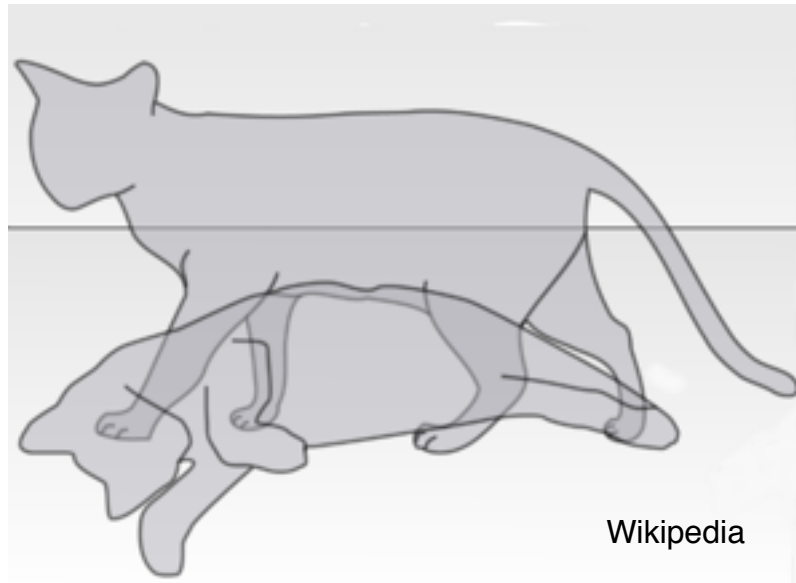


# **Report from Physics Coordinator**

Keisuke Fujii  
Aug. 10, 2016

# X750

*had been Schrödinger's cat state*



# Now the box is open

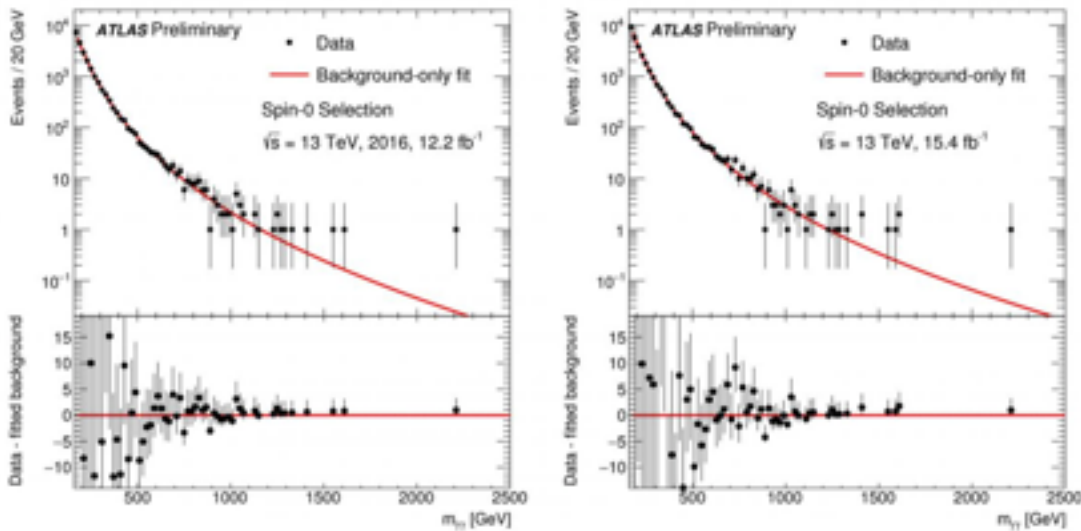


Figure 2: Invariant-mass distribution of the selected diphoton candidates, with the background-only fit overlaid, for 2016 data (left) and the combined 2015 and 2016 data (right). The difference between the data and this fit is shown in the bottom panel. (Image: ATLAS Experiment/CERN)

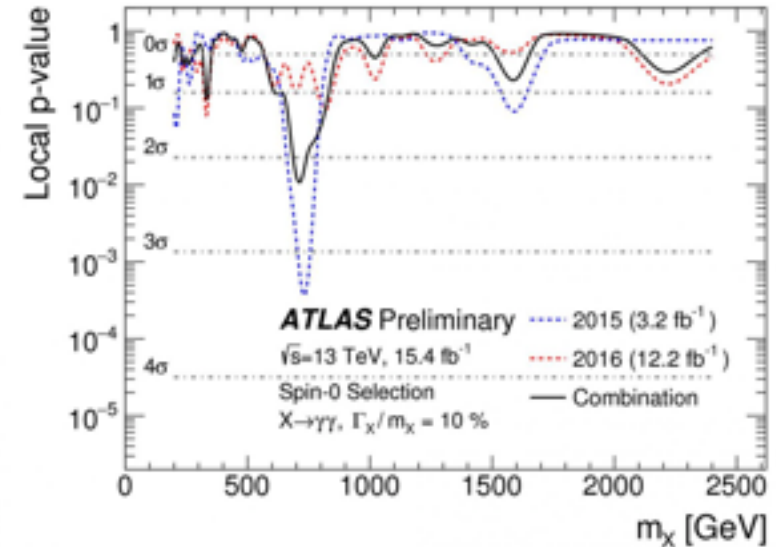
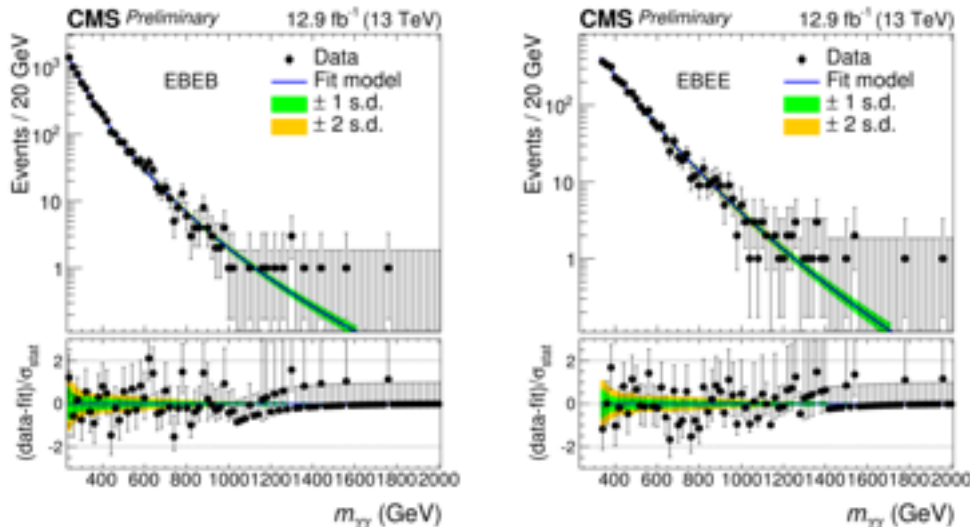


Figure 3: Probability that the background alone fluctuates up by the amount seen in data or more as a function of the mass for a certain width hypothesis of the new particle assumed in the search. (Image: ATLAS Experiment/CERN)



The [CMS di-photon spectrum](#) obtained with  $12.9 \text{ fb}^{-1}$  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  $m_{\gamma\gamma} \sim 750 \text{ GeV}$  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

KEISUKE FUJII<sup>1</sup>, CHRISTOPHE GROJEAN<sup>2,3</sup>, MICHAEL E. PESKIN<sup>4</sup>(CONVENERS);  
TIM BARKLOW<sup>4</sup>, YUANNING GAO<sup>5</sup>, SHINYA KANEMURA<sup>6</sup>, HYUNGDO KIM<sup>7</sup>,  
JENNY LIST<sup>2</sup>, MIHOKO NOJIRI<sup>1,8</sup>, MAXIM PERELSTEIN<sup>9</sup>, ROMAN PÖSCHL<sup>10</sup>,  
JÜRGEN REUTER<sup>2</sup>, FRANK SIMON<sup>11</sup>, TOMOHIKO TANABE<sup>12</sup>, JAEHOON YU<sup>13</sup>,  
JAMES D. WELLS<sup>14</sup>; ADAM FALKOWSKI<sup>15</sup>, SHIGEKI MATSUMOTO<sup>8</sup>,  
TAKEO MOROI<sup>16</sup>, FRANCOIS RICHARD<sup>10</sup>, JUNPING TIAN<sup>12</sup>, MARCEL VOS<sup>17</sup>,  
HIROSHI YOKOYA<sup>18</sup>; HITOSHI MURAYAMA<sup>8,19,20</sup>, HITOSHI YAMAMOTO<sup>21</sup>

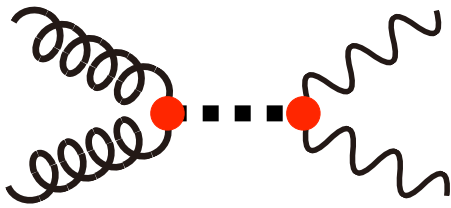
### ABSTRACT

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.

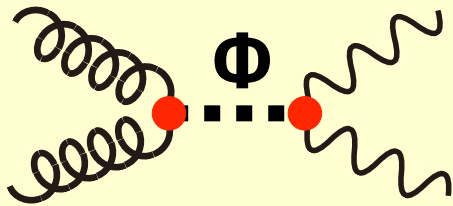
arXiv:1607.03829v2 [hep-ph] 31 Jul 2016

# Representative Models and Effects

## Effective Couplings



$\Phi = \text{RS radion}$

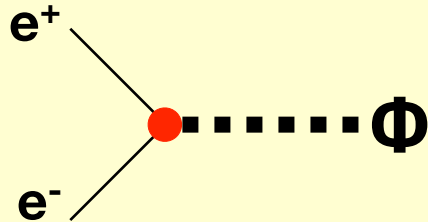


**KK-loop correction**  
 →  $hWW, hZZ$

~8% deviation expected for 5 TeV  
 KK gluon.

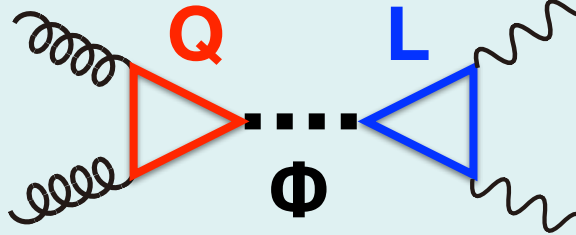
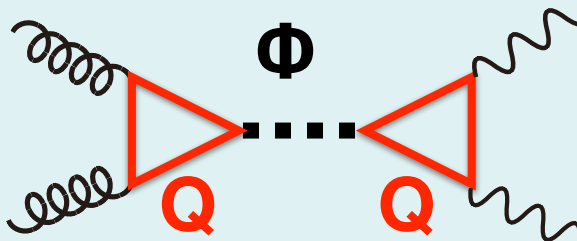
$\Phi = \text{RS graviton}$

**$J=2$**

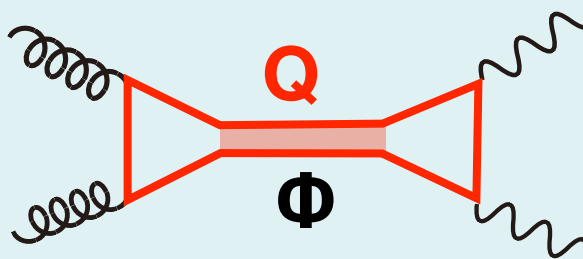


**direct coupling to  $e^+e^-$**   
 →  $s\text{-channel } \Phi \text{ production}$   
 still not completely excluded.

## Elementary Scalar

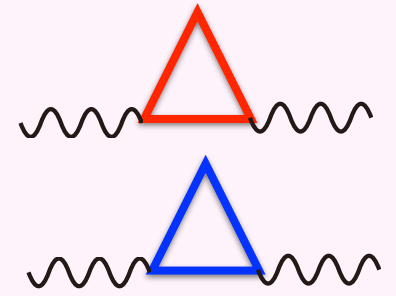


## Resonance/pNGB

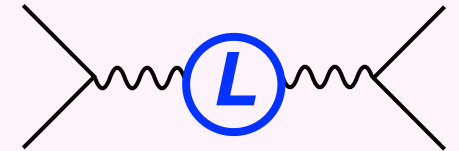


might be accompanied by  
 DM within ILC's reach

## Oblique Corrections



→ 2-to-2 processes



with  $\delta\sigma/\sigma = 0.1\%$ , ILC  
 sensitivity exceeds LHC

## Mixings

**Q-t mixing** →  $ttZ$

**L- $\tau$  mixing**

**$\Phi$ -h mixing**

→  $h\gamma\gamma, hgg$

→  $hWW, hZZ$

a few % deviation expected  
 → well within H20 target

	$hWW$ $hZZ$	$hb\bar{b}$ $h\tau\tau$	$h\gamma\gamma$ $hgg$	$ht\bar{t}$	$h \rightarrow$ invis.	$h\tau\mu$	$t\bar{t}Z$	$ee \rightarrow$ $ee, \mu\mu$	$ee \rightarrow$ $\gamma +$ 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  $\Phi$  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  $\Phi$***  or any other new particle that turns up in the early 13 TeV LHC data. ***Indeed it is.***



# ***Physics focus schedule***

Aug 10: BSM (today)

Aug 24: top/QCD

Sep 7: Higgs/EW

## Clarification:

Software talks (organised by Frank&Akiya) will come in addition, as well as the overall software and physics coordination updates in the beginning of each meeting.

## ***Subgroup meetings***

Aug. 31: first Higgs/EW group meeting