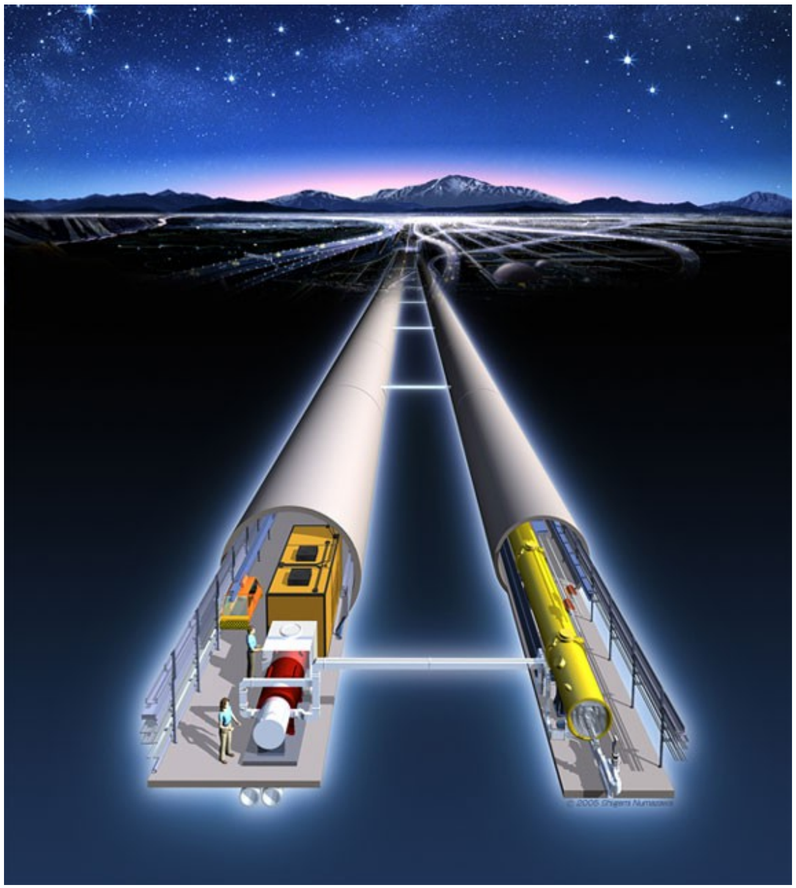
ILC Physics Case



Roman Pöschl
Directeur de Recherche of CNRS

CNRS IN2P3 Les deux infinis

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

UNIVERSITÉ PARIS SUD Comprendre le monde, construire l'avenir®

P2IO Physique des 2 Infinis et des Origines

R.P. is indebted to many authors from whom I have reused their material

XXI Cracow EPIPHANY Conference – January 2015

Outline of talk

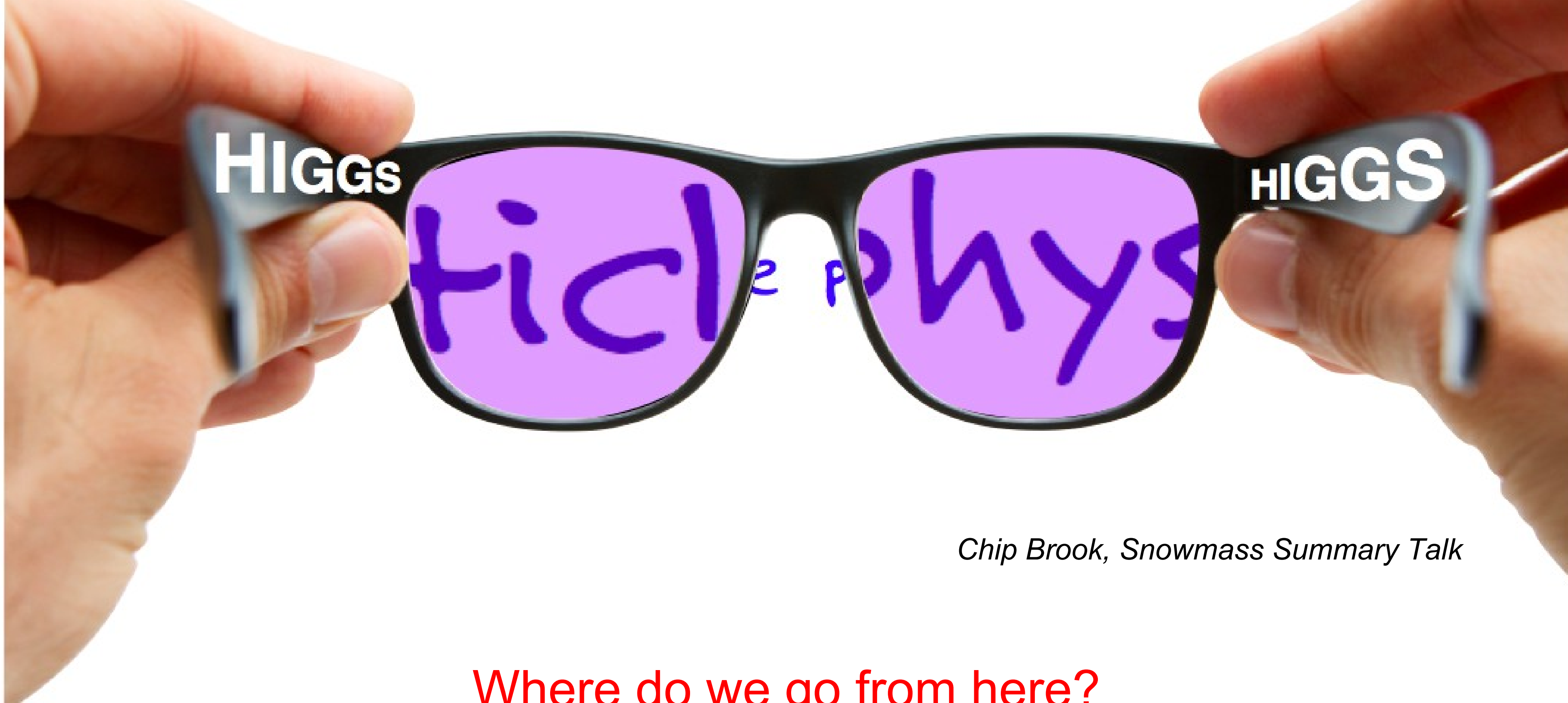
- Chapter 1: Introduction
- Chapter 2: Higgs Physics at the ILC
- Chapter 3: Top Physics at the ILC
- Chapter 4: BSM Physics at the ILC

1. Introduction

New view on Particle Physics ...

Coronation of the Standard Model
and
First step on a road yet largely unexplored

Slightly modified citation of Barbieri arXiv:1309.3447



Chip Brook, Snowmass Summary Talk

Where do we go from here?

Open questions

How to make progress?

1) Collisions at energies well above the electroweak scale
   - Requires now and in the foreseeable future Hadron colliders
   - Direct production of new particles
   - Produce large number of rare particles and study rare decays
   - First precision measurements of key particles of electroweak theory

-> High energy, High luminosity LHC

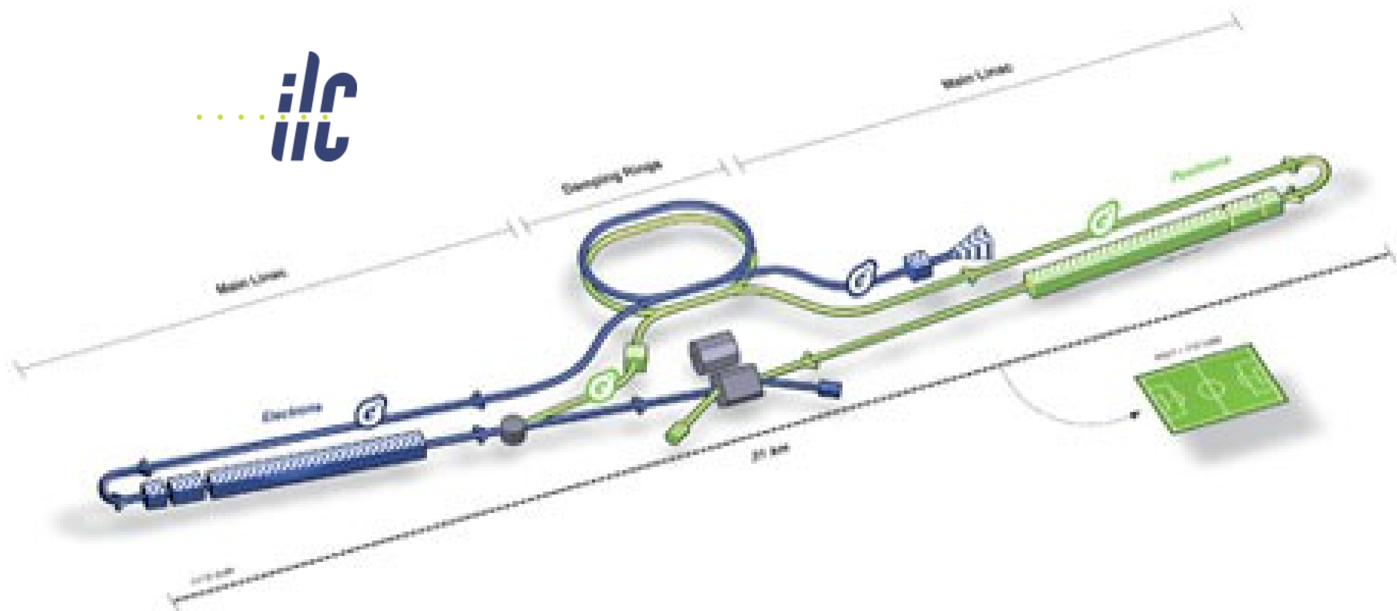
2) e+e-Collisions at energies at the electroweak scale
   - Probe the electroweak scale with high precision
   - ... in particular particles that carry the “imprint of the Higgs Field such as W, Z and top”

-> ILC

3) e+e- collisions at 'smaller' energies
   - Requires high luminosity to get sensitive to tiny quantum effects

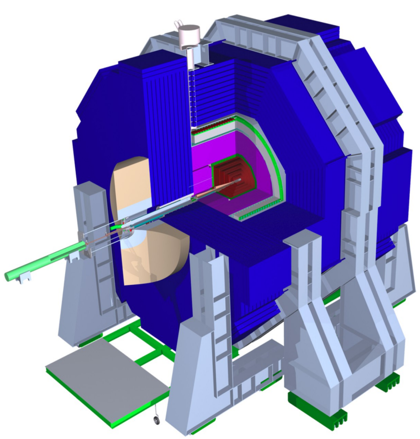
-> SuperKEKB

ILC Project - Machine and detectors

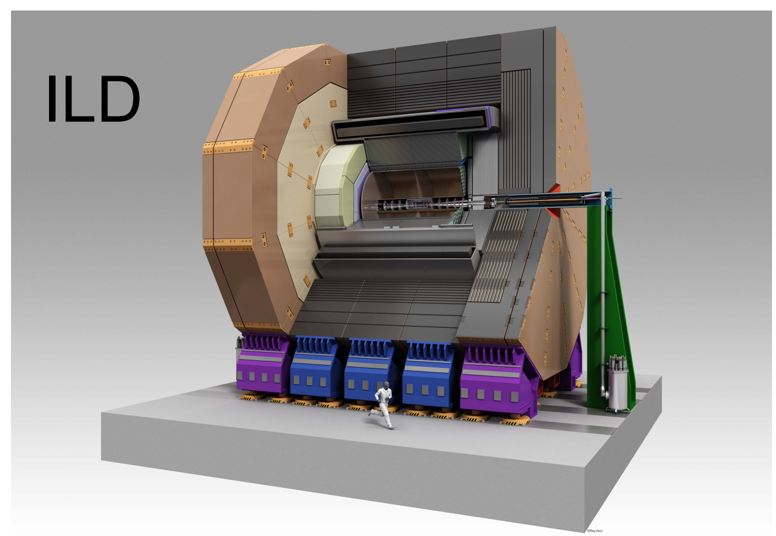


ILC design parameters	
$\sqrt{s}$	91-500 GeV
$\mathcal{L}$	2×10^{34} cm^{-2}s^{-1}
P_{e^-}	>80%
P_{e^+}	~30%
Length	~31 km

-> Talk by Steinar Stapnes



SiD



ILD

Talks by:

Imad Laktineh
Frank Simon
Marek Idzik
Lucie Linssen

Machine TDR in 2013 + DBD for detectors

Detector requirements

Track momentum: $\sigma_{1/p} < 5 \times 10^{-5}$/GeV (1/10 x LEP)

(e.g. Measurement of Z boson mass in Higgs Recoil)

Impact parameter: $\sigma_{d0} < [5 \oplus 10/(p[\mathrm{GeV}]\sin^{3/2}\theta)]$ μm(1/3 x SLD)

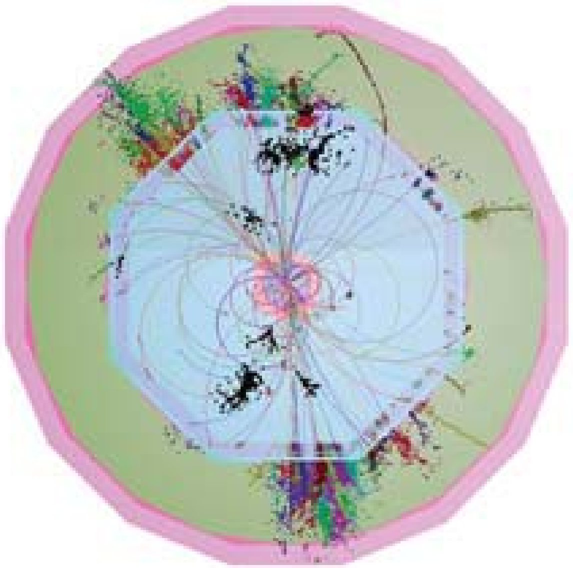
(Quark tagging c/b)

Jet energy resolution : $dE/E = 0.3/(E(\mathrm{GeV}))^{1/2}$ (1/2 x LEP)

(W/Z masses with jets)

Hermeticity : $\theta_{min} = 5$ mrad

(for events with missing energy e.g. SUSY)

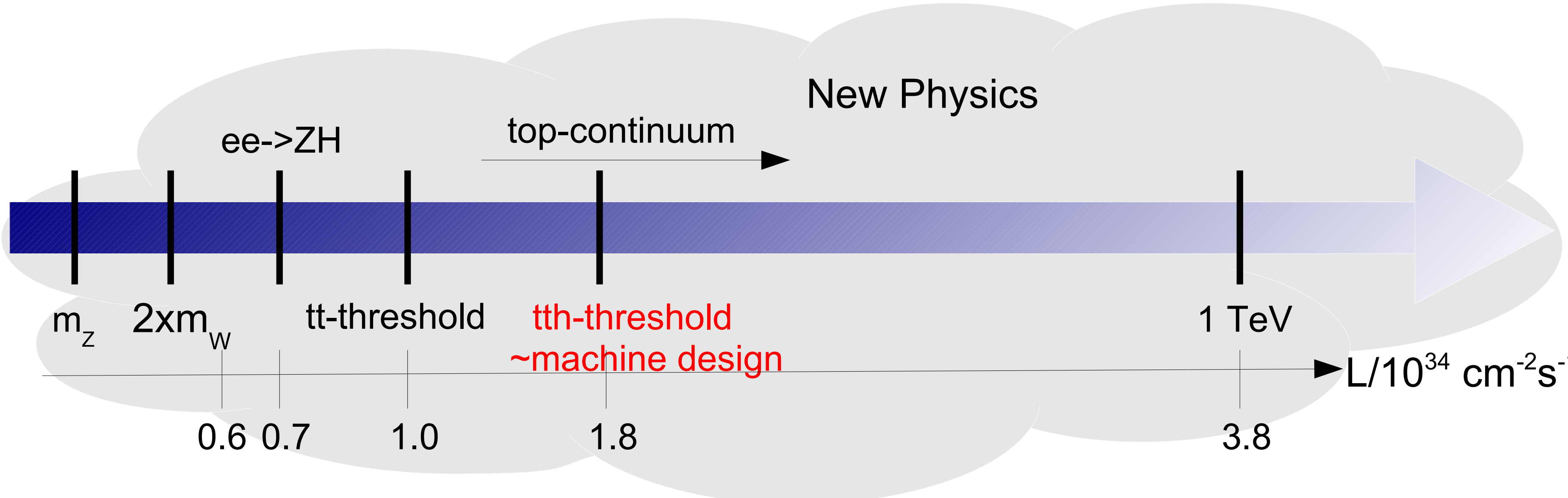


Final state will comprise events with a large number of charged tracks and jets(6+)

- High granularity
- Excellent momentum measurement
- High separation power for particles

- Particle Flow Detectors

ILC Physics program



- All Standard Model particles within reach of ILC
  - High precision tests of Standard Model over wide range to detect onset of New Physics
- Machine settings can be “tailored” for specific processes
  - Centre-of-Mass energy
  - Beam polarisation

$$\sigma_{P,P'} = \frac{1}{4}[(1-PP')(\sigma_{LR}+\sigma_{RL})+(P-P')(\sigma_{RL}-\sigma_{LR})]$$

- “Background free” searches for BSM through beam polarisation

Not covered in this talk

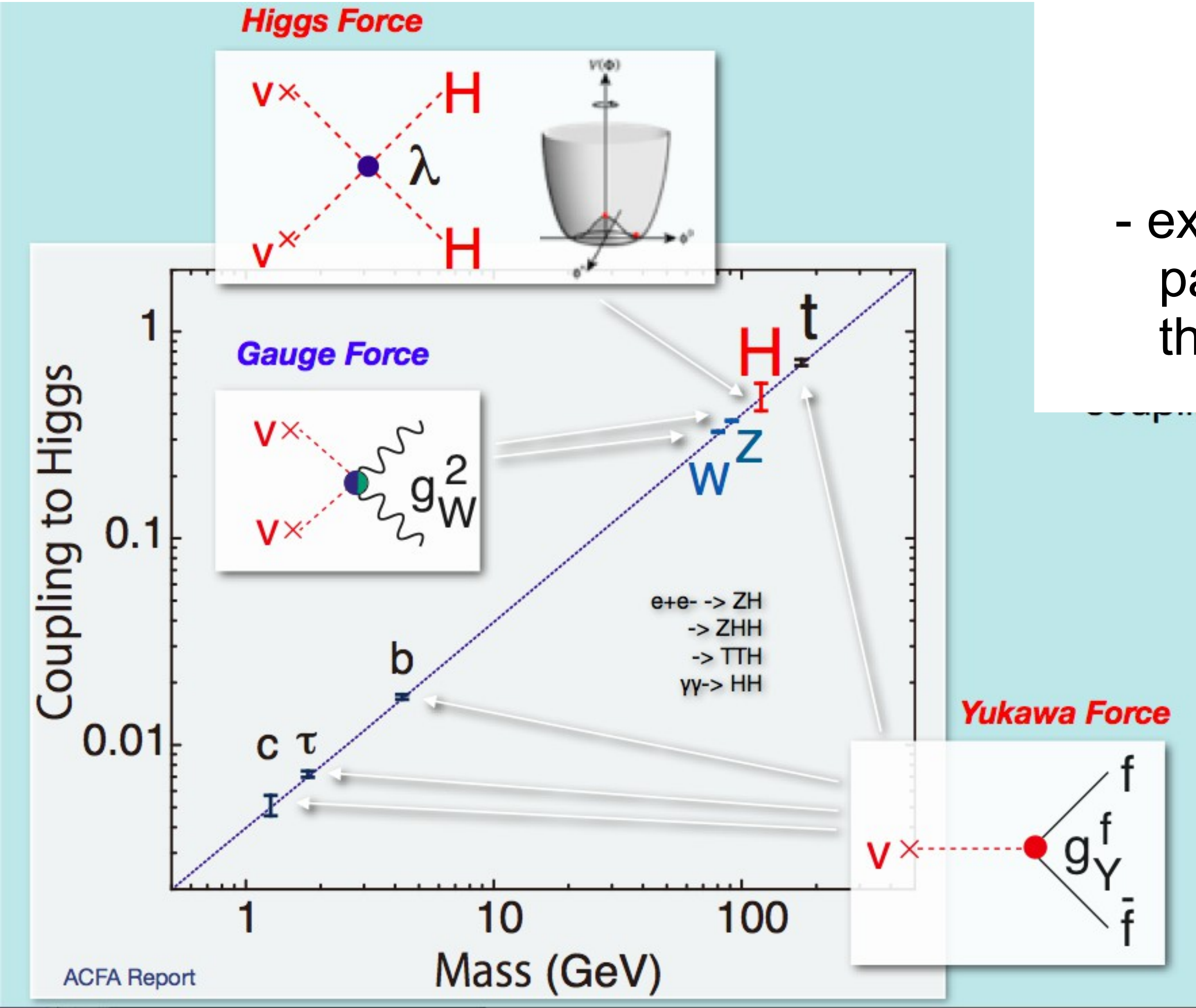
- ILC in GigaZ option
  - Remeasurement of Weak Mixing angle with polarised beams
  - W Mass measurements

- W and Z physics
  - Triple Gauge Boson Couplings
  - Longitudinal Boson Scattering

- Two fermion processes other than ee -> tt

2. Higgs Physics at the ILC

Precision Higgs Physics



- exact correlation between particle masses couplings to the Higgs in Standard Model

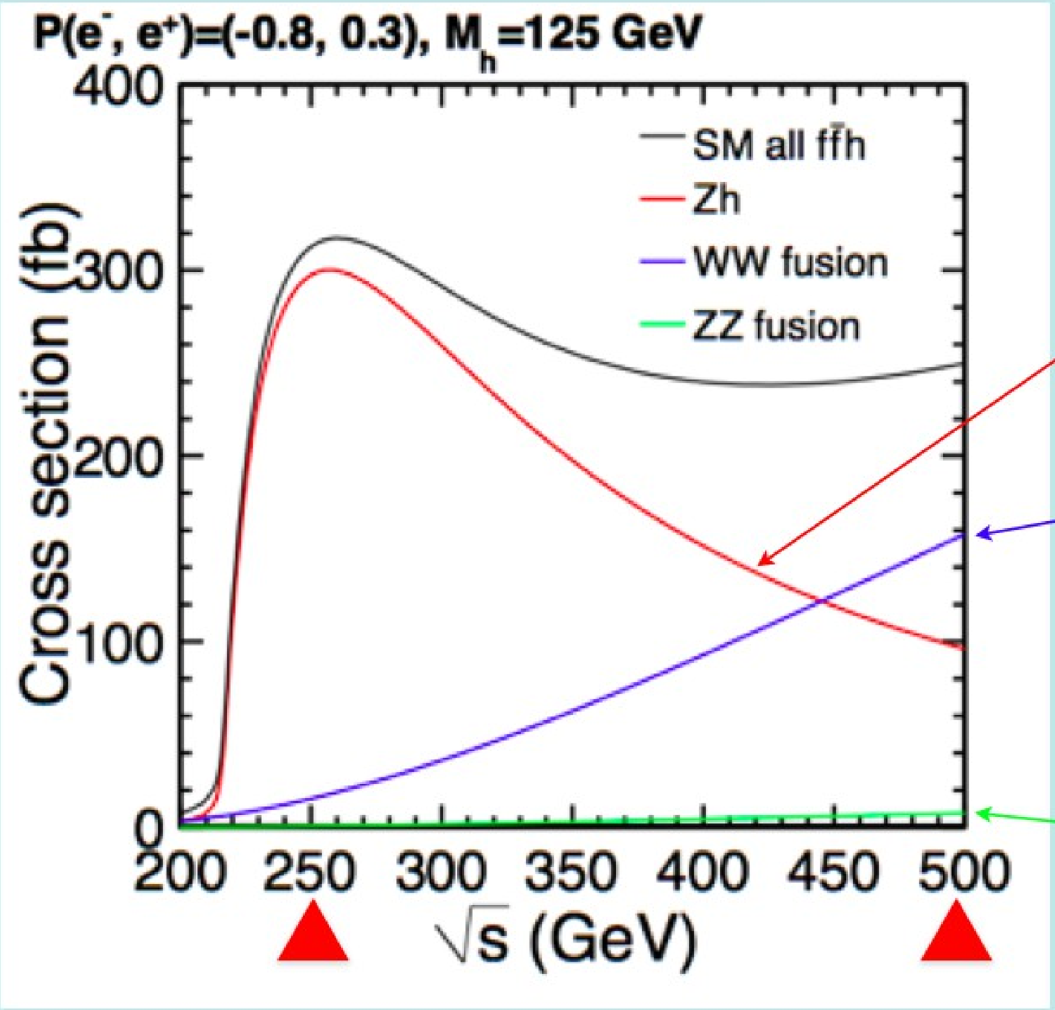
- Any tiny deviation is New Physics

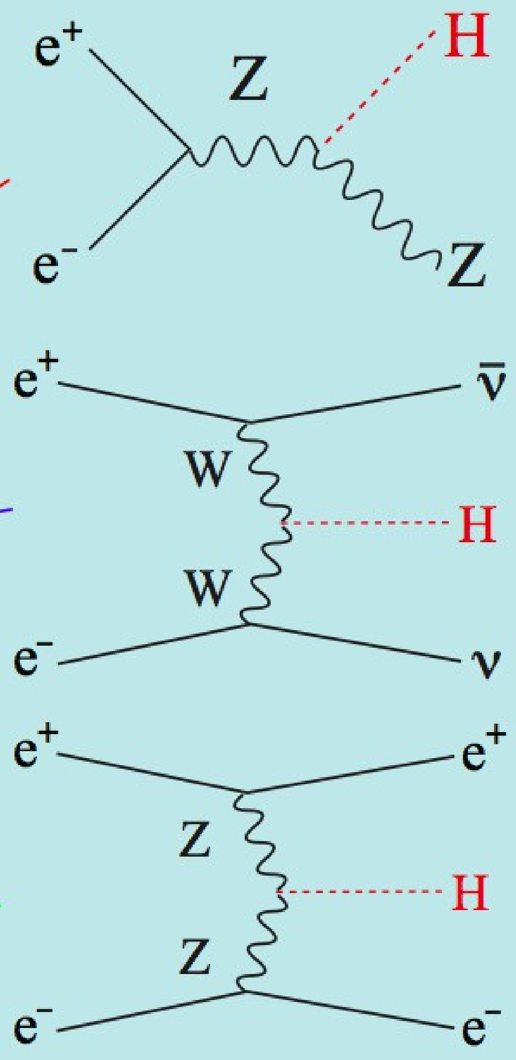
	ΔhVV	$\Delta h\bar{t}t$	$\Delta h\bar{b}b$
Mixed-in Singlet	6%	6%	6%
Composite Higgs	8%	tens of %	tens of %
Minimal Supersymmetry	$< 1\%$	3%	$10\%^a$, $100\%^b$
LHC 14 TeV, 3 ab^{-1}	8%	10%	15%

- Need precision on Higgs couplings at 1% level

Single Higgs Production at the ILC

Production cross section



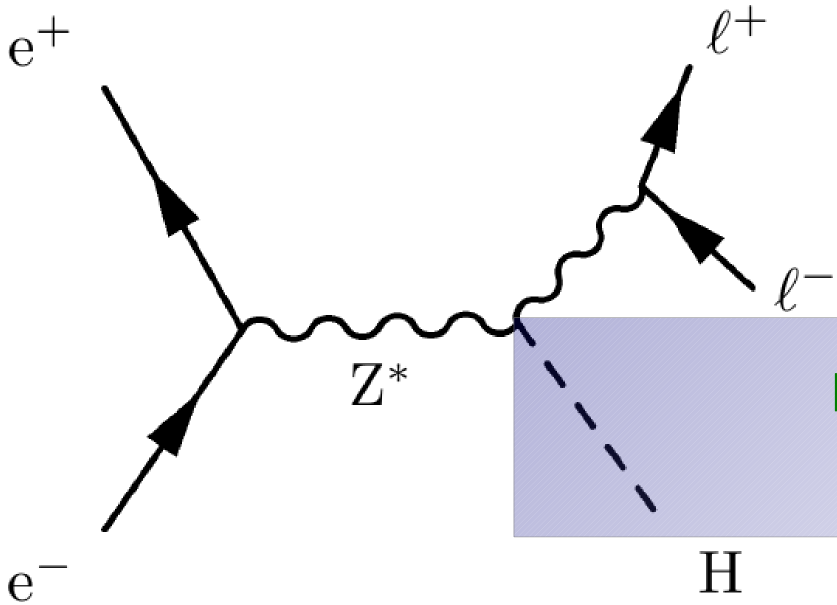


ZH dominates at 250 GeV
(~80k ev: 250 fb^{-1})

νvH takes over at 500 GeV
(~125k ev: 500 fb^{-1})

K. Fujii, LC School 2014

Higgs Mass and ZZH coupling by
Model Independent
measurement

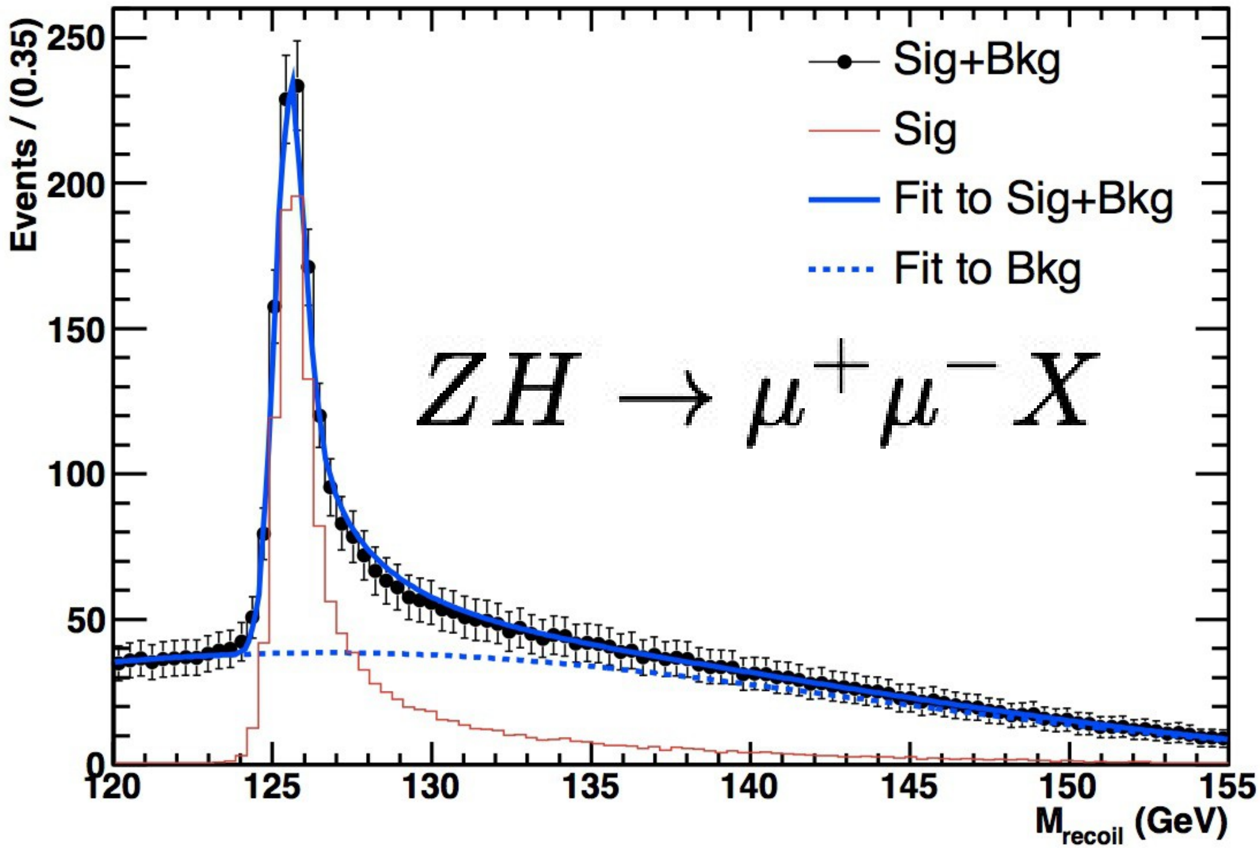


Well measurable
decay leptons from Z
μ Pairs, e pairs

No assumption on Higgs
decay modes

Higgs Recoil Mass: $M_h^2 = M_{recoil}^2 = s + M_Z^2 - 2E_Z\sqrt{s}$

Full simulation study at 250 GeV

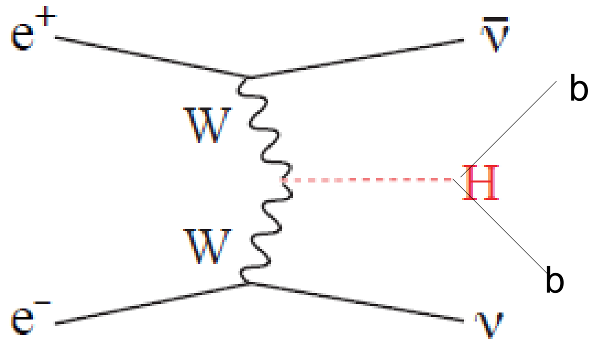


$$M_h = 125.3 \pm 0.03\,\mathrm{GeV}$$

$$\sigma_{ZH} = 10.32 \pm 0.37\,\mathrm{fb},\ 3.6\%$$

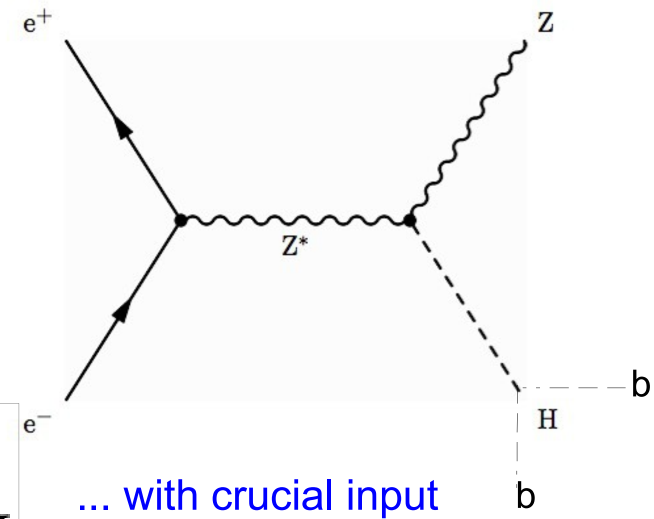
The Total Higgs Width

Can be derived from model independant measurements

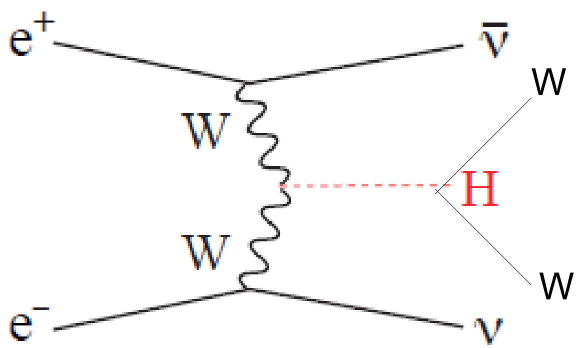


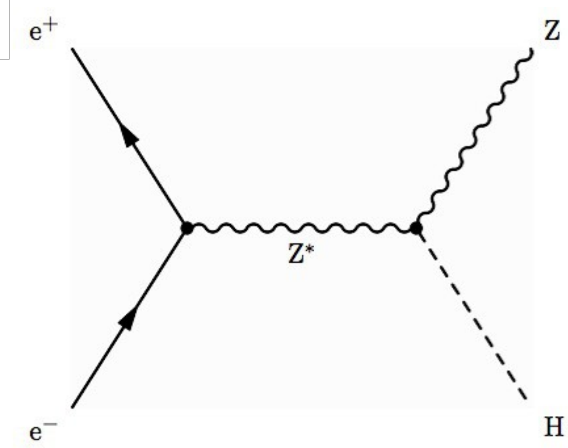
Requires running at 500 GeV

$$\Gamma_t \sim \frac{\left(\sigma_{\nu\bar{\nu}b\bar{b}} / \sigma_{Zb\bar{b}}\right)^2}{\left(\sigma_{\nu\bar{\nu}WW} / \sigma_{ZH}\right)} \times \sigma_{ZH}$$



... with crucial input from 250 GeV running



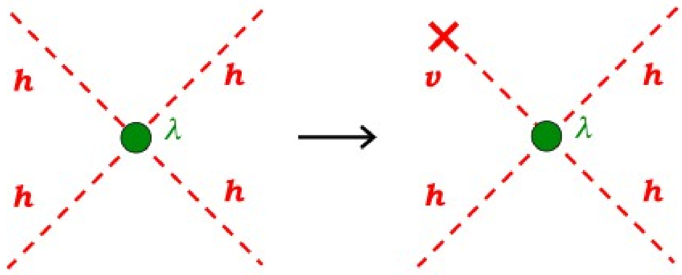


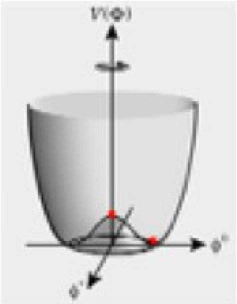
Current prospects - $\delta\Gamma_{tot}$ ~ 5% @ 500 GeV

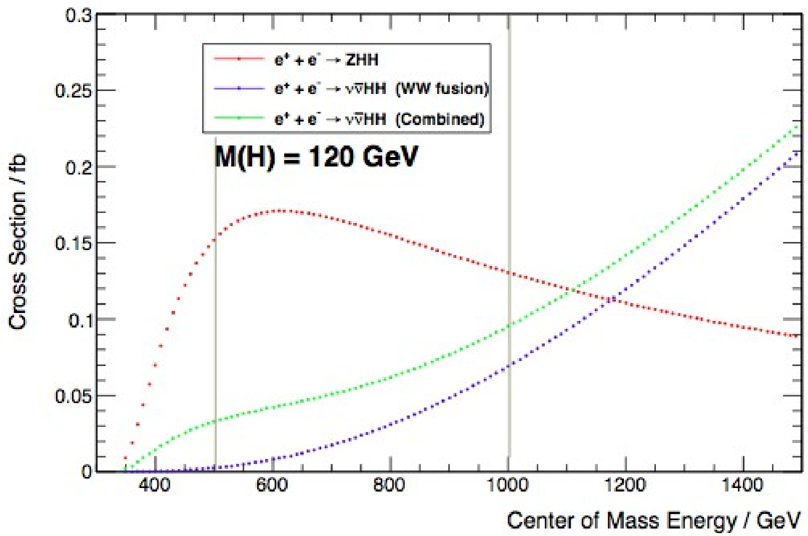
~ 4% @ 1 TeV (2% technically possible)

Higgs self-coupling

Existence of hhh coupling =
Direct evidence of vacuum condensation

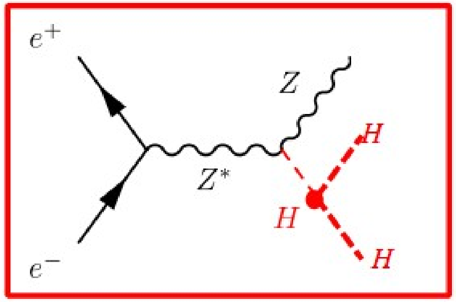




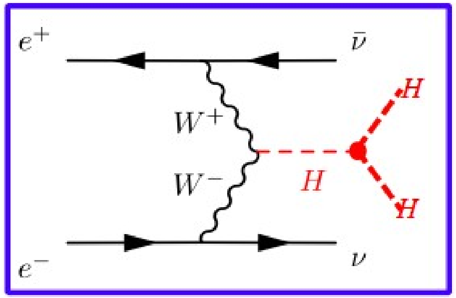


Challenging measurement because of:

- Small cross section (Zhh 0.2 fb at 500 GeV)
- Many jets in the final state
- ***Presence of interference diagrams***



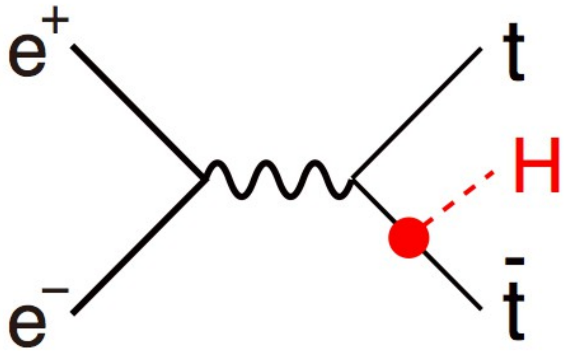
arXiv:1310.0763	ILC500	ILC500-up	ILC1000	ILC1000-up
$\sqrt{s}$ (GeV)	500	500	500/1000	500/1000
$\int \mathcal{L}dt$ (fb^{-1})	500	1600‡	500+1000	1600+2500‡
$P(e^-, e^+)$	$(-0.8, 0.3)$	$(-0.8, 0.3)$	$(-0.8, 0.3/0.2)$	$(-0.8, 0.3/0.2)$
$\sigma(ZHH)$	42.7%		42.7%	23.7%
$\sigma(\nu\bar{\nu}HH)$	–	–	26.3%	16.7%
λ	83%	46%	21%	13%

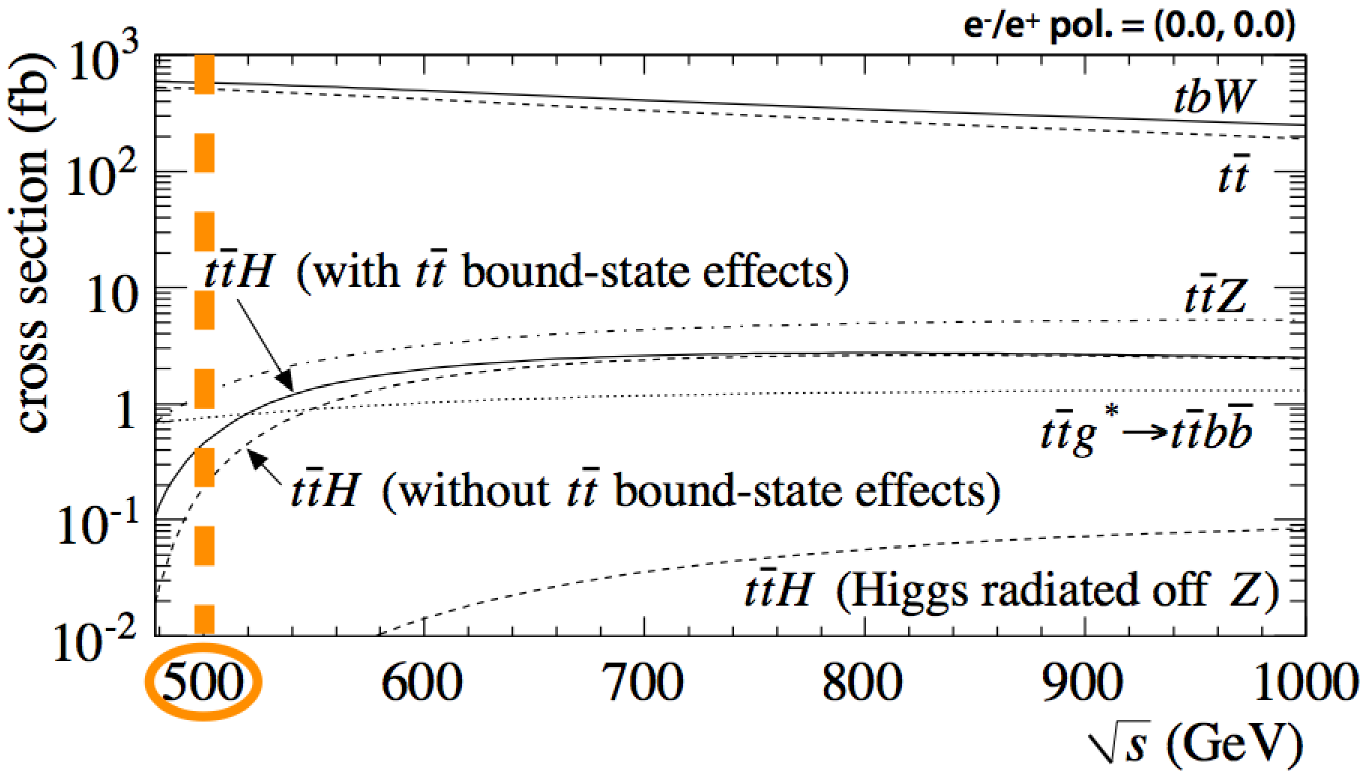


T. Tanabe, K. Fuji, LCWS14

Hard(est) measurement, 10% accuracy seems possible

Top Yukawa Coupling



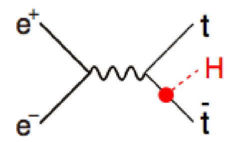


- Coupling of Higgs to heaviest particle known today

- Up to eight final state jets

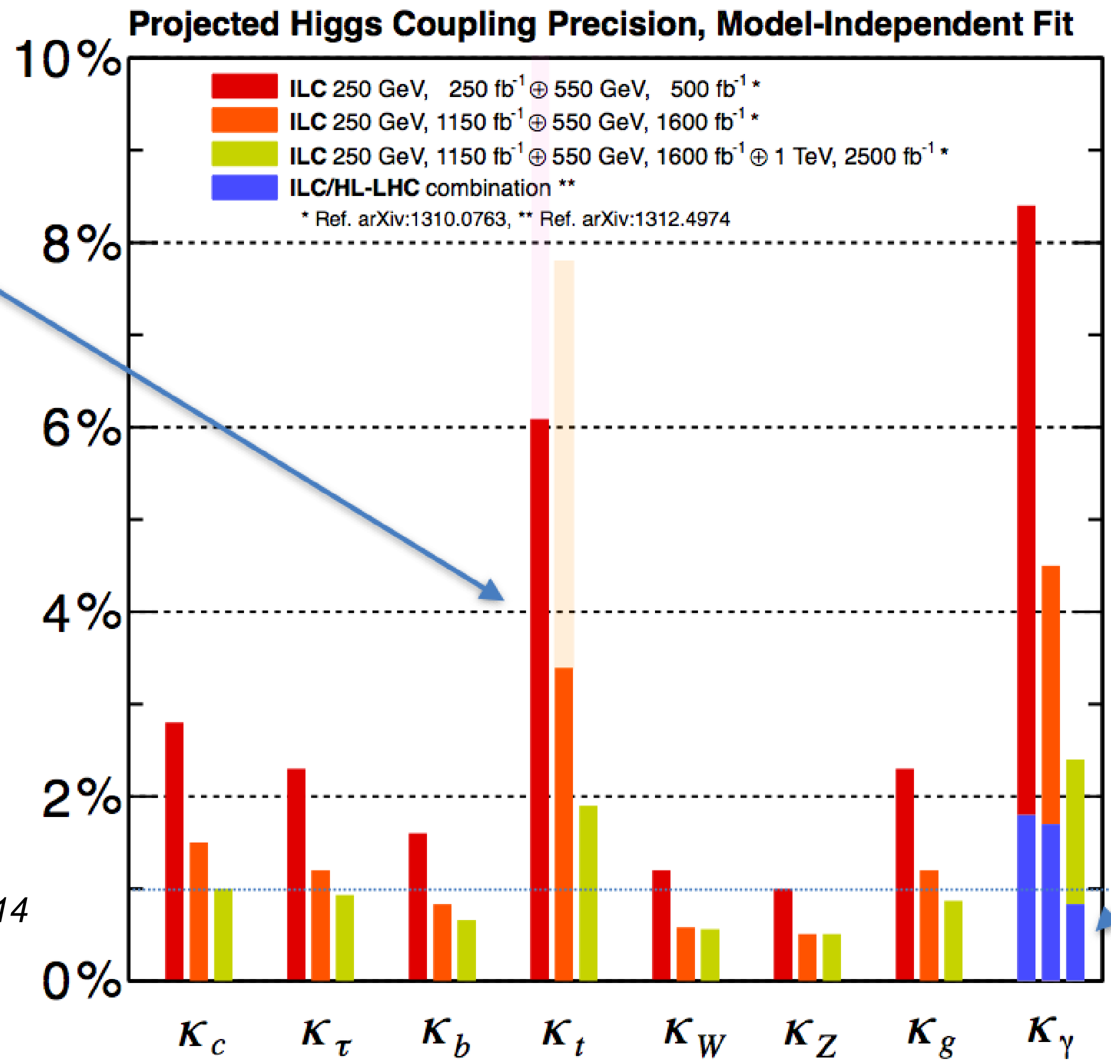
$\Delta g_{ttH} / g_{ttH}$	500 GeV	500 GeV + 1 TeV	
Canonical	14%	3.2%	← ILC TDR
LumiUP	7.8%	2.0%	← Technically possible

R. Horiguchi et al.
T. Tanabe, T. Price



Top Yukawa improves by going to 550 GeV

Near threshold → a factor of 4 enhancement of σ_{tth} by going from 500GeV to 550 GeV



T. Tanabe, K. Fuji, LCWS14

LHC can precisely measure

$BR(h\to\gamma\gamma) / BR(h\to ZZ^*)$ $= (K_\gamma / K_Z)^2$

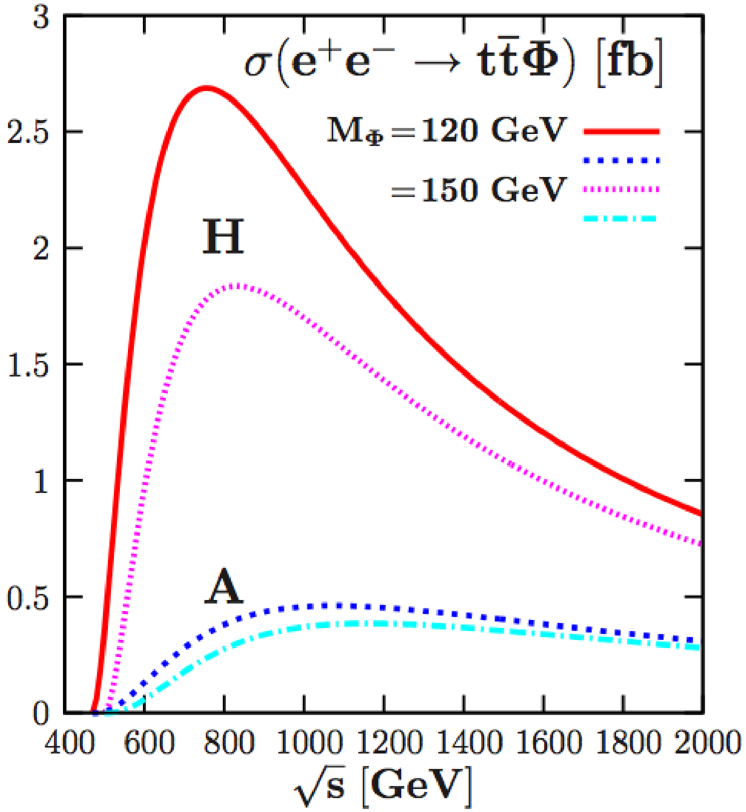
ILC can precisely measure K_Z

Better hγγ with LHC/ILC synergy

- Precise measurements of relevant Higgs couplings
- Precision matters: Detect deviations, for example due to extended Higgs sectors (SUSY,composite, ...):Expected on the 10% - 15% level in fermions,on the few % level in gauge bosons in typical Two-Higgs-Doublet models (Chapter 4)

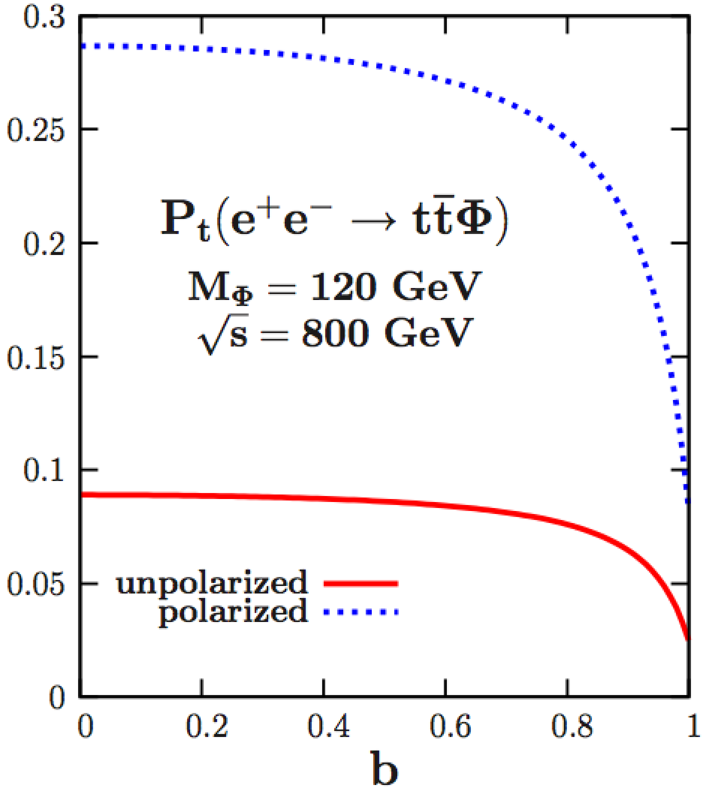
Direct coupling of top quark to CP odd and CP even scalar

Cross section



Dramatic differences for
CP odd and CP even scalar

Top quark polarisation



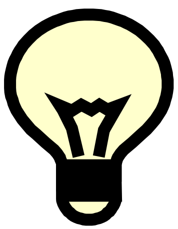
Sensitivity to CP odd admixture b
Merit of beam polarisation

Determination of CP nature of scalar boson in an unambiguous way

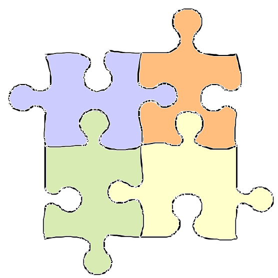
Godbole et al., LCWS07

3. Top physics at the ILC

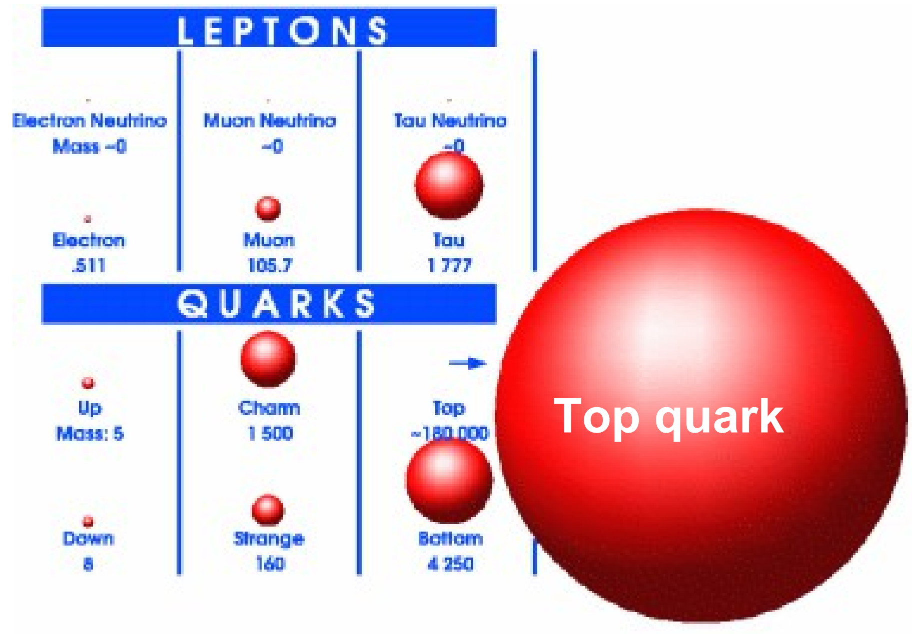
An enigmatic couple



Elementary Scalar?



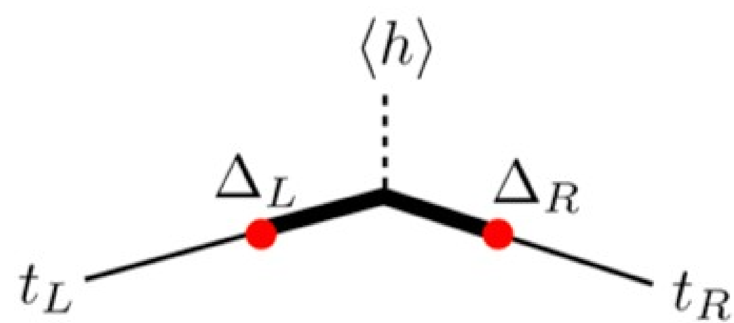
Composite object?



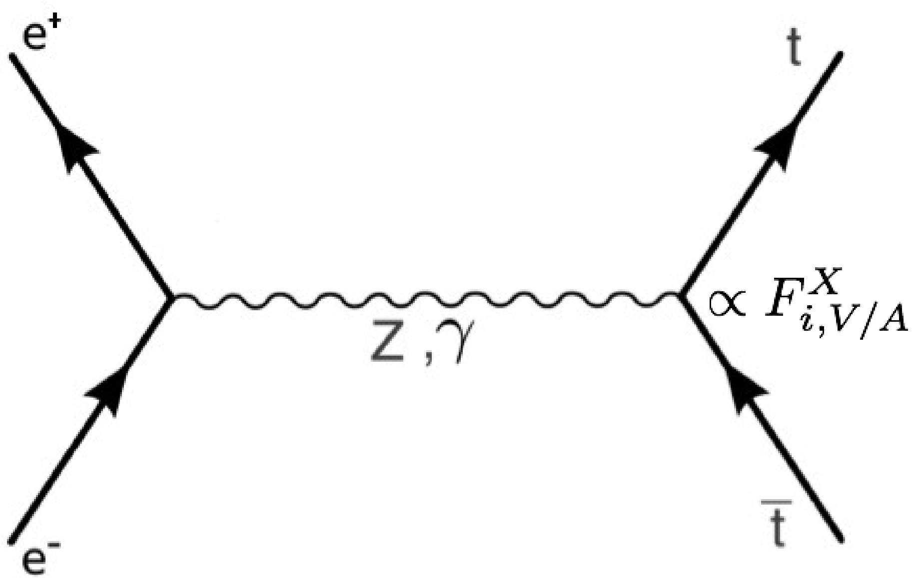
- Higgs and top quark are intimately coupled!
  Top Yukawa coupling O(1) !
  => Top mass important SM Parameter

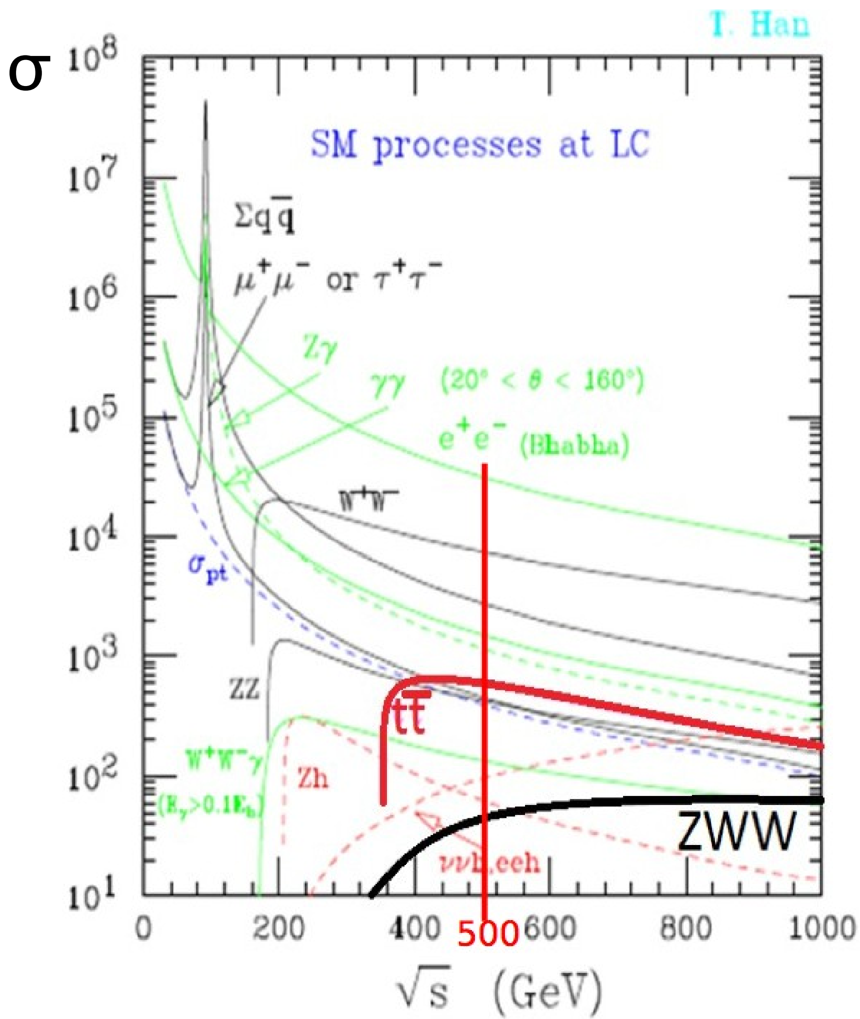
- New physics by compositeness?
  Higgs <u>and</u> top composite objects?

- LC perfectly suited to decipher both particles



Courtesy of S. Rychkov





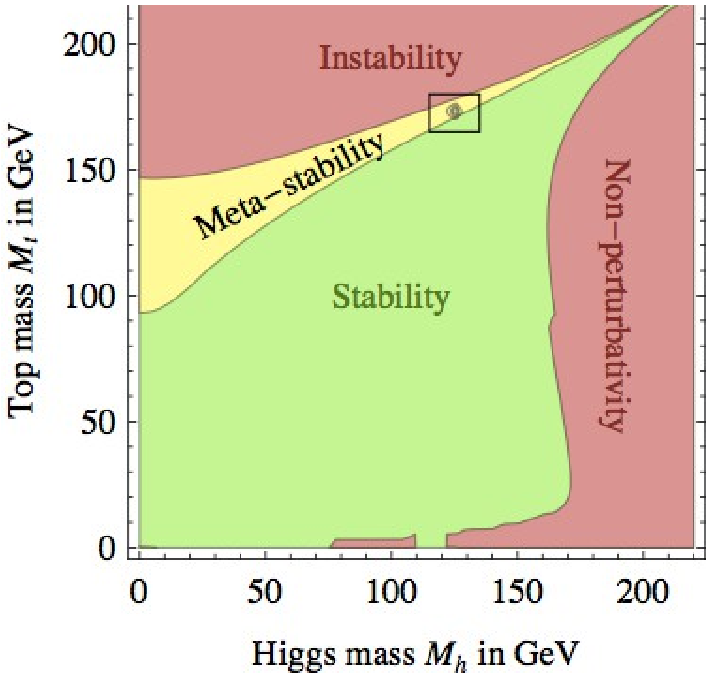
- Top quark production through electroweak processes
  no competing QCD production => Small theoretical errors!

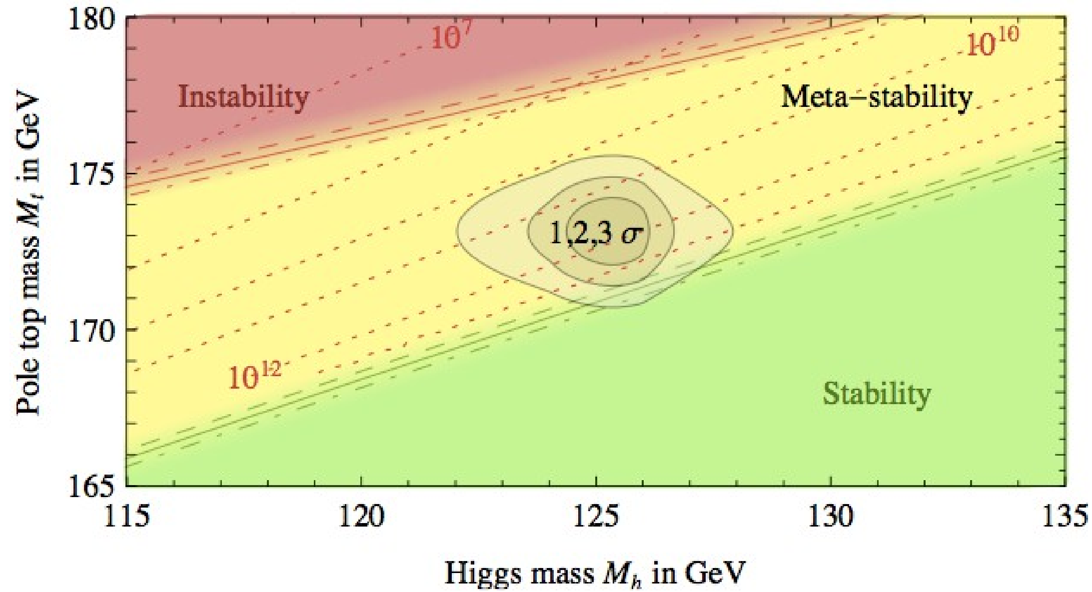
- High precision measurements
  -Top quark mass at ~ 350 GeV through threshold scan
  - Polarised beams allow testing chiral structure at ttX vertex
    => Precision on form factors F

Vacuum stability and Top Quark Mass

Degrassi et al. arXiv:1205.6497

$$M_h\ [\mathrm{GeV}] > 129.4 + 1.4\left(\frac{M_t\ [\mathrm{GeV}] - 173.1}{0.7}\right) - 0.5\left(\frac{\alpha_s(M_Z) - 0.1184}{0.0007}\right) \pm 1.0_{\mathrm{th}}\ .$$

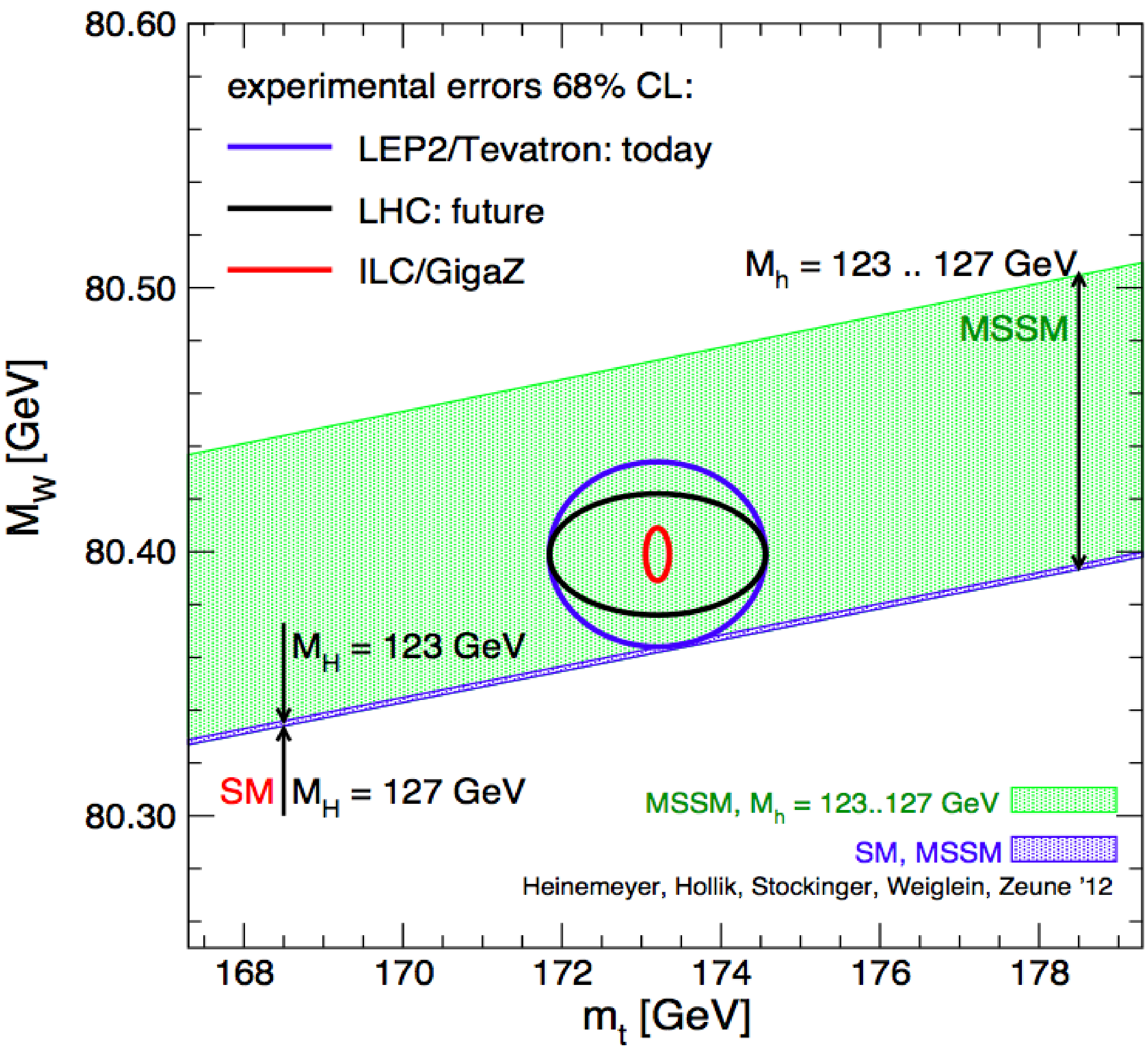




Type of error	Estimate of the error	Impact on M_h
M_t	experimental uncertainty in M_t	± 1.4 GeV
α_s	experimental uncertainty in α_s	± 0.5 GeV
Experiment	**Total combined in quadrature**	± 1.5 GeV
λ	scale variation in λ	± 0.7 GeV
y_t	$\mathcal{O}(\Lambda_{\mathrm{QCD}})$ correction to M_t	± 0.6 GeV
y_t	QCD threshold at 4 loops	± 0.3 GeV
RGE	EW at 3 loops + QCD at 4 loops	± 0.2 GeV
Theory	**Total combined in quadrature**	± 1.0 GeV

Uncertainty on **(pole)** top quark mass dominates uncertainty on stability conditions

Top Mass, Higgs Mass and BSM – SM vs. MSSM



Precise Top (and W) mass crucial to test compatibility of measured Higgs mass

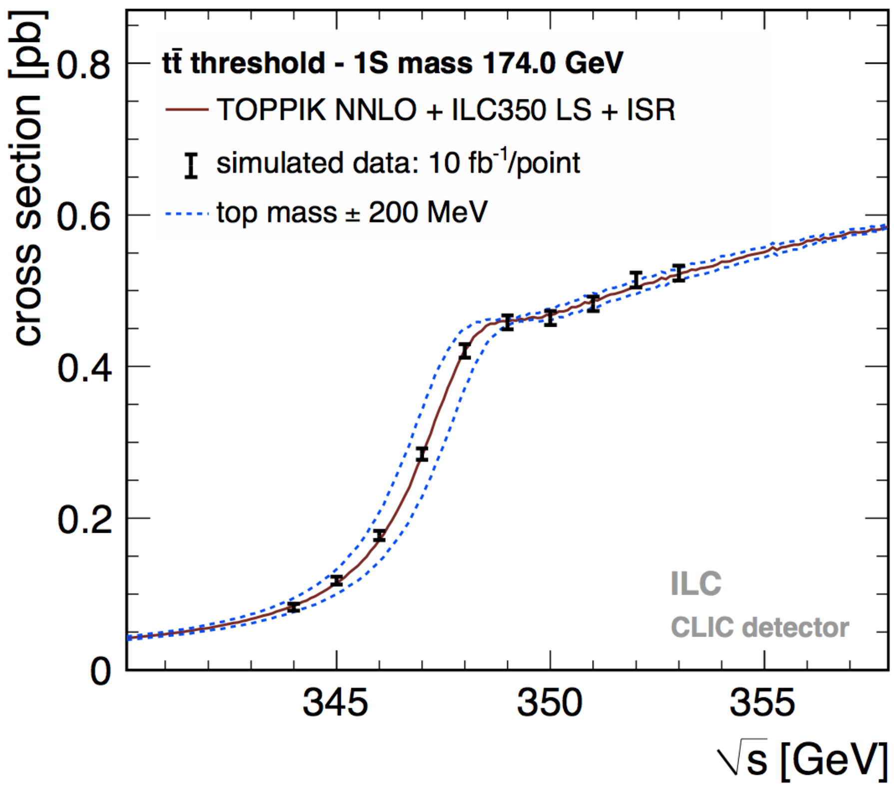
MS might not be sufficient to explain Higgs mass

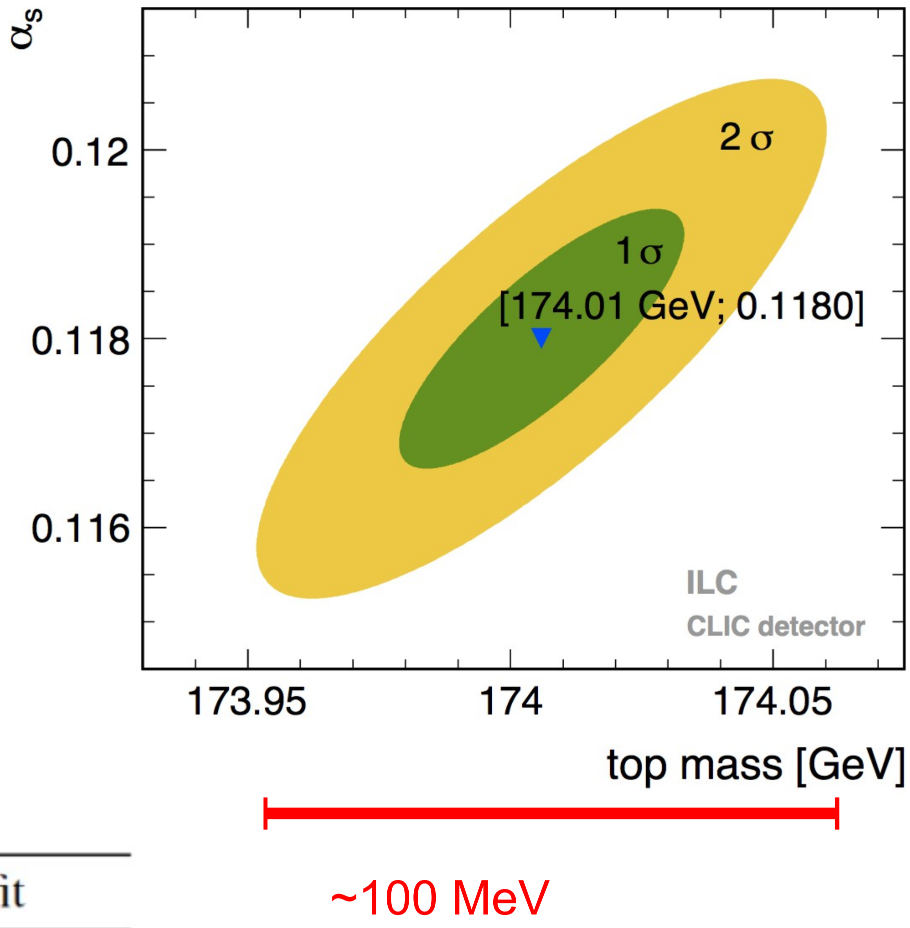
LHC may not reach sufficient discriminative power

A lepton collider will

Mass and α_s

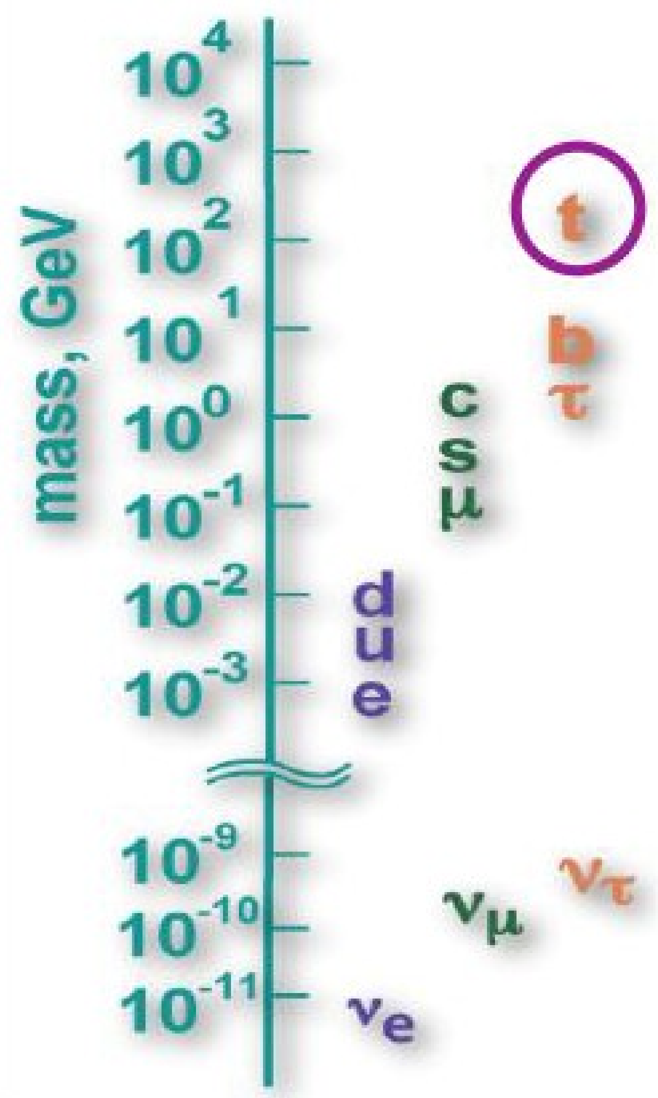
EPJC C73 (2013) 2530





1S top mass and α_s combined 2D fit	
m_t stat. error	27 MeV
m_t theory syst. (1%/3%)	5 MeV / 9 MeV
α_s stat. error	0.0008
α_s theory syst. (1%/3%)	0.0007 / 0.0022

Top Quark and Flavor Hierarchy

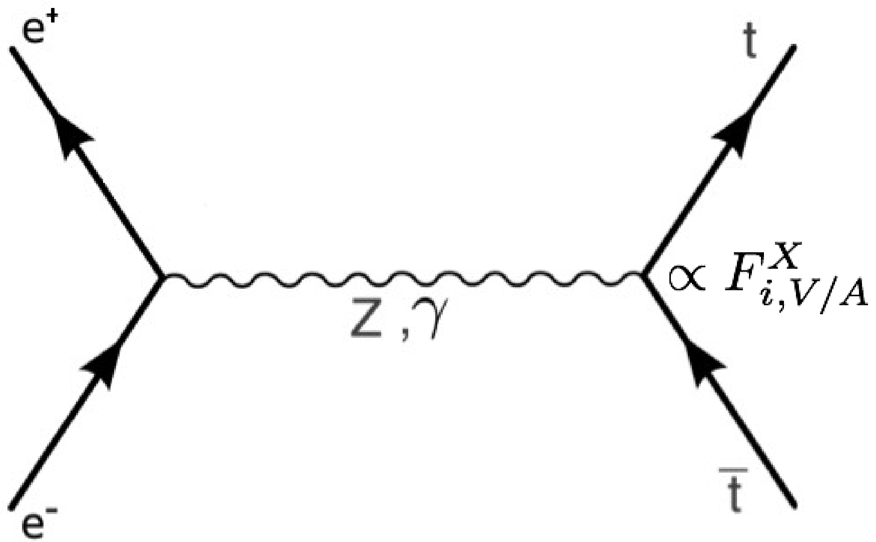


- SM does not provides no explanation for mass spectrum of fermions (and gauge bosons)

- Fermion mass generation closely related to the origin electroweak symmetry breaking

- Expect residual effects for particles with masses closest to symmetry breaking scale
  - A_{FB} anomaly at LEP for b quark

Strong motivation to study chiral structure of top vertex in high energy e+e- collisions



$$\Gamma^{ttX}_{\mu}(k^2, q, \bar{q}) = -ie\left\{\gamma_\mu\left(F^X_{1V}(k^2) + \gamma_5 F^X_{1A}(k^2)\right) + \frac{\sigma_{\mu\nu}}{2m_t}(q+\bar{q})^\mu\left(iF^X_{2V}(k^2) + \gamma_5 F^X_{2A}(k^2)\right)\right\}, \quad (2)$$

Pure γ or pure Z^0 : $\sigma \backsim (F_i)^2 \Rightarrow$ No sensitivity to sign of Form Factors

Z^0/γ interference : $\sigma \backsim (F_i) \Rightarrow$ Sensitivity to sign of Form Factors

Disentangling

At ILC **no** separate access to ttZ or ttγ vertex, but ...

ILC 'provides' two beam polarisations

$P(e^-) = \pm 80\%$ $P(e^+) = \mp 30\%$

There exist a number of observables sensitive to chiral structure, e.g.

σ_I

x-section

$$A^t_{FB,I} = \frac{N(\cos\theta > 0) - N(\cos\theta < 0)}{N(\cos\theta > 0) + N(\cos\theta < 0)}$$

Forward backward asymmetry

$$(F_R)_I = \frac{(\sigma_{t_R})_I}{\sigma_I}$$

Fraction of right handed top quarks

⇩

Extraction of relevant unknowns

$F^{\gamma}_{1V},\ F^{Z}_{1V},\ F^{\gamma}_{1A} = 0,\ F^{Z}_{1A}$
$F^{\gamma}_{2V},\ F^{Z}_{2V}$

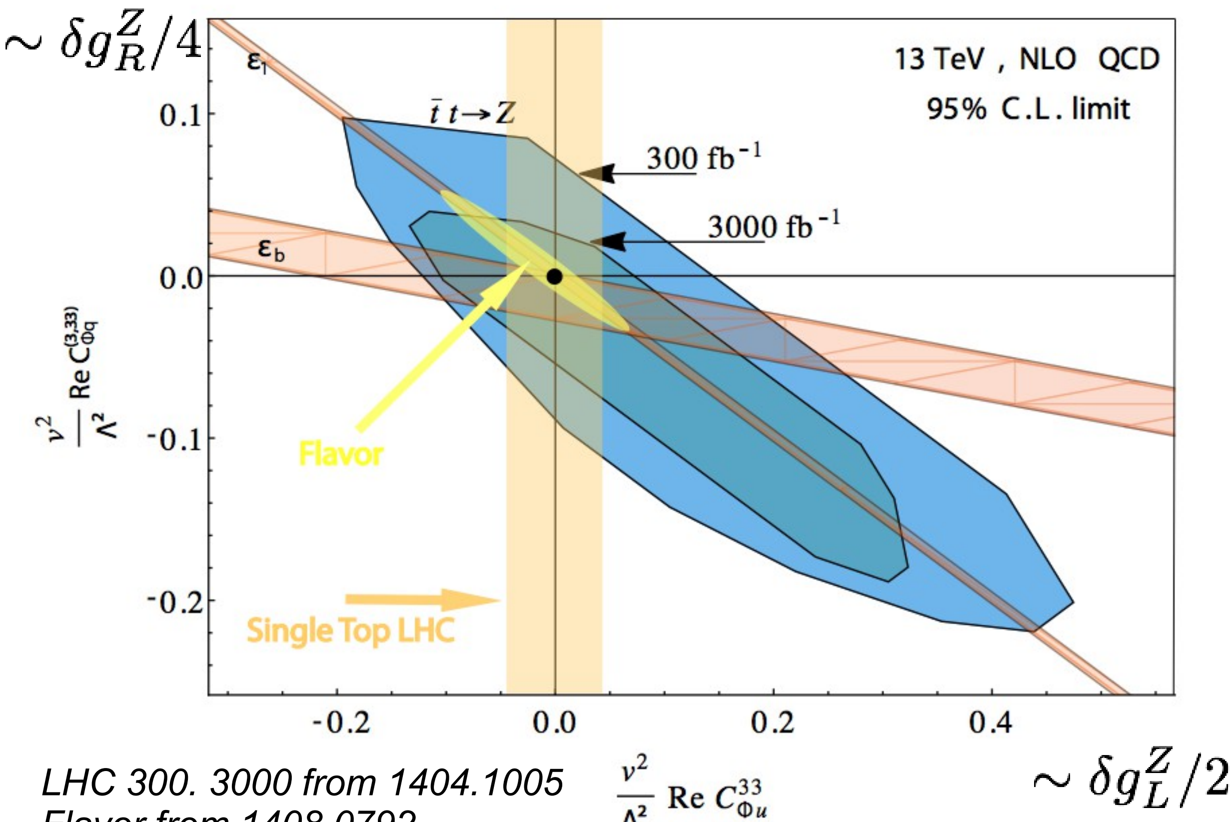
or equivalently $g^{\gamma}_L,\ g^{\gamma}_R,\ g^{Z}_L,\ g^{Z}_R$

Results of full simulation study at $\sqrt{s}$ = 500 GeV and L=500 fb^{-1}

ArXiv: 1307.8102

Precision cross section ~ 0.5%, Precision A_{FB} ~ 2%, Precision λ_t ~ 3-4%

Accuracy on SM Z couplings compared with other experiments



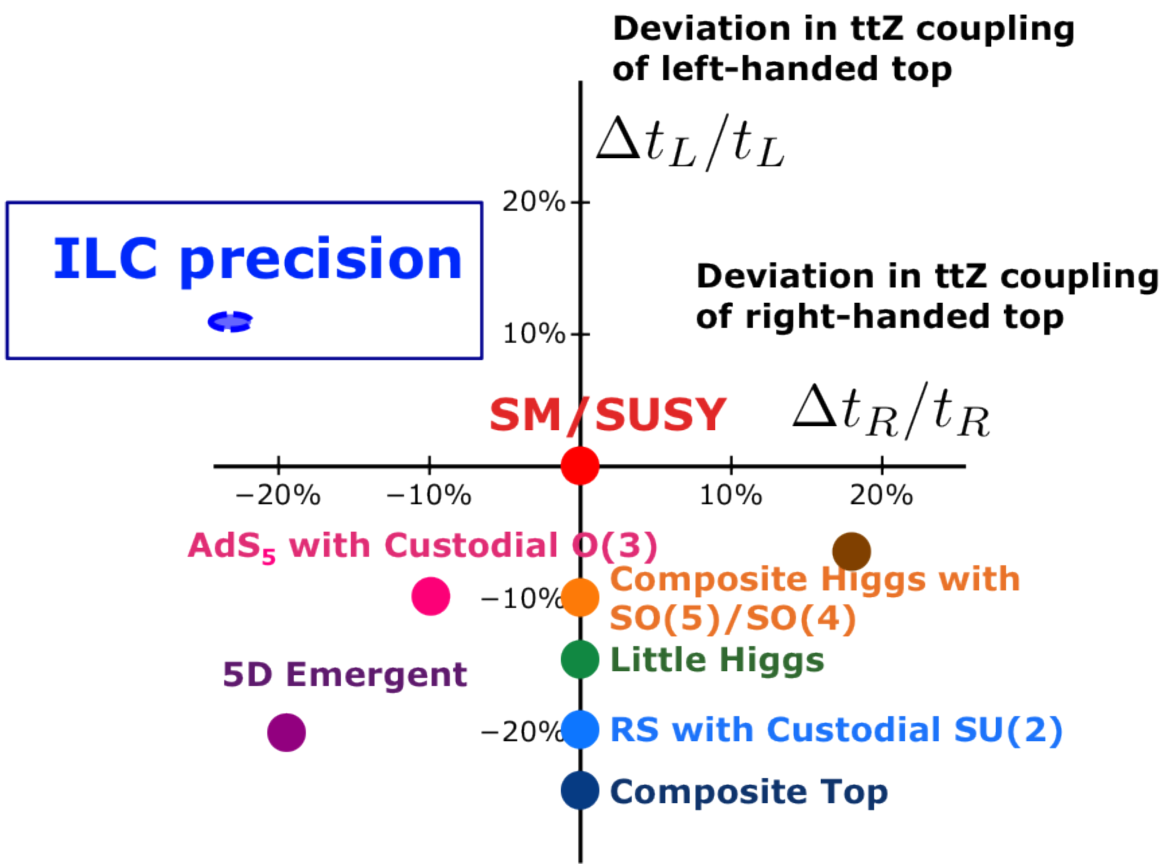
LHC 300. 3000 from 1404.1005
Flavor from 1408.0792
LHC Single top added by F. Richard

- ILC with polarised beams outperforms all present and future experiments (Stringent limits only from LEP)
- Before ILC single top at LHC and B factories can deliver complementary information
- In particular g_R can only be constrained by ILC!
- Maintaining this high level still requires substantial experimental and theoretical work

ILC promises to be high precision machine for electroweak top couplings

Sensitivity to New Physics

Top is primary candidate to be a messenger new physics in many BSM models
Incorporating compositeness and/or extra dimensions

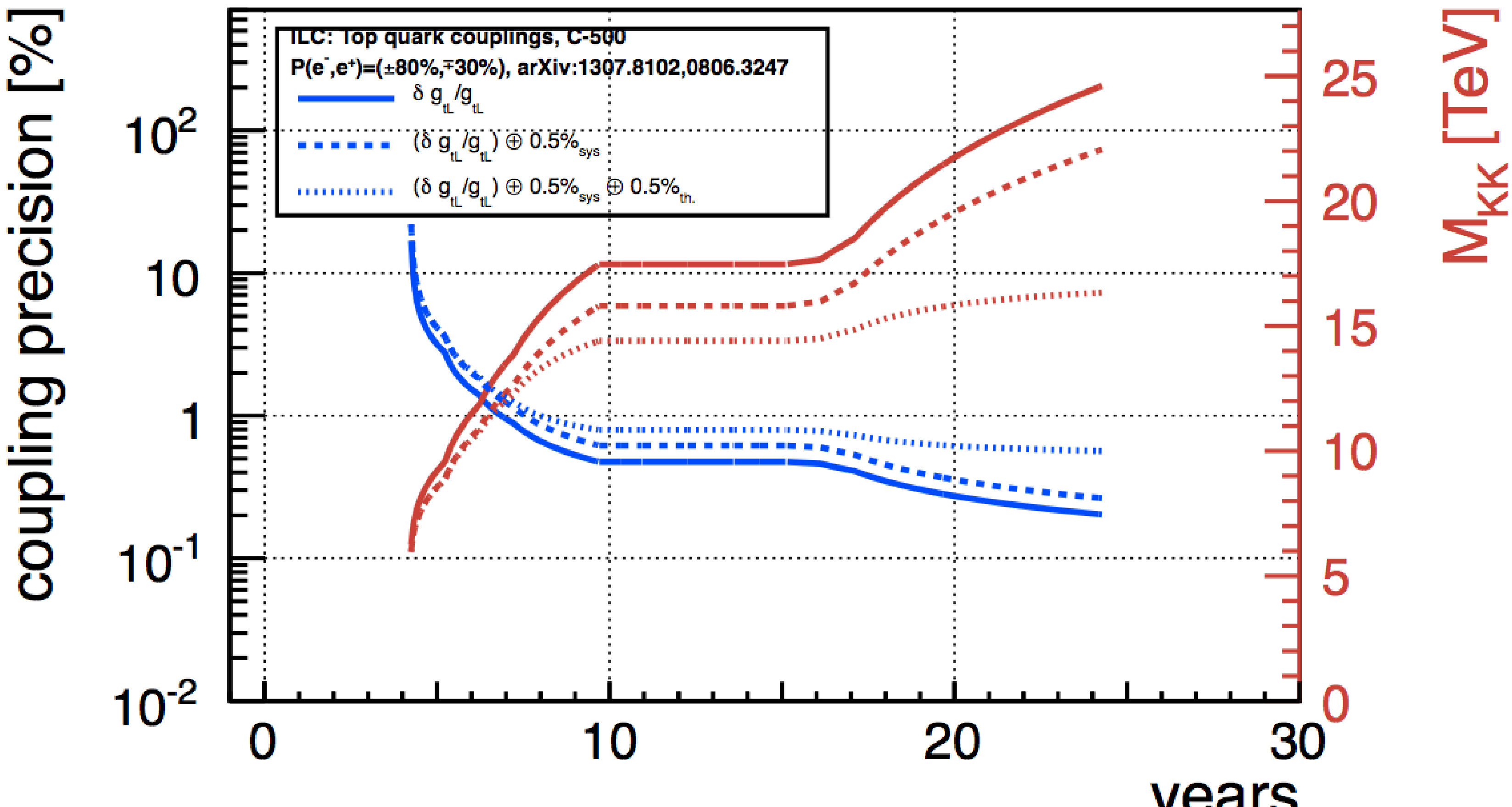


Precision expected for top quark couplings will allow to distinguish beween models

Example for physics reach

New physics reach for typical BSM scenarios with composite Higgs/Top and or extra dimensions

Based on phenomenology described in Pomerol et al. arXiv:0806.3247



Can probe scales of ~25 TeV in typical scenarios

(… and up tp 80 GeV for extreme scenarios)

=> Important guidance for e.g. 100 TeV pp-collider

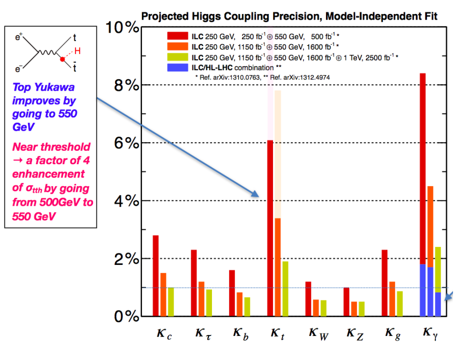
4. BSM Physics at the ILC

Supersymmetric Higgs Boson (MSSM)

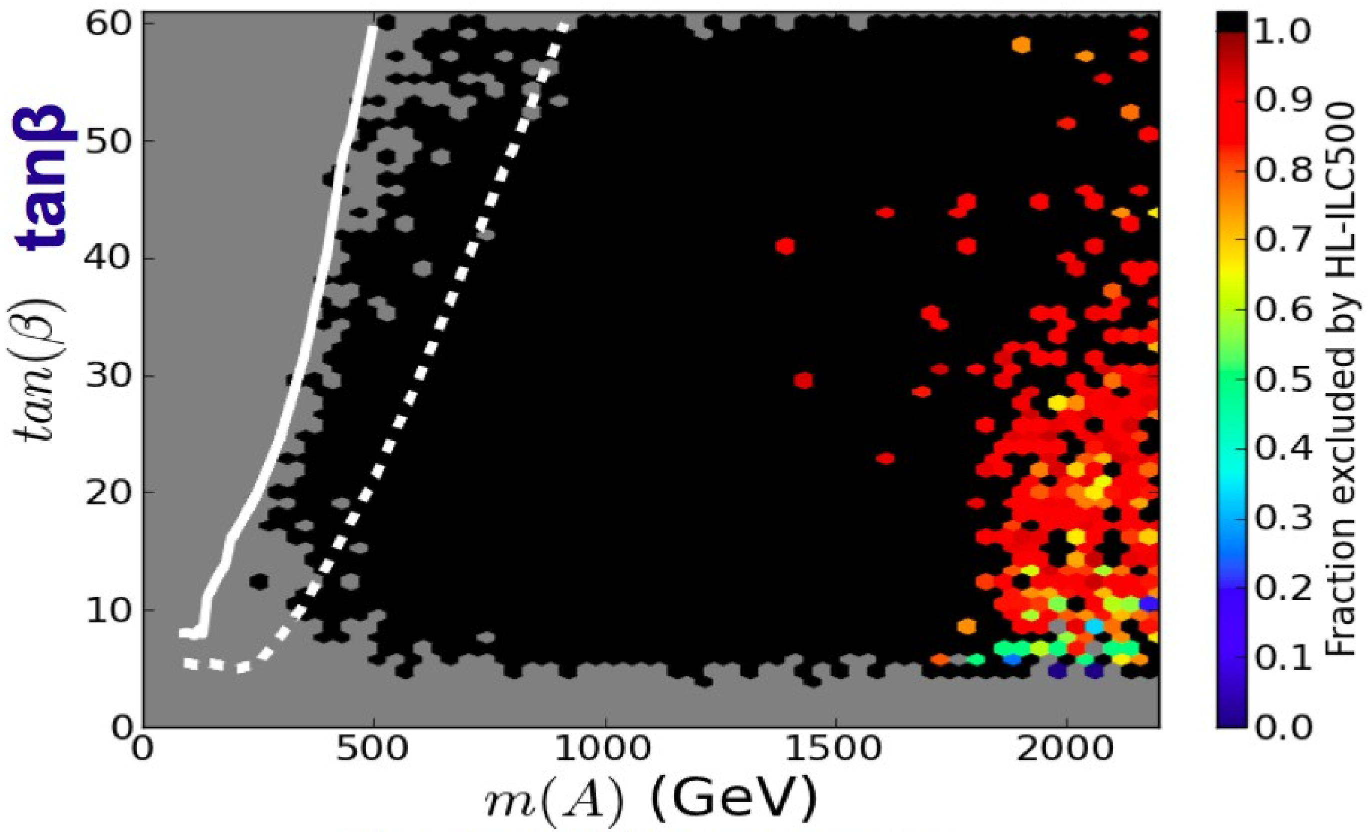
Exclusion of pMSSM points via Higgs Couplings – arXiv 1407.7021

ILC (1150 fb^{-1}@250 GeV & 1600 fb^{-1}@500 GeV)

See Chapter 2



tanβ

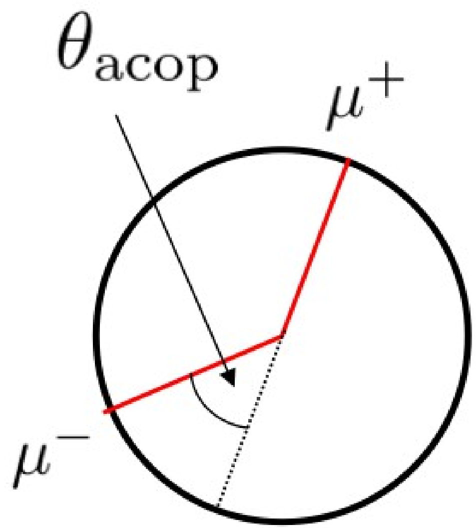


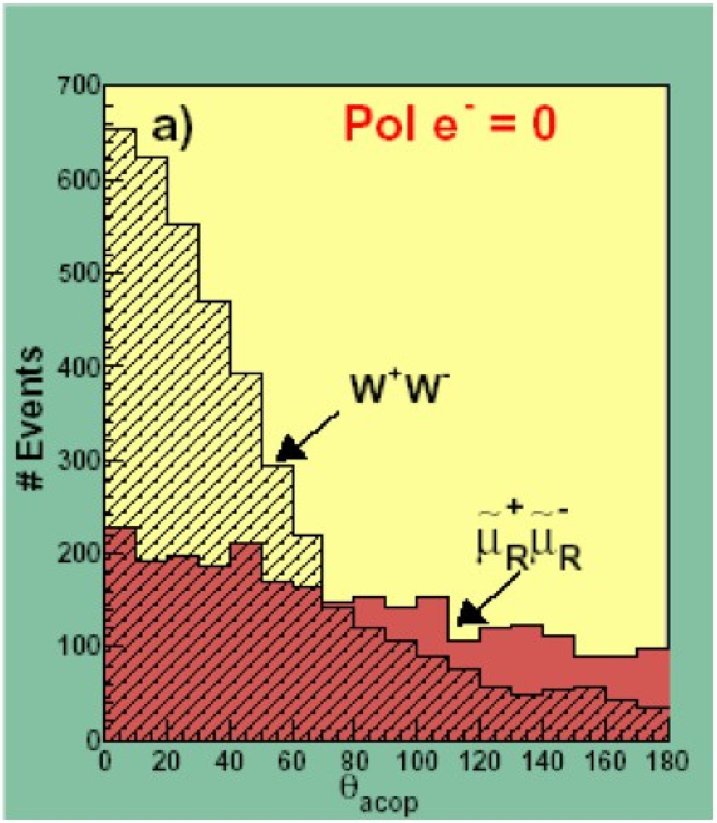
Heavy Higgs mass

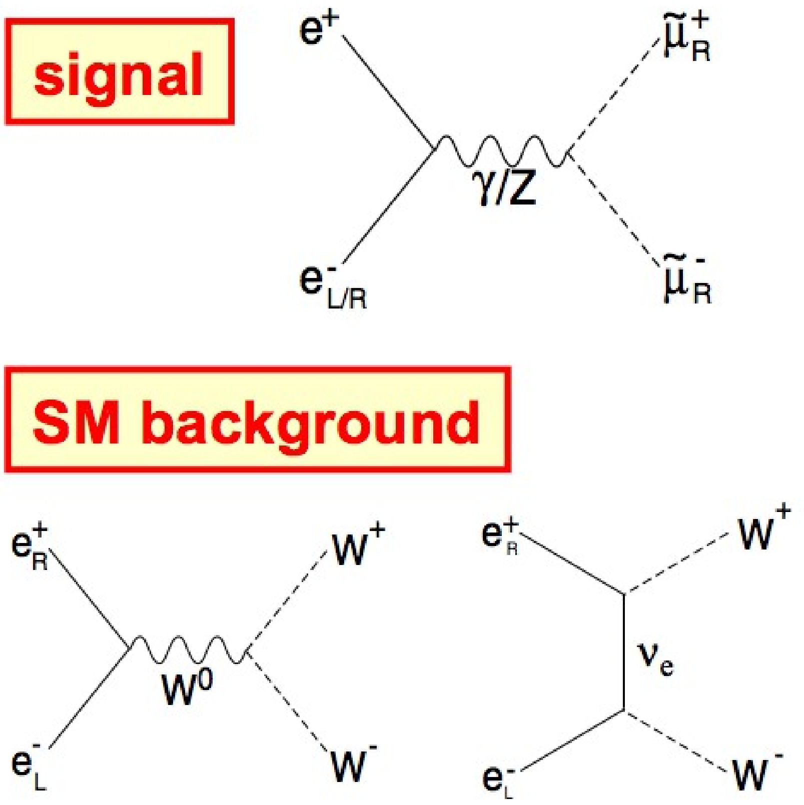
Precision Higgs coupling measurements are sensitive probe for heavy Higgs Bosons m_A ~ 2 TeV reach for any tanβ in high energy e+e- collisions

Power of Beam Polarisation

Example: Smuon pair production



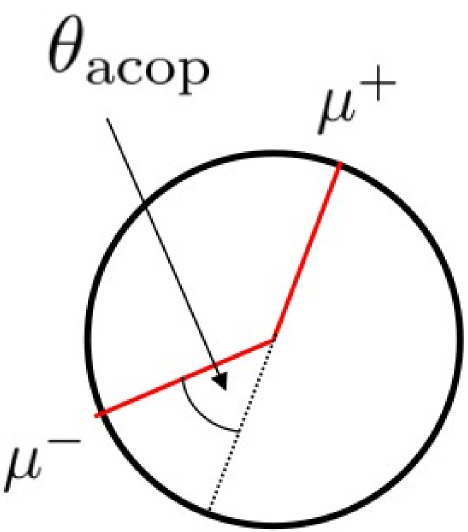


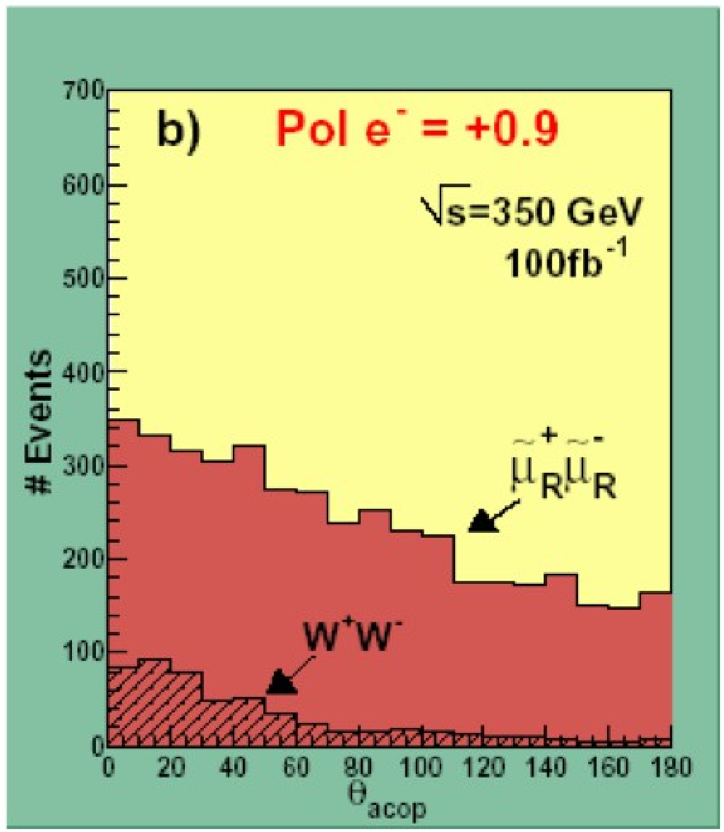


M. Thomson, IoP Meeting 2007

Strong SM Background

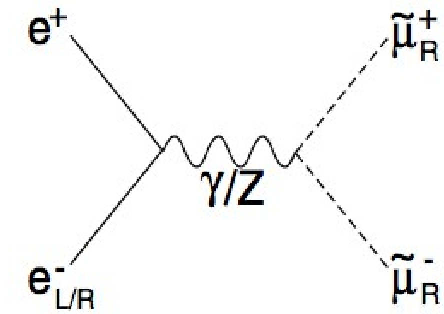
Example: Smuon pair production



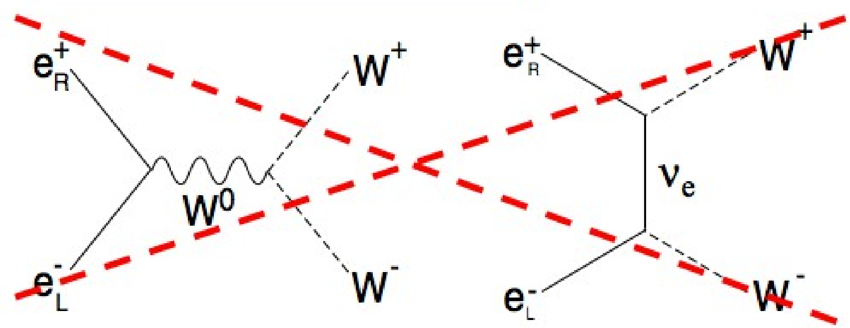


M. Thomson, IoP Meeting 2007

signal

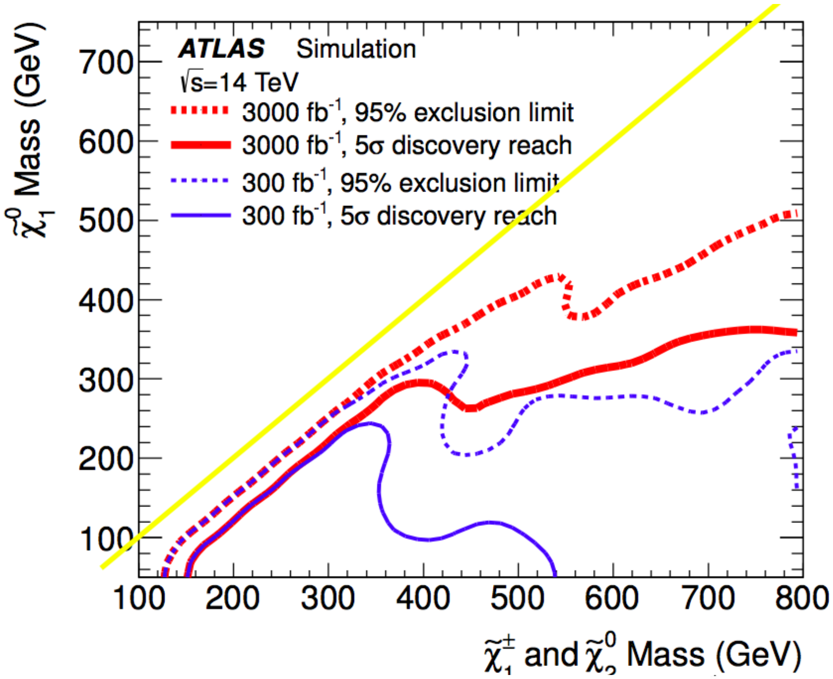


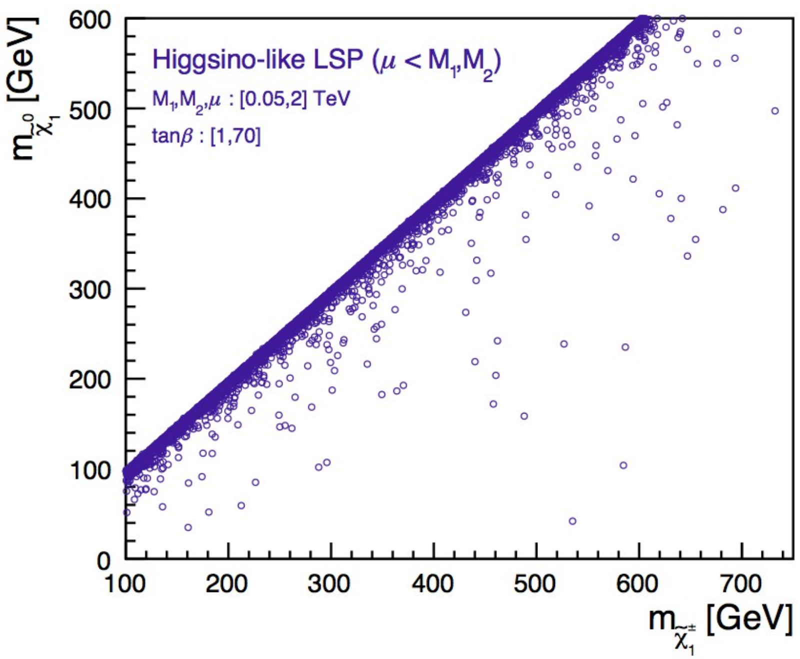
SM background



Strong background suppression through beam polarisation

Direct searches





- Hadron colliders have a great potential to discover supersymmetric particles
  - coloured and neutral

- Hadron colliders cannot exclude low mass SUSY with light neutralino and chargino(s) Degenerated in mass

- Example: scenario with light higgsinos $\mu \sim O(v)$

Tracking Light Higgsinos at the ILC

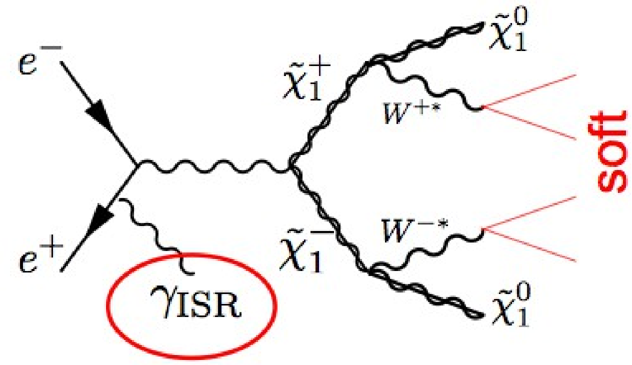
Study of Higgsino pair production, with ISR tag

Benchmark models with

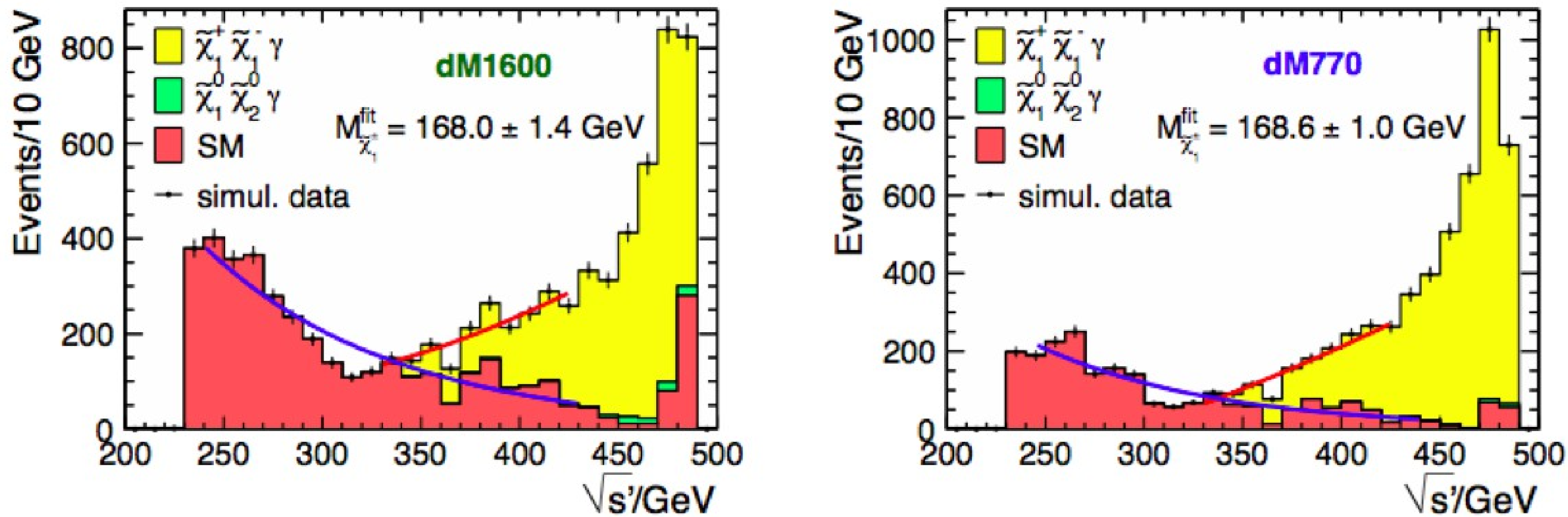
m(NLSP) – M(LSP) = 1.6 GeV and 0.8 GeV

$$\sigma(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-) = 78.7\ (77.0)\ \text{fb}$$

$$\Delta M = 1.60\ (0.77)\ \text{GeV}$$



Berggren, Bruemmer, List, Moortgat-Pick, Robens, Rolbiecki, Sert, EPJ C73 (2013) 2660 [arXiv:1307.3566]



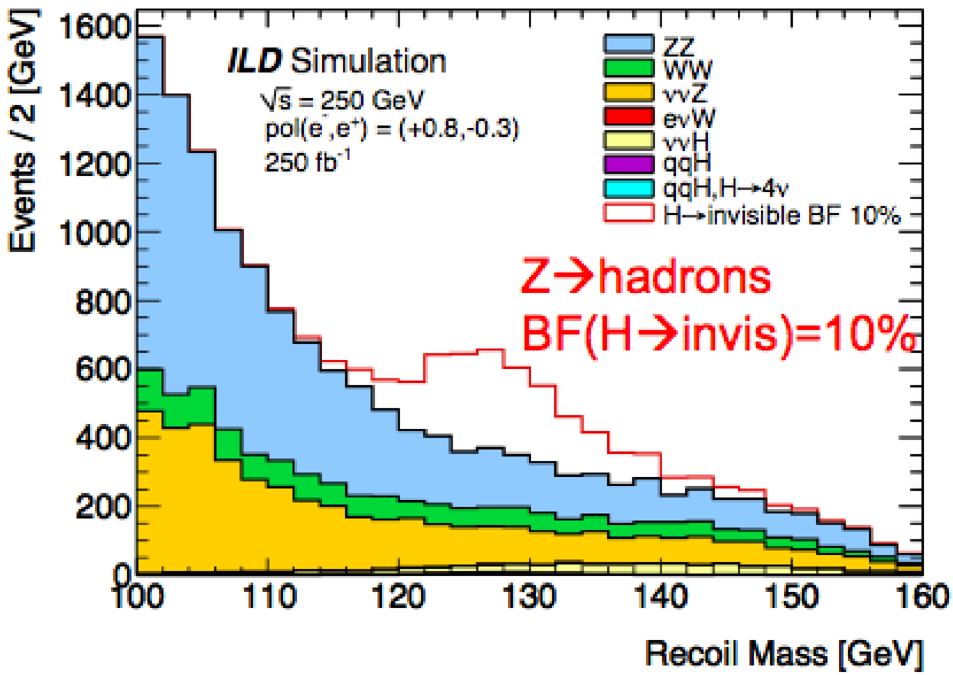
$\sqrt{s}$=500 GeV, Lumi=500 fb^{-1}, P(e-,e+)=(-0.8,+0.3) → LSP mass resolution ~1%

Clear signal => ILC covers important corner of phase space for SUSY Searches

WIMP and Dark Matter Searches

WIMP searches at colliders are complementary to direct/indirect searches.
Examples at the ILC:

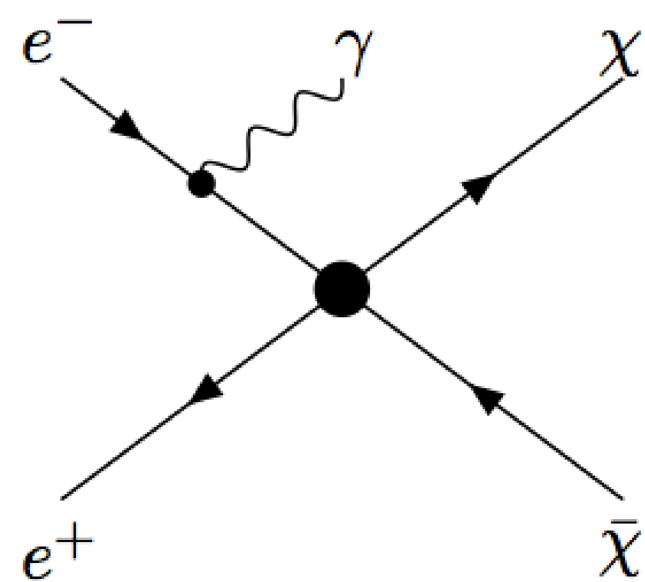
Higgs Invisible Decays



BR(H→invis.) < 0.4% at 250 GeV, 1150 fb^{-1}

Impact of jet energy resolution

Monophoton Searches



→ DM mass sensitivity nearly half √s

Soft photons, forward detectors

Tomohiko Tanabe
ILD Meeting 2014

Dark Matter Search – A spectacular example

arXiv:1411.0088

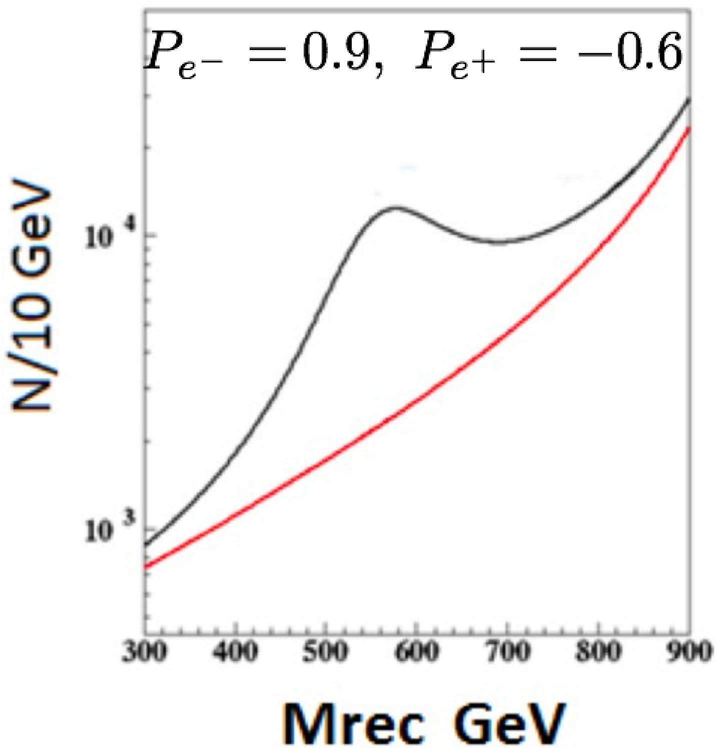
Z' with vector couplings to Dirac type Dark Matter X and axial couplings to ordinary matter

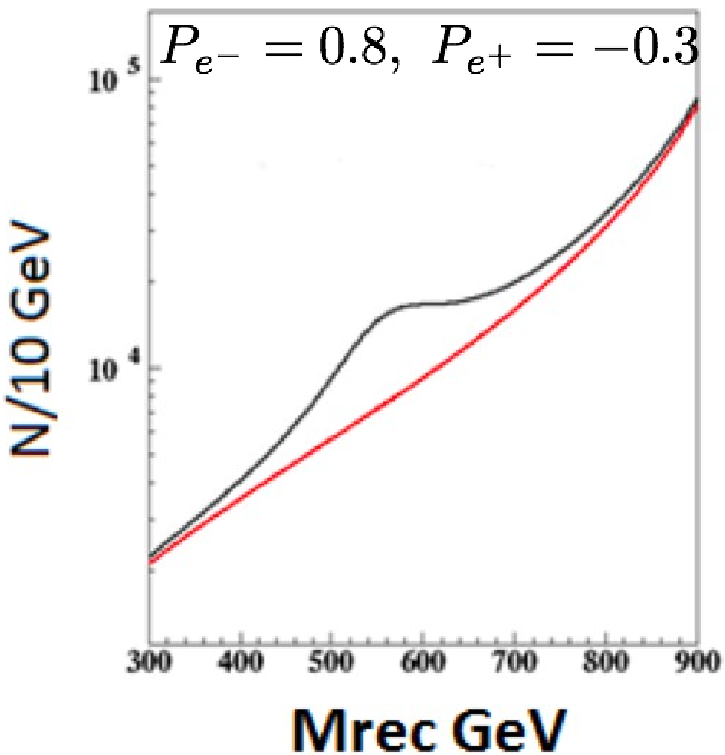
$$\sigma v = |g_V^X|^2 K^2 \sum_f n_{cf} |g_A^f|^2 \frac{2m_X^2 + s}{12\pi\left[(s - m_{Z'}^2) + (m_{Z'}\Gamma_{Z'})^2\right]}$$

-> Monophoton search

-> Background suppression through polarised beams

$$\sqrt{s} = 1\,\mathrm{TeV}, \quad m_{Z'} = 550\,\mathrm{GeV}, \quad L = 1\,\mathrm{ab}^{-1}, \quad K^2 = 0.1$$

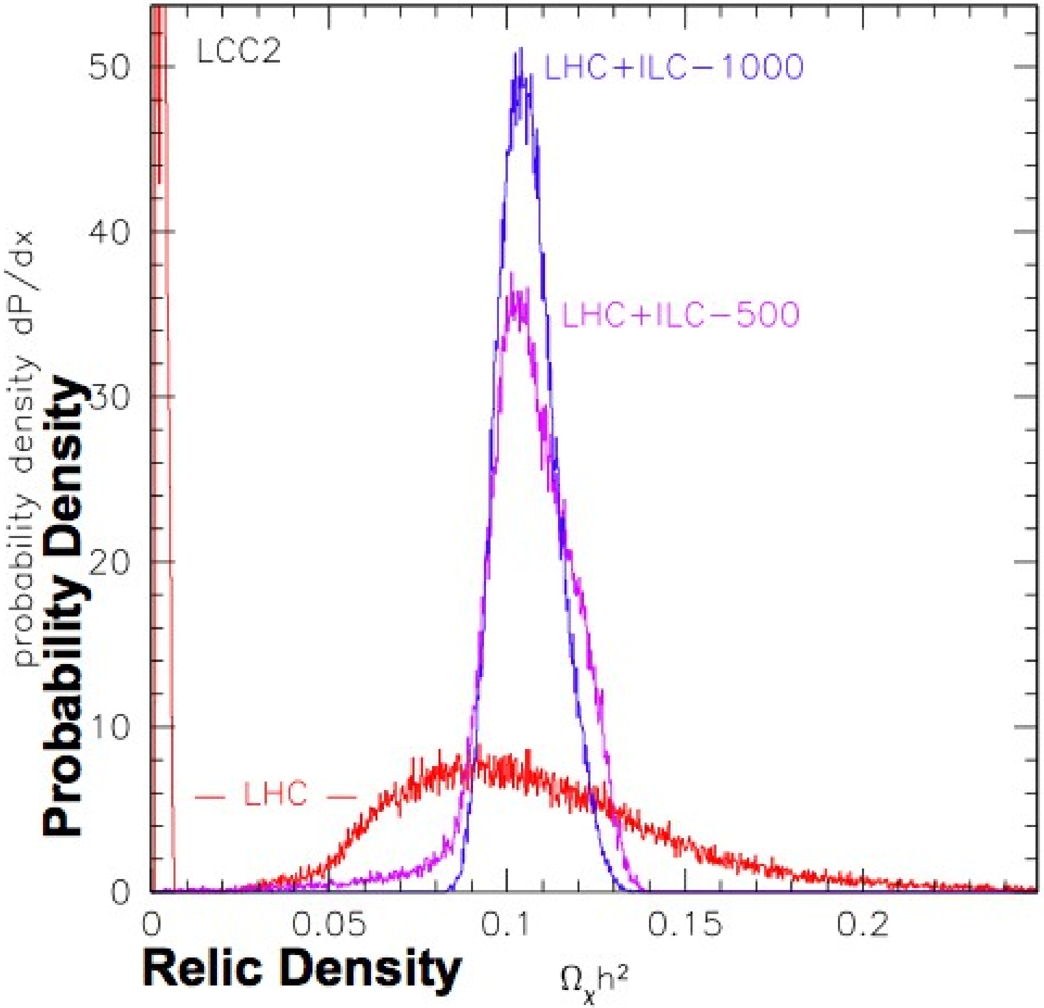




Connection to relic dark matter density

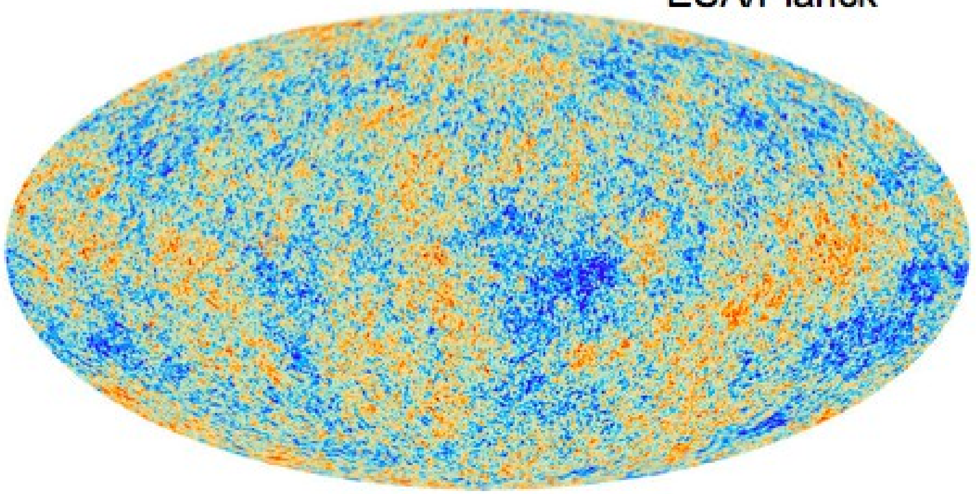
WMAP/Planck (68% CL)

$$\Omega_c h^2 = 0.1196 \pm 0.0027$$



Baltz, Battaglia, Peskin, Wizansky
PRD74 (2006) 103521, arXiv:hep-ph/0602187

ESA/Planck



Once a DM candidate is discovered, need to check the consistency with the measured DM relic abundance.

→ ILC's precise measurements of the mass and cross sections provide crucial input.

Tomohiko Tanabe
ILD Meeting 2014

Summary

- The ILC is versatile machine for precision physics in the range m_Z – 1 TeV

  Polarised beams to test chiral theory!

- Higgs and top quark are physics guaranteed

  (My conviction) both are messengers to New Physics

- Discovery potential for Supersymmetry and Dark Matter

  Senstivity in phase space left by LHC and Dark Matter Experiments

- Technologies are getting mature

  ILC is ready to be constructed (see talk by S. Stapnes)
  Well advanced detector technologies
  (see talks by F. Simon, I. Laktineh, M. Idzik and L. Linssen)

Backup ....

ILC Basic Parameters and Comments

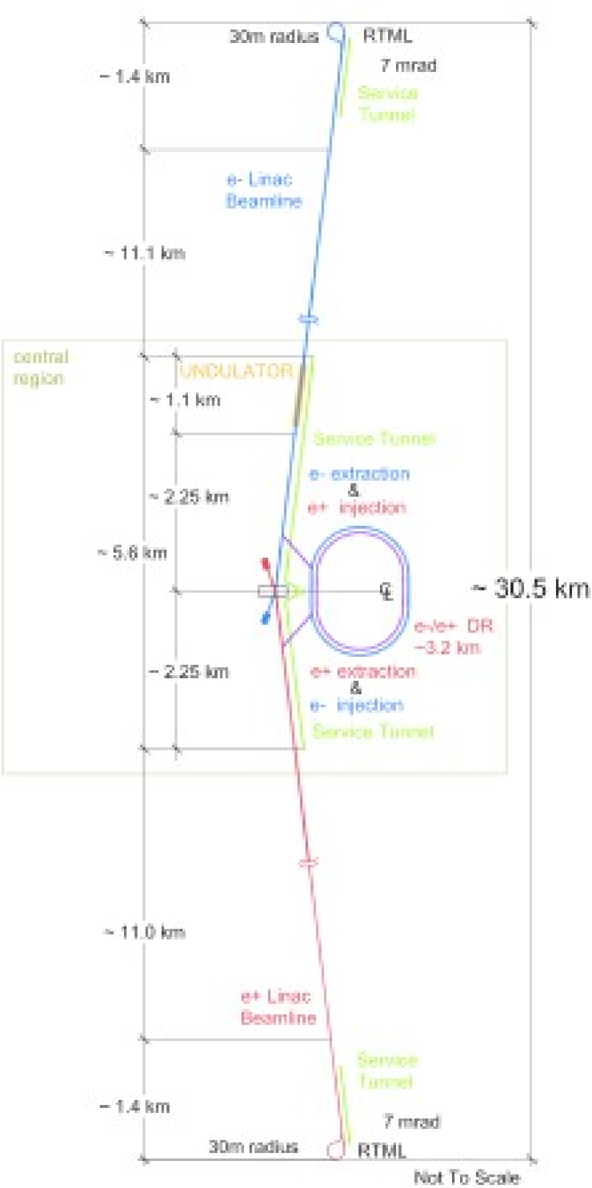
ILC design parameters		Comment
$\sqrt{s}$	91-500 GeV	500 GeV is baseline Option to upgrade to 1 TeV
$\mathcal{L}$	$2 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$	~Factor 4 technically possible
P_{e^-}	>80%	Proven by SLC
P_{e^+}	upto 30%	~Conservative estimate
Length	~31 km	Current site allows for 50km

- Discussion on possible running scenarios has started

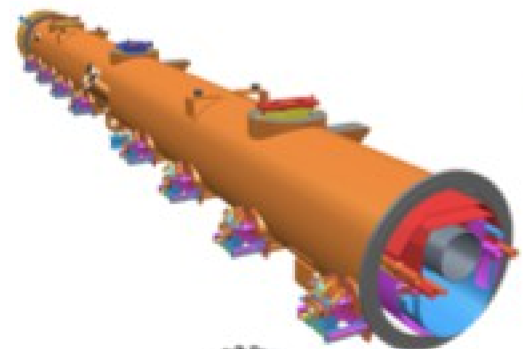
- Luminosity and running time to achieve at a ~25 years research programme
  That includes running at 250 GeV, 350 GeV, 500 GeV and 1 TeV

- No official statement yet but integrated luminosities indicated in following transparencies are realistic

ILC in a Nutshell



N. Walker, ILC School 2013



- **SCRF Technology**
  - 1.3GHz SCRF with 31.5 MV/m
  - 17,000 cavities
  - 1,700 cryomodules
  - 2×11 km linacs

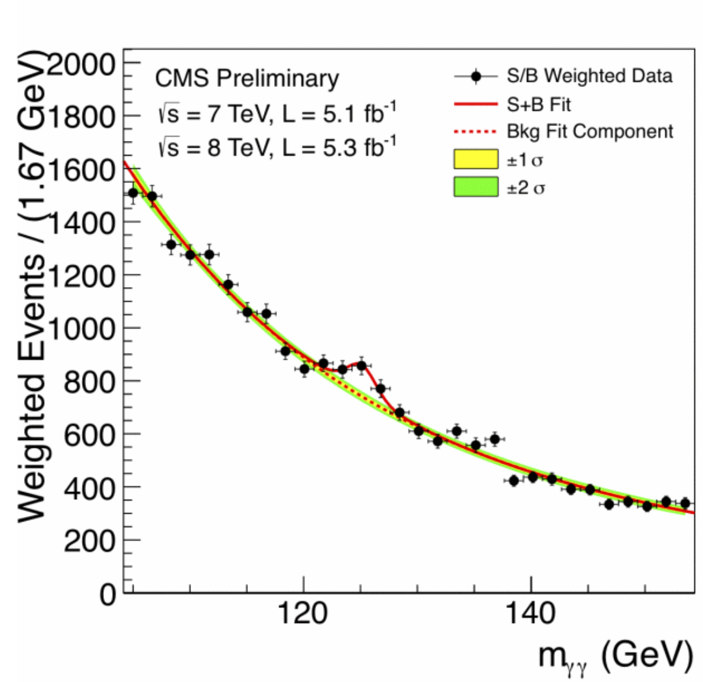
Luminosity

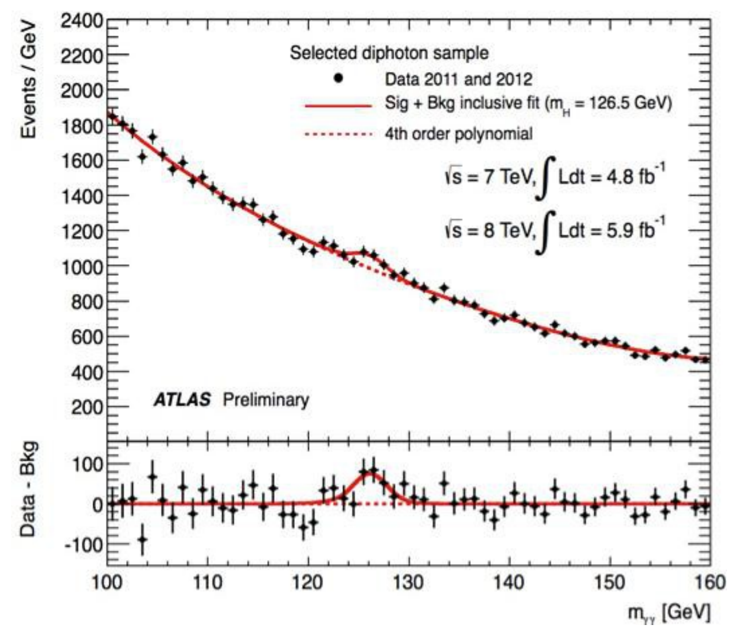
$$L \propto \frac{\eta_{RF} P_{RF}}{E_{cm}} \sqrt{\frac{\delta_{BS}}{\varepsilon_{n,y}}} H_D$$

η_{RF} ~ 40% for SCRF technology

-> efficient technology

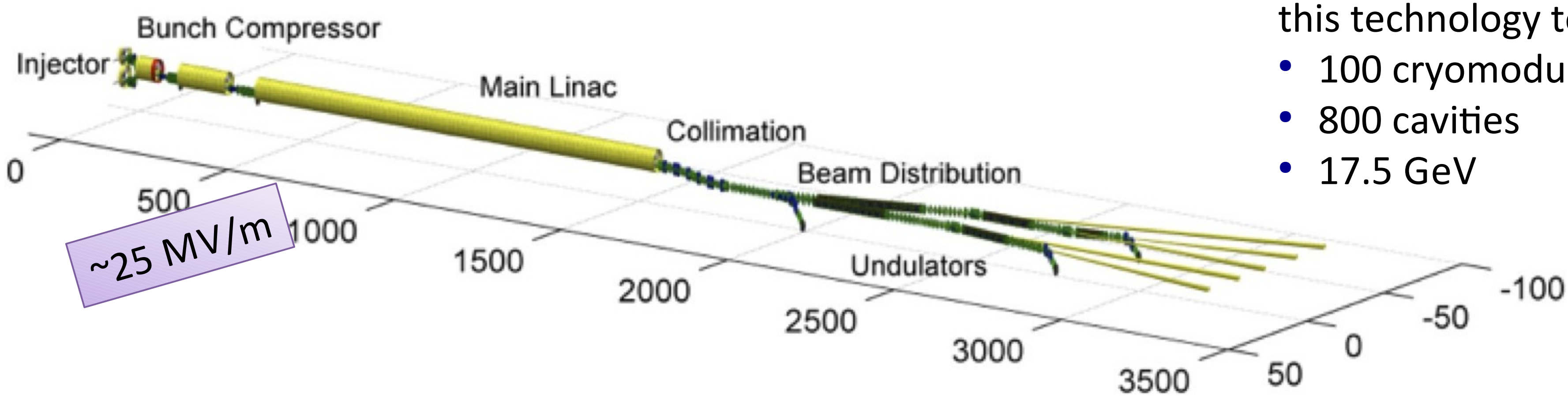
4th of July 2012





Accelerator - Test and reality

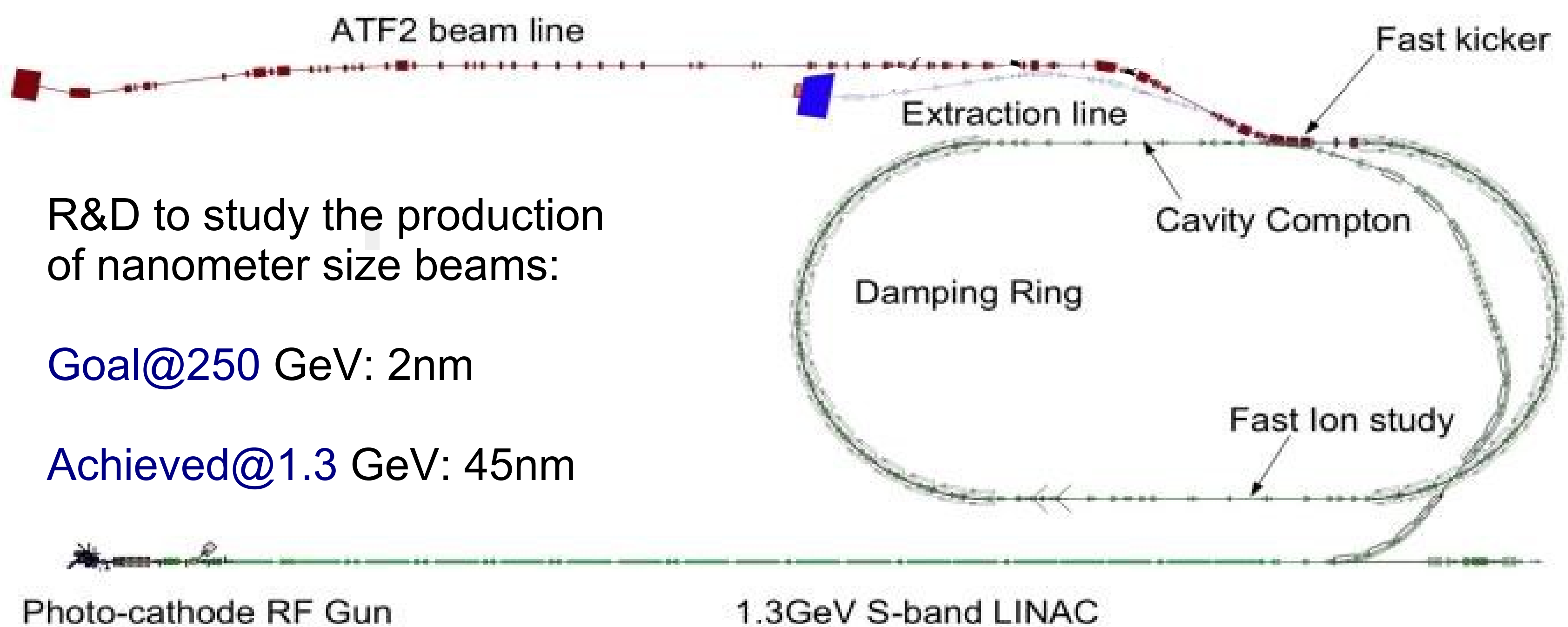
[European XFEL Project: Location DESY Hamburg, Start 2015]



Largest deployment of this technology to date

- 100 cryomodules
- 800 cavities
- 17.5 GeV

[ATF at KEK Japan:]

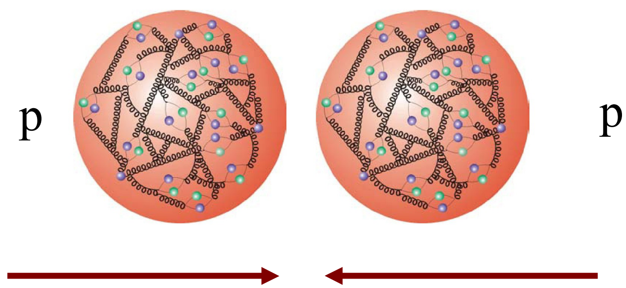


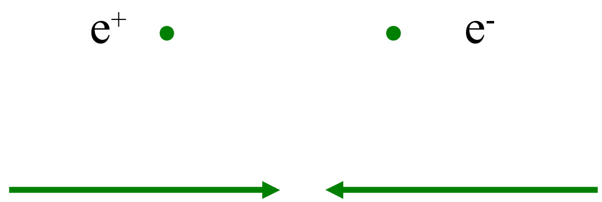
R&D to study the production of nanometer size beams:

Goal@250 GeV: 2nm

Achieved@1.3 GeV: 45nm

Why e+e- collisions?





Proton:

Composed particle (hadron)
Unknown energy of collision partners
Parasitic reactions
Strong interaction
=> Considerable physics background
Advantage: Scan of energy Range within one experiment

Electron:

Elementary particle
Well known and adjustable energy of collision partners

Each energy point needs a New set of machine parameters

High precision measurements

How do the particles get their masses?

Higgs Mechanism

Scalar field which doesn't vanish in the vacuum

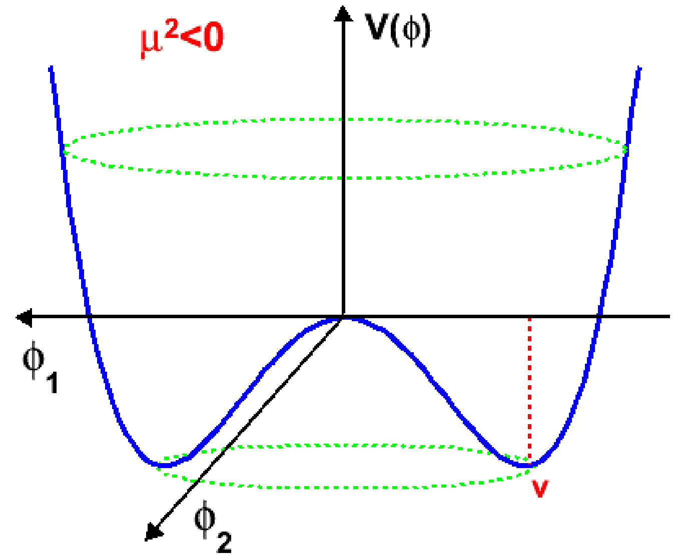
Choice in SM:
Doublet Field

$$\Phi = \begin{pmatrix} \phi^{+} \\ \phi^{0} \end{pmatrix}$$

4 degrees of freedom

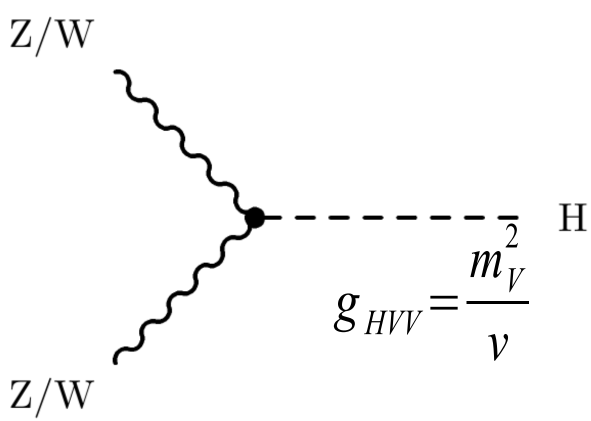
Higgs Boson

Longitudinally degrees of W,Z Bosons

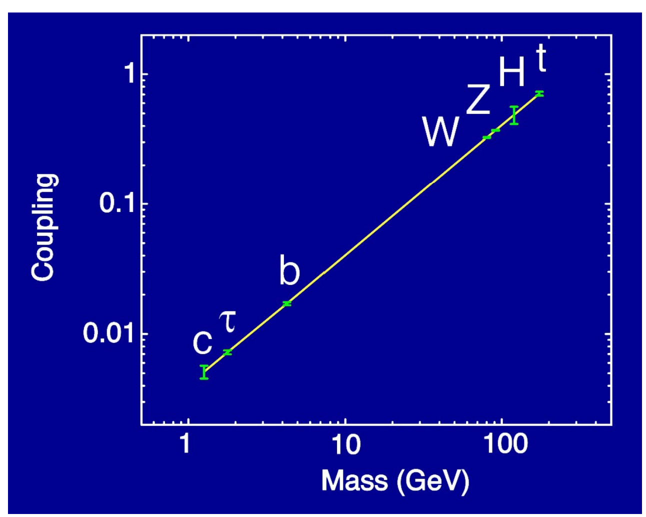


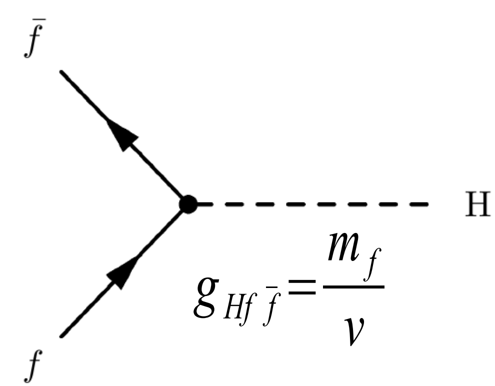
Couplings to Higgs Boson in Standard Model

Increase with particle mass

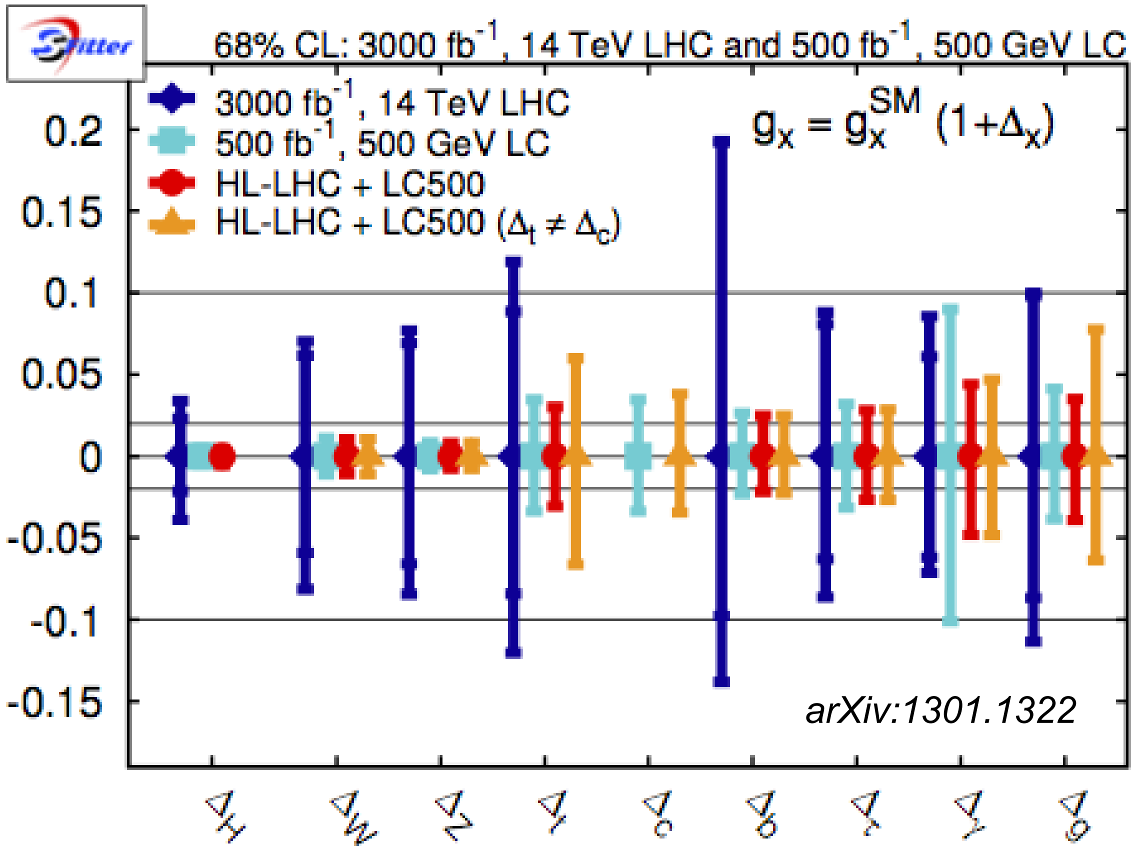


$$g_{HVV} = \frac{m_V^2}{v}$$



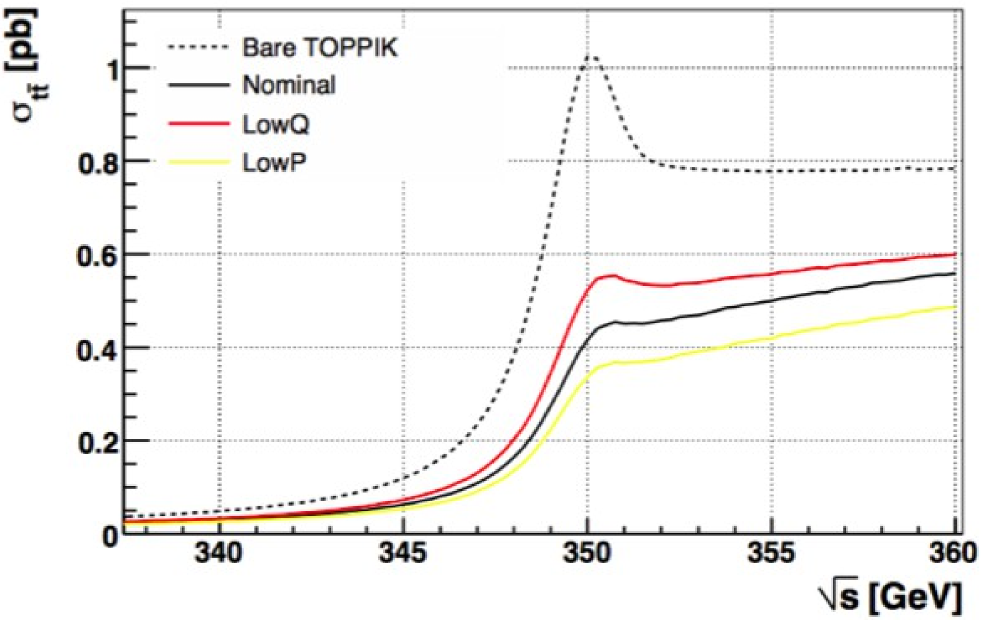


$$g_{Hf\bar{f}} = \frac{m_f}{v}$$



- A e+e- machine (Linear Collider) running at several energies will provide precise measurements of relevant Higgs couplings: Possibility to confirm the Higgs mechanism of the SM
- Precision matters: Detect deviations, for example due to extended Higgs sectors (SUSY,composite, ...):Expected on the 10% - 15% level in fermions,on the few % level in gauge bosons in typical Two-Higgs-Doublet models

Total tt Cross Section in e+e- Collisions



Principle: m_t from $\sigma_{tt}(m_t)$

Advantages:

- count number of $t\bar{t}$ events
- color singlet state
- background is non-resonant
- physics well understood (renormalons, summations)
- Top decay protects from non-pert effects

Much of the discriminating power of the approach related to the strong mass-dependence (ttbar resonance).

Peak position very stable in theory predictions (threshold mass scheme).

Typical results:

$\rightarrow \delta m_t^{\mathrm{exp}} \simeq 50$ MeV

$\rightarrow \delta m_t^{\mathrm{th}} \simeq 100$ MeV

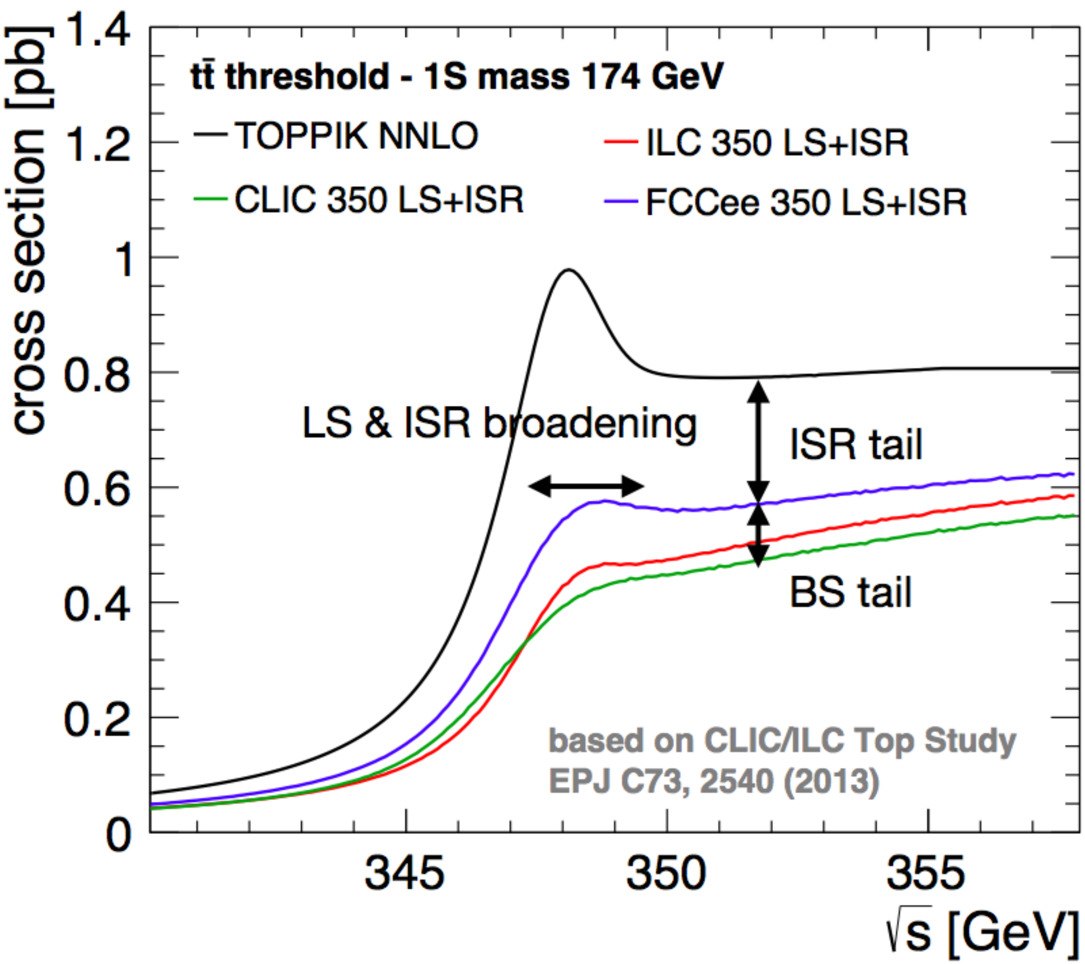
What mass?

$\sqrt{s}_{\mathrm{rise}} \sim 2m_t^{\mathrm{thr}}$ + pert.series

(short distance mass: 1S $\leftrightarrow$ $\overline{\mathrm{MS}}$)

A. Hoang

Top Quark Mass – Influence of Luminosity Spectrum



- Initial State Radiation
  Lowers effective L at top energy
- BeamStrahlung
  Lowers effective L
  at top energy
  Not at FCCee Gaussian spectrum
- Luminosity spectrum & Initial State Radiation broadening
  Smearing of cross section
  Due to beam energy spread
  ILC and FCCee comparable
  Worse at CLIC

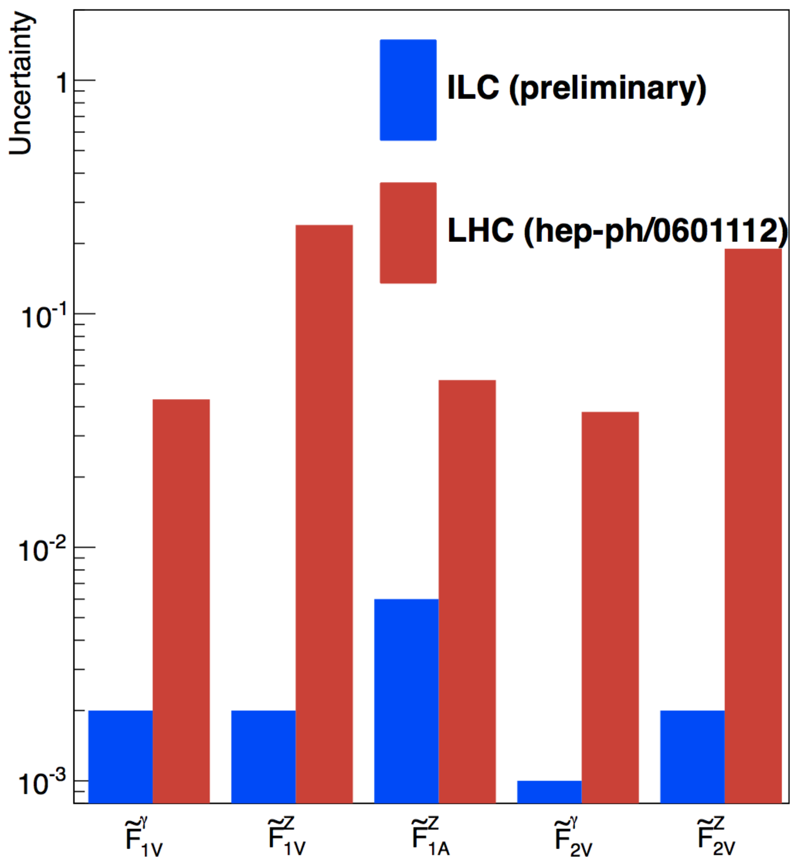
1) Main effect on L spectrum is ISR
   => Reduces Luminosity, smears out 1s bound state peak
2) LC somewhat smaller L due to BeamStrahlung

F. Simon
AWLC14

ArXiv: 1307.8102

Precision: cross section ~ 0.5%, Precision A_{FB} ~ 2%, Precision λ_t ~ 3-4%

Accuracy on CP conserving couplings



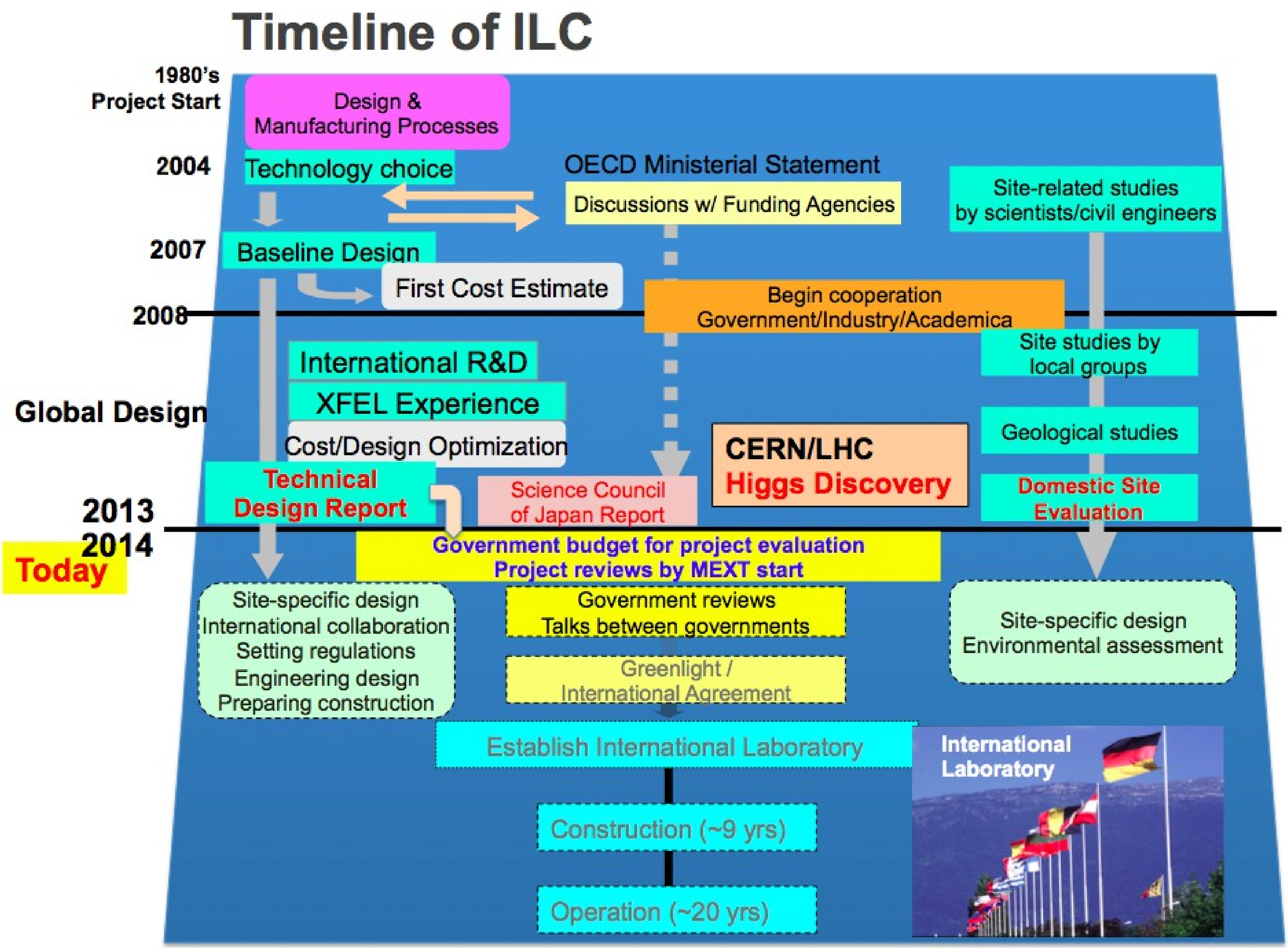
- ILC might be up to two orders of magnitude more precise than LHC ($\sqrt{s}$ = 14 TeV, 300 fb^{-1})
  Disentangling of couplings for ILC
  One variable at a time For LHC
  However LHC projections from 8 years old study

- Need to control experimental (e.g. Top angle) and theoretical uncertainties (e.g. Electroweak corrections)
  -> Dedicated work has started

- Potential for CP violating couplings at ILC under study

ILC promises to be high precision machine for electroweak top couplings

ILC Roadmap



Remark R.P.: MEXT report in March 2016