Prospects for measuring Top Pair Production using likelihood method at ATLAS in 10 TeV p-p Collisions

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Dilip Jana
University of Oklahoma
on behalf of ATLAS Collaboration

Introduction and Motivation

- **Any new physics related with EWSB may be coupled to top quark leading to deviation of ttbar production cross-section and top kinematics.**
- **Top quark is one of the main backgrounds for Higgs and SUSY searches.**
  - Have to measure accurately inclusive ttbar cross section
  - Have to investigate the ttbar kinematic characteristics

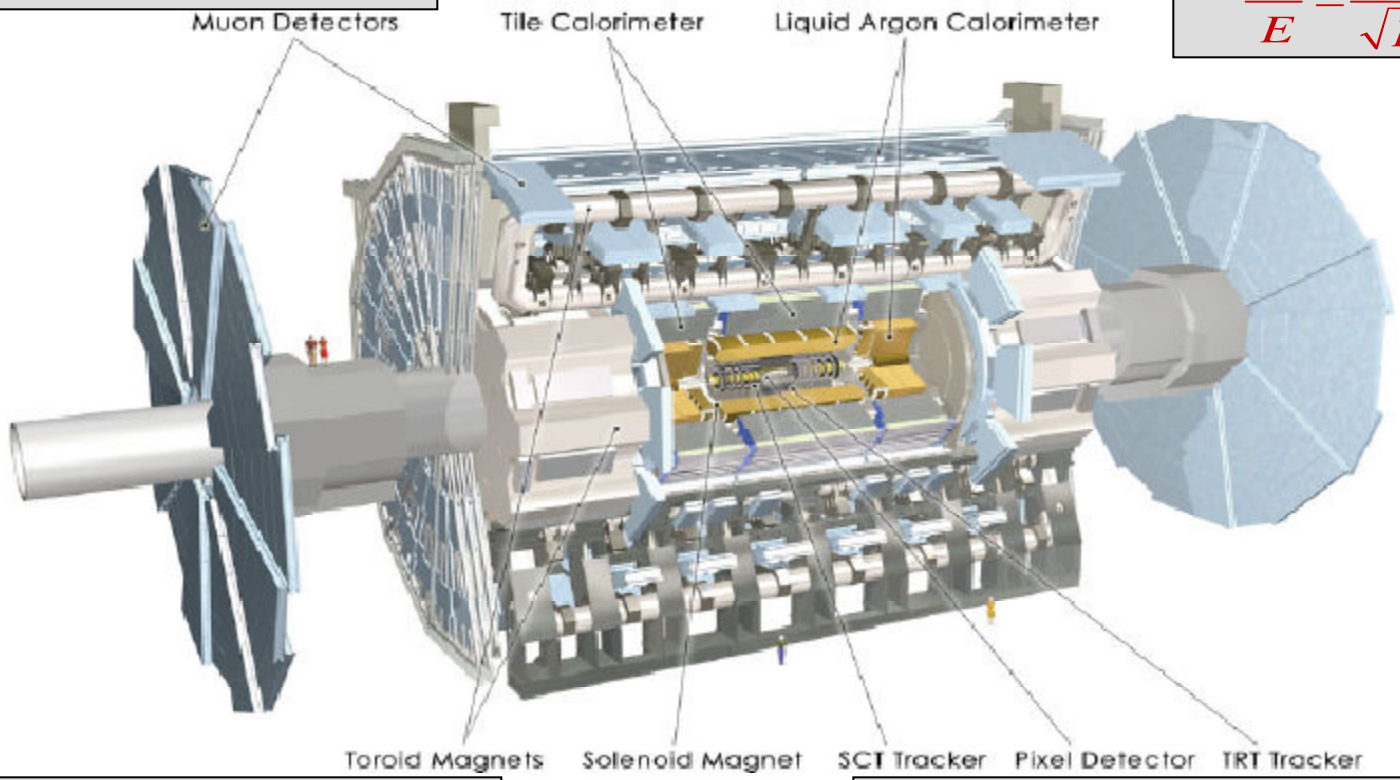
- **ttbar events will be useful for the detector calibration, in particular for the b-tagging efficiency measurements.**

ATLAS Detector (A Toroidal LHC ApparatuS)

Muon Spectrometer
Muon ID and pT resolution
$\frac{\sigma_{pT}}{p_T} = 10\%$ at pT = 1 TeV

Hadronic calorimeter
Jet and MET performance
$\frac{\sigma_E}{E} = \frac{50\%}{\sqrt{E}} \oplus 3\%$

EM calorimeter
Photon and Electron ID
$\frac{\sigma_E}{E} = \frac{10\%}{\sqrt{E}} \oplus 0.7\%$

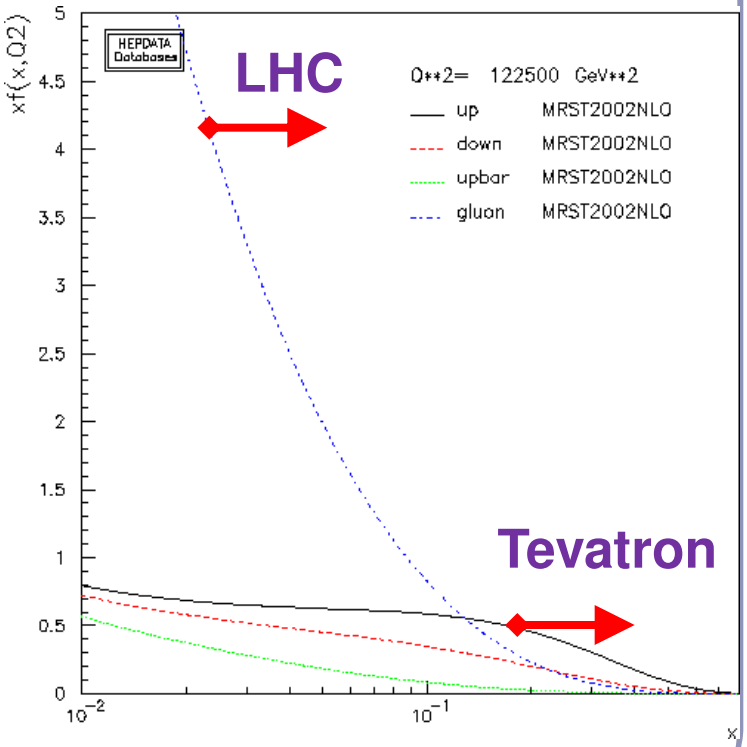


Magnets :
2T Solenoid Magnet
4.1T Toroid Magnet

Inner Detector
Tracking performance
$\frac{\sigma_{pT}}{p_T} = 0.05\% p_T \oplus 1$

Top quark pair production at the LHC

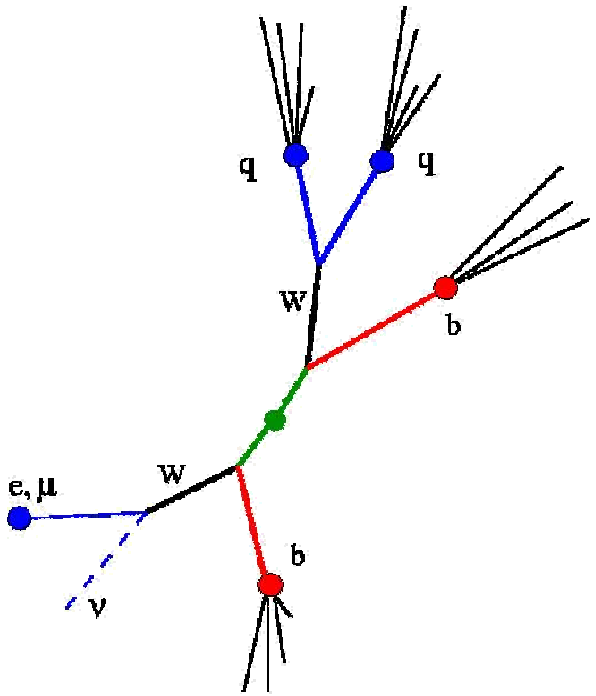
- Dominant process of the top quark pair production at LHC is gluon fusion



90% gg

10% qq

Top quark decays



Name	Signature	BR	X-sec
Fully Hadronic	jets	45.7%	191.5
Lepton + Jets	e + jets	17.2%	71.9 pb
	μ + jets	17.2%	71.9 pb
Dilepton	eμ + jets	3.18%	13.3 pb
	μμ + jets	1.59%	6.67 pb
	ee + jets	1.59%	6.67 pb
Tau + jets	τ + jets	9.49%	39.8 pb
Lepton + Tau	τ + e/μ + jets	3.54%	14.8 pb
Tau + Tau	2τ+ jets	0.49%	2.06 pb
total	all	100%	419 pb

Lepton + jets Channel

- Signal: $t\bar{t} \rightarrow WWb\bar{b} \rightarrow (jj)(l\nu)b\bar{b}$ $\quad l = e, \mu$
- Background:
  - W+Jets production
  - Single top production
  - Di-boson production
  - QCD multijet production
- Method:
  - Make use of the kinematical differences between signal and background events → construct likelihood templates for signal and (combined) backgrounds
  - Use likelihood templates to estimate the number of expected ttbar events.

Object Selection

- **Electron Selection:**
  - reconstructed in inner tracker and EM calorimeter
  - one Isolated electron with pT > 20 GeV
  - $0 < |\eta| < 2.47$
    - $1.37 < |\eta| < 1.52$ excluded
  - E_T in a cone of radius 0.2 around the electron axis < 6 GeV

- **Muon Selection:**
  - reconstructed in inner detector and muon spectrometer
  - one isolated muon with pT > 20 GeV
  - $0 < |\eta| < 2.5$
  - E_T in a cone of radius 0.2 around the muon axis < 6 GeV

Object Selection

- **Jet Selection:**
  - Jets are reconstructed in η-ϕ space with the cone of radius 0.4 based on the energy deposited in the calorimeter towers.
  - $pT > 20$ GeV
  - $0 < |\eta| < 2.5$
  - No overlap between jet and lepton
    - ΔR (e, jet) > 0.2
    - ΔR (μ, jet) > 0.3

- **Missing Et (MET) Selection:**
  - MET> 20 GeV

Event pre-selection

- Pass trigger:
- Require exactly one isolated lepton
- EtMiss > 20 GeV
- At least 4 jets with Pt > 20 GeV
- At least 3 jets with Pt > 40 GeV

ATLAS work in progress	Muon Analysis	Electron Analysis
$t\bar{t}$	1573	1302
W+jets	835	589
Single top	110	105
Di boson	8	7
S/B	1.65	1.85

Expected events at 10 TeV and at 100 pb^{-1}

Likelihood Analysis

- Find topological variables that will help to separate ttbar from Background (e.g: W+jet, QCD, single top, di-boson).

$$L = \frac{\exp\left(\sum_i \ln\left(\frac{S}{B}\right)_i^{fit}\right)}{\exp\left(\sum_i \ln\left(\frac{S}{B}\right)_i^{fit}\right)+1}$$

Likelihood Variables

- Following variables used:
  - Exp(-8*Aplanarity)
    - Aplanarity $= \frac{3}{2}\lambda_3$
  - Centrality
    - C=H_T/H;

      H_T= scalar sum of pT of jets,

      H= scalar sum of energy of jets
  - Sphericity $\left(= \frac{3}{2}(\lambda_2 + \lambda_3) \right)$
  - $\Delta\eta$(j2,j3)
  - Lepton Eta
  - θ(lepton, jet) $\longrightarrow \theta(lepton, Jet_i) = 2 * \left| a\tan\left(e^{-\eta(lepton)}\right) - a\tan\left(e^{\eta(Jet_i)}\right) \right|$

Normalized momentum tensor

$$M_{ij} = \frac{\sum p_i^\circ p_j^\circ}{\sum \left|\overrightarrow{p^\circ}\right|^2}$$

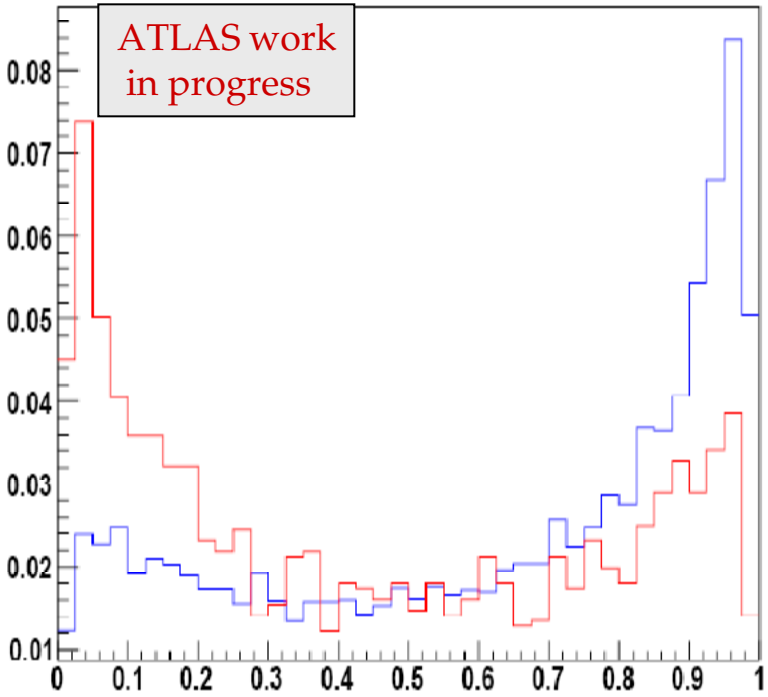
Eigen values

$$\lambda_1 \geq \lambda_2 \geq \lambda_3$$

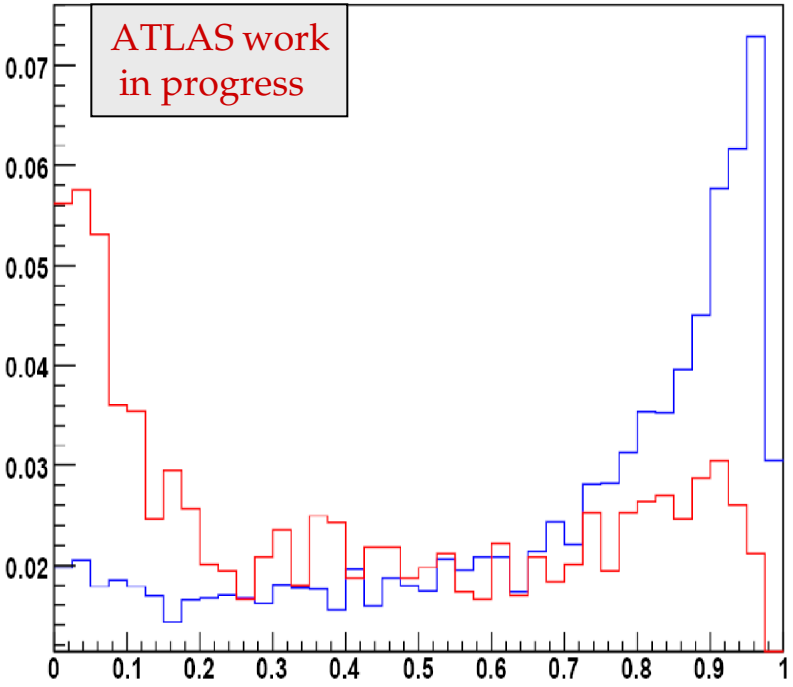
$$\lambda_1 + \lambda_2 + \lambda_3 = 1$$

Likelihood templates

Muon Channel



Electron Channel



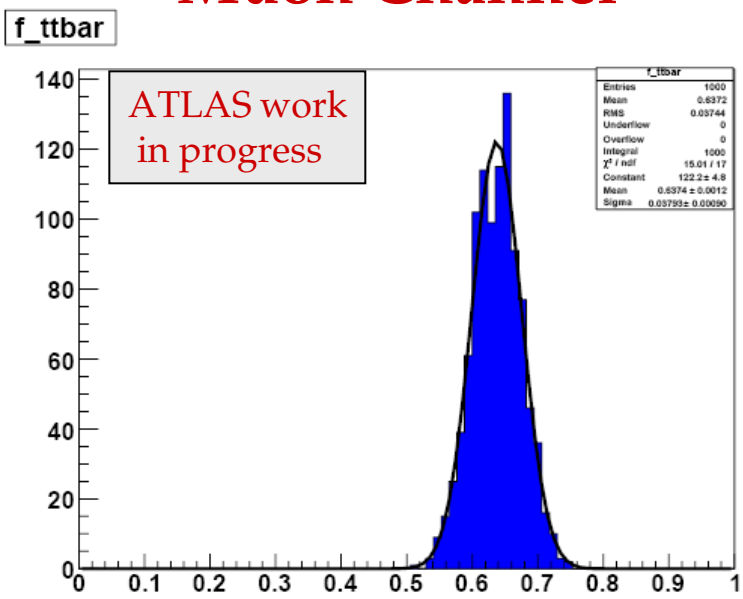
Red histograms show background templates, blue - signal templates

Pseudo-experiment

- To check the stability of the LH and to estimate the expected statistical error with likelihood method, perform ensemble tests with different mixture of the signal and backgrounds.
- In each case used the numbers of events corresponding to 100 pb^{-1}.
- Plot the likelihood distribution for the "data" (mixture of signal and backgrounds).
- Use LH templates for ttbar and W+jets to fit the "data" likelihood distribution and compare initial fractions to the fractions obtained from fit

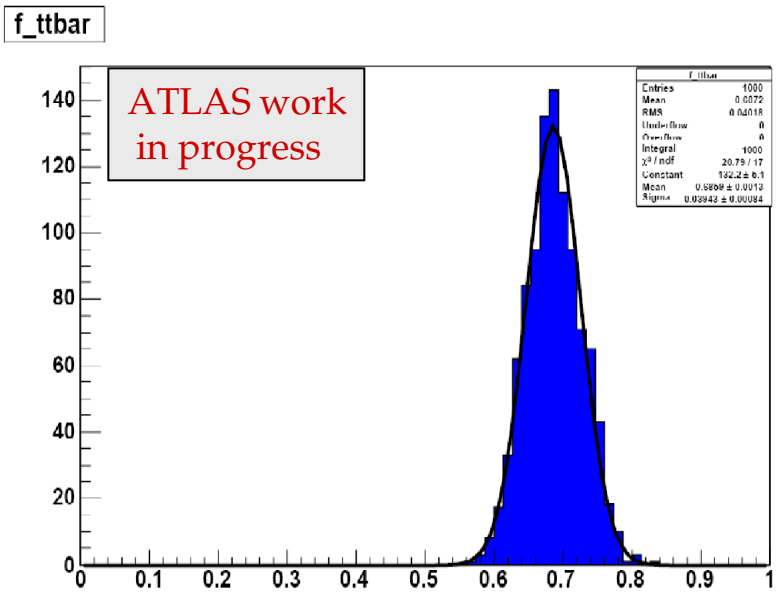
Result from the Pseudo-experiments (100 pb^{-1})

Muon Channel



Initial fraction	Fitted fraction	RMS
65%	63.72%	3.74%

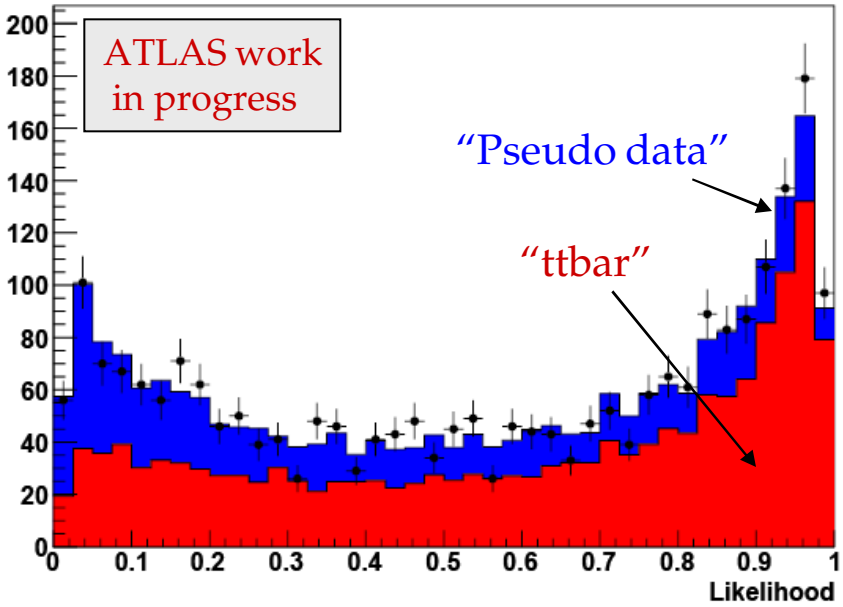
Electron Channel



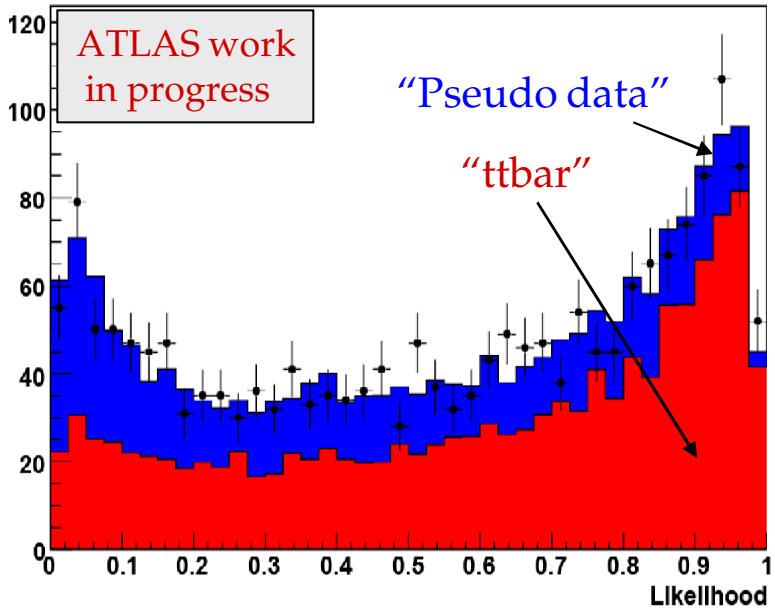
Initial fraction	Fitted fraction	RMS
69%	68.72%	4.01%

Result from the Pseudo-experiments

Muon Channel



Electron Channel



Systematics uncertainty

- Major source of systematics:
  - JES
  - MC generator dependence
  - Trigger
  - Muon ID, Electron ID
  - ISR/FSR
  - PDF

$$\sigma_i = \sigma \pm \Delta\sigma_i = \frac{N^{t\bar{t}} \pm \Delta N_i^{t\bar{t}}}{(\varepsilon \pm \Delta\varepsilon_i) BL}$$

i = systematics uncertainty is determined by varying the source by 1 standard deviation up and down. Propagate this variation into both the fitted number and the signal efficiency resulting a new value of the cross-section (as shown in the formula above).

Summary of Systematic uncertainties

Source	Error
Trigger	± 1.0%
Lepton ID	± 1.0%
JES : 5% 10%	± 10% ± 20%
MC generator	±5.0 %
ISR/FSR	Work in progress
PDF	Work in progress

ATLAS work in progress

$t\bar{t}$ cross-section (100 pb^{-1})

- **Muon Channel**

ATLAS work in progress

$$\frac{\Delta\sigma}{\sigma} = 3.74\%(stat) \pm 11\%(syst)$$

- **Electron Channel**

$$\frac{\Delta\sigma}{\sigma} = 4\%(stat) \pm 11\%(syst)$$

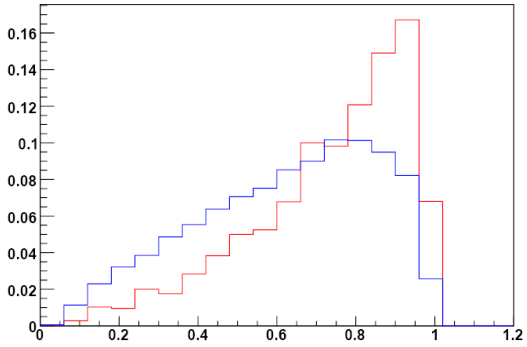
Conclusions

- Top quark pair cross section measurements will be among the first physics measurements in ATLAS.
- The measurement with likelihood templates provides a good cross check for more simple measurements, and is complimentary in many ways to other methods.
- First results on the top quark pair cross section can be obtained with 100 pb^{-1} in lepton + jets channel.

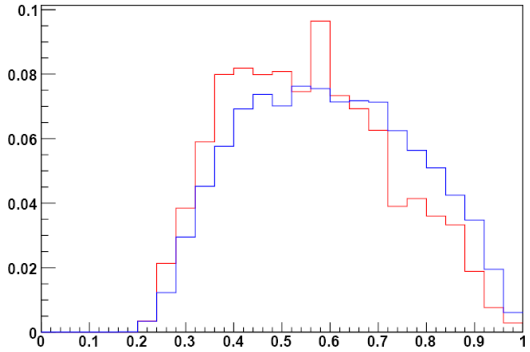
Backup Slides

Discriminating Variables

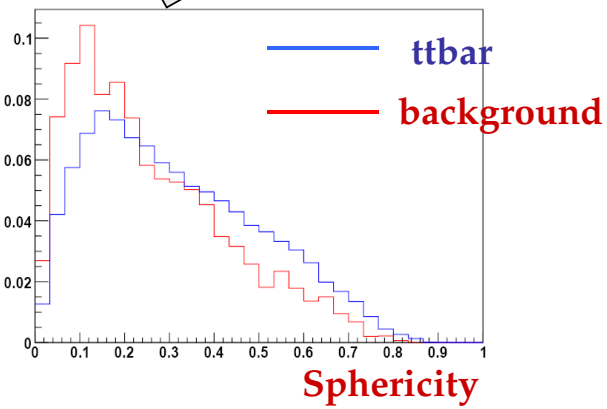
ATLAS work in progress



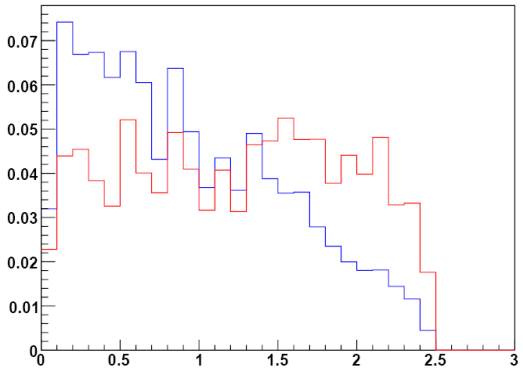
Exp(-8*Aplanarity)



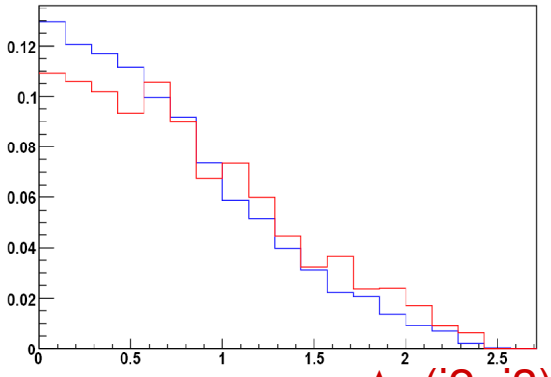
Centrality



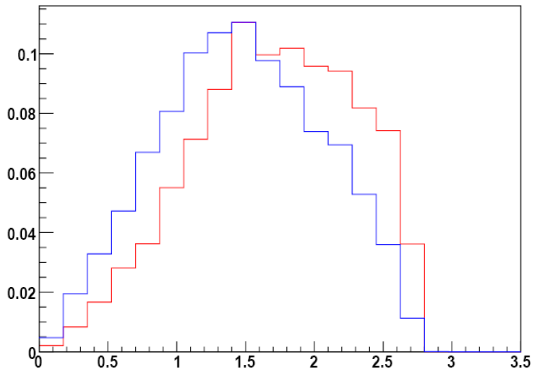
Sphericity



lepton eta



Δη(j2, j3)



ɵ(lepton, jet)