Higgs physics at LHCb

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on behalf of the LHCb Collaboration

The 22nd Workshop of the LHC Higgs Working Group

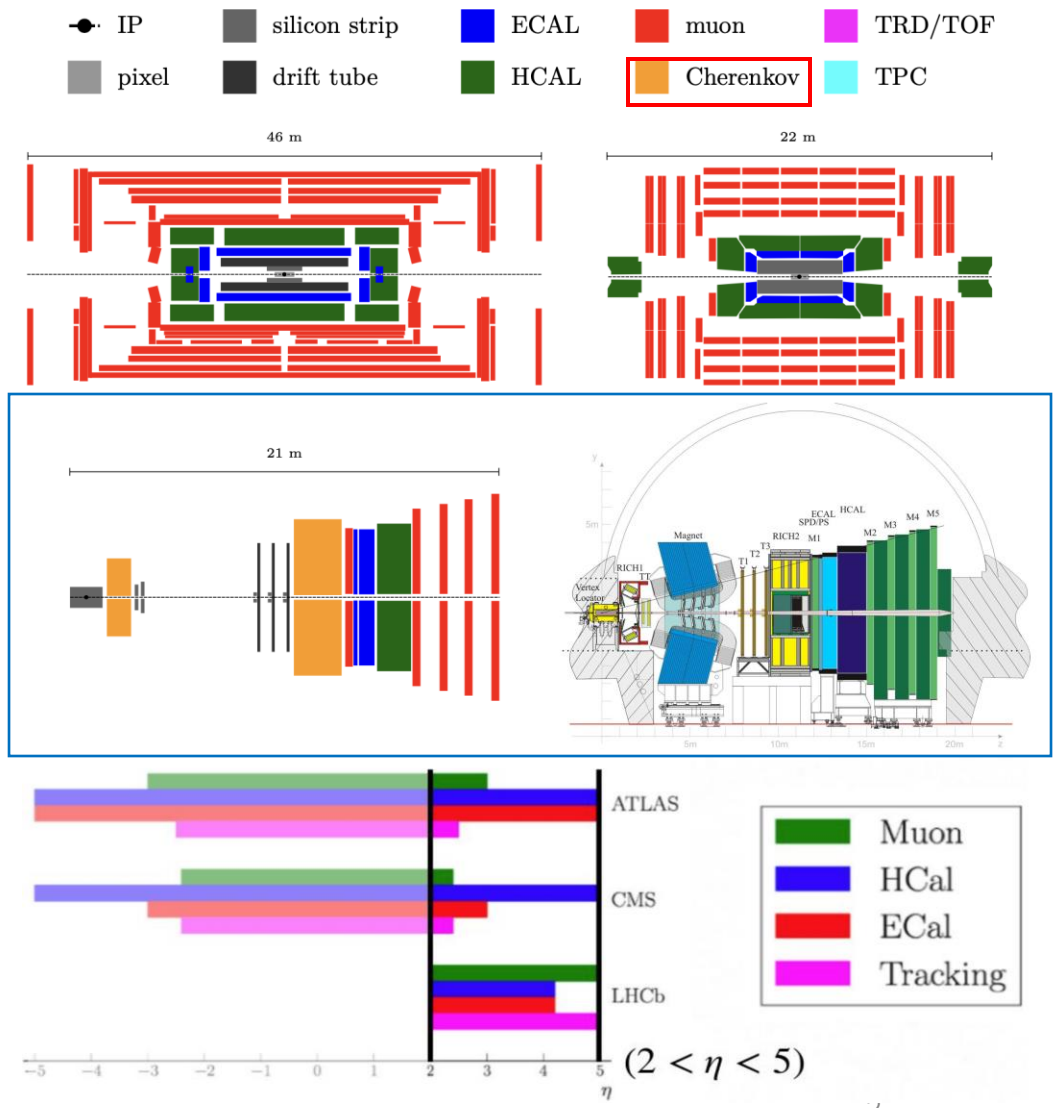
CERN, 3-5 December 2025

LHCb experiment

JINST 3 S08005

LHCb is a single-arm forward region spectrometer which were originally designed to study b and c hadron physics

- A phase space region complementary to ATLAS and CMS
- **Disadvantages**
  - Limited acceptance
  - Low luminosity
- **Strengths**
  - Lower pile-up
  - Complementary coverage
  - Low energy/momentum threshold triggers
  - Excellent secondary vertex (SV) reconstruction
  - Particle identification by two Ring-Imaging Cherenkov detectors



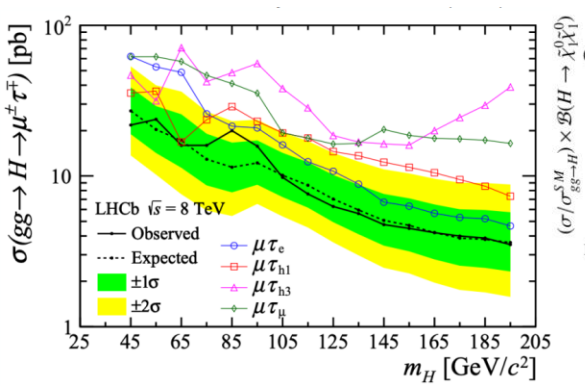
LHCb Physics

With the LHC operations more than ten years, LHCb experiment has become the General Purpose Forward Detector

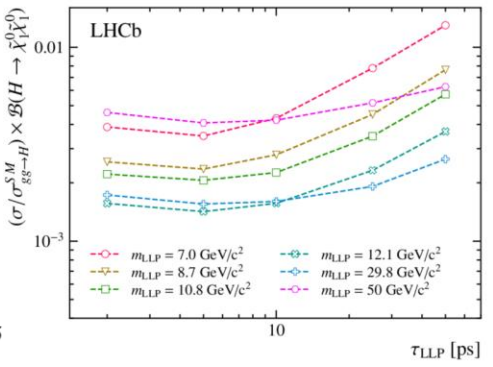
- CP violation
- Rare decays
- Spectroscopy
- Electroweak
- Heavy ions & fixed target
- Dark sector ...

In Higgs physics

- Standard Model
  - Search for $H \to b\bar{b}$ and $H \to c\bar{c}$ (VH) LHCb-CONF-2016-006
  - Production inclusive Search for $H \to b\bar{b}$ and $H \to c\bar{c}$ LHCb-PAPER-2025-034
- Beyond Standard Model
  - Study the lepton-flavour-violating decay $H \to \mu^{\pm}\tau^{\mp\mp}$
  - Search for massive long-lived particles decaying semileptonically
  - Search for long-lived particles decaying to $e\mu\nu$



Eur. Phys. J. C 78, 1008 (2018)



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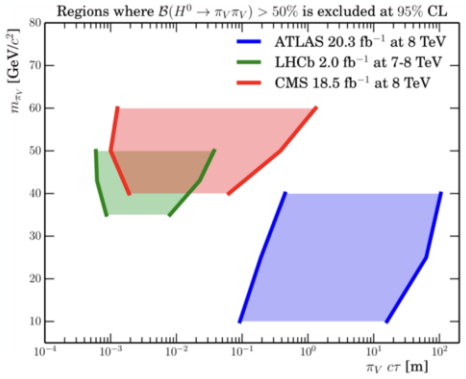
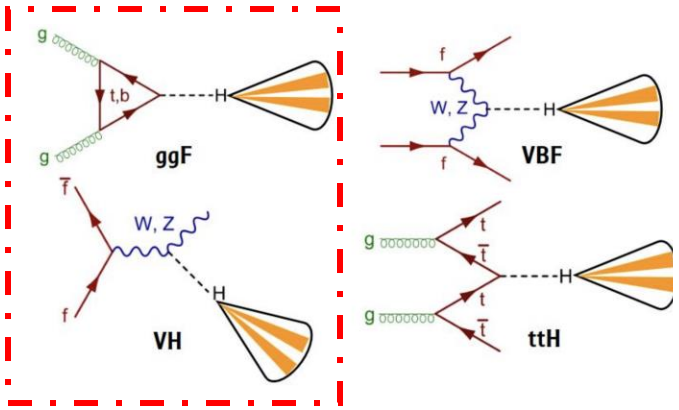
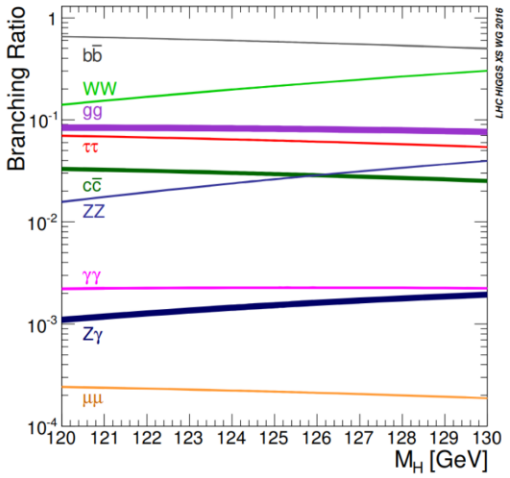
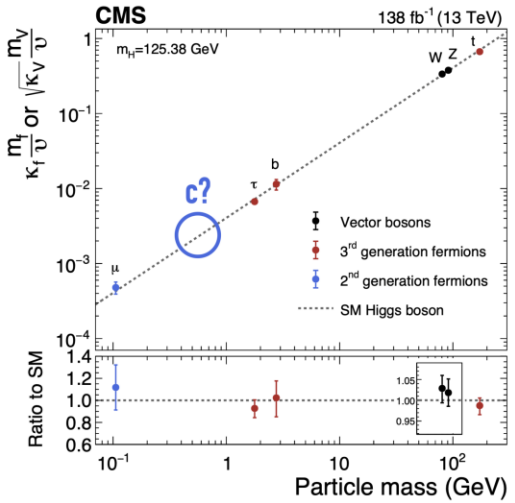


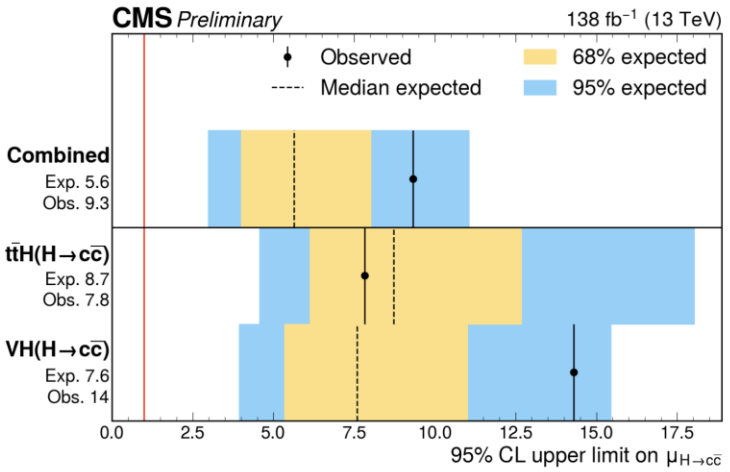
Eur. Phys. J. C 77, 812 (2017)

Search for $H \to b\bar{b}$ and $H \to c\bar{c}$







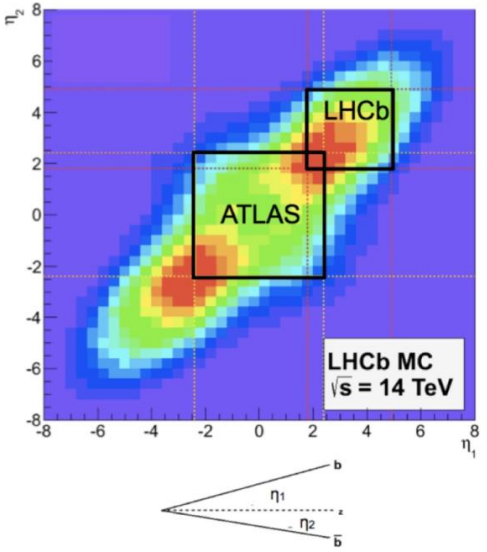


$H \to b\bar{b}$ has been observed by ATLAS[1] and CMS[2], and set an observed upper limit of $H \to c\bar{c}$ by CMS [3]

LHCb has the potential to search for $H \to b\bar{b}$ and $H \to c\bar{c}$ to become the **3th (1th in forward region) experiment** for measuring Higgs properties in the future

- Low pile-up provide clean events
- Excellent track momentum resolution
- Excellent vertex reconstruction in b- and c-jet tagging
- …

$b\bar{b}$ production



[1] Phys. Lett. B 786 (2018) 59 [2] Phys. Rev. Lett. 121, 121801 (2018) [3] arXiv:2509.22535

Search for $H \to b\bar{b}$ and $H \to c\bar{c}$

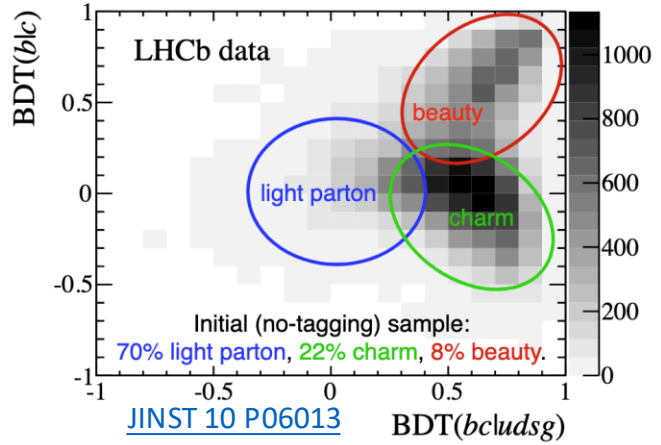
LHCb-CONF-2016-006

Search for $H \to b\bar{b}$ and $H \to c\bar{c}$ produced in association with a W or Z boson

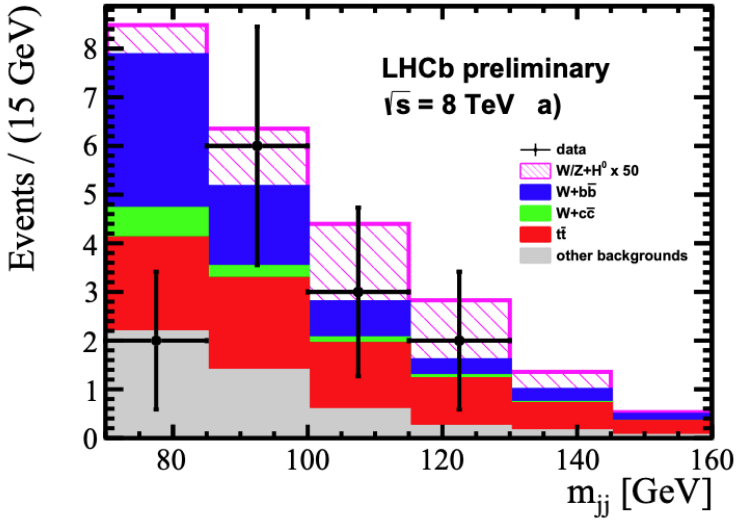
- The final state includes one or two high pT leptons (electrons or muons) for a cleaner signal samples
- Jets are clustered using the anti-k_T algorithm with distance parameter 0.5
- Two BDTs are used to identify b and c jets
- Upper limits on the cross section and Yukawa coupling

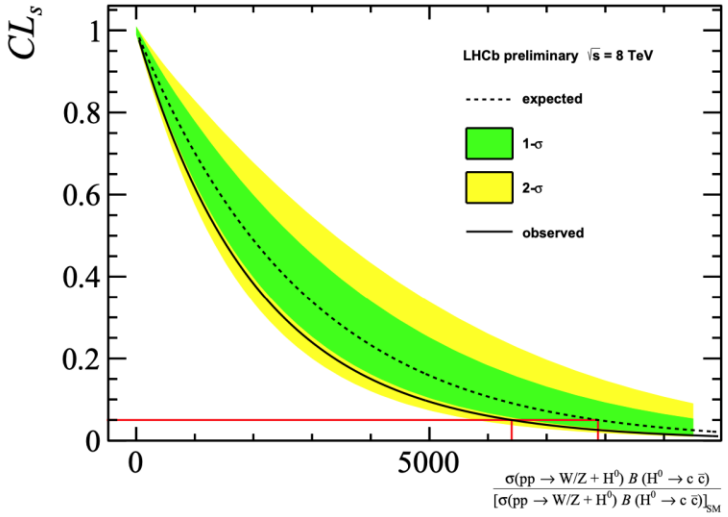
$$\sigma(pp \to W/Z + H^0) \times \mathcal{B}(H^0 \to b\bar{b}) < 1.6 \text{ pb},$$
$$\sigma(pp \to W/Z + H^0) \times \mathcal{B}(H^0 \to c\bar{c}) < 9.4 \text{ pb}.$$

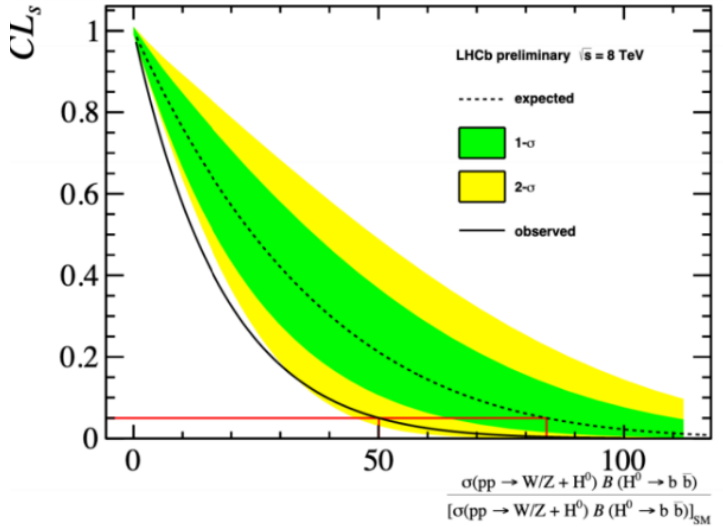
$$y^b < 7y^b_{SM}\,,\; y^c < 80y^c_{SM}$$



JINST 10 P06013





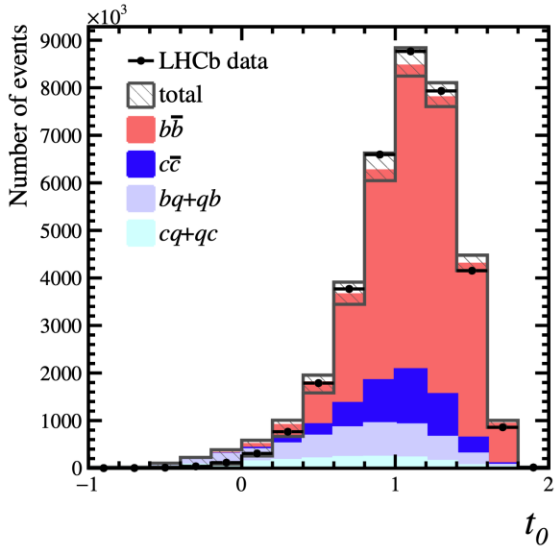


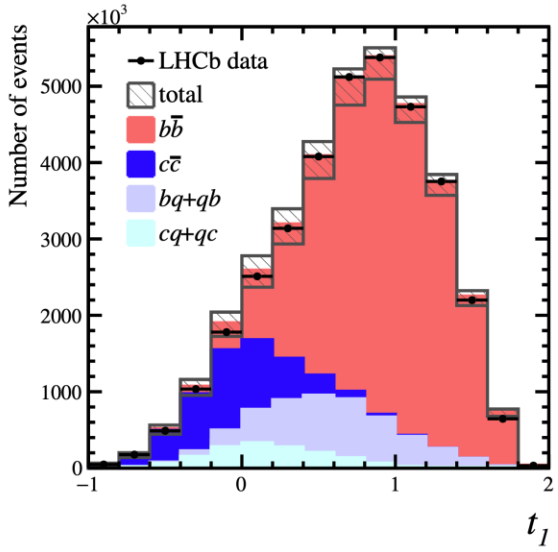
Search for $H \to b\bar{b}$ and $H \to c\bar{c}$

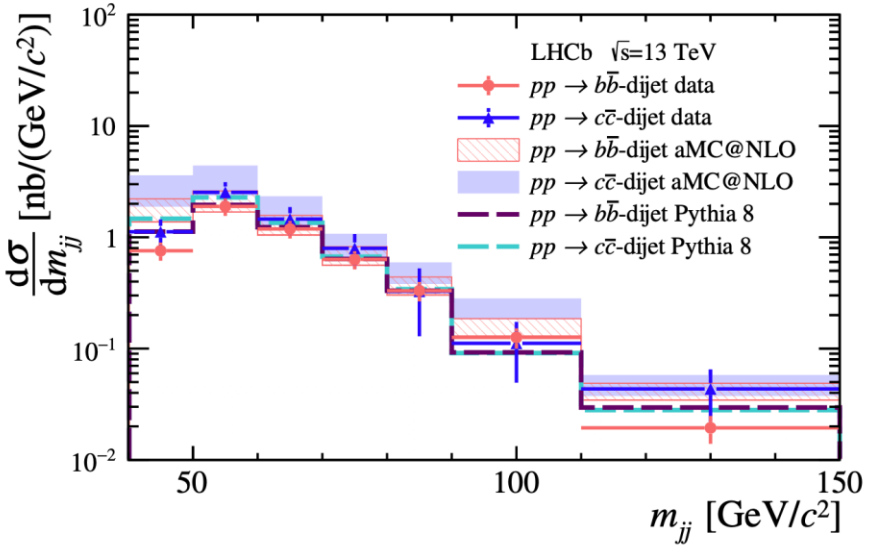
JHEP 02 (2021) 023

Measure the inclusive $b\bar{b}$ and $c\bar{c}$ production to understand the background contribution in search for $H \to b\bar{b}$ and $H \to c\bar{c}$

- Simultaneous fits to get flavour composition
- The results are agreement with theoretical predictions at NLO
- **First inclusive, direct measurement of the differential cc cross-section**
- **Improve the background uncertainties in search for $H \to b\bar{b}$ and $H \to c\bar{c}$**







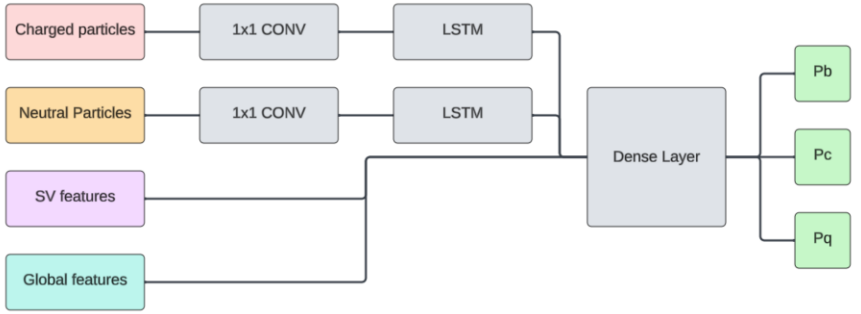
Search for $H \to b\bar{b}$ and $H \to c\bar{c}$

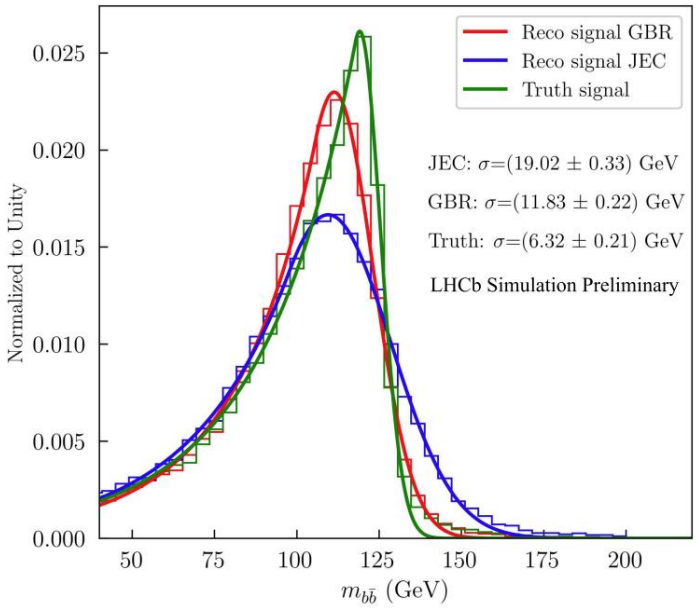
LHCb-PAPER-2025-034

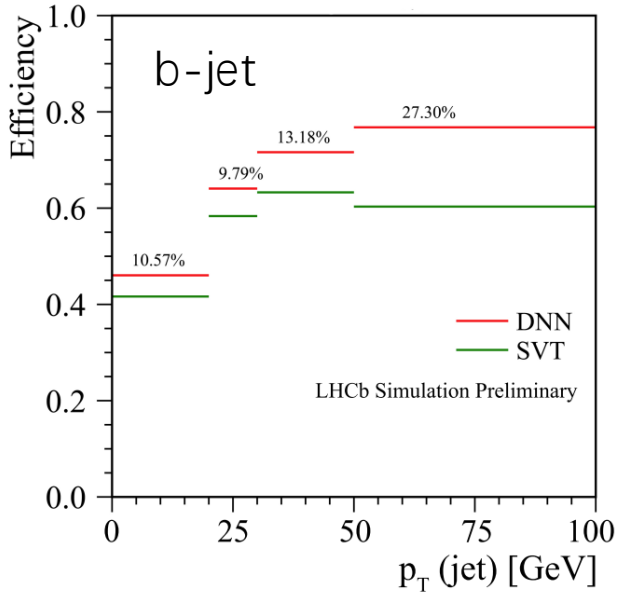
Regression techniques for jet energy correction and Deep Neural Network for jet identification

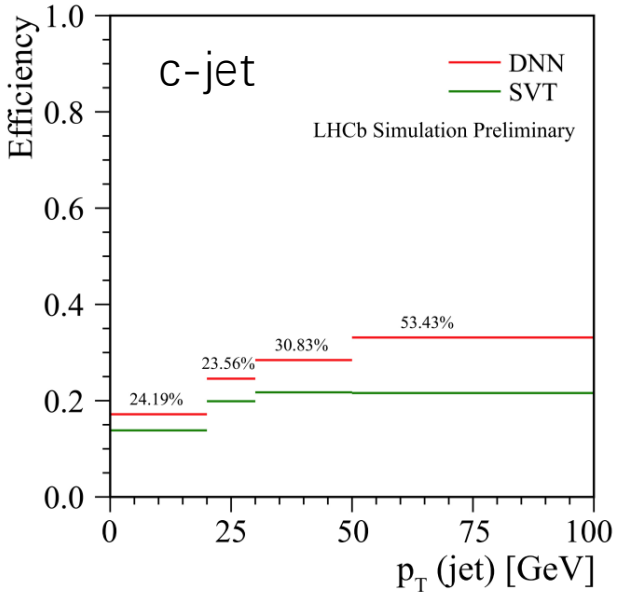
- New jet techniques based on Machine Learning
- Improve the LHCb sensitivity to b- and c-jet measurements

  In regression in jet energy correction, the improvement on limits, $H \to b\bar{b}$ ~ 12%, $H \to c\bar{c}$ ~ 32%









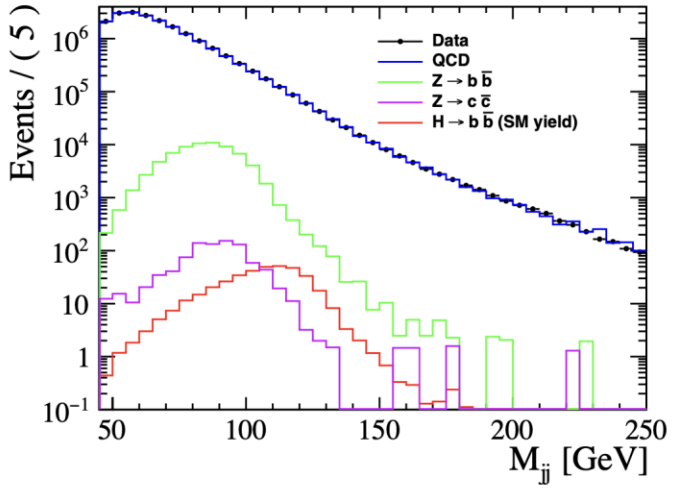
Search for $H \to b\bar{b}$ and $H \to c\bar{c}$

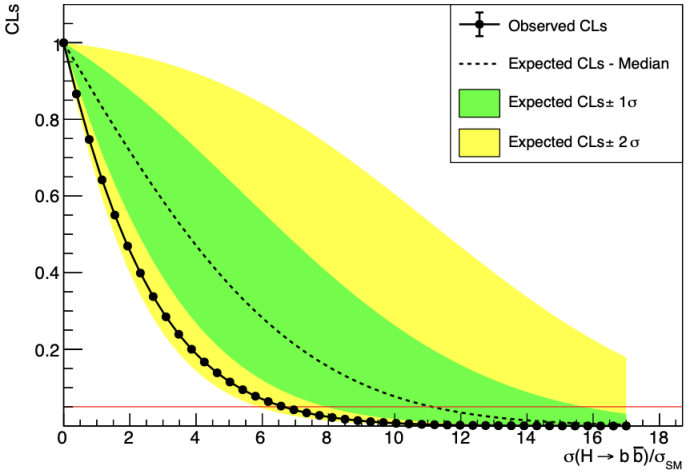
LHCb-PAPER-2025-034

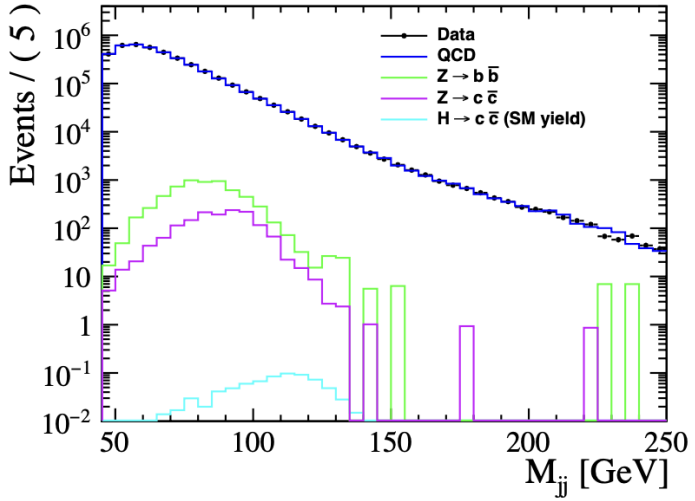
- Use the 2016 data set (1.6 fb^{-1})
- Directly triggering on di-jets with an identified SV
- Model independent approach
- The new jet techniques based on ML to apply the measurements
- Signal extraction from fit to dijet mass
- Upper limit from CLs method

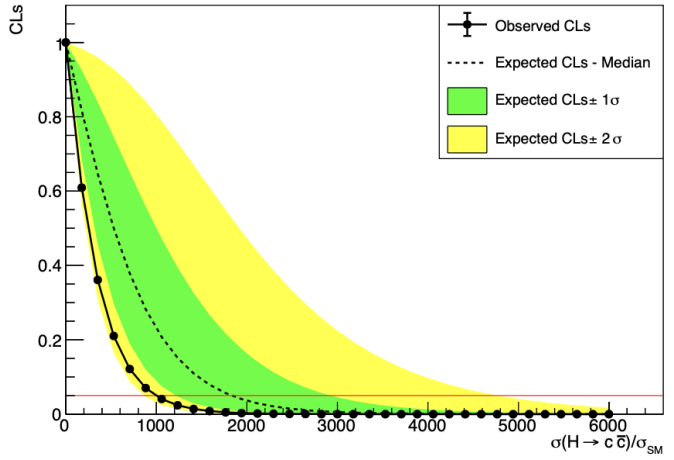
Process	σ_{UP}/σ_{SM}	N_{up}	σ_{UP} [pb]
$H \to b\bar{b}$	11.1	2652	353
$H \to c\bar{c}$	1834	1414	2939

Process	σ_{UP}/σ_{SM}	N_{up}	σ_{UP} [pb]
$H \to b\bar{b}$	6.64	1587	211
$H \to c\bar{c}$	1003	722	1605







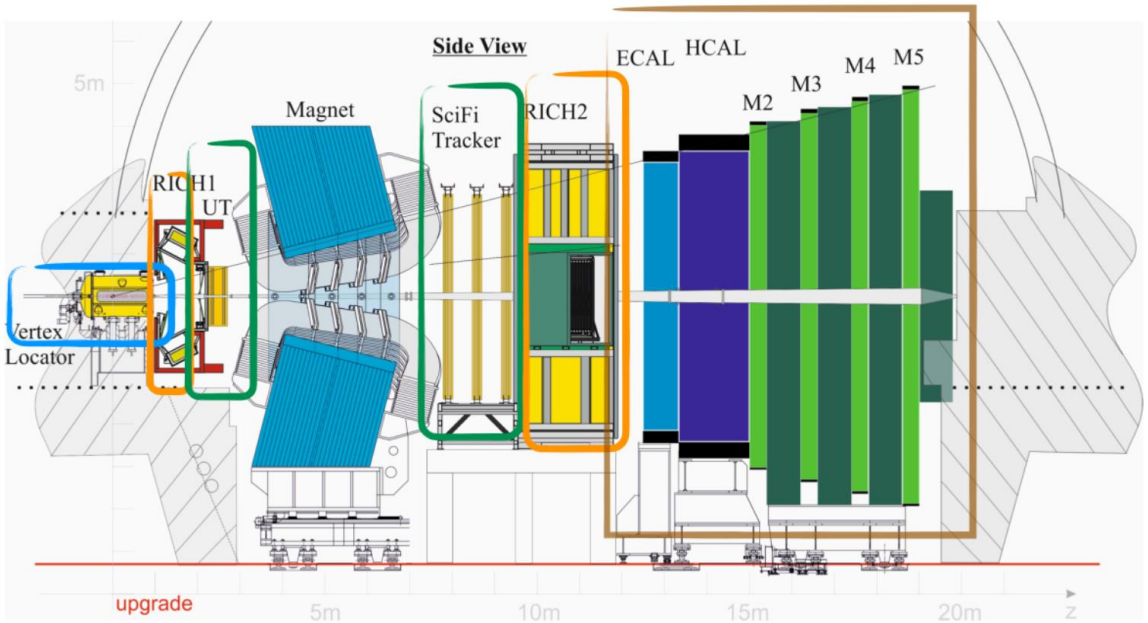


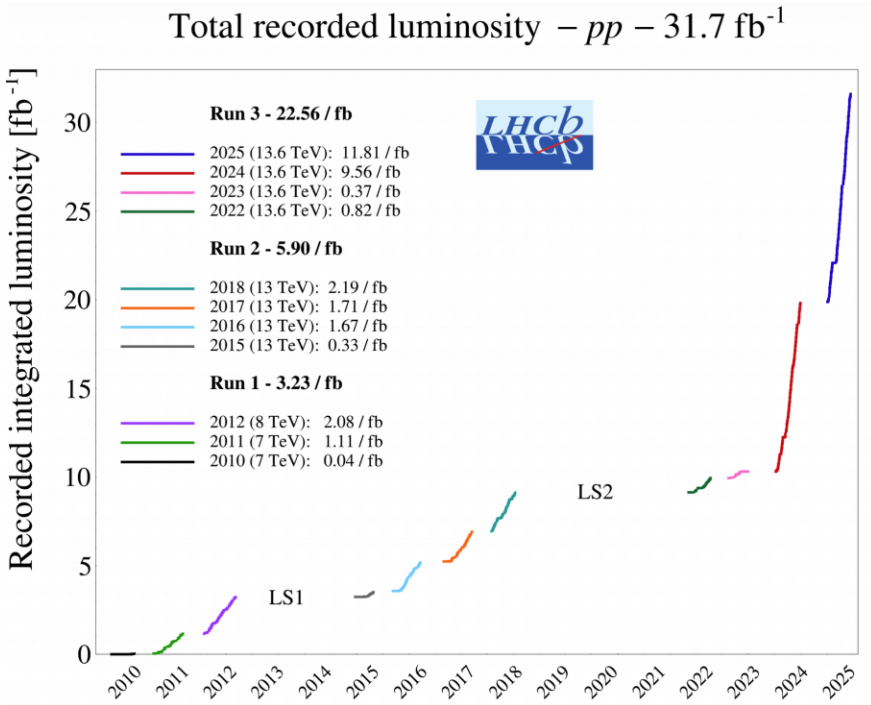
LHCb Run3

JINST 19 (2024) P05065

LHCb has completed significant upgrades during LHC LS2

LHCb has successfully collected 22.56 fb^{-1} of high-quality pp data at on-going Run3





New Vertexing Detector, **Enhanced PID detectors**,
New tracking system, **New Readout systems**, **Triggers**.

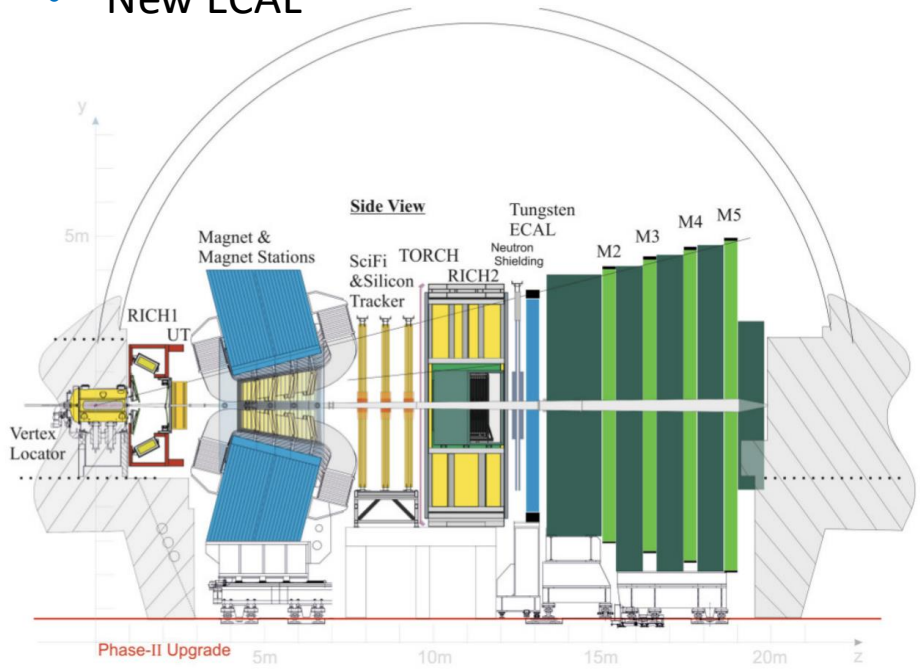
HL-LHC era

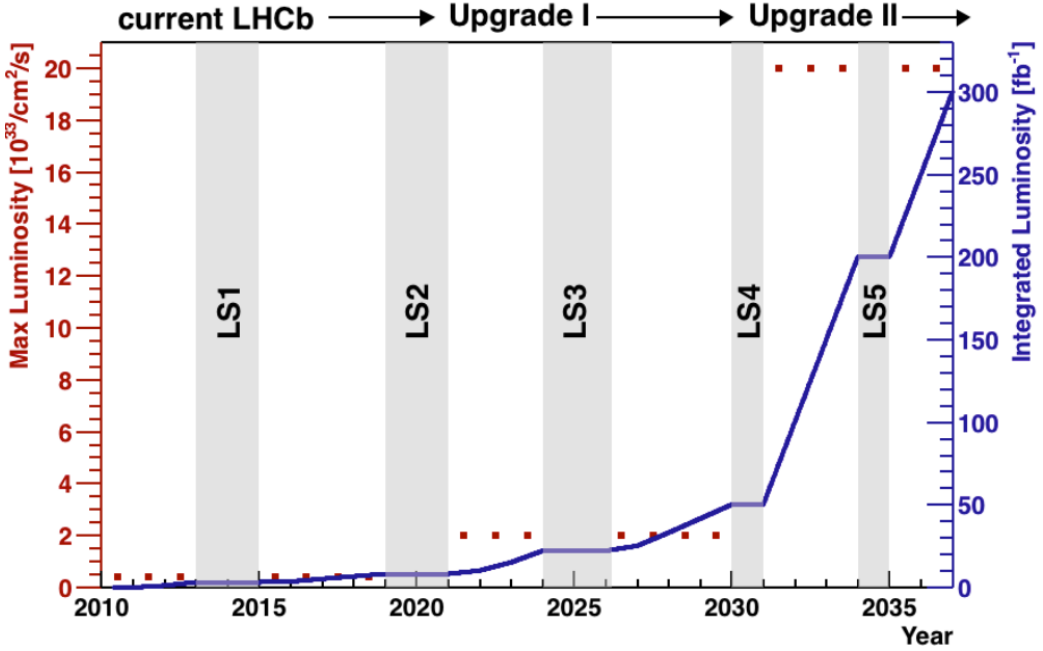
CERN-LHCC-2018-027

The LHCb Collaboration has proposed an upgrade for the HL-LHC era

The goal is to collect 300 fb-1 of integrated luminosity

- Vertex locator with 4D hybrid sensors
- New ECAL





Higgs studies at LHCb in the future

Increase luminosity will provide good performances

- Run4 ~ 50 fb^{-1}, U2 ~ 300 fb^{-1}

Measure SM Higgs cross section in the forward region

- All possible production modes (ggF, VH and VBF)
- **Target the $H \to b\bar{b}$ cross section measurement at the end of Run4**
- **Contribution to a global combination to measure the charm Yukawa coupling**

	σ_{UP}/σ_{SM} 2016	σ_{UP}/σ_{SM} Run 2	σ_{UP}/σ_{SM} Run 4	σ_{UP}/σ_{SM} U2
$H \to b\bar{b}$	6.64	3.59	0.684	0.232
$H \to c\bar{c}$	1003	542	78.8	26.8

y_c/y_c^{SM} 2016	y_c/y_c^{SM} Run 2	y_c/y_c^{SM} Run 4	y_c/y_c^{SM} U2
31.7	23.3	8.88	5.18

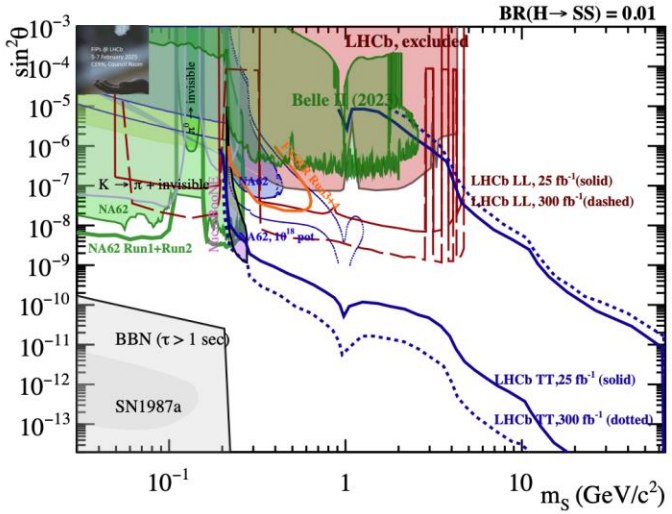
More Higgs measurement channels

- $H \to ZZ \to 4\mu$, $H \to WW$, $H \to J/\varphi\,\gamma$, ...

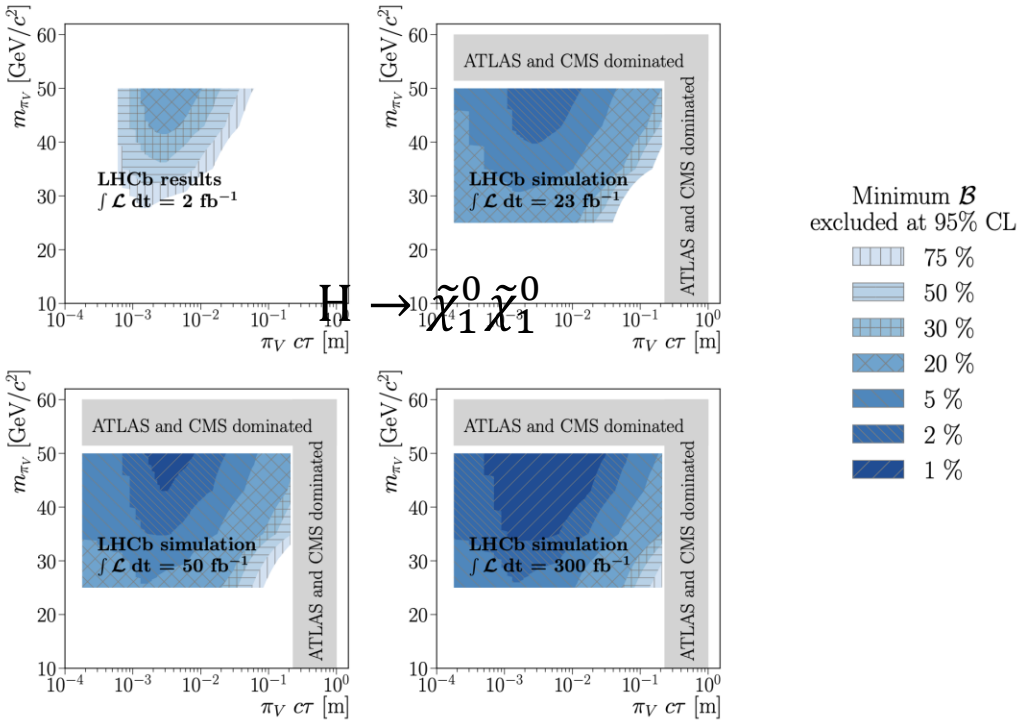
Higgs studies at LHCb in the future

LHCb can search for **BSM Higgs** in a phase space complementary to other experiments

- Low-mass Drak Scalar
- LLPs exclusive hadronic decay modes
- Higgs decay to LLPs
- …



arXiv:2510.05257v2



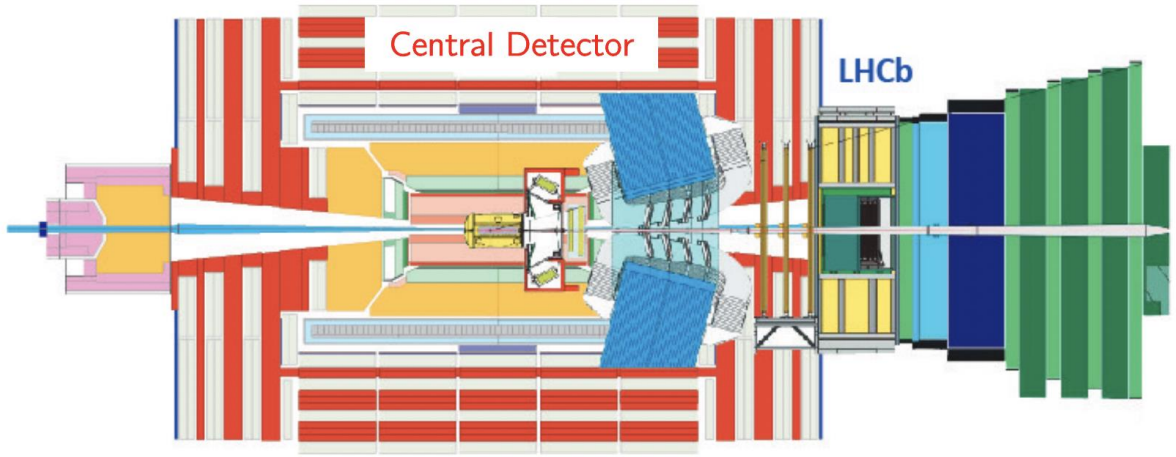
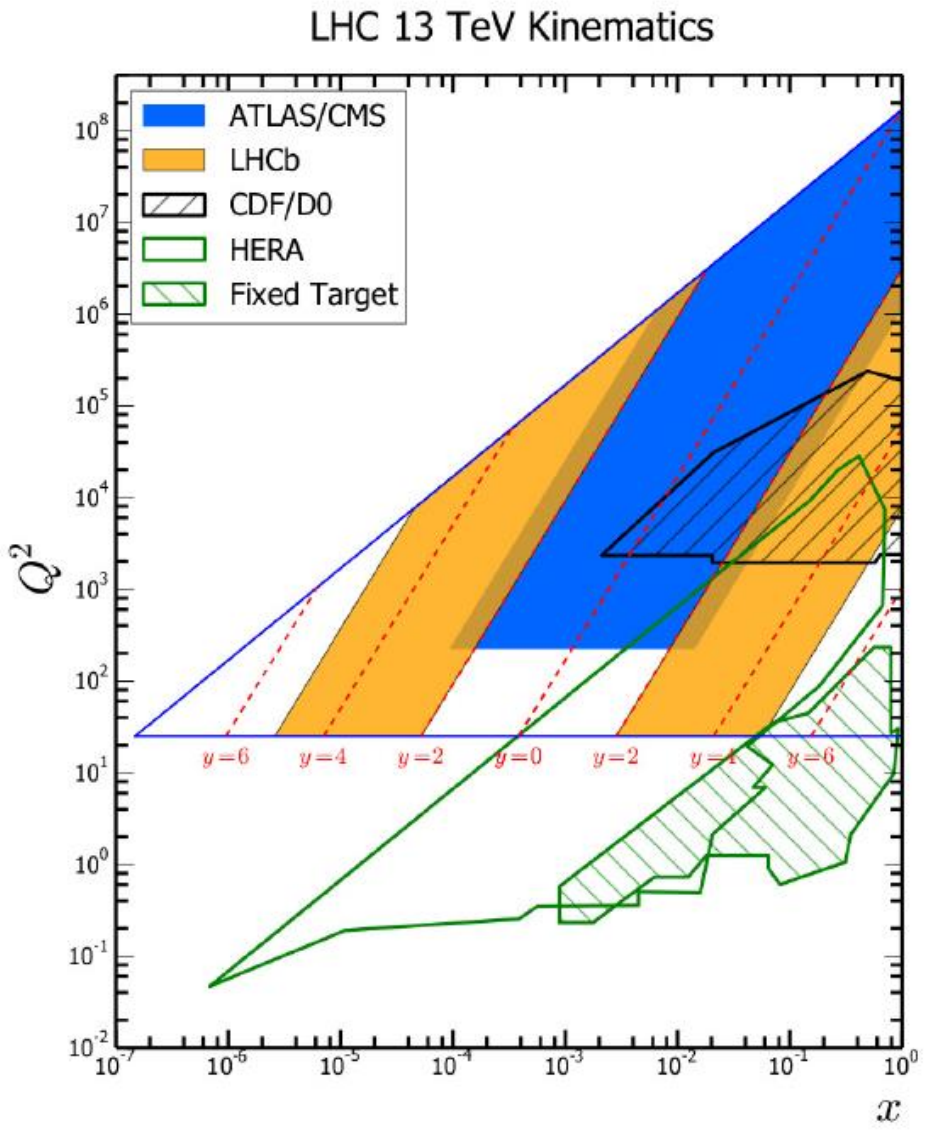
LHCb-CONF-2018-006

Conclusion

- **LHCb is a general purpose forward detector**
- **Higgs physics at LHCb is possible**
- **In Run3 and beyond, LHCb will have more studies of Higgs physics**

Thanks for your attention.

Backup

Kinematic regions at LHC

ATLAS, CMS and LHCb are complementary phase space to study electroweak processes