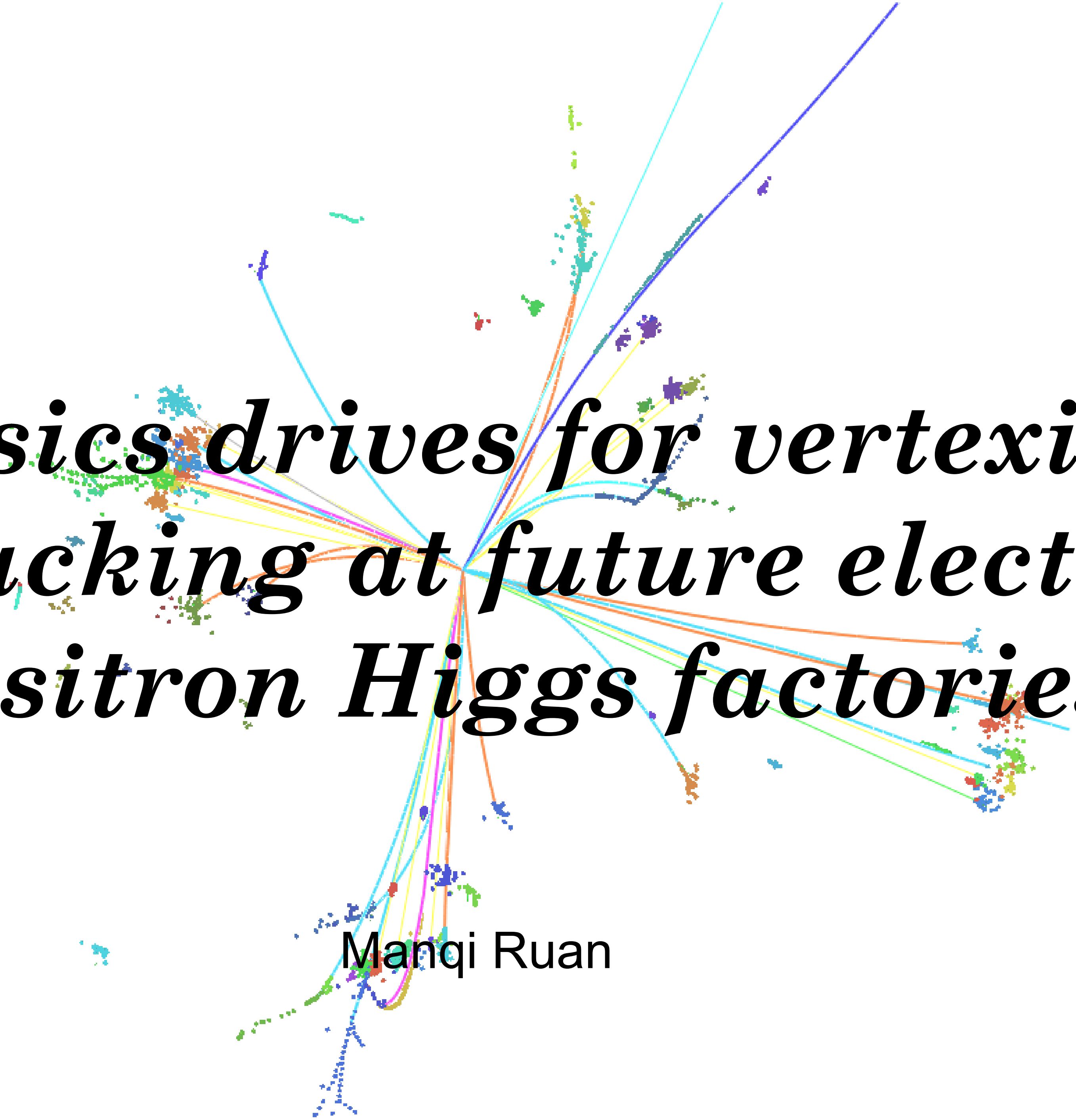


Physics drives for vertexing & tracking at future electron positron Higgs factories

Manqi Ruan

Electron Positron Higgs factories

High-priority future initiatives

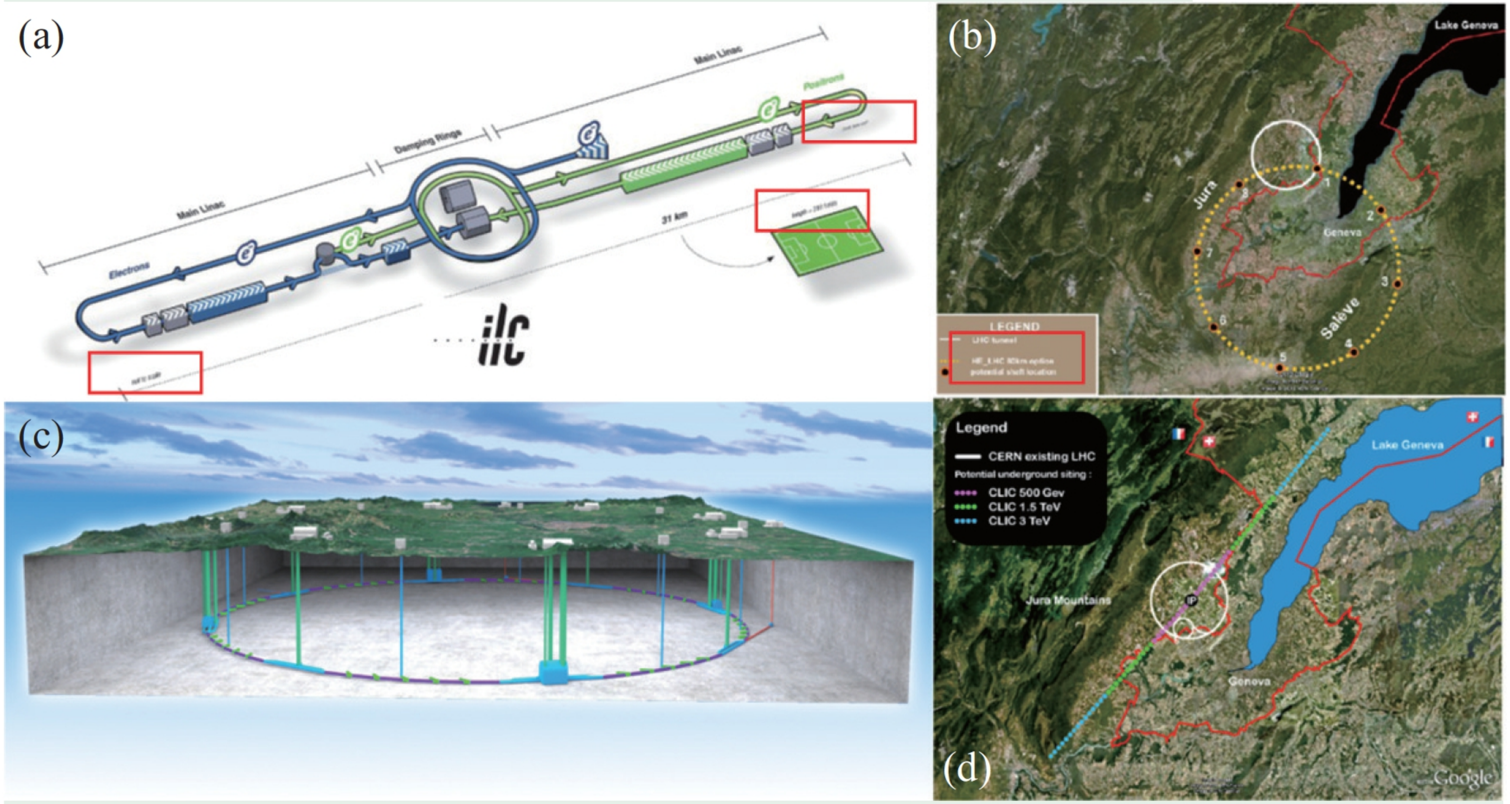
An electron-positron Higgs factory is the highest-priority next collider. For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy. Accomplishing these compelling goals will require innovation and cutting-edge technology:

ILC (a):	TDR @ 2013
FCC (b):	CDR @ 2019
CEPC (c):	CDR @ 2018
CLIC (d):	CDR @ 2013

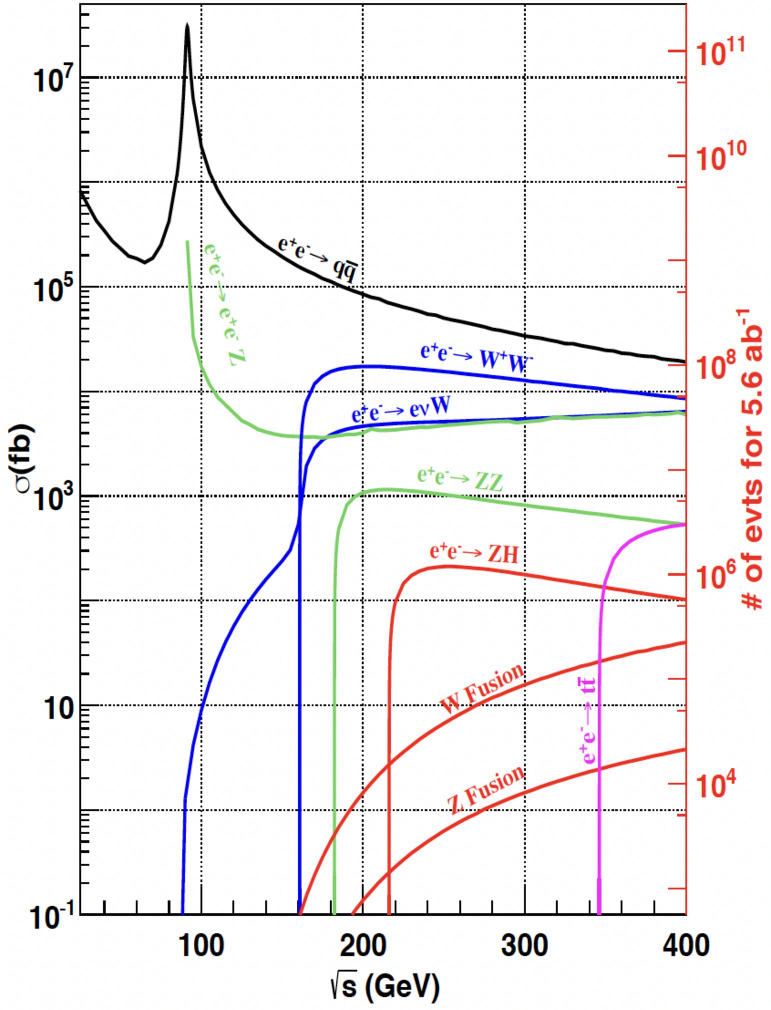
DELIBERATION DOCUMENT
ON THE 2020 UPDATE OF THE EUROPEAN STRATEGY
FOR PARTICLE PHYSICS

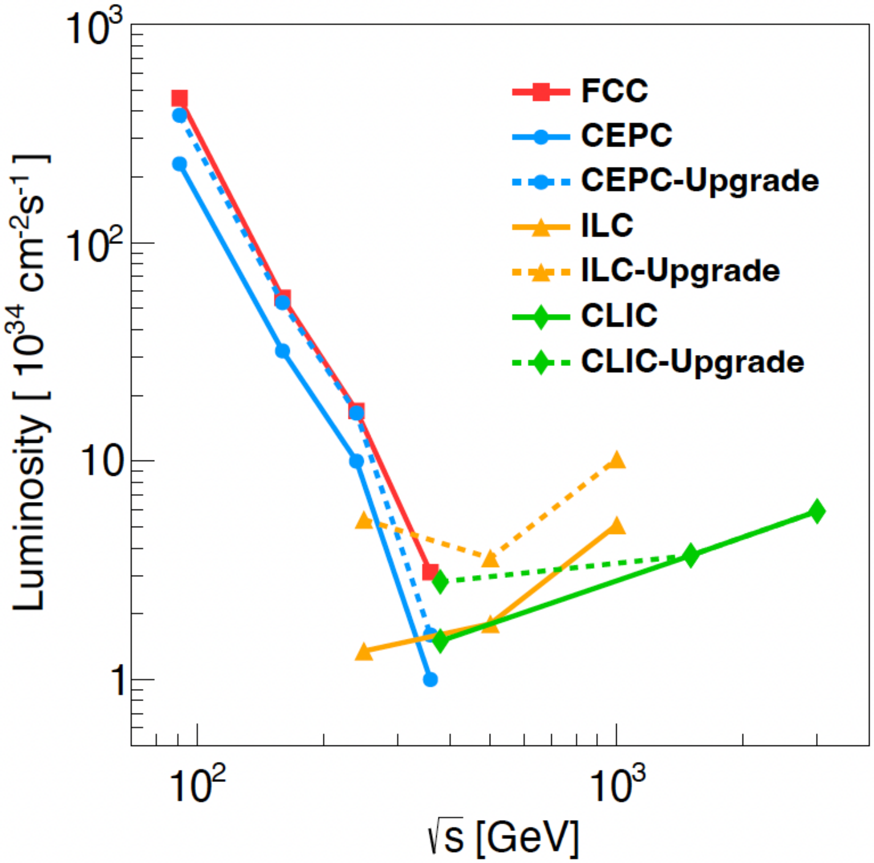
The European Strategy Group

European Strategy
Update



Yields ~ Xsec * Lumi

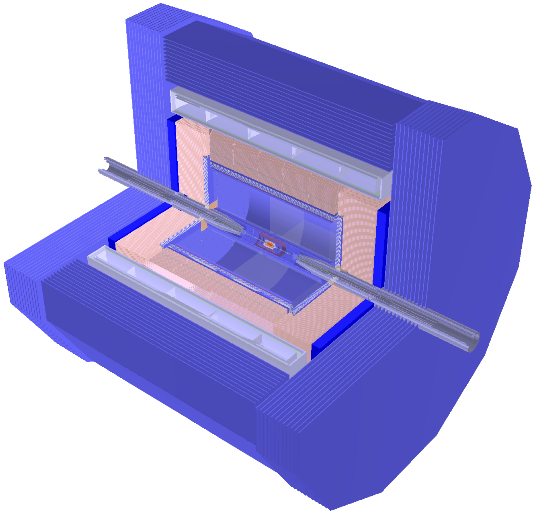


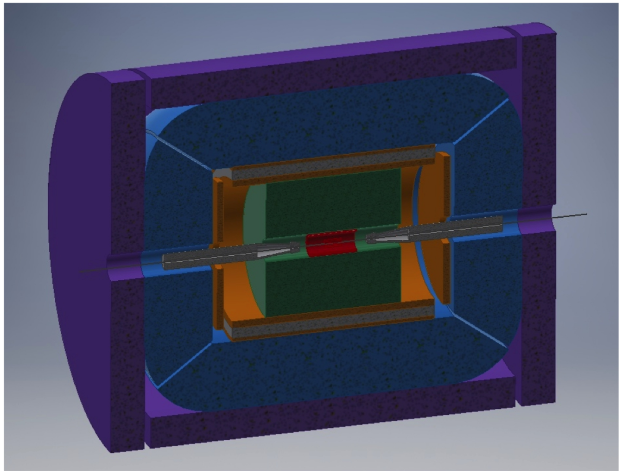


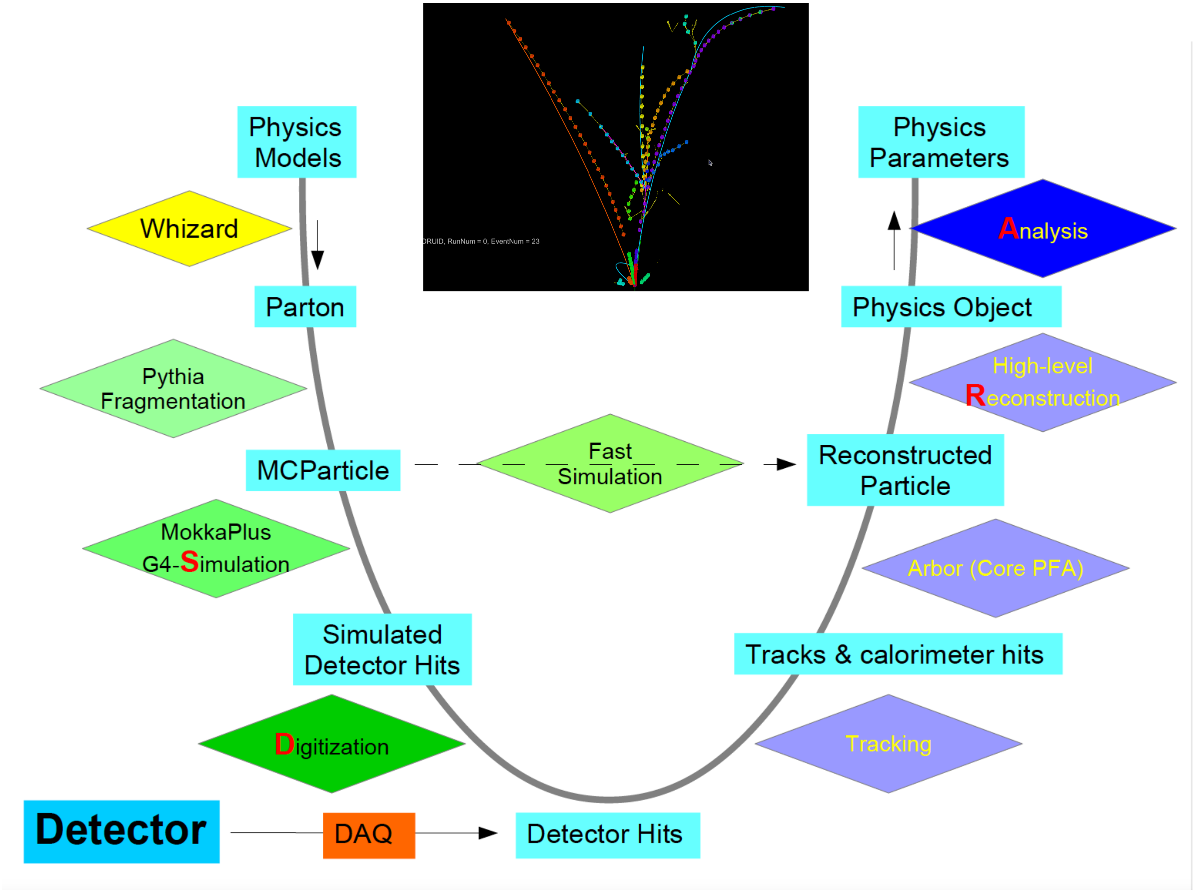
Key figures of the CEPC-SPPC

- **Tunnel ~ 100 km**
- **CEPC (90 – 240 GeV)**
  - Higgs factory: **4M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **~ 4 Tera** Z boson
    - Precision test of the SM
    - Rare decay
    - Flavor factory: b, c, tau
    - QCD studies
- **Upgradable to ttbar threshold (360 GeV)： 1 M t/t-bar**
- **SPPC (~ 100 TeV)**
  - Direct search for new physics
  - Complementary Higgs measurements to CEPC g(HHH), g(Htt)
  - ...
- **Heavy ion, e-p collision...**

Detector & Software







Physics Models

Whizard

Parton

Pythia Fragmentation

MCParticle

MokkaPlus G4-Simulation

Simulated Detector Hits

Digitization

Detector

DAQ

Detector Hits

Tracking

Tracks & calorimeter hits

Arbor (Core PFA)

Reconstructed Particle

Fast Simulation

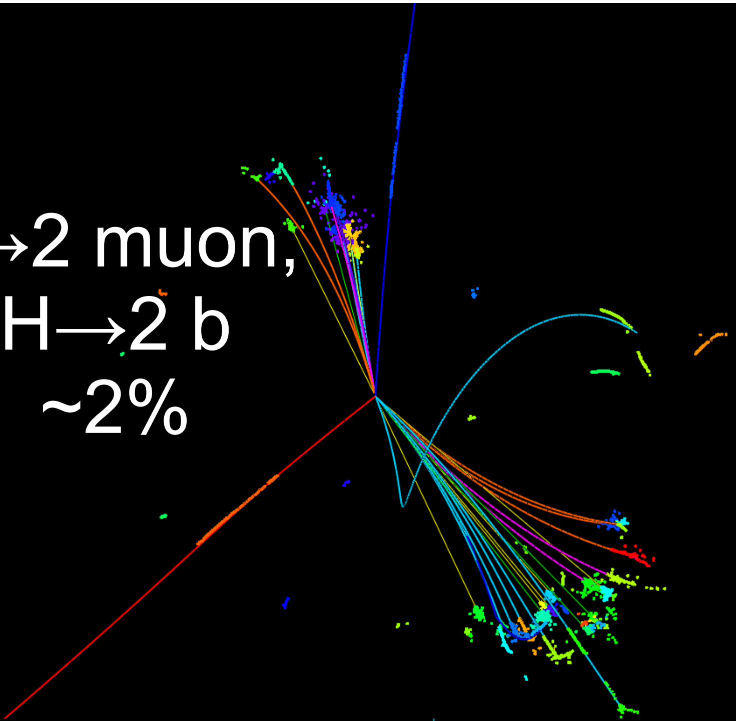
High-level Reconstruction

Physics Object

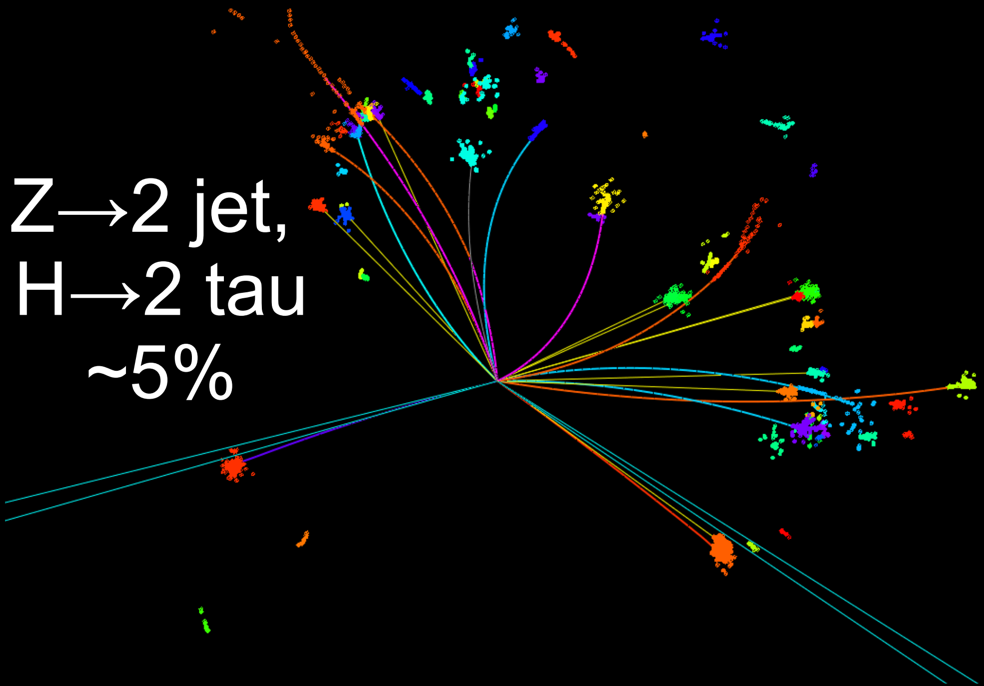
Analysis

Physics Parameters

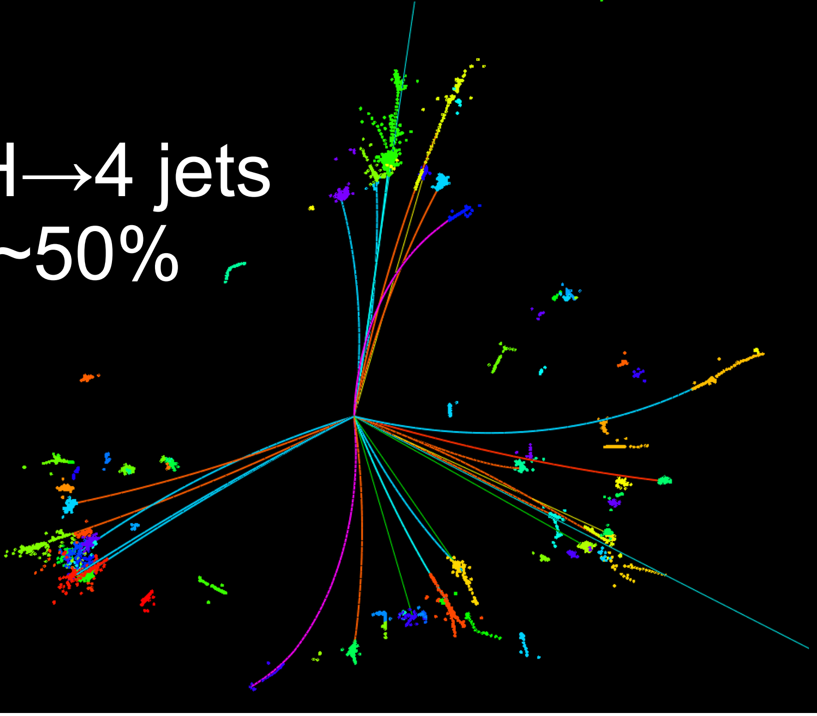
Full simulation reconstruction Chain with Arbor, iterating/validation with hardware studies



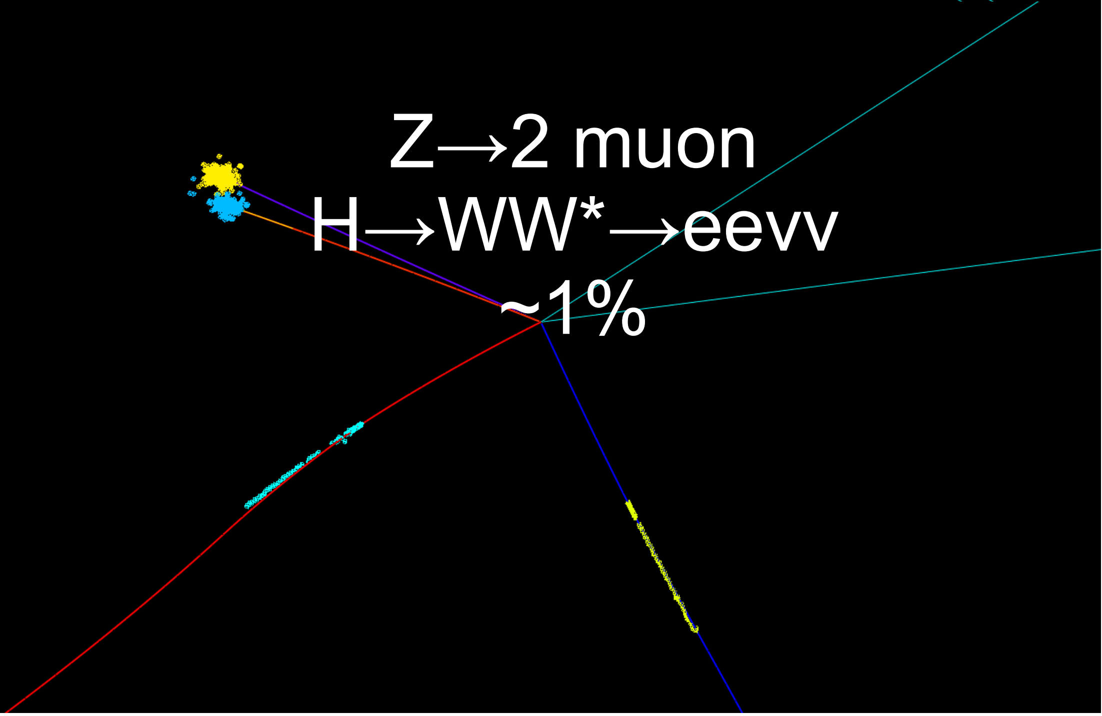
Z→2 muon,
H→2 b
~2%



Z→2 jet,
H→2 tau
~5%

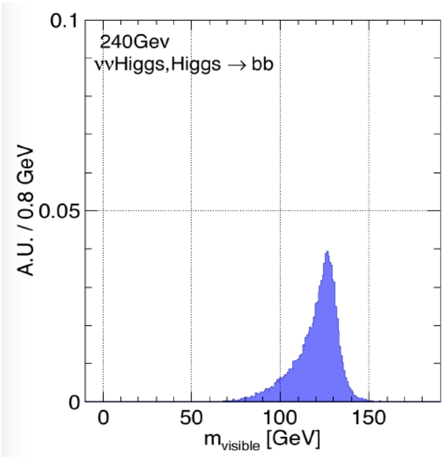


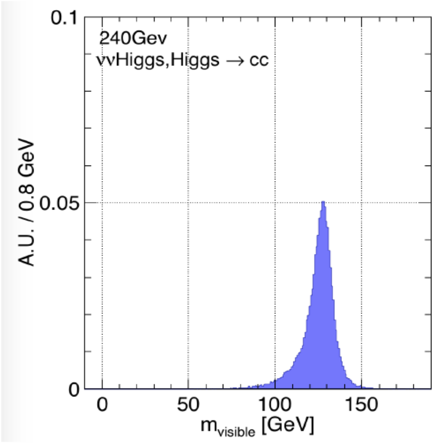
ZH→4 jets
~50%

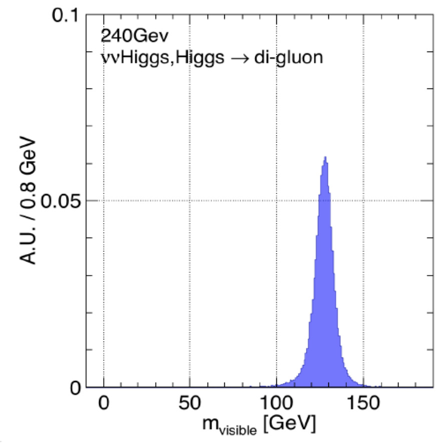


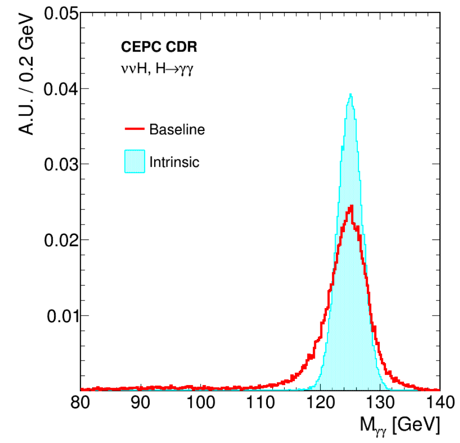
Z→2 muon
H→WW*→eevv
~1%

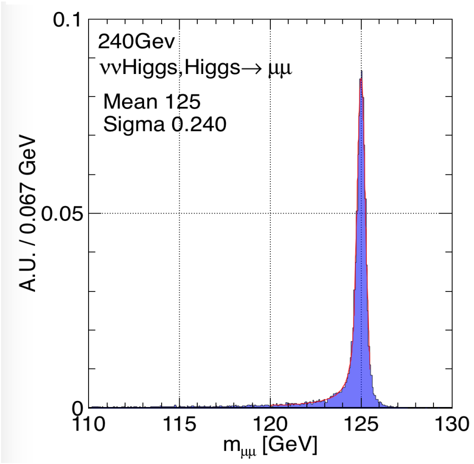
Reconstructed Higgs Signatures

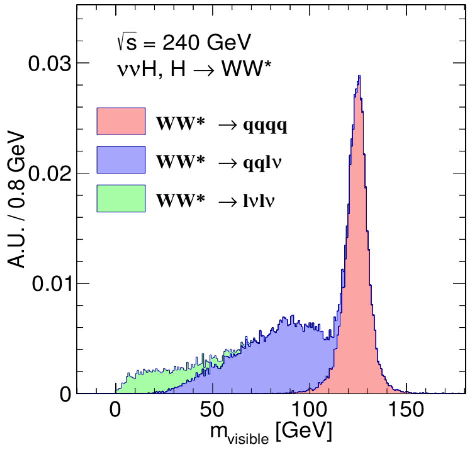


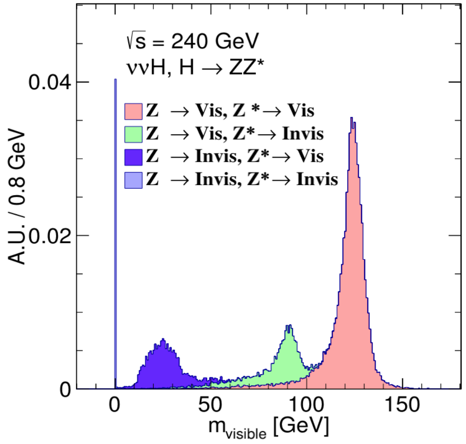


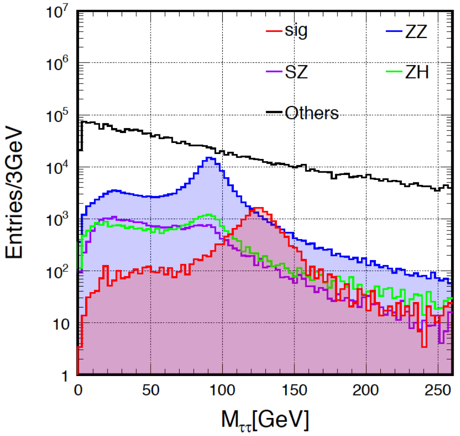










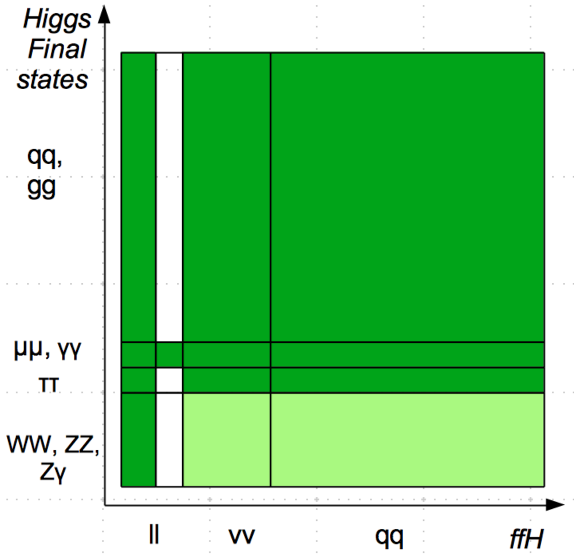


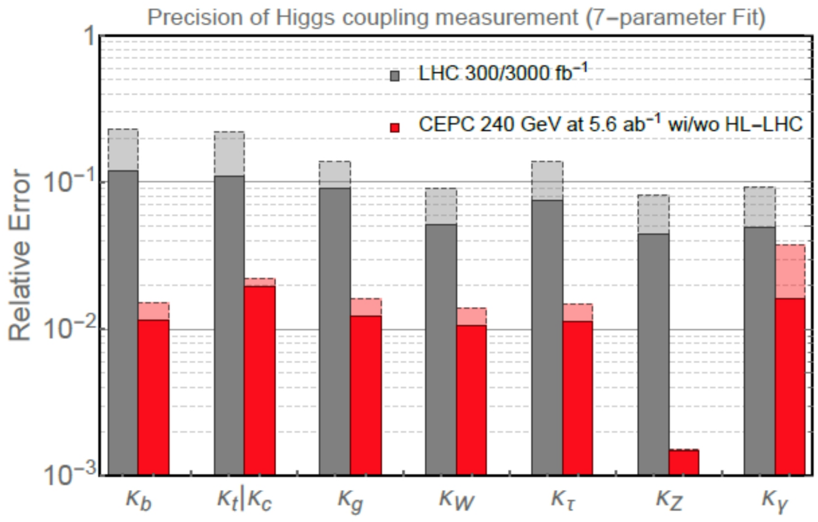
Clear Higgs Signature in all SM decay modes

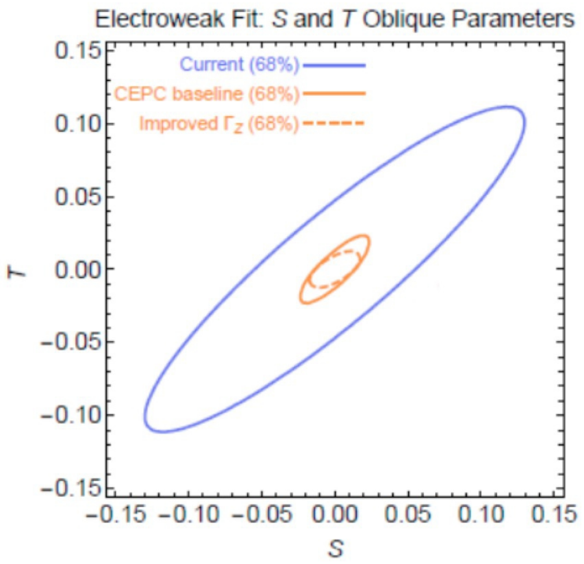
Massive production of the SM background (2 fermion and 4 fermions) at the full Simulation level

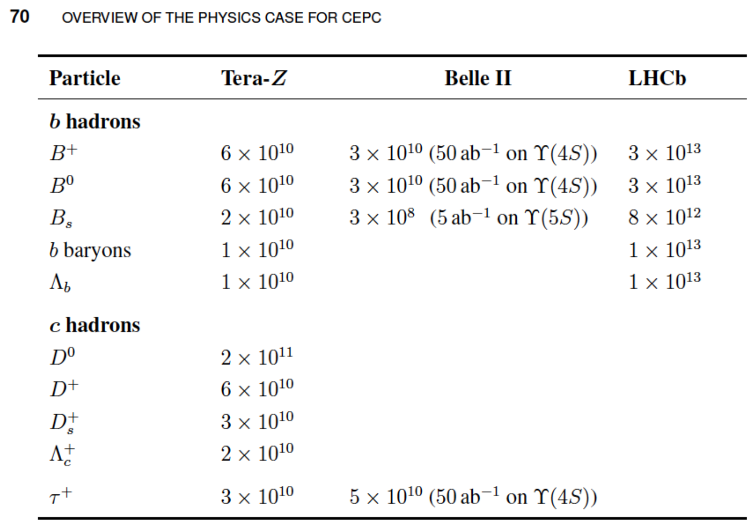
Right corner: di-tau mass distribution at qqH events using collinear approximation

Excellent physics potential



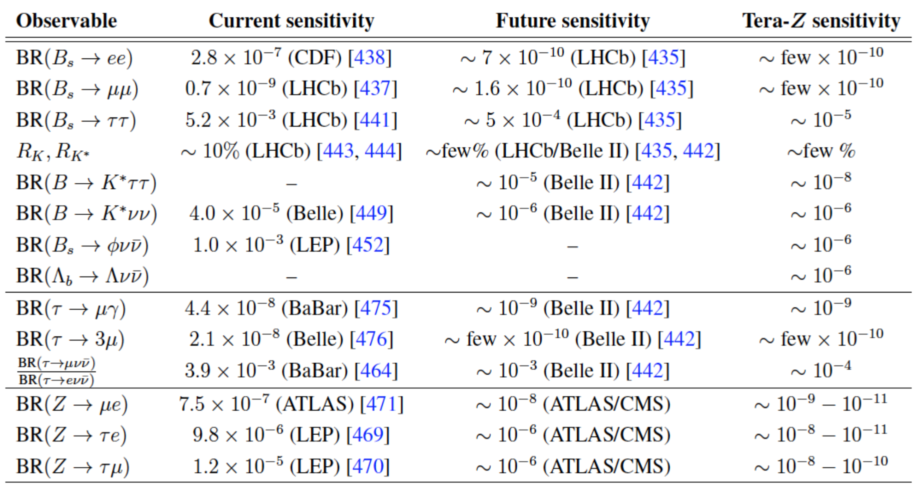






70 OVERVIEW OF THE PHYSICS CASE FOR CEPC

Particle	Tera-Z	Belle II	LHCb
b hadrons			
B^+	6×10^{10}	3×10^{10} (50 ab^{-1} on $\Upsilon(4S)$)	3×10^{13}
B^0	6×10^{10}	3×10^{10} (50 ab^{-1} on $\Upsilon(4S)$)	3×10^{13}
B_s	2×10^{10}	3×10^{8} (5 ab^{-1} on $\Upsilon(5S)$)	8×10^{12}
b baryons	1×10^{10}		1×10^{13}
Λ_b	1×10^{10}		1×10^{13}
c hadrons			
D^0	2×10^{11}		
D^+	6×10^{10}		
D_s^+	3×10^{10}		
Λ_c^+	2×10^{10}		
τ^+	3×10^{10}	5×10^{10} (50 ab^{-1} on $\Upsilon(4S)$)	



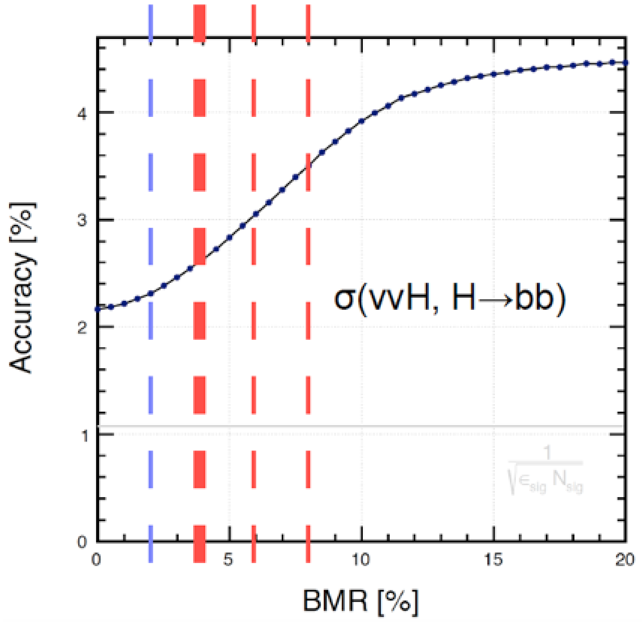
Observable	Current sensitivity	Future sensitivity	Tera-Z sensitivity
$\mathrm{BR}(B_s \to ee)$	2.8×10^{-7} (CDF) [438]	$\sim 7 \times 10^{-10}$ (LHCb) [435]	$\sim$ few $\times 10^{-10}$
$\mathrm{BR}(B_s \to \mu\mu)$	0.7×10^{-9} (LHCb) [437]	$\sim 1.6 \times 10^{-10}$ (LHCb) [435]	$\sim$ few $\times 10^{-10}$
$\mathrm{BR}(B_s \to \tau\tau)$	5.2×10^{-3} (LHCb) [441]	$\sim 5 \times 10^{-4}$ (LHCb) [435]	$\sim 10^{-5}$
R_K, R_{K^*}	$\sim 10\%$ (LHCb) [443, 444]	$\sim$few% (LHCb/Belle II) [435, 442]	$\sim$few %
$\mathrm{BR}(B \to K^*\tau\tau)$	–	$\sim 10^{-5}$ (Belle II) [442]	$\sim 10^{-8}$
$\mathrm{BR}(B \to K^*\nu\nu)$	4.0×10^{-5} (Belle) [449]	$\sim 10^{-6}$ (Belle II) [442]	$\sim 10^{-6}$
$\mathrm{BR}(B_s \to \phi\nu\bar{\nu})$	1.0×10^{-3} (LEP) [452]	–	$\sim 10^{-6}$
$\mathrm{BR}(\Lambda_b \to \Lambda\nu\bar{\nu})$	–	–	$\sim 10^{-6}$
$\mathrm{BR}(\tau \to \mu\gamma)$	4.4×10^{-8} (BaBar) [475]	$\sim 10^{-9}$ (Belle II) [442]	$\sim 10^{-9}$
$\mathrm{BR}(\tau \to 3\mu)$	2.1×10^{-8} (Belle) [476]	$\sim$ few $\times 10^{-10}$ (Belle II) [442]	$\sim$ few $\times 10^{-10}$
$\frac{\mathrm{BR}(\tau \to \mu\nu\bar{\nu})}{\mathrm{BR}(\tau \to e\nu\bar{\nu})}$	3.9×10^{-3} (BaBar) [464]	$\sim 10^{-3}$ (Belle II) [442]	$\sim 10^{-4}$
$\mathrm{BR}(Z \to \mu e)$	7.5×10^{-7} (ATLAS) [471]	$\sim 10^{-8}$ (ATLAS/CMS)	$\sim 10^{-9} - 10^{-11}$
$\mathrm{BR}(Z \to \tau e)$	9.8×10^{-6} (LEP) [469]	$\sim 10^{-6}$ (ATLAS/CMS)	$\sim 10^{-8} - 10^{-11}$
$\mathrm{BR}(Z \to \tau\mu)$	1.2×10^{-5} (LEP) [470]	$\sim 10^{-6}$ (ATLAS/CMS)	$\sim 10^{-8} - 10^{-10}$

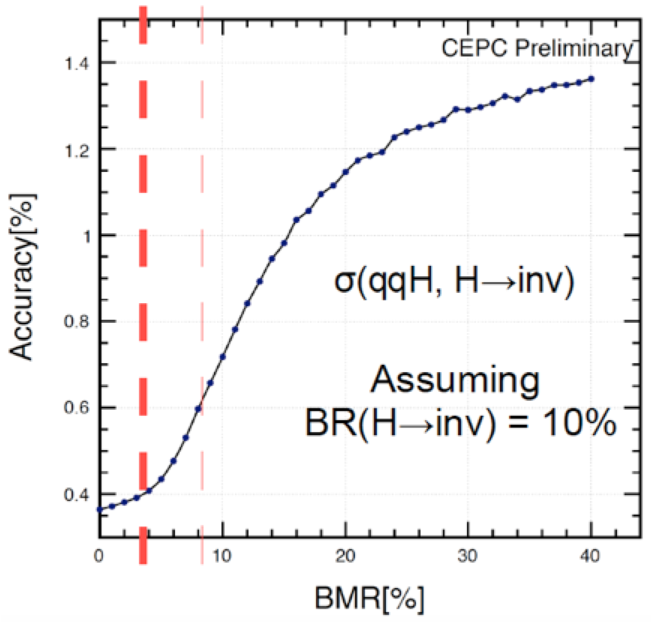
Table 2.5: Order of magnitude estimates of the sensitivity to a number of key observables for which the tera-Z factory at CEPC might have interesting capabilities. The expected future sensitivities assume luminosities of 50 fb^{-1} at LHCb, 50 ab^{-1} at Belle II, and 3 ab^{-1} at ATLAS and CMS. For the tera-Z factory of CEPC we have assumed the production of 10^{12} Z bosons.

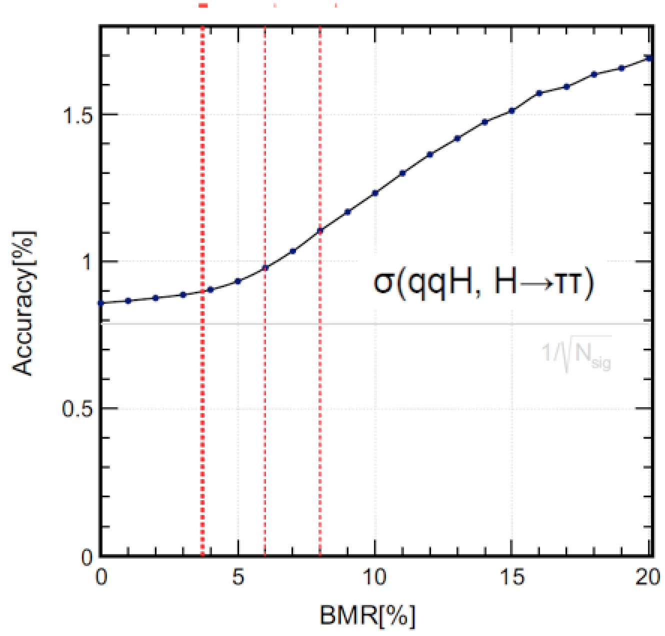
Performance requirements

- A clear separation of the final state particles
  - Identification of Physics Objects, isolated & inside jet
    - Single final state particle object, i.e., Leptons
    - Composited objects:
      - Two/three final state particles: Pi-0, K-short, Lambda, Phi,Tau, D meson...
      - Jets
  - Improving the E/P resolution for composited objects, especially jets
- BMR (Boson Mass Resolution)
  - < 4% for Higgs measurements
  - Much demanding for Flavor/New Physics Measurements
- Pid: Pion & Kaon separation > 3 σ
- Jet: Flavor Tagging & Charge Reconstruction
- Flavor Physics: EM resolution, momentum resolution...

Key requirement: BMR



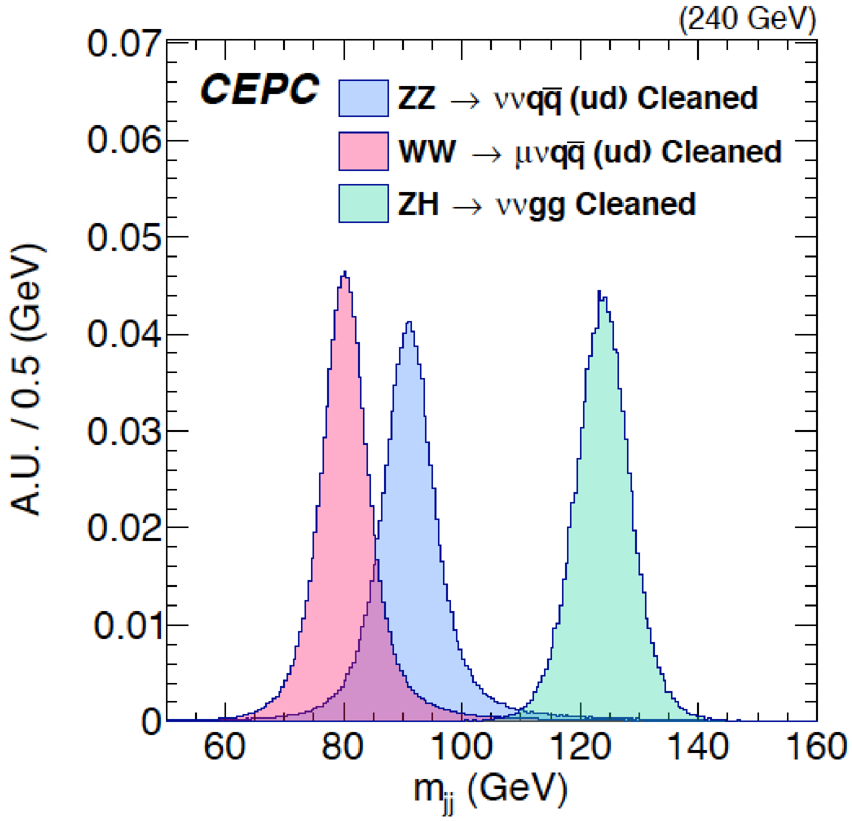




- Boson Mass Resolution: relative mass resolution of vvH, H→gg events
    - Free of Jet Clustering
    - Be applied directly to the Higgs analyses
- The CEPC baseline reaches 3.8%

	BMR = 2%	4%	6%	8%
σ(vvH, H→bb)	2.3%	2.6%	3.0%	3.4%
σ(vvH, H→inv)	0.38%	0.4%	0.5%	0.6%
σ(qqH, H→ττ)	0.85%	0.9%	1.0%	1.1%

CEPC Baseline: BMR ~ 3.8%



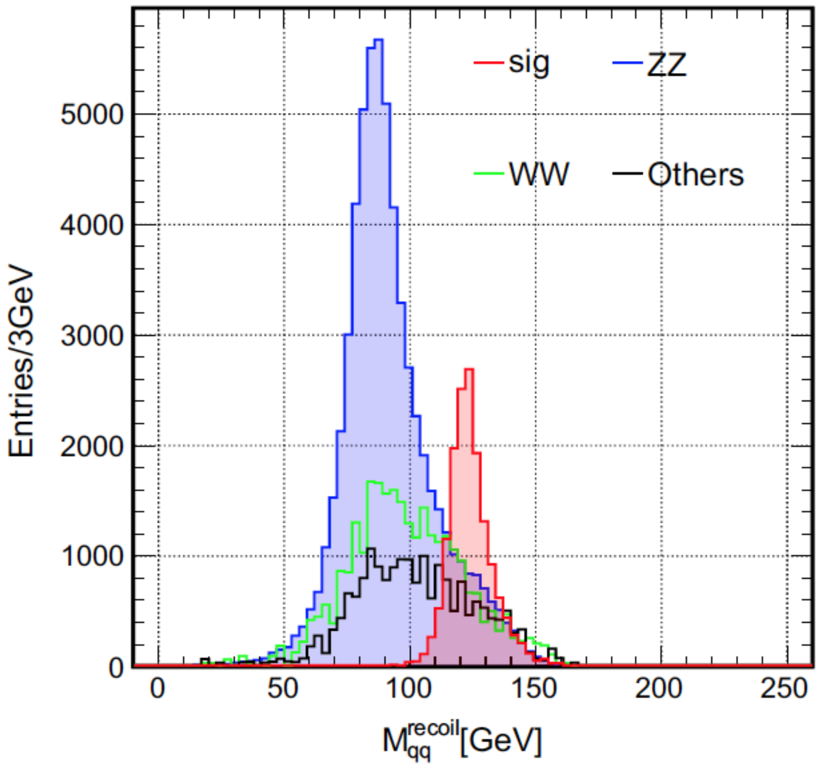


Fig. 7 Distribution of the recoil mass of the qq, M_{qq}^{recoil} for $Z \to qq$, $H \to \tau\tau$ and each background at $\sqrt{s} = 240$ GeV after the previous cuts

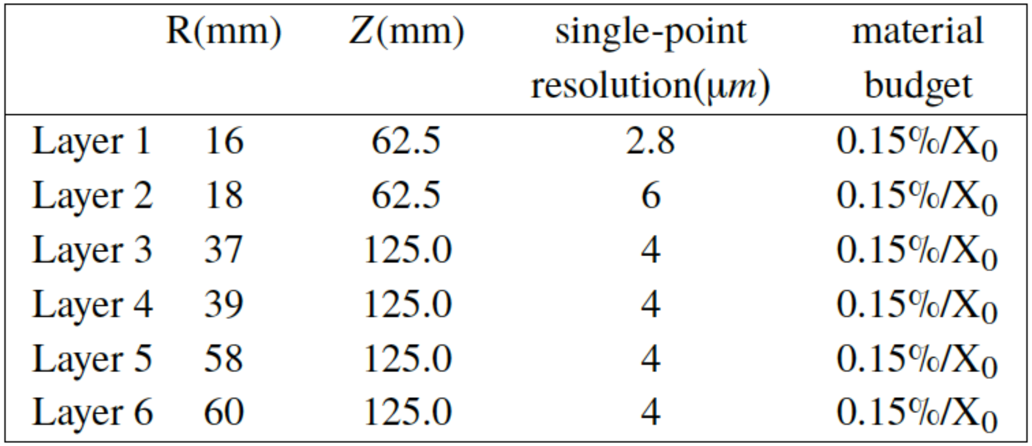
Vertex

Track momentum resolution...

Impact Para. Reconstruction: Tau finding, exotic signals...

Jet: Flavor Tagging & Charge measurements...

Vertex



	R(mm)	Z(mm)	single-point resolution(μm)	material budget
Layer 1	16	62.5	2.8	$0.15\%/X_0$
Layer 2	18	62.5	6	$0.15\%/X_0$
Layer 3	37	125.0	4	$0.15\%/X_0$
Layer 4	39	125.0	4	$0.15\%/X_0$
Layer 5	58	125.0	4	$0.15\%/X_0$
Layer 6	60	125.0	4	$0.15\%/X_0$

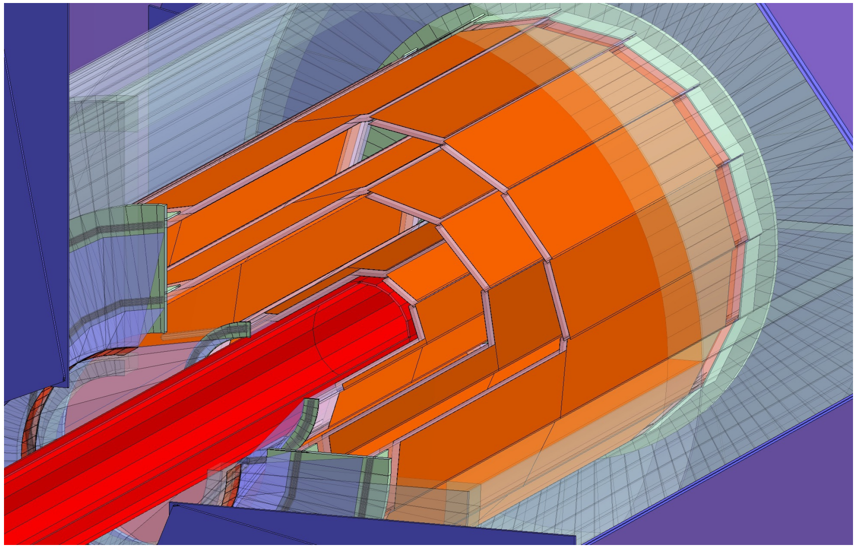
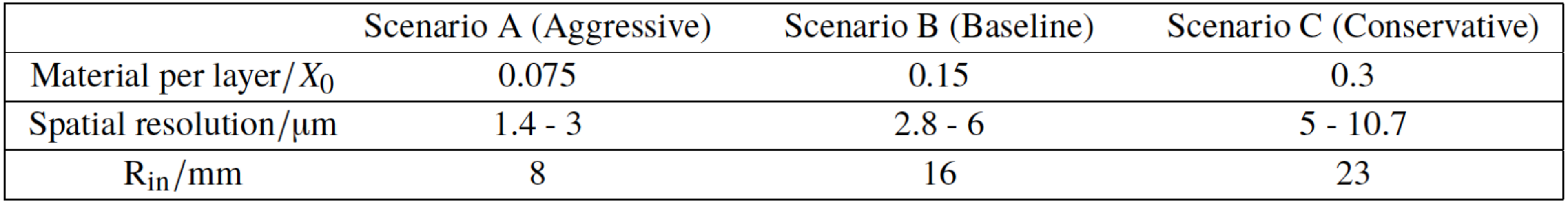


Table 2. Reference geometries.

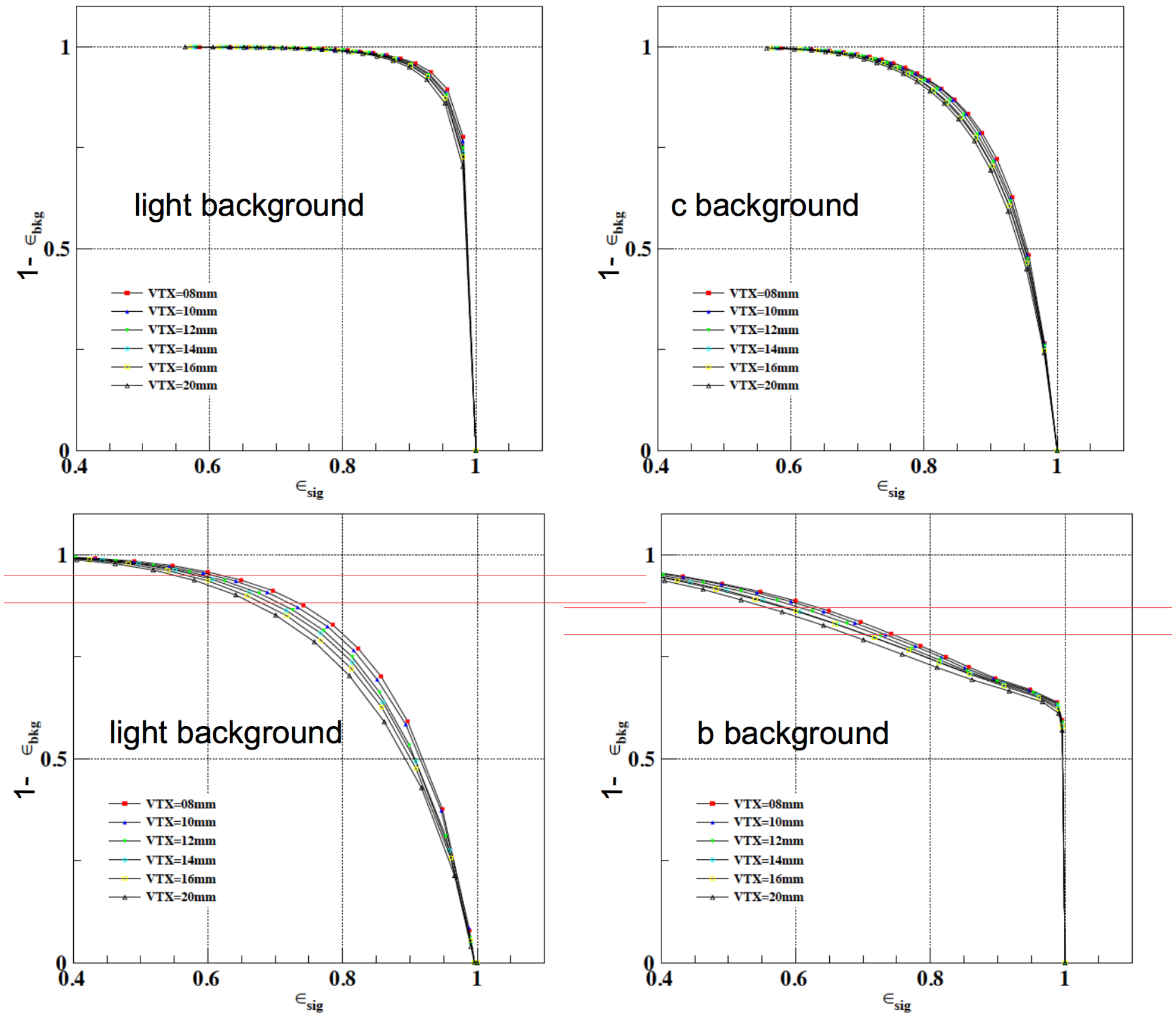


	Scenario A (Aggressive)	Scenario B (Baseline)	Scenario C (Conservative)
Material per layer/X_0	0.075	0.15	0.3
Spatial resolution/µm	1.4 - 3	2.8 - 6	5 - 10.7
R_{in}/mm	8	16	23

Flavor Tagging

- LCFIPlus Package
- Typical Performance at Z pole sample:
  - *B-tagging: eff/purity = 80%/90%*
  - *C-tagging: eff/purity = 60%/60%*

- Geometry Dependence of the Performance evaluated



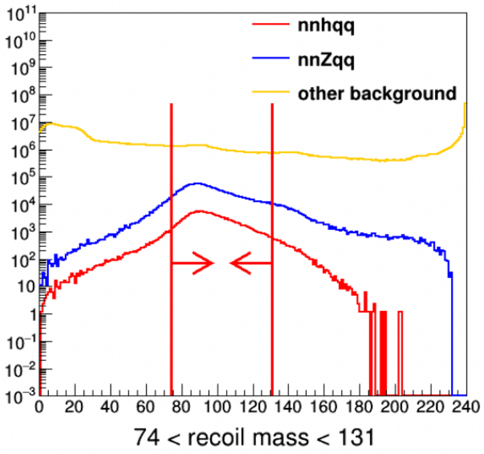
https://agenda.linearcollider.org/event/7645/contributions/40124/

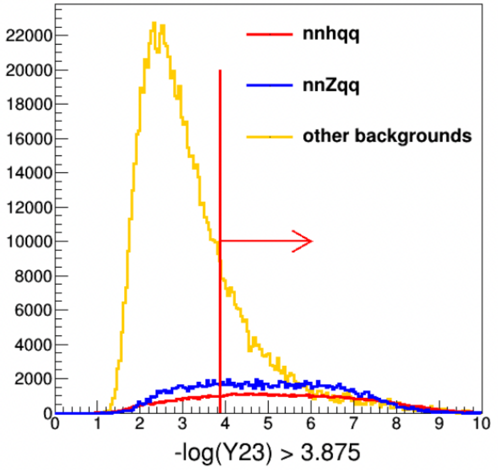
H→bb, cc, gg

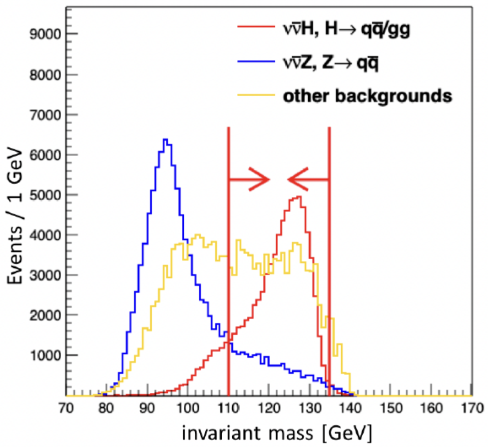
- Core physics measurements, benchmarks for BMR, Flavor Tagging & Color Singlet Identification
- Tactic
  - Analysis
    - Concentrate Higgs to di-jet event using Cut Chain + BDT
    - Using Flavor Tagging to disentangle different decay modes, and extract/resolve the relevant signal strengths
  - Optimization
    - Modeling the different Flavor tagging performance using interpolation method, and resolve the corresponding accuracies
- Ref:
  - *JINST 13 T09002 (2018)*
  - *JHEP 11 (2022) 100*

vvH, H→bb, cc, gg

	$\nu\nu Hq\bar{q}/gg$	2f	SW	SZ	WW	ZZ	Mixed	ZH	$\frac{\sqrt{S+B}}{S}$ (%)
total	178890	8.01E8	1.95E7	9.07E6	5.08E7	6.39E6	2.18E7	961606	16.86
recoilMass (GeV) $\in (74, 131)$	157822	5.11E7	2.17E6	1.38E6	4.78E6	1.30E6	1.08E6	74991	4.99
visEn (GeV) $\in (109, 143)$	142918	2.37E7	1.35E6	8.81E5	3.60E6	1.03E6	6.29E5	50989	3.92
leadLepEn (GeV) $\in (0, 42)$	141926	2.08E7	3.65E5	7.24E5	2.81E6	9.72E5	1.34E5	46963	3.59
multiplicity $\in (40, 130)$	139545	1.66E7	2.36E5	5.24E5	2.62E6	9.07E5	4977	42751	3.29
leadNeuEn (GeV) $\in (0, 41)$	138653	1.46E7	2.24E5	4.72E5	2.49E6	8.69E5	4552	42303	3.12
Pt (GeV) $\in (20, 60)$	121212	248715	1.56E5	2.48E5	1.51E6	4.31E5	999	35453	1.37
Pl (GeV) $\in (0, 50)$	118109	52784	1.05E5	74936	7.30E5	1.13E5	847	34279	0.94
-log10(Y23) $\in (3.375, +\infty)$	96156	40861	26088	60349	2.25E5	82560	640	10691	0.76
InvMass (GeV) $\in (116, 134)$	71758	22200	11059	6308	77912	13680	248	6915	0.64
BDT $\in (-0.02, 1)$	60887	9140	266	2521	3761	3916	58	1897	0.47

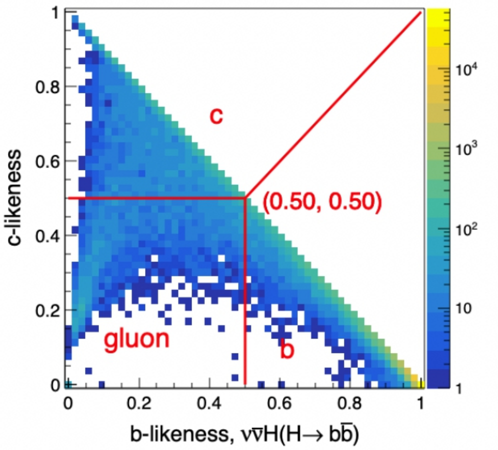


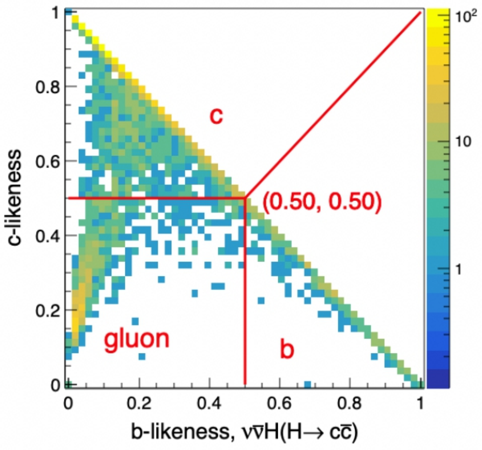


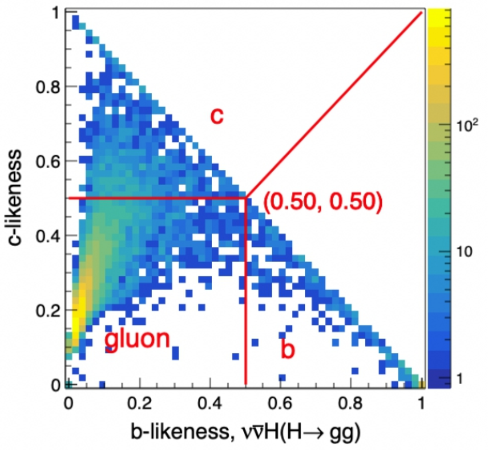


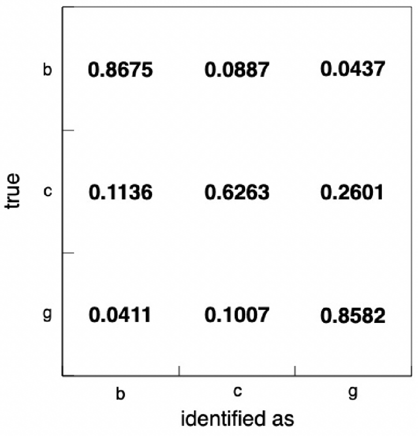
Thanks to BMR ~ 3.8%!

Flavor tagging @ vvH

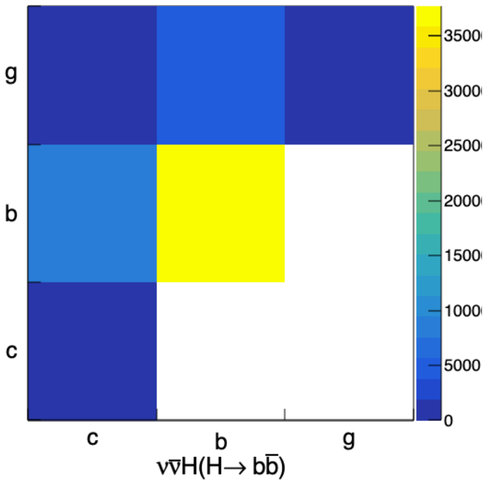


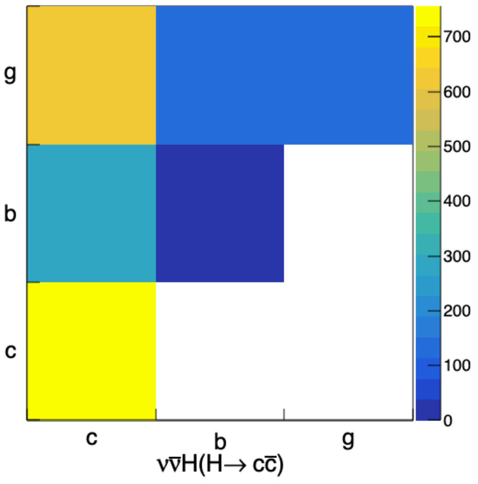


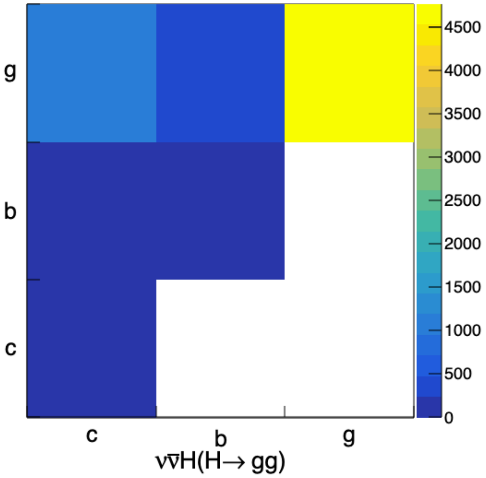


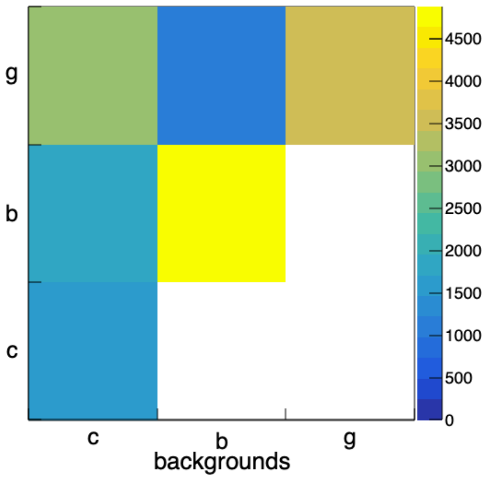


true \ identified as	b	c	g
b	0.8675	0.0887	0.0437
c	0.1136	0.6263	0.2601
g	0.0411	0.1007	0.8582

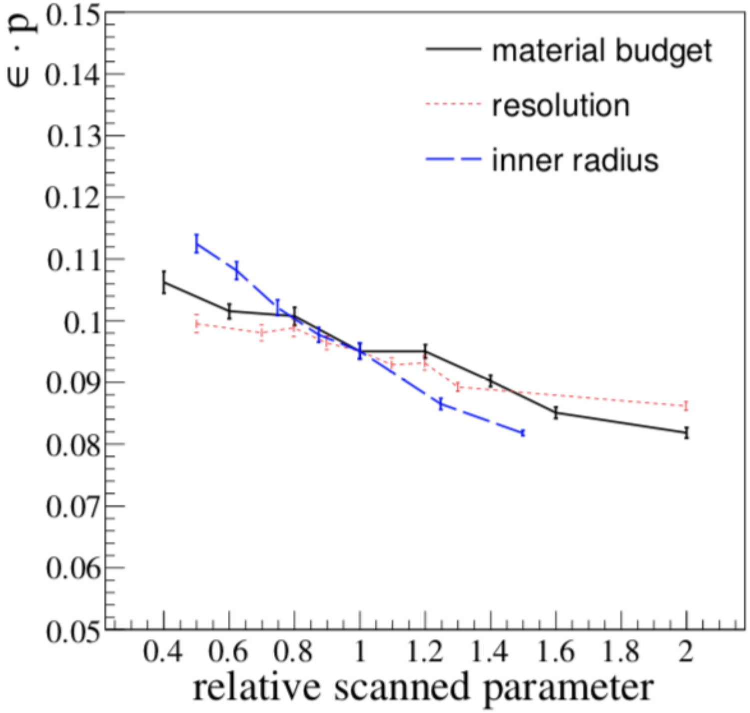








Flavor tagging V.S VTX geometry



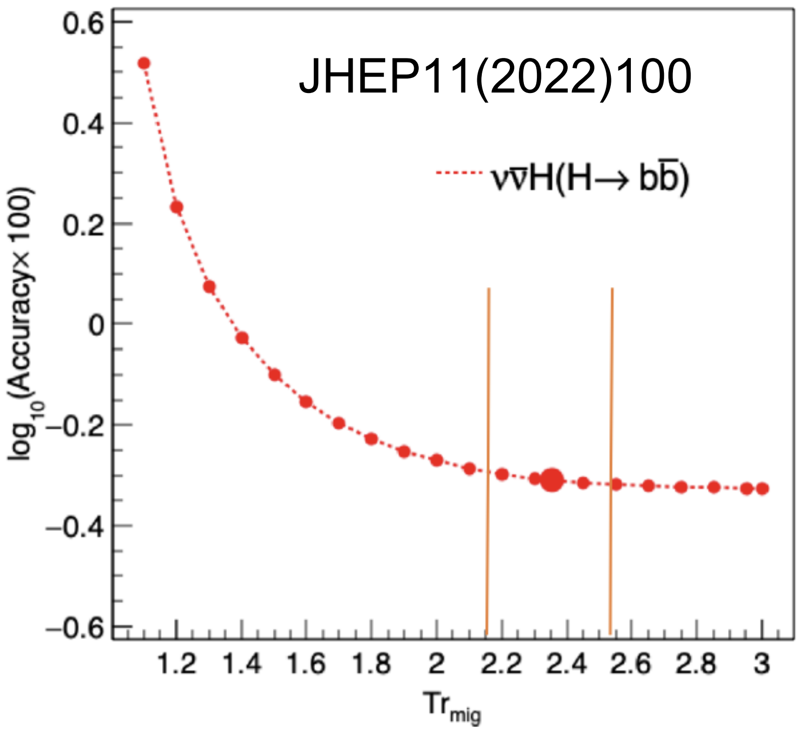
$$\epsilon \cdot p = 0.095(1 - 0.14\frac{\Delta x_{\mathrm{material}}}{x_{\mathrm{material}}})(1 - 0.09\frac{\Delta x_{\mathrm{resolution}}}{x_{\mathrm{resolution}}})(1 - 0.23\frac{\Delta x_{\mathrm{radius}}}{x_{\mathrm{radius}}})$$

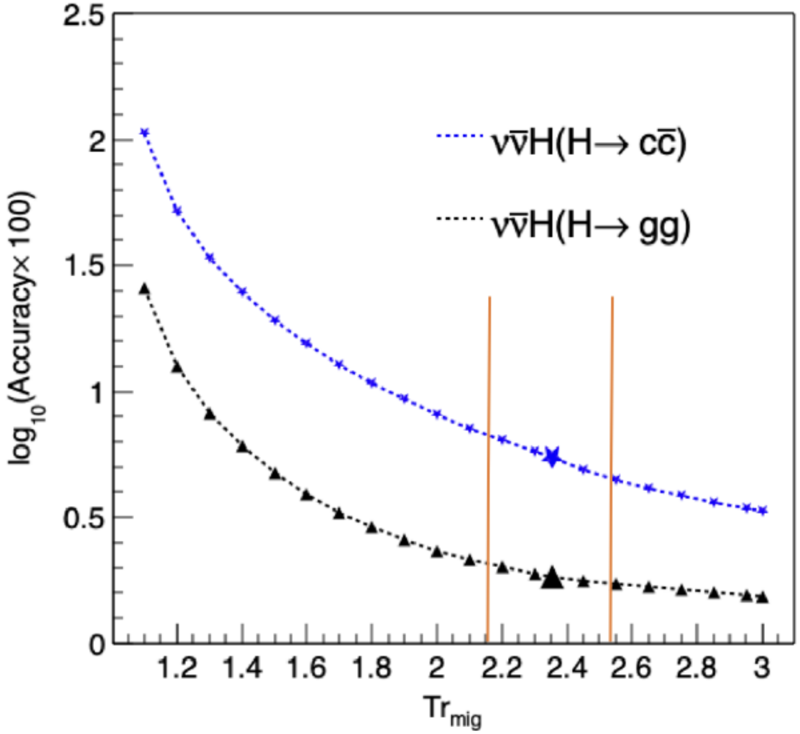
Table 2. Reference geometries.

	Scenario A (Aggressive)	Scenario B (Baseline)	Scenario C (Conservative)
Material per layer/X_0	0.075	0.15	0.3
Spatial resolution/µm	1.4 - 3	2.8 - 6	5 - 10.7
$\mathrm{R_{in}}$/mm	8	16	23
trace	2.3	2.1	1.9

$$Tr_{\mathrm{mig}} = 2.35 + 0.05 \cdot log_2 \frac{R^0_{\mathrm{material}}}{R_{\mathrm{material}}} + 0.04 \cdot log_2 \frac{R^0_{\mathrm{resolution}}}{R_{\mathrm{resolution}}} + 0.10 \cdot log_2 \frac{R^0_{\mathrm{radius}}}{R_{\mathrm{radius}}}.$$

Vertex



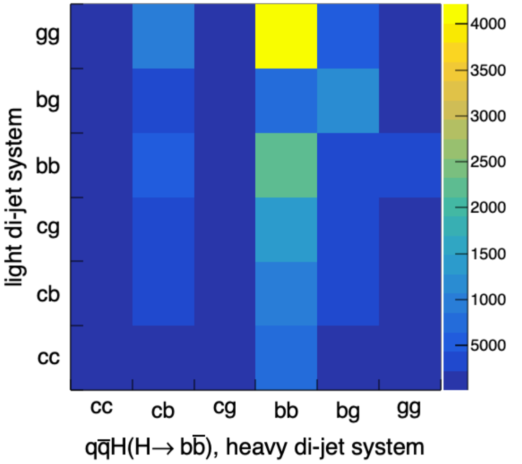


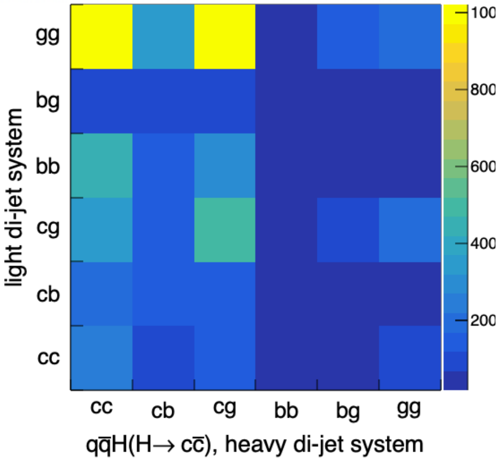
$$Tr_{\rm mig} = 2.35 + 0.05 \cdot log_2 \frac{R^0_{\rm material}}{R_{\rm material}} + 0.04 \cdot log_2 \frac{R^0_{\rm resolution}}{R_{\rm resolution}} + 0.10 \cdot log_2 \frac{R^0_{\rm radius}}{R_{\rm radius}}.$$

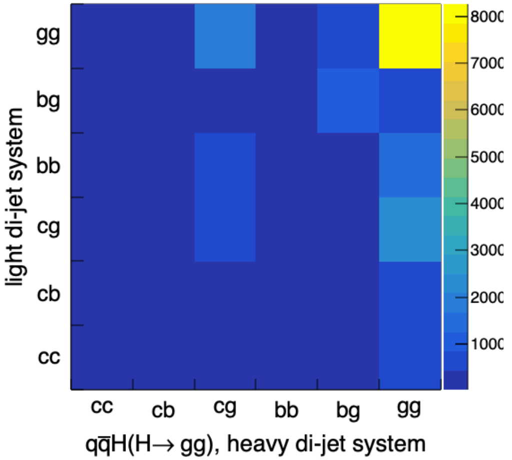
- Vertex: track impact para & 2nd vertex reconstruction: Flavor Tagging, etc
  - As close to the IP as possible
  - Limited by the beam induced background (~ beam energy & B-Field)

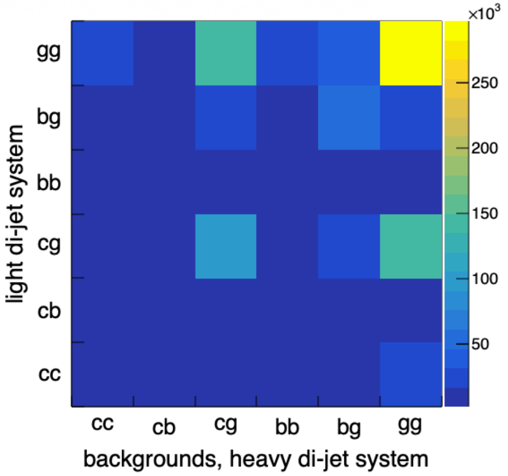
qqH, H→bb, cc, gg

	qqHqq	2f	SW	SZ	WW	ZZ	Mixed	ZH	$\frac{\sqrt{S+B}}{S}(\%)$
total	527488	8.01*E*8	1.95*E*7	9.07*E*6	5.08*E*7	6.39*E*6	2.18*E*7	613008	5.71
multiplicity $\in (27, +\infty)$	527488	3.04*E*8	1.46*E*7	3.37*E*6	4.85*E*7	6.00*E*6	1.81*E*7	577930	3.77
leadLepEn $\in (0, 59)$	527036	2, 98*E*8	6.76*E*6	2.44*E*6	3.93*E*7	5.40*E*6	1.79*E*7	531411	3.65
visEn $\in (199, 278)$	510731	1.21*E*8	1.29*E*6	551105	2.14*E*7	3.06*E*6	1.71*E*7	180571	2.52
leadNeuEn $\in (0, 57)$	509623	5.68*E*7	716161	168030	2.04*E*7	2.93*E*6	1.65*E*7	176387	1.94
thrust $\in (0, 0.86)$	460535	7.81*E*6	473732	132126	1.88*E*7	2.60*E*6	1.54*E*7	167863	1.47
$-log(Y_{34})$ $\in (0, 5.8875)$	451468	4.90*E*6	181432	119836	1.74*E*7	2.40*E*6	1.45*E*7	165961	1.40
HiggsJetsA $\in (2.18, 2\pi)$	326207	2.83*E*6	110156	58613	4.54*E*6	870276	3.74*E*6	96560	1.08
ZJetsA $\in (1.97, 2\pi)$	279030	1.37*E*6	33491	37101	2.39*E*6	496611	2.00*E*6	74005	0.93
ZHiggsA $\in (2.32, 2\pi)$	274530	1.32*E*6	17026	33847	2.28*E*6	468340	1.91*E*6	69620	0.92
circle	268271	1.20E6	10193	31567	2.13*E*6	424514	1.79E6	65434	0.90
BDT $\in (0.02, 1)$	192278	378300	40	307	271436	141446	244126	30022	0.57









Relative accuracies on signal strength: 0.35%/7.7%/4.0%, for bb/cc/gg respectively.

Interpolation

$$M_{mig} = \frac{Tr_{mig} - Tr_{opt}}{Tr_{I} - Tr_{opt}} \cdot (M_{I} - M_{opt}) + M_{opt}$$

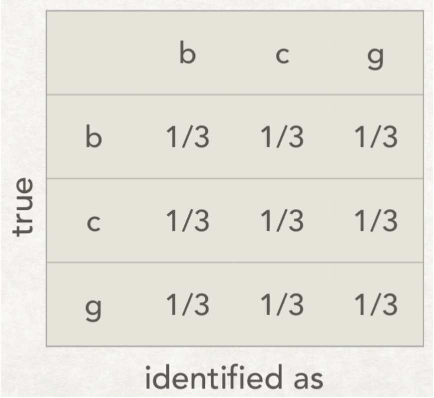
$$M_{mig} = \frac{Tr_{mig} - Tr_{opt}}{Tr_{1/3} - Tr_{opt}} \cdot (M_{1/3} - M_{opt}) + M_{opt}$$

Perfect

true	b	c	g
b	1	0	0
c	0	1	0
g	0	0	1

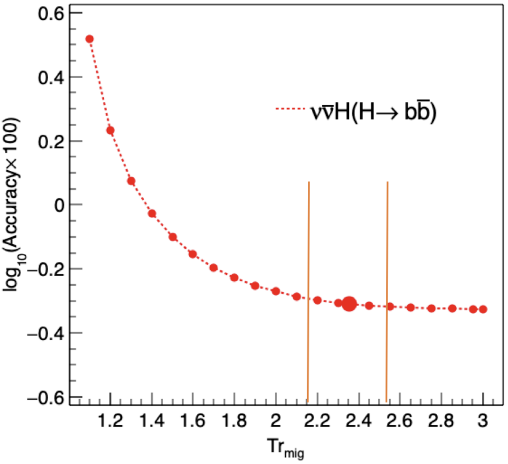
identified as

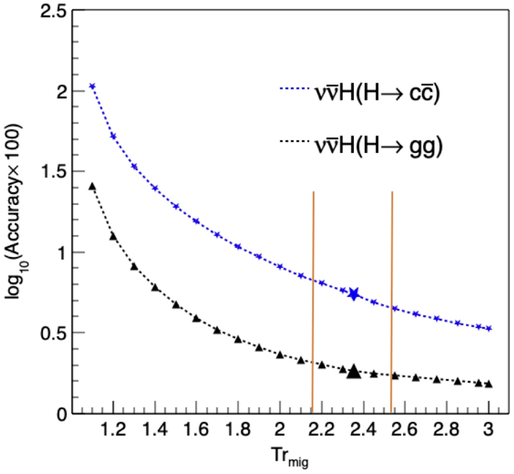
Worst

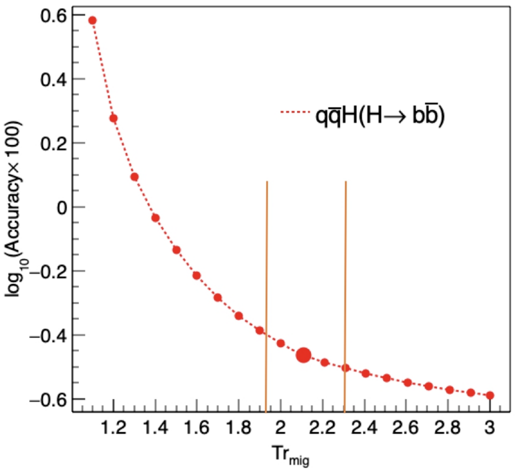


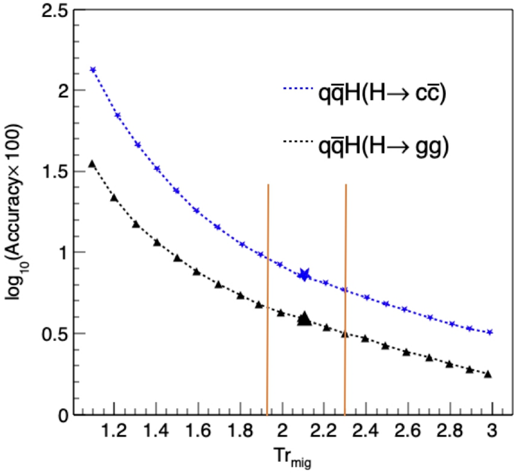
true	b	c	g
b	1/3	1/3	1/3
c	1/3	1/3	1/3
g	1/3	1/3	1/3

identified as









- Compared to baseline, perfect Flavor tagging improves the accuracy by 2%/63%/13% for vvH and 35%/120%/180% for qqH channels (bb, cc, gg)

Vcb from W decay

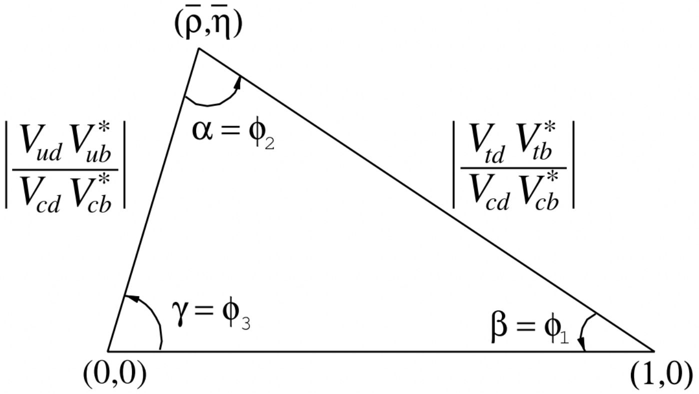
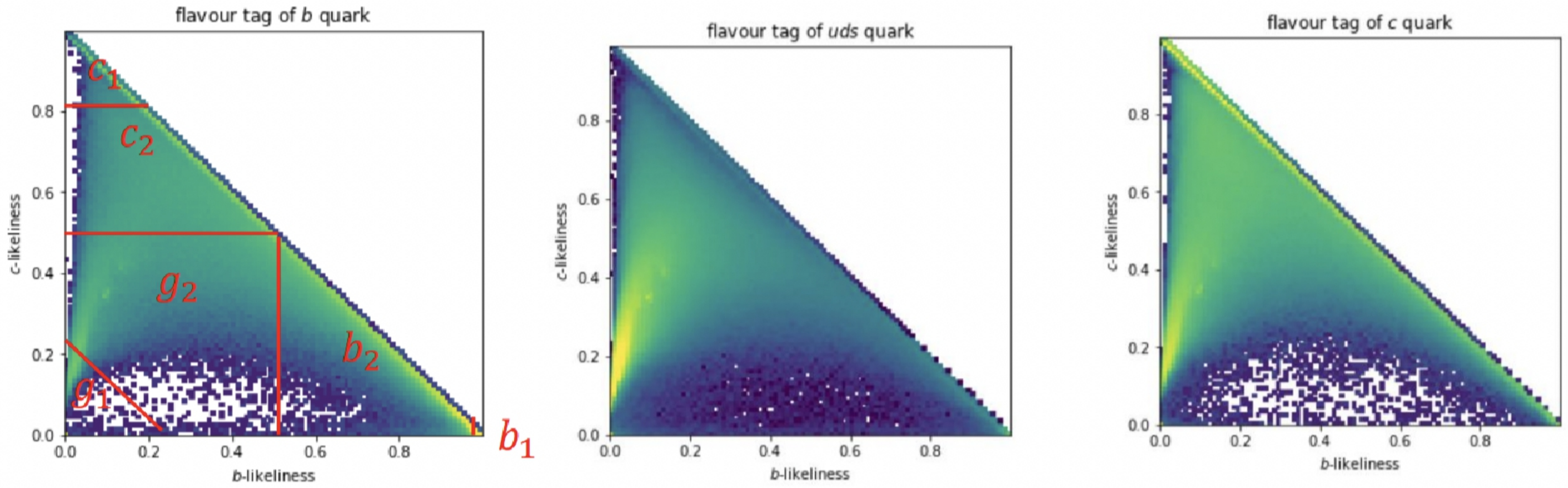


Figure 12.1: Sketch of the unitarity triangle.

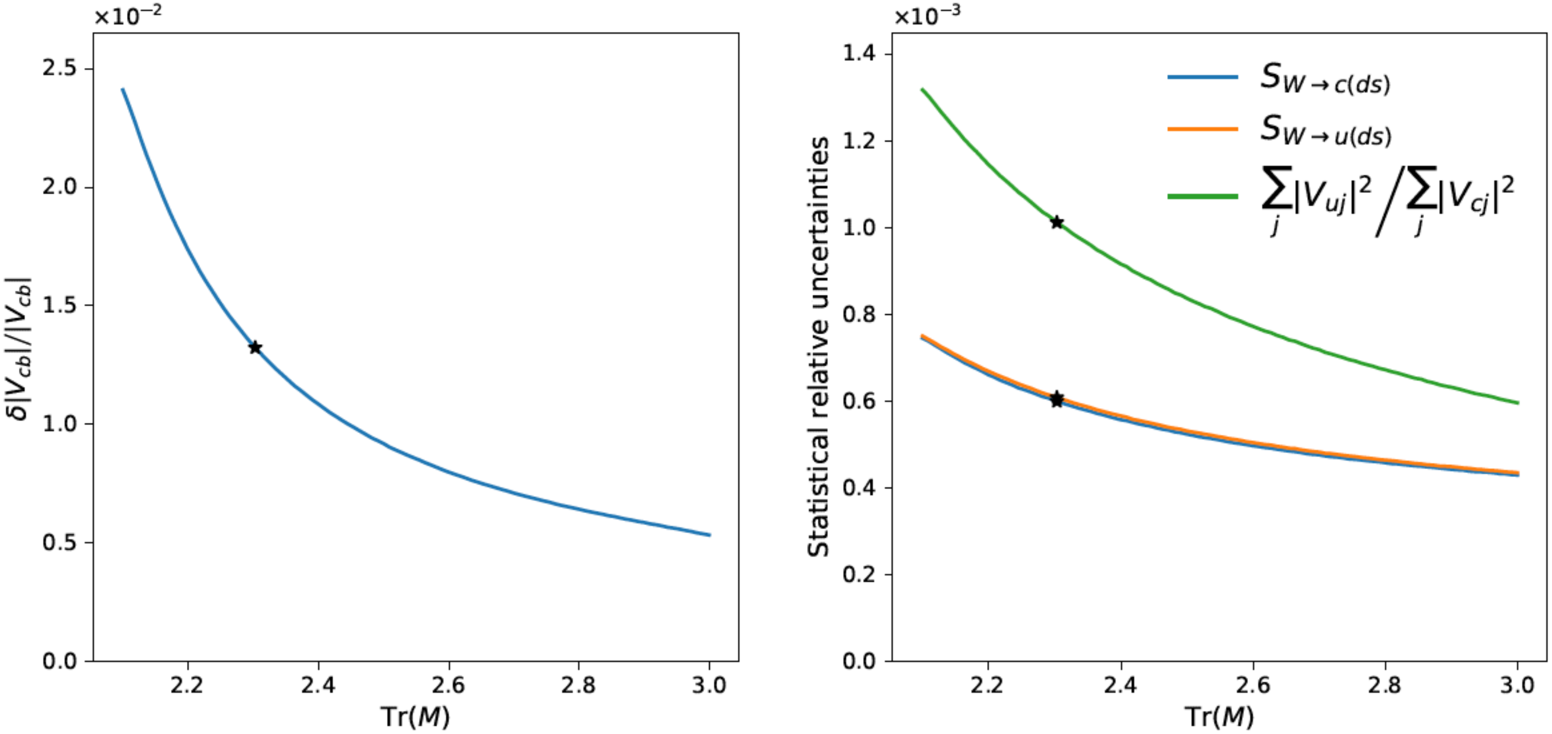
$$|V_{cb}| = (41.0 \pm 1.4) \times 10^{-3} .$$

$$M = \begin{array}{c|cccccc} & \mathbf{b1} & \mathbf{b2} & \mathbf{c1} & \mathbf{c2} & \mathbf{g1} & \mathbf{g2} \\ \mathrm{b} & 0.47 & 0.378 & 0.0197 & 0.0965 & 0.00397 & 0.0315 \\ \mathrm{c} & 0.00042 & 0.078 & 0.298 & 0.373 & 0.0682 & 0.182 \\ \mathrm{uds} & 0.000104 & 0.00477 & 0.00145 & 0.054 & 0.538 & 0.401 \end{array}$$

Flavour tagging at Z-pole

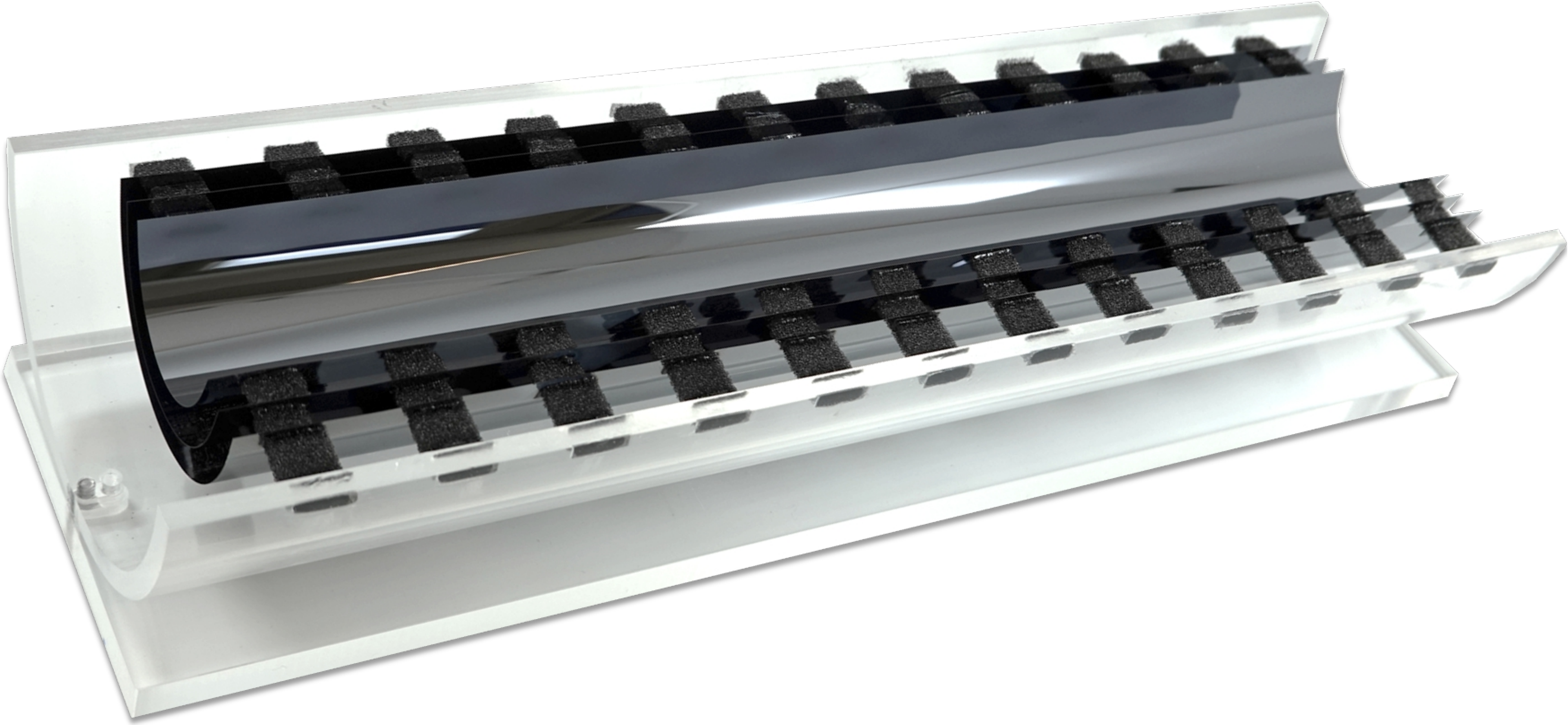


Vertex



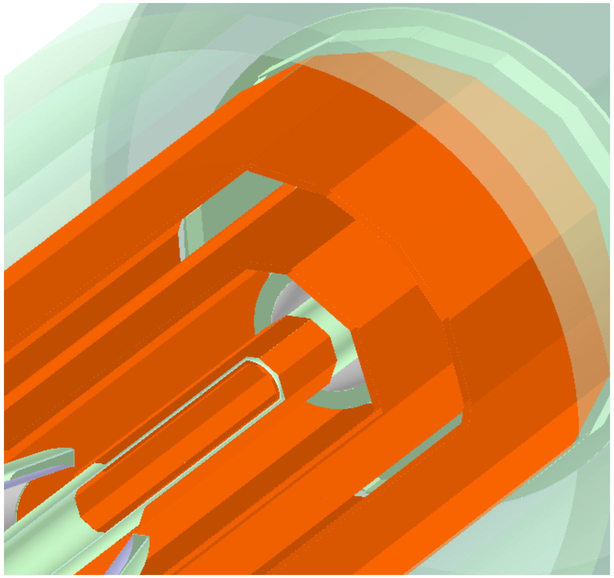
Similar performance dependence on CKM measurements at 240 GeV using semi-leptonic WW events

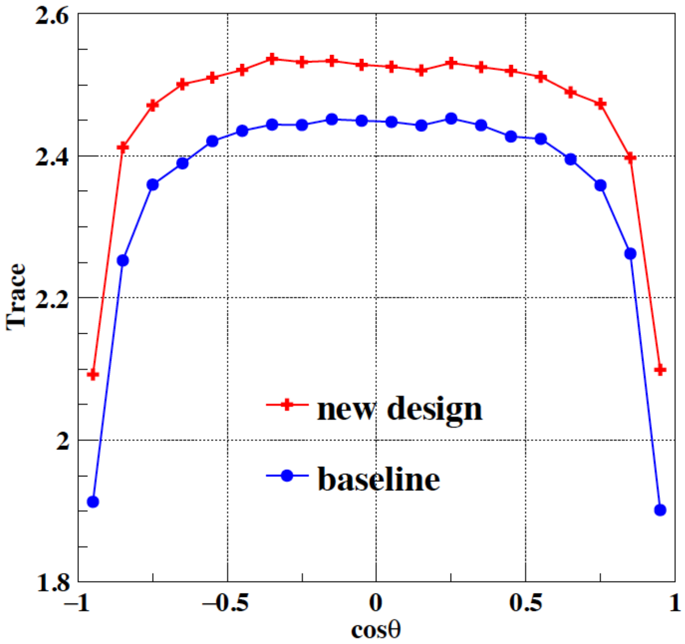
...ALICE ITS3...



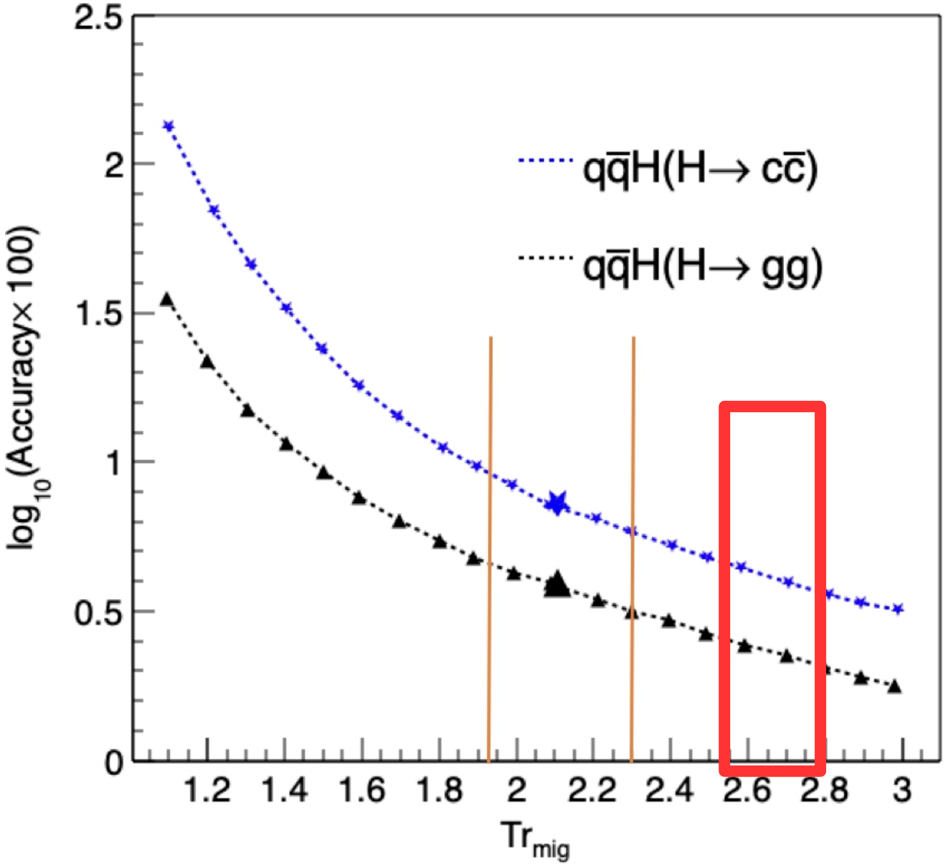
Vin

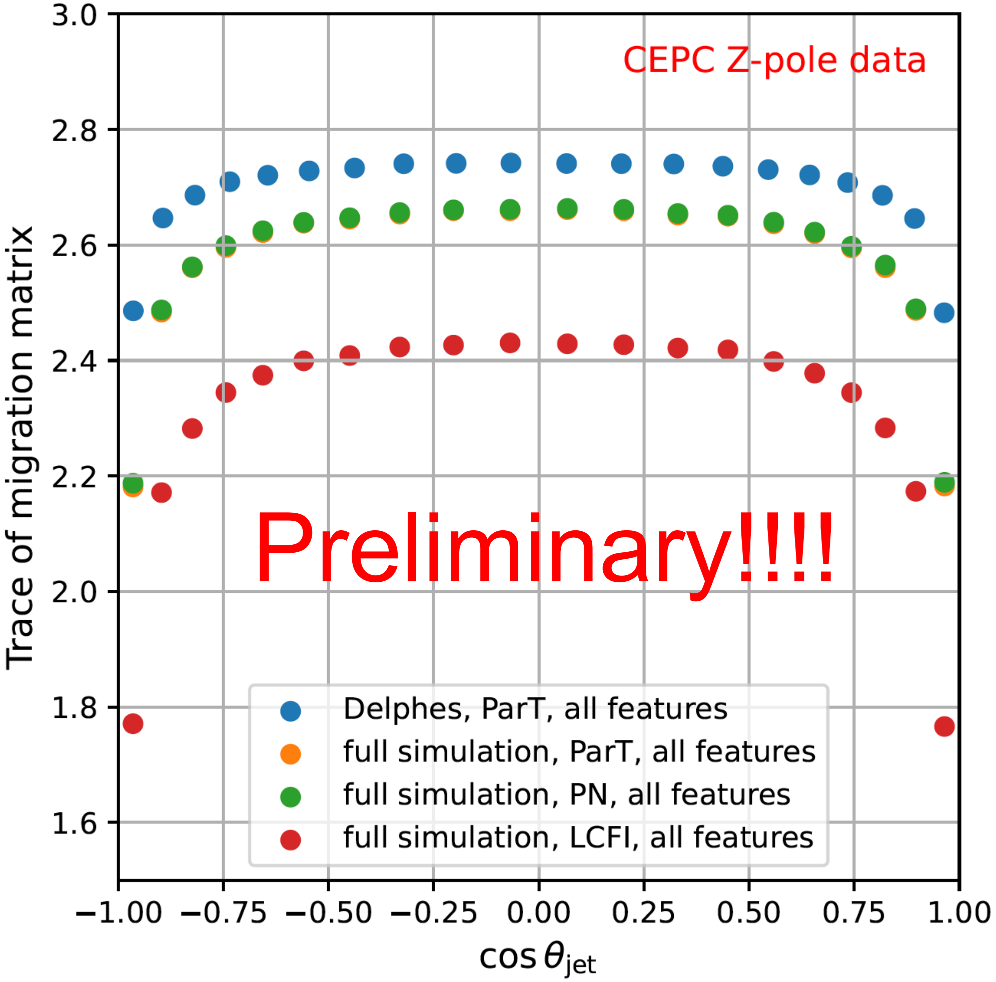
- Tr(MM) in the barrel
  - 2.45 for baseline (?)
  - 2.55 for 8 mm inner radius (9 mm)
- Compared to Baseline:
  - 10 mm beam pipe with silicon outside/inside improves the accuracy of g(Hcc) and |Vcb| measurement by ~20%
- Vin:
  - Pro:
    - Closer to the IP with same beam pipe radius
    - No multiple scattering to the 1st layer
    - Loose the material constrain of beam pipe: more efficient cooling, etc
  - Challenges:
    - Vacuum level
    - Radiation tolerance
    - Power & Signal → Wireless?





Perspective to the far future





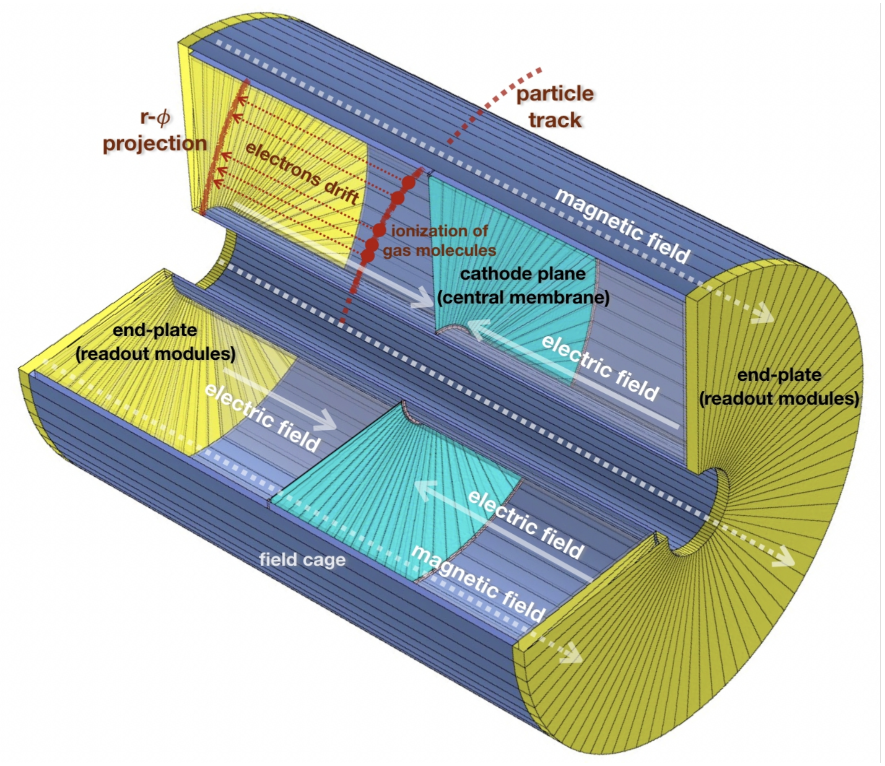
- Vin
- Much intelligent algorithm...: ~ 50% improvements

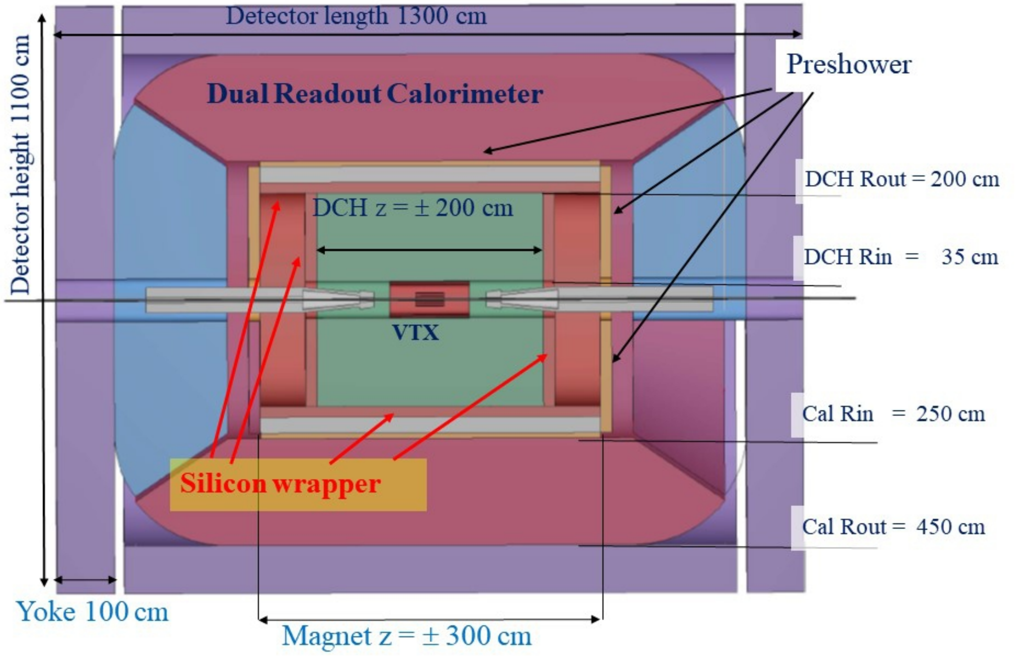
Tracker

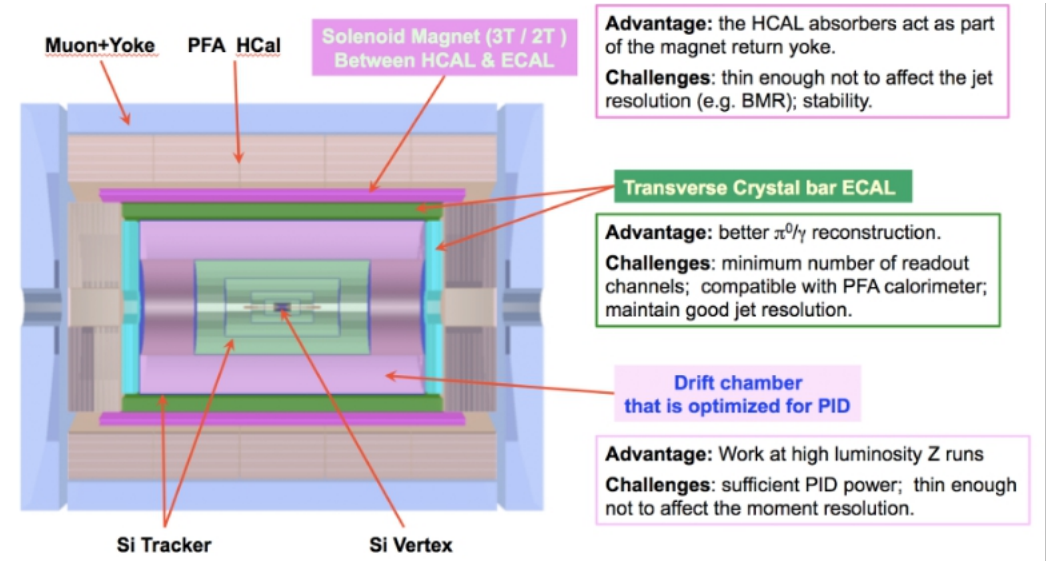
Tracking & Pid

Requirement

- Acceptance |cos(theta)| < 0.99 – 0.995...
- Momentum threshold: ~o(0.1 GeV) for Flavor Program (D*→D + pi)
- Efficiency: should ~ 100% within the energy & solid angle acceptance
- Momentum resolution:
  - δ(m)/m ~ 0.1% for Higgs with di-muon final state
  - δ(m)/m < 0.1% for narrow hadrons in the flavor program
    - Heavy flavor Hadron: D, B, ...
    - Lambda, Ks, Phi...
    - J/psi, Upsilon, ...
- Pid:
  - 3 sigma pi-kaon separation
  - 3% dE/dx (dN/dx) resolution
  - > 95% efficiency/purity for charged Kaon id in hadronic Z sample







Advantage: the HCAL absorbers act as part of the magnet return yoke.

Challenges: thin enough not to affect the jet resolution (e.g. BMR); stability.

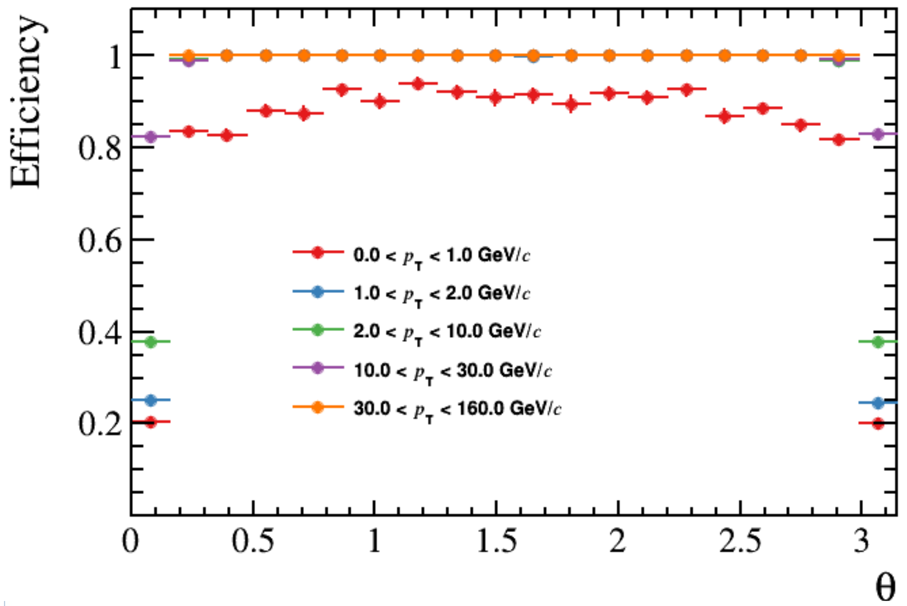
Advantage: better π^0/γ reconstruction.

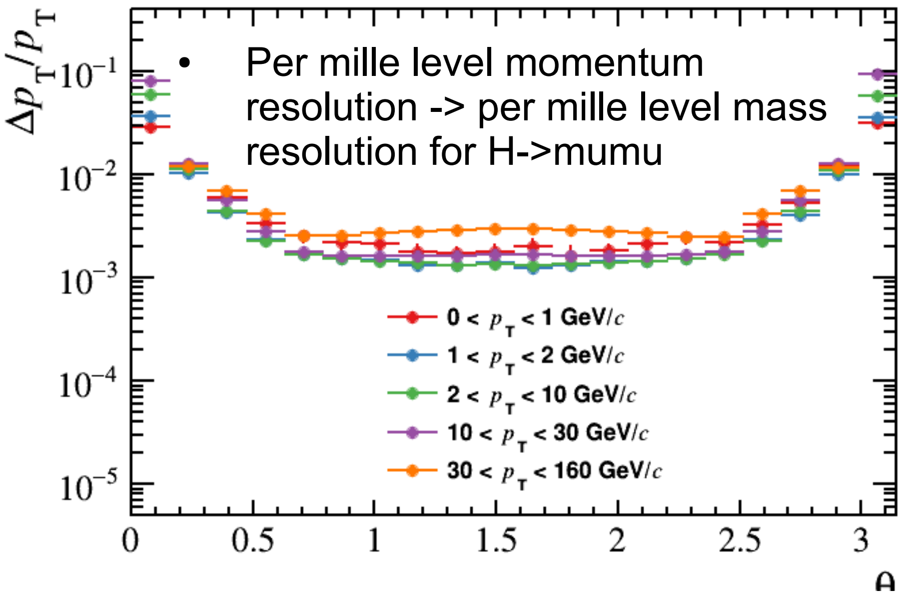
Challenges: minimum number of readout channels; compatible with PFA calorimeter; maintain good jet resolution.

Advantage: Work at high luminosity Z runs

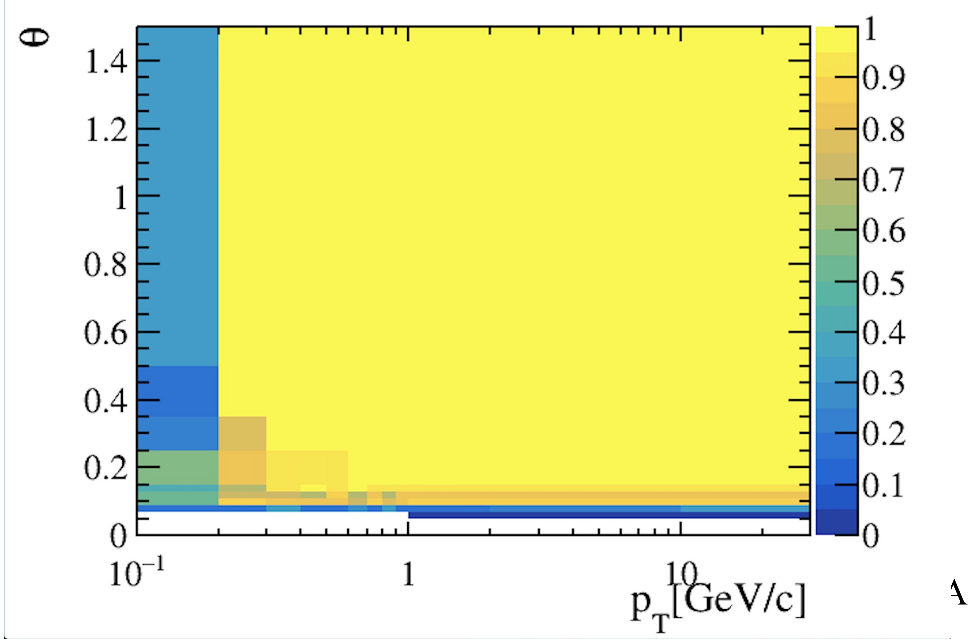
Challenges: sufficient PID power; thin enough not to affect the moment resolution.

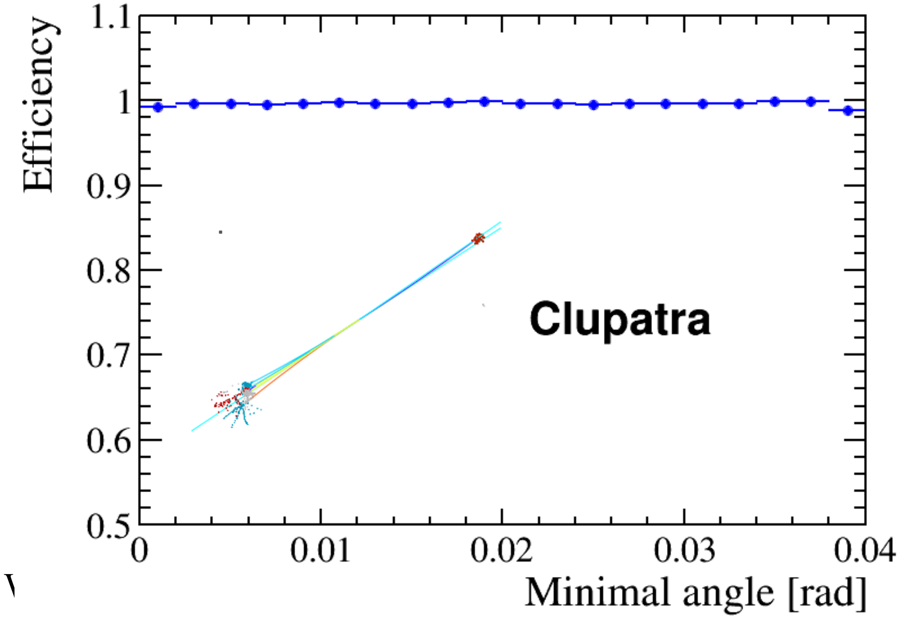
Tracking performance at baseline





- Per mille level momentum resolution -> per mille level mass resolution for H->mumu





Bs→Phi vv

PHYSICAL REVIEW D 105, 114036 (2022)

https://arxiv.org/pdf/2201.07374.pdf

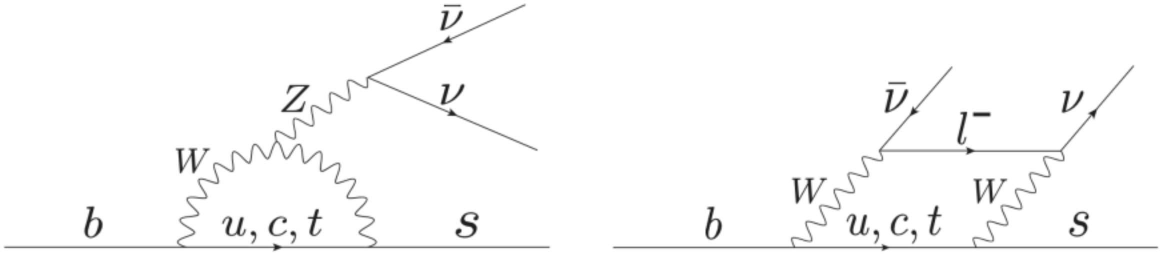
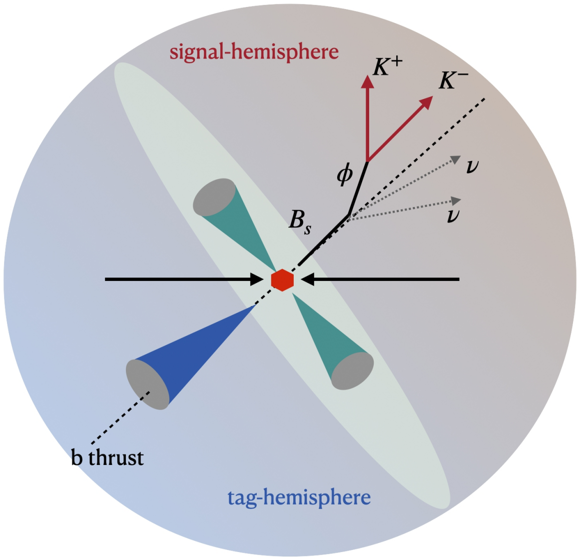
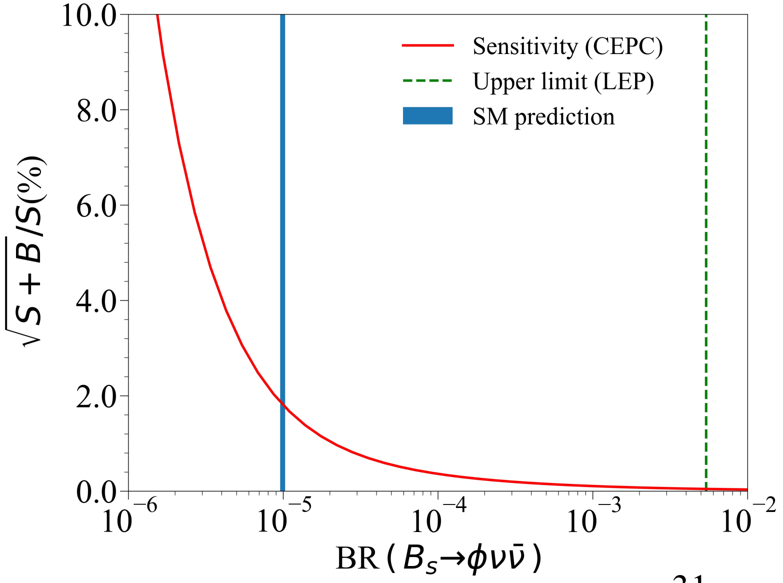


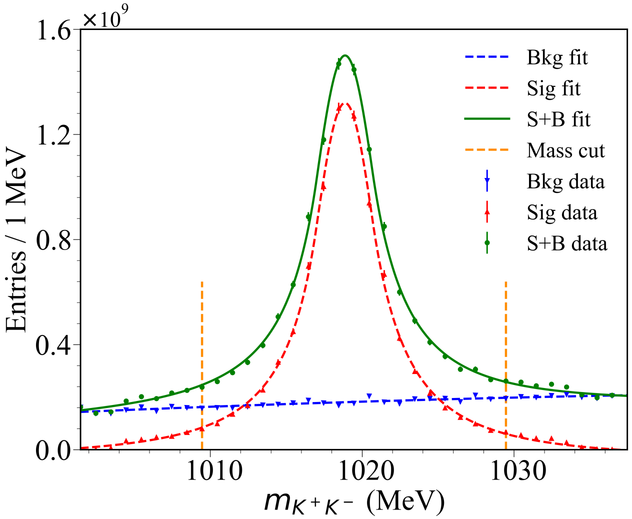
FIG. 1. The penguin and box diagrams of $b \to s\nu\bar{\nu}$ transition at the leading order.

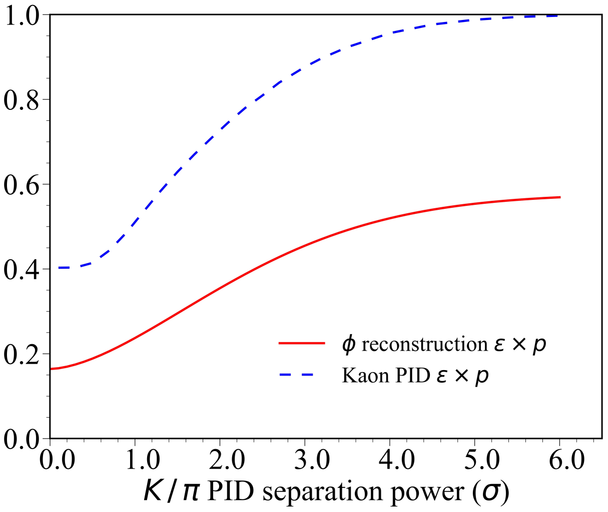


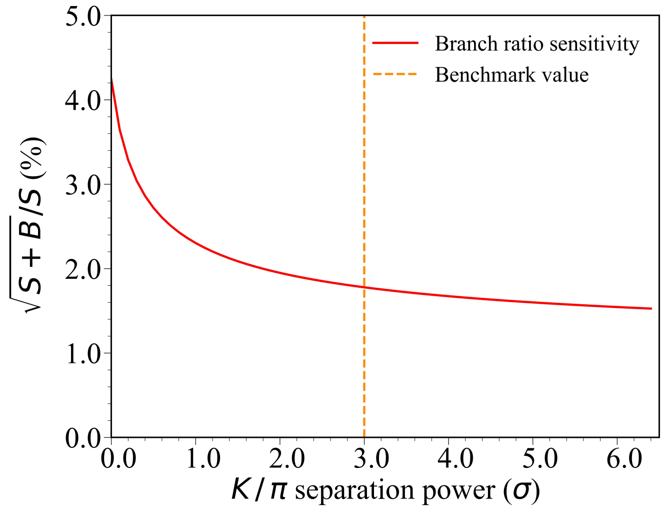


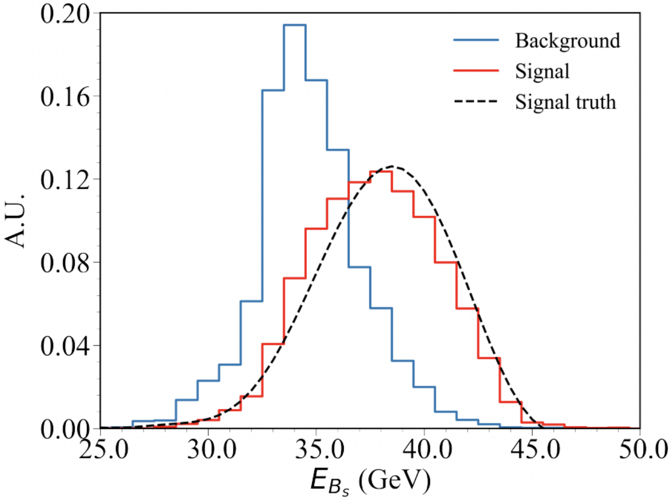
- Key ingredient to understand FCNC anomaly...
- Critical Physics Objects: Phi (and charged Kaon), 2nd VTX, Missing E/P, b-jet at opposite side
- Percentage level accuracy anticipated at Tera-Z

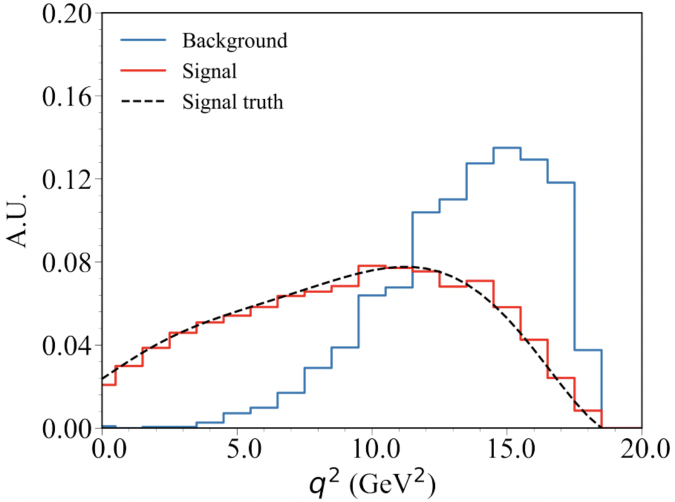
Bs→Phi vv









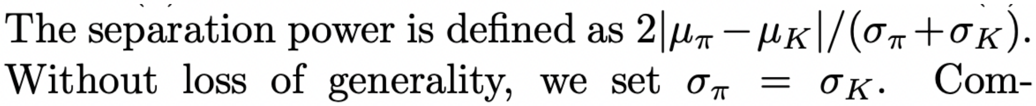


$$M_{\text{tag}} = \sqrt{\left(\sum p^{\text{vis}}_{\text{tag}}\right)^2}\,,$$

$$M^{(i)}_{\text{sig}} = \sqrt{\left(\sum p^{\text{vis}}_{\text{sig}} + p^{(i-1)}_{B_s} - p_\phi\right)^2}\,,$$

$$E^{(i)}_{B_s} = \frac{s + (M^{(i-1)}_{\text{sig}})^2 - M^2_{\text{tag}}}{2\sqrt{s}} - E_{\text{sig}} + E_\phi\,,$$

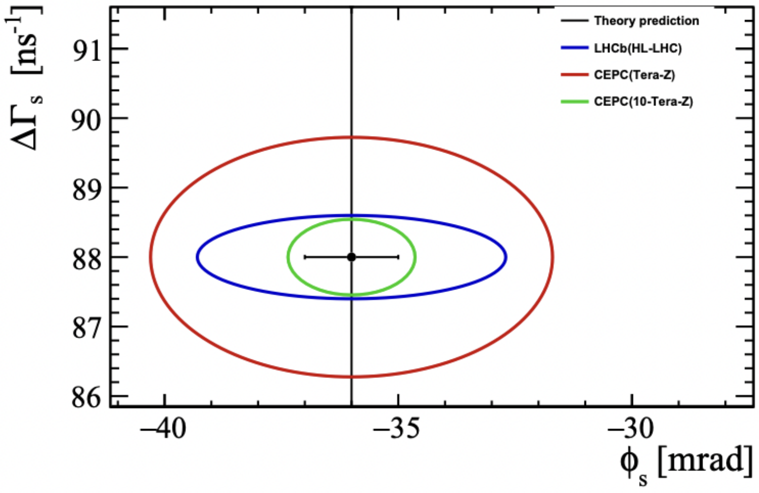
$$(q^2)^{(i)} = (p^{(i-1)}_{B_s} - p_\phi)^2\,,$$

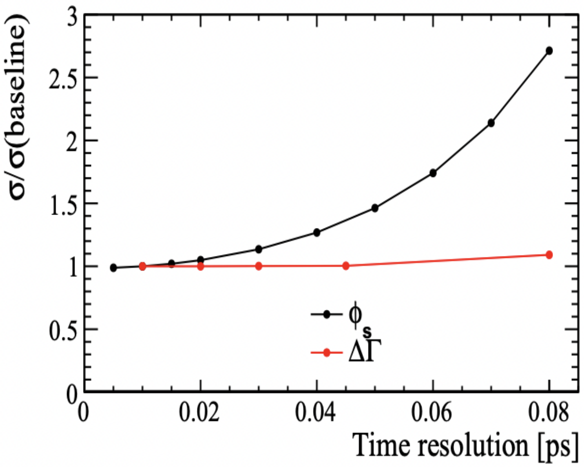


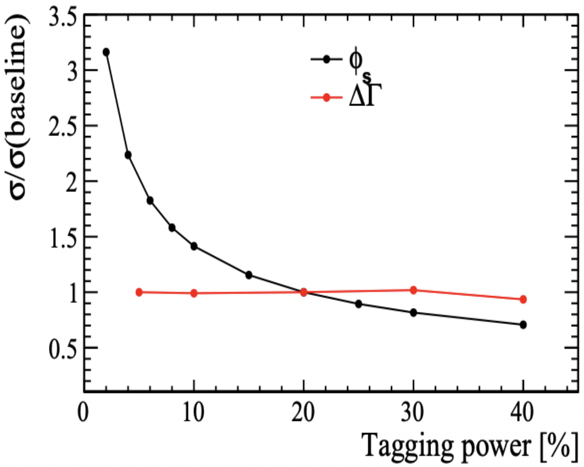
The separation power is defined as $2|\mu_\pi - \mu_K|/(\sigma_\pi + \sigma_K)$. Without loss of generality, we set $\sigma_\pi = \sigma_K$. Com-

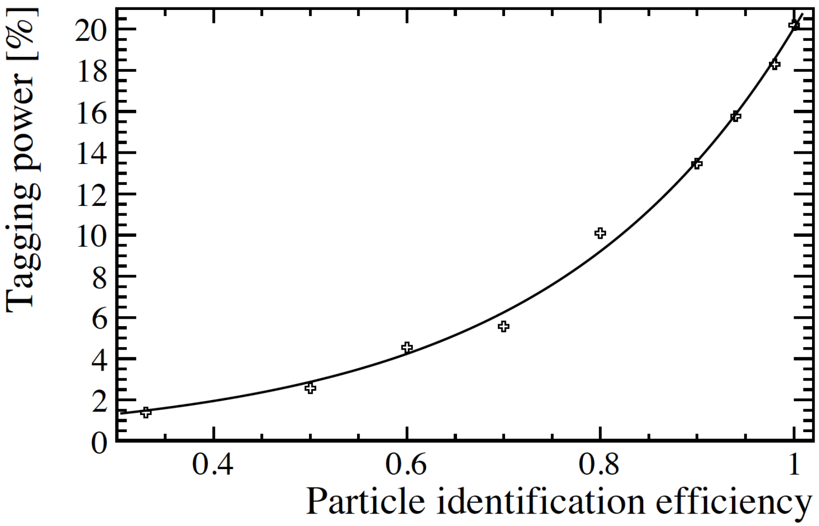
Bs→Jpsi/Phi

	LHCb(HL-LHC)	CEPC(Tera-Z)	CEPC/LHCb
$b\bar{b}$ statics	43.2×10^{12}	0.152×10^{12}	1/284
Acceptance×efficiency	7%	75%	10.7
Br	6×10^{-6}	12×10^{-6}	2
Flavour tagging	4.7%	20%	4.3
Time resolution $(\exp(-\frac{1}{2}\Delta m_s^2\sigma_t^2{}^2)$	0.52	1	1.92
scaling factor ξ	0.0014	0.0019	0.8
$\sigma(\phi_s)$	3.3 mrad	4.3 mrad	



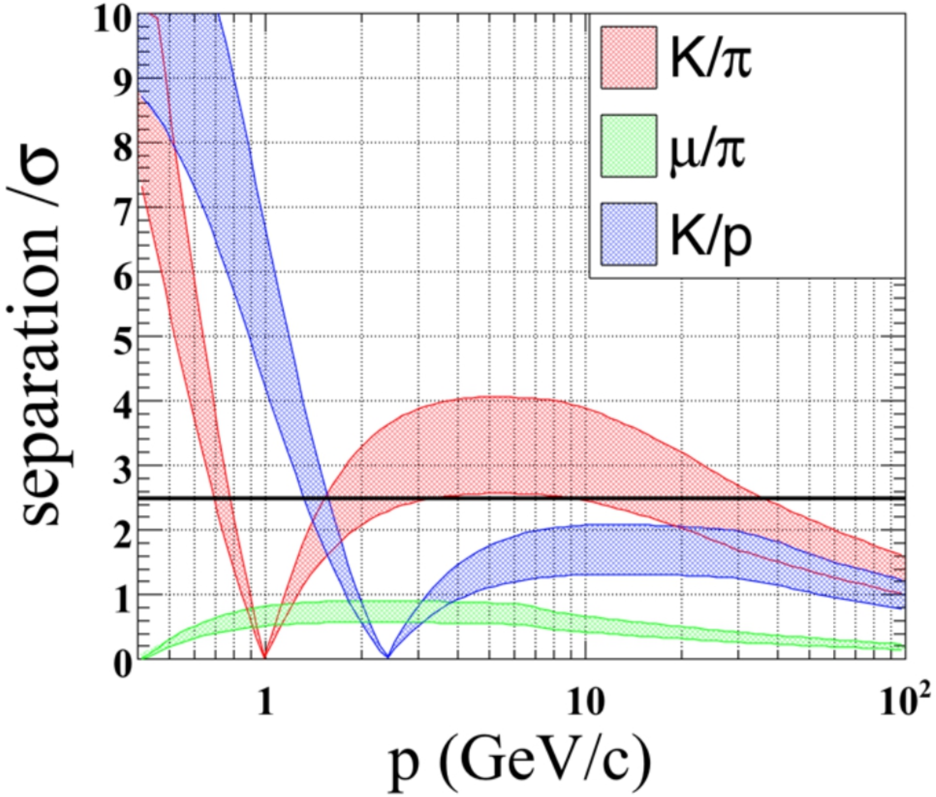


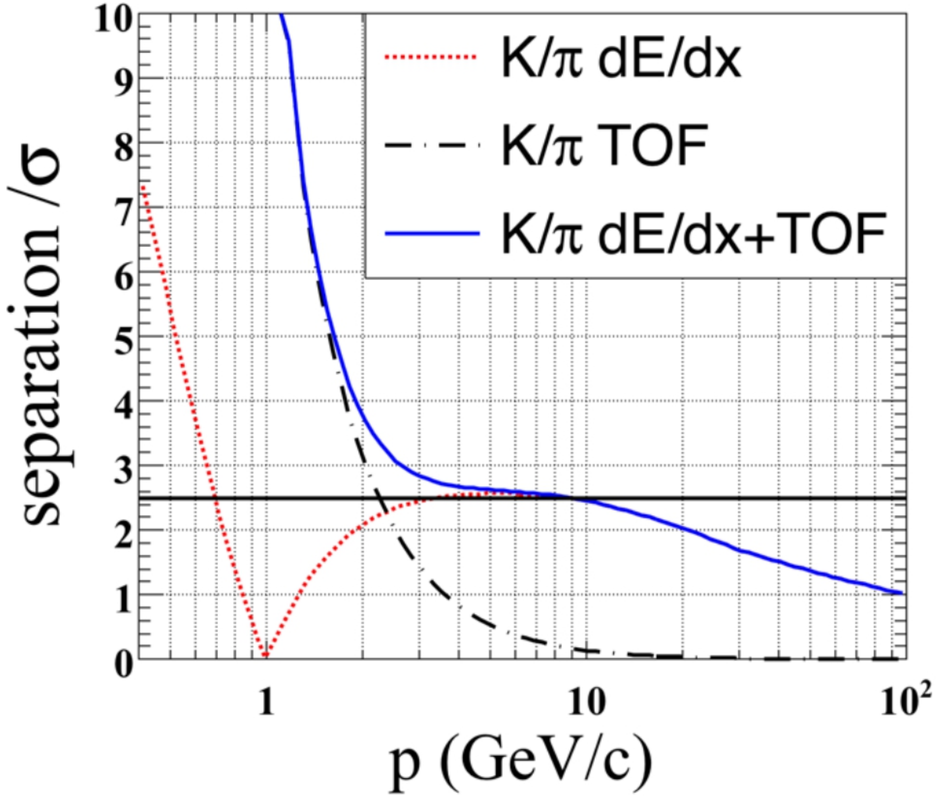




https://arxiv.org/abs/2205.10565

Kaon





Highly appreciated in flavor physics @ CEPC Z pole

TPC dEdx + ToF of 50 ps

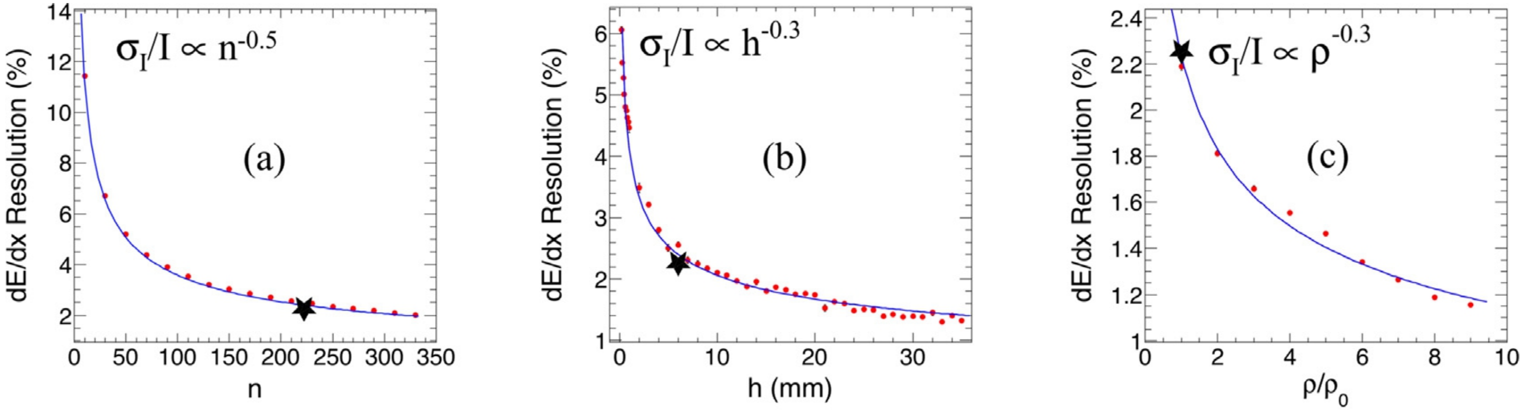
At inclusive Z pole sample:

Conservative estimation gives efficiency/purity of 91%/94% (2-20 GeV, 50% degrading +50 ps ToF)

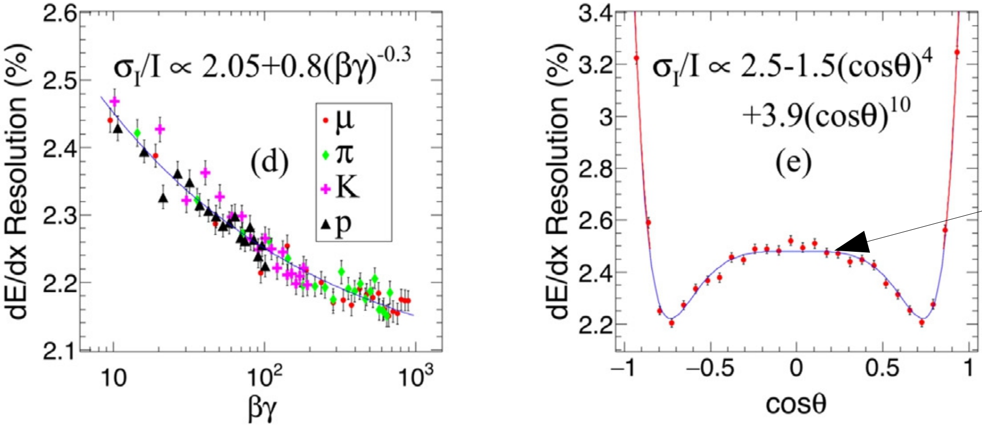
Could be improved to 96%/96% by better detector/DAQ performance (20% degrading + 50 ps ToF)

Eur. Phys. J. C (2018) 78:464

Dedx at truth level: Differential



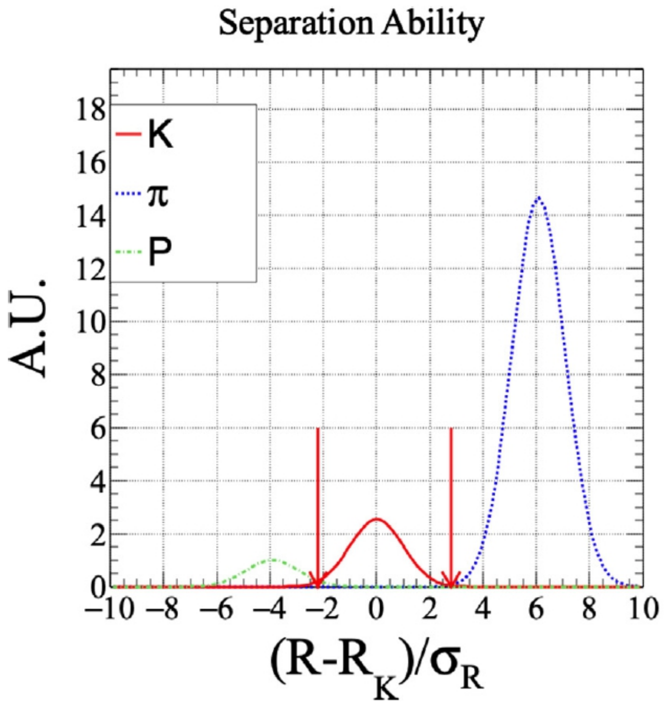
(a) (b) (c)

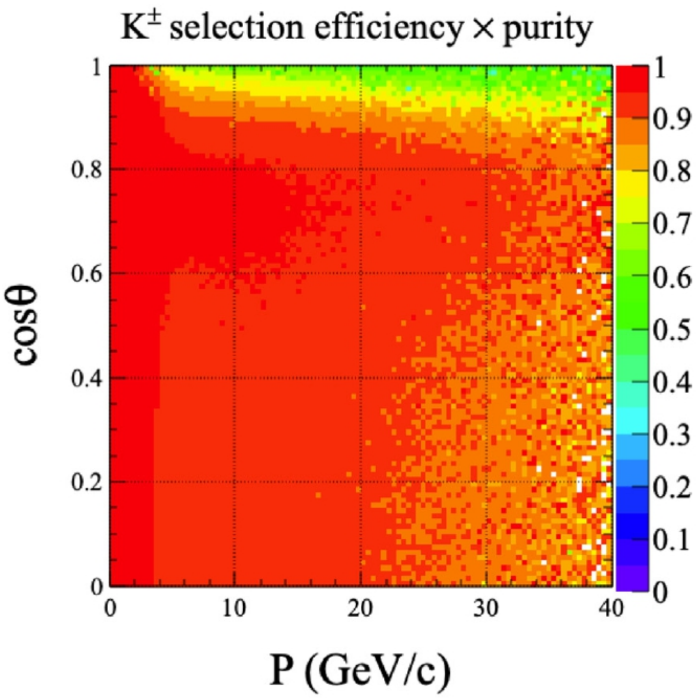


(d) (e)

2.5% relative accuracy of dE/dx at truth level, in barrel

Pid performance





	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

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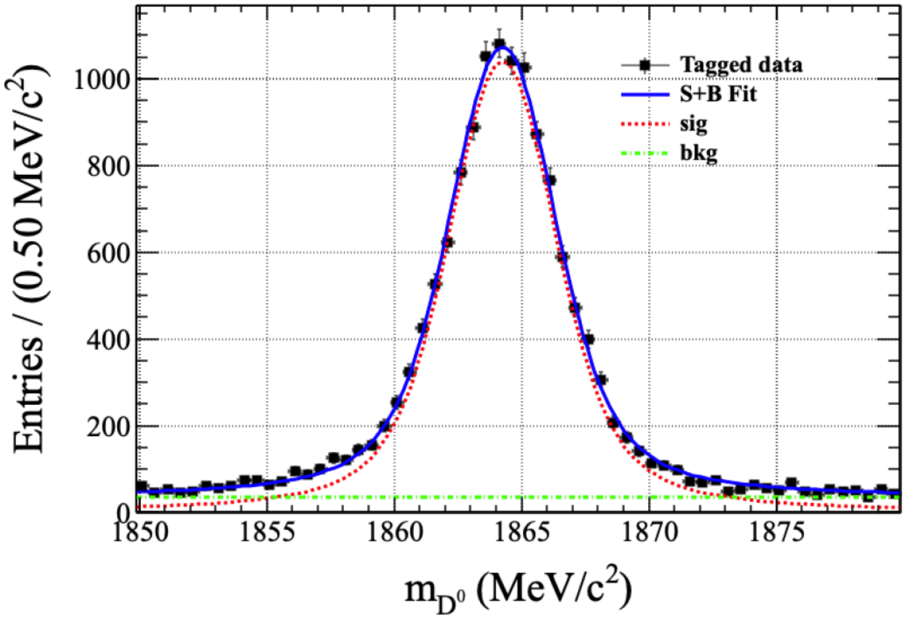
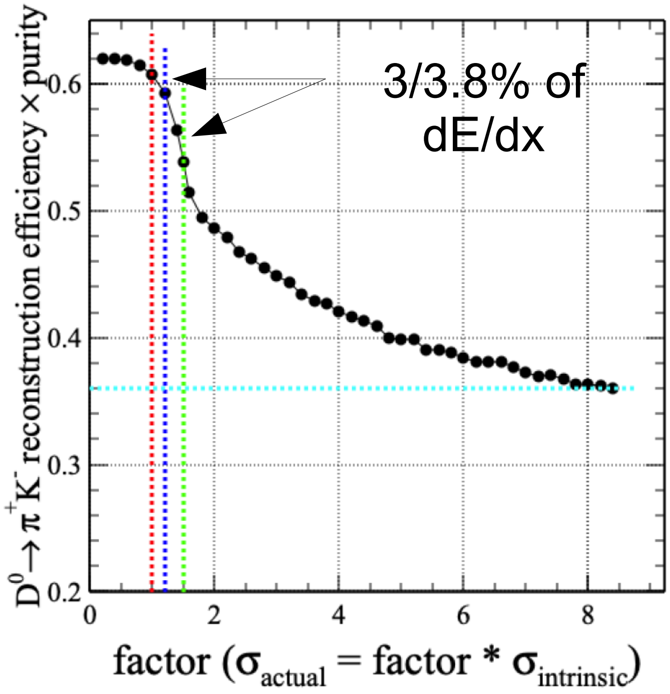
$D^0 \rightarrow \pi^+ K^-$ reconstruction

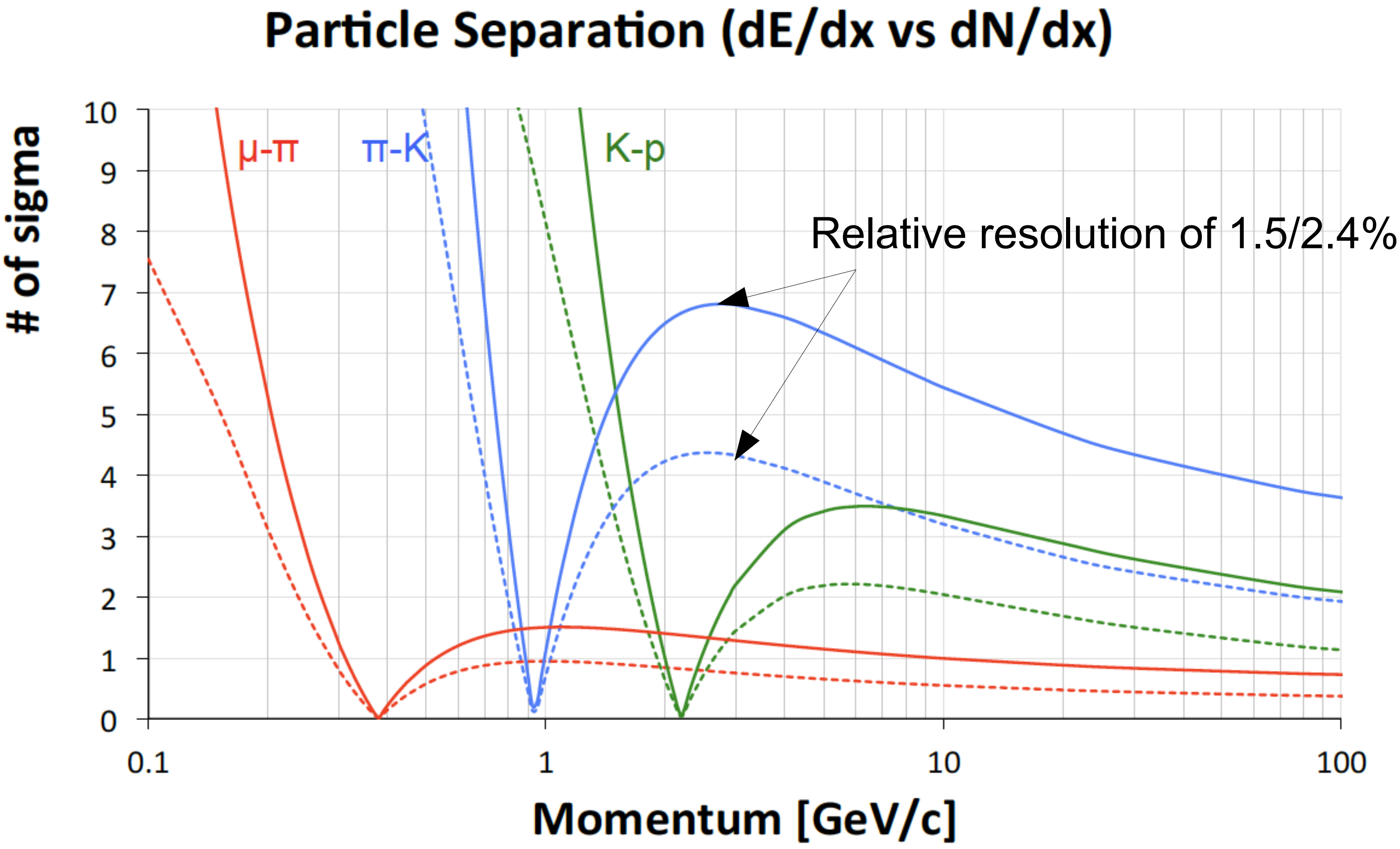
	ϵ (%)	p (%)
$\lvert mass - mass_{D0} \rvert < 0.01\, GeV/c^2$	90.39	2.16
IMP $> 0.02\, mm^2$	79.12	5.04
vertex fitted $\chi^2 < 5.15$	72.62	15.36
dis of vertex to IP $> 0.305\, mm$	69.24	28.41
PID	68.19	89.05





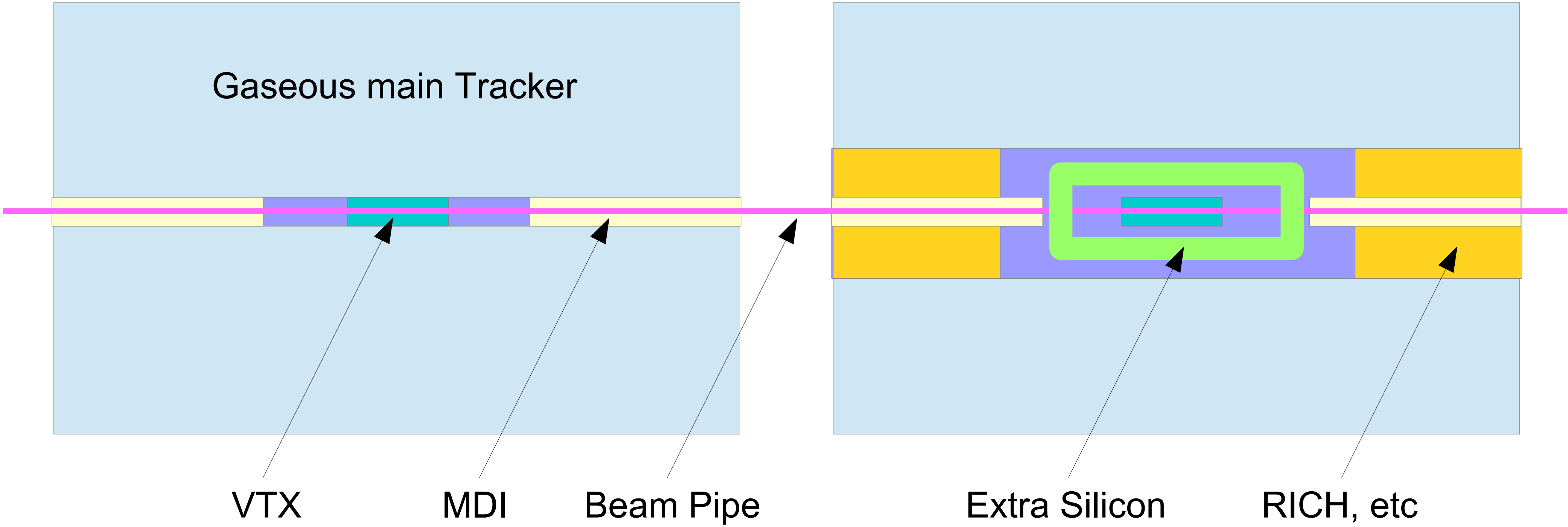
fitted mass : $1864.259 \pm 0.025\, \mathrm{MeV/c^2}$

IDEA Pid based on dN/dx



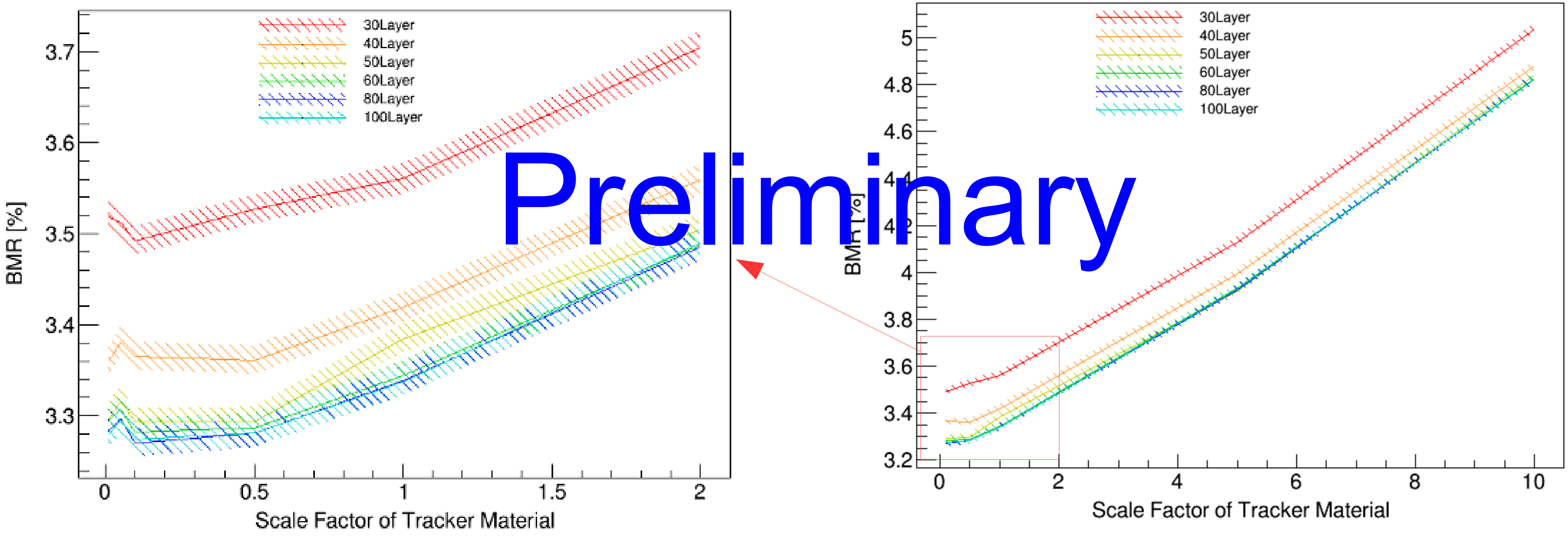
Convention difference case 40% difference in separation power counting

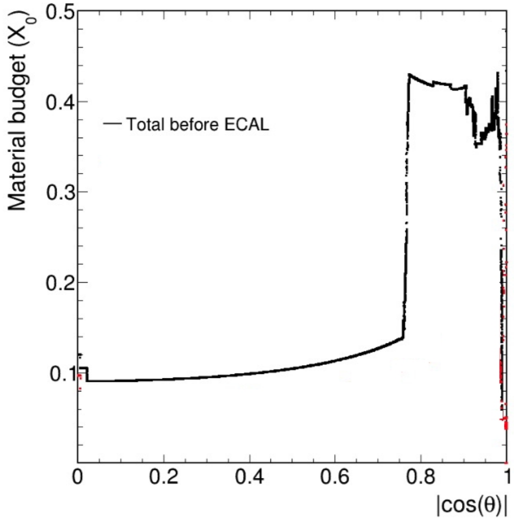
2.5 Tracker Scenarios



- Our understanding to Beam background & MDI design not fully converged
  - Beamstrahlung background seems to be very challenge to gaseous tracker
- I will discuss mainly the 1st scenario (Left)：
  - Tracker inner radius of 25 cm to have good Pid in fwd region
- The 2.5 scenario: Silicon Tracker with Pid (like AMS, with much better precision...)

BMR VS upstream material





- Baseline: 10% X0 material in the barrel region.
- Would be great to half the upstream material.

Summary

- Future electron positron Higgs factory requires outstanding vertex & tracking
- Vertex: critical to tau finding, flavor tagging, etc.
  - From CEPC baseline: go closer, lighter & thinner
  - Propose **Vin**: to have inner most silicon layer inside beam pipe – which could enhance the H->cc measurements by at least 20% compared to baseline
  - **Advanced algorithms** could significant boost the performance: need more study
- Track: Pid & Tracking
  - Verify the compatibility to the beam background & event rate with increasing luminosity: especially for large volume gaseous detector
  - ~o(100 MeV) Pt threshold, ~o(0.1%) relative momentum resolution, material < 0.1 X0
  - Pid:
    - Essential for the flavor physics: i.e. time-dependent CP measurements as it has significant impact on jet charge determination.
    - Via dE/dx (dN/dx) + ToF: 3% relative accuracy required for the barrel region
    - Geo. Acceptance is crucial, especially for Z factory modes. **Smaller inner radius, or dedicated Pid** device in the fwd!

Backup

Pid: Identify charged hadrons with energy up to 20 GeV...

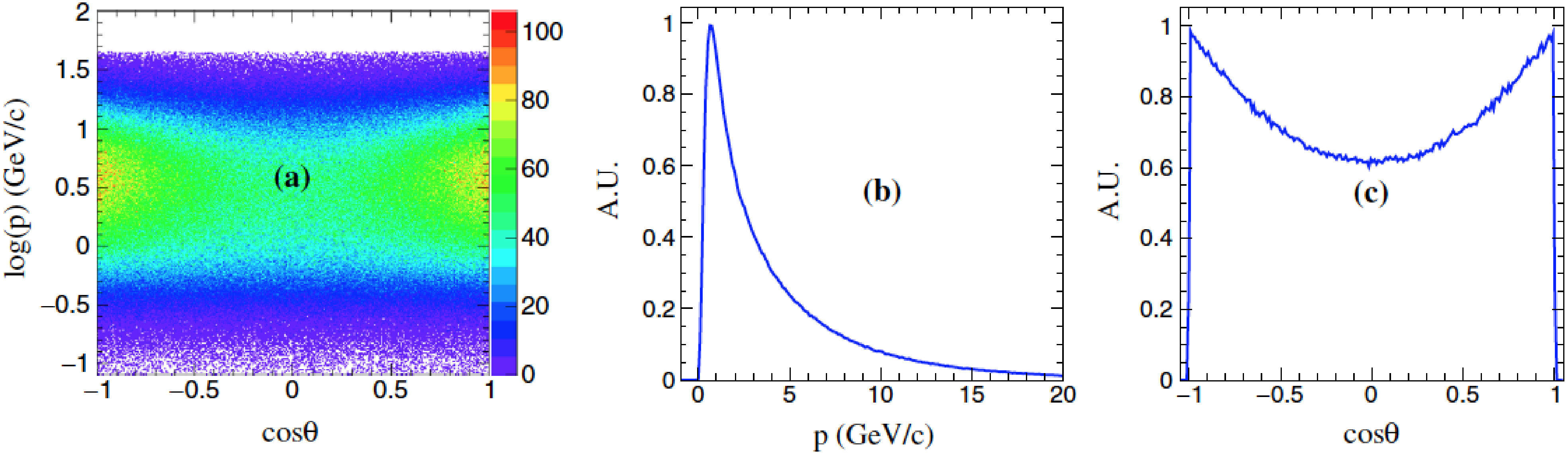
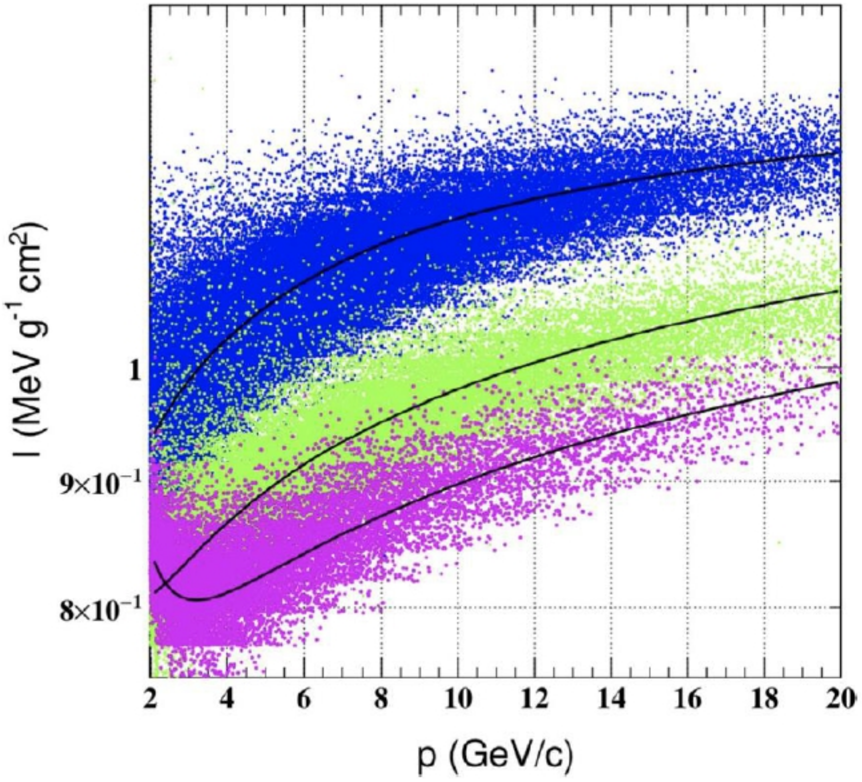


Fig. 3 Kinematic distribution of kaons in $e^+e^- \rightarrow Z \rightarrow q\bar{q}$ MC events as a function of $\log(p)$ and $\cos\theta$ (**a**), p (**b**), and $\cos\theta$ (**c**)

Pid & dEdx

Fenfen, Taifan, Zhiyang, etc



MC result of single-particle events with the theoretical prediction by the Bethe equation [16] overlaid. In the right plot the dots are from simulation of $e^+e^- \rightarrow Z \rightarrow q\bar{q}$ events

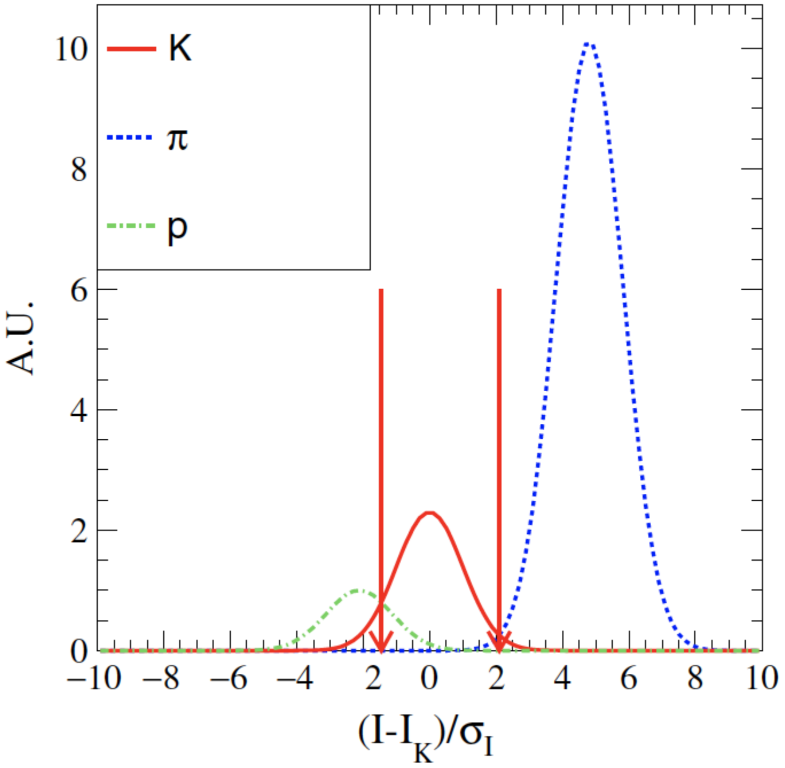
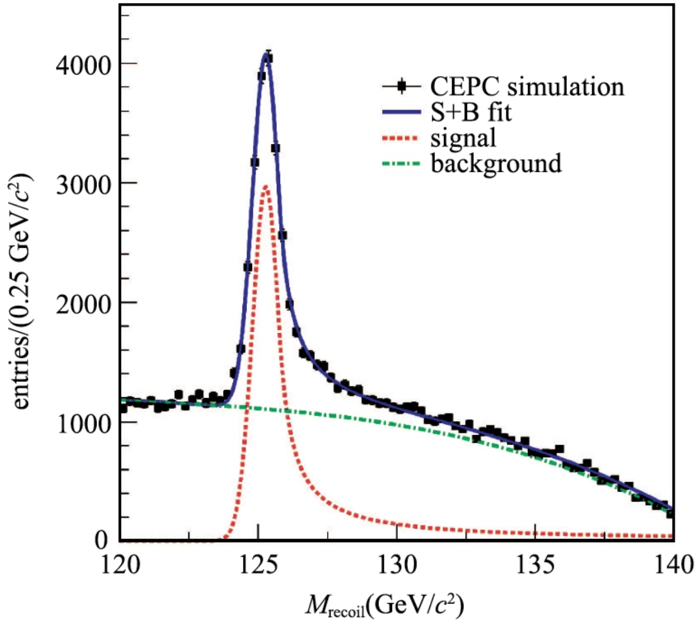


Fig. 6 The scaled spectra of $(I - I_K)/\sigma_I$ using dE/dx measurements alone for particles with a momentum of 5 GeV/c, assuming a 20% degradation. The relative populations are $N_\pi = 4.4N_K$ and $N_K = 2.3N_p$ according to MC simulation. The intersections marked by the arrows are chosen as the cut points

MumuH, H->tautau measurements



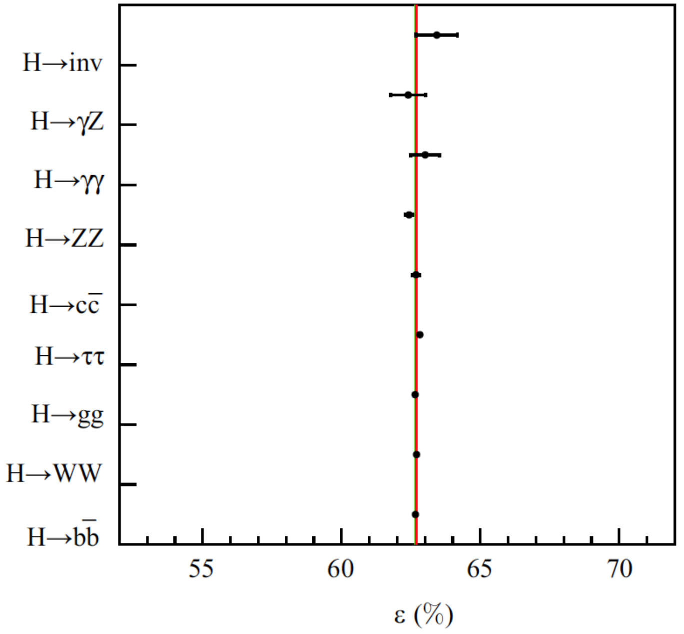
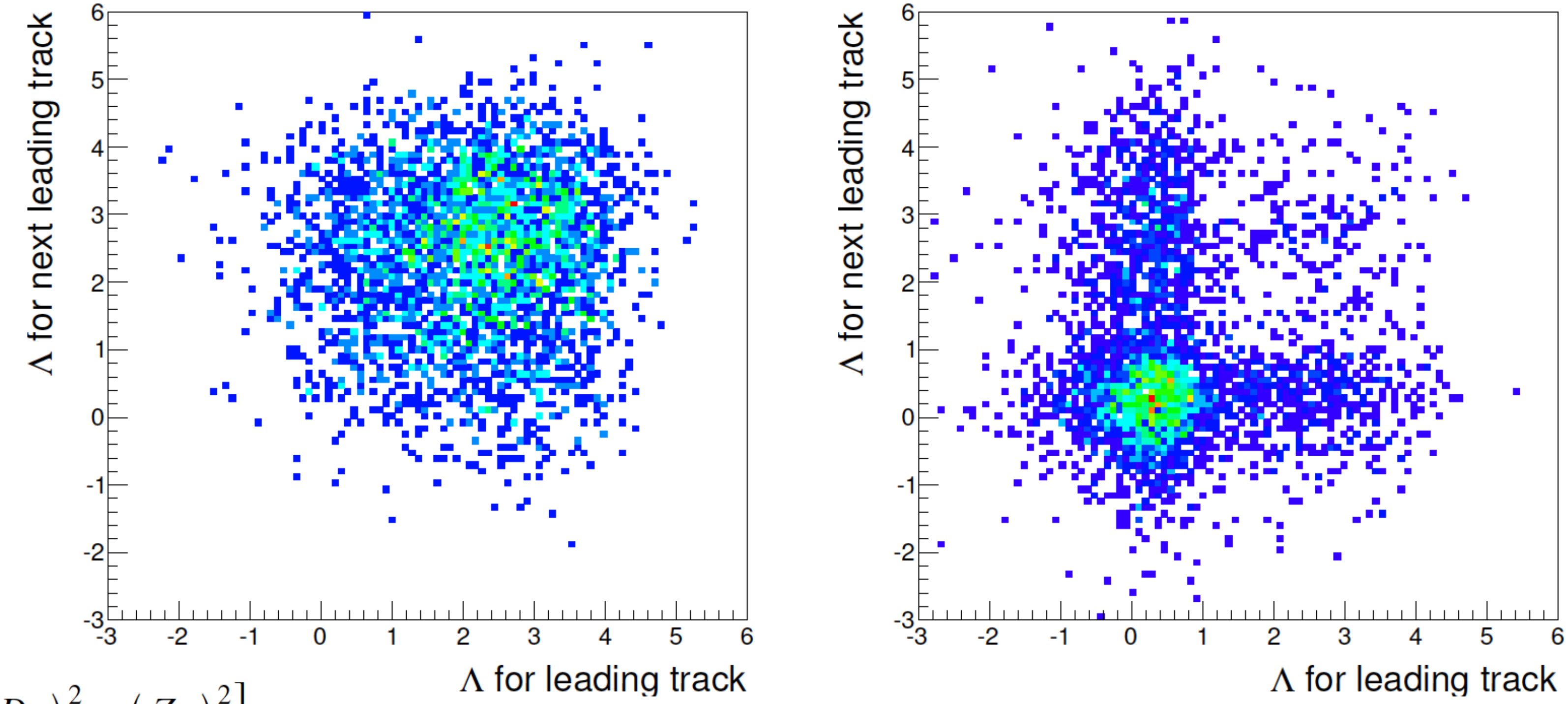


Table 2. Efficiencies of signal and background in the model-independent analysis

	$Z(\mu^+\mu^-)H$	ZZ	WW	ZZ or WW	single Z	$Z(2f)$	$\gamma\gamma$
total generated	35247	5347053	44180832	17801222	7809747	418595861	161925000
$N_{\mu^+} \geqslant 1$, $N_{\mu^-} \geqslant 1$	95.7%	11.95%	0.65%	3.92%	9.75%	1.64%	17.31%
120 GeV $< M_{\mathrm{recoil}} <$ 150 GeV	93.2%	1.71%	0.23%	0.70%	1.93%	0.17%	3.06%
80 GeV $< M_{\mu^+\mu^-} <$ 100 GeV	85.5%	0.68%	0.06%	0.22%	0.22%	0.10%	0.11%
$p_{\mathrm{T}\mu^+\mu^-} >$ 20 GeV	80.2%	0.57%	0.06%	0.17%	0.16%	0.02%	0.04%
$\Delta\phi < 175°$	77.8%	0.51%	0.05%	0.17%	0.15%	0.01%	0.04%
BDT cut	63.0%	0.25%	0.01%	0.05%	0.06%	0.01%	0.01%
fit window	62.8%	0.25%	0.01%	0.05%	0.05%	0.01%	0.01%

MumuH, H->tautau measurements



$$\Lambda = \log_{10}\left[\left(\frac{D_0}{\sigma_{d_0}}\right)^2 + \left(\frac{Z_0}{\sigma_{z_0}}\right)^2\right]$$

(a) signal

(b) background

Figure 6. The Λ distribution of the signal (a) and background (b) for τ-tagging in baseline design.

Table 5. Maximum $\epsilon \cdot p$ value comparison for the $Br(H \to \tau^+\tau^-)$ measurement.

	Scenario A	Scenario B	Scenario C
$\epsilon \cdot p$	0.77 ± 0.01	0.71 ± 0.01	0.68 ± 0.01

Kshort & Lambda

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https://doi.org/10.1140/epjp/s13360-020-00272-4

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Regular Article

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Reconstructing K_S^0 and Λ in the CEPC baseline detector

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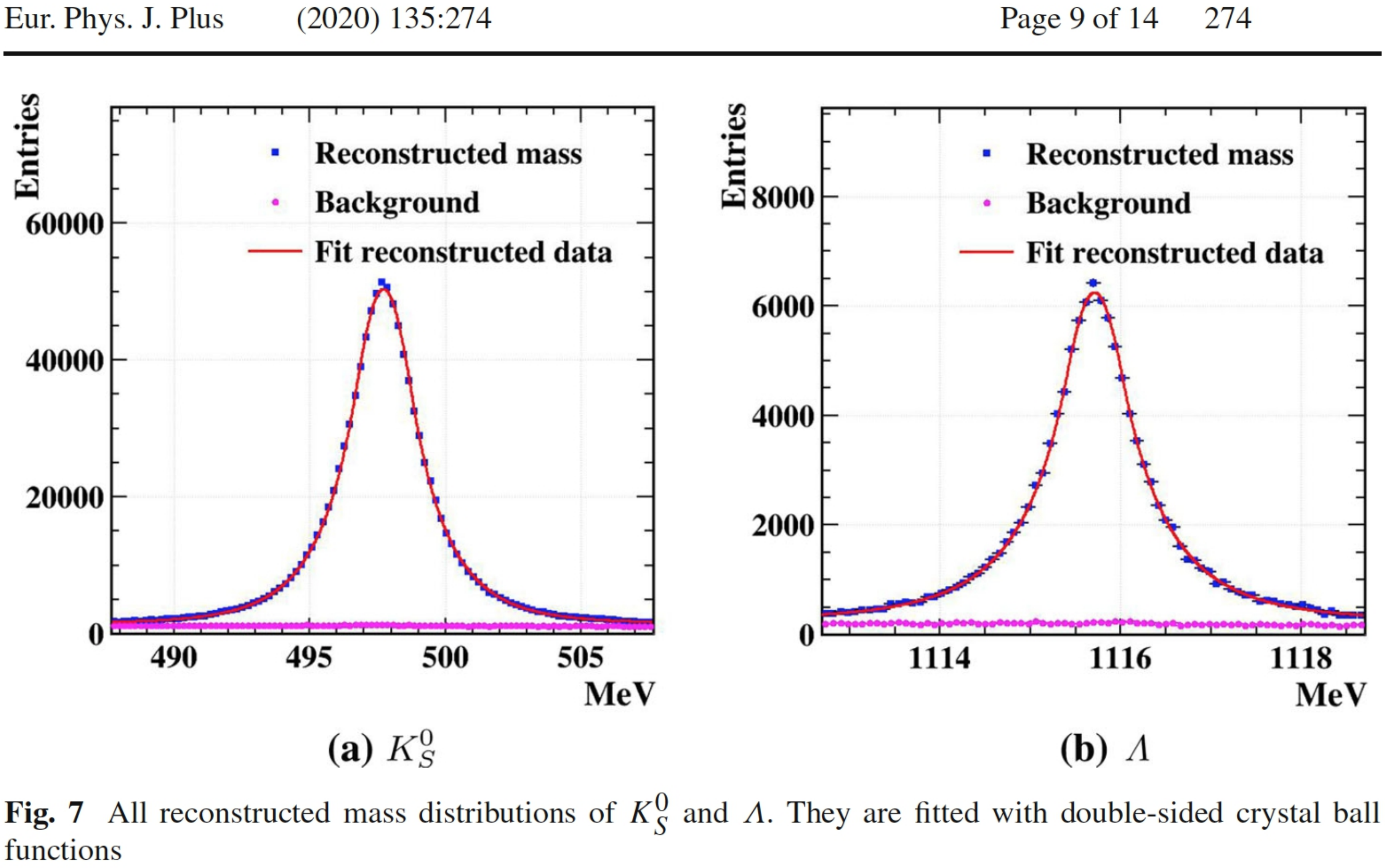
Kshort & Lambda



Eur. Phys. J. Plus (2020) 135:274 Page 9 of 14 274

(a) K_S^0 **(b)** Λ

Fig. 7 All reconstructed mass distributions of K_S^0 and Λ. They are fitted with double-sided crystal ball functions

Kshort & Lambda

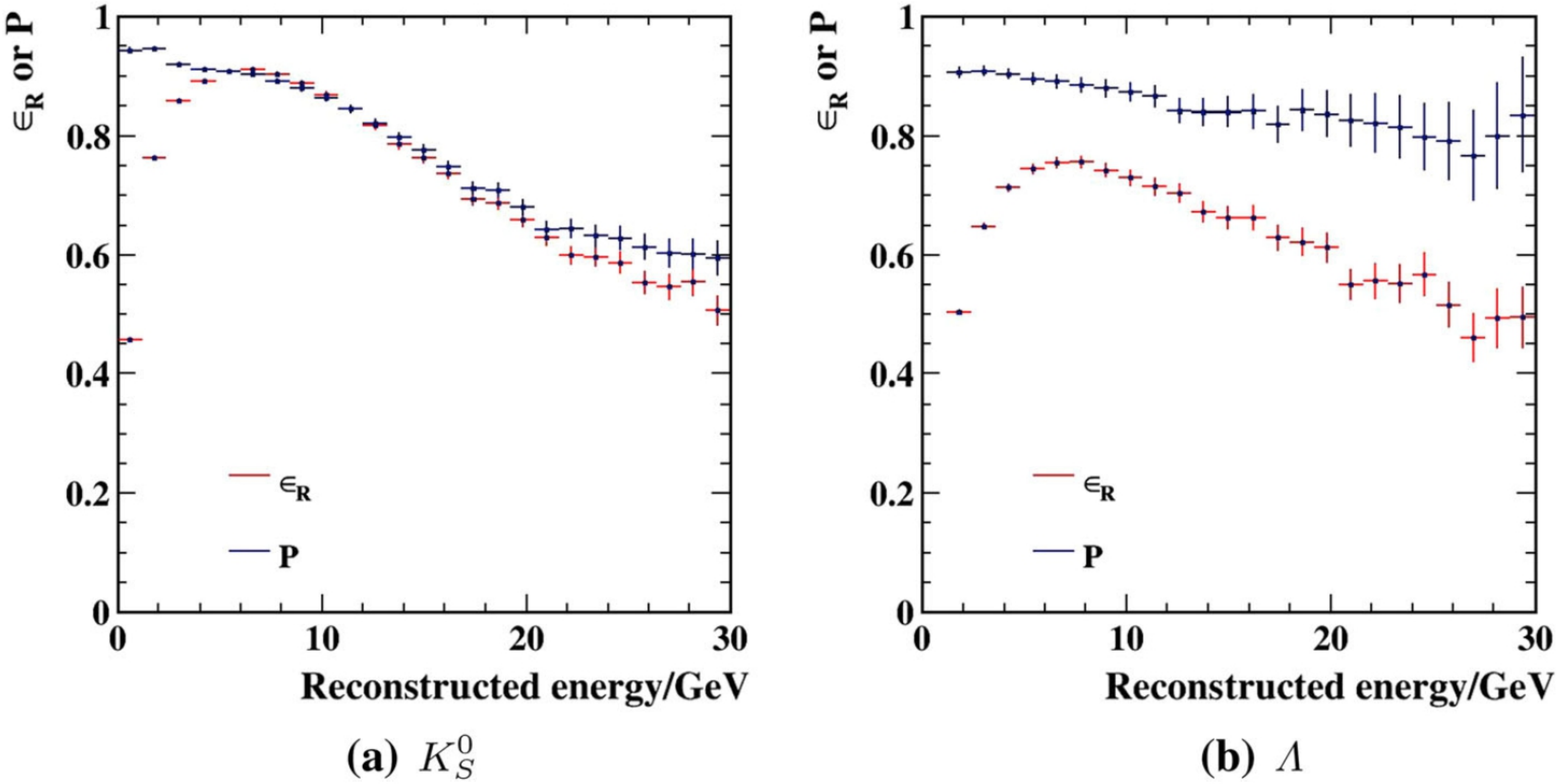


Fig. 9 Energy dependence of ϵ_{R} and P

Kshort & Lambda

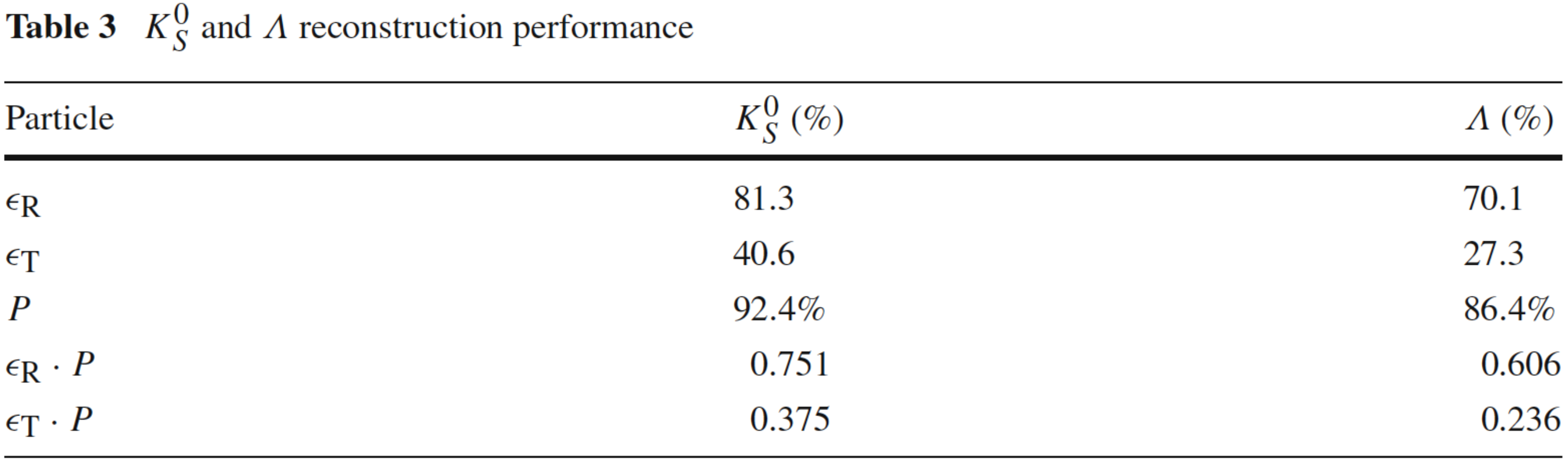


Table 3 K_S^0 and Λ reconstruction performance

Particle	K_S^0 (%)	Λ (%)
ϵ_R	81.3	70.1
ϵ_T	40.6	27.3
P	92.4%	86.4%
$\epsilon_R \cdot P$	0.751	0.606
$\epsilon_T \cdot P$	0.375	0.236

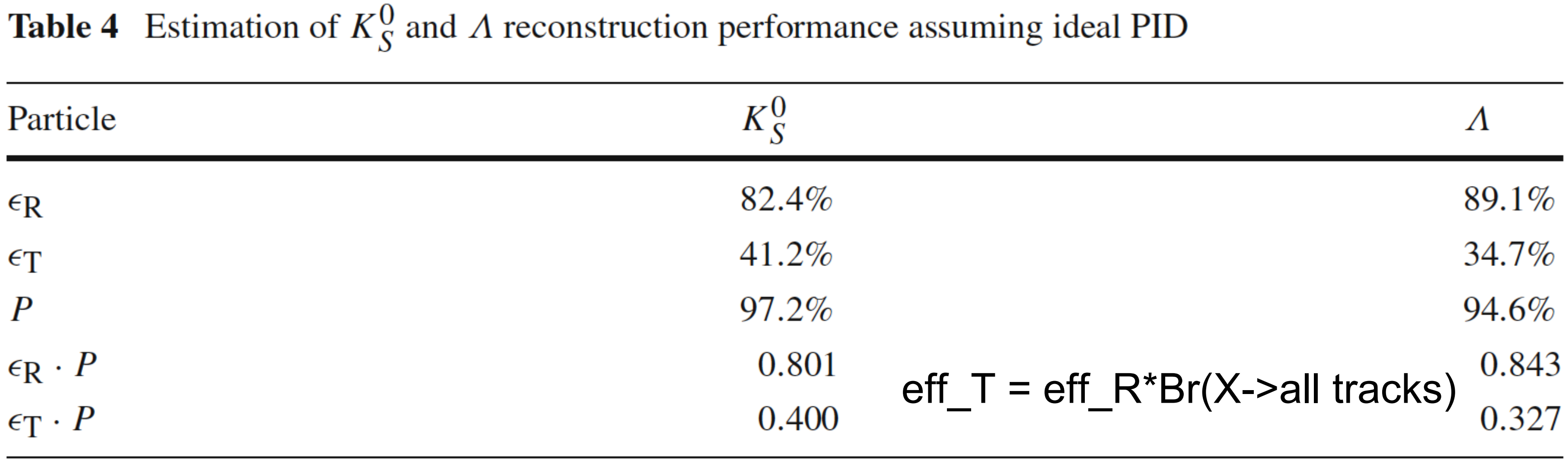


Table 4 Estimation of K_S^0 and Λ reconstruction performance assuming ideal PID

Particle	K_S^0	Λ
ϵ_R	82.4%	89.1%
ϵ_T	41.2%	34.7%
P	97.2%	94.6%
$\epsilon_R \cdot P$	0.801	0.843
$\epsilon_T \cdot P$	0.400	0.327

eff_T = eff_R*Br(X->all tracks)