Prospects for charm tagging and the Higgs

HL/HE-LHC Meeting

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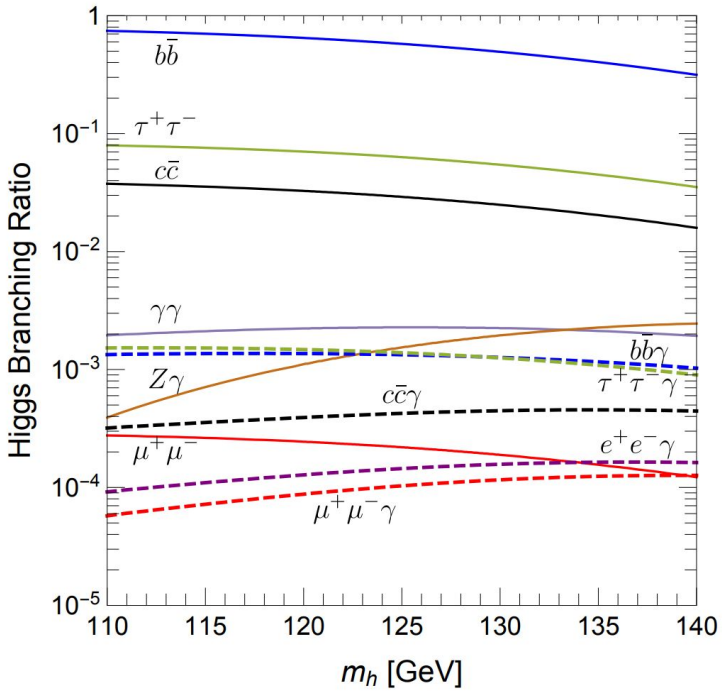
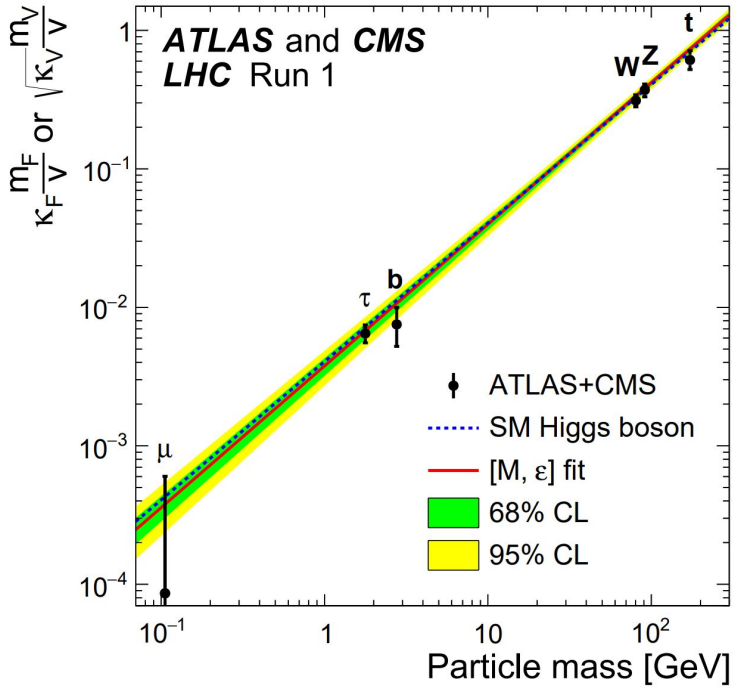
Overview

- Observation of a Higgs boson at 125 GeV/c^2 standout achievement of LHC Run I
- Gauge sector seems to be SM-like
- Less known about fermions
- Thus far, only third-generation decays observed
- $H^0 \to c\bar{c}$ has largest SM BF of second-generation decays
- $\sim 30\times$ suppressed *cf.* $b\bar{b}$

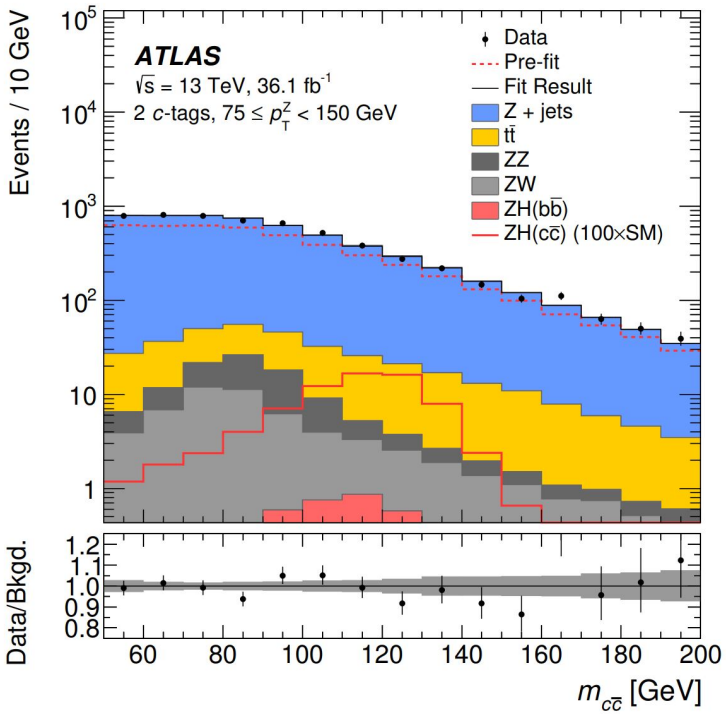


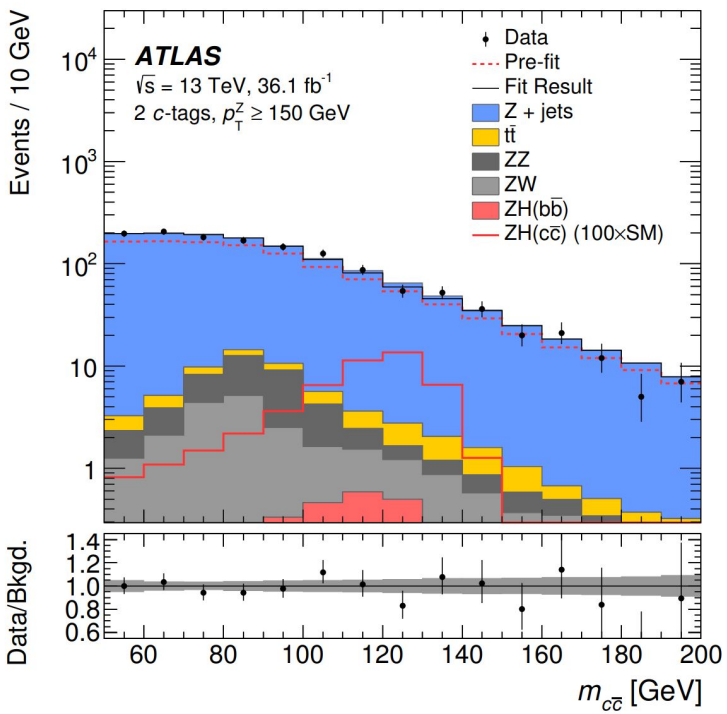


$H^0 \to c\bar{c}$ @ Atlas

arXiv:1802.04329

- Atlas recently performed a search for $H^0 \to c\bar{c}$ produced through $Z + H$
- Used 36.1 fb^{-1} of data at 13 TeV
- Limit set is $\sim 100\times$ SM prediction





Higgs searches @ LHCb

Disadvantages

- Lower luminosity
- Smaller acceptance
- Non-hermetic

Advantages

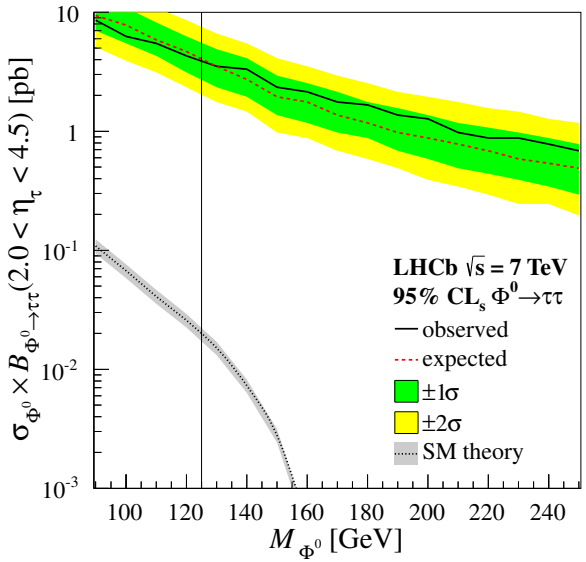
- Low pileup
- Excellent secondary vertex reconstruction
- Complementary coverage

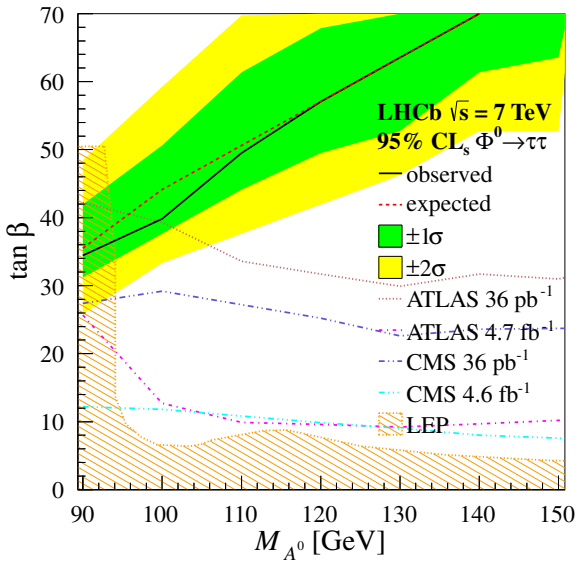
Focus on b, c and τ channels

Higgs searches @ LHCb: $\tau^+\tau^-$

JHEP **05** (2013) 132

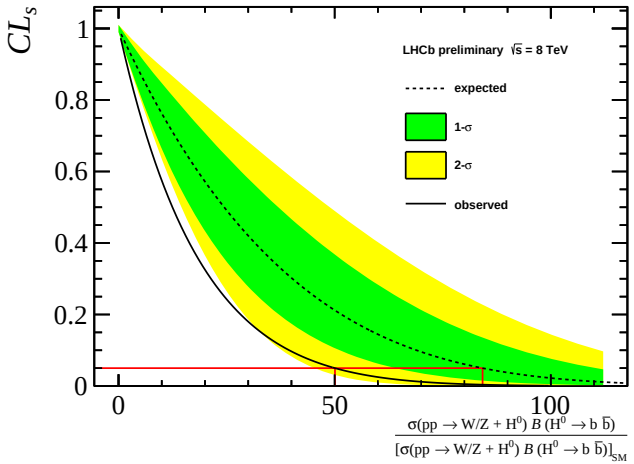
- Limits set on $H^0 \to \tau^+\tau^-$ in forward region as a function of Higgs mass
- Analysis used 1 fb^{-1} of data at 7 TeV
- τ decays to muon, electron and hadronic final states considered
- No requirements on H^0 production mechanism
  - Trigger on τ decays
- Limit $\sim 100\times$ SM prediction
- Also set limits on $\tan\beta$ in MSSM

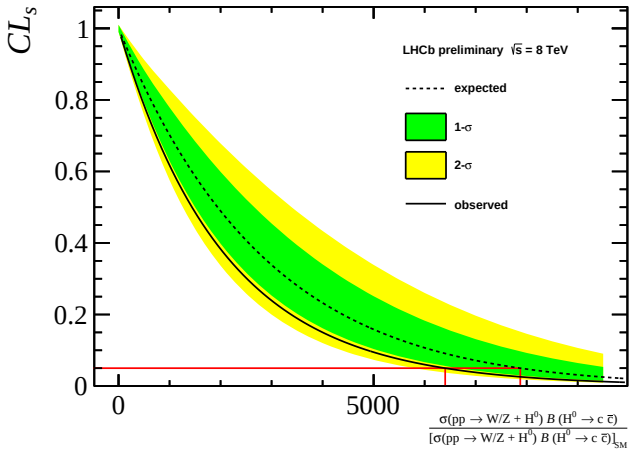




Higgs searches @ LHCb: $b\bar{b}$ and $c\bar{c}$

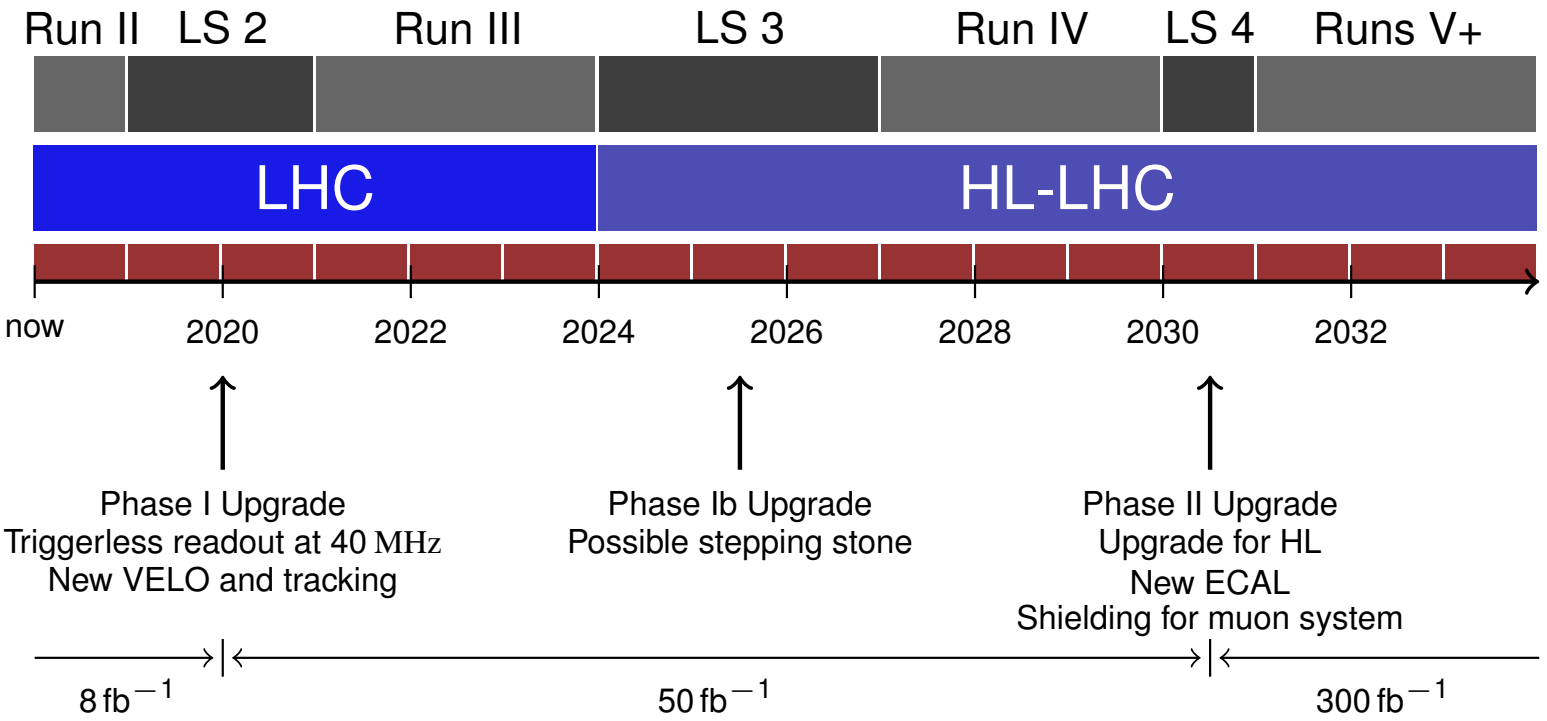
LHCb-CONF-2016-006





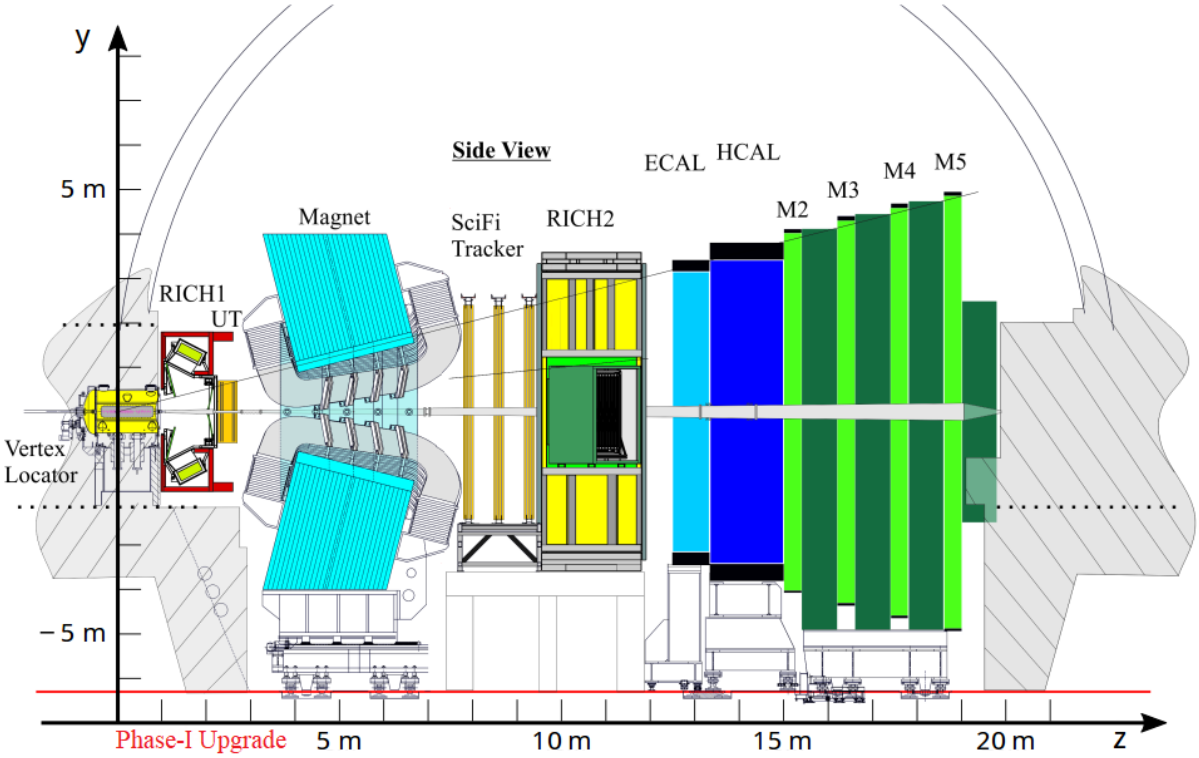
- Also studied $b\bar{b}$ and $c\bar{c}$ final states
- Analyses used $2\,\text{fb}^{-1}$ of data at $8\,\text{TeV}$
- Use VH associated production
- Trigger on the vector boson
- Upper limits on Yukawa couplings of $y^b < 7y^b_{\text{SM}}$ and $y^c < 80y^c_{\text{SM}}$
- How much better can we do after upgrades?

LHCb upgrade timeline



The LHCb detector: phase 1 upgrade

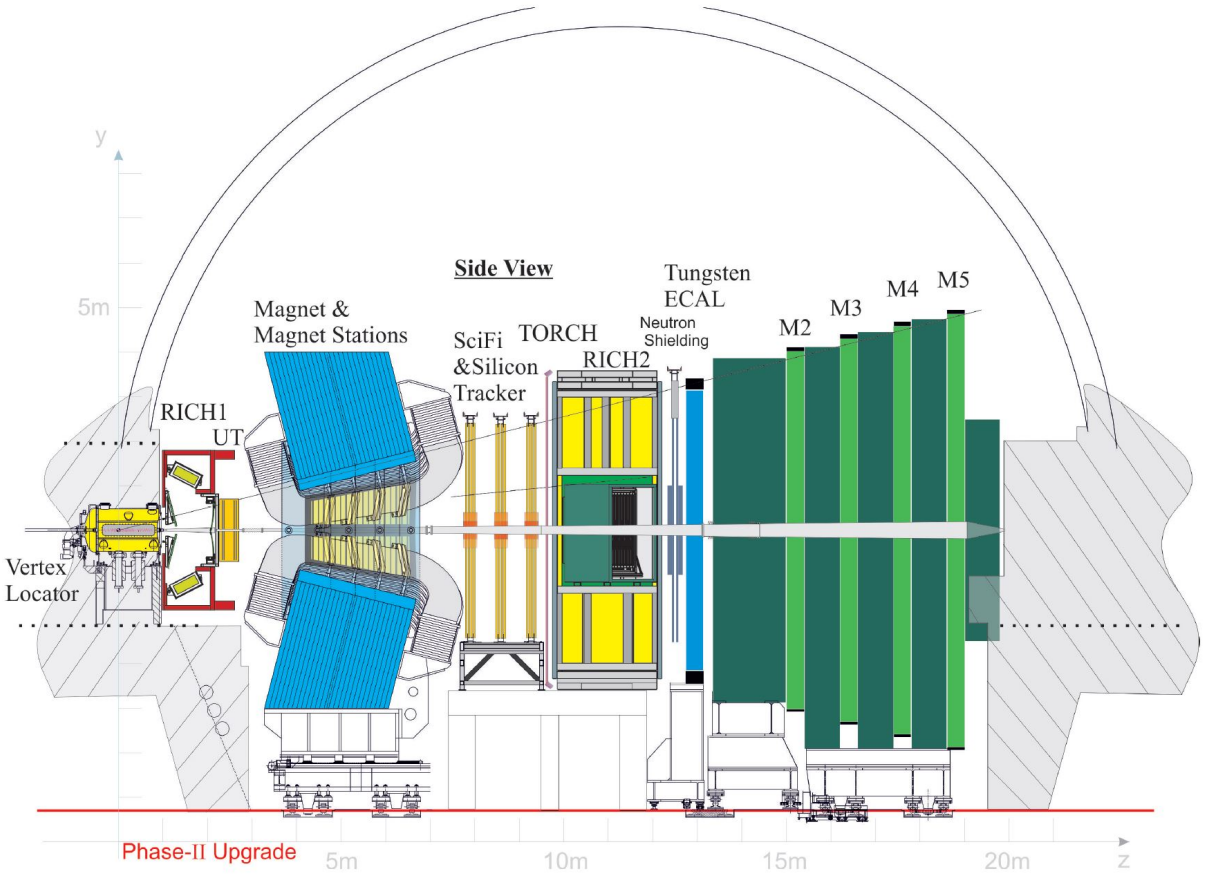
CERN-LHCC-2012-007



- Triggerless readout at 40 MHz
- New vertex locator
- New tracking (UT, SciFi)

The LHCb detector: phase 2 upgrade

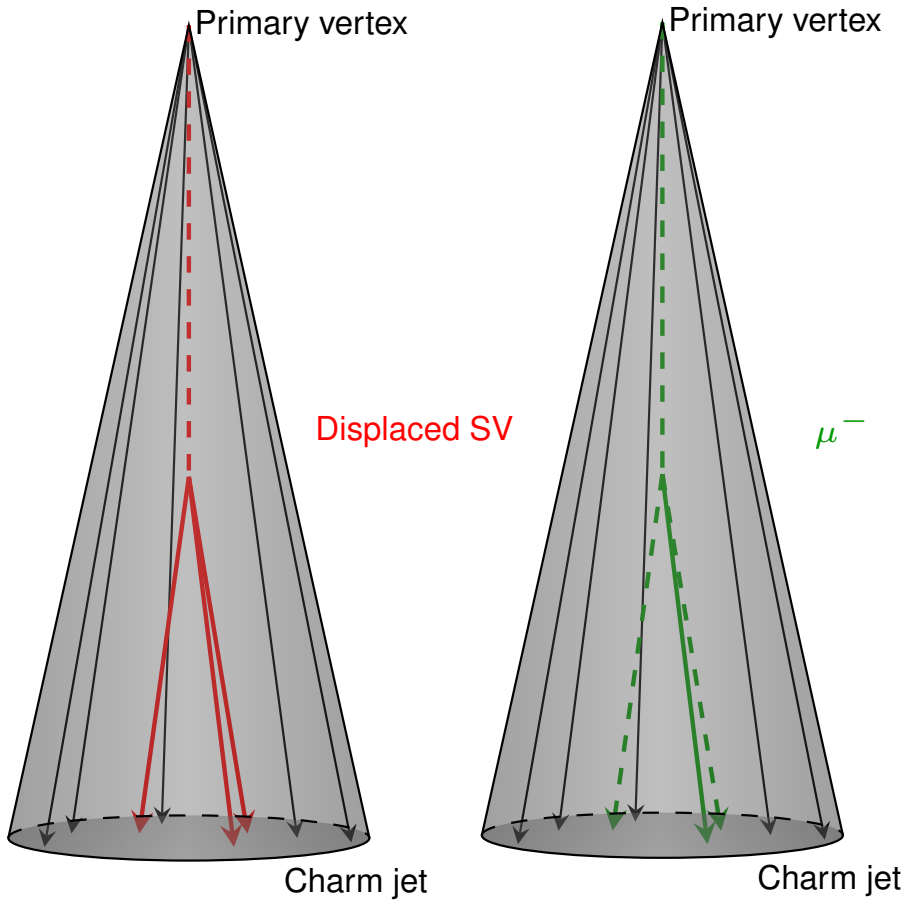
CERN-LHCC-2017-003



- Tracking in magnet
- ECAL upgrade
- TORCH for PID or ToF
- Replace HCAL with shielding
- Some changes could happen as part of phase Ib

Charm tagging @ LHCb

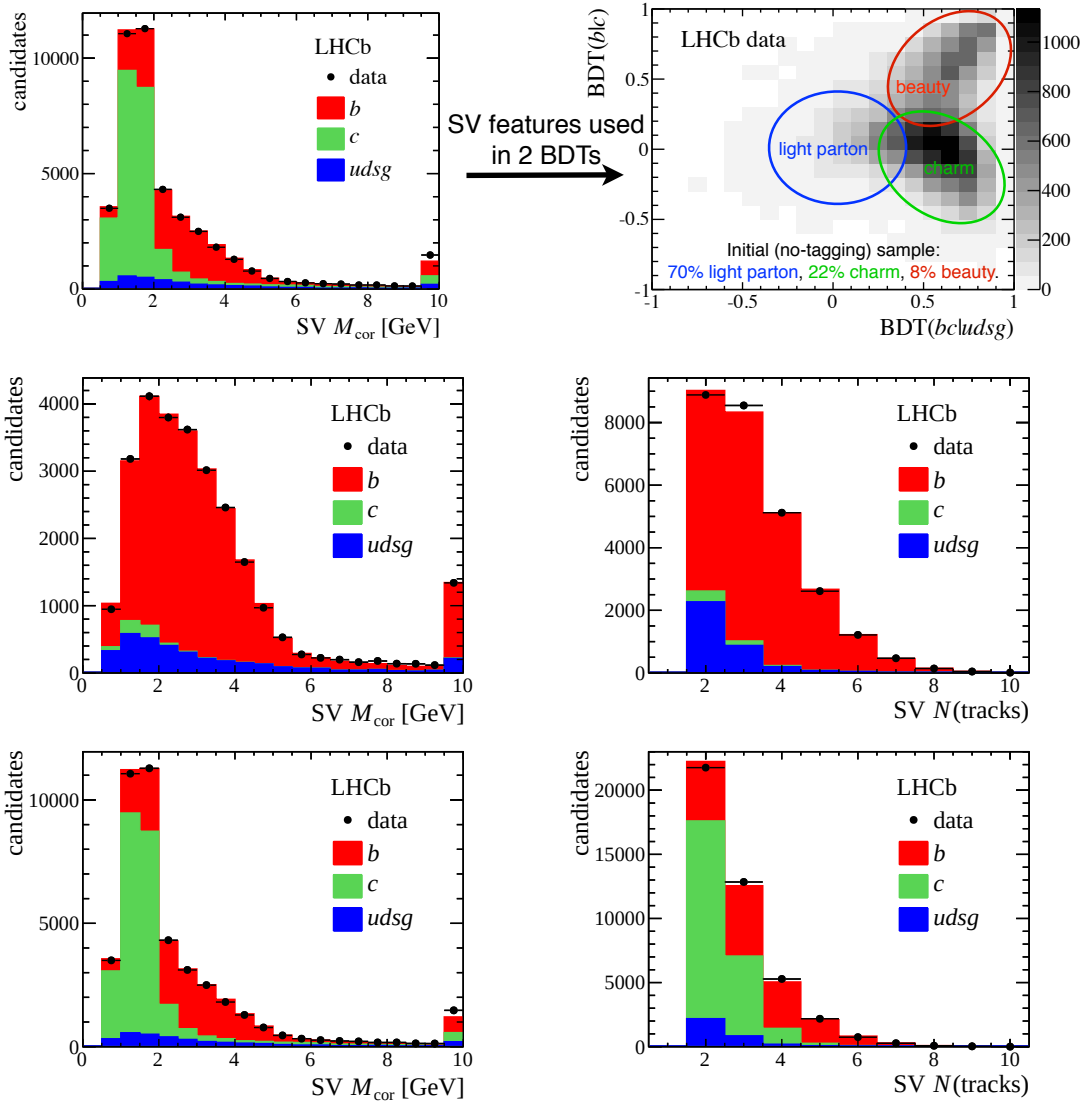
- Charm tagging non-trivial
- Charm has long lifetime (displaced vertex/muon or exclusive D)
- But so does beauty...
- Distinguish using features of SV
- Need to calibrate using data...



Charm tagging @ LHCb

JINST **10** (2015) P06013

- BDTs developed to tag jets in Run 1 data
- Efficiency determined on flavour-enriched samples
  - *e.g.* tagged by fully reconstructed (middle) B or (bottom) D decays on "other" jet
- 2D fit to corrected mass and track multiplicity of reconstructed secondary vertices also gives good separation of jet flavours



Charm tagging @ LHCb: future

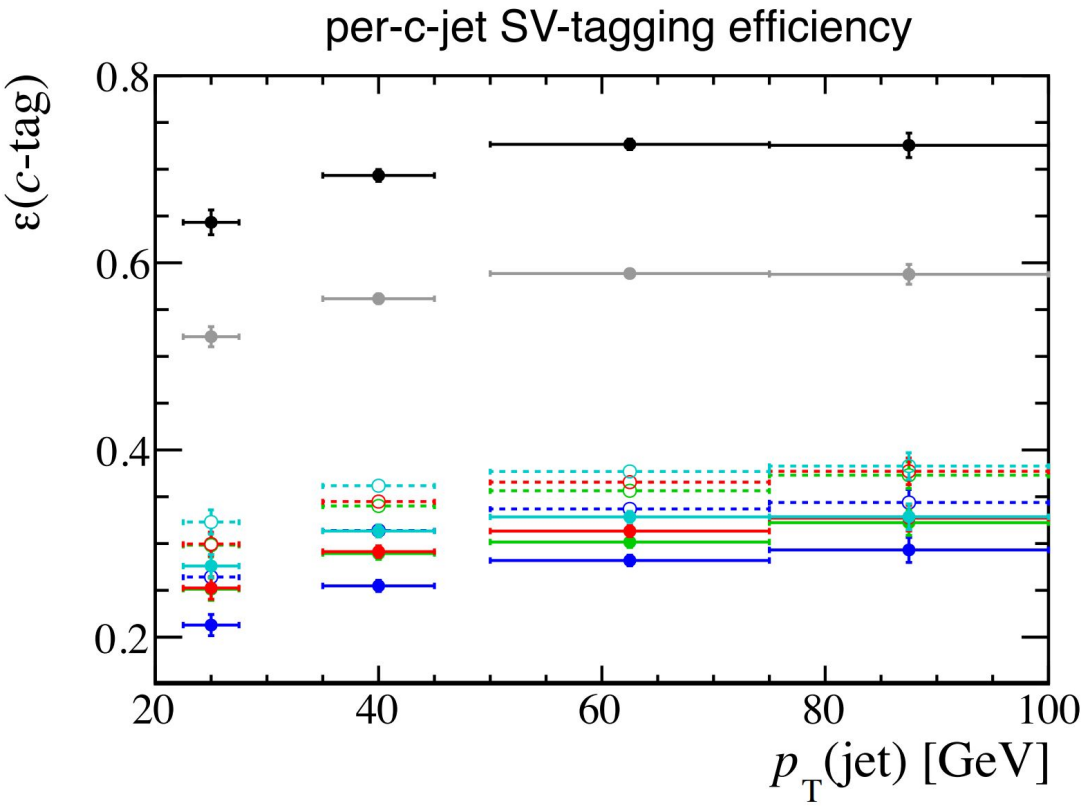
Run II

- Jet tagging efficiency studies underway on 13 TeV dataset
- Unlike in Run I, these benefit from dedicated calibration samples
- New 13 TeV jet studies to follow

Beyond

- Need to handle pileup
- Displaced vertex tagging will benefit from VELO/tracking upgrades
- Tagging efficiency expected to be maintained or improved

Charm tagging @ LHCb: future



- **Run I**
- Expectations for **Run III**, **Phase II Upgrade** options.
- **Perfect detector** and **perfect with reconstruction efficiency**
- Dashed lines have lower χ^2_{IP} requirement

- Requiring a two-body SV limits *c*-jet efficiency to $\sim 55\,\%$
- Can boost dijet efficiency by only requiring a single jet to pass tight *c*-tagging requirements

$H^0 \to c\bar{c}$ @ LHCb: future

Prospects for upgrade phase 2

- *VH* cross-section in LHCb acceptance increases by a factor of ~ 7 from 8 TeV to 14 TeV
- After 300 fb^{-1}, expect to set limit on Yukawa coupling of $\sim 7 y^c_{\text{SM}}$
- With improvements to detector performance and $b - c$ separation, and looser tagging requirements, this could be brought to $\sim 2 y^c_{\text{SM}}$
- If VBF production can also be utilised, this could yield similar statistics

Summary

- Charm tagging performance at LHCb expected to be maintained or improved in the HL-LHC era
- With modest improvements, SM $H^0 \to c\bar{c}$ may be within reach
- On the same timescale, LHCb should provide the first observation of $VH(b\bar{b})$ in the forward region