



# WAVING A RED RAG TO A PULL: CALCULATING PULL FOR NON-SINGLET QCD JETS

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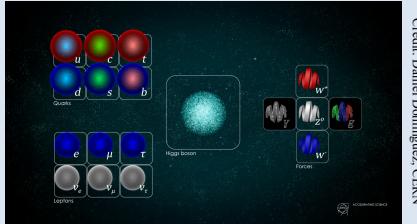
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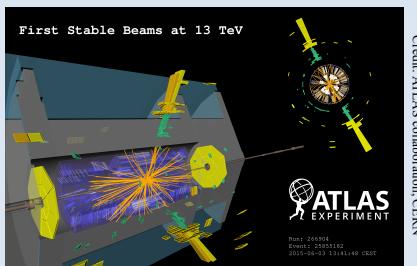
## Introduction

Pull vector is an observable sensitive to the color flows [1] in collision experiments [2]. Extending a previous study on leading-order calculations [3], we investigate the soft and collinear behavior of the pull vector due to non-color-singlet dipoles. We found that although the dominant behavior of a non-singlet configuration is similar to the singlet configuration, the sub-leading behavior differs significantly.

## Colors and Collision Experiments



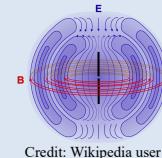
- Fundamental interactions: Gravity, electromagnetism, weak force, & strong force;
- QCD: Quantum chromodynamics, the study of the strong force;
- Colors: 3 parameters (charges) that weight the interaction strength.



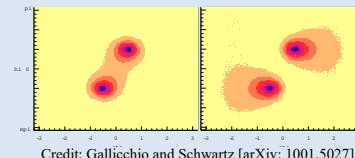
- Observable: Measured quantity e.g. energy, velocity (momentum), charge, etc.
- With these observables, infer what interaction happened, what particles were involved, what properties of the particle we could extract, etc.

## Dipole Radiation and Pull

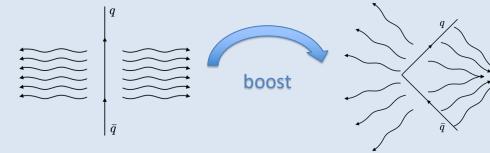
Dipole radiation in electromagnetism



Dipole radiation in QCD



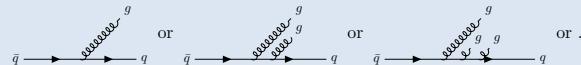
Not a color dipole radiation



$$\mathbf{t}_{\text{orig}} \triangleq \sum_{i \in J} \frac{p_{\perp i} |\mathbf{r}_i|}{p_{\perp J}} \mathbf{r}_i, \quad \mathbf{r}_i \triangleq (y_i - y_J, \phi_i - \phi_J)$$

## Collinear and Soft Divergence

Probability of observing a soft (low-energy) or a collinear (small-angle) gluon is overwhelmingly high.



$$P(q\bar{q}g) \propto \frac{x_q^2 + x_{\bar{q}}^2}{(1-x_q)(1-x_{\bar{q}})}, \quad x_i = \frac{2E_i}{E_{\text{tot}}}$$

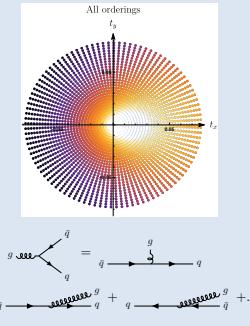
Soft and collinear emissions are dominant behaviors, and we should concentrate on understanding the dominant behavior analytically.

## References

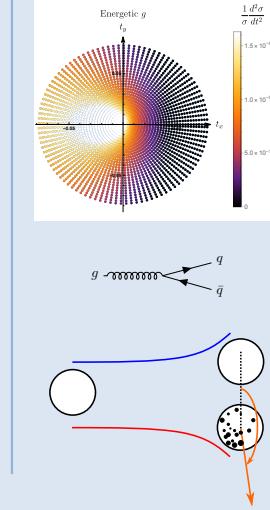
- [1] J. Gallicchio and M. D. Schwartz, *Seeing in Color: Jet Superstructure*, Phys. Rev. Lett. **105** (2010) 022001, [arXiv:1001.5027].
- [2] ATLAS Collaboration, Morad Aaboud et al., *Measurement of Colour Flow Using Jet-pull Observables in tt events with the ATLAS experiment at  $\sqrt{s} = 13$  TeV*, Eur. Phys. J. C **78** (2018) no.10 847
- [3] A. J. Larkoski, S. Marzani, and C. Wu, *Theory Predictions for the Pull Angle*, Phys. Rev. D **99** (2019) 091502, [arXiv: 1903.02275].
- [4] Y. Bao, and A. J. Larkoski, *Calculating Pull for Non-singlet Jets*, J. High Energ. Phys. **2019**, 35 (2019) [arXiv:1910.02085]

## Results: Cross section of pull

### Full Distribution



### Subleading Case



## Conclusion and Acknowledgment

The pull vector is sensitive to the color flow in a collision event. Specifically, the angular distribution of the pull vector is indicative of the direction of the color flow. Our calculation elucidates using pull to discriminate between  $H \rightarrow b\bar{b}$  and  $g \rightarrow b\bar{b}$ , potentially useful for Higgs investigation at LHC. More details can be found in [4].

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