Investigation Of Shower Influences On $t\bar{t}$ Pairs With The CMS Experiment

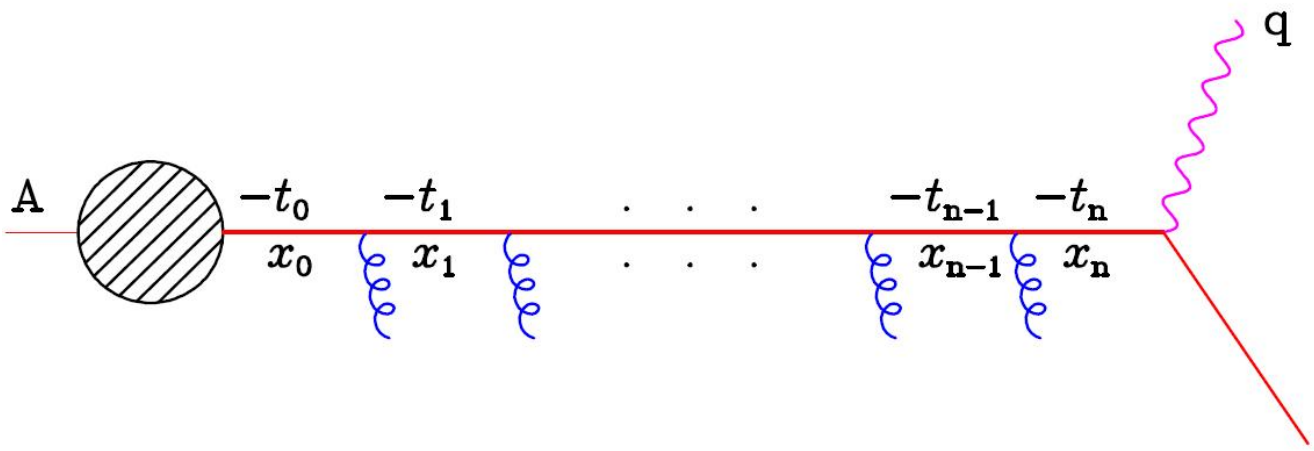
Alexander Flossdorf

DESY

MC Group Meeting, 03/03/2009

Contents

Parton Shower



B. Webber, CERN Training Lecture, Februrary 2008

- Evolution of parton from hadron A to hard process
- t: Virtuality of parton
- x: Parton's momentum fraction of initial hadron momentum
- Parton gets transverse momentum due to radiation
- Understanding of radiation will play a crucial role for $t\bar{t}$

Used Generators

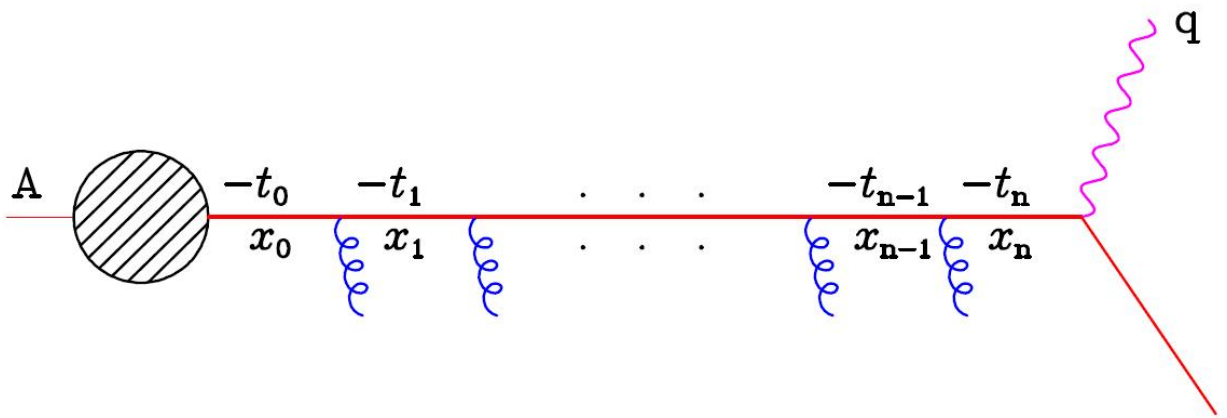
Standalone Event Generators

- Herwig (angular ordered showers)
- Herwig++ (angular ordered showers)
- Pythia 6 (Q^2 and p_T^2 ordered showers)
- Pythia 8 (p_T^2 ordered showers)

Generators Including Higher Order Contributions On ME Level

- MC@NLO (NLO computation on matrix element level)
  - uses Herwig for showering and hadronisation
- Alpgen (accounts for additional hard partons at ME level)
  - uses Herwig or Pythia 6 for showering and hadronisation

Shower Types



B. Webber, CERN Training Lecture, Februrary 2008

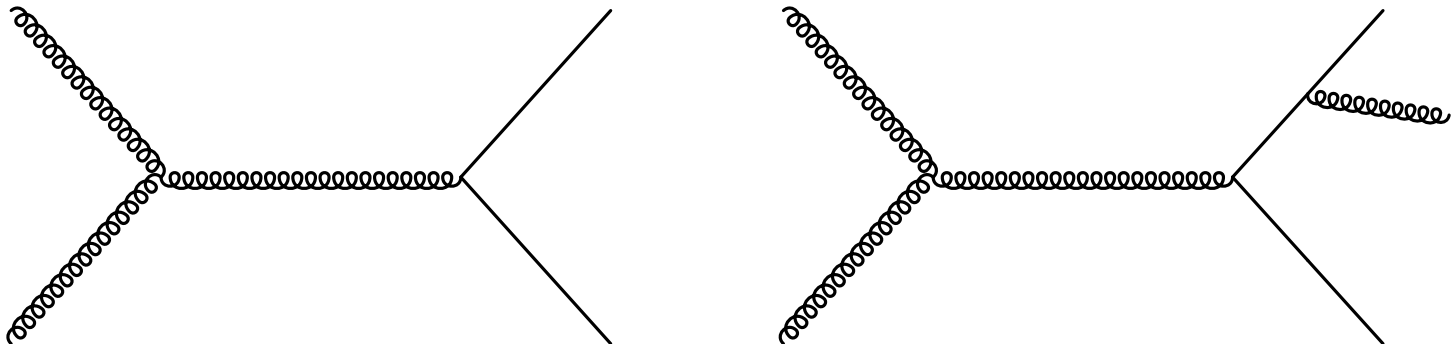
Wimpy Showers

- Maximum scale for shower is $t_{max} \sim t_{hard}$
- Cutoff in shower evolution

Power Showers

- Maximum scale for shower is $t_{max} = s$
- Whole phase space is used

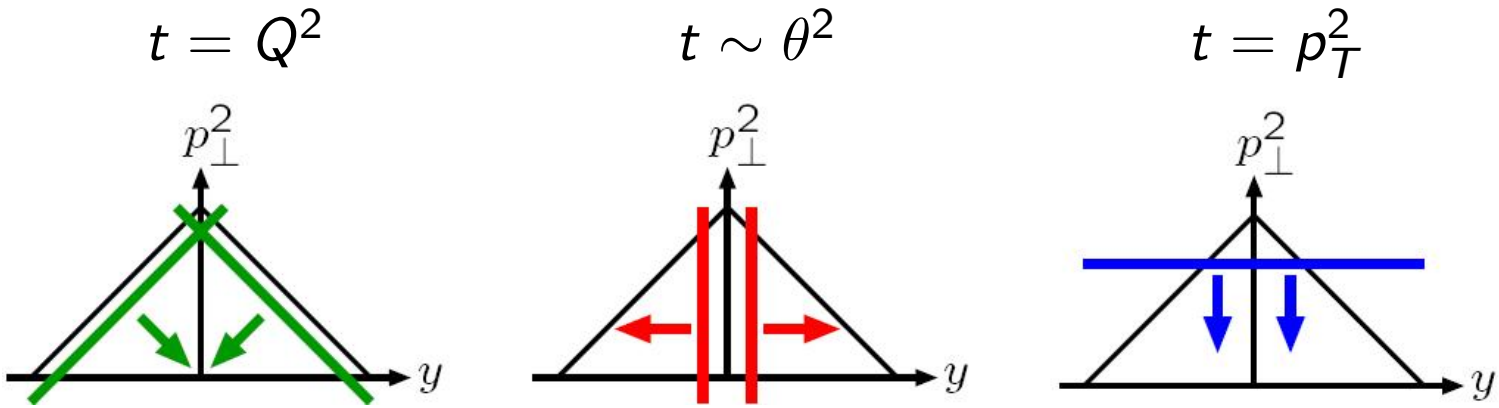
Matching



Matched Showers

- Hardest radiation is calculated on tree level (NLO diagrams)
- Parton shower accounts for soft radiation
- Matching with parton shower to avoid double counting
- MC@NLO uses subtraction method internally
- Alpgen uses a veto algorithm to discard events wich suffer from double counting

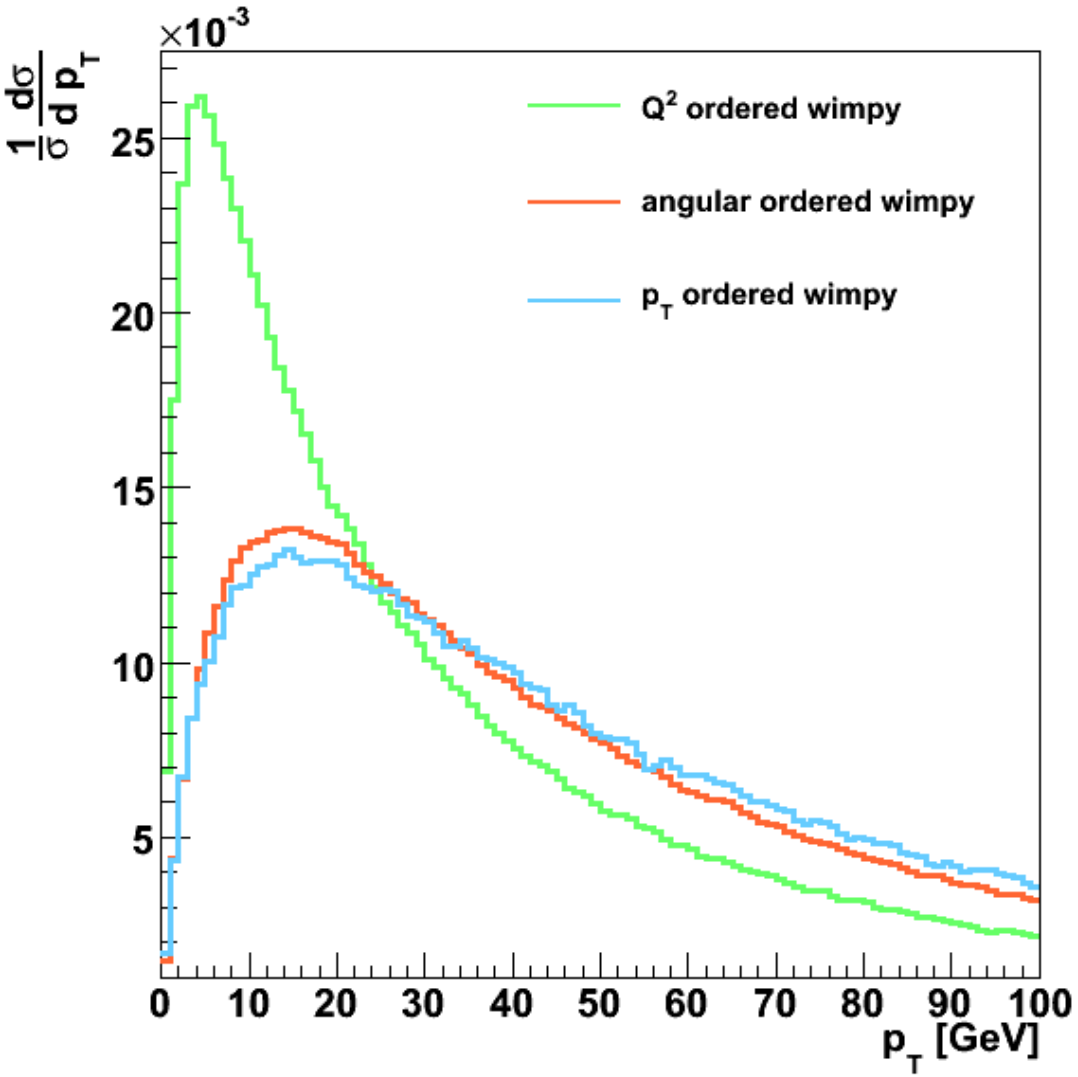
Shower Algorithms



T. Sjöstrand, European School of HEP, June 2006

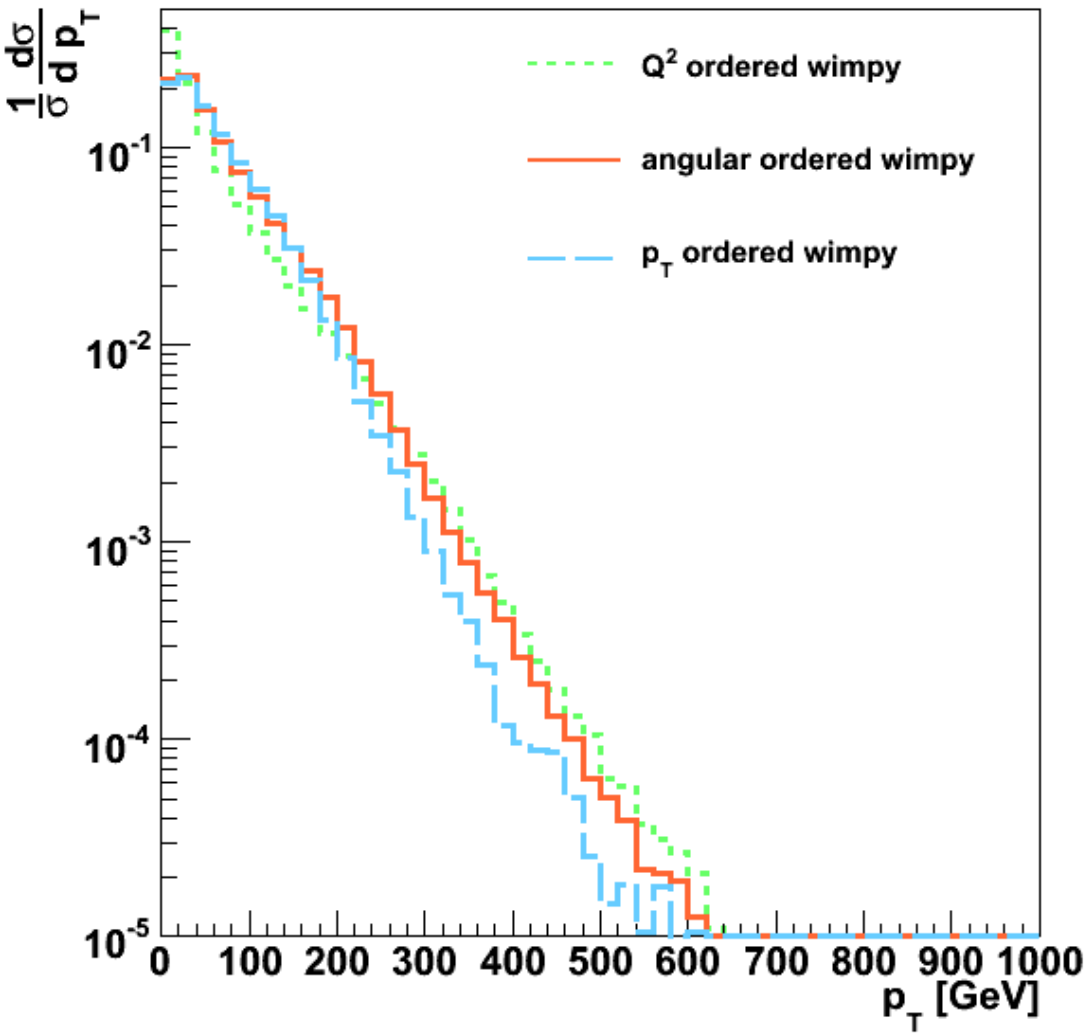
- evolution from the hard interaction (ME) on
- decreasing in Q^2: Pythia 6
- decreasing in p_T^2: Pythia 6 and Pythia 8
- decreasing in angle: Herwig and Herwig++

p_T of $t\bar{t}$ system



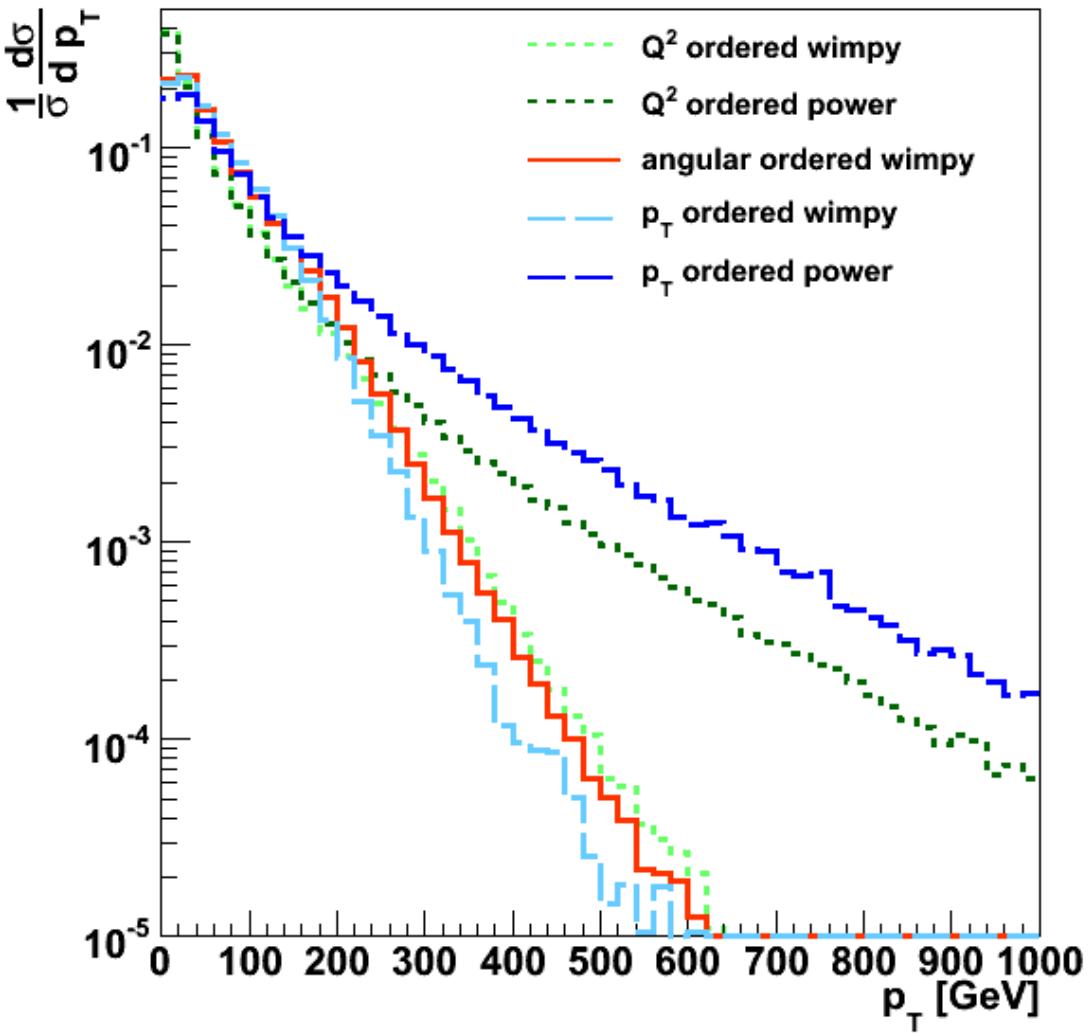
- Big difference in distribution depending on tuning
- Amount of radiation depends on scale for α_s
- Nearly independent of phase space cut

Tail of p_T distribution



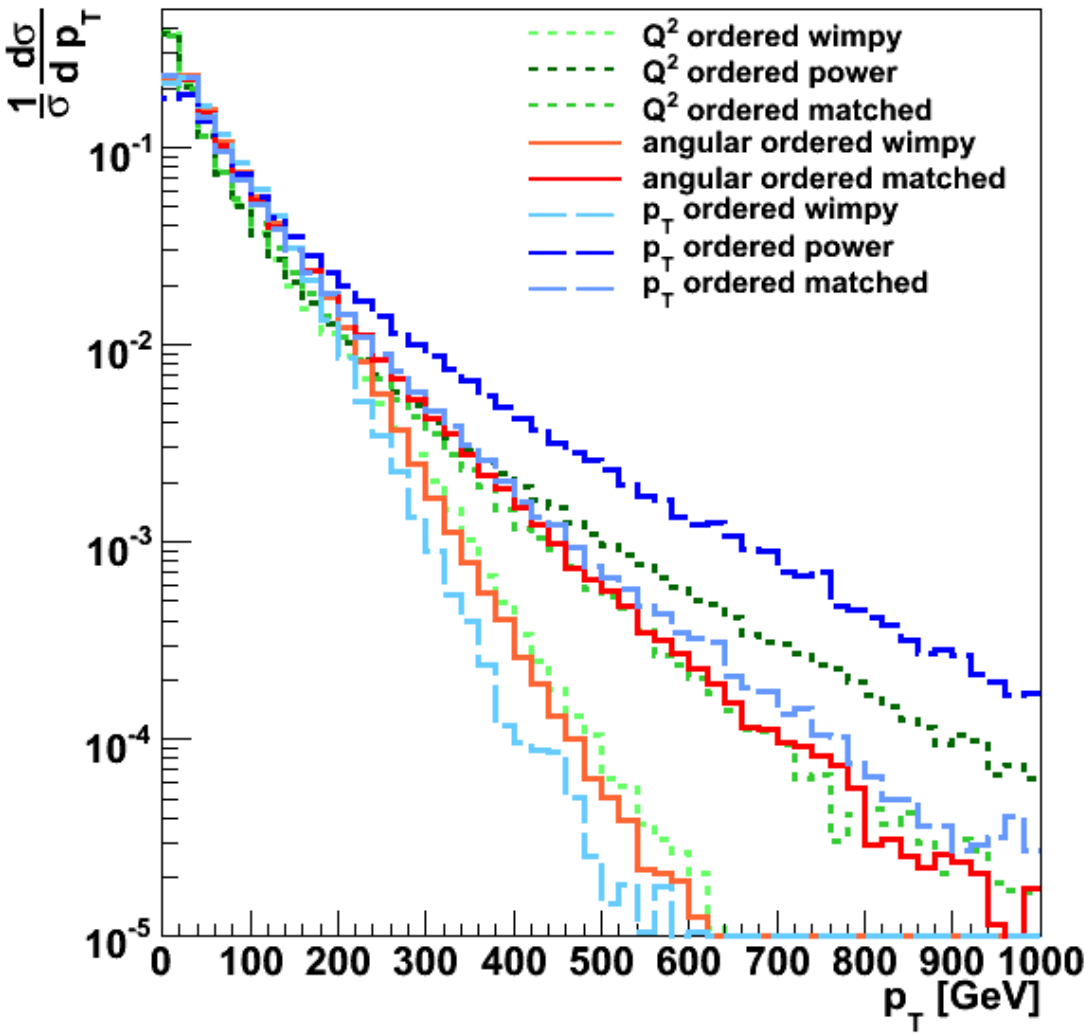
- All wimpy showers show similar behaviour

Tail of p_T distribution



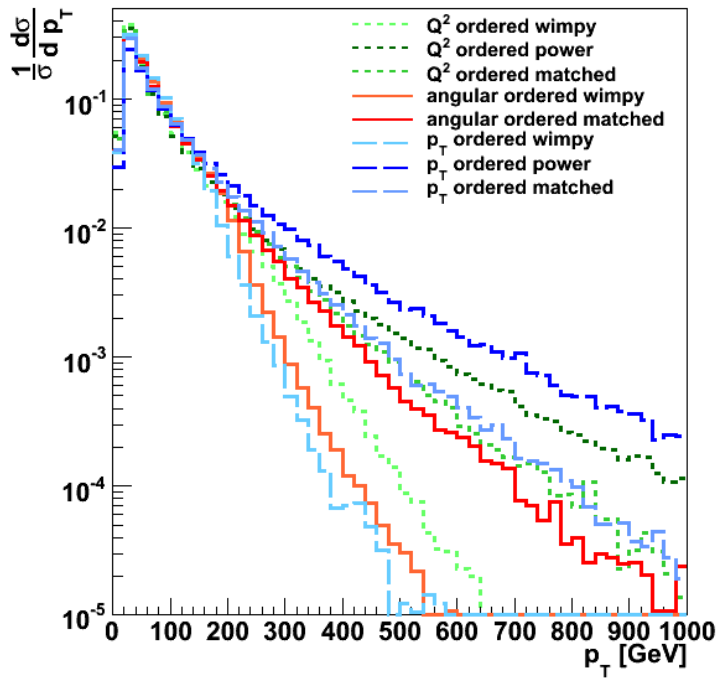
- All wimpy showers show similar behaviour
- p_T ordered power shower favours high p_T regions

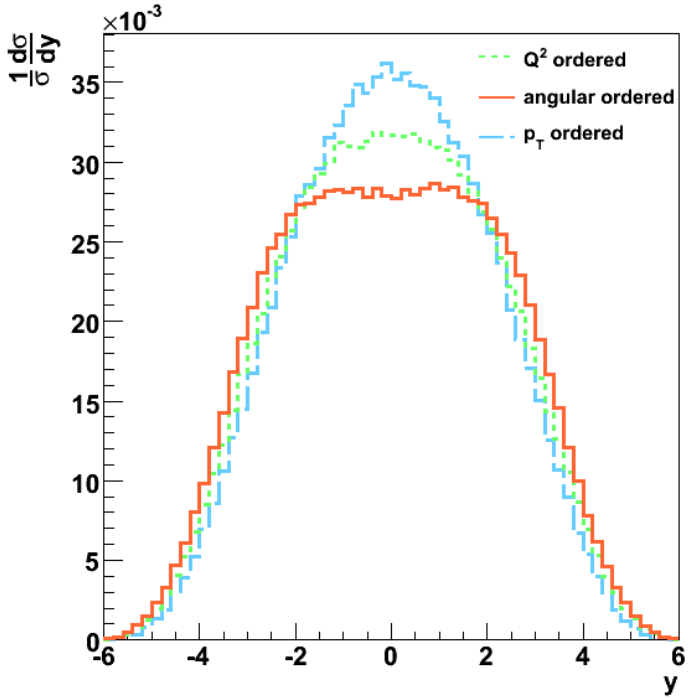
Tail of p_T distribution



- All wimpy showers show similar behaviour
- p_T ordered power shower favours high p_T regions
- Samples with hardest radiation on ME level agree quite well

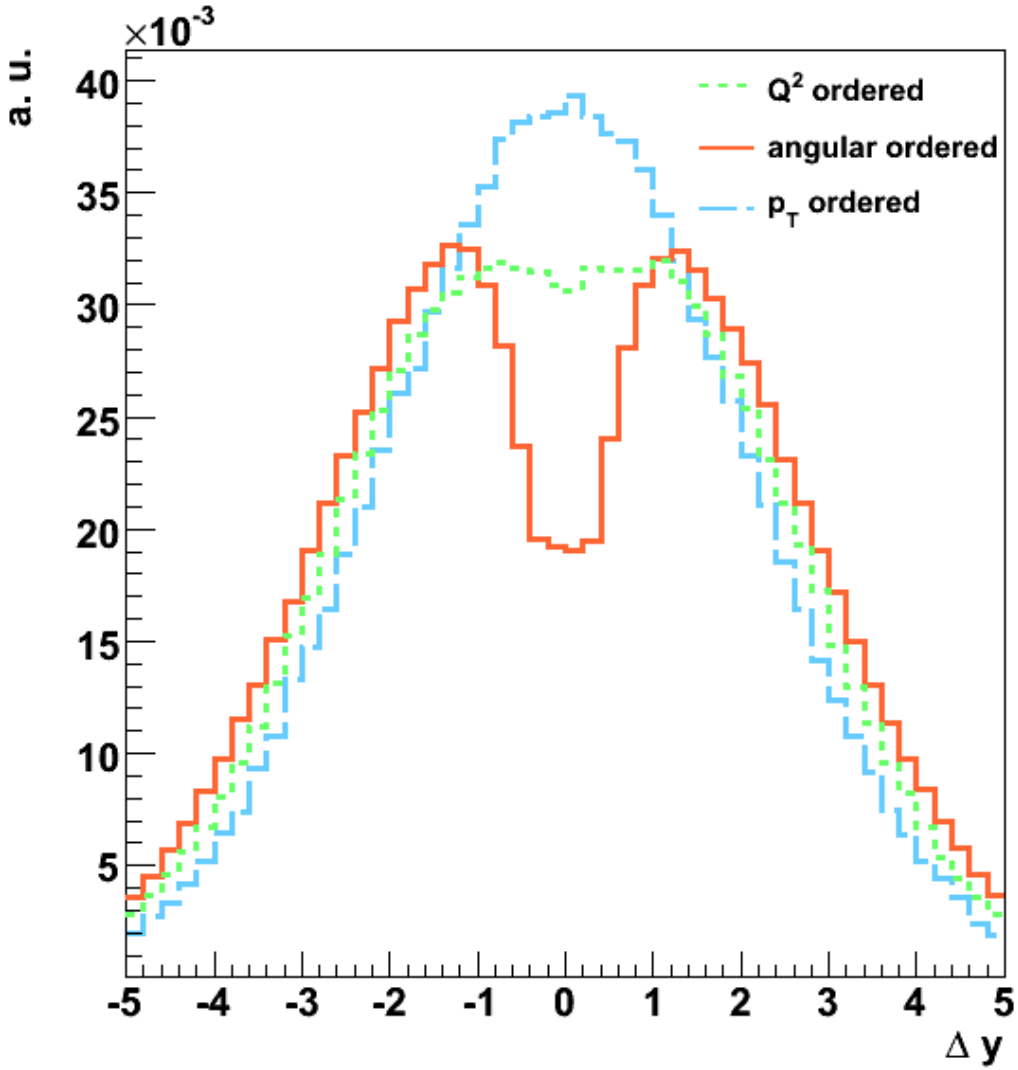
Parton jets





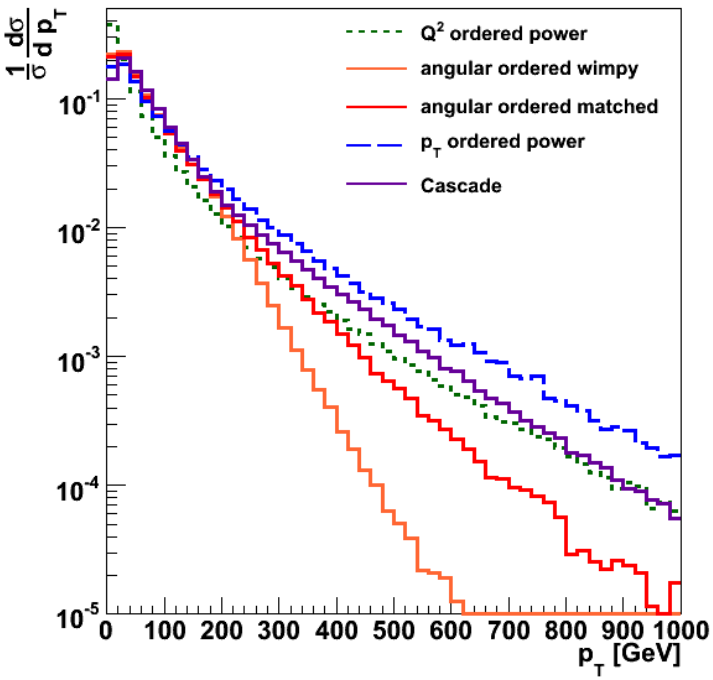
- Leading jet p_T corresponds with $t\bar{t}$ p_T
- Rapidity of leading jet depends on ordering

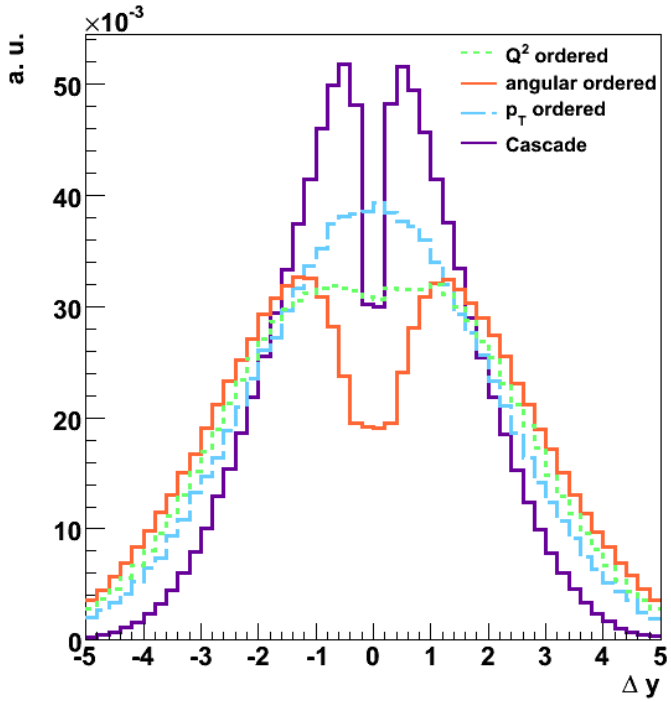
Δy between $t\bar{t}$ and first additional jet



- Δy depends on evolution variable

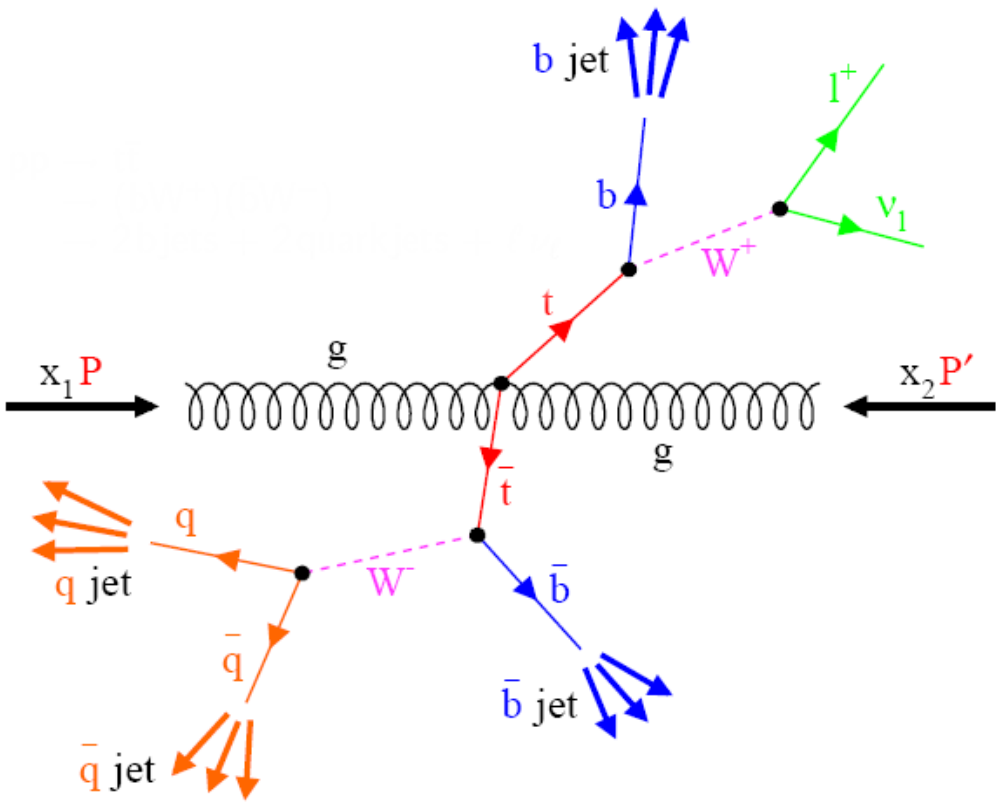
Cascade





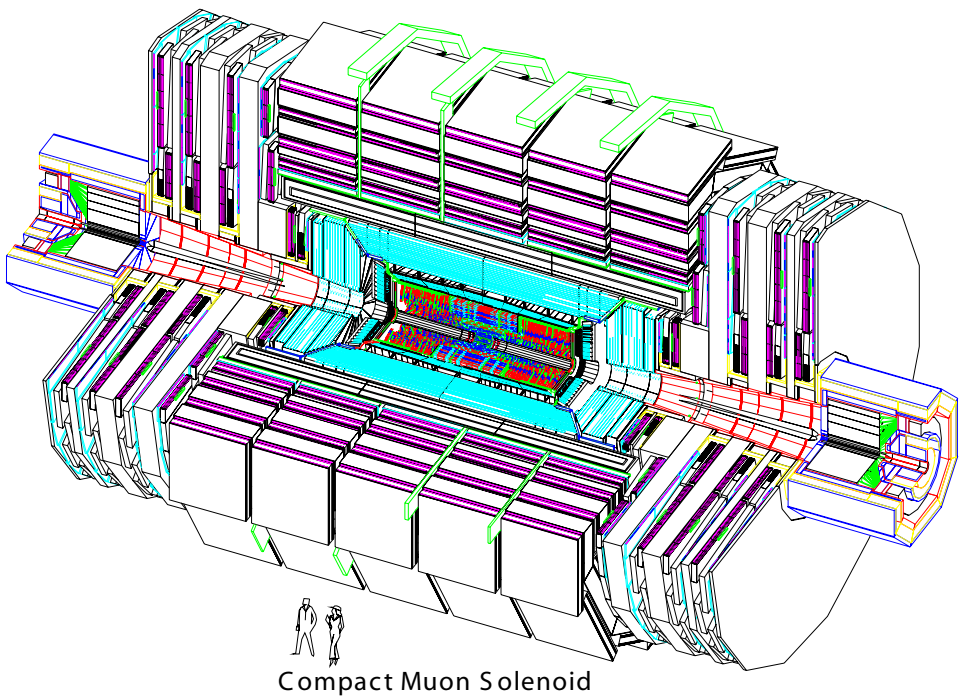
- Cascade behaves power shower like
- Completely different prediction from Cascade

Reconstruction of $t\bar{t}$ pairs



- Analysis of semileptonic decays with a muon
- Study for integrated luminosity of $15\,\mathrm{fb}^{-1}$ at $\sqrt{s} = 14\,\mathrm{TeV}$
- Background from SM processes:
  - $t\bar{t}$ other decay modes
  - W + jets
  - Z + jets
  - QCD (as good as possible)

CMS Experiment



Simulated signal events

- Herwig, wimpy shower, angular ordered
- MC@NLO, first order ME matched to angular ordered shower
- Pythia, power shower, Q^2 ordered
- Pythia, power shower, p_T^2 ordered

Reconstruction

Reconstruction of objects

- KT4 jet algorithm
- B-tagging by checking consistency of tracks with the primary vertex
- Jets corrected to final hadron state
- Muon isolation:
  - → Tracker: $0.01 \cdot p_T(\mu) < \sum_{\Delta R=0.3} p_T - p_T(\mu) < 0.15 \cdot p_T(\mu)$
  - → Calorimeter: $\sum_{\Delta R=0.3} E_T < 0.15 \cdot p_T(\mu)$

Preselection and selection

Preselection

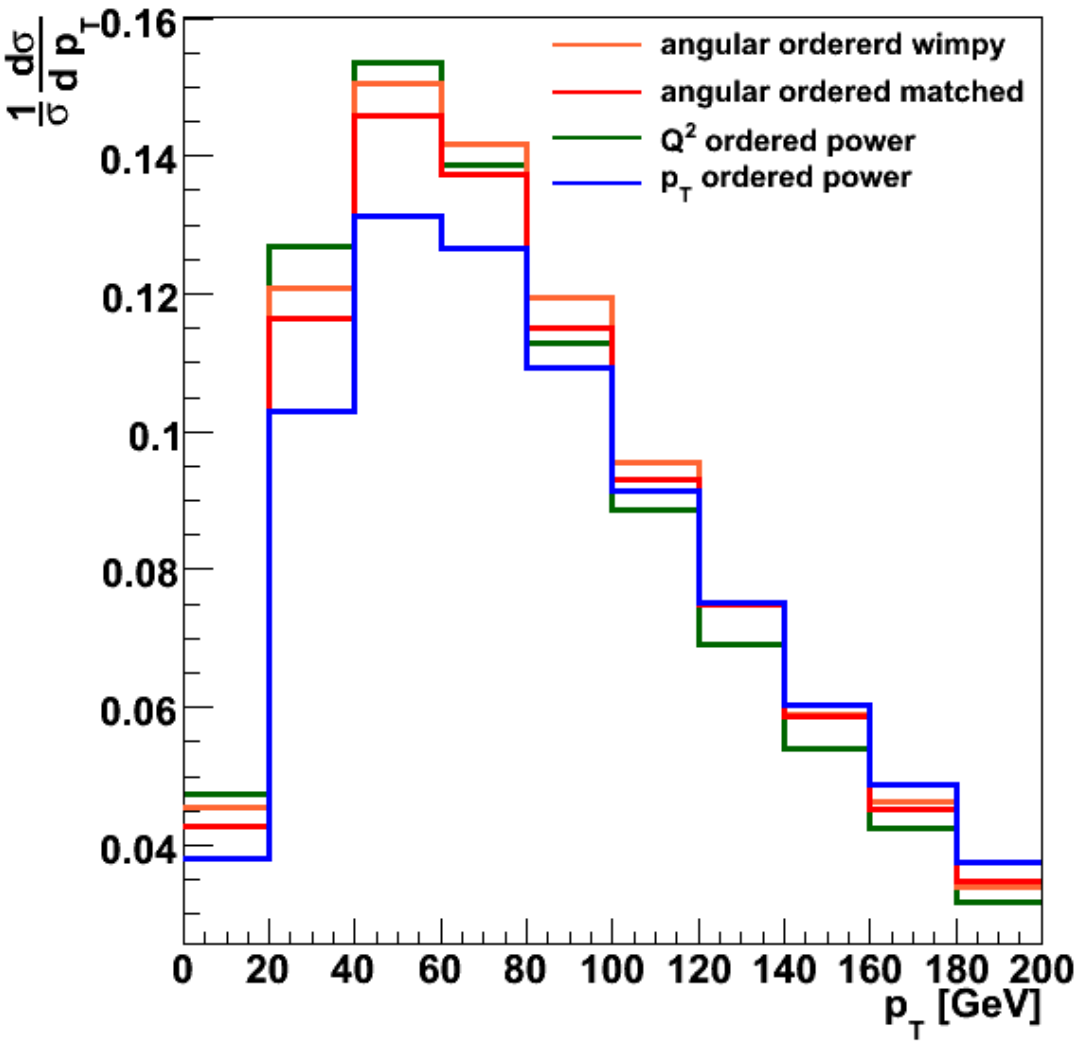
- Exactly one isolated muon
- At least three jets with $p_T > 35\,\mathrm{GeV}$ and four jets with $p_T > 25\,\mathrm{GeV}$

Selection

- Reconstruct system via kinematic fit
- Fit probability > 0.01
- Highest b-tag > 0.4
- $H_T(t\bar{t}\mathrm{jets}) > 150$

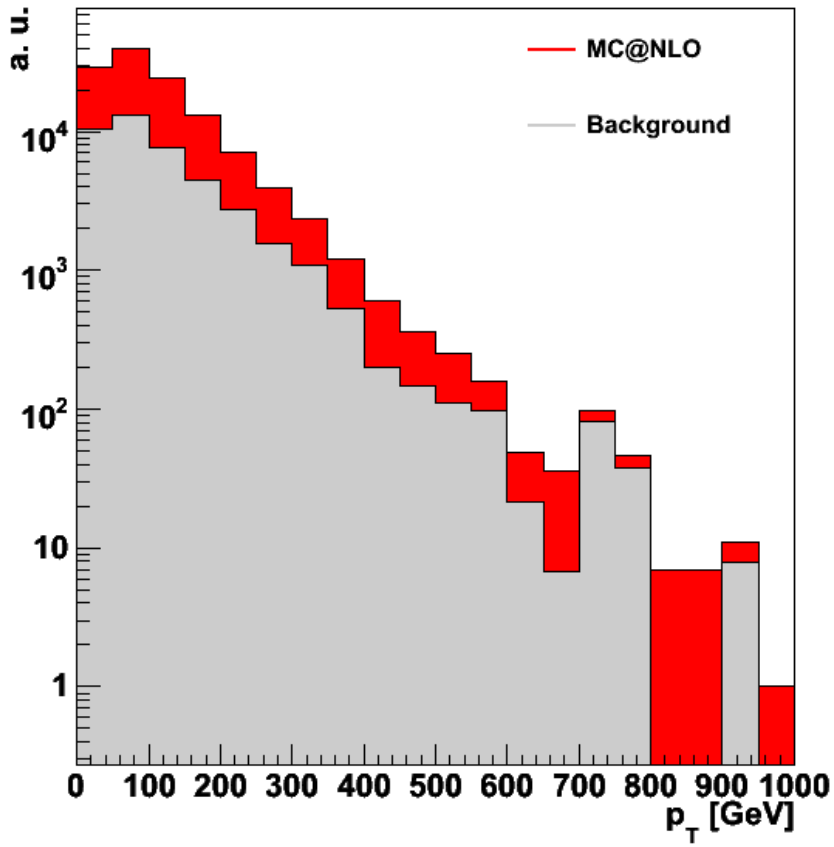
Result: S/B: 2.2 - 2.8, depending on generator

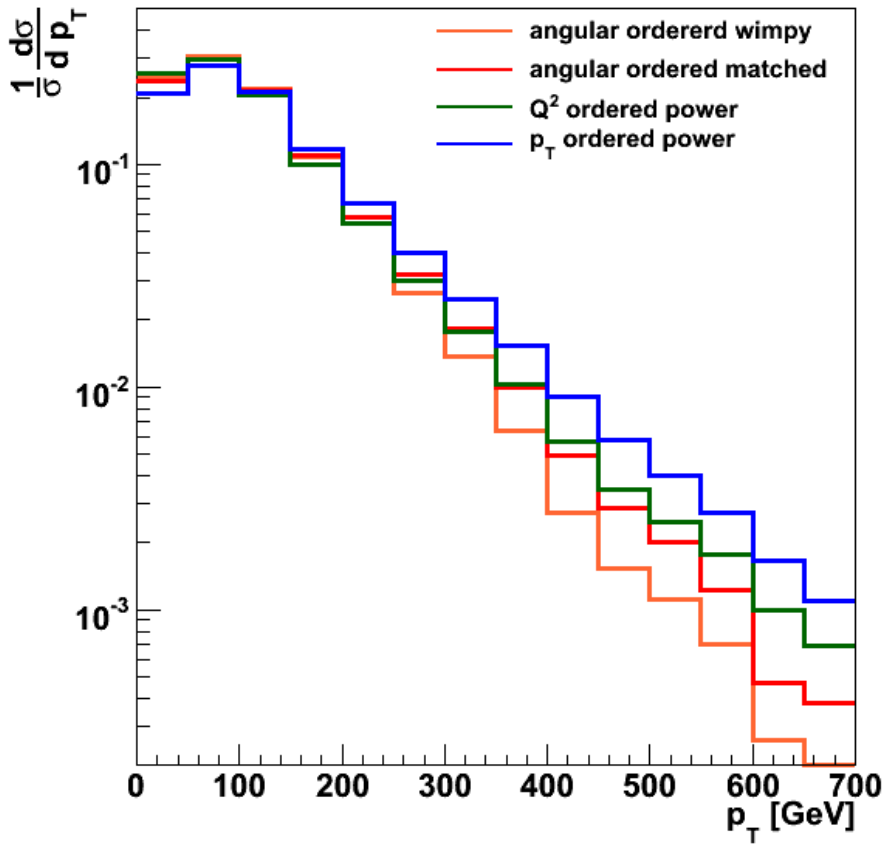
Fitted $t\bar{t}$ system



- Distribution distorted
- Large migration effects

Fitted $t\bar{t}$ system



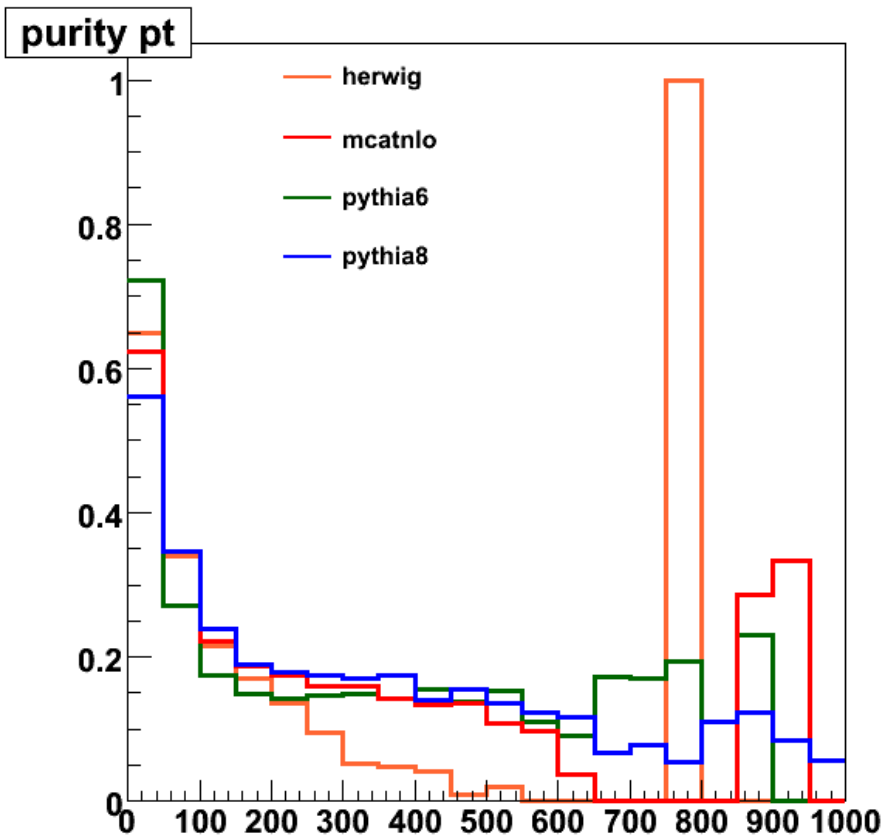


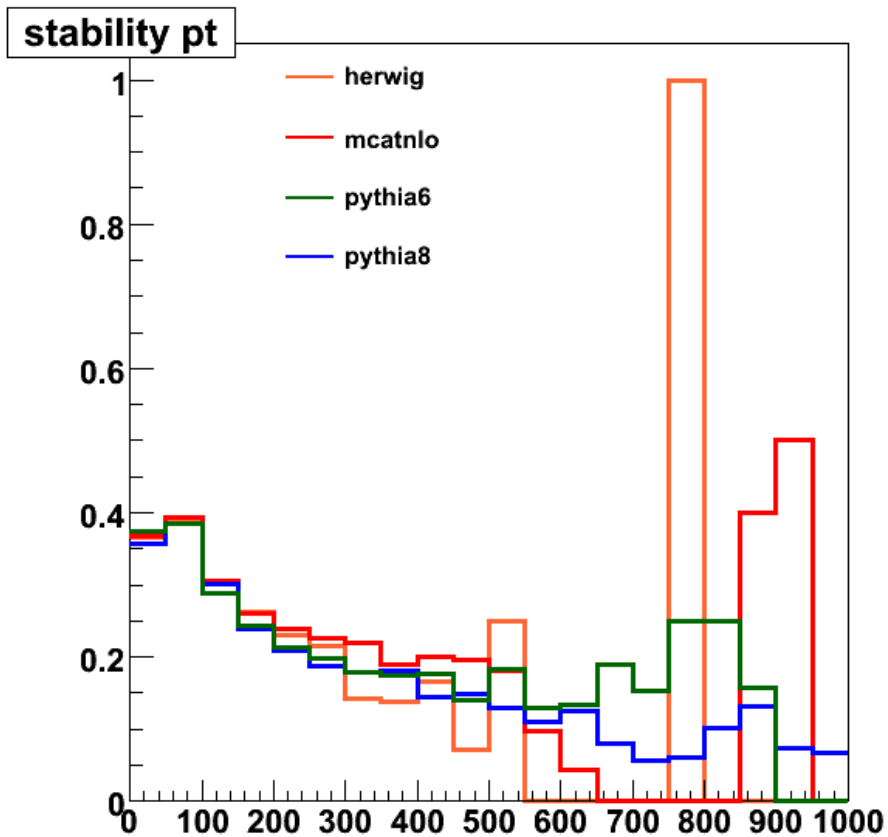
- Reconstruction of $t\bar{t}$ system p_T tail possible
- Background has similar shape as signal
- Huge migration effects that have to be corrected for

Purity and stability

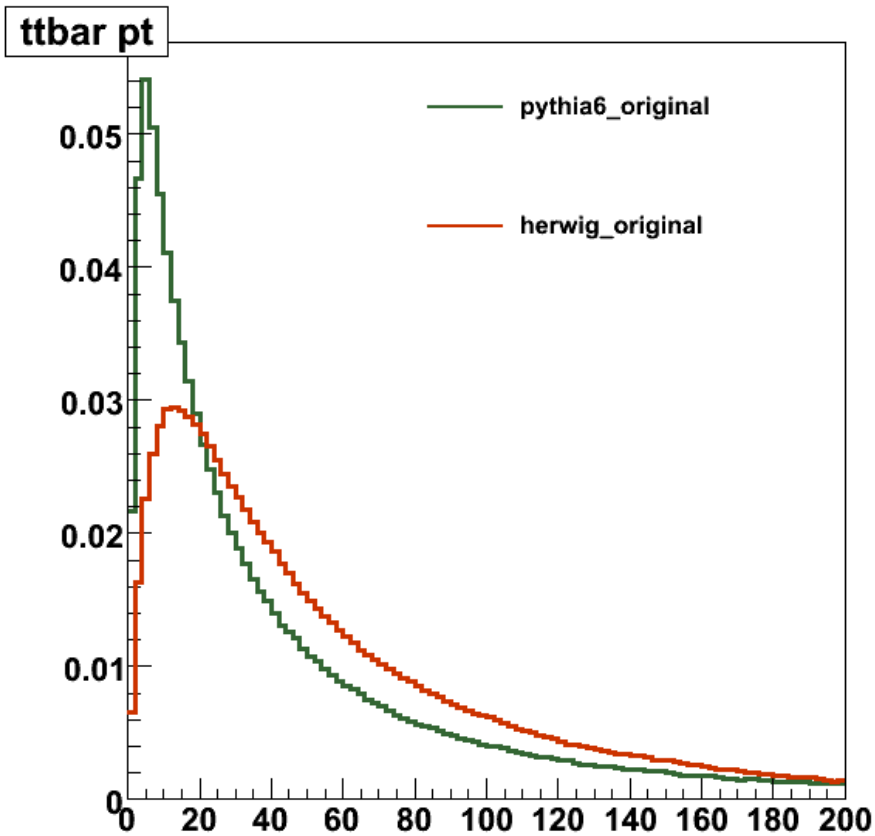
Effects resulting from migration of signal events:

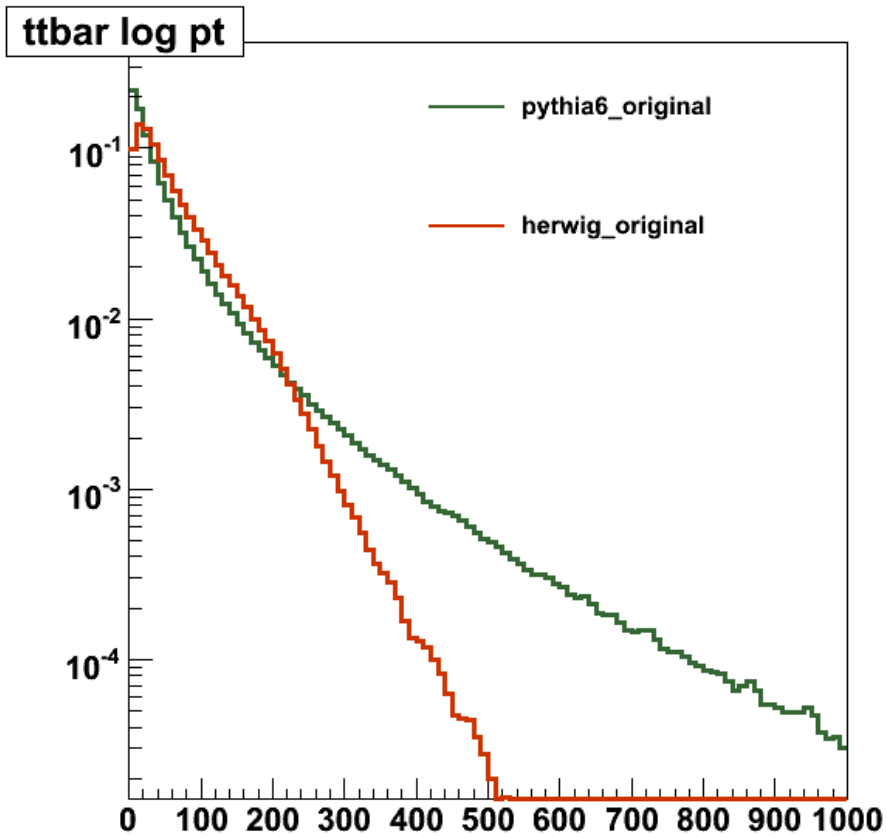
$$purity = \frac{events(gen\&\&rec)}{events(reco)} \qquad stability = \frac{events(gen\&\&rec)}{events(gen)}$$



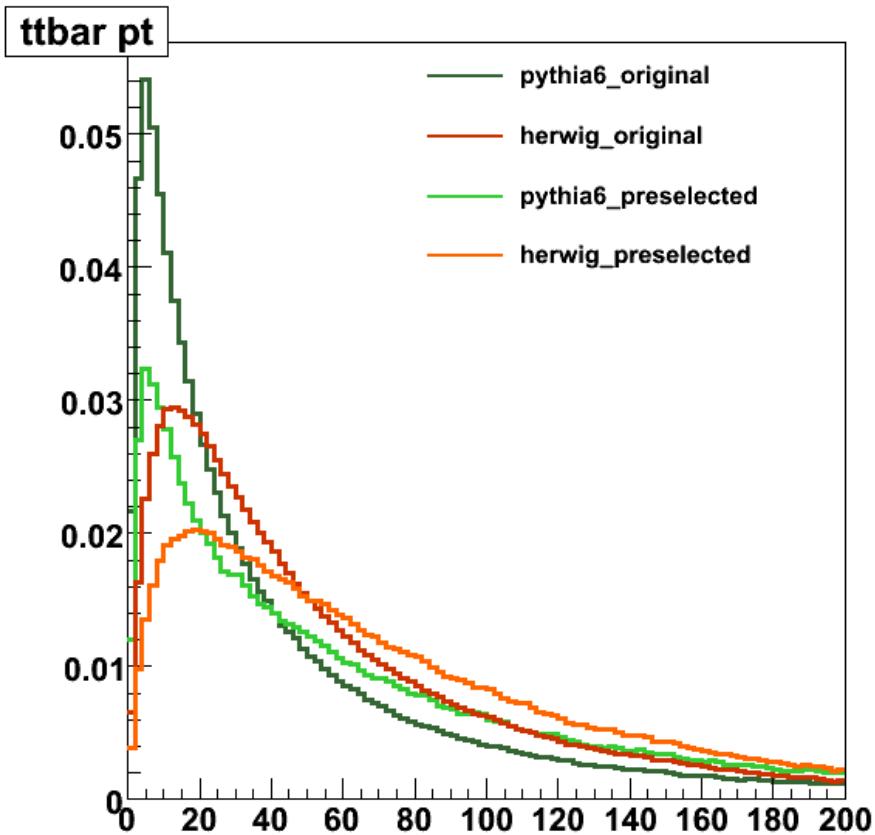


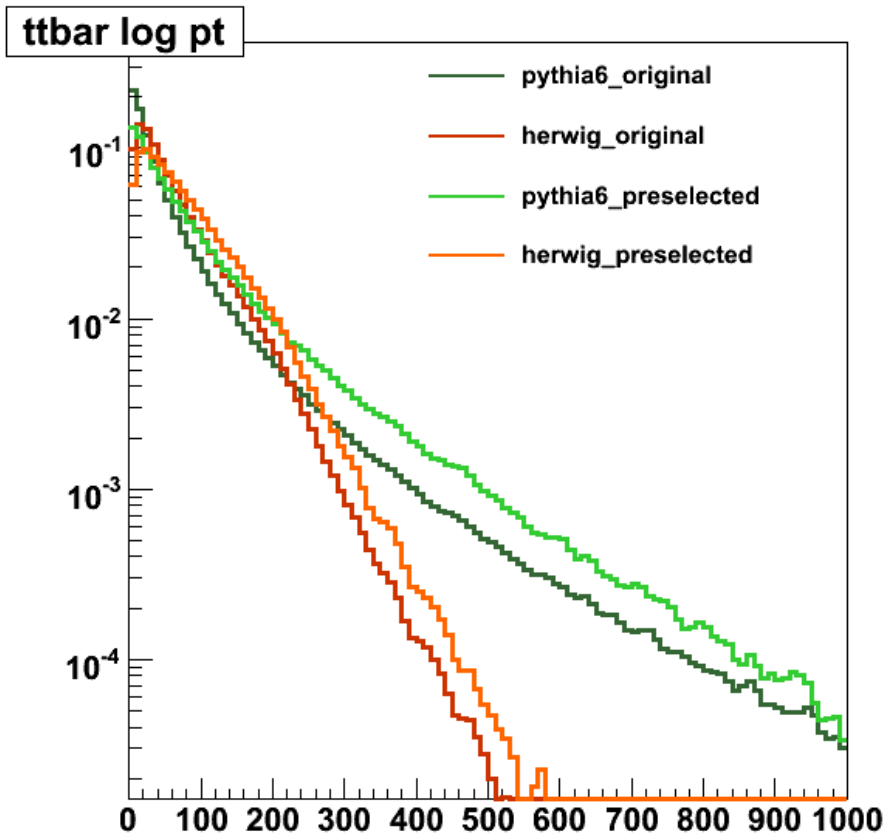
Bias of selection procedure





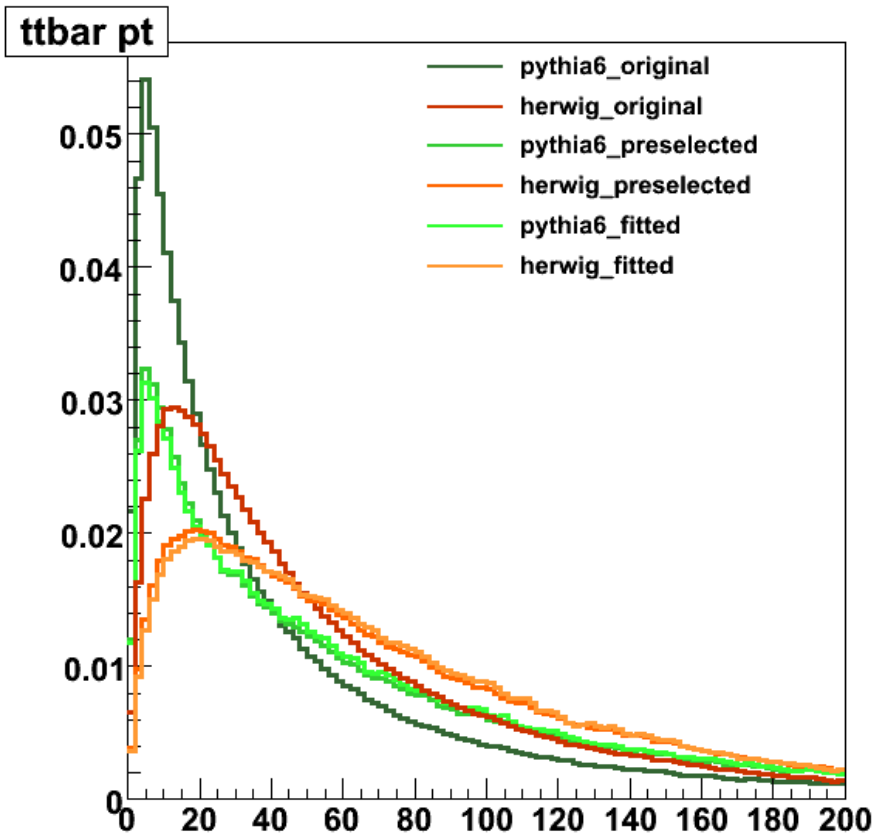
Bias of selection procedure

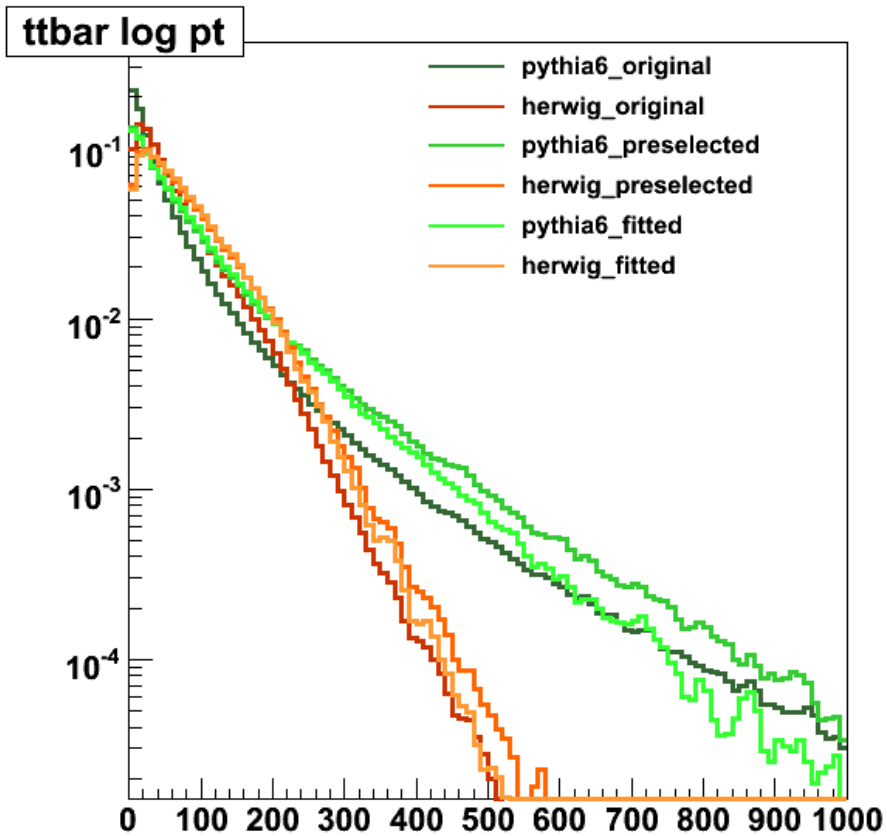




- Large bias in phase space in preselection

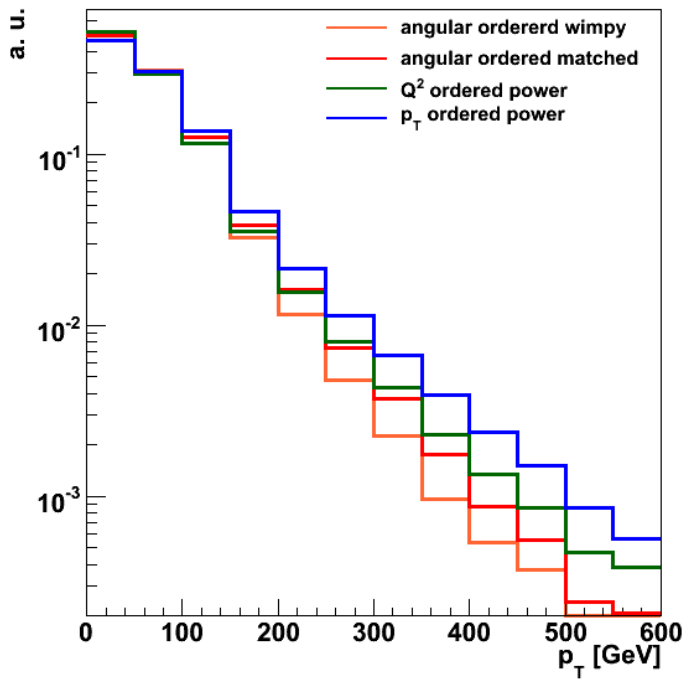
Bias of selection procedure

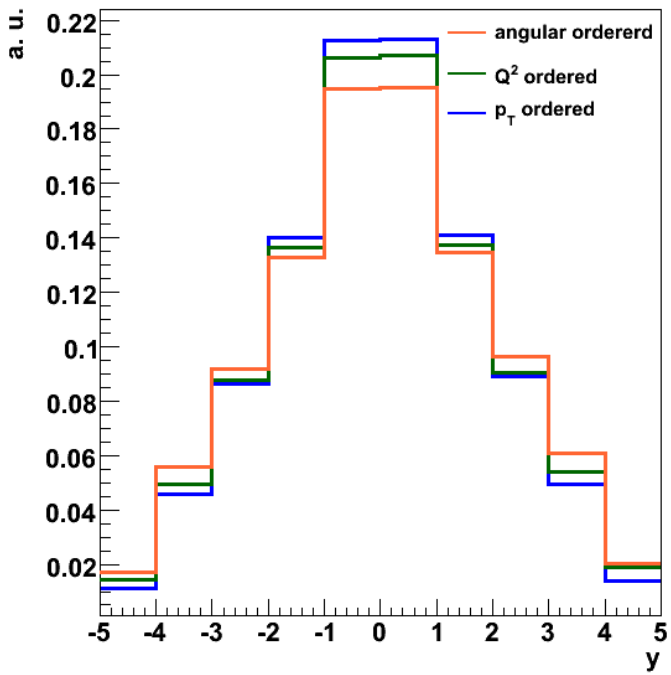




- Large bias in phase space in preselection
- High p_T tail gets reconstructed less often than intermediate region

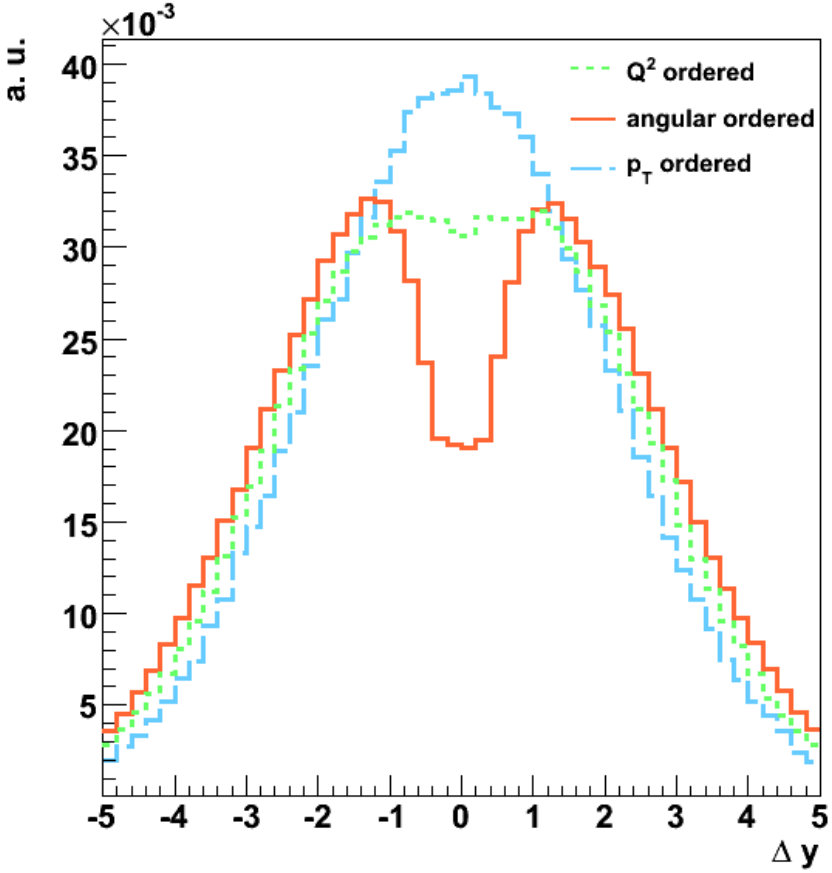
Leading additonal jet

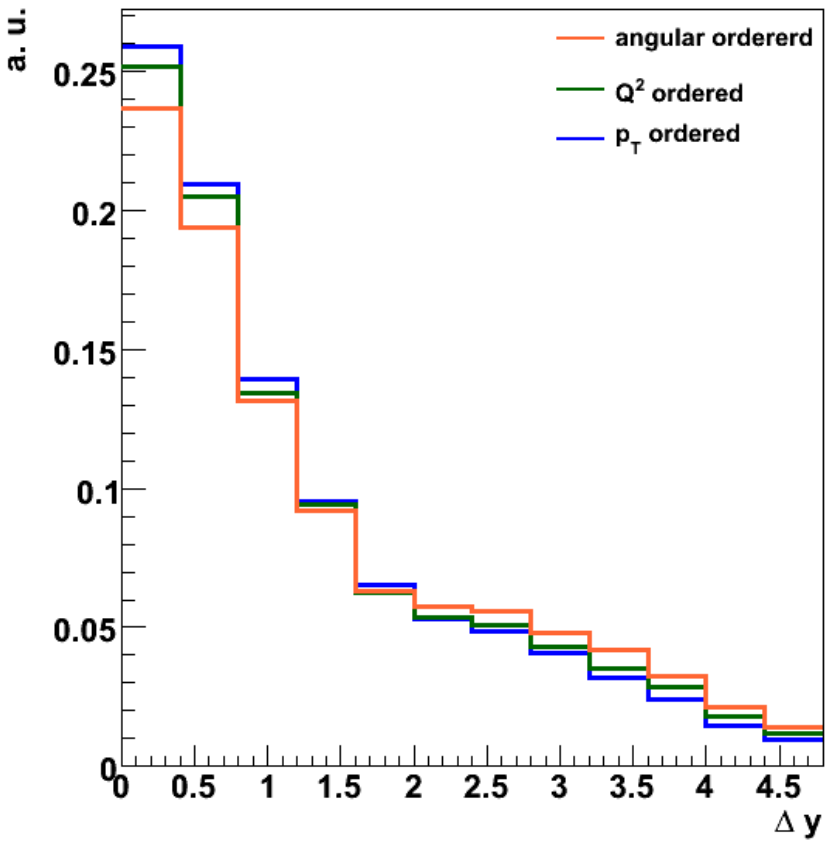




- principal structure of leading jet p_T and y reconstructed correctly
- both observables suffer from physical and huge combinatorial background

Δy fitted $t\bar{t}$ system and leading jet





- Strong distortion of the distribution
- Ordering of the distributions correct

Summary

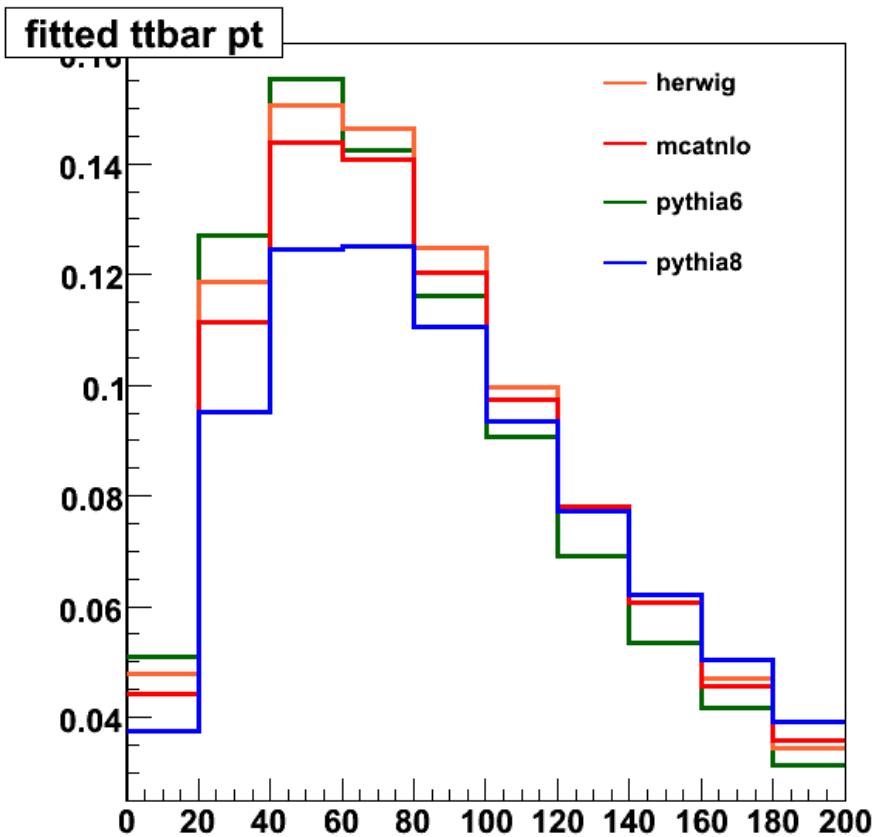
Summary

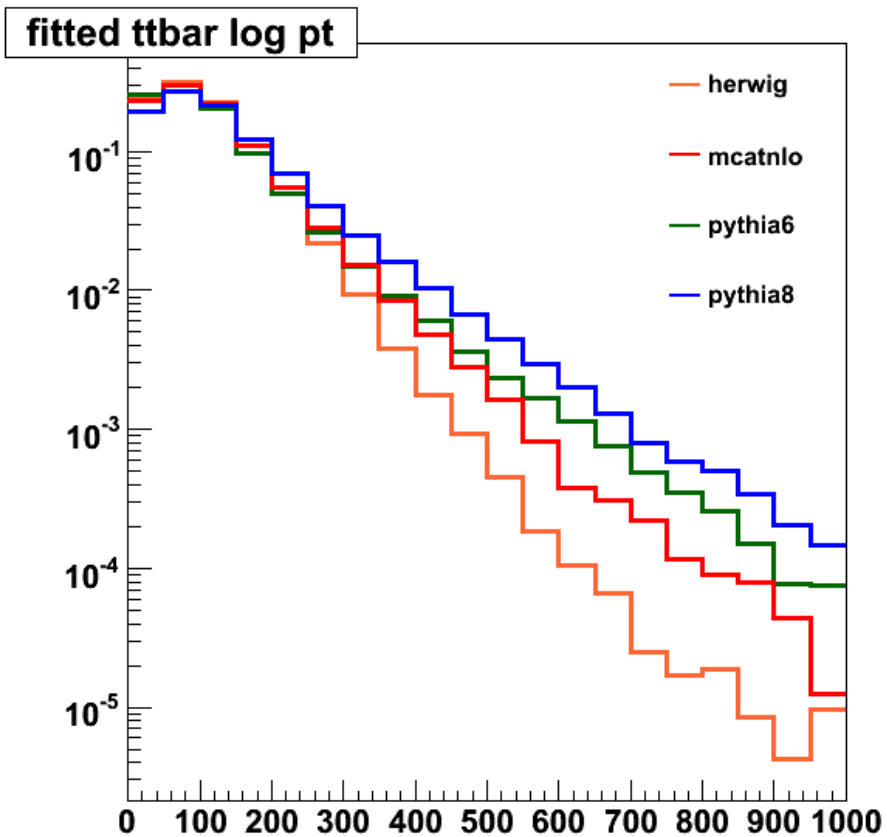
- Tail of p_T distribution of $t\bar{t}$ system sensitive to phase space populated by radiation
- First additional jet sensitive to ordering variable of the parton shower
- Reconstruction of $t\bar{t}$ pairs and identification of additional hardest jet reproduce the effects qualitatively

Outlook

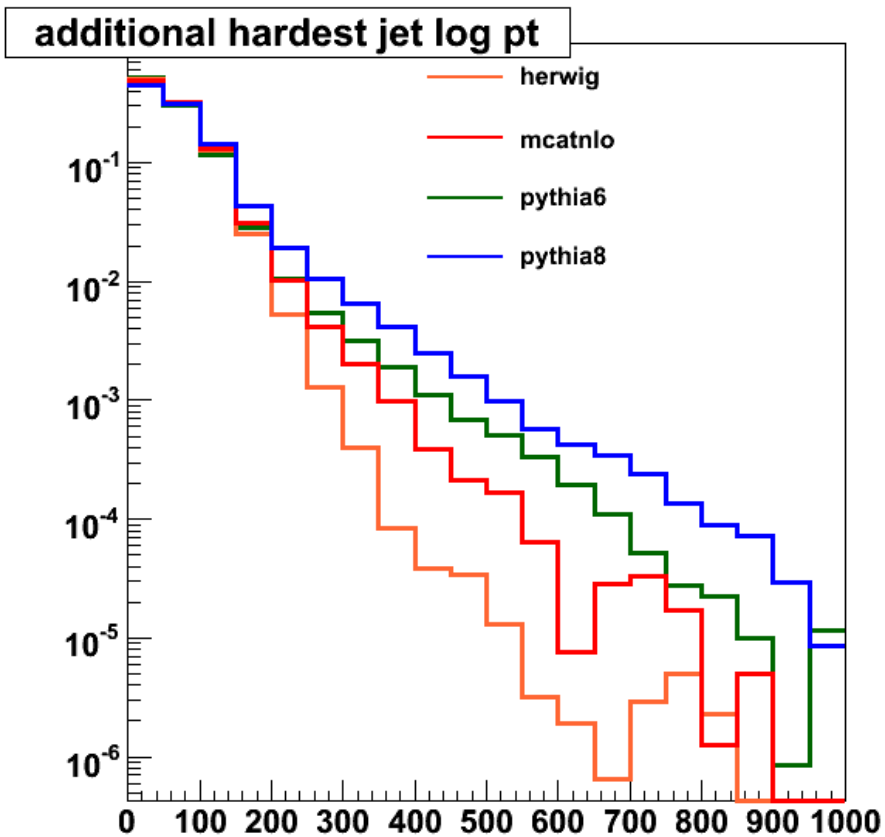
- Background and combinatorics need proper treatment
- Background subtraction and unfolding may improve the result

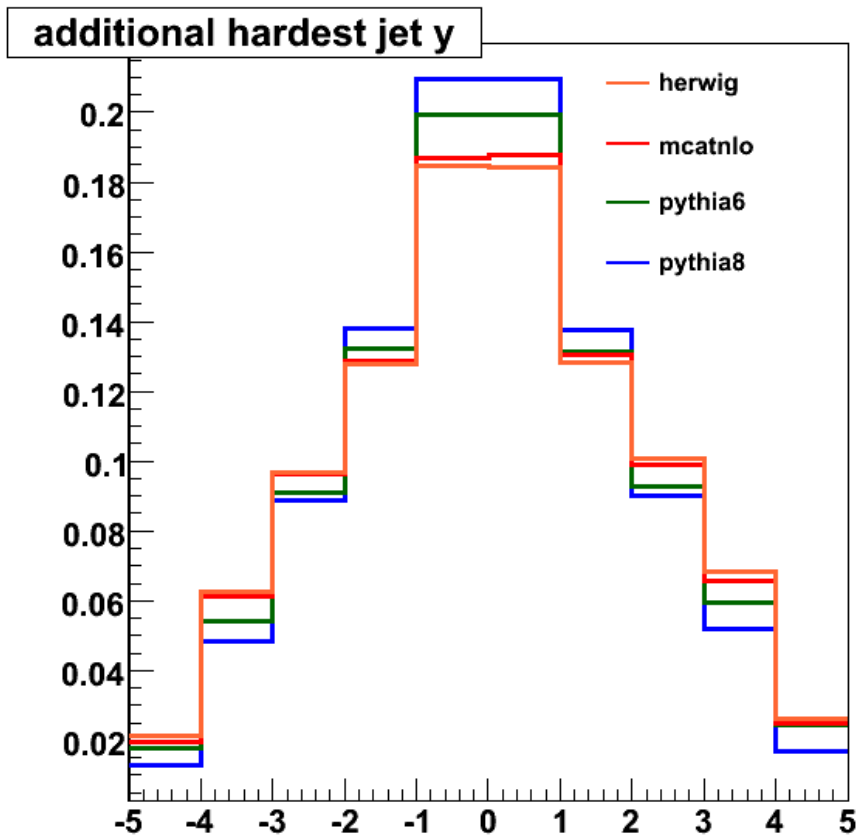
Fitted $t\bar{t}$ system





Fitted $t\bar{t}$ system





Fitted $t\bar{t}$ system