XXVI Epiphany conference

Exotic searches at LHCb

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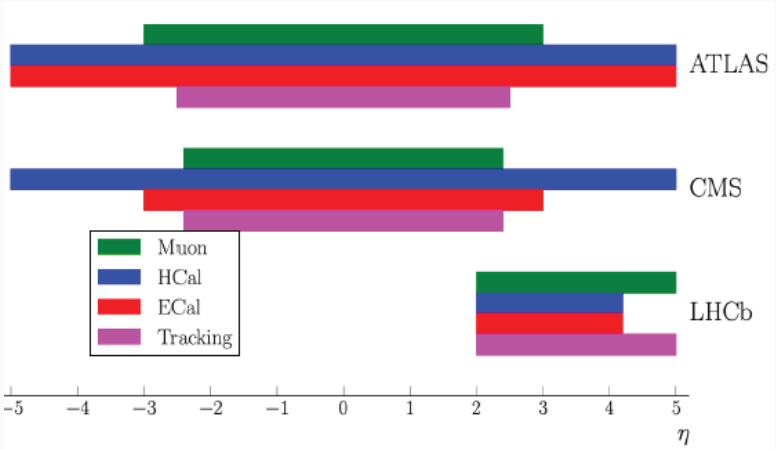
Outline

- $W + c\bar{c}$, $W + b\bar{b}$ and $t\bar{t}$ production at 8 TeV
- Z production in association with two b-quarks at 13 TeV
  - ongoing
- search for long-lived particles decaying to jet pairs at 7 and 8 TeV

LHCb detector

- single arm forward spectrometer
- general purpose detector in the forward region ($2 < \eta < 5$)
  - complementary to ATLAS and CMS



- excelent tracking
- excelent momentum resolution
- very good particle identification
- low pile-up

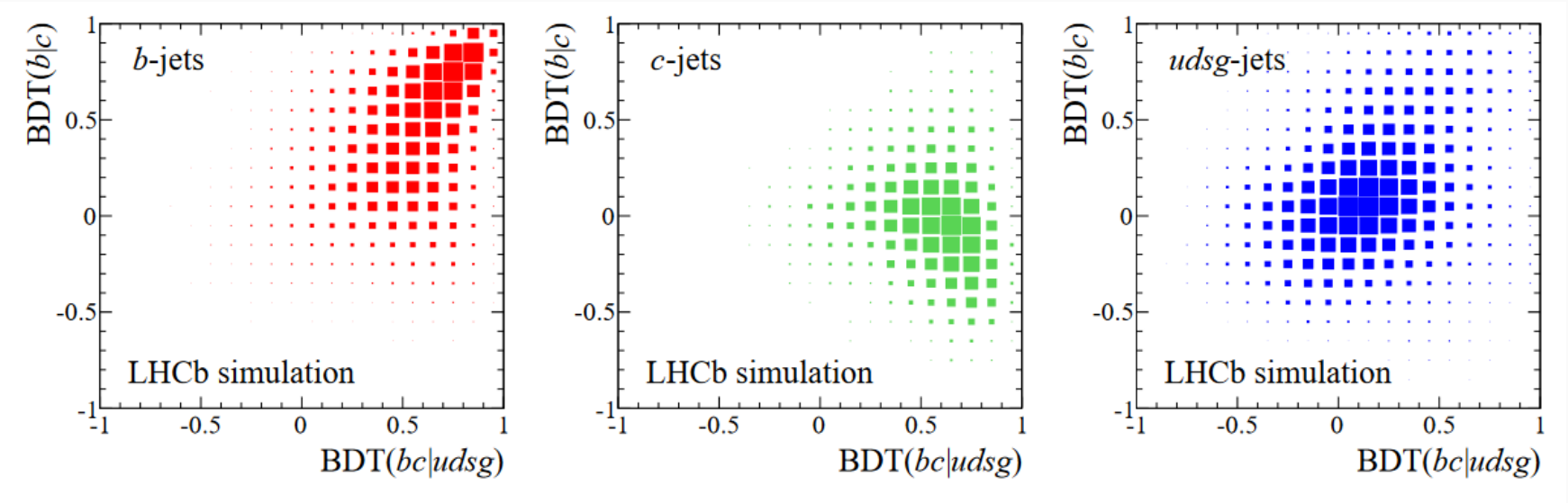
Physics motivation

- sensitive to Standard Model and Beyond the Standard Model physics
- important test of perturbative QCD
  - PDF parametrization
- both high and low x-Bjorken regions accesible
  - W/Z production by colliding low- and high-x partons
  - low-x region still remains mostly unexplored
- top measurements possible by partial final state reconstruction

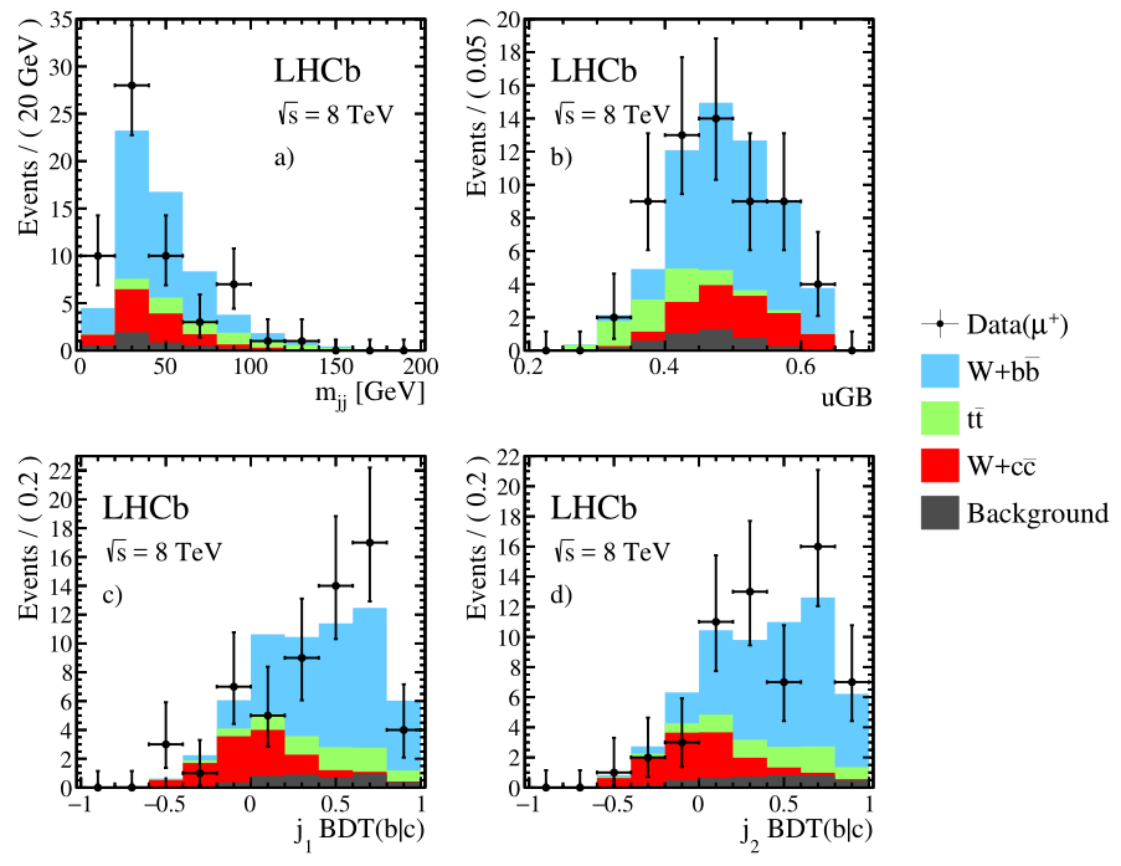
$W + c\bar{c}$, $W + b\bar{b}$ and $t\bar{t}$ production at 8 TeV

- published in Phys. Lett. B767 (2017) 110
- samples:
  - 2 fb^{-1} of 8 TeV data
  - signal events from ALPGEN, showering with Pythia8
  - background events from Pythia8
    - W + jets, Z + jets, single-top, WZ, ZZ
- requirements:
  - two heavy-flavoured jets
    - $p_t > 12.5$ GeV
    - $2.2 < \eta < 4.2$
  - single isolated electron or muon with high transverse momentum
    - $p_t > 20$ GeV
    - $2.0 < \eta < 4.25$ (4.5) for electron (muon)
    - $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} > 0.5$ for both jets

- jet tagging based on BDT response trained primarily on secondary vertex parameters
- JINST 10 (2015) P06013

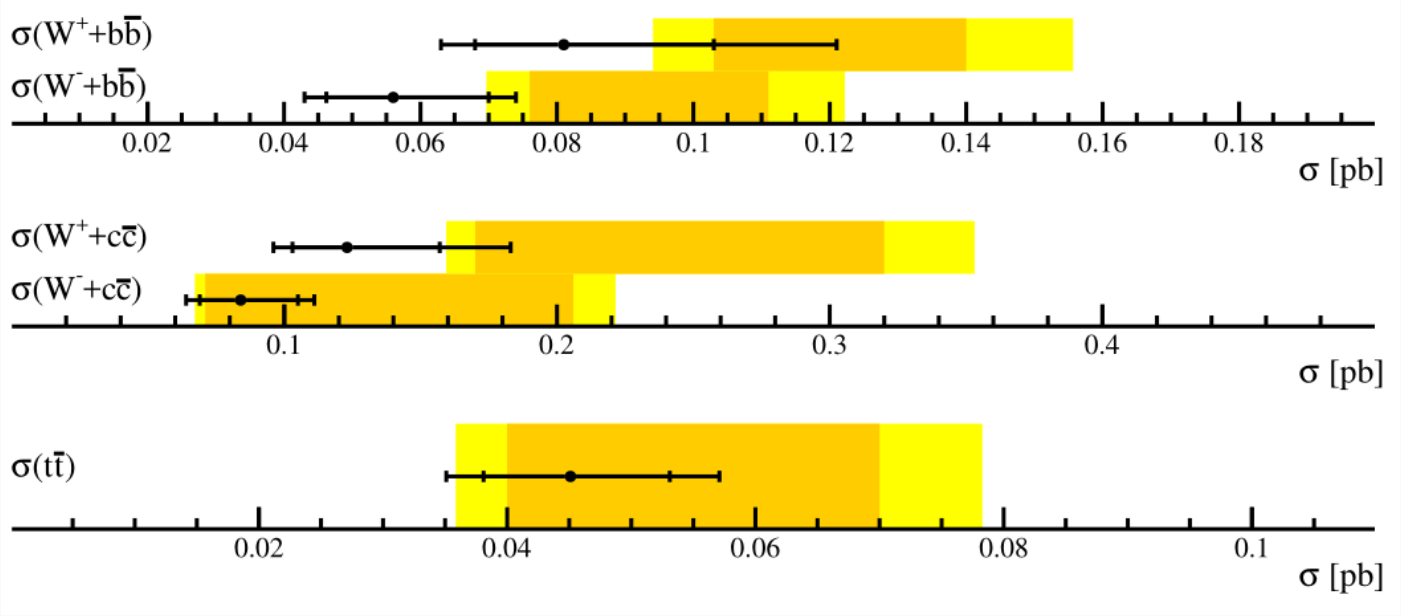


- strategy:
  - four sub-samples according to lepton flavour and charge
  - simultanous fit of four variables to determine yield of each signal
    - invariant mass of the two jets
    - classifier trained to distinguish between $t\bar{t}$ and $W + b\bar{b}$ events
    - BDT(b|c) classifiers for each jet



Fit results for μ^+ sample.

- results:
  - good agreement with NLO predictions (MCFM NLO with PDF set CT10; black bars)
  - statistical uncertainty in dark yellow and total in bright yellow



sample	significance
$W^+ + b\bar{b}$	7.1σ
$W^- + b\bar{b}$	5.6σ
$W^+ + c\bar{c}$	4.7σ
$W^- + c\bar{c}$	2.5σ
$t\bar{t}$	4.9σ

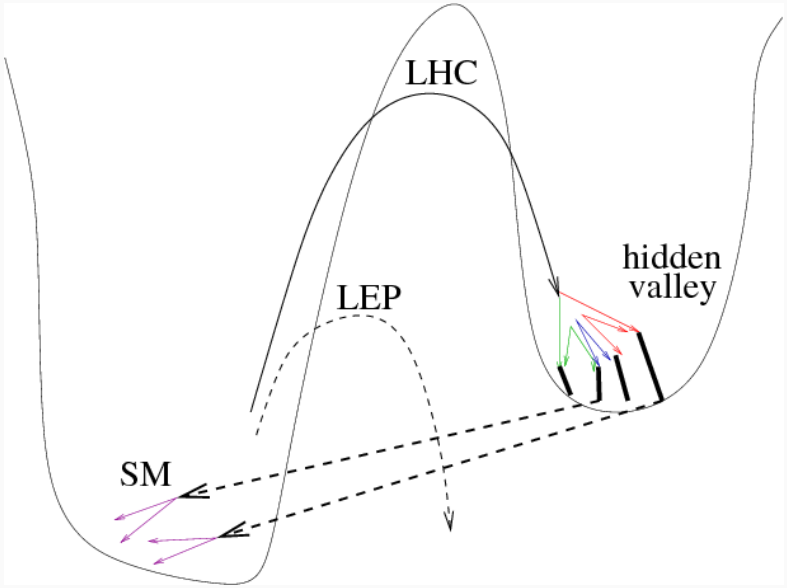
Z production in association with two b-jets at 13 TeV

- advanced stage
- motivation:
  - search for exotics – b', Z'
  - and Higgs
    - SM – ZH($\rightarrow$bb)
    - BSM – pp $\rightarrow$ H $\rightarrow$ ZA $\rightarrow$ b$\bar{\text{b}}$l$\bar{\text{l}}$
  - PDF tuning
- samples:
  - 2 fb^{-1} of 13 TeV data
  - signal and background from Madgraph at NLO
    - $t\bar{t}$, WZ, ZZ, $W + b\bar{b}$, $Z + q\bar{q}$, single top, inclusive $b\bar{b}$

- strategy:
  - muon channel (electron in the future)
  - background study using jet kinematics and underlying events
- preliminary studies show promising separation of main background source ($t\bar{t}$)

Hidden Valley

- new particle sector introduced via additional gauge group
- unreachable because of energy barrier, but unstable v-particles may decay to Standard Model final states

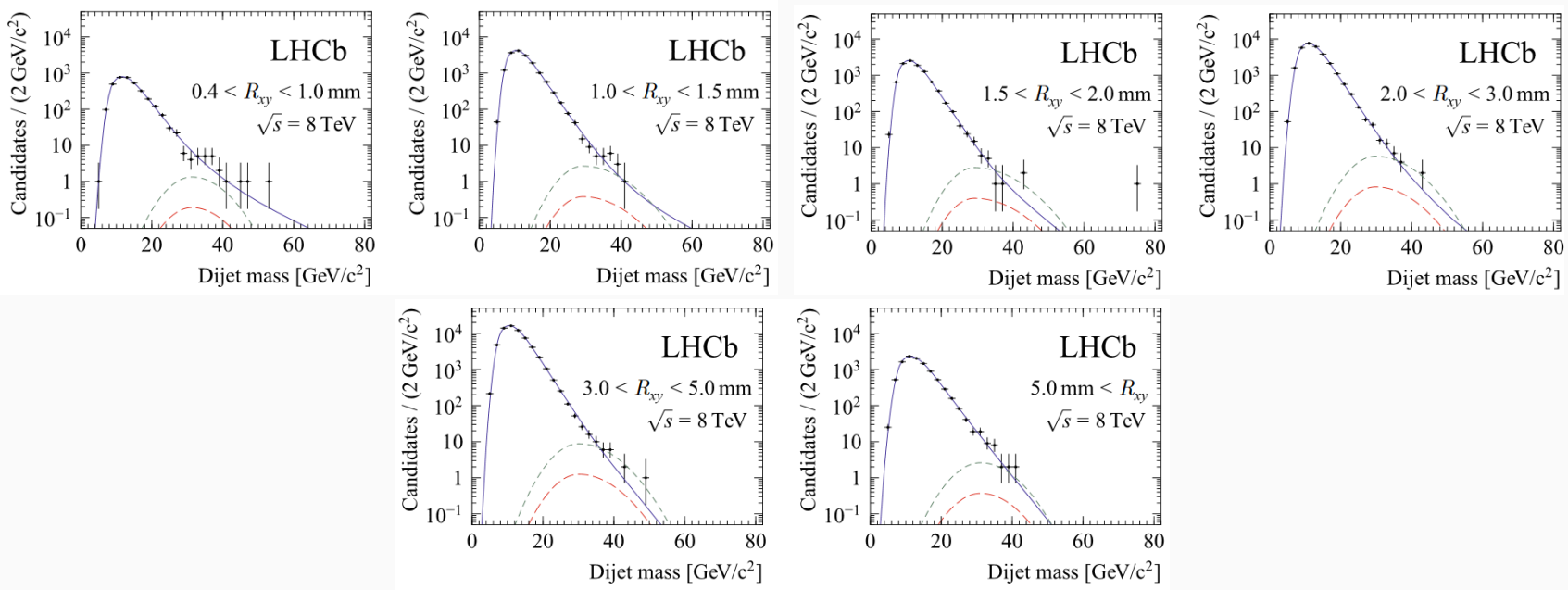


- may coexist with other SM extensions like SUSY
- Higgs boson can play a role of a communicator between SM and Hidden Valley sector
  - $H \to \pi_v \left(\to b\bar{b}\right) \pi_v \left(\to b\bar{b}\right)$

long-lived particles decaying to jet pairs at 7 and 8 TeV

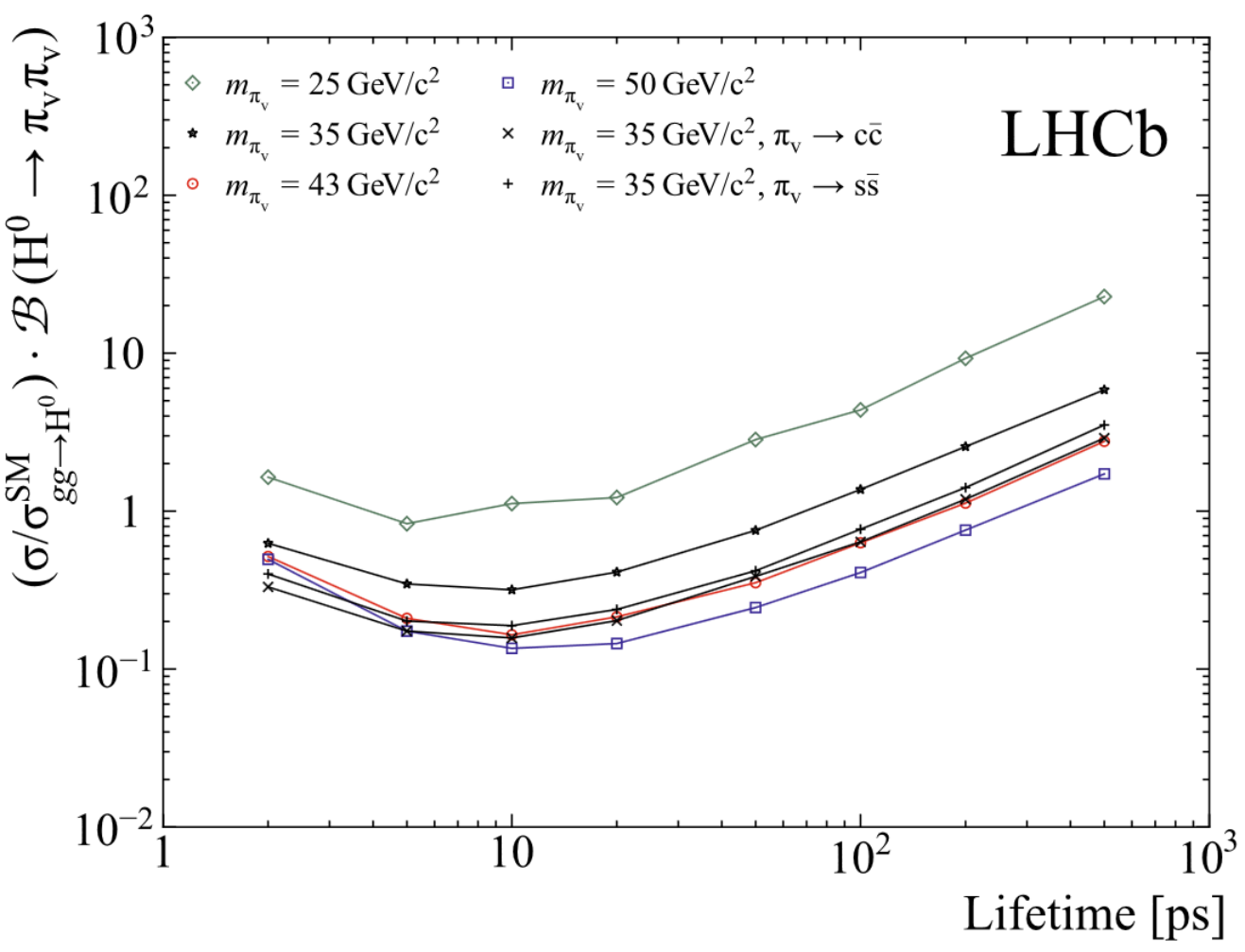
- update of arXiv:1412.3021
- published in Eur. Phys. J. C77 (2017) 812
- focus on Hidden Valley pions produced in Higgs decays
- samples:
  - 2 fb^{-1} of 7 and 8 TeV data
  - Monte Carlo from Pythia8
- requirements:
  - single displaced vertex with two associated jets
    - usually only one of the pions falls into the LHCb acceptance
  - dijet alligned with the vector from PV to the displaced vertex
  - distance between jets $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 2.2$
    - suppressing back-to-back dijet background

- strategy:
  - $\pi_v \to b\bar{b}$ dominates
  - subsamples with different π_v mass and lifetime
    - 25 GeV, 35 GeV, 43 GeV and 50 GeV for $\pi_v \to b\bar{b}$ events
    - 35 GeV for $\pi_v \to c\bar{c}$ and $\pi_v \to s\bar{s}$
    - 10 ps and 100 ps for $\pi_v \to b\bar{b}$ events
    - 10 ps for $\pi_v \to c\bar{c}$ and $\pi_v \to s\bar{s}$
  - background level strongly dependent on the distance of displaced vertex to the beam axis (R_{xy}) – binned fit approach



8 TeV, background in blue, signal of strength 1 in green and best-fit signal in red.

- results:
  - no significant excess of signal in the data
  - upper limits on the signal strength at 95% confidence level set and reweighted for multiple lifetime hypotheses
  - $\mathcal{B}_{q\bar{q}} = \mathcal{B}(\pi_v \to q\bar{q})$ assumed to be 100%, limits scale as $1/(\mathcal{B}_{q\bar{q}}(2 - \mathcal{B}_{q\bar{q}}))$



Conclusions

- jet measurements offer a great way to study both BSM and SM physics
- the cross-sections for production of W boson with jet pairs and $t\bar{t}$ pair production have been measured at 8 TeV and are in good agreement with NLO predictions
- a new search for Z' and b' at 13 TeV is underway and in advanced stage
- although no significant evidence for Hidden Valley pions has been observed, new constraints have been placed on the signal strength