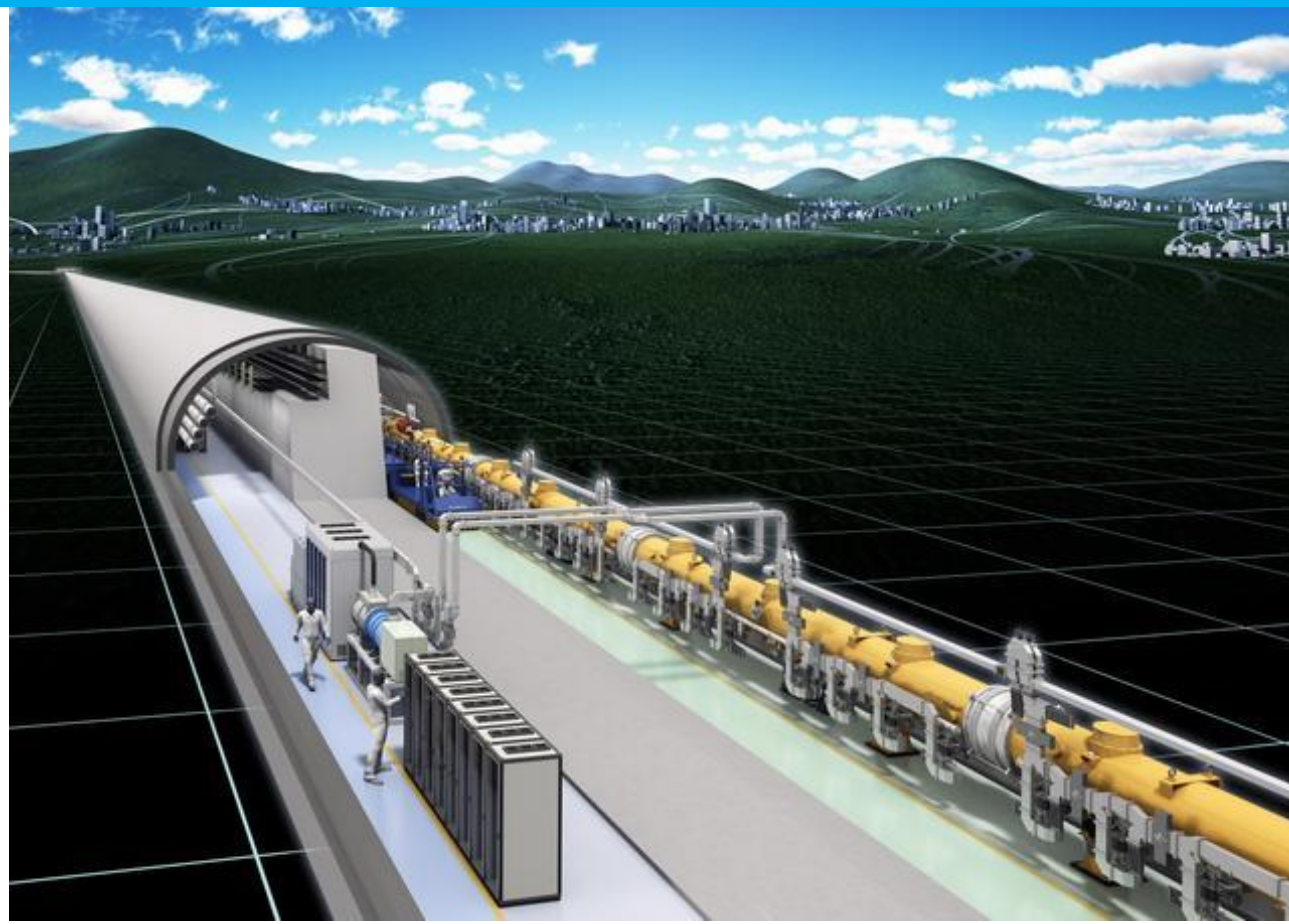
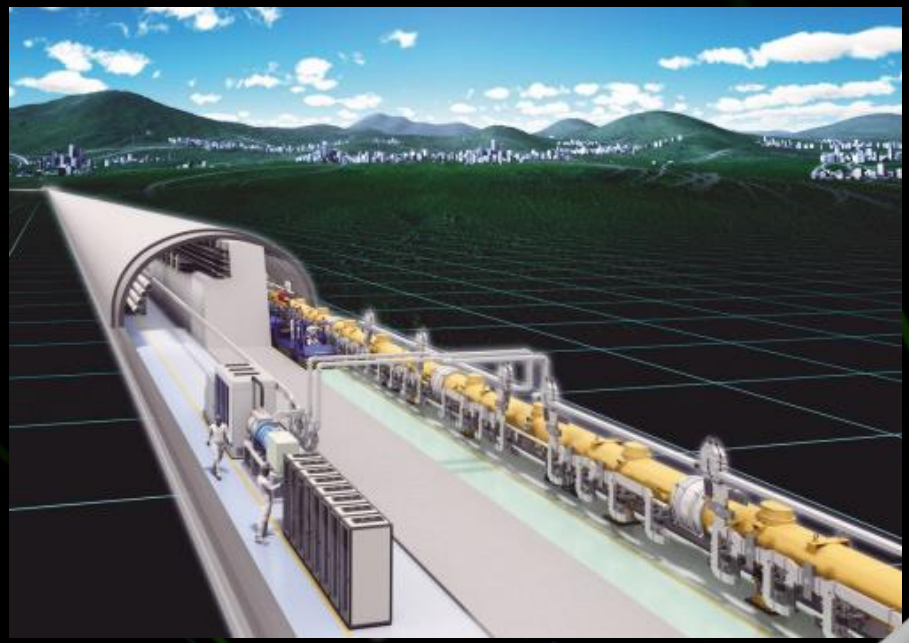
International Linear Collider in Japan

20st July 2013
EPSHEP 2013

Stockholm, Sweden



Department of Physics, School of Science and ICEPP, the University of Tokyo
Chair: High Energy Physics Committee of Japan Sachio Komamiya



International Linear Collider ILC

The next major accelerator project driven by truly international efforts

Superconducting linear accelerator of ~30km length will be constructed underground

Colliding electrons and positrons face-to-face to study the universe of 10^{-12} second after its creation.

Specially, detailed properties of the Higgs boson, top quark, dark matter particle, … will be studied.

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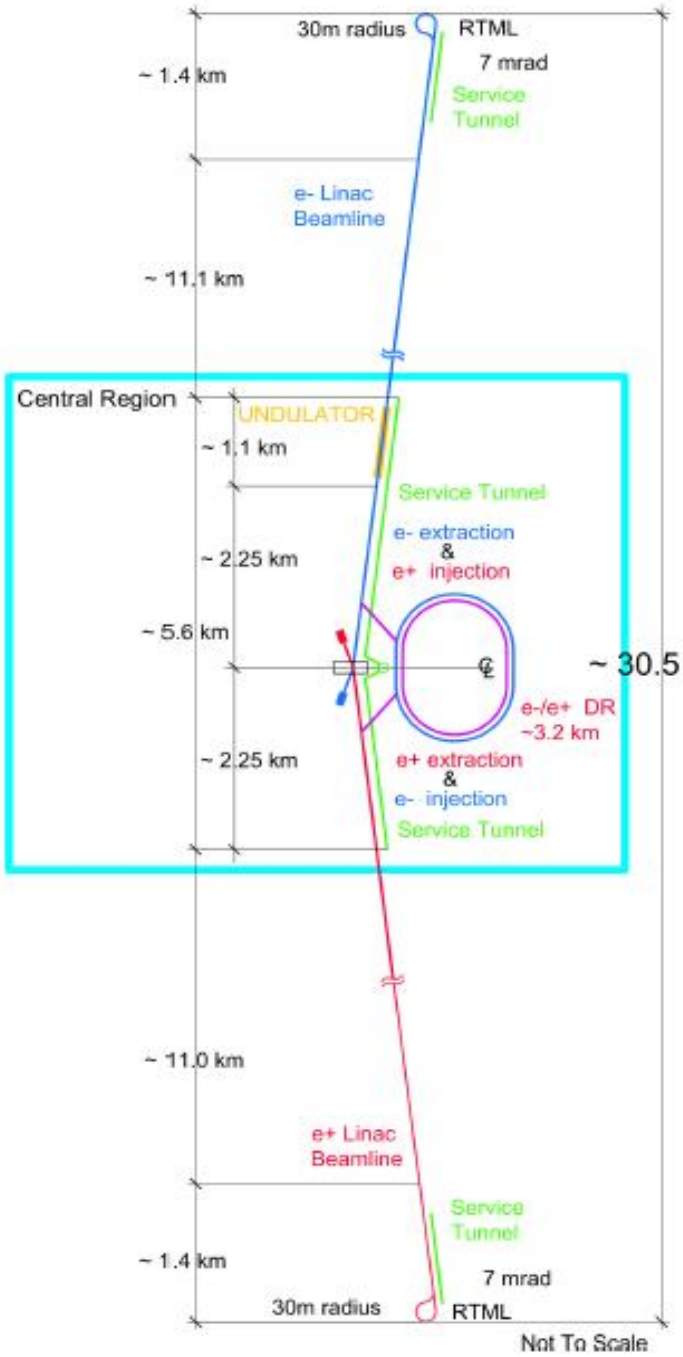
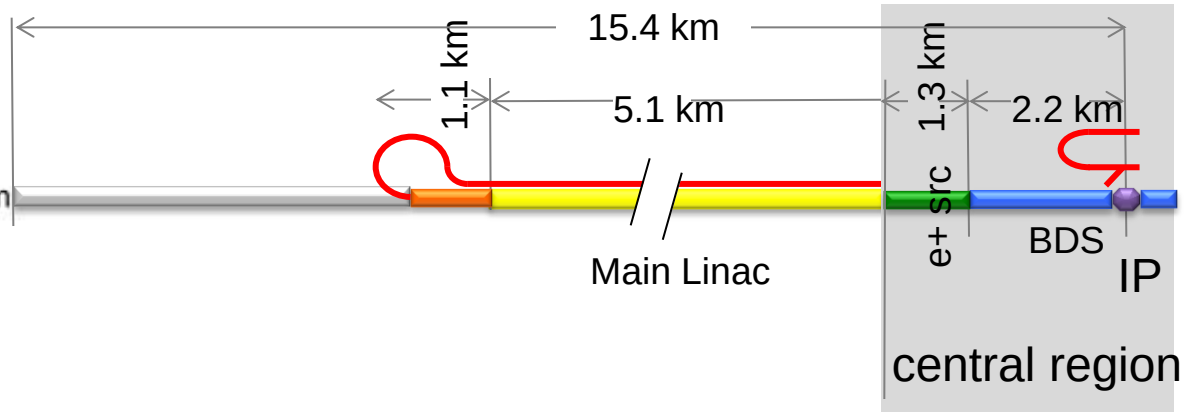
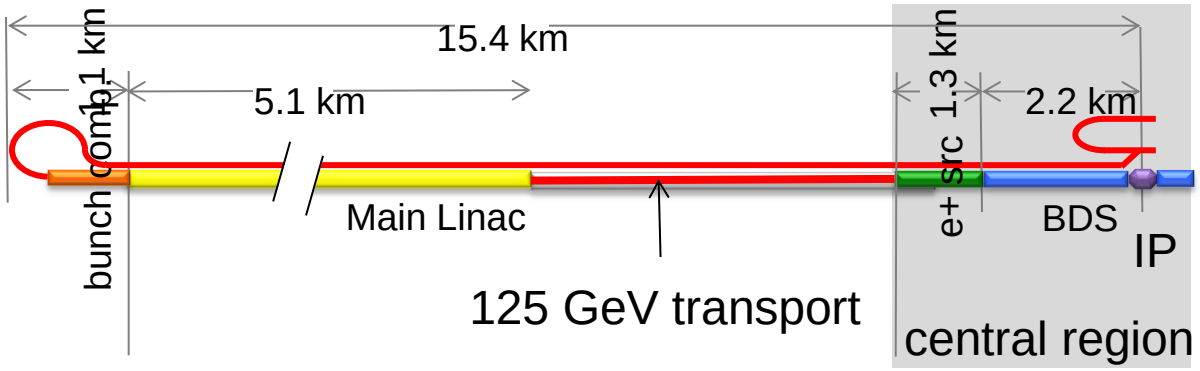
Advantage of linear collider

(1) No energy loss due to synchrotron radiation

(2) Extendability (length ⇒energy)







Challenging technology of ILC

(1) Very high acceleration gradient with super-conducting linac

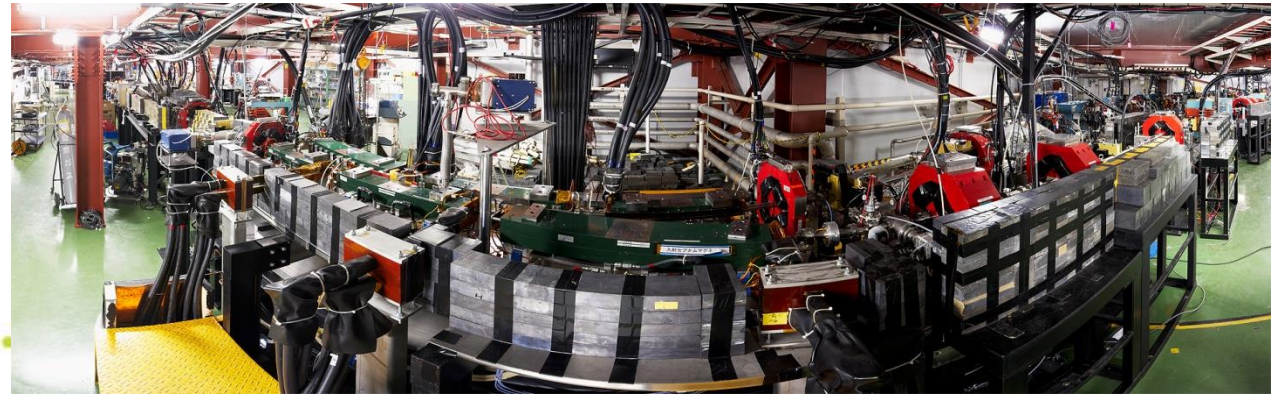
⇒ shorter length ⇒ low construction cost

super-conducting ⇒ low running cost

(2) Face-to-face collision of very narrow (flat) beams

⇒ increase interaction probability ⇒lower running cost

Both technologies are established as shown in TDR



Very Brief History of the Linear Collider Project

1980s LC Accel. R&D was started at DESY, KEK, SLAC

1991 **First Linear Collider Workshop (Finland)**

1990s Five major accelerator technologies were under hard competition：
TESLA , S-band, C-band, X-band, CLIC

1998 Physics and detector issues are rather accelerator independent
World-wide-studies of physics and detector for LCs was formed (grass-roots-organization)

2000 Under OECD Global Science Forum, Consultative Group of High Energy Physics started (2000-2002)

2002 ICFA created **ILC Steering Committee (ILCSC)**

2004 International Technology Recommendation Panel **(ITRP) chose super-conducting RF for the main linac technology**

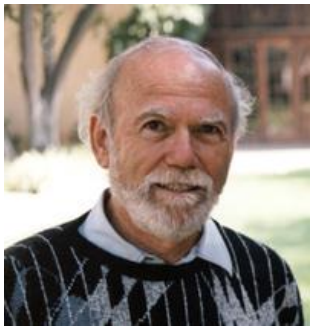
International Technology Recommendation Panel Meeting
August 11 ~ 13, 2004. Republic of Korea

2004 KEK DG Yoji Totsuka held first workshop at KEK on LC with Superconducting RF technology

2005 Global Design Effort (GDE) was established

Snowmass Meeting

GDE Director
Barry Barish



2007 Reference Design Report（basic design with cost)

Project Managers

Marc Ross

Nick Walker

Akira Yamamoto

Regional Directors

Michael Harrison

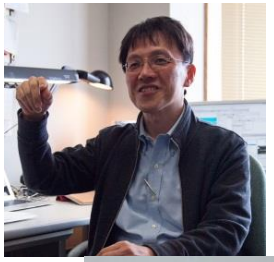
Bryan Foster

Kaoru Yokoya

2009 LOI for detector concepts (ILD,SiD)

Research Director Sakue yamada

Recent Activities



2012 March Recommendation of subcommittee for future projects of Japanese HEP (chair: Toshinori Mori)

May ILC strategy council (chair:Satoru Yamashita)
Site selection committee was formed under this council (cochair: K. Kawagoe, H.Yamamoto)

July **Higgs Boson was discovered at LHC**

Oct. A Proposal for a Phased Execution of the International Linear Collider Project
(The Japan Association of High Energy Physicists)

Dec. **Technical Design Report（TDR)**

2013 Feb. ICFA creates Linear Collider Board（LCB） and Linear Collider Collaboration (LCC) (Director: Lyn Evans)

A Proposal for a Phased Execution of the International Linear Collider Project

The Japan Association of High Energy Physicists (JAHEP) endorsed the document on 18 October 2012

ILC shall be constructed in Japan as a global project based on agreement and participation by the international community.

Physics : Precision study of “Higgs Boson” , top quark, “dark matter” particles, and Higgs self-couplings,

Scenario : Start with a Higgs Boson Factory ~250 GeV. Upgraded in stages up to a center-of-mass energy of ~500 GeV, which is the baseline energy of the overall project.
Technical extendability to a 1 TeV region shall be secured.

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.

Supports from the World

Asia ACFA-HEP

Chair: Mitsuaki Nozaki (KEK) 3rd ACFA-HEP Meeting on 17.07.2013 in Chiba Japan A document will be ready soon

European Strategy

Chair: Tatsuya Nakada (Swiss Federal Institute of Technology Lausanne)

e) There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. *Europe looks forward to a proposal from Japan to discuss a possible participation.*

Obviously the highest priority is for Europe is LHC and LHC Luminosity upgrade.
ILC should not interfere with the LHC upgrade (the timing and the budget)

HEPAP Facilities Subpanel :
Report on High Energy Frontier Facilities

Sally Dawson

US Participation in Japanese Hosted ILC

- Science drives the need for e^+e^- collider
  - ILC addresses absolutely central physics questions and is complementary to the LHC
  - Japanese hosted ILC could be under construction before 2024
- Parameters of a potential US contribution are not known and depend on international agreements
  - The US has made substantial contributions to detector and accelerator development through the global effort
  - Should an agreement be reached, the US particle physics community would be eager to participate in both the accelerator and detector construction

Federation of Diet members to promote a construction of international laboratory for LC

31st July 2008 established a suprapartisan ILC supporters

(July 2008～)

President	Kaoru Yosano
Deputy	Yukio Hatoyama
Secretary-General	Takeo Kawamura
、	Yoshihiko Noda
Director	Norihisa Tamura
	Masamitsu Naito

proposers

Akihito Ohhata、Koji Omi、Ikuo Kamei, Takeo Kawamura, Tetsuo Saito, Yoshiaki Takagi, Norihiko Tamura, Masamitsu Naito, Yoshihiko Noda, Yukio Hatoyama、Fumuhiro Himori, Kosuke Hori, Eisuke Mori, Kaoru Yosano、Hidekatsu Yoshii

Renewed on 1st Feb 2013 lead by Takeo Kawamura

New Officers (October 2011～)

Supreme advisor	Kaoru Yosano
President	Yukio Hatoyama
Acting president	Takeo Kawamura
Secretary-general	Tatsuo Kawabata
Deputy	Tatsu Shionoya
Dupty President	Tetsuo Saito
President of bureau	Norihisa Tamura
Director of bureau	Keisuke Tsumura
Deputy	Takeshi Kai

Advanced Accelerator Association of Japan (AAA)

June 2008 established an industry-academy collaboration

Industry: >90 companies (Mitsubishi HI、Toshiba、Hitachi、Mitsubishi Electric、Kyoto Ceramic et al.) Academy: 38 institutes (KEK, Tokyo、Kyoto、Tohoku, Kyushu, RIKEN, JAEA et al.)

AAA homepage http://aaa-sentan.org

Supreme advisor	Kaoru Yosano
President Emeritus	Masatoshi Koshiba
President	Takashi Nishioka (Mitsubishi HI)
Trustee	Atsuto Suzuki (KEK)
〃	Akira Maru (Hitachi)、
〃	Yoshiaki Nakaya (Mitsubishi Electric)
〃	Yasuji Igarashi (Toshiba)、
〃	Akira Noda (Kyoto University)
〃	Keijiro Minami (Kyoto ceramic)
Auditor	Sachio Komamiya (University of Tokyo)

Lyn Evans visits Prime Minister Abe et al.

Apr 25-27, 2013, Tokyo

- Visited
  - Prime Minister Shinzo Abe
  - Miinitster of sicence and technology, Ichita yamamoto:
  - Takeo Kawamura: chair of the federation of diet members for ILC, former MEXT minister

    With Koshiba, Murayama, Yamashita
  - Hakubun Shimomura: MEXT minister
  - HIroya Masuda: former minister of interior
  - Kiyohiko Ito: managing director JACE (Japanese Association of
  - Corporative Executives: Industry)
  - etc. etc.

Very Recent Activities

2013 April ILC Taskforce started in MEXT Japan

2014 May ECFA LC (DESY, Hamburg)

2013 June ILC Event TDR Review is completed

(Tokyo ⇒Geneva ⇒Chicago)

2013 June-August In Science Council of Japan

ILC Review Committee was formed

2013 July EPS-HEP 2013 (Stockholm, Sweden)

2013 Summer A site in Japan will be chosen by scientists (MEXT, Politicians all agree to the process)

2013 Nov. 11-15 LCWS2013 The University of Tokyo

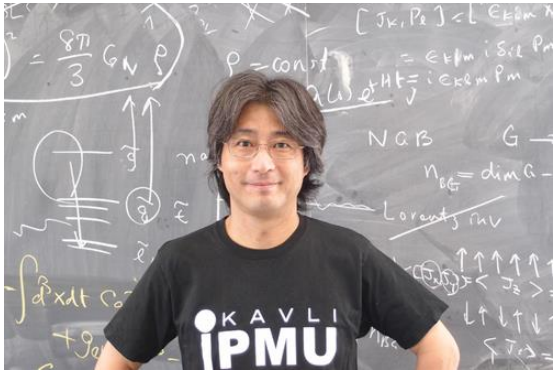
The new leaders (TD phase to ED phase)
Linear Collider Directorate = LCD

Michael Harrison
ILC Accelerator

Hitoshi Yamamoto
Physics and Detector

Steinar Stapnes
CLIC Accelerator

Lyn Evans
Director



Hitoshi Murayama
Deputy

The Next Step

- Move from the Technical Design Phase to the Engineering Design Phase towards the real construction

  Both Accelerator and Detectors

- Reinforce Public relations as a the global project

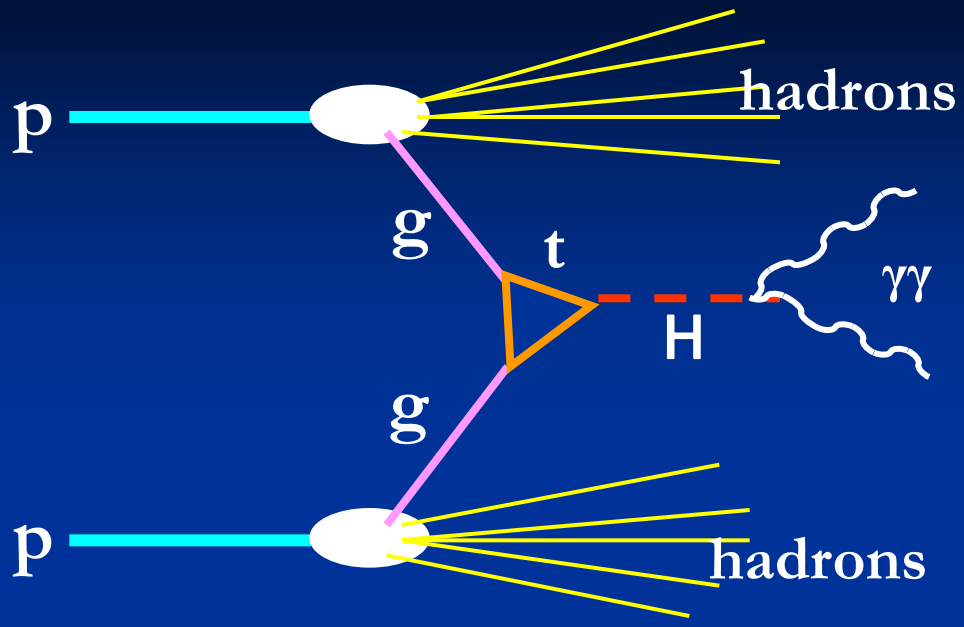
Work with governments

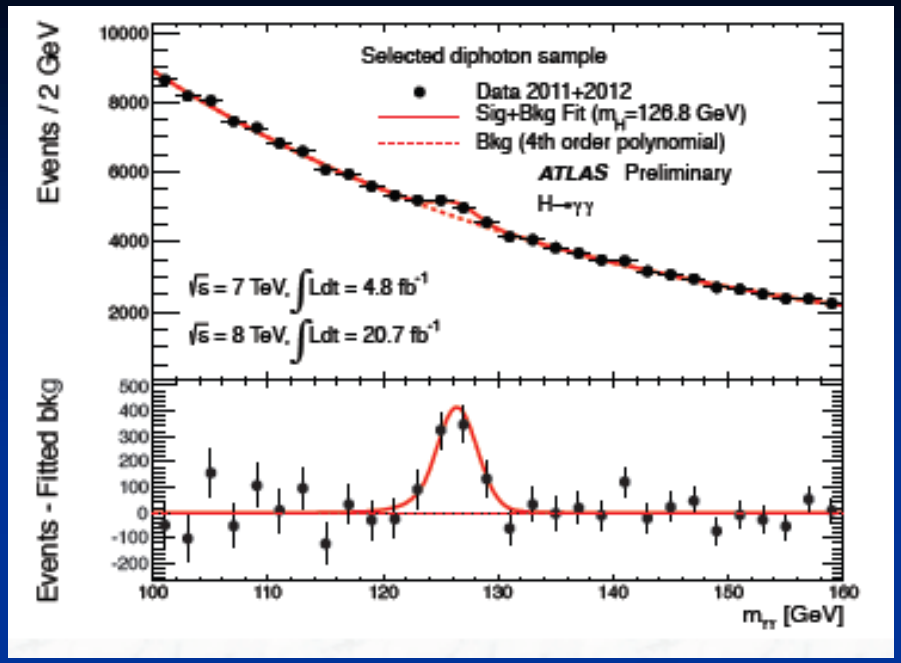
- Site and host country establishment
- Establish the organization of ILC laboratory

  refer to the “Project Implementation Plan” of TDR

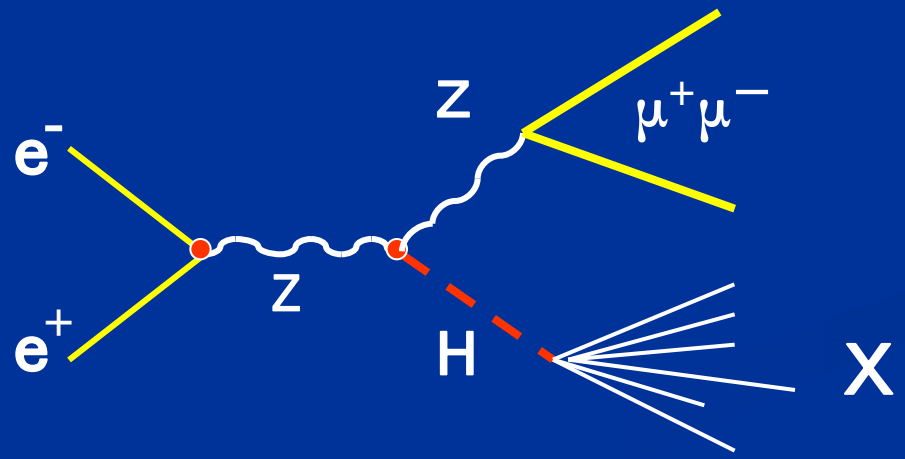
- International negotiation of the cost share etc.

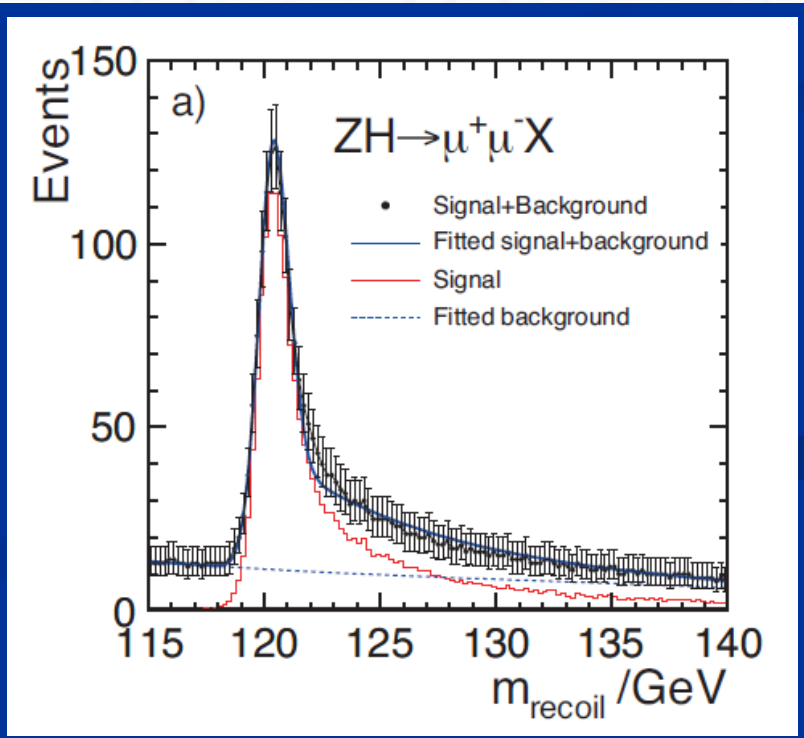
LHC $H\rightarrow\gamma\gamma$ mass distribution





ILC $\mu^+\mu^-$ recoil mass distribution





Higgs Boson

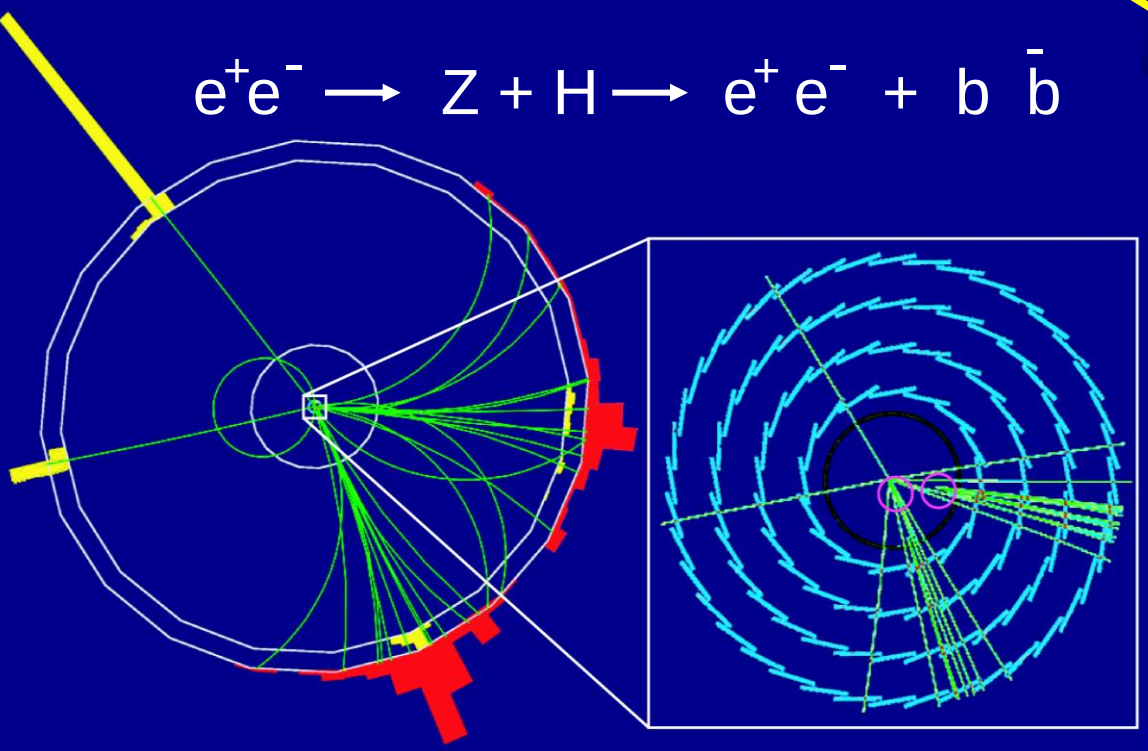
Precise measurement of Higgs Boson
⇒Deduce Principal Low in the Nature

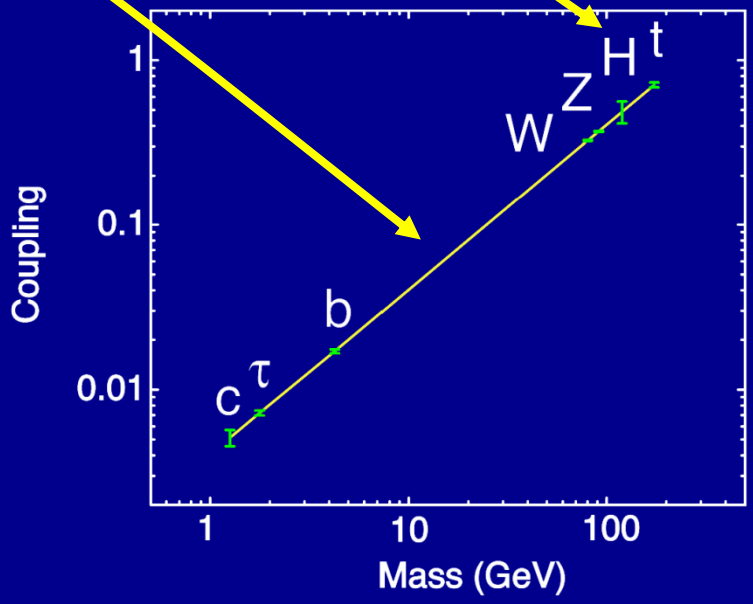
ILC in the first phase is the Higgs Boson Factory

O(10^5) such events will be collected and studied.

Origin of mass ⟷ Structure of the 'vacuum`

$e^+e^- \longrightarrow Z + H \longrightarrow e^+ e^- + b\ \bar{b}$





Importance of Precise Measurement of Higgs Properties
Decoupling Theory Light Higgs Boson ~ SM Higgs Boson

Just for example: Two Doublet Model (SUSY) ILC TDR

Coupling of h = 126GeV Higgs and weak gauge bosons

V = W, Z

$$g(hVV)/g(hVV)_{SM}$$

$$= \sin(\beta-\alpha)$$

$$\sim 1-2c^2 m_Z^4 \cot^2\beta/m_A^4$$

$$\sim 1-0.3\%(200\ \mathrm{GeV}/m_A)^4$$

Coupling of h and SU2(2) I_w=1/2 quark

$$g(htt)/g(htt)_{SM} = g(hcc)/g(hcc)_{SM}$$

$$= \cos\alpha/\sin\beta = \sin(\beta-\alpha) + \cot\beta\cos(\beta-\alpha)$$

$$\sim 1-2c\cdot m_Z^2\cot^2\beta/m_A^2$$

$$\sim 1-1.7\%(200\ \mathrm{GeV}/m_A)^2$$

Deviations from the Standard Model Higgs couplings are very small even for ILC precise measurements.

Coupling of h and quarks and leptons with $I_w = -1/2$

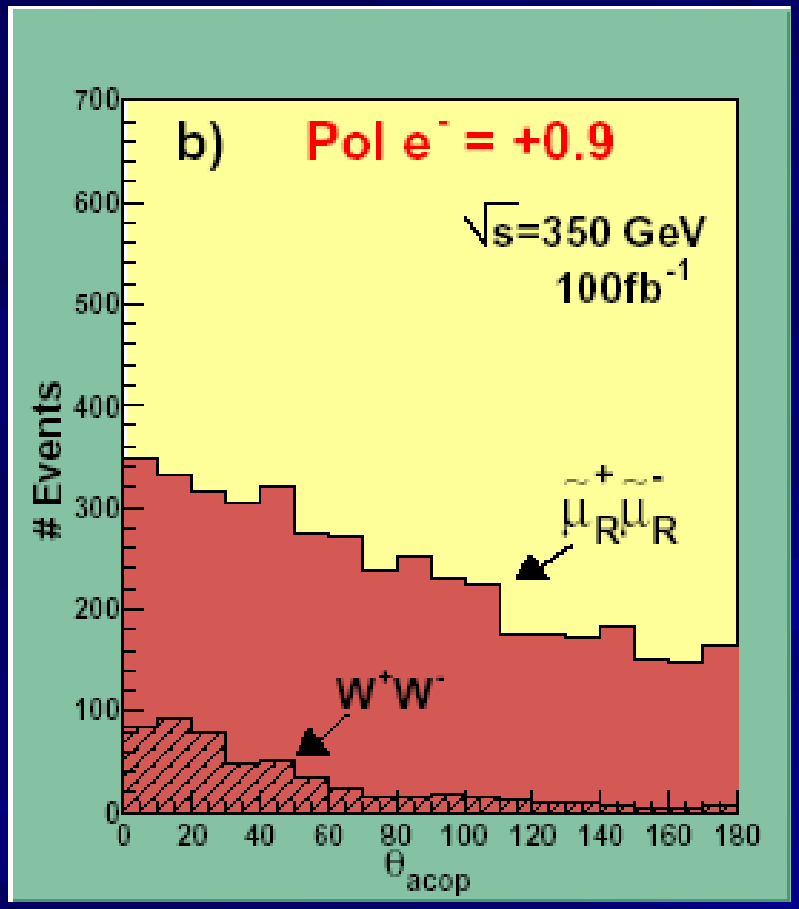
$g(hbb)/g(hbb)_{SM} = g(h\tau\tau)/g(h\tau\tau)_{SM}$
$= -\cos\alpha/\cos\beta = \sin(\beta-\alpha) - \tan\beta\cos(\beta-\alpha)$
$\sim 1+2c\cdot m_Z^2/m_A^2$
$\sim 1 + 40\%(200\ \mathrm{GeV}/m_A)^2$

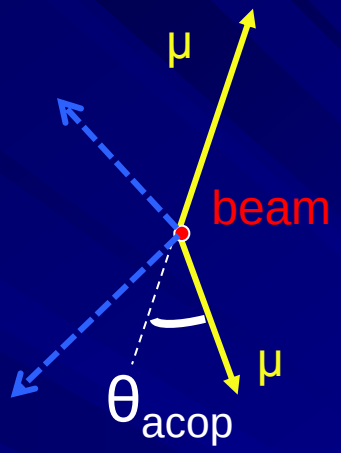
The deviations must be seen at ILC even for m_A ~1000GeV.

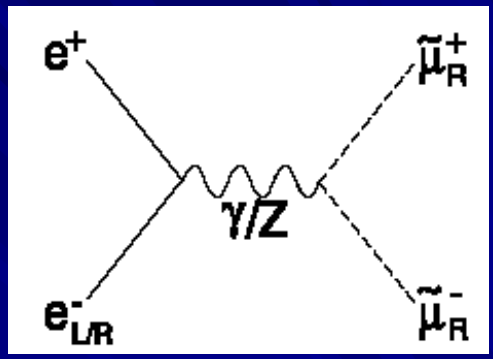
Very difficult for LHC

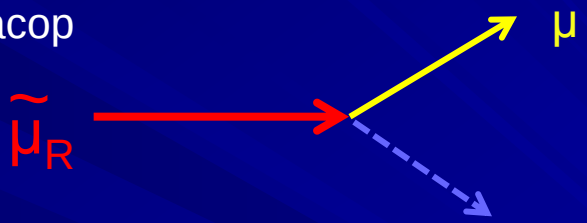
Power of electron polarization at ILC

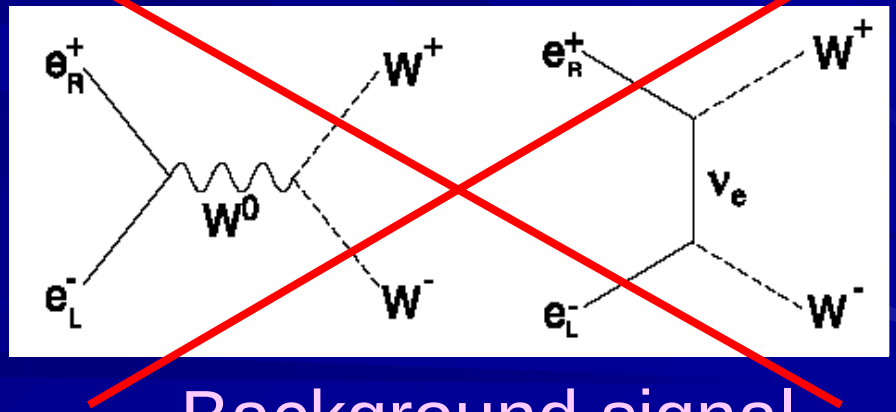
Scalar muon production







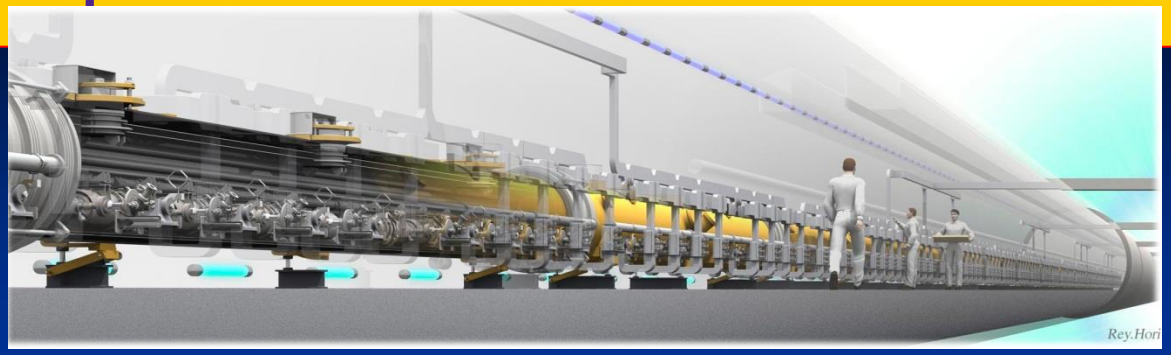




Polarized (90% e^-_R) :ed

Background signal

Possibility of Japan to be a host of ILC



Some facts to believe Japan to host ILC, if we work very hard for the next few years.

1) Discovery of Higgs Boson at LHC
2) TDR of ILC project is completed.
3) CERN is expected to work on LHC upgrade
   Support from international community
   Europe, Americas, Asians
4) Supports of Political and Industrial sectors
   ・Advanced Accelerator Association of Japan
5) Started site studies with dedicated funding
6) Agreement in the HEP community in Japan
   ・Report from subcommittee of future HEP projects of Japan (March 2012)
   ・Phased Excecution of ILC（October 2012）

The Jump-Start Scenario (Very optimistic but not impossible)

2013 July Site evaluation by scientists will be completed in Japan

2013 fall New organization within Japanese government is expected to be formed and in preparation to bid to host the ILC

2014-15 Intergovernmental negotiation
Linear Collider Collaboration (Lyn Evans and ILC sector) continue to refine the design and organization of the global lab for ILC

2015 International Review of the ILC project (LHC physics @13-14 TeV)

2016 Construction starts (accelerator + detectors)

2026 Commissioning of the ILC machine

Quest for Birth-Evolution of Universe

International Linear Collider (ILC)

Quest for Unifying Matter and Force

KEK DG keeps showing this ugly slide since 2008

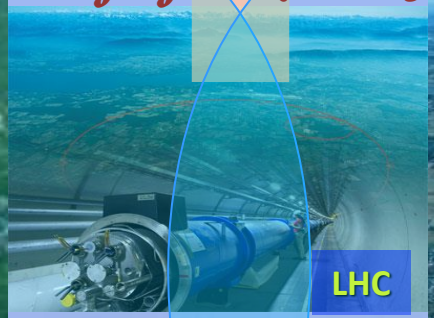
Lepton CP Asymmetry

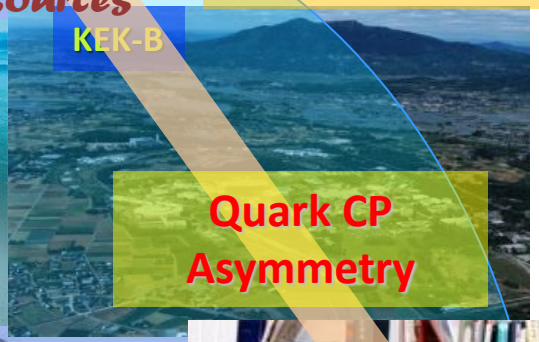
Scientific Activities
Technology Innovation
Encouraging Human Resources

Beyond Standard Physics

Power-Upgrade

Super-KEKB



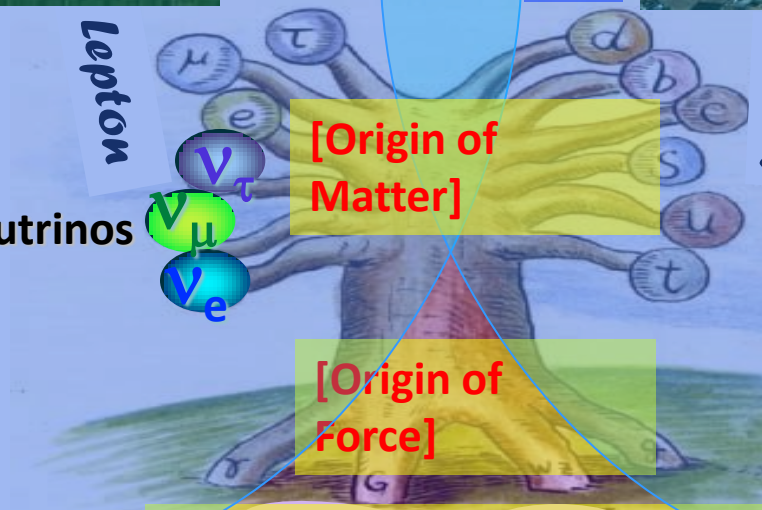


Quark CP Asymmetry

Quest for 6 Quarks

Lepton

Quark

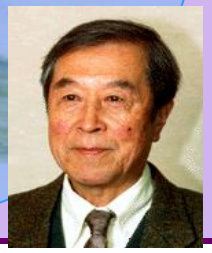


Quest for Neutrinos

[Origin of Matter]

[Origin of Force]

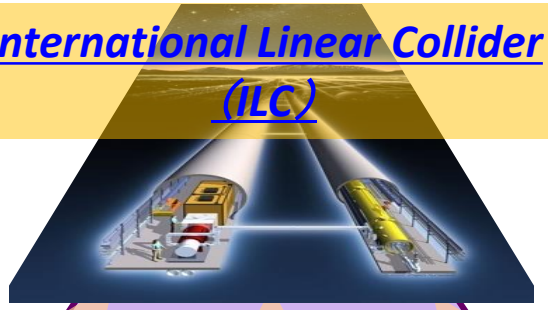
Higgs Particle [Origin of Mass]



Quest for Birth-Evolution of Universe

International Linear Collider (ILC)

Quest for Unifying Matter and Force



Lepton CP Asymmetry

Scientific Activities
Technology Innovation
Encouraging Human Resources

Beyond Standard Physics

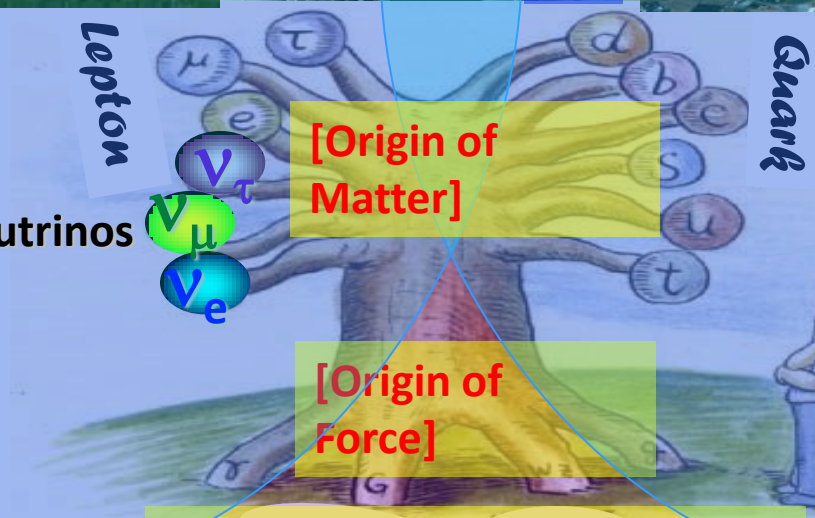
Power-Upgrade

Super-KEKB

All roads lead to ILC

Lepton

Quark

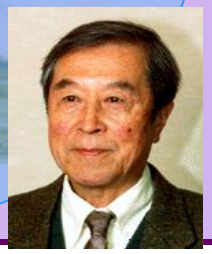


Quest for Neutrinos

[Origin of Matter]

Quest for 6 Quarks

[Origin of Force]



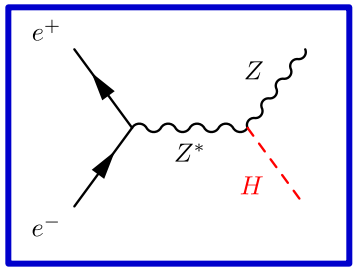
Higgs Particle [Origin of Mass]

Until 4th July 2012, for more than 20 years, we keep agitating that a Revolution in the field of particle physics is inevitable.

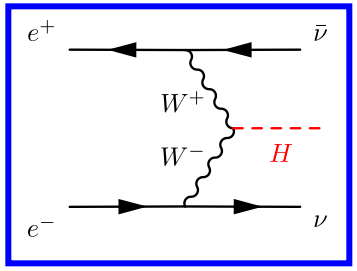
⇒ Discovery of "Higgs Boson" = The July revolution has started

⇒ This is just a start of an enormous revolutionary era overwhelming the Standard Model = the Ancien Regime.

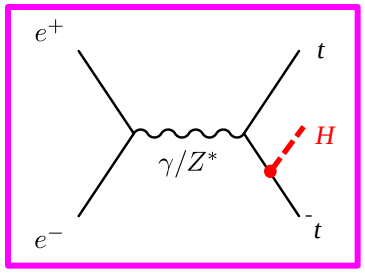
Higgs Couplings at ILC



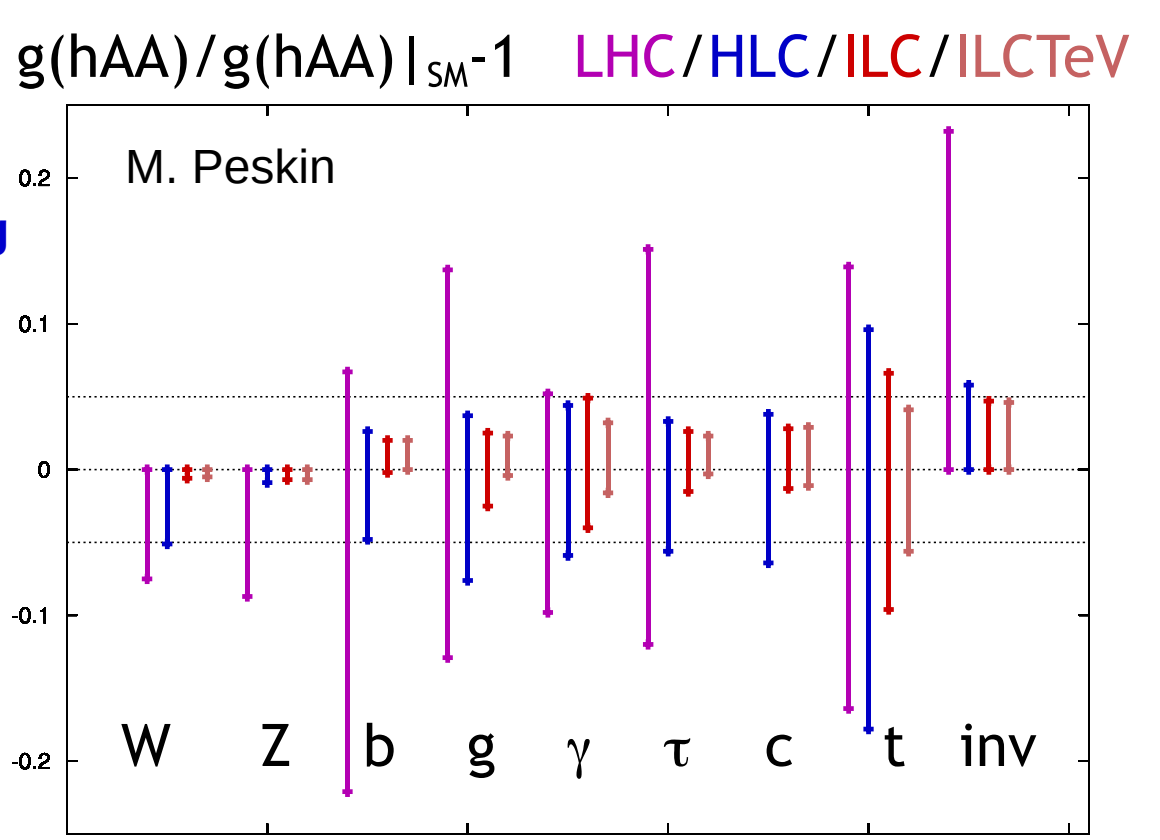
250 GeV~ Higgs BR via Higgs-strahlung



350 GeV~ Higgs BR via WW fusion



500 GeV~ Top Yukawa Coupling



LHC 14 TeV 300 fb^{-1}
ILC 250 GeV 250 fb^{-1} 500 GeV 500 fb^{-1} 1TeV 1000fb^{-1}

Measurement of σ × BR → Input to global fit → Extract Higgs couplings
Exploit LHC / ILC synergy. M. Peskin hep-ph 1207.2516

Deviations from SM prediction is expected to be small O(%) level

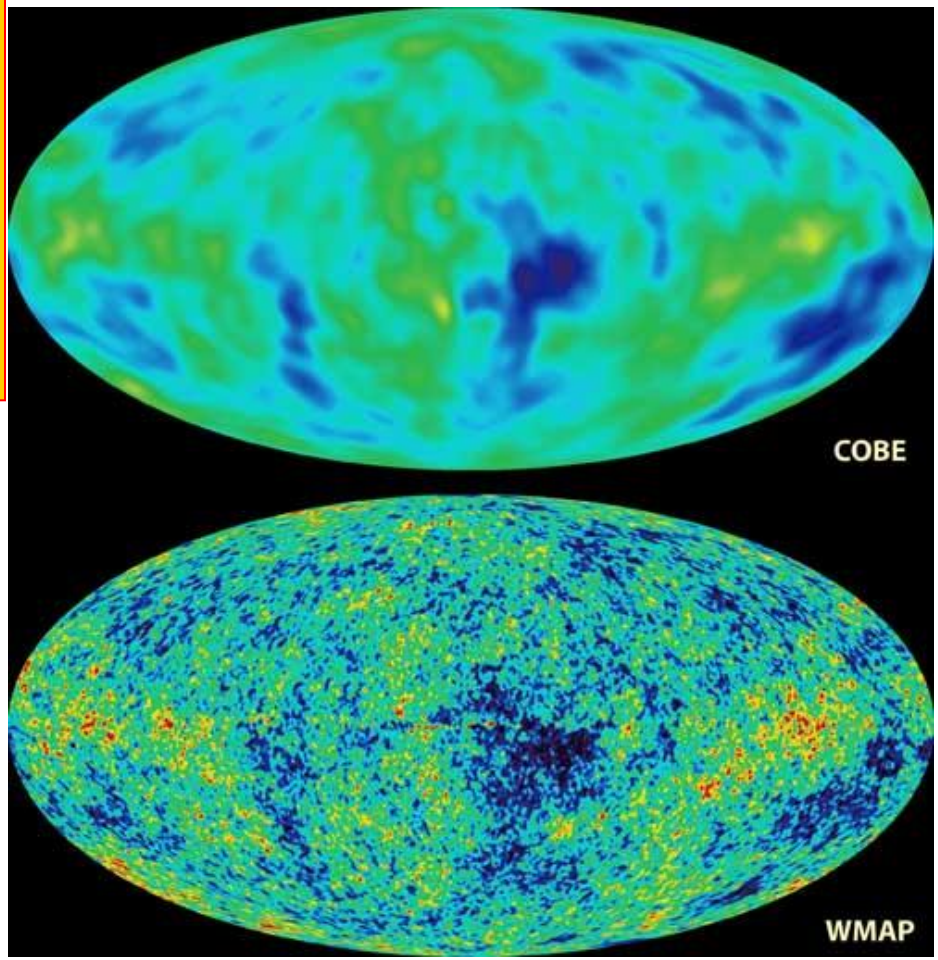
Impact of Precise Measurement

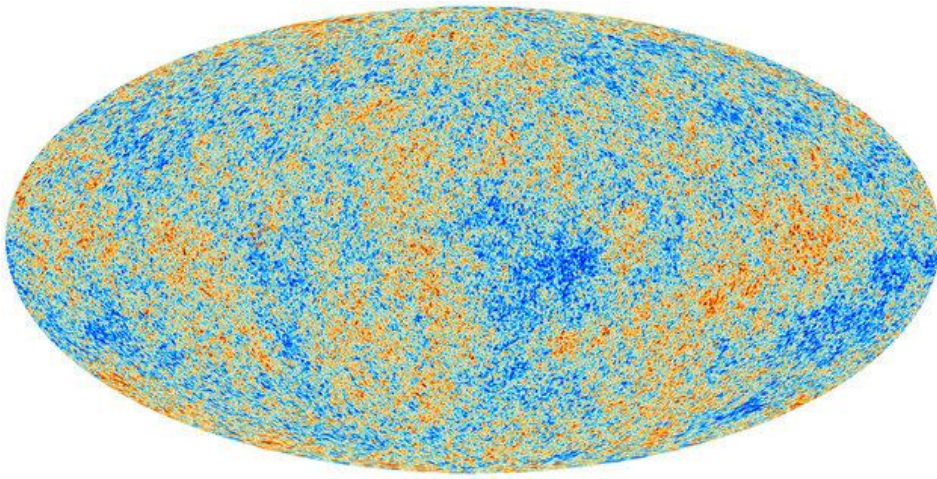
A. Wagner

COBE 1990
Angular resolution = 10˚
Temperature fluctuation 10^{-5}K

WMAP 2003
Angular resolution = 10’
τ(the Universe) =13.69±0.13 Gyr
Polarization measurement

Planck 2013
τ(the Universe) =13.796±0.058 Gyr





Complementarity and synergy between hadron and e^+e^- colliders (based on the experimental facts)

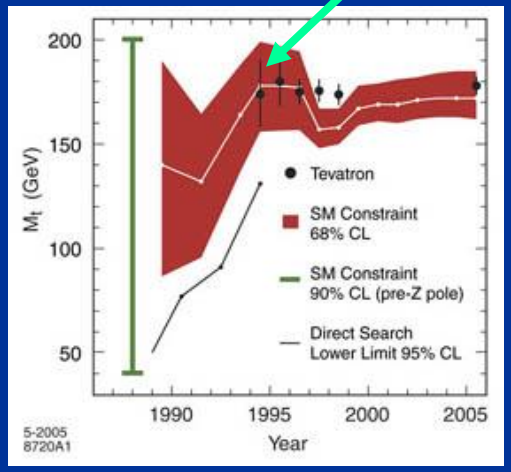
Story of Top Quark and Higgs Boson

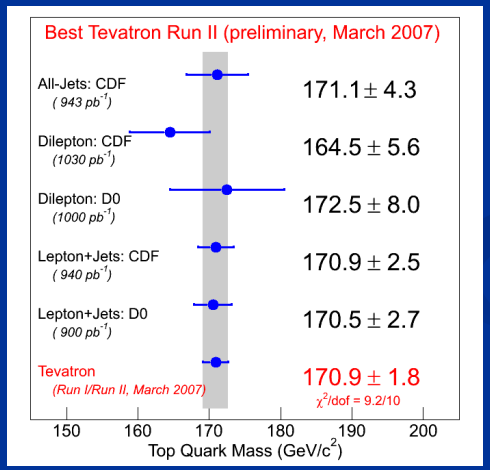
From precise electro-weak measurements at LEP, top mass was predicted

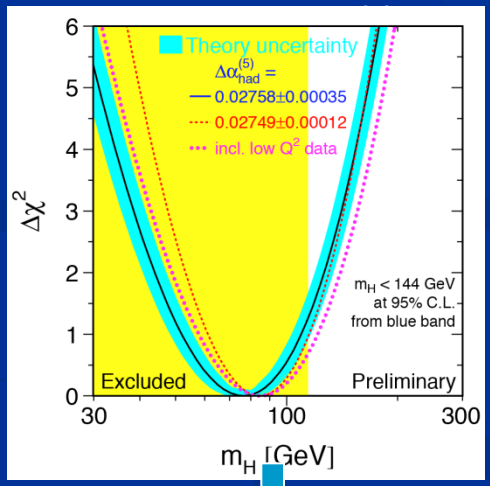
Discovery to Top

Precise Measurement of Top mass at the TEVATRON

Higgs mass is restricted into a narrow mass range using precise top mass and LEP/SLC electro-weak data
$114\ \text{GeV} < M_H < 160\ \text{GeV}$

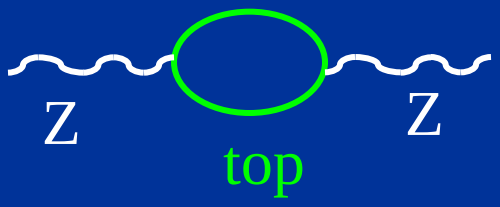




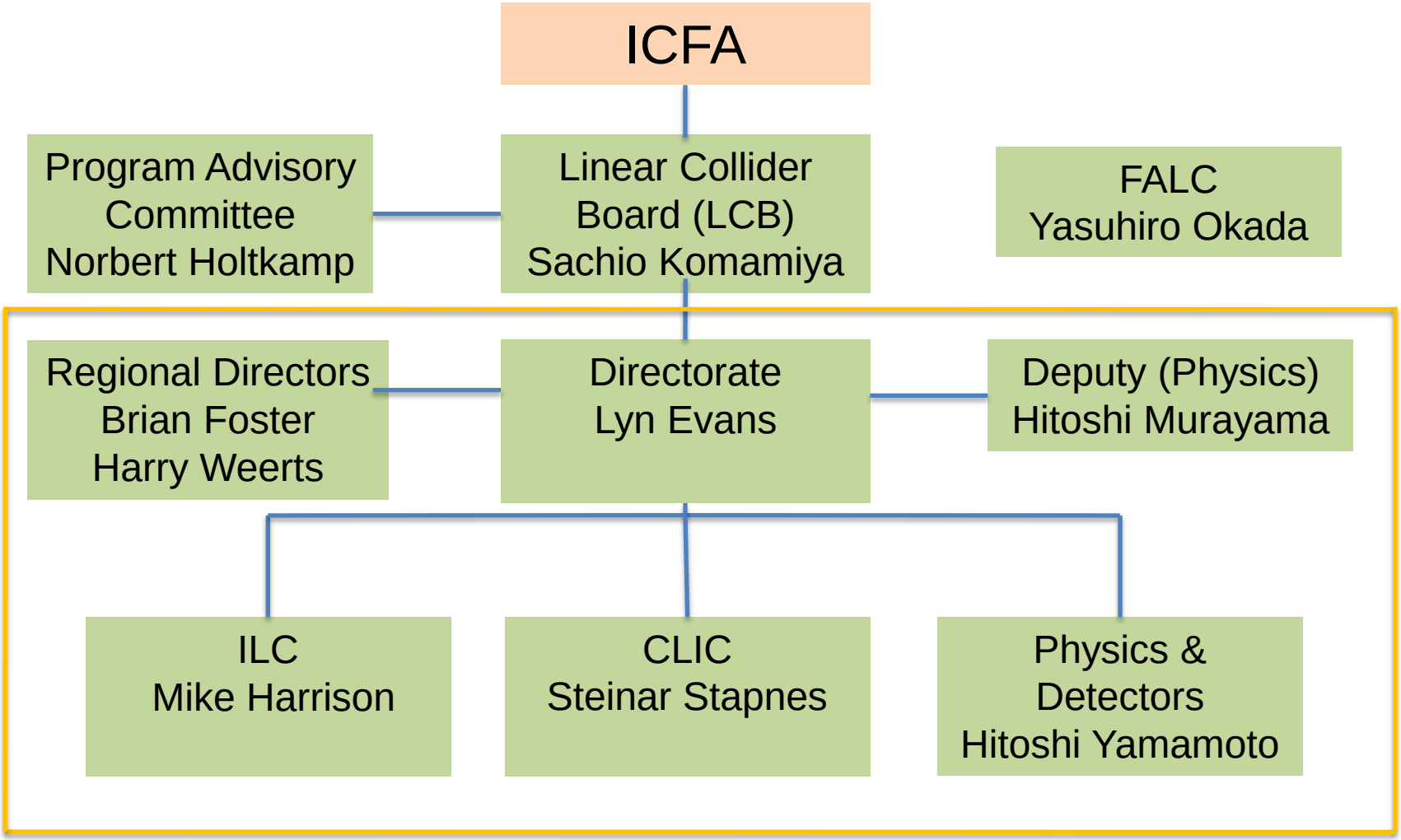


Discovery of Higgs at LHC

Precise measurements of Higgs properties at **ILC**



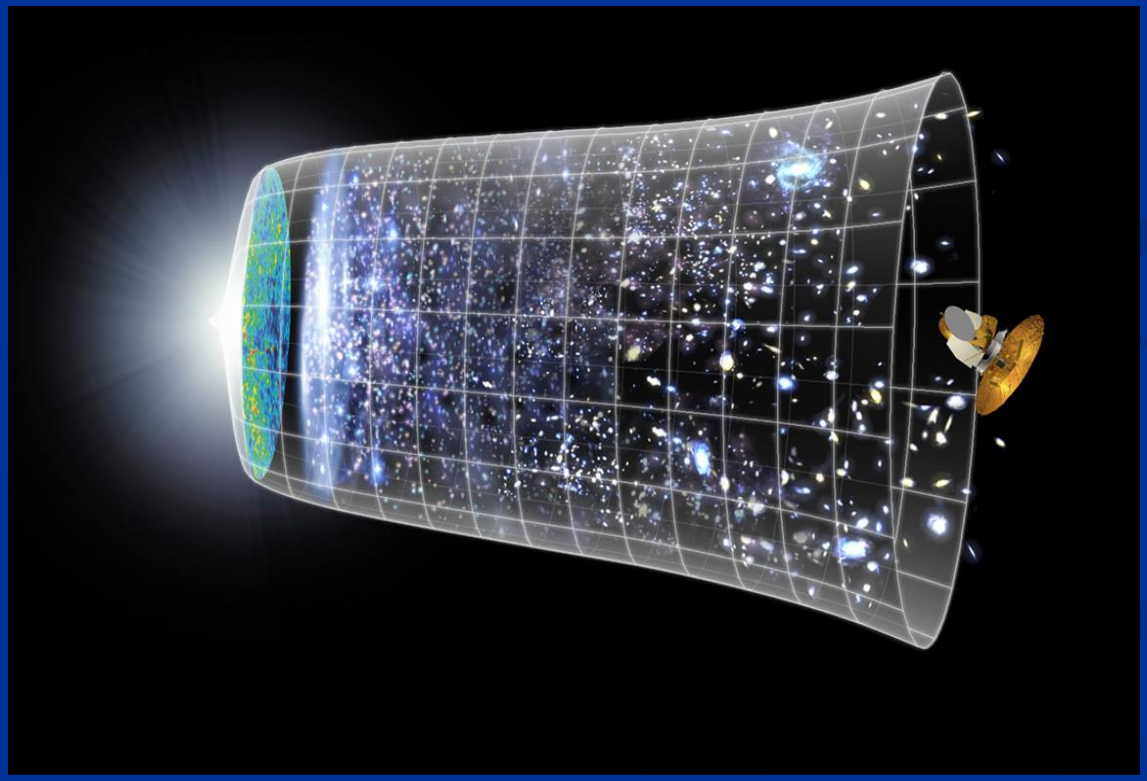
Organization of Linear Collider Projects

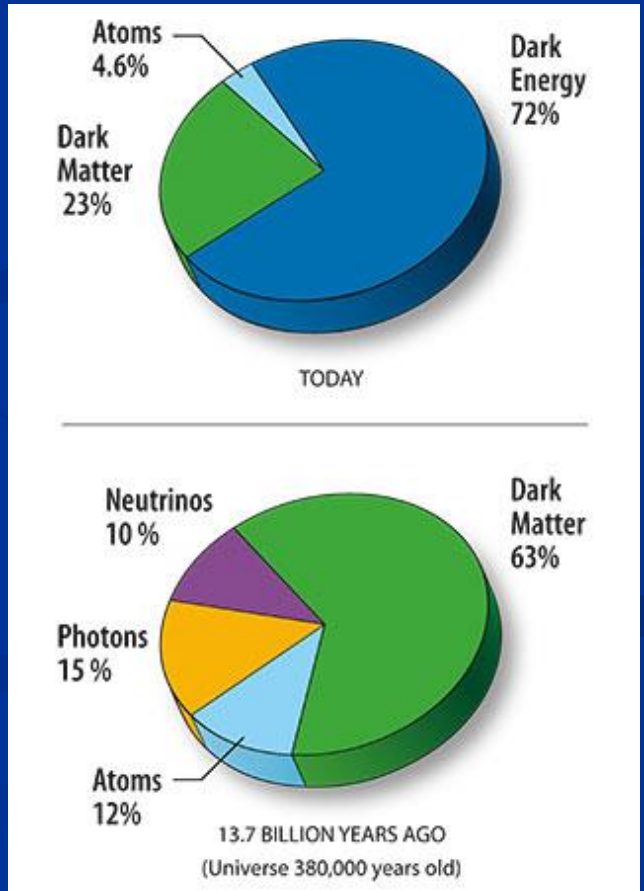


Linear Collider Collaboration = LCC

From Higgs to the Universe

Investigation of Higgs boson (scalar particle has the same quantum numbers as for the vacuum) can be the zeroth step to understand inflation of the universe and dark energy.

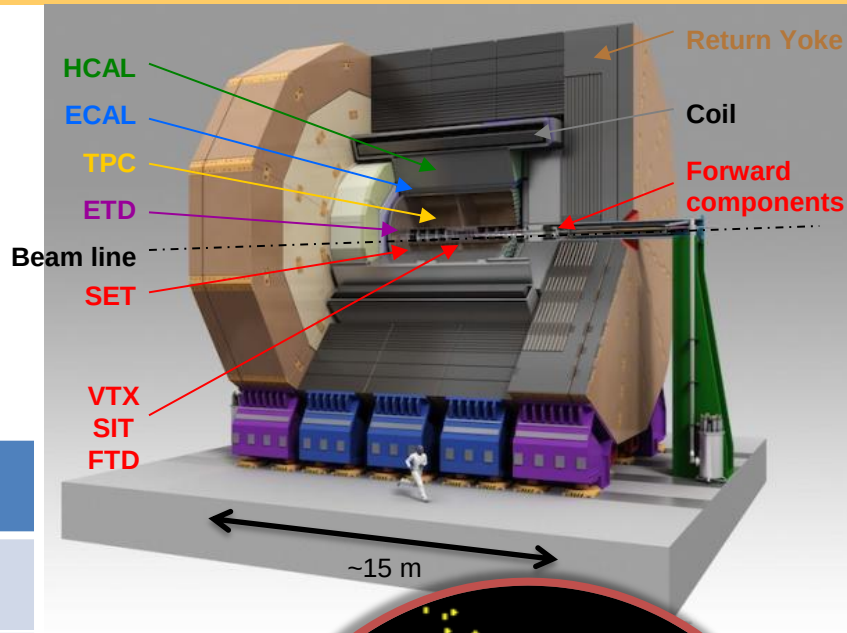




ILC Detector R&D

Tanabe, ICEPP

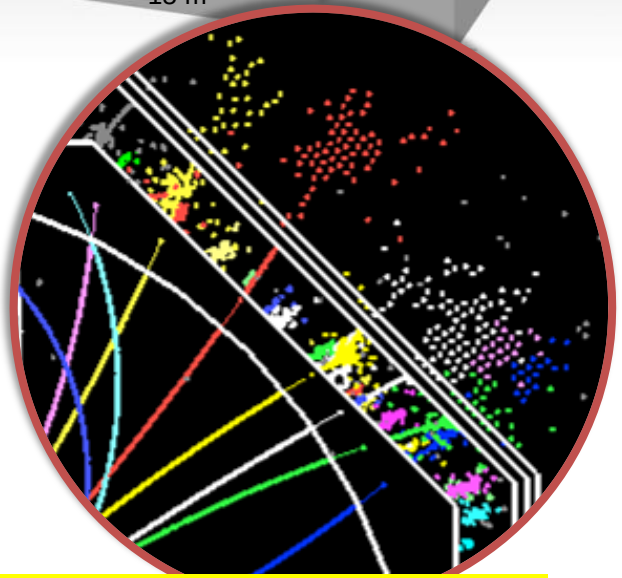
- **Vertex Detector: pixel detectors & low material budget**
- **Time Projection Chamber: high resolution & low material budget, MPGD readout**
- **Calorimeters: high granularity sensors, 5x5mm^2 (ECAL)、3x3cm^2 (HCAL)**



Sensor Size	ILC	ATLAS	Ratio
Vertex	5 × 5 mm^2	400 × 50 mm^2	x800
Tracker	1 × 6 mm^2	13 mm^2	x2.2
ECAL	5 × 5 mm^2 (Si)	39 × 39 mm^2	x61

Particle Flow Algorithm

Charged particles → Tracker,
Photons → ECAL, Neutral Hadrons → HCAL
Separate calorimeter clusters at particle level
→use *best* energy measurement for *each* particle.
→offers unprecedented **jet energy resolution**

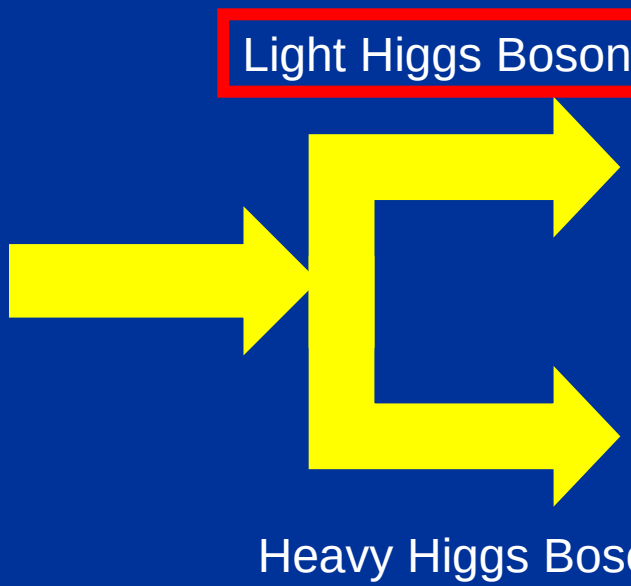


State-of-the-art detectors can be designed for ILC

Higgs Boson mass is responsible for a big branching in the particle physics history
Higgs Boson is a window beyond the Standard Model

~125 GeV Higgs Boson is categorized as a light Higgs Boson

Elementary Higgs Boson
Supersymmetry ?
Stabilization of Higgs mass

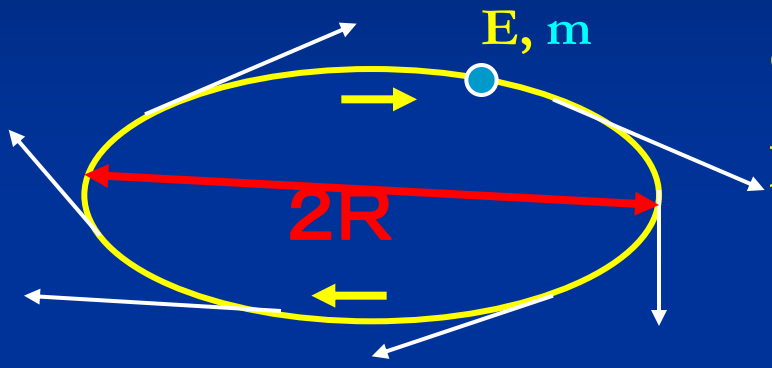


Composite Higgs Boson
Technicolor etc. ???

Many experiementalists could not trust the existence of the Higgs Boson, since it looks too expedient and artificial.

Limit of High Energy Circular e+e- Colliders

Reaction is simple, experiment is clean but…



Electron and positrons loose energy due to synchrotron radiation

Energy loss per trun ΔE is given by

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

E : particle energy

m : particle mass R : radius

Like a bankruptcy by loan interest

Recover the energy loss and obtain higher collision energy

(1) Use heavier particle (proton mass/electron mass = 1800) ⇒ LHC

(2) Larger radius ⇒ R = ∞ ⇒ Linear collider