B-Tagging at LHC

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Outline

- Introduction to b-tagging @ LHC
- Efficiency and rejection
  - vs Energy and Eta
  - Low/High luminosity
- Trigger
- Detector effects
- Calibration

b-Tagging introduction

Goal: identify jets originating from b-quarks

- lifetime based algorithms

Those algorithms exploit the fact that B hadrons decays far (~mm) from the primary interaction vertex.

- soft lepton algorithm

Those algorithms are based on the presence of a “soft lepton”(muon/electron) in the jet.

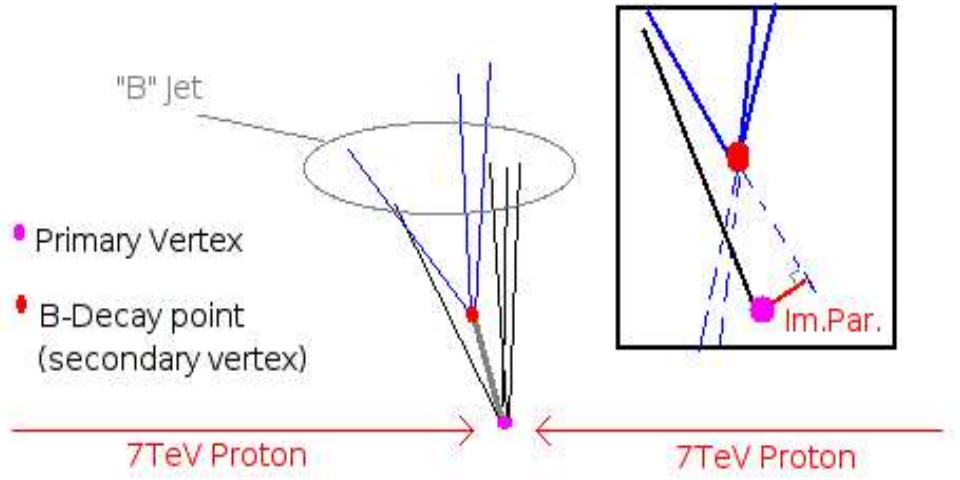
b-tagging is crucial in many channels (top studies, ttH, susy, ...) to tag signal or reject bkgnd.

Life time based algorithms

In b-jets it is likely to find:

- tracks with high impact parameter wrt P.V.
- Displaced secondary vertex

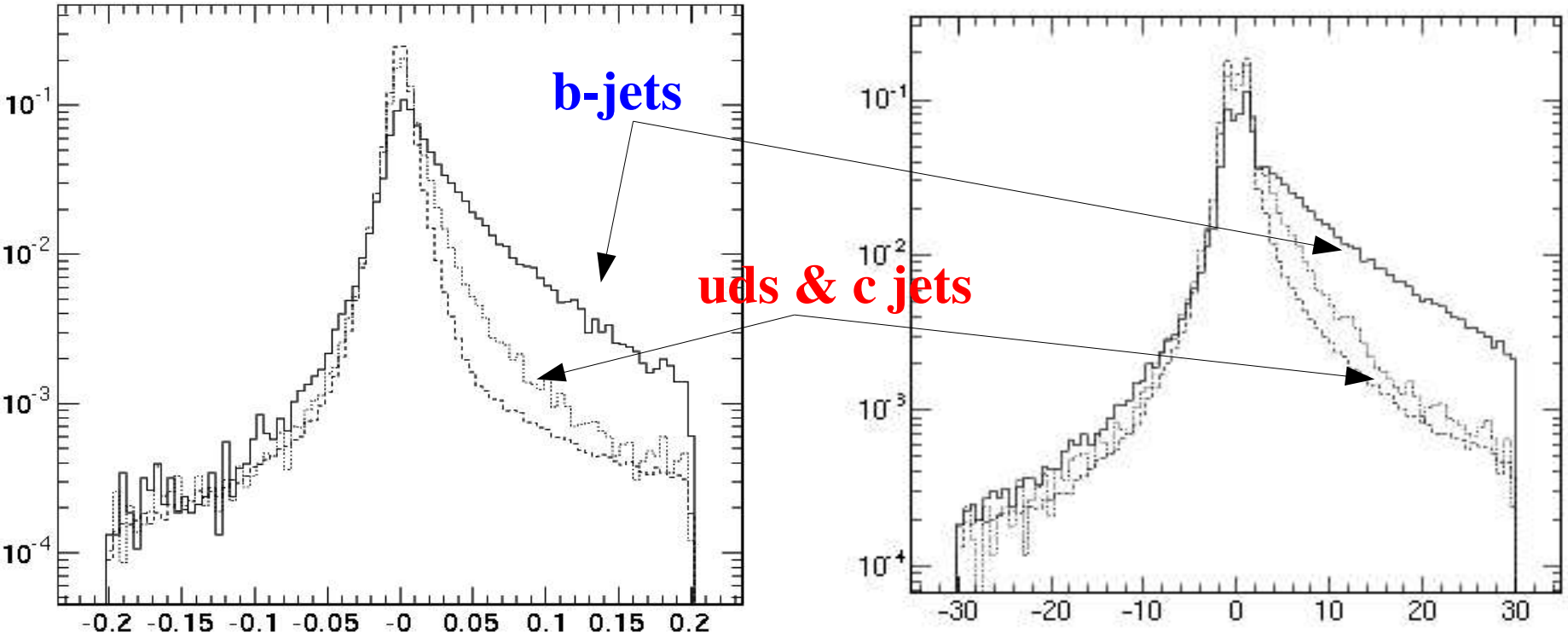
Good inner tracking needed



Different algorithms exist based on:
- transverse / longitudinal / 3D **impact parameter** (or combination of those)
- **secondary vertex** reconstruction and properties: decay length, mass at vertex, fraction of charged tracks,..

Different methods are then used:
- Significance of the i.p. / d.l.
- Probability density functions
- Likelihood methods
- Neural networks

Life time based algorithms



3D Impact parameter distribution for tracks of b-jets vs tracks of uds and c jets

distribution of significance
S = ip / sigma_ip

Two algorithms described...

CMS Track counting

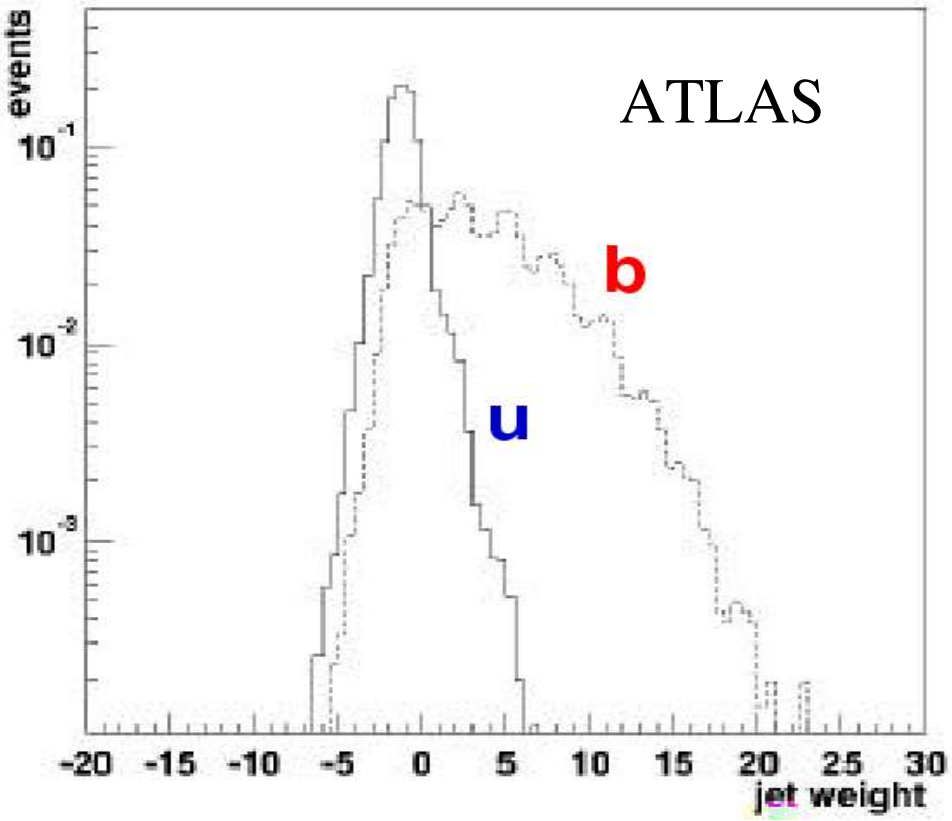
- Order track in decreasing impact parameter signigicance S
- Use the significance of n^{th} track as "discriminator"
- Parameter *n* can be tuned according to analysis needs

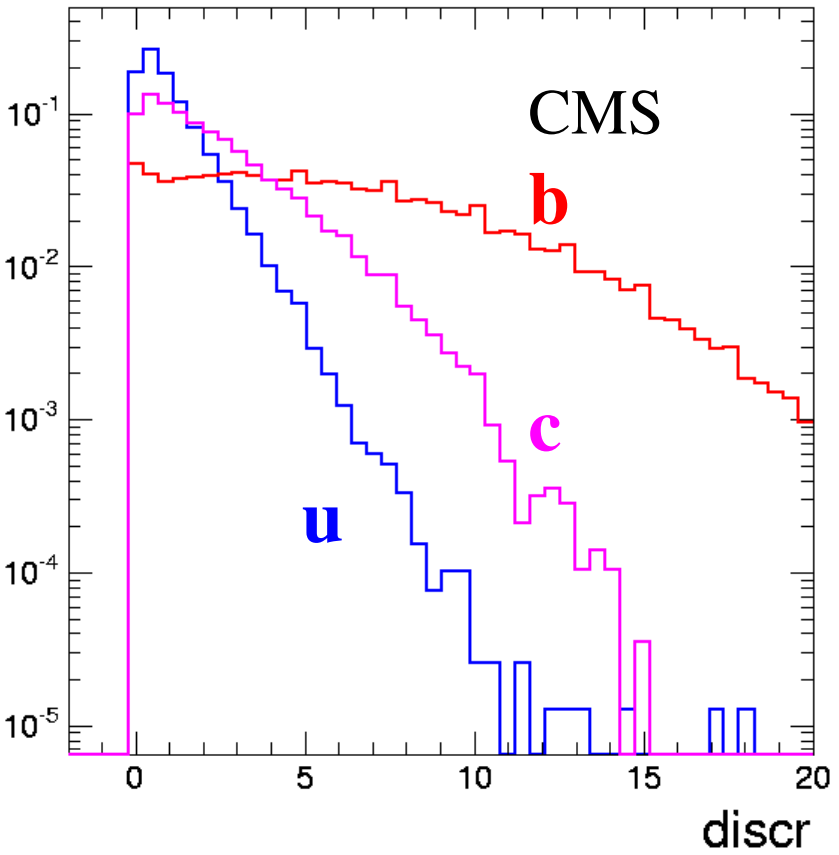
Atlas 2D algorithm

- Compute S
- Probability of a track to come from "b" or "uds" S-distribution is computed
- Ratio between b and uds probability computed
- Ratios of all tracks combined to give a "jet weight"

Algorithms based on secondary vertex reconstruction are more powerful and are implemented by both experiments

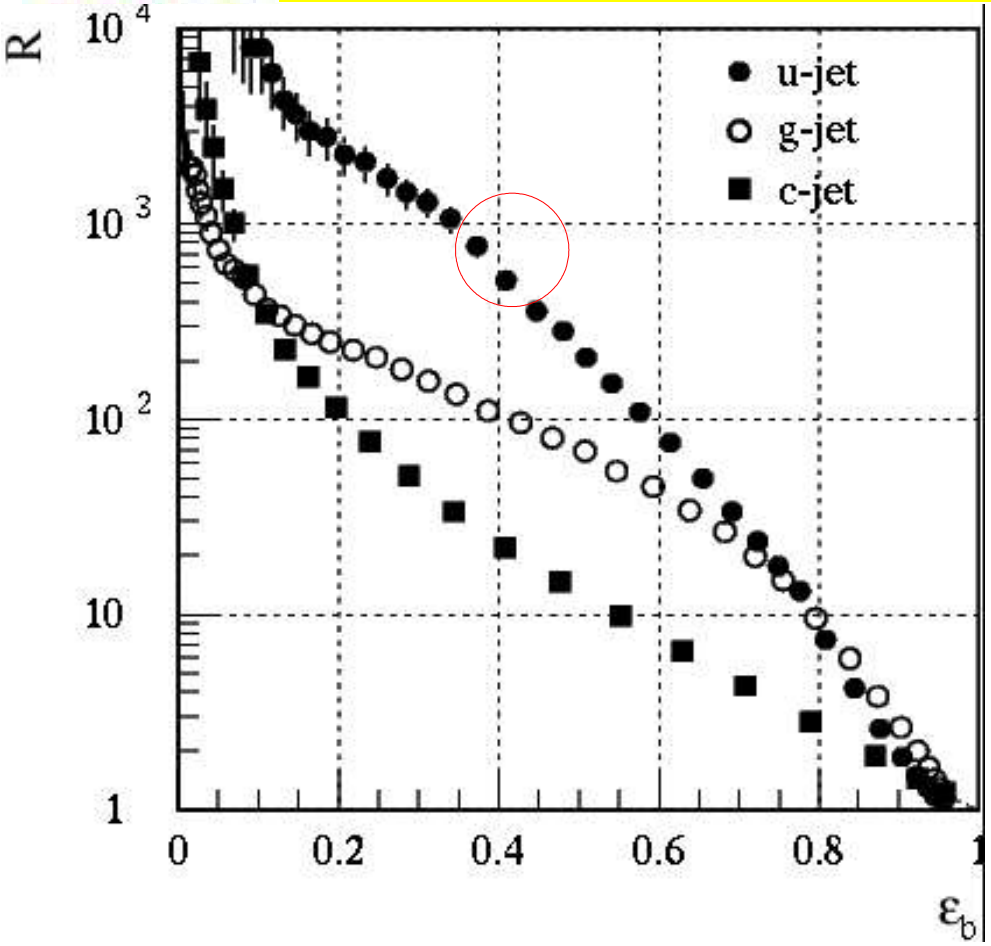
Algorithms output

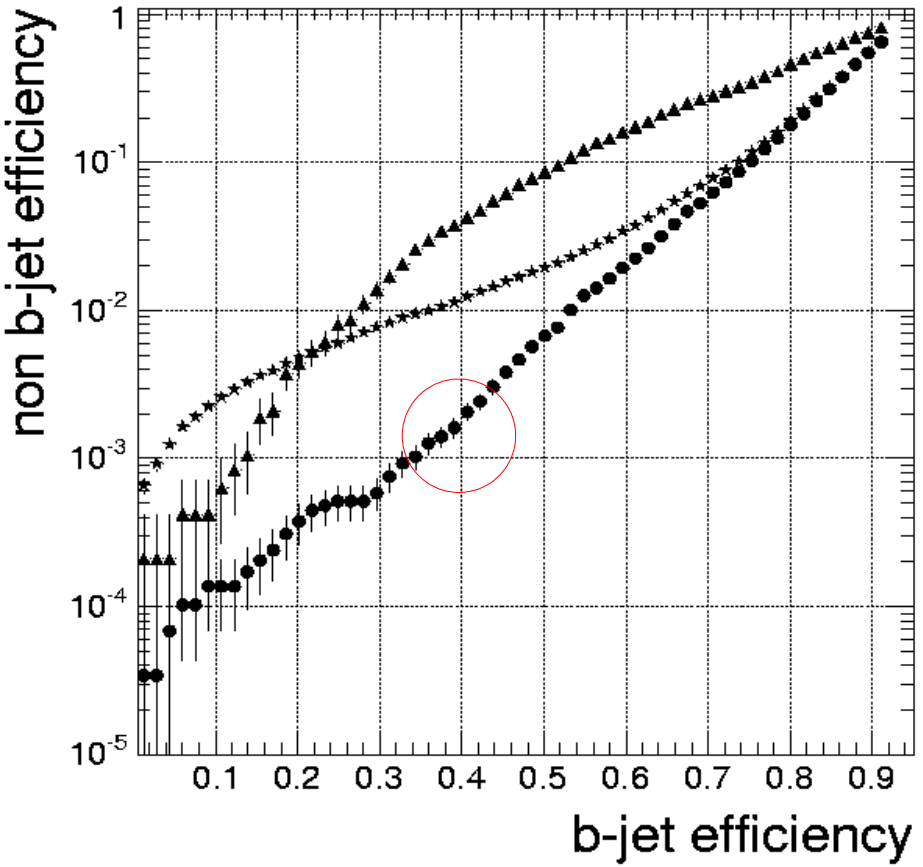




The typical output of a b-tagging algorithm is a float variable indicating the "b-likeness" of a jet

Identification efficiency





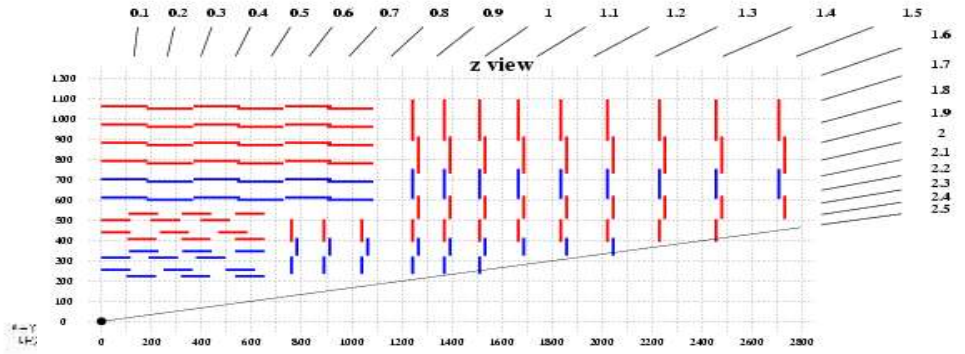
Atlas and CMS obtain similar b-tagging performances:
rejection ~300 (=mis-tagging 3 10^{-3}) at efficiencies ~50%

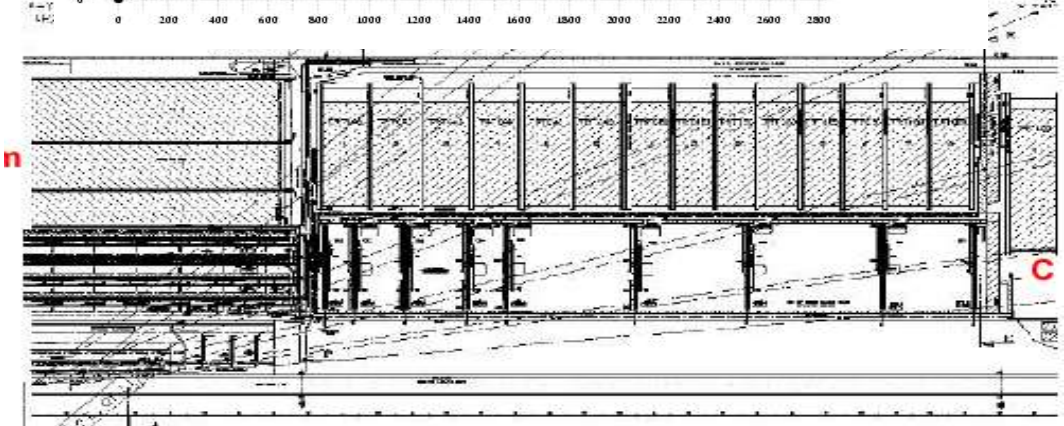
mis-identification vs eta

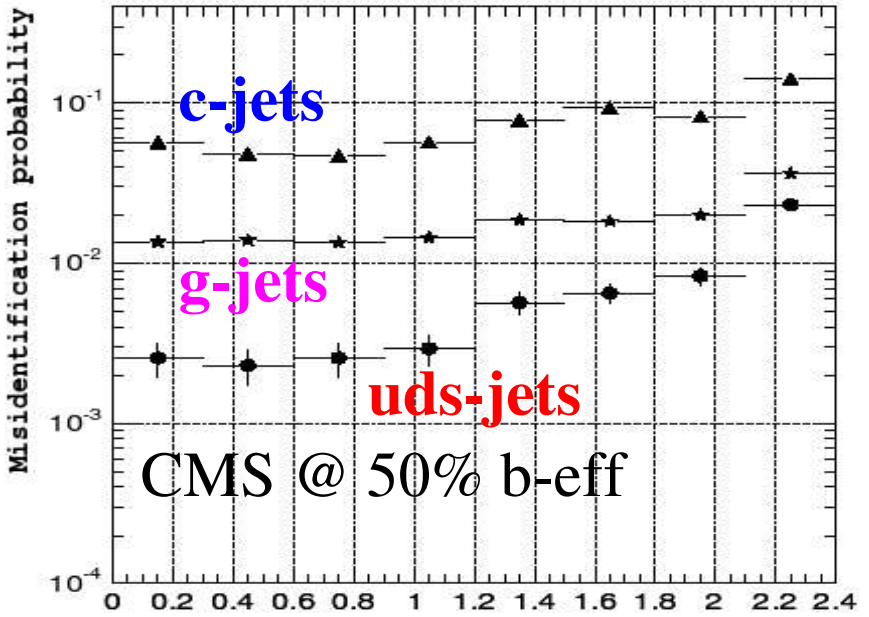
The rejection of uds, g and c jets is better in central eta region.

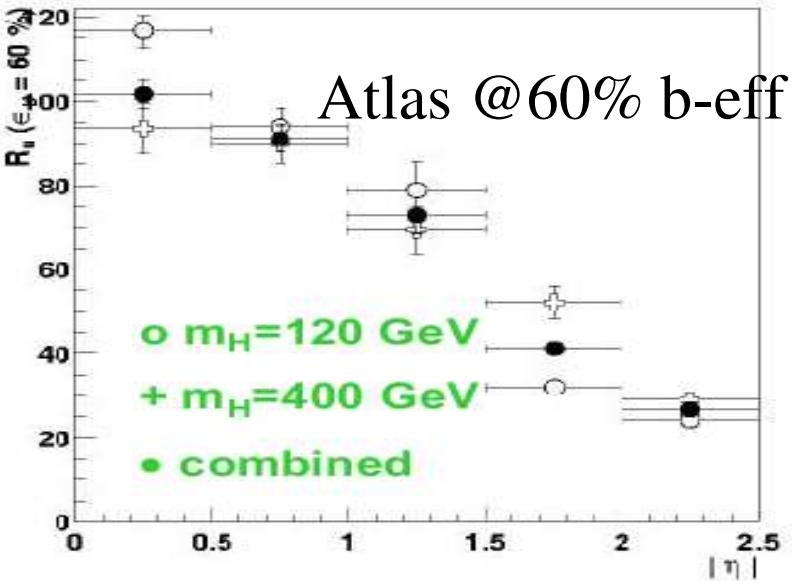
b-tagging reconstruction is limited by tracking to the region

-2.5 < eta < 2.5



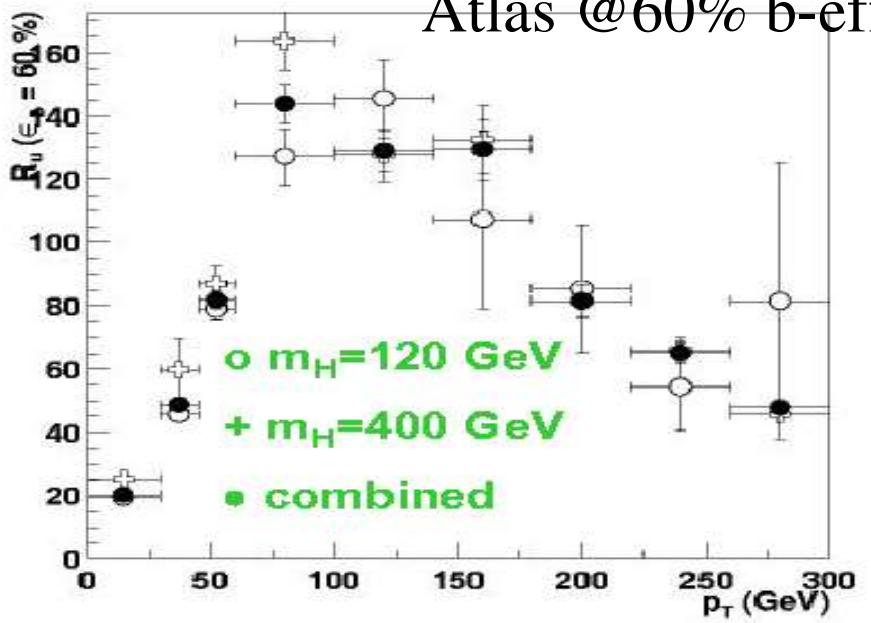


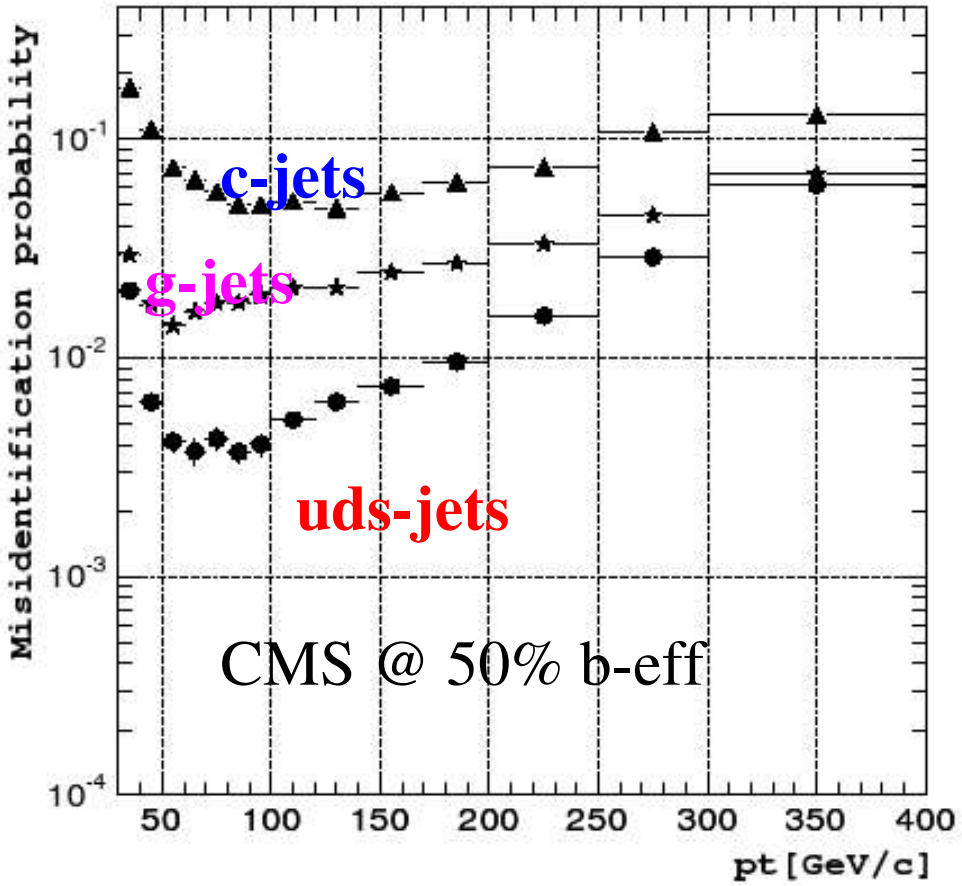




mis-identification vs Pt

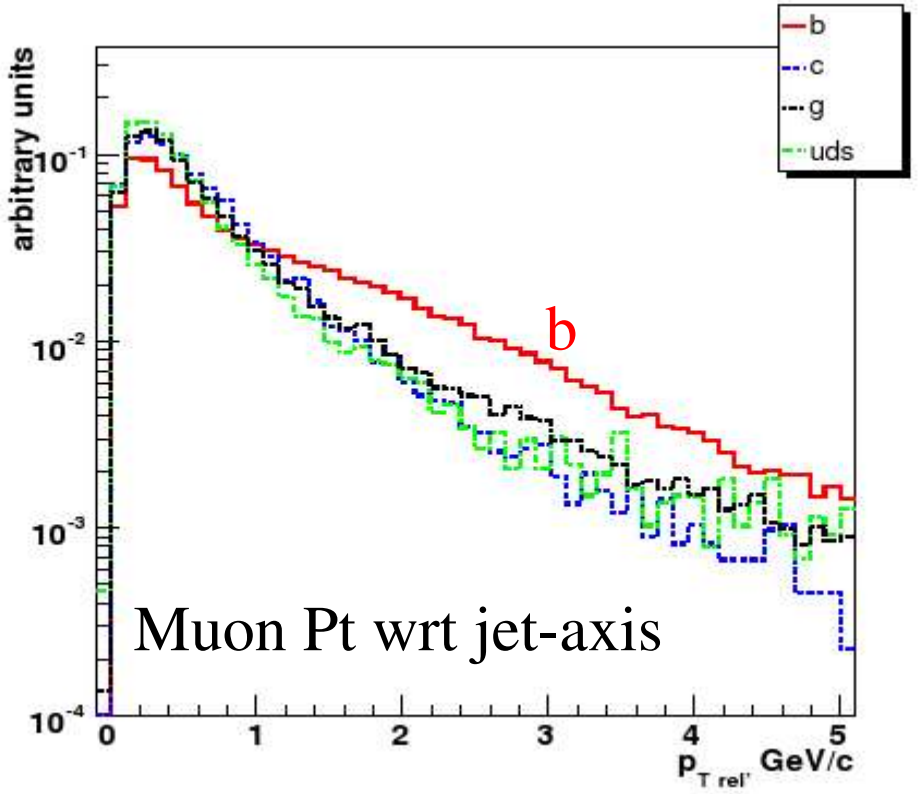
Atlas @60% b-eff

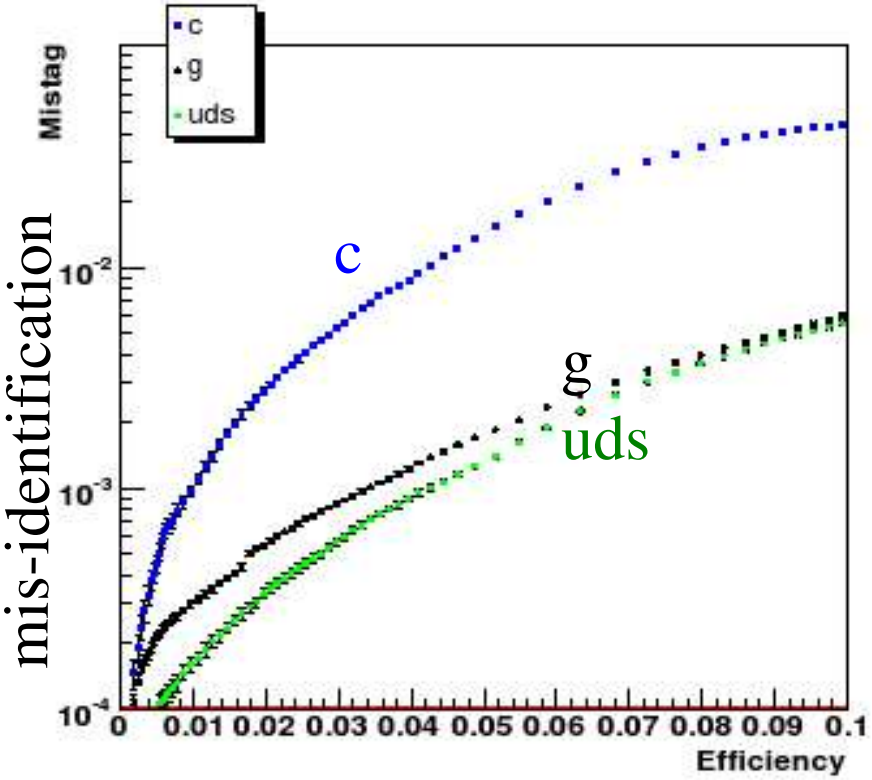




- At too low energies tracks have a low Pt and the multiple scattering rise the I.P. uncertainty
- At high energy:
  - track reconstruction is harder
  - more tracks -> easier to find high I.P. tracks in light

Soft lepton tagging



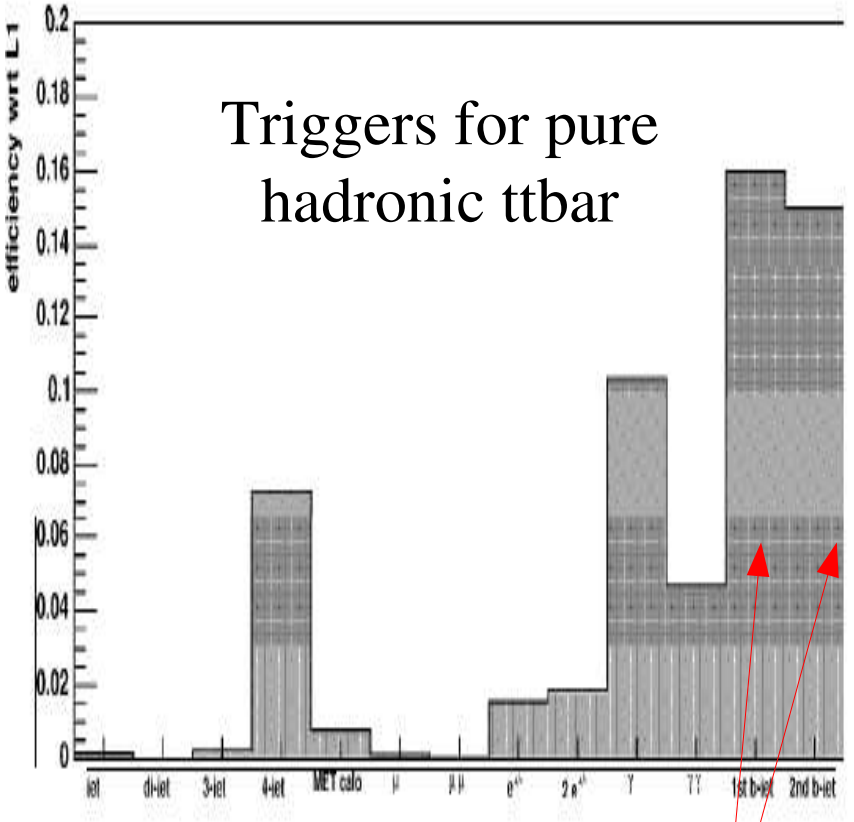


- limited by BR of B to leptons (~10% per lepton)
- can be used without vertex information
- exploit different information wrt lifetime base algorithms

b-tag trigger

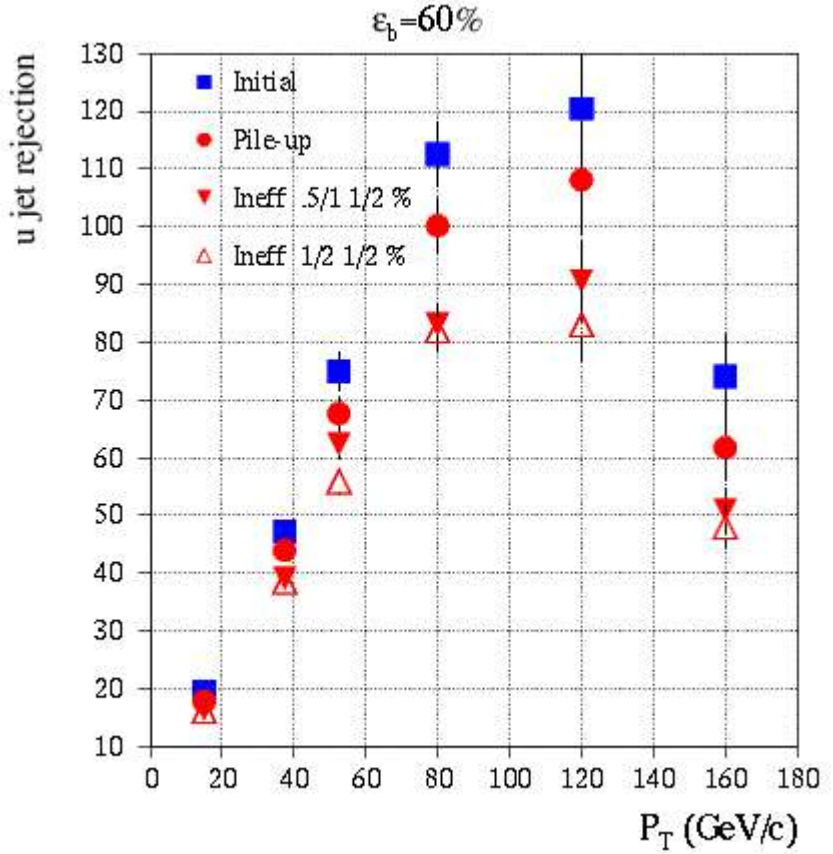
Trigger based on b-tagging can be used at High Level Triggers (>L1) when tracker data is available

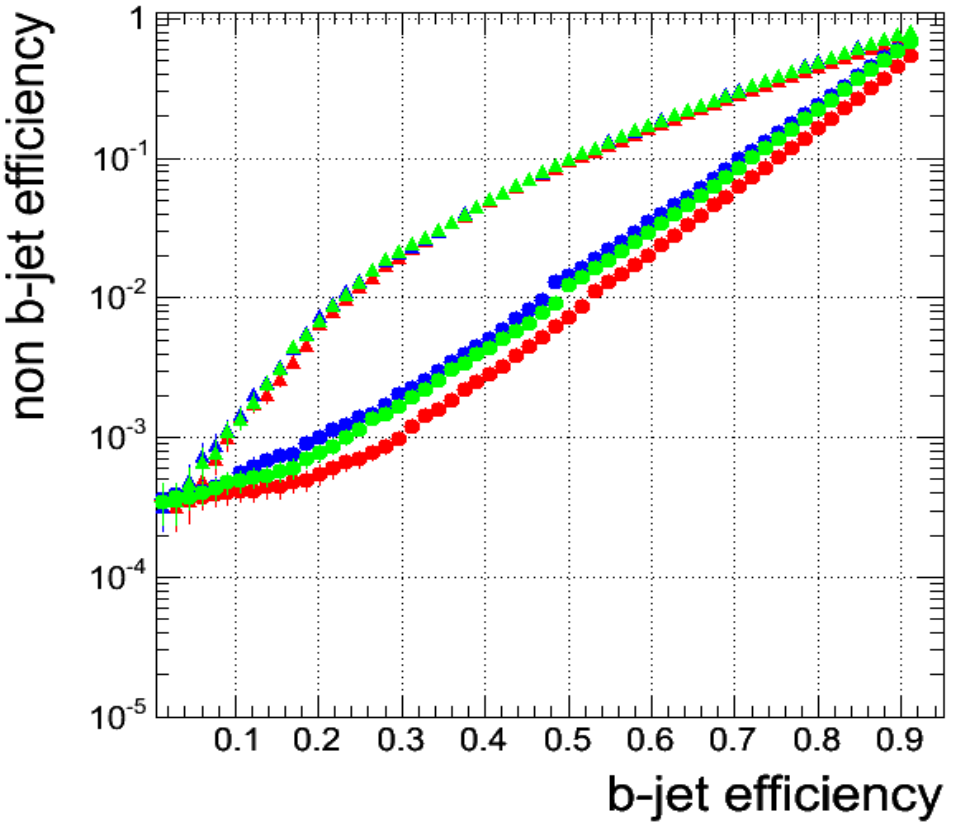
- regional track reconstruction is needed
- simple algorithms
- reconstruction applied to 1st and 2nd most energetic jets



useful e.g. in pure hadronic ttbar

Ideal vs actual performances





Atlas studies on performance loss:

- initial detector (2 pixel layers)
- pile up events
- pixel inefficiencies

CMS studies on misaligment:

- Perfect detector
- Initial alignment
- Track based "realignment"

Calibration

Two type of “calibrations” on data:

- studies of track impact parameter distributions (used by several b-tagging algorithms)
- direct study of efficiency on ttbar sample
  - select pure top sample without b-tagging (or tagging only one b)
  - using only kinematic constraints (W mass, top mass) identify q-jets and b-jets
  - measure algorithm efficiency

semileptonic ttbar is studied by both CMS and Atlas for this purpose

Generators

Generator used for b-tag studies:

- Pythia (CMS and Atlas)
- MC@NLO (top Atlas)

Possible generator effects:

- Number of charged tracks in light jets
- B-decay (number of tracks, angular distribution)

no specific study on that (as far as I know)

Italian activities

Italian groups are deeply involved in b-tag both in Atlas and CMS

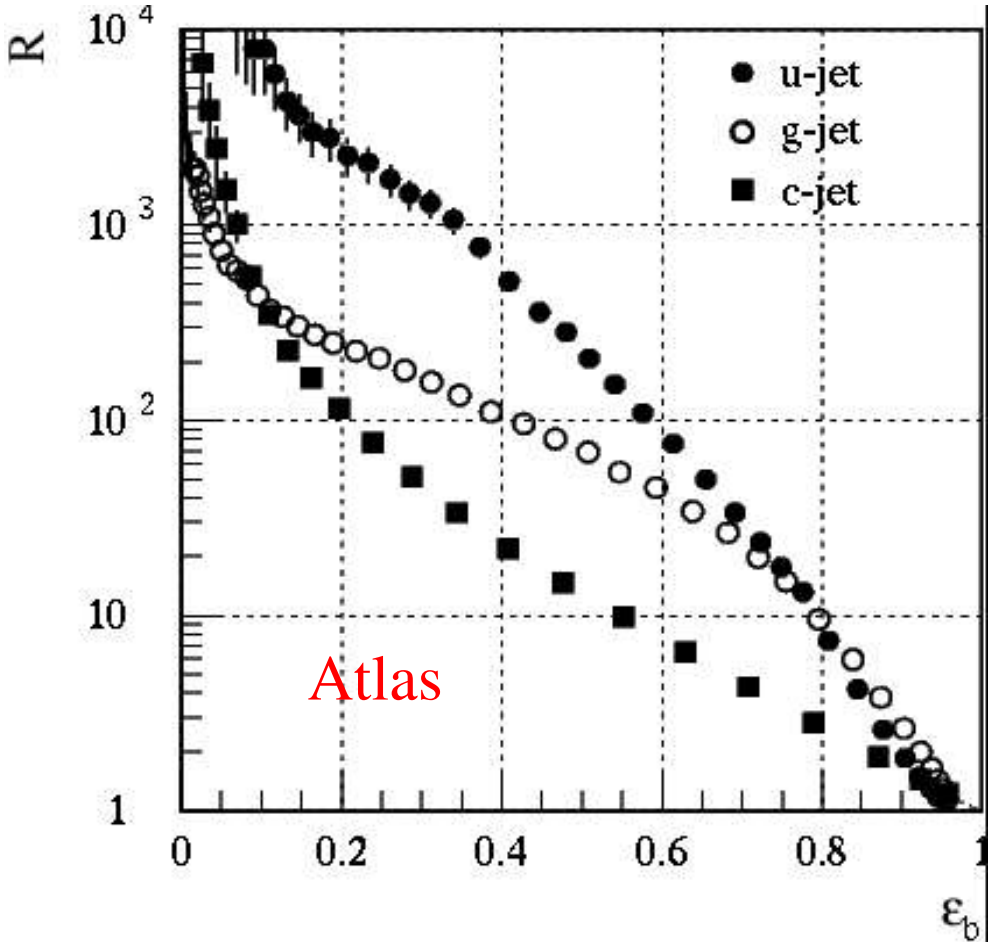
- CMS
  - Pisa: Impact Parameter based algorithms, HL Trigger
  - Firenze: Soft Muons algorithm
- ATLAS
  - Genova: Algorithms, trigger and calibration
  - Milano: Susy b-tag
  - Udine: top studies

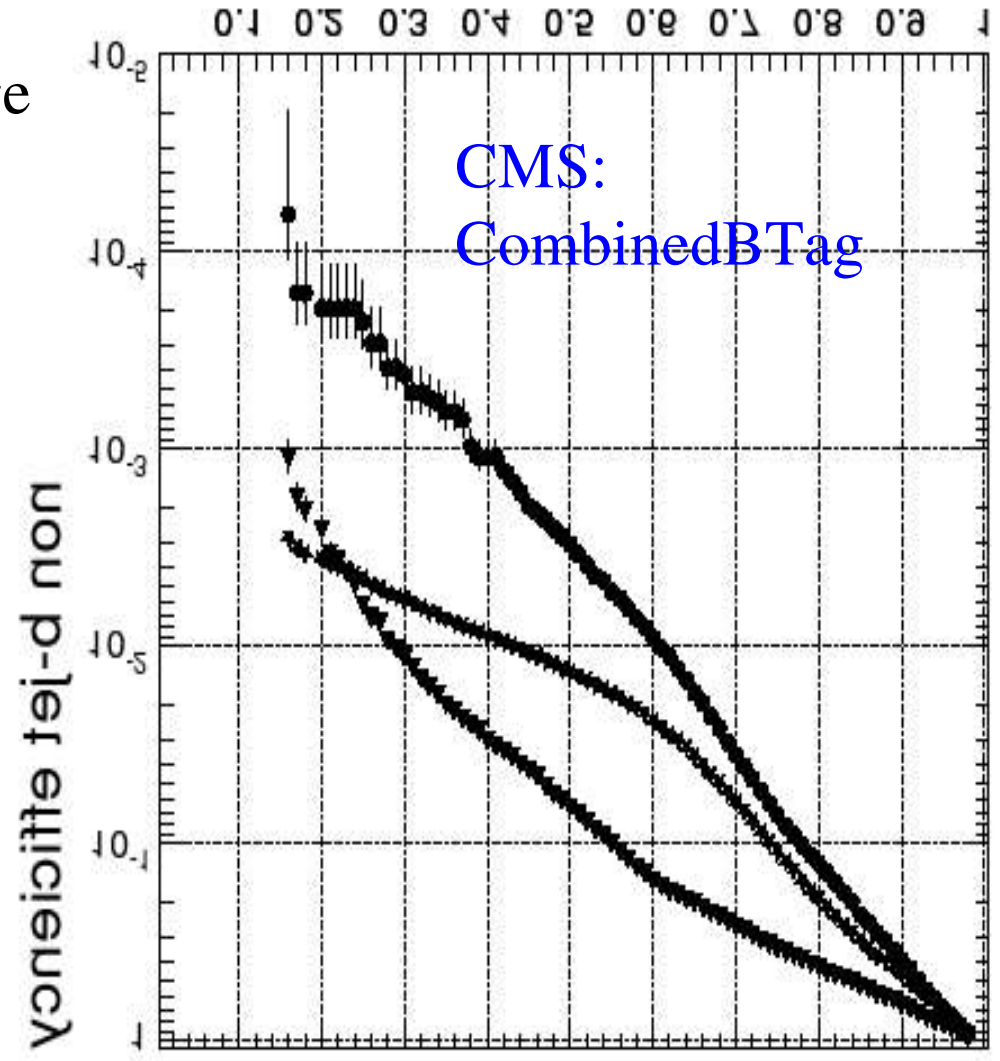
Backup

Backup slides

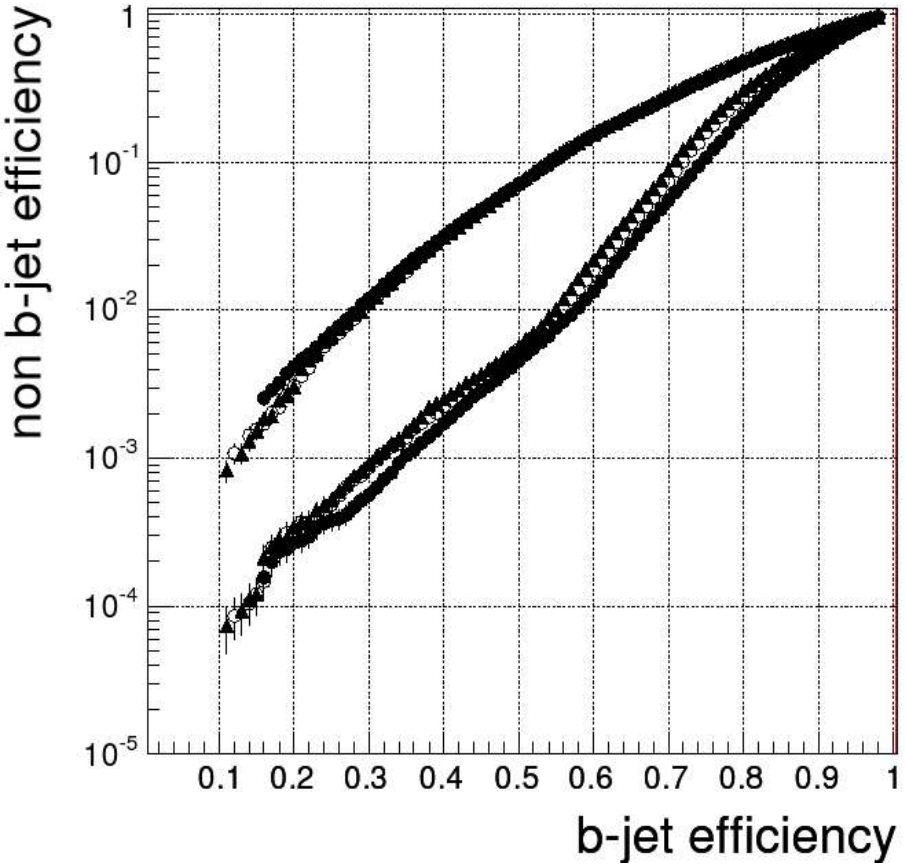
Identification efficiency

DISCLAIMER:
Different sample/Jet energy/Eta range

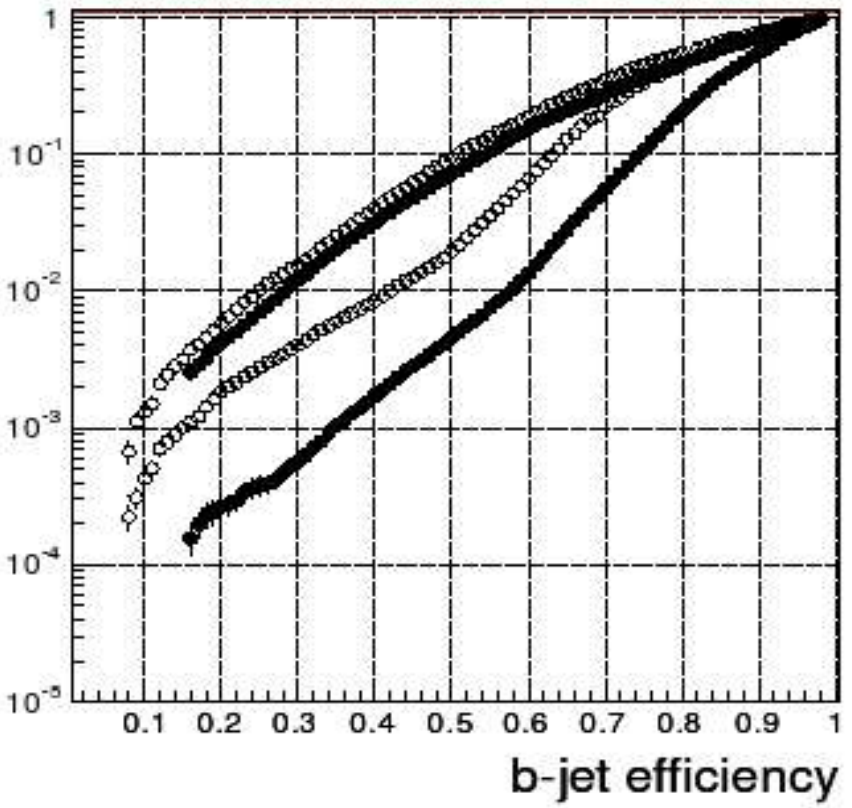




More on mis-alignment



Misalignment effects on secondary vertex based algorithm



Pixel misalignment increased by a factor 3

Conclusion

- Different type of algorithms are implemented
- Atlas and CMS experiments reach similar performances of efficiency vs rejection
- Expected “detector effects” (misalignment, inefficiency, staging in initial detectors) can change rejection up to a factor 2
- ttbar is expected to be best channel for calibration