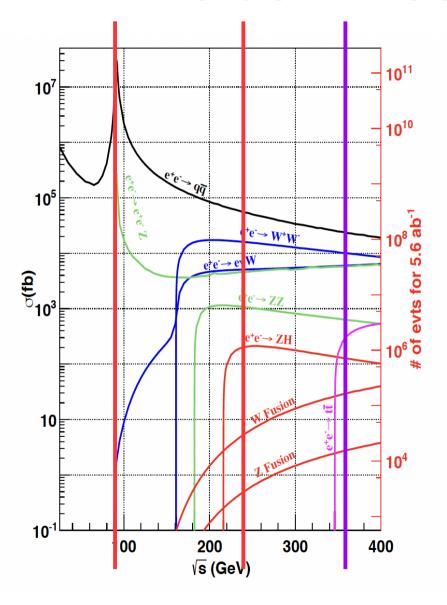
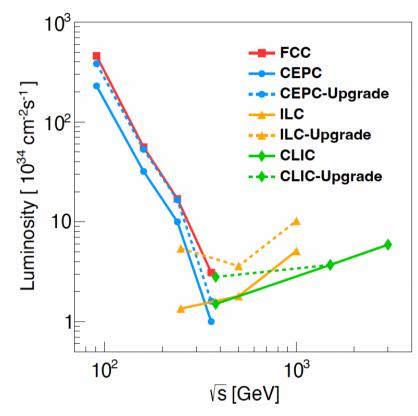
An holistic approach of reconstruction and analysis: AI usage at future Higgs factory

Mangi

14/07/25 WCEPP

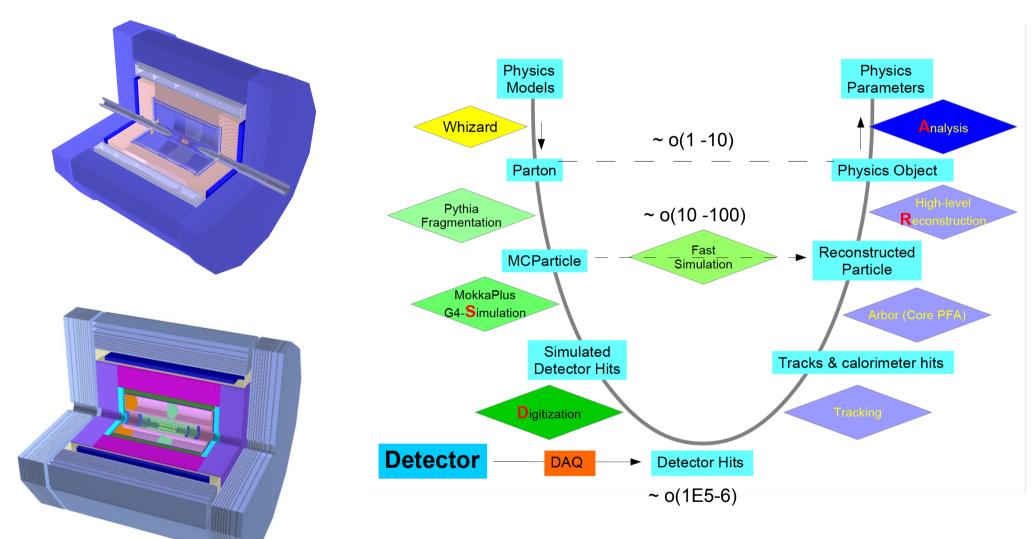
Yields ~ Xsec * Lumi * Time



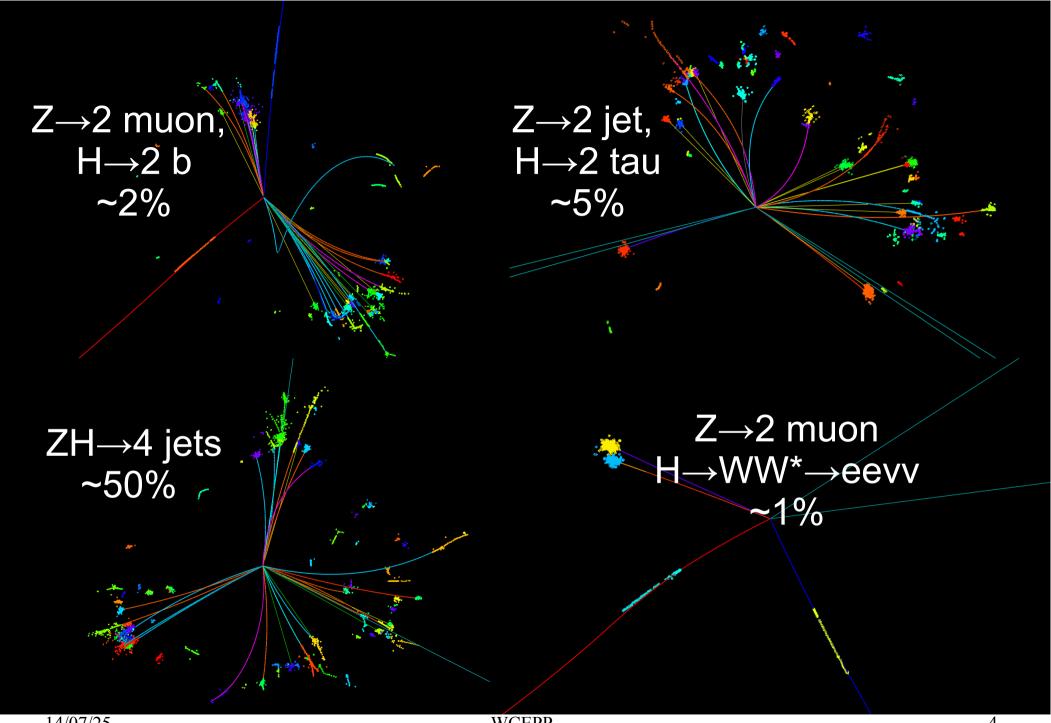


- CEPC: 100 km main ring circumference
- 4 Million Higgs (10 years)
- ~ 1 Giga W (1 year) + 4 Tera Z (2 years)
- Upgradable: Top factory (500 k ttbar)

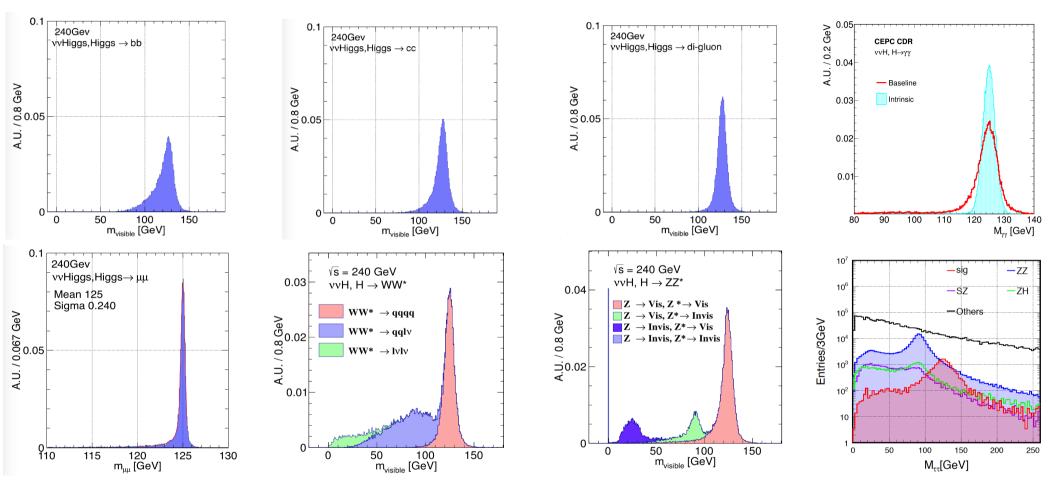
CEPC Detector & Reconstruction



PFA oriented Approach: Arbor, etc



Reconstructed Higgs Signatures



Clear Higgs Signature in all SM decay modes

Massive production of the SM background (2 fermion and 4 fermions) at the full Simulation level

Right corner: di-tau mass distribution at qqH events using collinear approximation

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CEPC Physics: 4 Million Higgs + 4 Tera Z...

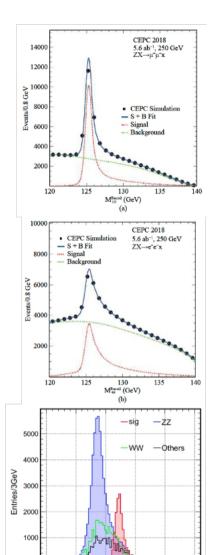






Table 2.1: Precision of the main parameters of interests and observables at the CEPC, from Ref. [1] and the references therein, where the results of Higgs are estimated with a data sample of 20 ab⁻¹. The HL-LHC projections of 3000 fb⁻¹ data are used for comparison. [2]

	W,Z and top				
Observable	HL-LHC projections	CEPC precision	Observable	Current precision	CEPC precision
M_H	20 MeV	3 MeV	M_W	9 MeV	0.5 MeV
Γ_H	20%	1.7%	Γ_W	49 MeV	2 MeV
$\sigma(ZH)$	4.2%	0.26%	M_{top}	760 MeV	O(10) MeV
$B(H \rightarrow bb)$	4.4%	0.14%	M_Z	2.1 MeV	0.1 MeV
$B(H \to cc)$	-	2.0%	Γ_Z	2.3 MeV	0.025 MeV
$B(H \rightarrow gg)$	-	0.81%	R_b	3×10^{-3}	2×10^{-4}
$B(H \to WW^*)$	2.8%	0.53%	R_c	$1.7 imes 10^{-2}$	1×10^{-3}
$B(H o ZZ^*)$	2.9%	4.2%	R_{μ}	2×10^{-3}	1×10^{-4}
$B(H \rightarrow \tau^+\tau^-)$	2.9%	0.42%	$R_{ au}$	1.7×10^{-2}	1×10^{-4}
$B(H \to \gamma \gamma)$	2.6%	3.0%	A_{μ}	1.5×10^{-2}	$3.5 imes 10^{-5}$
$B(H \rightarrow \mu^{+}\mu^{-})$	8.2%	6.4%	A_{τ}	$4.3 imes 10^{-3}$	$7 imes 10^{-5}$
$B(H \to Z\gamma)$	20%	8.5%	A_b	2×10^{-2}	2×10^{-4}
Bupper(H o inv.)	2.5%	0.07%	N_{ν}	$2.5 imes 10^{-3}$	2×10^{-4}

Scientific Significance quantified by CEPC physics studies, via full simulation/phenomenology studies:

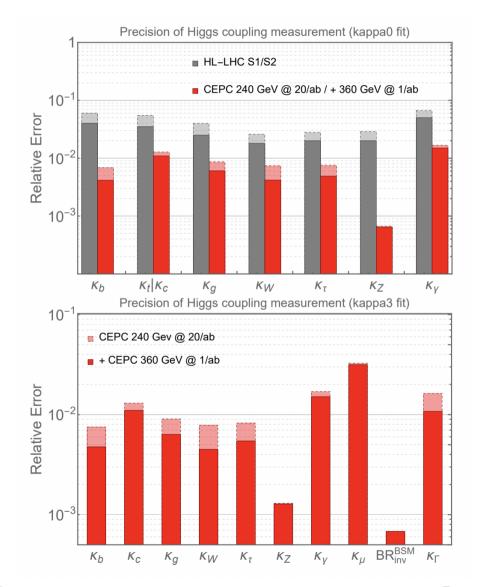
- Higgs: Precisions exceed HL-LHC ~ 1 order of magnitude.
- EW: Precision improved from current limit by 1-2 orders.
- Flavor Physics, sensitive to NP of 10 TeV or even higher.
- Sensitive to varies of NP signal.

White papers +

~300 Journal/AxXiv citables

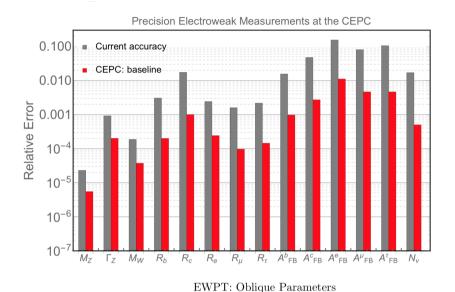
Higgs & Snowmass White Paper

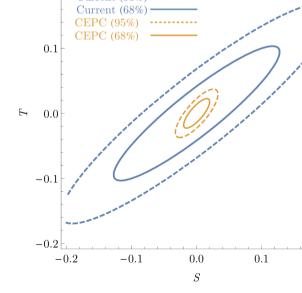
	$240{ m GeV},20~{ m ab}^{-1}$		$360\mathrm{GeV},1\;\mathrm{ab^{-1}}$		ab^{-1}
	ZH	vvH	ZH	vvH	eeH
inclusive	0.26%		1.40%	\	\
H→bb	0.14%	$\boldsymbol{1.59\%}$	0.90%	1.10%	4.30%
Н→сс	2.02%		8.80%	16%	20%
H→gg	0.81%		3.40%	4.50%	12%
$H{ ightarrow}WW$	0.53%		2.80%	4.40%	6.50%
$H{ ightarrow}ZZ$	4.17%		20%	21%	
H o au au	0.42%		2.10%	4.20%	7.50%
$H o \gamma \gamma$	3.02%		11%	16%	
$H o \mu \mu$	6.36%		41%	57%	
$H o Z \gamma$	8.50%		35%		
$\boxed{ \text{Br}_{upper}(H \to inv.)}$	0.07%				
Γ_H	1.	65%		1.10%	

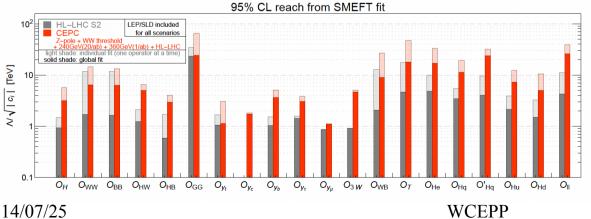


EW measurements & SMEFT

Observable	current precision	CEPC precision (Stat. Unc.)	CEPC runs	main systematic
Δm_Z	$2.1 \; \mathrm{MeV} \; [37-41]$	$0.1~{ m MeV}~(0.005~{ m MeV})$	Z threshold	E_{beam}
$\Delta\Gamma_Z$	$2.3 \ \mathrm{MeV} \ [37-41]$	$0.025~{ m MeV}~(0.005~{ m MeV})$	Z threshold	E_{beam}
Δm_W	9 MeV [42–46	$0.5~\mathrm{MeV}~(0.35~\mathrm{MeV})$	WW threshold	E_{beam}
$\Delta\Gamma_W$	49 MeV [46-49]	$2.0~\mathrm{MeV}~(1.8~\mathrm{MeV})$	WW threshold	E_{beam}
Δm_t	$0.76~\mathrm{GeV}~[50]$	$\mathcal{O}(10)~\mathrm{MeV^a}$	$t\bar{t}$ threshold	
ΔA_e	4.9×10^{-3} [37, 51–55]	$1.5 \times 10^{-5} \ (1.5 \times 10^{-5})$	Z pole $(Z \to \tau \tau)$	Stat. Unc.
ΔA_{μ}	$0.015 \ [37, 53]$	$3.5\times 10^{-5}\ (3.0\times 10^{-5})$	Z pole $(Z \to \mu\mu)$	point-to-point Unc.
$\Delta A_{ au}$	4.3×10^{-3} [37, 51–55]	$7.0\times 10^{-5}\ (1.2\times 10^{-5})$	Z pole $(Z \to \tau \tau)$	tau decay model
ΔA_b	0.02 [37, 56]	$20 \times 10^{-5} \ (3 \times 10^{-5})$	Z pole	QCD effects
ΔA_c	$0.027 \ [37, 56]$	$30\times 10^{-5}\ (6\times 10^{-5})$	Z pole	QCD effects
$\Delta \sigma_{had}$	37 pb [37–41]	2 pb (0.05 pb)	Z pole	lumiosity
δR_b^0	0.003 [37, 57–61]	$0.0002 (5 \times 10^{-6})$	Z pole	gluon splitting
δR_c^0	0.017 [37, 57, 62–65]	$0.001~(2 \times 10^{-5})$	Z pole	gluon splitting
δR_e^0	0.0012 [37-41]	$2\times 10^{-4}\ (3\times 10^{-6})$	Z pole	E_{beam} and t channel
δR_{μ}^{0}	0.002 [37–41]	$1\times 10^{-4}\ (3\times 10^{-6})$	Z pole	E_{beam}
$\delta R_{ au}^0$	0.017 [37-41]	$1 \times 10^{-4} \ (3 \times 10^{-6})$	Z pole	E_{beam}
$\delta N_{ u}$	0.0025 [37, 66]	$2\times 10^{-4}\ (3\times 10^{-5}\)$	ZH run $(\nu\nu\gamma)$	Calo energy scale





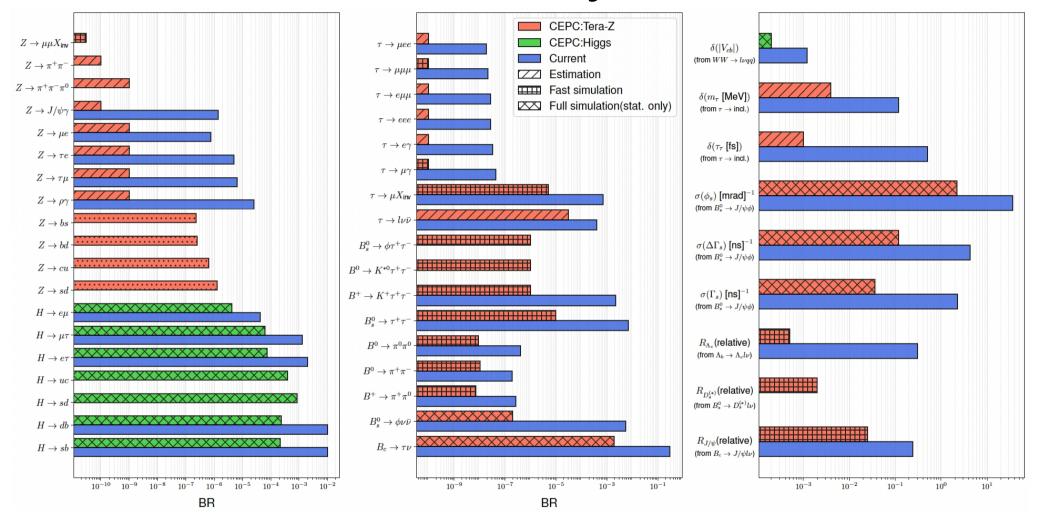


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0.2

Flavor Physics

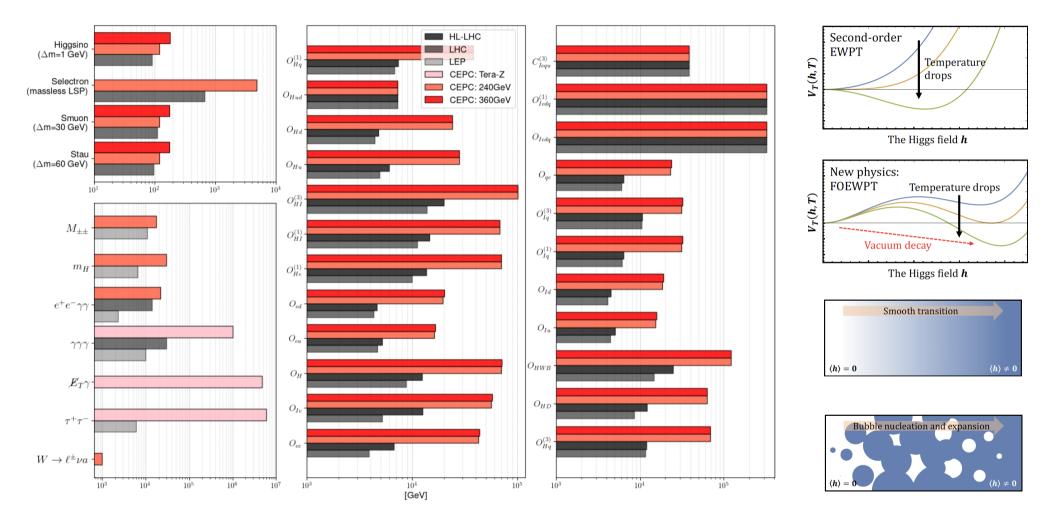


See the non-seen: i.e, Bc→tauv, Bs→Phivv Orders of magnitudes improvements (1 – 2.5 orders...).

https://arxiv.org/pdf/2412.19743

Access New Physics with energy scale of 10 TeV, or even above

New Physics

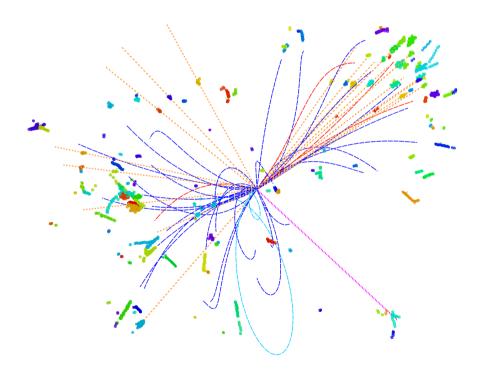


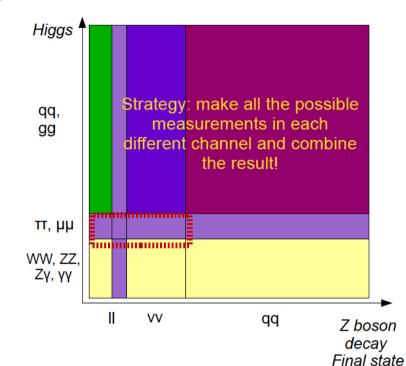
https://arxiv.org/pdf/2505.24810

Matter Origin, Dark matter... Access to NP ~ 100 TeV...

Performance requirements

- To reconstruct all Physics Object, especially Jets
 - Z & W: ~ 70% goes to a pair of jets
 - Higgs: ~97% final state with jets (ZH events)
 - Top: $t \rightarrow W + b$



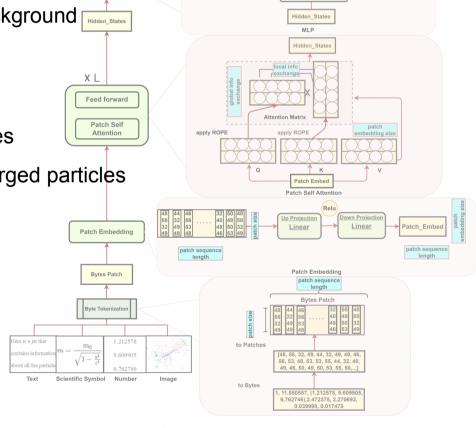


- Look inside the jet: 1-1 correspondence reco.
 - ~ confusion free PFA
 - Larger acceptance...
 - Excellent intrinsic resolutions
 - Extremely stable...
- Be addressed by state-of-art detector design, technology, and reconstruction algorithm!

Holistic approach

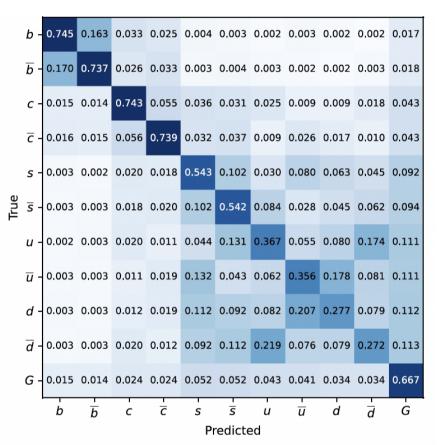
Loss

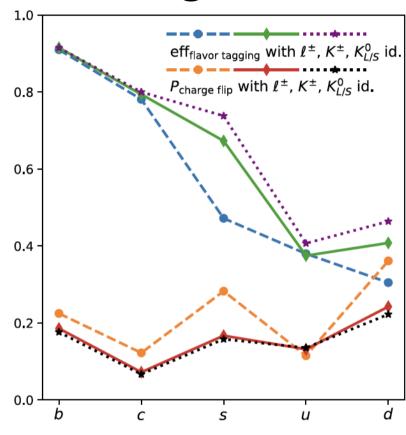
- Provide all reconstructable for classification
 - Reco: Jet origin identification
 - Analysis: to distinguish the signal from the background
- In the context of 1-1 correspondence/PFA, inputs =
 - 4 momentum + Pid of all reconstructed particles
 - Track impact parameters of reconstructed charged particles
 - Potentially: parenting info
 - Photon to Pi-0, pions to kaon...
 - Color Singlet (from Z or H)
 - ...
 - Uncertainties (as suggested by Vincent)



Challenge: high quality simulation, knowledge of Detector response & Theory/interpretation models...

Holistic Reco: Jet origin id

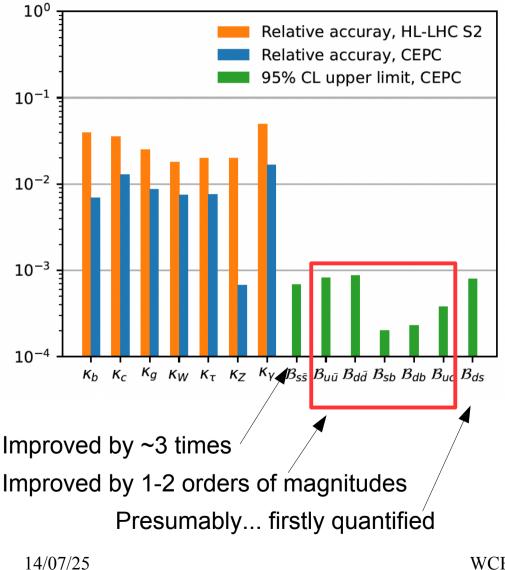


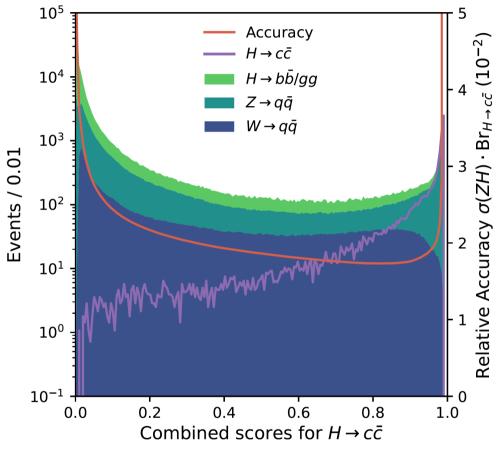


- 11 categories (5 quarks + 5 anti quarks + gluon) identification, realized at Full Simulated di-jet events at CEPC CDR baseline with Arbor + ParticleNet
- Published in PRL 132, 221802 (2024). Comment from the referee: "demonstrate the world-leading performance of tagger", "a "game changer" and opens new horizons for precision flavor studies at all future experiments."

14/07/25

Impact on Physics: Higgs & W





- Compared to Conventional:
 - vvH, H \rightarrow cc: 3% \rightarrow 1.7%
 - Vcb: $0.75\% \rightarrow 0.5\%$
 - Applicable to Vcs, Vts, etc.

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Updated result on $\sin^2 \theta_{eff}^l$ measurement

Table 2. Sensitivity S of different final state particles.

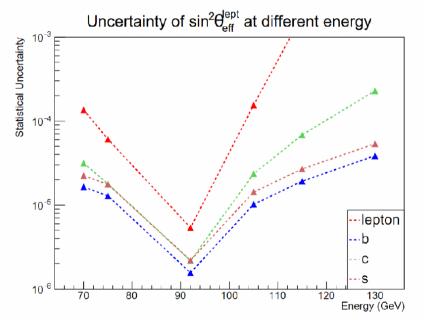
\sqrt{s} /GeV	S of $A_{FB}^{e/\mu}$	S of A_{FB}^d	S of A_{FB}^u	S of A_{FB}^s	S of A_{FB}^c	S of A_{FB}^b
70	0.224	4.396	1.435	4.403	1.445	4.352
75	0.530	5.264	2.598	5.269	2.616	5.237
92	1.644	5.553	4.200	5.553	4.201	5.549
105	0.269	4.597	1.993	4.598	1.994	4.586
115	0.035	3.956	1.091	3.958	1.087	3.942
130	0.027	3.279	0.531	3.280	0.520	3.261

Table 3. Cross section of process $e^+e^- \rightarrow f\bar{f}$ calculated using the ZFITTER package. Values of the fundamental parameters are set as $m_Z = 91.1875 \text{ GeV}$, $m_t = 173.2 \text{ GeV}$, $m_{II} = 125 \text{ GeV}$, $\alpha_x = 0.118$ and $m_W = 80.38 \text{ GeV}$.

√s/GeV	σ_{μ}/mb	$\sigma_d/{ m mb}$	$\sigma_u/{ m mb}$	$\sigma_{ m s}/{ m mb}$	$\sigma_{ m c}/{ m mb}$	$\sigma_b/{ m mb}$
70	0.039	0.032	0.066	0.031	0.058	0.028
75	0.039	0.047	0.073	0.046	0.065	0.043
92	1.196	5.366	4.228	5.366	4.222	5.268
105	0.075	0.271	0.231	0.271	0.227	0.265
115	0.042	0.135	0.122	0.135	0.118	0.132
130	0.026	0.071	0.068	0.071	0.066	0.069

Verify the RG behavior... using ~1 month of data taking

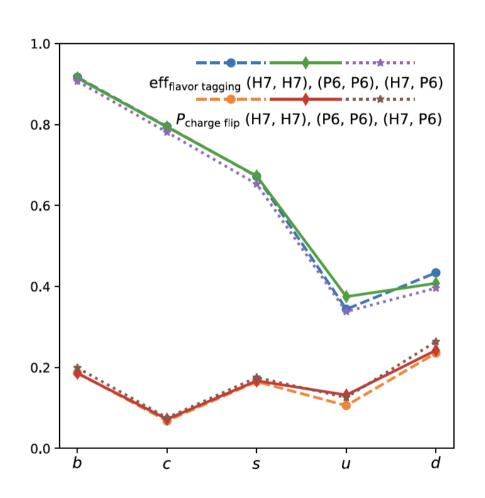
Expected statistical uncertainties on $\sin^2\theta_{eff}^l$ measurement. (Using one-month data collection, \sim **4e12/24 Z events** at **Z** pole)

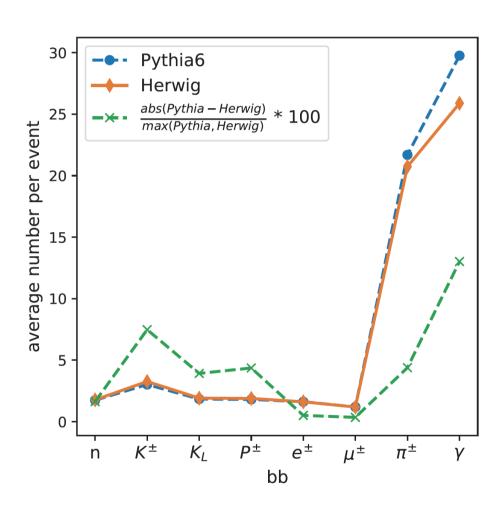


\sqrt{s}	b	С	S
70	1.6×10^{-5}	3.2×10^{-5}	2.2×10^{-5}
75	1.3×10^{-5}	1.8×10^{-5}	1.8×10^{-5}
92	1.6×10^{-6}	2.2×10^{-6}	2.2×10^{-6}
105	1.0×10^{-5}	2.4×10^{-5}	1.4×10^{-5}
115	1.9×10^{-5}	6.8×10^{-5}	2.7×10^{-5}
130	3.9×10^{-5}	2.3×10^{-4}	5.4×10^{-5}

...+ Significant impact on Flavor Physics measurements, i.e., those with Bs oscillation...

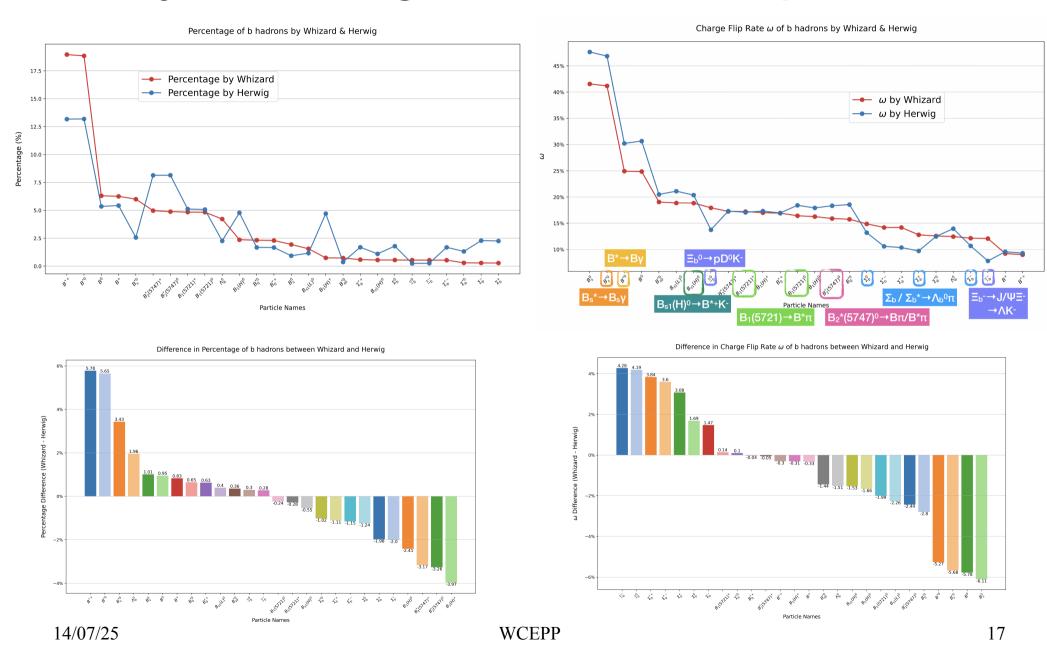
V.S. Hadronization models



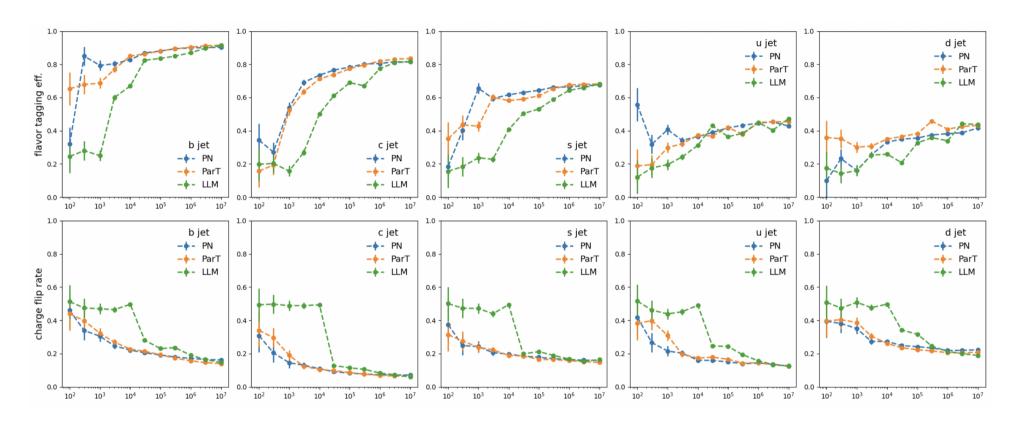


Different hadronization model have significantly different predictions...

b-jet: leading b-hadrons & flip rates



From specialized Models to LLM



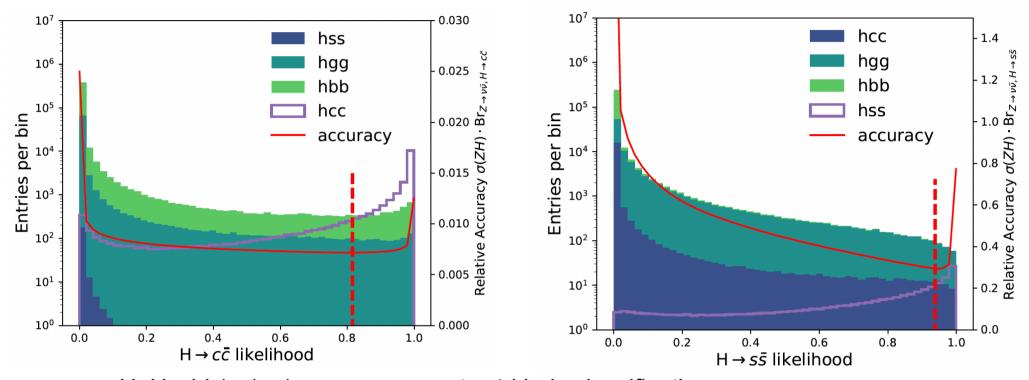
- Comparable result with different scaling behavior
- Para. Numbers: PN 360k, ParT 2.4M, BINBBT(Large Language Base Model) 150 M





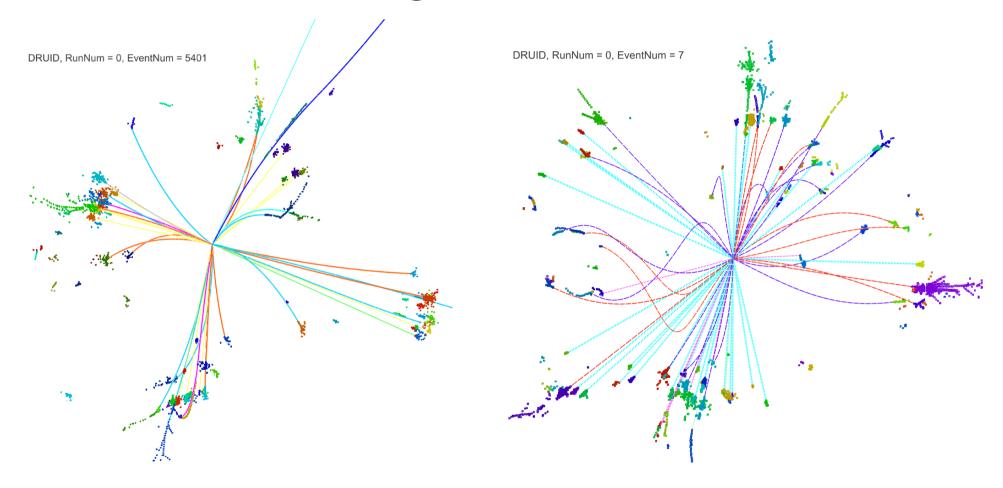
More details at: https://arxiv.org/pdf/2412.00129

Holistic Analysis: vvH, H→2 jet



- vvH, H→bb/cc/gg/ss measurements: 4 kinds classification
- Simplified analysis with irreducible background...
- Accuracies: 2-6 times better than previous studies (include other bkgrd, BDT based, etc)
- H→ss: close to confirmation!

Color Singlet Identification



at full hadronic ZH event

CSI: bottleneck for measurement at full hadronic events



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JHEP11(2022)100

The Higgs $\rightarrow b\bar{b}, c\bar{c}, gg$ measurement at CEPC

Yongfeng Zhu, Hanhua Cui and Manqi Ruan

Institute of High Energy Physics, Chinese Academy of Sciences, 19B Yuquan Road, Beijing 100049, China University of Chinese Academy of Sciences, 19A Yuquan Road, Beijing 100049, China

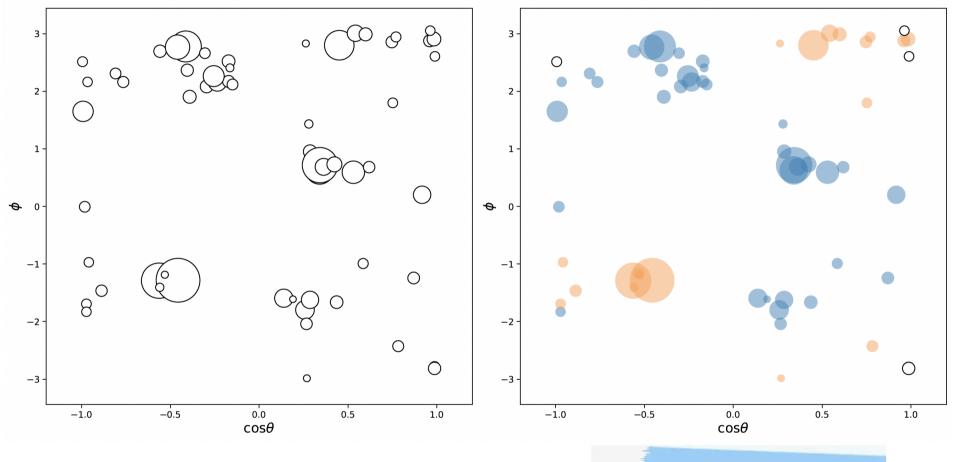
E-mail: ruanmq@ihep.ac.cn

Z decay mode	$H \to b \bar b$	$H \to c\bar{c}$	$H\to gg$
$Z \rightarrow e^+e^-$	1.57%	14.43%	10.31%
$Z \to \mu^+ \mu^-$	1.06%	10.16%	5.23%
$Z \to q\bar{q}$	0.35%	7.74%	3.96%
$Z o u \bar{ u}$	0.49%	5.75%	1.82%
combination	0.27%	4.03%	1.56%

Table 3. The signal strength accuracies for different channels.

- H→cc & gg measurements at qqH channel is much worse vvH channels, despite the former has 3.5 times more signal statistic
- Reason: Failure of Color Singlet Identification to distinguish the decay products of each Color Singlet
 - Z & H for 240/250 GeV Higgs factory
 - Which Higgs boson for Higgs self-coupling (i.e., at vvHH events at 500 GeV, etc)

Advanced CSI using AI



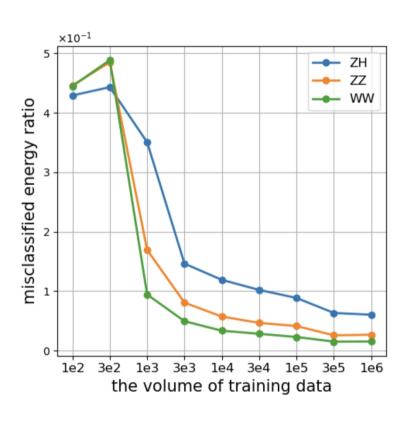
Yongfeng, Hao, Yuexin, etc

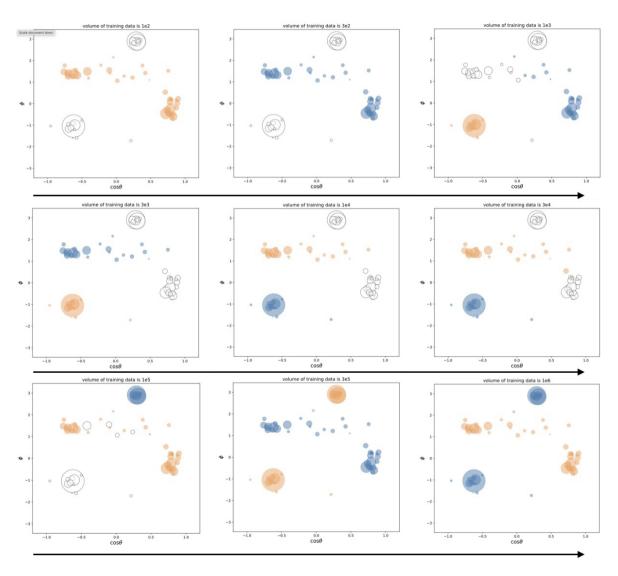


14/07/25

WCEPP

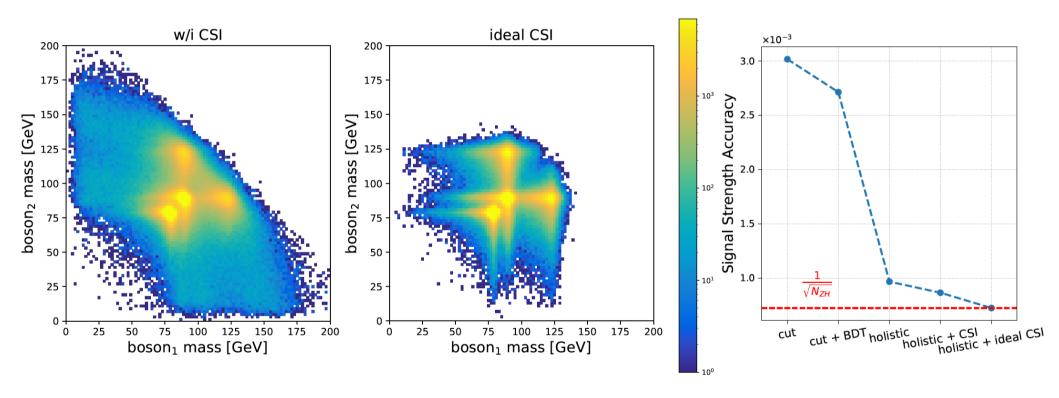
Scaling...





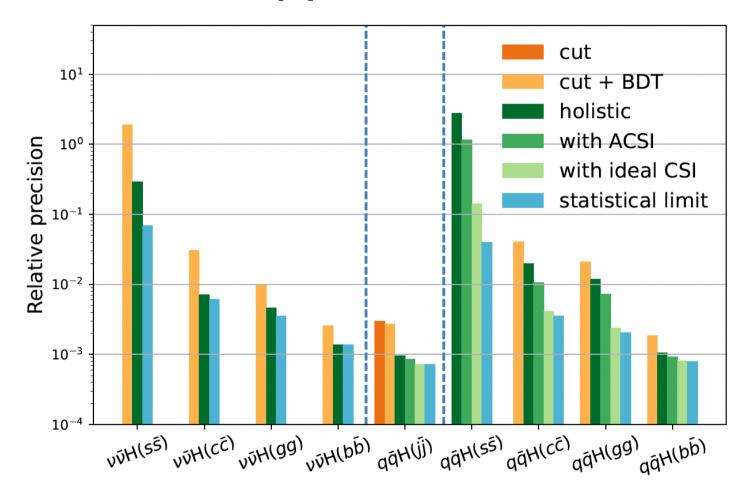
A toy analysis: identify full hadronic ZH signal from ZZ + WW background

540k ZH + 3.1M ZZ + 47 M WW full hadronic events (~ 5.6 iab), result scale to 20 iab



Holistic: use all the reconstructable info to category signal & different background

Holistic approach + ACSI



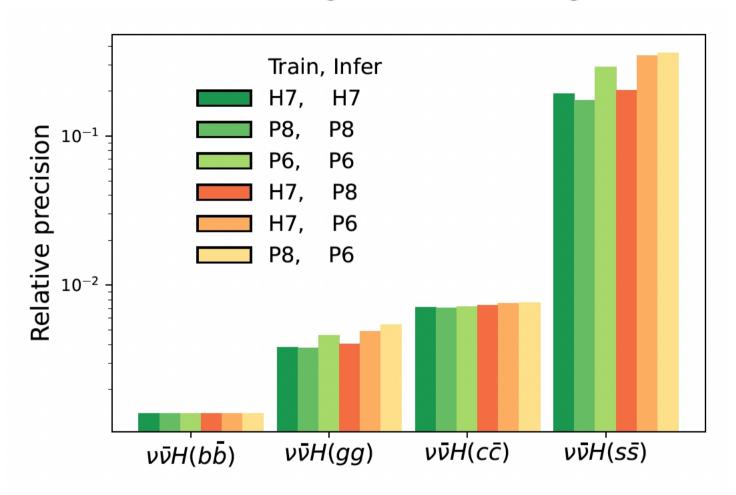
Holistic + ACSI: improves the accuracy by 2 – 6 times

ACSI makes a leap even from Holistic, but still has significant room to improve...

H→ss within the reach...

https://arxiv.org/pdf/2506.11783

Supervised learning: need High Quality MC

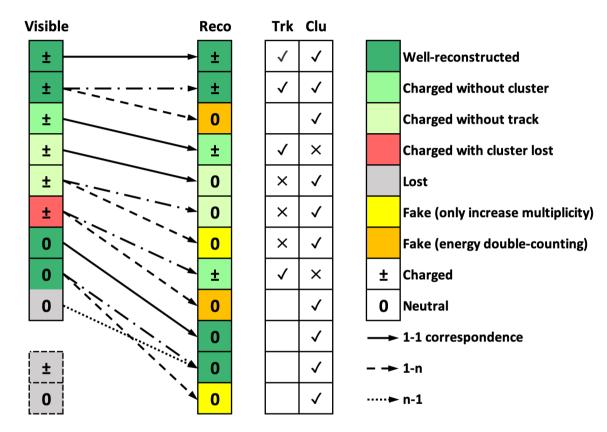


The Holistic approach is in principle free from human intervene...

Human define the goal (the signal), Al serves as the mean...

From PFA to 1-1 correspondence

Final state particles



Computer Physics Communications 314 (2025) 109661



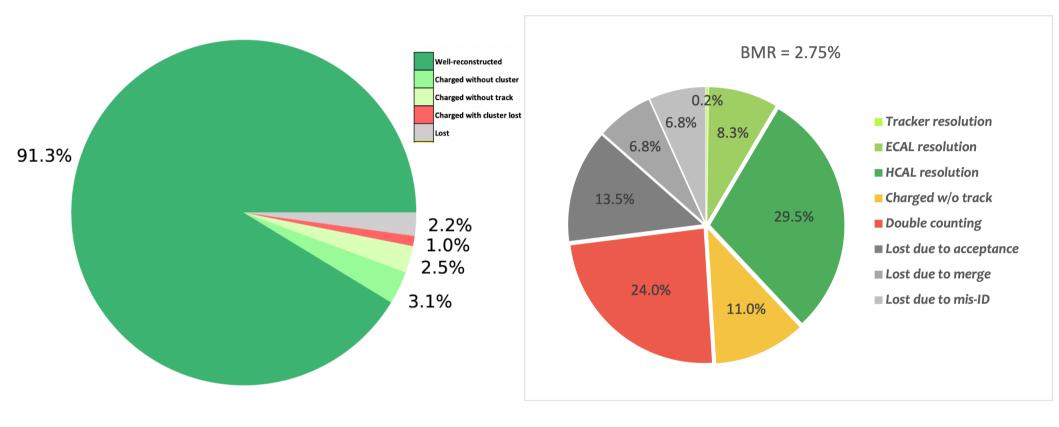
Computational Physics

One-to-one correspondence reconstruction at the electron-positron Higgs factory $\,$

Yuexin Wang a.b.⁹, Hao Liang a.c.^d, Yongfeng Zhu e, Yuzhi Che a.f., Xin Xia a.c., Huilin Qu e, Chen Zhou e, Xuai Zhuang a.c., Manqi Ruan a.c.e



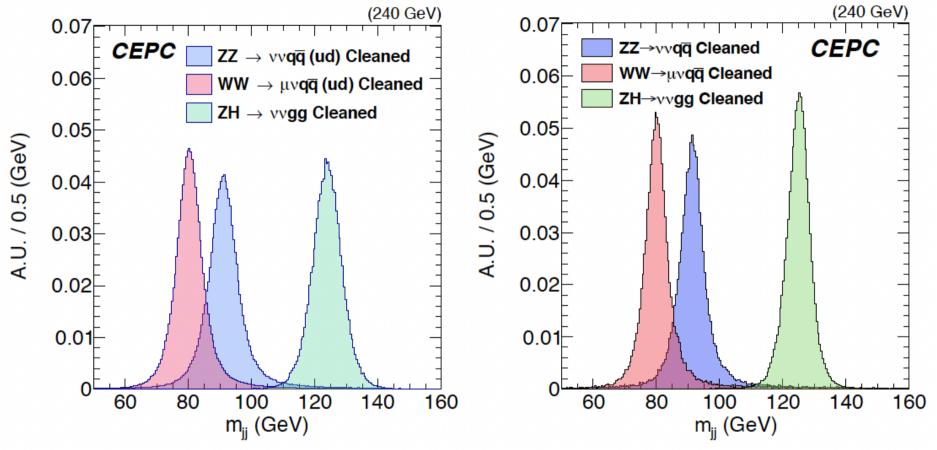
BMR decomposition @ AURORA



1-1 corresponding type: contributing to the BMR via resolution: \sim o(0.1 – 0.001) of its mean value

Double Counting & Lost type: contributing to the BMR ~o(1) to its mean value

BMR of 2.75% reached

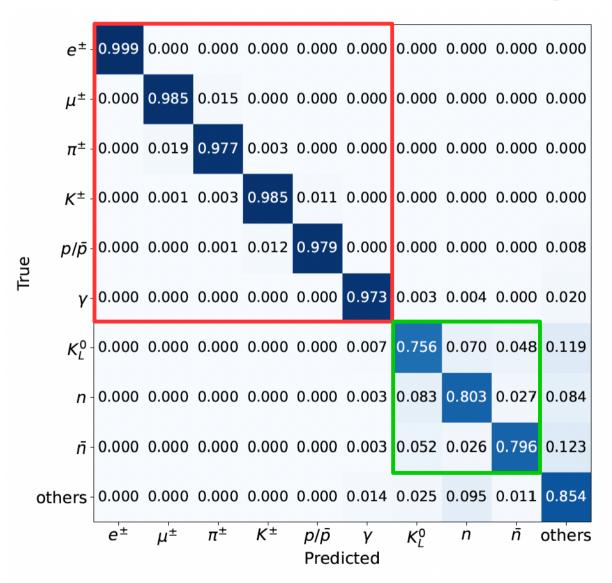


Detector change (usage of high density scintillating glass HCAL): BMR 3.7% → 3.4%;

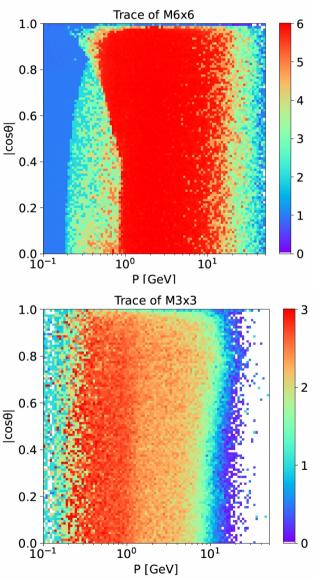
Al enhanced reconstruction: $3.4\% \rightarrow 2.8\%$.

Recent update: further optimization + Pid, etc, current value ~2.68%

Pid: differential performance



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Necessary studies...

- Beam induced backgrounds: comparative studies...
- Event building with realistic detector time response, including electronic pulse shape & time sequence...
- TPC & Tracker:
 - Dependence of dE/dx or dN/dx performance on the shifting distance & readout threshold/Noise
 - Ion distortion VS shielding & possible correction
 - B-Field mapping
 - Mechanic stability
 - Low Pt track reconstruction
- Calorimeter
 - SiPM: response uniformity & Dynamic range, especially towards large Tile/Bar configuration in ECAL
 - Requirement on the Attenuation length for scintillating materials...
 - Homogenates in space & stability in time
 - Development of Energy & Time Estimator...
- Dead zone/dead channel tolerance
- Performance degrading with different Noise: rates, intrinsic, and radiation relevant ones
- Calibration Procedure & Monitoring methodologies...

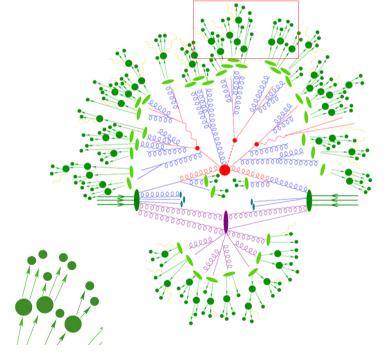
Summary

- ... Higgs factory has strong discovery power to NP, its detector & reconstruction should and could have excellent performance...
- Al as the trend...
 - Holistic approach
 - Reco: Jet origin id, 'see' the quark & gluons...
 - Analysis: enhance the discovery power of Higgs factory by ~3 times. Processing in principle free from Human intervene.
 - + ACSI for full hadronic events
 - 1-1 correspondence reconstruction: excellent PID + BMR of 2.7%
 - See Yuexin's talk for more details 5-d calo is the key
- Multiple challenges need to be addressed... with intriguing prospects...
 - Precise Simulation is critical to utilize supervised learning, which request profound understanding of relevant factors – be developed iteratively
 - To explore other methodologies: non/weakly-supervised, enhanced, LLM...
 - Lots more to explore, with unsupervised, LLM, ... rich interplay & synergies.

- ...

Future: From leaves to the trees

- The hadronization process is ~ tree like
 - PFA & 1-1 corresponding committed to reconstruct well the leaves the final state particles that actually interacts with detector/calorimeter
 - Possible to identify the entire tree: reco parenting info of final state particles
 - Pi-0.
 - K_short, Lambda, EPJP (2020) 135:274
 - Phi, PRD 105, 114036 (2022)
 - ...
 - Tau, D, B...
- Impact:
 - Essential for Flavor & New Physics
 - Enhance Jet Origin Identification
- Methodology: Comparative analysis
 - Conventional + Al
- Synergies with Event building Trigger + On line + Off line...

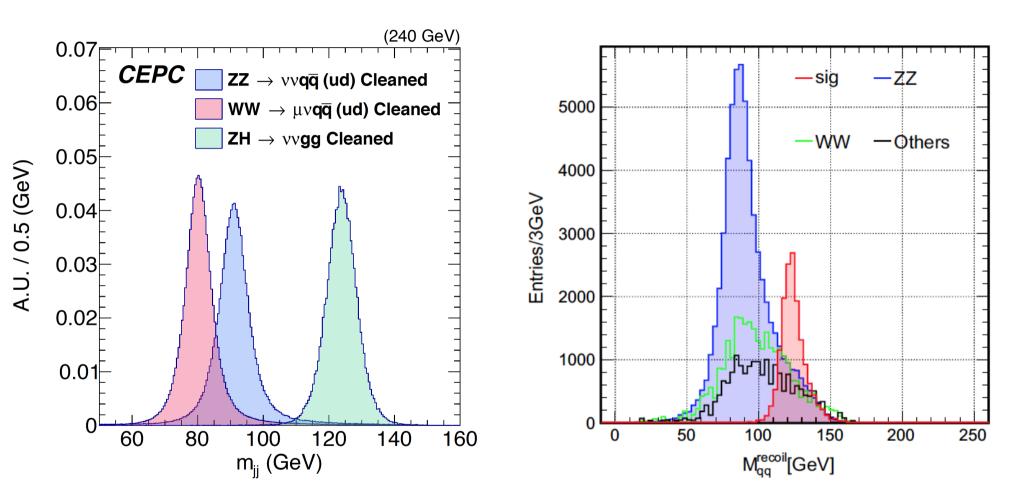


Back up

Al era: Holistic approach

- Feed all reconstructable info. to the classifier in principle free of human intervene (no need to find Cut variables, etc..). Require excellent detector & reconstruction, where 1-1 serves as a benchmark & standard
- Supervised Learning Systematic uncertainty control is the challenge, esp. for precision measurements. Relies strongly on accurate simulation
 - Theoretical: need dedicated efforts on theoretical framework, For the Higgs factory, the challenges include high precision perturbative calculation, the hadronization models, and potentially QCD effect like color-reconnection effects
 - Experimental: need profound understanding of the detector response requires innovative Calibration & Monitoring, plus Digitization & Validation. For which, the 1-1 provides much more observable and ways...
 - Need comparative analysis over the relevant phase space, to control & to understand the scaling behavior, which will also shed light on AI development.
 - Exploration just started
- Longer term... non-supervised learning, or even migrate to LLM/General models...
- Even longer term: Data stream + information compressing using reco + analysis + interpretation... Al is essential, plus we need to set check points & mile stones to quantify and understand its behavior

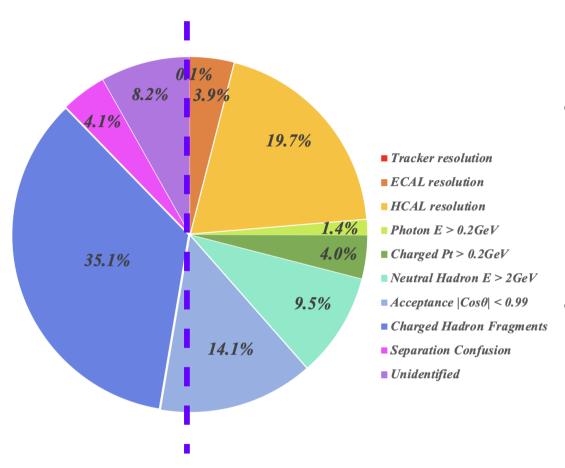
Boson Mass Resolution



Higgs factory: need BMR < 4% (critical for qqH & qqZ separation using recoil mass to di-jet) Strongly motivated to improve BMR to 3% or even lower, especially for NP & Flavor CDR baseline (left plot): BMR = 3.75%

14/07/25

BMR decomposition @ CDR



- 1st HCAL resolution dominant the uncertainties from intrinsic detector resolution: need better HCAL → R & D of GSHCAL
- 2nd Leading contribution:
 Confusion from shower
 Fragments (fake particles),
 need better Pattern Reco.

CDR baseline - GRPC HCAL

GSHCAL: simulation

Nuclear Instruments and Methods in Physics Research A 1059 (2024) 168944



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Nuclear Inst. and Methods in Physics Research, A





Full Length Article

GSHCAL at future e^+e^- Higgs factories

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ARTICLE INFO

Keywords: Higgs factory CEPC HCAL Glass scintillator

ABSTRACT

The excellent jet energy resolution is crucial for the precise measurement of the Higgs properties at future e^+e^- Higgs factories, such as the Circular Electron Positron Collider (CEPC). For this purpose, a novel design of the particle flow oriented hadronic calorimeter based on glass scintillators (GSHCAL) is proposed, the designs based on gas or plastic scintillators, the GSHCAL can achieve a higher sampling fraction and more compact structure in a cost-effective way, benefiting from the high density and low cost of glass scintillators. In order to explore the physics potential of the GSHCAL, its intrinsic energy resolution and the contribution to the measurement of the hadronic system was investigated by Monte Carlo simulations. Preliminary results show that the stochastic term of hadronic energy resolution can reach around 24% and the Boson Mass Resolution (BMR) can reach around 3.38% when the GSHCAL is applied. Besides, the key technical R&D of high-performance glass scintillator tiles is also introduced.

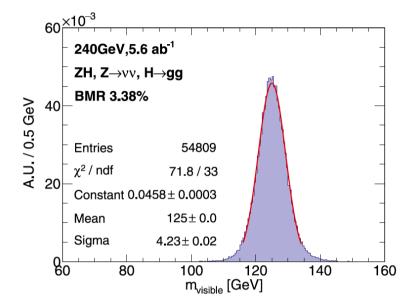


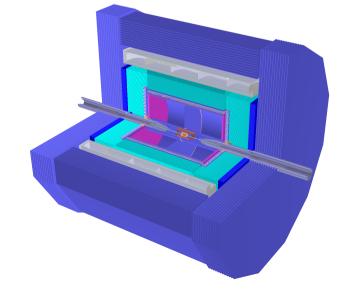
Fig. 5. Distribution of the reconstructed total visible invariant mass for $v\bar{v}H \to v\bar{v}gg$ channel. The distribution is fitted with a Gaussian function extented to ± 2 standard deviations.

Y. Wang, H. Liang, Y. Zhu et al.

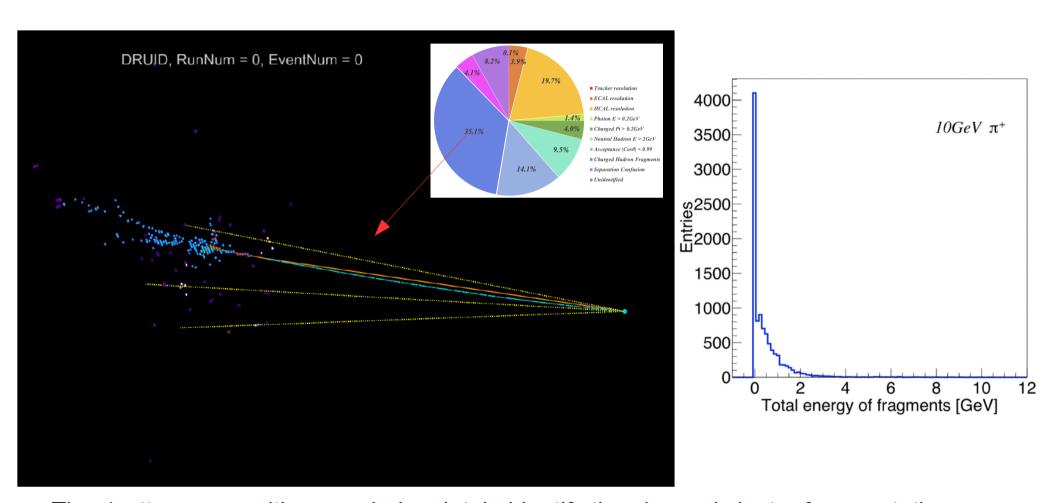
Computer Physics Communications 314 (2025) 109661

Table A.1
AURORA detector geometry parameters.

Sub-detector	Thickness (mm)	Inner radius (mm)	Outer radius (mm)	Length (mm)	Volume (m³)	Transverse cell size	#Layers	#Channels
Vertex	-	-	16-60	125-250	-	25 × 25 μm ²	6	5.3 × 10 ⁸
			155	736				
Si-strip	-	-	300	1288	-	$20 \ \mu m \times 2 \ cm$	3	3.0×10^{7}
Tracker			1810	4600				
TPC	-	300	1800	4700	47	$1 \times 6 \text{ mm}^2$	220	2.9×10^{6}
ECAL	173	1845	2018	5250	15	$1 \times 1 \text{ cm}^2$	30	2.5×10^{7}
HCAL	1145	2072	3250	7590	180	$2 \times 2 \text{ cm}^2$	48	1.8×10^{7}
Solenoid	700	3275	3975	7750	120	-	-	-
Yoke	1200	4000	5200	10500	470	-	-	-

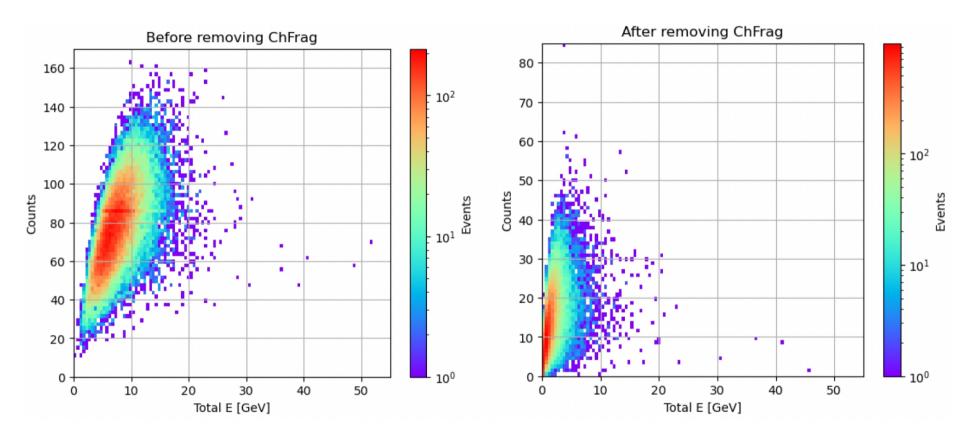


Cluster splitting: the most severe confusions



Time/pattern recognition may help a lot, in identify the charged cluster fragmentations without arise the threshold for the neutral hadron significantly...

Confusion: frag. Identification & veto

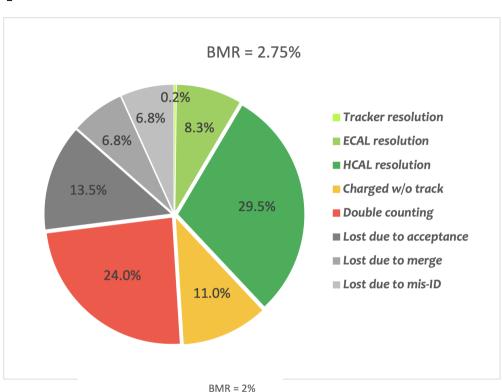


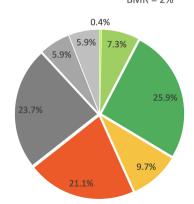
Fake particle originated Confusion reduced by 1 order of magnitude, at nominal vvH, H→gg event, at the cost of create mis-vetoed energy of < 1 GeV.

Frag Total Energy (MPV/Mean): 6.3/7.6 GeV → 0.7/1.4 GeV

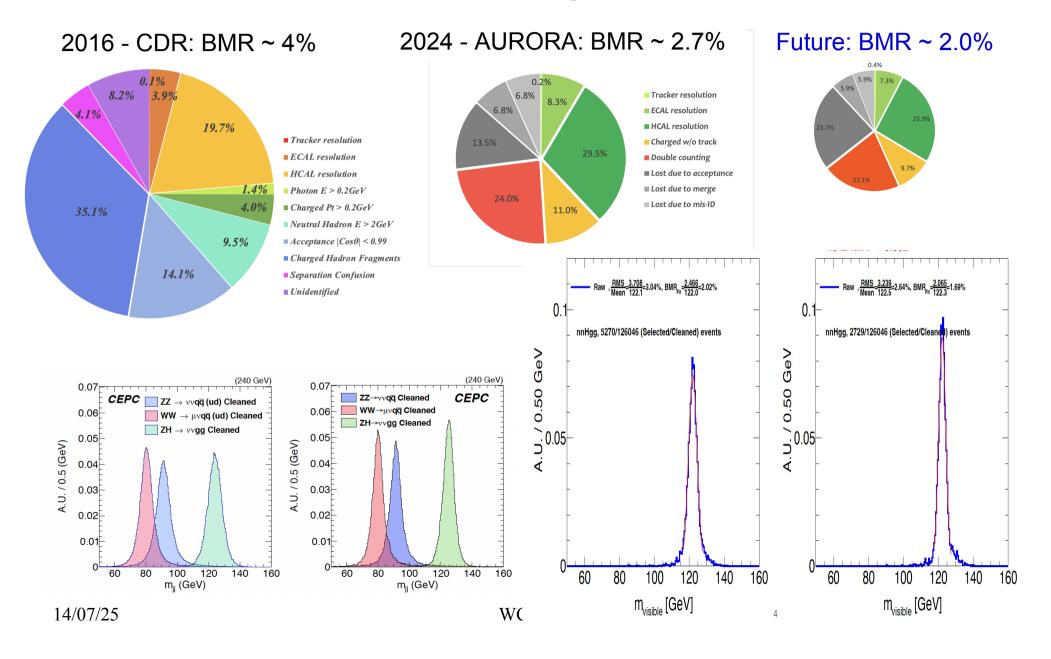
BMR: perspectives

- Resolutions: assume improved by 50%
 - Crystal ECAL: With efficient control of confusion
 - Detector optimization + Innovative Estimator (Energy, Time, Spatial...) with 5d calorimeter (ToF) & AI: ToF could determine very precisely the energy of low-E hadron – Giving its type identified...
- Charged w/o track: improved by 20% via Improve tracking efficiency, etc
- Double Counting: improved by 60% via Improve matching in the core PFA, i.e., Arbor
- Lost: improved by 15% (mainly at Mis vetoing & Merging, both improving by 30%)
- Need to better understand, identify & control the impact of secondary particles... (those generated in interactions between primary V.S. Upstream material, plus back-scattering)





BMR: from CDR to possible future...



Perspectives with 1-1 correspondence

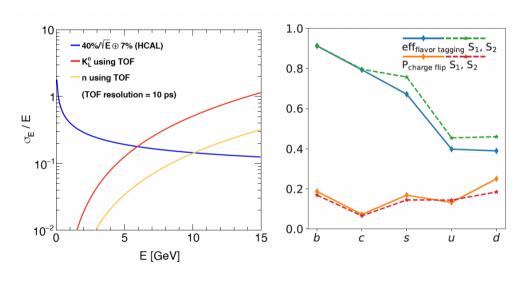
Jet (hadronic events) with Calo

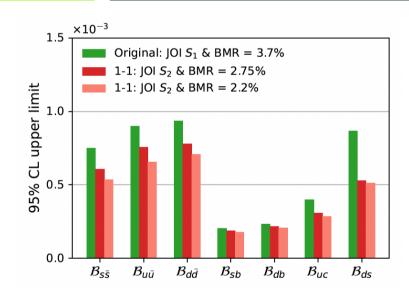
Jet with PFA
Charged in Tracker
Neutral in Calo

Jet with 1-1

Charged in Tracker + ToF

Neutral in Calo + ToF



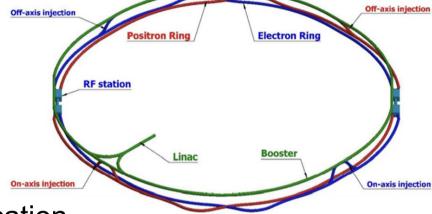


- 5d calo is critical: ToF for all visible particle, thus Pid...
- ToF enhanced energy measurement: expecting BMR: 2.8 → 2.2-2.4, Strongly Boost the light quark ID.
 - Need excellent CALO + ToF ~ o(10 ps)/Cluster
 - Assume Low energy neutrons & secondary particles can be tamed... still challenge...

Outline

CEPC Physics at a glance

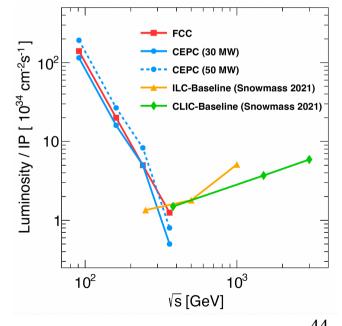
Jet origin identification & Scaling



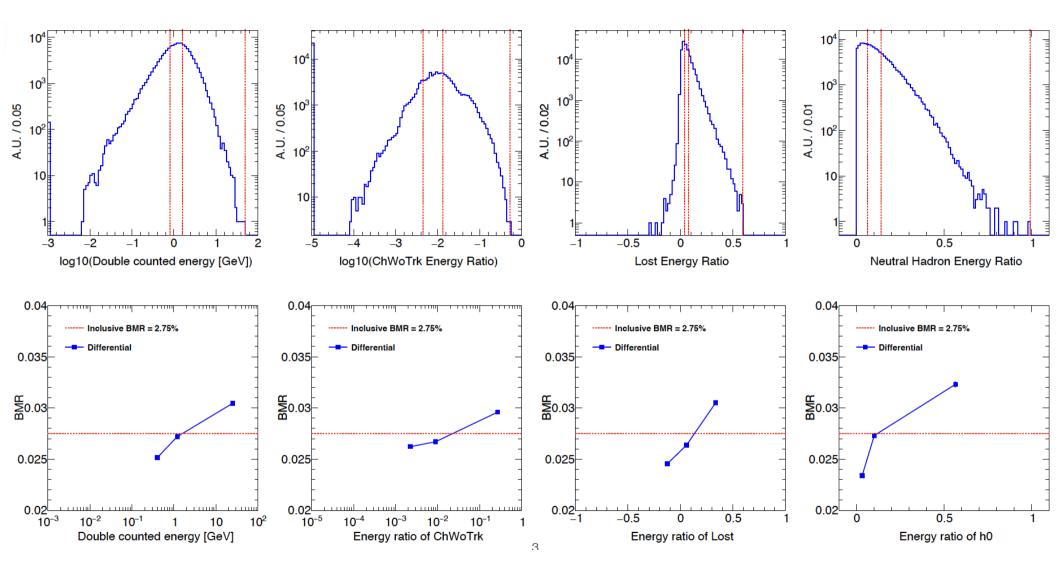
Holistic Approach & Color Singlet identification

1-1 correspondence reconstruction

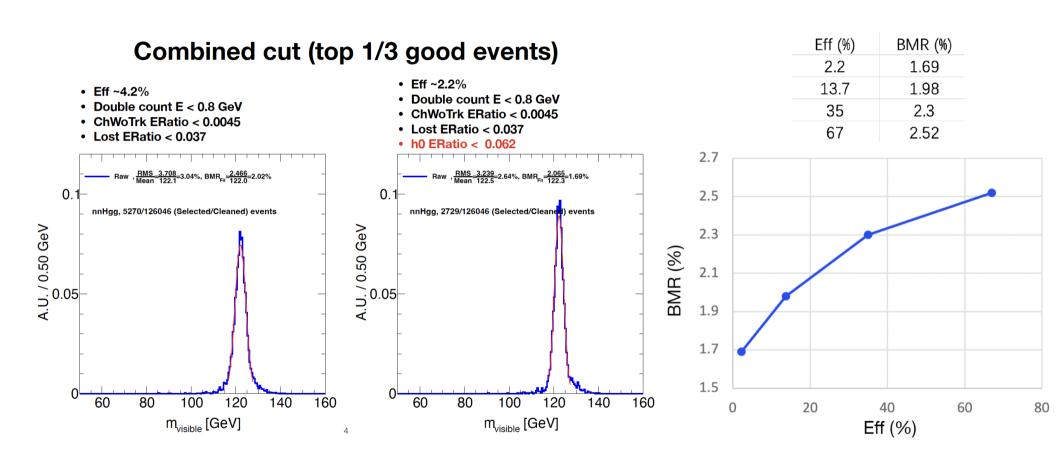
Discussion



BMR dependence to its components



BMR dependence on Cut...



...If the High Values tails could be tamed...

BMR: receipt & comparison to JER

Chinese Physics C Vol. 43, No. 2 (2019) 023001

The Higgs signatures at the CEPC CDR baseline*

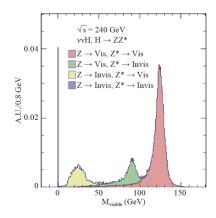
Hang Zhao(赵航)^{1,2,3} Yong-Feng Zhu(朱永峰)^{1,4} Cheng-Dong Fu(傅成栋)¹
Dan Yu(于丹)¹ Man-Qi Ruan(阮曼奇)^{1,2;1)}

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Abstract: As a Higgs factory, the CEPC (Circular Electron-Positron Collider) project aims at precision measurements of the Higgs boson properties. A baseline detector concept, APODIS (A PFA Oriented Detector for the Higgs factory), has been proposed for the CEPC CDR (Conceptual Design Report) study. We explore the Higgs signatures for this baseline design with $\nu\bar{\nu}$ Higgs events. The detector performance for reconstructing charged particles, photons and jets is quantified with $H \to \mu\mu$, $\gamma\gamma$ and jet final states, respectively. The resolutions of reconstructed Higgs boson mass are comparable for the different decay modes with jets in the final states. We also analyze the $H \to WW^*$ and ZZ^* decay made where a class acceptable between different decay modes with jets in the final states.

Table 3. Higgs boson mass resolution (sigma/Mean) for different decay modes with jets as final state particles, after event cleaning.

$H \rightarrow bb$	$H \rightarrow cc$	$H \rightarrow gg$	$H \to WW^*$	$H \rightarrow ZZ^*$
3.63%	3.82%	3.75%	3.81%	3.74%



← Standard Definition & Process

Relationship to JER→



Published by IOP Publishing for Sissa Medialab

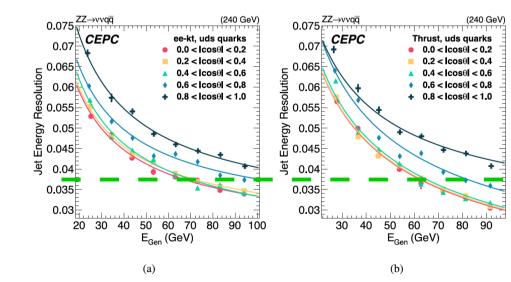
RECEIVED: January 15, 2021 ACCEPTED: April 13, 2021 Published: July 21, 2021

Jet performance at the circular electron-positron collider

P.-Z. Lai, a M. Ruan b,* and C.-M. Kuo a

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E-mail: Manqi.ruan@ihep.ac.cn



b Experimental Physics Division, Institute of High Energy Physics, 19B Yuquan Road, Beijing, China

At ILD: Preliminary

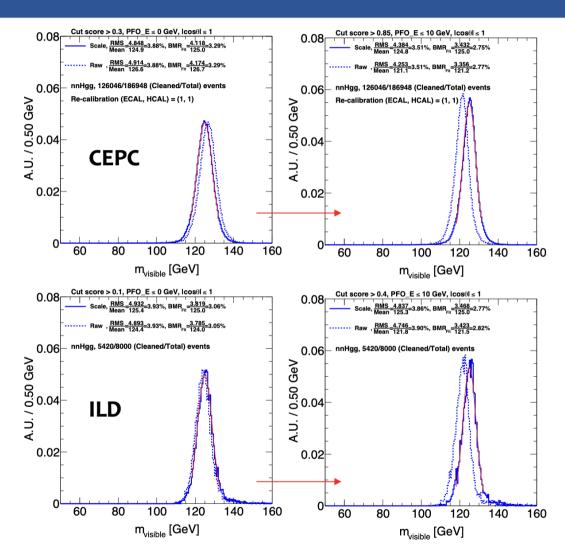
- BMR (wo PU) & Pid
- PU study

Need to further confirm the det. Para + PU condition

Fake particle identification and BMR

Optimal working point (wrt BMR)

- **≻** CEPC
 - > score > 0.85
 - ➤ BMR: 3.3% → 2.75% (relative 16%)
 - > eff. ~77%, purity ~97.5%
- > ILD
 - > score > 0.4
 - ➤ BMR: 3.06% → 2.77% (relative 9.5%)
 - > eff. ~84%, purity ~72%

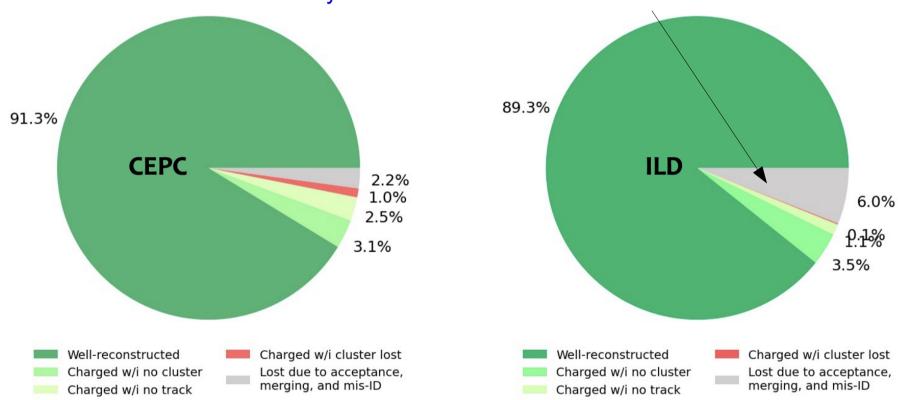


Energy fraction

Increased fractions in ILD

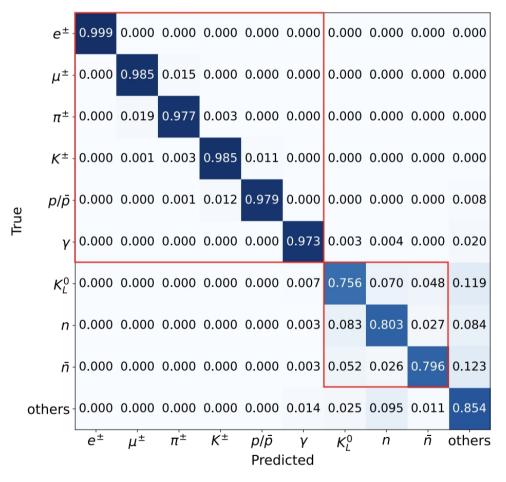
- ➤ Charged w/o cluster
- ➤ Lost (need further decomposition... using 3-stage particle mapping)



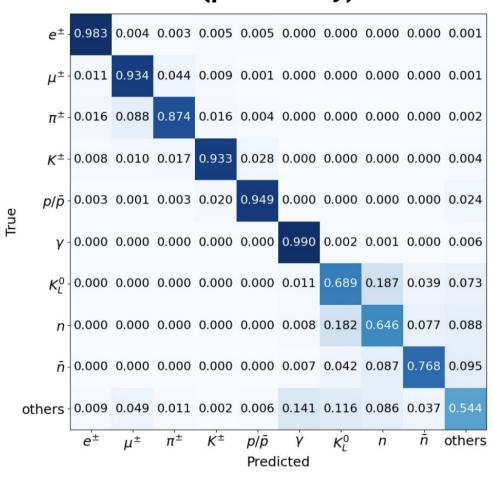


Preliminary! One-one framework needs further polish to be more precise & descriptive

CEPC

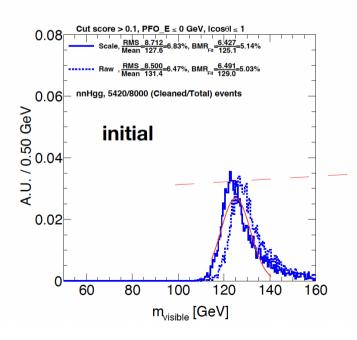


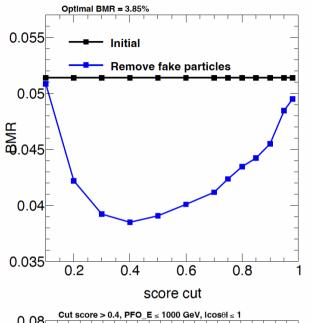
ILD (preliminary)

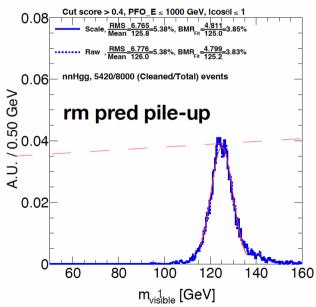


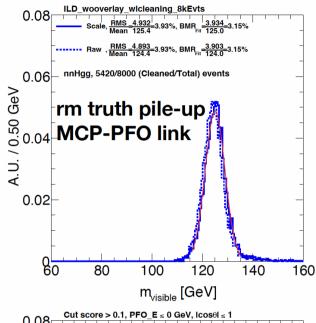
pile-up subtraction

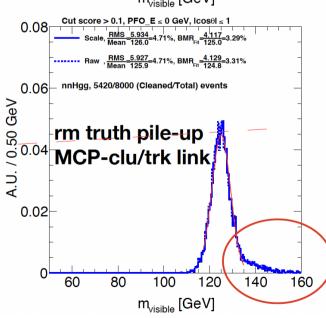
- BMR
 - initial ~5.14%
 - rm pred pile-up 3.85%
 - rm truth pile-up 3.29%
 - using MCP-clu/trk link
 - rm truth pile-up 3.15%
 - using MCP-PFO link



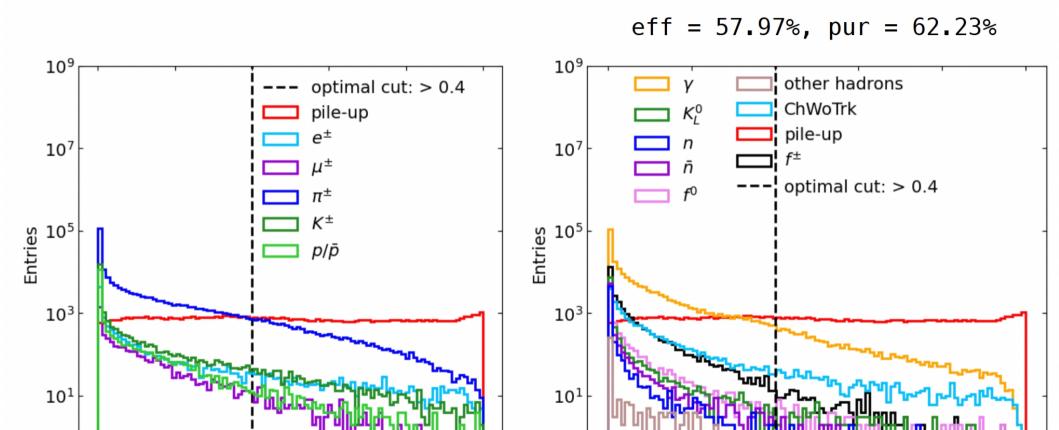








PU pfo identification...



0.0

0.2

0.6

pileup-likelihood

0.8

0.0

0.2

1.0

1.0

0.8

pileup-likelihood

Design-2: Crystal bar + Mesh

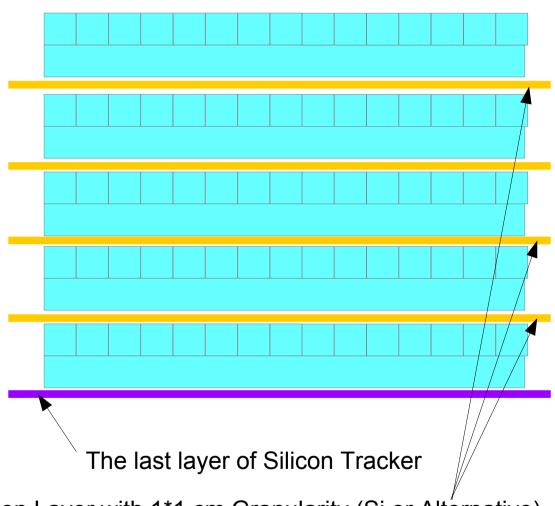
Geometry

- Total Crystal Volume: 24 m³
- Single Crystal Bar Dimension:
 2.67cm * 2.67cm * 40cm =
 291 cc, In total 80k bars
- Inner Area: 80 m²
- Total Readout Channel:
 - 80000*2 = 160k (Crystal)
 - 800000*4 = 3.2 M (Si)

Comments

Extra material budget ~ o(1%)
 of the total radiation length is
 tolerable for the EM resolution

~ 2-3 mm of Cu. per layer



Position Layer with 1*1 cm Granularity (Si or Alternative)