Top Rediscovery in the Dimuon Channel

Dirk Dammann

Top Physics

Event Selection

BG Description

Kinematic Event Reconstruction

Summary

Preparation of top rediscovery and cross section measurement in early CMS data in the dimuon channel

Dirk Dammann

DESY

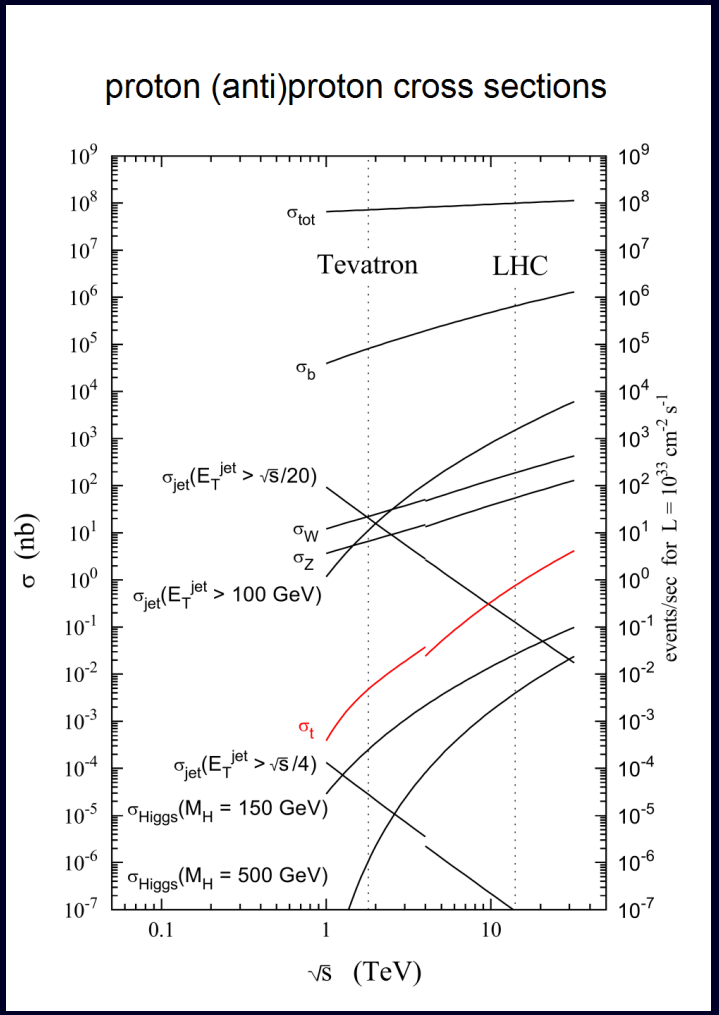
2009-02-25

Outline

1. Top Physics
2. Event Selection
3. BG Description
4. Kinematic Event Reconstruction
5. Summary

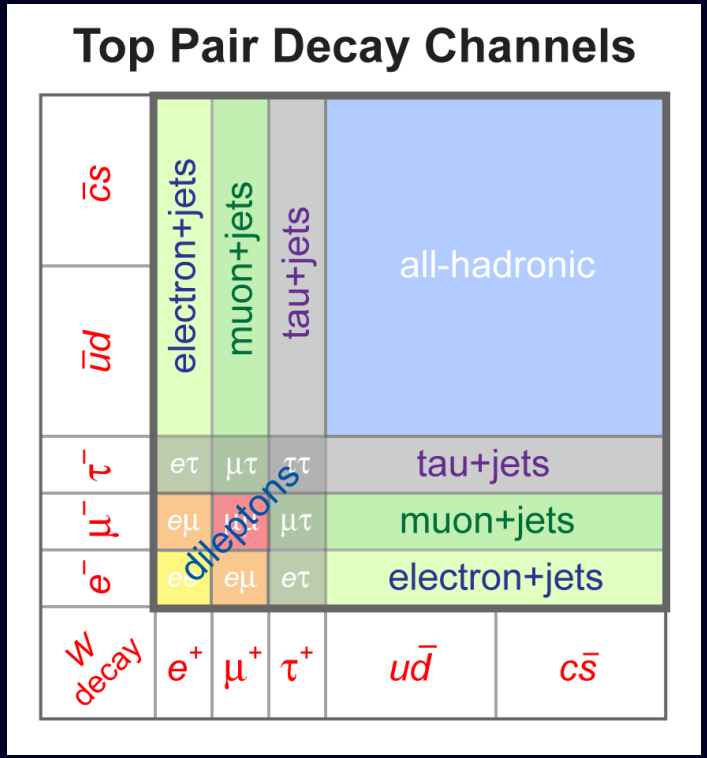
Top Physics
Motivation

- Until today the top has only been observed in O(10^3) events at Tevatron
- At the LHC the $t\bar{t}$-production cross section and luminosity will be much larger
  $\rightarrow$ about 1 $t\bar{t}$ evt/s
- precision measurements are important for understanding QCD
- mass measurements sets limits on higgs mass
- top is background for BSM processes



Top Physics
Decay Channels

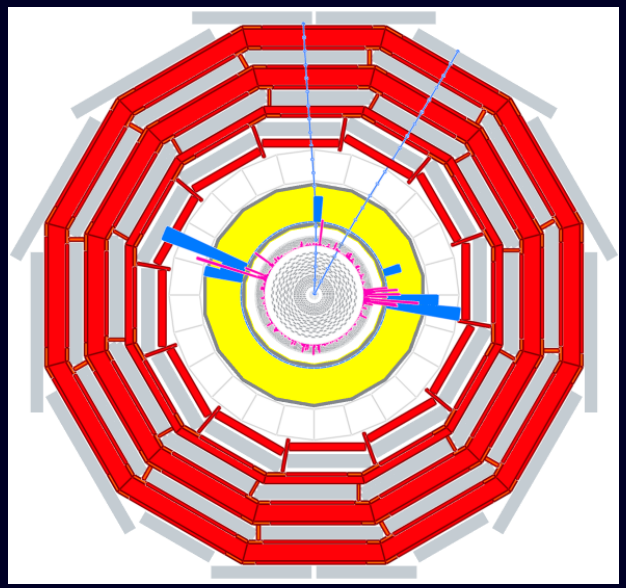
- top decays dominantly to b+W
- classifications of $t\bar{t}$-decays via W-decays:
  - fully hadronic
  - semi-leptonic
  - di-leptonic

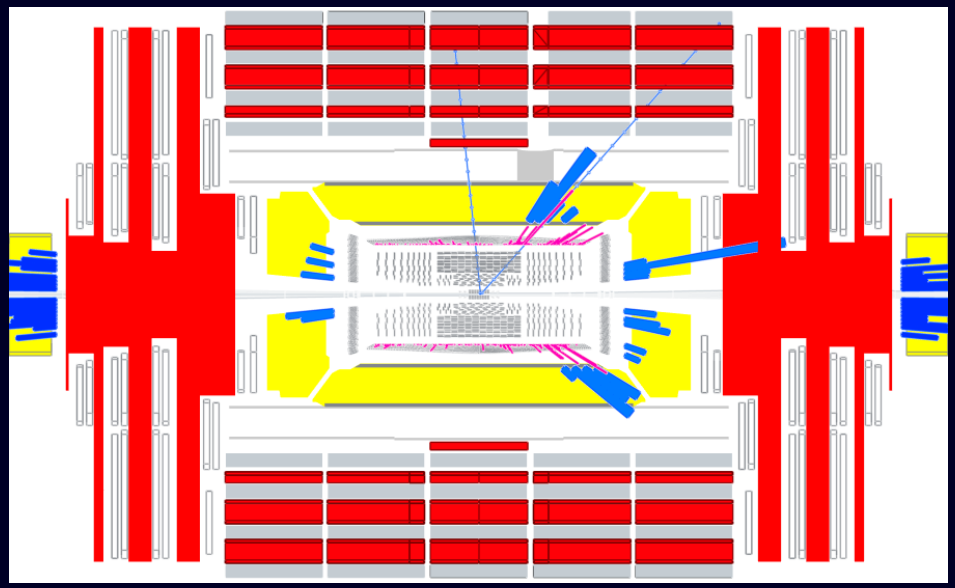


dimuon channel:

- clear event signature, good to trigger
- can be separated well from background
- low branching ration (about 1,2%)

Top Physics
Event Signature





- 2 muons
- 2 b-jets
- 2 neutrinos $\longrightarrow \not{E}_t$

Top Physics
Background Processes

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- Z / DY $\rightarrow 2\mu$
- dileptonic $t\bar{t}$-decays with W$\rightarrow \tau \rightarrow \mu$
- events with two heavy bosons: WW, WZ, ZZ
- further QCD-events have to be taken into account $\rightarrow$ large cross section

Event Selection
Kinematic Object Selection

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Summary

- current plots with $\sqrt{s}$ =14TeV
- have to be redone with Summer08 production ($\sqrt{s}$=10TeV)

Cuts

- 2 muons with p_t >20GeV and $|\eta|$ <2.1
- 2 jets with p_t >40GeV and $|\eta|$ <2.4
- no cut on $\not{E}_t$

Event Selection
Muon Isolation

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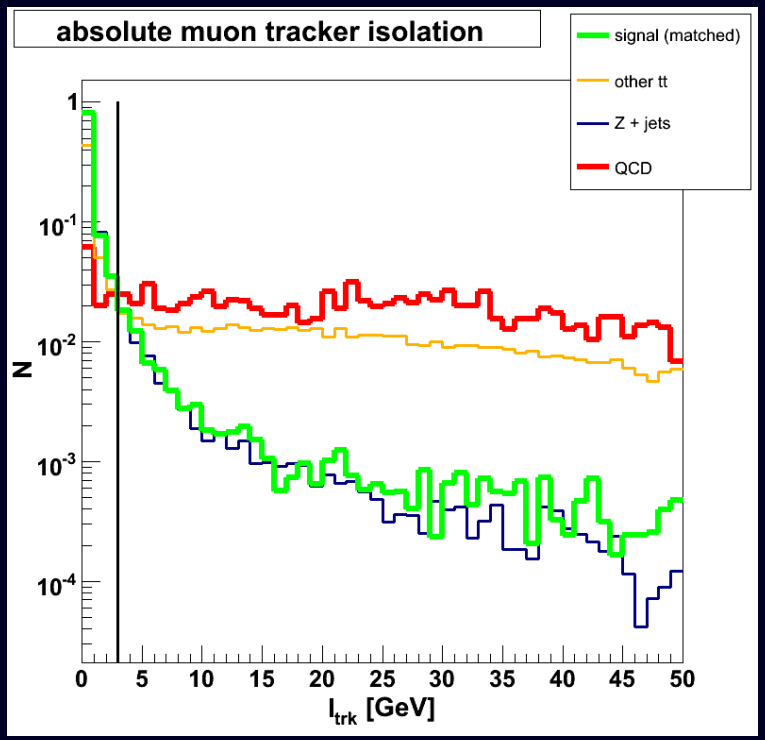
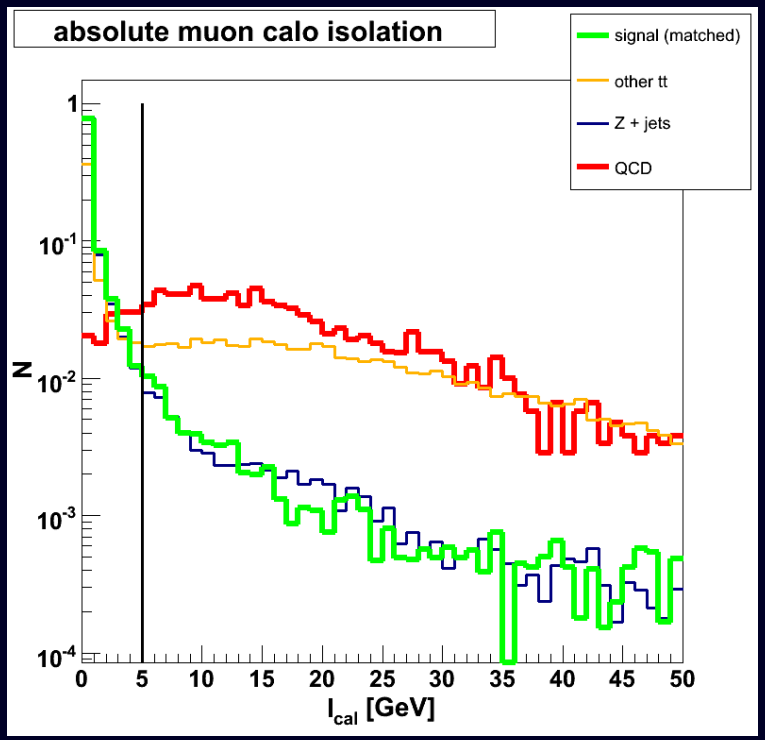
- Most muons from heavy particle decays are isolated, i. e. outside jets.
- Isolation can be used to get rid of QCD-background
- Isolation can be measured as well in the tracker as in the calo.
- Tracker Isolation: sum of all track's p_t in cone $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$ around μ-track: $I_{track} = \sum_{\Delta R} p_t$
- Calo Isolation: sum of E_t around μ: $I_{calo} = \sum_{\Delta R} E_t$
- ΔR =0.3 is used for this analysis
- Tried different ways to cut on isolation

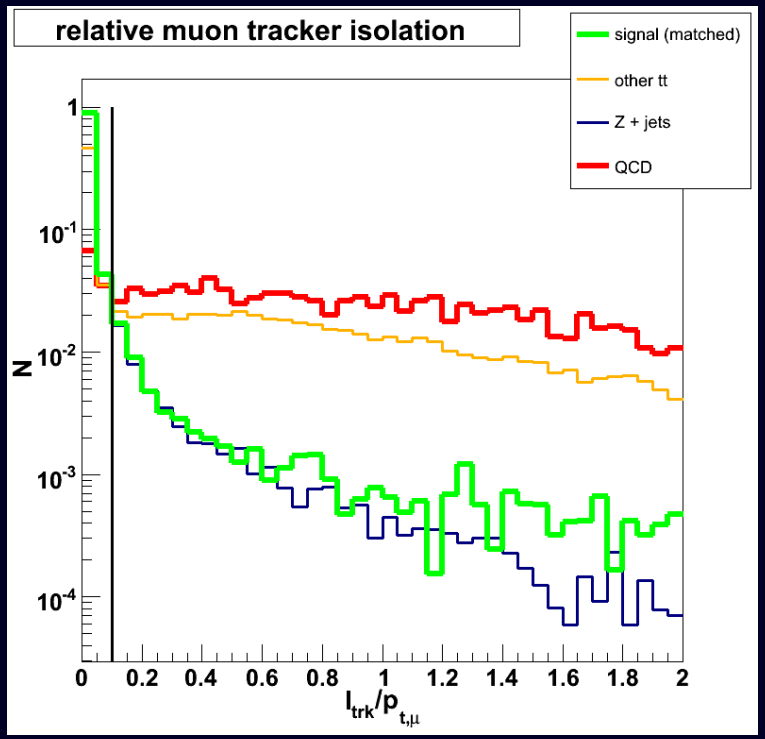
Event Selection
Absolute Muon Isolation

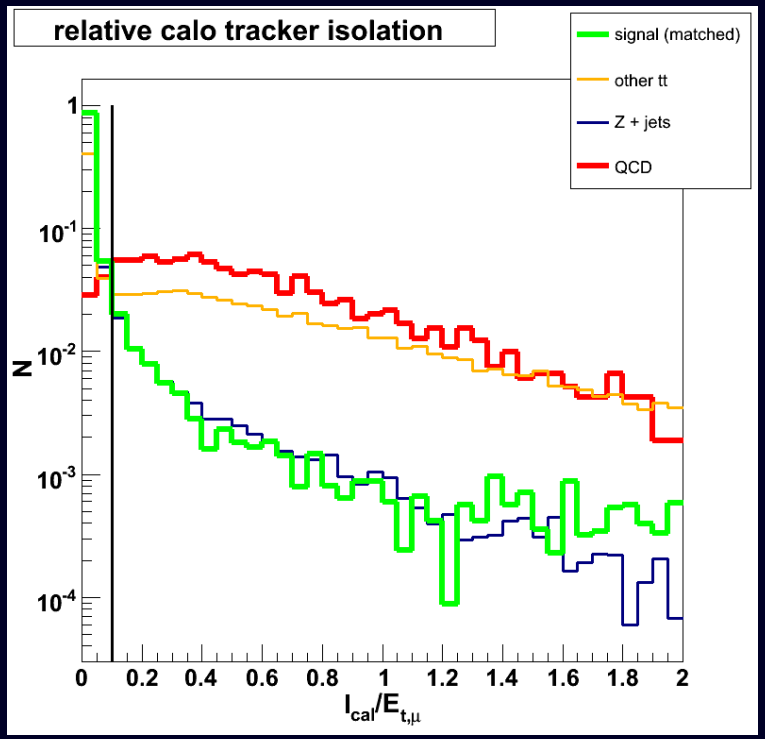




- absolute cuts, old standard in Top Analyses Framework: $I_{track} < 3\text{GeV}$ and $I_{calo} < 5\text{GeV}$)
- efficiency for signal muons: 87.6±0.6%
- efficiency for muons from QCD: 2.64±0.3%

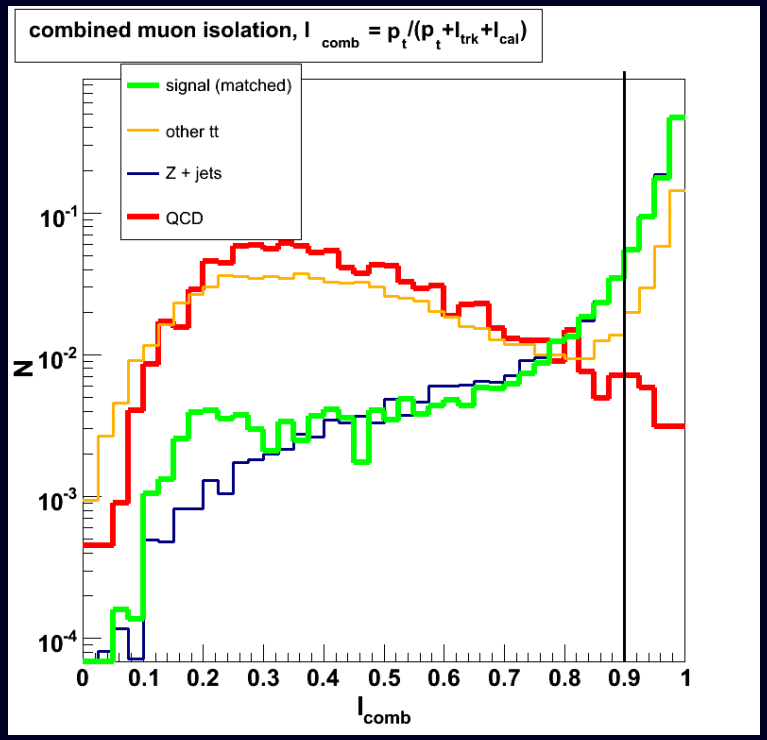
Event Selection
Relative Muon Isolation





- cuts on relative isolation $I_{track}/p_{t,\mu}$ >0.1 and $I_{calo}/E_{t,\mu} > 0.1$
- $\epsilon_{sig} = 89.2 \pm 0.6\%$
- $\epsilon_{QCD} = 2.19 \pm 0.03\%$
- clearly better than absolute cuts

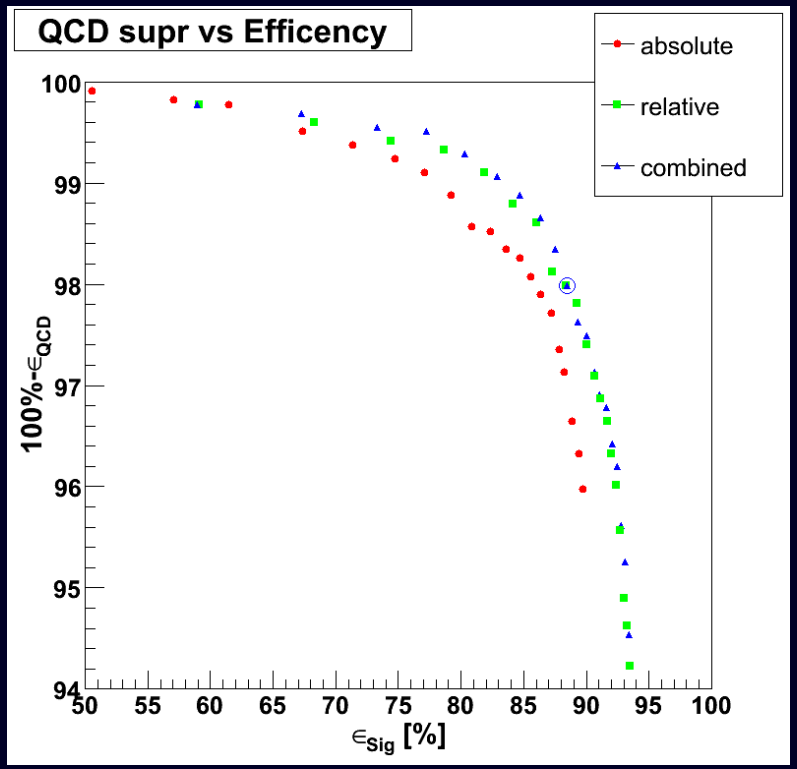
Event Selection
Combined Muon Isolation



- combined variable: $I_{comb} = \frac{p_{t,\mu}}{p_{t,\mu}+I_{track}+I_{calo}}$
- $\epsilon_{sig} = 88.5 \pm 0.6\%$
- $\epsilon_{QCD} = 2.01 \pm 0.03\%$
- as good as two separated relative cuts

Event Selection
Muon Isolation

QCD-suppression vs signal efficiency curves for diverse cut values:



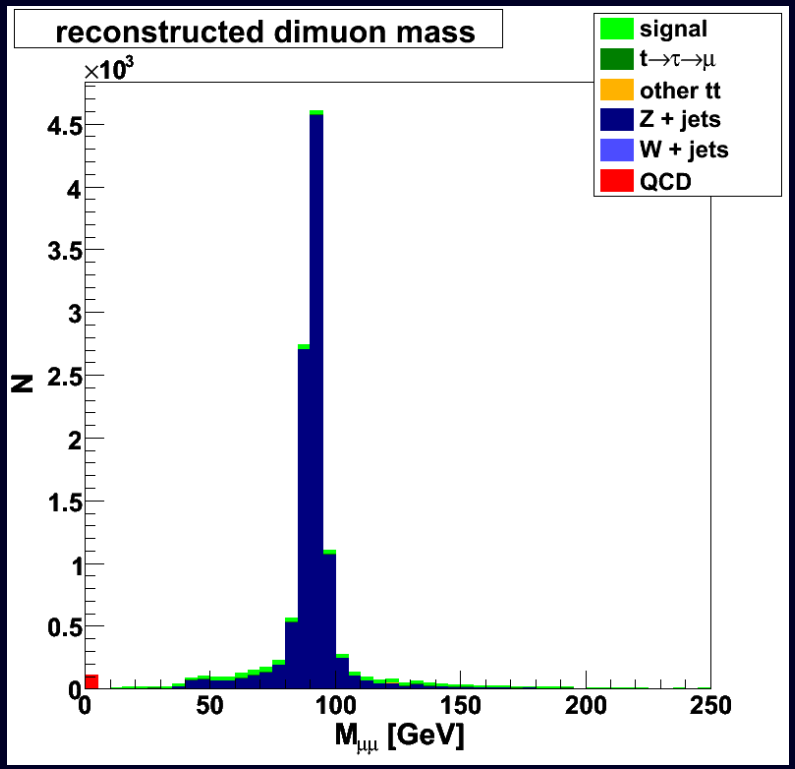
Results

- left plot shows that relative and combined isolation cuts have similar performance
- for my analysis cut on combined variable is used
- $I_{comb} > 0.9$

Event Selection

Z-mass Veto

- after isolation cuts Z is main background
- can be removed easy by rejecting events with 80GeV$< M_{\mu\mu} <$100GeV



BG Description
Wrong Charge Method

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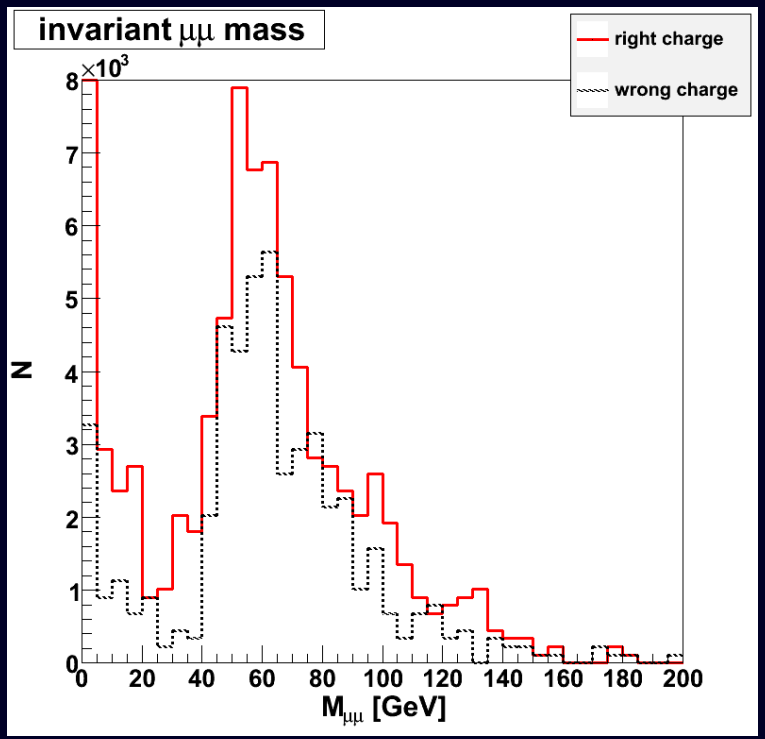
Summary

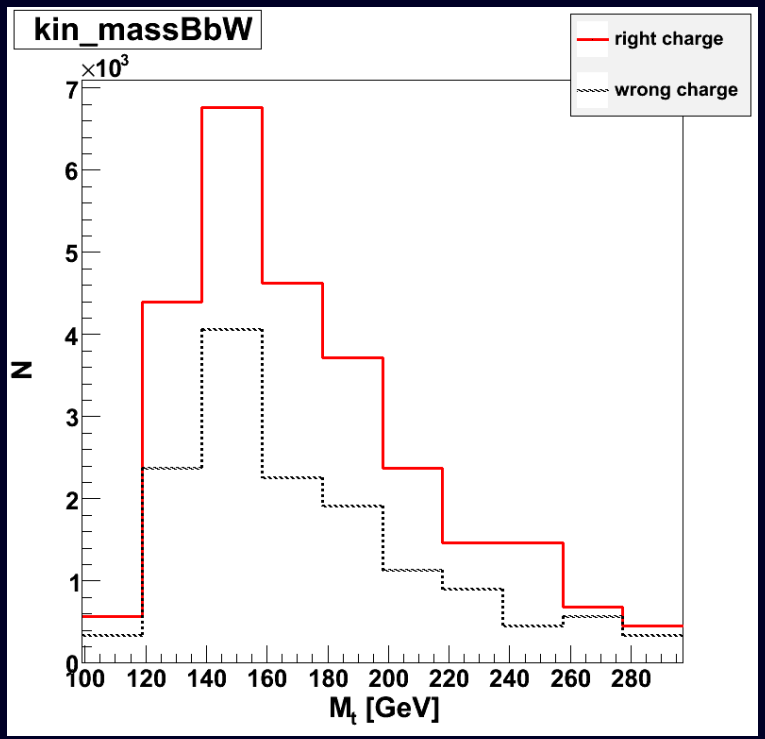
- Only two QCD-events pass selection cuts.
- But this events have an event weight of about 100!
- Background can be described with wrong charge method (data driven):
  - Signal events and main BGs like Z+jets, WW, ... produce oppositely charged muons
  - $\longrightarrow$ Also select events with two equally charged muons
  - From each plotted distribution with oppositely charged muons the same distribution for events with equally charged muons is subtracted
  - In most cases a normalization is required.

Event Selection
QCD Background Description

Example:

- For $M_{\mu\mu}$ >10GeV the shapes of the invariant $\mu\mu$-mass look alike for right and wrong charge muon pairs.
- For lower plots the isolation cuts have been loosened to have enough statistics.





Kinematic Event Reconstruction

System of kinematic equations

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BG Description

Kinematic Event Reconstruction

Summary

- missing information due to to unobserved neutrinos
- instead x- and y- component of their energy is measured as $\not{E}_t$
- using W-mass eliminates two further unknown variables

Kinematic Event Reconstruction

System of kinematic equations

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- missing information due to to unobserved neutrinos
- instead x- and y- component of their energy is measured as $\not{E}_t$
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2 linear and 6 nonlinear equations:

$$\not{E}_{t,x} = p_{\nu,x} + p_{\bar{\nu},x} \qquad E_\nu^2 = p_{\nu,x}^2 + p_{\nu,y}^2 + p_{\nu,z}^2$$
$$\not{E}_{t,y} = p_{\nu,y} + p_{\bar{\nu},y} \qquad E_{\bar{\nu}}^2 = p_{\bar{\nu},x}^2 + p_{\bar{\nu},y}^2 + p_{\bar{\nu},z}^2$$

$$m_{W^+} = (E_{l^+} + E_\nu)^2 - (p_{l^+,x} + p_{\nu,x})^2 - (p_{l^+,y} + p_{\nu,y})^2 - (p_{l^+,z} + p_{\nu,z})^2$$
$$m_{W^-} = (E_{l^-} + E_{\bar{\nu}})^2 - (p_{l^-,x} + p_{\bar{\nu},x})^2 - (p_{l^-,y} + p_{\bar{\nu},y})^2 - (p_{l^-,z} + p_{\bar{\nu},z})^2$$

$$m_t = (E_{l^+} + E_\nu + E_b)^2 - (p_{l^+,x} + p_{\nu,x} + p_{b,x})^2 - (p_{l^+,y} + p_{\nu,y} + p_{b,y})^2 - (p_{l^+,z} + p_{\nu,z} + p_{b,z})^2$$

$$m_{\bar{t}} = (E_{l^-} + E_{\bar{\nu}} + E_{\bar{b}})^2 - (p_{l^-,x} + p_{\bar{\nu},x} + p_{\bar{b},x})^2 - (p_{l^-,y} + p_{\bar{\nu},y} + p_{\bar{b},y})^2 - (p_{l^-,z} + p_{\bar{\nu},z} + p_{\bar{b},z})^2$$

Kinematic Event Reconstruction

Solution of kinematic equations (1)

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Kinematic Event Reconstruction

Summary

- system of equations can be transformed into a single equation (with simplifying assumptions)
- 4th order polynomial in one neutrino momentum component, e. g. $p_{\nu,x}$
- coefficients h_i are functions of m_t and $m_{\bar{t}}$

$$p_{\nu,x}^4 + h_3 p_{\nu,x}^3 + h_2 p_{\nu,x}^2 + h_1 p_{\nu,x} + h_0 = 0$$

- equation can be solved analytically for constant h_i
- fourfold ambiguity

Kinematic Event Reconstruction

Solution of kinematic equations (2)

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Summary

2 methods:

1. assume $m_t = m_{\bar{t}}$ and vary top mass parameter in 1GeV-steps between 100GeV and 300GeV
2. take measured top mass from Tevatron for m_t and $m_{\bar{t}}$ and look if there are solutions for that mass

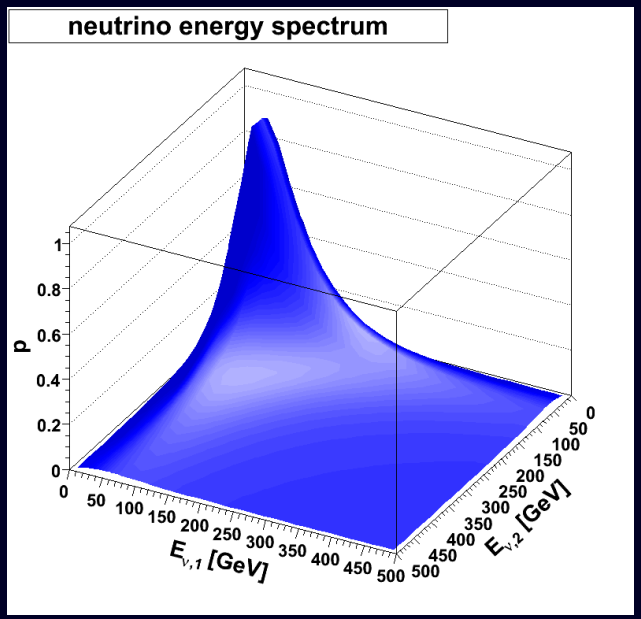
Kinematic Event Reconstruction

Solution of kinematic equations (2)

2 methods:

1. assume $m_t = m_{\bar{t}}$ and vary top mass parameter in 1GeV-steps between 100GeV and 300GeV
2. take measured top mass from Tevatron for m_t and $m_{\bar{t}}$ and look if there are solutions for that mass

- In both cases calculated E_ν and $E_{\bar{\nu}}$ are compared to normalized model spectrum from MC
- Probability value from spectrum is taken as weight for each solution



Kinematic Event Reconstruction

Use and Implementation

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Summary

- first method gives a approximation of the top mass distribution
- this method was already implemented in TQAF as TtDilepEventSolution

- second method with fixed mass can be used to reduce BG by kinematic constraints
- valuable for spin correlation studies (Benedikt Hegner used it)
- not yet implemented

- during the next weeks different event building algorithms for dileptonic $t\bar{t}$-events are to be implemented in analogy to the semileptonic $t\bar{t}$-event hypotheses implemented by Sebastian

Summary
Conclusion

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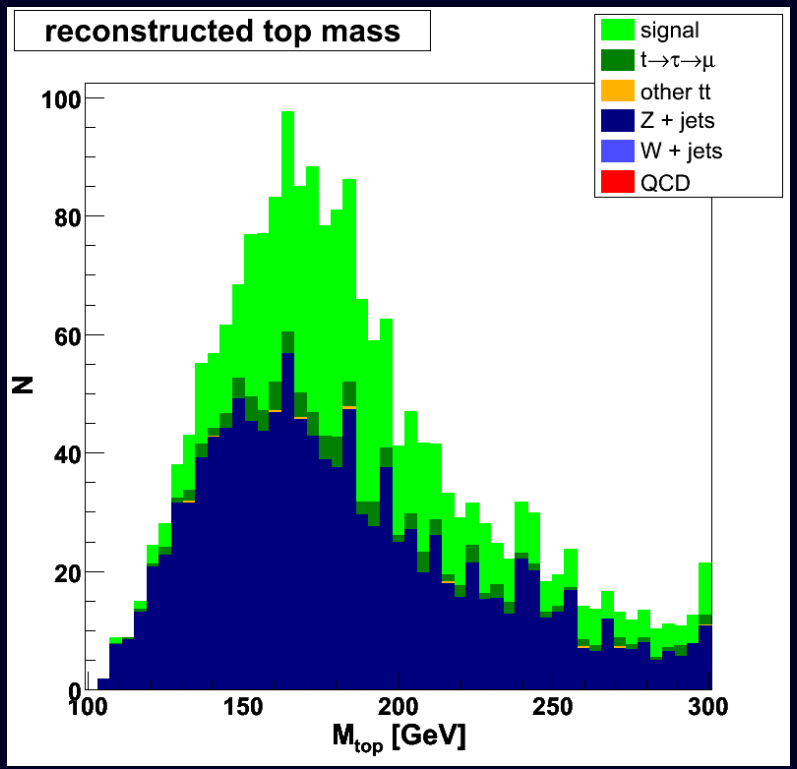
Summary

- good S/BG-ratio with simple cuts
- different methods to solve the kinematic equations will go into next TQAF release



Summary
Outlook

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Summary

- test how solving the kinematic equations can help to further reduce BG
- redo all plots with $\sqrt{s}$ =10TeV-samples
- b-tagging an cut on $\not{E}_t$ have not been applied
  $\rightarrow$have to wait for real data

Backup Slides

Addition To Wrong Charge