



# Higgs physics at the ILC



**Tomohiko Tanabe**

ICEPP, The University of Tokyo

August 16, 2013

*International Symposium on Higgs Physics*  
IHEP, Beijing



# Why ILC?



Precision Higgs  
measurement to uncover  
the EWSB sector



Many positive signs

Discovery potential  
complementary to the  
LHC / HL-LHC

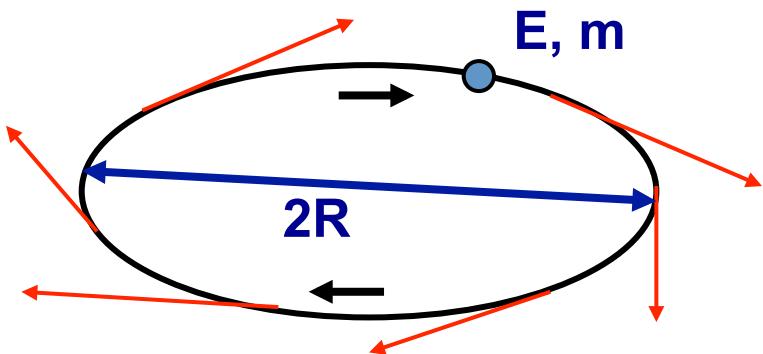


**Technical Maturity**  
ILC TDR published June 2013

# Why linear?



## Synchrotron radiation



e+e- ring colliders lose energy due to synchrotron radiation. The energy loss per turn is proportional to:

$$P \propto (E/m)^4/R$$

E: particle energy

m: particle mass

R: radius

## Recover the energy loss and obtain higher collision energy with

### 1. Heavier particle:

→ LHC ( $M_{\text{proton}}/M_{\text{electron}} = 1800$ )

→ Muon Collider ( $M_{\mu\text{on}}/M_{\text{electron}} = 200$ )

### 2. Larger radius:

→ Ring Collider (e.g.  $R=80\sim100\text{km}$ )

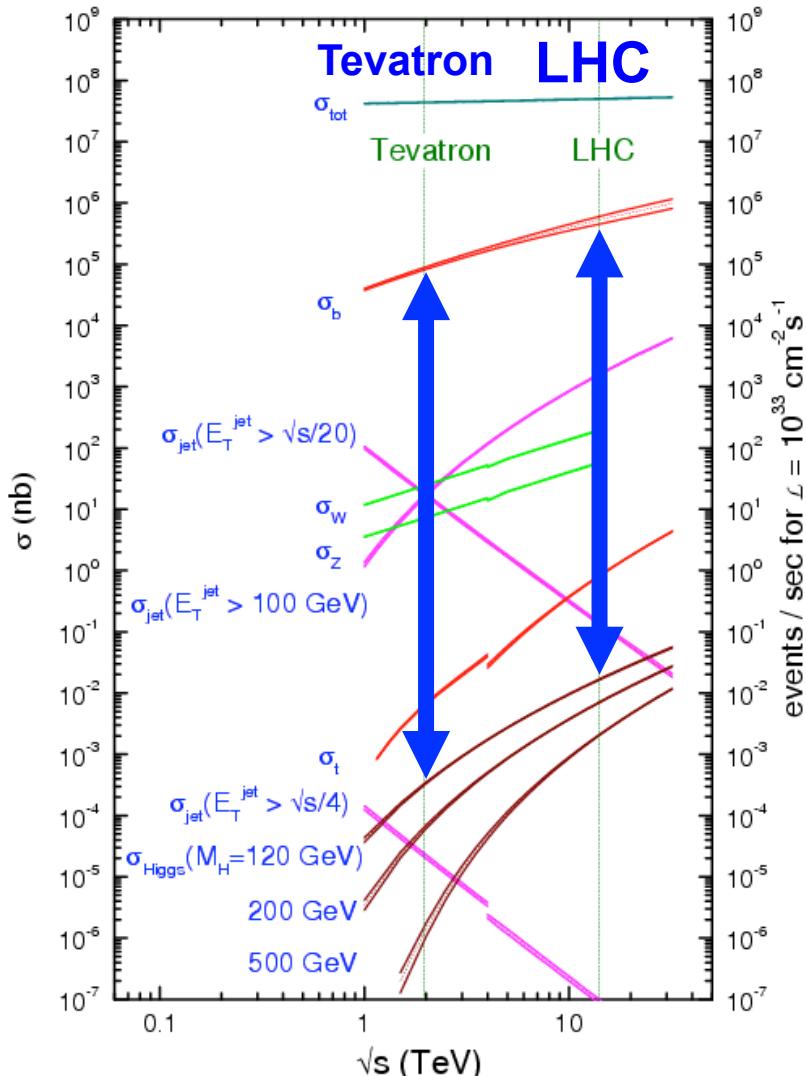
→ Linear Collider ( $R \rightarrow \infty$ )

**Only way to reach 1+ TeV in e+e- collisions**

# Cross Sections



proton - (anti)proton cross sections

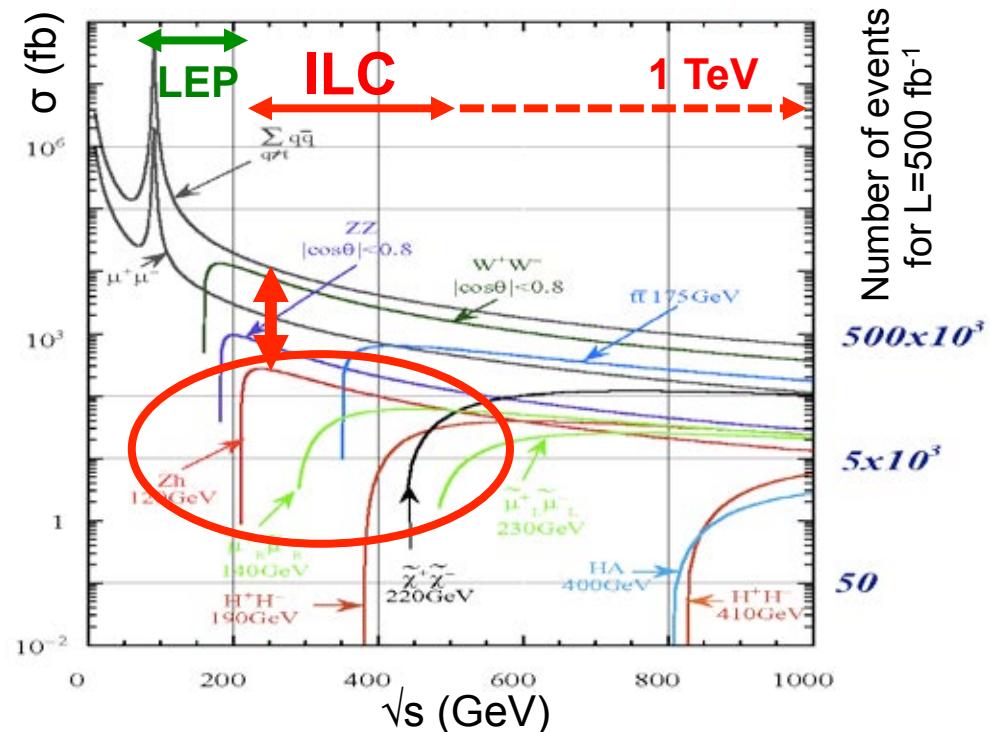


Typically,

$$N_{\text{sig}}^{pp} > N_{\text{sig}}^{e^+ e^-}$$

$$N_{\text{bkg}}^{pp} \gg N_{\text{bkg}}^{e^+ e^-}$$

$e^+ e^-$  cross sections



# Power of precision



1978 Precise measurement of  $\sin\theta_W$  @ SLAC  
via polarized electrons  $e^- D \rightarrow e^- X$

→ Prediction of W and Z mass



1983 Discovery of W and Z bosons at SppS



1989- Precise measurement of W and Z @  
SLC/LEP → Prediction of top mass



1995 Discovery of top quark at Tevatron



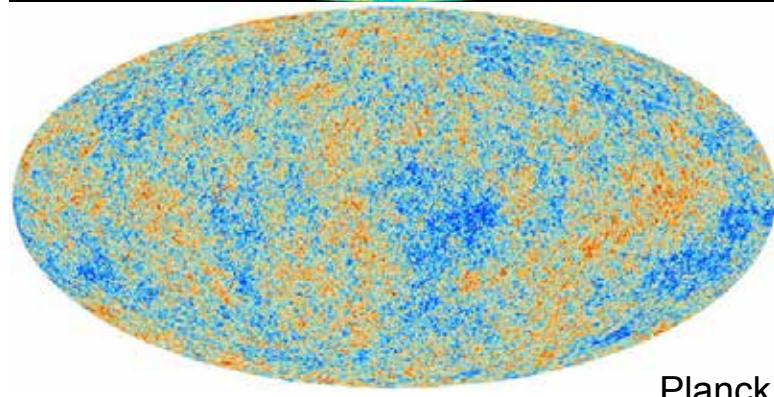
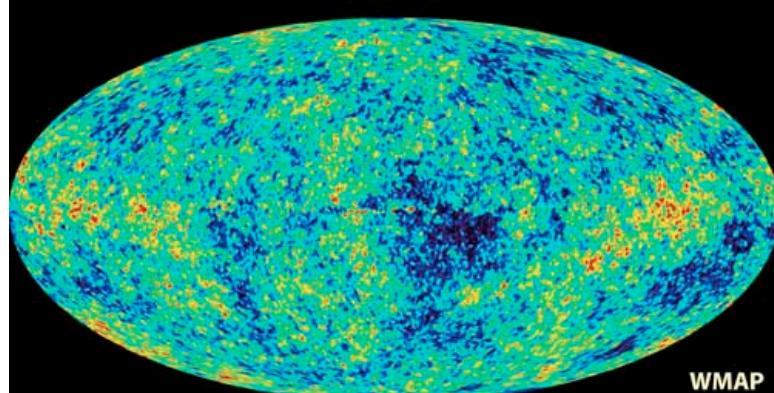
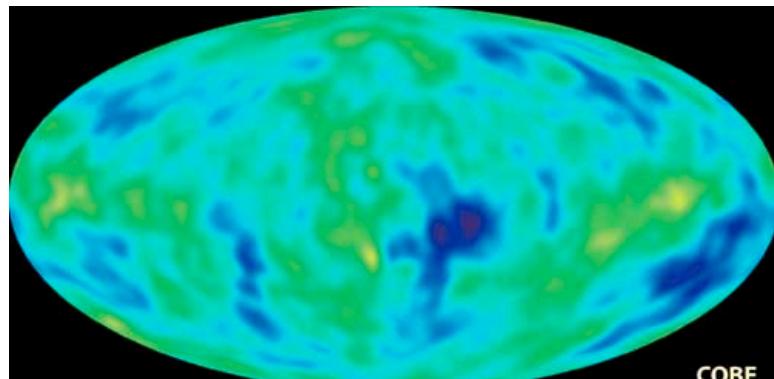
Precise measurement of W, Z, top @ SLC/  
LEP/Tevatron → Prediction of Higgs mass



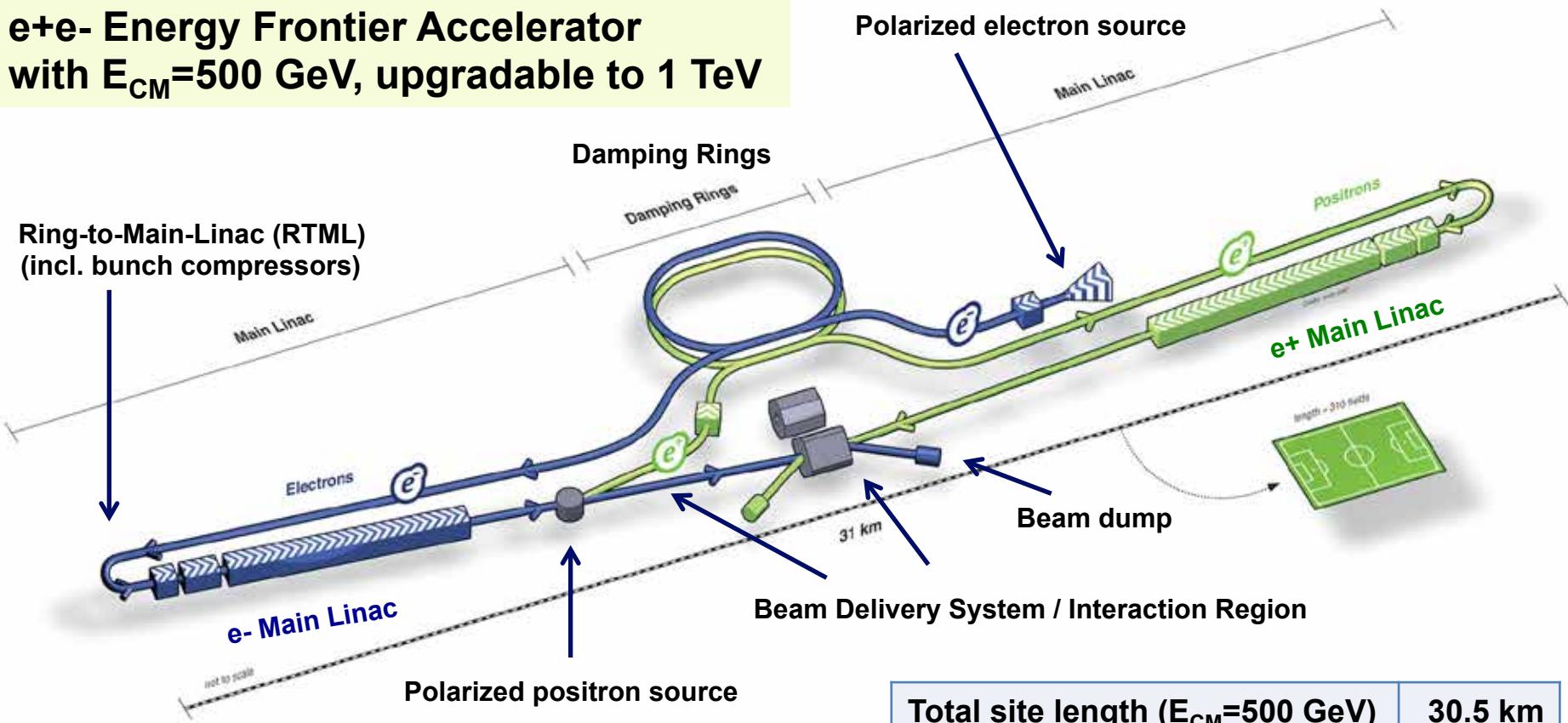
2012 Discovery of Higgs boson



Precise measurement of W, Z, top, Higgs @  
LHC/ILC → Prediction of ???



e+e- Energy Frontier Accelerator  
with  $E_{CM}=500$  GeV, upgradable to 1 TeV



# of DRFS Klystrons: 7280

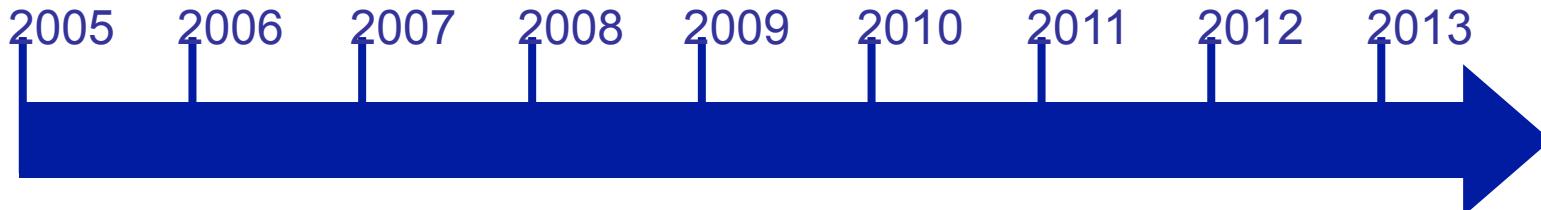
# of Cryomodules: 1680

# of SRF Cavities: 14560



Total site length ( $E_{CM}=500$ GeV)	30.5 km
SRF Main Linac	22.2 km
RTML (bunch compressors)	2.8 km
Positron source	1.1 km
BDS / IR	4.5 km
Damping Rings (circumference)	3.2 km

# Technology-Driven Timeline



LHC physics **Higgs**

Case and Research Strategy

1<sup>st</sup> Ecm range

or Design (Research Directorate process)

R&D  
**Ref. Design Letter of Intent**

R&D / Design

TDR

ator Design (Global Design Effort process)

baseline

**Ref. Design**

TDP-1

Re-baseline

TDP-2

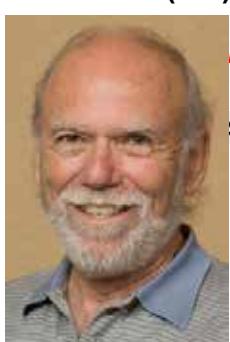
**Technical Design Phase (TDP) 1&2**



L. Evans (LCC)



S. Yamada (RD)



B. Barish (GDE)



# Linear Collider Collaboration



PAC = Project Advisory Committee

ICFA

ICFA = International Committee for Future Accelerators

**PAC**

Chair: Norbert Holtkamp

**Linear Collider Board**

Chair: Sachio Komamiya

## Linear Collider Collaboration

**Regional Directors**

Harry Weerts, Brian Foster

**Director**

Lyn Evans



**Deputy Director**

Hitoshi Murayama



**ILC Accelerator**

Mike Harrison

**CLIC Accelerator**

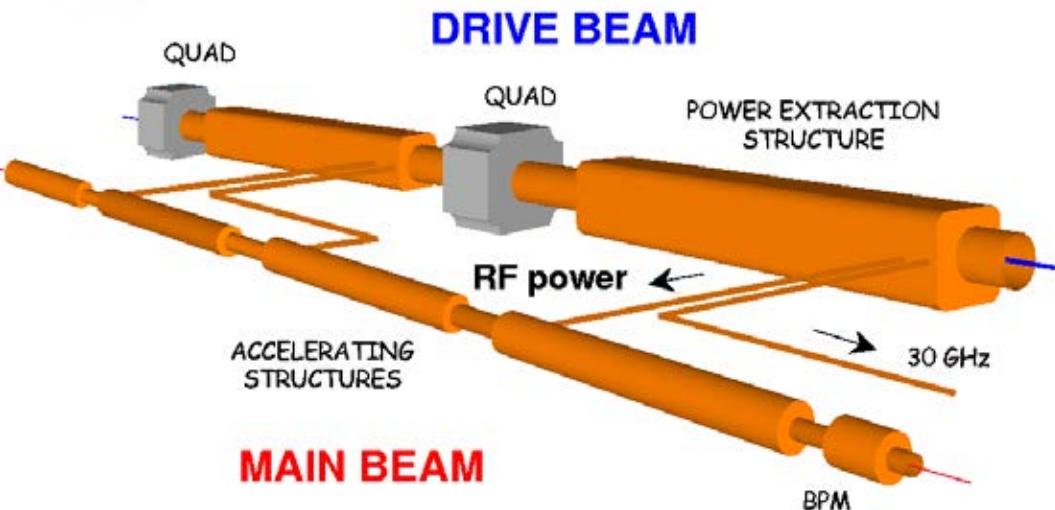
Steinar Stapnes

**Physics & Detectors**

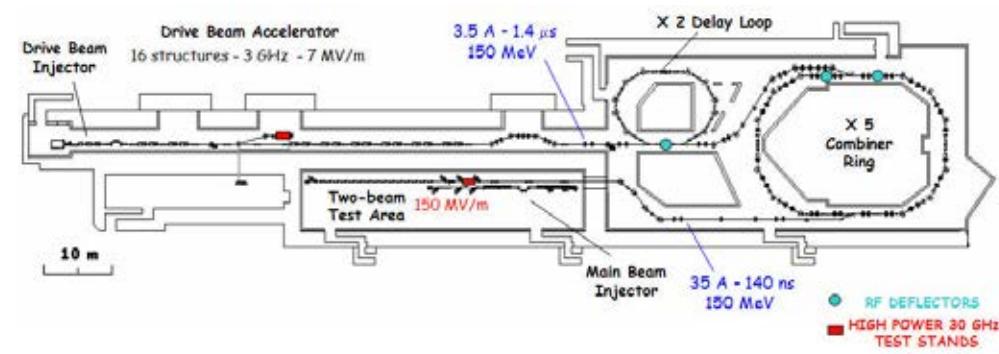
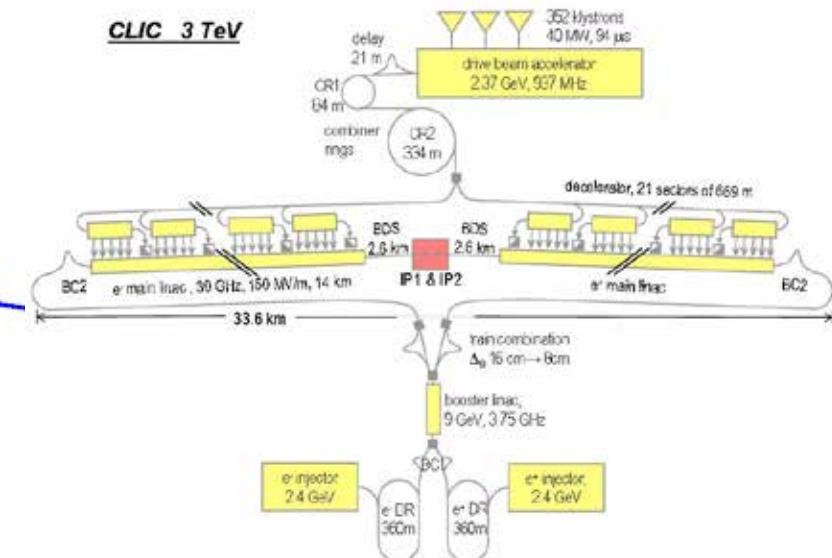
Hitoshi Yamamoto



# CLIC: Compact Linear Collider



CLIC 3 TeV



CDR published in 2012

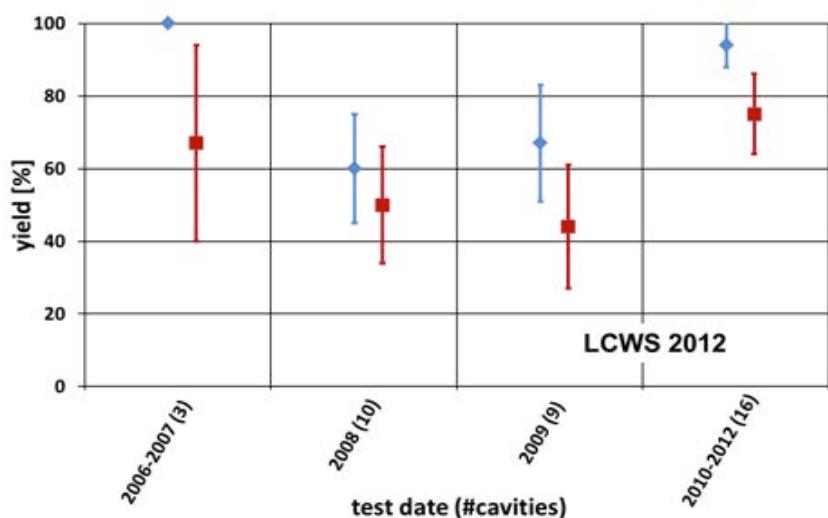
→ Most mature technology for multi-TeV lepton collider

# Acceleration: Superconducting RF Cavities



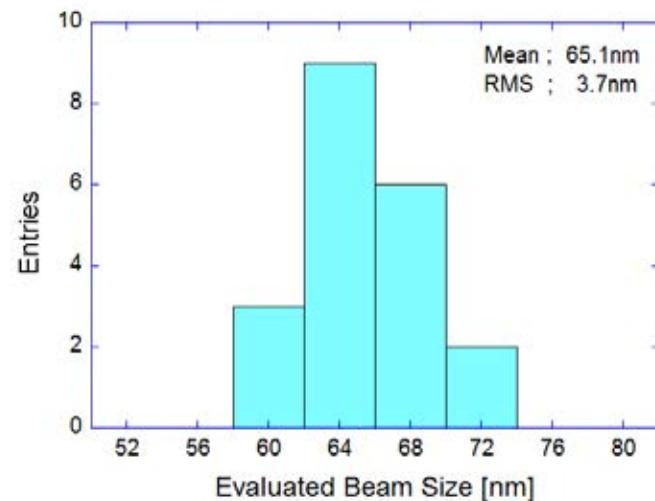
2nd pass yield - established vendors, standard process

◆ >28 MV/m yield   ■ >35 MV/m yield



Production yield: **94%** at >28 MV/m  
Average gradient: **37.1 MV/m**

# Flat beams: Emittance ATF@KEK



Achieved <70 nm @ 1.3 GeV  
Need 37 nm



IHEP-01 Cavity



IHEP cryomodule

IHEP input coupler: reached  
ILC spec, 1MW, 1.5ms, 5Hz

Proceedings of IPAC2013, Shanghai, China

WEPWO018

### STATUS OF THE IHEP 1.3 GHz SUPERCONDUCTING RF PROGRAM FOR THE ILC\*

J. Gao<sup>#</sup>, Y.L. Chi, J.P. Dai, R. Ge, T.M. Huang, S. Jin, C.H. Li, S.P. Li, Z.Q. Li, H.Y. Lin, Y.L. Liu, Z.C. Liu, Q. Ma, Z.H. Mi, W.M. Pan, Y. Sun, J.Y. Zhai, T.X. Zhao, H.J. Zheng  
IHEP, Beijing 100049, China

#### *Abstract*

The 1.3 GHz superconducting radio-frequency (SRF) technology is one of the key technologies for the ILC. IHEP is building an SRF Accelerating Unit, named the IHEP ILC Test Cryomodule (IHEP ILC-TC1), for the ILC SRF system integration study, high power horizontal test and possible beam test in the future. In this paper, we report the components test results and the assembly

The cavity quenches at 20 MV/m with  $Q_0 = 1.4 \times 10^{10}$  at 2 K (Fig. 2), 298 degree in cell#9, 2 mm from the equator (Fig. 3). The quench location has sharp and deep grain boundary step made during half cell pressing (Fig. 3). We didn't make intensive manual grinding. By passband mode test, all the other cells reach around 40 MV/m except cell#1 symmetrically limited by cell#9.

The cavity frequency under vacuum after vertical test is





## Benefit from European XFEL:

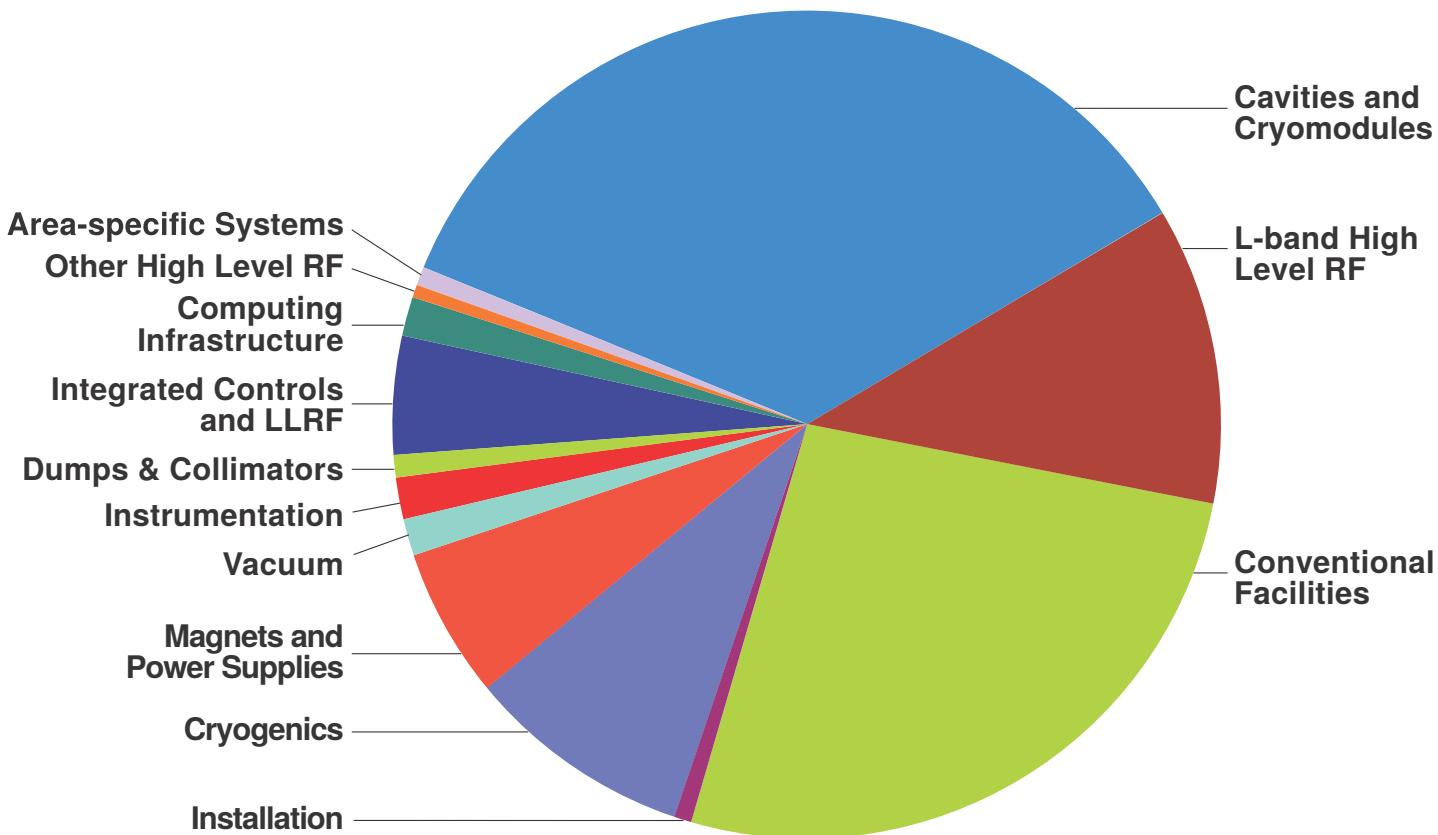
800 SRF cavities @ 23.6 MV/m

(16,000 SRF cavities @ 31.5 MV/m for ILC)



M. Altarelli, ASEPS13

# ILC Cost Estimate



ILC TDR Cost Estimate: **7.8 billion ILC Units (= 2012 USD)**

Cost estimate for 500 GeV machine, averaged over three regions

**International cooperation needed to provide:**  
personnel, in-kind contributions, funds

**Breakdown of estimated AC power for a 500 GeV baseline machine:**  
 (Source: ILC TDR, Volume 3, Part II)

Accelerator section	RF Power	RF Racks	NC magnets & Power supplies	Cryo	Conventional		Total
					Normal load	Emergency load	
e <sup>-</sup> source	1.28	0.09	0.73	0.80	1.02	0.16	4.08
e <sup>+</sup> source	1.39	0.09	4.94	0.59	2.19	0.35	9.56
Damping Ring	8.67		2.97	1.45	1.84	0.14	15.08
RTML	4.76	0.32	1.26	part of ML cryo	0.12	0.14	6.59
Main Linac	58.1	4.9	0.914		32	5.18	109.16
BDS			10.43	0.41	0.24	0.28	11.36
Dumps					1		1.00
IR			1.16	2.65	0.09	0.17	4.07
Total	74.2	5.4	22.4	37.9	14.6	6.4	161

Unit in MW



The luminosity can be enhanced by

- Increasing the number of bunches
- Increasing the collision rate

This can be achieved with a small footprint in both the construction cost and running cost.

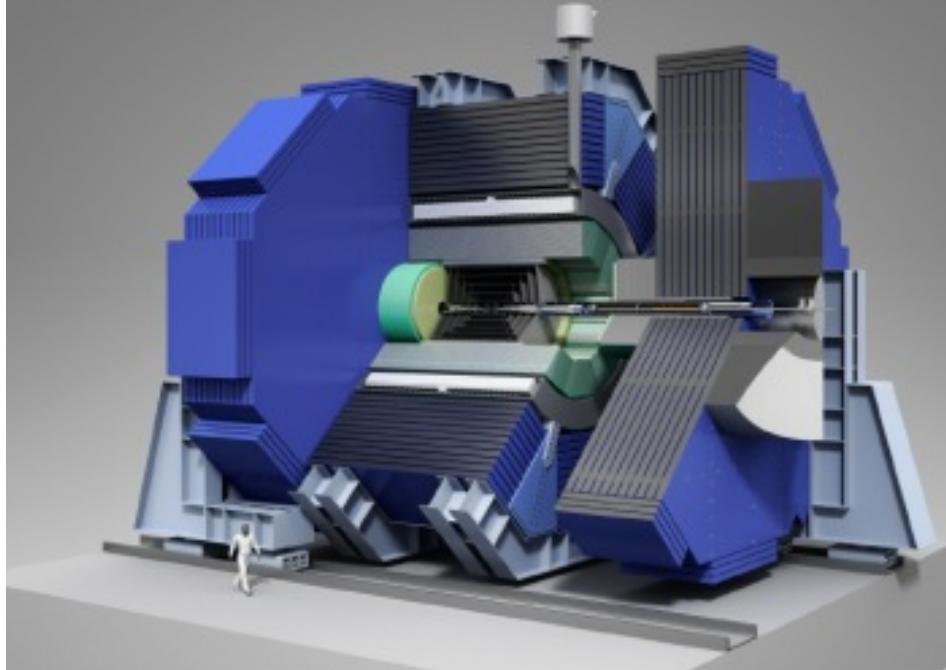
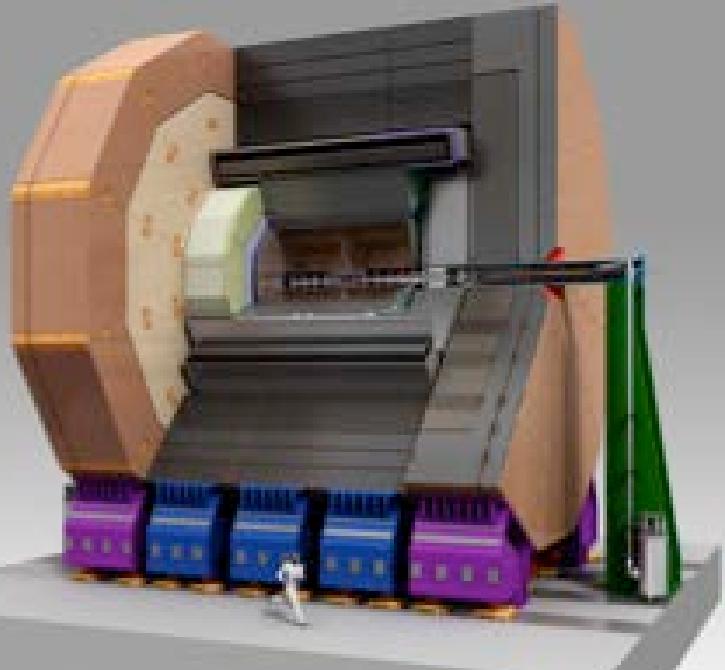
*“Full technical designs where performance has been explicitly sacrificed in order to achieve something that can be built, and to fit within a specific budget profile”* (M. Palmer, CSS2013)

= Documented in ILC TDR

CM Energy	GeV	Baseline			Luminosity Upgrade		
		250	500	1000	250	250	500
Luminosity	$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	0.75	1.8	4.9	1.5	3.0	3.6
Collision rate	Hz	5	5	4	5	10	5
Number of bunches	Hz	1312	1312	2450	2625	2625	2625
Avg. total beam power	MW	5.9	10.5	27.2	11.8	21.0	21.0
AC power	MW	122	163	300	161	204	204
Relative cost		69%	100%	166%	74%	106%	106%

Nickname	Ecm(1) (GeV)	Lumi(1) ( $\text{fb}^{-1}$ )	+	Ecm(2) (GeV)	Lumi(2) ( $\text{fb}^{-1}$ )	+	Ecm(3) (GeV)	Lumi(3) ( $\text{fb}^{-1}$ )	Runtime (yr)	Wallplug E (MW-yr)
ILC(250)	250	250							1.1	130
ILC(500)	250	250		500	500				2.0	270
ILC(1000)	250	250		500	500		1000	1000	2.9	540
ILC(LumUp)	250	1150		500	1600		1000	2500	5.8	1220

# ILC Detector Concepts



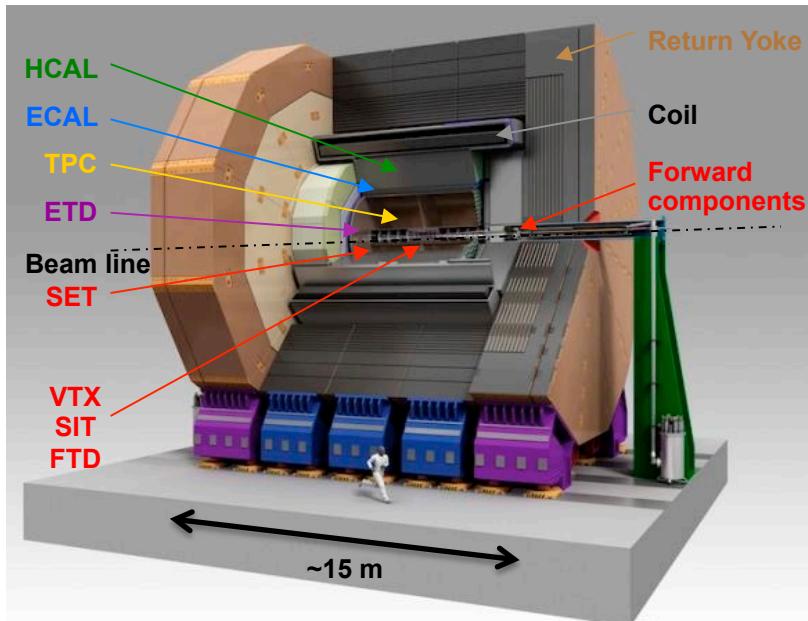
	ILD (International Large Detector)	SiD (Silicon Detector)
Height x Length	16 m x 14 m	14 m x 11 m
Weight	14,000 t	10,100 t
Magnetic field	3.5 T	5 T
ECAL inner radius	1.8 m	1.3 m
Tracker	TPC	Silicon strip

**Both optimized for particle flow performance  $\sim BR^2$**



- **Vertex Detector:** low mass pixel sensors
- **Time Projection Chamber:** high resolution & low mass
- **Calorimeters:** high granularity sensors,  $5 \times 5 \text{ mm}^2$  (ECAL),  $3 \times 3 \text{ cm}^2$  (HCAL); absorbers for compact showers
- **Solenoid:** outside ECAL + HCAL

Sensor Size	ILC	ATLAS	Ratio
Vertex	$5 \times 5 \text{ mm}^2$	$400 \times 50 \text{ mm}^2$	x800
Tracker	$1 \times 6 \text{ mm}^2$	$13 \text{ mm}^2$	x2.2
ECAL	$5 \times 5 \text{ mm}^2$ (Si)	$39 \times 39 \text{ mm}^2$	x61

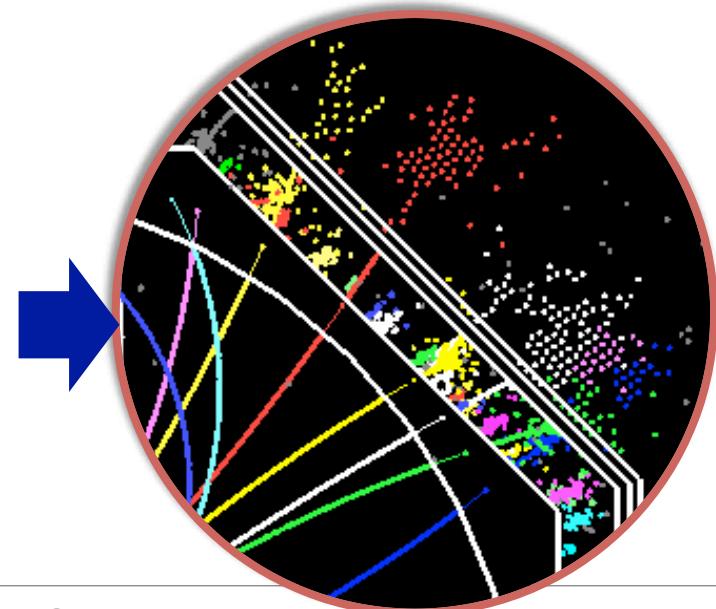


## Optimized for Particle Flow Algorithm

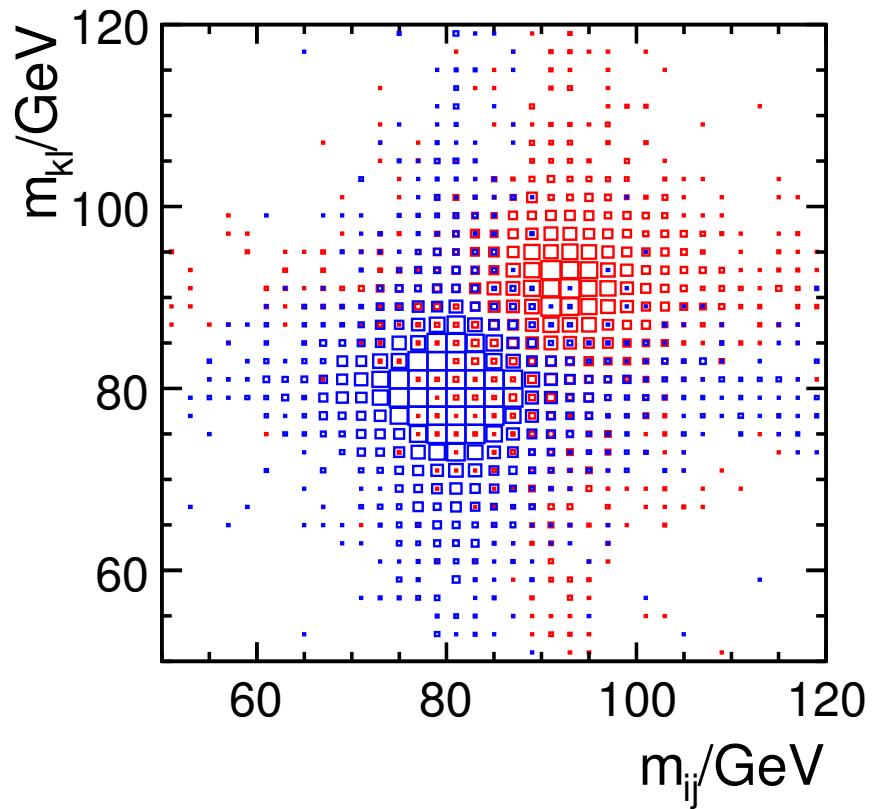
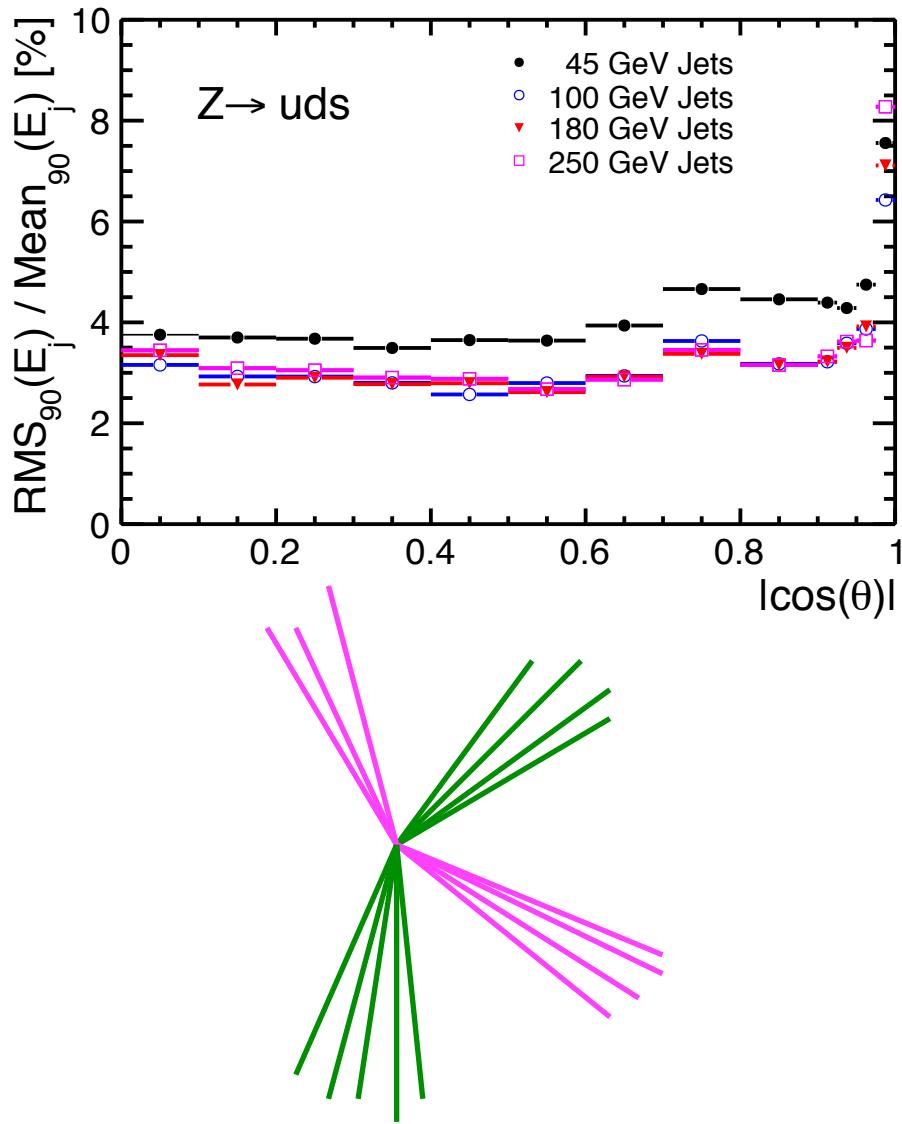
Identify calorimeter hits for each particle

- use *best* energy measurement for *each* particle
- offers unprecedented **jet energy resolution**

Charged Tracks	→ Tracker
Photons	→ ECAL
Neutral Hadrons	→ HCAL



# Jet Energy Resolution

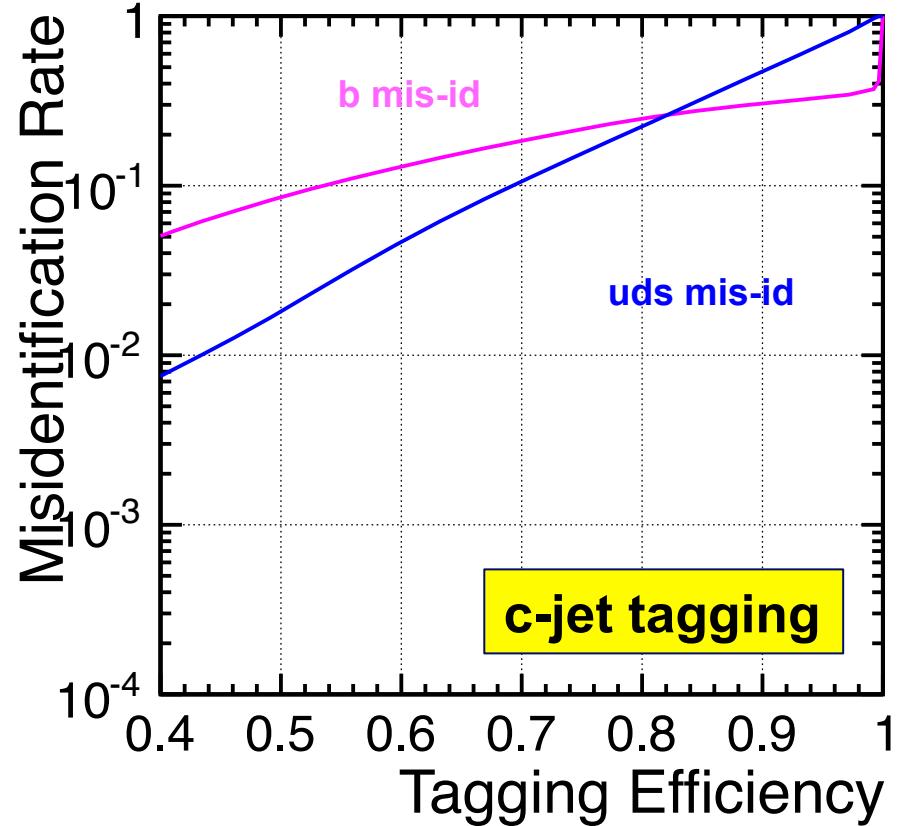
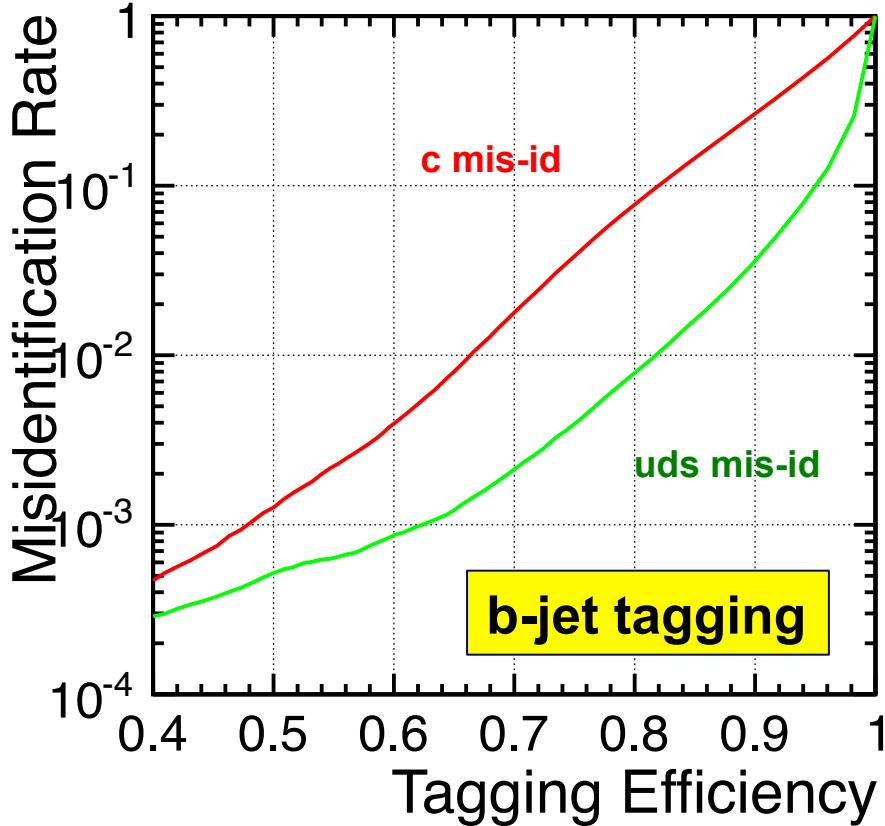


3-4% jet energy resolution  
→ Good W/Z separation

# Flavor tagging at ILC



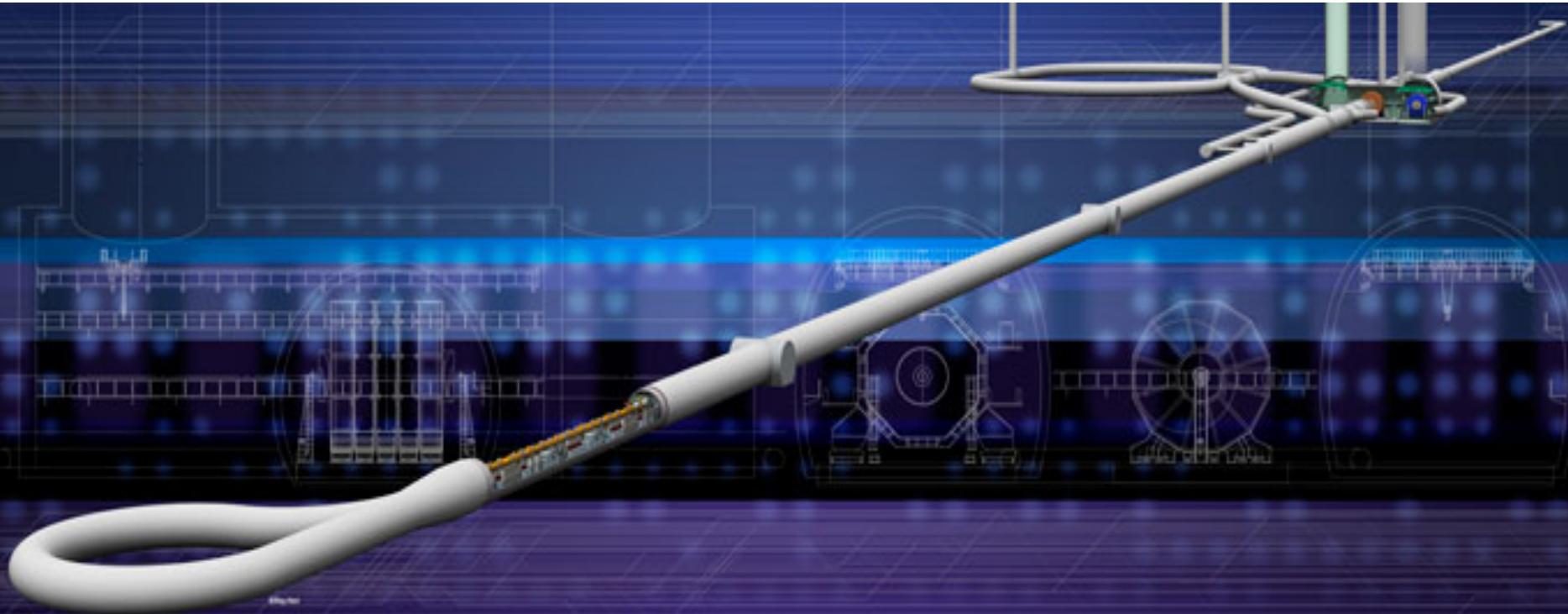
$Z \rightarrow qq$ ,  $E_{CM} = 91.2$  GeV, ILD Full Simulation [LCFIPlus: T. Suehara, TT]



b eff	c mis-id	uds mis-id
80%	8%	0.8%
50%	0.1%	0.05%

c eff	b mis-id	uds mis-id
80%	20%	20%
50%	0.8%	0.2%

# Physics at the ILC

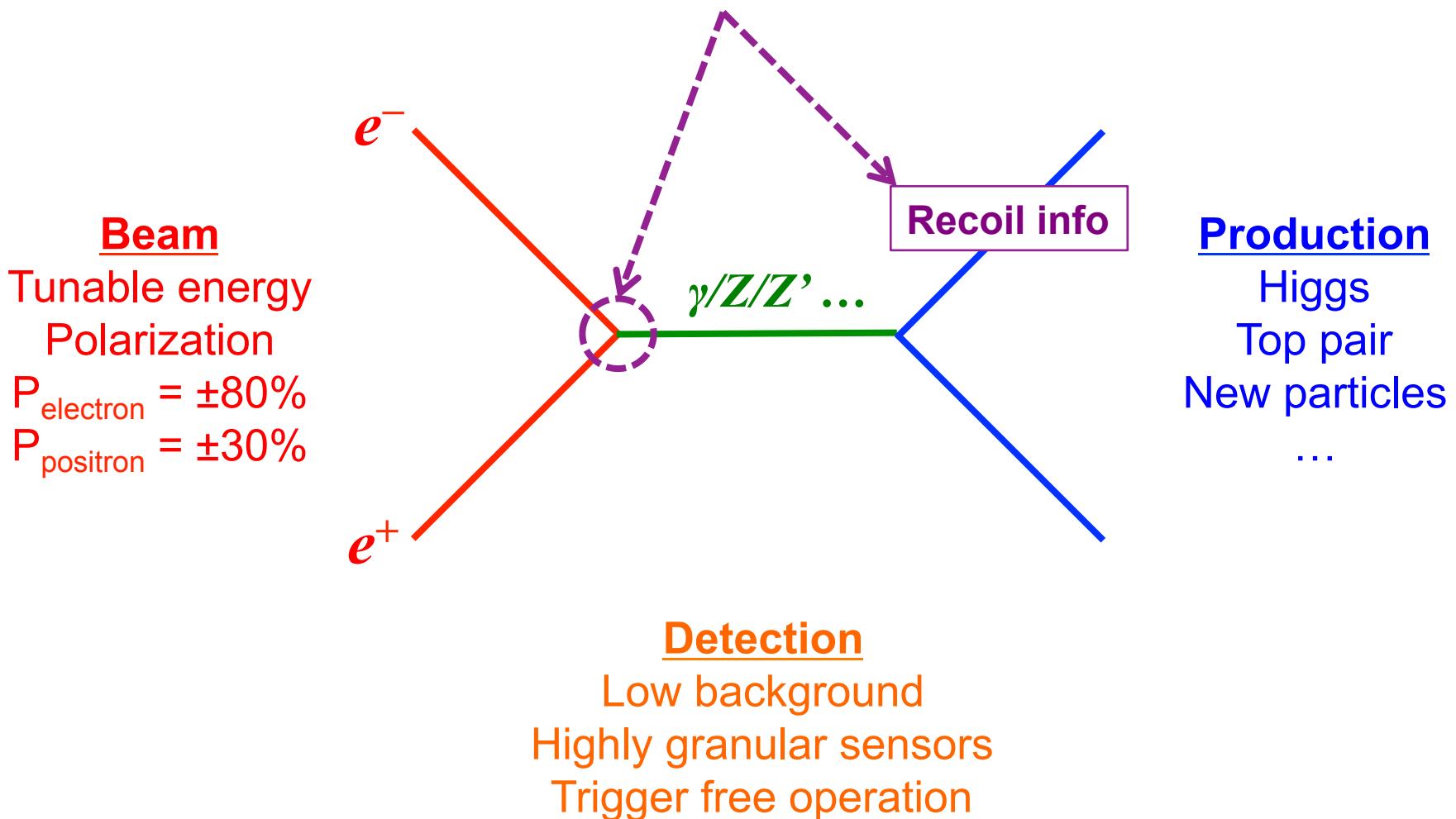


# Characteristics of ILC



## Elementary process

Well-understood theoretically and experimentally (SLC/LEP)

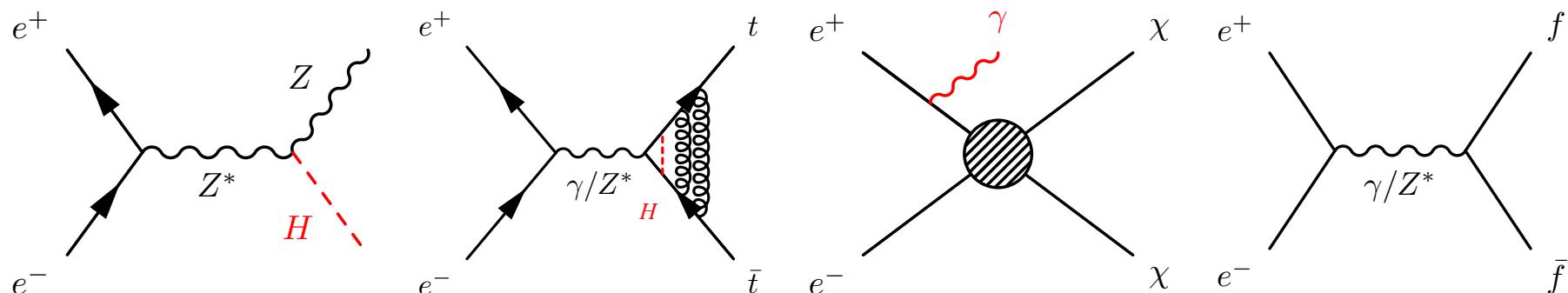
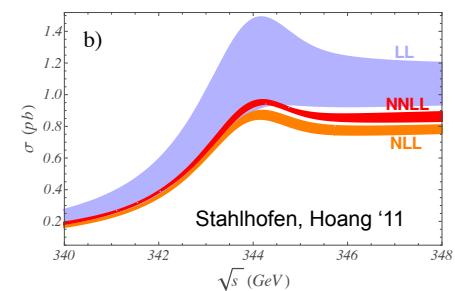
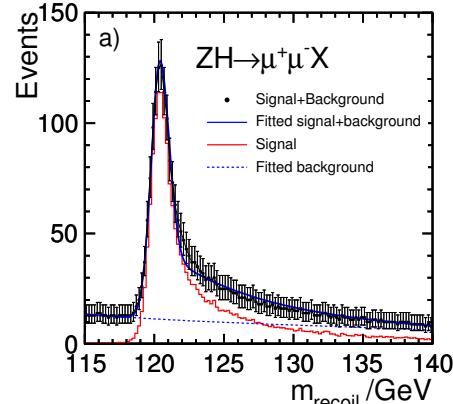


# Physics at the ILC



Main goals of the ILC physics program:

- Precise measurements of:
  - Properties of the **Higgs sector**
  - Interactions of **top, gauge bosons, and new particles**
- Searches for new physics
  - Discovery reach for **color-neutral states** (e.g. dark matter) can significantly exceed LHC
  - Sensitivity to new physics through **tree-level** and **quantum effects**



SUSY is a special case. There is a potentially large positive contribution to the Higgs mass term that must be cancelled.

$$m_Z^2 = 2 \frac{M_{Hd}^2 - \tan^2 \beta M_{Hu}^2}{\tan^2 \beta - 1} - 2\mu^2$$

No large cancellations:

$\mu \lesssim 200$  GeV                      Higgsino mass

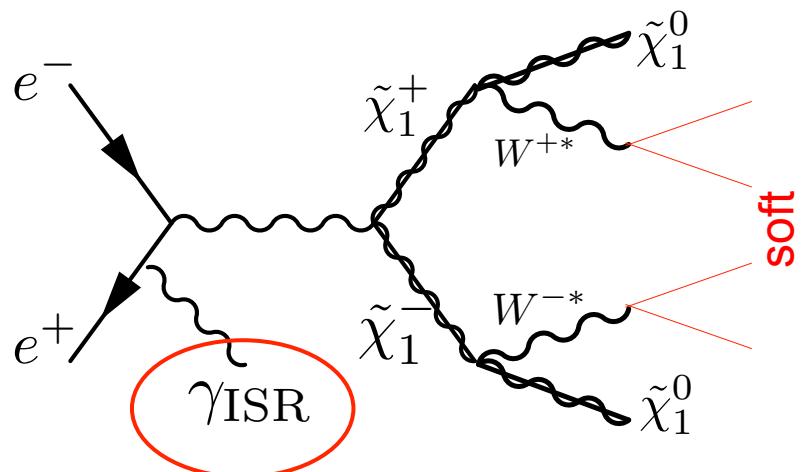
$m(\tilde{t}) \lesssim 1$  TeV                      stop mass

$m(\tilde{g}) \lesssim 3$  TeV                      gluino mass

Optimistically, we will get there at HL-LHC.

M. Peskin, CSS2013

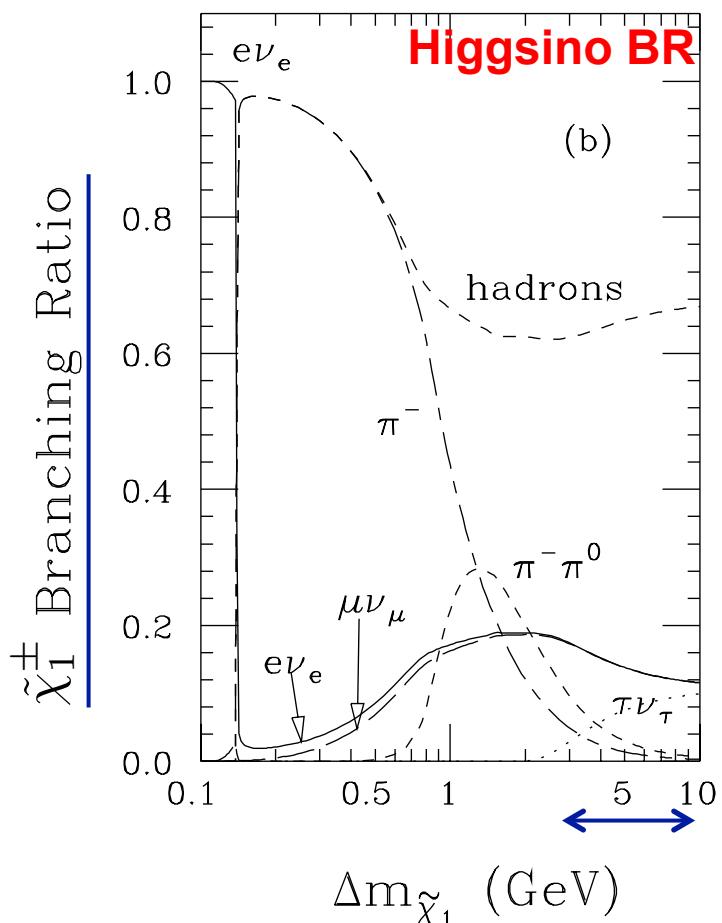
→ If this is the case, ILC will be a Higgsino factory!



The **ISR tag** is critical in reducing  $\gamma\gamma$  backgrounds by kicking the **hard forward electrons** into detector acceptance.

### For the soft particles:

Choose characteristic signature, e.g.  
lepton on one side + pions on the other side.



Chen, Drees, Gunion  
[arXiv:hep-ph/9902309]

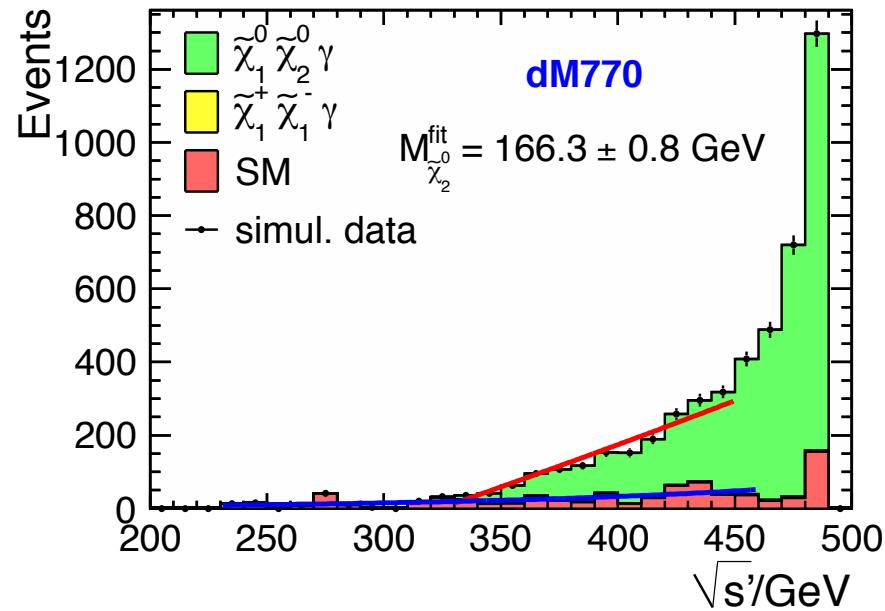
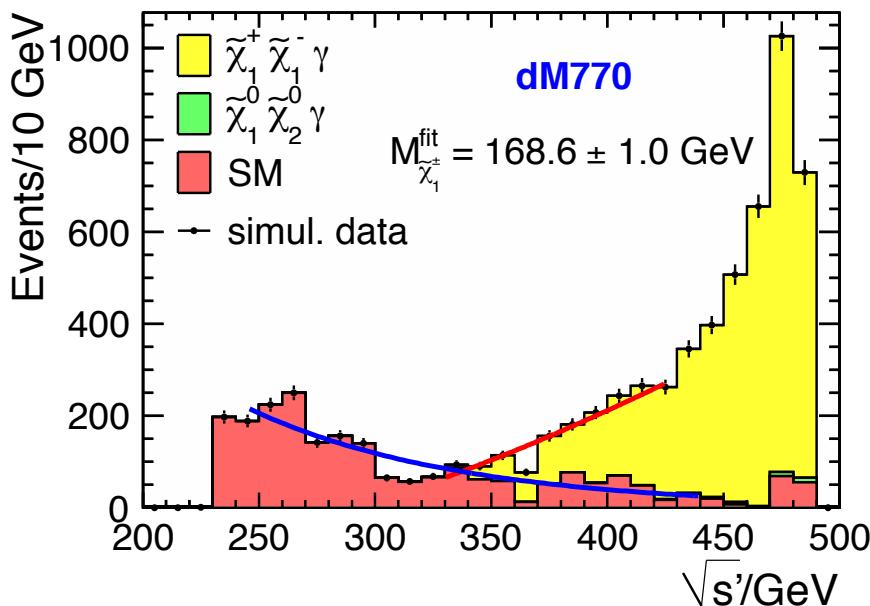
# Higgsino pair production



Naturalness argument calls for light Higgsinos e.g. in the case of MSSM:

$$m_{Z'}^2 = -2 \left( m_{H_u}^2 + |\mu|^2 \right) + \mathcal{O}(\cot^2 \beta)$$

**Higgsinos → small mass gaps**



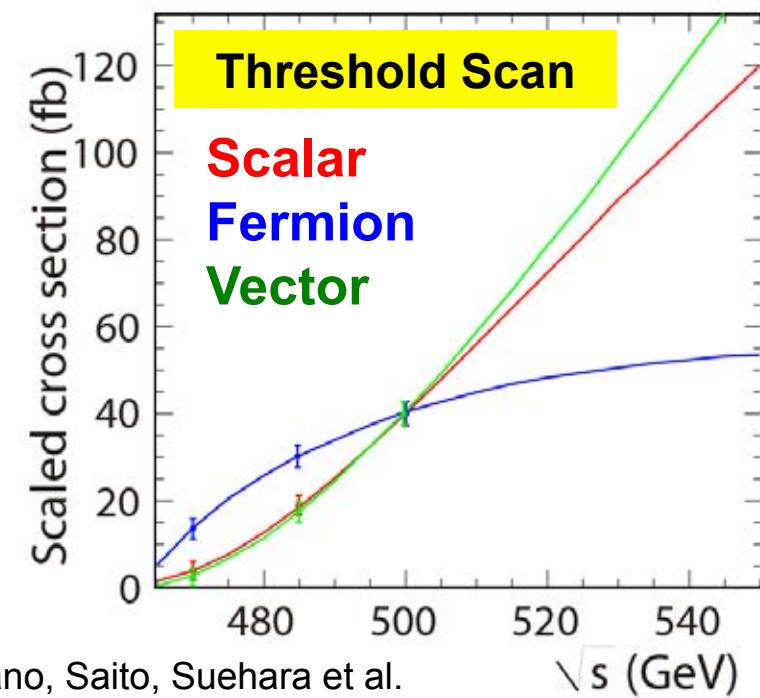
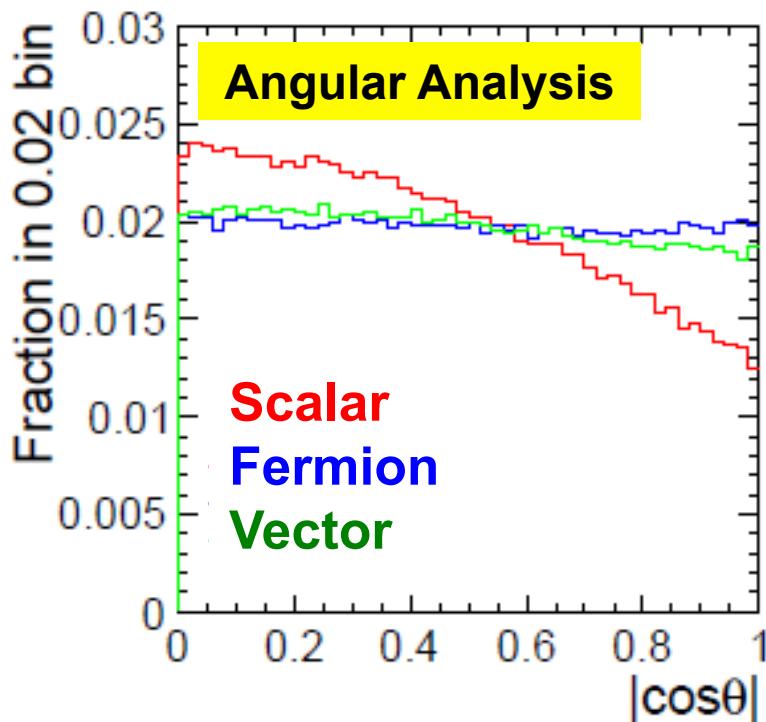
Berggren, Bruemmer, List, Moortgat-Pick,  
Robens, Rolbiecki, Sert [arXiv:1307.3566]

Even for sub-GeV mass differences, the charginos/neutralinos can be discovered / measured to  $O(1)\%$  in mass.

# Model Discrimination

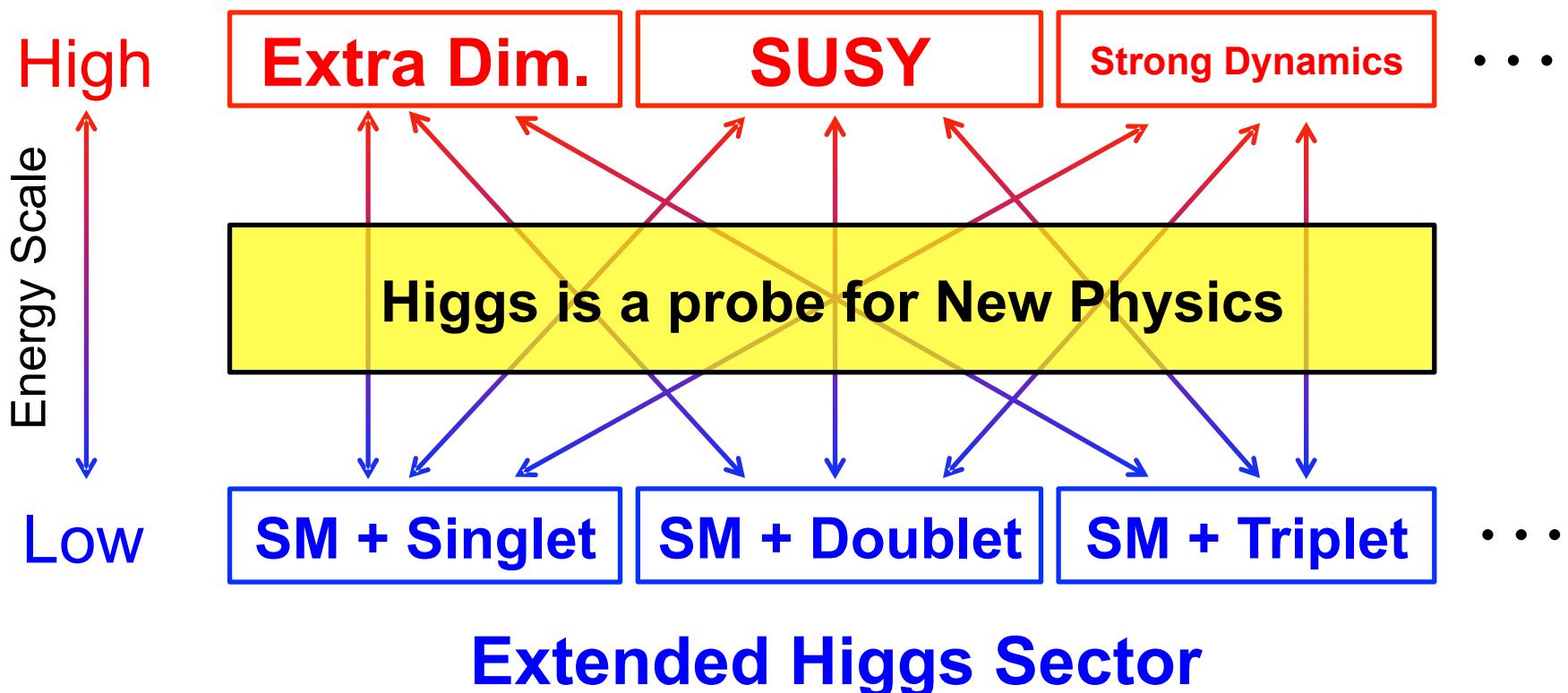


- Phenomenology:  $X^+ + X^- \rightarrow W^+ + DM + W^- + DM$
- How to discriminate different physics models?
  - **Spin of X**: e.g. Inert Higgs (0), SUSY (1/2), Little Higgs (1)
- **Angular analysis** of X production + **Threshold Scan**



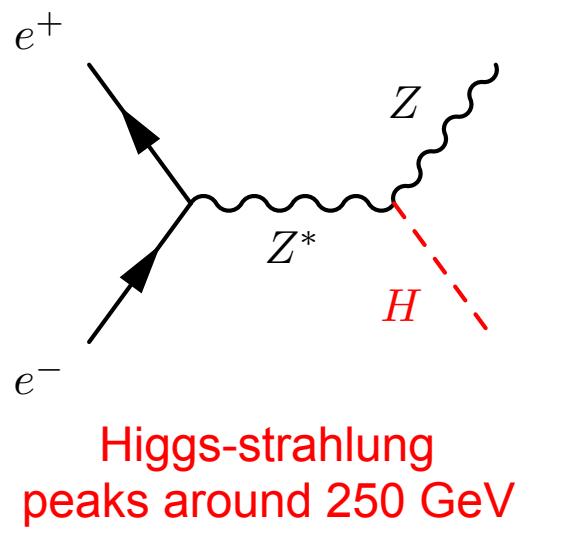
→ Model Discrimination with spin information

New physics can affect the Higgs sector

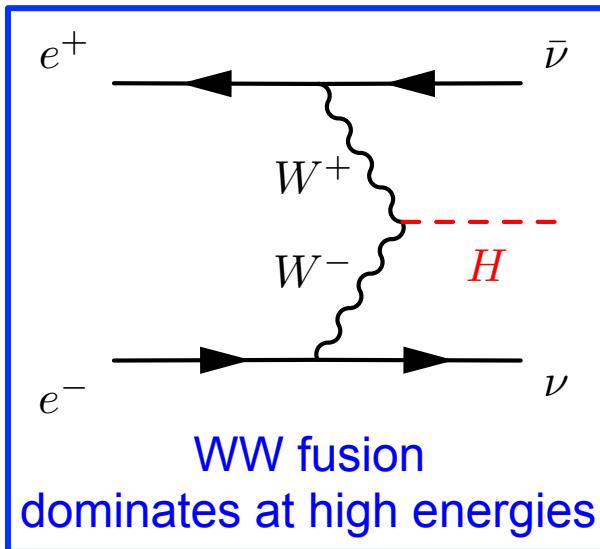
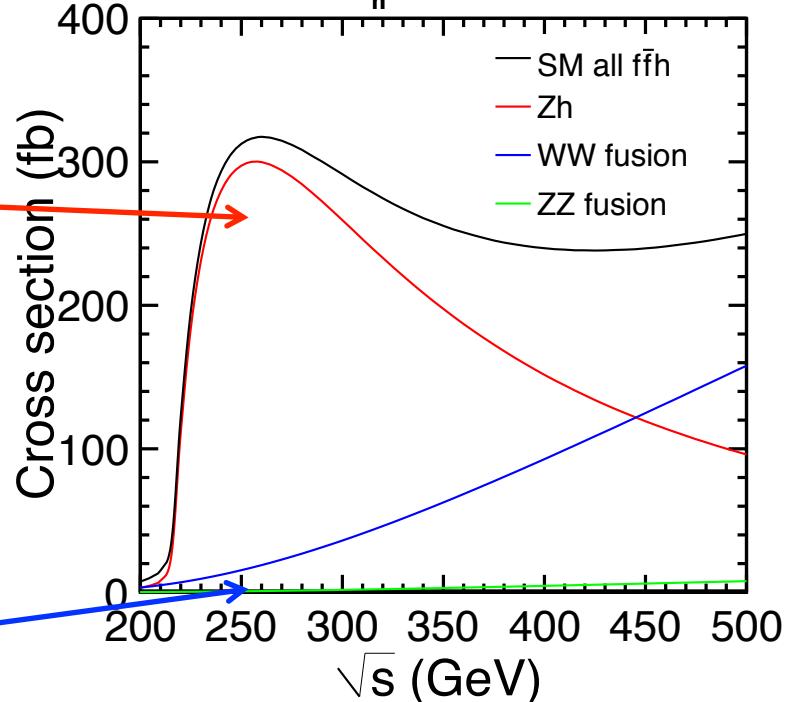


May be able to explain well-established BSM phenomena:  
dark matter, neutrino oscillation, baryon asymmetry, etc.

# Higgs Production at ILC



ILC TDR, cross section by WHIZARD  
 $P(e^-, e^+) = (-0.8, 0.3)$ ,  $M_h = 125$  GeV



ILC is a  
Higgs  
Factory

	250 GeV	500 GeV
$\sigma(e^+e^- \rightarrow ZH)$	303 fb	100 fb
$\sigma(e^+e^- \rightarrow vvH)$	16 fb	150 fb
Int. Luminosity	$250 \text{ fb}^{-1}$	$500 \text{ fb}^{-1}$
# ZH events	76,000	50,000
# vvH events	4,000	75,000

# Higgs recoil mass

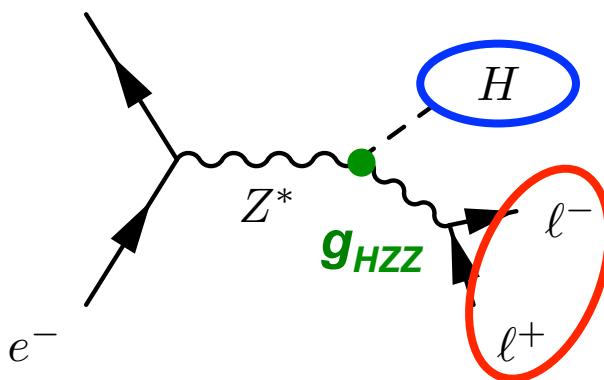


Reconstruct  $Z \rightarrow l^+l^-$

independent of Higgs decay

sensitive to invisible Higgs decays

$e^+$



$$m_{\text{recoil}}^2 = (\sqrt{s} - E_{\ell\ell})^2 - |\vec{p}_{\ell\ell}|^2$$

Model-independent,  
absolute measurements

( $Z \rightarrow e^+e^-$ ,  $\mu^+\mu^-$  combined):

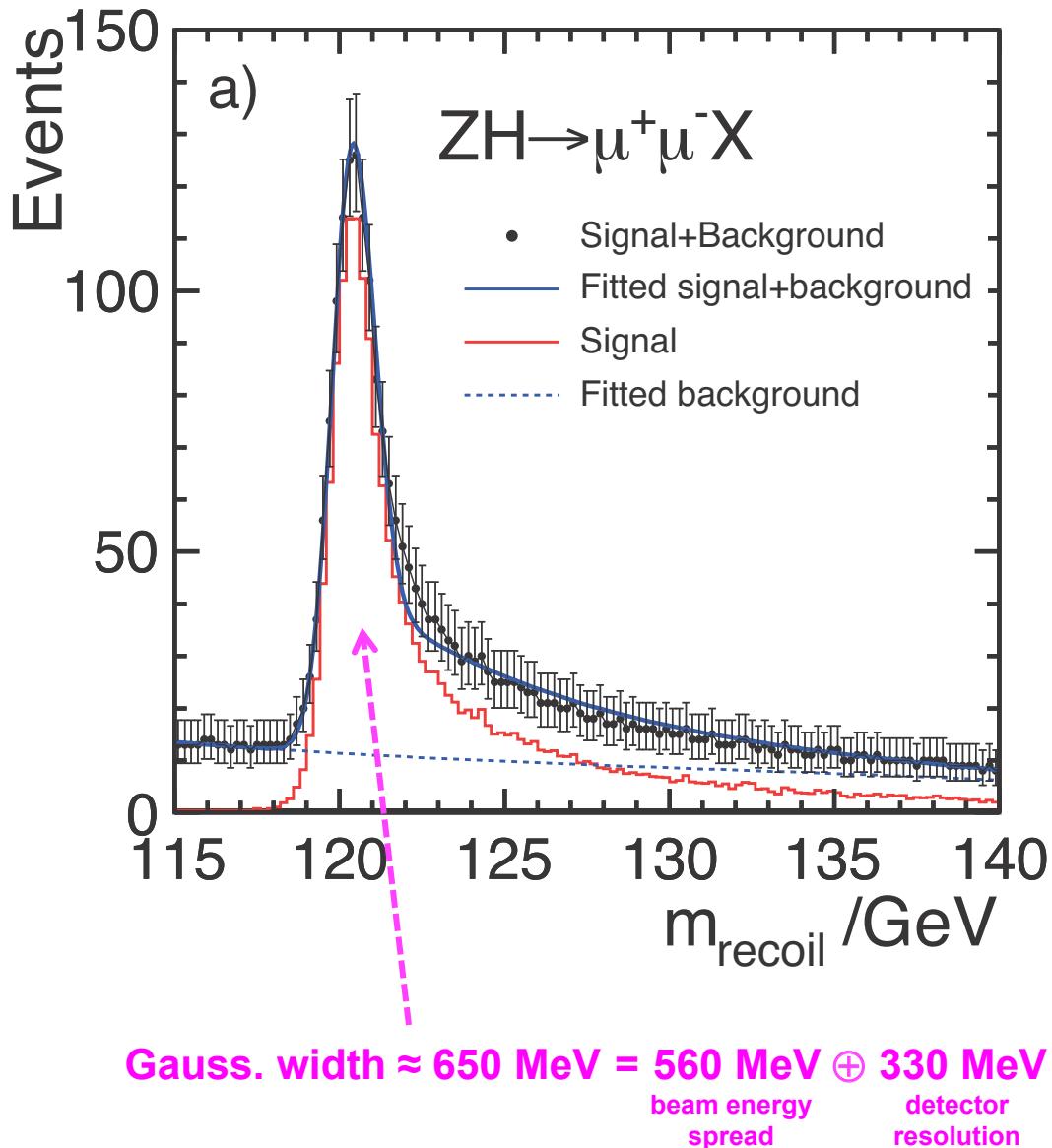
$\sqrt{s}=250 \text{ GeV}$ ,  $L=250 \text{ fb}^{-1}$

$\Delta m_H \leq 32 \text{ MeV}$

$\sigma_{ZH} \leq 2.5\%$

$g_{HZZ} \leq 1.2\%$

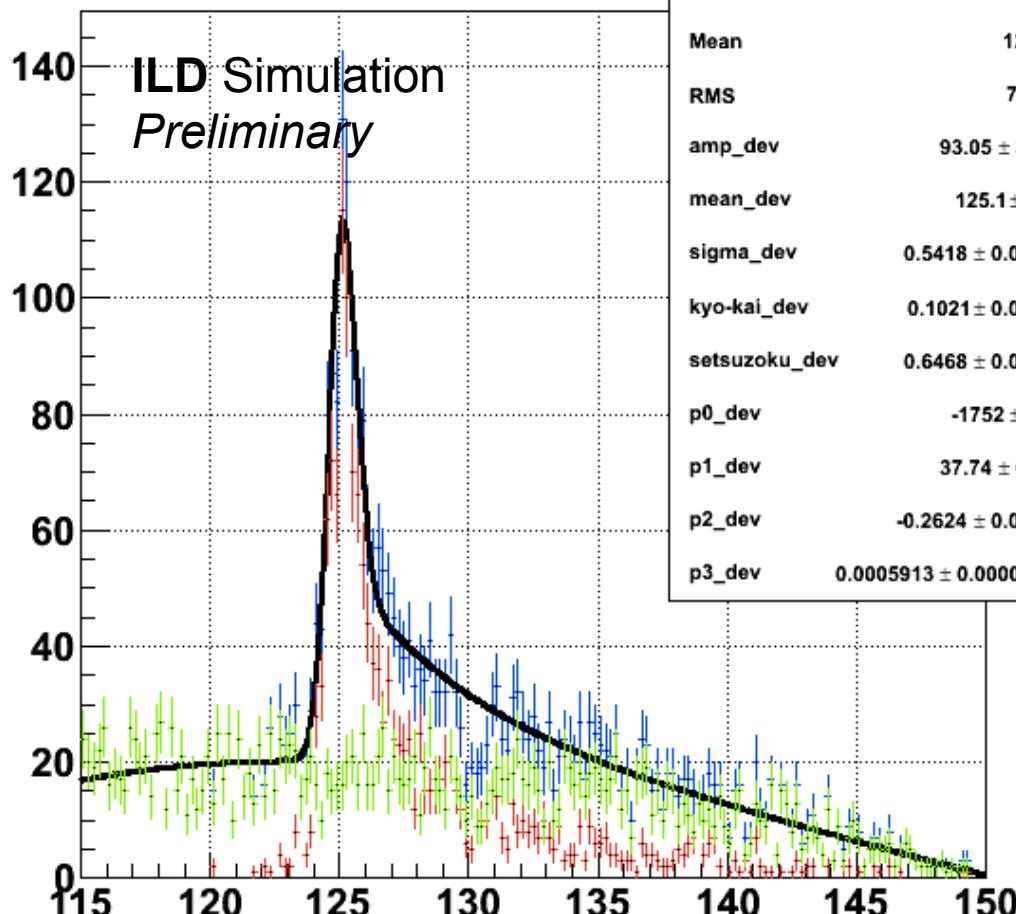
ILC TDR,  $\sqrt{s}=250 \text{ GeV}$ ,  $L=250 \text{ fb}^{-1}$



# Higgs recoil mass



recoil\_dev\_all\_bg\_toy



Watanuki, Ishikawa, Suehara [to appear]  
Update to  $m_H=125$  GeV in progress...



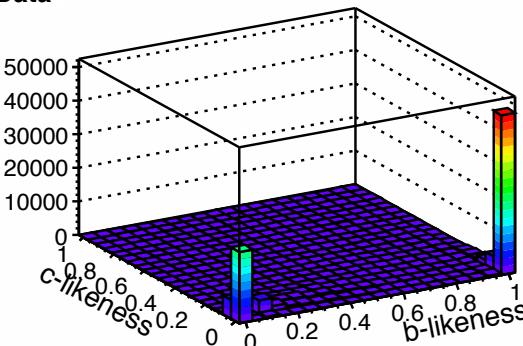
# Higgs: hadronic BRs



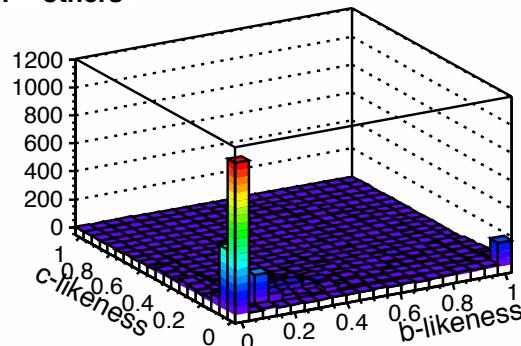
Measuring the Higgs BR into  $bb$ ,  $cc$ ,  $gg$  require flavor-tagging.  
Apply flavor template fit to ZH sample:

[Hiroaki Ono]

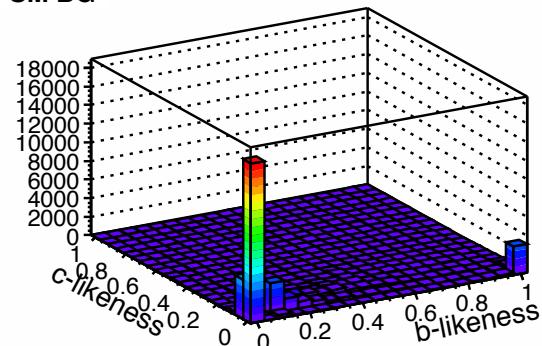
Data



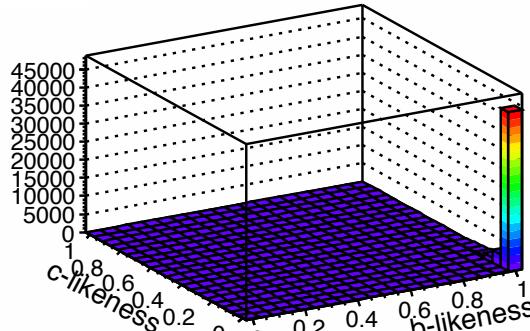
$h \rightarrow \text{others}$



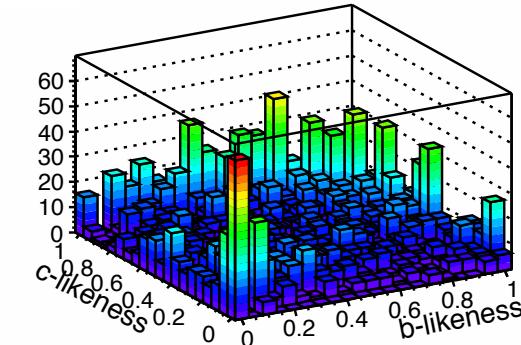
SM BG



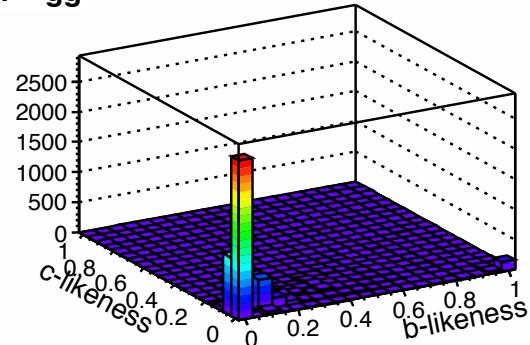
$h \rightarrow bb$



$h \rightarrow cc$



$h \rightarrow gg$



$h \rightarrow bb$ : ~1%,  $h \rightarrow cc$ : ~7%,  $h \rightarrow gg$ : ~9% at 250 GeV ILC with 250 fb<sup>-1</sup>  
improves with more luminosity at higher energies

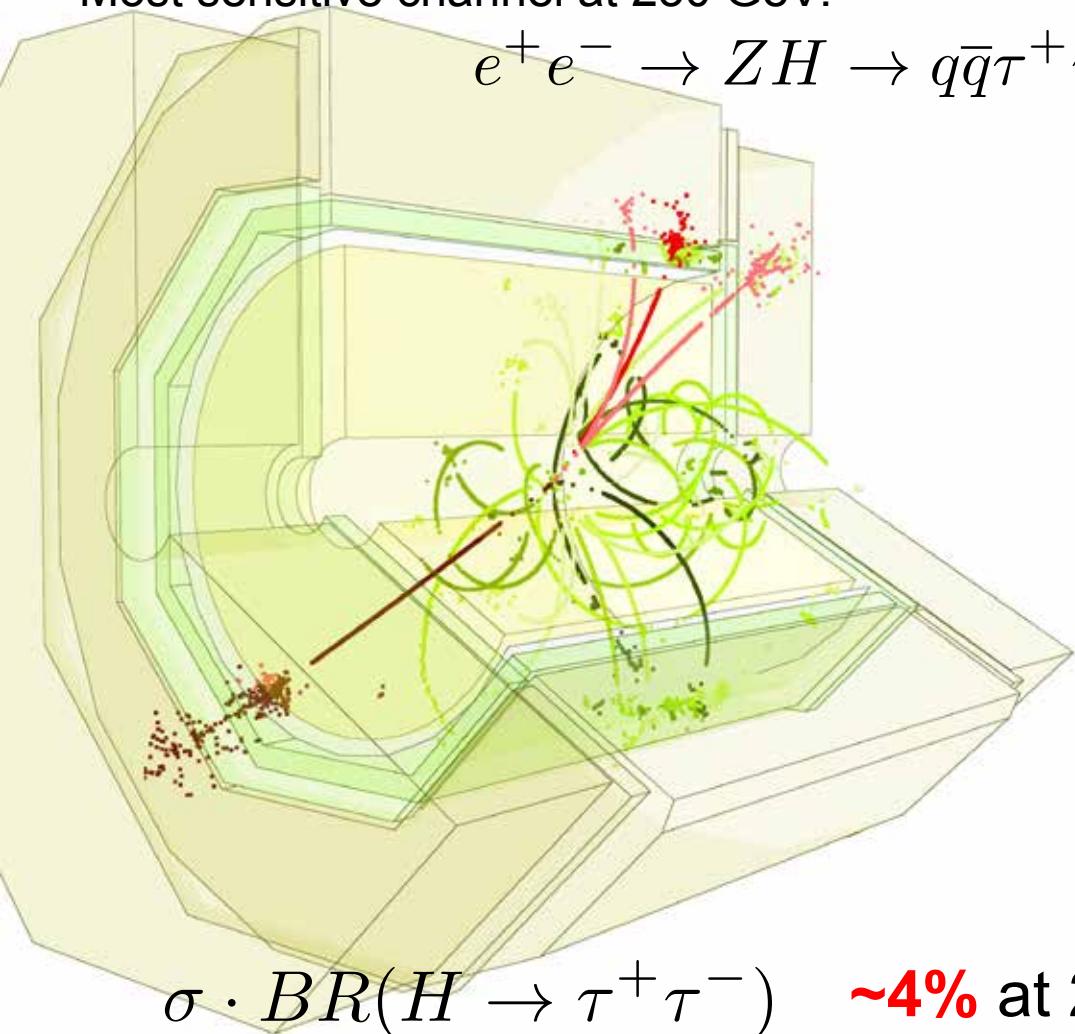
# Higgs to tau pair decays



$H \rightarrow \tau\tau$  good probe: small uncertainty in mass

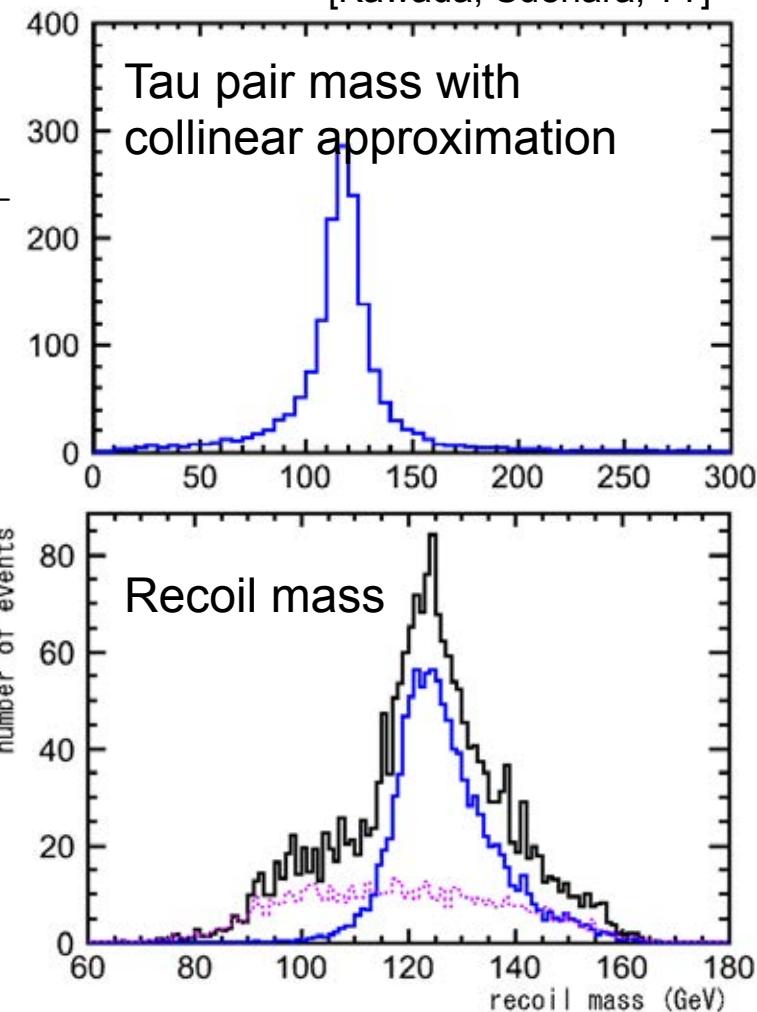
Most sensitive channel at 250 GeV:

$$e^+ e^- \rightarrow ZH \rightarrow q\bar{q} \tau^+ \tau^-$$



$\sigma \cdot BR(H \rightarrow \tau^+ \tau^-)$  ~4% at 250 GeV ILC with 250 fb<sup>-1</sup>

[Kawada, Suehara, TT]

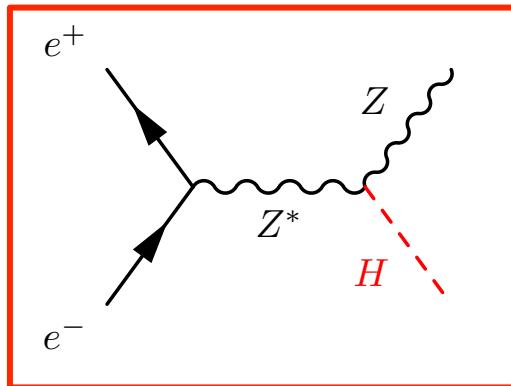


## (model-independent)

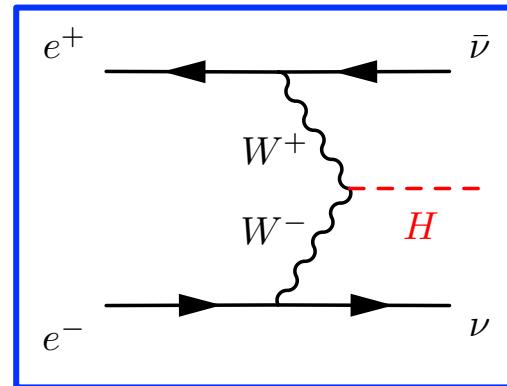
Facility	ILC		ILC(LumiUp)	
$\sqrt{s}$ (GeV)	250	500	1000	250/500/1000
$\int \mathcal{L} dt$ (fb $^{-1}$ )	250	+500	+1000	1150+1600+2500
$P(e^-, e^+)$	(-0.8, +0.3)	(-0.8, +0.3)	(-0.8, +0.2)	(same)
$\Gamma_H$	11%	5.9%	5.6%	2.7%
$BR_{\text{inv}}$	< 0.69%	< 0.69%	< 0.69%	< 0.32%
$\kappa_\gamma$	18%	8.4%	4.1%	2.4%
$\kappa_g$	6.4%	2.4%	1.8%	0.93%
$\kappa_W$	4.8%	1.4%	1.4%	0.65%
$\kappa_Z$	1.3%	1.3%	1.3%	0.61%
$\kappa_\mu$	—	—	16%	10%
$\kappa_\tau$	5.7%	2.4%	1.9%	0.99%
$\kappa_c$	6.8%	2.9%	2.0%	1.1%
$\kappa_b$	5.3%	1.8%	1.5%	0.74%
$\kappa_t$	—	14%	3.2%	2.0%

## (model-dependent)

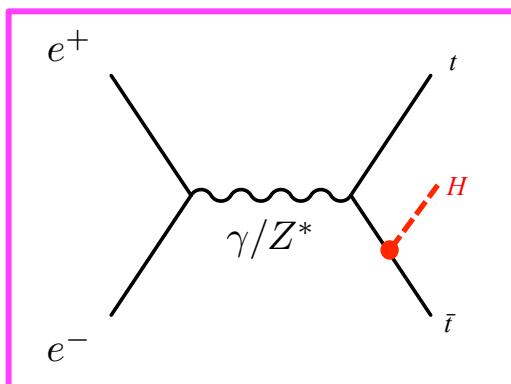
Facility	LHC	HL-LHC	ILC500	ILC500-up	ILC1000	ILC1000-up
$\sqrt{s}$ (GeV)	14,000	14,000	250/500	250/500	250/500/1000	250/500/1000
$\int \mathcal{L} dt$ (fb $^{-1}$ )	300/expt	3000/expt	250+500	1150+1600	250+500+1000	1150+1600+2500
$\kappa_\gamma$	5 – 7%	2 – 5%	8.3%	4.4%	3.8%	2.3%
$\kappa_g$	6 – 8%	3 – 5%	2.0%	1.1%	1.1%	0.67%
$\kappa_W$	4 – 6%	2 – 5%	0.39%	0.21%	0.21%	0.13%
$\kappa_Z$	4 – 6%	2 – 4%	0.49%	0.24%	0.44%	0.22%
$\kappa_\ell$	6 – 8%	2 – 5%	1.9%	0.98%	1.3%	0.72%
$\kappa_d$	10 – 13%	4 – 7%	0.93%	0.51%	0.51%	0.31%
$\kappa_u$	14 – 15%	7 – 10%	2.5%	1.3%	1.3%	0.76%



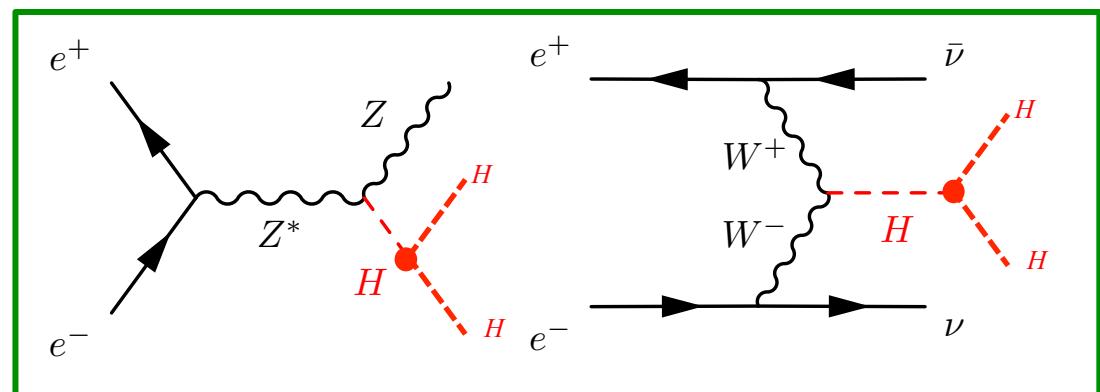
**250 GeV~  
Higgs-strahlung**



**350 GeV~  
WW fusion**



**500 GeV~  
Top Yukawa Coupling**



**500 GeV~  
Higgs Self-Coupling**

# Higgs self-coupling @ 500 GeV (combined)

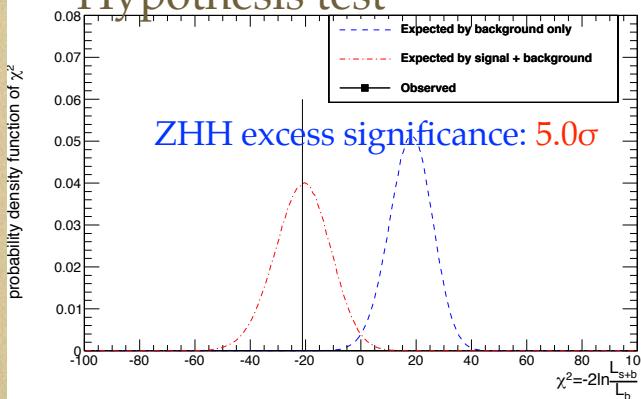
$P(e^-, e^+) = (-0.8, +0.3)$

$$e^+ + e^- \rightarrow ZHH$$

$$M(H) = 120\text{GeV} \quad \int L dt = 2ab^{-1}$$

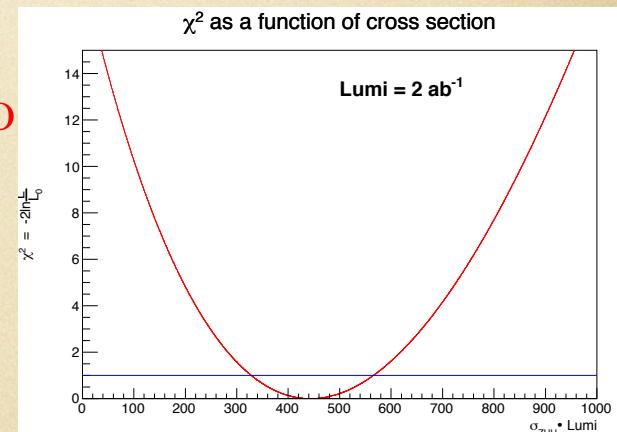
Energy (GeV)	Modes	signal	background (tt, ZZ, ZZH/ ZZZ)	significance	
				excess (I)	measurement (II)
500	$ZHH \rightarrow (l\bar{l})(b\bar{b})(b\bar{b})$	3.7	4.3	$1.5\sigma$	$1.1\sigma$
		4.5	6.0	$1.5\sigma$	$1.2\sigma$
500	$ZHH \rightarrow (\nu\bar{\nu})(b\bar{b})(b\bar{b})$	8.5	7.9	$2.5\sigma$	$2.1\sigma$
500	$ZHH \rightarrow (q\bar{q})(b\bar{b})(b\bar{b})$	13.6	30.7	$2.2\sigma$	$2.0\sigma$
		18.8	90.6	$1.9\sigma$	$1.8\sigma$

Hypothesis test



$$\sigma_{ZHH} = 0.22 \pm 0.06 \text{ fb}$$

$$\frac{\delta\sigma}{\sigma} = 27\%$$

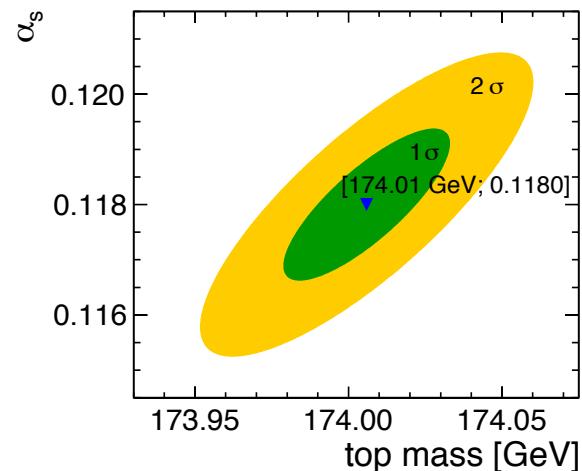
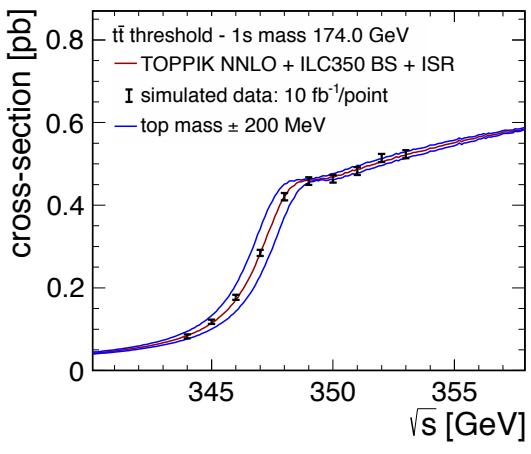


Higgs self-coupling:

$$\frac{\delta\lambda}{\lambda} = 44\%$$

	ILC500	ILC500-up	ILC1000	ILC1000-up
$\sqrt{s}$ (GeV)	500	500	500/1000	500/1000
$\int \mathcal{L} dt$ (fb $^{-1}$ )	500	1600 $^{\ddagger}$	500+1000	1600+2500 $^{\ddagger}$
$P(e^-, e^+)$	(-0.8, 0.3)	(-0.8, 0.3)	(-0.8, 0.3/0.2)	(-0.8, 0.3/0.2)
$\sigma(ZHH)$	42.7%	?	42.7%	23.7%
$\sigma(\nu\bar{\nu}HH)$	—	—	26.3%	16.7%
$\lambda$	83%	46%	21%	13%

At ttbar threshold ~350 GeV:  
precise measurement of the  
top mass

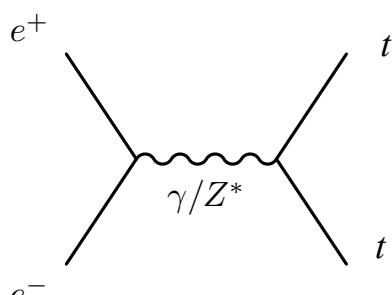


At 500 GeV:

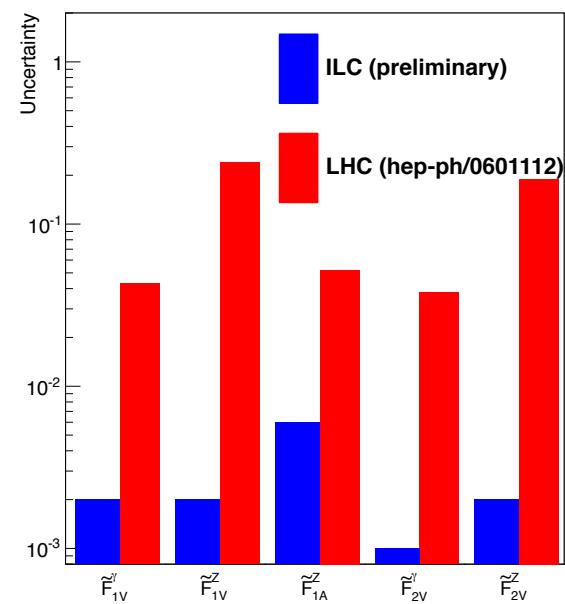
**Beam Polarization**  
 → disentangle  $\gamma/Z$

$A_{FB}$ ,  $A_{LR}$ ,  $A_{hel}$ , etc

Precise measurement of  
the ttZ / tτγ form factors



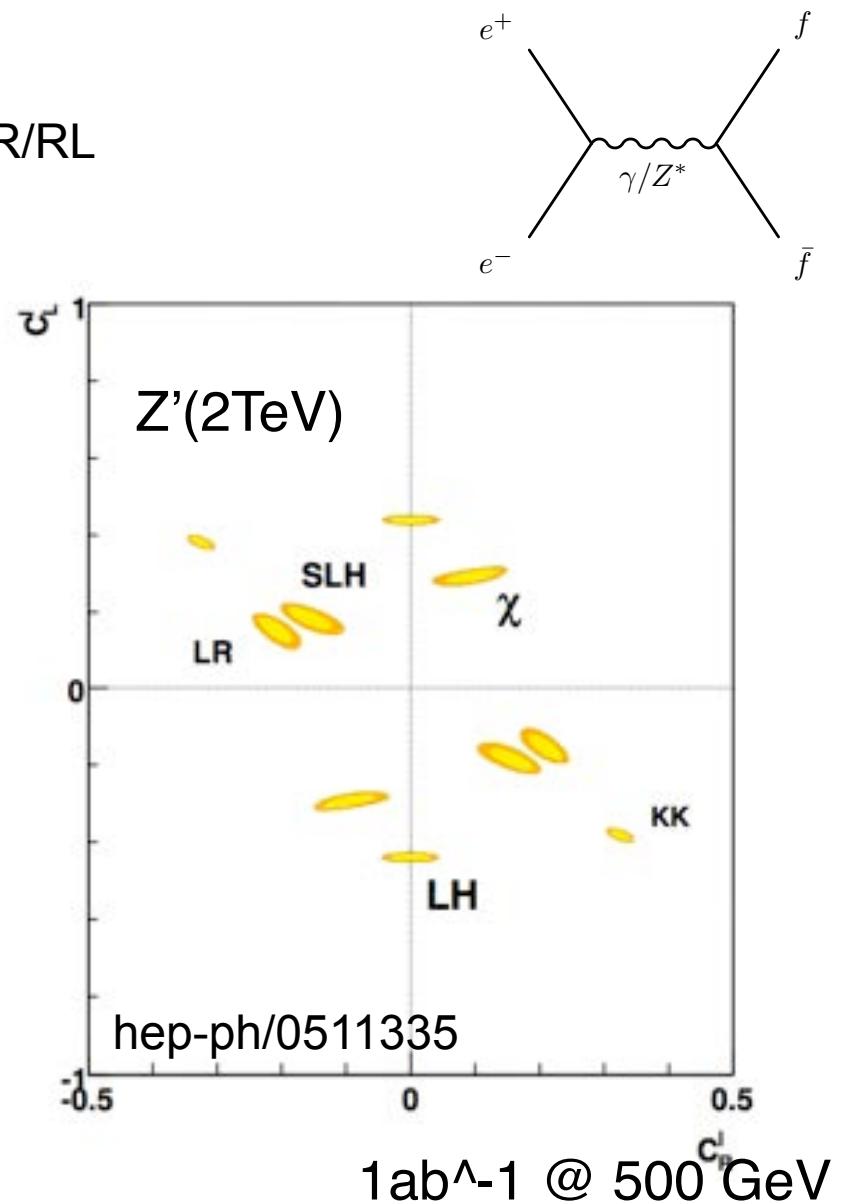
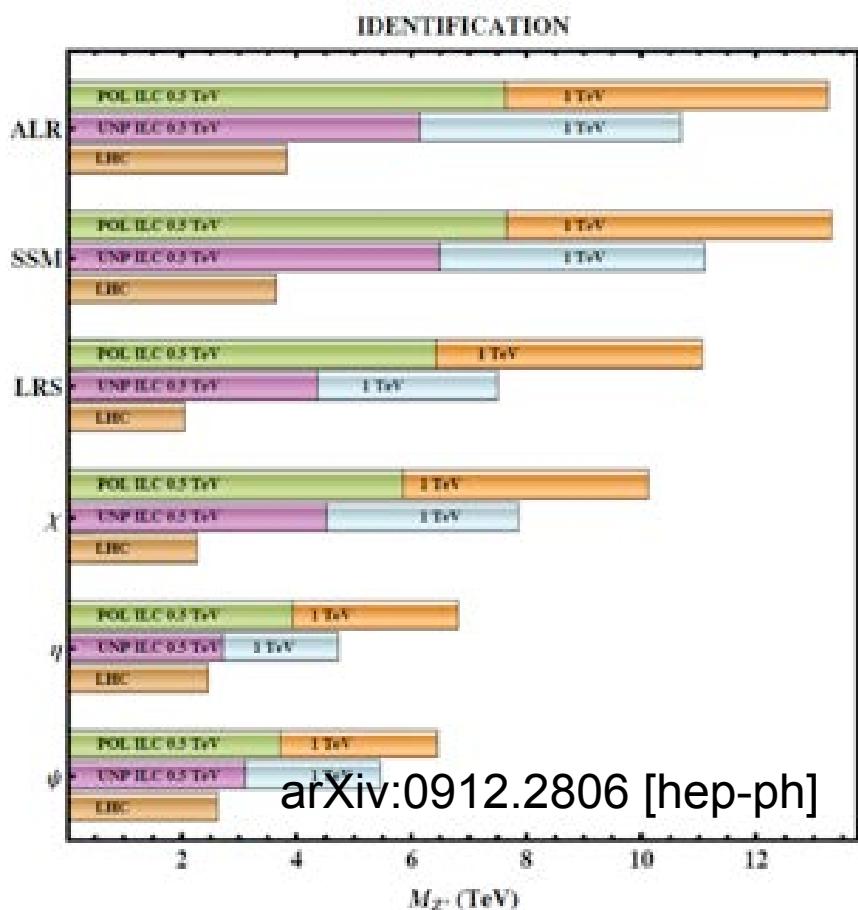
$$\Gamma_\mu^{ttX}(k^2, q, \bar{q}) = ie \left\{ \gamma_\mu \left( \tilde{F}_{1V}^X(k^2) + \gamma_5 \tilde{F}_{1A}^X(k^2) \right) + \frac{(q - \bar{q})_\mu}{2m_t} \left( \tilde{F}_{2V}^X(k^2) + \gamma_5 \tilde{F}_{2A}^X(k^2) \right) \right\}$$



## Search for Z' boson

Polarized differential cross sections: LL/RR/LR/RL

Forward-backward asymmetries

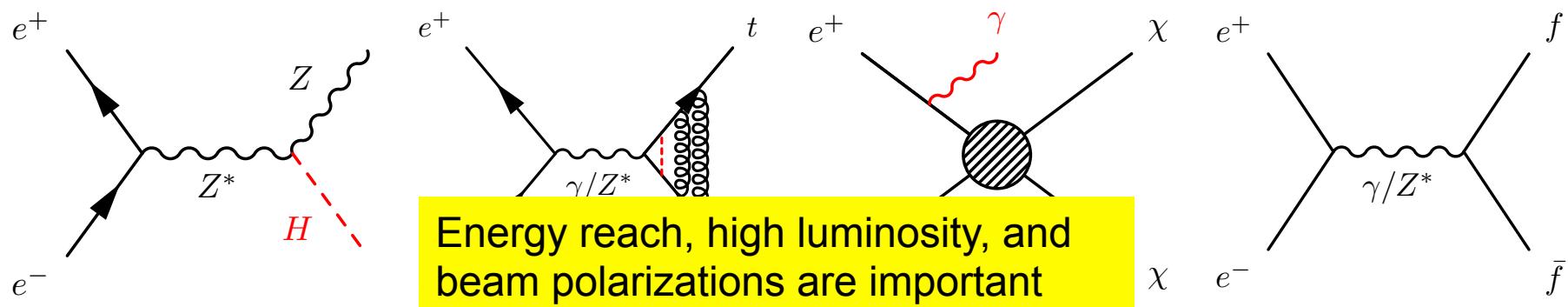
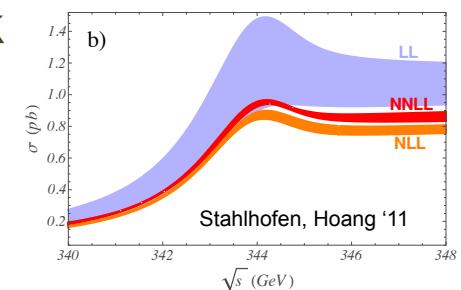
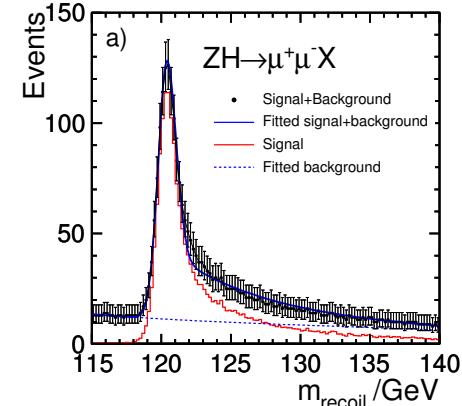


# Physics at the ILC



Main goals of the ILC physics program:

- Precise measurements of:
  - Properties of the **Higgs sector**
  - Interactions of **top, gauge bosons, and new particles**
- Searches for new physics
  - Discovery reach for **color-neutral states** (e.g. dark matter) can significantly exceed LHC
  - Sensitivity to new physics through **tree-level** and **quantum effects**



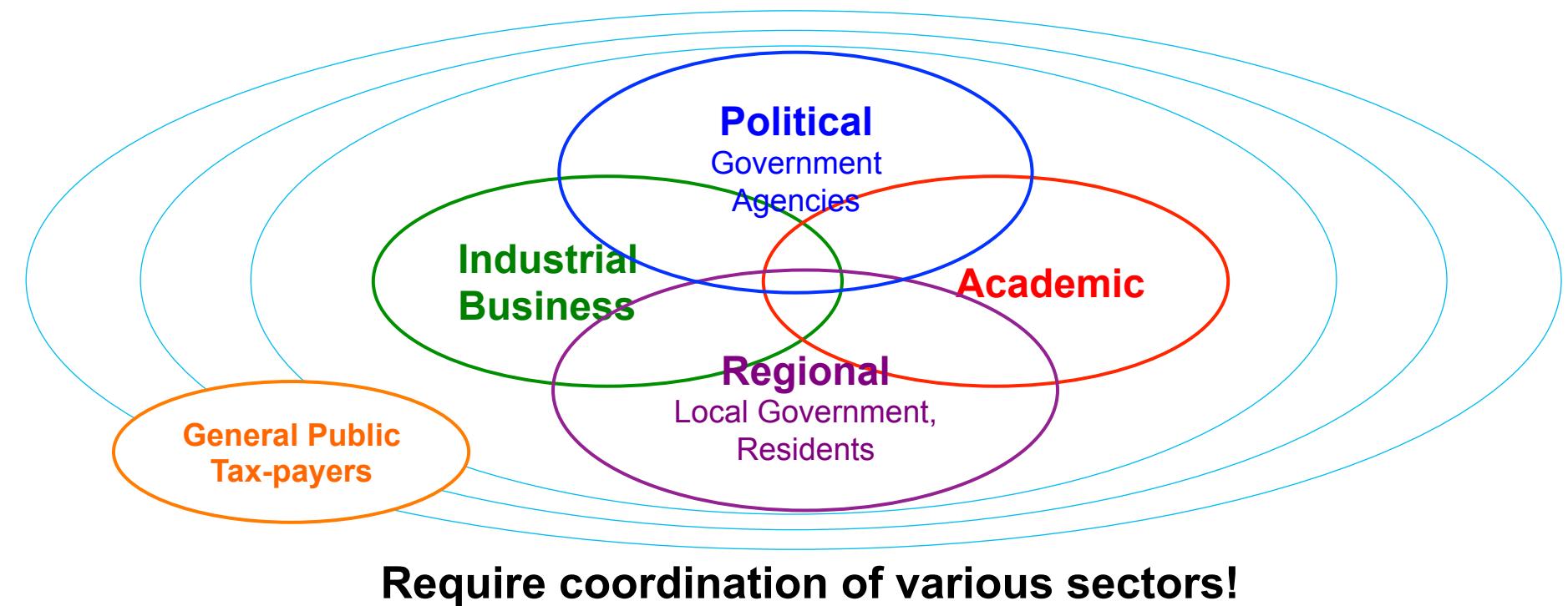
# Efforts toward realizing the ILC



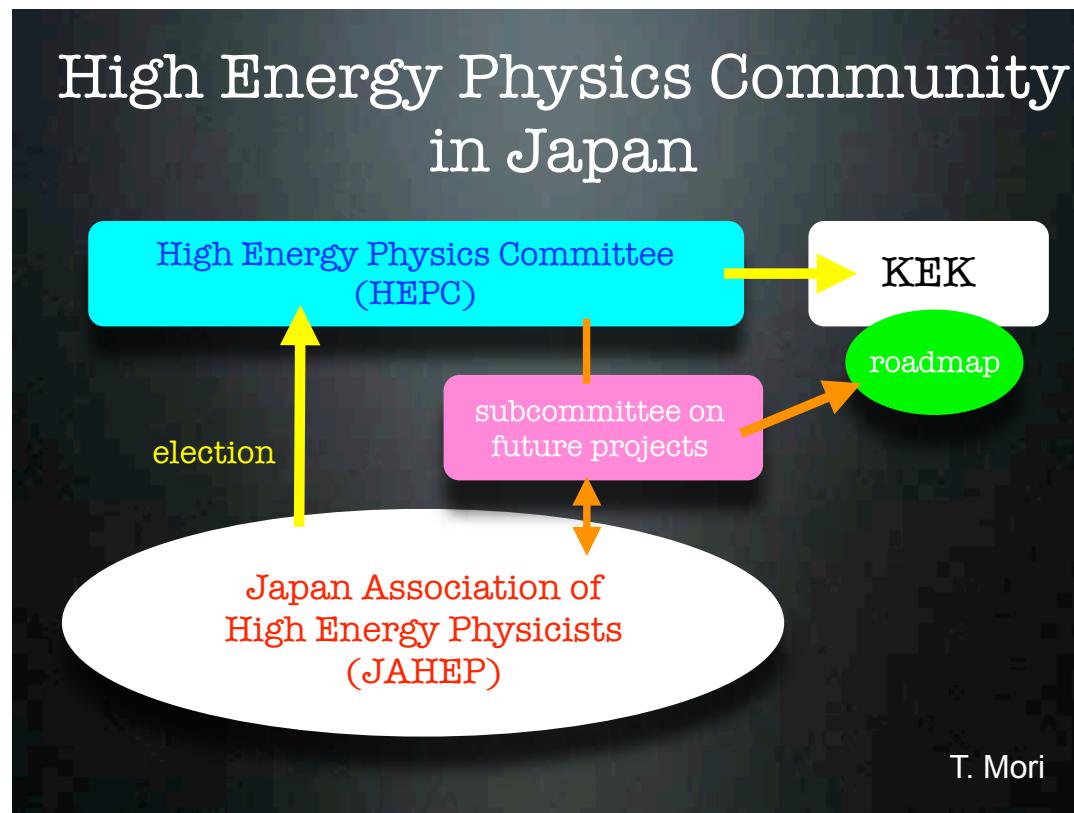
ILC is a genuine global project: most important key to its realization

- Global governance of the project
- Global cooperation
- Global design, construction, and operation

Realization of ILC requires both **international and domestic** efforts.



- Japanese Association of High Energy Physicists (JAHEP) – 800+ members
  - “**Recommendations by Subcommittee on Future Projects**” (Mar. 2012)
  - “**Proposal for Phased Execution of ILC**” (Oct. 2012)
- “**ILC Strategy Council**” formed for consistent, community-wide efforts to realize ILC
- Preparation of **KEK Roadmap 2014~** underway





Chair: Toshinori Mori <http://www.icepp.s.u-tokyo.ac.jp/hecsubc/>  
Recommendations received in Feb. 2012 by HEPC (Chair: Sachio Komamiya)

The committee makes the following recommendations concerning large-scale projects, which comprise the core of future high energy physics research in Japan.

- **Should a new particle such as a Higgs boson with a mass below approximately 1 TeV be confirmed at LHC, Japan should take the leadership role in an early realization of an  $e^+e^-$  linear collider.** In particular, if the particle is light, experiments at low collision energy should be started at the earliest possible time. In parallel, continuous studies on new physics should be pursued for both LHC and the upgraded LHC version. Should the energy scale of new particles/physics be higher, accelerator R&D should be strengthened in order to realize the necessary collision energy.
- **Should the neutrino mixing angle  $\theta_{13}$  be confirmed as large, Japan should aim to realize a large-scale neutrino detector through international cooperation, accompanied by the necessary reinforcement of accelerator intensity, so allowing studies on CP symmetry through neutrino oscillations.** This new large-scale neutrino detector should have sufficient sensitivity to allow the search for proton decays, which would be direct evidence of Grand Unified Theories.

Also mentioned: SuperKEKB, J-PARC, dark matter, neutrinoless double beta decays, CMB B-mode polarization, and dark energy

## Translation of official JAHEP statement, Oct 2012

In March 2012, the Japan Association of High Energy Physicists (JAHEP) accepted the recommendations of the Subcommittee on Future Projects of High Energy Physics<sup>(1)</sup> and adopted them as JAHEP's basic strategy for future projects. In July 2012, a new particle consistent with a Higgs Boson was discovered at LHC, while in December 2012 the Technical Design Report of the International Linear Collider (ILC) will be completed by a worldwide collaboration.

On the basis of these developments and following the subcommittee's recommendation on ILC, JAHEP proposes that ILC be constructed in Japan as a global project with the agreement of and participation by the international community in the following scenario:

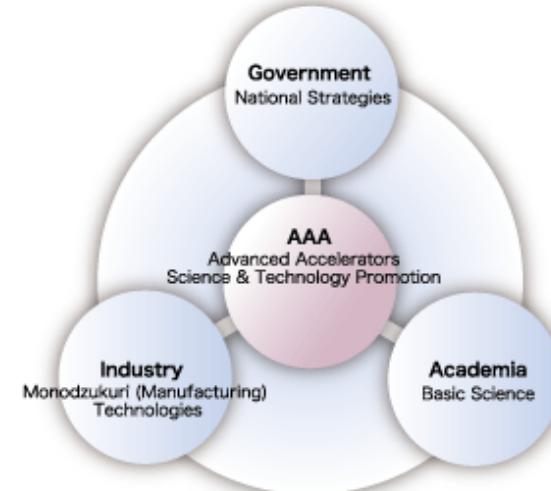
(1) Physics studies shall start with a precision study of the "Higgs Boson", and then evolve into studies of the top quark, "dark matter" particles, and Higgs self-couplings, by upgrading the accelerator. A more specific scenario is as follows:

- (A) A Higgs factory with a center-of-mass energy of approximately 250 GeV shall be constructed as a first phase.
- (B) The machine shall be upgraded in stages up to a center-of-mass energy of ~500 GeV, which is the baseline energy of the overall project.
- (C) Technical extendability to a 1 TeV region shall be secured.

(2) A guideline for contributions to the construction costs is that Japan covers 50% of the expenses (construction) of the overall project of a 500 GeV machine. The actual contributions, however, should be left to negotiations among the governments.

Cost estimate will be available in TDR.

Established in 2008 to promote accelerator research and ILC. Members include 91 corporations (e.g. Kyocera, Hitachi, Mitsubishi Electric, Mitsubishi Heavy Industries, Toshiba) and 38 universities and institutions.



<http://www.aaa-sentan.org/>



**Takashi Nishioka, Chairman**  
Former Chairman of the Board, MHI



**Kaoru Yosano, Supreme Advisor**  
Former Minister of Finance, MEXT,  
Former Chief Cabinet Secretary



**Atsuto Suzuki, Trustee**  
Director General, KEK



**Masatoshi Koshiba, Honorary Chairman**  
Professor Emer., The University of Tokyo

In 2006, members from LDP members established the Federation of Diet members for ILC.

In 2008, expanded into “**Joint Federation**” including LDP, DPJ, New Komeito, ...

Aims to promote accelerator R&D and Japanese bid for ILC if supported by global society



Core Members of the Federation + AAA Directorates



Annual Symposium jointly hosted by AAA + Federation (Dec 15, 2011)  
Prime Minister Yoshihiko Noda was a speaker.

## March 27, 2013: Lyn Evans meets Prime Minister Abe Shinzo



From left: Hitoshi Murayama, LCC Deputy Director, Masatoshi Koshiba, 2002 Nobel laureate in Physics, Lyn Evans, Shinzo Abe, and Takeo Kawamura, Chair of the Federation of Diet members supporting the ILC.

April 10, 2013 @ Washington, DC  
US-Japan Advanced Science and Technology Symposium



(Left) Daniel B. Poneman, Deputy Secretary of Energy  
(Right) Takeo Kawamura, Member of the Lower House and Chair of the Federation of Diet members supporting the ILC.



**Japan Policy Council:** experts in policy making, economics, labor, or sociology aiming to create a grand design of Japan for the next decade.

<http://www.policycouncil.jp/>



**Hiroya Masuda,  
Chairman**

Professor at The University of Tokyo, former Minister of MIC, and former Governor of Iwate Prefecture

## Recommendations: “Creation of Global Cities by hosting the ILC” (Jul 2012)

“Japan should revitalize its provincial cities to revitalize Japan itself...”

“... explore ‘Domestic Globalization’ taking advantage of the opportunity of Japan’s possible bid to host the International Linear Collider...”

## Business communities in support of ILC:

Japan Chamber of Commerce and Industry



日本商工会議所  
The Japan Chamber of Commerce and Industry

Japan Association of Corporate Executives



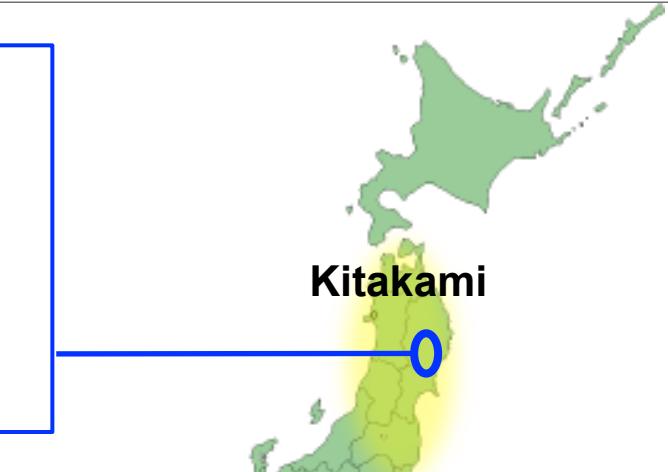
公益社団法人 経済同友会  
Japan Association of Corporate Executives

# Candidate Sites



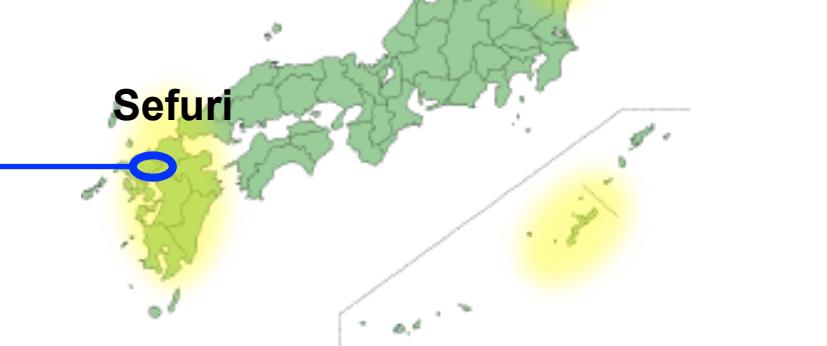
## Kitakami site in Tohoku region

- **Iwate and Miyagi** Prefectures + all Tohoku area
  - Local governments officially proposed ILC as a core project for the disaster recovery effort.
- **Tohoku University**
- **Tohoku Economic Federation**



## Sefuri site in Kyushu region

- **Saga and Fukuoka** Prefectures
  - Expanded efforts in all Kyushu, and Yamaguchi, Okinawa
- **Kyushu University and Saga University**
- **Kyushu Economic Federation**



Japanese government approved supplementary budget for geological survey for ILC (Dec. 2011)  
(This is in addition to R&D grants.)

# Media Coverage



Sefuri



Kitakami



## 次世代加速器 ILC、宇宙・物質の謎に挑む 国内候補地今夏決定へ

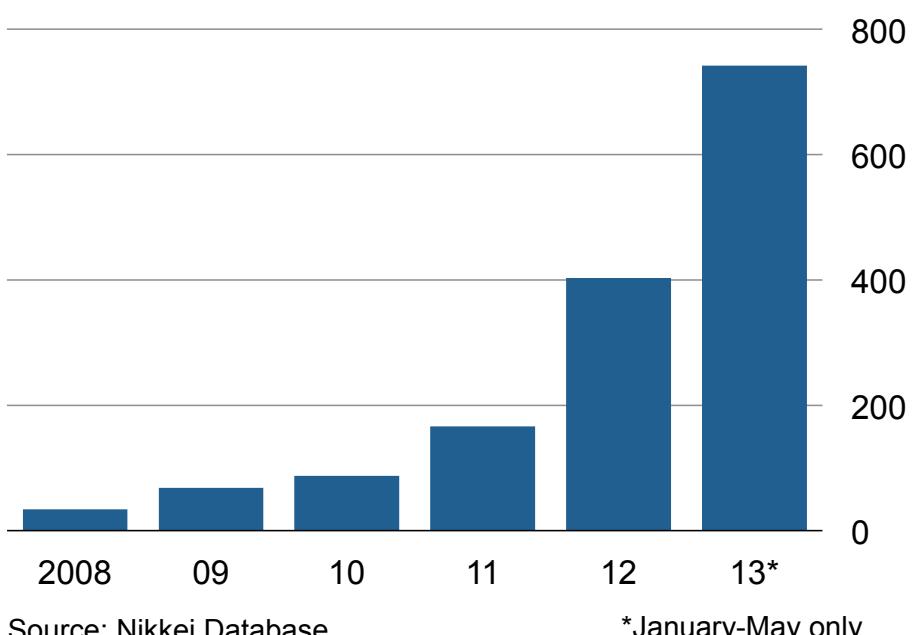
2013.1.1 07:00

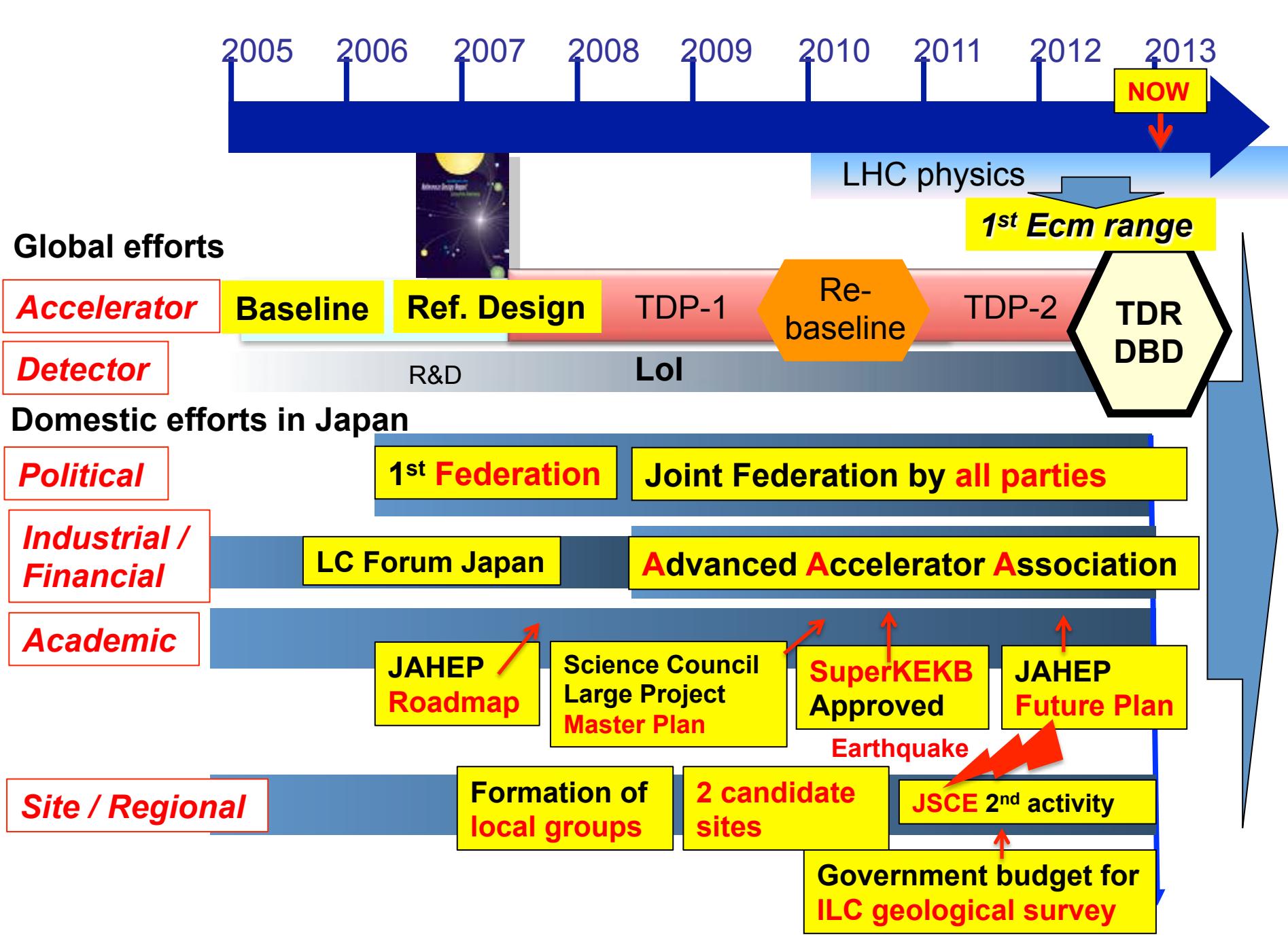
宇宙誕生の謎に迫る素粒子物理学の壮大な実験施設の構想が進んでいる。日米欧などが目指す次世代加速器「国際リニアコライダー」(ILC) 計画だ。建設地は日本が最も有力で、今夏に国内候補地が決まり誘致が本格化する。物理学に革命を起こすノーベル賞級の発見が日本で実現する期待が高まっている。(草下健夫、黒田悠希)

物質の根源を探る素粒子物理学で昨年7月、歴史的大発見があった。すべての物質に質量(重さ)を与える「ヒッグス粒子」とみられる新粒子が、スイス・ジュネーブ郊外にある欧州合同原子核研究所(CERN)の大型ハドロン衝突型加速器(LHC)で見つかったのだ。



Number of articles covering the ILC in Japanese newspapers







<b>End 2013</b>	Japanese government announces intent to bid
<b>2013-2015</b>	Inter-governmental negotiations Engineering design for ILC Preparation of ILC laboratory
<b>~2015</b>	Input from LHC 14 TeV, decision to proceed
<b>2015-2016</b>	Begin construction (including bidding)
<b>2026-2027</b>	Commissioning



The discovery of “**a Higgs boson**” at the **LHC** opened a new era in particle physics.

**ILC** is the ideal machine for the precise study of the **Higgs sector**.

Search for **new physics** at the **ILC** is in many ways complementary to that of the **LHC**. Unique opportunities available at **ILC**!

There are strong efforts to promote the **ILC**.

**Support from the international community** is vital to the success of **ILC** as a truly global project.

# International Workshop on Future Linear Colliders



11-15 November 2013, The University of Tokyo

The workshop will be devoted to the study of the physics case for a high energy linear electron-positron collider, taking into account the recent results from LHC, and to review the progress in the detector and accelerator designs for both ILC and CLIC projects.

**Website:** <http://www.icepp.s.u-tokyo.ac.jp/lcws13/>

**Contact:** lcws13@icepp.s.u-tokyo.ac.jp



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**LCWS13 will be held at The University of Tokyo  
11-15 November 2013**

Registration now open: <http://www.icepp.s.u-tokyo.ac.jp/lcws13/>