Impact parameter b-tagging in DELPHES

CP3 - Center for Cosmology, Particle Physics and Phenomenology
UCL, Louvain-la-Neuve
Belgium

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General Idea

- b-jets have charged constituents with large impact parameter
- for each track inside jet, compute $sig(IP) = \frac{IP}{\sigma(IP)}$ in 2D (simpler thanks to analytical formulas)
- count tracks with $sig(IP) >$ cut
- if find more than 2 (high purity) or 3 (high efficiency) such tracks $\rightarrow$ jet is b-tagged

inspired from CMS NOTE 2006 019 and BTV-11-002

Impact parameter smearing module

- In RECO, impact parameter IP is derived from track fitting
- $sigma(IP)$ is correlated with error on p_T, R_{curv} ... (encoded in track covariance matrix)
- Here we assume error can be simply parametrized as f(p_T,η).

Module :

- takes as input tracks
- parameters needed for computation (R_{curv}, (X_c, Y_c)) already saved as members of Candidates in the ParticlePropagator module.
- specify (absolute) impact parameter resolution f(p_T,η) in mm (here we take res = 10 μm if p_T<5 GeV and res = 5 μm if p_T>5 GeV)
- computes coordinates of point of closest approach (X_d, Y_d) to vertex (0,0) and smears (X_d, Y_d) independently $X_d(sm) = X_d + Gaus(0, res)$ (idem for $Y_d(sm)$).
- derive IP(sm) from $(X_d(sm), Y_d(sm))$
- compute independently $\sigma(IP) = |Gaus(0, res)|$.
- save these quantities as track members.

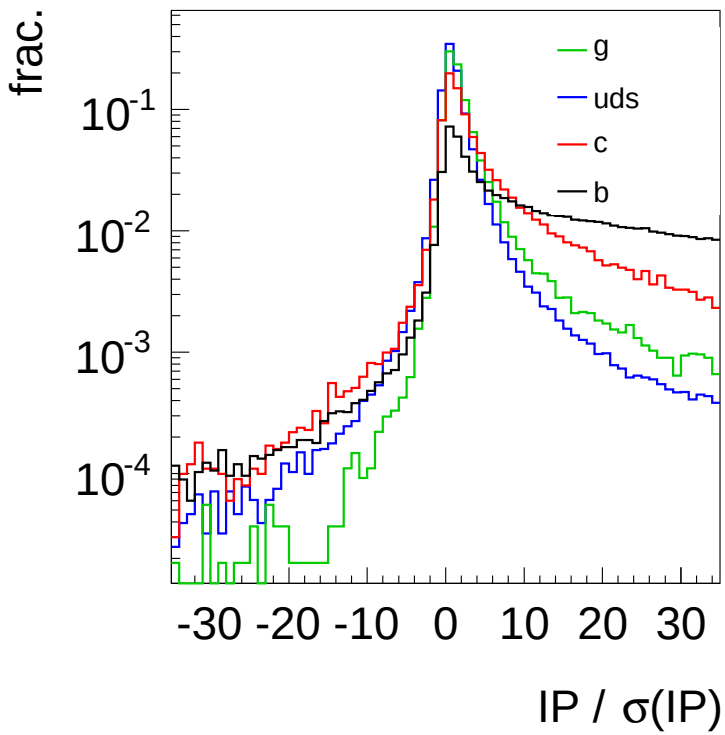
IP BTagging module

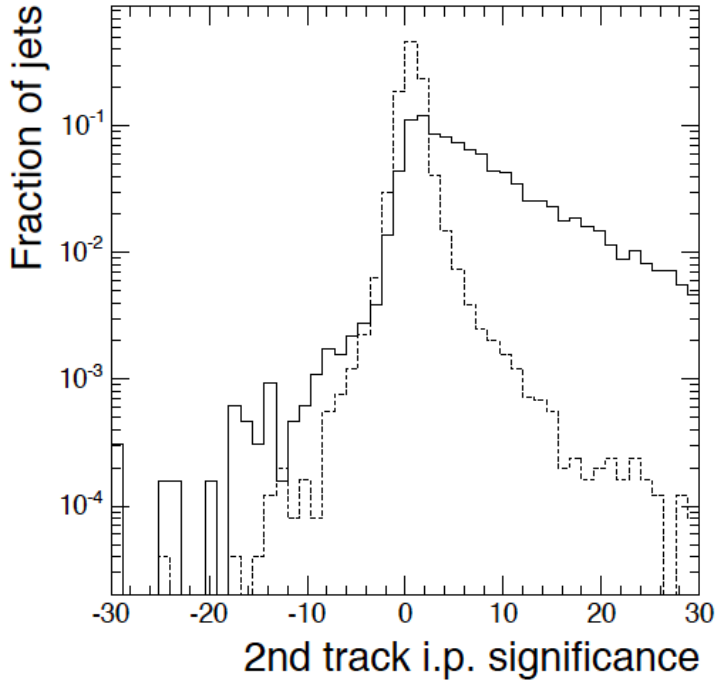
- takes as input track and jet collections (alternatively could take simply jet collection using chaged jet constituents as tracks)
- parameters :
  - p_T^{min} = 1 GeV of the tracks
  - ΔR cone to associate tracks with jet (typically $\Delta R = 0.3$)
  - IP_{max} = 2 mm
  - $sig(IP)_{min}$ (algo working point)
  - N_{tracks}, defines algorithm. Minimum number of tracks that pass sig(IP) cut ($=$ 2 for HP, $=$ 3 for HE)
- compute sig(IP) = sign($\mathbf{p_T^{jet}} \cdot \mathbf{IP}$) IP.
- flag BTAG set to true if at least N_{tracks} with $sig(IP) > sig(IP)_{min}$ are found.

IP BTagging module

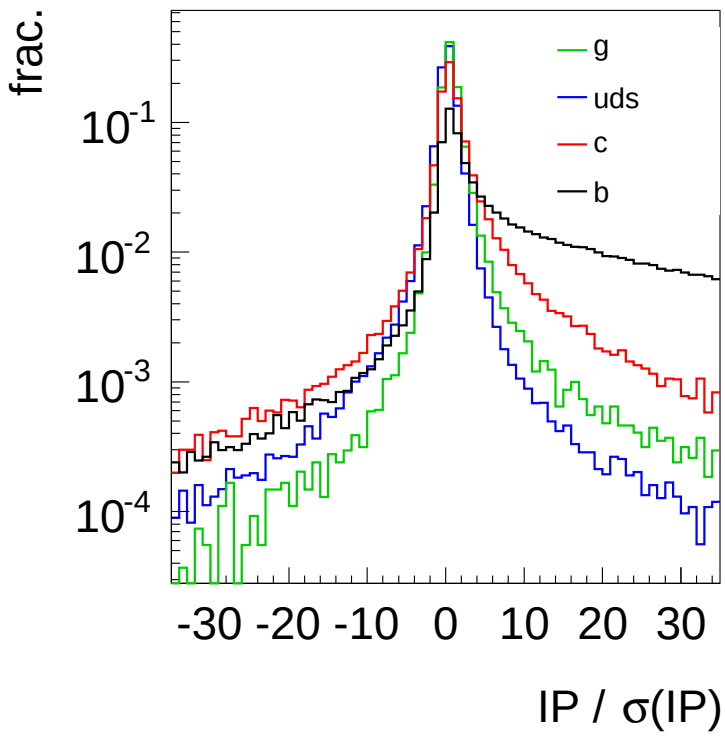
```
#############################
# Track Counting b-tagging
#############################

module TrackCountingBTagging TrackCountingBTagging {
  set TrackInputArray Calorimeter/eflowTracks
  set JetInputArray JetEnergyScale/jets

  set BitNumber 0

  # maximum distance between jet and track
  set DeltaR 0.3

  # minimum pt of tracks
  set TrackPTMin 1.0

  # minimum transverse impact parameter (in mm)
  set TrackIPMax 2.0

  # minimum ip significance for the track to be counted
  set SigMin 6.5

  # minimum number of tracks (high efficiency n=2, high purity n=3)
  set Ntracks 3
}
```

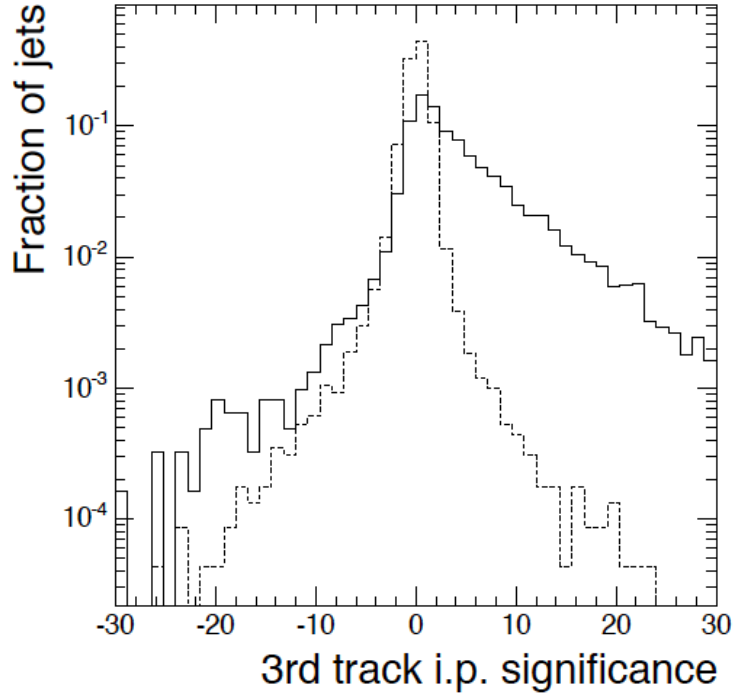
IP Significance (HE)



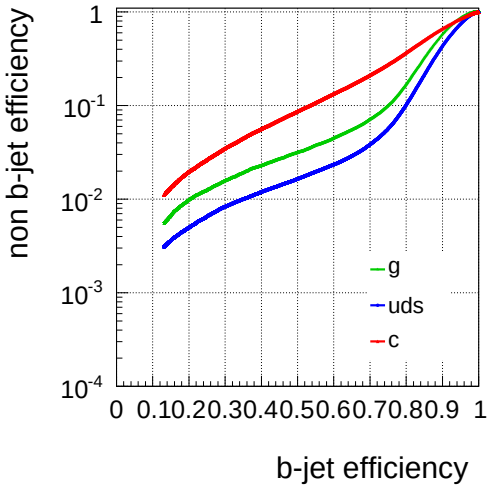


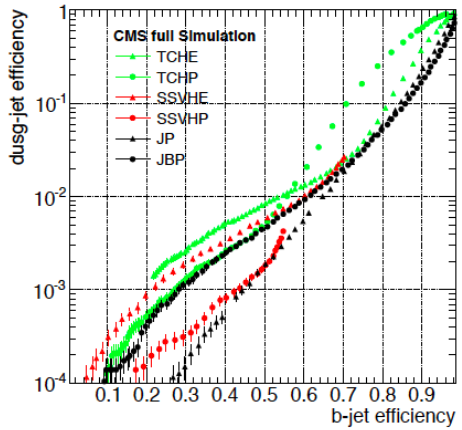
IP Significance (HP)

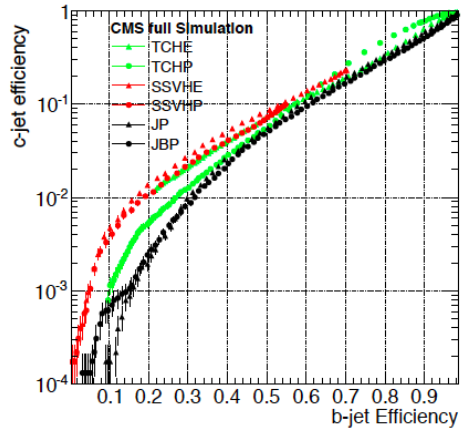




Performance : High Efficiency







- c mistag rate agrees ok
- too pessimistic light rejection for low btagging efficiency

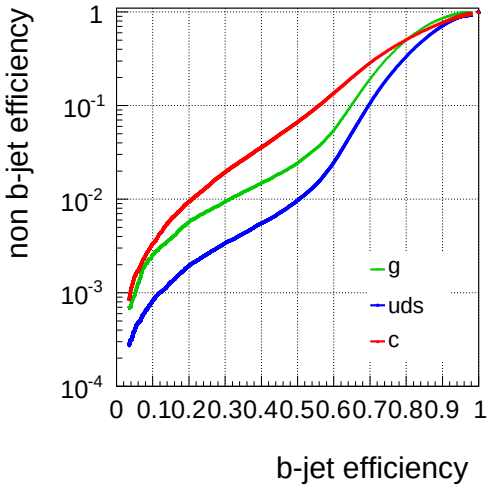
At 80% b-tagging efficiency (Loose working point) :

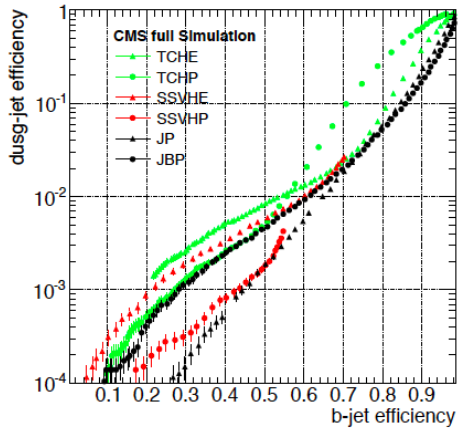
DELPHES : l-mis = 10%, c-mis = 35%

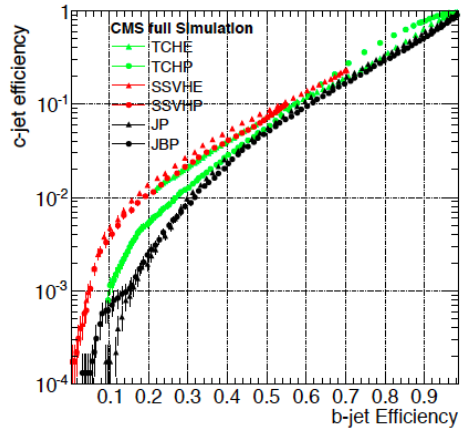
CMS : l-mis = 10%, c-mis = 30%

$$sig(IP)_{min} = 4.5$$

Performance : High Purity







- c mistag rate agrees ok
- too pessimistic light rejection for low btagging efficiency

At 55% b-tagging efficiency (Medium working point) :

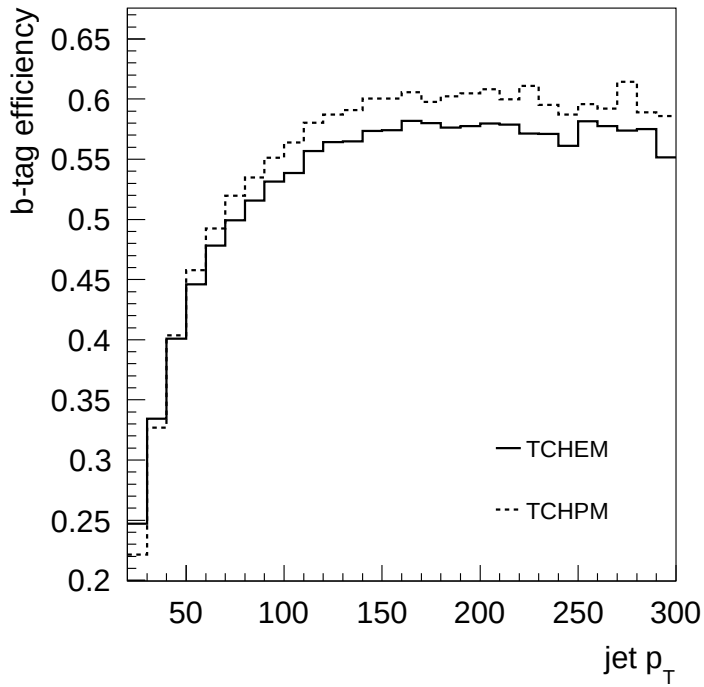
DELPHES : l-mis = 1.5%, c-mis = 10%

CMS : l-mis = 1.0%, c-mis = 10%

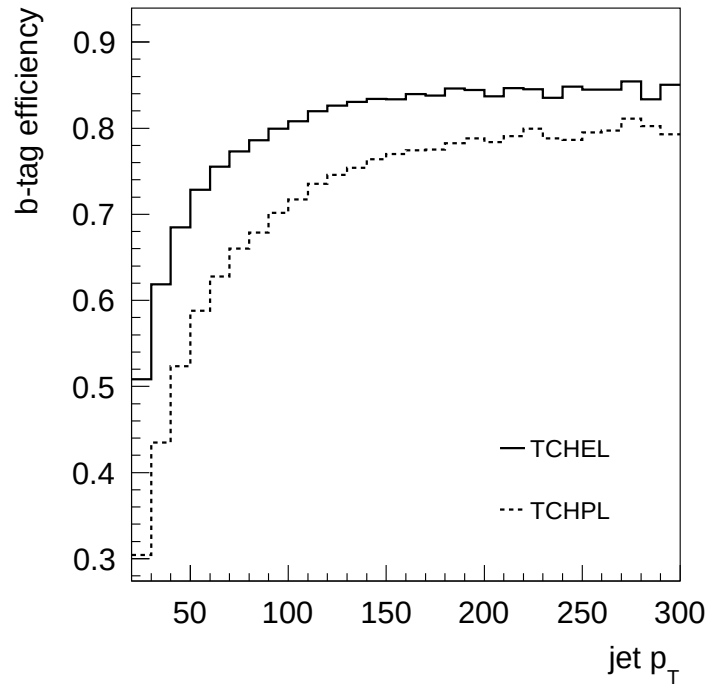
$$sig(IP)_{min} = 6.5$$

Performance : b-tag efficiency vs. p_T

Medium working point

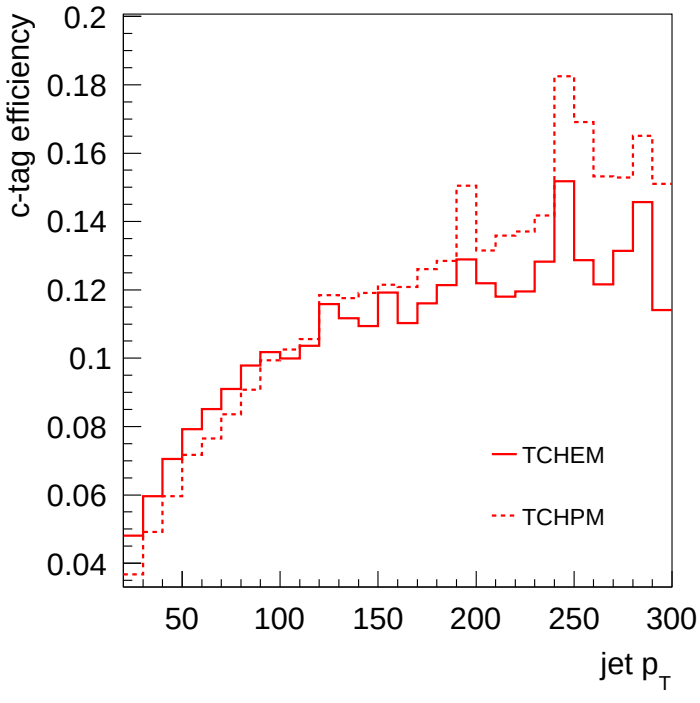


Loose working point

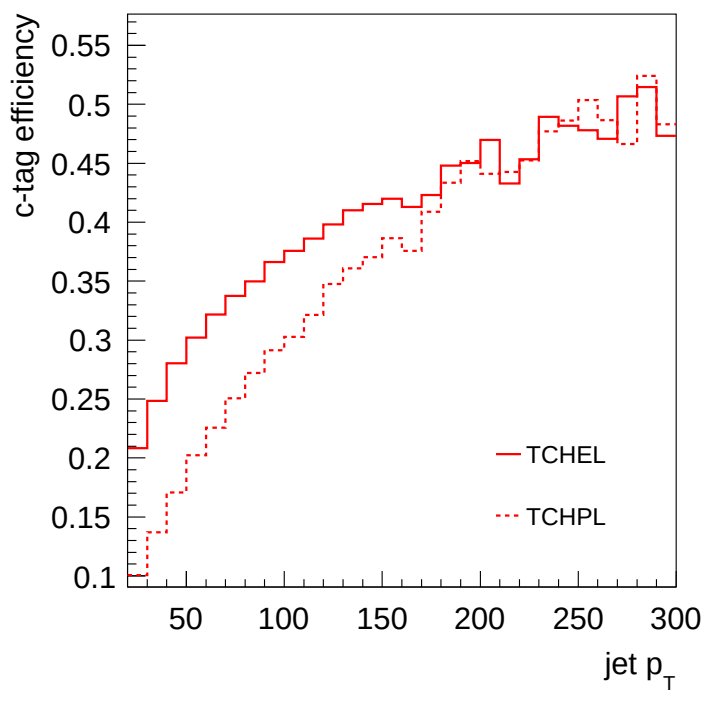


Performance : c-tag efficiency vs. p_T

Medium working point

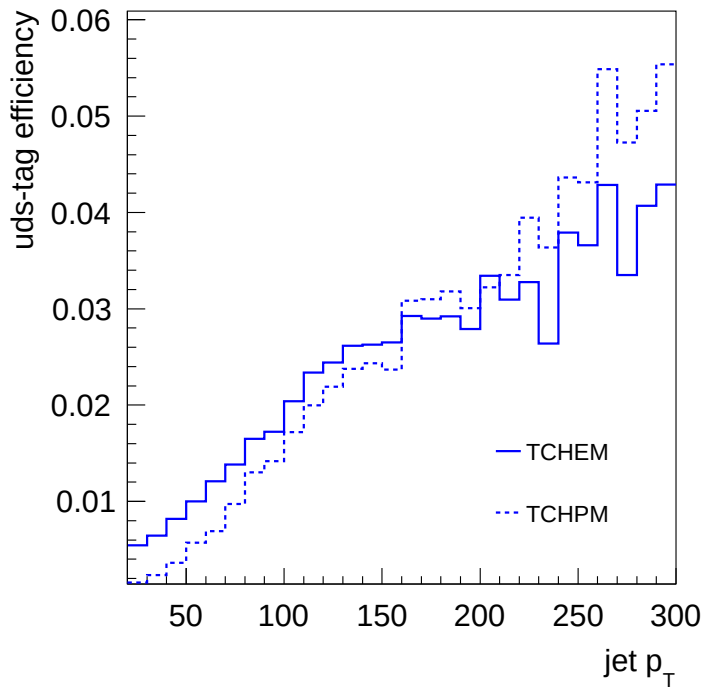


Loose working point

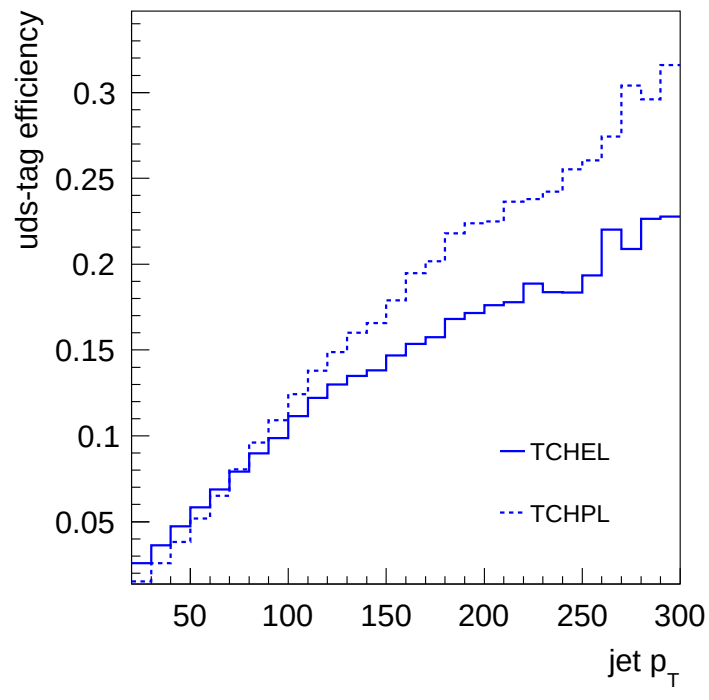


Performance : light-tag efficiency vs. p_T

Medium working point

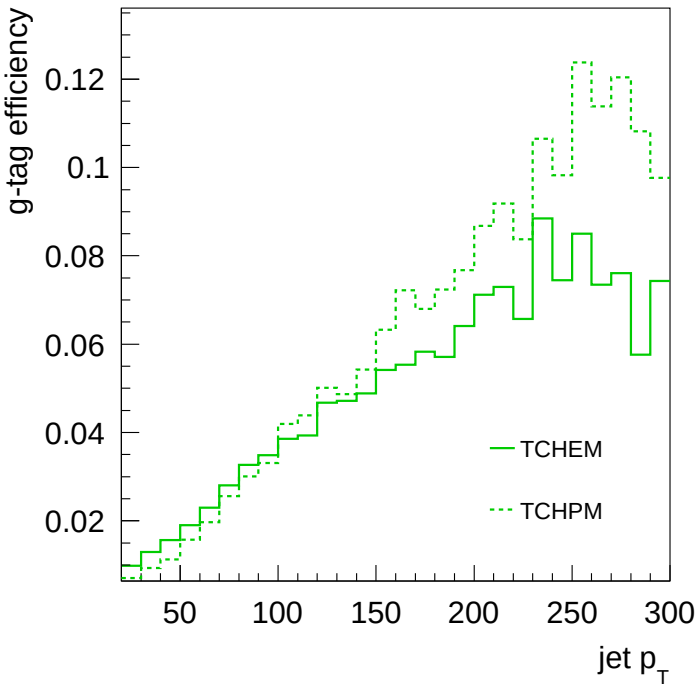


Loose working point

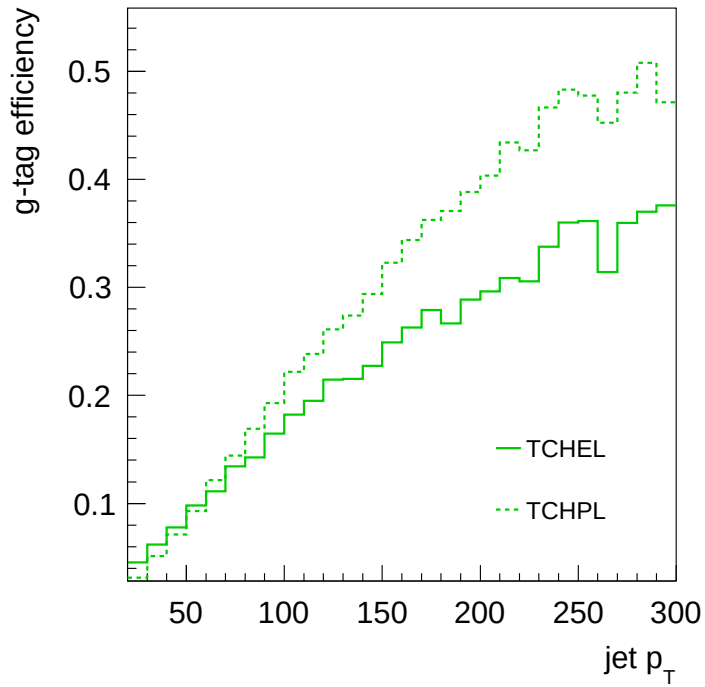


Performance : gluon-tag efficiency vs. p_T

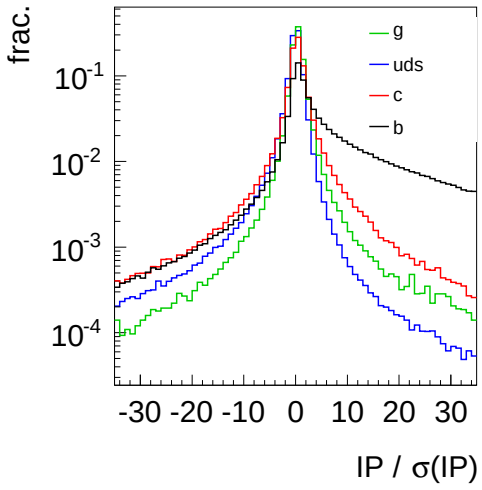
Medium working point

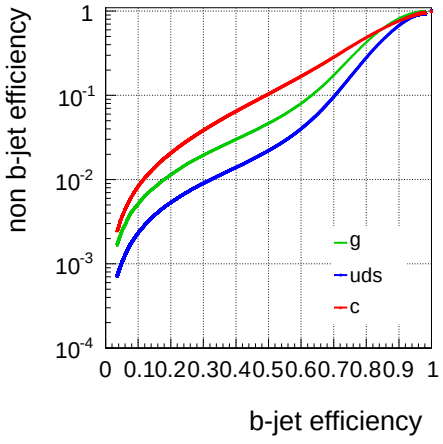


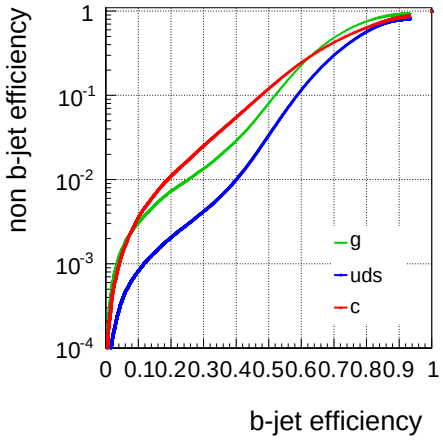
Loose working point



Performance vs impact parameter resolution (1)



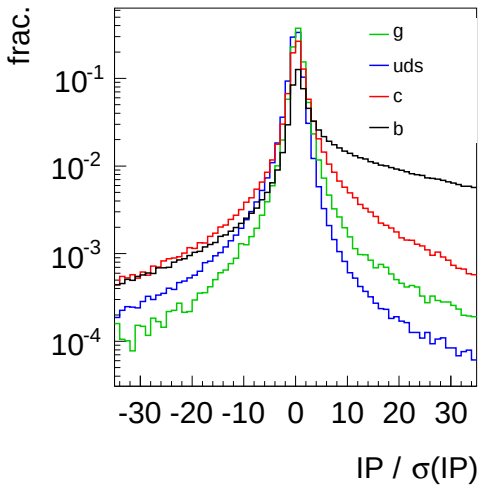


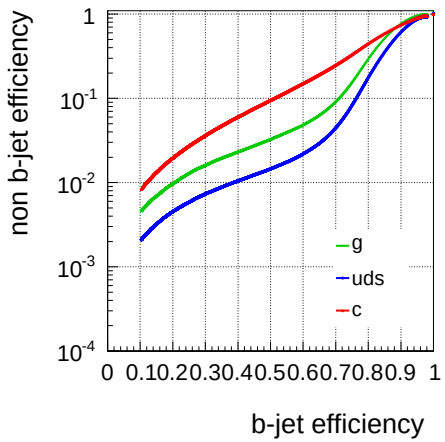


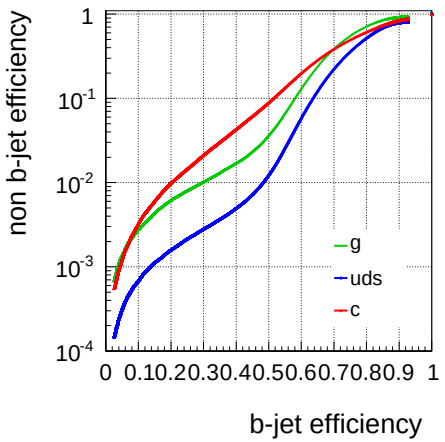
$$p_T < 5GeV\ \sigma(IP) = 20\ \mu m$$

$$p_T > 5GeV\ \sigma(IP) = 10\ \mu m$$

Performance vs impact parameter resolution (2)



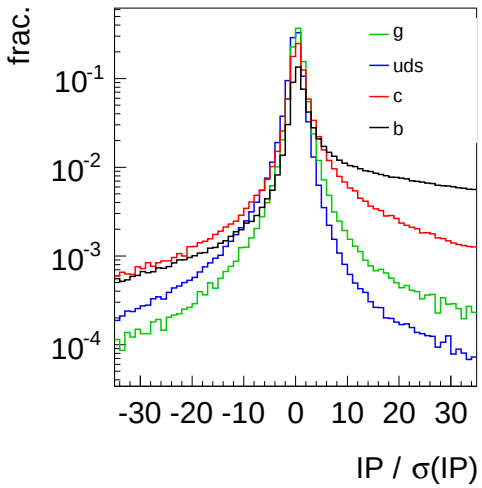


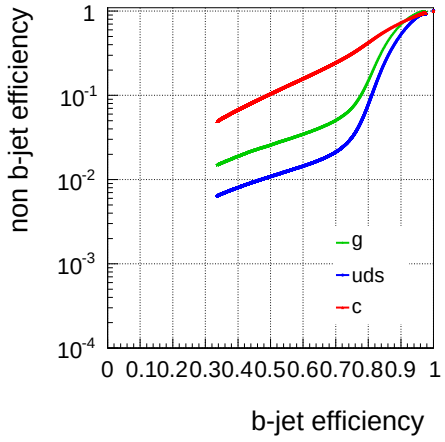


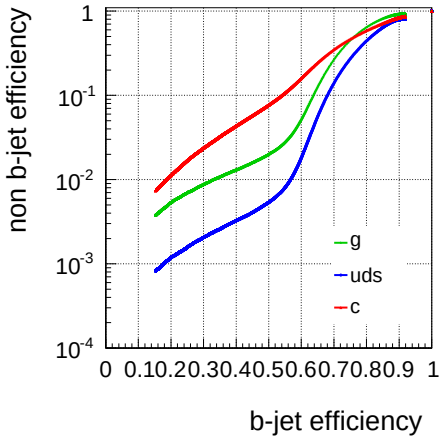
$$p_T < 5GeV\ \sigma(IP) = 10\ \mu m$$

$$p_T > 5GeV\ \sigma(IP) = 5\ \mu m$$

Performance vs impact parameter resolution (3)







$$p_T < 5GeV \ \sigma(IP) = 5 \ \mu m$$

$$p_T > 5GeV \ \sigma(IP) = 1 \ \mu m$$

Conclusions

- decent agreement, but needs to be tuned
- present module can be modified by user to incorporate additionnal features (3D IP, flight distance ...)