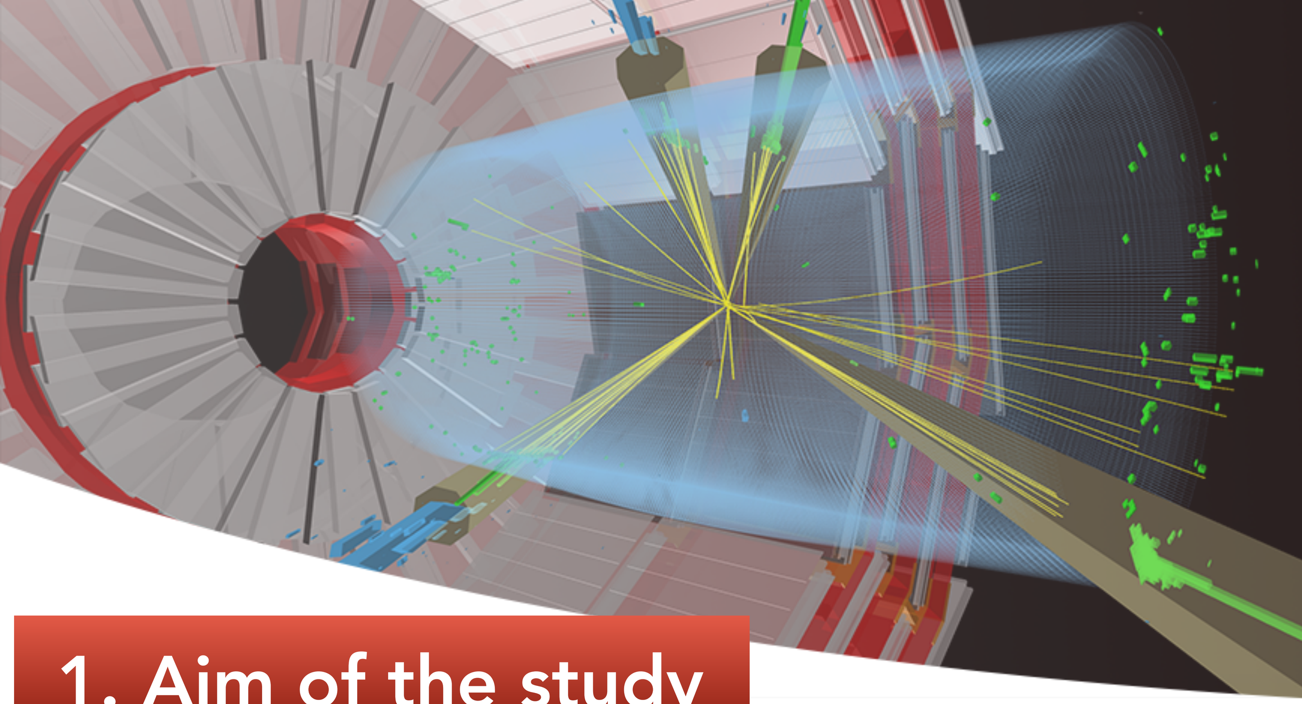


Search for Higgs boson decay to a charm quark-antiquark pair in proton-proton collisions at $\sqrt{s}$ = 13 TeV

Congqiao Li (Peking University) on *behalf of the CMS Collaboration*

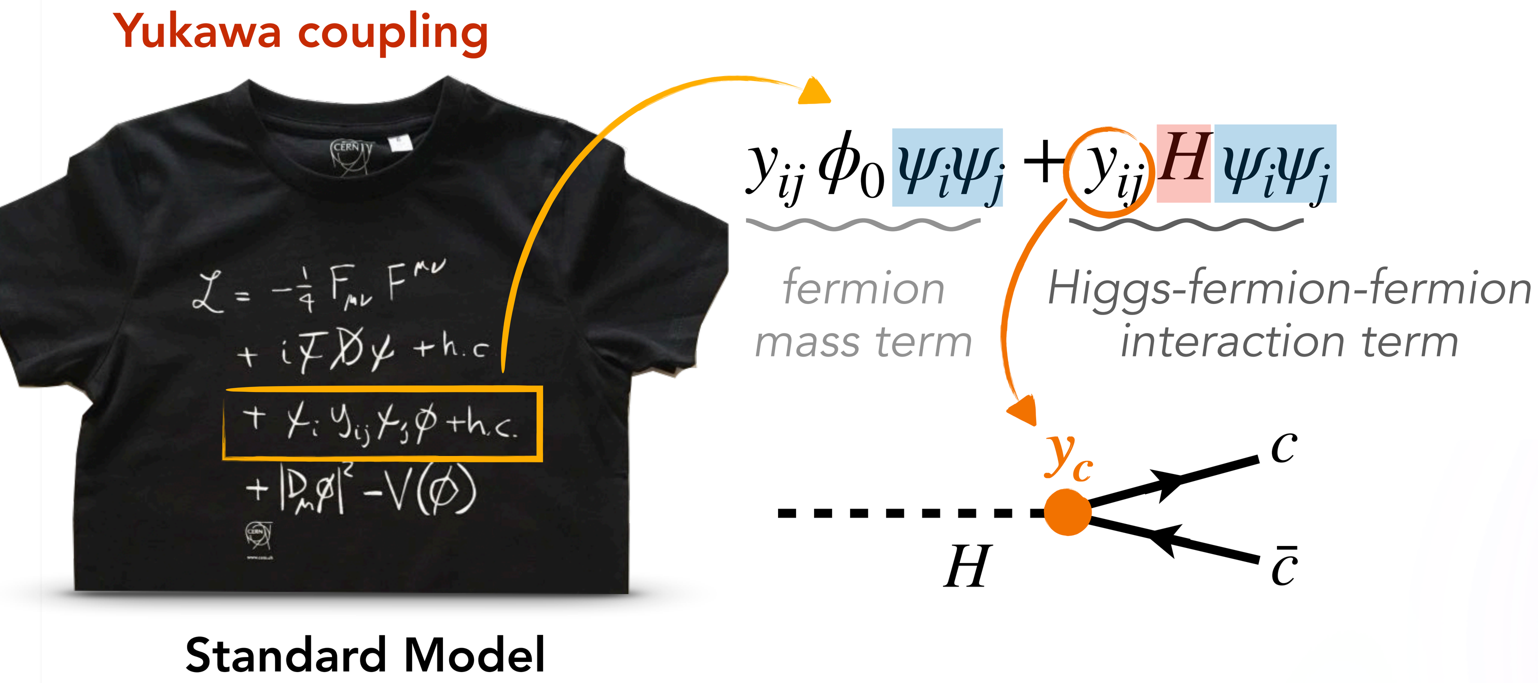
LHCC Poster Session, 29 November, 2022

Based on
CMS-HIG-21-008
CMS Collaboration. arXiv:2205.05550
(Accepted by Phys.Rev.Lett)

1. Aim of the study

(A) Goal

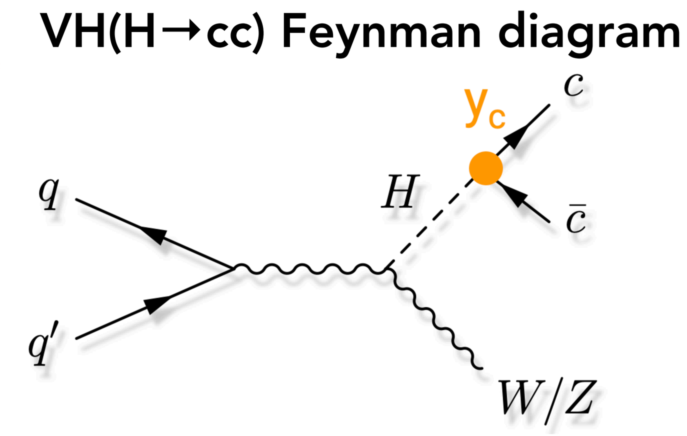
- This work aims to measure the **Higgs and charm quark Yukawa coupling**

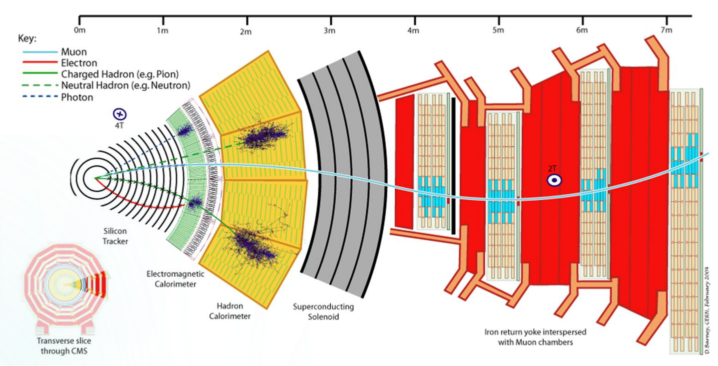


(B) Why do we measure y_c?

- Higgs coupling to the 3rd generation fermions (b/t/τ) has been well-established; next milestone is to measure the Higgs coupling to 2nd generation quarks
- Measuring H-c coupling: a further check of Higgs mechanism and a potential probe of new physics

VH(H→cc) Feynman diagram

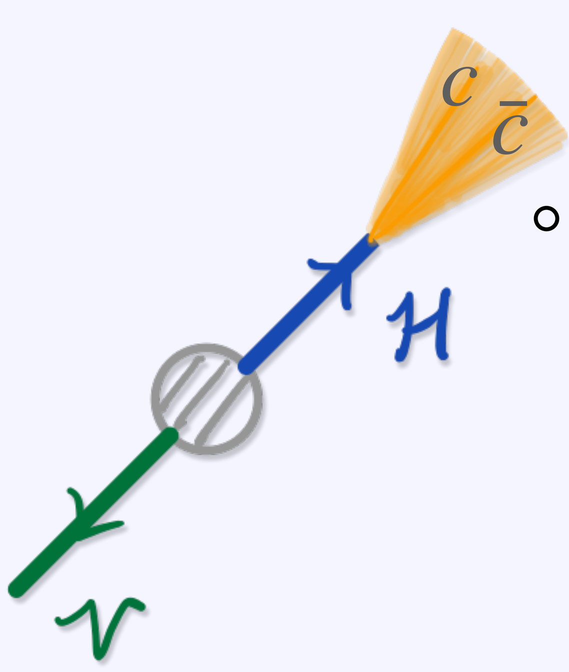




(C) How do we measure y_c?

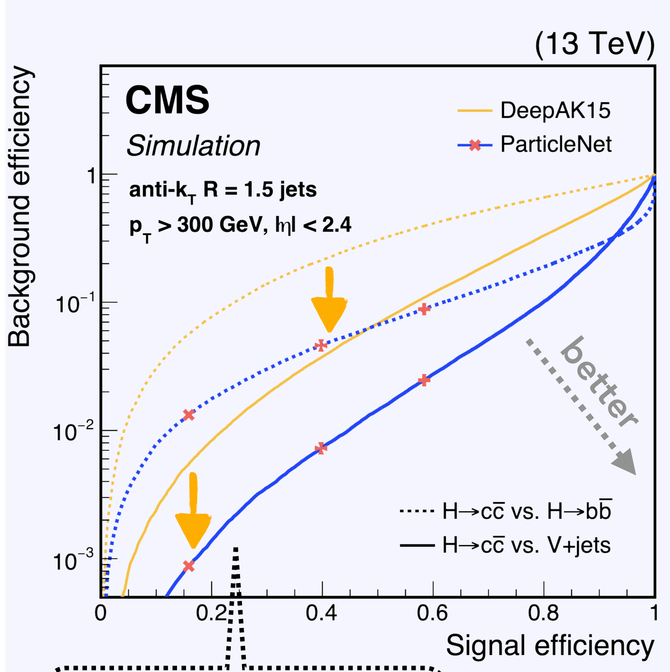
- Search for physics process: H→cc̄ in association with W/Z in CMS detector
- Leptonic decay of W/Z provides a handle to suppress multijet background
- Higgs candidate reconstructed by one large-R jet or two small-R jets

2. Merged-jet topology



New phase-space!

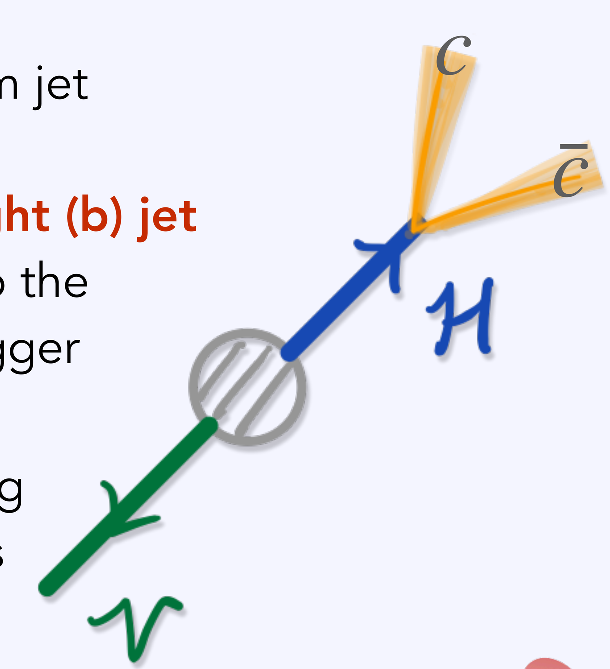
- Identify di-charm jet with the **ParticleNet** tagger (graph neural network architecture): **x5 better background rejection** compared to the previous DeepAK15 tagger
- Regress on the Higgs mass with ParticleNet-based algorithm: 20–25% final sensitivity↗
- BKG further suppressed by a kinematic BDT
- ParticleNet cc-tagger used for defining 3 cc-flavor enriched region
- Finally, apply fit on the regressed Higgs candidate mass

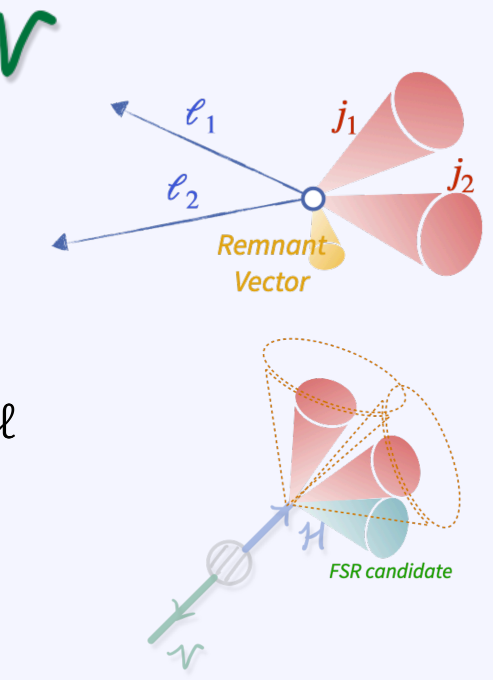


x5 more background rejection

3. Resolved-jet topology

- Adopt improved charm jet tagger, **DeepJet**: **x2 (~40%) gain on light (b) jet rejection** compared to the previous DeepCSV tagger
- Methods for improving Higgs candidate mass resolution:
  - new DNN-based charm jet energy regression (20% resolution↗)
  - kinematic fit in the 2L channel to balance Z→ℓℓ and H→cc system (30% resolution↗)
  - recovery of FSR jets
- Event-level BDT to maximize signal vs. BKG separation and use in fit for extracting the signal

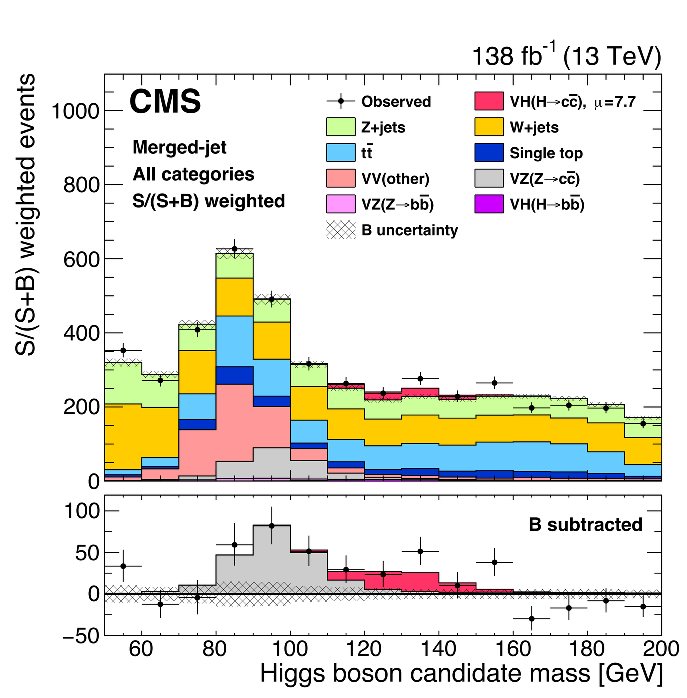


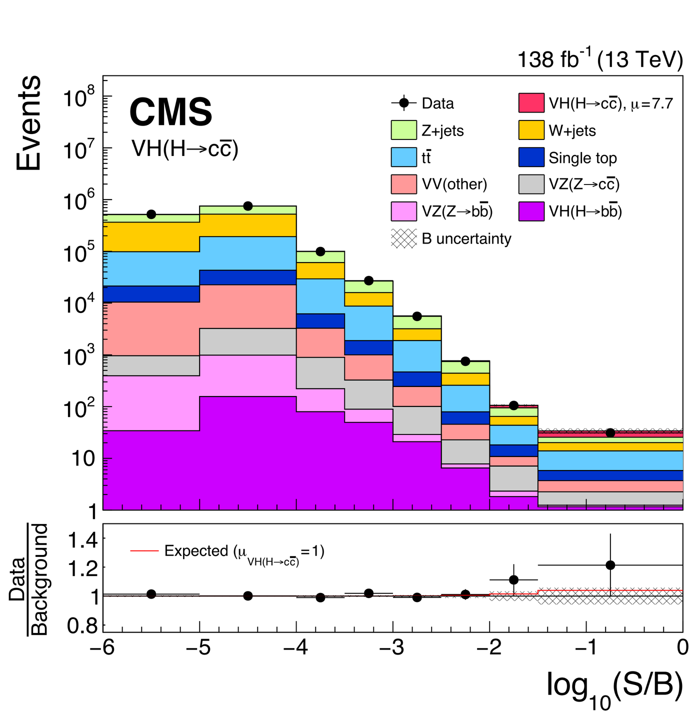


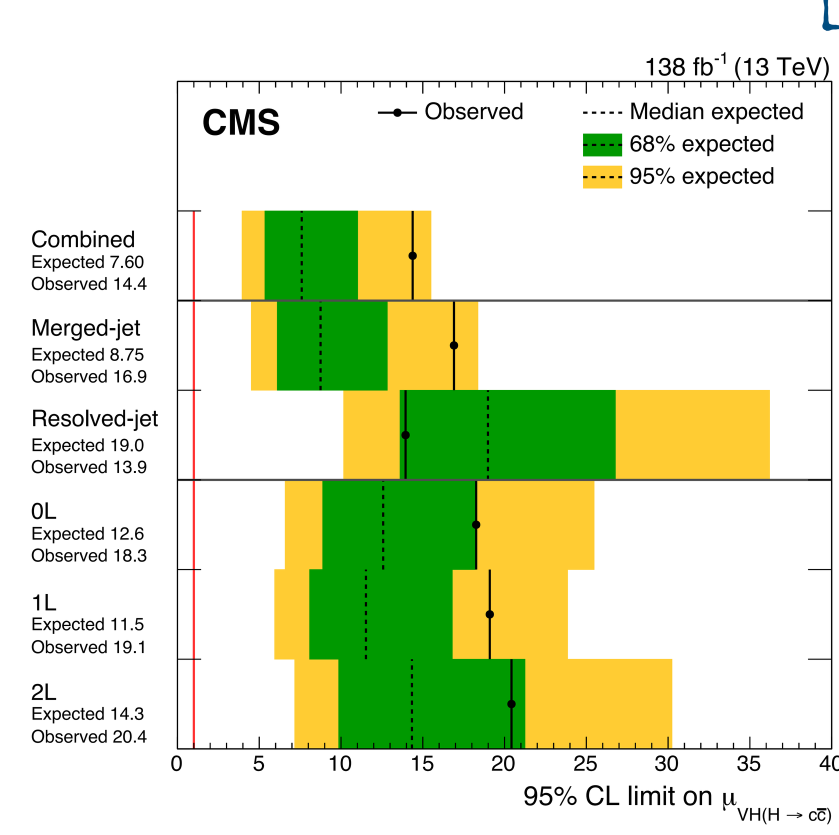
4. Results

1. VZ(Z→cc) validation

- The full analysis procedure is validated by measuring the VZ(Z→cc) process
- Best-fit signal strength: $\mu_{VZ(Z\to cc)} = 1.01^{+0.23}_{-0.21}$ → very good agreements with Standard Model expectation
- Observed significance of $5.7\,\sigma$ → **marks the first observation of Z→cc at a hadron collider!**



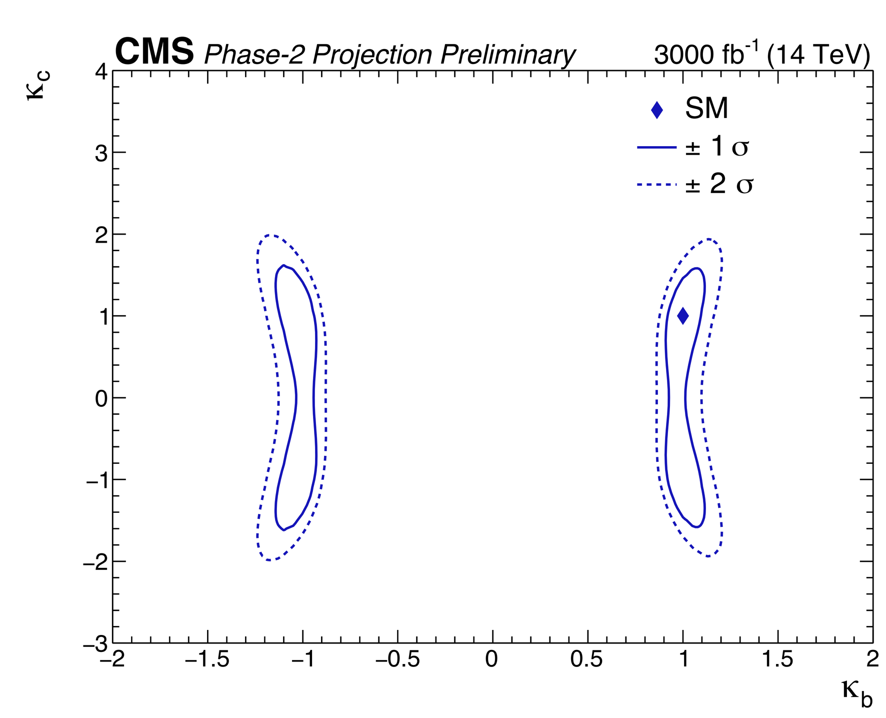




2. VH(H→cc) result

- Upper limit on the obs. (exp.) VH(H→cc) signal strength at 95% CL: $\mu_{VH(H\to cc)} < 14\ (7.6)$
- Translate to the observed H-c coupling modifier κ_c : $1.1 < |\kappa_c| < 5.5$ **→ most stringent constraint to date!**

3. HL-LHC extrapolation

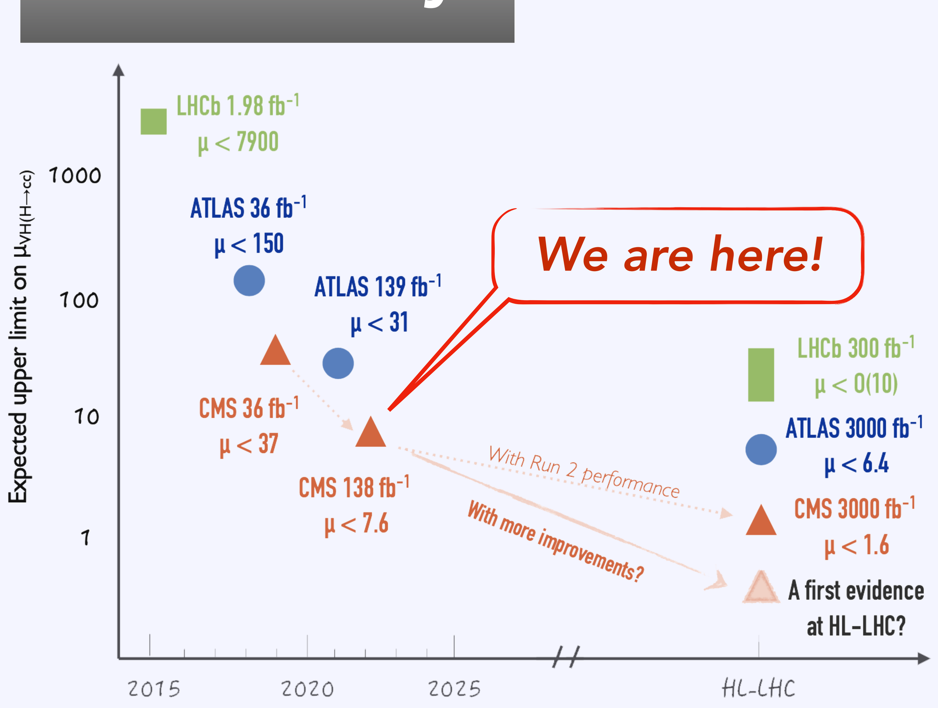


- Extrapolation of merged-jet analysis to HL-LHC condition
- Simultaneous constraint on H→bb and H→cc:

$$\mu_{VH(H\to bb)} = 1.00 \pm 0.03\ \text{(stats.)} \pm 0.04\ \text{(syst.)}$$

$$\mu_{VH(H\to cc)} = 1.0 \pm 0.6\ \text{(stats.)} \pm 0.5\ \text{(syst.)}$$

5. Summary



- We delivered the measurement on H-c Yukawa coupling using CMS full Run 2 data, reaching the best sensitivity to date
- Improvements come from advanced analysis techniques:
  - deep-learning-based charm tagging
  - advanced regression method of jet mass
  - reduction of systematic uncertainties
- More "charming" journey ahead!