

Higgs $\rightarrow \tau\tau$ Channel Signal Strength in CEPC_V4

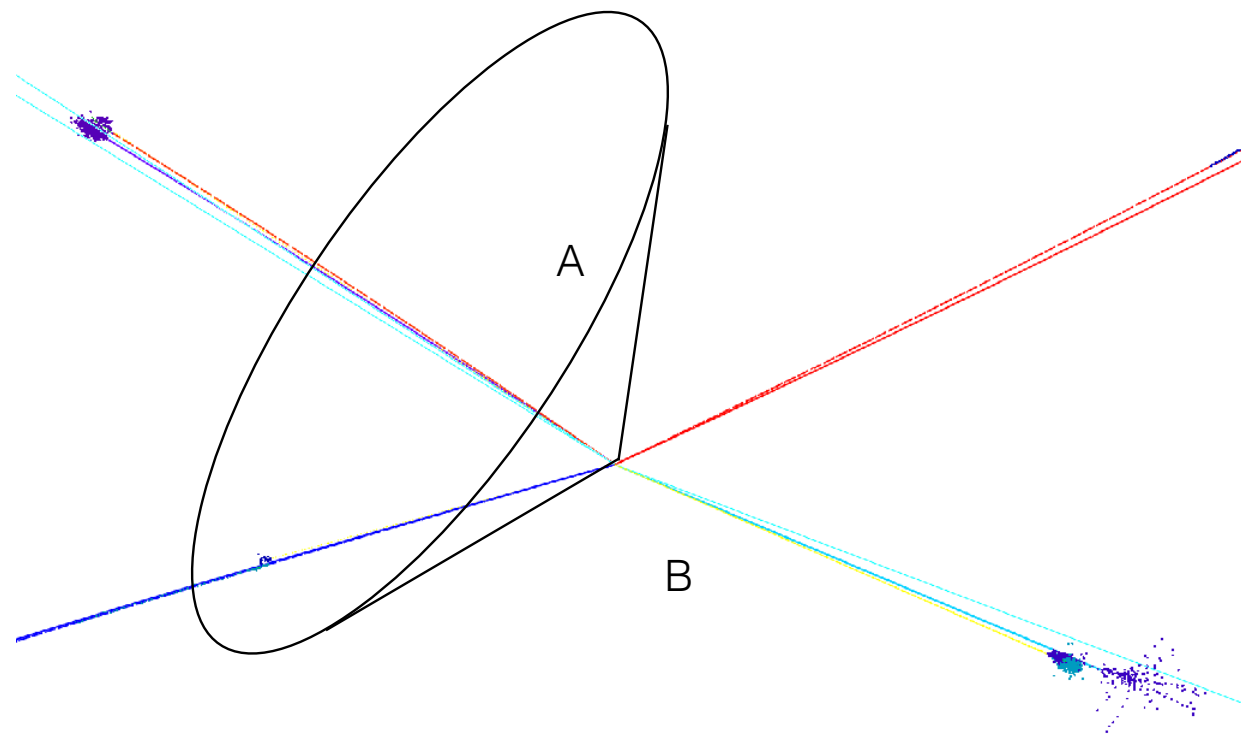
The 4th CEPC Physics and Software Workshop
27 June 2018

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Plan

- CEPC_V1 results
 - llH
 - qqH
- CEPC_V4
 - Comparison
 - Sample productions

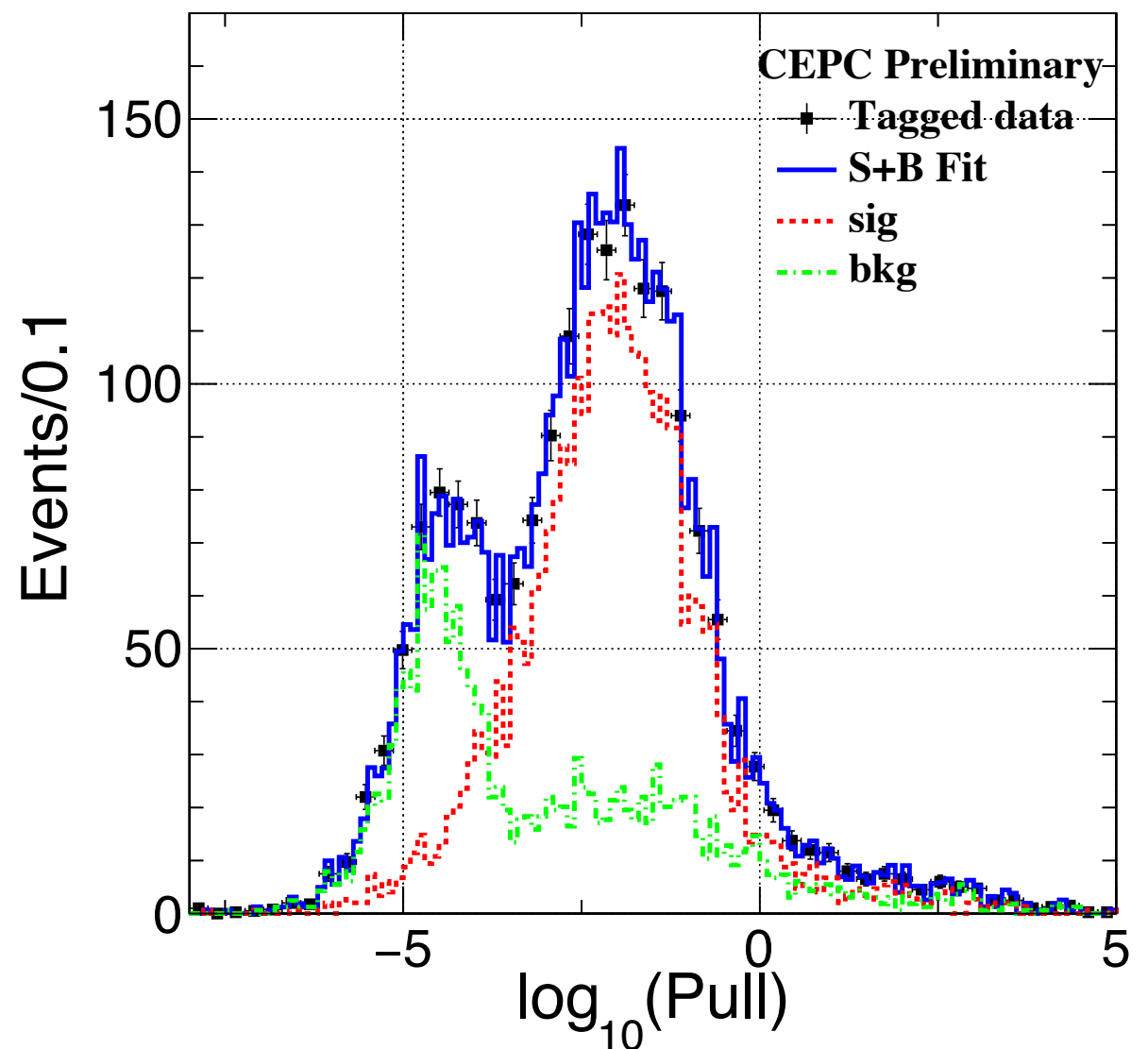
Tau Finder (llH)



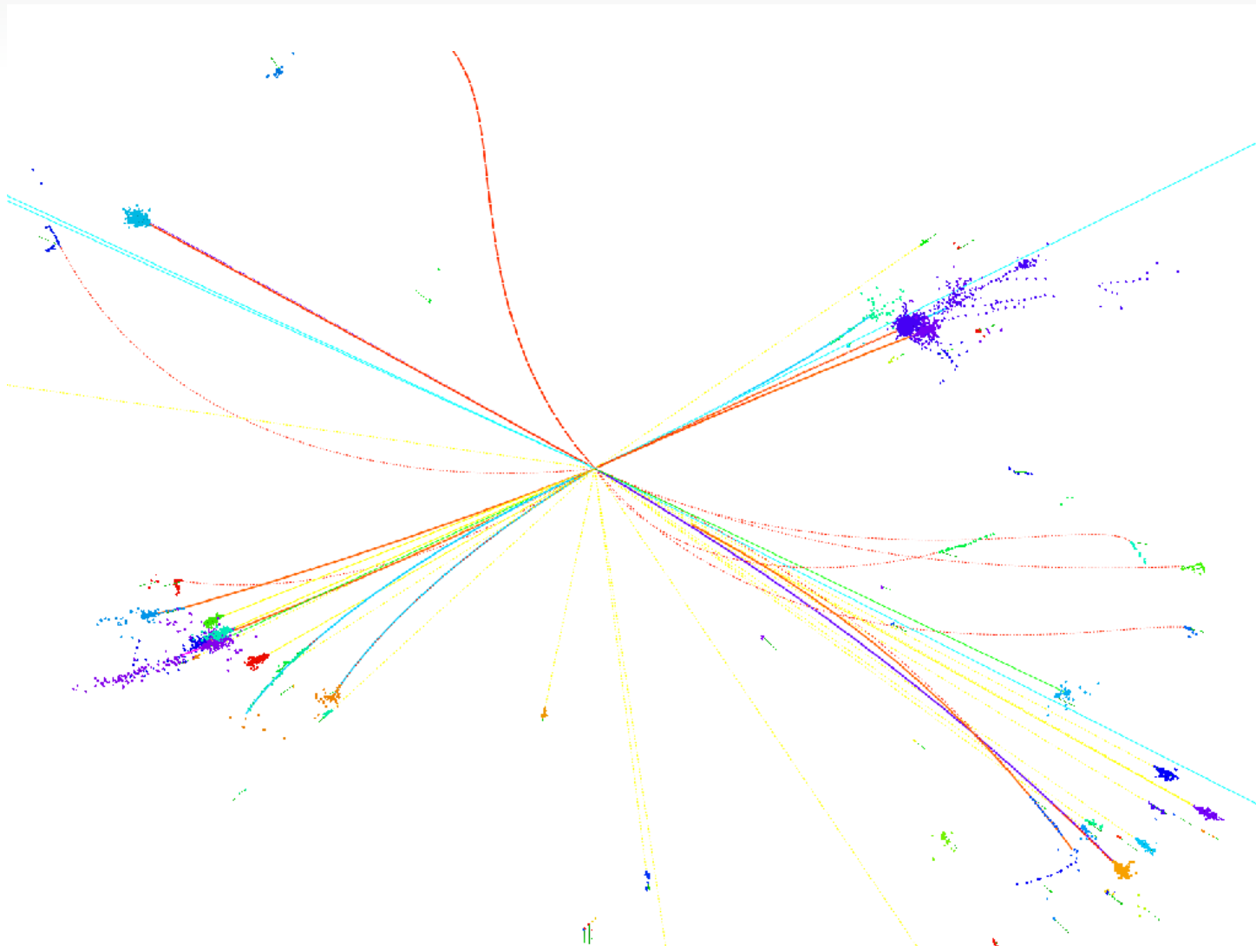
- llH channel:
 - Pre-selection
 - τ finding
 - Multiplicity
 - Rejection: jets
 - Impact parameter
 - Vertex information
 - Rejection: $H \rightarrow WW$

Tau Finder (IIH)

- Cut efficiency: 93.15%
- Impact parameter: starting points for tracks decayed from τ s > others
- Fit result: signal $\sim 2137 \pm 48$
- mumuH Accuracy: **2.26%**
- nnH: 4.29% (Huge background)



Tau Finder (qqH)



qqH channel:

- Pre-selection
- τ finding
 - Multiplicity and isolation
- Rejection: jets
- Event finding
 - $\tau\tau$ information
 - qq information
- Impact parameter

Tau Finder (qqH)

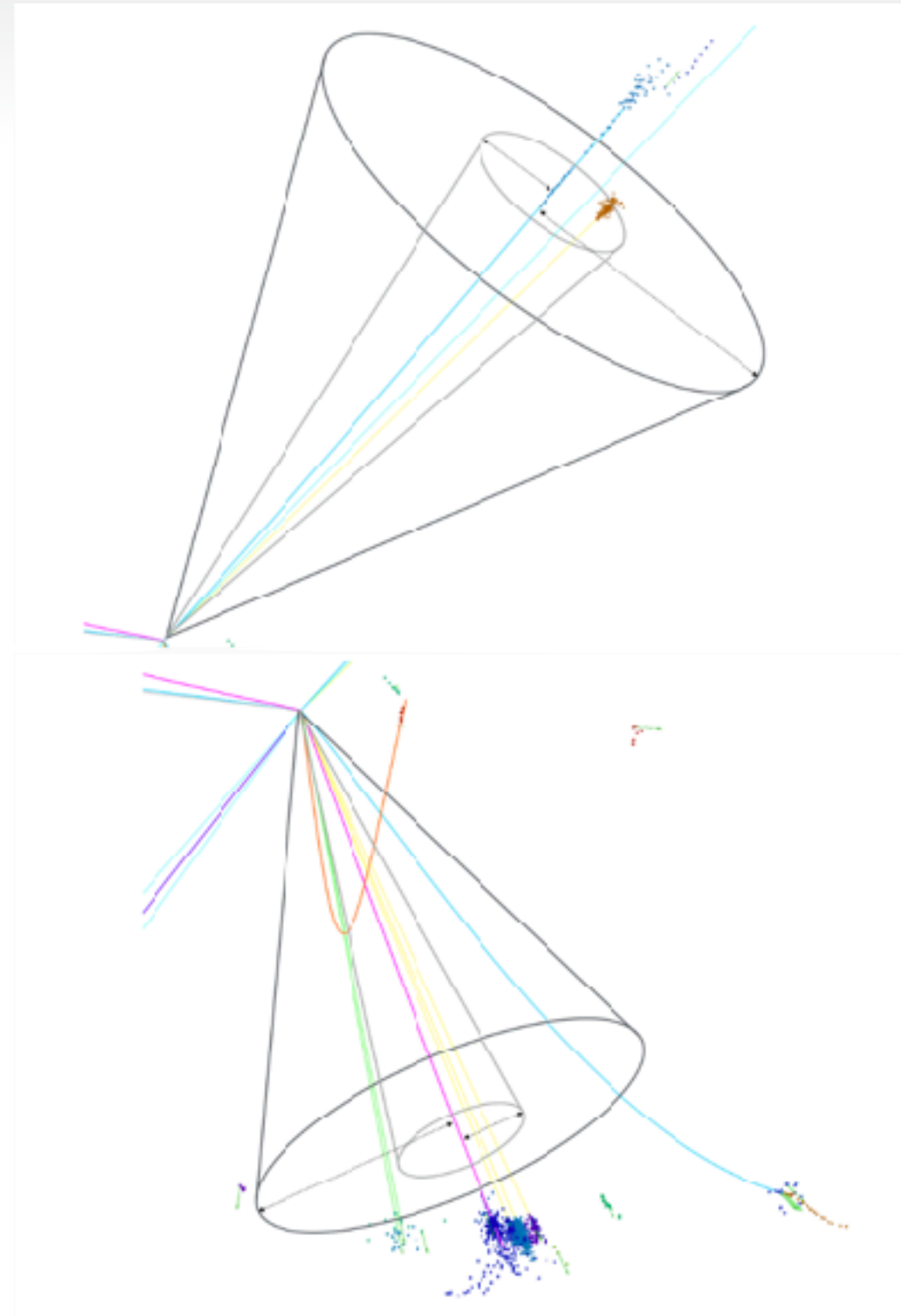
- Tracks energy ($> 1.5\text{GeV}$)
- $N_{\text{tracks}} < 7$, $N_{\text{photons}} < 10$ in $\text{cone}_s(0.15)$
- Isolated: energy ratio of cone_s to $\text{cone}_l(0.45) > 0.92$
- visible mass ($< 2.0\text{GeV}$)
- existing opposite charged τ s
- optimized to efficiency $\times$ purity (58%)

efficiency:

$$N(\tau^+\tau^-)/N(\text{qqH}\tau\tau)$$

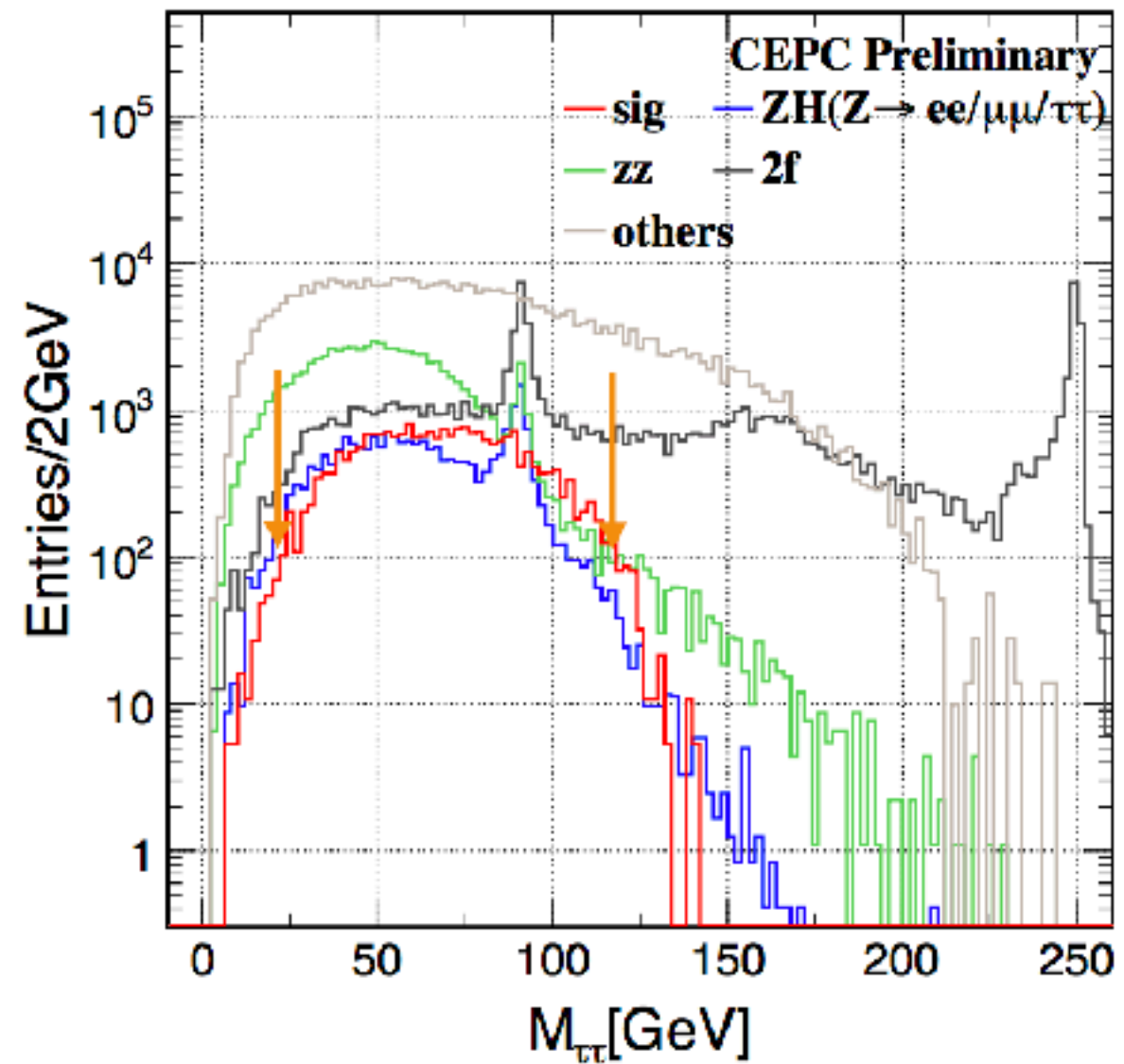
purity:

$$1 - N(\tau^+\tau^-)/N(\text{qqH inclusive})$$



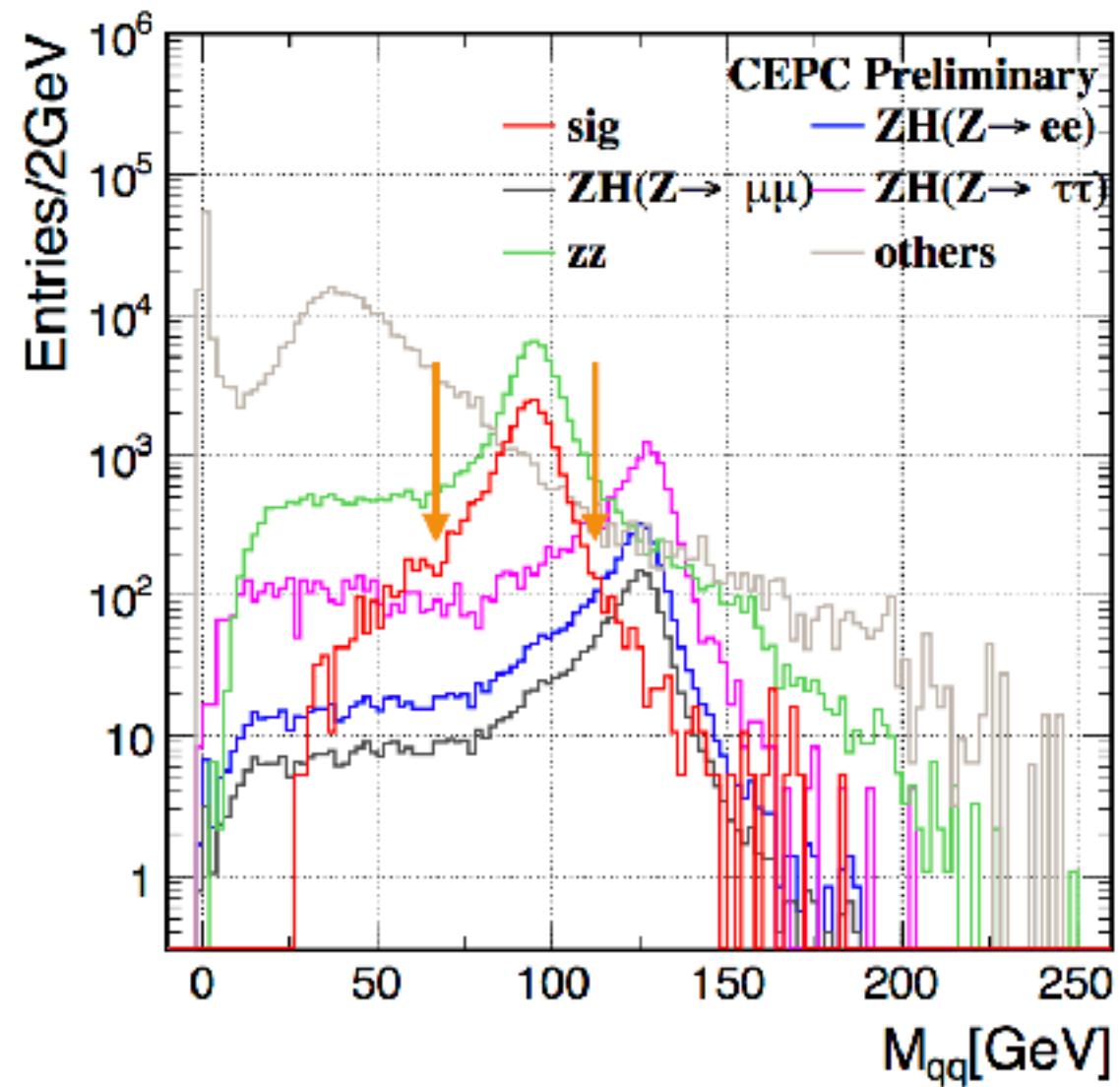
TauTau Invariant Mass

- (20GeV, 120GeV)
- Main background reduced:
 - 2f
 - fake tau candidate
- Main background remaining:
 - ZH
 - ZZ
 - WW



qq Invariant Mass

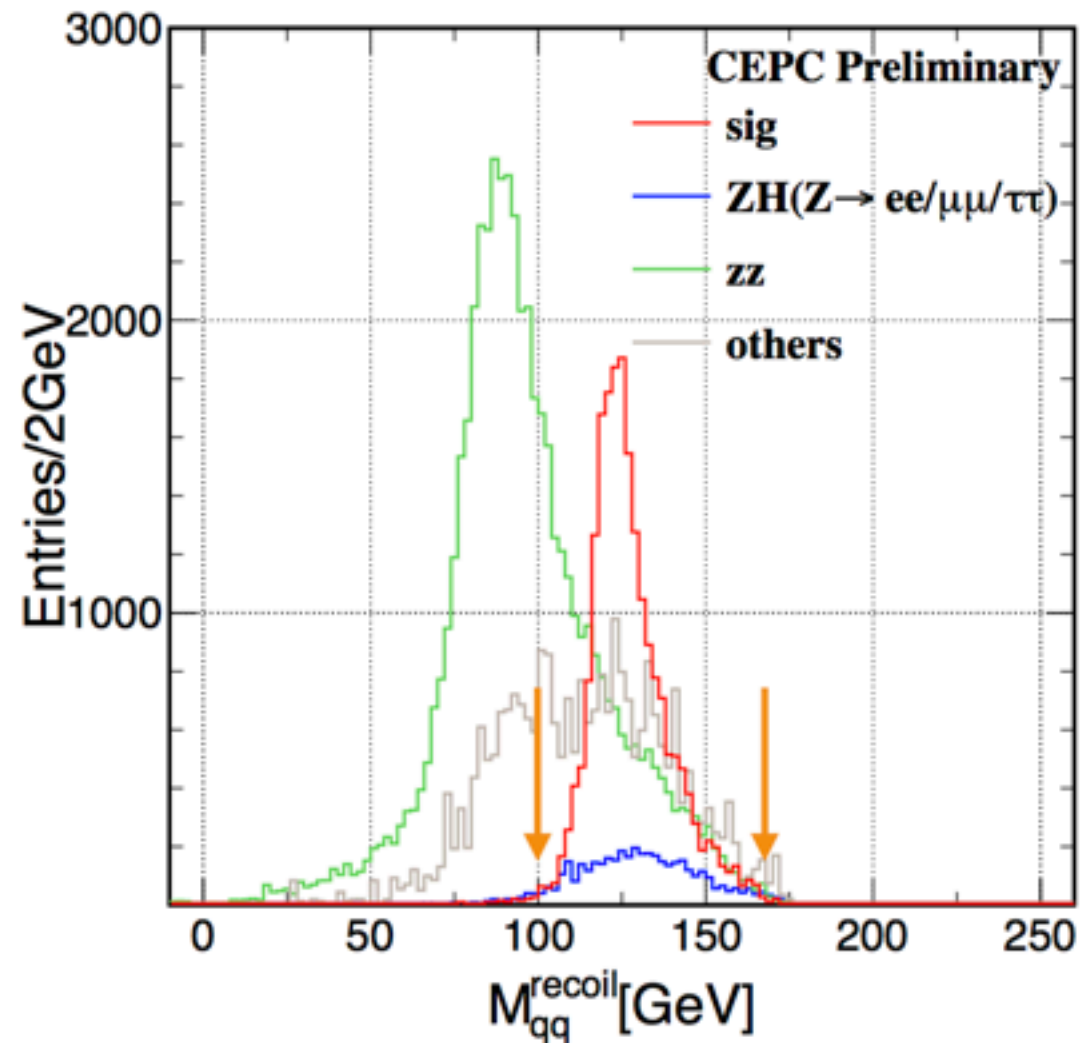
- Peak @ M_Z
- Main background reduced:
 - ZH with Z to tau
 - WW semi-leptonic
- Main background remaining:
 - ZZ



M_Z : signal, ZZ
 M_H : ZH conjugation

qq Recoil Mass

- Peak @ M_H
- Main background reduced:
 - $ZZ \rightarrow qq\tau\tau$
- Main background remaining:
 - irreducible backgrounds

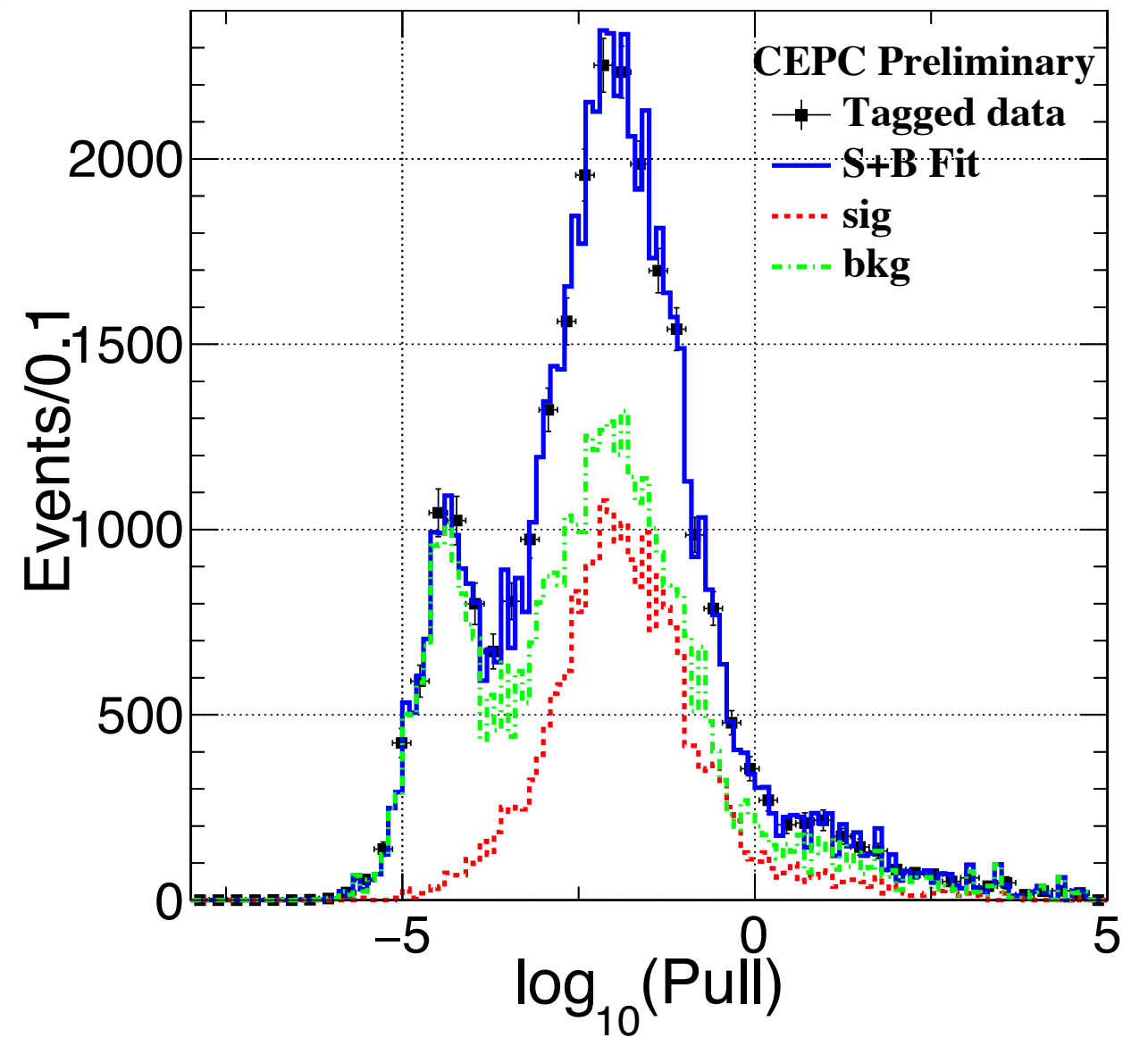


M_Z : ZZ

M_H : signal

Tau Finder (qqH)

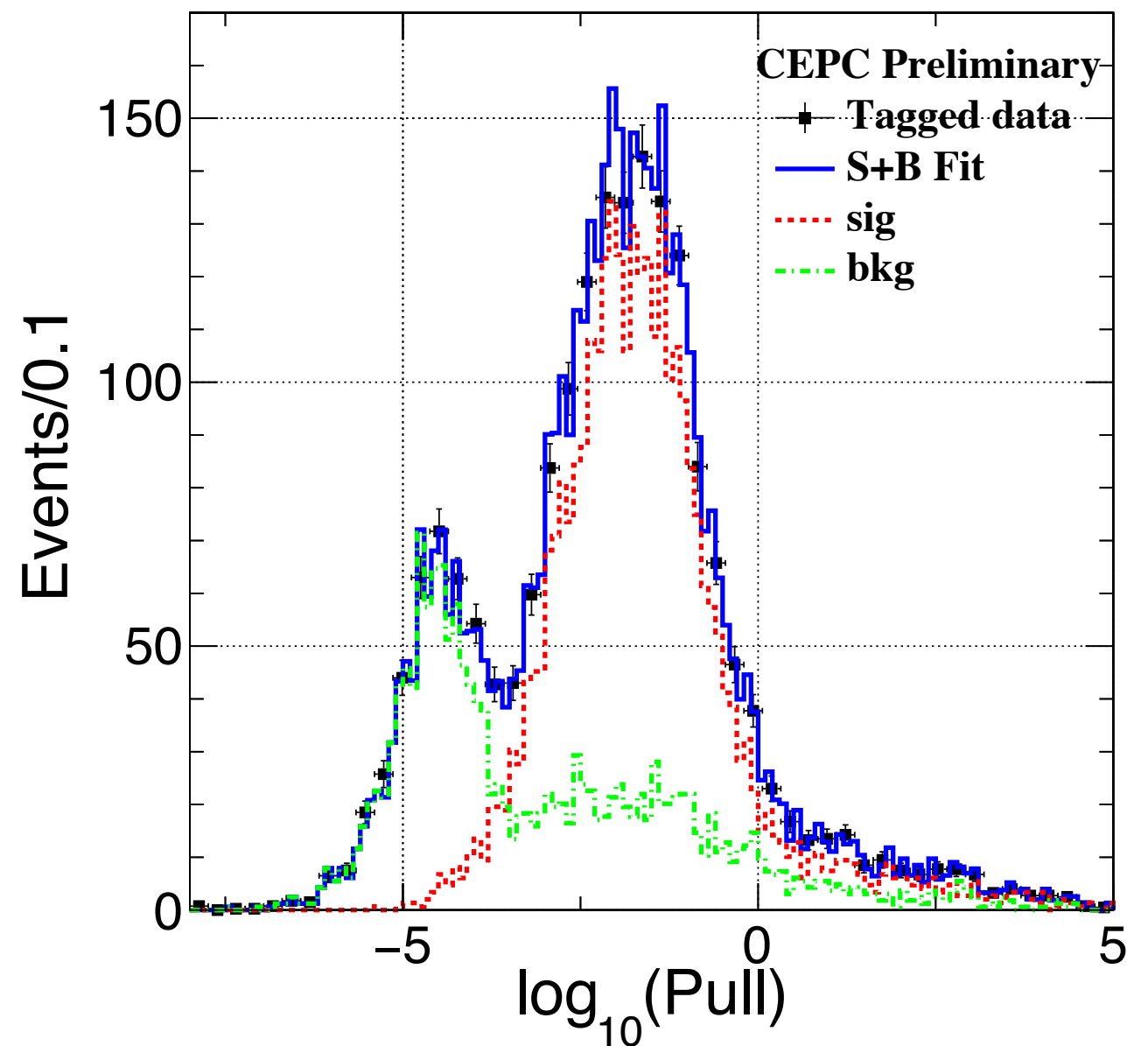
- Fit result: signal
 22153 ± 206
- Accuracy: $0.93 \pm 0.01\%$



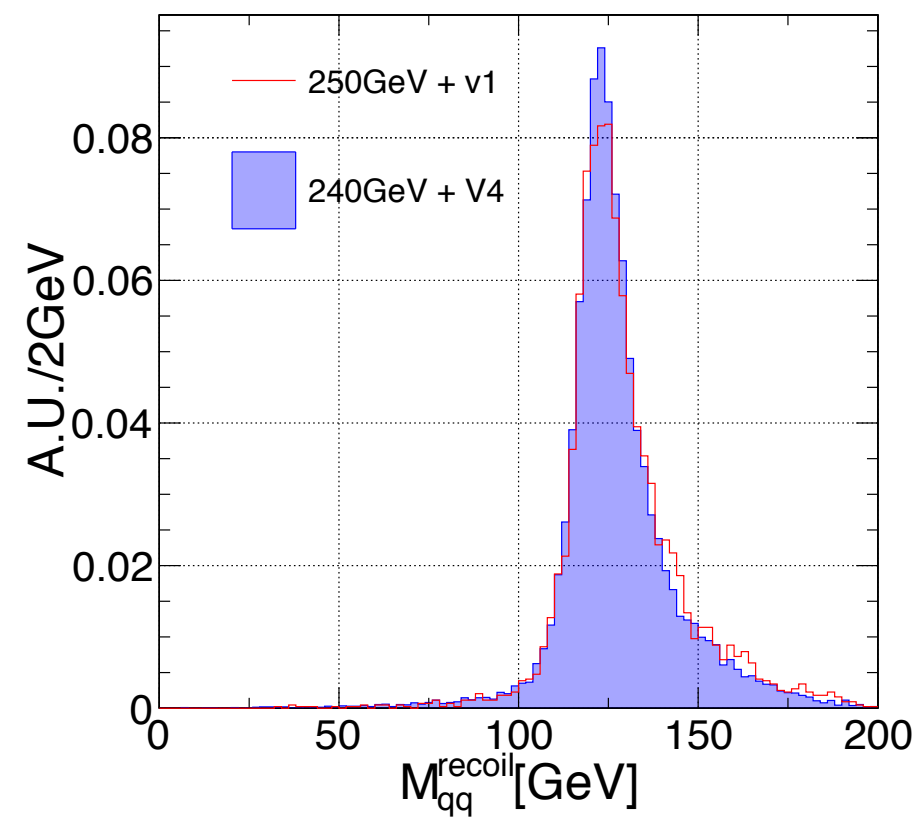
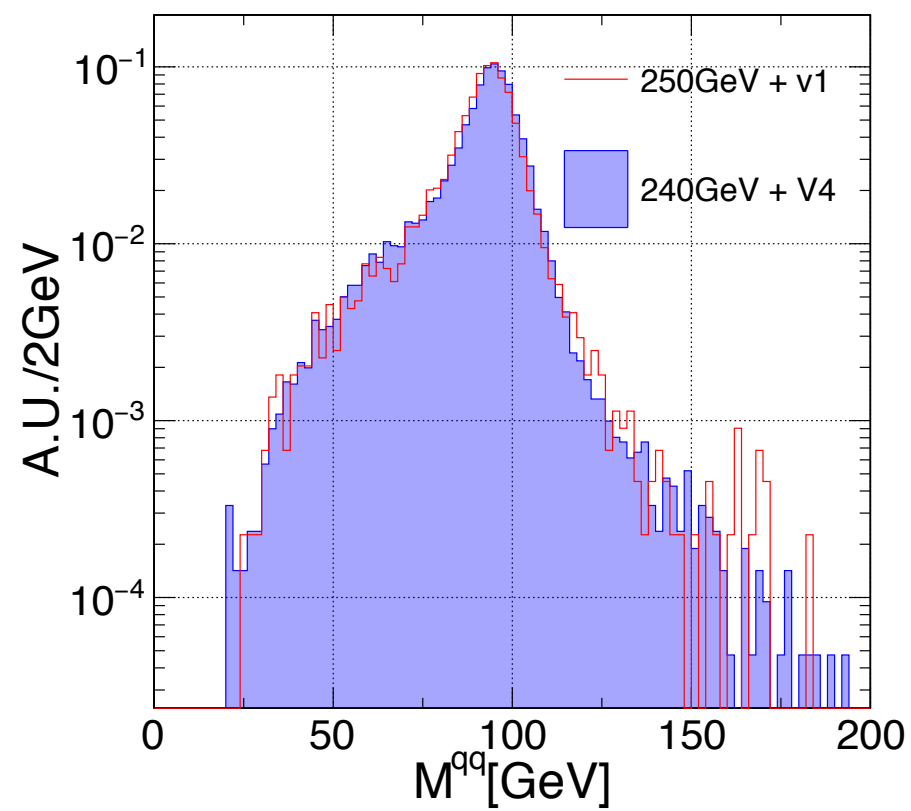
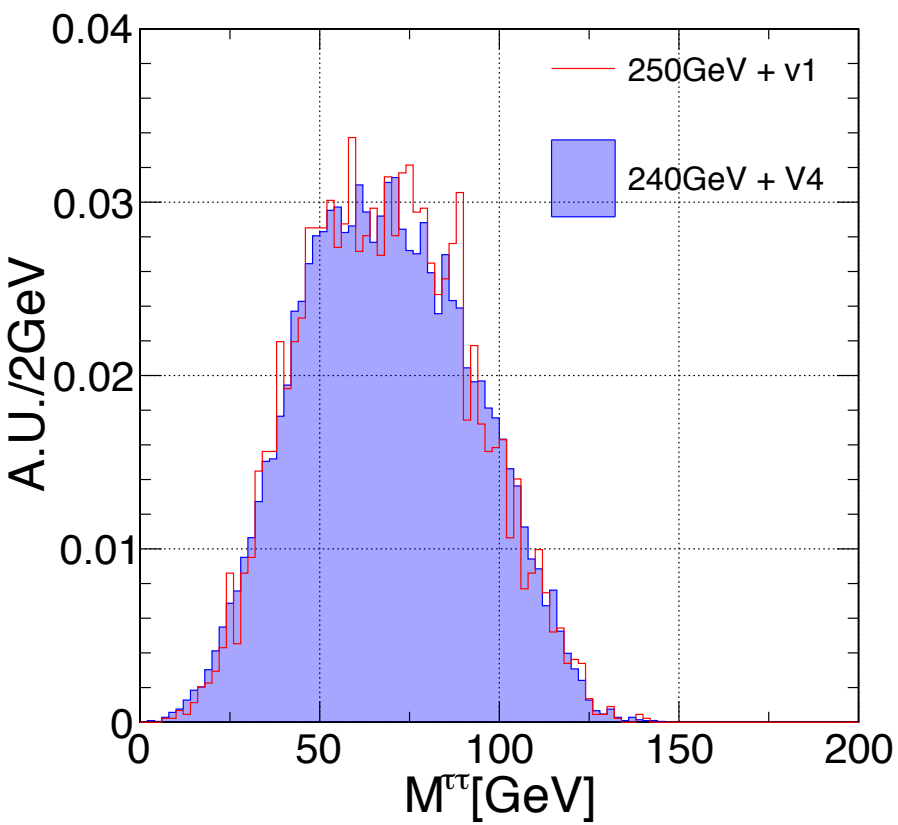
CEPC_V4

Tau Finder (IIH) - APODIS(240GeV)

- Cut efficiency: 95.81%
- Fit result: signal $\sim 2037 \pm 45$
- Background scaled from CEPC_V1 + 250 GeV
- mumuH Accuracy: $2.21 \pm 0.05\%$



Parameters Comparison

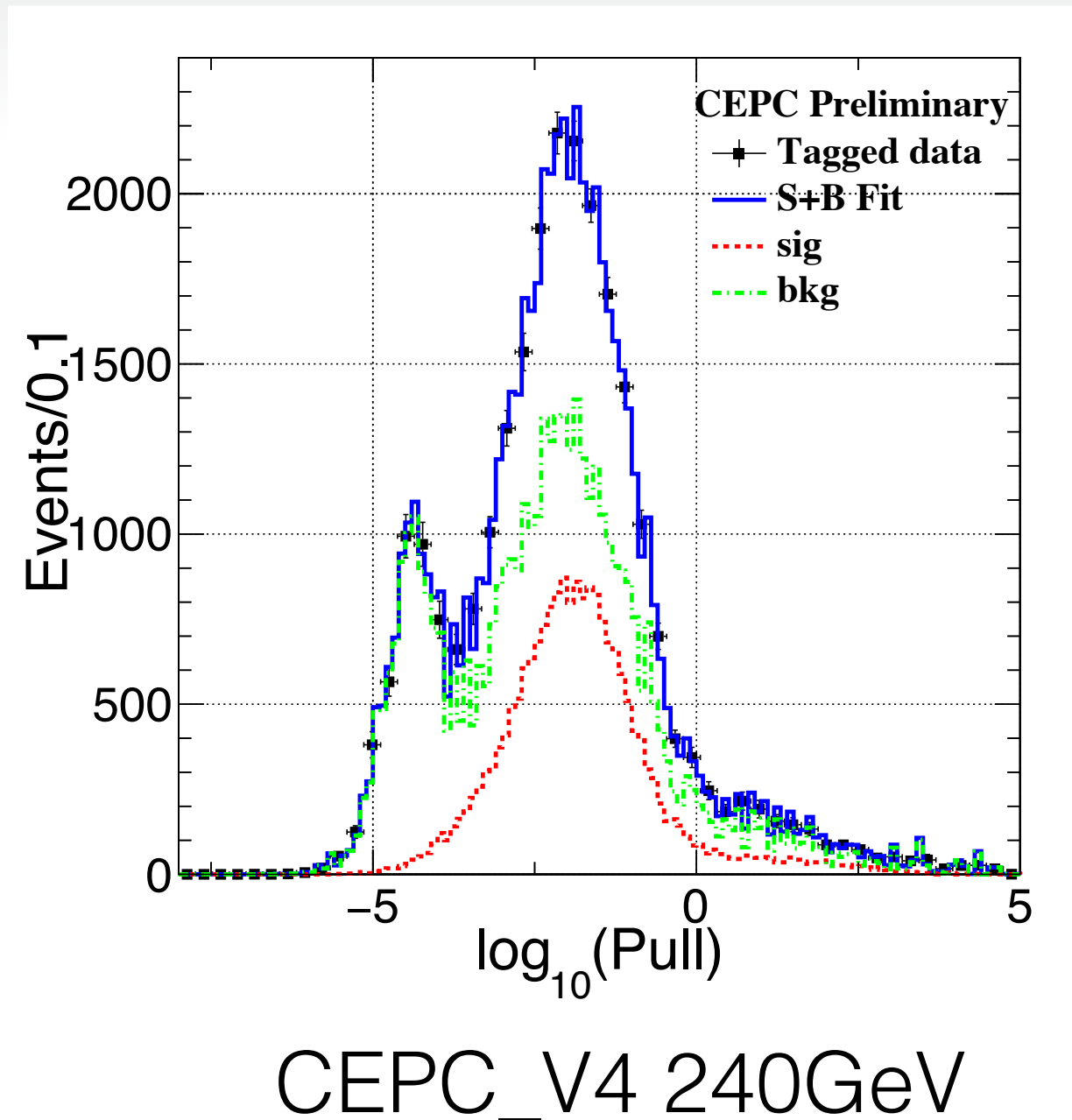


Cut Chain & signal strength

Sample	CEPC_V1 + 250GeV		CEPC_V4 + 240GeV	
	sig	qqH bkg	sig	qqH bkg
a pair of tau	54.66%	4.20%	54.16%	4.34%
M(tautau)	53.79%	3.60%	53.10%	3.67%
M(qq)	50.80%	1.21%	48.38%	1.26%
RecoilM(qq)	50.29%	1.17%	47.80%	1.19%
qqH accuracy	0.93%		0.97%	
convolute accuracy	0.81%		0.87%	

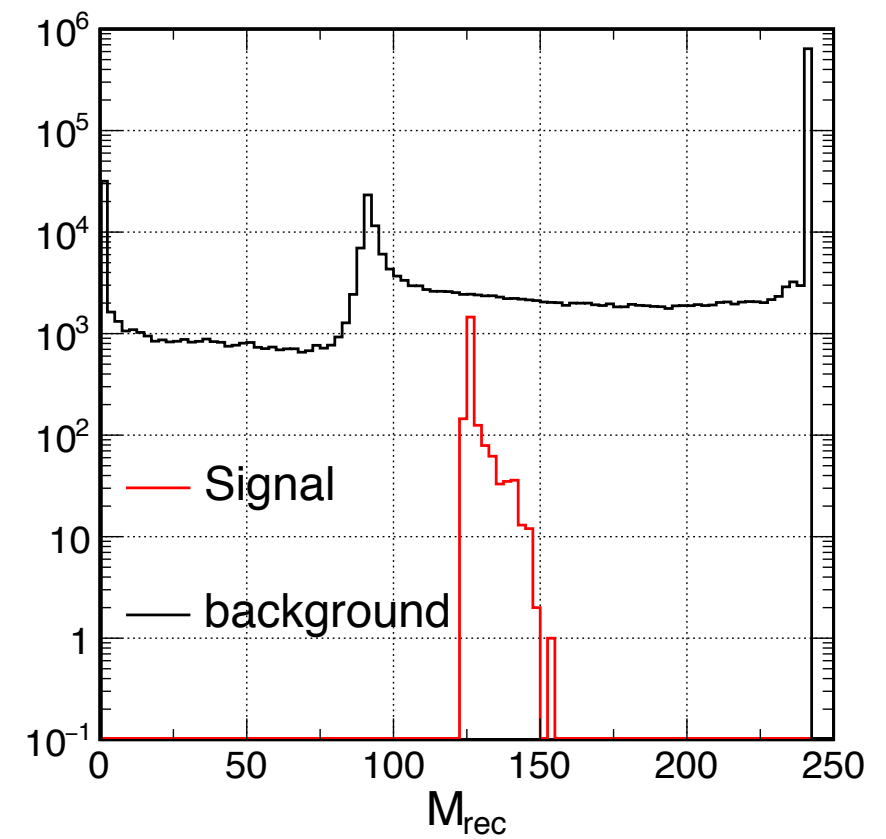
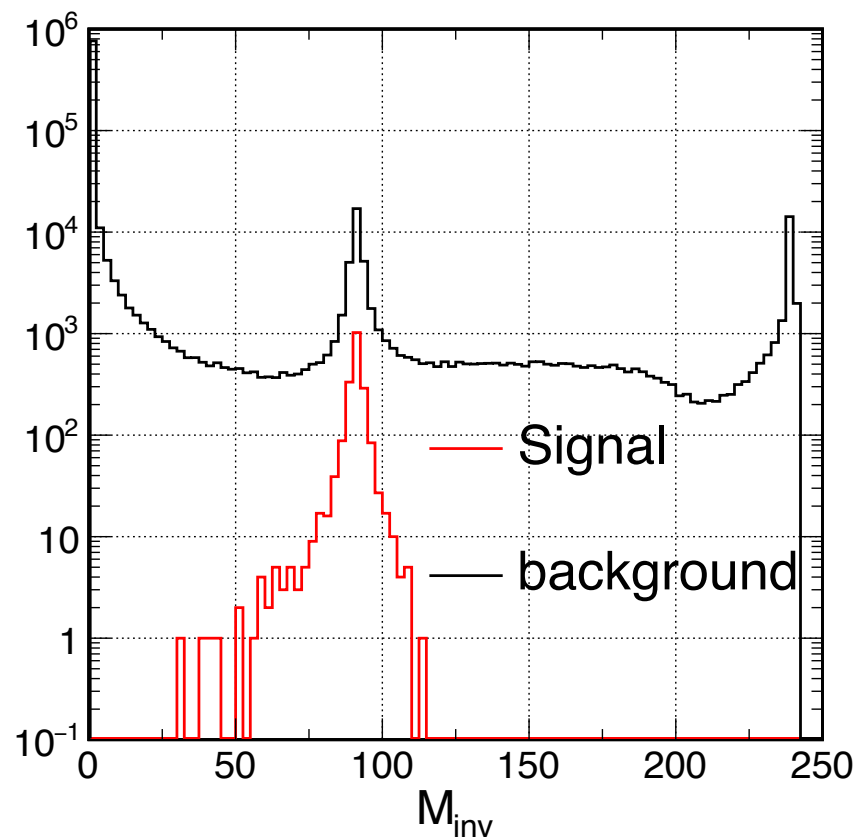
Impact Parameter Fit

- Cut efficiency: 47.80%
- Fit result: signal $\sim 19343 \pm 187$
- Background scaled from CEPC_V1 + 250 GeV
- qqH Accuracy: $0.97 \pm 0.01\%$



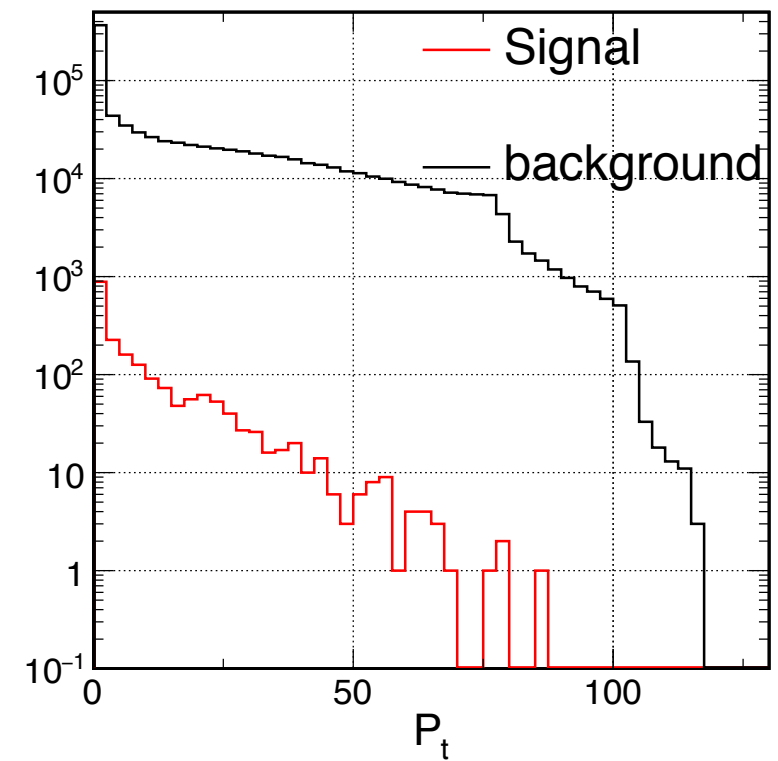
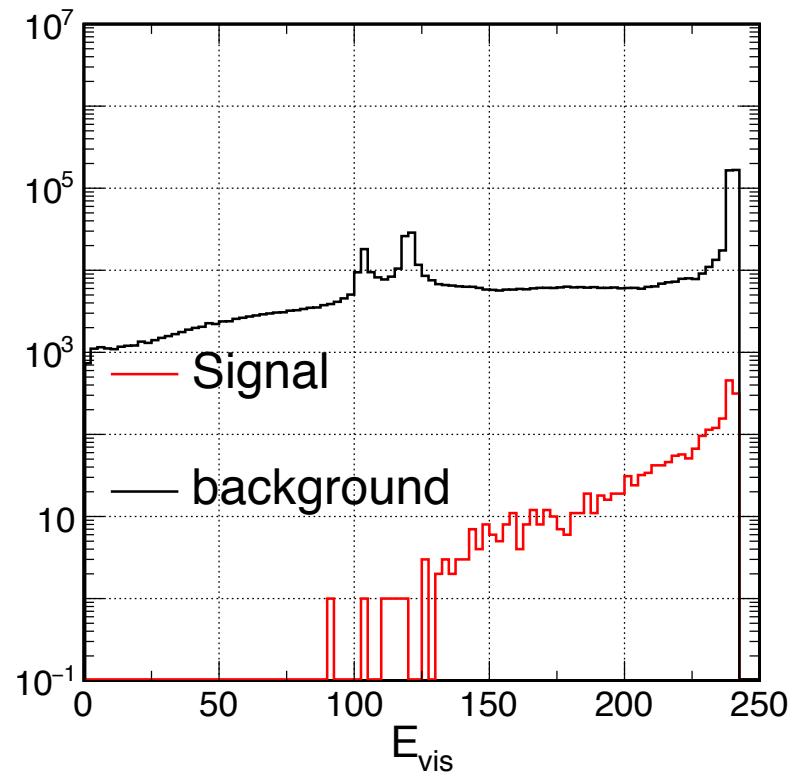
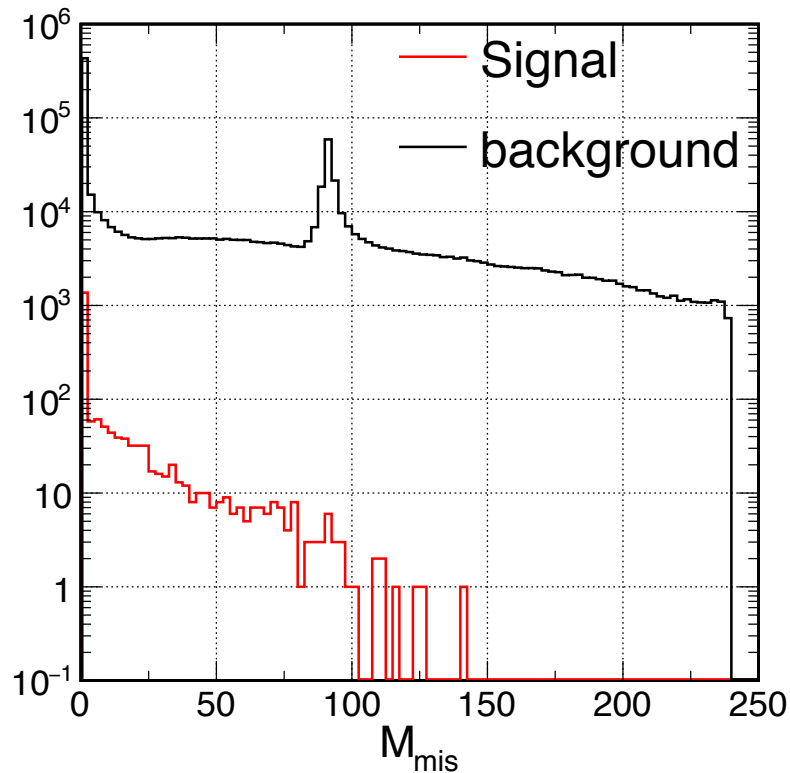
CEPC_V4 Bkg— $\mu\mu H$

- (only for illustration)
- Larger cross section of $2f(\mu\mu)$ background



	signal	$\mu\mu H$ bkg	SM bkg
total generated	2186	31997	520841381
after preselection	2183	31964	1779920

CEPC_V4 Bkg— qqH

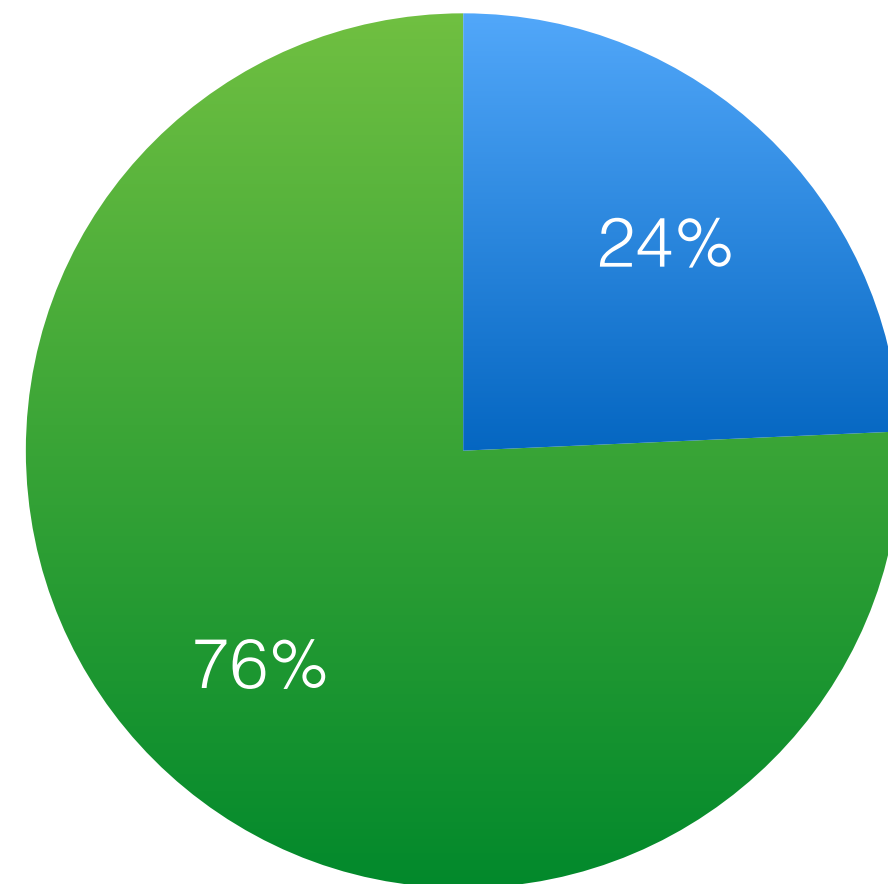


	signal	qqH bkg	SM bkg
total generated	43504	647038	520841381
after preselection	43395	645419	172624958
2nd preselection	43089	166293	21306934

CEPC_V4 Bkg

- Total: 23086854
- done: 2585800
- remaining time:
3 weeks
- eeH+nnH:
 - only signal?

● done ● waiting



Summary

- $H \rightarrow \tau\tau$ has been analyzed @ CEPC_V1 (IIH/qqH)
 - Idea: Multiplicity + Impact Parameter + (Event info)
 - Result: $\delta(\sigma \times \text{Br})/(\sigma \times \text{Br}) \sim 0.81\%$
- Full simulation for $\mu\mu H + qqH$ @ CEPC_V4 (240GeV)
- Backgrounds and other channels are extrapolated
- Still need time for further solid results

	$\mu\mu H$	eeH	nnH	qqH	combination
CEPC_V1	2.26 ± 0.05	2.72 ± 0.05	4.29 ± 0.02	0.93 ± 0.01	0.81 ± 0.01
APODIS	2.21 ± 0.05	2.69 ± 0.05	4.95 ± 0.02	0.97 ± 0.01	0.83 ± 0.01

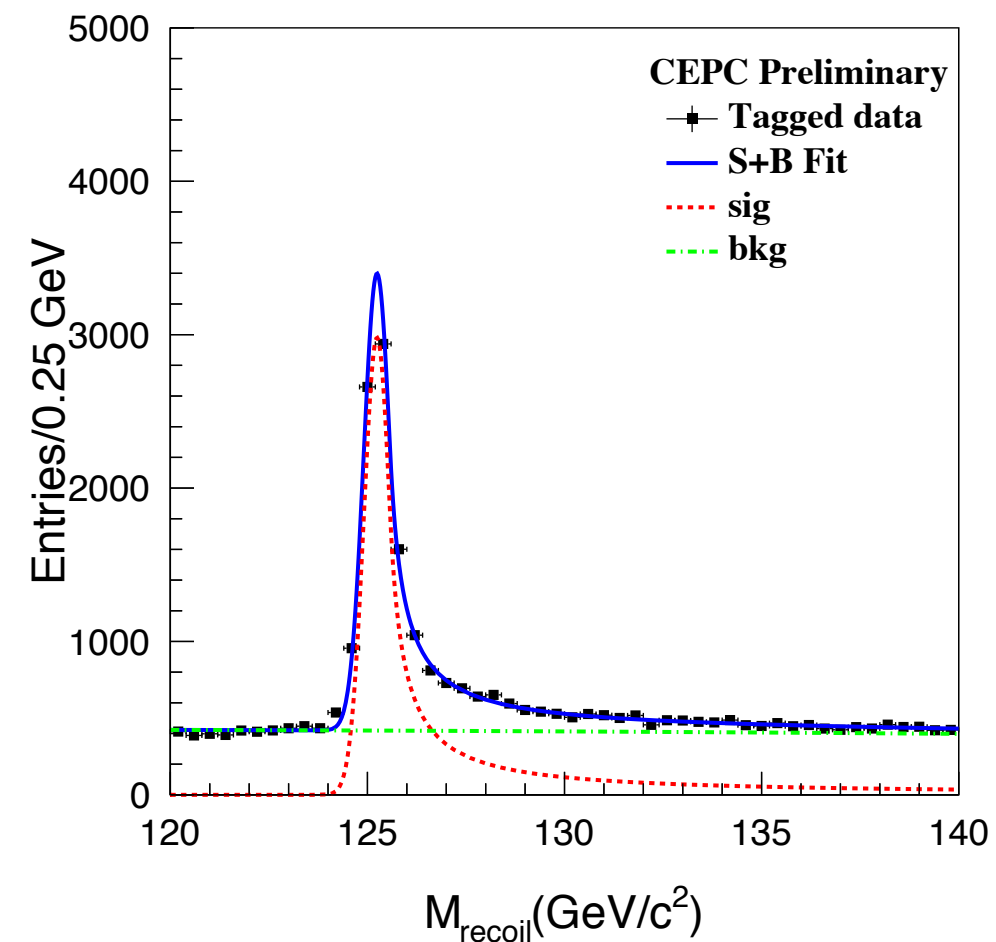
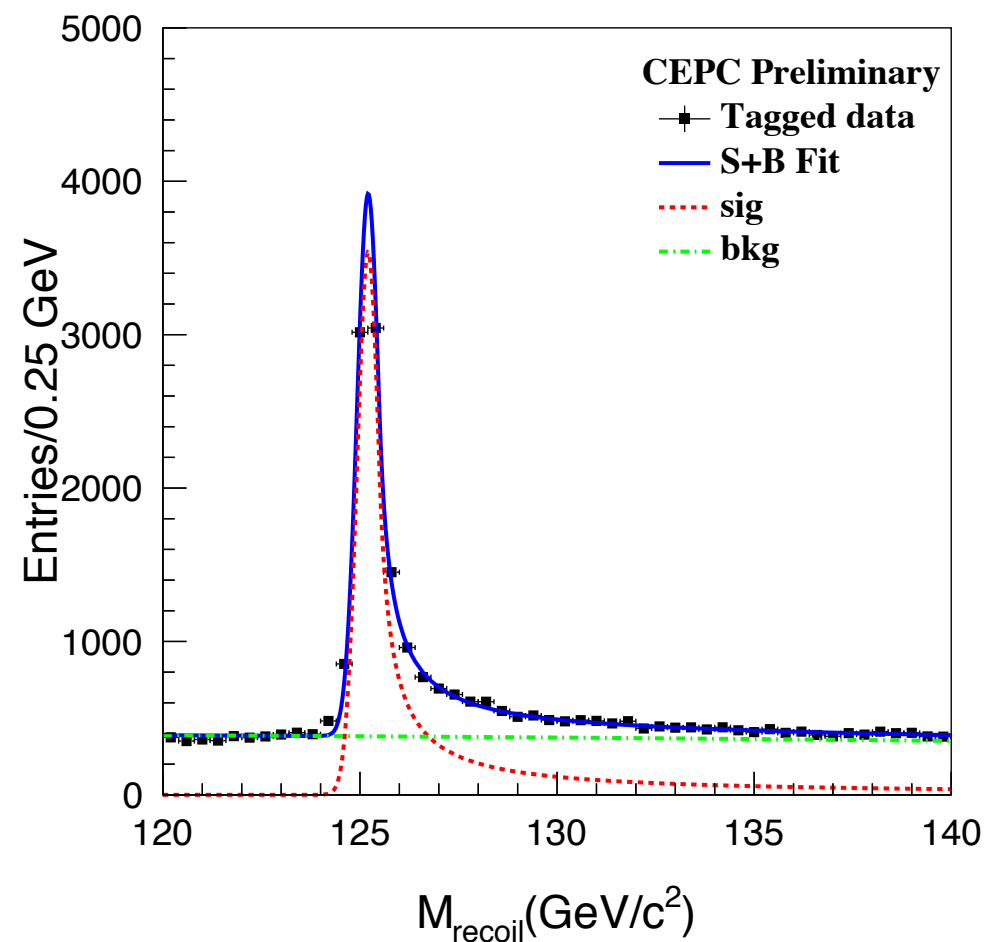
ZH cross section

$\mu\mu H$ recoil mass

- V1: Chen
Zhenxing's analysis

*CPC 2017, 41 (2) :
33-40*

- Statistics
- B field — lower
momentum
resolution



	CEPC_v1	APODIS
$\delta\sigma_{ZH}/\sigma_{ZH}$	0.81%	0.85%
$\delta M_H(M-I)$	6.5 MeV	6.9 MeV
$\delta M_H(M-D)$	5.4 MeV	5.9 MeV

Thank you for you attention!

Back up

- Similar procedure as $\mu\mu H$, without vetoing charged track
- Signal efficiency after pre-selection: 60.8% (not optimized)
- Signal efficiency after τ finder: 57.02%
- Huge irreducible background: tough to fit...
- Accuracy: 4.29%

	$\nu\nu H\tau\tau$	$\nu\nu H$ inclusive bkg	ZZ	WW	singleW	single Z	2f
total generated	15497	231670	5711445	44180832	17361538	7809747	418595861
after preselection	9434	214830	1239457	7463105	3327803	956694	12826280
$N_{Trk}(A/B) < 6$ & $N_{Ph}(A/B) < 7$	9260	8858	24760	1354852	17389	676185	1535029
BDT > 0.78	8836	6587	15450	89729	1355	10739	11243
efficiency	57.02%	2.84%	0.27%	0.20%	$<0.01\%$	0.14%	$<0.01\%$

Combine & extrapolation

Combined result for CEPC (5 ab^{-1})

	$\delta (\sigma \times \text{BR}) / (\sigma \times \text{BR})$
$\mu\mu\text{H}$	2.26%
eeH(extrapolated)	2.72%
$\nu\nu\text{H}$	4.29%
qqH	0.93%
combined	0.81%

Extrapolation to ILC250 (2 ab^{-1}):

Type	(-80%,30%)	(80%,-30%)	non-pol
Total Higgs	604224	396196	424000
$\mu\mu\text{H}$	2.98	3.63	3.57
$\nu\nu\text{H}$	5.48	4.34	6.78
qqH	1.26	1.36	1.47
combined	1.13	1.22	1.33

	$\mu\mu H\tau\tau$	$\mu\mu H$ inclusive bkg	ZZ	WW	single W	single Z	$2f$
total generated	2292	33557	5711445	44180832	15361538	7809747	418595861
after preselection	2246	32894	122674	223691	0	86568	1075886
$N_{Trk}(A/B) < 6$ & $N_{Ph}(A/B) < 7$	2219	1039	2559	352	0	9397	25583
BDT>0.78	2135	885	484	24	0	157	161
efficiency	93.15%	2.63%	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%

	$qqH\tau\tau$	qqH inclusive bkg	ZH inclusive bkg	ZZ	WW	single W	single Z	$2f$
total generated (scaled to 5 ab ⁻¹)	45597	678158	357249	5711445	44180832	17361538	7809747	418595861
1st preselection	45465	677854	310245	5039286	42425195	1267564	1398362	148401031
2nd preselection	45145	174650	226059	293306	12452091	125735	117306	547402
$N_{\tau^+} > 0, N_{\tau^-} > 0$	24674	7342	33721	93955	723989	33887	54386	103642
$20GeV < M_{\tau^+\tau^-}$ < 120GeV	24284	6290	32344	88245	597480	24927	36039	56615
$70GeV < M_{qq}$ < 110GeV	22937	2103	4887	65625	21718	738	1893	556
$100GeV < M_{qq}^{Rec}$ < 170GeV	22703	2045	4524	23789	13154	315	306	193
efficiency	49.97%	0.31%	1.26%	0.41%	0.04%	<0.01%	<0.01%	< 0.01%