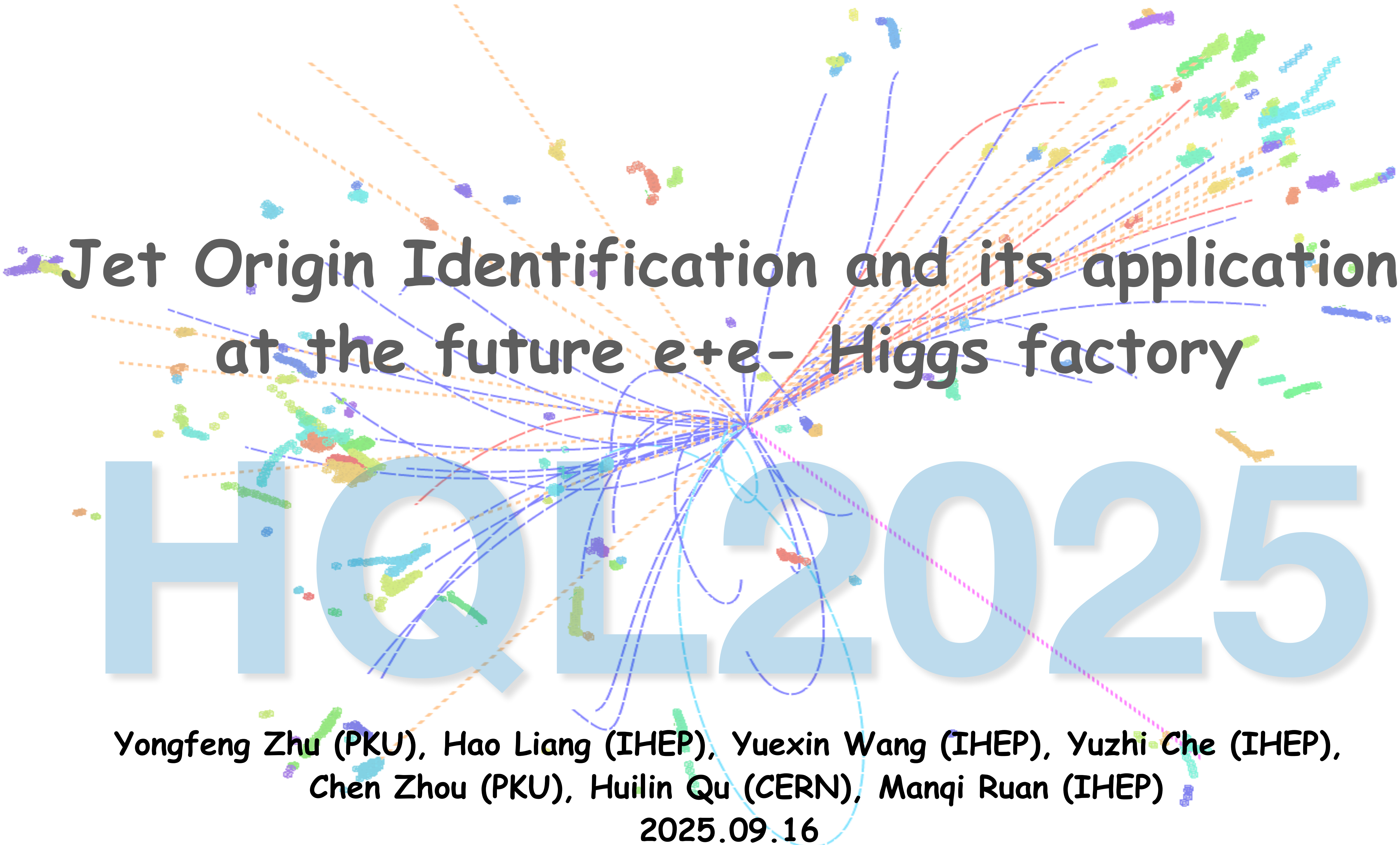
Jet Origin Identification and its application at the future e+e- Higgs factory



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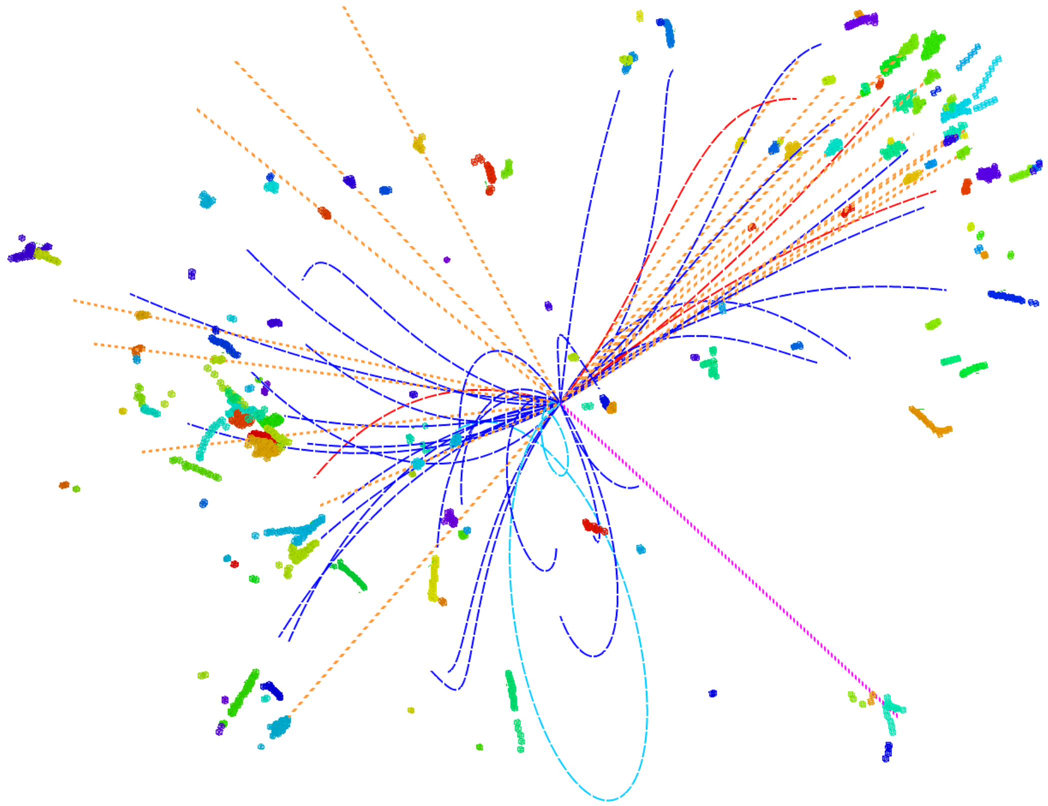
Definition of Jet Origin Identification

Quarks and gluons can not travel freely.
Instead, they would fragment into numerous particles, which are called jets.

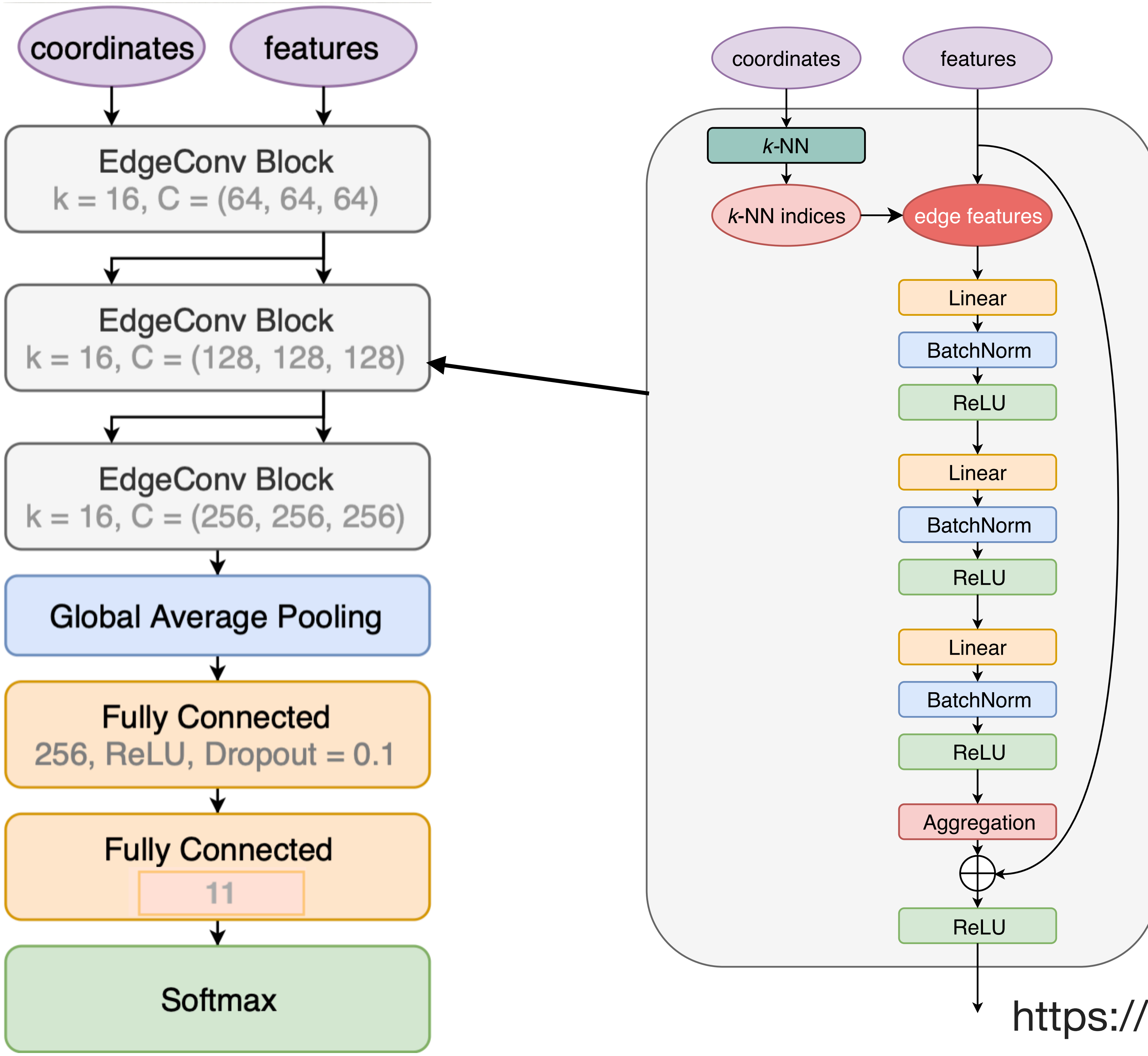


$\nu\bar{\nu}H, H \rightarrow gg$ at $\sqrt{s} = 240\ GeV$

Jet Origin Identification: categorizes jets into 5 quarks (b, c, s, u, d), 5 anti-quarks, and gluon.

Samples and ParticleNet

samples: Based on the CEPC baseline detector, full simulation of $e^+e^- \rightarrow \nu\bar{\nu}H, H \rightarrow b\bar{b}/c\bar{c}/s\bar{s}/u\bar{u}/d\bar{d}/gg$ at $\sqrt{s} = 240\ GeV$



input features:
impact parameters,
kinematic variables,
and PID information of
particles in a jet

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the performance of jet origin identification

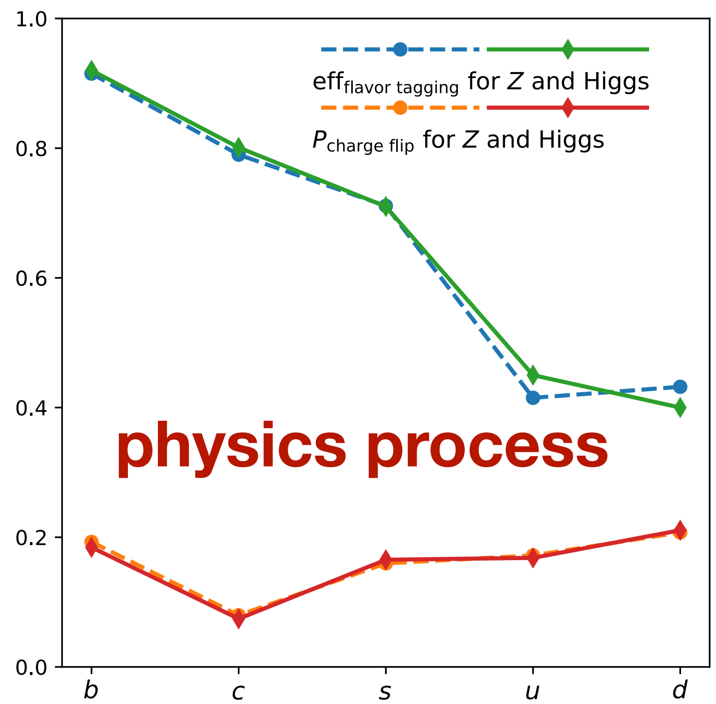
ParticleNet algorithm attaches each jet with 11 likelihoods corresponding to 11 types of jets.
Then the jet type is determined according to the maximum likelihood.

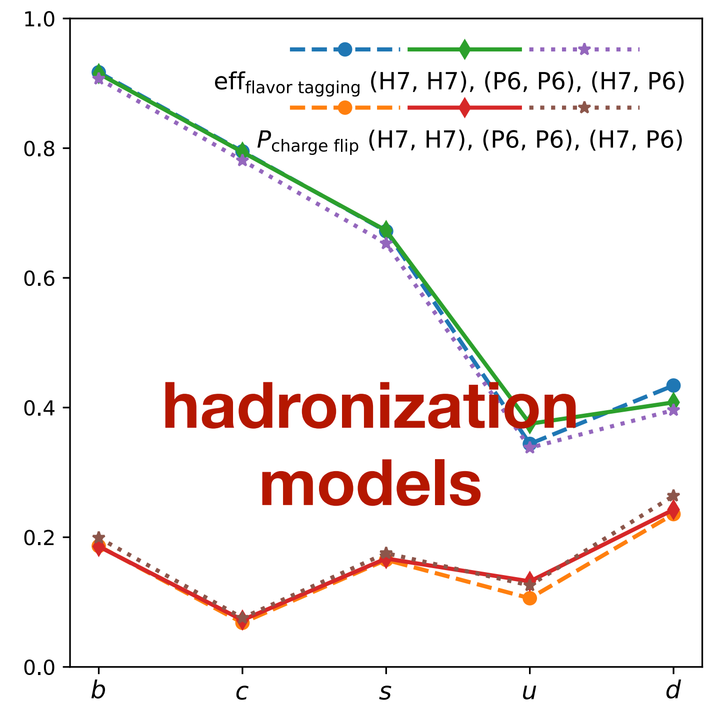
True \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$	G
b	0.745	0.163	0.033	0.025	0.004	0.003	0.002	0.003	0.002	0.002	0.017
$\bar{b}$	0.170	0.737	0.026	0.033	0.003	0.004	0.003	0.002	0.002	0.003	0.018
c	0.015	0.014	0.743	0.055	0.036	0.031	0.025	0.009	0.009	0.018	0.043
$\bar{c}$	0.016	0.015	0.056	0.739	0.032	0.037	0.009	0.026	0.017	0.010	0.043
s	0.003	0.002	0.020	0.018	0.543	0.102	0.030	0.080	0.063	0.045	0.092
$\bar{s}$	0.003	0.003	0.018	0.020	0.102	0.542	0.084	0.028	0.045	0.062	0.094
u	0.002	0.003	0.020	0.011	0.044	0.131	0.367	0.055	0.080	0.174	0.111
$\bar{u}$	0.003	0.003	0.011	0.019	0.132	0.043	0.062	0.356	0.178	0.081	0.111
d	0.003	0.003	0.012	0.019	0.112	0.092	0.082	0.207	0.277	0.079	0.112
$\bar{d}$	0.003	0.003	0.020	0.012	0.092	0.112	0.219	0.076	0.079	0.272	0.113
G	0.015	0.014	0.024	0.024	0.052	0.052	0.043	0.041	0.034	0.034	0.667

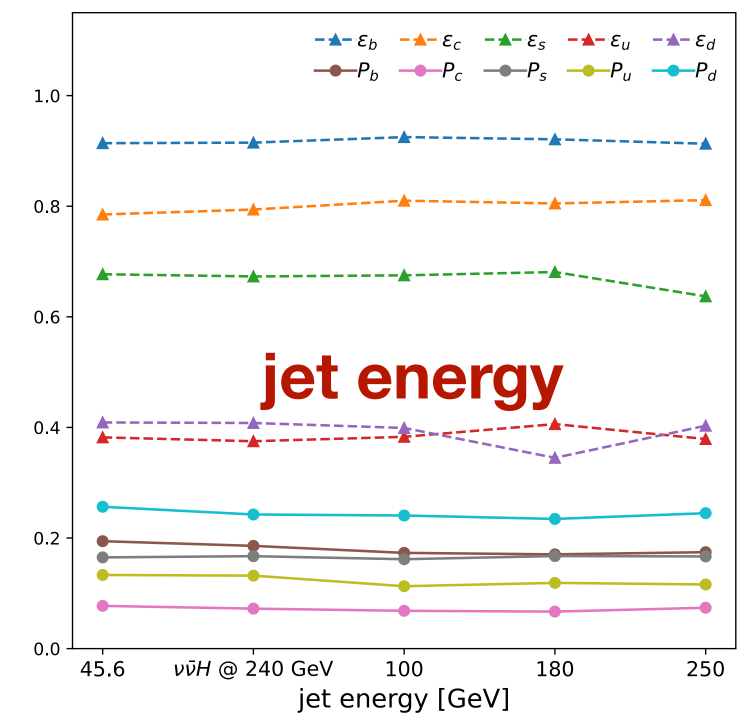
the stability of jet origin identification

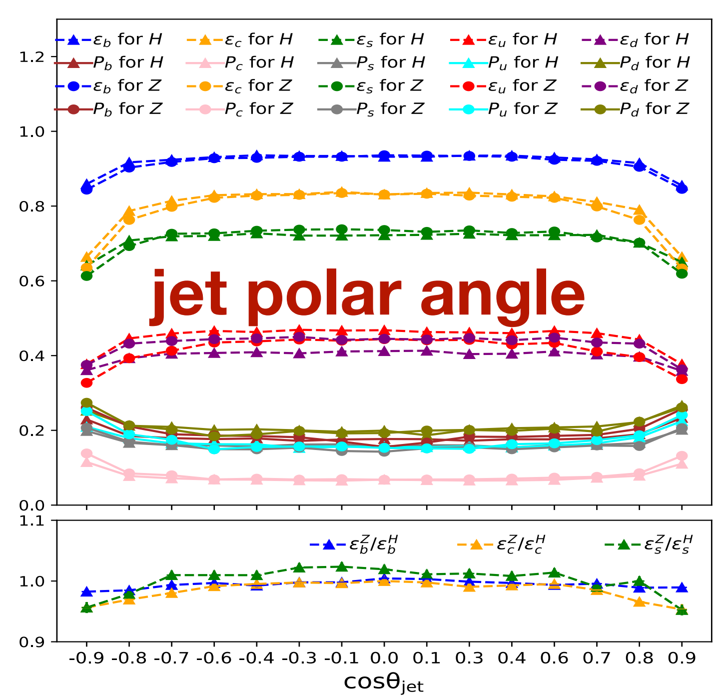
Jet flavor tagging efficiency: only separate different flavors

jet charge flip rate: only separate different charges among the same flavor





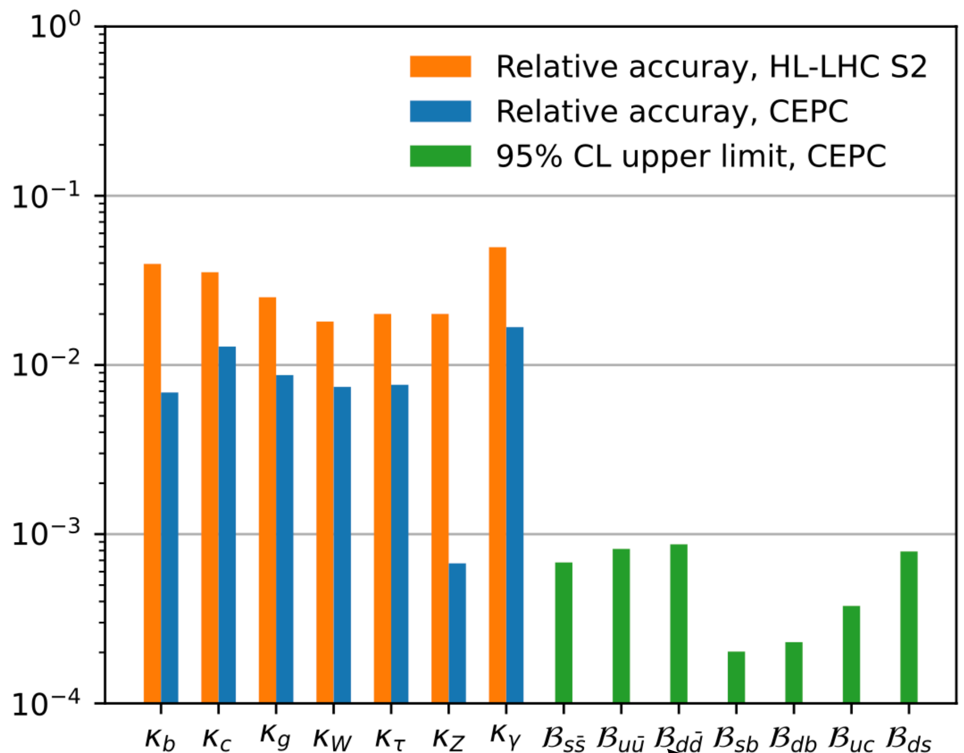




All comparative results show that the performance of jet origin identification are stable.

rare and exotic Higgs decay modes

Begin with the existing analyses of $\nu\bar{\nu}H, H \to b\bar{b}/c\bar{c}/gg$, (arXiv:2203.01469) and combining the jet origin identification, we obtain the upper limits on branching ratios of seven Higgs rare and FCNC hadronic decay modes.



improved by 2 times **improved by one order of magnitude**

FIG. 5: The upper limits on the branching ratios of Higgs rare decays from this work are shown in green. The relative uncertainties of Higgs couplings anticipated at the CEPC [19] are shown in blue, and those at HL-LHC [42] are shown in orange, both with the kappa-0 fit scenario [53] and scenario S2 of systematics [54], as cited in Ref. [19].

TABLE I: Summary of background events for $\to b\bar{b}/c\bar{c}/gg$, Z, and W prior to the flavor-based event lection, along with the expected upper limits on Higgs lecay branching ratios at 95% CL. These expectations are derived based on the background-only hypothesis.

	Bkg. (10^3)			Upper limits on Br. (10^{-3})						
	H	Z	W	$s\bar{s}$	$u\bar{u}$	$d\bar{d}$	sb	db	uc	ds
$\nu\bar{\nu}H$	151	20	2.1	0.81	0.95	0.99	0.26	0.27	0.46	0.93
$u^+\mu^-H$	50	25	0	2.6	3.0	3.2	0.5	0.6	1.0	3.0
e^+e^-H	26	16	0	4.1	4.6	4.8	0.7	0.9	1.6	4.3
Comb.	-	-	-	0.75	0.91	0.95	0.22	0.23	0.39	0.86

[23] J. Duarte-Campderros, G. Perez, M. Schlaffer, and A. Soffer, Phys. Rev. D **101**, 115005 (2020), arXiv:1811.09636 [hep-ph].

[44] A. Albert *et al.*, "Strange quark as a probe for new physics in the higgs sector," (2022), arXiv:2203.07535 [hep-ex].

[53] J. de Blas *et al.*, JHEP **01**, 139 (2020), arXiv:1905.03764 [hep-ph].

[54] J. De Blas, G. Durieux, C. Grojean, J. Gu, and A. Paul, JHEP **12**, 117 (2019), arXiv:1907.04311 [hep-ph].

$|V_{cb}|$ Measurement from $W \to cb$ decay

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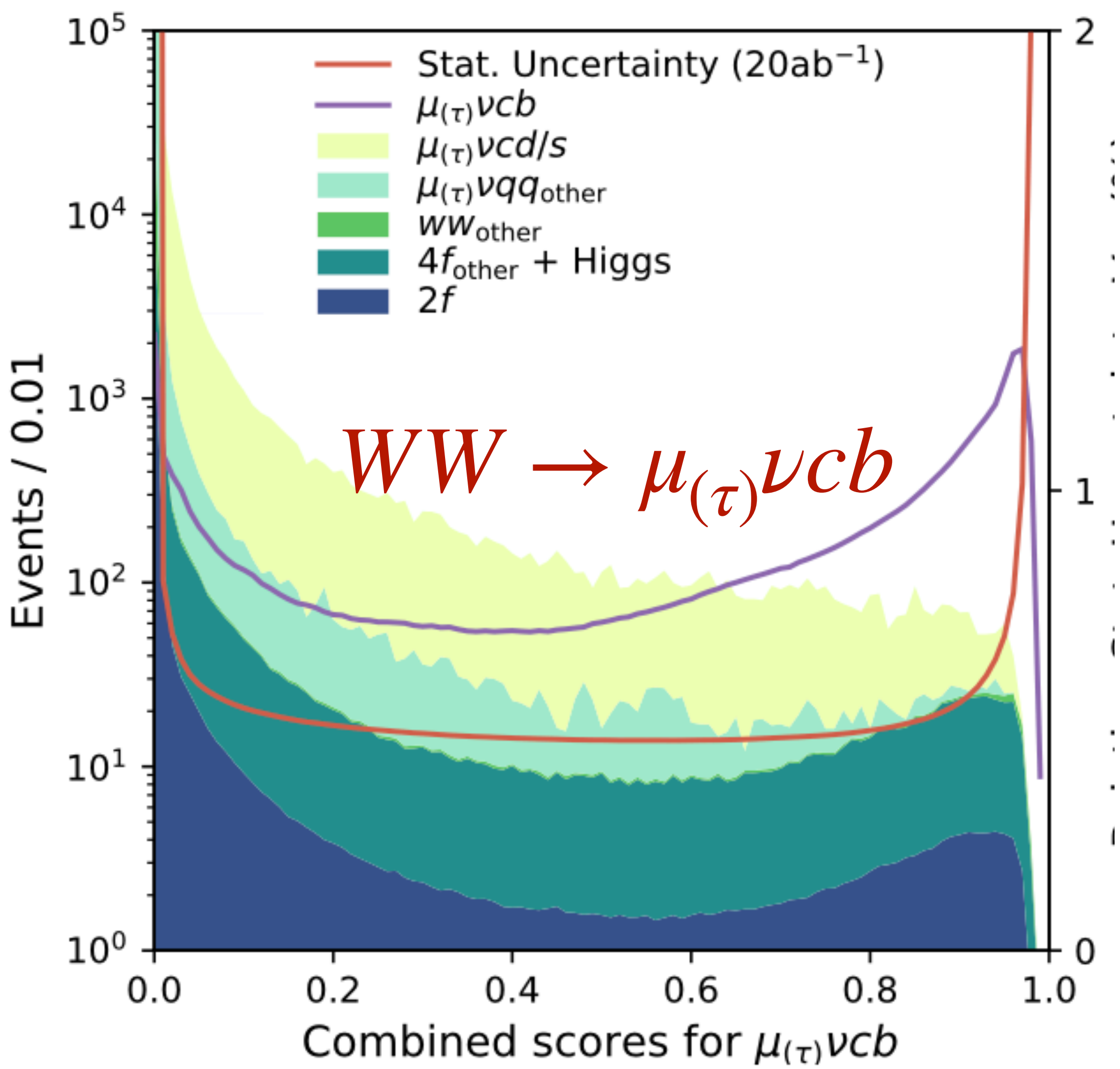
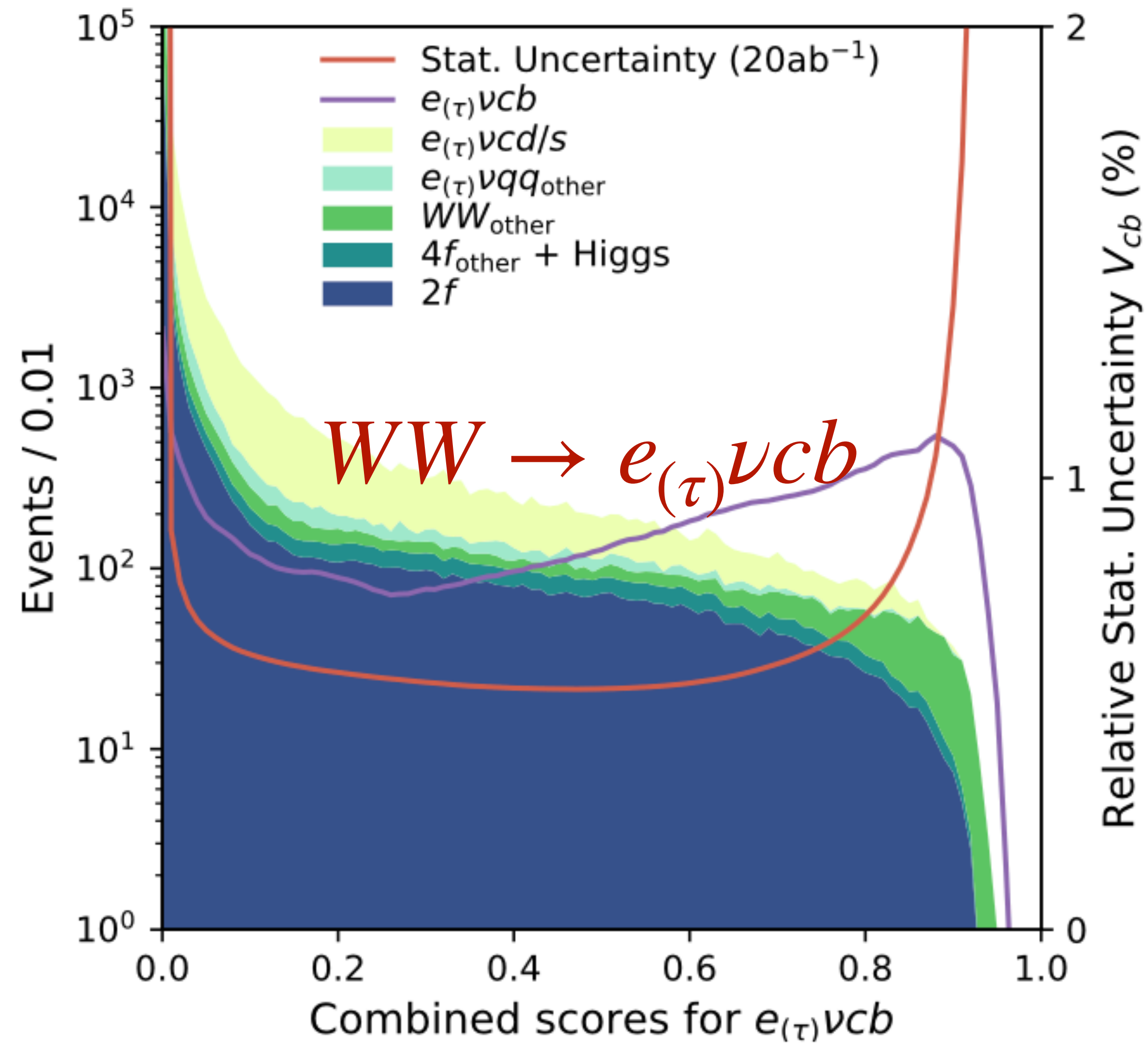
- Measure $|V_{cb}|$ through $W \to cb$ decay is a complementary method to b-hadron decay. However, the Br($W \to cb$) is 6×10^{-4}, while in future Higgs factories, the $e^+e^- \to W^+W^-$ production rate is significant with a high integrated luminosity.
- After kinematic cuts and flavor tagging cuts based on the JOI, the relative statistical uncertainties $|V_{cb}|$ are projected to be 0.91% for the $WW \to \mu_{(\tau)}\nu cb$ channel and 1.2% for the $WW \to e_{(\tau)}\nu cb$ channel, assuming a baseline integrated luminosity of $5ab^{-1}$.





Many thanks !