Searches for ttbar resonances with the ATLAS detector

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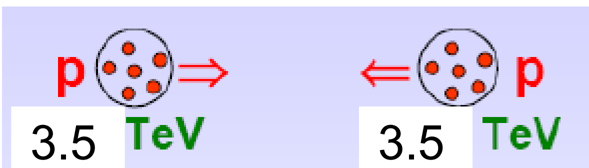
Outline

- The LHC and the ATLAS detector
- ttbar physics @LHC
- What we can learn from ttbar resonances
- Mass reconstruction
- Searches for Z' bosons
- Searches for Quantum Black Holes (QBH)
- Conclusions

LHC

Proton-proton collider installed at CERN.

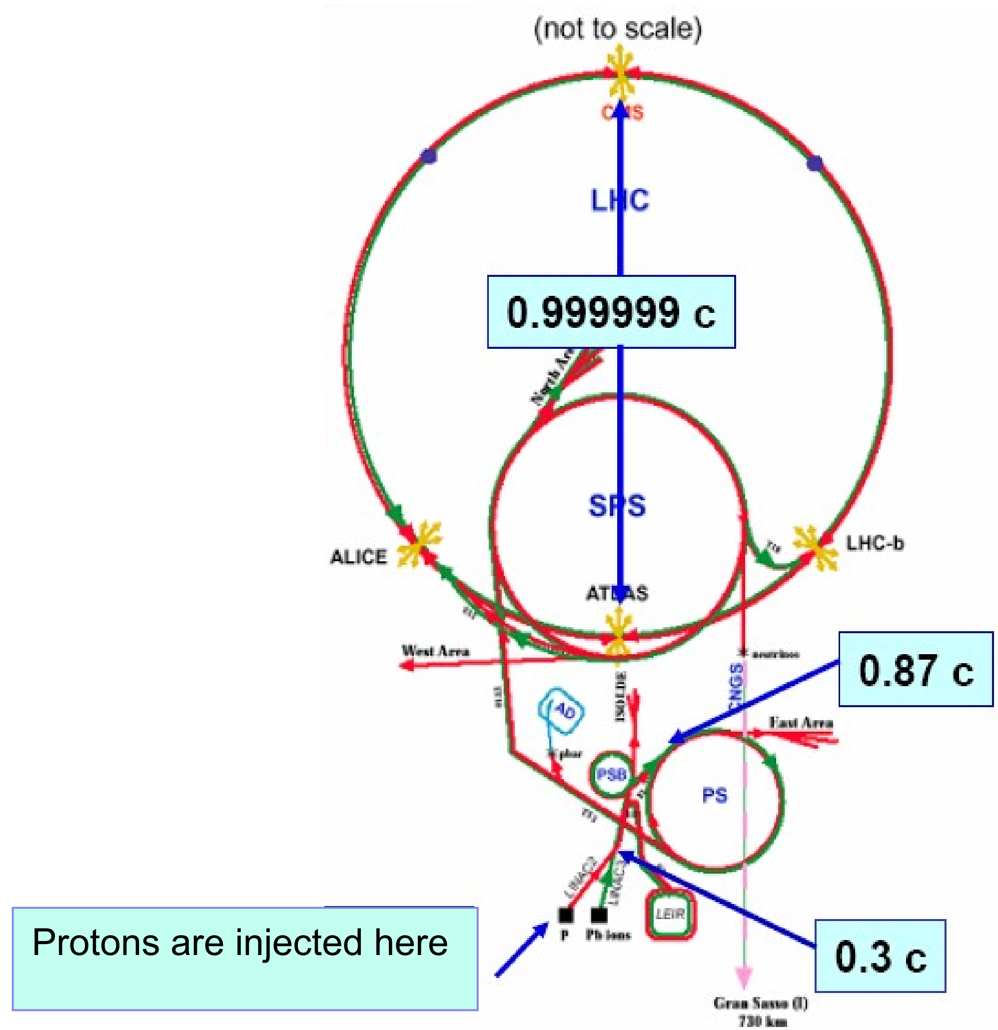


Highest energy ever reached

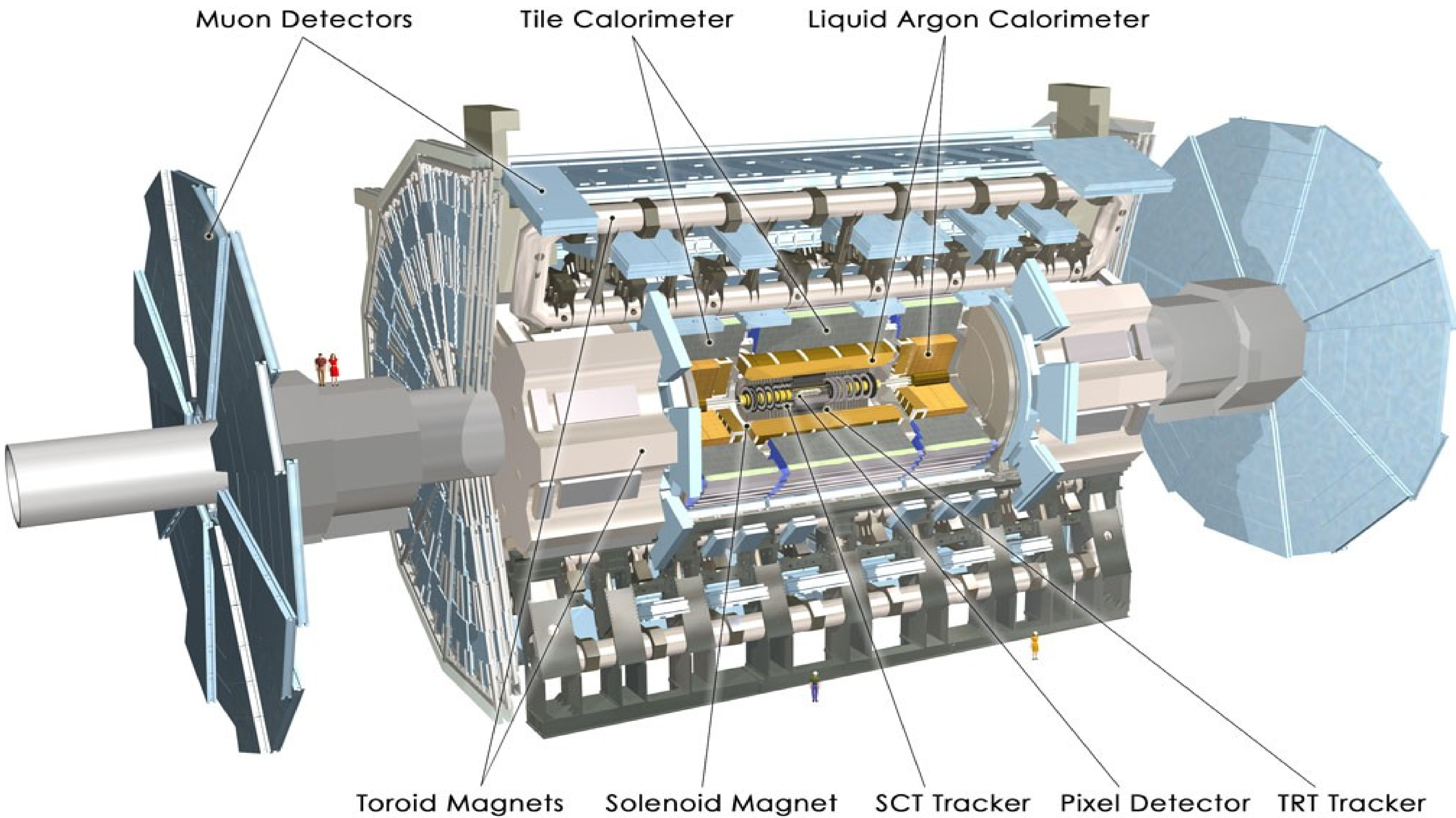
Nominal Luminosity = 10^{34} cm^{-2} s^{-1}

Four main experiments installed:

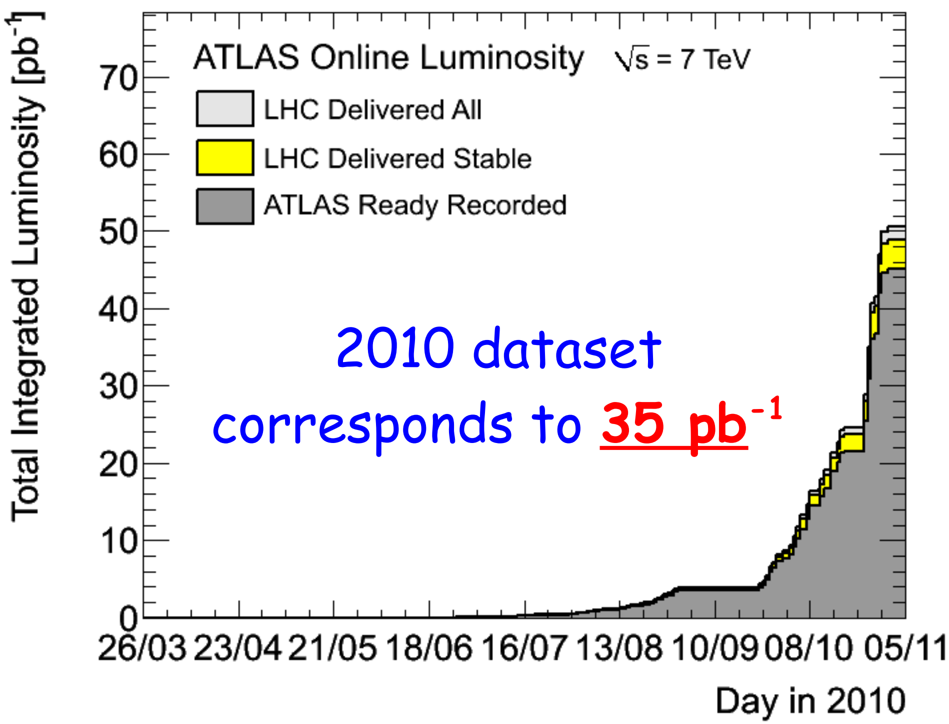
- ✓ ATLAS (general purpose)
- ✓ CMS (general purpose)
- ✓ LHCb (B-physics)
- ✓ ALICE (Pb-Pb collisions)

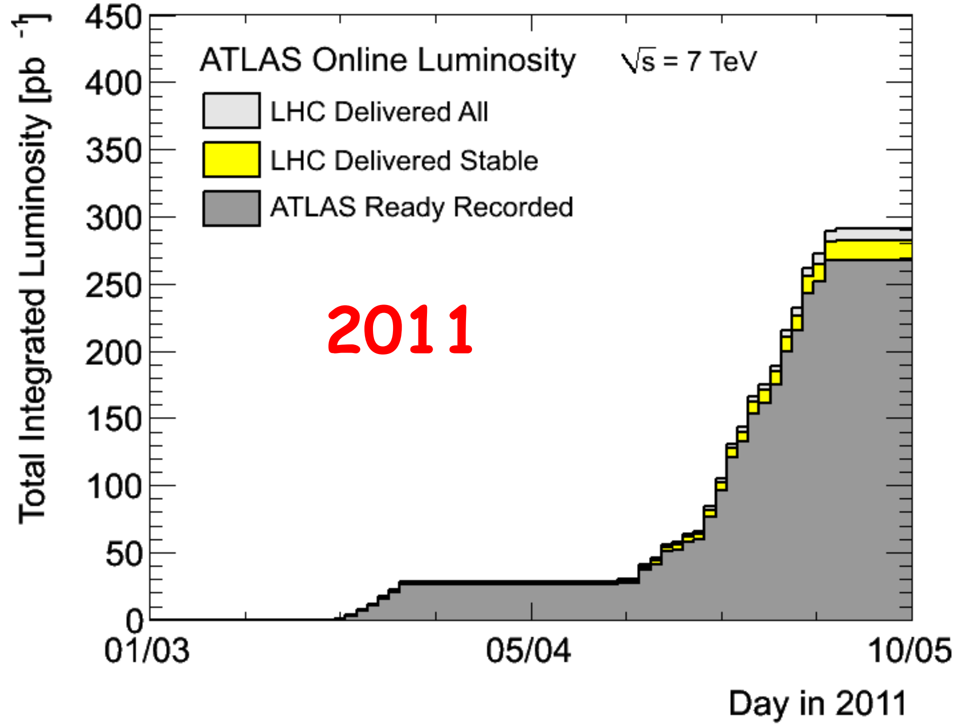


ATLAS Detector



Integrated luminosity





What we can learn from ttbar events

Properties :

- Large mass m_t = 172.0±0.9± 1.3 GeV *(PDG value)*

- Interact strongly with the Higgs sector

→ Top quarks may play a specific role in the electro weak symmetry breaking (EWSB)

→ Some new phenomena connected with EWSB should couple preferentially with Top quark :

The top sector is a laboratory to search for new physics

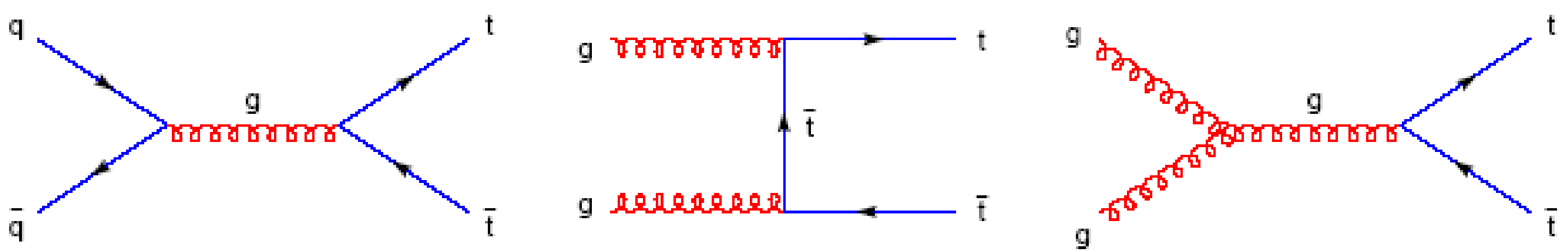
Several models could be revealed in the mass spectrum (distortion or resonance), for instance :

- Search for new resonances decaying to ttbar: leptophobic topcolor Z' as benchmark model (*hep-ph:9911288*)

- Search for enhanced t+X cross-section at high mass : QBH as a benchmark model (*JHEP 0805 (2008) 003*)

ttbar physics@LHC

- Production @ LHC ($\sigma=164_{-16}^{+11}$ pb @ 7 TeV) *arXiv:1012.1792 [hep-ex]*



qq->ttbar

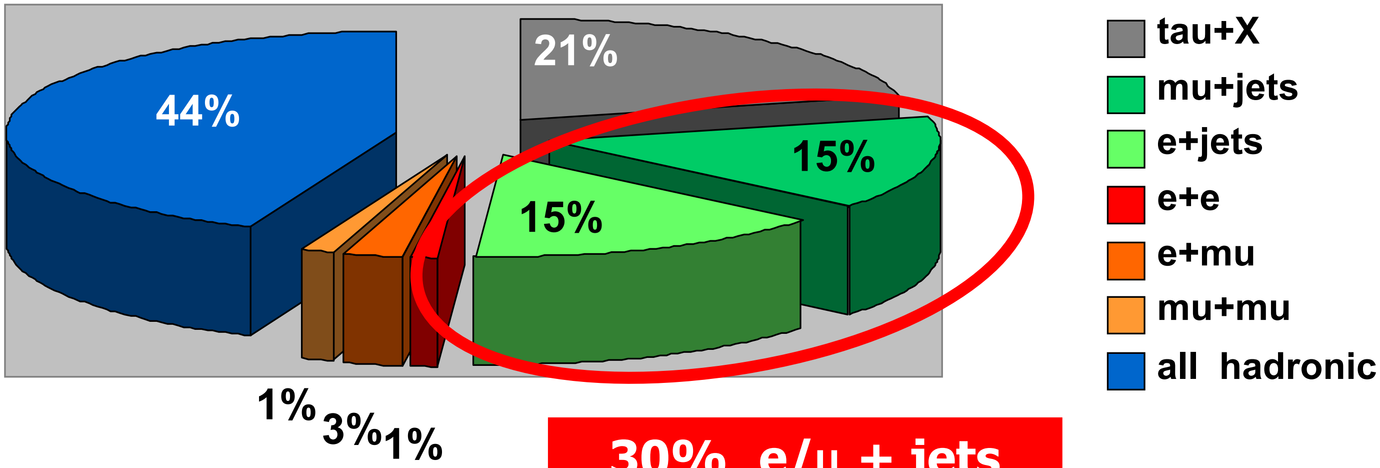
20%

gg->ttbar

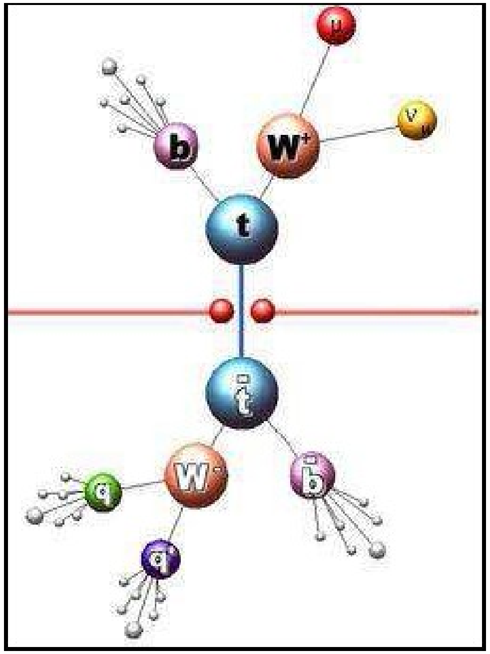
80%

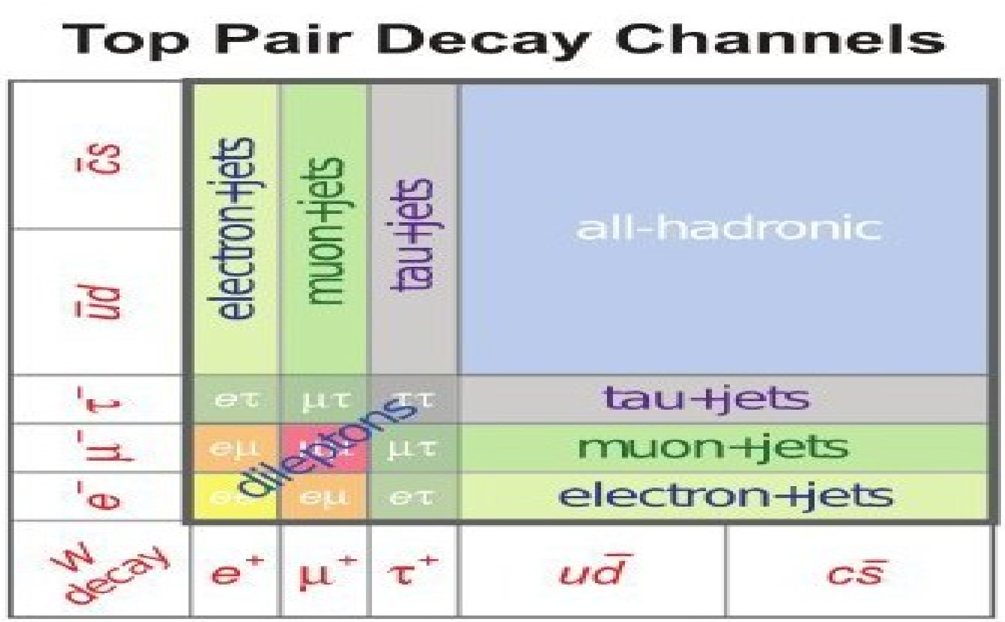
Opposite to TeVatron

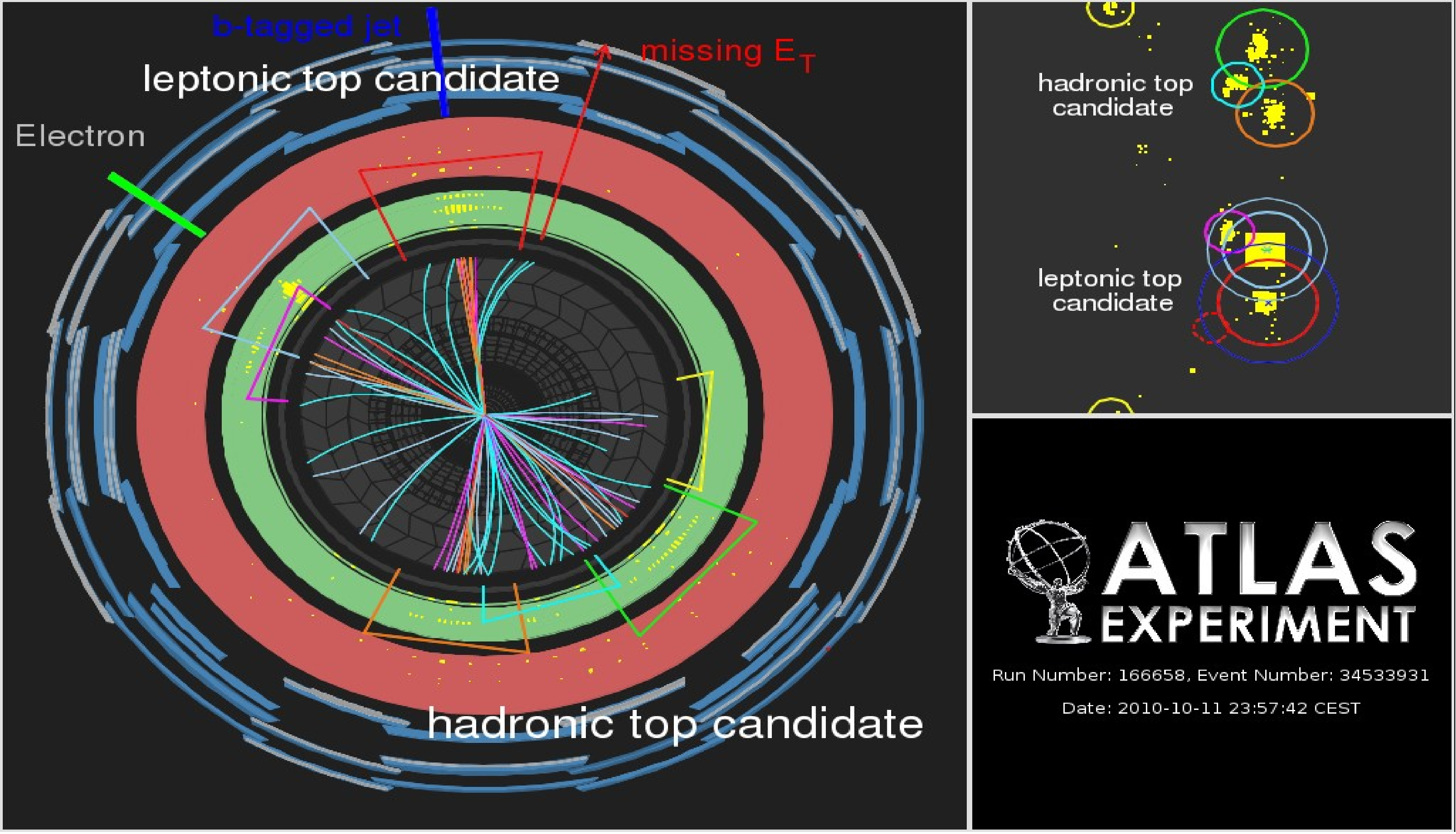
ttbar physics@LHC



30% e/μ + jets







High mass ttbar candidate
m_{ttbar} = 714 GeV

ttbar mass reconstruction

Looking for ttbar lepton+jets decay (ttbar->bqqblv)*ATL-CONF-2011-070*

- Leptonic W from the lepton and E_T^{miss}, neutrino p_Z obtained from a quadratic equation imposing the W mass :
  - If the discriminant is positive, the solution with the smallest p_Z is taken
  - If the discrimant is negative, the minimum variation necessary to obtain a null discriminant is applied to E_T^{miss}
- The jets are not assigned to each decay of the top

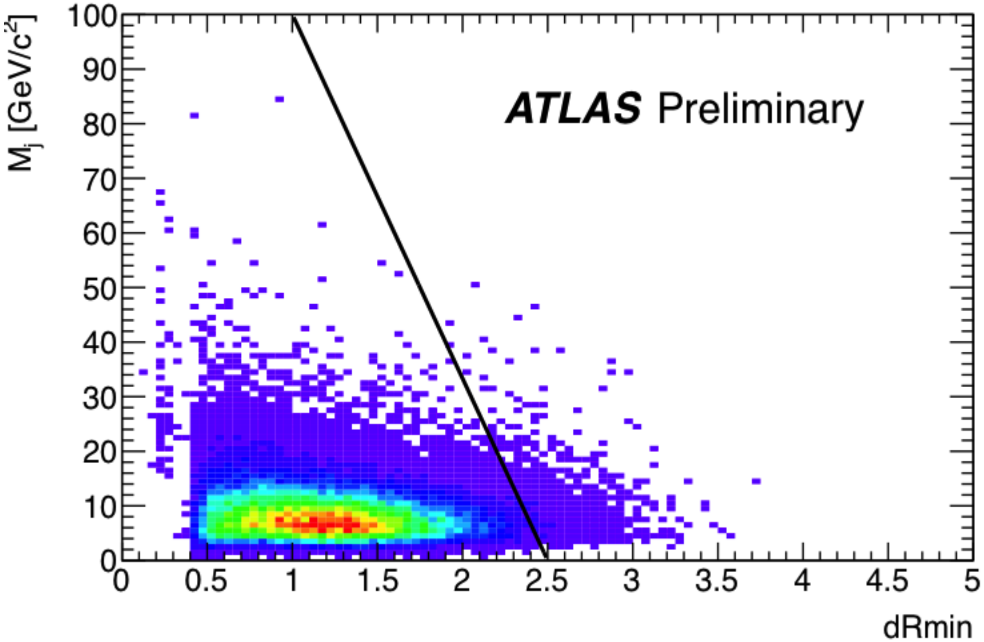
Two different methods used to reconstruct the mass :

- dRmin variant
- 4 hardest jets

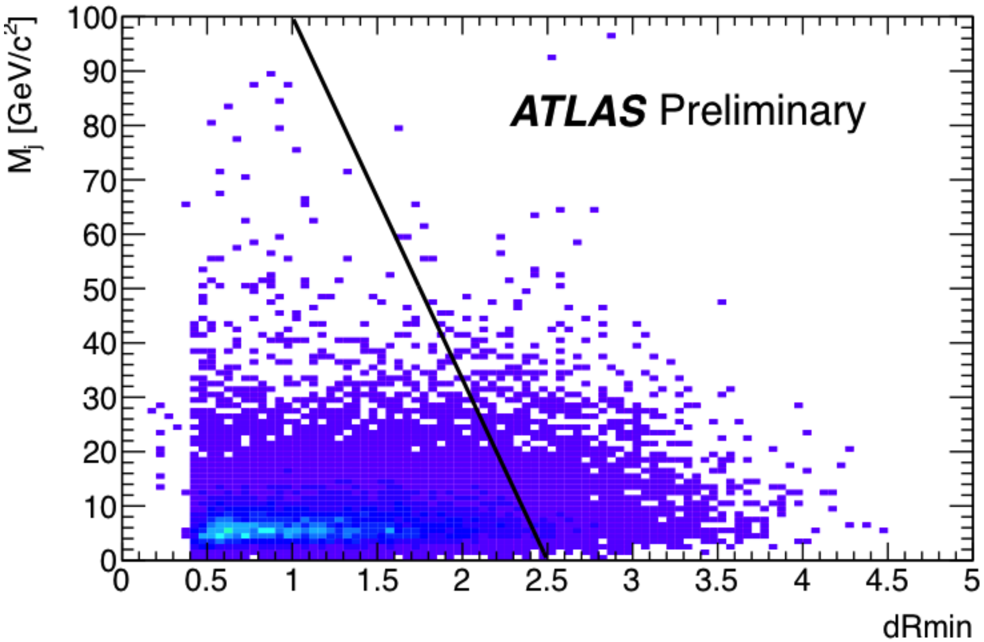
dRmin variant

→The four jets with the highest p_T are considered and a jet is removed if it is too far from the other reconstructed objects (lepton or jets) and has a too high mass (dRmin > 2.5 - 0.015 * mj)

→If a jet was rejected and the event has still at least four jets with p_T>20 GeV and |eta|<2.5, the procedure is iterated

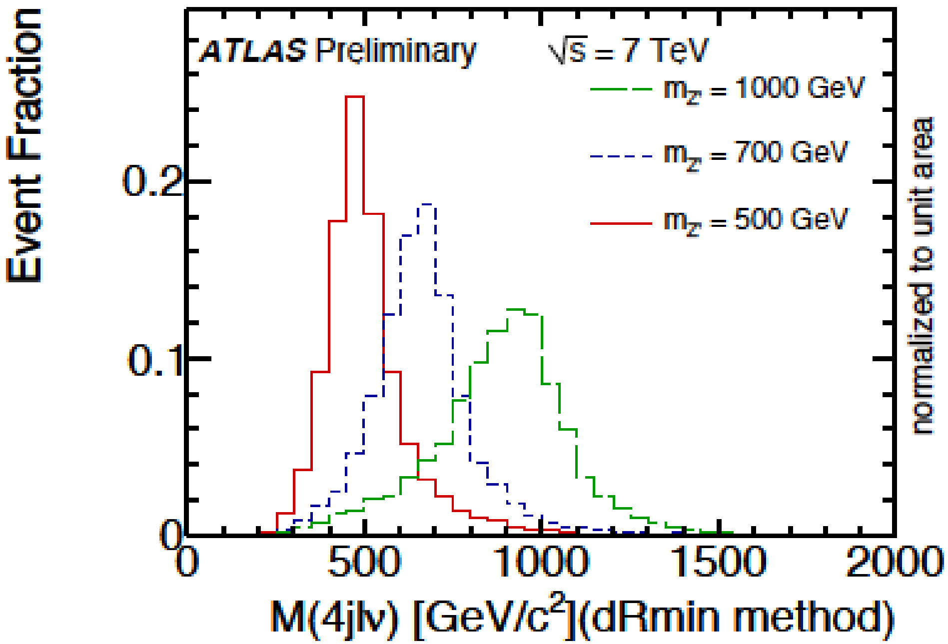


Matched jet



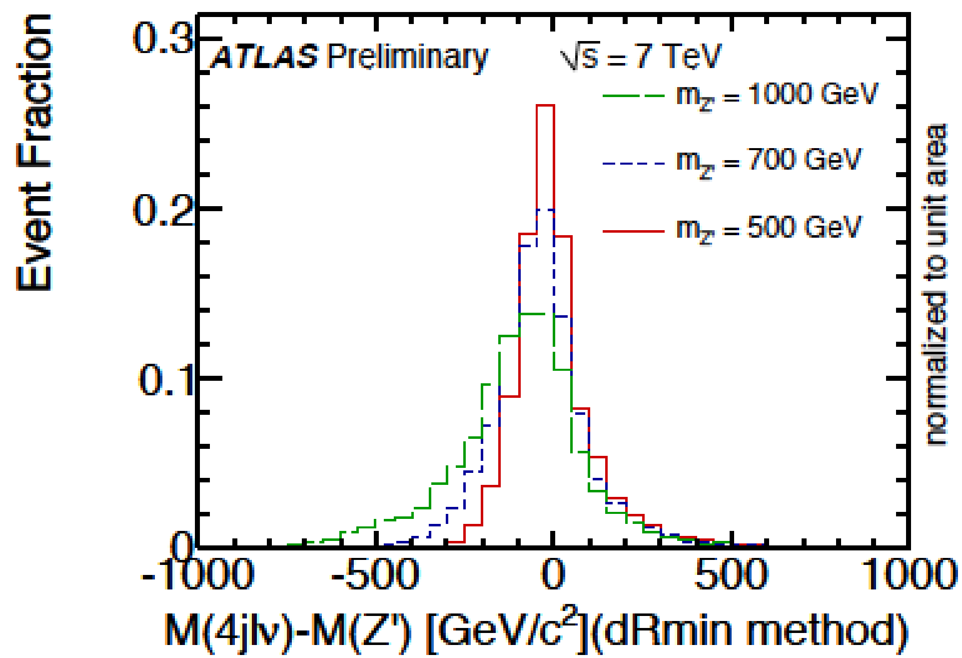
Unmatched jet

dRmin variant

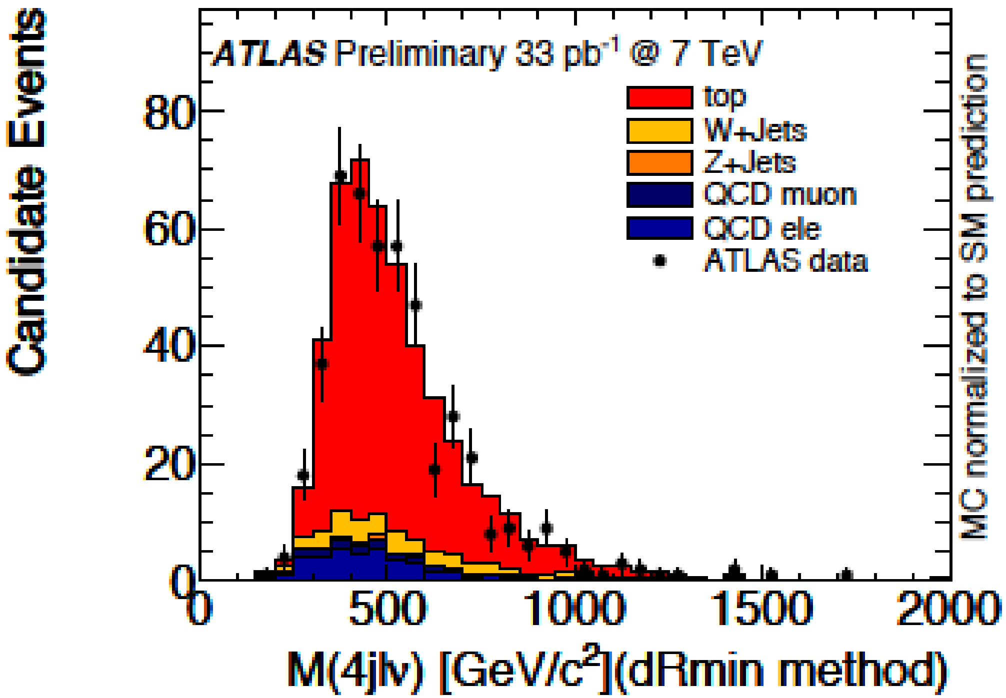


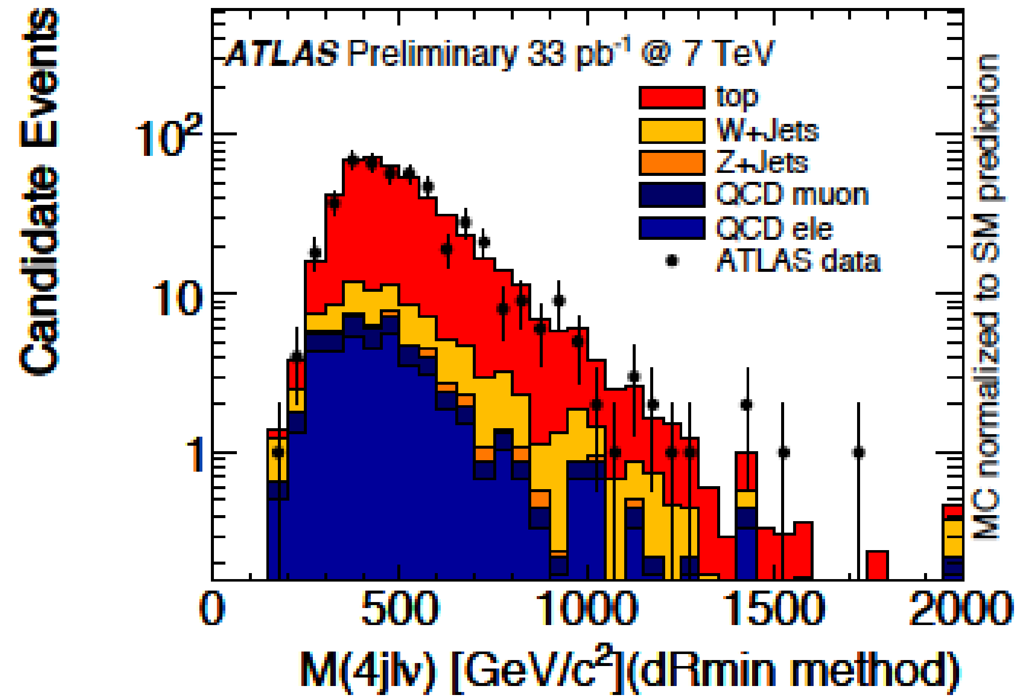
Reconstructed ttbar invariant mass using the dRmin method for three different Z' masses.

Resolution on the reconstructed ttbar invariant mass using the dRmin method for three different Z' masses.



dRmin variant



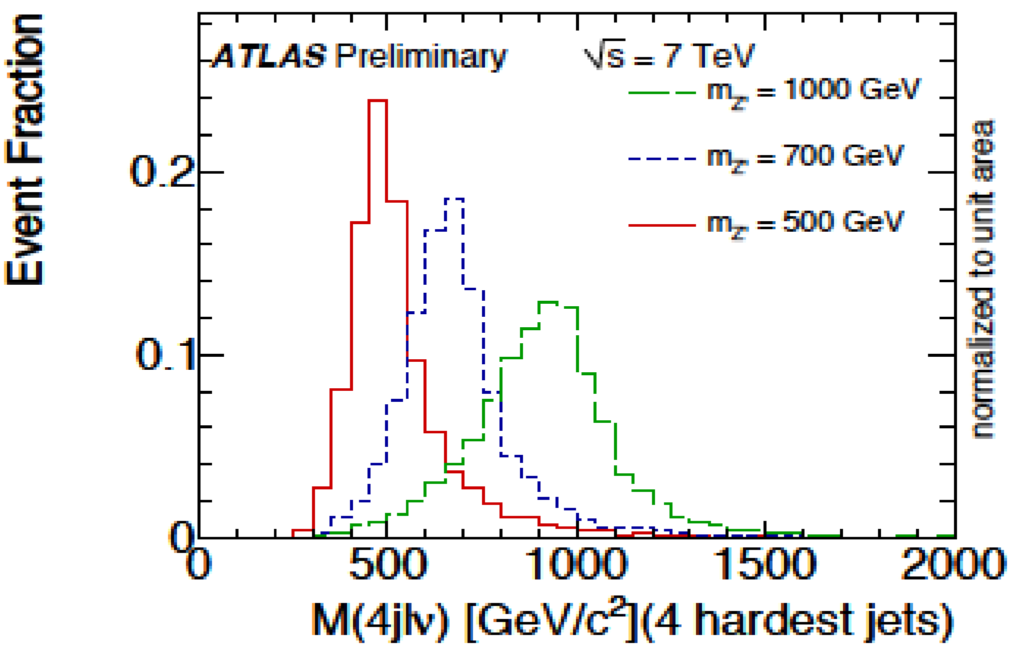


No evidence for a bump in the ttbar mass spectrum

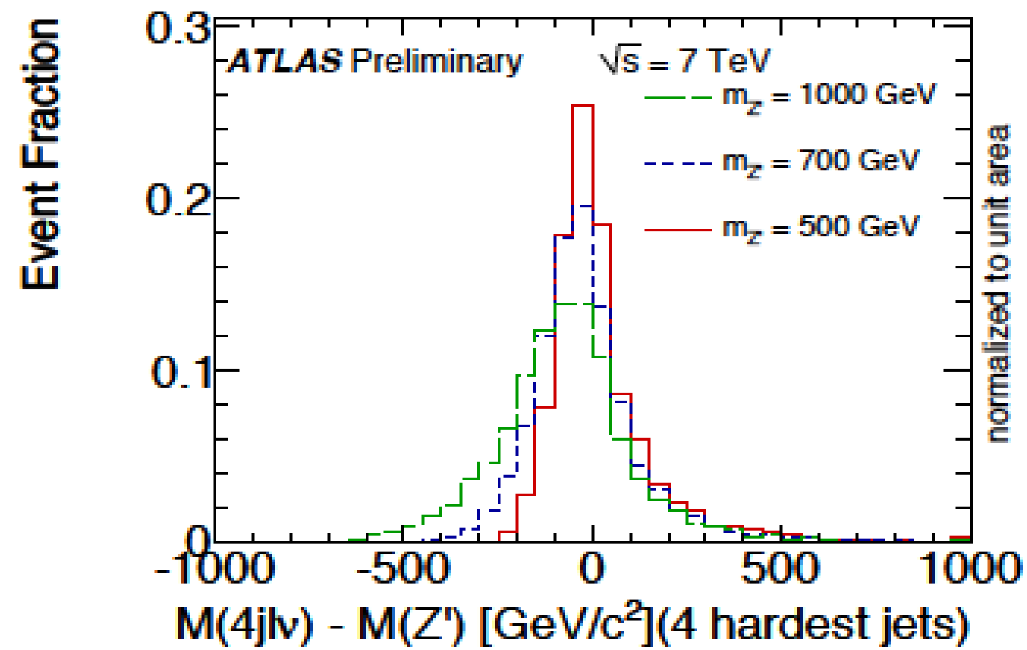
Checked with the BumpHunter tool (*arXiv:1101.0390*)

4 hardest jets

The 4 jets with the highest pt are assumed as coming from the top pair decay.

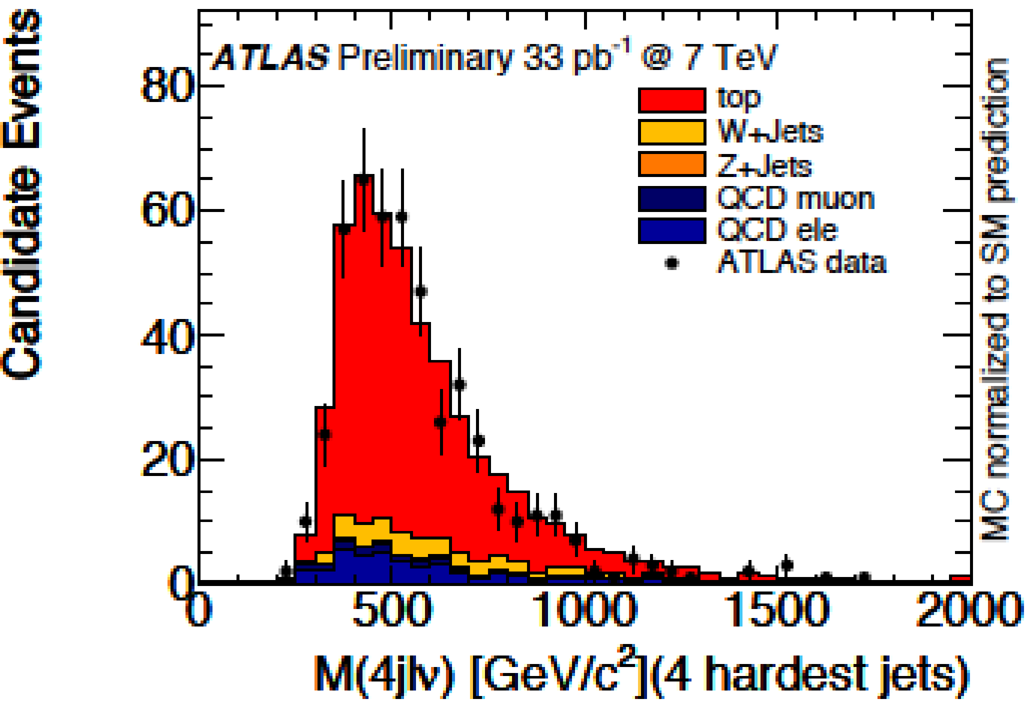


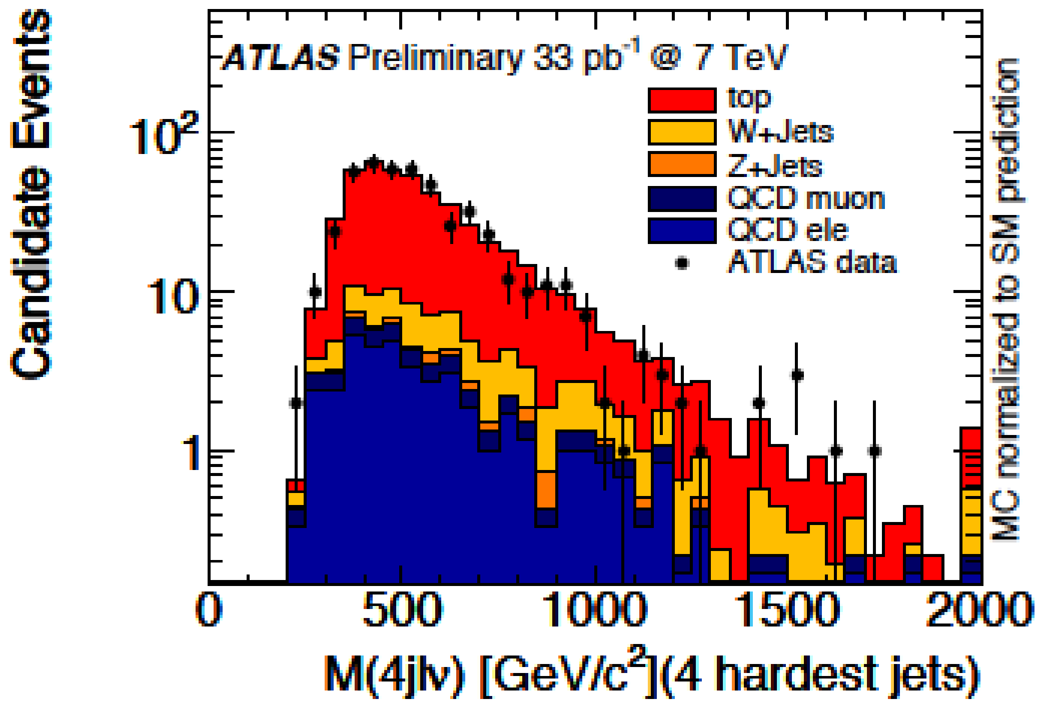
Reconstructed ttbar invariant mass using the 4 hardest jets method for three different Z' masses.



Resolution on the reconstructed ttbar invariant mass using the 4 hardest jets method for three different Z' masses.

4 hardest jets





No evidence for a bump in the ttbar mass spectrum

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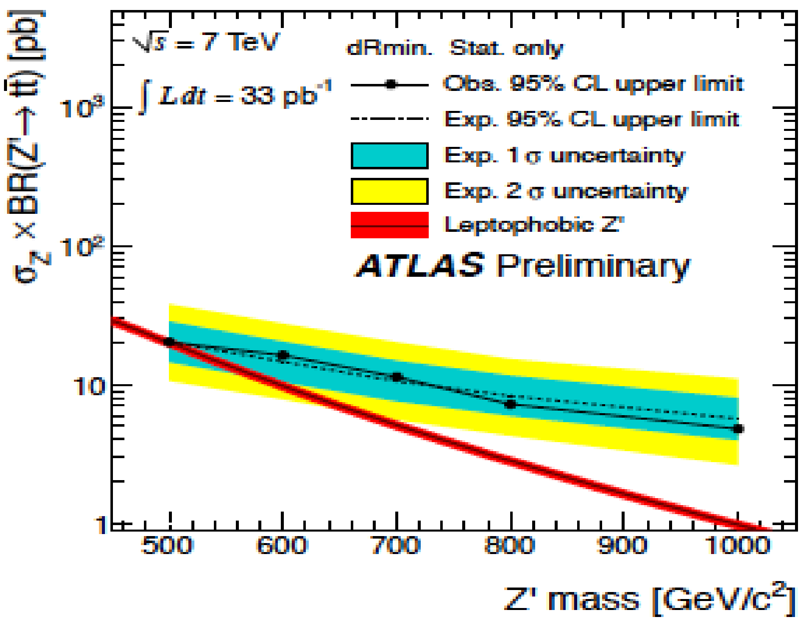
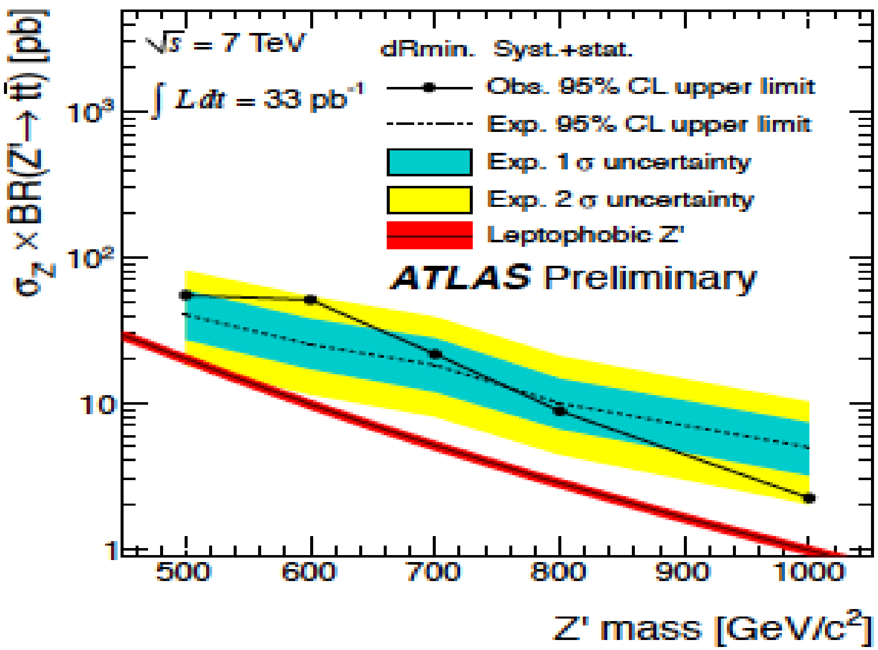
Topcolor Z' searches

Statistical unc. only



Statistical+Systematic unc



The considered model cannot be yet excluded with the dR method.
Good sensitivity for $m_{4jl\nu}$>800 GeV

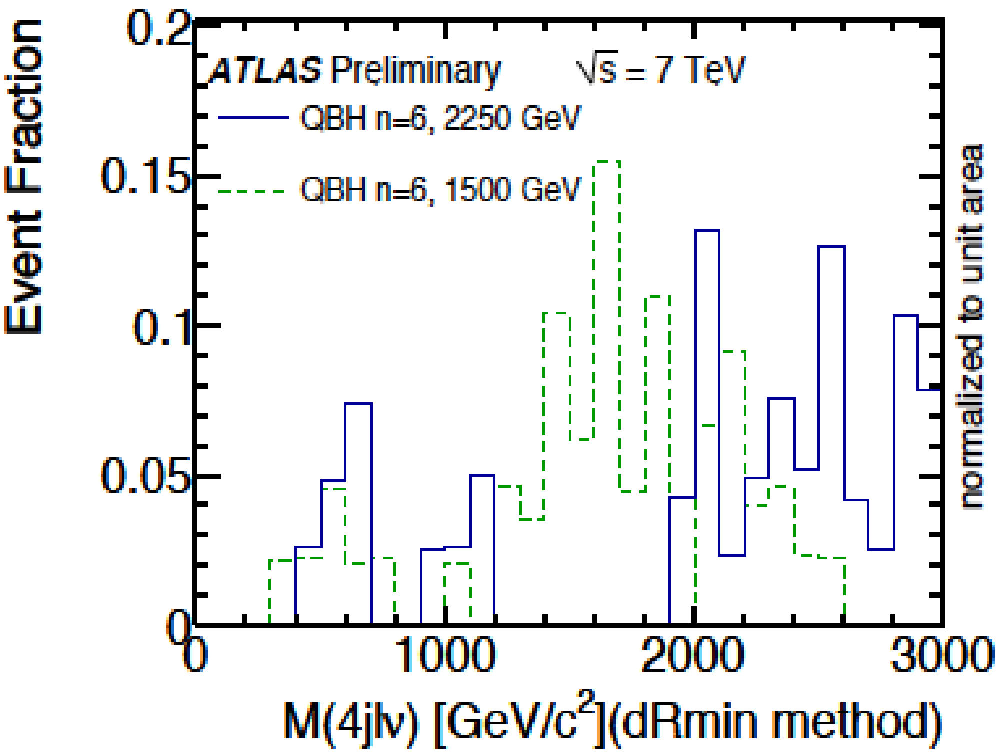
Bayesian approach :

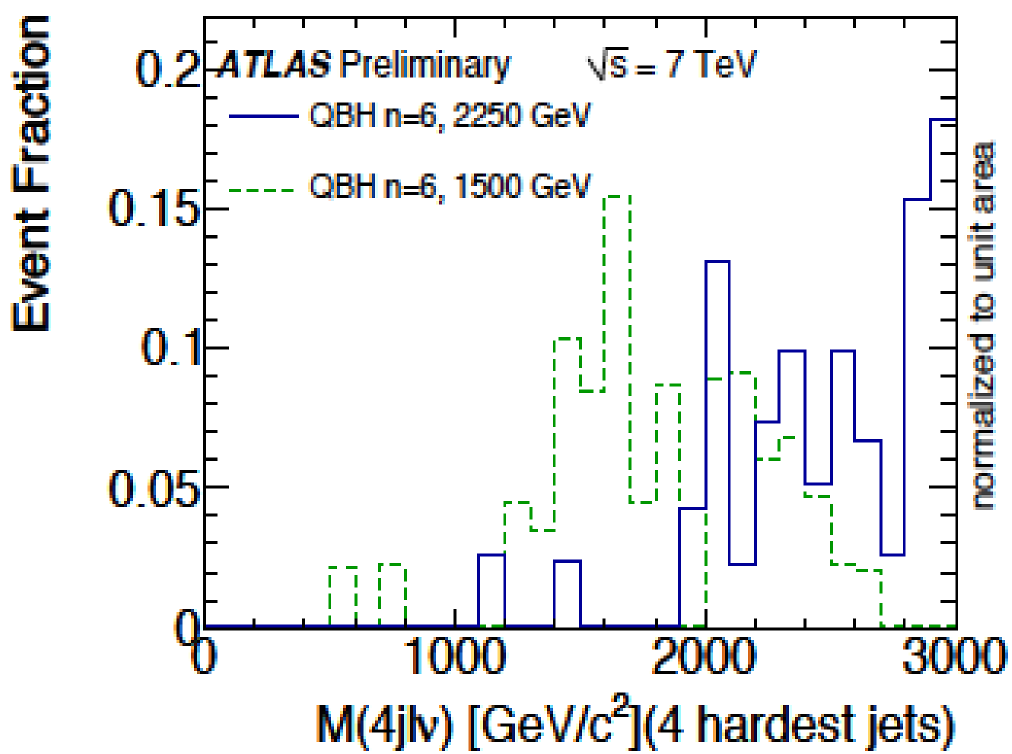
→use of a binned likelihood in $m_{4jl\nu}$

→Bayesian limit extraction method with flat priors

Quantum Black Hole (QBH) searches

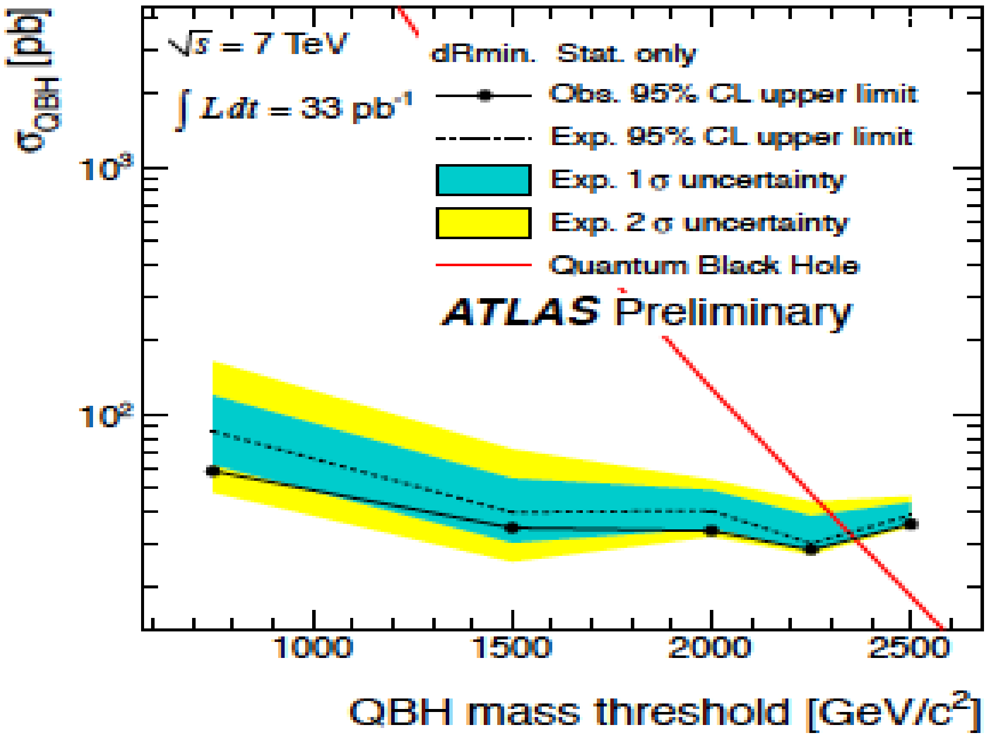
Looking for an anomalous increase in high mass t+X, where X is any kind of particle.

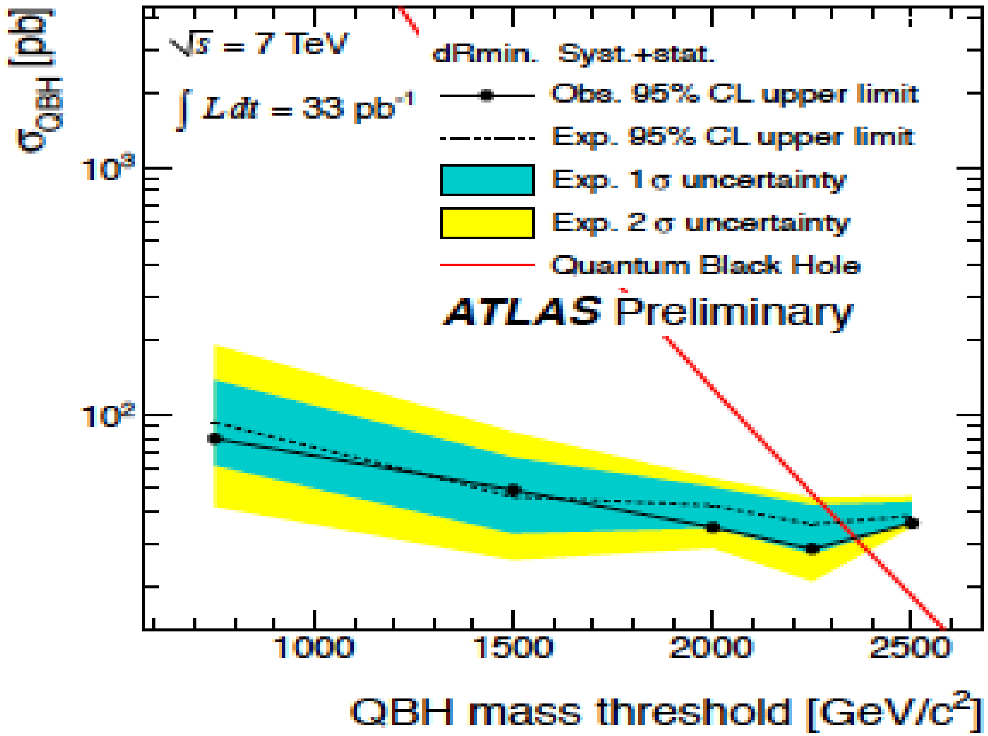




Reconstructed t+X invariant mass using the 4 hardest jet method (right) and dRmin (left) method for two different mass thresholds.

QBH searches





QBH with mass threshold below 2.35 TeV are excluded using the dRmin method

Bayesian approach :

→use of a binned likelihood in $m_{4jl\nu}$

→Bayesian limit extraction method with flat priors

Conclusions

- Small data sample but already good sensitivity to ttbar resonances
- QBH with mass threshold below 2.35 TeV are excluded by both methods

For the future

- Put limits for leptophobic topcolor Z'
- Test more models (KK gluons)

Backup

Event selection

1. The electron or muon trigger for the corresponding data-taking period, as given in Tables 1 and 2 had to have fired.
2. A primary vertex had to be reconstructed with more than four tracks originating from it.
3. If an event contained any jets with $p_T > 10$ GeV (at EM scale) that was flagged as *bad*, the event was rejected.
4. Events were required to contain at least one electron with $E_T > 20$ GeV (electron channel) or one muon with $p_T > 20$ GeV (muon channel). (This cut allows for more than one lepton, enabling reconstruction of the Z boson peak to check modeling of lepton momentum resolution.)
5. Events were required to contain exactly one electron with $E_T > 20$ GeV (electron channel) or exactly one muon with $p_T > 20$ GeV (muon channel).
6. The selected lepton was required to match the trigger lepton.
7. Events were not allowed to contain a muon with $p_T > 20$ GeV (electron channel) or electron with $E_T > 20$ GeV (muon channel).
8. Events where the electron shared a track with a muon close to a jet were rejected.
9. The missing transverse energy (E_T^{miss}) was required to be larger than 20 GeV.
10. A "triangle cut" was imposed: $E_T^{miss} + M_T > 60$ GeV, where M_T denotes the lepton+E_T^{miss} transverse mass.
11. Events were required to have at least 2 jets with $p_T{}^{jet} > 25$ GeV and $|\eta^{jet}| < 2.5$.
12. Events were required to have at least 4 jets with $p_T{}^{jet} > 25$ GeV and $|\eta^{jet}| < 2.5$.
13. At least one of the jets was required to be tagged as a b-jet.

Bump Hunter (test the null hypothesis)

- The BumpHunter looks for bumps in the spectrum: the window for which the probability that the deviation from the background is caused by a statistical fluctuation is smallest. The window sizes vary.
- The check is run on each of the channels independently, comparing electron data with electron background, and then the same for the muon channel. The most interesting bump, with window, is noted.
- *Combination of channels*: The windows found, for each channel, are compared. If they do not overlap, it is called "no signal".
  If they overlap, the combined probability is taken as the product of the individual probabilities.
- Finally the combined probability (for channel combination) or the single channel probability is compared with the probability found when running N pseudoexperiments, in which "data" is the MC background or the exponential fit with random Poisson smearings.

Backgrounds

→ tt & single top from MC (MC@NLO)
→ Z+jets & diboson from MC

W+jets background *arXiv:0804.3664 [hep-ex]*

→Taken from MC (Alpgen + Herwig)
→Scale factors for light parton subsamples fitted to data using a W sample
- Tight E_T^{miss}, M_T
- b-veto
- Normalize in 2-j bin

QCD background *arXiv:1012.1792 [hep-ex]*

→Shape templates from events with "bad" electrons
- jet-electron method (baseline): require a high-em fraction jet (jet triggers)
- anti-electron method (alternative): electron fails hadronic leakage (e triggers)

→Normalization from E_T^{miss} distribution

Systematic uncertainties

Normalization: lumi (3.4%), tt (6%), single top (10%), W+jets (35%), diboson (5%), electron trigger (1%), Reco (1.5%)

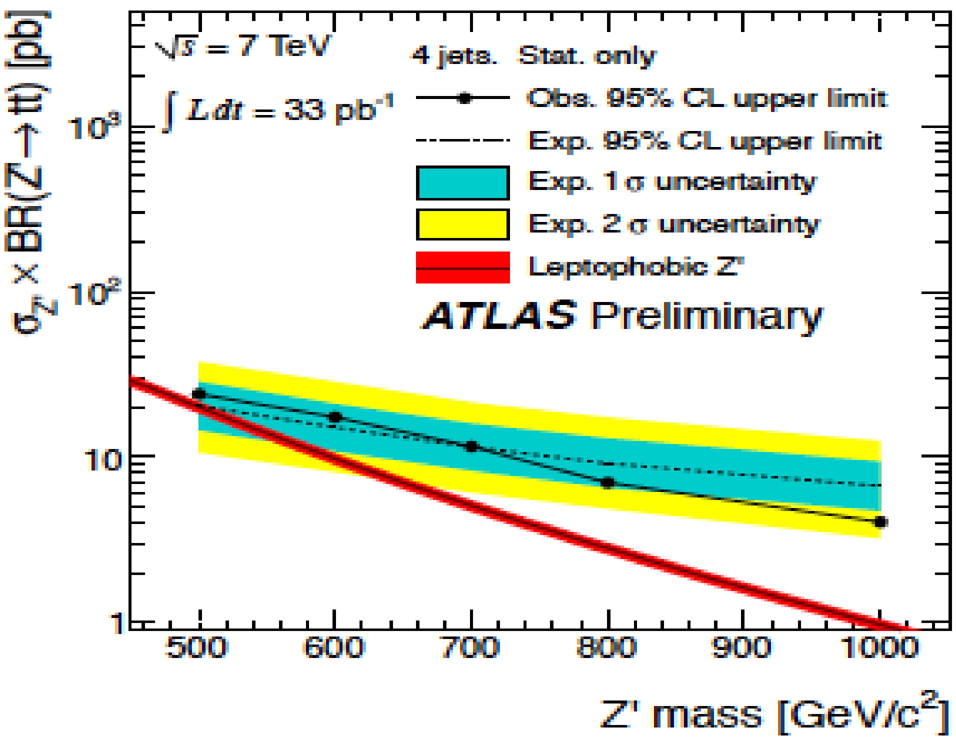
All the rest included as shape uncertainties

Dominant ones:

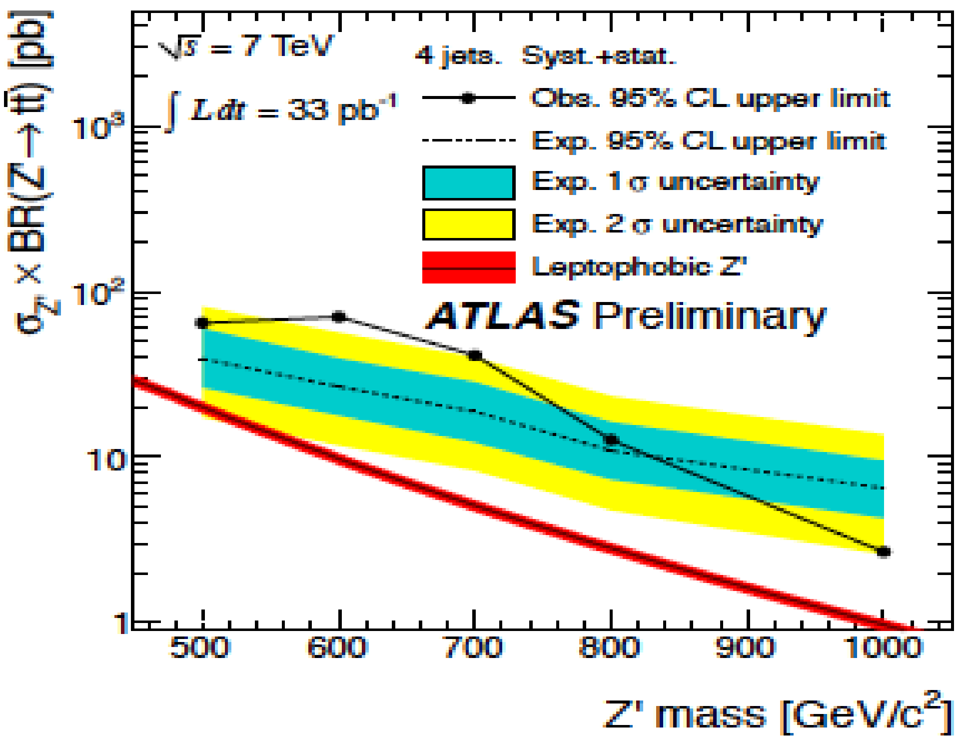
- Jet Energy Scale
- b-tagging efficiency uncertainty
- W+jets from our studies

Topcolor Z' searches (4 hardest jets)

Statistical unc. only

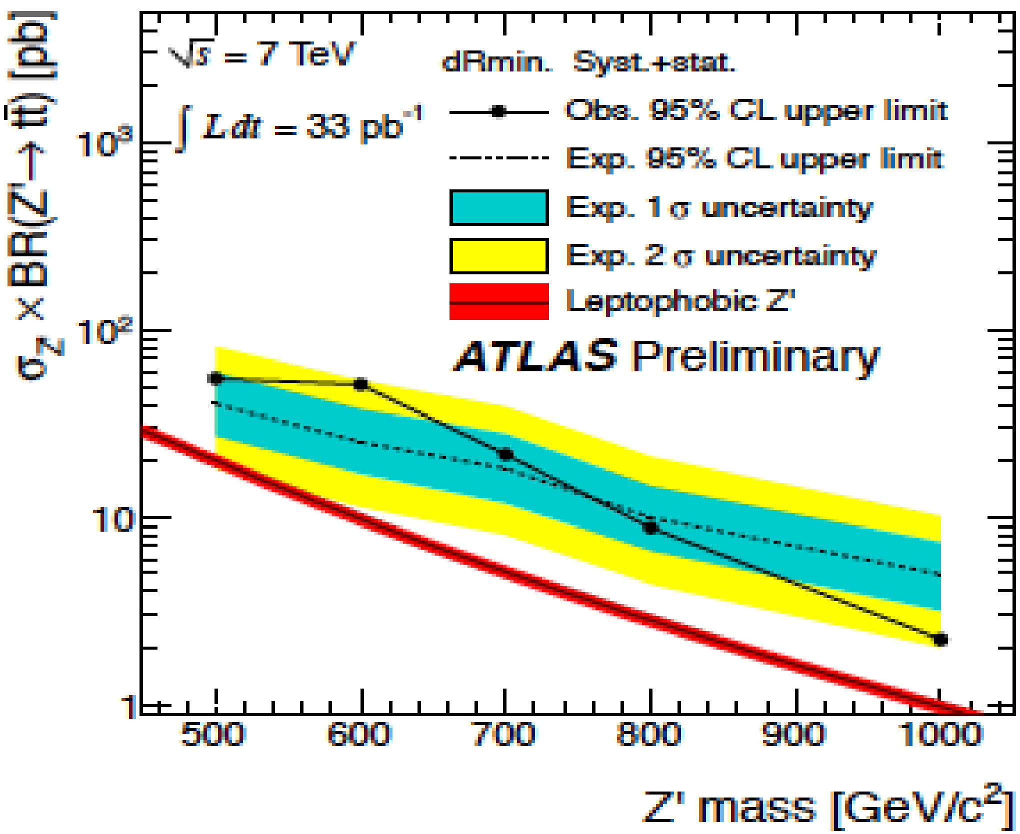


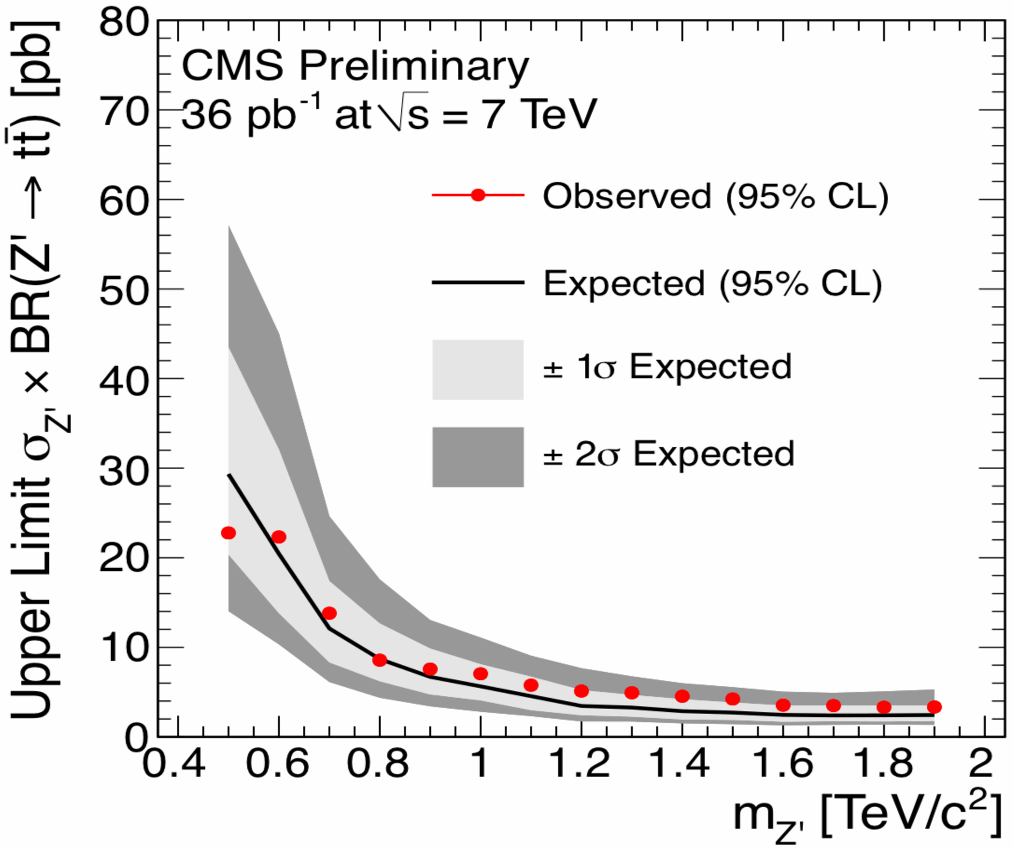
Statistical+Systematic unc



The considered model cannot be yet excluded with the 4 hardest jets method.
Good sensitivity for m_{4jlv}>800 GeV

ATLAS vs CMS

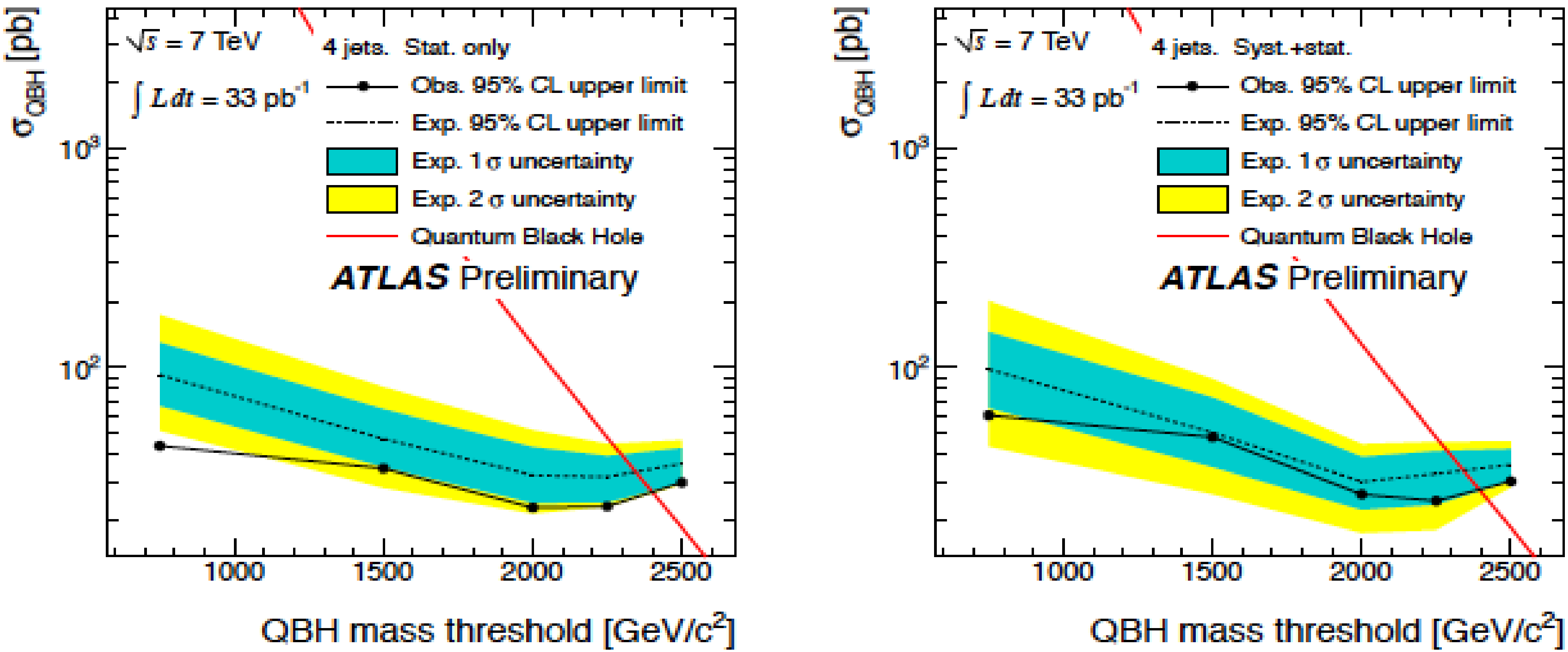




Limits range from 55 pb for Z' mass of 500 GeV to 2.2 pb at 1 TeV

Limits range from 25 pb for Z' mass of 500 GeV to 7 pb at 1 TeV
CMS PAS TOP-10-007

QBH searches (4 hardest jet)



Results obtained with dRmin method are confirmed using 4 hardest jet method