Search for new resonances in the diphoton final state in the mass range between 80 and 110 GeV in pp collisions at $\sqrt{s} = 8$ TeV

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Outline

- Higgs boson discovery at LHC
- Lightest scalar Higgs boson $h_1 \rightarrow \gamma\gamma$ in NMSSM
- Searching results with CMS 8TeV data
- Summary and Outlook

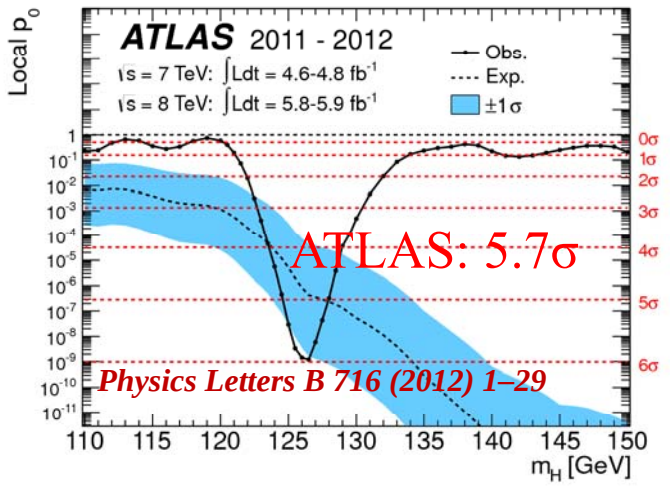
Higgs boson discovery

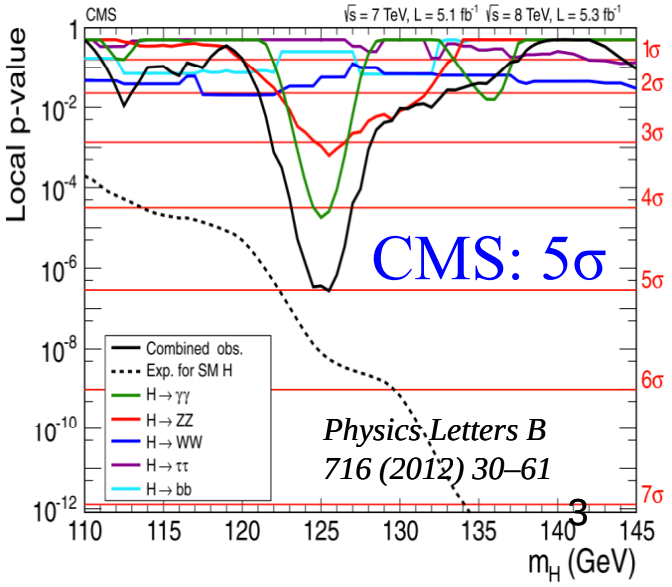
- In July 2012, ATLAS and CMS discovered a new particle (m~125 GeV).

- Is it the SM Higgs boson ?

  Or is this particle part of an extended scalar sector postulated by several extensions to the SM ?

- The discovery of additional Higgs boson-like particles will be an unambiguous sign of NEW PHYSICS !





NMSSM introduction (I)

➢ As suggested by theorists, we studied the scalar Higgs bosons in Next-to-Minimal Supersymmetric Standard Model (NMSSM).

➢ NMSSM predict 7 Higgs bosons: **3 CP-even (h_1, h_2 and h_3)**, 2 CP-odd (a_1,a_2), 2 charged.

➢In general, the Higgs sector of the NMSSM is described by the six parameters:

$$\lambda, \quad \kappa, \quad A_\lambda, \quad A_\kappa, \quad \tan\beta = \langle H_u \rangle / \langle H_d \rangle, \quad \mu_{eff} = \lambda \langle S \rangle \qquad (2)$$

$$\begin{aligned} -L_{soft} = {} & m_{H_u}^2 |H_u|^2 + m_{H_d}^2 |H_d|^2 + m_S^2 |S|^2 + m_Q^2 |Q|^2 + \\ & m_U^2 |U_R|^2 + m_D^2 |D_R|^2 + m_L^2 |L|^2 + m_E^2 |E_R|^2 + \\ & h_u A_u Q \cdot H_u U_R^c - h_d A_d Q \cdot H_d D_R^c - h_e A_e L \cdot H_d E_R^c + \\ & \lambda A_\lambda H_u \cdot H_d S + \frac{1}{3} \kappa A_\kappa S^3 + h.c. \end{aligned} \qquad (1)$$

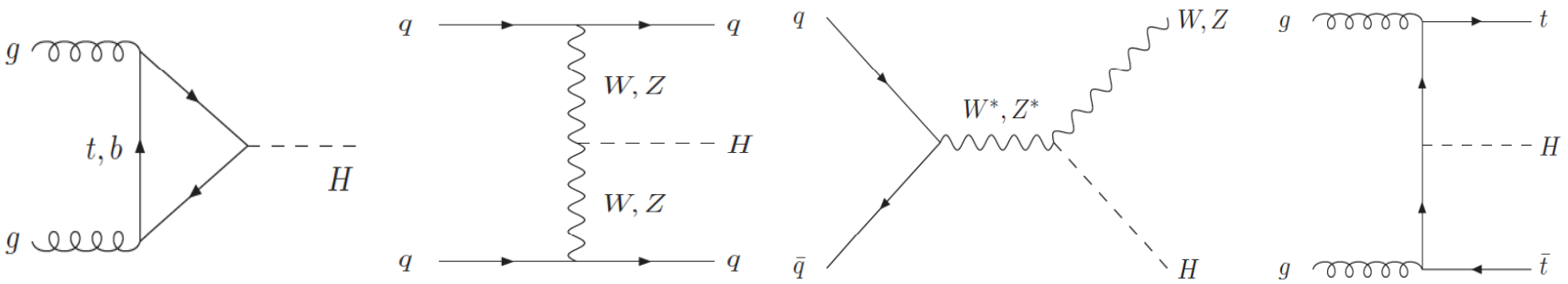
U. Ellwanger, C. Hugonie and A. M. Teixeira, Phys. Rept. 496 (2010):1-77

NMSSM introduction (II)

- We assume the next-to-lightest scalar Higgs bosob h_2 corresponds to the state observed in LHC.

- Focus on the signal strength of lightest Higgs boson h_1.

- Take all the four production modes into account.

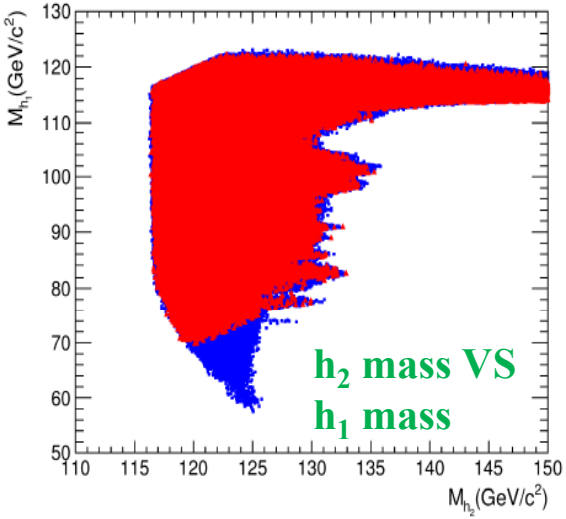


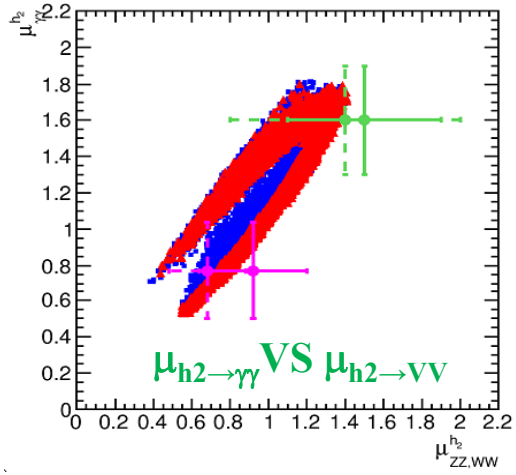
Exploit all four production modes

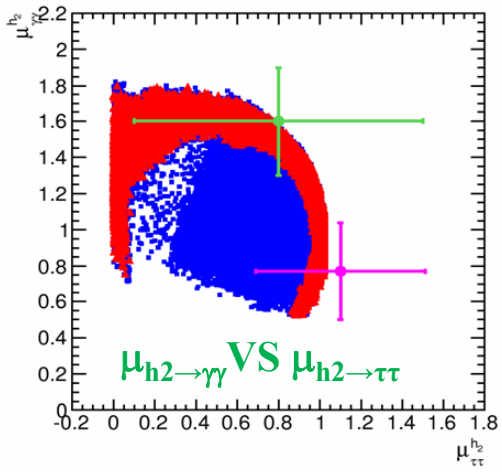
Scan results

➢ First show the NMSSM Higgs boson mass spectrum. Our parameter set can fulfill our motivation stated above.

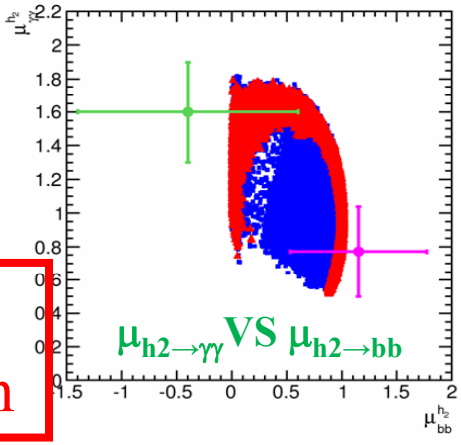
J. Fan et al. (IPNL/IHEP), Chin. Phys. C，38 (2014): 073101

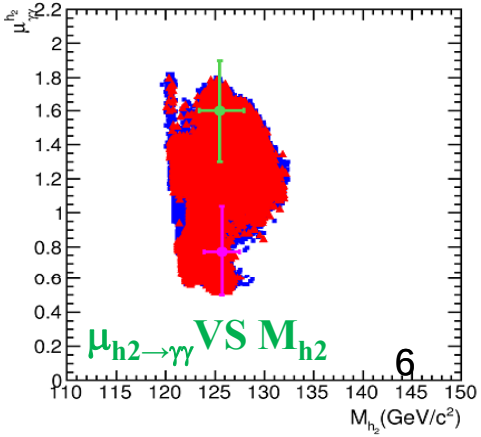






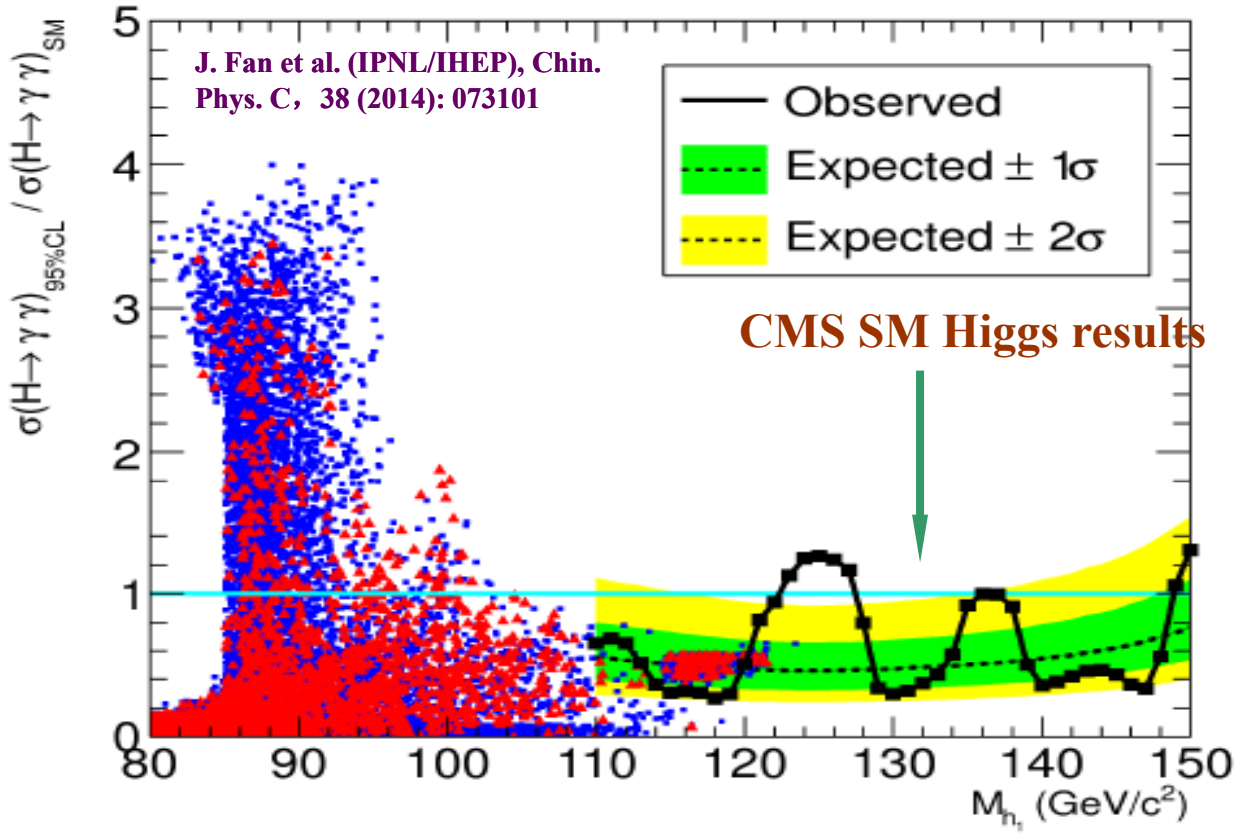
➢ Compare the h2 signal strength in γγ, ZZ, WW, ττ and bb decay modes with the ATLAS and CMS results: magenta cross for CMS and green for ATLAS.





NMSSM h_2 is compatible with the LHC-discovered Higgs boson

Lightest Higgs h_1 : $\sigma_{\gamma\gamma}/\ \sigma_{\gamma\gamma}^{SM}$ as function of M_{h1}



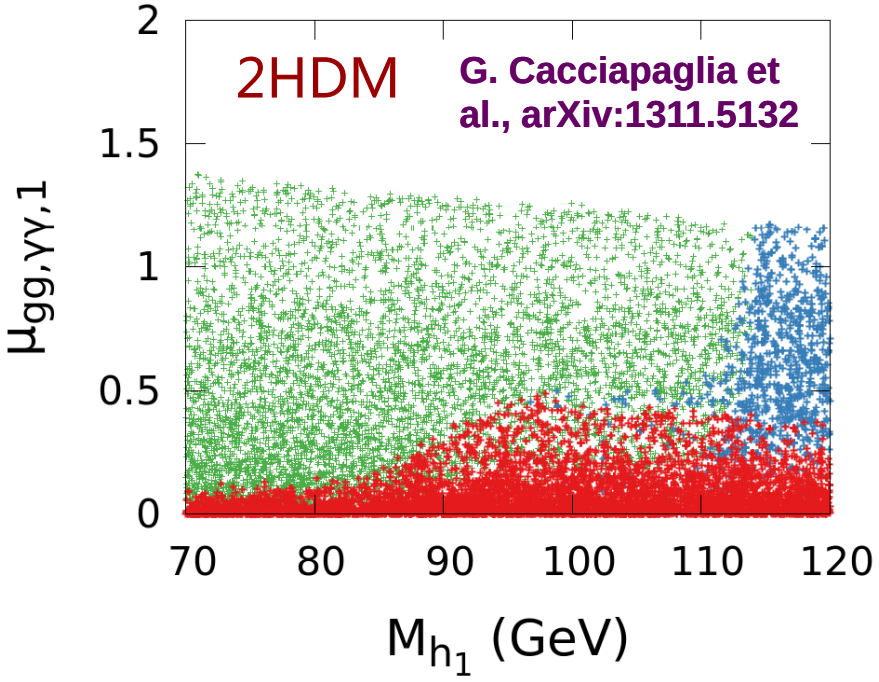
- The lightest Higgs h_1 signal strength can be enhanced by **a factor up to 4** compared with the corresponding SM value in the diphoton mass range 85 to 95GeV.

- The **first published paper** exclusively from the IPNL/IHEP team.

Additionally in 2HDM

➢Additionally, general Two-Higgs-Doublet-Models (2HDM) postulate the existence of additional light Higgs bosons and even admit the possibility that the observed H(125) is only the next-to-lightest Higgs.

Green (light grey) points are all points passing flavour and theoretical constraints
Blue points (grey) are a subset of those which also pass LEP constraints on h_1
Red (dark grey) points pass in addition the LHC couplings constraint on h_2



➢ So, we extend the CMS data analysis to the low- mass range down to 80 GeV, to search for possible additional Higgs bosons.

CMS search with 8TeV data

✓ We performed the search for new diphoton resonances with mass in the range of [80,110] GeV and with 8 TeV 19.7 fb^{-1} data .

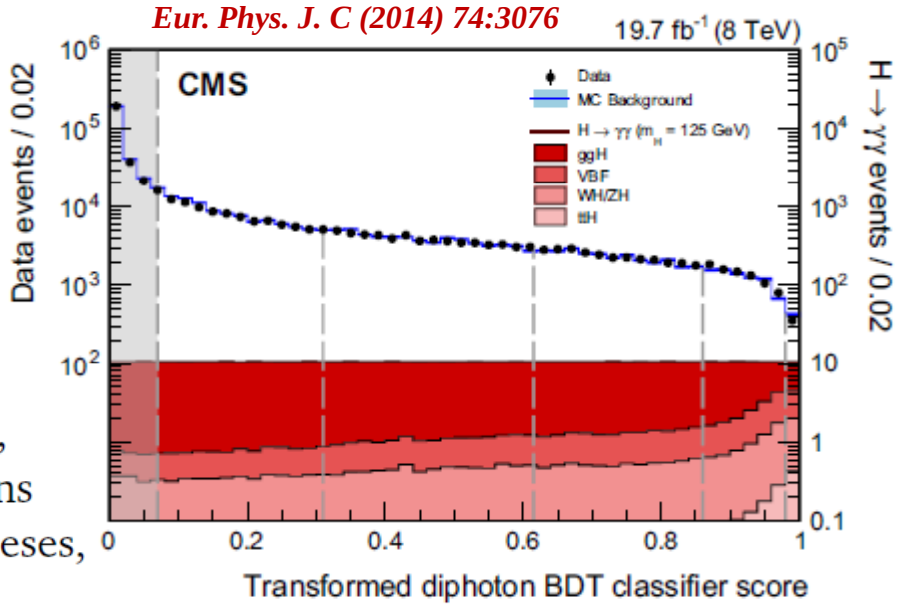
CMS PAS HIG-14-037

✓ Kinematic selections:

- $pt_{lead}/m_{gg} > (hlt_{lead} + 2\ GeV)/m_{\gamma\gamma min}) = 28/80$
- $pt_{trail}/m_{gg} > (hlt_{\mathbf{trail}} + 2\ GeV)/m_{\gamma\gamma \mathbf{min}}) = 20/80$
- $|\eta| < 2.5$ but excluding $1.4442 < |\eta| < 1.566$

✓ Events were split into 4 classes to improve the sensitivity, based on the **diphoton mass resolution and kinematics MVA** also used in the standard CMS H→γγ analysis

Input variables: pT/mγγ and η of both photons, $\cos(\Delta\phi_{\gamma\gamma})$, pho ID score, relative mass resolutions under correct/incorrect vertex selection hypotheses, vertex probability estimate

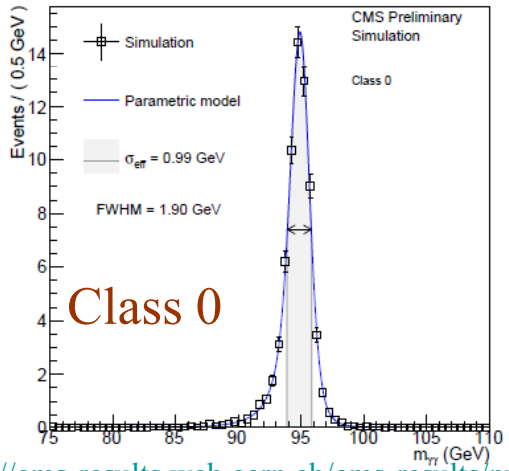


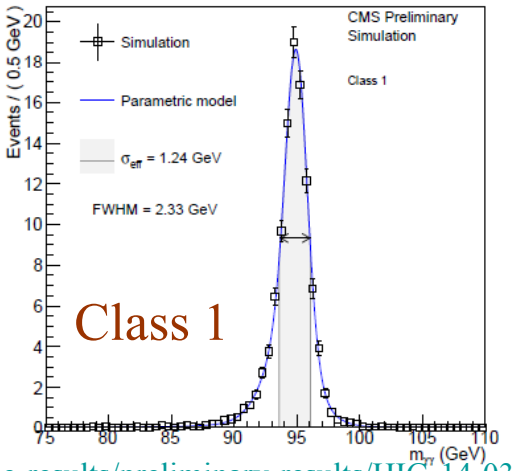
http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/HIG-14-037/index.html

Signal modelling

Parametric signal modelling procedure: Use a sum of Gaussian functions to fit signal MC at each mass point, for **each production process** in **each of the 4 event classes**

CMS PAS HIG-14-037





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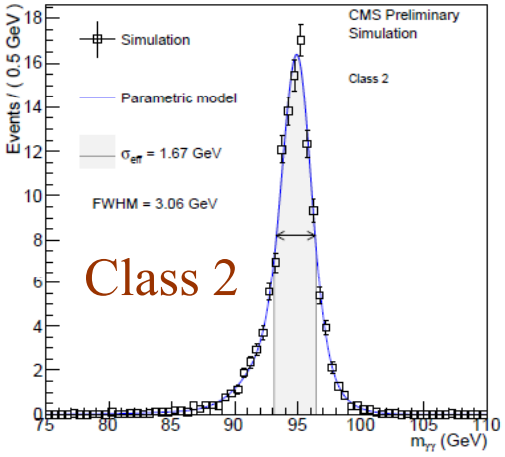
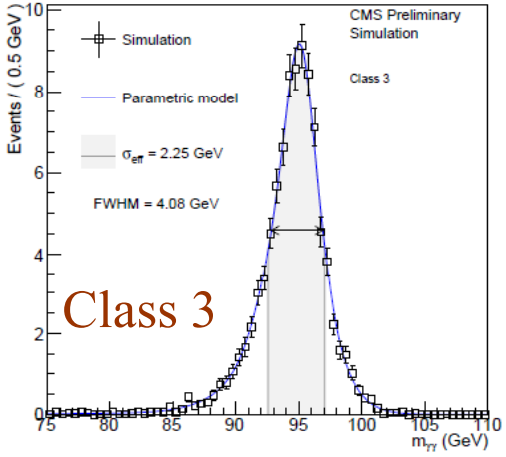
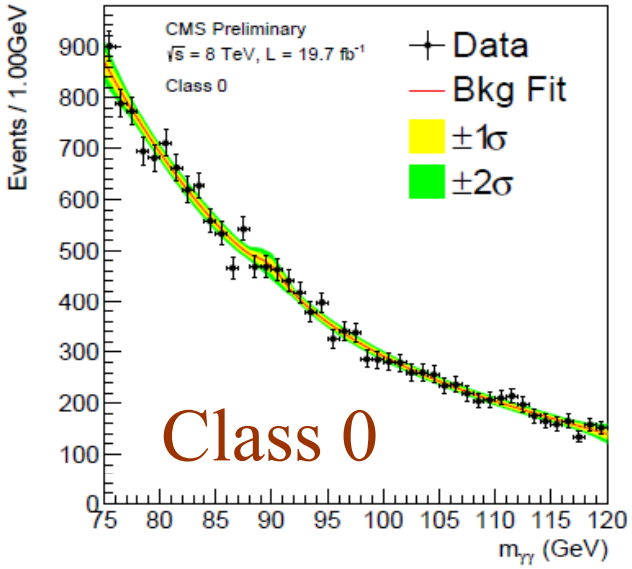
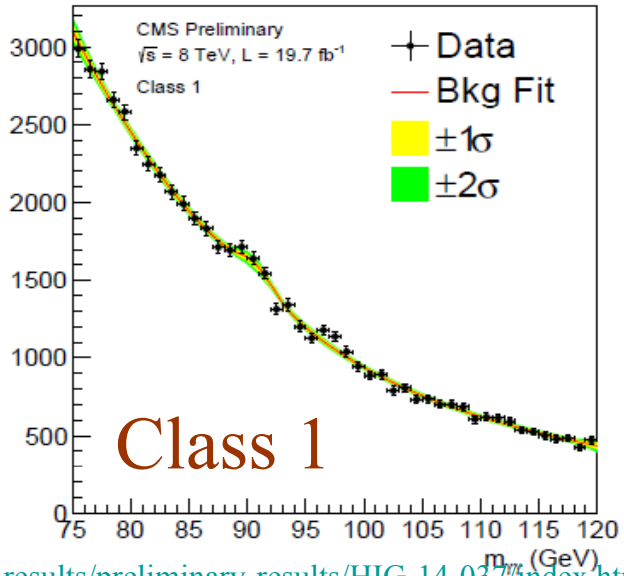




Background modelling

CMS PAS HIG-14-037





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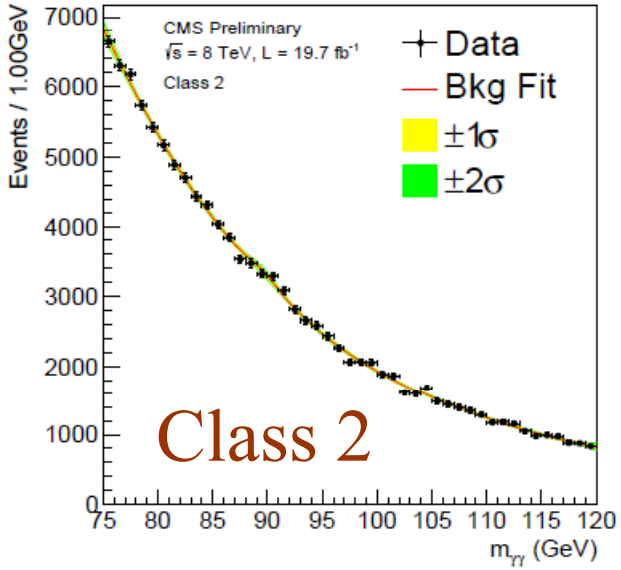
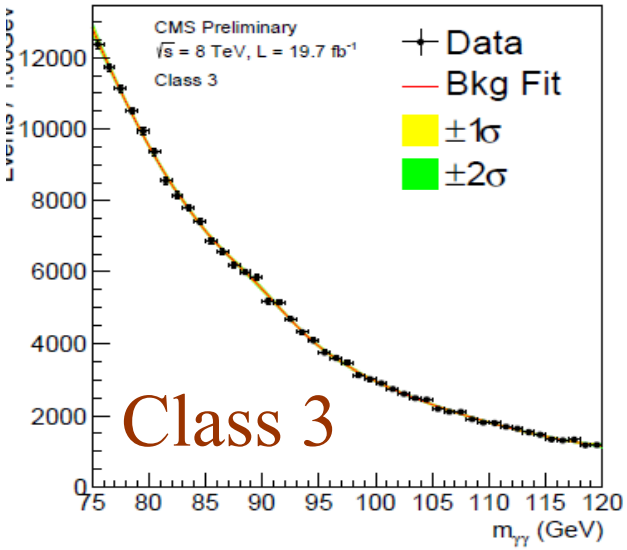


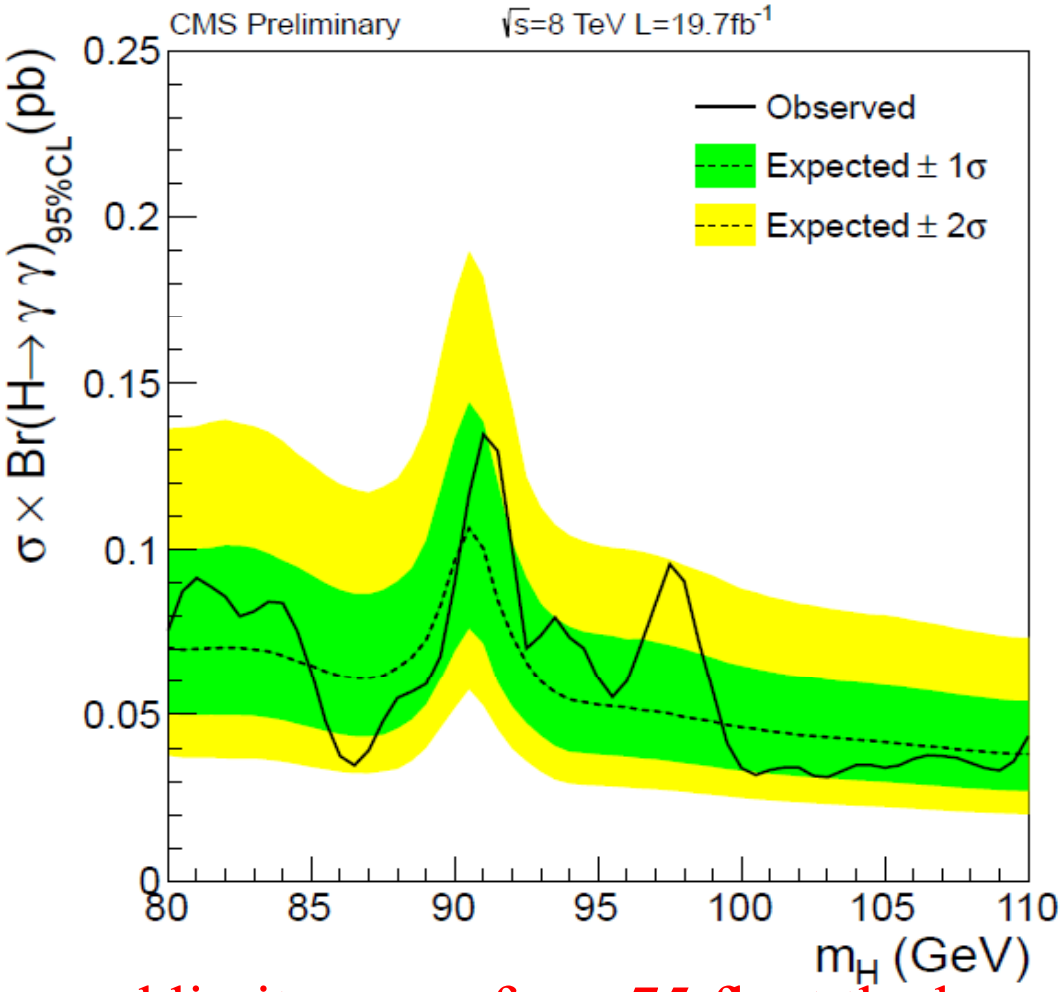


- Background model fits to data in the 4 event classes

- For each class, N^{th} order (N=4/5/5/5) of Bernstein polynomial function plus additional double sided Crystal Ball (DCB) function for Z→ee events where both electrons are mistakenly identified as photons

$$\mathrm{NBer(x)} + \mathrm{DCB(x)} = \sum_{i=0}^{N} \beta_i b_{i,N} + \mathrm{DCB(x)}$$

Upper limits on σ×BR

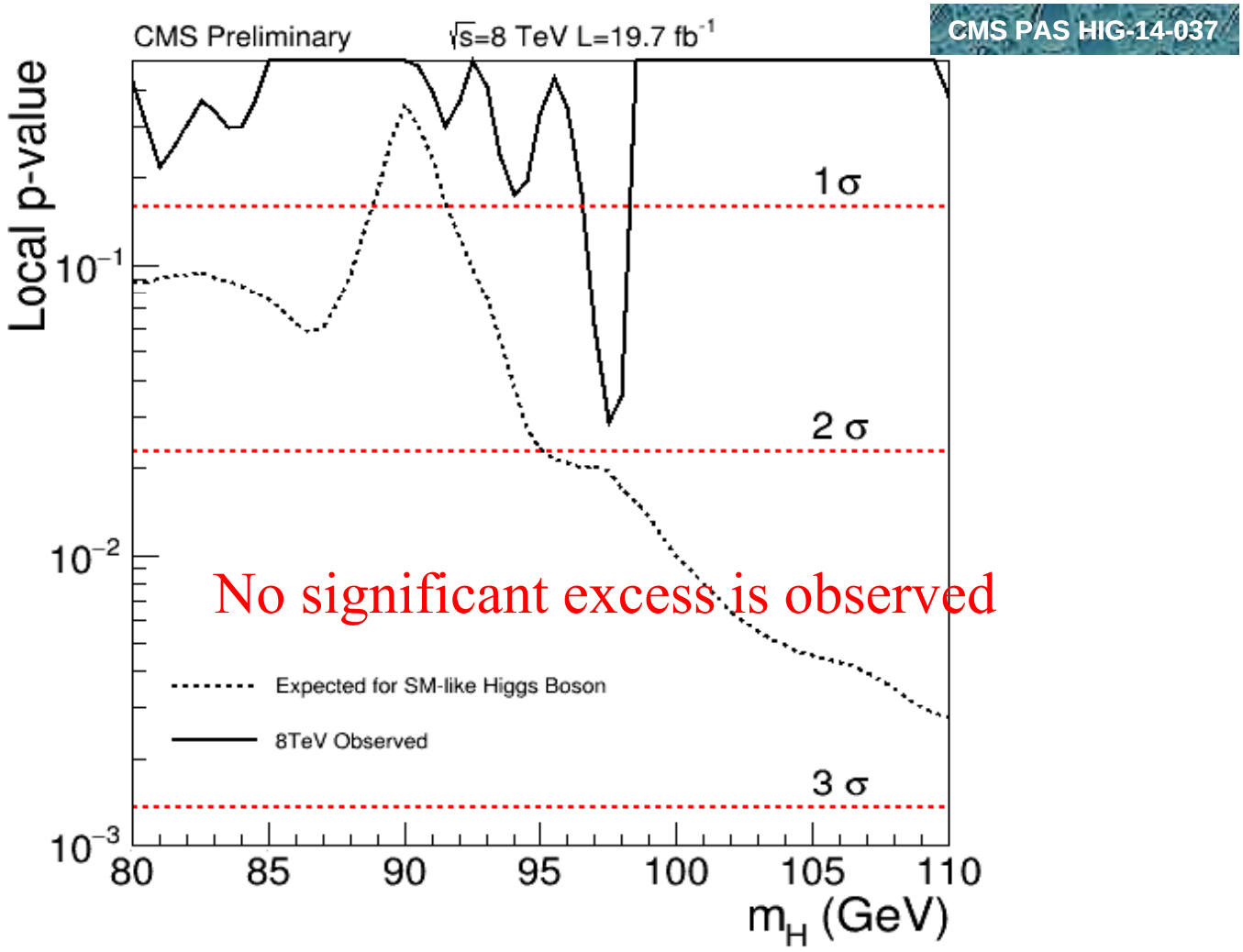


Statistical treatment for extraction of limits and p-values is the same as that used by all CMS Higgs boson search channels as well as for the combination of channels

Observed limit ranges from 75 fb at the hypothesis mass of 80 GeV to 40 fb at the hypothesis mass of 110 GeV

http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/HIG-14-037/index.html

Combined Local p-value



Maximum significance: ~1.9σ at m_H=97.5 GeV

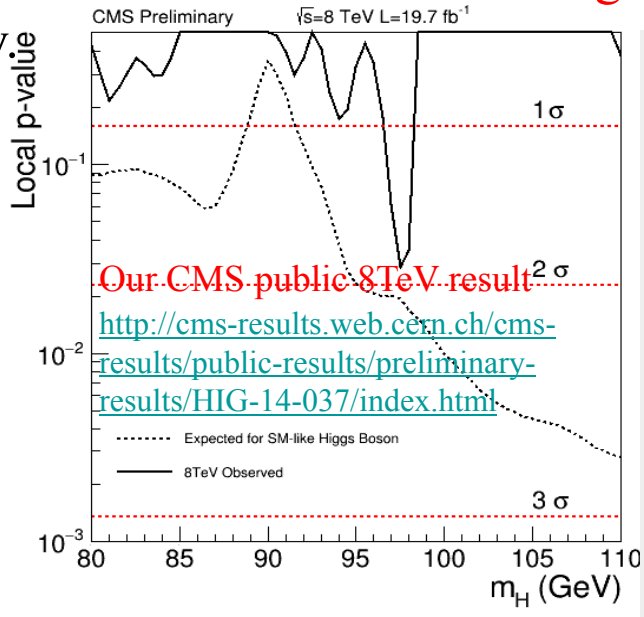
http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/HIG-14-037/index.html

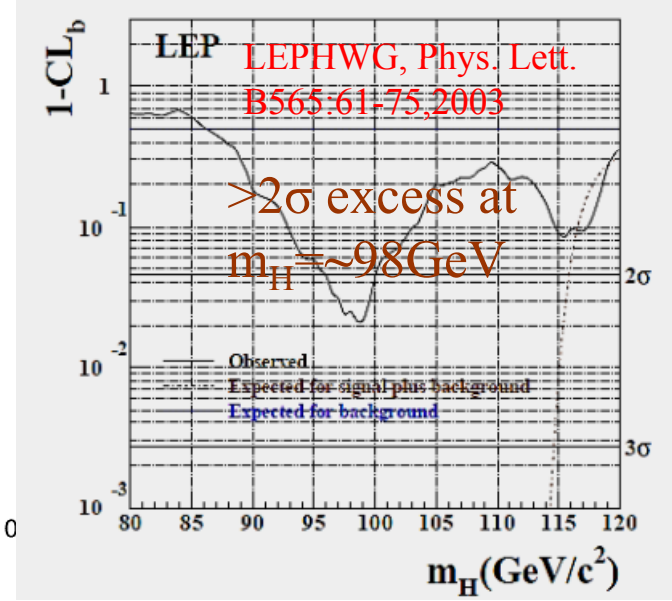
Summary and Outlook

- In our scan of NMSSM (**Chin. Phys. C，38 (2014): 073101**), the signal strength of the lightest scalar Higgs boson h_1 with an enhancement in SM-normalized σ×BR up to a factor ~4 is possible, in the mass range m_{h1}=[85,95]GeV.

- The searches for new resonances in γγ channel (**CMS PAS HIG-14-037**) are performed in the range of [80,110]GeV with 19.7/fb of data at √s=8TeV: **First public CMS data analysis to have been entirely and solely the work of the IHEP-IPNL team**.

- With 13TeV and future 14 TeV collisions at LHC, the signal for the low-mass NMSSM Higgs boson h1 could still be interesting with higher collision energy and integrated luminosity.





The End

Thank you!

谢谢！

Merci!