Using colour flow in analyses

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European Research Council

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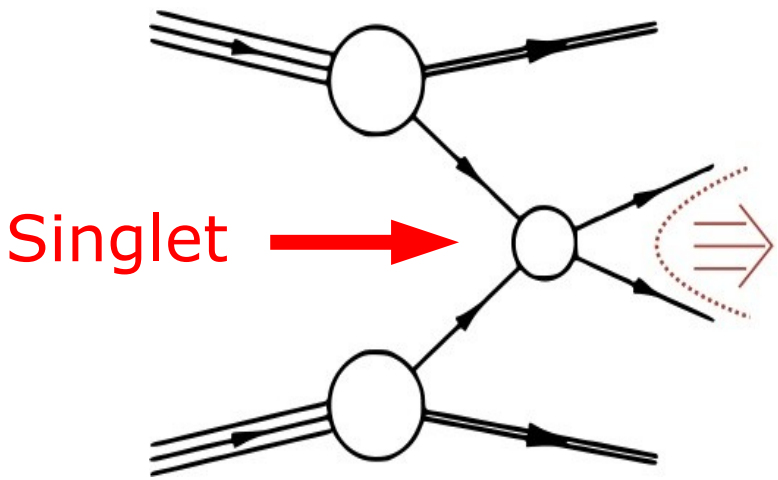
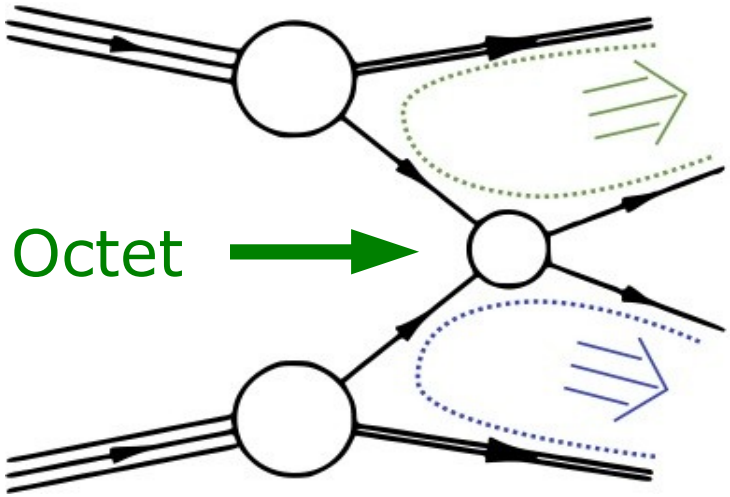
Color Flow between Jets

- Jets carry color, and are thus color connected to each other
  - Pairing of connection depends on nature of decaying particles





- Particles created during hadronization should be concentrated along angular region spanned by the color connected partons
  - Transverse jet profiles should not be round
  - Shape influenced by direction of color flow!

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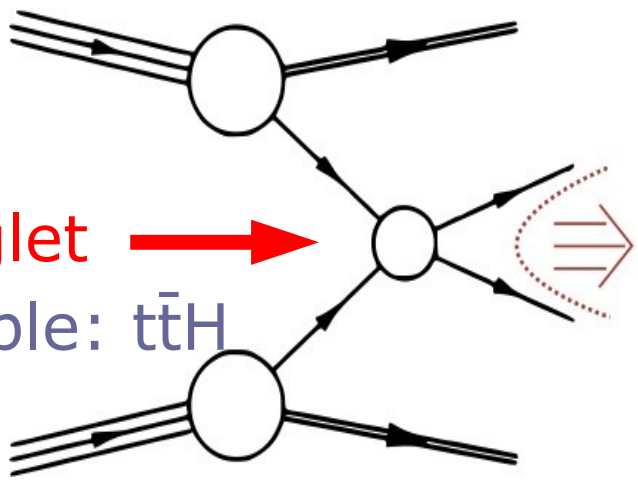

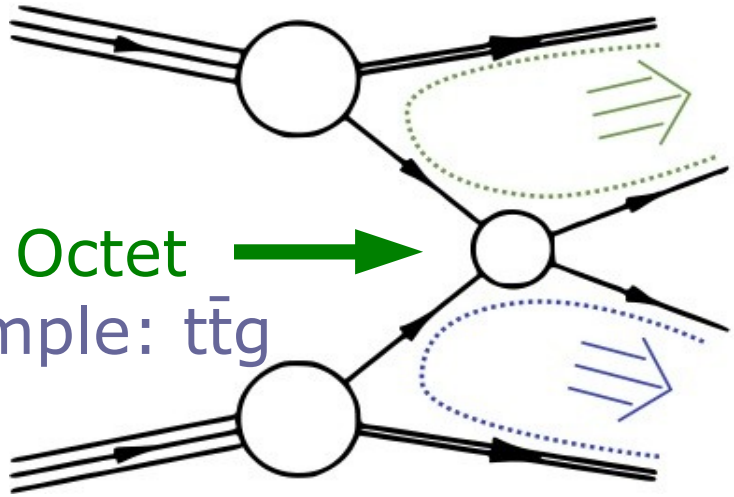

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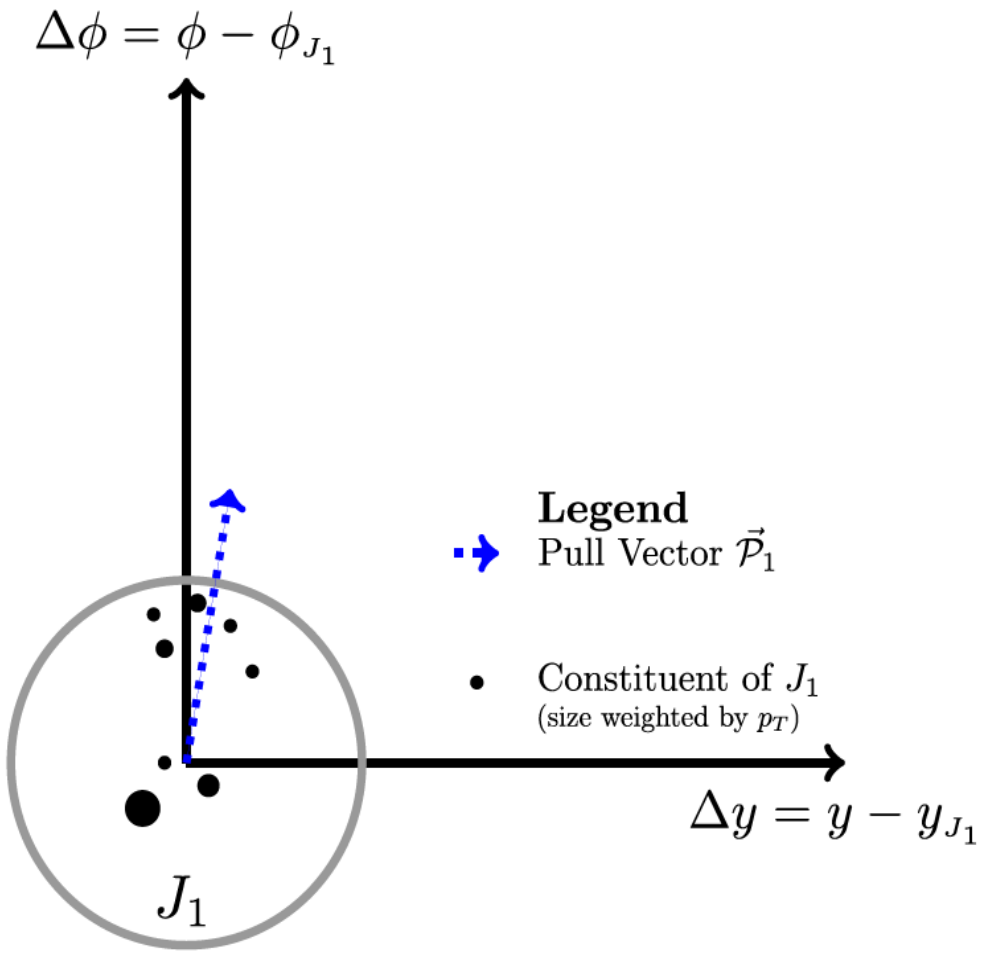
Color Flow Observable

Construct a local observable, constructed from particles within a chosen jet cone: Jet pull

- Pick a pair of jets in the event
- Build vectorial sum of jet components:

$$\vec{p} = \sum_i \frac{E_T^i |r_i|}{E_T^{jet}} \vec{r}_i$$

  - $\vec{r}_i$: position of jet component i relative to center of jet
  - E_T^i: transverse energy of component i
  - E_T^{Jet}: transverse energy of jet



Gallicchio, Schwartz, PRL 105, 022001 (2010)

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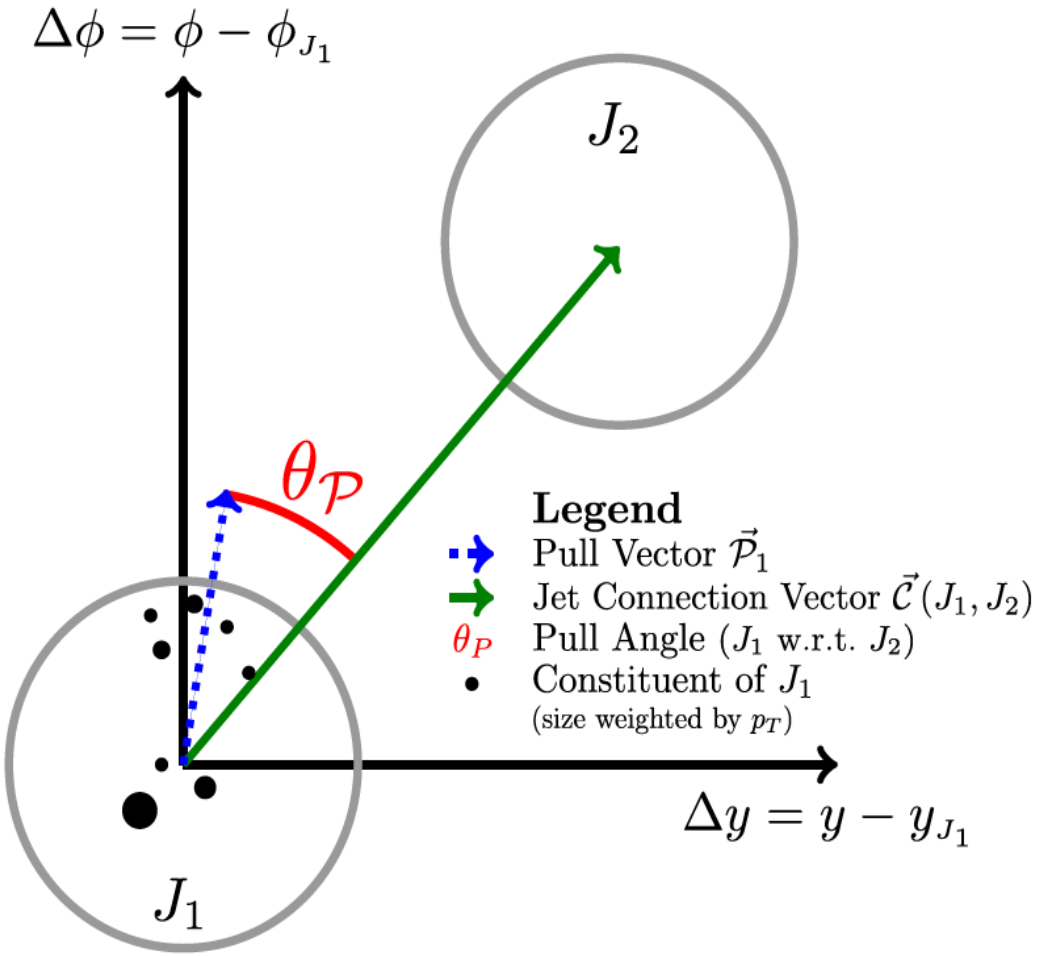

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Colour Flow in Top

- Top events as laboratory to test colour-flow tool
- Jets carry color, and are thus color connected to each other
  - Pairing of connection depends on nature of decaying particles

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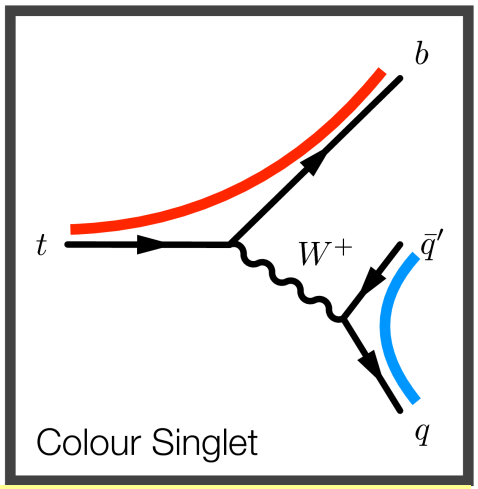
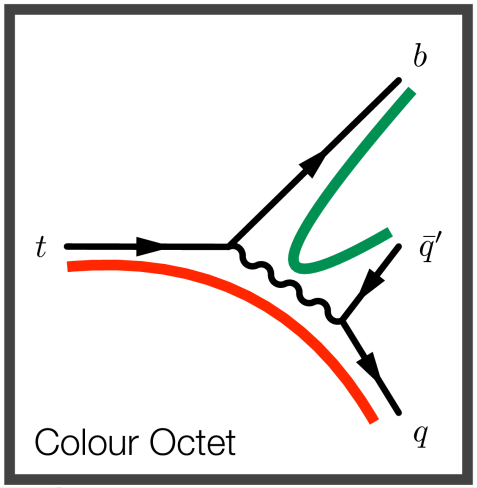
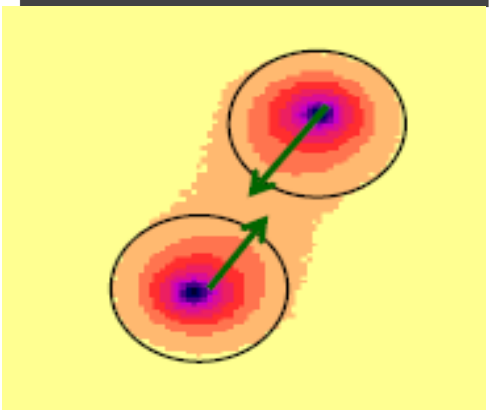
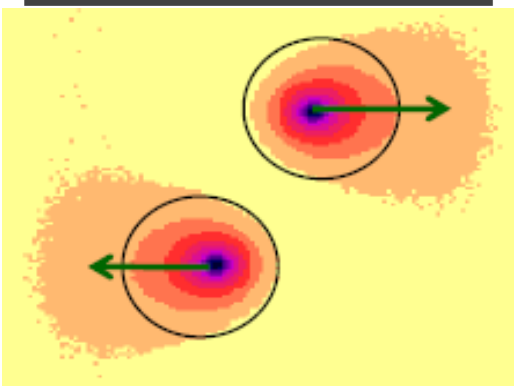






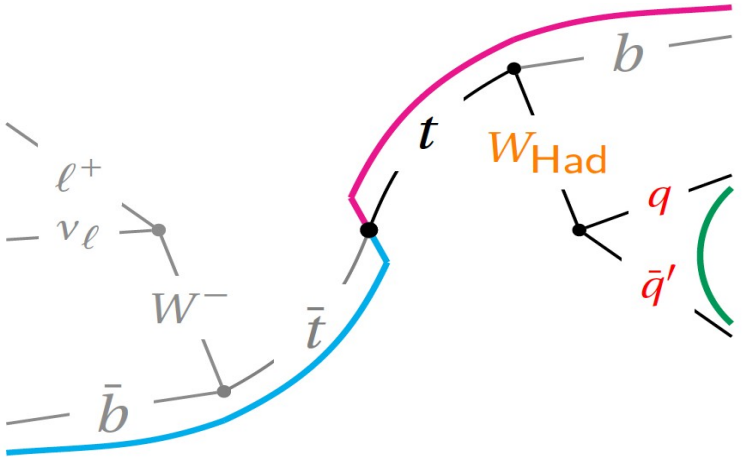


Jet pull: vectorial sum of components within each jet → jet pull angle: angle wrt. connection line of pair of jets

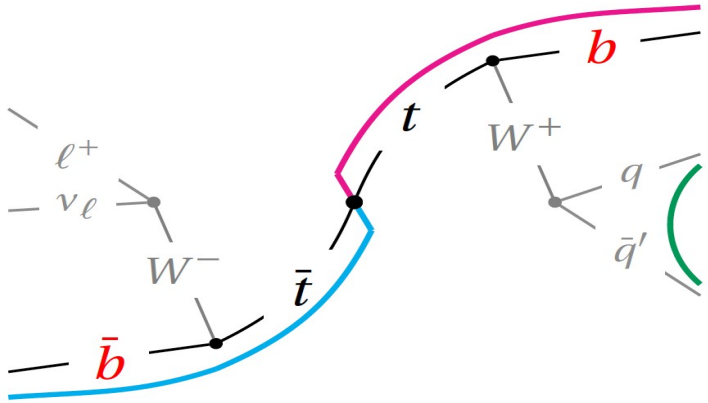
Colour Flow in Top

- Latest ATLAS analysis:
  Consider 4 variables in semileptonic $t\bar{t}$ events (>1 b-tagged jet)

- Two non-b-tagged jets:
  - Relative jet pull angles
  - Jet pull magnitude



- Two b-tagged jets
  - Relative jet pull angle

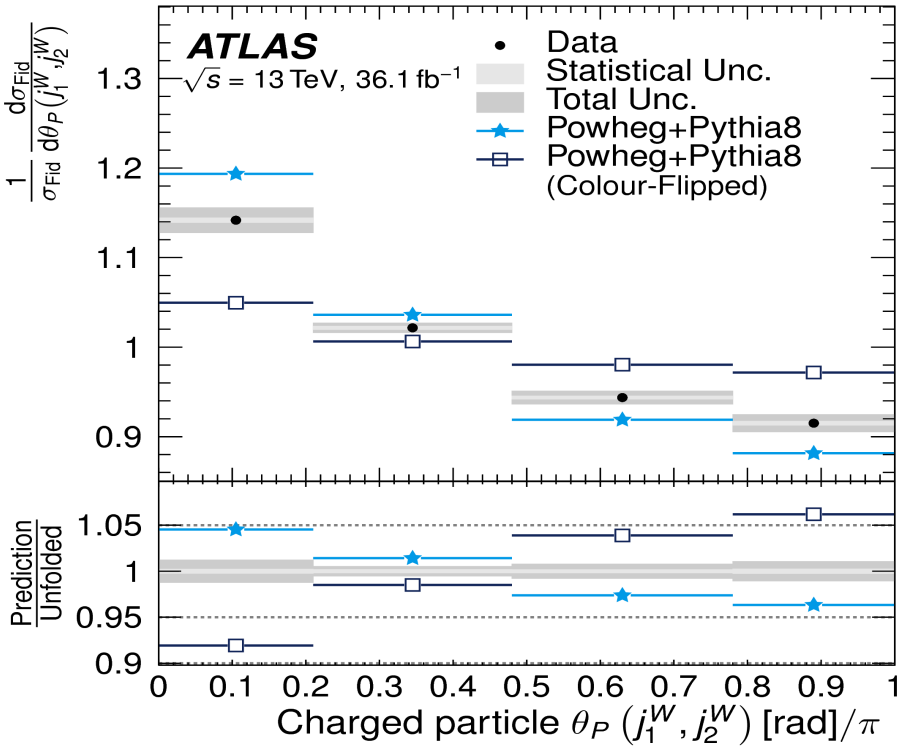


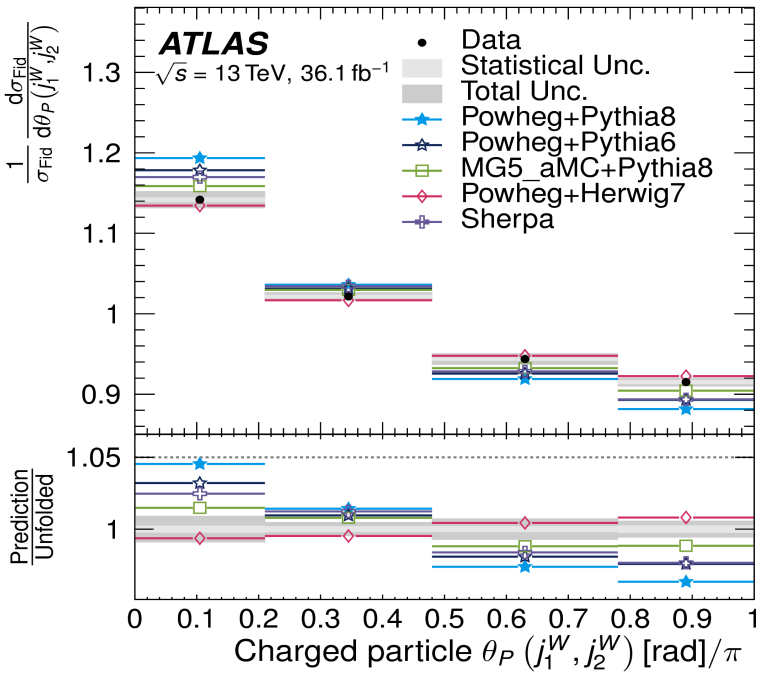
- Results corrected back to particle level

arXiv:1805.02935

Results for W daughters

- Correction to stable particle-level (iterative Bayesian unfolding)





- Colour-flipped model disfavoured by the data
- MC modeling has room for improvement

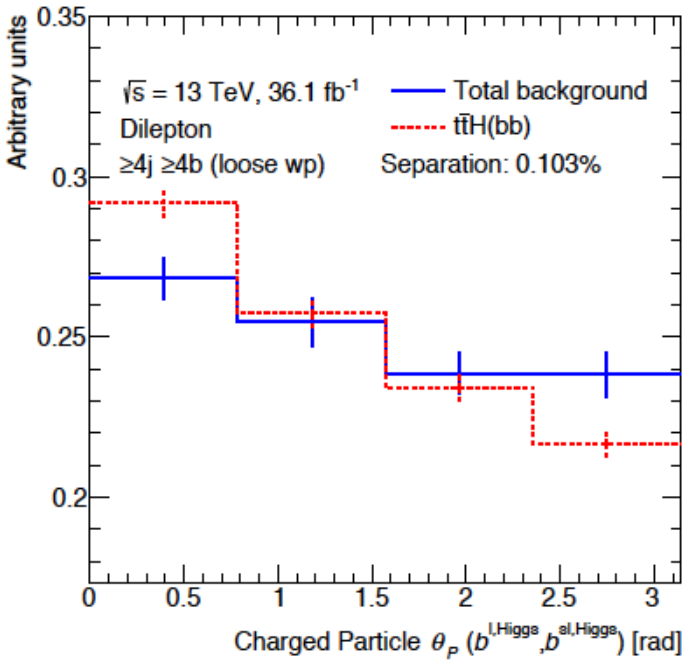
arXiv:1805.02935

Discussion

- What is required to improve modeling?
- Do we need all variables well modeled (or just from “singlet”)?
- …?

Colour Flow and ttH?

- Jet pull: very subtle "tool"
  - Usage in $t\bar{t}H$ requires more studies
    - Some studies by J. Raine: use signal region with >3 b-jets
      - Compare jet pull of b-jets from Higgs for signal versus all backgrounds
- Shape looks as expected
  - First step (imo): do full jet pull measurement in signal-enriched region

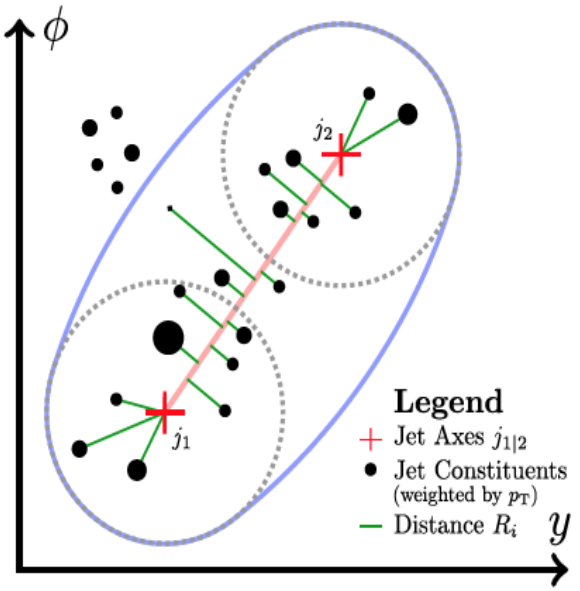


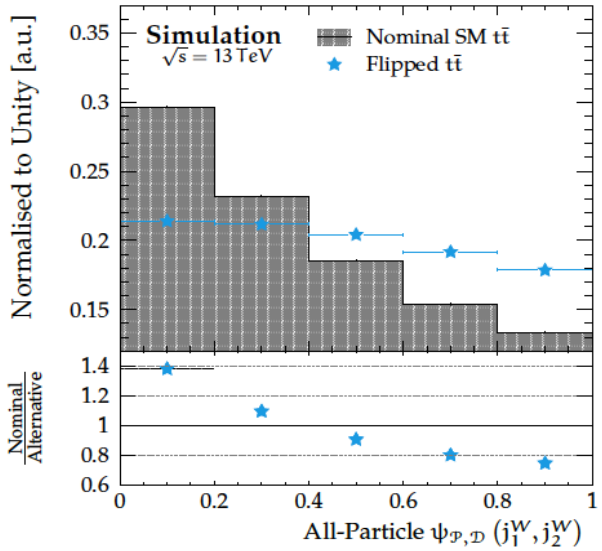
Discussion

- Any direct application for s/b improvement?
  - What about allhadronic? Potential for reduction of multijet background?
- Use for NP searches?
- …?

Colour flow and fat jets?

- Idea: extra handle to get information of 2 sub-jets from W boson for top-tagging?
- Jet pull: not ideal on its own
  → overlapping sub-jets
  → small cones
- Idea: combine with dipolarity
- Studies by F. Wilk
  - Boosted top-tagged large R jet





(a) Jet pull-dipolarity angle $\psi_{\mathcal{P},\mathcal{D}}(j_1^W, j_2^W)$

Looks promising
→ more studies needed

Discussion

- How much can we gain for boosted top-tagging?
  - → further optimized variables?
  - → combination with DeepLearning?
- Other applications for jets/performance/reconstruction?
- ….?

Summary

- Top events: use as laboratory to test colour-flow tools
- Idea: extract extra information beyond kinematics
  - $t\bar{t}H$ versus $t\bar{t}b\bar{b}$
  - Use for boosted techniques
- Analyses/Studies look promising
  - More studies needed

BACKUP

Colour Flow: Systematics

$\Delta\theta_P\left(j_1^W, j_2^W\right)$ [%]	$\theta_P\left(j_1^W, j_2^W\right)$			
	0.0 – 0.21	0.21 – 0.48	0.48 – 0.78	0.78 – 1.0
Hadronisation	0.55	0.13	0.24	0.14
Generator	0.32	0.25	0.50	0.01
b-tagging	0.35	0.13	0.20	0.31
Background model	0.30	0.16	0.16	0.27
Colour reconnection	0.22	0.16	0.16	0.18
JER	0.11	0.12	0.23	0.02
Pile-up	0.19	0.16	0.00	0.01
Non-closure	0.14	0.07	0.07	0.18
JES	0.12	0.06	0.14	0.06
ISR / FSR	0.15	0.02	0.12	0.02
Tracks	0.05	0.04	0.03	0.06
Other	0.02	0.01	0.01	0.02
Syst.	0.88	0.44	0.71	0.51
Stat.	0.23	0.19	0.19	0.25
Total	0.91	0.48	0.73	0.57