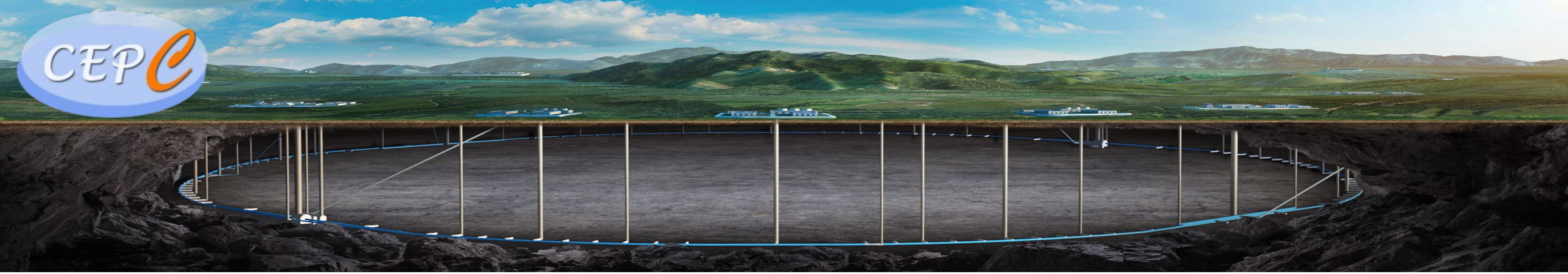


Physics Benchmarks and Global Performance

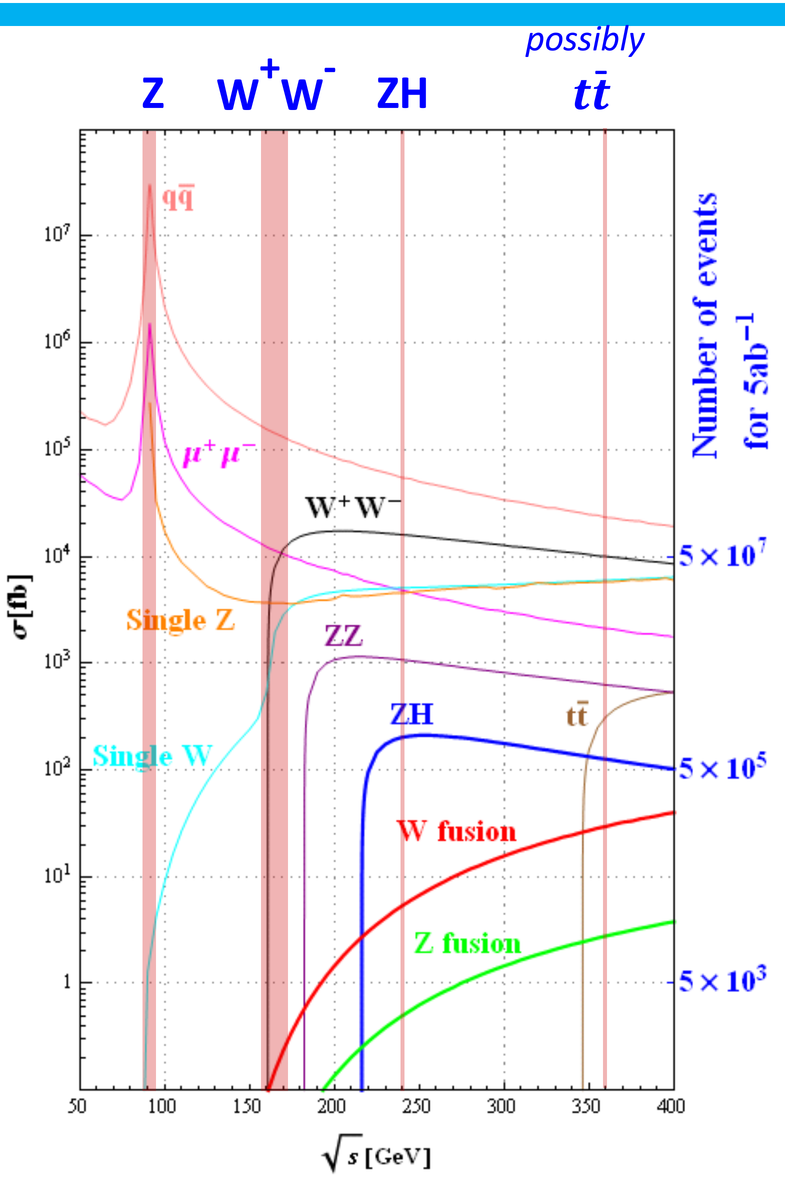
Mingshui Chen
for Physics & Performance group

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Content

- Introduction to CEPC Physics
- Physics Benchmarks and Global Performance
  - Key Detector Requirements
  - Algorithm Development: Jet Origin ID & Its Application
- Physics Benchmarks Reach with the CDR detector for reference
- Global Performance of the Ref-TDR detector
- Physics Benchmarks Prospects at the Ref-TDR
- Challenges, Plans, and Team
- Summary

Operation Plan from Acc. TDR



Operation mode		ZH	Z	W^+W^-	$t\bar{t}$
$\sqrt{s}$ [GeV]		~240	~91	~160	~360
Run Time [years]		10	2	1	5
30 MW	L / IP [$\times10^{34}$ cm^{-2}s^{-1}]	**5.0**	**115**	**16**	**0.5**
	$\int L\,dt$ [ab^{-1}, 2 IPs]	13	60	4.2	0.65
	Event yields [2 IPs]	2.6×10^6	2.5×10^{12}	1.3×10^8	4×10^5
50 MW	L / IP [$\times10^{34}$ cm^{-2}s^{-1}]	**8.3**	**192**	**26.7**	**0.8**
	$\int L\,dt$ [ab^{-1}, 2 IPs]	21.6	100	6.9	1
	Event yields [2 IPs]	4.3×10^6	4.1×10^{12}	2.1×10^8	6×10^5

CEPC accelerator TDR (Xiv:2312.14363)

While aiming to meet the needs of the whole energy range, emphasizes more on the Higgs operation mode.

CEPC physics

Higgs

m_H, σ, Γ_H
self-coupling
H→ bb, cc, ss, gg
H→inv, H→sb, ...

Flavor

CKM matrix
CPV measurements
LFV, LUV
τ properties (lifetime, BRs..)
$B_c \to \tau\,\nu$, $B_s \to D_s\,K/\pi$
$B_s \to K^*\tau\,\tau$, $B \to K^*\,\nu\,\nu$
$B_s \to \varphi\,\nu\,\nu$ …

4 million Higgs
4 trillion Z bosons
200 million W pairs
600 k ttbar

Top

m_{top}, Γ_{top},
top quark coupling,
…

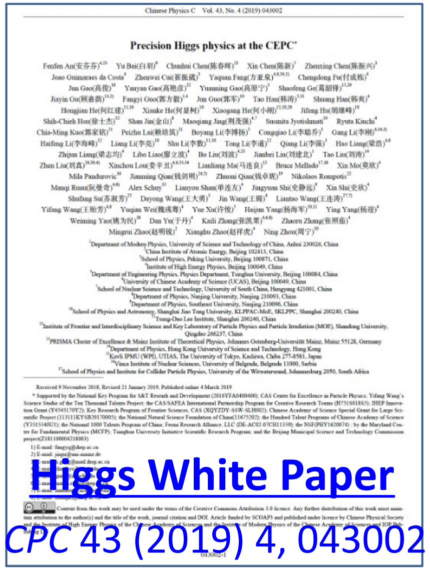
BSM

Heavy Neutral Leptons
Dark Photons Z_D
Axion Like Particles
Exotic Higgs decays
…

EWK/QCD

m_Z , Γ_Z , Γ_{inv}
$\sin^2\theta_W$, m_W, Γ_W ,
$A_{FB}^{b,c}$, τ pol.
α_S ,…

CEPC physics

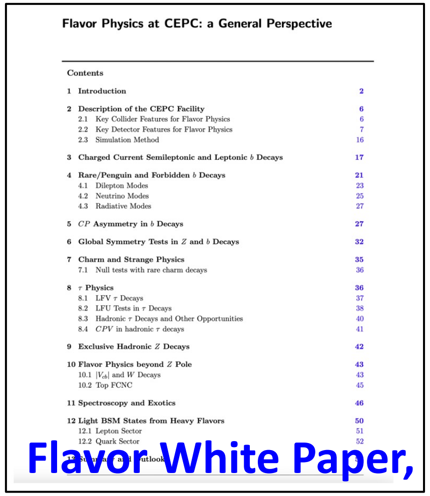


Chinese Physics C Vol. 43, No. 4 (2019) 043002

Precision Higgs physics at the CEPC

Higgs White Paper

CPC 43 (2019) 4, 043002



Flavor Physics at CEPC: a General Perspective

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Flavor White Paper,

summarizing ~ 40 benchmarks, to be submitted soon

Higgs

m_H, σ, Γ_H
self-coupling
$H \to bb, cc, ss, gg$
$H \to inv$, $H \to sb$, …

Flavor

CKM matrix
CPV measurements
LFV, LUV
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$B_c \to \tau\nu$, $B_s \to D_s K/\pi$
$B_s \to K^*\tau\tau$, $B \to K^*\nu\nu$
$B_s \to \phi\nu\nu$ …

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4 trillion Z bosons
200 million W pairs
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BSM

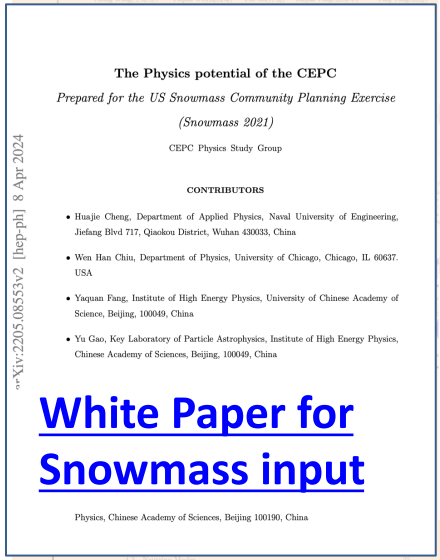
Heavy Neutral Leptons
Dark Photons Z_D
Axion Like Particles
Exotic Higgs decays
…

EWK/QCD

m_Z, Γ_Z, Γ_{inv}
$\sin^2\theta_W$, m_W, Γ_W,
$A_{FB}^{b,c}$, τ pol.
α_S, …

- Physics merit quantified by simulation & phenomenology studies:
  - **Higgs Phyiscs**: precisions exceed HL-LHC by ~ one order of magnitude
  - **EW Studies**: precision improved by one to two orders of magnitude over current limits
  - **Flavor Physics**: sensitive to new physics at energy scales of 10 TeV or higher
  - **BSM physics**: sensitivity to a variety of potential signals

CEPC physics



arXiv:2205.08553v2 [hep-ph] 8 Apr 2024

The Physics potential of the CEPC

Prepared for the US Snowmass Community Planning Exercise

(Snowmass 2021)

CEPC Physics Study Group

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White Paper for Snowmass input

Physics, Chinese Academy of Sciences, Beijing 100190, China

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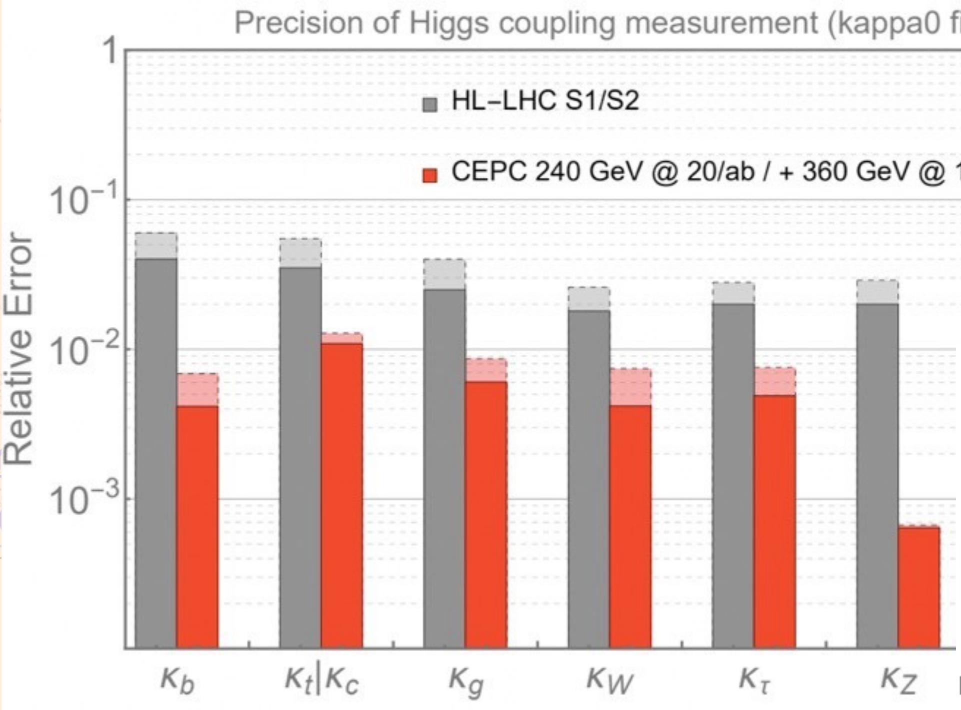


vor

matrix

urements

LUV

fetime, BRs..)

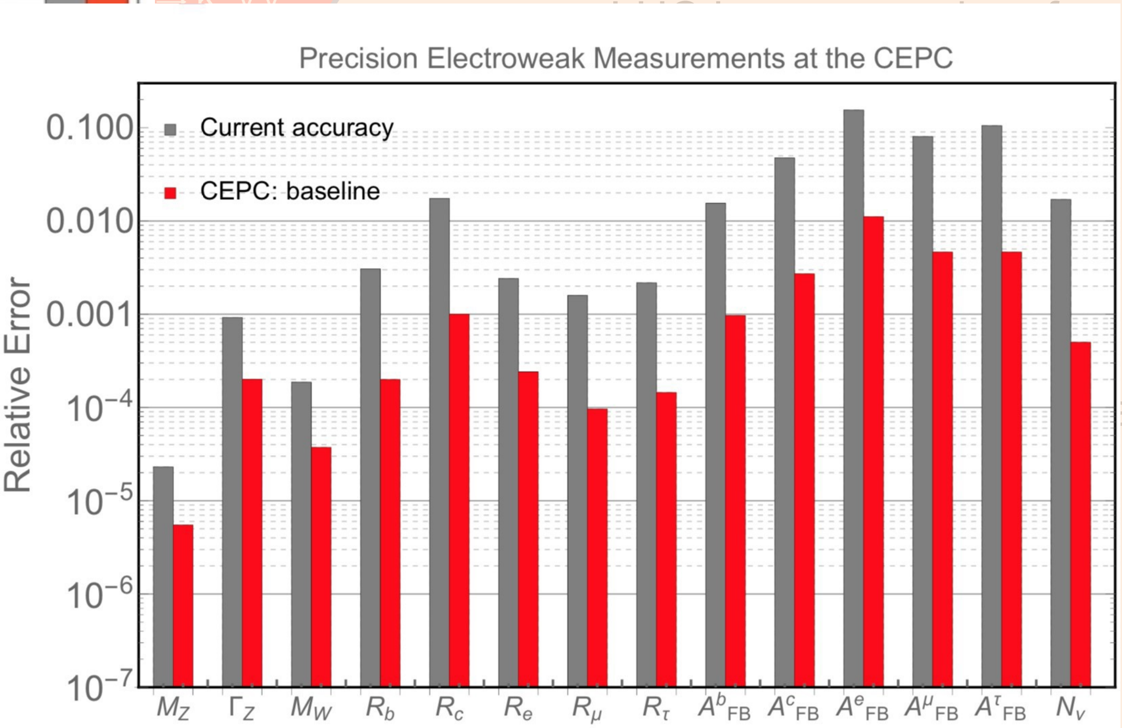
→ D_s K/π

→ K* ν ν

m_{top}, Γ_{top},

top quark coupling,

…



EWK/QCD

m_Z , Γ_Z , Γ_{inv}

$\sin^2\theta_W$, m_W, Γ_W ,

$A_{FB}^{b,c}$, τ pol.

α_S ,…

Flavor White Paper,

summarizing ~ 40 benchmarks, to be submitted soon

- Physics merit quantified by simulation & phenomenology studies:
  - ◆ **Higgs Phyiscs**: precisions exceed HL-

signals

CEPC Detector Requirements

Excellent tracking resolution/
Jet energy resolution
Impact parameter resolution
for b,c,s tagging

Higgs

m_H, σ, Γ_H
self-coupling
H→ bb, cc, ss, gg
H→inv, H→sb, …

Flavor

CKM matrix
CPV measurements
LFV, LUV
τ properties (lifetime, BRs..)
$B_c \to \tau \nu$, $B_s \to D_s K/\pi$
$B_s \to K^* \tau \tau$, $B \to K^* \nu \nu$
$B_s \to \varphi \nu \nu$ …

Superior impact parameter resolution for vertices, tagging;
Energy resolution for π^0 or γ reco;
PID: K/π separation over wide momentum range for b and τ physics

4 million Higgs
4 trillion Z bosons
200 million W pairs
600 k ttbar

Top

m_{top}, Γ_{top},
top quark coupling,
…

BSM

Heavy Neutral Leptons
Dark Photons Z_D
Axion Like Particles
Exotic Higgs decays
…

LLP sensitivity via far detached vertices (mm→m):
Tracking, Calorimetry, Muon

EWK/QCD

m_Z , Γ_Z , Γ_{inv}
$\sin^2\theta_W$, m_W, Γ_W ,
$A_{FB}^{b,c}$, τ pol.
α_S , …

Small systematics:
Absolute normalisation (luminosity， 10^{-4})
Momentum resolution

Physics Benchmarks and Requirements

	Process @ c.m.e	Domain	Relevant Det. Performance
H→ss/cc/sb	ννH @ 240 GeV	Higgs	PFA + Jet Origin ID (JOI)
H→inv	qqH	Higgs/NP	PFA, MET
Vcb	WW→ℓνqq @ 240/160 GeV	Flavor	JOI + PID (lepton, tau)
W fusion Xsec	ννH @ 360 GeV	Higgs	PFA + JOI
α_S	Z→ττ @ 91.2 GeV	QCD	PFA, tau ID
CKM angle $\gamma - 2\beta$	Z→bb, B→DK @ 91.2 GeV	Flavor	PFA + JOI + PID (kaon)
Weak mixing angle	Z @ 91.2 GeV	EW	JOI
Higgs recoil	ℓℓH	Higgs	Lepton ID, track dP/P
H→bb, gg	ννH + qqH	Higgs	PFA + JOI
H→μμ	qqH	Higgs	PFA, lepton ID, tracking
H→γγ	qqH	Higgs	PFA, photon ID, EM resolution
W mass & width	Threshold scan @ 160 GeV	EW	Beam energy
Top mass & width	Threshold scan @ 360 GeV	EW	Beam energy
Bs→$\nu\nu\phi$	91.2 GeV	Flavor	Object (ϕ) in jets; MET
Bc→$\tau\nu$	91.2 GeV	Flavor	Object (τ) in jets; MET
$B_0 \to 2\pi^0$	91.2 GeV	Flavor	π^0 in jets; EM resolution
H→LLP	qqH	NP	Tracking in calo/muon detector
H→aa→4γ	qqH	NP	EM resolution

PFA is essential for the majority of benchmarks, emphasizing **global reconstruction performance**

- **BMR < 4%** required, with a target to achieve 3% for optimal resolution
- **PID**: crucial to efficiently reconstruct and accurately identify final state particles with a one-to-one correspondence
  - **Kaon ID with eff and purity > 95%**
- Capable to find composited objects in jets

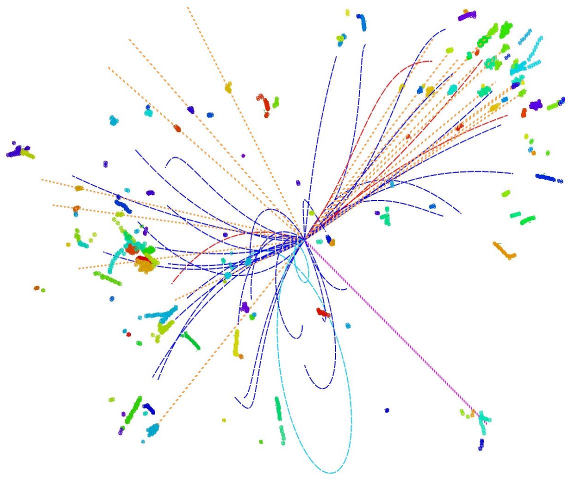
Sub-Det level performance

- **Tracking: ~0.1% momentum resolution**
- **EM resolution: ~1% level**
- **VTX: position resolution ~ 5 μm**

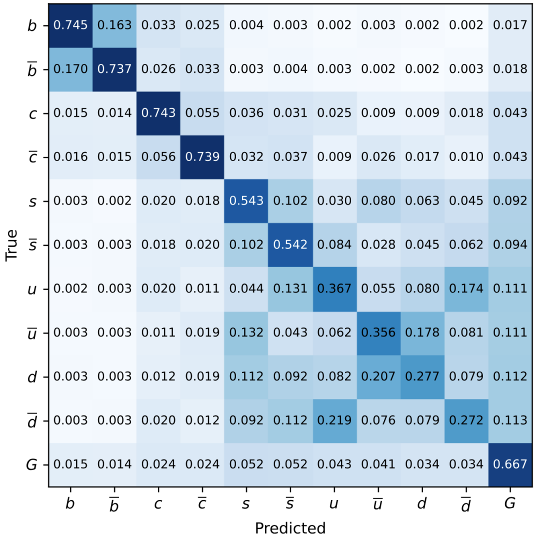
- **Reliance on both sub-detector performance and advanced global reconstruction algorithms is essential**
  - **CyberPFA** being developed to address the challenges of Crystal Bar ECal
    - Relying heavily on full simulation of the detector
  - New concepts emerge, such as **Jet Origin ID** and Color Singlet ID

Jet Origin ID

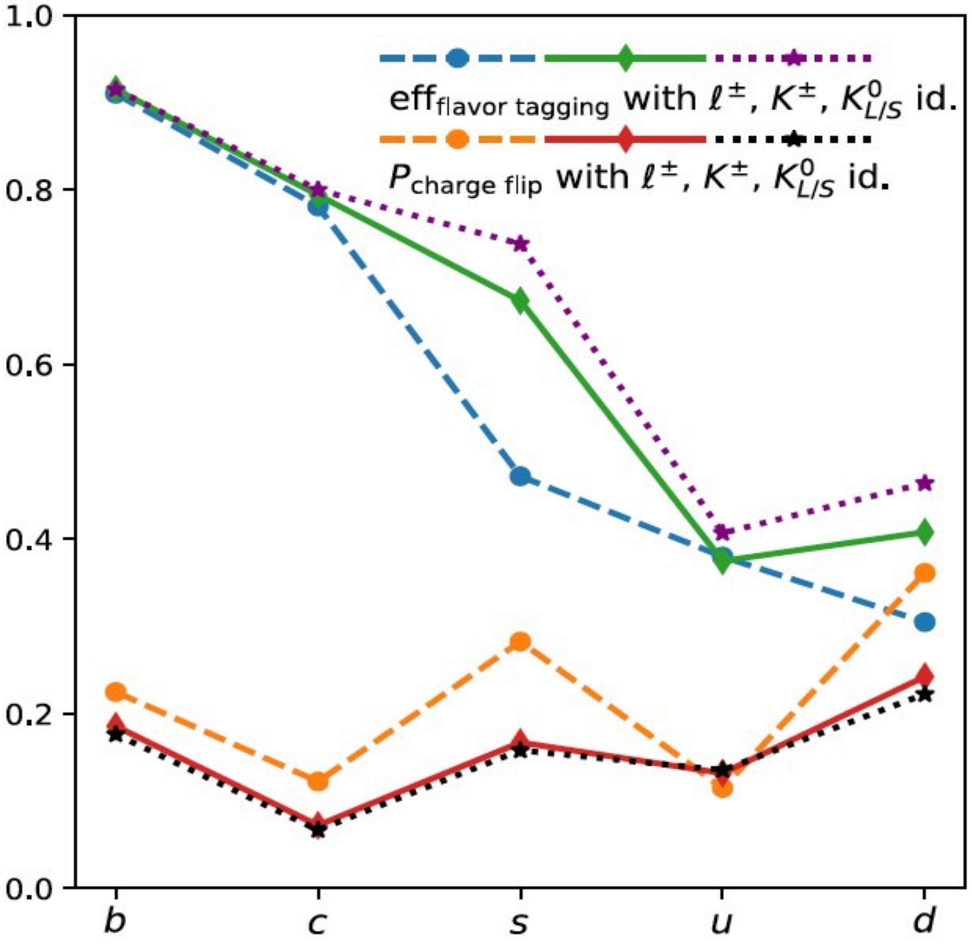
PRL 132, 221802 (2024)



Confusion matrix M_{11}



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



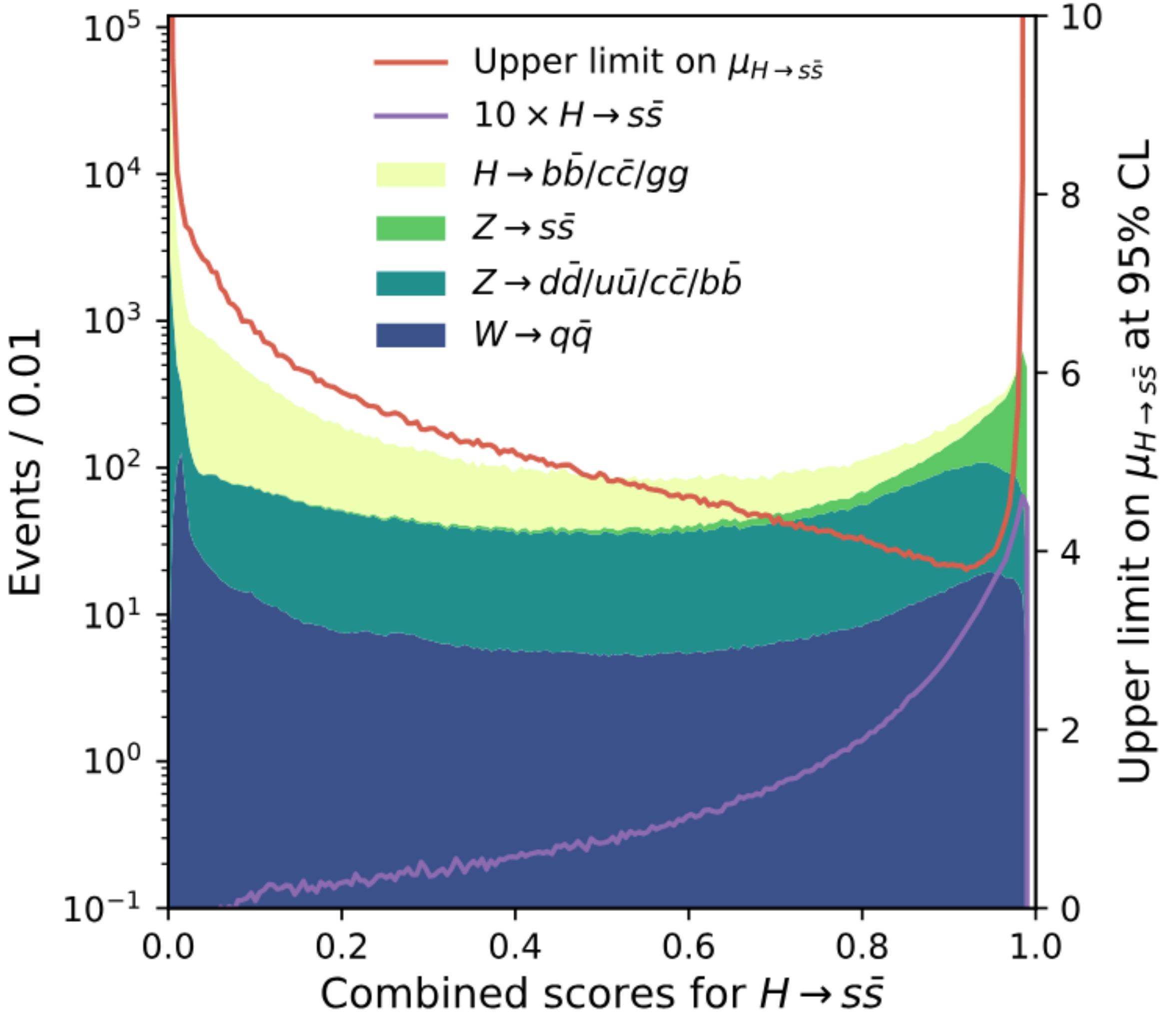
Jet flavor tagging efficiencies and charge flip rates with perfect identifications

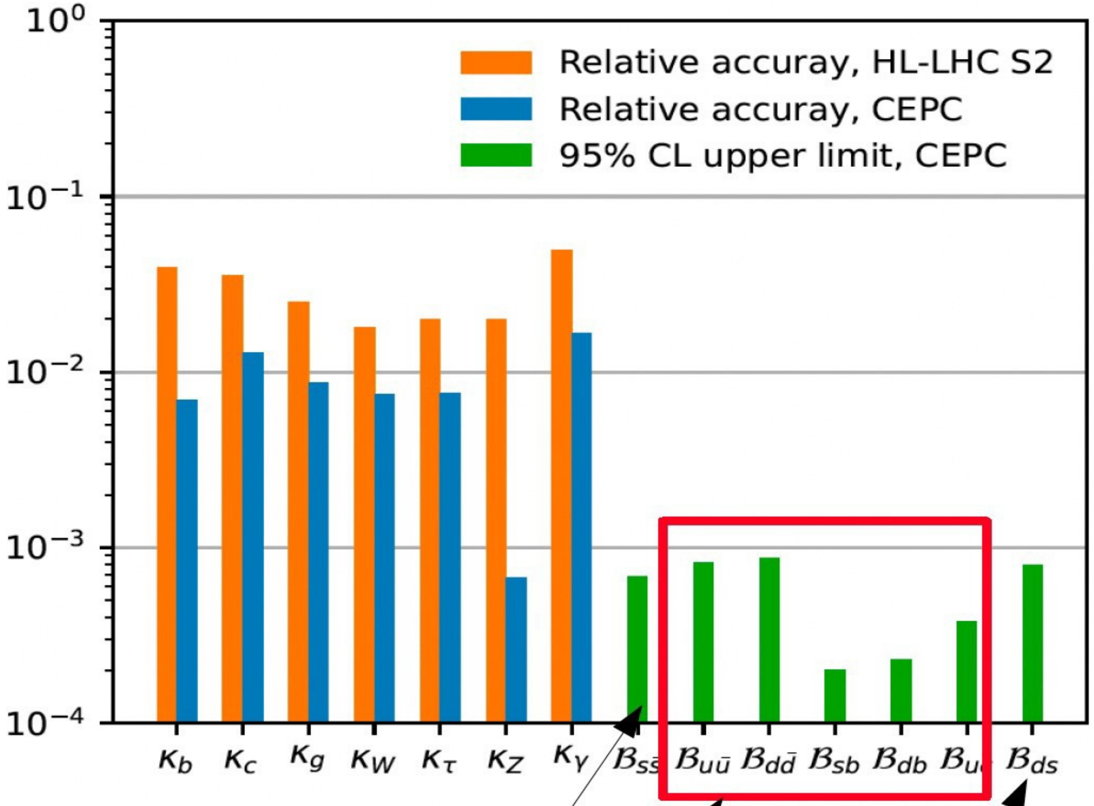
- **Jet Origin ID**: 11 categories (5 quarks + 5 antiquarks, + gluon)
  - Jet flavor (b, c, **s, gluon, u & d)** tagging and **charge**
  - Input: PID & 4-momentum of all reconstructed particles + impact parameters for charged ones (~o(50) particles)

JOI concept successfully demonstrated using CEPC CDR baseline detector and Arbor PFA, along with perfect PID (di-jet events (ννH(qq) & Z→qq) simulated)

Physics Benchmarks: H→ss

PRL 132, 221802 (2024)





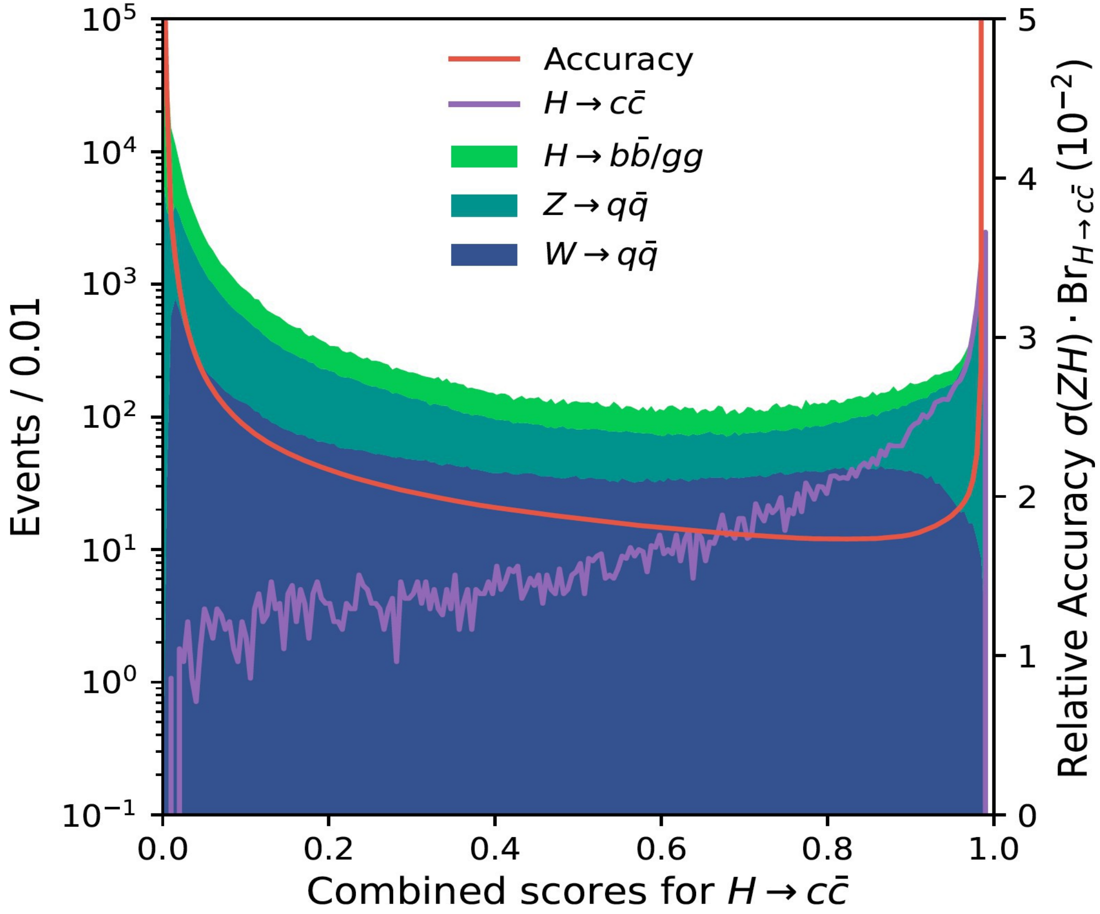
Improved by ~3 times

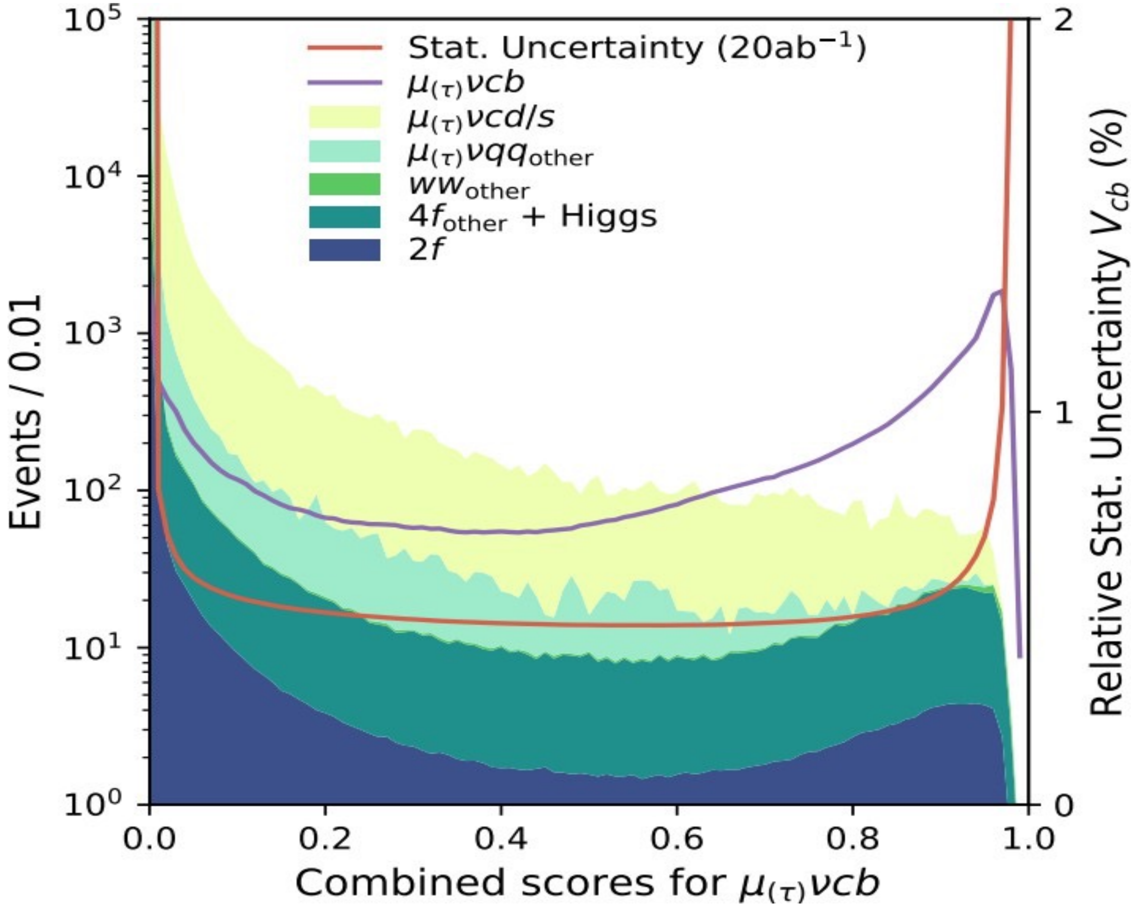
Improved by 1-2 orders of magnitudes

Presumably... firstly quantified

Physics Benchmarks: H→cc & Vcb

PRL 132, 221802 (2024)





- From Jet Flavor Tagging to Jet Origin ID:
  - ννH, H→cc: 3% → 1.7%
  - Vcb: 0.75% → 0.45% (μνqq channel, eνqq: 0.6%, combined 0.4%)

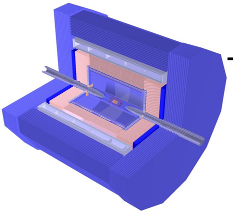
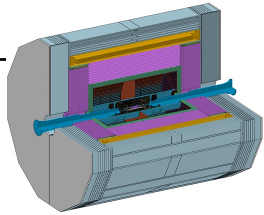
Physics Benchmarks using CDR detector and TDR lumi

	Process @ c.m.e	Domain	Sensitivities using CDR baseline detector + TDR lumi., with JOI
H→cc	ννH @ 240 GeV	Higgs	1.7%
H→ss [1]			95% UL of 0.75E-3
H→sb [1]			95% UL of 0.22E-3
H→inv [2]	qqH	Higgs/BSM	95% UL of 0.13%
Vcb [3]	WW→ℓνqq @ 240/160 GeV	Flavor	0.4%
W fusion Xsec [2]	ννH @ 360 GeV	Higgs	1.1%
α_s	Z→ττ @ 91.2 GeV	QCD	NAN
CKM angle $\gamma-2\beta$	Z→bb, B→DK @ 91.2 GeV	Flavor	NAN
Weak mixing angle [4]	Z @ 91.2 GeV	EW	2.4E-6 using 1 month of Z pole data (~2E11 Z)
Higgs recoil [5]	ℓℓH	Higgs	δm = 2.5 MeV; δσ/σ = 0.25%/0.4% (wi/wo qqH)
H→bb, gg [2]	ννH + qqH	Higgs	bb: 013%; gg: 0.65%
H→μμ [2]	qqH	Higgs	6.4%
H→γγ [2]	qqH	Higgs	3%
W mass & width [6]	Threshold scan @ 160 GeV	EW	0.7 MeV & 2.4 MeV @ 6 iab
Top mass & width [7]	Threshold scan @ 360 GeV	EW	9 MeV & 26 MeV @ 100 ifb
Bs→$\nu\nu\phi$ [8]	91.2 GeV	Flavor	0.9% (1.8%@Tera-Z)
Bc→$\tau\nu$ [9]	91.2 GeV	Flavor	0.35% (0.7%@Tera-Z)
B_0→2π^0 [10]	91.2 GeV	Flavor	NAN
H→LLP	qqH	BSM	NAN
H→aa→4γ	qqH	BSM	NAN

1. H. Liang, et al, PHYSICAL REVIEW LETTERS 132, 221802 (2024)
2. CEPC Phy-Det Snowmass White Paper, arXiv:2205.08553v1
3. H. Liang, Ph.D thesis
4. Z. Zhao, et al., Chinese Physics C Vol. 47, No. 12 (2023) 123002
5. Z. Yang, et al., Chinese Physics C Vol. 41, No. 2 (2017) 023003
6. P. Shen, et al., Eur. Phys. J. C (2020) 80:66
7. Z. Li, et al., arXiv:2207.12177
8. Y. Wang, et al., PHYSICAL REVIEW D 105, 114036 (2022)
9. T. Zheng, et al., Chinese Physics C Vol. 45, No. 2 (2021) 023001
10. Y. Wang, et al., JHEP12(2022)135

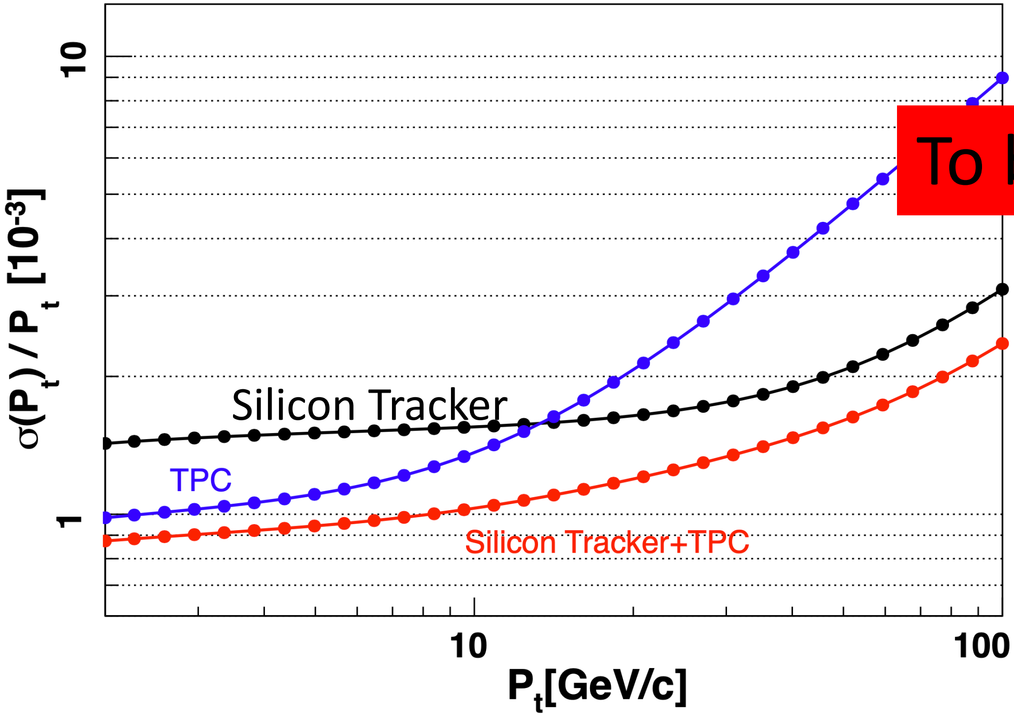
We need to demonstrate this table using RefTDR design

Detector Concepts: from CDR to refTDR

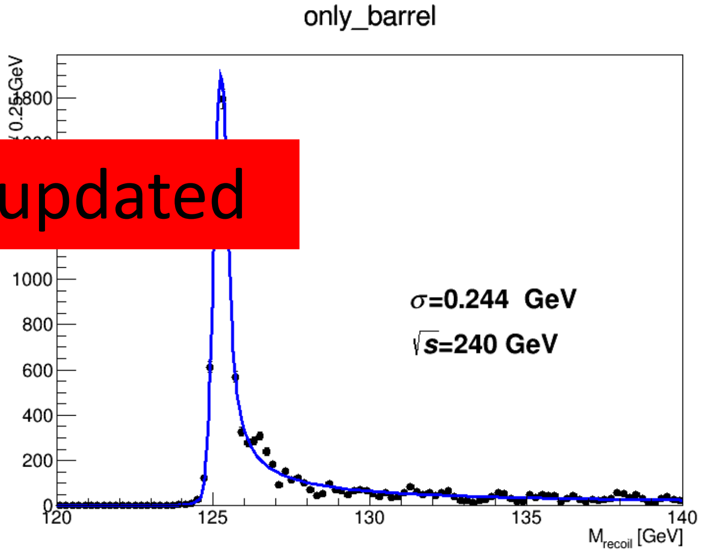
	CDR 	**Ref-TDR** 
VTX	Inner radius of **16 mm**	Inner radius of **11 mm**
	Material Budget: 0.15%*6+0.14%(beampipe)= **1.05% X0**	Material Budget: 0.06%*4(inner)+0.25%*2(outer)+0.16%(beampipe)= **0.9% X0**
Gaseous Tracker	TPC with **1 mm* 6 mm** readout	TPC with **0.5 mm* 0.5 mm** readout To have **dE/dx or dN/dx resolution 3%** (Drift Chamber with the capability of dN/dx as alternative)
ToF	**-**	AC-LGAD, with **50 ps** per MIP
ECAL	Si-W-ECAL: **17%**/√E ⨁ 1%	Crystal Bar-ECAL: **1.5%**/√E ⨁ 1%
HCAL	RPC-Iron: **60%**/√E ⨁ 2%	Glass-Iron: **30%**/√E ⨁ 6%

To be updated, and also redo the extrapolation

Tracking @ simulation

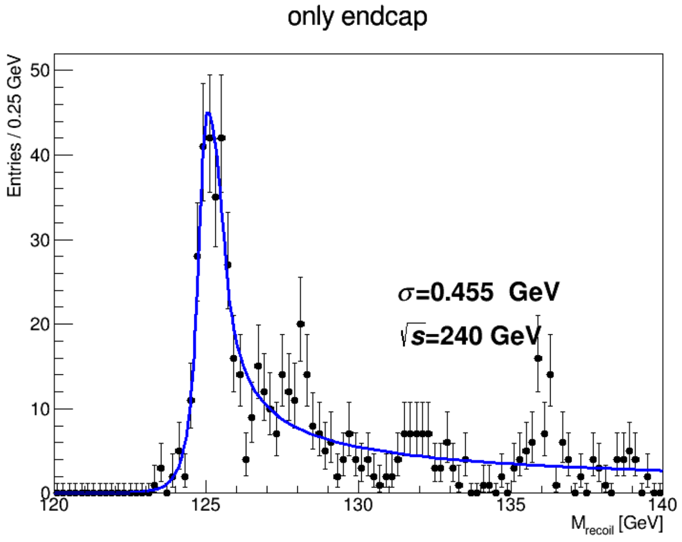


To be updated



Z(μμ)H – recoil mass

σ_m ~ 0.1% @ Barrel



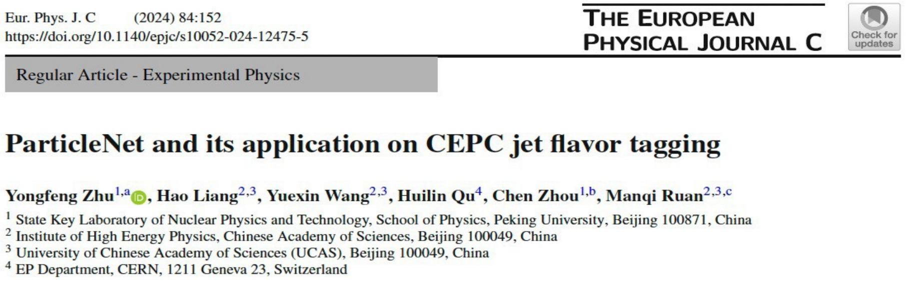
Z(μμ)H – recoil mass

σ_m ~ 0.2% @ Endcap

- To be updated with full tracking system, and also versus costheta
- ~0.1% achievable for the majority of tracking resolution

VTX and Jet Flavor/Charge measurement

Eur.Phys.J.C 84 (2024) 2, 152



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THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

ParticleNet and its application on CEPC jet flavor tagging

Yongfeng Zhu[1,a], Hao Liang[2,3], Yuexin Wang[2,3], Huilin Qu[4], Chen Zhou[1,b], Manqi Ruan[2,3,c]

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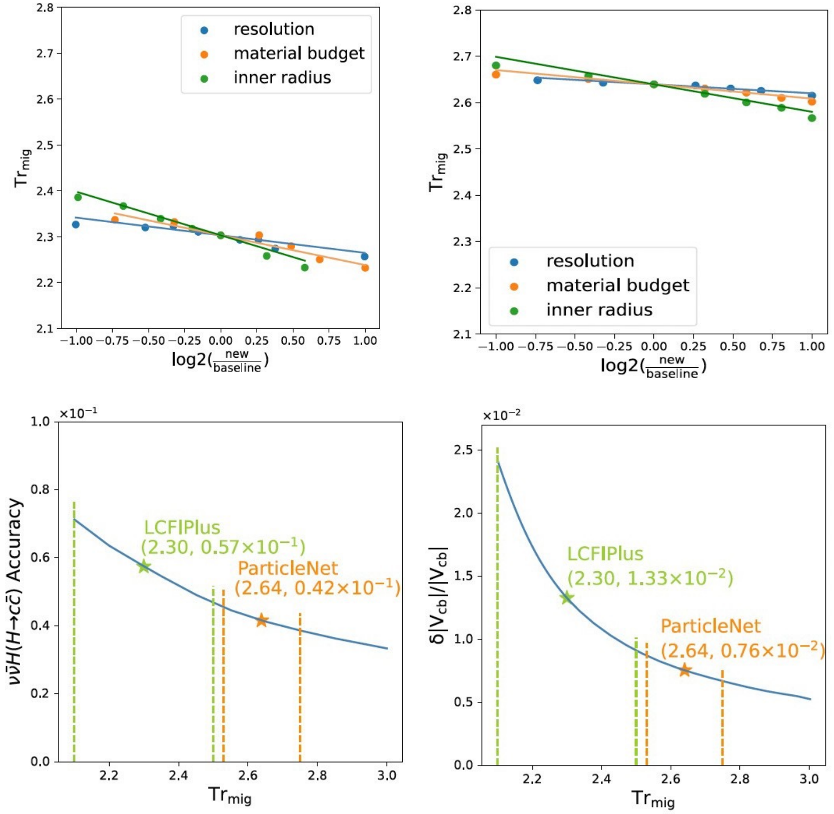
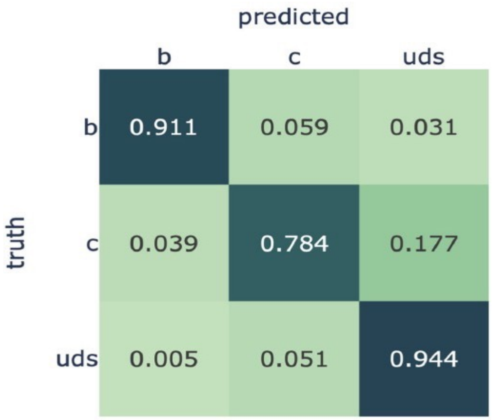




predicted

truth	b	c	uds
b	0.911	0.059	0.031
c	0.039	0.784	0.177
uds	0.005	0.051	0.944

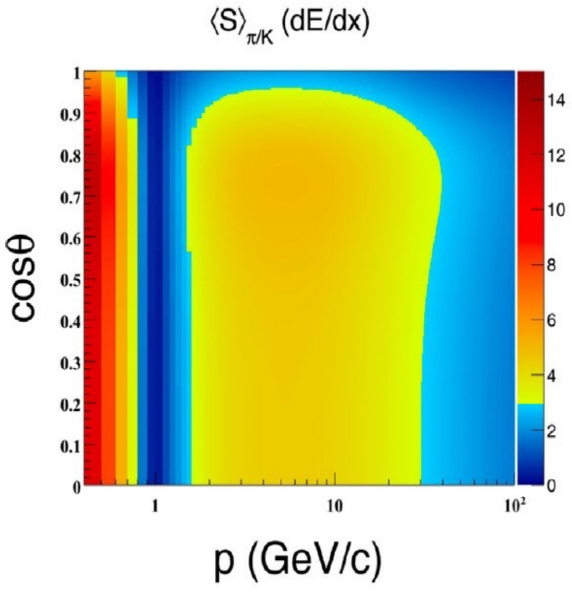
$$Tr_{mig} = 2.30 + 0.06 \cdot \log_2 \frac{R^0_{material}}{R_{material}} + 0.04 \cdot \log_2 \frac{R^0_{resolution}}{R_{resolution}} + 0.10 \cdot \log_2 \frac{R^0_{radius}}{R_{radius}} \quad (1)$$

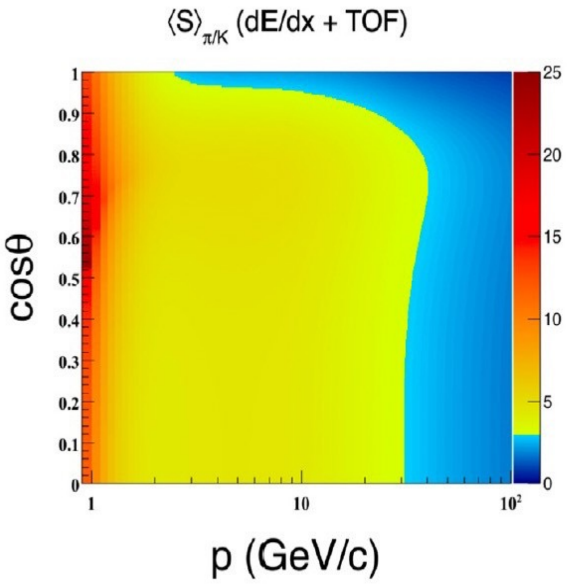
$$Tr_{mig} = 2.64 + 0.03 \cdot \log_2 \frac{R^0_{material}}{R_{material}} + 0.02 \cdot \log_2 \frac{R^0_{resolution}}{R_{resolution}} + 0.06 \cdot \log_2 \frac{R^0_{radius}}{R_{radius}} \quad (2)$$

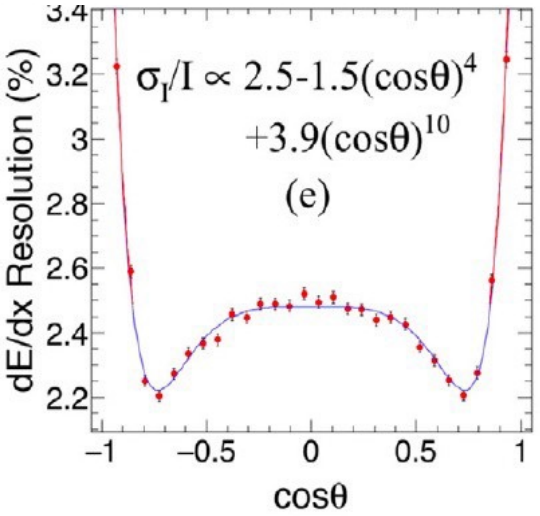
- Compared to the CDR, the VTX at TDR has:
  - Inner radius reduced by 40% (16 mm ⟶ 11 mm)
  - Material reduced by 10% (1.05% ⟶ 0.9% X0)
- Trace(Migration Matrix) increased from 2.64 ⟶ 2.68
  - H ⟶ cc accuracy improved by ~5%
  - Vcb accuracy improved by ~10%

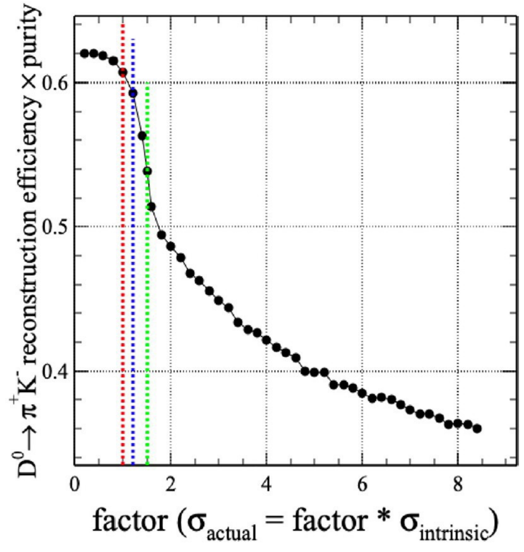
PID: dE/dx or dN/dx + TOF

Nucl.Instrum.Meth.A 1047 (2023) 167835









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Requirement analysis for dE/dx measurement and PID performance at the CEPC baseline detector

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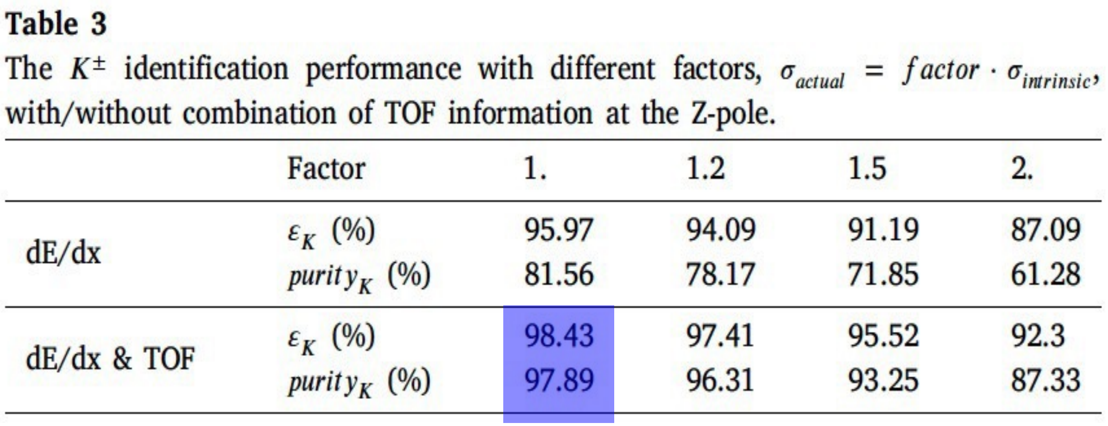


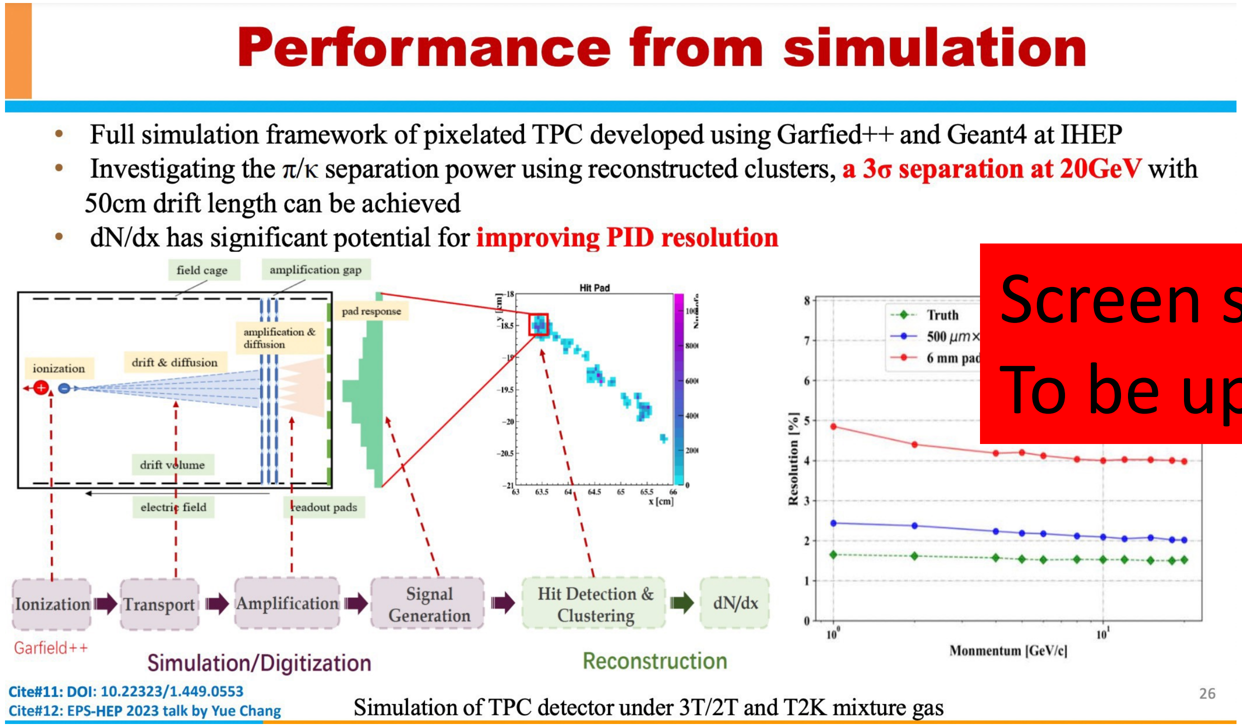
Table 3

The $K^{\pm}$ identification performance with different factors, $\sigma_{actual} = factor \cdot \sigma_{intrinsic}$, with/without combination of TOF information at the Z-pole.

	Factor	1.	1.2	1.5	2.
dE/dx	ε_K (%)	95.97	94.09	91.19	87.09
	$purity_K$ (%)	81.56	78.17	71.85	61.28
dE/dx & TOF	ε_K (%)	98.43	97.41	95.52	92.3
	$purity_K$ (%)	97.89	96.31	93.25	87.33

- dE/dx or dN/dx with resolution of **3%** + TOF of **50 ps**: **eff & purity of Kaon ID > 95%**

dE/dx or dN/dx @ ref-TDR goal



Performance from simulation

- Full simulation framework of pixelated TPC developed using Garfied++ and Geant4 at IHEP
- Investigating the π/κ separation power using reconstructed clusters, **a 3σ separation at 20GeV** with 50cm drift length can be achieved
- dN/dx has significant potential for **improving PID resolution**

Cite#11: DOI: 10.22323/1.449.0553
Cite#12: EPS-HEP 2023 talk by Yue Chang

Simulation of TPC detector under 3T/2T and T2K mixture gas

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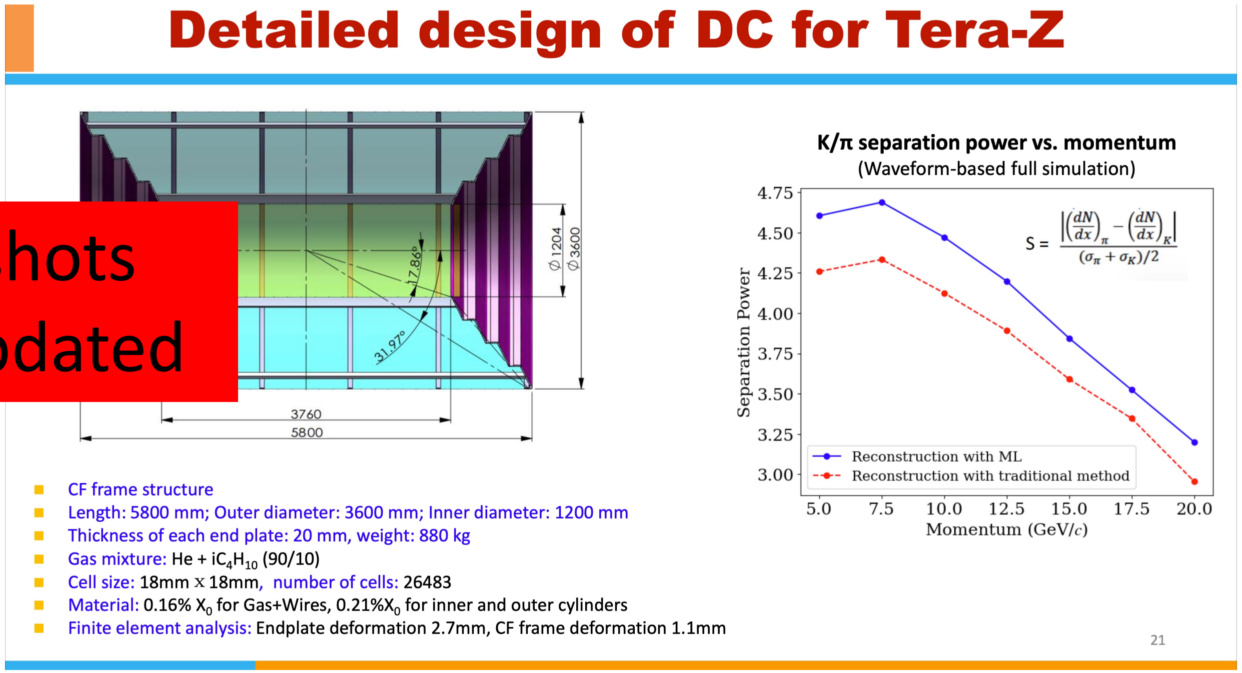
Screen shots
To be updated



Detailed design of DC for Tera-Z

- CF frame structure
- Length: 5800 mm; Outer diameter: 3600 mm; Inner diameter: 1200 mm
- Thickness of each end plate: 20 mm, weight: 880 kg
- Gas mixture: He + iC_4H_{10} (90/10)
- Cell size: 18mm x 18mm, number of cells: 26483
- Material: 0.16% X_0 for Gas+Wires, 0.21%X_0 for inner and outer cylinders
- Finite element analysis: Endplate deformation 2.7mm, CF frame deformation 1.1mm

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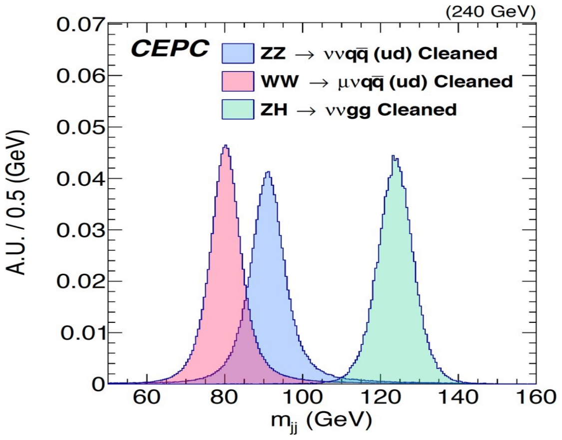
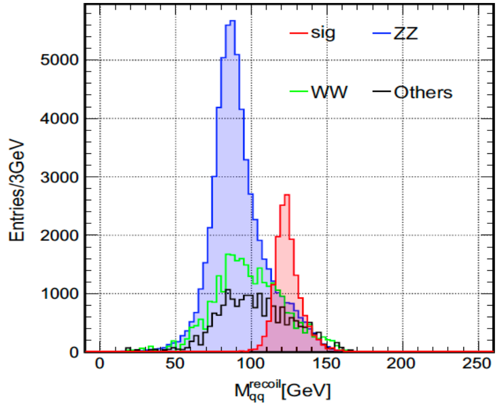
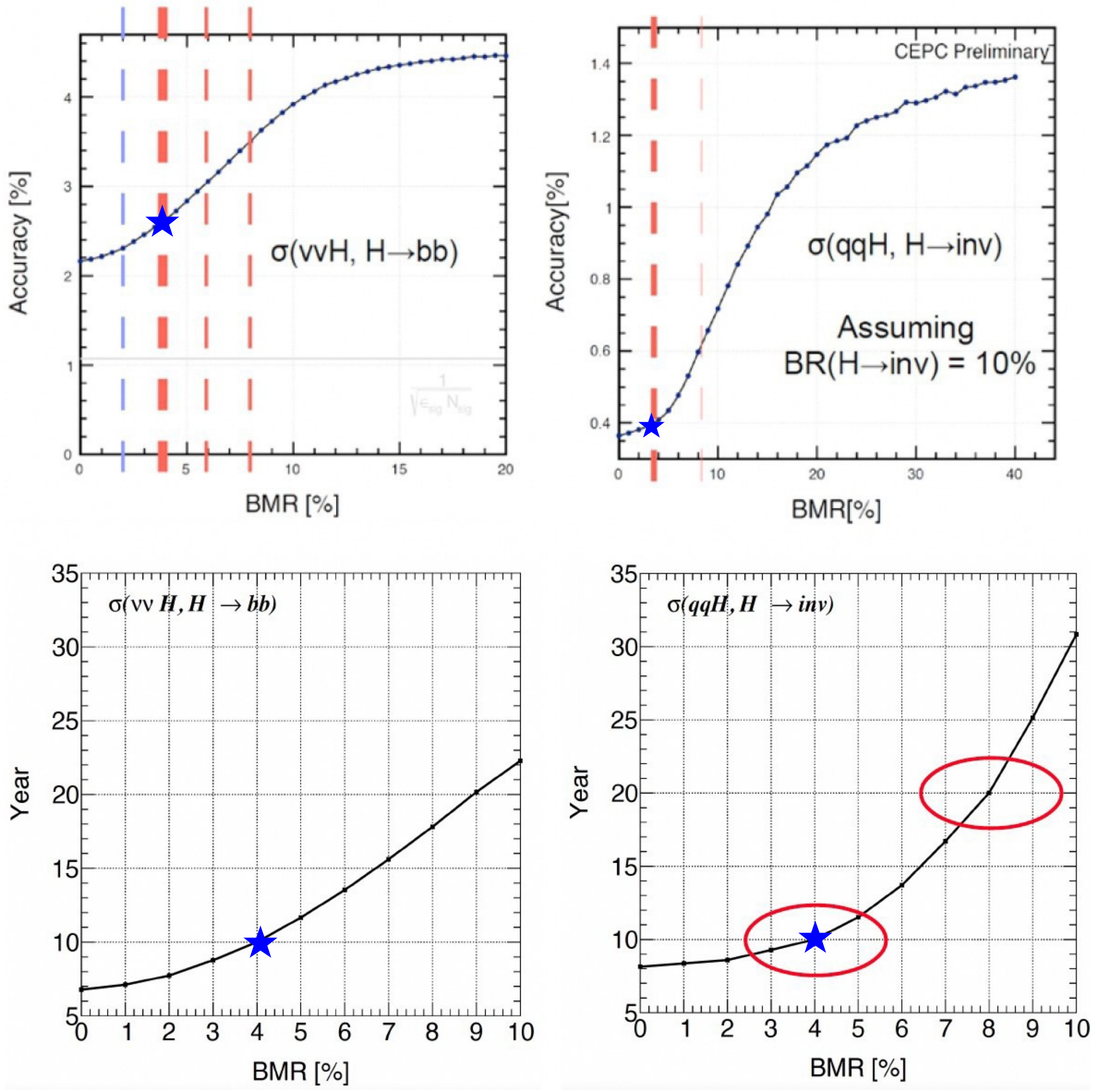
- A major goal for the Ref-TDR Gaseous Tracker is the PID: to achieve 3% dE/dx or dN/dx performance
- Initial results are promising, and will be confirmed through further studies, especially test beam
- Gaseous Tracker inner radius: to be optimized – for endcap performance

PFA Goal: BMR < 4% & pursue 3%

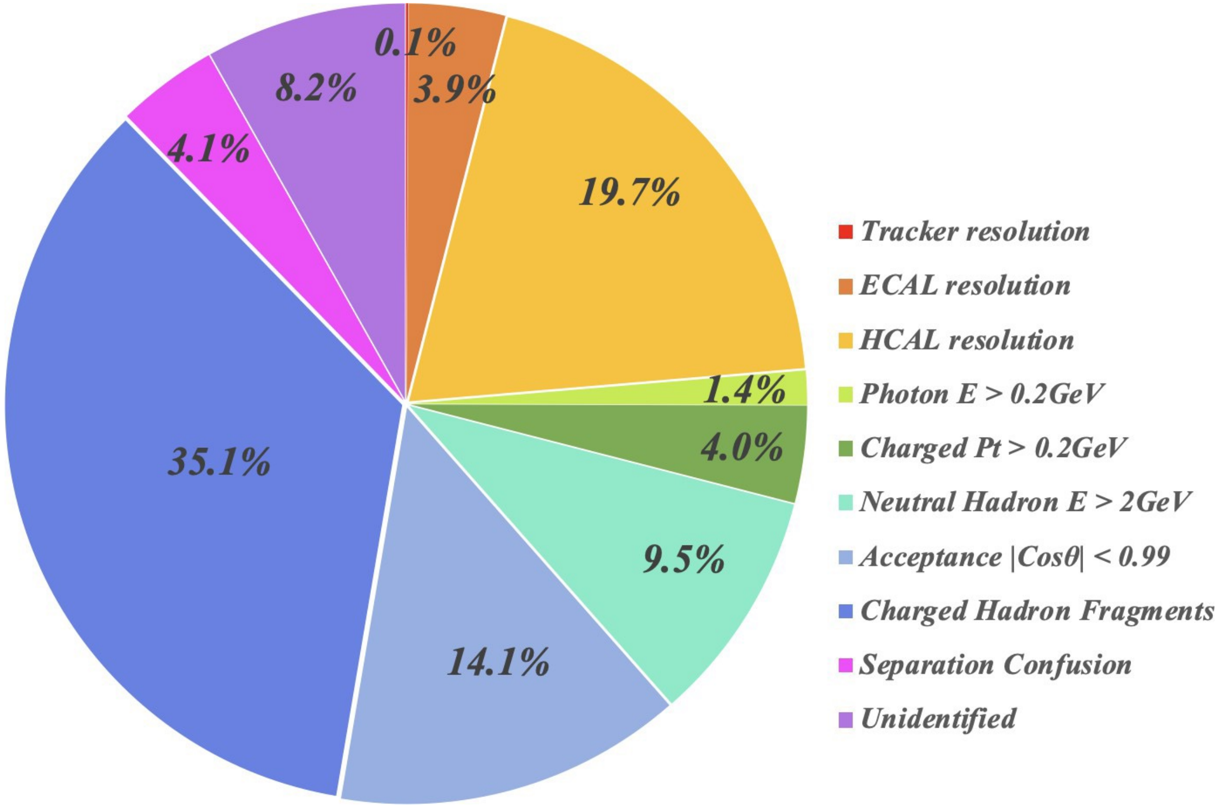


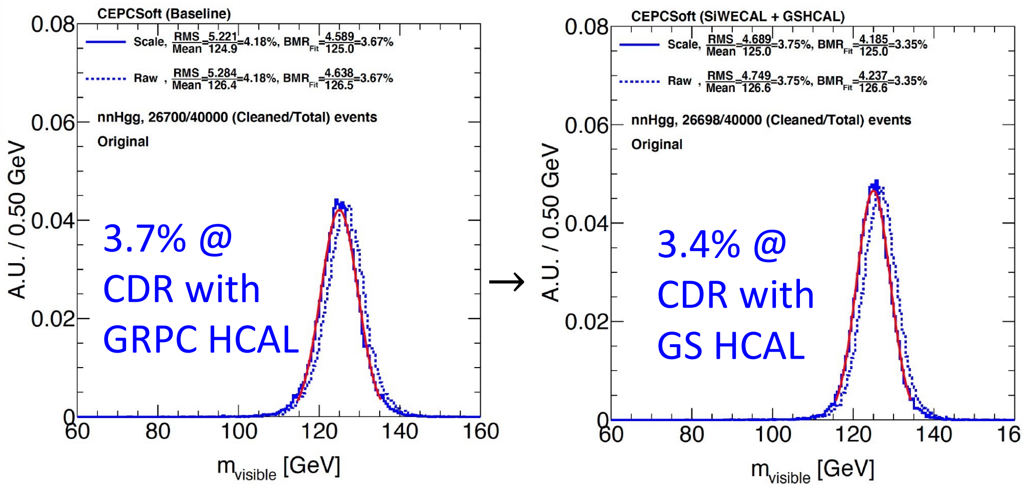




- BMR used to quantify jet reconstruction: 4% will well separate W/Z and Higgs, and separate ZH from the ZZ
  - Accuracies of different physics benchmarks as a function of the BMR show a turning point at roughly BMR of 4%
- H → inv as an example:
  - BMR from **4% to 8%** (typical LHC experiment performance), one need to **double the luminosity** to reach same accuracy
  - BMR from **4% to 3%, save roughly one year** of operation

BMR Decomposition



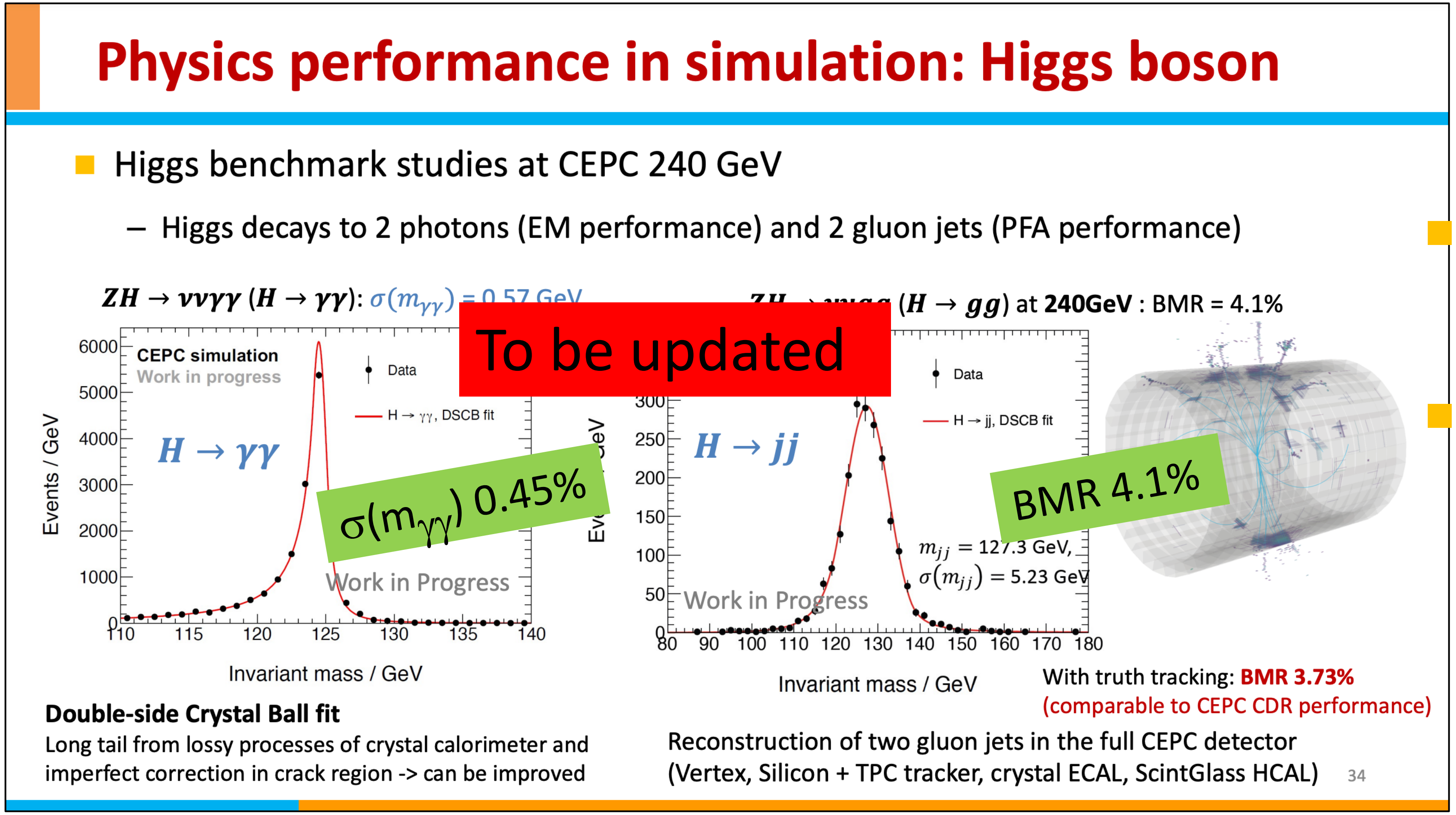


(for BMR of 3.7% at CDR)

- ~50% from confusion
- ~25% from detector resolution
- ~25% from acceptance

- HCAL resolution dominates among the uncertainties from detector resolutions:
  - Using Glass Scintillator (TDR HCAL) - Iron with thickness of 6 lambda (compared to GRPC - Iron of 5 lambda) → BMR of 3.4%

BMR of ~ 4% at refTDR



Physics performance in simulation: Higgs boson

- Higgs benchmark studies at CEPC 240 GeV
  - Higgs decays to 2 photons (EM performance) and 2 gluon jets (PFA performance)

$ZH \to \nu\nu\gamma\gamma$ ($H \to \gamma\gamma$): $\sigma(m_{\gamma\gamma})$ = 0.57 GeV

($H \to gg$) at **240GeV** : BMR = 4.1%

To be updated

$\sigma(m_{\gamma\gamma})$ 0.45%

BMR 4.1%

With truth tracking: **BMR 3.73%**
(comparable to CEPC CDR performance)

Double-side Crystal Ball fit
Long tail from lossy processes of crystal calorimeter and imperfect correction in crack region -> can be improved

Reconstruction of two gluon jets in the full CEPC detector (Vertex, Silicon + TPC tracker, crystal ECAL, ScintGlass HCAL)

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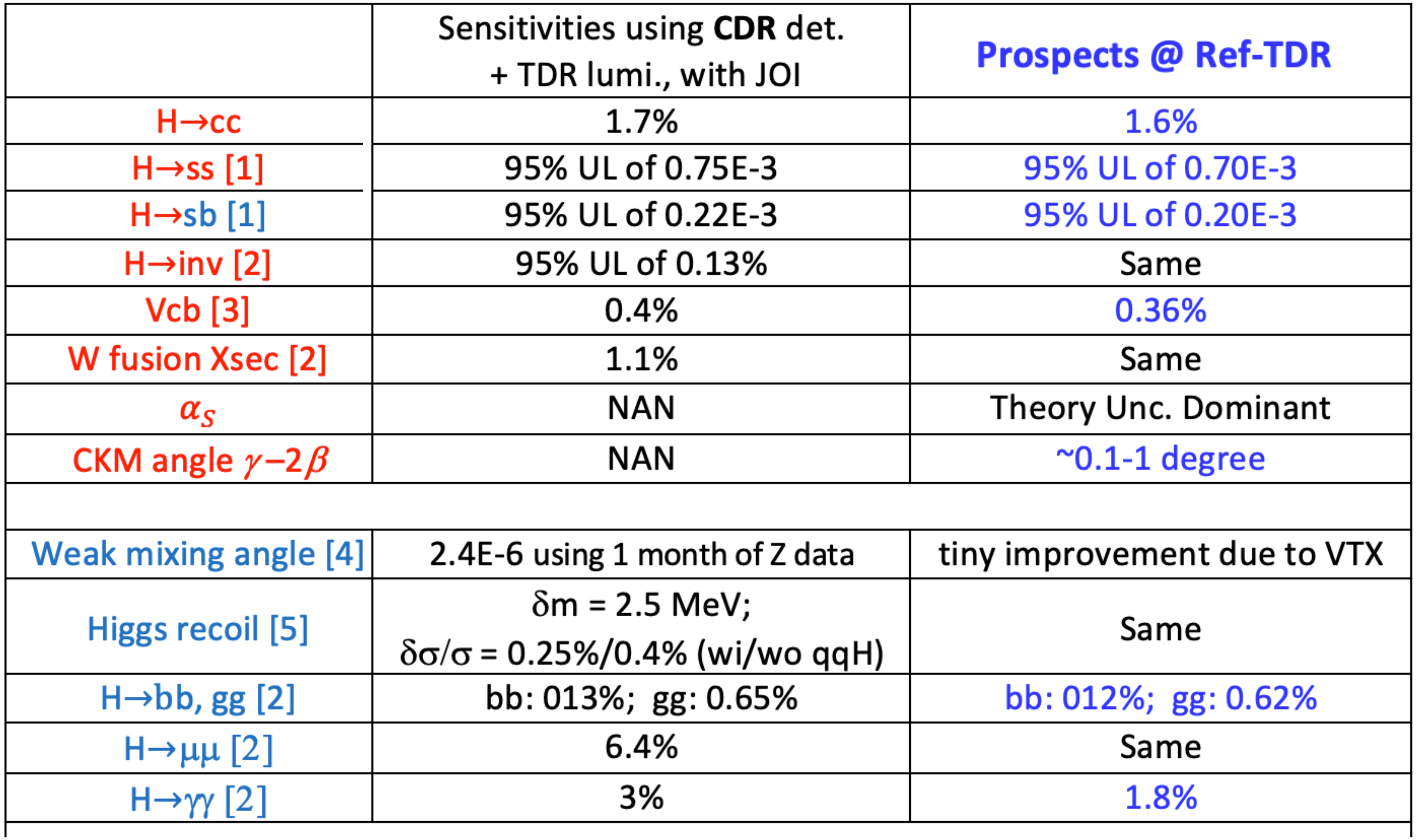
- Preliminary BMR at ref-TDR: 4.1%, close to the CDR value of 3.7%
- Effective control of confusion (such as fake particles) is crucial, necessitating optimization and further development in reconstruction techniques

Physics Benchmarks at CDR & refTDR

	Process @ c.m.e	Domain	Sensitivities using **CDR** det. + TDR lumi., with JOI	**Prospects @ Ref-TDR**
H→cc	ννH @ 240 GeV	Higgs	1.7%	1.6%
H→ss [1]			95% UL of 0.75E-3	95% UL of 0.70E-3
H→sb [1]			95% UL of 0.22E-3	95% UL of 0.20E-3
H→inv [2]	qqH	Higgs/BSM	95% UL of 0.13%	Same
Vcb [3]	WW→$\ell\nu qq$ @ 240/160 GeV	Flavor	0.4%	0.36%
W fusion Xsec [2]	ννH @ 360 GeV	Higgs	1.1%	Same
α_S	Z→ττ @ 91.2 GeV	QCD	NAN	Theory Unc. Dominant
CKM angle $\gamma - 2\beta$	Z→bb, B→DK @ 91.2 GeV	Flavor	NAN	~0.1-1 degree
Weak mixing angle [4]	Z @ 91.2 GeV	EW	2.4E-6 using 1 month of Z data	tiny improvement due to VTX
Higgs recoil [5]	$\ell\ell$H	Higgs	δm = 2.5 MeV; δσ/σ = 0.25%/0.4% (wi/wo qqH)	Same
H→bb, gg [2]	ννH + qqH	Higgs	bb: 013%; gg: 0.65%	bb: 012%; gg: 0.62%
H→μμ [2]	qqH	Higgs	6.4%	Same
H→γγ [2]	qqH	Higgs	3%	1.8%
W mass & width [6]	Threshold scan @ 160 GeV	EW	0.7 MeV & 2.4 MeV @ 6 iab	Same
Top mass & width [7]	Threshold scan @ 360 GeV	EW	9 MeV & 26 MeV @ 100 ifb	Same
Bs→$\nu\nu\phi$ [8]	91.2 GeV	Flavor	0.9% (1.8%@Tera-Z)	Same, if object recon. ~ CDR
Bc→$\tau\nu$ [9]	91.2 GeV	Flavor	0.35% (0.7%@Tera-Z)	Same, if object recon. ~ CDR
$B_0 \to 2\pi^0$ [10]	91.2 GeV	Flavor	NAN	0.3% (need to validate photons finding)
H→LLP	qqH	BSM	NAN	Work in progress
H→aa→4γ	qqH	BSM	NAN	Work in progress

- Precision of H $\rightarrow \gamma\gamma$ could be improved significantly when the low mass is controlled
- Physics measurements using JOI, benefit from better VTX and have 5-10% improvements, and assuming that the TDR BMR could eventually reach 3.7%
  - If BMR of 3% achieved, precisions of most benchmarks could be further improved by 5-10%
  - Further development required for the pattern recognition capability of Crystal Bar ECAL

Physics Benchmarks at CDR & refTDR



	Sensitivities using **CDR** det. + TDR lumi., with JOI	**Prospects @ Ref-TDR**
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H→ss [1]	95% UL of 0.75E-3	95% UL of 0.70E-3
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H→inv [2]	95% UL of 0.13%	Same
Vcb [3]	0.4%	0.36%
W fusion Xsec [2]	1.1%	Same
α_S	NAN	Theory Unc. Dominant
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H→μμ [2]	6.4%	Same
H→γγ [2]	3%	1.8%

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  - If BMR of 3% achieved, precisions of most benchmarks could be further improved by 5-10%
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Challenges & Plans

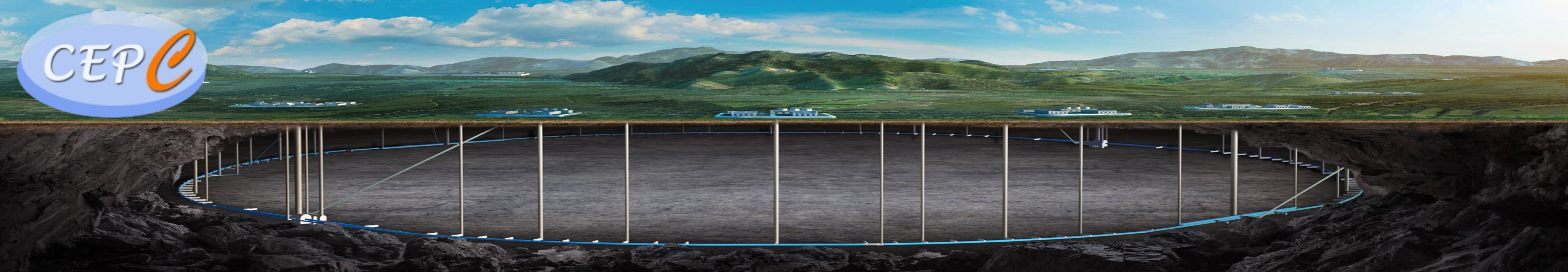
- Challenges:
  - Impact of beam induced background
  - High data rate @ Z pole: need to reconstruct in Space time (PFA in space time)
  - New CyberPFA development: rely on full simulation, as it significantly impacts the final resolution on hadronic objects
- Plans:
  - Quantify the impact of beam induced background, the readout, especially at Z pole (~ Nov. 2024)
  - Further develop reconstruction algorithms, and validate with full simulation (Dec. 2024)
    - PFA, smarter algorithm with AI tools
  - Physics benchmarks analyses with full simulation (H measurements) + fast simulation
  - Involve more efforts from theory community to ensure that theoretical uncertainties will be under control

Team

- Physics and performance team:
  - ~ 10 staff members + 4 postdocs + ~10 students, more joining
- Synergizing efforts with sub-detector teams
- Collaboration with PKU, LLR & CERN on Machine Learning algorithms
- Physics white paper efforts: IHEP team + ~ > 20 staffs from ~ 10 Universities
  - Flavor Physics: Tao Liu (HKUST), Lorenzo (NKU), Shanzhen Chen(IHEP) etc
  - New Physics: Xuai Zhuang (IHEP), Mengchao Zhang (JNU)
  - EW: Zhijun Liang (IHEP), Jiayin Gu (FuDan U), Siqi Yang (USTC)
  - QCD: Zhao Li (IHEP), Meng Xiao (ZJU), Huaxing Zhu (PKU)
- Physics studies in pace with ECFA physics focus studies

Summary

- Intensive CEPC Physics studies
  - Well quantified Physics Merits
  - Iterates with Detector R&D
- CEPC Ref-TDR detector provides
  - PID: critical for Higgs/Flavor physics
  - Better VTX: improves precisions on benchmark analysis by 10-20%
  - PFA Compatible Calorimeter with larger sampling:
    - HCAL improves the BMR by ~10%
    - Crystal Bar ECAL: improve EM resolution by an order of magnitude, but pattern recognition is challenging



Thank you for your attention!

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