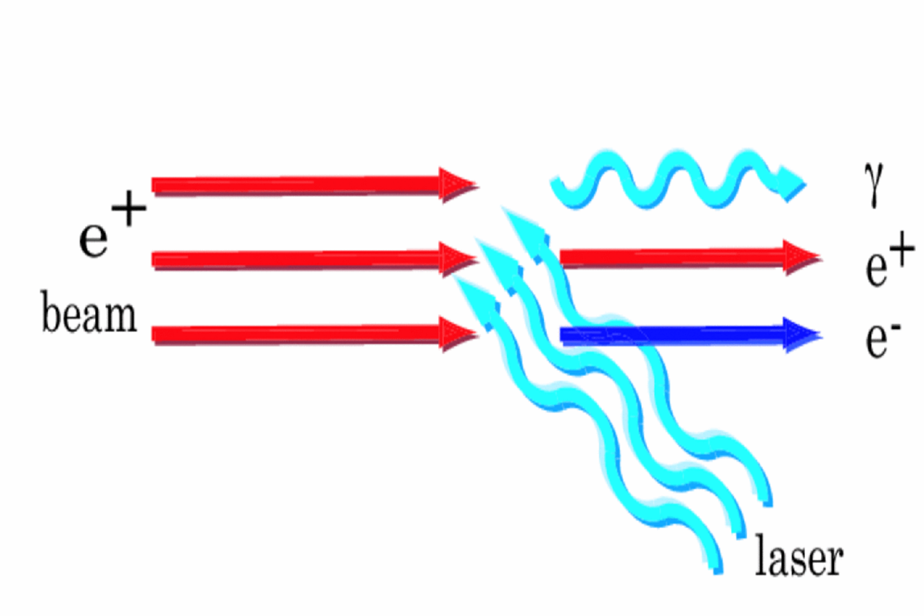
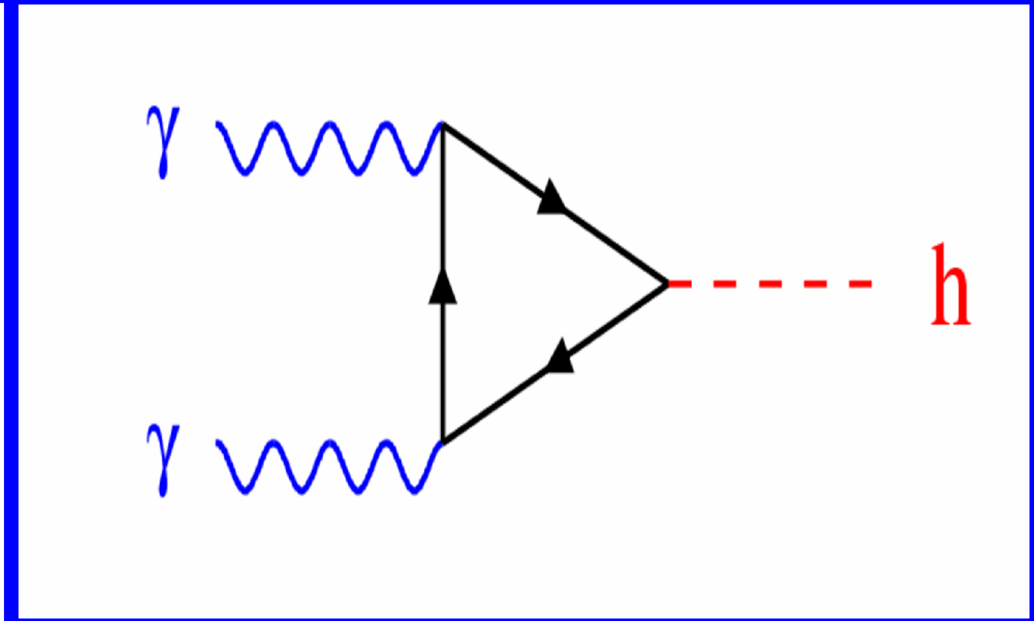
Gamma Gamma (gC) & e- Gamma Colliders





Mayda M. Velasco

Northwestern Univ.

April 23, 2004

Pleanary LCWS-2004 Paris

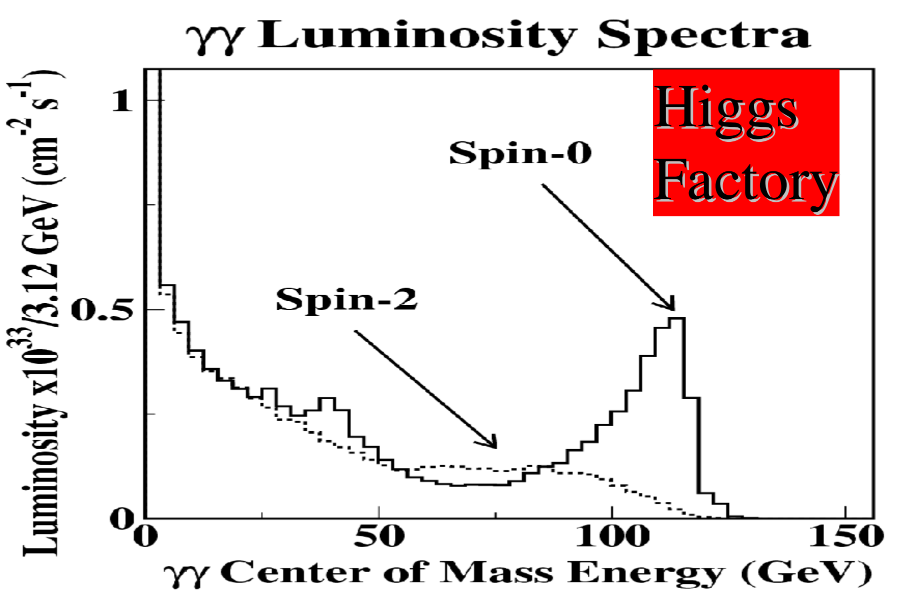
2002: @ Jeju it was discussed....

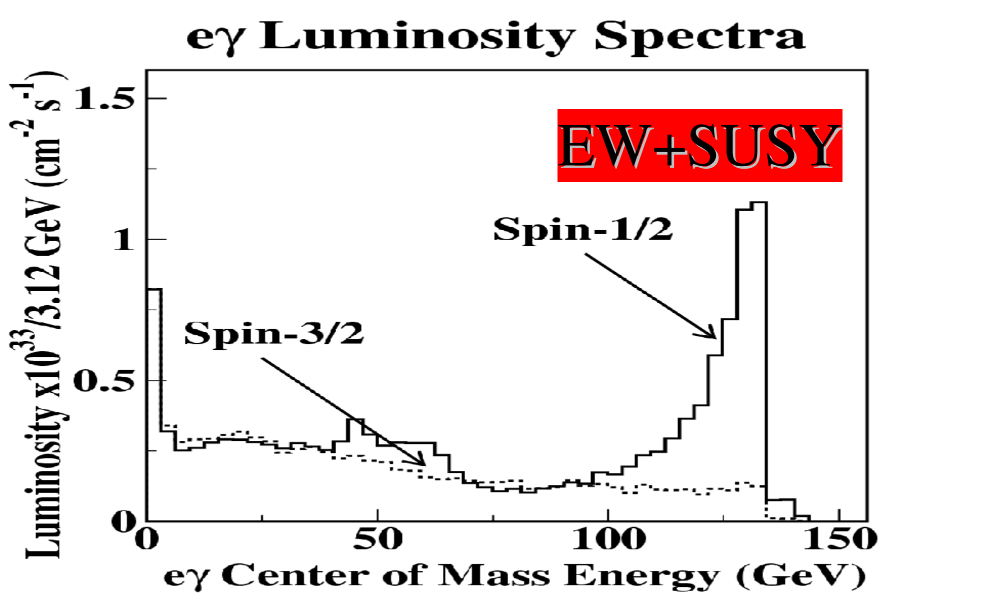
- **To make LC as versatile as possible:**
  a 2nd IR capable of working as γγ & eγ machine was desireable.

- **Concluded γγ:**
  - **Complemented in important ways the LC & the LHC program:** ***i.e.*** **precisions measurements of the light Higgs.**
  - **Provided unique opportunities:** ***i.e.*** **measurements of CP admixture (from polarization asymmetries).**
  - **Extended discovery reach:** ***i.e.*** **Heavy Higgs.**

High event rate expected at a low energy γC: Light SM Higgs

Machine	$E_{e^+e^-}$(GeV)	$M_{h_{SM}}$(GeV)	Yield/year	Ref.
* CLICHE	150	115	22.5k	hep-ex/0110056
CLICHE	160	120	23.6k	Correct for $\Gamma_{\gamma\gamma}$
# TESLA	160	120	21.0k	hep-ex/0101056
# NLC	160	120	11.0k	hep-ex/0110055



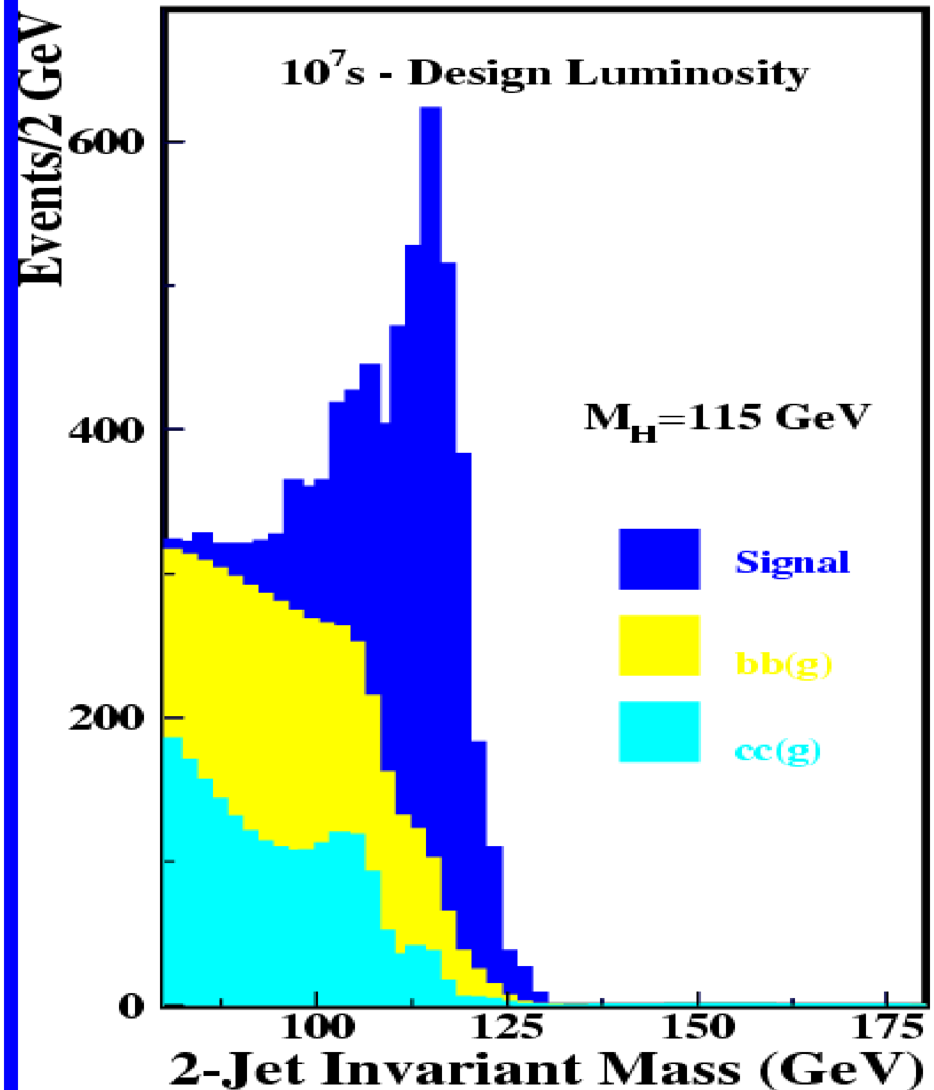


*** Is a 10% CLIC TEST MACHINE # DESIGNS @ SNOWMASS**

Example: gC for 115-120 GeV SM Higgs

@ gC in one year

Asner, Schmitt,Velasco



Measurement	Precision
$\Gamma_{\gamma\gamma} \times Br(h \to bb)$	2%
$\Gamma_{\gamma\gamma} \times Br(h \to WW)$	5% *
$\Gamma_{\gamma\gamma} \times Br(h \to \gamma\gamma)$	22% *

* Only hep-ex/0110056 available

- LC + gC gives a precise value for

$\Gamma_{\gamma\gamma}$ & Γ_{TOTAL}

- LHC + gC test anomalous couplings

Γ_{gg} / $\Gamma_{\gamma\gamma}$

- bb study in great detail by several groups, all results are in agreement

-----> ASIA, EUROPE & USA

Resolved background photons is not a big effect in h to bb!

<u>Good progress since Jeju....</u>

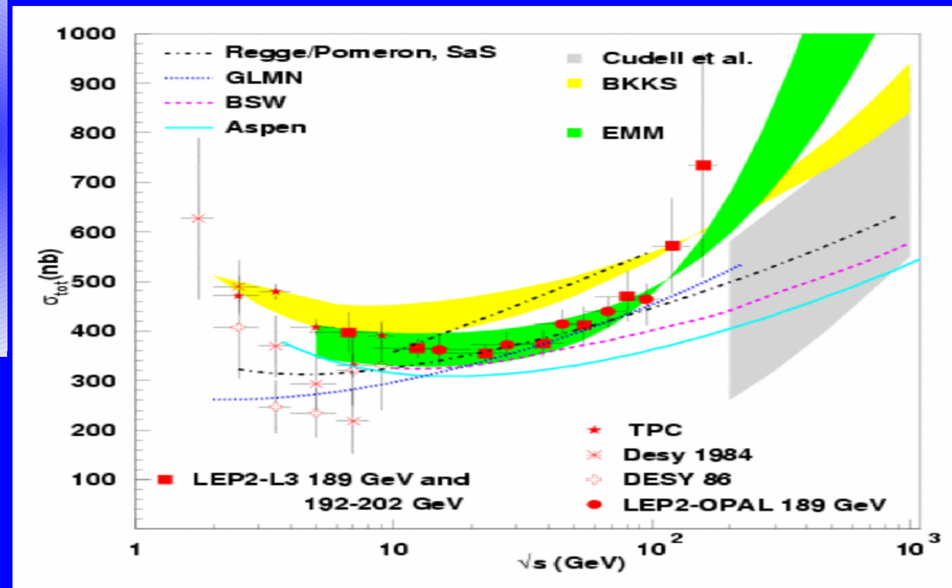
@ Praga all group converged on PYTHIA parameter for X-section

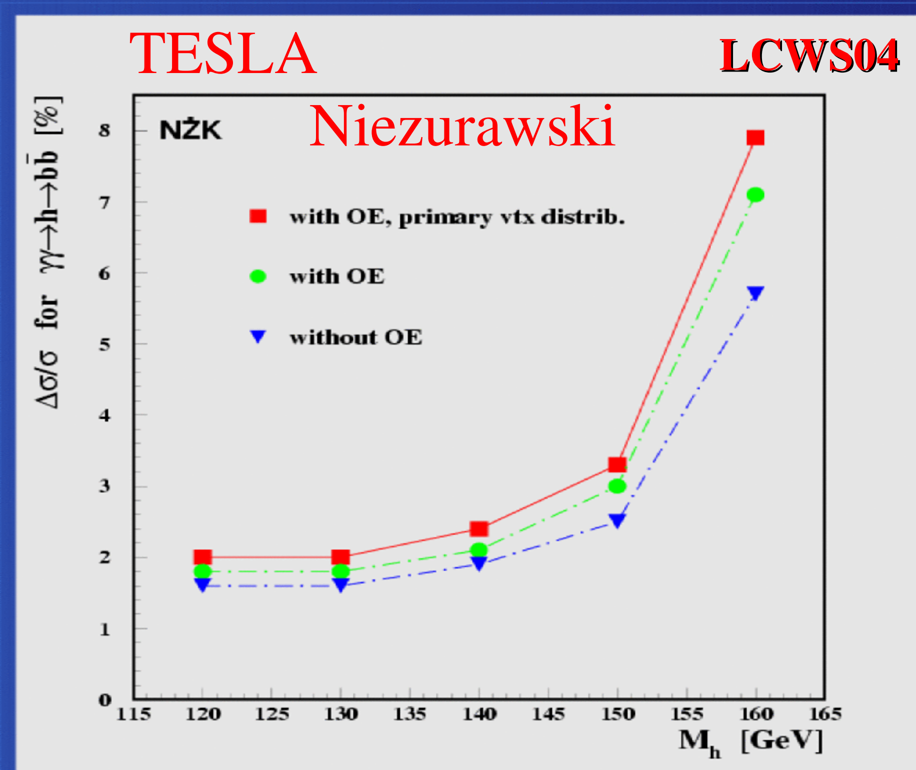
TABLE III: Event Multiplicity Due to Resolved Photon Backgrounds.

NLC: hep-0308103

	160 GeV	500 GeV
Events/Crossing	0.6	1.8
Tracks/Crossing ($p > 0.2$ GeV, $\|\cos\theta\| < 0.9$)	3.7	14.6
Energy/Track ($p > 0.2$ GeV, $\|\cos\theta\| < 0.9$)	0.70 GeV	0.74 GeV
Clusters/Crossing ($E > 0.1$ GeV, $\|\cos\theta\| < 0.9$)	5.5	21.8
Energy/Cluster ($E > 0.2$ GeV, $\|\cos\theta\| < 0.9$)	0.45 GeV	0.49 GeV

Godbole, De Roeck, Grau, Pancheri





Other analysis can be more sensitive... needs to be study before making detector recommendations,... if any

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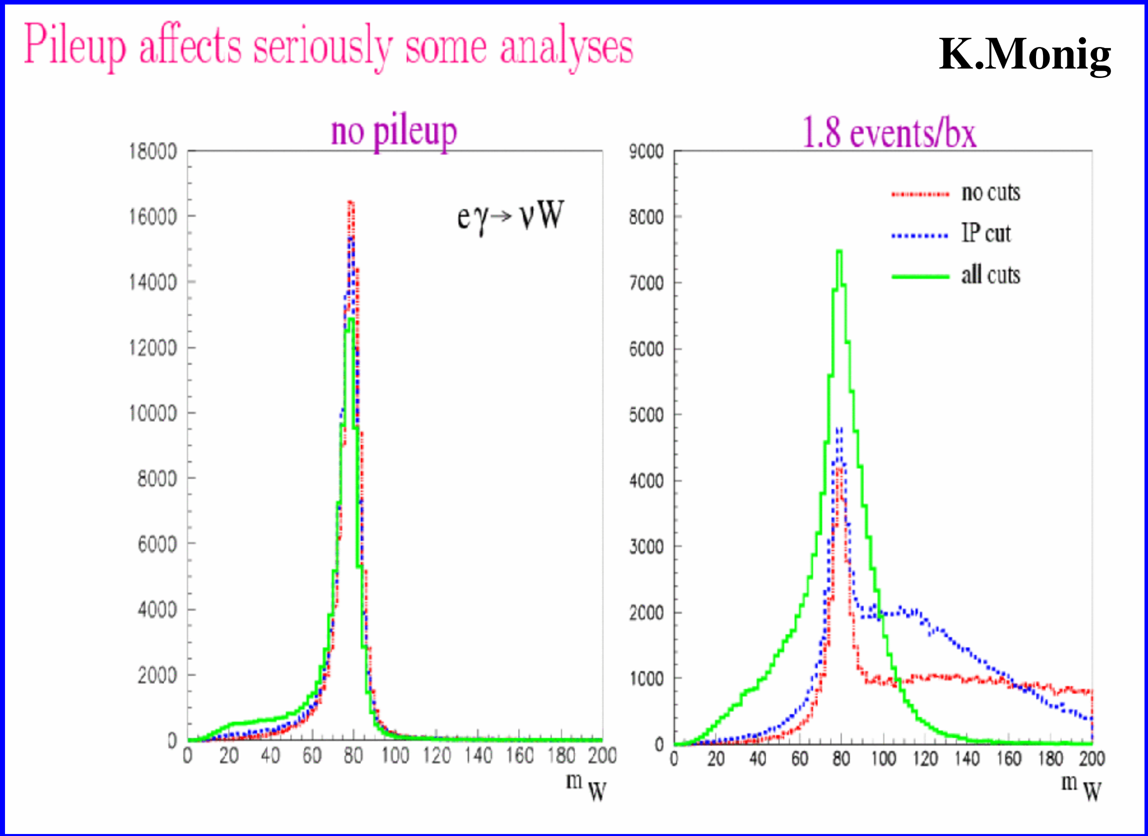
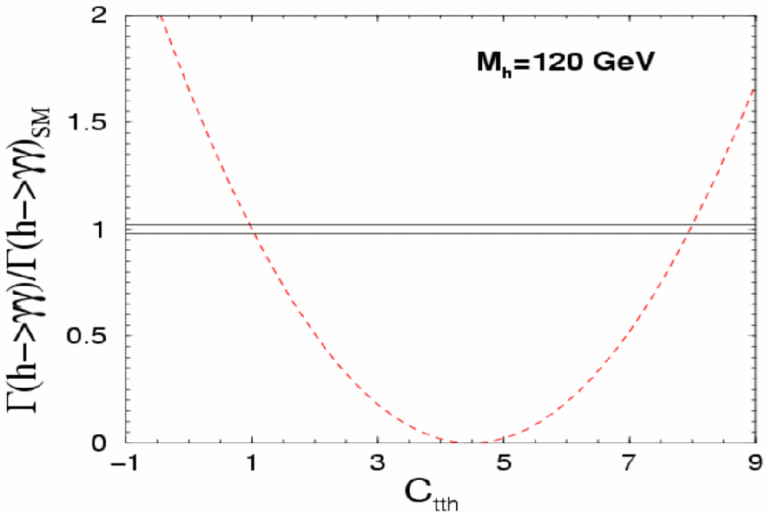


In the absence of a technology choice we need to do the studies on WARM and COLD in a consistent manner

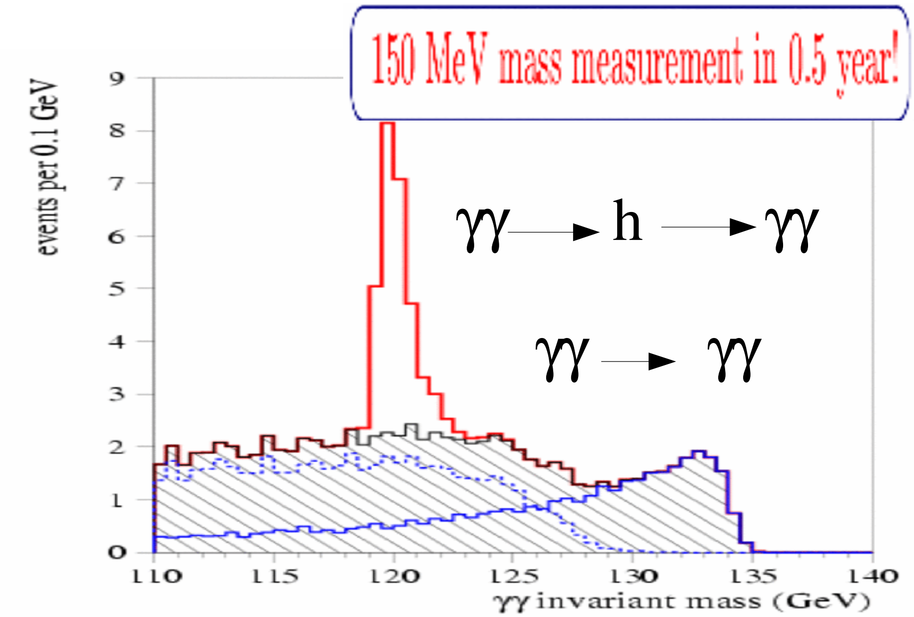
Measurement of $\Gamma_{\gamma\gamma}$ is best at gC & give us tt-Yukawa couplings & access to new physics $\Gamma_{\gamma\gamma}$ = 2% in 1 year

Higgs coupling to mass is an essential prediction in Higgs-theory. ⇒ We need to test it!!! Dawson, $\gamma\gamma$WS2001.



$\gamma\gamma \to h$ depends on the tth coupling, and a 2% measurement of this cross section results in a 4% constraint on Y_t.

Besides that ratio of Br for bb, WW & γγ. Low energy gG Higgs factory will provide important test of SM given with good or better precision than LHC and LC:



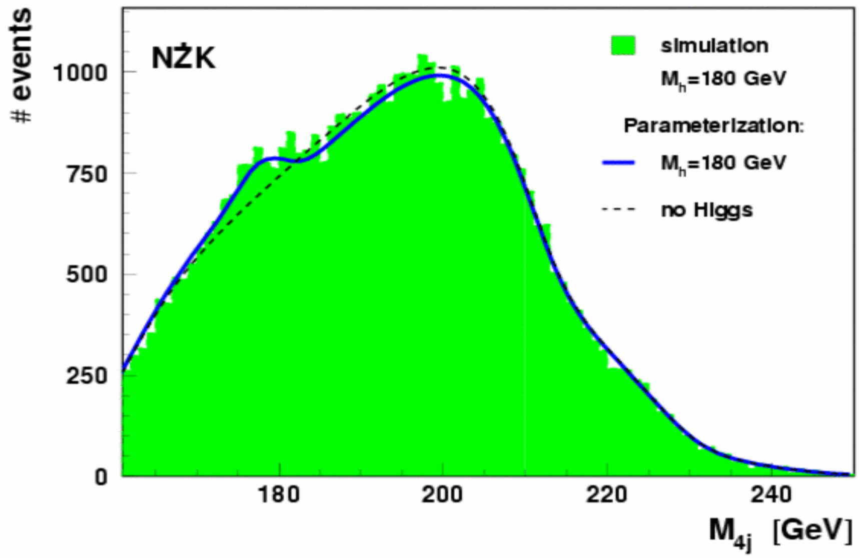
SM heavy Higgs (200-350 GeV) @ gC can measure partial width and phase

$\gamma\gamma \to \mathcal{H} \to WW,\ ZZ$

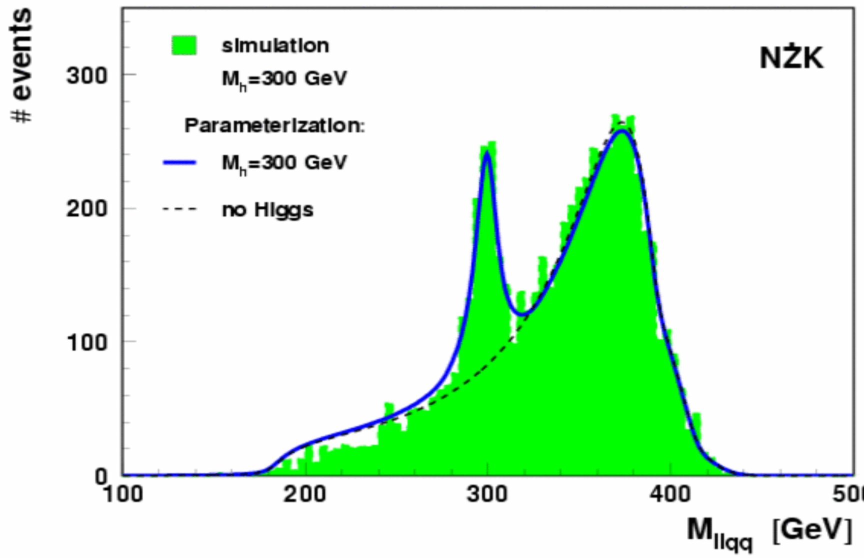
Niezurawski
Zarnecki
Krawczyk

From the simultaneous fit to the observed W^+W^- and ZZ mass spectra both the two-photon width $\Gamma_{\gamma\gamma}$ and phase $\phi_{\gamma\gamma}$ can be determined.

W^+W^-



ZZ



For SM: $\Gamma_{\gamma\gamma}$ with precision $\sim 4-9\%$, $\phi_{\gamma\gamma}$ with precision $40-120$ mrad

JHEP 0211 (2002) 034 [hep-ph/0207294]

A.F.Żarnecki, ECFA/DESY workshop, November 2002, Praha (including systematic uncertainties)

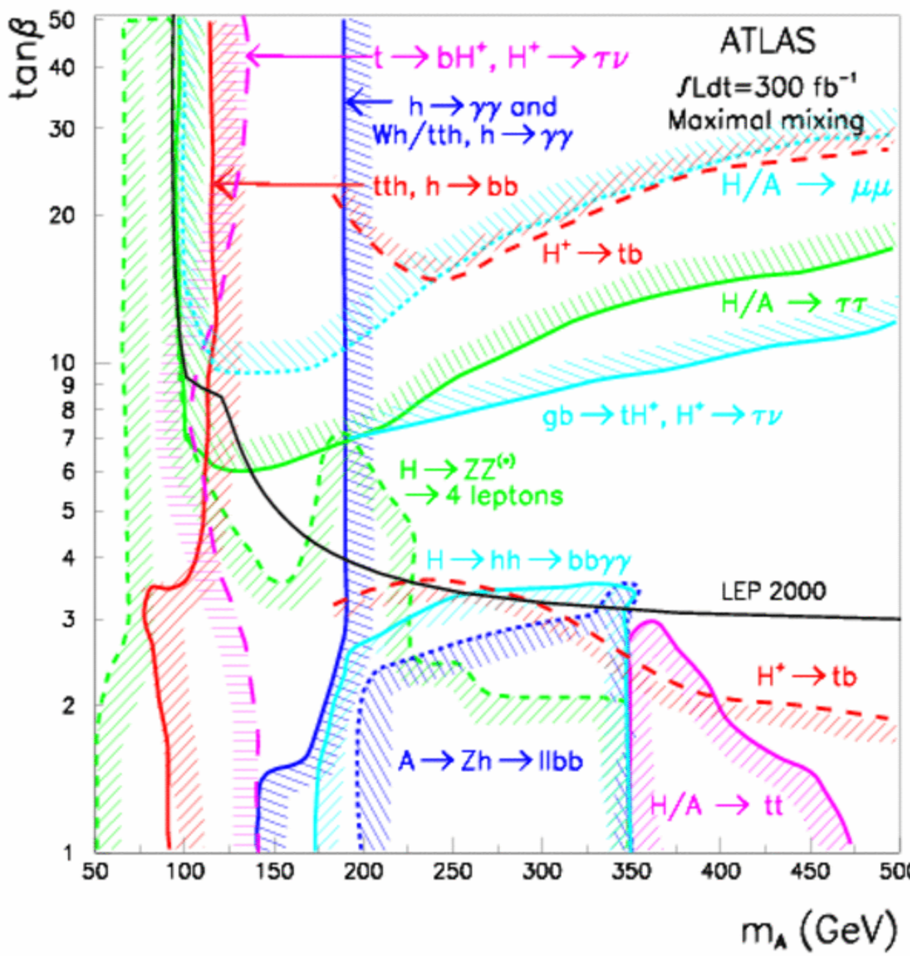
gC also important for Higgs Physics Beyond the SM

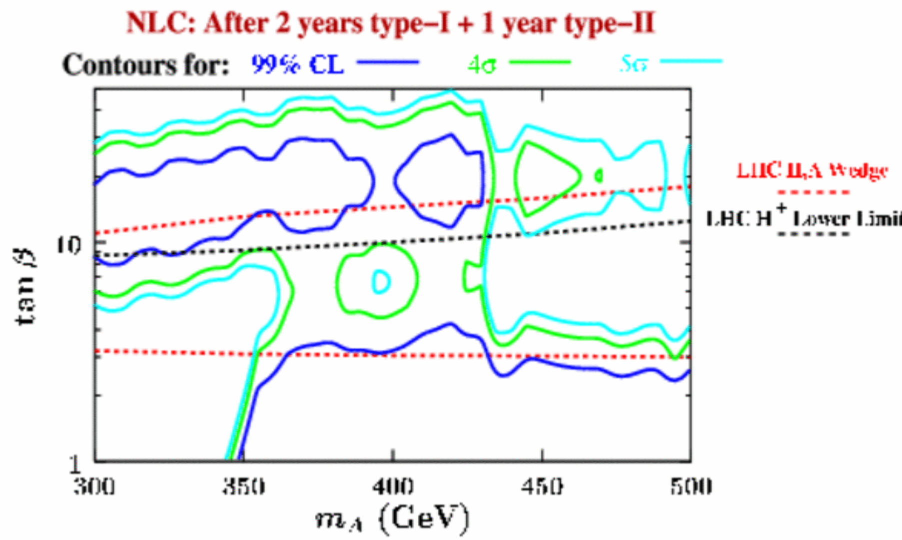
- SUSY (Now, h, H, A , H+, H-)
  - Real MSSM (Heinemeyer, Weiglein, et al, Logan, et al, etc)
  - Real NMSSM (Gunion, Szleper, h -> aa -> bbbb, bbττ,ττττ)
  - Etc...
- 2HDM (Ginzburg, Osland, Krawczyk, etc.)
- Littlest Higgs (Logan, etc.)
- Exotic Higgs-Radion mixing (Cheung, Gunion, Hewett, etc.)

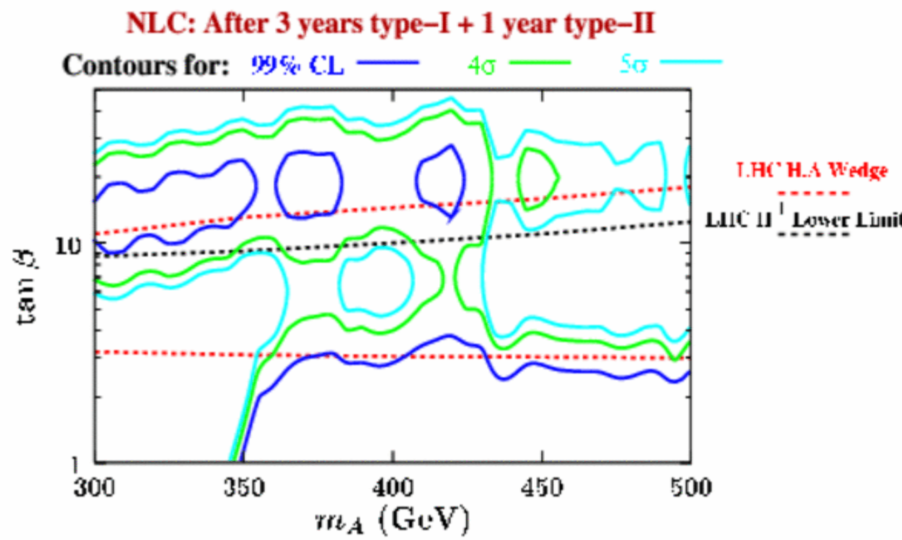
Most of the work is on: How gC complement the other Machines in the case of all the above? Exception --> Heavy Higgs, also seen as discovery machine.

@ Jeju: Neutral Heavy Higgs analysis in gC fills LHC wedge!

Asner, Gromberg, Gunion







Jeju: H+ @ gC Higher X-Sections & Model Independent!

V. Martin

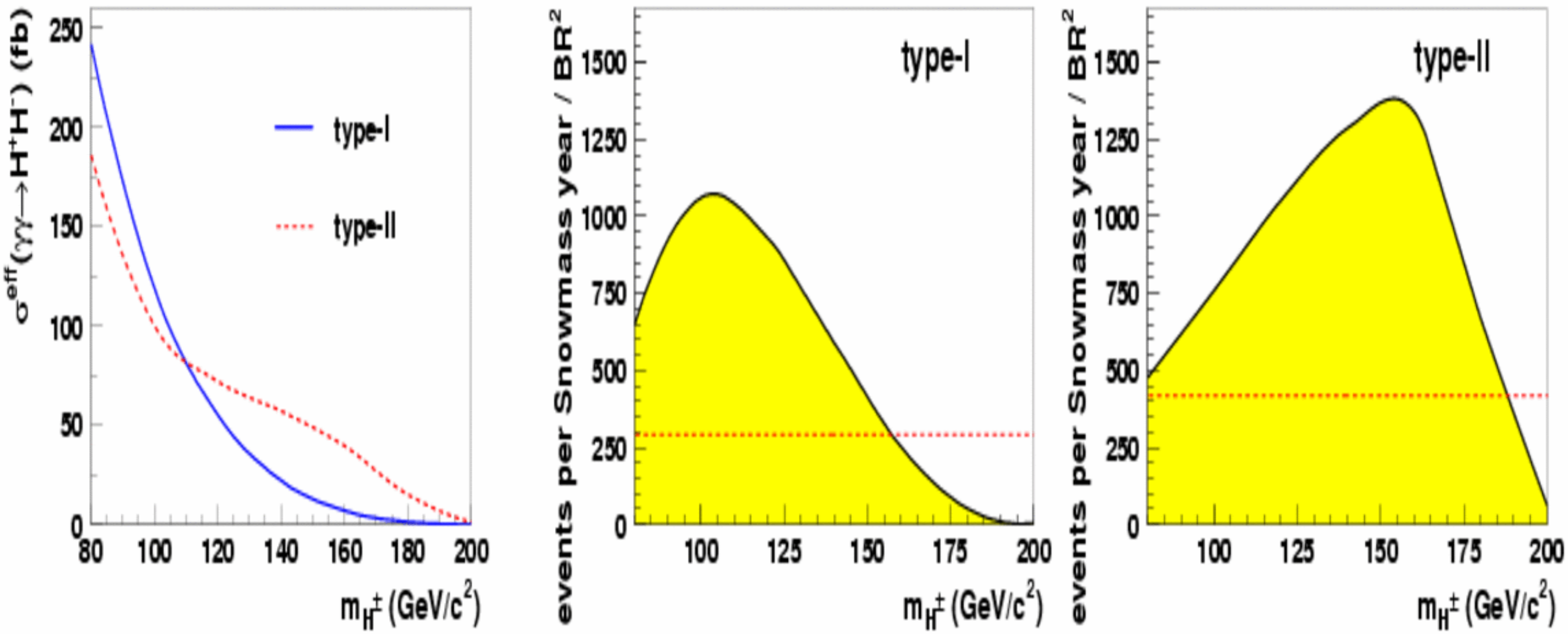


FIG. 12: On the left: The effective cross section for $\gamma\gamma \to H^+H^-$ for the two beam configurations. The center and right plots show the number of accepted events per BR$(H^+ \to \tau^+\nu_\tau)^2$ per Snowmass year, as a function of $m_{H\pm}$. The dashed horizontal line shows the number of accepted background $\gamma\gamma \to W^+W^-$ events.

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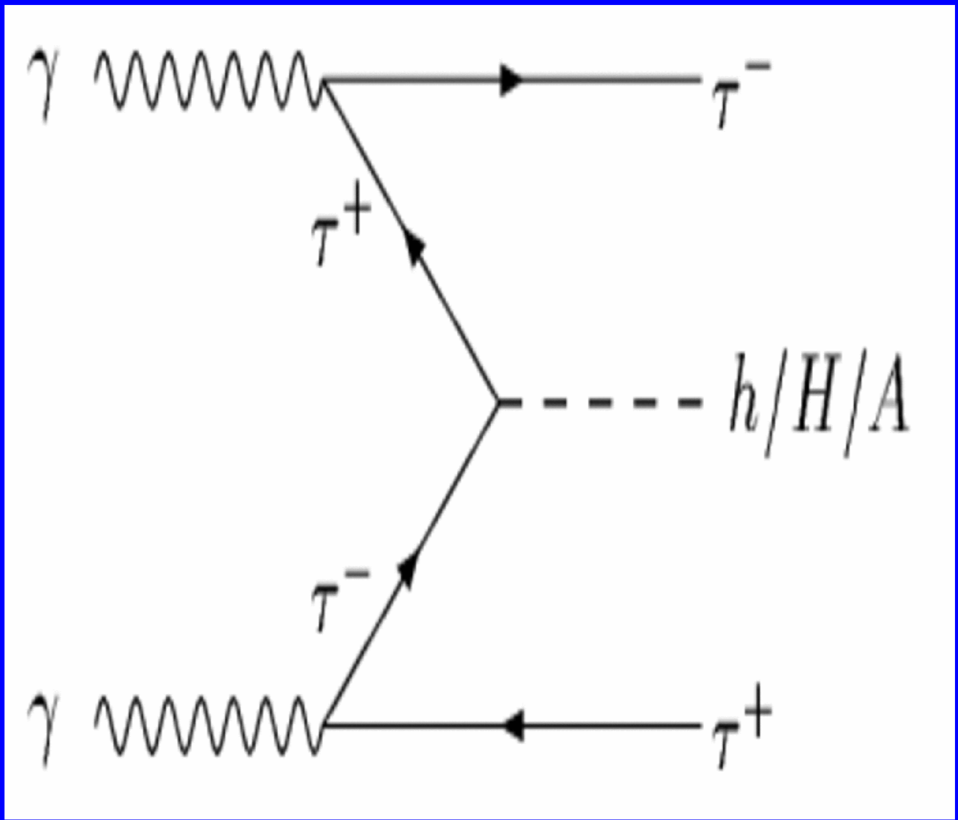
gC besides, $\Gamma_{\gamma\gamma}$ that could help to distinguish among SUSY model, complements LHC/LC measurements of Tan Beta

Choi, Kalinowski, Lee, Muhlleitner, Spira, Zerwas



$$g_{\Phi\tau\tau} = \tan\beta \quad \text{for } \Phi = A$$
$$g_{\Phi\tau\tau} \simeq \tan\beta \quad \text{for } \Phi = h, H$$

- Error on $\Delta(\tan\beta) \sim 1$ for $\tan\beta > 10$
- All tools available to make the experimental study (Szleper, $h_2 \rightarrow h_1 h_1$)

CP violation... Special role for gC

- **Model independent at gC vs Model dependent at LC**
- **Significant Progress in CP violation detection:**
  - **Light & Heavy**
- **With Linear and Circularly polarized beam**
  - **Linearly polarized beam designed made two times better with repect to what was shown at SNOWMASS by using 10 μm laser increasing beam energy by a factor of two (Higher degree of linear polarization and luminosity).**

Complex MSSM: we have MASS and CP Eigenstates

- **CP Eigenstates**
  - ✔ **h, H (CP-EVEN)** $VV\phi:\ c_V \frac{g m_V^2}{m_W} g_{\mu\nu}$
  - ✔ **A (CP-ODD)** $= 0$
- **Mass Eigenstates** $M_{h_1} < M_{h_2} < M_{h_3}$

$$\begin{pmatrix} h_1 \\ h_2 \\ h_3 \end{pmatrix} = \begin{pmatrix} u_{11} & u_{12} & u_{13} \\ u_{21} & u_{22} & u_{23} \\ u_{31} & u_{32} & u_{33} \end{pmatrix} \begin{pmatrix} h \\ H \\ A \end{pmatrix} \equiv U \begin{pmatrix} h \\ H \\ A \end{pmatrix}$$

LC & LHC can study the CP quantum #'s from angular correlations...But only gC could see CP admixture in a model independent way

- **Linear polarization** $\alpha\ \zeta_1, \zeta_3$
- **Circular polarization** $\alpha\ \zeta_2$

$\mathcal{A}_3 > (<)\ 0$ for CP EVEN(ODD)

$$dN = dL_{\gamma\gamma} d\Gamma \frac{1}{4}\left(|M_{++}|^2 + |M_{--}|^2\right)\Big\{\left(1 + \langle\zeta_2\tilde{\zeta}_2\rangle\right) + \left(\langle\zeta_2\rangle + \langle\tilde{\zeta}_2\rangle\right)\mathcal{A}_1 + \left(\langle\zeta_3\tilde{\zeta}_1\rangle + \langle\zeta_1\tilde{\zeta}_3\rangle\right)\mathcal{A}_2 + \left(\langle\zeta_3\tilde{\zeta}_3\rangle - \langle\zeta_1\tilde{\zeta}_1\rangle\right)\mathcal{A}_3\Big\},$$

Grzadkowski & Gunion (1992)

$\mathcal{A}_1 = \mathcal{A}_2 = 0$ if there is no CP admixture

In Models where LC cannot see $h_2 \dashrightarrow h_1\, h_1'$

gC will do the job...

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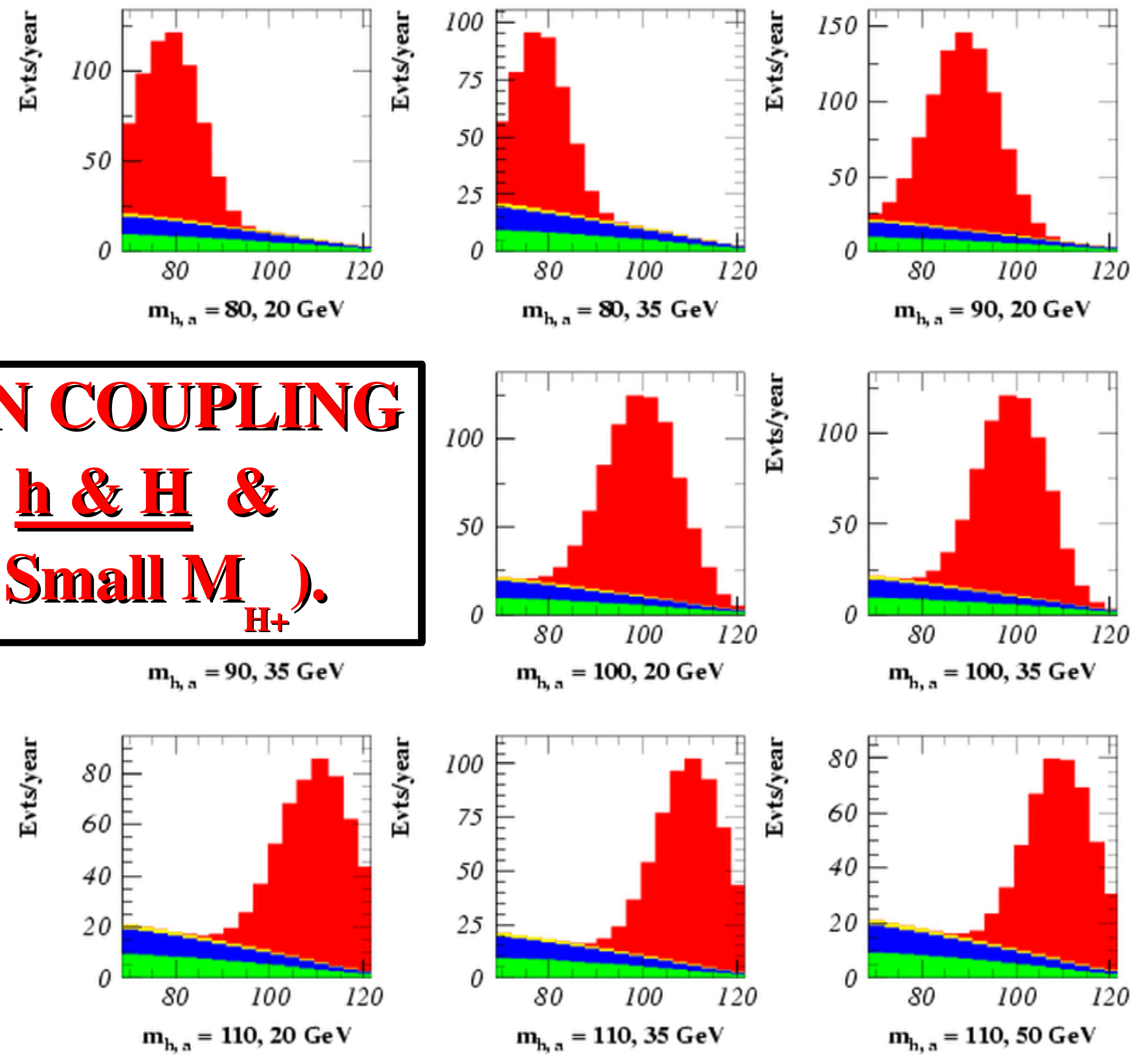
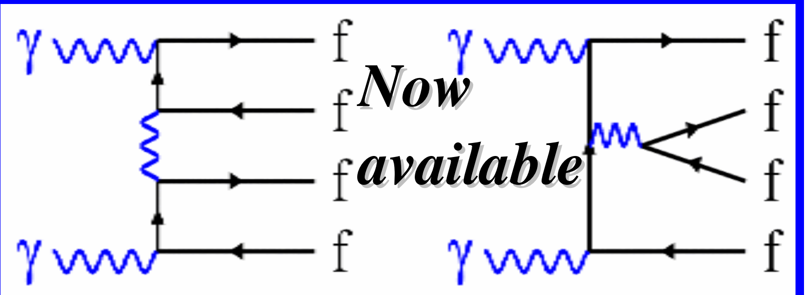
Gunion, Szleper

LHC: Could see some of them, but will not be able to measure their masses

==> bbbb,ττbb,ττττ all available... clear signal

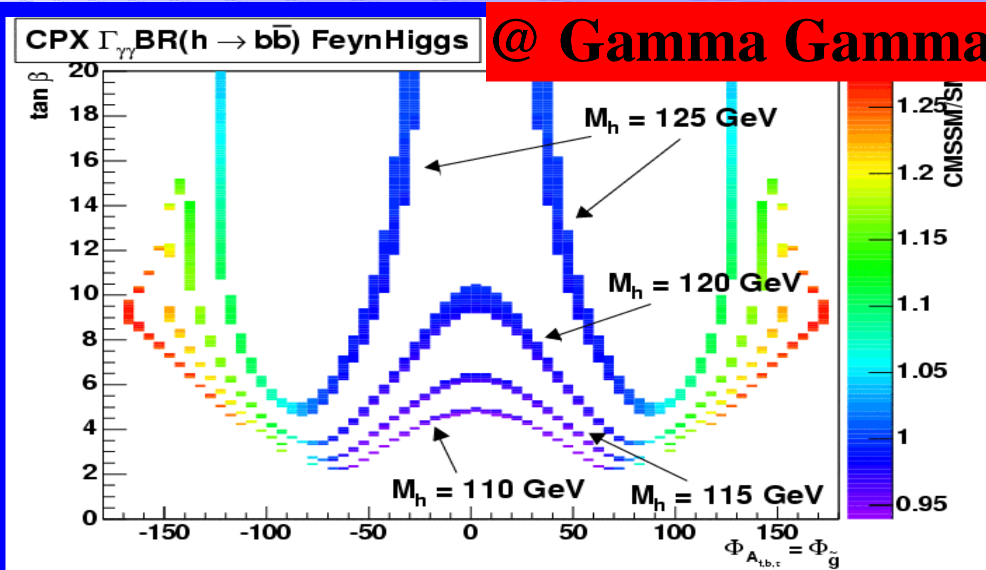


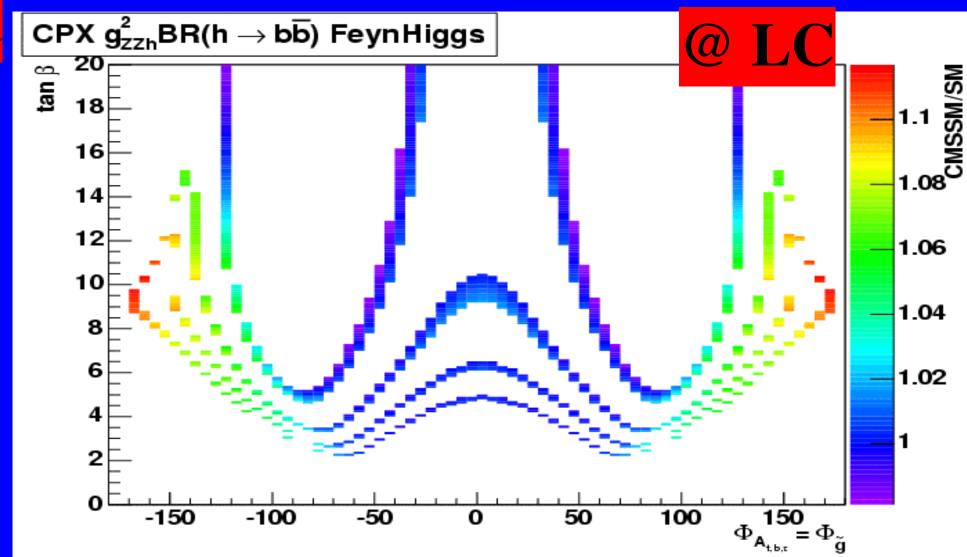
==> WORRIES FOR WHEN COUPLING TO THE Z GETS LOST BY <u>h & H</u> & <u>h1,h2,h3</u> CLOSE IN MASS (Small M_{H+}).

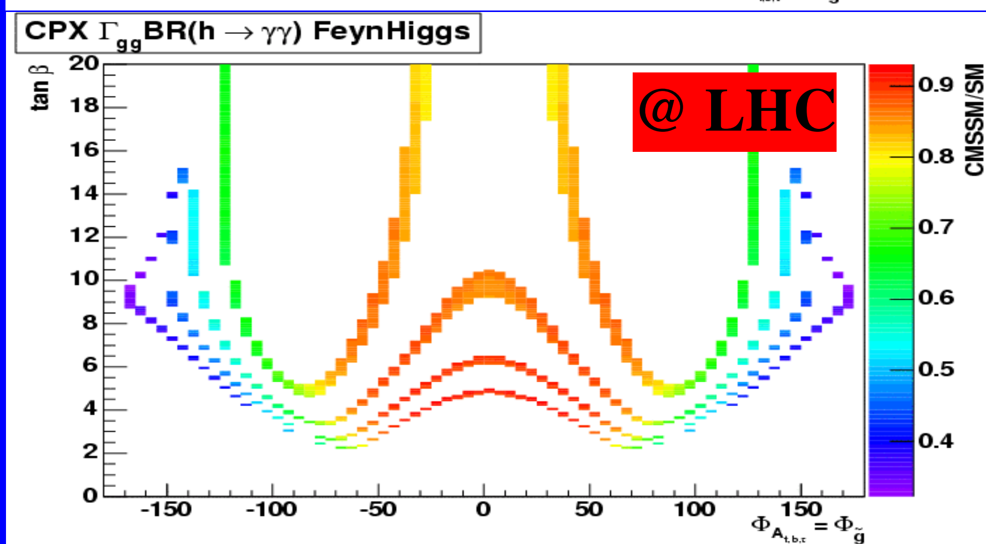


Now available

CP violation bigger @ gC than @ LC in bb decay & filling regions difficult @ LHC







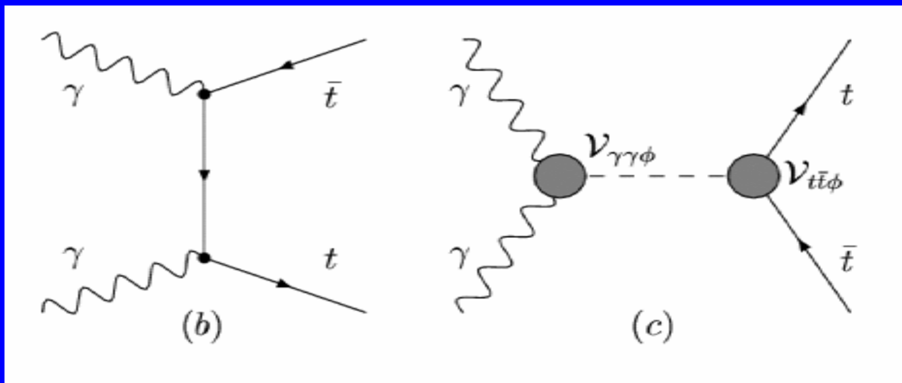
MSSM

- LHC Suppresion ↓
- LC Small Effect ↔
- gC Enhacement ↑

LCWS04

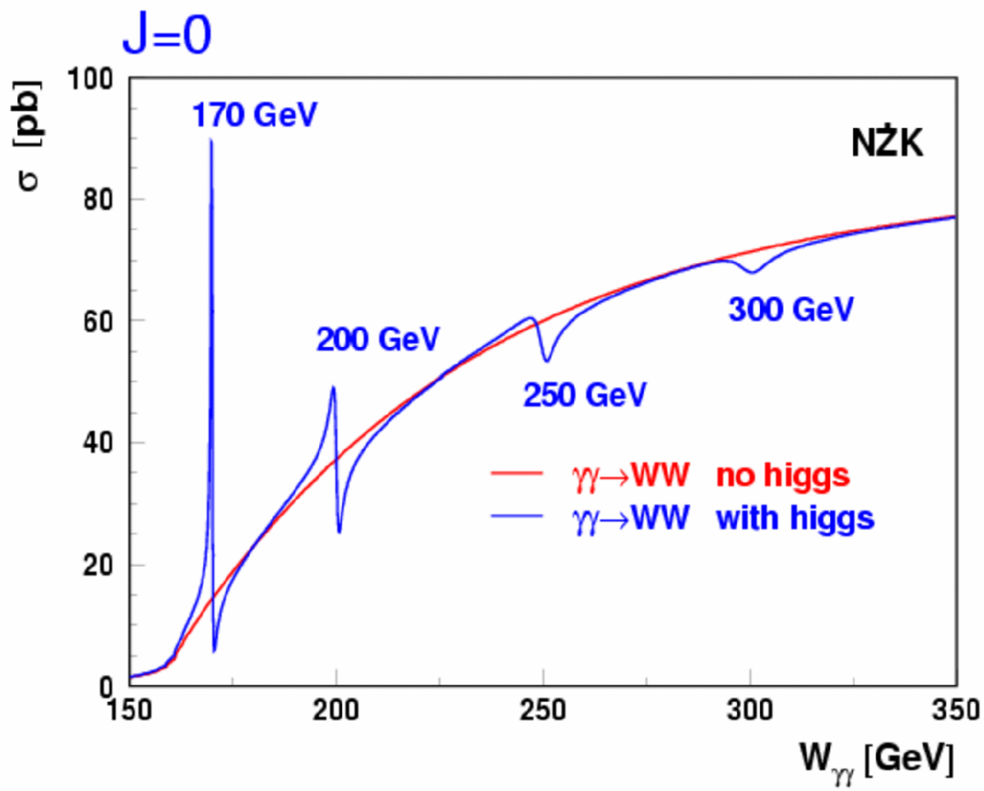
Heinemeyer Velasco Wood

Only in gC can we exploit interference effects to extract phases needed to study CP violations in an effective way



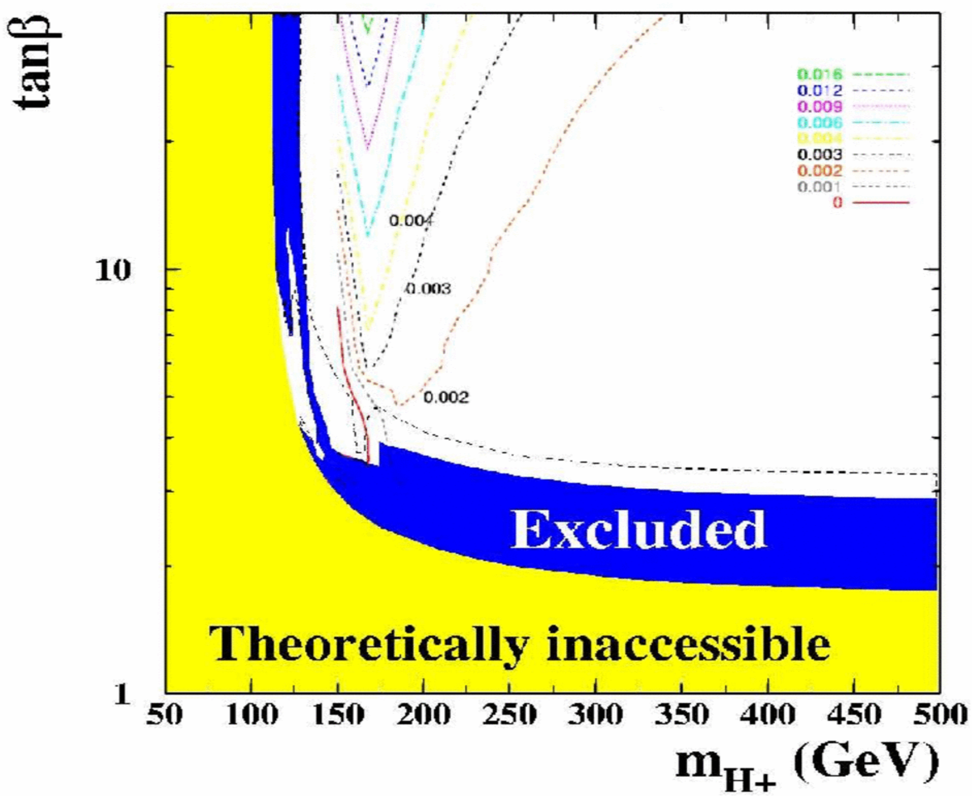
- **Exploit interference:**
  - **W+W-, Warsaw & Krawczyk**
  - **Top pairs, Asakawa et al, Godbole et al, Lee et al**

Large interference effects are expected in the considered mass range



New idea: *CP violation for* *Light Higgs* *in the MSSM using interference & tau polarization* (no need for mass peak)

Scan over MSSM parameters



Predicted change in the tau polarization measureable in regions of parameter space not excluded by LEP

Godbole & Krans

Experimental error 1 oder of magnitude smaller than the expected effect

Exotic... Tecni-pion best at gC

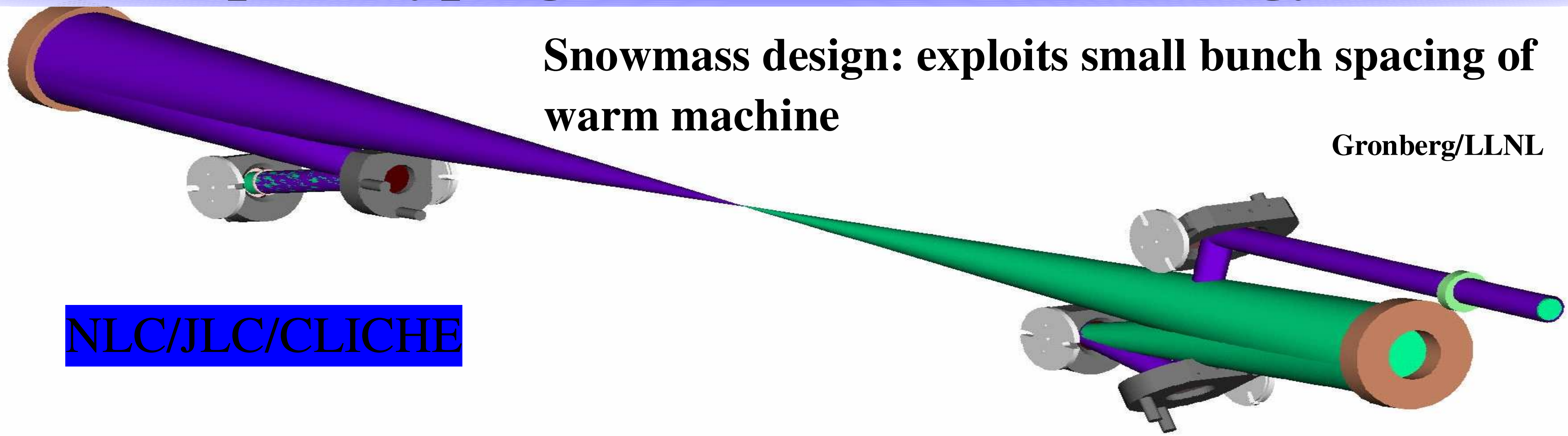
Cheung, Hioki, Hewett, Rizzo, Gunion, Pietrello, etc...

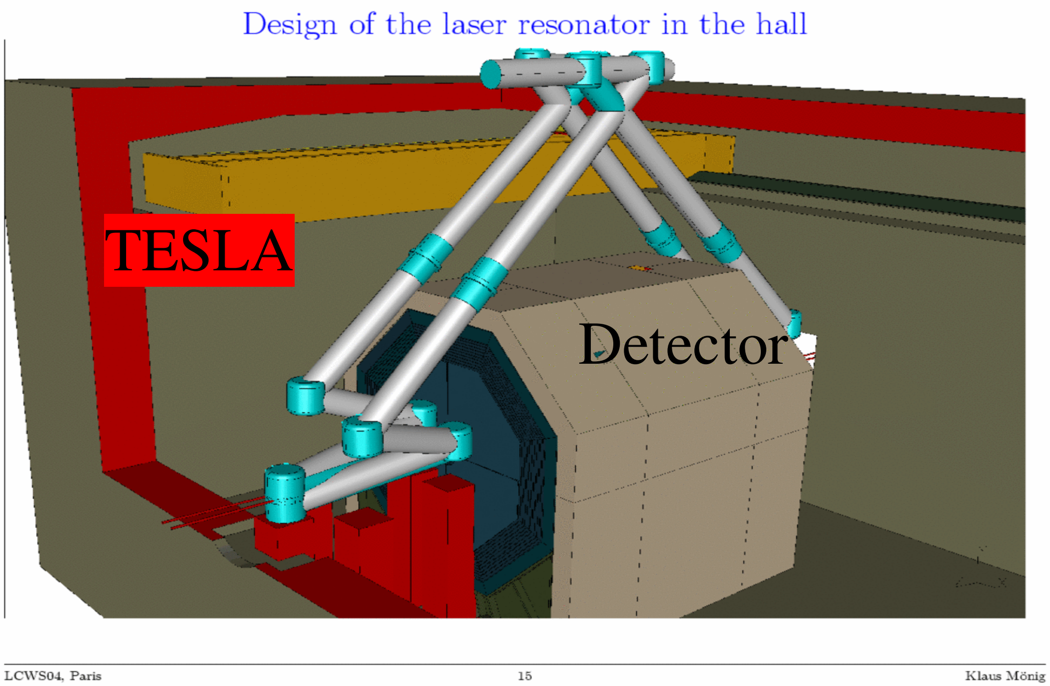
- Light-by-light scattering and $\gamma\gamma \to ZZ$ proceed via box diagrams in the SM.
- Large extra dimenions: continuous spectrum of graviton exchanges.
- Randall Sundrum model, discrete unevenly spaced graviton resonances.
- RS radion has an anomalous coupling to photons, giving rise to large production. **Combine with LHC --> gluon anomaluos coupling**
- $\gamma\gamma \to G_{\mu\nu}^{(n)} \to h\phi$ can test for the Higgs-radion mixing.
- Universal extra dimenion model: KK states of quarks and leptons give rise to multijet or multi-lepton plus missing energies.
- Technicolor models: anomaly-type coupling of techni-pion to photons.

All technologies have advanced designs
Serious prototyping will start after technology decision

Snowmass design: exploits small bunch spacing of warm machine

Gronberg/LLNL





- ATF in Japan planning to do a $\gamma\gamma$ interaction region as part of their machine R&D Takahashi

TESLA: Exploit long bunch spacing to save laser power

Conclusion I

- **Physics motivations continues to get stronger:**
  - **OLD: Precision measurements of the Higgs ... $\Gamma_{\gamma\gamma}$**
  - **OLD: Extend physics reach of heavy Higgs searches**
  - **NEW: Sensitivity to CP violation in Higgs by exploiting interference effects in both light & heavy Higgses**
  - **NEW: Measurement of SUSY parameters like tan β**
  - **NEW: Unique opportunities in NEW-PHENOMENA**
    - **Techni-pion**
    - **Anomalous coupling of the radions**
    - **Light-on-Light Scattering...**

Conclusion II

- Once technology decision is made:
  - Prototyping of gg technology will begin
  - Detector issues will be made in details
- Strong reason to believe that gC will be an important program in the future, either as:
  - An option of one of the 2 IR,
  - Or, as a 10% test of CLIC technology, while providing physics information that will complement the LHC & e+e- program.