Azimuthal Angular Correlation as a New Boosted Top Jet Substructure

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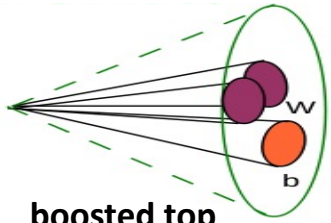
Zhite Yu and C.-P. Yuan, arXiv:2110.11539

Boosted top quark

❑ Why boosted top quark? [1012.5412]

- Important portal to new physics $pp \to X_{\text{heavy}} \to t \to bW(\to f\bar{f}')$
- Easier to separate top signal from background
- Hadronic mode is important

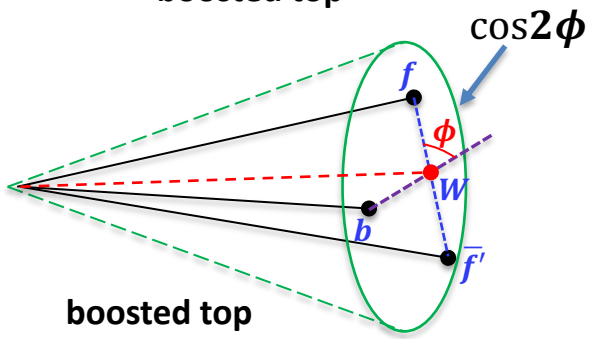


boosted top

❑ Tagging of boosted top quark jet

- W and t masses
- 3-subjet structure
- Azimuthal angular correlation

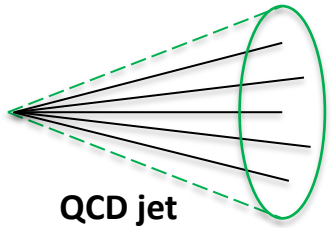
CMS-PAS-JME-13-007,
1006.2833, 1808.07858



boosted top

❑ Measurement of top polarization in *boosted* regime

- Production mechanism [arXiv:1103.3274]
- Polarization of top ⟸ azimuthal angular correlation



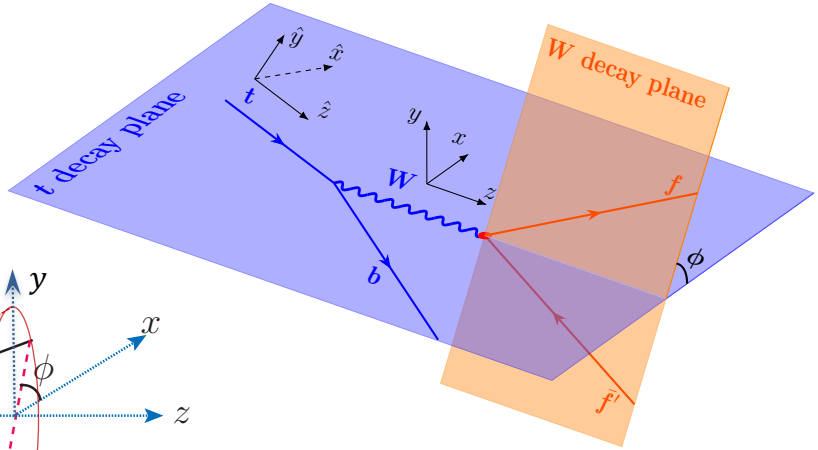
QCD jet

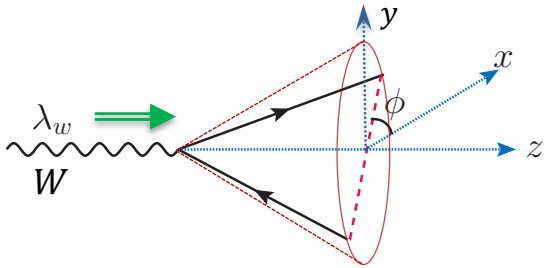
Azimuthal angular correlation and W polarization

- **Azimuthal correlation angle**

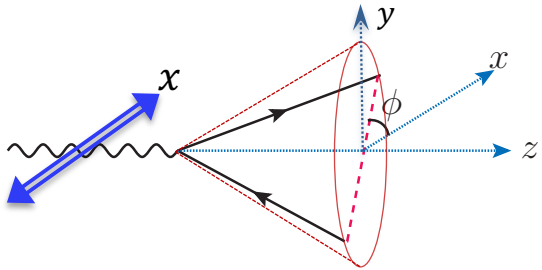
  $\sigma^{-1}\mathrm{d}\sigma/\mathrm{d}\phi$ is the ***angular correlation.***

- **Depends on W polarization**



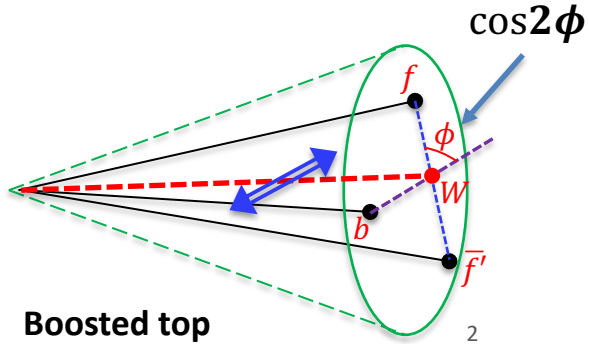


$|\lambda_w\rangle$: $\mathrm{d}\sigma/\mathrm{d}\phi \propto 1$



$|x\rangle$: $\mathrm{d}\sigma/\mathrm{d}\phi \propto A - B\cos 2\phi$

- W decay plane tends to be $\perp$ W linear polarization.
- Direction: $\parallel$ tbW plane



Boosted top

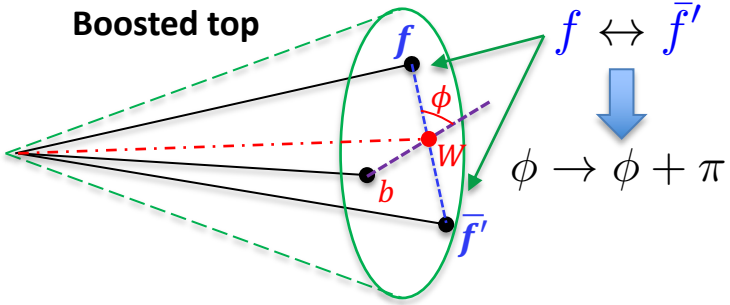
Azimuthal angular correlation

❑ Azimuthal correlation

W linear polarization

$$\frac{\mathrm{d}\Gamma_t}{\mathrm{d}\phi} = \frac{\Gamma_t}{\pi}\left[1 + \xi \cos 2\phi\right], \quad \phi \in [0, \pi)$$

$\cos 2\phi = \cos 2(\phi + \pi)$ ⇒ **Hadronic mode**

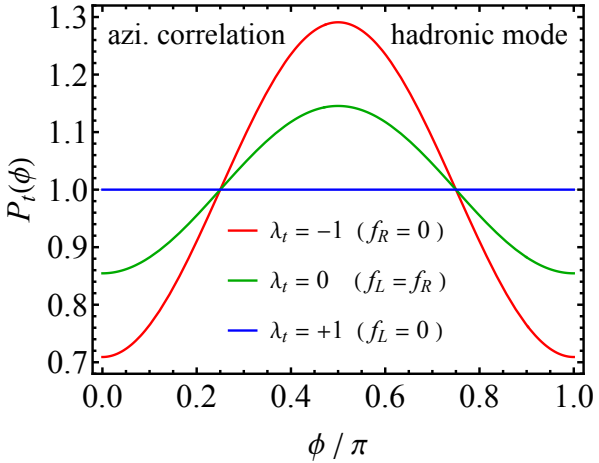


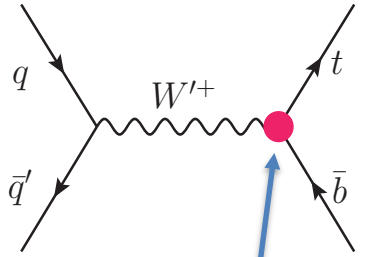
❑ Boosted limit

SM prediction

$$\xi = \xi(\lambda_t) = 0.145(\lambda_t - 1)$$

Angular correlation helps measure *top polarization λ_t*





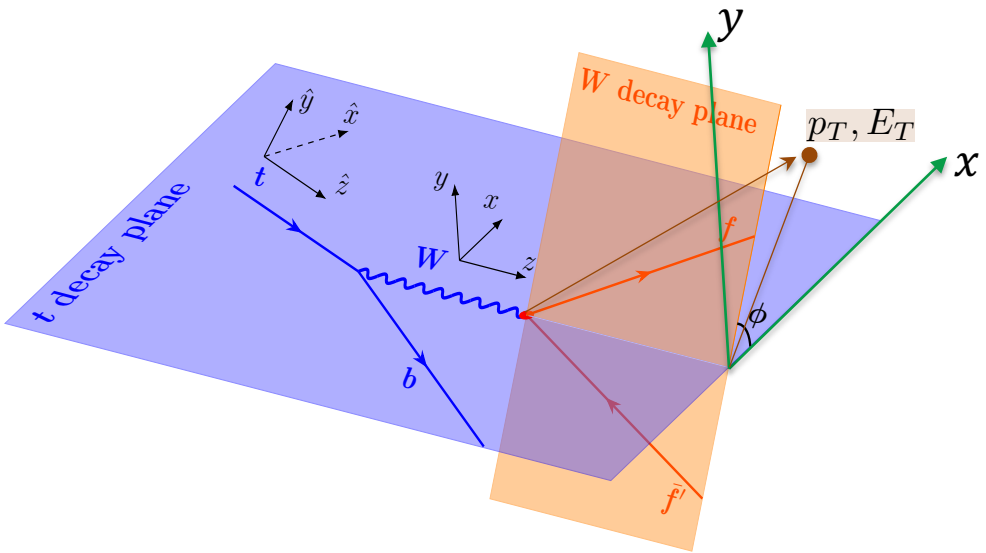
$$\bar{t}\gamma^\mu (f_L P_L + f_R P_R)\, b\, W'_\mu + \text{h.c.}$$

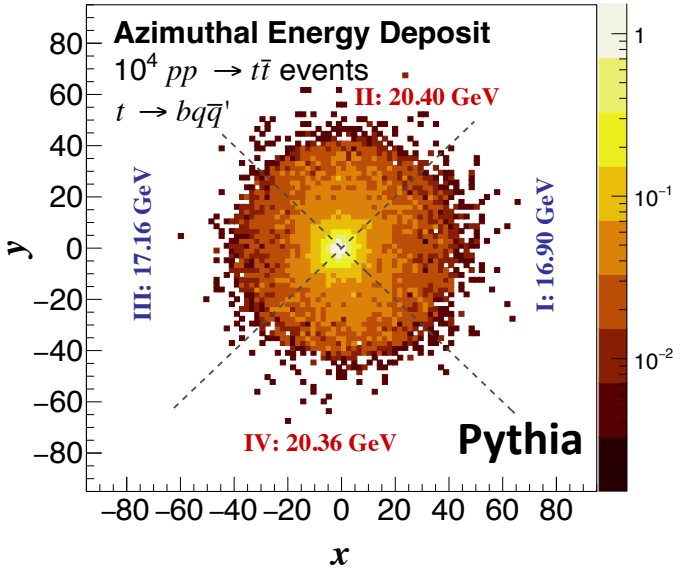
How to measure: Transverse energy distribution

Insensitive to parton showering, which does not change energy flow.

$$\frac{\mathrm{d}\Gamma_t}{\mathrm{d}\phi} = \frac{\Gamma_t}{\pi}\left[1 + \xi\cos 2\phi\right] \Rightarrow \frac{\mathrm{d}E}{\mathrm{d}\phi} = \frac{E_{\mathrm{tot}}}{2\pi}\left[1 + \xi\cos 2\phi\right]$$

IR safe

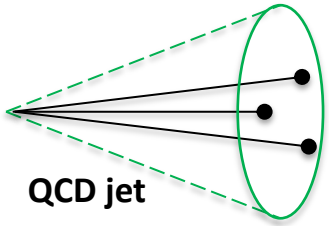




$$\xi = \frac{\pi}{2}\cdot\frac{(E_1+E_3)-(E_2+E_4)}{(E_1+E_3)+(E_2+E_4)} = -0.141$$

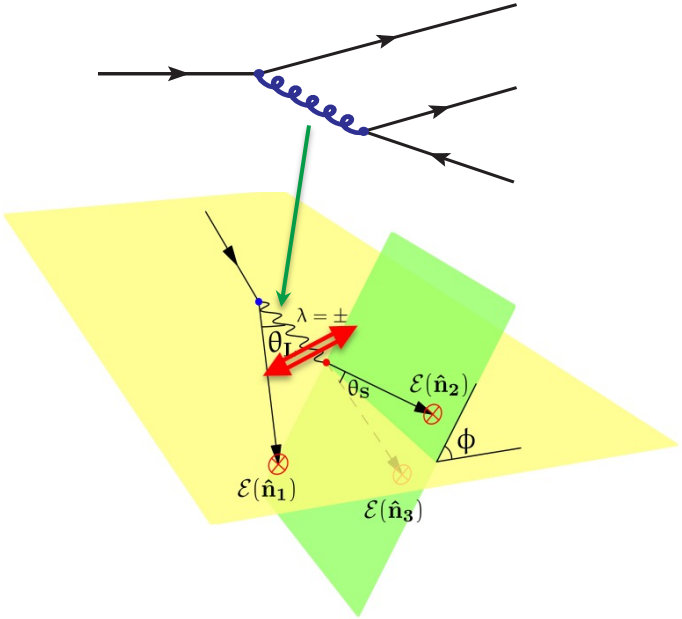
Boosted top tagger

❑ 3-point energy correlator of QCD jet [2011.02492]



$1 + \xi_j \cos 2\phi$ $\quad \phi \in [0, \pi)$

$|\xi_j| \simeq 1\%$ is small



❑ Comparison to QCD jet

Top jet: $1 + \xi \cos 2\phi$

Polarization λ_t	-1	0	$+1$
Top ξ	-29%	-14.5%	0

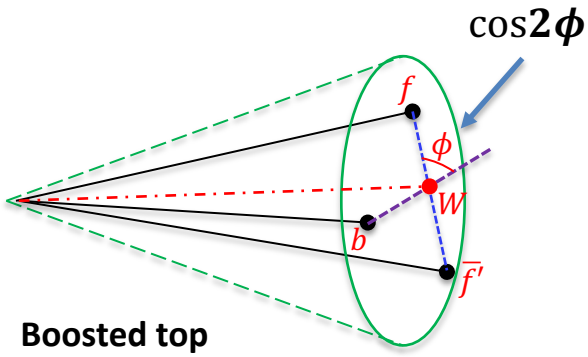
$|\xi| \gg |\xi_j|$ for most values of λ_t

➡ $\cos 2\phi$ correlation can be a boosted top quark tagger

Summary

❑ Proposed a new observable

- $\cos 2\phi$ angular correlation
- Due to W linear polarization
- Asymmetry of azimuthal energy deposits



❑ Phenomenological significance

- Measuring longitudinal polarization of boosted top
- Distinguish from QCD jet

Thank you!