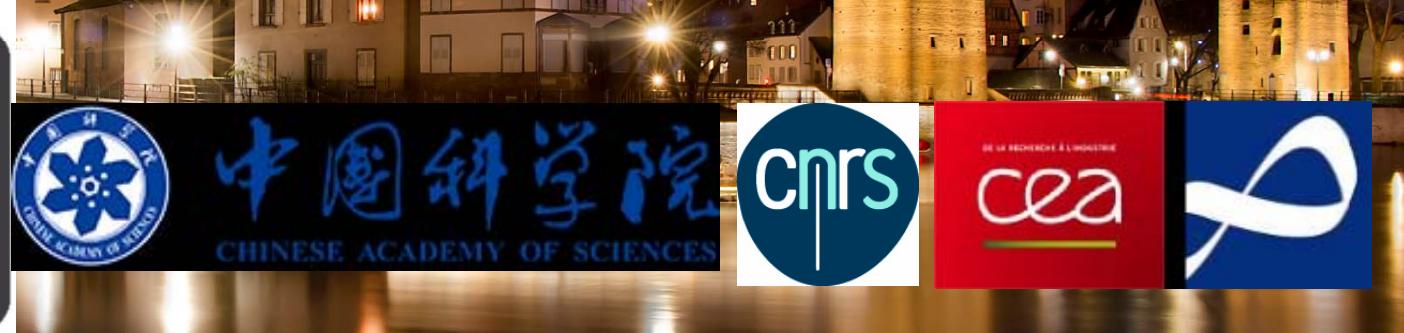
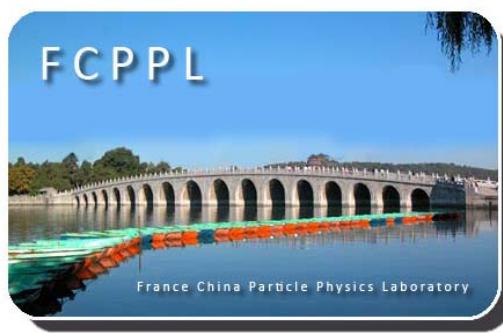


IPNL/IHEP collaboration at CMS

Guoming Chen (1), Suzanne Gascon-Shotkin (2), Junquan Tao(1)

(1) Institute of High Energy Physics, Chinese Academy of Sciences
(2) Institut de Physique Nucléaire de Lyon, Université Claude Bernard Lyon 1 IN2P3-CNRS



9th France-China Particle Physics Workshop

IPHC, STRASBOURG

30th March – 1st April, 2016



Outline



- A brief history about the IPNL/IHEP collaboration
- Work together for
 - ❖ $H \rightarrow \gamma\gamma$ with lots of photon studies for the **Higgs discovery on July 2012, Run 1 $H \rightarrow \gamma\gamma$ legacy paper** and **first 13 TeV results**
 - ❖ Search for a **2nd boson** with $m < 110$ GeV and $\gamma\gamma$ decay
 - ❖ $\gamma\gamma + X$ Differential Cross-section Measurements
- Summary and FCPPL Proposal for 2016
- Acknowledgements



A brief history of IPNL/IHEP collaboration



- Our collaboration started in year 2007 : my great honor as the first IHEP student to work with IPNL
- Participation to the organizing committees of the founding workshop at IHEP in 2006 and of all the FCPPL workshops (IPNL co-chaired the 3rd FCPPL workshop)
- First co-phD student defended last April (Dr. Jiawei FAN) with also the support from the CSC scholarship
- Congratulation to Sijing ZHANG as the first CMS awardee of the Eiffel scholarship to spend 10 months at IPNL starting October 2016, and thus will become our 2nd co-PhD student !

IHEP Beijing → IPN Lyon:

- ⦿ TAO Junquan (Doctoral Student)—January-May 2007 (IN2P3)
- ⦿ ZHANG Zhen (Doctoral Student)— November 2007-May 2008 ([FCPPL](#))
- ⦿ TAO Junquan (Postdoc)—March-August 2009 (PICS 4162)
- ⦿ XIAO Hong (Doctoral Student)—January-July 2010 (PICS 4162)
- ⦿ FAN Jiawei (Doctoral Student)---April-October 2011 (PICS 4162)
- ⦿ XIAO Hong (Doctoral Student)---June-July 2011 ([FCPPL](#))
- ⦿ FAN Jiawei (Doctoral Student)—August-September 2012 ([FCPPL](#)) + October 2012-April 2014 (CSC Scholarship) + November-December 2014 ([FCPPL](#))
- ⦿ SHEN Yuqiao (Doctoral Student)—May-September 2013 ([FCPPL](#))
- ⦿ ZHANG Sijing (Doctoral Student)—October-December 2015 (partly by [FCPPL](#))

IPN Lyon → IHEP Beijing:

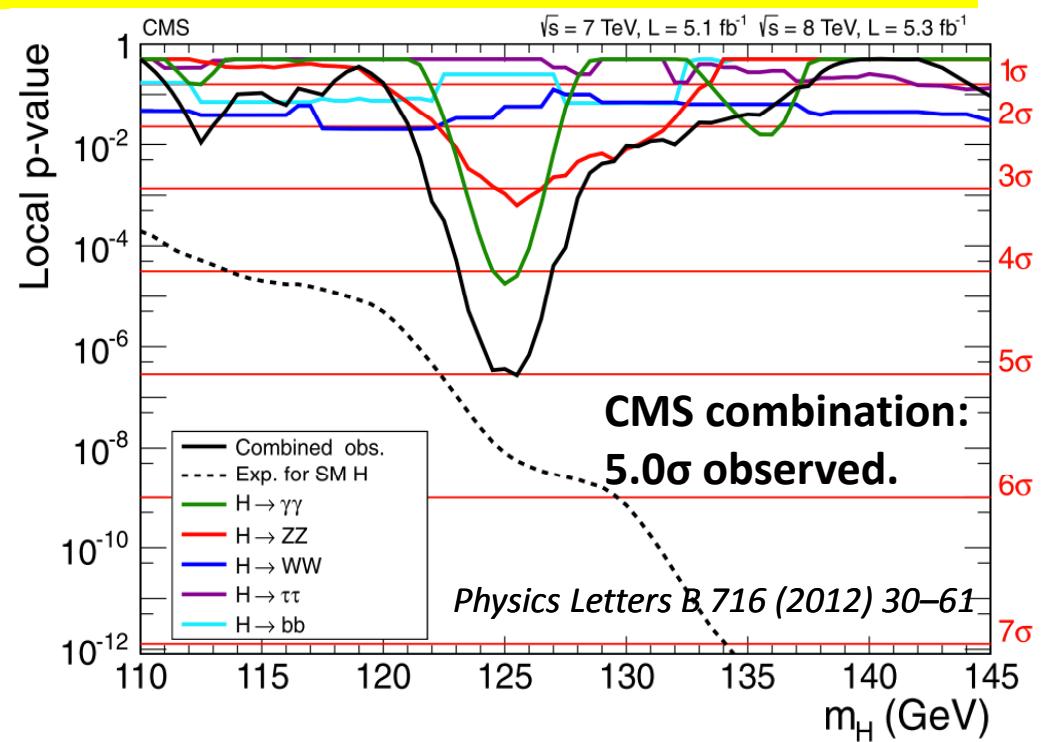
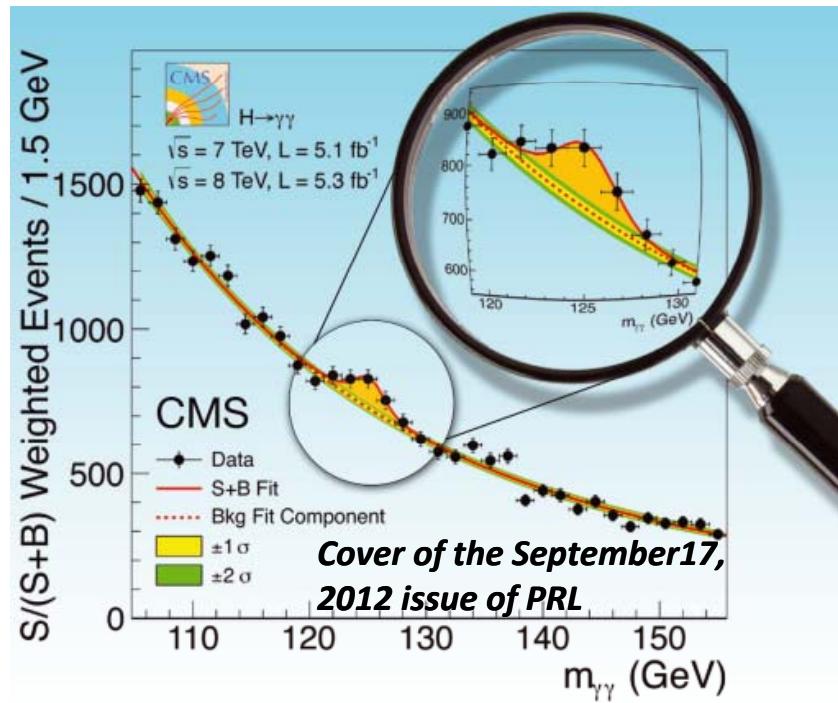
- ⦿ Nicolas CHANON (Doctoral Student)—March-May 2009 ([FCPPL](#))
- ⦿ Hugues BRUN (Doctoral Student)—October-December 2010 ([FCPPL](#))
- ⦿ Olivier BONDU (Doctoral Student)– April-May 2011 ([FCPPL](#))
- ⦿ Louis SGANDURRA (Doctoral Student)-October-December 2012 ([FCPPL](#))
- ⦿ Camilo CARRILLO (Postdoc)-September 2014 ([FCPPL](#))



Higgs discovery on 4th July 2012



Thanks largely to FCPP support, the CMS groups of IHEP and IPNL, working together since 2007, were able to contribute significantly to the discovery of a Higgs boson through analysis of the $H \rightarrow \gamma\gamma$ channel.



But this reward came only after years of painstaking work in many areas of study of photons....



Electromagnetic cluster and Photon Commissioning for Run 1 and Run 2



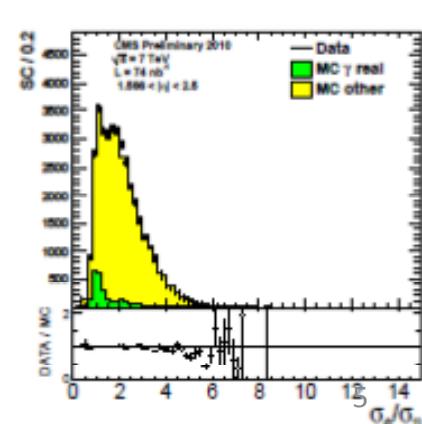
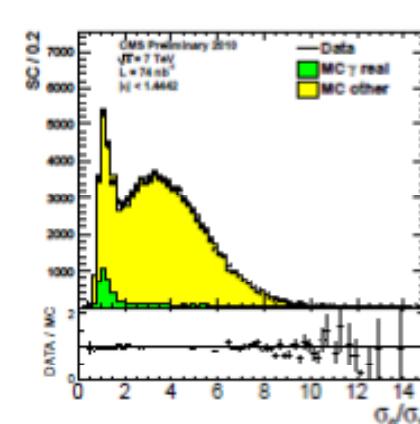
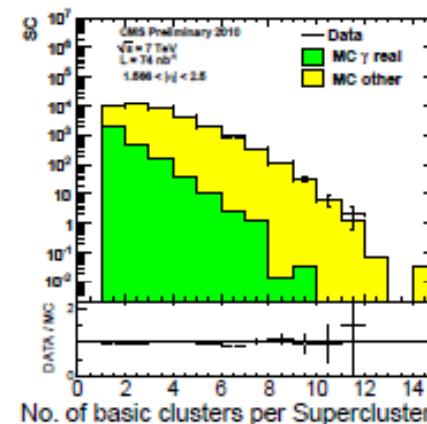
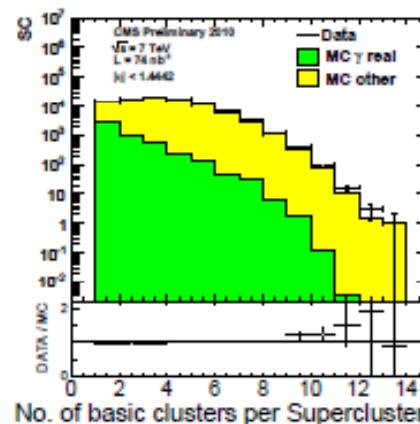
(2008...): (O. BONDU, H. BRUN, A. FALKIEWICZ, M. LETHUILLIER, S. GASCON, J. FAN, J. TAO, H. XIAO, Z. ZHANG, B. COURBON

- Run 1 startup (Public results EGM-10-001 and EGM-10-005):
 - Check understanding of key observables for photon reconstruction and identification: Cluster constituent multiplicities, Cluster shapes and Isolation energies
 - Check goodness of GEANT4 simulation of EM shower
- Run 2 startup: Reoptimize and validate regression energy corrections for photons
- Upgrades Technical Proposal: Check photon performance

Loose Photon Id

Variable	Barrel	Endcap
pixel seed	require none	
E_T	30 GeV	
Tracker Iso	2.0 GeV	
ECAL Iso	4.2 GeV	
HCAL Iso	2.2 GeV	
H/E	0.05	
σ_{inj}	0.01	0.03

$$\sigma_\eta = \sqrt{\sum_{i=1}^n \frac{E_i}{E_{SC}} (\eta_i - \eta_{SC})^2}$$





Energy scale and photon validations



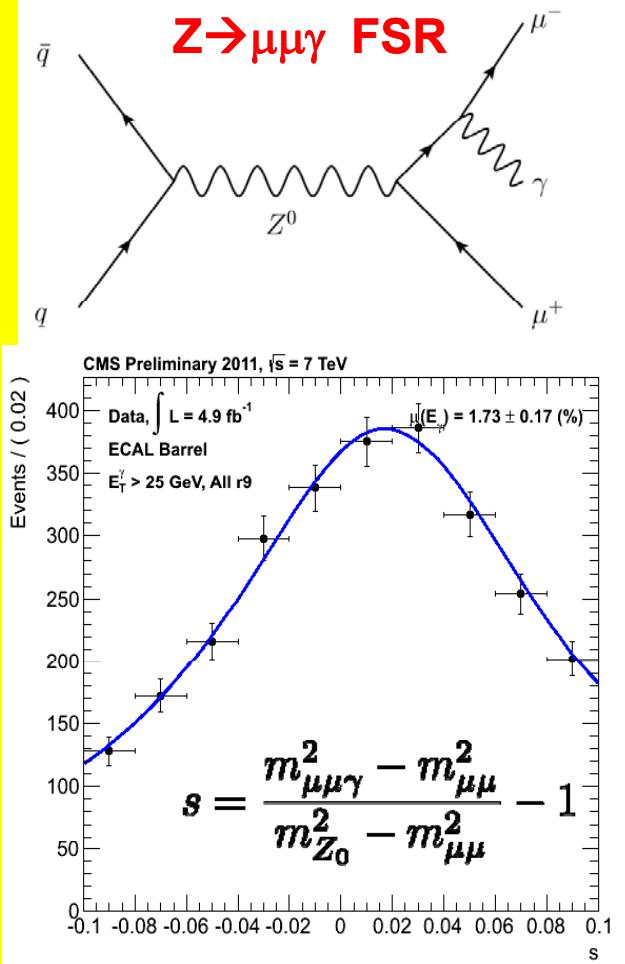
(2007-..): (C. BATY, O. BONDU, H. BRUN, M. LETHUILLIER, S. GASCON, L. SGANDURRA, J. FAN, Y. SHEN, J. TAO, H. XIAO, Z. ZHANG, S. ZHANG)

- Isotropic source of relatively high-pT γ enables the extraction of

- **Photon energy scale:** one of two CMS-approved methods

- **Photon energy correction validation**
 - **Photon trigger efficiency**

- Result used to estimate systematic error on photon energy scale for first Measurement of the $W\gamma$ and $Z\gamma$ inclusive cross-sections with 2010 dataset (Phys. Lett. B701, 535-555 (2011))
- Used to validate understanding of photon ID MVA input variables and output score, and compute electron veto efficiency for the $H \rightarrow \gamma\gamma$ discovery analysis (Eur. Phys. J. C 74 (2014) 3076), 7 TeV diphoton cross section measurements (Eur. Phys. J. C 74 (2014) 3129), and the first $H \rightarrow \gamma\gamma$ result with Run2 13TeV data (HIG-15-005)



CMS-DP-2011/008,
CMS-DP-2012/024

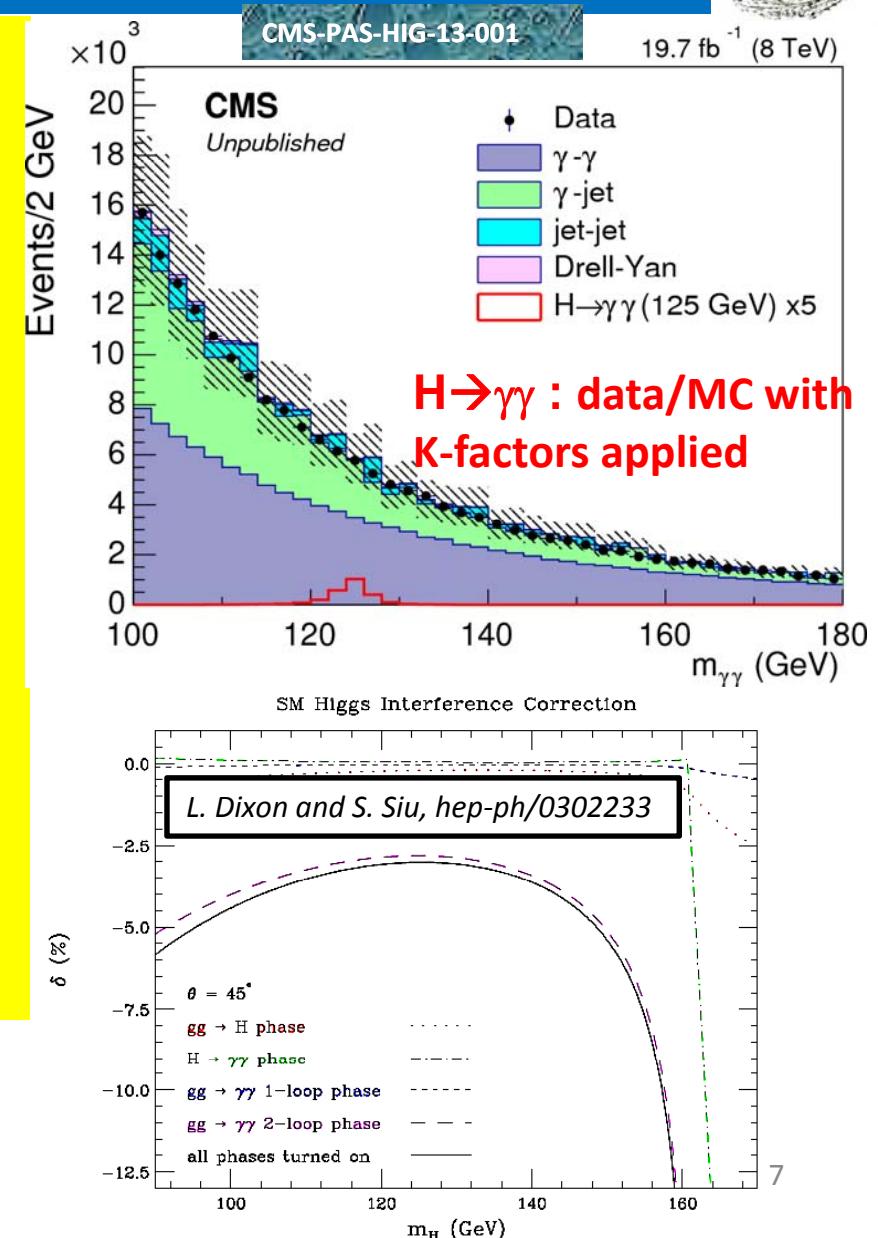


H $\rightarrow\gamma\gamma$: Impact of higher-order calculations on kinematical observables in 2 γ processes



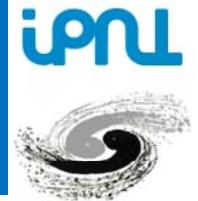
(2007-...): (O. BONDU, N. CHANON, M. LETHUILLIER, S. GASCON, J. TAO, Y. SHEN)

- Implemented doubly-differential reweighting scheme with dynamical **k-factors** for H $\rightarrow\gamma\gamma$ signal (NNLO/NLO) and diphoton background (NLO/LO)
- Contributed significantly to LHC Higgs XS WG 'Yellow Report 2: Handbook of Cross sections: Differential Distributions (CERN-2012-002, arXiv:1201.3084), furnished the integrated k-factors for the analysis
- Evaluated the effect of **destructive signal-background interference** δ from digluon-induced processes (gg \rightarrow H $\rightarrow\gamma\gamma$ / gg $\rightarrow\gamma\gamma$)





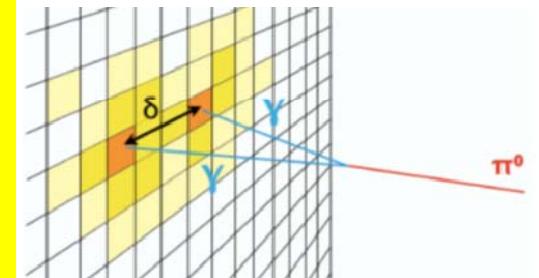
$H \rightarrow \gamma\gamma$: γ/π^0 discrimination and photon identification



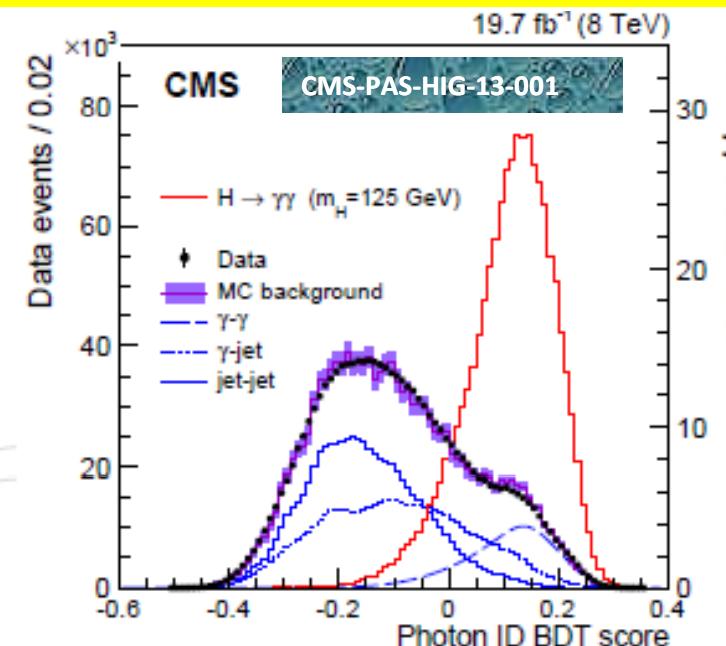
γ/π^0 discrimination (2008-...): (H. BRUN, N. CHANON, G. CHEN, J. FAN, S. GASCON, M. LETHUILLIER, Y. SHEN, J. TAO, H. XIAO, Z. ZHANG) for both converted and non-converted photons

Exploit particular cluster and shower shape observables proper to our crystal calorimeter in a photon id using multivariate approach (boosted decision tree).

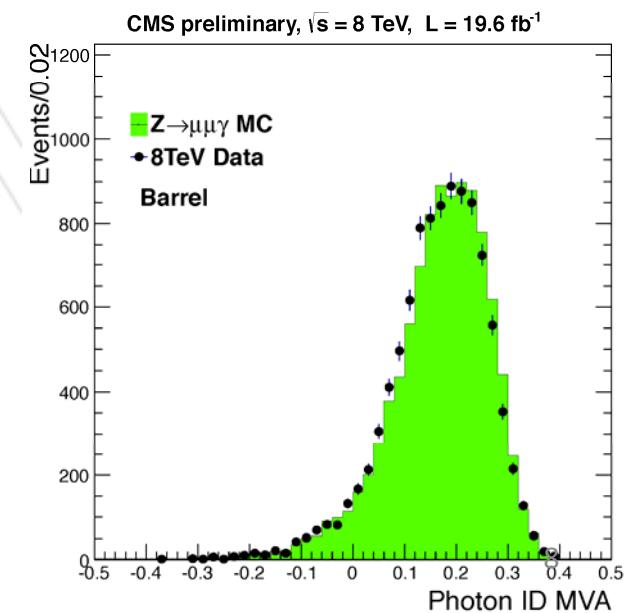
Photon ID BDT: Direct input to the overall MVA analysis for the $H \rightarrow \gamma\gamma$ search in both Run1 and Run2, but possibly also useful in other analyses using photons.



Fight reducible background, mostly from π^0 (~30% after preselection)



Validation on $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$ events



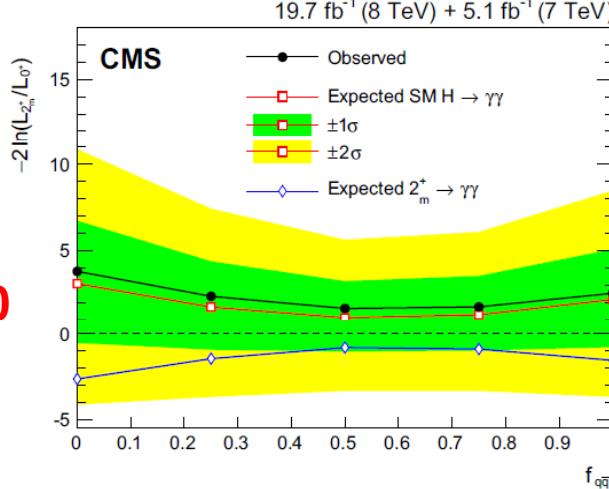
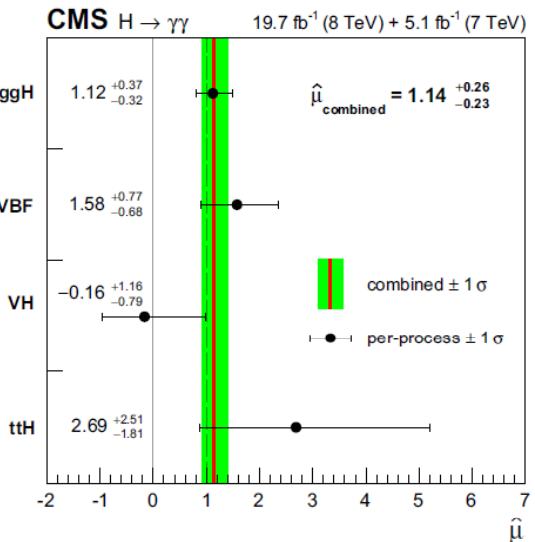
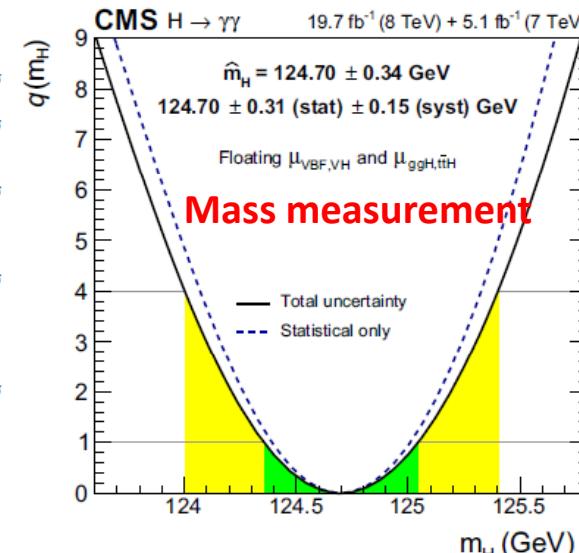
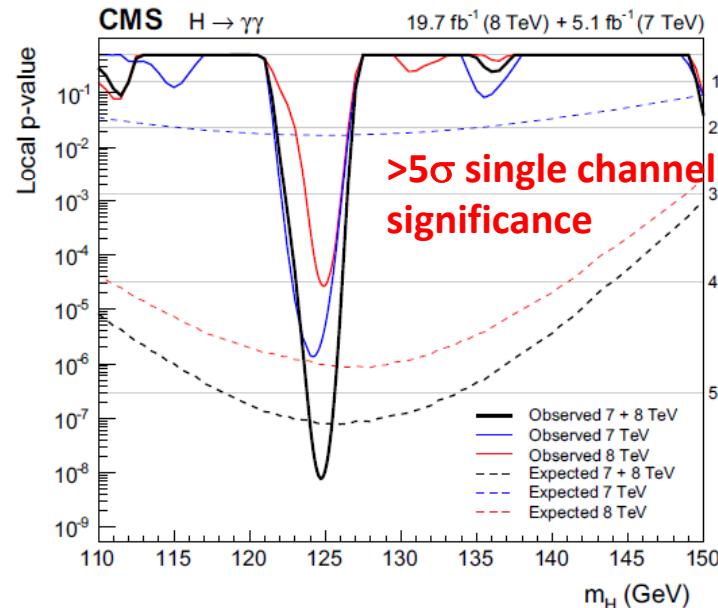


H $\rightarrow\gamma\gamma$: Run 1 Legacy Results

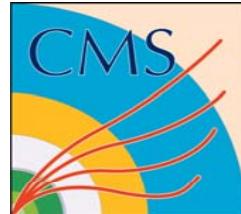


(2007-2014): (O. BONDU, H. BRUN, N. CHANON, G. CHEN, M. LETHUILLIER, S. GASCON, L. SGANDURRA, M. CHEN, J. FAN, J. TAO, Z. ZHANG)

Eur. Phys. J. C (2014) 74:3076



Spin compatible with 0



H \rightarrow $\gamma\gamma$: First Results with 13 TeV

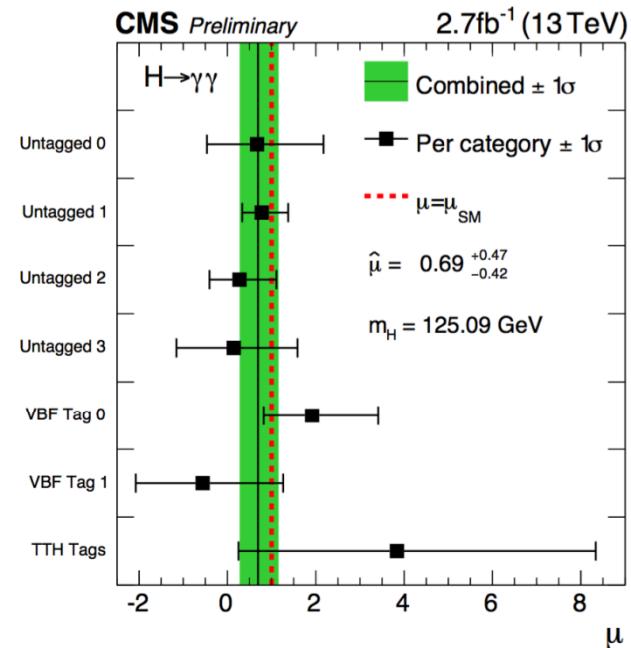
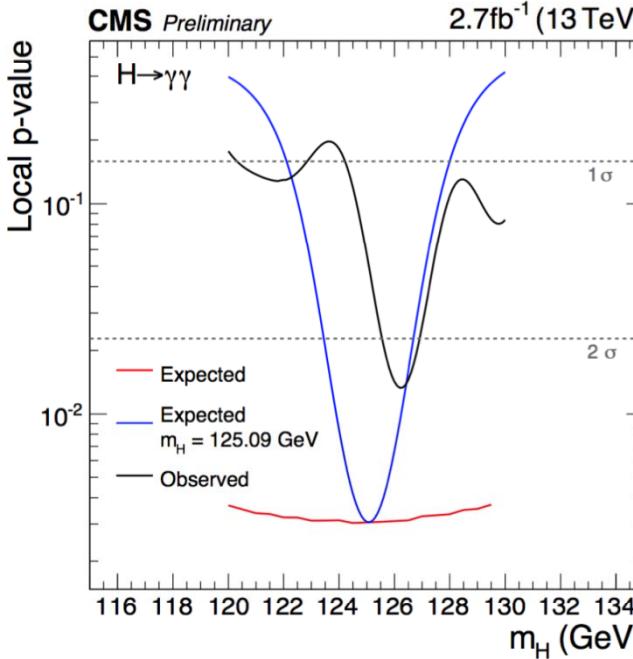
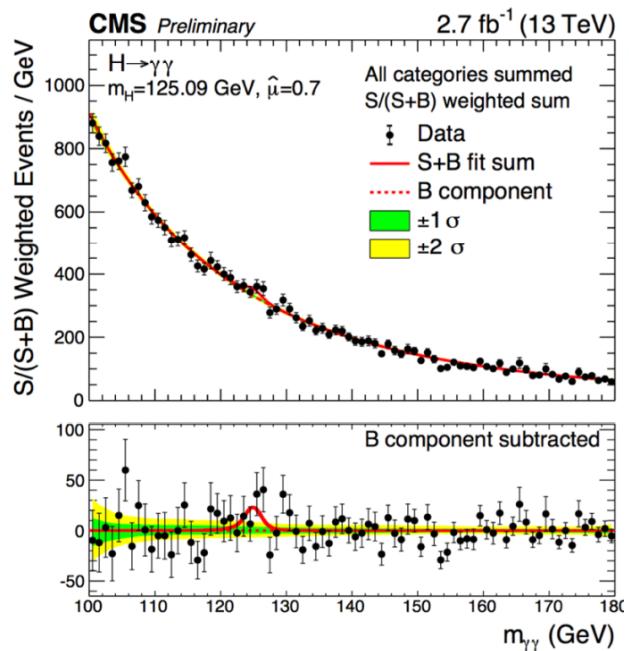


(2014-...): (G. CHEN, M. LETHUILLIER, S. GASCON, C. CARRILLO, J. TAO, Y. SHEN, B. COURBON, S. ZHANG)

CMS PAS HIG-15-005

- Run2 analysis framework (flashgg) development
- High-level trigger development
- Photon regression energy corrections
- Photon ID MVA validations for inputs and output
- Photon selection efficiency and data/MC scale factors

See dedicated talk
by C. Carrillo later



- Observed (expected significance at 125.09 GeV: 1.7σ (2.7σ))
- $\hat{\mu} = 0.69^{+0.47}_{-0.42}$ @ fixed 125.09 GeV



Search for a 2nd boson with m<110 GeV



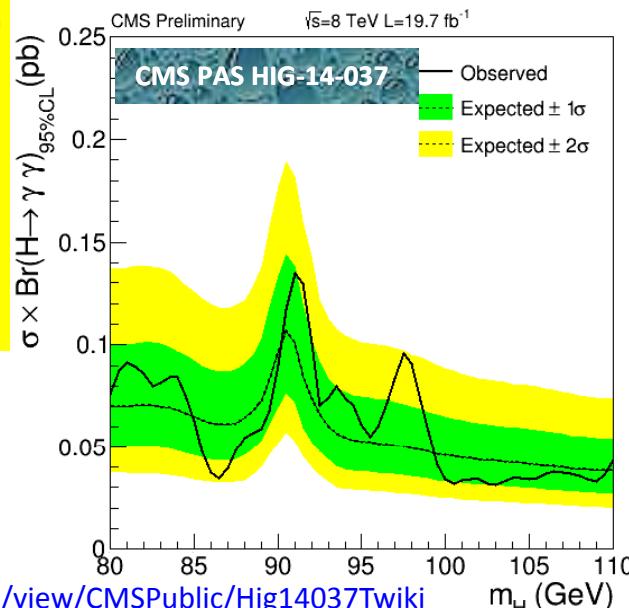
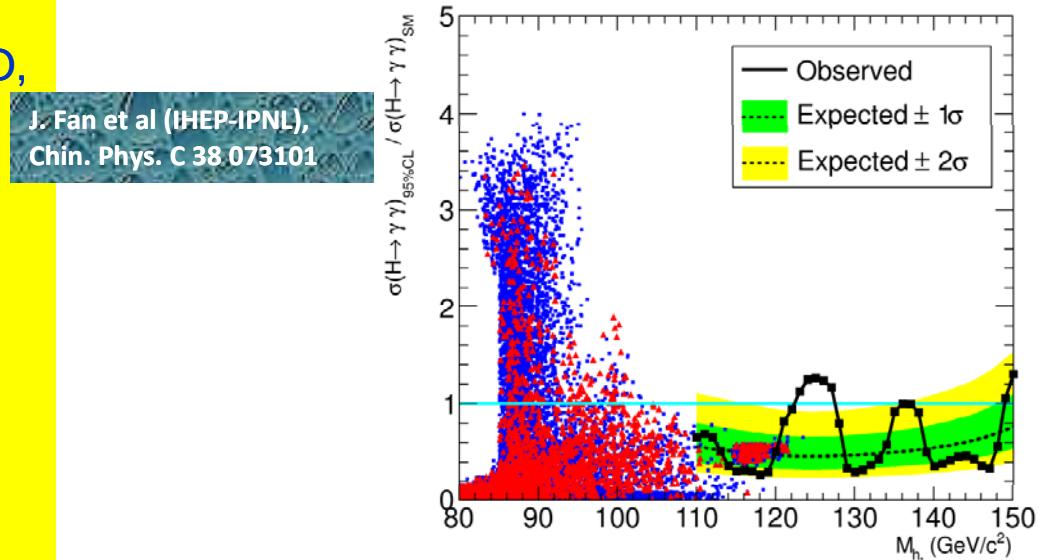
(2013-...): (G. CHEN, M. CHEN, M. LETHUILLIER, S. GASCON, C. CARRILLO, D. SABES, L. SGANDURRA, J. FAN, J. TAO, Y. SHEN, B. COURBON, S. ZHANG)

J. Fan et al (IHEP-IPNL),
Chin. Phys. C 38 073101

- A lighter 2nd Higgs boson (h_1) with $m=[60-110]$ GeV still a possibility in some BSM models:(N)MSSM, 2HDM....
- Compatible with the already-discovered boson as 2nd lightest (h_2)
- Scan within NMSSM shows $\sigma/\sigma_{\text{SM}}$ for h_1 possible up to $4\sigma_{\text{SM}}$, for $60 \text{ GeV} < m < 120 \text{ GeV}$
- Run 1 analysis public (CMS HIG-14-037): No evidence for new particle has been observed
- Run 2 analysis in preparation

See dedicated talk by
Sijing ZHANG later

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/Hig14037Twiki>



Important in 2015:
First public CMS data analysis to have been entirely and solely the work of the IHEP-IPNL team

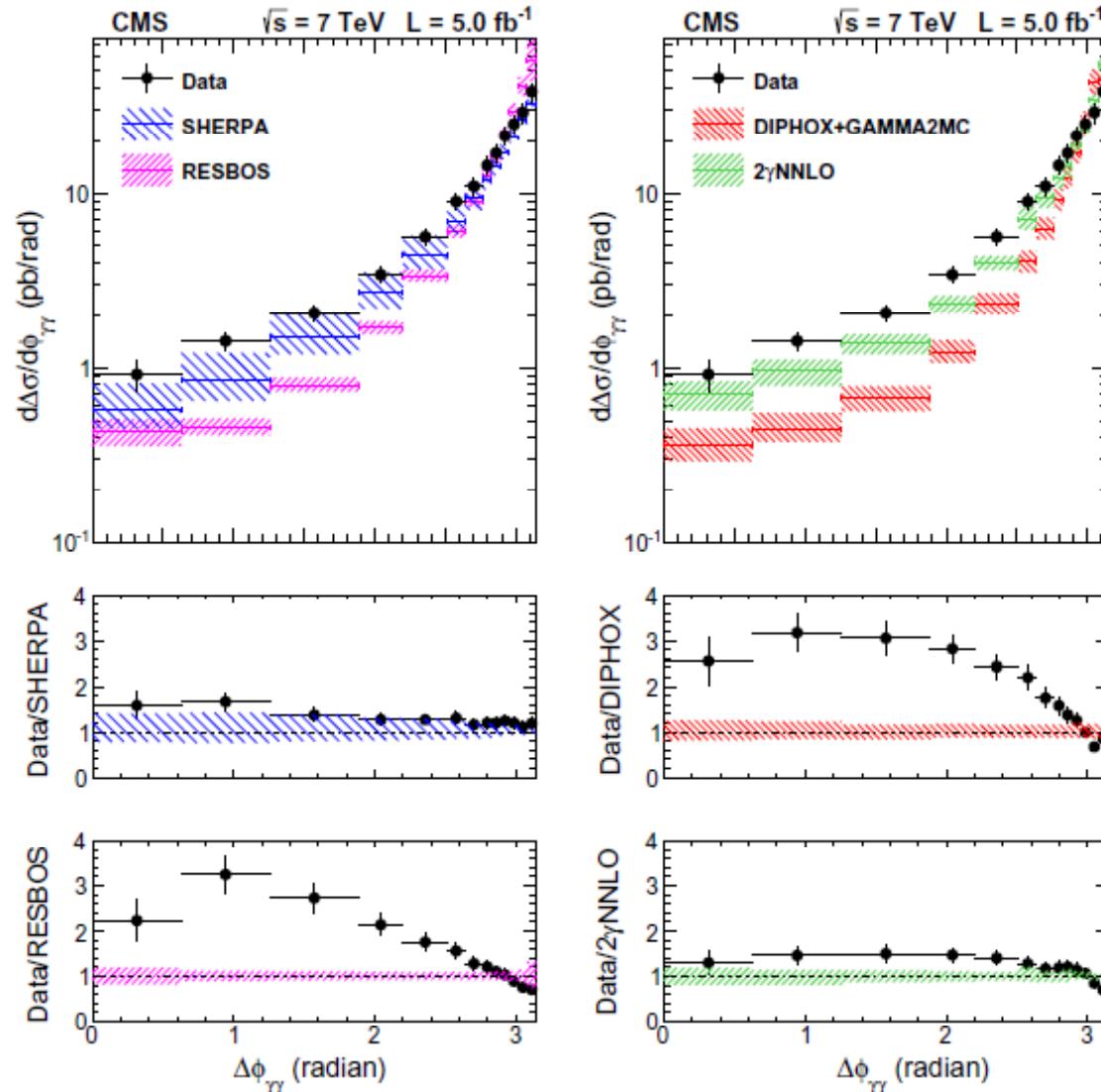


$\gamma\gamma + X$ Differential Cross Section Measurements



(2010-...): (H. BRUN, N. CHANON, G. CHEN, M. LETHUILLIER, S. GASCON, J. TAO, H. XIAO, J. FAN, Y. SHEN)

- For measurement of SM backgrounds to $H \rightarrow \gamma\gamma : \gamma\gamma + X$ and $\gamma + X$; Can probe gluon PDF at unprecedented E_T and reduce gluon NLO PDF error by $\sim 20\%$
- Use data-driven electromagnetic (2010, [JHEP 01 \(2012\) 13](#)) or Particle-Flow (2011, [Eur.Phys.J. C74 \(2014\) 11](#)) isolation templates
- Comparison to pQCD predictions, determination of efficiencies





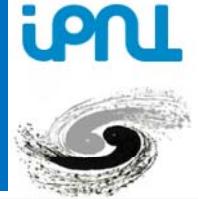
Summary and FCPPL 2016 proposal



- ❖ IPNL/IHEP CMS groups working together, with the help of the FCPPL, were able to **make key contributions to the Higgs discovery and 13TeV results**, in one of the two ‘golden’ decay channels, $H \rightarrow \gamma\gamma$
- ❖ IPNL/IHEP CMS groups are **leading the CMS search**, in both Runs 1 and 2, for a new ‘peak’, a 2nd, lighter Higgs boson decaying into two photons, allowed in the context of several BSM models
- ❖ IPNL/IHEP CMS groups have collaborated on the **SM diphoton cross section measurements** in Run1
- ❖ We look forward to **continue our efforts in more and more common activities.**
- ❖ We ask for FCPPL support in year 2016 for travel and **2 months** of a 5-month stay at IPNL for **Sijing** starting immediately after the workshop, travel for a **1-month** stay of a **possible new IPNL postdoc** at IHEP and for **IPNL-CMS researchers** to attend the Strasbourg FCPPL workshop



Acknowledgements



Many thanks:

- To the **IN2P3/CNRS**, the **IHEP-CAS**, and the **CSC**
- To the **FCPPL** directorate and steering committee
- To the **local organising committee** of this workshop here at **IPHC** for the wonderful hospitality and working environment

Merci

