Summary of the $\gamma\gamma$ ECFA parallel session

Christophe Royon
IRFU-SPP, CEA Saclay

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On behalf of the $\gamma\gamma$ session conveners, Maria Krawczyk, Stephen Maxfield, Margarete Mühlleitner, Christophe Royon

$\gamma\gamma$ physics

Contents:

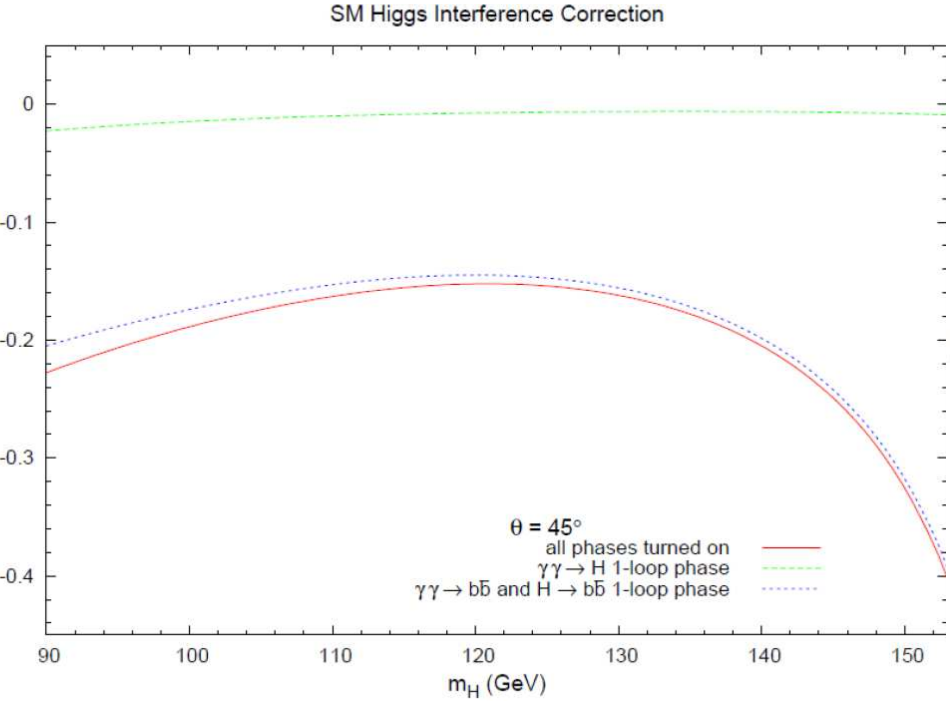
- Triple gauge and quartic anomalous coupling studies - Oldrich Kepka
- $\gamma\gamma \rightarrow$ hadrons for CLIC - Rohini M. Godbole
- Resonance-continuum interference effects for light Higgs Boson production at a photon collider, ie in $\gamma\gamma \rightarrow H \rightarrow b\bar{b}$ - Lance Dixon
- Feasibility study of Higgs pair production in a photon collider - Tohru Takahashi
- A sneak preview of the CLIC/PLC string hunter's companion - Tomasz Taylor
- Stop mass determination at ILC - Anna Skachkova (in Higgs/SUSY session)
- DIRAC gauginos and their scalar partners - Jan Kalinowski (in Higgs/SUSY session)

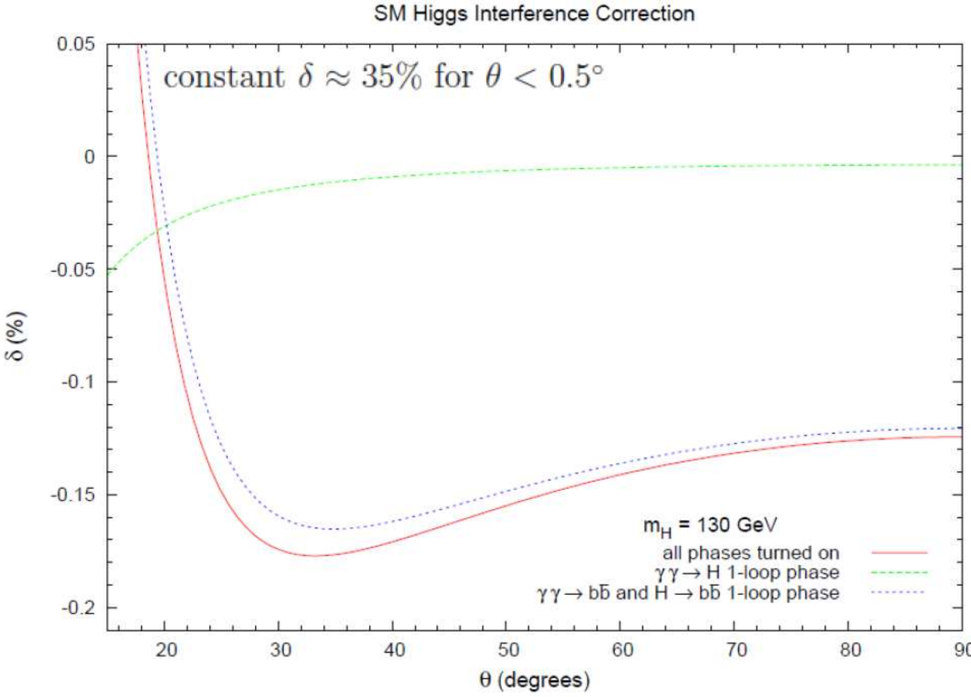
- One of the principal motivations for building a $\gamma\gamma$ collider is to produce a light Higgs boson via $\gamma\gamma \to$ H, and then detect its dominant decay to b quark pairs.
- In order to extract Higgs couplings, would like to interpret the size of the bump as

$$\Gamma(H \to \gamma\gamma) \times \mathrm{Br}(H \to b\bar{b}) = \frac{\Gamma_\gamma \Gamma_b}{\Gamma_{\mathrm{tot}}}$$

- But this is not necessarily true if the signal interferes appreciably with the continuum background, in this case $\gamma\gamma \to b\bar{b}$

Resonance-Continuum interference in $\gamma\gamma \to H \to b\bar{b}$





- In SM, interference term negligible (less than 0.2% for a scattering angle of 45 degrees) except at very small scattering angle which cannot be measured experimentally
- Situation might be worse in beyond SM, needs to be studied in more details as a function of the model parameters (the b quark Yukawa coupling can be greatly enhanced)

Higgs pair production in a $\gamma\gamma$ collider - Tohru Takahashi

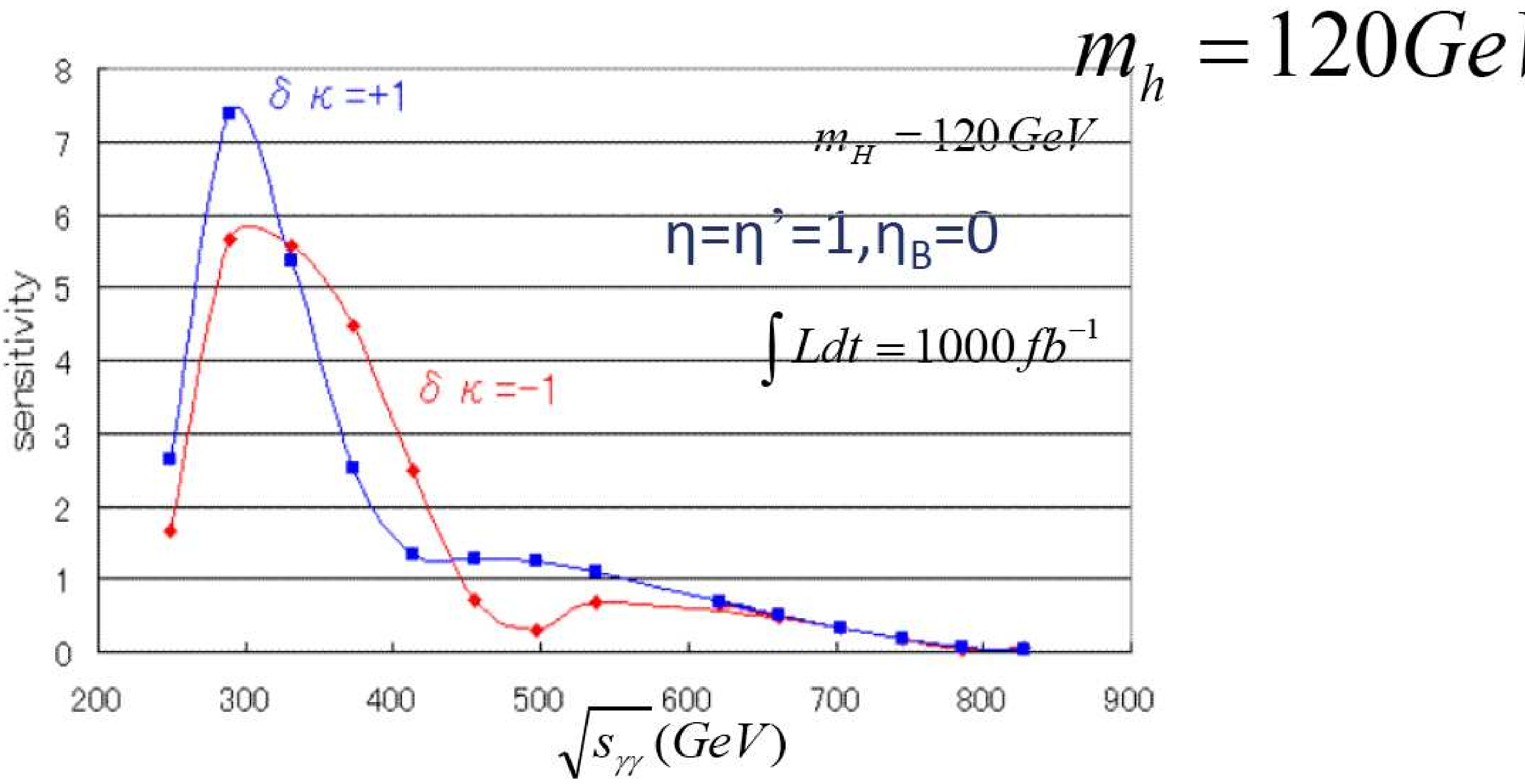
- Purpose of this study: Study of Higgs self-coupling

$$\lambda = \lambda^{SM}(1 + \delta\kappa)$$

Self-coupling constant in the SM

Parameter of deviation from the SM

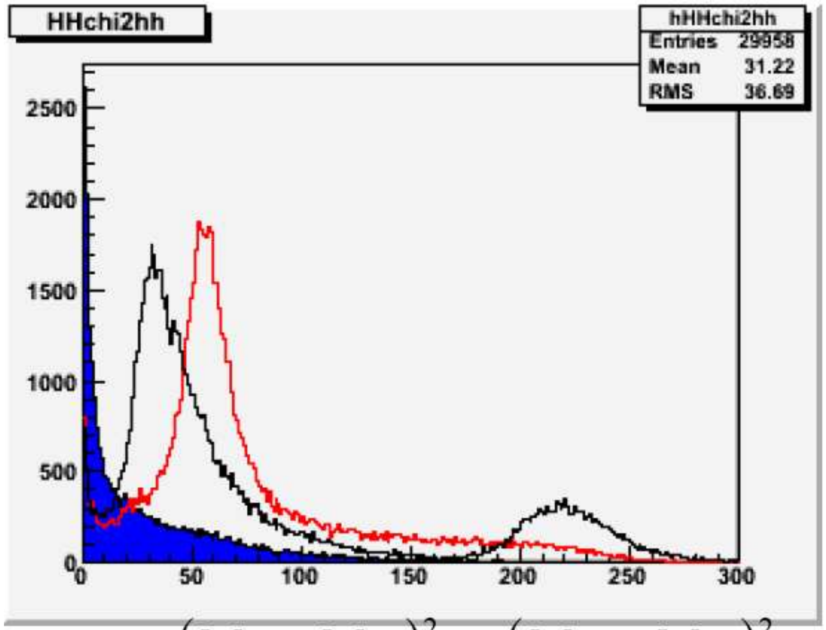
- Large enhancement of cross section with respect to $\delta\kappa$



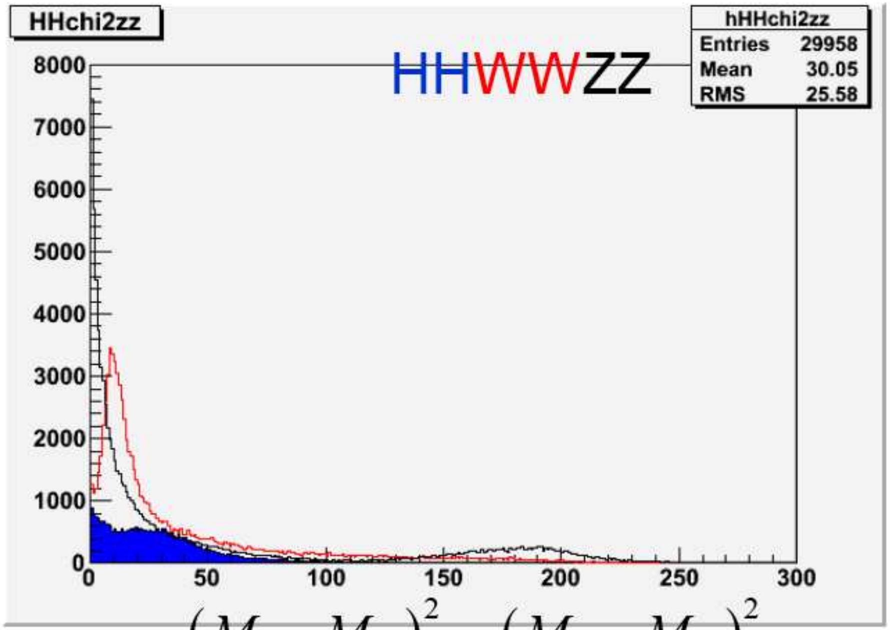
Optimal energy: 300 GeV

Feasibility study of Higgs pair production in a $\gamma\gamma$ collider

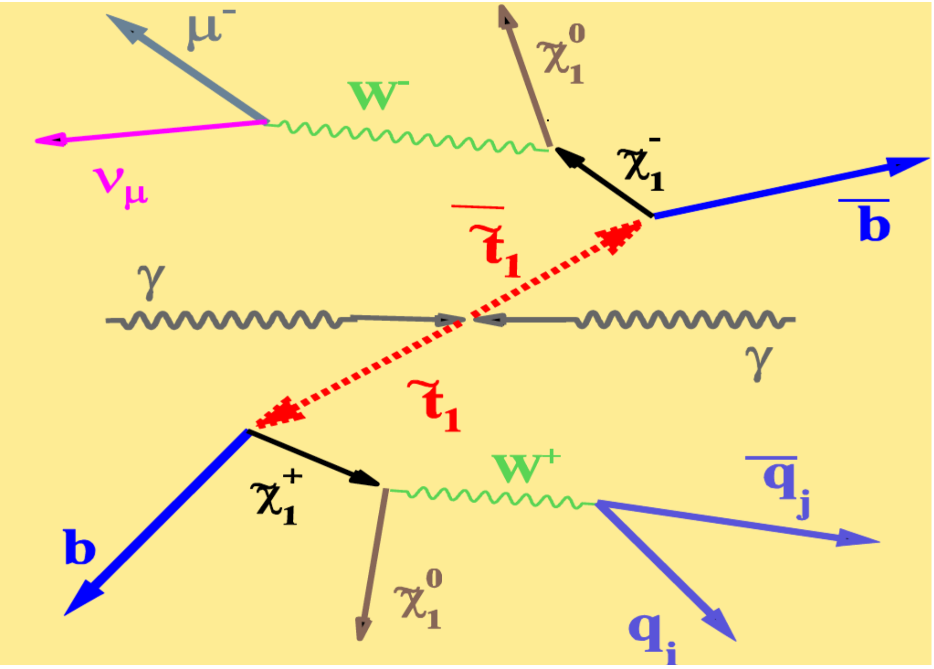
- Before cuts: 16.4 $\gamma\gamma \rightarrow H \rightarrow 4b$, 1.5 10^7 $\gamma \rightarrow WW \rightarrow 4q$, 1.2 10^4 $\gamma \rightarrow WW \rightarrow 4b$ per year for ILC standard parameters
- Neural net analysis based on χ^2 to reconstruct the Higgs or Z mass, transverse momentum, number of b-flavour jets... in progress: suppression of almost WW background, ZZ background still an issue (improved jet clustering improves the results)
- To be pursued with better jet clustering improvement, study $\gamma\gamma \rightarrow 4b$ background, different Higgs masses



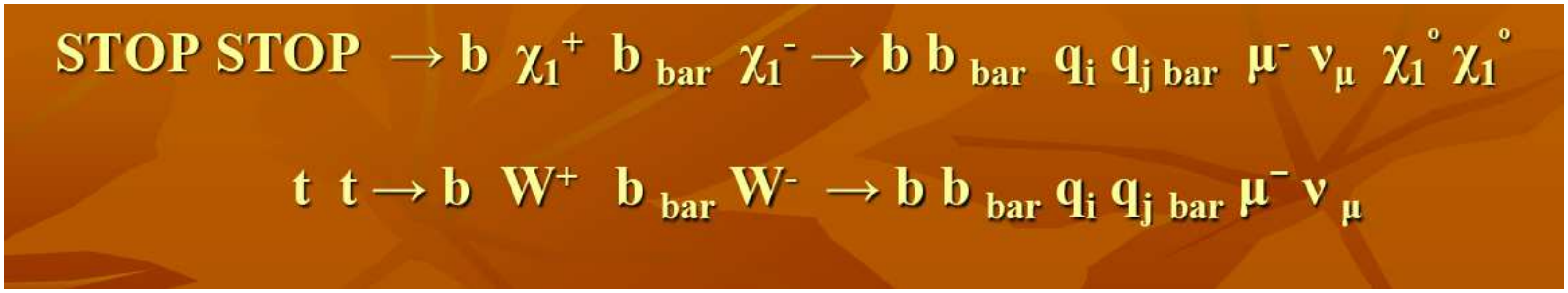
$$\chi_H{}^2 = \frac{(M_1 - M_H)^2}{\sigma_{2j}^2} + \frac{(M_2 - M_H)^2}{\sigma_{2j}^2}$$



$$\chi_Z{}^2 = \frac{(M_1 - M_Z)^2}{\sigma_{2j}^2} + \frac{(M_2 - M_Z)^2}{\sigma_{2j}^2}$$



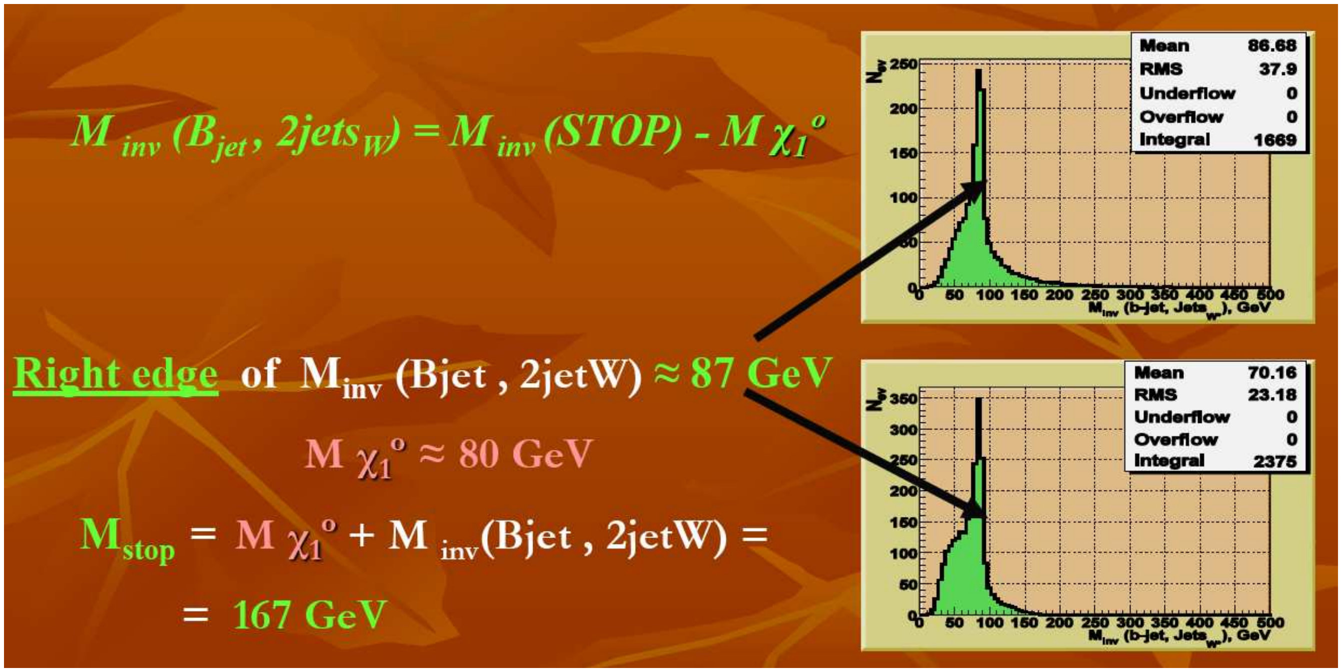
- Considered process:


$$\mathrm{STOP\ STOP} \rightarrow b\ \chi_1^+\ b_{\mathrm{bar}}\ \chi_1^- \rightarrow b\ b_{\mathrm{bar}}\ q_i\ q_{j\,\mathrm{bar}}\ \mu^-\ \nu_\mu\ \chi_1^\circ\ \chi_1^\circ$$

$$t\ \ t \rightarrow b\ \ W^+\ \ b_{\mathrm{bar}}\ W^- \rightarrow b\ b_{\mathrm{bar}}\ q_i\ q_{j\ \mathrm{bar}}\ \mu^-\ \nu_\mu$$

- The only difference of stop/top pair production is the presence of two non-detectable neutralinos in the case of stop pair production

Stop pair production in polarized $\gamma\gamma$ collisions at ILC



$M_{inv}(B_{jet}, 2jets_W) = M_{inv}(STOP) - M\chi_1^o$

Right edge of M_{inv} (Bjet , 2jetW) ≈ 87 GeV

$M\chi_1^o \approx 80$ GeV

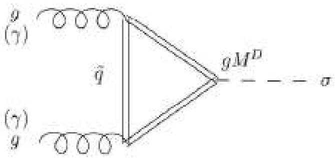
$M_{stop} = M\chi_1^o + M_{inv}(\text{Bjet}, \text{2jetW}) =$

$= 167$ GeV

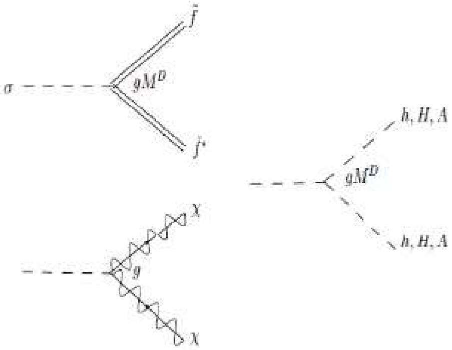
- New code for cross section of STOP pair production that allows to take into account the polarizations of colliding photons implemented in PYTHIA 6
- Invariant mass of the final jets and the visible energy variables is the most efficient for signal/background separation
- Possibilty of a good M_{stop} reconstruction using the right-hand edge point of $(B_{jet} + 2jets_W)$ demonstrated

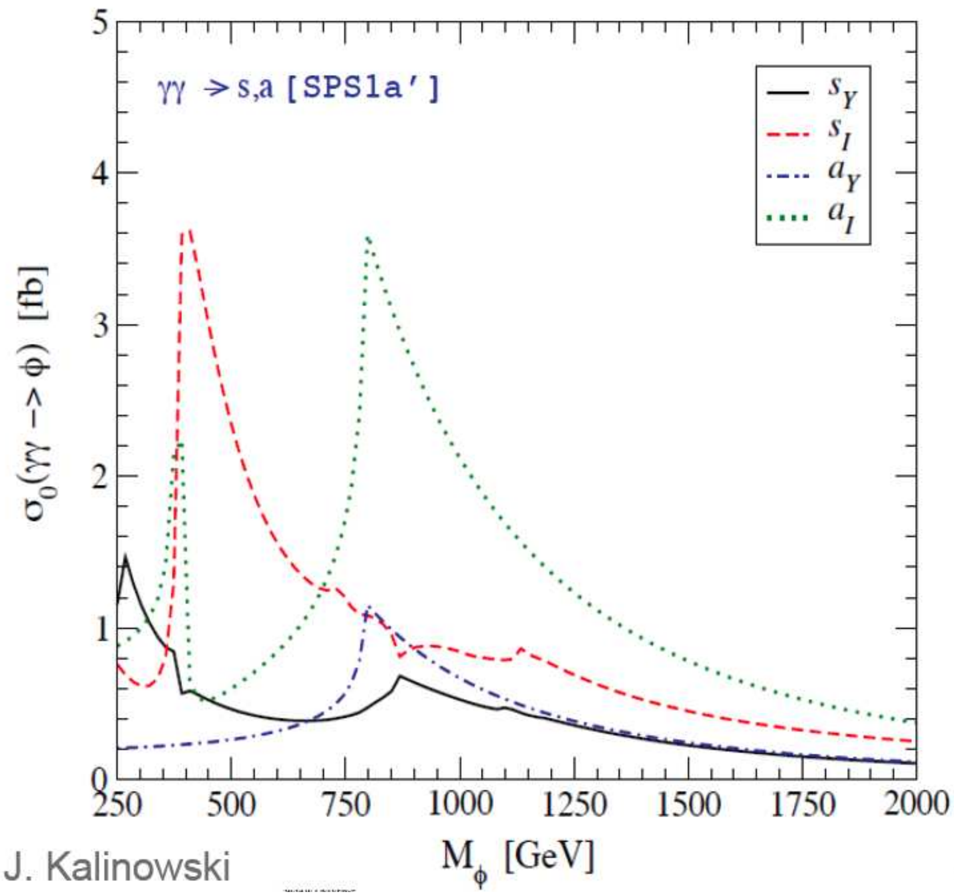
DIRAC gauginos and their scalar partners - Jan Kalinowski

Gamma colliders ideal for searching
for heavy scalars/pseudoscalars



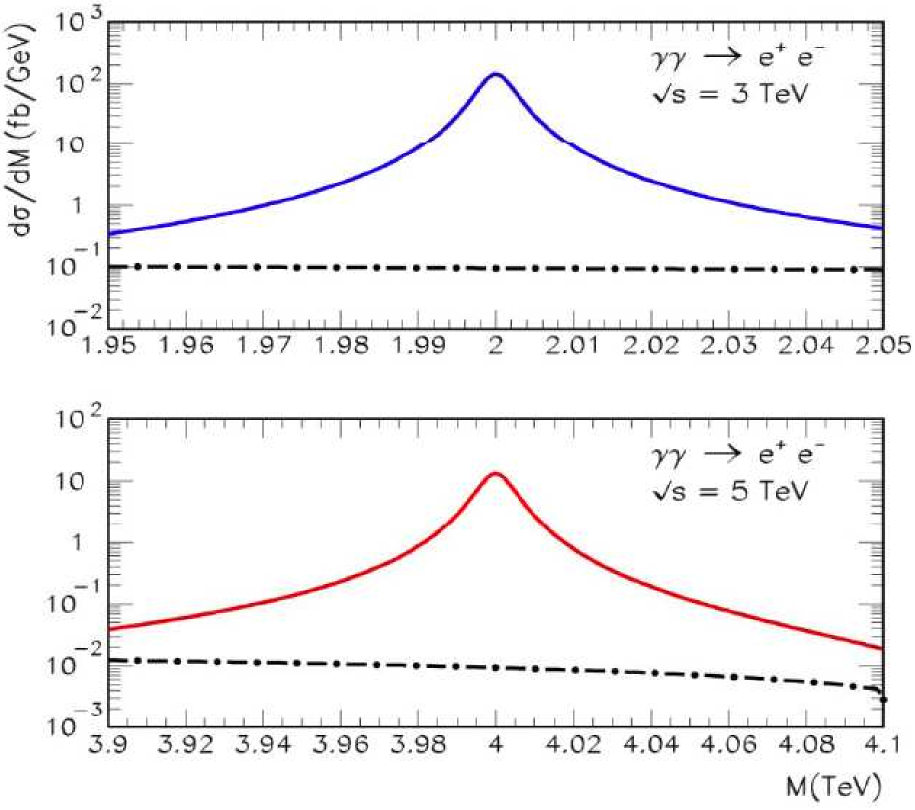
decays via





A preview of the string hunter's companion - Tomasz Taylor

- In string theory, elementary particles are quantized vibrations of fundamental strings. The zero modes are massless, the first harmonic have masses equal to the fundamental mass M, the second $\sqrt{2}M$, and in general $M_N = \sqrt{N}M$
- At LHC: Gluon gluon interactions can lead to resonances decaying into 2 or more jets
- If $M \sim TeVs$ (if extra dimensions $\sim$ 1 mm), possibility of seeing some resonances at a $\gamma\gamma$ collider in a much cleaner way



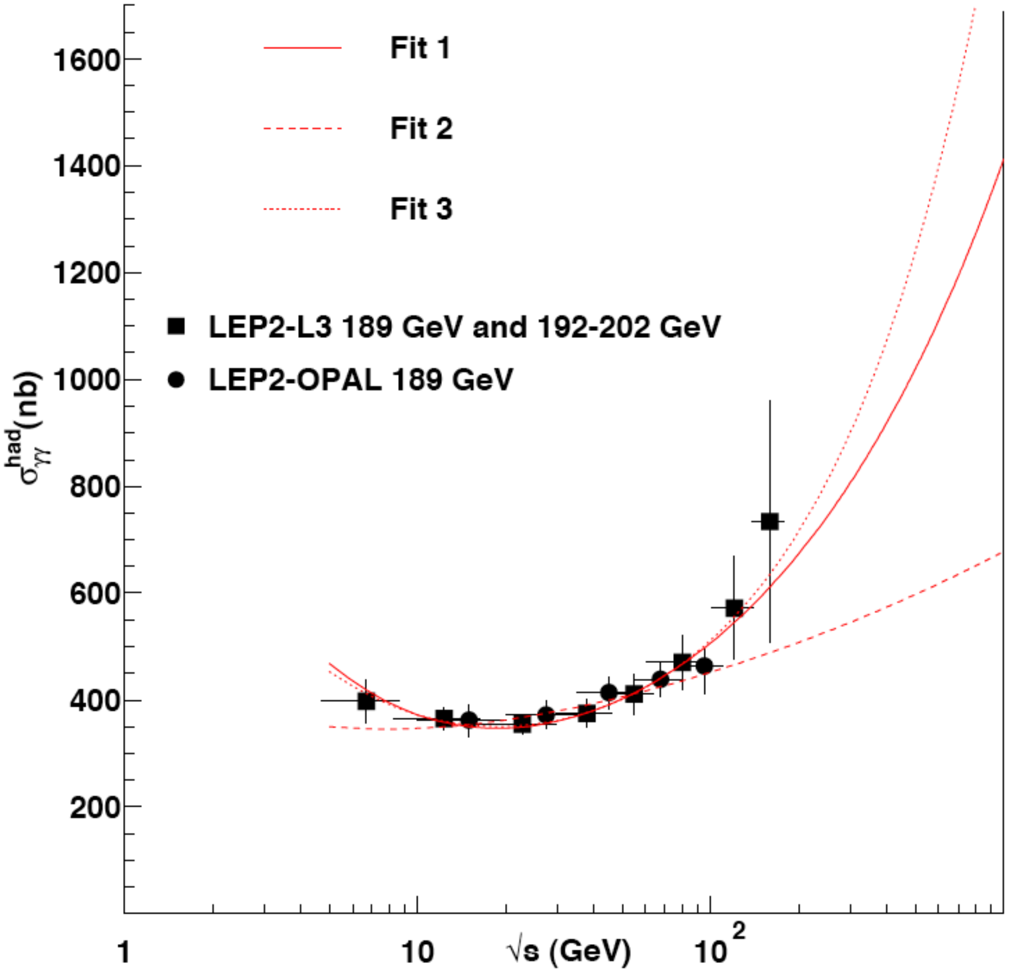
$\frac{d\sigma}{dM}$ (units of fb/GeV) vs. M (TeV) plotted for the case of SM background (dashed line) and the (first resonance) string signal + background for $\sqrt{s}$ = 3 TeV (assume M=2 TeV) and $\sqrt{s}$ = 5 TeV (assume M=4 TeV).

The next resonance would appear at $\sqrt{3}M$ because photons do not couple to $\sqrt{2}M$ resonances

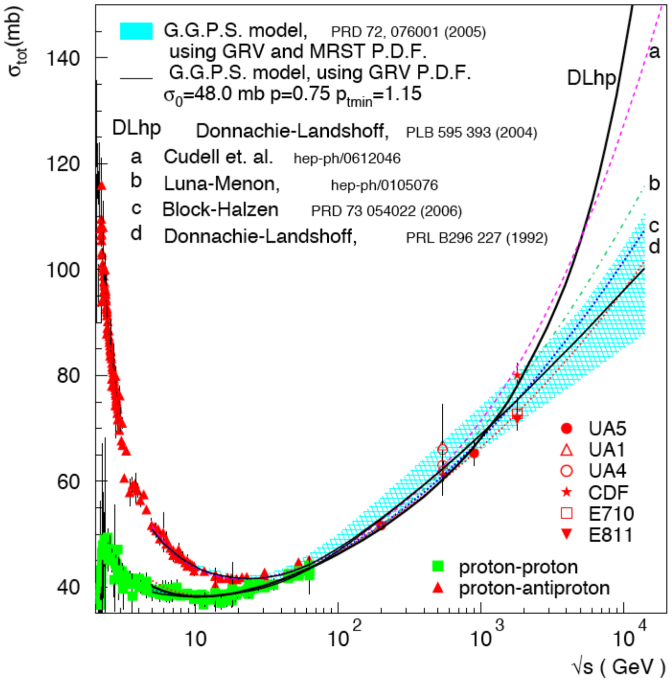
(γ DFs from Jikia, Eboli et al [arXiv:hep-ph/9210277], Cheung [arXiv:hep-ph/9211262])

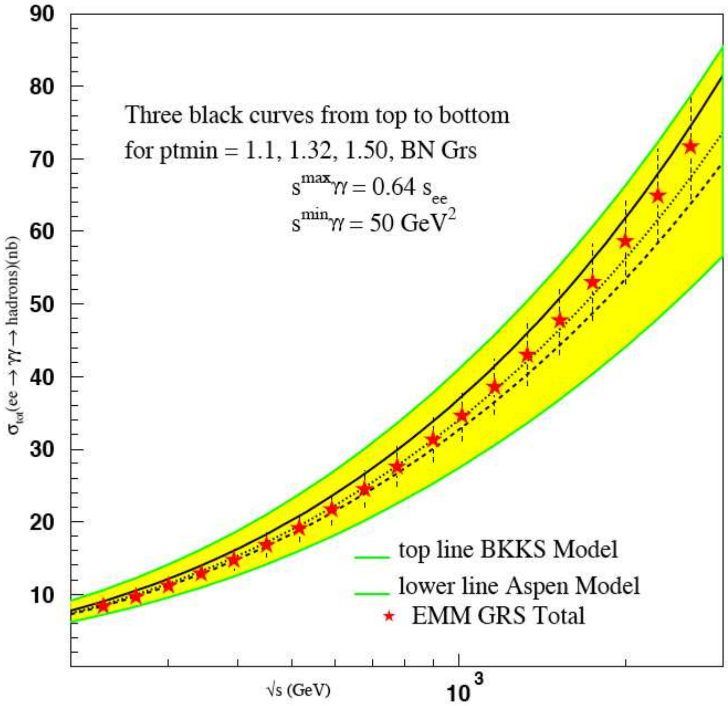
Hadronic backgrounds due to $\gamma\gamma$ processes in e^+e^- - Rohini Godbole

- Hadron production in $\gamma\gamma$ collisions estimated using LEP data, soft and hard part (photon structure function) of the $\gamma\gamma$ cross sections
- Description of LEP data: large uncertainty leading to 3 possible fits



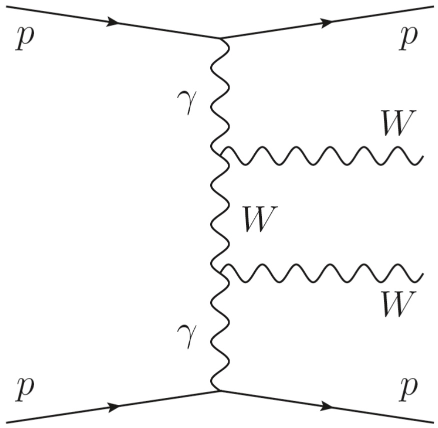
Hadronic backgrounds due to $\gamma\gamma$ processes at e^+e^- colliders

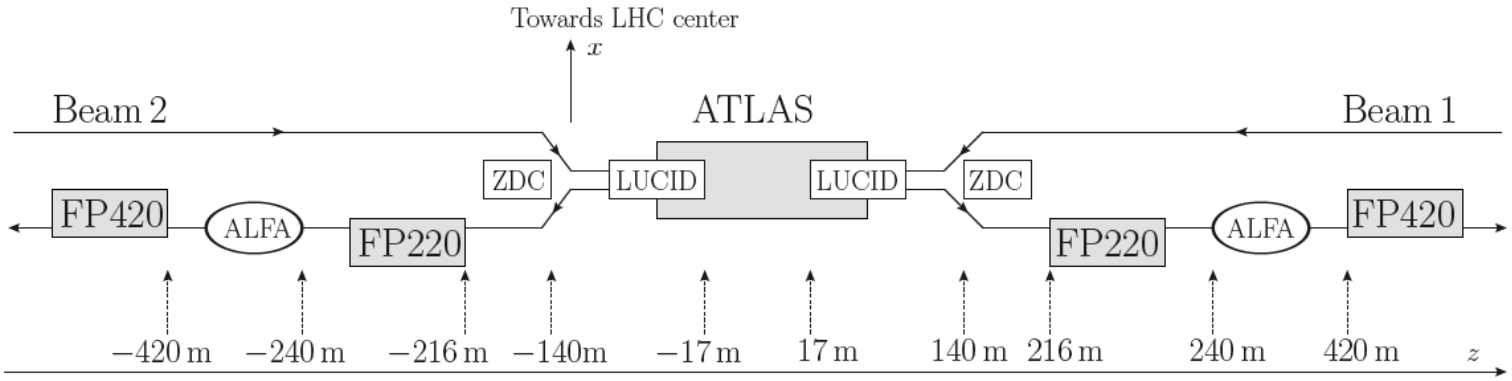




- Model leading to a good description of total cross section
- Large $\sigma(ee \rightarrow hadrons)$ at large $\sqrt{S}$, especially at CLIC
- Leads to large number of underlying events due to $\gamma\gamma$ collisions at CLIC, 4 to 5 at 3 Tev!, background to be taken into account in searches/precision measurements

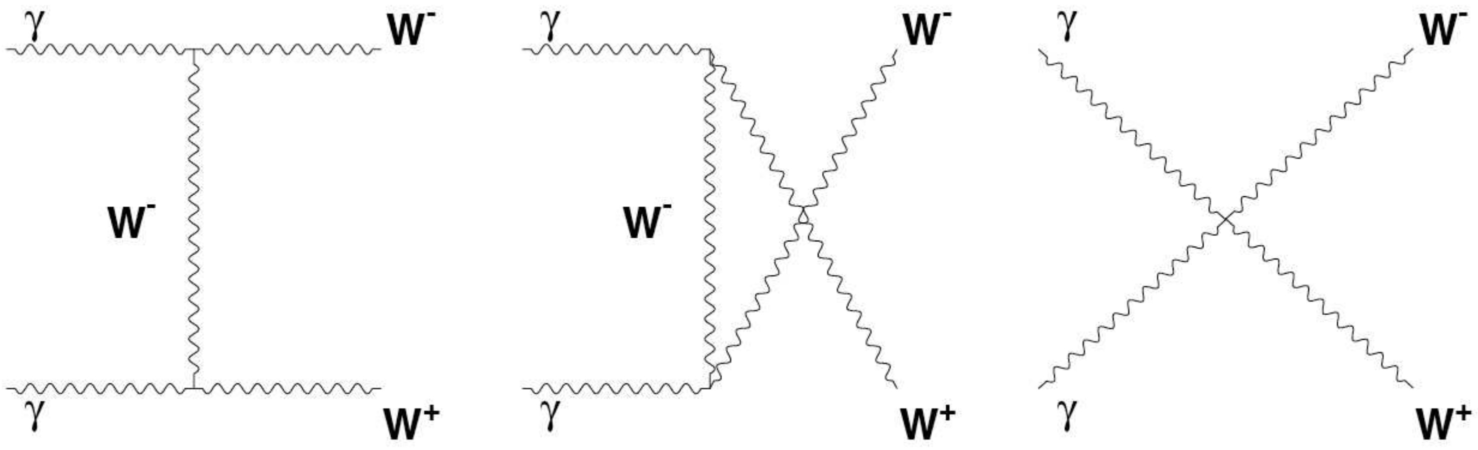
W/Z pair production at the LHC and at ILC/CLIC - Oldřich Kepka

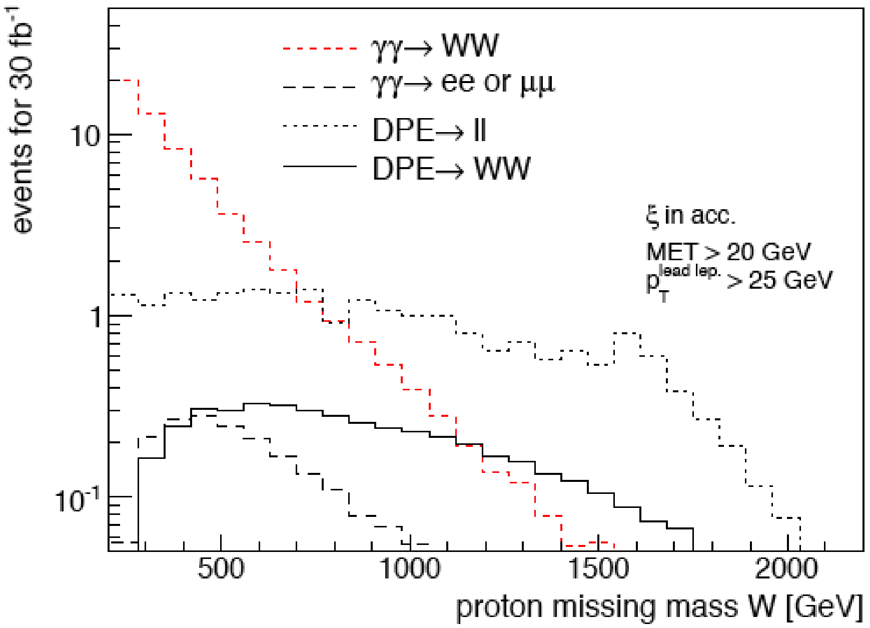




- Rich $\gamma\gamma$ physics at LHC
- Need to install forward proton detectors to tag final state intact protons (ATLAS Forward Physics project, same in CMS)

SM Observation of $W\ \gamma$-induced production at the LHC

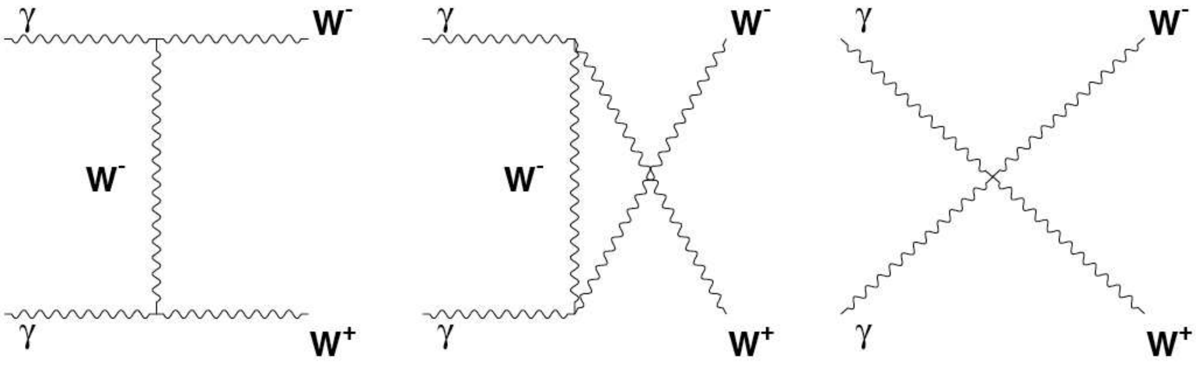




- discovery with $\mathcal{L}$=5 fb^{-1} (8 events, 1 background)
- big advantage, missing mass reconstructed with AFP: $W = \sqrt{s\xi_1\xi_2}$

cut / process 30 fb^{-1}	$\gamma\gamma \to ee$ ($\mu\mu$)	$\gamma\gamma \to \tau\tau$	DPE→ ll	DPE→ WW	$\gamma\gamma \to WW$
$p_T > 10$ GeV	24896	177	17931	8.8	95
after cuts	0	0	1.0	0.67	51

Quartic anomalous couplings



$$\mathcal{L}_6^0 = \frac{-e^2}{8}\frac{a_0^W}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W_\alpha^- - \frac{e^2}{16\cos^2\theta_W}\frac{a_0^Z}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}Z^\alpha Z_\alpha$$

$$\mathcal{L}_6^C = \frac{-e^2}{16}\frac{a_C^W}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W_\beta^- + W^{-\alpha}W_\beta^+) - \frac{e^2}{16\cos^2\theta_W}\frac{a_C^Z}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}Z^\alpha Z_\beta$$

Anomalous couplings a_0^W, a_C^W, a_0^Z, a_C^Z equal to zero in SM

Sensitivities at high luminosity

Couplings	OPAL limits [GeV^{-2}]	Sensitivity @ $\mathcal{L} = 30$ (200) fb^{-1} 95% CL
a_0^W/Λ^2	[-0.020, 0.020]	2.6×10^{-6} (1.4×10^{-6})
a_C^W/Λ^2	[-0.052, 0.037]	9.4×10^{-6} (5.2×10^{-6})
a_0^Z/Λ^2	[-0.007, 0.023]	6.4×10^{-6} (2.5×10^{-6})
a_C^Z/Λ^2	[-0.029, 0.029]	24×10^{-6} (9.2×10^{-6})

- improvement of sensitivities up to 4 orders of magnitude with 30 fb^{-1}

Study in progress for CLIC/ILC as a $\gamma\gamma$ collider

Conclusion

- Rich $\gamma\gamma$ physics at a $\gamma\gamma$ collider: Higgs pair production, SUSY (stop mass determination, gauginos...), strings
- Resonance-continuum interference effects for light Higgs boson production in $\gamma\gamma \rightarrow H \rightarrow b\bar{b}$ small for SM
- Feasibility study of Higgs pair production in a photon collider ($\gamma\gamma \rightarrow H \rightarrow 4b$): in progress, ZZ background still an issue, study better jet clustering algorithms
- Large $\sigma(ee \rightarrow hadrons)$ at large $\sqrt{S}$, especially at CLIC: Leads to large number of underlying events due to $\gamma\gamma$ collisions at CLIC, 4 to 5 at 3 Tev!, background to be taken into account in searches/precision measurements
- Anomalous coupling studies: especially interesting to probe higgsless and extra-dimensions models which appear as new $\gamma\gamma WW$ and $\gamma\gamma ZZ$ couplings