Top-pair Reconstruction with KLFitter at the ATLAS Detector

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Introduction

KLFitter

Performance of KLFitter

Summary & Outlook

GEFÖRDERT VOM

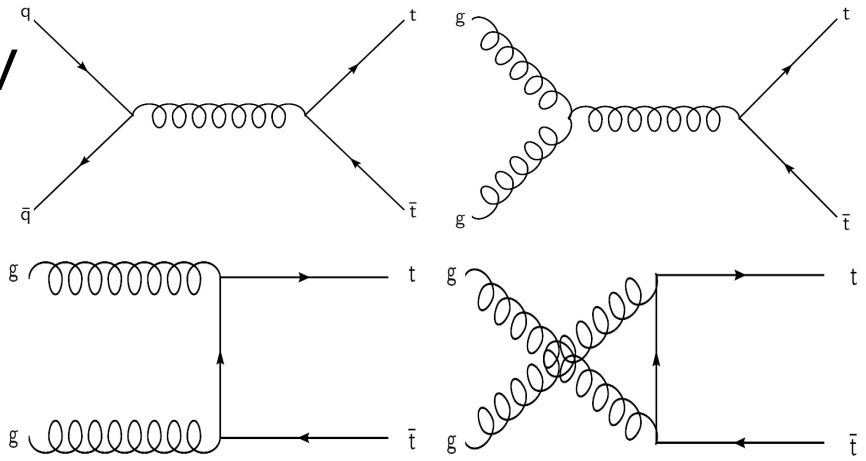
Bundesministerium
für Bildung
und Forschung

PHYSICS AT THE TERA SCALE
Helmholtz-Alliance

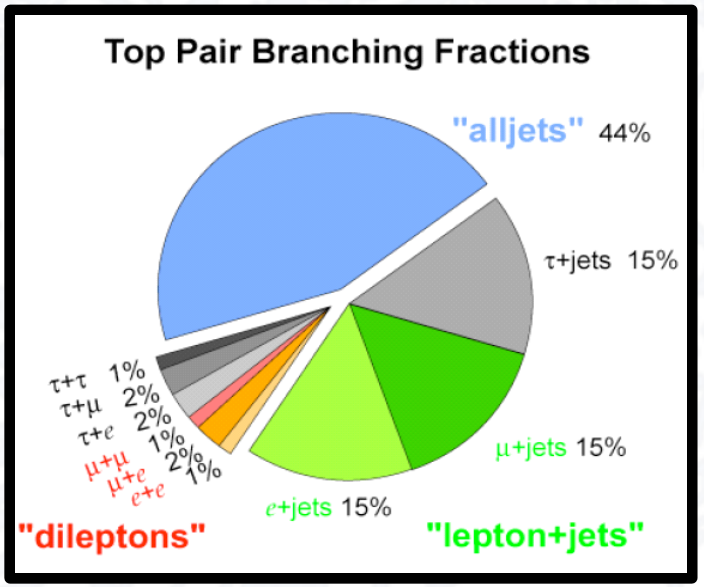
FSP 101 ATLAS

Top Physics

- Top pair production at LHC at 7 TeV
  - via strong interaction
  - dominated by gluon fusion (~83 %)
  - $q\bar{q}$ annihilation (~17 %)
  - four leading order diagrams

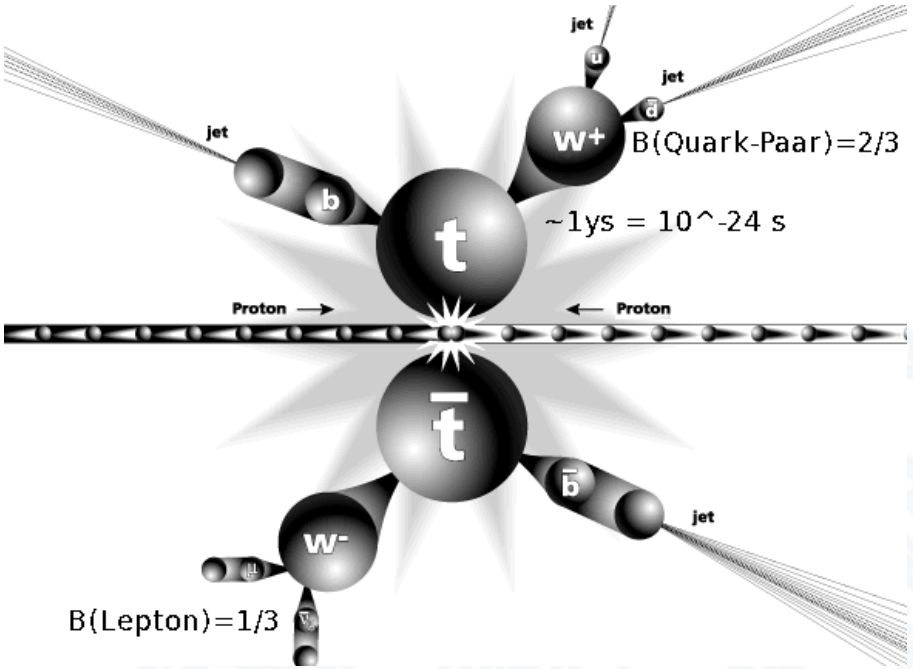


- Top quark decay
  - Almost 100 % to b-quark and W-boson
  - final states are classified according to W decay
    - dileptons
    - lepton + jets
    - alljets



Lepton + Jets Decay Channel

- Lepton + jets
  - + large branching ratio (15% each)
  - - neutrino
  - + complex signature:
    - four jets
    - one lepton
    - Missing ET



- Combinatorics
  - Jets are flavor/charge blind
    → 24 combinations (jets/partons)
  - Indistinguishable light quarks
    → 12 combinations left

- Main background sources
  - Combinatorial background
  - W → lν + 4 jets
  - Multijet background (QCD)
    - Fake isolated μ or fake e
    - Mis-reconstructed MET

KLFitter (1)

Principle of Kinematic Fitting:

- Decay scheme is assumed to be known
  → use constraints from the kinematics and particle properties
- Applicable to every topology / signature

Aims for Top Topology:

- Identify correct jet-parton assignment with kinematic fit
- Find better estimate for energies, angles of objects
- Determine all properties of objects (mass, pt, eta, ...)
- Identify b-jets

Tool: KLFitter – kin. Likelihood Fitter, developed in Göttingen

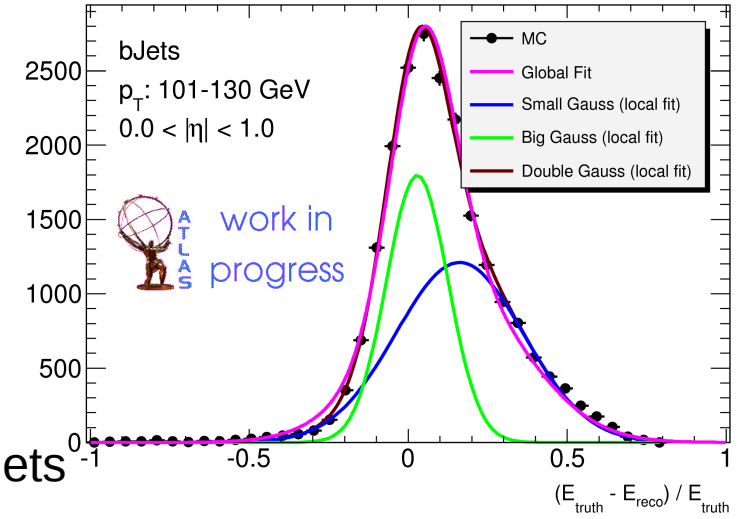
Likelihood Approach: Set up likelihood function ***L*** for ttbar → e+jets:

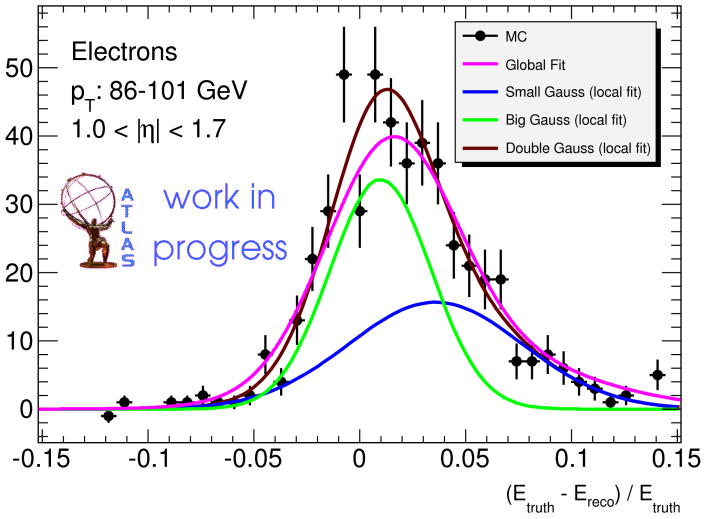
$$L = \left(\prod_{i=1}^{4} W(\tilde{E}_i, E_i)\right) \cdot W(\tilde{E}_l, E_l) \cdot W(E_x^{\mathrm{miss}}|p_x^{\nu}) \cdot W(E_y^{\mathrm{miss}}|p_y^{\nu}) \cdot \left(\prod_{i=1}^{4} W(\tilde{\Omega}_i|\Omega_i)\right) \cdot BW(m_{jj}|M_{\mathrm{W}}) \cdot BW(m_{e\nu}|M_{\mathrm{W}}) \cdot BW(m_{jjj}|M_{\mathrm{top}}) \cdot BW(m_{e\nu j}|M_{\mathrm{top}})$$

KLFitter (2)

- Constraints: Breit-Wigner W-boson masses, similar top masses
- Transfer functions W (E_{calo} | E_{parton})
  - double-Gaussian parameterization in
    - different η regions
    - E intervals

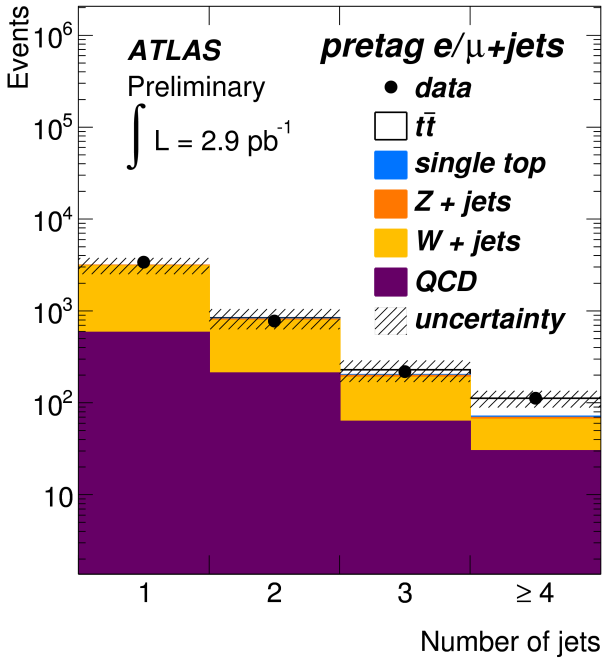
  → take asymmetric tails into account
  - Separately for electrons, light quarks and b-jets
- Maximize L in global parameter space, pick permutation with best L
- 17 Parameters:
  - Energy: E_{jet} (4), E_e (1)
  - Angle: Ω_{jet} (2x4)
  - Neutrino $p_{x,y,z}$ (3)
  - Top Mass M_t (1)

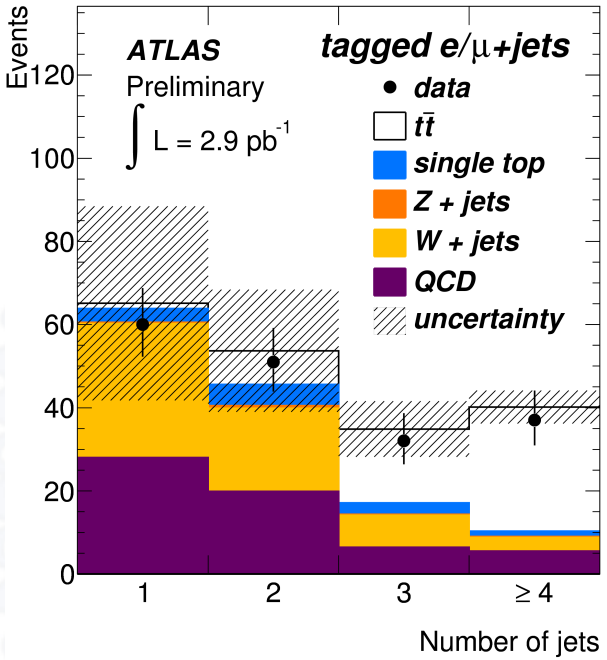




Selection & Jet Multiplicity

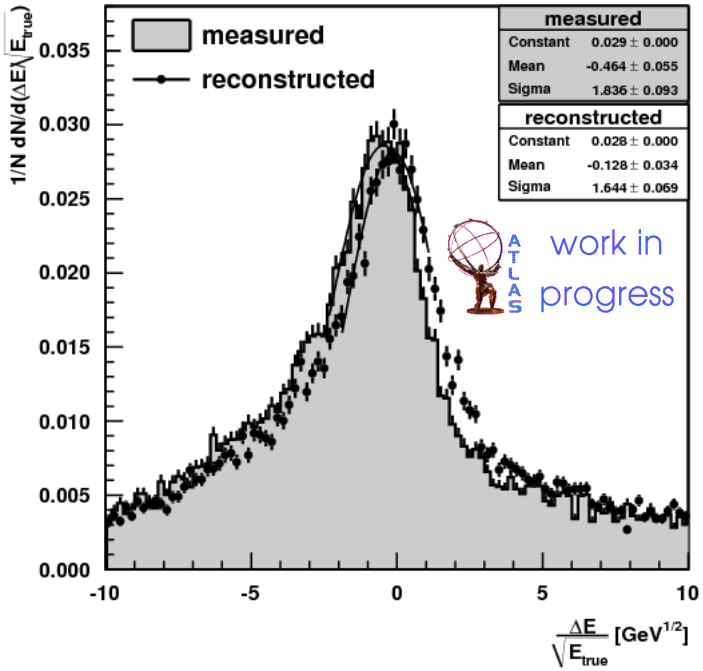
- Event selection
  - Exactly 1 e/mu with pT > 20 GeV
  - MET > 20 GeV
  - MET + mT(W) > 60 GeV (triangular cut)
  - >= 4 jets with pT > 25 GeV, |eta| < 2.5 & >= 1 of them with SV0 weight > 5.72
  - Some additional cleaning cuts & overlap removal



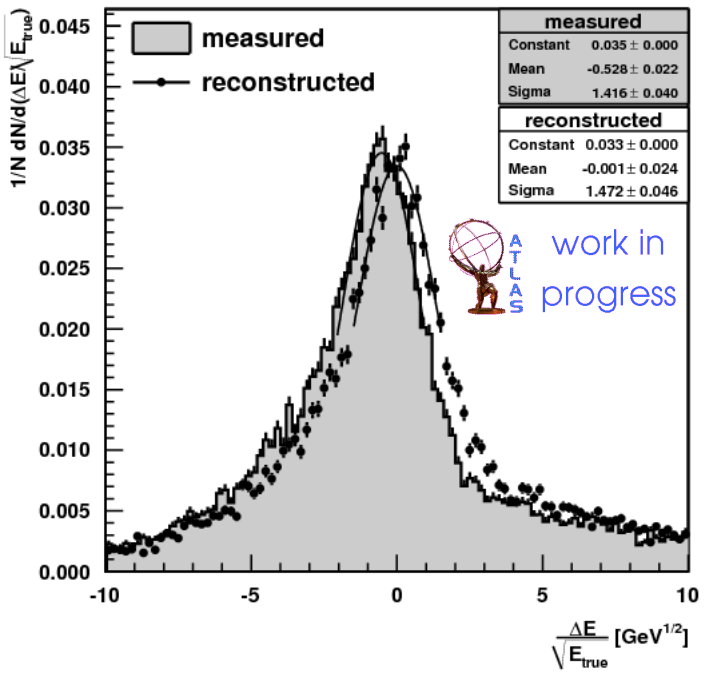


Jet Energy Resolution

- hadronic b-quark
  - measured → reconstructed
    - Mean: -0.46∓0.06 → -0.13∓0.04
    - Sigma: 1.84∓0.09 → 1.65∓0.07
  - Improvement
    - more centered
    - ~10% smaller sigma

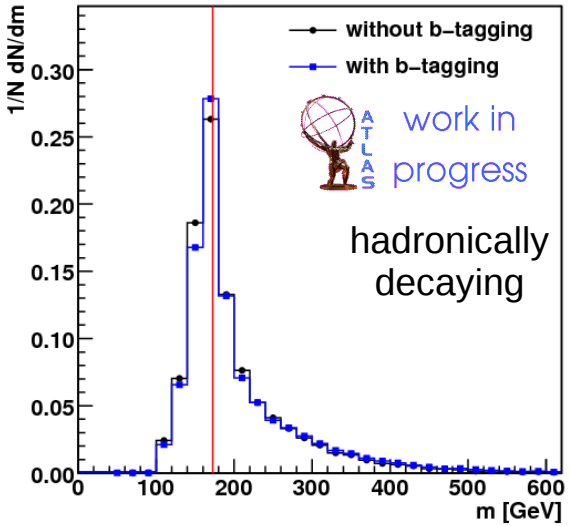


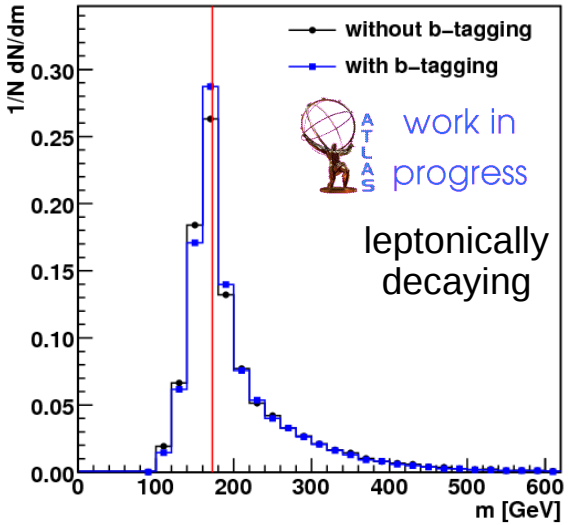
- leptonic b-quark
  - measured → reconstructed
    - Mean: -0.53∓0.02 → -0.00∓0.02
    - Sigma: 1.42∓0.04 → 1.47∓0.05
  - Improvement
    - perfectly centered w.r.t errors
    - no smaller sigma



KLFitter with b-tagging

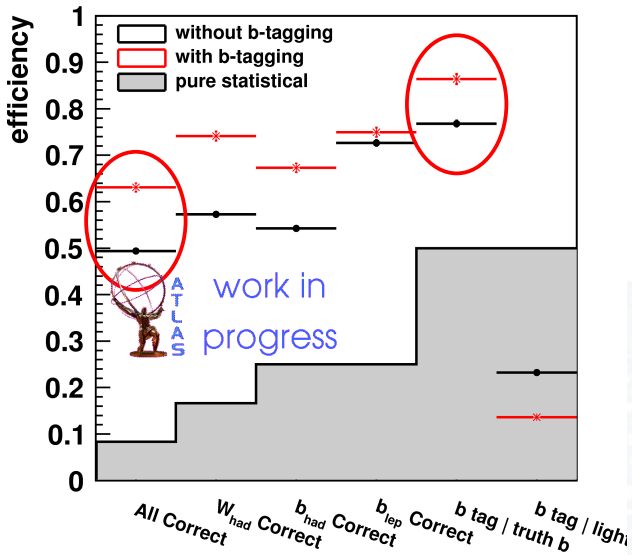
- Very simple b-tagging method applied
  - Weigh likelihood of certain permutation with zero if tagged b-jet is in position of a light quark
  - Further plans: use b-tagging probability instead
- Test on signal MC in mu+jets channel
  - Hadronically decaying top mass (top)
    - Slightly more pronounced peak
    - → less combinatorics
  - Leptonically decaying top mass (bottom)
    - Relatively larger improvement in peak
    - → very unlikely to interchange b-jets
    - → if leptonic b-jet tagged, no combinatorial background in leptonic hemisphere

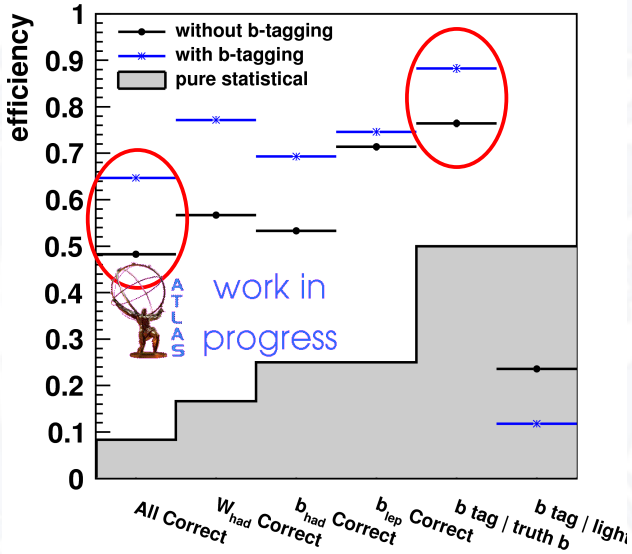




Reconstruction Efficiency

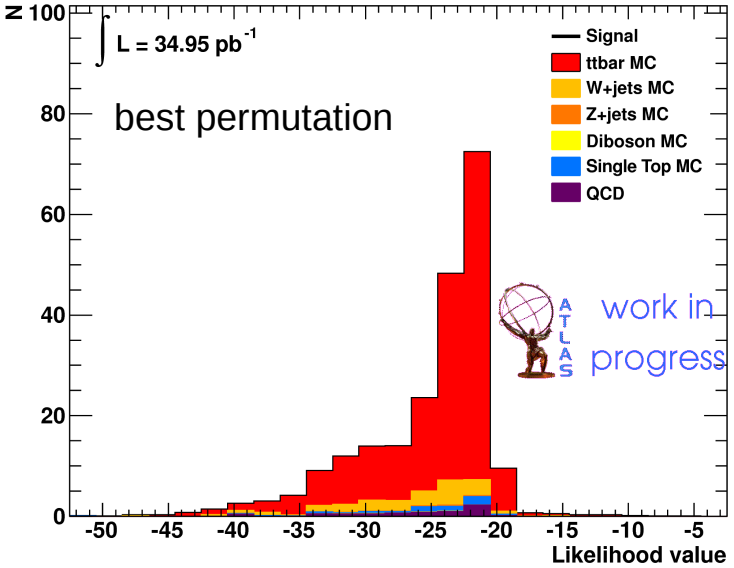
- Based on truth matched events
  - Simple matching: dR < 0.3
- e+jets (31.2% are matched)
  - without b-tagging
    - ~50 % all correct
    - ~76 % b-jet correct
  - with b-tagging
    - ~63 % all correct
    - ~87 % b-jet correct
- mu+jets (29.6 % are matched)
  - without b-tagging
    - ~48 % all correct
    - ~76 % b-jet correct
  - with b-tagging
    - ~ 65 % all correct
    - ~ 88 % b-jet correct

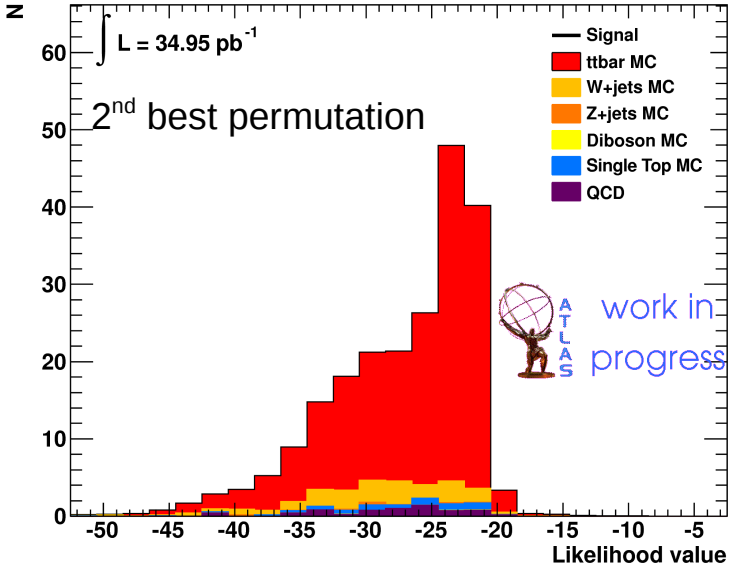


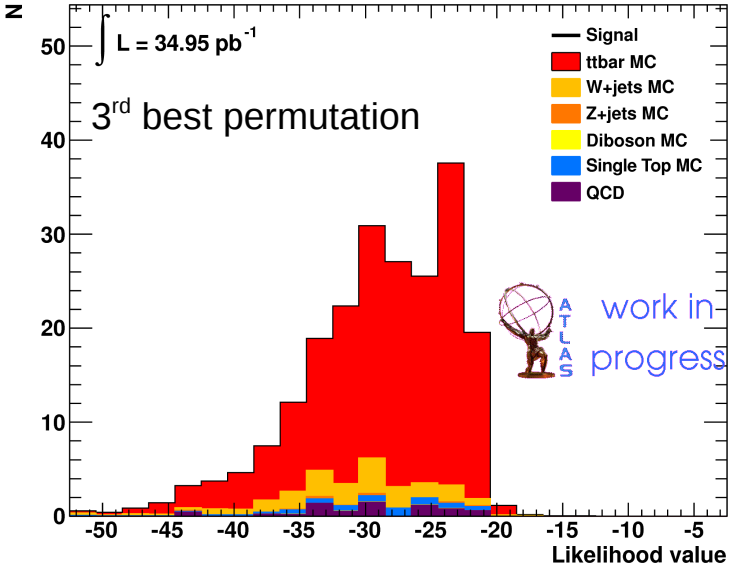


Likelihood Function

- Following plots: mu+jets
- LogLikelihood Distribution
  - best permutation (top right)
  - 2nd best permutation (bottom left)
  - 3rd best permutation (bottom right)
- well distinguishable
- some separation power for signal / bkg

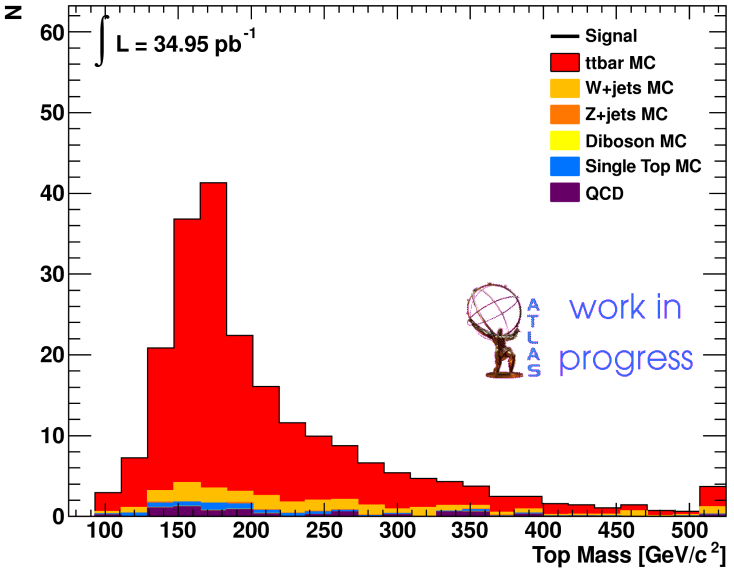


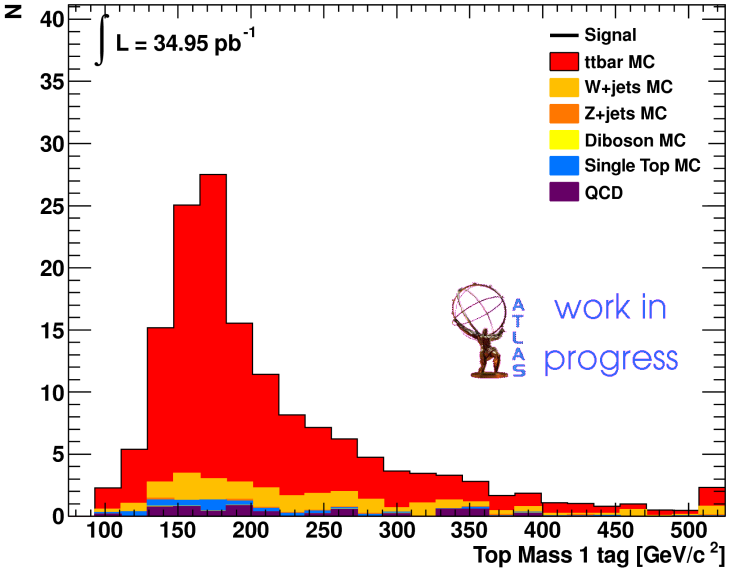


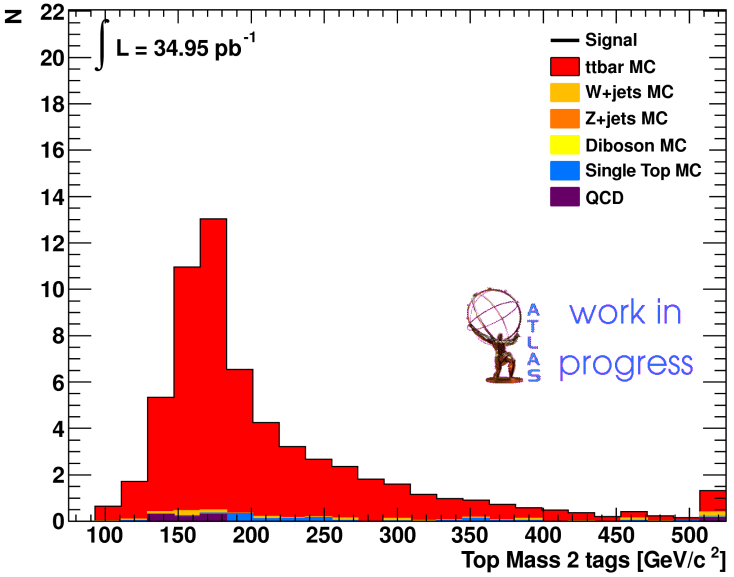


Top Mass Parameter with b-tag

- Top pole mass parameter
  - at least 1 b-tag required (top right)
  - 1 b-tag required (bottom left)
  - 2 b-tags required (bottom right)
- well pronounced top mass peaks
- b-tags improve signal / bkg ratio
- b-tags reduce combinatorics

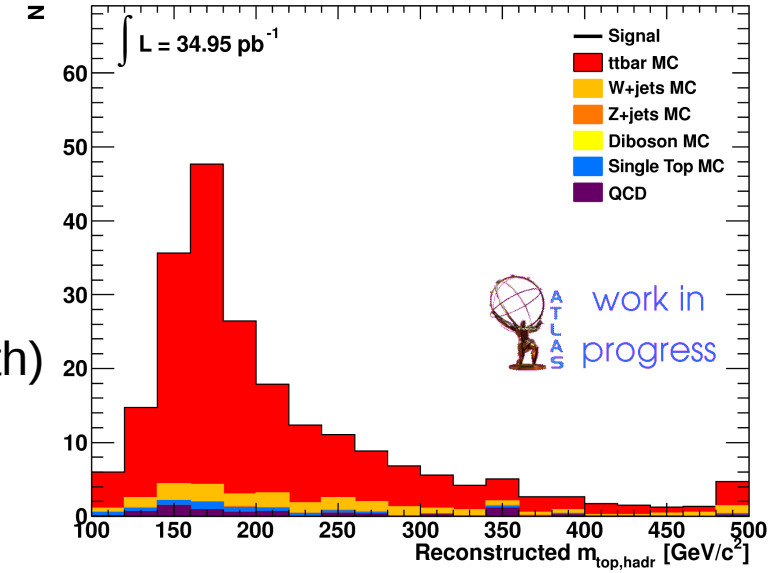


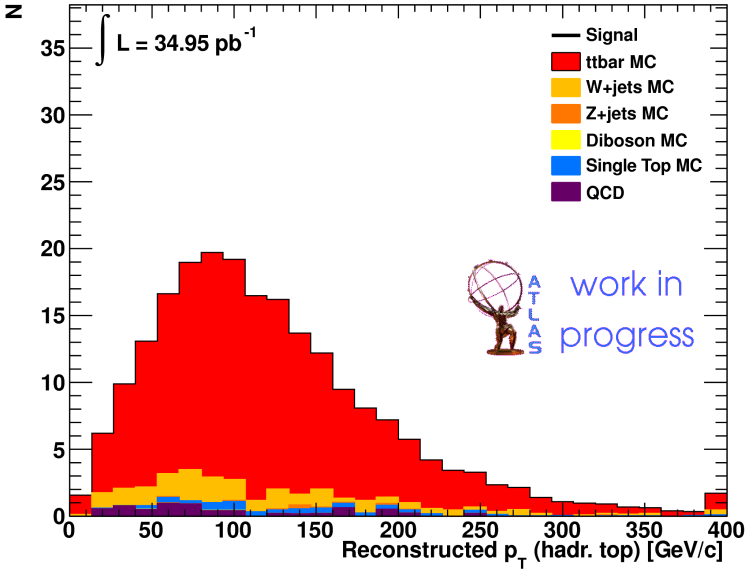


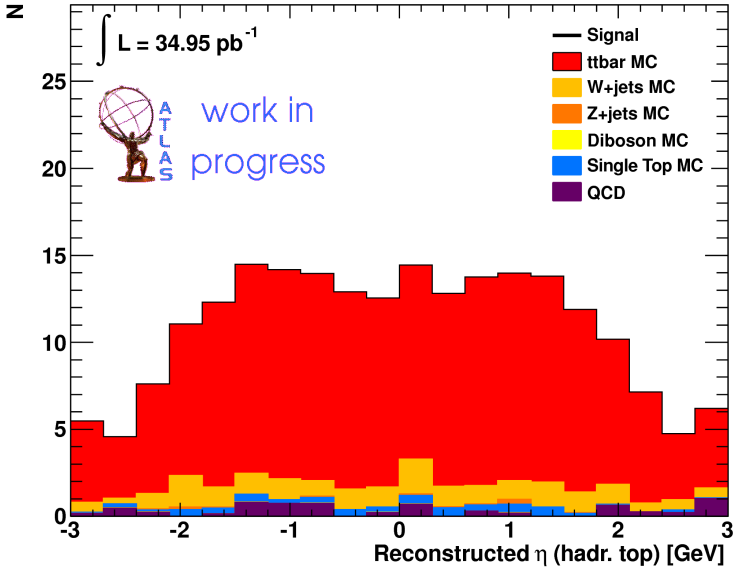


Top Mass & Kinematic

- Hadronically decaying top
  - mass (top right)
  - pT (bottom left)
  - eta (bottom right)
- shapes are reconstructed as expected (truth)
- good signal over background ratio

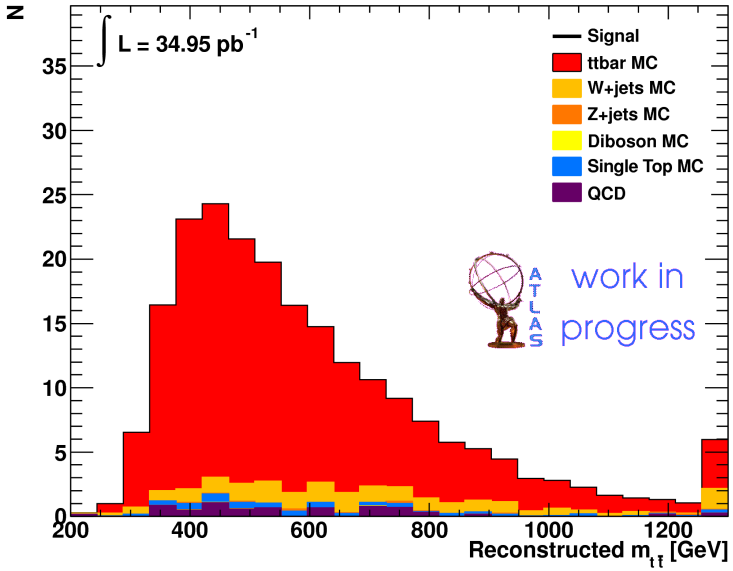


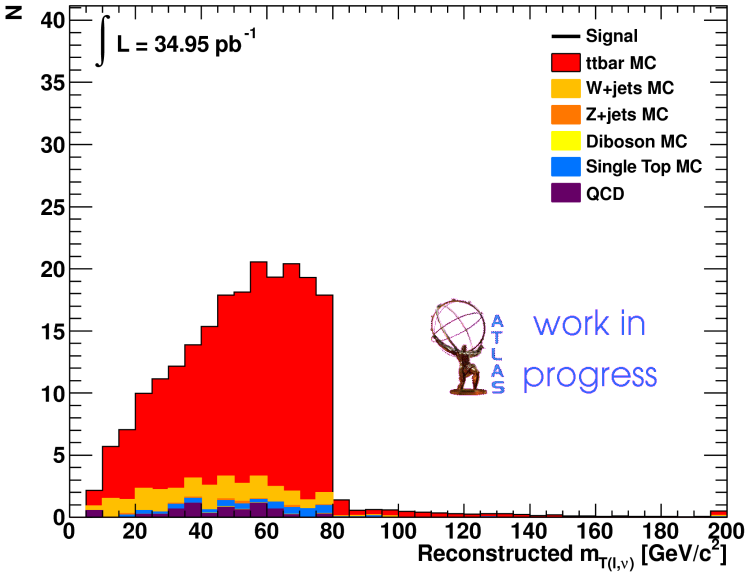


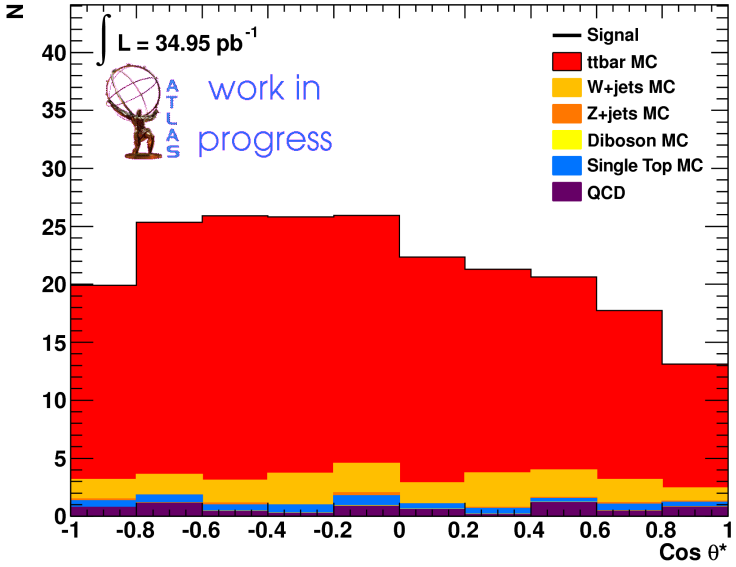


Miscellaneous

- tT mass (top right)
  - can be reconstructed, but peak less pronounced compared to truth
- Transverse Mass of lept. W (bottom left)
  - hard cut due to BW constraint
- Cosine theta star (bottom right)
  - shape as expected
  - nice example of good reconstruction







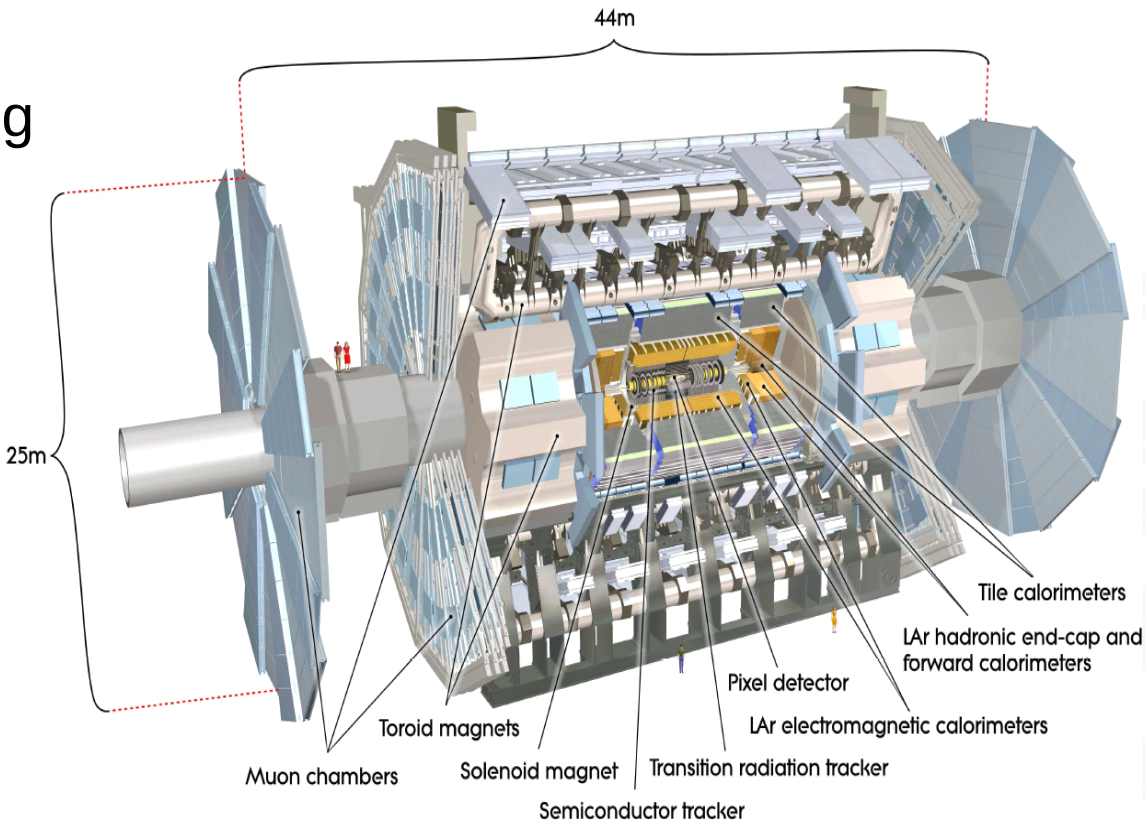
Summary & Outlook

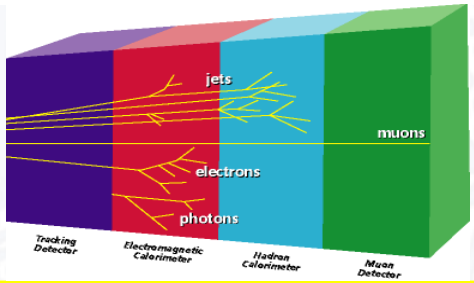
- Summary
  - KLFitter performs well with a good reconstruction efficiency and improvement in jet energy resolution
  - b-tagging in KLFitter further improves the reconstruction
  - The first 35 pb^{-1} of LHC data is in quite good agreement to MC
  - Top mass is well reconstructed around the expected value
  - Kinematics and properties of final state and reconstructed objects are well estimated
- Outlook
  - Data validation for e+jets channel is in preparation
  - KLFitter is used in several analyses
    - Göttingen
      - W-Helicity (Andrea Knue)
      - top mass (Stefan Guindon)
      - tT + γ (Johannes Erdmann)
    - Other universities and institutes are using or planning to use KLFitter for their studies

BACKUP

ATLAS

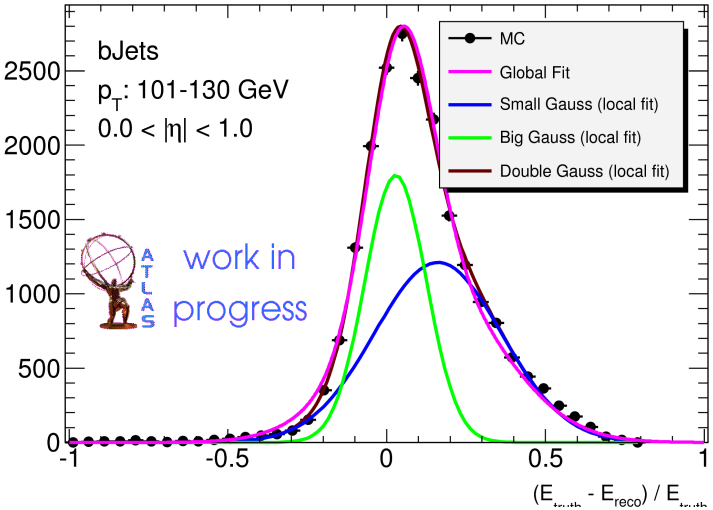
- Inner detector – Tracking
  - Pixel
  - SCT
  - TRT: e/π separation
- Calorimetry
  - ECal: LAr
  - HCal: scint./steel + LAr
- Muon System
  - Trigger: RPC,TGC (fast)
  - Tracking: MDT,CSC (precise)

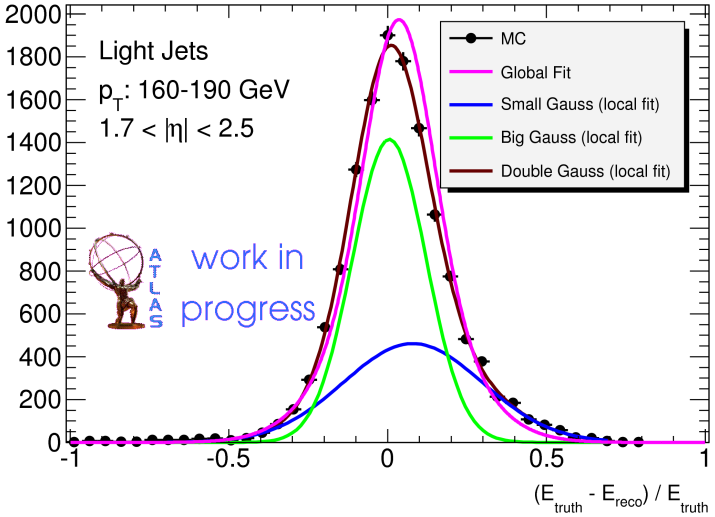


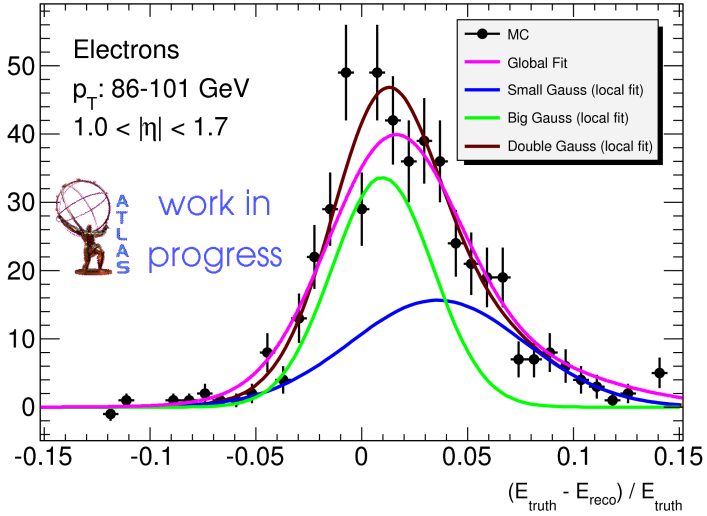


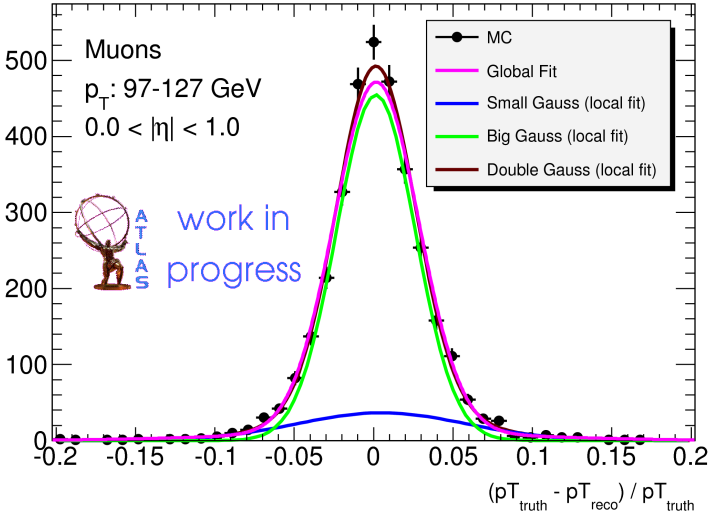
Transfer Functions

- New transfer functions for ttbar @ 7 TeV









Matching & Reconstruction

Truth Matching Efficiency

- Truth matching necessary for calculating reconstruction efficiencies

$$\Delta R = \sqrt{(\Phi_{reco} - \Phi_{truth})^2 - (\eta_{reco} - \eta_{truth})^2} < 0.3$$

- Matched event: One-to-one assignment of all truth partons to jets
- **The more jets, the higher the probability to match the event**

Reconstruction Efficiency

- Only matched events can be taken into account
- Ratio of reconstructed events with correct permutation and matched events
- **The more jets, the harder to find correct permutation**
  - Statistical probability for n jets: P(all correct) = 2*(n-4)! / n!
  - Remove indistinguishable jet permutations

→ **Total Efficiency affected by these two competing effects**