Sensitivity of the ILC to light Higgs masses

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- *Question: ILC sensitivity to light scalar masses?*
- *Method validation: LEP results traditional versus recoil*
- *Extrapolations for ILC*
- *Conclusions*

Theoretical framework

- **If several Higgs fields Φ_i exist, e.g. singlet extended SM, 2HDM, MSSM, NMSSM, etc.…**

  Higgs fields can mix, but have to fulfil sumrule:

$$(g^{SM}_{HVV})^2 = \sum (g_{\Phi iVV})^2 , \qquad V \in \{W,Z\}$$

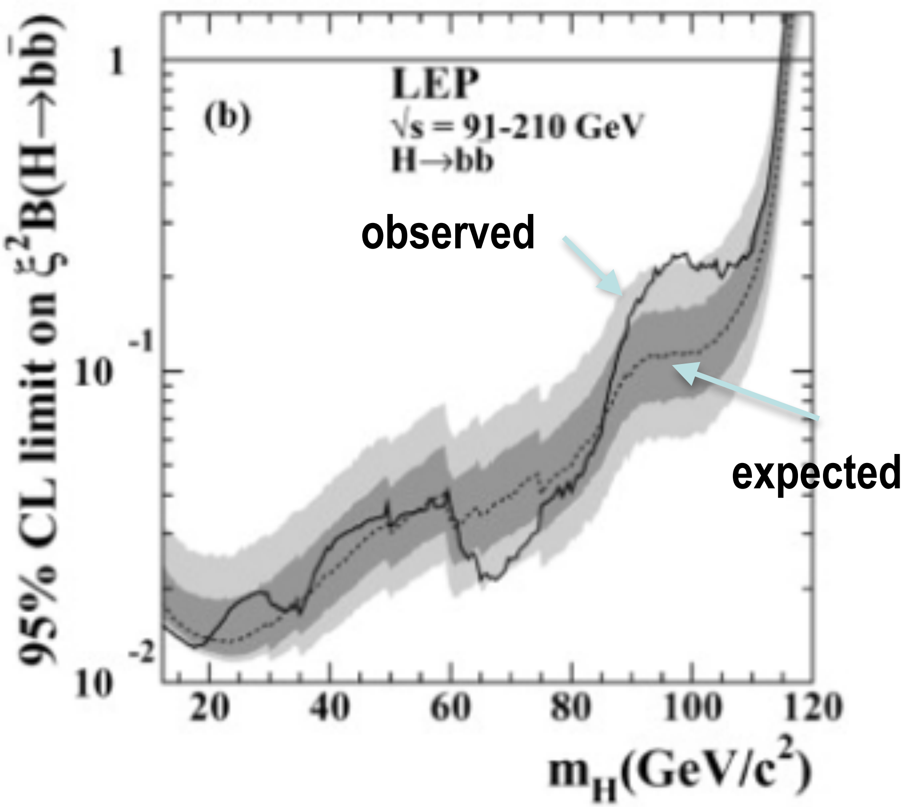
- **Limits on $g_{\Phi iVV}$ provide constraints for wide classes of BSM models!**
- **Additional Higgs bosons have significantly suppressed couplings to gauge bosons!**

- **Additional Higgs bosons can be heavier (decoupling limit) but also lighter than the 125 GeV state !**

- ***LEP +LHC limits leave significant room for additional light Higgs!***

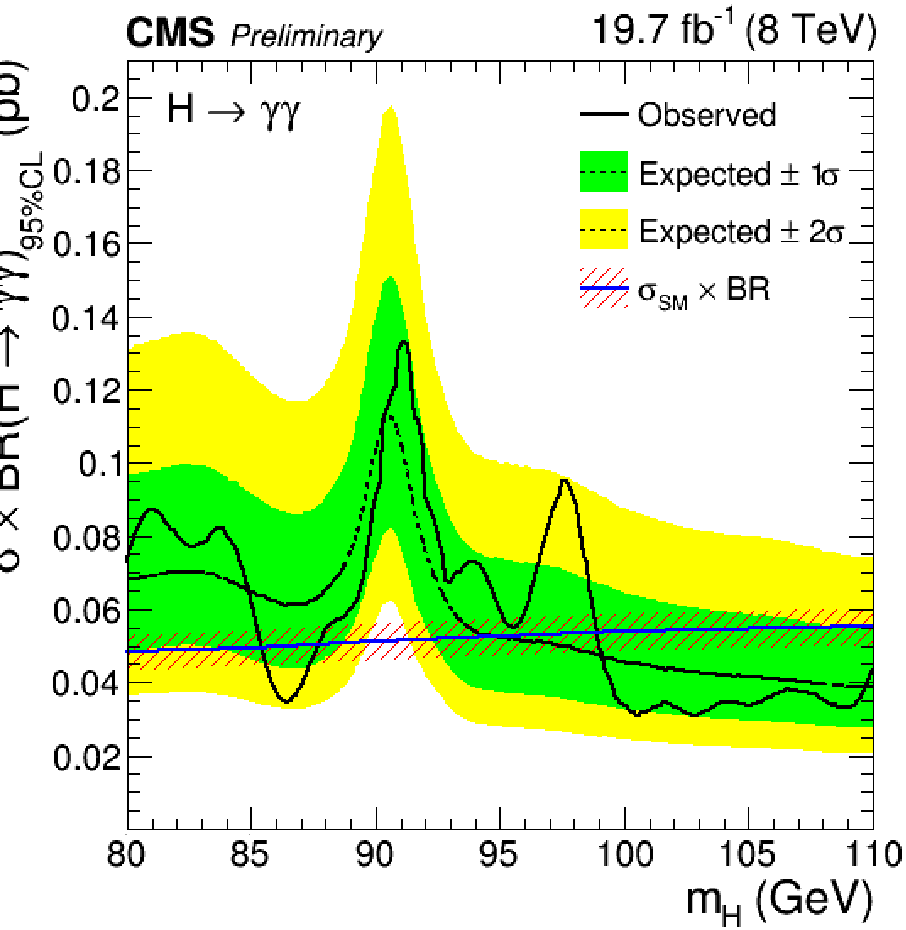
Limit from traditional LEP method

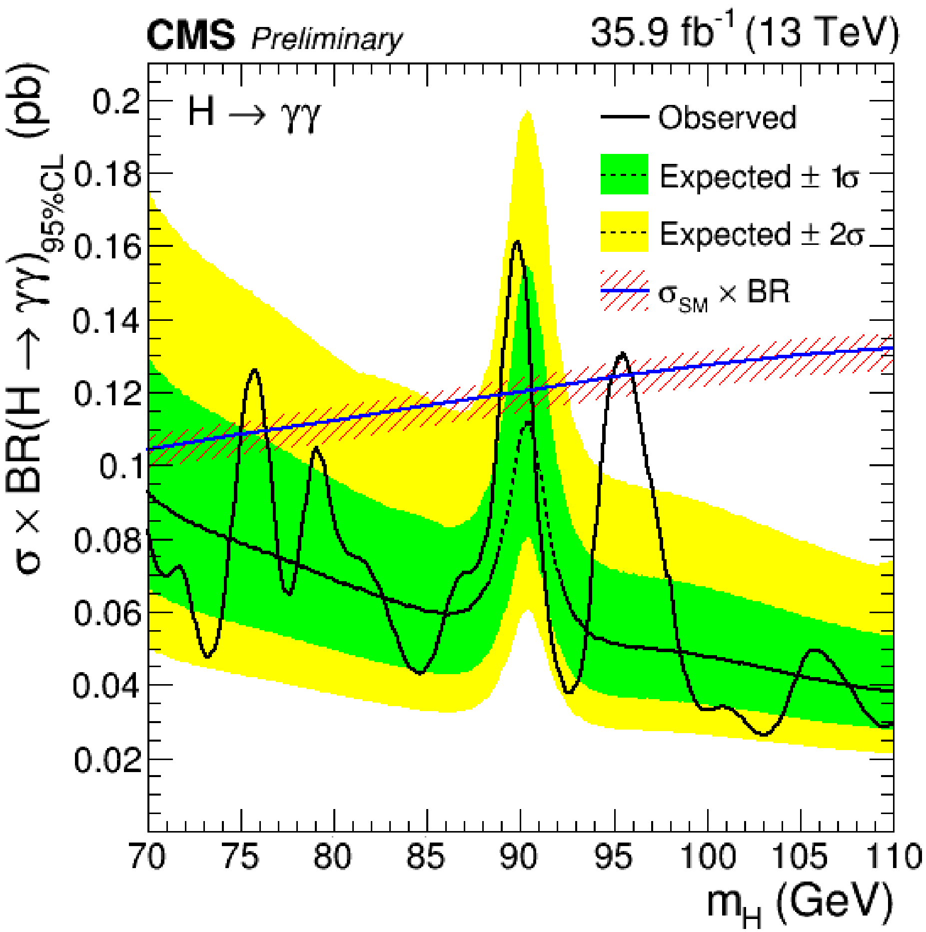
- **Limit from LEP:**



- **in the range of [80-100]GeV: Limit of 10% in g^2**
  - **30% deviation in g_{VVH}** → ***pretty large!***
- ***No additional constraint from LEP!***

CMS search for Φ → γ γ : limits from run1+2

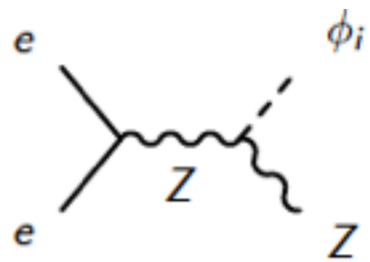




- **Interesting excess near 95 GeV from LEP and LHC**

Strategy

- Study process with a coupling $(g_{\Phi i VV})^2$
- Strategy: Higgsstrahlung process e+e- $\rightarrow$ Z$\Phi \rightarrow \mu^+\mu^-$bb



$$\sigma_{ee\to\phi_i Z} \sim \left| \cdots \right|^2 \sim g^2_{\phi_i ZZ}$$

- exploit a) 'LEP' method ($\Phi \rightarrow$ bb)

  b) 'recoil method' (Z$\rightarrow \mu^+\mu^-$, arbitrary decays of Φ)

1. step: validate with LEP expected limits
2. step: prospects for ILC at $\sqrt{s}$=250 GeV,…

- Use statistical method S95
- Interprete coupling limits for Φ

Statistical method: S95

- **Definition:**

$$S_{95} = \left[\frac{\hat{\sigma}_{ee\to\phi_i Z}}{\sigma^{\mathrm{ref}}_{ee\to\tilde{h}Z}}\right]_{\substack{g_{\tilde{h}ZZ}=g_{hZZ} \\ m_{\tilde{h}}=m_{\phi_i}}} = \frac{\hat{n}}{n_{\mathrm{ref}}} = \frac{\hat{g}^2_{\phi_i ZZ}}{g^2_{hZZ}}$$

- $\hat{\sigma}$ upper limit on cross section for 'background only' at 95%
- reference cross section: HZ in the SM
- Use Monte Carlo events (Whizard) for e+e- →μ+μ-bb
  - contains 'Signal' processes e+e- → ZΦ→ μ+μ-bb
  - 'Background only': faked via m_Φ beyond kinematical limit
  - method already used at LEP

LEP'03,
P. Bock 04,
P. Bechtle, Thesis 04

- Therefore test: compare with LEP expected limits

Comparison with LEP

- **Use LEP luminosities:**

Assmann '02

LEP1: LEP2:

$\sqrt{s}$/GeV	91.2	172	184	189	202	206
$\int dt\mathcal{L}/\mathrm{pb}^{-1}$	208.44	24.7	73.4	199.7	253	233.4

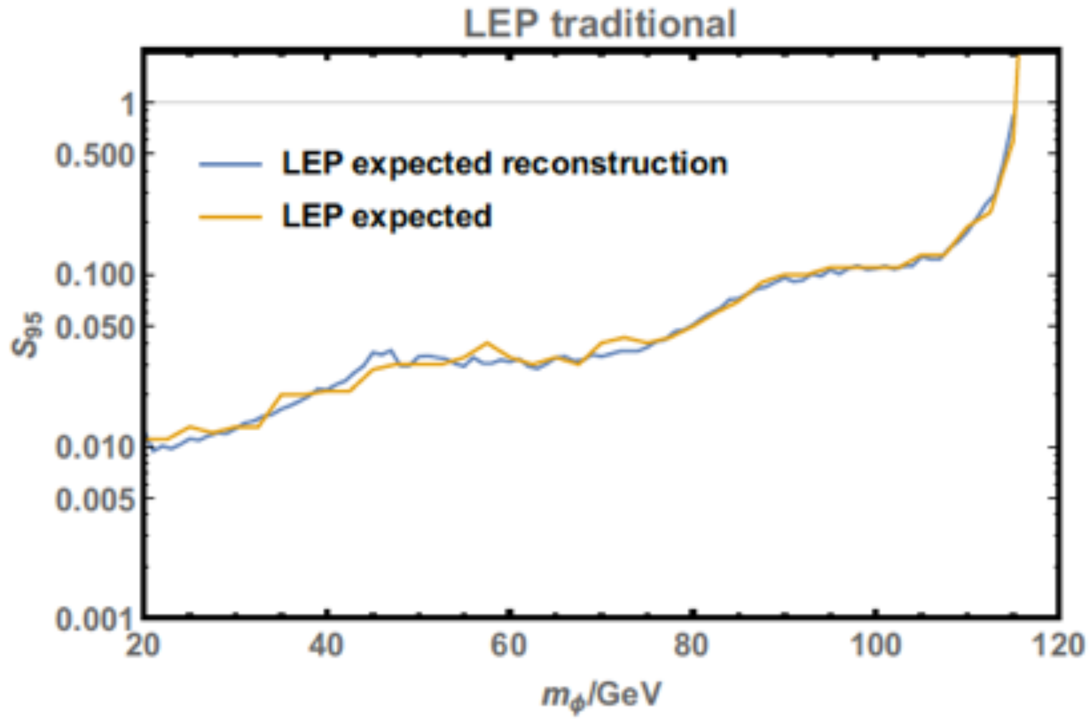
- **2 approaches:**
  - method at LEP:
    use bb-channel: determine 'B_{only}' and 'B+S'
    μμ-channel: just for validation

    'LEP traditional'

  - OPAL method via recoil:
    only use Z-decay into μμ
    → extrapolate to total LEP luminosity

LEP results: 'traditional'

- **method at LEP:**
  use bb-channel: determine 'B_{only}' and 'B+S',
  μμ-channel: just for validation



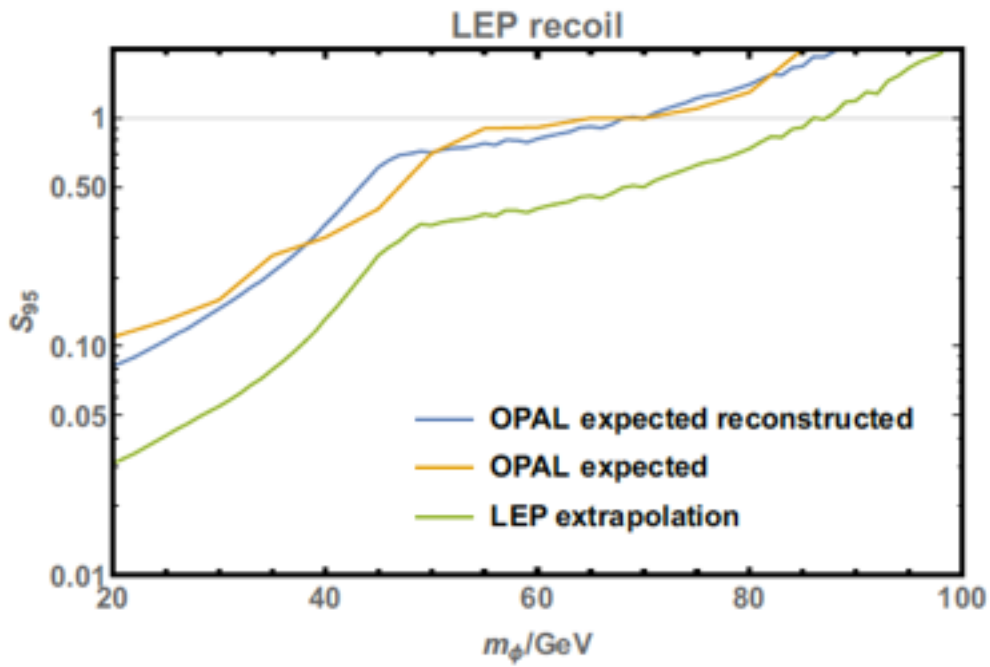
scaling factor ~4 used for LEP2 results to account for detector effects+ restriction to μμ

- **expected limits for LEP: well reconstructed**

LEP results: 'recoil'

- **OPAL method via recoil:**
  only use Z-decay into μμ and calculate $m_t^{(\text{rec})} = \sqrt{s + M_Z^2 - 2E\sqrt{s}}$
  → extrapolated to total LEP luminosity

OPAL '02

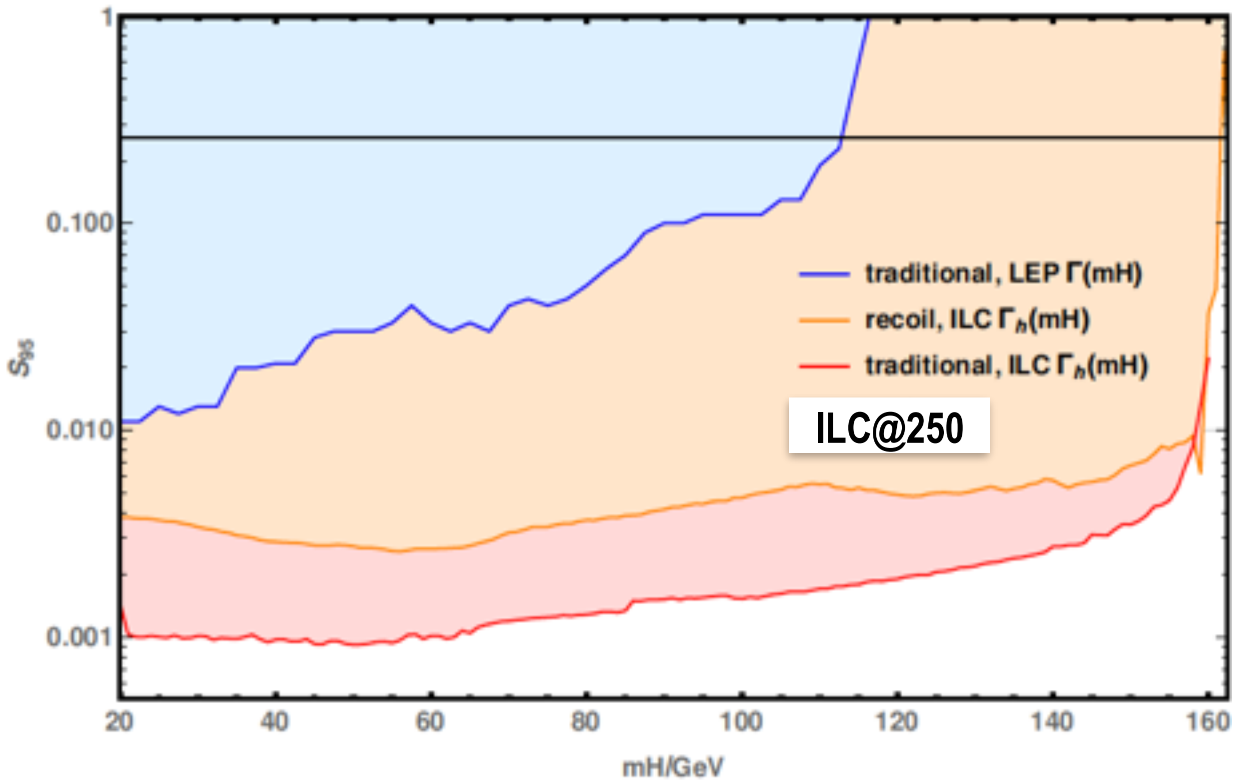


- **Rather well reconstructed: with efficiency from OPAL of 30%, no scaling needed (effects from neglecting hadronization and detector effects roughly compensated by neglecting ee channel)**

- ***Now extrapolation for ILC***

Application to ILC

- Combined limits for ILC at $\sqrt{s}$=250 GeV, (-80%,+30%), $\mathscr{L}$=2000fb^{-1}



Projection from future LHC accuracy on couplings of state at 125 GeV

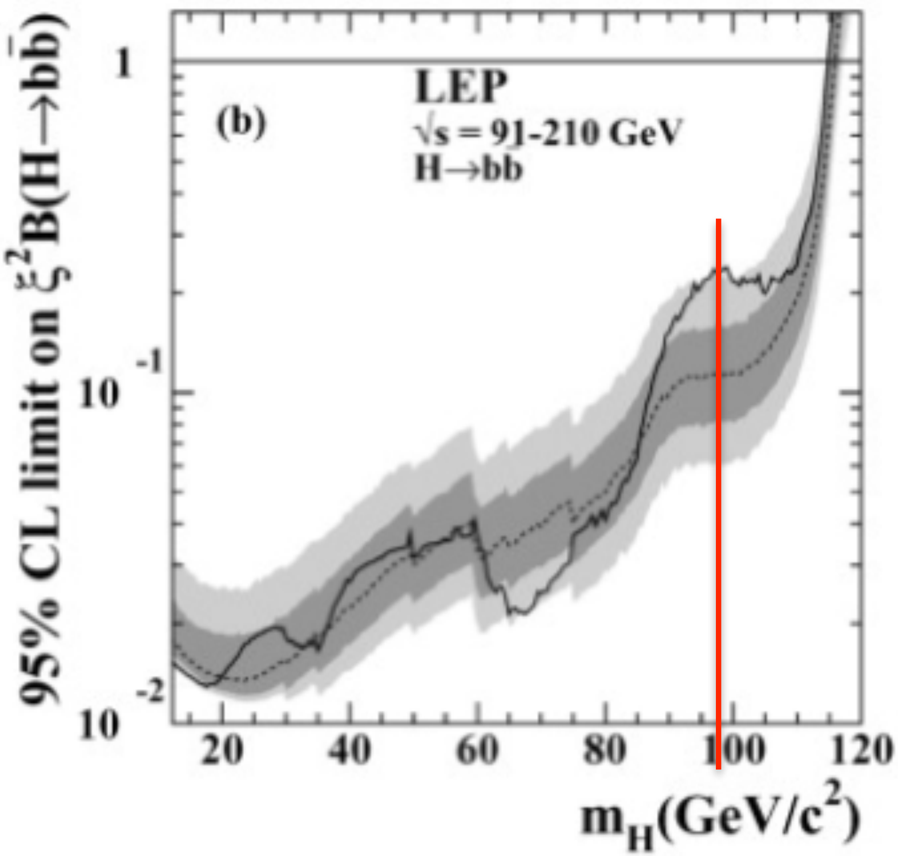
Klute ea '13,Lopez-Val ea '13

- *S95 ∈ [0.001-0.002] ('traditional' ILC) and [0.003-0.005] ('recoil',ILC)*

→ *g_{h1Z}/g^{SM}_{HZ} ∈ [0.032-0.045] and [0.055- 0.071]*

What's about a 'cms'-light higgs?

- **S95 @ LEP in H→bb:**



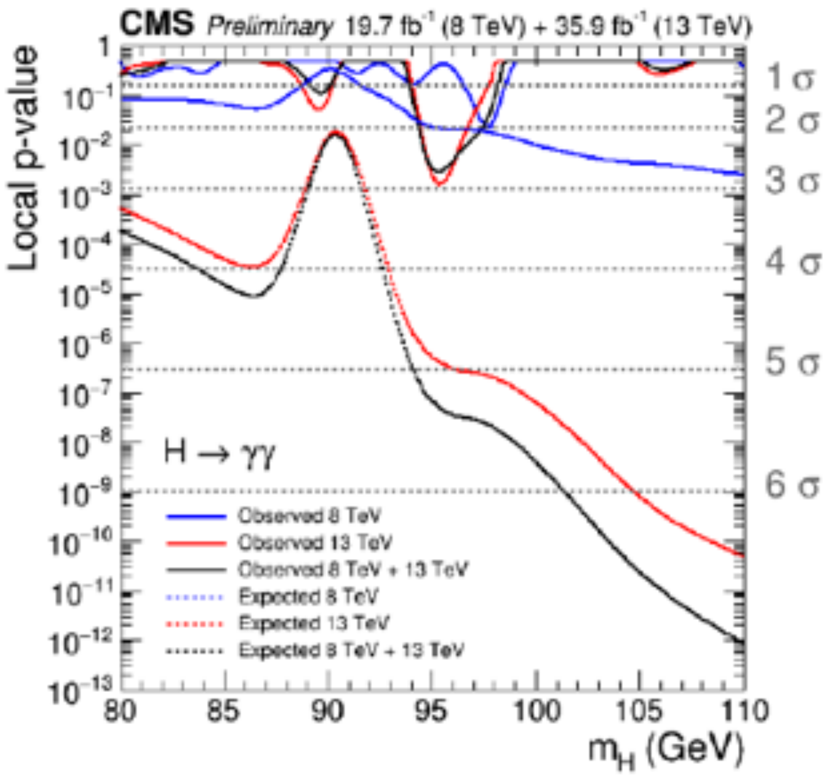
- ***Interesting region around m_H ~ [95-97] GeV ….. ?!?***

CMS results

Sijing Zhang, CMS@LCWS2017

h-->γγ (80-110 GeV) Runs 1+ 2

New!



CMS PAS HIG-17-013

8 TeV: Excess with ~2.0 σ local significance at m=97.6 GeV

13 TeV: Excess with ~2.9 σ local (1.47 σ global) significance at m=95.3 GeV

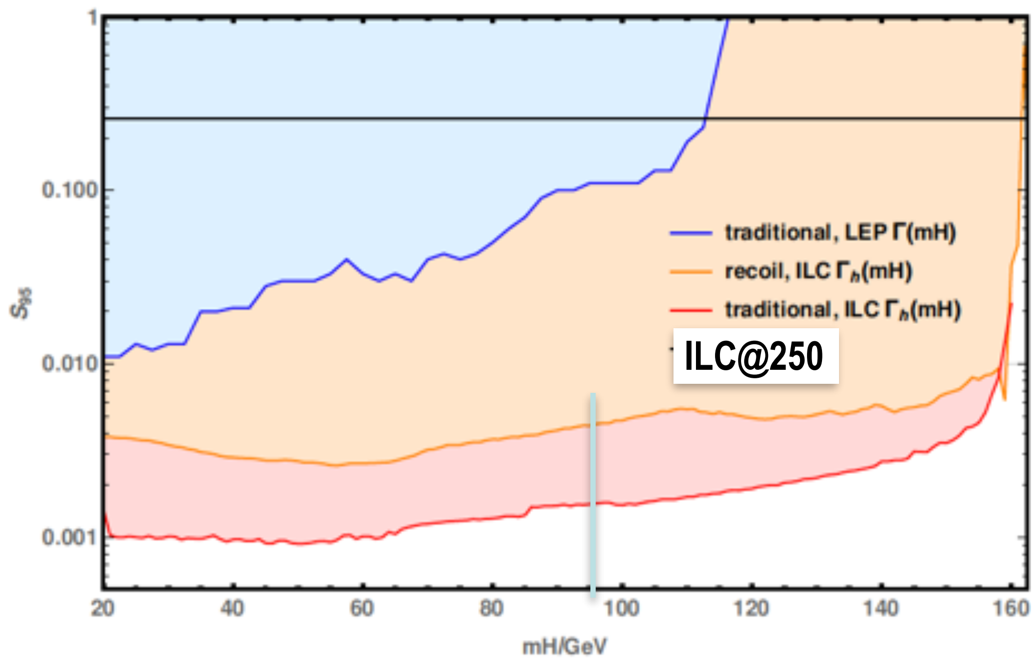
8TeV+13 TeV: Excess with ~2.8 σ local (1.3 σ global) significance at m=95.3 GeV

More data are required to ascertain the origin of this excess

- ***Of course, not overwhelming, but room for visions,….***

‘cms-Higgs’ at ILC?

- If a signal around m_H~95 GeV would be real, how sensitive to non SM-coupling would the ILC with √s=250 GeV?



- *S95 =0.0015, i.e. g_{h1Z}/g^{SM}_{HZ}=3.9%*
- *Sensitive to deviations within 2HDM, MSSM, NMSSM, etc.*

Great potential for accessing unexplored regions, in part. LEP+cms excess!

Conclusions

- Sum rule in $g_{VV\Phi}$ is very restrictive! (since H125~SM-like)
- Used S95: method validated via LEP data
  - in [80-100] GeV range: LEP sensitive to >30% deviations in $g_{VV\Phi}$
  - two aproaches: LEP 'traditional' bb and OPAL 'recoil' μμ
- Extrapolated to ILC $\sqrt{s}$=250 GeV with (-80%,+30%)
  - higher sensitivity for $m_H \in$ in [20,115] GeV than LEP/LHC !
  - excess at ~95 GeV: can be probed
  - even sensitive to >4% deviations in $g_{VV\Phi}$!
  - great potential for ILC@250GeV with polarized beams !