ATLAS EXPERIMENT

Universidade do Minho
Escola de Ciências

LIP
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

[search for monotop events]

CFTC-UL, UA and LIP meeting - Experiment vs. theory
Braga, 31 jan 2020

Big Data HEP

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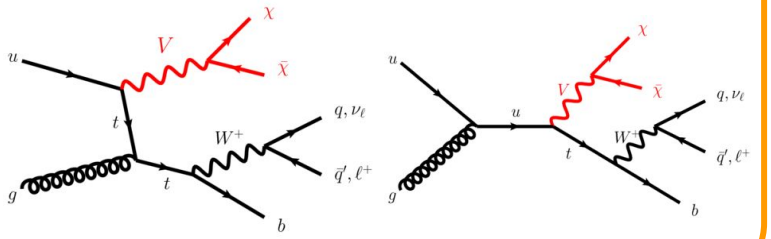
Monotop signals - one search to rule them all

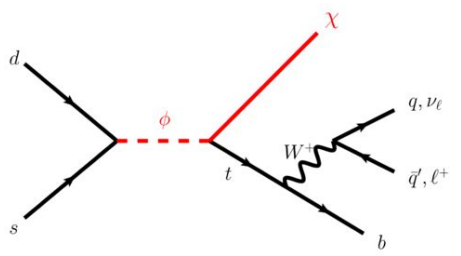
- **Single top + large MET topology** :
  - Same topology for dark matter and single vector-like top search
  - Both leptonic(**W → lν**) and hadronic(**W → qq'**) W decay covered

Non-resonant Monotop



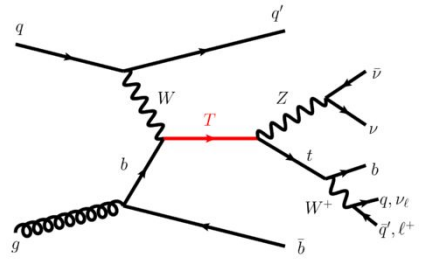
- ❑ Vector mediator **V** decays to invisible fermion pair as DM
- ❑ FCNC interactions in **u-t-V** vertex
- ❑ Additional scenario using **V** directly as DM

Resonant Monotop



- ❑ Coloured, charged scalar **ϕ** decaying to top and DM
- ❑ Majorana fermion as DM

Single VLT T→tZ (Z→νν)



- ❑ Vector-like top quark **T→tZ**
- ❑ Additional forward jet

From our fellow theorists, the lagrangians we are using

$$\mathcal{L}_{\text{int}} = aV_\mu \bar{u}\gamma^\mu P_{\text{R}} t + g_\chi V_\mu \bar{\chi}\gamma^\mu \chi + \text{h.c.}$$

$$\mathcal{L}_{\text{int}} = \lambda\phi \bar{d}^c P_{\text{R}} s + y\phi\bar{\chi} P_{\text{R}} t + \text{h.c.}$$

$$\mathcal{L} = \kappa_T \left\{ \sqrt{\frac{\zeta_i \xi_W^T}{\Gamma_W^0}} \frac{g}{\sqrt{2}} \left[\bar{T}_{L/R} W_\mu^+ \gamma^\mu d_{L/R}^i\right] + \sqrt{\frac{\zeta_i \xi_Z^T}{\Gamma_Z^0}} \frac{g}{2c_W} \left[\bar{T}_{L/R} Z_\mu \gamma^\mu u_{L/R}^i\right] - \sqrt{\frac{\zeta_i \xi_H^T}{\Gamma_H^0}} \frac{M}{v} \left[\bar{T}_{R/L} H u_{L/R}^i\right] \right\}$$

Regions, regions and more regions

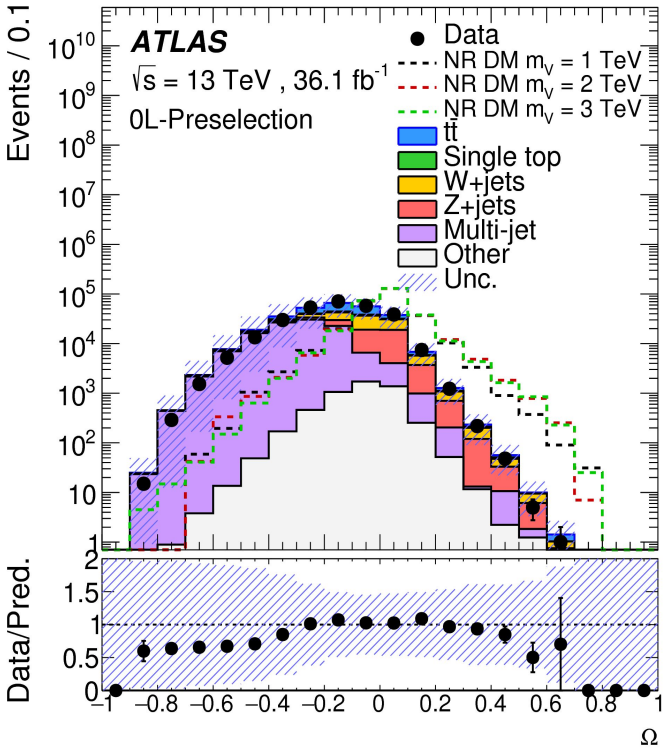
Selections (leptonic channel)	1L-DM-SR	1L-TCR	1L-WCR
Number of leptons	= 1	= 1	= 1
$p_{\mathrm{T}}(\ell)$ [GeV]	> 30	> 30	> 30
Lepton charge	> 0	> 0	> 0
Number of jets	= 1	= 2	= 1
Number of b-tagged jets	= 1	= 2	= 1
$p_{\mathrm{T}}(b\text{-tagged jet})$ [GeV]	> 30	> 30	> 30
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 50	> 50	> 50
$m_{\mathrm{T}}^{W} + E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 60	> 60	> 60
m_{T}^{W} [GeV]	> 260	$60 < m_{\mathrm{T}}^{W} < 100$	$60 < m_{\mathrm{T}}^{W} < 100$
$\lvert\Delta\phi(\ell, b)\rvert$	< 1.2	-	-

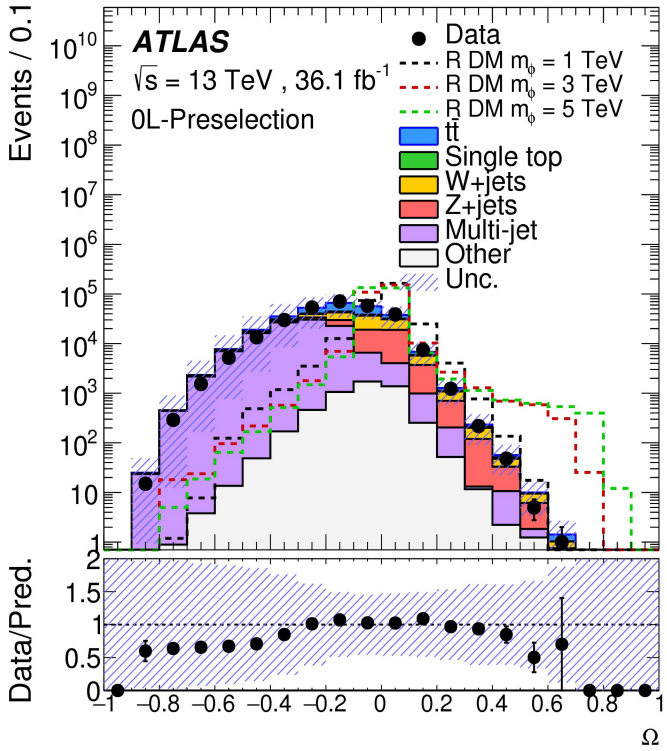
Selections (hadronic channel)	0L-DM-SR	0L-VLT-SR	0L-TCR	0L-VCR
Number of forward jets	= 0	≥ 1	-	-
Number of leptons	= 0		= 0	= 0
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 200		> 200	> 200
Number of large-R jets	≥ 1		≥ 1	≥ 1
Number of top-tagged jets	≥ 1		≥ 1	≥ 1
$\Delta\Phi(E_{\mathrm{T}}^{\mathrm{miss}}, J)$	> $\frac{\pi}{2}$		> $\frac{\pi}{2}$	> $\frac{\pi}{2}$
Number of track-jets	≥ 1		≥ 1	≥ 1
Number of b-tagged track-jets	= 1		≥ 2	= 0
Veto jet (masked tile-calo)	-		applied	-
$\Omega = \frac{E_{\mathrm{T}}^{\mathrm{miss}} - p_{\mathrm{T}}(J)}{E_{\mathrm{T}}^{\mathrm{miss}} + p_{\mathrm{T}}(J)}$	> –0.3		> –0.3	> –0.3
$\Delta\Phi_{\mathrm{min}}(E_{\mathrm{T}}^{\mathrm{miss}}, \text{calo jets})$	> 1.0		$0.2 < \Delta\Phi_{\mathrm{min}} < 1.0$	> 1.0

Regions, regions and more regions
pre-fit yields

	1L-DM-SR	1L-TCR	1L-WCR	0L-DM-SR	0L-VLT-SR	0L-TCR	0L-VCR
$t\bar{t}$	390 ± 140	12 300 ± 3100	8400 ± 1700	10 200 ± 2900	3700 ± 1200	7000 ± 1700	6100 ± 1800
Single top	66 ± 21	2930 ± 760	12 200 ± 1700	1020 ± 260	356 ± 97	274 ± 71	890 ± 250
W+jets	34.2 ± 8.4	1890 ± 640	92 000 ± 24 000	2240 ± 900	770 ± 310	147 ± 87	28 000 ± 12 000
Z+jets	0.40 ± 0.86	112 ± 49	3410 ± 990	2700 ± 1100	850 ± 360	139 ± 83	27 000 ± 11 000
Other	14 ± 15	640 ± 880	7000 ± 10 000	530 ± 190	89 ± 28	1060 ± 640	2730 ± 760
Total Background	500 ± 140	17 900 ± 3400	123 000 ± 26 000	16 600 ± 4500	5800 ± 1700	8600 ± 2000	66 000 ± 22 000
Data	511	17 662	127 286	15 781	5454	8493	62 304
R DM $m_\phi = 1$ TeV	-	-	-	11 300 ± 1300	-	56 ± 13	8100 ± 1600
R DM $m_\phi = 2$ TeV	-	-	-	469 ± 83	-	4.3 ± 1.1	349 ± 86
NR DM $m_\phi = 1$ TeV	165 ± 23	1.02 ± 0.47	20.2 ± 2.8	2090 ± 280	-	29.0 ± 5.9	1600 ± 320
NR DM $m_\phi = 2$ TeV	6.5 ± 2.7	0.027 ± 0.013	0.496 ± 0.097	95 ± 13	-	1.08 ± 0.21	75 ± 15
VLT $m_{\text{VLT}} = 0.9$ TeV	-	-	-	-	112 ± 20	21.0 ± 5.3	76 ± 17

hadronic channel: Ω = (ETmiss - pT(J))/(ETmiss + pT(J))

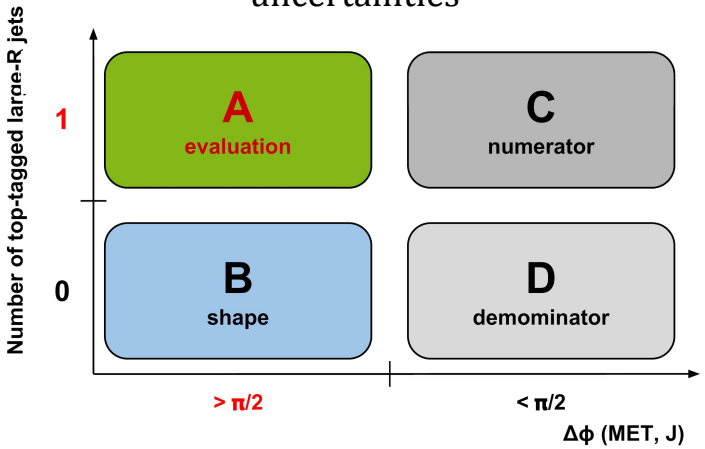


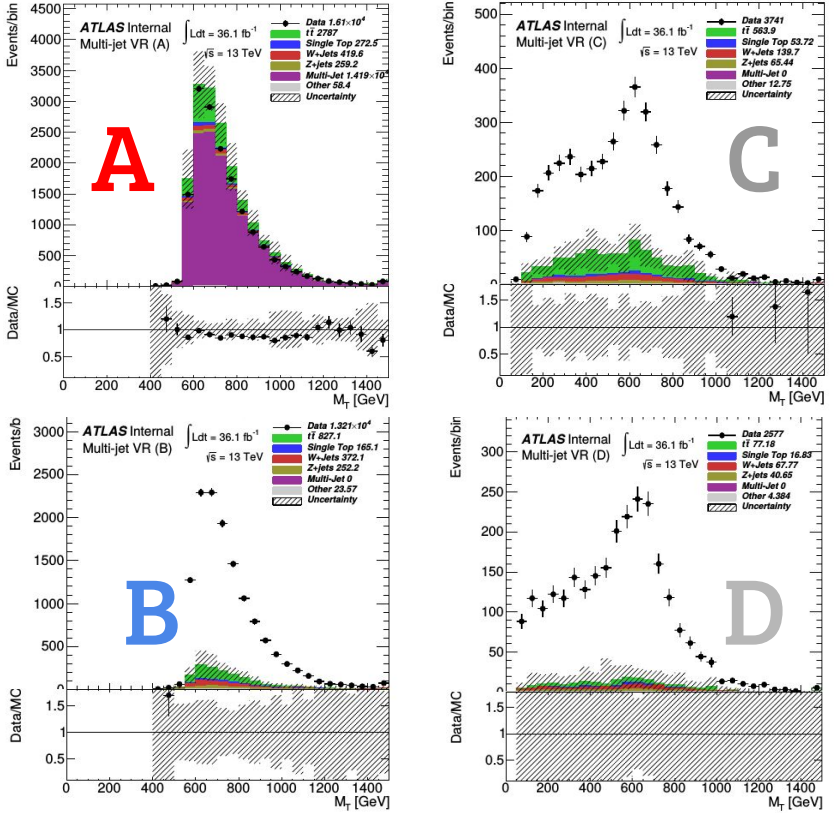


hadronic channel: multijet estimate

ABCD method used :

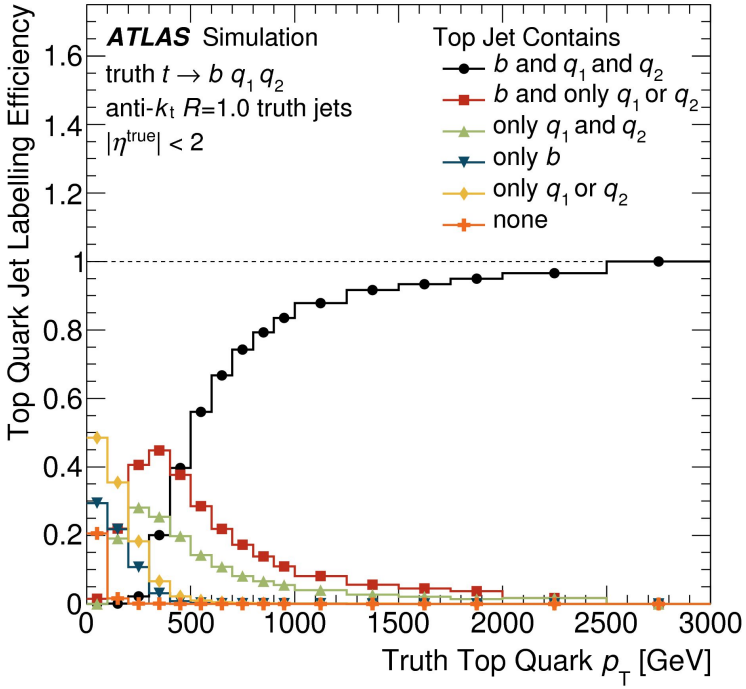
- SR requirements varied to define multi-jet estimation region
- Binned shape distribution (B) scale with global correction factor (C/D)
- Multi-jet shape reasonably modeled
- Slight norm. offset
  - Covered by stats. & syst. uncertainties

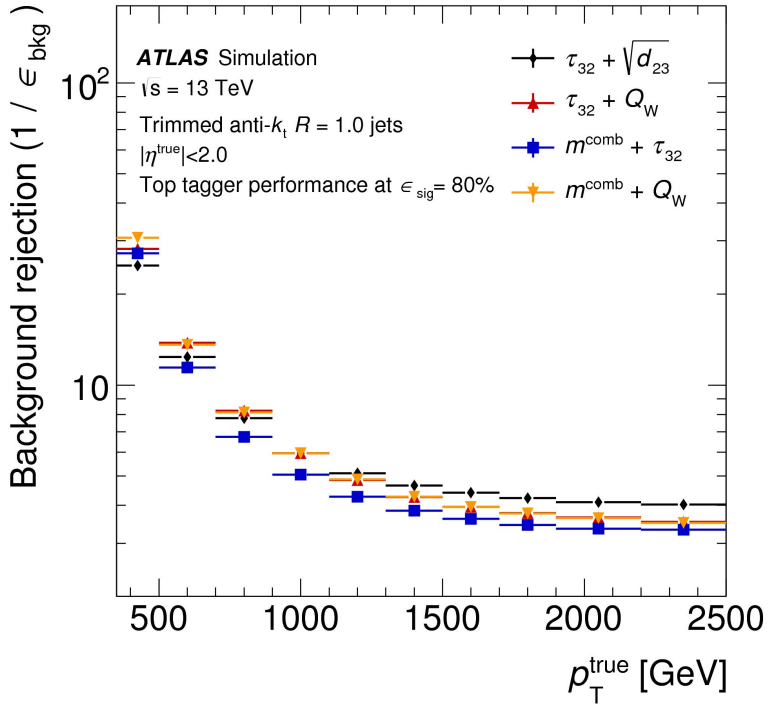




hadronic channel: top tagging

https://arxiv.org/abs/1808.07858





hadronic channel: top tagging

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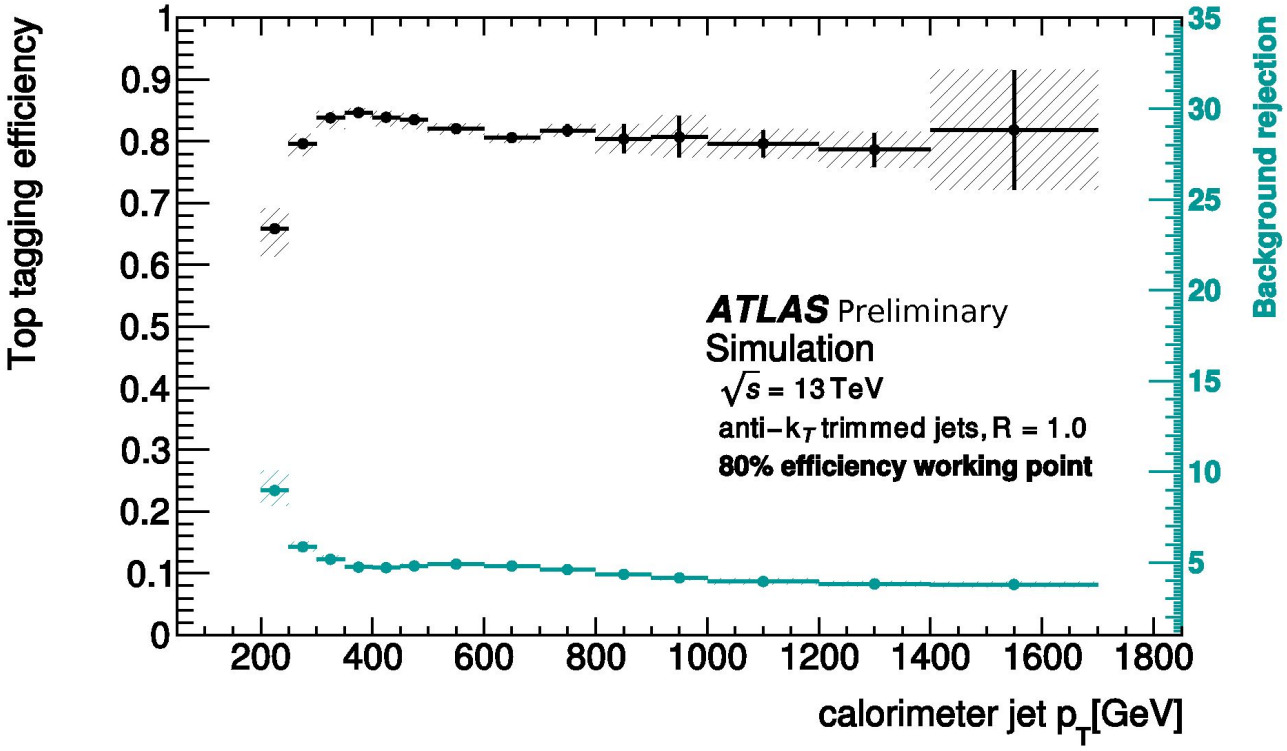
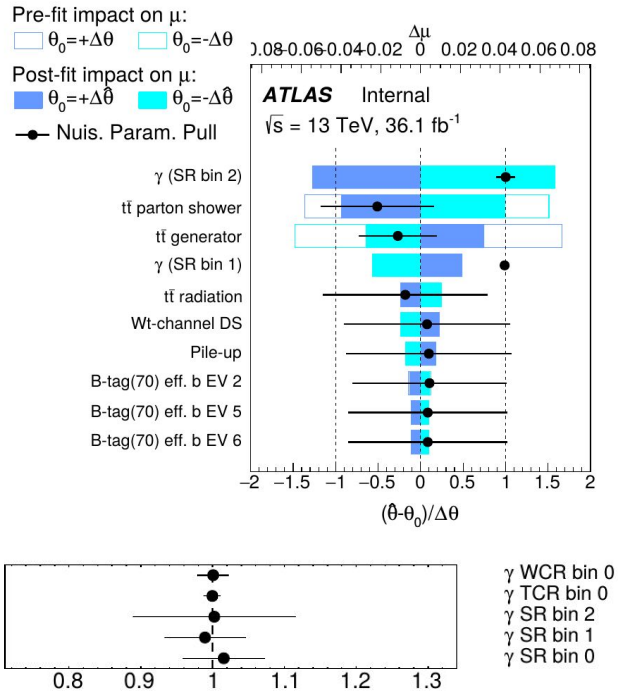
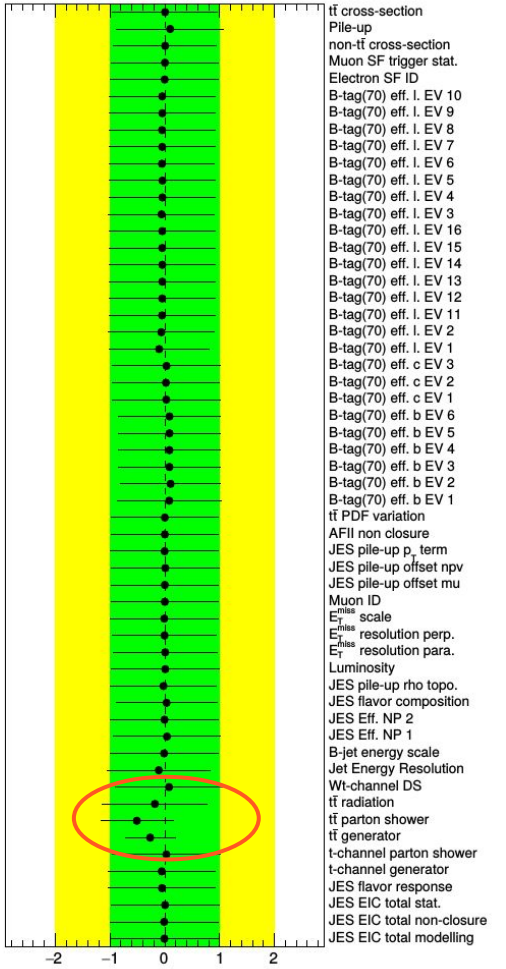


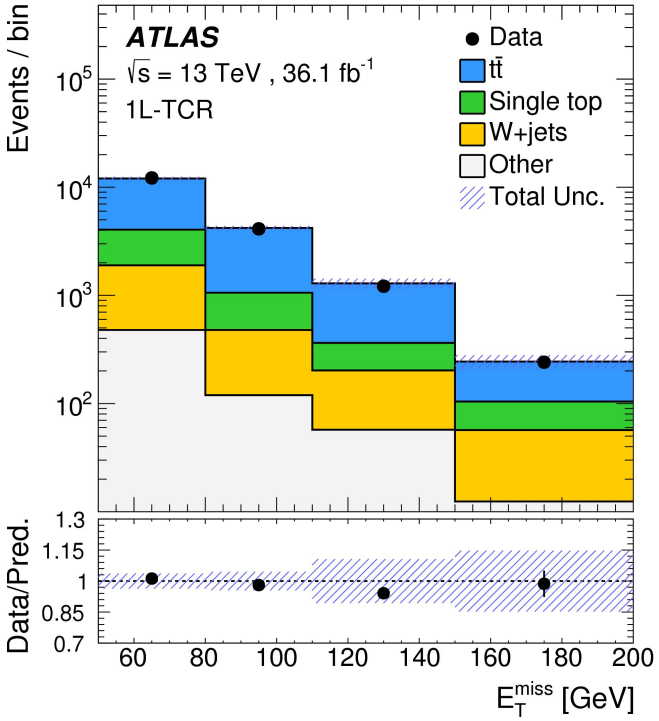
fitting: single lepton channel

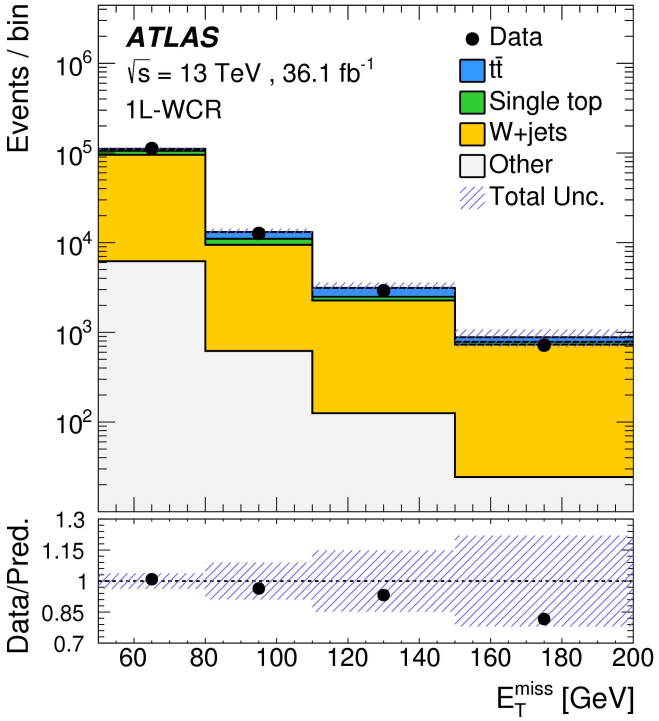
- Some slight pulls of ttbar modeling uncertainties observed
- Ranking of systs. pre-/post-fit impact on μ :
  - Main impact from ttbar modeling uncert.
  - Also larger impact of MC statistics in single SR bin





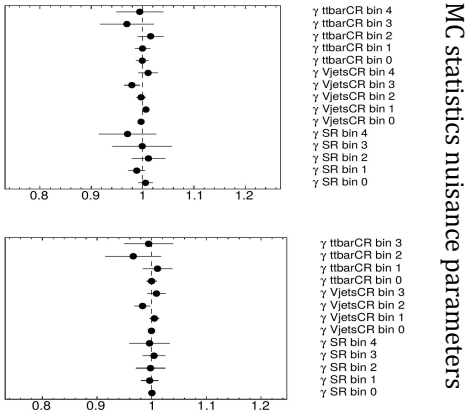
leptonic channel - post-fit plots

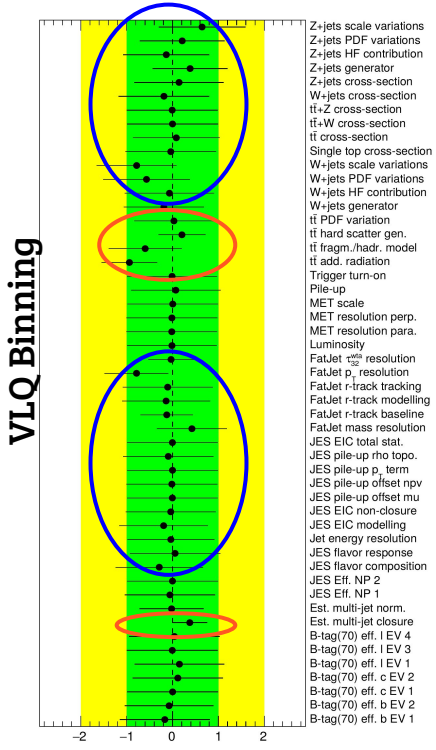


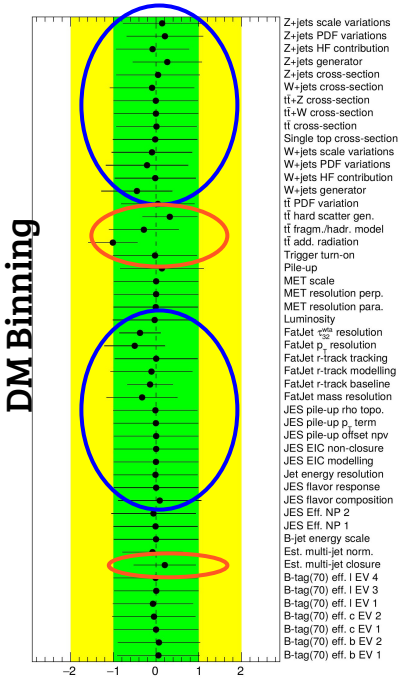


fitting: hadronic channel

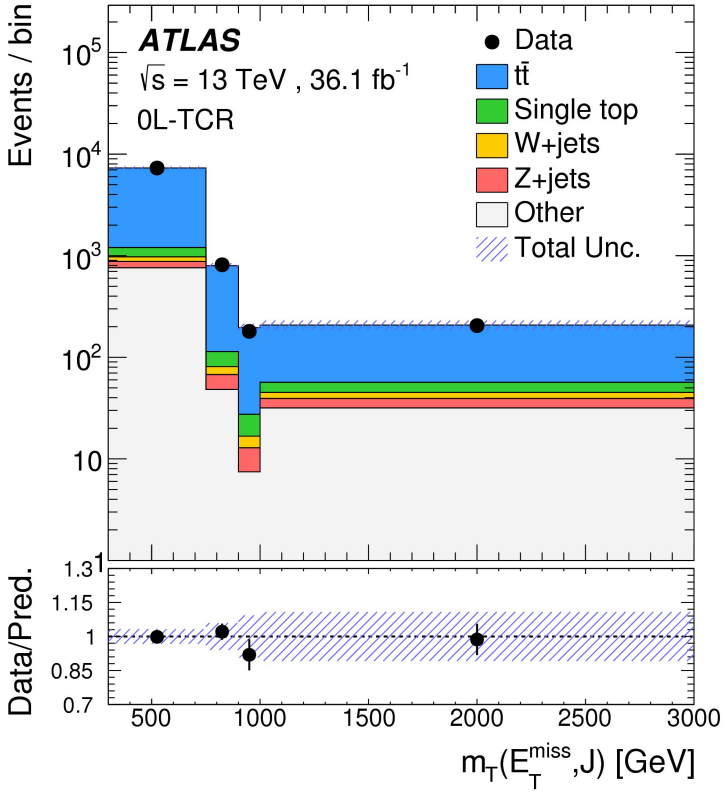
- Similar behavior for each binning
- ttbar modeling & multi-jet syst. pulls :
  - Account for top p_T mis.modeling
- V+jets modeling & large-R jet syst. pulls :
  - Account for norm. offset and compensate ttbar syst. pulls

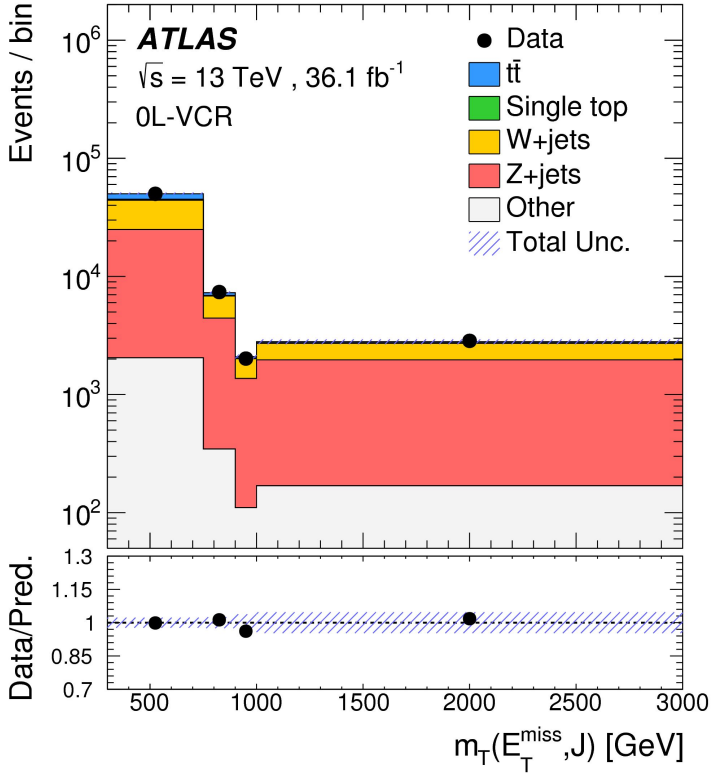






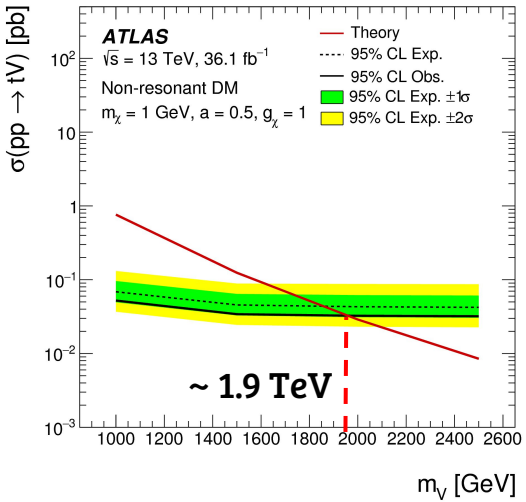
hadronic channel: post-fit plots

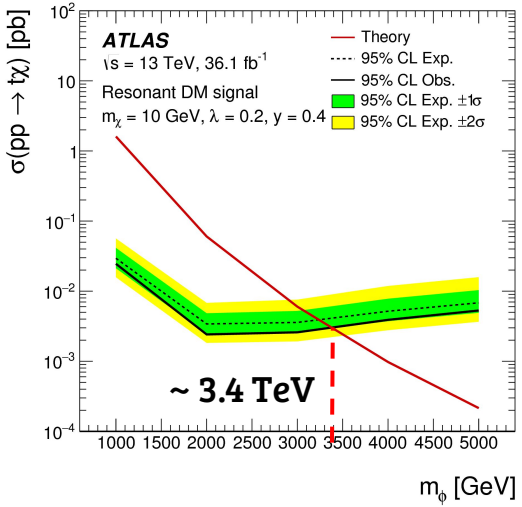




fitting: results

no evidence for signal found (yet…) so we have limits



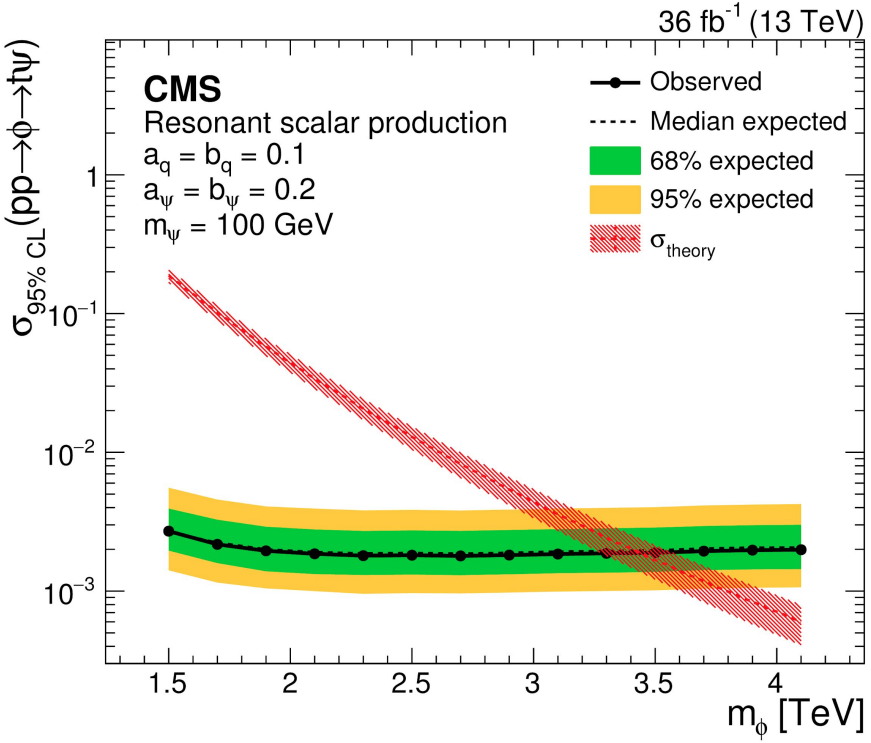


- Non resonant DM model:
- **Combined limits (1-L & 0-L channels)**
  - 1-L channel : more sensitive for lower m(V)
  - 0-L channel : more sensitive for higher m(V)

- Resonant DM model:
- Limits exclusively from 0-L channel

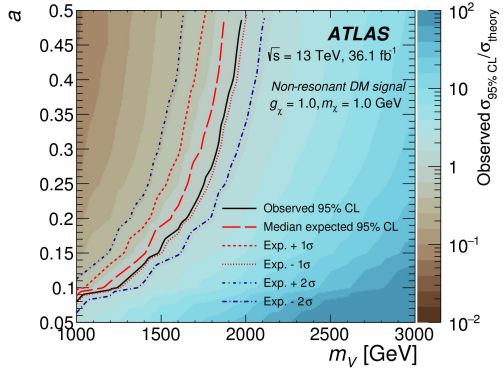
fitting: results from the competition...

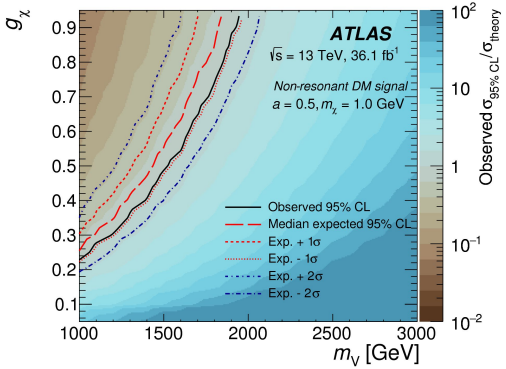
https://arxiv.org/abs/1801.08427

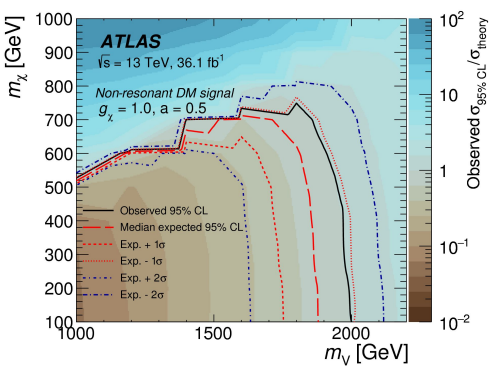


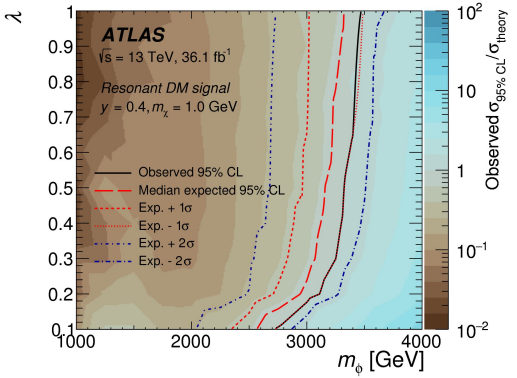
fitting: 2D plots

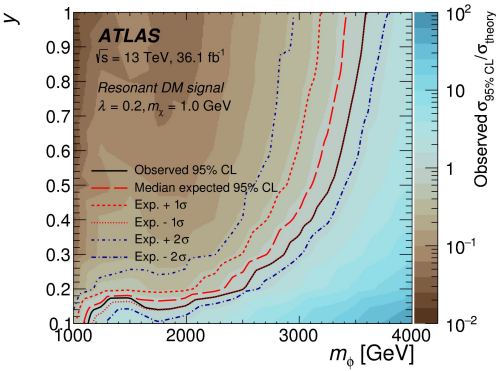
NR DM : Norm. uncert. ~10%











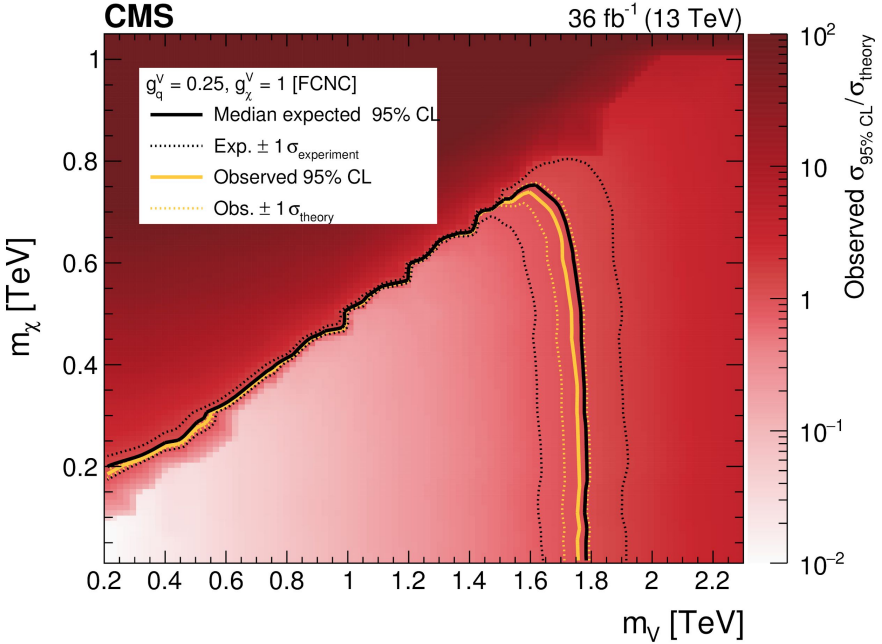
R DM : Norm. uncert. ~25%

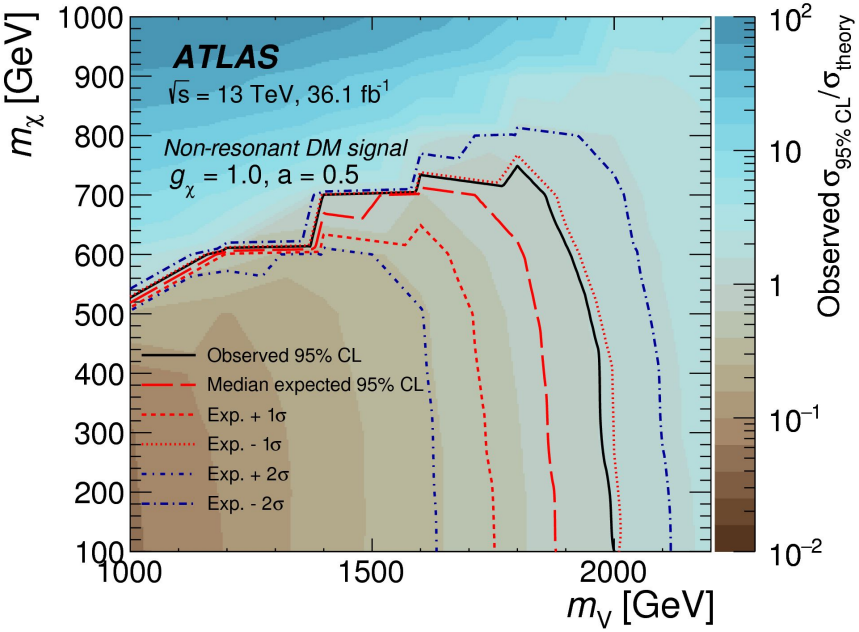
DM signals :

- Binned re-weights derived as function of truth MET
- Re-weighting to different theory parameters
  - NR DM : m(V), m(χ), a, g_χ
  - R DM : m(ϕ), y, λ

fitting: results from the competition...

https://arxiv.org/abs/1801.08427





fitting: results from the competition...

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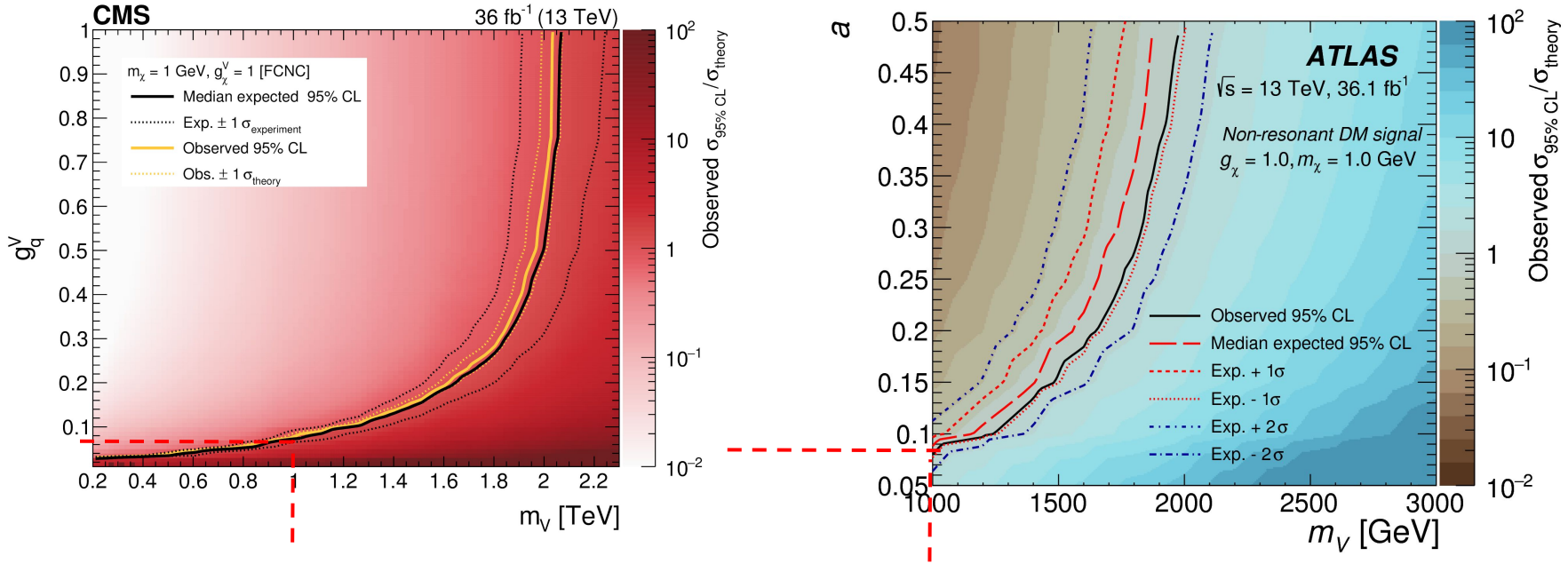
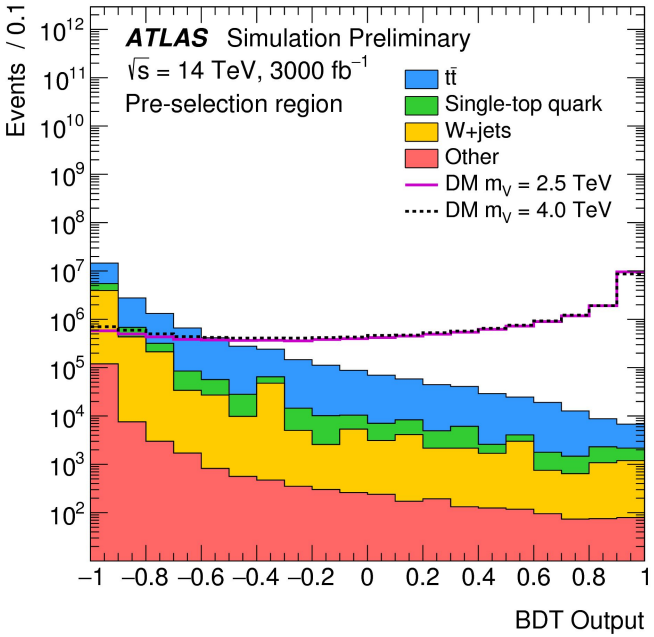
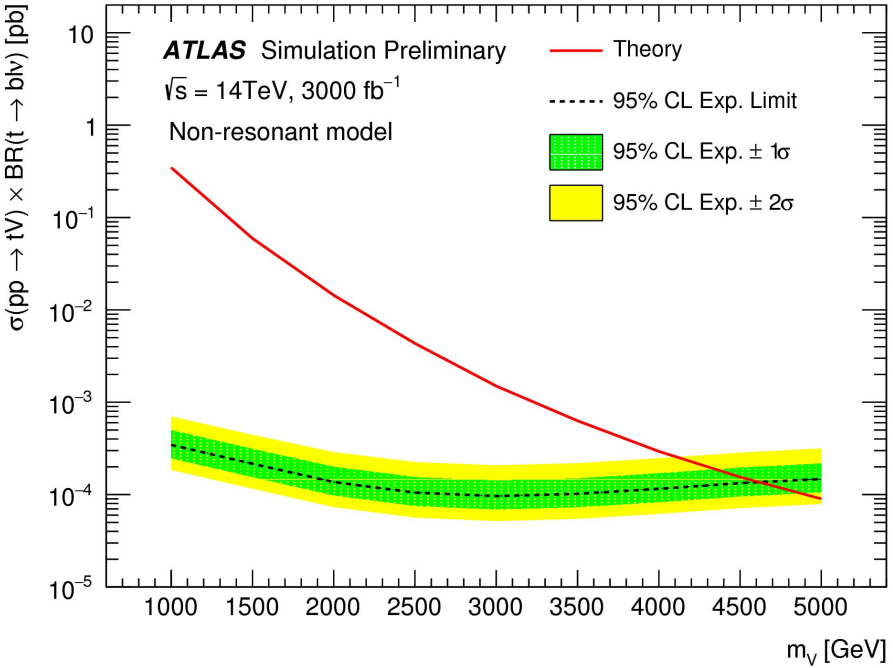


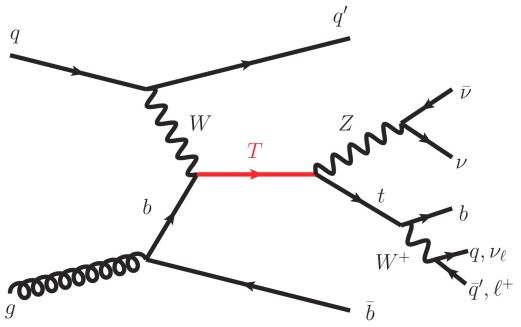
https://cds.cern.ch/record/2645274

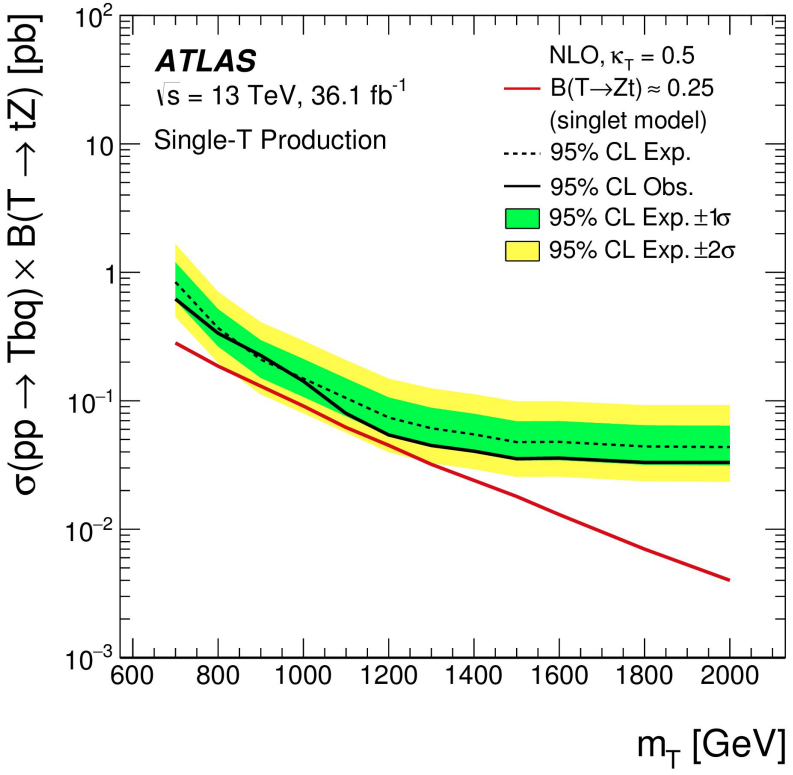
prospects for the future
HL-LHC



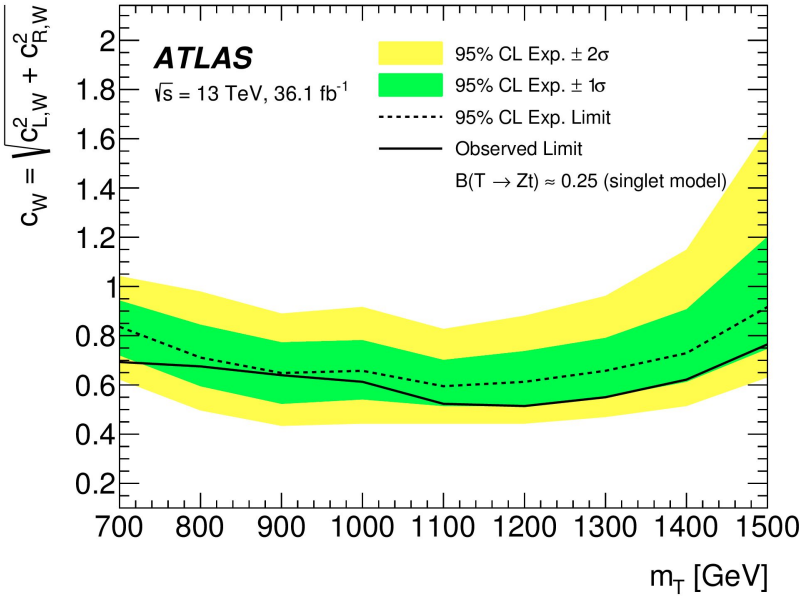


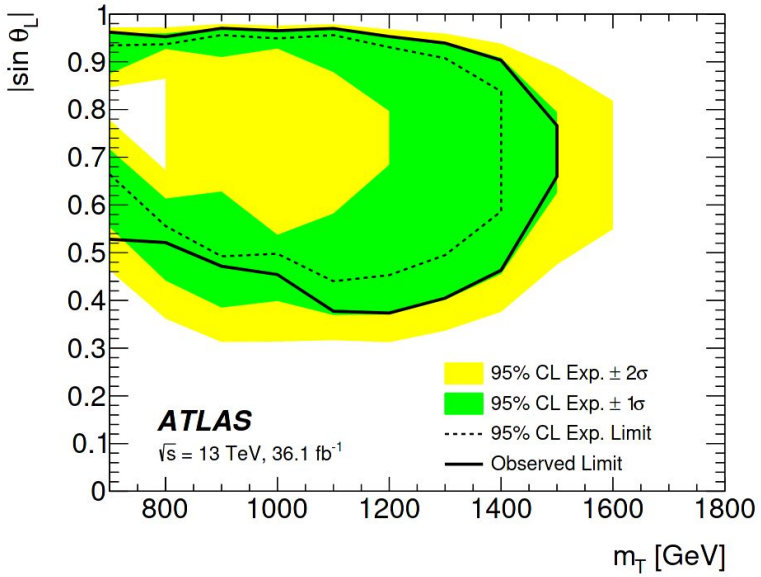
VLQs


q
q′
W
Z
T
ν̄
ν
t
b
b
W+
q, νℓ
q̄′, ℓ+
g
b̄


ATLAS
√s = 13 TeV, 36.1 fb-1
Single-T Production
NLO, κT = 0.5
B(T→Zt) ≈ 0.25
(singlet model)
95% CL Exp.
95% CL Obs.
95% CL Exp. ±1σ
95% CL Exp. ±2σ
σ(pp → Tbq) × B(T → tZ) [pb]
10^2
10
1
10^-1
10^-2
10^-3
600
800
1000
1200
1400
1600
1800
2000
mT [GeV]

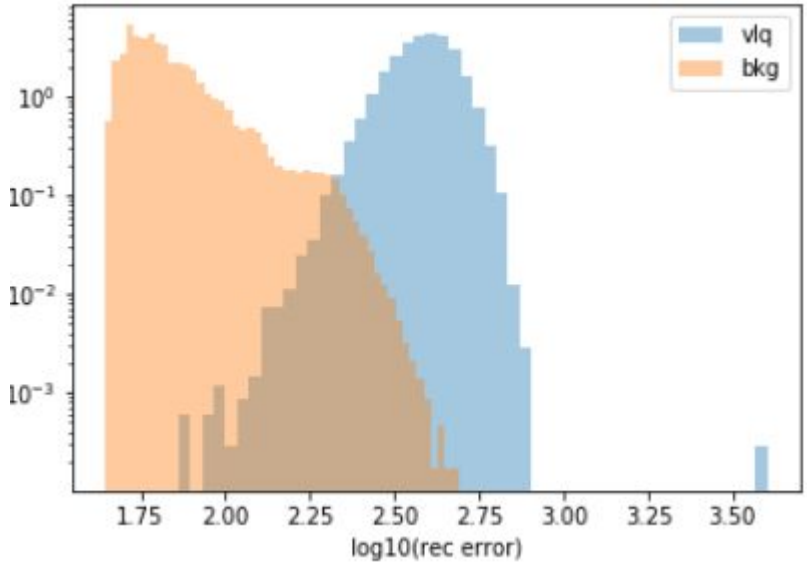
VLQs

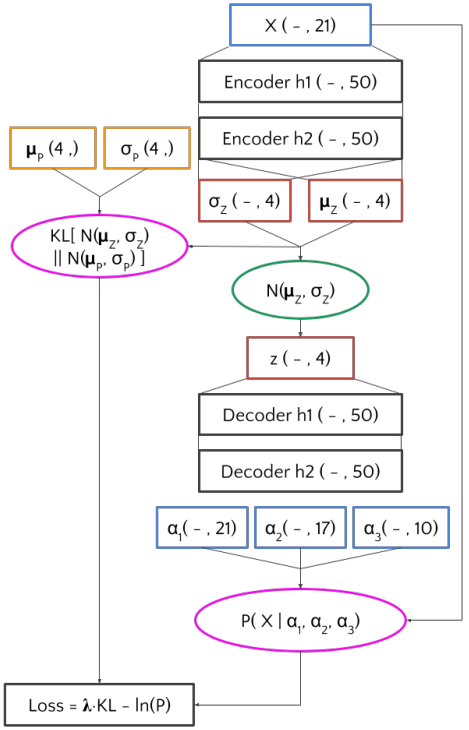

ATLAS
√s = 13 TeV, 36.1 fb-1
95% CL Exp. ± 2σ
95% CL Exp. ± 1σ
95% CL Exp. Limit
Observed Limit
B(T → Zt) ≈ 0.25 (singlet model)
cW = √(c²L,W + c²R,W)
mT [GeV]


ATLAS
√s = 13 TeV, 36.1 fb-1
95% CL Exp. ± 2σ
95% CL Exp. ± 1σ
95% CL Exp. Limit
Observed Limit
|sin θL|
mT [GeV]

prospects for the future
anomaly detection using ML

arXiv:1811.10276





Random thoughts

- Impossible to tackle every possible final state at LHC
- But we do want to make sure we don’t miss new physics in our (present and future) dataset

- How to have general (or as general as possible) searches without compromising sensitivity?
  - clever choice of inclusive signatures
  - machine learning
  - ???