Introduction to Physics Session

2015/12/08 Keisuke Fujii

Physics 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.
  The LHC has started its Run2 at 13TeV. This will probably bring us more. It is important to stress that ILC, too, is an energy frontier machine. It will access the energy region never explored with any lepton collider. 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. Be prepared for LHC Run2 results!

- 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 ILC parameter WG published a run scenario document (arXiv:1506.07830) and the ILC Physics WG published a physics case document (arXiv:1506.05992) as a byproduct of its effort to clarified issues discussed in the MEXT's physics WG. Given the interim summary from the MEXT expert panel, we now need to prepare a short summary of BSM scenario (new particle discovery potential in particular) by the end of CY2015 and a longer report by the end of the next summer.

What we need

- We have the 125 GeV boson that is a powerful tool to explore the symmetry breaking sector (SBS).
  We need to invent a way to make maximal use of it.
  - Is it possible to map various BSM models in ideally a single and hopefully a small number of generic parameter spaces so as to compare the physics reach of ILC with that of the future upgraded LHC?
  - If yes, explore the possibility of fingerprinting BSM models in the generic parameter space. --> done to certain ext. for Snowmass, now being refined.
- The most important Mission of ILC = bottom-up reconstruction of the SBS and clarification of its relation to other open questions of elementary particle physics.
  - Make a strategy to reconstruct the SBS
    - Shape of SBS: Multiplet Structure (a SM-like 2-let main but what about small admixtures of 1-let?, 3-let? If there, how many?, ...)
    - Dynamics behind SBS: weakly/strongly interacting = elementary/composite
  - Clarify relation to other open questions: DM, Baryogenesis, Neutrino mass, Hierarchy, ... --> done to certain ext. for Snowmass, now continuing.
- ILC is an energy frontier machine. We need to re-examine the possibilities given the existence of the 125GeV boson, other LHC results, and their relations to the open questions.

Classification of Parameter Space

(a) Both ILC and 13TeV LHC can access some new particle(s)
(b) Only 13TeV LHC can access some new particle(s)
(c) Ony ILC can access some new particle(s)
(d) Neither ILC nor 13TeV LHC can access any new particle

Need to decide we make a table for each of the 4 cases or combine some of the cases such as (a,b)(c,d) or (a,c)(b,d)

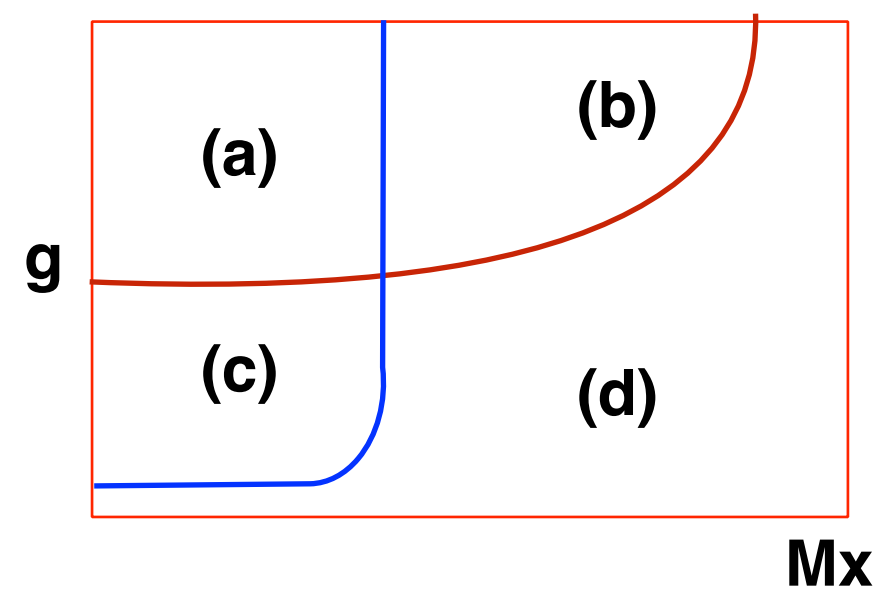
Key point:

- LHC-ILC synergy (in reconstructing Lagrangian in particular when some new particles are found)
- What will ILC's precision bring to us (even when the new particle is beyond the ILC's reach)

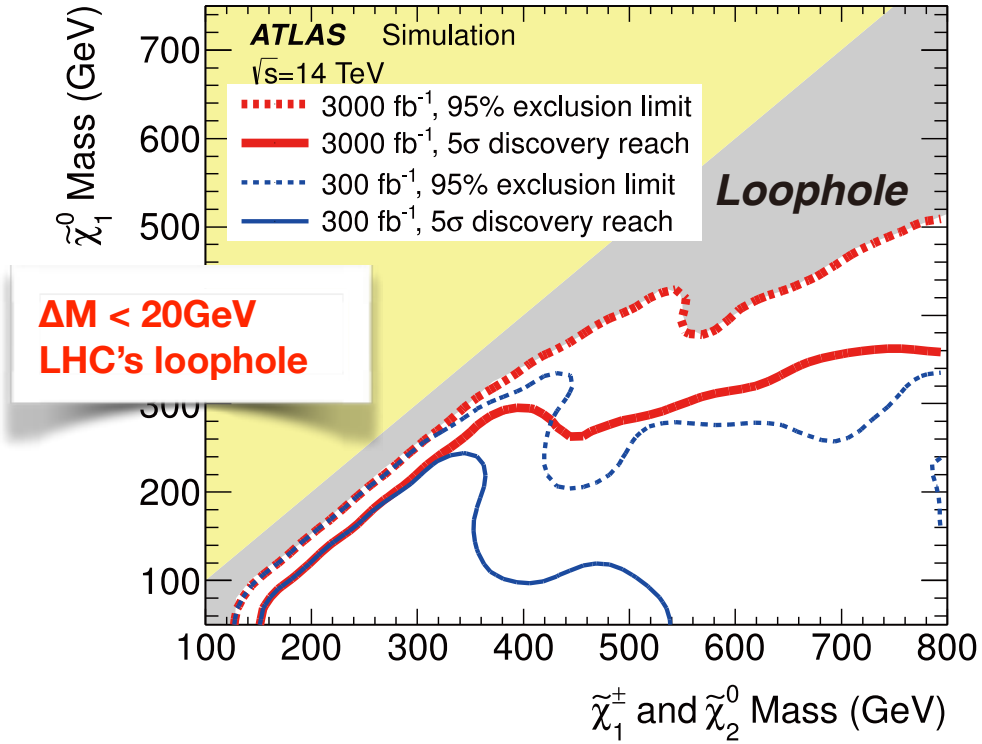
Visualization of Parameter Space

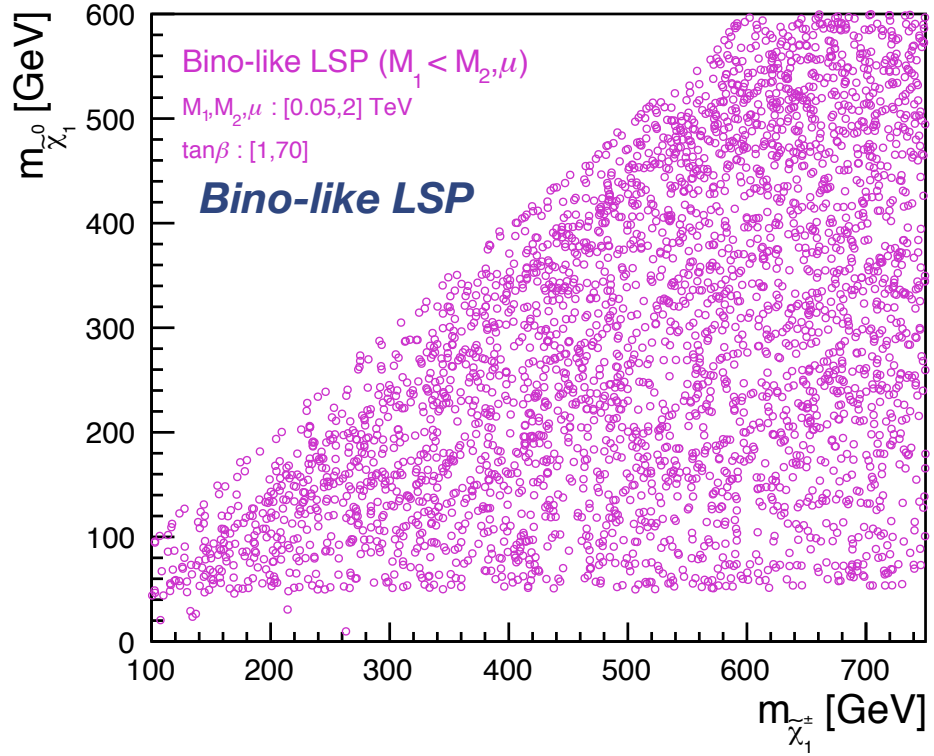
Although the measure in the parameter space is unknown a priori it may help show prospects.

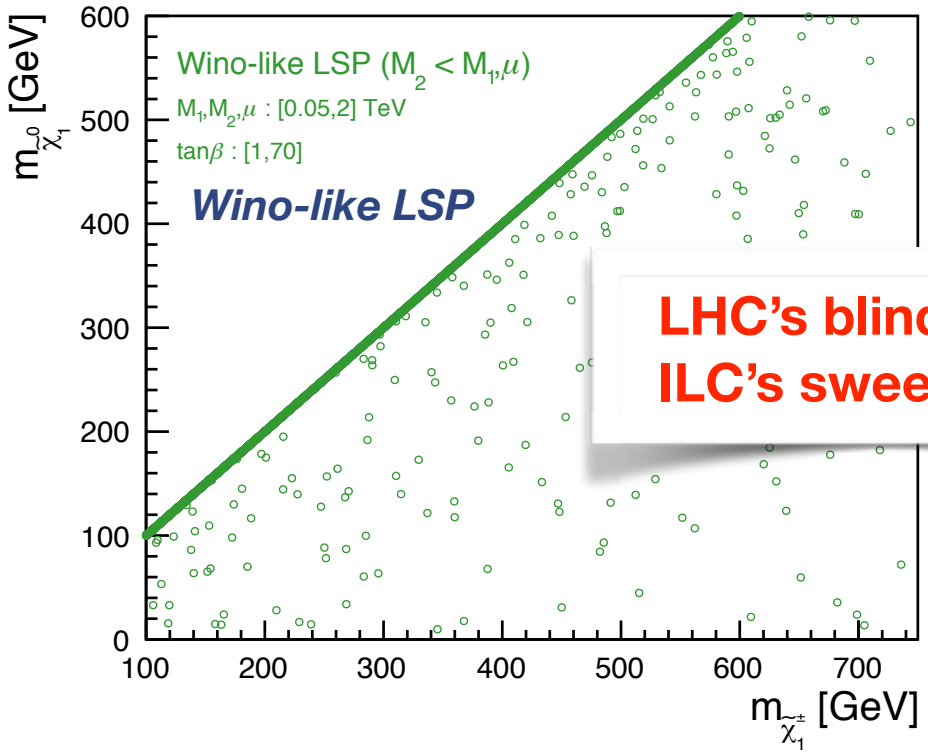
e.g.)



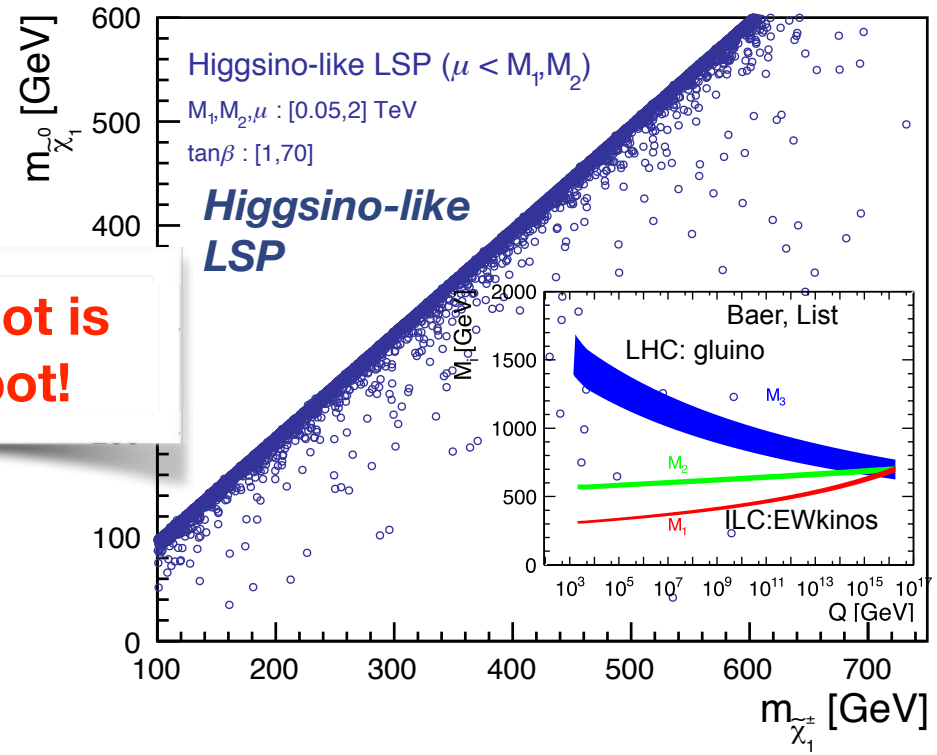
Chargino Search







LHC's blind spot is ILC's sweet spot!



Composite Higgs: Reach

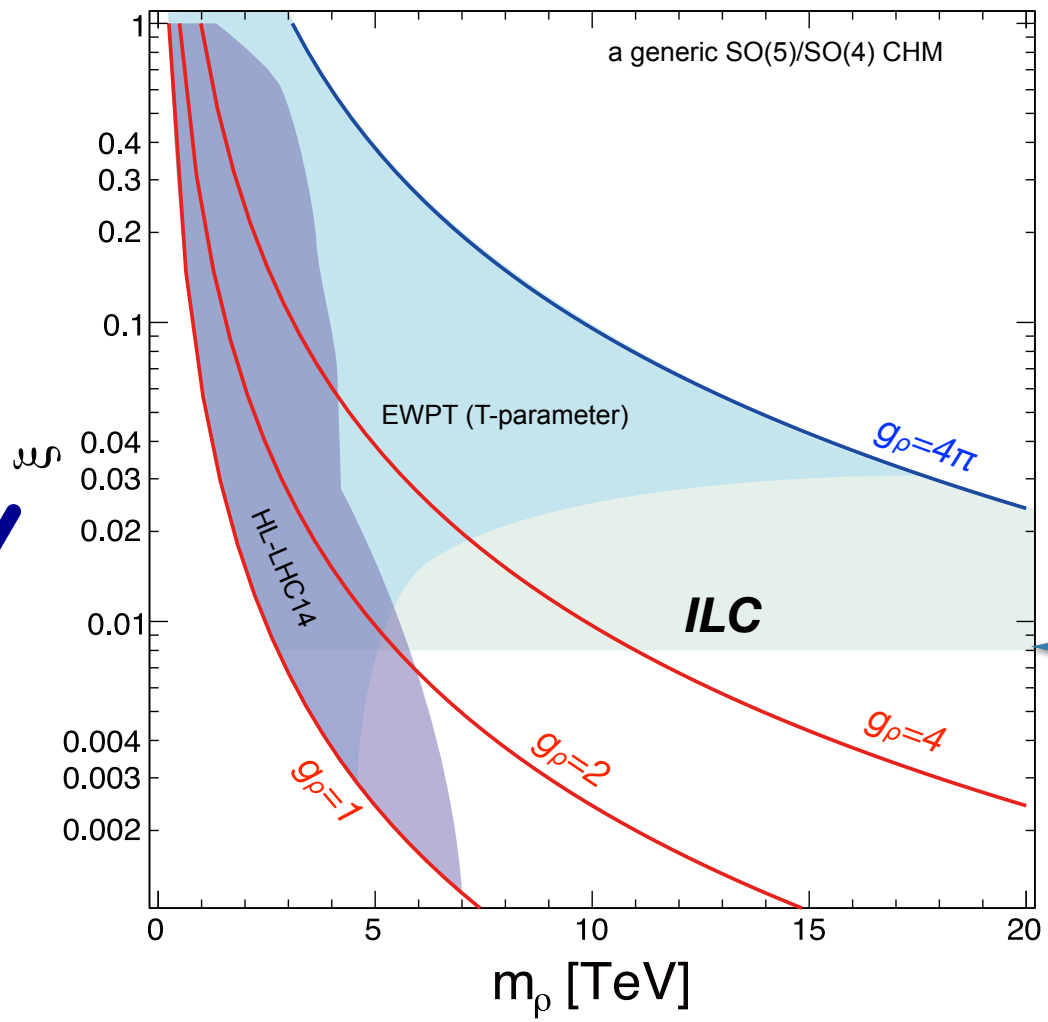
Complementary approaches to probe composite Higgs models

- Direct search for heavy resonances at the LHC
- Indirect search via Higgs couplings at the ILC

Comparison depends on the coupling strength (g_*)

Direct Search

Higgs Couplings



Based on Contino, et al, JHEP 1402 (2014) 006
Torre, Thamm, Wulzer 2014
Grojean @ LCWS 2014

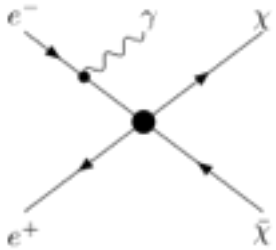
$$\xi = \frac{g_\rho^2}{m_\rho^2} v^2 = \frac{v^2}{f^2}$$

$$\frac{g_{hVV}}{g_{h_{\rm SM}VV}} = \sqrt{1-\xi}$$

ILC (250+500 LumiUP)

$$\Delta \frac{g_{hVV}}{g_{hVV}} = 0.4\%$$

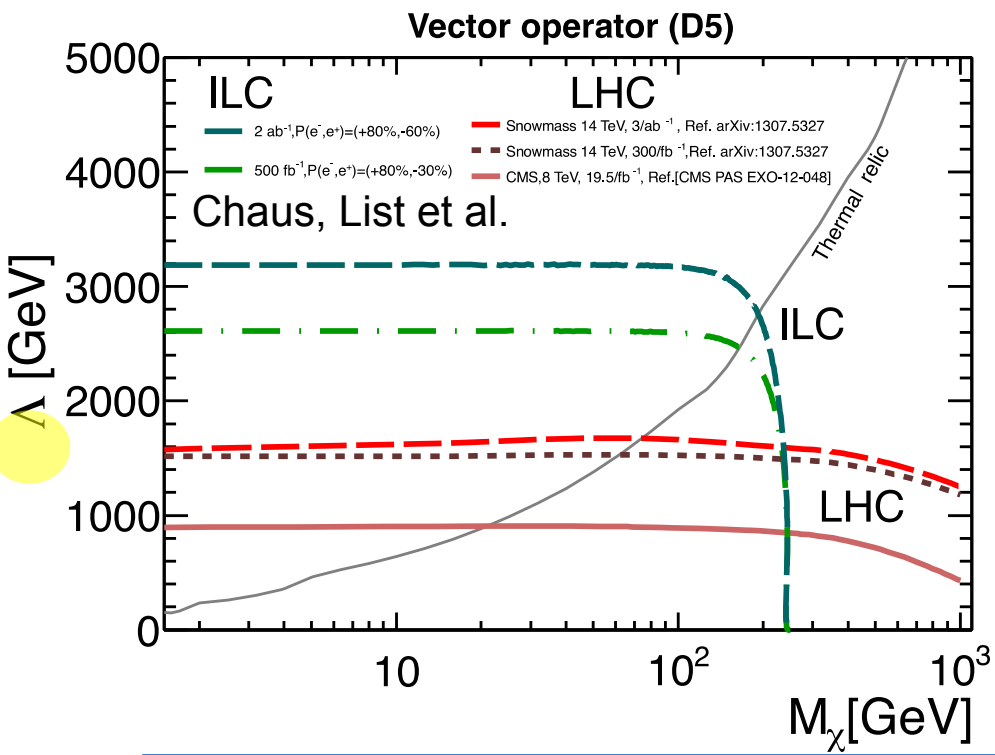
DM: Effective Operator Approach

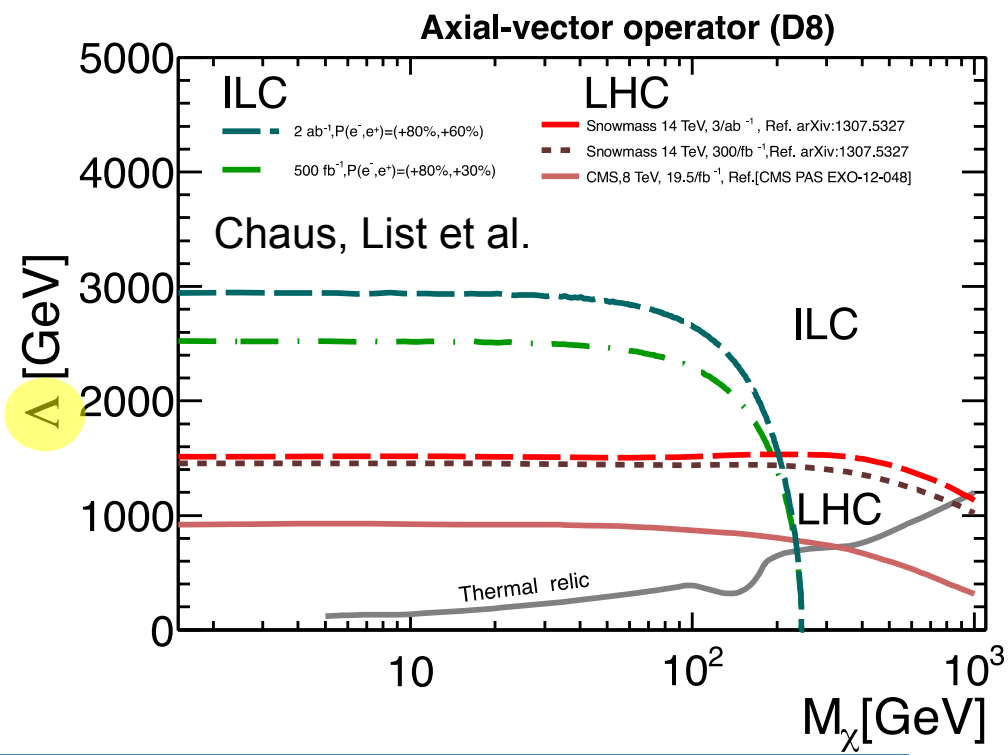


$$\mathcal{L}_{\rm int} = \frac{1}{\Lambda^2}\mathcal{O}_i$$

$$\mathcal{O}_V = (\overline{\chi}\gamma_\mu\chi)(\overline{\ell}\gamma^\mu\ell)$$

$$\mathcal{O}_A = (\overline{\chi}\gamma_\mu\gamma_5\chi)(\overline{\ell}\gamma^\mu\gamma^5\ell)$$





LHC sensitivity: Mediator mass up to Λ~1.5 TeV for **large DM mass**

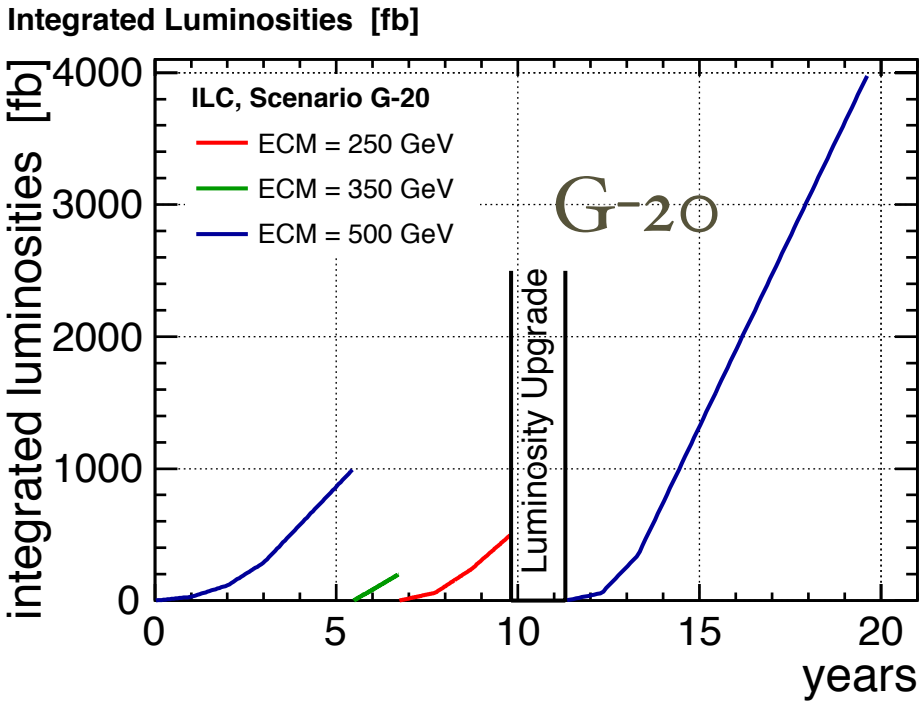
ILC sensitivity: Mediator mass up to ***Λ~3 TeV*** for ***DM mass up to ~√s/2***

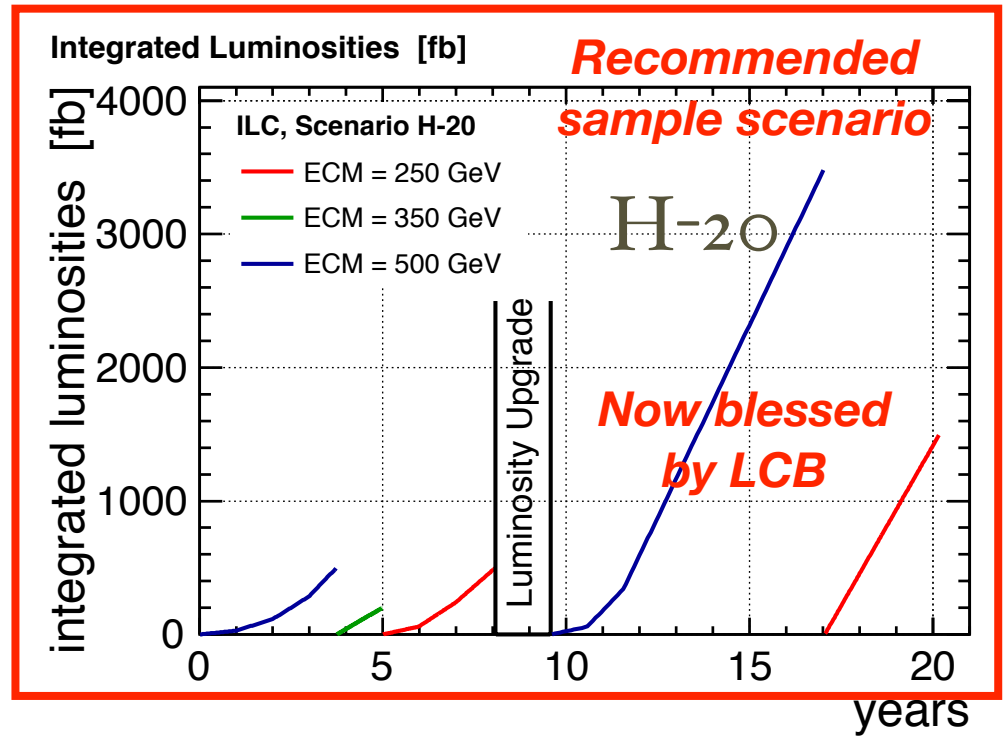
LHC-ILC synergy!

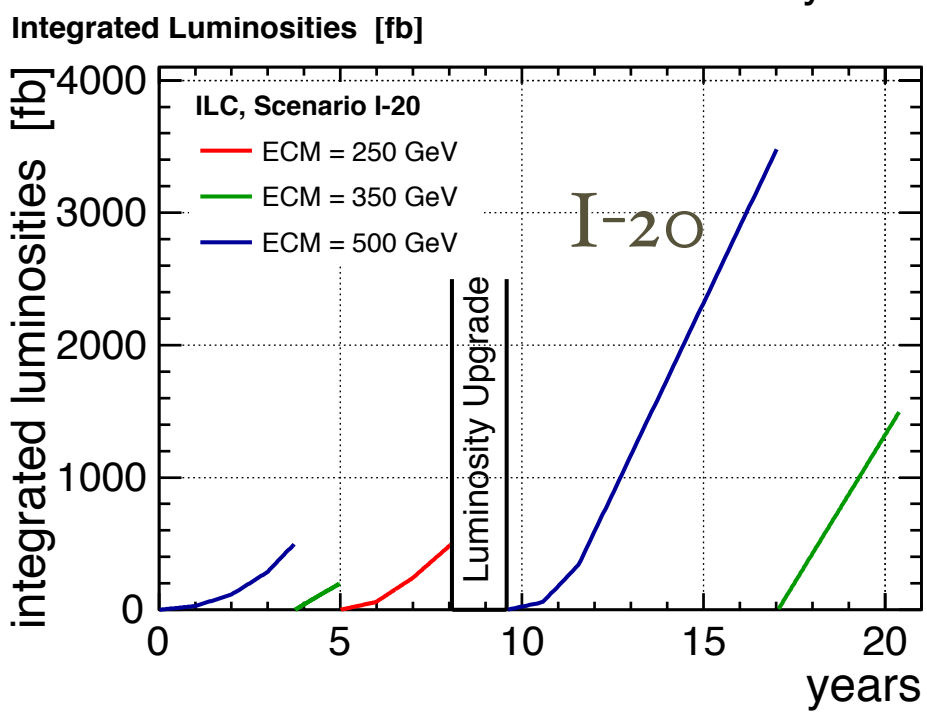
More Exercises Needed

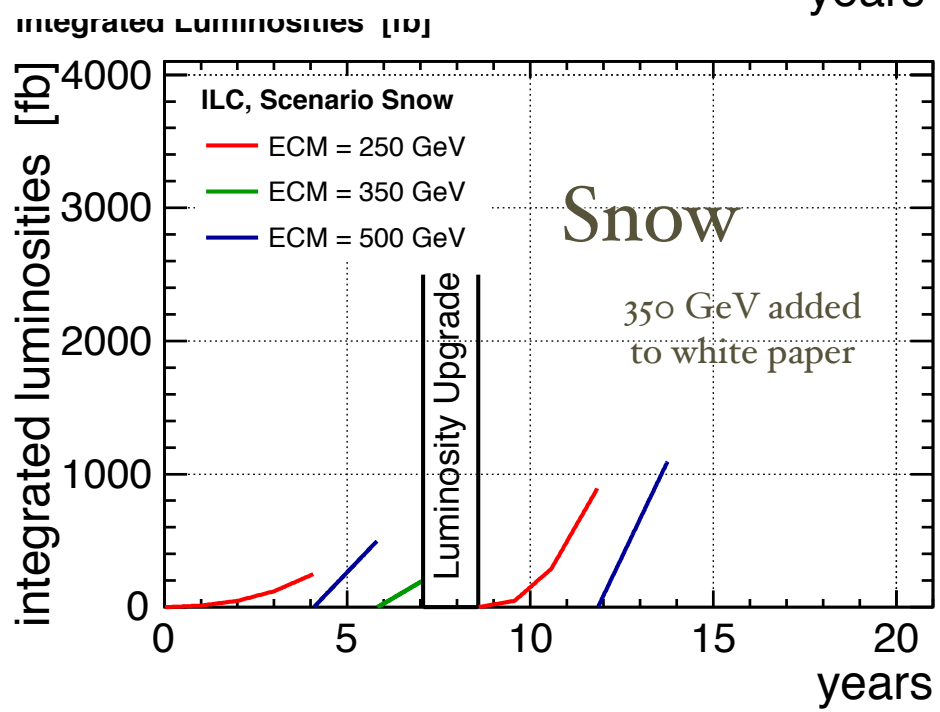
- For theorists:
  - ILC can measure various quantities such as mh, gamma_h, ghxx, mt, etc. far better than LHC. But how accurately do we really need to measure them?
  - What will be the ultimate theoretical uncertainties in various predictions for LHC and ILC, respectively?
  - Update various ILC physics plots to accommodate LHC constraints, etc.
- For Experimentalists:
  - Update all the old analyses with mh=120 GeV to mh=125GeV: → mostly done!
  - Complete the analyses such as rare Higgs decays: on going.
  - Improve the analyses such as self-coupling, H->gamma gamma, recoil mass (jets?), where the results are not yet satisfactory. → on going
  - Studies at Ecm = 350 GeV → mostly done!
  - With the projected running scenarios described in DBD, the most measurements are still statistically limited and should improve by a luminosity upgrade or by running longer. Nevertheless, ILC, too, will hit systematics limits, eventually. It is probably the right time to start more serious studies of expected systematic errors. → partially done in the Snowmass, on going.
    - Identify possible sources of systematic errors
    - Estimate to what degree we can control them

Running Scenarios


Integrated Luminosities [fb]
ILC, Scenario G-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
G-20
Luminosity Upgrade
integrated luminosities [fb]
years


Integrated Luminosities [fb]
Recommended sample scenario
ILC, Scenario H-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
H-20
Luminosity Upgrade
Now blessed by LCB
integrated luminosities [fb]
years

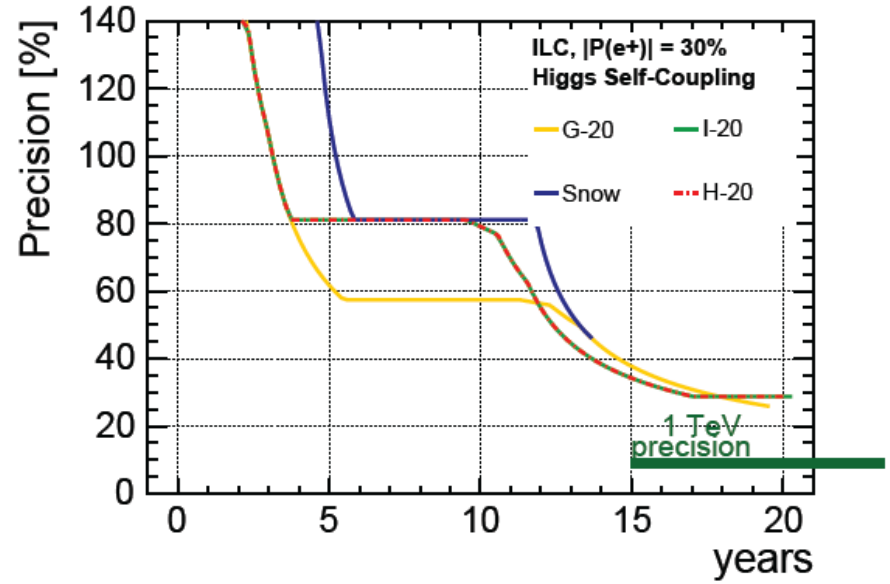

Integrated Luminosities [fb]
ILC, Scenario I-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
I-20
Luminosity Upgrade
integrated luminosities [fb]
years

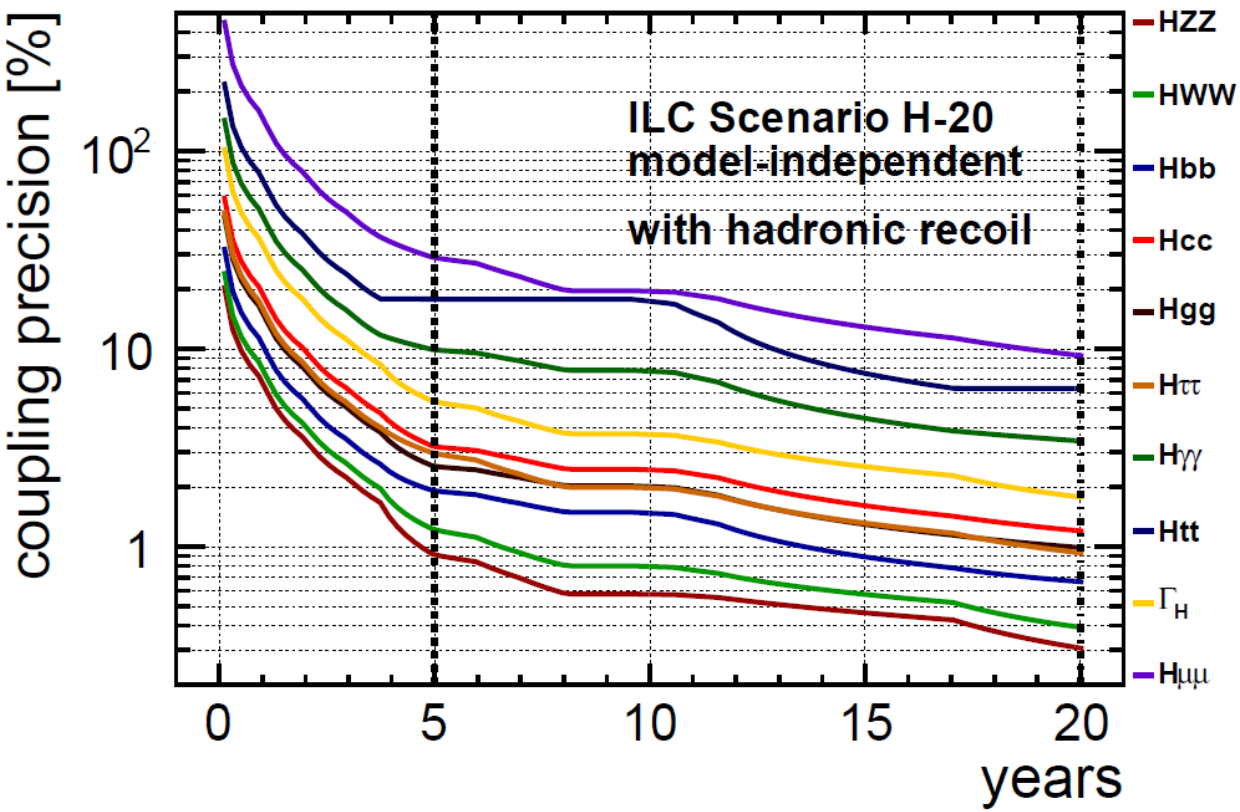

ILC, Scenario Snow
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
Snow
350 GeV added to white paper
Luminosity Upgrade
integrated luminosities [fb]
years

Higgs Measurements

H-20

	first phase	lumi upgrade	total
250 GeV	500 fb^{-1}	1500 fb^{-1}	2 ab^{-1}
350 GeV	200 fb^{-1}		0.2 ab^{-1}
500 GeV	500 fb^{-1}	3500 fb^{-1}	4 ab^{-1}
time	8.1 yrs	10.6 yrs	20.2 yrs*





Self-coupling reaches <30% for SM case.
<15% if λ=2xSM

ILC parameter WG report *Jim BRAU*

Most couplings reach <1% even with model-independent fitting

Rationales for H20

- high mass reach for new particles from the beginning
- g_{HWW} and Γ_H well balanced with g_{HZZ} in the early running period
- thus better precisions for most fermion couplings in the early running period
- full sensitivity to top quark anomalous couplings from the beginning
- access to ttH and ZHH from the beginning
- higher sensitivity to high scale for 2-fermion processes
- high precision mH and gHZZ will limit the coupling measurements only in the later stage after the luminosity upgrade

Actual running scenario, however, will depend on LHC and early ILC physics results!

Our Groups 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 (revision done, resubmitted to P.R.D.) -> P.R.D88,013010(2013)
  H->other modes: Tino (AA,mu+mu-) + Kawada/Tanabe/Suehara/Daniel (tau+tau-)->publication
  Recoil mass: Jacqueline -> draft-1, Suehara (qq), CP mixing in h->tau+tau-: Yokoyama, Ogawa (HVV couplings)
- 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: Kurata, Junping, LCFIPlus: Suehara
  New analysis: ZHH->ZbbWW*: Kurata
- nnHH : full simulation @ 1TeV, done for DBD: Junping -> publication
- nnH, eeH : precision measurements of HVV couplingsm, mh=125GeV: Junping
  BR measurements: Ono, Christian, Kawada (tau+tau-)
- 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 left) + Ishikawa + KF, Theory: Kiyo + Sumino -> publication? (cf. a recent significant theoretical development!): Ozawa
- Anomalous ttZ coupling in open top production: Sato
- New analysis (enW) : Koya Tsuchimoto (controlling systematic uncertainties)
- 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 analysis: Tanabe + Jacqueline + DESY group
- Extra U(1), etc. -> Z' tail, etc. DM -> 2-fermion process: Nakagawa
  - TT : full simulation studies for LOI -> publication in conjunction with tau tau
  - tau tau : full simulation studies for LOI -> ditto
- 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 --> New student: Takuaki Mori (Tokyo)
- Quasi stable stau: Yamaura (Master's thesis) + Kotera + Kasama —> reactivated
- Higgs portal/h->Invisible: Honda -> Yamamoto -> Ishikawa, Ogawa, Junping
- W-H+/W+H-: (Shinzaki), Ishikawa (exp) + Kanemura, yagyu (th)
- New projects?
  - AMSB: Tanabe
  - Single photon (DM search): Tanabe
  - Heavier Higgs bosons?: Yokoya, (Abhinav) -> Ishikawa?
  - Radiative correction to Higgs couplings in 2HDM: Kikuchi
  - H125->ccbar: Hidaka
  - m_nu, DM, baryogenesis: Machida

Physics Sessions

Thursday 8 Dec. 2015

13:30 - 16:00 Physics & Optimization

Conveners: Keisuke Fujii (KEK), Dr. Junping Tian (KEK), Mr. Masakazu Kurata (The university of Tokyo)

13:30 **Introduction** *20'*
Speaker: Keisuke Fujii (IPNS, KEK)

13:50 **experimental review: Higgs (I)** *25'*
Speaker: Dr. Junping Tian (KEK)

14:15 **experimental review: Higgs (II)** *25'*
Speaker: Mr. Masakazu Kurata (The university of Tokyo)

14:40 **systematics and quartic HHZZ coupling (t.b.c)** *25'*
Speaker: Dr. Timothy Barklow (SLAC)

15:05 **Dark Matter and SUSY direct searches at ILC (experiment)** *30'*
Speaker: Tomohiko Tanabe (The University of Tokyo)

15:35 **Electroweak review: W mass measurement and control of systematics** *25'*
Speaker: Koya Tsuchimoto (Shinshu University)

Thursday 9 Dec. 2015

17:40 - 18:05 Physics & Optimization

Conveners: Keisuke Fujii (KEK), Keisuke Fujii (KEK), Dr. Junping Tian (KEK), Mr. Masakazu Kurata (The university of Tokyo)

17:40 **experimental review: Top (I)** *25'*
Speaker: Dr. Akimasa Ishikawa (Tohoku University)

Thursday 10 Dec. 2015

13:20 - 15:20 Physics & Optimization

Convener: Keisuke Fujii (KEK)

13:20 **theoretical review: Higgs** *30'*
Speaker: Shinya Kanemura (University of Toyama)

13:50 **theoretical review: Top** *30'*
Speaker: Dr. Yuichiro Kiyo (Juntendo University)

14:20 **experimental review: Top (II)** *30'*
Speaker: Roman Poeschl (Laboratoire de l'Accelerateur Lineaire (FR))

14:50 **ILD optimisation: status and plan** *30'*
Speaker: Jenny List (Deutsches Elektronen-Synchrotron (DE))