Colouring the Higgs boson

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Introduction

Studying the internal structure of hadronic jets is crucial in the context of new physics searches and Standard Model constraints

With jet modelling as one of the dominant sources of uncertainty in many analyses, a deeper understanding of the substructure can be used to develop better models

Ideas on the design of better observables to understand the jet substructure algorithms are sprouting

QCD dipole radiation

Colour is a good quantum number of QCD interactions (before hadronisation), in principle diagrams with the same final-state but different colour do not interfere

Several observables were designed to be sensitive to the colour of QCD jets that are detected close in angle to one another (Pull angle, dipolarity, etc.)

Colour singlets (like H-> bb) and backgrounds to them are typically characterised by different colour correlations

Main interest in boosted topologies
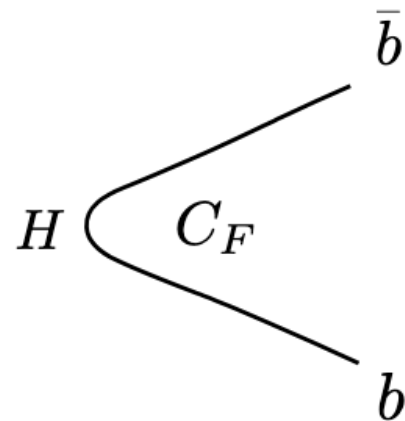
Direction of color flow for the singlet configuration of bb quarks from Higgs boson decay
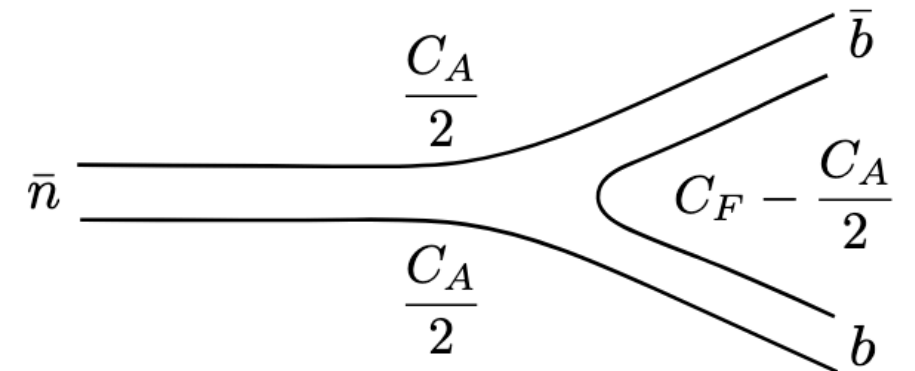
Direction of colour flow for the octet configuration of bb quarks, in the collinear limit

Introducing the color ring

The colour ring is a new simple and versatile observable designed to tag colour-singlets by looking at the behaviour of the matrix element

Adds awareness of the dipole orientation and opening angle to boosted H->bb studies, unlike other jet-structure correlation functions, C2, D2, etc.
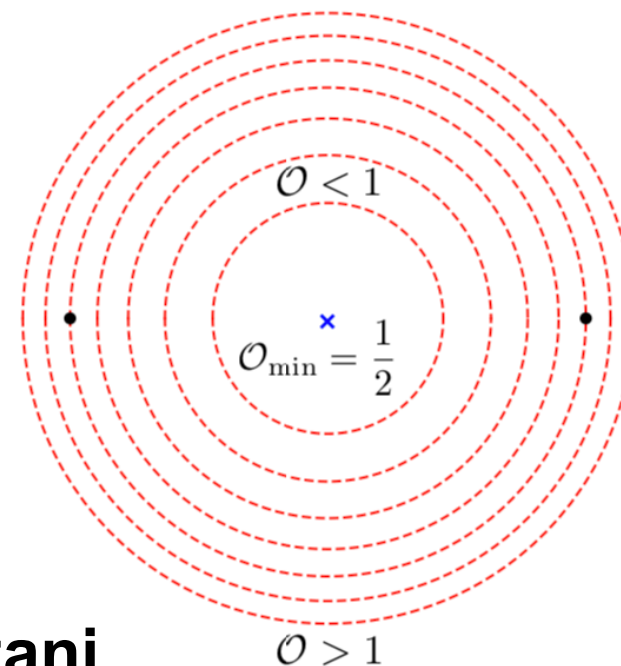
Neyman-Pearson lemma -> Ratio of matrix elements for singlet vs background dipole production

Collinear approximation:

$$\frac{|\mathcal{M}_{\mathcal{B}}|^2}{|\mathcal{M}_{\mathcal{S}}|^2} = \frac{C_{\mathcal{B}}}{C_{\mathcal{S}}} + \frac{\widetilde{C}_{\mathcal{B}}}{C_{\mathcal{S}}} \left(\frac{(n_a \cdot \bar{n})(n_b \cdot k)}{(n_a \cdot n_b)(\bar{n} \cdot k)} + \frac{(n_b \cdot \bar{n})(n_a \cdot k)}{(n_a \cdot n_b)(\bar{n} \cdot k)} \right) \simeq \frac{1 - \cos\theta_{ak} + 1 - \cos\theta_{bk}}{1 - \cos\theta_{ab}}$$

By Taylor expanding:

$$\mathcal{O} = \frac{\theta_{ak}^2 + \theta_{bk}^2}{\theta_{ab}^2}$$

See also Charanjit Kaur Khosa's talk in the Monday session

A. Buckley, G.Callea, A.Larkoski, S.Marzani
SciPost Phys. 9, 026 (2020)

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Performances

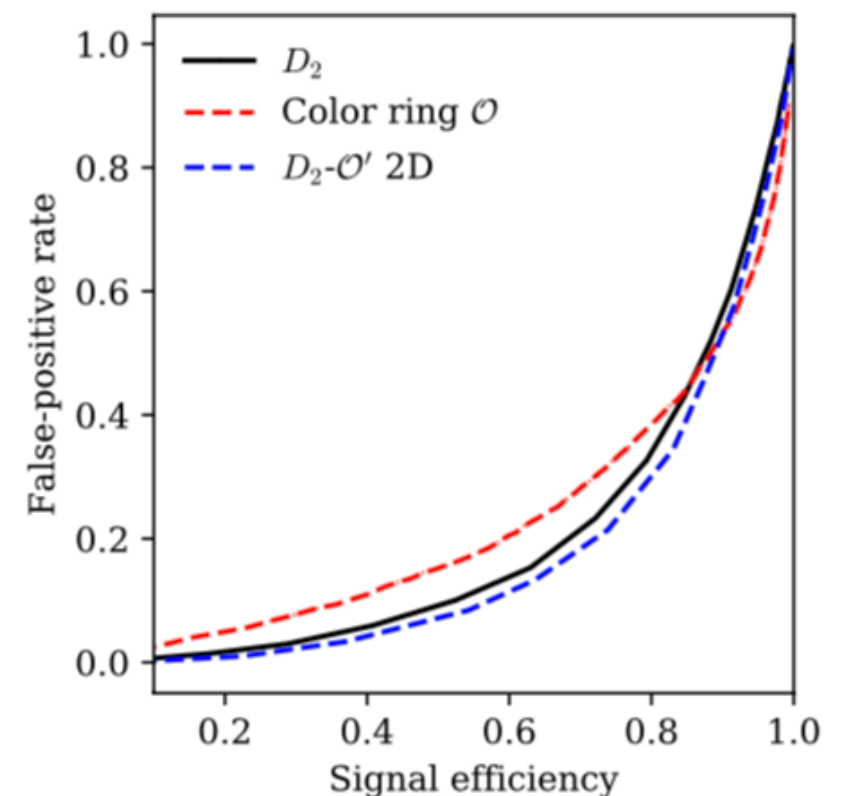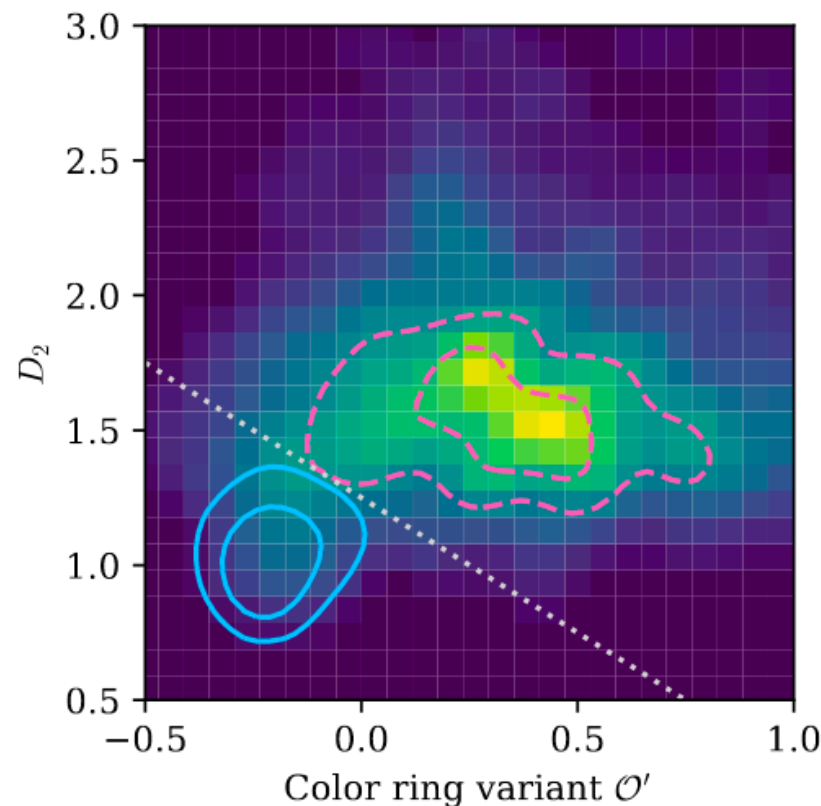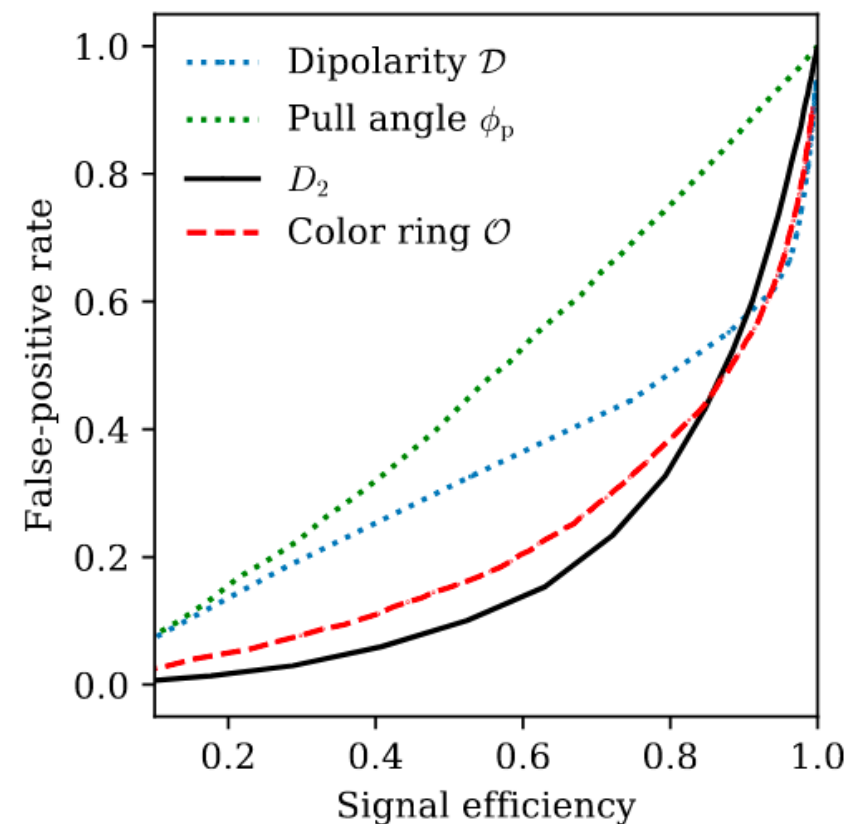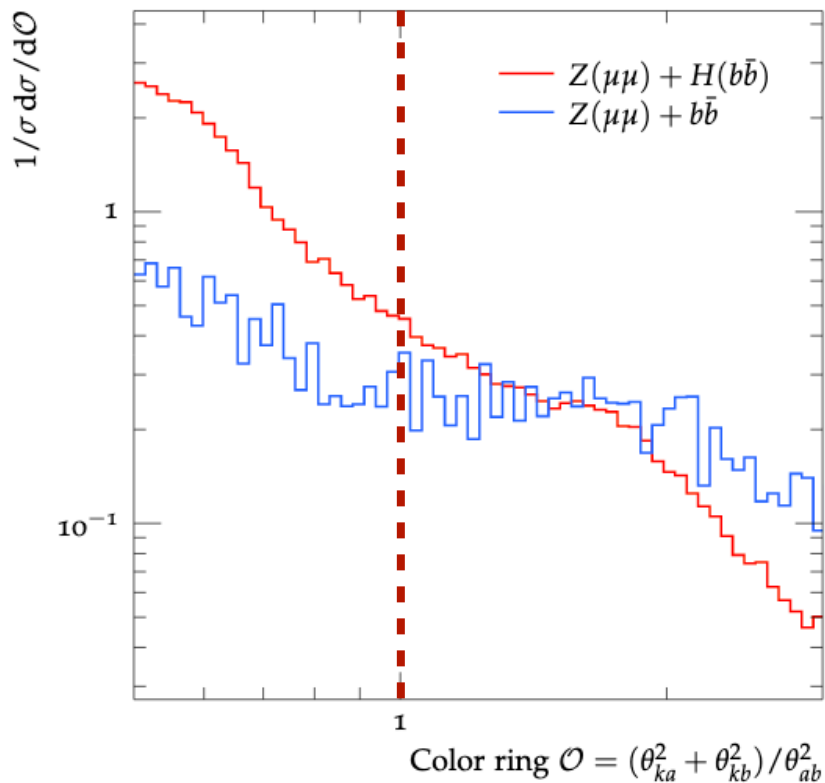$$\text{Color ring } \mathcal{O} = (\theta_{ka}^2 + \theta_{kb}^2)/\theta_{ab}^2$$

Samples generated with MG5+Pythia8

anti-kt jet with R=1, b-tagged track-jets

Good separation between ZH(bb) and Z+bb

The VH signal mostly populates the $\mathcal{O} < 1$ region

ROC curves for different taggers show that $\mathcal{O}$ is suboptimal compared to D2, but higher discriminating power compared to other colour singlet taggers

Summary

New colour-singlet tagger using matrix elements

Room for further refinements using e.g. p_T-weighted sums over large-R jet constituents and remove the third track-jet requirement

Reco level studies needed to see the performances for the purely directional colour ring vs more calo-sensitive energy correlators

Poster available in Room4

"Looking for a new tagger? Colour it!"

Thank you!