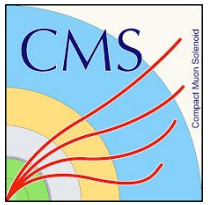


Charge asymmetry measurement in WH($\tau\tau$) at CMS

Markus Klute, Ralf Schmieder, **Nicolò Trevisani**, Roger Wolf
on behalf of the CMS collaboration

KIT - Karlsruhe Institute of Technology

4 December 2025

Introduction

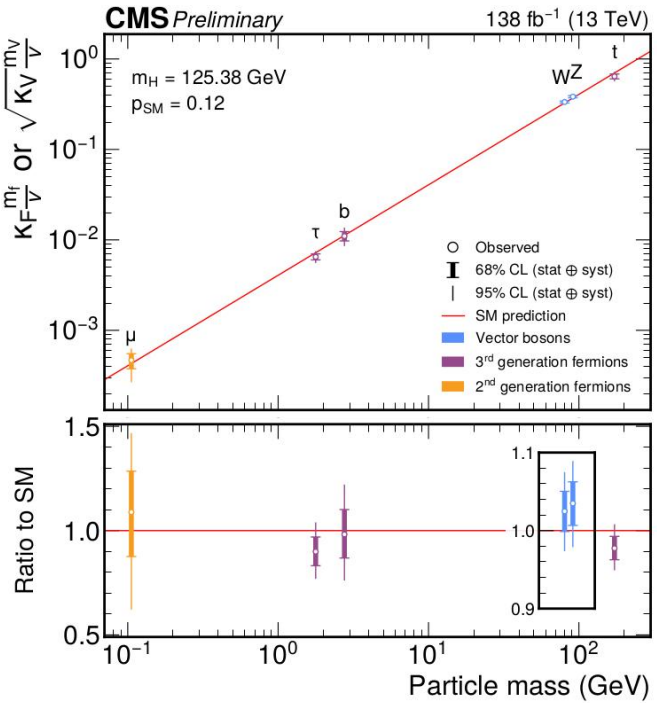
Experimentally, the Higgs boson coupling to fermions:

- Has been measured for top and bottom quarks and τ lepton
- Showed evidence of following the standard model prediction for muons

The next target is the measurement of the charm Yukawa coupling:

- Competitive upper limits set exploiting the H→ cc channel
  - CMS: 1.1 < |κc| < 5.5 (|κc| < 3.4) at 95% CL
  - ATLAS: |κc| < 8.5 (12.4) at 95% CL

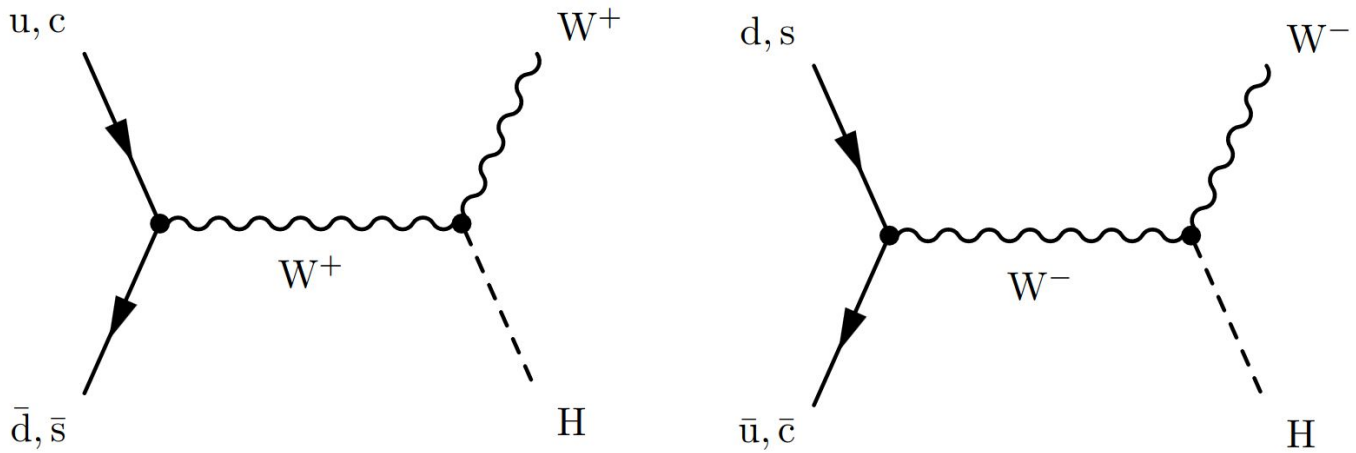
CMS-PAS-HIG-21-018



Introduction

Felix Yu: HEP02(2017)083

At the LHC, the production of a Higgs boson in association with a W boson can happen (at LO) through the following diagrams:



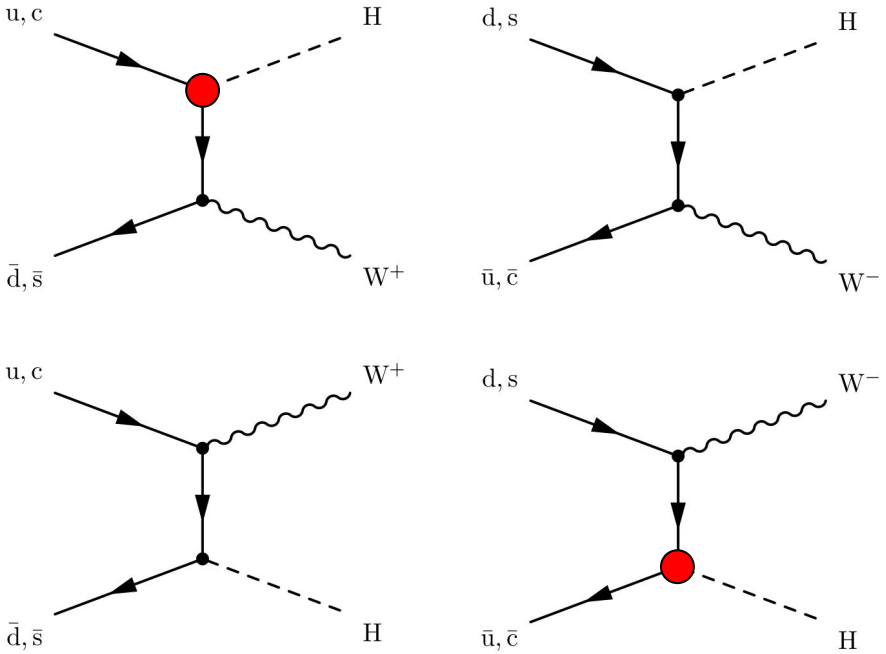
Valence quarks lead to an asymmetry between the W^+H and W^-H productions, according to the PDFs

Introduction

Felix Yu: HEP02(2017)083

But also through additional diagrams:

- Here, valence quarks are still involved, but their contribution is suppressed by the Yukawa coupling to the Higgs boson.
- The W^+H vs W^-H asymmetry is affected by these diagrams.
- Additionally, they allow to test the Yukawa couplings to light quarks.
- Deviations from the SM values of the Yukawa couplings would affect the asymmetry.



Asymmetry Definition

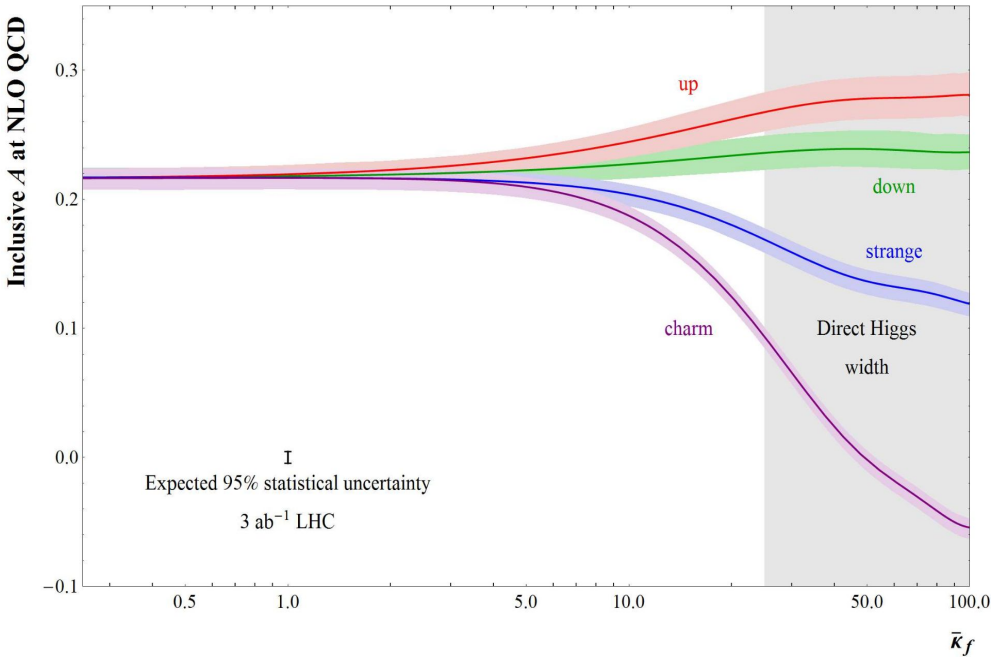
Felix Yu: HEP02(2017)083

The **asymmetry** , defined as:

$$A = \frac{\sigma(W^+h) - \sigma(W^-h)}{\sigma(W^+h) + \sigma(W^-h)}$$

is affected by the Yukawa couplings, as shown in the right plot, where:

$$\bar{\kappa}_f \equiv \frac{m_f(\mu = 125\ \text{GeV})}{m_b(\mu = 125\ \text{GeV})}\kappa_f$$

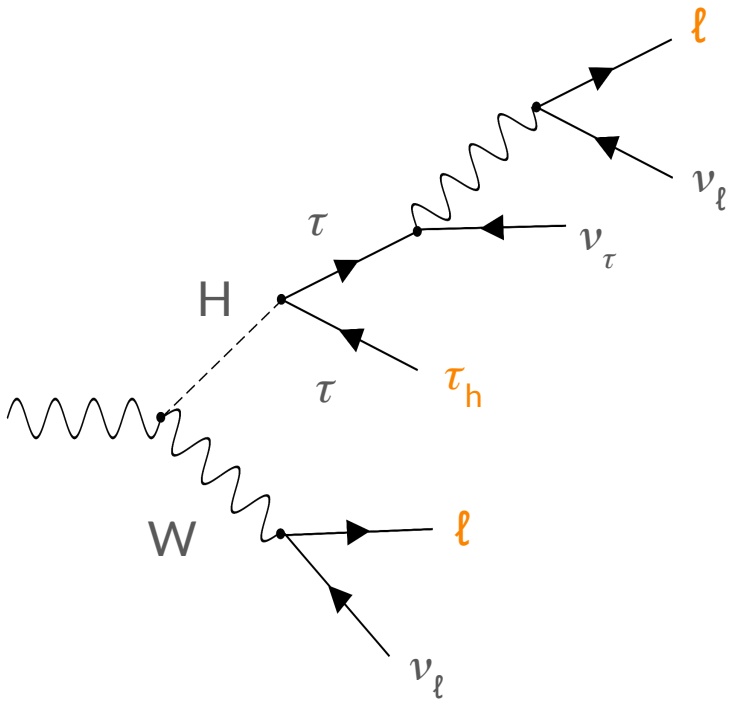


Analysis Strategy

Public result: CMS-PAS-HIG-24-019

The starting point is the WH cross-section measurement, with minor modifications to make it sensitive to the charge of the associated W boson:

- $W \rightarrow \ell\, \nu_\ell$ (ℓ = e, μ)
- **$H \rightarrow \tau\tau$**
  (with at least one τ decaying hadronically)
- In final states with two light leptons, these must have the same charge
- The two leptons assigned to the Higgs boson must have opposite charges
- **DNN** used to enhance sensitivity



Analysis Strategy

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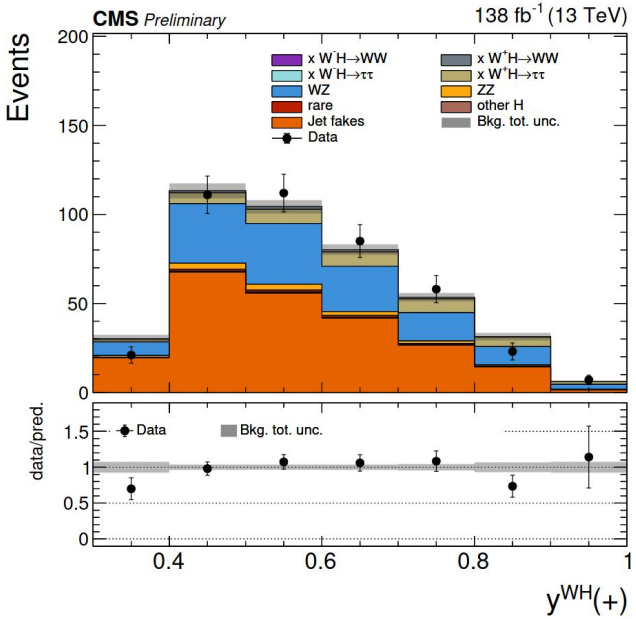
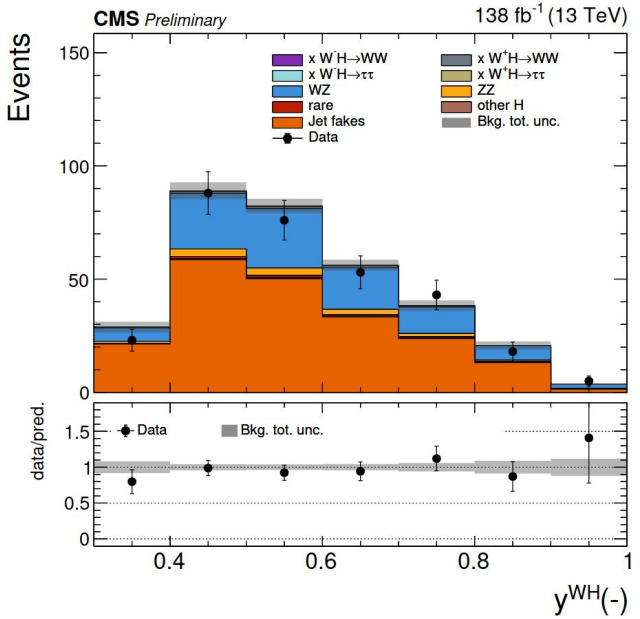
DNN Score in W^+H signal region



DNN Score in W^-H signal region



Results

Results are provided in terms of:

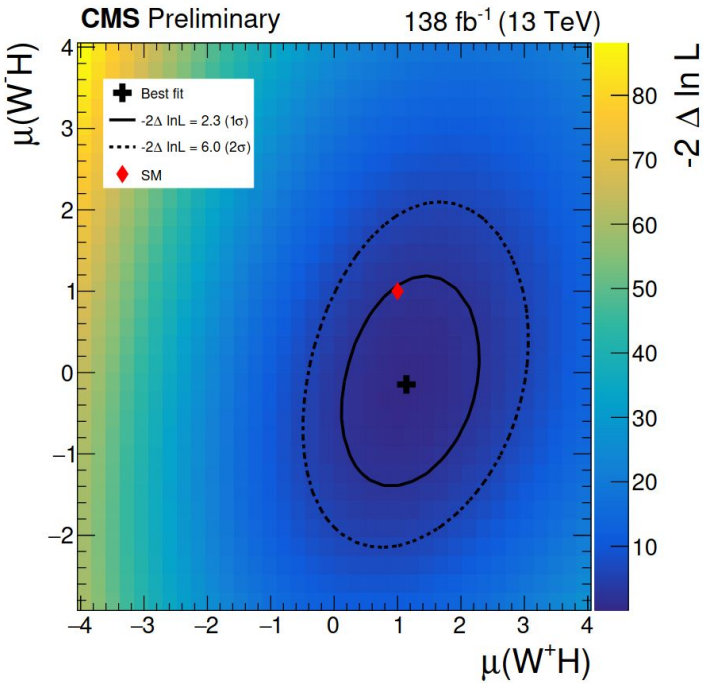
- Individual W^+H and W^-H **signal strengths**
- **Asymmetry** and total WH cross-section

Good agreement with the SM, but ...

... what about the interpretation in terms of the charm Yukawa coupling?

- The current (**statistical**) uncertainties are so large that no actual limits can be set
- A larger dataset and a combination of channels are required

CMS-PAS-HIG-24-019



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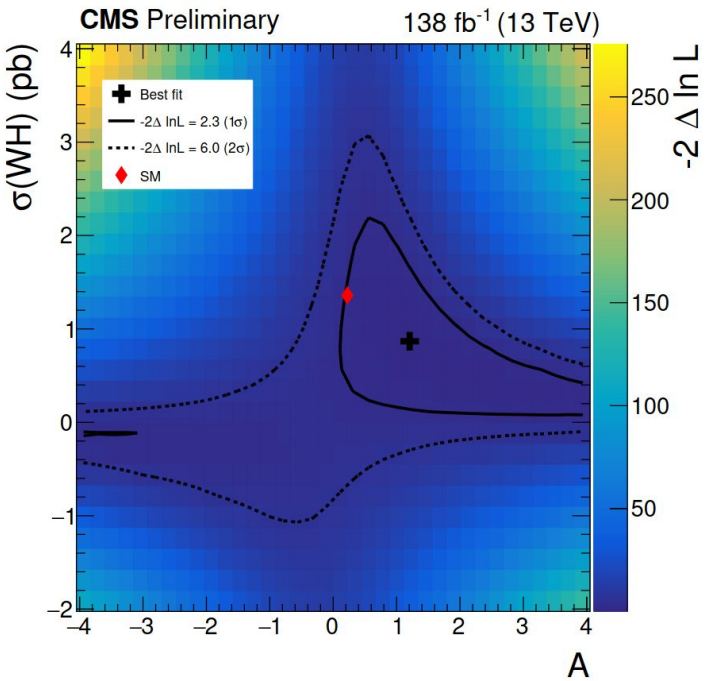
CMS-PAG-HIG-24-019



Signal Modeling

The current version of the analysis uses only the centrally-produced CMS samples with **SM coupling** values:

- Samples are generated using **POWHEG-JHUGEN727** , with parton shower described by Pythia

Nevertheless, we need to describe the change in cross-section and kinematics induces by the **varied Yukawa couplings** :

- UFO model: SM_dusc_NLO_py3 (from JHEP02(2017)083)
- Feynman gauge (from JHEP02(2017)083)
- PDF = NNPDF31, LHAPDF ID = 325300 (same as in the POWHEG sample)
- **Madgraph 3.3.2** , with the following command:
  generate p p > w- h [QCD] @0
  add process p p > w- h j [QCD] @1

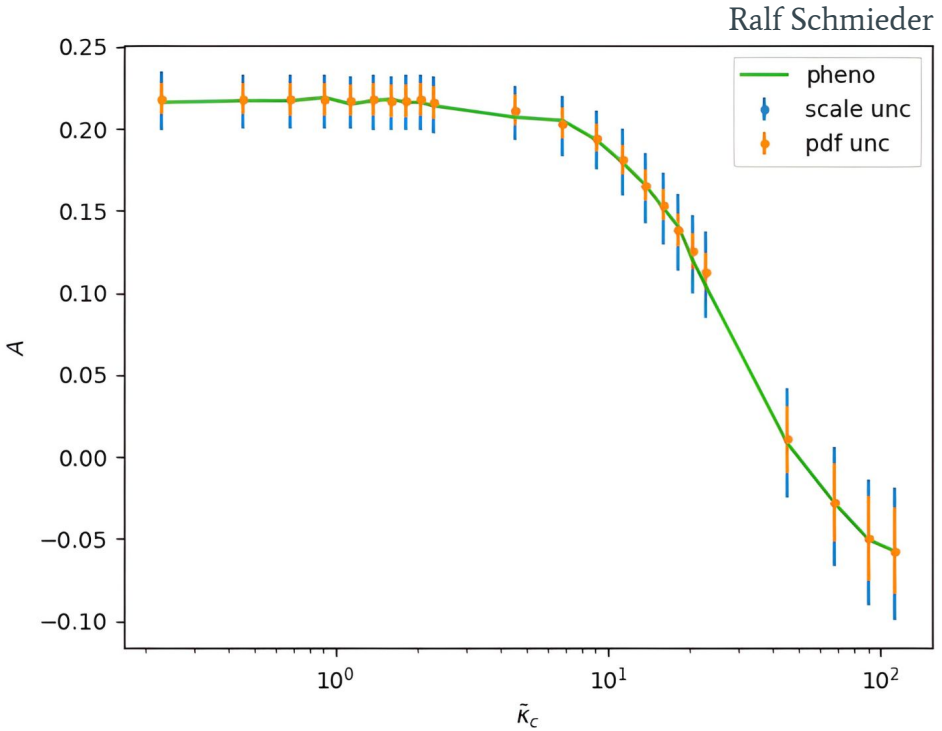
Asymmetry: Pheno Paper vs Our MadGraph Model

Reminder:

$$A = \frac{\sigma(W^+h) - \sigma(W^-h)}{\sigma(W^+h) + \sigma(W^-h)}$$

Here, only the **cross-section** prediction is involved

- Good agreement between the phenomenological prediction of HEP02(2017)083 and our scan



Additional Checks

On top of the pure cross-section validation, we looked at some generator-level distributions, comparing the **POWHEG** sample with our **MadGraph** model:

- Higgs pT, pseudorapidity, and azimuthal angle
- Associated W boson pT, pseudorapidity, and azimuthal angle
- Overall, nice agreement
    - The largest **discrepancies are below 5%** at very low Higgs/W pT

Conclusions

The WH process provides an indirect probe of **light quarks' Yukawa couplings** :

- Currently investigated in the H→ττ decay channel
  - A **larger dataset** and the **combination** with other final states are needed to achieve sensitivity to the couplings
- Detailed studies on the **signal modeling** have been carried out, following the prescriptions in HEP02(2017)083
  - Thanks to Felix Yu for the support and guidance

BACK-UP

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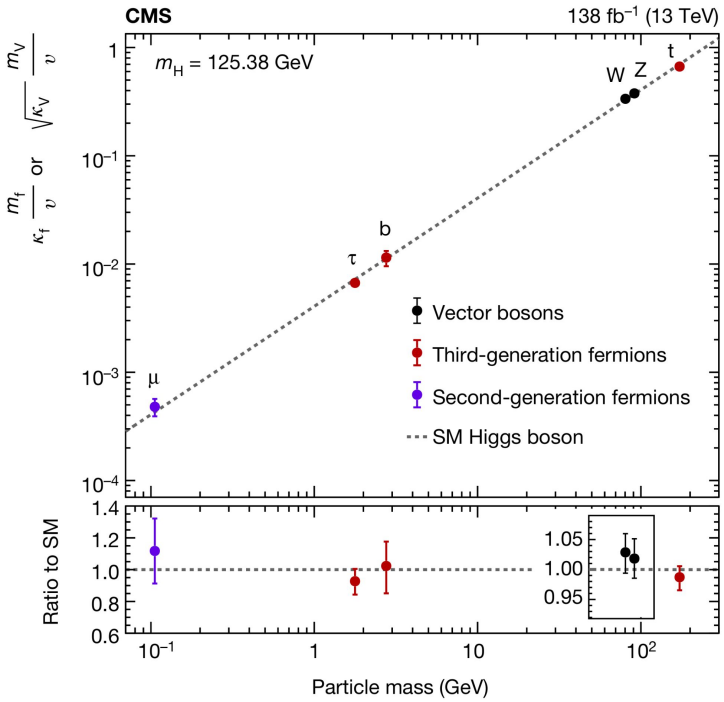
Nature volume 607, pages 60–68 (2022)