Searches for H$\to b\bar{b}$ and H$\to c\bar{c}$ at LHCb

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University and INFN of Padova

Higgs Hunting 2017

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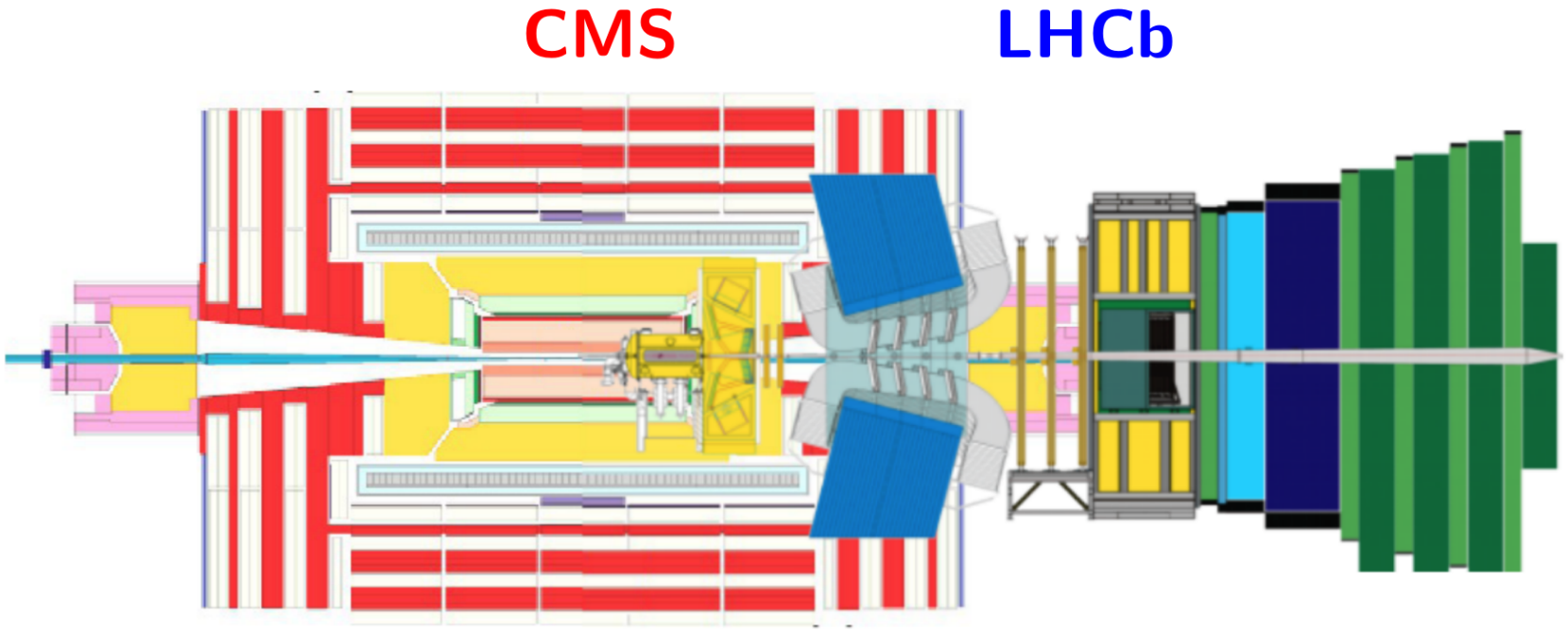
The LHCb detector

The LHCb detector is a **forward** spectrometer designed to perform precision measurements of the **b** and **c hadrons** properties



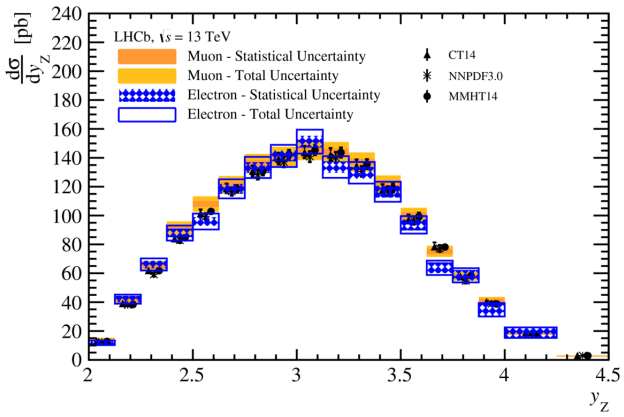
Unique detector at LHC: JINST 3 (2008) S08005

- Lower luminosity, $\sim 3\text{fb}^{-1}$ in Run 1
- Complementary η coverage ($2 < \eta < 5$)
- Excellent vertexing (IP resolution of 13-20 μm), momentum resolution (0.4%-0.6%), particle ID

LHCb as general purpose forward detector

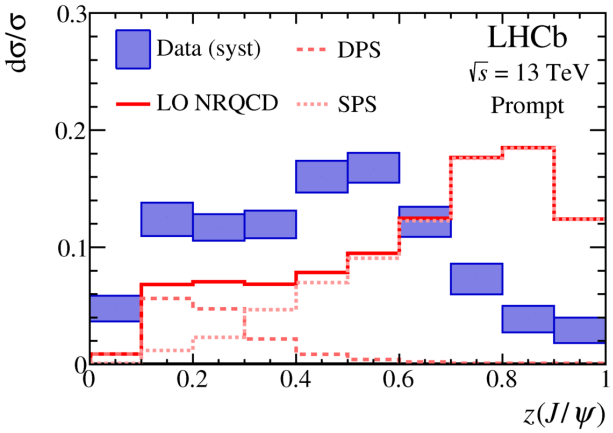
Beside flavor physics measurements, LHCb has demonstrated his capability also as a **general purpose forward detector**

EW measurements



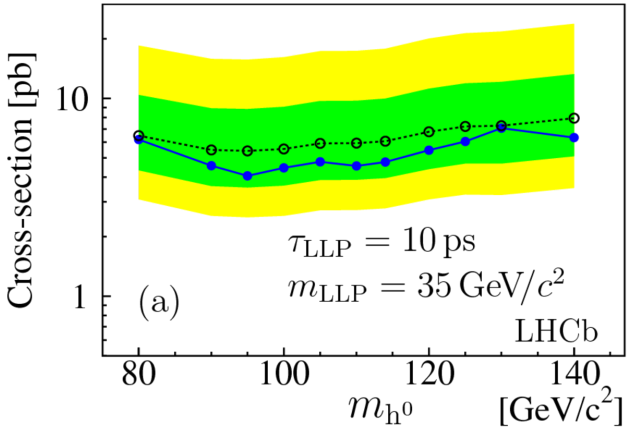
JHEP 09 (2016) 136

QCD measurements



PRL 118 (2017) 192001

Exotic searches



EPJ C 76 (2016) 664

Higgs boson at LHCb

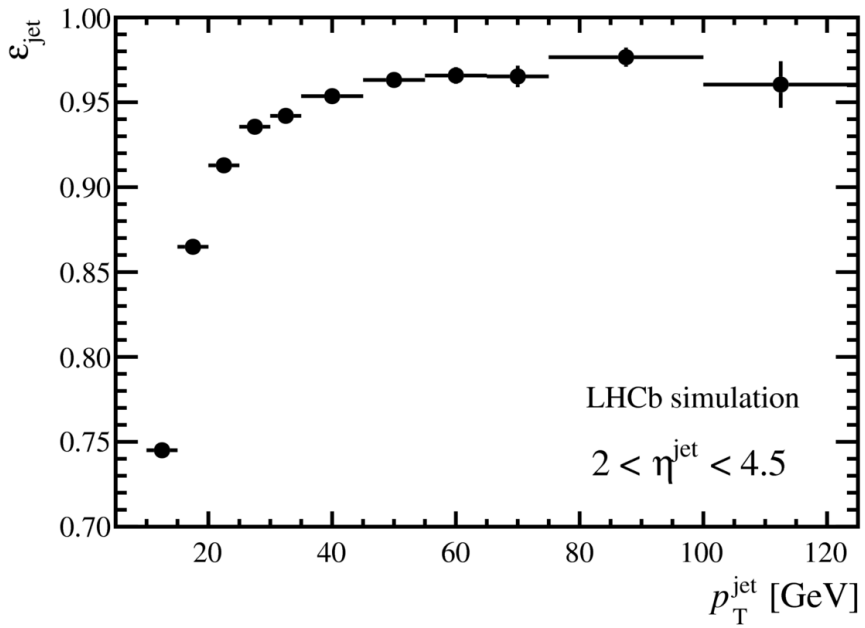
Lower acceptance wrt CMS and ATLAS, but:

- Low p_T triggers
- Low pile up thanks to the leveled luminosity
- Tracking in the forward region, b/c jet tagging

Jets at LHCb

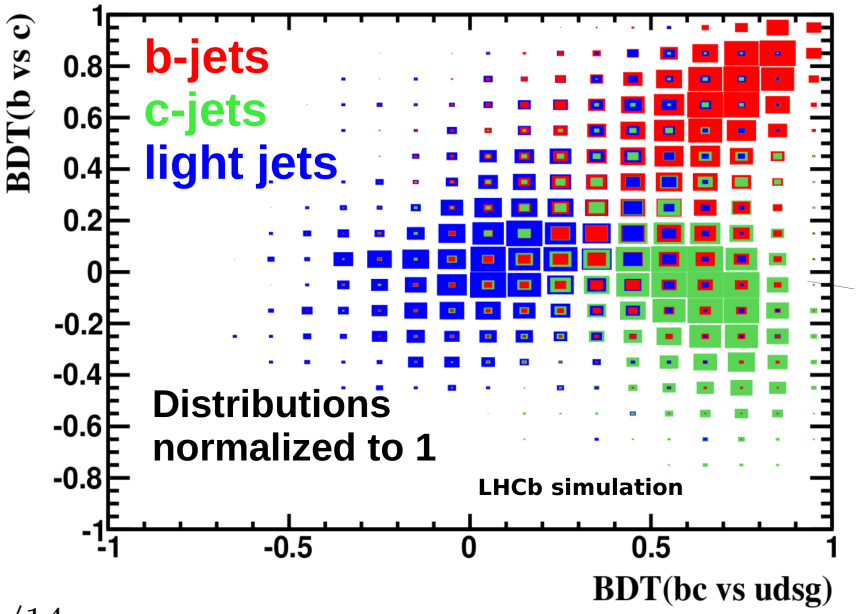
JHEP01 (2014) 033

- Particle Flow approach, with neutral recovery
- Reconstructed using anti-kT (R = 0.5)
- Calibration in data, using $Z \to \mu\mu$+jets
- Since Run 2, reconstructed both offline and online



b/c jet tagging

JINST 10 (2015) P06013



- Require jet with a secondary vertex (SV)
- SV properties and jet properties combined in two BDTs
- BDT($bc|udsg$) trained to separate (b,c) jets from light-parton jets
- BDT($b|c$) trained to discriminate b jets from c jets
- $\epsilon_b \sim 65\%$, $\epsilon_c \sim 25\%$ light jet mistag probability $\sim 0.3\%$

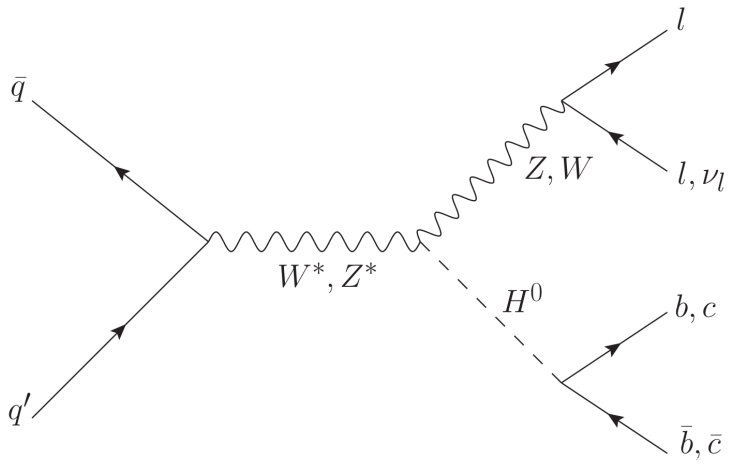
$H \to b\bar{b}(c\bar{c})$ in association with a Z or W

Signal signature: one high-p_T lepton and two $b(c)$-jets

Main background processes at LHCb

- $W + b\bar{b}$
- $W + c\bar{c}$
- $t\bar{t}$

studied with an ad-hoc analysis:



Analysis sample: 2 fb^{-1} at 8 TeV

- one high-p_T isolated lepton (electron or muon) and two heavy-flavour jets
- Jets: $p_T > 12.5$ GeV/c and $2.2 < \eta < 4.2$
- Lepton: $p_T > 20$ GeV/c and $2 < \eta < 4.5$
- 4 categories: $l_{flavour} \times l_{charge}$

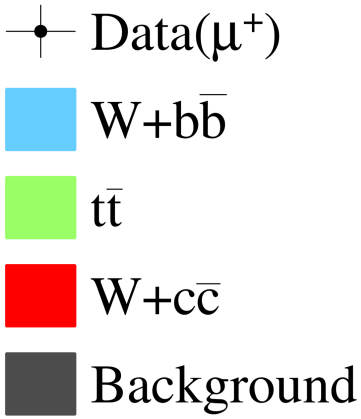
Backgrounds for the $H \to b\bar{b}(c\bar{c})$ in association with a Z or a W

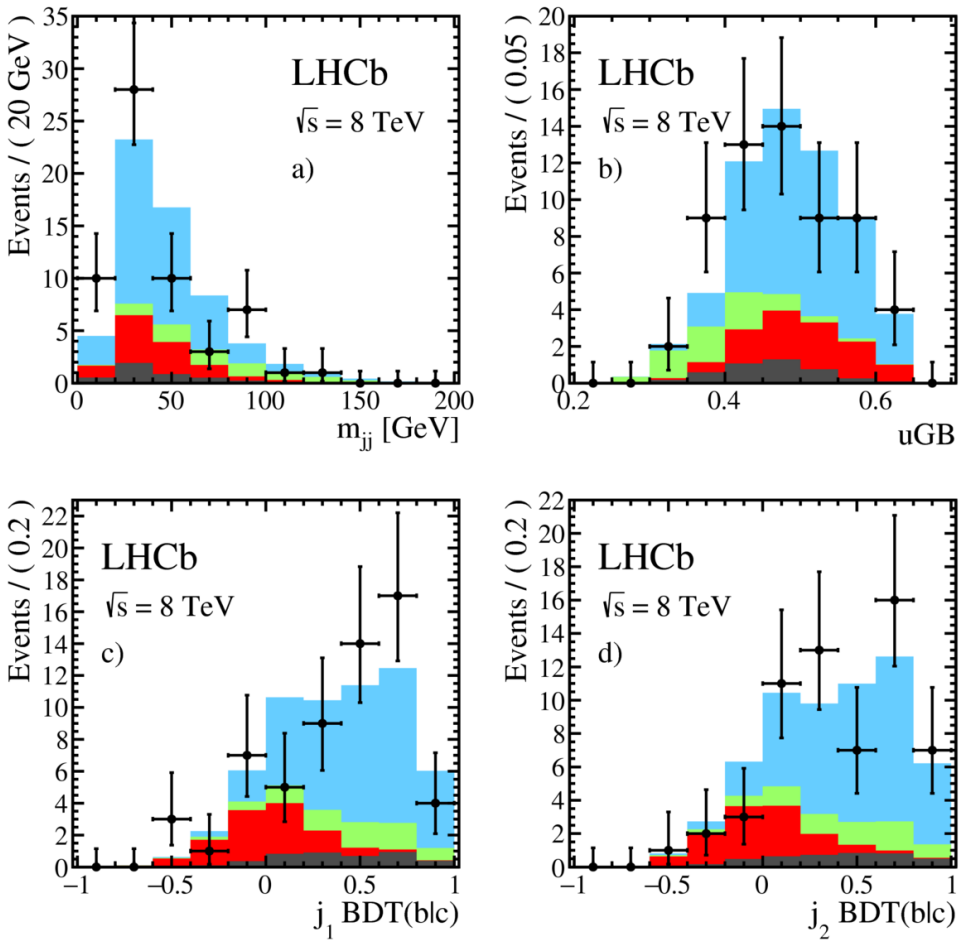
Fit strategy

Simultaneous 4D fit to the four data categories (μ^+, μ^-, e^+, e^-)

Fit variables:

- MVA (uGB) to separate $W + b\bar{b}$ from $t\bar{t}$ ▸ JINST 10 (2015) T03002
- BDT($b|c$) for both jets
- Di-jet mass

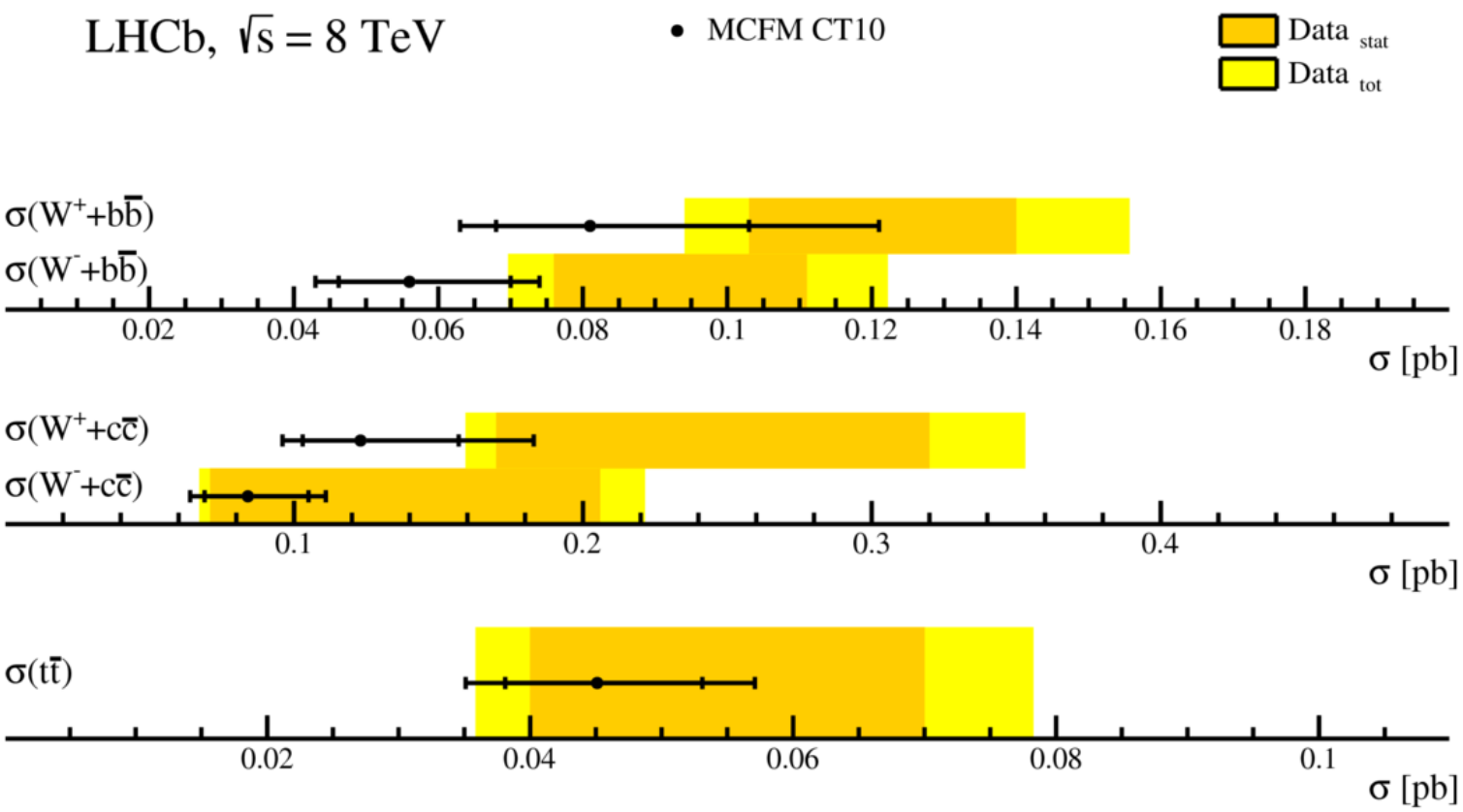




Backgrounds for the $H \to b\bar{b}(c\bar{c})$ in association with a Z or a W @ 8 TeV

Result:

▸ Phys. Lett. B767 (2017) 110



Nice agreement between measurement and prediction
Measurements dominated by statistic uncertainty

Search for the $H \to b\bar{b}$ in association with a Z or a W

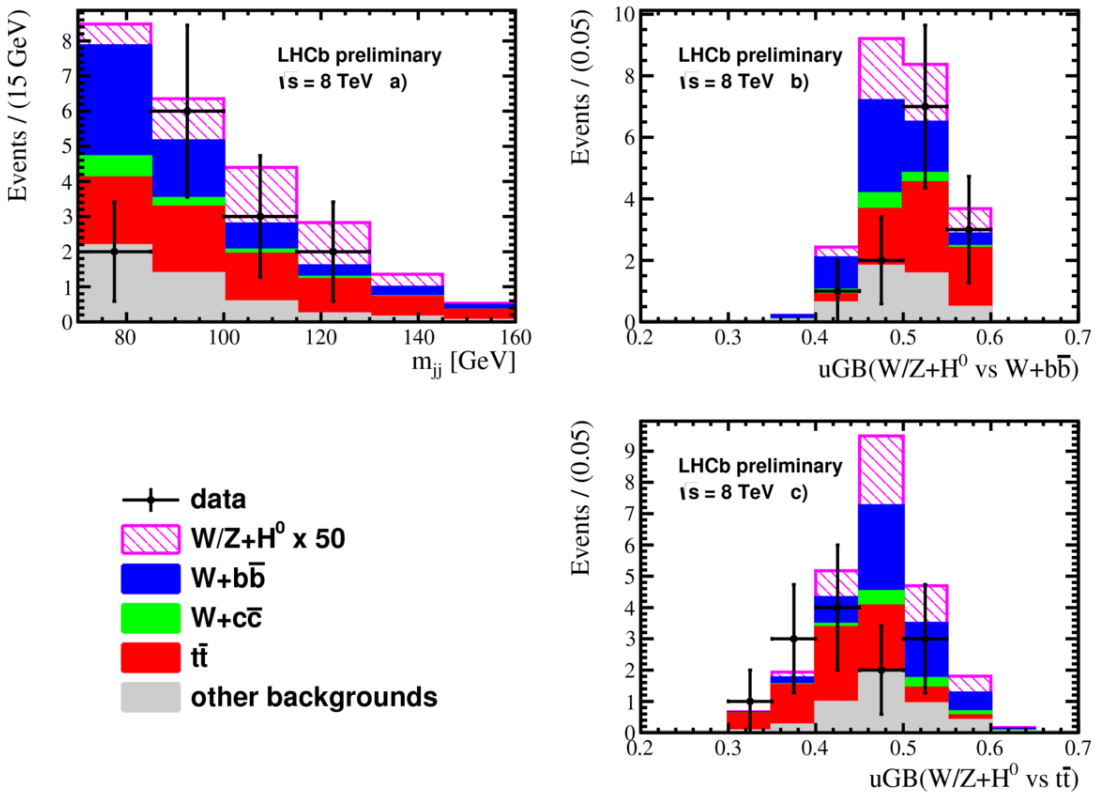
Backgrounds are well understood: moving toward the $H \to b\bar{b}$ search:

- Same selection, except for tighter p_T cut on the jets (20 GeV/c)
- Background yields fixed to theory predictions

Signal searched using three variables:

- Dijet invariant mass (m_{jj})
- MVA (uGB) to separate signal from $W + b\bar{b}$
- MVA (uGB) to separate signal from $t\bar{t}$

LHCb-CONF-2016-006



Search for the $H \to c\bar{c}$ in association with a Z or a W

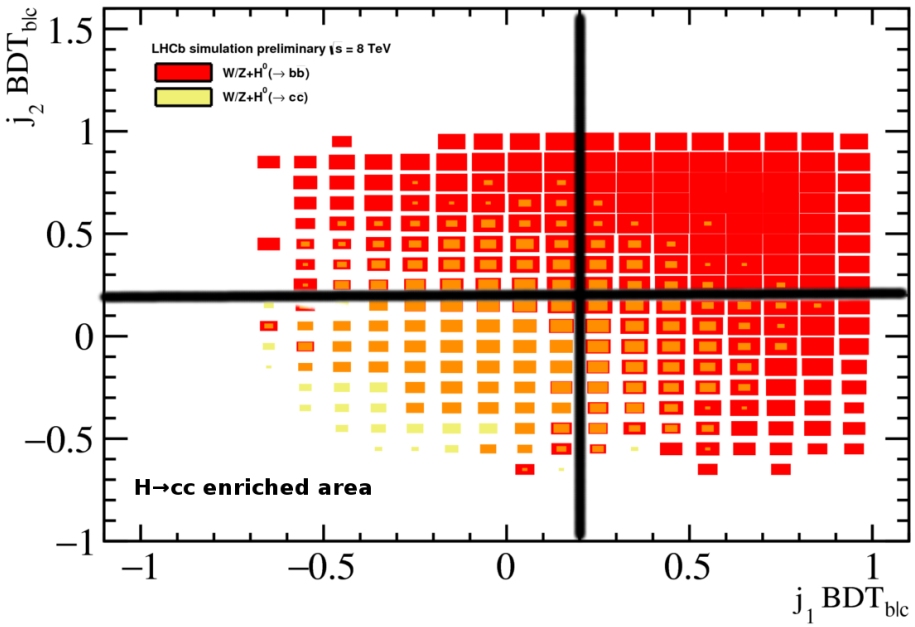
The good jet tagging performance gives the possibility to discriminate b- and c-jets

$\Longrightarrow$ unique possibility to search for the $H \to c\bar{c}$ at LHC

An enhancement of the SM predictions due to new physics have been suggested ▸ PRD 92 (2015) 033016

Same event selection used for the $W/Z + H(b\bar{b})$ process, but:

▸ LHCb-CONF-2016-006



Additional requirement on the BDT $b|c$ tagging variable:

- Separation of b jets from c jets is applied
- It removes about 90% of $W/Z + H(b\bar{b})$ events while retaining 62% of the $W/Z + H(\bar{c}c)$

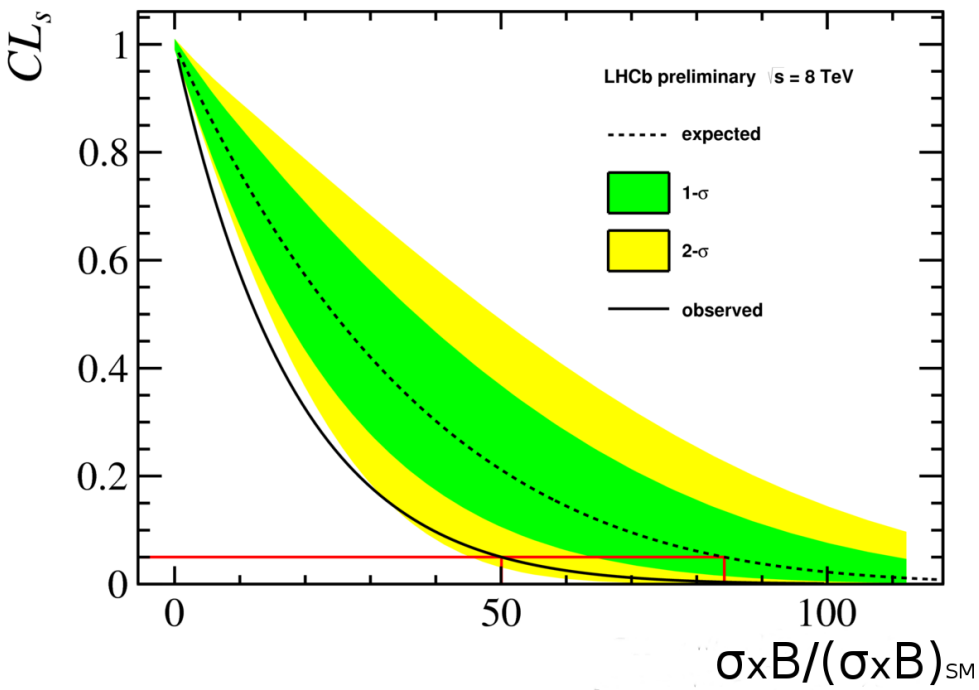
$W/Z + H(b\bar{b}/c\bar{c})$ results @ 8 TeV

No excess has been found either in the $W/Z + H(b\bar{b})$ or the $W/Z + H(c\bar{c})$ channel

95% C.L. upper limit set using the CL_s method

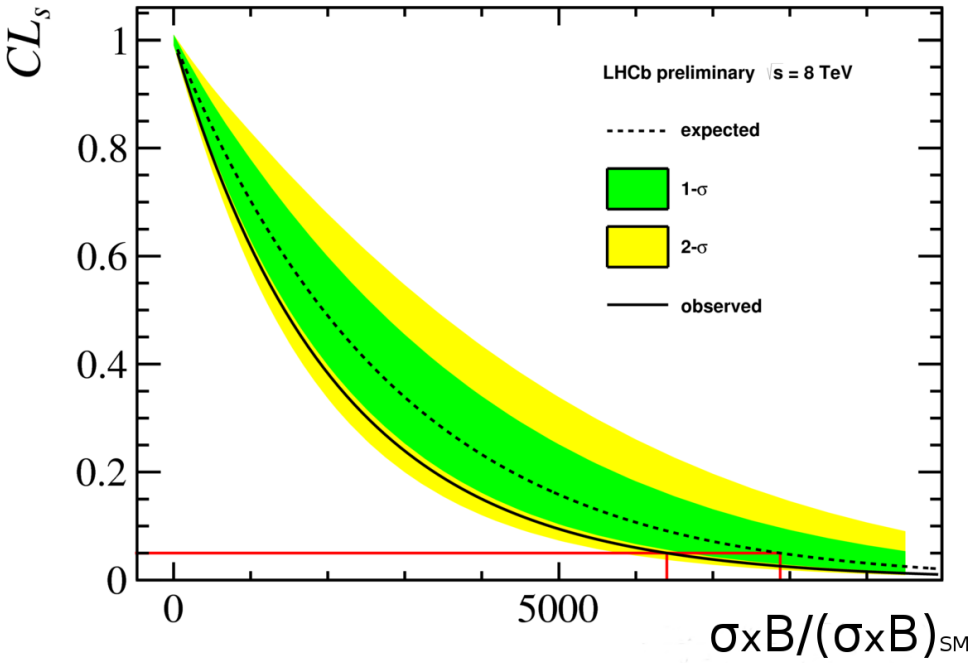
▸ LHCb-CONF-2016-006

$H \to b\bar{b}$



Limit: < 1.6 pb (50 times SM)

$H \to c\bar{c}$

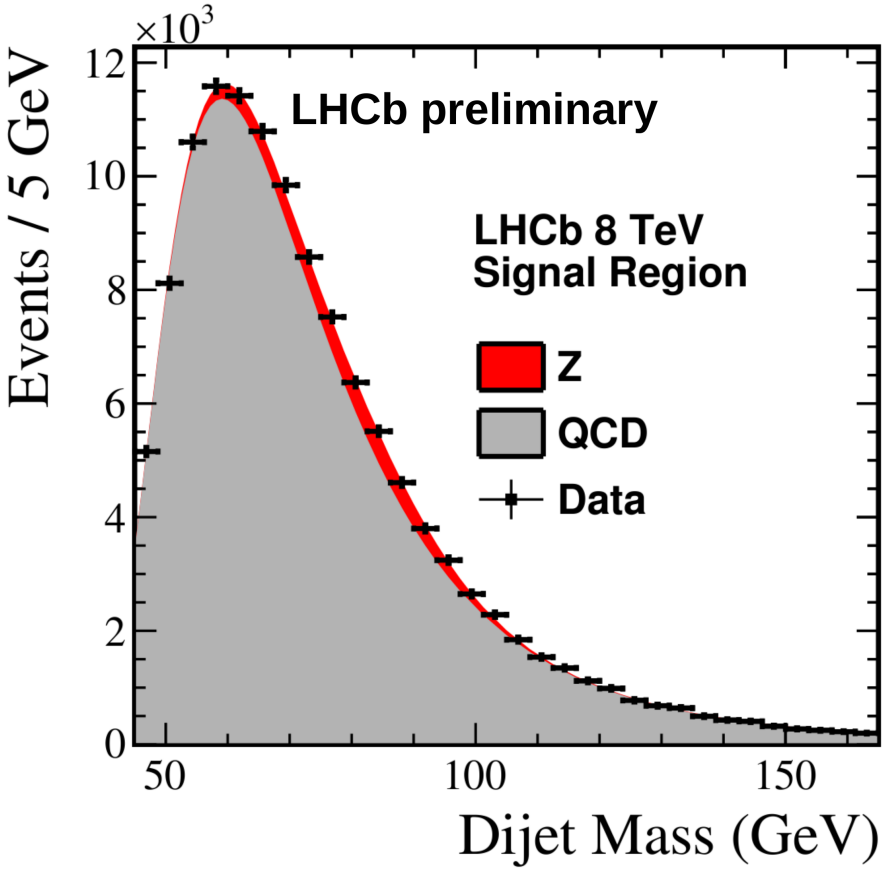


Limit: < 9.4 pb (6400 times SM)

Toward the inclusive $H \to b\bar{b}$: $Z \to b\bar{b}$ cross section measurement @ 8 TeV

Recent measurement of the $Z \to b\bar{b}$ cross section ▸ Paper in preparation

Benchmark for the inclusive $H \to b\bar{b}$ search



Key point: balancing jet (jet_3) that makes $p_T(\text{Z+jet}_3)$ minimum to separate $Z \to b\bar{b}$ from QCD
Discrimination achieved using an uGB

$$\sigma \times \mathcal{B} = 332 \pm 46(stat) \pm 59(sys)$$

In nice agreement with the aMC@NLO prediction

This measurement shows the LHCb capability to describe the QCD multijet background and validates the inclusive search for the $H \to b\bar{b}$ with the new data

Conclusion and outlook

LHCb has proved its capability also in the Higgs sector:

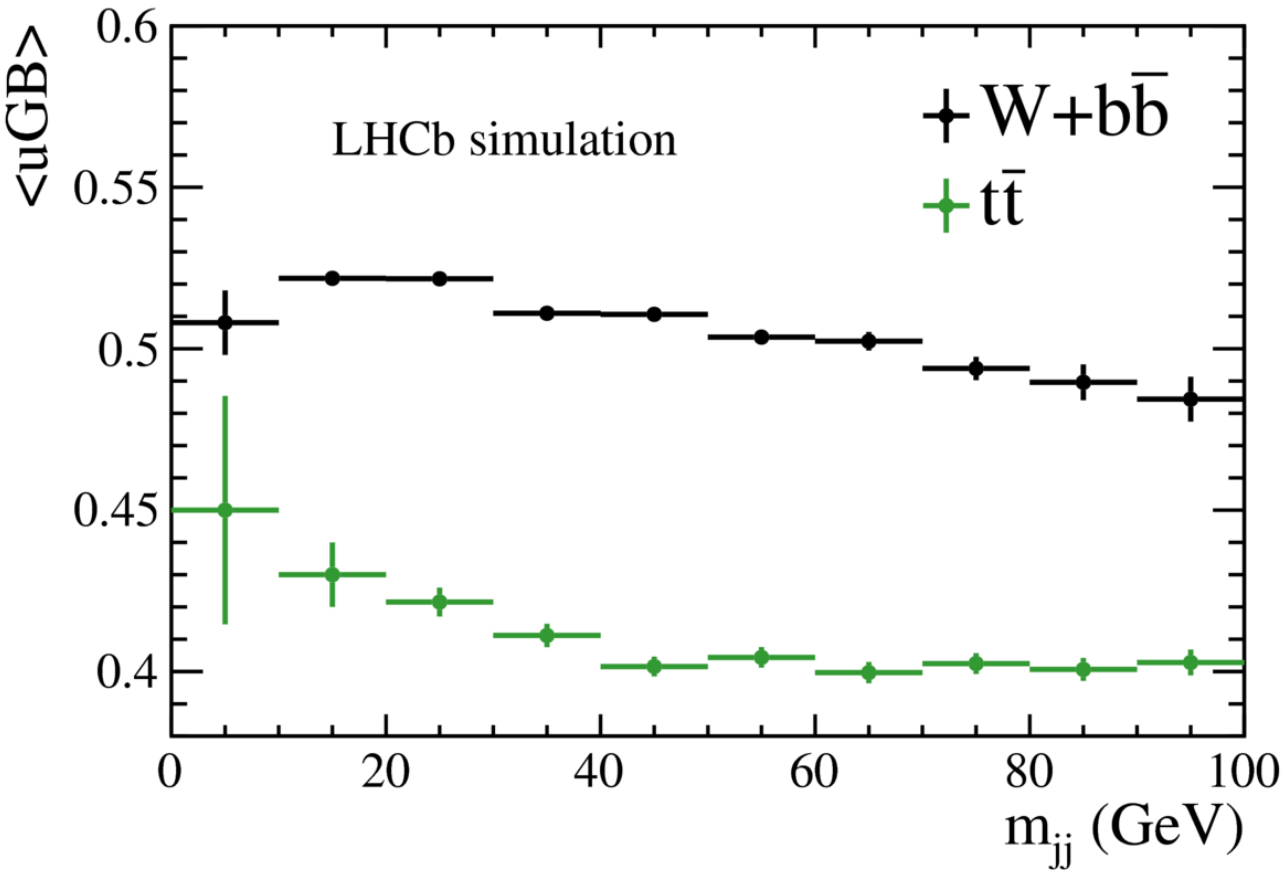
- Limit on the $W/Z + H(b\bar{b})$ process
- First limit on the $W/Z + H(c\bar{c})$ process
- Measurement of the $Z \to b\bar{b}$ cross section

It can take advantage of its unique features to search in a phase space and in decay channels complementary to ATLAS and CMS

Outlook for Run II

- More statistics, about 5 fb^{-1}
- Higgs cross section more than a factor 2 greater
- Factor 2 in acceptance due to more boosted Higgs
- New dedicated trigger lines for jets
- Work is ongoing to improve the jet tagging performance

After Run II, much better tagging (upgraded vertex detector, only 5mm from the beams)

Backup

uGB response in different intervals of m_{jj} for $W + b\bar{b}$ and tt