Search for the Supersymmetric Stop: Top Reconstruction Techniques in 0-Lepton Direct Stop Searches

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Overview

- ❑ATLAS and the Big Picture
- ❑Project Introduction
- ❑Completed Work
- ❑Results
- ❑Future Plans
- ❑Pictures

ATLAS AND THE BIG PICTURE

A Toroidal LHC Apparatus

- 1 of the 2 "general purpose" detectors at the LHC.
- Goals:
  - Precise measurement of Standard Model processes
  - Search for the Higgs Boson
  - Search for new physics such as SUSY, extra dimensions, etc.

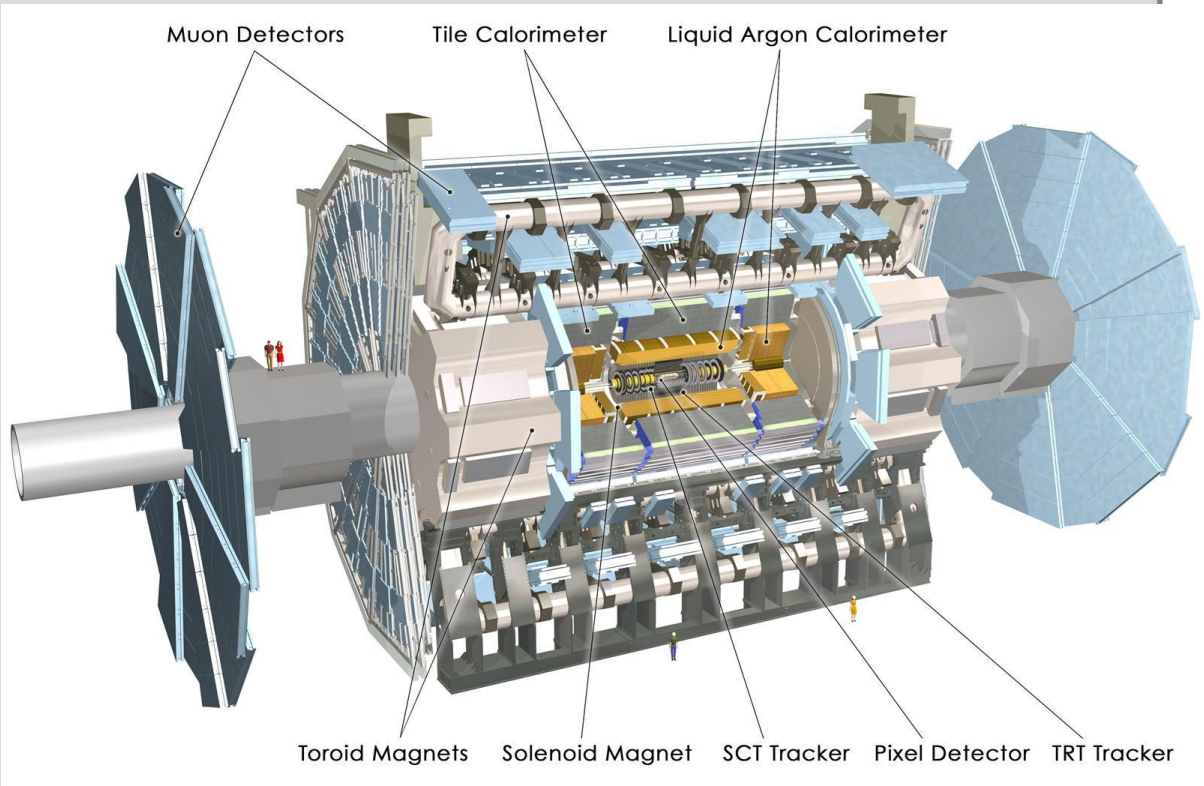


Image Courtesy of CERN: CERN-GE-0803012

The Big Picture

- **<u>Why Supersymmetry (SUSY)?</u>**
  1. Provides answers to the "fine-tuning" problem of the Higgs Boson Mass.
  2. May help us understand Dark Matter.
  3. Is a component in nearly all String Theory Models. No SUSY, no String Theory.
- **<u>Why stop?</u>**
  1. Often one of the lightest SUSY particles, meaning it is one of the most likely to be found at the LHC.
  2. Biggest contributor to the stabilization of the Higgs mass.

PROJECT INTRODUCTION

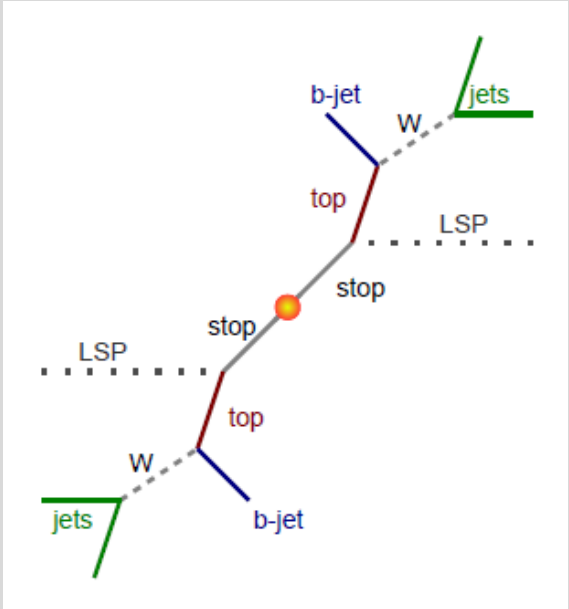
0-Lepton Direct Stop Squark Searches

- Proton collisions produce a stop anti-stop pair:

$$pp \rightarrow \tilde{t}\bar{\tilde{t}} + X$$

- Stop decays within the detector to a top quark and an undetected particle (model dependent e.g. neutralino):

$$\tilde{t} \rightarrow t + \tilde{\chi}^0{}_1$$



- Each top quark decays hadronically to 3 jets (for a total of 6):

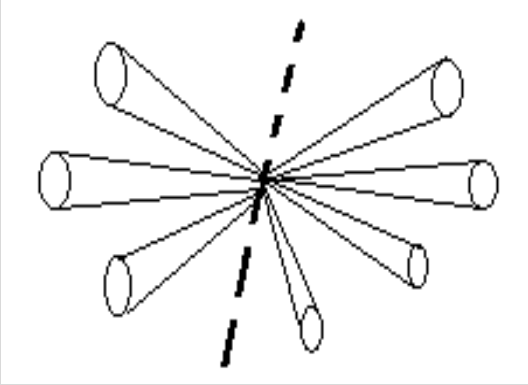
$$t \rightarrow b + W, W \rightarrow \text{jets}$$

- Largest Background: $t\bar{t} \rightarrow bjj + b\tau\nu$

Top Reconstruction

Goal:

Determine a more efficient way to reconstruct two top quarks, given an event with 6+ jets. Where "efficient" refers to recovering top quarks that decay from stop squarks more often than those from non-stop processes (for example ttbar).



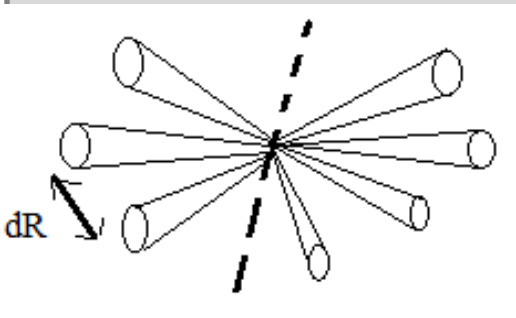
How Will It Be Used?:

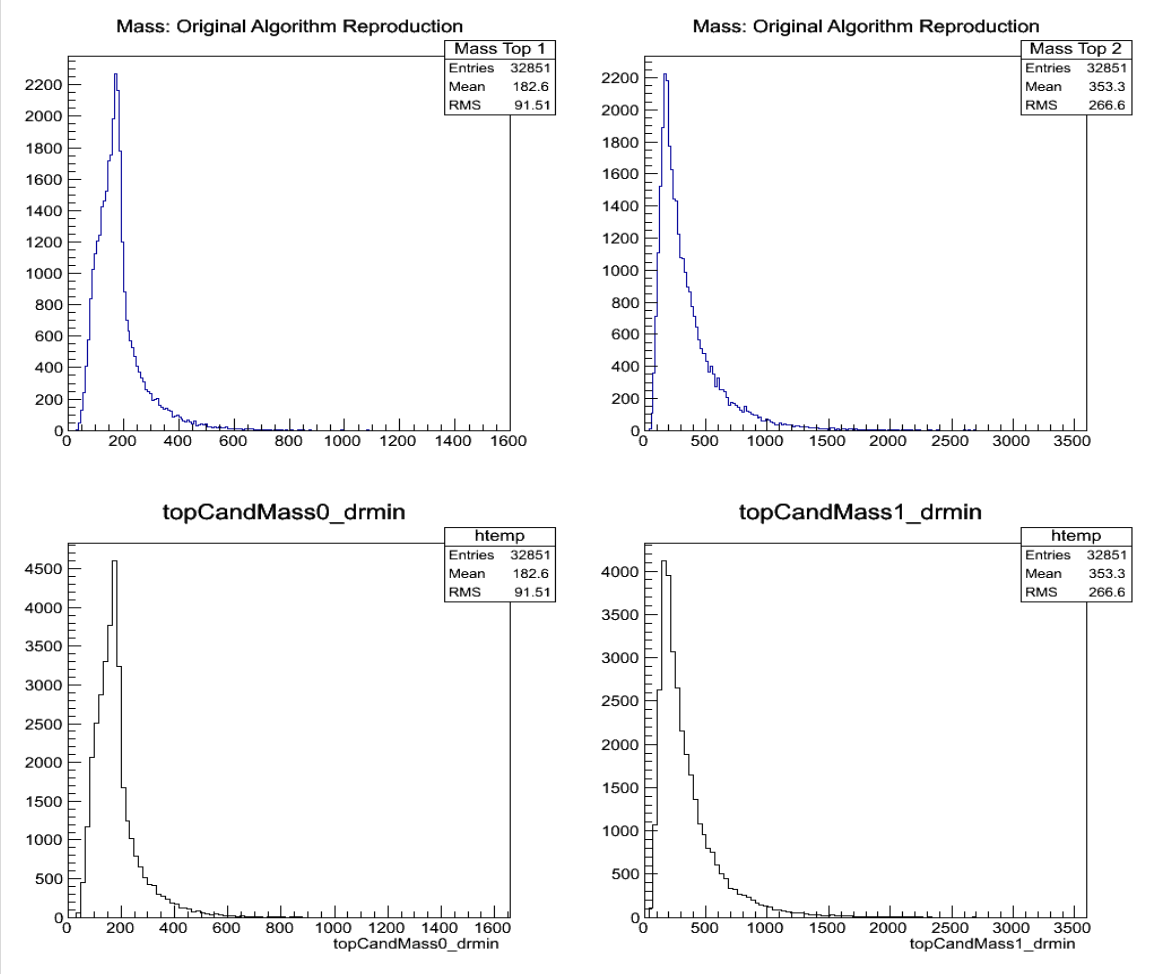
The most efficient algorithm will be implemented into the 0-lepton direct stop search. Events with large amounts of missing E_T will be reconstructed into two top quarks. If two tops are found, it may be an indication that a stop squark pair decayed in the event.

WORK COMPLETED

Recreating “dR Method”

Background:



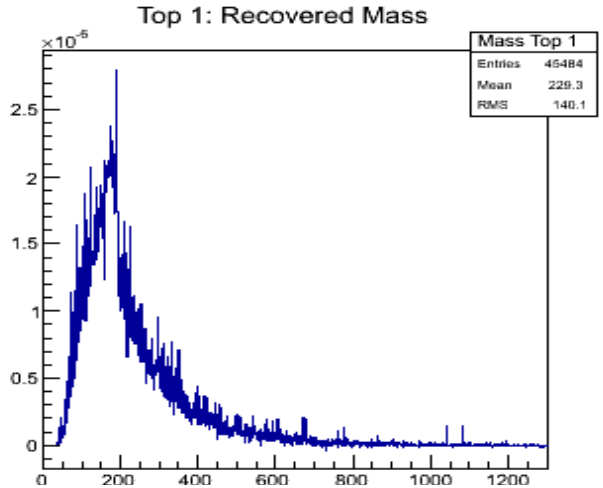


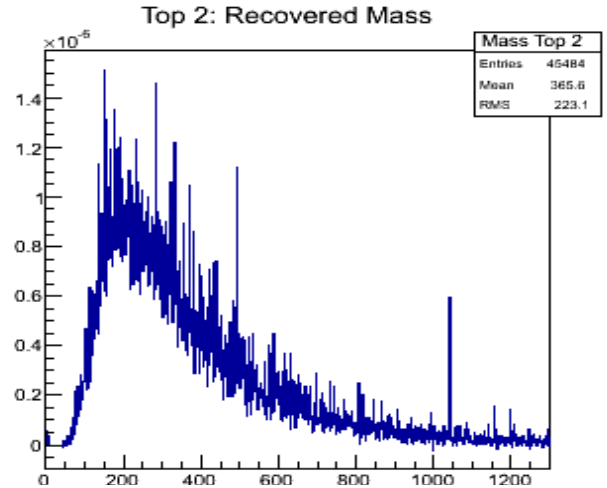
Developing First "New Methods"

- Used different looping schemes to determine their effect on the recovered top masses.
- dR method determines the first W, then the first top as a whole, then repeats for the second W and top.
- dRBothAtOnce determines both W's in the same looping structure, then creates the tops (adding a b to each W) in a separate loop.
- sixAngle recreates both tops at once, using B tagging information to limit the possibilities.
- threeAngle recreates one top at a time, all at once.

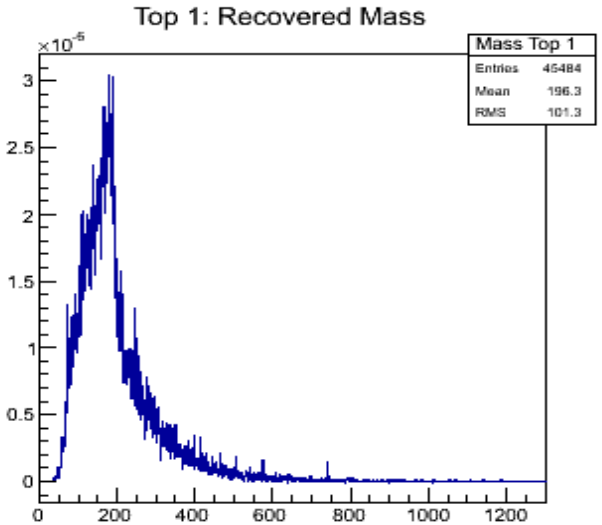
Background Histograms

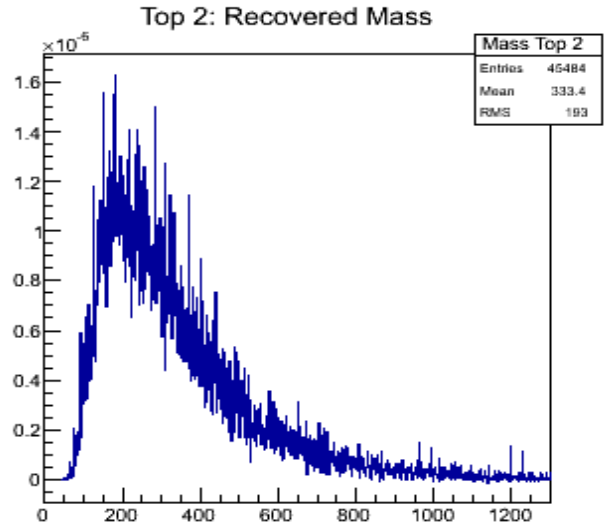
dR method:





sixAngle:

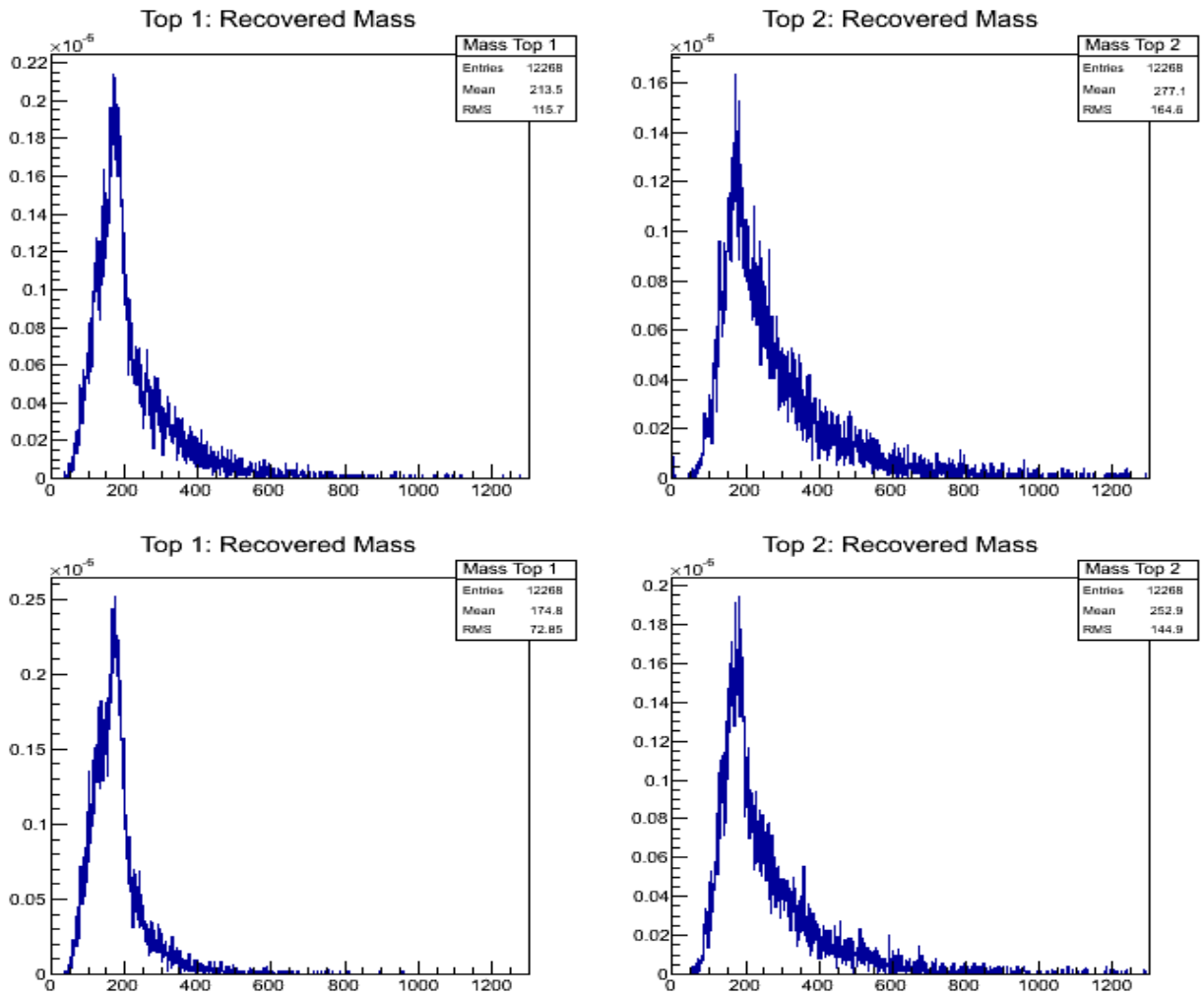




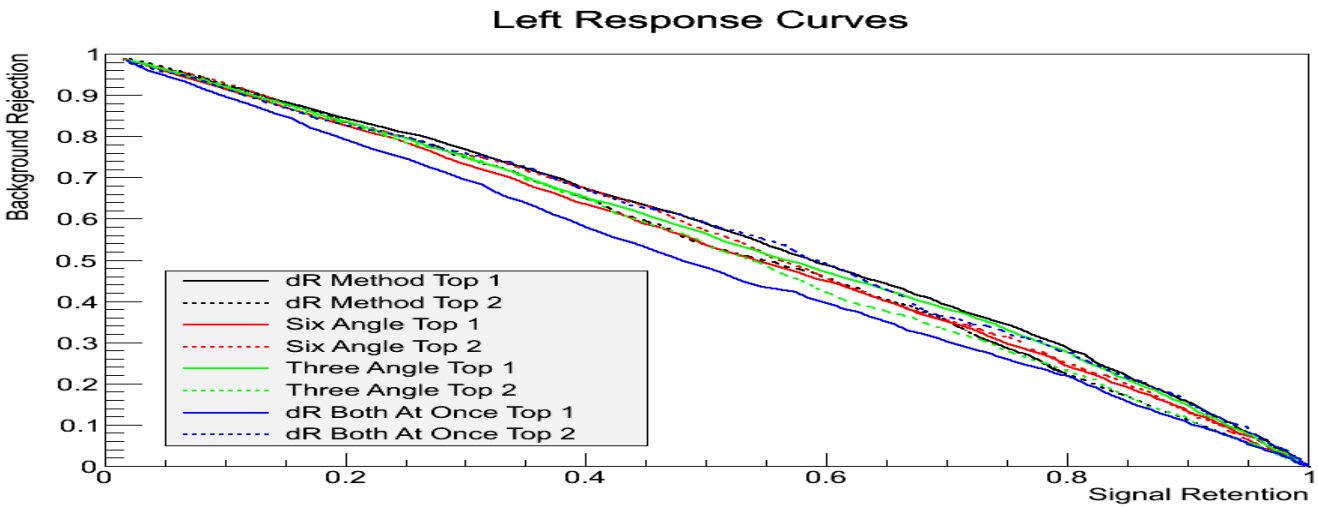
Signal Histograms

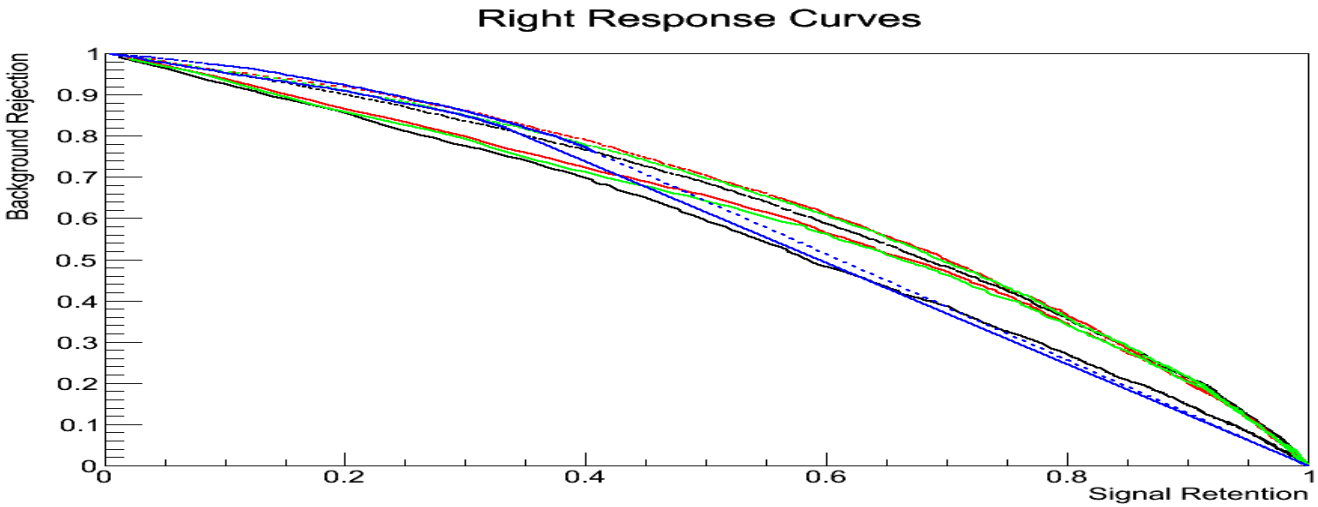
dR method:

sixAngle:



Response Curve: Clustering Methods





χ^2 ttbar Method

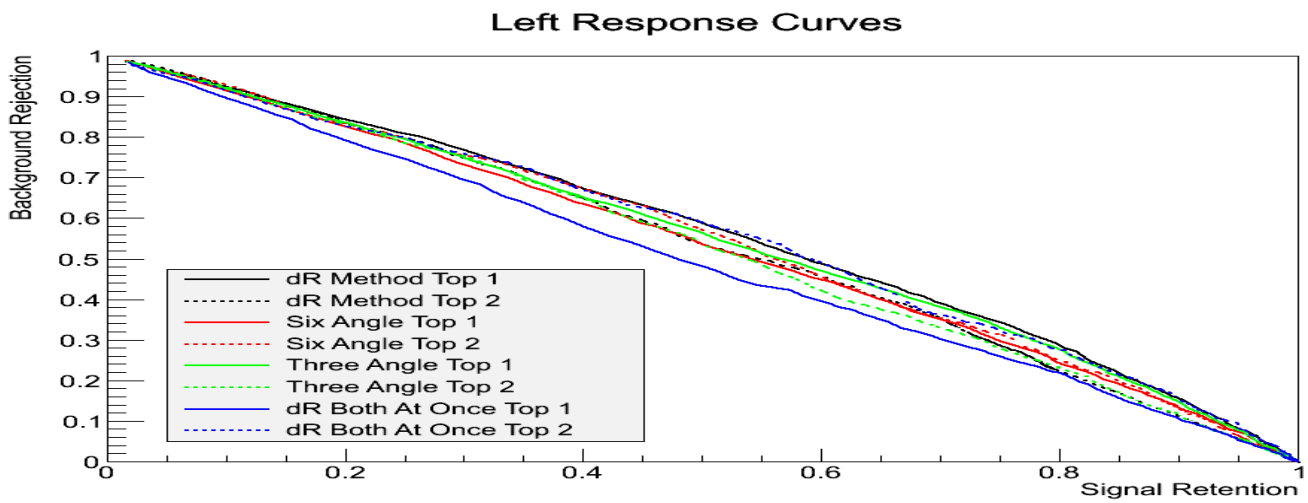
- Define a χ^2 variable*:

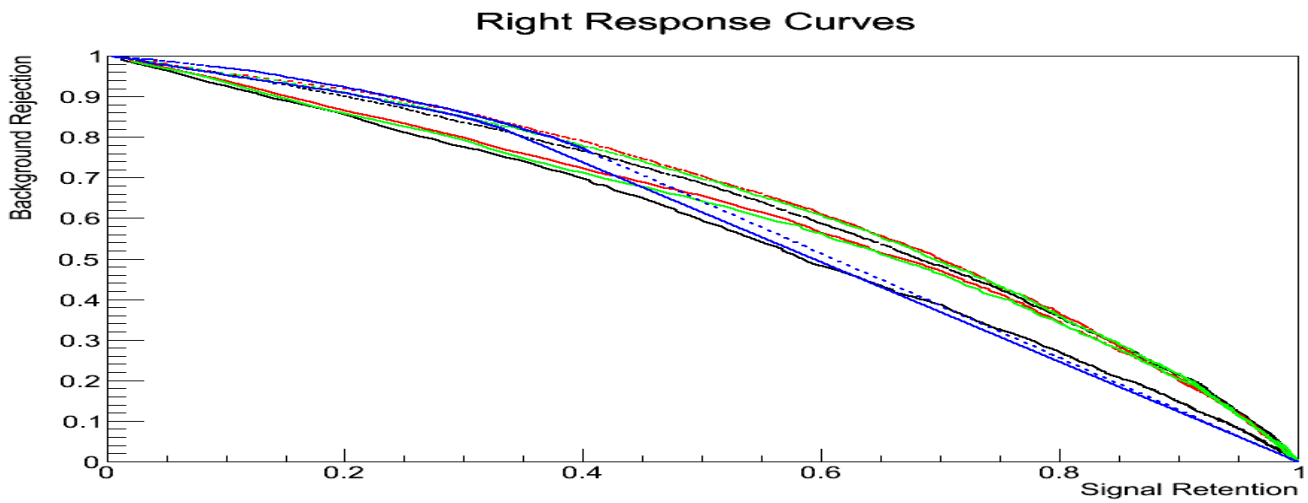
$$\chi^2 = \frac{(m_{j_1,j_2} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_1,j_2,b_1} - m_t)^2}{\sigma_t^2} + \frac{(m_{j_3,j_4} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_3,j_4,b_2} - m_t)^2}{\sigma_t^2}$$

- σ_W = 10.2GeV and σ_t = 17.4 GeV are the respective mass resolutions given by Monte Carlo*.
- Loop over all combinations to minimize the global value of χ^2 for the two recovered tops.

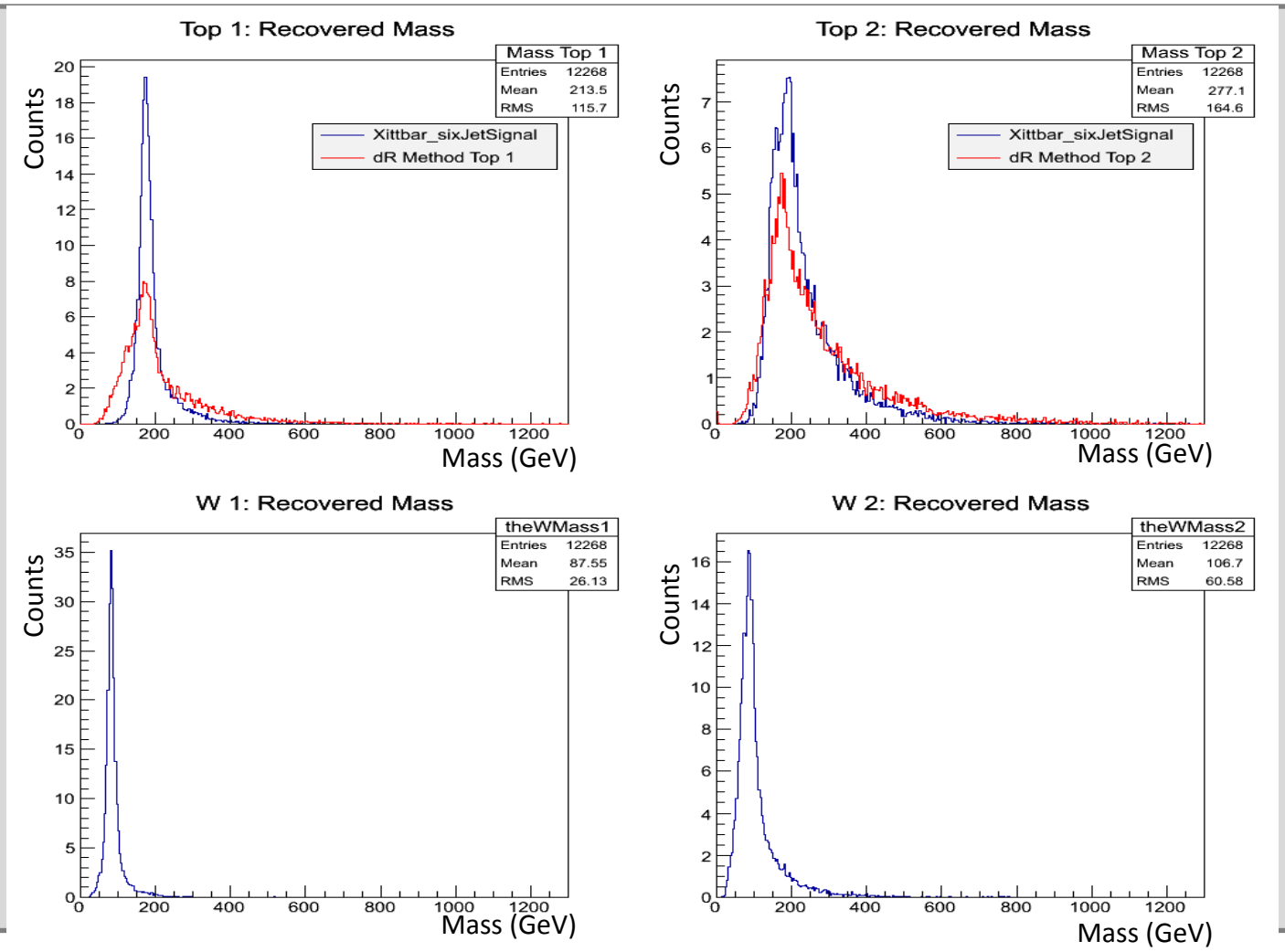
*See: ATLAS Collaboration, *Determination of the Top Quark Mass with a Template Method in the All-Hadronic Decay Channel*. ATLAS-CONF-2011-030.

Response Curve: χ^2 ttbar

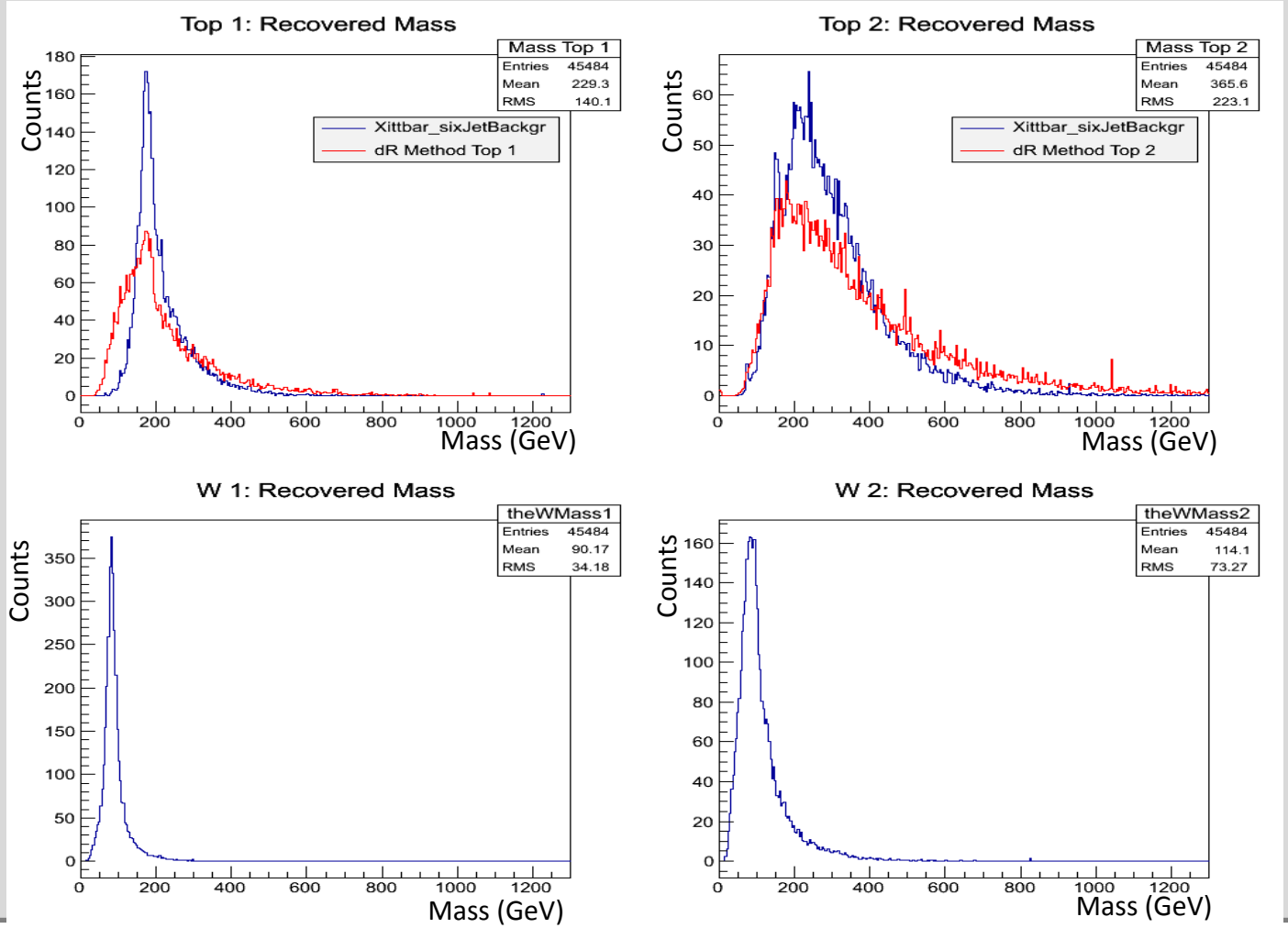




χ^2 ttbar Histograms, Signal



χ^2 ttbar Histograms, Background



χ^2 ttbar b Weighting Method

- Same χ^2 variable*:

$$\chi^2 = \frac{(m_{j_1,j_2} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_1,j_2,b_1} - m_t)^2}{\sigma_t^2} + \frac{(m_{j_3,j_4} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_3,j_4,b_2} - m_t)^2}{\sigma_t^2}$$

- σ_W = 10.2GeV and σ_t = 17.4 GeV are the respective mass resolutions given by Monte Carlo*.
- ***<u>But:</u>*** Require that the two highest b weight jets are used as the two b's in the event.

*See: ATLAS Collaboration, *Determination of the Top Quark Mass with a Template Method in the All-Hadronic Decay Channel*. ATLAS-CONF-2011-030.

χ^2 b Method

- Define a χ^2 variable*:

$$\chi^2 = \frac{(m_{j_1,j_2} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_1,j_2,b_1} - m_t)^2}{\sigma_t^2} + \frac{(m_{j_3,j_4} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_3,j_4,b_2} - m_t)^2}{\sigma_t^2} + \frac{(1-b)^2}{\sigma_b^2}$$

- σ_W = 10.2GeV and σ_t = 17.4 GeV are the respective mass resolutions given by Monte Carlo*.
- σ_b is approximated as 0.1. (This could be adjusted).
- Loop over all combinations to minimize the global value of χ^2 for the two recovered tops.

*See: ATLAS Collaboration, *Determination of the Top Quark Mass with a Template Method in the All-Hadronic Decay Channel*. ATLAS-CONF-2011-030.

χ^2 ttbar with Mass Virtuality Weighting

- Define a χ^2 variable*:

$$\chi^2 = \frac{(m_{j_1,j_2} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_1,j_2,b_1} - m_t)^2}{\sigma_t^2} + \frac{(m_{j_3,j_4} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_3,j_4,b_2} - m_t)^2}{\sigma_t^2} + \frac{(m_{top}/pT_{top})^2}{\sigma_{MV}^2}$$

- σ_W = 10.2GeV and σ_t = 17.4 GeV are the respective mass resolutions given by Monte Carlo*.
- σ_{MV} is approximated as 10. (This could be adjusted).
- Loop over all combinations to minimize the global value of χ^2 for the two recovered tops.

*See: ATLAS Collaboration, *Determination of the Top Quark Mass with a Template Method in the All-Hadronic Decay Channel*. ATLAS-CONF-2011-030.

χ^2 ttbar with pT Weighting

- Define a χ^2 variable*:

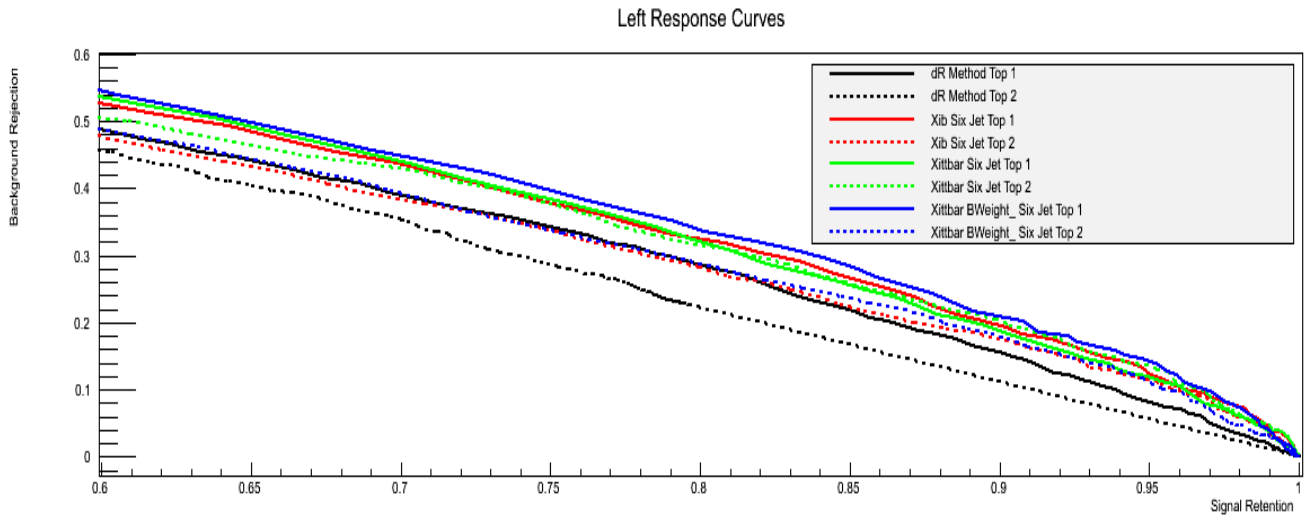
$$\chi^2 = \frac{(m_{j_1,j_2} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_1,j_2,b_1} - m_t)^2}{\sigma_t^2} + \frac{(m_{j_3,j_4} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_3,j_4,b_2} - m_t)^2}{\sigma_t^2} + \left(\frac{1}{pT^2}\right) * \left(\frac{1}{\sigma_{pT}^2}\right)$$

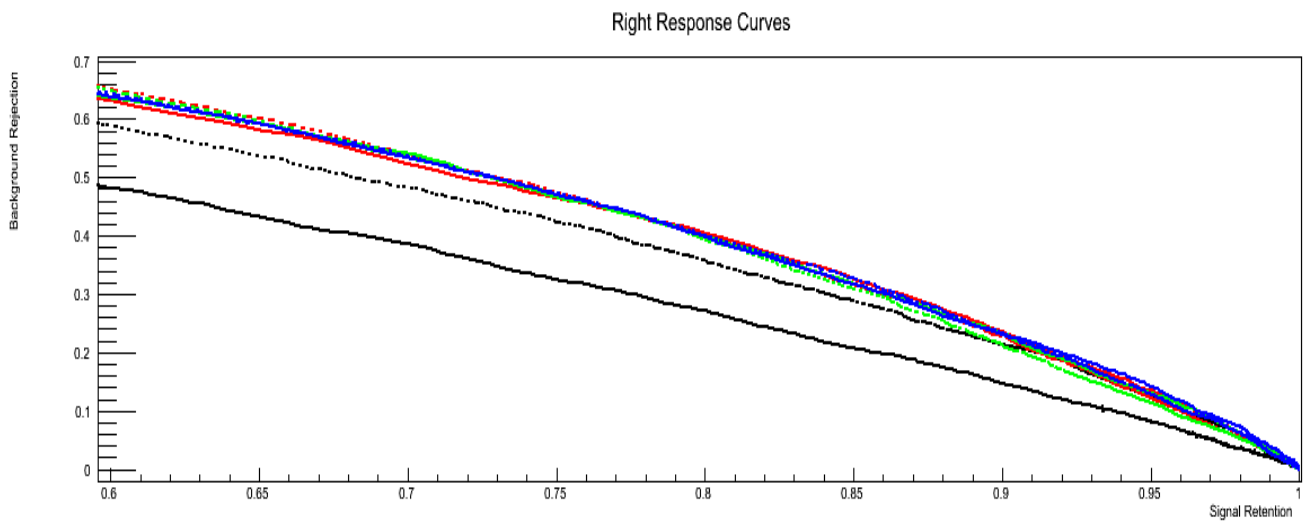
- σ_W = 10.2GeV and σ_t = 17.4 GeV are the respective mass resolutions given by Monte Carlo*.
- σ_{pT} is set to 0.01. (This could be adjusted).
- Loop over all combinations to minimize the global value of χ^2 for the two recovered tops.

*See: ATLAS Collaboration, *Determination of the Top Quark Mass with a Template Method in the All-Hadronic Decay Channel*. ATLAS-CONF-2011-030.

RESULTS

The Best: Response Curve





NEXT STEPS
AND MY TIME OUTSIDE THE OFFICE

Next Steps

- Refine the sigma parameters for the Xi-squared models.
- Go after the background directly by reconstructing and removing leptonic events.
- Test the most promising method on 2011 data. If there is an improvement over previous results, it will be run on the 2012 data set.

Outside the Office

Trevi Fountain, Rome, Italy

Overlook of Barcelona, Spain

Crêt de la Neige, Jura Mountains, France

"Tebowing" the Matterhorn, Zermatt, Switzerland

Thank You

- I would like to thank my advisors Dr. George Redlinger and Dr. Nathan Triplett for all of their help and assistance this summer.
- I would also like to thank the University of Michigan, the National Science Foundation, CERN, Brookhaven National Laboratory, and the University of Michigan Staff (Dr. Krisch, Dr. Neal, Dr. Goldfarb, Dr. Zhu, and Future Dr. Roloff) for this extraordinary opportunity.

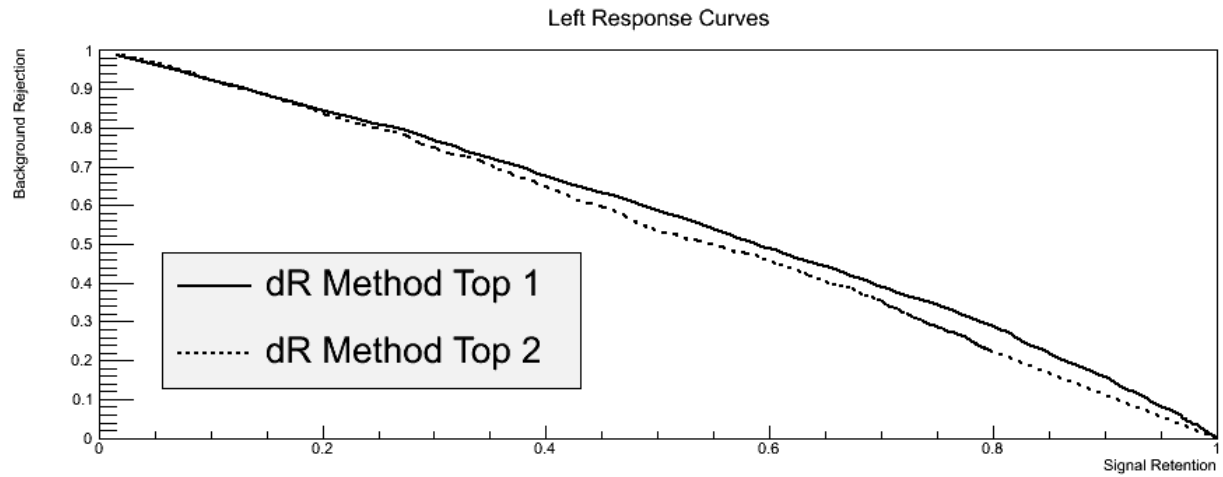
Questions?

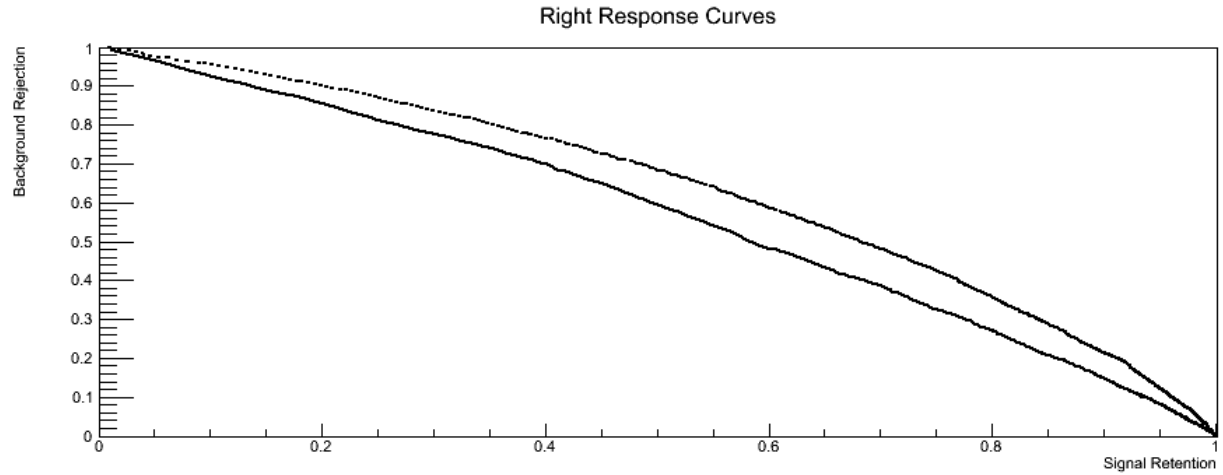
BACKUP SLIDES

Monte Carlo

- Signal Events -HERWIG++ with MRST2007LO* parton-distribution functions
- Ttbar -ALPGEN using CTEQ6L1 PDF interfaced with HERWIG for particle production.
  -JIMMY used for underlying event model.
- Ttbar+V -MadGraph interfaced with PYTHIA.
- Single top events -MC@NLO and ACERMC
  -associated W and Z productions made using ALPGEN.

A Quick Aside: Response Curves



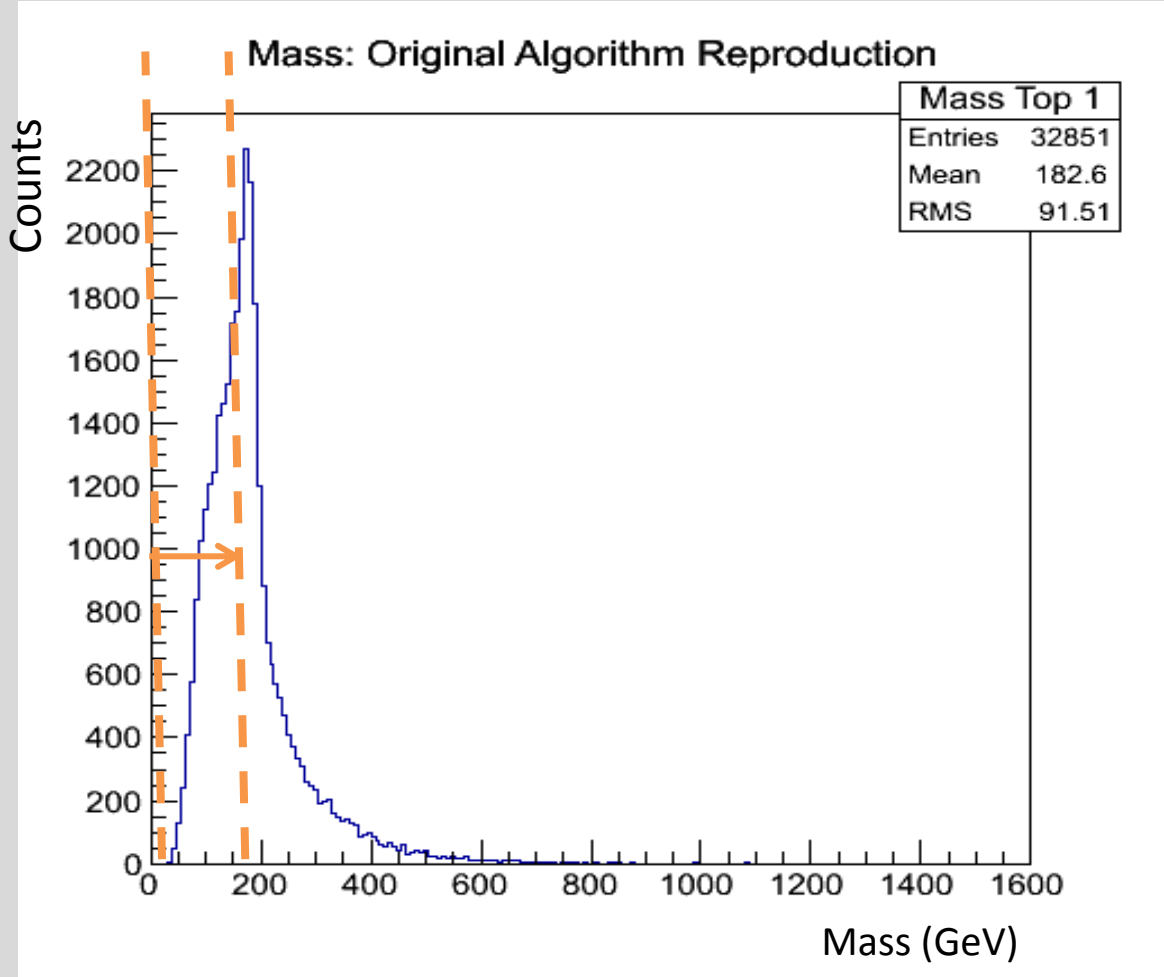


Response Curves: Explanation

- Create an array of integrated values for top 1 and top 2 for both background and signal (4 total).
- Each index contains the number of events in the specific range of top mass values. Increasing index has an increasing number of allowed top masses.

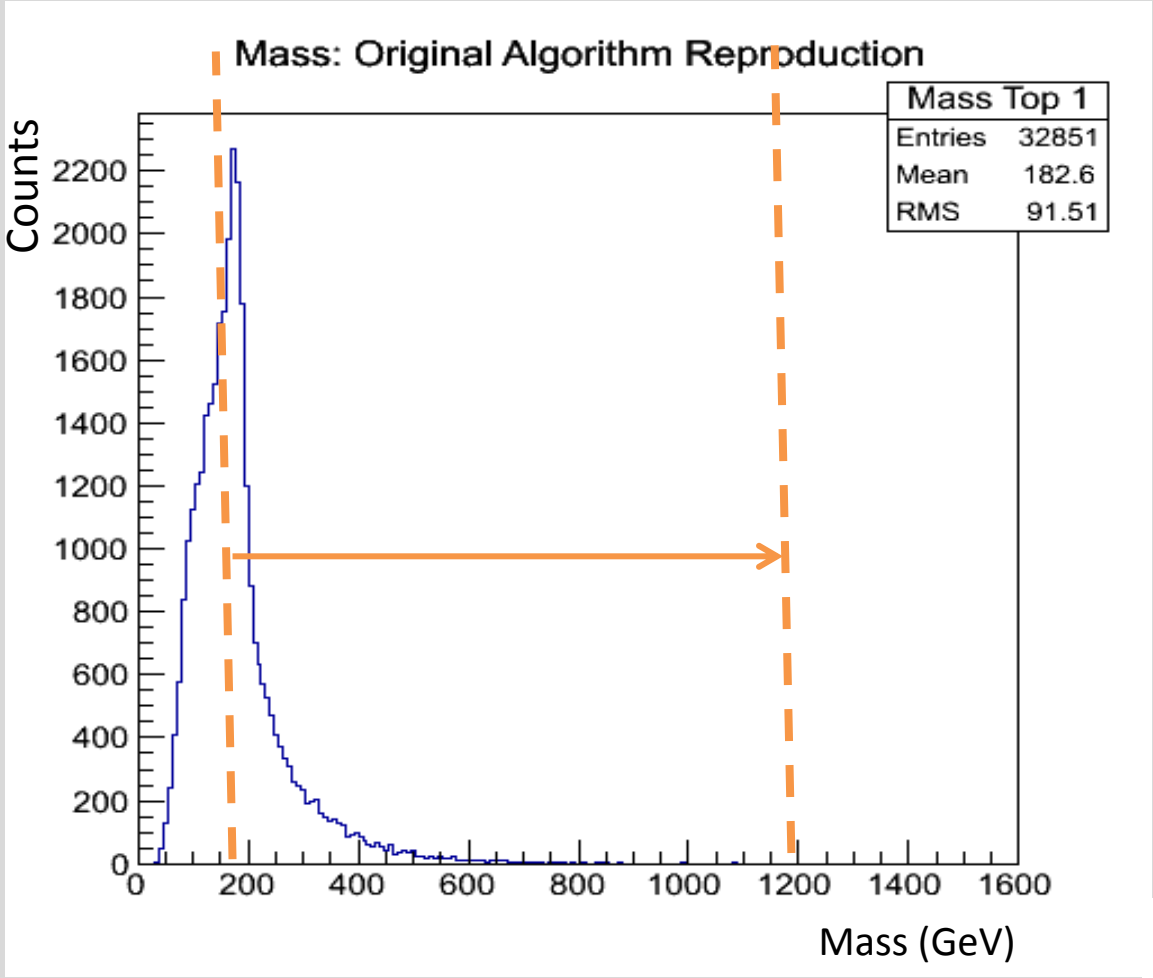
Left Response Curve: Explanation

- Integrate with varying lower bound and holding the upper bound fixed at the top mass.



Right Response Curve Explanation

- Integrate from top Mass to points more than the top mass.

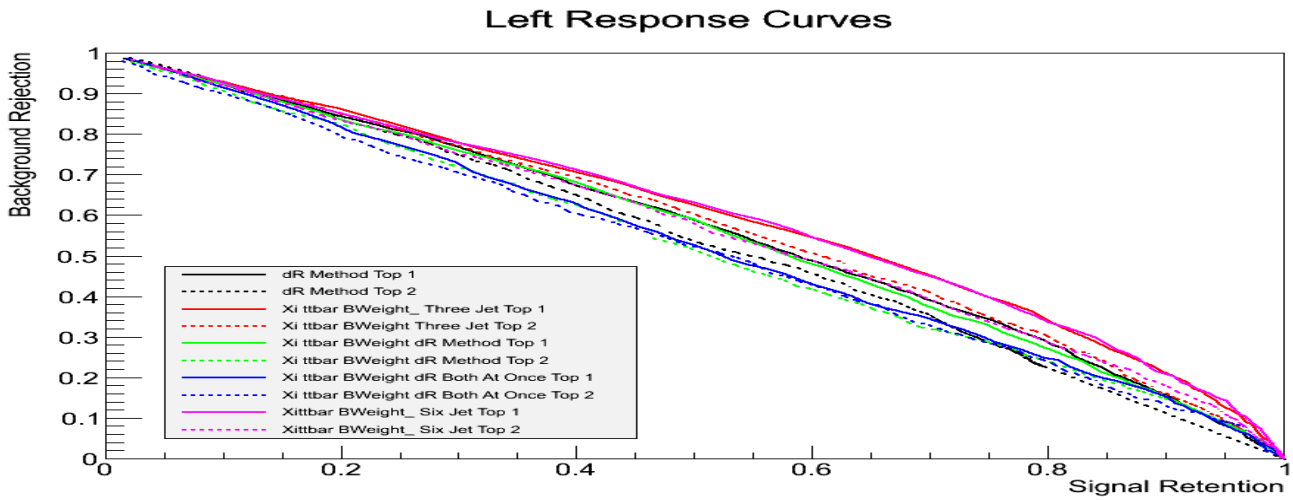


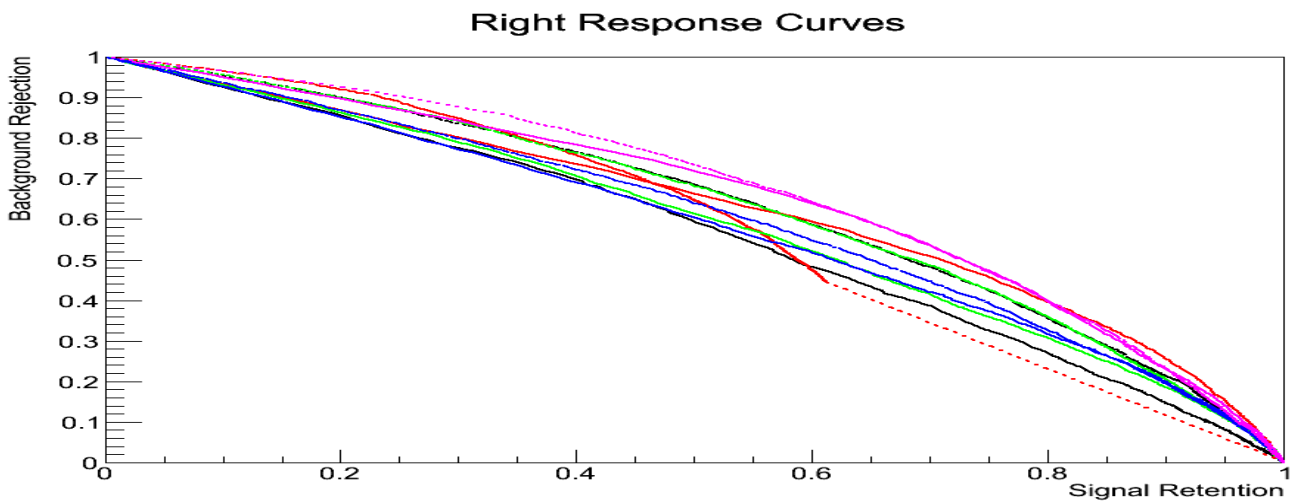
Response Curve: Explanation

- This is done for both signal and background separately for top 1 and top 2.
- Array is normalized by the total number of events (top masses) above or below the actually top mass.
- Response curve shows:

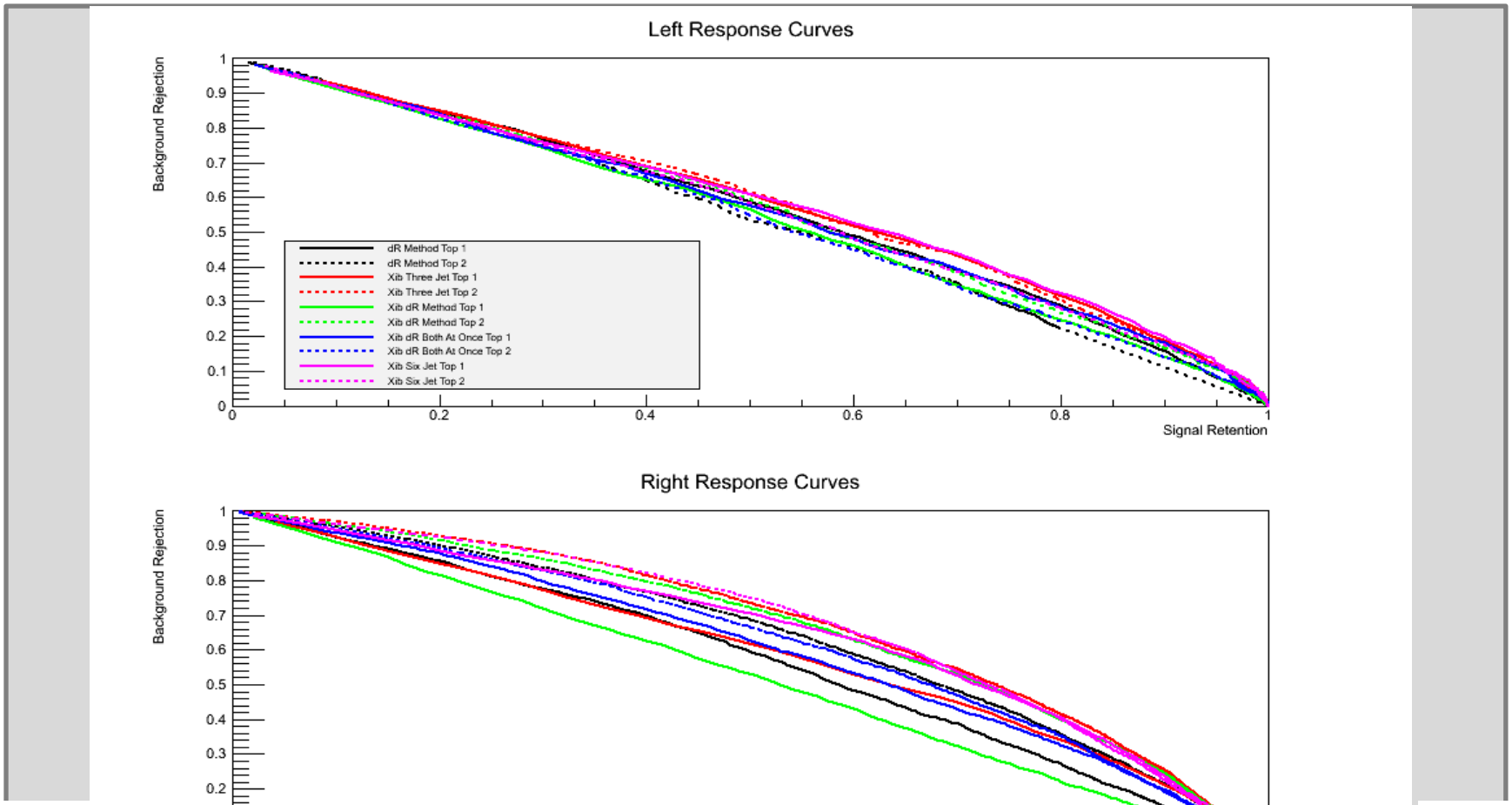
  signal vs. (1-background)
- I.e. for a specific top mass cut (specific index value in the array) it shows the percent of signal events that are kept versus the percent of background events that are removed, given that cut.

χ^2 ttbar b Weighting Response Curve

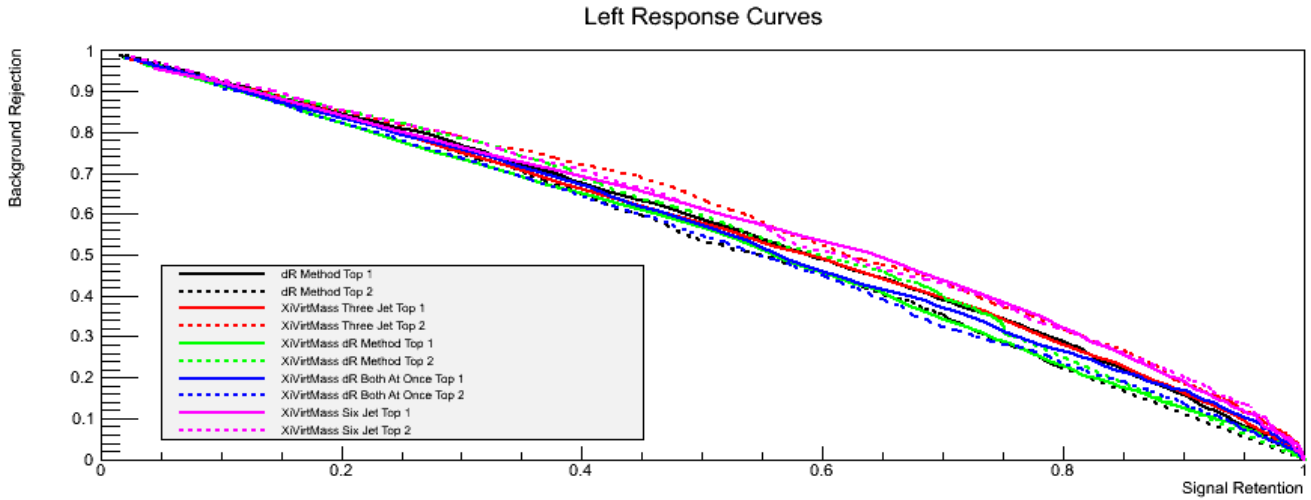


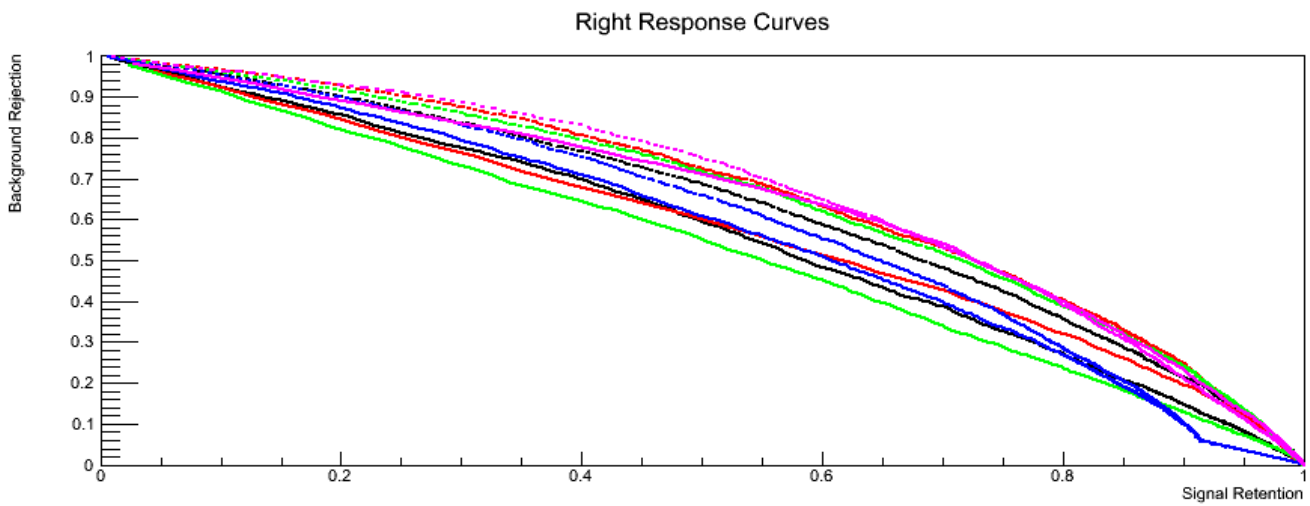


χ^2 b Response Curve

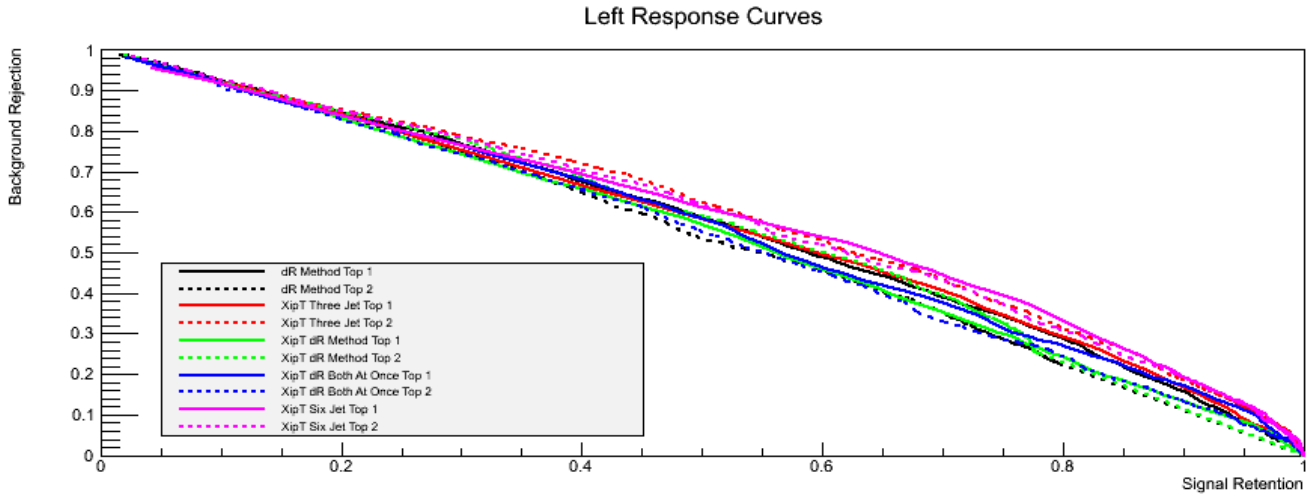


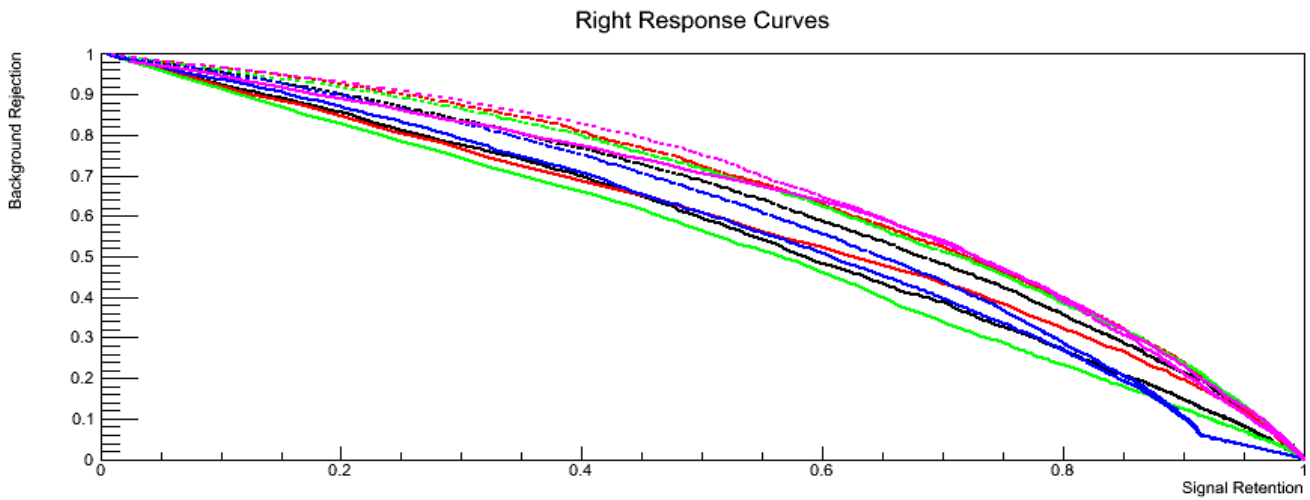
χ^2 ttbar with Mass Virtuality Response Curve



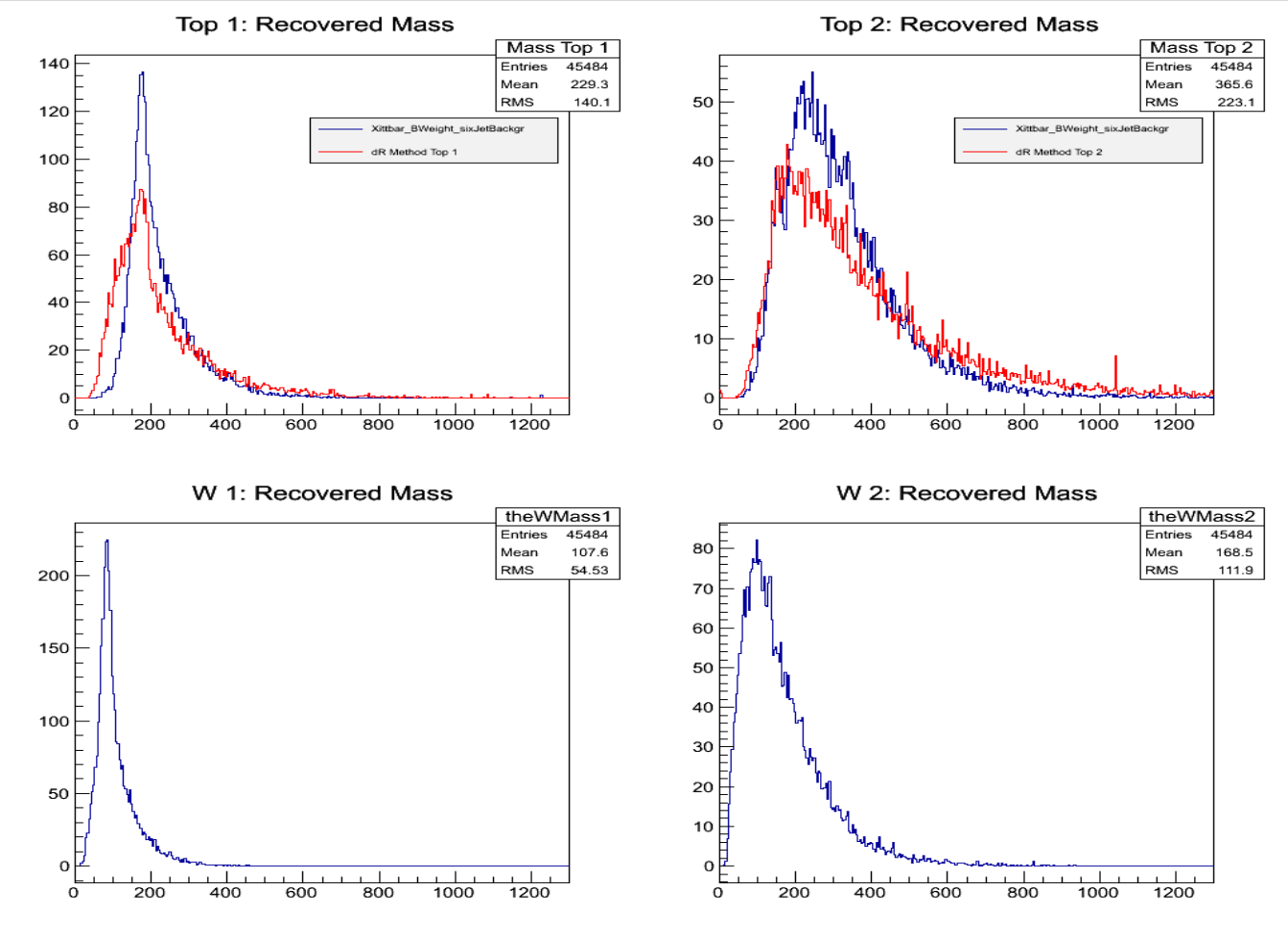


χ^2 ttbar with pT Response Curve

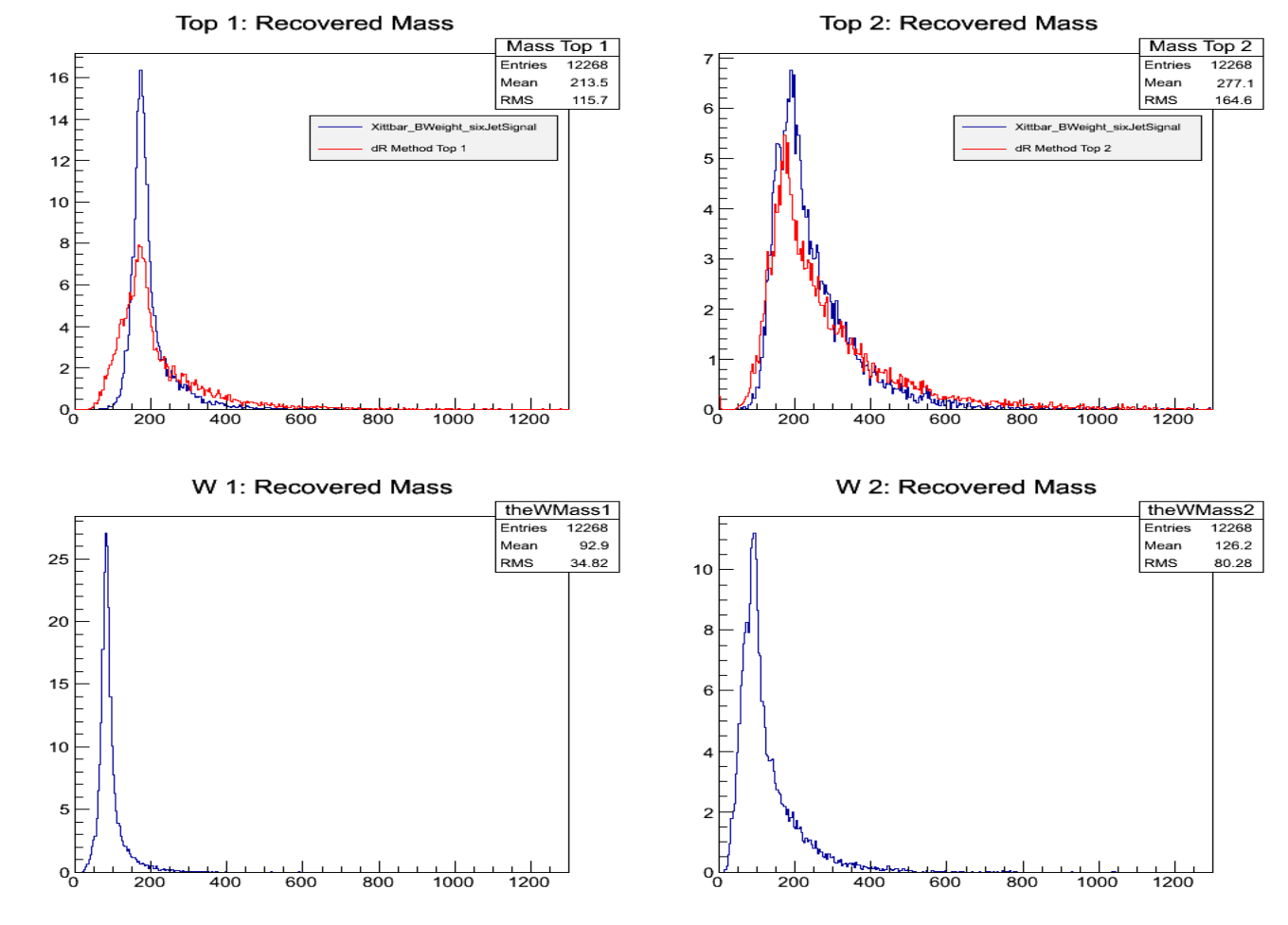




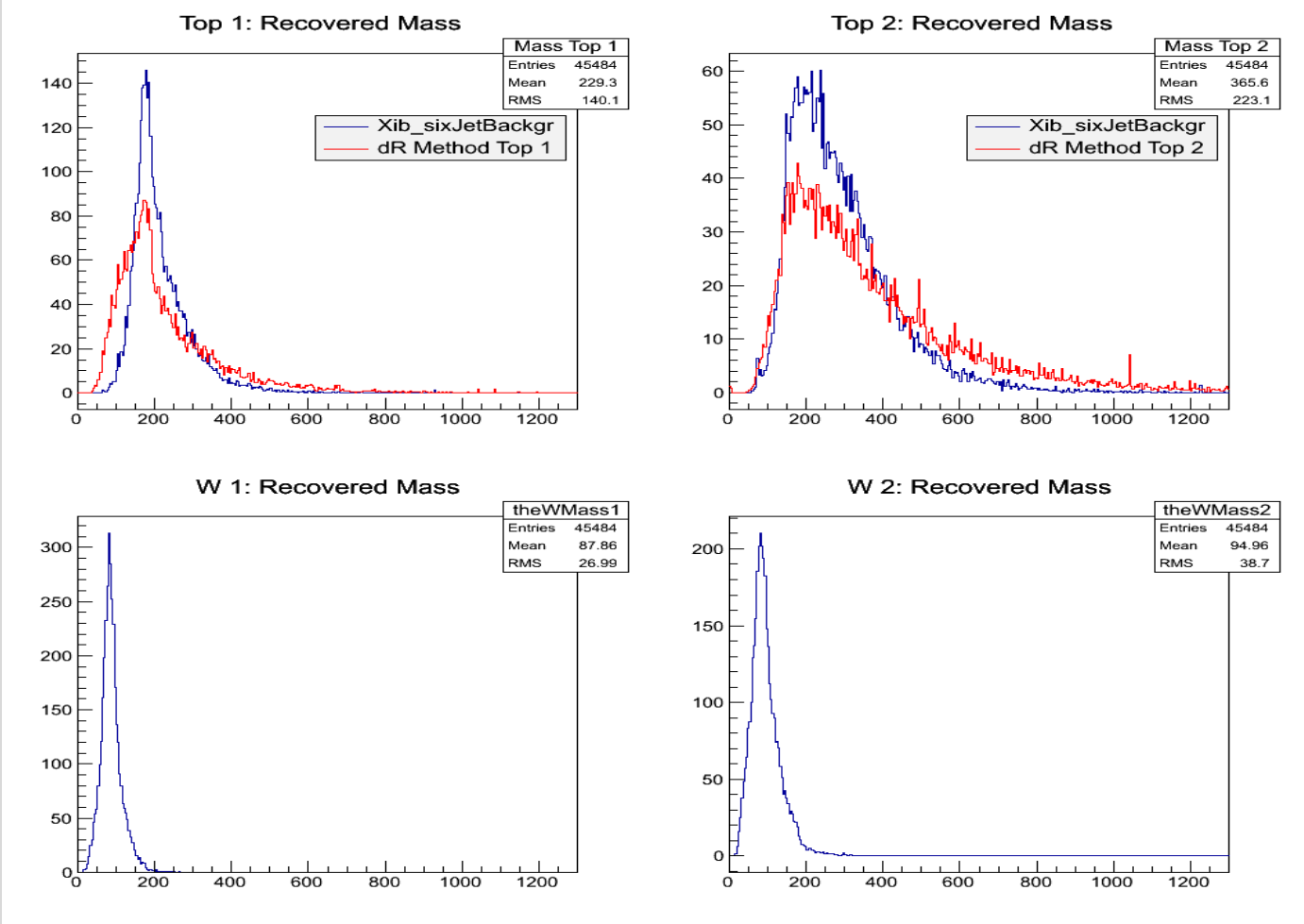
χ^2 b Weight Histograms, Background



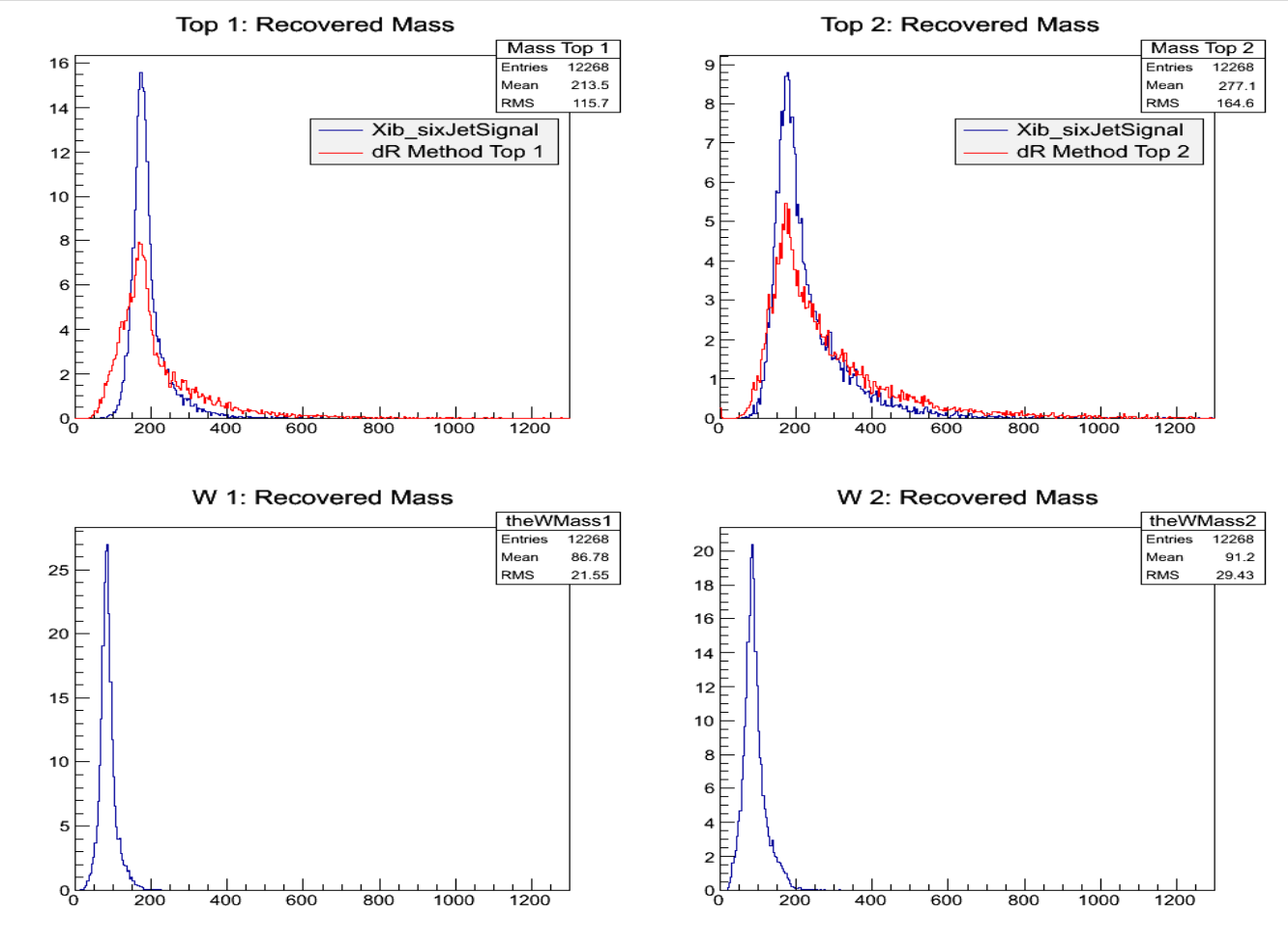
χ^2 b Weight Histograms, Signal



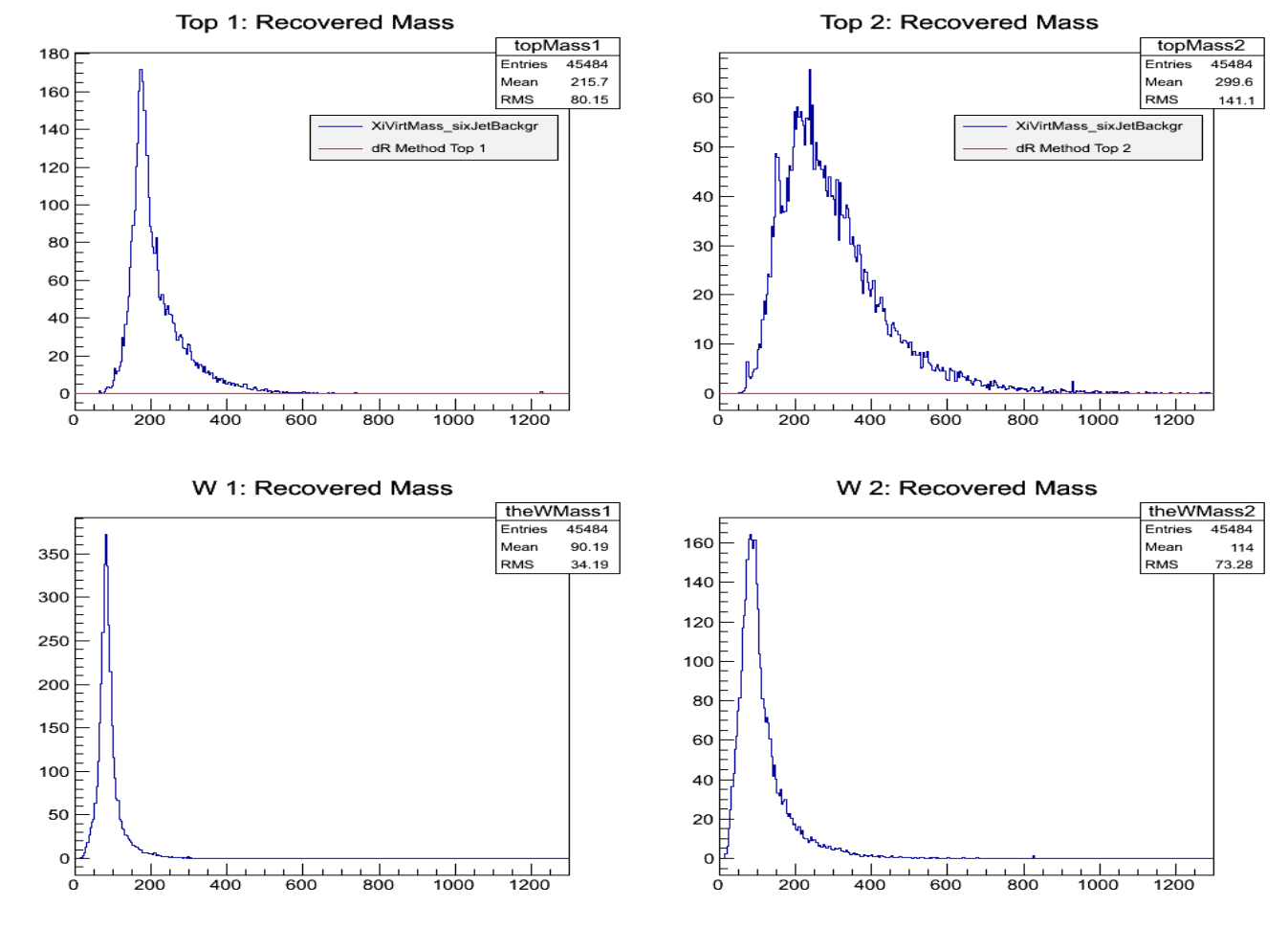
χ^2 b Histograms, Background



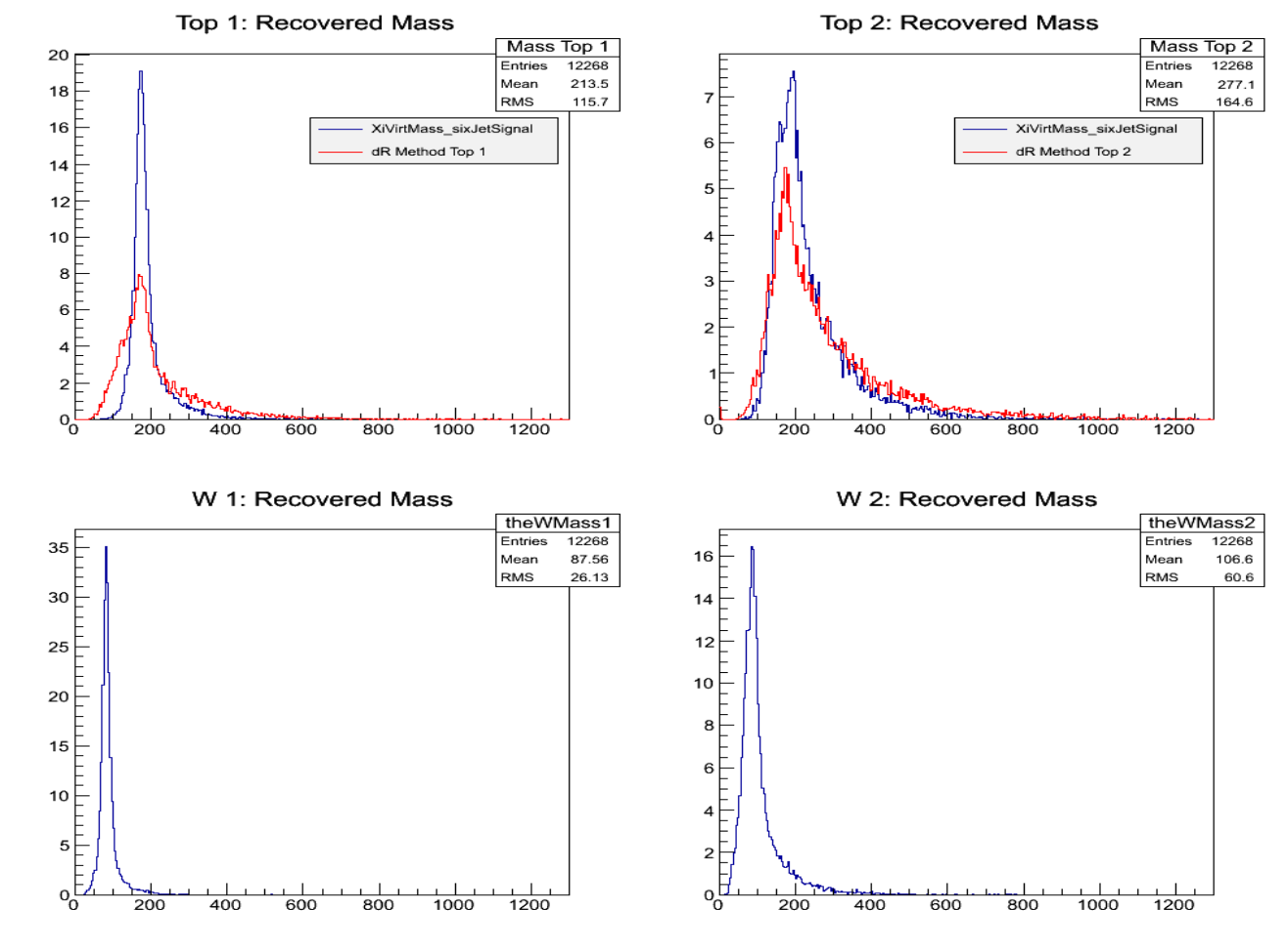
χ^2 b Histograms, Signal



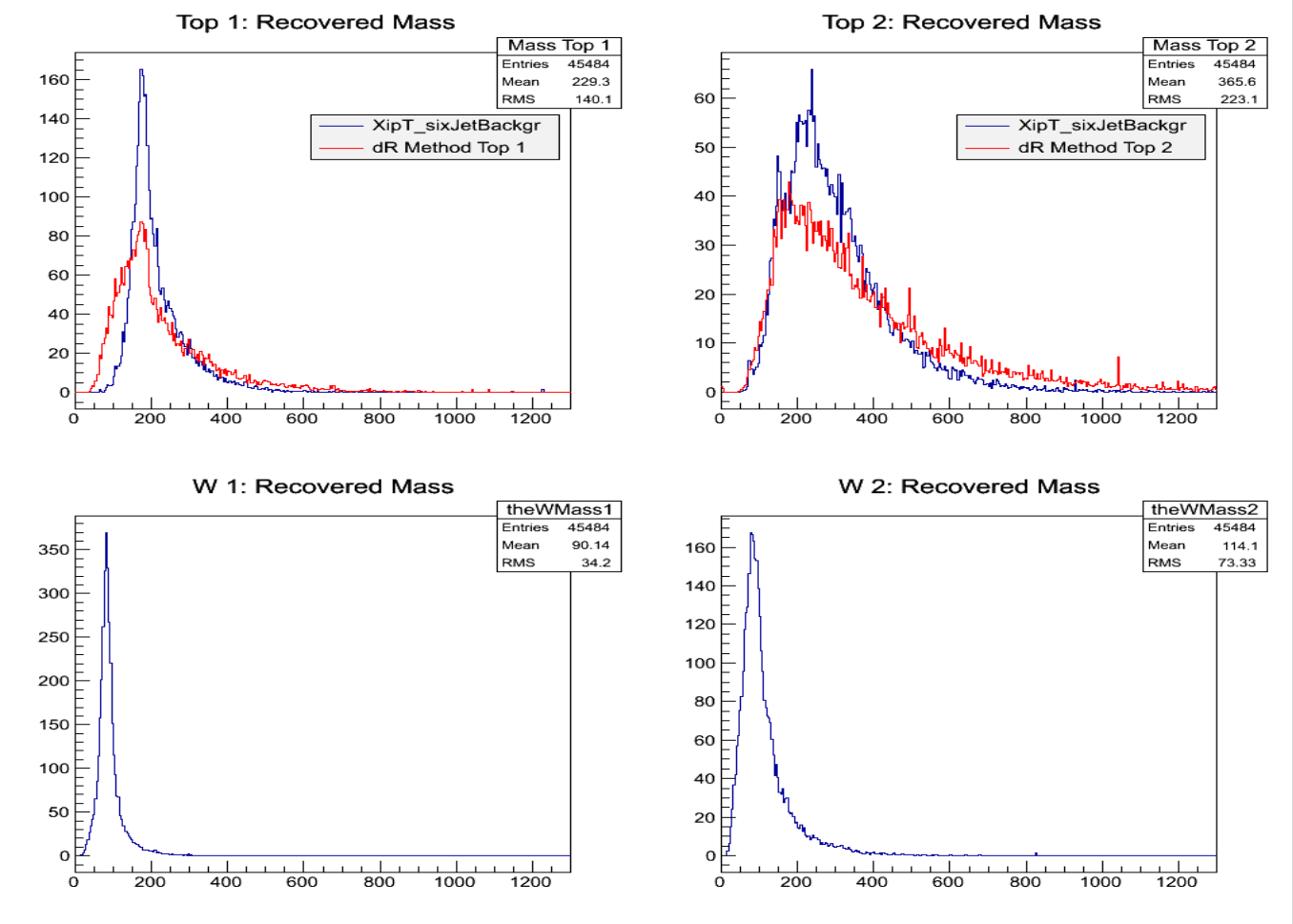
χ^2 ttbar with Mass Virtuality Histograms, Background



χ^2 ttbar with Mass Virtuality Histograms, Signal



χ^2 ttbar with pT Histograms, Background



χ^2 ttbar with pT Histograms, Signal