Search for $H \to c\bar{c}$ at CMS *in VBF production* with Run-3 data

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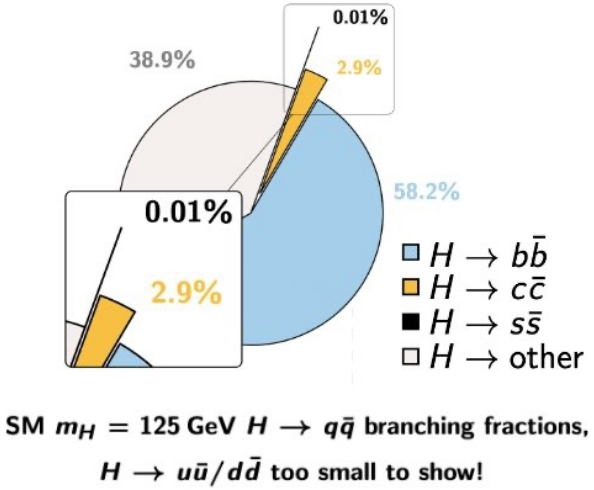
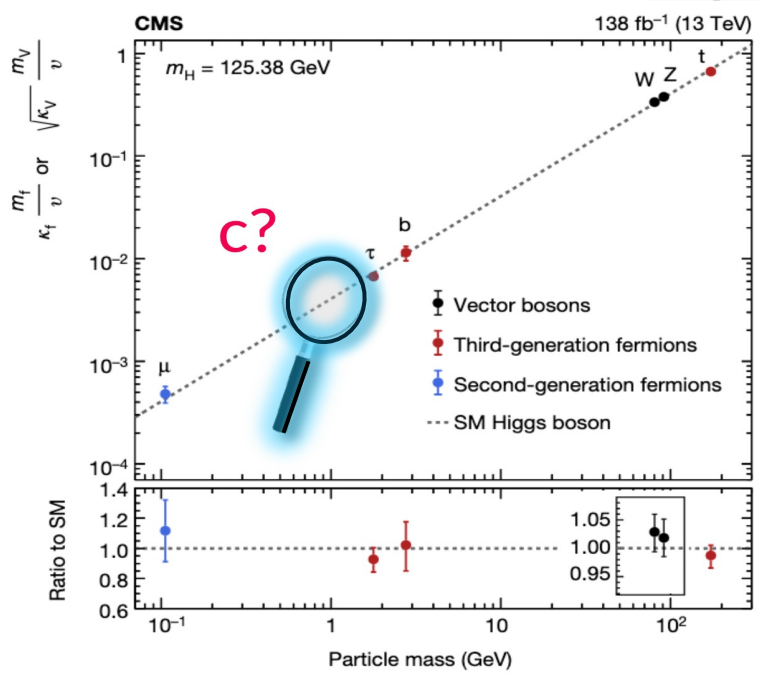
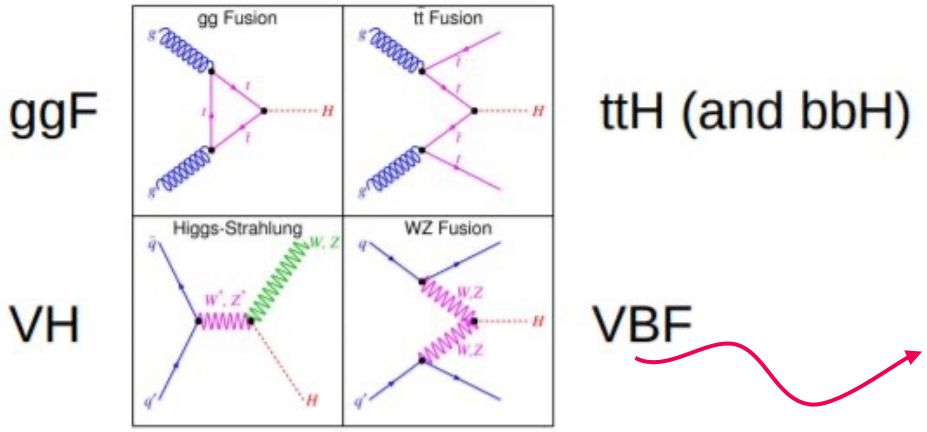
Search for $H \to c\bar{c}$ at CMS

- To access the **Yukawa coupling** of the Higgs to the **charm quarks**, not been observed yet
  - Possible valuable insights into **new physics**
- Extremely challenging:
  - **Small branching ratio**
  - Overwhelming **QCD background**
  - Difficult identification of c-quark jets and distinction from **b-quark** jets



SM $m_H = 125$ GeV $H \to q\bar{q}$ branching fractions, $H \to u\bar{u}/d\bar{d}$ too small to show!





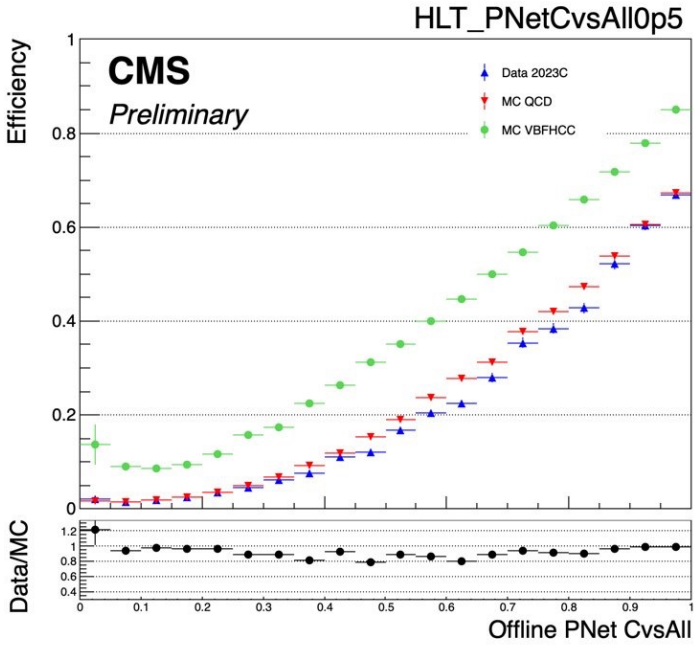
- **H → cc searches performed by CMS** with Run-2 data (140 fb^{-1})
  - CMS: $\frac{\sigma(VH)\cdot B(H\to c\bar{c})}{\sigma(VH)_{SM}\cdot B(H\to c\bar{c})_{SM}} < 14$ @95%CL $1.1 < |k_c| < 5.5$
  - NEW: $\frac{\sigma(ttH)\cdot B(H\to c\bar{c})}{\sigma(ttH)_{SM}\cdot B(H\to c\bar{c})_{SM}} < 7.8$ @95% CL $|k_c| < 3.0$

Most stringent constraints to date

- First-ever investigation through **VBF production** mode at **Run-3** performed in **Bari** :
  - Second-highest **cross section** (~7% of the total XS)
  - Distinctive signature: VBF jets produced forward and backward

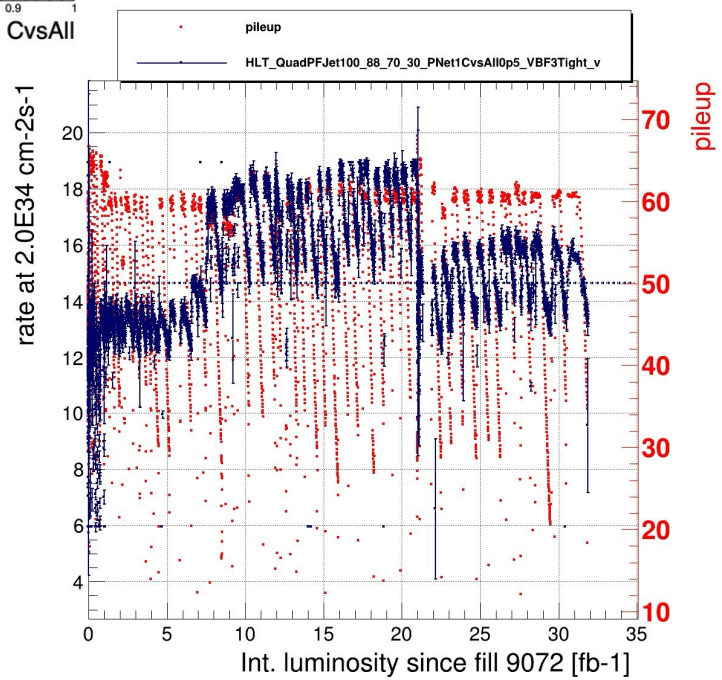
VBF $H \to c\bar{c}$ at Run3

1. **New dedicated trigger for Run-3**
2. Conducted analysis of the 2023 data (27fb^{-1}) collected by this trigger
   - Offline preselection and Higgs candidate reconstruction
   - Machine learning for signal vs QCD background discrimination
   - Advanced signal extraction, correctly modelling the signal, resonant backgrounds (H→bb, Z , W+jets), and the dominant QCD
3. **Limit extraction and projections**



- First **online** trigger with **c-tagging**, deployed for the 2023 data-taking
- Among the first **HLT** paths to utilize **ParticleNet** for heavy-flavour tagging

Trigger acceptance: 1.8%
Operational since the beginning of **2023**



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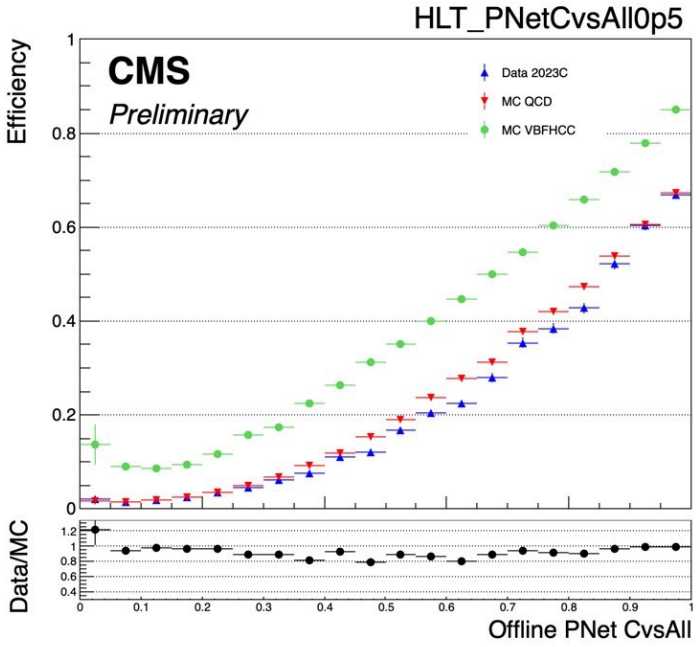

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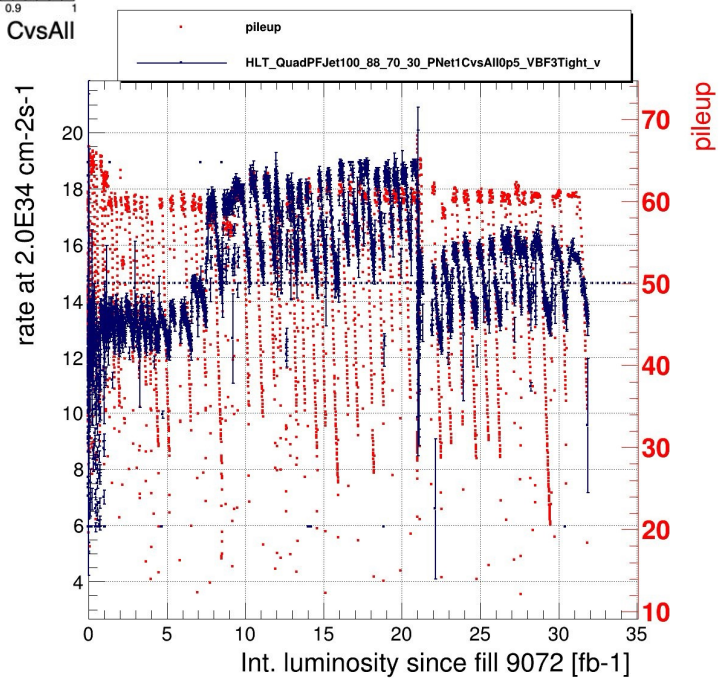

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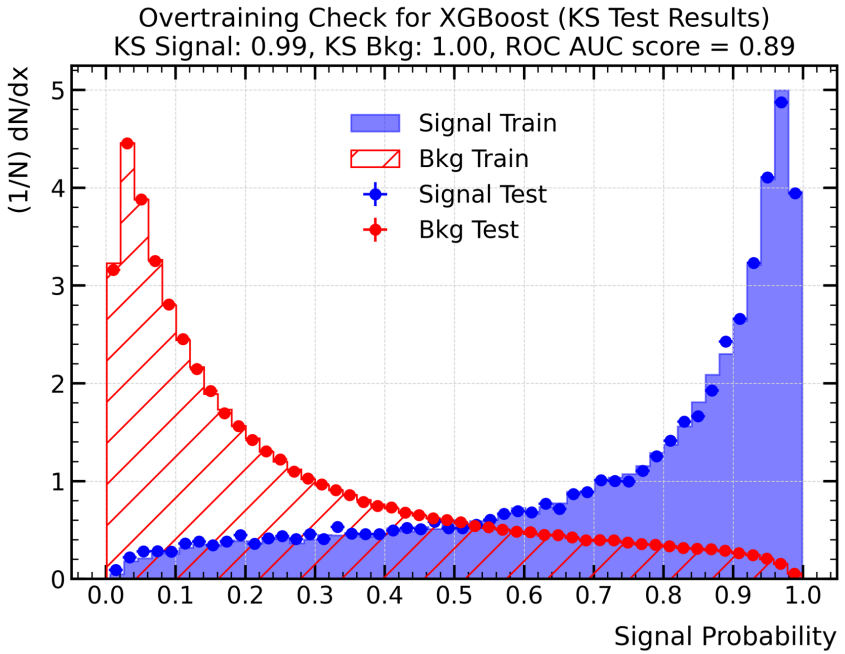
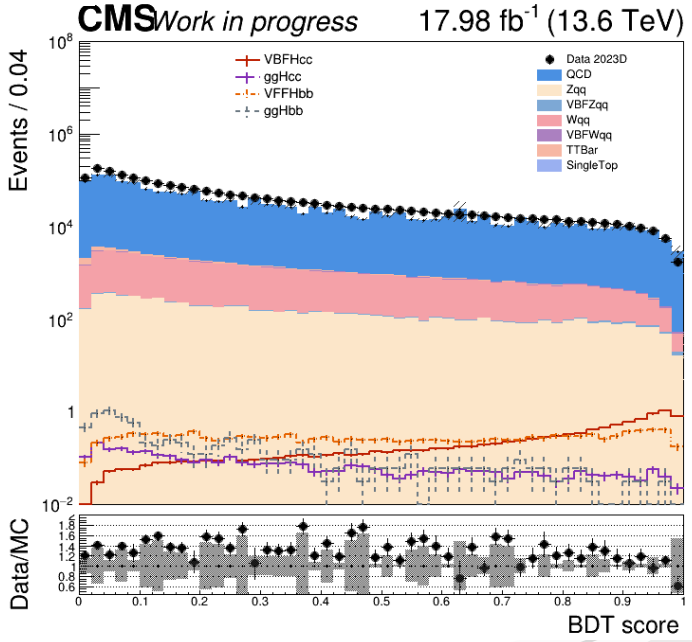


- **X-Gboost BDT** trained over signal (from MC) and background (from data sidebands)
- **Input features**: kinematic and angular variables, tagger scores

- **Three categories** based on the BDT score optimized by maximizing the significance

category	BDT score
CAT0	0.55– 0.85
CAT1	0.85 – 0.95
CAT2	0.95 – 1.0



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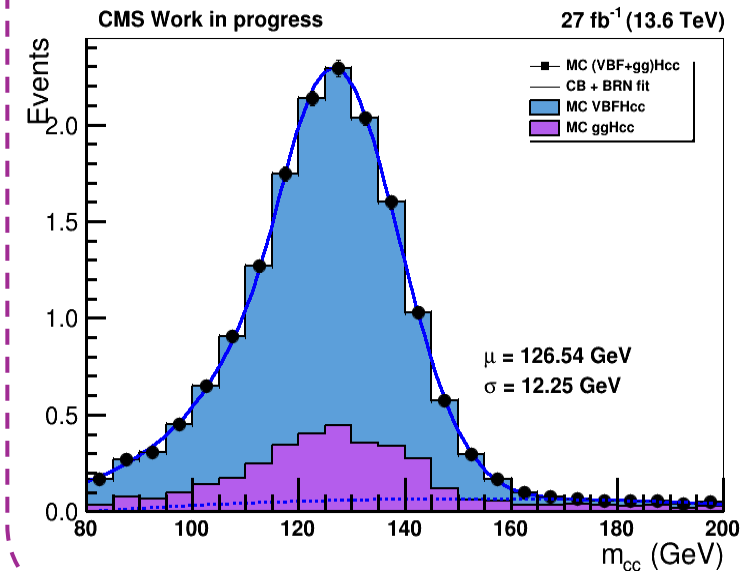
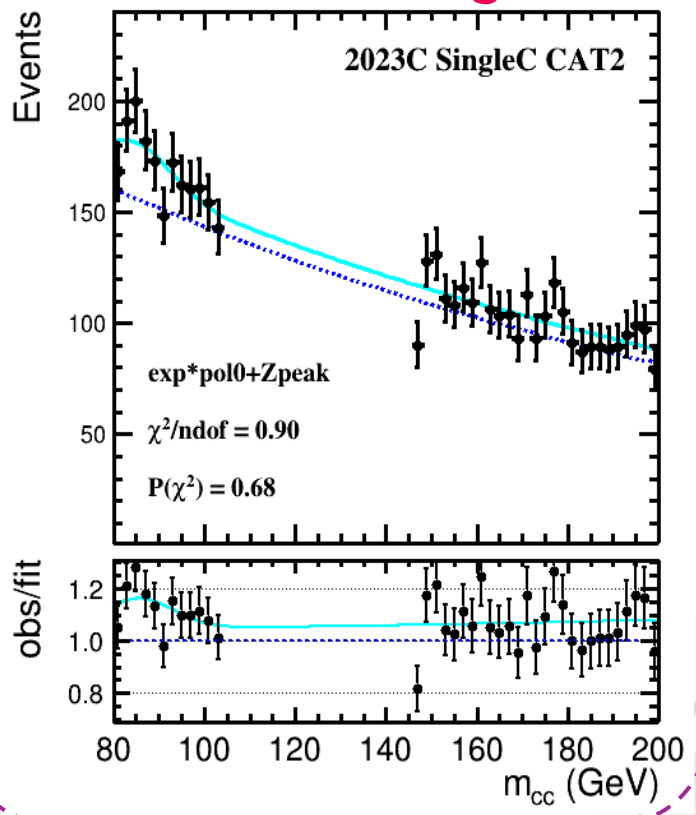
MC Hcc Shape



Continuum background



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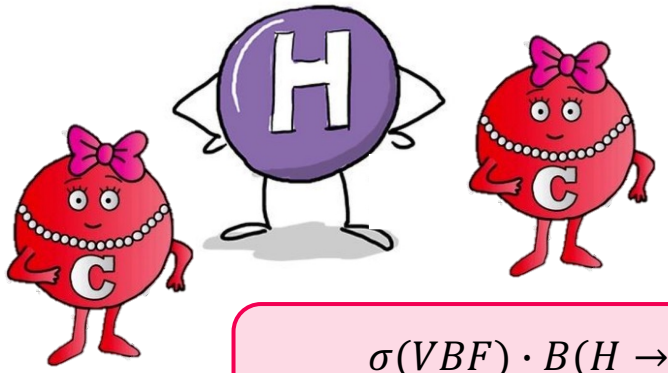

Extracted upper limit

$$\frac{\sigma(VBF)\cdot B(H\to c\bar{c})}{\sigma(VBF)_{SM}\cdot B(H\to c\bar{c})_{SM}} < 32.62 \quad @95\%\ CL$$

Full Run3 projection (expected L = 360 fb^{-1})

$$\frac{\sigma(VBF)\cdot B(H\to c\bar{c})}{\sigma(VBF)_{SM}\cdot B(H\to c\bar{c})_{SM}} < 8 \quad @95\%\ CL$$

Compatible with other channels !

What' s next …

- Trigger: **VBF parking** dataset → increased signal acceptance
- No selection on the taggers → possibility to **simultaneously** extract **Hbb** and **Hcc**
- Much larger statistics → room for improvement in the **ML** discriminating techniques
- New c-tagger : **UParT**

THANK YOU

FOR YOUR ATTENTION

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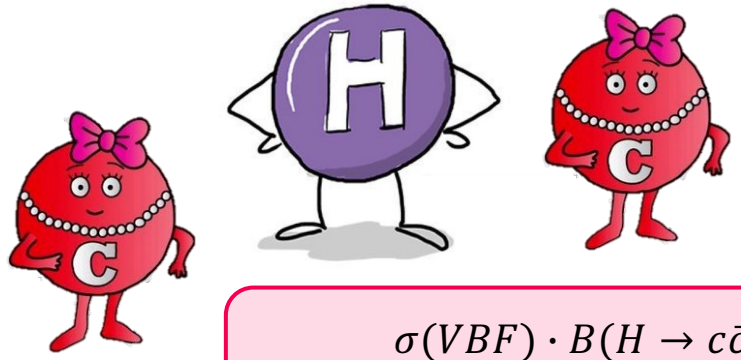

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Projection at HL-LHC + combination of VH, VBF & ttH

$$\frac{\sigma\cdot B(H\to c\bar{c})}{\sigma_{SM}\cdot B(H\to c\bar{c})_{SM}} < 2 \quad @95\%\ CL$$