Physics at TeV e^+e^- collisions

and prospects for the I L C

(the International Linear Collider)

by K. Hagiwara (KEK, SOKENDAI)

2006.8.2 @ YITP, Kyoto U.
2006.8.9 @ BSM2006, Beijing.

Why do we want a TeV e^+e^- collider in addition to the LHC?

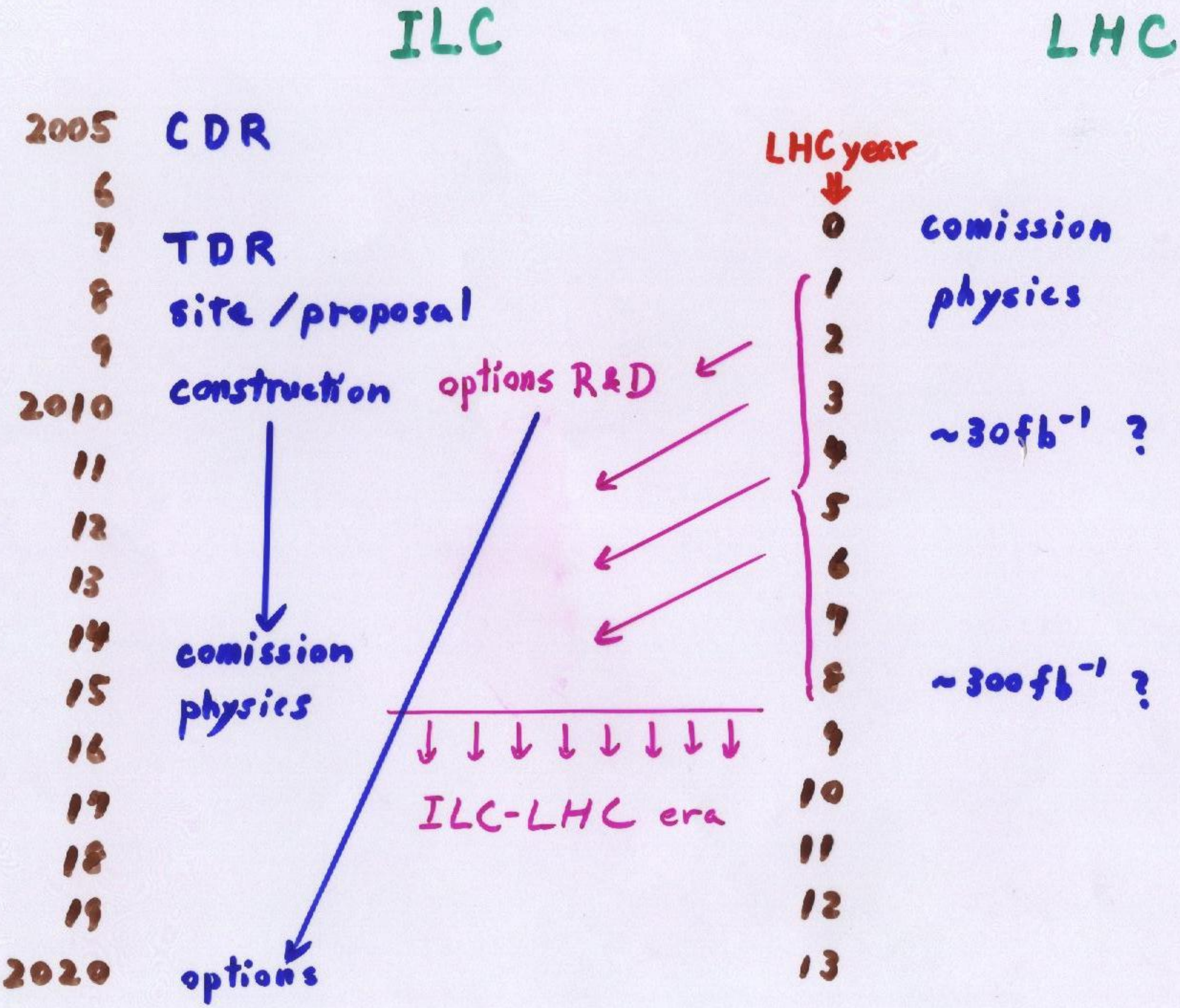
ILC

LHC will discover the Higgs	⇒	detailed properties
will discover new particles	⇒	quantum numbers un-colored partners
will discover new phenomena	⇒	clean effects in e^+e^-, $\gamma\gamma$ collisions
will find no new phenomenon	⇒	precision measurements
masses and couplings of new particles	⇐	masses & couplings of new particles to look for anomaly.

Synergy

Because 14 TeV pp collisions & 0.5 ~ 1 TeV e^+e^- collisions probe TeV physics in a very different environment, we can expect complementality & synergy.

LHC : high energy, high background
ILC : lower energy, clean environment


ILC
LHC
2005 CDR
6
7 TDR
8 site / proposal
9
construction
options R&D
2010
11
12
13
14 comission
15 physics
16
17
18
19
2020 options
LHC year
0 comission
1 physics
2
3
4 ~30 fb^-1 ?
5
6
7
8 ~300 fb^-1 ?
9
ILC-LHC era
10
11
12
13

ILC-I (base design)

- $\sqrt{s}$ = 200-500 GeV — Zh, $\nu\bar{\nu}h$, $t\bar{t}$, W^+W^-
- L > 100 fb^{-1}/year — $>10^4$ h, m_t, W-couplings
- $P(e^-) \sim 80\%$ — quantum #'s of new particles
- EW tests

Physics case independent of LHC

Needed as early as possible for ILC-LHC synergy.

* next pages.

ILC-II, options

- $\sqrt{s}$ = 1 TeV — tunnel length, MV/m
- e^-e^-, $e^-\gamma$, $\gamma\gamma$ — 2'nd int. region, crossing angle
- Giga Z
- e^+ polarization — e^+ source, pol. scheme

} Inputs from LHC

- fixed target (beam dump) — additional detector

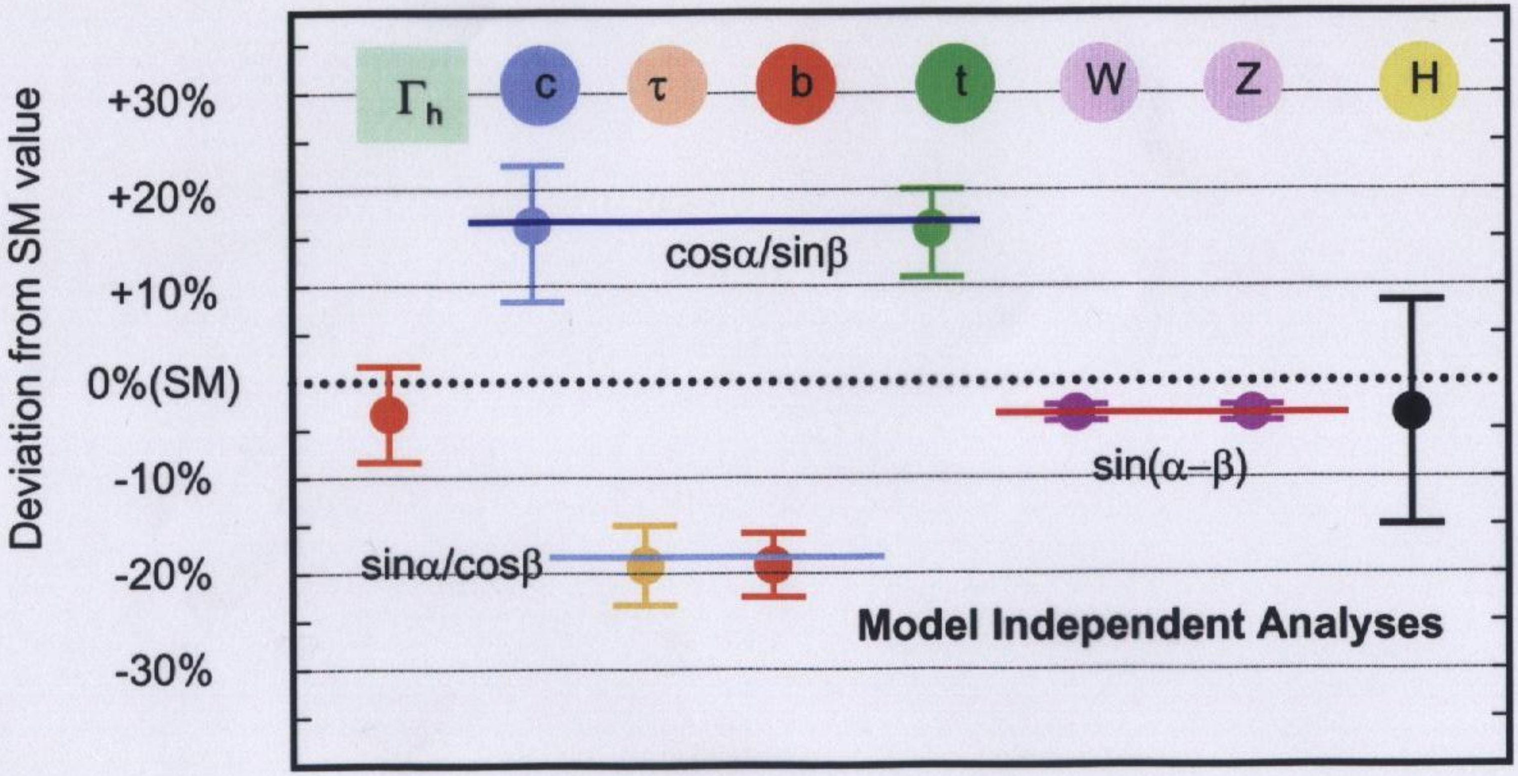
cf. Kanemura et al

$eN \to \tau X$ measures $e\tau$ FCNC

10^3 times better than $\tau \to \mu\gamma$, $\mu\eta$, ...

SUSY or 2HDM

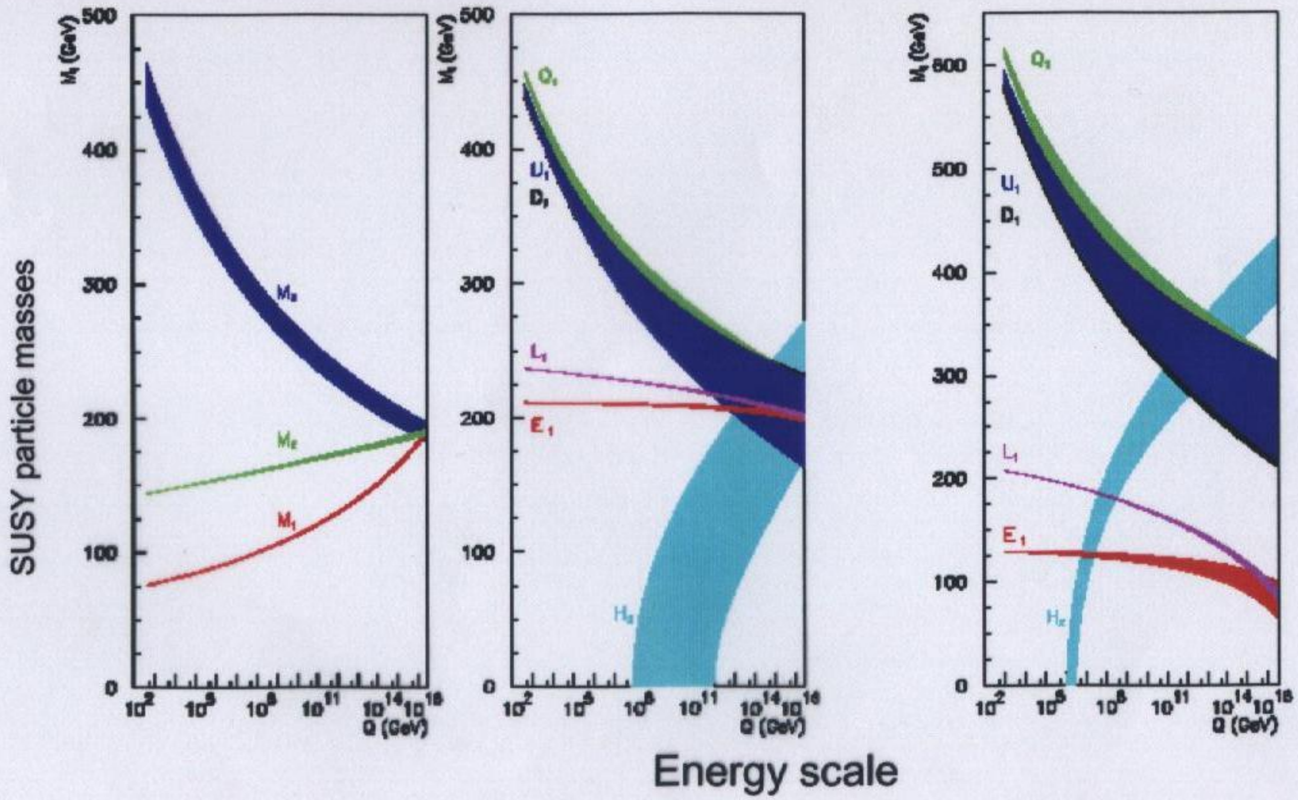
ILC



Determining SUSY breaking mechanism

LHC+ILC
Combined analysis

→ **SUSY breaking** scenario

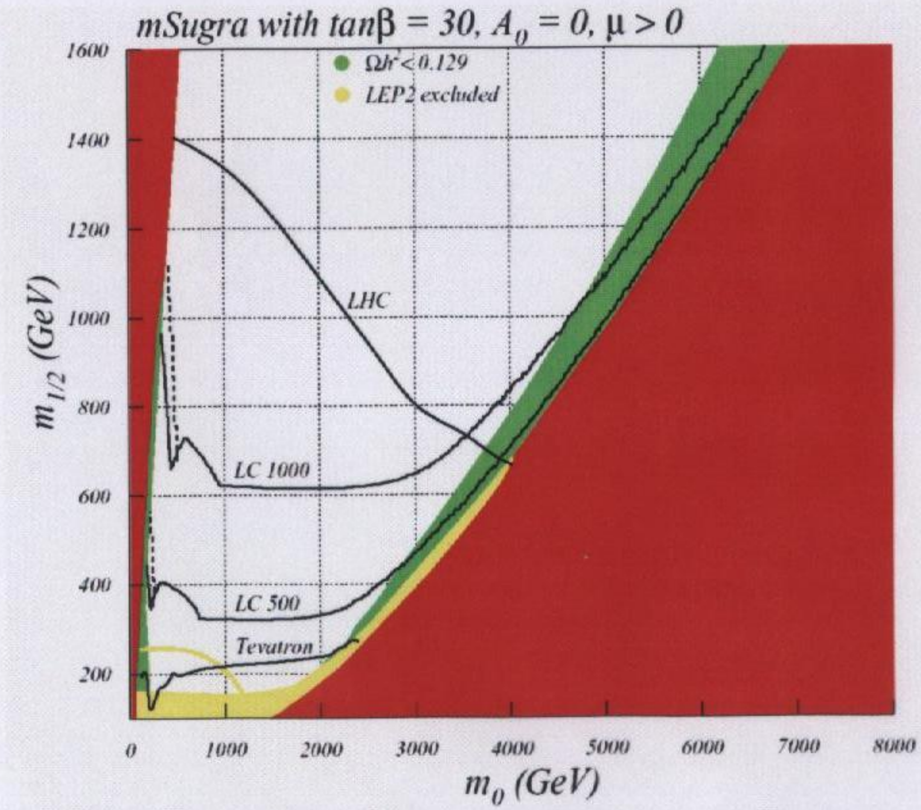


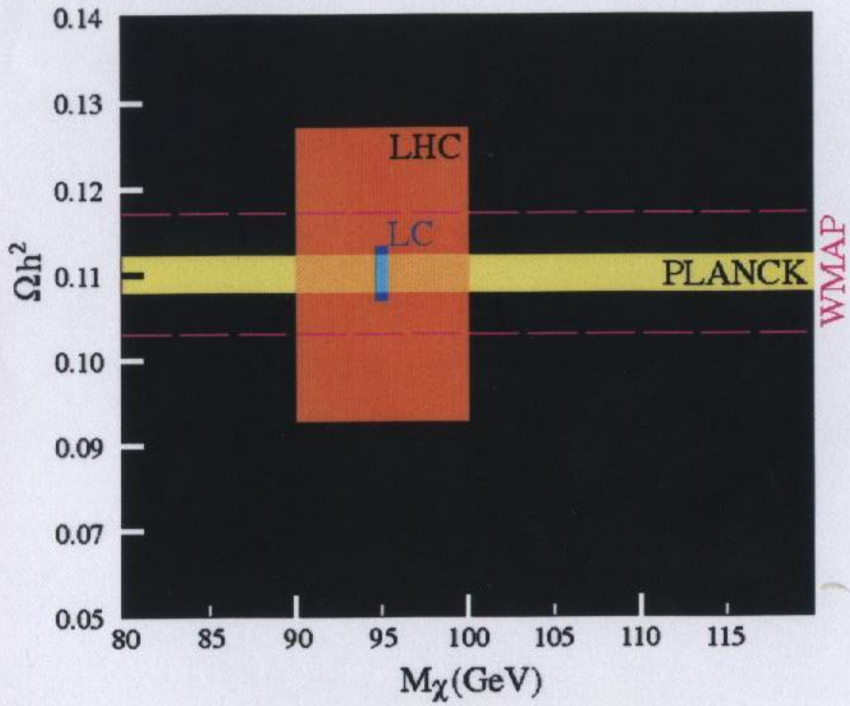
Super Gravity (mSUGRA)

Gauge Mediation

G.A.Blair, W.Porod,and P.M.Zerwas

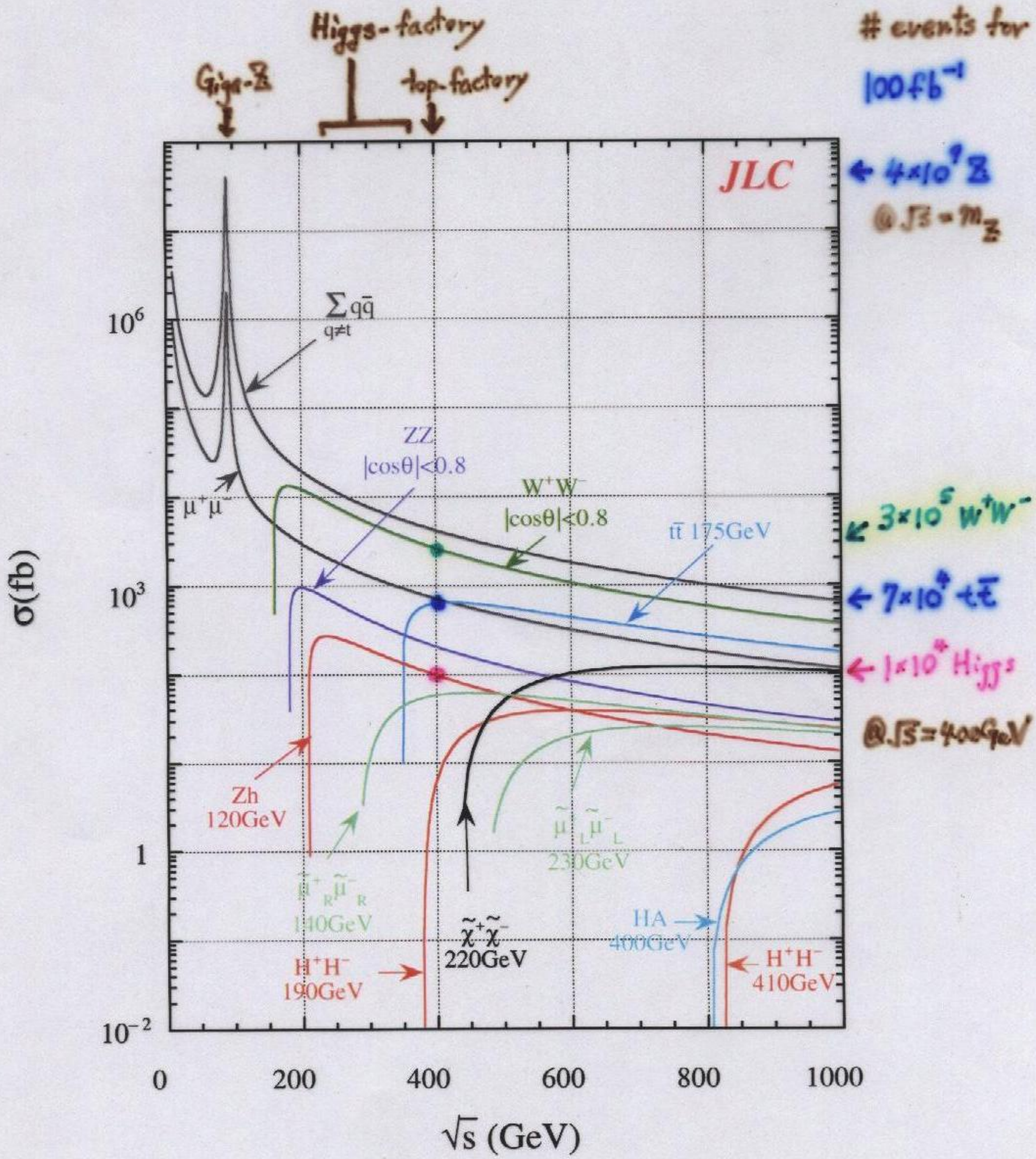
Cosmology: Dark Matter = LSP ?!





'WMAP'	7 %
LHC	~15 %
'Planck'	~2 %
ILC	~3 %

WMAP $.094 < \Omega h^2 < .128$ (2 sigma)

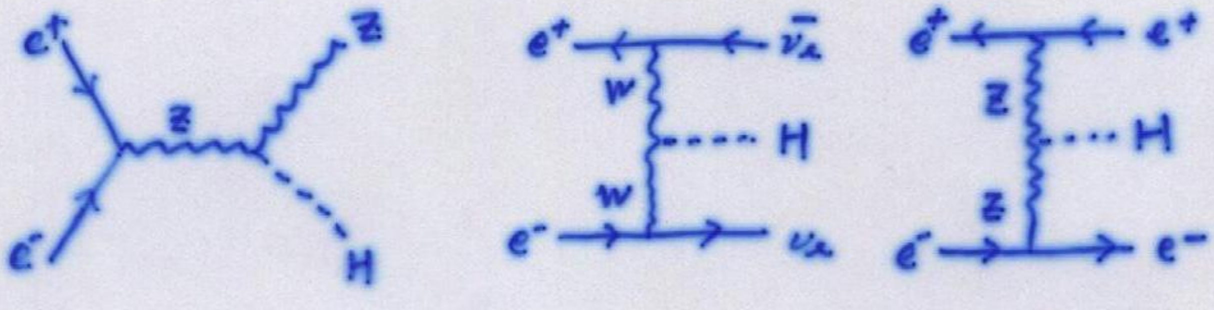


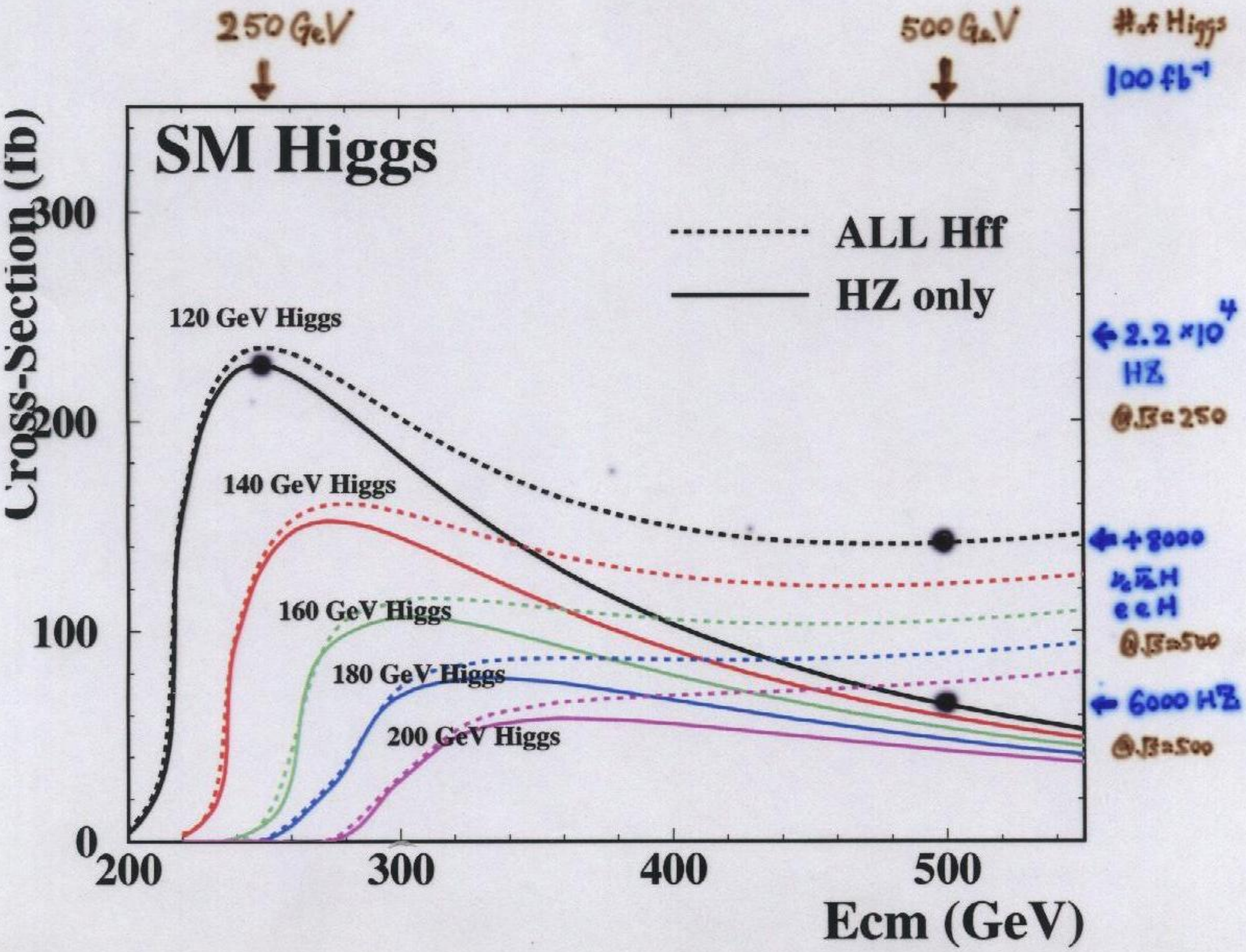
from ACFA L.C report (2001)

Higgs factory at $\sqrt{s}$ = 250 ~ 500 GeV

250 ~ 300 GeV ZH

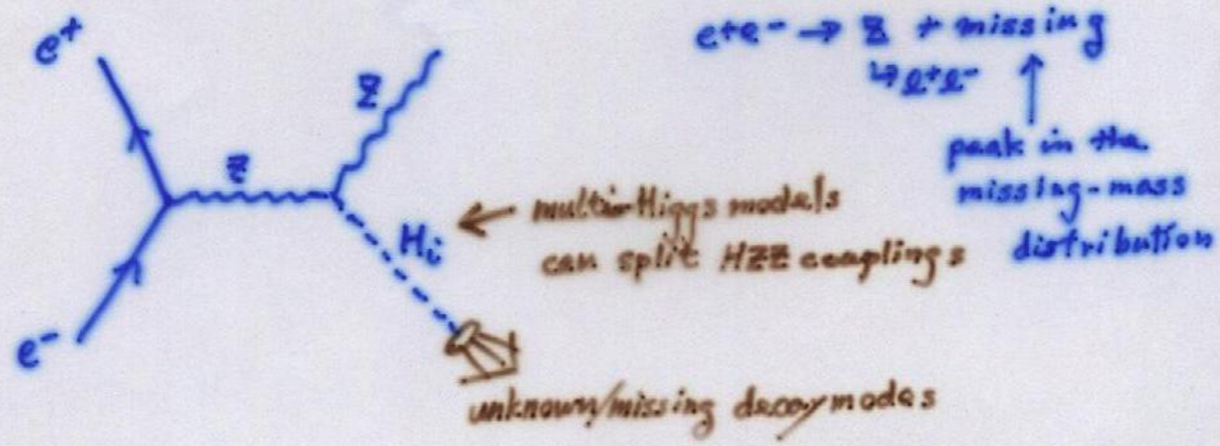
400 ~ 500 GeV ZH + $\nu_e \bar{\nu}_e$ H + ee H

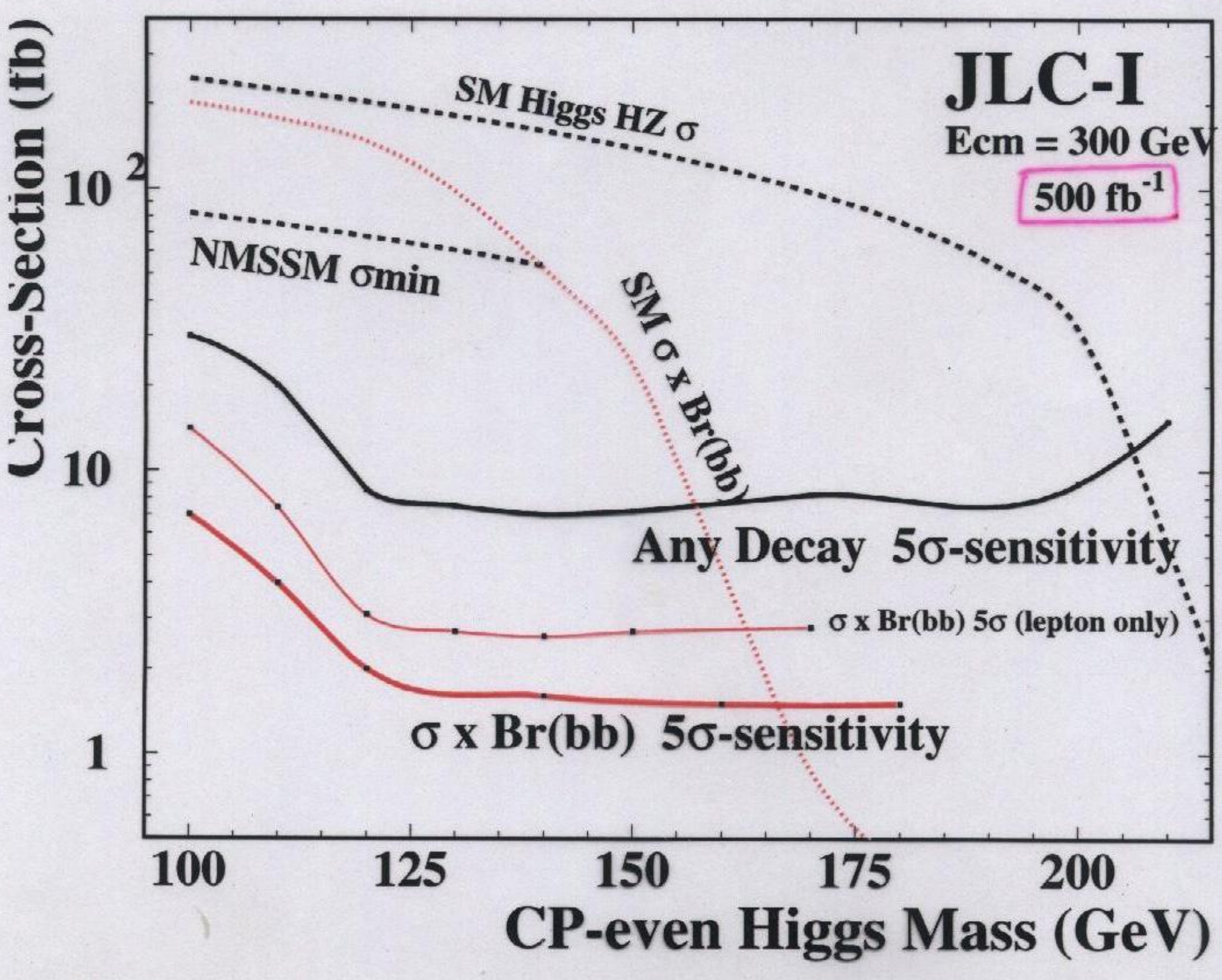




Light Higgs can be discovered independent of models.

⇒ "TeV-scale SUSY with Unification" can be ruled out definitively.





Precision Higgs physics

$\sqrt{s} = 300\,\text{GeV}$, $\mathcal{L} = 500\,\text{fb}^{-1}$ for $m_h = 120\,\text{GeV}$ — from ACFA LC report (2001)

$\Delta m_h = 40\,\text{MeV}$

$\Delta\sigma_{Zh} = 1.3\%$

$\Delta\Gamma_h = 5.5\%$

$\Delta\sigma\cdot B(h\to b\bar{b}) = 1.1\%$

$\Delta\sigma\cdot B(h\to WW) = 5.1\%$

$\Delta\sigma\cdot B(h\to\tau^+\tau^-) = 4.4\%$

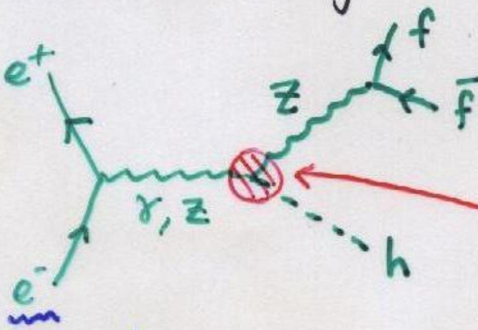
} $\Delta g_{HZZ} = 1.1\%$, $\Delta g_{HWW} = 1.6\%$, $\Delta\lambda_b = 2.8\%$, $\Delta\lambda_\tau = 3.5\%$, $\Delta\lambda_c = 11.3\%$

$\Delta\sigma\cdot B(h\to c\bar{c}) = 22\%$

$\Delta\sigma\cdot B(h\to gg) = 10\%$

} $\Delta\sigma B(h\to c\bar{c}, gg) = 6.3\%$

Measurements of general HZZ, Zγ, γγ, WW couplings



... { f = ℓ; f = b-tagging; f = τ-pol.

beam pol.

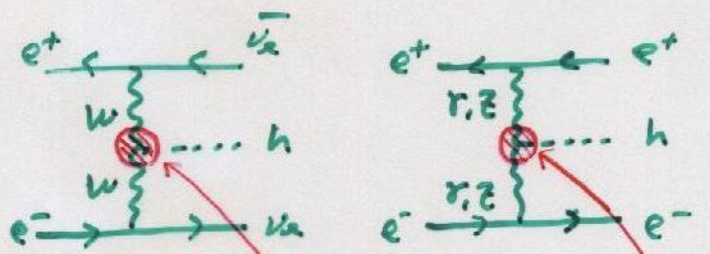
formalism: KH+MLStong ZPC62:99:1994

quantitative study: KH+SI+JK+BAKniehl EPJC14:457:2000

5 CP-even } couplings are constrained
2 CP-odd

$10^{-2} \sim 10^{-4}$ level @ $100\,\text{fb}^{-1}$

can have sensitivity to loop-level physics



KH + JKamoshita + YUehara

$\sqrt{s} = 500\,\text{GeV}$ t-channel processes

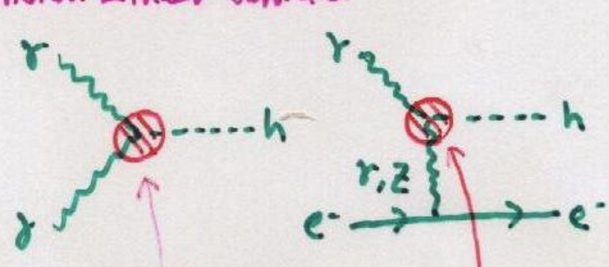
3 CP-even
1 CP-odd

6 CP-even } couplings are constrained
3 CP-odd

$10^{-2} \sim 10^{-4}$ level @ $100\,\text{fb}^{-1}$

Photon Linear Collider

ATBanin+IFGinzburg+IPIvanov PRD59:115001:1999



1 CP-even
1 CP-odd

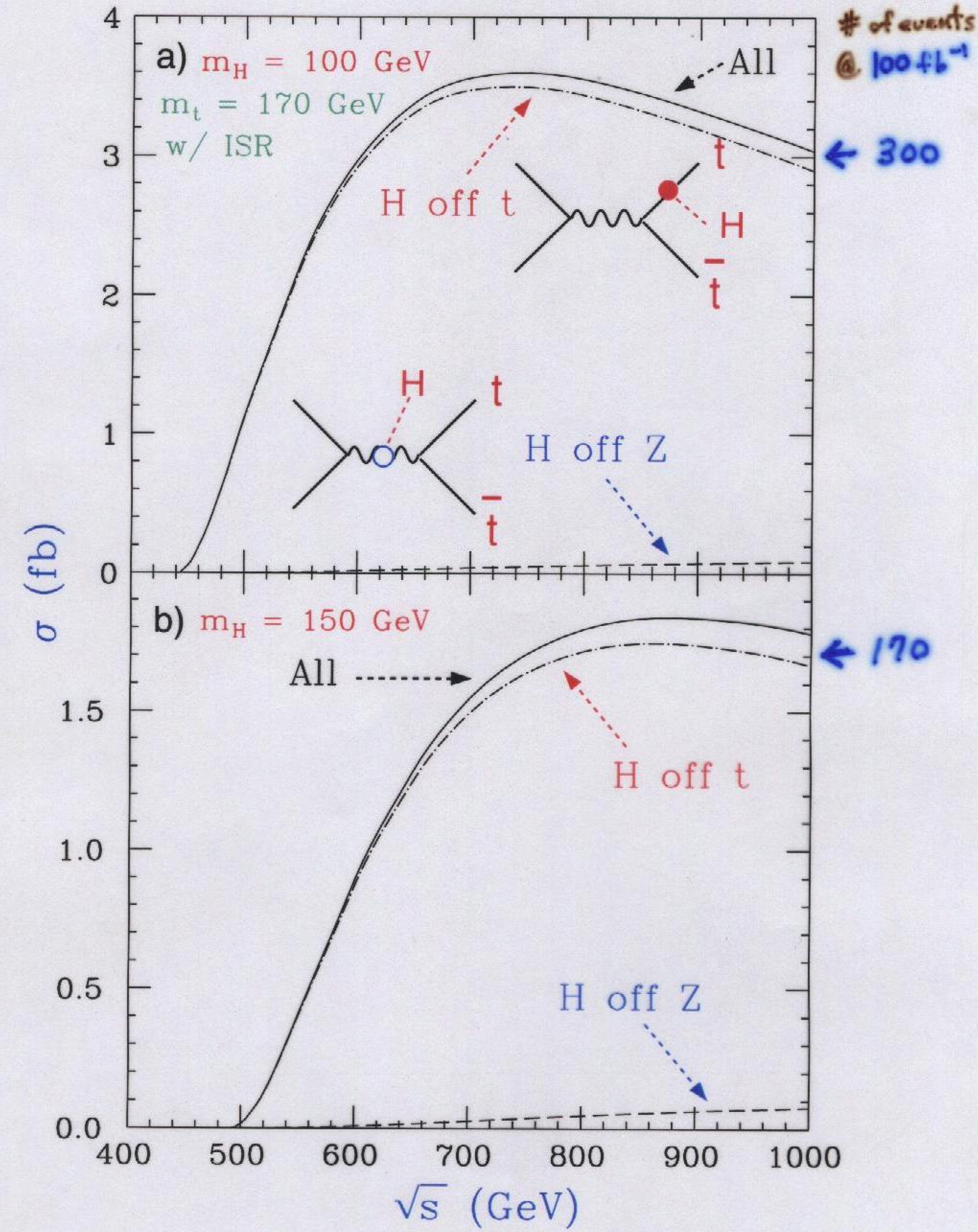
2 CP-even
2 CP-odd

10^{-6} level sensitivity with the same normalization

because { s-channel; loop-level process

7

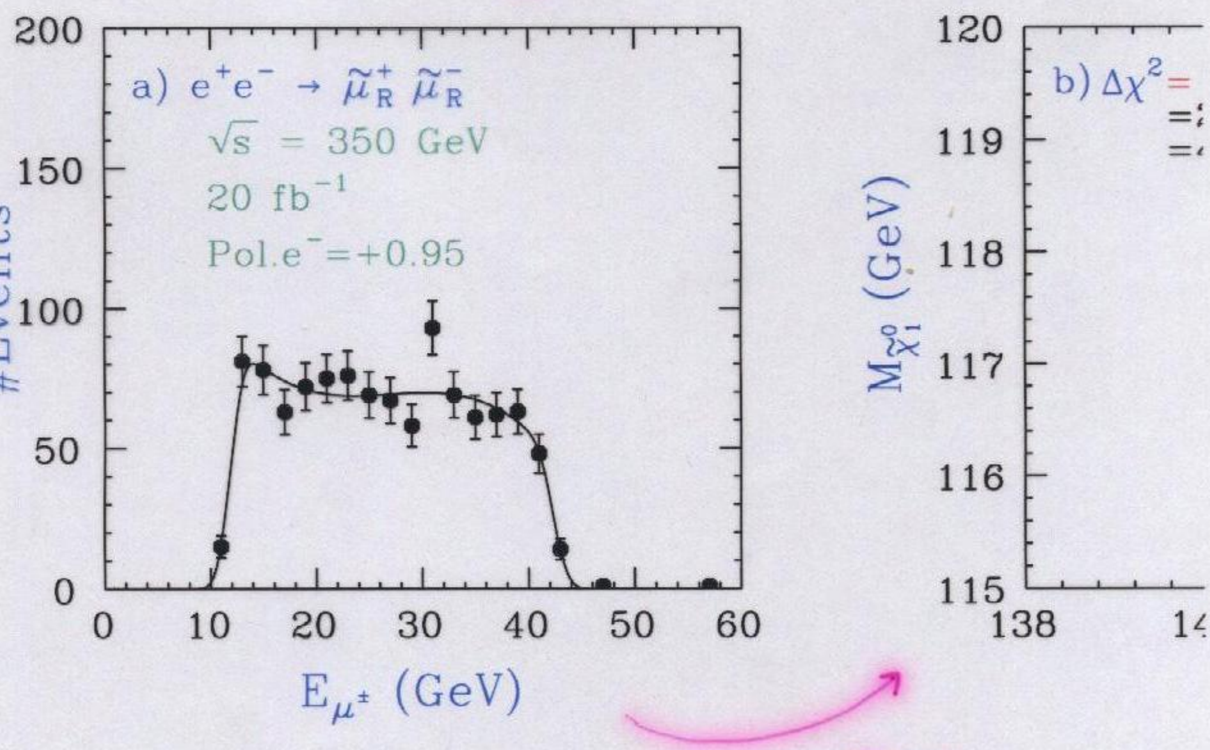
Study of ttH couplings require High Energies ~1 TeV and High Luminosities ~1 ab⁻¹



Ex) SUSY studies

$e^+e^- \rightarrow \tilde{\mu}_R^+ \ \tilde{\mu}_R^- \rightarrow \mu^+\mu^- X$

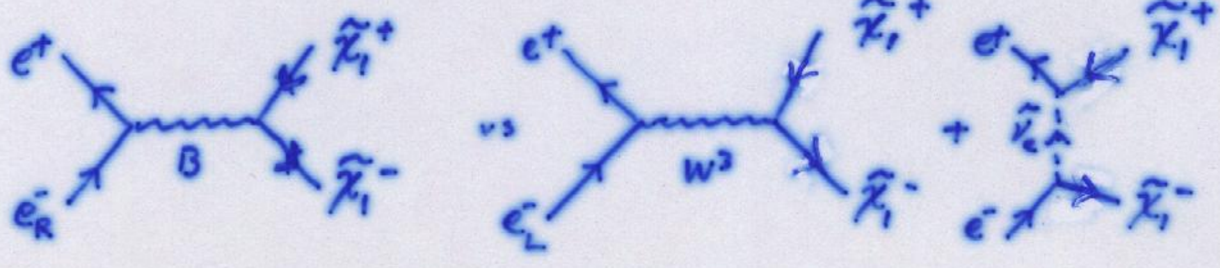
$\quad \hookrightarrow \mu^+\tilde{\chi}_1^0 \ \hookrightarrow \mu^-\tilde{\chi}_1^0$

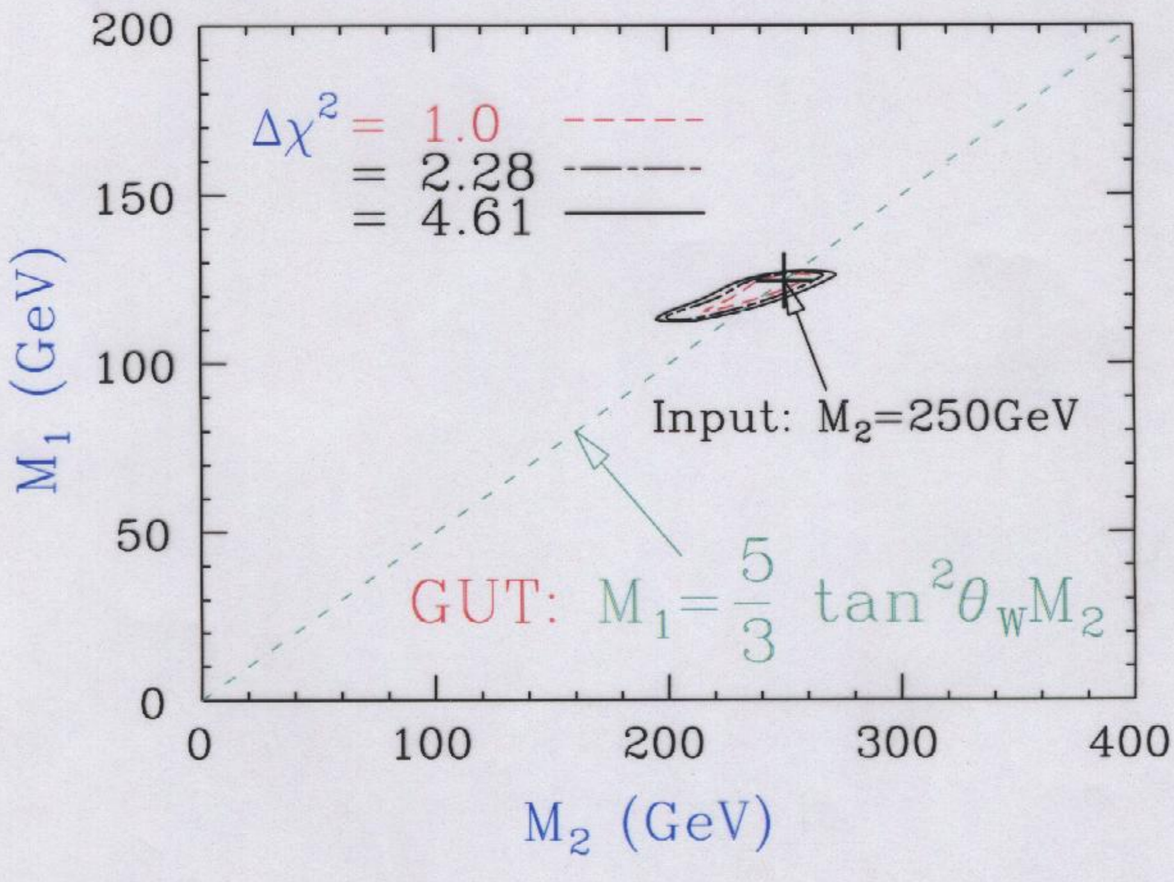


$m_{\tilde{\mu}_R}$ & $m_{\tilde{\chi}_1^0}$

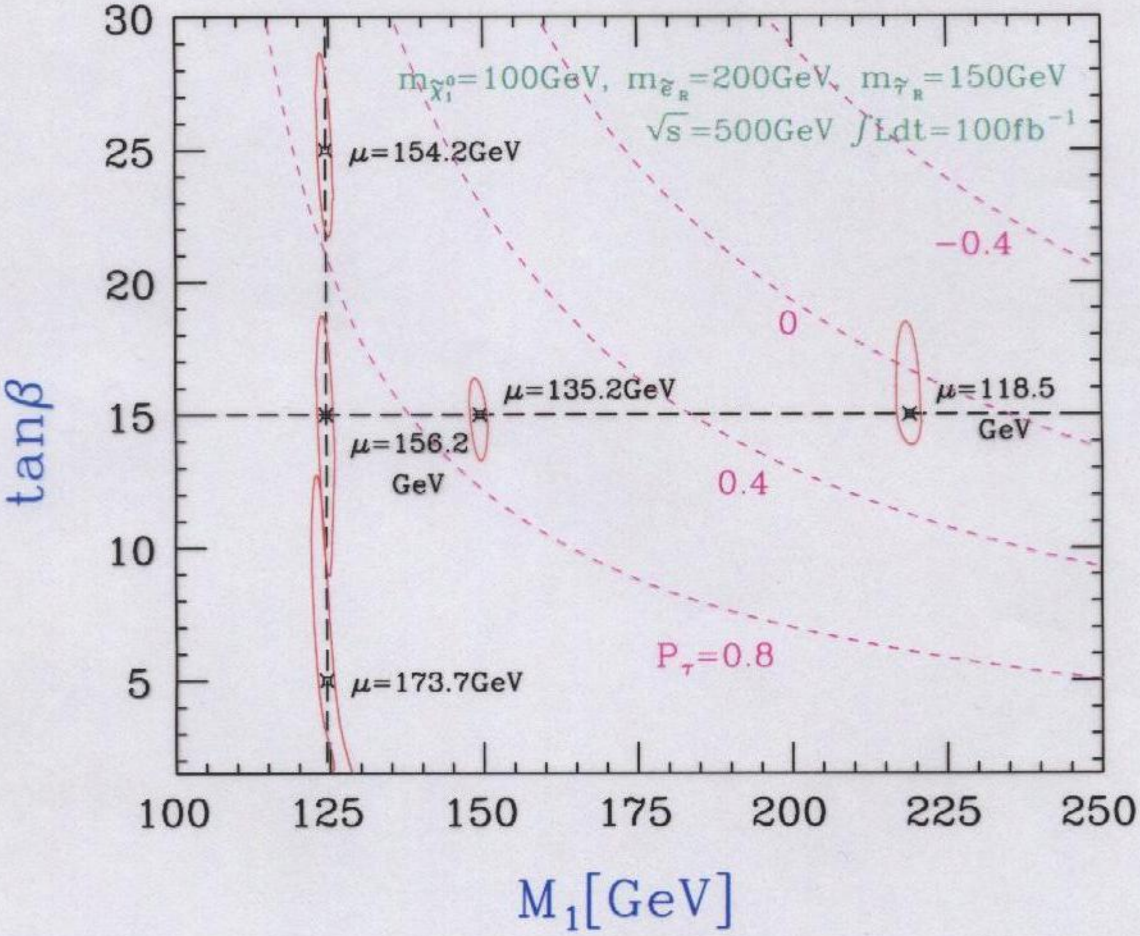
< 1% measurements

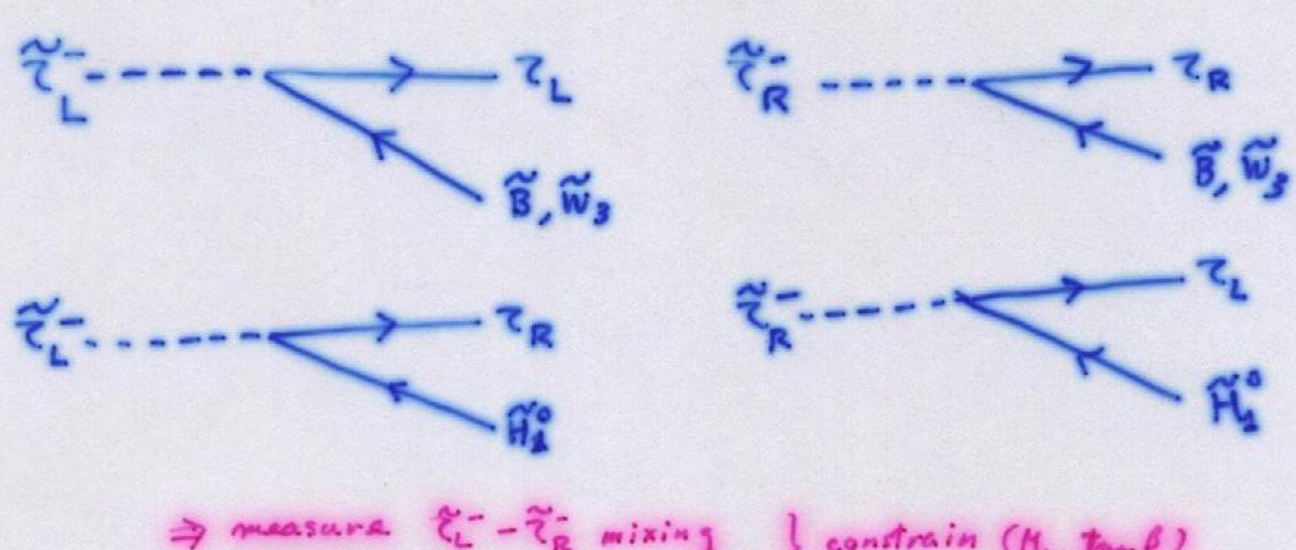
$e^+ e^-_R \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$





U(1) & SU(2) gaugino masses can be extracted.





⇒ measure $\tilde{\tau}_L^- - \tilde{\tau}_R^-$ mixing, $\tilde{B} - \tilde{W}_3 - \tilde{H}_1^0$ mixing } constrain $(M_1, \tan\beta)$

$e^- e^-$

easy to realize

$L_{e^-e^-} \sim (0.1 - 0.3)\, L_{e^+e^-}$

3 physics channels

$e_L^- \; e_L^- \rightarrow \nu_L \nu_L W^- W^-$ .... $W^- W^-$ scattering

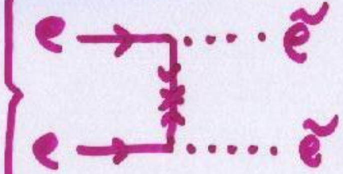
$\rightarrow \nu_L \nu_L H^{--}$ ....

$\rightarrow W^- W^-$ .... heavy Majorana ν's @ TeV

$\rightarrow \tilde{e}_L^- \tilde{e}_L^-$

$e_L^- \; e_R^- \rightarrow \tilde{e}_L^- \tilde{e}_R^-$

$e_R^- \; e_R^- \rightarrow \tilde{e}_R^- \tilde{e}_R^-$



Majorana neutralino's

S-wave threshold

$\Rightarrow m_{\tilde{\chi}}$

$\gamma\gamma$

Compton back scattering of laser light off beam e^-

Large crossing angle ⇒ 2'nd int. region.

Laser cavity for long beam bunch.

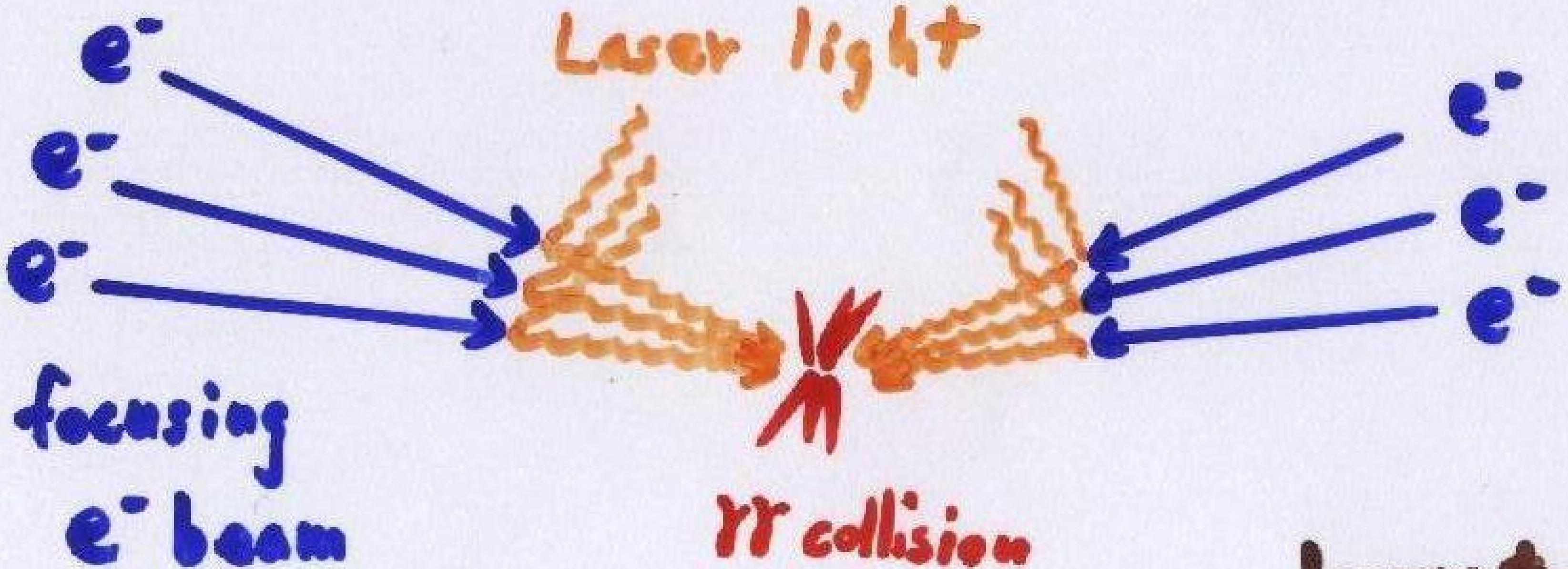
Polarized Laser light

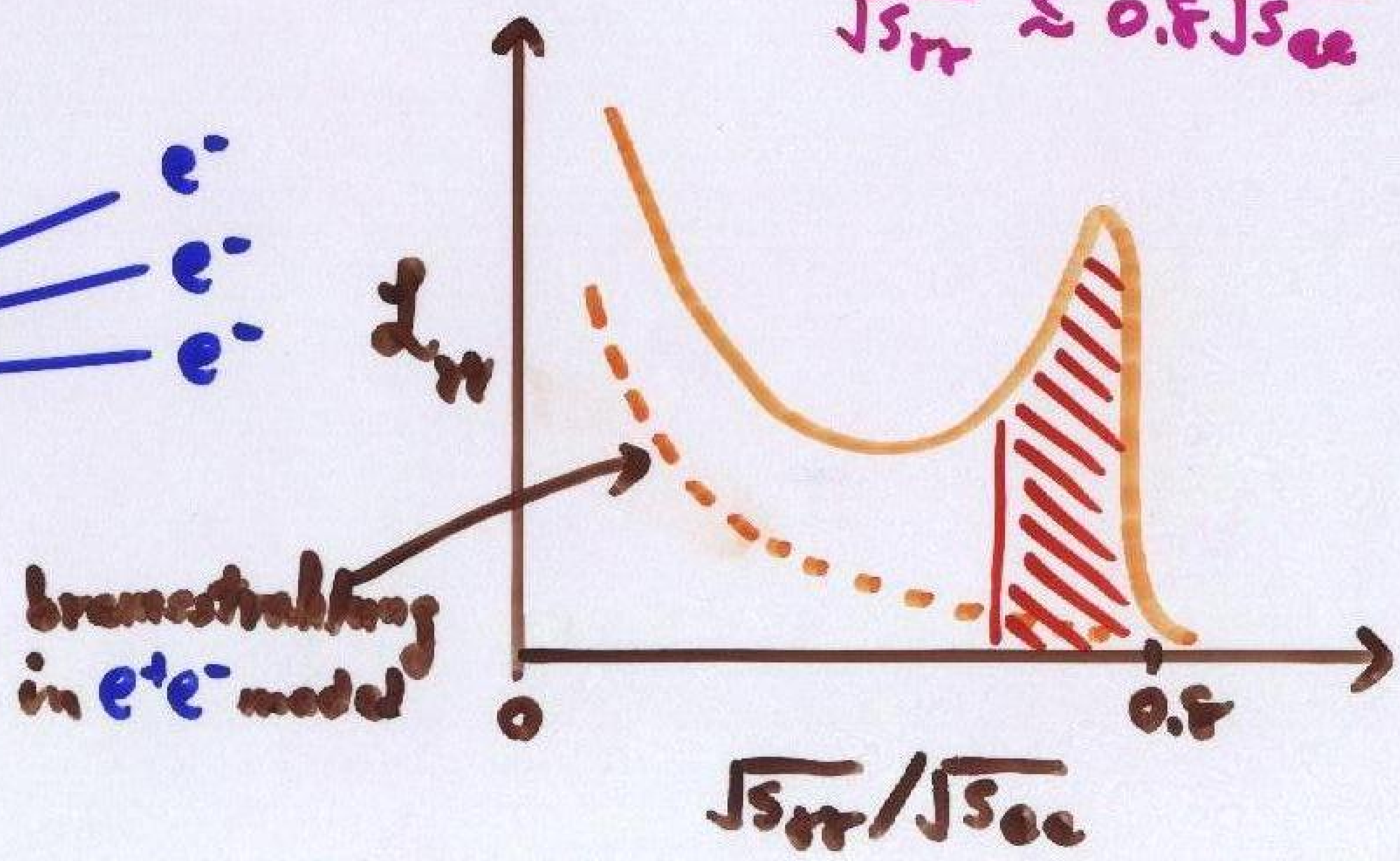
→ Compton scattering →

Polarized high energy γ's

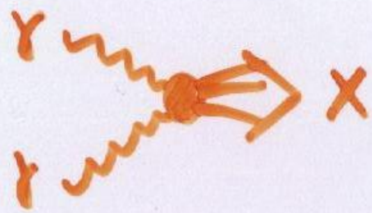
Higg $\sqrt{s_{\gamma\gamma}}$ $\gamma\gamma$ scattering

$$\sqrt{s_{\gamma\gamma}} \lesssim 0.8 \sqrt{s_{ee}}$$





$\gamma\gamma$



$J_X = 0$ — s-channel production of h, H, A and their mixture if $\not{CP}$

circular pol. $\Rightarrow J_z = 0$ — enhances S/N of h, H, A signals

$J_z = \pm 2$ — spin 2 effect search

linear pol. $\Rightarrow CP = \pm$ — select h, H vs A

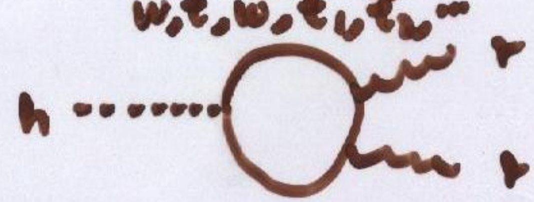
aid $\not{CP}$ search

$J^{PC} = 0^{++}$ $\Rightarrow$ s-wave threshold for $\tilde{\ell}^+\tilde{\ell}^-$, $\tilde{t}_1\bar{\tilde{t}}_1$, …

Large cross sections : σ_{WW} , $\sigma_{\ell\bar{\ell}}$, …

$$\mathcal{L}_{\gamma\gamma}(\sqrt{s_{\gamma\gamma}} > 0.8\sqrt{s_{\gamma\gamma,max}}) \sim (0.1-0.3)\,\mathcal{L}_{e^+e^-}$$

We need $\gamma\gamma$ because



if light h : $\Gamma(h \to \gamma\gamma)\, B(h \to b\bar{b}) \sim 2\%$

$\Rightarrow \Gamma(h \to \gamma\gamma) \sim 2\%$

sensitive to new particles

$\not{CP}$ by $\gamma\gamma$ polarization

far more sensitive than $e^+e^- \to hZ$ because $h\gamma\gamma$ is a loop amp.

if $m_{H,A} < 0.8\sqrt{s_{e^+e^-}}$: Possible discovery

CP & $\not{CP}$

↳ mixing (ϵ) and direct (ϵ')

$\gamma\gamma \to$ H, A / QED $\to t\bar{t}$, W^+W^-

interference allows us to measure the phase of $\phi\gamma\gamma$ vertex.

in addition : $\gamma\gamma \to W^+W^-, t\bar{t}$ ($J = 0, 2$) to supplement $e^+e^- \to W^+W^-, t\bar{t}$ ($J = 1$) precision phys.

e^+ Polarization

e^+ source ~150 GeV e^- undulator } pol. γ → pol. e^+
~5 GeV e^- laser back-scattering

T. Omori et al, K. Mönig

The roles of e^+ polarization in e^+e^- collisions

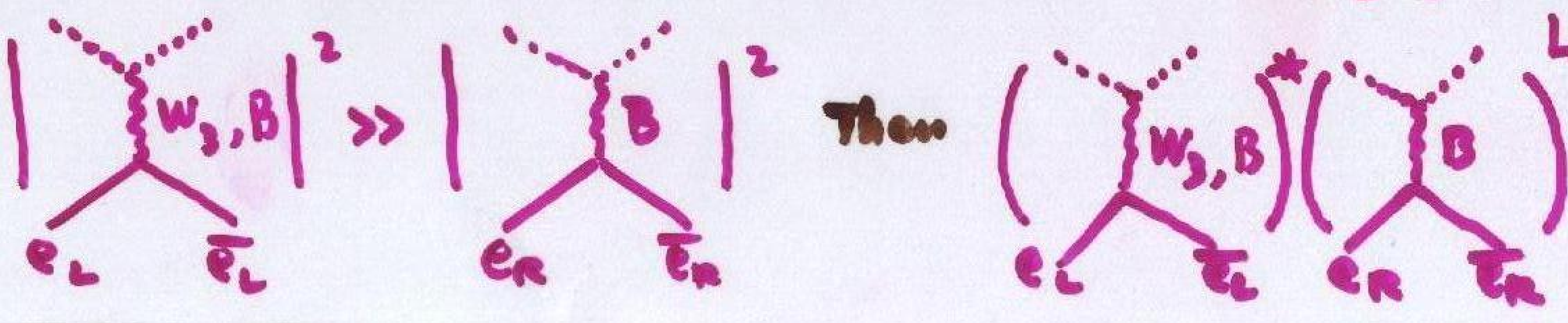
e^+e^- annihilation → $e_L \bar{e}_L$ & $e_R \bar{e}_R$ only (e-chirality)

W-exchange processes → $e_L \bar{e}_L$ only ($SU(2)_L$)

⇒ $P_{e^+} \sim 0.4$ helps enhancing of $\sigma(e_L \bar{e}_L \to X)$
reducing b.g. from $e_L \bar{e}_L \to W^+W^-$ etc. ⇐ ★
increases P_{eff} from $P_{e^-} = 0.8$ to $P_{eff} = 0.95$

Transverse Pol. of both $e^\pm$ beams could be useful ★ ex.) $e^+e^- \to \tilde{\tau}_1^+ \tilde{\tau}_1^-$
↳ $\tau^+ \tilde{\chi}_1^0$ ↘ $\tau^- \tilde{\chi}_1^0$

ex: If



can be probed by $P_\perp(e^\pm)$

Giga Z

10^9 polarized Z's ⇒ A_{LR} precision measurement

- LEP1 A_{FB}^b suffers from hadron/QCD uncertainty

but $\frac{\delta A_{LR}}{A_{LR}} \sim \frac{\delta P_{e^-}}{P_{e^-}} \sim 0.5\%$

With e^+ Polarization we can measure σ_{LR}, σ_{RL}, P_{e^-}, P_{e^+} from

$$\left.\begin{aligned}
\sigma_{++} &= \frac{1-P}{2}\frac{1+\bar{P}}{2}\sigma_{LR} + \frac{1+P}{2}\frac{1-\bar{P}}{2}\sigma_{RL} \\
\sigma_{+-} &= \frac{1-P}{2}\frac{1-\bar{P}}{2}\sigma_{LR} + \frac{1+P}{2}\frac{1+\bar{P}}{2}\sigma_{RL} \\
\sigma_{-+} &= \frac{1+P}{2}\frac{1+\bar{P}}{2}\sigma_{LR} + \frac{1-P}{2}\frac{1-\bar{P}}{2}\sigma_{RL} \\
\sigma_{--} &= \frac{1+P}{2}\frac{1-\bar{P}}{2}\sigma_{LR} + \frac{1-P}{2}\frac{1+\bar{P}}{2}\sigma_{RL}
\end{aligned}\right\} \Rightarrow A_{LR} = \frac{\sigma_{LR} - \sigma_{RL}}{\sigma_{LR} + \sigma_{RL}}$$

with 4×10^{-5} error

$\Rightarrow \delta \sin^2\theta_W^{eff} \sim 1\times10^{-5}$!!

Note $\frac{\delta G_F}{G_F}$, $\frac{\delta m_Z}{m_Z} \sim 2\times10^{-5}$, $\frac{\delta\alpha}{\alpha(m_Z^2)} \sim 25\times10^{-5}$ Powerful EW constraints!

Physics case for ILC-I (base)

$\sqrt{s} = 200 - 500$ GeV

$L > 100\ fb^{-1}/yr$

$P(e^-) \sim 80\%$

is clear indep. of LHC.

but is much stronger if its comission is in the 1'st 10 yr's of LHC

⇓

Proposed Time Schedule should be respected as much as possible

① Technological reliability

② Cost ③ Time Schedule

④ Flexibility to accomodate options later.

★ Longer tunnel for TeV

★ 2'nd Int. Sect. for $\gamma\gamma$

LHC scenarios

A: finds nothing (not even a Higgs)

⇒ ILC-I — Zh search, $t\bar{t}$, W^+W^- prec. exp. (→ n-page)

⇒ Giga-Z + $P(e^+)$ — check our starting point.

⇒ TeV — search

⇒ $\gamma\gamma$ — $t\bar{t}$, W^+W^- prec. exp.

B: finds a light Higgs only

⇒ ILC-I — precision Higgs, $t\bar{t}$, WW

⇒ $\gamma\gamma$ — $\Gamma(h\to\gamma\gamma)$, CP, heavy H,A search

⇒ TeV — tth, hhh, search

C: finds a heavy Higgs only

⇒ ILC-I — confirm nothing lighter, prec.

⇒ TeV, $\gamma\gamma$ — ZH, $\nu\bar{\nu}H$, $\gamma\gamma\to H$

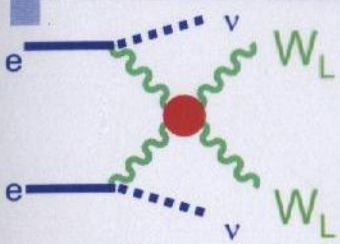
⇒ Giga-Z + $P(e^+)$ — hint of new phys. signal

D: finds many new particles, non-SM effects

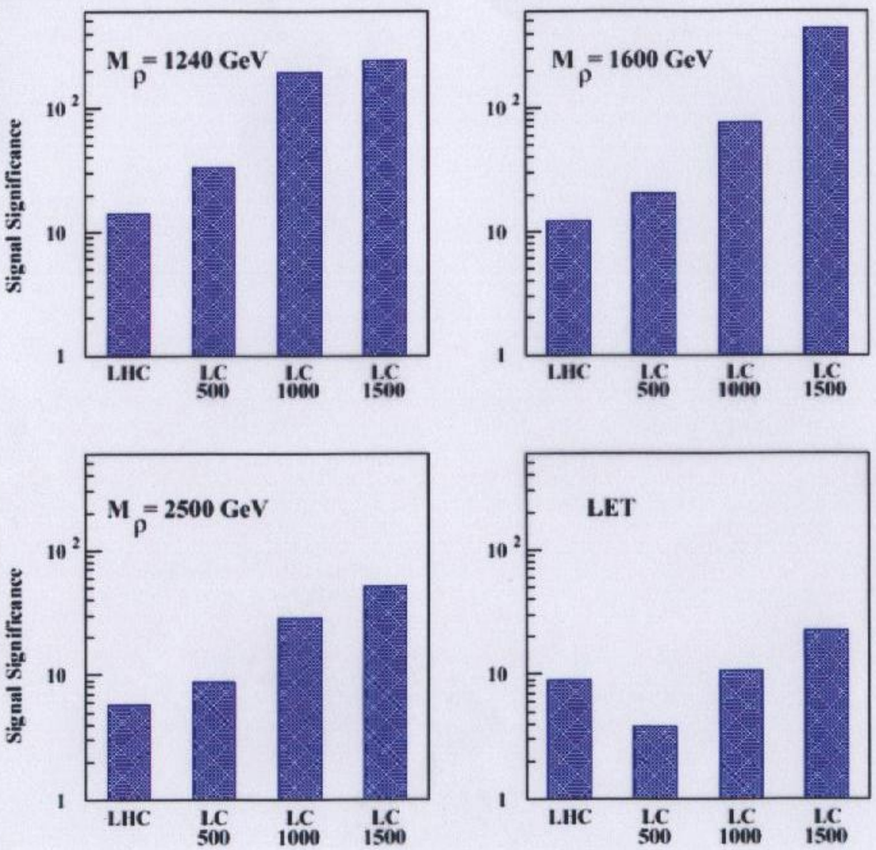
⇒ ILC-I — prec. spectroscopy

⇒ TeV — " "

⇒ $\gamma\gamma$ — J=0 channel, scalar sector

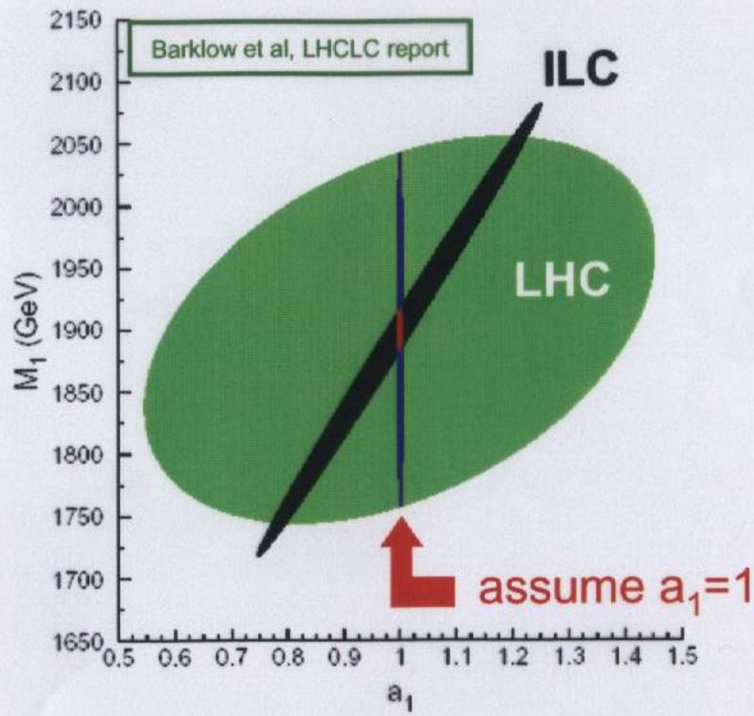


$\nu\bar{\nu}W^+W^-,\ \nu\bar{\nu}ZZ$



ILC is very sensitive to ννWW, ννZZ

sensitivity to new heavy resonances in ee →ννWW



M = 1.9 TeV
SM couplings (a=1)

ILC: 500 GeV, 500 fb^{-1}

2006.4.26 The US National Academy of Science

Board on Physics and Astronomy

made announcement of EPP2010 report

http://www7.nationalacademies.org/bpa/EPP2010.html

... U.S. should maintain its leadership in particle physics and bid to host the ILC.

The National Academies (Advisers to the Nation on Science, Engineering and Medicine)

NAS NAE IOM

EPP2010 report by Committee on Elementary Particle Physics in the 21st Century, National Research Council

"Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics"

ISBN: 0-309-66042-4, 196 pages (2006) ⇒ PDF download free!

Remarks of Harold T. Shapiro, Chair, EPP2010 (4 pages)

Division on Engineering and Physical Sciences • Committee on Elementary Particle Physics in the 21st Century • Board on Physics and Astronomy • www.nas.edu/bpa

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At the dawn of the 21st century, elementary particle physics is poised to address some of the most basic questions in science. Obtaining the answers to these questions will require a global effort of great scale and complexity. A committee with membership drawn both from inside and outside the field of elementary-particle physics is charged to construct a plan for U.S. participation in this effort through an in-depth assessment that will identify, articulate, and prioritize the scientific questions and opportunities that define elementary-particle physics and provide a 15-year plan for the future of the field.

The committee will publicly release its final report with a live webcast press conference at the Keck Center of The National Academies in Washington, DC (500 Fifth St, NW, Washington, DC 20001) on Wednesday, April 26 at 2:30pm EDT. On behalf of committee chair Harold T. Shapiro, president emeritus and professor of economics and public affairs at Princeton University, we invite you to attend the public briefing. Participants will each receive a copy of the report in unedited prepublication form; advance registration is requested (please visit http://www7.nationalacademies.org/bpa/EPP2010.html).

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Remarks of H.T. Shapiro Chair, EPP2010

The U.S. has been at the forefront of EPP for more than half a century.

. . . .

Our leadership position is now in jeopardy.

. . . .

This looming loss of leadership could not be happening at a worse time. Particle physics is entering one of the most exciting periods in its history.

Physics at the Terasale

- The SM & Higgs
- The gravity & quantum mechanics
- Cosmological observation (4% Matter, 20% DM, 76% DE)

⇓

The Large Hadron Collider

SUSY?

Yet these tremendously exciting possibilities are emerging just as the intellectual center of gravity within particle physics is moving from the U.S. to other countries.

The U.S. should remain globally competitive in EPP by playing a leading role in the world wide effort to aggressively study the Terascale.

The committee believes that only a strategy that includes an important accelerator based component to explore the Terascale can sustain the distinction of the U.S. program.

|| ILC

Advices to D.O.E. and N.S.F. :

1. LHC
2. ILC
3. expand the program in particle astrophysics
   pursue international program in neutrino physics

priority ↓

Diversity in research :

① Accelerator based exp's	1 & 2
② space based exp's	3
③ underground lab's	3
④ precision measurements	g-2 etc

Revealing the Hidden Nature of Space and Time Charting the Course for Elementary Particle Phy

Select the chapters you want in PDF format from the following list. Simply click on the title to download.

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Quest for Unification

- static electricity
- magnetism
- light

} Maxwell's electro-magnetic theory ⇒ QED

- nuclear force
- π, K, ...

⇒ QCD

- β decays
- ν's

} Fermi's theory

QED + Fermi's theory → EW unification (TeraScale)

QCD + EW → Grand Unification

- gravity   Newton ⇒ Einstein ⇒ Quantum Gravity

Grand Unification + Quantum Gravity → String Unification

⇒ Unification

‖

Symmetry Breaking ⇐

: Terascale is the first test ground for gauge sym. breakdown.

⇓

Origin of all the masses of fundamental particles

Particle Properties

- 3 generations
- masses, mixing angles
- FCNC, $\not{CP}$

} ⇐ "Key"

Origin of all the masses of fundamental particles ⇕ ?

Cosmological Challenges

- 4% Matter $\not{B}$ & $\not{CP}$ (Sakharov 1967)   New Physics
- 20% DM   New stable particle   New Physics
- 76% DE   ?   ???
- flatness

$M : DM = 1 : 5$?

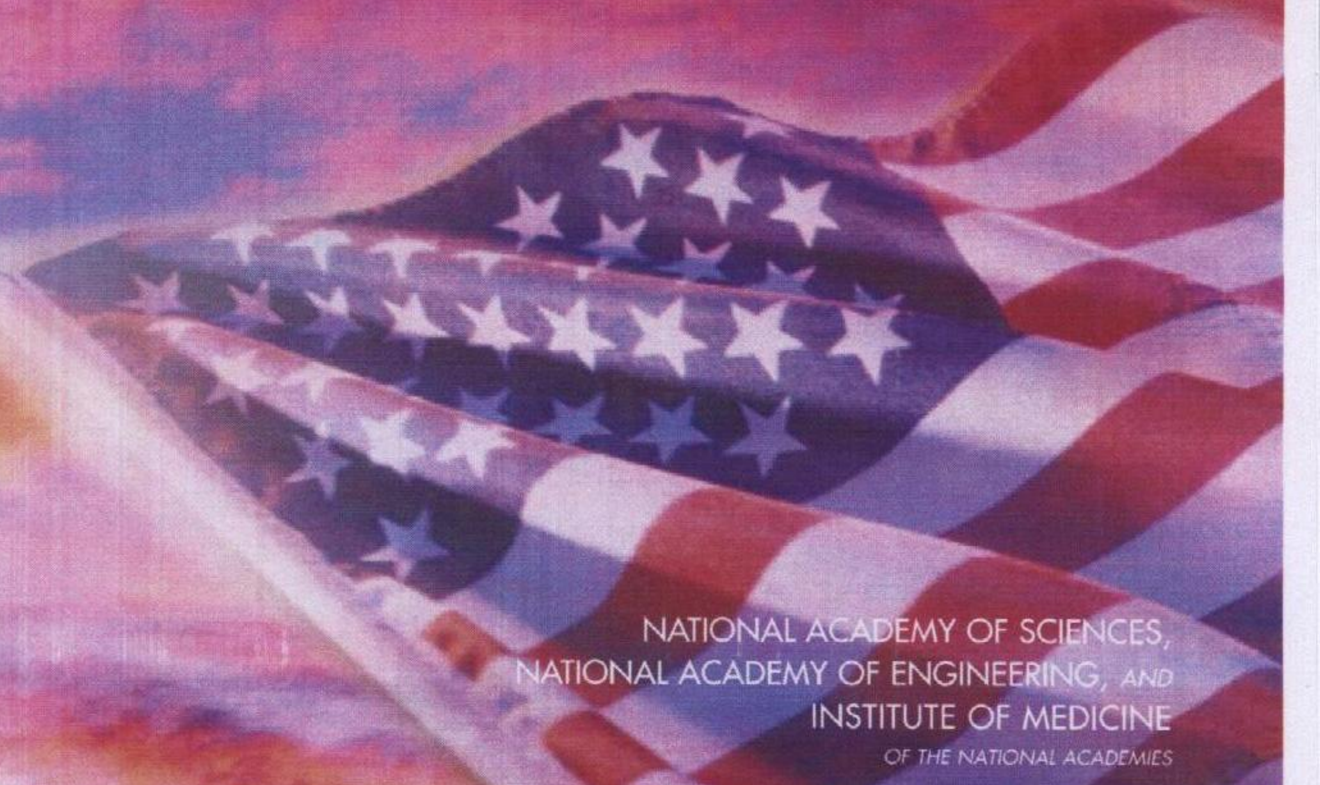
$(M+DM) : DE = 1 : 3$?

$\Lambda \sim (0.01\,eV)^4 \Leftrightarrow m_\nu$?

EXECUTIVE SUMMARY

RISING ABOVE THE GATHERING STORM

Energizing and Employing America for a Brighter Economic Future



NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, *AND*
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES

2005 reported 2006 published

COMMITTEE BIOGRAPHIC INFORMATION

NORMAN R. AUGUSTINE [NAE*] (Chair) is the retired chairman and CEO of the Lockheed Martin Corporation. He serves on the President's Council of Advisors on Science and Technology and has served as undersecretary of the Army. He is a recipient of the National Medal of Technology.

CRAIG BARRETT [NAE] is chairman of the Board of the Intel Corporation.

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SHIRLEY ANN JACKSON [NAE] is president of Rensselaer Polytechnic Institute. She is the immediate past president of the American Association for the Advancement of Science and was chairman of the US Nuclear Regulatory Commission.

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PETER O'DONNELL JR. is president of the O'Donnell Foundation of Dallas, a private foundation that develops and funds model programs designed to strengthen engineering and science education and research.

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CHARLES M. VEST [NAE] is president emeritus of MIT and a professor of mechanical engineering. He serves on the President's Council of Advisors on Science and Technology and is the immediate past chair of the Association of American Universities.

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RICHARD N. ZARE [NAS] is the Marguerite Blake Wilbur Professor of Natural Science at Stanford University. He was chair of the National Science Board from 1996 to 1998.

Principal Project Staff

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Tom Arrison, Innovation
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Peter Henderson, Higher Education
Jo Husbands, National Security

FOR MORE INFORMATION

*This report was developed under the aegis of the National Academies Committee on Science, Engineering, and Public Policy (COSEPUP), a joint committee of the three honorific academies—the National Academy of Sciences [NAS], the National Academy of Engineering [NAE], and the Institute of Medicine [IOM]. Its overall charge is to address cross-cutting issues in science and technology policy that affect the health of the national research enterprise.

More information, including the full body of the report, is available at COSEPUP's Web site, www.nationalacademies.org/cosepup.

NOTE

This report was reviewed in draft form by individuals chosen for their technical expertise, in accordance with procedures approved by the National Academies's Report Review Committee. For a list of those reviewers, refer to the full report.

EXECUTIVE SUMMARY

The United States takes deserved pride in the vitality of its economy, which forms the foundation of our high quality of life, our national security, and our hope that our children and grandchildren will inherit ever-greater opportunities. That vitality is derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living. Economic studies conducted even before the information-technology revolution have shown that as much as 85% of measured growth in US income per capita was due to technological change.[1]

Today, Americans are feeling the gradual and subtle effects of globalization that challenge the economic and strategic leadership that the United States has enjoyed since World War II. A substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe, and leading-edge scientific and engineering work is being accomplished in many parts of the world. Thanks to globalization, driven by modern communications and other advances, workers in virtually every sector must now face competitors who live just a mouse-click away in Ireland, Finland, China, India, or dozens of other nations whose economies are growing. This has been aptly referred to as "the Death of Distance."

CHARGE TO THE COMMITTEE

The National Academies was asked by Senator Lamar Alexander and Senator Jeff Bingaman of the Committee on Energy and Natural Resources, with endorsement by Representative Sherwood Boehlert and Representative Bart Gordon of the House Committee on Science, to respond to the following questions:

> What are the top 10 actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?

The National Academies created the Committee on Prospering in the Global Economy of the 21st Century to respond to this request. The charge constitutes a challenge both daunting and exhilarating: to recommend to the nation specific steps that can best strengthen the quality of life in America—our prosperity, our health, and our security. The committee has been cautious in its analysis of information. The available information is only partly adequate for the committee's needs. In addition, the time allotted to develop the report (10 weeks from the time of the committee's first gathering to report release) limited the ability of the committee to conduct an exhaustive analysis. Even if unlimited time were available, definitive analyses on many issues are not possible given the uncertainties involved.[2]

This report reflects the consensus views and judgment of the committee members. Although the committee consists of leaders in academe, industry, and government—including several current and former industry chief executive officers, university presidents, researchers (including three Nobel prize winners), and former presidential appointees—the array of topics and policies covered is so broad that it was not possible to assemble a committee of 20 members with direct expertise in each relevant area. Because of those limitations, the committee has relied heavily on the judgment of many experts in the study's focus groups, additional consultations via e-mail and telephone with other experts, and an unusually large panel of reviewers. Although other solutions are undoubtedly possible, the committee believes that its recommendations, if implemented, will help the United States achieve prosperity in the 21st century.

[1]For example, work by Robert Solow and Moses Abramovitz published in the middle 1950s demonstrated that as much as 85% of measured growth in US income per capita during the 1890-1950 period could not be explained by increases in the capital stock or other measurable inputs. The unexplained portion, referred to alternatively as the "residual" or "the measure of ignorance," has been widely attributed to the effects of technological change.

[2]Since the prepublication version of the report was released in October, certain changes have been made to correct editorial and factual errors, add relevant examples and indicators, and ensure consistency among sections of the report. Although modifications have been made to the text, the recommendations remain unchanged, except for a few corrections, which have been footnoted.

FINDINGS

Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength. We strongly believe that a worldwide strengthening will benefit the world's economy—particularly in the creation of jobs in countries that are far less well-off than the United States. But we are worried about the future prosperity of the United States. Although many people assume that the United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost—and the difficulty of recovering a lead once lost, if indeed it can be regained at all.

The committee found that multinational companies use criteria[3] such as the following in determining where to locate their facilities and the jobs that result:

- Cost of labor (professional and general workforce).
- Availability and cost of capital.
- Availability and quality of research and innovation talent.
- Availability of qualified workforce.
- Taxation environment.
- Indirect costs (litigation, employee benefits such as healthcare, pensions, vacations).
- Quality of research universities.
- Convenience of transportation and communication (including language).
- Fraction of national research and development supported by government.
- Legal-judicial system (business integrity, property rights, contract sanctity, patent protection).
- Current and potential growth of domestic market.
- Attractiveness as place to live for employees.
- Effectiveness of national economic system.

Although the US economy is doing well today, current trends in each of these areas indicate that the United States may not fare as well in the future without government intervention. This nation must prepare with great urgency to preserve its strategic and economic security. Because other nations have, and probably will continue to have, the competitive advantage of a low wage structure, the United States must compete by optimizing its knowledge-based resources, particularly in science and technology, and by sustaining the most fertile environment for new and revitalized industries and the well-paying jobs they bring. We have already seen that capital, factories, and laboratories readily move wherever they are thought to have the greatest promise of return to investors.

RECOMMENDATIONS

The committee reviewed hundreds of detailed suggestions—including various calls for novel and untested mechanisms—from other committees, from its focus groups, and from its own members. The challenge is immense, and the actions needed to respond are immense as well.

The committee identified two key challenges that are tightly coupled to scientific and engineering prowess: creating high-quality jobs for Americans, and responding to the nation's need for clean, affordable, and reliable energy. To address those challenges, the committee structured its ideas according to four basic recommendations that focus on the human, financial, and knowledge capital necessary for US prosperity.

The four recommendations focus on actions in K–12 education (*10,000 Teachers, 10 Million Minds*), research (*Sowing the Seeds*), higher education (*Best and Brightest*) and economic policy (*Incentives for Innovation*) that are set forth in the following sections. Also provided are a total of 20 implementation steps for reaching the goals set forth in the recommendations.

Some actions involve changes in the law. Others require financial support that would come from reallocation of existing funds or, if necessary, from new funds. Overall, the committee believes that the investments are modest relative to the magnitude of the return the nation can expect in the creation of new high-quality jobs and in responding to its energy needs.

The committee notes that the nation is unlikely to receive some sudden "wake-up" call; rather, the problem is one that is likely to evidence itself gradually over a surprisingly short period.

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[3] D.H. Dalton, M.G. Serapio, Jr., P.G. Yoshida. 1999. Globalizing Industrial Research and Development. US Department of Commerce, Technology Administration, Office of Technology Policy. Grant Gross. 2003, October 9. "CEOs defend moving jobs offshore at tech summit." InfoWorld. Mehlman, Bruce. 2003. Offshore Outsourcing and the Future of American Competitiveness. "High tech in China: is it a threat to Silicon Valley?" 2002, October 28. Business Week online. B. Callan, S. Costigan, K. Keller. 1997. Exporting U.S. High Tech: Facts and Fiction about the Globalization of Industrial R&D, Council on Foreign Relations, New York, NY.

INTERACTIONS.ORG
Particle Physics News and Resources

CERN Council report on EU strategy for particle physics

Interactions News Wire #55-06
14 July 2006 http://www.interactions.org
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Source: CERN Council
Content: Press Release
Date Issued: 14 July 2006
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CERN Council adopts European strategy for particle physics

Lisbon, 14 July 2006. At a special meeting in Lisbon today, the CERN Council[1] unanimously adopted a European strategy for particle physics. This is an important step for the field, outlining a leading role for Europe in this increasingly globalised endeavour.

The strategy adopted by the Council today provides for European engagement and leadership in the field. It builds on European strengths at Universities, in national laboratories – frequently of international standing – and at the CERN laboratory.

The President of the Council, Professor Enzo Iarocci, will brief media on the strategy at 12.00 on Monday 17 July at the EIROforum stand in the exhibition area of ESOF 2006, the Euroscience Open Forum being held in Munich.

Professor Gago, Minister of Science and Technology of Portugal, highlighted in his opening address the importance of CERN and of particle physics research for Europe. Professor Gago stated that CERN was a model for scientific cooperation and has achieved a unique success in attracting to Europe scientists and resources from the world at large. CERN is therefore an essential asset for the future strengthening of European scientific and technological impact at the global level.

Created along with the European Organization for Nuclear Research (CERN) in 1954, the Council has been responsible for one of the world's leading centres for fundamental physics for over 50 years. The CERN laboratory near Geneva, which has evolved into a leading example of successful collaboration among nations, is host to a scientific community of over 6700 users representing 85 nationalities. It has made significant contributions to our understanding of the Universe, brought major contributions to technological innovation in fields as diverse as medical imaging and information technology, and given us the World Wide Web.

Today, the world's particle physicists are embarking on a new adventure, the Large Hadron Collider (LHC) project, scheduled to start up at the Geneva laboratory in 2007. It will provide a focus for particle physics for many years to come, addressing questions such as what gives matter its mass, what the invisible 96% of the Universe is made of, why nature prefers matter to antimatter and how matter evolved from the first instants of the Universe's existence.

LHC

The LHC is a discovery machine at the high-energy frontier. A full understanding of the Universe's mysteries, and of the discoveries that will be made, requires a multi-stranded approach, with global coordination. Major new facilities and other frontier projects, such as the International Linear Collider, will require such coordination.

ILC

The Council took the initiative to launch the strategy process in 2005, recognising that the LHC is a unique facility for the world's particle physicists, and considering that this was the right time to address the issue of how European particle physics will engage with other regions of the world to develop the next generation of particle physics facilities.

The Council appointed a representative group of European physicists to define the role that Europe should play in the unfolding adventure of understanding our Universe. This group engaged in a broad consultative process, hearing the voices of European physicists, as well as representatives from the Americas and Asia. Its conclusions were discussed in Council today and unanimously approved.

Notes for Editors:

Full details of the process leading to the strategy are available at:
http://council-strategygroup.web.cern.ch/council-strategygroup/

The Strategy Statement is available at:
http://council-strategygroup.web.cern.ch/council-strategygroup/Strategy_Statement.pdf

For the full Strategy brochure see:
http://council-strategygroup.web.cern.ch/council-strategygroup/Strategy_Brochure.pdf

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GERMANY

創刊号
2006年7月15日発行

ILC通信

国際リニアコライダー (International Linear Collider)

アジア発のノーベル賞を

小柴昌俊

ILC通信の創刊おめでとうございます。

ILCで電子と陽電子を衝突させると、137億年前の宇宙のビッグバンと同じ現象が加速器の中で再現できます。これは素晴らしいことです。

1968年、旧ソビエト連邦のブドケル博士に「電子と陽電子をぶつける国際共同実験に参加しないか」と誘われました。電子と陽電子の衝突実験は今でこそ素粒子研究の王道のように言われていますが、当時は朝永先生が量子電気力学でノーベル賞を受賞した頃で、ほとんどの物理屋は電子と陽電子の反応はそれですべて理解出来た気でいました。ある偉い先生からは「そんな実験をしても量子電気力学が正しいということを証明するだけで、何も新しい事は出てこない」と反対されました。私はその時、勘が働いて「電子と陽電子がぶつかって消滅したらエネルギーの塊になるから、どんな粒子でも作れる。いままで見つかってなかった新しい粒子が見つかる可能性がある。加速器の中で宇宙のビッグバンと同じ状態を作ることができる。」と考えました。幸いなことに同じ教室に西島和彦というとても優秀な理論屋がいました。彼は「わからないことがまだあるんだから、このような新しいタイプの実験はやらせてみる価値があるんじゃないですか」と言って、概算要求を出すことを許してくれました。

その頃、ブドケル博士が健康を害してしまったので、私はドイツのDESYという研究所で建設が始まっていた電子陽電子衝突実験に参加することになりました。私の教え子達はそこで電子と陽電子の衝突実験の実績を積み上げていったのです。

加速器分野のフロンティアは、これまでアメリカとヨーロッパに独占されてきました。日本はTRISTANで世界のフロンティアに立つ時期がありましたが、ごく短期間のことで、アジアはフロンティアから遅れてしまいました。中国には素粒子分野でノーベル賞受賞者が3人いますが、3人ともアメリカで教育を受け、アメリカでの研究成果に対して受賞したのです。自国で教育を受け、研究装置を使い、研究を行った科学者がノーベル賞を受賞したら、どれだけたくさんの若い人たちを勇気付けることでしょうか。

これからは、若い人たちが基礎科学の分野で活躍できるように状況をととのえてあげる必要があります。それが大人の役割です。日本が日本の中だけでナショナルマシンを提案しても孤立してしまいます。アジアのおもだった国々が一緒になってちゃんと議論して「アジアにリニアコライダーを作りたい」という合意を作ることが大事です。

ILCをアジアに招致し、たくさんの若い人たちにその研究に携わって欲しい。そして、そこで自分が本当にやりたいことについてたくさんたくさん考えて欲しい。そうすれば、将来の日本やアジアの科学が本当のフロンティアに立つ日も、そう遠くはないはずです。

最近の話題

■第1回国際リニアコライダースクール開校

5月19～27日に総合研究大学院大学（神奈川県葉山市）で第1回目の国際リニアコライダースクールが、国際共同設計チーム（GDE）、国際リニアコライダー運営委員（ILCSC）、ICFAビームダイナミクスパネルの

共催で開催され、Weiren Chou 氏（カリキュラム委員長、米国フェルミ研究所）は「加速器分野での若手の物理学者の研究奨励が目的」と述べました。

44 カ国 500 人以上の応募の中、18 カ国 74 人の学生を受け入れ、世界中から一流の講師 21 名も集められました。宿題は取り組み甲斐のあるものでしたが、将来 ILC にかかわる研究がしたいと学生を刺激するものでした。「ILC に研究焦点を移すつもり」と、Karyanappillil Ranjini 氏（Variable Energy Cyclotron Centre、インド）は述べました。

ILCSC 委員長で、現地実行委員長の黒川眞一氏（KEK）は「スクールの目的が達成されたかどうかは、次の 10 年努力を続けないと判断できません。ILC に関わらなくてもこの経験を活かし、将来それぞれの国で加速器の専門家になり、そして国際交流も持ち続けて欲しいです。」

実際に現場に携わっている人から実験及び理論を学ぶことができる唯一の機会、また設計、建設および運用に重要な役割を果たす様々な分野の専門家が世界各地から集まる、という点からスクールは重要でした。次回リニアコライダースクール計画は進行中です。

■リニアコライダー議員連盟設立される

「リニアコライダー国際研究所建設推進議員連盟」の第 1 回総会が 6 月 15 日に東京で開かれました。議員連盟は ILC を基礎科学における重要な国際的プロジェクトとしてその実現に向け強く支持することを決めました。

議員連盟は自由民主党の 55 人の国会議員が設立し、そのうち 27 名が発起人として名前があがっています。議員連盟の会長には、与謝野馨衆議院議員（経済財政・金融担当大臣）が選ばれました。河村建夫衆議院議員（元文部科学大臣、自民党文教制度調査会長）が幹事長、そして森英介衆議院議員（衆議院予算委員会理事、元厚生労働副大臣）が事務局長に就任する予定です。ノーベル賞受賞者小柴昌俊先生、西島和彦先生（文化勲章受章、東京大学・京都大学名誉教授）、西澤潤一先生（文化勲章受章、首都大学東京学長）、そして庄山悦彦総合科学技術会議議員（株式会社日立製作所会長、日本経団連副会長）など学術界・産業界のリーダーも参加しました。

LC 推進室長より

創刊ご挨拶

横谷馨

ILC は国際協力で進めているプロジェクトです。私たちは世界中の人々と密接に協力しながら研究を進めています。一方、私たち日本の研究者は日本国内の皆様にもっと良く ILC を知っていただく必要を常に感じています。この ILC 通信がその為の一助になれば幸いです。

カレンダー

イベント名	期間	場所
ILC GDE全体会議	7/19-7/22	バンクーバー（カナダ）
ILC加速器諮問委員会	9/20-9/22	KEK（つくば）
ILC GDE全体会議	11/6-11/10	ヴァレンシア（スペイン）
FALC（監督官庁連絡会議）	11/20	KEK（つくば）
アジアR&Dワークショップ	11/27-11/29	北京（中国）

来訪者一覧（6 月）

氏名	所属	滞在期間
Doublet, Philippe	ENS, フランス	4/14- 8/7
K Pant, Kamal	RRCAT , インド	4/19- 6/18
Chouksey, Sanjay	RRCAT, インド	4/19- 7/16
HONG, Juho	POSTEC, 韓国	5/8- 3/31
Howell, David	オックスフォード大学, 英国	5/9- 6/2
Moon, Sung Ik	POSTEC, 韓国	5/10- 10/31
Deacon, Lawrence	RHUL, 英国	5/14- 6/3
Seleznev, Igor	JINR, ロシア	5/19- 6/4
Delerue, Nicolas	オックスフォード大学, 英国	5/26- 6/2 6/7- 6/14
Trubnikov, Grigory	JINR, ロシア	5/27- 6/4
Blair, Grahame	RHUL, 英国	5/27- 6/3
Ross, Marc	SLAC, 米国	5/27- 6/1
Dixit, Sudhir	オックスフォード大学, 英国	5/28- 6/4
Urner, David	オックスフォード大学, 英国	5/28- 6/2
Bambane, Philipe	LAL, フランス	5/28- 6/1
Levi, Sanchez Allister	ミンダナオ州立大学, フィリピン	5/28- 6/2
Woodley, Mark	SLAC, 米国	5/29- 6/2
Seryi, Andrei	SLAC, 米国	5/29- 6/2
Spencer, Cherrill	SLAC, 米国	5/29- 6/2
Bellomo, Paul	SLAC, 米国	5/29- 6/2
Burrows, Philip	オックスフォード大学, 英国	5/29- 6/1 6/12 6/16
Alexey, Lyapine	オックスフォード大学, 英国	6/5- 6/17
XU, Qing Jin	IHEP, 中国	6/5- 9/2
Clarke, Christine	SLAC, 米国	6/7- 6/17
White, Glen	SLAC, 米国	6/7- 6/17
Christian, Glenn	オックスフォード大学, 英国	6-11- 6/18
Dabiri, Khah	オックスフォード大学, 英国	6/11- 6/18
Kim, Young Im	慶北大学, 韓国	6/17- 7/5

ILC 関連記事など（6 月）

掲載日	媒体	内容
6/15	読売新聞（夕刊）	リニアコライダー誘致へ議連
6/15	共同通信（配信）	巨大加速器、日本に誘致を 自民が建設推進議連
6/21	神戸新聞（夕刊）	「宇宙創生」直後再現へ
6/27	朝日新聞（夕刊）	宇宙誕生の謎に迫る加速器「リニアコライダー」国内誘致へ米と綱引き
6/30	科学新聞	ビッグバン解明めざす「リニアコライダー国際研」

Linear Collider Project Office at KEK

Asian Regional Team for Linear Collider Accelerator Development

KEK Home | KEK Acc. Lab. | GDE (ILC-World) | ILC-Asia Accelerator | ILC-Asia Physics

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1st ILC Workshop
2nd ILC Workshop

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- **Mailing Lists**

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- **STF**

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Additional Resources
- **World Efforts**
- **ILC Newsline (J)**
- **Useful Links**

LC Office Contact Information

- **Kaoru Yokoya** (Acc Lab, KEK), starting April 1, 2006
- Members: **Kaoru Yokoya** (Acc Lab, KEK), **Mitsuaki Nozaki** (IPI **Hayano** (Acc Lab, KEK), **Nobu Toge** (Acc Lab, KEK), **Junji Ural** KEK), **Satoru Yamashita** (ICEPP, Univ of Tokyo), **Fumihiko Ta** IPNS, KEK)
- Admin/Secretary: Tomiko Shirakata (KEK)
- Contact: **ml-lc-office@lcdev.kek.jp**

ILC News (Japanese ILC Communication) NEW

- ILC News (Japanese ILC Communication) is a monthly, two-page aimed at communicating the status of ILC efforts in Japan and in both the non-technical- and technical-oriented audience in Japan **note** in Japanese.)
- To subscribe to a paper copy (free), send email to: **subscribe@l**
- To communicate inquiries and comments on the contents, send e **lcnews@lcdev.kek.jp**

- Online PDF Files:
  - **Issue 1** (2006/7/15)

GDE-related Information

- **GDE main web site** (http://www.linearcollider.org)
- **Archives** of messages notifying new articles of ILC Newsline (bo Japanese).
- **ILC Newsline** (English, original. Main Site)
- **ILC Newsline** (Japanese translation. Main Site) To subscribe, tr

Meetings

- **Regular/Semi-regular Local Meetings** (3/2005-)
- **Scheduled Activities** (10/3/2004-)

- **9/13/2004 Meeting Memo (Japanese only)** (9/22/2004)
- **9/6/2004 Invitation to SC-LC Seminar (Japanese only)** (8,
- **8/26/2004 Meeting Memo (Japanese only)** (8/30/2004)

ILC-Asia Study Work Groups

- **ILC-Asia Study Work Groups** (9/13/2004)

Summary

The LHC will comission in 2007, and produce physics results from 2008.

There is a consensus among particle physicists (+α) that a TeV scale e^+e^- collider (0.5TeV ··· I ↗? 1TeV ··· II) should produce physics within the first 10 years of the LHC.

2007 TDR
⇒ 2008 site/proposal
2009 budget
2010 construction starts

USA — Rising above the gathering storm — 2005

10,000 math + science teachers

10% increase/year of basic science budget

Increase support for higher education

EPP 2010 report endorces the ILC — 2006.4

EU — CERN Council Report endorces the ILC — 2006.7

ILC vs CLIC ?

Asia — High Energy Physicists in Japan support the ILC — 1986 ~

← ACFA activities — 1998 ~
→ Forum of buisness people — 2003 ~
→ Forum of LDP representatives — 2006

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