

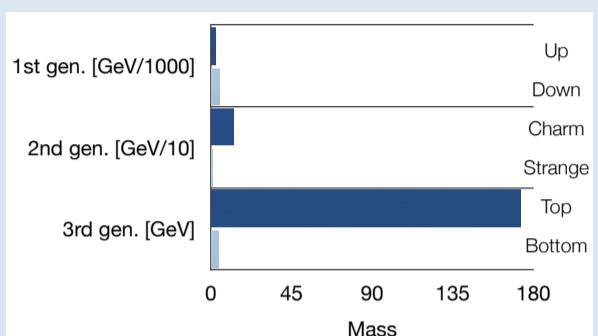
# Novel broad-mass search for new scalar particles in FCNC top quark decays using the full Run 2 data of the ATLAS detector

ATLAS-CONF-2022-027

## Introduction

### Physics motivation and objectives

#### Quarks mass



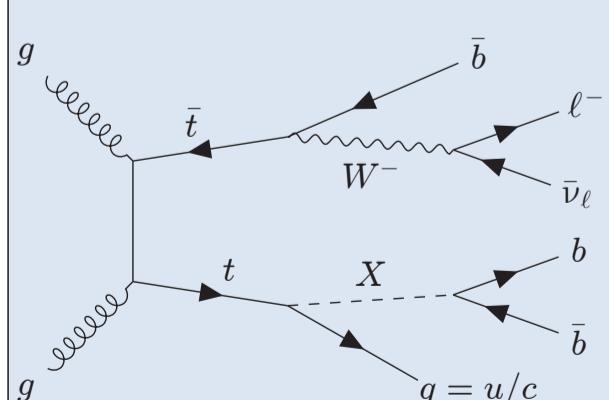
- Standard Model (SM) extensions such as “Flavon” models explain the flavour problem by introducing a new broken gauge group
- New goldstone boson (“X”) leading to enhanced FCNC compared to the SM
- Large couplings to the top quark

### Target signal benchmark

- Look for FCNC couplings of the top quark and up or charm
- $m_X$  in [20, 160] GeV
- **New search at LHC**

### Experimental signature

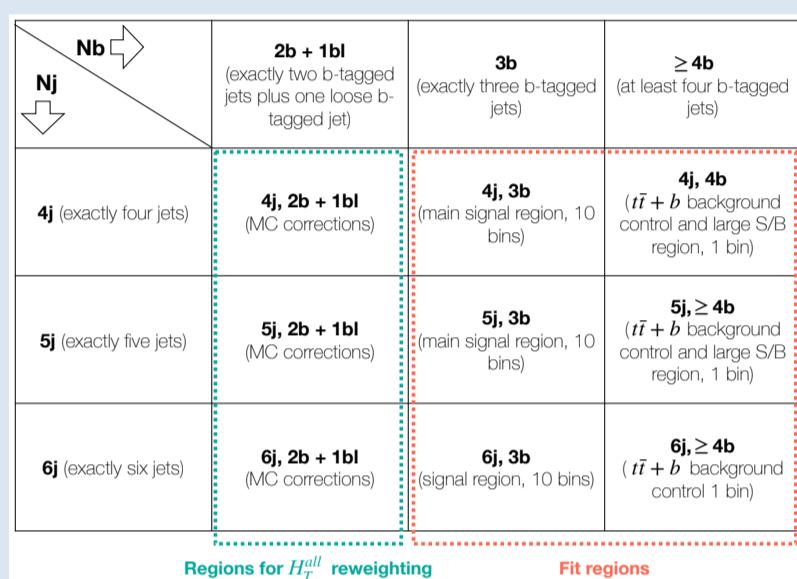
- One lepton, at least four jets, at least two or three b-tagged jets
- Largest background originates from  $t\bar{t}$  production



## Analysis Strategy

### Events Categorisation

- Events categorised based on jets and b-jet multiplicity
- Low b-jet multiplicity ( $< 3$ ) → modelling of the  $t\bar{t}$  background
- High b-jet multiplicity ( $\geq 3$ ) → search for a signal



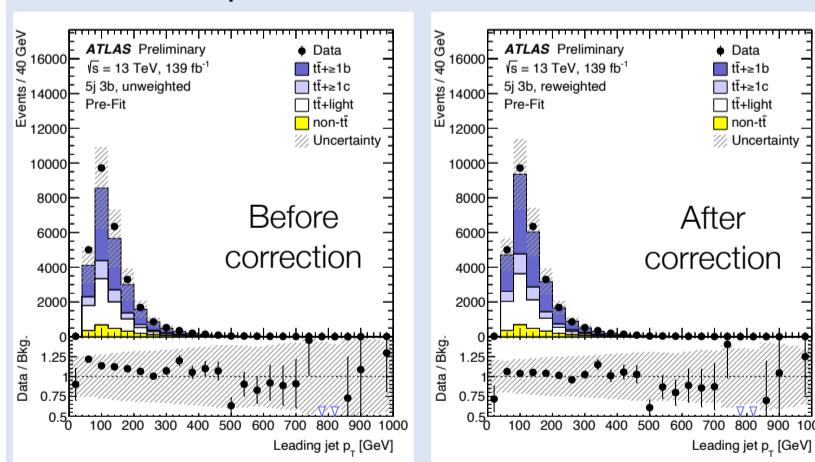
### $t\bar{t}$ background modelling

- In each jet multiplicity parametrise with a rational function the quantity

$$R(H_T^{\text{all}}) = \frac{N_{\text{Data}}(H_T^{\text{all}}) - N_{\text{MC}}^{\text{non-}t\bar{t}}(H_T^{\text{all}})}{N_{\text{MC}}^{t\bar{t}}(H_T^{\text{all}})}$$

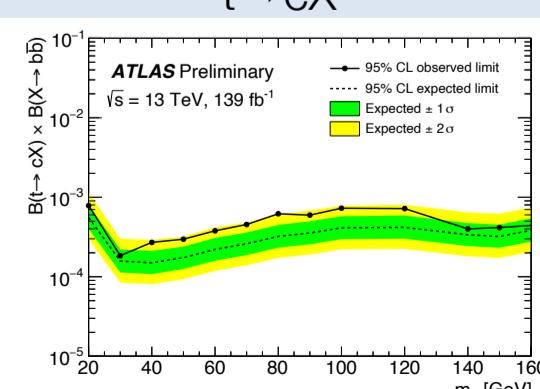
$H_T^{\text{all}}$ : scalar sum of traverse energy of all objects  
 - Correction as large as about 20%  
 - Improves significantly agreement of Monte Carlo (MC) predictions with data

### Impact of the correction



## Results

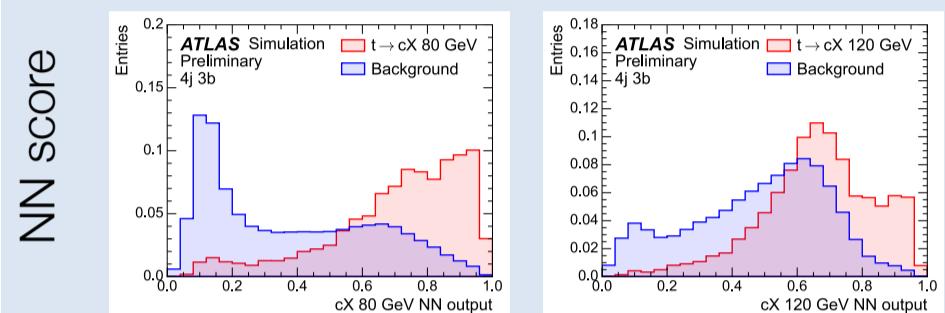
### $t \rightarrow cX$



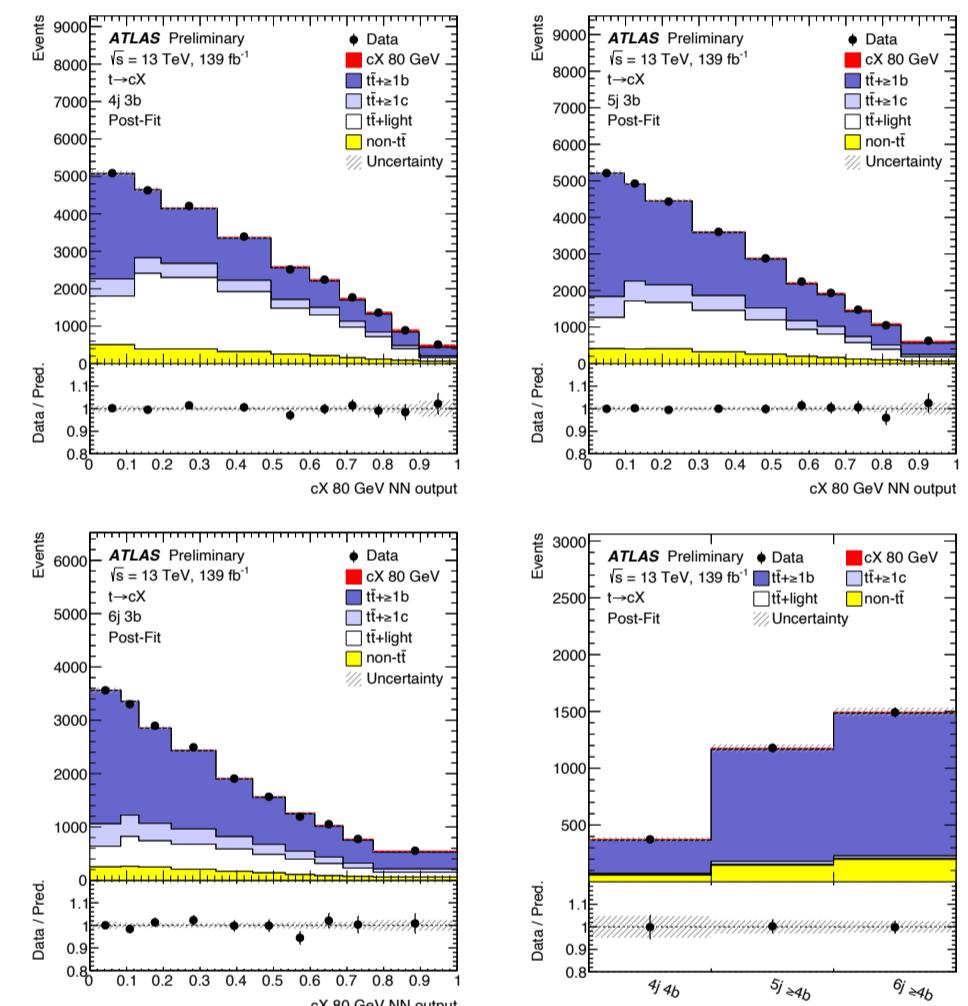
## Statistical analysis

### Neural network model

- Feed forward neural network parametrised as a function of X mass
- Input variables are basic kinematic distributions of all objects and invariant mass permutations



### Post-fit, fit regions

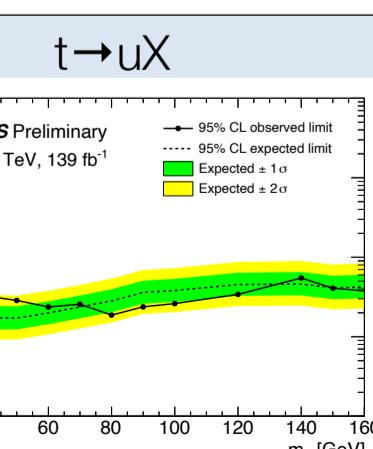


### Background yields and uncertainties

- Leading systematic uncertainties are related to modelling of the  $t\bar{t}$  background

Uncertainty source	$\Delta\mu(cX_{30})$	$\Delta\mu(cX_{80})$	$\Delta\mu(cX_{120})$
$t\bar{t}+1b$ modelling	0.034	0.074	0.079
$t\bar{t}+1c$ modelling	0.010	0.012	0.040
$t\bar{t}+light$ modelling	0.003	0.049	0.038
$t\bar{t}+1b$ normalisation	0.026	0.038	0.001
$t\bar{t}+1c$ normalisation	0.019	0.048	0.013
$W \rightarrow cb$ modelling	0.001	0.020	0.015
Reweighting	0.005	0.013	0.019
Other backgrounds	0.009	0.057	0.047
Luminosity, JVT, pile-up	0.005	0.005	0.003
Lepton trigger, identification, isolation	0.001	0.004	0.003
Jet energy scale and resolution	0.017	0.049	0.051
b-tagging efficiency for b-jets	0.003	0.016	0.023
b-tagging efficiency for c-jets	0.010	0.038	0.091
b-tagging efficiency for light jets	0.009	0.065	0.125
$E_{miss}$	0.001	0.003	0.008
Total systematic uncertainty	0.056	0.150	0.208
Signal statistical uncertainty	0.017	0.012	0.008
Total statistical uncertainty	0.064	0.067	0.058
Total uncertainty	0.079	0.162	0.217

	$t \rightarrow uX, m_X = 80 \text{ GeV}$
$t\bar{t}+1b$	10500 ± 1000    5.3 ± 2.9
$t\bar{t}+1b$	3200 ± 1100    14.4 ± 10.0
$t\bar{t}+1c$	390 ± 60    8.1 ± 2.2
$t\bar{t}+light$	1200 ± 400    24.4 ± 10.0
$W \rightarrow cb$	101 ± 13    6.3 ± 0.9
$t\bar{t}+1b$	130 ± 80    8.5 ± 5.0
$t\bar{t}+1c$	100 ± 40    6.3 ± 3.1
$t\bar{t}+light$	350 ± 200    6.0 ± 3.8
Signal	-170 ± 130    -0.34 ± 0.31
Total	26620 ± 250    374 ± 18
Data	26614    374    28394    1179    19302    1492



- Excluded  $t \rightarrow qX$  branching ratio between 0.02% and 0.08%
- Lowest  $p_0 = 0.016$  for  $m_X = 80 \text{ GeV}$  and decay mode  $t \rightarrow cX$