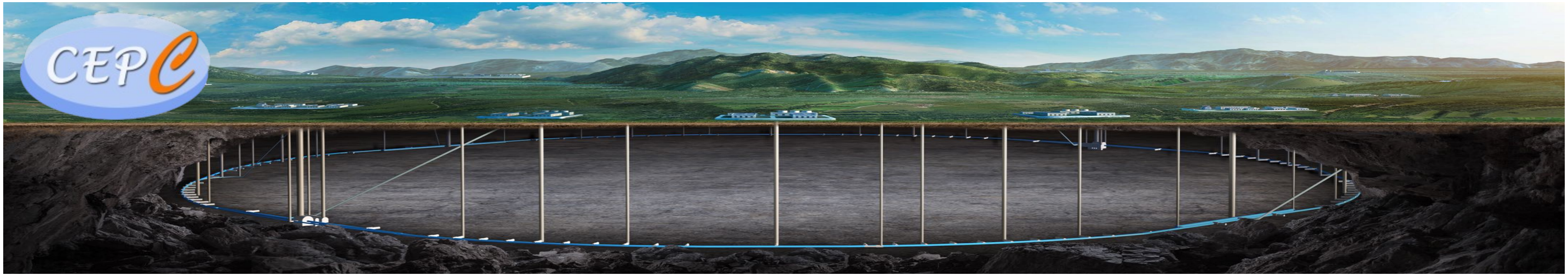

Global Performance

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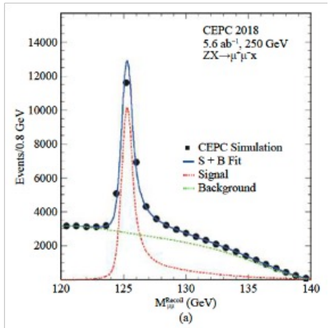
Content

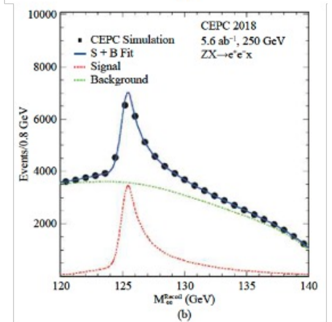
- Introduction: Physics benchmarks & relevant Global performance
- Status of CEPC Physics Studies
  - Snowmass studies
  - Key technologies: Jet origin id & its application
- Physics benchmarks at CDR detector
- Comparison between CDR and Ref-TDR detector: Pid, VTX & PFA.
- Physics benchmarks at Ref-TDR
- Challenges and team
- Summary

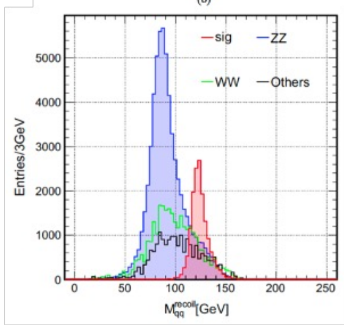
Physics Benchmarks & Global Performances

	Processes @ c.m.s.	Domain	Total Det. Performance	Sub-D
H->ss/cc/sb	vvH @ 240 GeV	Higgs	PFA + JOI (Jet origin id)	All sub-D, especially VTX
H->inv	qqH	Higgs/NP	PFA	All
Vcb	WW@ 240/160 GeV	Flavor	JOI + Particle (lepton) id	All
W fusion Xsec	vvH @ 360 GeV	Higgs	PFA + JOI	All
α_S	Z->tautau @ 91.2 GeV	QCD	PFA: Tau & Tau final state id	ECAL + Tracker material
B->DK	91.2 GeV	Flavor	PFA + Particle (Kaon) id	All, especially Tracker & ToF
Weak mixing angle	Z	EW	JOI	All
Higgs recoil	llH	Higgs	Leptons id, track dP/P	Tracker, All
H->bb, cc, gg	vvH	Higgs	PFA + JOI	All
	qqH	Higgs	PFA + JOI + Color Singlet id	All
H->di muon	qqH	Higgs	PFA, Leptons id	Calo, All
H->di photon	qqH	Higgs	PFA, Photons id	ECAL, All
W mass & Width	WW@160 GeV	EW	Beam energy	NAN
Top mass & Width	ttbar@360 GeV	EW	Beam energy	NAN
Bs->vvPhi	Z	Flavor	Object in jets; MET	All
Bc->tauv	Z	Flavor	-	All
B0->2 pi0	Z	Flavor	Particle/pi-0 in jets	ECAL

Physics Study : Status





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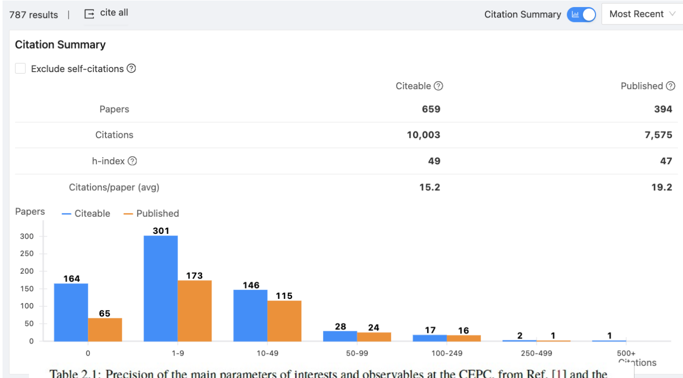
Precision Higgs physics at the CEPC*

Received 9 November 2018, Revised 21 January 2019, Published online 4 March 2019



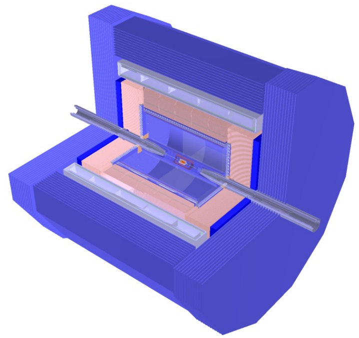
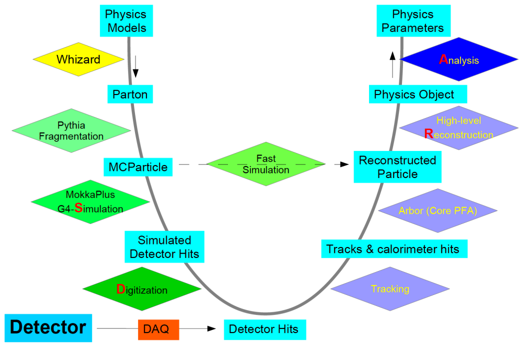


Table 2.1: Precision of the main parameters of interests and observables at the CEPC, from Ref. [1] and the references therein, where the results of Higgs are estimated with a data sample of 20 ab^{-1}. The HL-LHC projections of 3000 fb^{-1} data are used for comparison. [2]

Higgs			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	$\mathcal{O}(10)$ MeV
$B(H \to bb)$	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
$B(H \to gg)$	-	0.81%	R_b	3×10^{-3}	2×10^{-4}
$B(H \to WW^*)$	2.8%	0.53%	R_c	1.7×10^{-2}	1×10^{-3}
$B(H \to ZZ^*)$	2.9%	4.2%	R_μ	2×10^{-3}	1×10^{-4}
$B(H \to \tau^+\tau^-)$	2.9%	0.42%	R_τ	1.7×10^{-2}	1×10^{-4}
$B(H \to \gamma\gamma)$	2.6%	3.0%	A_μ	1.5×10^{-2}	3.5×10^{-5}
$B(H \to \mu^+\mu^-)$	8.2%	6.4%	A_τ	4.3×10^{-3}	7×10^{-5}
$B(H \to Z\gamma)$	20%	8.5%	A_b	2×10^{-2}	2×10^{-4}
Bupper$(H \to$ inv.)	2.5%	0.07%	N_ν	2.5×10^{-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.
- …

CEPC Physics Studies at Snowmass

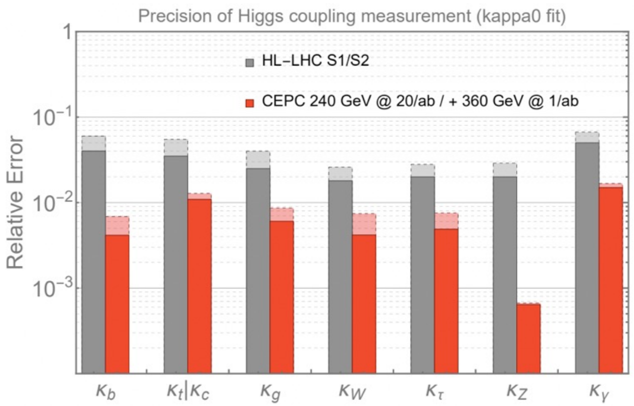
The Physics potential of the CEPC

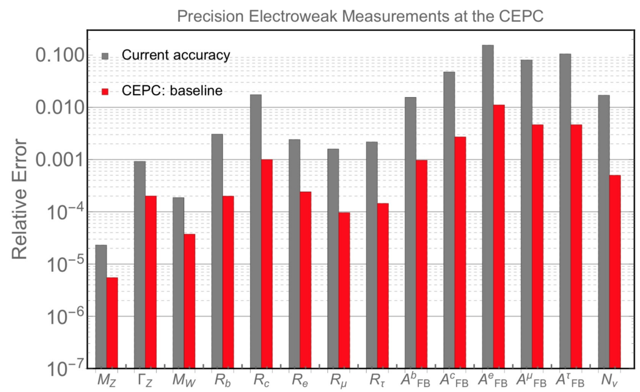
Prepared for the US Snowmass Community Planning Exercise

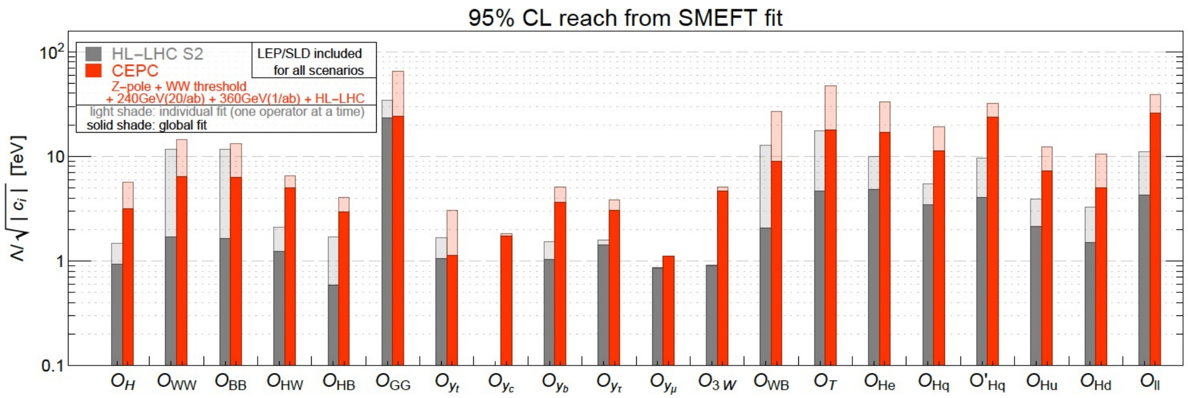
(Snowmass 2021)

CEPC Physics Study Group

	240 GeV, 20 ab^{-1}		360 GeV, 1 ab^{-1}		
	ZH	vvH	ZH	vvH	eeH
inclusive	0.26%		1.40%	\	\
H→bb	0.14%	1.59%	0.90%	1.10%	4.30%
H→cc	2.02%		8.80%	16%	20%
H→gg	0.81%		3.40%	4.50%	12%
H→WW	0.53%		2.80%	4.40%	6.50%
H→ZZ	4.17%		20%	21%	
$H \to \tau\tau$	0.42%		2.10%	4.20%	7.50%
$H \to \gamma\gamma$	3.02%		11%	16%	
$H \to \mu\mu$	6.36%		41%	57%	
$H \to Z\gamma$	8.50%		35%		
$Br_{upper}(H \to inv.)$	0.13%				
Γ_H	1.65%		1.10%		

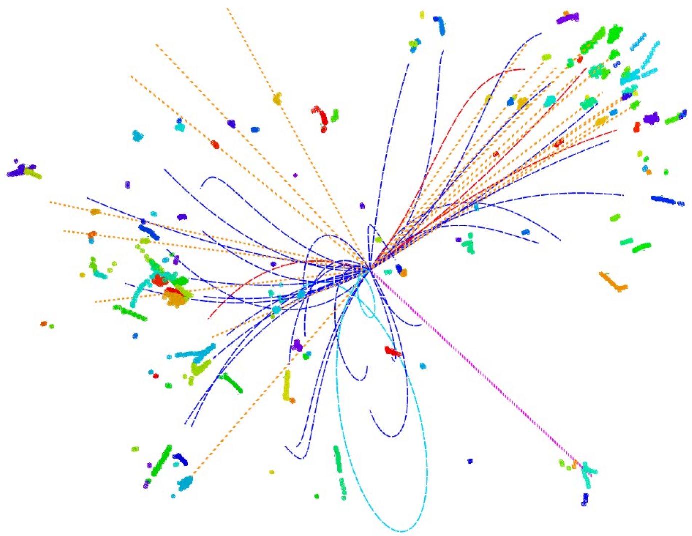




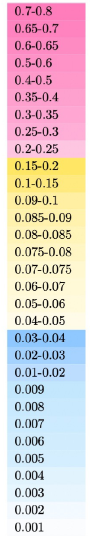


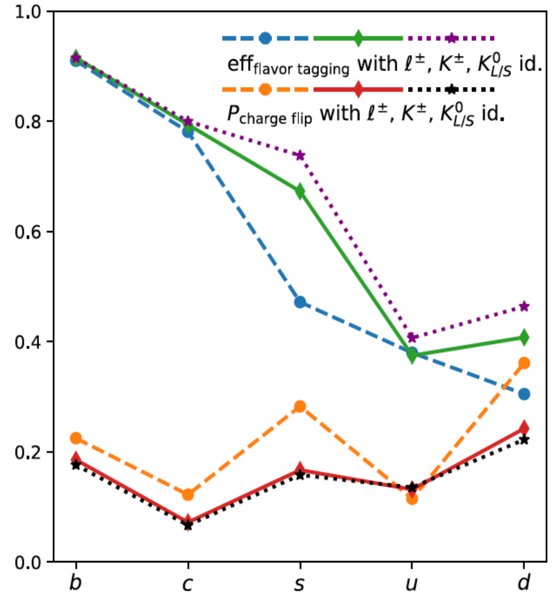
arXiv:2205.08553v1

Jet Origin ID



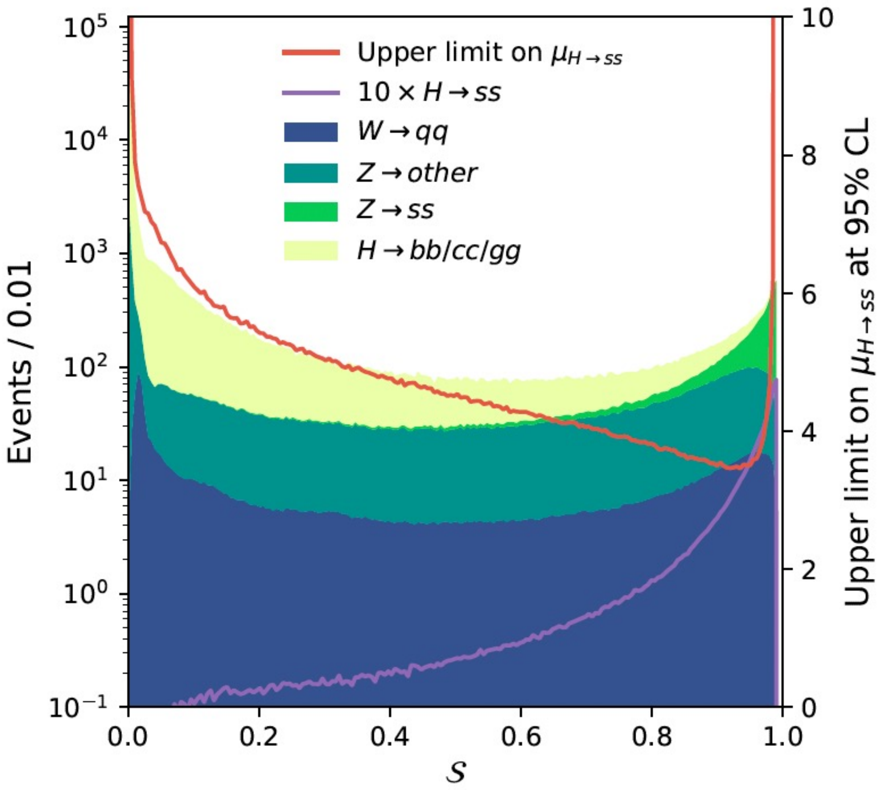
True \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$	G
b	0.738	0.167	0.034	0.026	0.005	0.003	0.002	0.003	0.002	0.002	0.018
$\bar{b}$	0.167	0.737	0.026	0.034	0.003	0.004	0.003	0.002	0.002	0.003	0.018
c	0.015	0.015	0.740	0.057	0.037	0.032	0.026	0.010	0.009	0.017	0.043
$\bar{c}$	0.015	0.015	0.055	0.741	0.032	0.037	0.010	0.026	0.016	0.010	0.043
s	0.003	0.003	0.020	0.018	0.541	0.104	0.030	0.082	0.062	0.045	0.092
$\bar{s}$	0.002	0.003	0.018	0.021	0.101	0.543	0.085	0.028	0.044	0.062	0.092
u	0.002	0.003	0.019	0.012	0.044	0.132	0.375	0.057	0.079	0.168	0.109
$\bar{u}$	0.003	0.002	0.011	0.020	0.132	0.043	0.062	0.368	0.166	0.084	0.108
d	0.003	0.003	0.012	0.020	0.111	0.093	0.083	0.223	0.261	0.080	0.110
$\bar{d}$	0.003	0.003	0.020	0.013	0.093	0.113	0.226	0.079	0.076	0.265	0.110
G	0.015	0.014	0.025	0.025	0.053	0.053	0.043	0.044	0.033	0.035	0.661

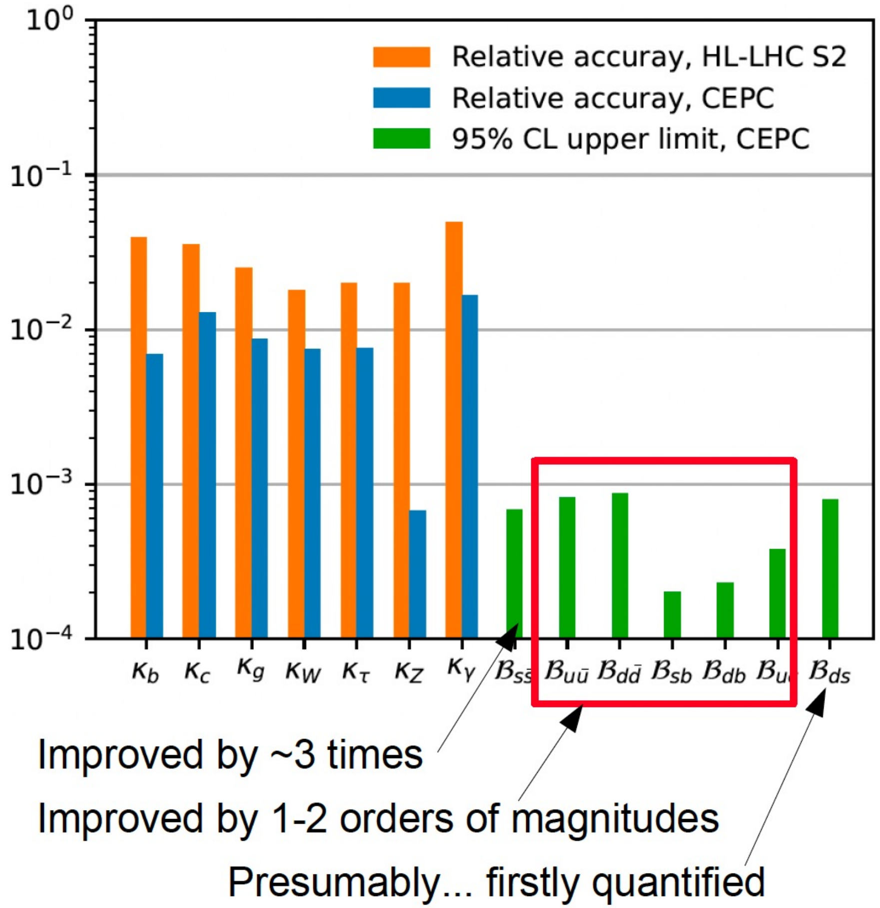




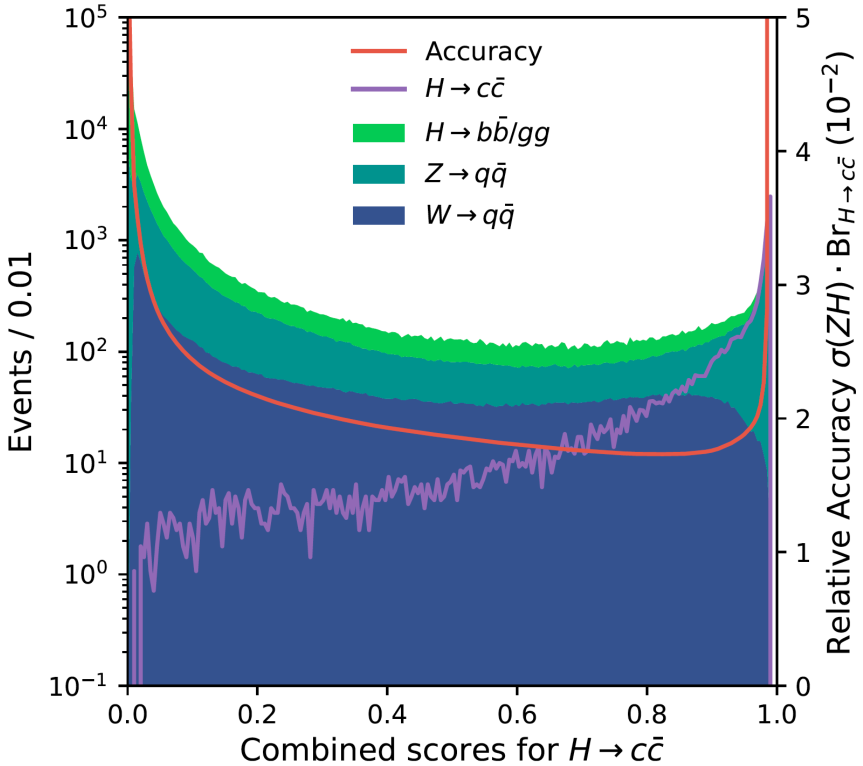
- **Jet origin identification: 11 categories (5 quarks + 5 anti quarks + gluon)**
  - Jet Flavor Tagging + Jet Charge measurements + s-tagging + gluon tagging…
- Full Simulated vvH, Higgs to two jets sample at CEPC baseline configuration: CEPC-v4 detector, reconstructed with **Arbor + ParticleNet (Deep Learning Tech.)**
- 1 Million samples each, 60/20/20% for training, validation & test

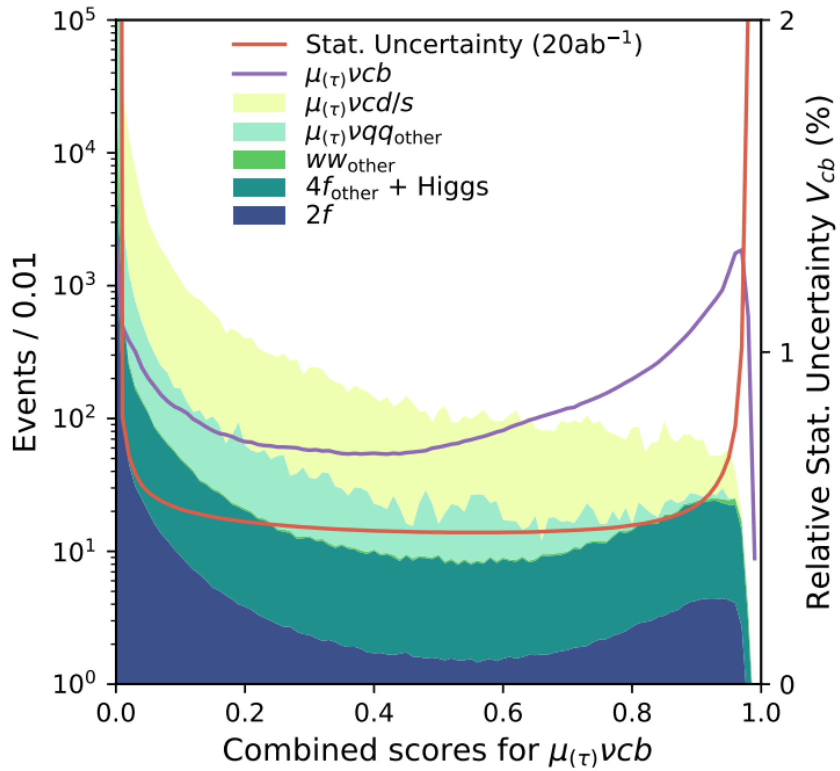
Physics benchmarks: H->ss





Physics benchmarks: H→cc & Vcb





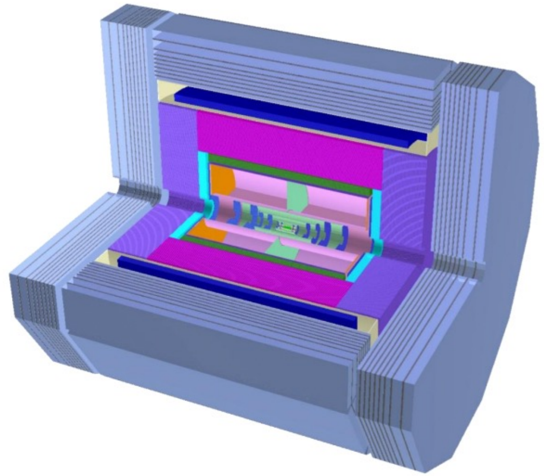
- From Jet Flavor Tagging to Jet Origin ID:
  - vvH, H→cc: 3% → 1.7% (**Preliminary**)
  - Vcb: 0.75% → 0.45% (muvqq channel. evqq: 0.6%, combined 0.4%)

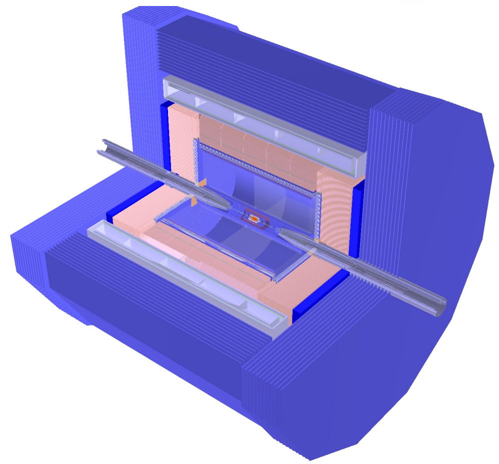
Physics Benchmarks using CDR baseline

	Processes @ c.m.s.	Anticipated relative accuracies/up limit with CDR baseline detector + TDR Luminosity	Using Jet Origin id with ideal Kaon id
H->cc	vvH @ 240 GeV	3% (Snowmass)	1.7%
H->ss		NAN	95% up limit of 0.75E-3
H->sb		NAN	95% up limit of 0.22E-3
H->inv	qqH @ 240 GeV	95% up limit of 0.13%	
Vcb	WW-> lvqq @ 240/160 GeV	0.65%	0.4%
W fusion Xsec	vvH @ 360 GeV	1.1%	
α_S	Z->tautau @ 91.2 GeV	NAN	
B->DK	Z->bb @ 91.2 GeV	NAN	

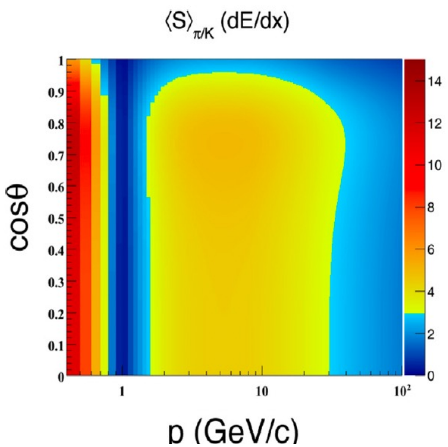
Det. Concepts: CDR to TDR

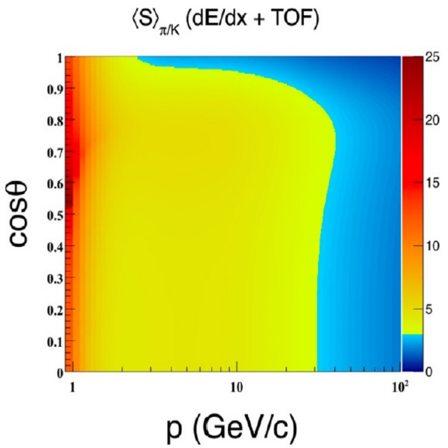
- The TDR detector has
- Better Pid via
  - dE/dx or dN/dx from Gaseous detector
  - ToF of 50 ps
- Better Jet origin identification via a Stitching VTX detector:
  - Inner radius reduced from 26 mm to 20 mm)
  - Material budget reduced by 1/2 compared to CDR
- PFA compatible Calorimeter with larger sampling fractions:
  - Glass Scintillator HCAL
  - Xstal ECAL

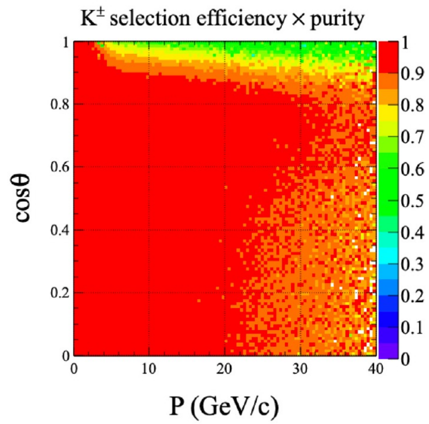




Pid via ToF + dE/dx or dN/dx





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

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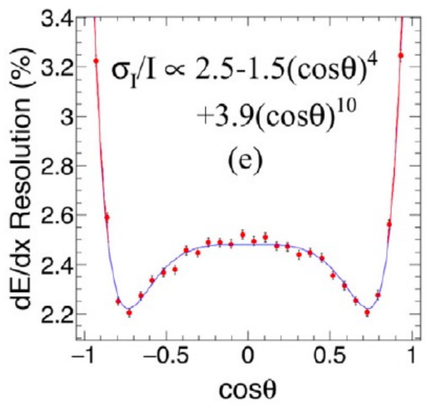
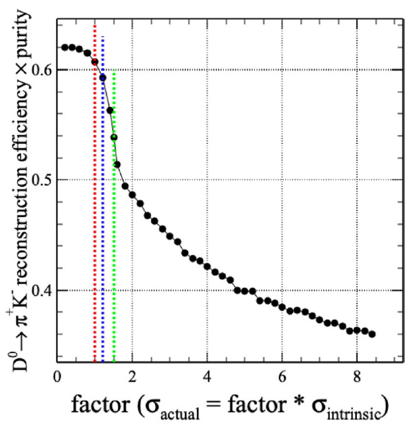




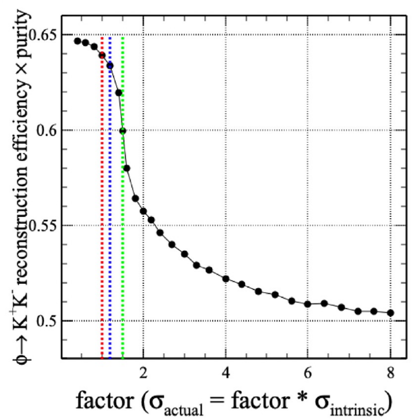


Table 3
The $K^\pm$ identification performance with different factors, $\sigma_{actual} = factor \cdot \sigma_{intrinsic}$, with/without combination of TOF information at the Z-pole.

	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

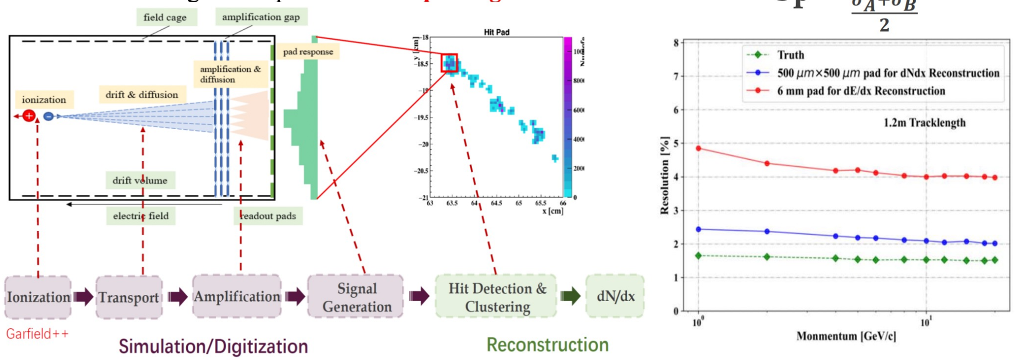
- dE/dx or dN/dx with relevant uncertainty of **3%** + ToF of 50 ps: eff & purity of Kaon id > 95%

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**

$$Sp = \frac{|\mu_A - \mu_B|}{\frac{\sigma_A + \sigma_B}{2}}$$

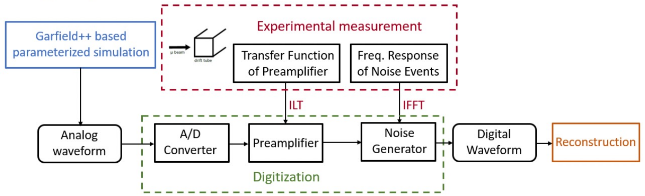


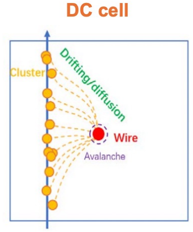
Cite#11: DOI: 10.22323/1.449.0553
Cite#12: EPS-HEP 2023 talk by Yue Chang

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

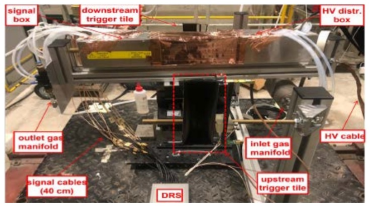
DC R&D efforts and results

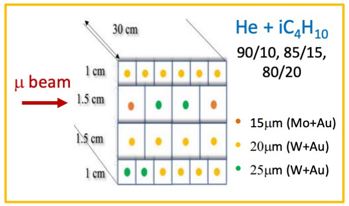
- Develop sophisticated software tools for DC PID simulation

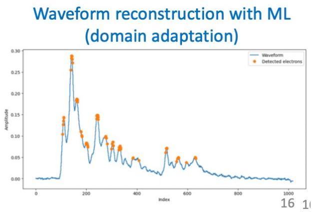


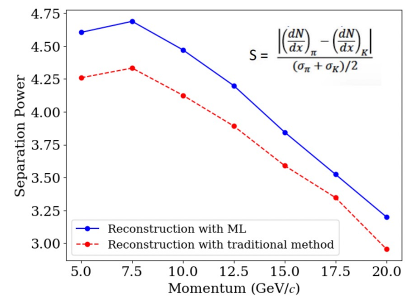


- International collaboration of the beam test









- A major goal for the Ref-TDR Gaseous Tracker is the Pid: to achieve 3% dE/dx or dN/dx performance.
- Promising results, to be validated with further studies, especially test beam.
- Gaseous Tracker inner radius: to be optimized.

VTX and Jet Flavor/Charge measurement

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https://doi.org/10.1140/epjc/s10052-024-12475-5
THE EUROPEAN PHYSICAL JOURNAL C
Regular Article - Experimental Physics

ParticleNet and its application on CEPC jet flavor tagging

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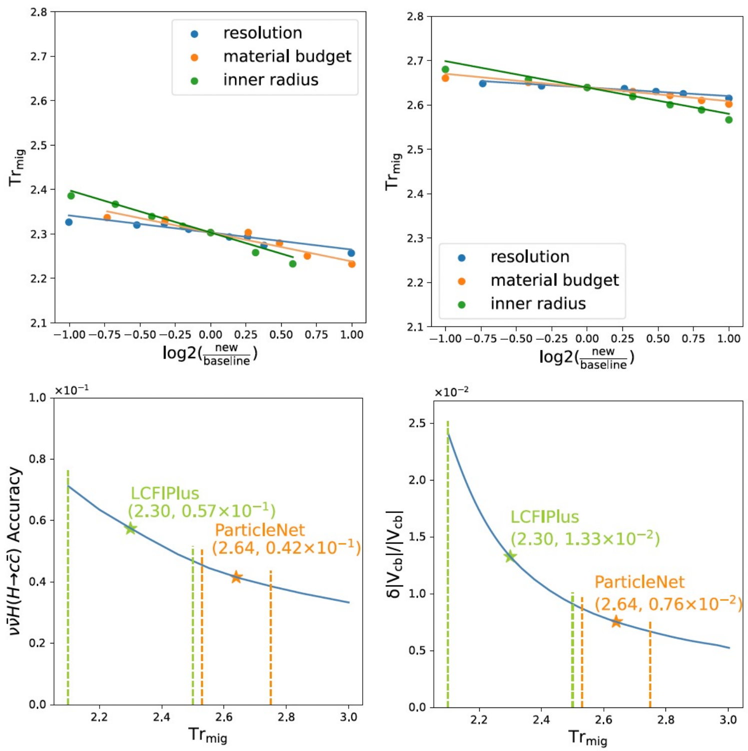


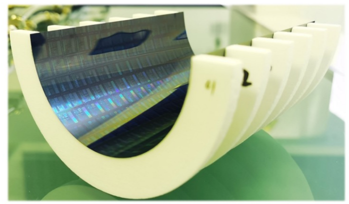
predicted

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

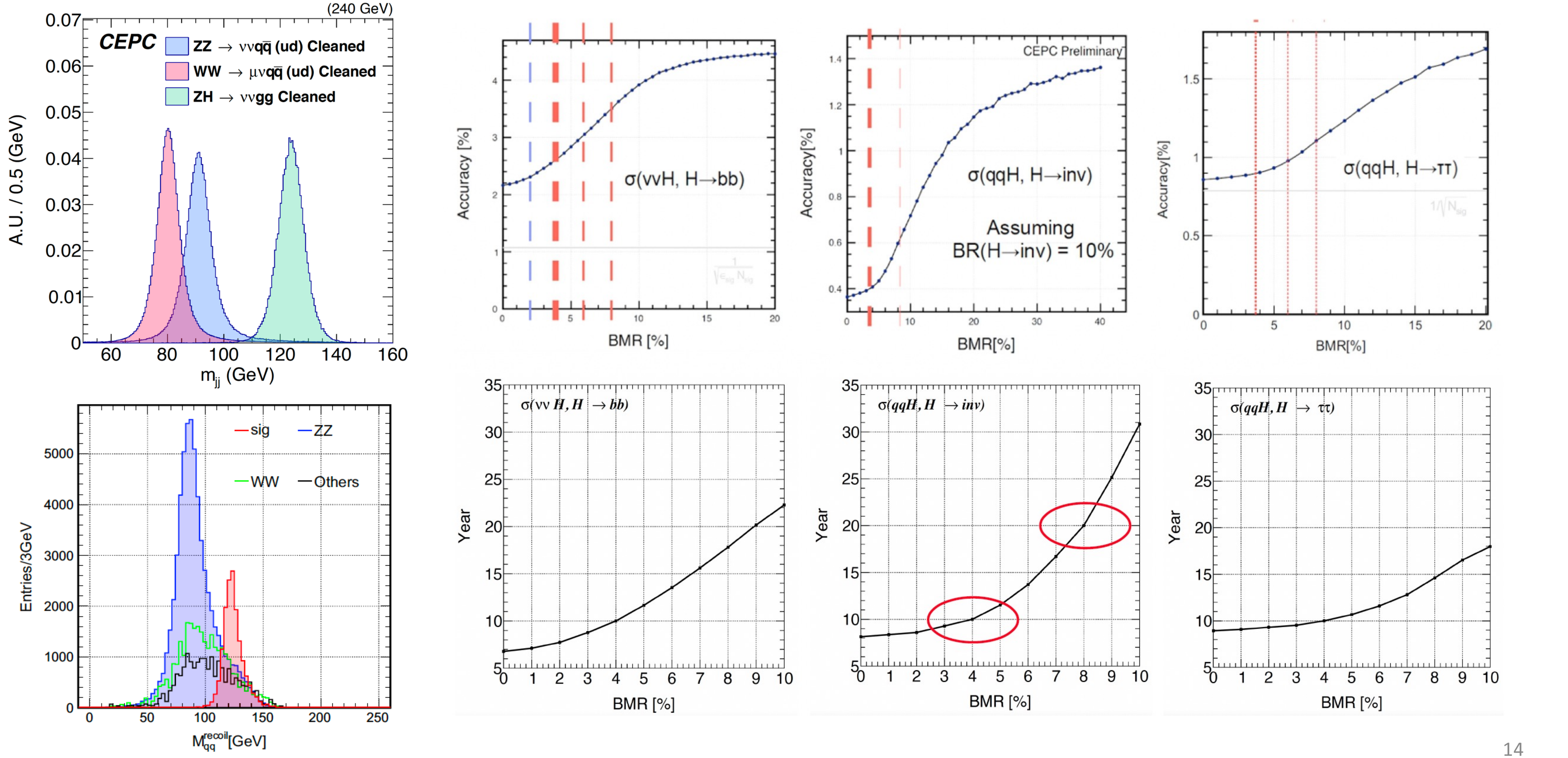
$$Tr_{mig} = 2.30 + 0.06 \cdot \log_2 \frac{R^0_{material}}{R_{material}} + 0.04 \cdot \log_2 \frac{R^0_{resolution}}{R_{resolution}} + 0.10 \cdot \log_2 \frac{R^0_{radius}}{R_{radius}} \quad (1)$$

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

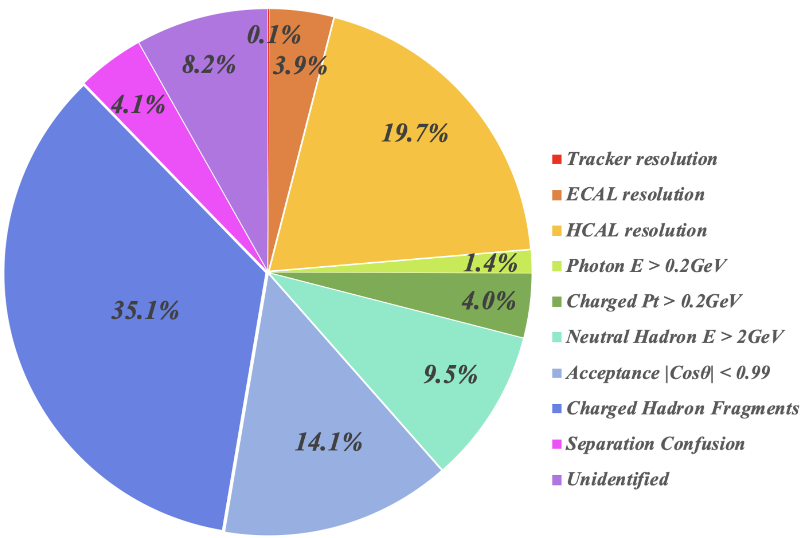
- Compared to CDR, VTX at TDR:
  - Inner radius reduced by 30% (26 mm -> 20 mm)
  - Material reduced by 1/2 (Stitching Technology)
- Tr(Mig): 2.64 -> 2.7
  - H->cc accuracy improved by ~o(10%)
  - Vcb accuracy improved by ~o(20%)

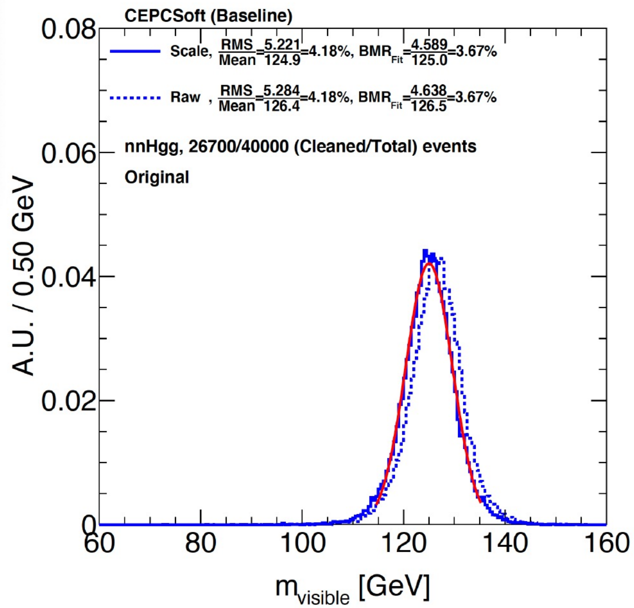


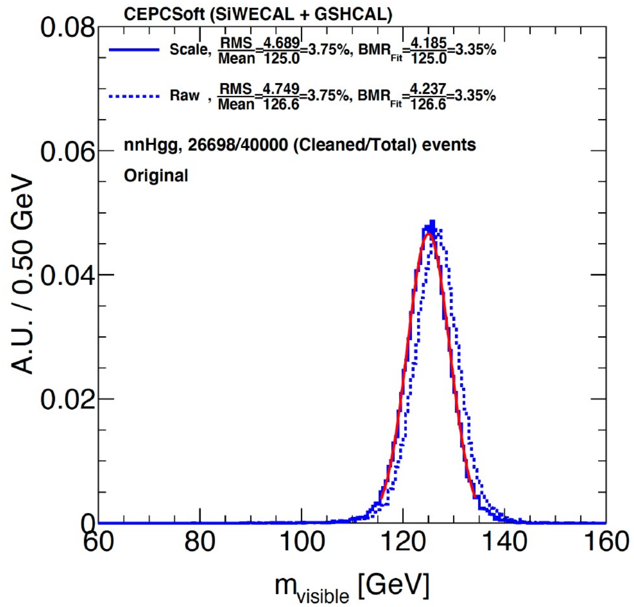
PFA Goal: BMR < 4% & pursue 3%



BMR Decomposition







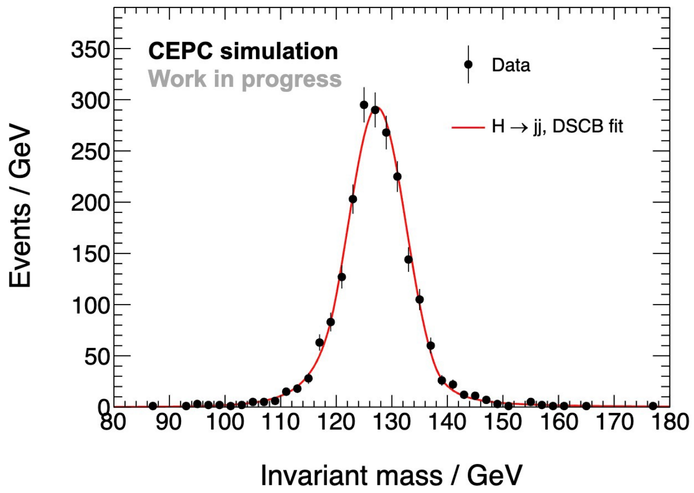
1st, 50% from Confusion, 25% from detector resolution & 25% from acceptance, for BMR of 3.7% at CDR

2nd, HCAL resolution dominant the uncertainties from detector resolution:
TDR HCAL: Glass Scintillator - Iron with thickness of 6 lambda (compared to GRPC - Iron of 5 lambda) BMR of 3.4%

BMR of ~ 4% at TDR baseline

Physics performance: $H \to gg$

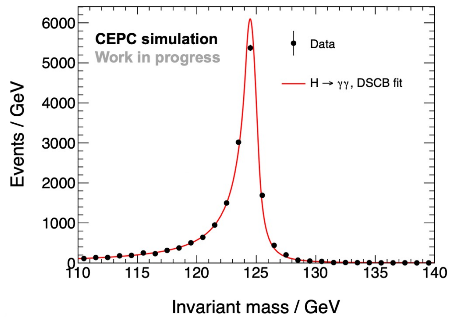
- **Physics process: $ee \to ZH \to \nu\nu gg$ in $\sqrt{s} = 240$ GeV**
  - Full reconstruction in CEPC detector: Silicon + TPC tracker, crystal ECAL, glass tile HCAL.



$m_{jj} = 127.3$ GeV, $\sigma(m_{jj}) = 5.23$ GeV

Boson mass resolution (BMR) 4.11%.

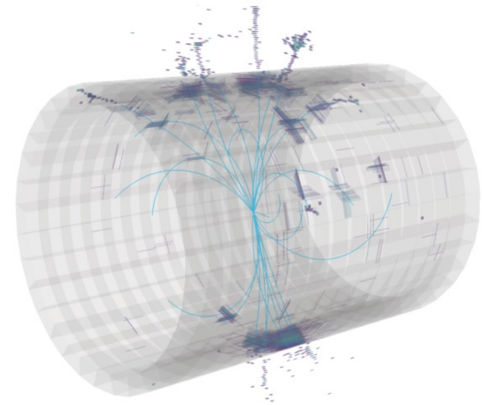
With truth track: BMR 3.73%.

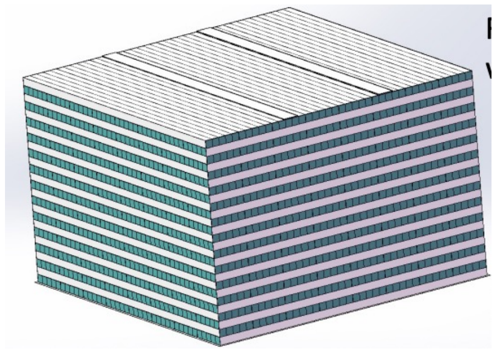


Double-side CB fit, $\sigma(m_{\gamma\gamma}) = 0.57$ GeV

Long tail from
- Lossy processes of crystal calorimeter
- Imperfect correction in crack region.

Can be fixed with better photon energy correction in the future.





- BMR at ref-TDR: not far from CDR (BMR of 3.7%).
- To control the confusion (fake particles, etc) is the critical: Need optimization + reconstruction development.

Physics Benchmarks at CDR & TDR

	Processes @ c.m.s.	Anticipated relative accuracies/up limit with CDR baseline detector + TDR Luminosity, with JoI	@ Ref TDR
H->cc	vvH @ 240 GeV	1.7%	1.5%
H->ss [1]		95% up limit of 0.75E-3	95% up limit of 0.68E-3
H->sb [1]		95% up limit of 0.22E-3	95% up limit of 0.20E-3
H->inv [2]	qqH @ 240 GeV	95% up limit of 0.13%	0.13%
Vcb [3]	WW-> lvqq @ 240/160 GeV	0.4%	0.32%
W fusion Xsec [2]	vvH @ 360 GeV	1.1%	~1%
α_S	Z->tautau @ 91.2 GeV	NAN	Theoretical uncertainty dominant
B->DK	Z->bb @ 91.2 GeV	NAN	~o(0.1) degree

[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

Physics Benchmarks at CDR & TDR

	Processes @ c.m.s.	Anticipated relative accuracies/up limit with CDR baseline detector + TDR Luminosity	@ Ref TDR
Weak mixing angle [4]	Z	2.4E-6 using 1 month of Z pole data (~ 2E11 Z)	~ 10% improvement due to VTX
Higgs recoil [5]	llH	δm = 2.5 MeV $\delta\sigma/\sigma$ = 0.25%/0.4% (wi/wo qqH)	Same
H->bb, cc, gg [2]	ννH + qqH	bb: 0.14% -> 0.13% gg: 0.81% -> 0.65% (wi/wo JoI)	bb: 0.12% gg: 0.60%
H->di muon [2]	qqH	6.4%	Same
H->di photon [2]	qqH	3%	1.8% if low mass tail could be controlled
W mass & Width [6]	WW@160 GeV	0.7 MeV & 2.4 MeV @ 6 iab	Same
Top mass & Width [7]	ttbar@360 GeV	9 MeV & 26 MeV @ 100 ifb	Same
Bs->$\nu\nu\phi$ [8]	Z	0.9% (1.8% @ Tera-Z)	Same
Bc->tauv [9]	Z	0.35% (0.7%@Tera-Z)	Same
B0->2 pi0 [10]	Z	NAN	0.3% photon finding need to be validated

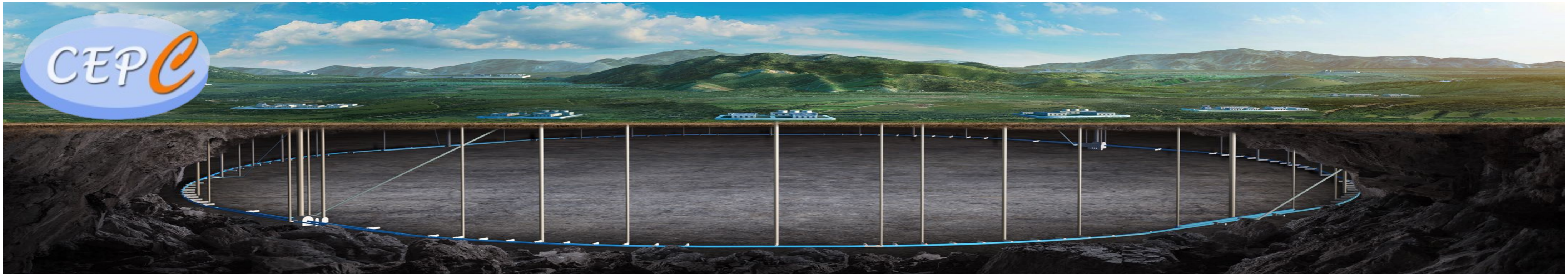
- If BMR of 3% achieved, precisions of all Higgs benchmarks could be further improved for 5-10%

Team

- Core team: ~ 2 staff (FTE) + 2 PostDoc + 5 Students + 2 Visitors
- Performance: with sub-detector team
- Advanced Algorithms: collaboration with PKU, LLR & CERN
- Benchmark: in pace with physics white paper efforts
  - Higgs: Yaquan Fang (IHEP)
  - 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 communication 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 Physics.
  - Better VTX: improves precisions on benchmark analysis by 10-20%
  - PFA Compatible Calorimeter with larger samplings: HCAL improves the BMR by ~10%, while for the Xbar ECAL the pattern recognition is challenging.
- To do:
  - To quantify & to ameliorate the impact of Beam induced background, the T-DAQ effect, especially at Z pole
  - To develop Smart Reco. Algo, especially with AI tools.

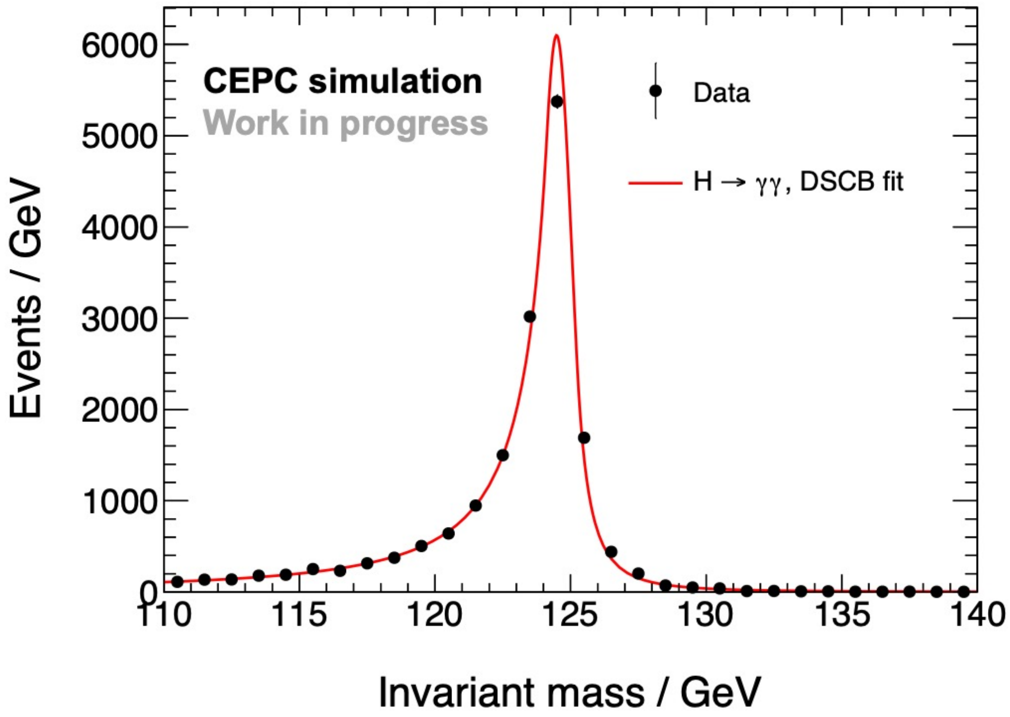


Thank you for your attention!

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

Back Up

- Physics process: $ee \to ZH \to \nu\nu\gamma\gamma$ in $\sqrt{s} = 240$ GeV
  - Full simulation and digitization, with energy correction in crack regions



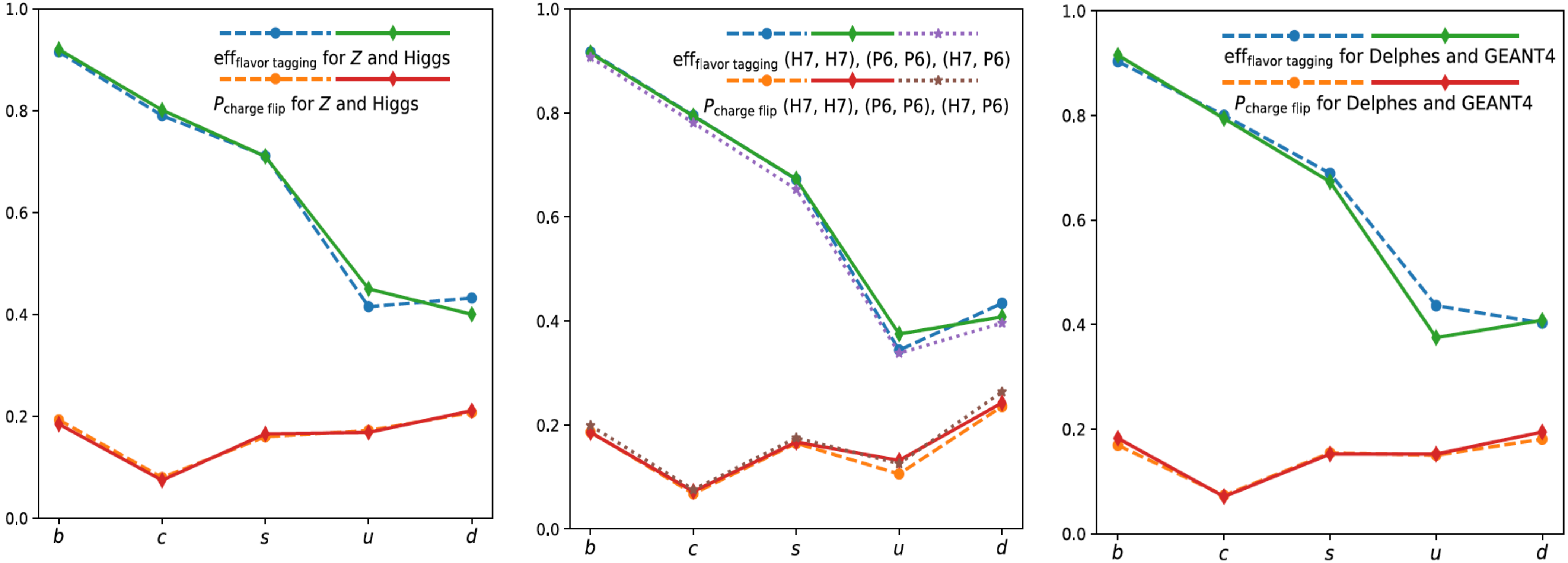
Double-side CB fit, $\sigma(m_{\gamma\gamma})$ = 0.57 GeV

Long tail from

- Lossy processes of crystal calorimeter
- Imperfect correction in crack region.

Can be fixed with better photon energy correction in the future.

JOI: validation & comparison



- Could be calibrated using Z->qq. (10 category id, without gluon)
- Stable at different Hadronization model, different simulation method (Geant 4 & Delphes - Fast Sim)
- *Referee: A "game changer" and opens new horizon for precise flavor studies at all future experiments*

Challenges

- More realistic collision environments: Beam induced background, Primary IP reco, etc
  - To be addressed by a few benchmark performance study wi. Beam induced background & to be included in TDR

- Event overlap in time (Z pole):
  - To be solved by **PFA in Space time: Future Plan.**

- More Realistic Digitization, including Noise & TDAQ effects

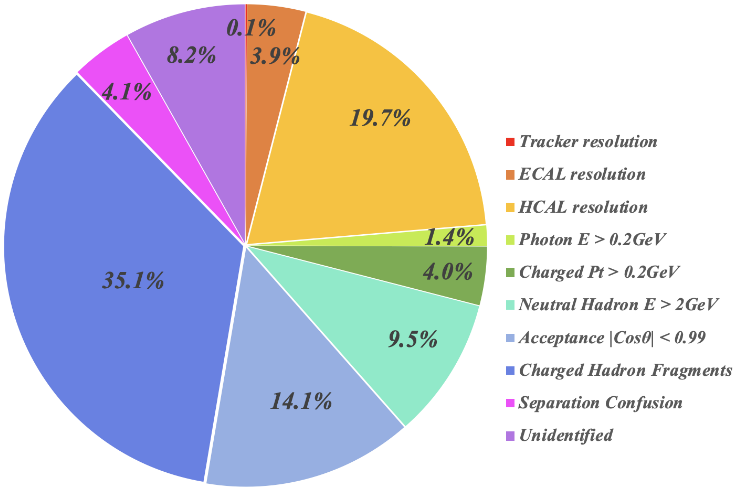
+

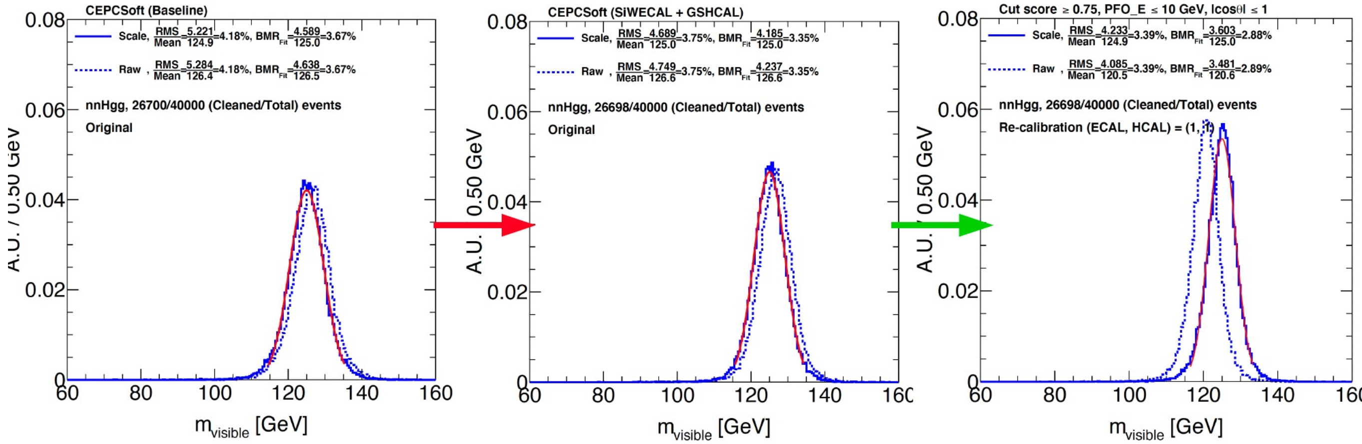
- Further Optimization (5D Calorimerter, Time resolution, cell configuration, etc)
  - To be addressed by joint study with Sub-detector & Software team (Long term plan)
  - AI enhanced reco. algorithm. will be the key.

T.o.C. at Ref TDR

- Introduction: Physics requirements
- Recap of sub-detector performance, tracking, Pid, etc
- Detector global Performance:
  - BMR
  - JoI
  - Pid
  - Outlook: 1-1 correspondence reco.
- Physics Benchmarks
- Challenges & Plan
- Teams
- Summary

BMR Decomposition





1st, 50% from Confusion, 25% from detector resolution & 25% from acceptance, for BMR of 3.7% at CDR

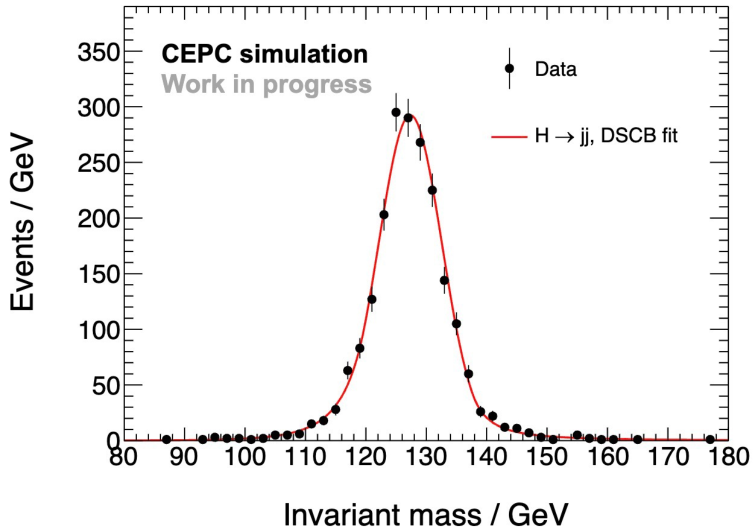
2nd, HCAL resolution dominant the uncertainties from detector resolution:
TDR HCAL: Glass Scintillator - Iron with thickness of 6 lambda (compared to GRPC - Iron of 5 lambda) BMR of 3.4%

3rd, Leading contribution: Confusion from shower Fragments (fake particles), need better Pattern Reco.
Mostly can be reduced by AI enhanced Arbor at SiW ECAL + GS HCAL: BMR of 2.9%

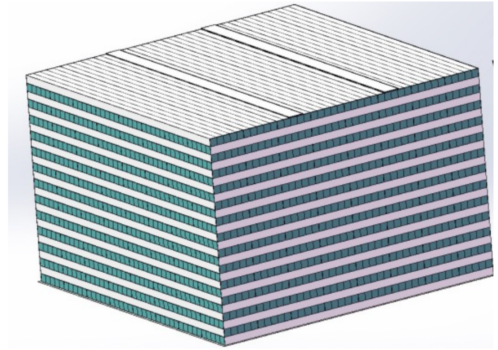
BMR of ~ 4% at TDR baseline

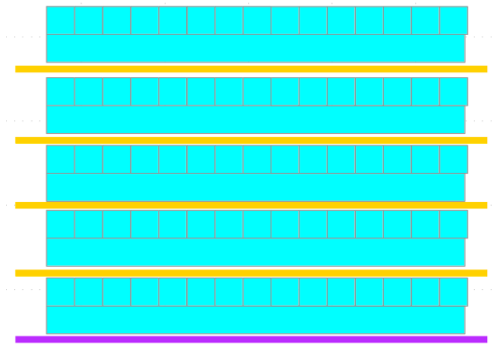
Physics performance: $H \rightarrow gg$

- **Physics process: $ee \rightarrow ZH \rightarrow \nu\nu gg$ in $\sqrt{s} = 240$ GeV**
  - Full reconstruction in CEPC detector: Silicon + TPC tracker, crystal ECAL, glass tile HCAL.



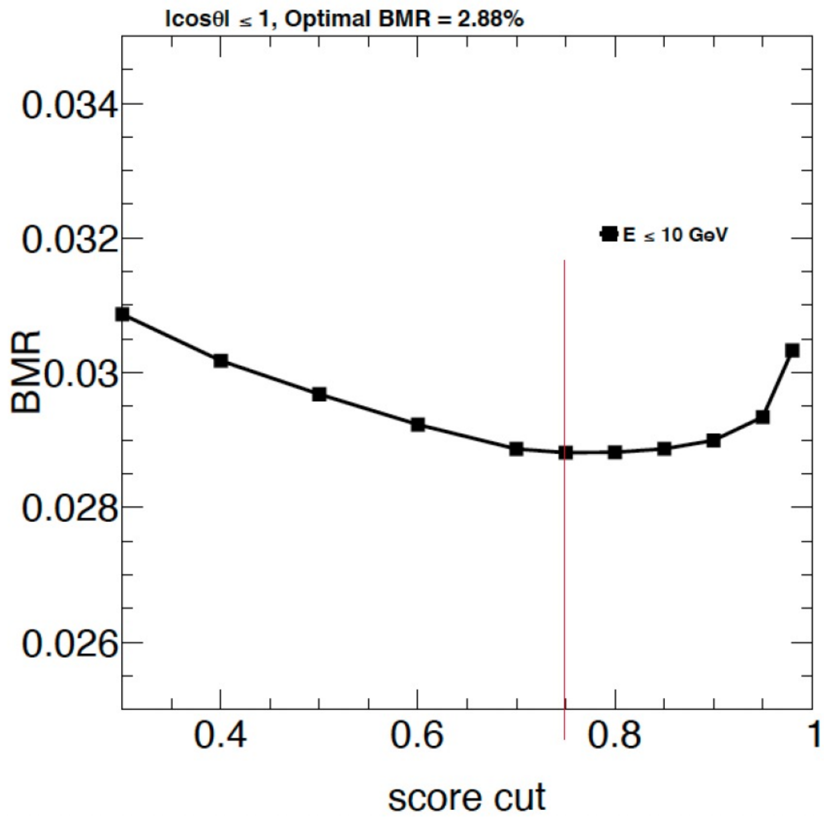
$m_{jj} = 127.3$ GeV, $\sigma(m_{jj}) = 5.23$ GeV
Boson mass resolution (BMR) 4.11%.
With truth track: BMR 3.73%.



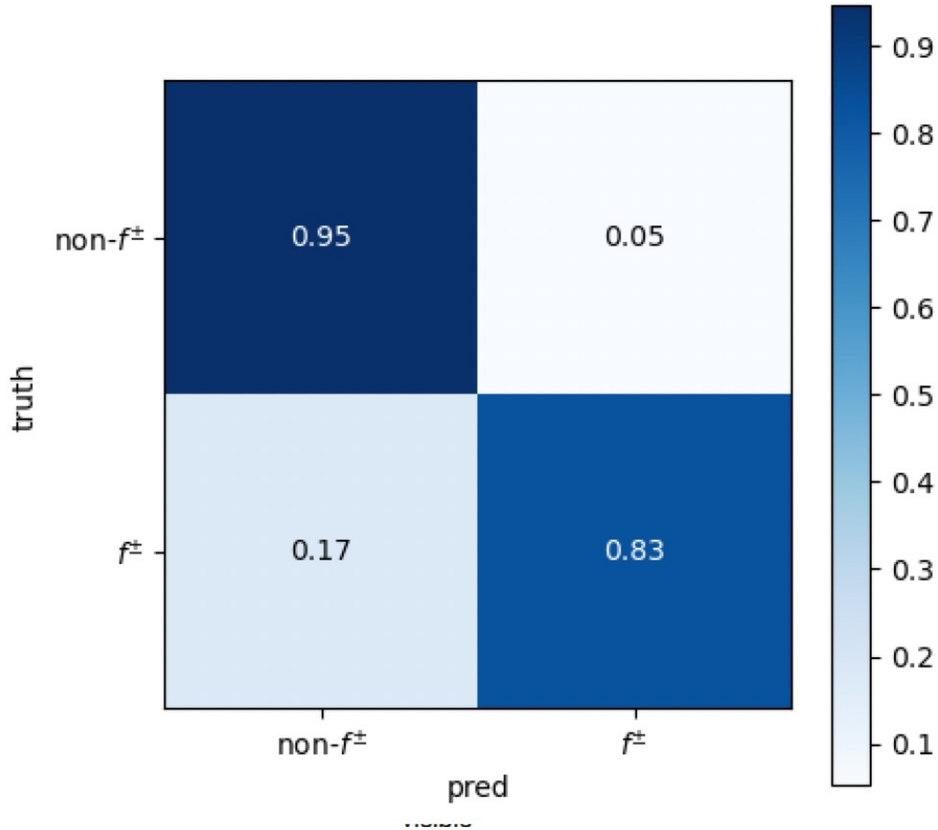


- BMR at ref-TDR: not far from CDR (BMR of 3.7%).
- To control the confusion (fake particles, etc) is the critical: Need optimization + reconstruction development.
- One solution is to add a few timing & positioning layers.

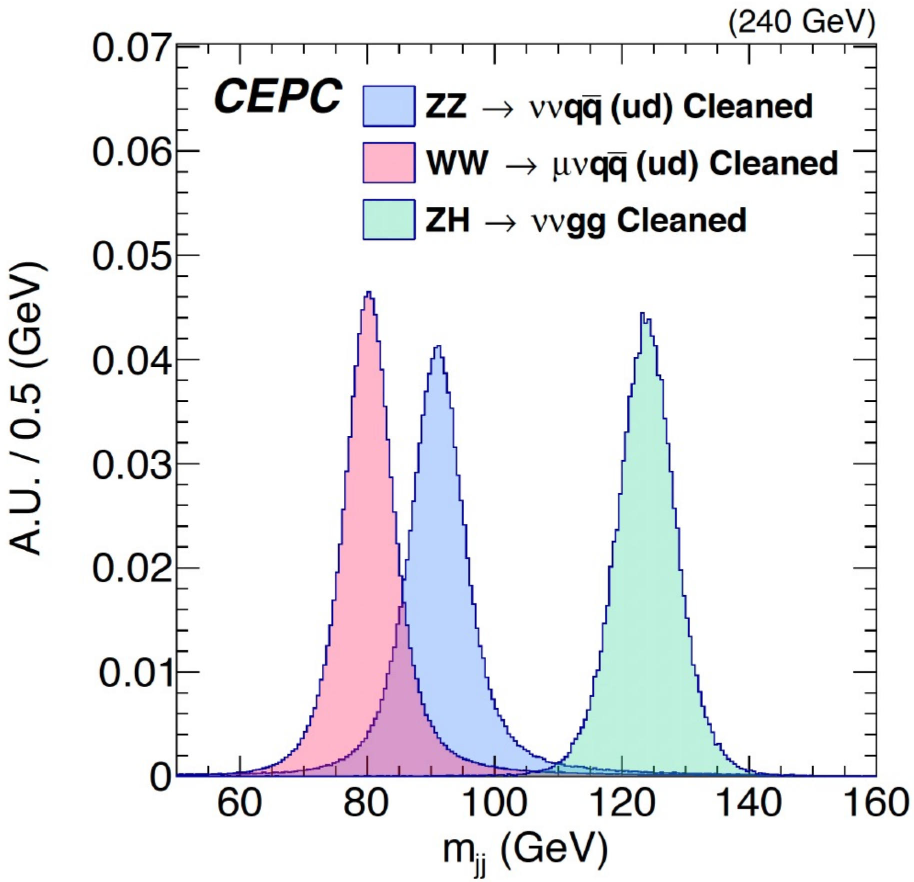
Fake particle veto using AI

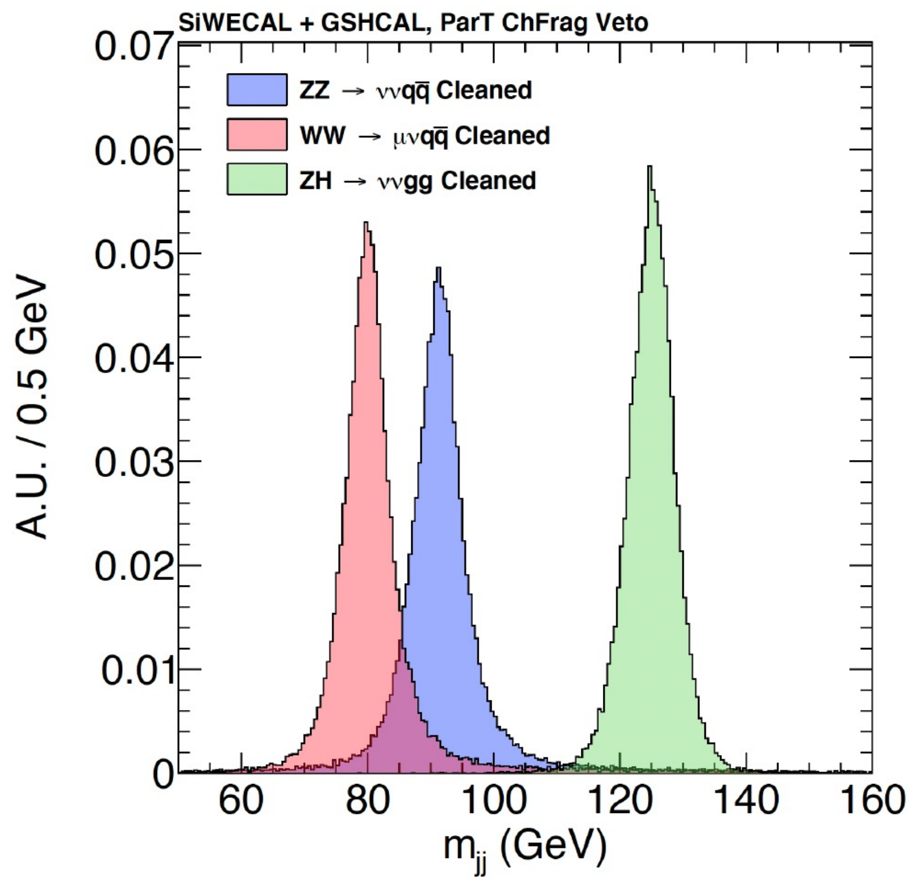


(stemmed from Charge Shower Fragments)

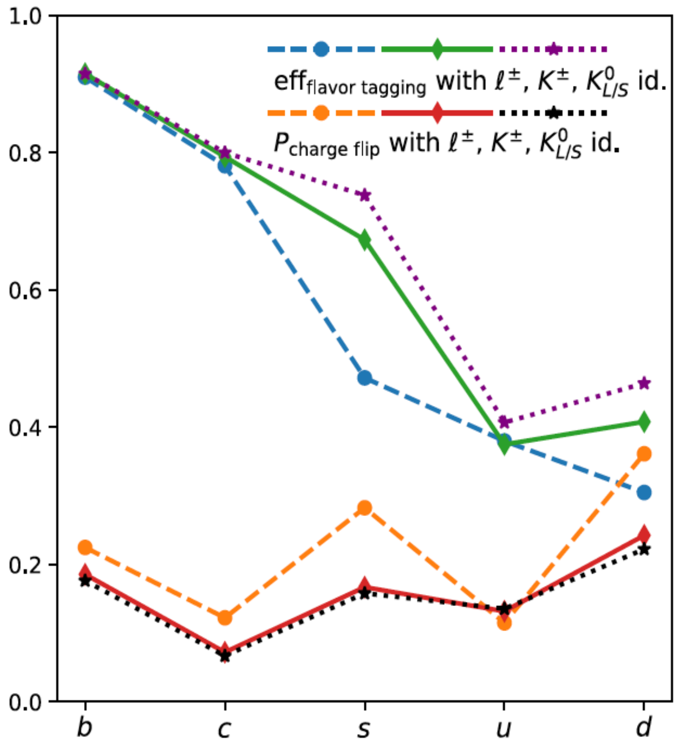


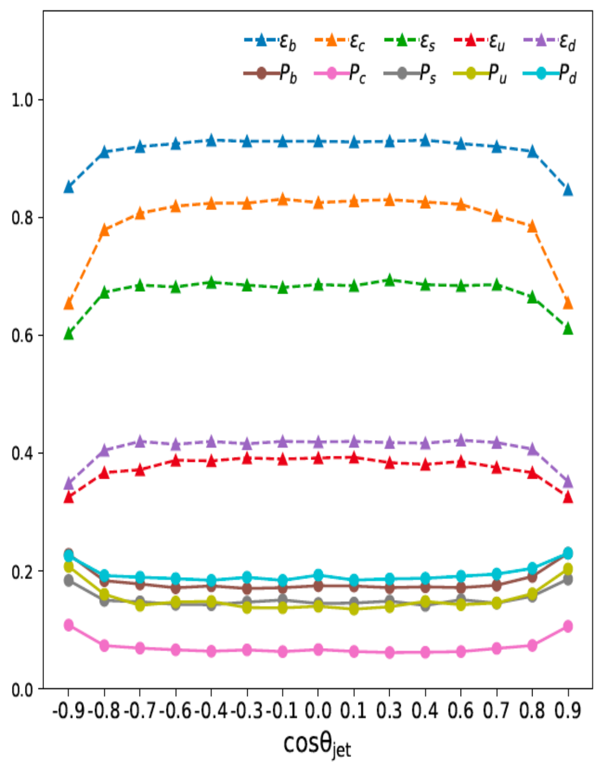
BMR @ CDR & AURORA: 3.7% & 2.9%

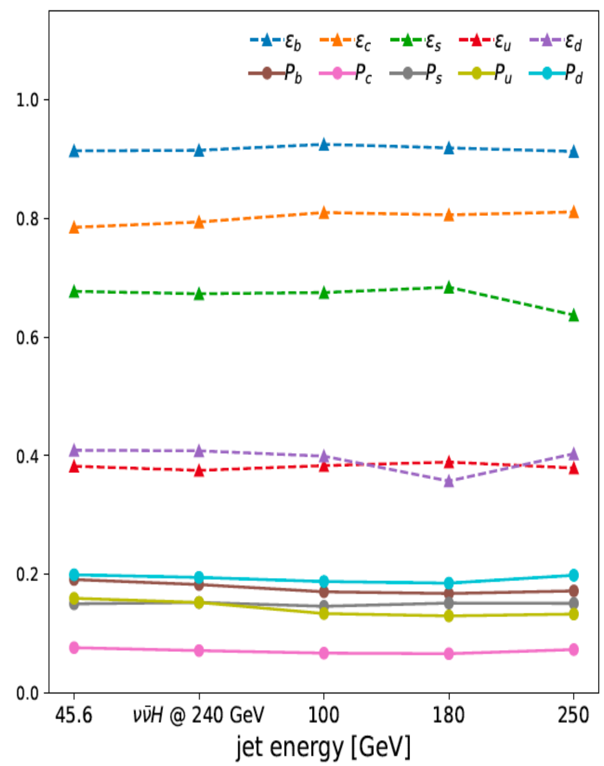




JOI: tagging efficiency & flip rates

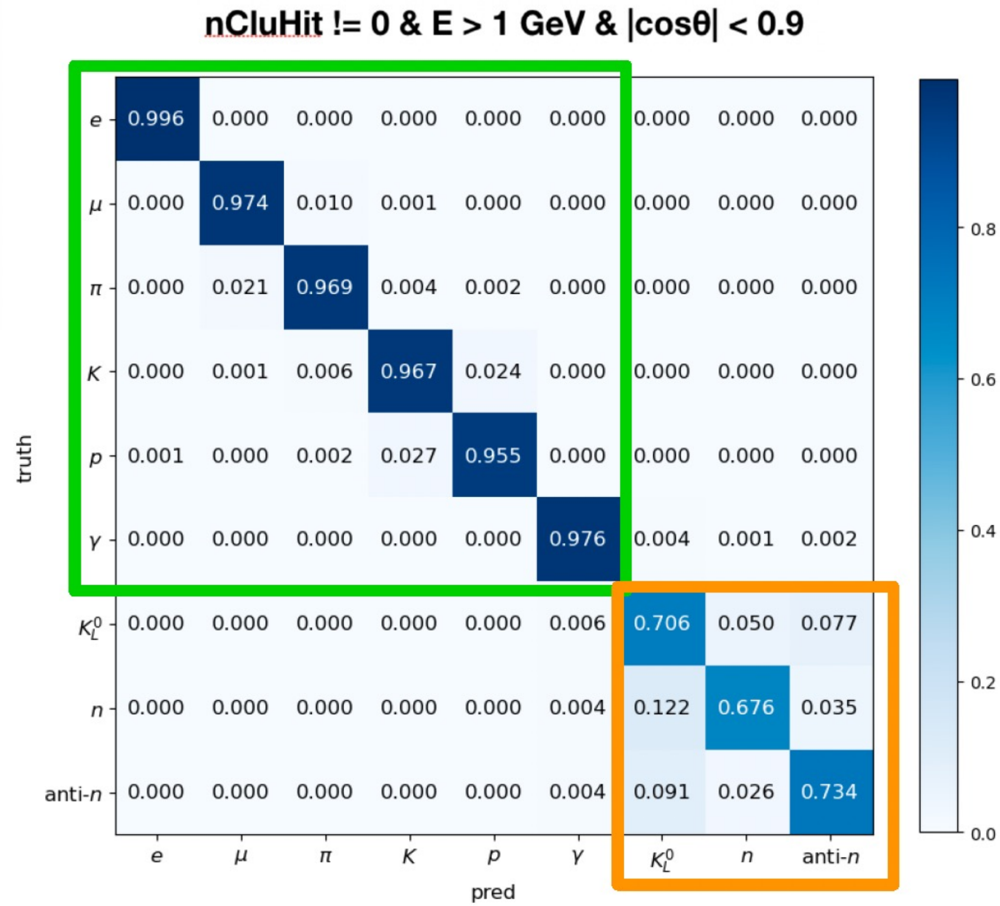


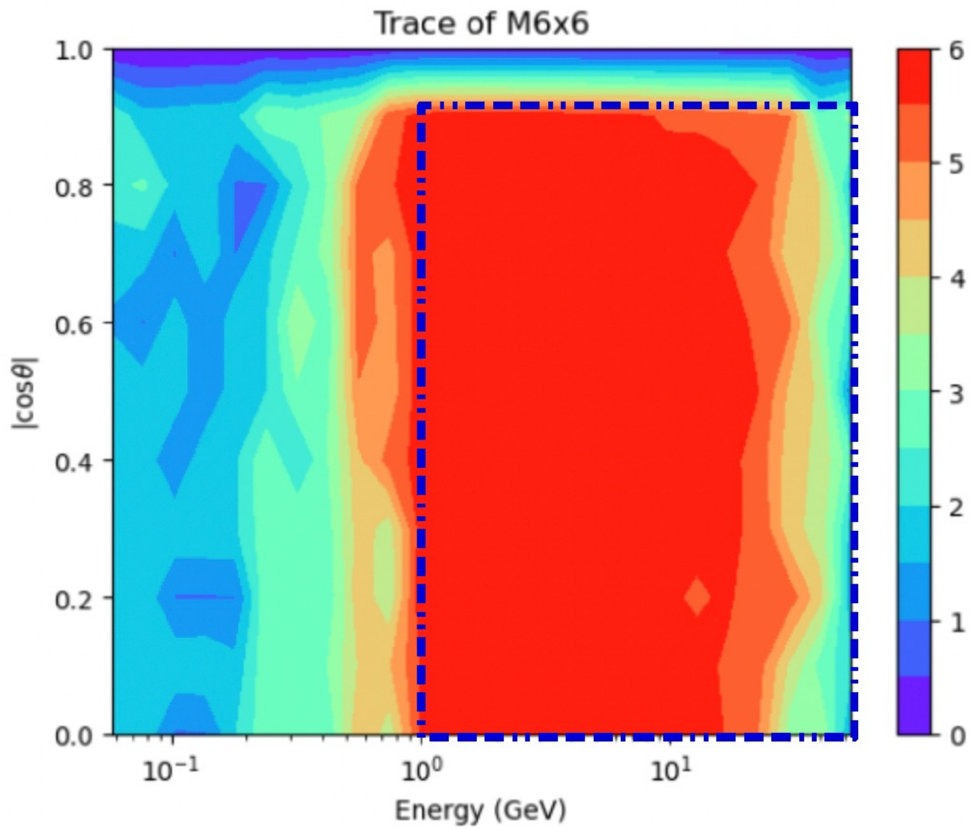




- Kaon id: a must
- Could be calibrated on Z->qq events, and is relatively stable VS hadronization models, etc

Pid of all final state particle...





At vvH, H->gg events @ 240 GeV, Using AURORA, No TPC dE/dx Digitization.

1-1 correspondence between Reco particle & real particle in detector fiducial volume

=

Confusion free PFA + Particle Identification

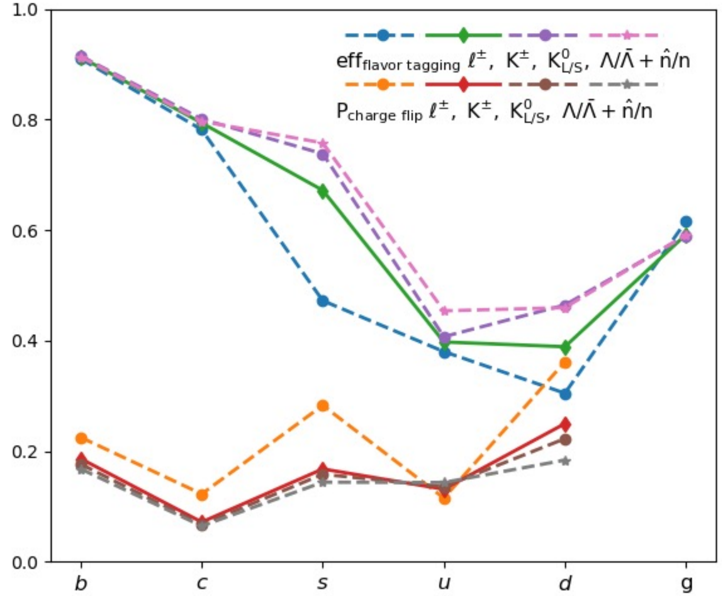
Impact on JoI

M11 2 — PID $l^{\pm}$, $K^{\pm}$

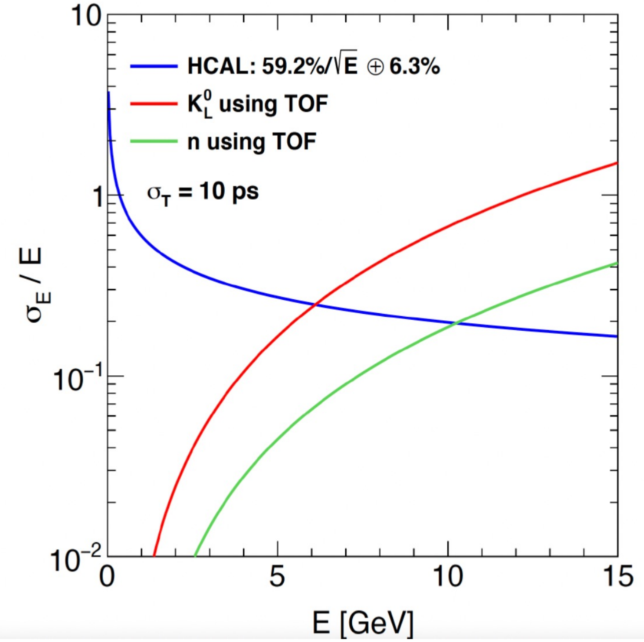
True \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$	G
b	0.738	0.167	0.034	0.026	0.005	0.003	0.002	0.003	0.002	0.002	0.018
$\bar{b}$	0.167	0.737	0.026	0.034	0.003	0.004	0.003	0.002	0.002	0.003	0.018
c	0.015	0.015	0.740	0.057	0.037	0.032	0.026	0.010	0.009	0.017	0.043
$\bar{c}$	0.015	0.015	0.055	0.741	0.032	0.037	0.010	0.026	0.016	0.010	0.043
s	0.003	0.003	0.020	0.018	0.541	0.104	0.030	0.082	0.062	0.045	0.092
$\bar{s}$	0.002	0.003	0.018	0.021	0.101	0.543	0.085	0.028	0.044	0.062	0.092
u	0.002	0.003	0.019	0.012	0.044	0.132	0.375	0.057	0.079	0.168	0.109
$\bar{u}$	0.003	0.002	0.011	0.020	0.132	0.043	0.062	0.368	0.166	0.084	0.108
d	0.003	0.003	0.012	0.020	0.111	0.093	0.083	0.223	0.261	0.080	0.110
$\bar{d}$	0.003	0.003	0.020	0.013	0.093	0.113	0.226	0.079	0.076	0.265	0.110
G	0.015	0.014	0.025	0.025	0.053	0.053	0.043	0.044	0.033	0.035	0.661

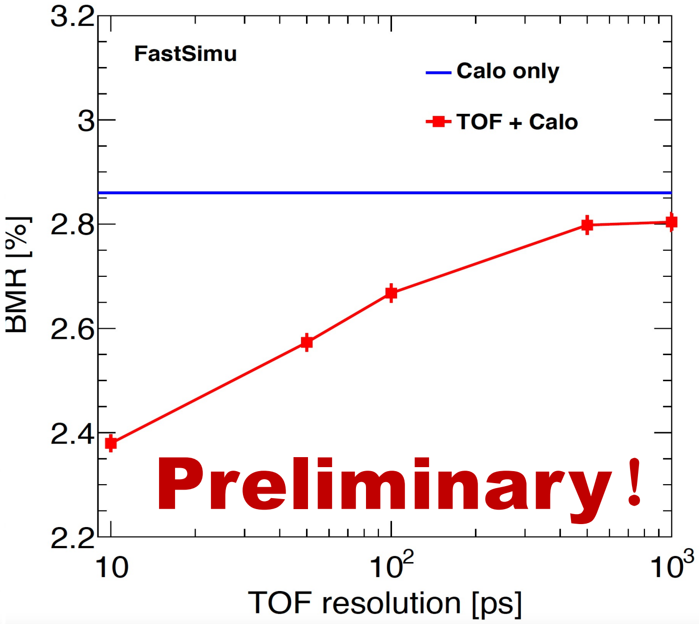
M11 4 — PID $l^{\pm}$, $K^{\pm}$, K_L/K_S, $\Lambda/\bar{\Lambda}$, $n/\bar{n}$

True \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$	G
b	0.761	0.146	0.034	0.022	0.005	0.003	0.002	0.003	0.003	0.002	0.018
$\bar{b}$	0.155	0.750	0.024	0.033	0.003	0.005	0.003	0.003	0.002	0.003	0.018
c	0.016	0.014	0.751	0.049	0.042	0.033	0.021	0.008	0.009	0.017	0.039
$\bar{c}$	0.015	0.017	0.051	0.745	0.034	0.044	0.008	0.022	0.016	0.010	0.039
s	0.004	0.002	0.025	0.018	0.635	0.101	0.020	0.052	0.036	0.036	0.071
$\bar{s}$	0.002	0.003	0.019	0.024	0.101	0.637	0.050	0.019	0.036	0.035	0.073
u	0.003	0.003	0.017	0.008	0.031	0.092	0.400	0.063	0.095	0.183	0.105
$\bar{u}$	0.003	0.003	0.009	0.015	0.089	0.03	0.067	0.396	0.191	0.092	0.105
d	0.003	0.003	0.01	0.015	0.068	0.065	0.097	0.195	0.365	0.073	0.105
$\bar{d}$	0.003	0.003	0.017	0.01	0.066	0.068	0.204	0.095	0.075	0.353	0.107
G	0.015	0.014	0.024	0.023	0.049	0.049	0.044	0.044	0.042	0.041	0.655



BMR with perfect Neutral hadron id

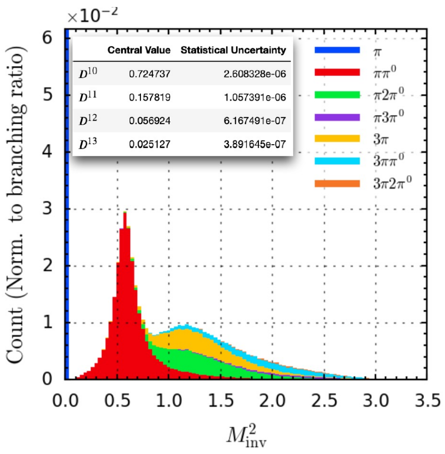




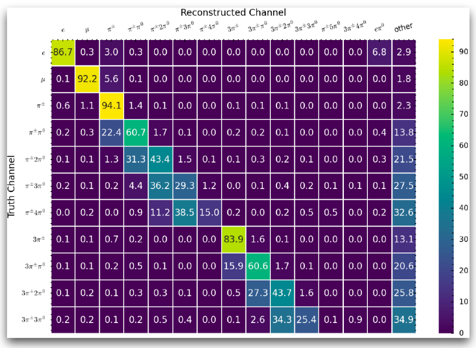
	Charged	Neutral
Non-PFA	Calorimeter	
PFA	Track + Calo (Calo for Pid & Energy matching)	Calorimeter
Future (1-1)	Track + Calo with Time (ToF)	Calo with Time (5D Calo.)

- 5D Calorimeter is essential for
  - Pid, including neutral hadron (~ o(10 ps))
  - PFA Confusion id & Control (~ ns)
  - Event Overlap at Z pole (~ ns)

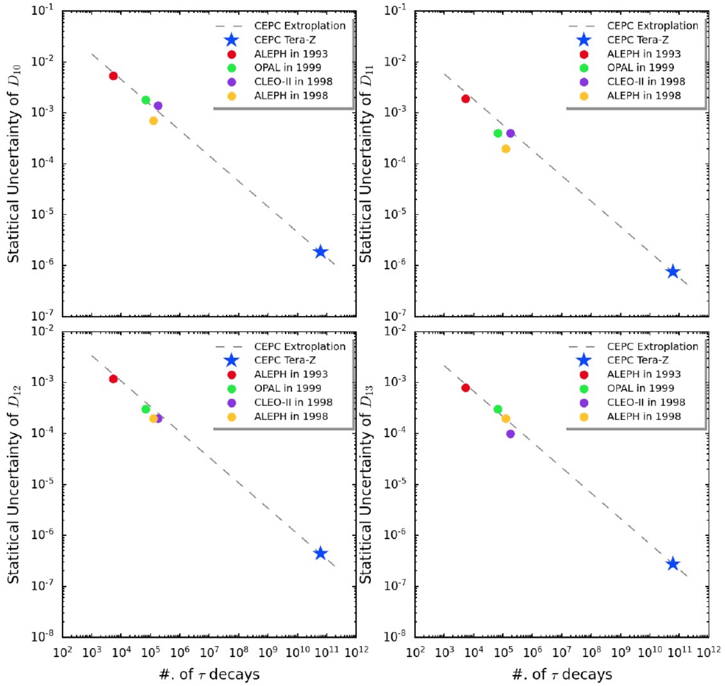
Physics benchmarks: alpha-s



Inclusive $M^2_{\rm inv}$ spectrum merged from exclusive ture $M^2_{\rm inv}$ spectra by associated branching ratio.



Confusion matrix of leptonic and pionic τ decay modes. The migration chance are normalized to truth channel.



Extracting α_S at future e^+e^- Higgs factory with energy correlators

Zhen Lin,[a] Manqi Ruan,[b] Meng Xiao,[a] and Zhen Xu[a]

[a] *Zhejiang Institute of Modern Physics, Department of Physics, Zhejiang University, Hangzhou, Zhejiang 310027, China*

[b] *Institute of High Energy Physics, Chinese Academy of Sciences, 19B Yuquan Road, Shijingshan District, Beijing 100049, China*

E-mail: zhenlin@zju.edu.cn, ruanmq@ihep.ac.cn, mxiao@zju.edu.cn, zhen.xu@zju.edu.cn

Abstract: The prospected sensitivity in α_S determination using an event shape observable, ratio of energy correlators at future electron-positron collider is presented. The study focuses on the collinear region which has suffered from large theoretical and hadronization uncertainty in the past. The ratio effectively reduces the impacts of the uncertainties. With the amount of data that future electron-positron collider could produce in 1 minute (40 pb^{-1}) and 0.5 hour (1 fb^{-1}), a 1% and 0.2% precision of α_S could be reached.

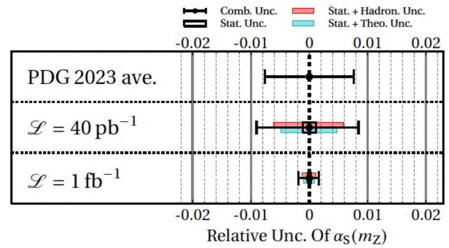
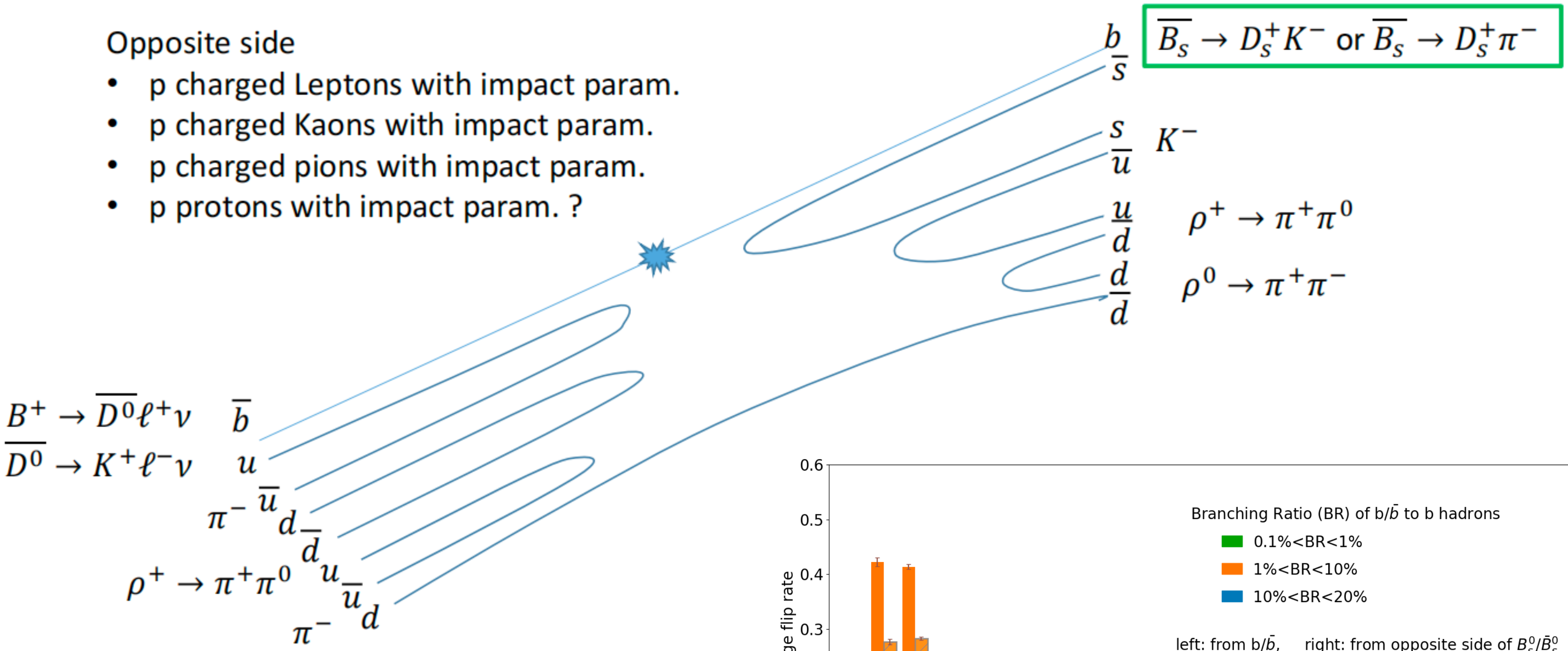


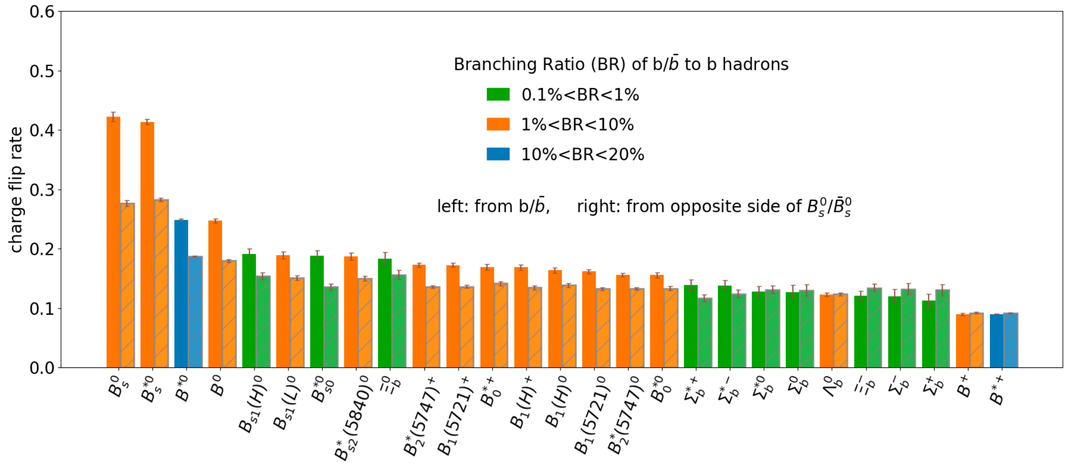
Figure 3: The expected sensitivity to $\alpha_S(m_Z)$ using E3C/E2C at CEPC in different luminosity scenarios. The world average precision for α_S extraction is shown for a comparison [1]. The breakdown of statistical, hadronization, and theoretical uncertainties is shown.

Physics benchmarks: Bs oscillation

Opposite side

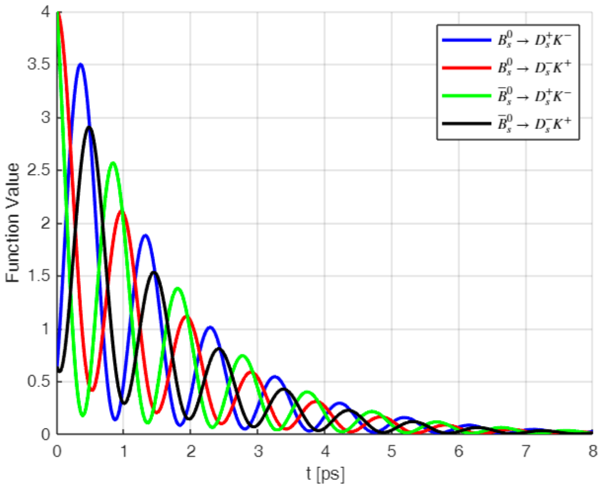
- p charged Leptons with impact param.
- p charged Kaons with impact param.
- p charged pions with impact param.
- p protons with impact param. ?

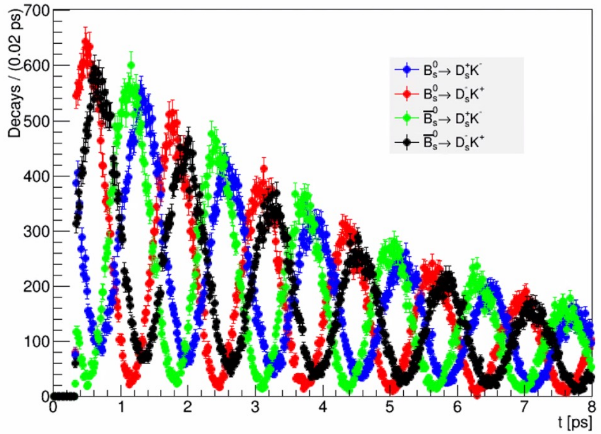


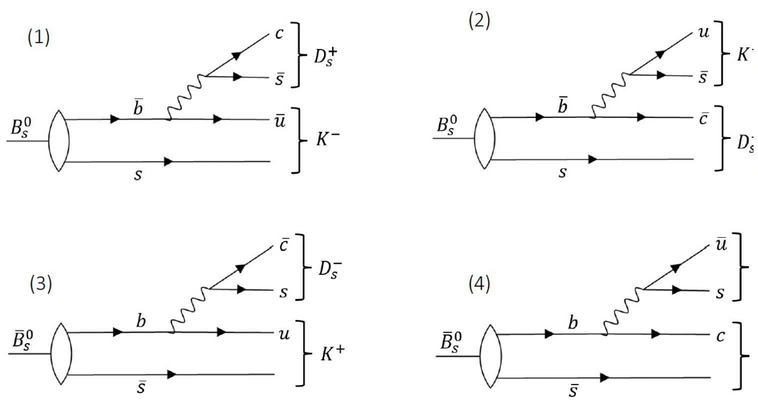


Effective tagging power (eff*(1-2*ω)^2) ~ 40%, one order of magnitude better than LHCb

Physics benchmarks: Bs oscillation







$$P_{++} \propto e^{-\Gamma t}\left(\cosh\left(\frac{\Delta\Gamma}{2}t\right) - C\cos(\Delta m t) + D_{\bar f}\sinh\left(\frac{\Delta\Gamma}{2}t\right) - S_{\bar f}\sin(\Delta m t)\right) \quad (19)$$

$$P_{+-} \propto e^{-\Gamma t}\left(\cosh\left(\frac{\Delta\Gamma}{2}t\right) + C\cos(\Delta m t) + D_{\bar f}\sinh\left(\frac{\Delta\Gamma}{2}t\right) - S_{\bar f}\sin(\Delta m t)\right) \quad (20)$$

$$P_{-+} \propto e^{-\Gamma t}\left(\cosh\left(\frac{\Delta\Gamma}{2}t\right) + C\cos(\Delta m t) + D_{\bar f}\sinh\left(\frac{\Delta\Gamma}{2}t\right) + S_{\bar f}\sin(\Delta m t)\right) \quad (21)$$

$$P_{--} \propto e^{-\Gamma t}\left(\cosh\left(\frac{\Delta\Gamma}{2}t\right) - C\cos(\Delta m t) + D_{\bar f}\sinh\left(\frac{\Delta\Gamma}{2}t\right) + S_{\bar f}\sin(\Delta m t)\right) \quad (22)$$

$$C = \frac{1-r^2}{1+r^2}, \quad (23)$$

$$D_f = \frac{-2r\cos(\delta-(\gamma-2\beta_s))}{1+r^2}, \qquad D_{\bar f} = \frac{-2r\cos(\delta+(\gamma-2\beta_s))}{1+r^2}, \quad (24)$$

$$S_f = \frac{2r\sin(\delta-(\gamma-2\beta_s))}{1+r^2}, \qquad S_{\bar f} = \frac{-2r\sin(\delta+(\gamma-2\beta_s))}{1+r^2}. \quad (25)$$

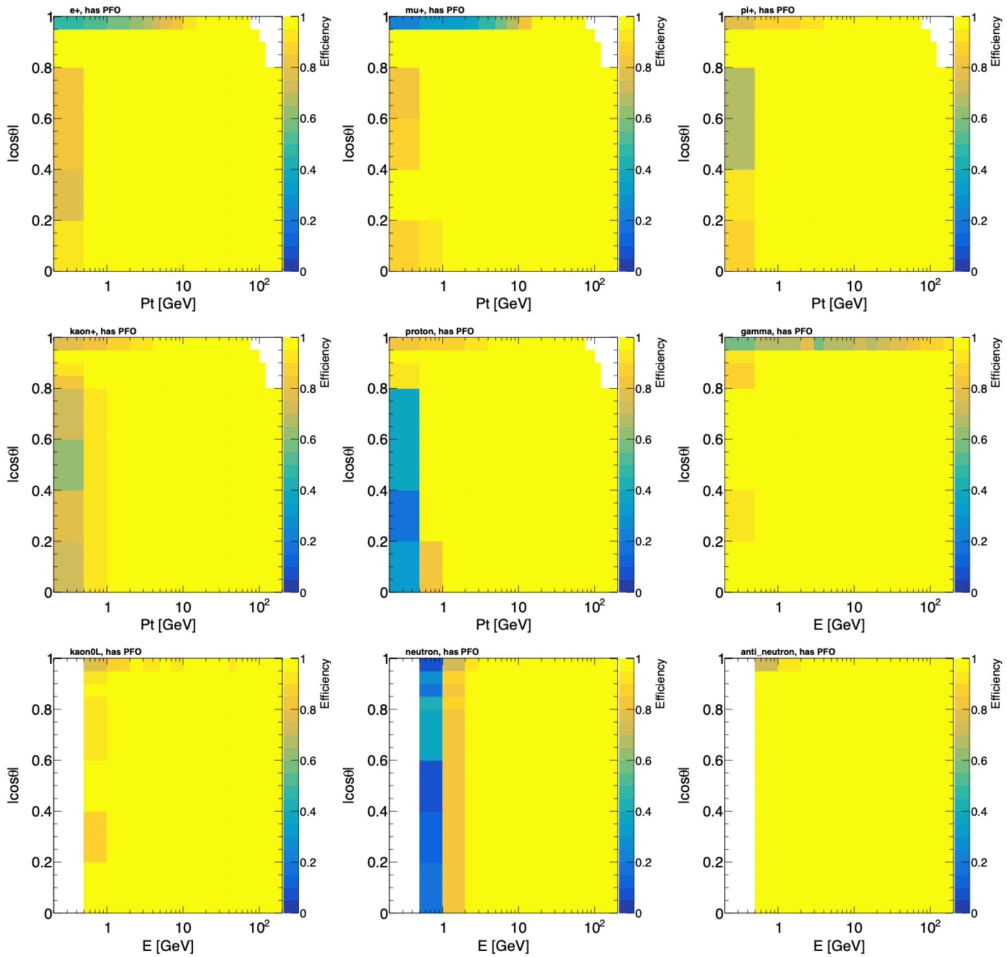
From Peng Ji (IHEP), Xiaoling Wang (SCNU), Mingrui Zhao (CIAE), etc

Preliminary Estimation based on Yield & Key Performance comparison:

measure $\gamma - 2\beta_s$ to precision of o(0.1 degree)

~ 20 times better than current precision…
~ 4 times better than LHCb @ HL-LHC

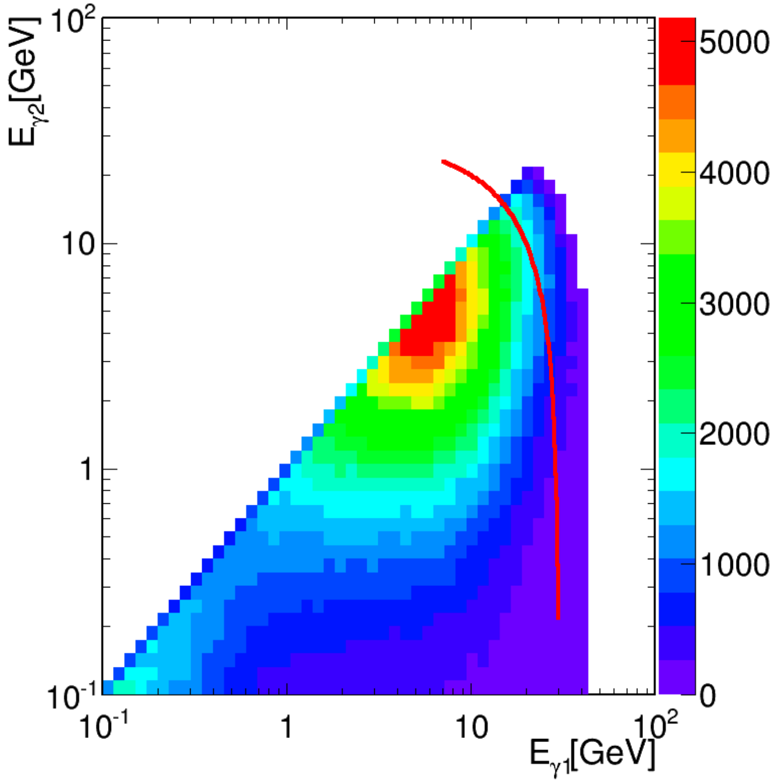
Single Particle: differential efficiency



Sep. power.

Sub-detector	Key technology	Key Specifications
Silicon vertex detector	Spatial resolution and materials	$\sigma_{r\phi} \sim 3\ \mu\mathrm{m},\ X/X_0 < 0.15\%$ (per layer)
Silicon tracker	Large-area silicon detector	$\sigma(\frac{1}{p_T}) \sim 2 \times 10^{-5} \oplus \frac{1\times10^{-3}}{p\times\sin^{3/2}\theta}(\mathrm{GeV}^{-1})$
TPC/Drift Chamber	Precise dE/dx (dN/dx) measurement	Relative uncertainty 2%
Time of Flight detector	Large-area silicon timing detector	$\sigma(t) \sim 30$ ps
Electromagnetic Calorimeter	High granularity 4D crystal calorimeter	EM energy resolution $\sim 3\%/\sqrt{E(\mathrm{GeV})}$ Granularity $\sim 2 \times 2 \times 2\ \mathrm{cm}^3$
Magnet system	Ultra-thin High temperature Superconducting magnet	Magnet field $2-3$ T Material budget $< 1.5X_0$ Thickness < 150 mm
Hadron calorimeter	Scintillating glass Hadron calorimeter	Support PFA jet reconstruction Single hadron $\sigma_E^{had} \sim 40\%/\sqrt{E(\mathrm{GeV})}$ Jet $\sigma_E^{jet} \sim 30\%/\sqrt{E(\mathrm{GeV})}$

These specifications continue to be optimized



Pi0 energies at Z->tautau events at Z pole.

Sep power ~ 1.6 cm ~ 30 GeV Pi0

Sub D recap

- Tracking: efficiency & resolutions as a function of cos(theta) & Pt
- Calorimeter: efficiency & resolution – linearity of photon, neutral hadron
- Pid relevant: ToF, dE/dx, dN/dx, etc.