Measurement of the $|V_{cb}|$ element of the CKM matrix in $t\bar{t}$ decays with the ATLAS detector

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Mo Ghani, Supervised by Paul Harrison
Mo.Ghani@warwick.ac.uk
University of Warwick
Department of Physics

[1] Ceccucci, A., Ligeti, Z., Sakai, Y., 2020. The CKM quark-mixing matrix.
[2] Harrison, P.F. and Vladimirov, V.E., 2019. A method to determine $|V_{cb}|$ at the weak scale in top decays at the LHC. Journal of High Energy Physics.
[3] De Cian, M. 2021. $|V_{cb}|$ and $|V_{ub}|$ measurements at LHCb and Belle (II)

1. Motivation

- $|V_{cb}|$ element of the CKM matrix has only been measured using either inclusive or exclusive B-meson decays.
  - Energy scale much below that of the weak scale.
  - Tension of 2.4σ [1].
- This analysis attempts to make the first measurement of $|V_{cb}|$ at the weak scale by studying the semileptonic decays of $t\bar{t}$ pairs.
  - Mediated by on-mass shell W-bosons at the weak energy scale [2].
  - Can extract a value of $|V_{cb}|$ not heavily impacted by theoretical calculation uncertainties.
  - An important test of the weak top decay model, and could be sensitive to deviations from it.

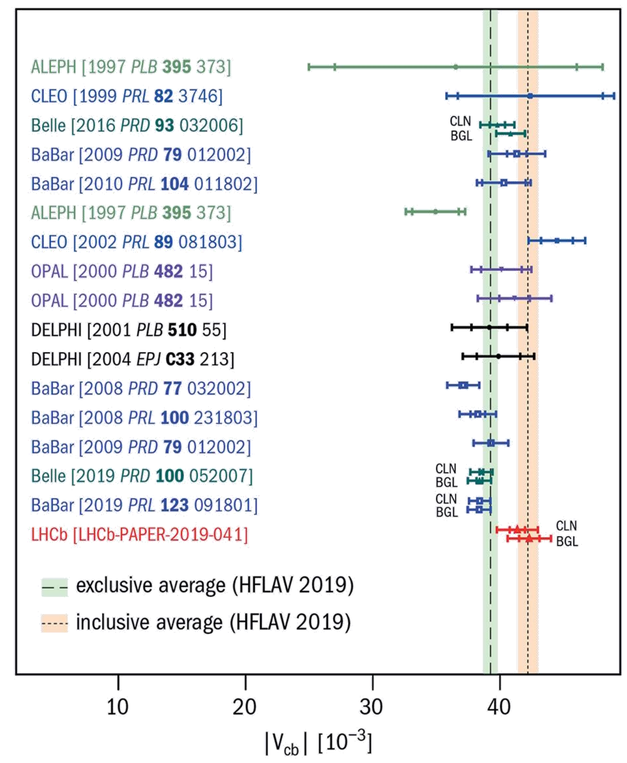
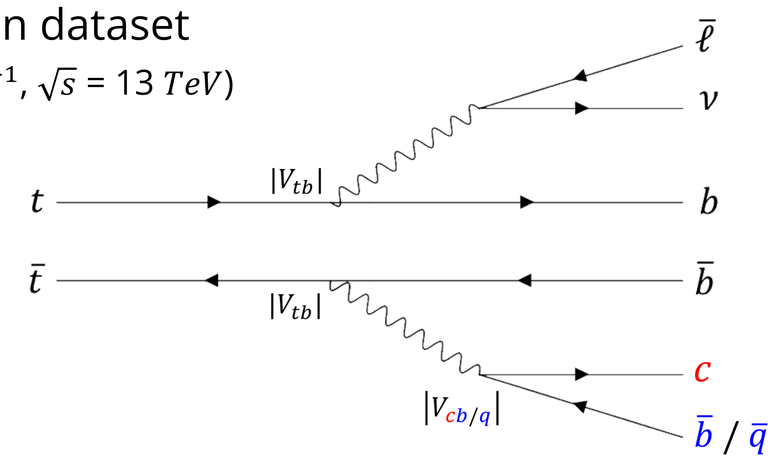


Image from [3]

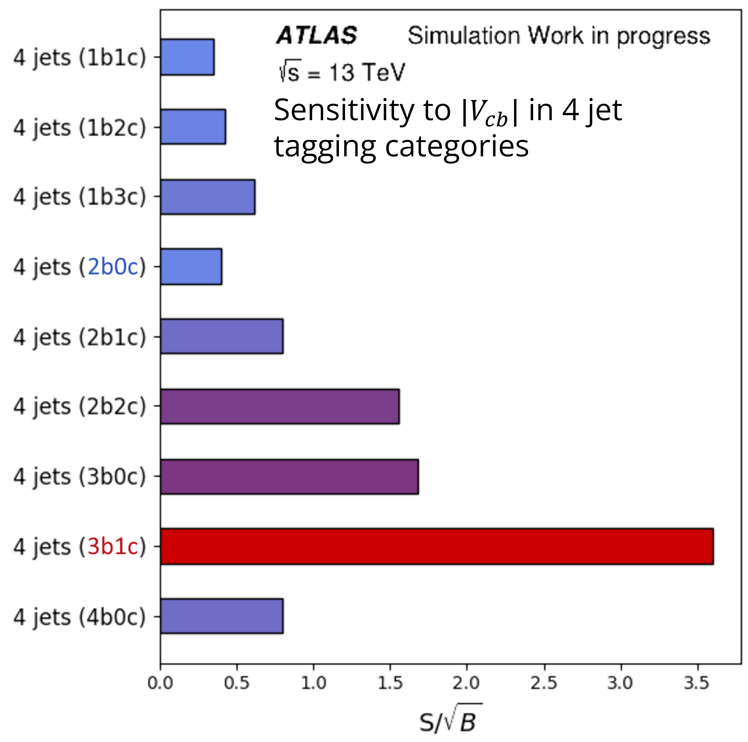
2. Method

- Search for $t\bar{t}$ decays in the full ATLAS Run 2 pp collision dataset
  (140 fb^{-1}, $\sqrt{s}$ = 13 TeV)



$$|V_{cb}|^2 = \frac{\mathrm{BF}(t\bar{t} \to \ell\nu\, b\bar{b}\, c\bar{b})}{\mathrm{BF}(t\bar{t} \to \ell\nu\, b\bar{b}\, c\bar{q})}$$

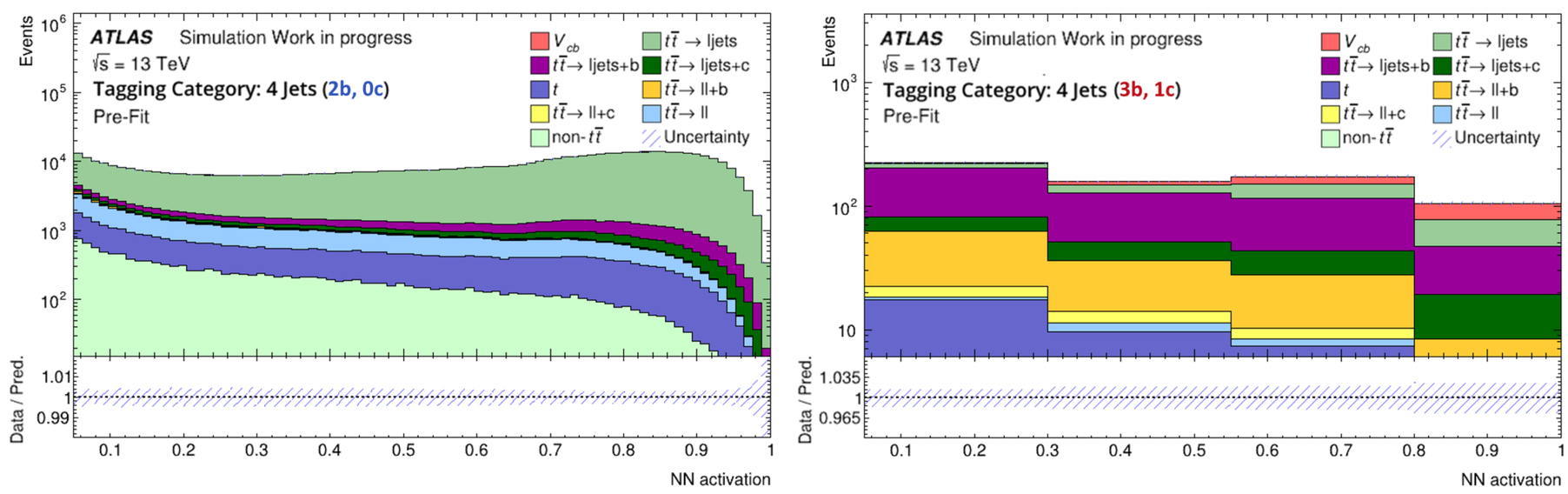
- Signal defined as semileptonic $t\bar{t}$ decays with $|V_{cb}|$ = 1, and background as non-$t\bar{t}$ and $t\bar{t}$ $|V_{cb}|$ = 0
- Categorise accepted events based on their number of jets, number of b-tags, and number of c-tags
- Use a neural network classifier to discriminate signal from background



3. Fit

- Neural network activation used as a fit variable in all tagging categories
- Use a binned profile likelihood fit to measure the normalisation of the $|V_{cb}|$ = 1 sample
- Measured normalisation directly extracts $|V_{cb}|^2$

Tagging category population examples



4. Sensitivity

Pre-fit $|V_{cb}|$ = 0.0418

Sample Normalisation	Stat.(%)	Syst.(%)	Tot.(%)
$t\bar{t} \to$ ljets ($\|V_{cb}\|^2 = 1$)	**28**	**16**	**32**
$t\bar{t} \to$ ljets	0.2	3	3
$t\bar{t} \to$ ll	2	5	6
$t\bar{t} \to$ ljets + b	2	4	5
$t\bar{t} \to$ ljets + c	7	8	10

$$\frac{\delta|V_{cb}|}{|V_{cb}|} = 14\ (\mathrm{Stat.}) \oplus 8\ (\mathrm{Syst.})\ \%$$

5. Outlook

- Aim to begin committee review before summer
- Strong prospects for future measurements of $|V_{cb}|$ at ATLAS
  - Improved flavour tagging
  - Run 3 and HL-LHC datasets
- Framework of this $|V_{cb}|$ analysis could lead to new flavour physics studies at ATLAS
  - CP-violation in $|V_{tb}|$
  - CKM matrix unitarity tests