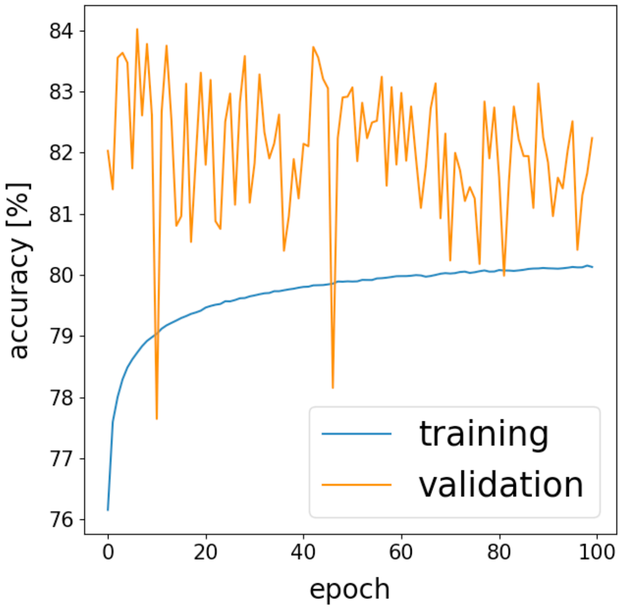
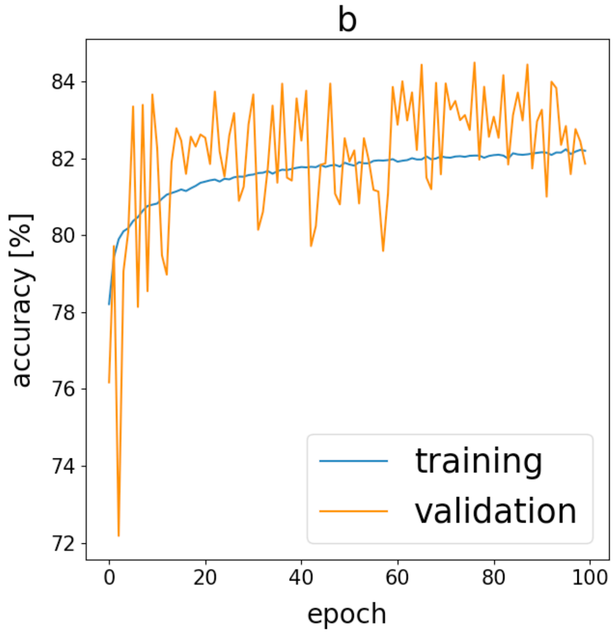
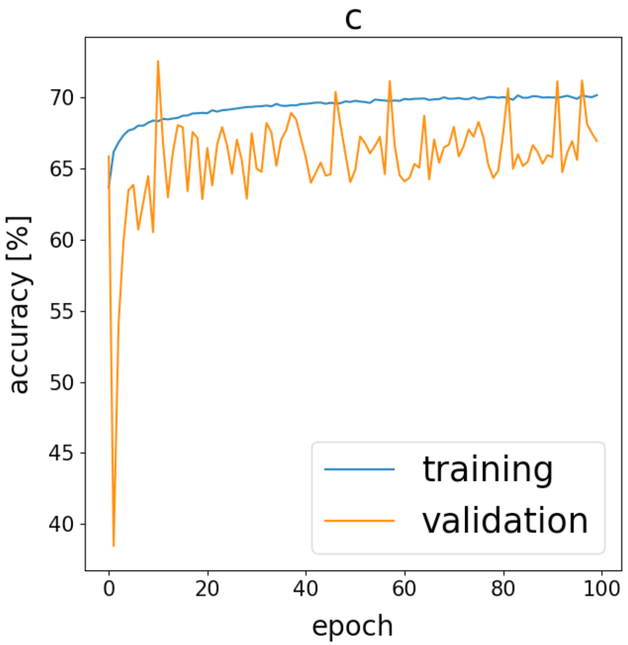
News

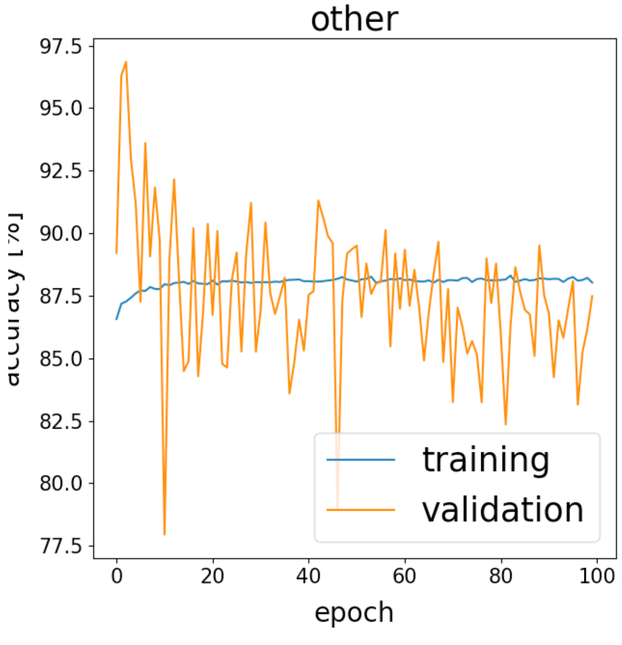
- further optimization of DeepJet and Particle Net architecture
- discussed integration into iLCSoft with Thomas
- started studying sensitivity of tagging s quarks

Particle Net architecture with DeepJet input variables

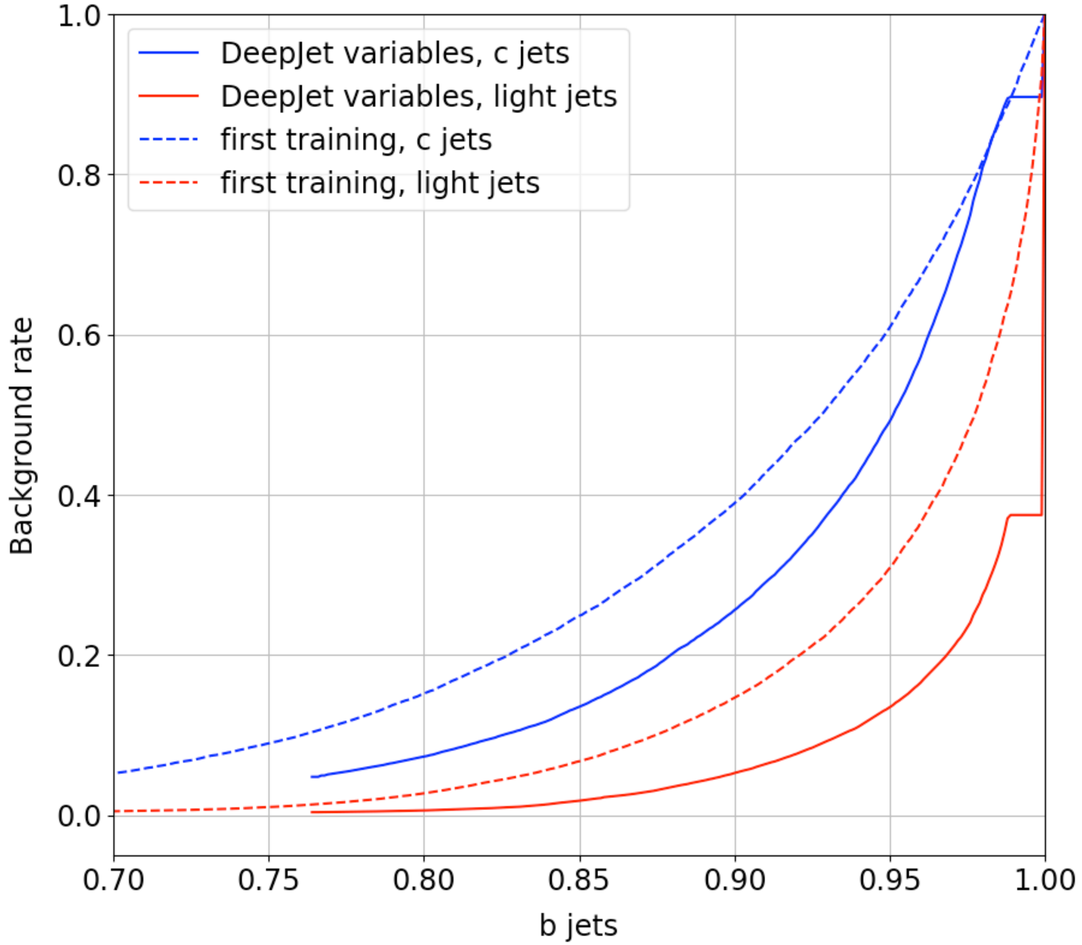


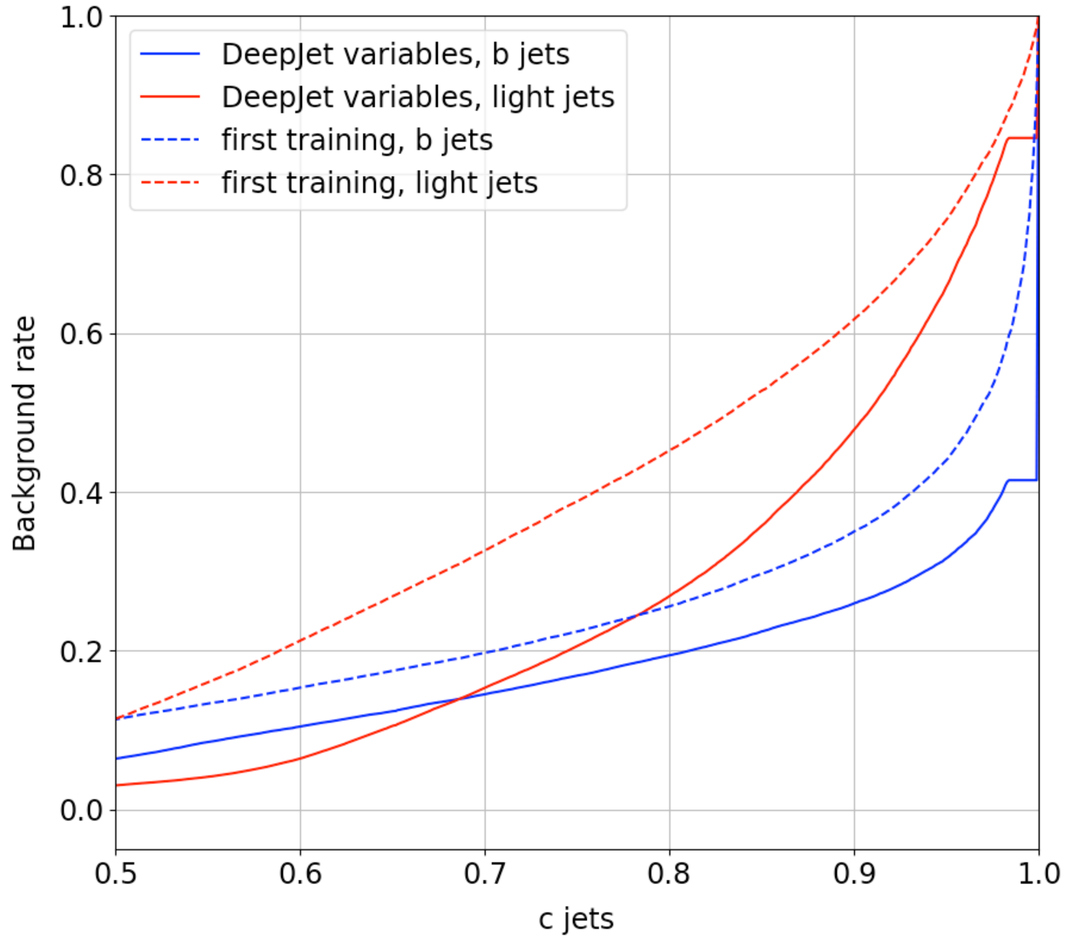






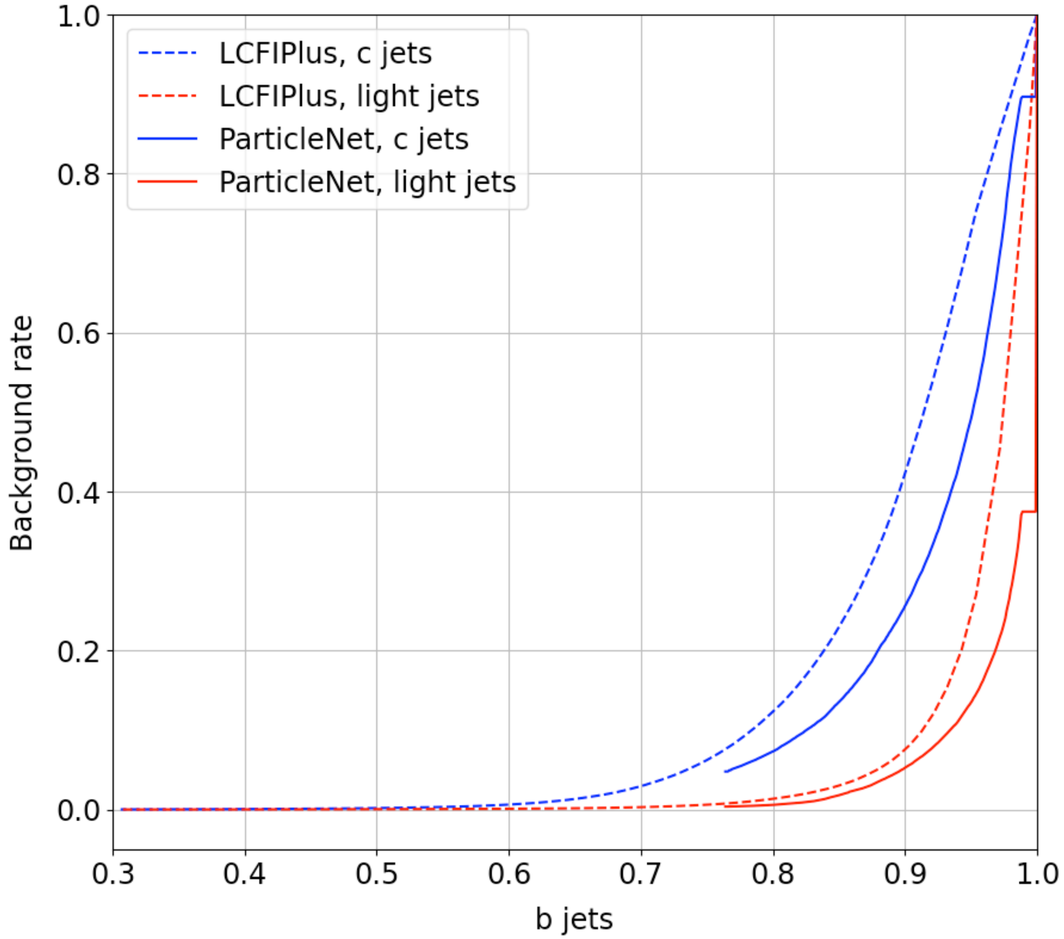
Particle Net architecture with DeepJet input variables

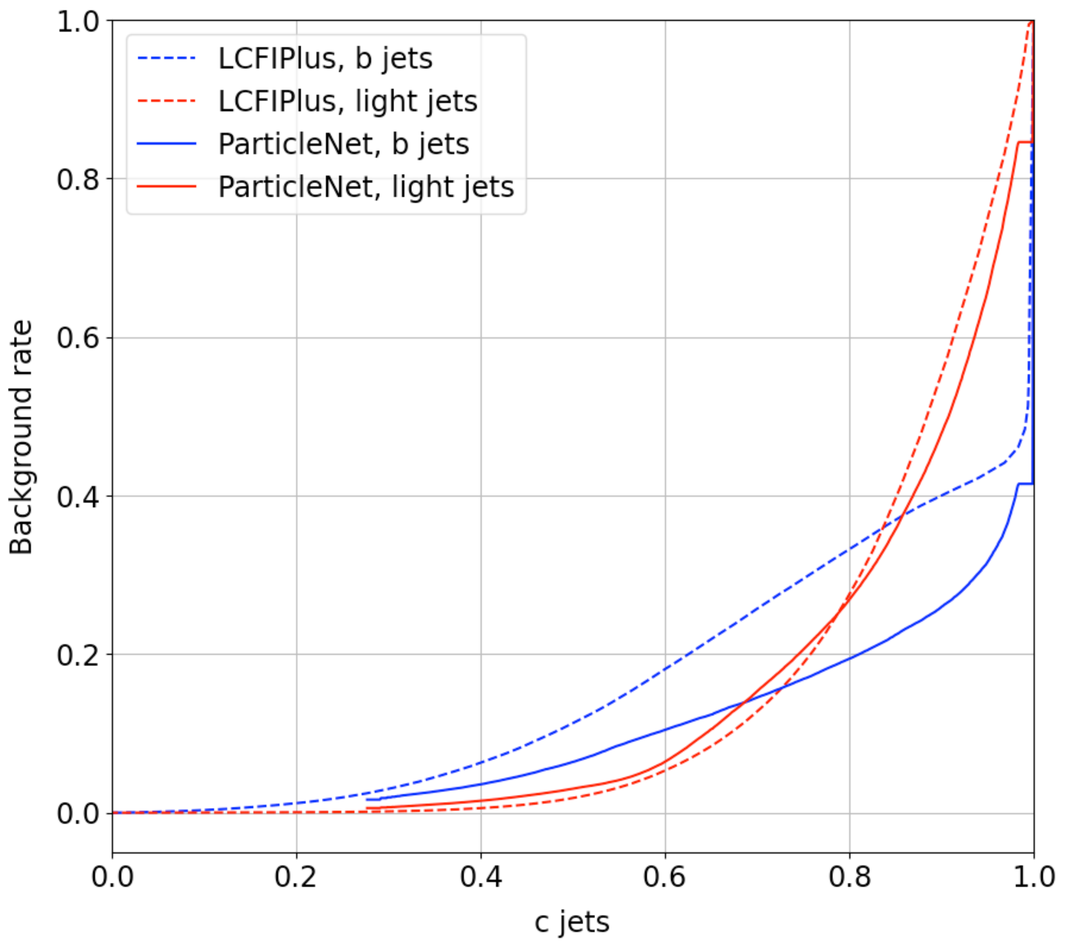




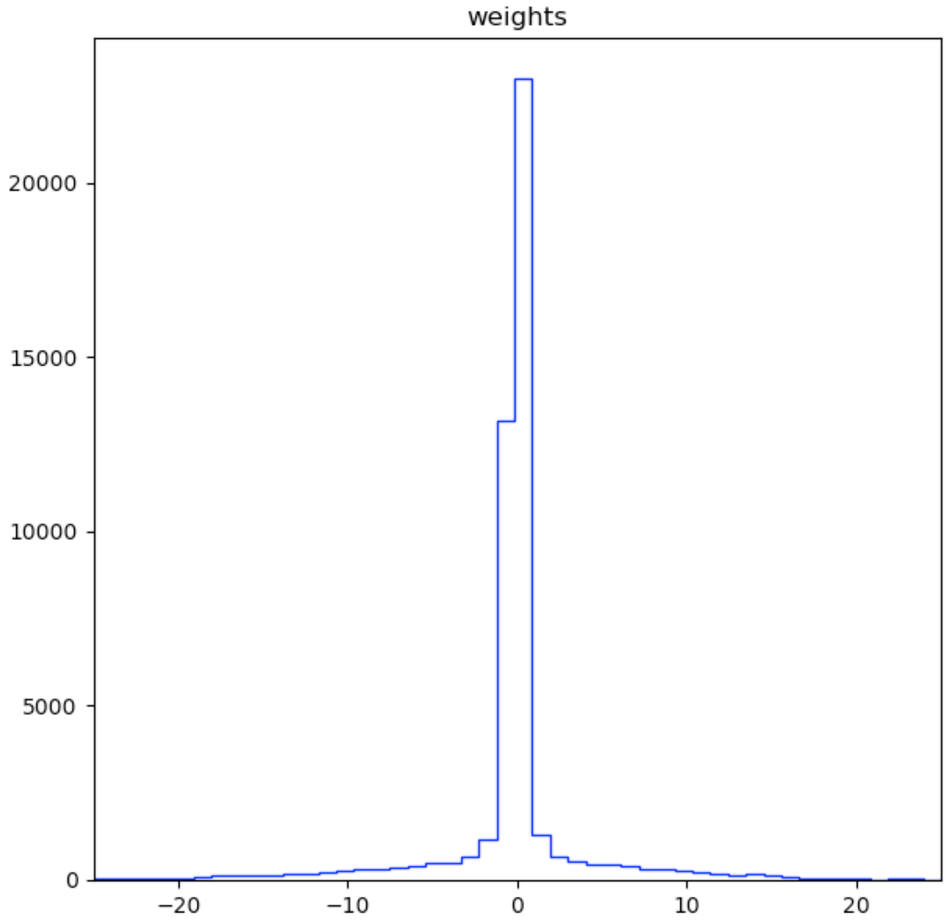
- Can I add more variables? Different variables?

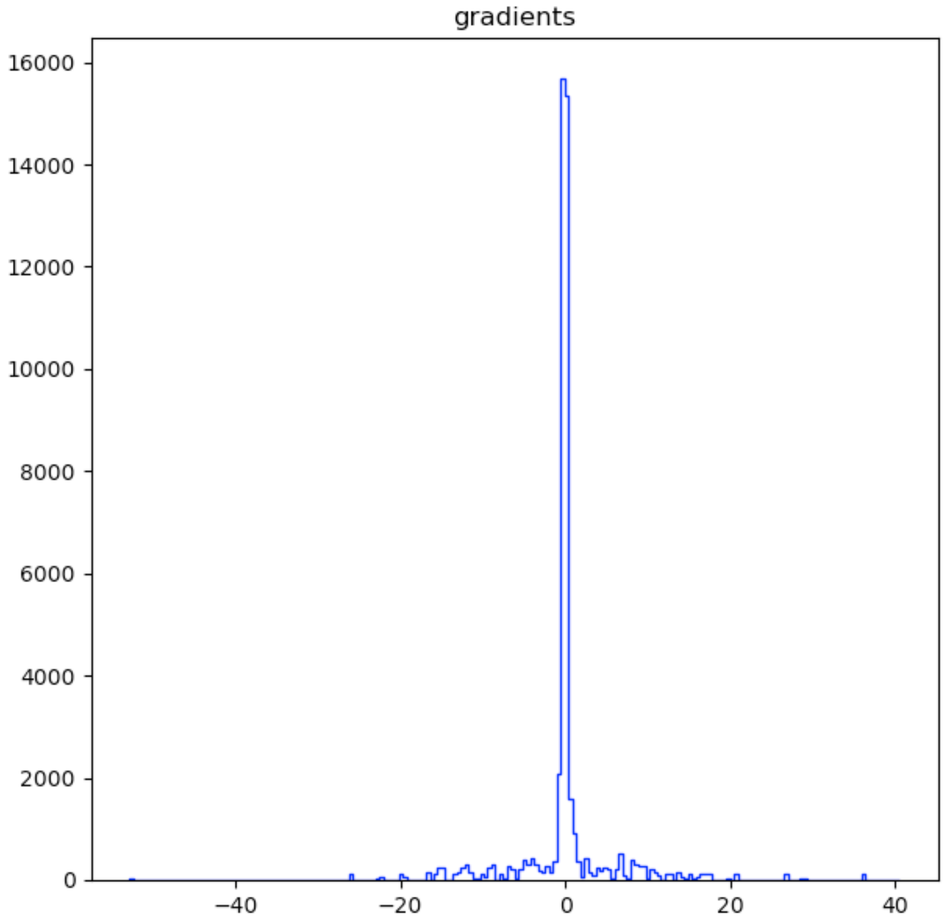
Particle Net architecture with DeepJet input variables



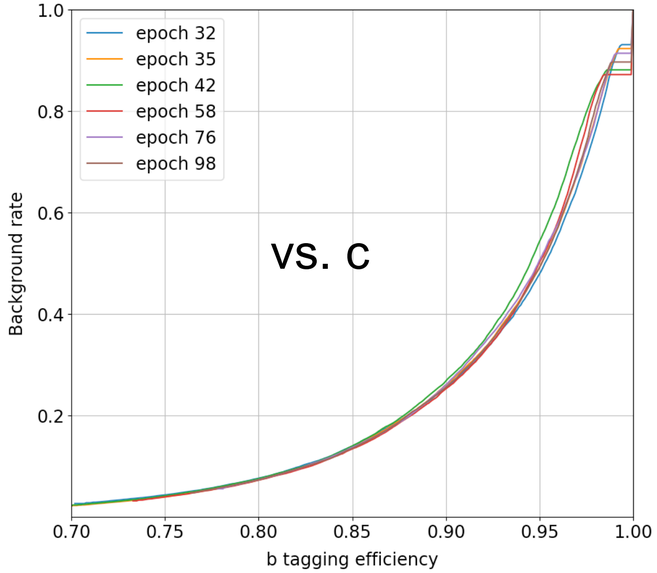


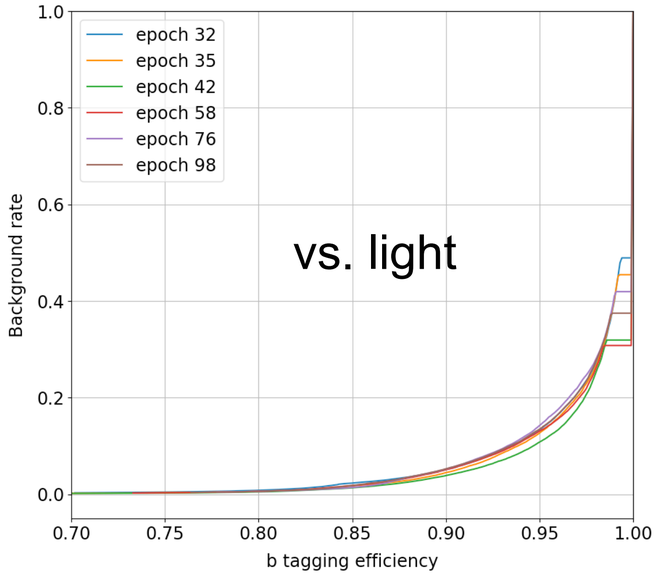
Particle Net architecture with DeepJet input variables

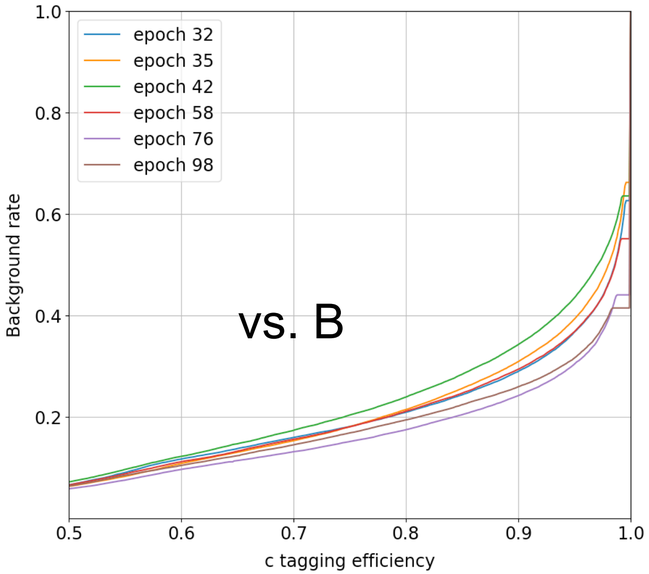


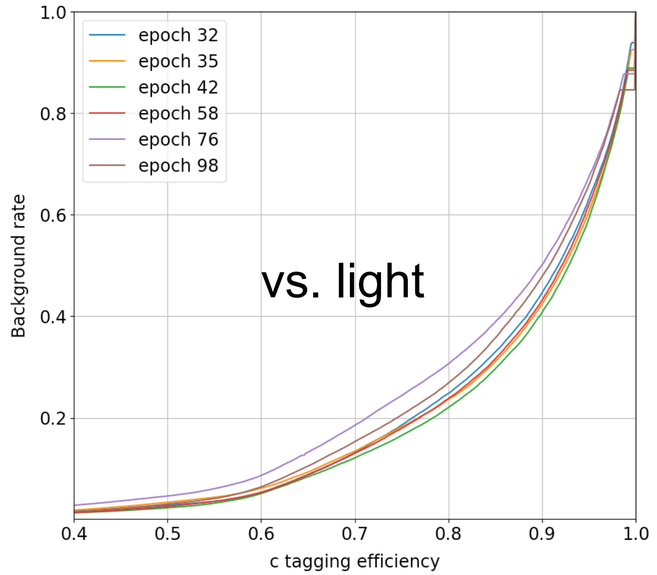


Particle Net architecture with DeepJet input variables









- epoch 32: min. average distance in accuracy in training and validation
- epoch 35: max. relative fluctuation of AUC
- epoch 42: minimum loss validation
- epoch 58: max. average accuracy in validation
- epoch 76: max. accuracy validation
- epoch 98: minimum loss training

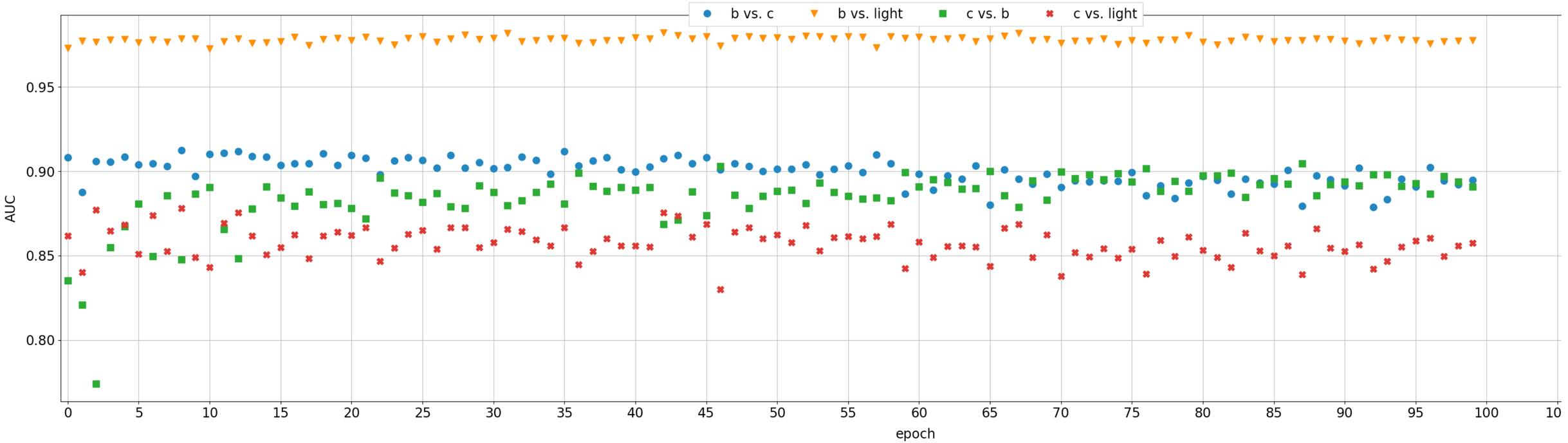
Backup

Particle Net: variables

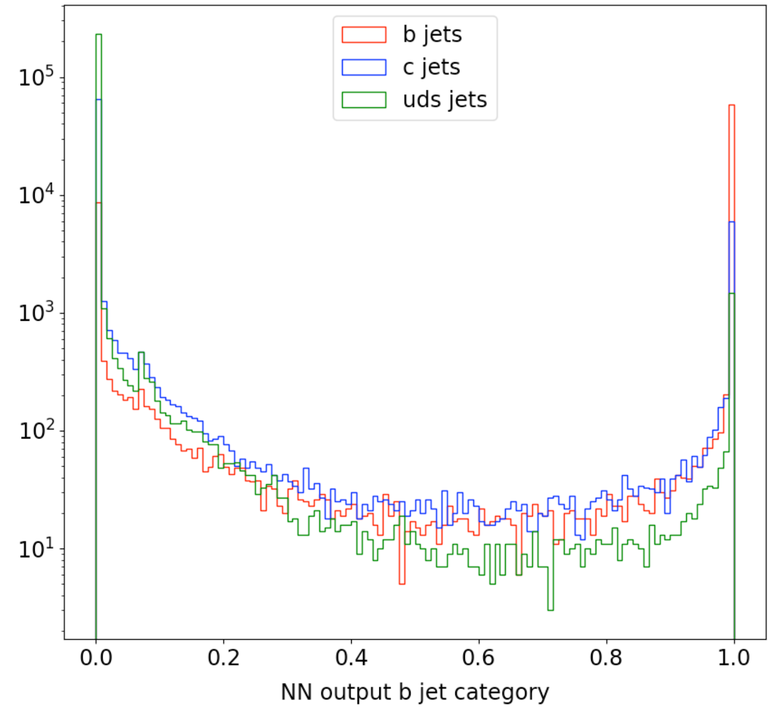
Variable	Definition
$\Delta\eta$	difference in pseudorapidity between the particle and the jet axis
$\Delta\phi$	difference in azimuthal angle between the particle and the jet axis
$\log p_T$	logarithm of the particle's p_T
$\log E$	logarithm of the particle's energy
$\log \frac{p_T}{p_T(\text{jet})}$	logarithm of the particle's p_T relative to the jet p_T
$\log \frac{E}{E(\text{jet})}$	logarithm of the particle's energy relative to the jet energy
ΔR	angular separation between the particle and the jet axis ($\sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$)
q	electric charge of the particle
`isElectron`	if the particle is an electron
`isMuon`	if the particle is a muon
`isChargedHadron`	if the particle is a charged hadron
`isNeutralHadron`	if the particle is a neutral hadron
`isPhoton`	if the particle is a photon

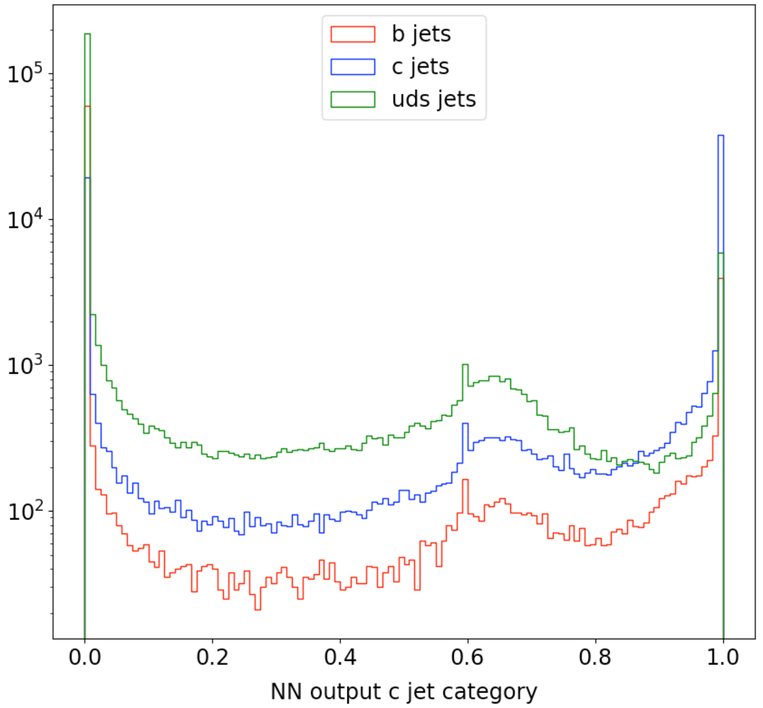
- d0, Z0, 3D IP + significances
- probabilities from LCFIPlus (but per track)
- Track used in PV?, lepton momentum relative to jet, lepton momentum fraction, kaoness, weighted kaoness momentum fraction, dot product jet and track (norm), HCAL fraction, Chi2/NDF
- secondary vertices:
  - coordinates: Δη, ΔΦ
  - features: log(pT), mass, number of tracks, χ2/ndf, 2D & 3D IP and their significances, cos(mom, pos), energy/jet energy, energy, rapidity

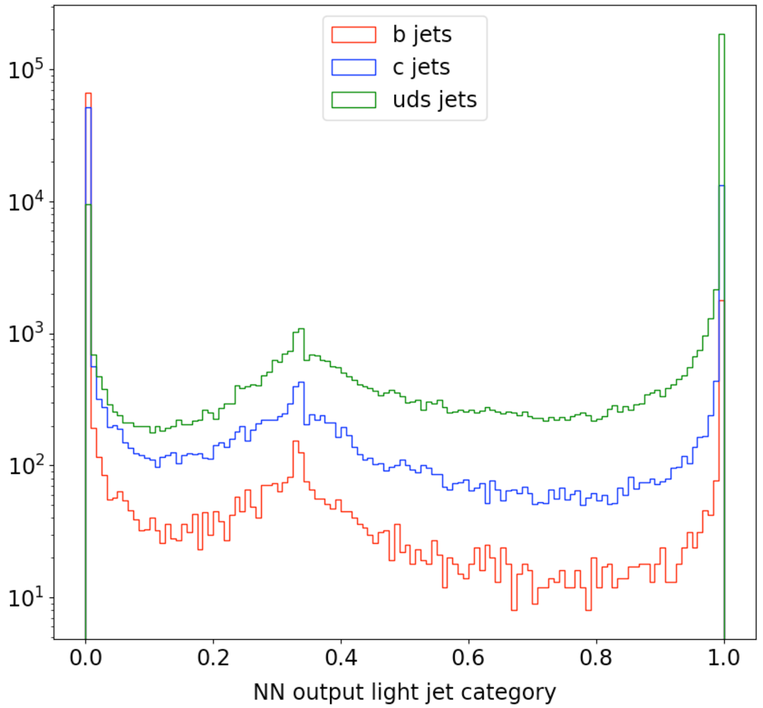
Particle Net architecture with DeepJet input variables



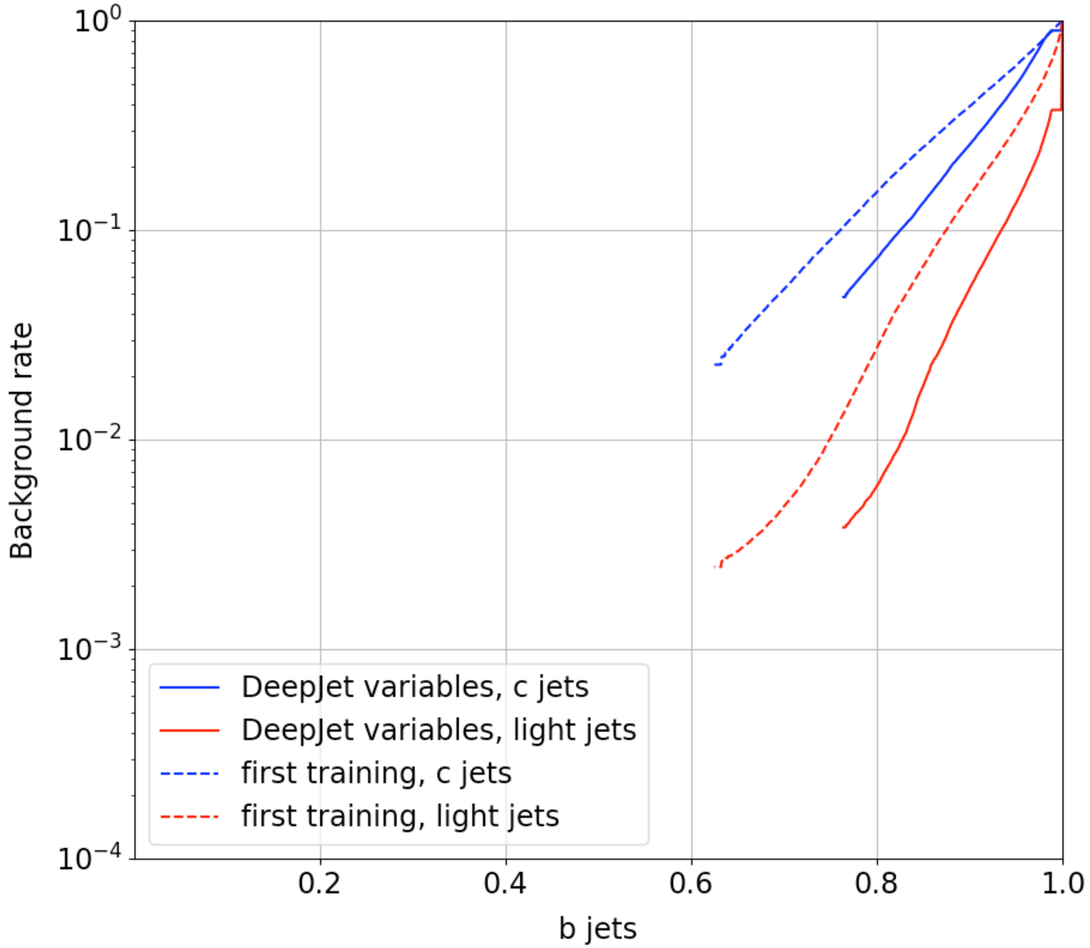
Particle Net architecture with DeepJet input variables

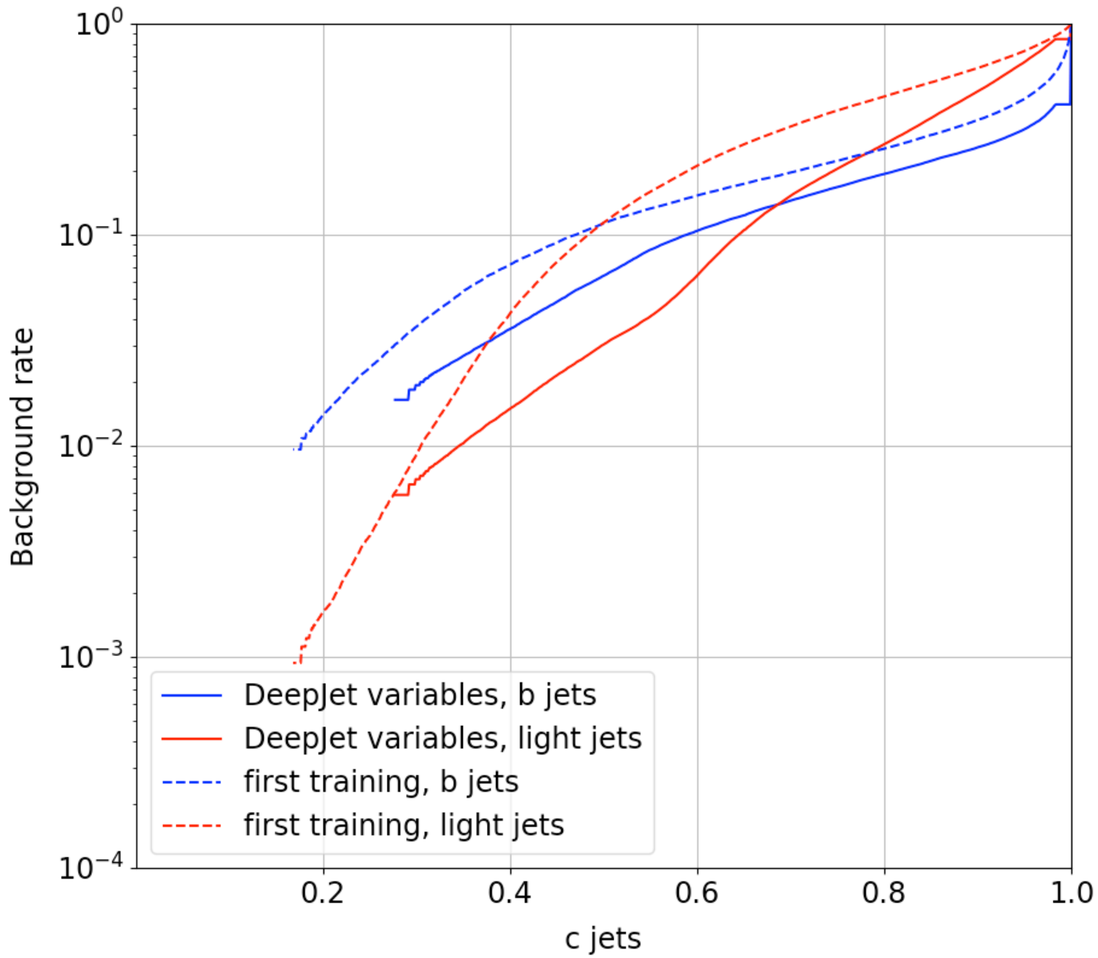




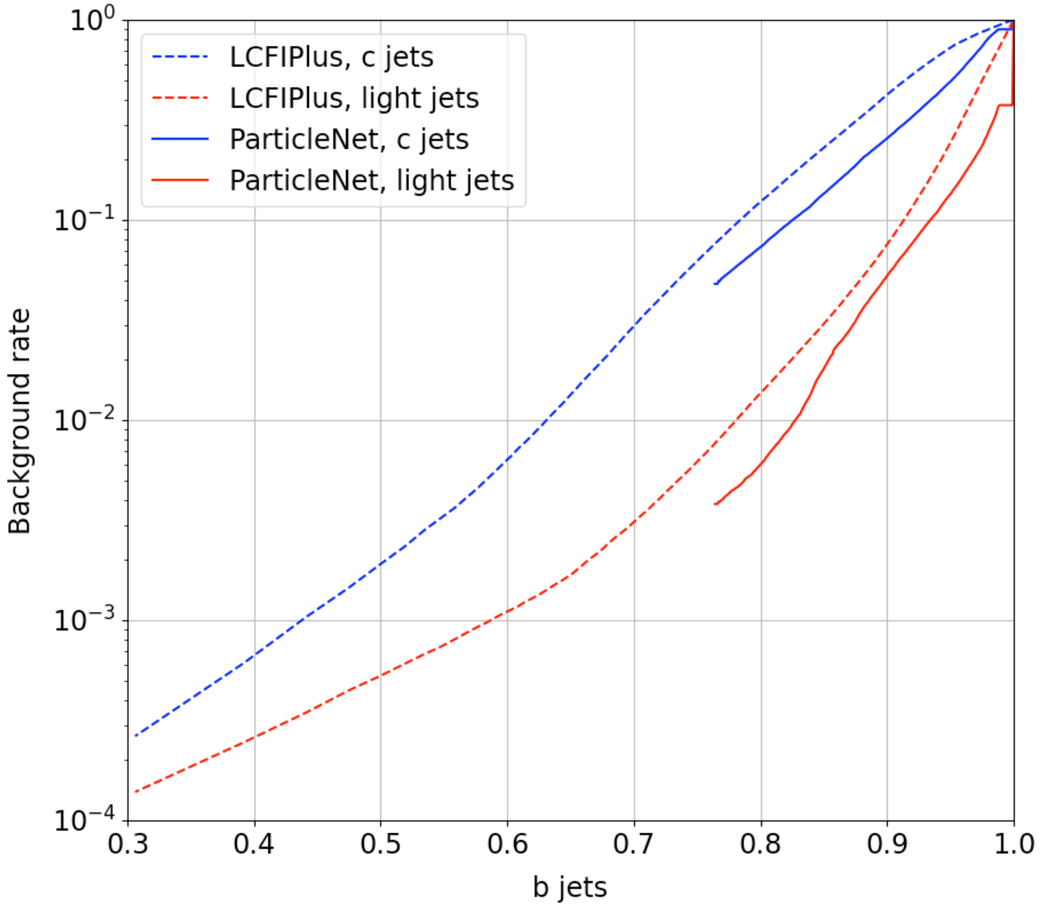


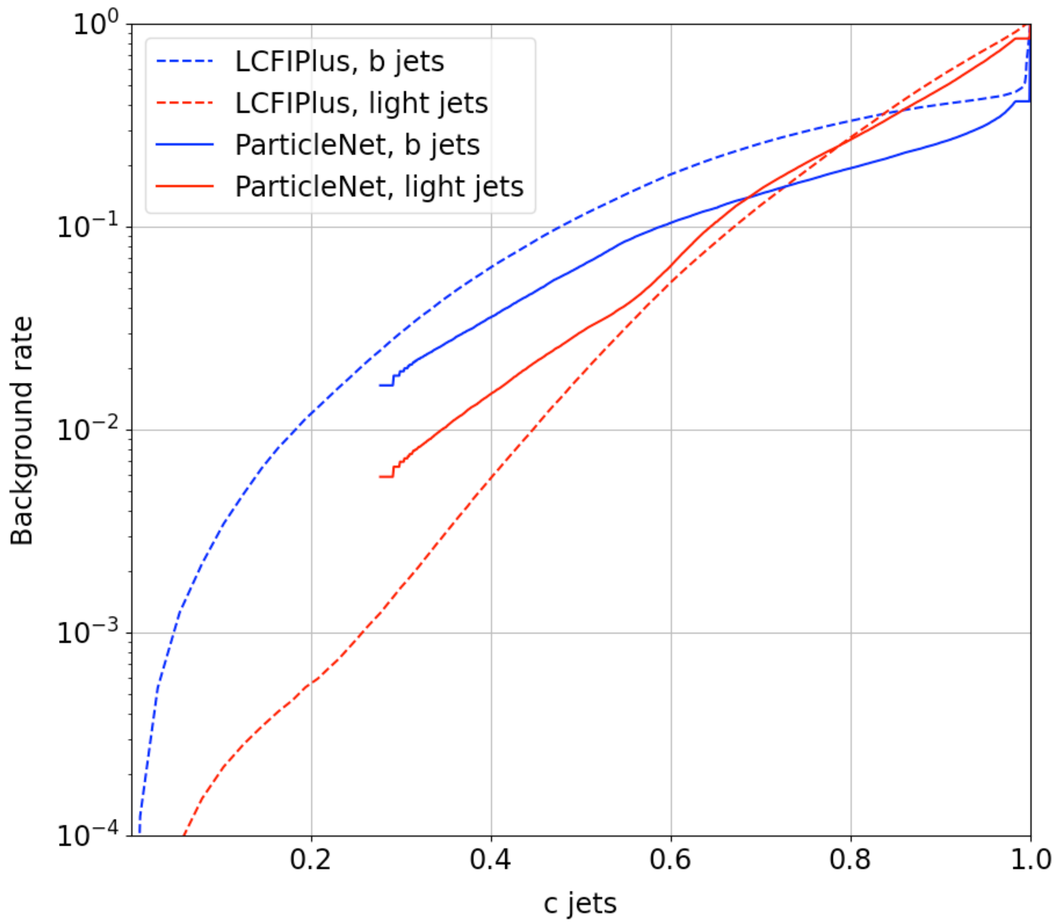
Particle Net architecture with DeepJet input variables



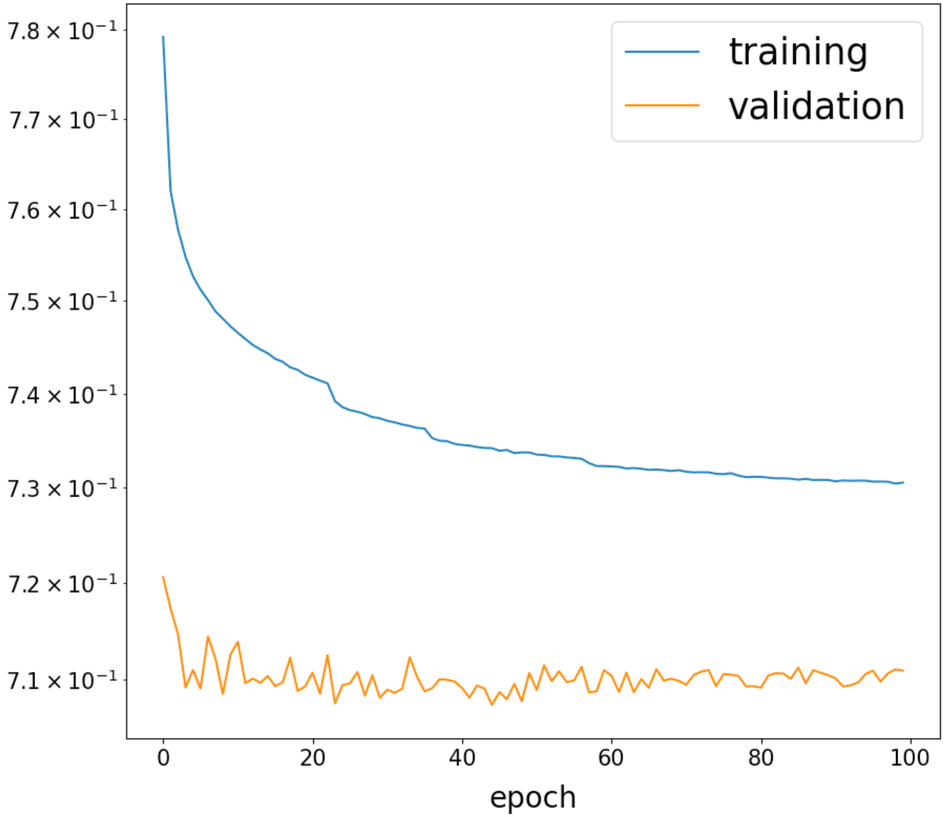


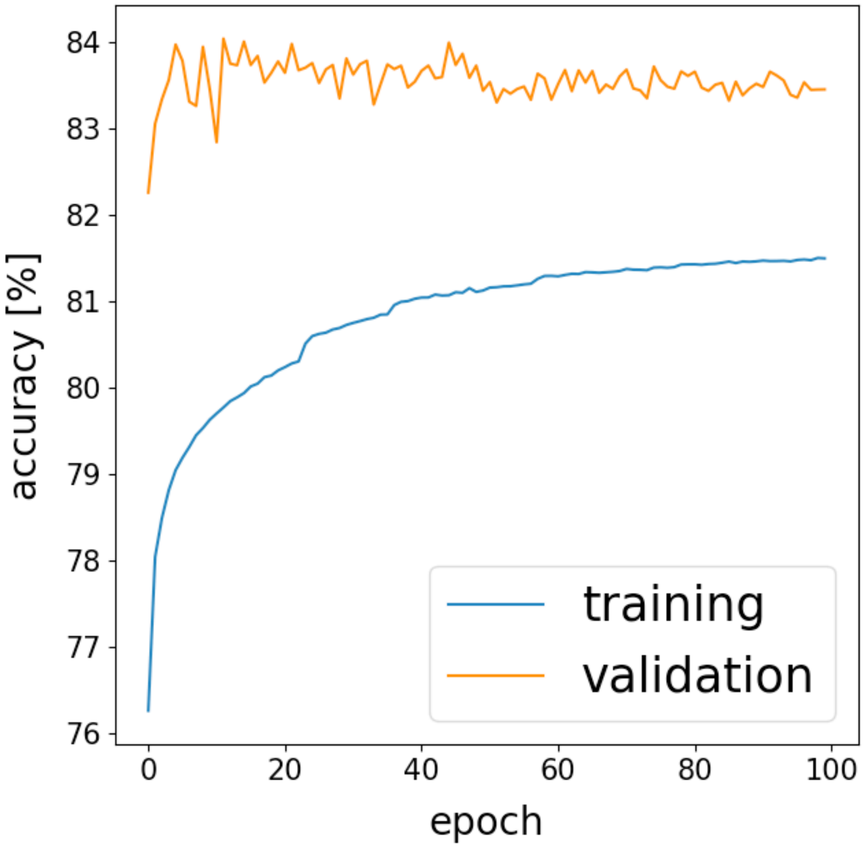
Particle Net architecture with DeepJet input variables



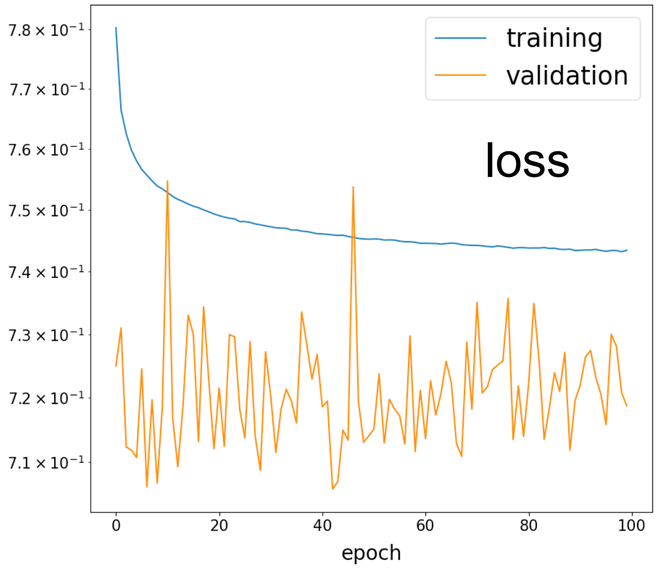


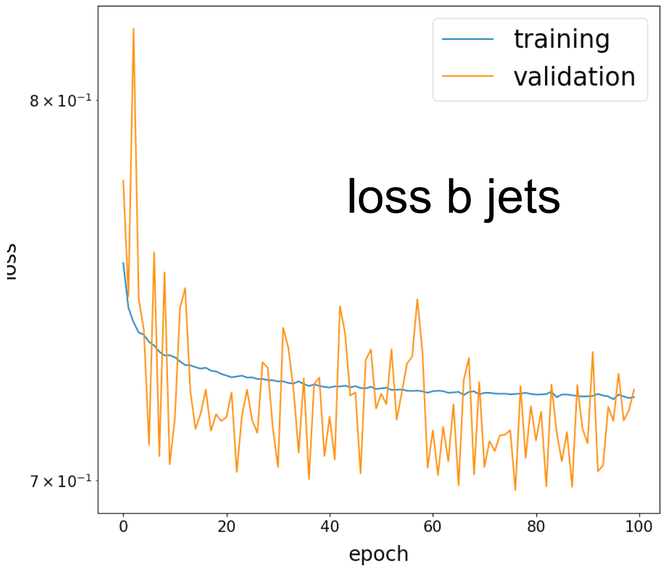
DeepJet

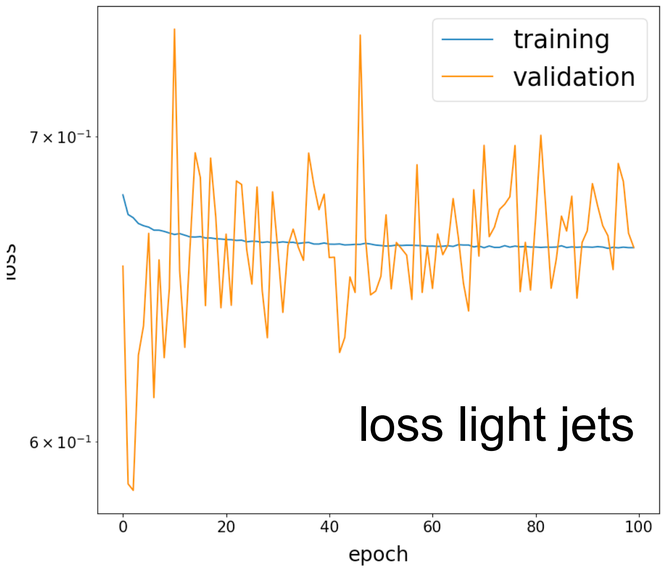

7.8×10^{-1}
7.7×10^{-1}
7.6×10^{-1}
7.5×10^{-1}
7.4×10^{-1}
7.3×10^{-1}
7.2×10^{-1}
7.1×10^{-1}
training
validation
0
20
40
60
80
100
epoch

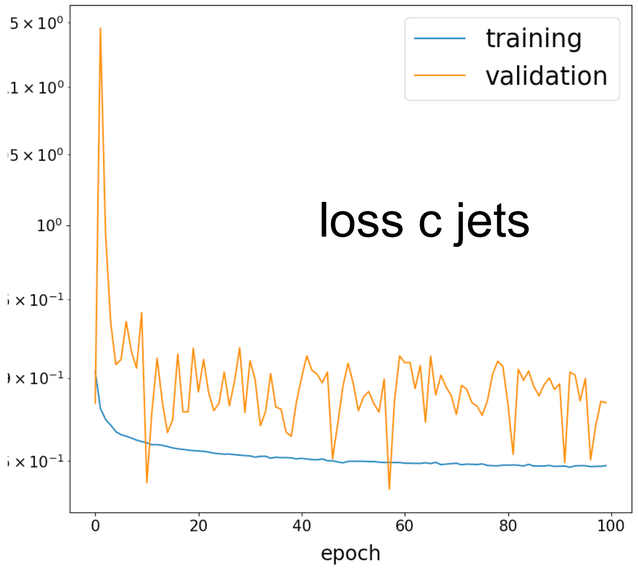

accuracy [%]
84
83
82
81
80
79
78
77
76
training
validation
0
20
40
60
80
100
epoch

Particle Net architecture with DeepJet input variables

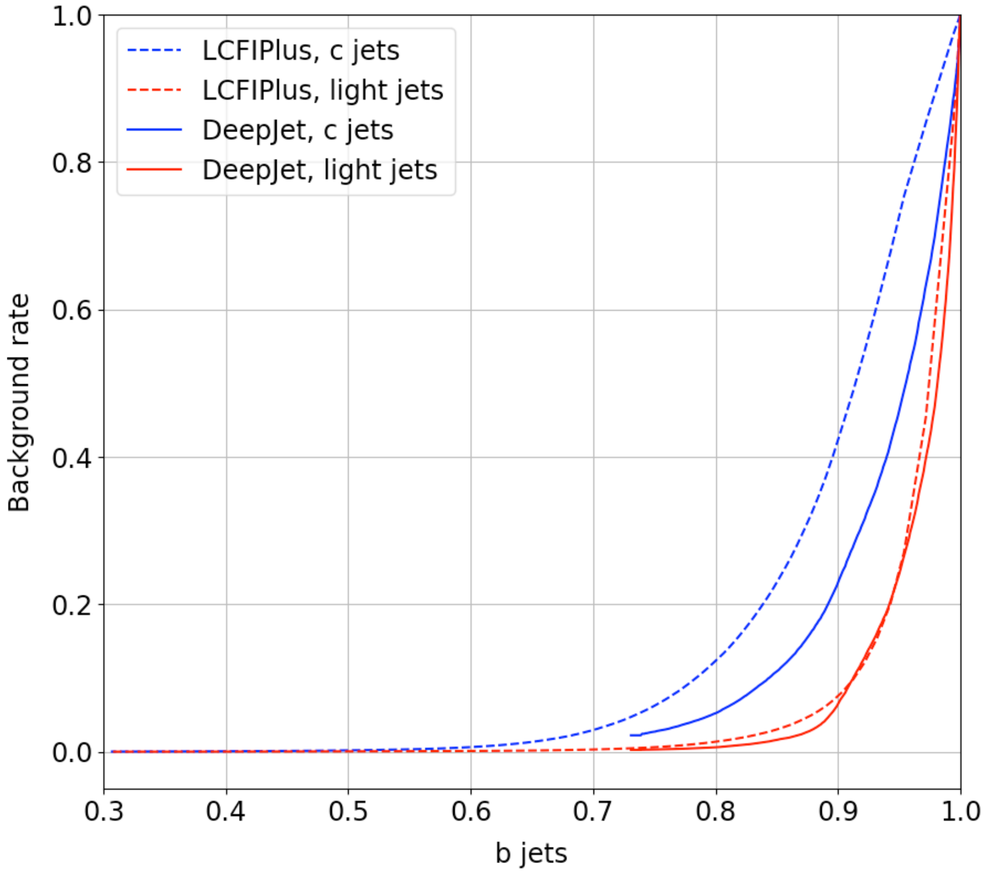


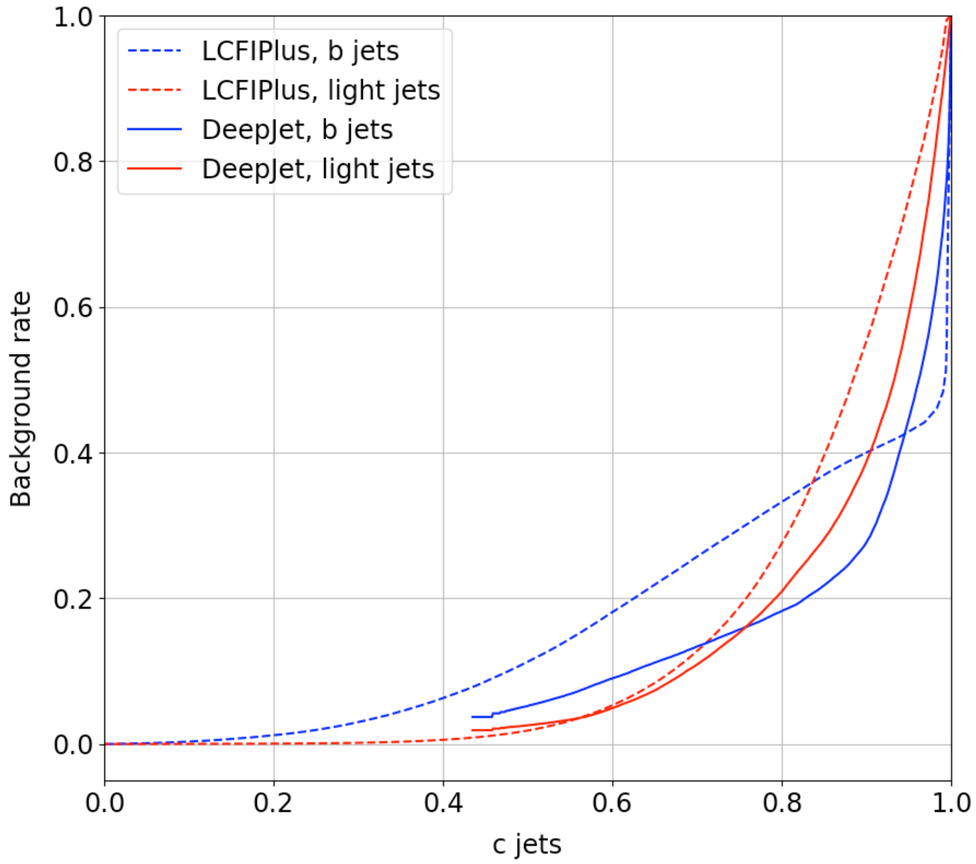






DeepJet



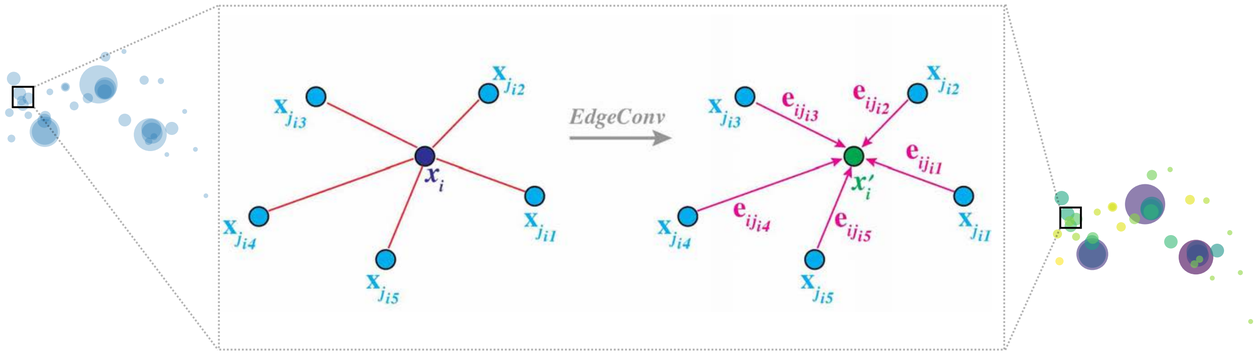


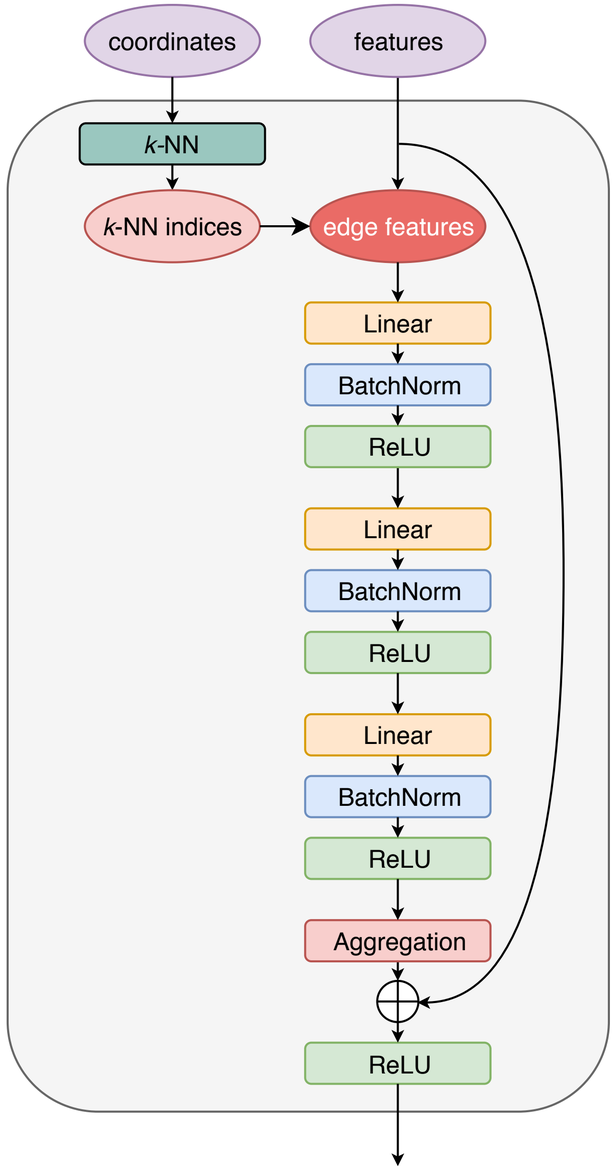
- further optimization of DeepJet architecture
- training: b/c/light jets 1:1:1 (over-sampling of b & c), validation: b/c/light jets 1:1:3
- dropout rate reduced to 5%
- flipped order of the inputs

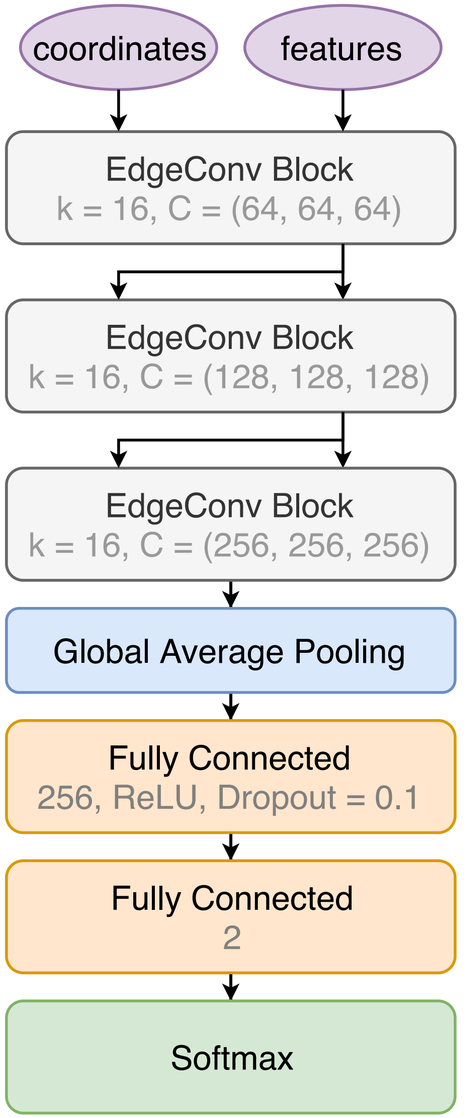
Particle Net: introduction

https://arxiv.org/pdf/1902.08570.pdf, https://indico.cern.ch/event/980214/contributions/4413544/attachments/2277334/3868991/ParticleNeXt_ML4Jets2021_H_Qu.pdf

- based on Dynamic Graph CNN (Y. Wang et al., arXiv:1801.07829)
- treat jet as „particle cloud“, input are all jet constituents
- key building block of Particle Net: EdgeConv
  - treat point cloud as a graph, each point is a vertex, edges are constructed as connections between each points and k nearest neighboring points
  - learn an „edge feature“ for each pair $e_{ij} = MLP(x_i, x_j)$
  - MLP: parameters are shared among all edges
  - aggregation of edge features: $x_i' = \text{mean}_j\, e_{ij}$

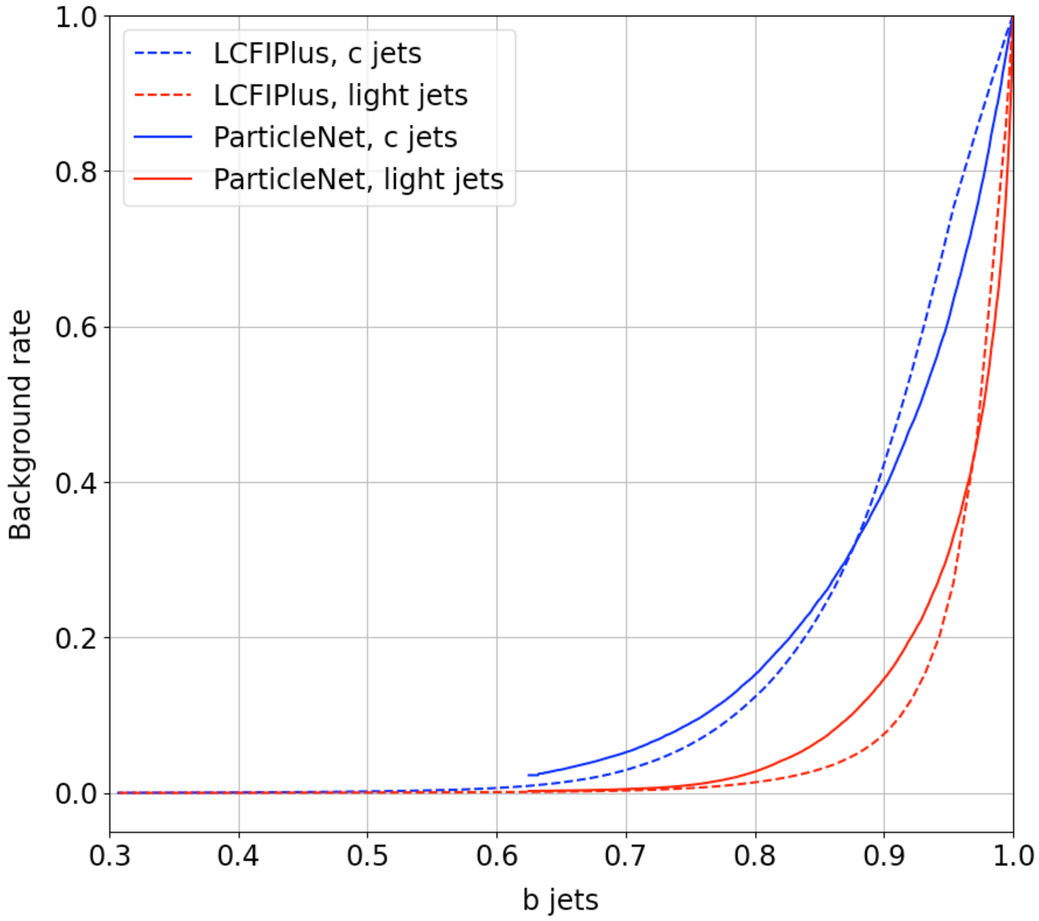


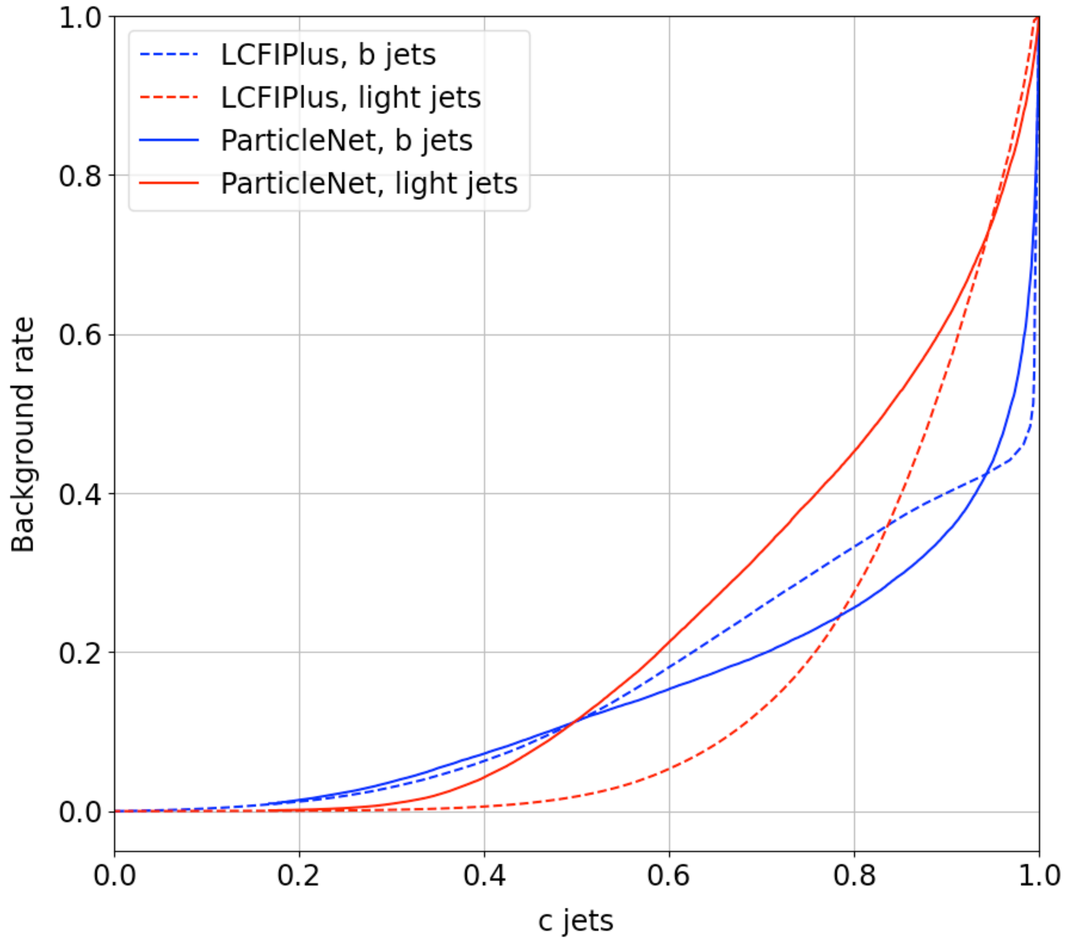




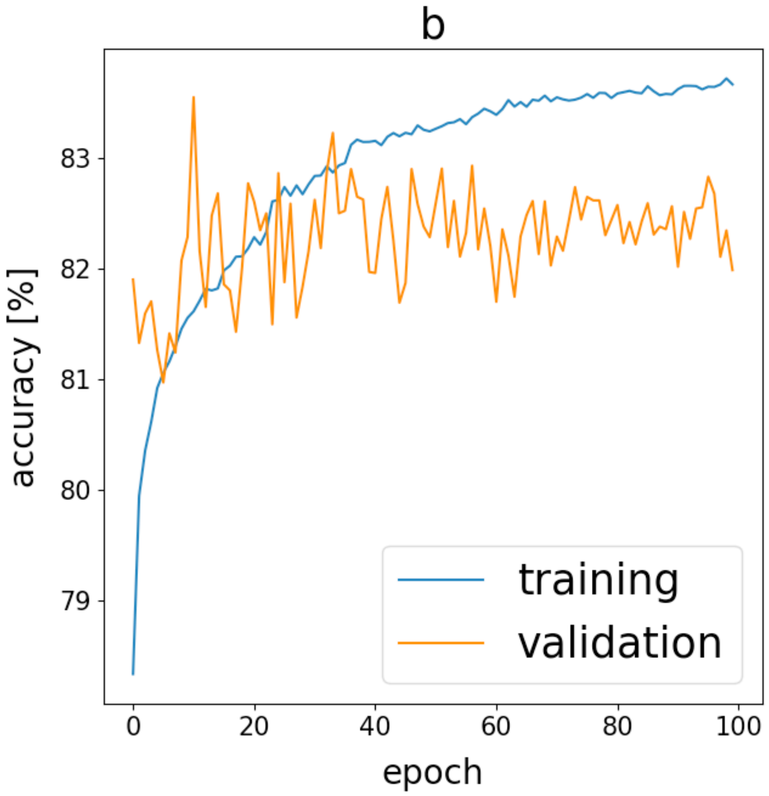
(a) ParticleNet

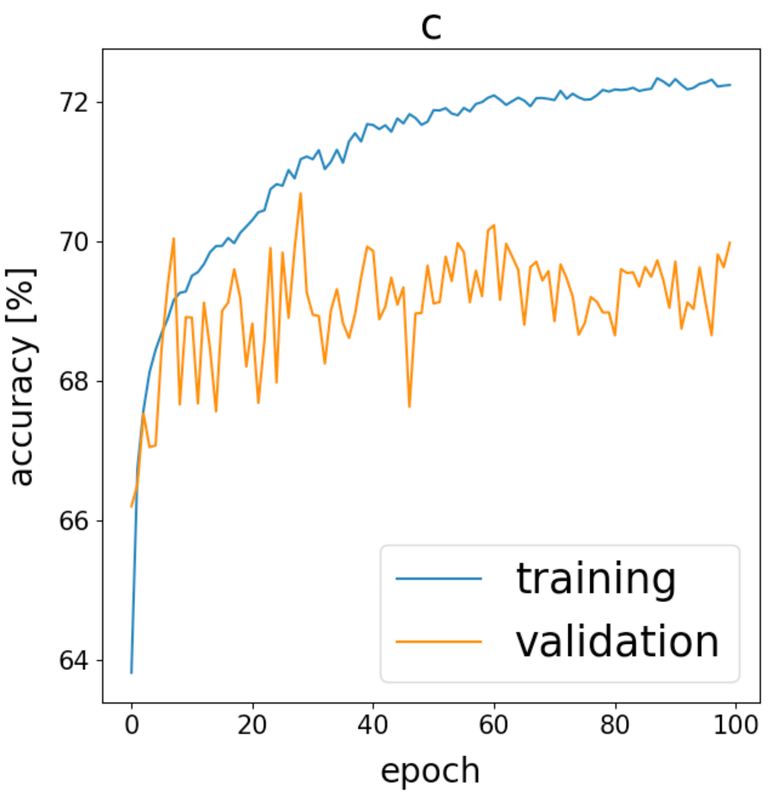
Particle Net : first results

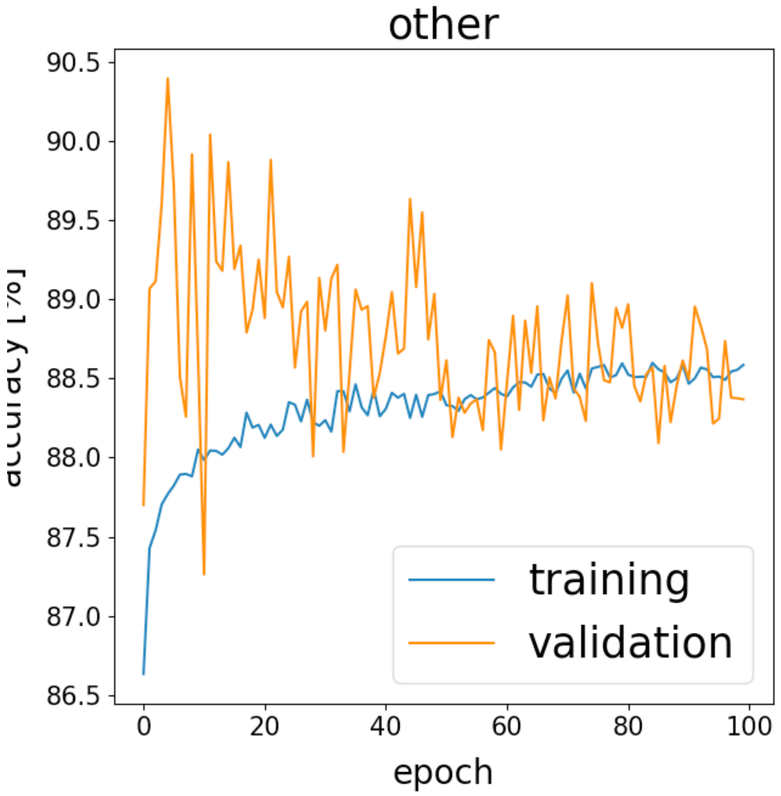




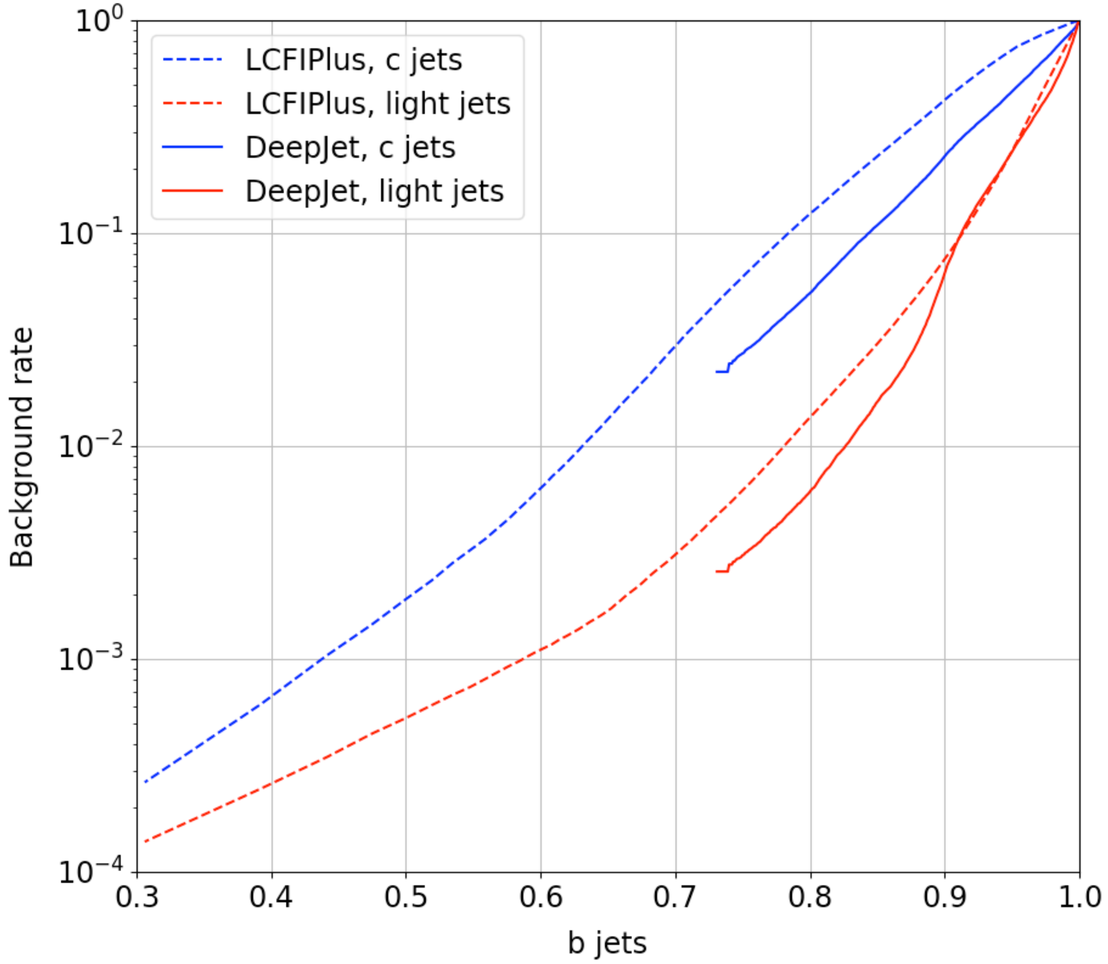
DeepJet

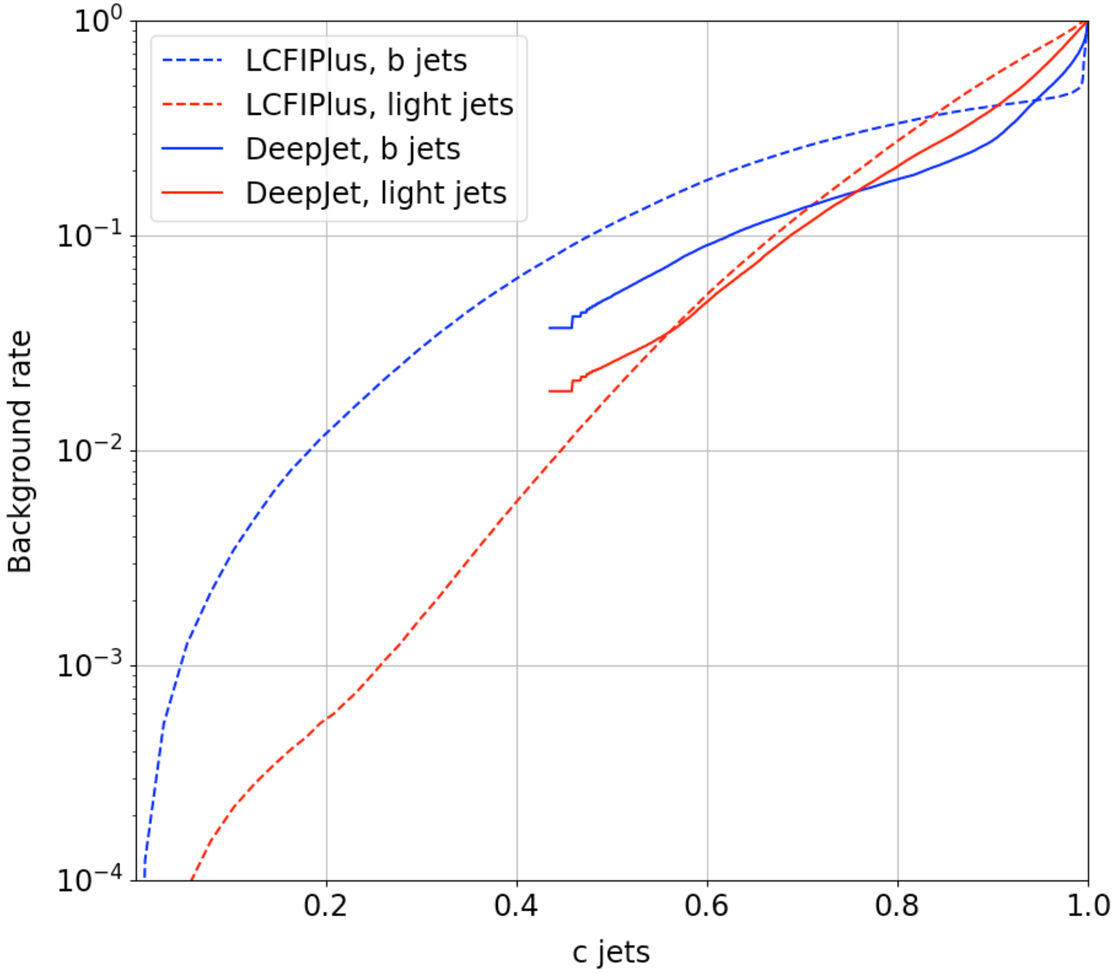

b
accuracy [%]
epoch
training
validation


c
accuracy [%]
epoch
training
validation

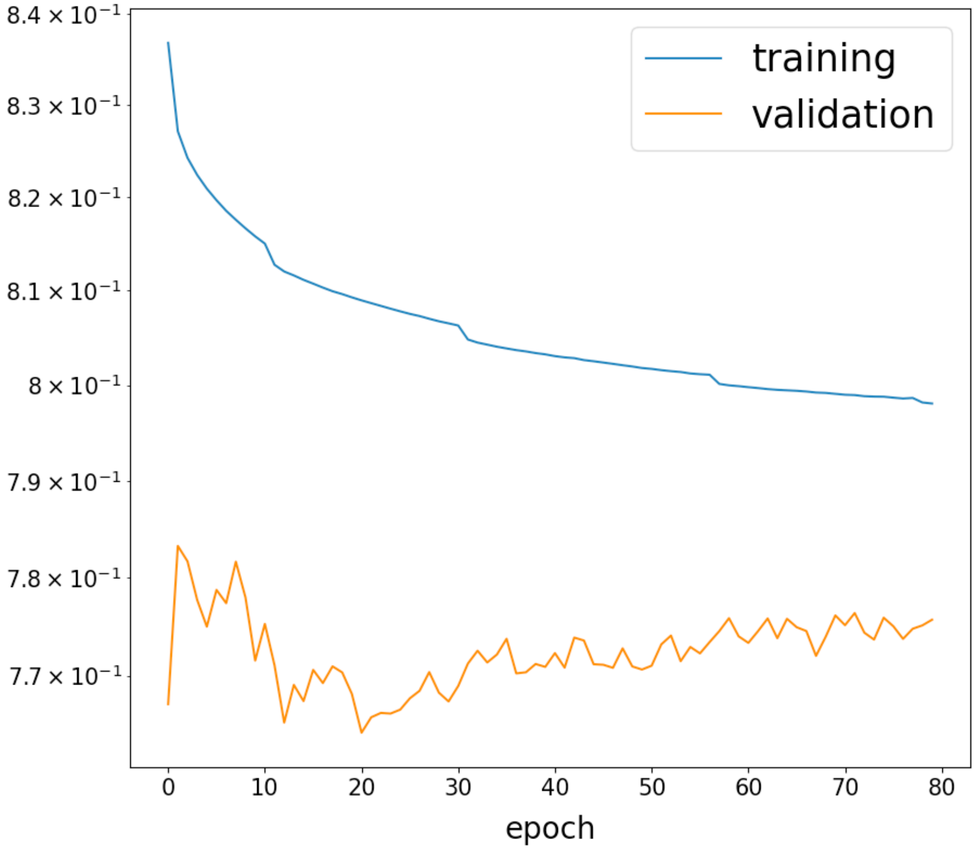

other
epoch
training
validation

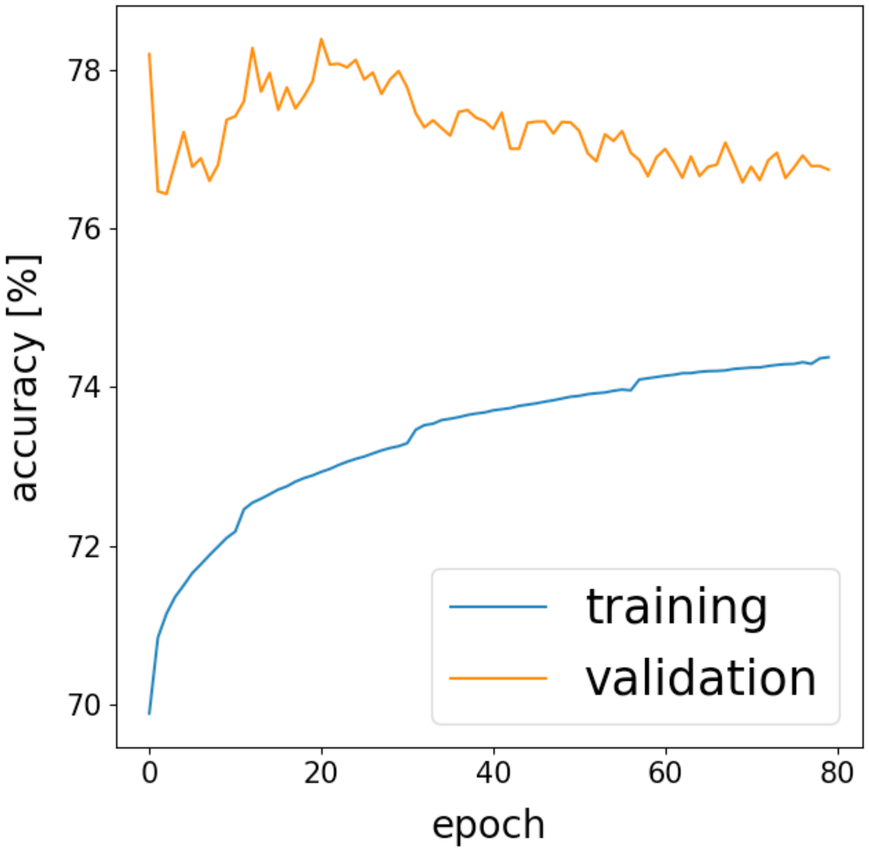
DeepJet


LCFIPlus, c jets
LCFIPlus, light jets
DeepJet, c jets
DeepJet, light jets
Background rate
b jets
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

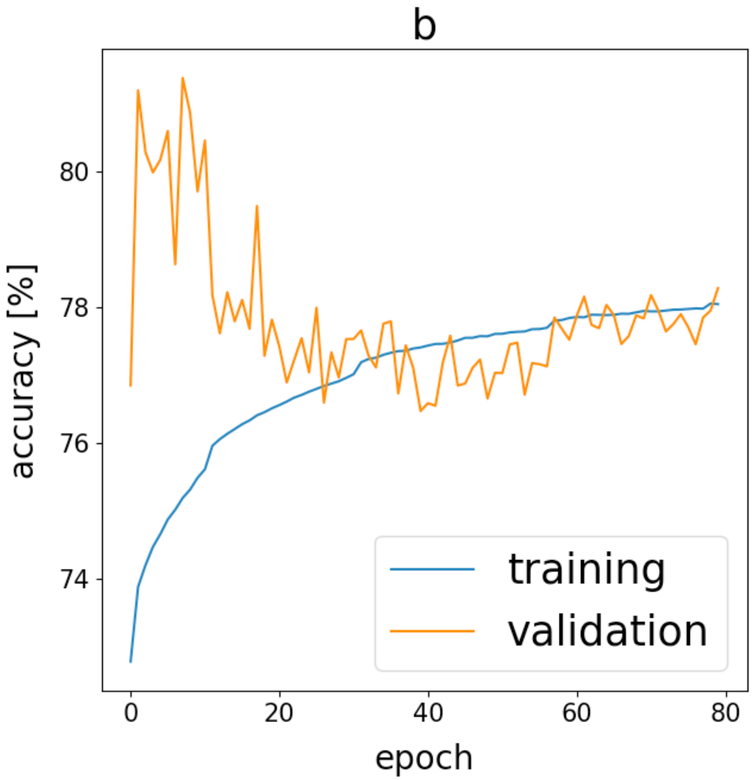

LCFIPlus, b jets
LCFIPlus, light jets
DeepJet, b jets
DeepJet, light jets
Background rate
c jets
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0.2
0.4
0.6
0.8
1.0

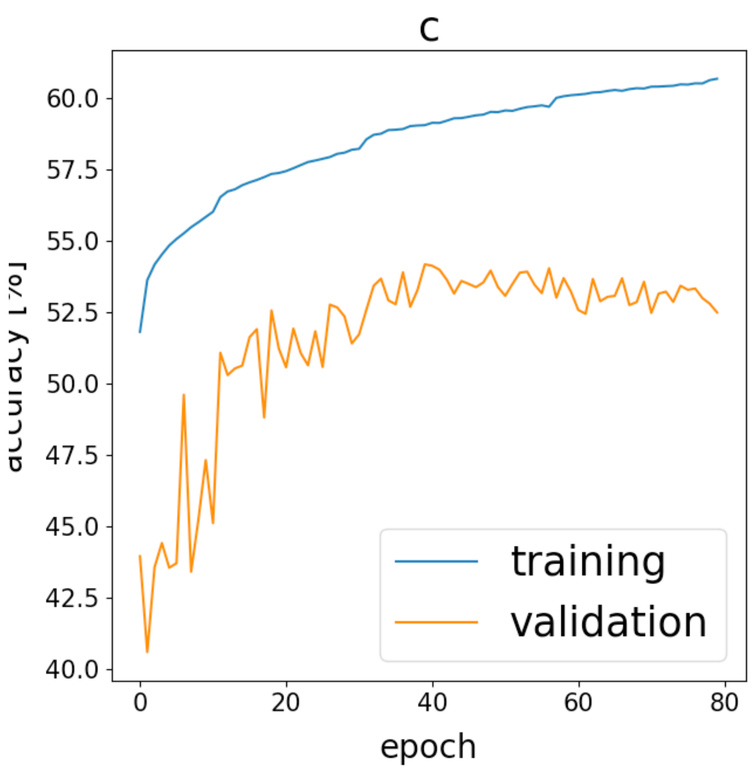
Particle Net : first results

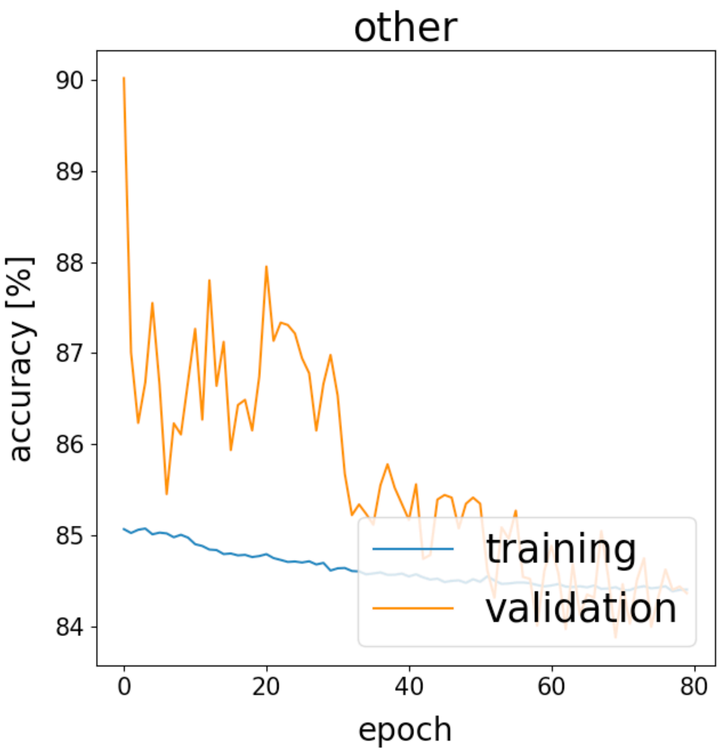




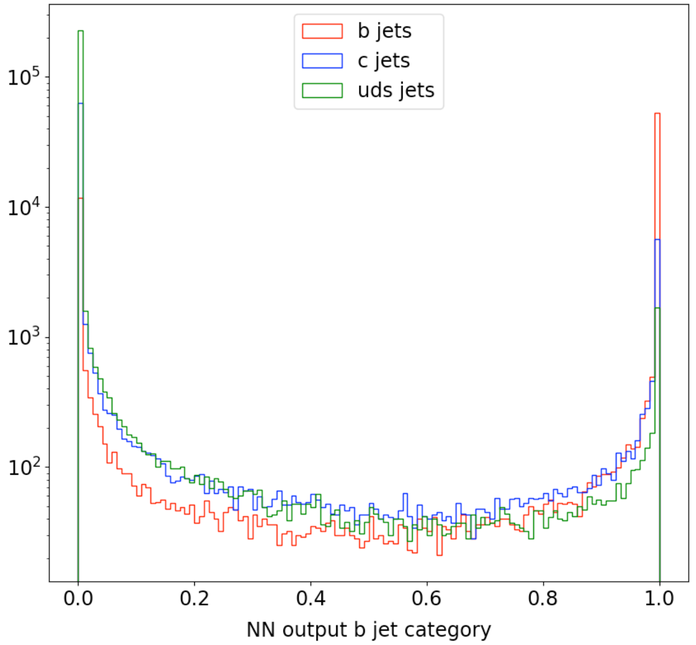
Particle Net : first results

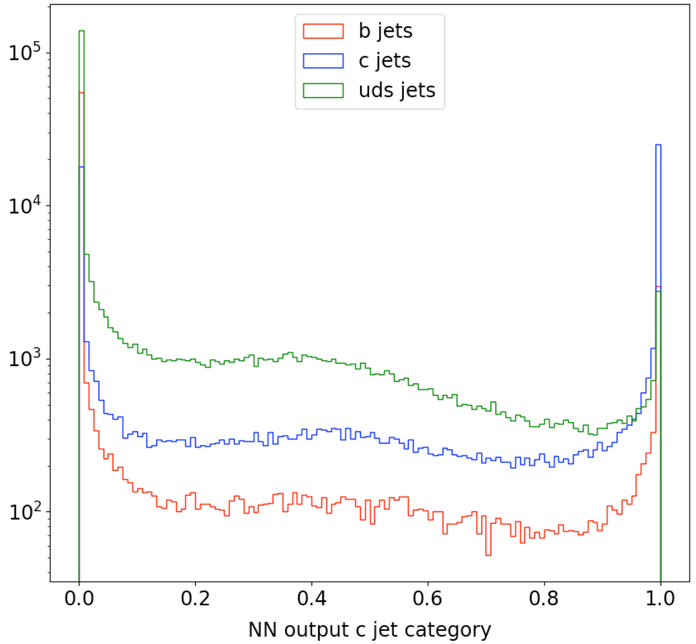


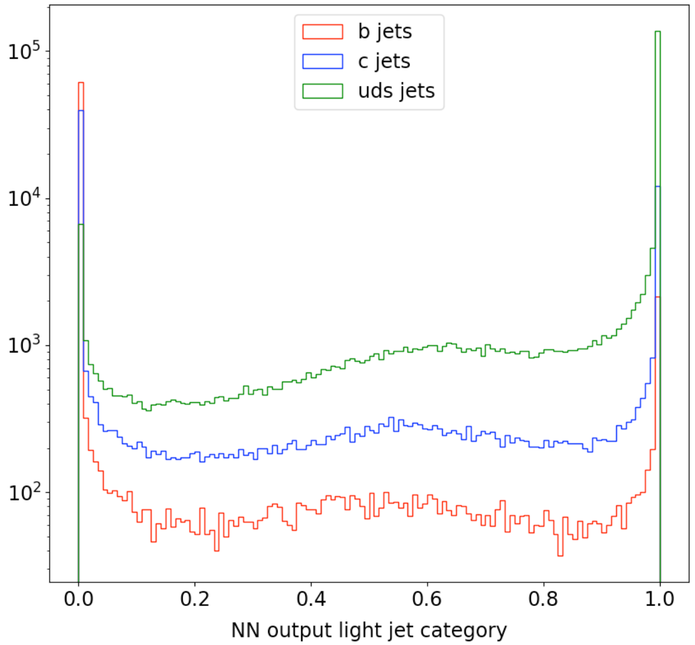




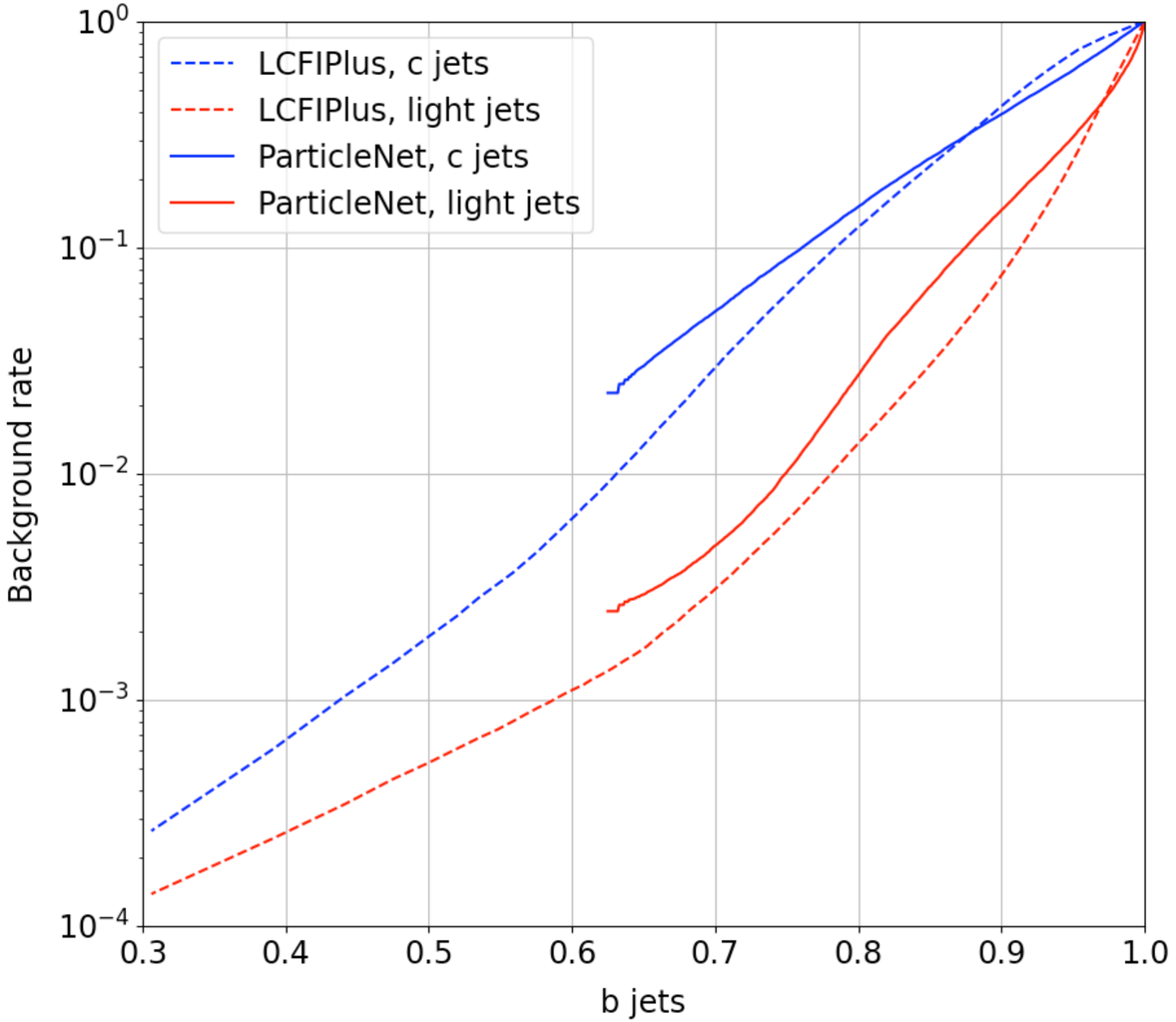
Particle Net : first results

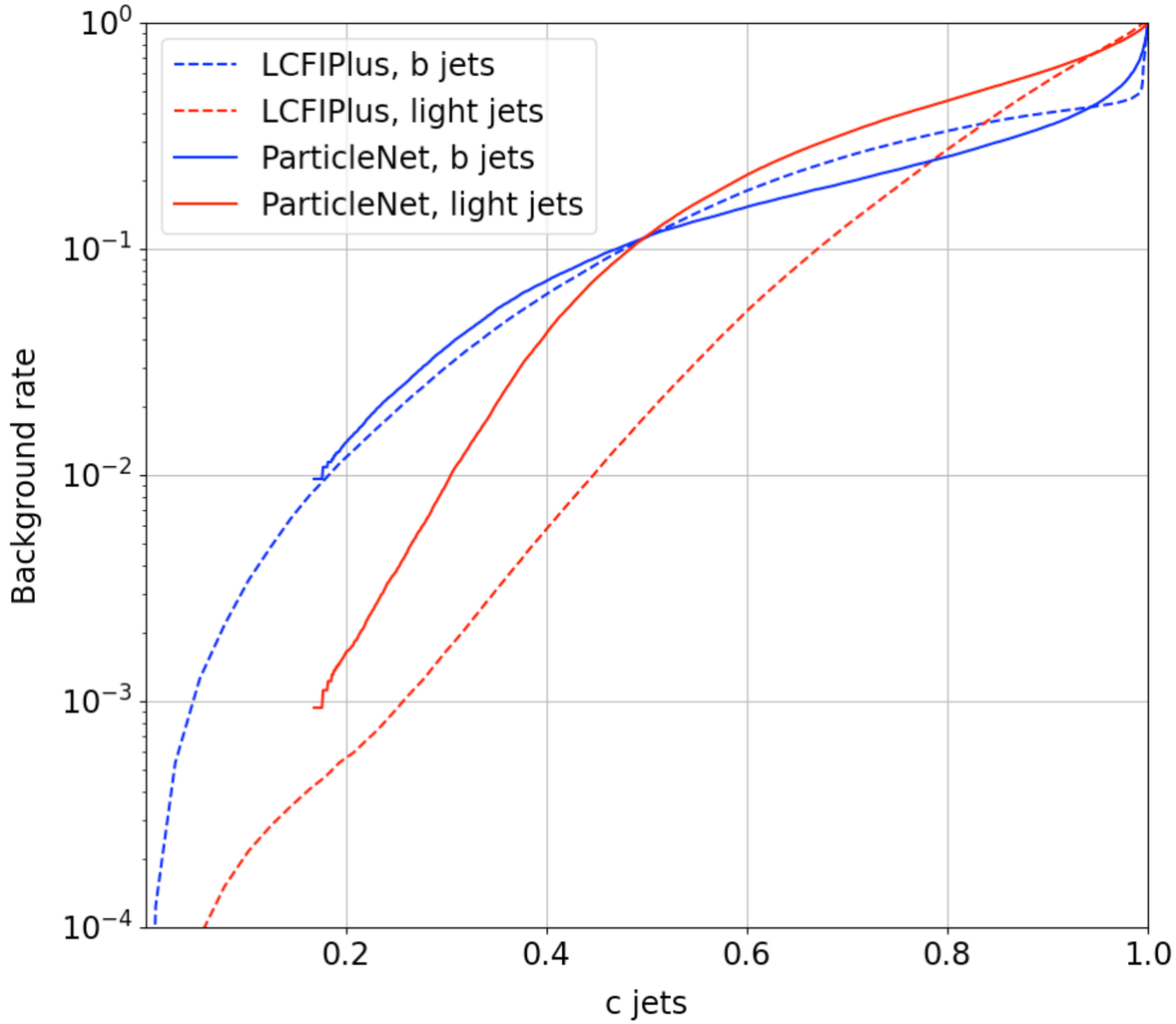






Particle Net : first results



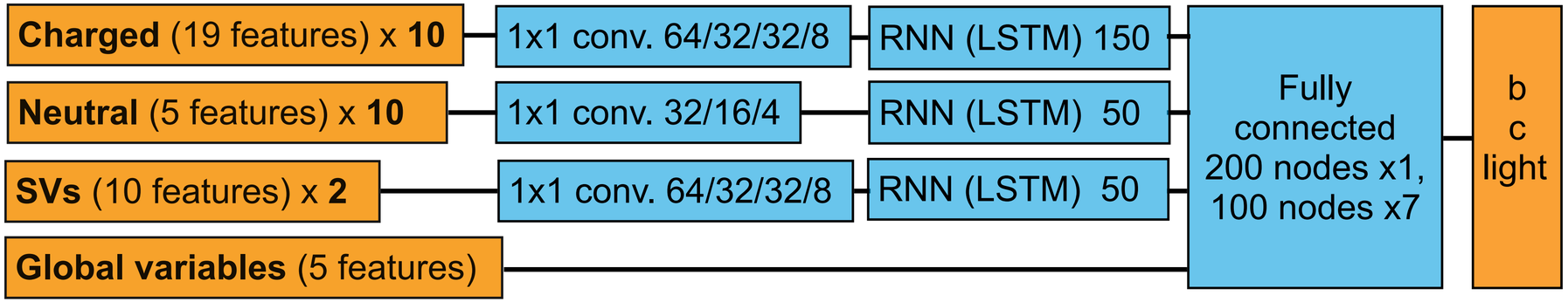


Next steps

- optimize Particle Net:
  - NN complexity, LR
  - more input features
  - less jet constituents?

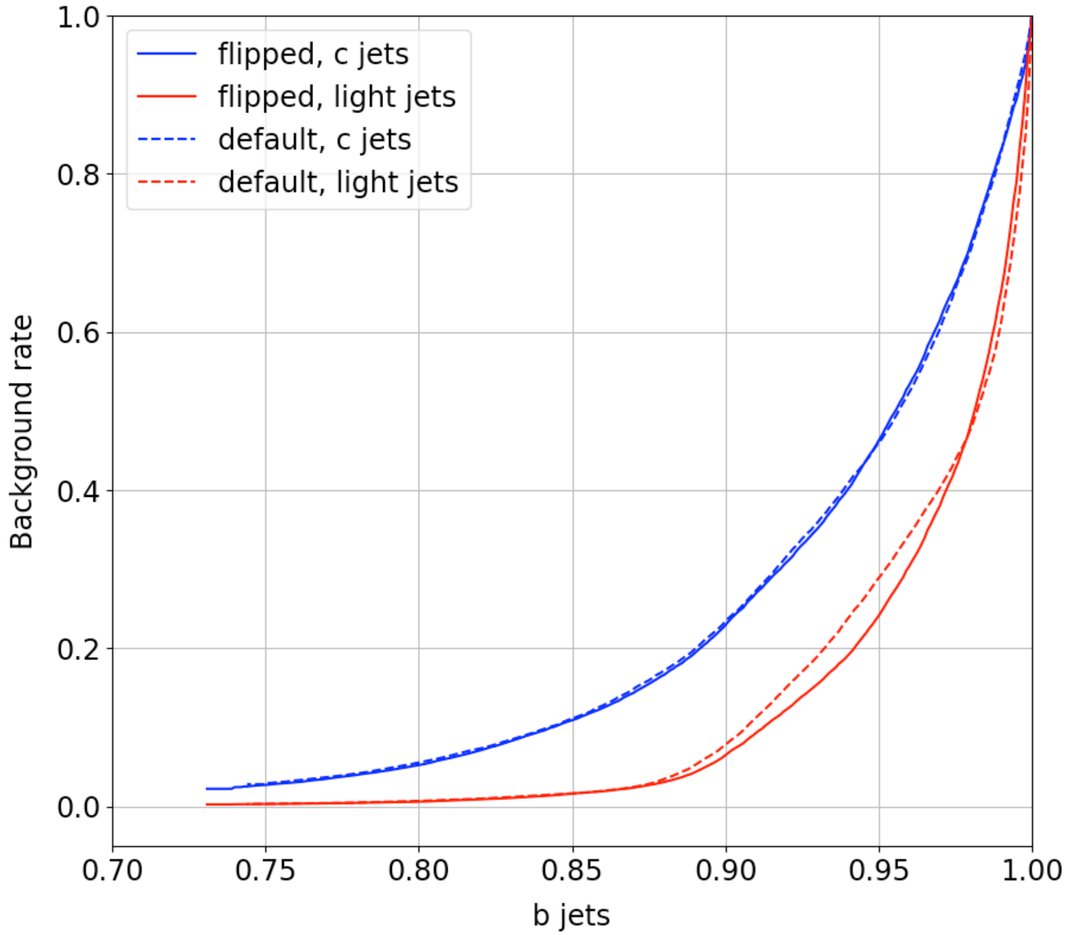
- study sensitivity of identifying s jets
- integration into iLCSoft

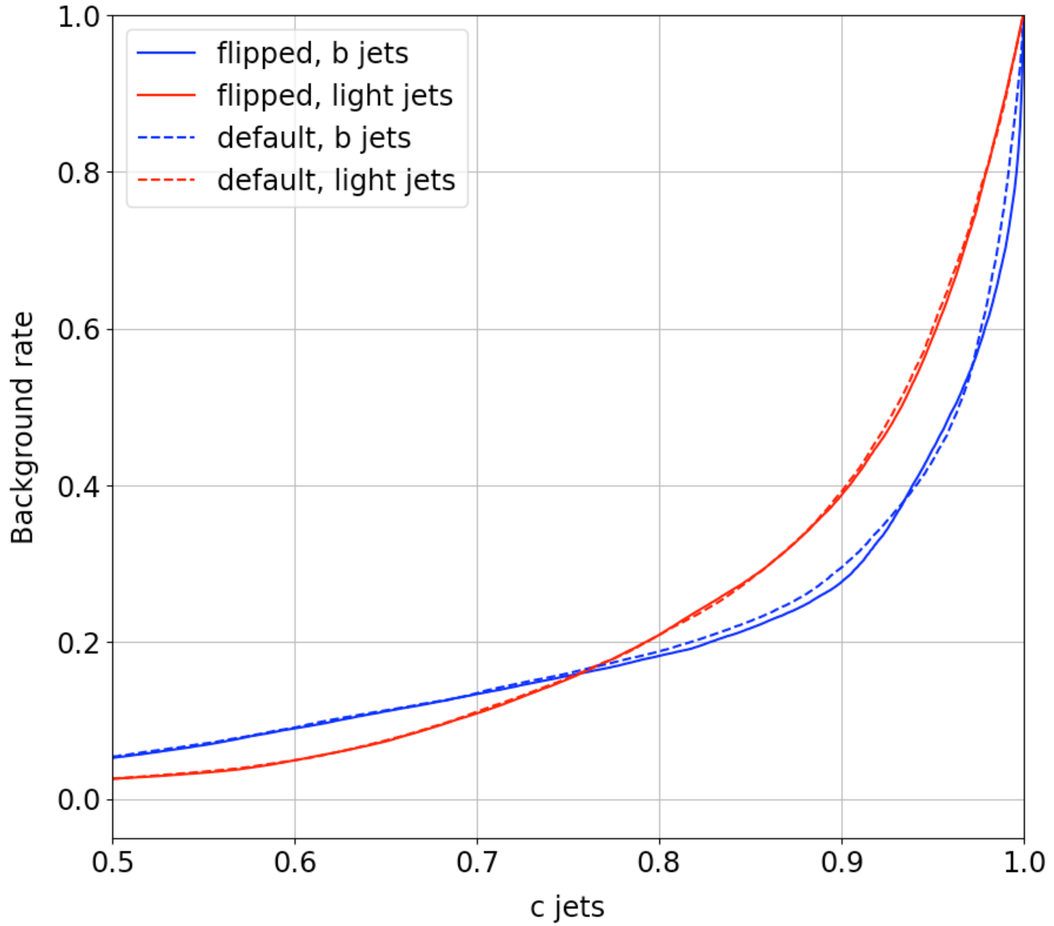
Architecture & data pre-processing



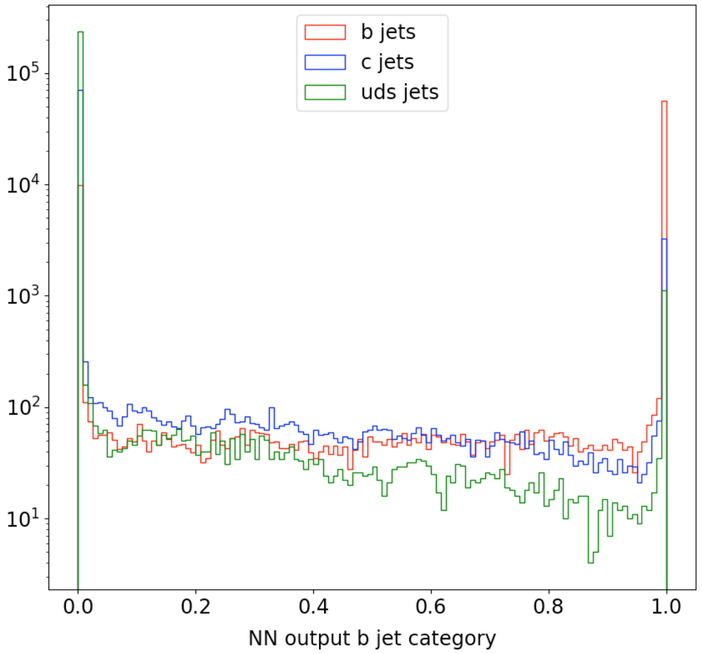
- classify jets into **three classes**: b jets, c jets & light jets
- **ordering of input particles** by (as applied in CMS)
  - impact parameter significance for charged jet constituents
  - shortest angular distance to a secondary vertex (by momentum if there is no secondary vertex) for neutral jet constituents
  - flight distance significance for secondary vertices
- if a value of a features is not available, the value is set to -10
- **normalize input features** to mean 0, std 1

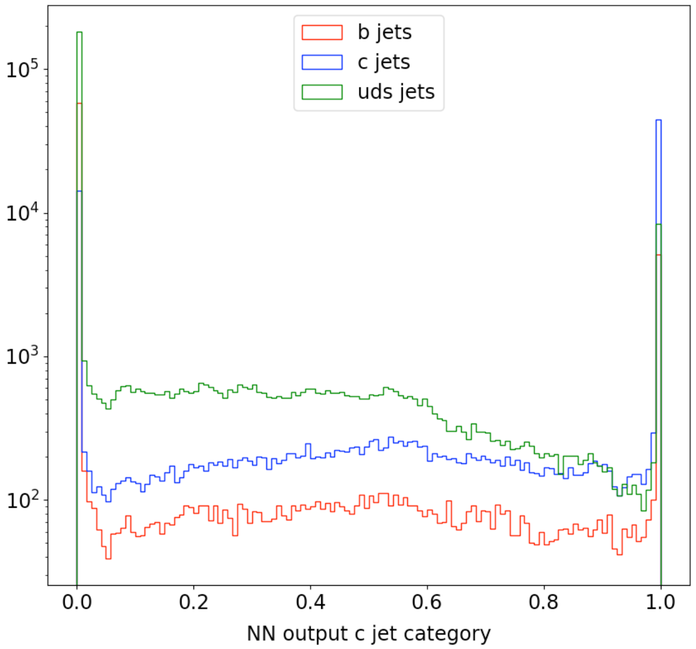
DeepJet

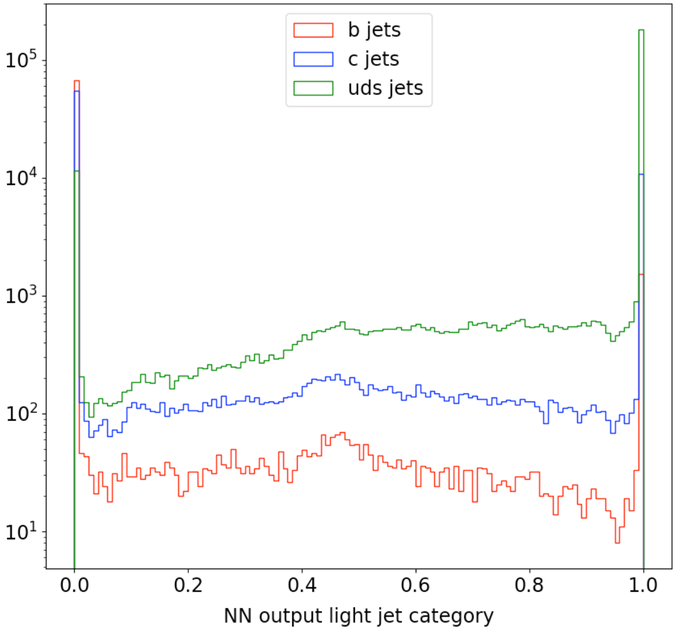

flipped, c jets
flipped, light jets
default, c jets
default, light jets
Background rate
b jets
1.0
0.8
0.6
0.4
0.2
0.0
0.70
0.75
0.80
0.85
0.90
0.95
1.00


flipped, b jets
flipped, light jets
default, b jets
default, light jets
Background rate
c jets
1.0
0.8
0.6
0.4
0.2
0.0
0.5
0.6
0.7
0.8
0.9
1.0

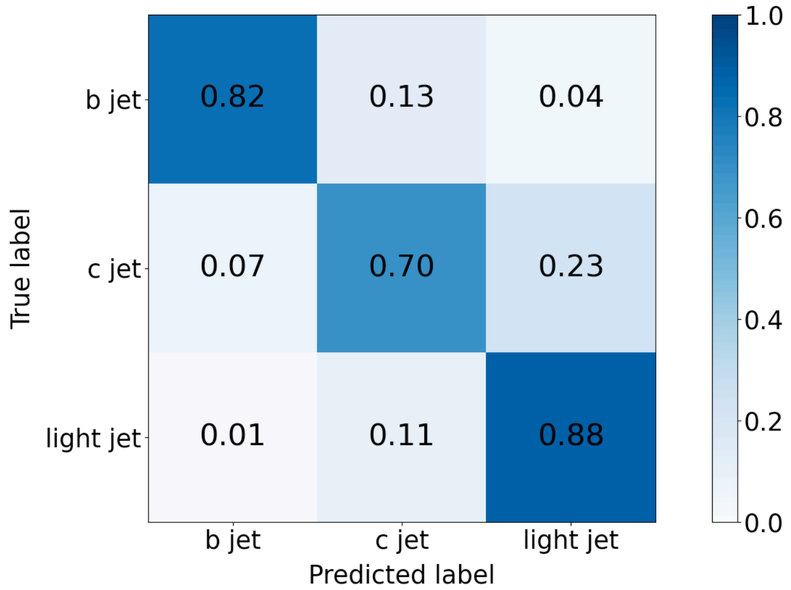
DeepJet


b jets
c jets
uds jets
10^5
10^4
10^3
10^2
10^1
0.0
0.2
0.4
0.6
0.8
1.0
NN output b jet category

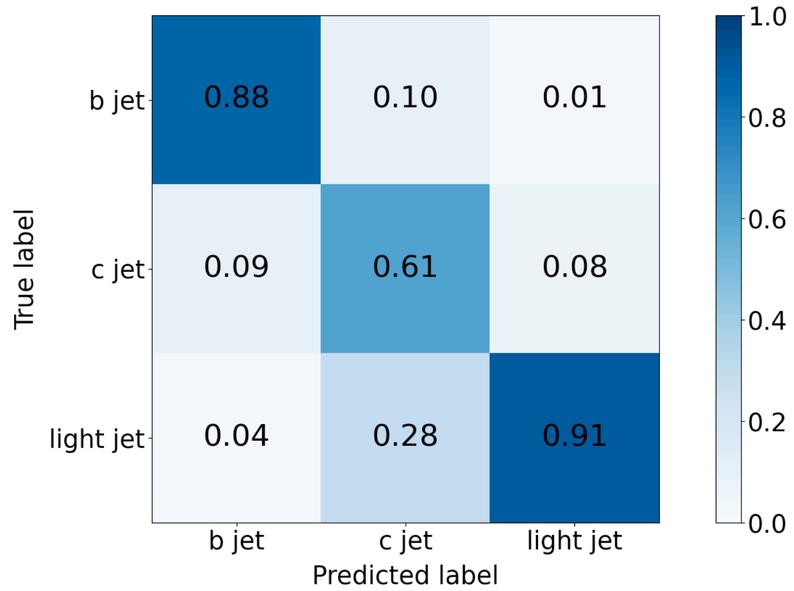

b jets
c jets
uds jets
10^5
10^4
10^3
10^2
0.0
0.2
0.4
0.6
0.8
1.0
NN output c jet category


b jets
c jets
uds jets
10^5
10^4
10^3
10^2
10^1
0.0
0.2
0.4
0.6
0.8
1.0
NN output light jet category

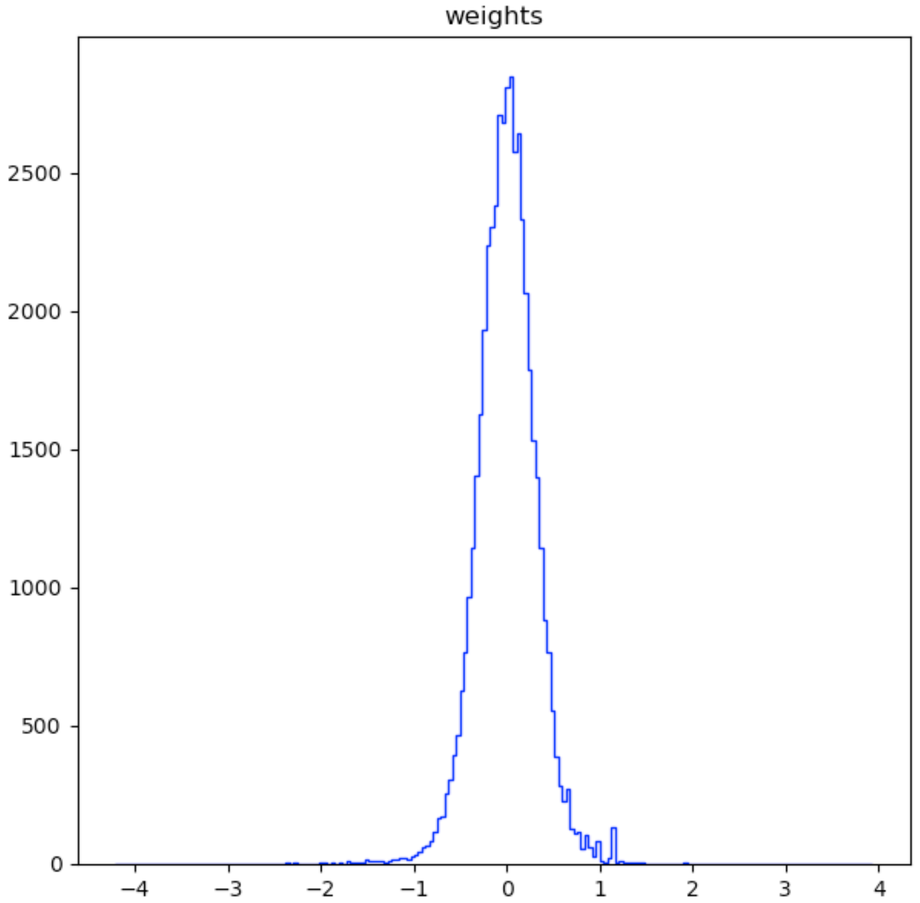
DeepJet

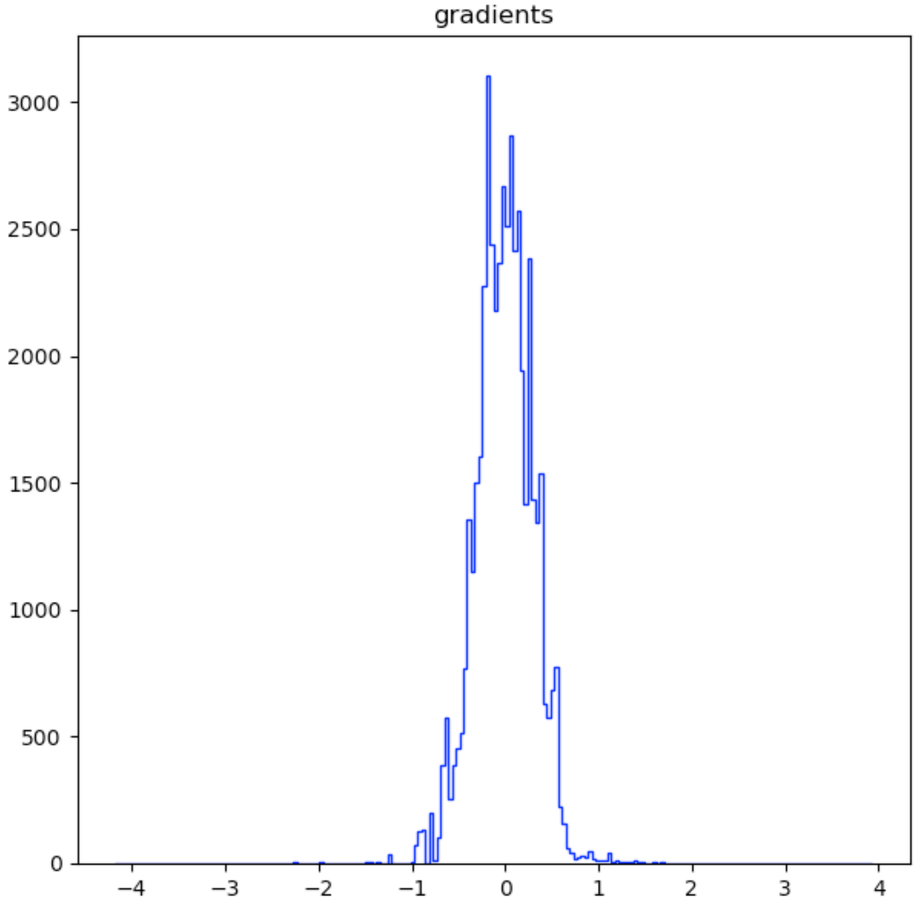


Purity



Particle Net





Particle Net