



Search for CPT Violation in the Top Quark Sector at ATLAS

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Motivation


- The CPT Theorem (combination of **C**harge, **P**arity, **T**ime reversal) states:
 - *Any local theory, which is invariant under Lorentz Transformations and defined by a Hermitian Hamiltonian is said to conserve CPT*
- CPT Conservation implies:
 - Equal masses for particles and antiparticles
 - Equal lifetimes for particles and antiparticles
- Any mass difference between a particle and its antiparticle is unambiguous evidence of CPT violation
- CPT is a fundamental piece of QFT, on which particle physics is based

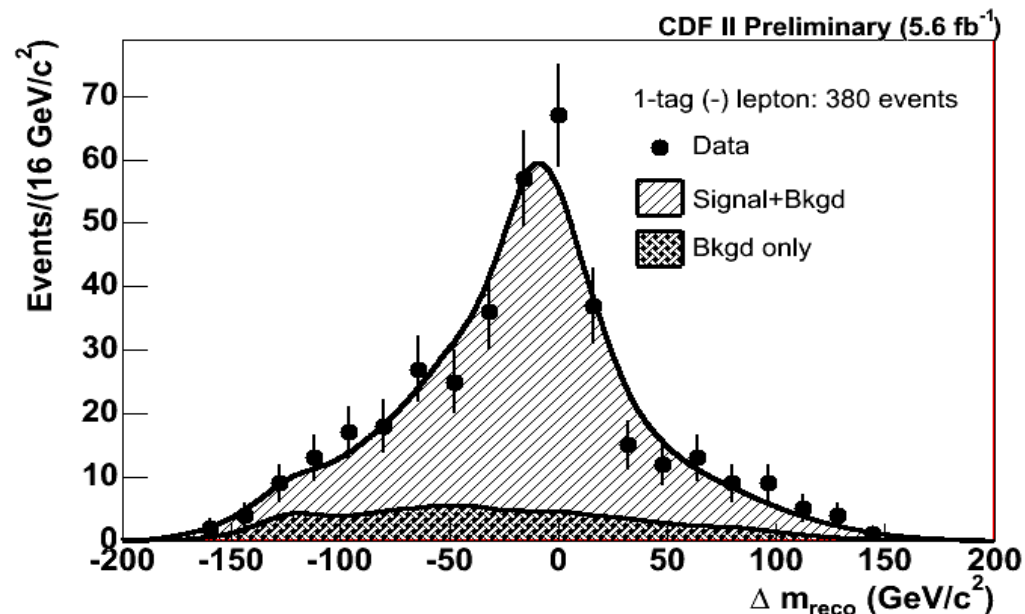


Top Antitop Mass Difference

- A mass difference between top and antitop quarks would be evidence of CPT Violation
 - No CPT Violation in SM – clear signal of new physics
- Currently, there have been two measurements made on the $t\bar{t}$ mass difference at the Tevatron

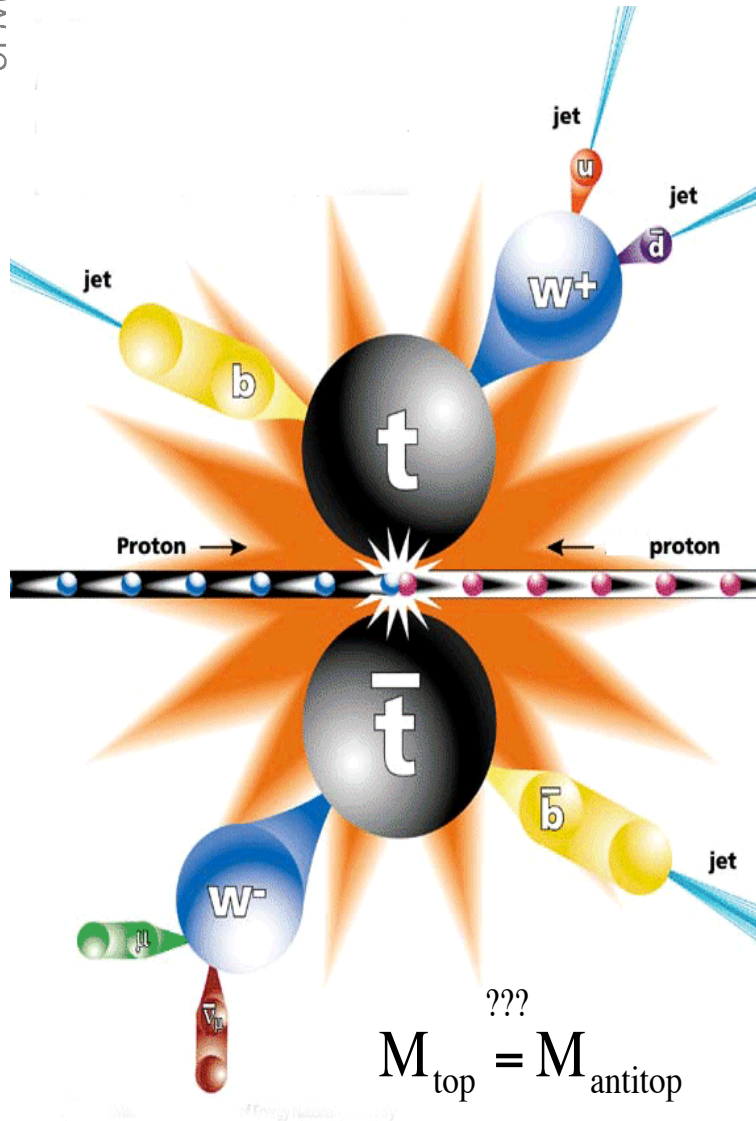
 $\Delta M_{\text{top}} (=M_t - M_{\bar{t}}) = 3.8 \pm 3.7 \text{ GeV}/c^2$ (1 fb^{-1}) (arXiv:0906.1172v3)

 $\Delta M_{\text{top}} = -3.33 \pm 1.7 \text{ GeV}/c^2$ (5.6 fb^{-1}) (arXiv: 1103.2782)





Event Selection



- The Leptons + Jets channel is used for the analysis.
- This is known as the “Golden Channel” as it has a high branching ratio with manageable background
- Events which pass the following cuts are used in the analysis (high-Pt e/mu triggers)
 - 1 lepton with Pt >20GeV
 - 4 jets Pt >20GeV (using Anti-Kt algorithm)
 - Missing Et >20GeV
 - At least 1 b-tagged jet using Secondary Vertex Tagging
 - $\chi^2 < 20$ cut is applied

Cut Flow



- Below are the Cut Flow tables for the muon channel corresponding to 35pb^{-1} of collected ATLAS data

	1 Muon + 4 Jets	≥ 1 b-tag	Trigger	$\chi^2 < 20$
Data	639	257	242	111
SM ttbar + bkgd	-	-	233.77	125.22
SM ttbar	313	228	194	107.3
Single Top	12.43	7.83	6.5	3.36
W+Jets	280.28	25.51	21.67	8.3
Z+Jets	20.14	1.08	1	0.4
QCD	-	-	10.6	5.86

SM ttbar: $M_t = M_{t\bar{t}}$ using MC@NLO with $M_t = 172.5\text{GeV}/c^2$



Reconstruction of Top-Antitop Masses

- Kinematic fitter:
 - Find the best combinations using the lowest χ^2
 - Recalibrate the lepton/jet energies

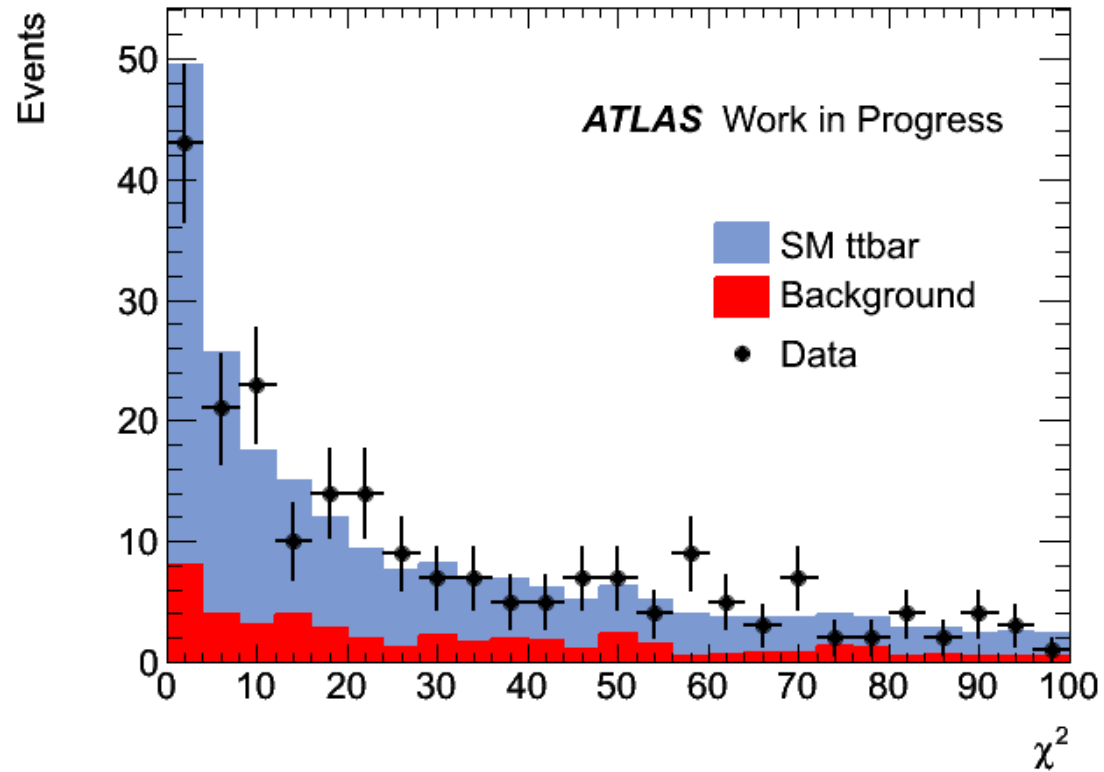
$$\chi^2 = \sum_{i=l,4 \text{ jets}} \frac{(P_T^{i,fit} - P_T^{i,meas})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(P_j^{UE,fit} - P_j^{UE,meas})^2}{\sigma_{UE}^2} + \left(\frac{M_{lv} - M_W}{\sigma_W^2} \right)^2 + \left(\frac{M_{jj} - M_W}{\sigma_W^2} \right)^2$$

$$+ \frac{\left(M_{t,leptonic} - \left(M_t - \frac{1}{2} \Delta M_t \right) \right)^2}{\sigma_t^2} + \frac{\left(M_{t,hadronic} - \left(M_t + \frac{1}{2} \Delta M_t \right) \right)^2}{\sigma_t^2}$$

- 3rd and 4th terms: W mass constraint (leptonic & jet energies)
- Last two terms: fit ΔM_t with constraint on the $(M_t + M_{tbar})/2$ to be the PDG value
- Jet and leptons energies are allowed to be varied within their uncertainties.

χ^2 Distribution with 35pb^{-1}

MC vs Data

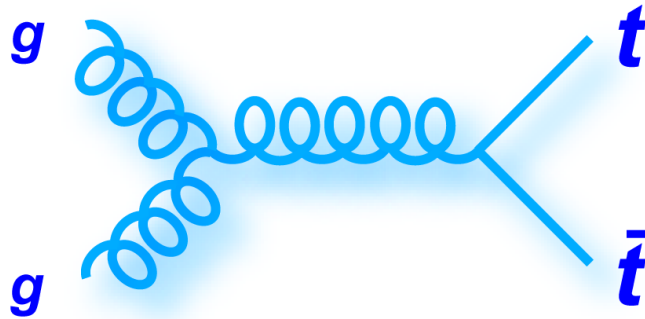


- A good agreement between data and MC



Signal MC Generation with $\Delta M_{\text{top}} \neq 0$

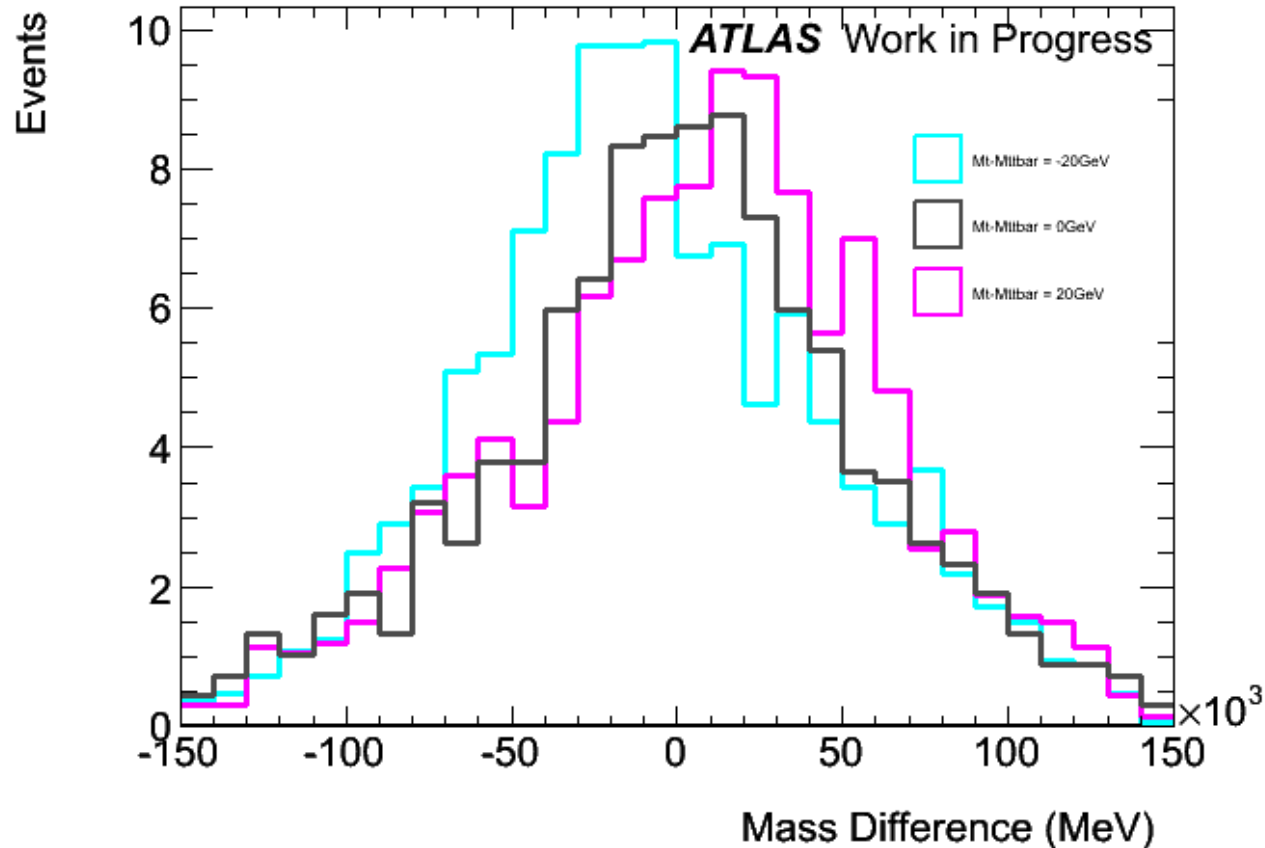
- In SM $t\bar{t}$ production, top and antitop have the same mass (true in the SM MC).



- A Modification to Pythia had to be made to allow individual tuning of the top and antitop masses in order to create some samples in which the $\Delta M_{\text{top}} \neq 0$, for the analysis
- Eleven high statistic samples were made with various ranges of mass differences between -20GeV and 20GeV.



MC Signal Samples: $M_t \neq M_{t\bar{t}}$

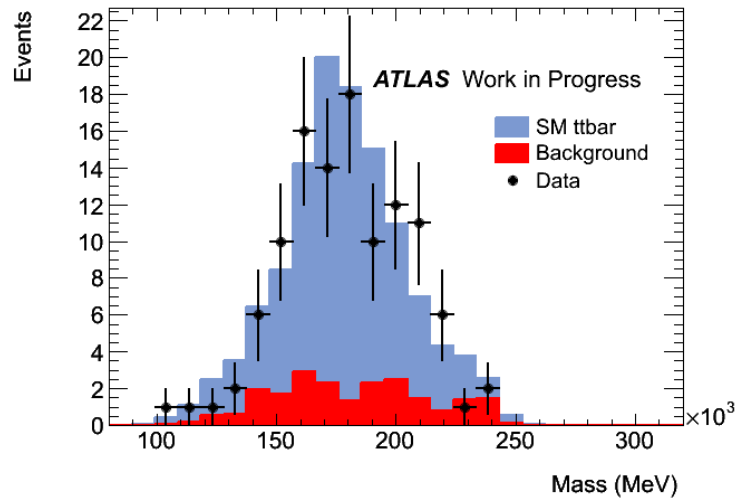


- The plot above shows reconstructed mass difference for 3 signal samples, -20GeV , 0GeV and 20GeV .
- One can see 3 different peak positions for the different Mass plots

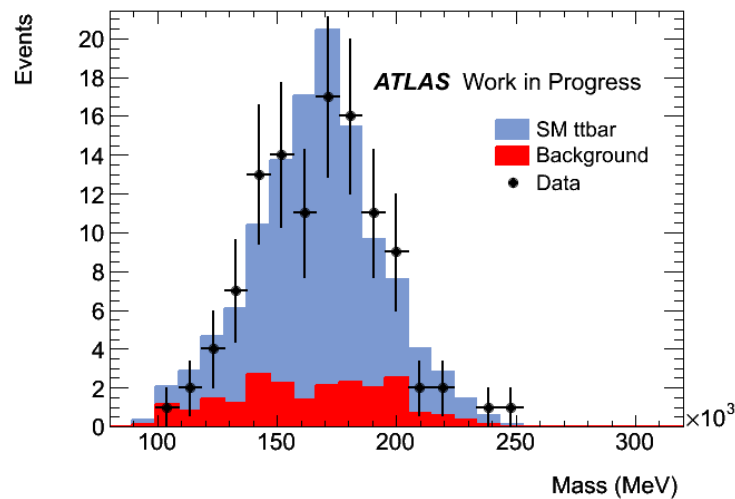


ΔM_t , M_t , & $M_{t\bar{t}}$ for Positive Lepton

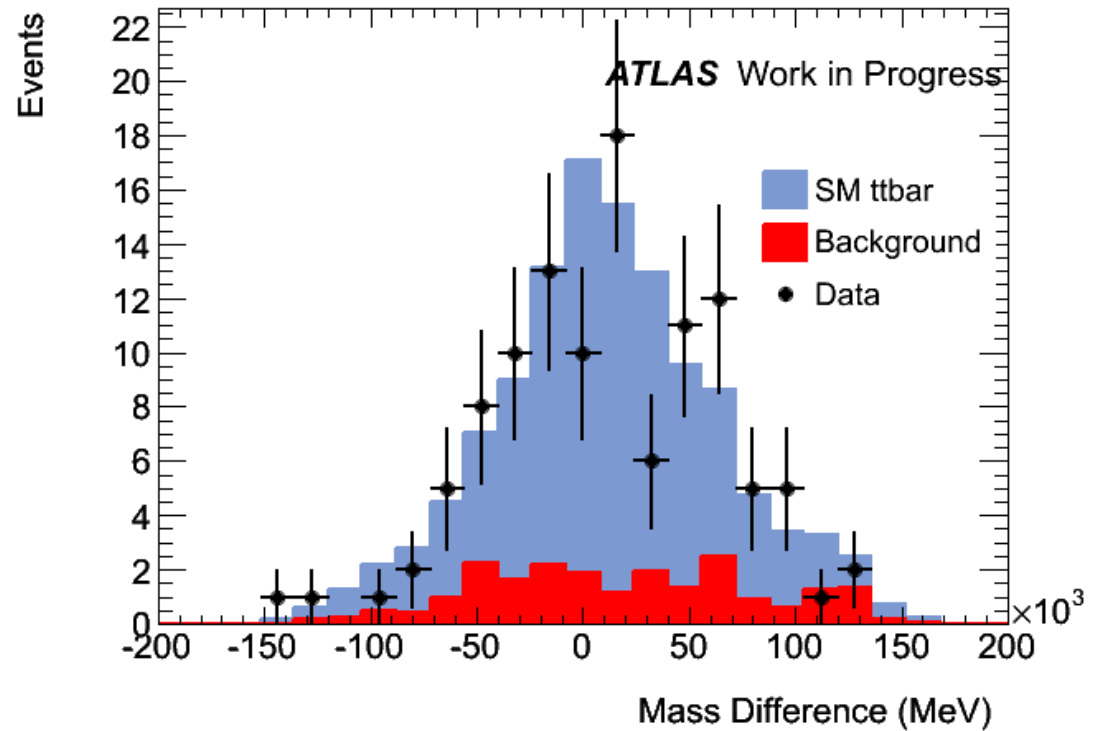
Top (leptonic)



Antitop (hadronic)



Mass Difference: Top (leptonic) – Antitop (hadronic)

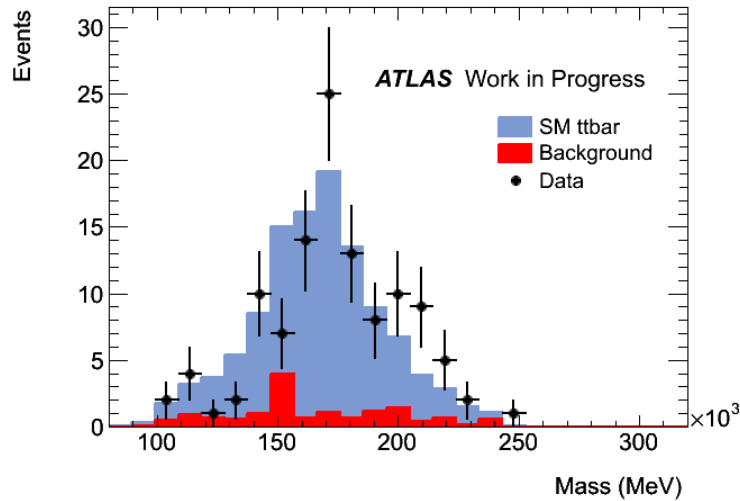


Top charge is identified by the lepton charge

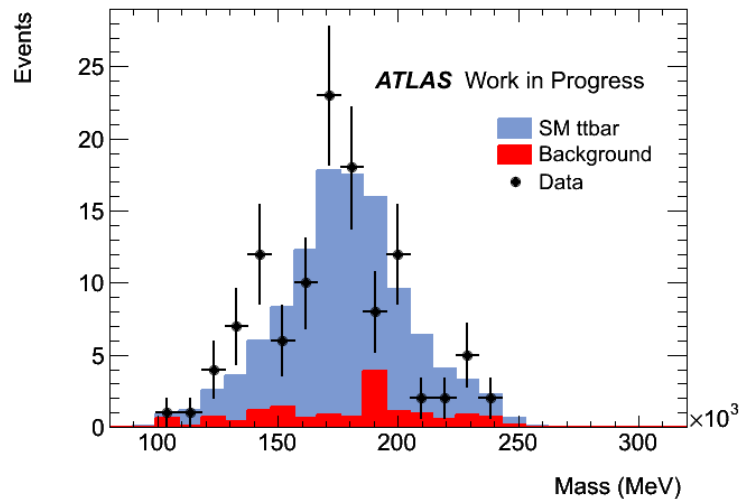


ΔM_t , M_t , & $M_{t\bar{t}}$ for Negative Lepton

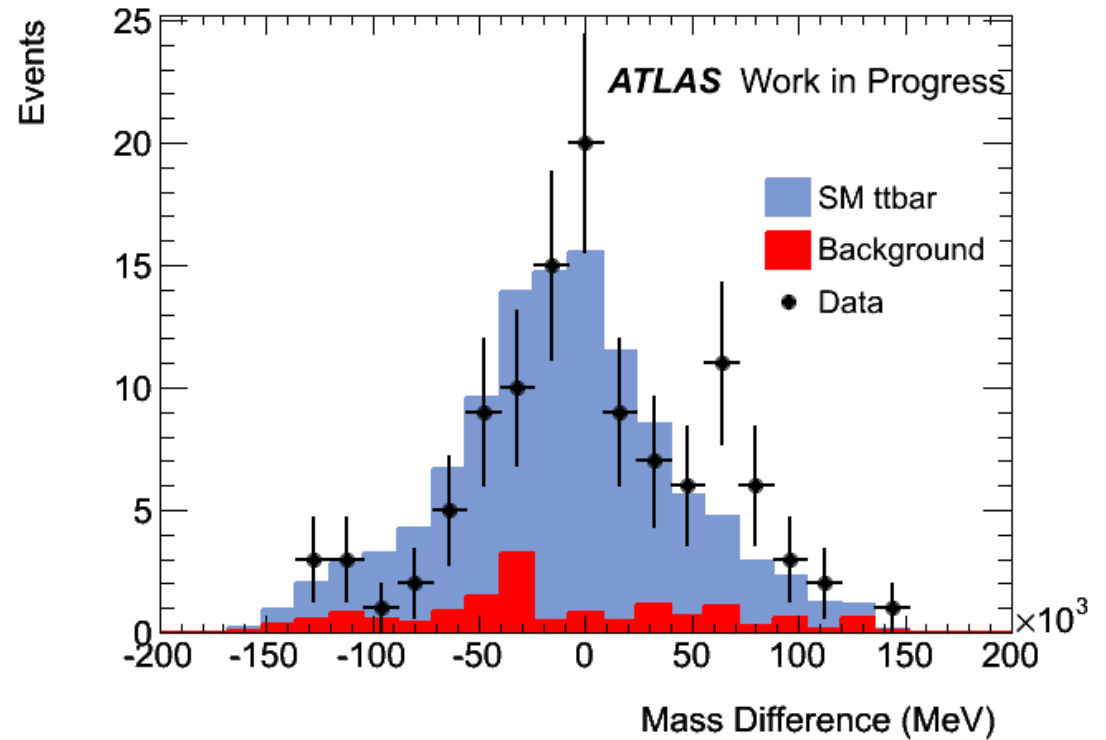
Top (hadronic)



Antitop (leptonic)



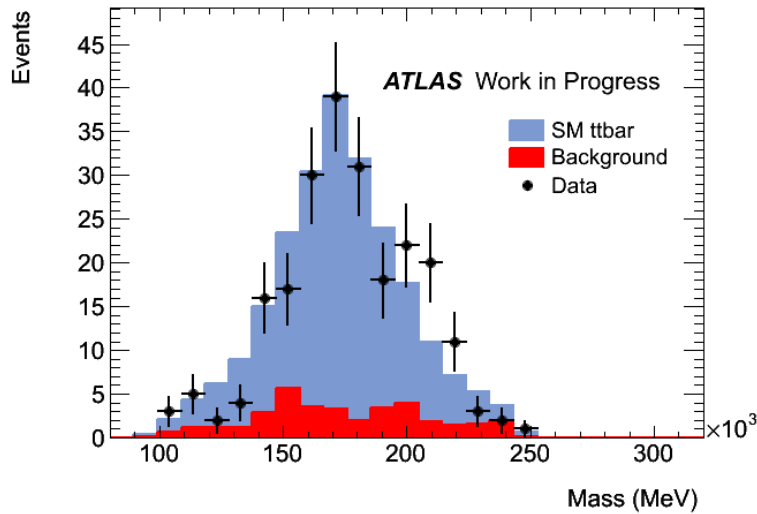
Mass Difference: Top (hadronic) – Antitop (leptonic)



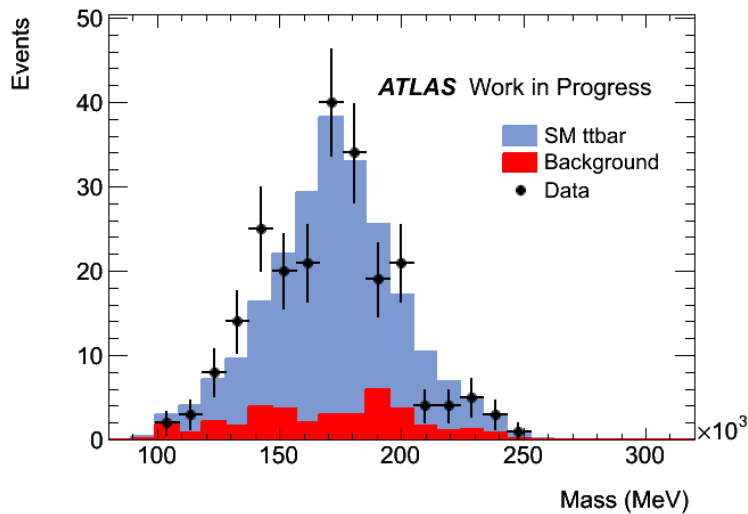


Combined for Positive and Negative Leptons

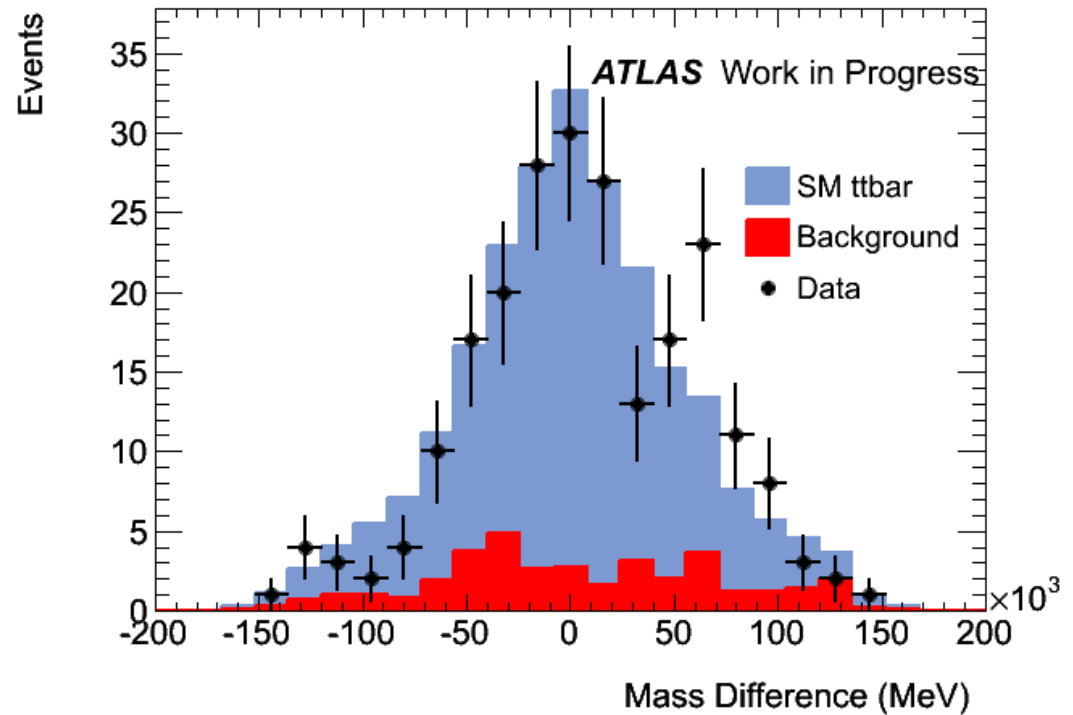
Top Mass



Antitop Mass



Mass Difference: Top – Antitop





Summary and Plans

- A first look at the mass difference between the Top and the Antitop looks quite promising:
 - A reasonable agreement between data (35pb^{-1}) and MC (SM $t\bar{t}$ bar + backgrounds)
- Plan to extract the mass difference using Maximum Likelihood fit.
- Expect to show the results in coming summer conference