Update on jet flavour tagging using ParticleNet

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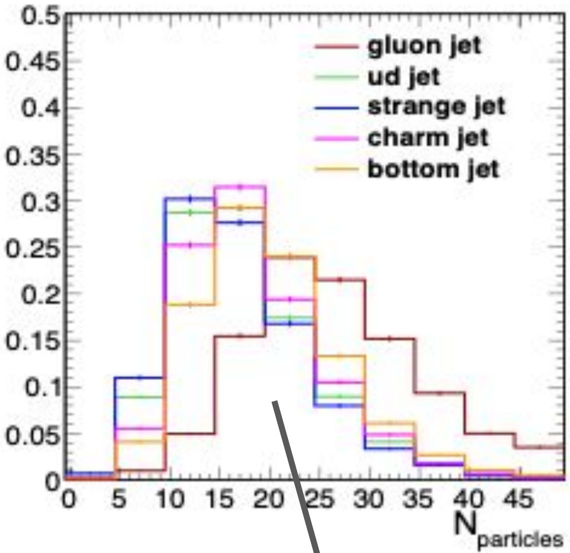
FCCee Physics Performance meeting
Mon, Oct 19, 2020

Introduction

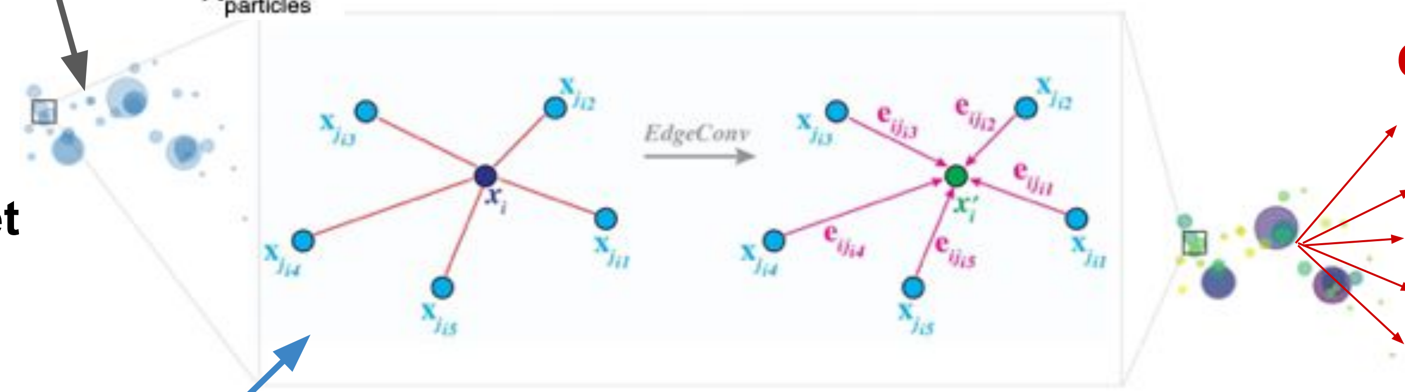
- General goal of the study:
  - Flavour identification (tagging) at FCCee
  - Application on challenging physics processes, e.g., ZH(→bb/cc/gg)
  - Aid the detector’s design (i.e, inner tracking)
- Recap from last FCC-ee Physics Performance meeting (Sep 21):
  - presented a first implementation of flavour tagging algorithm [slides]
    - Based solely on low-level features [i.e. PF candidates]
    - Precesses [Z(→vv)H→(bb/cc/ss/uu(dd)/gg)] generated using MG5+P8
    - Detector response simulated using Delphes
      - FastTrackCovariance [from Franco Bedeschi] included
    - Jets clustered using the generalized kT algorithm with R=1.5
      - Another area to study further
- Short term plans:
  - Optimize the flavour tagging algorithm
  - Compare performance with BDT-based approach [i.e. higher level inputs]
  - Compare performance between FullSIM and Delphes
- Today:
  - Algorithm optimization + comparison between CLD and IDEA

ParticleNet for jet tagging at the FCCee



Training details:
- 1M jets split equally between classes
- preprocessing of inputs
- Lots of room for improving the training details

Inputs:
50 particles/jet



Output:
g
ud
s
c
b

Particle features: 21/particle

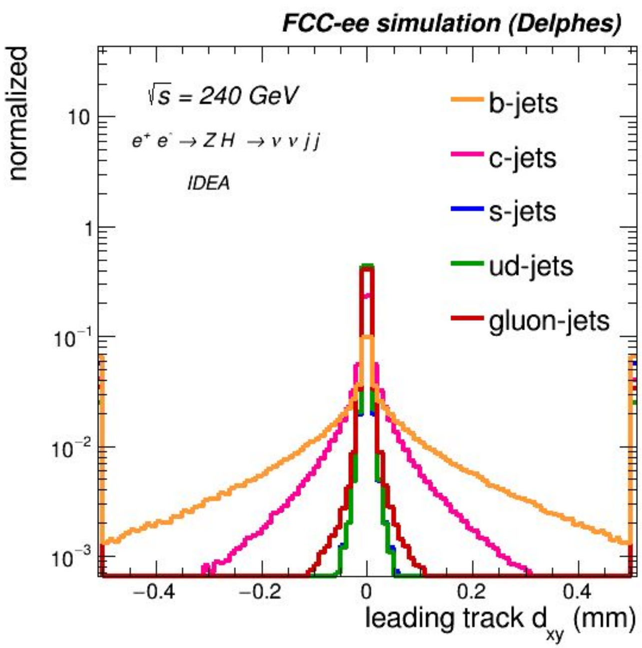
Particle kinematics, charge,
Impact parameter (d0, dz) and significance,
particle type (el, mu, gamma,...)

More details: talk

Input variables: IDEA

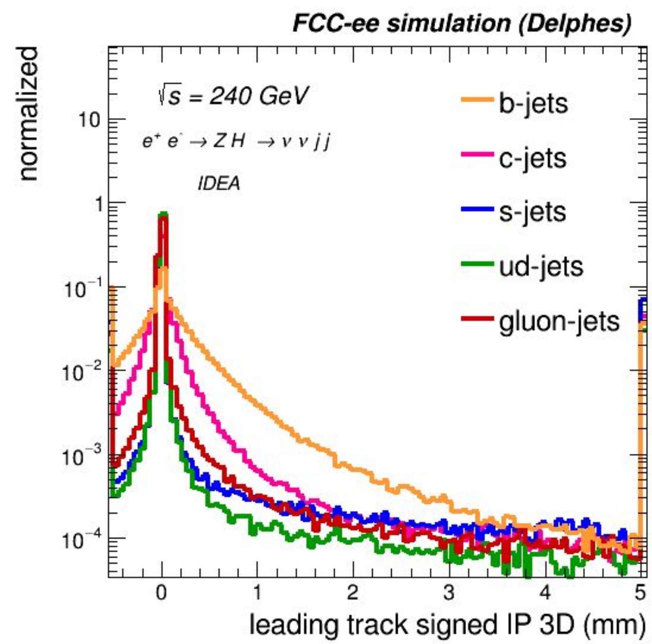
- Comparison of the input distributions for different jet flavours:
  - https://selvaggi.web.cern.ch/selvaggi/FCC/FCCee/FlavourTagging/flavour/
  - Includes also comaprisons for different clustering algorithms and detector configurations (IDEA vs. CLD)

d_{xy} impact parameter



IDEA

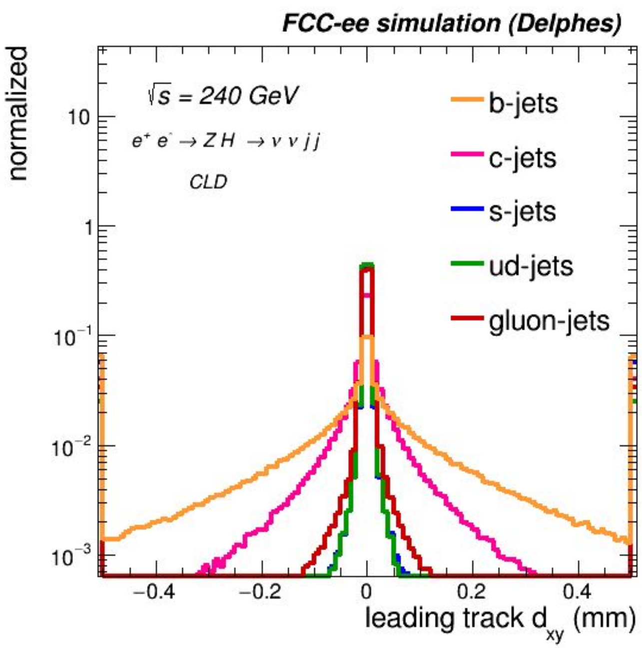
Signed IP 3D



Input variables: CLD

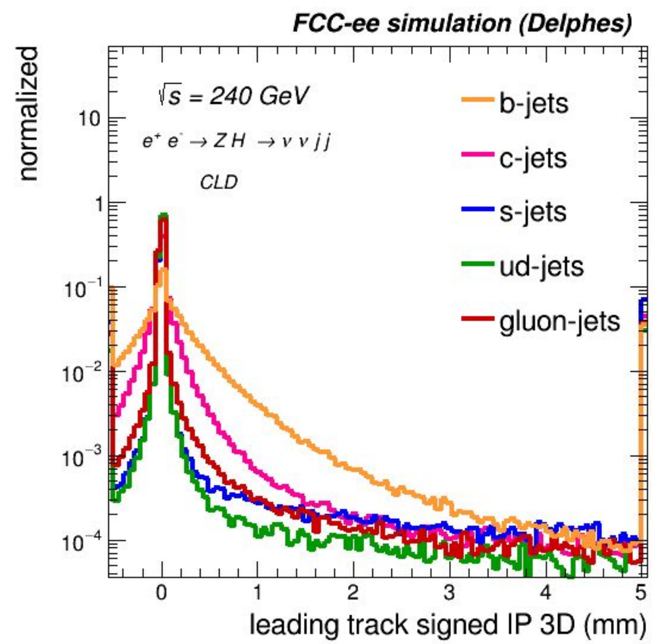
- Comparison of the input distributions for different jet flavours:
  - https://selvaggi.web.cern.ch/selvaggi/FCC/FCCee/FlavourTagging/flavour/
  - Includes also comaprisons for different clustering algorithms and detector configurations (IDEA vs. CLD)

d_{xy} impact parameter



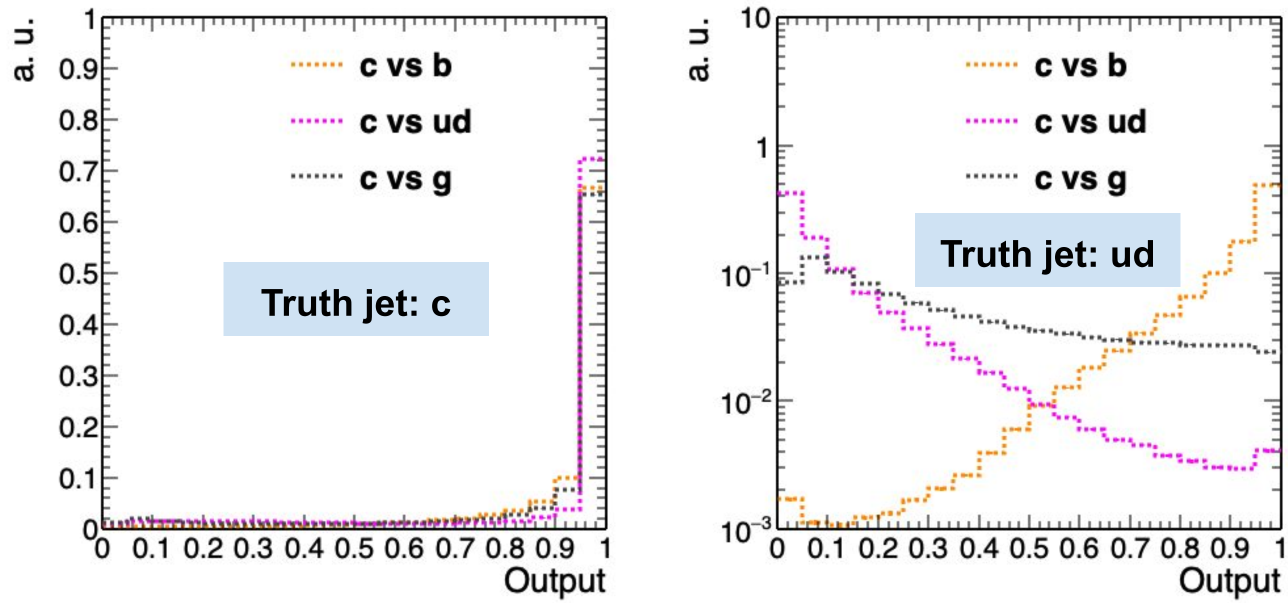
CLD

Signed IP 3D

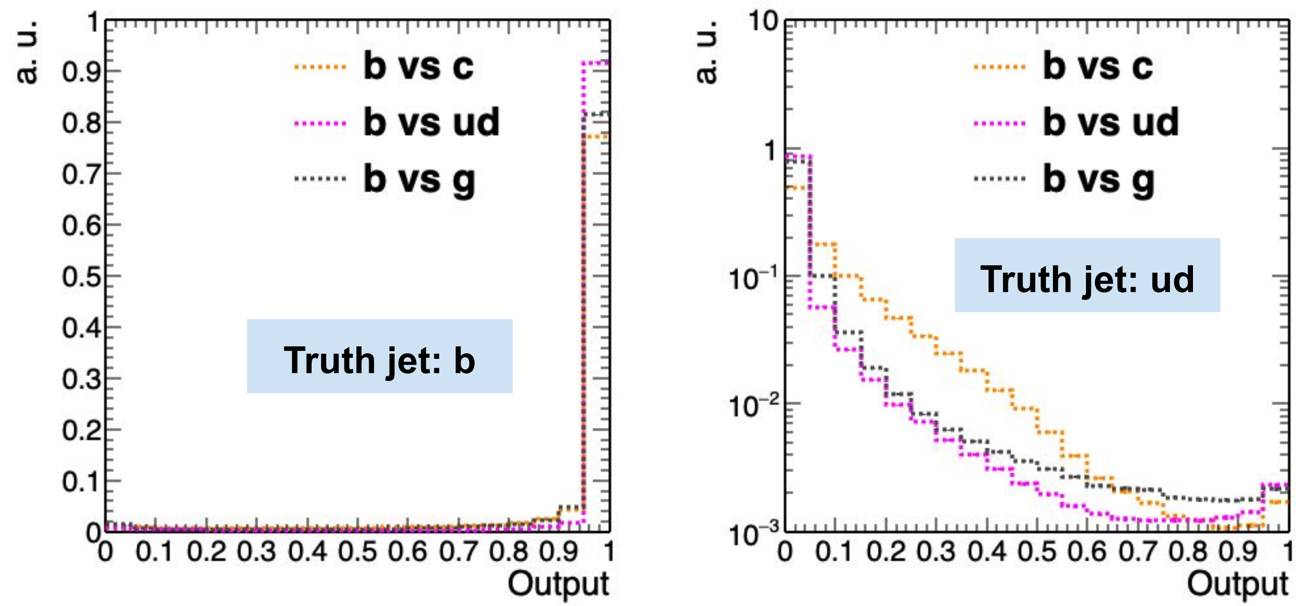


Output scores: b and c tagging

- Charm tagging:

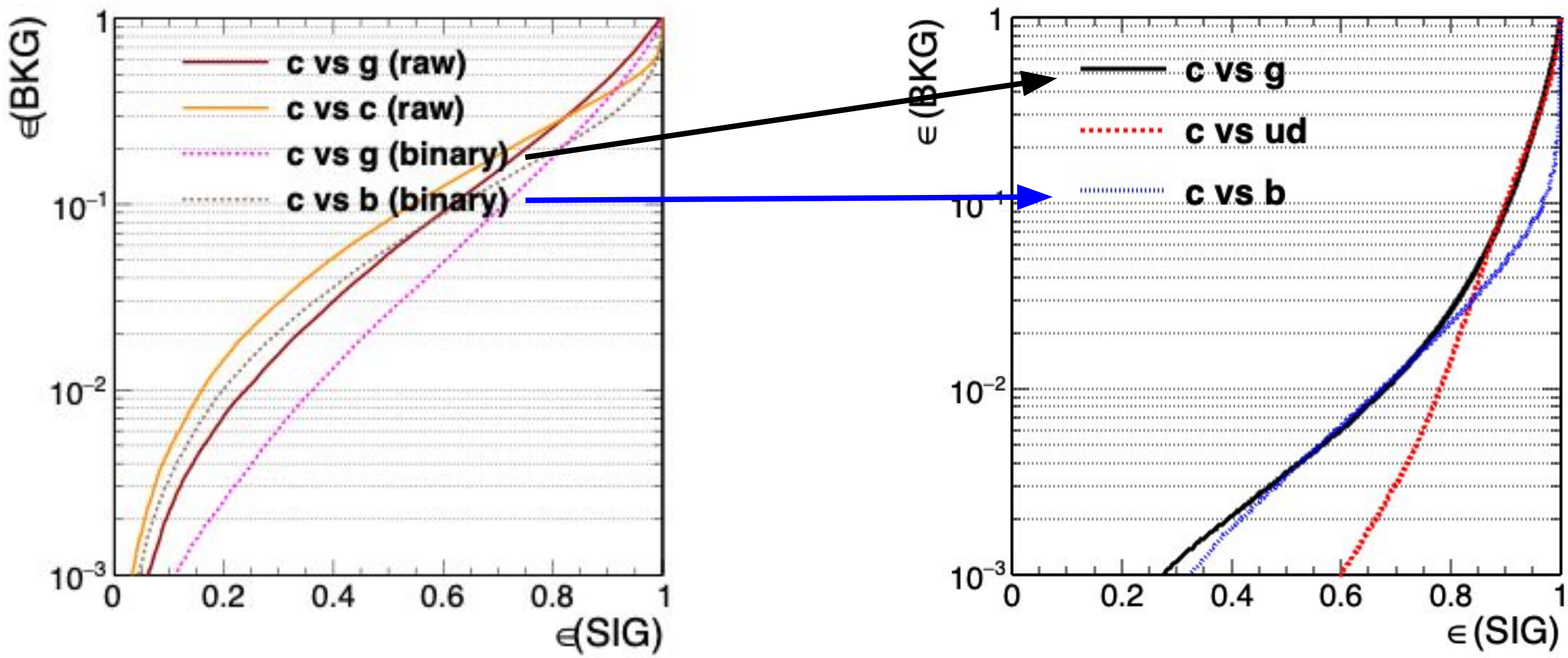


- Bottom tagging:



Performance [IDEA]

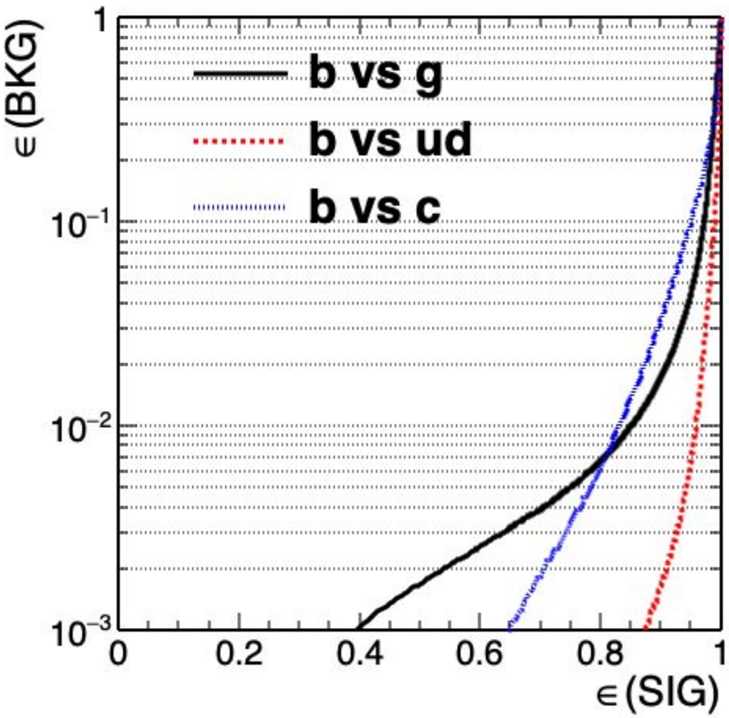
From Sep 21: → **Today:**



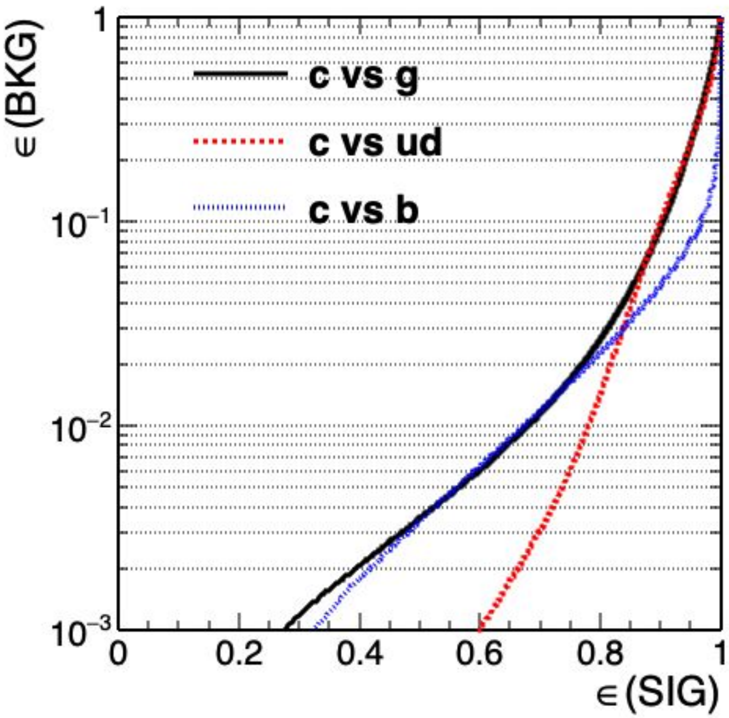
- Improvement in performance mainly due to optimization of the training details (sample size, training configuration..)
- Small tweaks in the input features and #of particles

Performance IDEA (II)

b-tagging



c-tagging



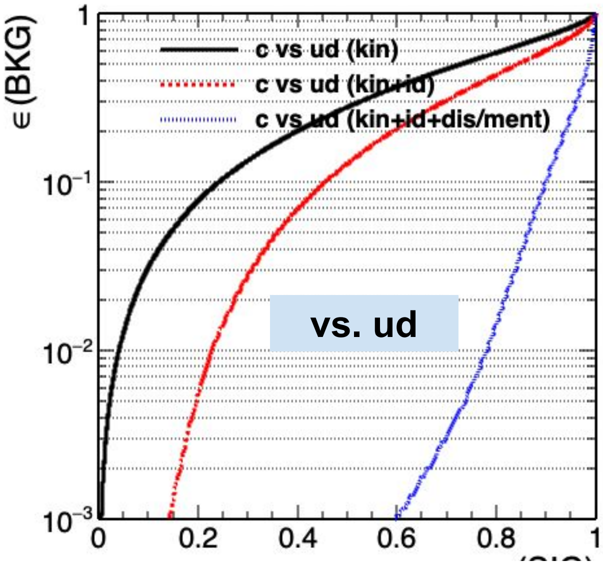
- B-tagging: ~95 (85)% eff, for ~1% ud (g) mistag
- C-tagging: ~75 (65)% eff, for ~1% ud (g/b) mistag

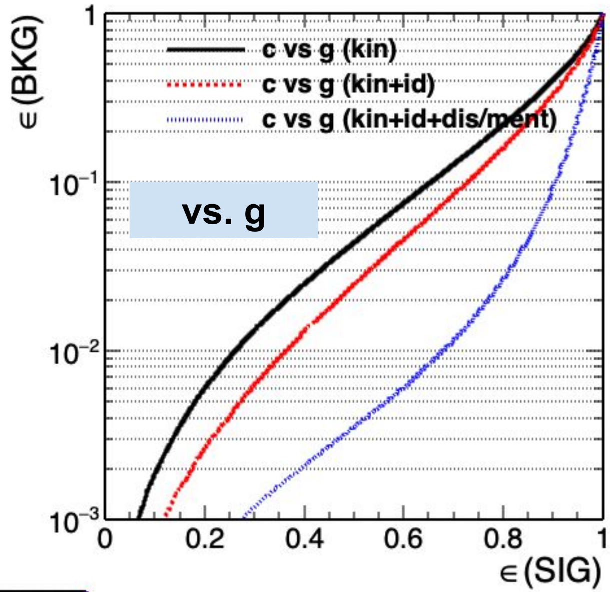
NB: based on Delphes samples [parametrized response, no fakes..]

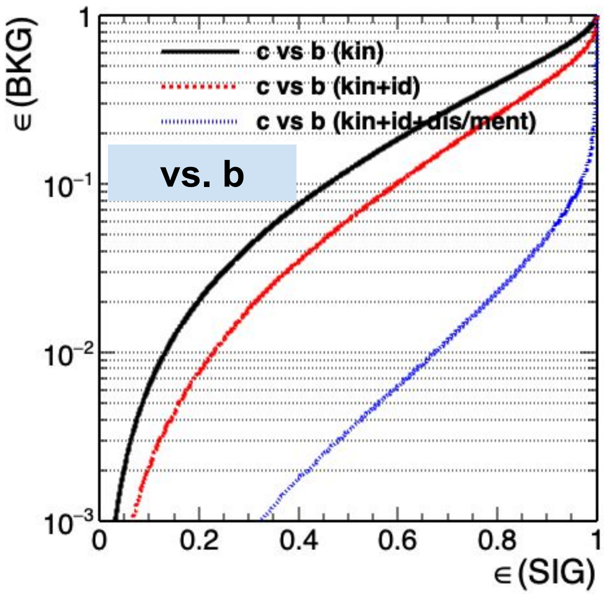
Understanding performance: c-tagging

- Perform algorithm training using different sets of inputs:
  - **"Kin":** PF candidate 4-vector
  - **"Kin+id":** "kin" + PF charge and PF type [el, mu, γ, nhadron, chadron]
  - **"Kin+id+dis/ment":** "kin + id" + info related to track displacement
    - Nominal version of tagger [used for the previous slides]

Understanding performance: c-tagging

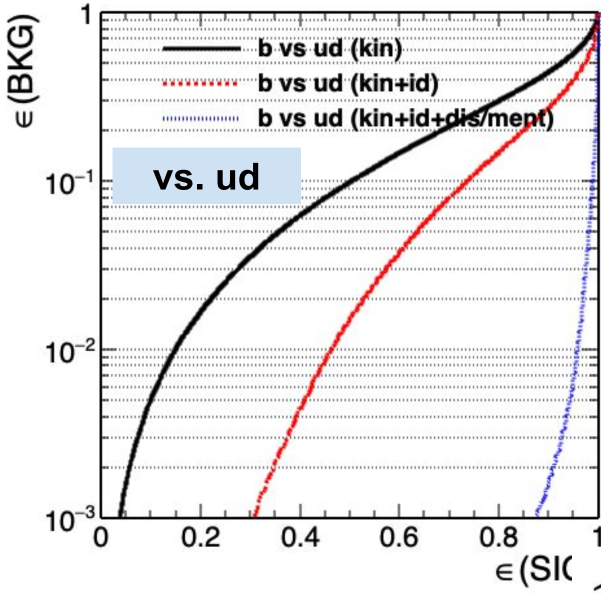


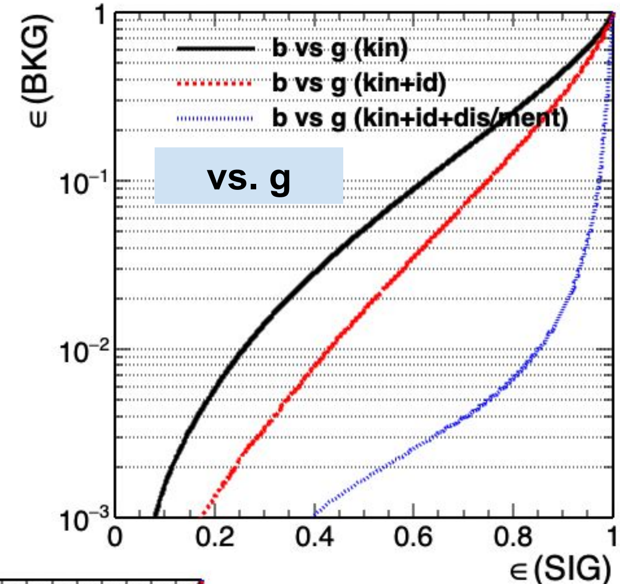


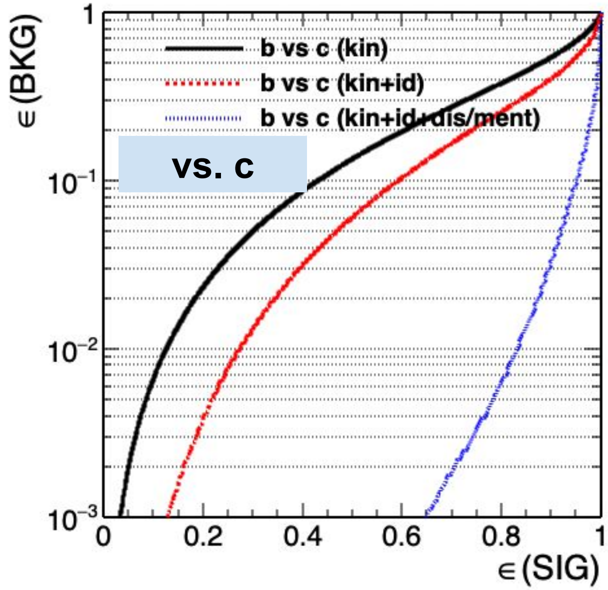


- Behavior as expected [at least qualitatively]

Understanding performance: b-tagging



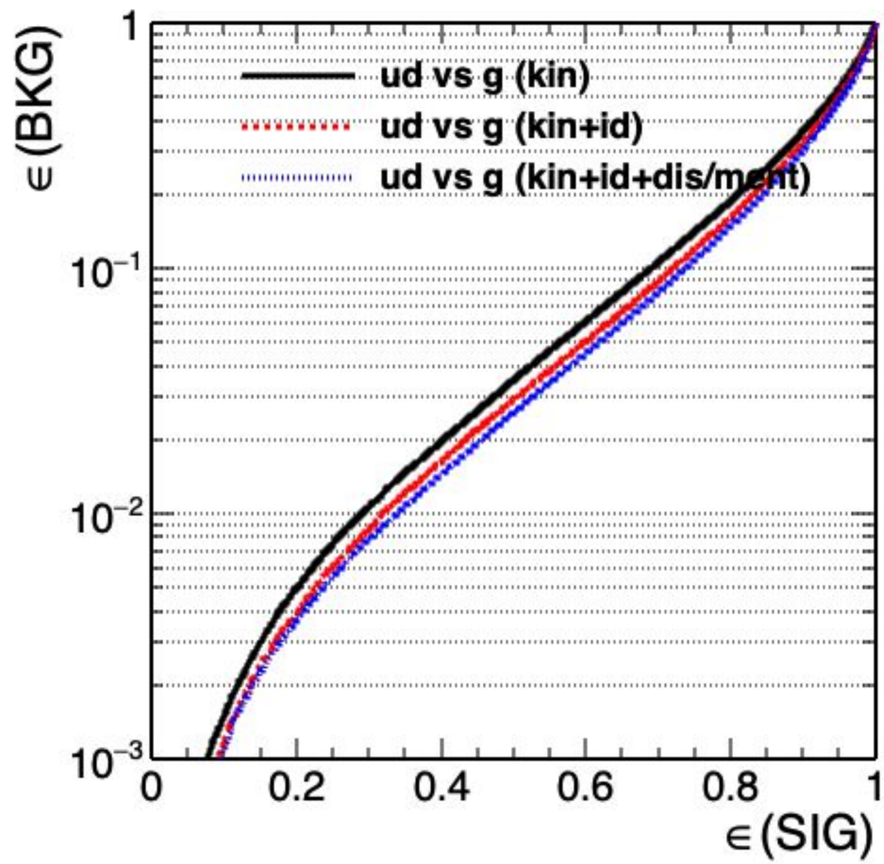




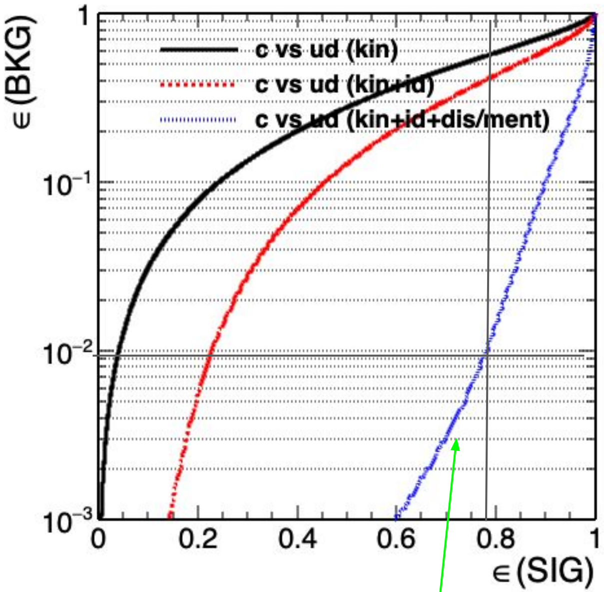
- Behavior as expected [at least qualitatively]

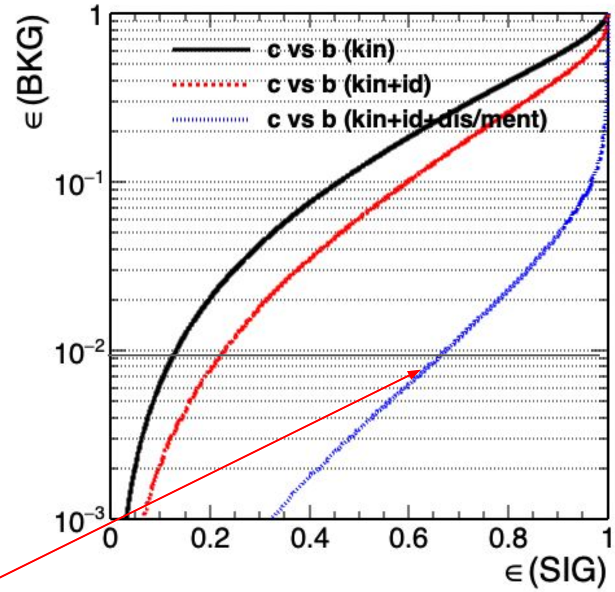
Understanding performance:qg tagging

- On the other hand:
  we do not expect big difference in light quark-gluon separation on top of "kin" set of inputs

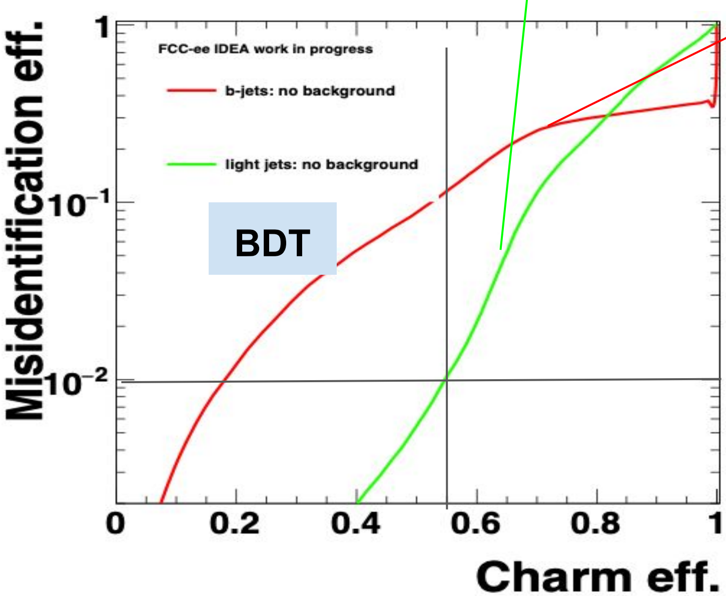


Comparison with BDT





From Clement's talk:

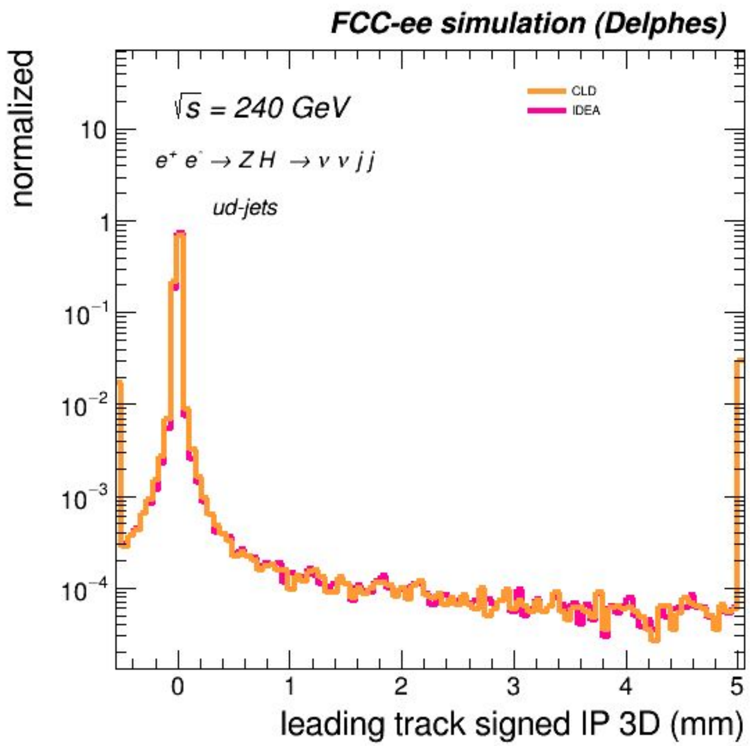


BDT approach:
- Super early attempt [clearly not for final conclusions]
- Parametrized detector response (Delphes) [but different processes for the training Z→qq (BDT) vs. H→qq (ParticleNet)]
- Higher level inputs [human inspired]

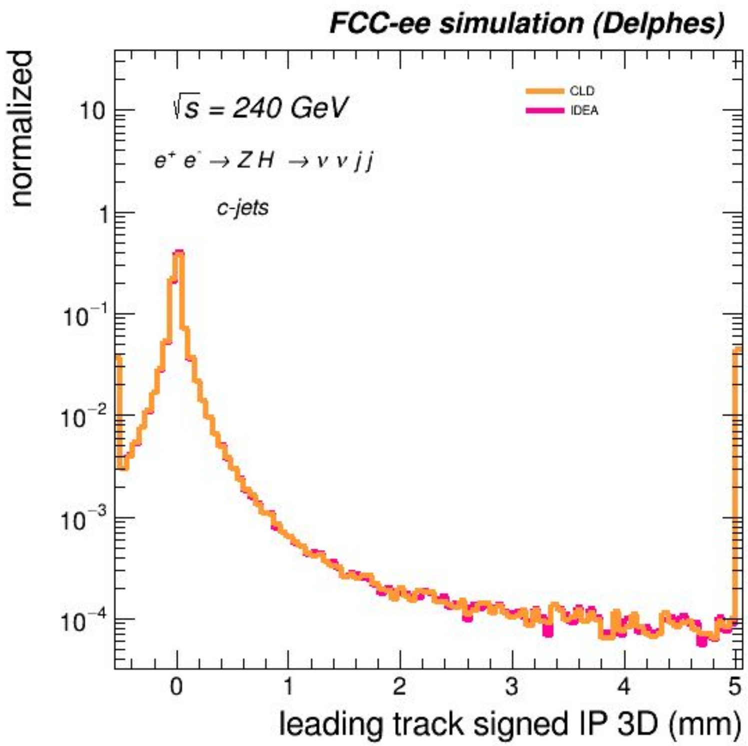
Comparison: IDEA vs. CLD

- No big differences between in input variables between IDEA & CLD
  - small difference in material budget observed on light jets since dxy ~ 0
    - expect slightly better performance for IDEA detector for discrimination vs light

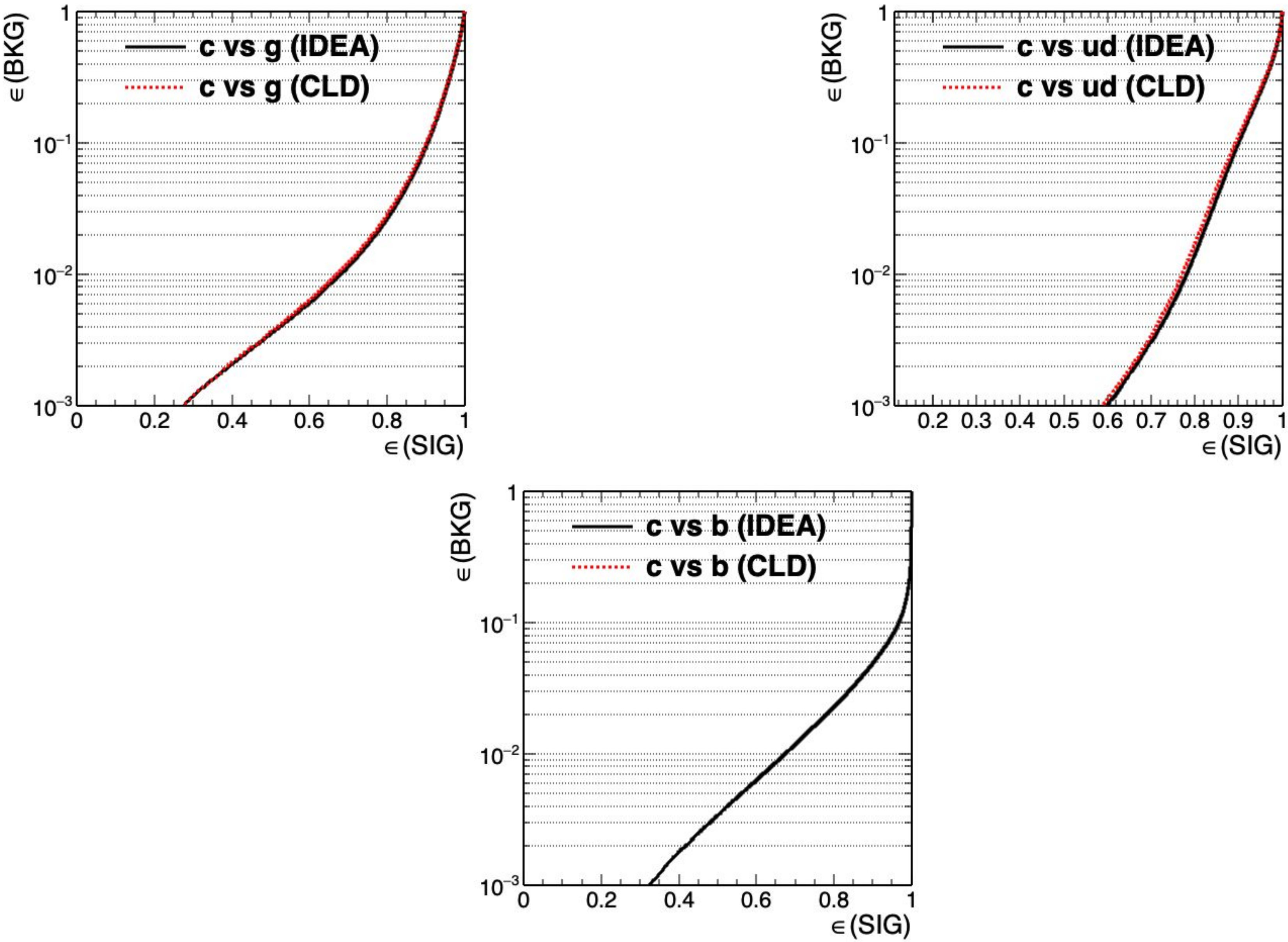
ud-jets



c-jets



Comparison: IDEA vs. CLD [c-tagging]



In practice

Back of the envelop estimate:

– FCCee: σ(ZH) = 200 fb, L = 5ab-1(2IP) ~ 1M ZH events

[600k H→bb, 100k H→gg, 30k H→cc]

– Scenario:

OLD: c-tag: 70%, b-mistag: 10%, g-mistag:~10%

NEW: c-tag: **80%**, b-mistag: **2.5%**, g-mistag:**~2.5%**

δ(σBR)/σBR (%) ~ 1.5 → **1.0** [no systematics]

– Improved b/g rejection resulted to ~1% uncertainty (not yet optimize detector design)

Summary & outlook

- A first version of a jet identification algorithm based on PF candidates and advanced ML in place
  - Results promising [that beg scrutiny!]
- Next [short term] steps:
  - Compare performance with existing BDT-based algorithms using the same events (FastSim low-level vs High level)
    - Partially shown here but $H \rightarrow jj$ vs. $Z \rightarrow jj$
  - Compare Delphes vs. FullSim (both using “low” and “high” level training)
  - Check the impact of perfect PID on tagging performance
- Next [med-term] steps:
  - Add reco. vertex information in “low level” training (cf. Clement’s talk)
    - Check impact of V0 rejection
  - Optimize vertex detector

Backup

IDEA vs CLD material budget