Search for boosted resonances and semi-visible jets in ATLAS

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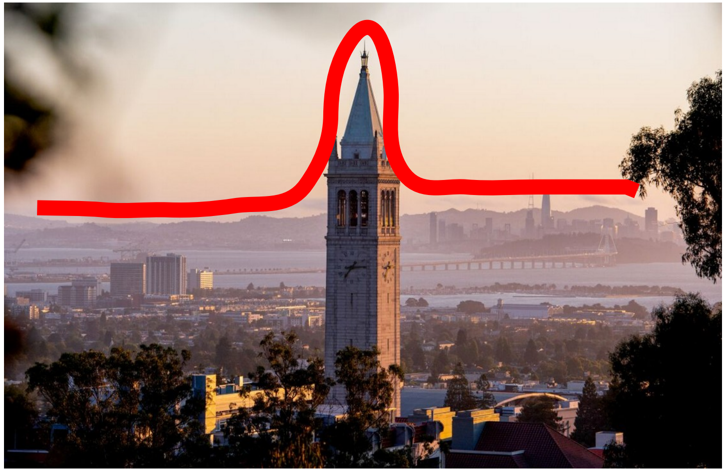
On Behalf of the ATLAS collaboration

BOOST 2023



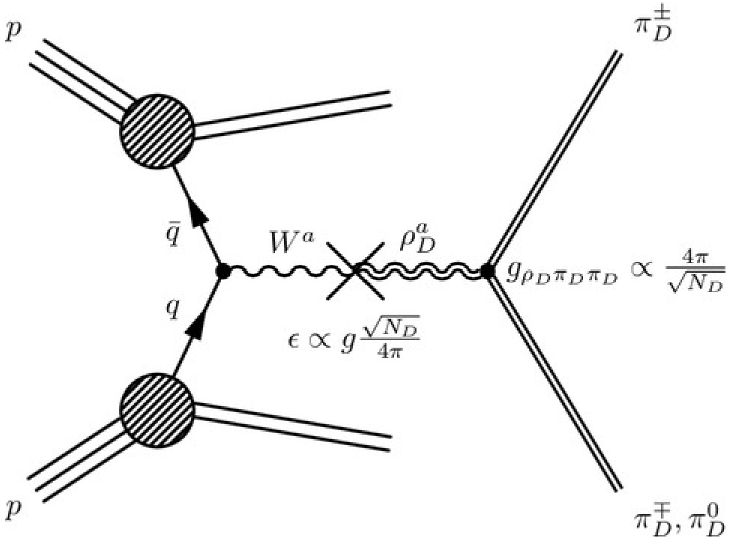
Introduction

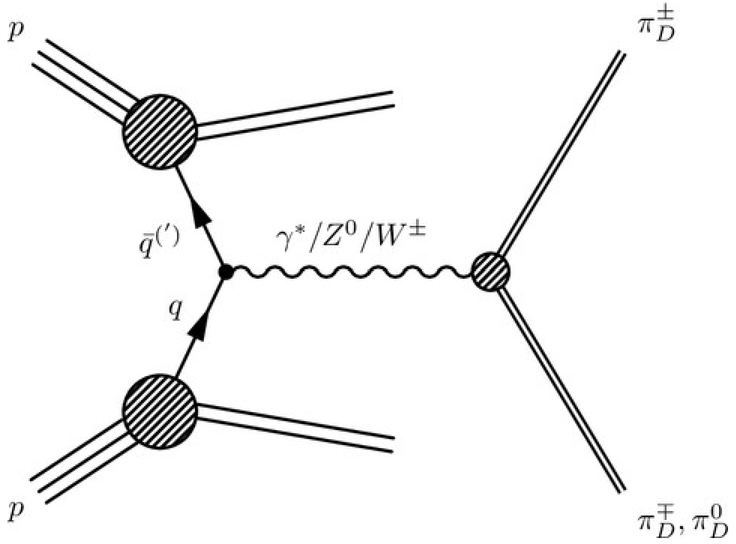
- Since “traditional” new physics searches keep yielding negative results:
  - New non-conventional signatures are being explored, in particular Hidden Sector
    - A set of new invisible particles and interactions only interacting with the SM through “portal” fields, coupling with both the SM and the HS
  - With limits pushed to higher and higher masses, boosted topologies are getting more and more important even for final states involving multiple heavy objects

Dark mesons decaying to top and b quarks

ATLAS-CONF-2023-21

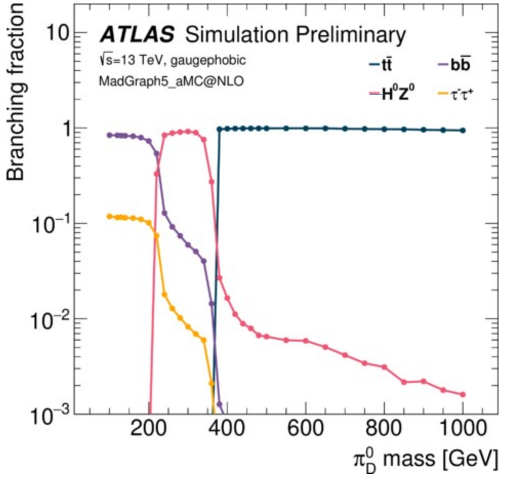
- Example of HS particles producing boosted heavy final states
- Mesons from strongly-coupled SU(2) dark flavoured symmetry
- Decay to multiple SM heavy quarks

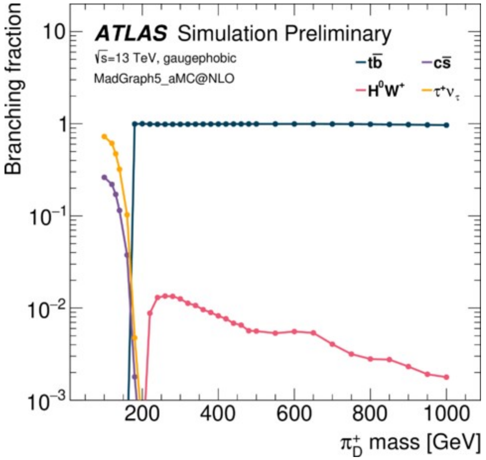


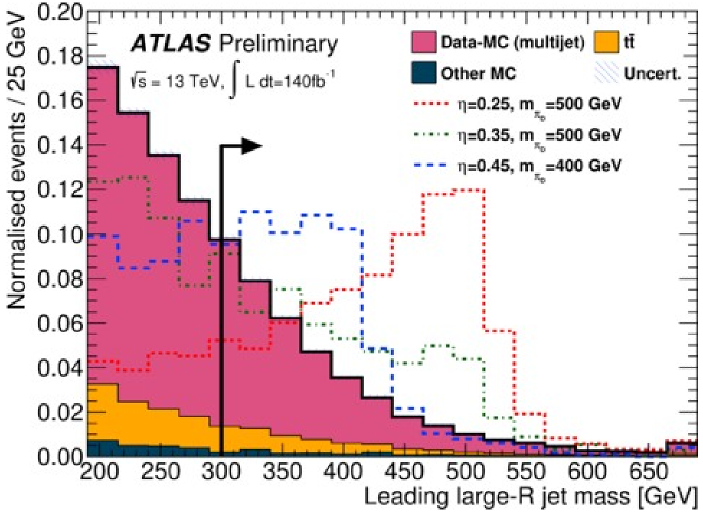


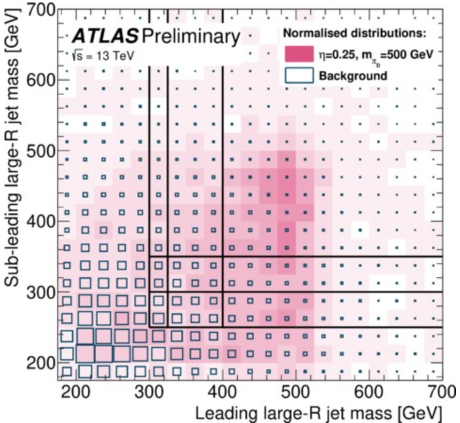
Final states

- Can have charged or neutral dark pions, that will decay to the heaviest available pair. For this analysis, tt or tb
- Due to boost, decay products reconstructed as single jet with mass endpoint to dark pion mass





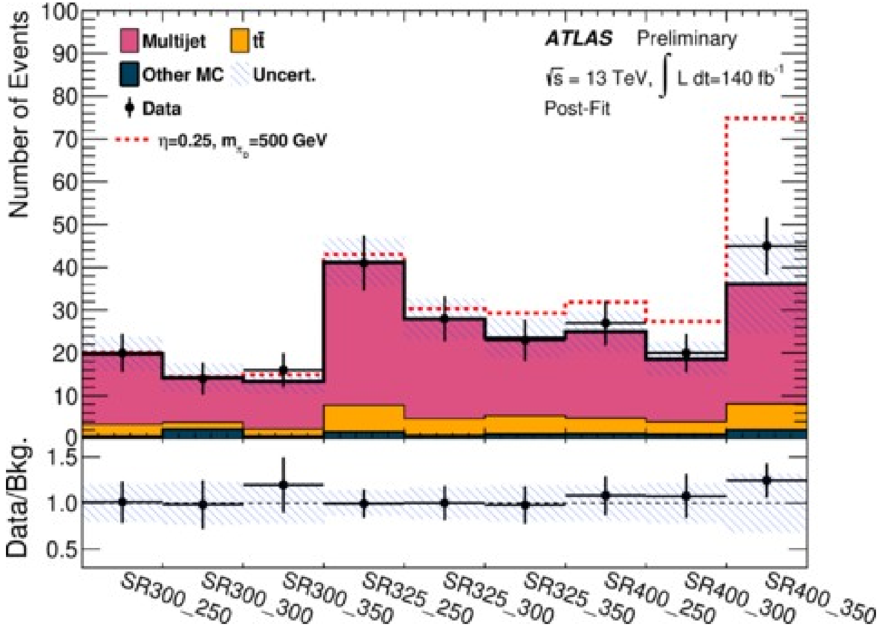




Lines indicate signal regions for various mass hypotheses

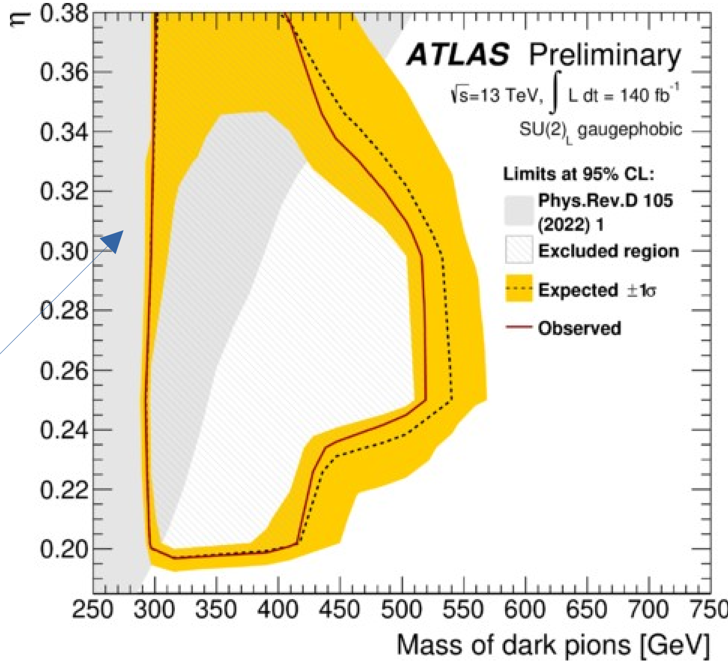
Signal and Control Regions

- Jets must have 2 b-tagged subjets with $m_{bb}/pT_{bb}>0.25$; 9 Signal Regions identified from masses of the two jets
- For each SR, Control Regions for ABCD BG estimation, for correlations or validation identified by inverting m_{bb}/pT_{bb} or b-tagging requirements
- BG estimated from MC, rescaled after a fit to CR for each CR. Limits in plane of dark pion and rho/pion mass



Grey area already excluded by re-interpretation of
- high mass DY
- jets
- leptons + MET

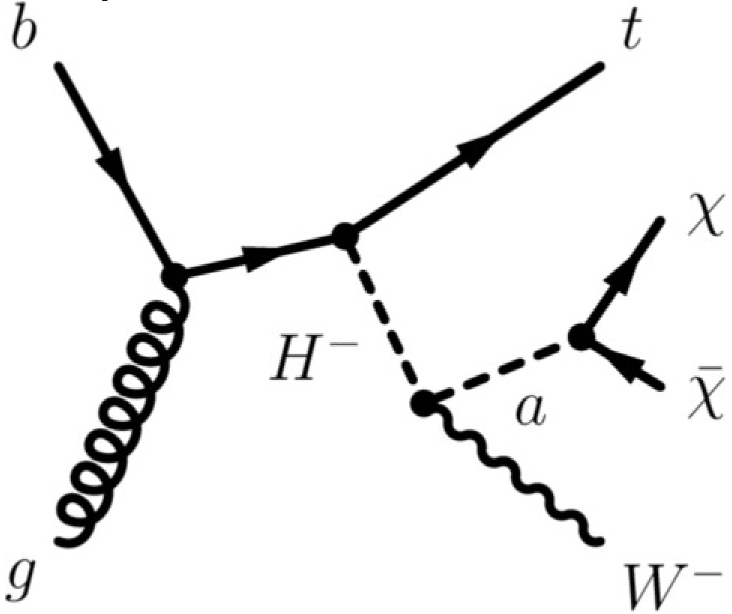
PRD 105 (2022) 015008.



Associated production of DM, top and W

Eur. Phys. J. C 83 (2023) 603

- Model-independent search, interpreted in the context of a 2HDM + a pseudoscalar mediator (a) coupling with fermionic DM candidates (simplest UV-complete and renormalisable framework)
- Several parameter assumptions to reduce dimensionality of phase space for interpretation



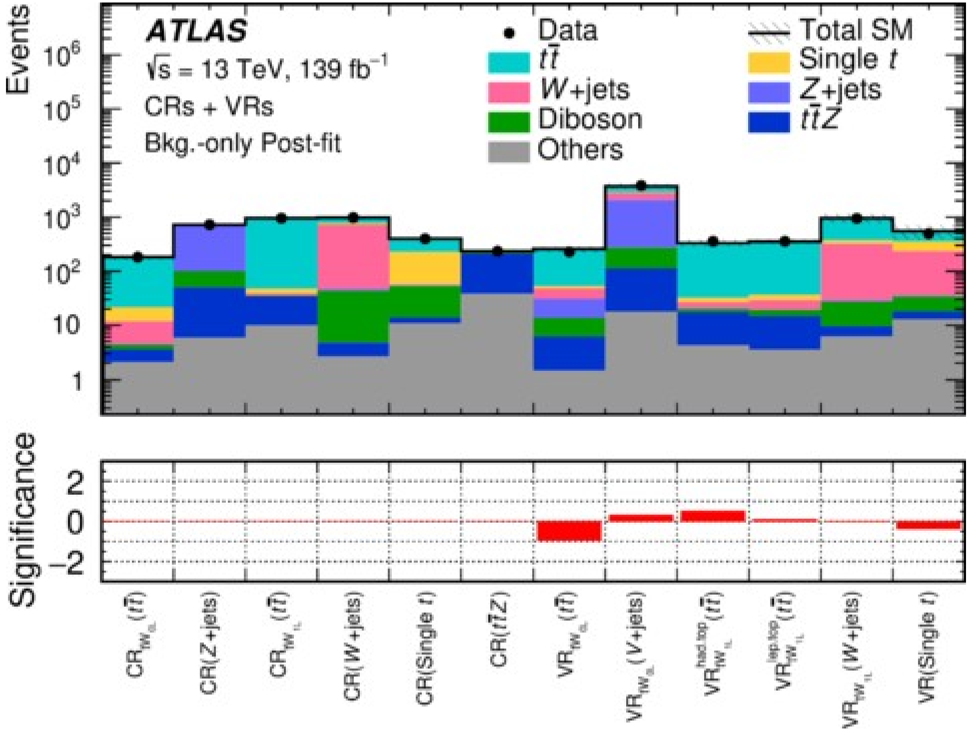
t→Wb so two Ws in final state; separate analysis of 0L and 1LW and 1Ltop cases.

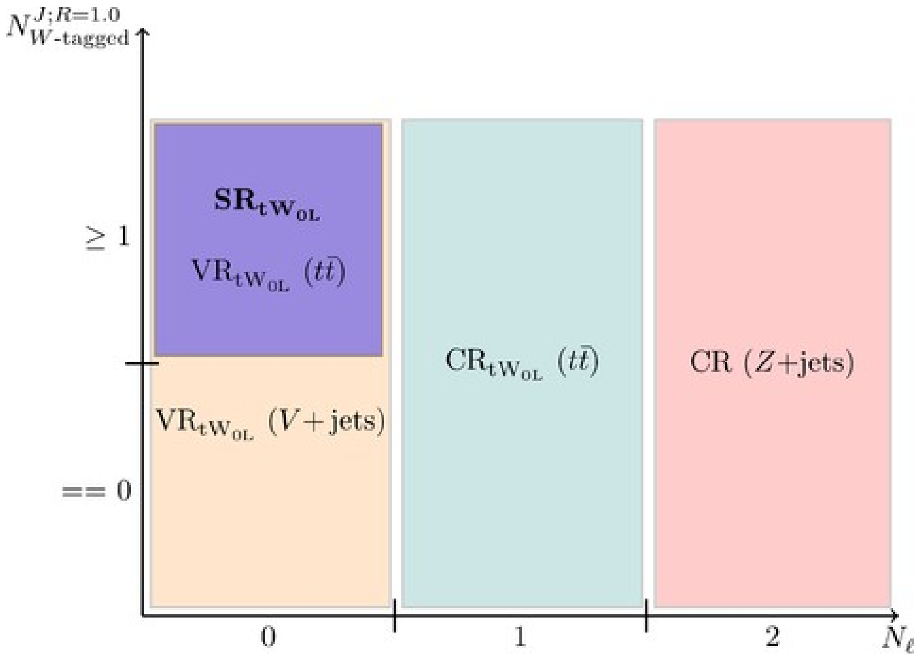
MET defines 5 signal regions from 250 to 450 GeV

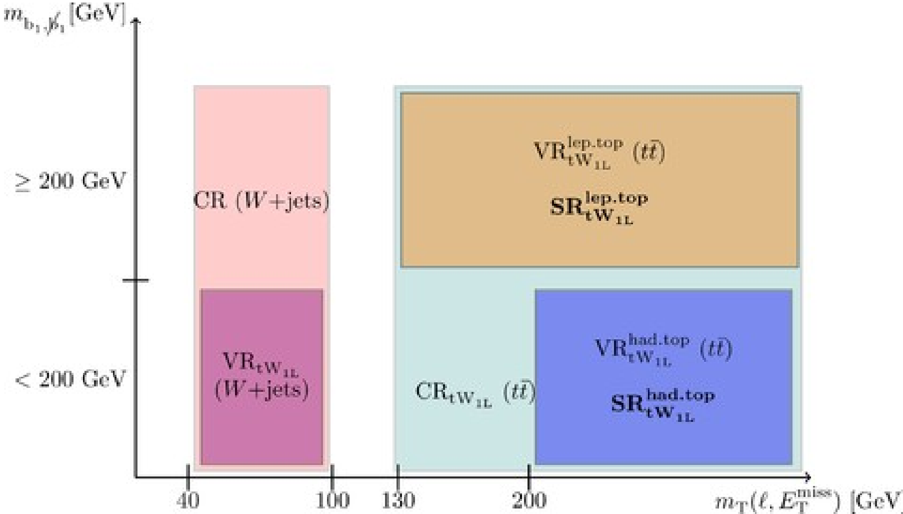
Hadronic Ws identified from trimmed R=1.0 jets, cutting on D_2

Background control

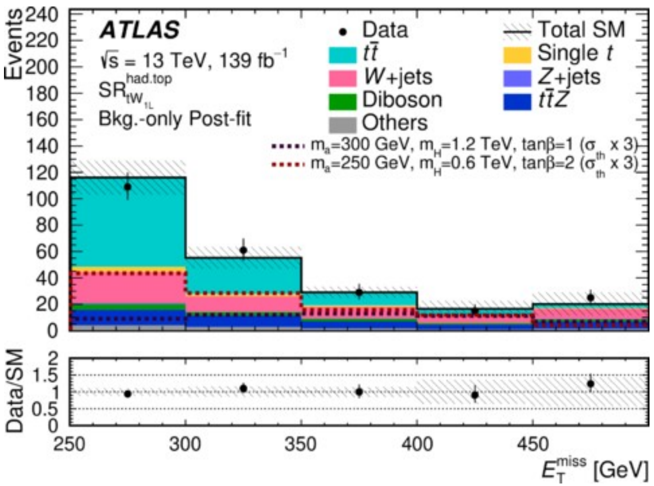
- A series of orthogonal cuts define 2 signal, 6 control and 6 validation regions
- Normalisation of BG samples obtained from fit to data.

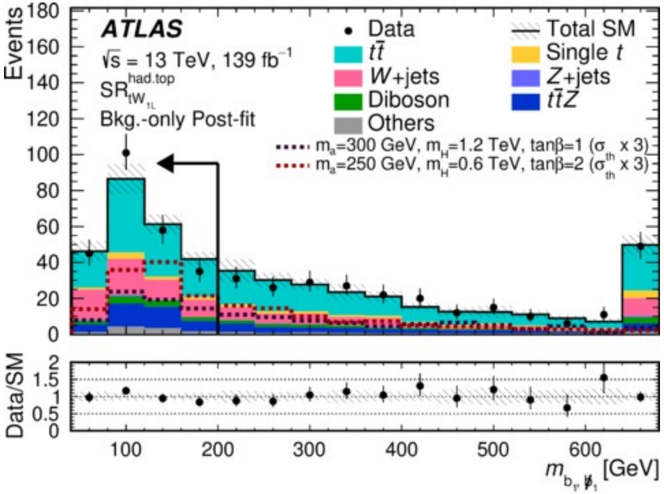


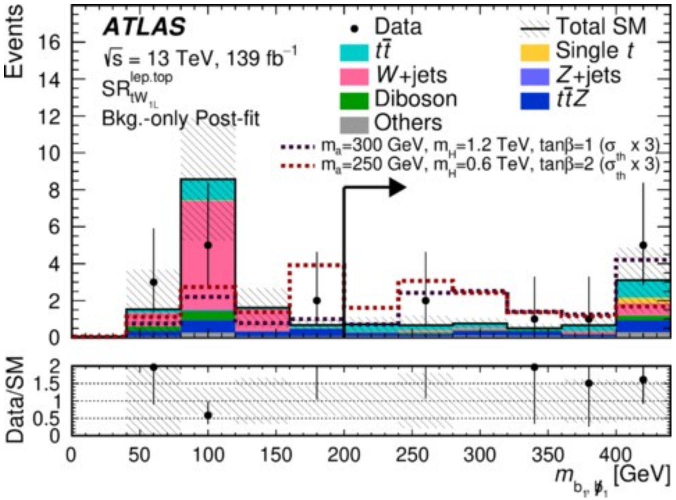




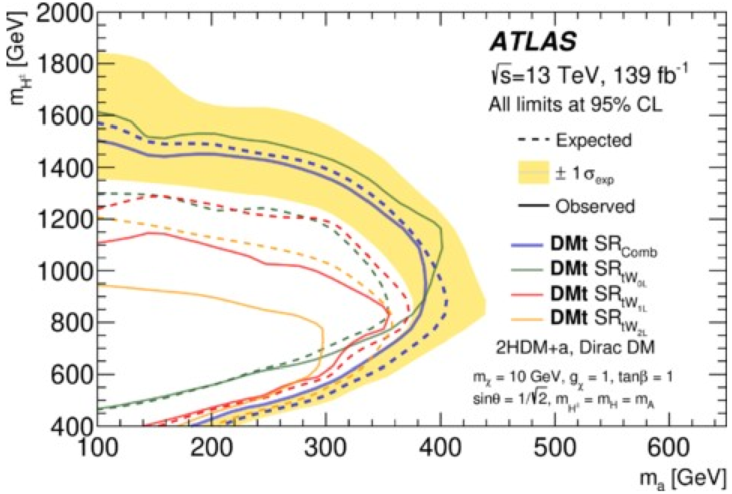
Representative distributions in SR and results







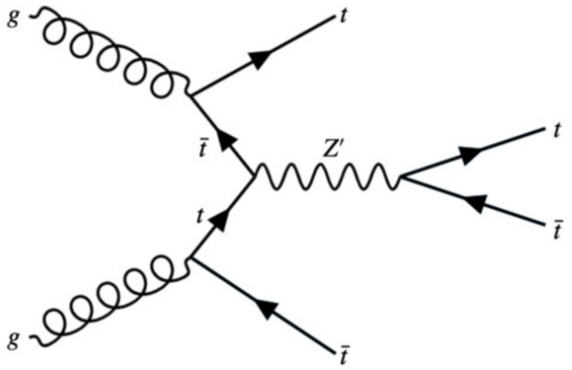
No significant excess found, limits set in the ($m_{H^\pm}$-m_a) and ($m_{H^\pm}$-tan β) planes, the latter assuming m_a = 150 and 250 GeV

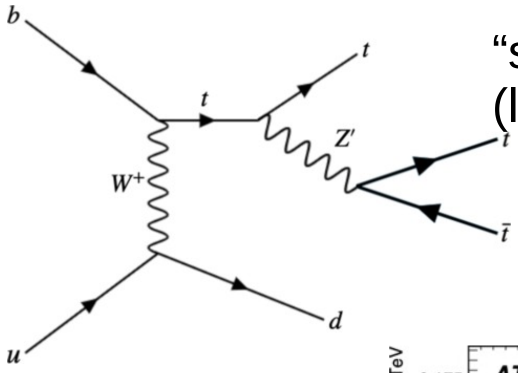


Top-philic heavy resonances

2304.01678 [hep-ex]

The large Yukawa coupling between top and Higgs leads naturally to vector resonances coupling almost exclusively to top (e.g. composite Higgs models)

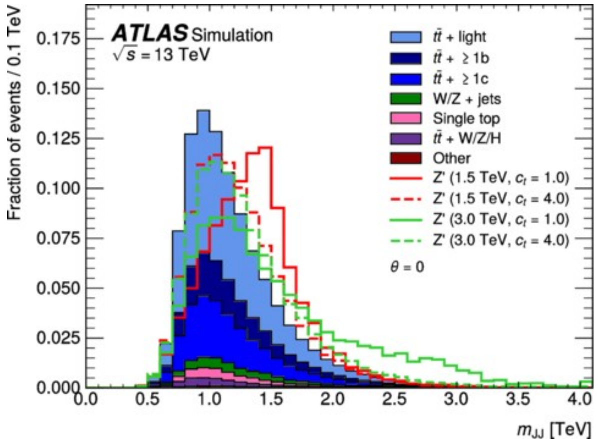




“spectator” top quarks
(leptonic decay)

“resonance” top quarks
(full hadronic decay)

Main BG is tt + jets, in semil-leptonic decay mode
Hadronic top decays reconstructed from trimmed R=1.0 jets with
pT > 300 GeV and M > 100 GeV

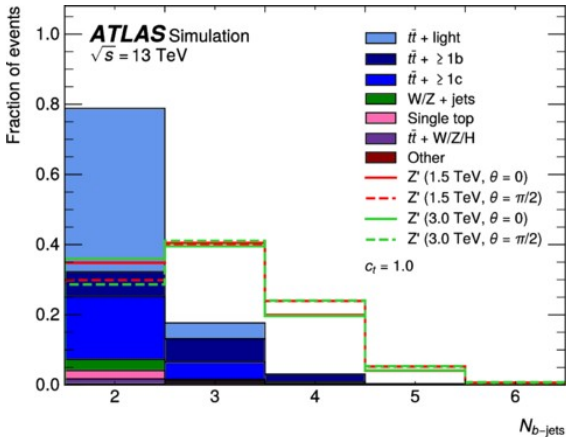


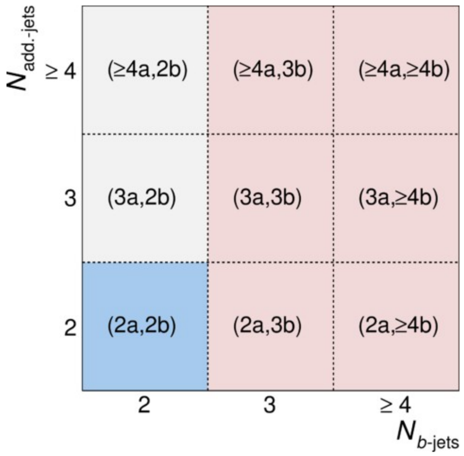
A signal would show up as events with high jet multiplicity and a peak or broad tail in the tt invariant mass

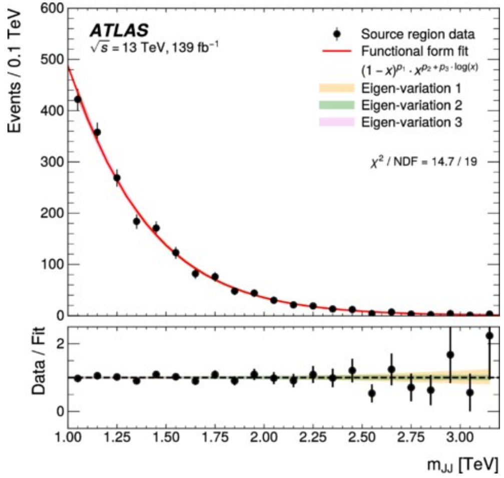
Background determination

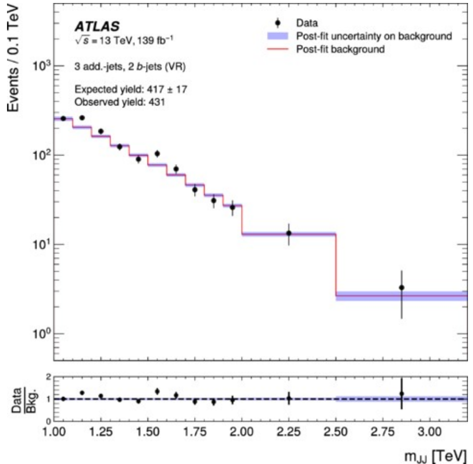
Background and expected signal have different jet multiplicity. Events are classified into background, validation and signal regions according to number of light and b jets.

BG is estimated by a fit of the M_{JJ} distribution in the source region.





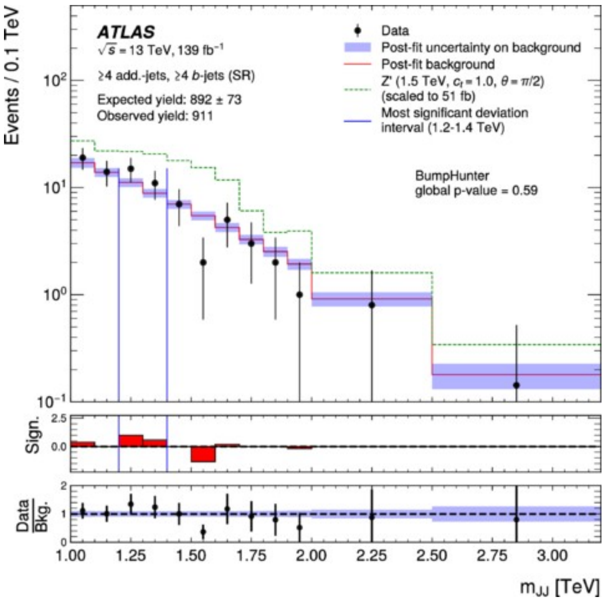


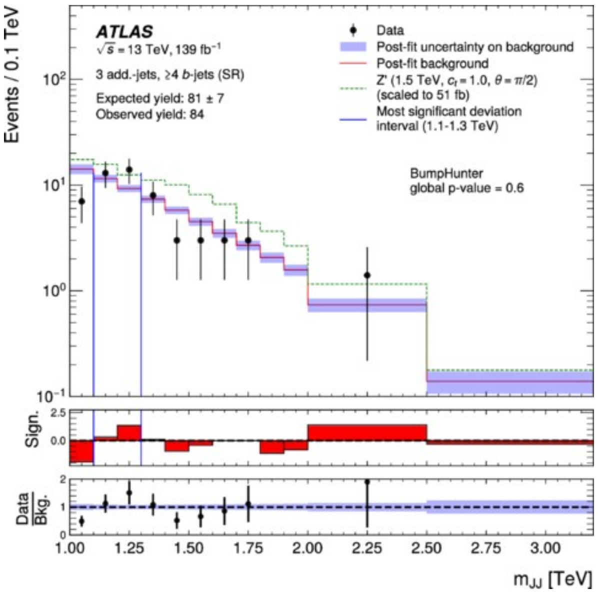


BG fit checked in invariant mass of the validation region under the background-only assumption

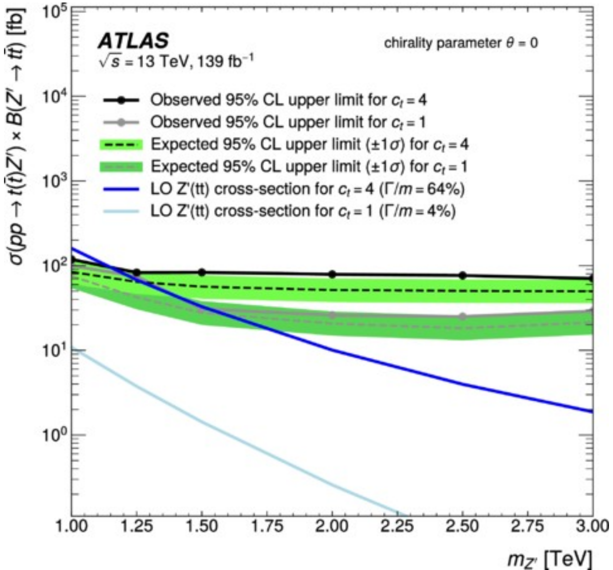
Results on signal region

Dijet invariant mass in various signal regions does not show significant excess.





Limits on top-philic resonance production almost mass-independent

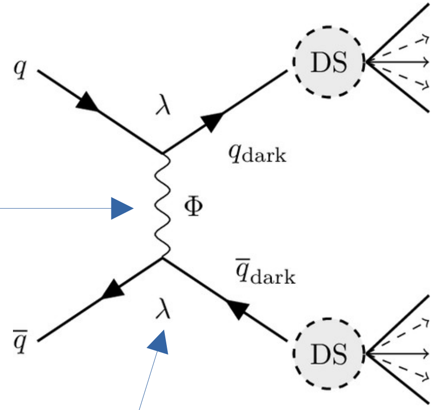


Semi-visible jets

arXiv:2305.18037 [hep-ex]

In a strongly interacting dark sector, dark quarks can initiate a parton shower mixing SM and dark partons

Mediator between SM and dark sector



Coupling between dark sector and SM

Dark shower:
Dark hadrons do not interact with detector → MET

Rint = fraction stable/all dark hadrons in jet

Due to incomplete shower, relative directions of jets and MET are correlated. Use pT balance between closest and furthest jet to MET

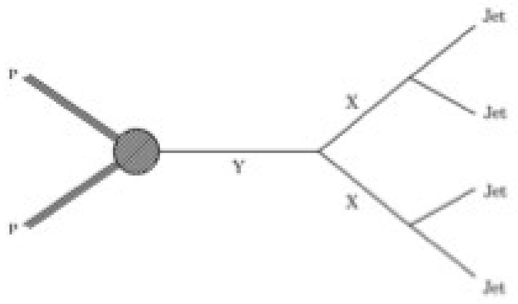
$$p_{\mathrm{T}}^{\mathrm{bal}} = \frac{|\vec{p}_{\mathrm{T}}(j_1) + \vec{p}_{\mathrm{T}}(j_2)|}{|\vec{p}_{\mathrm{T}}(j_1)| + |\vec{p}_{\mathrm{T}}(j_2)|},$$

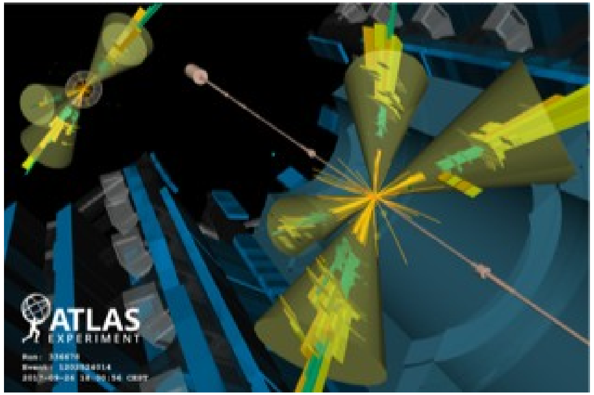
Paired jet resonance search

arxiv: 2307.14944

An unknown resonance Y could decay into two more (unknown!) resonances X producing 4 final-state jets.

Not really substructure, but certainly boosted!



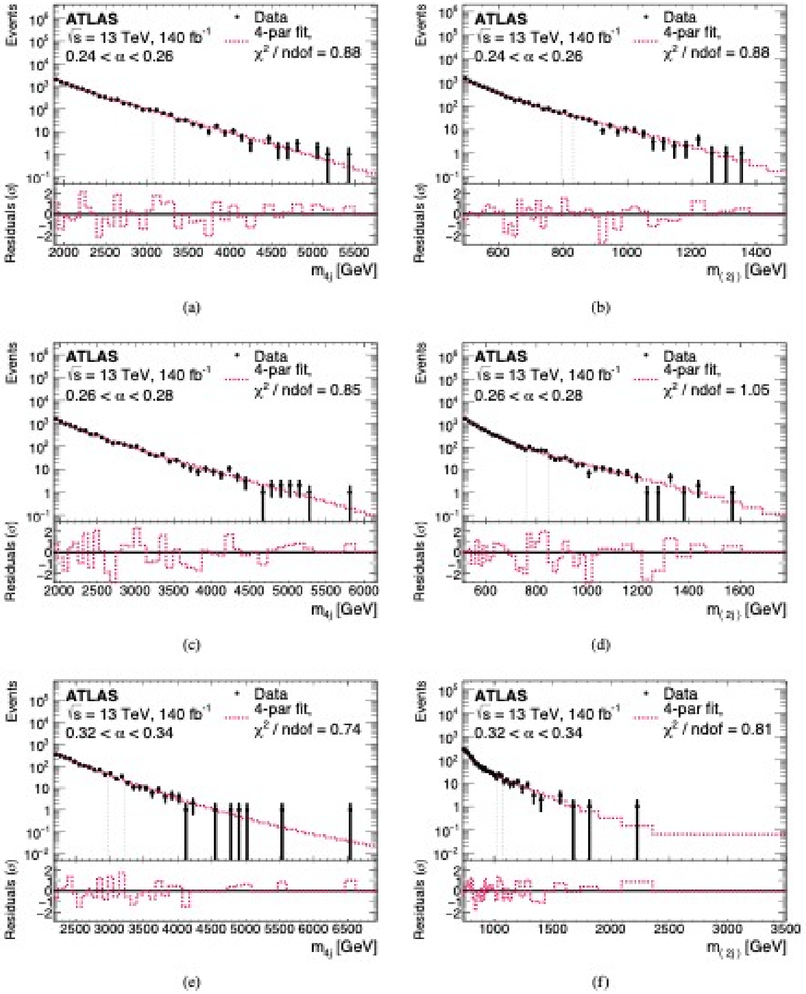


At least 4 jets with pT > 60 GeV and $\eta < 2.4$, paired by minimising
$\Delta R = |\Delta R_{AB} - 0.8| + |\Delta R_{CD} - 0.8|$
Also require
$\Delta R_{AB}, \Delta R_{CD} < 2.0$
$|\eta_{AB} - \eta_{CD}| < 1.1$

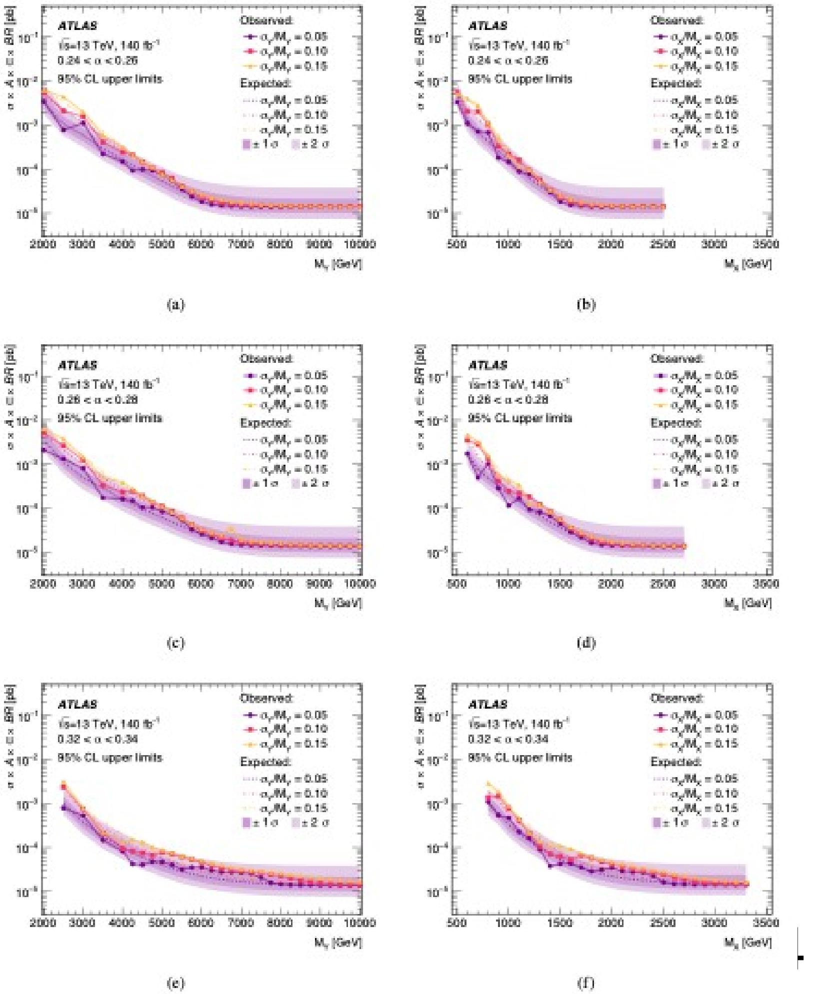
$$\frac{m_{AB} - m_{CD}}{m_{AB} + m_{CD}} < 0.1$$

Analysis performed in bins of $\alpha = \langle m_{2j}\rangle / m_{4j}$: the $\langle m_{2j}\rangle$ and m_{4j} distributions are fitted with a function $f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln(x) + p_5 \ln(x)^2}, x = m/\sqrt{s}$ plus a possible Gaussian (or Crystal Ball) signal

BG fits and results

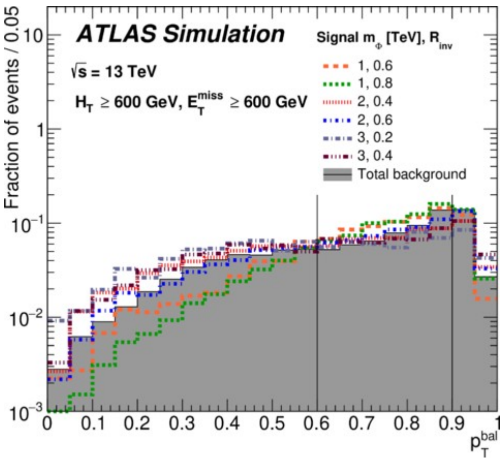


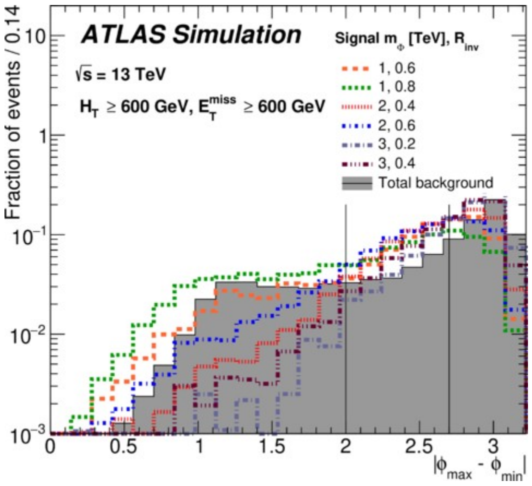
A BumpHunter analysis shows that data are compatible with BG-only fits for 4J and 2J masses.



Cross-section limits on model-independent and model-dependent production are derived

Signal and control regions





Events in 9 bins of pT balance and ΔΦ between closest and furthest jet to MET.

Dark showers only selected from kinematics, no specific substructure technique used

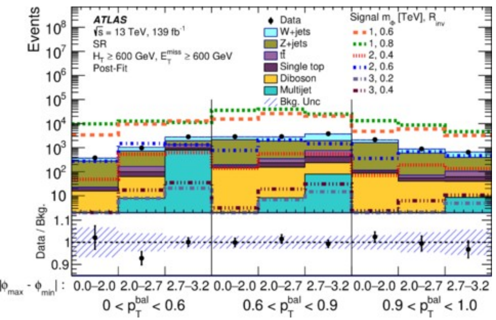
MET > 600 GeV H_T > 600 GeV

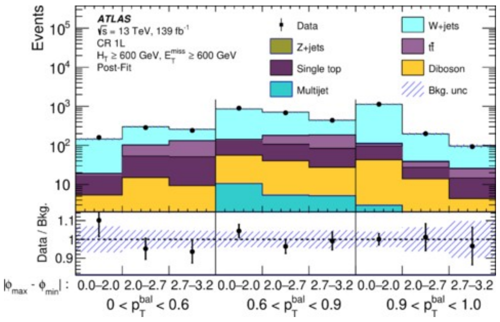
Signal Region

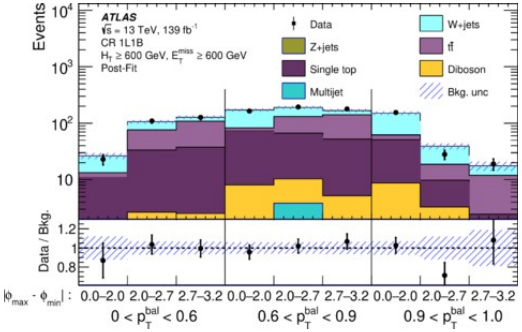
1L CR: 1 muon, no b-tag (Ws)

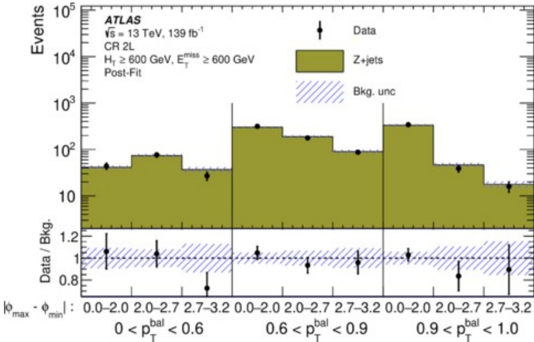
1L1B: 1 muon, 1 b-tag (tt)

2L: 2 OS muons with 66< $m_{\mu\mu}$ < 116 (Z)

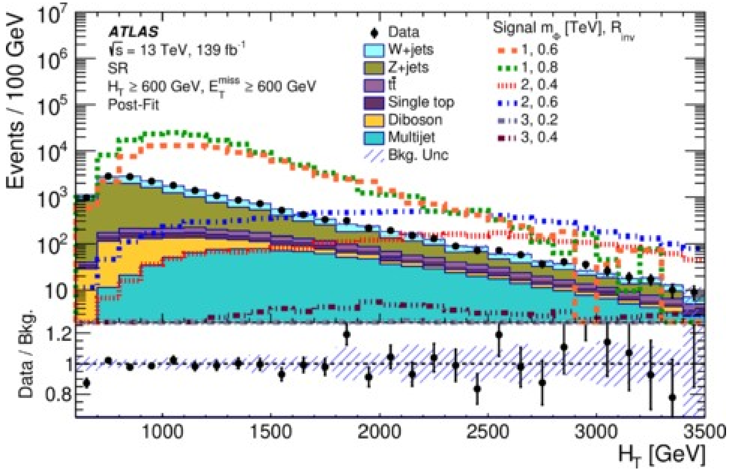


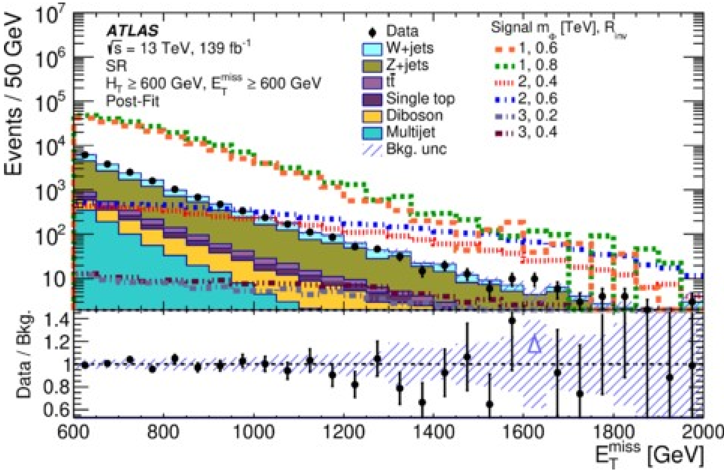




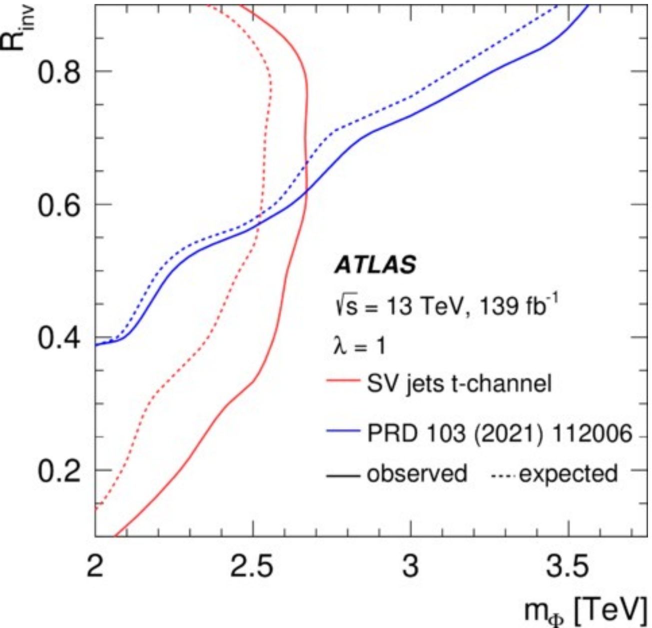


Results



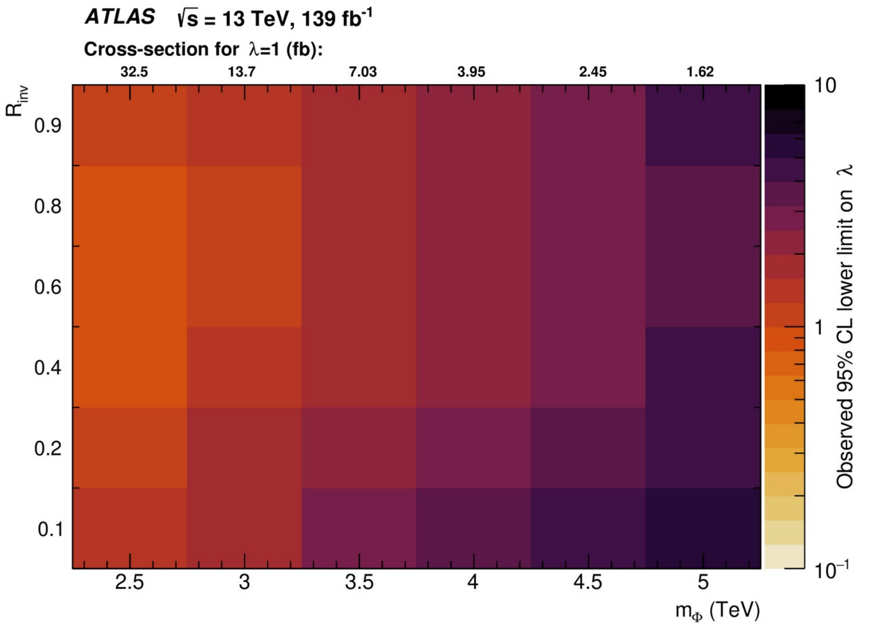


No excess in HT nor MET distribution after rescaling from fit of control regions



Exclusion assuming coupling between SM and DS λ=1

Values of λ excluded at 95% C.L.



Conclusions

- For all these analyses, the emphasis is not on fancy substructure or ML techniques, but rather on the use of non-standard jets and jet tagging to search for exotic physics
- Even if no positive search result, it shows that non-standard QCD objects have entered the mainstream of LHC analysis

- ps. the LHC jet WG is writing a summary paper on substructure, if interested to contribute (esp. from LHCb, ALICE, theory) please contact me mario.campanelli@cern.ch