Opening Comments

2016/09/10 Keisuke Fujii

WG Objectives

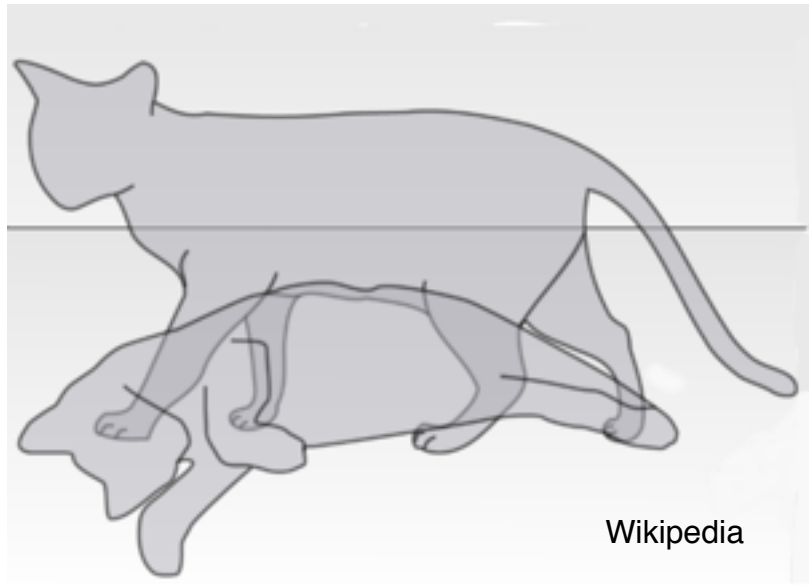
- On July 4, 2012, ATLAS and CMS announced the discovery of a Higgs-like boson with a mass of about 125GeV and the data that followed strongly indicates that it is a Higgs boson indeed. The world has changed since then. The discovery has vaulted the question of its properties on the top of the list of questions in HEP. The 125GeV boson is a window to BSM physics and ILC is the best machine to use it.
  The LHC Run2 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. The MEXT ILC Advisory Panel says "it is necessary to closely monitor, analyze and examine the development of LHC experiments". 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 detector optimization effort will continue. In response to the interim summary from the MEXT panel, ICFA sent a letter concerning issues raised there including a 4-page long summary of BSM scenario (new particle discovery potential in particular) in mid. Dec. A full summary of BSM scenario is due by the end of this summer. The next target for us to show our activities to the LC community is LCWS16 on Dec. 5 to 9 in Morioka.

X750

had been Schrödinger's cat state



Now the box is open

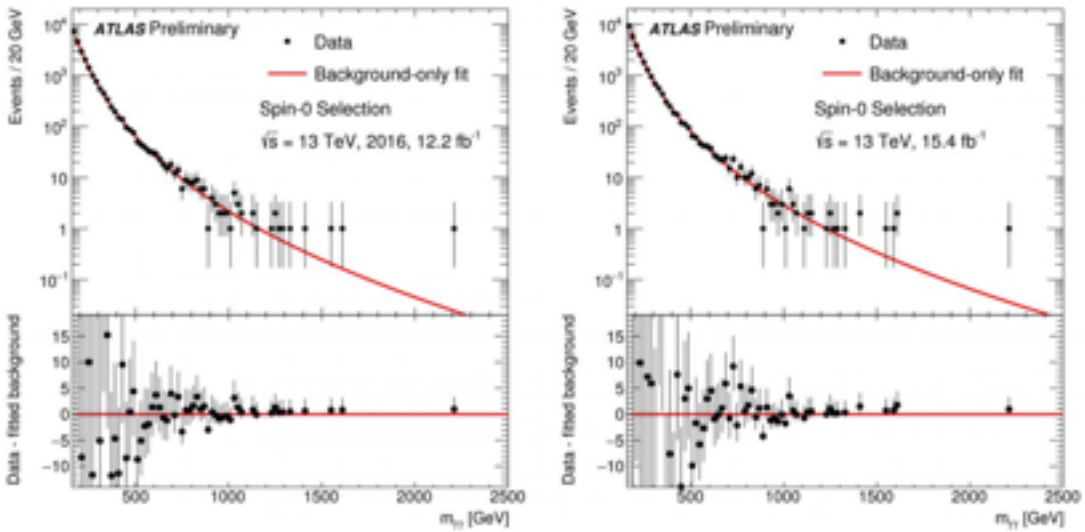


Figure 2: Invariant-mass distribution of the selected diphoton candidates, with the background-only fit overlaid, for 2016 data (left) and the combined 2015 and 2016 data (right). The difference between the data and this fit is shown in the bottom panel. (Image: ATLAS Experiment/CERN)

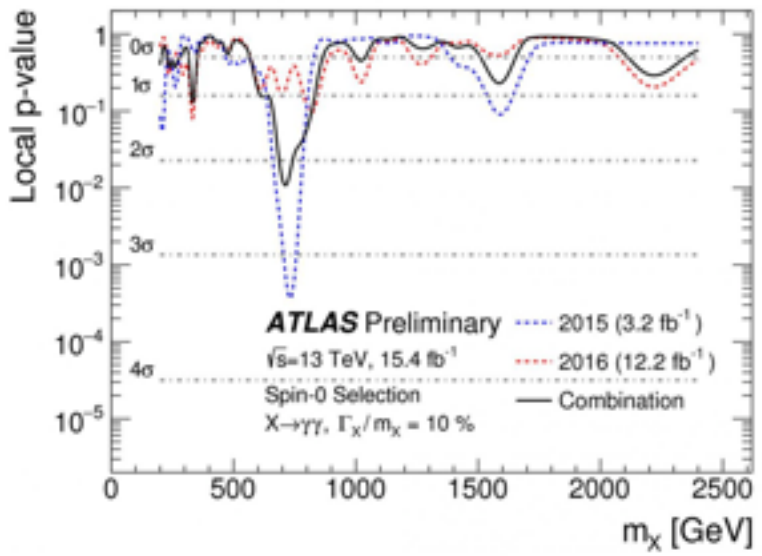
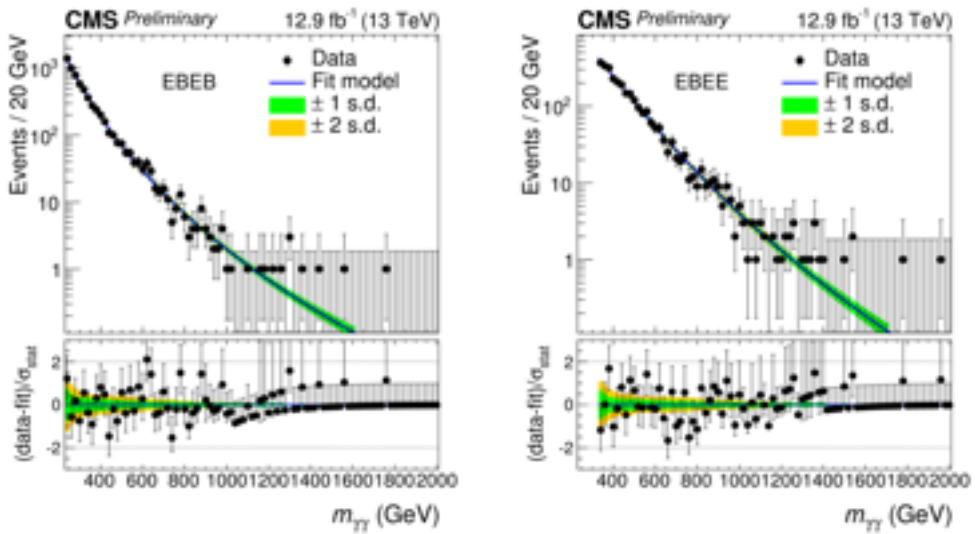


Figure 3: Probability that the background alone fluctuates up by the amount seen in data or more as a function of the mass for a certain width hypothesis of the new particle assumed in the search. (Image: ATLAS Experiment/CERN)



The CMS di-photon spectrum obtained with 12.9 fb^{-1} of 2016 data at 13 TeV (both photons in the ECAL barrel: left; at least one photon in the ECAL endcaps: right). No significant excess of events is observed over the background-only hypothesis. The mild excess near $m_{\gamma\gamma}$ ~750 GeV reported by CMS with 2012 and 2015 data is not confirmed with 2016 data.

and the cat is found dead.

Our (LCC Physics WG's) Stance has been

1. It's too early to get excited,
2. but if it is real, it is ***a good example of case 3*** in the ICFA letter to MEXT's ILC Advisory Panel:
   case 3: LHC discovers relatively heavy new particles *(which cannot be directly produced at the 500 GeV ILC)*
3. Since the MEXT Panel recommended to ***closely monitor, analyze, and examine the development of LHC experiments***, this is ***a good opportunity to do exercise for case 3***. → motivation for this note
4. In LCC's letter to the panel, it is stated that "***While performing precision studies of the Higgs boson and the top quark, we will prepare for the energy upgrade of the ILC*** *taking advantage of energy expandability enabled by its linear shape."*
5. *The note is intended to show*
   1. ***The 500 GeV ILC has a lot to say about X750*** ***through precision measurements*** *plus* ***possible discovery of NPs associated with X750****.* → *1st part (section 3)*
   2. ***Possible energy upgrade with PLC option will open up even greater opportunities*** ***to uncover the new physics operating behind X750 together with LHC****.* → *2nd part (section 4)*

And did the homework following MEXT's recommendation

ILC–NOTE–2016–067
DESY 16–145, IPMU16-0108
KEK Preprint 2016–9, LAL 16–185
MPP–2016–174, SLAC–PUB–16751

July, 2016

Implications of the 750 GeV $\gamma\gamma$ Resonance as a Case Study for the International Linear Collider

LCC Physics Working Group

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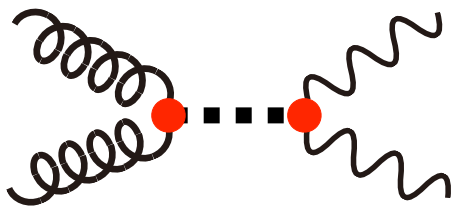
ABSTRACT

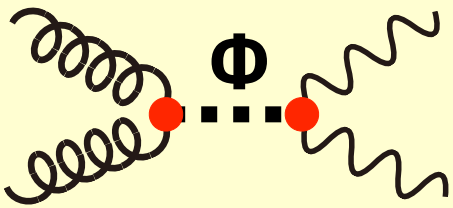
If the $\gamma\gamma$ resonance at 750 GeV suggested by 2015 LHC data turns out to be a real effect, what are the implications for the physics case and upgrade path of the International Linear Collider? Whether or not the resonance is confirmed, this question provides an interesting case study testing the robustness of the ILC physics case. In this note, we address this question with two points: (1) Almost all models proposed for the new 750 GeV particle require additional new particles with electroweak couplings. The key elements of the 500 GeV ILC physics program—precision measurements of the Higgs boson, the top quark, and 4-fermion interactions—will powerfully discriminate among these models. This information will be important in conjunction with new LHC data, or alone, if the new particles accompanying the 750 GeV resonance are beyond the mass reach of the LHC. (2) Over a longer term, the energy upgrade of the ILC to 1 TeV already discussed in the ILC TDR will enable experiments in $\gamma\gamma$ and e^+e^- collisions to directly produce and study the 750 GeV particle from these unique initial states.

Representative Models and Effects

Effective Couplings



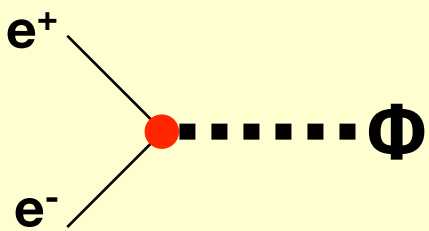
Φ=RS radion



KK-loop correction
→ hWW, hZZ

~8% deviation expected for 5 TeV KK gluon.

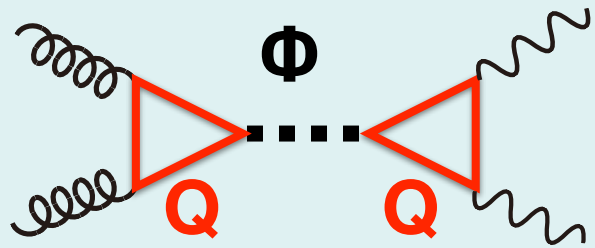
Φ=RS gravition J=2

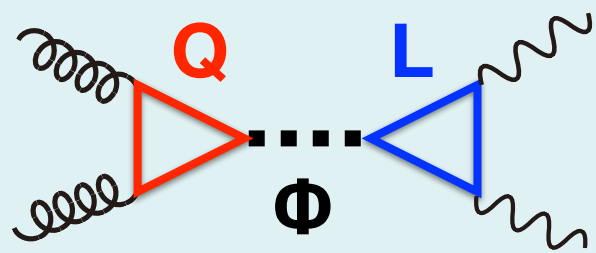


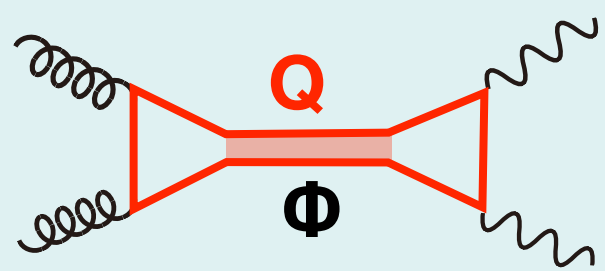
direct coupling to e^+e^-
→ s-channel Φ production

still not completely excluded.

Elementary Scalar



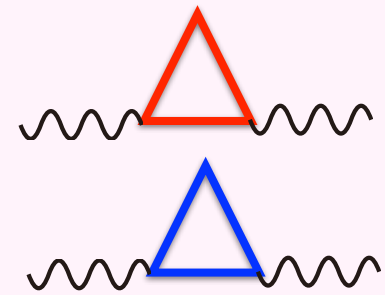




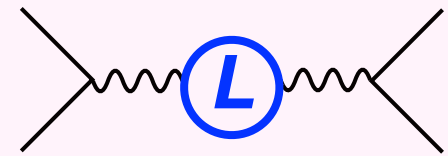
Resonance/pNGB

might be accompanied by DM within ILC's reach

Oblique Corrections



→ 2-to-2 processes



with δσ/σ=0.1%, ILC sensitivity exceeds LHC

Mixings

Q-t mixing → ttZ

L-τ mixing

Φ-h mixing
→ hγγ, hgg
→ hWW, hZZ

a few % deviation expected
→ well within H20 target

	hWW hZZ	$hb\bar{b}$ $h\tau\tau$	$h\gamma\gamma$ hgg	$ht\bar{t}$	$h \to$ invis.	$h\tau\mu$	$t\bar{t}Z$	$ee \to$ $ee, \mu\mu$	$ee \to$ $\gamma+$ invis.
Vectorlike fermions		X	X	X			X	X	
2 Higgs doublet	X	X	X	X					
Higgs singlet	X	X		X			X		
NMSSM	X	X	X	X	X				X
Flavored Higgs	X	X	X			X			
NR bound state		X		X				X	
Pion of new forces		X	X	X	X		X	X	X
RS radion	X	X	X	X			X		
RS graviton	X	X		X			X		

Table 2: Anomalies in precision measurements expected to be visible at the ILC for the models of the Φ discussed in this section.

1. *The note is intended to show*

- ***The 500 GeV ILC has a lot to say about X750*** ***through precision measurements*** *plus* ***possible discovery of NPs associated with X750****.*

Section 3: This part is still relevant!

- ~~***Possible energy upgrade with PLC option will open up even greater opportunities to uncover the new physics operating behind X750 together with LHC.***~~ ***Section 4: now moot.***

2. ***Our strategy stated in the ICFA letter to MEXT's ILC Advisory Panel is intact***:
While performing precision studies of the Higgs boson and the top quark, we will prepare for the energy upgrade of the ILC *taking advantage of energy expandability enabled by its linear shape.*

This always applies!

Caution

For this reason, ***it is premature to discuss a new accelerator intended specifically to target the Φ*** or any other new particle that turns up in the early 13 TeV LHC data.

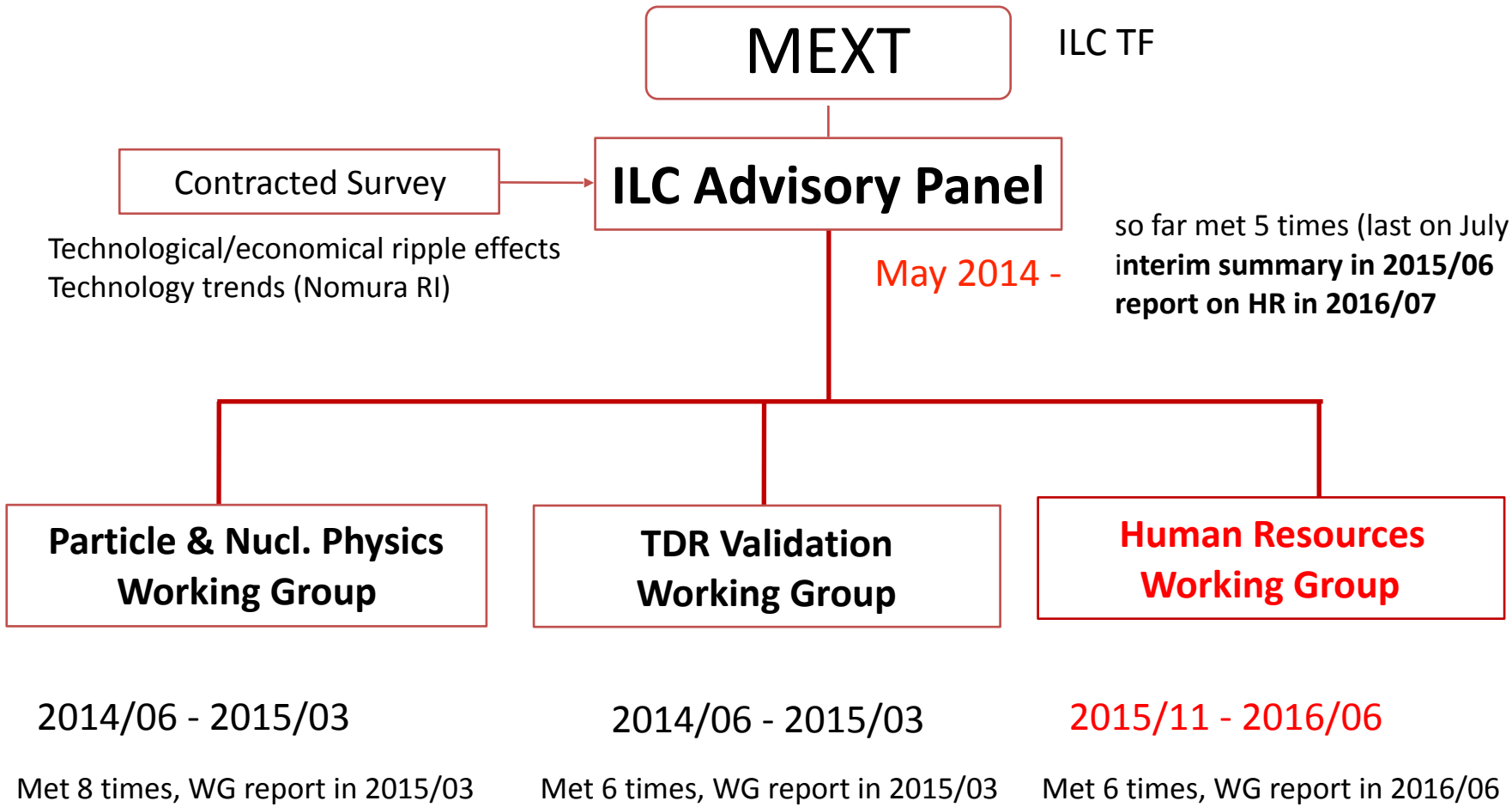
Indeed it is.

MEXT's ILC Review

MEXT = Japan's **M**inistry of **E**ducation, **C**ulture, **S**ports, **S**cience and **T**echnology

ILC Advisory Panel

Set up in May 2014 under MEXT ILC Task Force to investigate various issues concerning the possibility of hosting the ILC in Japan



Interim Summary

http://www.mext.go.jp/b_menu/shingi/chousa/shinkou/038/gaiyou/1360593.htm

- ILC Advisory Panel publicized an interim summary of their discussions based on the reports from the two working groups (Particle & Nuclear Physics WG and TDR Validation WG).

- The interim summary pointed out the following issues
  - Obtain clear vision for international cost sharing
  - **Make clear scientific merits (not only precision studies of Higgs and top but also possibilities of new particle discoveries) that match the investment**
  - **Monitor, analyze, and examine the development of LHC experiments.**
  - Solve remaining technological issues and mitigate cost risk.
  - Get understanding from the general public and other scientific communities.

Report on HR

http://www.mext.go.jp/component/b_menu/shingi/toushin/__icsFiles/afieldfile/2016/08/08/1374377_2_1.pdf

- **MEXT is seriously investigating various issues to be solved to host the ILC in Japan.**

- Recently, ILC Advisory Panel publicized a report on HR based on the report from the Human Resource Securing and Developing Working Group.

Support Document for the ICFA Letter

The ILC's Potential for Discovering New Particles

Document Supporting the ICFA Response Letter to the ILC Advisory Panel

The purpose of this document is to provide in-depths material supporting statements on the ILC's discovery potential for new particles sketched out in the answer of ICFA to the ILC Advisory Panel of MEXT, taking into account LHC Run II development.

Target: Particle physicists (a version for the MEXT ILC Advisory Panel will be prepared based on this)

Length: 25 - 30 pages

Deadline: originally the end of summer 2016, but since X750 is gone and no immediate action seems to be expected, we could postpone it a little bit. Maybe a first presentable draft by the Morioka WS.

Guideline:

1. Minimize overlap with the ILC physics case update document from last year. → focus should be on the ILC's new particle discovery potential and the relation to LHC (and others like direct/indirect detection, flavor, neutrinos, ... where appropriate).
2. We will hand this document to ICFA who will decide how to use it best in the political process.
3. Assign two main authors responsible for each subsection, who will then be in charge of organizing smaller contributions (e.g. subsubsections) etc.
4. Of course every author, as well as the whole LCC Physics Group will have the opportunity to comment on and give input to the whole document.

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->other modes: Tino (AA,mu+mu-) + Kawada/Tanabe/Suehara/Daniel (tau+tau-)->publication -> EPJC (2015) 75:617.
  Recoil mass: Jacqueline -> submitted to PRD, revising the manuscript, Suehara (qq), CP mixing in h->tau+tau-: Daniel -> draft being reviewed by ILD, HVV couplings: Ogawa
  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*: Kurata, Systematic Error: Tim, 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
- W mass (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 (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: a new student
- 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) -> Ishikawa?
  - X(750) : Junping -> submitted to PRD -> manuscript being revised.
  - Quark flavor violation in H125->ccbar and bbbar: 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. 26, 2016 (KEK MCU2 conf. ID:XXX)
- LCWS 2016, Morioka, Dec. 5-9, 2016