b Tagging in CMS

- b tagging algorithms
  - b-lifetime based
  - b → lepton based
  - Combined

- Measuring b tagging performance with data

- Uses of b tagging in High-Level Trigger.

Introduction

- **Tag b-jets by exploiting B hadron properties:**
  - Long lifetime (τ ~ 1.5 ps)
    $\Rightarrow$ decay length ~ 4.5 mm for p = 50 GeV/c.
  - Decays to average of 5 charged tracks.
  - High B hadron mass ~ 5 GeV/c^2.
  - 35% of B hadrons decay directly/indirectly to e/μ.
- **Difficulties:**
  - Long D+ lifetime (τ = 1.0 ps) in c-jets
    $\Rightarrow$ decay length ~ 8.0 mm for p = 50 GeV/c.
  - Gluon splitting to bb or cc.

CMS Detector Performance

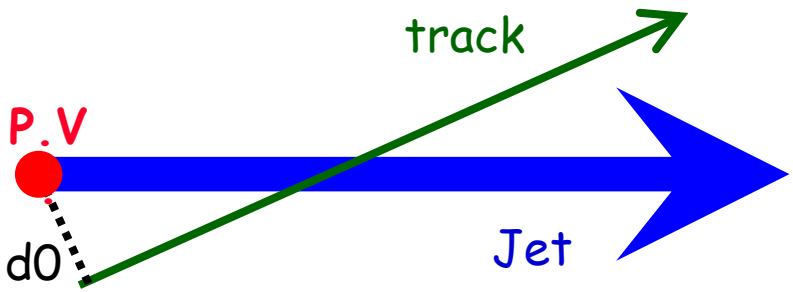
CMS Tracker

- $\sigma(d0) \sim \sigma(z0) \sim 20\ \mu m$ at $P_t = 10$ GeV/c (but x5 worse at 1 GeV/c)
- Beam width only 16 μm.
- π tracking efficiency in jets ~ 80% for $|\eta| < 2.4$.

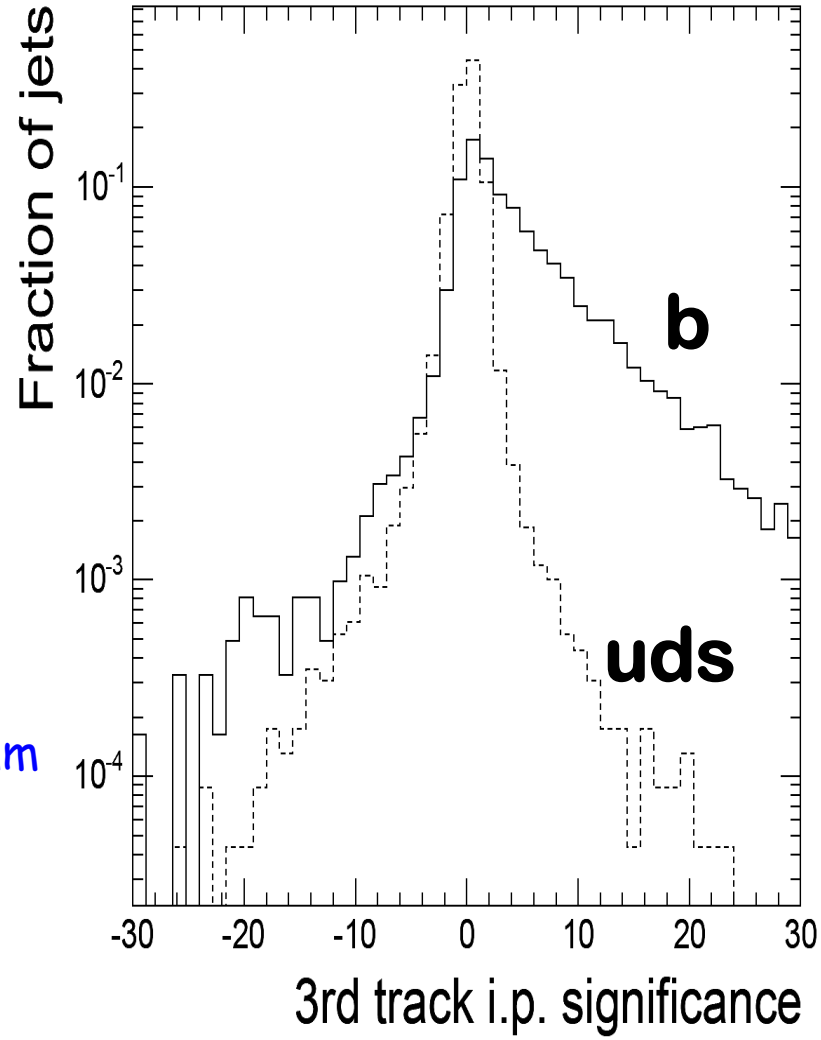
- Jet resolution at Et = 100 GeV: σ (Et) ~ 14 GeV, σ (angle) ~ 3^0.
- lepton efficiency in jets ~85% for Pt > 6 GeV/c (and improving …)

b Tagging with Track Impact Parameters "Track Counting" Algorithm

- Calculate signed 3-D impact parameter significance.



- Track quality cuts, e.g.:
  - $|d0| < 2$ mm
  - track-jet miss distance < 0.7 mm
- "Track Counting" b tag discriminator is $d0/\sigma$ of 2nd or 3rd most significant track.

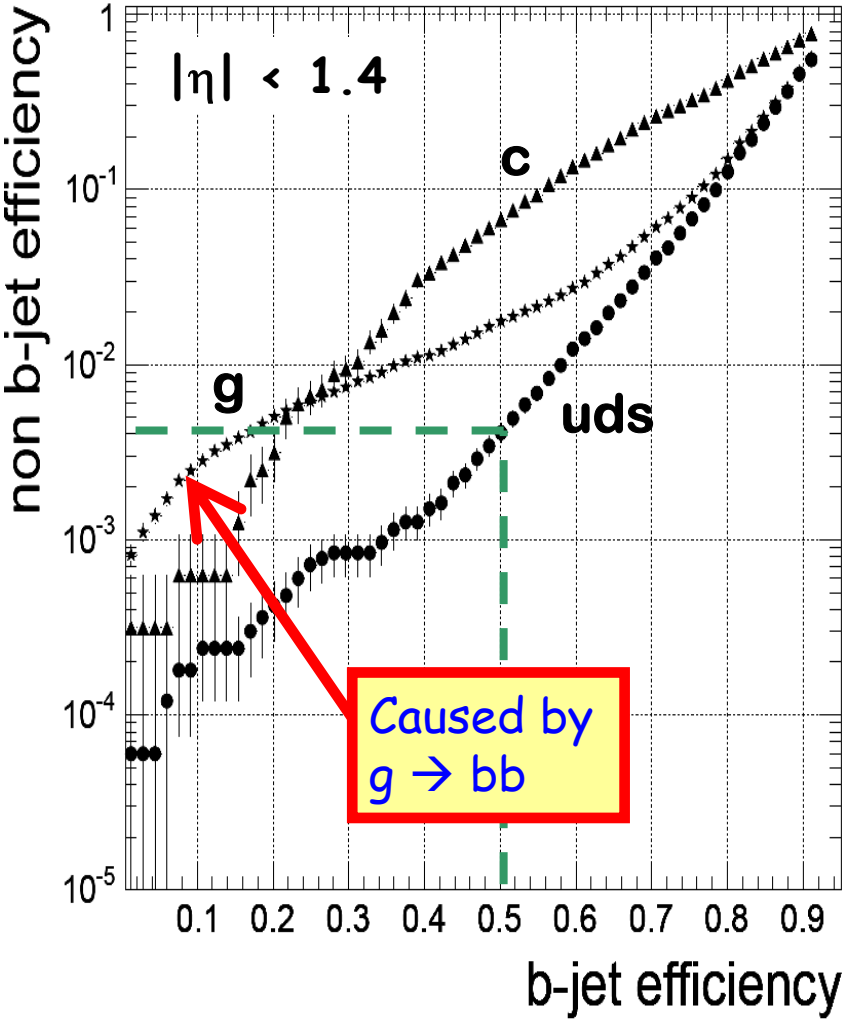


b Tagging with Track Impact Parameters "Probability" Algorithm

"Probability" b tag rejects x2 more uds-jets, by combining info from all tracks …

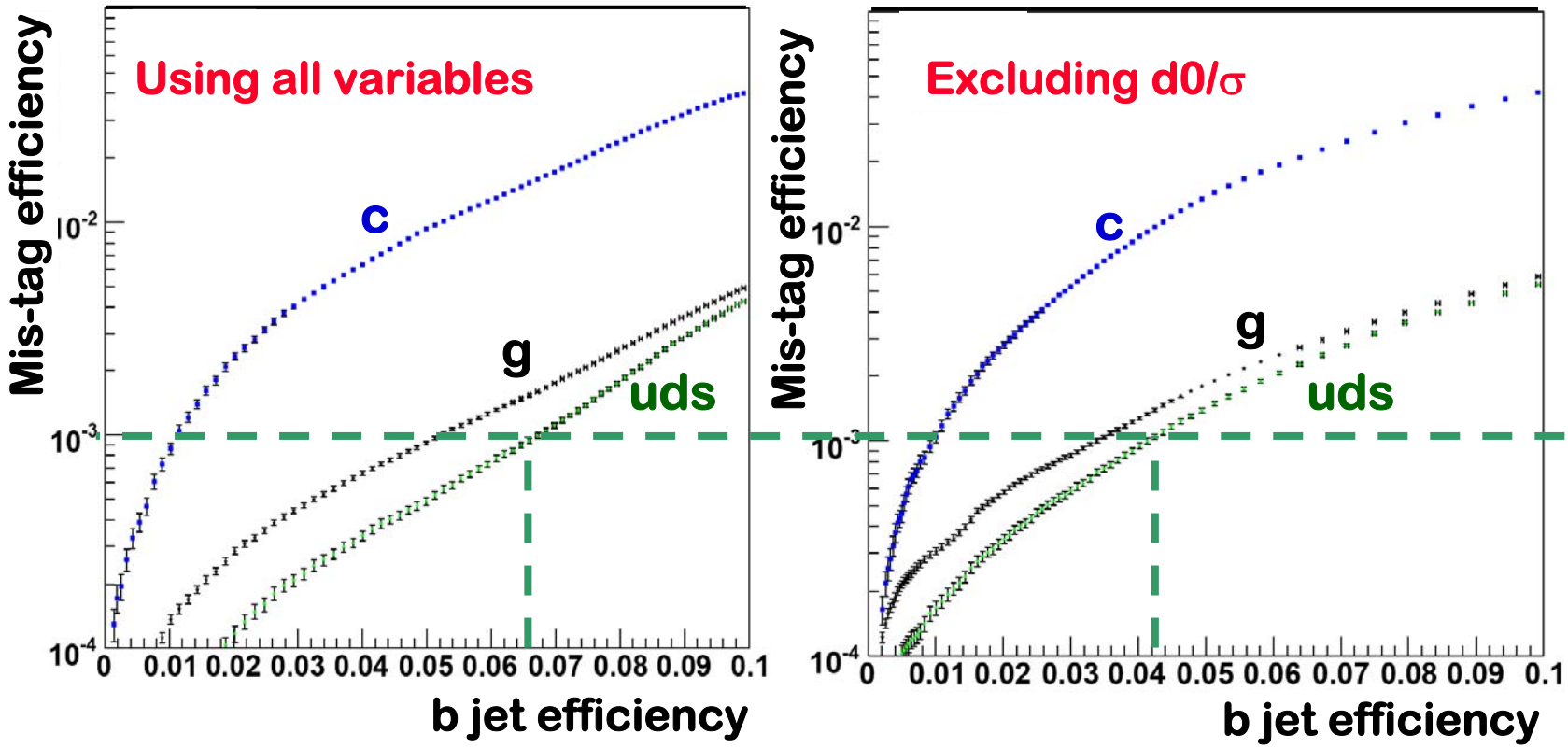
Method:

- Measure d0/σ resolution function for several track categories (track χ^2, # pixel hits …)
- Calculate confidence-level each track comes from P.V.
- b tag discriminator is `confidence-level' that all tracks in jet come from P.V.



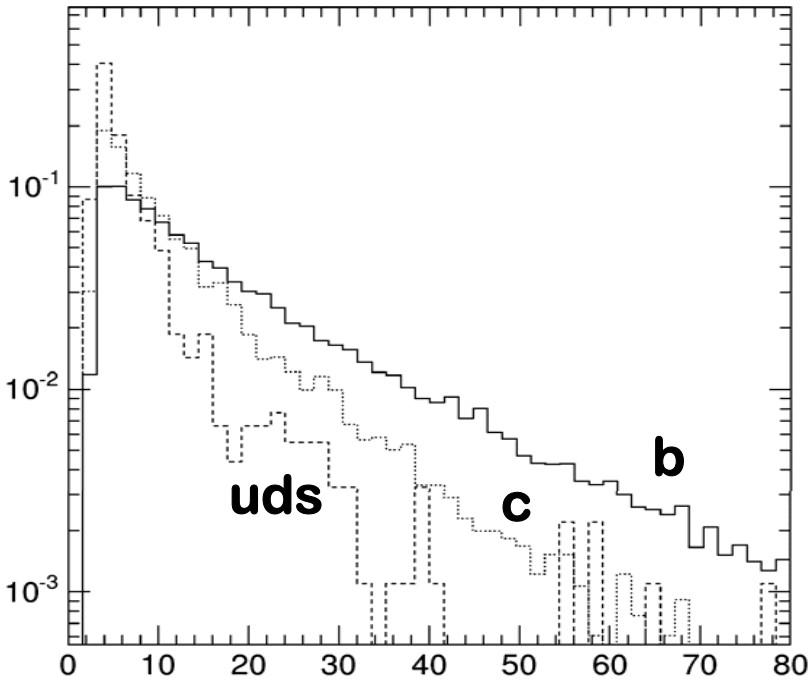
b Tagging with Leptons

- Tag b → l using large Pt_rel of lepton to jet.
- Also use d0/σ of lepton.
- Combined with other variables (ΔR, p_l/E_{jet}) in neural net.

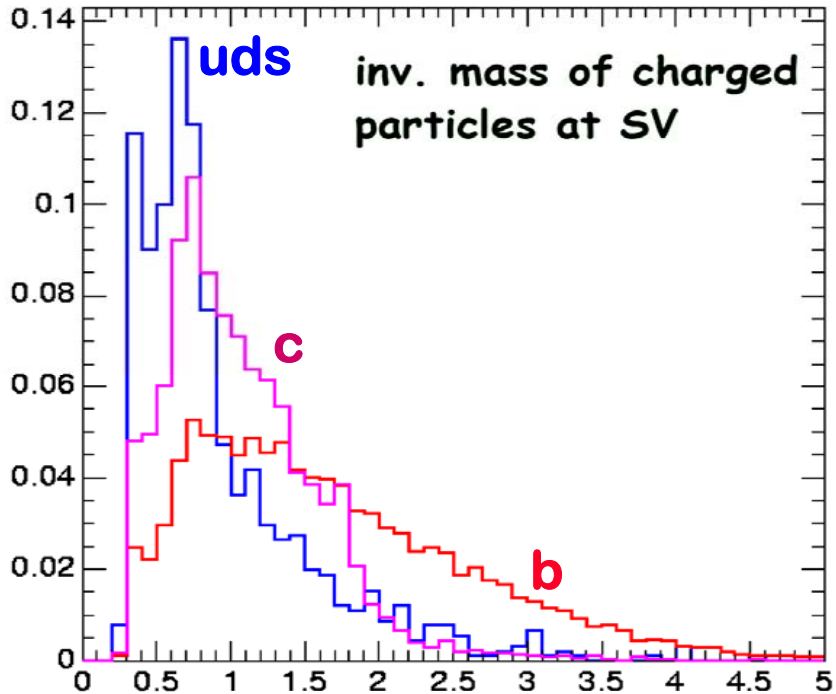


"Combined Secondary Vertex" b Tag

- Reconstruct 2ndary vertex in jet (W.Erdmann's talk).
  (Use tracks inconsistent with P.V. if no 2ndary vertex found).
- Calculate vertex decay length significance, mass & multiplicity, rapidity of decay products, energy relative to jet energy …



Decay length significance

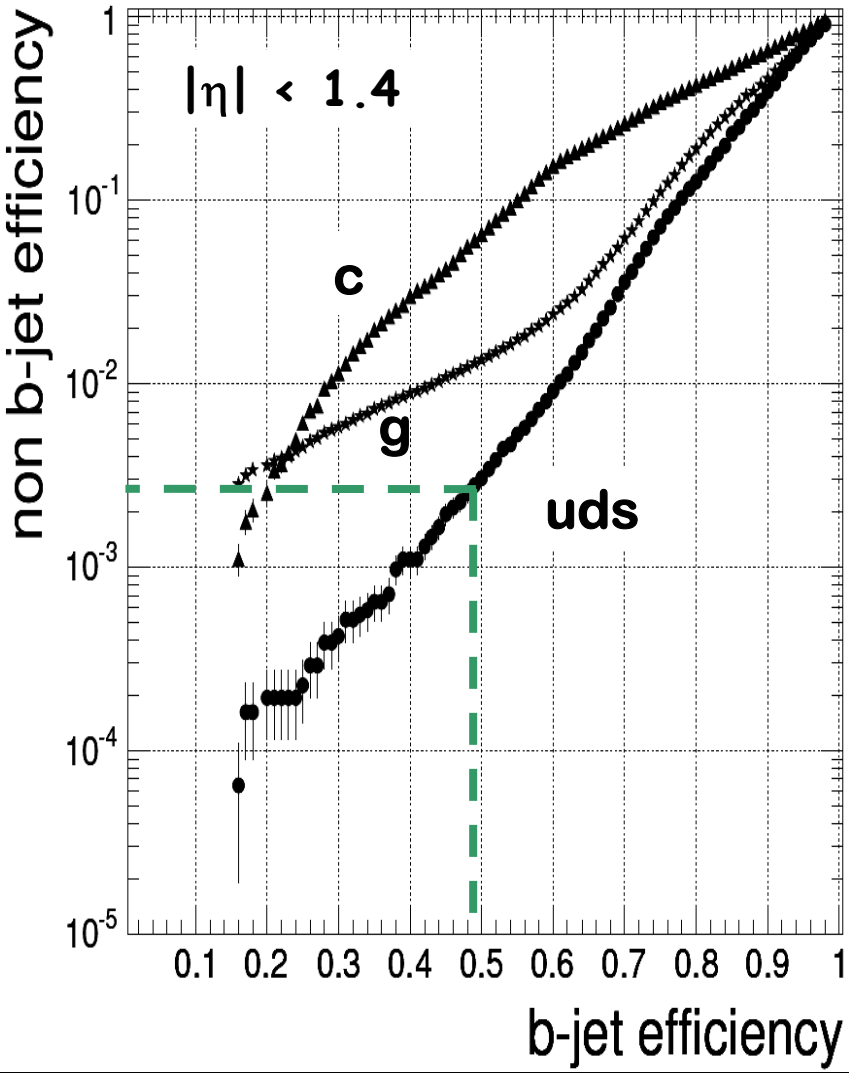


Mass of secondary vertex

"Combined Secondary Vertex" b Tag

- Calculate additional variables, like track d0/σ, even if no vertex present.
- Combine all variables using b/udsc likelihood ratio.

(Ongoing improvements include use of leptons & use of neural nets, MVA etc.).



Measuring b Tag Performance with Data

Idea:

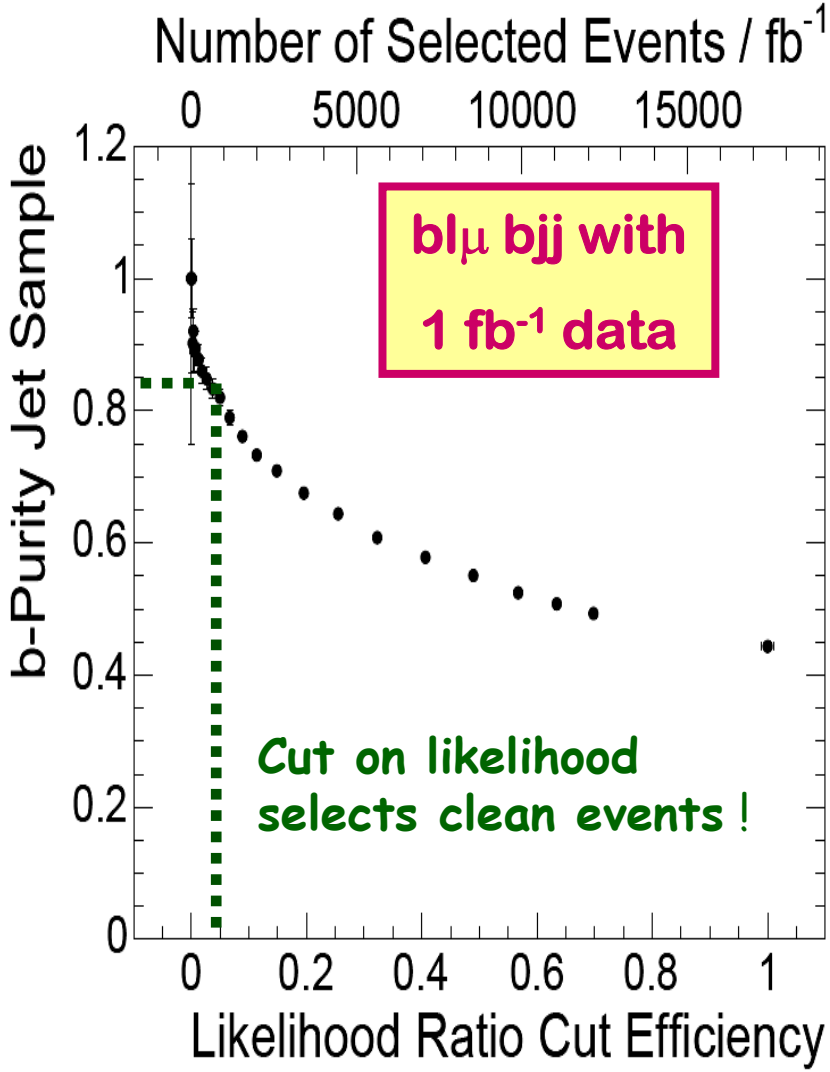
Select pure sample of b jets in t-tbar events & see what fraction are b tagged !

tt → blν blν:

- Require 1 μ∓, 1 e±, 2 jets & Pt(miss)
- Get 6000 fb tt & 900 fb WW / Zj

tt → blν bjj:

- Kinematic fit using t & W mass constraints.
- Jet assignment uses likelihood function based on fit χ^2 etc.
- Jet assigned to hadronic top must be b tagged.
- Get 27000 fb tt & 600 fb Wj.



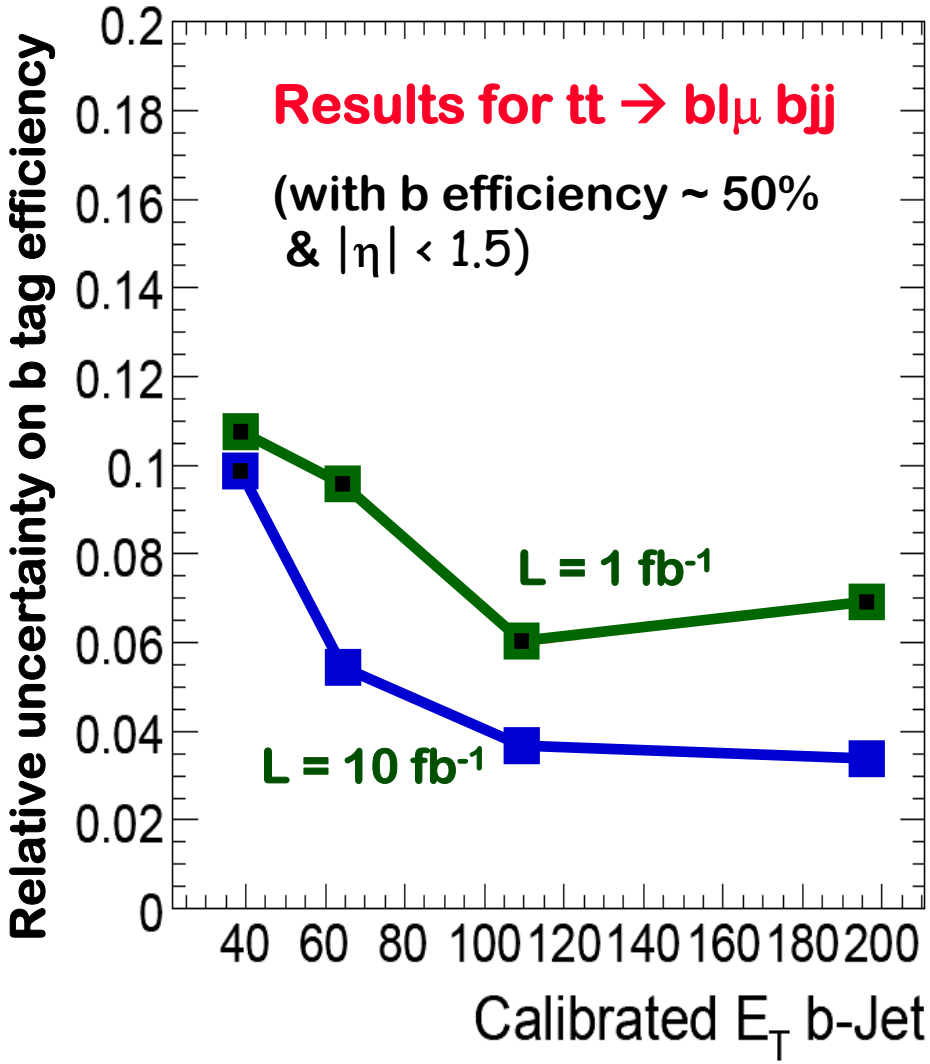
Measuring b Tag Performance with Data

- Dominant systematic uncertainty due to QCD ISR/FSR …

  … extra jets confuse b jet assignment.

  Reduced by cutting harder on likelihood.

- tt → blν blν gives similar performance to blν bjj, as lower statistics, but can use both b jets.

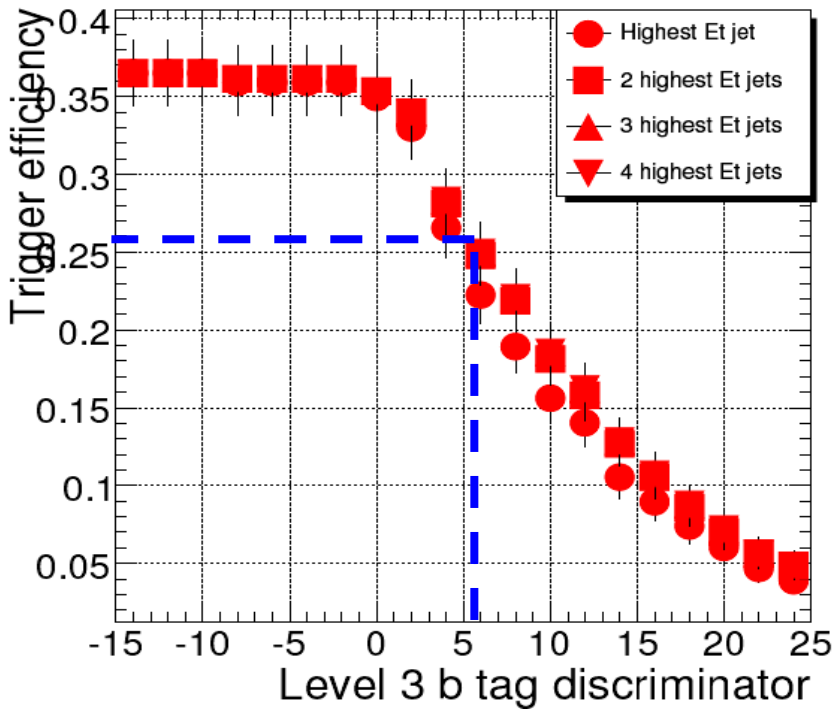


Use of b Tag in High-Level Trigger

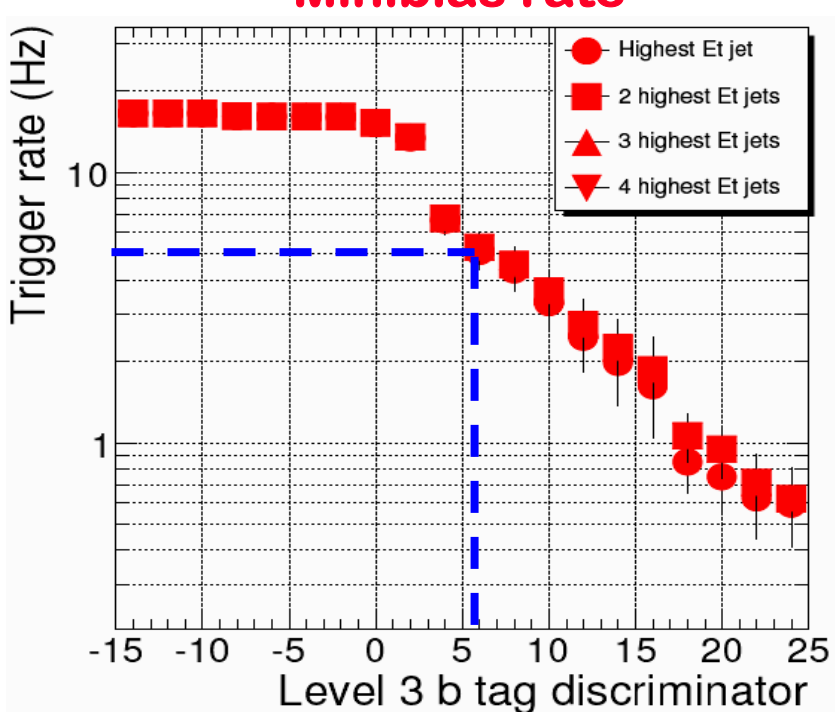
CMS HLT runs software on huge computer farm.

- Uses b tagging, which lets one use lower jet Et thresholds.
- L2.5: b tag using tracks found in Pixel Tracker ! (18 ms/event).
- L3: b tag using tracks reconstructed locally in full Tracker (300 ms/event)

t-tbar efficiency



Minibias rate



b Tagging in CMS
Conclusions !

- Several b tag algorithms ready for use in CMS !
  - Impact parameter, lepton, combined secondary vertex.
  - Performance reaches ε (uds) ~ 0.003 for ε (b) ~ 0.5.

- Several techniques being developed to measure b tag performance with data.
  - b efficiency from t-tbar events or uncorrelated lepton & lifetime tags, uds mistag rate from tags using –ve d0/σ.

- b Tagging can be run in CMS High-Level Trigger