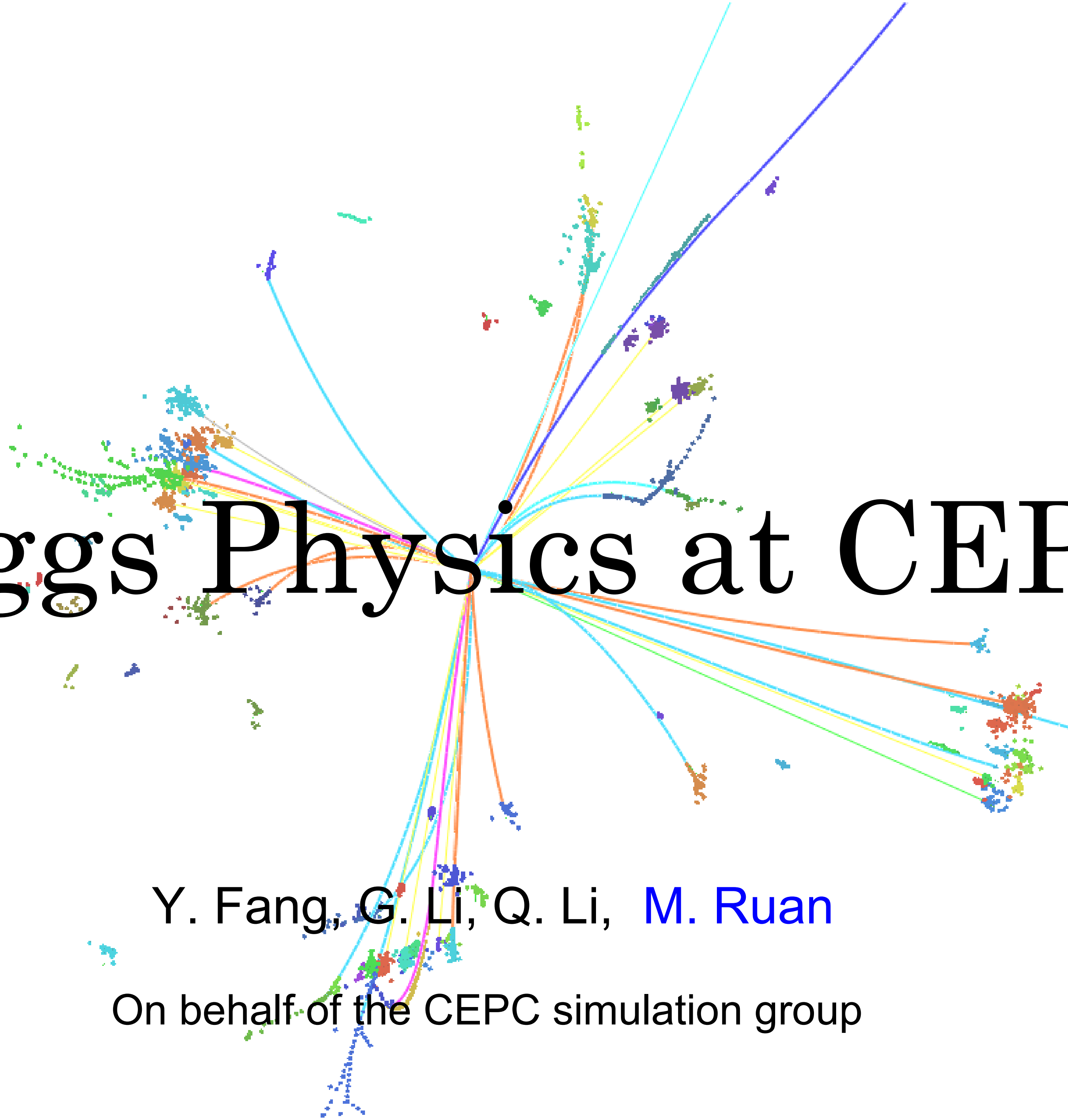
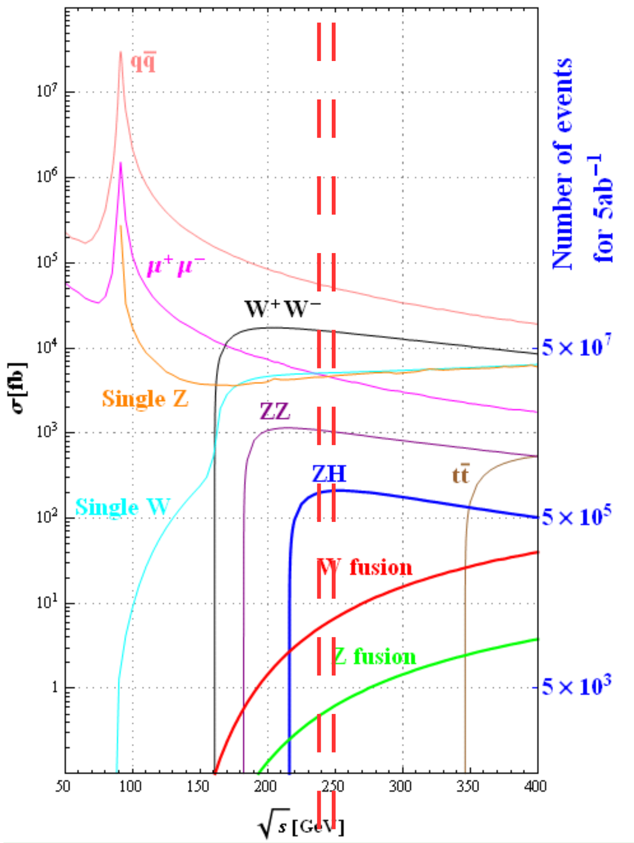


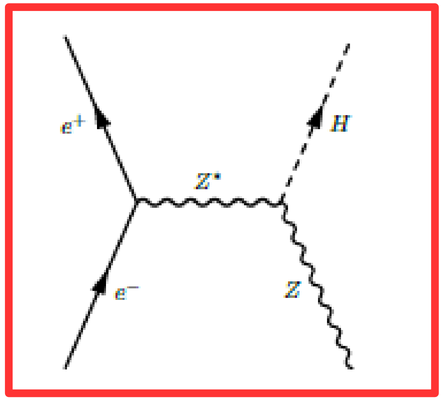
Higgs Physics at CEPC

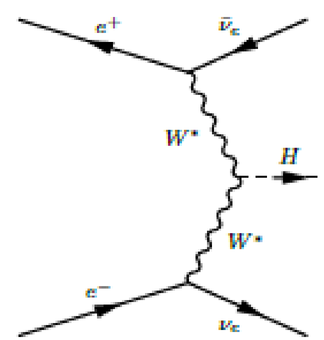
Y. Fang, G. Li, Q. Li, M. Ruan

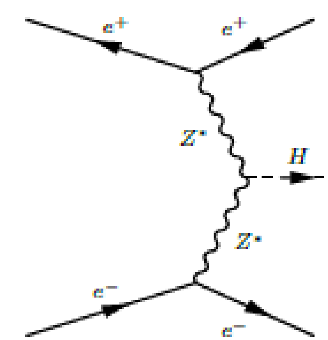
On behalf of the CEPC simulation group

Higgs program at CEPC







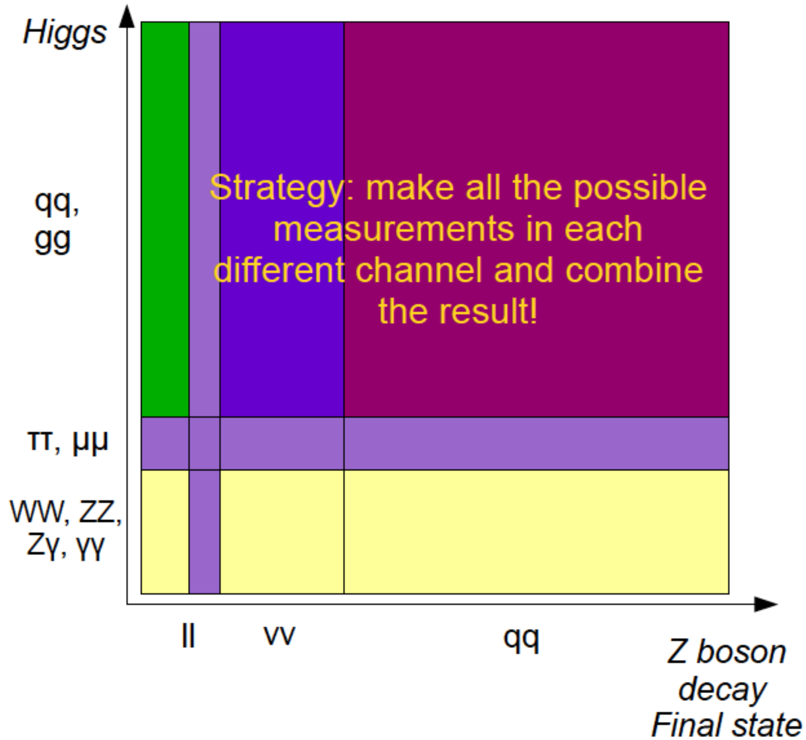


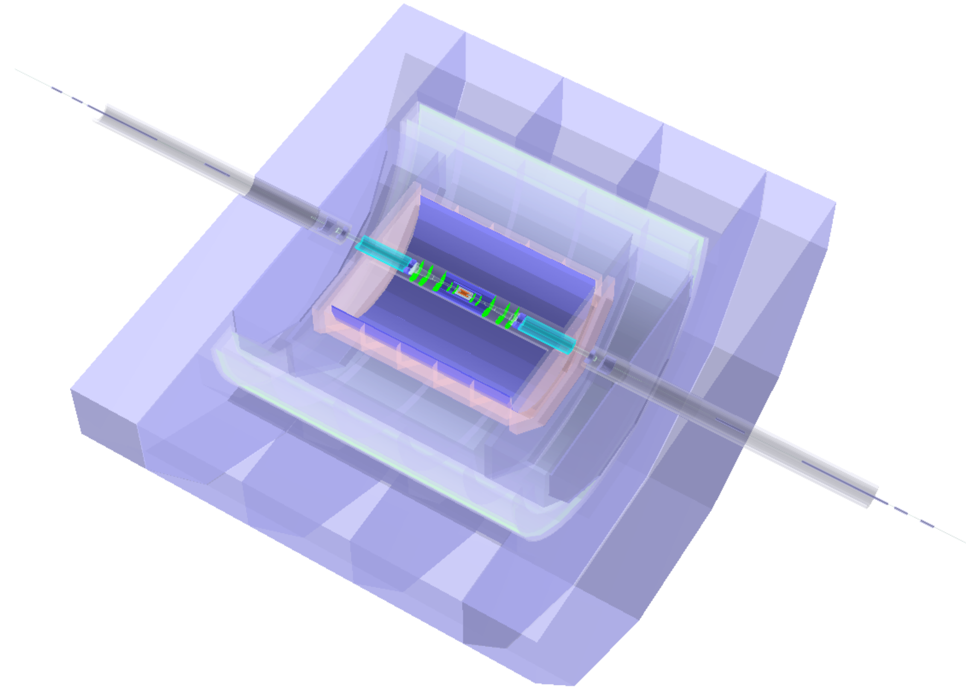
Process	Cross section	Events in 5 ab^{-1}
Higgs boson production, cross section in fb		
$e^+e^- \to ZH$	212	1.06×10^6
$e^+e^- \to \nu\bar{\nu}H$	6.72	3.36×10^4
$e^+e^- \to e^+e^-H$	0.63	3.15×10^3
Total	219	1.10×10^6

Observables: Higgs mass, CP, σ(ZH), and σ(ZH, vvH)*Br(H→X)

Derive: **Higgs width**, **Br(exotic),** absolute values of branching ratios & of couplings

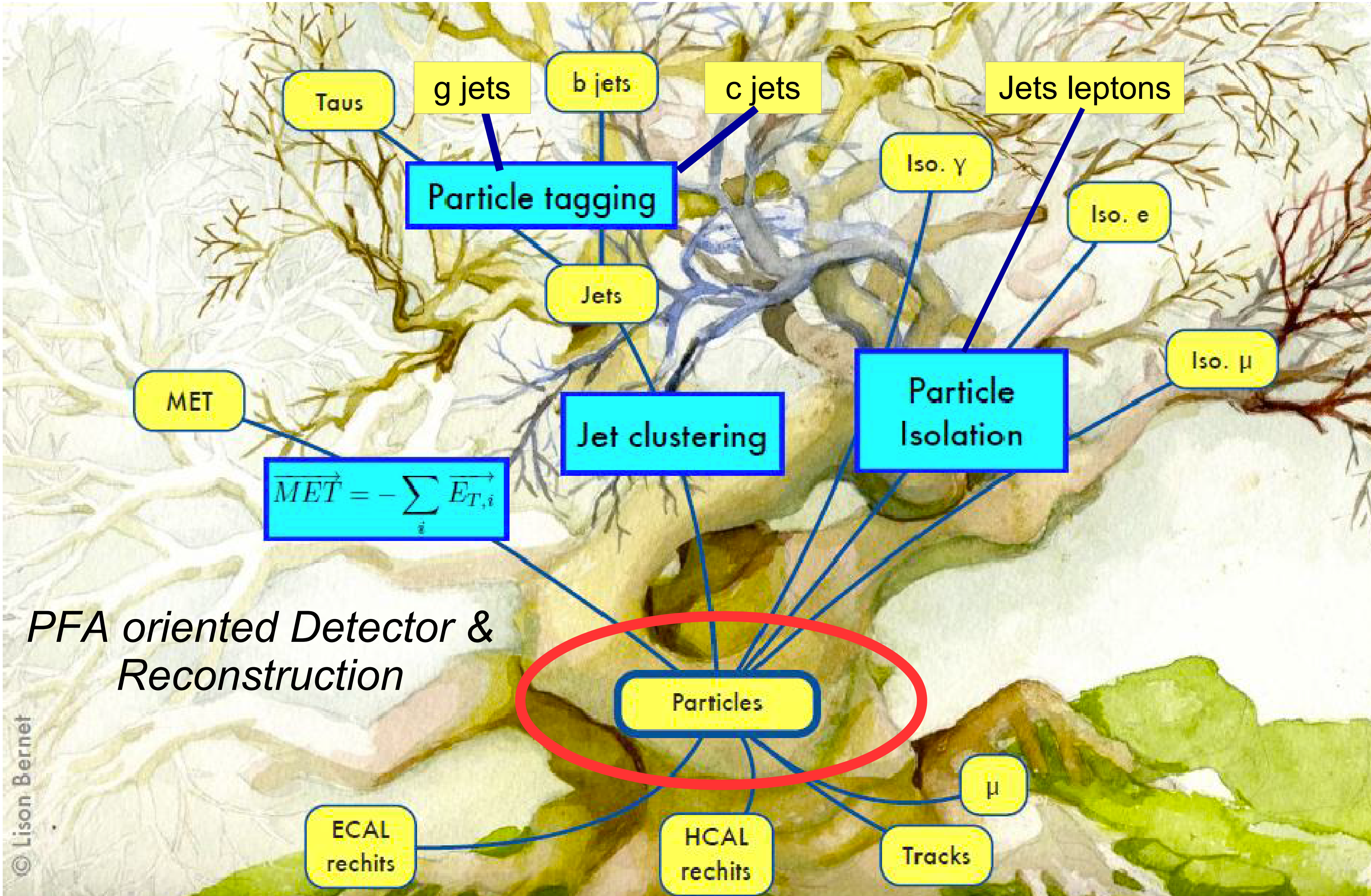
CEPC Conceptual detector, developed from ILD



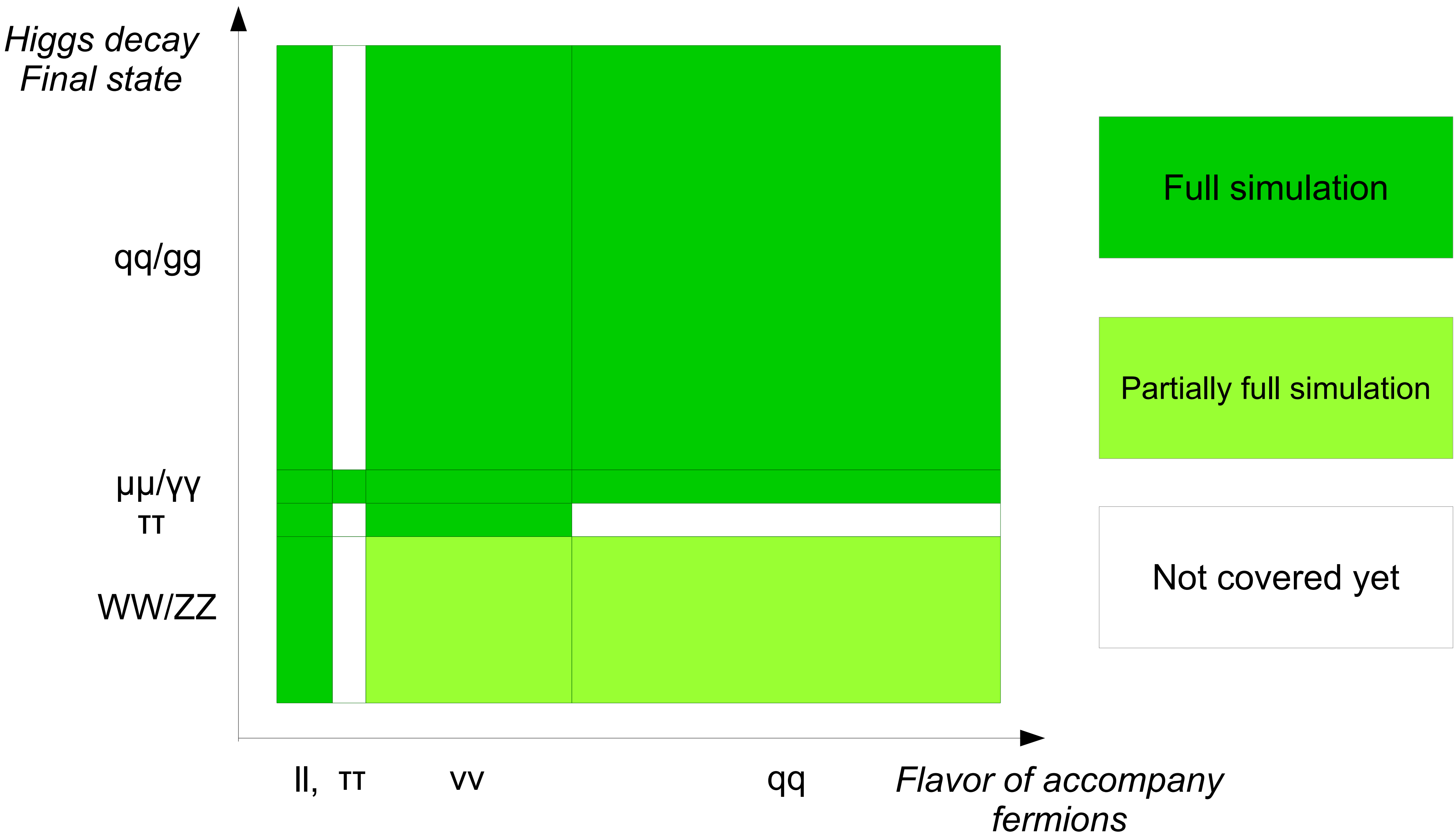


A detector reconstruct all the physics objects (lepton, photon, tau, Jet, MET, ...) with high efficiency/precision

High Precision VTX located close to IP: b, c, tau tagging
High Precision Tracking system: $\delta(1/Pt) \sim 2*10^{-5}(GeV^{-1})$
PFA oriented Calorimeter System ($\sim o(10^{8})$ channels): Tagging/ID, Jet energy resolution, etc

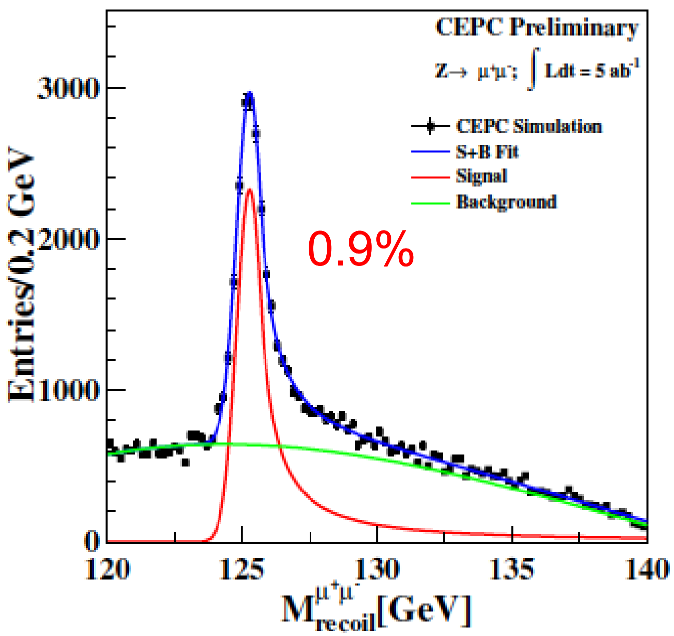

Taus
g jets
b jets
c jets
Jets leptons
Particle tagging
Iso. γ
Iso. e
Jets
Iso. μ
MET
Jet clustering
Particle Isolation
$\overrightarrow{MET} = -\sum_i \overrightarrow{E_{T,i}}$
PFA oriented Detector & Reconstruction
Particles
μ
ECAL rechits
HCAL rechits
Tracks
© Lison Bernet

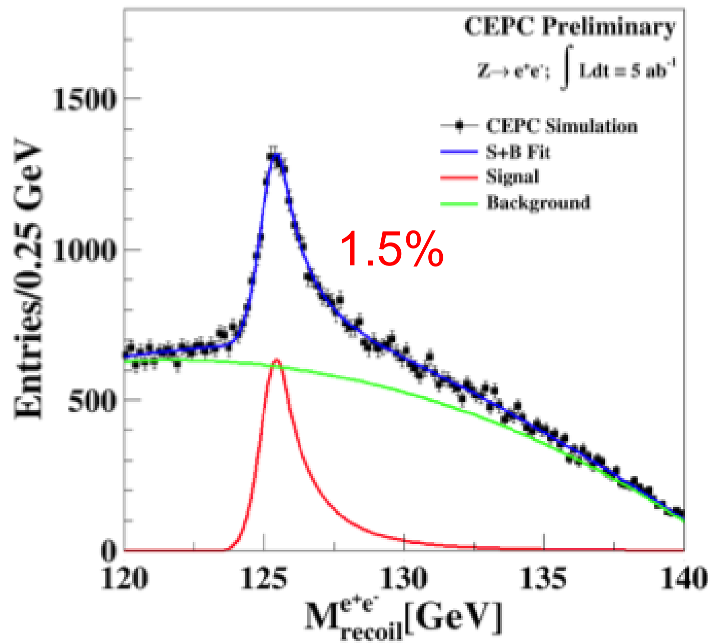
Higgs measurements: status

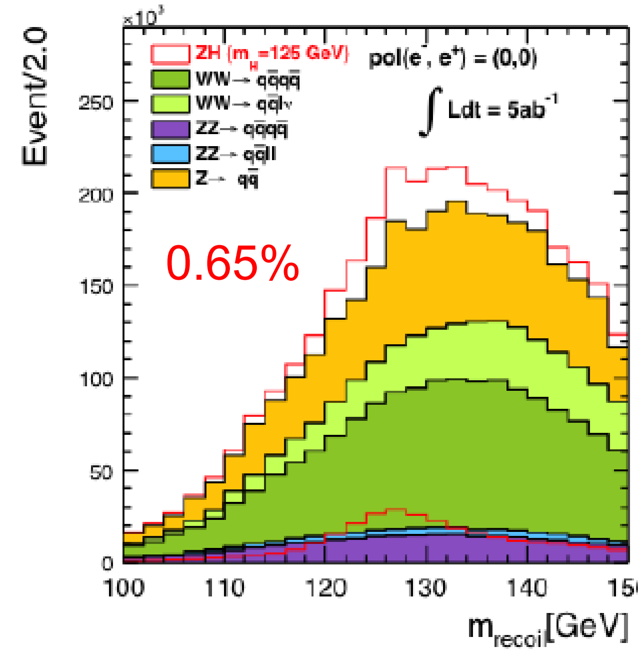


Model-independent measurement of σ(ZH)

Zhenxing Chen

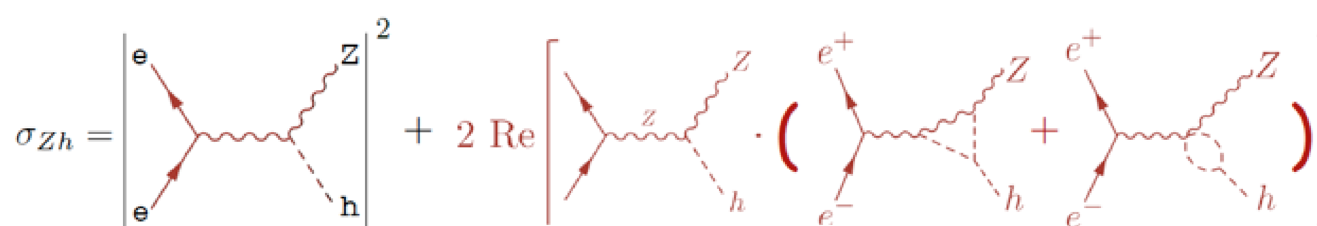






- Recoil mass method. Combined precision:
  δσ(ZH)/σ(ZH) = 0.5% -
  δg(HZZ)/g(HZZ) = 0.25%

- Indirect Access to g(HHH)



$$\delta_\sigma^{240} = 100\,(2\delta_Z + 0.014\delta_h)\,\%$$

Phys. Rev. D 90, 015001

Higgs width

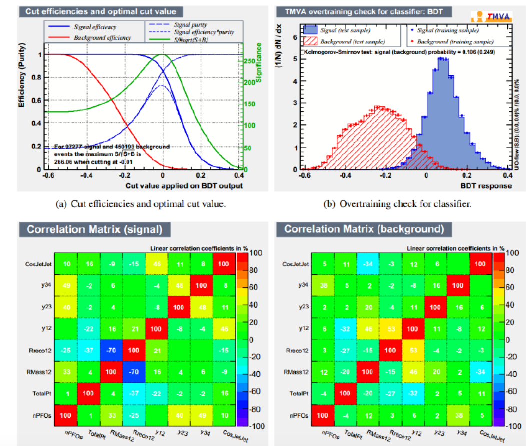
Br(H->bb, cc, gg) measurements

More details see Yu Bai's poster

2. Selection

Cut Definition	*Sig.*	*qq*	*qqnn*	*qqln*	*xxh*
FSClasser output	148955	25M	183687	3698817	63194
$N_{\mathrm{PFO}(E>0.4\mathrm{GeV})} > 20$	148808	23M	163088	3439927	58882
$110 < E_{\mathrm{total}} < 150$	132561	10M	125878	705357	34215
$P_T > 19$	126006	34198	116314	627602	32300
Isolation lepton veto	123586	33775	115867	327206	23773
$100 < M_{\mathrm{inv}} < 135$	117845	9506	10420	162511	21277
$70 < M_{\mathrm{rec}} < 125$	111886	7521	10045	110426	20458
$0.15 < y_{12} < 1$	111353	7405	9702	101797	19983
$y_{23} < 0.06$	105078	6644	8456	69313	14495
$y_{34} < 0.008$	100117	6504	7878	58532	6899
$-0.98 < \cos(\theta^{(2\mathrm{jets})}_{\mathrm{included}}) < -0.4$	97277	5178	5365	33293	6273
$BDT > -0.01$	76666	344	118	69	1594
Significance	**265.20**				
Efficiency	**51.5%**				

3. BDT & final results



(a) Cut efficiencies and optimal cut value.
(b) Overtraining check for classifier.

Flavor tagging

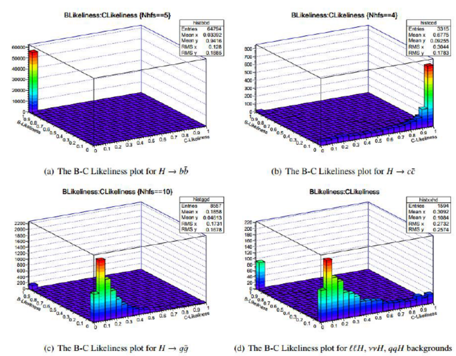
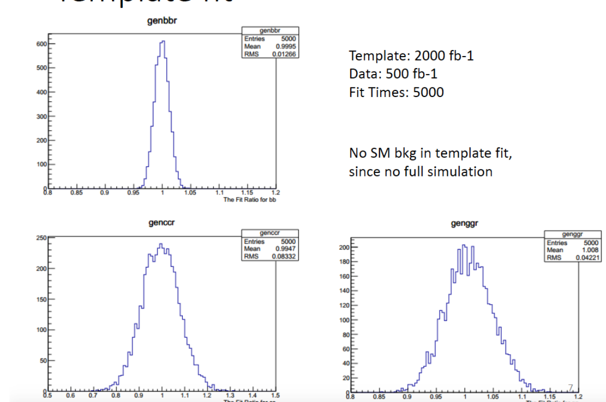

(a) The B-C Likeliness plot for $H \to b\bar{b}$
(b) The B-C Likeliness plot for $H \to c\bar{c}$
(c) The B-C Likeliness plot for $H \to g\bar{g}$
(d) The B-C Likeliness plot for $\ell\ell H$, $\nu\nu H$, qqH backgrounds

Figure 7: The B-C Likeliness characteristics for Signal and other Higgs Background. The Standard Model Background isn't included in because there is no B-C Likeliness.

vvH events

Template fit



δB(H->bb)/Br(H->bb) ~ 0.2%

Br(H→WW)

ZH, H->WW*	Yield	Object reconstructed	Isolation	Signal Efficiency	Main Background	Accuracy	Combined
Z(μμ)H(evev)	88	76(86.36%)	61(80.26%)	36(40.91%)	4(ZH)	17.57%	
Z(μμ)H(μvμv)	89	80(89.89%)	77(96.25%)	52(58.43%)	6(ZH&ZZ)	14.65%	
Z(μμ)H(evμv)	174	157(90.23%)	147(93.63%)	105(60.34%)	0	9.76%	2.68%
Z(μμ)H(evqq)	1105	1042(94.30%)	864(82.92%)	663(60.00%)	45(ZH)	4.02%	
Z(μμ)H(μvqq)	1110	1056(95.14%)	988(93.56%)	717(64.59%)	159(ZH&ZZ)	4.13%	
Z(μμ)H(qqqq)	Preliminary						~3.5%
Z(ee)H(evev)	91	62(68.13%)	60(96.77%)	22(24.16%)	16(SZ)	28.02%	
Z(ee)H(μvμv)	82	63(76.83%)	63(100%)	44(53.66%)	24(SZ)	18.74%	
Z(ee)H(evμv)	178	132(74.16%)	124(93.94%)	82(46.07%)	25(ZH&SZ)	12.61%	2.87%
Z(ee)H(evqq)	1182	1041(88.07%)	916(87.99%)	621(51.78%)	188(SZ&ZH)	4.62%	
Z(ee)H(μvqq)	1221	1194(97.79%)	1048(87.77%)	684(56.02%)	49(ZH&SZ)	3.96%	
Z(ee)H(qqqq)	Preliminary estimation						~4%

- Full Simulation on 12 independent channels
  - Very high object reconstruction efficiency
  - Combined result: 1.57%
- Extrapolation from other ILC channels: 1.59%
- Combined: 1.12%

<table>
<tr><th></th><th>Z→ll</th><th>tautau</th><th>vv</th><th>qq</th></tr>
<tr><td>H→WW*→4q</td><td rowspan="6">1.6%</td><td>3.45k</td><td>2.3%</td><td>69.1k</td></tr>
<tr><td>μvqq</td><td>1.14k</td><td>6.47k</td><td rowspan="2">2.2%</td></tr>
<tr><td>evqq</td><td>1.14k</td><td>6.47k</td></tr>
<tr><td>eevv</td><td>93</td><td>527</td><td>1.9k</td></tr>
<tr><td>μμvv</td><td>93</td><td>527</td><td>1.9k</td></tr>
<tr><td>eμvv</td><td>186</td><td>1154</td><td>3.7k</td></tr>
<tr><td>X + tau</td><td>3.2k</td><td>1.6k</td><td>9.14k</td><td>32.0k</td></tr>
</table>

Br(H→ZZ)

ZZZ*	Yield	Object reconstructed	Signal Efficiency(%)	Main Background	Accuracy (%)	Comments
μμννqq	128	118	63.3	h->ww&zz_sl	**12.9**	Tau finder would be highly appreciated Reconstructed efficiency of electron need to be improved
μμqqνν	128	125	-	h->bb&zz_sl	>25	
eeννqq	132	91	53.8	h->ww&sze_sl	**15.8**	
eeqqνν	132	88	-	h->bb&zz_sl	>25	
ννμμqq	158	144	61.4	h->t,w&zz_sl	**11.0**	
ννqqμμ	158	149	51.9	h->w,b&zz_sl	**12.9**	
νveeqq	151	118	43.1	h->w&sze_sl	**21.3**	
ννqqee	151	134	-	h->bb&sze_sl	>25	
qqμμνν	135	115	-	h->tt&zz_sl	>25	Compare to ll recoil, qq recoil mass has much worse distinguishing power to SM background
qqννμμ	135	122	-	h->t,w&zz_sl	>25	
qqeeνν	127	107	-	h->tt&sze_sl	>25	
qqννee	127	123	-	h->t,w&sze_sl	>25	
μμμμqq/qqμμ	43	39	69.8	h->tt&zz_sl	**19.9**	Tau finder & Electron Reconstruction
μμeeqq/qqee	43	39	60.5	h->tt&zz_sl	**21.2**	
eeeeqq/eeqqee	43	33	-	h->tt&sze_sl	>25	
eeμμqq/eeqqμμ	43	41	58.2	h->tt&sze_sl	**19.9**	

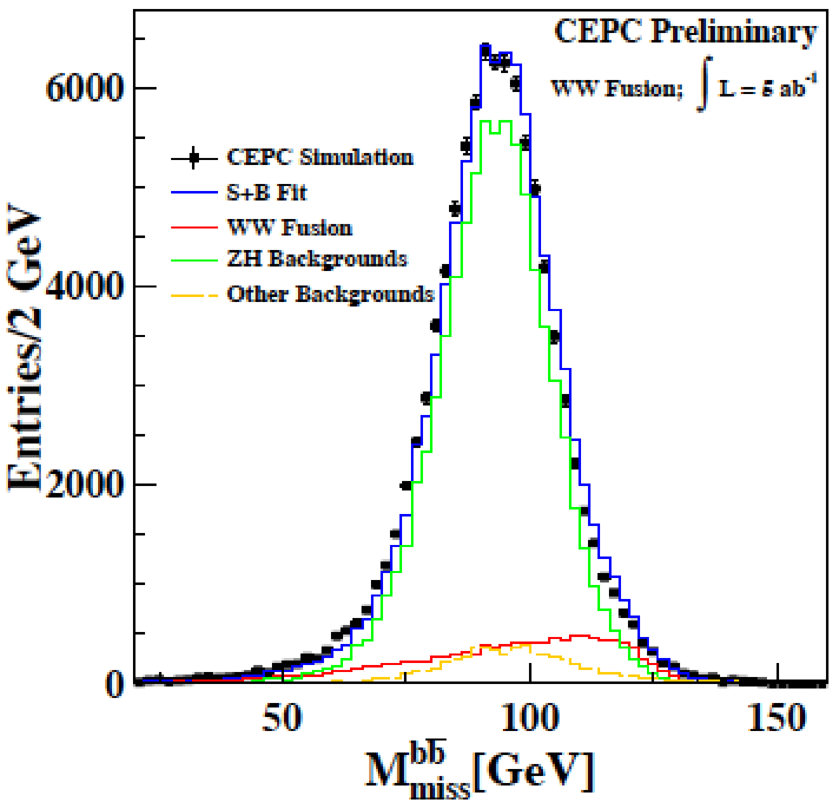
Full Simulation analysis performed on 16 independent channels.
8 Channels acquire accuracy better than 25%.

Combined accuracy: **5.4%**

TLEP extrapolation**: 4.3%**

σ(vvH)*Br(H→bb) and Higgs width

- Accuracy of σ(ZH)*Br(H→bb) = 2.8%
- Γ_{total} : determined to:
  - 4.4% from σ(ZH) (~g^2(HZZ)) and σ(ZH)*Br(H→ZZ) (~g^4(HZZ)/Γ_{total})
  - 3.3% from σ(ZH)*Br(H→bb), σ(vvH)*Br(H→bb), σ(ZH)*Br(H→WW), σ(ZH)
  - Combined accuracy: 2.7%

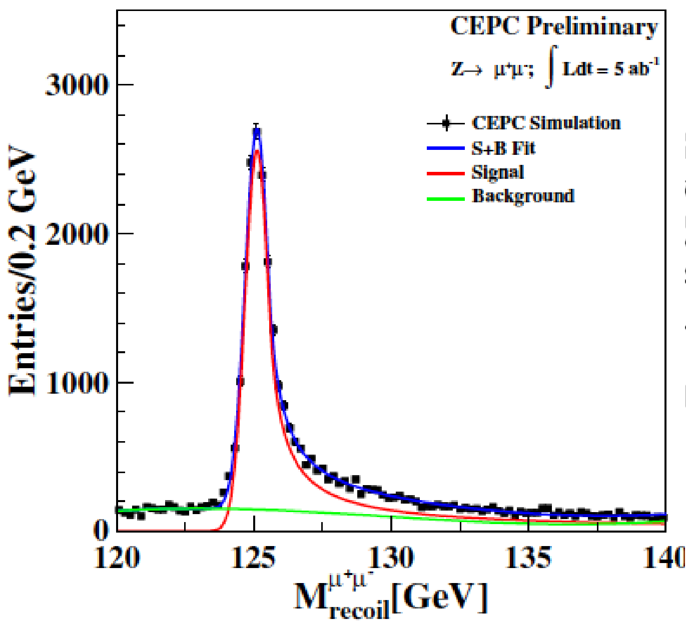


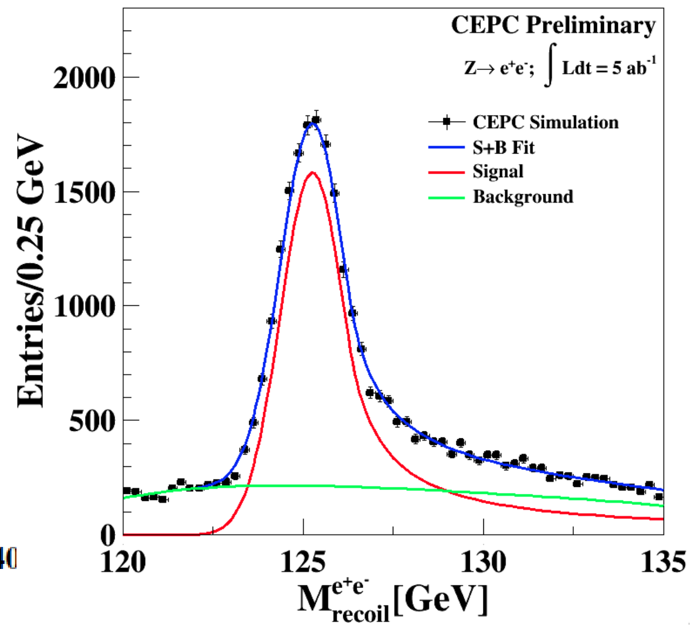
More details: see Zhenxing's presentation

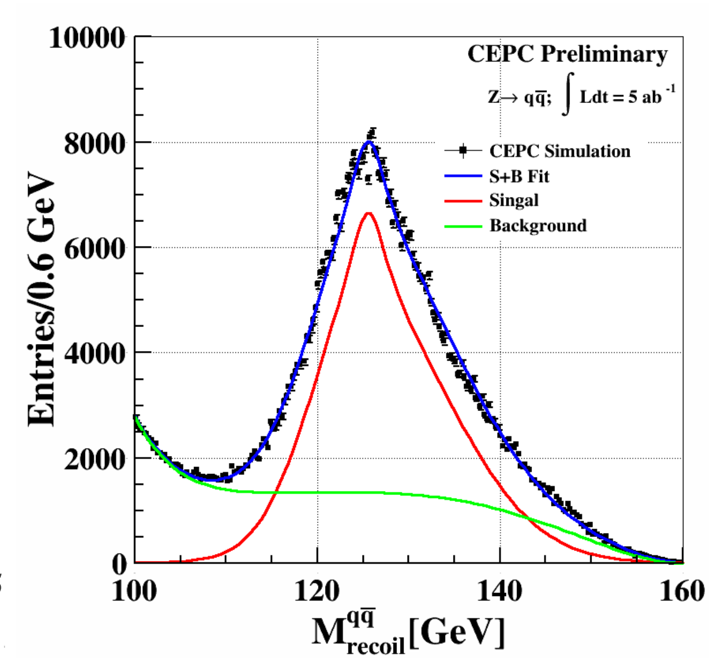
BSM

Higgs invisible decays

*Assuming sigma(ZH)*Br(H->inv) = 200 fb*





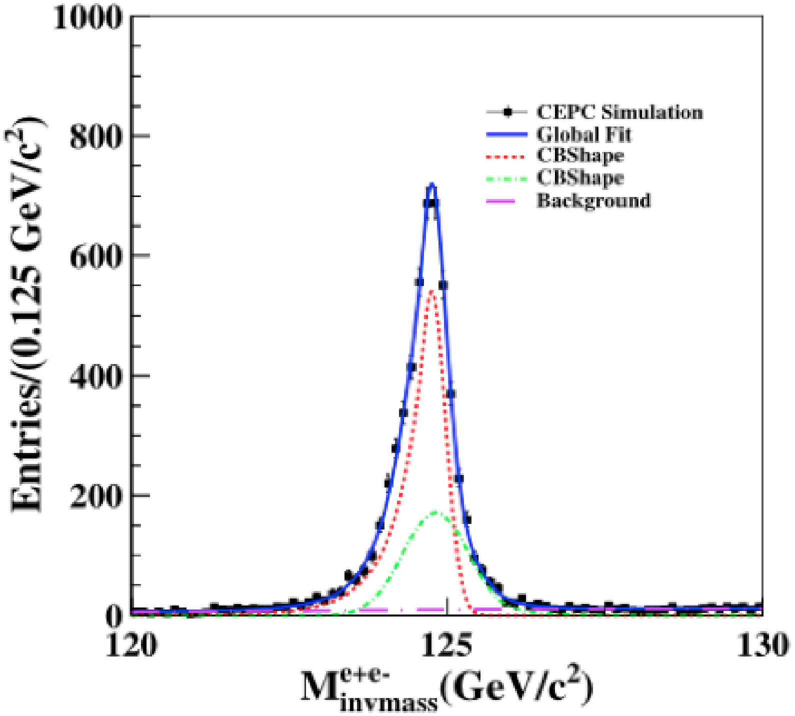


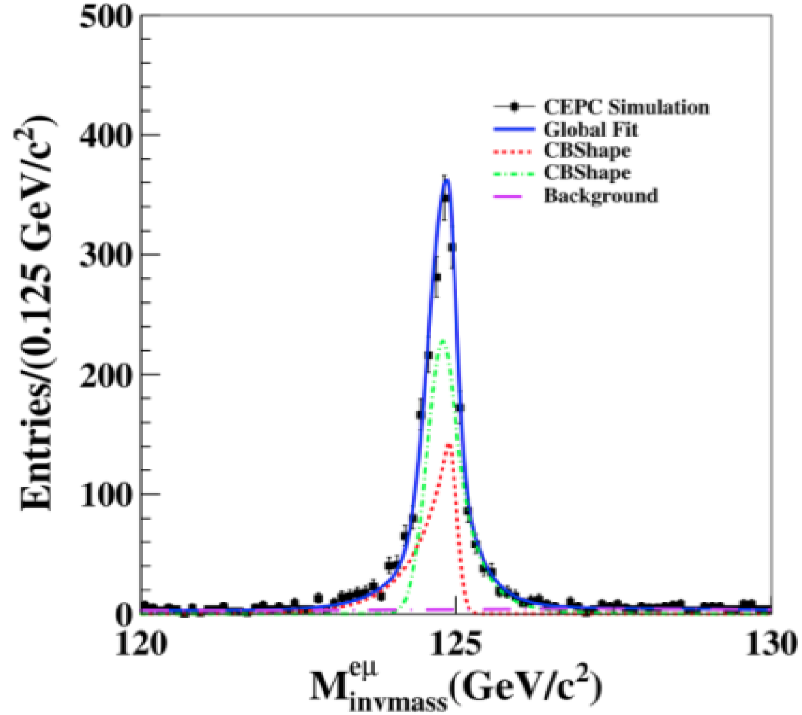
Invisible upper limit at CEPC: 0.14% at 95% C.L

H→Exotic, Leptonic

Lei Wang

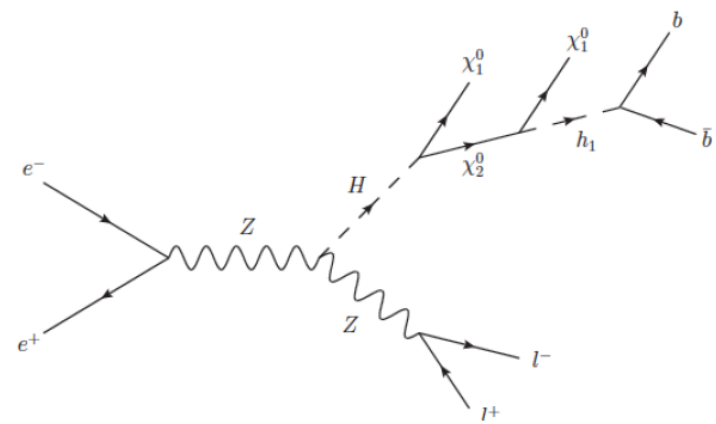
*Assuming sigma(ZH)*Br(H->ee/eμ) = 200 fb*





95% up limit: Br(H->ee) = 1.7e-4;
Br(H->emu) = 1.2e-4;

H→Exotic, Hadronic



Benchmark Points

Scan over the parameter space for sensitivity:

1. Fix $m_{\tilde{\chi}_1^0} = 0$ GeV and make exclusion contours on the m_{h^0} and $m_{\tilde{\chi}_2^0}$ plane with the range:

   10 GeV < m_{h^0} < 60 GeV (15,25,35,45,55 GeV)

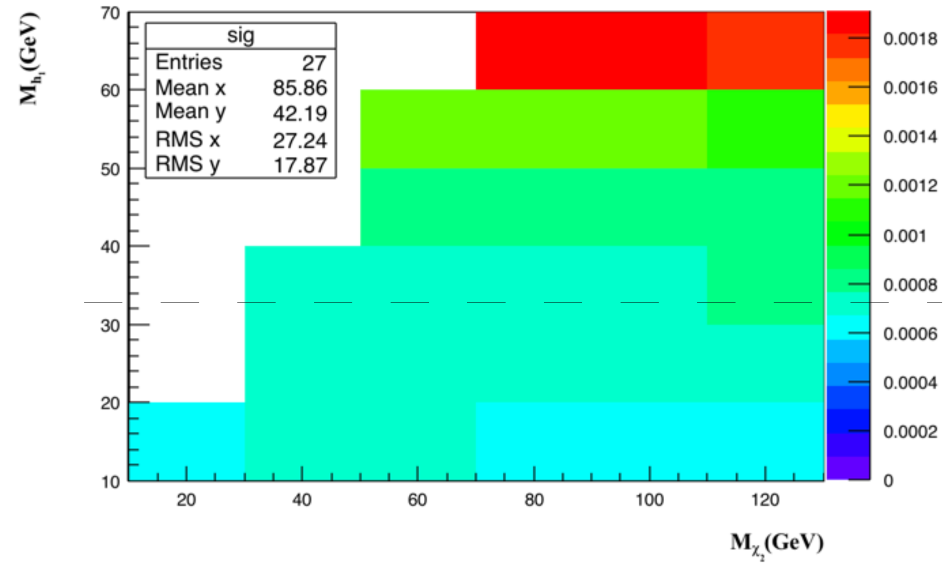
   10 GeV < $m_{\tilde{\chi}_2^0}$ < 125 GeV (20,40,60,80,100,120 GeV)

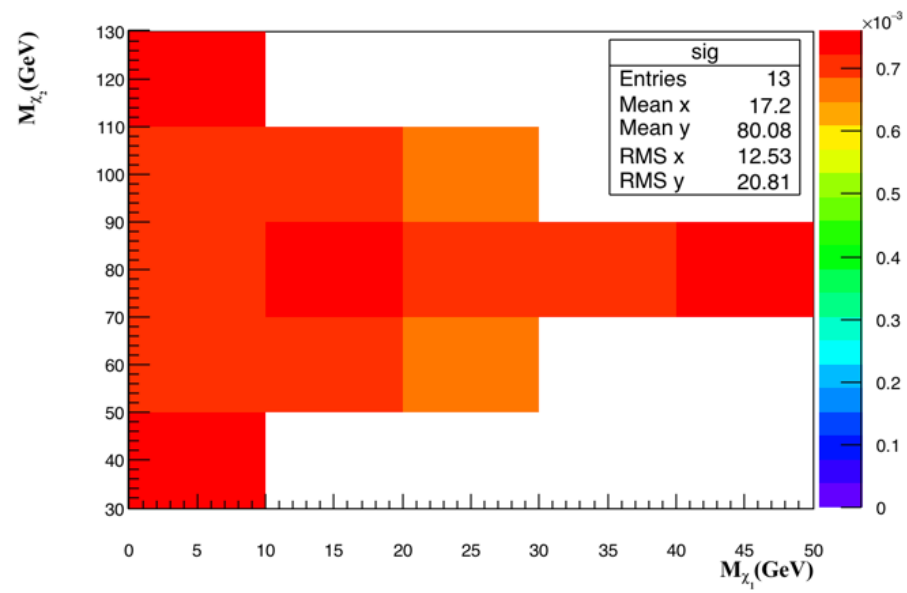
2. Fix $m_{h^0} = 30$ GeV and make exclusion contours on the $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\chi}_2^0}$ plane, with the range:

   0 GeV < $m_{\tilde{\chi}_1^0}$ < 60 GeV (5,15,25,35,45,55 GeV)

   10 GeV < $m_{\tilde{\chi}_2^0}$ < 125 GeV (20,40,60,80,100,120 GeV)

Suggested by prof. Liu



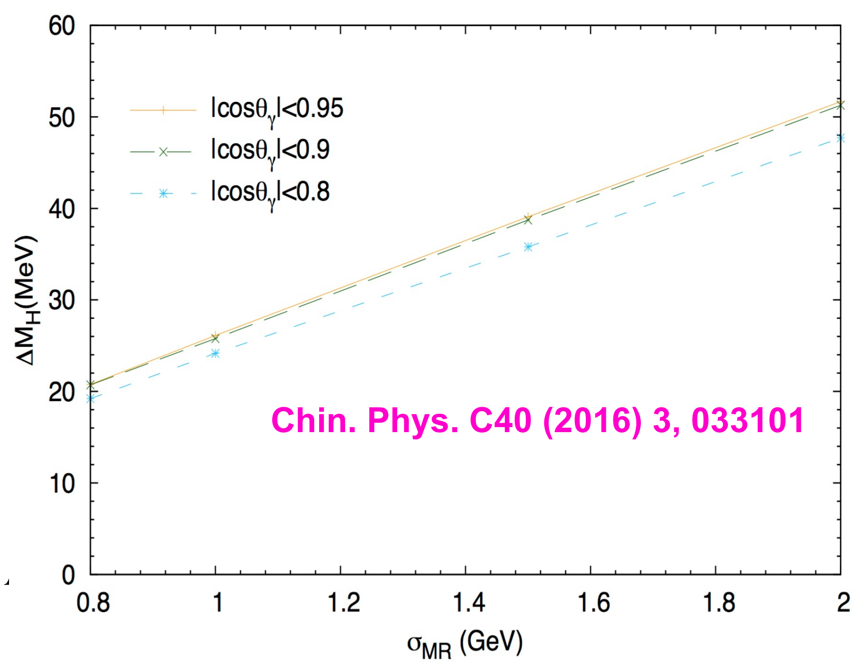


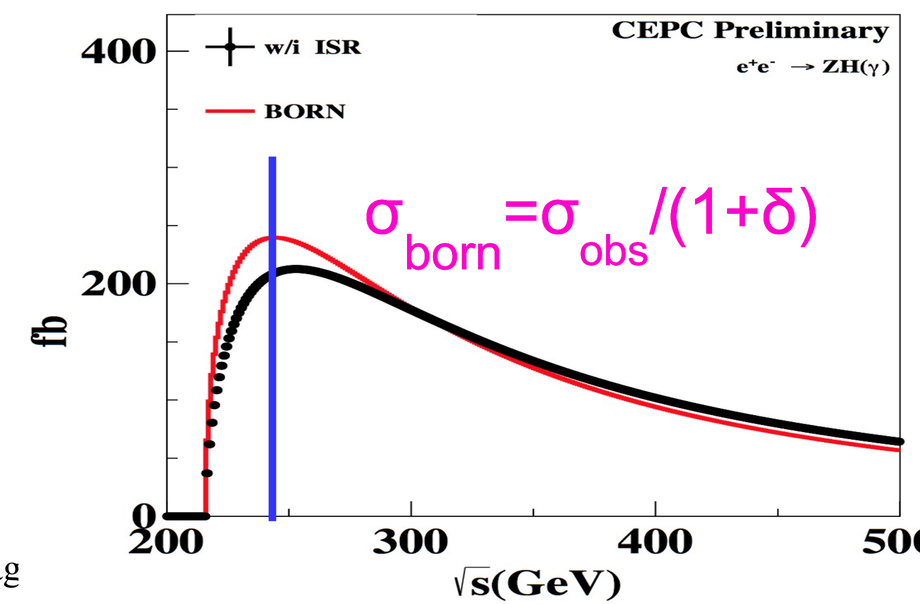
Higgs measurements: accuracies

	PreCDR	Present
σ(ZH)	0.51%	0.50%
σ(ZH)*Br(H→bb)	0.28%	0.21%
σ(ZH)*Br(H→cc)	2.1%	2.5%
σ(ZH)*Br(H→gg)	1.6%	1.3%
σ(ZH)*Br(H→WW)	1.5%	1.1%
σ(ZH)*Br(H→ZZ)	*4.3%*	5.4%
σ(ZH)*Br(H→ττ)	1.2%	<1.0%
σ(ZH)*Br(H→γγ)	9.0%	9.0%
σ(ZH)*Br(H→μμ)	17%	17%
σ(vvH)*Br(H→bb)	2.8%	2.8%
Higgs Mass/MeV	5.9	5.0
σ(ZH)*Br(H→inv)	95%. CL = 1.4e-3	1.4e-3
Br(H→ee/emu)	-	1.7e-4/1.2e-4
Br(H→bbχχ, 4b)	$<10^{-3}$	Br(H→bbχχ) ~ 3e-4

CEPC a precision experiment

- Many sub-percentage measurements
- Systematics should be taken into account in design stage
- Integrated luminosity must be ~ 1 per mille for σ(ZH)
- Beam energy calibration must be ~ 1MeV for Higgs mass,1MeV~10^-5
- ISR correction: (1+δ) change the cross section ~20%, which must be corrected by MC: already 0.5%?
- Interference effect in mass measurement: H->2γ, 20-50MeV shift





Summary

- CEPC Higgs Physics
  - σ(ZH), Total Width, absolute branching ratios, invisible/exotic decays
  - Requirements on the detector/reconstruction/systematics
- Significant Progress since PreCDR, toward CDR and a realistic experiment
- Perspectives
  - Two detector geometries: pure silicon detector initialized
  - Iterate with Detector Design/Optimization
  - Systematics -> detector design/optimization: reconstruction, tracking, PID, jet flavor correlation, luminosity monitoring, beam energy calibration, ISR correction, interference effects ...
- Welcome to join this effort