Trigger techniques for B-Physics at CMS

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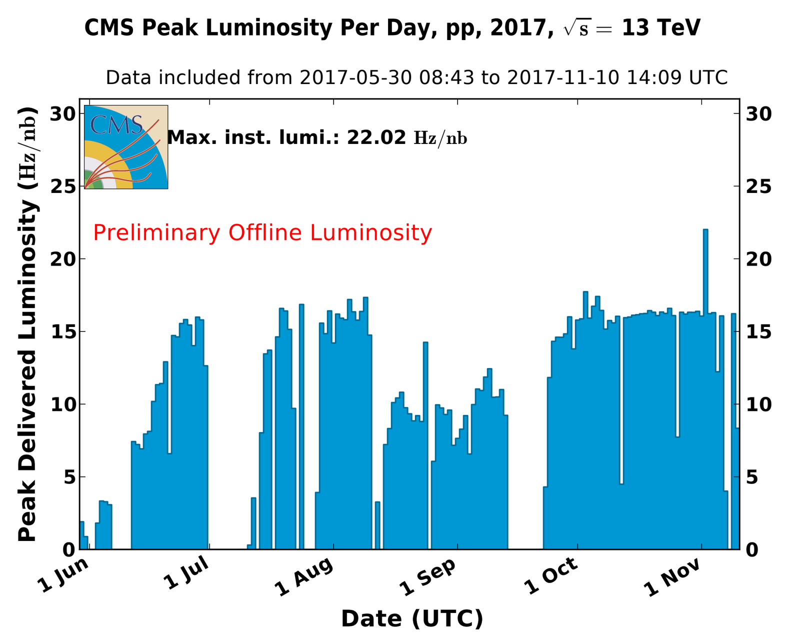
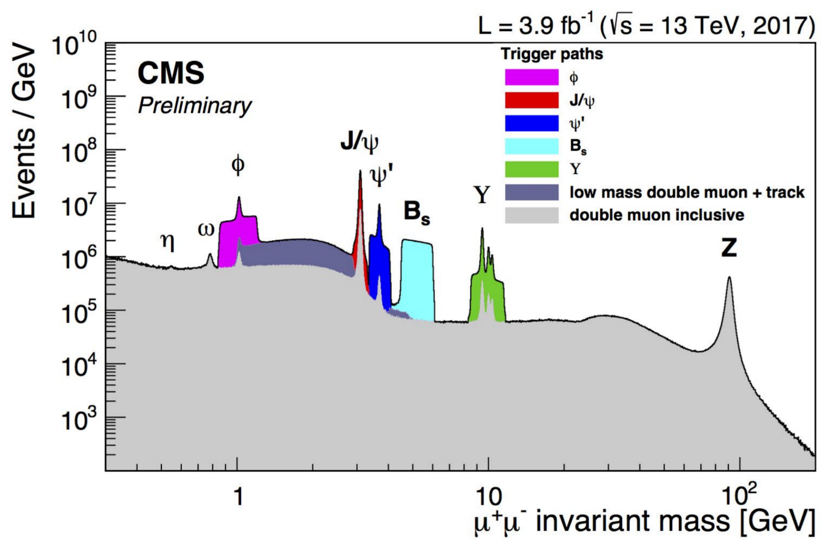
Introduction



The large instantaneous luminosity delivered by LHC to the CMS experiment in Run 2 is an important opportunity for the study of rare B-hadron decays, like $\mathrm{B}^0_{(s)} \to \mu\mu$ and $\mathrm{B}^0 \to \mathrm{K}^{*0}\mu\mu$. The main drawback of this luminosity increase is that the trigger selections need to be more tight, in order to fit the rate of recorded events in the limits imposed by the available computer resources. This constraint imposes a challenge in the development of new trigger tools and algorithms, optimized to keep high acceptance on signal events while reducing the rate of collected background events, both at Level-1 Trigger (L1T) and at High-Level Trigger (HLT)



Level-1 Trigger

Triggering B-Physics events at L1T presents many challenges, due to the absence of information from the silicon detector:

- no dimuon vertexing prevents the rejection of events coming from different interaction points
- no rejection of muons produced in a pion or kaon decay

In these years, many upgrades has been made in the L1T muon reconstruction criteria, in order to reduce the contamination from fake detector signals and to improve the resolution of the kinematical variables assigned to the muon.

Two important improvements, introduced before the 2017 data-taking, are the possibility to use the muon η and ϕ coordinates extrapolated at the interaction point, and the possibility to perform selections involving variables of the muon pairs, instead of only single muon quantities. They allowed to add new selection criteria to the B-Physics triggers:

- A selection on $\Delta R_{\mu\mu}$, used for triggers selecting events with dimuon masses lower than 6 GeV, for which the spread of the muons is limited. The threshold has been set to 1.2 and 1.4 for the two triggers used for these channels, assuring a complete acceptance on signal events.
- A selection on the dimuon invariant mass, used for triggers selecting events in the Υ mass range. The mass window set for the L1 triggers ranges from 8 GeV to 17 GeV, to guarantee a complete acceptance over the whole mass window selected at HLT.

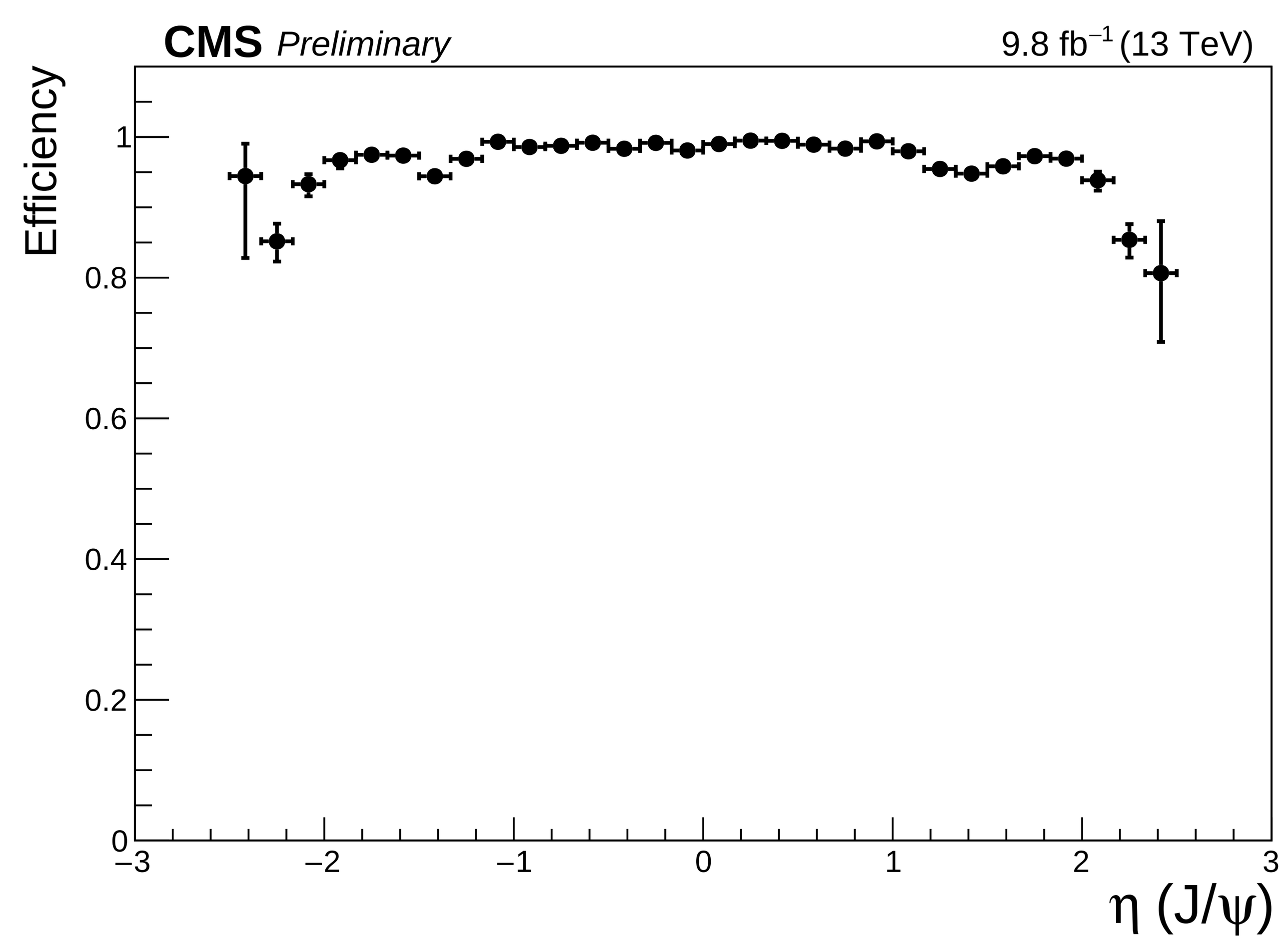


Figure: The efficiency of the Level-1 Trigger requirement $\Delta R_{\mu\mu} < 1.2$ is shown against the pseudorapidity of the J/ψ candidate.

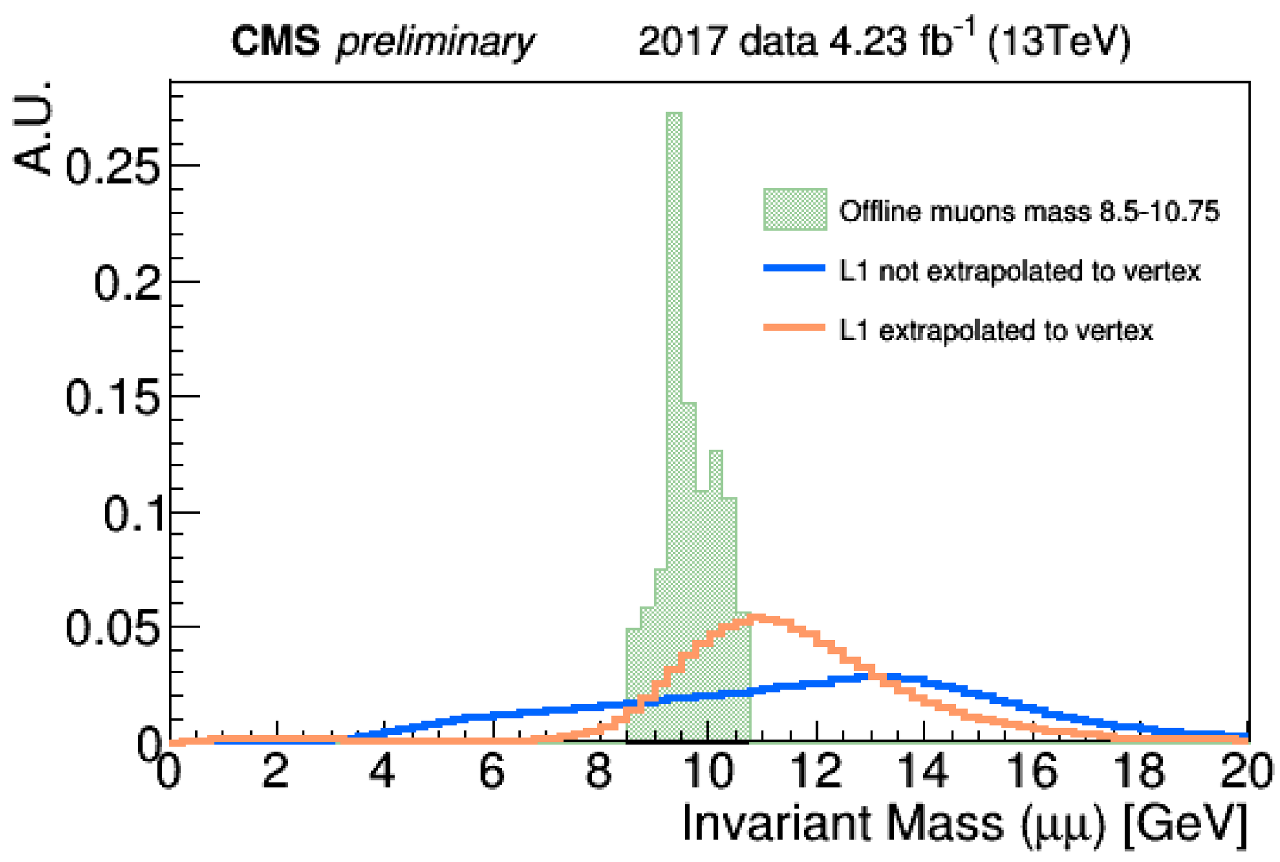


Figure: The $\mathrm{M}^{\mathrm{offl}}$ spectrum with a cut at $8.5 < \mathrm{M}^{\mathrm{offl}} < 10.75$ GeV and the M^{L1} spectrum of the L1 muons that match the offline muons in this interval. The L1 track extrapolation to the vertex improves the L1 dimuon resolution.

High-Level Trigger

At HLT, a muon candidate reconstruction is performed, using both the information from muon chambers and silicon detector. This leads to a better rejection of fake muons and muons from pion and kaon decays. In addition, performing the vertexing between the muons allows to select candidates originating from the same interaction point.

The triggers used for B-Physics decay channels can be divided in two categories:

inclusive triggers, requiring a pair of muons (and some triggers one or two additional muons) with the invariant mass compatible with one resonant state (ϕ, ψ, $B^0_{(s)}$, or Υ) and with a vertexing requirement, without applying criteria on the vertex position with respect to the interaction point

displaced triggers, requiring a pair of muons and an additional object (a track to select B hadron decays, or a muon to select candidates for $\tau \to 3\mu$ searches). The invariant mass of the muon pair is required to be compatible with J/ψ or $\psi(2S)$ states, or in a non-resonant window in the range from 0.2 GeV to 4.8 GeV. A vertexing requirement is applied, with a selection on the significance of the transverse displacement with respect to the interaction point, $d_{xy}/\sigma(d_{xy}) > 3$.

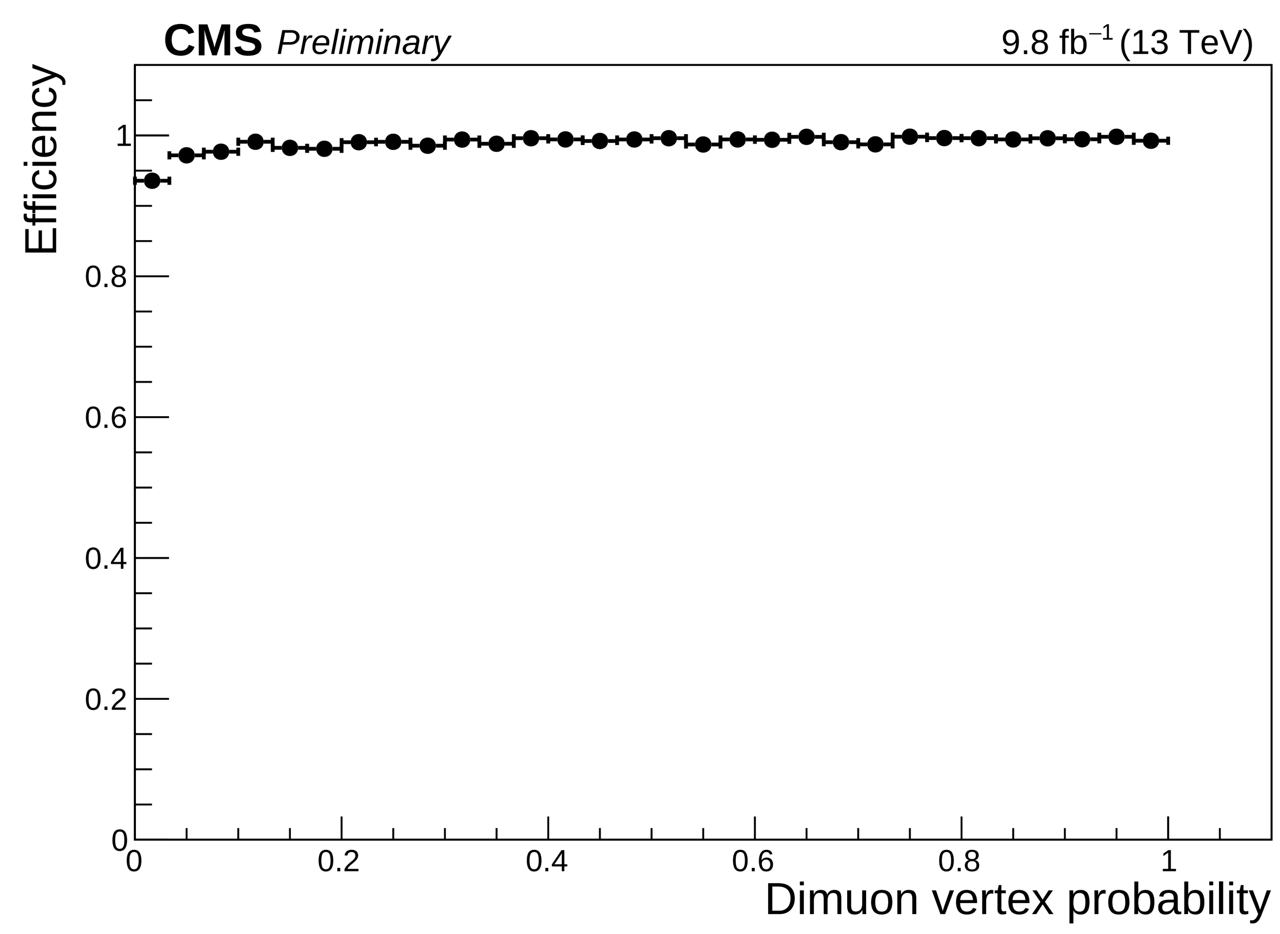


Figure: The efficiency of the High-Level Trigger requirement of a vertex between two muons, with no displaced topology, is shown against the offline dimuon vertex probability

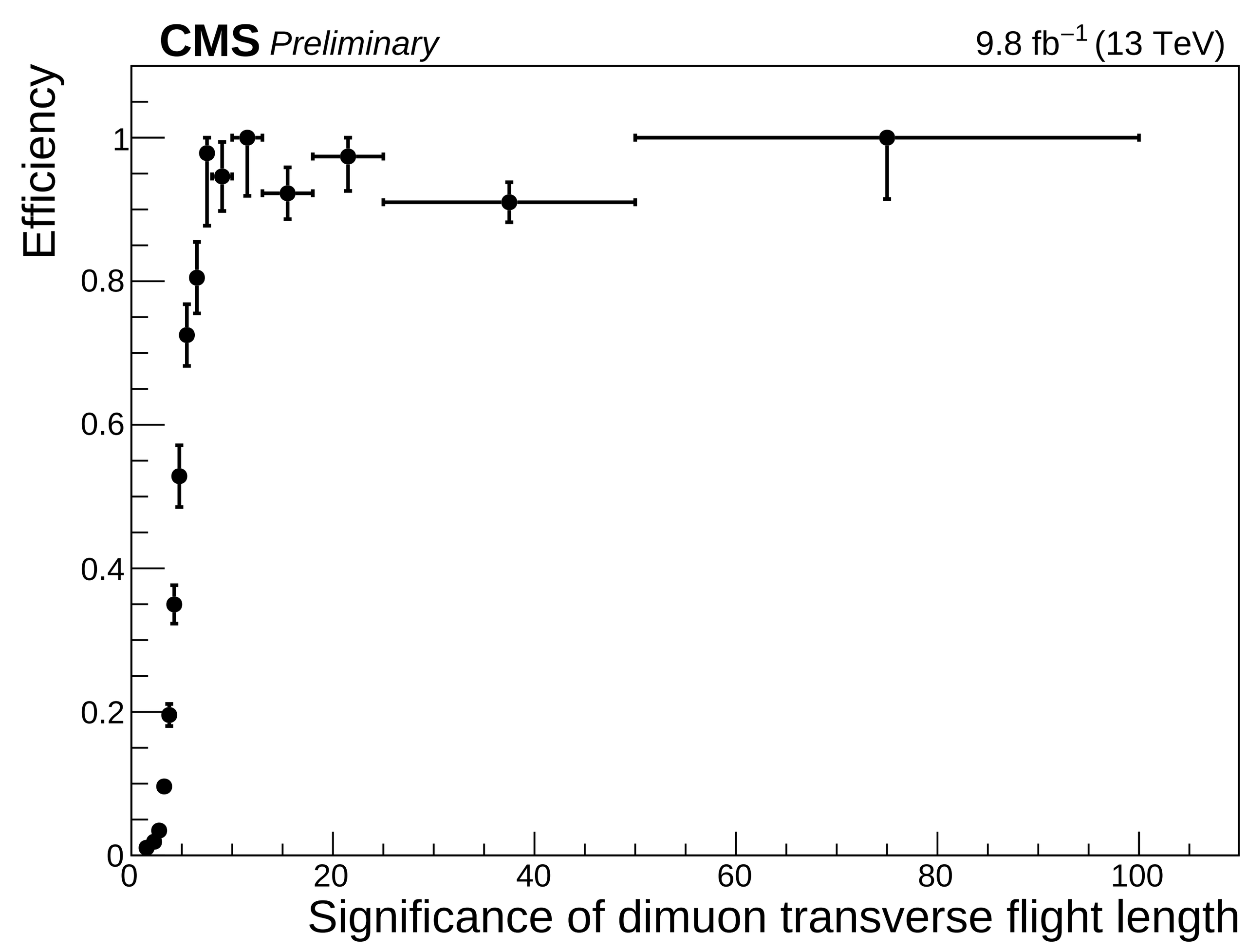


Figure: The efficiency of the High-Level Trigger requirement of a displaced vertex between two muons, used to select B-hadron decays, is shown against the significance of dimuon transverse flight length