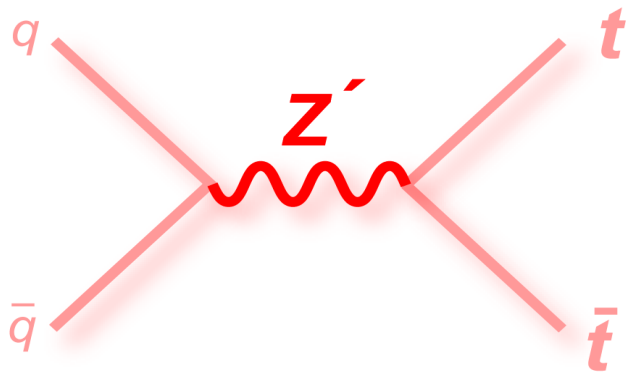
# Analysis status:

# *Search for a resonance in the invariant mass spectrum of the top-antitop-system*




Deutsche Forschungsgemeinschaft
DFG

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CMS Germany Meeting
DESY Zeuthen
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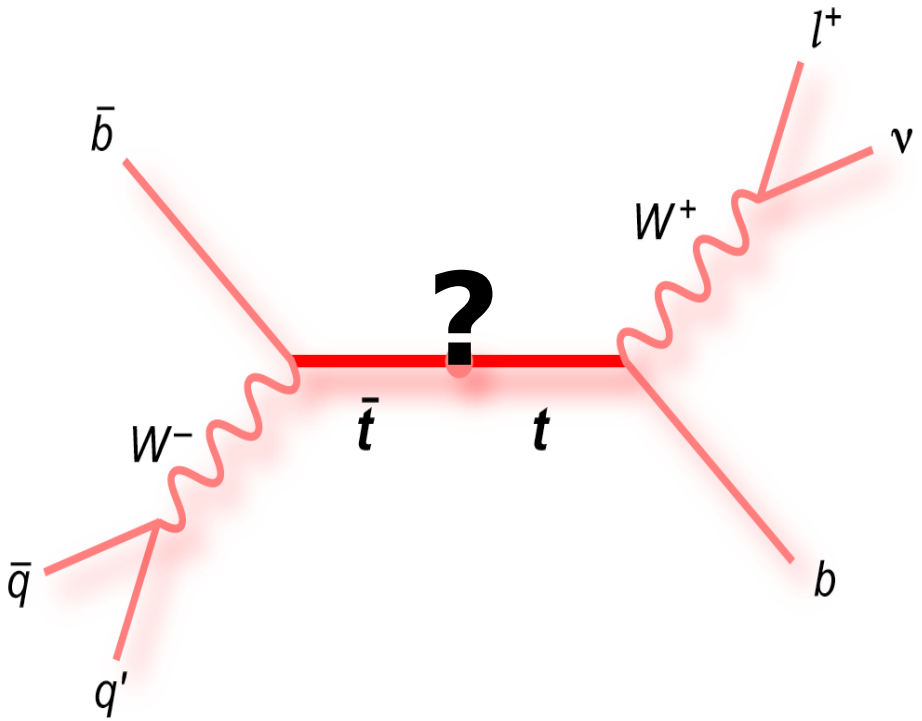
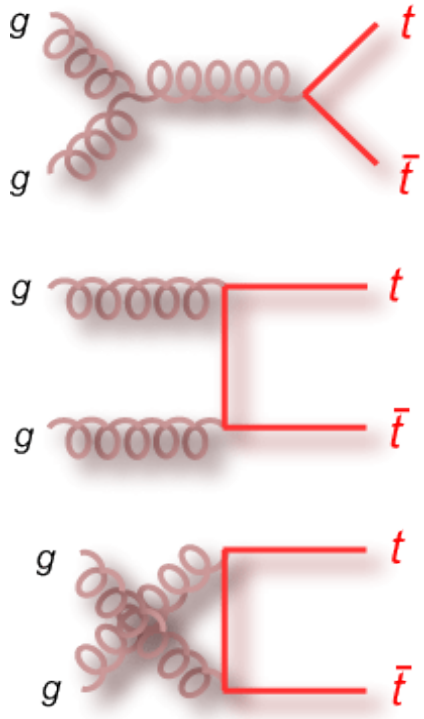
RWTH AACHEN UNIVERSITY

# Topics

- *top pair production at the LHC*
- *production of a resonance*
- *reconstruction of the top-antitop-system*
- *kinematic fitting*
- ***resolution of m(tt̄)***
- *conclusion & outlook*



# Top pair production at the LHC




- **~87% gluon fusion**, ~13% quark-anti-quark annihilation
- **high increase of $t\bar{t}$ production cross section**
  - extrapolated from *Tevatron* event selection, fraction of semileptonic ttbar events in 4-jet-events will rise from ~30% to ~90%

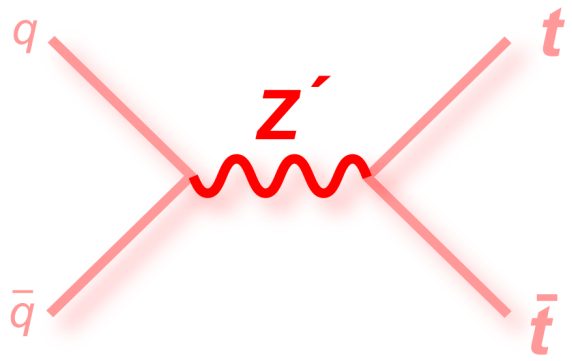
| | W+Jets | ttbar | bbar+Jets | |
|---|---|---|---|---|
| 1.96 TeV | ~1200 pb | **~ 6 pb** | ~ 2.4 x $10^5$ | (Tevatron) |
| 14 TeV | ~7500 pb | **~ 800 pb** | ~ 5 x $10^5$ | (LHC) |

- first main goal:
  - investigate **top pair production** in detail (as backgrounds considerably low)

# Production of a “resonance”

- **what?**

➔ an unknown particle of high mass decaying into a *top-antitop-quark pair*




- **how?**

➔ *standard example: Z' with SM couplings,* but *high(er) mass*

➔ *models:* (MSSM) Higgs, Technicolor, Top-color, Randall-Sundrum gravitons, ...

**properties:**
- ✗ high mass
- ✗ no charge
- ✗ spin 0, 1, 2

- **why?**

➔ *model independent*

➔ to first order, *complementary* to searches for *supersymmetry*

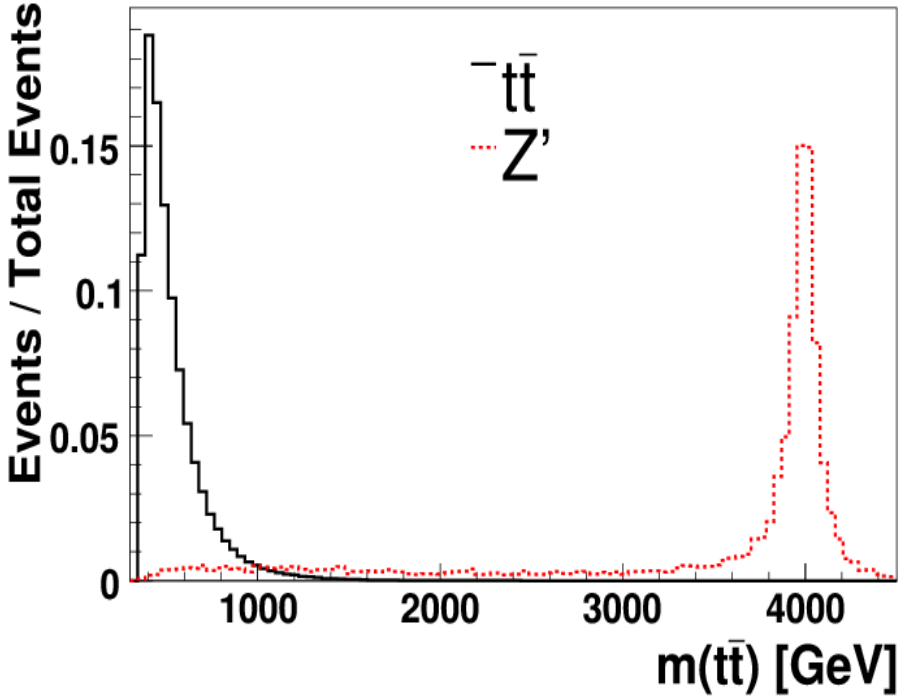
➔ *high mass* of top quark *(~ scale of EWSB)*

– indicates connection to new physics?

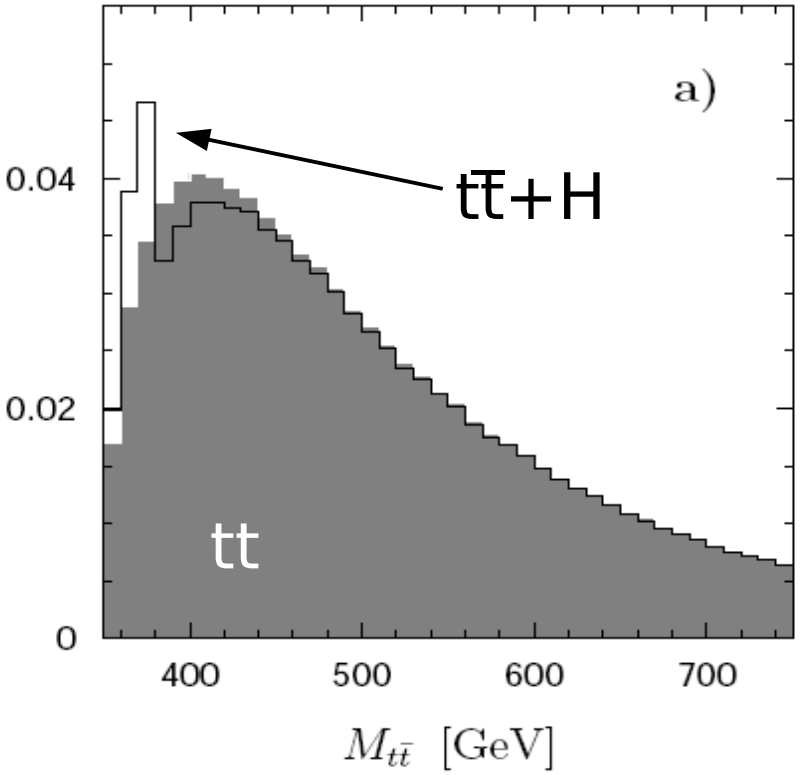
# The invariant mass of the $t\bar{t}$ system

- theory: solid variable
*(cf. D-LHC top workshop)*

- production threshold: 2 x top mass
- Z' (mass of 4 TeV):




- Higgs (mass 375 GeV, decay width 20 GeV):
(Bernreuther, Flesch, Haberl 1997)



# Technical setup

- **samples**

➔ Spring '07 Alpgen samples

➔ *used here:* semileptonic ttbar + 0 jets

- **CMSSW & TQAF (Top Quark Analysis Framework)**

➔ CMSSW 1_3_6

➔ TQAF_136_070908 *(fixed object resolutions for kinematic fitting)*

- **Physics eXtension Library (PXL)**

➔ successor of the PAX toolkit

➔ supplies fast hypothesis evaluation

➔ well suited for analysis with high combinatorics → top physics

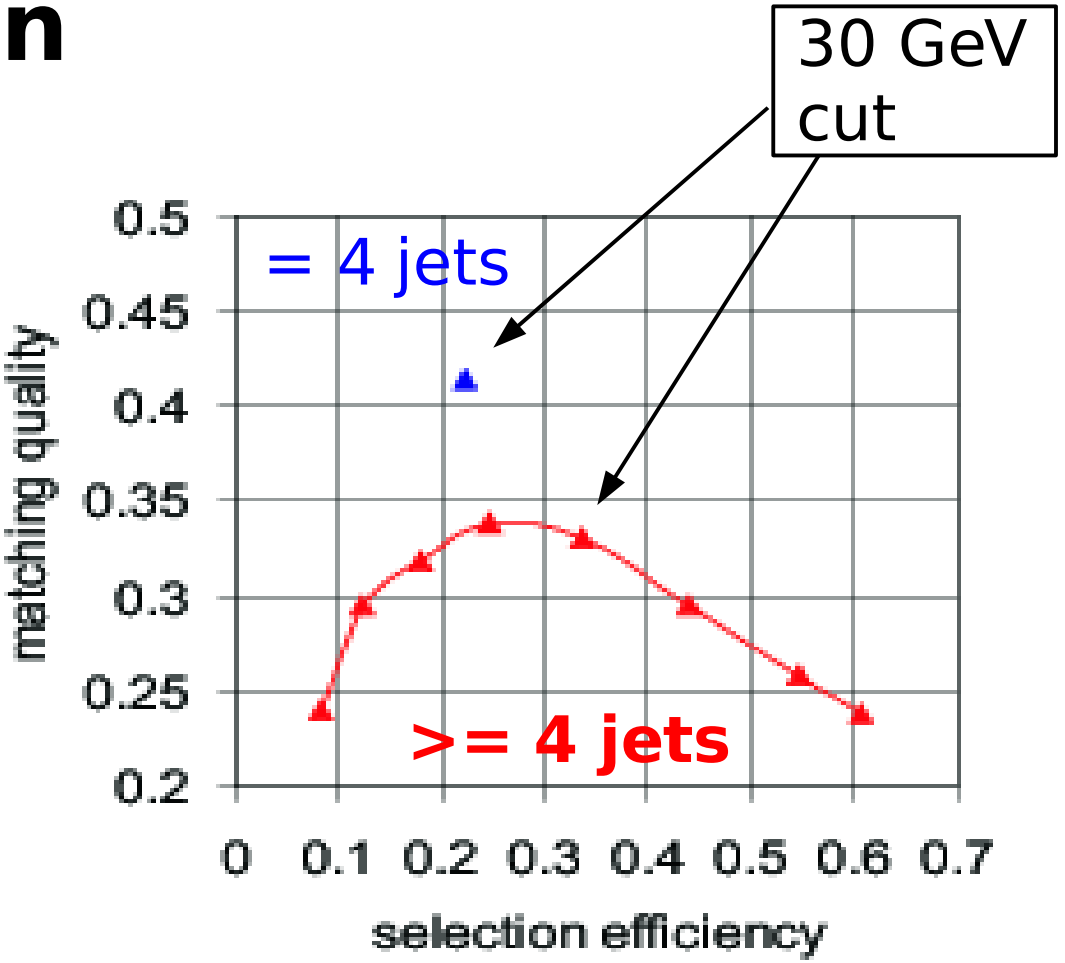
# Event selection

- **generated ttbar-events** *(no pile-up)* with **one muon** (semileptonic decay)

- **4 Jets** with transverse momentum > 30 GeV, $\eta < 2.4$

- **Muon** with transverse momentum > 20 GeV, $\eta < 2.4$

- **missing tranverse energy** > 10 GeV

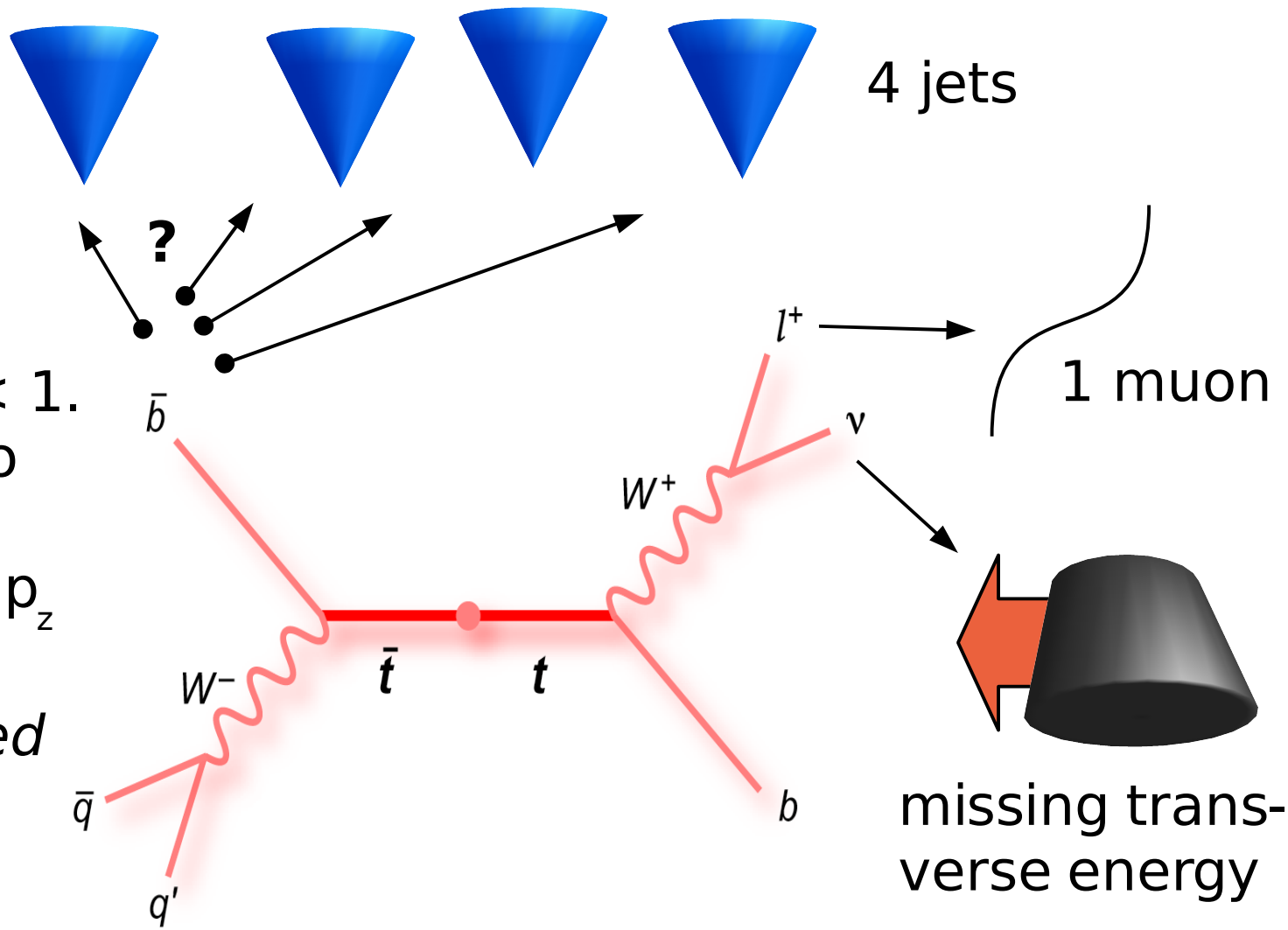



*no* b-tag requirement

# Matching reconstructed objects to partons

- combined ***DeltaR(η, φ)*** criterion:

- Σ DeltaR(jets) < 1.
- DeltaR(gen-reco muon) < 0.3
- better neutrino $p_z$ solution (dR)
  - → *event matched*



# Reconstruction of the top-antitop-system

## *4-Vector sum*

- simple and robust
- needs identification of top quark decay daughters *(as opposed to jets from ISR, underlying event, additional collisions)*
- resolution depends on:

➔ how often one includes objects not from top quark decay

➔ Jet Energy Scale

## *Kinematic Fitting*

- use additional information of the event
- can improve resolution
- well-suited at low m(ttbar)
- need assignment of final-state-objects to partons
- might be less robust at high m(ttbar) *(→D0 studies)*

➔ ***focus on kinematic fitting in the bulk region***

# Kinematic Fitting

• **extend knowledge** of observed event using information from an event hypothesis *(parton picture)*

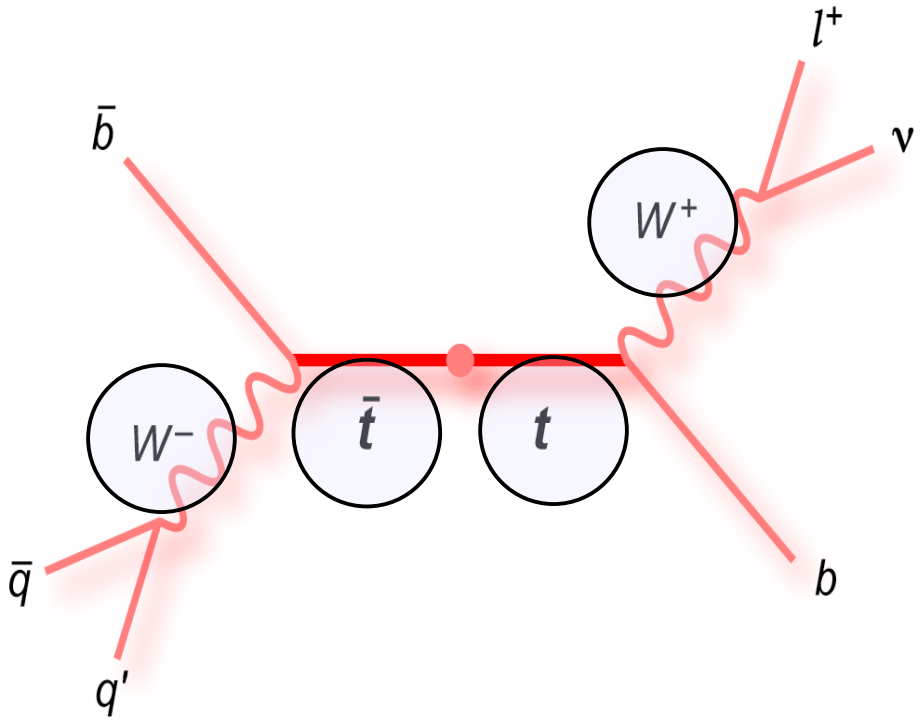
• change four-vectors of reconstructed particles to comply with ***kinematic constraints***

• ***need event hypothesis***
  ➔ 24 hypotheses in 4-jet-events *(<24 if kinematic fit finds unambiguous neutrino pz solution)*

• ***find solution that minimally alters four-vectors:***
➔ need **resolutions (covariance matrices)** for all final state objects
➔ **construct & minimise $\chi^2$** using Lagrangian multipliers

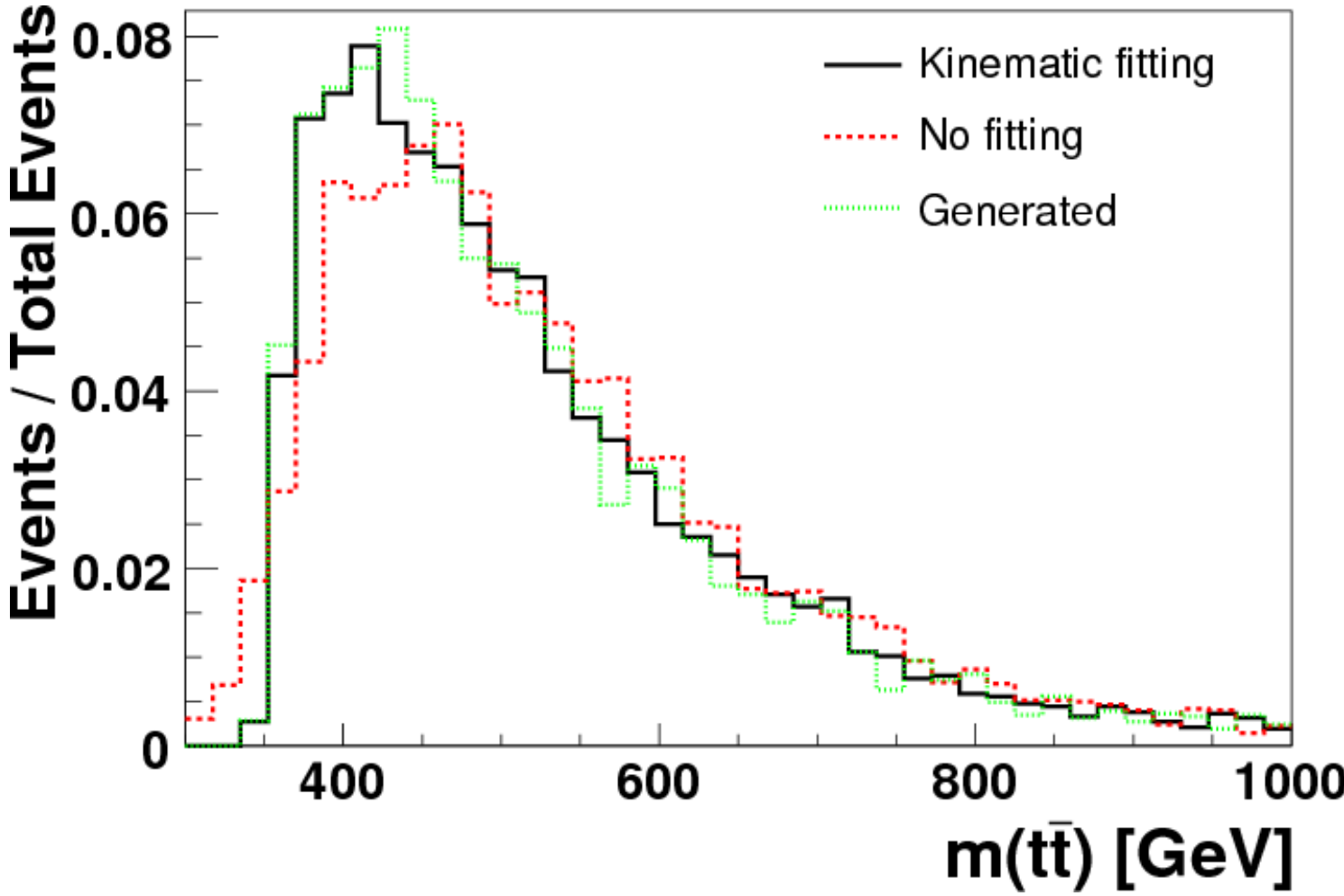
# Constraints for Kinematic Fitting

- both ***W* masses** must equal 80.4 GeV
- both **top quark masses** must equal 175 GeV *(MC)*
- results in an **over-constrained system**
- use the “EMom” parametrisation



# The invariant mass distribution of the top-antitop-system *[m(ttbar)]*

- reconstructed mass: **parton-matched** event
- kinematic fitting **improves description** (e.g., production threshold)

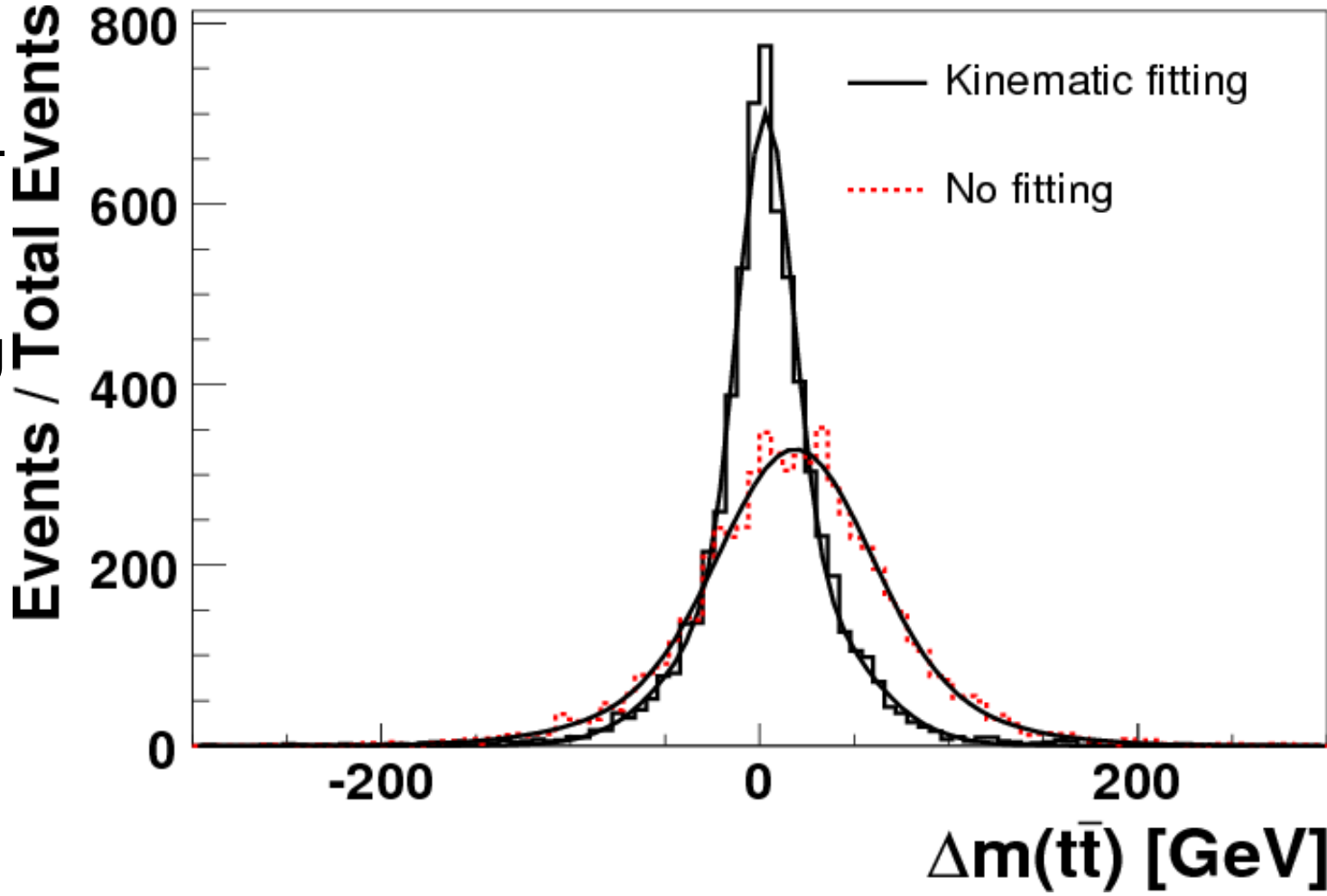


# Resolution of m(ttbar) with and without a kinematic fit

- both for the **generator-matched** jet-parton assignment

- kinematic fitting **significantly improves** the resolution

- *fits:* sum of two Gaussians

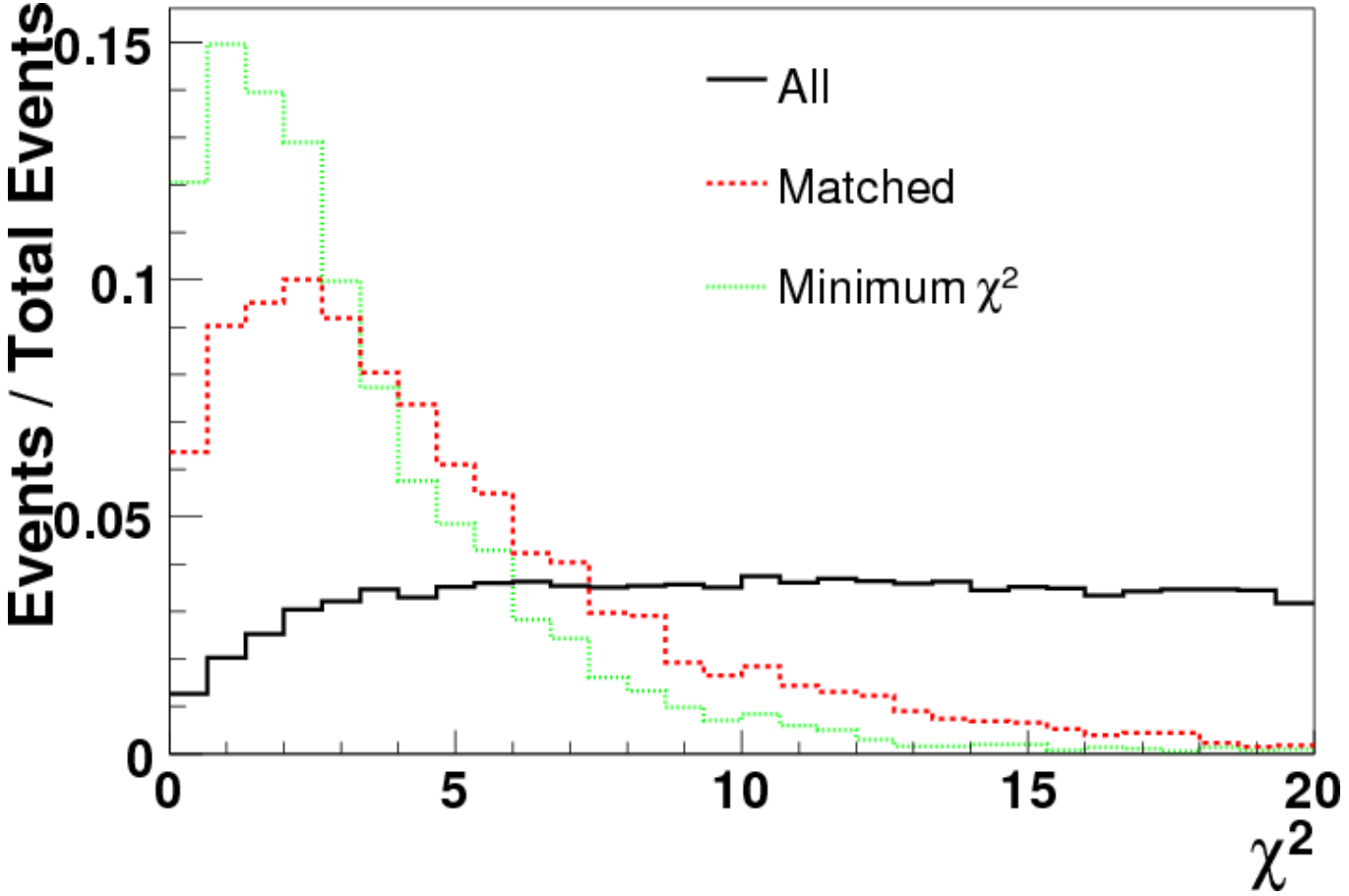


# Quality of the kinematic fit

compare:
- generator-matched solution
- solution with minimum chi2
- all other solutions

→ minimum $\chi^2$ *correspondance* to *generator-matched solution* >~20%

→ does lowest $\chi^2$ correspond to highest resolution?

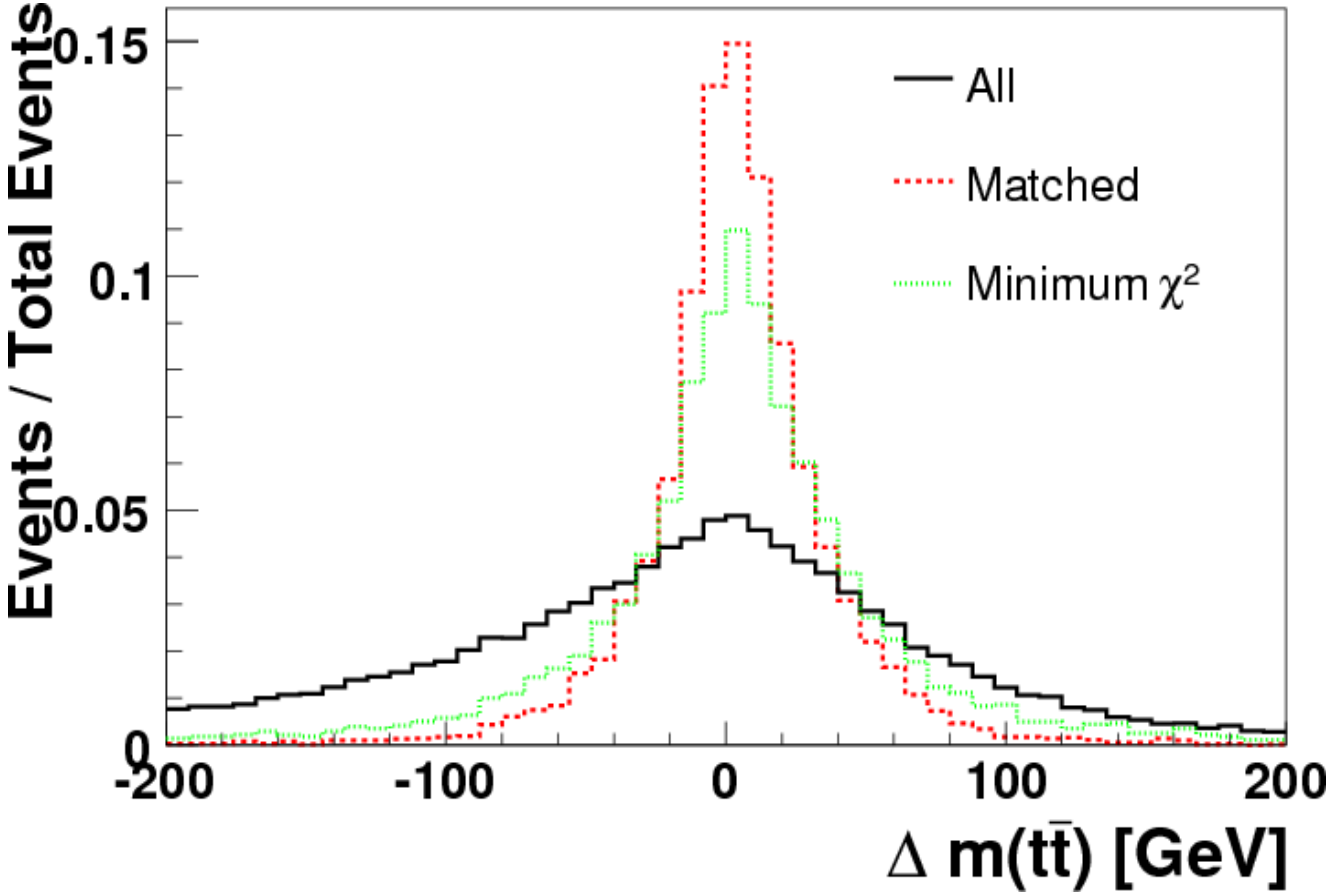


# Resolution of m(tt̄)

compare: $\sigma(\Delta m(ttbar))$
- generator-matched solution ~ 15 GeV
- solution with minimum chi2 ~ 25 GeV
- other solutions ~ 90 GeV

→ generator-matched solution has **best** resolution, minimum $\chi^2$ **good**

→ finding correct final-state-object-parton-assignment will *improve* resolution



# Conclusion & Outlook

• at present, $\Delta m(t\bar{t})$ of **25 GeV** with **kinematic fitting, 15 GeV** possible *(ttbar + 0 jets sample)*

• analysis part of a **CMS 2007 top paper** *(differential distributions)*

• MVA tools studied to resolve ambiguities in jet-parton-match: *slight improvement compared to* $\chi^2$ *only*

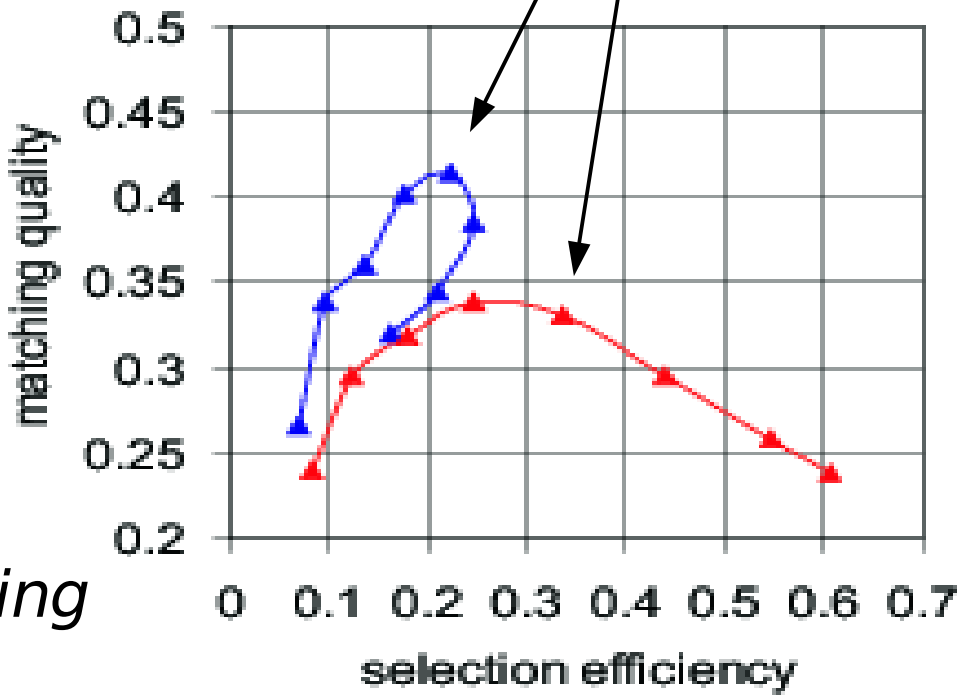
**next steps:**
• study inclusion/rejection of *intrinsic* background (wrong jets)
• study *physics* backgrounds

# backup...

# Event selection efficiency

**event quality:**
# matched events / # events

optima:
~ 30 GeV jet cuts



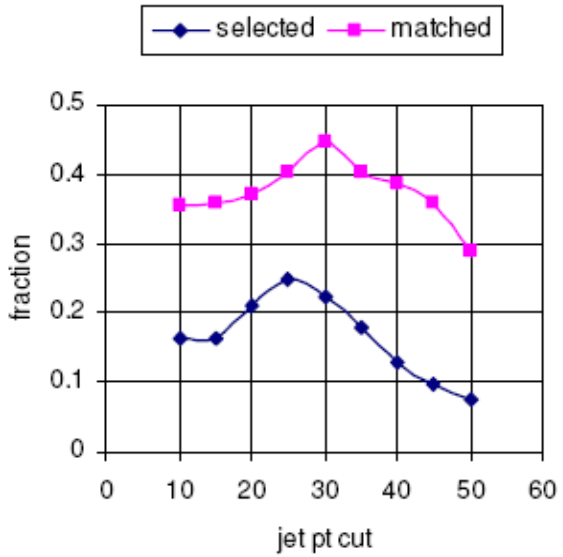

= 4 jets

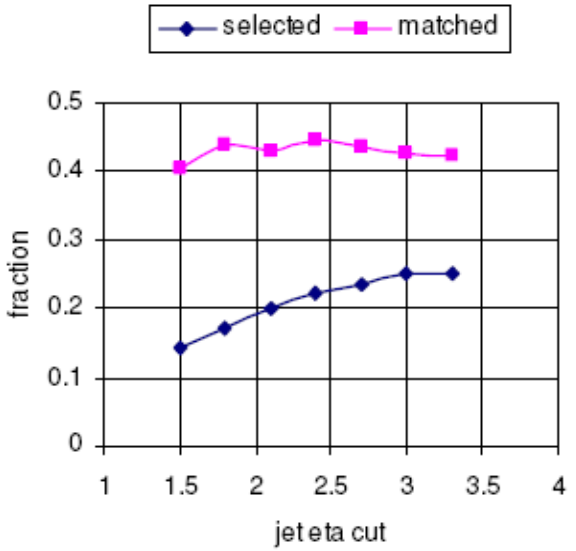
>= 4 jets

→ *see Andreas' talk at the CMS week top quark meeting*

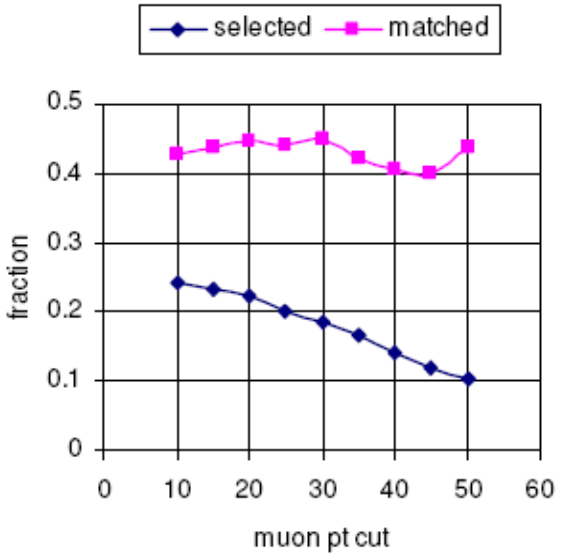
# Event selection efficiency

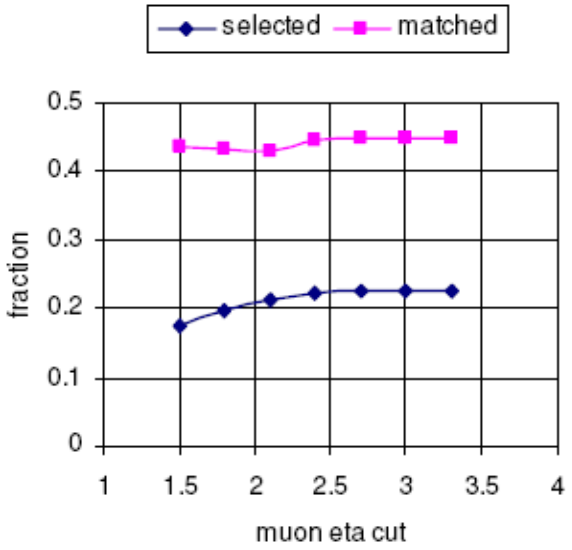
Jet cut



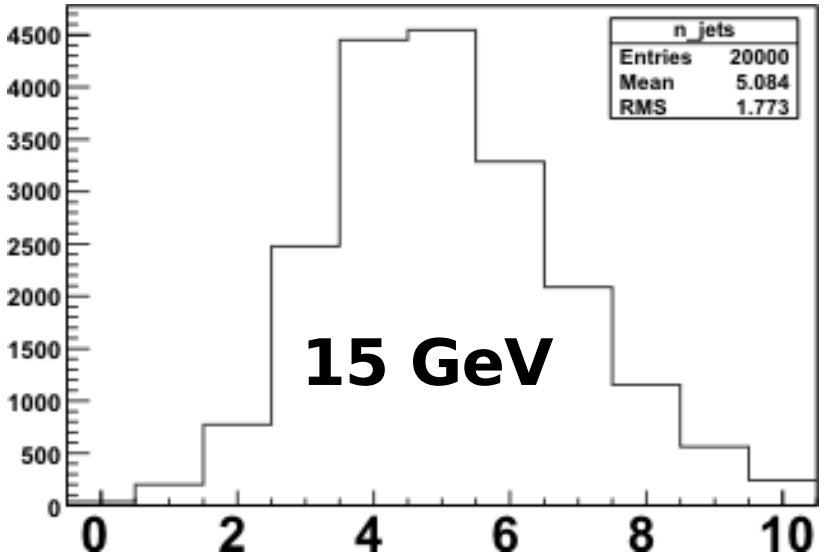



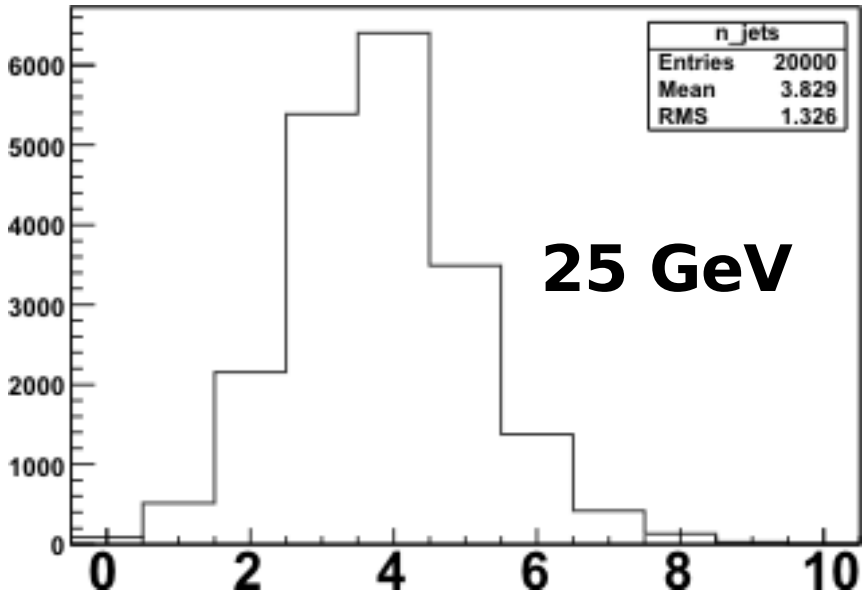

Muon cut

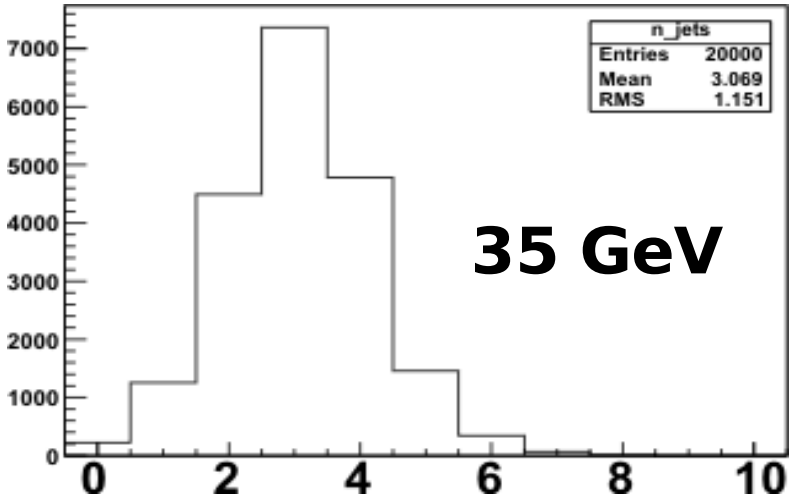


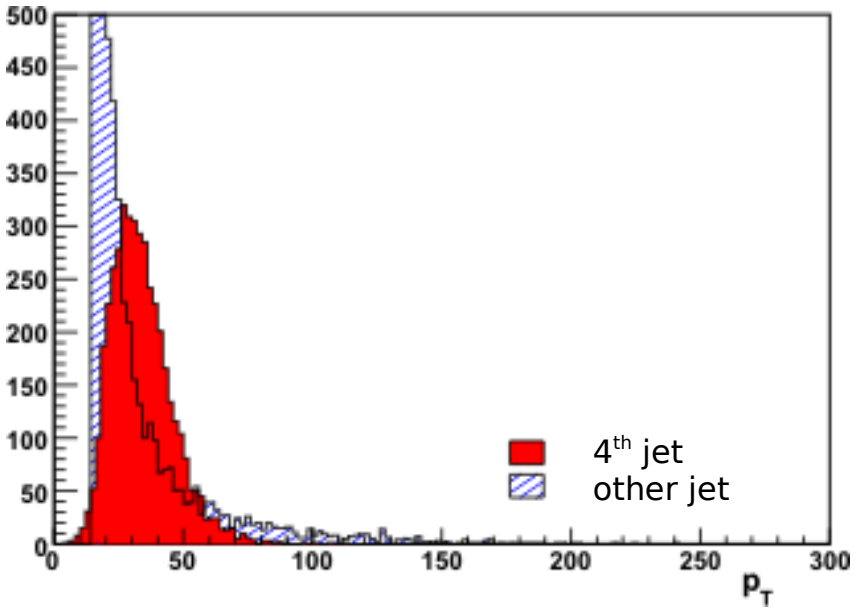
# Number of jets for different jet pt cuts



# Eta and pt of highest pt jet not from ttbar decay




jet from ttbar decay with 4th highest pt

highest pt jet not from ttbar decay