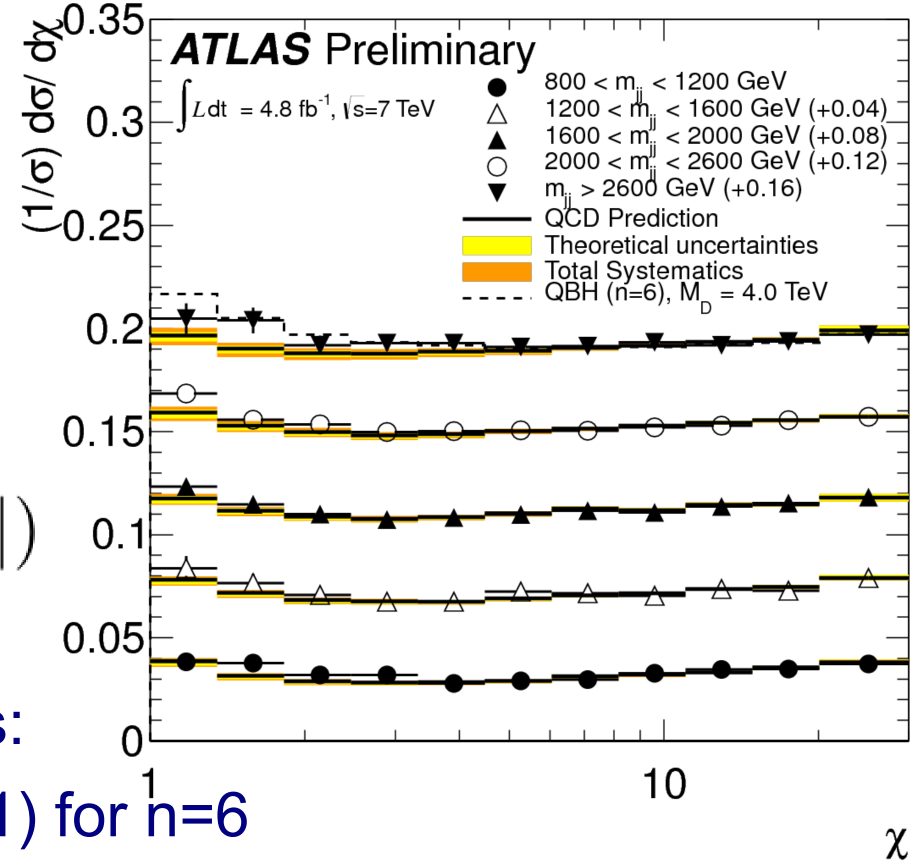


m(jet-jet) = 4.0 TeV **Missing E_T = 100 GeV**

Search for Heavy Resonance: Dijet Angular

- Most BSM signal are expected to be more central than QCD
- Study angular variable as a function of dijet mass
- Consider the two leading jets rapidity in their center of mass:

$$y^* = \pm\frac{1}{2}(y_1 - y_2)$$



- Variable chi defined as:

$$\chi \equiv \exp(|y_1 - y_2|) = \exp(2|y^*|)$$

as a function of m(jet-jet)

- Limit on Quantum Black Holes: m(QBH) > 4.14 TeV (exp. 4.11) for n=6

Search for Heavy Resonance: Dijet Angular

- Most BSM signal are expected to be more central than QCD
- Study angular variable as a function of dijet mass
- Alternatively, look at:

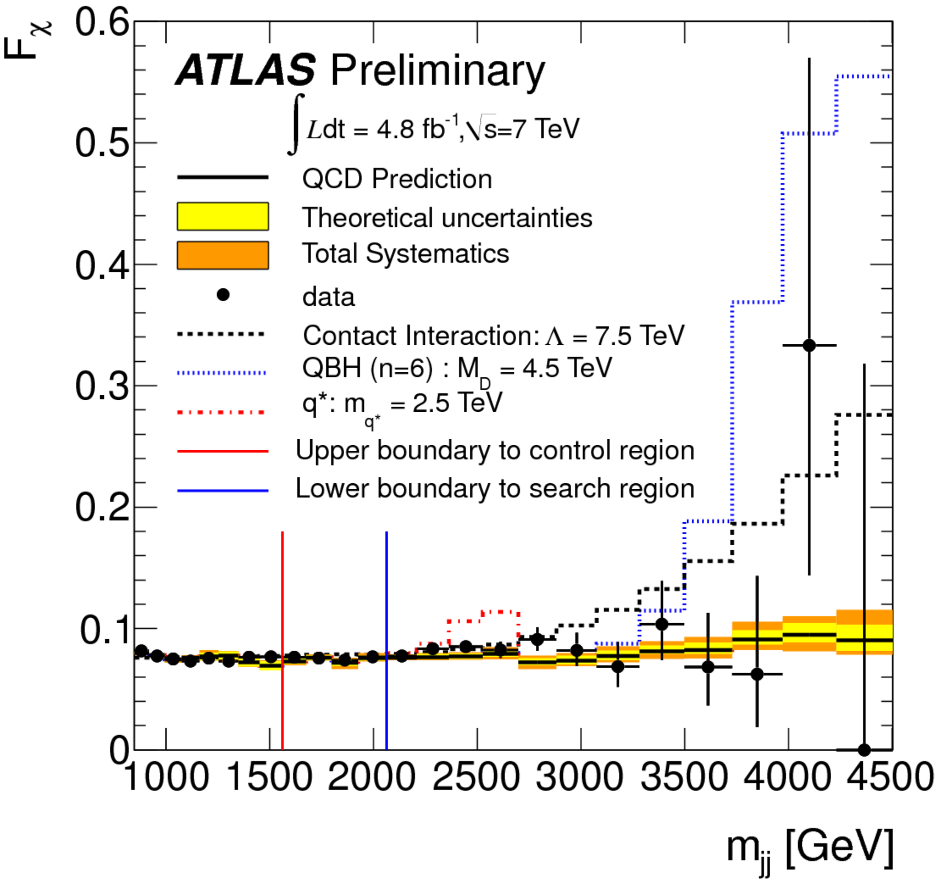
$$F_\chi = \frac{N_{\text{central}}}{N_{\text{total}}}$$

where $N_{central}$ is $|y^*| < 0.6$

- Limit on Contact Interaction:

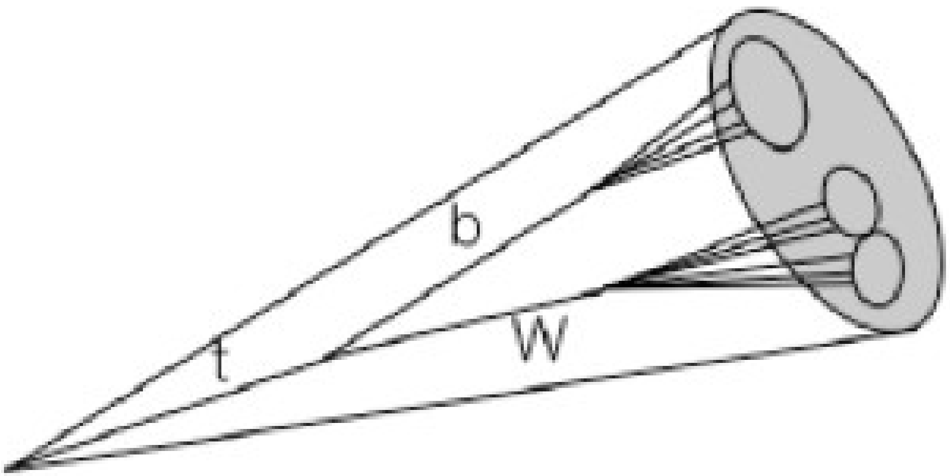
$\Lambda > 7.6$ TeV at 95% CL

(expected: 8.2 TeV)



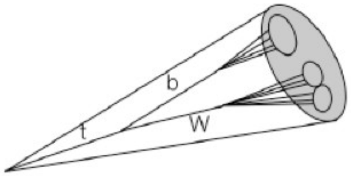
Search for Heavy Resonances: Top-antitop

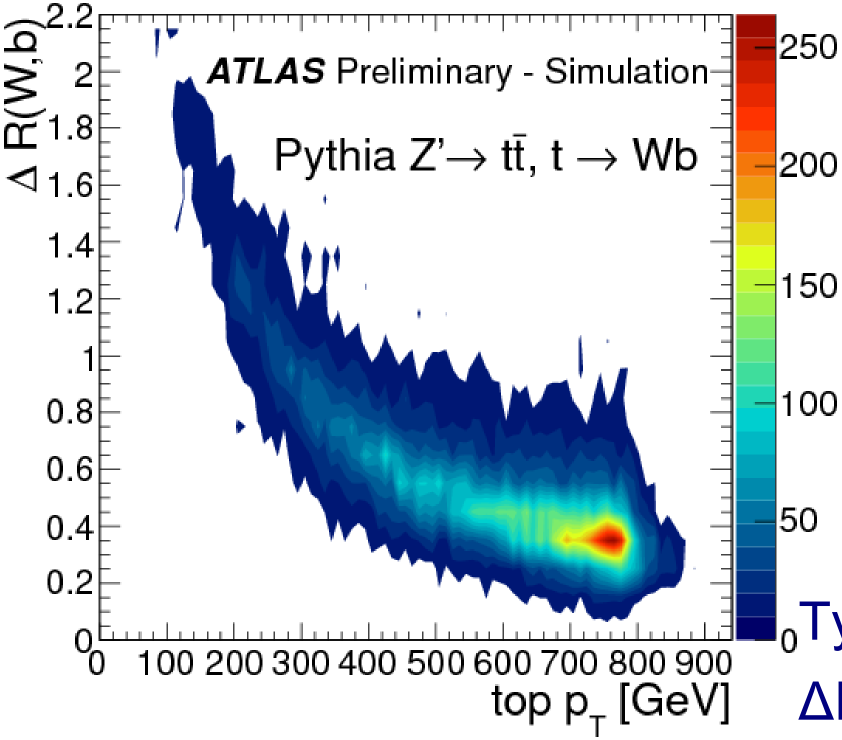
- Bulk RS: all fields propagate into the bulk → predicts KK of gauge bosons, esp. KK gluons
- Leptophobic Z'
- Large Branching Ratio to top-antitop



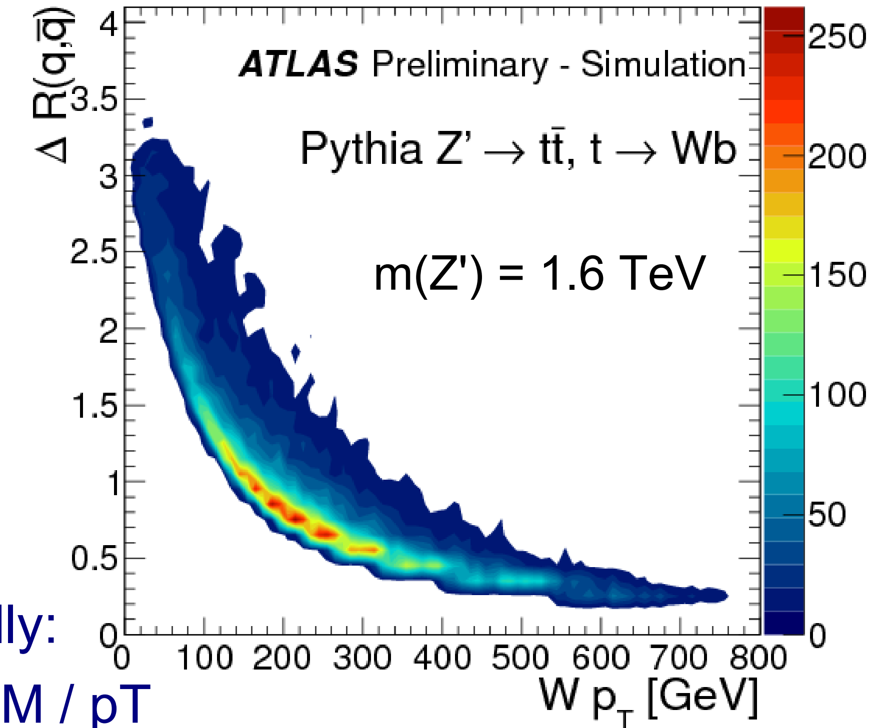
- For m(ttbar) > 1 TeV, specific boosted top reconstruction needed
  - → Experimentally: a whole new field!

Top-antitop Resonance



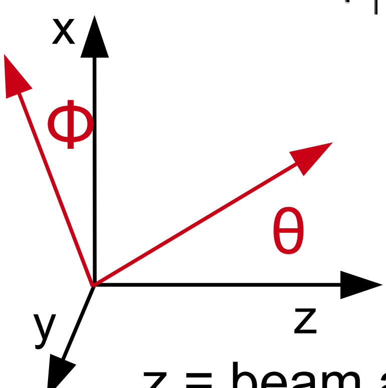


Typically:
$\Delta R \sim 2M / pT$



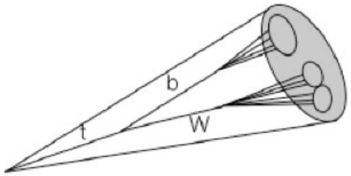
$\Delta R = \mathrm{sqrt}(\Delta\Phi^2 + \Delta\eta^2)$

η = pseudo-rapidity = $- \ln(\tan \theta/2)$
Φ = azimuthal angle in transverse plane



z = beam axis

Jet Clustering Algorithms



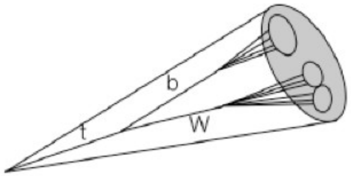
- Starting point: topological clusters in the calorimeters
- Iterative procedure of merging near-by clusters into bigger ones (a.k.a proto-jets) until convergence
- For all proto-jets and proto-jet pairs, define:

$$\rho_{ij} = \min\left(p_{Ti}^{2p}, p_{Tj}^{2p}\right) \frac{(\Delta R_{ij})^2}{R^2}$$

$$\rho_{iB} = p_{Ti}^{2p}$$

- If ρ_{IJ} is the smallest ρ_{ij} or ρ_i, merge I and J
- If ρ_I is the smallest of all ρ_{ij} , it is a jet (and removed from list)

Jet Clustering Algorithms



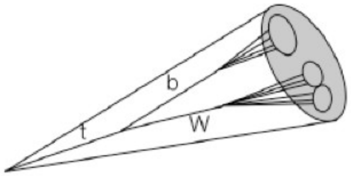
- Two parameters:
- Parameter R is the analogue of cone side in a cone algorithm
  - → Typicall R ~ 0.4 – 0.6
  - → Larger R ~ 1.0 (“fat jets”) also used for boosted objects
- Parameter p:
  - → p = 1: standard k_t algorithm
  - → p = 0: C/A algorithm
  - → p = -1: anti-k_t algorithm

$$\rho_{ij} = \min\left(p_{Ti}^{2p}, p_{Tj}^{2p}\right) \frac{(\Delta R_{ij})^2}{R^2}$$

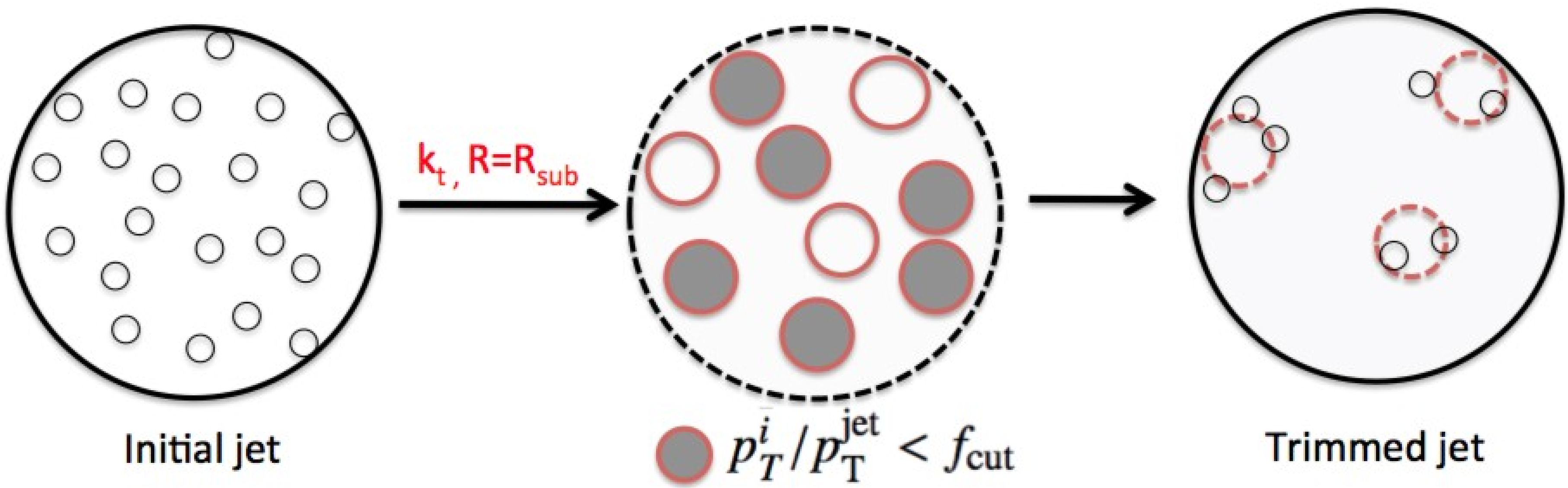
$$\rho_{iB} = p_{Ti}^{2p}$$

- Standard in ATLAS: R = 0.4 anti-kt algorithm
  - → But others are used to study boosted objects and jet sub-structure

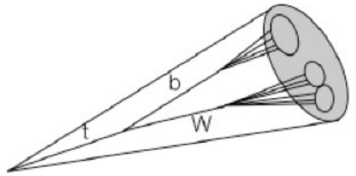
Jet "Grooming"



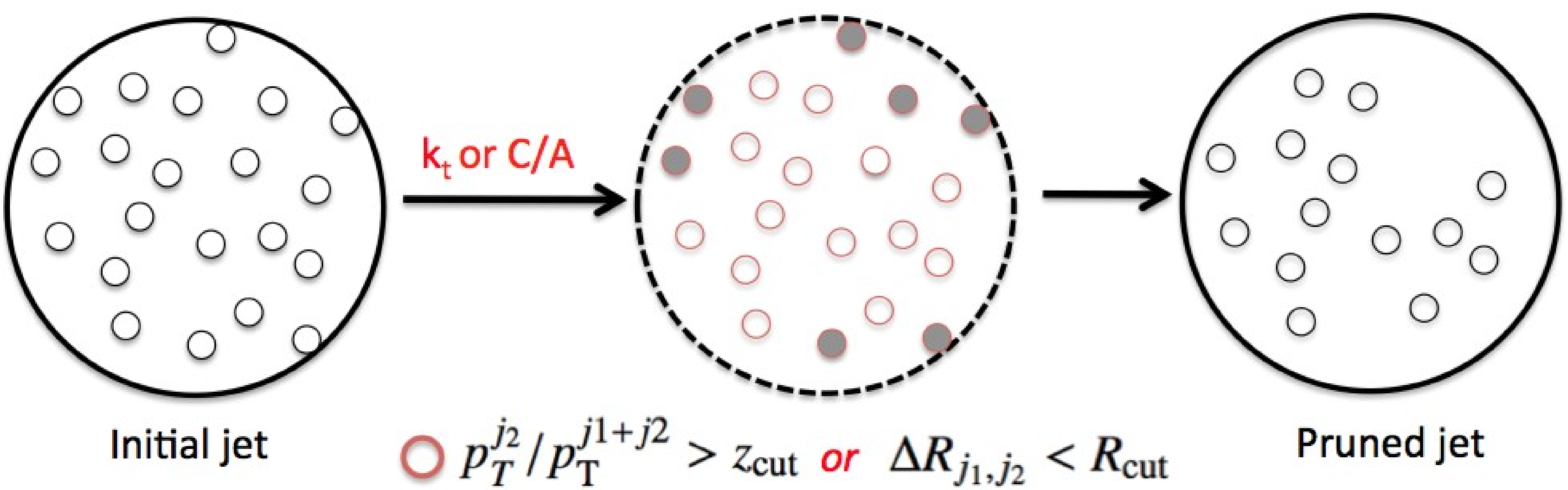
- "Trimming":
- Start with a fat jet (R ~ 1 or more)
- Run k_t algorithm on clusters within the fat jet
- Keep only jets with pT > pT(fat jet) . f_{cut}



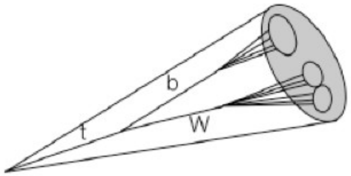
Jet "Grooming"



- "Pruning":
- Start with a fat jet (R ~ 1 or more)
- Run k_t or C/A algorithm on clusters within the fat jet
- At each step, if merging of two clusters fails, remove cluster with smallest pT



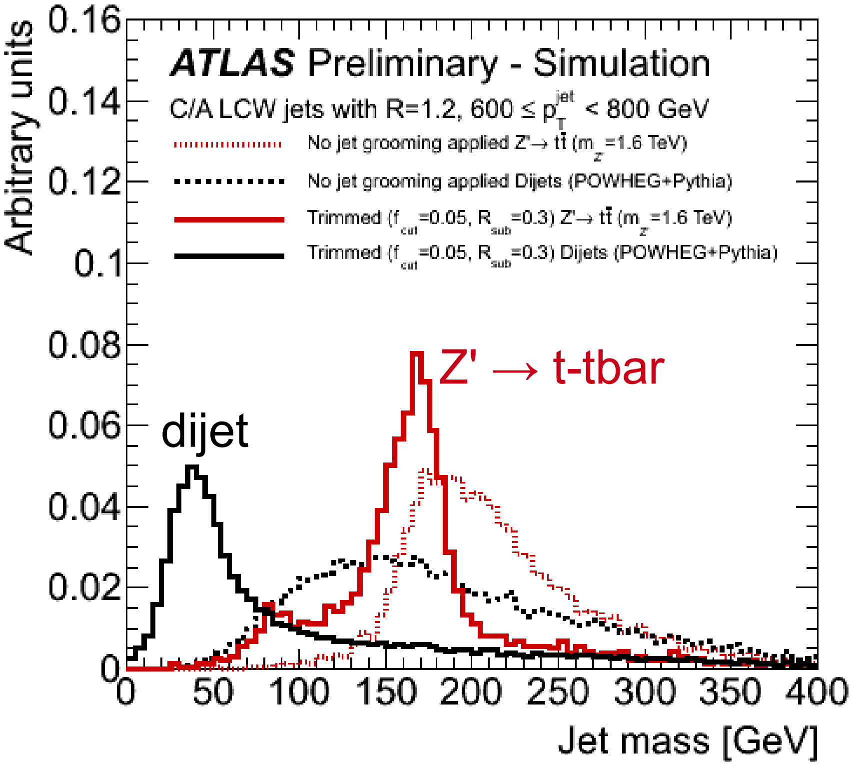
Jet Substructure Variables



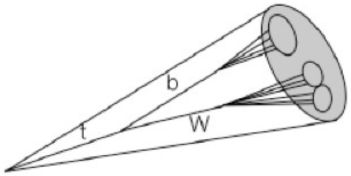
- Jet mass: $(m^{\text{jet}})^2 = (\sum_i E_i)^2 - (\sum_i p_i)^2$

  If top decay reconstructed within one jet, expect jet mass ~ 175 GeV

- Note effect of Trimming:



Jet Substructure Variables

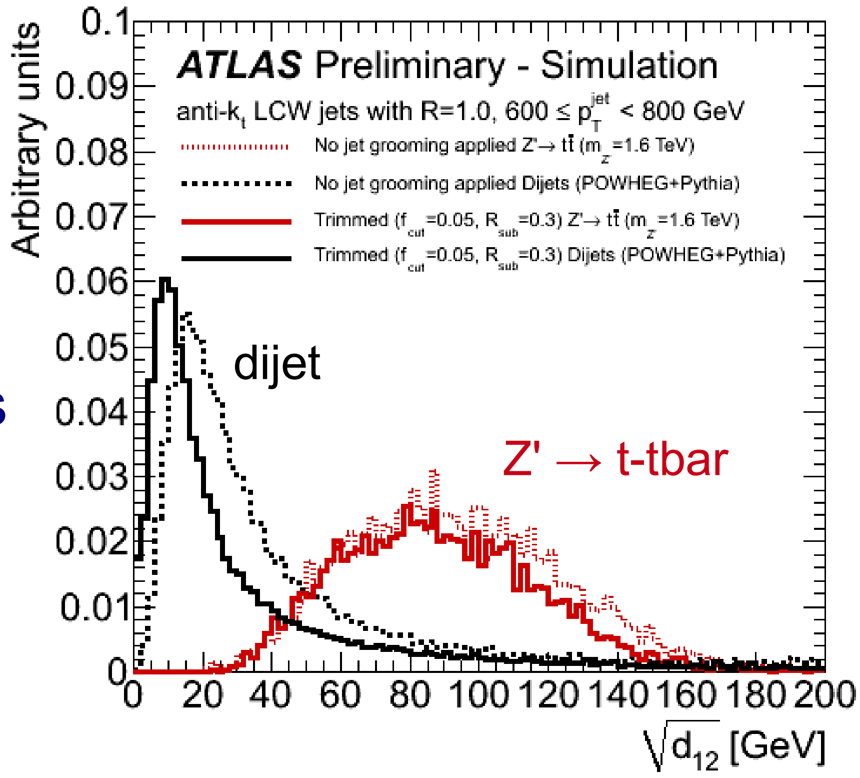


- Splitting scales: Un-do the last step(s) of the k_t algorithm and look at the properties of the protojets:

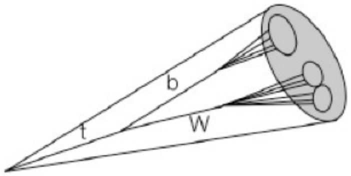
$$\sqrt{d_{ij}} = \min(p_{Ti}, p_{Tj}) \times \Delta R_{ij}$$

- Ex: Last two protojets $\sqrt{d_{12}}$
- Typically, for a W → qq decay:

  Last two proto-jets are the two jets from the W: $pT_1 \sim pT_2$ are large (while for a single jet $pT_2 << pT_1$)

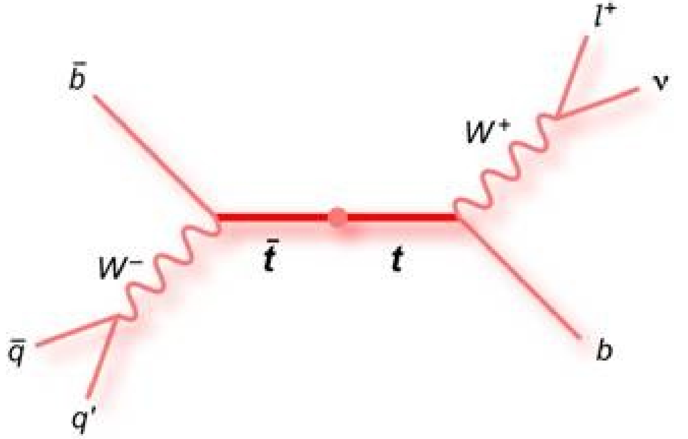


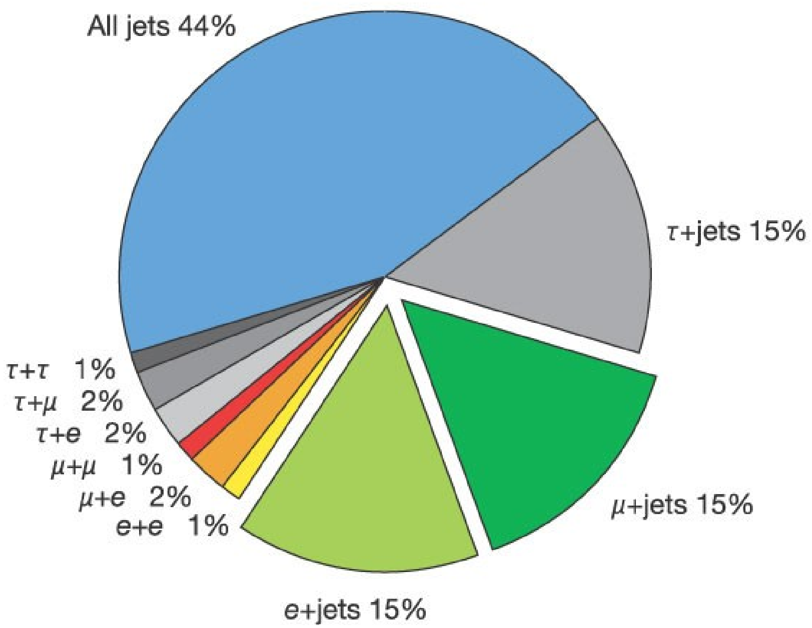
Top-antitop Resonance



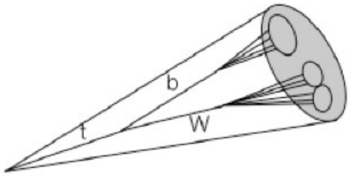
- Event Topology:
  T-tbar → Wb Wb
- Final state depends on W decays:
  - → Dilepton final state:
    Both W → lν (l = e or μ)
    2l + 2 b-jets (+2 neutrinos)
  - → <u>Lepton+Jets final state:</u>
    1 W → lν, 1 W → jj
    1l + 2 b-jets + 2 light jets (+1ν)
  - → All-hadronic final state:
    2 W → jj
    2 b-jets + 4 light jets (+0ν)

Large Branching Ratio but more background

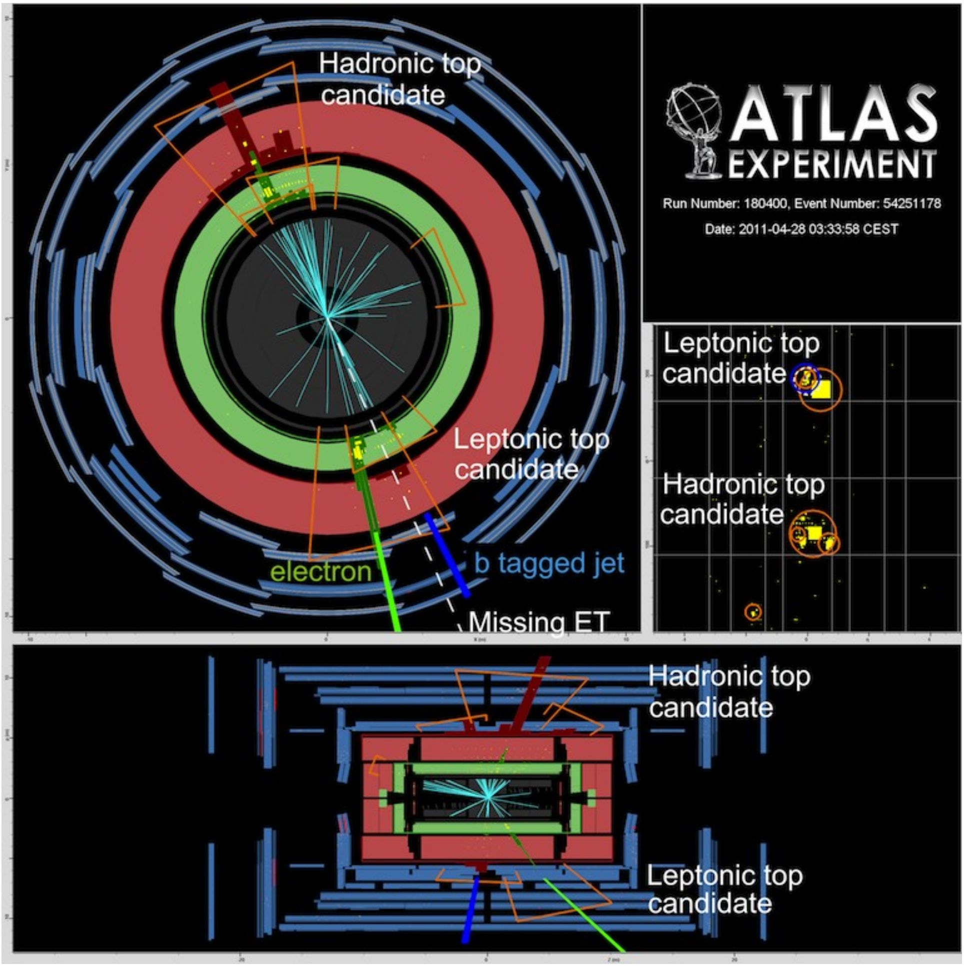




Top-antitop Resonance

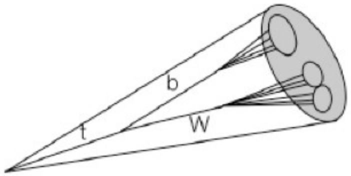


- Lepton+Jets final state:
  - 1 W → lν, 1 W → jj
  - 1l + 2 b-jets + 2 light jets (+1ν)
- Boosted topology:
- Leptonic (W → lν) side:
  lepton and b-jet overlap
- Hadronic (W → jj) side:
  b-jet and W jets overlap



Lepton + Jets channel:
A Boosted Event Candidate

Top-antitop Resonance Latest Results from ATLAS



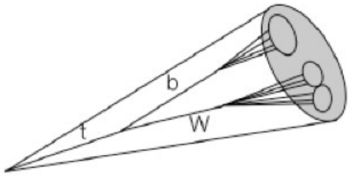
Event Selection

- AKT4: Anti-$k_\perp$ ($R = 0.4$) jets: $p_T > 25$ GeV, $|\eta| < 2.5$
- AKT10: Anti-$k_\perp$ ($R = 1.0$) jets: $|\eta| < 2.0$, $p_T > 350$ GeV, $m > 100$ GeV, $\sqrt{d_{12}} > 40$ GeV (expect $\sqrt{d_{12}} \approx m_t/2$ for $t \to bW$)

	resolved	boosted
trigger	single lepton trigger	fat jet (AKT10) trigger
leptons	1 lepton ($e^\pm$ or $\mu^\pm$), $p_T > 25$ GeV additional lepton ($e^\pm$ or $\mu^\pm$) veto, $p_T > 20$ GeV	
	lepton trigger match	—
$\not{E}_T$	$e^\pm$: $\not{E}_T > 30$ GeV, $\mu^\pm$: $\not{E}_T > 20$ GeV	
m_T^W	$e^\pm$: $M_T(W) > 30$ GeV, $\mu^\pm$: $M_T(W) + \not{E}_T > 60$ GeV	
jets	$\geq 4(3)$ jets (if one jet $m_{jet} > 60$ GeV)	"leptonic jet": AKT4 jet "hadronic jet": AKT10 jet
b-tag	≥ 1 b-tag using AKT4 jets ($\varepsilon_b = 70\,\%$)	

S. Fleischmann, Top2012

Top-antitop Resonance
Latest Results from ATLAS

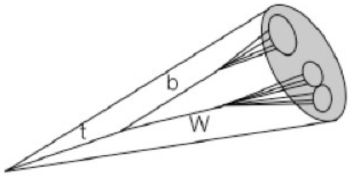


- Improve efficiency at high t-tbar mass with:

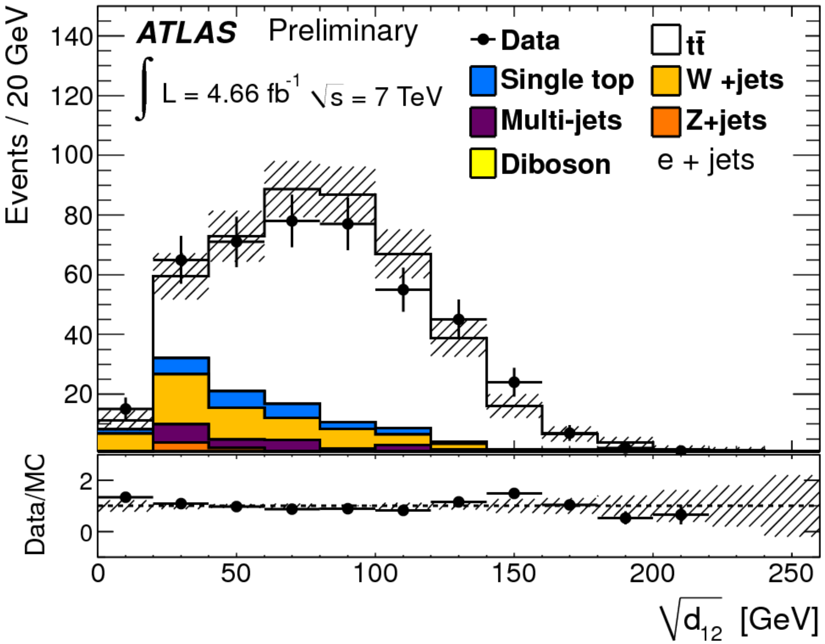
- Lepton “mini-isolation”: cone shrinks at high momentum
- Trigger: use Fat Jet trigger (anti-kt jet R=1.0, pT>240 GeV)
  - → Better efficiency than lepton trigger at high mass

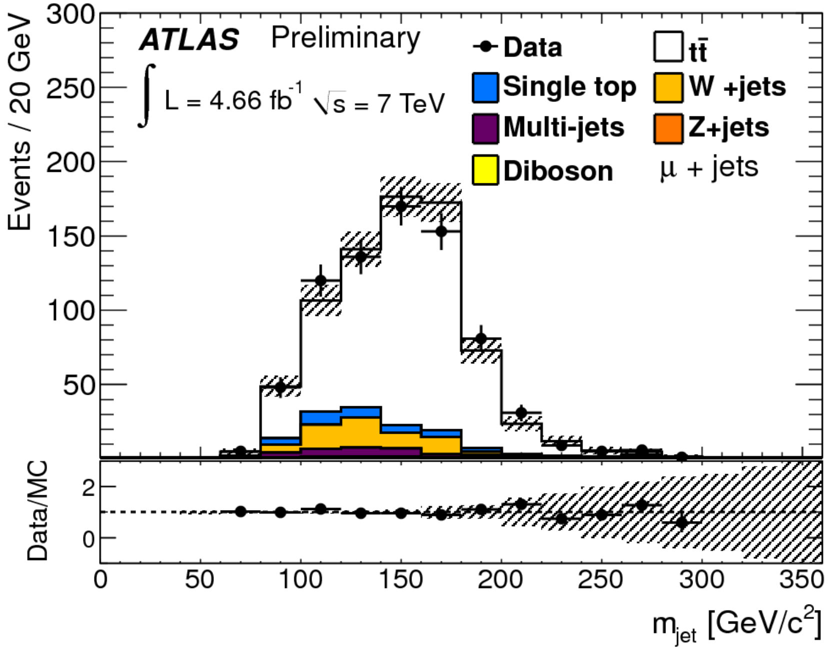
- Combine resolved and boosted selection: if an event is reconstructed by both methods, use the boosted one (better mass resolution)

Top-antitop Resonance Latest Results from ATLAS

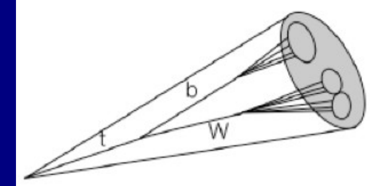


- About 1000 boosted t-tbar events reconstructed:

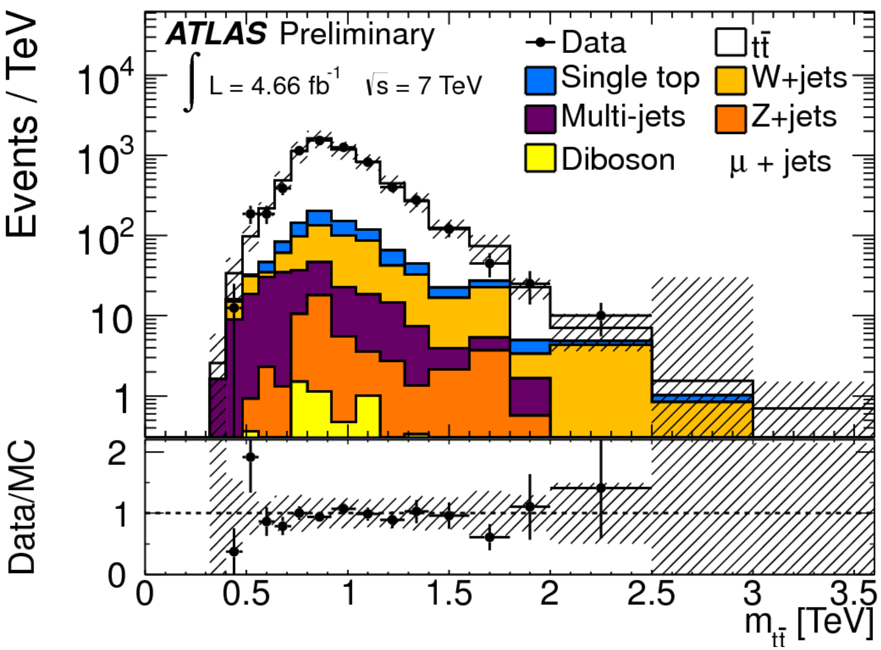


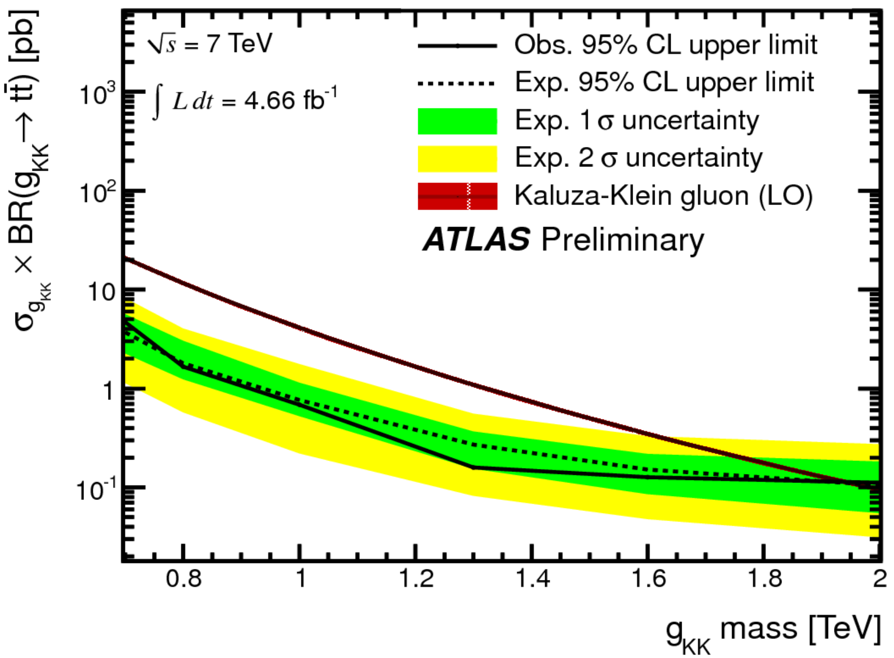


Top-antitop Resonance Latest Results from ATLAS



- m(KK gluon) > 1.9 TeV at 95% CL





Search for Heavy Resonances: others...

- Many other resonance signatures are searched for:

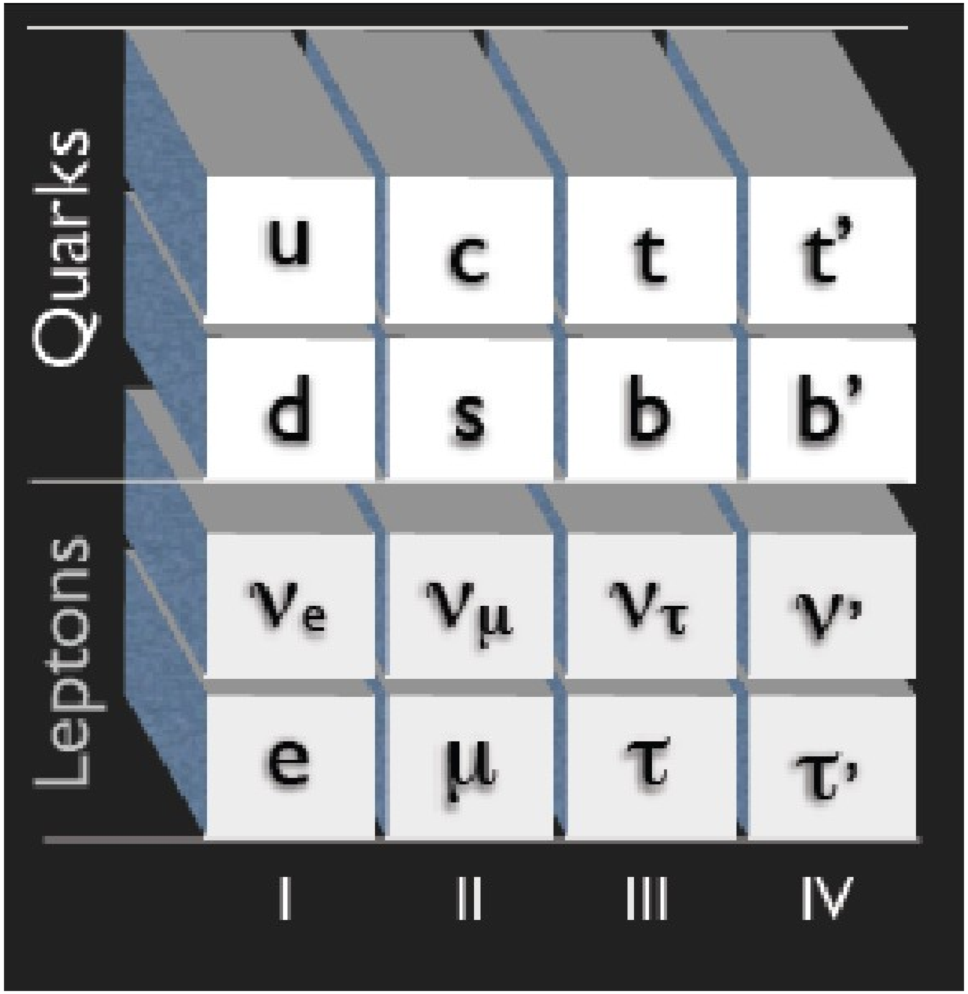
  RS1 $\rightarrow$ diphoton

  Bulk RS $\rightarrow$ ZZ or WW

  W' $\rightarrow$ WZ

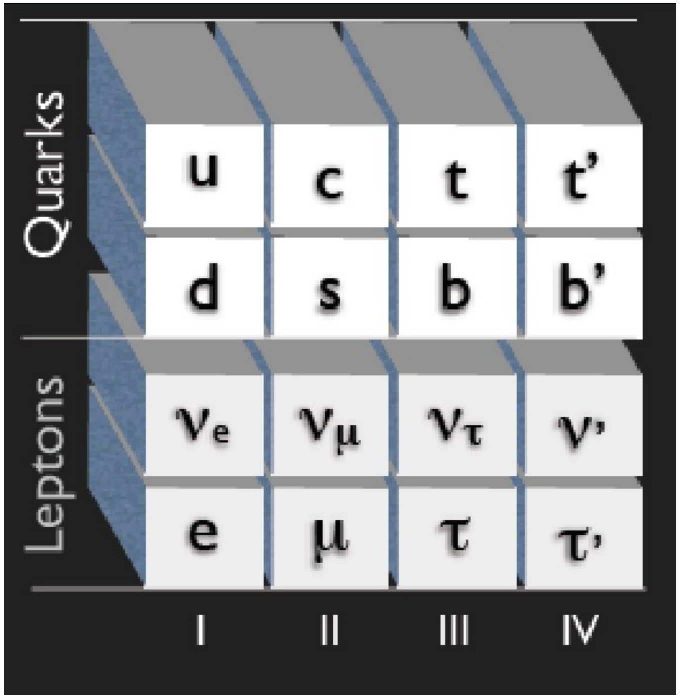
  Technihadrons $\rightarrow$ ee or μμ or ZZ or WZ
- Especially diboson hadronic final states are promising but require careful reconstruction of boosted decays

4th Generation and Heavy Quarks



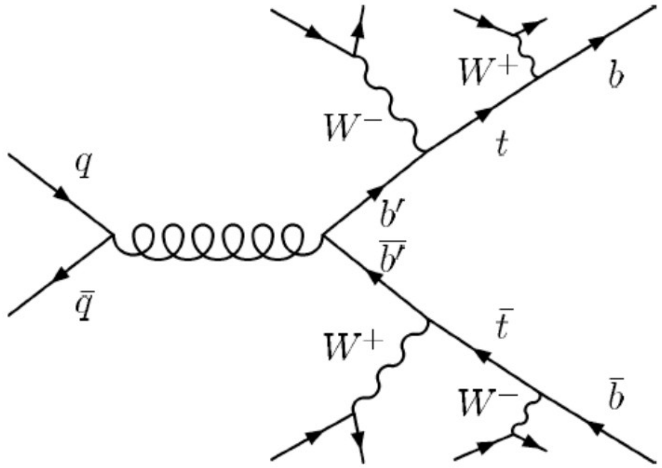
4^{th} Generation and Heavy Quarks

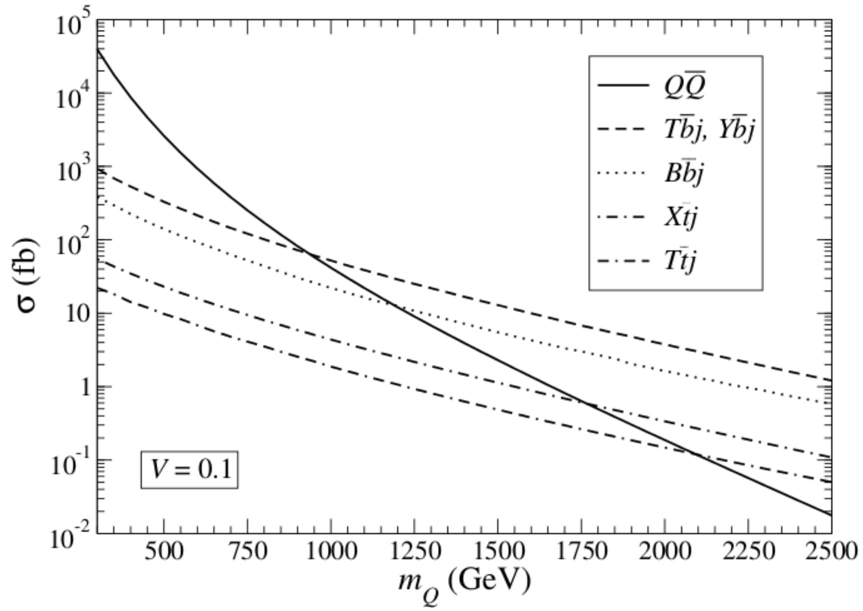
- 4^{th} generation would significantly enhance Higgs production cross section
  - → (almost) excluded by observed Higgs cross-section
- Beyond 4^{th} generation: Vector-Like Quarks in Composite Higgs theories (cf A. Falkowski's lecture)
  - → More diverse phenomenology
- Loose constraints on CKM4 → decays to light quarks possible!



"Standard" SM4 Phenomenology

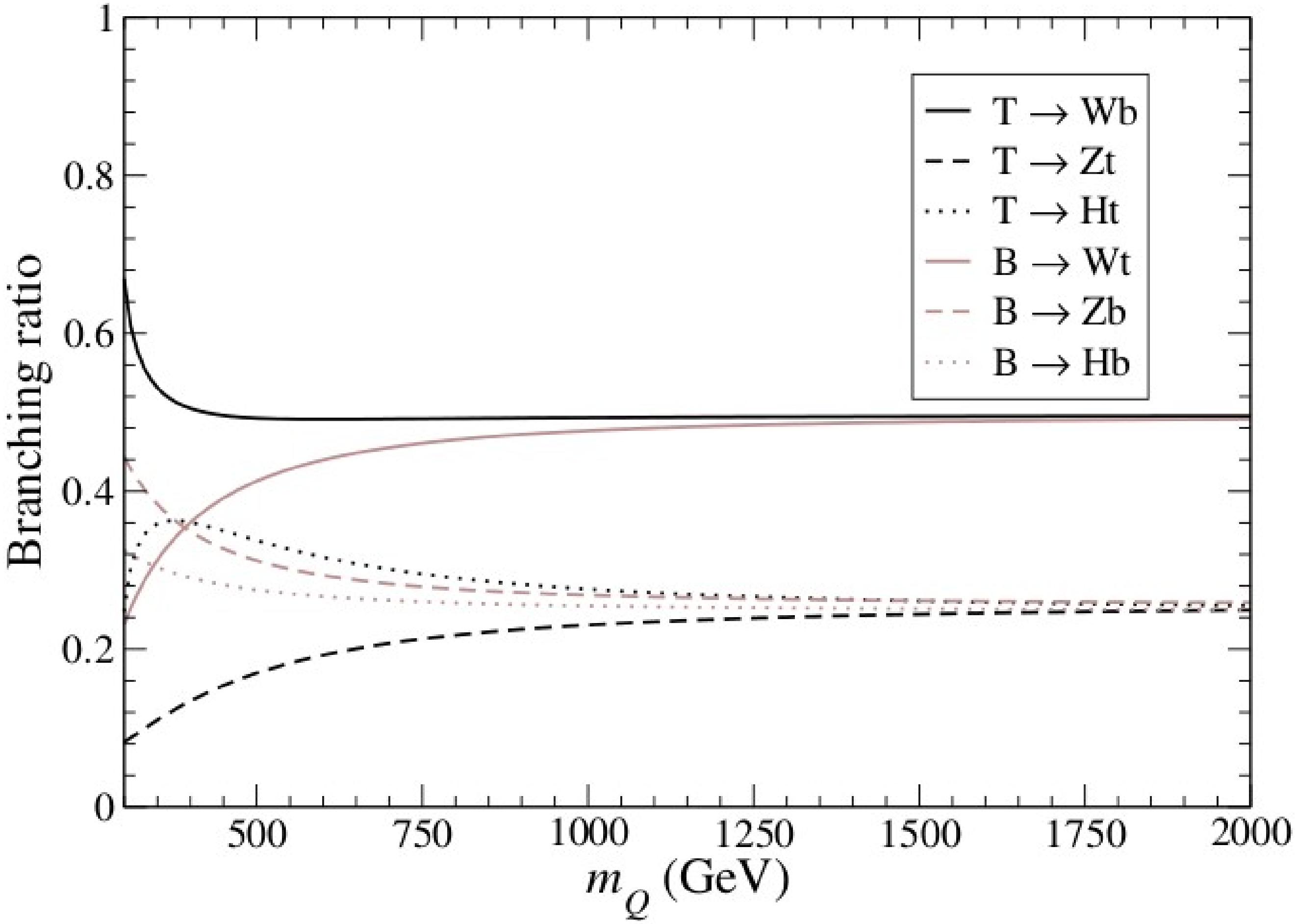
- t't' → WbWb: just like t-tbar but heavier
- b'b' → WtWt: just like t-tbar but messier (two additional W's)
- Single production becomes important at very large mass, but larger bgd: not really used.





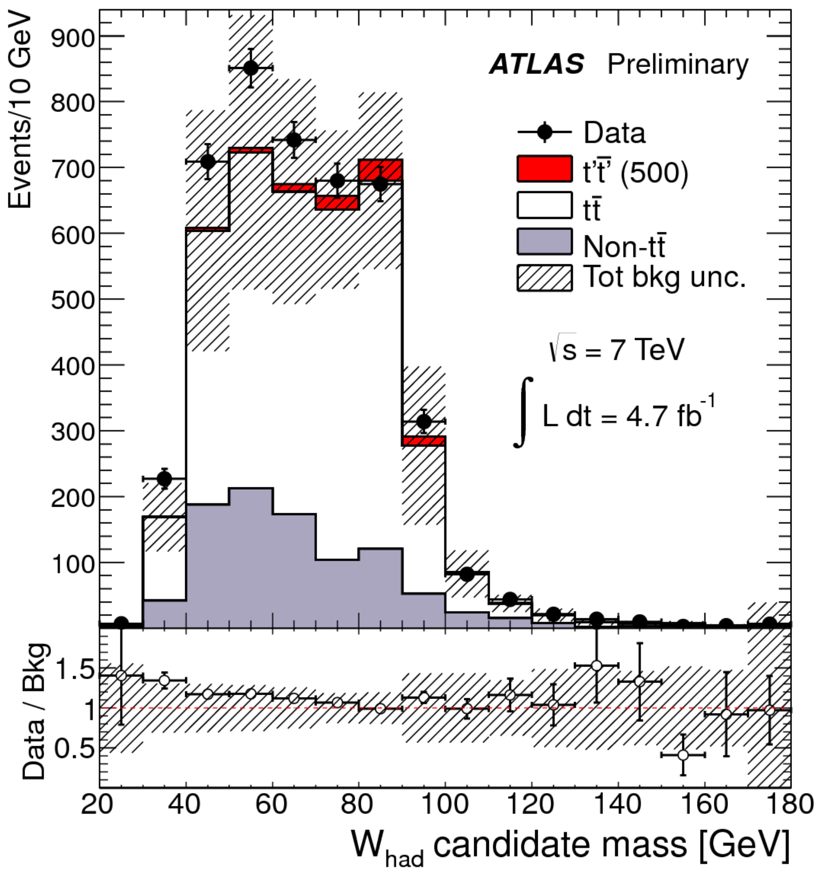
Vector-Like Quark Phenomenology

- T': Decays to Wb, Zt, Ht
- B': Decays to Wt, Zb, Hb



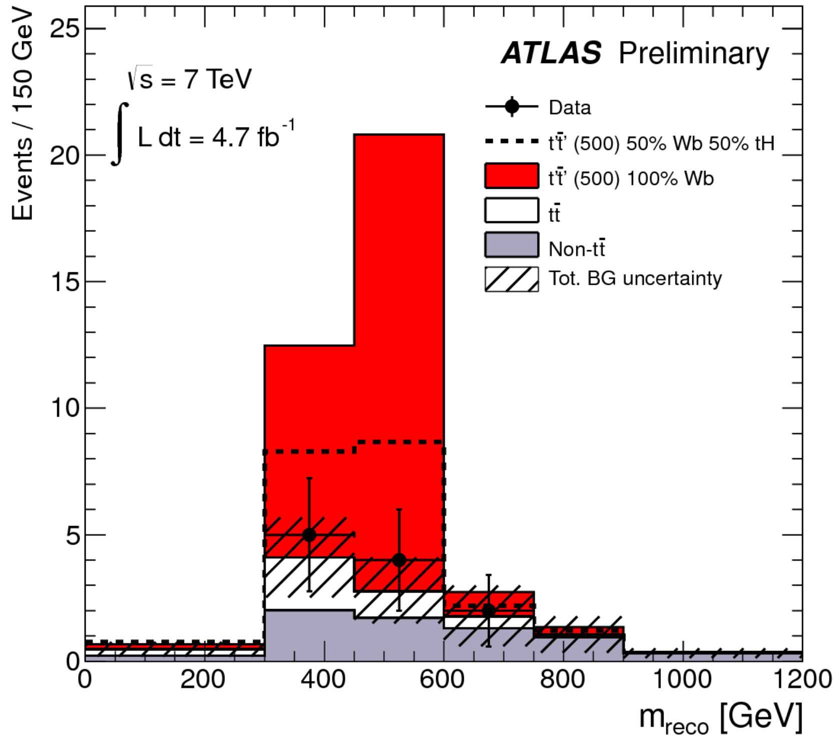
t't' → WbWb → lνbbqq (l+jets channel)

- Signature: l + ETmiss + 4 jets (l=e,μ) and b-tagging
- Select boosted W → jj from t'
- Reconstruct the t' mass



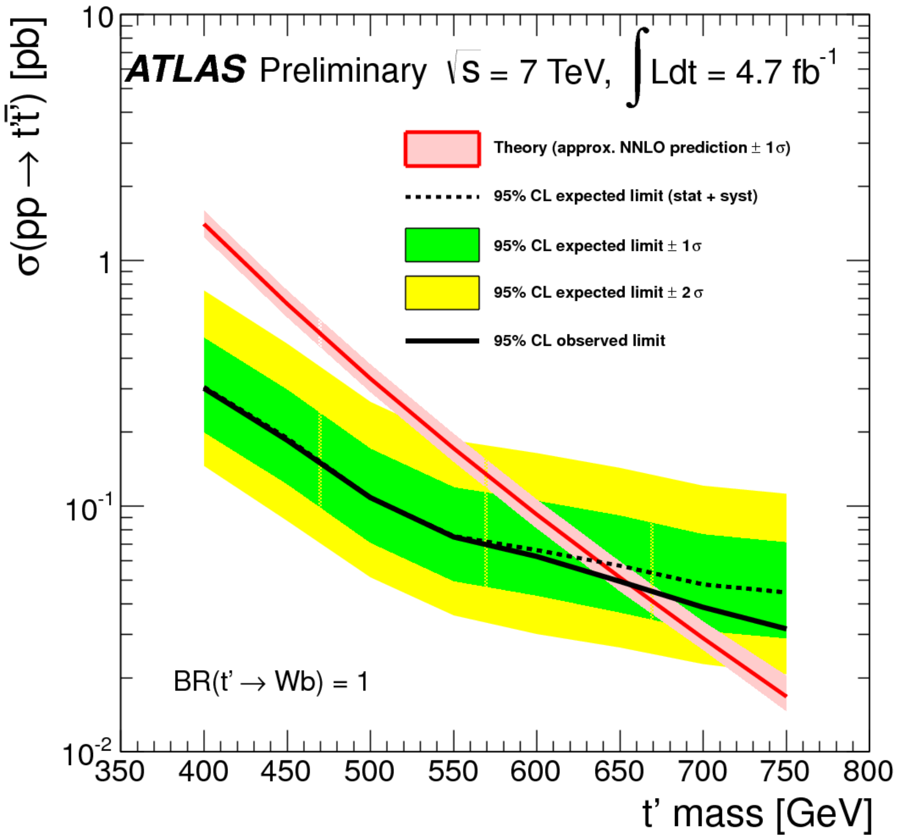
t't' → WbWb → lvbbqq (l+jets channel)

- Signature: l + ETmiss + 4 jets (l=e,μ) and b-tagging
- Select boosted W → jj from t'
- Reconstruct the t' mass

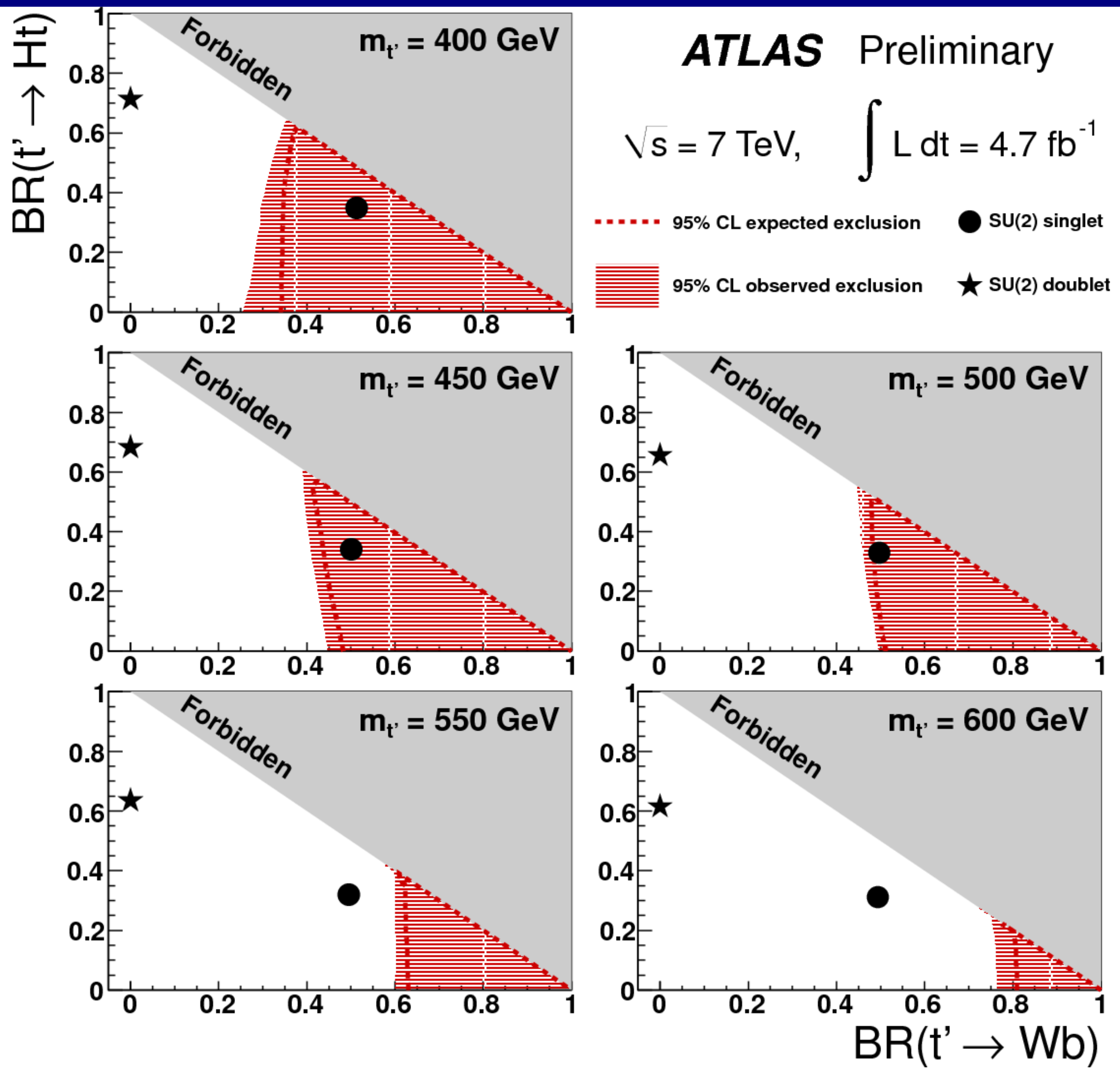


t't' → WbWb → lνbbqq (l+jets channel)

- Data in agreement with SM expectation
- Assuming BR(t' → Wb) = 100%, m(t') > 656 GeV at 95% CL (expected limit: 638 GeV)



t't' → WbWb → lvbbqq (l+jets channel)



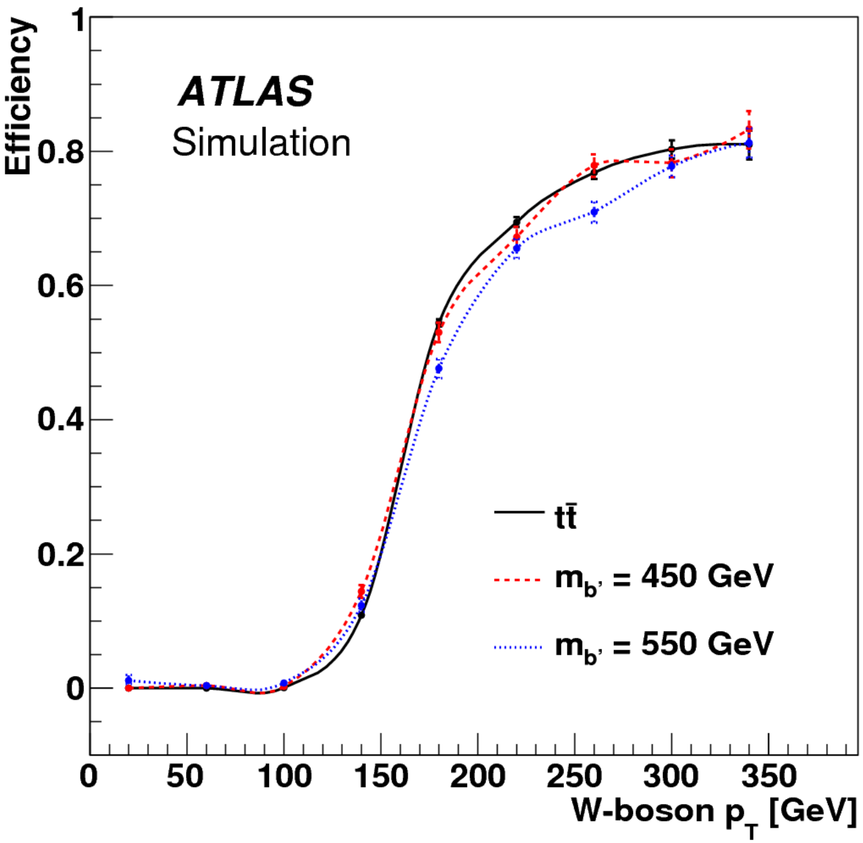
b'b' → WtWt → lvbbqq + qqqq (l+jets channel)

- Like top but messier
- Event selection: l + ETmiss + ≥6 jets (l=e,μ)
- Main background: top+jets (ALPGEN)
- Two additional W's decaying hadronically:

Identify high-pT (boosted) hadronic W's as pair of jets close to eachother:

$\Delta R(\text{jet-jet}) \sim 2m(W) / p_T(W)$

$\Delta R = \text{sqrt}(\Delta\eta^2 + \Delta\varphi^2)$



Select pairs of jets with:
$\Delta R < 1.0$
$70 < m(jj) < 100$ GeV

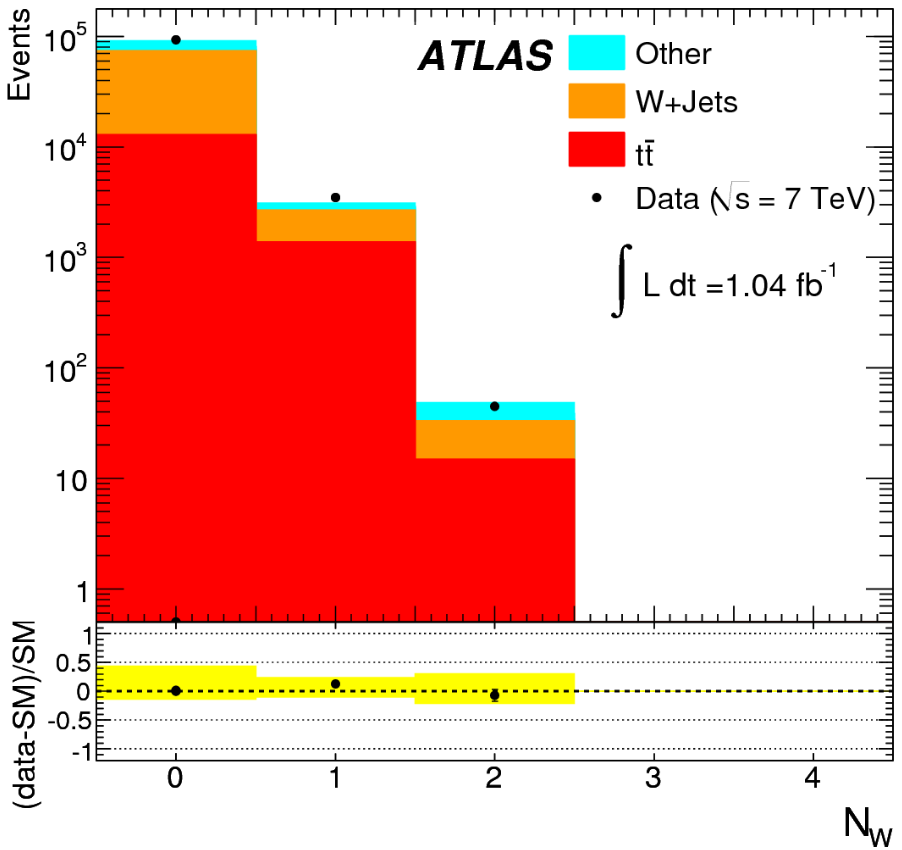
b'b' → WtWt → lvbbqq + qqqq (l+jets channel)

- Observables:

  # jets

  # identified hadronic W's
- Control region: # jets < 6 →

  dominated by top-antitop and W+jets
- # hadronic W's well-described by simulation



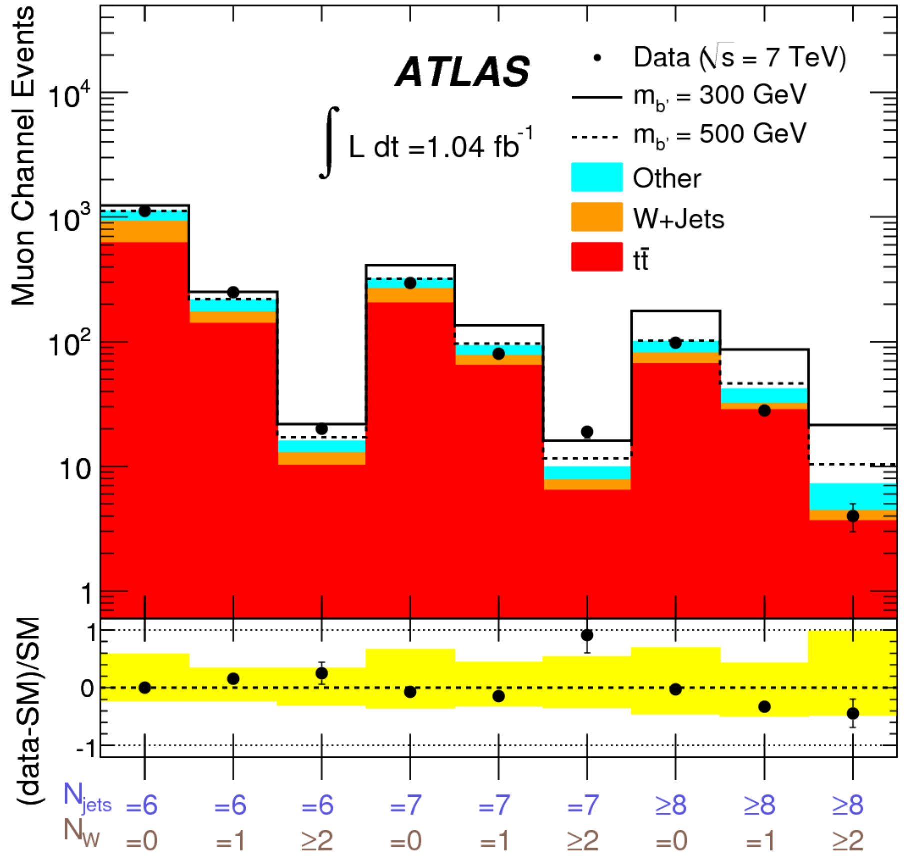
b'b' → WtWt → lvbbqq + qqqq (l+jets channel)

- Observables:

  \# jets

  \# identified hadronic W's
- Control region: # jets < 6

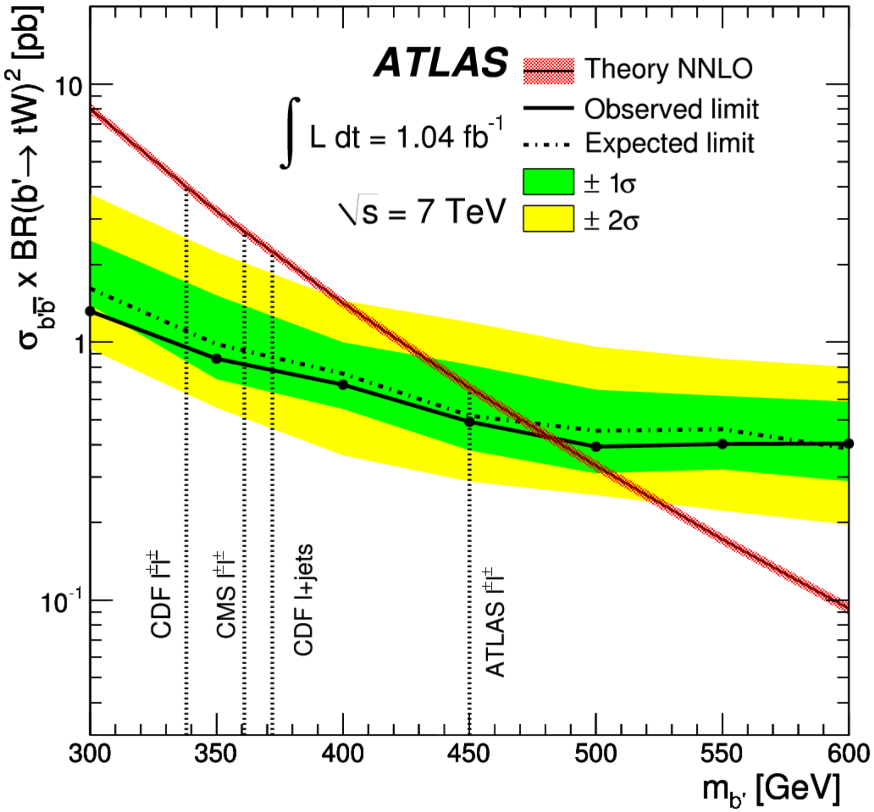
  dominated by top-antitop and W+jets
- \# hadronic W's well-described by simulation
- Signal region: # jets ≥ 6
- Constrain background in low jet and W multliplicity bins



b'b' → WtWt → lvbbqq + qqqq (l+jets channel)

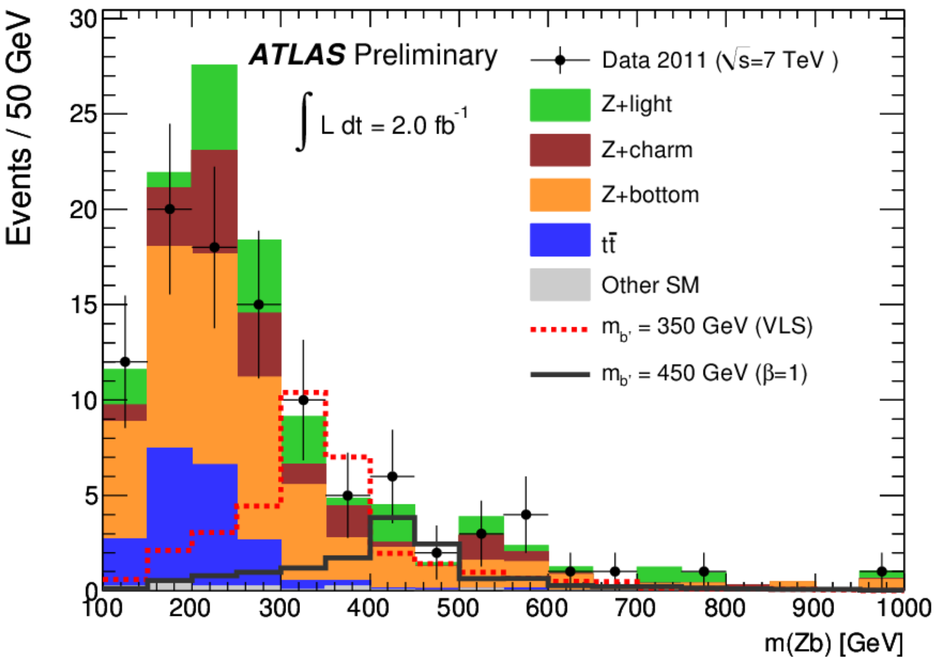
- Data in agreement with SM expectation
- Assuming BR(b' → tW) = 100% m(t') > 480 GeV at 95% CL

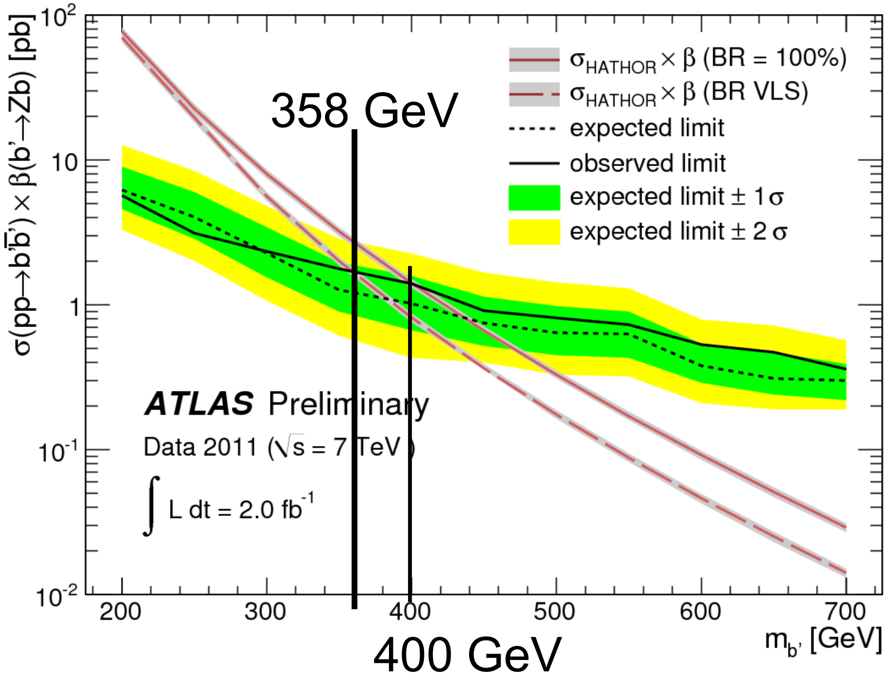
  (expected limit: 470 GeV)



b'b' → Zb + X

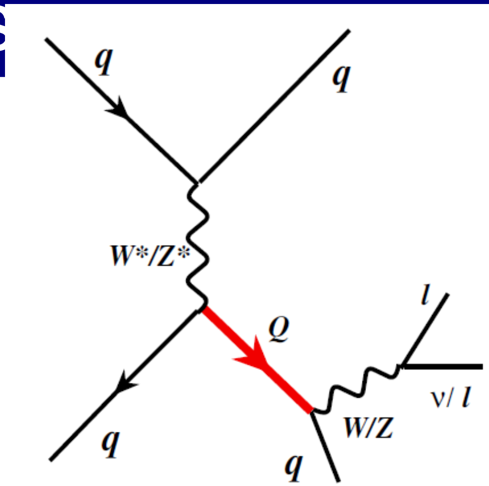
- Search for a resonance decaying to Z(→ee) + b-jet
- Inclusive search: reconstruc only one b' (other can decay to anything)
- Esp. relevant for Vector-Like Quarks
- Assuming VLQ coupling only to 3rd gen: m(b') > 358 GeV (95% CL)

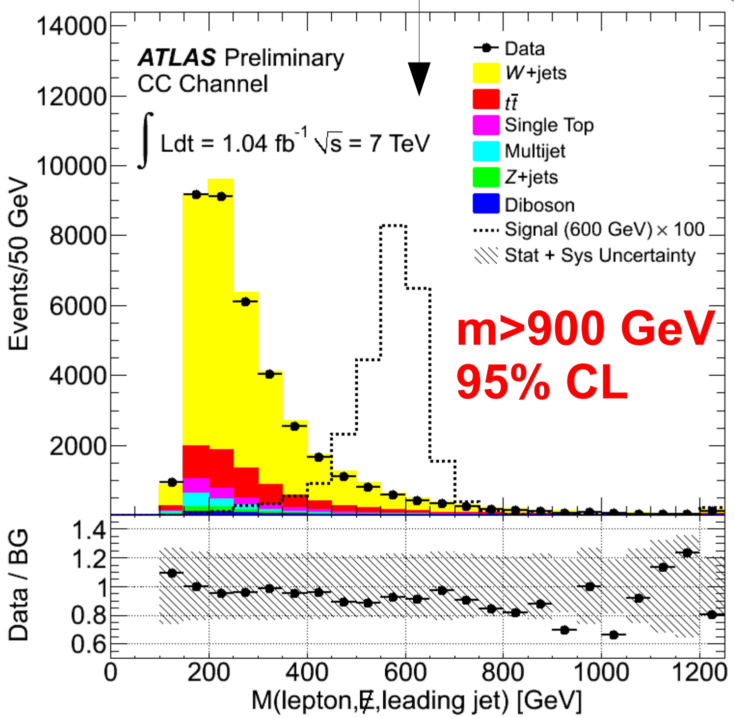


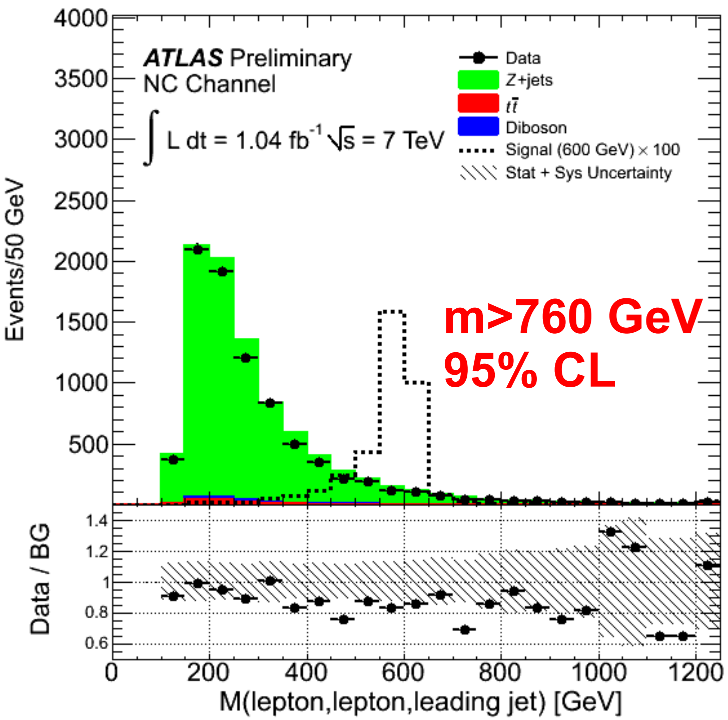


Vector-like Quarks
Coupling to Light Quarks

- Chiral fermions are seriously constrained, but room for vector-like quarks
- Look for Wq or Zq resonance





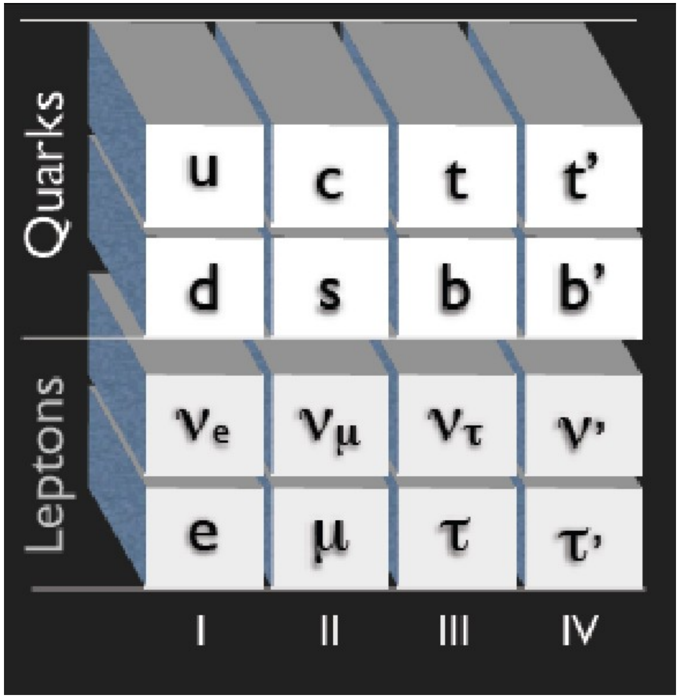


4^{th} Generation and Vector-Like Quarks: Summary

- No time to show other analyses:
  - → t' and b' dilepton searches (without b-tagging): sensitive to light quark decays

- Here limits assume 100% BR:

Analysis	Lower limit (95% CL)
t't' → WbWb (l+jets)	656 GeV
b'b' → WbWb (same-sign)	645 GeV
t't' → WqWq (dilepton)	350 GeV
b'b' → Wq Wq (l+jets)	480 GeV
QQ → Zb+X	400 GeV
t't' → tZtZ (CMS)	475 GeV
t't' → tA_0tA_0	420 GeV



Model-Independent Searches

With so much available model space, we need to make a generally applicable search, not just kill one model at a time (new ones grow too fast!)

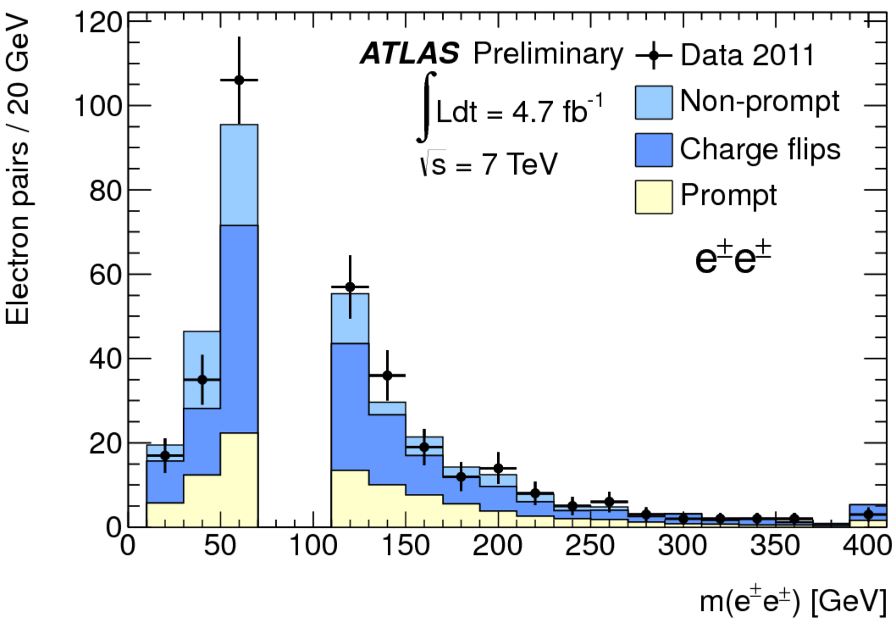
- recent ATLAS meeting, T. Golling

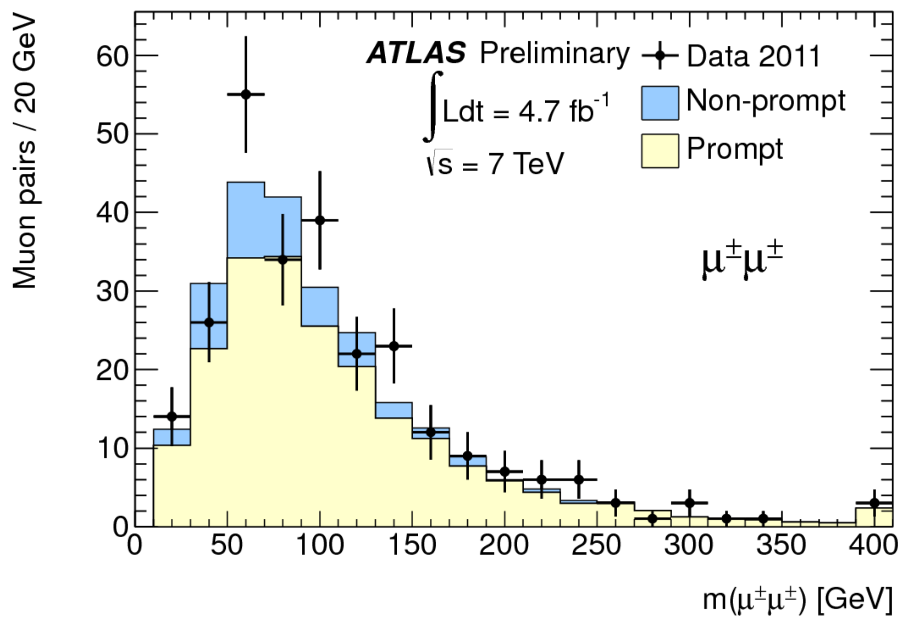
Model-Independent Searches

- Dedicated searches cannot cover every possible final state
- Complete the spectrum of analyses with model-independent searches
- Two examples:
  - → Inclusive same-sign search
  - → A generic search trying to look all possible final states (that may have been missed by the dedicated analyses)

Model-Independent Searches
Inclusive Same-Sign Dilepton

- Inclusive: only requirement is two isolation same-sign leptons
- Look for excess as a function of lepton pair properties, namely dilepton invariant mass





Model-Independent Searches
Inclusive Same-Sign Dilepton

- Limit presented in terms of fiducial cross-section limit, i.e. cross-section with detector and event-selection acceptance (as opposed to total cross-section):

$$\sigma_{95}^{\text{fid}} = \frac{N_{95}}{\varepsilon_{\text{fid}} \times \int \mathcal{L}dt}$$

95% CL upper limit on fiducial cross-section → σ_{95}^{fid}

95% CL upper limit on yield (given Nobserved and Nbackground) → N_{95}

Reconstruction and Selection efficiency **Within acceptance** → ε_{fid}

Integrated luminosity → $\int \mathcal{L}dt$

- σ_{fid} is (almost) model-independent
- Can turn σ_{fid} into σ_{total} with generator-level information only
- Caveat: not exactly model-independent → must be conservative

Model-Independent Searches
Inclusive Same-Sign Dilepton

- Particle-level definition of acceptance:

	Electron requirement	Muon requirement
Leading lepton p_T	$p_T > 25$ GeV	$p_T > 20$ GeV
Sub-leading lepton p_T	$p_T > 20$ GeV	$p_T > 20$ GeV
Lepton η	$\lvert\eta\rvert < 1.37$ or $1.52 < \lvert\eta\rvert < 2.47$	$\lvert\eta\rvert < 2.5$
Isolation	$p_T^{cone0.3}/p_T < 0.1$	$p_T^{cone0.4}/p_T < 0.06$ and $p_T^{cone0.4} < 4$ GeV $+ 0.02 \times p_T$

Particle-Level Isolation

- Also search for excess in ++ and -- separately

Mass range	95% C.L. upper limit [fb] expected $e^\pm e^\pm$	observed $e^\pm e^\pm$	expected $\mu^\pm\mu^\pm$	observed $\mu^\pm\mu^\pm$
$M > 15$ GeV	$45.0^{+17.3}_{-12.0}$	45.7	$23.4^{+8.6}_{-5.8}$	29.1
$M > 100$ GeV	$24.3^{+9.1}_{-7.0}$	25.6	$11.9^{+4.4}_{-2.9}$	14.6
$M > 200$ GeV	$8.8^{+3.2}_{-2.9}$	8.1	$4.2^{+1.8}_{-1.1}$	6.6
$M > 300$ GeV	$4.5^{+1.6}_{-1.3}$	3.9	$2.3^{+0.8}_{-0.7}$	2.5
$M > 400$ GeV	$2.9^{+1.1}_{-0.9}$	2.3	$1.6^{+0.6}_{-0.5}$	1.7
	e^+e^+		$\mu^+\mu^+$	
$M > 15$ GeV	$27.3^{+10.0}_{-7.9}$	23.8	$14.7^{+6.0}_{-3.2}$	14.9
$M > 100$ GeV	$16.2^{+6.0}_{-4.8}$	12.4	$8.2^{+3.2}_{-2.4}$	7.7
$M > 200$ GeV	$6.6^{+2.8}_{-1.5}$	6.5	$3.4^{+1.5}_{-0.7}$	4.2
$M > 300$ GeV	$3.5^{+1.6}_{-0.8}$	2.9	$2.0^{+0.8}_{-0.5}$	2.0
$M > 400$ GeV	$2.4^{+1.1}_{-0.6}$	1.7	$1.5^{+0.6}_{-0.3}$	1.7
	e^-e^-		$\mu^-\mu^-$	
$M > 15$ GeV	$24.6^{+8.5}_{-6.8}$	29.1	$11.9^{+4.4}_{-3.4}$	18.0
$M > 100$ GeV	$12.7^{+4.6}_{-3.9}$	19.9	$5.8^{+2.2}_{-1.9}$	9.8
$M > 200$ GeV	$4.7^{+1.9}_{-1.3}$	4.4	$2.7^{+1.1}_{-0.7}$	4.3
$M > 300$ GeV	$2.8^{+1.1}_{-0.8}$	2.7	$1.4^{+0.7}_{-0.3}$	1.7
$M > 400$ GeV	$1.8^{+1.0}_{-0.4}$	2.2	$1.2^{+0.4}_{-0.0}$	1.1

Model-Independent Searches
Generic Search

- Implemented in many ways in several experiments:
  - → Hera
  - → D0 Quary and CDF Sleuth
  - → CMS Music
  - → ATLAS generic search (shown here)
- Basic idea: look for an excess in the entire dataset (!)
- Caveats:
  - → Not optimized for any given signal. No complicated reconstruction.
  - → Background estimates not as accurate / trustworthy as in a dedicated search
  - → Very large trial factor: the more signal regions the more likely an excess is a statistical fluctuation → decrease sensitivity
- Observation of an excess would trigger additionial studies on additional data

Model-Independent Searches
Generic Search

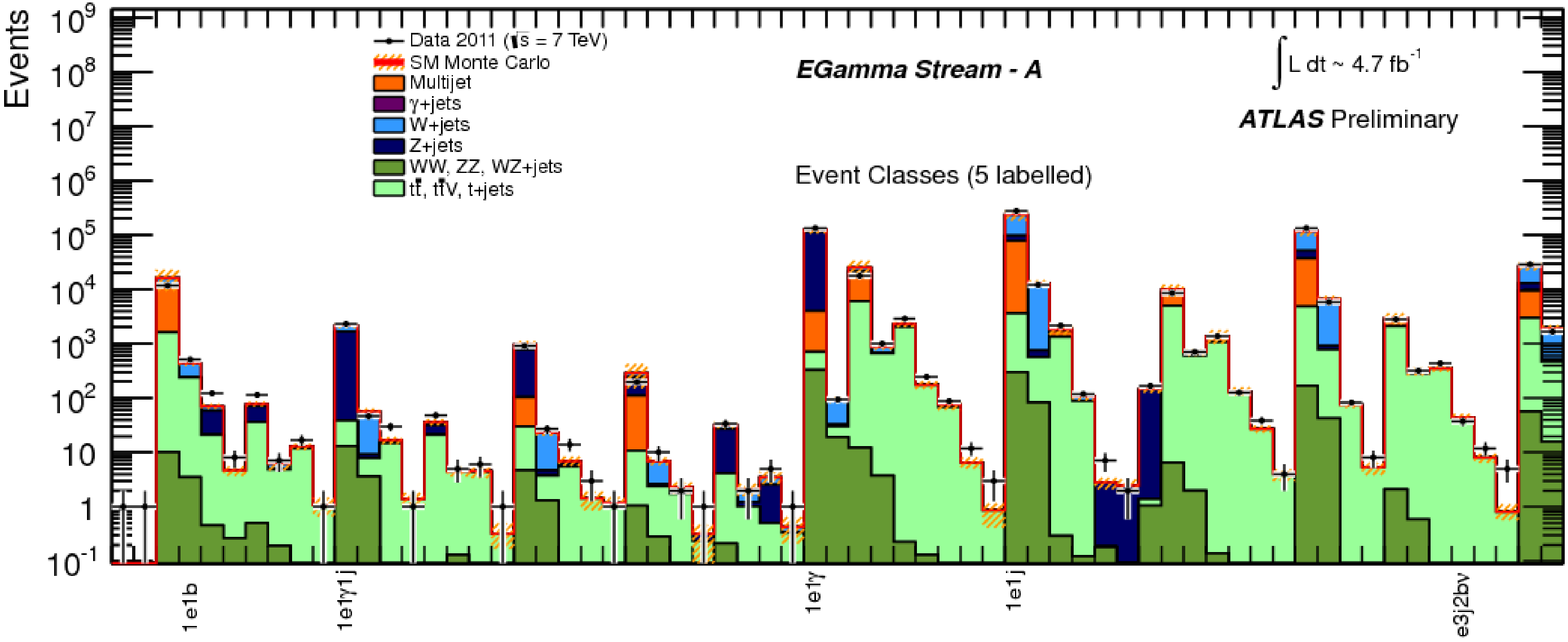
- ATLAS Generic Search
- 655 exclusive channels, as function of number of electrons, muons, photons, jets, b-jets, missing ET

object	jet	b-jet	electron	muon	photon	E_T^{miss}
label	j	b	e	μ	γ	ν
lower p_T cut	50 GeV	50 GeV	25 GeV	20 GeV	40 GeV	130 GeV

- Background estimated from Monte Carlo with conservative uncertainty on cross-sections
  - → QCD: 100% uncertainty
  - → Caveat: trust MC to simulate fake leptons

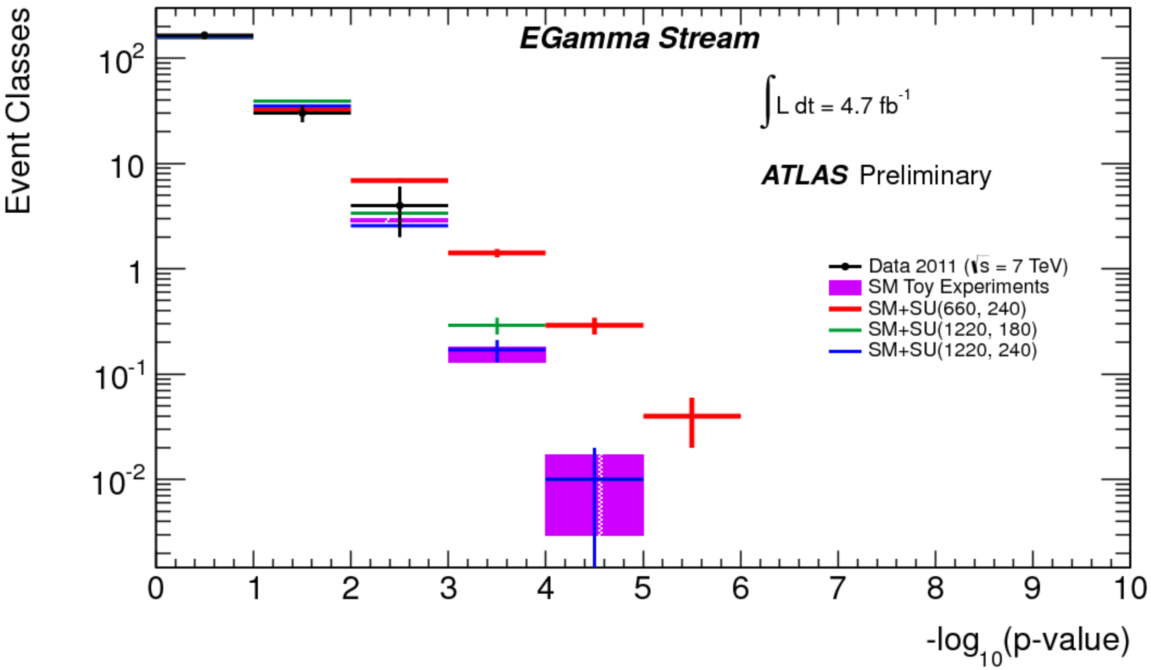
Model-Independent Searches
Generic Search

- Use lowest unprescaled trigger in each stream: electron/photon (e/g), muon, jet/MET/tau
- Part of the result for the e/g stream:



Model-Independent Searches
Generic Search

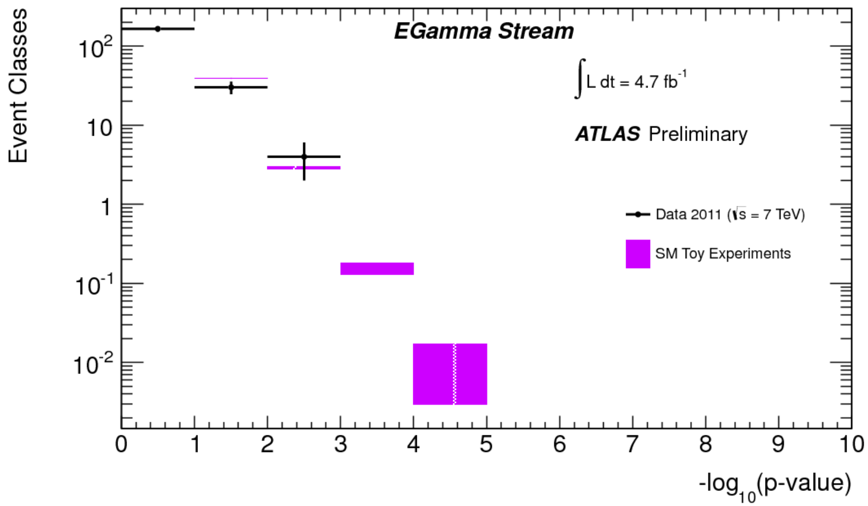
- Quantifying an excess: for each signal region, compute the p-value = probability that the background fluctuates at or above the observed number of events
- Take into account trial factor (a.k.a. Look-Elsewhere Effect) with pseudo-experiments (a.k.a. "toys")

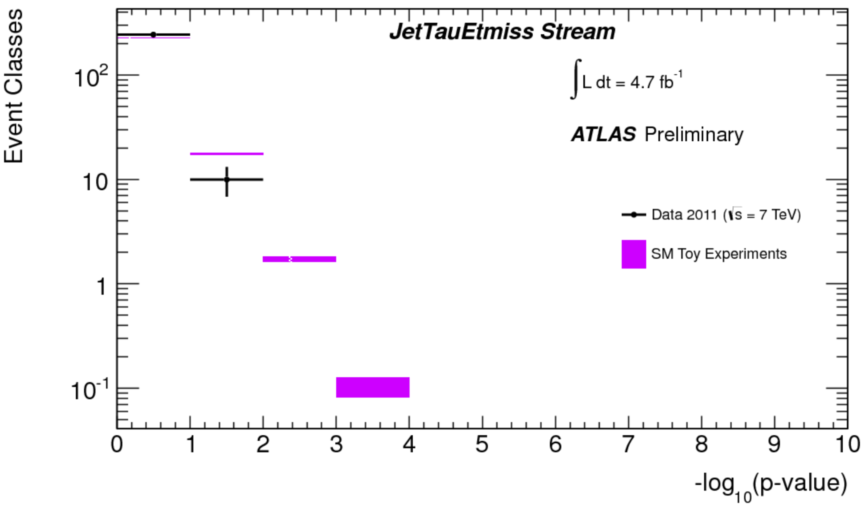


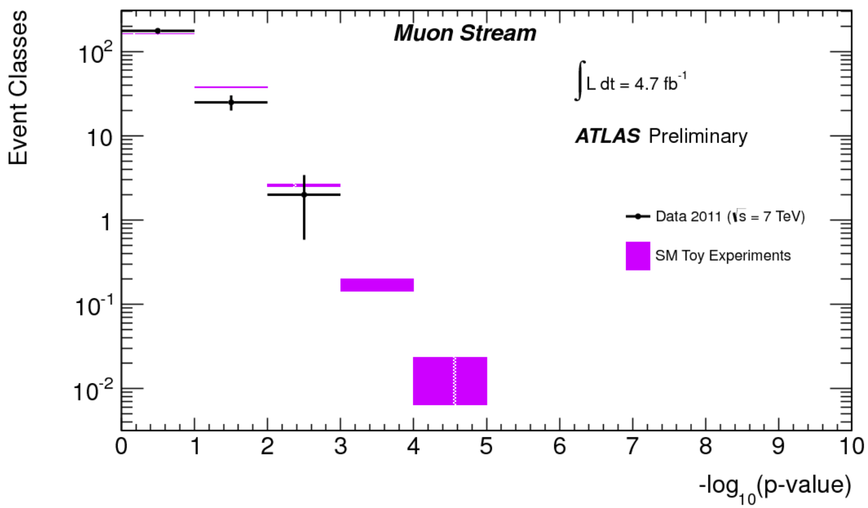
- Sanity/Sensitivity check:
  - → Compare with toys in which a signal is injected

Model-Independent Searches
Generic Search

- Result in the 3 streams
- No excess!
  - → A clear evidence that our simulation is pretty good!







Outlook: Life with a Higgs Boson

- A particle of mass ~ 126 GeV decaying to gg, ZZ, WW, was discovered this summer. How does it change the lanscape?
- Is it the SM Higgs boson? (see Louis'talk):
  - → Measure its branching ratios
  - → Measure its spin
- Exotic decays:
  - → Invisible Higgs : Higgs → LSP's (cf monojet analysis)
  - → Higgs to exotic objects. E.g. Hidden Valley dark photon → LLP's or lepton-jets
- Other Higgs? If there is one, there may be more (esp. SUSY)
- Technicolor and SM4 are in trouble. Most other models (esp. SUSY) live well with a light Higgs.
- From now on we must consider heavy particle decays to Higgs systematically (esp. Heavy Quarks, e.g. t' → tH)

Conclusion

- Unfortunately, New Physics was not “around the corner”...

  … unless the Higgs is not an SM Higgs?
- Weak-scale SUSY is being pushed, but is not dead yet
- Experimental challenges as we enter further the Multi-TeV world:
  - → TeV leptons
  - → Boosted objects (W, top)
  - → Investigate less obvious signatures and pursue precision measurements
- Expect 30 fb^{-1} at 8 TeV by the end of 2012
- And 30 fb^{-1} at 13 TeV by the end of 2015

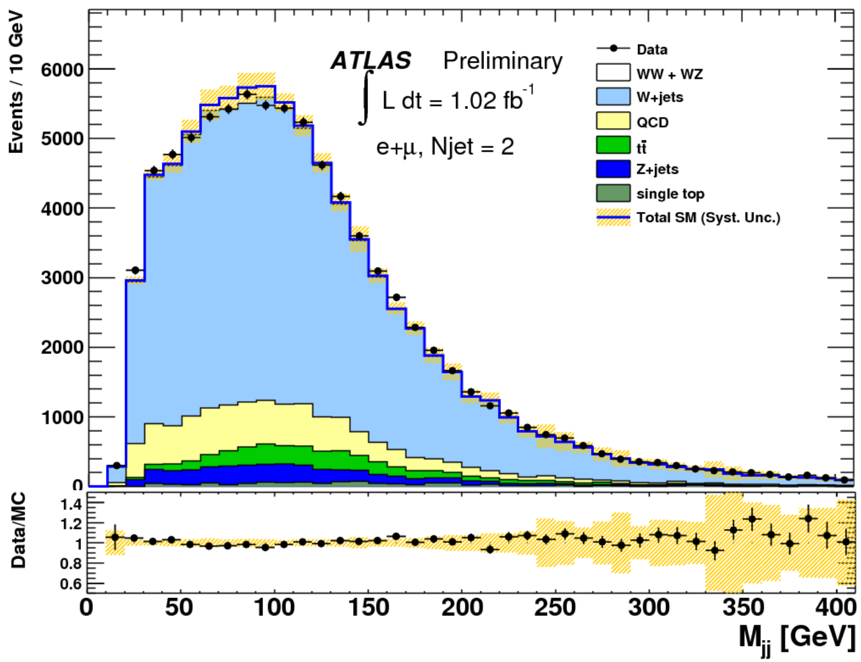
  followed by 300 fb^{-1} at 14 TeV by the end of the decade (?)
- It's only the beginning!

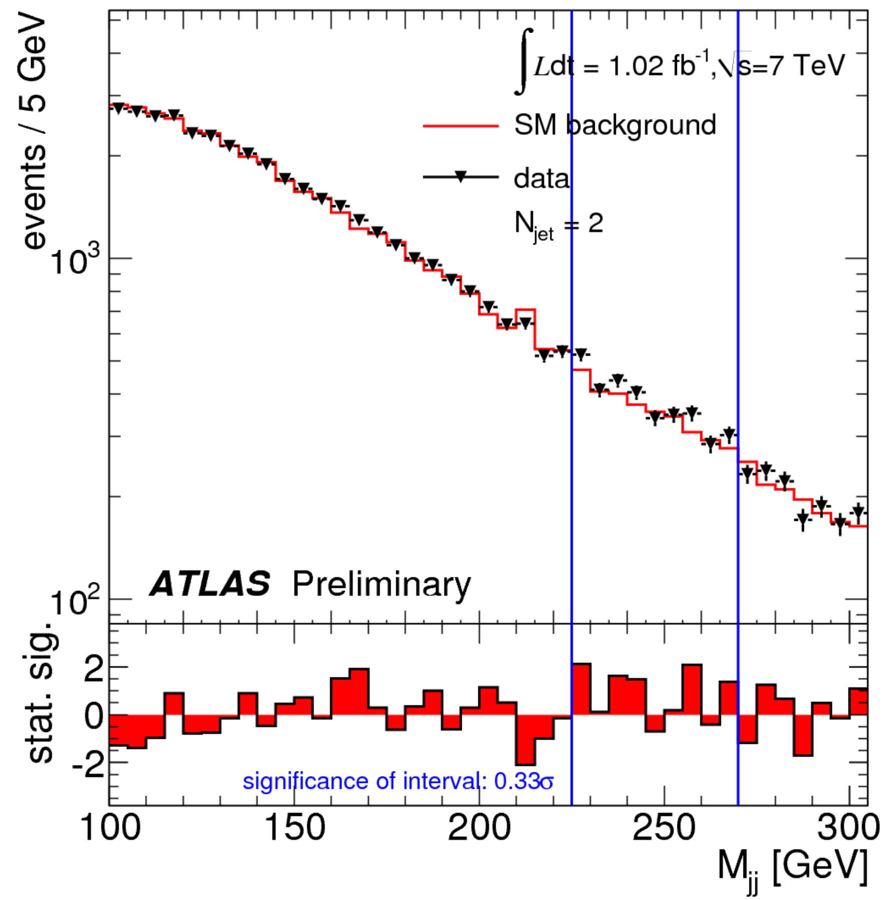
Bibliography, Ressources

- ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic
- CMS: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults
- P. Pralavorio, SUSY: https://pralavop.web.cern.ch/pralavop/conf.html
- BSM phenomenology review, Morrissey et al, arxiv0912.3259

Backup

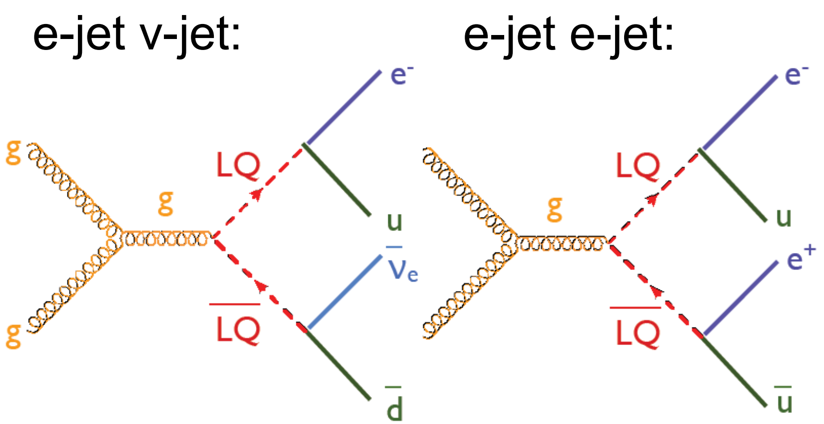
Wjj

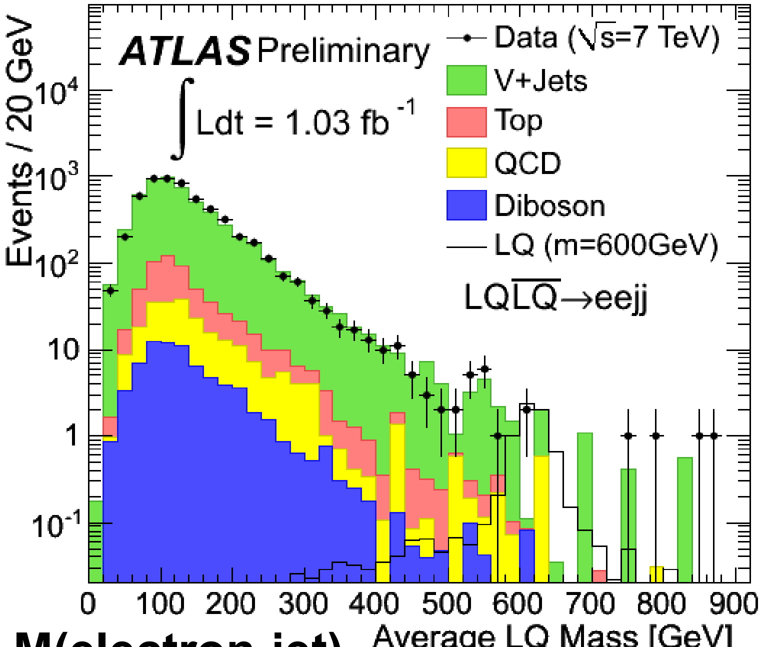

ATLAS Preliminary
∫ L dt = 1.02 fb⁻¹
e+μ, Njet = 2
Data
WW + WZ
W+jets
QCD
tt̄
Z+jets
single top
Total SM (Syst. Unc.)
Events / 10 GeV
Data/MC
M_jj [GeV]


∫Ldt = 1.02 fb⁻¹,√s=7 TeV
SM background
data
N_jet = 2
ATLAS Preliminary
events / 5 GeV
stat. sig.
significance of interval: 0.33σ
M_jj [GeV]

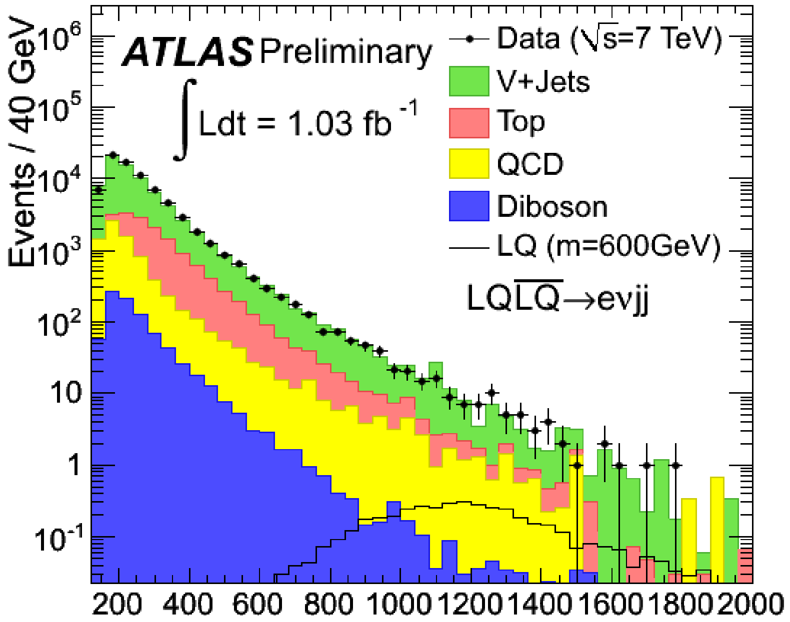
1st Generation Leptoquarks

- LQs carry both lepton and baryon number → decay to lepton-quark
- 1st generation: dielectron and electron neutrino channel
- Multivariate analysis, using mostly:





M(electron-jet)



Event Transverse Energy

1st Generation Leptoquarks

- New limits clearly surpass TeVatron
- Now working on 2nd and 3rd generation...

β=1 : m > 660 GeV
β=0.5: m > 607 GeV

100% to eejj

100% to ννjj

Channel not included here