ParticleNet-based flavour tagging including strange-tag for MiniDSTs

Uli Einhaus
ILD Sw & Ana Meeting
02.10.2024

HELMHOLTZ

KIT
Karlsruher Institut für Technologie

DESY.

Overview
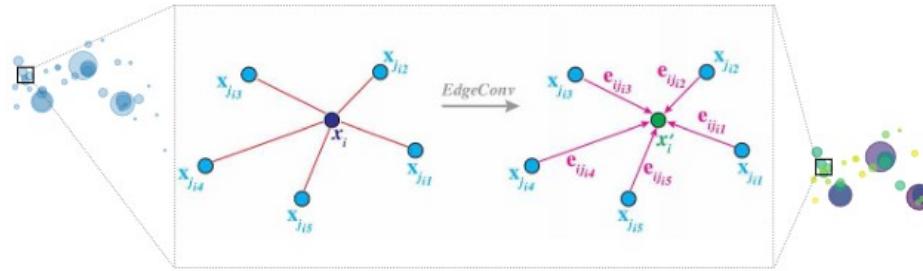
- LCFIPlus has been a standard tool for flavour tagging for 10+ years

- Possible architecture and inputs have improved, various studies with ML/NN approaches, several in the ECFA context

- Mareike Meyer used ParticleNet applied to ILD simulation data with inputs and tags (b/c/light) like LCFIPlus for a direct comparison → great improvement

- Also: great interest in strange tagging via kaonID

- New: added CPID to (ILD) ParticleNet, trained with s-tag output, implementation in ILD reconstruction chain ongoing

Karlsruher Institut für Technologie

ParticleNet

arXiv:1902.08570, *Pushing the Limit of Jet Tagging With Graph Neural Networks*, Huilin Qu, talk at ML4Jets2021, July 7, 2021

- treat jet as „particle cloud"
- input: **jet constituents**
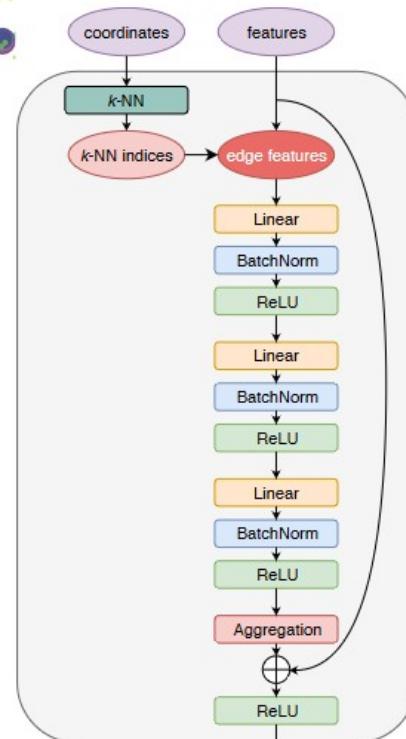
key building block: **edge convolution**

- particle cloud: graph, each point: vertex, connections between each point & k nearest neighboring points: edges
- learn an „**edge feature**" for each pair:
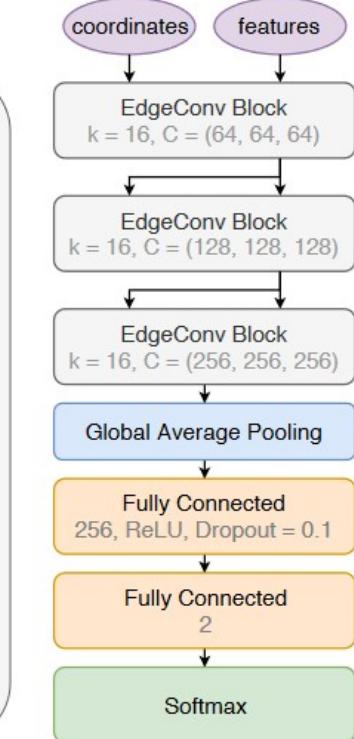
$$e_{ij} = MLP(x_i, x_j)$$

- **MLP**: parameters **shared among all edges**
- **aggregation** of edge features: $x_i' = \text{mean}_j\, e_{ij}$

edge convolution

ParticleNet

Used features

jet constituents: coordinates

$\Delta\eta$, $\Delta\Phi$

jet constituents: features

$\Delta\eta$, $\Delta\Phi$, η

$\log(p_T)$, $\log(E)$, $\log(p_T/p_T^{jet})$, $\log(E/E^{jet})$, $\vec{p}^{\,track} \cdot \vec{p}^{\,jet}/p^{jet}$

ΔR

q

isElectron, isMuon, isChargedHadron, isNeutralHadron, isPhoton

impact parameter & significances

impact parameter tag probabilities

track used in PV?

lepton related variables

pid variables → now including CPID: {e, μ, π, K, p} scores

$E_{HCAL}/E_{HCAL+ECAL}$

χ^2/ndf

~~34~~ **39 input features**

secondary vertices: coordinates

$\Delta\eta$, $\Delta\Phi$

secondary vertices: features

$\Delta\eta$, $\Delta\Phi$

$\log(p_T)$, E_{SV}/E_{jet}, E_{SV}

η

m_{SV}

$N_{tracks\ in\ SV}$

χ^2/ndf

impact parameters & significances

$\cos(\text{flight direction}_{SV}, \vec{p}_{SV})$

14 input features
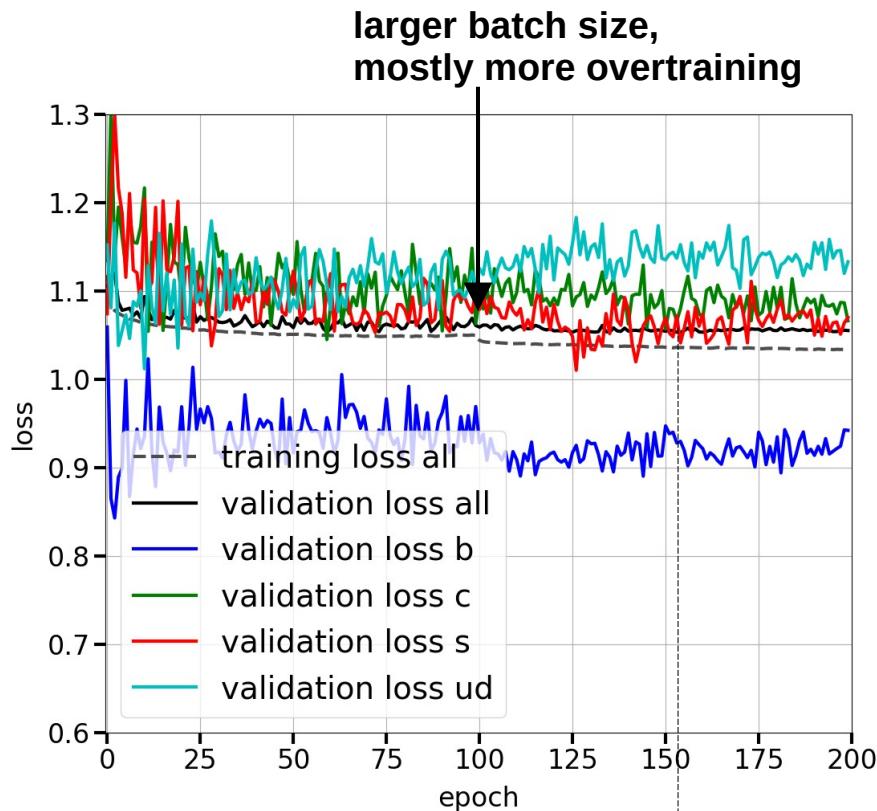
**2 SVs & all jet constituents considered, no ordering of inputs**
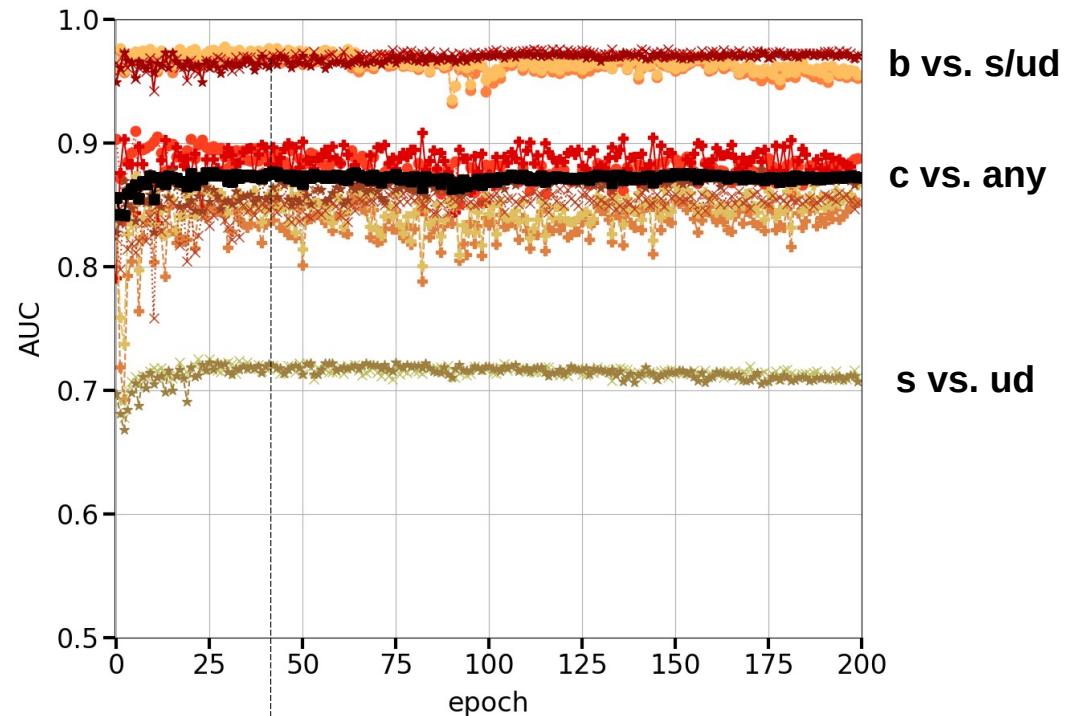
Data sample

- Using dedicated 4-quark samples for flavour tagging in ILD 250 GeV production

- 1 M jets per flavour, but due to data size use 1/4 of total

- 75% for training, 12.5% for testing and validation each

- Have output classes b, c, s and u/d; combine u and d into one sample class

larger batch size,
mostly more overtraining

training loss all
validation loss all
validation loss b
validation loss c
validation loss s
validation loss ud
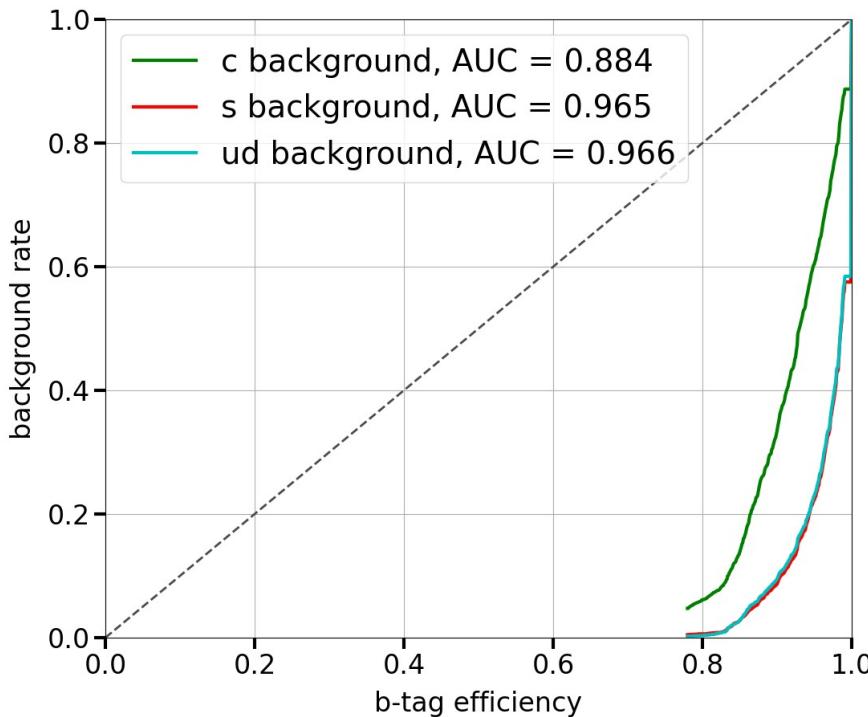
smallest validation
loss at epoch 154

b vs. s/ud

c vs. any

s vs. ud

largest average
AUC at epoch 42

Karlsruher Institut für Technologie

DESY.
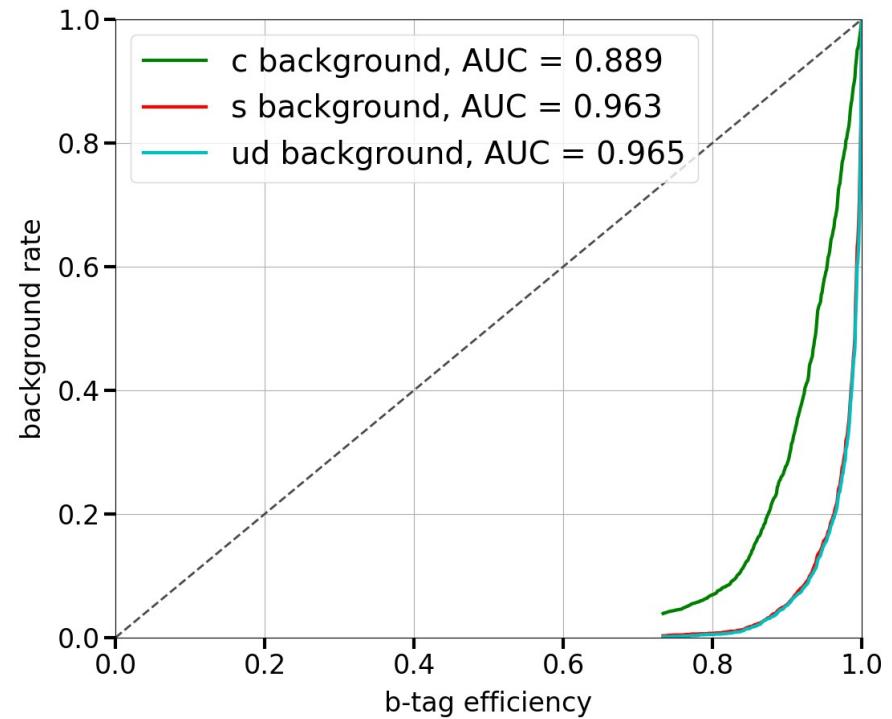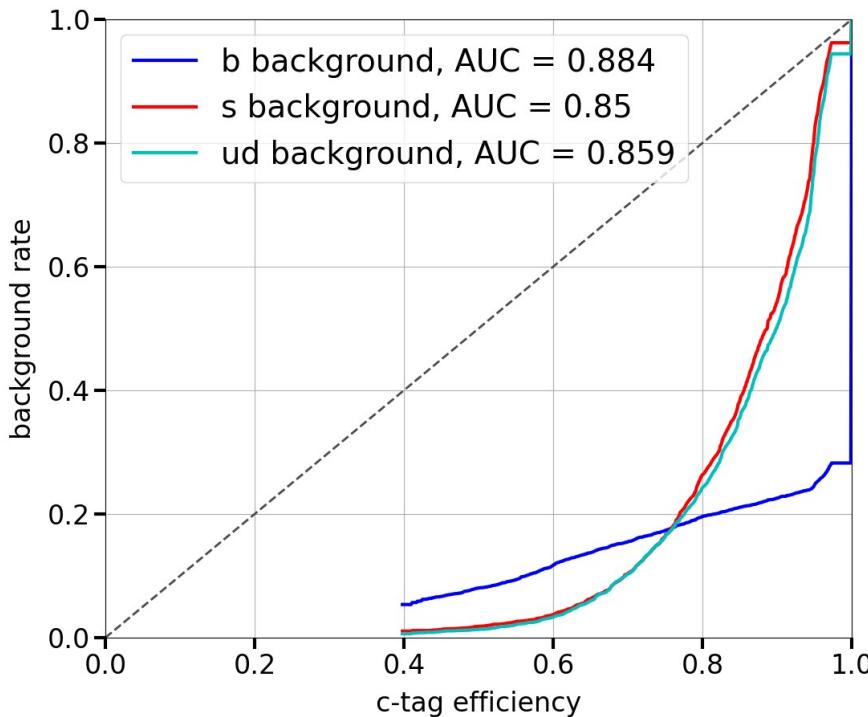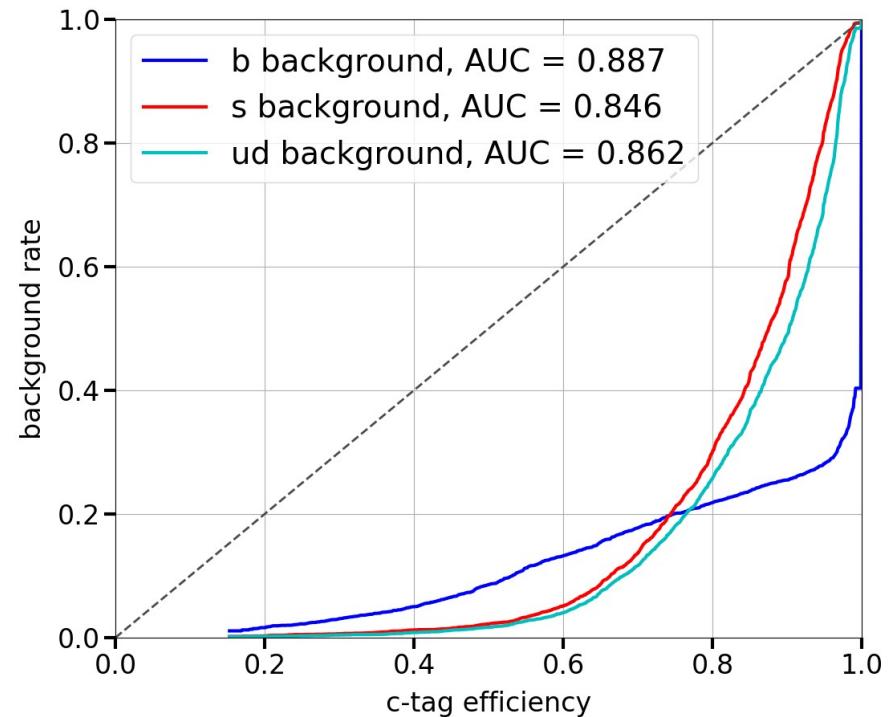
ROC Curves
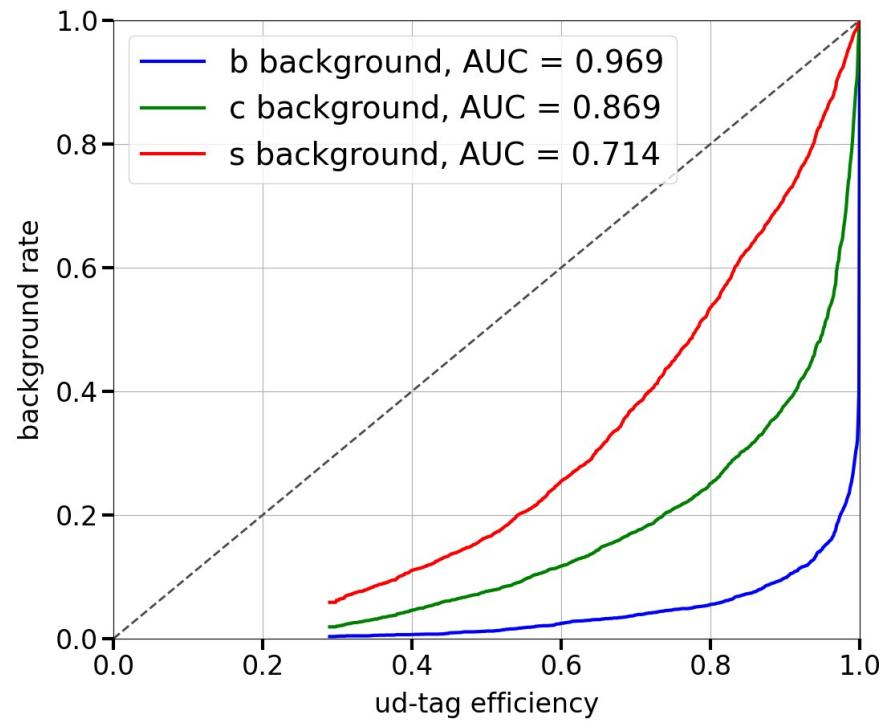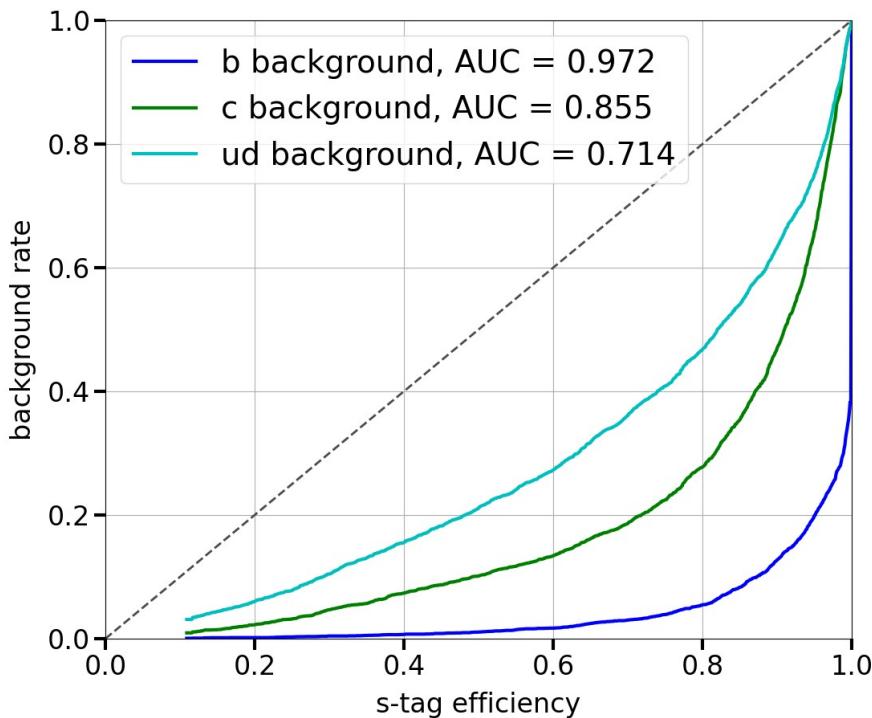
ROC Curves

## both max AUC

ROC Curves
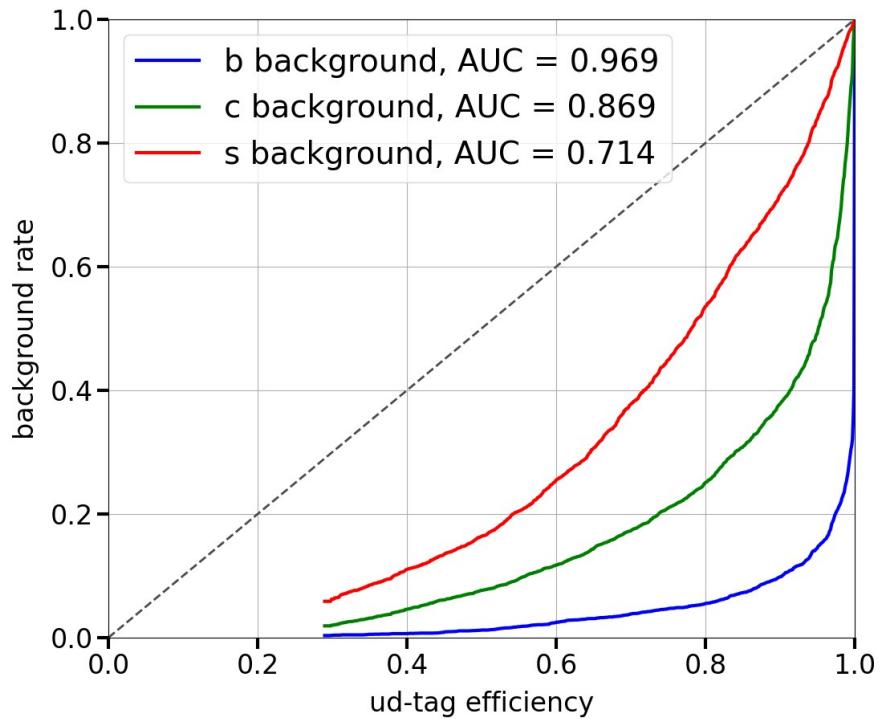
both max AUC
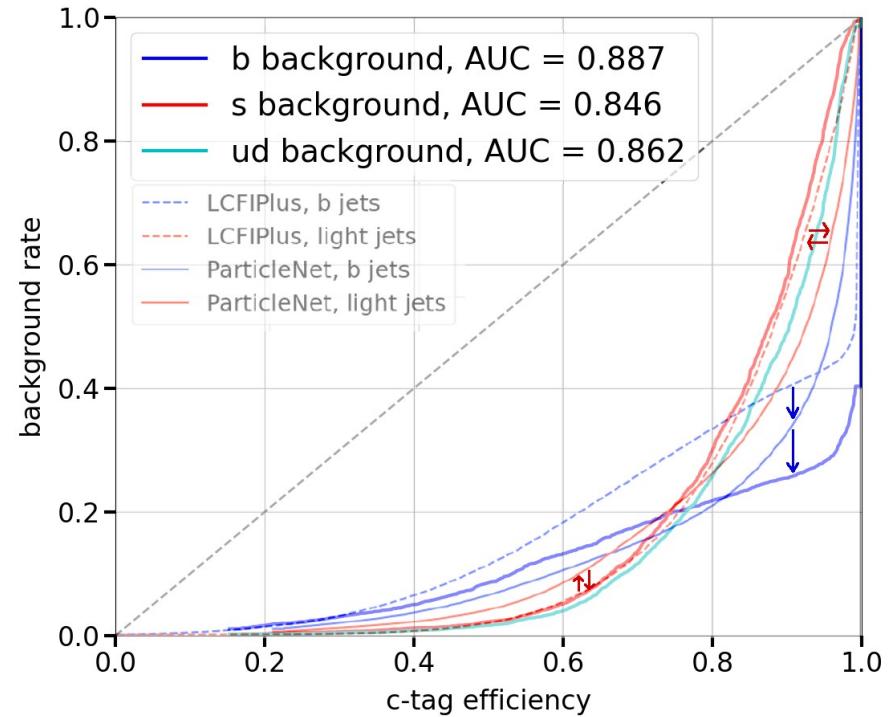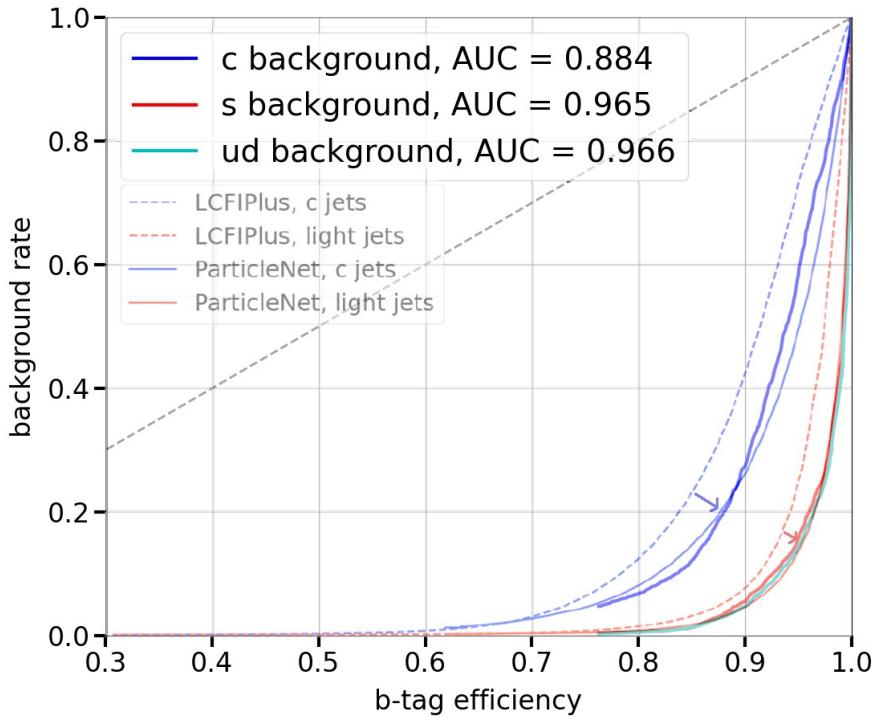
ud bkg. @ 80% s eff.: ~ 0.47
comparison with Taikan's talk: 0.43
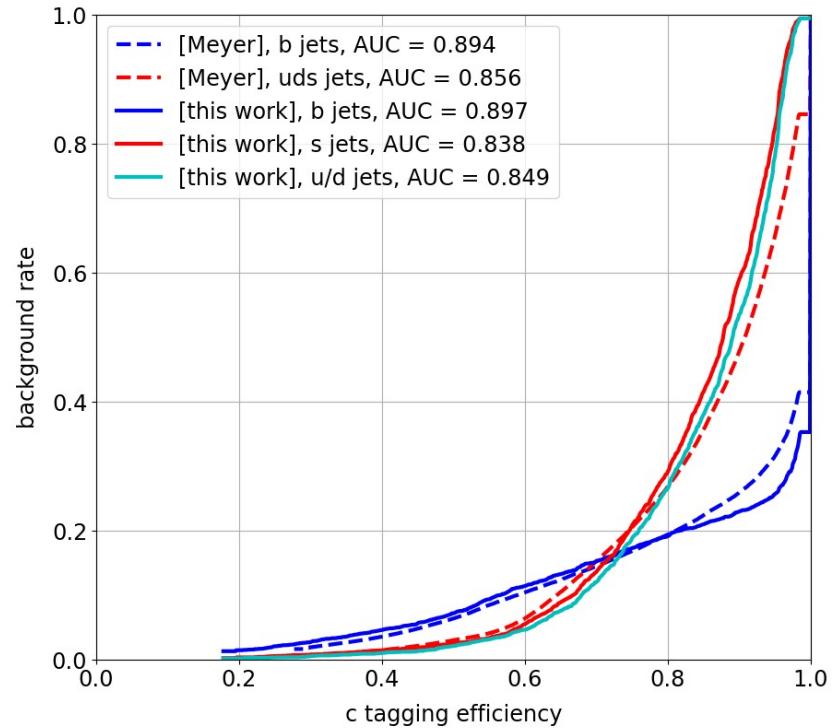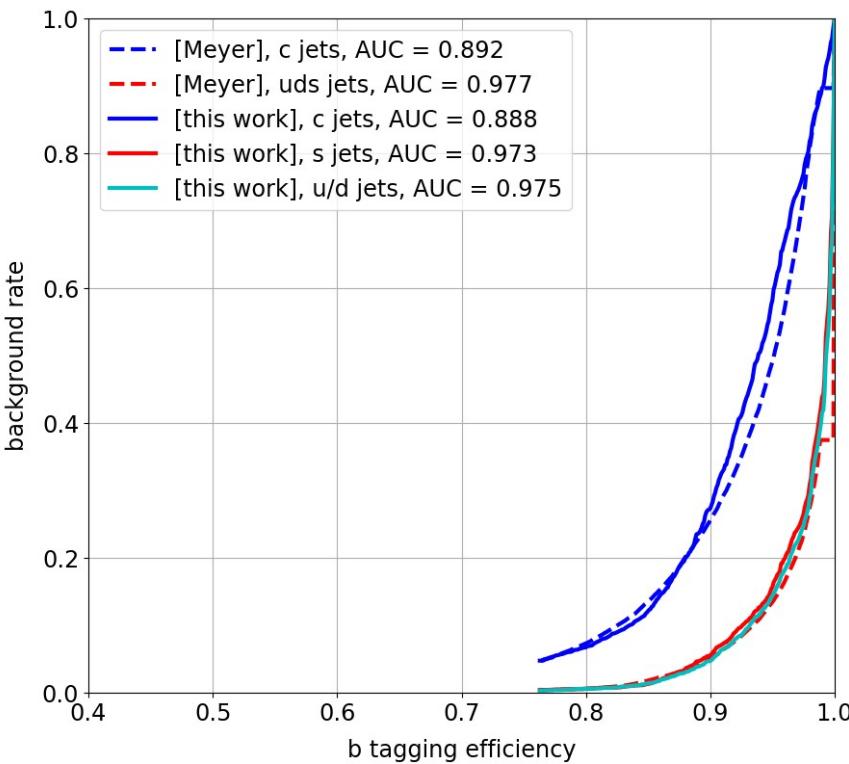
both have similar improvement wrt. LCFIPlus
new training seems to be at a different working point than Mareike's

comparison with
https://agenda.infn.it/event/34841/contributions/207748/

Karlsruher Institut für Technologie

DESY.

Comparison with 'best of' training by Mareike

very similar performance, overall slightly worse → space for CNN parameter improvements

Outlook & Conclusion

- CPID and strange tag implemented in ParticleNet @ILD flavour tagger

- Training successful, result similar for b/c tagging, established s vs. d/u tagging

- Inference included in ILD reconstruction chain in MiniDST steering file,
  so far only for existing weight file, conversion of new result to weight file ongoing

- Can still optimise model parameters for training, may slightly improve result

- May look into additional features (V0s for s, FSR gammas for u vs. d)

- Target: finish MiniDST steering file to run MiniDST production for analyses

- Intended application: CKM matrix element determination via hadronic W decays
  $\rightarrow$ use 250 GeV production 10^8 Ws, tag & count decays, V_{cb}, V_{ub} and V_{sc} of particular interest

Karlsruher Institut für Technologie

DESY.