Resolution and background studies for MSSM H → $b\bar{b}$

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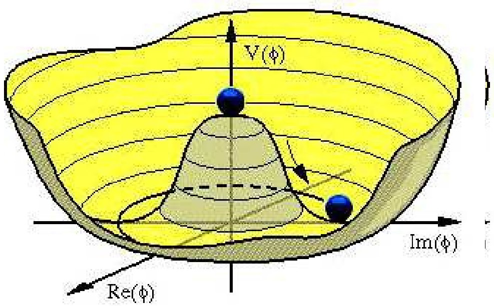
Outline

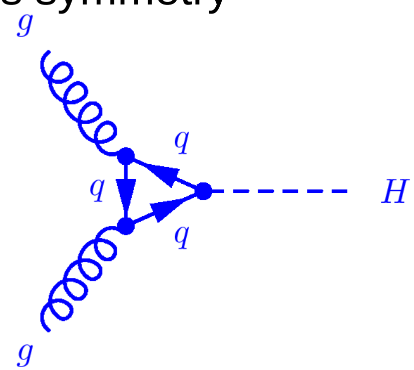
1. Introduction
2. Signal shape study
3. B-tagging study
4. $t\bar{t}$-background study
5. Summary

Introduction: what is Higgs?

- Standard model is a very successful theory, but particles are massless.
- Need mechanism of electroweak symmetry breaking to be complete.
- Most popular mechanism – proposed by Peter Higgs.



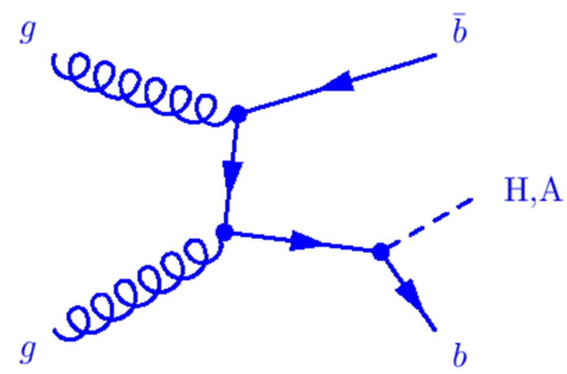
  - Need special potential ⇒ spontaneous symmetry breaking
  - Non-zero vacuum expectation value for breaking symmetry
  - Generates scalar field at physical state

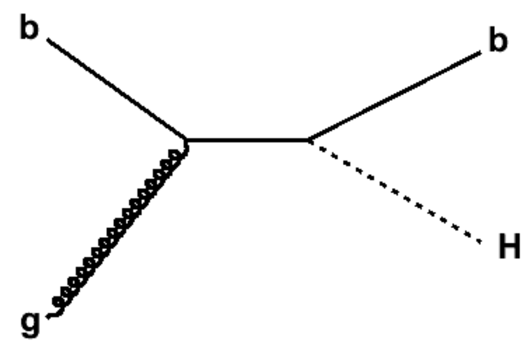


- Dominant production process in hadron collisions at LHC gg→H
- H→$b\bar{b}$ is the dominant decay channel in SM at low masses, but hard to trigger against QCD background
- Higgs was not yet seen at LEP and Tevatron, and now search in progress at LHC.

MSSM $H \rightarrow b\bar{b}$

- Higgs sector is enlarged in supersymmetry extension of SM – Minimal Supersymmetric Standard Model(MSSM):
  - 2 Higgs doublets.
  - 5 Higgs bosons: 3 neutral(h, H, A) and 2 charged $H^{\pm}$.
- Coupling of certain Higgs states to b quarks enhanced by tan β
  - → processes like gg ->Hb$\bar{b}$ become important
  - → easier to trigger wrt. QCD background
  - → associated production with b-quark will be enhanced.
- Popular assumptions e.g. tan β ~20
  - → cross section enhanced by factor $\tan^2\beta$ compared to standard Higgs.
  - → study of channel b($\bar{b}$)H, with H->b$\bar{b}$ may be feasible
- At Tevatron, both CDF+D0 observe ~2σ excess of background estimation at this channel
  - → Need to check this anomaly at the LHC

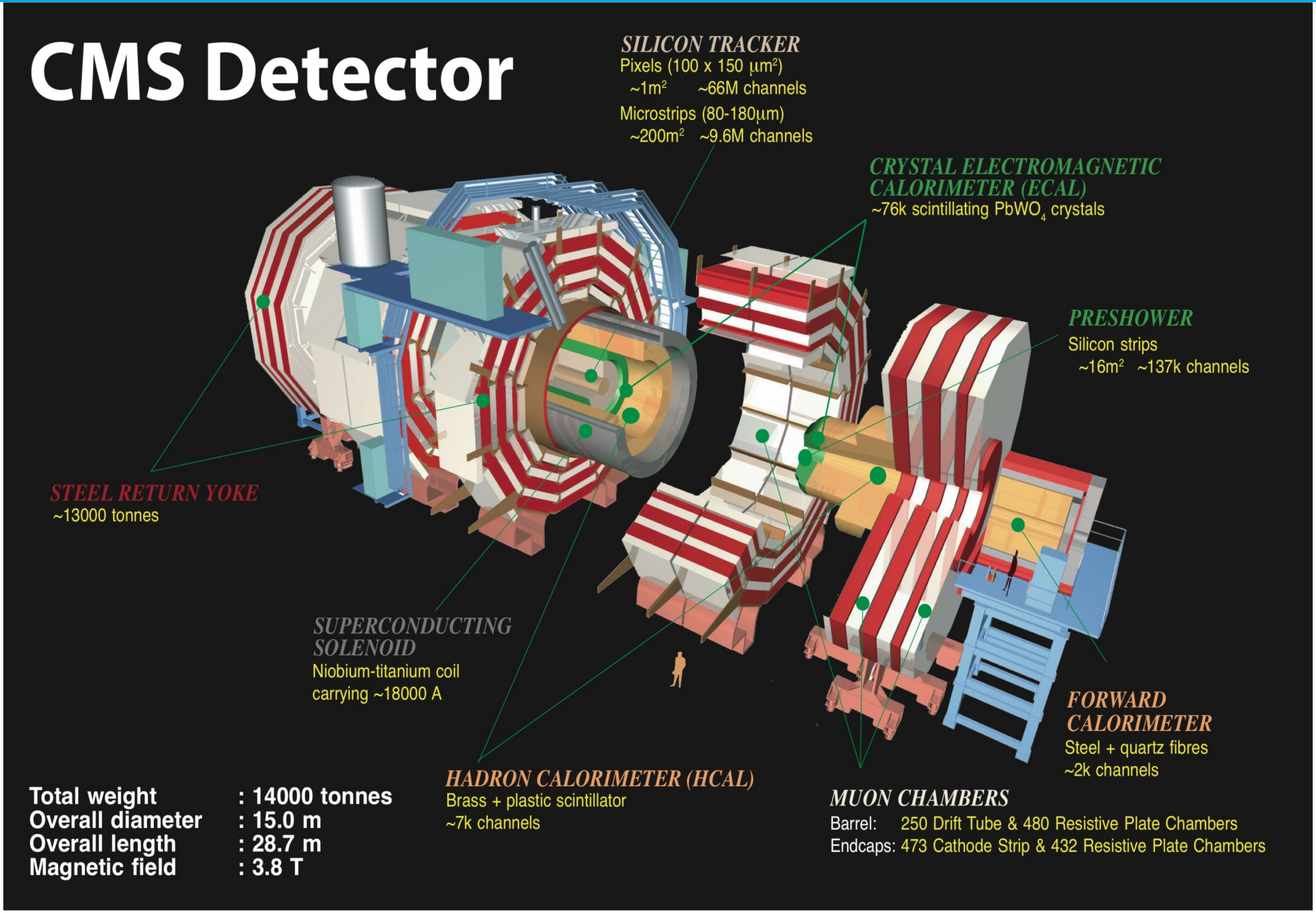




Important analysis aspects

- Experimental signature:
  - 3 b-jets at final state, transverse momentum of 4th jet is low
- Signal shape:
  - Mass resolution.
  - Combinatorial background → see part 2.
- Important background to consider:
  - QCD multijet production(full study is outside of scope of this work):
    - 3 b-jets at final state.
    - 2 true b-jets, and one light flavor jet →need good b-tagging, see part 3.
  - $t\bar{t}$ background → see part 4.

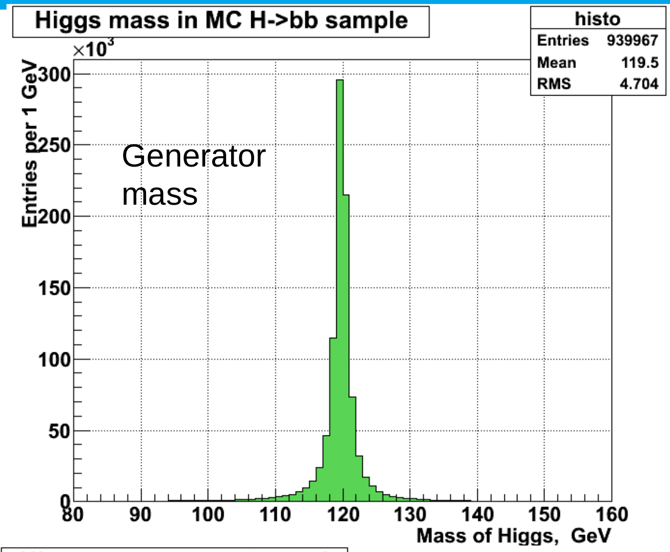
CMS detector



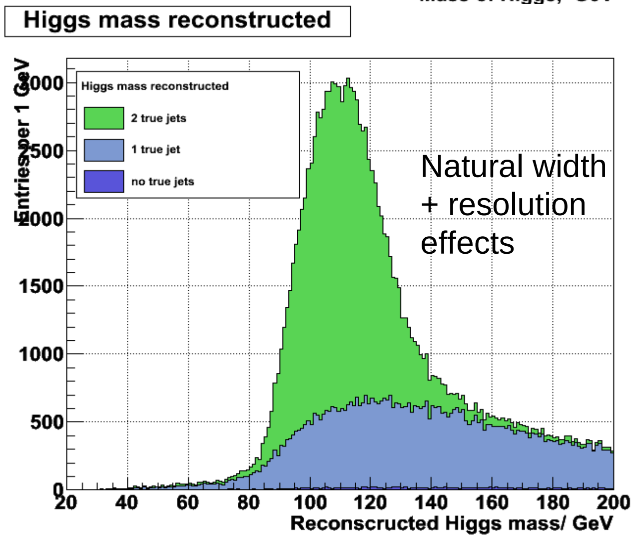
Signal shape: Higgs candidate reconstruction method

- Study signal shape using MSSM Higgs Monte Carlo sample with Higgs mass m_H=120 GeV. →

- Event selection: at least 3 jets with:
  1. $|\eta|<2.5$ – acceptance for b-tag(see part 3)
  2. 1^{st} jet P_T > 46 GeV.
  3. 2^{nd} jet P_T>38 GeV
  4. 3^{rd} jet P_T>15 GeV



- Study invariant mass computed from the first two leading jets
  → Reconstructed mass spectrum shows peak over a wide background shape:
  – isolate different components using Monte Carlo truth information
    → shows that wide component contributes to combinatorial background



Mass resolution

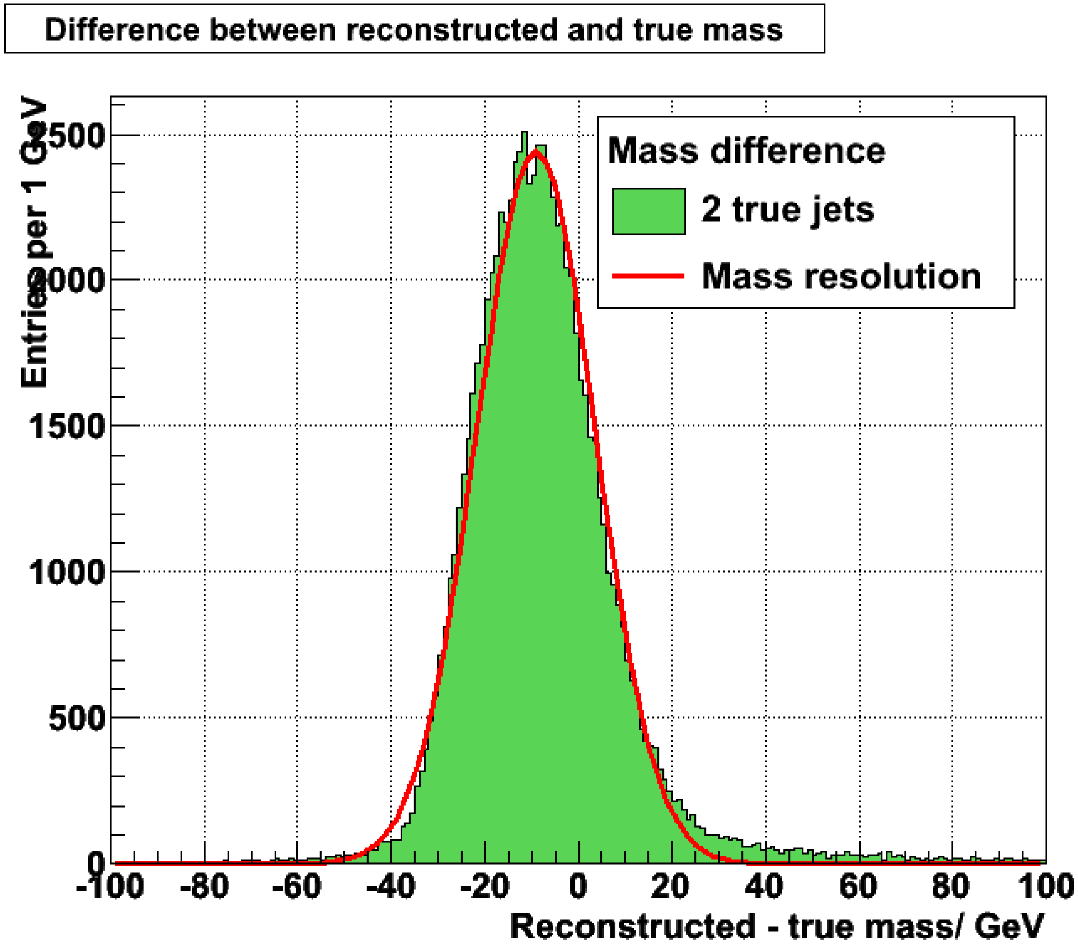
- To study mass resolution plot difference between reconstructed and true mass from MC generator

- From fit we observe the resolution:

$$\frac{\sigma_M}{M_H} = \frac{13\,GeV}{111\,GeV} \approx 11\%$$

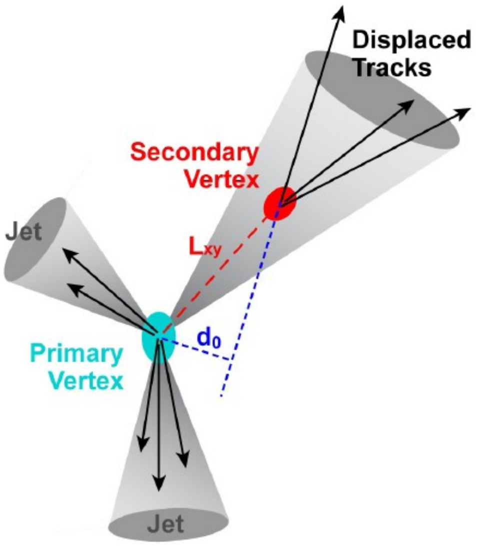
→ Mass resolution on a scale expected from jet energy resolution
→ also observe slight bias of peak position of -9 GeV

- in semileptonic B decays, energy of neutrino escapes from detection (see back-up slides)
- Need to apply specific b-jet energy corrections



B-tagging: track counting method

For selecting b-jets we need “b-tagging” method.
• B-hadron have large lifetime → search for tracks with high impact parameters within jets.



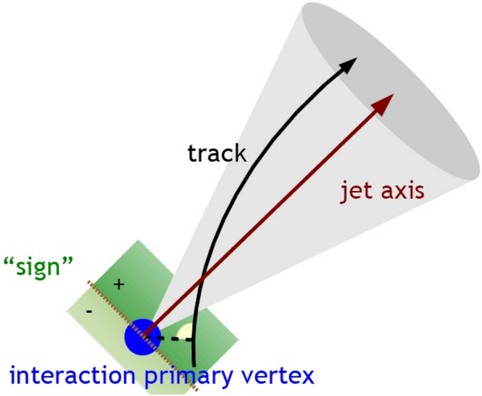
d_{3D} – 3D impact parameter of tracks in jet,
σ_{3D} – uncertainty of impact parameter.

Determine TCHE (**T**rack **C**ounting **H**igh **E**fficiency) criteria as 3D impact parameter significance:

$$TCHE = \frac{d_{3D}}{\sigma_{3D}}$$ - for 2nd track

Determine TCHP (**T**rack **C**ounting **H**igh **P**urity):

$$TCHP = \frac{d_{3D}}{\sigma_{3D}}$$ - for 3rd track

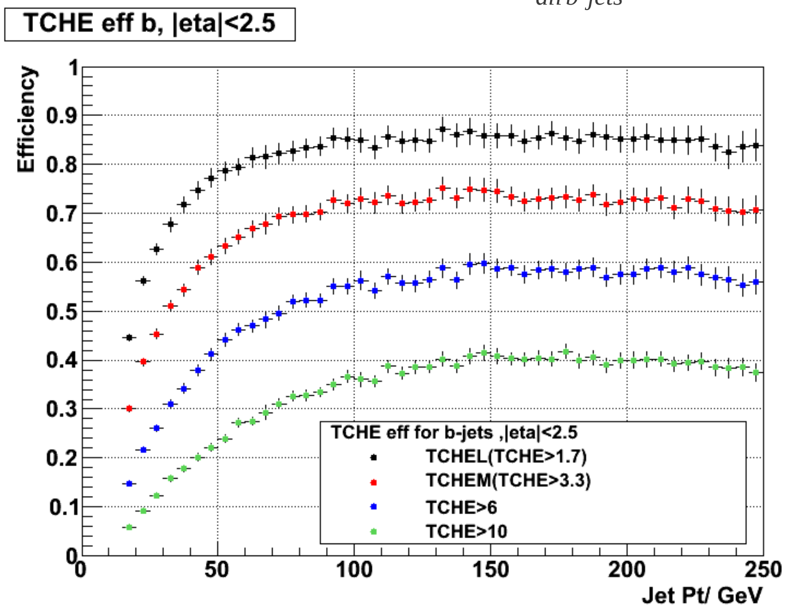


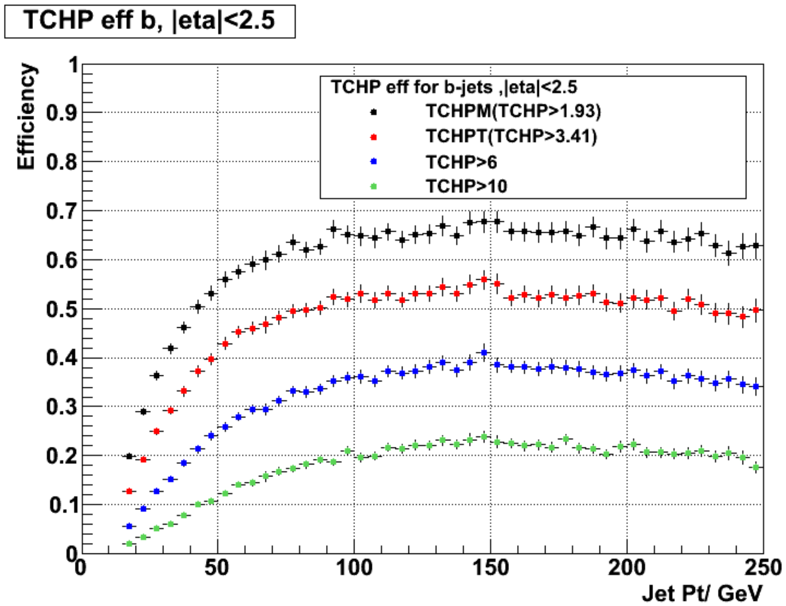
For more details: see lecture by Georg Steinbrück, Aug. 18
“Top Quark Physics. Flavor Physics.”

B-tagging: efficiency for b-jets

For calculating efficiency: select “real” b-jets with MC generator information(Pythia QCD MC)

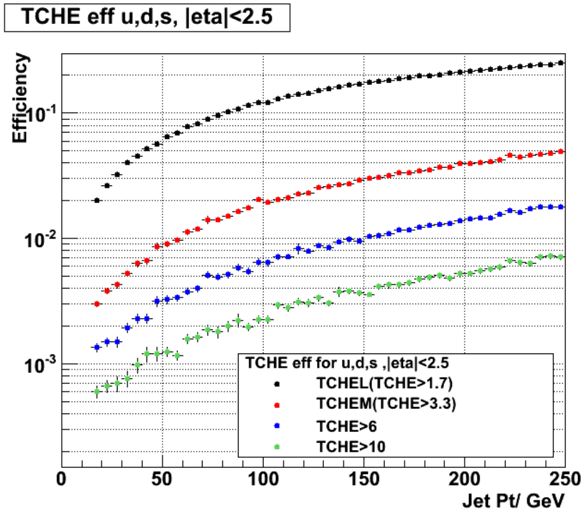
Efficiency $\varepsilon = \frac{N_{btagged\ b\ jets}}{N_{all\ b\ jets}}$

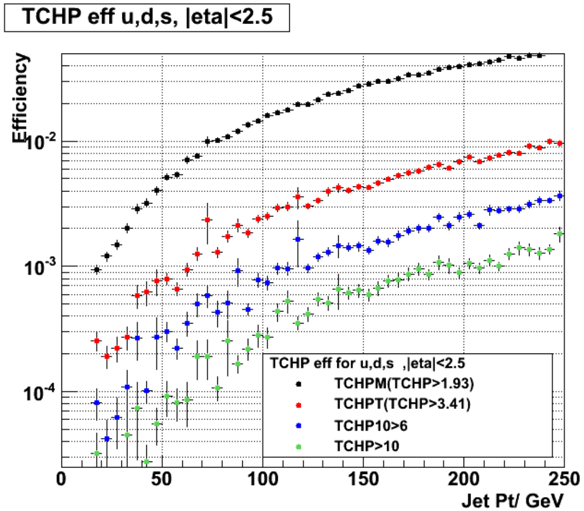




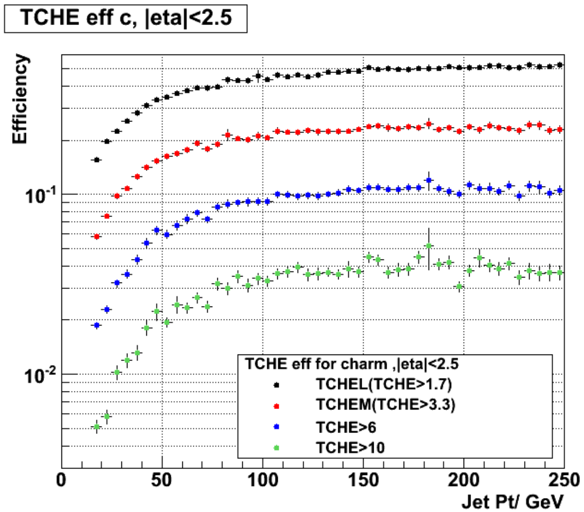
→ B-tag efficiency decreases with higher level of discriminant threshold.
→ Results are comparable with official paper by CMS b-tagging group(BTV-11-001).

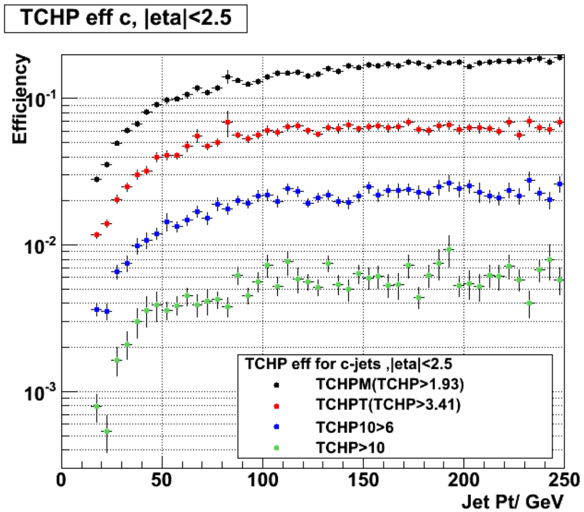
B-tagging: mis-tag probability





Similarly to previous slide – calculated "efficiency" for jets originating from light flavor and charm partons.

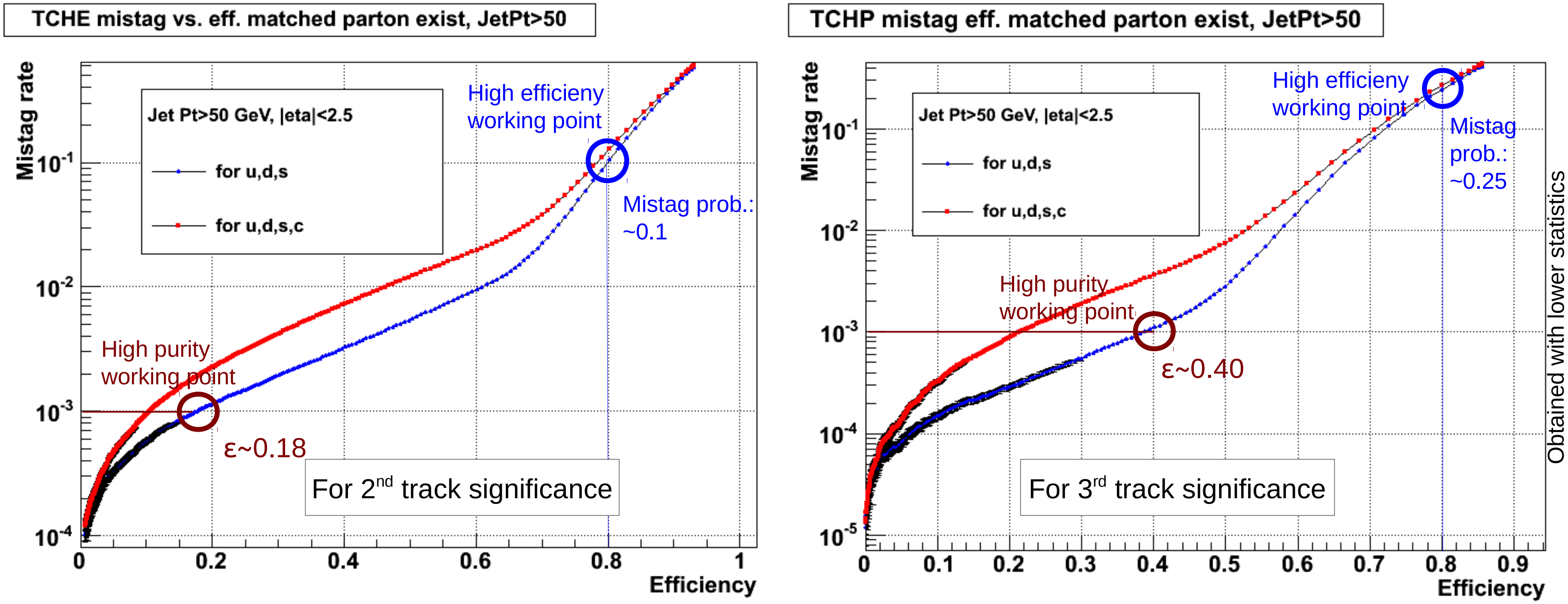




- ➔ Strong suppression for jets from light flavor.
- ➔Jets from charm quarks have much higher mis-tag rate than light flavor
  - due to large charm mean life time

B-tagging: b-tag working point diagrams

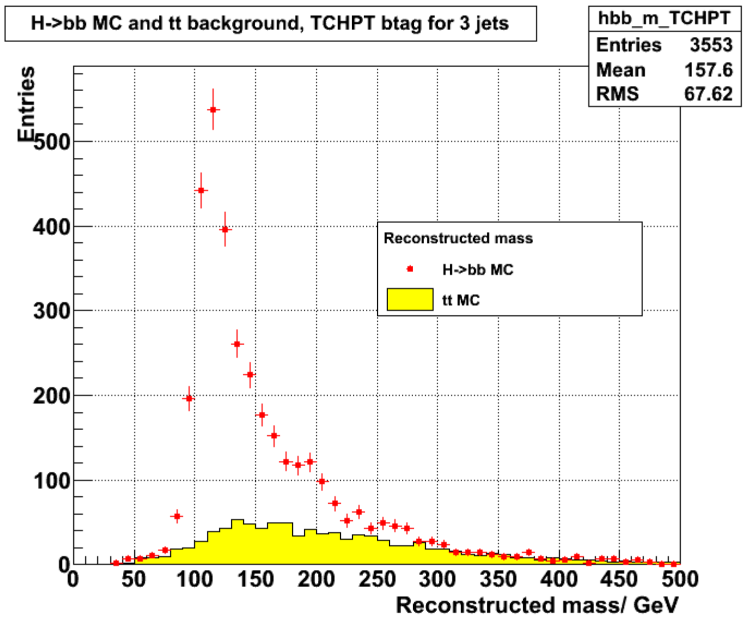
How does mis-tag rate depend on b-tag efficiency?
Plot mis-tag rate vs. efficency for jets with p_T > 50 GeV.

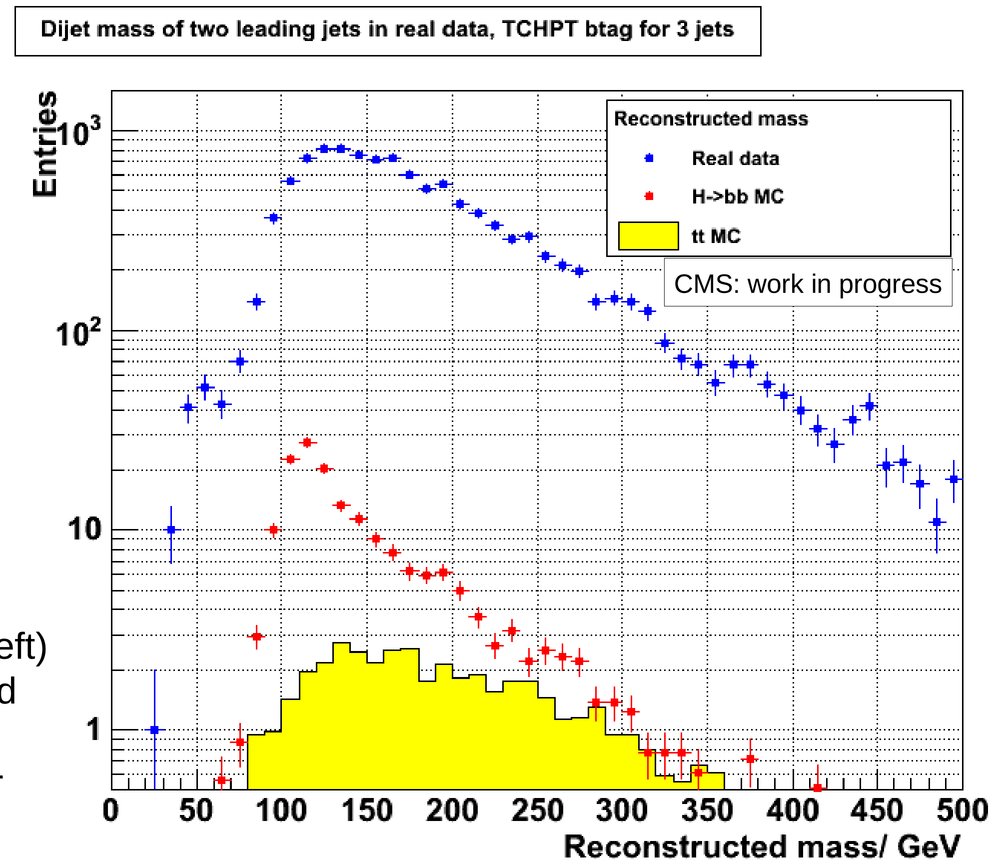


- Choice for working point is compromise between efficiency of b-tagging and its purity. Better mis-tag → lower efficiency.
- For MSSM H→b$\bar{b}$ analysis we need very high purity → consider cut at TCHPT or higher.

$t\bar{t}$-background study

LHC has much higher $\sqrt{s}$ than Tevatron. → Need to check if $t\bar{t}$ is a serious background





- Comparison of $t\bar{t}$ MC with Higgs signal MC (left) and first 501 pb^{-1} of real data (right), MC scaled according to integrated luminosity
  ➔ Background from $t\bar{t}$ is small, shape is wider than Higgs signal.
- Measurement of MSSM Higgs depends on optimization and careful subtraction of QCD background.

Summary

- Signal shape of reconstructed MSSM H->b$\bar{b}$ studied in Monte Carlo
  - mass resolution ~11%
  - small mass shift attributed to semileptonic decays and jet energy corrections
- B tagging:
  - efficiency & mistag probabilities of track counting methods studied
  - select working point in high purity regime
- t$\bar{t}$ background estimated:
  - shape is different from expected Higgs signal
  - relative contribution to overall background is low
  - background is dominated by QCD multi-jet production
    - needs careful treatment

Thank You for Your attention!

Thanks to: Rainer Mankel,
Roberval Walsh, Alexander Spiridonov, Alexei Raspereza

Back-up:Investigate the mass shift

- Study impact of semileptonic decays directly by selecting jets containing a high p_T muon.
- For muon matching using criteria:

$$\Delta R=\sqrt{(\Delta\phi)^2+(\Delta\eta)^2}<0.5$$

Muons in 2 jets	-14.3 GeV
Muon in 1 jet	-11.1 GeV
Muon in event	-8.7 GeV
No muons	-8.6 GeV

→ Semileptonic decays can explain ~-3 GeV of mass shift per such jet

- Attribute remaining mass bias to special properties of b-jets
  - → to be addressed by specific additional jet energy correction