A novel approach for distinguishing between hadronically decaying W^+, W^-, and Z bosons in the CMS experiment

CMS DP-2024/044

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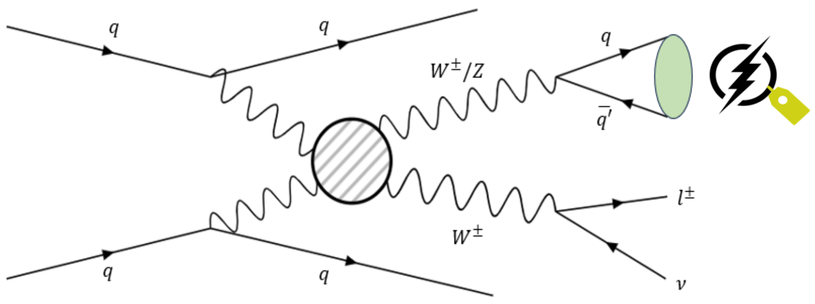
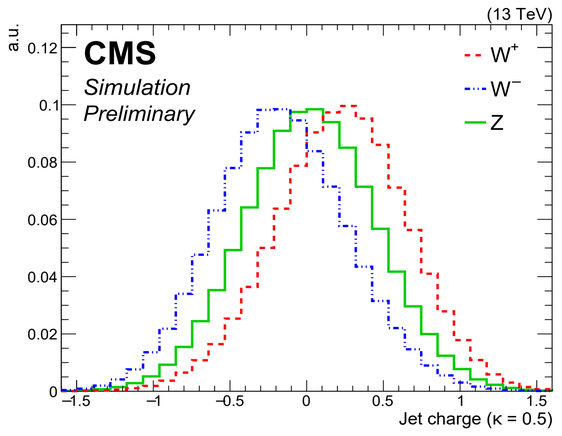
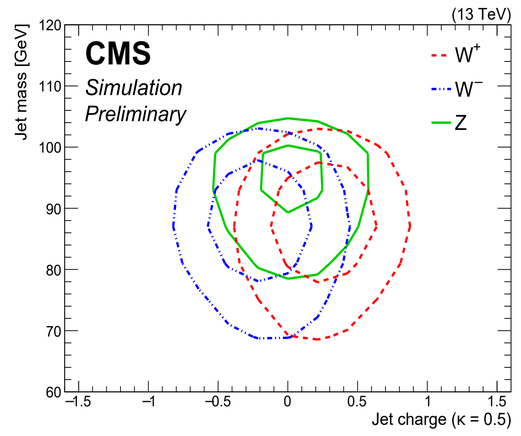
Motivation



- Same-sign WW Vector Boson Scattering (VBS), opposite-sign WW VBS, and WZ VBS are typically indistinguishable in the hadronic or semi-leptonic decay channels.
- These processes can be disentangled by identifying the charge of the jet(s).
- A novel method for identifying jet charge is presented in this poster, which can greatly help whenever the charge of the originating particle is a distinctive feature of a process.

Jet charge and jet mass



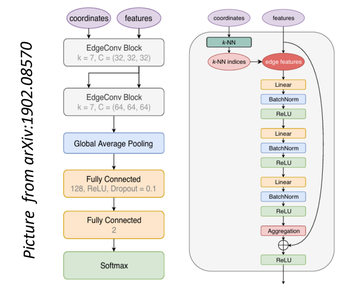


- Jet charge is defined as the p_T-weighted sum of the charge of all particles in the jet:

$$Q_\kappa = \frac{\sum_i q_i (p_T^i)^\kappa}{(p_T^{jet})^\kappa}$$

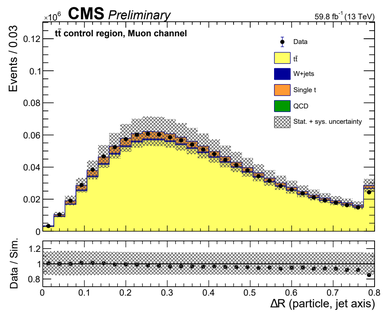
- The discrimination power of the jet charge and mass observables is weak by itself.

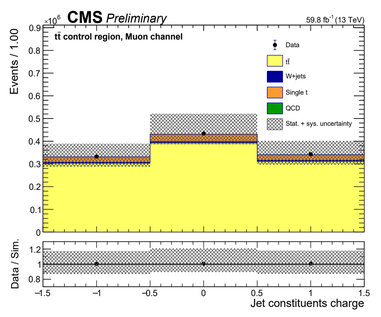
ParticleNet based jet charge tagger

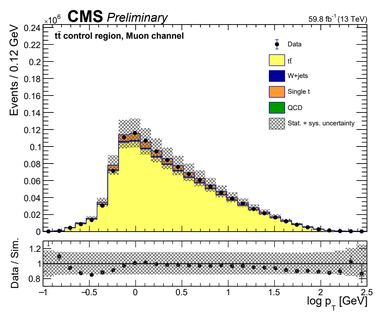


Picture from arXiv:1902.08570

Input variable	Description
ΔR	angular separation between the particle and the jet axis $\sqrt{(\Delta\eta)^2+(\Delta\phi)^2}$
Δη	difference in the pseudorapidity between the particle and the jet axis
Δϕ	difference in the azimuthal angle between the particle and the jet axis
log E	logarithm of the particle's energy
log p_T	logarithm of the particle's p_T
log E/log E^{jet}	logarithm of the particle's energy relative to the jet energy
log p_T/log p_T^{jet}	logarithm of the particle's p_T relative to the jet p_T
Jet constituents charge	electric charge of the particle



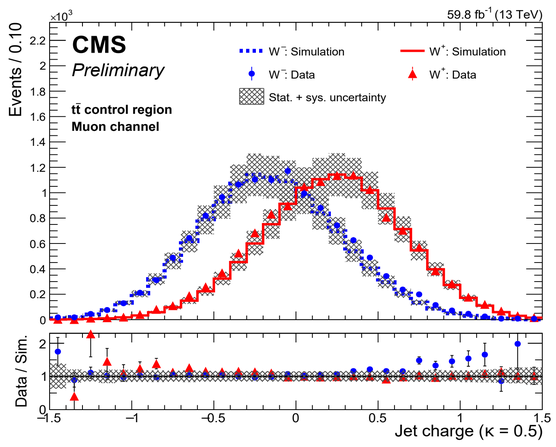


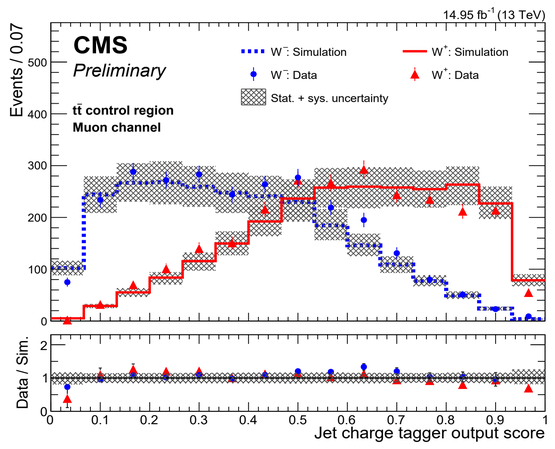


- The algorithm learns from low-level features of the jets that are well modelled in simulation to predict the charge.

Jet charge tagger as a binary classifier and validation in data

W^+ vs W^-

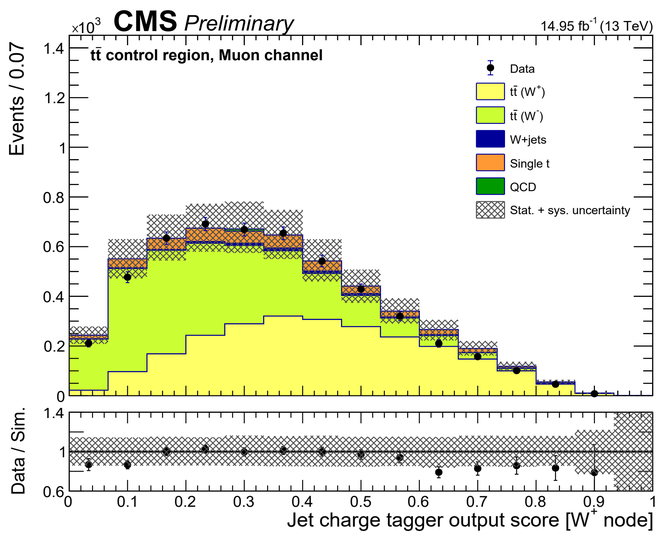


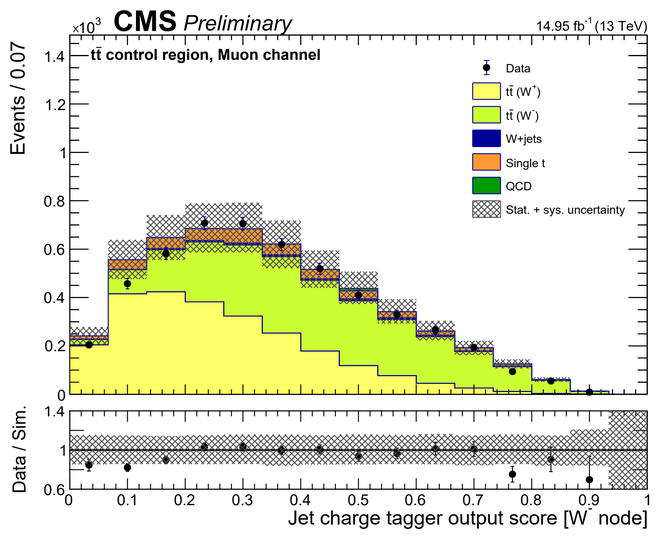


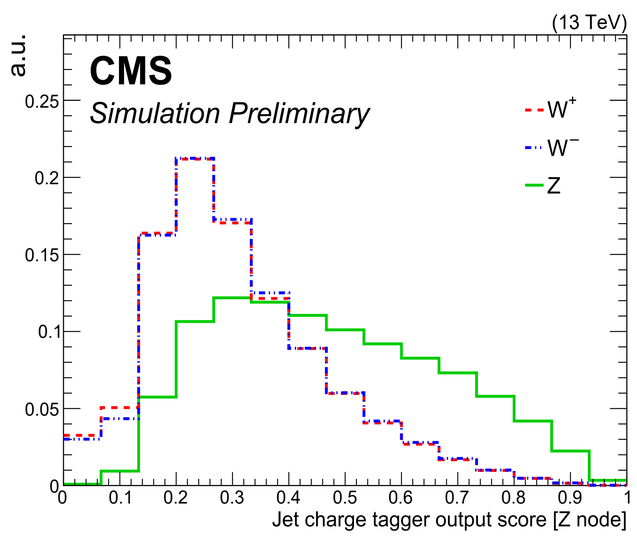
- W^+ and W^- are better separated in the jet charge tagger output score compared to the jet charge variable.
- The method is well described in data as well.

Jet charge tagger as a multi-classifier and validation in data

W^+ vs W^- vs Z



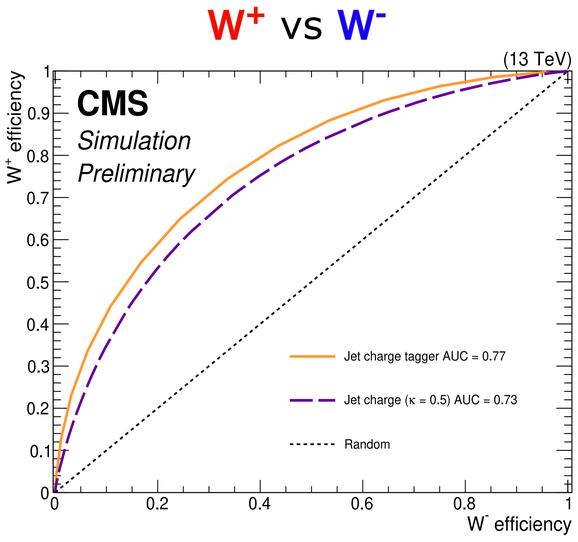




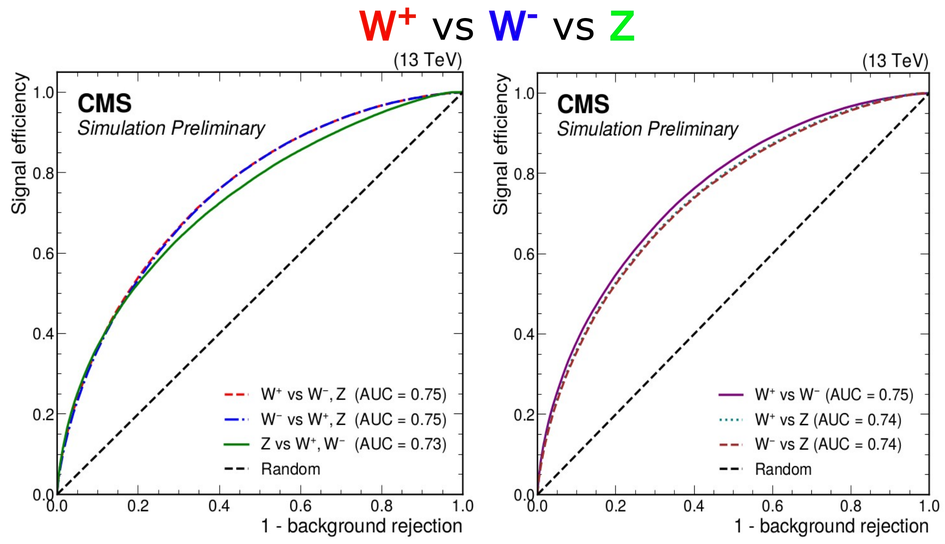
Jet charge tagger output score separating boosted jets coming from the decay of W^+, W^-, and Z bosons

Performance evaluation

W^+ vs W^-



W^+ vs W^- vs Z



ParticleNet based jet charge tagger outperforms traditional cut-based methods

Conclusion

- The first study in CMS at the center-of-mass energy of 13 TeV to distinguish hadronic decays of W^+, W^-, and Z bosons.
- Use of machine learning based algorithm shows substantial improvement compared to the variable-based methods.
- The jet charge tagger performs equally well to classify all three types of jets.
- The best performance is for W^+ vs W^-.
- Similar performance in data, expect scale factors close to unity.

scan to read the CMS DP-2024/044

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