FAIRNESS2017 — 29 May

Physics at CEPC and Higgs to Tau Measurement

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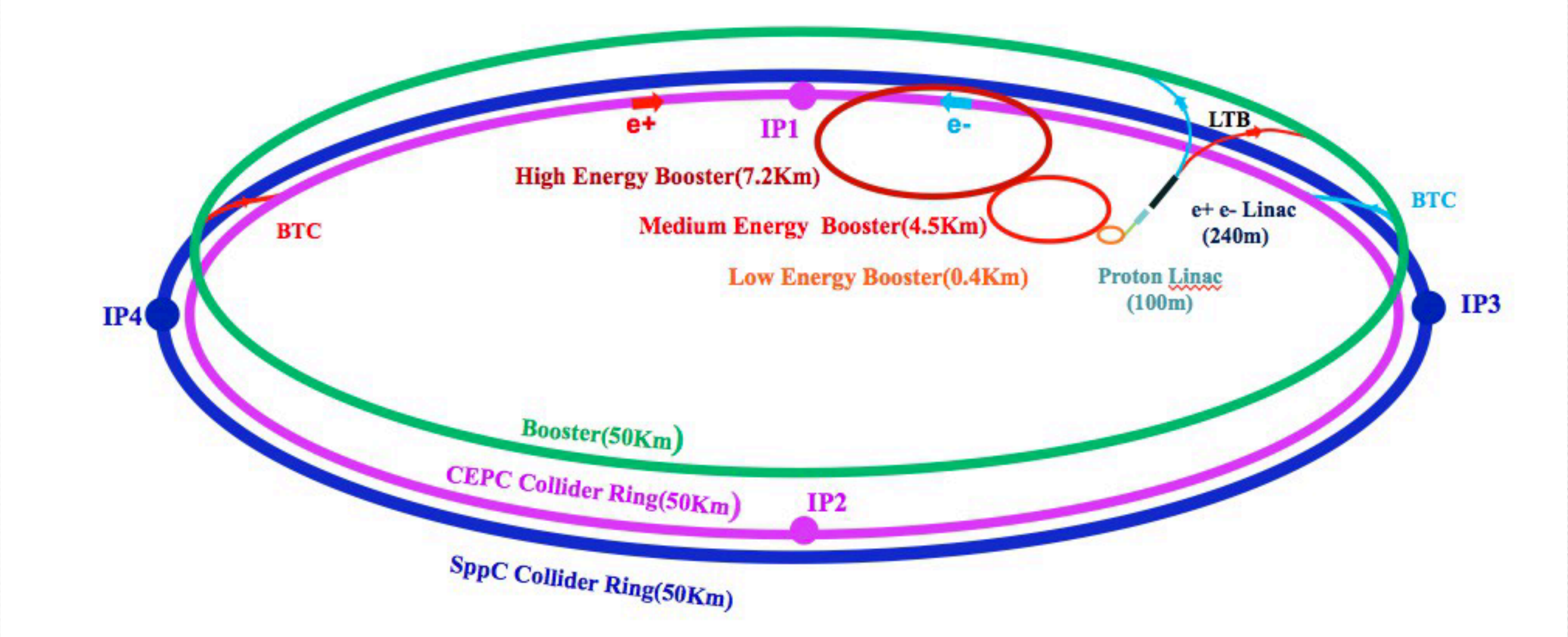
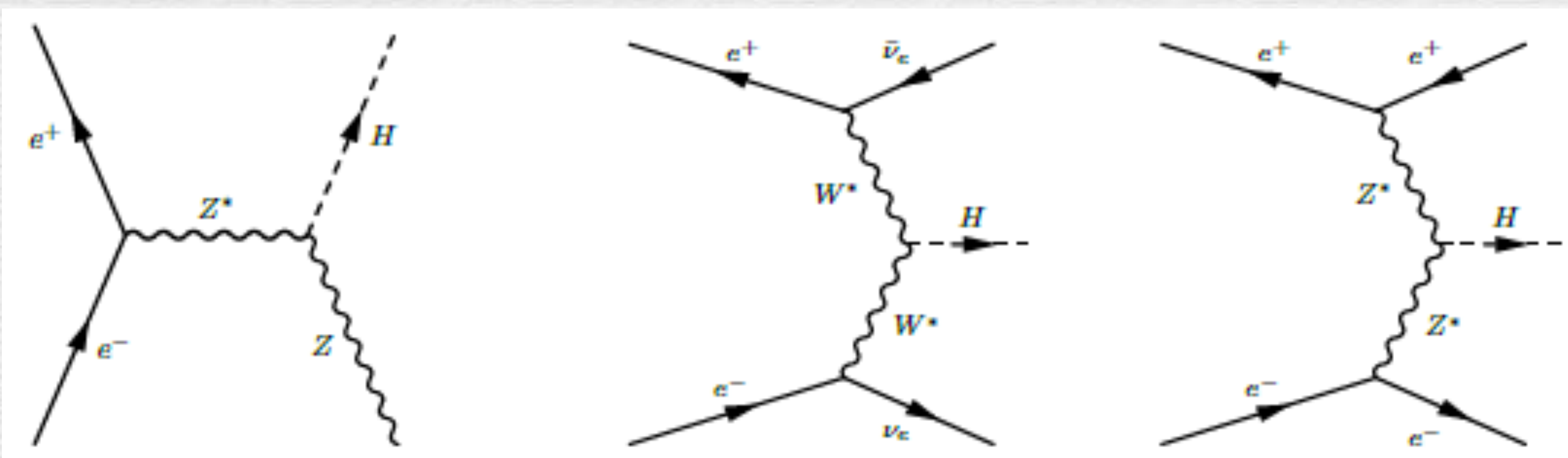
CEPC Overview

- Circular Electron Positron Collider (CEPC) operating at √s ~ 90 - 250 GeV
    - Tunnel ~ 100 km
    - Luminosity: $2 \times 10^{34} \mathrm{cm}^{-2} \mathrm{s}^{-1}$; Over ~10 years
    - Higgs Factory: 1M Higgs boson; Z/W factory: 10B Z boson
- Upgradable to Super proton-proton Collider (SppC) with √s~ 70 - 100 TeV

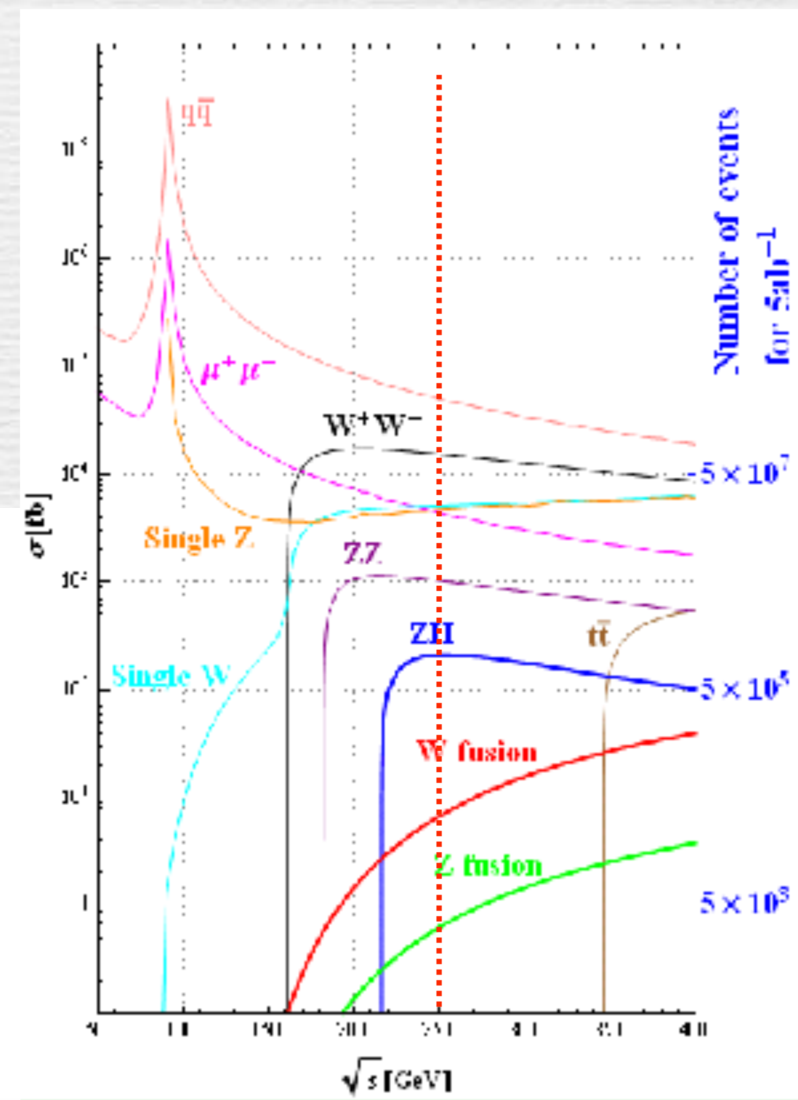


CEPC Physics

- Higgs: Absolute measurements of the Higgs boson width, BRs and couplings (percentage level accuracy); Searching for exotic Higgs decay modes (New Physics)
  - e^+e^- —>ZH
  - W / Z fusion
- Z/W: Precision test of the SM; Rare decay;
- Flavor factory: b, c, tau and QCD studies

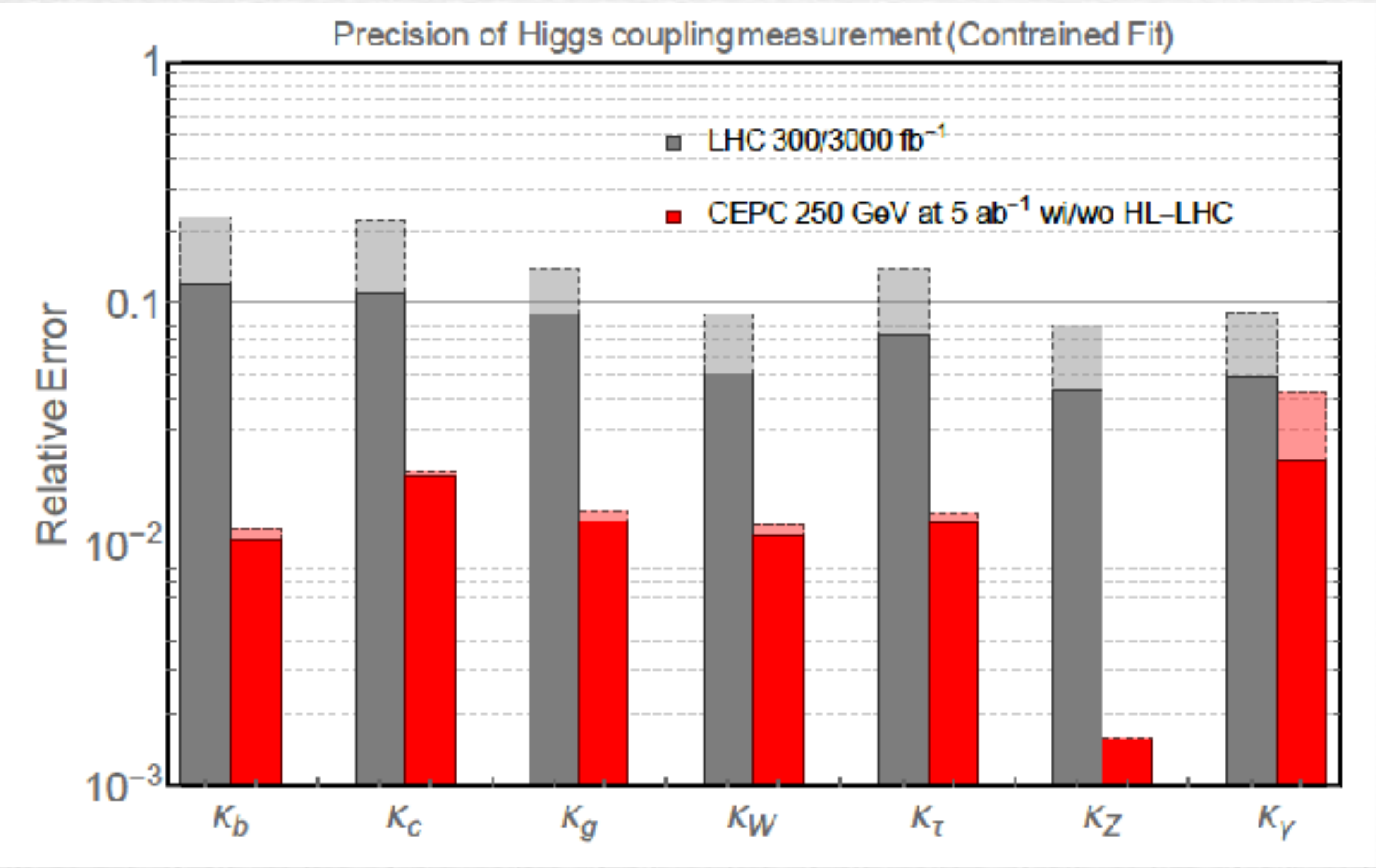


Process	Cross section	Events in 5 ab^{-1}
Higgs boson production, cross section in fb		
$e^+e^- \to ZH$	212	1.06×10^6
$e^+e^- \to \nu\bar{\nu}H$	6.72	3.36×10^4
$e^+e^- \to e^+e^-H$	0.63	3.15×10^3
Total	219	1.10×10^6

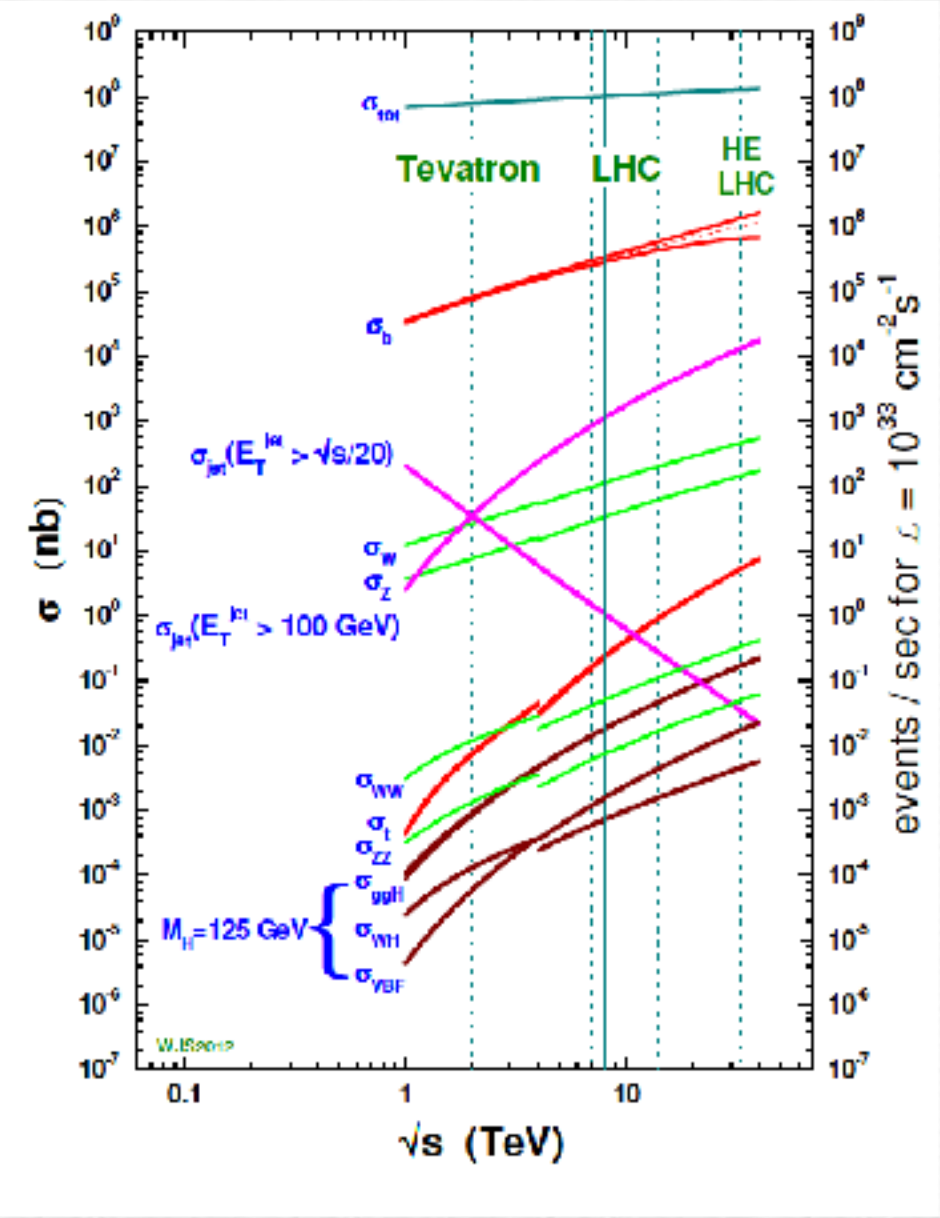


CEPC vs LHC

- LHC: High luminosity but low efficiency (high rate of backgrounds); Direct access to g(ttH)
- CEPC: Clean, absolute measurement



LHC proton-(anti)proton cross section



CEPC Timeline

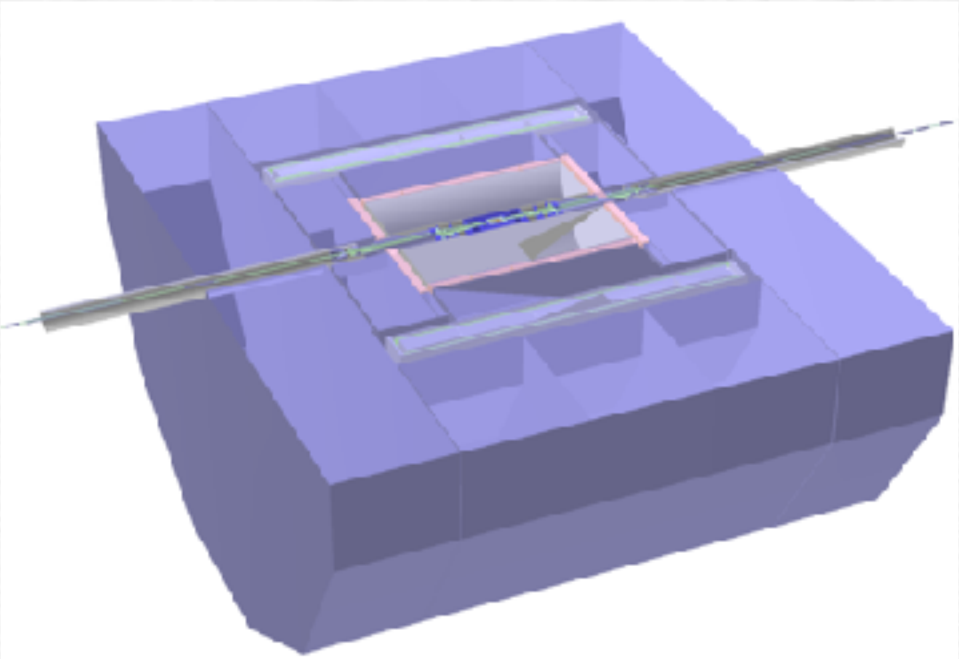
- 1st, PreCDR (end of 2014, http://cepc.ihep.ac.cn/preCDR/volume.html)
- 2nd, R&D funding from MOST (Middle 2016, 35 M CNY/5yr for the 1st phase)
- 3rd, CDR (end of 2017)

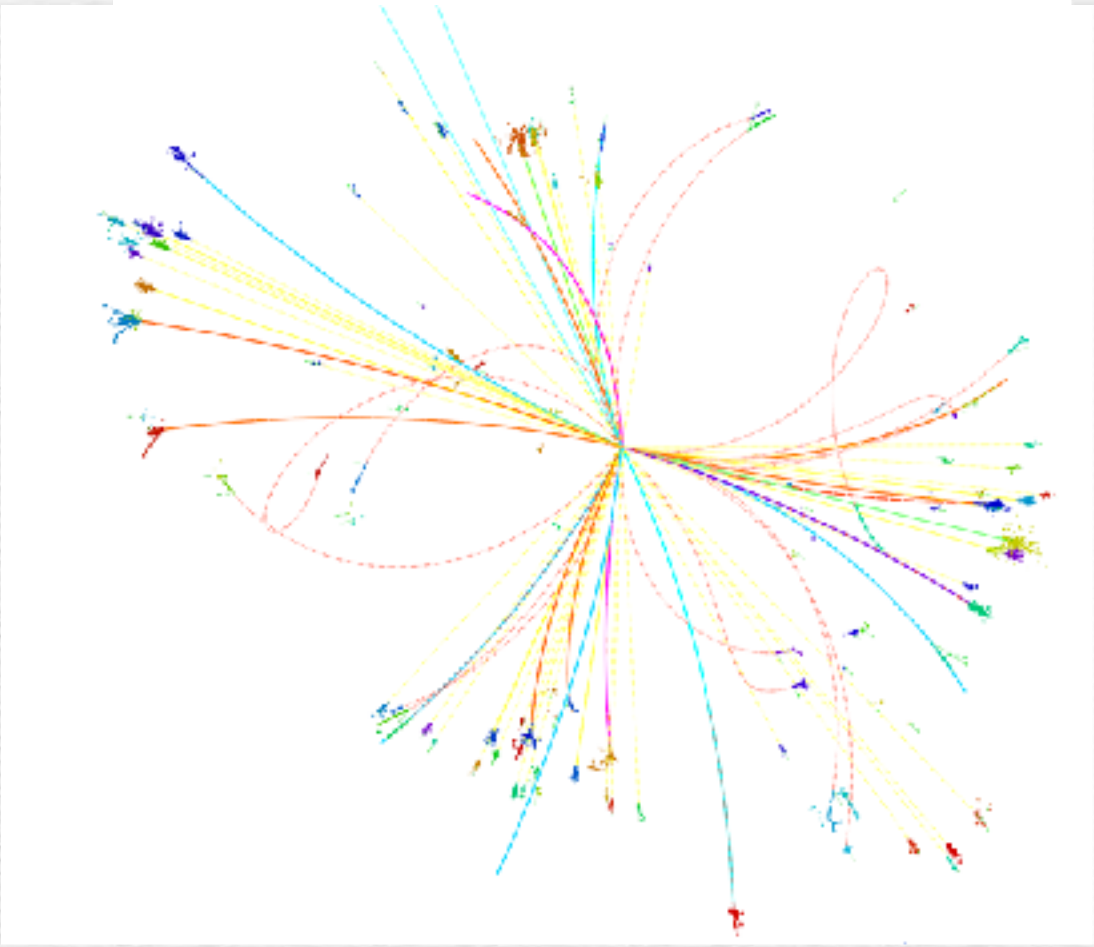
Current Status

- PreCDR delivered
  - No Show stopper
  - Tech. Challenges identified -> R&D forces formed
  - Preliminary Cost estimated (25/36 Billion CNY for 50/100 km)
- Working towards CDR
  - A working machine on paper
  - Ready to be reviewed by government at any moment
- Fundings
  - Seed money from IHEP: 10 Million CNY
  - MOST: 36 M/5 year, ~ 40 M to be asked
  - CAS: 8M/year
  - ...

Detector Overview

- Physics objective: high accuracy; reconstruct all the physics object with high efficiency/precision
- One option: PFA Oriented (Particle Flow Algorithm — reconstruct individual particles with trackers and calorimeters)
  - High Precision Tracking system
  - High Granularity Calorimeter: ~100M channels
- Alternative: Wire Chamber + Dual Readout Calorimeter
- PFA @ CEPC: Arbor - fully investigate the reconstruction potential from ultra-high granularity calorimeter





Particle ID: LICH

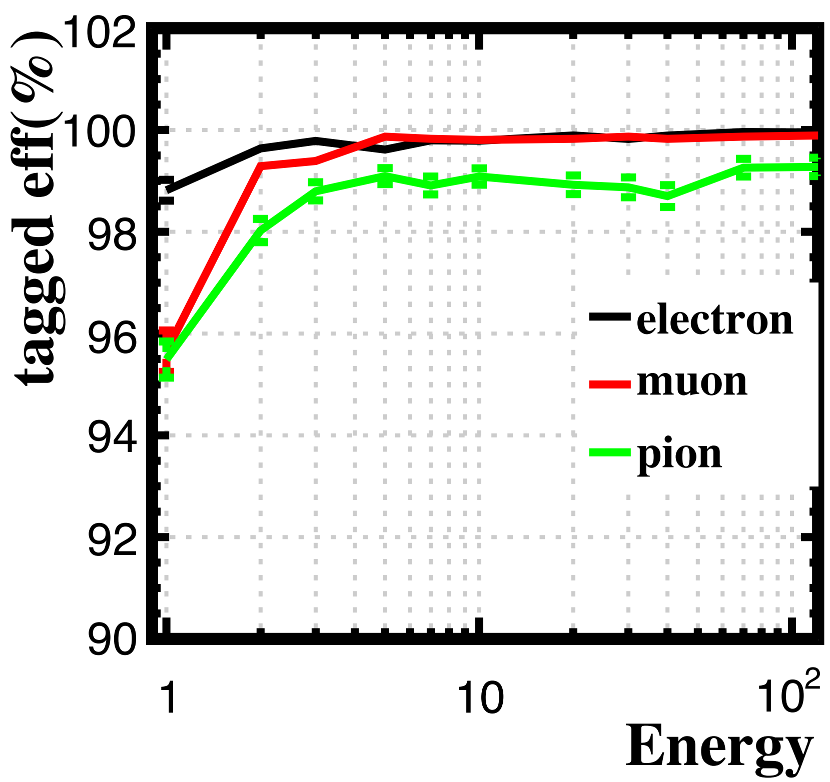
- Why charged particle identification matters:
  - essential to the precise Higgs measurements
  - jet flavor tagging and the jet charge measurement
  - Higgs boson generated together with leptons
  - a trigger signal for the proton colliders
- LICH (Lepton Identification for Calorimeter with High-granular)
  - based on PFA but independent; taking advantage of TPC information and high granularity

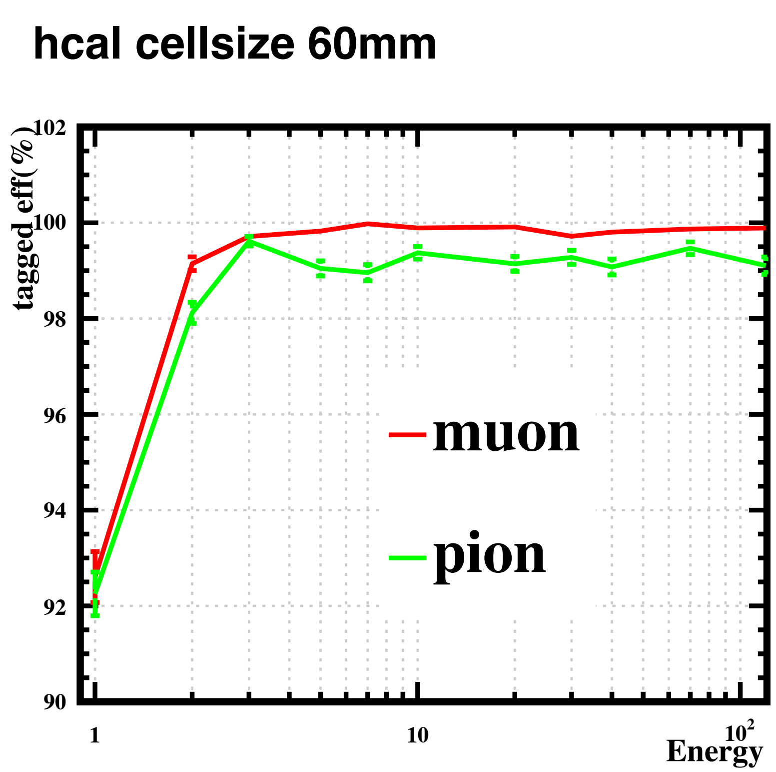
Particle ID: LICH

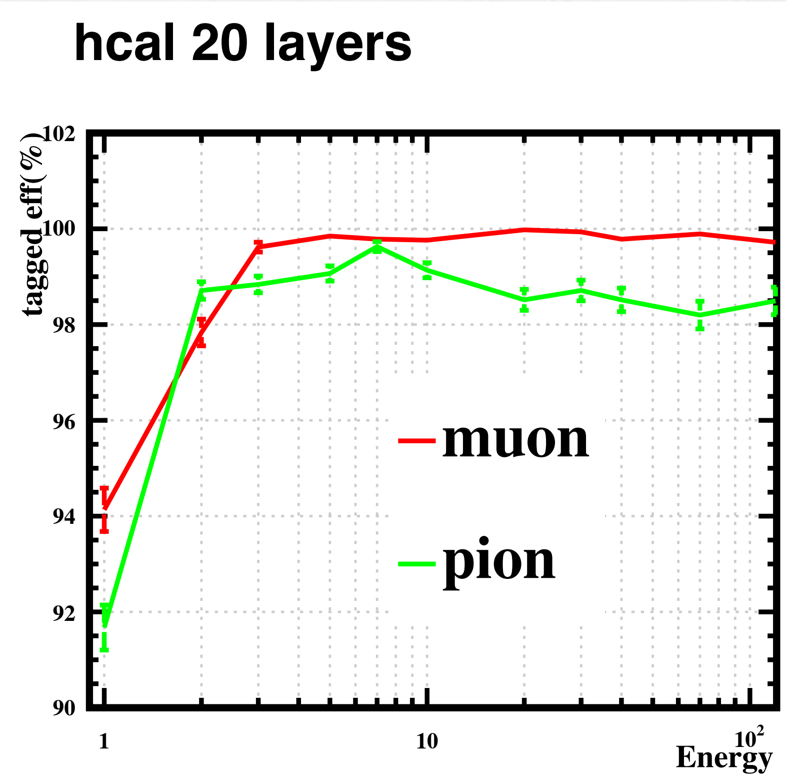
- Single particle: e, μ, π
- 24 variables in TMVA:
  - dE/dx
  - Shower shape
  - Energy deposition
- Efficiency of identification: >99.5% for lepton > 2GeV (ILD: 97% ALEPH: 98%)
- Adapt to different geometries

10 GeV single charged particle

Type	e^- like	μ^- like	π^+ like
e^-	99.71 ± 0.08	< 0.07	0.21 ± 0.07
μ^-	< 0.07	99.87 ± 0.08	0.05 ± 0.05
π^+	0.14 ± 0.05	0.35 ± 0.08	99.26 ± 0.12

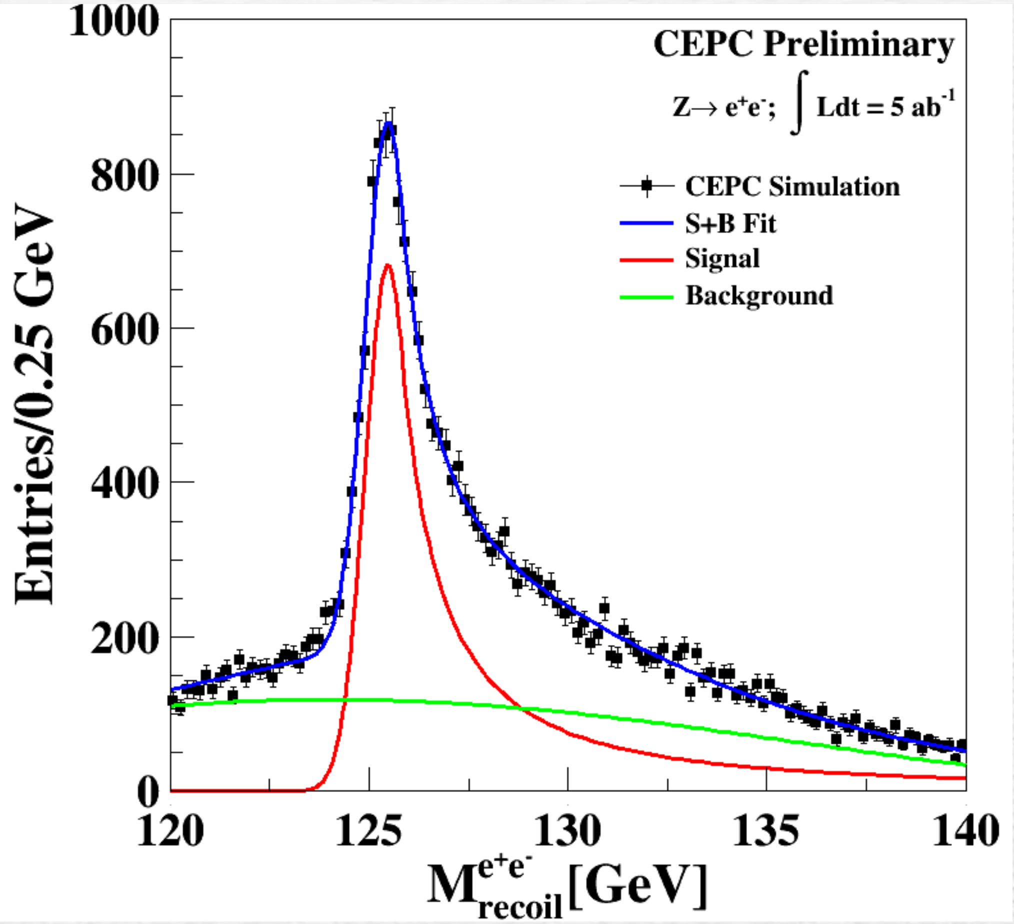






Particle ID: LICH

- In physics events: recoil mass
- Efficiency to find a di-lepton event > 97% (~ eff_single ²)
- Adaptable to different geometries: efficiency drops ~1%



	Geom 1 (ECAL and HCAL Cell Size $10\times10\ mm^2$)		Geom 2 (ECAL and HCAL Cell Size $20\times20\ mm^2$)	
	$\mu\mu$H	eeH	$\mu\mu$H	eeH
μ definition	L_μ>0.1	L_μ>0.1	L_μ>0.1	L_μ>0.1
e definition	L_e>0.01 L_μ<0.1	L_e>0.001 L_μ<0.1	L_e>0.01 L_μ<0.1	L_e>0.001 L_μ<0.1
ε_e	93.41 ± 0.92	$\mathbf{98.64\pm0.08}$	91.60 ± 1.02	$\mathbf{97.89\pm0.11}$
η_e	92.02 ± 1.00	$\mathbf{99.74\pm0.04}$	89.89 ± 1.10	$\mathbf{99.67\pm0.04}$
ε_μ	$\mathbf{99.54\pm0.05}$	95.53 ± 0.76	$\mathbf{99.19\pm0.06}$	86.48 ± 1.26
η_μ	$\mathbf{99.60\pm0.04}$	96.31 ± 0.70	$\mathbf{99.83\pm0.03}$	95.38 ± 0.81
ε_{event}	98.53 ± 0.13	97.06 ± 0.19	97.24 ± 0.18	95.40 ± 0.24

Tau Physics

- Dominant leptonic decay of the Higgs boson
- Control of detector optimization
- Rich relevant physics

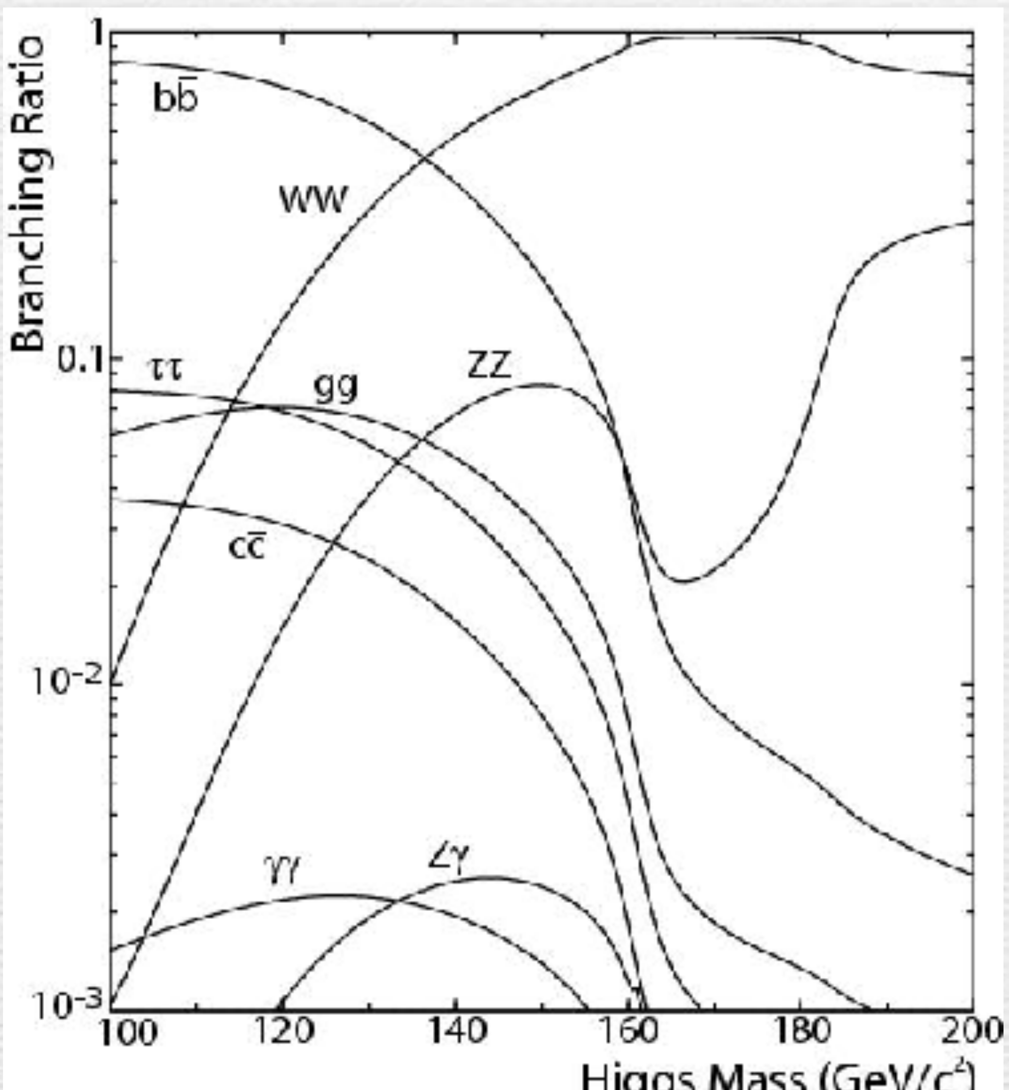
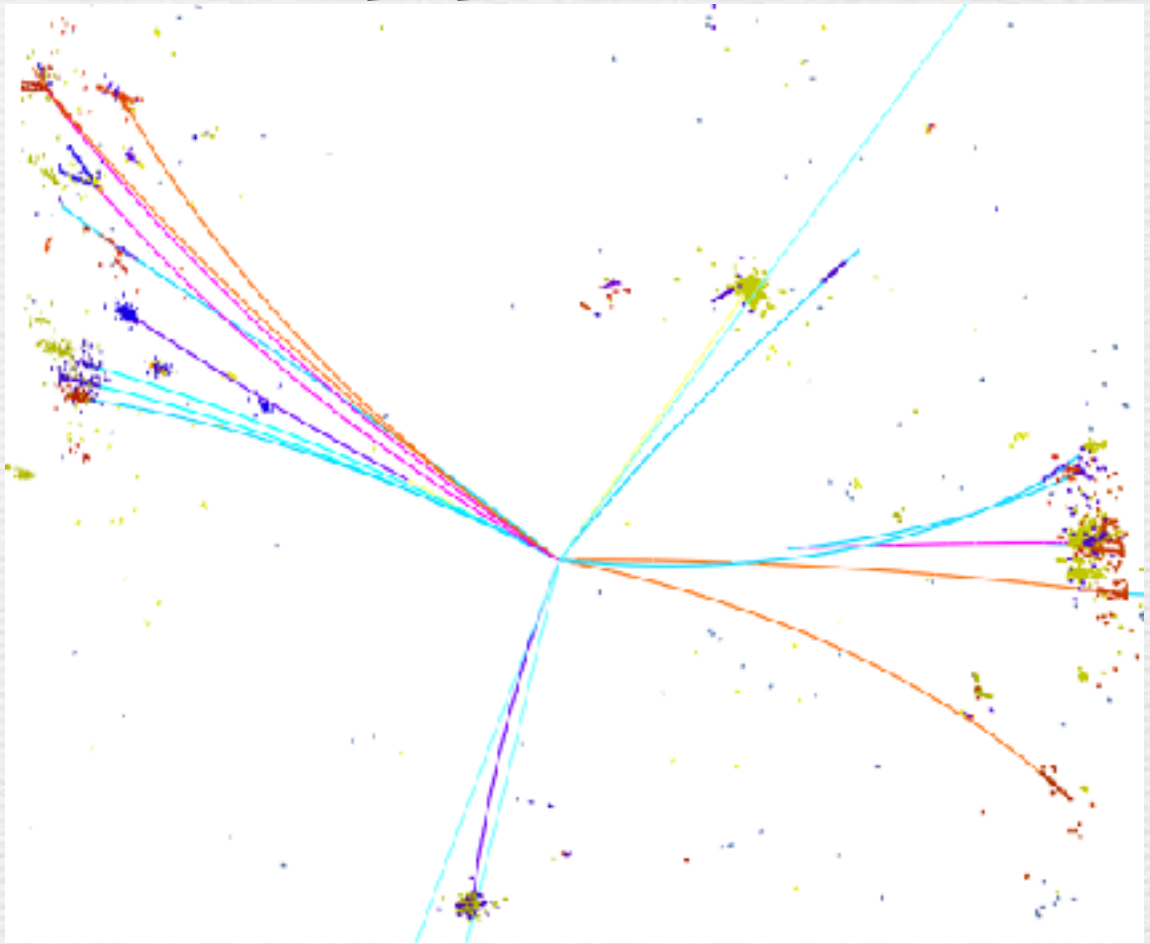


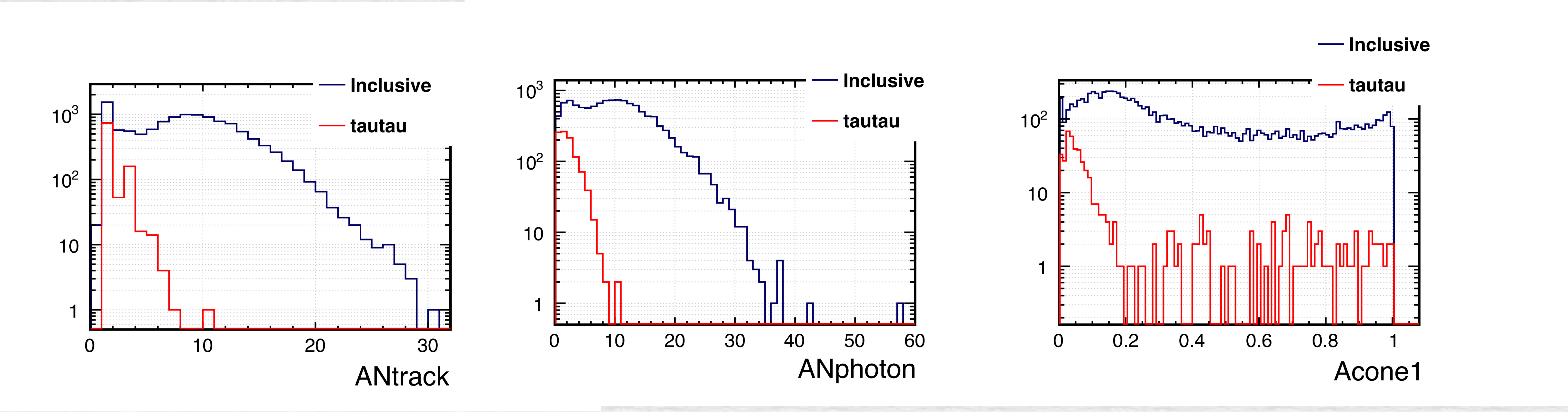
Table 1: Basis modes and fit values(%) for the 2013 fit to τ branching fraction data.

$e^-\overline{\nu}_e\nu_\tau$	17.83 ± 0.04
$\mu^-\overline{\nu}_\mu\nu_\tau$	17.41 ± 0.04
$\pi^-\nu_\tau$	10.83 ± 0.06
$\pi^-\pi^0\nu_\tau$	25.52 ± 0.09
$\pi^-2\pi^0\nu_\tau$ (ex. K^0)	9.30 ± 0.11
$\pi^-3\pi^0\nu_\tau$ (ex. K^0)	1.05 ± 0.07
$h^-4\pi^0\nu_\tau$ (ex. K^0, η)	0.11 ± 0.04
$K^-\nu_\tau$	0.700 ± 0.010
$K^-\pi^0\nu_\tau$	0.429 ± 0.015
$K^-2\pi^0\nu_\tau$ (ex. K^0)	0.065 ± 0.023
$K^-3\pi^0\nu_\tau$ (ex. K^0, η)	0.048 ± 0.022
$\pi^-\overline{K}^0\nu_\tau$	0.84 ± 0.04
$\pi^-\overline{K}^0\pi^0\nu_\tau$	0.40 ± 0.04
$\pi^-K^0_S K^0_S\nu_\tau$	0.023 ± 0.002
$\pi^-K^0_S K^0_L\nu_\tau$	0.12 ± 0.04
$K^-K^0\nu_\tau$	0.159 ± 0.016
$K^-K^0\pi^0\nu_\tau$	0.159 ± 0.020
$\pi^-\pi^+\pi^-\nu_\tau$ (ex. K^0, ω)	8.99 ± 0.06
$\pi^-\pi^+\pi^-\pi^0\nu_\tau$ (ex. K^0, ω)	2.70 ± 0.08
$K^-\pi^+\pi^-\nu_\tau$ (ex. K^0)	0.294 ± 0.015
$K^-\pi^+\pi^-\pi^0\nu_\tau$ (ex. K^0, η)	0.078 ± 0.012
$K^-K^+\pi^-\nu_\tau$	0.144 ± 0.005
$K^-K^+\pi^-\pi^0\nu_\tau$	0.0061 ± 0.0025
$h^-h^-h^+2\pi^0\nu_\tau$ (ex. K^0, ω, η)	0.10 ± 0.04
$h^-h^-h^+3\pi^0\nu_\tau$	0.023 ± 0.006
$3h^-2h^+\nu_\tau$ (ex. K^0)	0.0839 ± 0.0035
$3h^-2h^+\pi^0\nu_\tau$ (ex. K^0)	0.0178 ± 0.0027
$h^-\omega\nu_\tau$	2.00 ± 0.08
$h^-\omega\pi^0\nu_\tau$	0.41 ± 0.04
$\eta\pi^-\pi^0\nu_\tau$	0.139 ± 0.010
$\eta K^-\nu_\tau$	0.0152 ± 0.0008

Tau Recognition (μμH)

- Muon veto (Inv M ~ Z_Mass)
- Find leading track
- Collect particles nearby and in the opposite direction
- Count number of tracks and photons
- Get track-track angles, track-photon angles
- Training of these variables in TMVA





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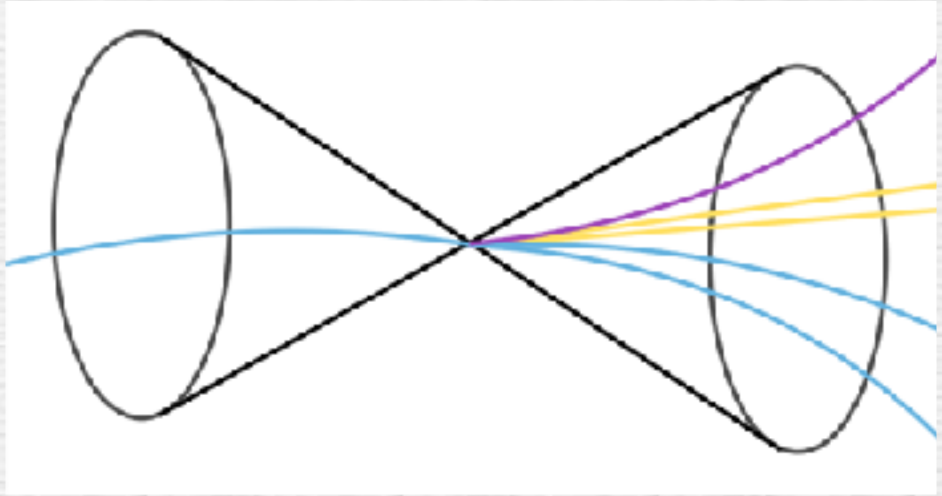
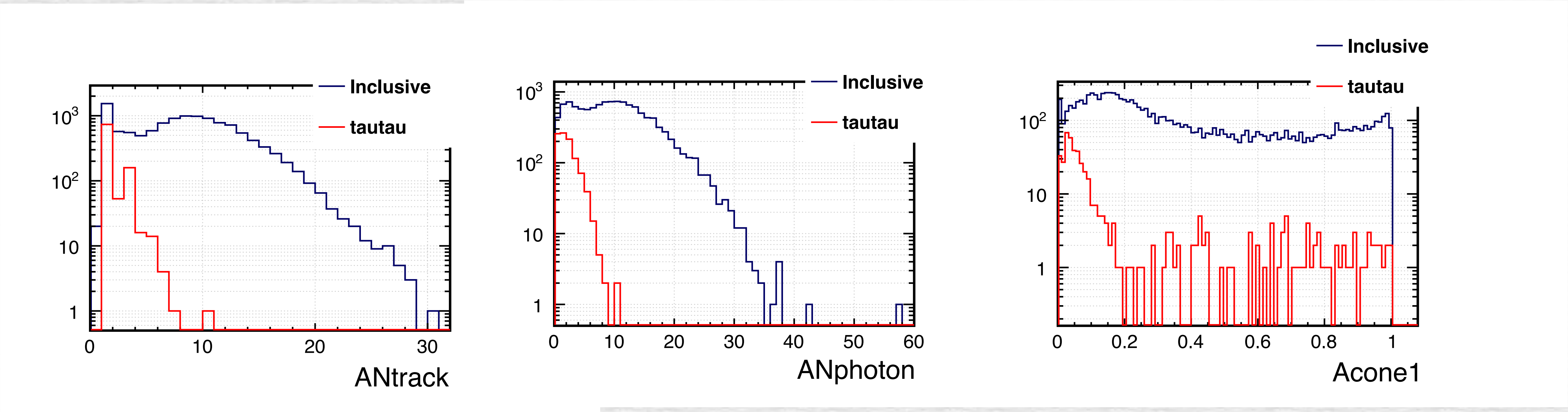
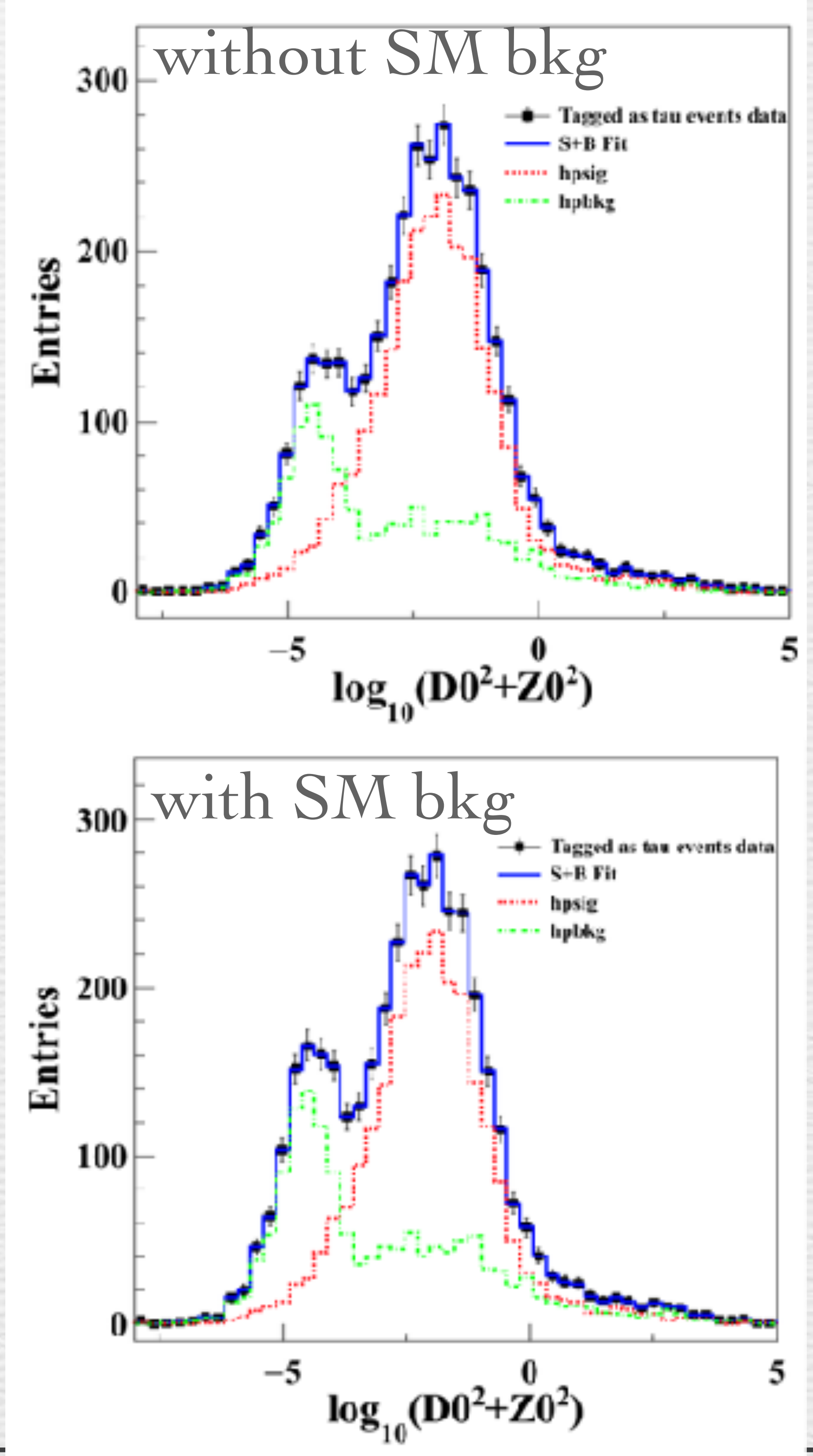




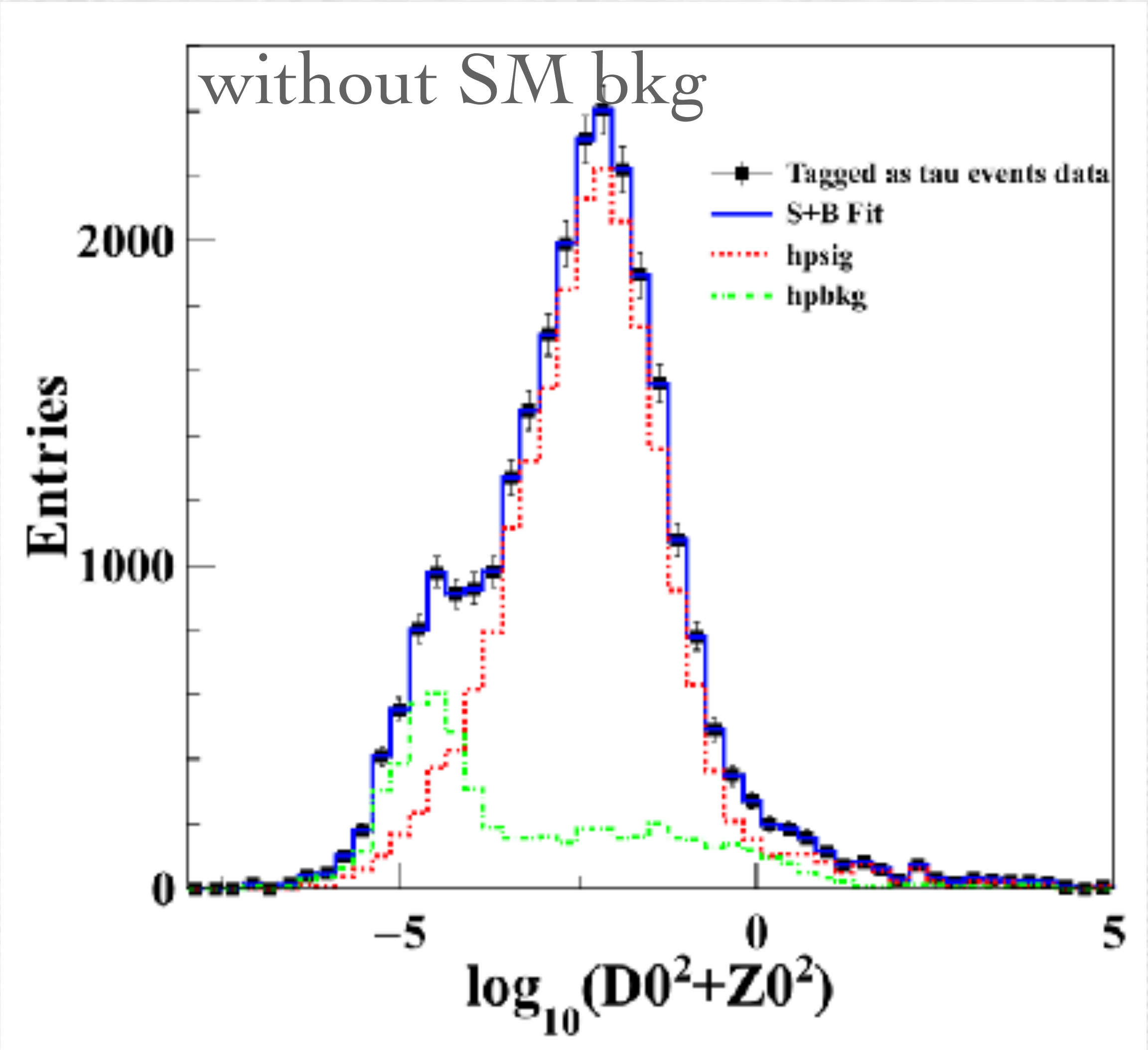
Tau Recognition (μμH)

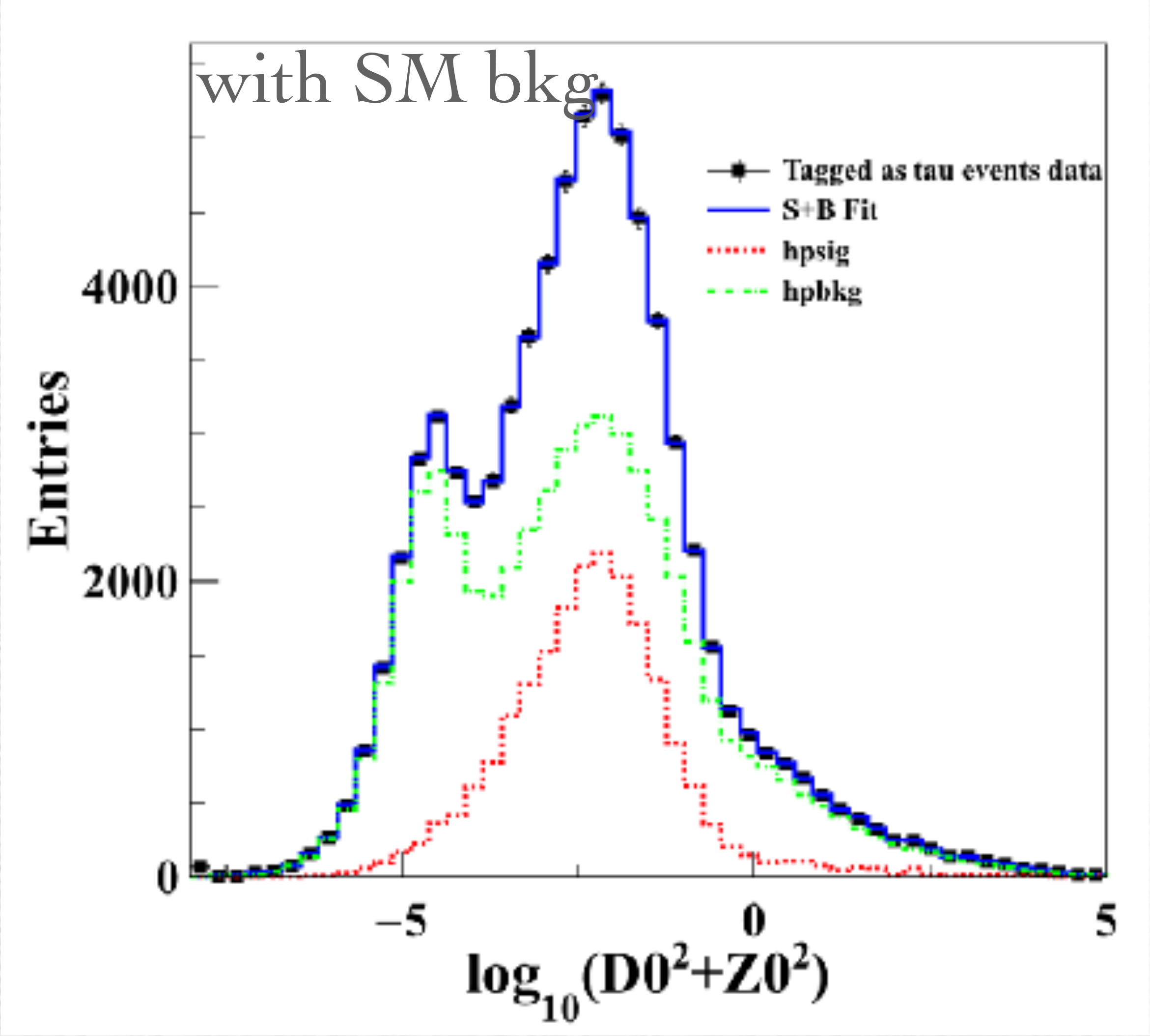
- Efficiency of finding a ττ event in μμττ: 94.47%
- Backgrounds:
  - ZH: H->WW with W leptonic decay
  - SM: WW/ZZ leptonic decay
- Impact parameter
- Fit result: BR(H->ττ) ~ 6.40±0.18
- Depends on vertex resolution



Tau Recognition (nnH)

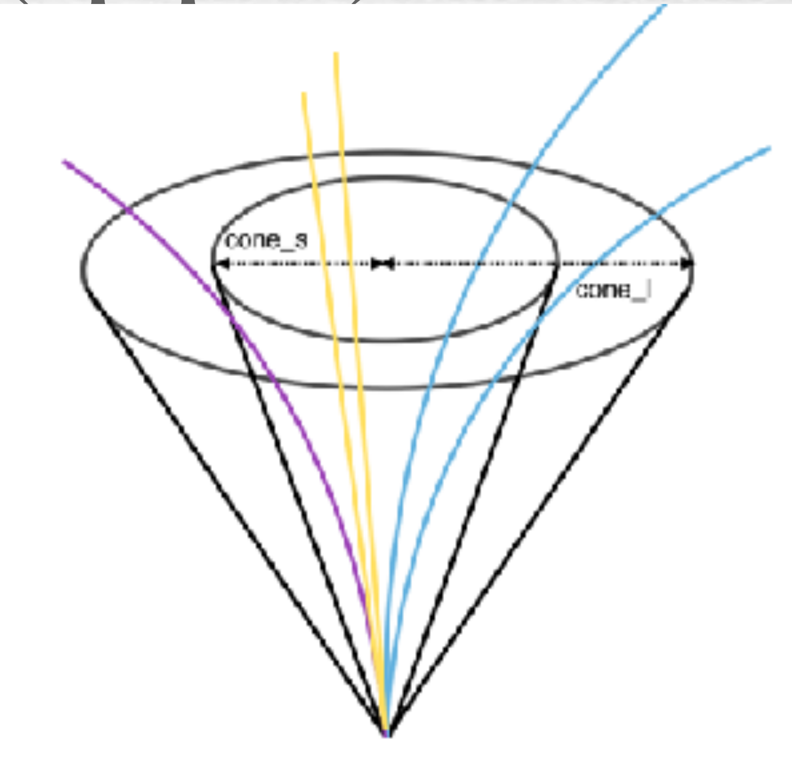
- Steps: similar procedure as μμH, without vetoing charged track
- Efficiency: 93.80%
- Fit result: BR(H->ττ) ~ 6.19±0.29%

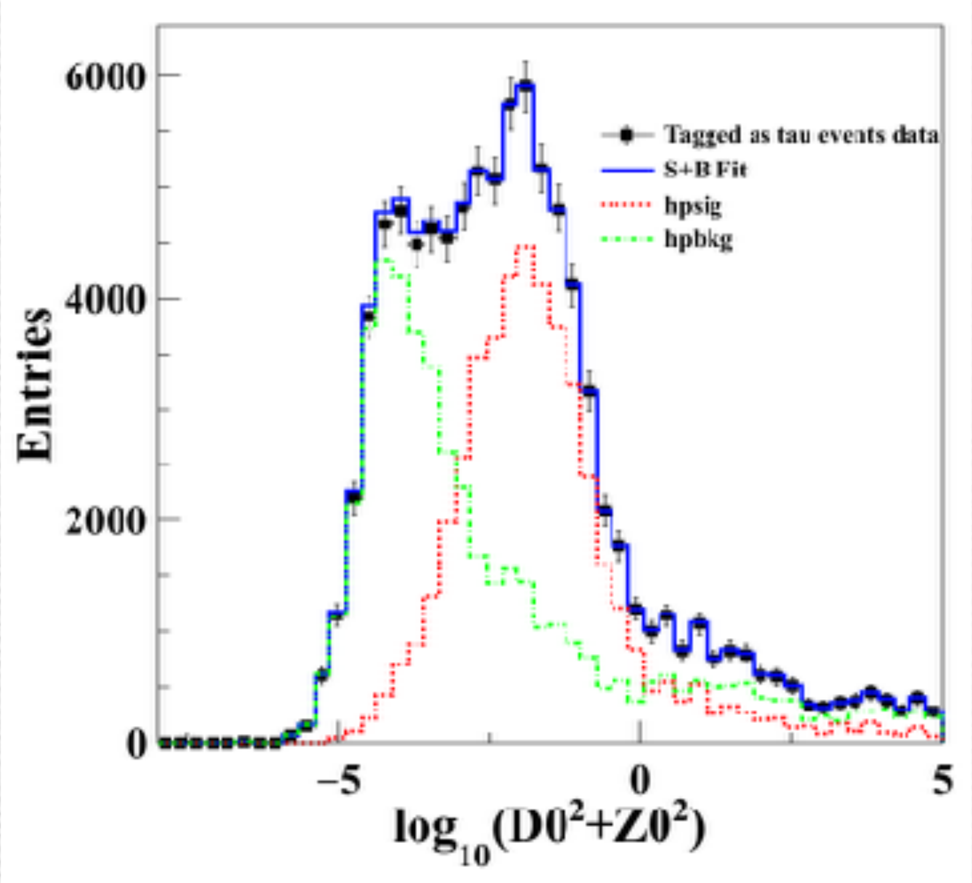




Tau Recognition (qqH)

- Cuts:
  - #tracks & #photons
  - isolated (Energy ratio)
  - visible mass
- Decay modes:
  - leptonic
  - hadronic
- Event cuts:
  - exist opposite charged tau
  - visible di-tau (leading opposite charged taus) mass
- SM background not included yet; ZZ, WW might be the most important background channel





Tau tagging results

(statistics scaled to 5 ab^{-1})

	Signal	BKG	SM BKG (after Z channel filter)	Signal after tagging	BKG after tagging	SM BKG after tagging	Signal after fit	main BKG after fit	H-> ττ BR (%)	Δ (σ × BR)/(σ × BR)
μμH	2237	32757	12471	2113	907	208	2117±55	1111 ± 48	6.40±0.18	2.68%
nnH	13235	199551	9743721	12478	3841	40528	12414 ± 348	40724 ± 380	6.19±0.17	1.86%
qqH	46463	686411	-	36024	36017	-	35500 ± 249	36543 ± 250	6.25±0.04	0.76%

Summary

- CEPC project
  - R&D towards the CDR end of this year
  - Welcome for international corporation
- Tau analysis at CEPC
  - New particle id applied
  - Impact parameter is a good way to fit the tau events
  - Leptonic decay channel SM background studied
  - (preliminary) Combined $\Delta (\sigma \times BR)/(\sigma \times BR)$:
    - $\mu\mu H$ + nnH: 1.52%
    - $\mu\mu H$ + nnH + eeH + qqH (prediction): 0.99%

Thanks for your attention!