

# Search of BSM physics in Higgs sector with CMS detector

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#### **The CMS detector:**



#### **Data collected:**

CMS Integrated Luminosity, pp, 2012,  $\sqrt{s}=$  8 TeV

![](_page_2_Figure_2.jpeg)

CMS Integrated Luminosity, pp, 2015,  $\sqrt{s}=$  13 TeV

![](_page_2_Figure_4.jpeg)

#### • Run 1

- LHC: 6.13 fb<sup>-1</sup> in 2011 and 23.30 fb<sup>-1</sup>
  in 2012
- CMS recorded: 5.5 fb<sup>-1</sup> recorded in 2011 and 21.79 fb<sup>-1</sup> in 2012
- Run 2
  - LHC delivered: 4.22 fb<sup>-1</sup>
  - CMS recorded @ 3.8 T : 2.8 fb<sup>-1</sup>

#### **<u>13TeV vs 8TeV:</u>**

Gluon fusion and VBF production get 2.6x boost relative to 8 TeV ⇒Discovery channels visible with ~5fb<sup>-1</sup>

data analyzed in the following slides = run I data: 5.1 fb<sup>-1</sup> in 2011 and 19.7 fb<sup>-1</sup> in 2012

### **BSM physics in Higgs sector:**

#### • Test the discovered Higgs at 125 GeV:

- Is Higgs deviating from SM ?
  ⇒ measure Higgs properties
- Exotic decays of the Higgs
- Search for Higgs as decay product of new particles

![](_page_3_Figure_5.jpeg)

#### • Search for more Higgs

- ⇒ Various BSM models are predicting more than 1 Higgs:
- Additional EW singlet: h, H
- 2HDM (as MSSM): H, A, h, H<sup>+</sup>, H<sup>-</sup>
- NMSSM (2HD+singlet):
- Higgs triplet models (SM doublet + triplet):
  H<sup>+</sup>, H<sup>-</sup>, H<sup>++</sup>, H<sup>-</sup>

organized here in 3 parts: -high mass (greater that 125 GeV boson) -low mass (lighter) -charged

#### **Outline:**

- Searches for exotic decay of the Higgs:
  - Higgs to Invisible
  - Lepton Flavour Violating decay
  - Higgs to light Higgs
- High mass searches:
  - high mass scalar resonance
  - MSSM neutral Higgs in ττ
  - production/decay in association with a Z
- Low mass searches:
  - h(125) in lighter neutral Higgs
  - 2 HDM low mass a in ττ
  - NMSSM low mass h in bb
- Charged Higgs searches:
  - H<sup>+-</sup>→τυ
  - H<sup>+</sup>→cs

![](_page_4_Picture_16.jpeg)

F

#### Searches for exotic decay of the Higgs:

![](_page_6_Figure_0.jpeg)

### Higgs to Invisible + y

Z

![](_page_7_Figure_2.jpeg)

- the neutralino decays then in a gravitino + a photon
- 2 cases:
  - if  $m_h/2 < m_{\chi_1} < m_h$ : 1 photon produced
  - if  $m_{\chi_1} < m_h/2$ : 2 photons produced
- both ZH and ggH production are considered

![](_page_7_Figure_8.jpeg)

- more that 1  $\gamma$  with  $E_T > 45 \text{ GeV}/c^2 + \text{MET}$ 

![](_page_7_Figure_10.jpeg)

![](_page_7_Figure_11.jpeg)

100

 $\widetilde{\chi}_{1}^{0}$  mass [GeV]

120

60

80

![](_page_7_Figure_12.jpeg)

![](_page_7_Figure_13.jpeg)

Η

![](_page_8_Figure_0.jpeg)

#### Lepton flavour violating dec: VBF 1.878 · 10<sup>3</sup> (exp.) 3.470 · 10<sup>3</sup> (obs.)

#### • constraints on Yukawa couplings:

![](_page_9_Figure_2.jpeg)

•

all

0.480 · 10<sup>-3</sup> (exp.)

0.358 · 10<sup>-3</sup> (obs.)

![](_page_10_Picture_0.jpeg)

![](_page_11_Figure_0.jpeg)

#### Search of a high mass scalar decaying in VV

![](_page_12_Figure_1.jpeg)

![](_page_12_Figure_2.jpeg)

### Search of X—hh

- Tiny h→hh SM cross-section but can be signature for radion, KK or RS graviton
- 3 channels are used:
  - hh $\rightarrow$ bbbb, hh $\rightarrow$ bbtt (large branching fraction of h $\rightarrow$ bb and h $\rightarrow$ tt)
  - hh $\rightarrow$ bbyy (h $\rightarrow$ yy small but benefits of the clear m<sub>yy</sub> resonance)

![](_page_13_Figure_6.jpeg)

![](_page_14_Figure_0.jpeg)

#### **Pseudo-Scalar Decay in Z + h**

Phys. Lett. B 748 (2015) 221 arXiv:1510.01181

- 2HDM at low tan  $\beta$
- A $\rightarrow$ Z+h (Z $\rightarrow$ ee, µµ, vv), (h $\rightarrow$ bb,  $\tau\tau$ )
- dominant for 220 GeV <  $m_A$  <  $2m_t$  (ttbar decay not possible)
- search for a resonance in  $m_{llbb}/m_{ll\tau\tau}$
- dominant production is  $gg \rightarrow A$ , narrow width approximation ( $\Gamma_A/m_A < O(1\%)$ )

![](_page_15_Figure_7.jpeg)

![](_page_15_Figure_8.jpeg)

![](_page_15_Figure_9.jpeg)

# Pseudo-Scalare Decay in Z + h

![](_page_16_Figure_1.jpeg)

B(A

10

![](_page_16_Figure_2.jpeg)

![](_page_16_Figure_3.jpeg)

limite also produced for type-I 2HDM

![](_page_16_Figure_5.jpeg)

![](_page_16_Figure_6.jpeg)

![](_page_17_Figure_0.jpeg)

CMS PAS HIG-15-001

#### **limit on tanß vs cos(\beta-\alpha)** for m<sub>H</sub> =350GeV,m<sub>A</sub> =150GeV

![](_page_17_Figure_3.jpeg)

### Low mass searches:

#### H(125) Decays in Ligher Neutral Bosons

- the H(125) can decay in lighter scalar bosons:  $H\rightarrow a/h$ 
  - search for lighter scalar boson with low mass (~10 GeV)
    - $\Rightarrow$  expected to be boosted

![](_page_19_Figure_4.jpeg)

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#### **Light Pseudo-Scalar in Association With a bbar Pair**

- production of a light pseudo-scalar A associated with a bbar pair in a Type II 2 HDM context
- A $\rightarrow \tau\tau$ :3 finals states considered
  - $e\tau_h$ ,  $\mu\tau_h$  and  $\mu e$

arXiv:1511.03610

19.7 fb<sup>-1</sup> (8 TeV)

CMS

10<sup>3</sup>

![](_page_20_Figure_5.jpeg)

### **Light Neutral Higgs in SUSY Cascades:**

- in NMSSM context
- search of a light neutral Higgs boson (h1) produced in SUSY cascades  $\overline{b}_{q}$

- consider h1 decay in bbar
  - fit on  $m_{bb}$
- NMSSM "P4" benchmark
  - h2 =h(125 GeV), h1 is mostly singlet i.e.
    suppressed couplings to V

q

- Interpretations:
  - Model independent limits on resonant production
  - MMSSM interpretation in 2 scenarios:
    - $M_3 = Mq = 1 \text{ TeV} \rightarrow \text{fully excluded}$
    - decoupled-squarks: vary M1, M2, M3

![](_page_21_Figure_12.jpeg)

### **Charged Higgs searches:**

#### $H^{+-} \rightarrow \tau v, H^{+-} \rightarrow tb$

• Two productions modes depending of  $m_{\rm H}^{+-}$ :

![](_page_23_Figure_3.jpeg)

### H⁺-→Tv, H⁺-→tb

# Interpretation of the result in various benchmark scenarios: updated $m_h^{max}$ , $m_h^{mod+}$ , $m_h^{mod-}$ , light stop, light stau, tau-phobic, and low-M<sub>H</sub>

![](_page_24_Figure_2.jpeg)

![](_page_25_Figure_1.jpeg)

![](_page_25_Figure_2.jpeg)

<u>Final state:</u> isolated lepton +>= 4 jets +large MET

- assumption of BR(cs)=100%
- tt fully reconstructed thanks to kinematic fits
  - relaxed constraint on mjj to match both
    W (background) and H<sup>+</sup> mass

![](_page_25_Figure_7.jpeg)

#### **Conclusion:**

- Large number of models tested → no sign of new physics yet:
  - Some models starting to be excluded
  - Many model starting to be tested (NMSSM)
  - Invisible decays of neutral Higgs probing O(30%) BR
- Run I data reaching O(fb) sensitivity on model independent limits on σxBR in many channels
- A lot of CMS run I results not presented in this talk
  - full list of results available <u>here</u>
- Starting to analyze run II data
  - Expand coverage of Run I with more low mass searches
  - Increase combined approach between exotica/SUSY/diboson searches and Higgs interpretations

#### Stay Tuned !

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