Search for tt resonances @ Atlas and CMS

Top LHC-France meeting

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tt resonance searches

- Many models predict new heavy resonances (Z', g_{KK}, G*, H^0)
  - They may decay predominantly into ttbar (because of the large top mass)

- Both Atlas and CMS have results on full-hadronic, semi- and di-leptonic final states
  - French groups mainly involve in semi-leptonic (e or mu)
    → the talk will be focused on this channel

- Comparison of the analyses Atlas ↔ CMS is highly instructive
  - Strategy
  - Selection
  - Background modeling
  - Reconstruction
  - Systematics uncertainties
  - Limits

ATLAS-CONF-2012-136

CMS: JHEP 12 (2012) 015

Signal benchmarks

CMS / Atlas

- Detector resolution on mtt O(10%)
- Sequential SM topcolor Z' (Γ/m=1.2% and 10%)
  - Pythia 8
  - Pythia 6
- KK gluon (Γ/m=15%)
  - Pythia 8
  - Madgraph 5

Backgrounds

CMS / Atlas

- SM ttbar
  - Irreducible background
  - Madgraph5 + Pythia6 + CTEQ6L, k-factor from MCFM (N?NLO)
  - MC@NLO + Herwig + CT10, k-factor from HATOR (NNLO)
- W+jets
  - Madgraph5 + Pythia6 + CTEQ6L
    - Normalized to NNLO
  - Alpgen + Herwig + CTEQ6L1
    - Normalized thanks W charge asymmetry
    - Heavy flavor fraction from the data
- Multijets:
  - Data-driven (“template”)
  - Data-driven (“matrix-method”)

Strategies

- Both experiments divides the search into 2 regimes
  - Low tt mass (“threshold” or “resolved” analysis)
  - High tt mass (“boosted” analysis)

- CMS uses the threshold analysis up to $m_{Z'}$=1TeV then uses the boosted one

- Atlas uses both analyses on the full range
  - Events that do not pass the boosted selection are considered by the resolved one
  - Sensitivity gain in the intermediate regime where both selections have some sensitivity

Objects: jets

CMS / Atlas

- Anti-kt 0.5 / 0.4 / 1.0
  - $|\eta_{0.5}|<2.4$, $|\eta_{0.4}|<2.5$, $|\eta_{1.0}|<2.0$
  - Threshold: pT>30 GeV
  - Boosted: pT>25GeV
  - $pT_{0.4}>25$ GeV, $pT_{1.0}>350$ GeV
- Btagging:
  - 70% efficient on b (only used on anti-kt 0.4 jets)

Objects: leptons

CMS / Atlas

- Electrons
  - $|\eta|<2.47$, $|\eta|<2.5$
  - $pT>25GeV$, $\Delta R(e, jet)>0.4$, isolated
  - Threshold: $pT>30GeV$, isolated
  - Boosted: $pT>70GeV$, no isolation requirement,
    ($\Delta R(e, jet)>0.5$ or $pT^{rel}(e, jet)>25GeV$)
- Muons
  - $|\eta|<2.5$, $|\eta|<2.1$
  - $pT>25GeV$, isolated
  - Boosted: $\Delta R(\mu, jet)>0.1$
  - Threshold: $pT>20GeV$, isolated
  - Boosted: $pT>42GeV$, no isolation requirement,
    ($\Delta R(\mu, jet)>0.5$ or $pT^{rel}(\mu, jet)>25GeV$)

Objects: lepton isolation CMS / Atlas

- CMS:
  - **(Σ E_T in R=0.4 cone)/p_T^{lepton}** <12.5% / 10% for muons/electrons
  - Reminder: no isolation for the boosted selection
- Atlas:
  - **(Σ P_T^{track} in R=x cone)/p_T^{lepton}**< 5%
    x=10GeV/p_T^{lepton}
  - Small cone size for the boosted regime

Triggers

CMS / Atlas

- Threshold/resolved:
  - e
    - Single isolated e (25GeV) + ≥3jets (30GeV)
    - Single e (20→22GeV), sometime isolated
  - μ
    - Single isolated μ (17GeV) + ≥ 0→3jets (30GeV)
    - Single μ (18GeV)
- Boosted
  - e
    - Single e (65GeV), no isolation (sometime prescaled -0.6fb^{-1})
    - Fat jet (240GeV)
  - μ
    - Single μ (40GeV), no isolation
    - Fat jet (240GeV)

“threshold”/“resolved” selections CMS / Atlas

CMS

- 1 lepton (30/20GeV)
- ≥3 jets (50GeV)
- **pT(jet1)>70GeV**
- MET>20GeV
- 4 **categories** * 2 (e/μ):
  - 3 jets and ≥1 b-tagged jet
  - ≥4 jets and 0 b-tagged jet
  - ≥4 jets and 1 b-tagged jet
  - ≥4 jets and ≥2 b-tagged jets

Atlas

- 1 lepton (25GeV)
- ≥4 jets (25GeV)
  - or +≥3 jets (25GeV), if one jet has mass>60GeV (→ semi-boosted)
- e: MET>25GeV, M_T^W>25GeV
- μ: MET>20GeV, MET+M_T^W>60GeV
- **Not selected by the “boosted” selection**
- ≥1 b-tagged jet

“boosted” selections

CMS / Atlas

CMS

- 1 lepton (70/42GeV)
- **≥2 jets (50GeV)**
- MET+P_T^{lepton}>150GeV
- e:
  - pT(jet1)>**150GeV**
  - MET>50GeV

$$-\frac{1.5}{75\,\mathrm{GeV}}E_{\mathrm{T}}^{\mathrm{miss}}+1.5<\Delta\phi\{(\mathrm{e\ or}\ j),E_{\mathrm{T}}^{\mathrm{miss}}\}<\frac{1.5}{75\,\mathrm{GeV}}E_{\mathrm{T}}^{\mathrm{miss}}+1.5$$

- μ:
  - pT(jet1)>**250GeV**
- 2 **categories** * 2 (e/μ):
  - 0 b-tagged jet
  - ≥1 b-tagged jet
- **Backgrounds normalized to data**

Atlas

- 1 lepton (25 GeV)
- e: MET>25GeV, M_T^W>25GeV
- μ: MET>20GeV, MET+M_T^W>60GeV
- **≥1 fat jet**
  - pT>350GeV, mass>100GeV, √d12>40GeV
  - Δϕ(l,$jet_{1.0}$)>2.3
- ≥1 jet
  - ≥1 b-tagged jet
  - ΔR($jet_{0.4}$, $jet_{1.0}$)>1.5

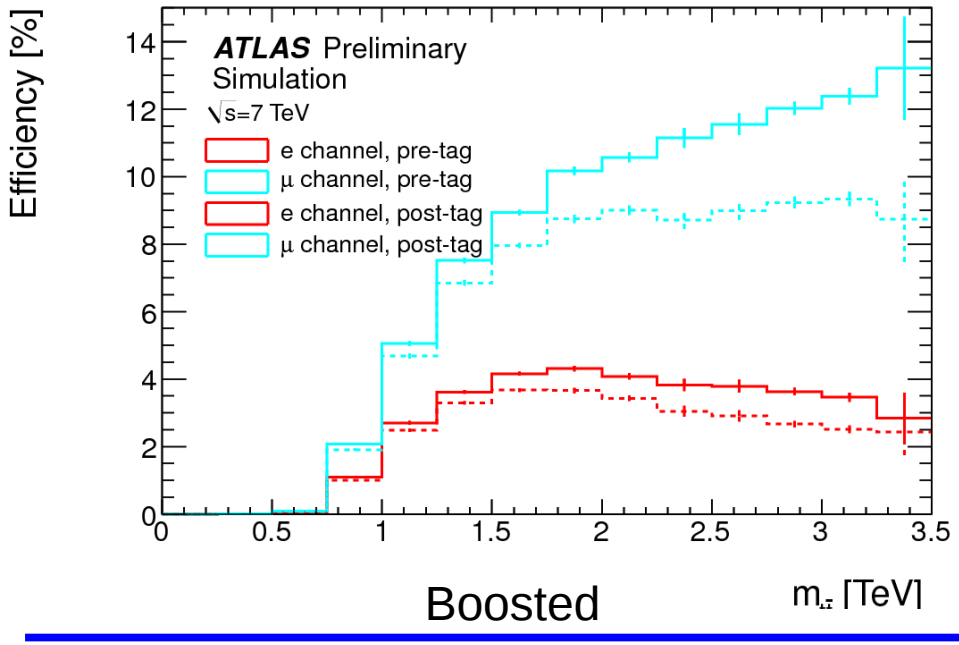
Selection efficiencies

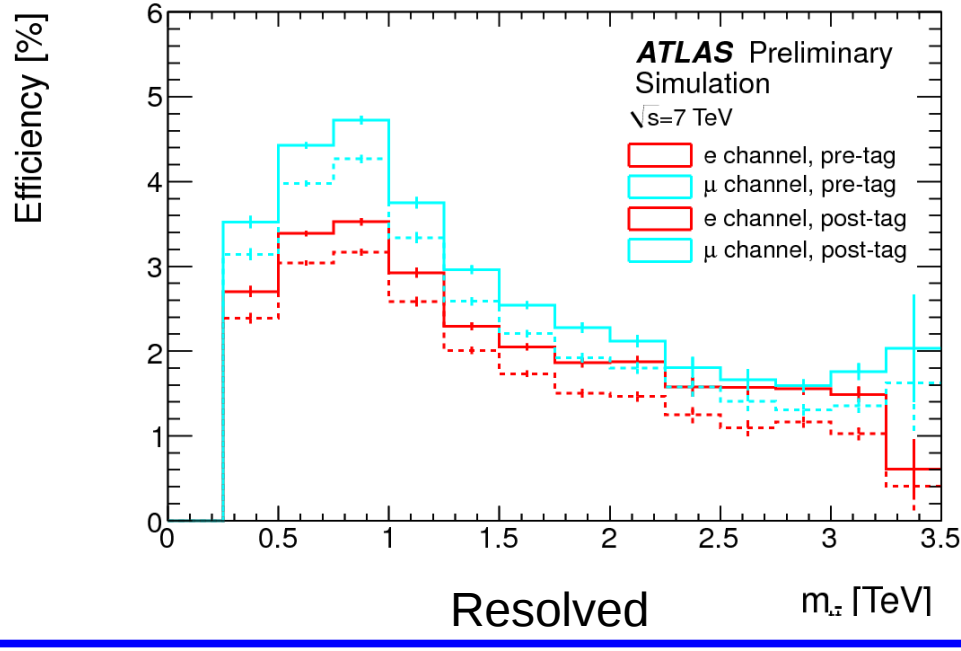
- CMS:

  semileptonic events → inclusive

  - Resolved : 16 to 35% (0.5TeV to 1TeV) → 7 to 15%
  - Boosted : 13 to 24% (1TeV to 3TeV) → 5 to 11%

- Atlas:
  - Wrt/ inclusive ttbar decays





Reconstruction - Neutrino

CMS / Atlas

- Assume MET=neutrino's pT, need to recover the p_z
- Neutrino p_z solution inferred from W mass constraint ==> quadratic equation
  - There are 2 solutions
    - Use both solutions, and test them in a χ^2
  - There is no solution
    - Boosted:
      - Real part of the complex solution
      - Minimal change of MET to get real solution
    - Threshold/resolved:
      - Minimal change of MET to get real solution

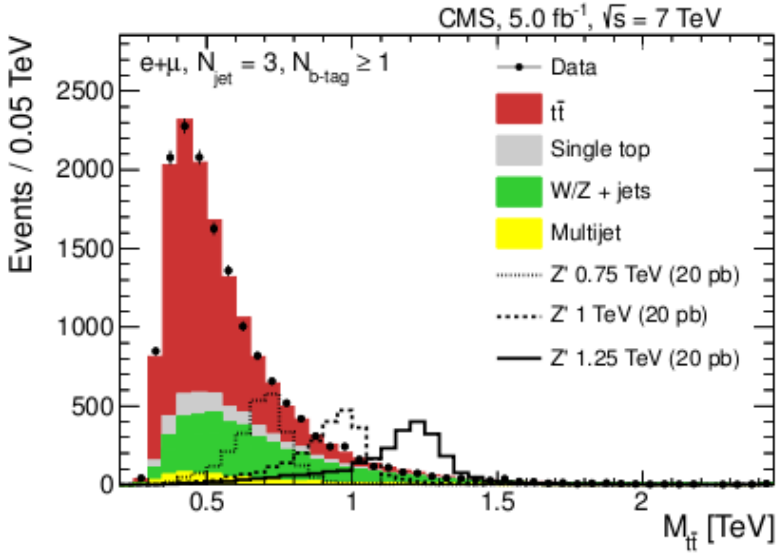
Reconstruction – Threshold/resolved m_{tt} CMS / Atlas

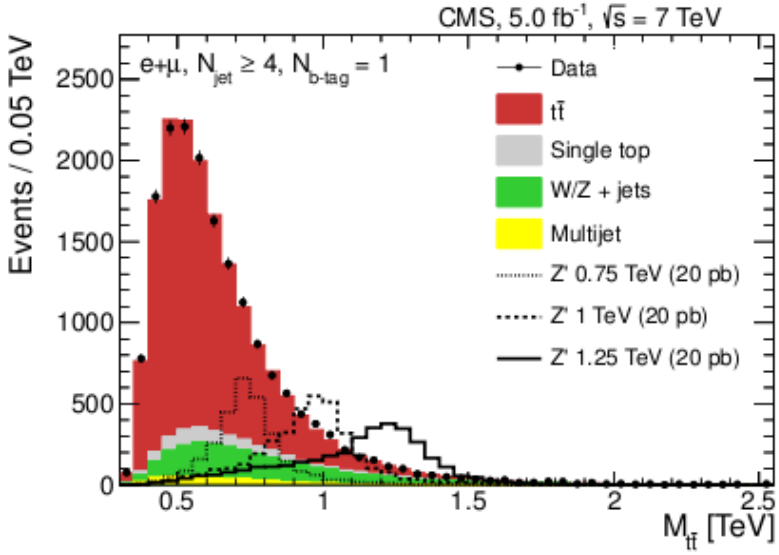
- CMS:
  - If ≥4 jets: χ^2
    - top masses, hadronic W mass, pT of tt system,
    - Σ pT of 4 selected jets / Σ pT of all jets
  - If 3 jets:
    - Use them
- Atlas:
  - If no high mass jet:

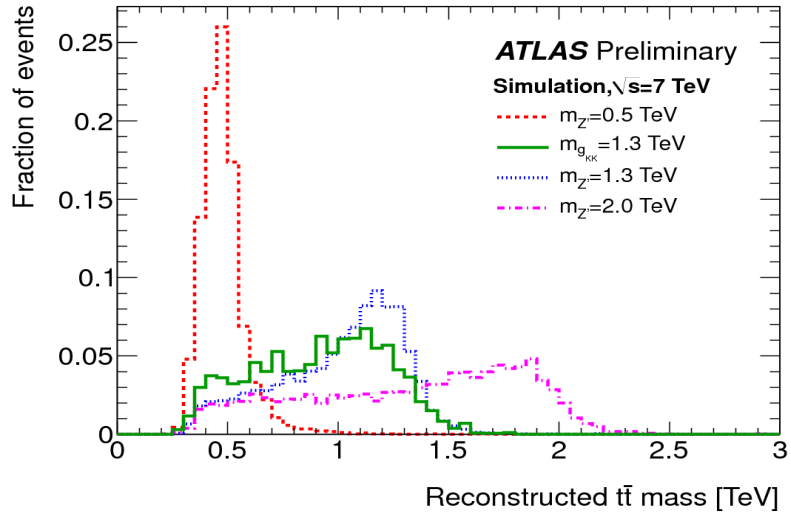
$$\chi^2 = \left[\frac{m_{jj} - m_W}{\sigma_W}\right]^2 + \left[\frac{m_{jjb} - m_{jj} - m_{t_h - W}}{\sigma_{t_h - W}}\right]^2 + \left[\frac{m_{j\ell\nu} - m_{t_\ell}}{\sigma_{t_\ell}}\right]^2 + \left[\frac{(p_{T,jjb} - p_{T,j\ell\nu}) - (p_{T,t_h} - p_{T,t_\ell})}{\sigma_{\mathrm{diff}\,p_T}}\right]^2$$

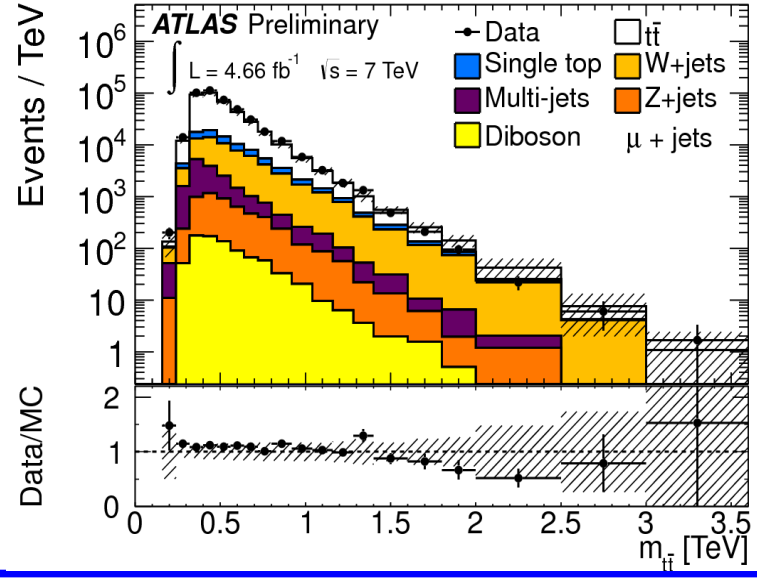
  - If high mass jet
    - It plays the role of the hadronic W

Reconstruction – Threshold/resolved m_{tt} CMS / Atlas









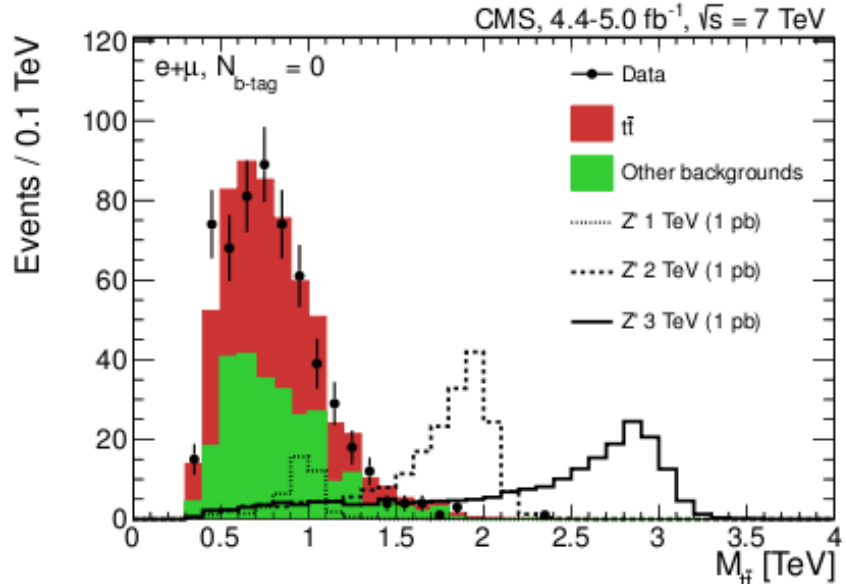
Reconstruction – boosted m_{tt} CMS / Atlas

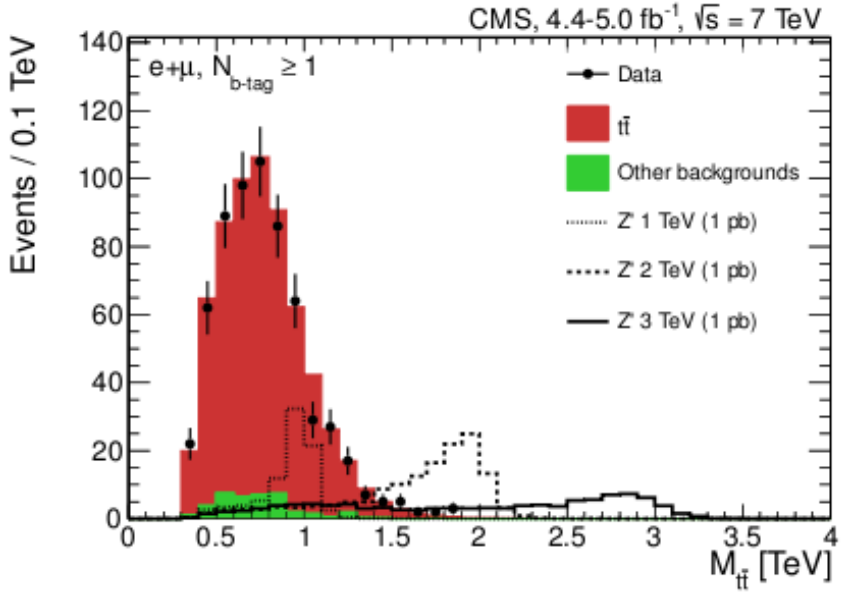
- CMS:
  - χ^2 (top masses)
    - Use 1, 2 or 3 jets for the hadronic tops
    - $pT^{\text{top had}} > 100GeV$
    - $X^2 < 8$ (50% for signal, 10% for W+jets)

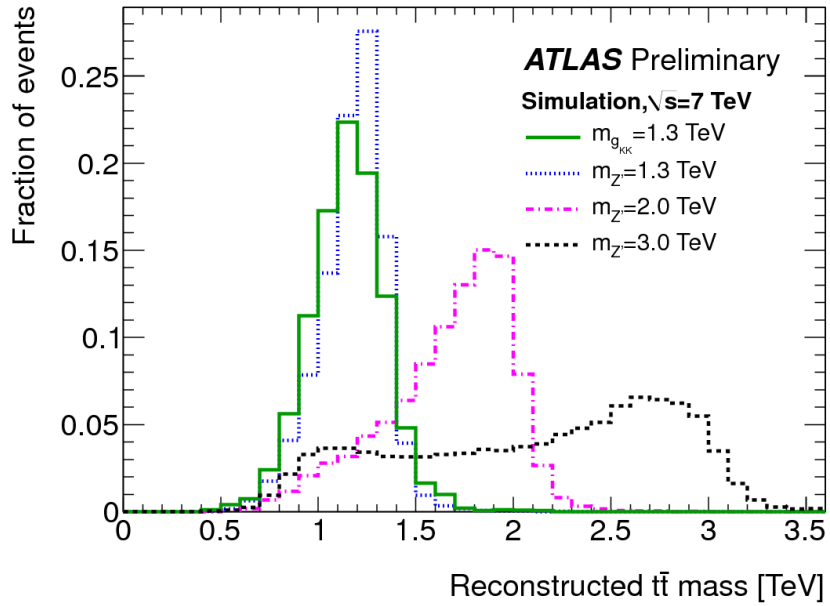
- Atlas:
  - Fat jet + lepton + neutrino + narrow jet
  - Narrow jet: closest to lepton

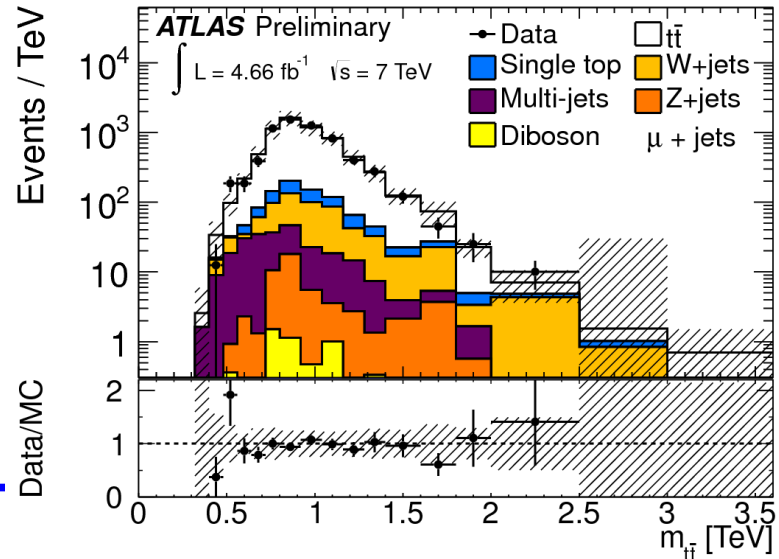
Reconstruction – boosted m_{tt}

CMS / Atlas









Systematic uncertainties

CMS

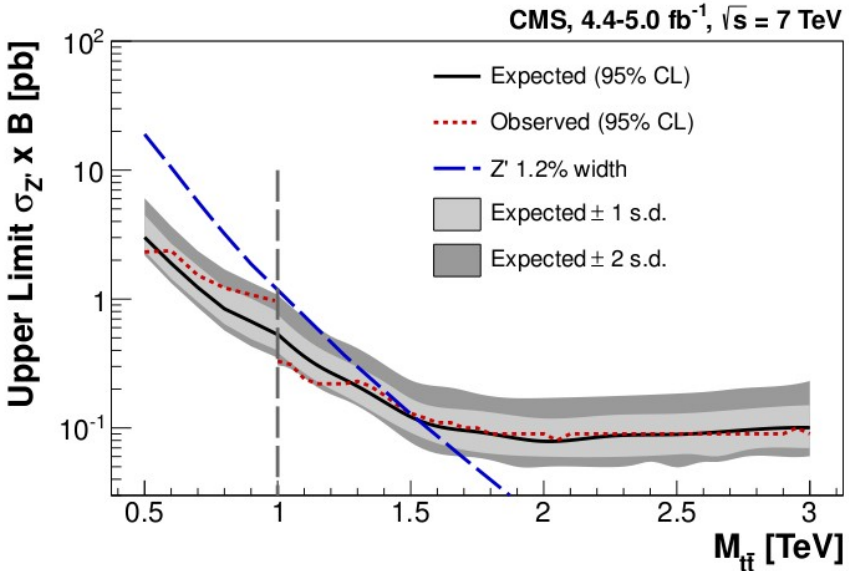
- tt: 15%
- W+jets:
  - +lights:
    - 50% correlated with Z+jets
    - 50% uncorrelated with Z+jets
  - + heavy flavors
    - 100%
- Multijets: ???
- Jet energy reso.: up to 20%

Atlas

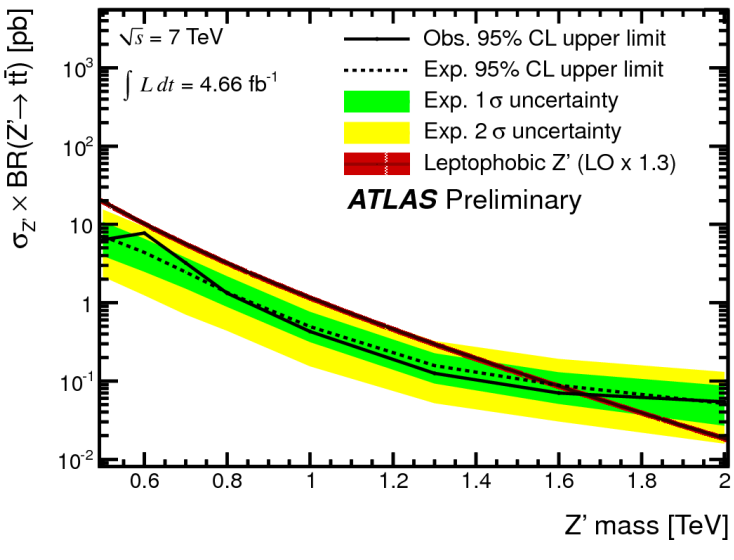
- tt:
  - 11%
  - Higher order QCD corr (10% - @low mtt- to 20% - @high mtt-)
- W+jets:
  - Resolved: 10.5%
  - Boosted: 19/18%
- Multijets: 60% + shape
- PDF: up to 50% @2TeV
- Fat jet JES: 17% on boosted yields

Limits

- CMS:
  - Modified frequentist CLs
  - Bin width chosen so the statistical error <30%
  - Z' (Γ/m=1.2%), Z' (Γ/m=10%), g_{KK} (Γ/m=10%)
- Atlas:
  - searches for the presence of excess/deficits (BumpHunter algorithm). If not → set limits
  - Bayesian limits
  - Bin width chosen to fit the mtt resolution
  - Z' (Γ/m=1.2%), g_{KK} (Γ/m=15%)



Similar exclusion ranges !



Conclusion

- Similar strategy (resolved ↔ boosted)

  … but very different selections

  - CMS: splits the analysis in many categories
  - Atlas: uses of fat jet

- Similar acceptance and reconstruction (at least for the “resolved”)

- Similar limits

Backup