Summary talk for ILC Physics

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Higgs Physics and electroweak symmetry breaking

O. Kong, Little Higgs

M. Tanabashi, Higgsless model

Y. Yasui, Higgs self-coupling

E. Senaha, 2HDM, self-coupling, EW baryogenesis

C.S. Kim , 2HDM, CPV

SUSY Higgs sector

S.Y. Choi CPV, photon-photon

R. Godbole, CPV, photon-photon

S. Kanemura, LFV. Fix target experiment

SUSY

M. Jimbo, tool

T. Nihei, Dark matter

R. Godbole, stau, stop, CPV

B.C. Chung, neutralino, CPV

T. Nihei, Dark matter

Other new physics model

N. Okada, Extra-dim

K. Cheung, Techni-pion, photon-photon

Others

C.A. Heusch e-e-

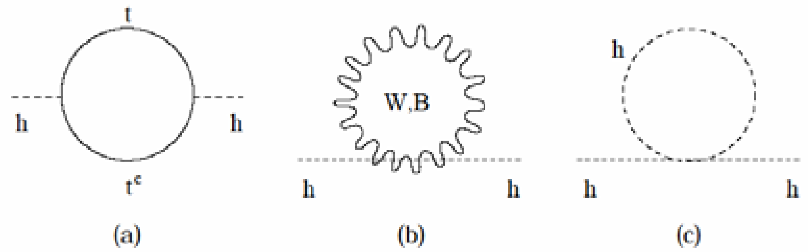
J.B. Choi, Jet

Higgs Physics

- Important goal of the ILC physics.
- Establish the mass generation mechanism of elementary particles => coupling determination
- Determine the dynamics of electroweak symmetry breaking. "What is the Higgs particle?" One mode of the superstring, or a composite state of a new strong interaction?
- Although the present EW analysis favors a light Higgs boson (<250 GeV) within the SM, the Higgs sector is largely unknown.
- There are new ideas on the Higgs mechanism.

Little Higgs model

Quadratic divergence of the Higgs boson mass can be cancelled by extra fermions and bosons about 1TeV.

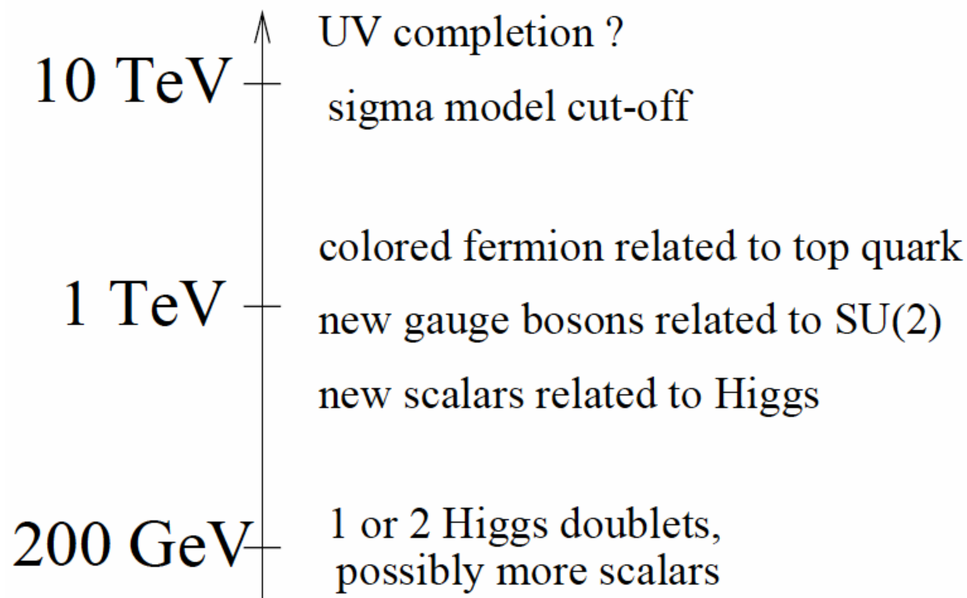


O. Kong
New models based on SU(N)xU(1)

331 little Higgs Model :-

— there is a solution (existence not *a priori* clear)

	Gauge anomalies					$U(1)_Y$ states	
	tX	LLL	LLX	CCX	X^3		
$(\mathbf{3_C}, \mathbf{3_L}, \frac{\mathbf{1}}{\mathbf{3}})$	3	3	1	1	$\frac{1}{3}$	$\frac{\mathbf{1}}{\mathbf{6}}[Q]$	$\frac{\mathbf{2}}{\mathbf{3}}(T)$
$2\ (\mathbf{3_C}, \bar{\mathbf{3}}_\mathbf{L}, \mathbf{0})$	0	−6	0	0	0	$2\ \frac{\mathbf{1}}{\mathbf{6}}[Q]$	$2\ \frac{\mathbf{-1}}{\mathbf{3}}(D,S)$
$3\ (\mathbf{1_C}, \mathbf{3_L}, \frac{\mathbf{-1}}{\mathbf{3}})$	−3	3	−1		$\frac{-1}{3}$	$3\ \frac{\mathbf{-1}}{\mathbf{2}}[L]$	$3\ \mathbf{0}(N)$
$4\ (\bar{\mathbf{3}}_\mathbf{C}, \mathbf{1_L}, \frac{\mathbf{-2}}{\mathbf{3}})$	−8			$\frac{-8}{3}$	$\frac{-32}{9}$	$4\ \frac{\mathbf{-2}}{\mathbf{3}}\ (\bar{u}, \bar{c}, \bar{t}, \bar{T})$	
$5\ (\bar{\mathbf{3}}_\mathbf{C}, \mathbf{1_L}, \frac{\mathbf{1}}{\mathbf{3}})$	5			$\frac{5}{3}$	$\frac{5}{9}$	$5\ \frac{\mathbf{1}}{\mathbf{3}}\ (\bar{d}, \bar{s}, \bar{b}, \bar{D}, \bar{S})$	
$3\ (\mathbf{1_C}, \mathbf{1_L}, \mathbf{1})$	3				3	$3\ \mathbf{1}\ (e^+, \mu^+, \tau^+)$	
Total	0	0	0	0	0		

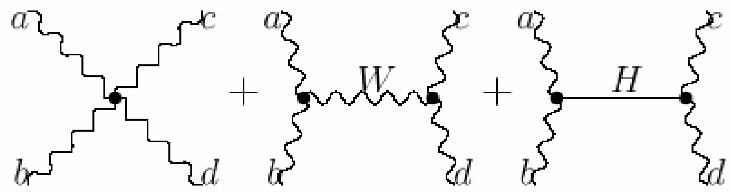


Collider physics => TeV new particles
Fermion structure =>FCNC

Higgsless model

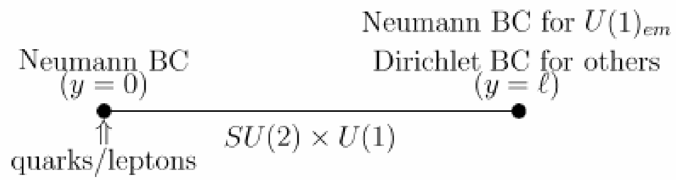
$W_L W_L$ scattering amplitude in the SM

$i\mathcal{M}(W_L^a W_L^b \to W_L^c W_L^d) =$



+crossed.

A toy model of 5D Higgsless



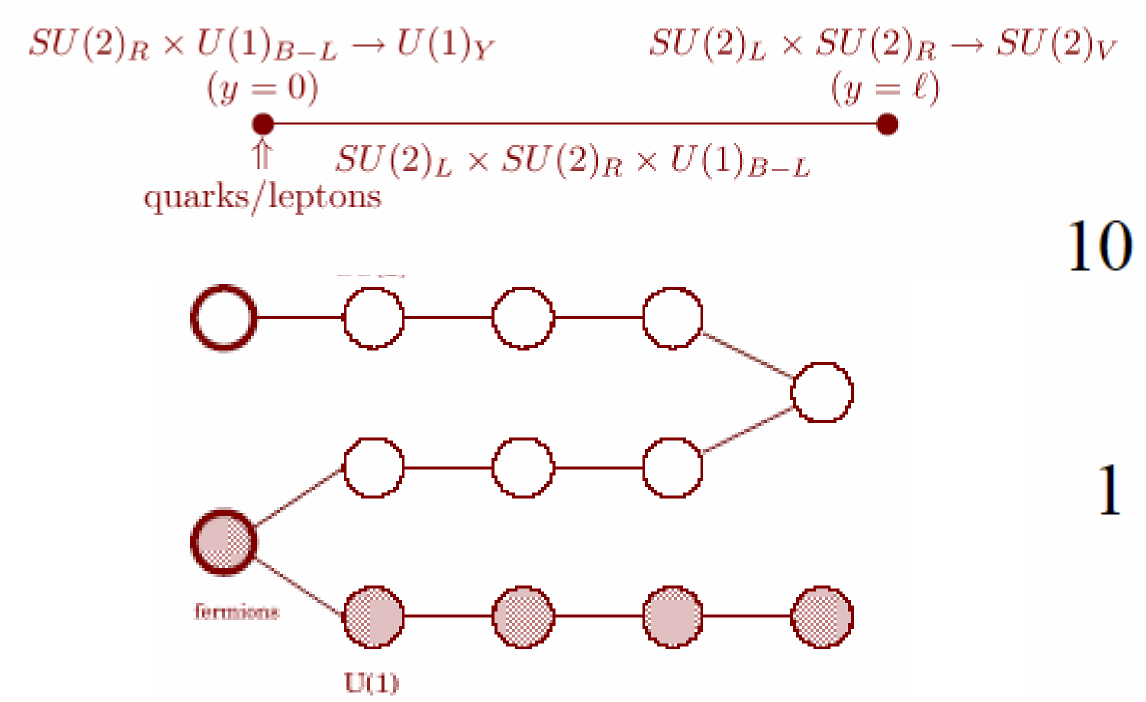
- Massless neutral boson: γ
- The lightest massive neutral KK mode: Z
- The lightest massive charged KK mode: W

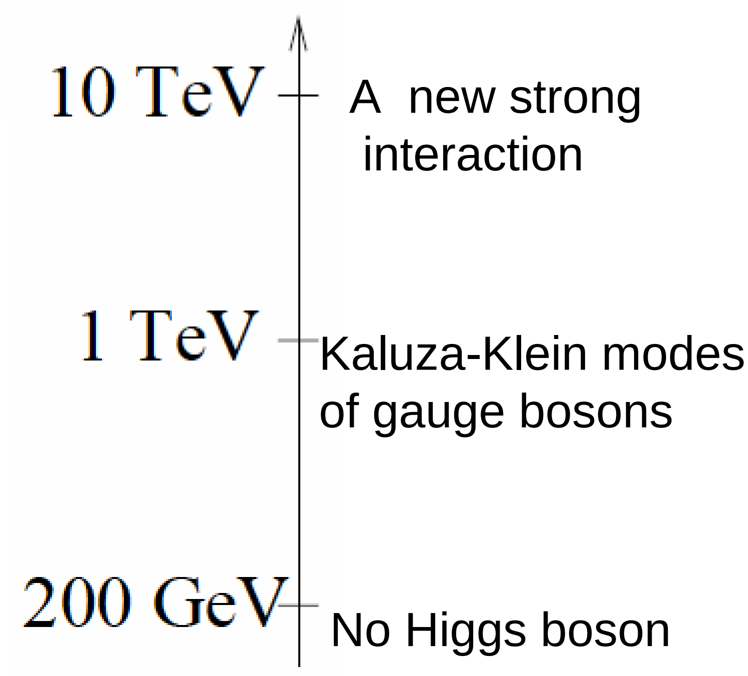
A new model based on 5 dim space-time. The unitarity of the WW scattering is saved by the Kaluza-Klein modes of the gauge bosons.

Realistic models based on this idea?
(Electroweak precision test)

M.Tanabashi

The Higgsless model can be considered as a type of a technicolor model .
(Deconstruction model or a lattice model in the 5 dim)





Models with "localized" fermions
do not satisfy the EW precision constraints
=>Need modifications.
Collider signals => W' Z' below 1 TeV

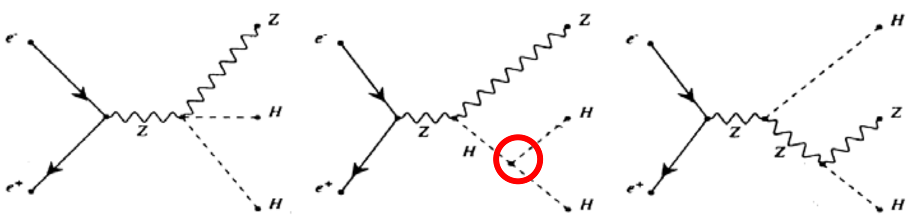
Higgs self-coupling

Y.Yasui

The first information on the Higgs potential

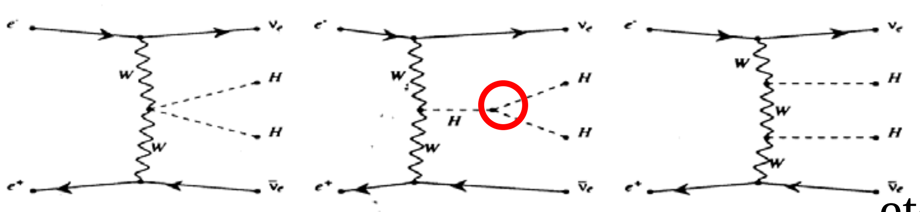
$\star\ e^+e^- \to ZHH$

produced by GRACEFIG

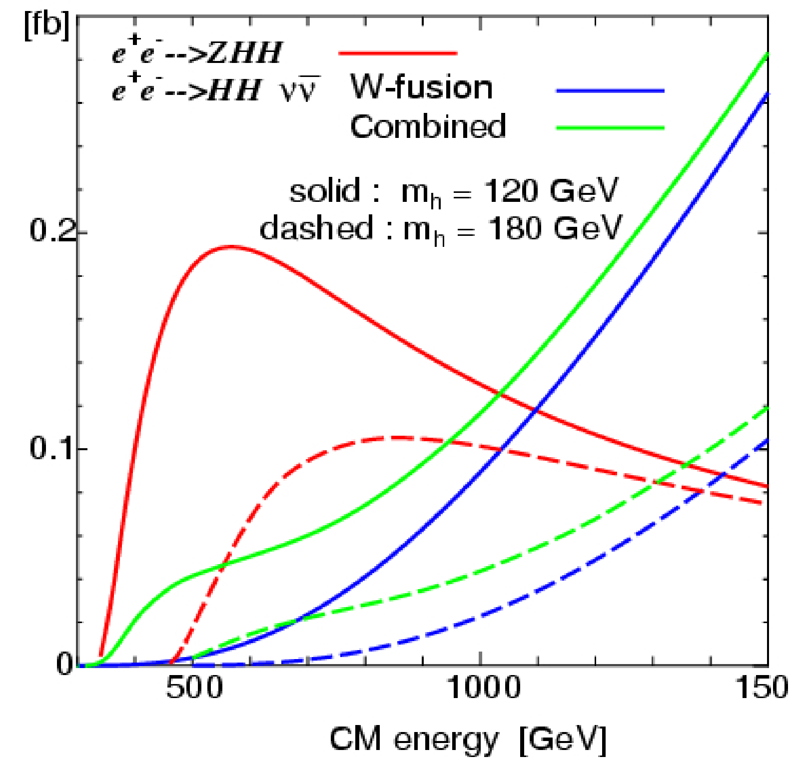


etc..

$\star\ e^+e^- \to (W^+W^-)\nu\bar{\nu} \to HH\nu\bar{\nu}$

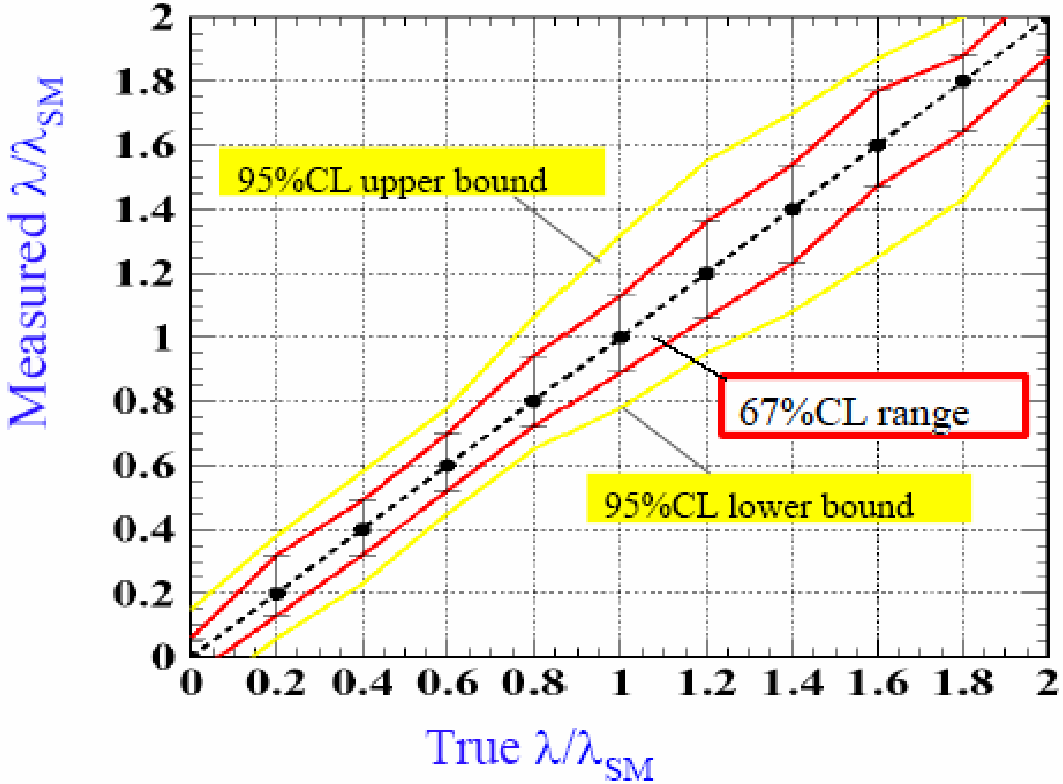


etc..



λ_{hhh} Measurement sensitivity

By Yamashita et.al. LCWS 2004



@1TeV

I_{lumi}=1 ab^{-1}

Pol_{beam}= -80%

M_h=120 GeV

(SM Higgs Br)

Use only hh→ 4b

(Br(hh→ 4b)~47%)

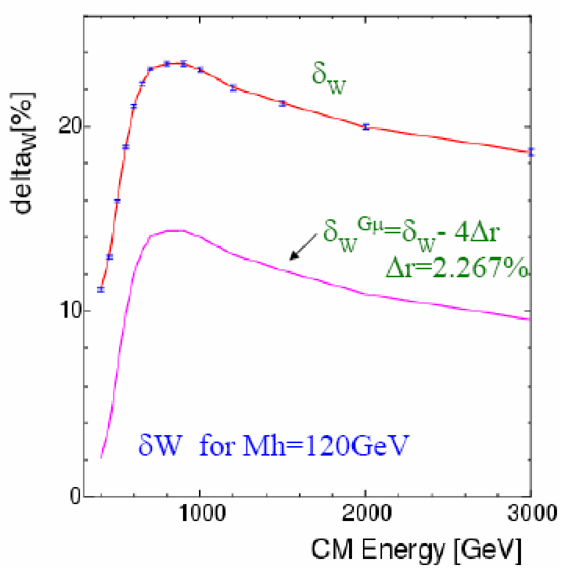
Eff.(4b) 80%

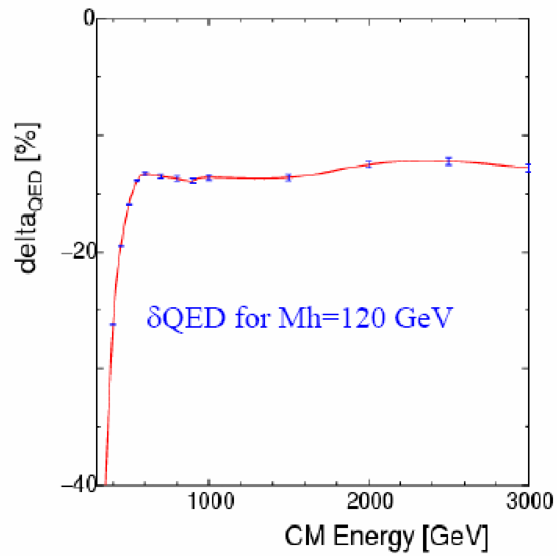
Determination of the self-coupling at 10% level

Radiative correction for $e^+e^- \to \nu_e\ \nu_e\ HH$

$\delta = \sigma(O(\alpha))/\sigma(\text{tree}) - 1$

Yasui et.al. ECFA2004 Durham UK





GRACE system
Minamitateya
collaboration

10 % effects as
pure EW corrections

Automatic calculation of Feynman diagrams (GRACE/SUSY/1LOOP) , M.Jimbo

GRACE /SUSY (tree-level) :completed http://minami-home.kek.jp/

Full electroweak one loop correction ex: $e^- e^+ \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$

1935 1loop diagrams x 7 tree diagrams

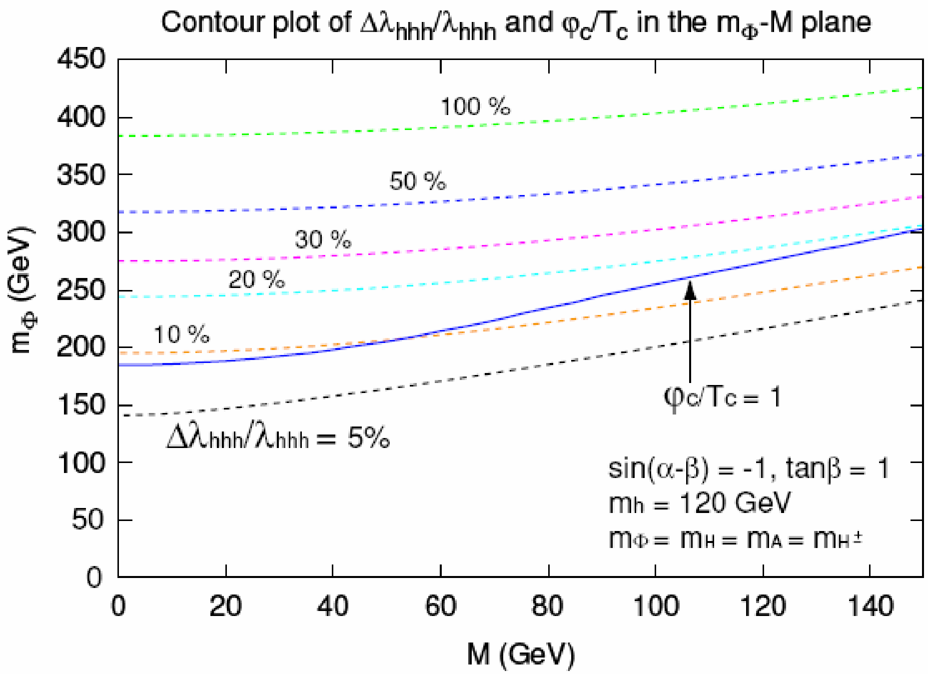
Electroweak baryogenesis and the Higgs self-coupling in 2HDM

E.Senaha

Baryon number asymmetry can be created at the EW phase transition in 2HDM.

The condition of the strong first order phase transition
=>
A large radiation correction to the triple Higgs boson coupling.

$$V_{eff}(\phi, T) \leftrightarrow V_{eff}(\phi, 0)$$



$$\Delta\lambda_{hhh}/\lambda_{hhh} \gtrsim 10\%$$

SUSY

- ILC is an ideal place to study SUSY.

  Mass, spin, and coupling determinations

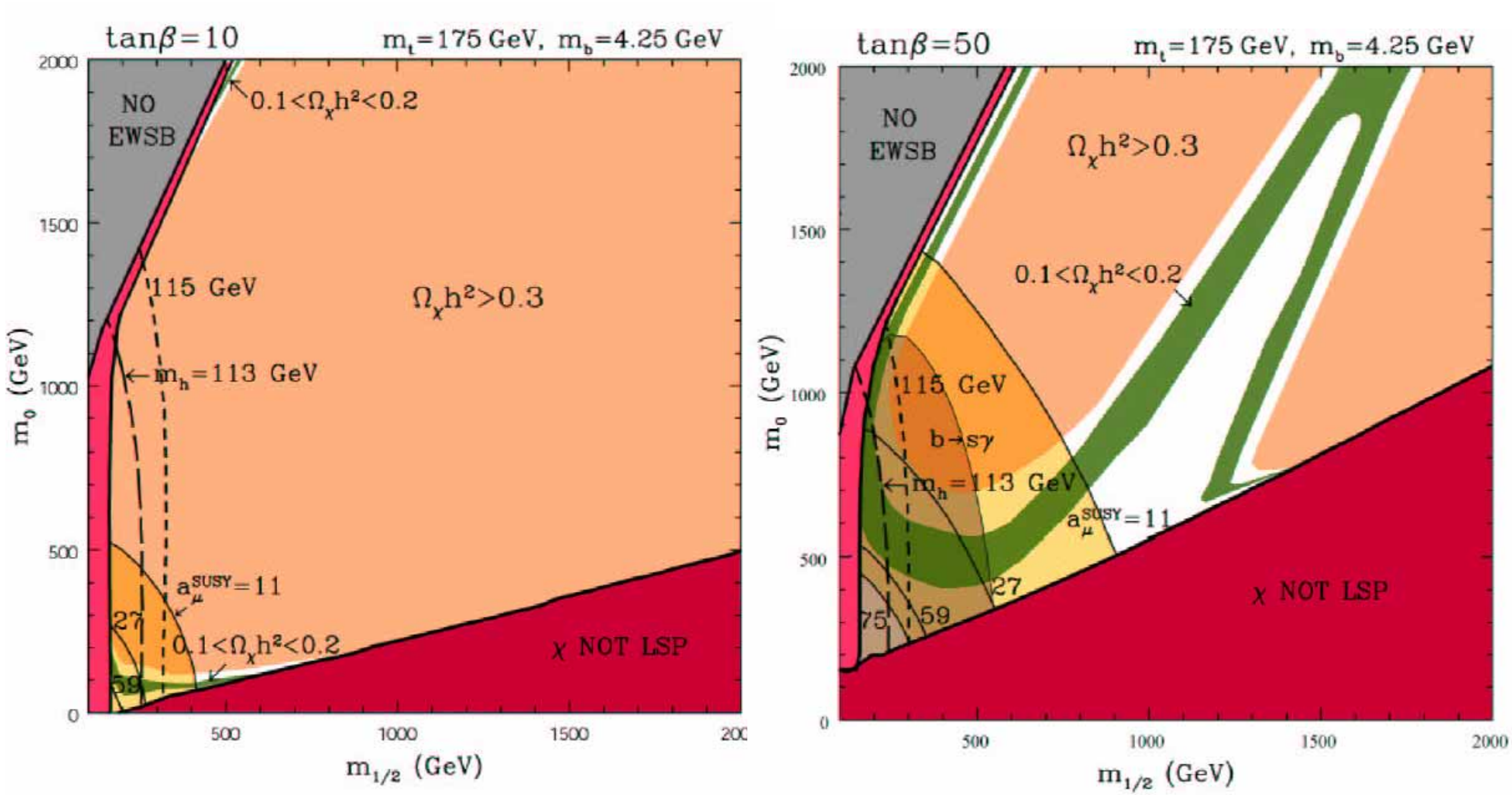
  Energy scan, beam polarization,

  photon-photon and e- e- options.
- Cosmological connection: SUSY dark matter
- New analysis includes CP violation

SUSY dark matter

T.Nihei

LSP neutralino relic abundance



Roszkowski, Ruiz, Nihei

WMAP -> an allowed line “focus point”, “stau coannihilation”, “A-pole”

Effects of CP phases in gaugino masses

$m_A = 500$ GeV

$m_{\tilde{f}} = 800$ GeV

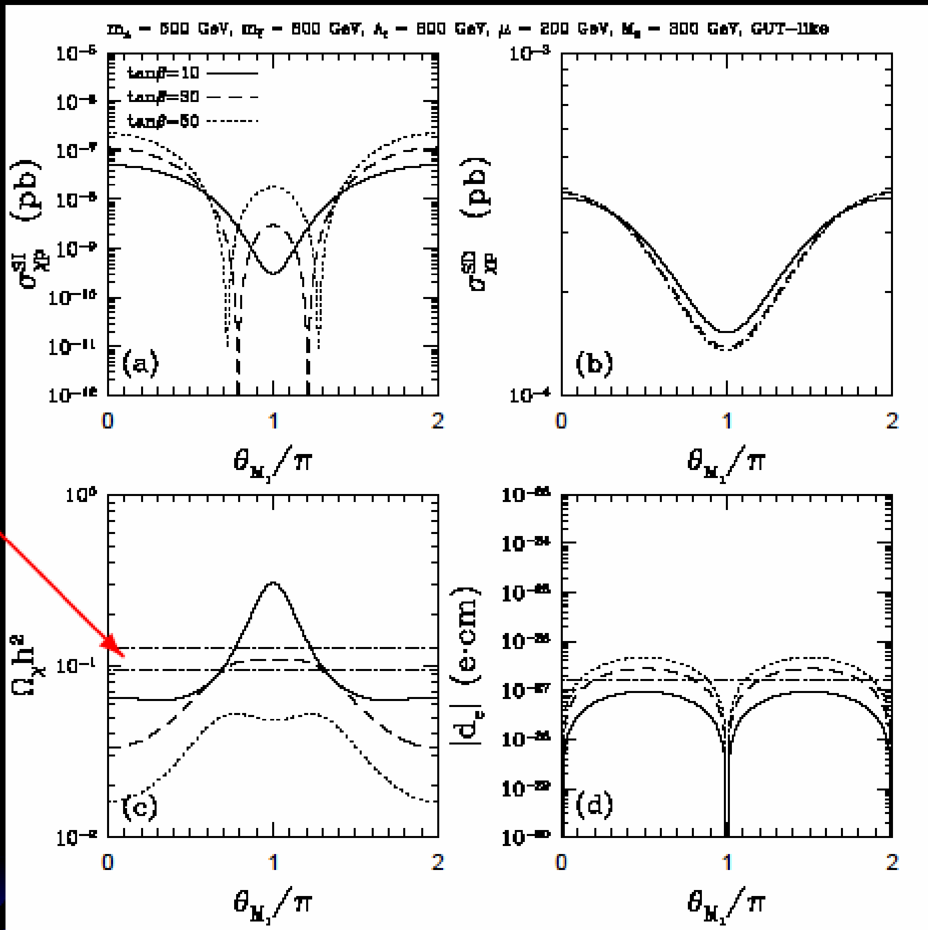
$A_f = 800$ GeV

$\mu = 200$ GeV

$M_2 = 300$ GeV

GUT-like

WMAP (2σ)



New allowed regions

Nihei,Sasagawa

CP violation in SUSY models

- Many new sources of CP violation in general SUSY model.

  Higgs sector, chargino/neutralino sector, squark/slepton sector.
- In general, various EDM experiments put strong constraints.
- Many phenomenological implications. (CP-even and CP-odd observables)

$$\gamma\gamma \to H/A(\to t\bar{t})$$

Heavy Higgs boson mixing including imaginary part, S.Y.Choi

$$\gamma\gamma \to H_i \to \tau^+\tau^-$$

Tau polarization for a light Higgs case (CPX scenario) R.Godbole

$$\tilde{\tau} \to \tau\chi^0(\tilde{t} \to t\chi^0)$$

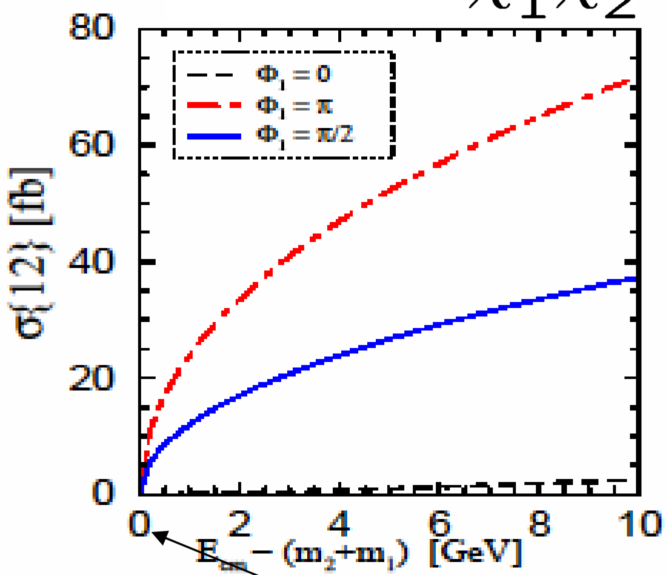
CP phase effects on tau (top) polarization. R.Godbole

CP violation in the neutralino sector

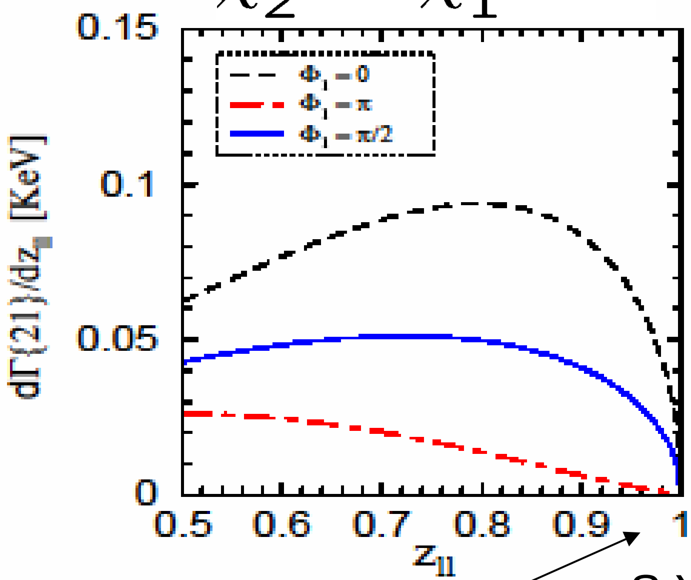
Neutralino pair production and decays B.C.Chung

Selection rules on the angular momentum at the production threshold and at the end point of lepton invariant distribution in the CP conserved case.

$e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2$



$\tilde{\chi}^0_2 \to \tilde{\chi}^0_1 l^+l^-$



S.Y.Choi

S wave <-> P wave

P wave <-> S wave

S wave <-> S wave (CPV case)

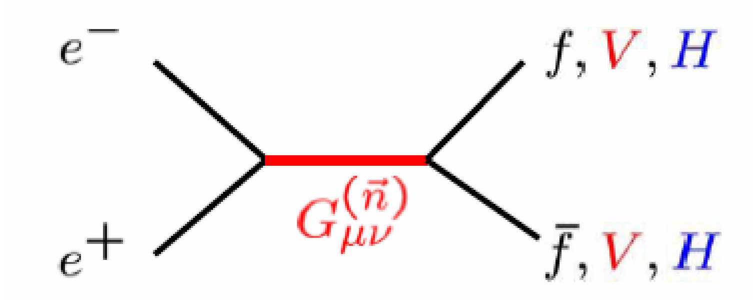
- Triple vector correlation in the decay of polarized $\tilde{\chi}^0_2$ from the selectron decay.

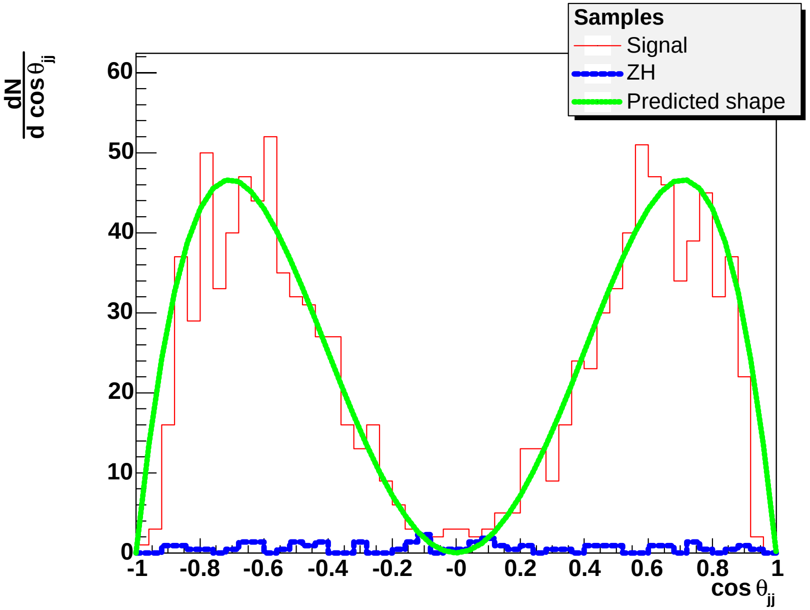
Large Extra Dim Model

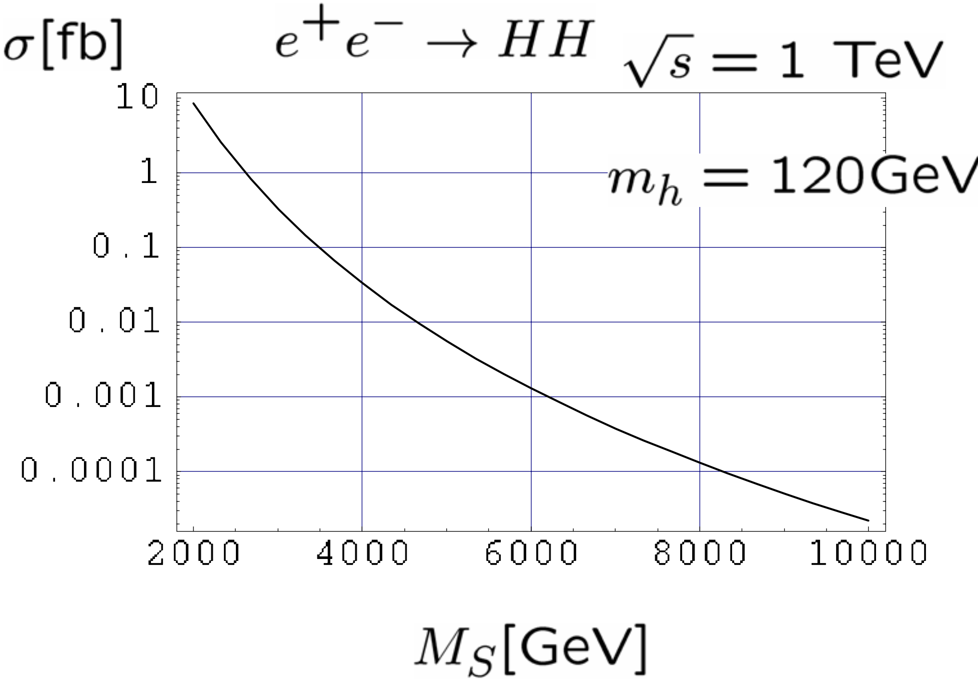
N.Okada

Indirect signal of KK gravitons

Angular distribution of ee-> HH
=> Spin two nature





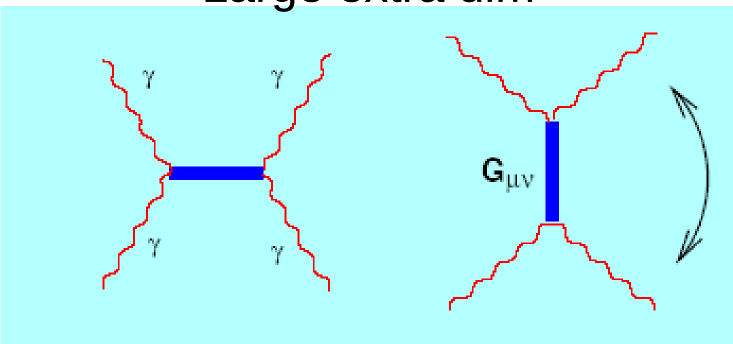


mh=120GeV, Ms=2 TeV, 500/fb

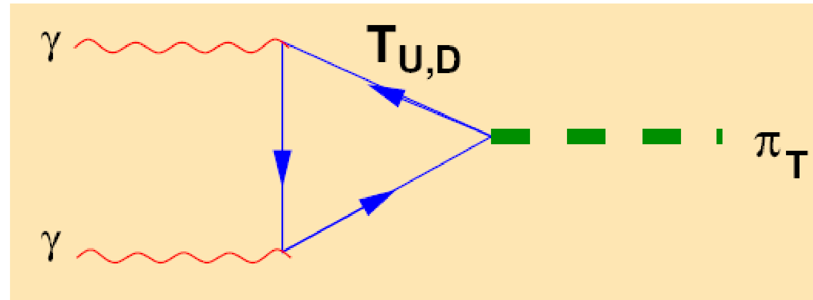
Photon-photon scattering at the photon collider

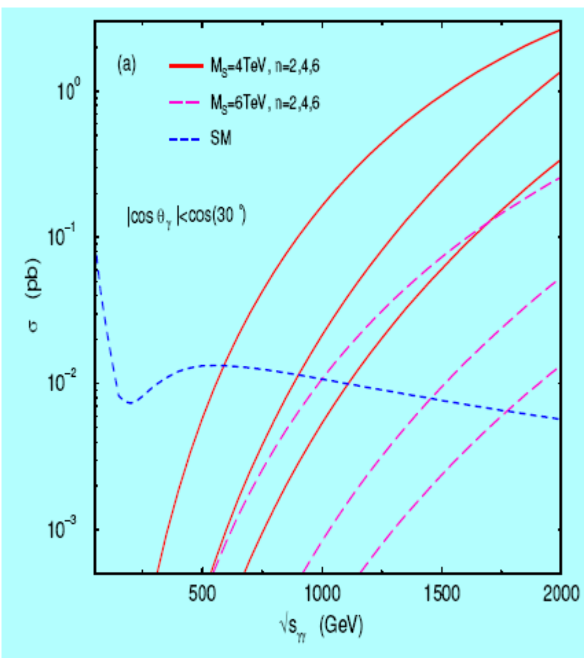
K. Cheung

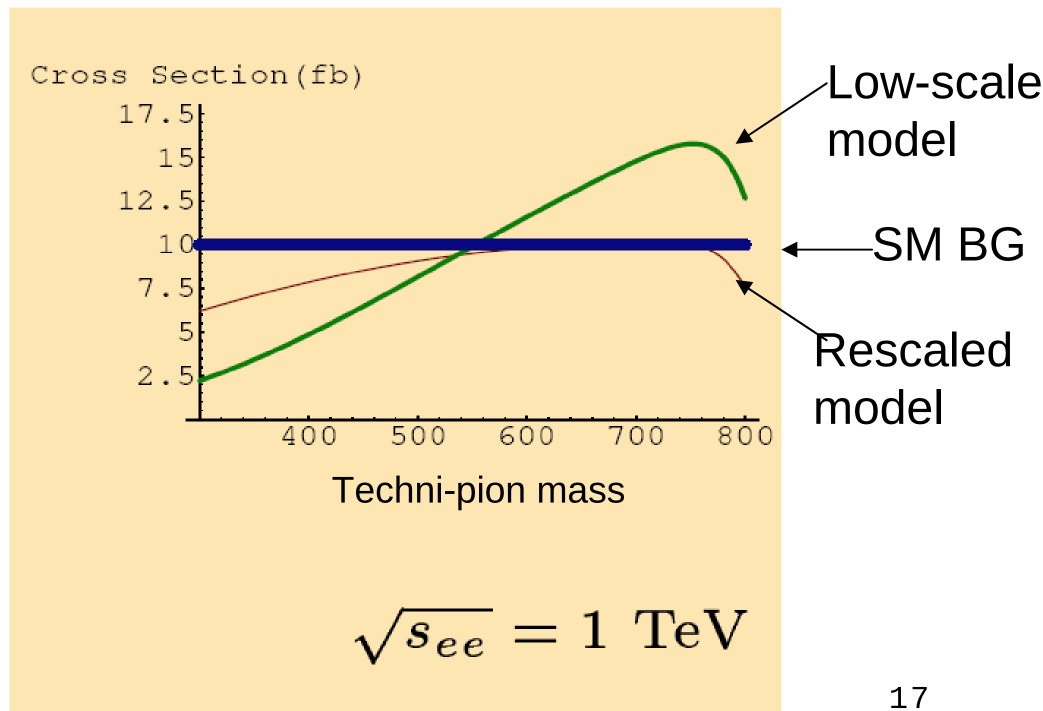
Large extra dim



Techni –pion production



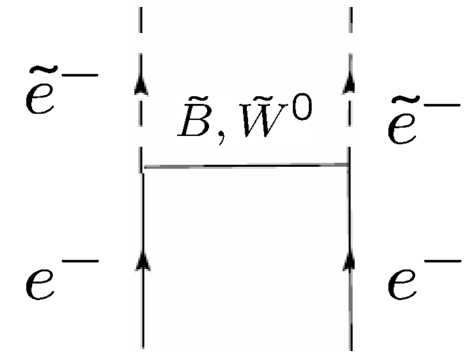




e-e- option

C.A.Heusch

Merits of e-e- options

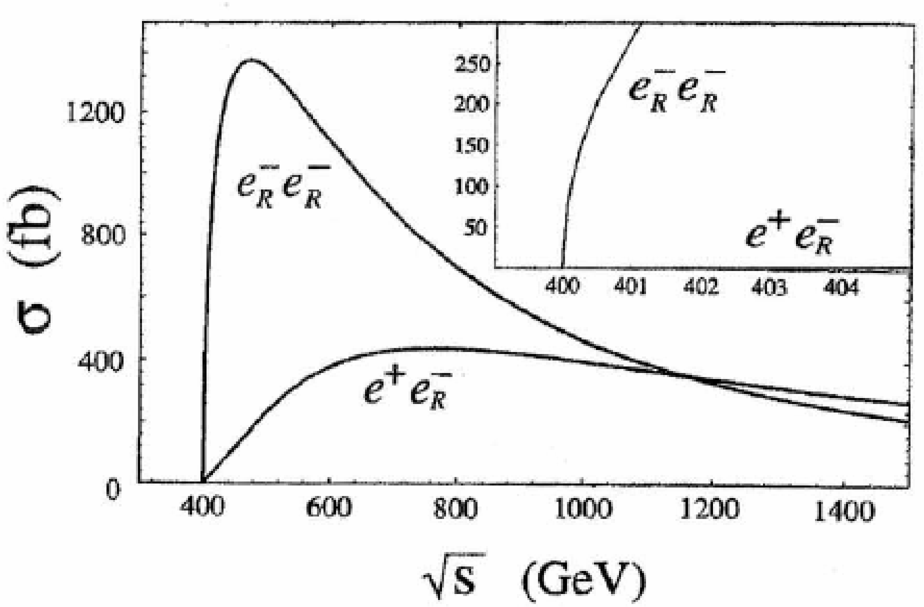


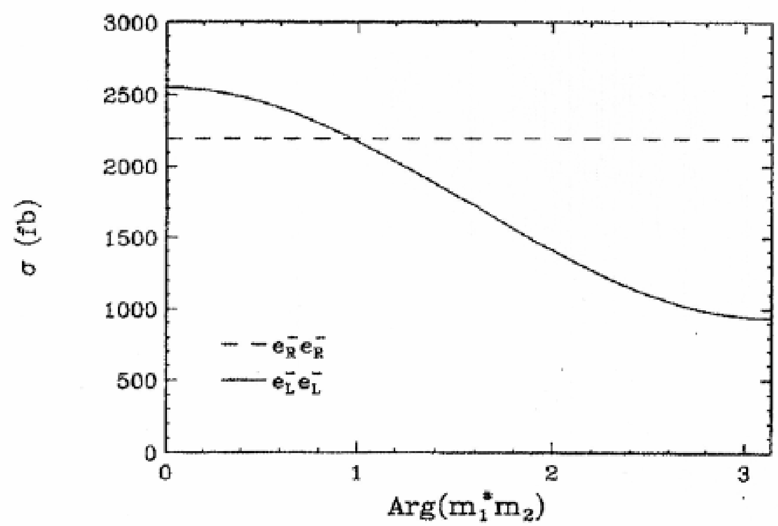
Right-handed selectron production

J.L.Feng

Left-handed and right-handed selectron productions

S.Thomas



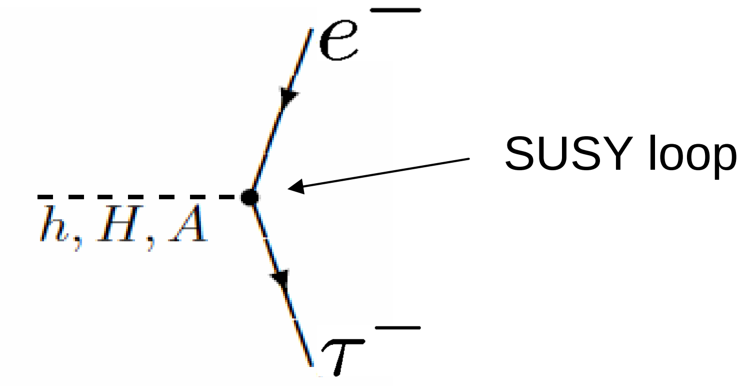


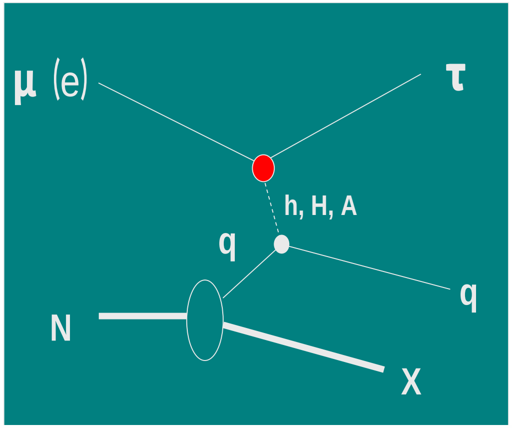
Precise mass determination

Gaugino phase dependence in the left-handed selectron production

LFV search in eN->τX process

SUSY loop effects can induce LFV Higgs couplings. S.Kanemura

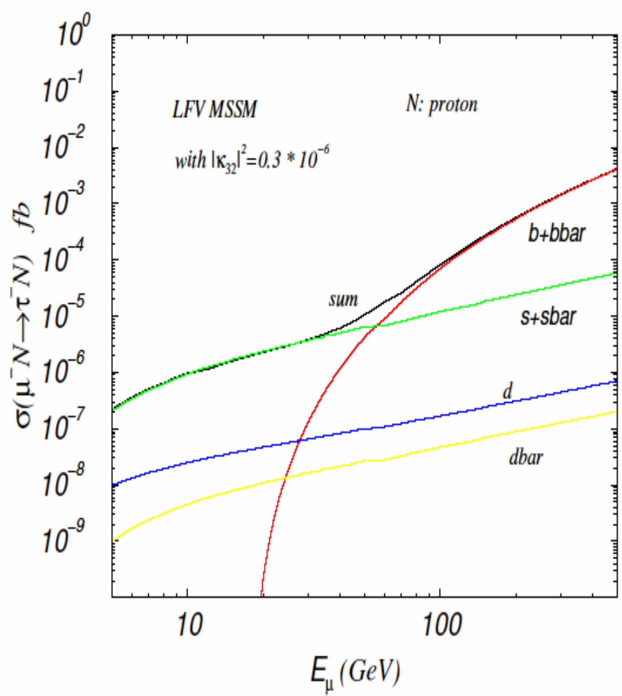




The eN->τX cross section becomes large for a larger electron energy .

10^5 taus at Ee=250 GeV.

Non-observation of the signal would improve the current limit on the **τ**-e-**Φ** coupling from tau LFV decay search by 10^(4-5).



Summary

- Higgs and electroweak symmetry breaking

  "Understanding the origin of the Higgs mechanism"
- New physics, "New directions"

  CPV, LFV, Cosmological connections, etc.
- Options

  "Physics case for each option"