H and A discrimination with linear photon polarization

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Outline

- Introduction
- H/A production at PLC with circular polarization
- Description of linear photon polarization
- Results
- Conclusions

Introduction

Higgs boson production at the Photon Linear Collider

Previous studies by P.Nieżurawski, A.F.Żarnecki, M.Krawczyk (NŻK):

$\mathcal{H} \to WW/ZZ$ decay channels

- Standard Model
  "Study of the Higgs-boson decays into W+ W- and Z Z at the photon collider," JHEP **0211** (2002) 034 [arXiv:hep-ph/0207294].
- 2HDM
  "Determination of the Higgs-boson couplings and CP properties in the SM-like two Higgs doublet model," JHEP **0502** (2005) 041 [arXiv:hep-ph/0403138].
- Generic model
  "Model-independent determination of CP violation from angular distributions in Higgs boson decays to W W and Z Z at the Photon Collider,"
  Acta Phys. Polon. B **36** (2005) 833 [arXiv:hep-ph/0410291].

Introduction

Higgs boson production at the Photon Linear Collider

Previous studies by P.Nieżurawski, A.F.Żarnecki, M.Krawczyk (NŻK):

$\mathcal{H} \to b\bar{b}$ decay channel

- Standard Model
  "The SM Higgs boson production $\gamma\gamma \to h \to b\bar{b}$ at the photon collider at TESLA,"
  Acta Phys. Polon. B **34** (2003) 177 [arXiv:hep-ph/0208234].
- MSSM
  "Extended analysis of the MSSM Higgs boson production at the photon collider,"
  Proceedings of LCWS 2005 [arXiv:hep-ph/0507006];
  "LHC wedge at the PLC: Observability of $\gamma\gamma \to A, H \to b\bar{b}$,"
  Acta Phys. Polon. B **37** (2006) 1187.

$\Rightarrow$ see also P. Nieżurawski, "Higgs-boson production at the photon collider at TESLA,"
arXiv:hep-ph/0503295 (PhD Thesis).

$\mathcal{H} \to b\bar{b}$

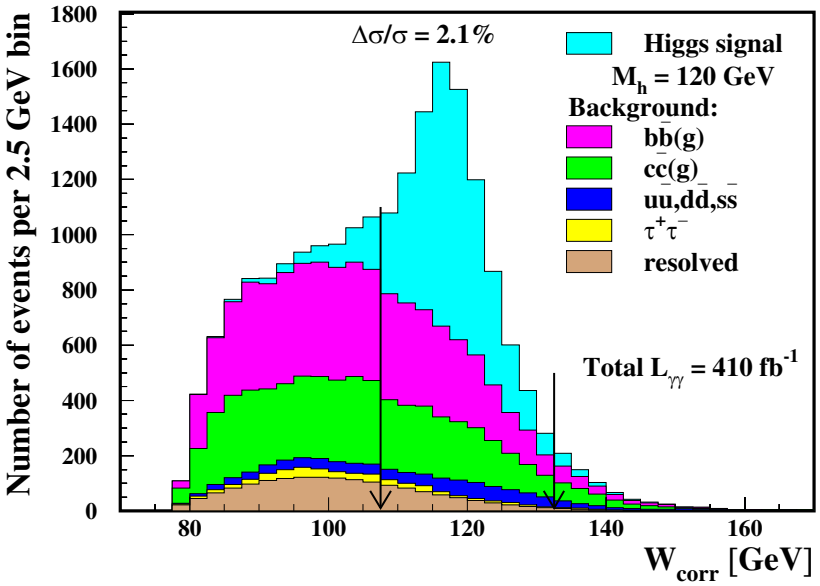
Results based on:

- Realistic $\gamma\gamma$ luminosity spectra
  V.Telnov simulation results and CompAZ parametrization
- Beams crossing angle, primary vertex distribution taken into account
- NLO calculations of QCD background $\gamma\gamma \to Q\bar{Q}(g)$ $(Q = c, b)$
- Other backgrounds: $\gamma\gamma \to WW$, $\gamma\gamma \to \tau\tau$, $\gamma\gamma \to q\bar{q}$ $(q = u, d, s)$
  not yet included for preliminary linear polarization results !
- Overlaying events $\gamma\gamma \to hadrons$: about 1–2 OE per bunch crossing
- Realistic b-tagging
  (*e.g.* for $M_h = 300$ GeV: $\varepsilon_h = 53\%$, $\varepsilon_{bb} = 47\%$, $\varepsilon_{cc} = 2.9\%$, $\varepsilon_{uds} = 0.5\%$)
- Realistic detector simulation (SIMDET)
- Full optimization of cuts

Circular polarization

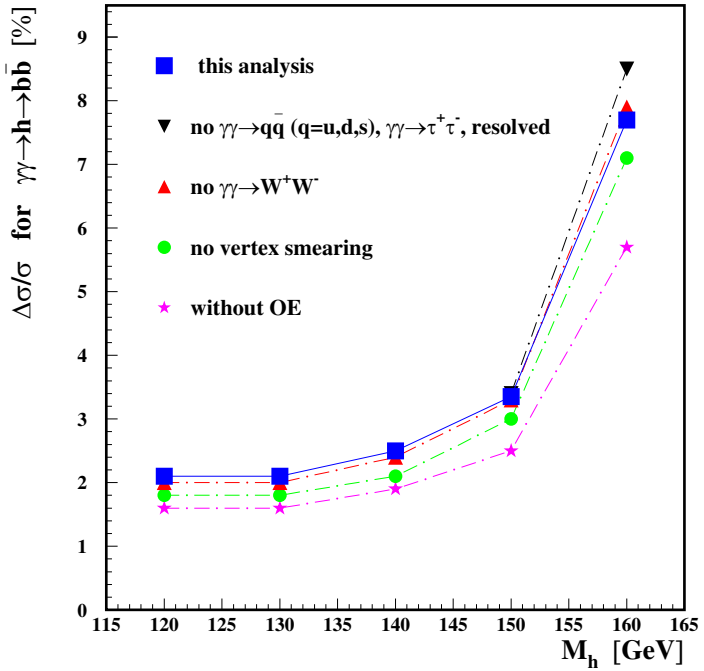
SM summary

Results for $M_h = 120$ GeV



Corrected invariant mass distributions for signal and background events

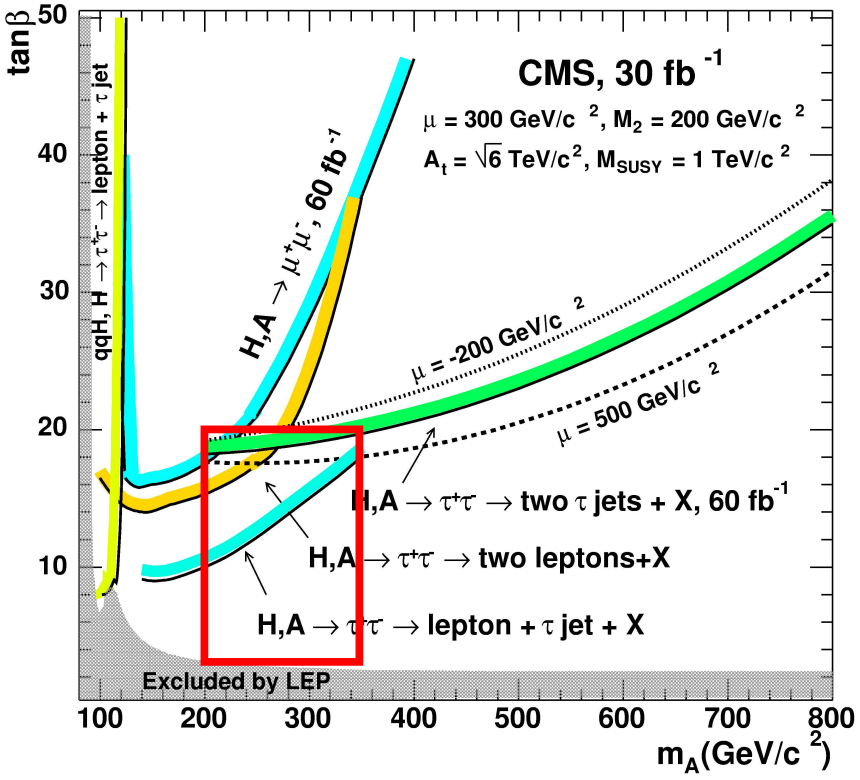
Results for $M_h = 120$-160 GeV



Cross section measurement precision

Circular polarization

MSSM: LHC wedge at PLC



From: CMS NOTE 2003/033

Four MSSM parameter sets considered:

Symbol	μ [GeV]	M_2 [GeV]	$A_{\tilde{f}}$ [GeV]
I	200	200	1500
II	-150	200	1500
III	-200	200	1500
IV	300	200	2450

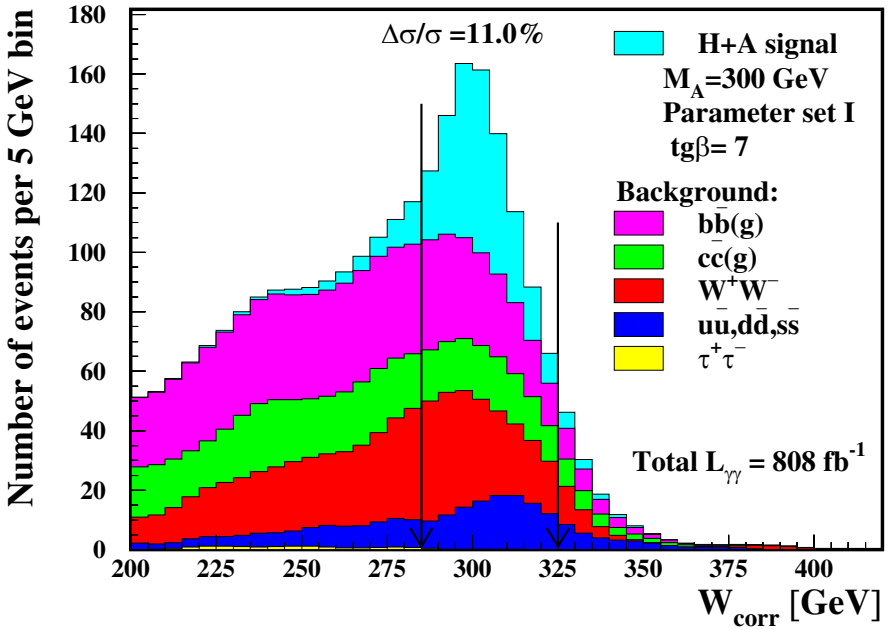
I and III – as in M. Mühlleitner *et al.*
with higher $A_{\tilde{f}}$ to have M_h above 114 GeV
II – an intermediate scenario

IV – as in CMS NOTE 2003/033

Circular polarization

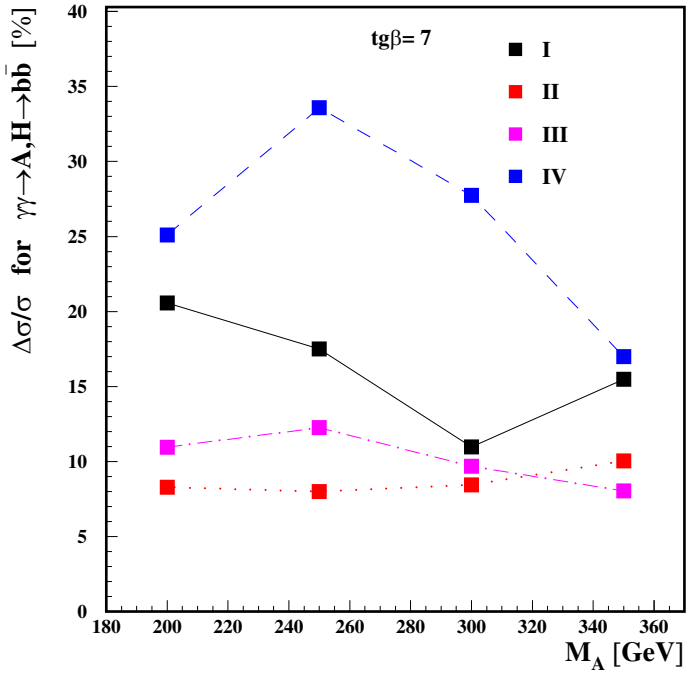
MSSM summary

Results for $M_A = 300$ GeV



Corrected invariant mass distributions

Results for $M_A = 200$-350 GeV

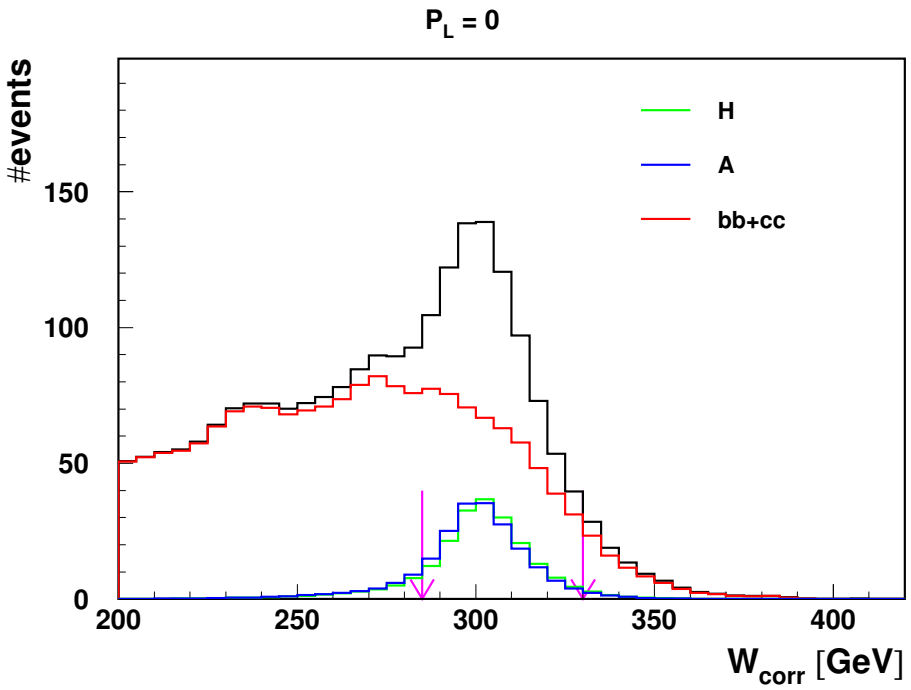


Cross section measurement precision

Circular polarization

MSSM results

Results for $M_A = 300$ GeV



We can not distinguish between H and A

$\Rightarrow$ measurement of

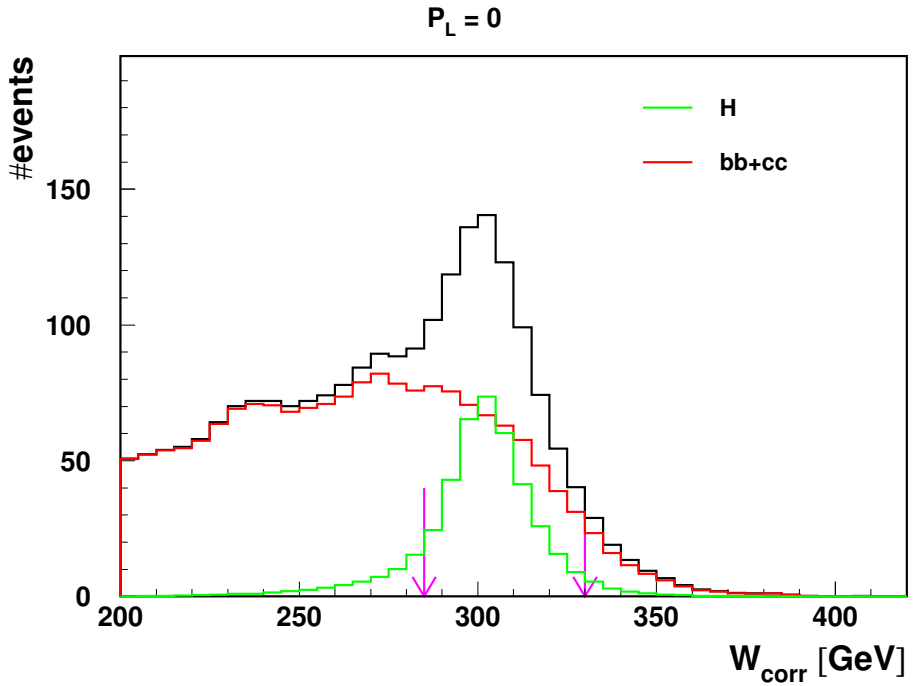
$$\sigma_{tot} = \sigma_H + \sigma_A$$

Corrected invariant mass distributions

Circular polarization

MSSM results

Results for $M_A = 300$ GeV



Corrected invariant mass distributions

We can not distinguish between H and A

$\Rightarrow$ measurement of

$$\sigma_{tot} = \sigma_H + \sigma_A$$

$\Rightarrow$ Need for linear photon polarization

Preliminary results

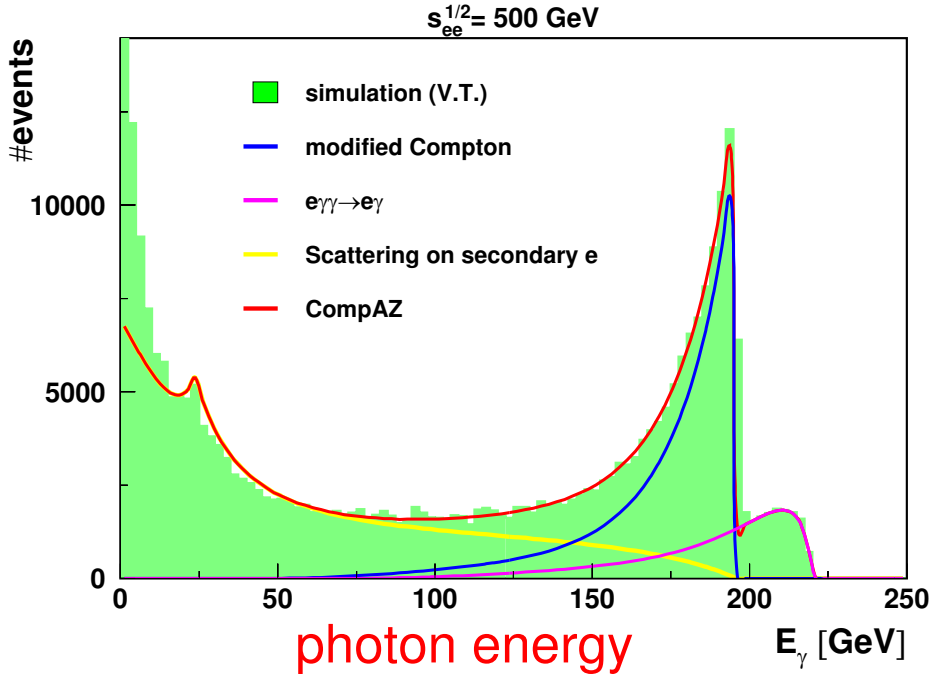
Only heavy quark background considered!

Luminosity spectra

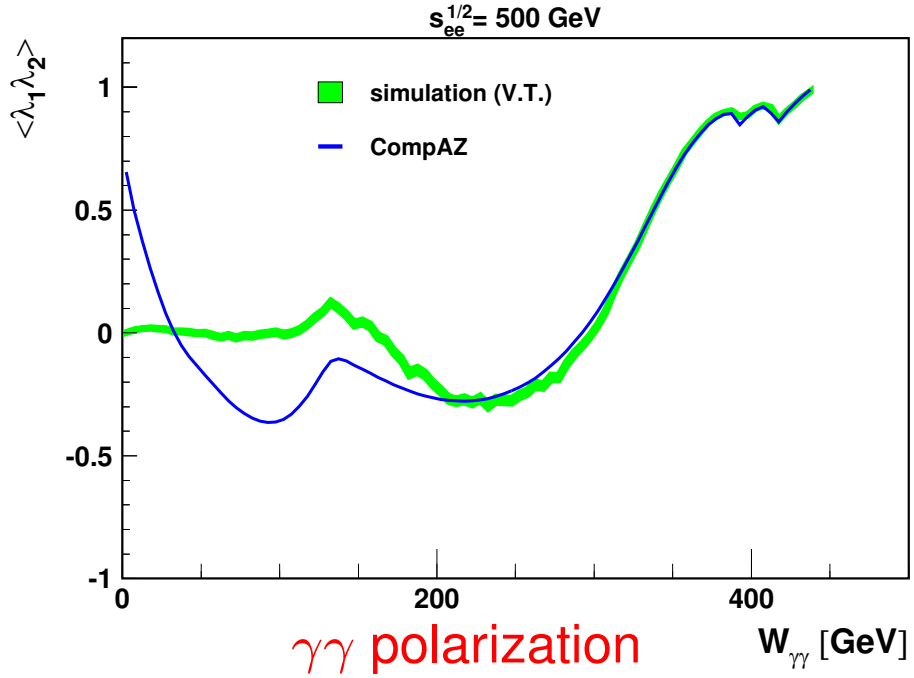
CompAZ

Parametrization of the spectra simulation results by V.Telnov

based on LO Compton cross section formula



photon energy



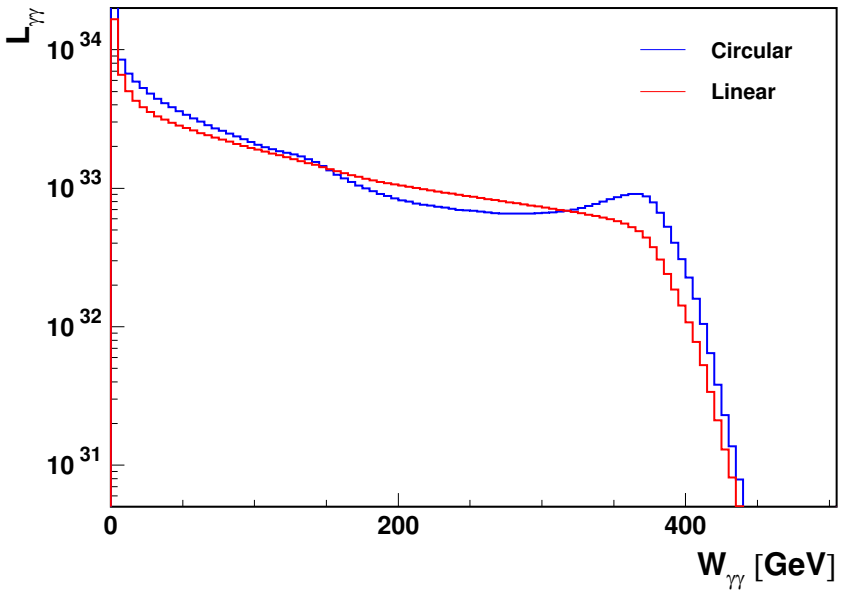
$\gamma\gamma$ polarization

Can it be used to describe $\gamma\gamma$ spectra for linear photon polarization ?

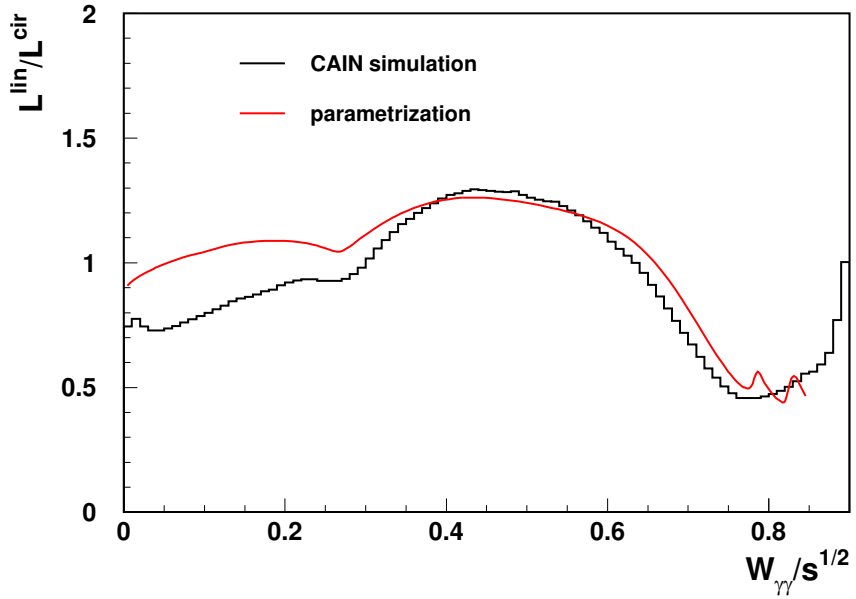
Linear polarization

CAIN simulation

$\gamma\gamma$ luminosity spectra for circular and linear laser beam polarization



Ratio of $\gamma\gamma$ luminosities

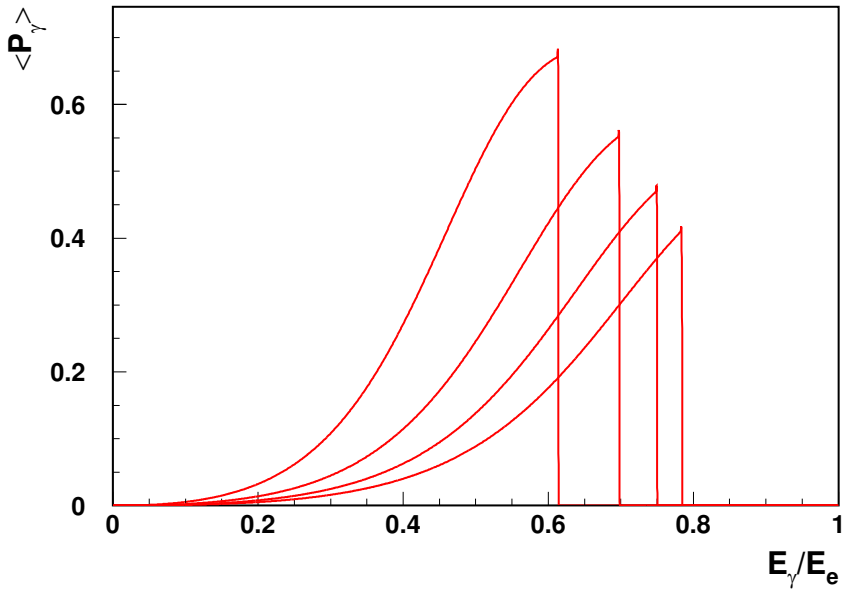


CompAZ gives proper description of the spectra modification

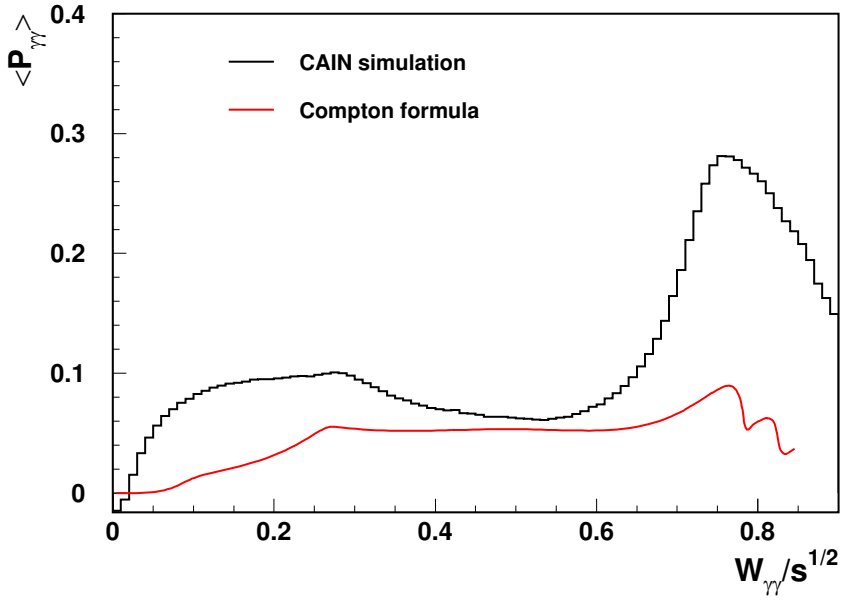
Linear polarization

CAIN simulation

Expected photon polarization
from LO Compton process



Average $\gamma\gamma$ polarization from CAIN



for $E_e = 100$, 150, 200 and 250 GeV

CompAZ fails to describe polarization !

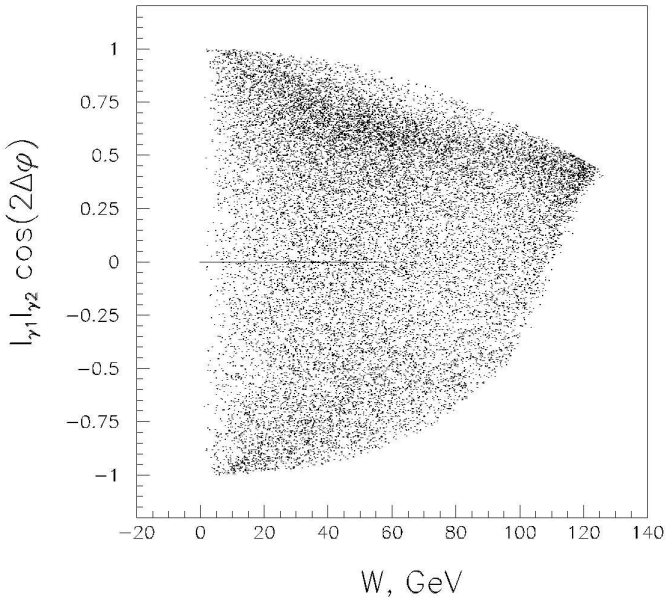
Linear polarization

Angular correlations

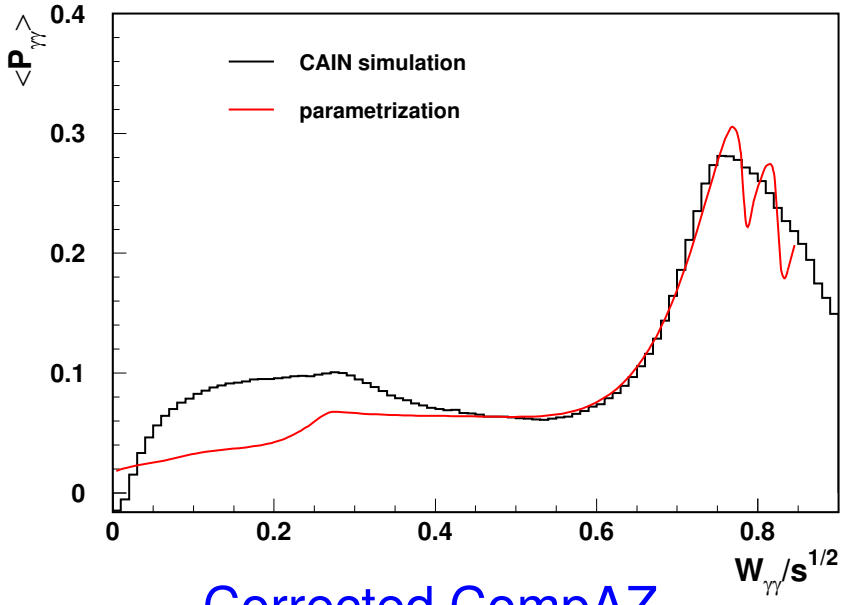
As pointed out by V.Telnov ("Nontrivial effects in linear polarization at photon colliders", ECFA workshop, Montepellier, November 2003) there are large correlations between photon polarization and scattering direction. In collision of two very thin beams:

$$\langle P_{\gamma_1} P_{\gamma_2} \rangle \gg \langle P_{\gamma_1} \rangle \cdot \langle P_{\gamma_2} \rangle$$

V.Telnov



Average $\gamma\gamma$ polarization from CAIN

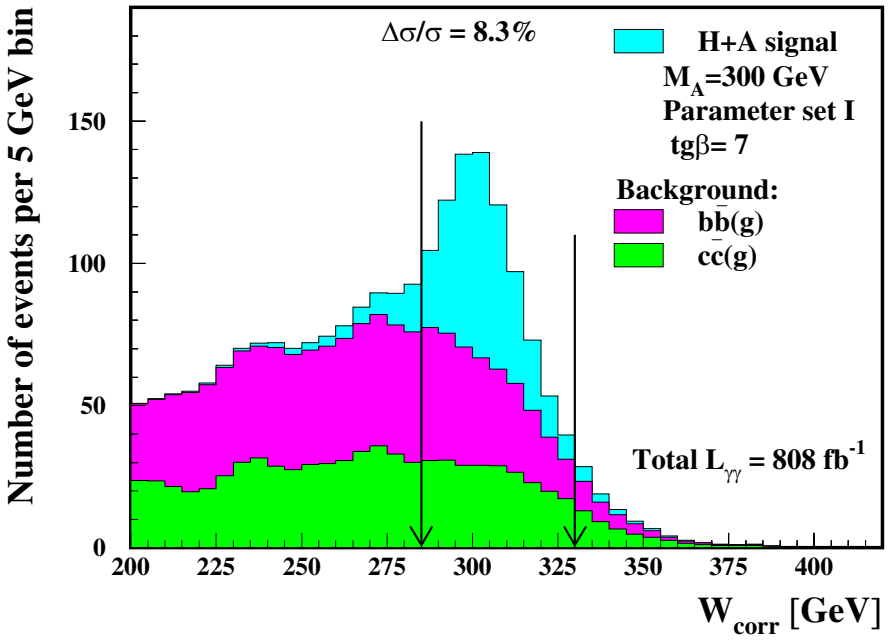


Corrected CompAZ

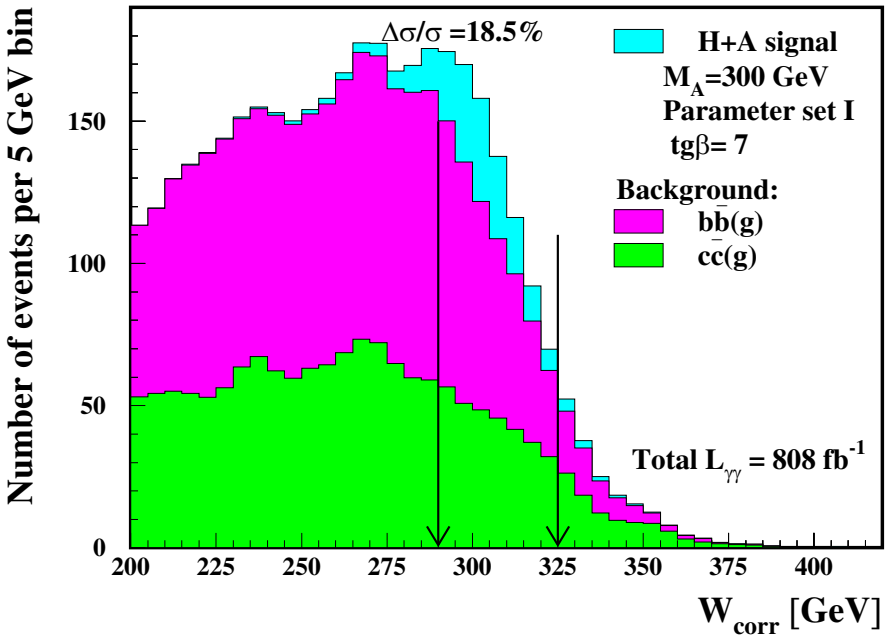
Results

$M_A = 300$ GeV

Circular laser polarization, $P_C = 100\%$



Linear laser polarization, $P_L = 100\%$



Lower luminosity at M_A, lower $J_z = 0$ contribution $\Rightarrow$ signal down by factor 2

Higher $J_z = 2$ contribution $\Rightarrow$ no background suppression $\Rightarrow$ background up by 40%

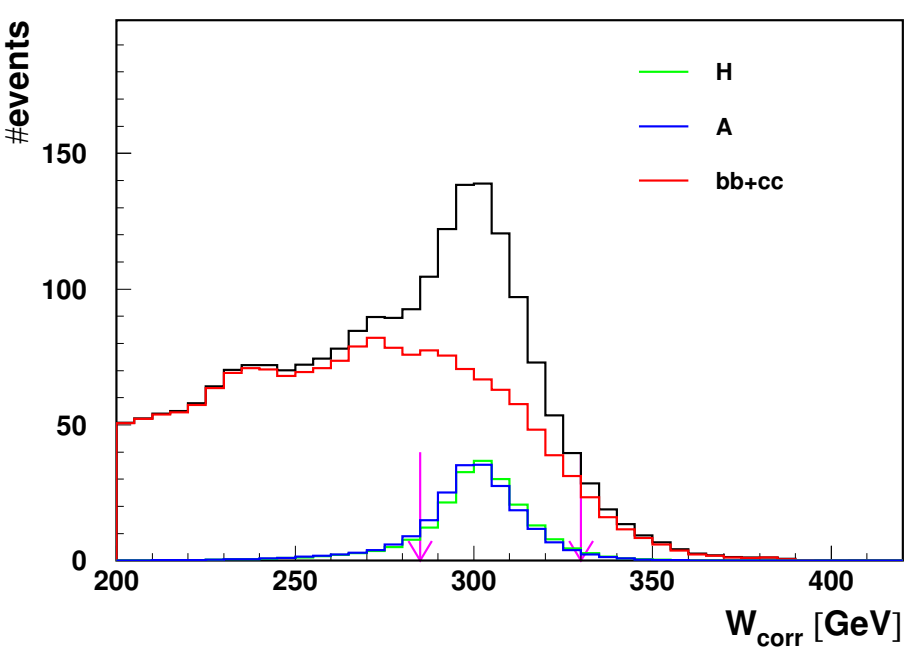
Selection cuts differ !!!

Results

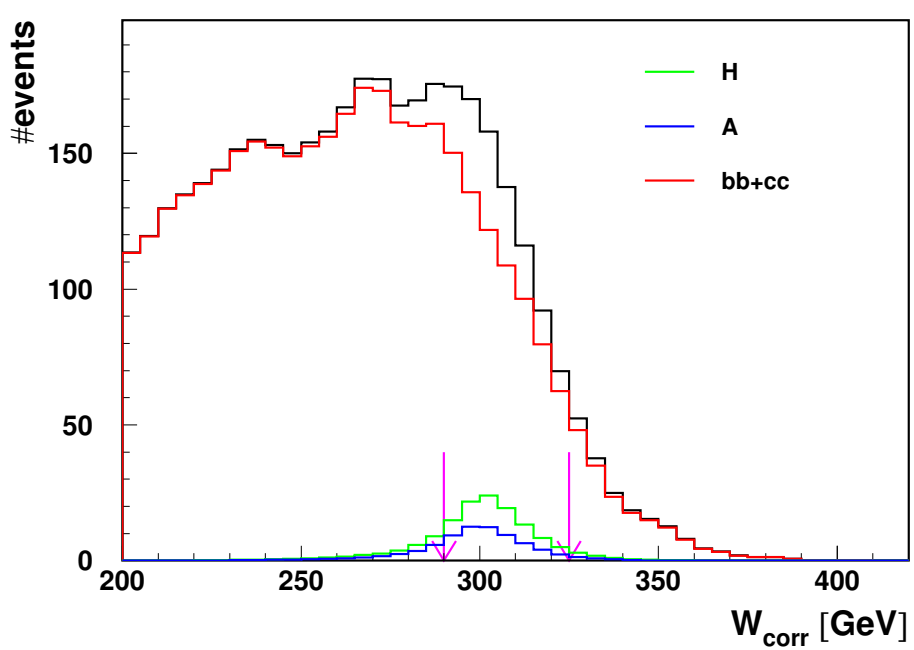
$M_A = 300$ GeV

Measurements start to be sensitive to the Higgs boson(s) CP properties.

Circular laser polarization, $P_C = 100\%$



Linear laser polarization, $P_L = 100\%$



$f \approx 0.5$

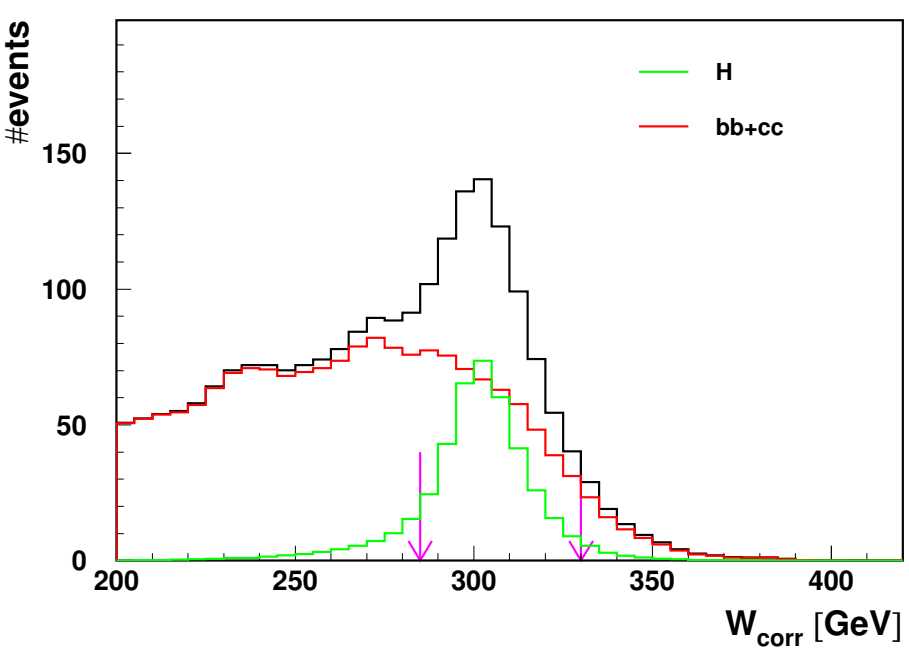
$\sigma_H = f \cdot \sigma_\circ, \quad \sigma_A = (1-f) \cdot \sigma_\circ$ where $\sigma_\circ \equiv \sigma_{H+A}(P_L = 0)$

Results

$M_A = 300$ GeV

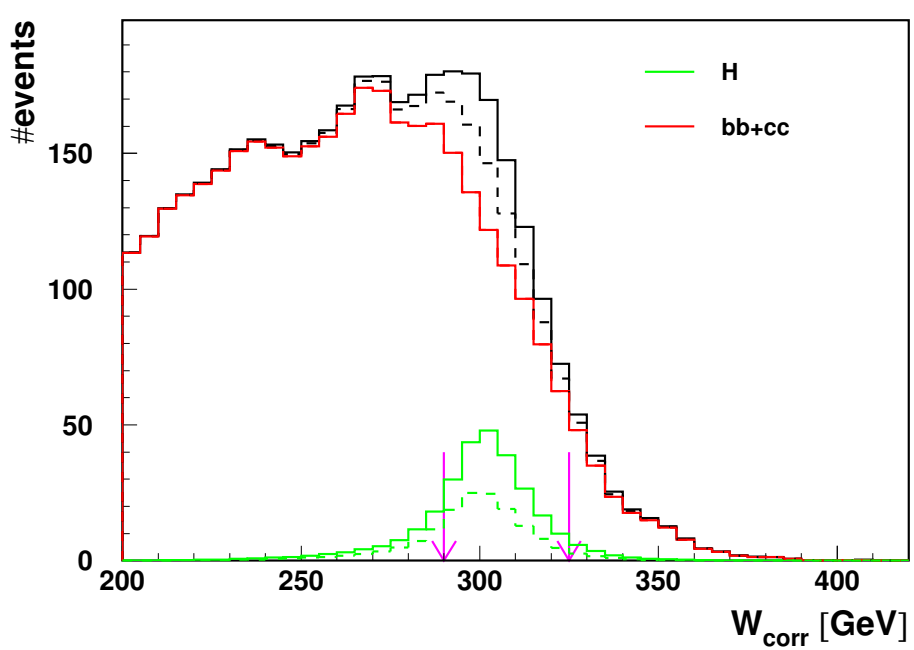
Measurements start to be sensitive to the Higgs boson(s) CP properties.

Circular laser polarization, $P_C = 100\%$



$f = 1$

Linear laser polarization, $P_L = 100\%$



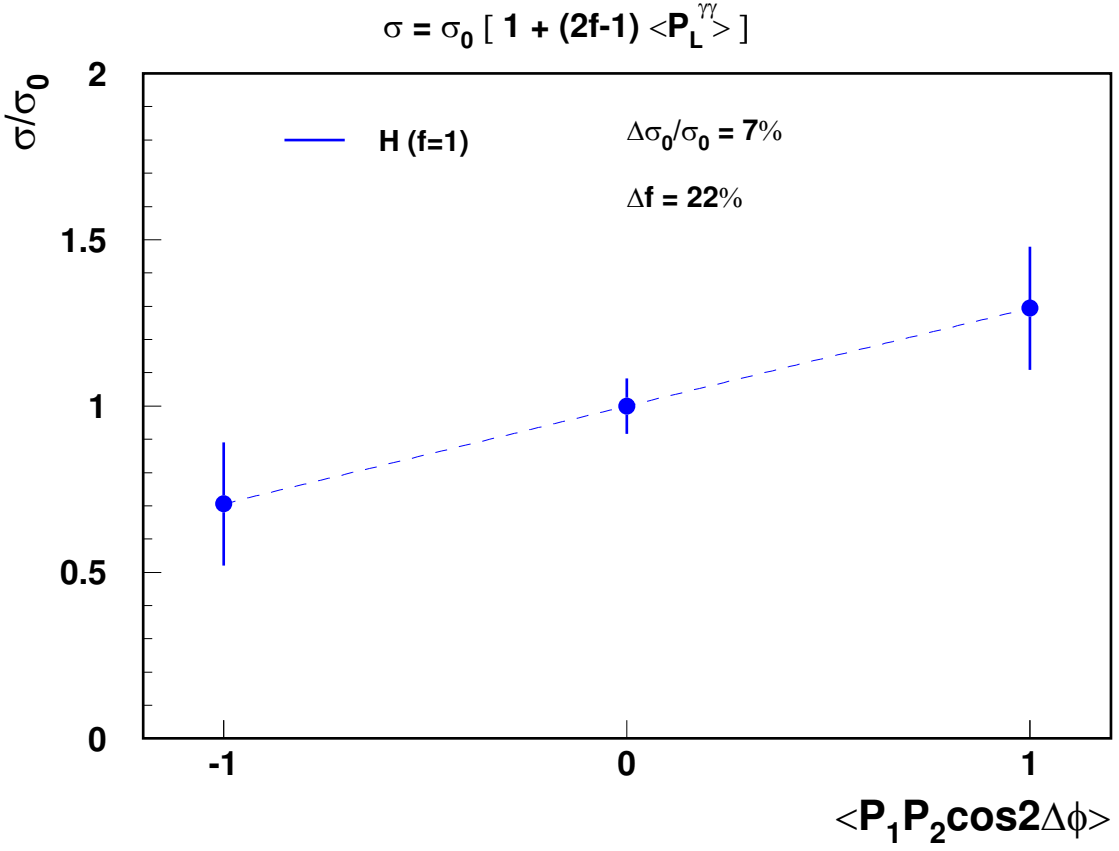
parallel (solid), perpendicular (dashed)

$\sigma_H = f \cdot \sigma_\circ, \quad \sigma_A = (1-f) \cdot \sigma_\circ$ where $\sigma_\circ \equiv \sigma_{H+A}(P_L = 0)$

Results

$M_A = 300$ GeV

Results expected after 3×1 years of PLC running

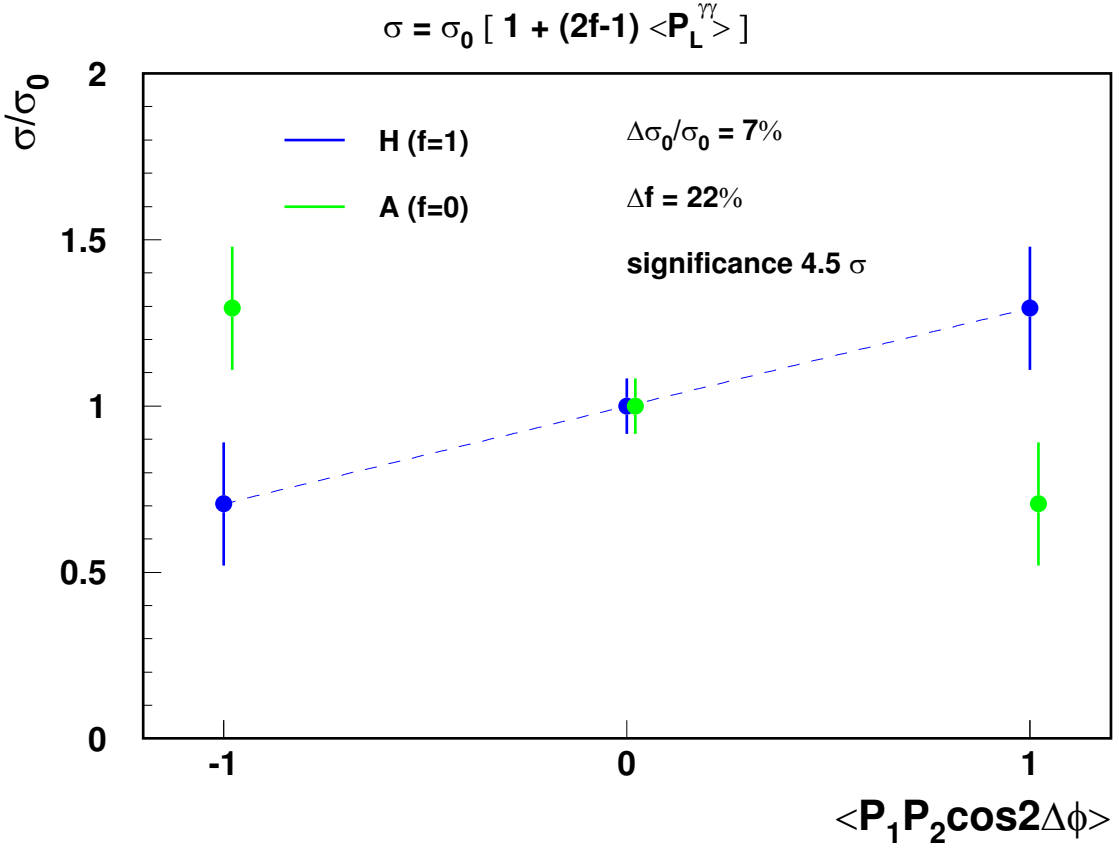


$\sigma_\circ$ corresponding to MSSM parameter set I

Results

$M_A = 300$ GeV

Results expected after 3×1 years of PLC running



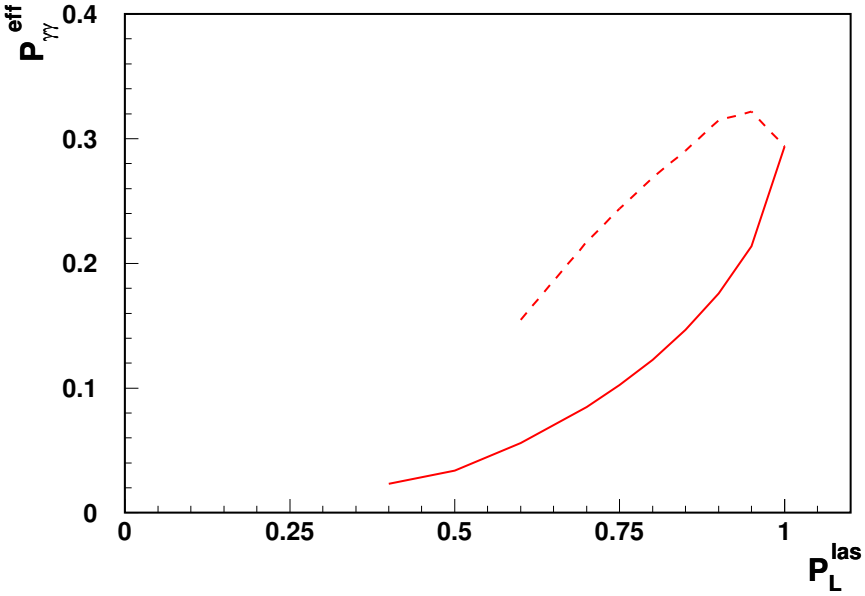
$\sigma_\circ$ corresponding to MSSM parameter set I

Results

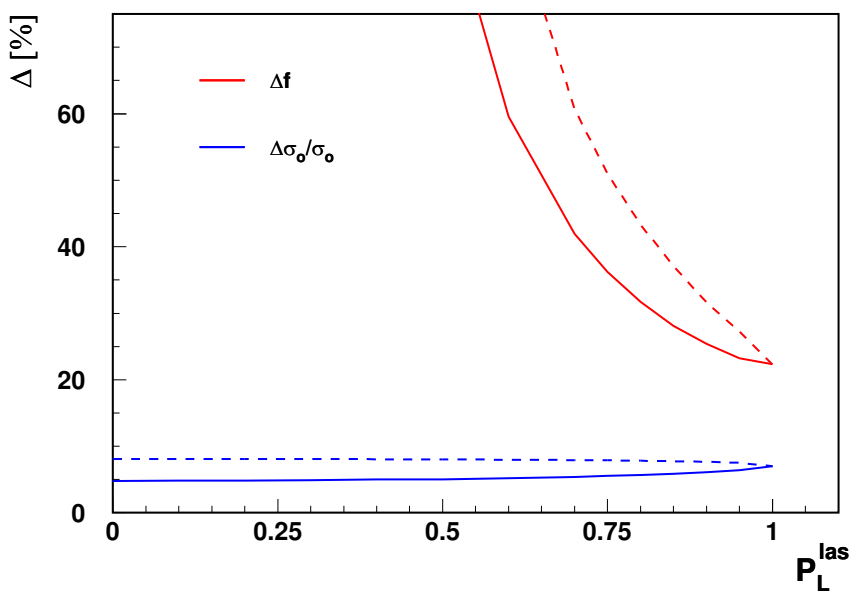
Mixed polarization

Consider possibility of mixed laser polarization $P_C^2 + P_L^2 = 1$

Effective $\gamma\gamma$ polarization



Measurement precision (3×1 year)



Dashed line: "reversed" circular laser polarization

$\Rightarrow$ Best measurement for 100% linear laser polarization, $P_L = 1$

Conclusions

Heavy MSSM Higgs bosons are likely to be almost degenerate in mass.

Circular polarization $\Rightarrow$ only total H+A production cross section measured.

$\Rightarrow$ linear polarization required to reconstruct σ_H and σ_A

CAIN simulation results used to adjust CompAZ parametrization
to describe photon beam polarization for linear laser polarization.

Preliminary results show that H/A contribution to the observed resonance
can be estimated with $\sim$ 20% precision.

H and A can be distinguished on 4.5σ level.

Assuming total cross section $\sigma_\circ$ as for MSSM parameter set I