Top Cross Section Measurement in the Lepton + Jets Channel

Stefan Guindon

In Discussion with or Supervised by:
James Dassoulas, Henrike Fleischhack, Anna Henrichs,
Florian Köhler, Kevin Kröninger, Jörg Meyer, Arnulf Quadt, Adam Roe,
Alexander Runde, Daniel Schiepel, Elizaveta Shabalina

2nd Institute Of Physics, Georg-August-Universität Göttingen

PHYSICS AT THE TERA SCALE
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GEFÖRDERT VOM
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Outline

Brief Introduction

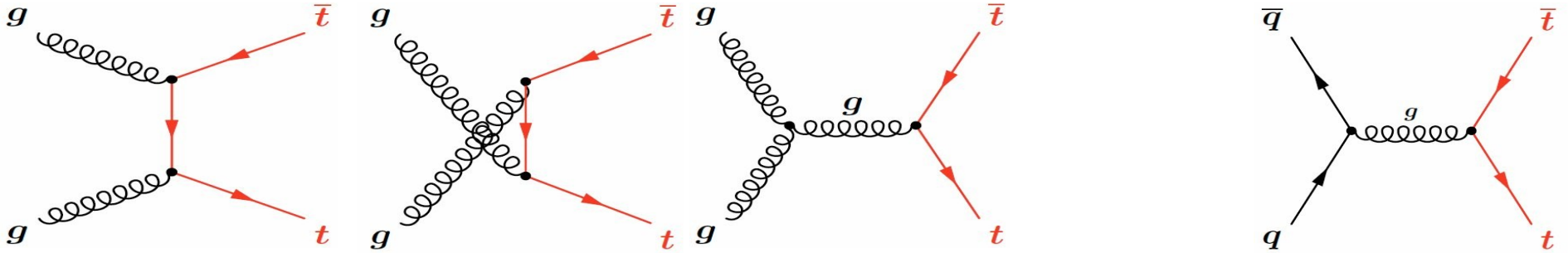
Trigger Studies

Muon Isolation Studies

Multivariate Analysis (MVA) of Topological Variables

Top Quarks at the LHC

Top quark pairs are produced at the LHC via gluon fusion or quark anti-quark annihilation.

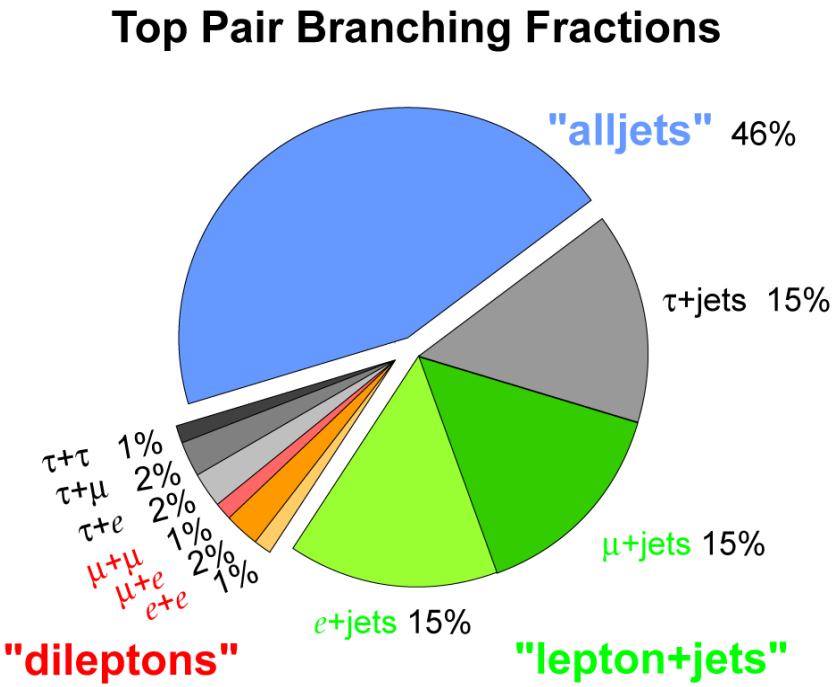


Expected theoretical cross section at 10 TeV and at 7 TeV

At 10 TeV -- 401.6 pb

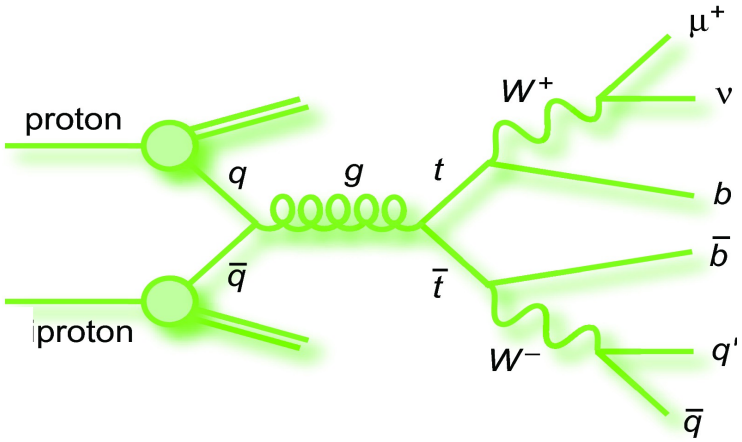
At 7 TeV -- 160.7 pb

The top quark pairs then decay either into an all hadronic channel, a semi-leptonic channel or a di-leptonic channel.



Signal and Background Features

For this study, we are interested in the top quark pair decay into the semi-leptonic muon or election + jets channel.



The physics background is largely dominated by W + jets. It is also important to discriminate the signal from other backgrounds such as Z + jets, single top and diboson events

Multijet QCD is a source of instrumental background if:

A jet is reconstructed as an electron (e + jets channel)

A muon from semi-leptonic b decays or decay in flight appears as isolated.

We study various isolation requirements to suppress QCD

Idea of the Analysis

Using a Likelihood method to separate signal from background

To do this, we first have to analyse the triggers to select as many top quark signal events as possible. We are looking at triggers for both electrons and muons and trying to maximize efficiency.

We need to define a lepton isolation requirement. Optimize muon isolation cuts to maximize the signal over background in the case of QCD background.

Select discriminating variables which discriminate between the top quark pair signal and the W + jets background.

Build a likelihood function and evaluate it for both signal and background.

Fit templates to data and extract the signal and background fractions in data.

Event Selection

Jets:

Cone jets with R = 0.4
Remove jets overlapping with electrons in $\Delta R < 0.2$
At least 4 jets with pT > 20 GeV, $|\eta| < 2.5$
At least 3 jets with pT > 40 GeV

Missing Transverse Energy:

Missing Energy > 20 GeV

Plus one of the following:

Muon:

Reconstructed in both the inner detector and muon system
Energy deposition in cone of 0.2 around muon < 6 GeV
Distance to closest jet > 0.3
pT > 20 GeV, $|\eta| < 2.5$

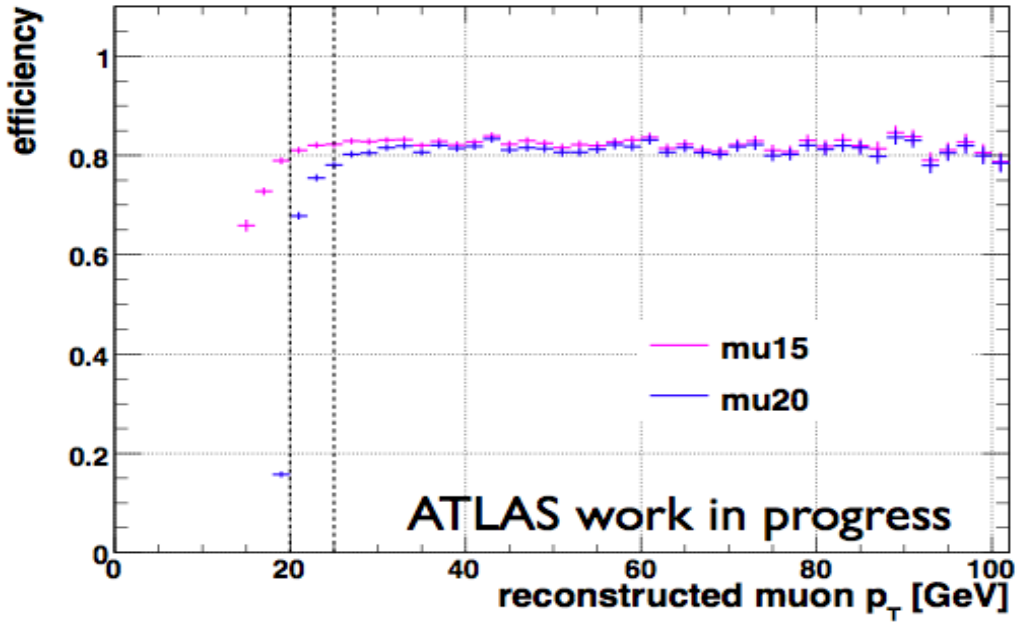
Electron:

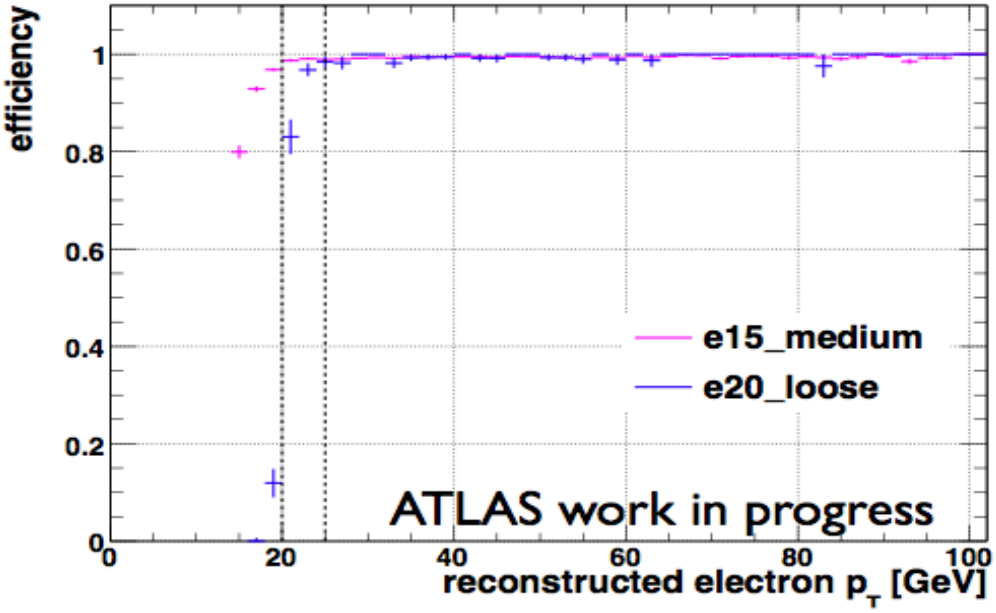
Medium type reconstruction
Energy deposition in cone of 0.2 around electron < 6 GeV
Excludes „crack“ region between the central tracker and endcap system
pT > 20 GeV, $|\eta| < 2.47$

Trigger Efficiencies

- check trigger efficiencies for relevant single lepton triggers
- 15 or 20 GeV trigger thresholds available
- match trigger object with reconstructed lepton in dR < 0.1

available triggers:
- mu15
- mu20
- e15_medium
- e20_loose

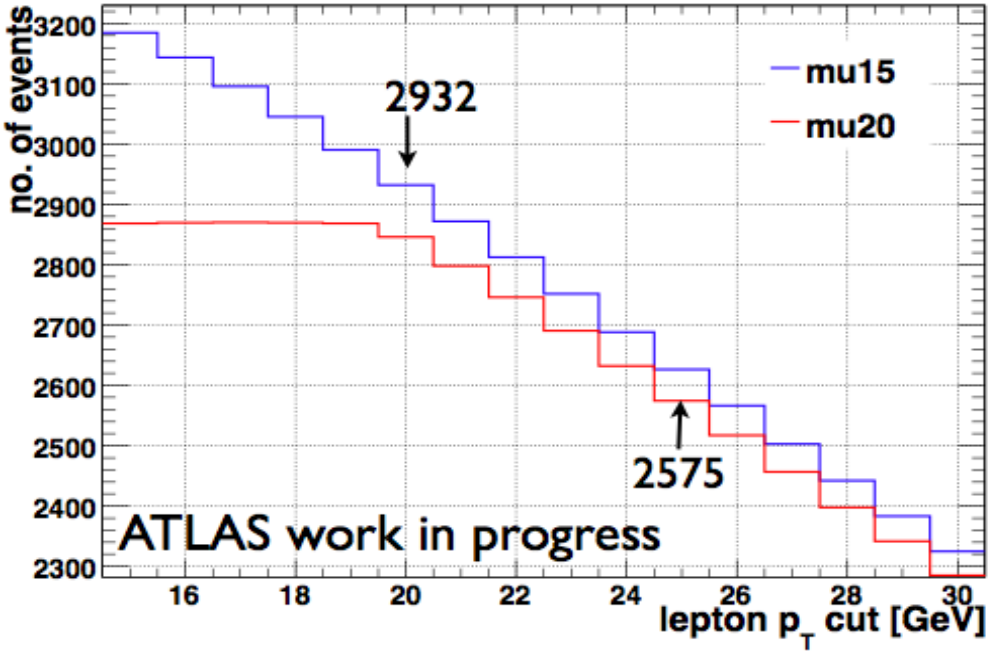


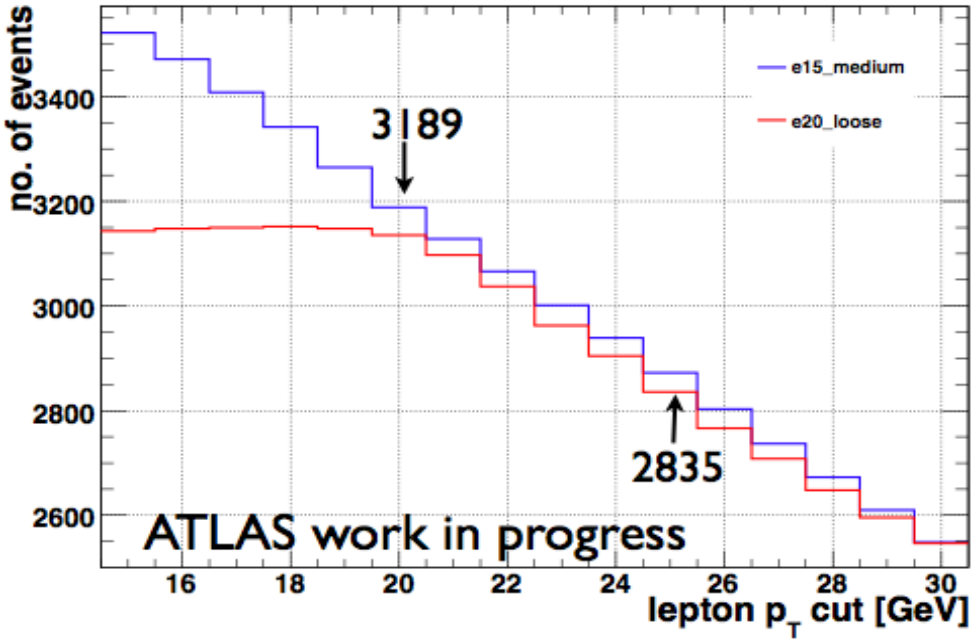


- muon trigger: 83% efficiency
- electron trigger: 99% efficiency
- proposed cuts:
  - 20 GeV for 15 GeV trigger threshold
  - 25 GeV for 20 GeV trigger threshold

Signal Efficiencies

- 10 TeV collisions and 200 pb^{-1}
- apply event selection
- vary cut on lepton pt between 15 and 30 GeV
- count number of signal events as function of the cut





- relative difference between 15 GeV trigger & 20 GeV cut and 20 GeV trigger & 25 GeV cut:
  - for muons 12%
  - for electrons 11 %

Muon Isolation Studies

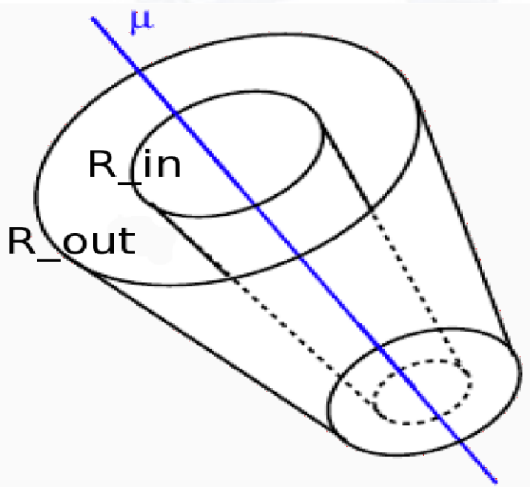
Isolating muons in the muon + jets channel is important to distinguish muons from a top quark decay and muons from QCD jets.

We are looking to improve upon the previous isolation requirement which was given as a calorimeter based cone isolation.

We studied the different effects of ΔR, track based cone isolation (pTcone), calorimeter based cone isolation (ETcone), the combination of both, and also scaled by the momentum of the muon.

We used the Signal over Background ratio as measure of optimal isolation between muons and QCD muons.

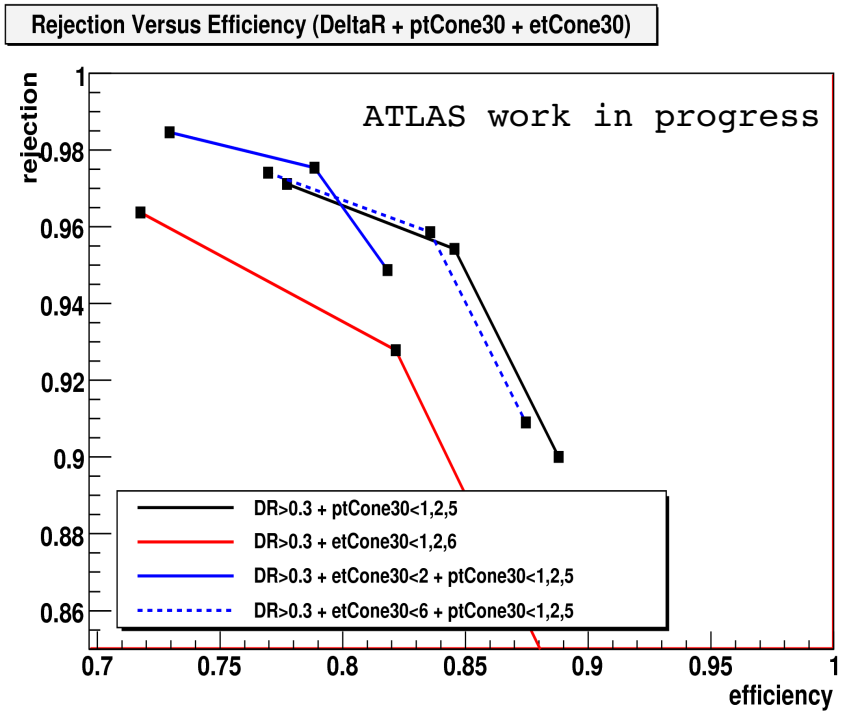
The Cone isolation algorithm measures the energy or momentum of tracks between the radius R_out and R_in.

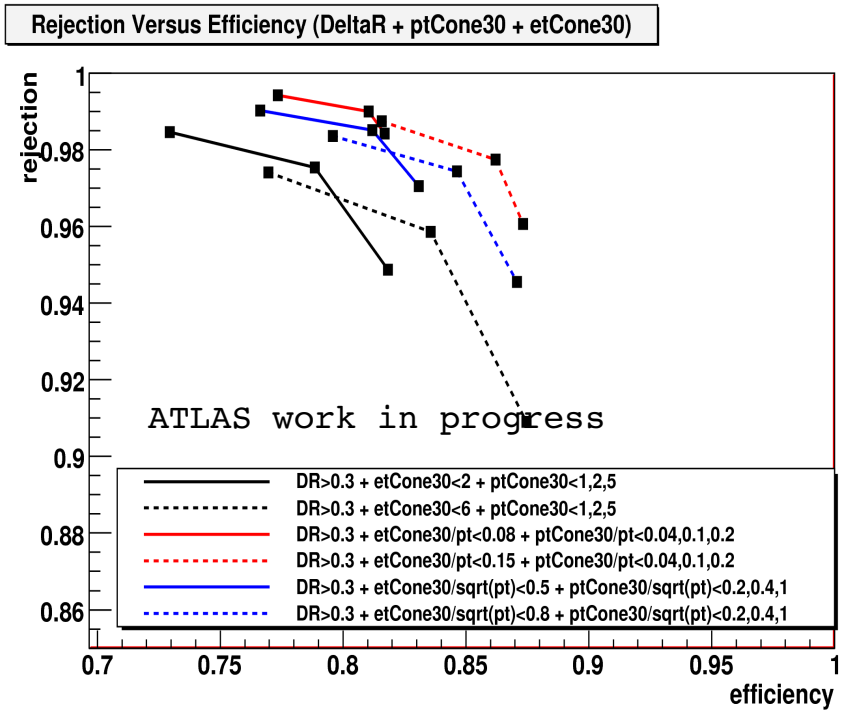


For this study the signal efficiency was determined from the MC@NLO sample containing muons which decayed semi-leptonically from the top quark (matched to truth information) and the rejection is determined from ALPGEN QCD Multijets with a muon filter.

Muon Isolation Studies

For this analysis, no event cuts were applied. It was required that muons be reconstructed with a pT > 15 GeV and |η| < 2.5





The efficiency vs. rejection was again improved significantly using the cone algorithm scaled by the momentum of the muon.

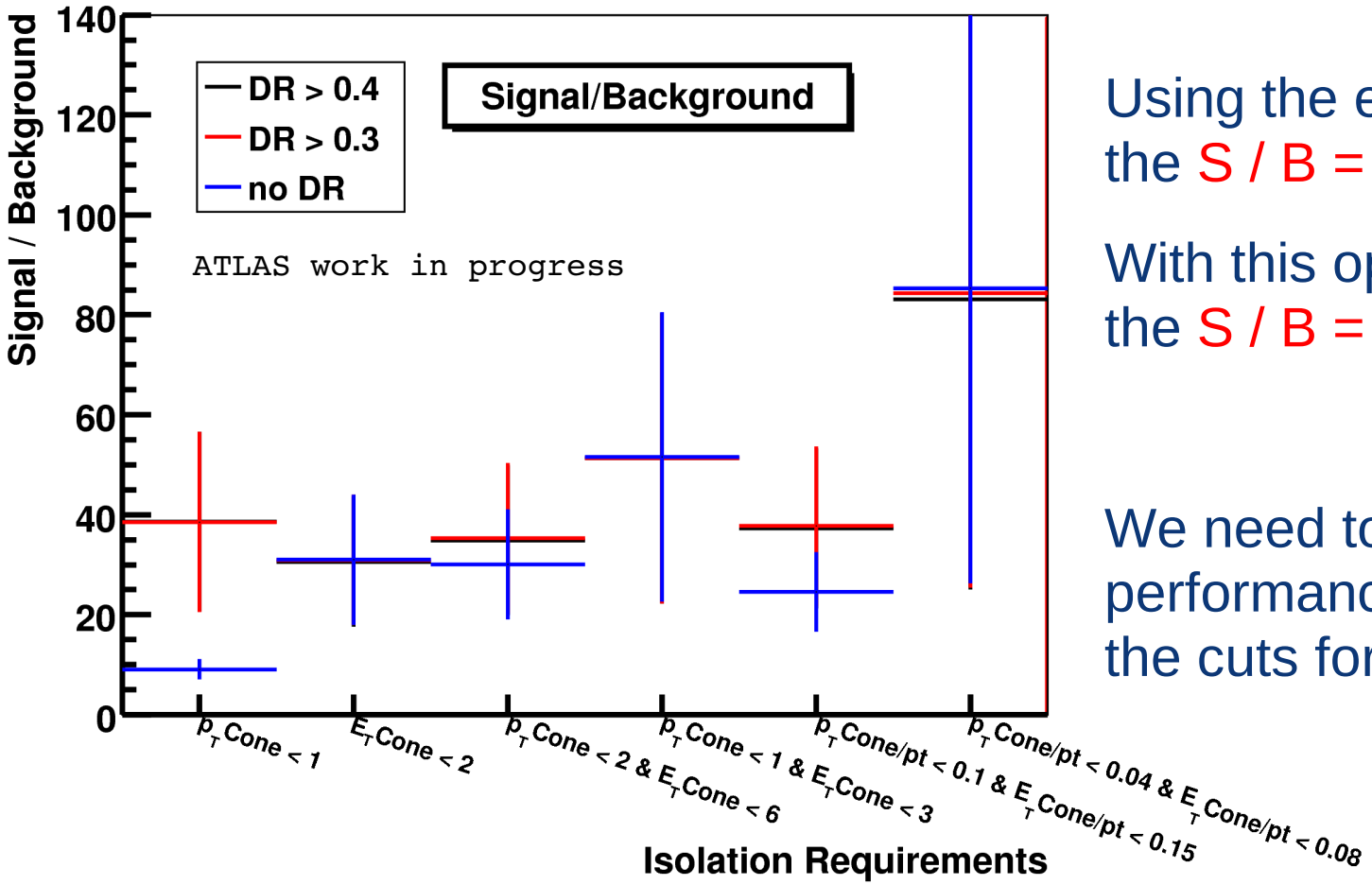
Track isolation performs better than calorimeter isolation. The combination of both track and calorimeter also has a better rejection than both individually.

Muon Isolation Study Results

The optimal cut was found with requiring:

ΔR > 0.3 + pTcone/pT < 0.04 + ETcone/pT < 0.08 (cone size 0.3)

Using this optimal selection, we then applied the event selection to the sample and measured the S/B.

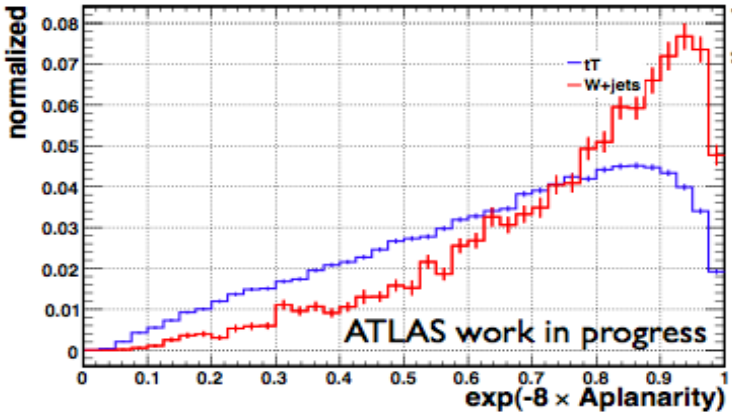


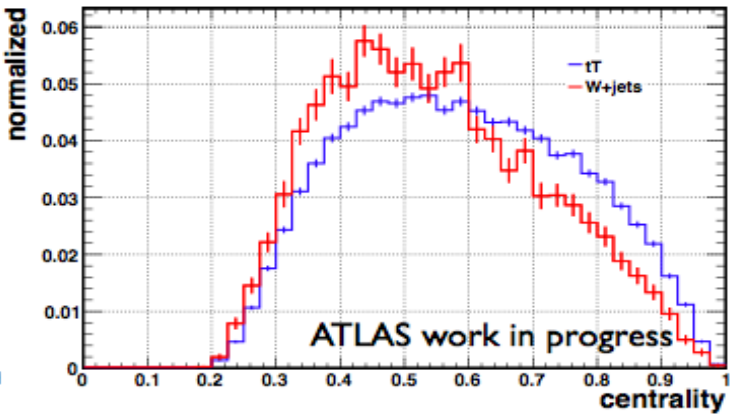
Using the event selection, the S / B = 6.7

With this optimal cut, the S / B = 85

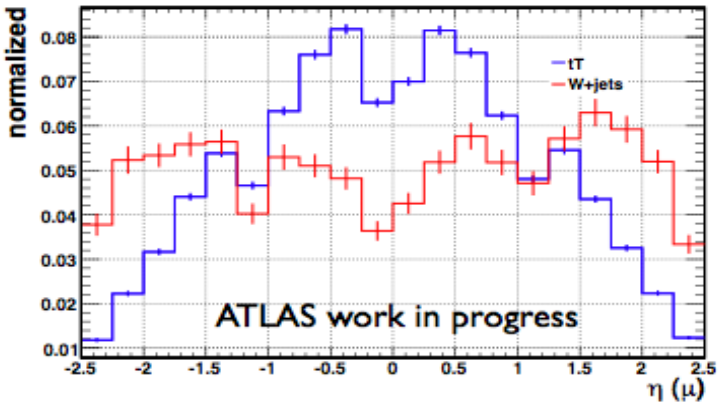
We need to check the performance in data to chose the cuts for analysis.

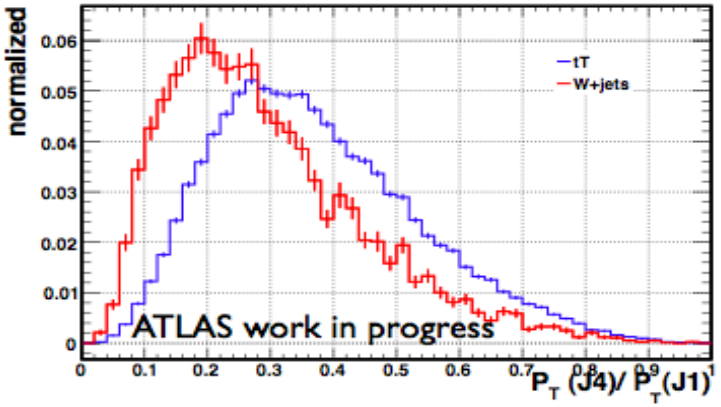
Input Variables



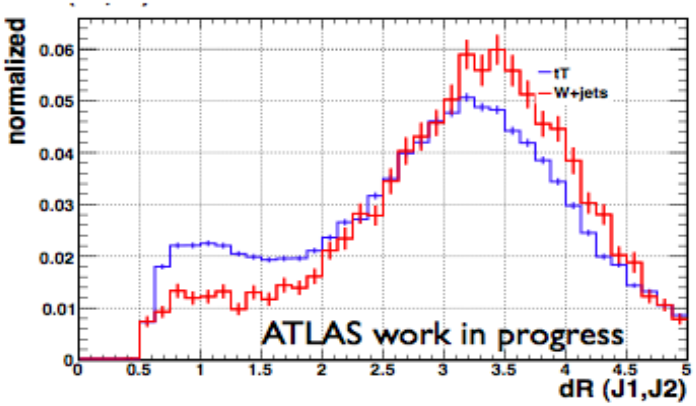


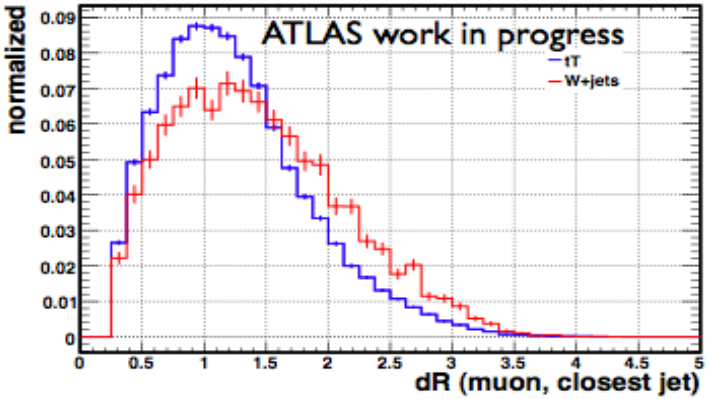
- select variables with small influence of jet energy scale





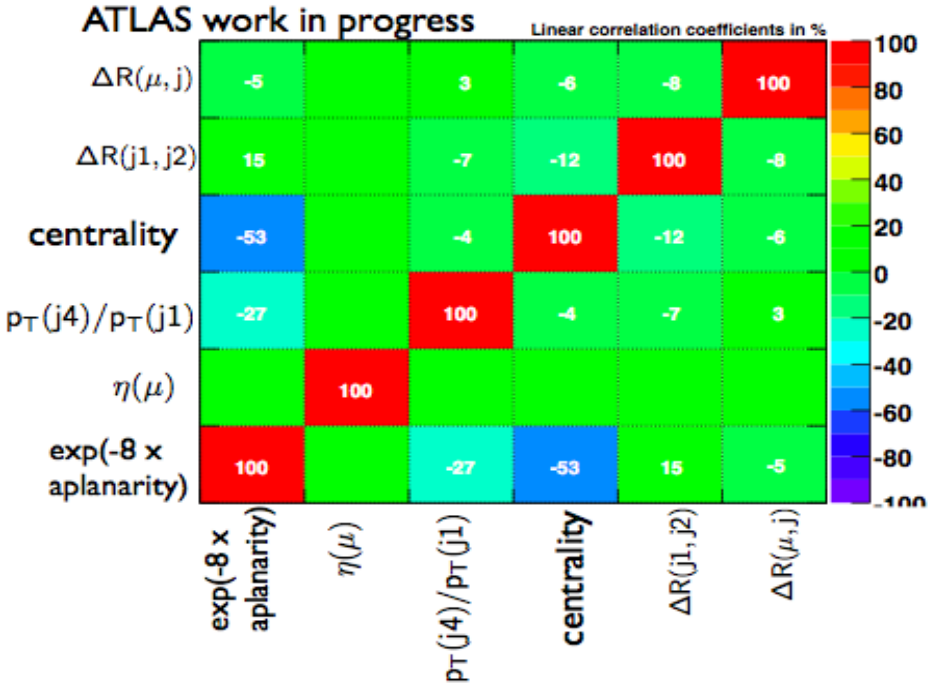
- combine topological variables - centrality, aplanarity - with kinematic properties





- currently studying KLfitter likelihood as additional variable (see talk J.Erdmann)

Method

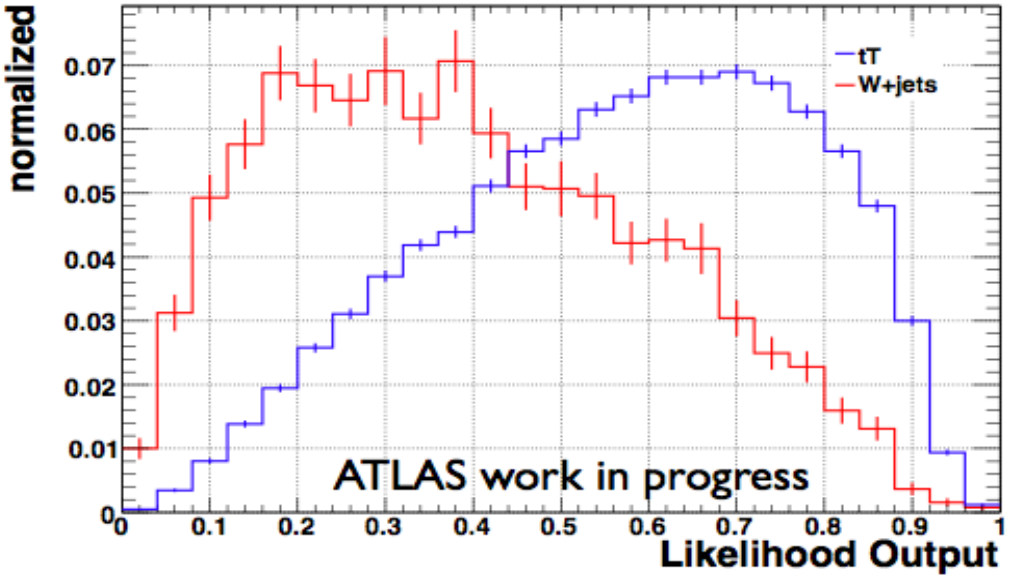


- use TMVA (www.tmva.sourceforge.net) - Toolkit for Multivariate Analyses
- use decorrelated likelihood, gives better separation
- diagonalise covariance matrix
- only valid for linear correlations

- create likelihood from template distributions (optimized smoothing and fitting within TMVA)

$$L = \frac{\prod_i P(x_i|S)}{\prod_i P(x_i|S) + \prod_i P(x_i|B)}$$

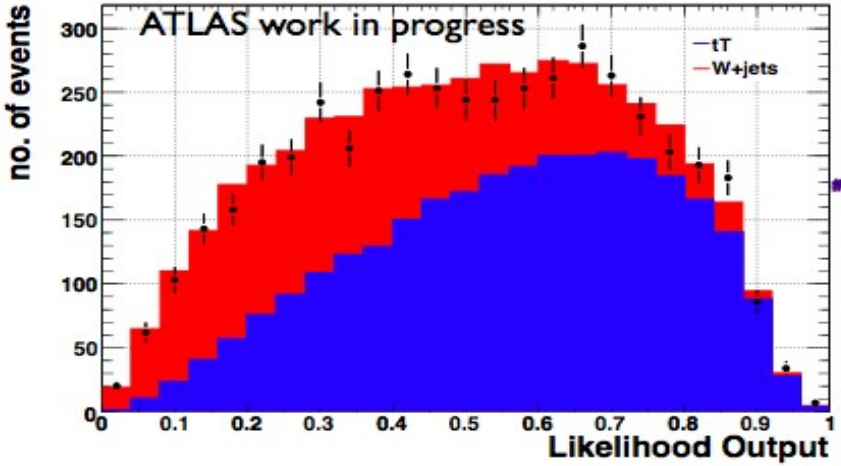
- assumes uncorrelated variables
- but cannot avoid some correlation



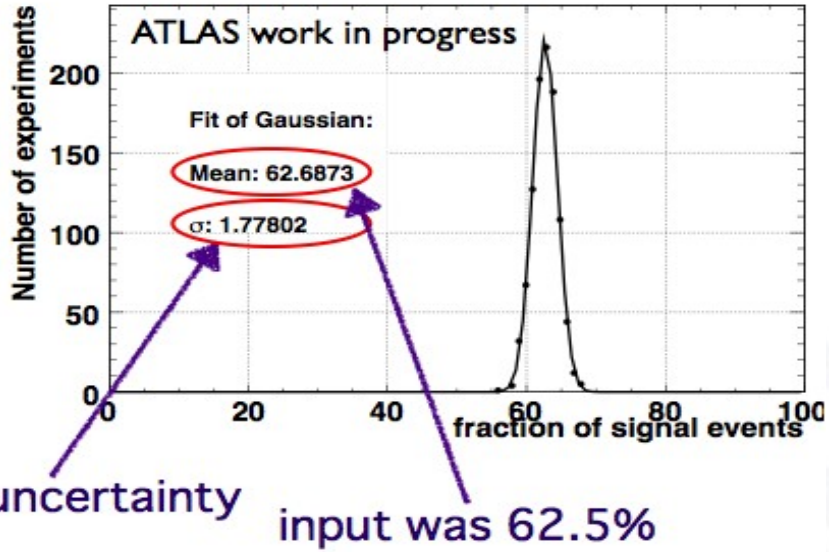
Extraction of the Signal Fraction

- extract fraction using maximum log-likelihood fit
- create pseudodata for testing/calibration of method

$$\sigma_{t\bar{t}} = \frac{N_{t\bar{t}}}{\varepsilon \int L} = \frac{N_{data} f_{t\bar{t}}}{\varepsilon \int L}$$

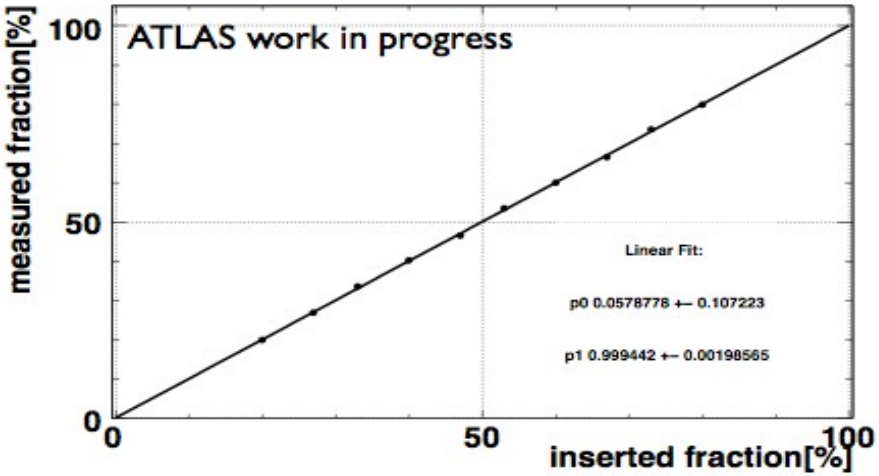


1000 times



- method is stable for nominal distributions
- check behaviour for different input fractions

- no offset
- slope close to 1
- method works!



Conclusion

The top quark cross section in the lepton + jets channel is a very important measurement for early data at the LHC

We have shown the efficiency of the triggers which will be used at ATLAS in both electron and muon channels.

We have optimized muon isolation with Monte-Carlo, arriving at a large S / B ratio, a factor of over 15 times higher than previous results but have to move to data driven estimation of the QCD background.

We have done initial studies on the Likelihood Method using a MVA which is geared towards calibration of first LHC data. However:

- Plan to study lower jet cuts – current high cuts degrade the discrimination between top quark pairs and W + jets.
- Check with data that selected variables are well-modelled.