Search for the single production of vector-like quarks that decay to a b quark and a Higgs boson in all-jet events with highly-boosted topologies

Giorgia Rauco (giorgia.rauco@cern.ch), Florencia Canelli and Annapaola de Cosa | on behalf of the CMS Collaboration
24 November 2017 | Annual Poster Event | University of Zurich

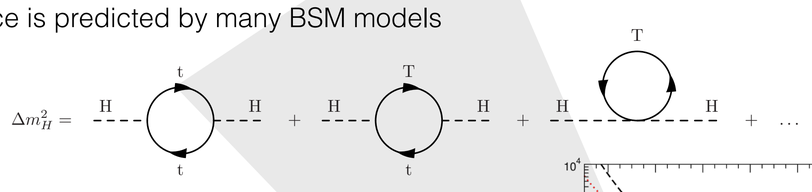
A search is presented for the single production of a heavy vector-like quark (B) decaying to a Lorentz-boosted Higgs boson and a bottom quark, B→Hb, with the Higgs boson decaying to a pair of bottom quarks. The analysis is performed using a data sample collected in 2016 by the CMS experiment at the LHC in proton-proton collisions at a centre-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 35.9 fb^{-1}. The observation is consistent with background expectation and upper limits are placed on the production cross section times the branching ratio. Values above 0.07 - 1.28 pb are excluded at 95% confidence level for masses of 700 - 1800 GeV , assuming a resonance with negligible width with respect to experimental resolution. Similar sensitivity is observed for different assumptions on the intrinsic width of the vector-like quark B.

Introduction and theory motivation

There are still **a lot of unanswered questions and unsolved problems** in particle physics, and more in general in physics. Therefore it is fundamental to test alternative theories predicting new physics and searching for new hypothetical particles, such as the **vector-like quarks** (VLQs).

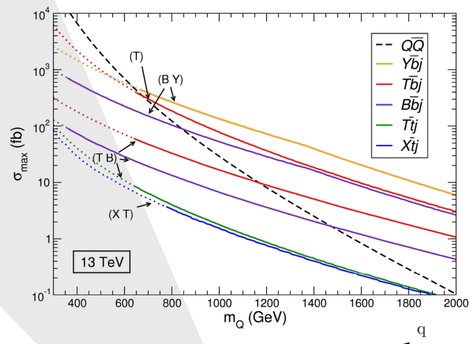
What are vector-like quarks?

- Their left and right-handed chiralities transform in the same way under SU(3)⊗SU(2)⊗U(1)
- Might help to solve the **fine tuning problem** mass and stabilize the Higgs boson mass
- Their existence is predicted by many BSM models



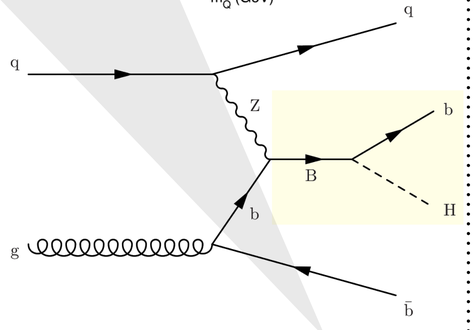
How can we search for them at the LHC?

- Produced in pairs or singly
  - single production dominant for high VLQ masses
- Decay in a SM quark and a vector or Higgs boson



Our search: single B → bH, all hadronic

- **All-jets signature** (and several b-quarks in the final state!)
- Main irreducible background is **multijet production**
- **Boosted topology**, B is massive (~ O(TeV))
- The VLQ B can be resolved and its **mass reconstructed**
- First time this channel is investigated and non-negligible resonances are studied for the B

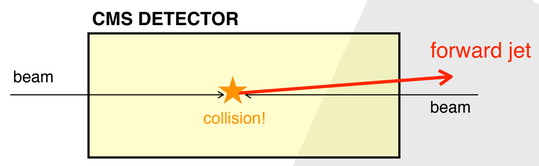


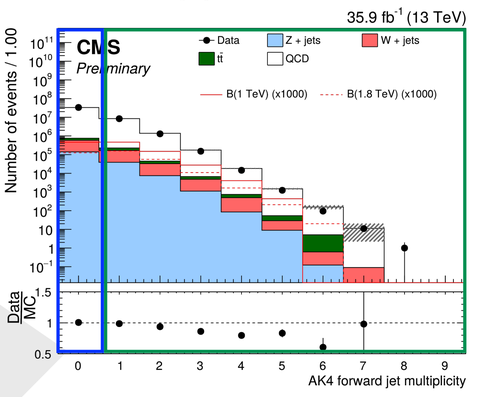
Signal characterization and analysis strategy

Forward jets

Typically **one jet is produced in the forward region of the detector** (i.e. close to the beam direction)

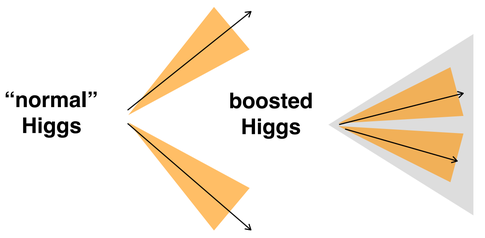
- events are split in two categories depending on the forward jet multiplicity: **cat 0** and **cat 1**





Higgs-jet identification

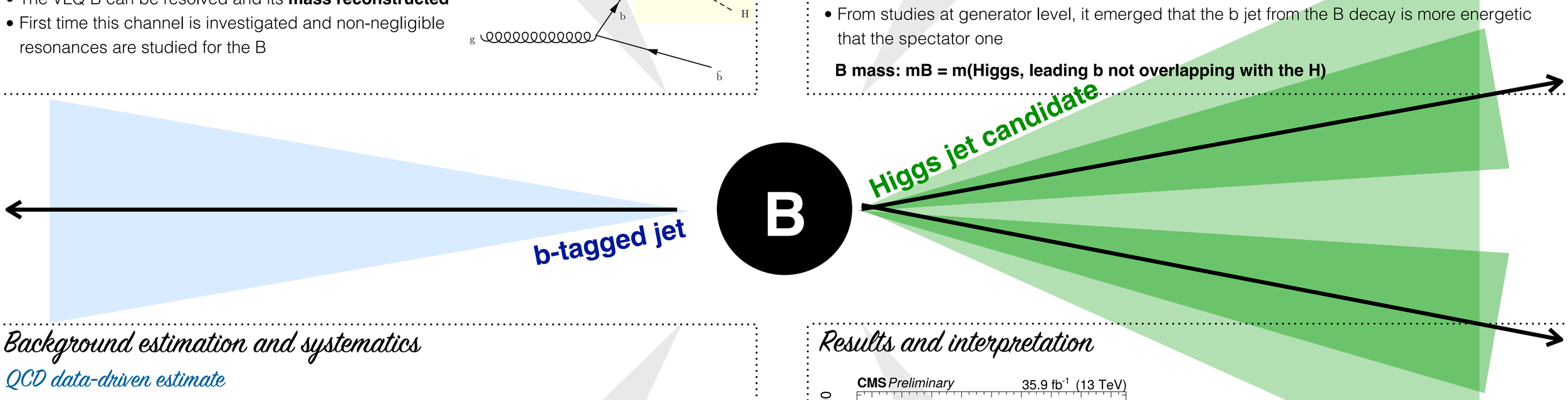
- Higgs is highly energetic and its decay produced are collimated
- The system is reconstructed as a unique large-cone jet with high p_T
- Mass peaking around the Higgs mass, i.e. 125 GeV



B mass reconstruction

- Several jets arising from the hadronization of b-quarks in the final state: the right assignment of jets to their mother particle is **challenging**
- Overlap between the Higgs jet and the additional b-jet removed
- From studies at generator level, it emerged that the b jet from the B decay is more energetic that the spectator one

B mass: mB = m(Higgs, leading b not overlapping with the H)



Background estimation and systematics

QCD data-driven estimate

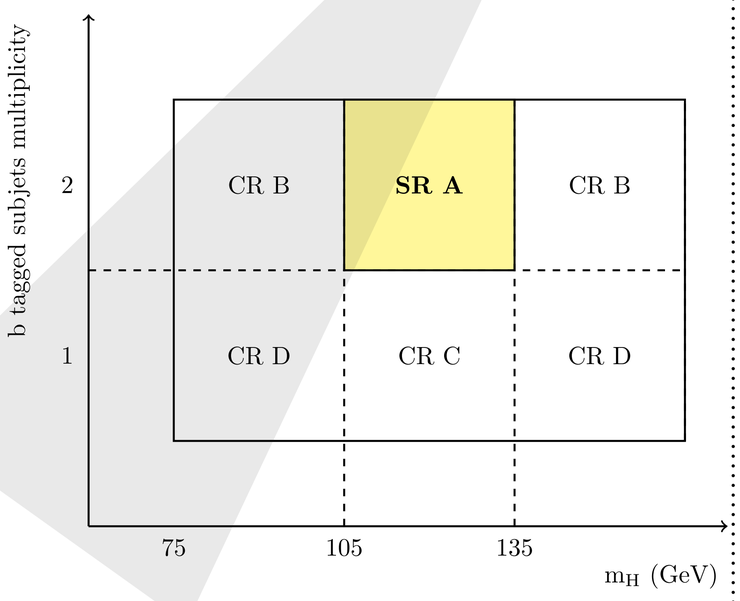
Instead of relying on MC simulation to extract the multijet background, data are used to estimate the contribution from QCD: **ABCD method** is employed.

3 regions enriched in QCD are defined by inverting signal requirements:

- Higgs-tagged jet mass window
- b-tagged subjets multiplicity

Workflow:

1. shape taken from **region C**
2. background normalization expectation in signal region (A): **$N_A = N_C \times N_B / N_D$**
3. multiple **closure tests** performed on simulation only and on data in modified control regions to check the validity of the method



Systematic uncertainties

The systematic uncertainties included in this analysis arise from several sources:

Physics object uncertainties

- b-tagging and mis-tagging
- Jet Energy Scale (JES) and Jet Energy Resolution (JER)
- Jet Mass Scale (JMR) and Jet Mass Resolution (JMS)
- Forward jet
- Simulation statistics
- HT-based triggers
- ABCD method for bkg estimation

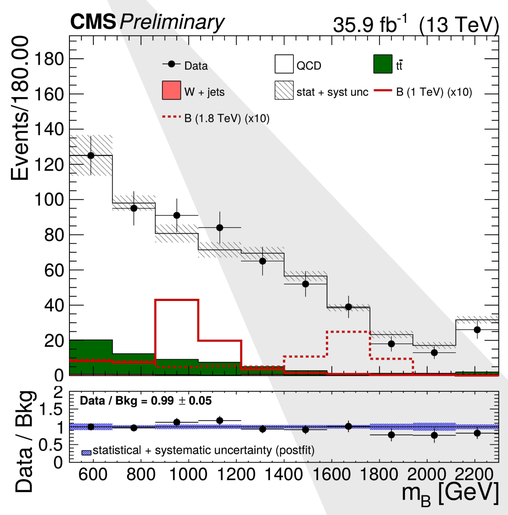
Theoretical uncertainties

- Factorization F and renormalization F scales
- Parton distribution functions

Experimental uncertainties

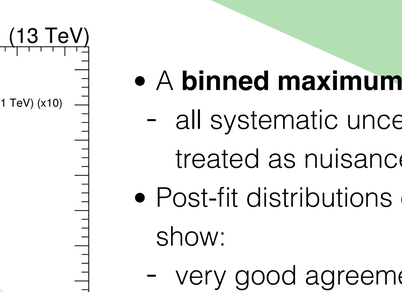
- Integrated luminosity
- Pileup modeling and reweighting

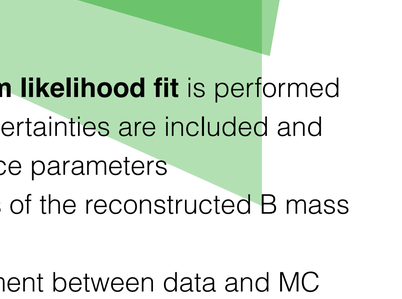
Results and interpretation



- A **binned maximum likelihood fit** is performed
  - all systematic uncertainties are included and treated as nuisance parameters
- Post-fit distributions of the reconstructed B mass show:
  - very good agreement between data and MC within uncertainties in all categories
  - **no excess of data over SM prediction → No sign of new physics**

- Results interpreted as upper limits on the signal production cross section times the branching fraction as a function of the VLQ B mass
- Approximation of **resonance narrow width** considered
  - additional **finite resonance width/mass** scenarios are investigated too
- Both isospin singlet and doublet models





CMS-PAS-B2G-17-009
Search for a singly produced vector-like quark B decaying to a b quark and a Higgs boson in a fully hadronic final state using boosted topologies