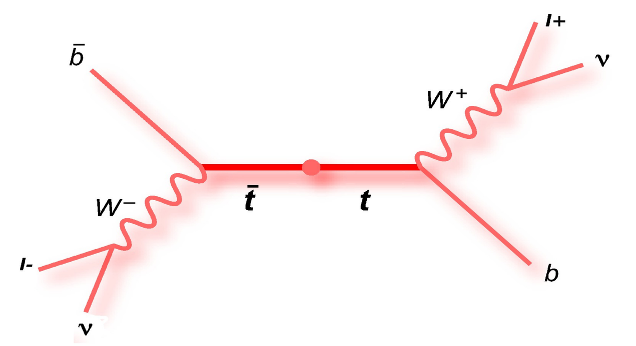
Probing the heavy flavour content of ttbar events in proton-proton collisions at CMS

Antonio Tropiano, Università degli Studi di Firenze e INFN Firenze,
on behalf of the CMS collaboration

In the framework of the standard model (SM), the top quark is expected to decay to a W-boson and a b-quark 99.8% of the times due to the Cabibbo-Kobayashi-Maskawa (CKM) matrix element Vtb being close to unity. The current experimental limits from the Tevatron on Vtb from top-quark pairs and single-top production are consistent with the SM predictions. The higher energy of proton-proton collisions and larger top quark production cross section at the Large Hadron Collider (LHC) may provide an improved reach in the measurement of Vtb. We present analysis strategies dedicated to measure ratios of branching ratios of the top quark using ttbar events collected with the CMS detector, in which either one or both W-bosons from the top-quark decays lead to a lepton and a neutrino. These di-leptonic and semi-leptonic final states provide high cross section with small background. The sensitivity of the measurement is evaluated after particle identification and detector reconstruction. Data-driven techniques to control the backgrounds are discussed and the expected simulation results are presented for the first physics run of the LHC, at √s=10 TeV. We also discuss how the method can be used to measure directly from data the efficiency of the algorithms used to discriminate jets coming from the hadronization of b quarks from the lighter quarks and gluons (b-tagging).

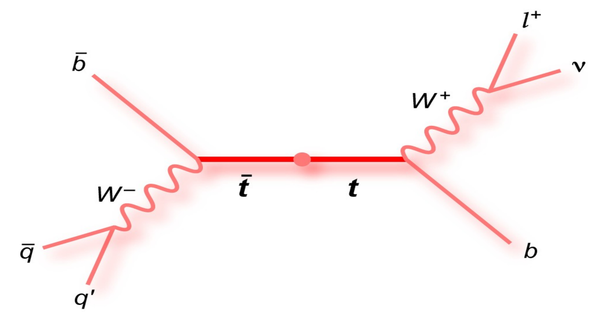
Dilepton channel. Event selection



- Trigger: -single muon Pt>9 GeV/c
  -single electron Et>15 GeV/c
- Exactly 2 leptons with: -Pt>20 GeV/c
  -|η|<2.4
  -d_0<400 μm
  -ΔR(leptons)>0.1
- At least 4 SISCone jets with: -Et>30 GeV
  -|η|<2.4
  -ΔR(lep,jets)>0.3
  -EM fraction<0.98
- Missing Et>30GeV
- Opposite sign leptons

Selected signal events for 250 pb^{-1}: 787
Selected background events for 250 pb^{-1}: 80

Lepton + jets channel. Event selection



- Trigger: -single muon Pt>15 GeV/c
  -single electron Pt>18 GeV/c
- Single lepton with: -Pt>30 GeV/c
  -Isolation<0.1
- At least 4 Iterative Cone (R=0.5) jets with: -Et>40 GeV
  -|η|<2.4
  -ΔR(lep,jets)>0.5
  -EM fraction<1
- Centrality>0.35

Compute invariant mass m_{ij} of every pair of jets among the most energetic 4.
Choose the nearest to the W mass and apply:
- $|m_{ij}-m_W|<\sigma(m_W)$

Associate the 2 remaining jets k,p to each of the top quark, to minimize:

$$\chi^2=\left(\frac{m_{ijk}-m_{tHad}}{\sigma(m_{tHad})}\right)^2+\left(\frac{m_{l\nu p}-m_{tLep}}{\sigma(m_{tLep})}\right)^2$$

- χ^2_{min}<4

Selected signal events for 1 fb^{-1}: 2650
Selected background events for 1 fb^{-1}: 530

Determination of the b jets multiplicity

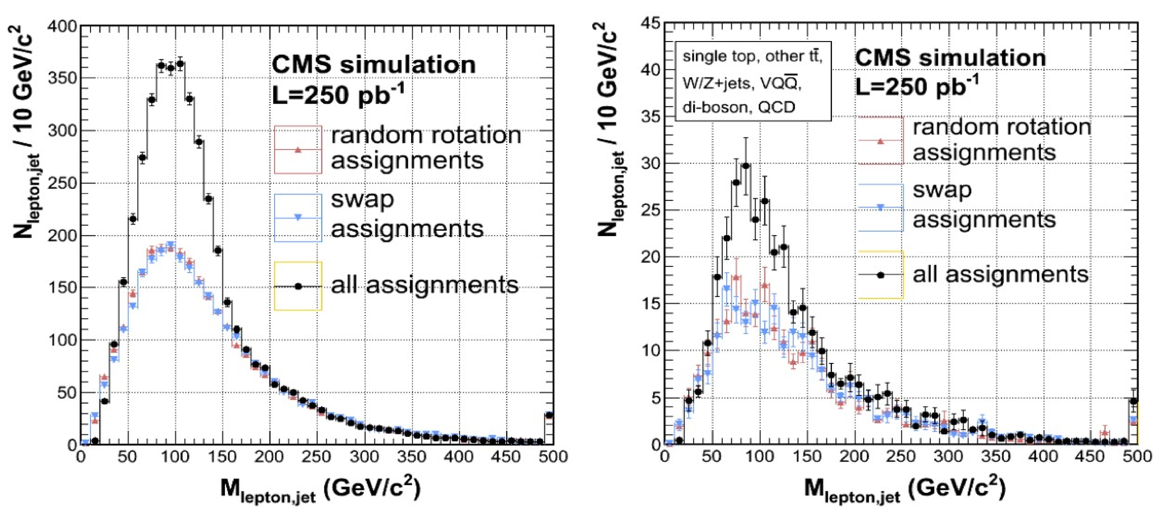
This is a function of the b tagging efficiency B, the mistagging probability M and R=B(t→Wb)/B(t→Wq). The probability to observe k b-tagged jets can be written as:

$$P_k=R^2\,P_k(tt\to bWbW)+2R(1-R)P_k(tt\to bWqW)+(1-R)^2P_k(tt\to qWqW)$$

Background estimation and subtraction for the dilepton channel

Selected events can be divided into 3 categories:
- No jet selected from the top decays
- Only one jet selected from the top decays
- Both jets selected from the top decays

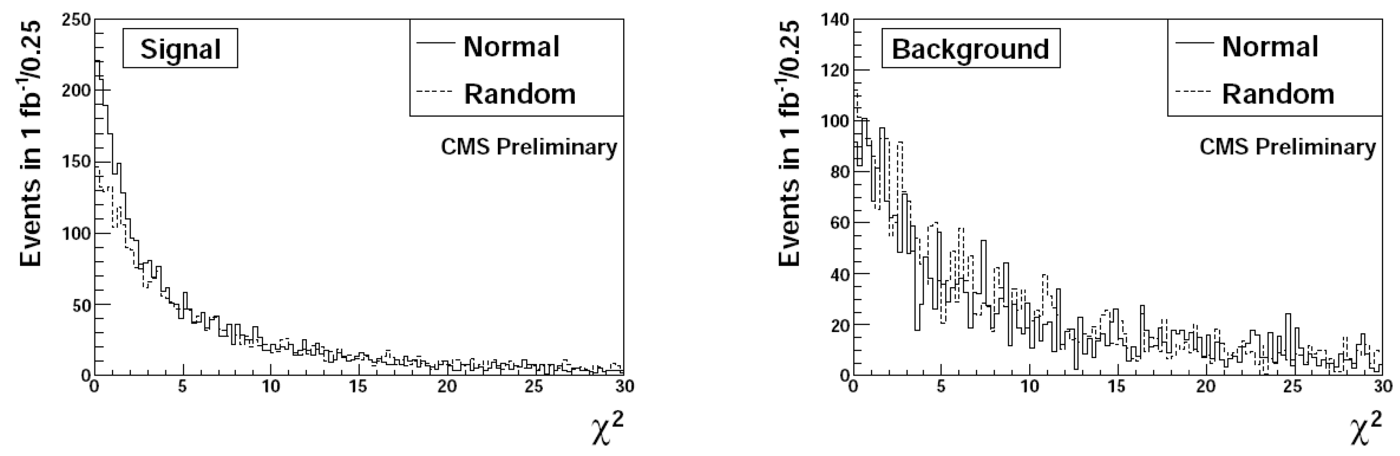
To estimate these jet misassignment fractions directly from data one can:
- "Swap" the jet in the lepton-jet pair with one from a different event
- "Randomly" rotate the momentum vector of the selected leptons



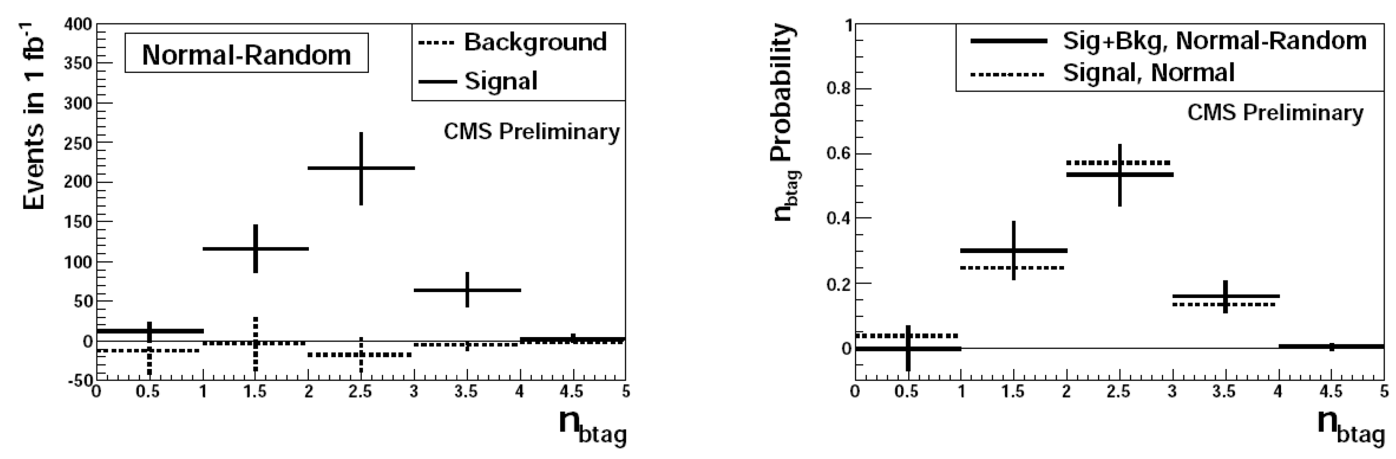
Left: invariant mass distribution for all selected events
Right: invariant mass distribution for background events only
The left "swapped" and "randomly rotated" distributions are normalized to fit the high end part of the spectrum. The normalization factor is related to the jet misassignment fractions.

Background estimation and subtraction for the lepton + jets channel

Signal events have a low χ^2_{min} if they are correctly reconstructed.
Background events have a peak at low values only due to random combinatorics.
Changing the direction of one of the 2 jets changes the signal χ^2_{min} distribution but not the background one.

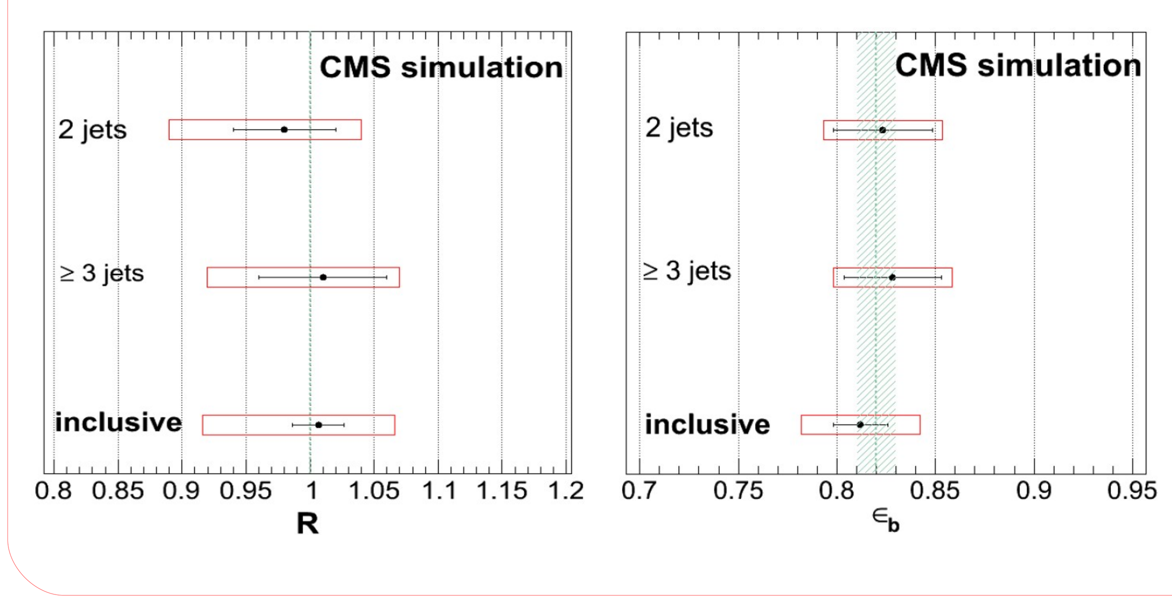


One can create 2 distributions of the number of b-tagged jets, one applying the cut on the normal χ^2, one applying the same cut on the random χ^2. Then the difference bin by bin of the 2 distributions is proportional to the signal only.



b-tagging efficiency and R measurement

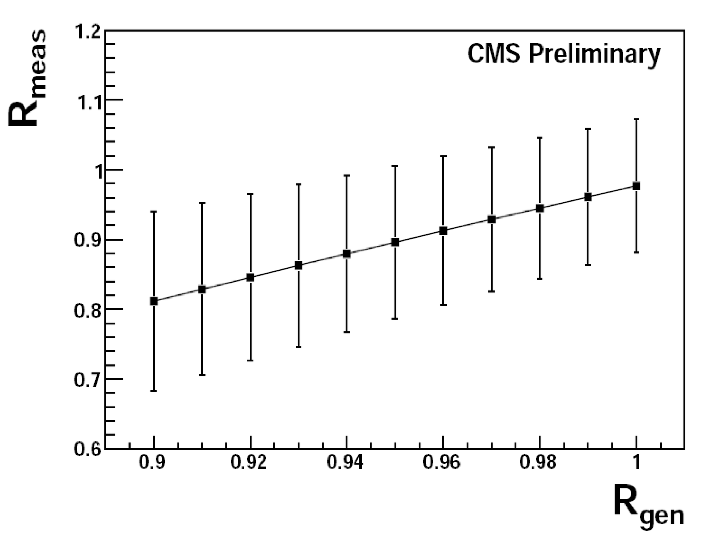
To measure the b-tagging efficiency R=1 is fixed and the fit is performed (inclusive and exclusive jet multiplicity).
To measure R the b-tagging efficiency is taken as input and the fit is performed.



The main sources of systematic error:
b-tagging efficiency(0.09)
background model
+ jet energy scale (0.03)
Expected total uncertainty on R is:
σ(stat)=0.02, σ(sys)=0.09

Measurement of R

R is measured comparing the number of b-tagged jets observed in the 0,1,2,3,4 jet bins. This is related to M, B and R. Since M, B and R are correlated only 2 of them can be fit simultaneously. B is determined in an indipendent QCD sample and M and R are fitted.



The main sources of systematic error are:
b-tagging efficiency (0.04)
b-tagging efficiency bias (0.04)
jet energy scale (0.09)
χ^2 cut (0.02)
Expected total uncertainty on R is:
σ(stat)=0.12, σ(sys)=0.11

References
CMS PAS TOP-09-001 *Probing the heavy flavour content of ttbar dilepton channel in proton proton collisions at √s =10 TeV*
CMS PAS TOP-09-007 *Plan for a B(t→Wb)/B(t→Wq) measurement in ttbar semi-leptonic decays at √s =10 TeV*