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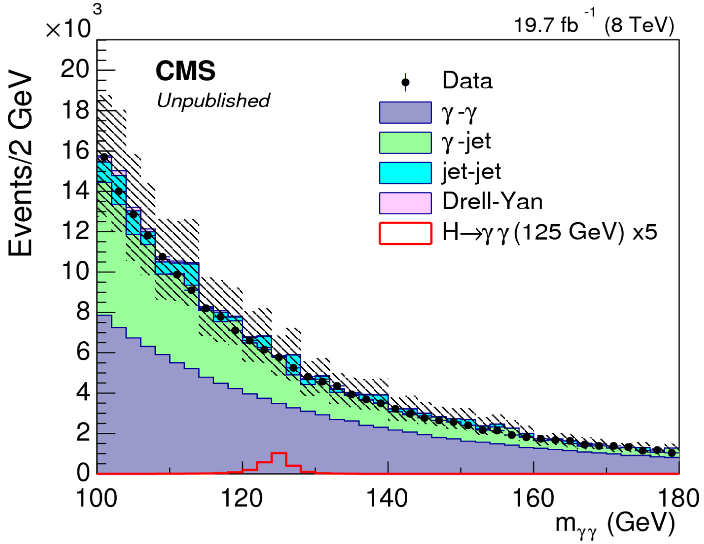
Thesis announcement found on the web (INSPIRE-HEP)

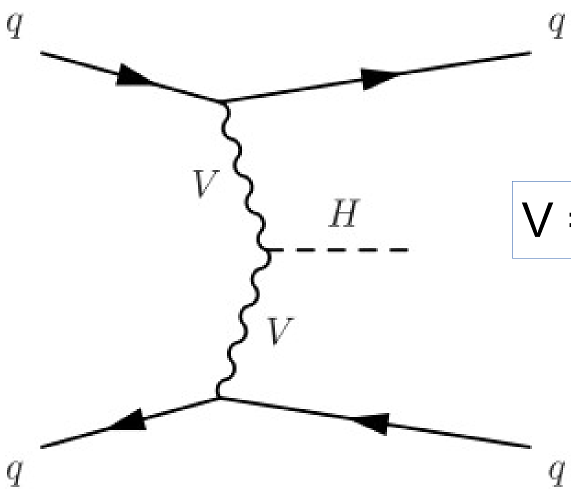
Motivations:

- Master thesis at CERN in the CMS experiment, with the Higgs boson as a subject
- A PhD in the same experiment and on the same subject was a natural continuation
- At CEA-Irfu, for the good reputation of the Institute

- Thesis subject: **Photon identification and properties of the Higgs boson in the VBF production mode using the H→γγ decay channel in the CMS experiment**

- CMS – photon identification – Higgs boson – vector boson fusion – pseudoscalar – HVV couplings





V = Z/W bosons

VBF = Higgs production by Vector Boson Fusion

The Higgs boson and its decay in two photons

The Higgs boson

- In 1970s: unification between weak and electromagnetic interactions $\rightarrow$ electroweak interaction

- Unified theory $\rightarrow$ massless interaction-mediator bosons.
  Experimentally: W and Z bosons massive (short range interaction)

  - **W/Z mass = 80/91 GeV,** m_{proton} = 1 GeV

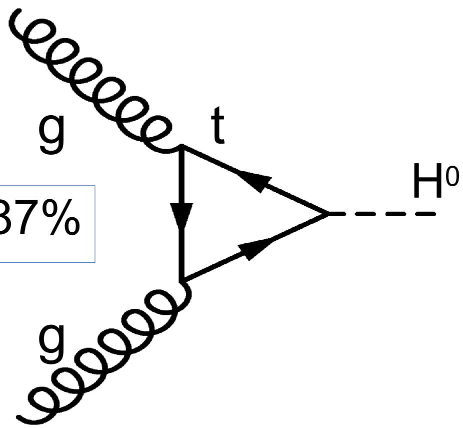
- Problem solved by the Higgs mechanism:

  - Spontaneous symmetry breaking of electroweak interaction $\rightarrow$ W and Z mass
  - There must exist a new spin 0 particle, called Higgs boson, footprint of the mechanism
  - Higgs boson discovered at the LHC, **mass = 125 GeV**
  - Next: study properties of the new particle

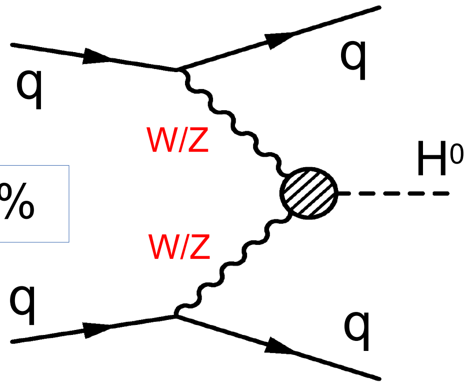
The Higgs boson: production and decays

SM: particles mass proportional to their coupling strength to the Higgs boson

ggH – 87%



VBF – 7%



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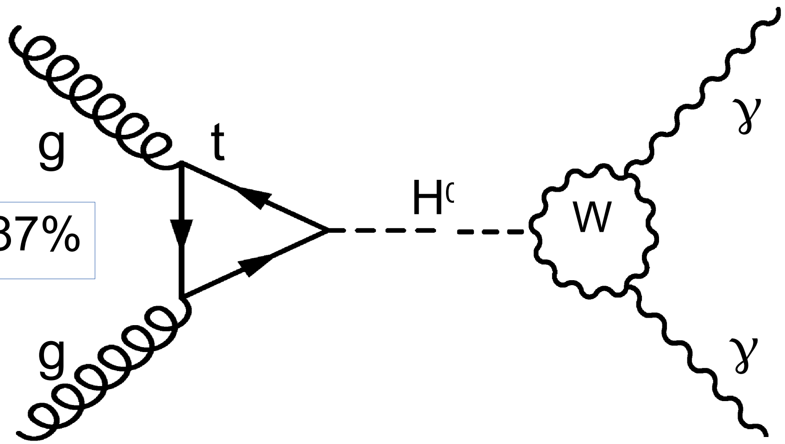

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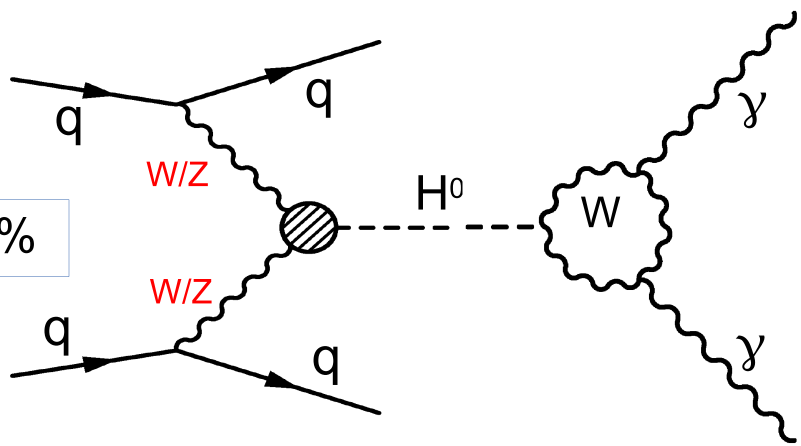
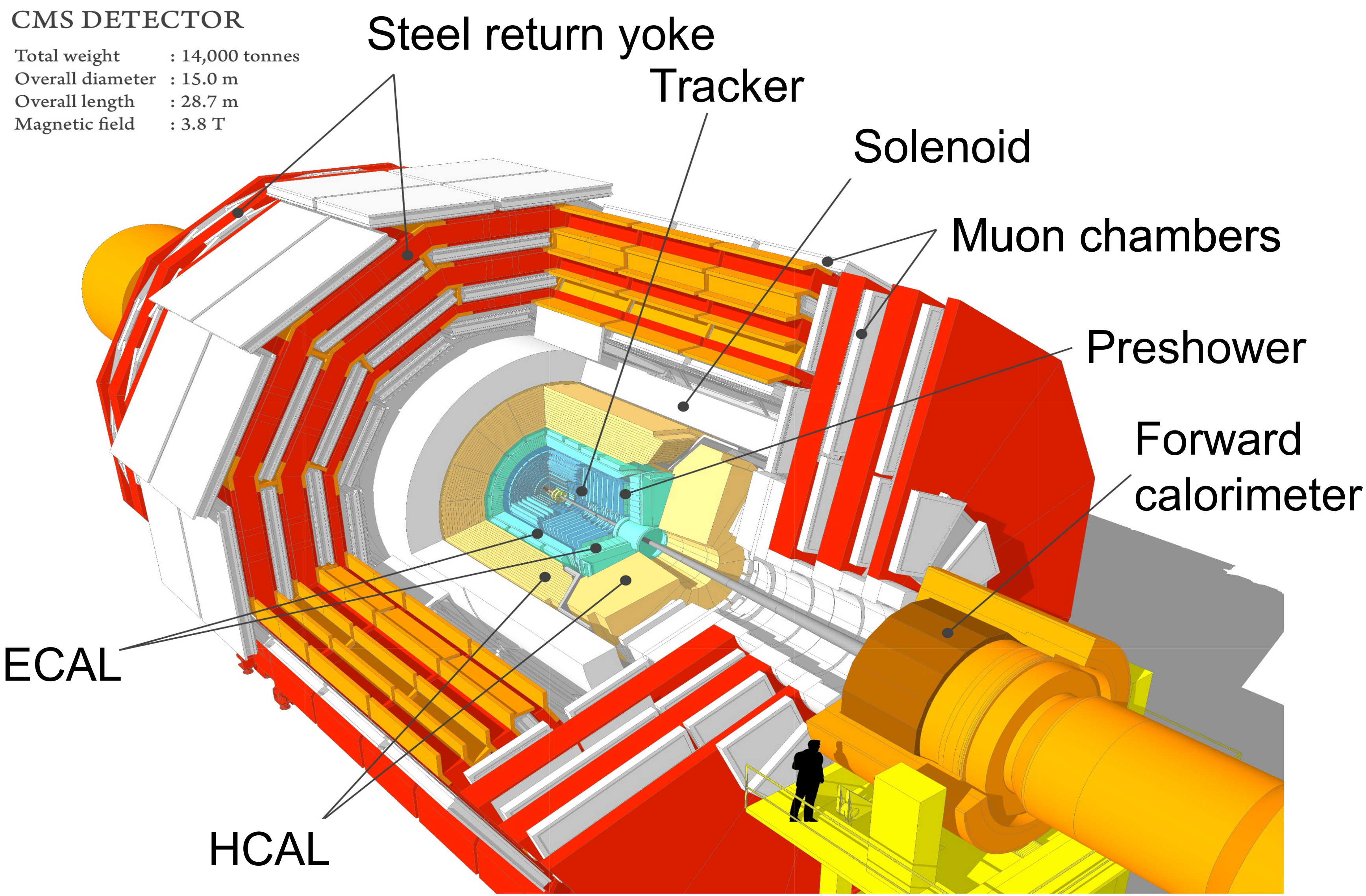


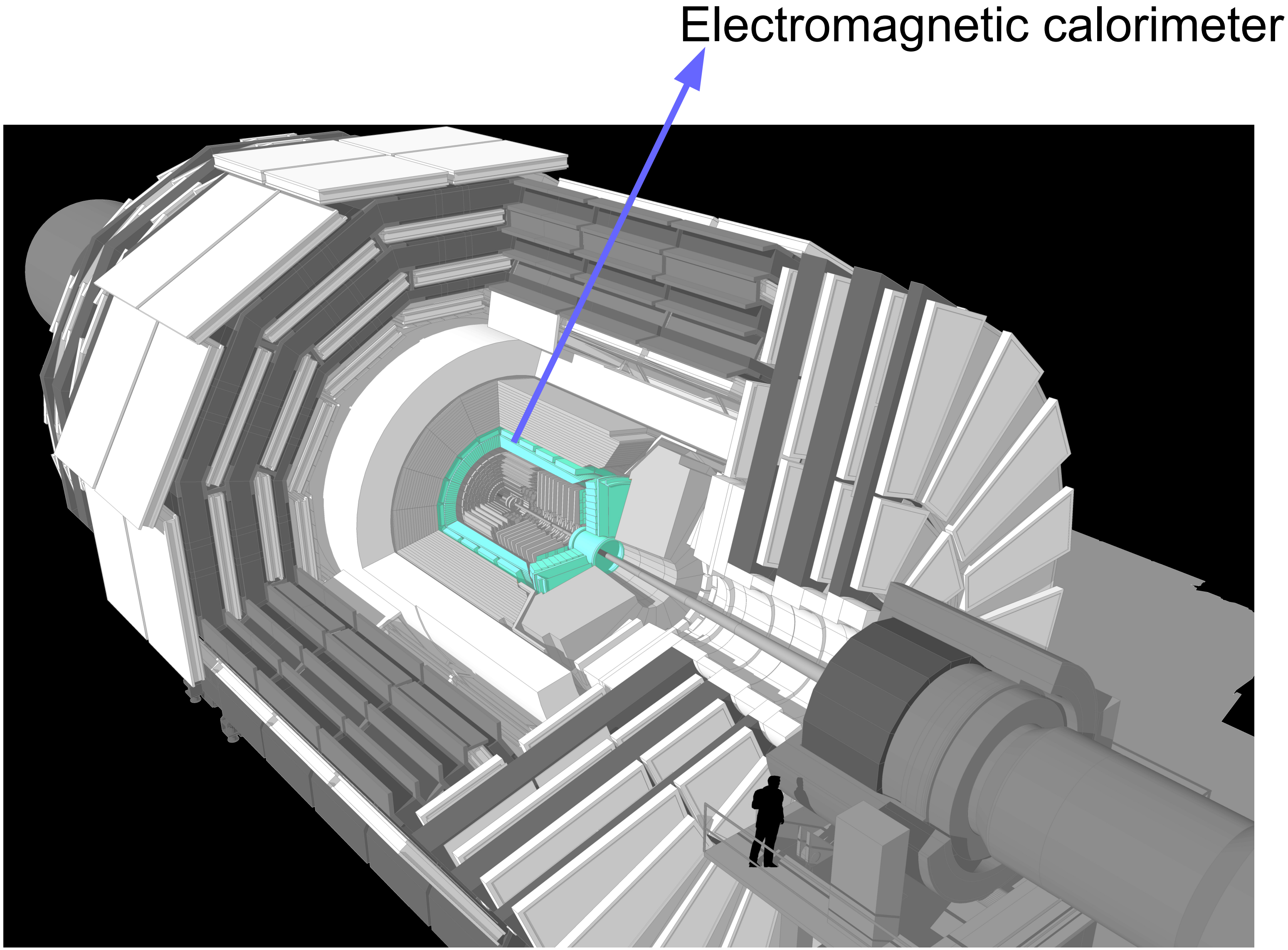
Decay	BR @125 GeV
bb	57%
WW	21%
ττ	6.4%
ZZ	2.6%
γγ	0.2%

Higgs decay in 2 photons: low branching ratio but clear experimental signature thanks to excellent diphoton mass resolution

The CMS detector and the electromagnetic calorimeter



The CMS detector and the electromagnetic calorimeter



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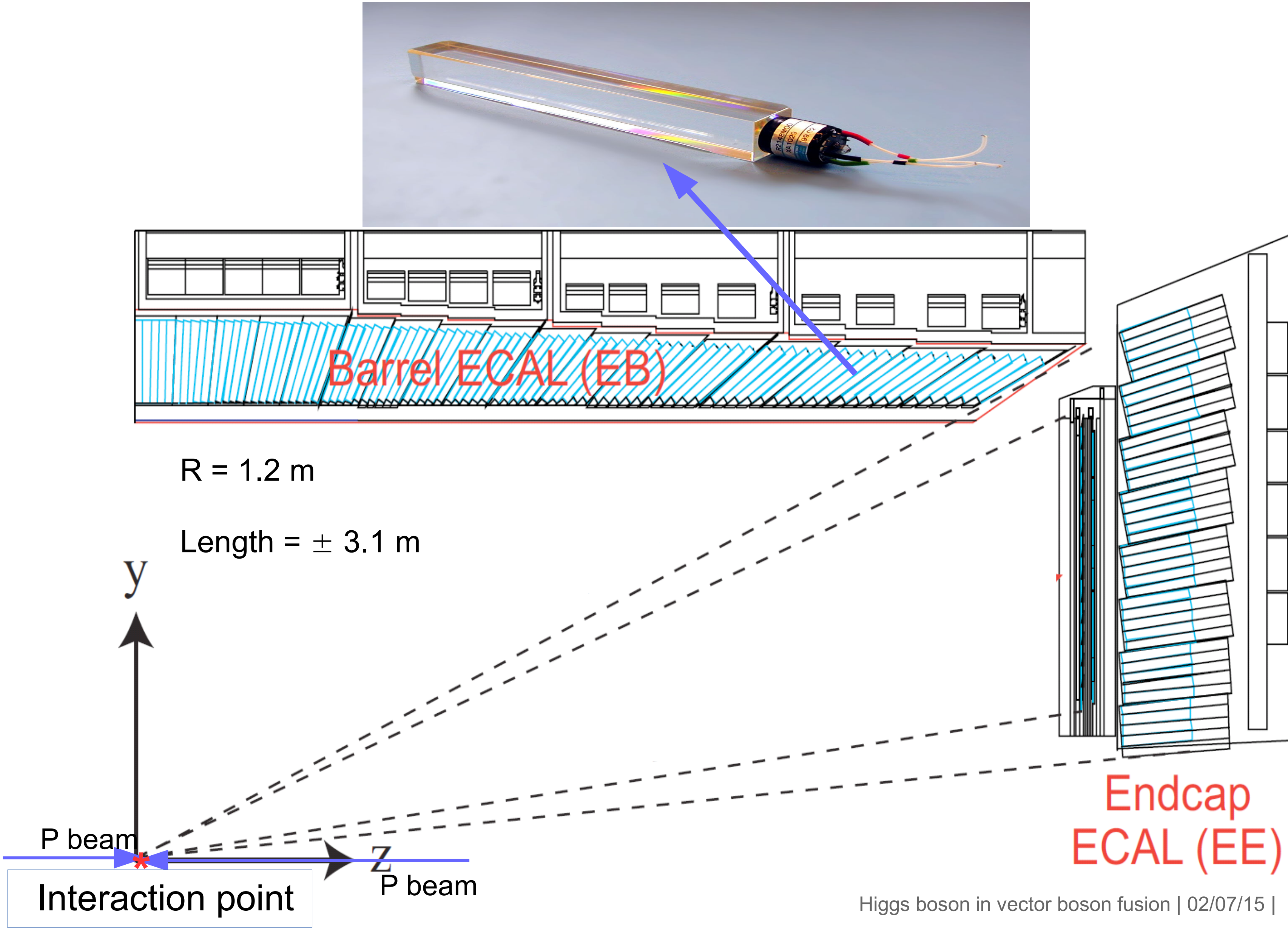
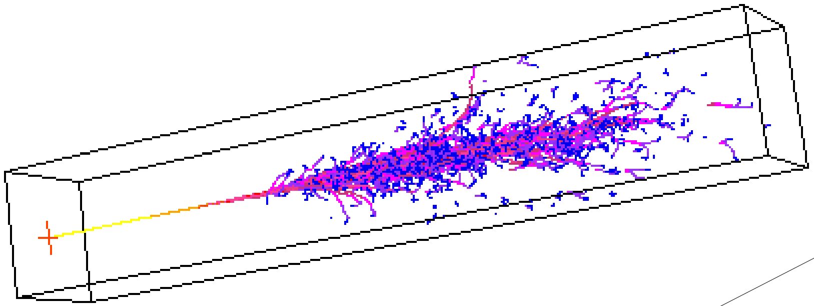
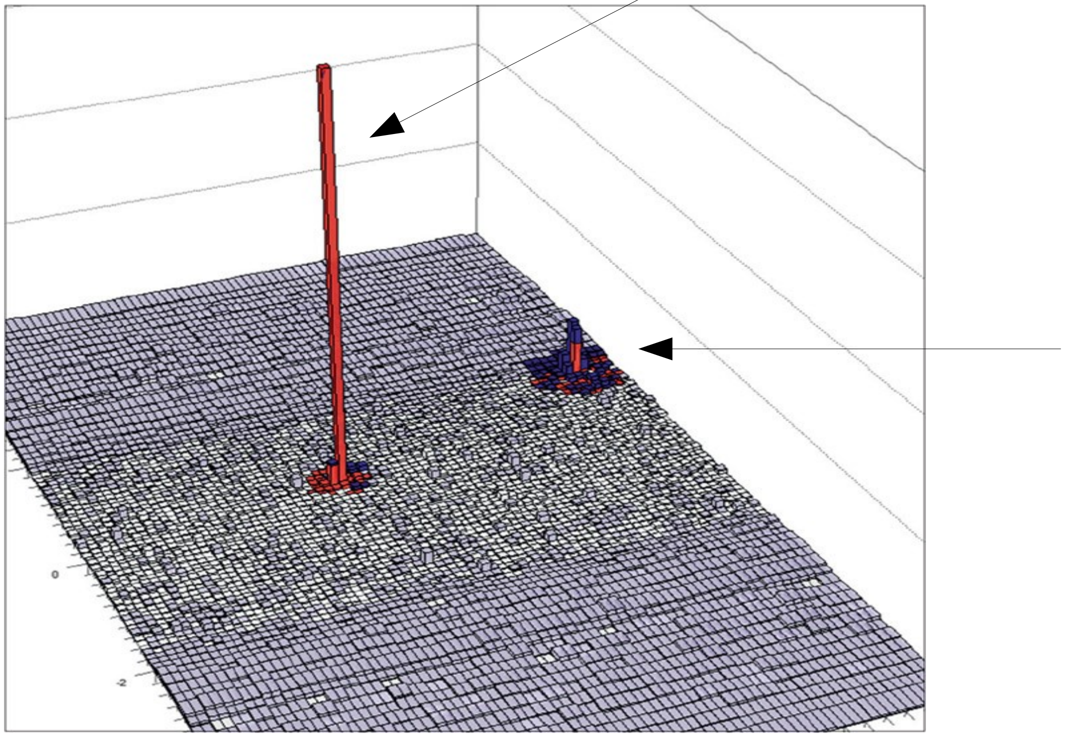


Photons reconstruction in CMS

Electromagnetic shower





prompt photon: directly emitted in the hard scatter vertex (as opposed to photons emitted in jets hadronization)

compact shower

fake photon: mostly jets (*e.g.* $\pi^0 \rightarrow \gamma\gamma$)

broader shower

Photon identification studies at 13 TeV

Photon identification principles

Photon identification: discriminate between prompt and fake photons :

- Prompt photons = signal (hard scatter vertex)
- Fake photons = background (jets)

How to do this?

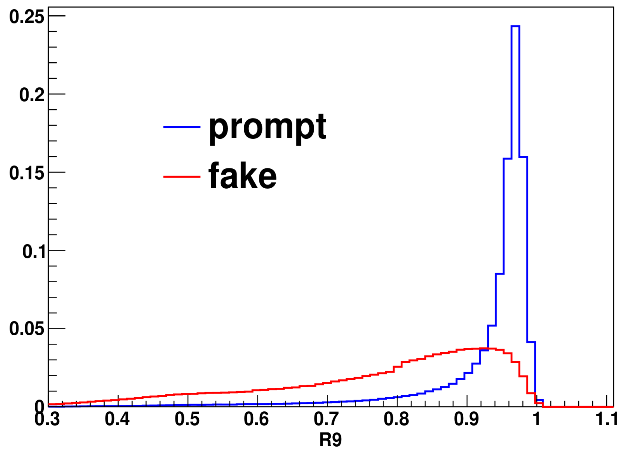
Using variables describing well the shower and energy deposits features:

- Electromagnetic Shower Shape Variables
- Isolation Variables

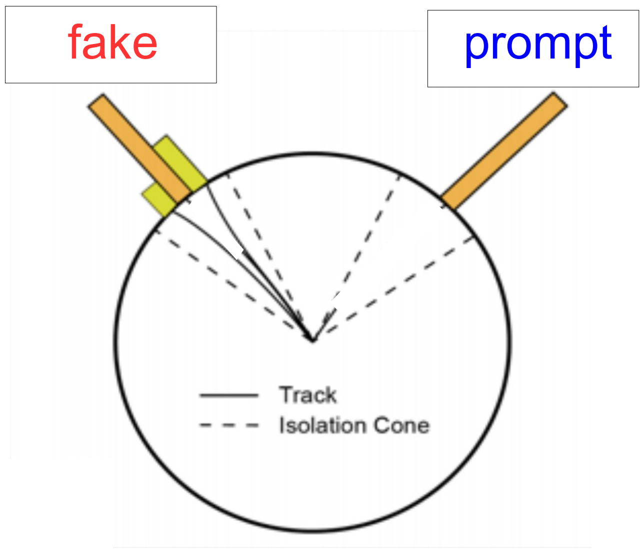
Photon identification variables

Some examples of interesting variables:

- **R9**: ratio of the energy in the 3x3 crystals matrix to the total energy of the shower

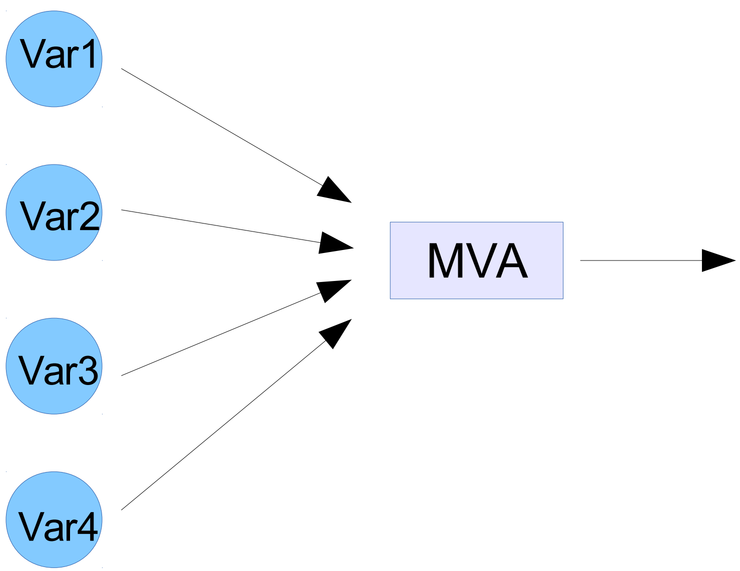


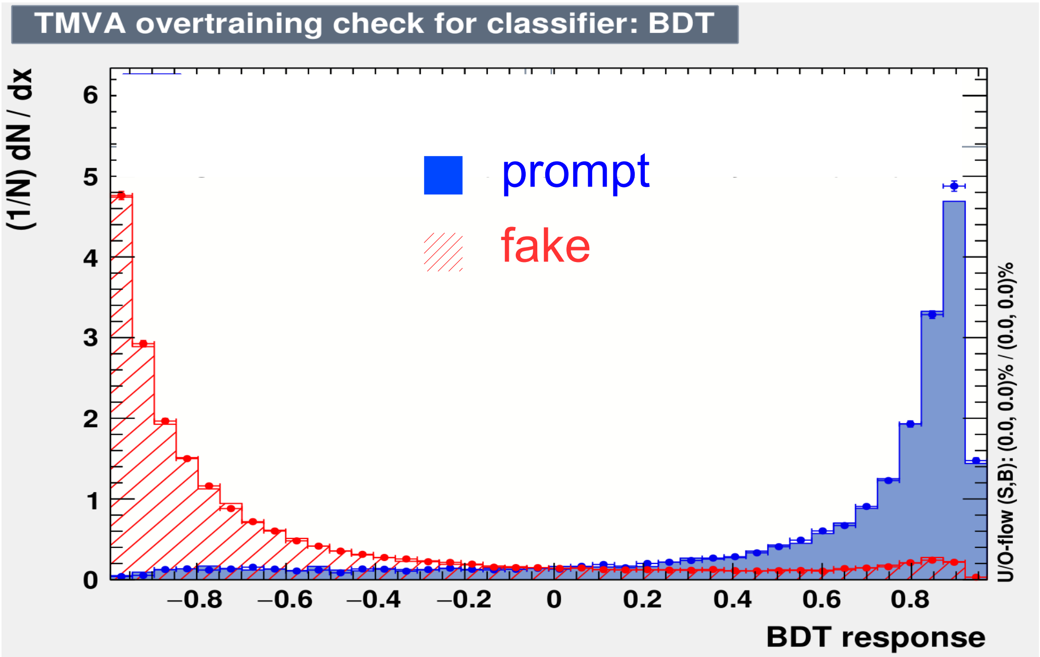
- **Isolation**: energy sum of all charged and neutral particles around the considered photon.
  Isolated photon = small value of this sum



All photon identification variables combined in a unique variable using MVA technique:

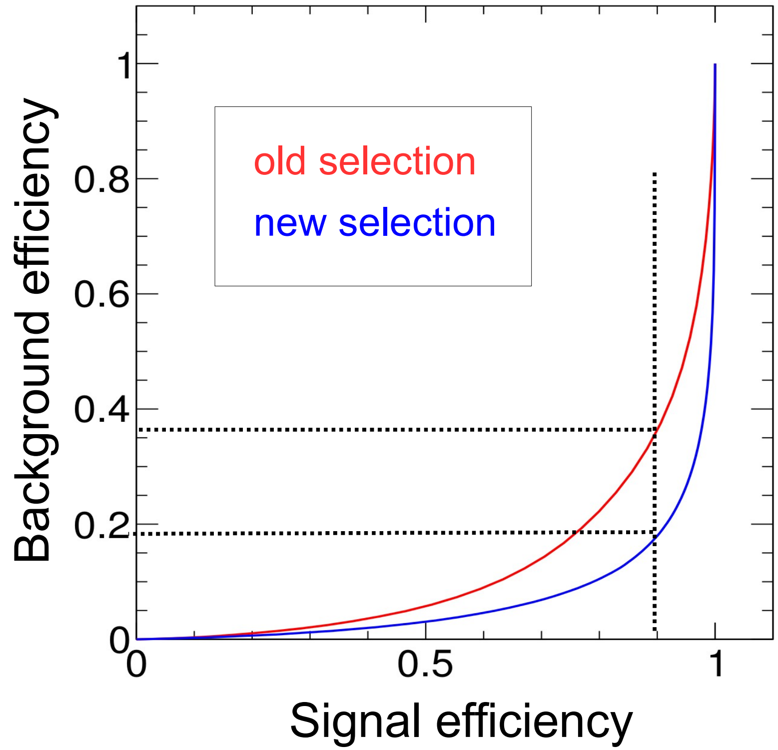
- MVA: util that allow to classify events belonging to different categories
- MVA trained on simulated samples of prompt and fake photons





Photon identification results

Need to optimize selection for 13 TeV analysis



Old selection = 7/8 TeV analysis

New selection = optimization for 13 TeV analysis

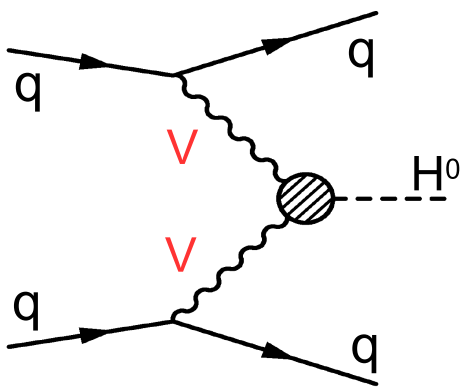
For a signal efficiency of ~90% the background efficiency is ~20%

Probing the HVV couplings in VBF production at 8 TeV

Theory and couplings to probe

3 amplitudes contribute to VBF production:

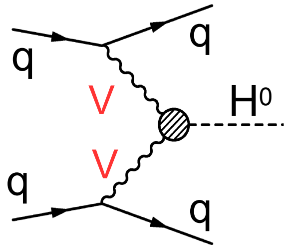
$$\mathcal{A}(HVV) \sim a_1\, m_V^2\, \mathcal{A}_{scalarSM} + a_2\, \mathcal{A}_{scalar\ anomalous} + a_3\, \mathcal{A}_{pseudo\text{-}scalar}$$

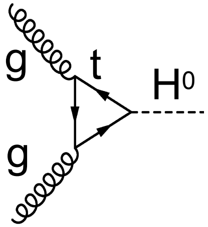


- a_i : all possible HVV couplings
  - **In SM: a_1= 1, a_2= a_3= 0**
- Want to measure the fraction of :
  - pseudo scalar production (related to a3)
  - anomualous scalar production (related to a2)
- For now concentrate on pseudo-scalar production

Goal: constrain the pseudoscalar contribution

VBF scalar (0^+)	VBF pseudoscalar (0^-)	ggH	non-Higgs background

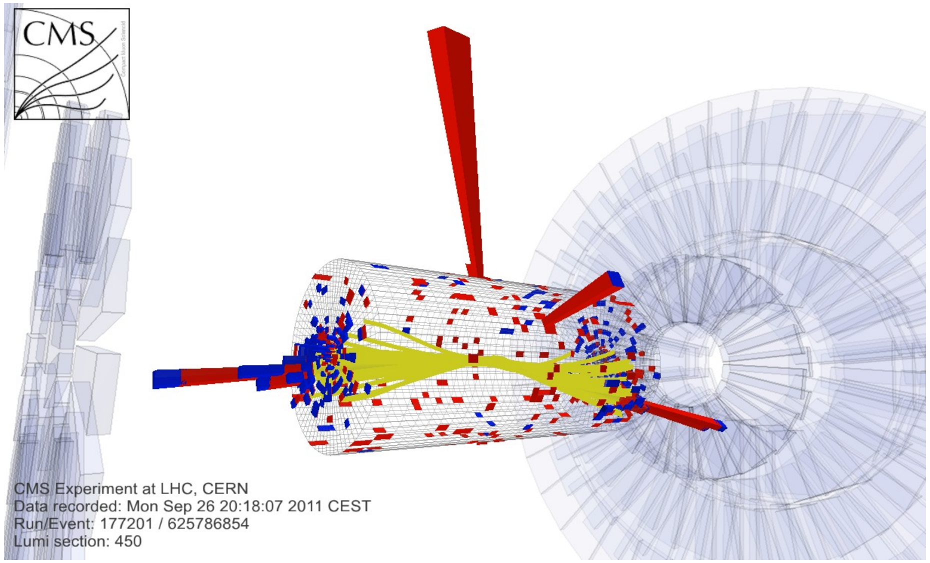




General Analysis Strategy:

- Apply VBF selection:

  require two isolated photons and two forward jets



Physics processes and analysis strategy

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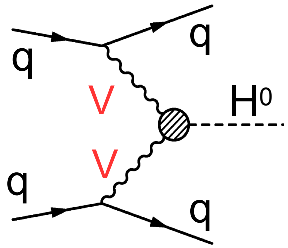

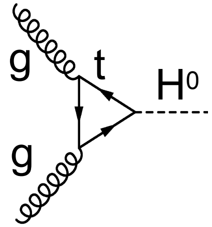

<u>General Analysis Strategy:</u>

- Apply VBF selection:

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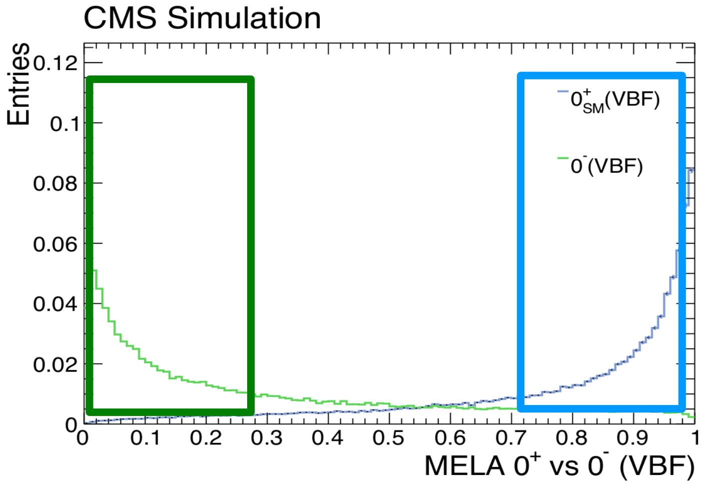
- Construct VBF vs ggH and VBF(0+) vs VBF(0-) discriminants to classify the different Higgs productions



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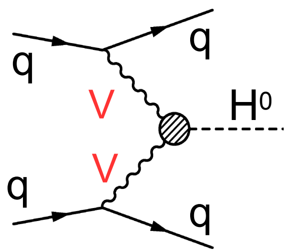
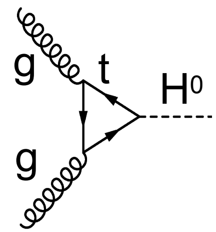




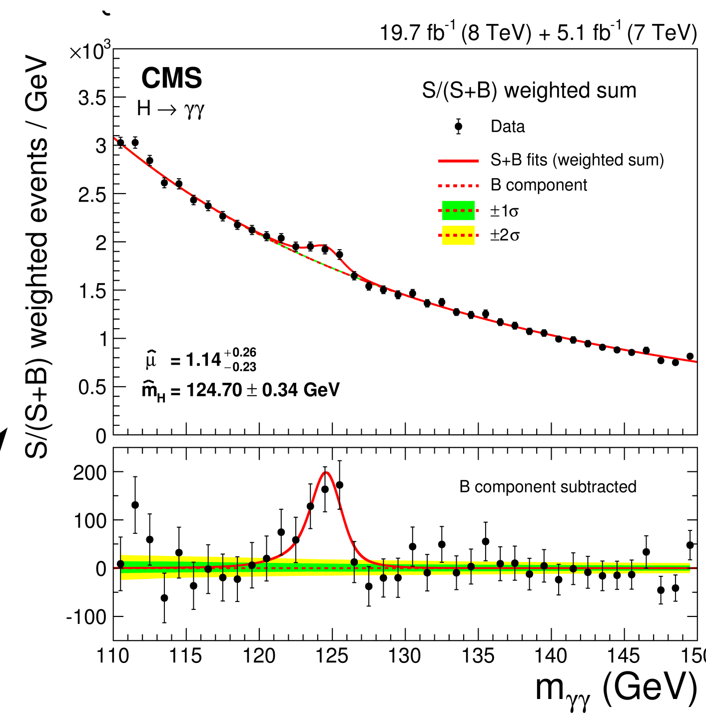
General Analysis Strategy:

- Apply VBF selection:

  require two isolated photons and two forward jets

- Construct VBF vs ggH and VBF(0+) vs VBF(0-) discriminants to disentangle the different Higgs productions

- Determine different regions of phase-space enriched with a certain process



Classifying Higgs boson production processes

diphoton and jet kinematics

↓

MELA
(Matrix Element Likelihood Analysis)

$$P_i(\vec{x}) = \frac{1}{\sigma_i}\frac{d\sigma_i}{d\vec{x}}$$

theoretical differential cross section for the different processes i assuming a given event kinematics x

$$D_{VBF} = \frac{P(0^+|VBF)}{P(0^+|VBF) + P(0^+|ggH)}$$

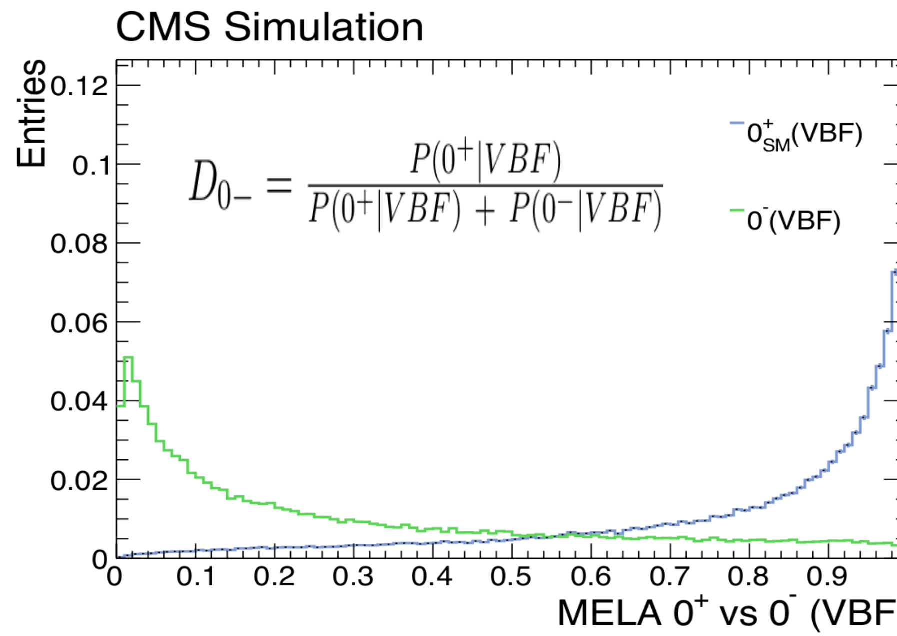
D_{VBF} = discriminate VBF vs ggH production

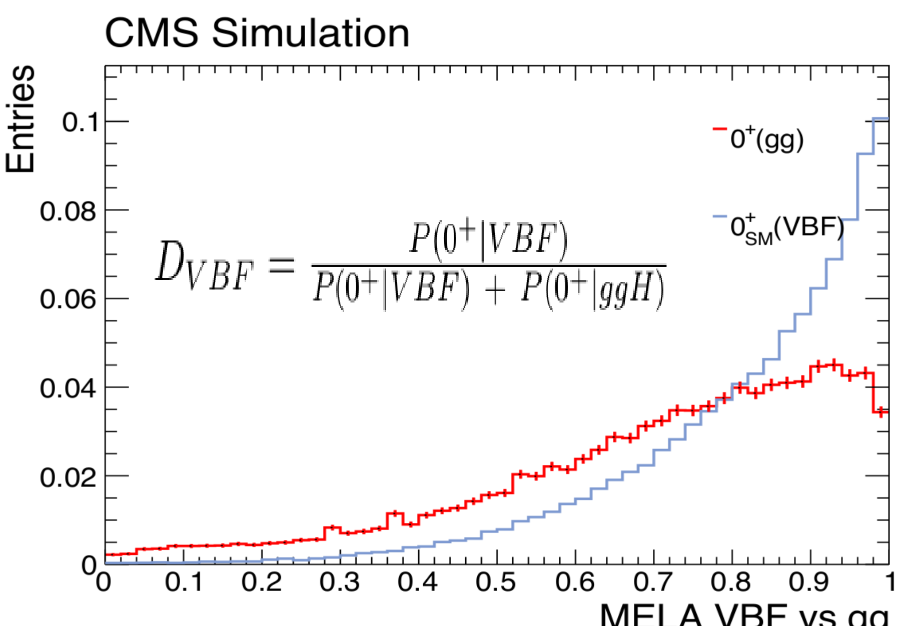
$$D_{0-} = \frac{P(0^+|VBF)}{P(0^+|VBF) + P(0^-|VBF)}$$

D_{0-} = discriminate VBF(0+) vs VBF(0-) production

MELA discriminants, 1D histograms

Very good VBF 0+/0- discrimination !



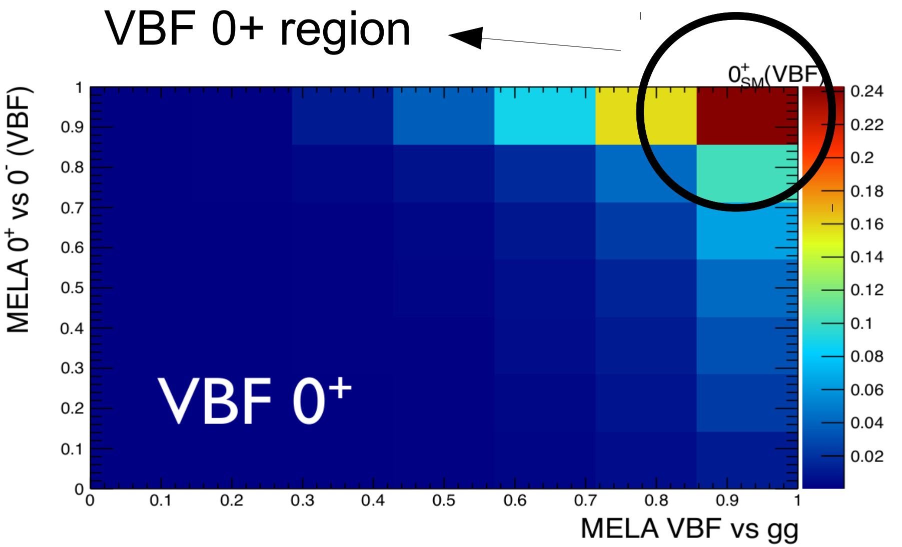


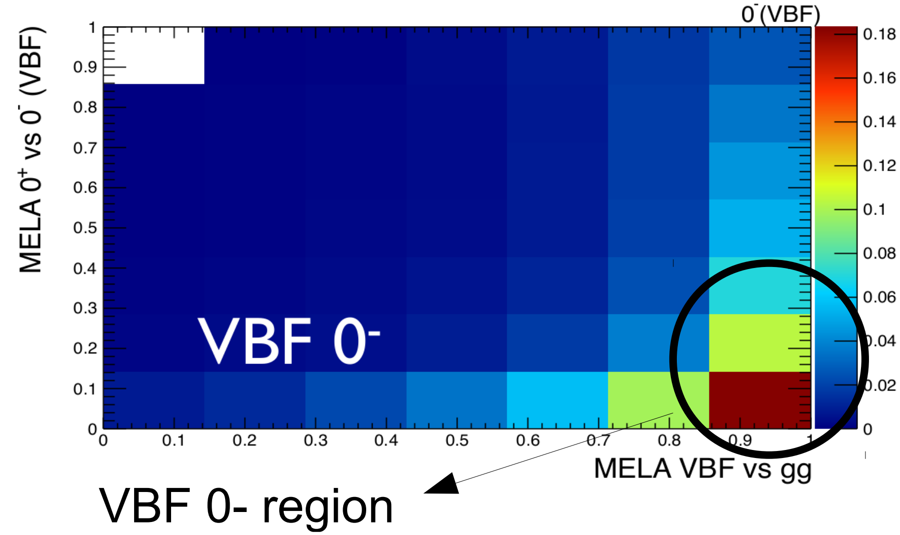
With VBF selection ggH events are VBF-like

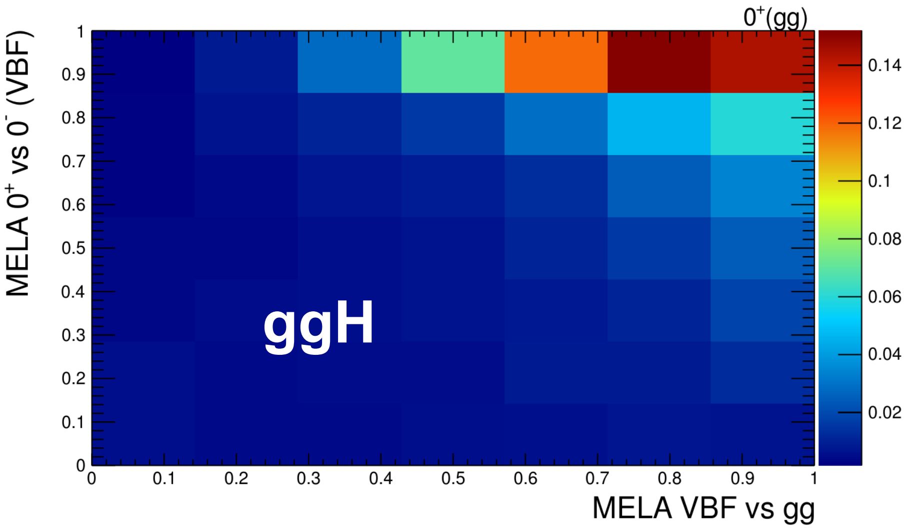
- Before selection: 7% VBF – 87% ggH
- After selection: 60% VBF – 40% ggH

MELA discriminants, 2D maps

normalised to 1







In each region extract Higgs signal yields from a fit to the diphoton mass
Allows to infer the yields due to the different productions: VBF(0+), VBF(0-), ggH

Conclusions and perspectives

- Involved in the preparation of the 13TeV data analysis
    - photon identification
    - development of analysis framework
    - in charge of $H\to\gamma\gamma$ simulated samples production
- First analysis of 13 TeV data for Higgs rediscovery
- HVV coupling analysis in VBF production using $H\to\gamma\gamma$ decay channel to be finalized (first with run 1 data)

Thanks for the attention !

DE LA RECHERCHE À L'INDUSTRIE

Backup

HZZ results

H→ZZ sensibility:

$$f_{a3}\ cos(\Phi_{a3}) \quad 0.00^{+0.33}_{-0.33}$$

Expected sensibility for the VBF→H→γγ analysis:

~ a factor 2 less sensible

But important for the combination with other channels and for the new approach