Waving a Red Rag to a Pull: Investigating an Observable in Particle Collision Experiments

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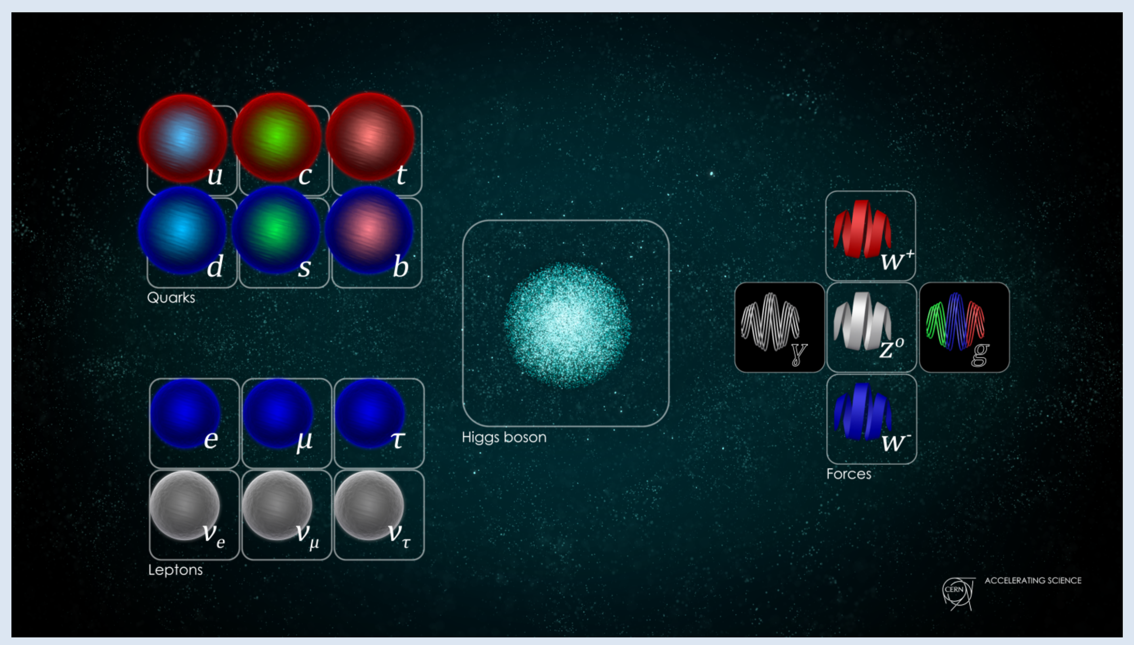
Abstract

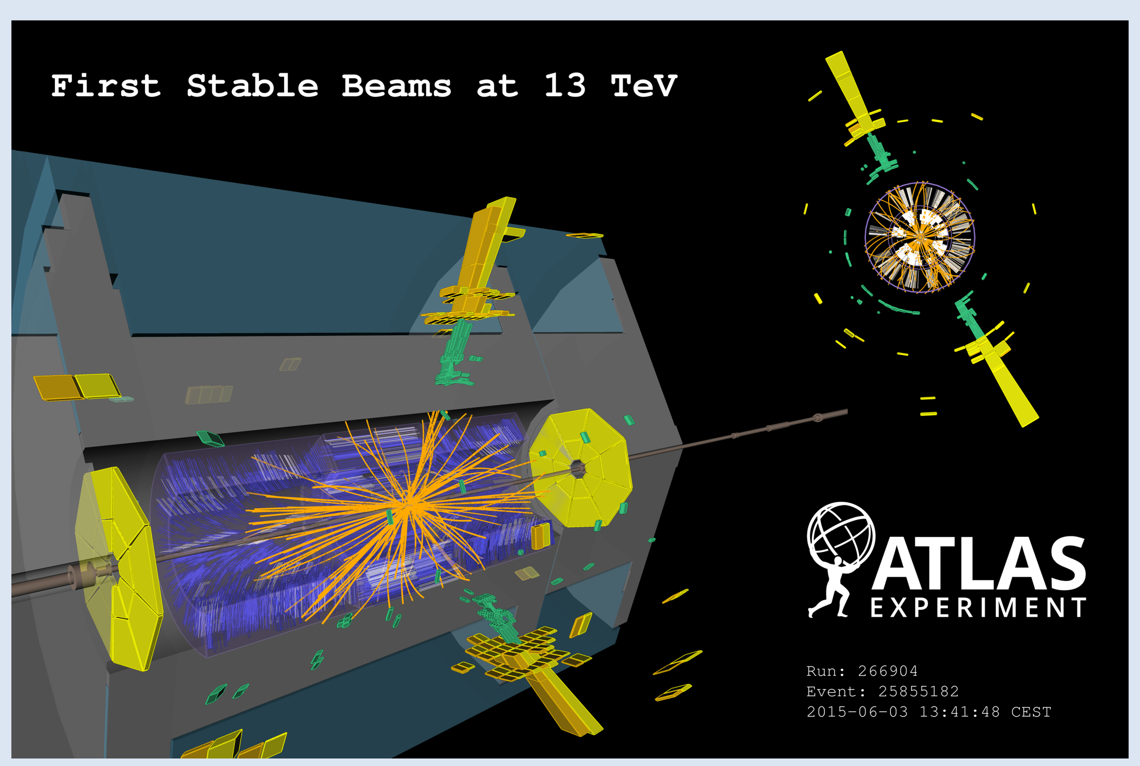
Pull vector is an observable sensitive to the color flows [1] in collision experiments [2,3]. Extending a previous study on leading-order calculations [4], we investigate the soft and collinear behavior of the pull vector due to non-color-singlet dipoles. We found that although the dominant behavior of a non-singlet configuration is similar to the singlet configuration, the sub-leading behavior differs significantly.

Colors and Collision Experiments



Credit: Daniel Dominguez, CERN

- 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.

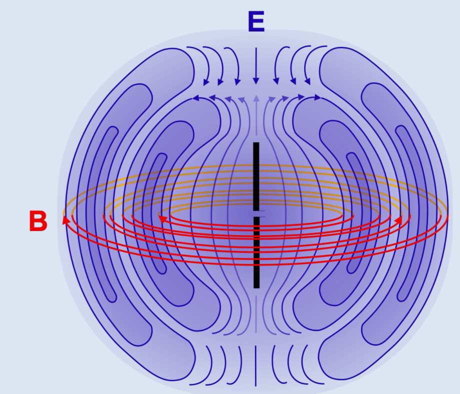


Credit: ATLAS collaboration, CERN

- 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.*

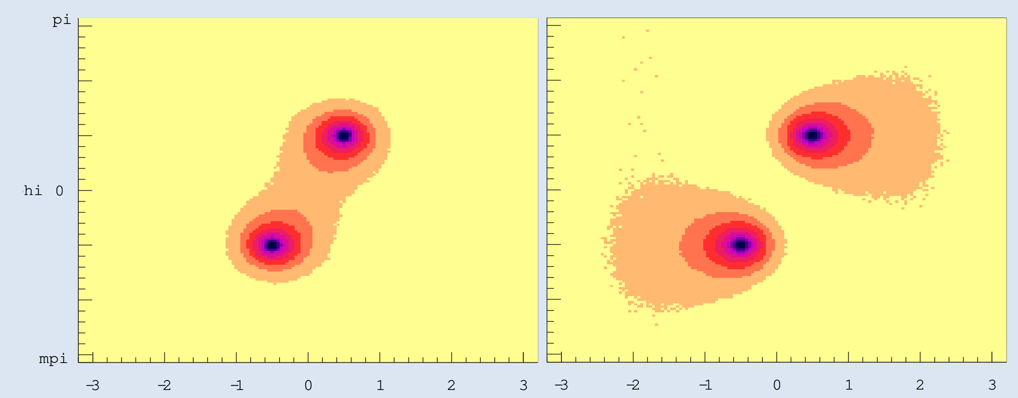
Dipole Radiation and Pull

Dipole radiation in electromagnetism

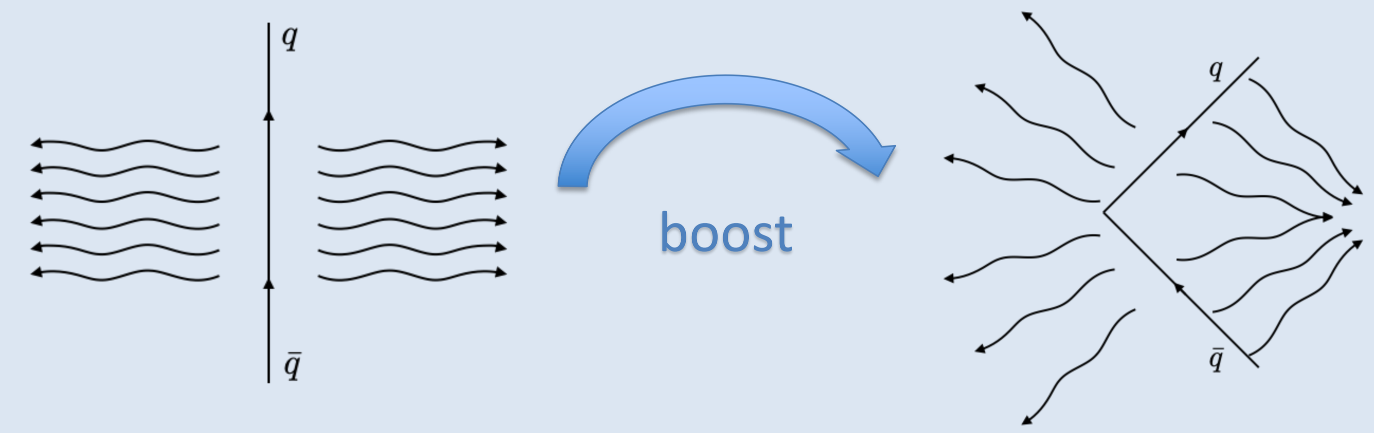


Credit: Wikipedia user

Dipole radiation in QCD | Not a color dipole radiation



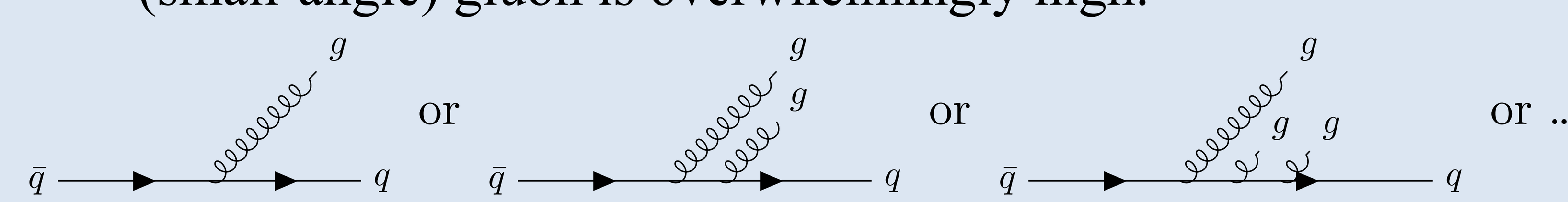
Credit: Gallicchio and Schwartz [arXiv: 1001.5027]



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

Collinear and Soft Divergence

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

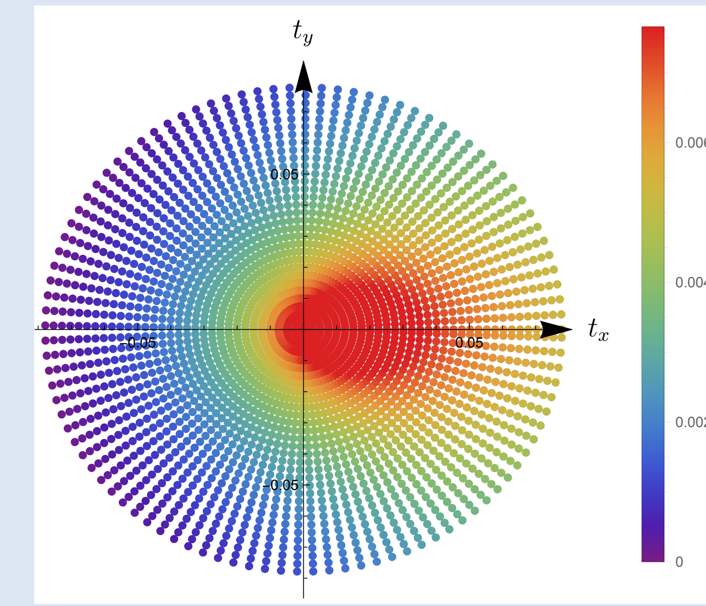


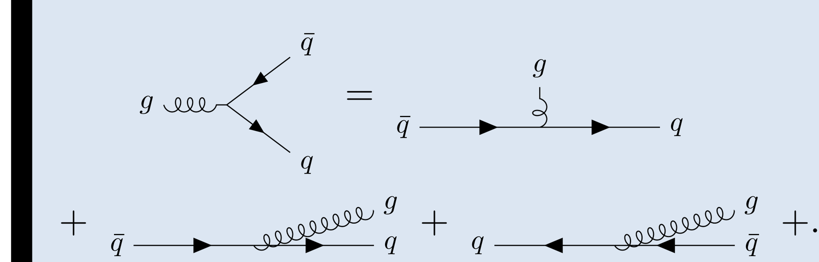
$$P(q\bar{q}g) \propto \frac{x_q^2 + x_{\bar{q}}^2}{(1-x_q)(1-x_{\bar{q}})}, \quad x_i = \frac{2E_i}{E_{\text{tot}}}$$

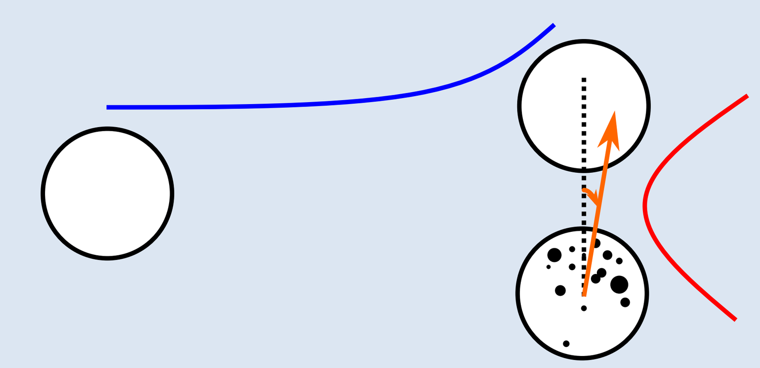
Soft and collinear emissions are dominant behaviors, and we should concentrating on understanding the dominant behavior analytically.

Results: Probability density of pull

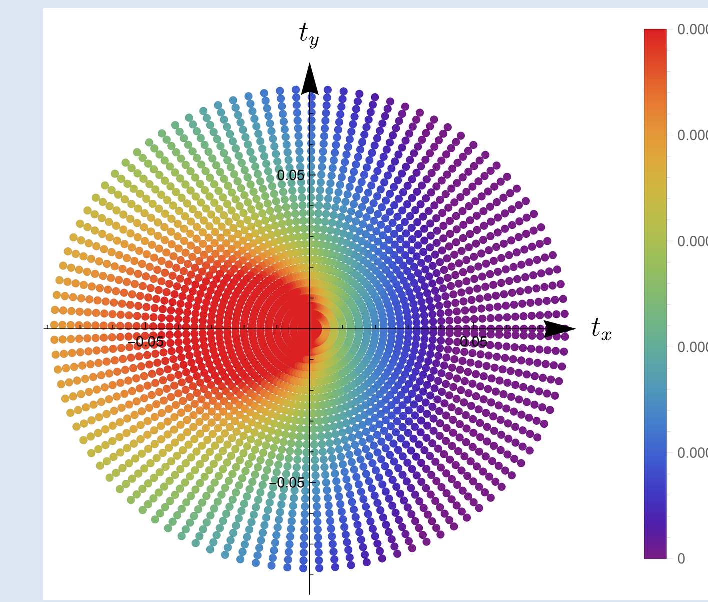
Full Distribution

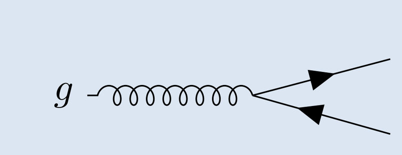


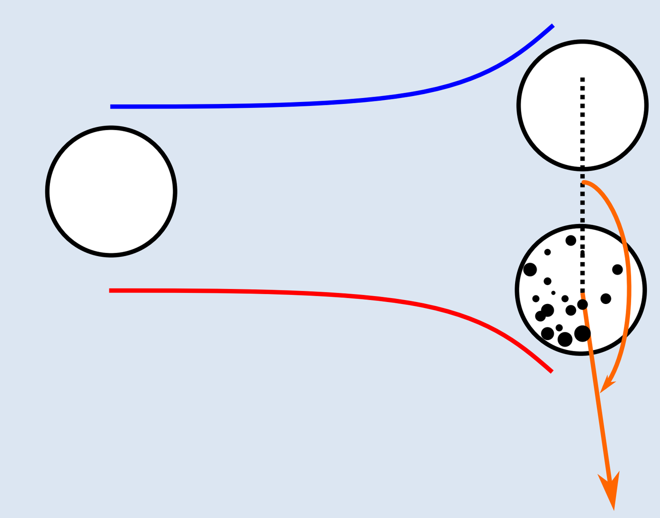




Subleading Case







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 dipole. Our calculation elucidates a potential discriminant between $H \to b\bar{b}$ and $g \to b\bar{b}$, which can support the Higgs research at Large Hadron Collider.

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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, Georges Aad *et al.*, *Measurement of Colour Flow with the Jet Pull Angle in $t\bar{t}$ Events Using the ATLAS Detector at $\sqrt{s}$ = 8 TeV, Phys. Lett. B* **750** (2015) 475-493, [arXiv: 1506.05629].

[3] **ATLAS** Collaboration, Morad Aaboud *et al.*, *Measurement of Colour Flow Using Jet-pull Observables in $t\bar{t}$ events with the ATLAS experiment at $\sqrt{s}$ = 13 TeV, Eur. Phys. J. C* **78** (2018) no.10 847

[4] A. J. Larkoski, S. Marzani, and C. Wu, *Theory Predictions for the Pull Angle, Phys. Rev. D* **99** (2019) 091502, [arXiv: 1903.02275].