Opening Comments

2017/09/09

Keisuke Fujii

WG Objectives

- On July 4, 2012, ATLAS and CMS announced the discovery of a Higgs-like boson with a mass of about 125GeV and the data that followed strongly indicates that it is a Higgs boson indeed. The world has changed since then. The discovery has vaulted the question of its properties on the top of the list of questions in HEP. The 125GeV boson is a window to BSM physics and ILC is the best machine to use it.
  So far no additional new particles or new phenomena have been found in the LHC Run 2, suggesting that there seem to be no easily discoverable new particles, which enhanced the importance of the precision measurements of H125 and loophole-less searches at ILC more than ever. There can be a zoo of new uncolored particles or new phenomena that are difficult to find at LHC but can be discovered and studied in detail at ILC.

  We need to demonstrate that ILC will advance our understanding of particle physics qualitatively beyond the information that will be available from the results expected from the future stages of the LHC. The MEXT ILC Advisory Panel says "it is necessary to closely monitor, analyze and examine the development of LHC experiments". We did and proposed ILC250 as a JAHEP agreement on July 22, 2017.

- The ILC project preparation office has been formed in KEK and the MEXT's ILC Task Force is reviewing the project. In parallel, site-specific design started and the detector optimization effort will continue. In response to the interim summary from the MEXT panel, we published a report on ILC's new particle discovery potential in last Feb. We are now revising ILC physics case with emphasis put on ILC250. The next target for us to show our activities at LCWS2017 on Oct. 23 to 27 at SLAC.

Japan **A**ssociation of **H**igh **E**nergy **P**hysicists

Town Meeting

on July 22

JAHEP Statement (July 22 revised on Aug.16)

http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf

Asai Committee's conclusions

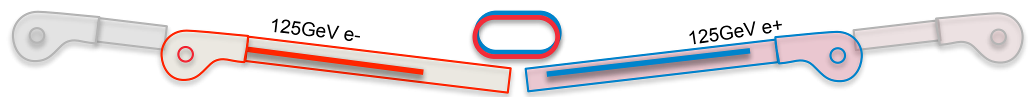
- ILC250 should run concurrently with HL-LHC to enhance physics outcomes from LHC.
- Given that a new physics scale is yet to be found, ILC250 is expected to deliver physics outcomes that are nearly comparable to those previously estimated for ILC500 in precise examinations of the Higgs boson and the Standard Model.
- The ILC250 Higgs factory, together with HL-LHC and SuperKEKB, will play an indispensable role in the discovery of new phenomena originating from new physics with the energy scale up to 2–3 TeV and the elucidation of the origin of matter-antimatter asymmetry.
- A linear collider has a definite advantage for energy-upgrade capability. ILC250 possesses a good potential for its upgrades to reach the higher energy of new physics that the findings of ILC250 might indicate.

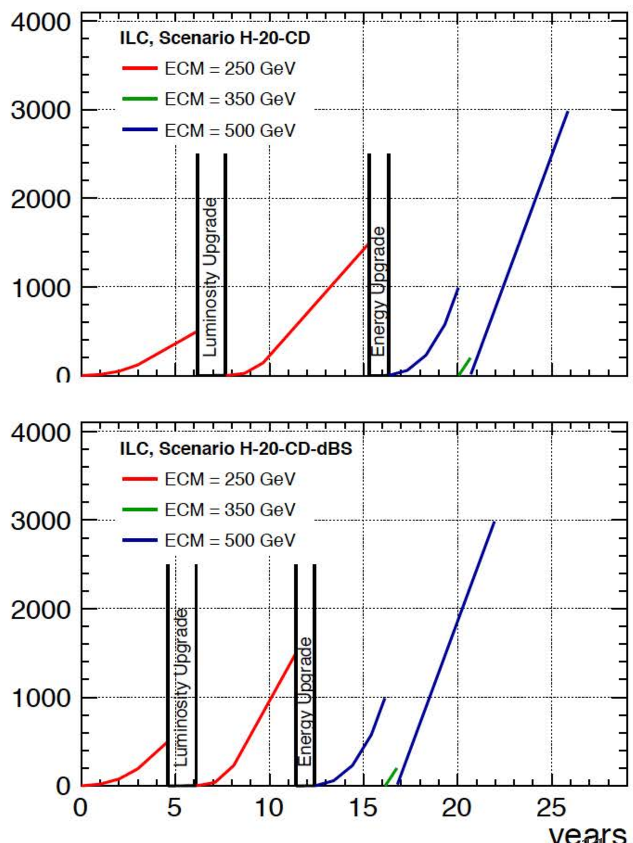
Physics Case for ILC250

Staging from 250 GeV

LCC ILC parameters WG

new scenarios: H-20-CD (-δ_{BS})





lumi upgrade after
$\int L dt \sim 500\ fb^{-1}$
(double bunches)

energy upgrade after
$\int L dt \sim 2\ ab^{-1}$ at 250 GeV in ~15 (11)y

ILC500 starts with x2 bunches directly

save ~4y with δ_{BS}

based on J. Tian, AWLC 2017

Staging from 250 GeV

What happens if we don't have 500 GeV data?

So far LHC Run II saw no clear signal of physics beyond the Standard Model.

→No new particle in the ILC's range or it is in the LHC's blind spot.

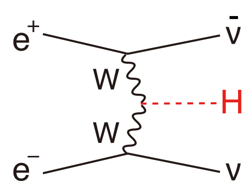
→Importance of precision Higgs measurements enhanced.

1st stage as a Higgs factory

Potential drawback:
Γ_h determination

$$\Gamma_h = \frac{\Gamma(h \to WW^*)}{BR(h \to WW^*)}$$

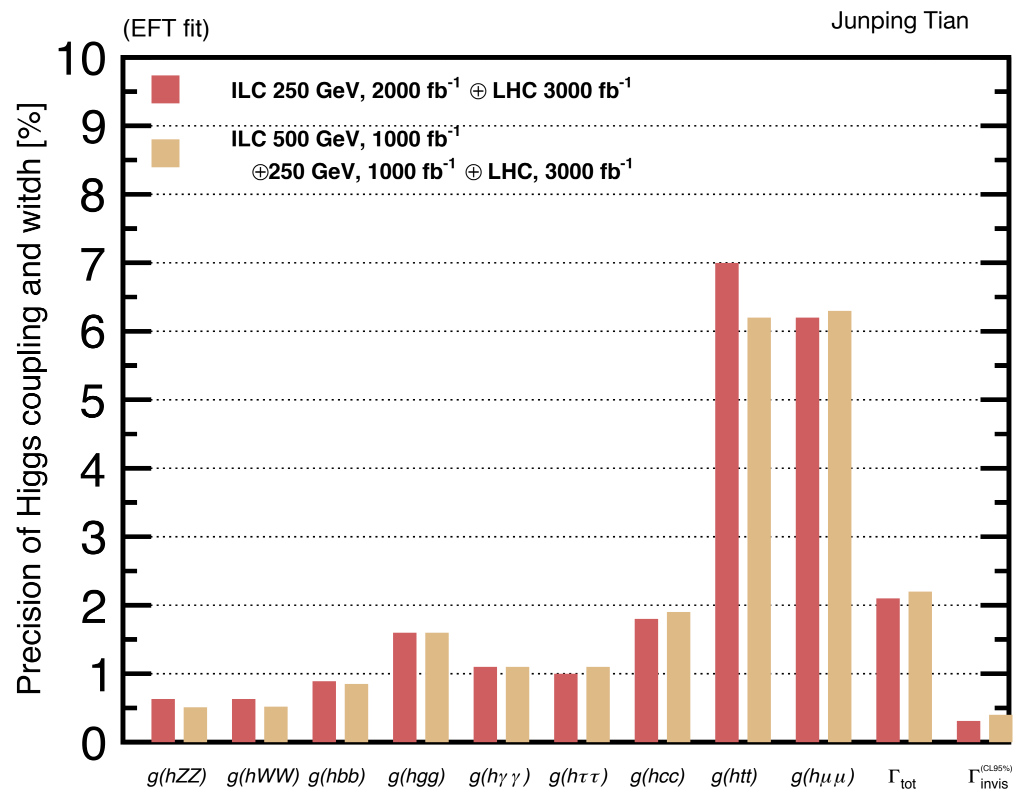
$$\Gamma(h \to WW^*) \propto \sigma(\nu\bar{\nu}h)$$



Small @ 250GeV

Solution: EFT
that relates hZZ and hWW couplings

Many EFT coefficients will have to be constrained by various SM processes that involve EW gauge bosons.
→possible at ILC250.



For the same integrated luminosity, the 250 GeV ILC performs equally well.

Beam polarization provides enough redundancy to test the validity of the EFT in case there is a light new particle

Recently appeared in arXiv: 1708.08912

DESY 17-120
KEK Preprint 2017–22
SLAC–PUB–17129
August, 2017

Improved Formalism for Precision Higgs Coupling Fits

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ILC250 vs Others

	2 ab^{-1} w. pol.	2 ab^{-1} 350 GeV	5 ab^{-1} no pol.	+ 1.5 ab^{-1} at 350 GeV	full ILC 250+500 GeV
$g(hb\bar{b})$	1.04	1.08	0.98	0.66	0.55
$g(hc\bar{c})$	1.79	2.27	1.42	1.15	1.09
$g(hgg)$	1.60	1.65	1.31	0.99	0.89
$g(hWW)$	0.65	0.56	0.80	0.42	0.34
$g(h\tau\tau)$	1.16	1.35	1.06	0.75	0.71
$g(hZZ)$	0.66	0.57	0.80	0.42	0.34
$g(h\gamma\gamma)$	1.20	1.15	1.26	1.04	1.01
$g(h\mu\mu)$	5.53	5.71	5.10	4.87	4.95
$g(hbb)/g(hWW)$	0.82	0.90	0.58	0.51	0.43
$g(hWW)/g(hZZ)$	0.07	0.06	0.07	0.06	0.05
Γ_h	2.38	2.50	2.11	1.49	1.50
$\sigma(e^+e^- \to Zh)$	0.70	0.77	0.50	0.22	0.61
$BR(h \to inv)$	0.30	0.56	0.30	0.27	0.28
$BR(h \to other)$	1.50	1.63	1.09	0.94	1.15

Table 3: Projected relative errors for Higgs boson couplings and other Higgs observables, in %, comparing the full EFT fit described in Section 4 to other possible e^+e^- collider scenarios. The second column shows a fit with 2 ab^{-1}, with 80% electron and zero positron polarization, and with a higher energy of 350 GeV. The third and fourth columns show scenarios with no polarization but higher intergrated luminosity, 5 ab^{-1} at 250 GeV in the third column and 5 ab^{-1} at 250 GeV plus 1.5 ab^{-1} at 350 GeV in the fourth column. The fifth column gives the result of the fit described in Section 6 including data from 250 and 500 GeV. The notation is as in Table 1.

Beam Polarizations

	no pol.	80%/0%	80%/30%
$g(hbb)$	1.33	1.13	1.04
$g(hc\bar{c})$	2.09	1.97	1.79
$g(hgg)$	1.90	1.77	1.60
$g(hWW)$	0.98	0.68	0.65
$g(h\tau\tau)$	1.45	1.27	1.16
$g(hZZ)$	0.97	0.69	0.66
$g(h\gamma\gamma)$	1.38	1.22	1.20
$g(h\mu\mu)$	5.67	5.64	5.53
$g(hb\bar{b})/g(hWW)$	0.91	0.91	0.82
$g(hWW)/g(hZZ)$	0.07	0.07	0.07
Γ_h	2.93	2.60	2.38
$\sigma(e^+e^- \to Zh)$	0.78	0.78	0.70
$BR(h \to inv)$	0.36	0.33	0.30
$BR(h \to other)$	1.68	1.67	1.50

Table 4: Projected relative errors for Higgs boson couplings and other Higgs observables with 2 ab^{-1} of data at 250 GeV, comparing the cases of zero polarization, 80% e^- polarization and zero positron polarization, and 80% e^- polarization and 30% positron polarization. In each case, the running is equally divided into two samples with opposite beam polarization orientation.

Beam polarization essentially doubles the number of independent observables and provides enough redundancy to test the validity of the EFT in case there is a light new particle!

Sensitivity of EFT Analysis

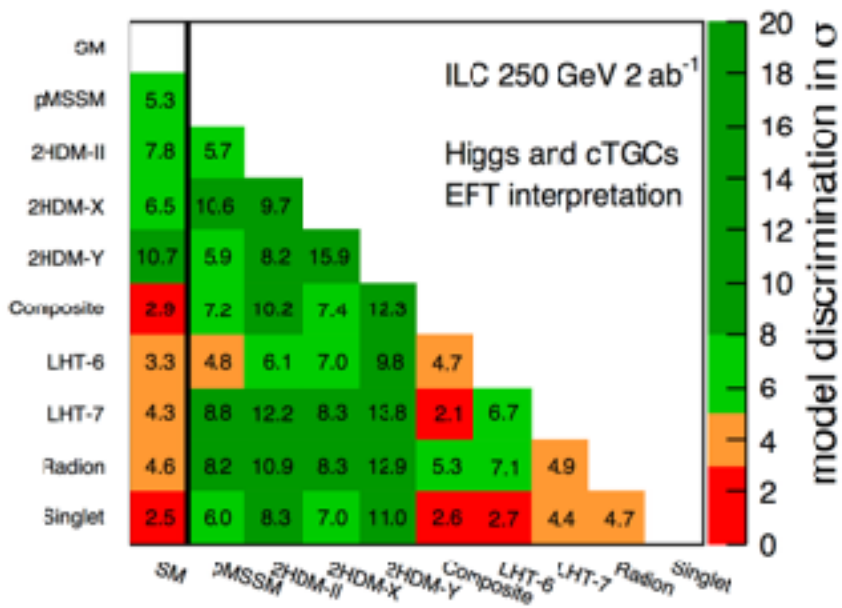
to sample new physics scenarios

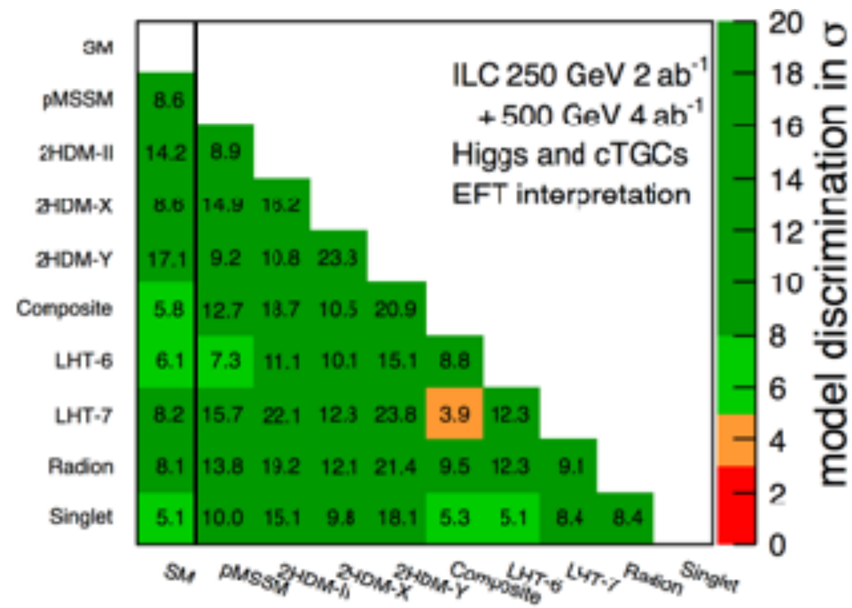
9 sample models and expected deviations (%)

	Model	$b\bar{b}$	$c\bar{c}$	gg	WW	$\tau\tau$	ZZ	$\gamma\gamma$	$\mu\mu$
1	MSSM [33]	+4.8	-0.8	- 0.8	-0.2	+0.4	-0.5	+0.1	+0.3
2	Type II 2HD [35]	+10.1	-0.2	-0.2	0.0	+9.8	0.0	+0.1	+9.8
3	Type X 2HD [35]	-0.2	-0.2	-0.2	0.0	+7.8	0.0	0.0	+7.8
4	Type Y 2HD [35]	+10.1	-0.2	-0.2	0.0	-0.2	0.0	0.1	-0.2
5	Composite Higgs [37]	-6.4	-6.4	-6.4	-2.1	-6.4	-2.1	-2.1	-6.4
6	Little Higgs w. T-parity [38]	0.0	0.0	-6.1	-2.5	0.0	-2.5	-1.5	0.0
7	Little Higgs w. T-parity [39]	-7.8	-4.6	-3.5	-1.5	-7.8	-1.5	-1.0	-7.8
8	Higgs-Radion [40]	-1.5	- 1.5	+10.	-1.5	-1.5	-1.5	-1.0	-1.5
9	Higgs Singlet [41]	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5

All new particles outside the projected reach of the HL-LHC

Discrimination power in σs





The details of the EFT formalism is described in

KEK Preprint 2017–23
SLAC–PUB–17130
August, 2017

Model-Independent Determination of the Triple Higgs Coupling at e^+e^- Colliders

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Recently appeared in arXiv: 1708.09079

There are many coefficients to decide. But remember that *W_L and Z_L are NGBs from the Higgs sector*.

We can use all kinds of SM processes involving *W* and *Z* to constrain them!

→ *Global Higgs+EWPO+TGC fit*

All the SM processes suddenly become equally important!

Higgs

- **$e^+e^- \to H\gamma$**
- **$H \to Z\gamma$**
- **…**

Precision EW

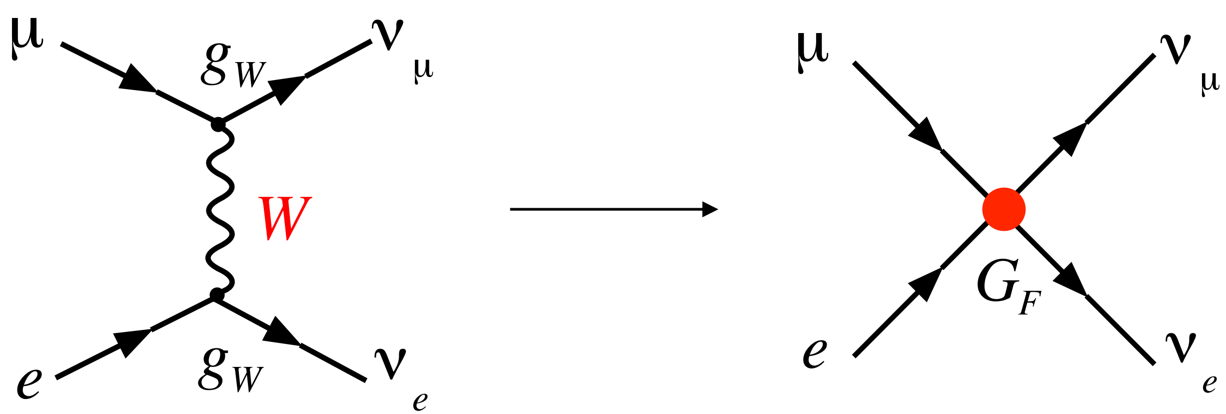
- **TGC**
- **$e^+e^- \to Z\gamma$ (A_{LR}), $\gamma\gamma$, …**
- **…**

One can, of course, question the validity of EFT

Truncation of the EFT series expansion is justifiable only when the BSM does not involve any light SU(2)xU(1) gauge invariant mass parameter or when the light new particles are decoupled from the relevant part of the SM sector.

Extra degrees of freedom will appear as a form factor in the EFT coefficient as q^2 goes up:

Example



$$
\begin{aligned}
J_\mu \frac{1}{q^2-\Lambda^2} J'^\mu &= -J_\mu \left(\frac{1}{\Lambda}\right)^2 \frac{1}{1-q^2/\Lambda^2} J'^\mu \\
&= -\left(\frac{1}{\Lambda}\right)^2 \left(\sum_{n=0}^{\infty} \left(\frac{q^2}{\Lambda^2}\right)^n\right) J_\mu J'^\mu \\
&\simeq -\left(\frac{1}{\Lambda}\right)^2 \left(1 + \left(\frac{q^2}{\Lambda^2}\right)\right) J_\mu J'^\mu
\end{aligned}
$$

$$\Lambda = m_W$$

Fit assuming q^2=0 in the 2nd parentheses would fail.

At ILC 250, we will have enough redundancy (#observables > #unknown) to test the validity of EFT.

If we see inconsistency, it suggests $\Lambda_{BSM} \sim E_{cm}$. We then expect to see significant deviations from the SM, or to find some new particle. In this case, we forget about EFT and try to build specific models to explain the observed deviation pattern and/or the new particle and test these specific models.

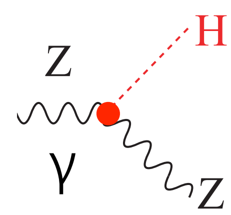
For new particle searches, we will work on particular models anyway.

J.Tian

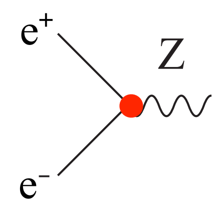
comments on beam polarizations

- not changed: important for systematics control, nature of new particle (once found), e.g. Higgsino, WIMPs
- new roles in EFT

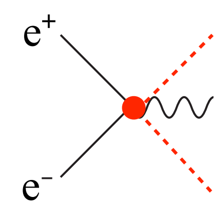
-> separate hZZ and hγZ couplings



-> improve A_{LR} in Z-e-e coupling



important to constrain contact interaction



Polarization is one of the most important tools that provide redundancy in EFT analysis!

250 ILC and Beyond

What we might lose

Personal View

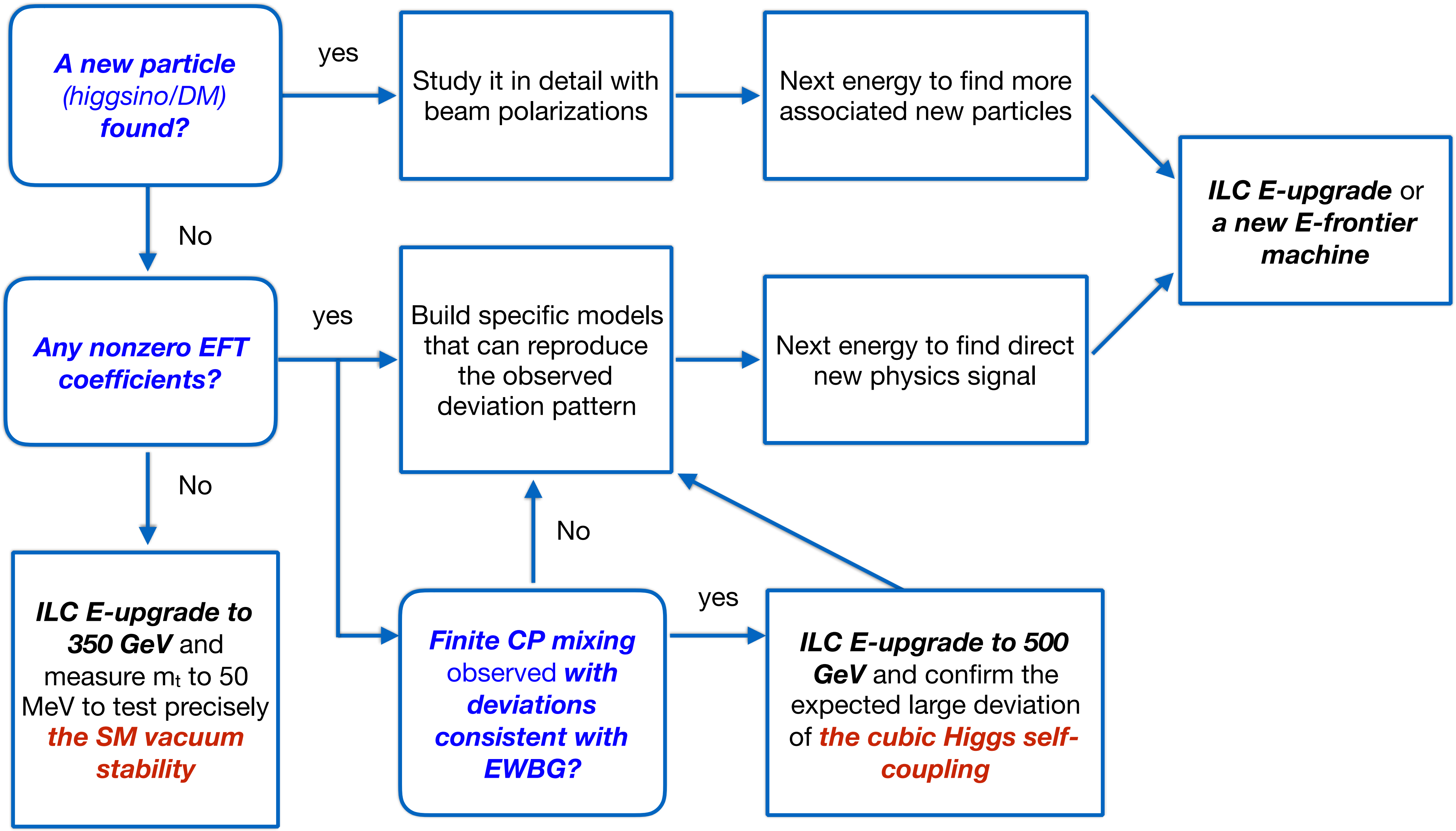
by staying at 250 GeV for long time

Challenging Tasks for ILC250	Issues	Possible Solutions/Measures
Higgs cubic self-coupling	A new interaction at the heart of EWSB, important in its own right. Large enhancement expected for models of EWBG. ***500 GeV needed for $e^+e^- \to ZHH$.***	Models of EWBG often predicts ***shifts in other Higgs couplings***, too. ***Synergy with HL-LHC, SuperKEKB, GW.***
Precision top mass	A parameter of SM, important in its own right. O(50) MeV desirable for vacuum stability test. ***Theoretically cleanest measurement requires ttbar threshold scan at around 350 GeV.***	***Direct top reconstruction at LHC with possible future theoretical progress*** to relate MC mass to pole mass (~200-300 MeV?).
Anomalous Top Couplings	Being heaviest in SM, top couples to new physics that caused EWSB. ***Needs at least 350 GeV, the best sensitivity expected at around 500 GeV.***	Most models of EWSB often predicts ***shifts in various Higgs couplings*** as well. ***Use the b-quark ($e^+e^- \to$bbbar) as another 3rd generation quark.***
Top Yukawa coupling	6 (3)% at 500 (550) GeV, ***not available at 250 GeV.***	***Synergy with HL-LHC (~7%).***
New Particles	***Direct search limited by $m_X < E_{cm}/2$.***	Natural SUSY prefers ***light higgsinos.*** Indirect search through oblique correction may reach ~200GeV ***($e^+e^- \to$ffbar)***. DM searches by ***$h \to$invisible. Exotic higgs decays.*** ***Synergy with HL-LHC.***

Which Way to Go

Personal View

after seeing the 250 GeV results



ILC250 will tell us the next step to take!

Our Group's Activities

Status & Next Step

Symmetry Breaking & Mass Generation Physics

- ZH : H->bb,cc,gg -> EPJ C (2013) 73:2343, now working on mh=125 GeV case: Ono+Miyamoto
  H -> WW* anomalous coupling: analysis done -> publication: Takubo -> P.R.D88,013010(2013)
  -> H -> WW* to be reexamined: Liao Libo
  H->other modes: Tino (AA,mu+mu-) + Kawada/Tanabe/Suehara/Daniel (tau+tau-)->publication
  -> EPJC (2015) 75:617.
  Recoil mass: Jacqueline -> P.R.D94,113002(2016), Suehara (qq), CP mixing in h->tau+tau-:
  Daniel -> draft being reviewed by ILD, HVV couplings: Ogawa, Yumi Aoki (Hgamma)
  direct mH reconstruction: Junping
- ZHH : full simulation of the H->bb&Z->all modes, fast simulation of nunuHH: finished:
  Junping + Takubo (Ph.D thesis: done) -> New analysis with improved analysis tools: Junping + Claude + Suehara + Tanabe, Jet-clustering: Shaofeng Ge, LCFIPlus: Suehara
  New analysis: ZHH->ZbbWW*: dE/dx: Kurata, Systematic Error: Tim, EFT: Junping
- nnHH : full simulation @ 1TeV, done for DBD: Junping -> publication
- nnH, eeH : precision measurements of HVV couplingsm, mh=125GeV: Junping
  BR measurements: Ono, Christian
- TTH : quick simulation studies with NRQCD corrections
  -> P.R.D84,014033(2011) -> full sim. @ 0.5 & 1 TeV: (Yonamine left) Tanabe + Sudo
- TT Threshold : Top Yukawa measurement: Horiguchi + Ishikawa + Tanabe, Theory: Kiyo + Sumino -> publication? (cf. a recent significant theoretical development!): Ozawa->Eda
- W mass (enW) : Koya Tsuchimoto -> Kotora (controlling systematic uncertainties)->Kotera
- AA->HH : quick simulation studies, so far H->bb and WW BG
  -> P.R.D85,113009(2012) : Kawada, Theory: Harada

Status & Next Step

Beyond the Standard Model

- SUSY : full simulation studies for LOI -> publication
  - EWkino (Compressed Spectrum Case): Jacqueline
- Extra U(1) (Z' tail), Compositeness, Extra Dimensions, etc.
  - TT : full simulation studies for LOI -> New study with MELA: Sato
  - tau tau : full simulation studies for LOI -> ditto
  - 2f: full simulation study: Yamashiro
- Hidden Sector / XD : P.R.D78, 015008 (2008)
- LHT : P.R.D79, 075013 (2009)
- Model discrimination: Saito + Suehara .. : P.R.D84, 115003 (2011)
- R-handed neutrinos: Saito : P.R.D82, 093004 (2010)
- LHT: Kato (exp) + Harigaya (th): ZHZH finished, working on eHeH, nHnH, ..: Draft (n-1)?
- Very light gravitino: Katayama (Master's thesis), Tanabe (exp) + Matsumoto (th) --> 1st Draft --> Takuaki Mori (Tokyo) -> ?
- Quasi stable stau: Yamaura (Master's thesis) + Kotera + Kasama —> reactivated?
- Higgs portal/h->Invisible: Honda -> Yamamoto -> Ishikawa, Ogawa, Junping -> Kato (Tokyo)
- W-H+/W+H-: (Shinzaki), Ishikawa (exp) + Kanemura, yagyu (th)
- Generic DM search: Tanabe
- New projects?
  - AMSB: Tanabe
  - Heavier Higgs bosons?: Yokoya, (Abhinav) -> Christian Drews
  - X(750) : Junping -> published in PRD (Phys.Rev. D94 (2016) no.9, 095015)
  - Correlation btw h->gamma gamma & h->gg in mSUGRA: Hidaka
  - m_nu, DM, baryogenesis: Machida

Short Term Schedule

- Weekly Meeting
  - Every Fri. at 14:00 (conf. ID: to be announced)
- General Meeting
  - 10:30 on Sat. Nov. 11?, 2017 (KEK MCU2 conf. ID:XXX)
- LCWS 2017, Strasbourg, Oct.23-27