studies of $t\bar{t}$ decay into 6-jets at the LHC

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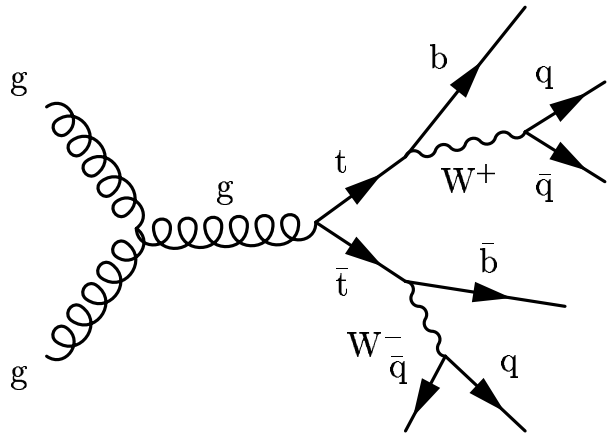
Overview

Motivation

- Analysis of the properties of top quarks is one of the main topics at LHC – LHC is a top quark factory.
- Expected $t\bar{t}$ cross section at LHC:
  $\sigma(pp \rightarrow t\bar{t}) \approx 833\ \mathrm{pb}$ (NLO)
  This corresponds to:
  $8 \cdot 10^6\ t\bar{t}$ events per year at $\int L\ dt = 10\ \mathrm{fb}^{-1}$
- Hadronic decay is most common top decay.
  Branching ratio 44 % $\rightarrow 3.7 \cdot 10^6$ multijet events for $\int L\ dt = 10\ \mathrm{fb}^{-1}$
- Problem: huge QCD multijet background;
  Presumed QCD multijet cross-section for $\mathrm{p_T} > 100\ \mathrm{GeV}$ (hard processes):
  $\sigma_{QCD} = 1.4\ \mu\mathrm{b}$ (2 to 6 jets)
  $\sigma_{QCD} = 0.3\ \mu\mathrm{b}$ (5 and 6 jets)

Event generation

- $t\bar{t}$ events ($\sim \alpha_s$):



Have been produced with the LO generator PYTHIA 6.2 in exclusive mode for PDF CTEQ6M. Jet reconstruction was done with the k_T algorithm. So far (O) 100000 $t\bar{t}$ events have been generated. Working on generation of events including detector simulation.

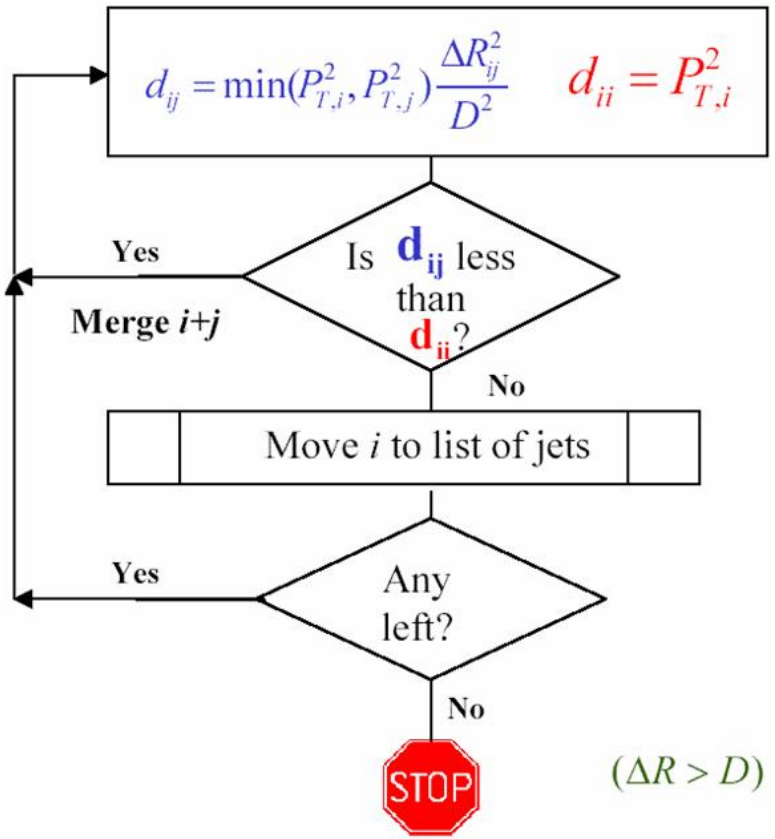
- QCD background:

  Has been generated by means of ALPGEN, which can produce up to six final state jets ($\sim \alpha_s^6$) at LO and PYTHIA 6.2.
  Several steps needed for generating the QCD multijet events:

  1) Weighted events with 3, 4, 5 and 6 jets in final state are generated with ALPGEN.
  2) Events are unweighted in second ALPGEN run.
  3) Unweighted events are run in PYTHIA (exclusive mode), where parton shower, MLM matching ($\cong \Delta R$) and jet algorithm are applied to the events.
  4) Events are scaled to the same luminosity:
     $L_{t\bar{t},PYTHIA} = 0.304\ fb^{-1}$

  By now 90000 QCD multijet background events have been generated with ALPGEN and PYTHIA.

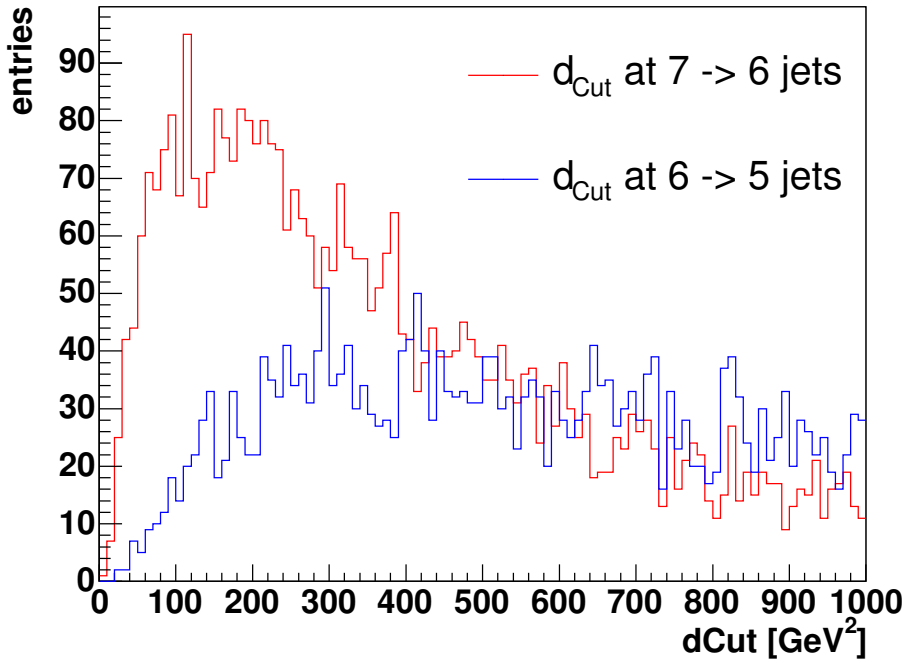
Jet reconstruction: the k_T algorithm



- $R_{ij} = (\eta_i - \eta_j)^2 + (\Phi_i - \Phi_j)^2$
- D is specified parameter (scaling parameter)
- d_{Cut}: cut-off parameter defines hard scale of event $\Lambda_{QCD}^2 \ll d_{Cut} \leq s$
- $d_{min} > d_{Cut}$: all remaining objects are classified as jets
- Size of jets is dynamic, no overlapping jets

First results

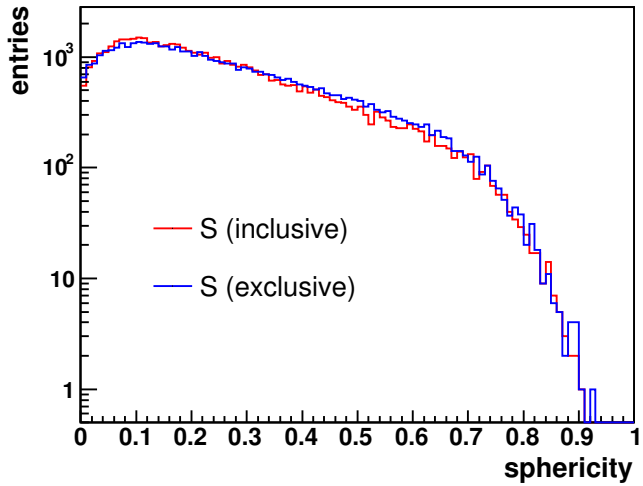
- Determination of cut-off parameter $\mathrm{d_{Cut}}$

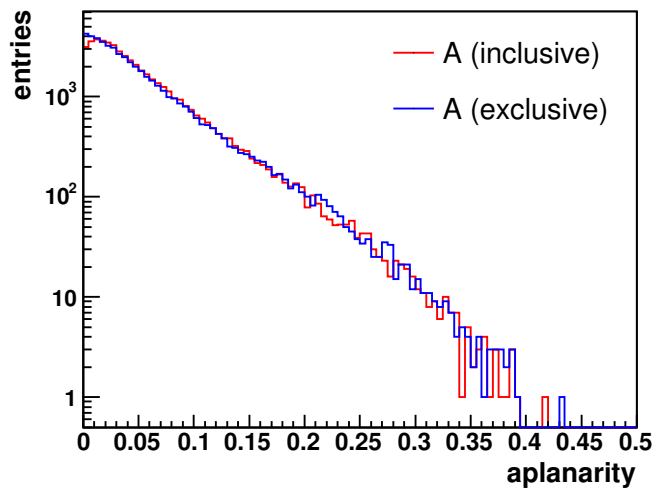


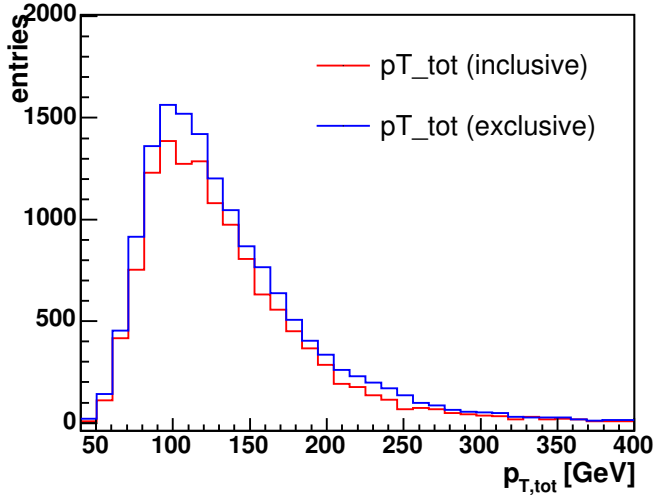
Distribution of $\mathrm{d_{Cut}}$ at jet merging $7 \longrightarrow 6$ jets and $6 \longrightarrow 5$ jets.
Best $\mathrm{d_{Cut}}$ for generating events with six jets in final state:

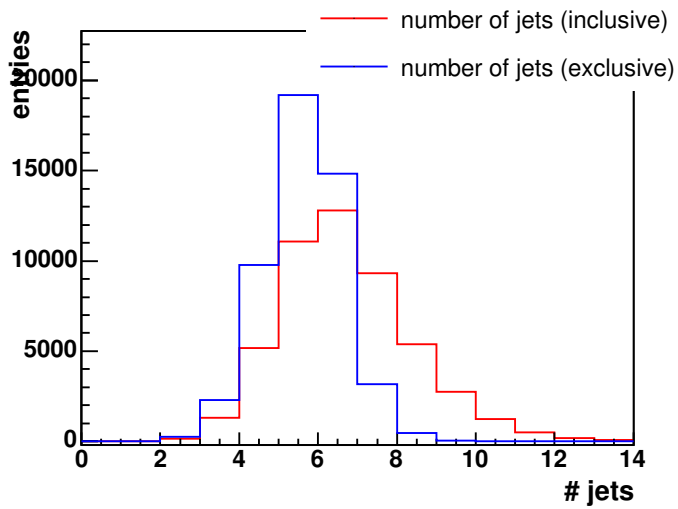
$$400 - 500\ \mathrm{GeV}^2$$

- Comparison between exclusive and inclusive alpgen 6-jets sample

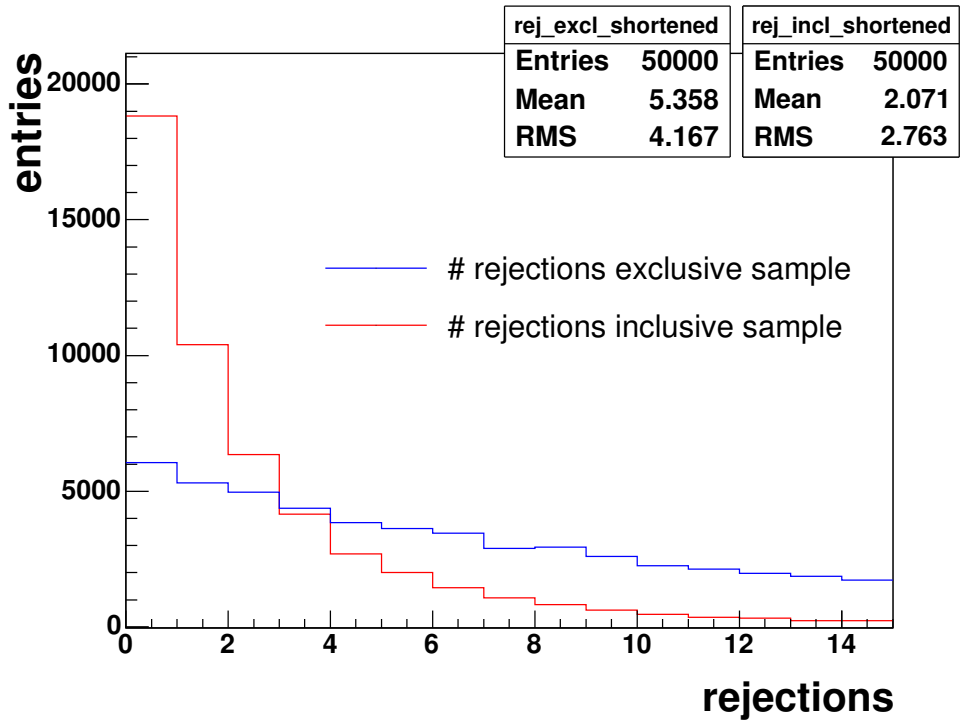






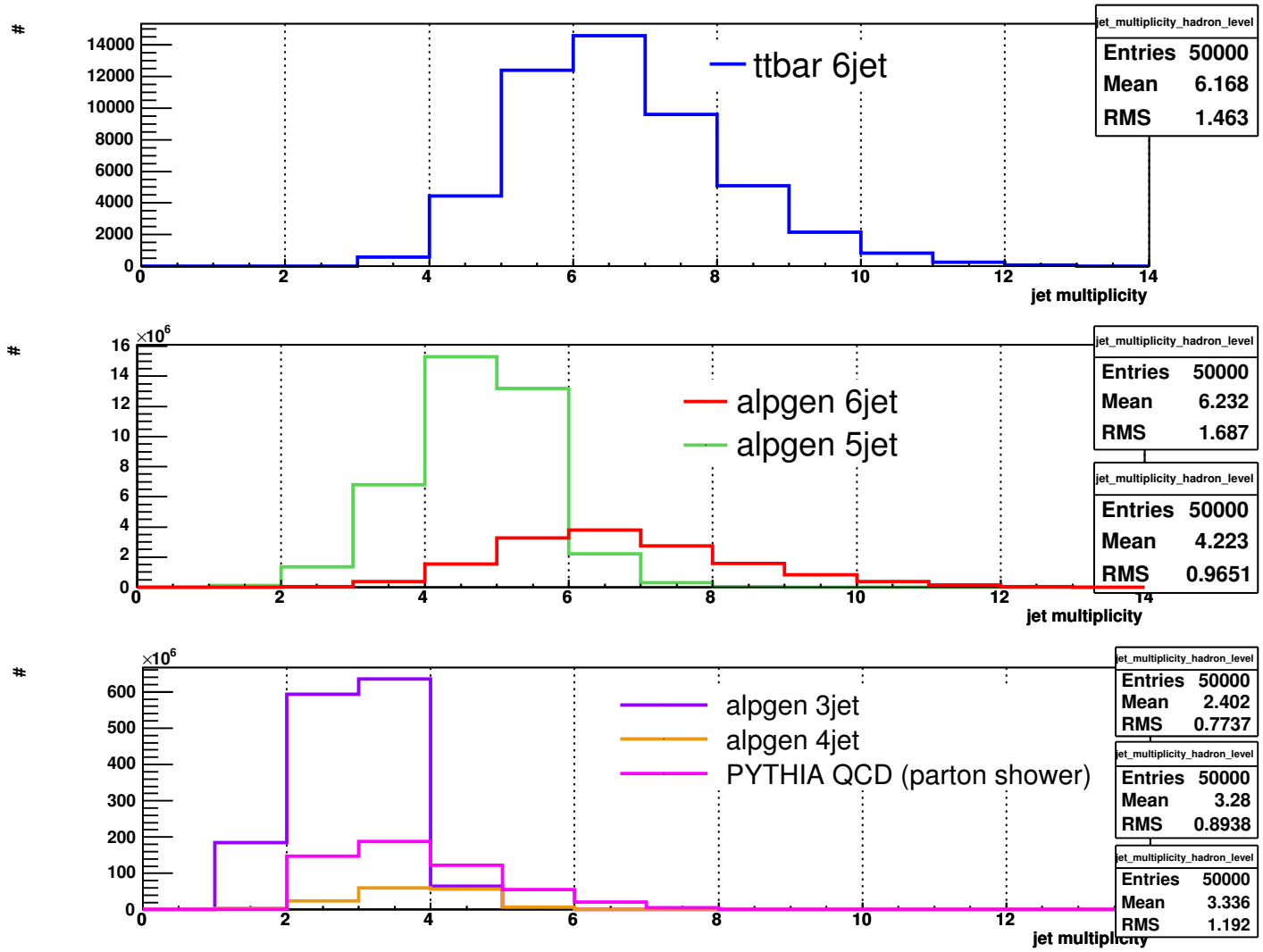


- Number of rejections of alpgen 6jets events (modified routine UPVETO in ALPGEN)



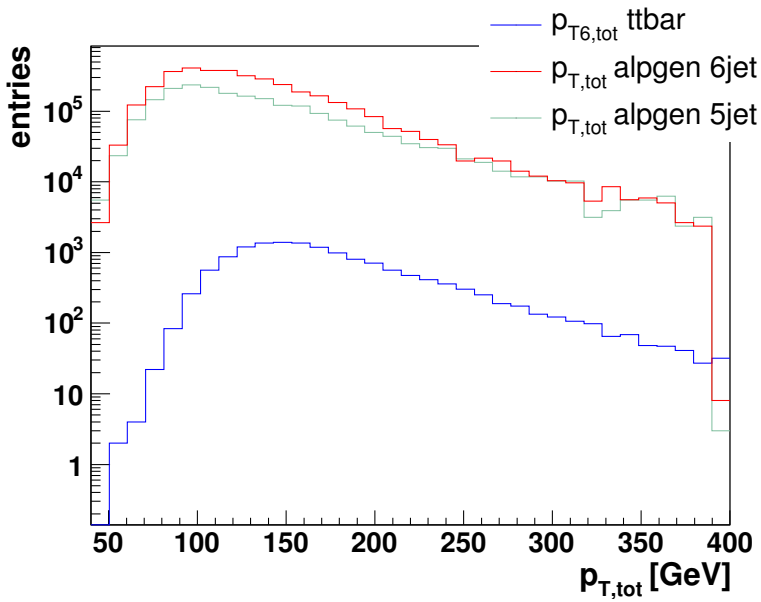
$\Rightarrow$ use inclusive alpgen 6-jets sample

- Jet multiplicity for $t\bar{t} \rightarrow$ 6-jets (PYTHIA), PYTHIA QCD parton shower (4-jets in LO) and ALPGEN 3-,4-,5- and 6-jets (inclusive) events on hadron level for $\mathrm{d_{Cut}} = 450\ \mathrm{GeV}^2$



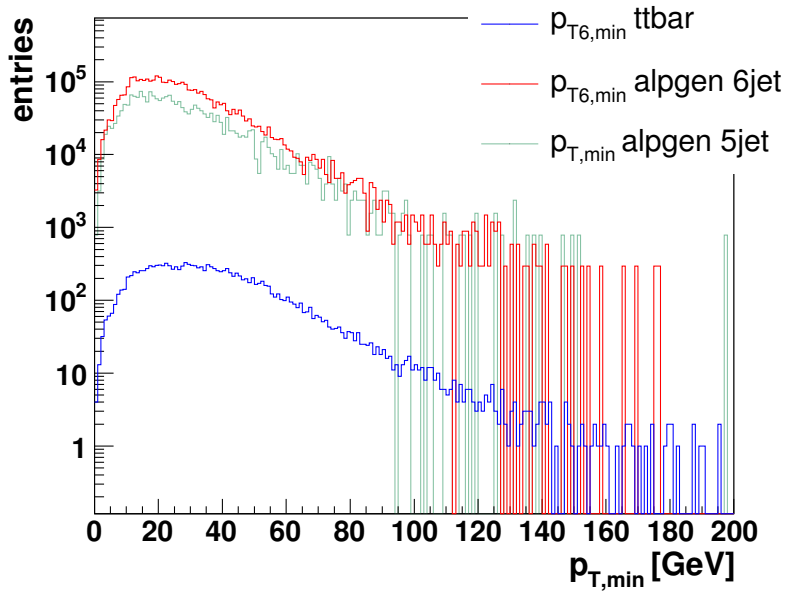
$\Rightarrow$ require ≥ 5 jets

- p_T of $t\bar{t}$ and background events on hadron level



total p_T in event

$\Rightarrow$ require $p_{T6,tot} \geq 125$ GeV

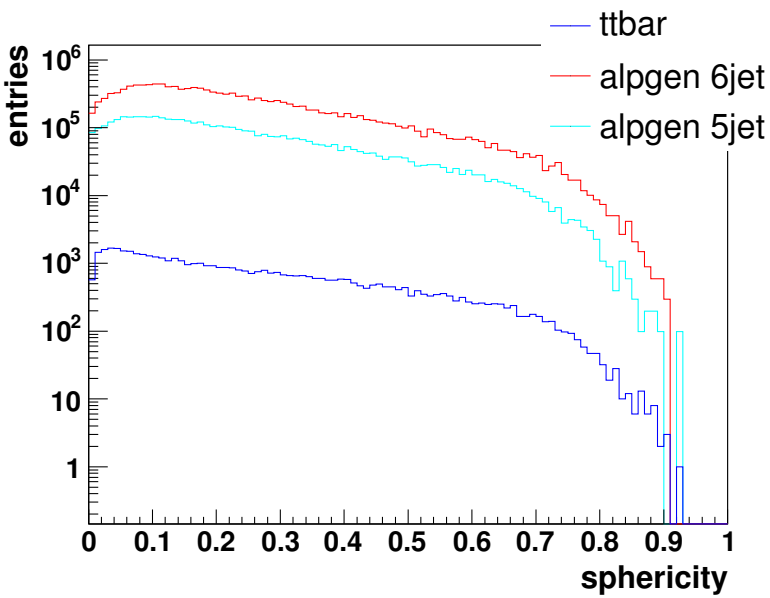


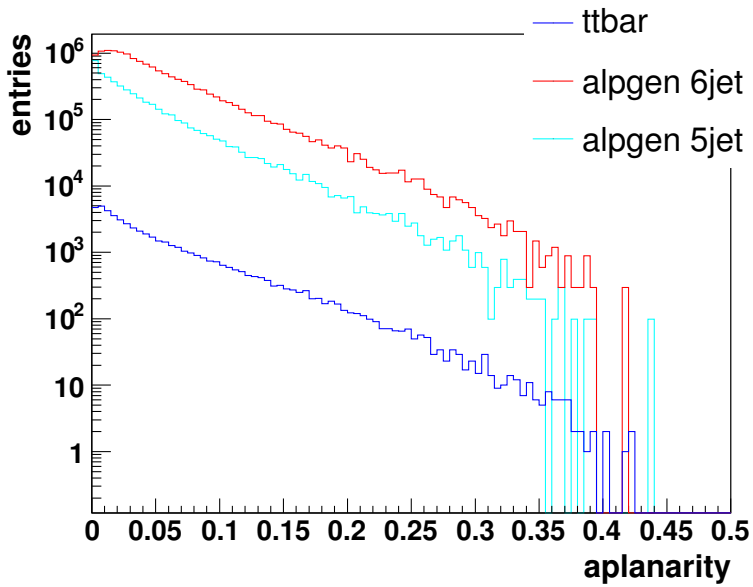
minimum p_T of jet in event

$\Rightarrow$ require

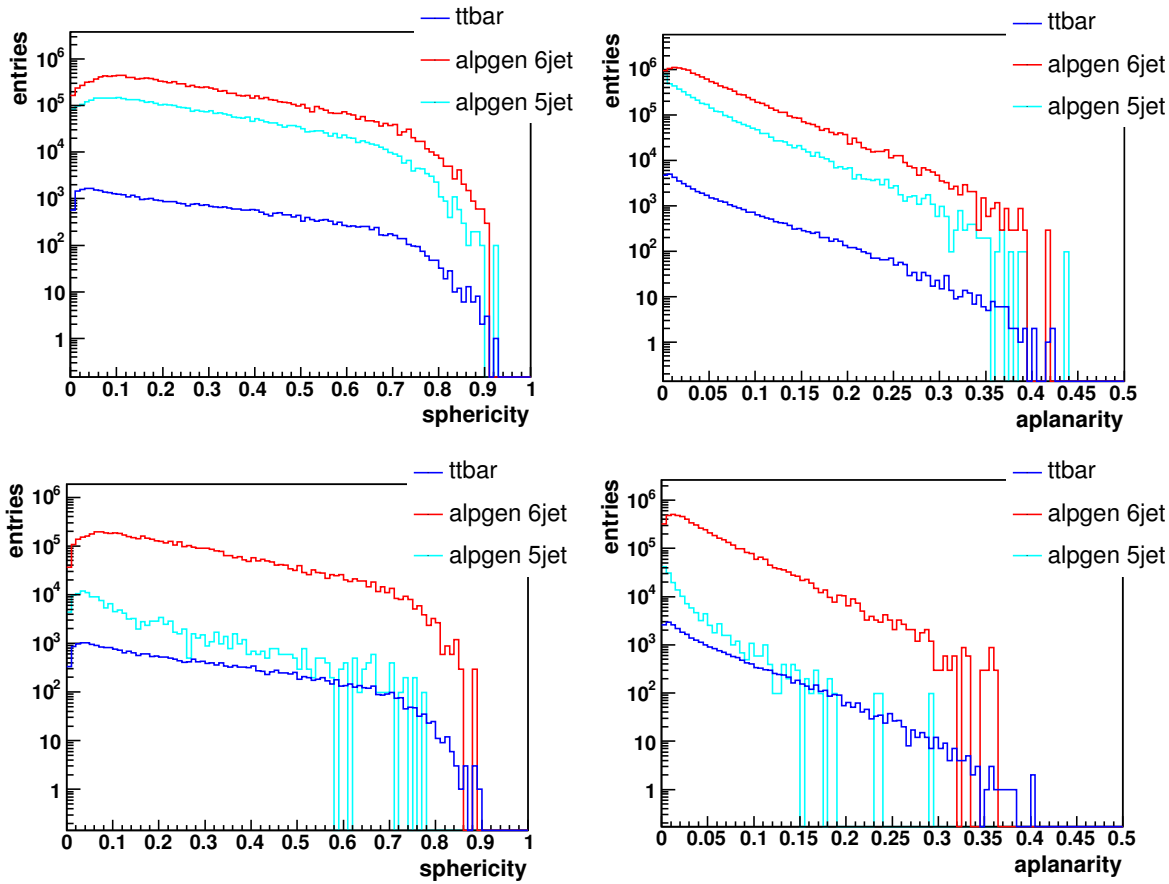
$10 \text{ GeV} \leq p_{T6,min} \leq 70 \text{ GeV}$

- Sphericity and aplanarity of $t\bar{t} \longrightarrow$ 6-jet and ALPGEN events on hadron level





- Sphericity and aplanarity of $t\bar{t} \longrightarrow$ 6-jet and ALPGEN events on hadron level for first selection cuts



Applied cuts:

- Number of jets ≥ 5
- $p_{T6,tot} \geq 125$ GeV
- 10 GeV $\leq p_{T6,min} \leq 70$ GeV

After applying cuts:

- 58% of $t\bar{t}$ signal left
- 3% of 5-jets evts left
- 39% of 6-jets evts left

Event selection (so far)

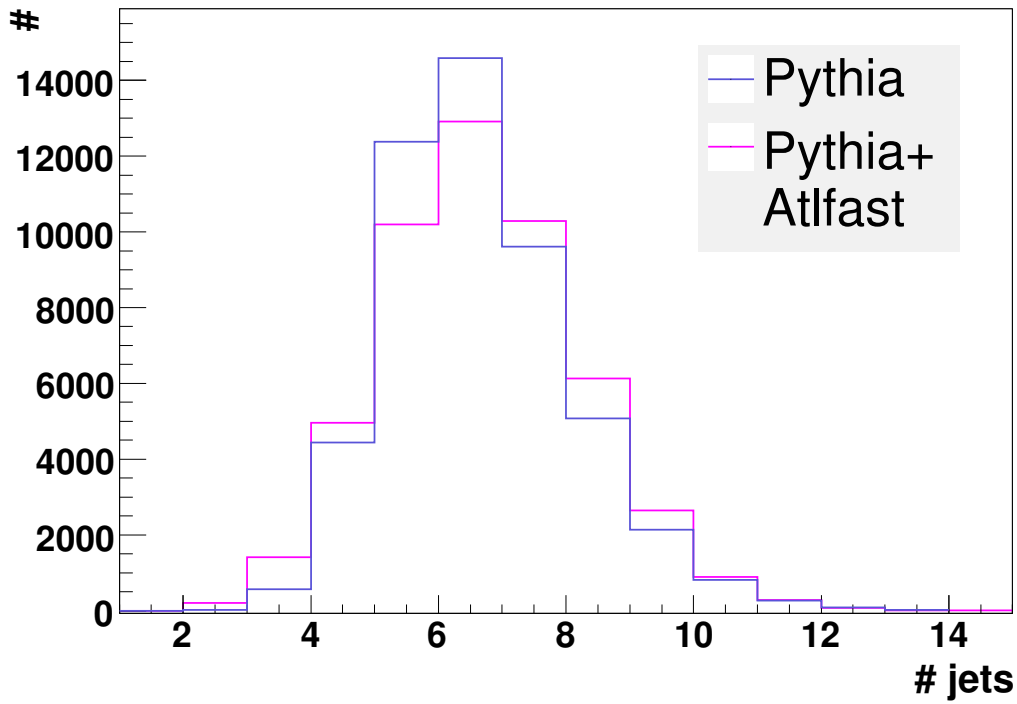
- Number of reconstructed jets ≥ 5
- Scalar sum of jets $\mathrm{p_T} \geq 125\ \mathrm{GeV}$ (reconstructed value)
- Minimum p_T of a jet $10\ \mathrm{GeV} - 70\ \mathrm{GeV}$
- Event shapes
  - $t\bar{t}$ event: $t\bar{t} \longrightarrow W^+W^-b\bar{b} \longrightarrow q\bar{q}'q\bar{q}'b\bar{b}$
    Large difference in mass in the decay levels $t \longrightarrow Wb$ and $W \longrightarrow q\bar{q}$. Leads to large angles between decay particles.
    $\Rightarrow$ Spherical structure of event
  - Background event: $gg \longrightarrow 6$ partons
    Dominated by collinear and infrared singularities. Leads to small angles between the jets.
    $\Rightarrow$ Flat structure of event

Event selection (still to do)

- $|\eta| < 3$ and $|\eta| < 2.5$ for b-jets
- b-tagging: identify secondary vertex in event
- Selection of dijet pairs from jets, which were not classified as b-jets
  $\Rightarrow$ $W \longrightarrow q\bar{q}$ candidates
- Calculation of invariant mass: $|m_{q\bar{q}} - m_W|$
- Reconstruction of invariant mass of top quarks

$\Rightarrow$ Need detector simulation!

- First attempts with Athena:
  $t\bar{t} \longrightarrow$ 6-jets events generated with Pythia and Atlfast using Athena version 11.0.41.
  [CTEQ6M PDF, jet reconstruction with k_T algorithm]



Summary and outlook

- Large QCD multijet background for $t\bar{t} \longrightarrow$ 6-jets decay
- So far isolation of the top signal by using kinematic cuts and cuts on the number of jets.

next steps:

- Implement and study further selection variables.
- Running ALPGEN background events in Atlfast.
- Studies of jet triggering in ATLAS $\longrightarrow$ additional selection cuts

Backup

- Inclusive alpgen 6-jets sample
  (comparison with and without modified routine in ALPGEN)