

Single top studies at ATLAS

Clemens Lange

Humboldt-Universität zu Berlin
DESY, Zeuthen



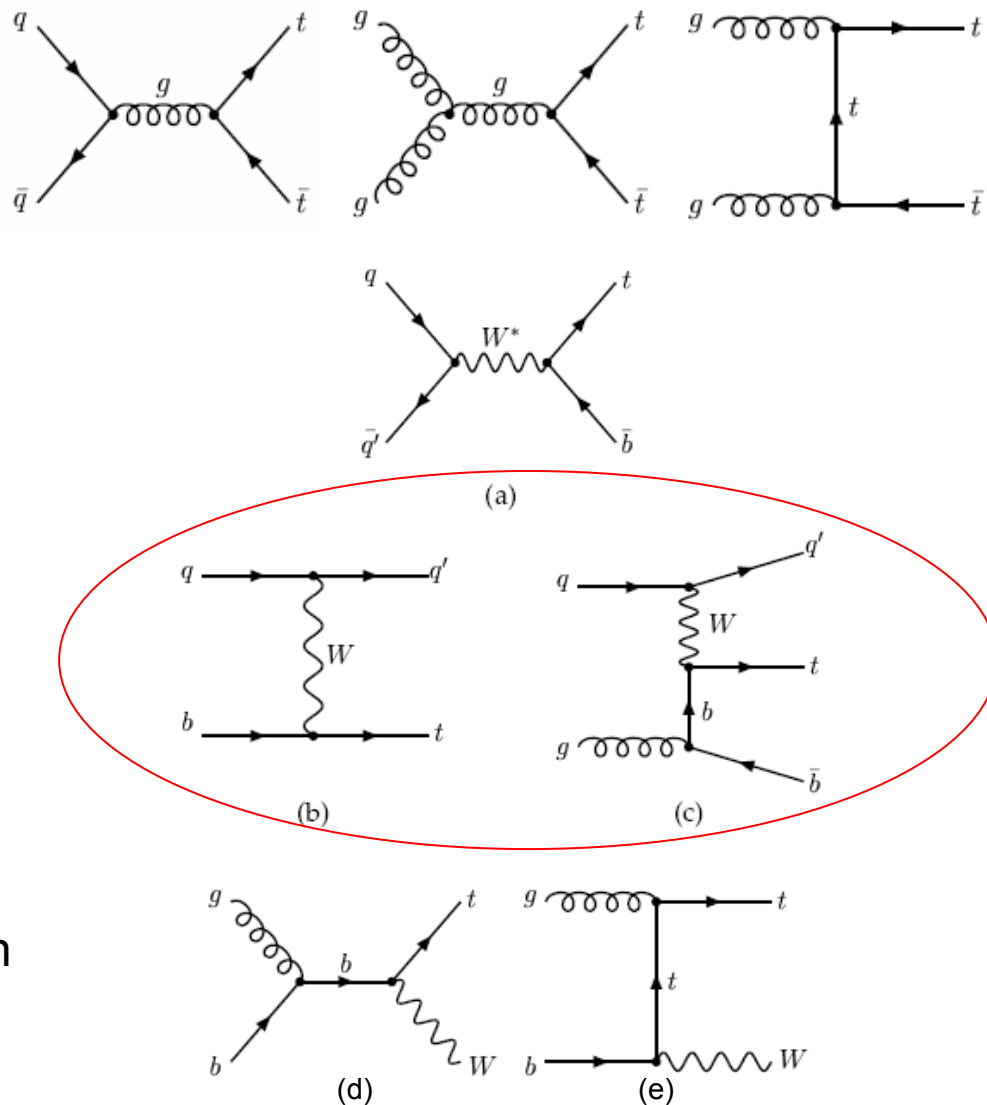
1. top quark cross-section
2. production and decay chain at LHC
3. cuts for t-channel
4. mass reconstruction
5. forward parton/jet
6. summary

top production at LHC

- production of $t\bar{t}$ pairs and single top

process	cross-section
$t\bar{t}$	833 pb
s-channel (a)	10 pb
t-channel (b,c)	239 pb
associated W (d,e)	64 pb
total single top	313 pb

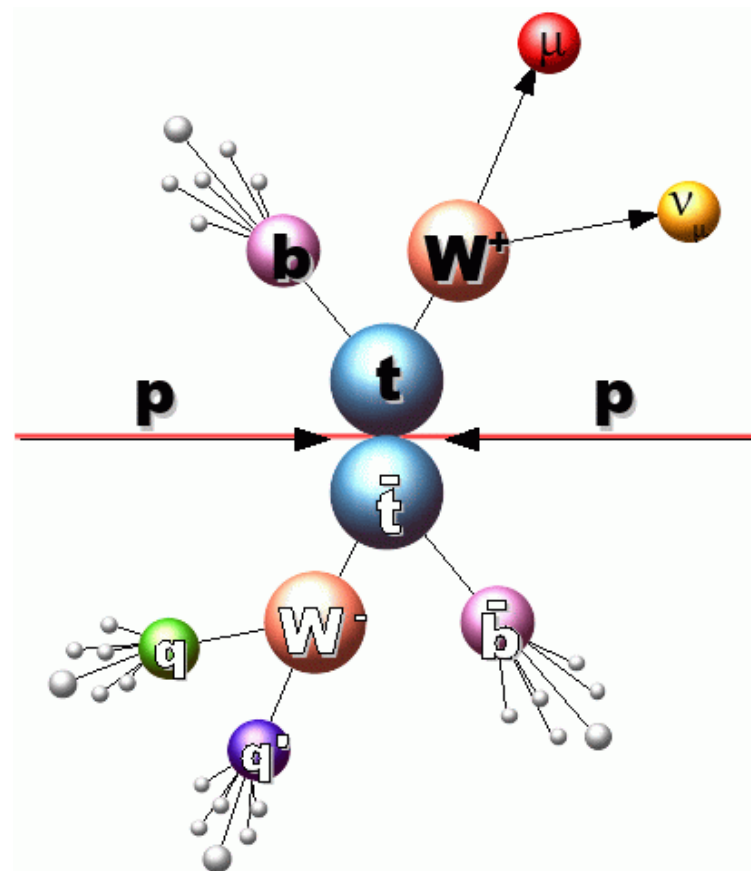
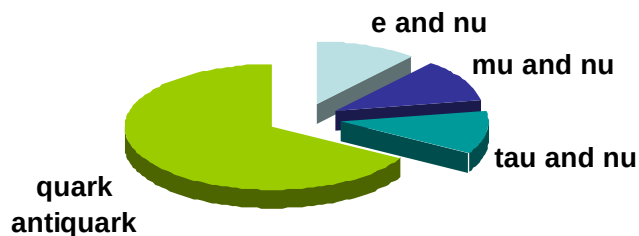
even at low luminosity over 8 million $t\bar{t}$ pairs and a few million single top events per year at LHC



top decay

- top lifetime of 4×10^{-25} s shorter than characteristic QCD hadronisation time of 28×10^{-25} s
- no fragmentation
- no toponium resonances
- spin retained

single top branching ratio

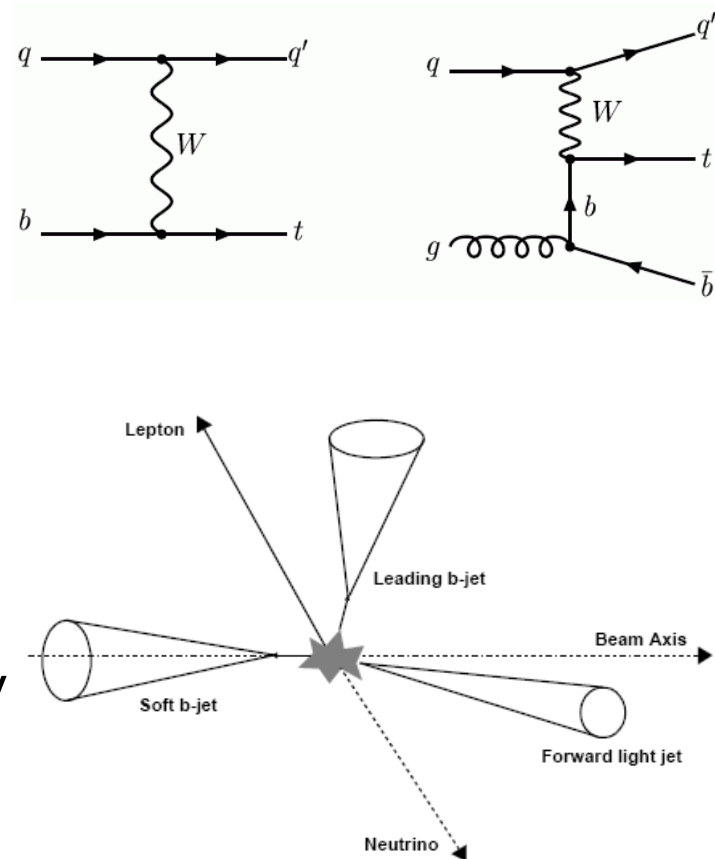


background to single top

- a lot of background to single top:
 - $t\bar{t}$
 - $W + b\bar{b}$
 - $W + \text{jets}$
- tight cuts have to be applied
- however: t-channel forward jet is unique for top physics (next slide)
- top mass window cuts to get rid of $W + \text{jets}$ (large cross-section)

cuts for single top

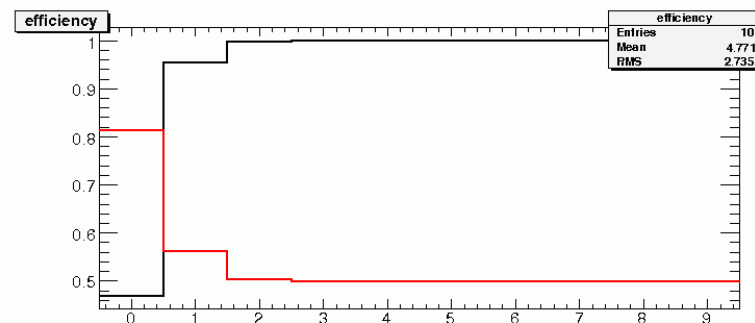
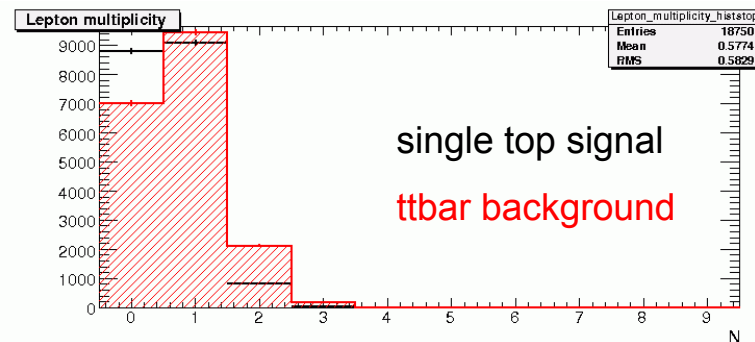
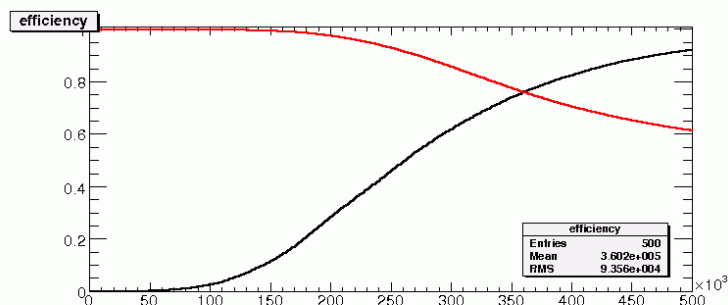
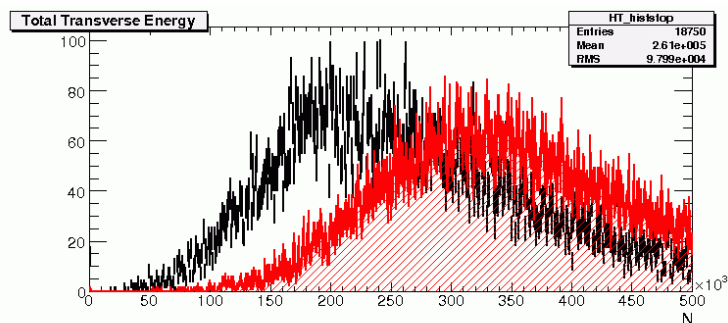
- $t\bar{t}$ is background to single top
- used t-channel with leptonic W-decay
- selection cuts:
 - exactly two jets with $p_T > 30$ GeV
 - one of the jets with $|\eta| > 2.5$
 - other jet b-tagged and $p_T > 50$ GeV
 - one lepton with $p_T > 20$ GeV
 - $H_T > 200$ GeV and total $m_{inv} > 300$ GeV
- efficiency drops to 2%, background below 0.01%



ttbar background analysis cuts

purity & efficiency curves for

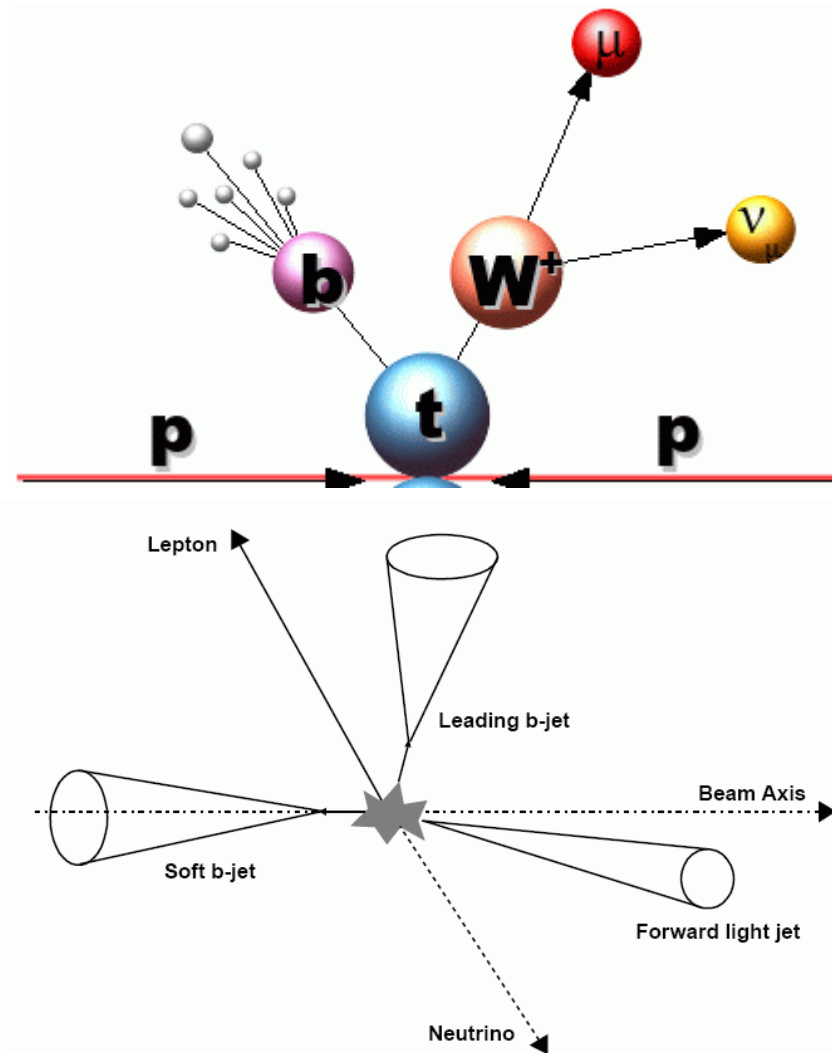
- multiplicities & p_T :
 - all jets, b jets
 - forward jets
 - leptons



- HT
- missing ET
- „Passed_1J1Jfwd“

→ planned: move to release 13 and also do same analyses with W+jets

- single-top t-channel leptonic decay
- reconstruct top via b jet and W ($l + \nu_l$)
- p_z of ν unknown
→ solve quadratic equation
- finding the correct solution not trivial



finding the correct pz with TMVA

- The **T**oolkit for **M**ultivariate **A**nalysis (TMVA) provides a ROOT-integrated machine learning environment for the processing and parallel evaluation of sophisticated multivariate classification techniques.
- tested methods: rectangular cuts, maximum likelihood, boosted decision trees (BDT)
- used variables (all from truth): Nu_{η} , $\Delta\eta$ between Nu and lepton, $\cos\theta$ of ($\bar{\nu}$ and b-jet), (W and lepton), (lepton in W rest frame and W in top r.f.).
- **low correlation**
- so far no forward jet as not available from truth so far (see later)
- only BDT lead to improvements
- planned: analyse forward jet and move from truth to reco

method	correct solution
smaller $ \eta $	73.0 %
cuts	70.8 %
likelihood	72.9 %
BDT	~ 83 %

boosted decision trees

Building Decision trees

- pick variable that gives best separation of background from signal
- repeated for each branch
- use criterion for quality of separation

- weight events (W_s & W_b , e.g. $1/N$)

- purity:
$$P = \frac{\sum_s W_s}{\sum_b W_b + \sum_s W_s}$$

- $P(1-P) = 0$ for pure sig/bg

- for given branch:

$$Gini = \left(\sum_{i=1}^n W_i \right) P(1-P)$$

- minimize $Gini_{\text{left son}} + Gini_{\text{right son}}$
- increase in quality = $Gini_{\text{father}} - Gini_{\text{left son}} - Gini_{\text{right son}}$

Boosting

Training

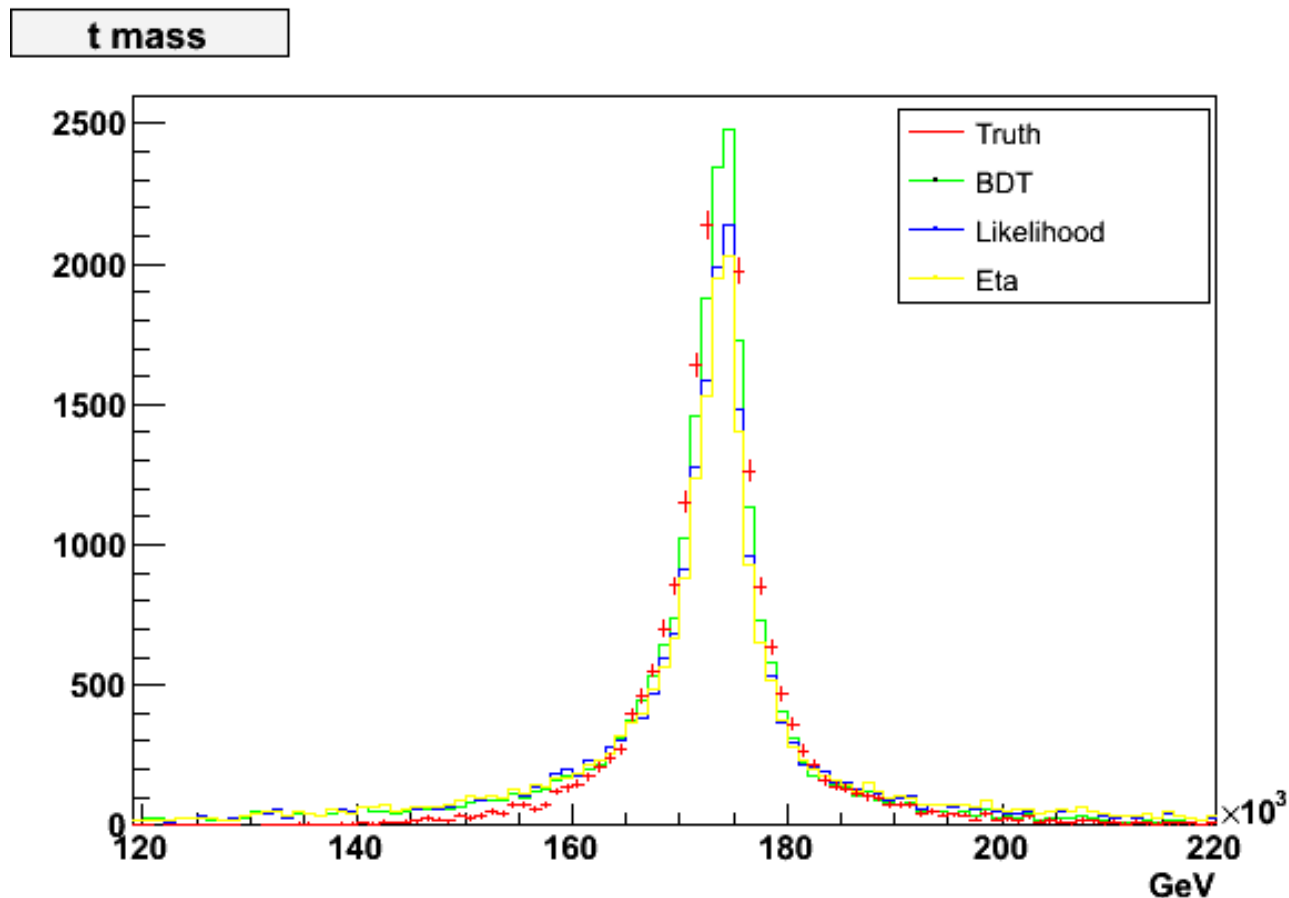
- start as before with unweighted events & build decision tree
- if event is misclassified $\rightarrow$ increase weight (boost)
- build new tree with new weights, repeat up to 1000 or 2000 times

Testing/Analysis

- assign score to event (+1 if ends up in signal branch, -1 if background branch)
- follow through each tree
- renormalised sum of scores is final score
- cut on scores for desired s/b ratio
- Popular algorithm: AdaBoost

effect on top mass

	Mean [GeV]	Gauß- Fit
small Eta	173.3	172.9
Likelihood	173.0	173.0
BDT	171.4	173.2
Truth	173.5	173.4

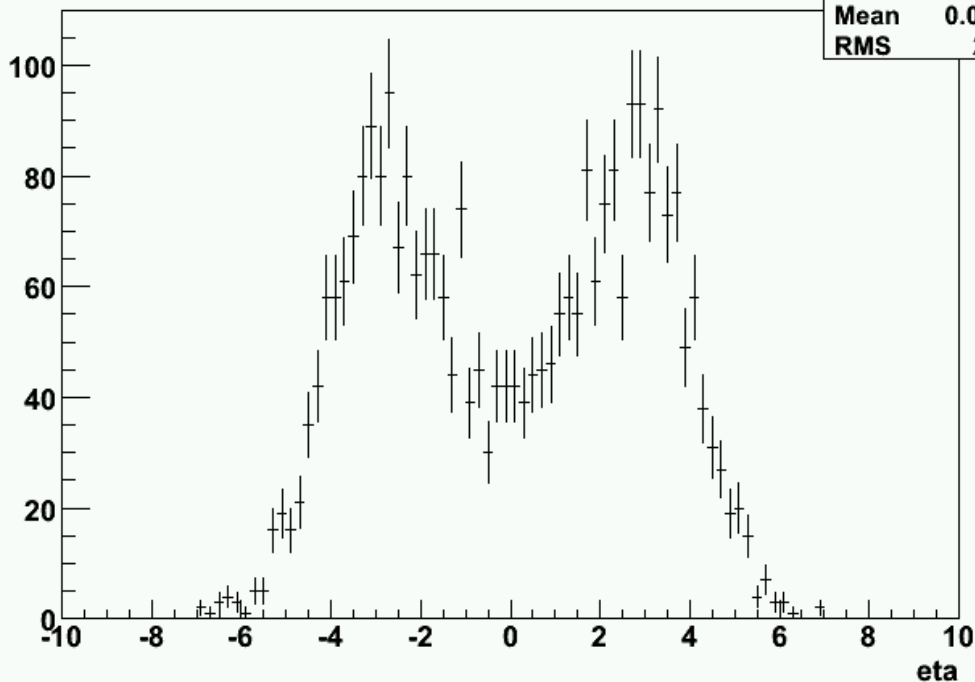


forward parton

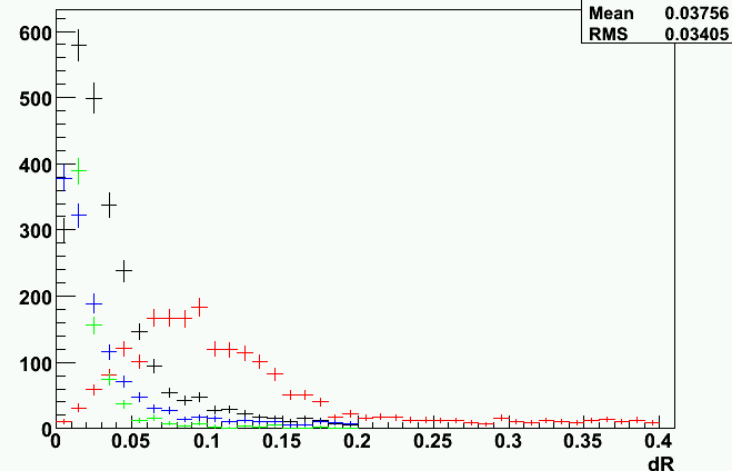
- examined single top production with AcerMC and MC@NLO
 - wrote own TopPhysTools code to select truth forward parton determined via barcode and mother
- will analyse single top production with different MC generators (LO & NLO) with focus on forward parton/jet

from forward parton to forward jet

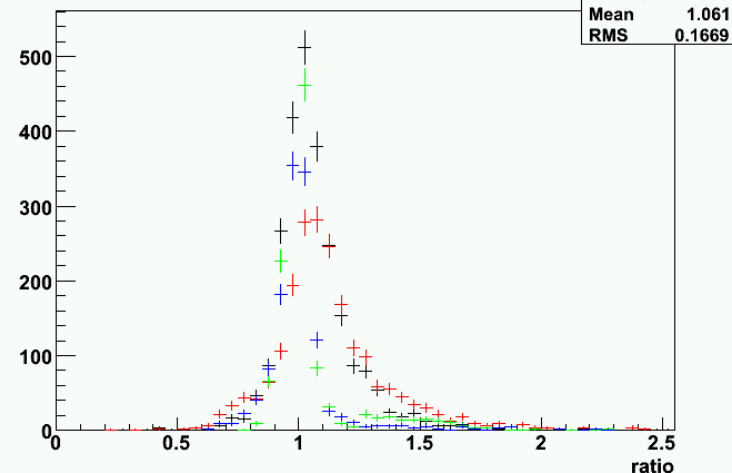
Tru_ForwardParton_eta



FJ Tru Reco dR-distribution



FJ Tru Reco p_T ratio



results seem reasonable, matched:

Truth to Reco L1 to Reco

L2 to Reco EF to Reco

- further background studies will be done in release 13 using forward jet triggers
- use forward parton/jet information for TMVA analysis for neutrino p_z
- tune TMVA analysis parameters with more statistics
- more studies on top mass reconstruction
- study generator independence of single top production



backup



LVL1 Trigger

- PassedL1: 0.373786
- PassedL1_2J45: 0.808838
- PassedL1_2J45_XE20: 0.695834
- PassedL1_2J45_lept: 0.432221
- PassedL1_XE20: 0.853303
- PassedL1_lept: 0.507503
- PassedL1_lept_XE20: 0.435213

LVL2 Trigger

- PassedL2: 0.377537
- PassedL2_2j20: 0.880967
- PassedL2_lept: 0.418412

Event Filter

- PassedEF: 0.326674
- PassedEF_jet20bEtEF_jet20bEt: 0.837722
- PassedEF_lept: 0.376571

Complete trigger chain

LVL2 Trigger

- PassedL2Combi: 0.287204
- PassedL2_2j20Combi: 0.373786
- PassedL2_leptCombi: 0.287204

Event Filter

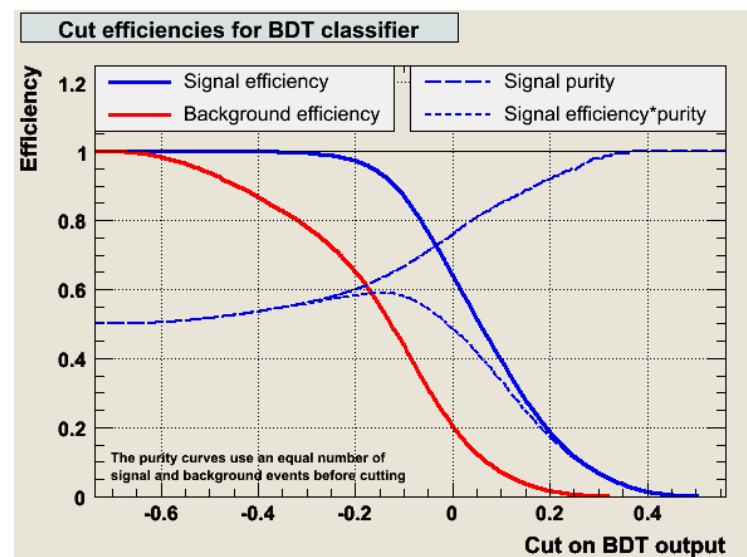
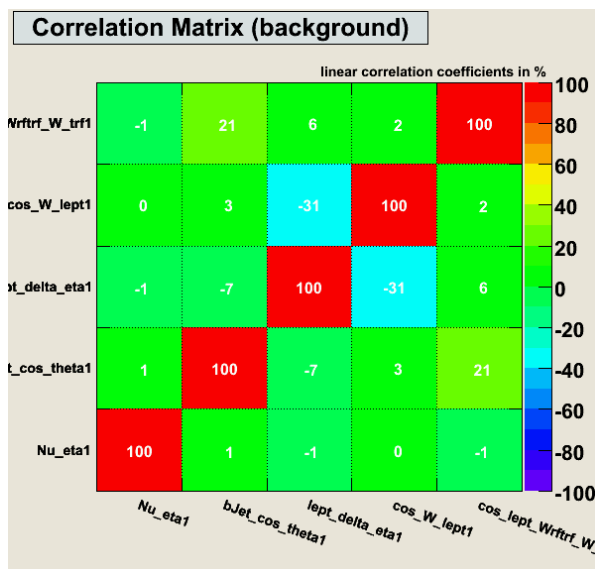
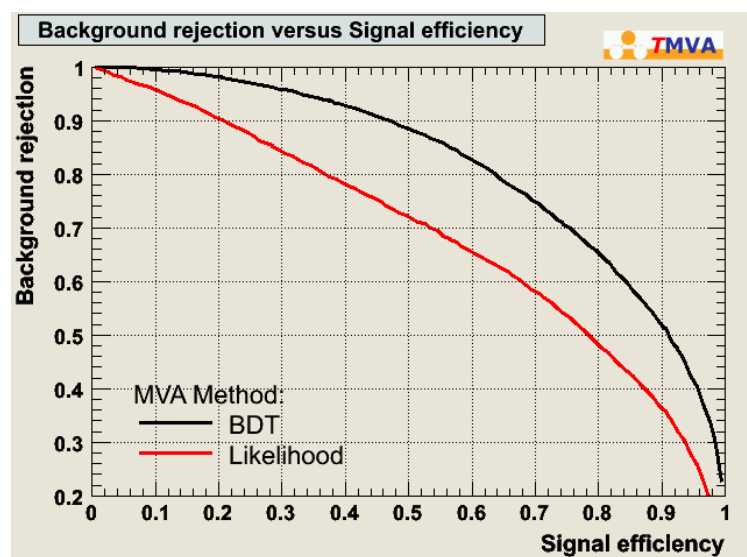
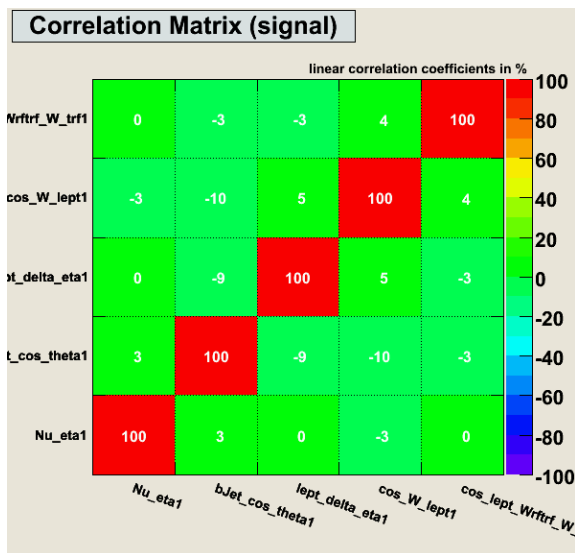
- PassedEFCombi: 0.24985
- PassedEF_jet20bEtEF_jet20bEtCombi : 0.280046
- PassedEF_leptCombi: 0.256272

Analysis cuts

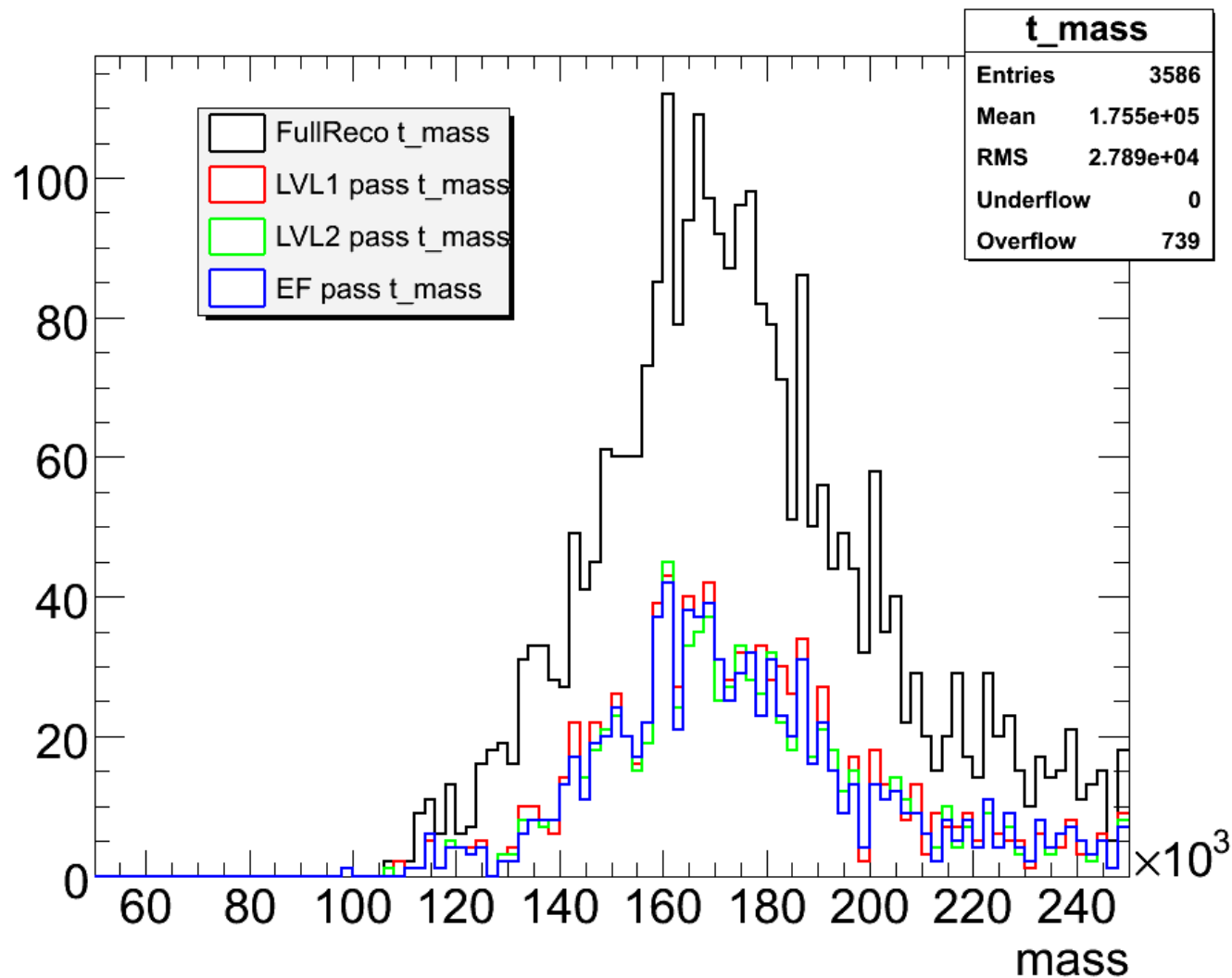
- PassedAna: 0.102854
- PassedAnaL1: 0.0523962
- PassedAnaL2: 0.0489125
- PassedAnaEF: 0.0449816
- Passedfwjet: 0.462738
- Passedbj50: 0.261542
- Passedlept20: 0.102854

→ agree with TDR studies

TMVA output



top mass @ trigger/reco

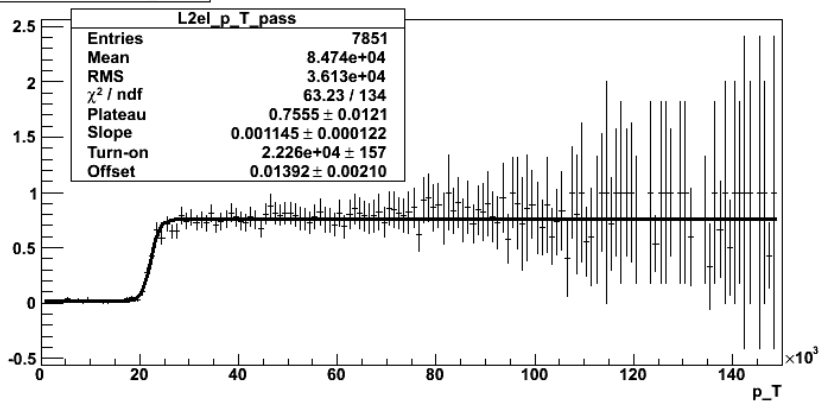


LVL2 & EF turn-on curves

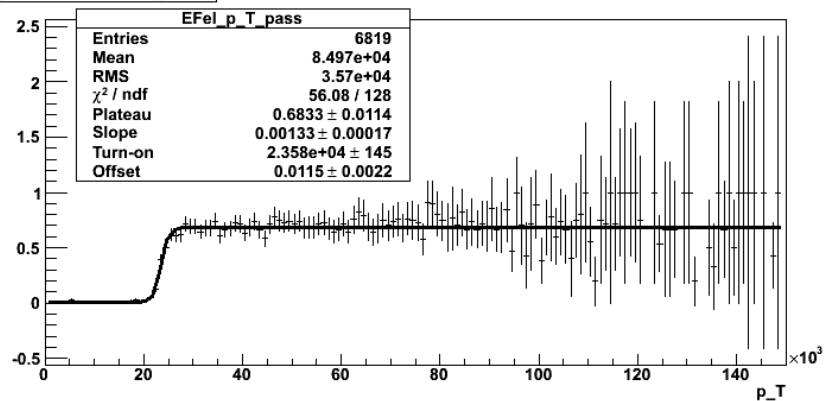
LVL2

EF

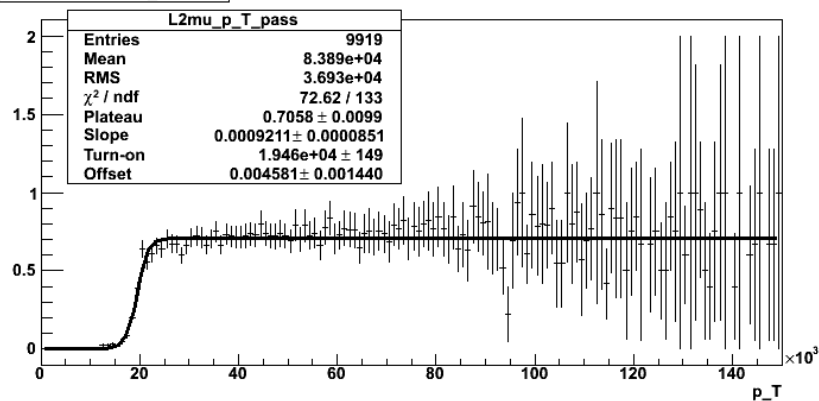
m_reco->PassedL2_e25i



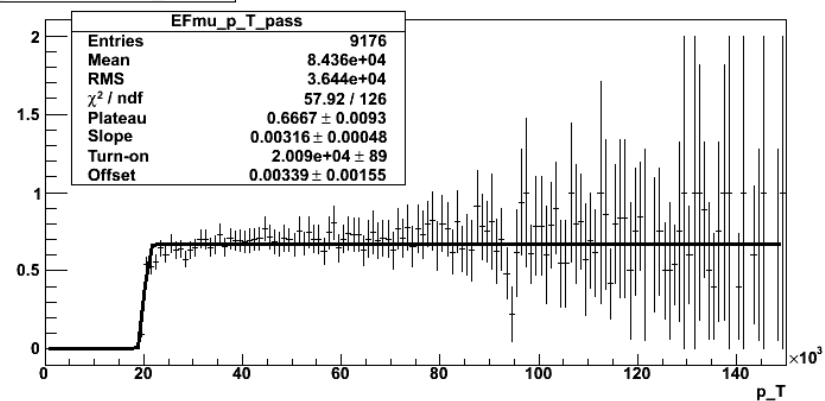
m_reco->PassedEF_e25i



m_reco->PassedL2_mu20i



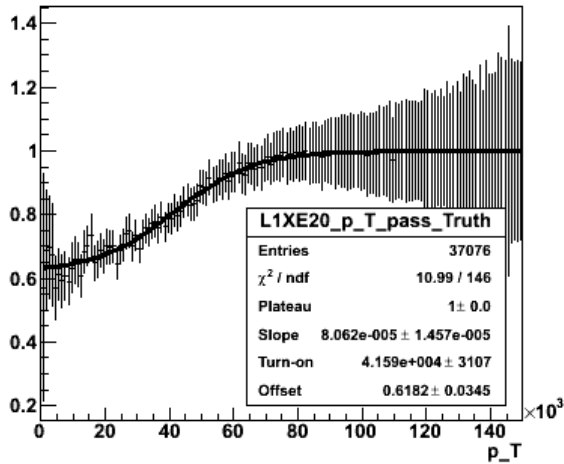
m_reco->PassedEF_mu20i



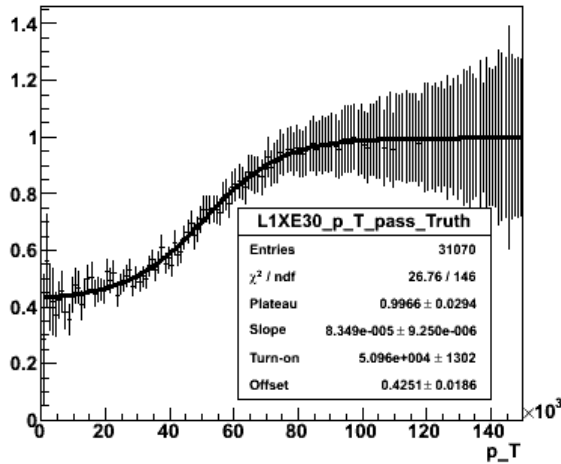
further improvement of turn-on behaviour

missing E_T turn-on curves

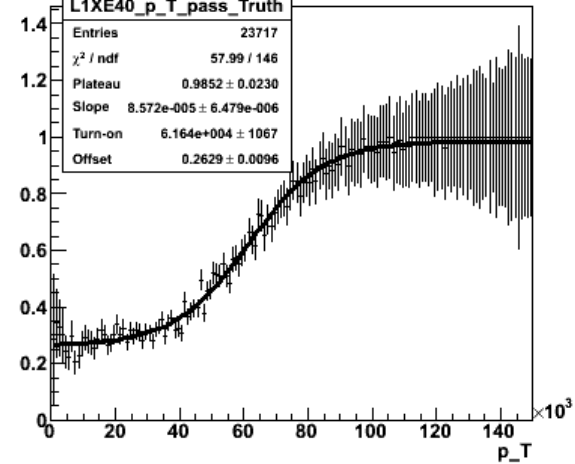
m_reco->PassedL1_XE20Truth



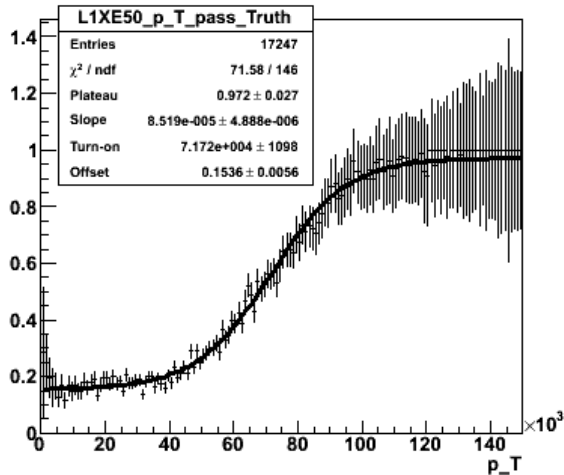
m_reco->PassedL1_XE30Truth



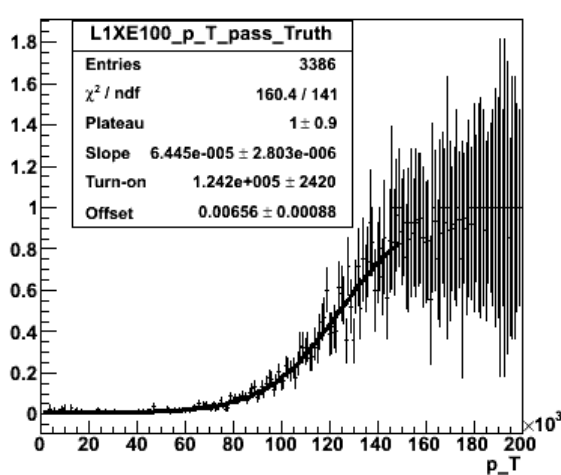
m_reco->PassedL1_XE40Truth



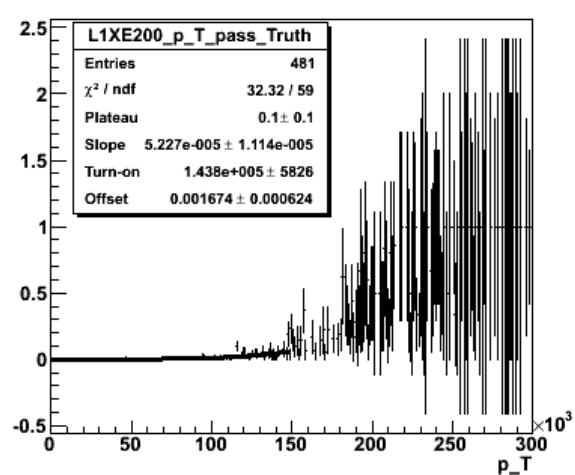
m_reco->PassedL1_XE50Truth



m_reco->PassedL1_XE100Truth



m_reco->PassedL1_XE200Truth



→ XE20 & 30 not useful, however loss of 35% of events for XE40 compared to XE20

E_T shift & E_T sum dependence

