Strange jet tagging at the FCC-ee using a transformer NN architecture and K short reconstruction

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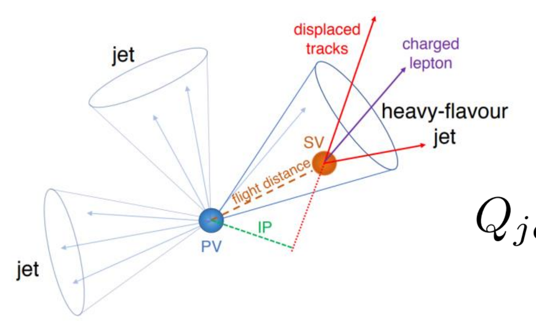
The successful identification of strange quark jets at the FCC-ee would enable the study of a multitude of largely unexplored processes, including the first ever study of Z->ss production, rare Higgs boson decays and the strange Yukawa coupling, CKM matrix elements via W decays, and BSM physics scenarios such as FCNCs. […]. A multiclassifier neural network using a transformer-based architecture is coupled with secondary vertexing and a novel implementation of K short reconstruction at the FCC-ee to discriminate strange quark initiated jets. This poster presents a state-of-the-art strange quark tagger at the FCC-ee, with a focus on light quark discrimination at the Z pole.

Introduction

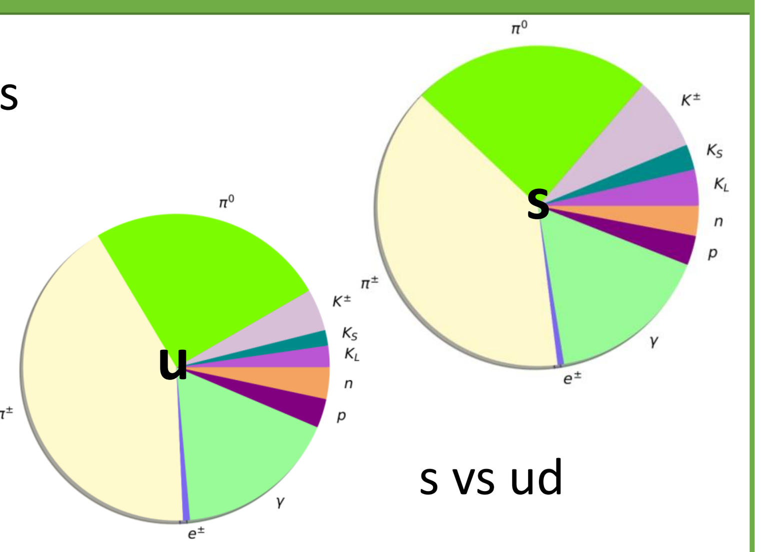
Quark initiated jets differ among themselves

b/c vs uds



u vs ds

$$Q_{jet} = \sum_i \frac{p^{\kappa}_{T,i}}{p^{\kappa}_{T,jet}} q_i$$



s vs ud

We exploit secondary vertex variables and the Kaon excess (K short reconstruction) via a Neural Network to distinguish jets

Input Variables & Samples

Consider $Z \rightarrow$ qq events at $\sqrt{s} = 91.2$ GeV

Reconstruction done in Delphes using IDEA detector configuration ("Spring2021" samples)

Events are exclusively clustered into 2 jets using ee-kt/Durham algorithm

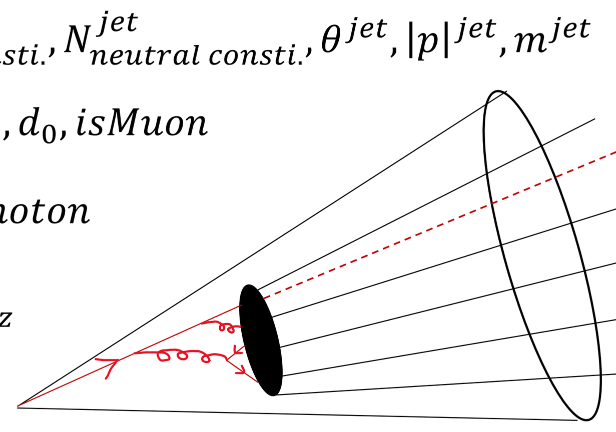
Jet Variables: $p_T^{jet}, \eta^{jet}, \phi^{jet}, E^{jet}, N^{jet}_{charged\ consti.}, N^{jet}_{neutral\ consti.}, \theta^{jet}, |p|^{jet}, m^{jet}$

Charged Constituents: $|p|\ ,\theta\ ,\phi\ ,m\ ,z_0, d_0, isMuon$

Neutral Constituents: $|p|\ ,\theta\ ,\frac{|p|}{|p|^{jet}}, isPhoton$

Secondary Vertex: $|p|\ ,m\ ,N_{tracks}, d_{xy}, d_{xyz}$

V0 Variables: $pid_{from\ reco.}, |p|\ ,\theta\ ,\phi\ ,m$

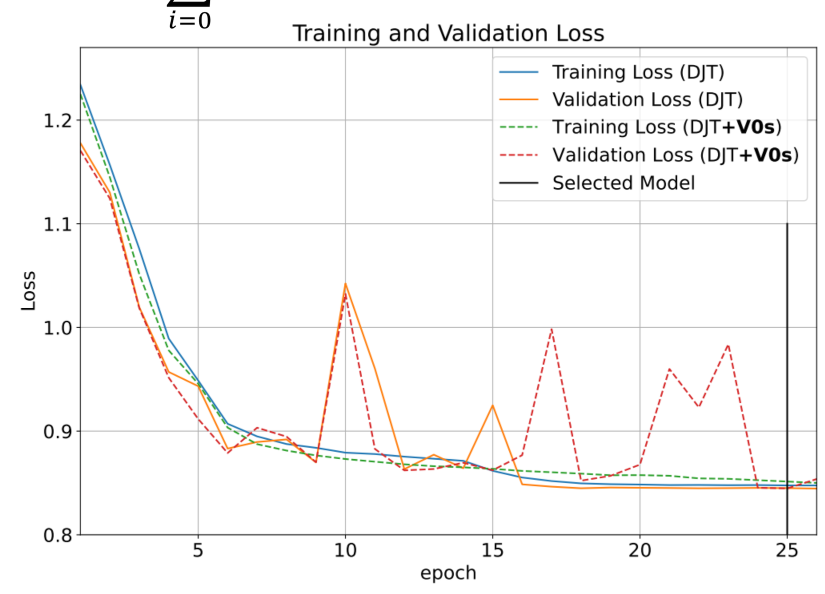


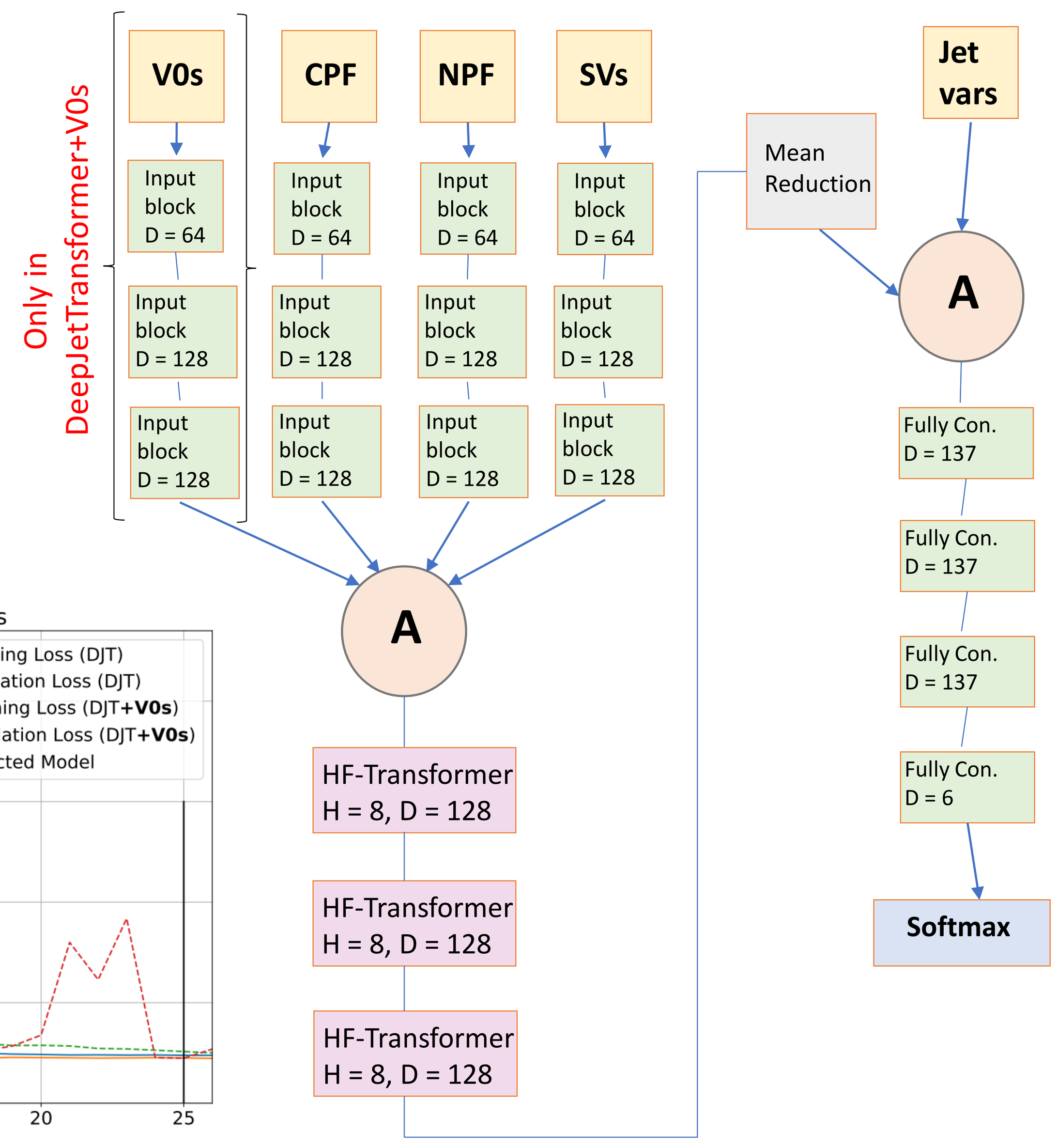
DeepJetTransformer(+V0s)

Neural Network (NN) relying on "attention[2]" mechanism dubbed HF-Transformer

Trained for 25 epochs on ~2.7M jets and optimized with ranger optimizer[3]

$$Loss = -\sum_{i=0}^{n} truth_i \times \ln(pred_i)$$

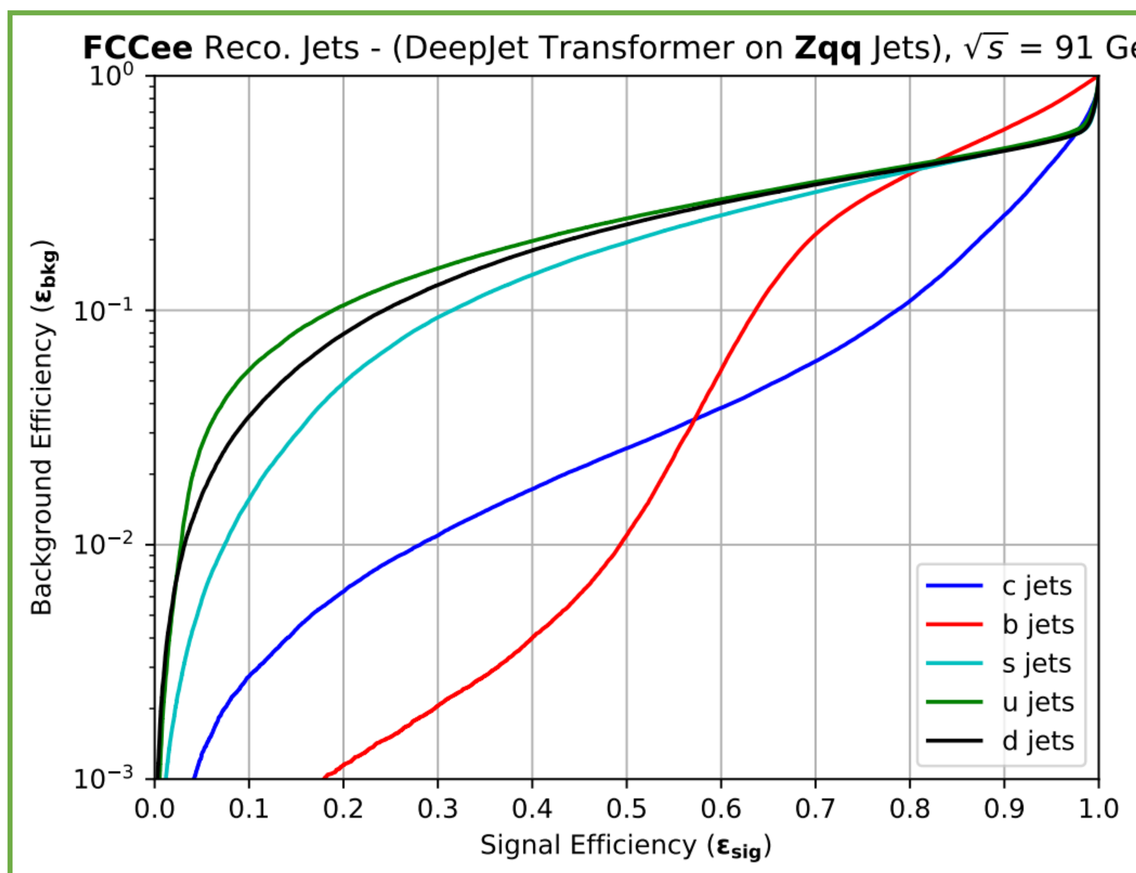




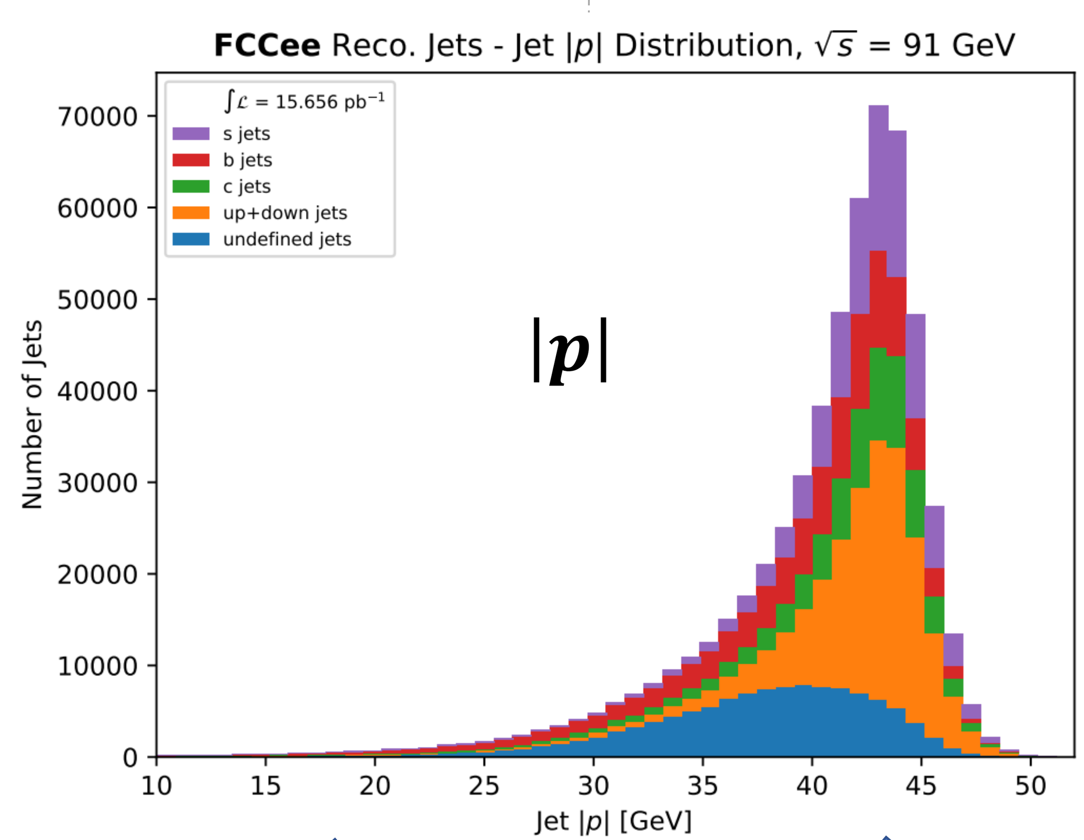
Results

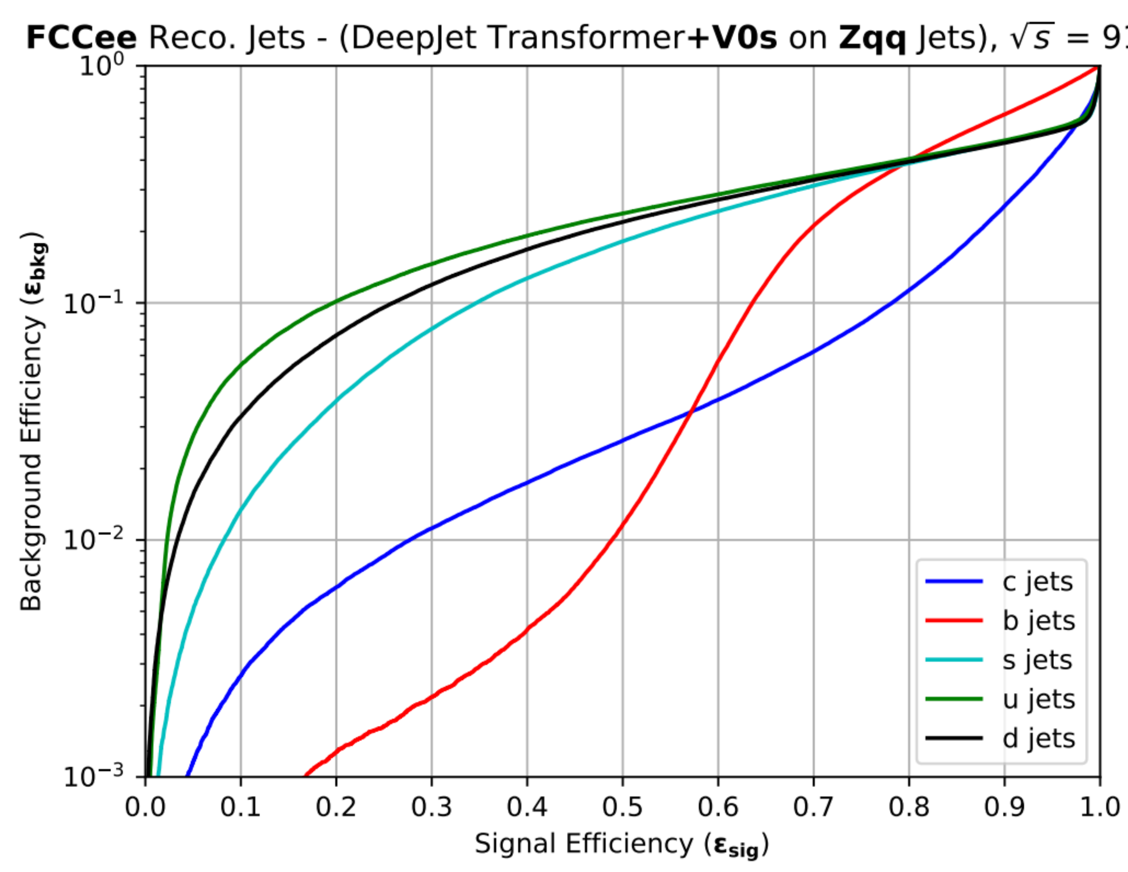
Jets (~667k) receive a u,d,s,c,b, NN score corresponding to the Softmax layer output

Working Points	$\varepsilon_{\mathbf{bkg.}}$	$\varepsilon_{\mathbf{s}}(DJT)$	$\varepsilon_{\mathbf{s}}(DJT{+}\mathbf{V0s})$
loose	10.0%	31.5%	**34.7%**
medium	5.0%	20.2%	**23.3%**
tight	1.0%	7.4%	**8.2%**



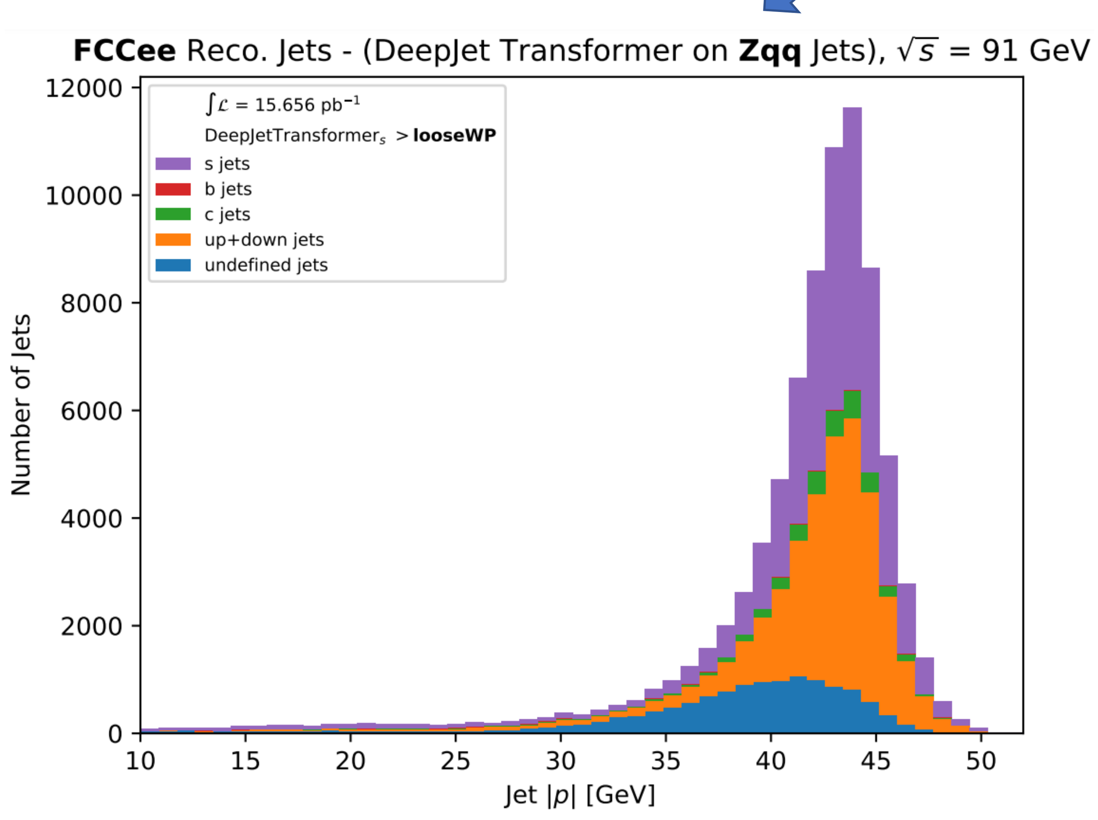
Discriminating performance strongest for b quark jets, and weakest for up quark jets

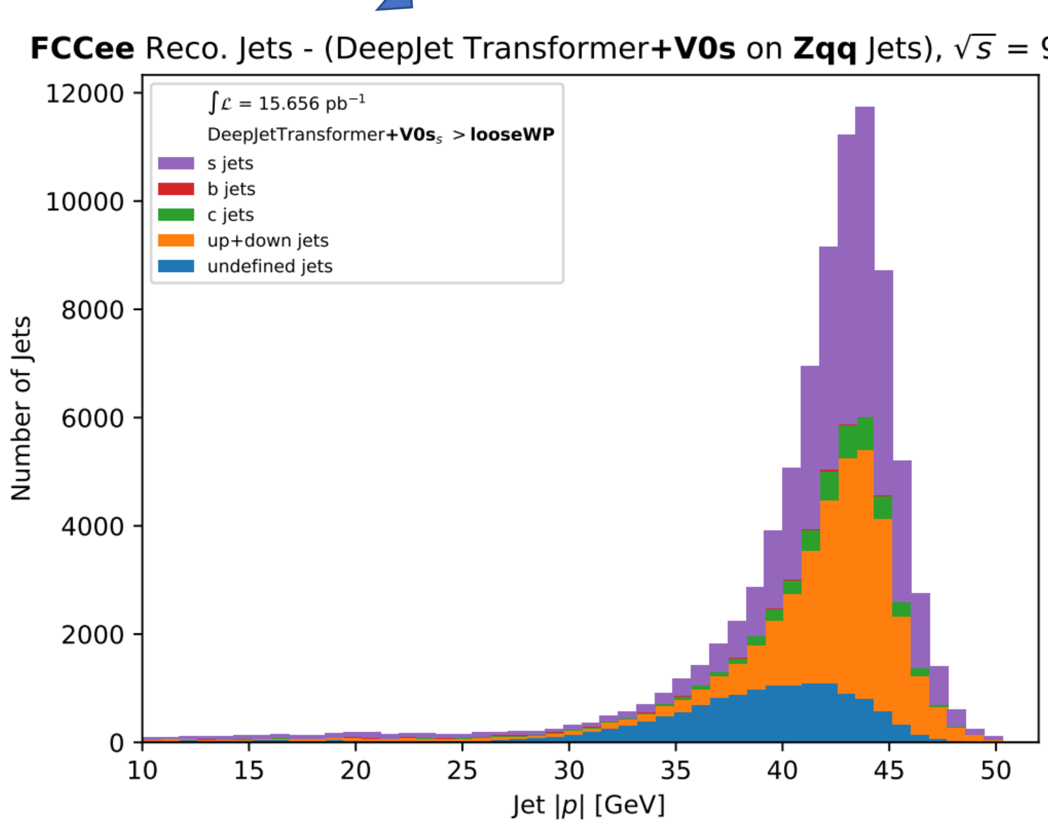




Addition of V0 variables improves primarily strange quark discrimination

Background to s quark jets consists almost exclusively of up+down quark jets





Up+down quark jet background relatively insensitive to V0 variables

Conclusions

First look at NN multiclass jet flavour tagger exploiting SV & V0 reconstruction at FCC-ee using central FCC samples ("Spring2021")

Strange jet tagging performance improves from 31.5% signal efficiency to 34.7% with addition of V0s at a 10% background efficiency

Up+down quark jets consititute main background. Improvements in discrimination between u/d and s quark jets requires PID variables (e.g. dN/dx, dE/dx)

=> Studies will be redone with larger sample sizes and inclusion of PID variables, application to Z->ss decay width extraction

[1] CMS Collaboration, arXiv:1712.07158; [2] Vaswani, et al., arXiv:1706.03762;
[3] M. Zhang, et al., arXiv:1907.08610; L. Liu, et al., arXiv:1908.03265];
[4] M. Cacciari, G. Salam, arXiv:0707.1378;