# The physics case response
## to the interim summary
## by the MEXT expert panel

ILC@DESY

Hamburg, December 12, 2015

heavily based on K. Fuji's talk at LCWS 2015


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# MEXT's ILC Review

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

# MEXT's ILC Review

**Oct., 2013: Japanese HEP community filed a petition for the Japanese government to invite the ILC to Japan. → ILC became a project officially recognized by the government.**

**May 8, 2014: An Advisory Panel including external members under MEXT's ILC TF started the official review process!**

**MEXT's ILCTask Force**

Established in May 2014

**ILC Advisory Pannel** (2014-5-1→2016-3-31: extensible if needed)
consisting of 13 academic experts from various fields

Research Contract on Survey of spin-off effects

Nomura Research Inst.

**Particle and Nuclear Physics WG**

Review ILC physics case, taking into account other HEP projects

15 from HEP(th/exp), nucl. phys., astronomy, CR research

Established in June 2014

**TDR Validation WG**

Evaluate ILC TDR from technical point of view (mostly on accelerator)

10 members, essentially all accelerator physicists

Established in June 2014

Particle and Nuclear Physics WG had 8 meetings and TDR validation WG had 6 meetings before producing their reports to the ILC Advisory Panel in March 2015. *The ILC advisory panel then published* ***an interim summary of discussions on Aug. 5, 2015***.

# Precision programme is not enough
# Want to know what ILC can discover
# LHC/ILC complementarity/competition

**3. Recommendations**

Based on the investigations and reports by the working groups and discussions by the advisory panel, the panel recommends the following on the ILC project;

**Recommendation 1: The ILC project requires huge investment that is so huge that a single country cannot cover, thus it is indispensable to share the cost internationally. From the viewpoint that the huge investments in new science projects must be weighed based upon the scientific merit of the project, a clear vision on the discovery potential of new particles as well as that of precision measurements of the Higgs boson and the top quark has to be shown so as to bring about novel development that goes beyond the Standard Model of the particle physics.**

- The objective of the ILC project is to uncover physics beyond the Standard Model through the precision measurements of the Higgs boson and top quark and through searches for new particles. In case of new discoveries beyond the Standard Model, its scientific impact on elementary particle physics will be significant.
- As the ILC project requires huge investment, it is indispensable and essential prerequisite for the implementation to have a clear vision of participation and cost sharing by international partners including European countries and the United States while taking into account mid-term and long-term domestic economic and financial situations.
- From the viewpoint the huge investments in new science projects must be weighed based upon the scientific merit of the project, it is necessary to have a clear strategy of the discovery potential of new particles such as supersymmetry particles which are considered as a candidate of the dark matter, in addition to that of precision measurements of the Higgs boson and top quark, has to be shown so as to bring about novel development that goes beyond the Standard Model.
- It is appropriate to proceed discussion on a possible international cost sharing scheme of the ILC project by not only taking into account the scheme used by CERN but also taking into account the schemes of existing large scale international projects such as the International Thermonuclear Experimental Reactor (ITER) and International Space Station (ISS).

LCB Chair, Sachio Komamiya

# Letter from ICFA to the ILC Advisory Panel of MEXT

Since the “Interim Summary” was translated in English for the international community, and there are so many open issues raised in this Summary, ICFA decided to write a letter to the Panel.
The Panel opened the Summary of their discussions but they did not ask anything to the international community, the purpose of the ICFA letter is just to clarify and to explain the issues raised in the Summary. KEK and Japanese ILC community is preparing the daft in cooperating with LCC and LCB.

***Panel made recommendations to MEXT, not us!***

0) Preface (based on request from KEK DG)

Appreciation of Panel’s work

“First of all, we would like to express our profound gratitude to the members of the ILC Advisory Panel for seriously considering, in response to a request from the Japanese government, the various issues concerning the hosting of ILC in Japan, which is being promoted by the international community of elementary particle physicists. …..”

High-brow discussions on scope of our field beyond the Panel’s Report
Social effects of fundamental science like ILC and the role of ICFA
Composition of this document

# Guideline

1. Start from the basic points made in the interim summary.
2. Reemphasize the importance of precision studies of the Higgs boson and the top quark.
3. Accept the questions asked by the MEXT panel as they were formulated:
   What if the LHC finds no new particles?
   What if the LHC finds relatively light new particles?
   What if the LHC finds heavy new particles?
4. Try to answer these questions as straightforwardly as possible.

# *Main Body*

**1. Particle Physics: Current Status, Issues, and Goals**

**2. The Higgs Boson and the Top Quark**

**3. Potential for Discovering New Particle**

Difference between LHC and ILC

**3-1) No discoveries of new particles at LHC Experiments**

Dark matter
SUSY
Mechanism for EWSB (self-coupling)

**3-2) LHC experiments discover relatively light new particles**

SUSY
Dark matter / Mechanism for EWSB (self-coupling)

**3-2) LHC experiments discover heavy new particles**

SUSY
Composite Particles
Particles that mediate a new force
Dark matter / Mechanism for EWSB (self-coupling)

One important point
we can discover New Physics without discovering new particles
e.g. neutrino oscillations -> new interactions

# Document in the hands of ICFA and LCB

preamble
physics part
accelerator part

now in a single and unified document

The success of the Standard Model creates a platform from which we can ask new fundamental questions about the universe:

• Why there are three generations of elementary particles, as well as three types of interactions linking them? Why do the masses of the fundamental constituents vary over many orders of magnitudes, ranging from the light, sub-eV neutrinos to the heavy top quark of 175 billion eV?
• What is the identity of the invisible dark matter that pervades the universe, the amount of which is about five times that of ordinary matter?
• Despite the existence of matter and anti-matter in equal amounts immediately after the Big Bang, why did a tiny surplus of matter survive, providing the basis of our very existence?
• The Standard Model does not encompass the theory of gravity, so how can we comprehend the universe in the moments immediately after its birth?

## Science Significance and Potential for Discovering New Particles

**1. Particle Physics: Current Status, Issues, and Goals**
**2. The Higgs Boson and the Top Quark**
**3. Potential for Discovering New Particles**
**3-1) LHC experiments do not discover new particles**
**3-2) LHC experiments discover relatively light new particles**
**3-3) LHC experiments discover relatively heavy new particles**

A Report on

# *Prospects for New Particle Discovery Potential*

Contents: Prospects for new particle discoveries at ILC
Target: MEXT Expert Panel (official name: MEXT ILC Advisory Panel)
Length: ??
Deadline: Summer 2016
Purpose: Backup the short report with updates taking into account LHC Run II development (as recommended by MEXT)

# Plan

**Report to be based on a ILC-LHC comparison table of discovery potential**

**Structure of the table**

**Typical discovery scenarios in Y-axis**

- SUSY (subdivision such as Bino-, Wino-, Higgsino-LSP, as needed)
- Minimal Composite Higgs Models (subdivision as needed)
- Dark matter particles

**Discovery channel/method in X-axis**

- Precision Higgs measurements
- Precision top measurements
- Indirect searches (other than H and t)
- Direct searches

**Each cell**

Prospects at ILC (depending on 13TeV LHC results)

Key message to deliver

There are other important kinds of discovery than new particle discovery!

| | Precision Higgs | Precision Top | Other Indirect Methods | Direct Searches |
|---|---|---|---|---|
| SUSY | | | | |
| Compositeness | | | | |
| DM | | | | |
| … | | | | |

**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

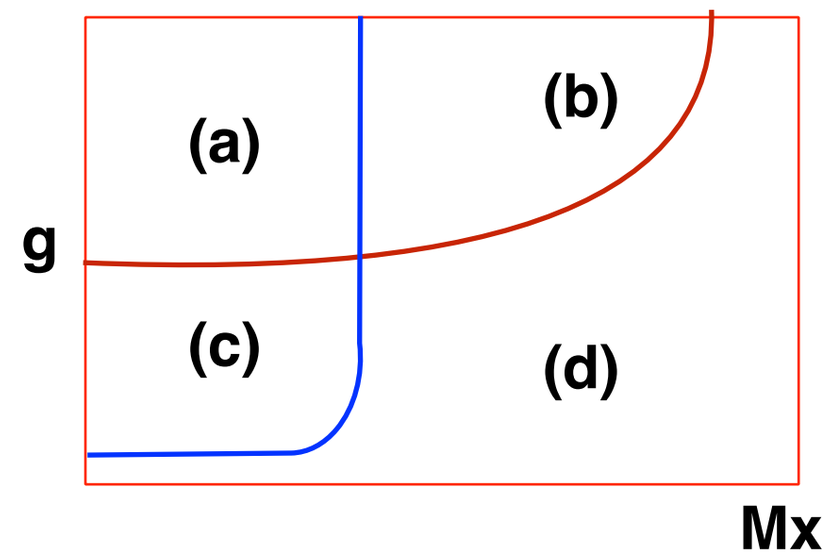
Need to decide we make a table for each of the 4 cases or combine some of the cases such as (a,b)(c,d) or (a,c)(b,d)

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**

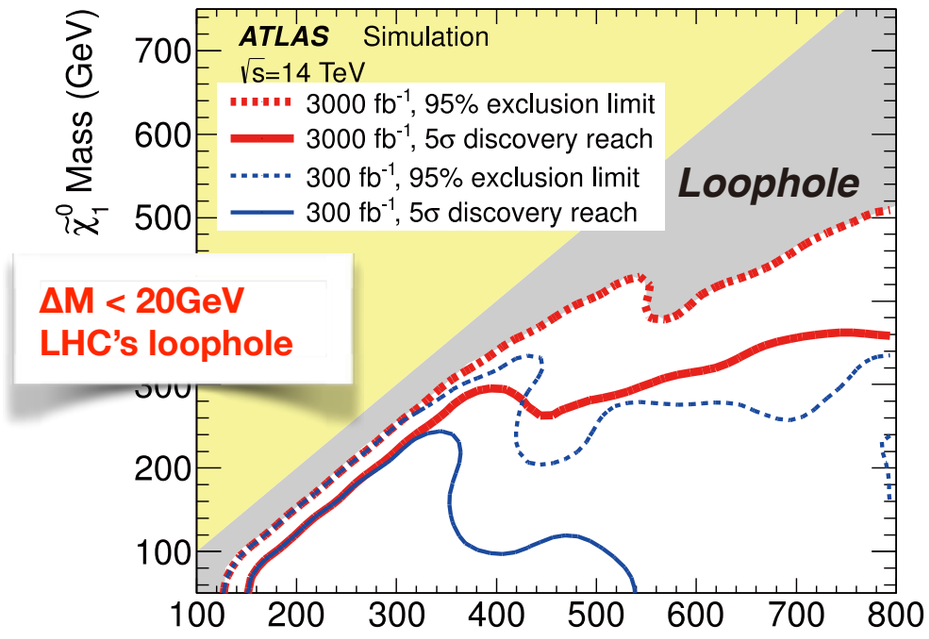
Although the measure in the parameter space is unknown a priori it may help show prospects.

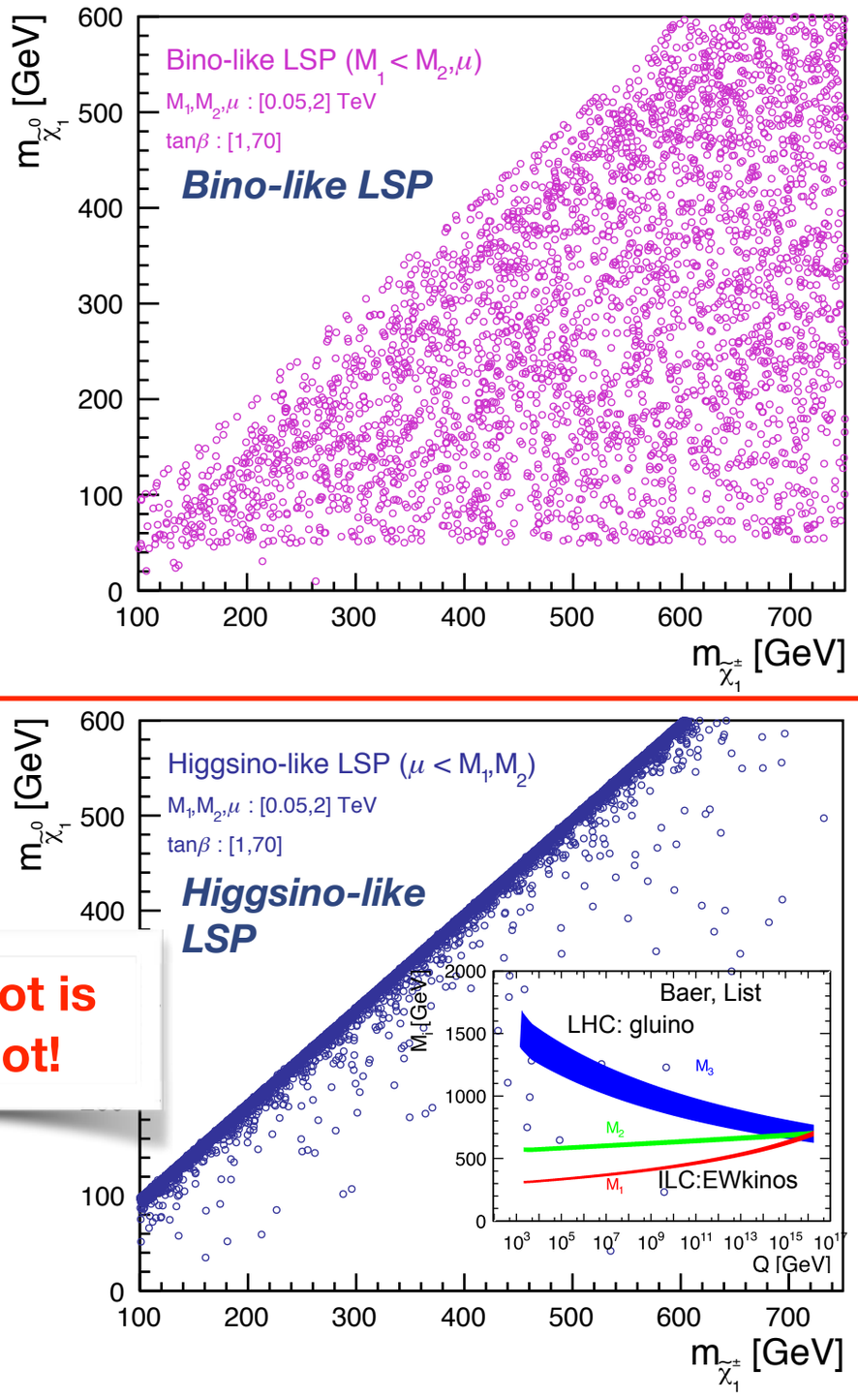
e.g.)

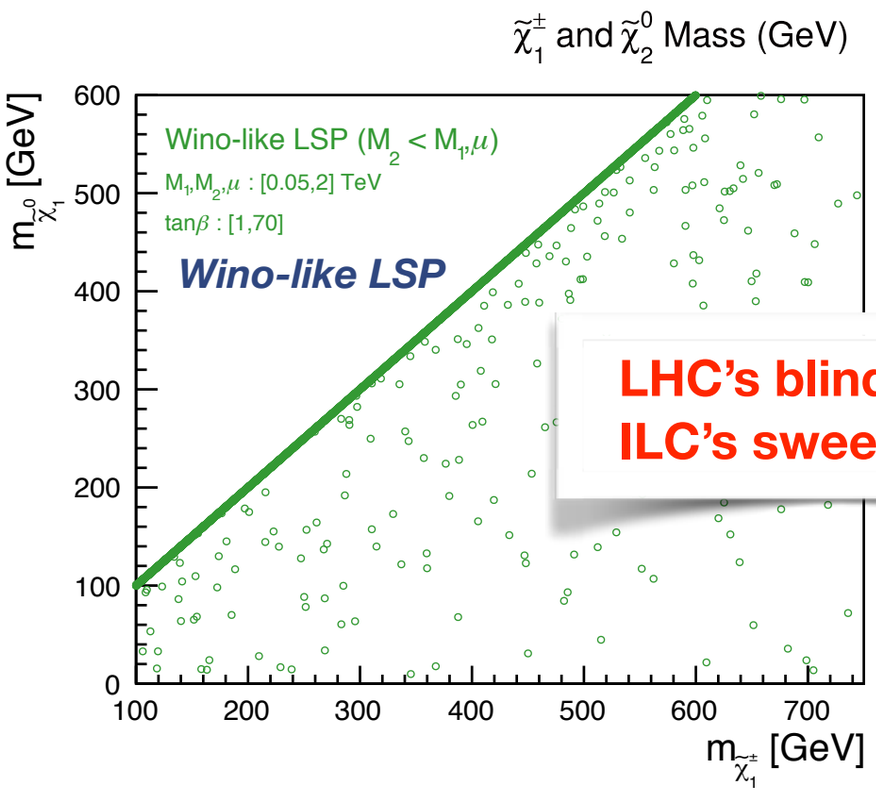


# Direct Searches

## Chargino Search



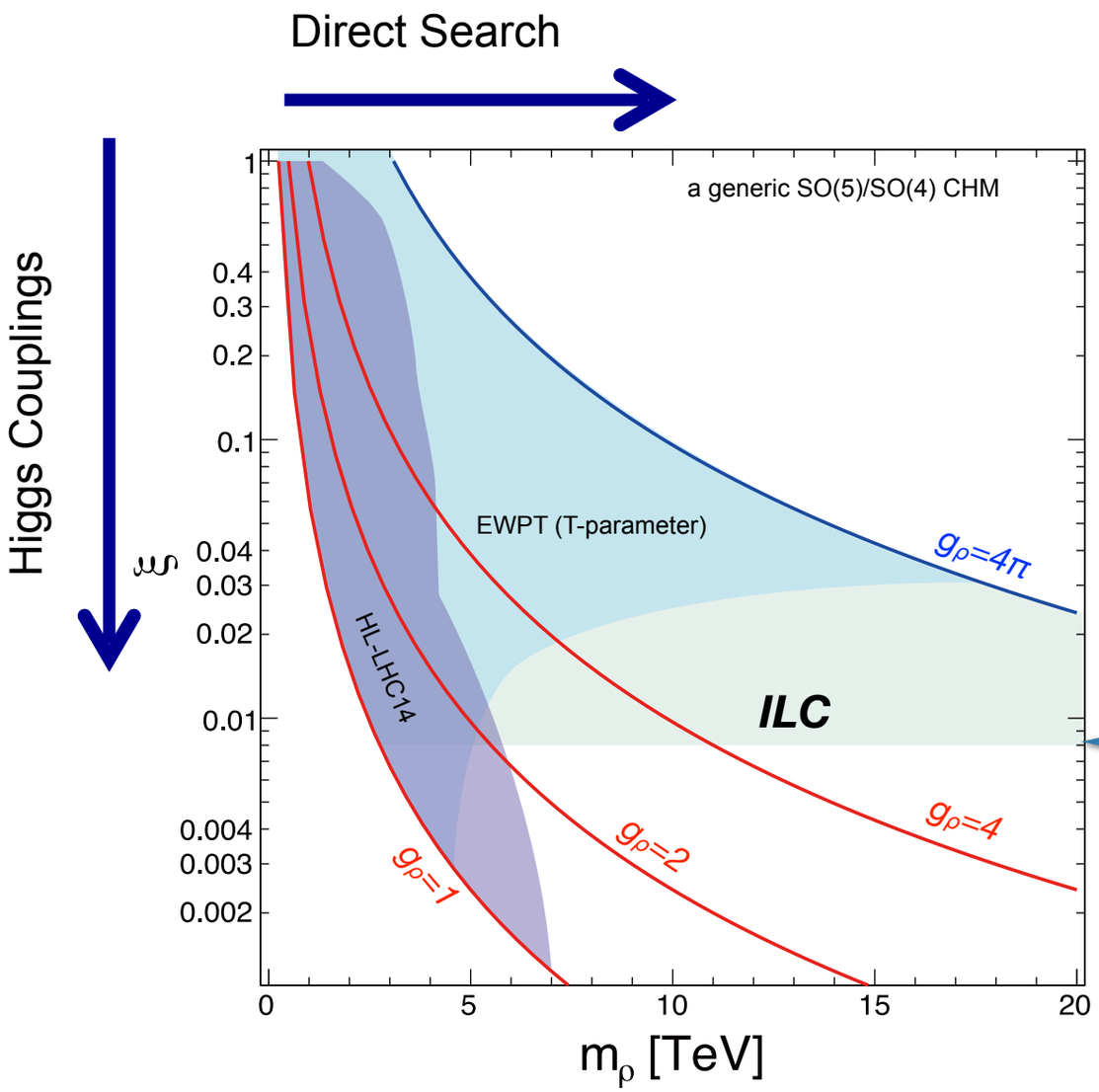

**LHC's blind spot is ILC's sweet spot!**

# Higgs precision measurements

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 ($g_*$)




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)**

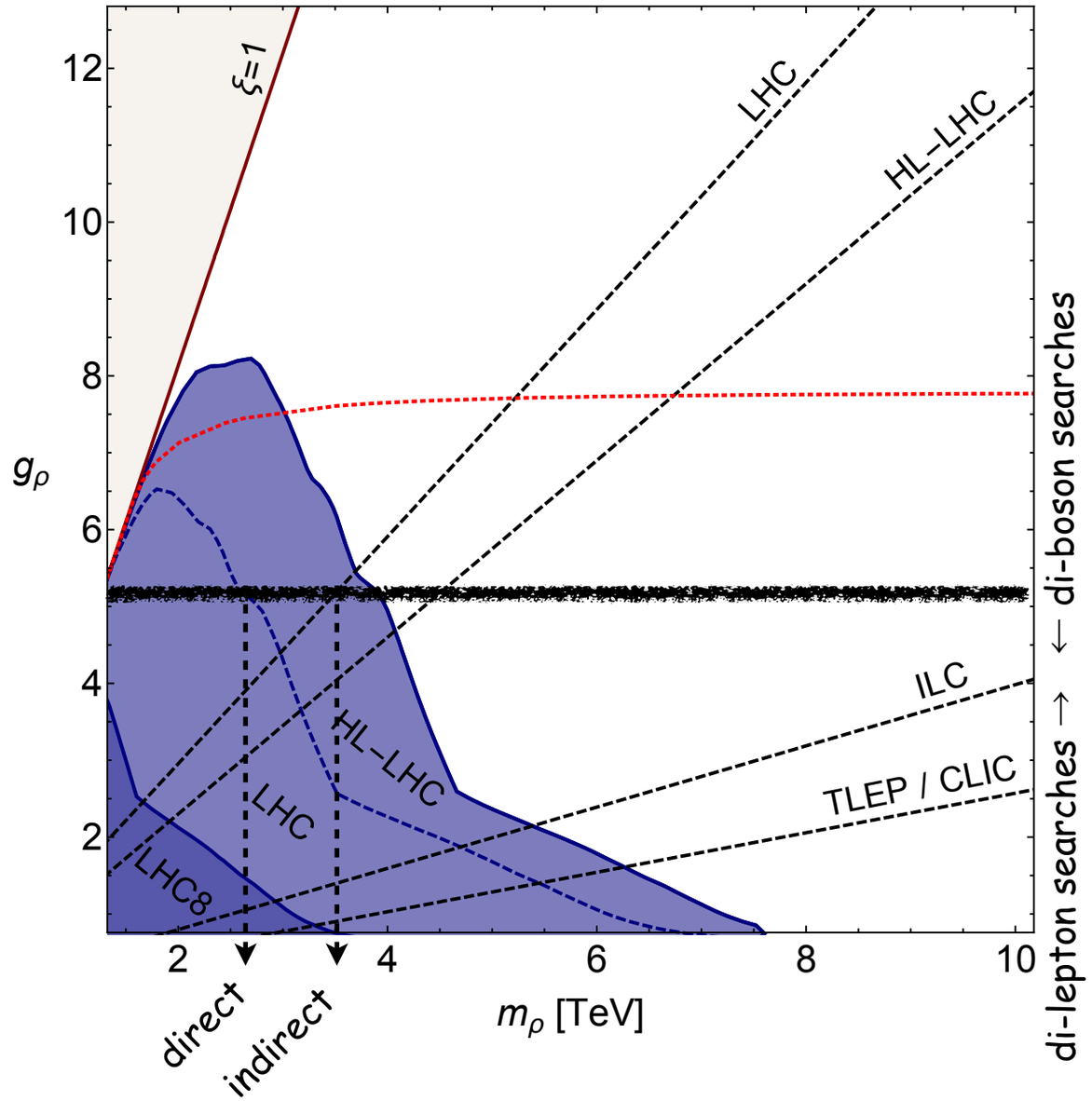
$$\Delta \frac{g_{hVV}}{g_{hVV}} = 0.4\%$$

# Higgs precision measurements

Torre, Thamm, Wulzer '15

| Collider | Energy | Luminosity | $\xi$ $[1\sigma]$ |
|---|---|---|---|
| LHC | 14 TeV | $300\,\text{fb}^{-1}$ | $6.6 - 11.4 \times 10^{-2}$ |
| LHC | 14 TeV | $3\,\text{ab}^{-1}$ | $4 - 10 \times 10^{-2}$ |
| ILC | 250 GeV | $250\,\text{fb}^{-1}$ | 4.8-7.8 $\times 10^{-3}$ |
| | + 500 GeV | $500\,\text{fb}^{-1}$ | |
| CLIC | 350 GeV | $500\,\text{fb}^{-1}$ | |
| | + 1.4 TeV | $1.5\,\text{ab}^{-1}$ | 2.2 $\times 10^{-3}$ |
| | + 3.0 TeV | $2\,\text{ab}^{-1}$ | |
| TLEP | 240 GeV | $10\,\text{ab}^{-1}$ | $2 \times 10^{-3}$ |
| | + 350 GeV | $2.6\,\text{ab}^{-1}$ | |

DY production xs of resonances decreases as $1/g_\rho^2$



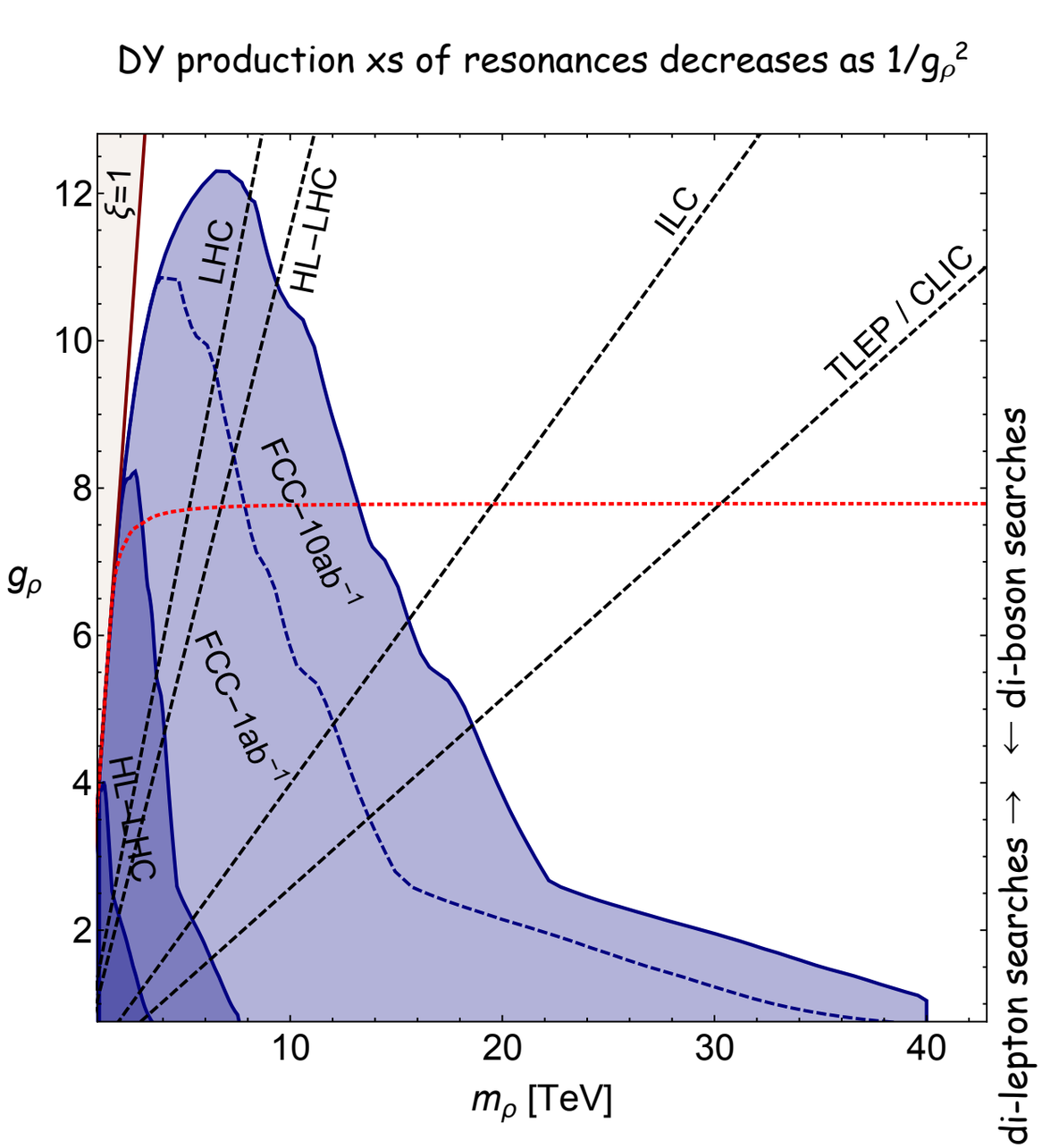

- **complementarity:**
  - direct searches win at small couplings
  - indirect searches probe new territory at large coupling

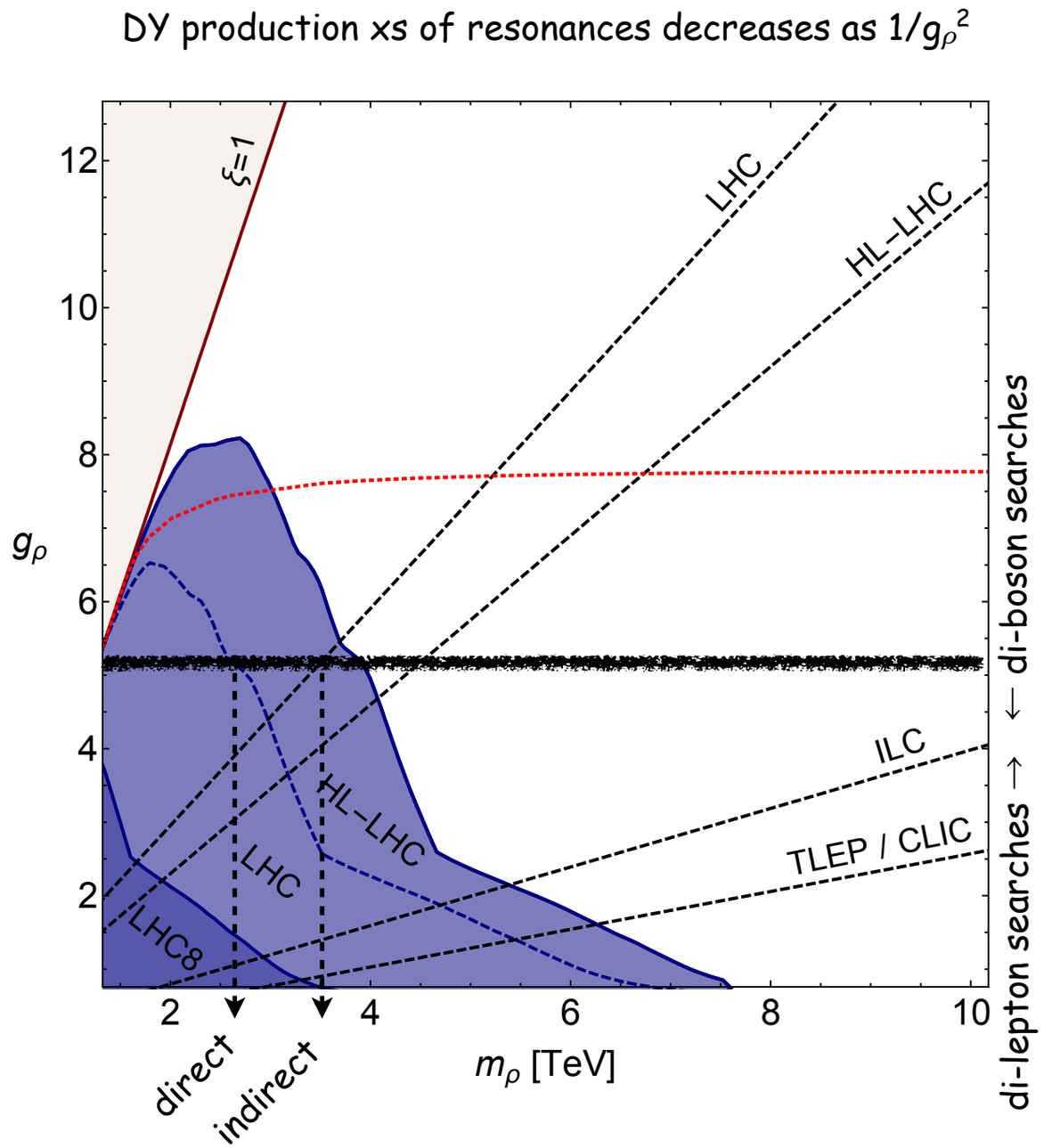
e.g.

indirect searches at LHC over-perform direct searches for $g > 4.5$

indirect searches at ILC over-perform direct searches at HL-LHC for $g > 2$

# Higgs precision measurements



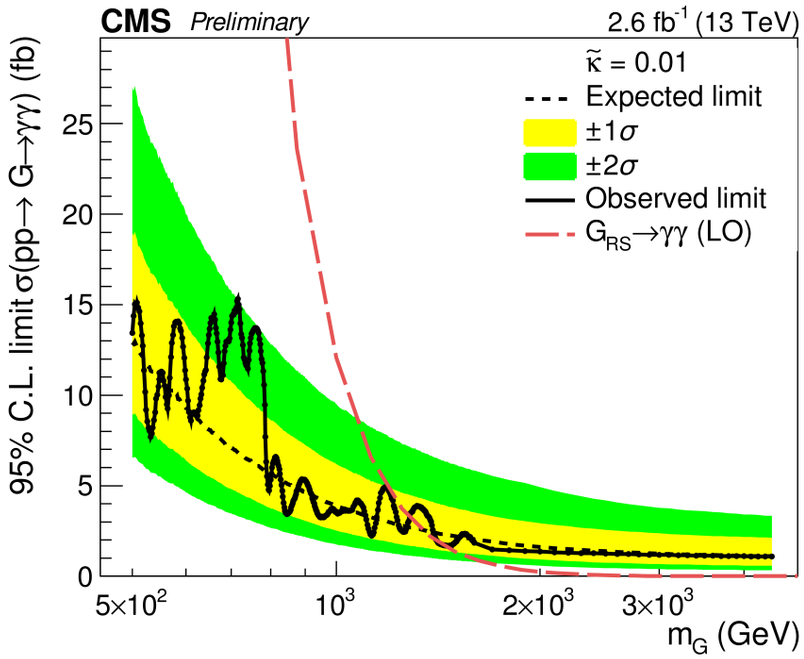



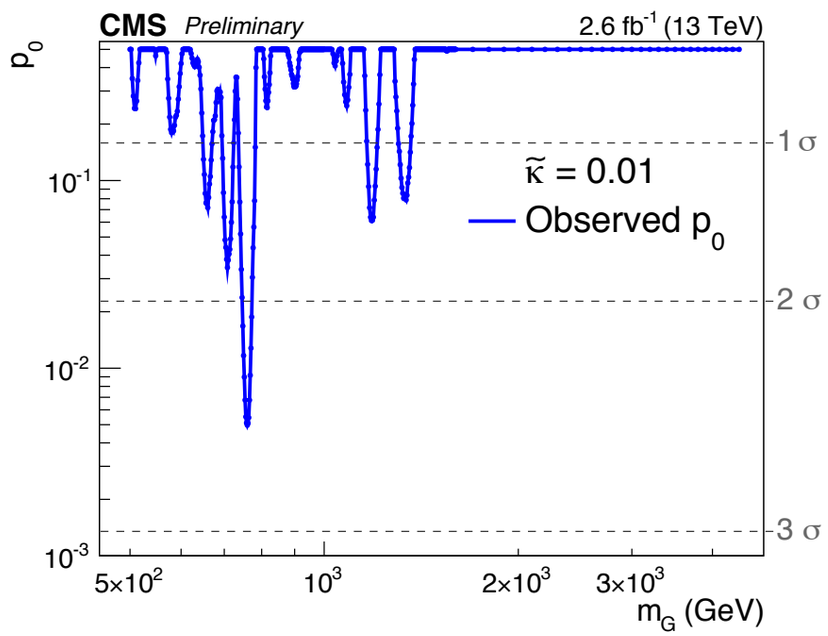

indirect searches at LHC over-perform direct searches for $g > 4.5$

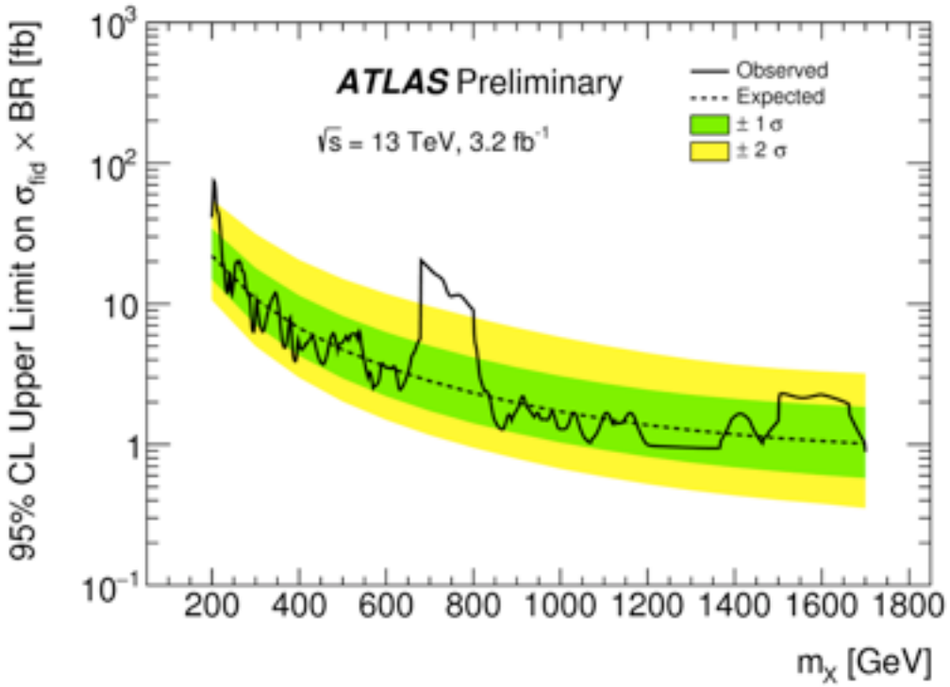
indirect searches at ILC over-perform direct searches at HL-LHC for $g > 2$

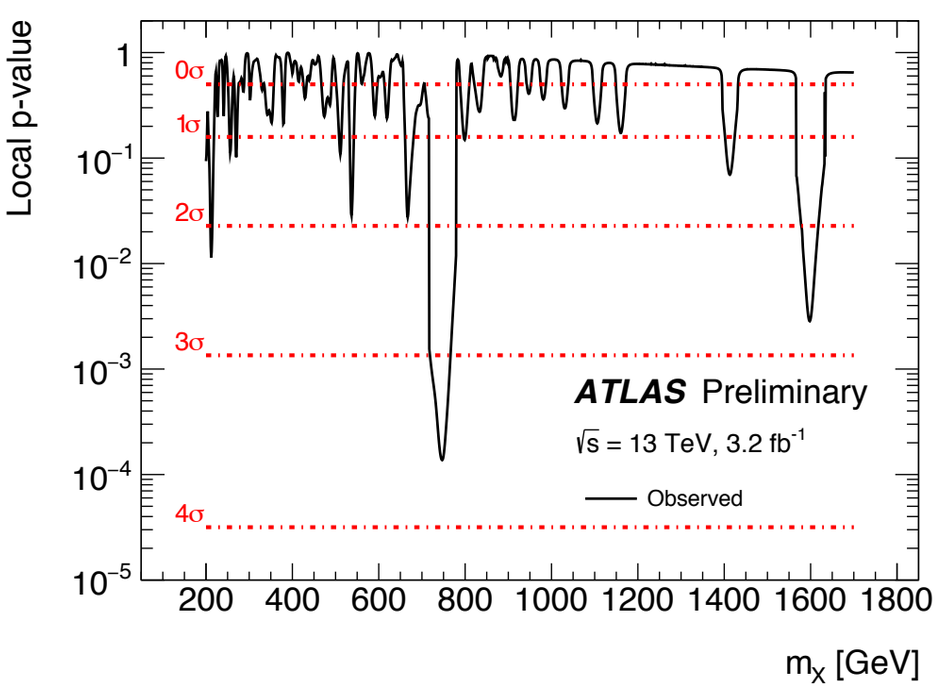
# X(750GeV) and ILC physics case

## a signal of a fluke?



# X(750GeV) and ILC physics case

**First thoughts:**

- 750 GeV resonance should be in the reach of ILC.

- even if it doesn't have couplings to e, it could be produced in the gamma-gamma option.
-> need to compute the xs?

- first analyses favor strong-coupled scenarios over weakly-coupled ones. It should make the case easier for a precision machine like ILC which is indirectly sensitive to higher energy in the case of strong coupling

- it seems also that the resonance cannot be alone and other states could be searched for and "measured" properly at the ILC.

LCC physics WG meeting Dec. 22 or 23 (tbd)