ECFA2008

Warszawa, 9-12 June 2008

gamma gamma physics

or physics at the Photon Linear Collider - PLC

Maria Krawczyk
University of Warsaw

International Linear Collider Workshops

Accelerator Physics

Year	Workshop	Location
1988	LC88	SLAC
1990	LC90	KEK
1991	LC91	Protvino
1992	LC92	Garmisch
1993	LC93	SLAC
1995	LC95	KEK
1997	LC97	BINP, Zvenigorod
1999	LC99	INFN, Frascati
2002	LC02	SLAC
2004	1st ILC Workshop	KEK
2005	2nd ILC Workshop	Snowmass

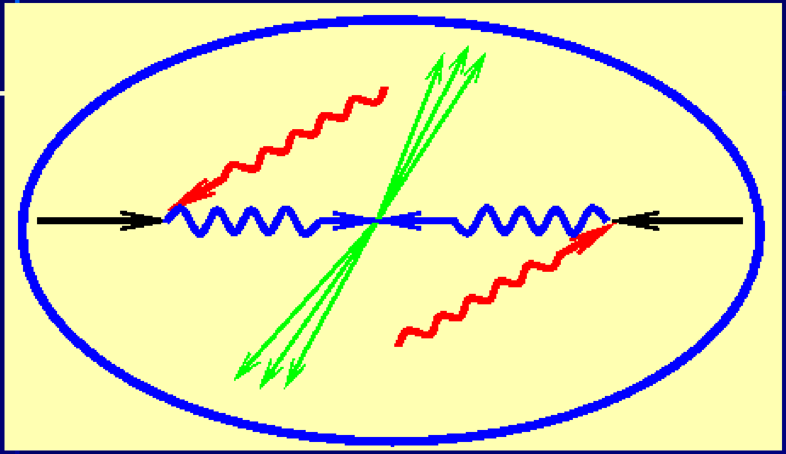
Particle Physics

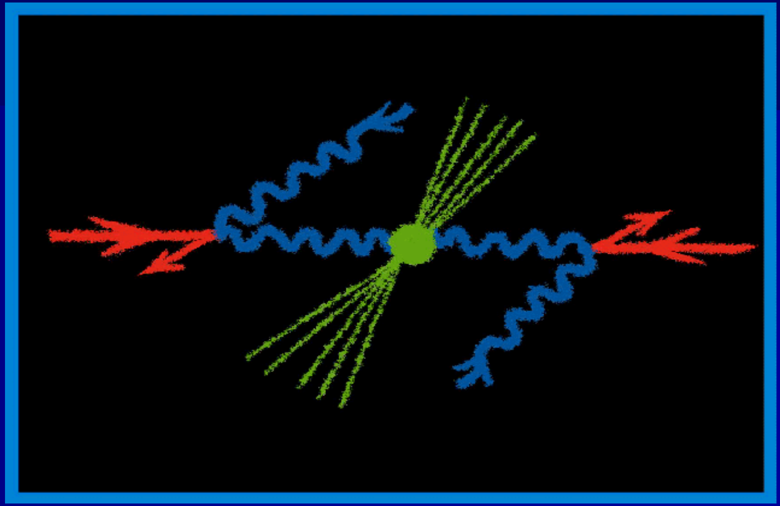
Year	Workshop	Location
1991	LCWS91	Saariselkä, Finland
1993	LCWS93	Waikoloa, HI
1995	LCWS95	Morioka-Appi, Japan
1999	LCWS99	Sitges, Barcelona, Spain
2000	LCWS00 PLC2000	Fermilab Batavia, IL USA
2002	LCWS02 PLC2001	Jeju, Korea
2004	LCWS04	Paris, France
2005	LCWS05 PLC2005	Stanford, USA
2006	LCWS06	Bangalore, India

LCWS2007–DESY

PHOTON2007-Paris

PLC - where we are ?





Physics

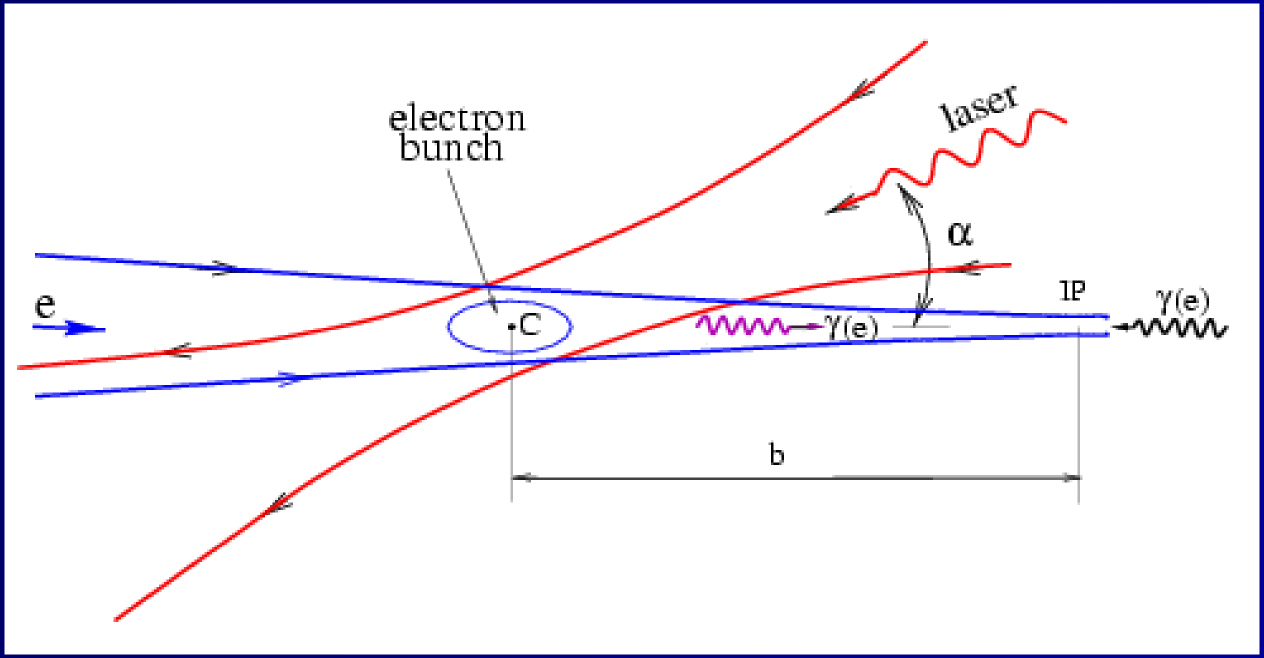
Collider

Question - at ILC, CLIC or simply low energy plc or?

In ILC DCR - physics included, PLC as an option

Backward Compton Scattering- basic idea of the photon collider

Ginzburg, Telnov '85



- PLC - γ γ and e γ options

The Photon Collider – main characteristics

- Variable energy and degree of polarization of the photon beams – both circular and linear
- (Almost) monochromatic spectrum possible (a high energy peak)
- Clean or dirty collider? Hadronic interaction of photon ……

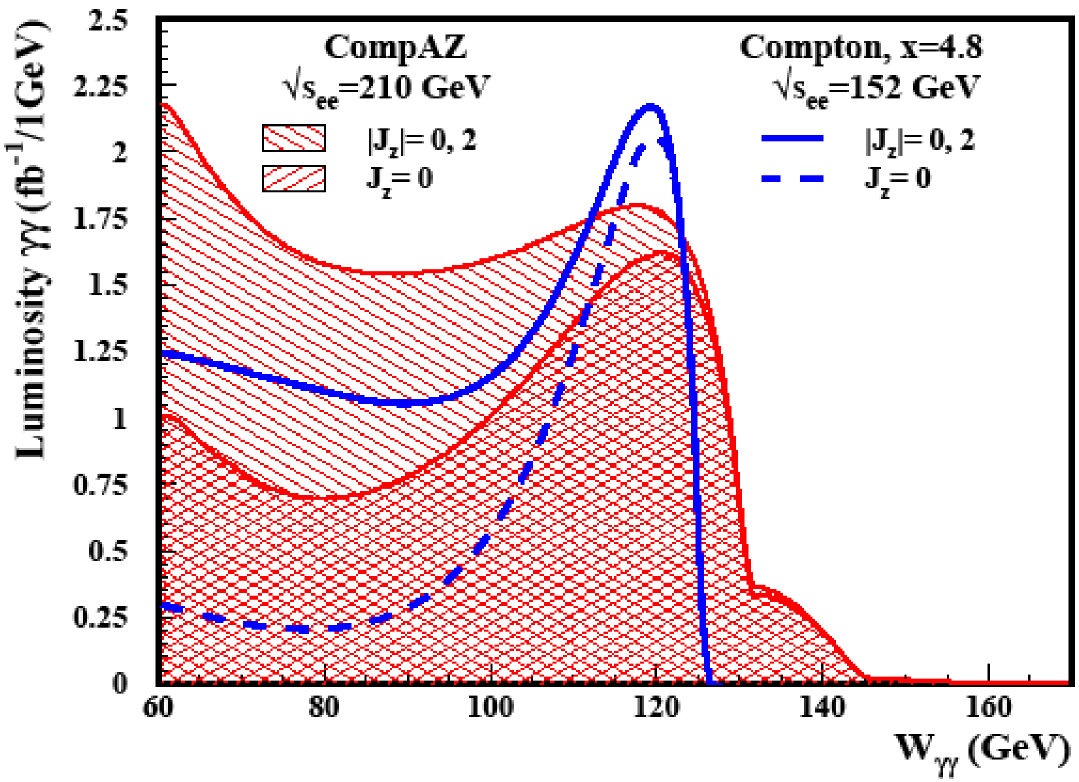
PLC at ILC

- For ILC with energy 500-1000 GeV:
- Energy $E_{\gamma\gamma}$ up to 0.8 E_{ee} (0.9 for $e\gamma$ option) $E_{\gamma\gamma}$ $e\gamma$
- Luminosity ~ 0.2 L_{ee}

  Annual luminosity 100 fb-1 (30 fb-1 in the peak)
- Mean energy spread in a peak: ~0.05-0.07
- Mean helicity at the peak: 0.9-0.95
- Important parameter x: $\omega_{max} = \frac{x}{x+1} E_0$ E_0 energy of e

  x=4.5 to avoid e+e- pair production

Realistic γ γ spectra (Telnov)

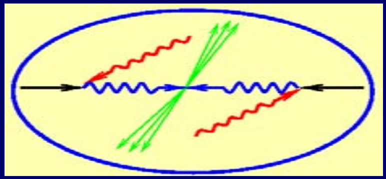


For $J_z = 0, 2$

Here $J_z=0$ peak for M=120 GeV

CompAZ parametrizaton (A.F.Żarnecki)

PLC: Photon Linear Collider
$\gamma\,\gamma$ and e γ

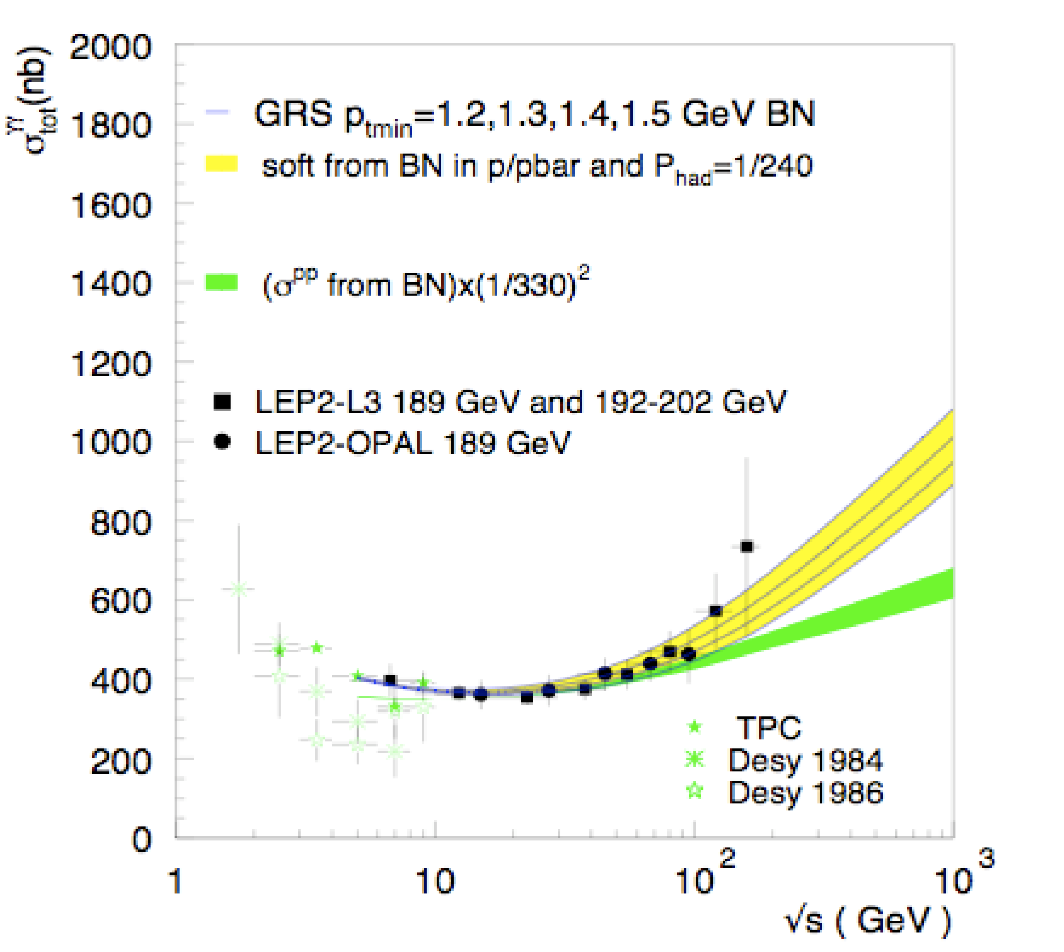


- Resonance production of C=+ states (eg. Higgs) Ginzburg et al
- Higher mass reach than at e^+e^- (Higgs, SUSY) Spira, Zerwas,Abdel
- Polarised beams – CP filter Gunion, Grzadkowski,Hagiwara, Godbole, Zarnecki
- H $\gamma\,\gamma$ coupling – sensitivity to charged particles in theory (nondecoupling) Ginzburg et al.., Gunion..
- Direct production of charged scalars, fermions and vectors – higher cross section Kanemura, Moenig, Belanger
- Pair production of neutral particles (eg. light-on-light) via loops Jikia, Gounaris, Velasco
- Study of hadronic interaction of the photon Godbole,Pancheri; MK Brodsky, deRoeck,Zerwas

Hadronic cross section

Godbole, Pancheri, deRoeck

- Large $\gamma\,\gamma \rightarrow$ hadrons cross section
- Various study of QCD possible
- Measurements of the hadronic (partonic) structure of the photon
- In e γ option DIS on a real photon for the first time possible
- The structure of polarized photon



New results at ecfa2008 by Pancheri

Precise Higgs Physics at ILC/PLC

- Precise measurements of the SM Higgs production cross section and branching ratios – especially Γ_γ

	Ohgaki, Takahashi, Watanabe	1997
	Jikia, Soldner-Rembold	1999
~ 2 %	Asner, Gronberg, Gunion	2001
	Niezurawski, Zarnecki, MK	2002
	Moenig, Rosca	2003

- Higgs self-coupling measurements →
- Heavy MSSM Higgs searches
- CP property of the Higgs boson

Higgs coupling to $\gamma\gamma$

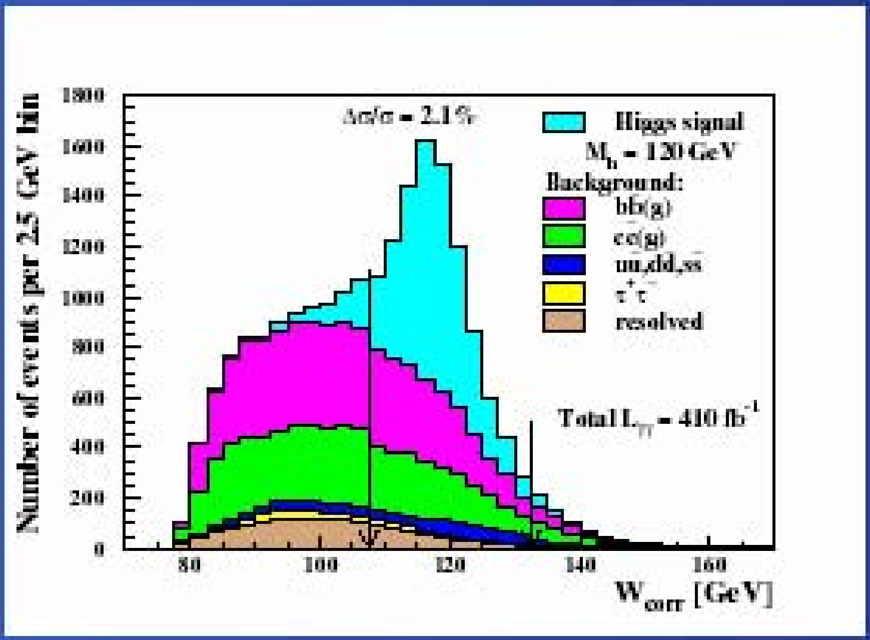
$$\gamma\gamma \to h \to b\bar{b}$$

Niezurawski et al.,

NŻK

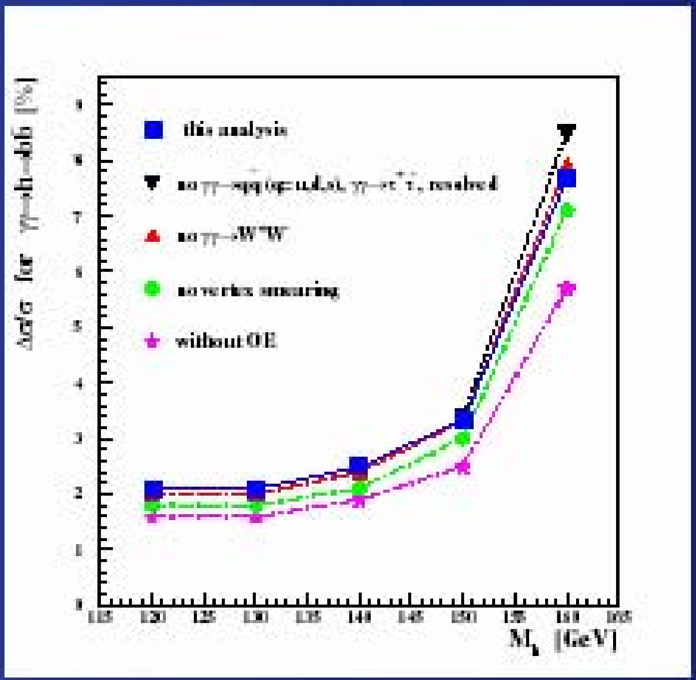
SM summary

Results for $M_h = 120$ GeV



Corrected invariant mass distributions for signal and background events

Results for $M_h = 120$-160 GeV

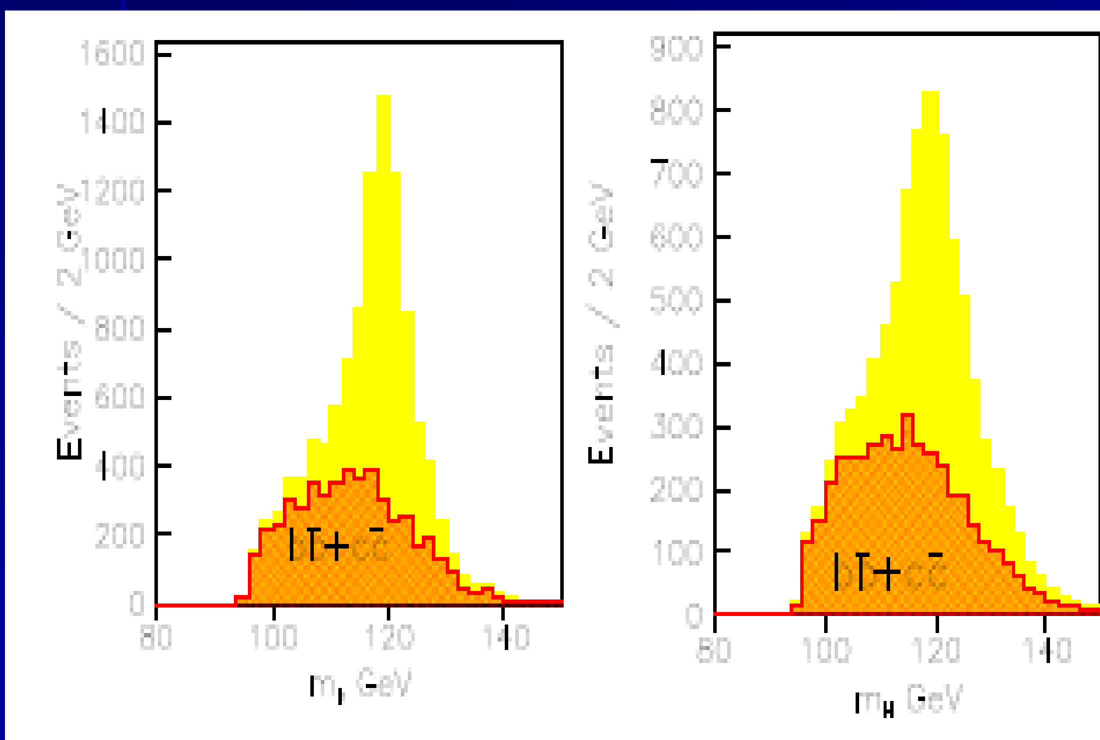


For $M_h = 150$, 160 GeV additional cuts to reduce $\gamma\gamma \to W^+W^-$

A. Rosca, K. Moening: hep-ph/0705.1259
SM Higgs 120 GeV at PLC

- Without and with overlying events

$$\frac{\Delta[\Gamma(H\to\gamma\gamma)\times BR(H\to b\bar{b})]}{[\Gamma(H\to\gamma\gamma)\times BR(H\to b\bar{b})]} = \sqrt{N_{obs}}/(N_{obs}-N_{bkg}) = 2.1\%.$$

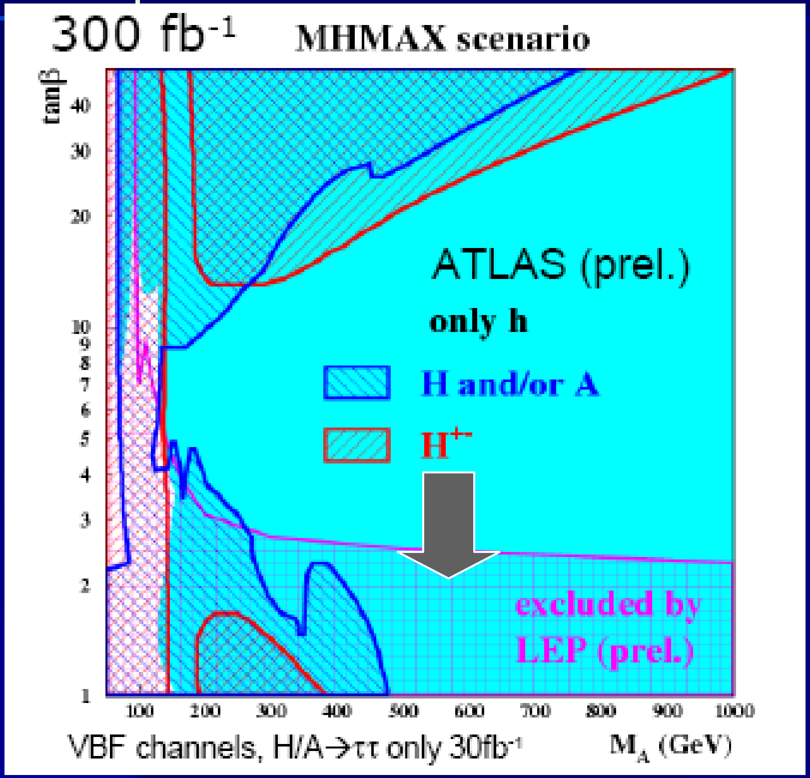


2.1 %

Knowing it and using Br from e^+e^- ->

Γ(h->$\gamma\ \gamma$) ~ 3 %

MSSM Higgs searches/overall discovery potential (300 fb^{-1}) at LHC



at least 1 Higgs boson is observable

• in some parts >1 Higgs bosons observable

• but large area in which only one Higgs boson h (SM-like) observable

LHC wedge

Result assuming no H→SUSY

Basic question: Could we distinguish SM and MSSM Higgs sector
- e.g via rate measurements?

MSSM: Precision at PLC

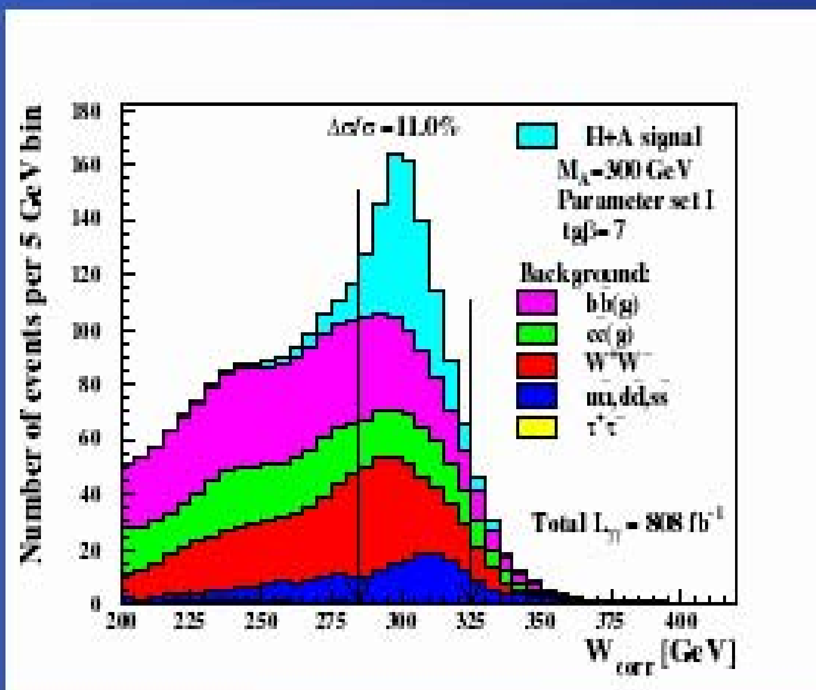
Spira et al

Niezurawski et al.,- simulation

Covering the LHC wedge at PLC

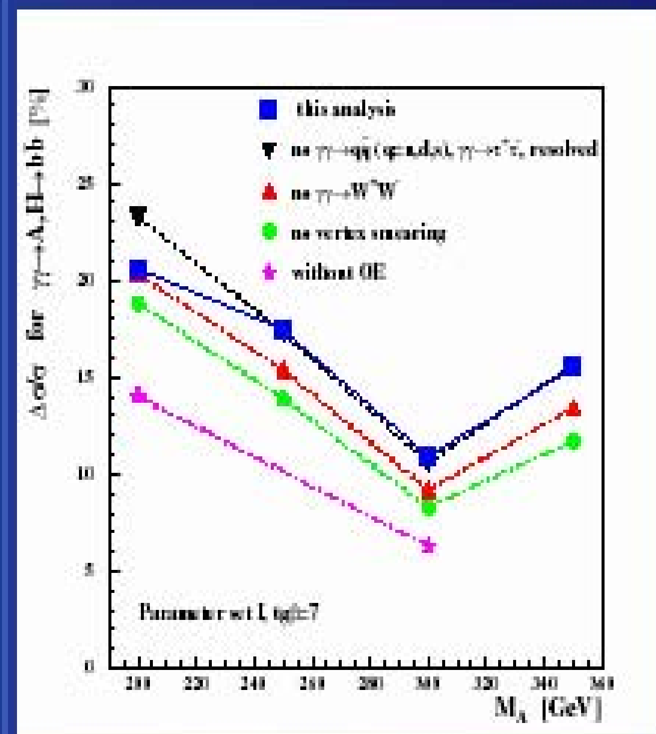
Precision of $\sigma(\gamma\gamma \rightarrow A, H \rightarrow b\bar{b})$ mesurement

Results for M_A = 300 GeV



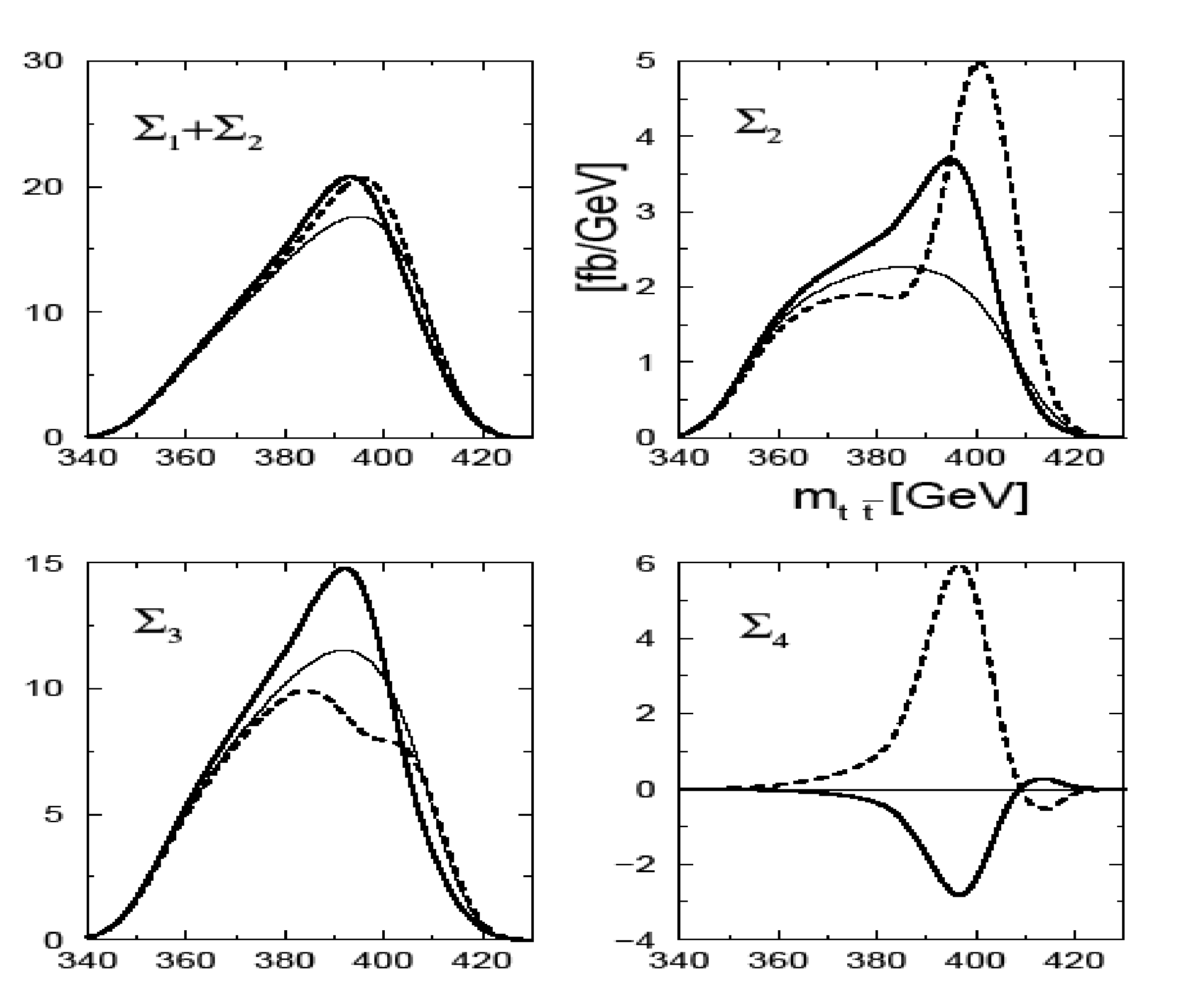
Corrected invariant mass distributions

Results for M_A = 200-350 GeV



our previous results compared

CP-even, CP-odd states in $\gamma\,\gamma \rightarrow t\,t$ Asakawa, Hagiwara.. 2000-



Scalar (dashed)

Pseudoscalar (thick)

Mass – 400 GeV

2HDM (II) with CP violation

$H - A$ mixing

Mass eigenstates of the neutral Higgs-bosons h_1, h_2 and h_3 do not need to match CP eigenstates h, H and A.

We consider weak CP violation through a small mixing between H and A states:

$$\begin{aligned}
\chi_X^{h_1} &\approx \chi_X^{h} \\
\chi_X^{h_2} &\approx \chi_X^{H} \cdot \cos\Phi_{HA} + \chi_X^{A} \cdot \sin\Phi_{HA} \\
\chi_X^{h_3} &\approx \chi_X^{A} \cdot \cos\Phi_{HA} - \chi_X^{H} \cdot \sin\Phi_{HA}
\end{aligned}$$

$\Rightarrow$ additional model parameter: **CP-violating mixing phase Φ_{HA}**

$\Rightarrow$ see our paper JHEP 0502:041,2005 [hep-ph/0403138]

In general case

combined analysis of LHC, Linear Collider and Photon Collider data is needed

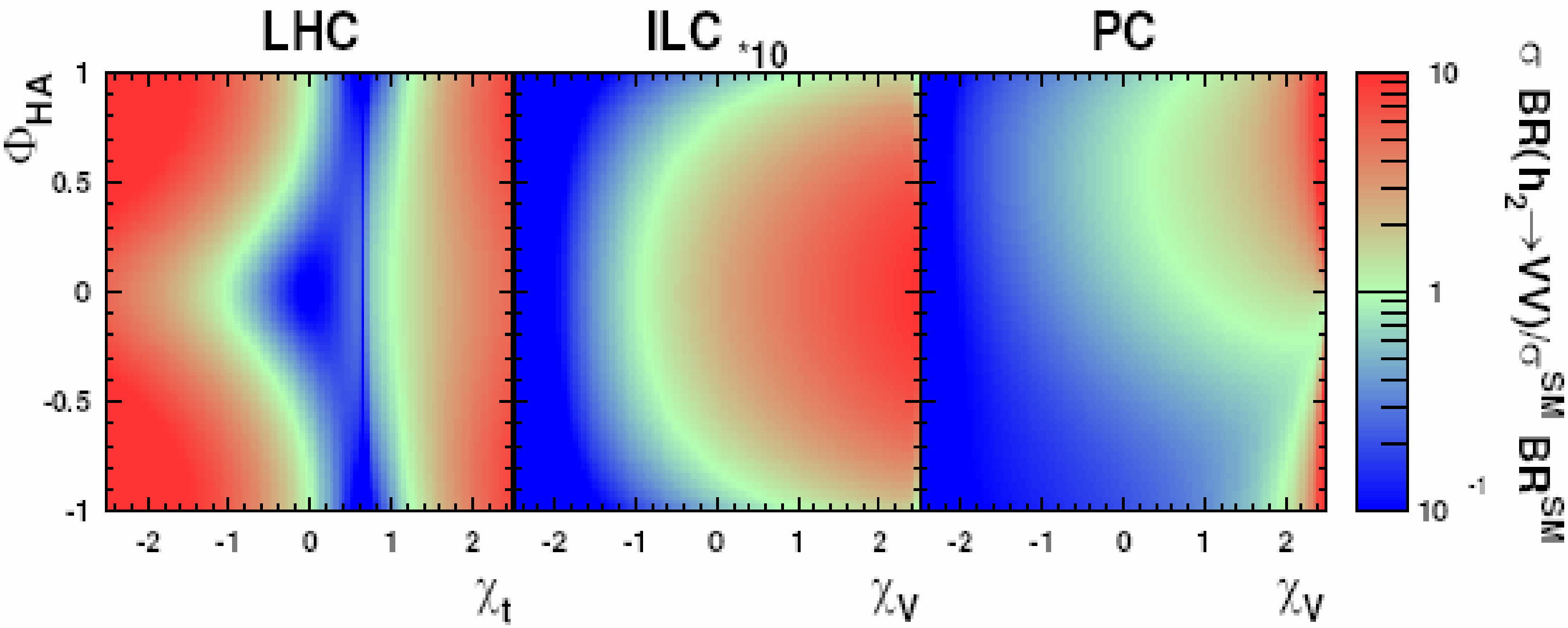
We consider h_2 production and decays, for $|\Phi_{HA}| \ll 1$ (weak CP violaion)

Zarnecki, Niezurawski, MK

LHC $\oplus$ ILC $\oplus$ PC

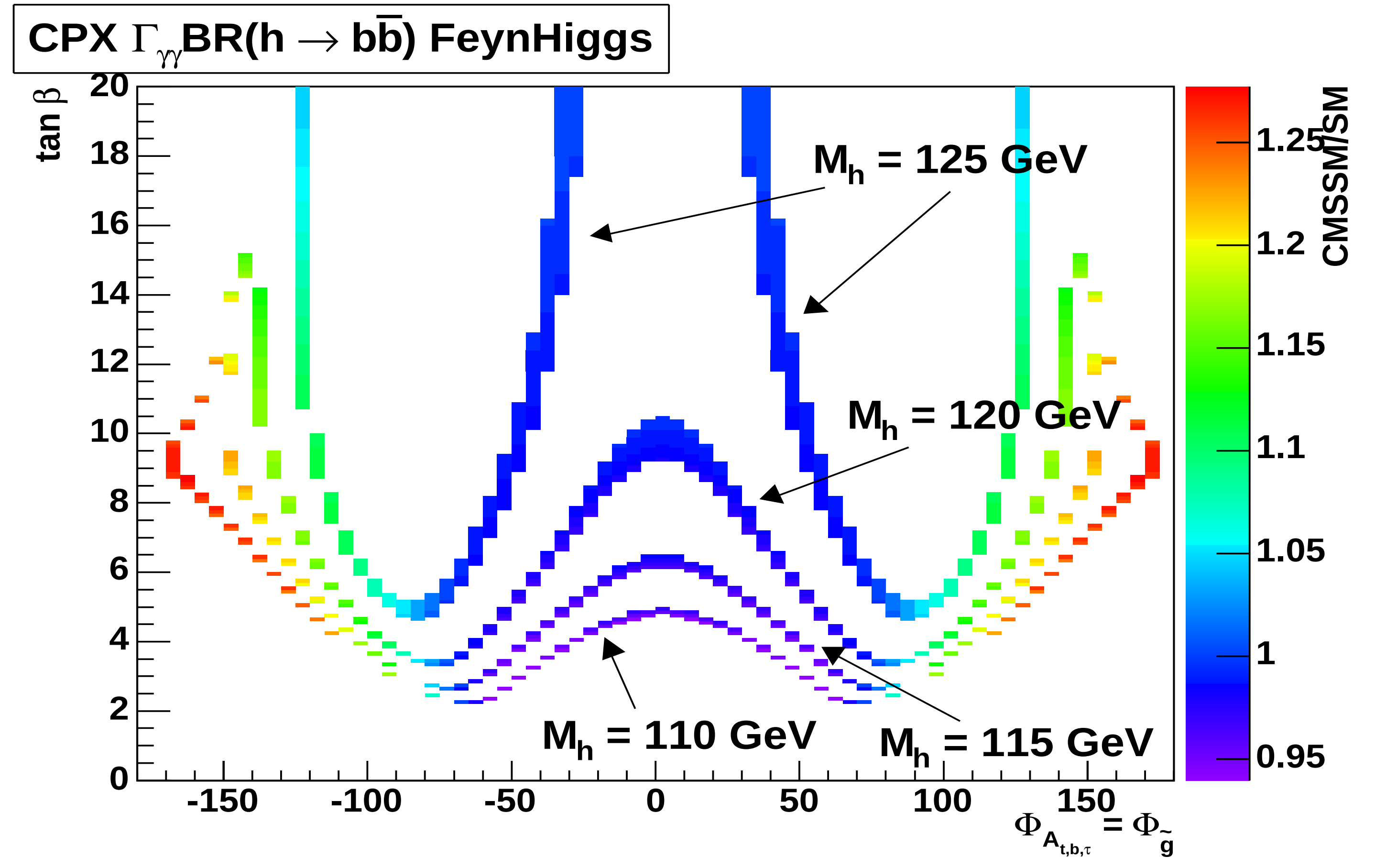
Sensitivity of LHC, ILC and Photon Collider measurements to CP-violating mixing phase Φ_{HA}

Cross sections $\times$ BR relative to SM $\qquad M_H = 250 GeV$



CPX scenario (max CP violation in CMSSM) studied for LHC, ILC, PLC (CLIC ?)

by Heinemeyer, Velasco 2004

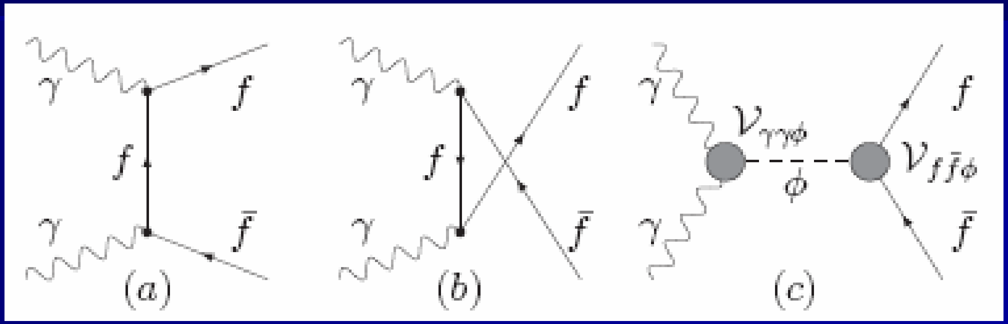


CP-violating Higgs mixing arising via radiative corrections with effect of complex Higgs masses Choi at al., J.S.Lee,

Probing the CP-violating Higgs contribution in $\gamma\gamma \to f\bar{f}$; Godbole, Kraml, Rindani, Singh – Phys. Rev. D (2006)

- For f = top, tau
- Using fermion polarization

to construct various asymmetries



- Both for CP conserving and CP violating case
- Model independent analysis and in addition

CPX scenario (MSSM) – for light Higgs numerical analysis

$$\phi f \bar{f} \; : \; \frac{-ig\, m_f}{2\, M_W} \left(v_f + i a_f \gamma_5\right) \qquad (1)$$

$$\phi VV \; : \; \frac{ig\, M_V^2}{M_W} \left(A_V\, g_{\mu\nu} + B_V \frac{p_\mu p_\nu}{M_Z^2} + i\, C_V\, \epsilon_{\mu\nu\rho\sigma} \frac{p^\rho q^\sigma}{M_Z^2} \right) \qquad (2)$$

ff democratic CP-even and CP-odd coupling

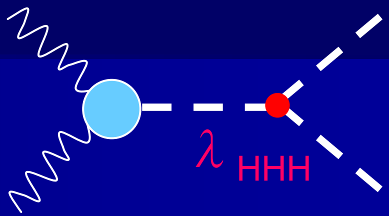
In contrast to VV case – typically A_V dominates

NEW RESULTS 2007-8

- Self-coupling
- New physics in $\gamma\gamma \rightarrow \gamma\gamma$
- Dark matter candidate

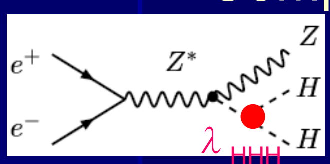
Measurement of Higgs self-coupling Eri Asakawa(Meiji Gakuin Univ., KEK) D. Harada (Sokendai),S. Kanemura (U. of Toyama),Y. Okada (Sokendai, KEK), K. Tsumura (ICTP) LEI 2007 Dec2007,Hiroshima

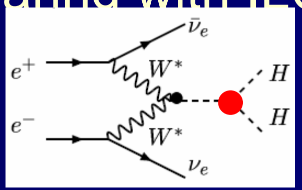
$\gamma\ \gamma \rightarrow$ HH at PLC.



And we try to answer a question:

Comparing with ILC, Superior? Comparable? Complement?



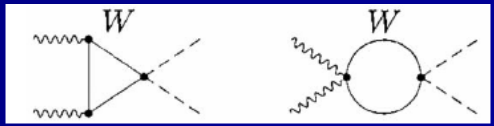


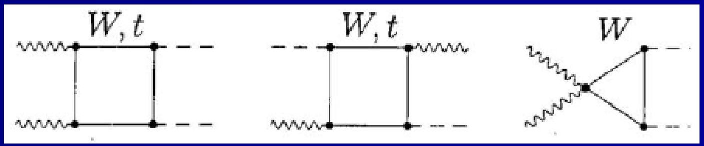
<u>seem-to-be advantage</u>

- 2 body final state
- Polarization (J_Z=0)

<u>seem-to-be disadvantage</u>

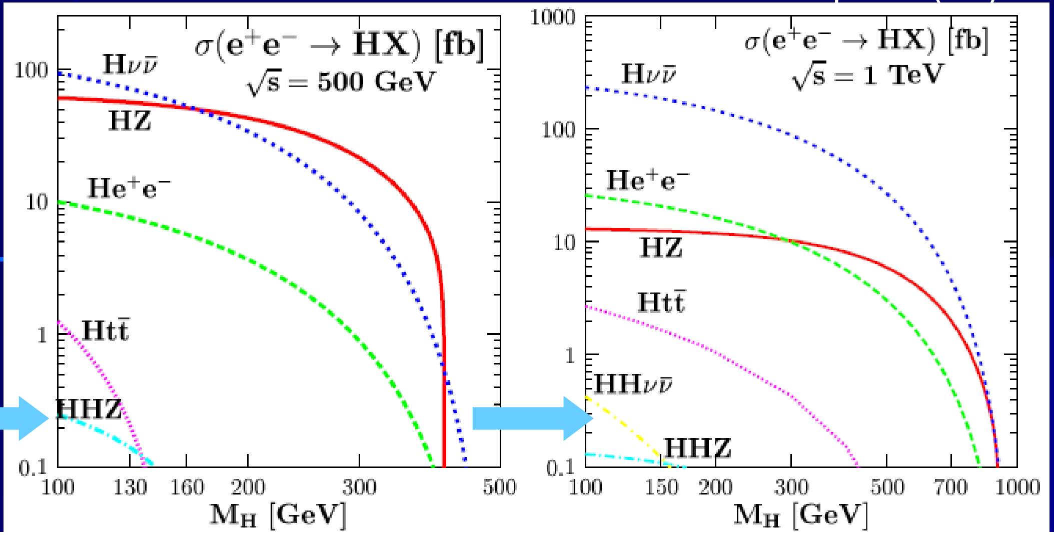
- Large contribution from the box diagrams
- Luminosity

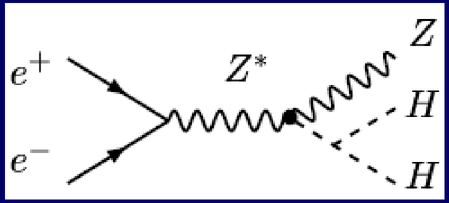


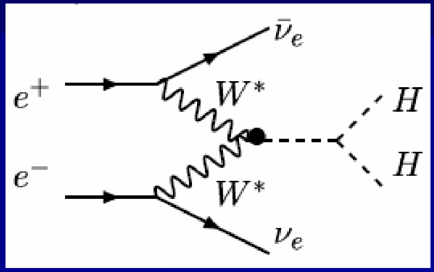


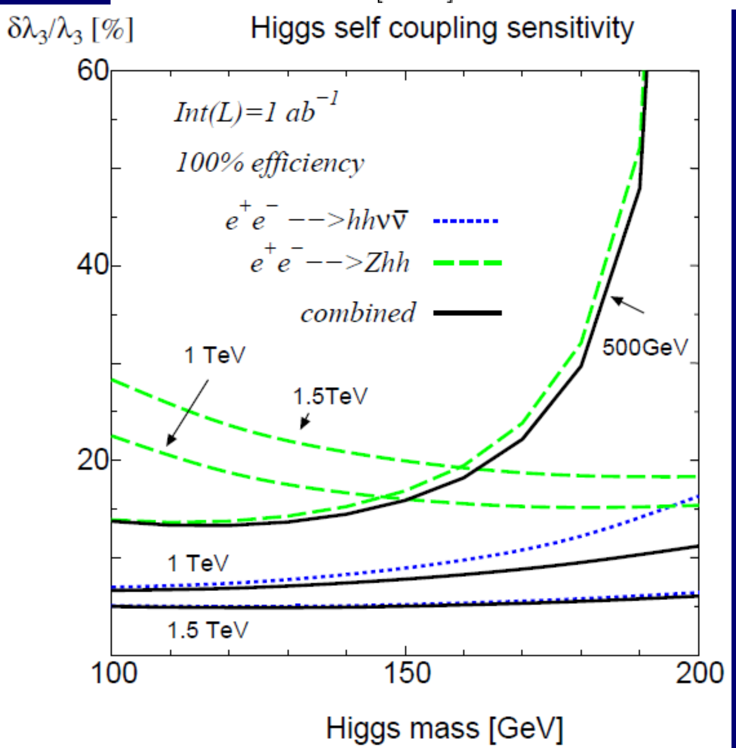
Measurement at ILC

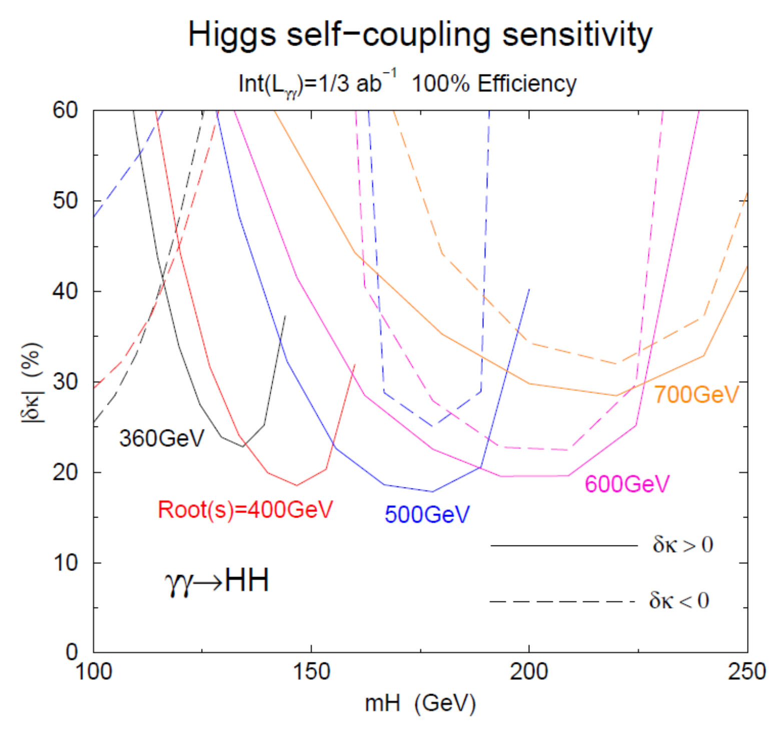
Djouadi(05)











ACFA Higgs Working group(02)

Asakawa 2007

measure the λ_{HHH} via $\gamma\gamma \to HH$ at PLC

✓Numerical results: consistent with previous works of Belusevic-Jikia(04)
✓Sensitivity study: preliminary

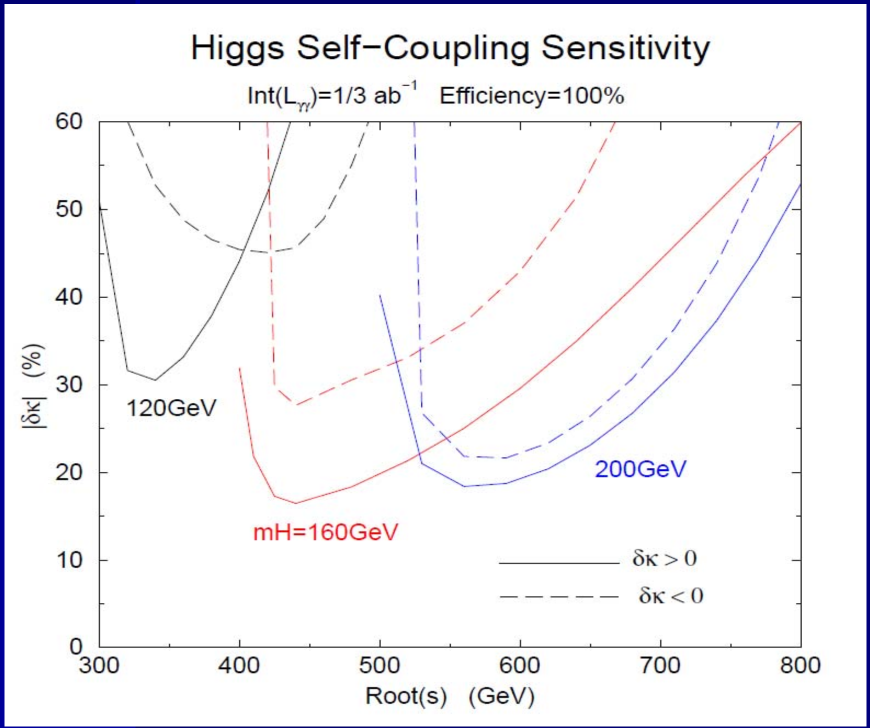
Conclusions at this stage

Sensitivity to $\delta\kappa$ becomes well around

$$\sqrt{s}_{ee} \approx 3m_H$$

$$\Uparrow$$

$$2m_H \approx 0.8\frac{x}{x+1}\sqrt{s}_{ee}$$



So, after H is found and m_H is known, we can examine the λ_{HHH} coupling by selecting the best $\sqrt{s}_{ee}$

Unparticle physics at the photon collider

Phys.Rev.D77:094012,2008 0801.0018 [hep-ph]

Tatsuru Kikuchi (KEK, Tsukuba) , Nobuchika Okada (KEK, Tsukuba & Tsukuba, Graduate U. Adv. Studies) , Michihisa Takeuchi (KEK, Tsukuba & Tsukuba, Graduate U. Adv. Studies & Kyoto U., Yukawa Inst., Kyoto)

A certain class of new physics models includes a scalar field which is singlet under the SM gauge group.

→Such a new particle can have a direct coupling with photons suppressed by a new physics scale in low energy effective theory.

Similar results Chun-Fu Chang (Taiwan, Natl. Tsing Hua U.) , Kingman Cheung (Taiwan, Natl. Tsing Hua U. & NCTS, Hsinchu) , Tzu-Chiang Yuan (NCTS, Hsinchu) . e-Print: arXiv:0801.2843

γγ → γ γ

Since this process occurs at loop level in the SM, the unparticle effects can be significant even if the cutoff scale is very high.

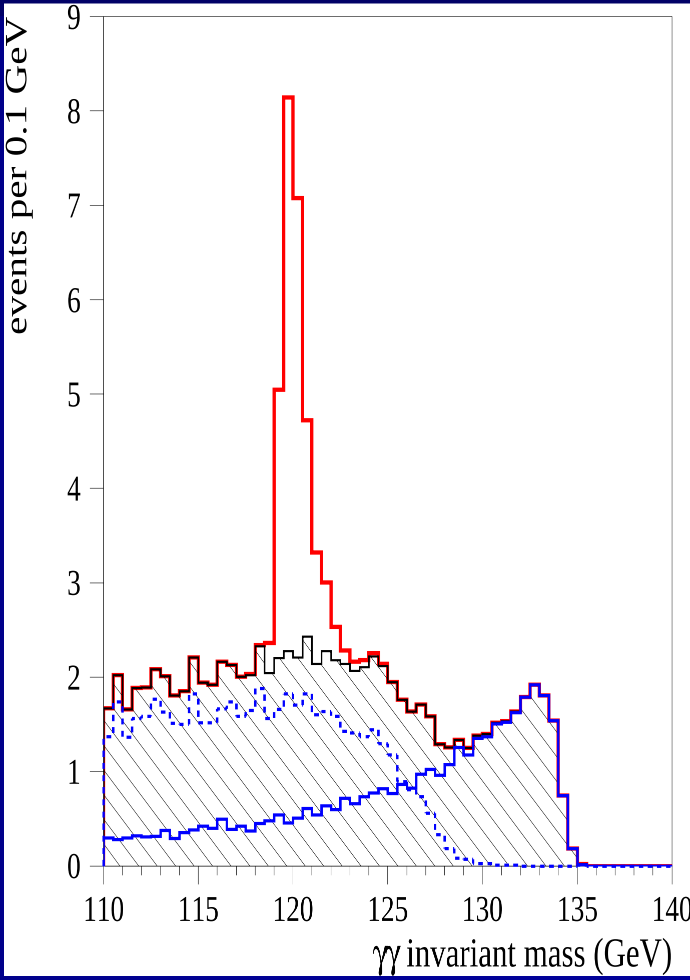
Background small →

Results: even for scale = 5 TeV, the unparticle effect → sizable deviations from the SM results with the incident e+e− collider energy at $\sqrt{s}$ = 500 GeV.

The signal over background ratio can be enhanced by choosing the initial beam polarization

At LHC effects in gg→γ γ

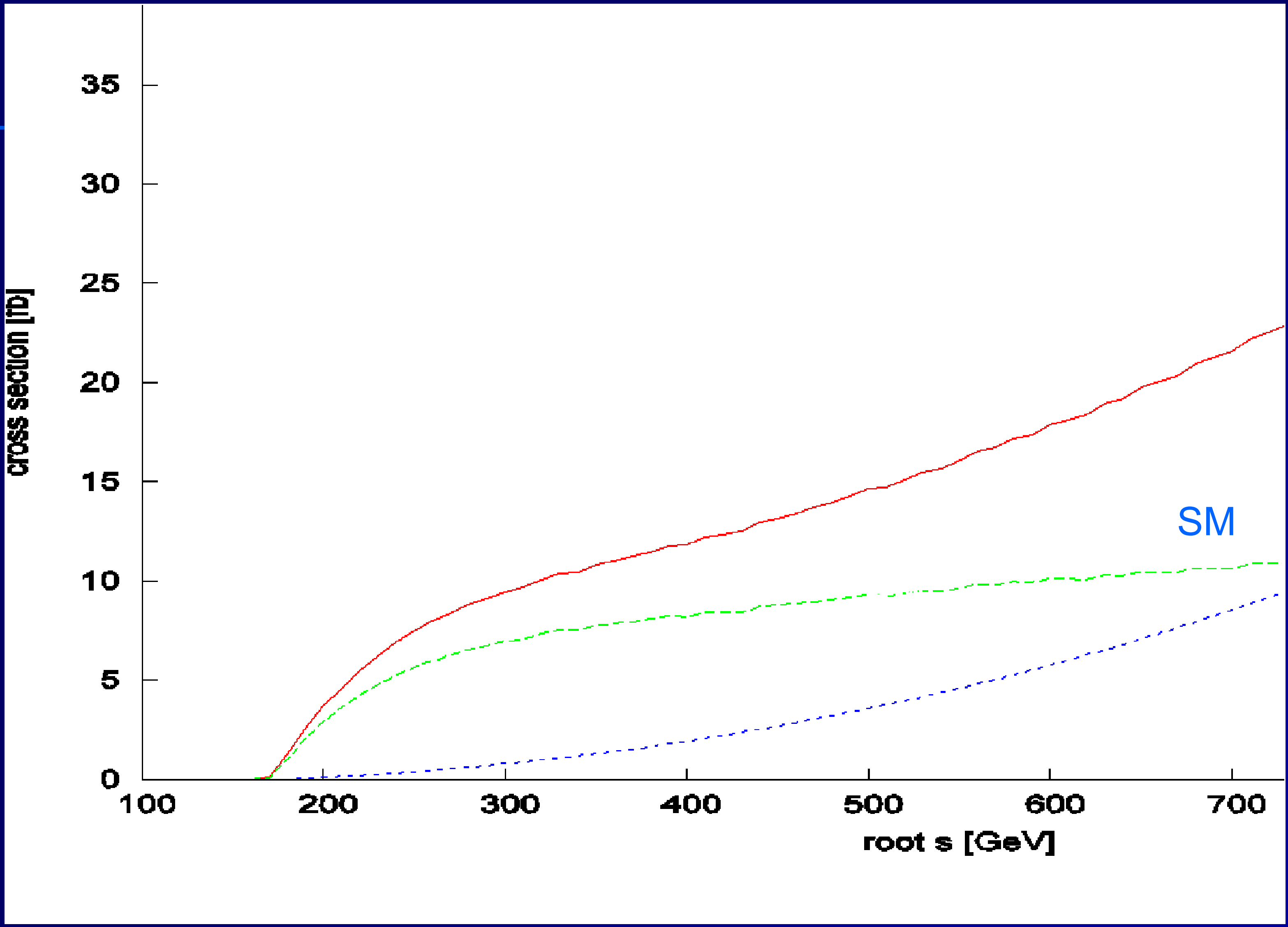
Here at ecfa2008 discussed by Ginzburg (also other new physics models)



SM, Velasco … 2002

SM vs Unparticle in $\gamma\gamma \rightarrow \gamma\gamma$

σ, fb



Λ = 5 TeV

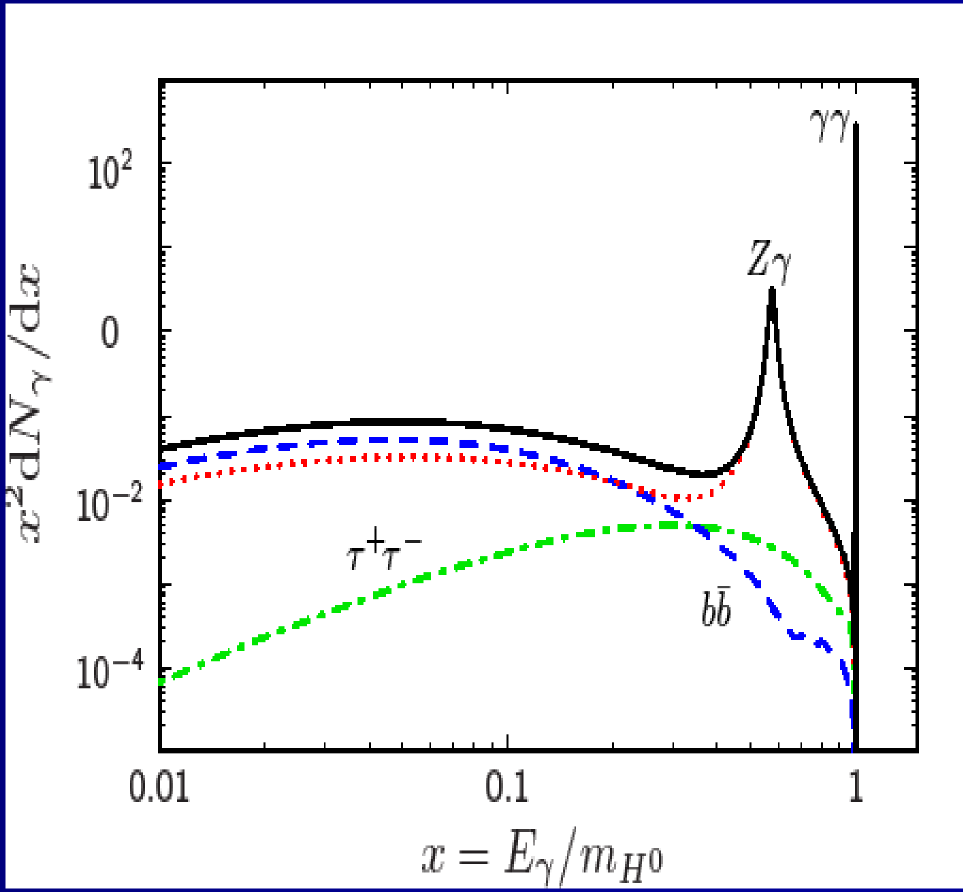
Energy, GeV

Inert Doublet Model

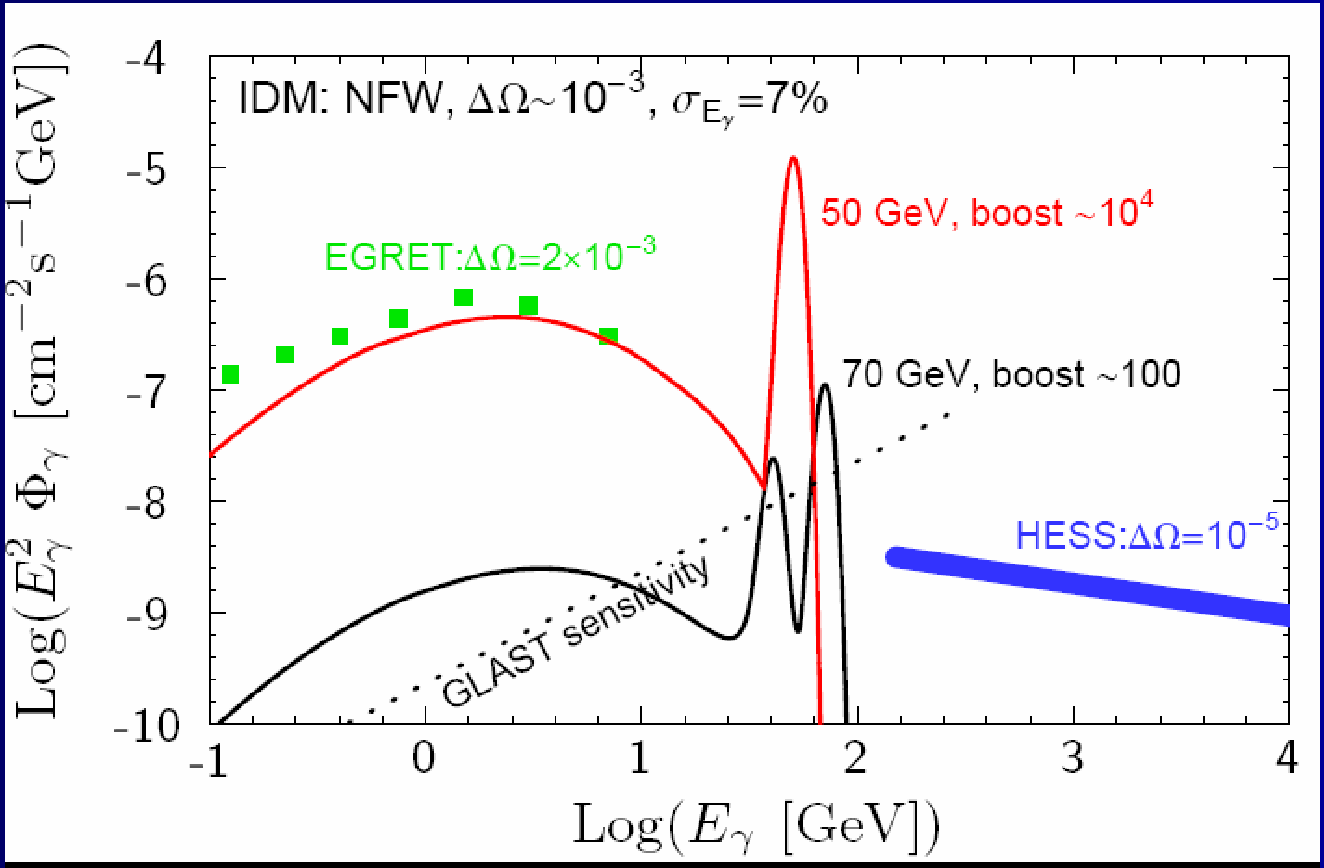
Ma'78, Barbieri..'05, Honorez..'07,..

Significant Gamma Lines from Inert Higgs Dark Matter - Gustafsson astro-ph/0703512

- Adding another scalar doublet with no direct coupling to fermions
- The unbroken discrete Z_2 symmetry makes the new scalars *inert* – the lightest one H is a candidate for Dark Matter. For a H mass between 40 and 80 GeV -> the correct cosmic abundance(WMAP).
- The loop-induced mono-chromatic $\gamma\gamma$ and the $Z\gamma$ final states (from HH -> $\gamma\gamma$ and the $Z\gamma$) would be exceptionally strong
- Ideal to search for in the upcoming GLAST exp.



For mass of H = 50 and 70 GeV
HH → γ γ **at GLAST**



γ γ → HH at PLC,

PLC = $GLAST^{-1}$?

June 11, 2008
NASA's GLAST Launch Successful

- NASA's Gamma-ray Large Area Space Telescope, or GLAST, successfully launched aboard a Delta II rocket from Cape Canaveral Air Force Station in Florida at 12:05 p.m. EDT today.

- After a 75-minute flight, the GLAST spacecraft was deployed into low Earth orbit. It will begin to transmit initial instrument data after about three weeks. The telescope will explore the most extreme environments in the universe, searching for signs of new laws of physics and investigating what composes mysterious dark matter.

- "After a 60-day checkout and initial calibration period, we'll begin science operations," said Steve Ritz, GLAST project scientist at Goddard. "GLAST soon will be telling scientists about many new objects to study, and this information will be available on the internet for the world to see."

A need for PLC?

Higgs physics at PLC

- Precision measurements of the light Higgs boson production (->bb) and distinguishing SM-like scenarios
- Establishing CP property of Higgs bosons
- Higher mass reach and covering LHC wedge
- Testing Higgs selfinteraction

Search for SUSY particles

New physics in $\gamma\,\gamma \rightarrow \gamma\,\gamma$

Conference on photon linear colliders and physics of photon-photon collisions

PHOTON2009 at DESY

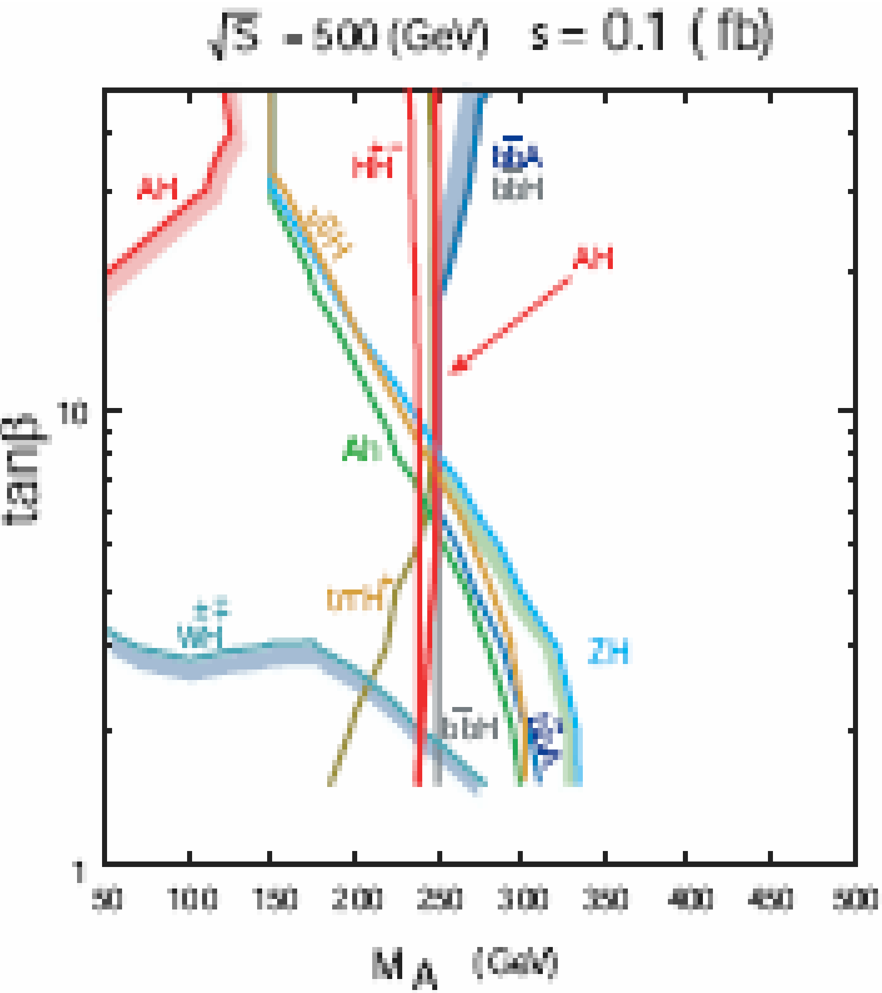
A need of a very low energy plc?

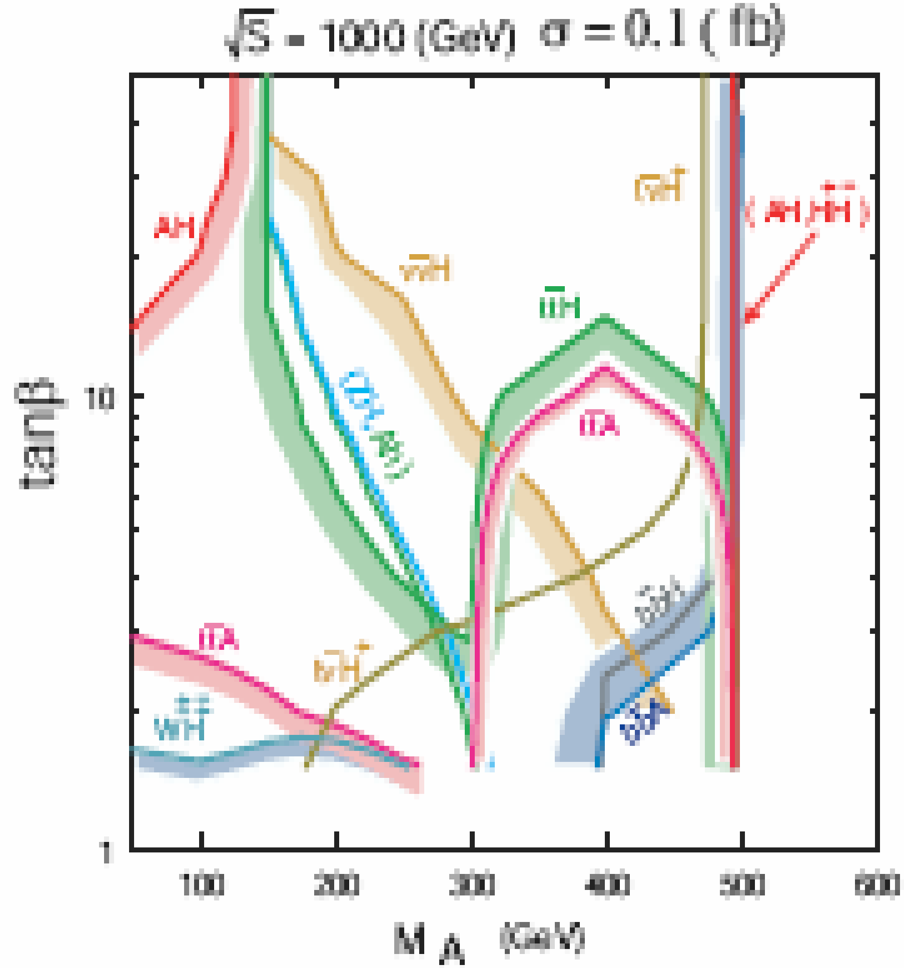
LEI2007
International Workshop on Physics and Technologies of Laser-Electron Interaction toward the ILC, Dec 12 – 14, 2007Hiroshima

PLC as an added value..

A. de Roeck

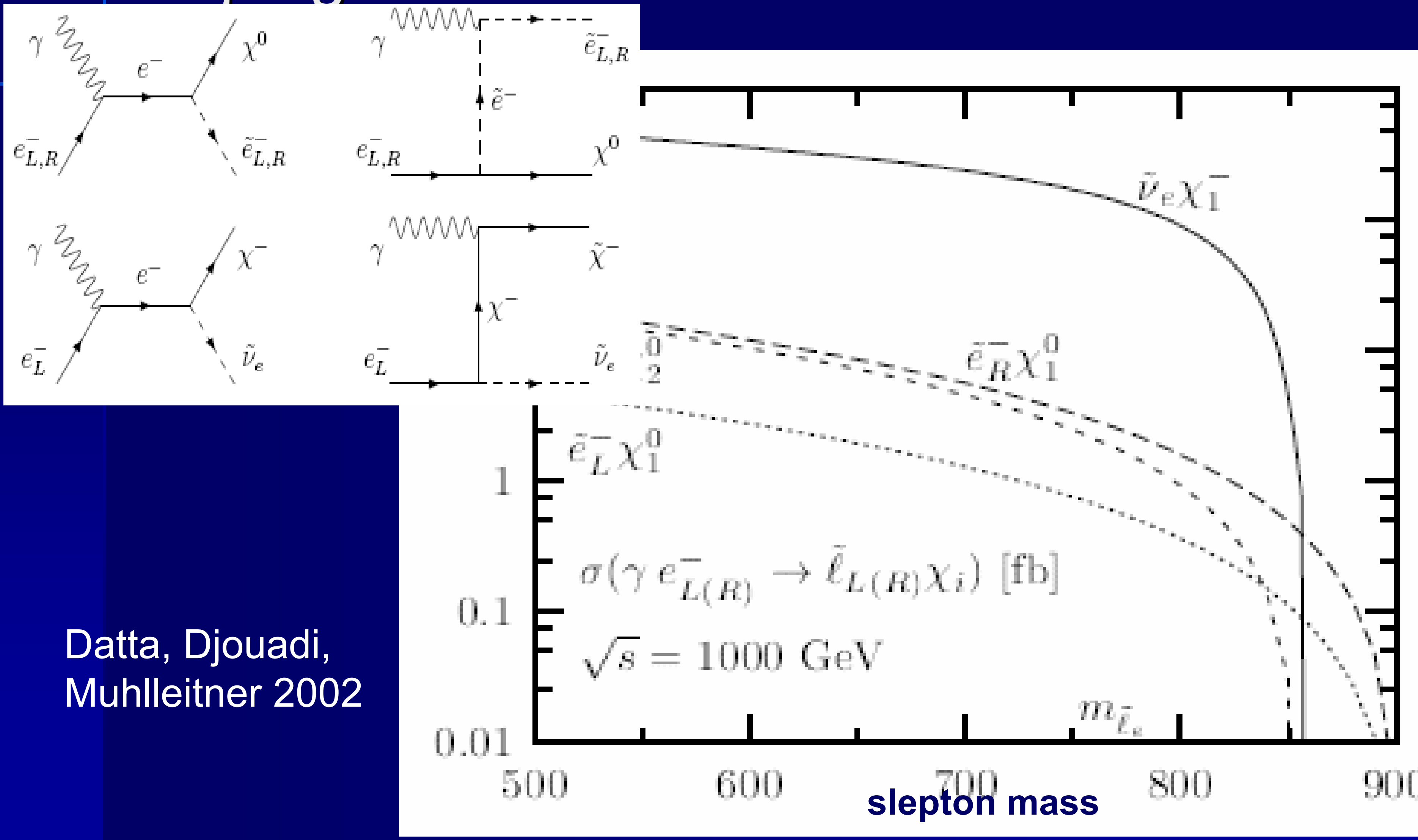
Golden processes	PLC2000 proc.
$\gamma\gamma \to H, h \to b\bar{b}$	SM/MSSM Higgs, $M_{H,h} < 160$ GeV
$\gamma\gamma \to H \to WW(^*)$	SM Higgs, 140$< M_H < 190$ GeV
$\gamma\gamma \to H \to ZZ(^*)$	SM Higgs, 180$< M_H < 350$ GeV
$\gamma\gamma \to H \to \gamma\gamma$	SM Higgs, 120$< M_H < 160$ GeV
$\gamma\gamma \to H \to t\bar{t}$	SM Higgs, $M_H > 350$ GeV
$\gamma\gamma \to H, A \to b\bar{b}$	MSSM heavy Higgs, interm. $\tan\beta$
$\gamma\gamma \to H^+H^-$	large cross sections
$\gamma\gamma \to \tilde{f}\bar{\tilde{f}},\ \tilde{\chi}_i^+\tilde{\chi}_i^-$	large cross sections
$\gamma\gamma \to \tilde{g}\bar{\tilde{g}}$	measurable cross sections
$\gamma\gamma \to S[\tilde{t}\bar{\tilde{t}}]$	$\tilde{t}\bar{\tilde{t}}$ stoponium
$\gamma e \to \tilde{e}^-\tilde{\chi}_1^0$	$M_{\tilde{e}^-} < 0.9 \times 2E_0 - M_{\tilde{\chi}_1^0}$
$\gamma\gamma \to \gamma\gamma$	non-commutative theories
$e\gamma \to eG$	extra dimensions
$\gamma\gamma \to \phi$	Radions
$e\gamma \to \tilde{e}\tilde{G}$	superlight gravitions
$\gamma\gamma \to W^+W^-$	anom. W inter., extra dimensions
$\gamma e \to W^-\nu_e$	anom.W couplings
$\gamma\gamma \to 4W/(Z)$	WW scatt., quartic anom. W,Z
$\gamma\gamma \to t\bar{t}$	anomalous top quark interactions
$\gamma e \to \bar{t}b\nu_e$	anomalous Wtb coupling
$\gamma\gamma \to$ hadrons	total $\gamma\gamma$ cross section
$\gamma e \to e^-X,\ \nu_e X$	NC and CC structure functions
$\gamma g \to q\bar{q},\ c\bar{c}$	gluon in the photon
$\gamma\gamma \to J/\psi\, J/\psi$	QCD Pomeron





Better at PLC ….

SUSY particle production
- in e γ higher mass reach



Datta, Djouadi, Muhlleitner 2002