Bundesministerium
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PHYSICS
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Helmholtz Alliance

Towards a Cross Section Measurement for the Production of Top Quark Pairs in the Fully Hadronic Decay Channel with CMS

(no official CMS results)

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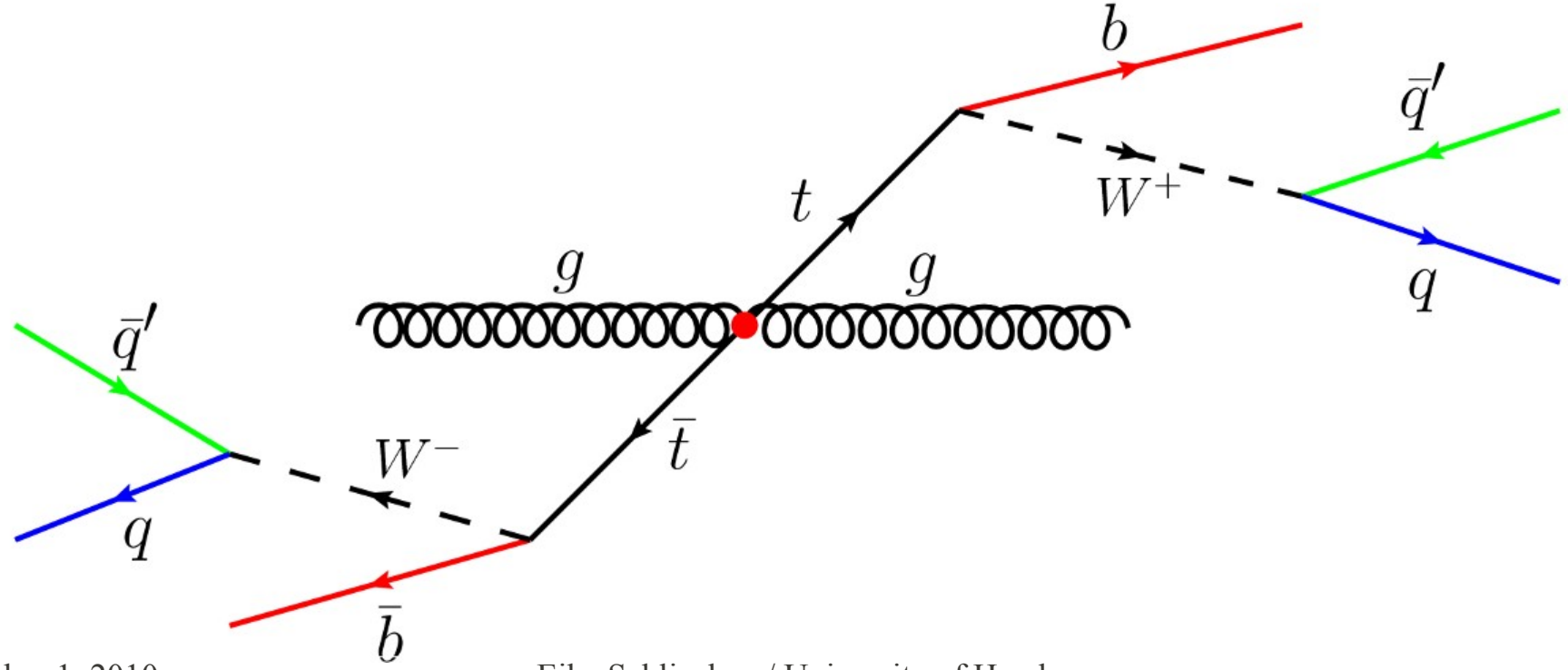
Motivation

- Motivation:
  - overall understanding of $t\bar{t}$
  - other systematic than other $t\bar{t}$ decay channels
  - overall performance of detector and reconstruction
  - benchmark for more complex processes



Data & MCs

- Data:
  - Full 2010 proton-proton collision dataset corresponding to **35 pb^{-1}** of good data
- MCs:
  - $t\bar{t}$ events generated with MC@NLO (ME) + Herwig (PS)
  - QCD multi-jet events generated with Pythia (ME + PS)
  - QCD multi-jet events for cross checks generated with:
    - MadGraph (ME) + Pythia (PS)
    - Herwig (ME + PS)

(ME = matrix element, PS = parton showering)

Selection Overview

1. Multi-Jet Selection

- trigger: $N_{jet}(p_t^{raw} > 25\ GeV) \geq 4$ (Iterative Cone with R = 0.5)
- offline: $N_{jet}(p_t > 40\ GeV) \geq 6$ (Anti-k_t with R = 0.5)

2. B-Tag Selection

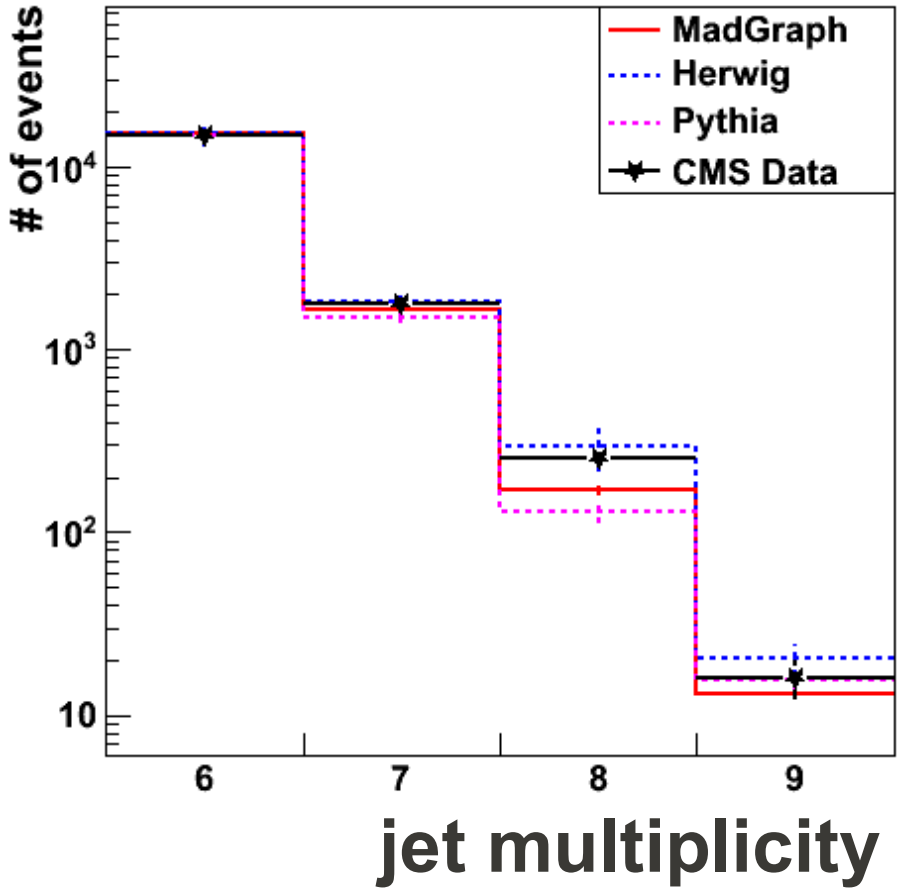
- $N_{jet}^{b\text{-}tag}(p_t > 40\ GeV) \geq 2$
  - 23% b-identification efficiency, 0.1% miss-tag rate

3. Kinematic Fit Selection

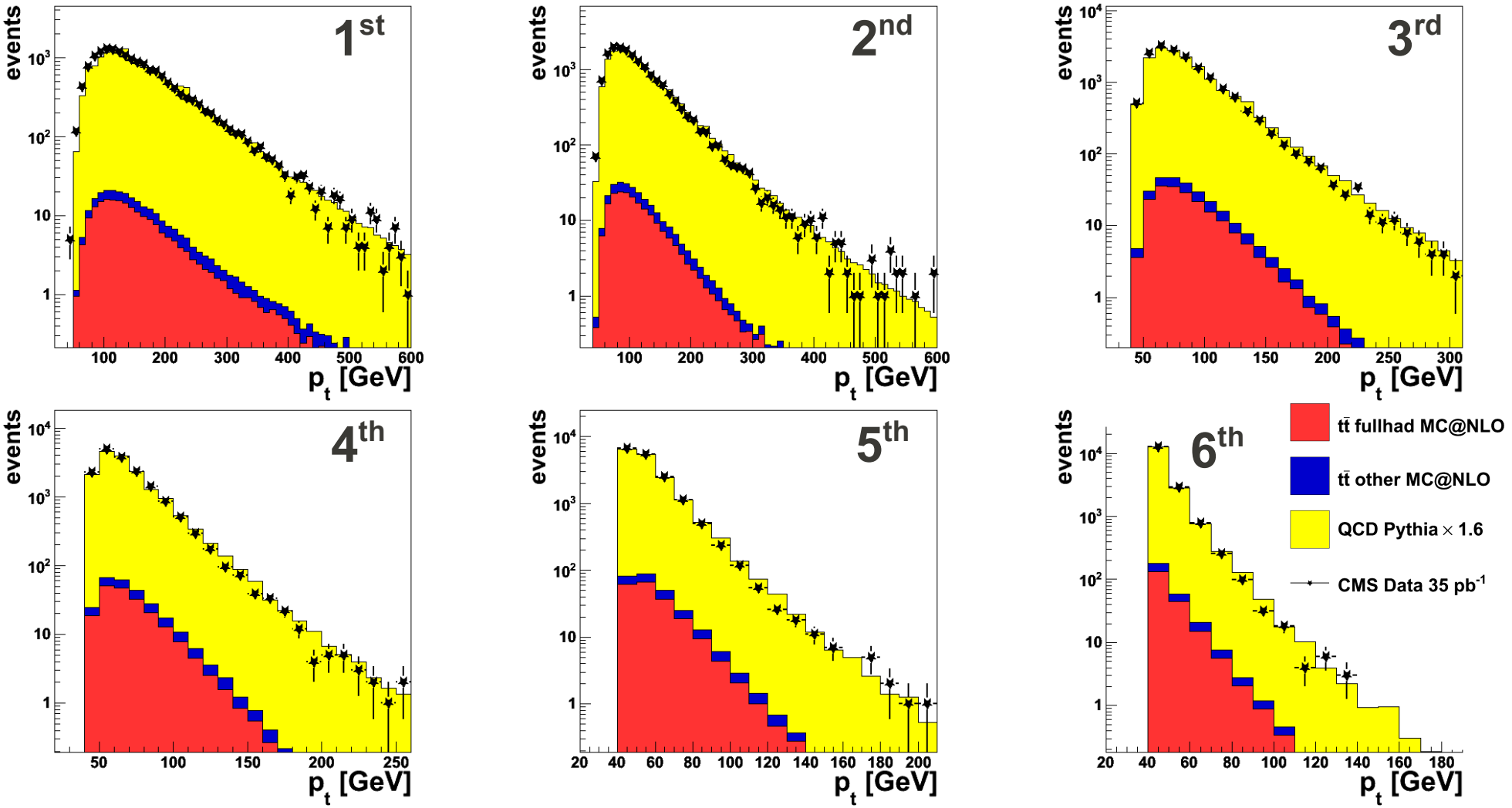
- $P(\chi^2) \geq 0.01$

Background Estimation

- After Multi-Jet Selection:
  - normalize QCD-MCs to events in data with at least 6 jets
  - normalization factors:
    - MadGraph : 3.0
    - Herwig : 1.1
    - Pythia : 1.6
  - acceptable description by all MCs
  - Pythia chosen as default

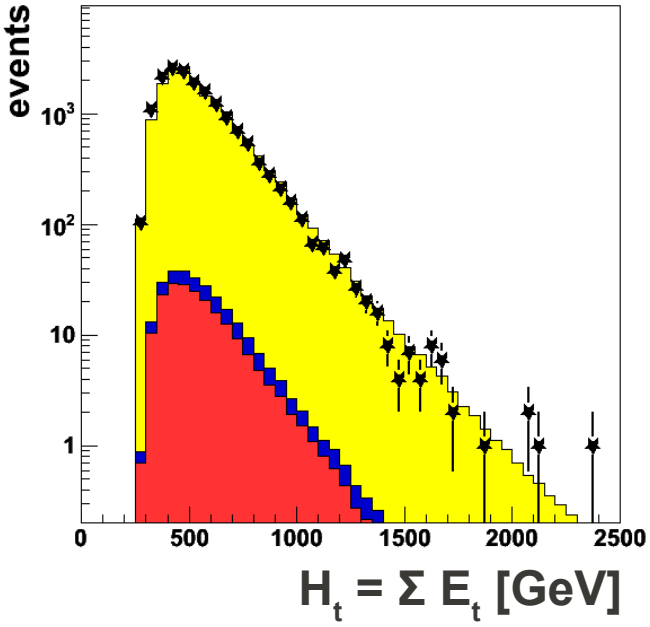


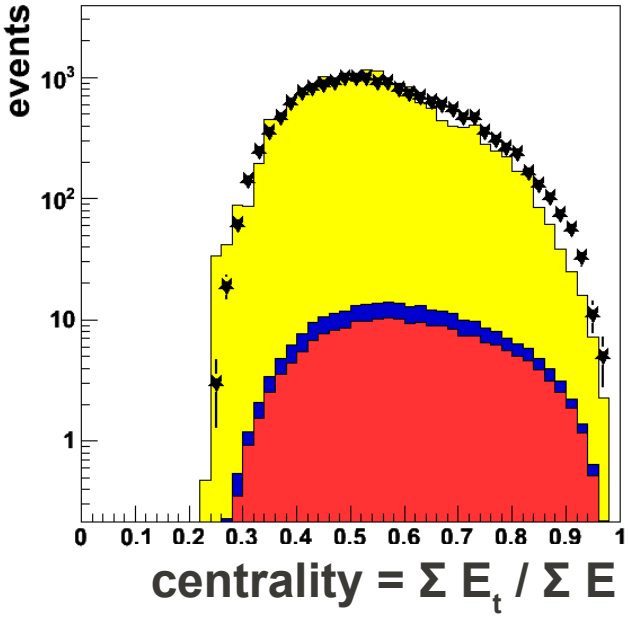
p_t Spectra After Multi-Jet Selection

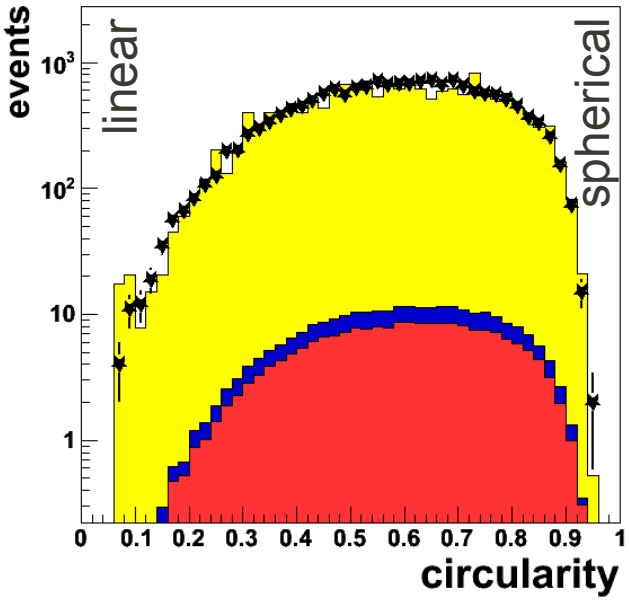


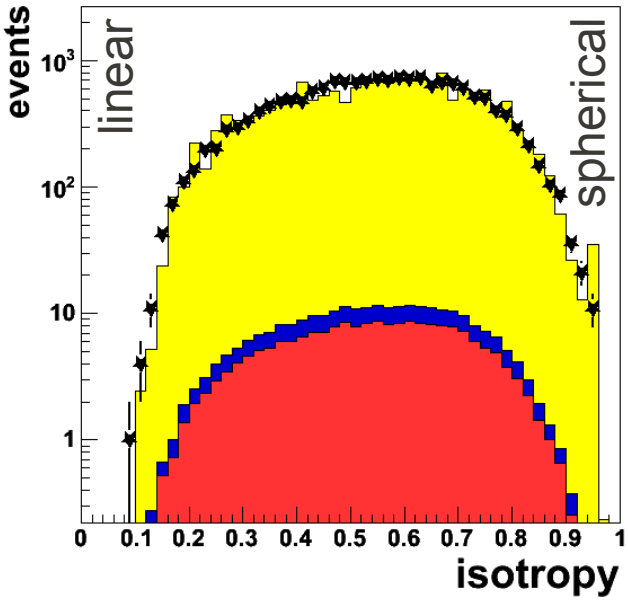
- signal to background ratio S/B = 1 / 100 = 0.01
- very good description of p_t spectra by MC
- data is only slightly softer than predicted by MC

Event Shape Variables









$t\bar{t}$ fullhad MC@NLO

$t\bar{t}$ other MC@NLO

QCD Pythia × 1.6

CMS Data 35 pb^{-1}

$$\text{circularity} = \min(C_i)$$

$$C_i = \frac{\pi}{2A} \sum_{jets} \left| x^{jet} \cos\varphi_i + y^{jet} \sin\varphi_i \right|$$

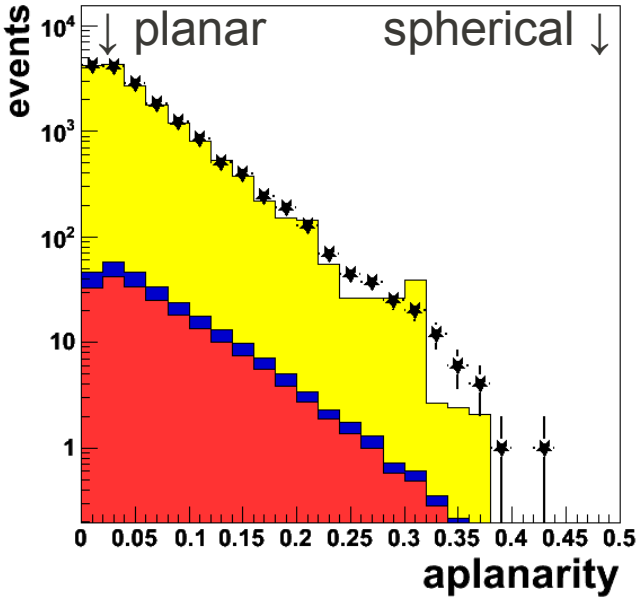
$$A = \sum_{jets} \sqrt{x^{jet} + y^{jet}}$$

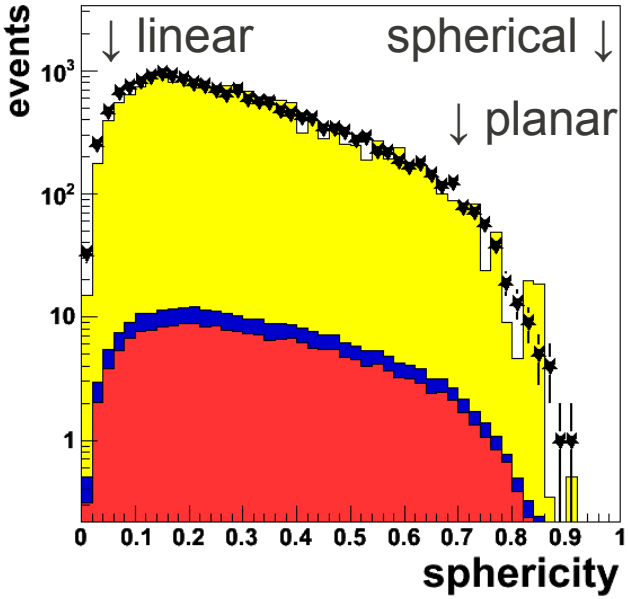
$$\text{isotropy} = \frac{\max(I_i) - \min(I_i)}{\max(I_i)}$$

$$I_i = \sum_{jets} \left| x^{jet} \cos\varphi_i + y^{jet} \sin\varphi_i \right|$$

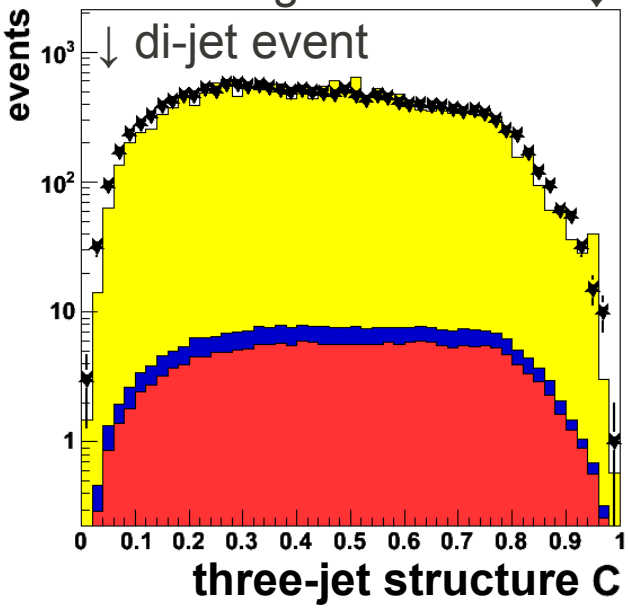
- H_t slightly softer in data
- events are more central in data
- circularity and isotropy are well described by MC

Event Shape Variables

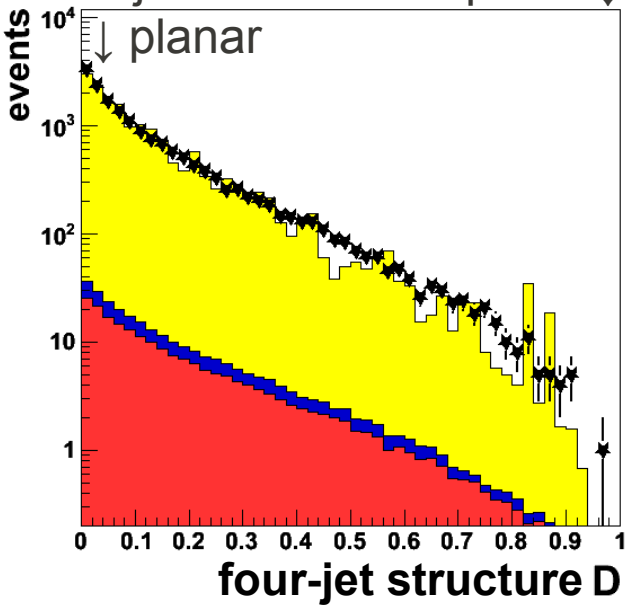




max. angular distance ↓



jets stick out of plane ↓



tt̄ fullhad MC@NLO

tt̄ other MC@NLO

QCD Pythia × 1.6

CMS Data 35 pb^{-1}

$$T_{ij} = \frac{\sum_{jets} p_i^{jet} p_j^{jet}}{\sum_{jets} \vec{p}^{\,2}}$$

with eigenvalues:

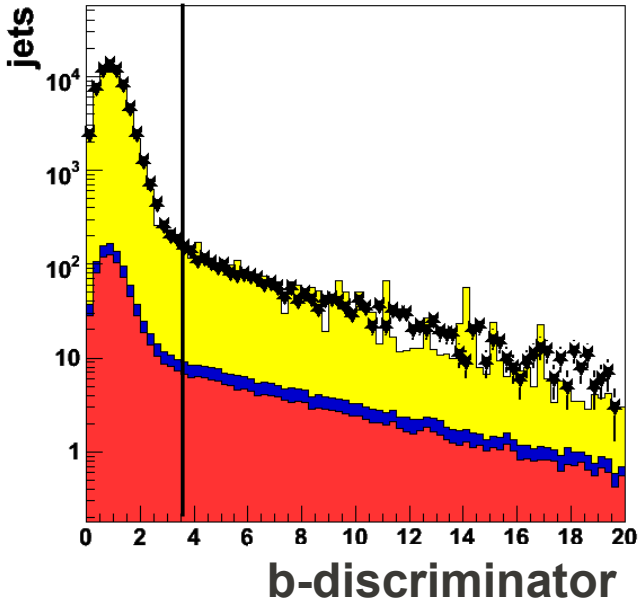
$$0 \leq q_1 \leq q_2 \leq q_3$$

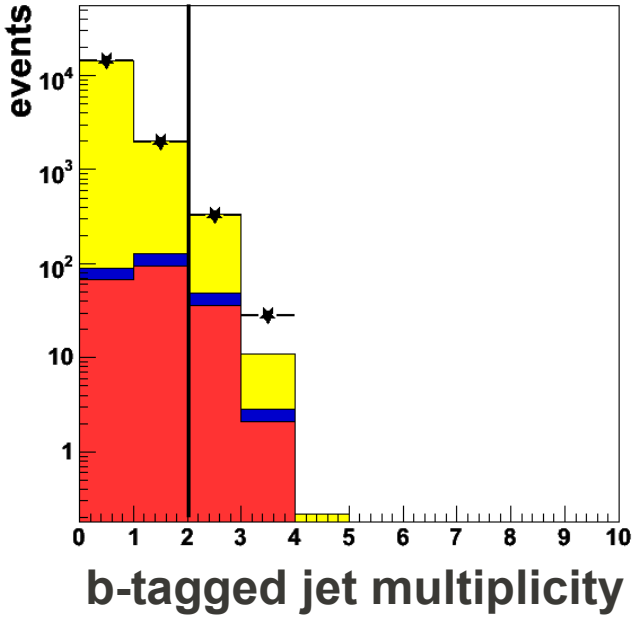
$$\text{aplanarity} = 1.5\, q_1$$
$$\text{sphericity} = 1.5\, (q_1 + q_2)$$
$$\text{C} = 3\,(q_1 q_2 + q_1 q_3 + q_2 q_3)$$
$$\text{D} = 27\,(q_1 q_2 q_3)$$

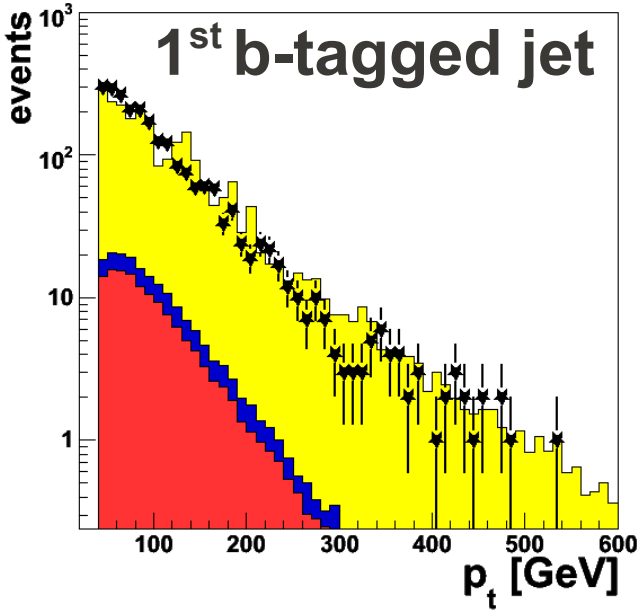
- **good agreement**
- **topology well described**

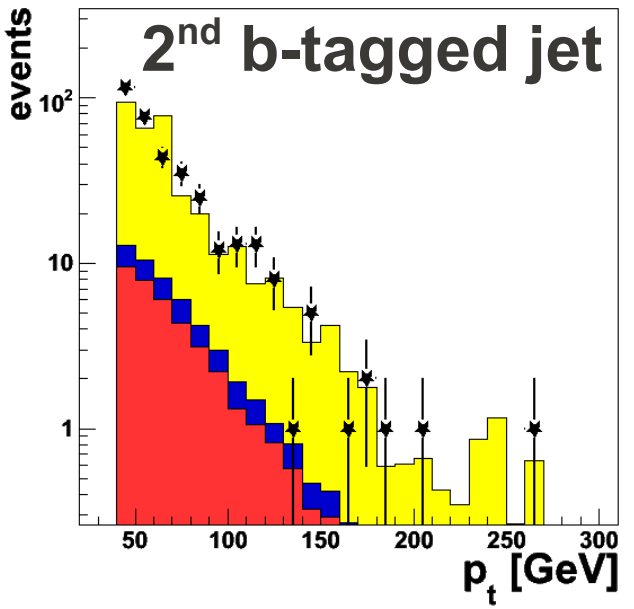
=> use MC for the estimation of QCD

B-Tag Selection





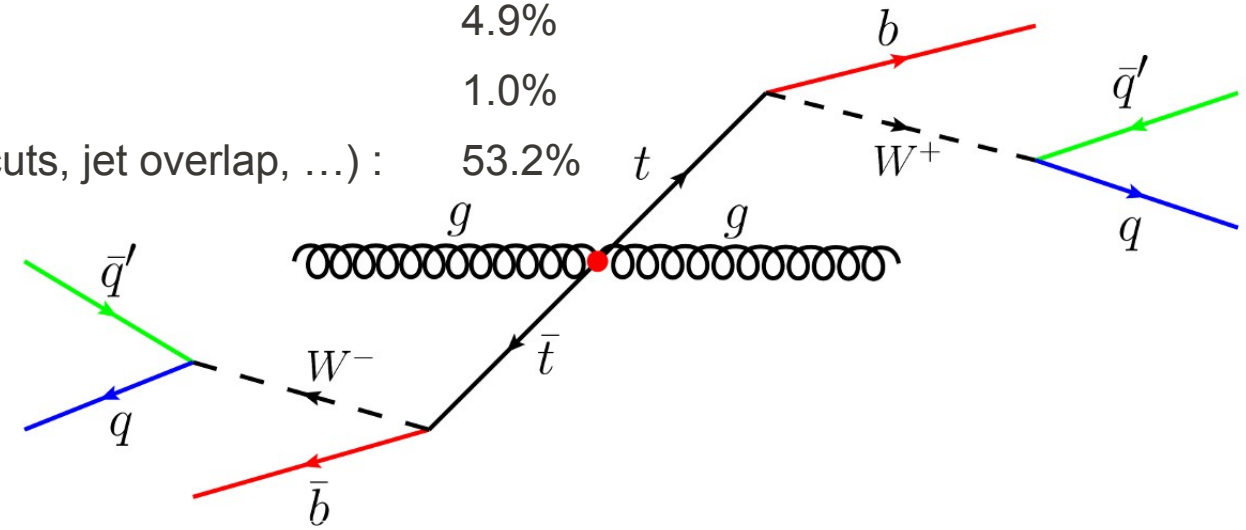




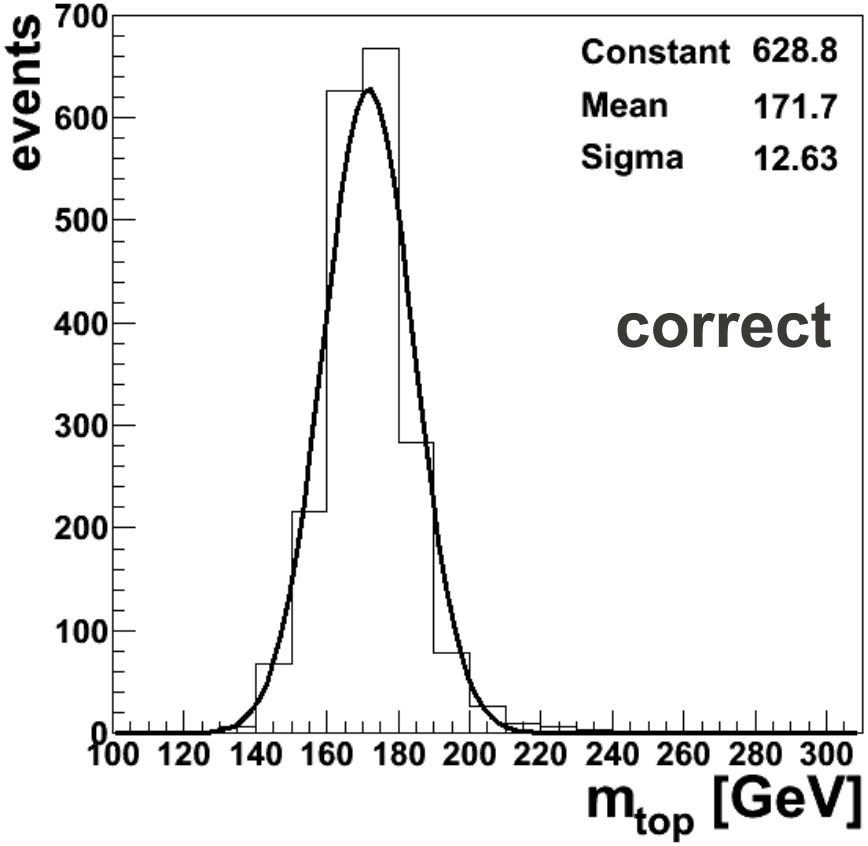
- b-jet multiplicity and b-jet discriminator are well described by MC
- b-jet spectrum softer in data than in MC
- S / B = 1 / 10 = 0.1

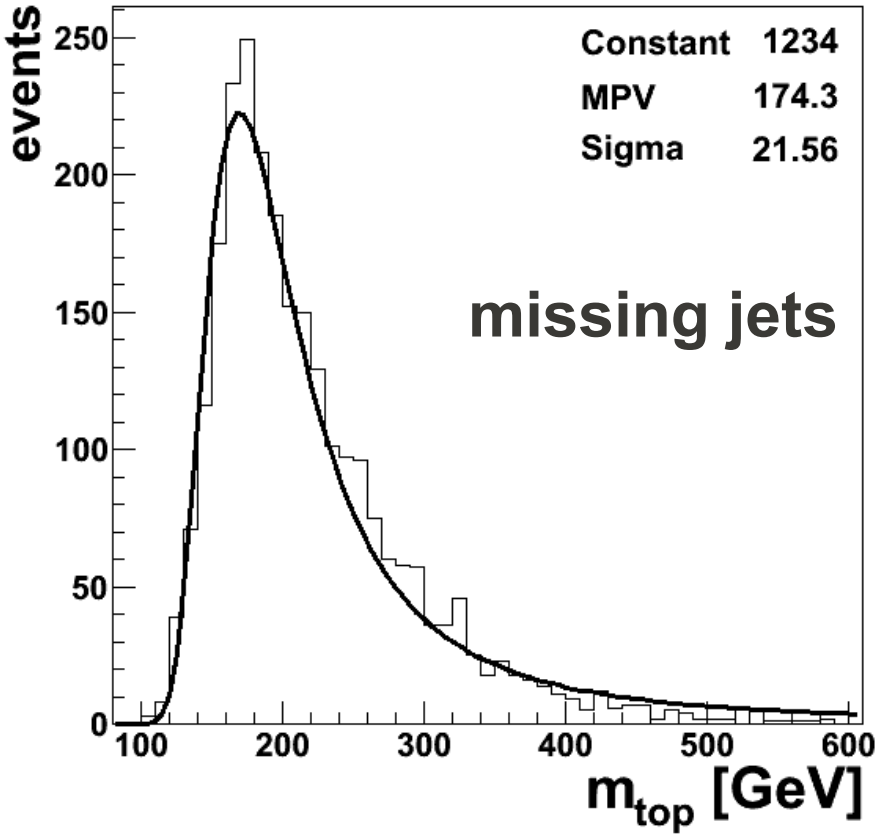
Kinematic Fit

- uses b-tagging information and all jets available
- least-squares fit with the following constraints:
  - m_W = 80.4 GeV for both W bosons
  - $m_t = m_{\bar{t}}$
- probability of fit > 0.15 (efficiency of 16% on signal)
- => jet-parton associations of lowest χ^2 in signal MC:
  - correct association: 40.9%
  - inner branch mixing: 4.9%
  - cross branch mixing: 1.0%
  - missing jets (acceptance cuts, jet overlap, …) : 53.2%



Kinematic Fit on Signal MC





- very good top mass reconstruction for the correct combination (generated top quark mass = 172.5 GeV)
- for missing jets peak at low masses (like correct combination), but large tales towards high masses

Cutflow for 35 pb^{-1}

selection step	fully hadronic	other $t\bar{t}$	QCD	S/B	Sum	data
multi-jet	201 ± 1	69 ± 1	16331 ± 381	1 / 100	16601 ± 381	16777 ± 130
b-tag tight	38 ± 0	14 ± 0	295 ± 46	1 / 10	347 ± 46	354 ± 19
$P(\chi^2) > 0.15$	6 ± 0	1 ± 0	2 ± 1	2.1	9 ± 1	12 ± 3

(only statistical error given, systematical errors still to be evaluated)

- Data and MC compatible within statistical errors
- Efficiency on top in fully hadronic channel: 0.3%

Summary and Outlook

- Summary
  - Multi-jet events are very well described by MC
  - S / B = 2, but more statistics needed for measurement
  - First indication of fully hadronic top pair decay seen
- Outlook
  - Data-driven background estimation
  - Measurement of cross section
  - Use of MVA techniques to improve selection
  - Differential measurements for BSM searches