

Searches with top quarks in ATLAS

Vector-like quarks and resonances

Loïc Valéry (DESY)

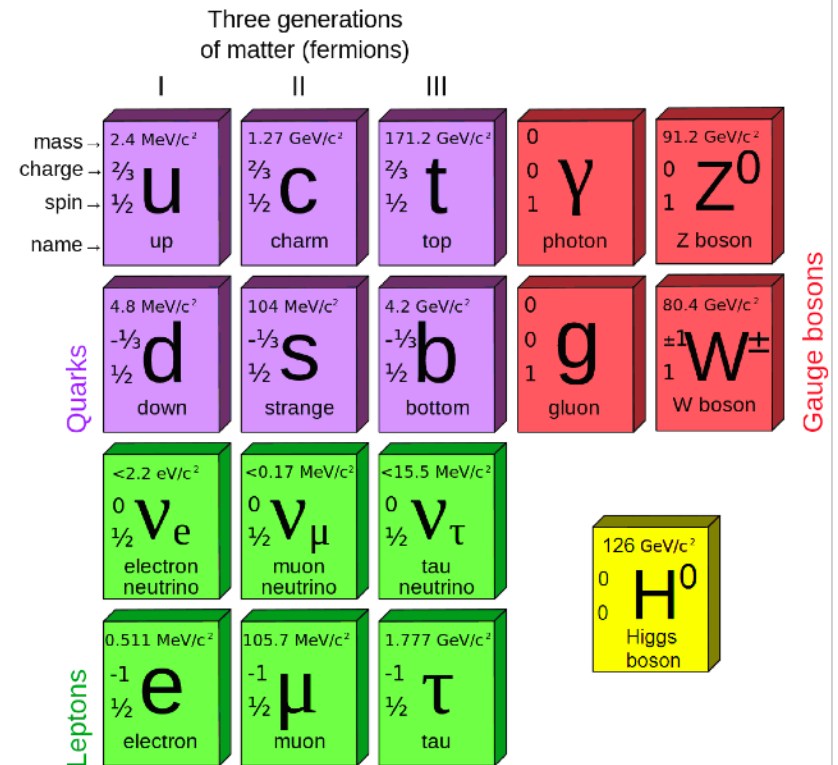
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LPSC Grenoble — 20/11/2018

Standard Model

Where we stand ...

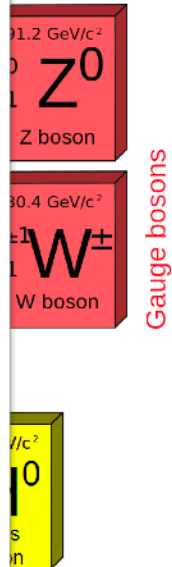
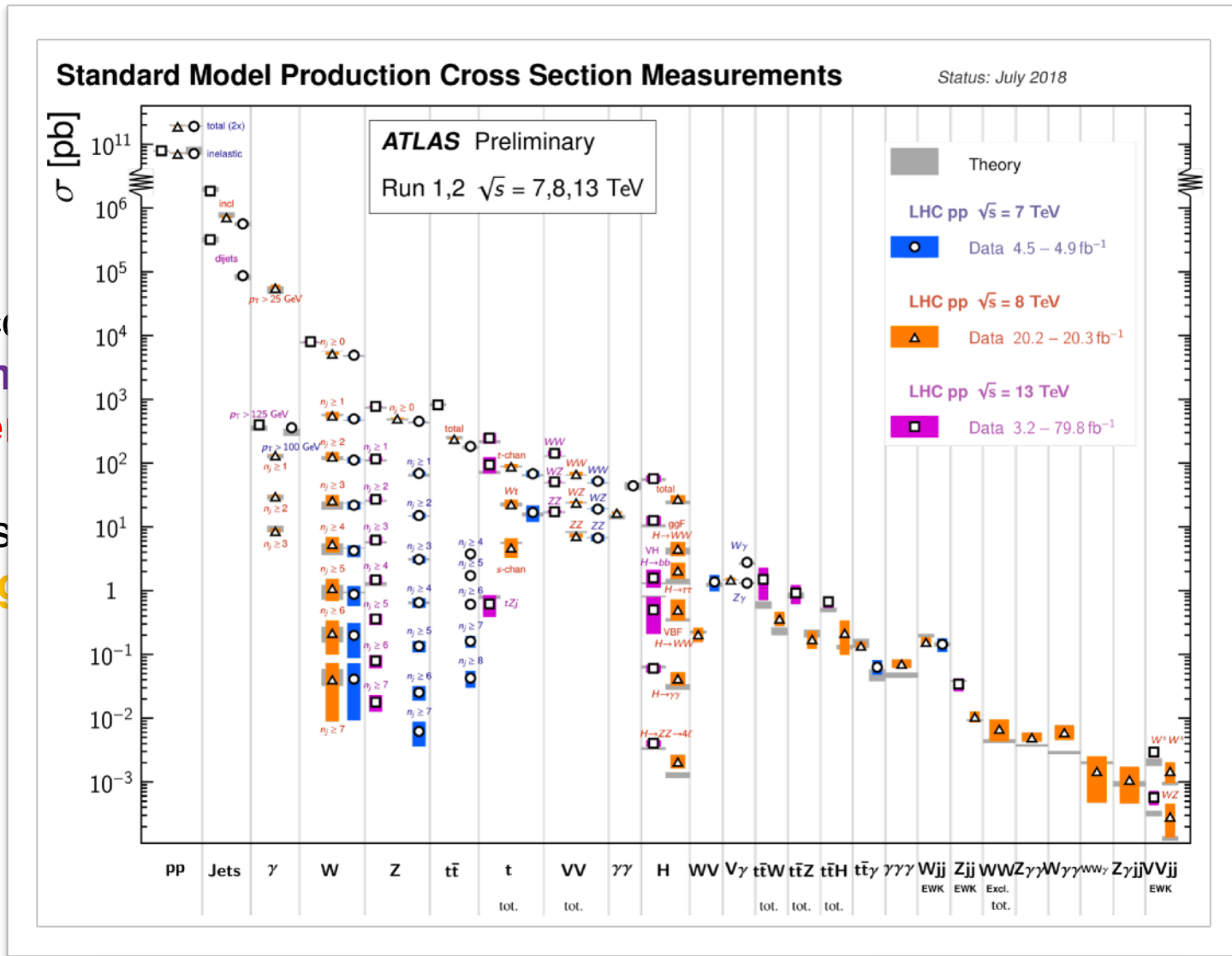
- Successfull theory: describes **elementary particles** & **interactions**
- "Last" piece discovered in 2012: **Higgs boson**



Standard Model

Where we stand ...

- Success of the Standard Model in describing elementary particle interactions
- "Last mile" of the Standard Model: Higgs boson



Standard Model

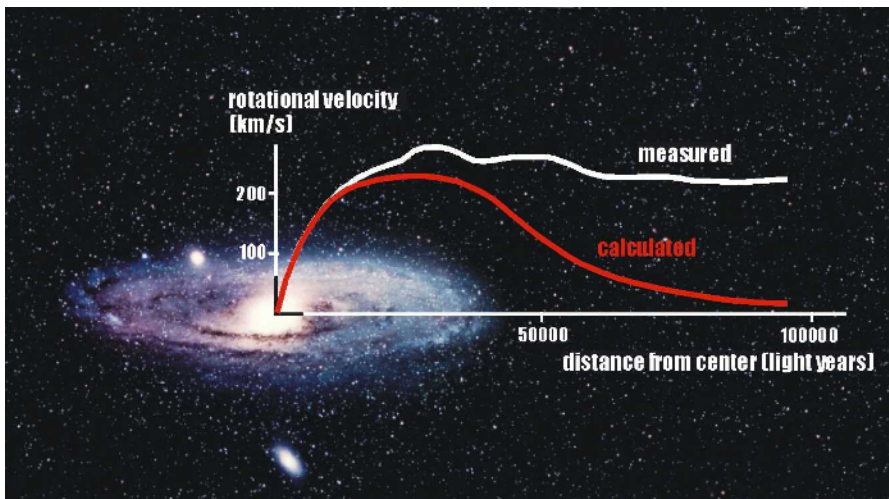
But ...

- **Limitations** / unnatural observations

Standard Model

But ...

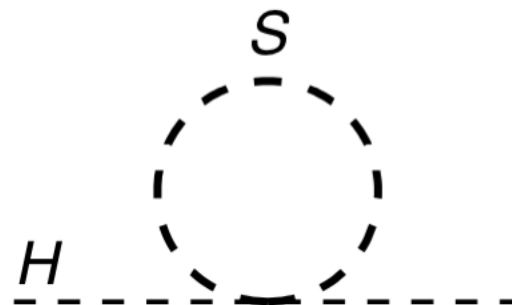
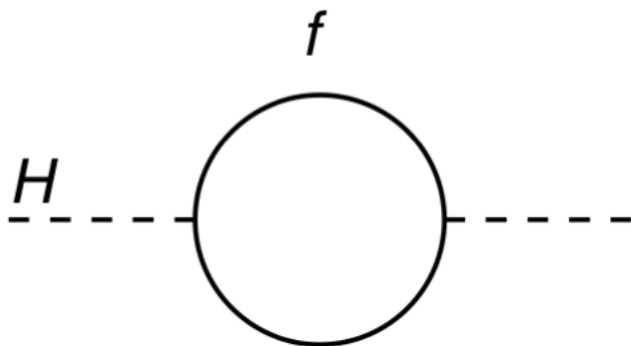
- **Limitations** / unnatural observations
 - **Dark Matter**: not described in Standard Model



Standard Model

But ...

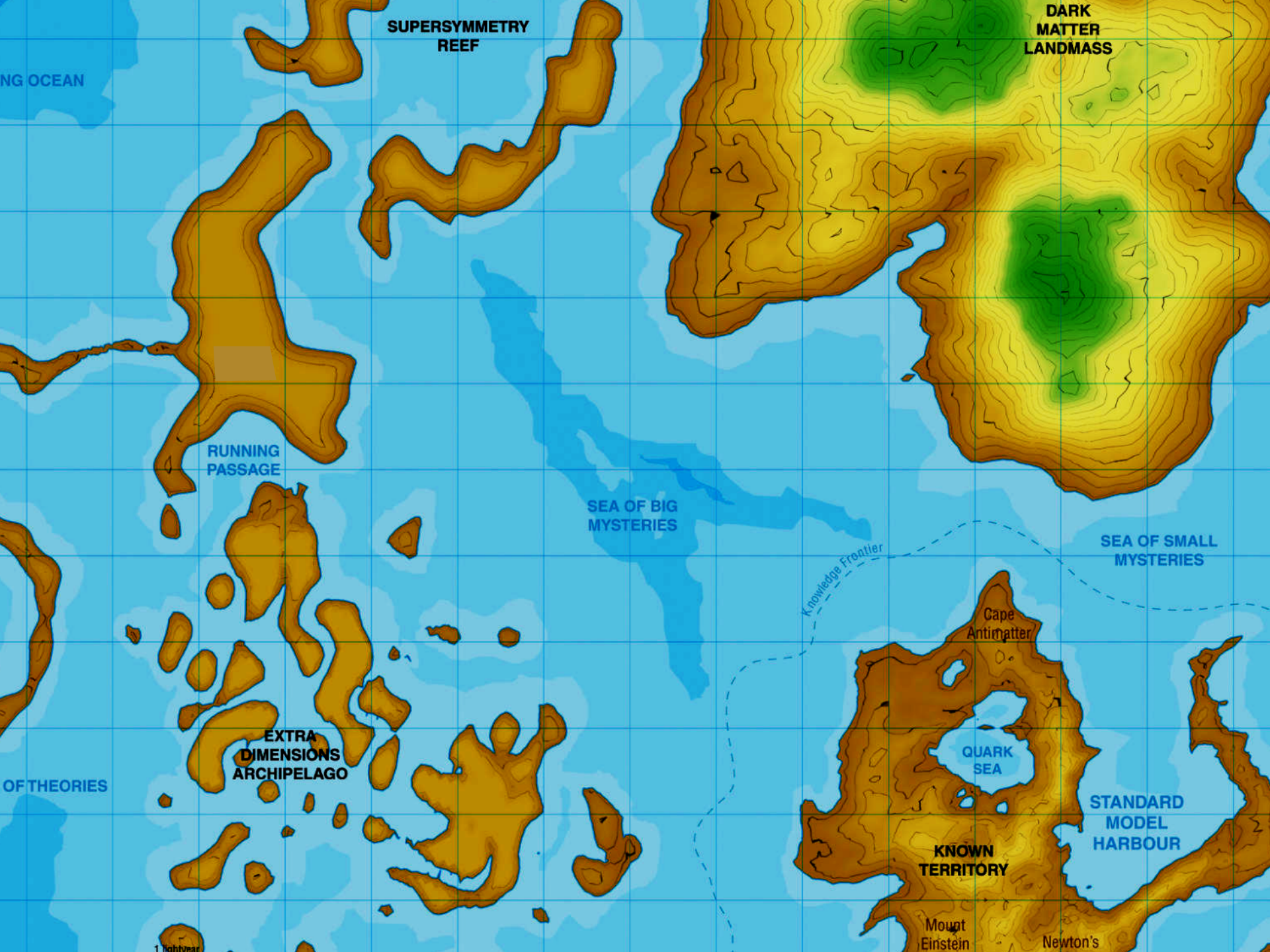
- **Limitations** / unnatural observations
 - **Dark Matter**: not described in Standard Model
 - **Higgs boson mass**: naturally expected to be heavier



Standard Model

But ...

- **Limitations** / unnatural observations
 - **Dark Matter**: not described in Standard Model
 - **Higgs boson mass**: naturally expected to be heavier
 - etc ...

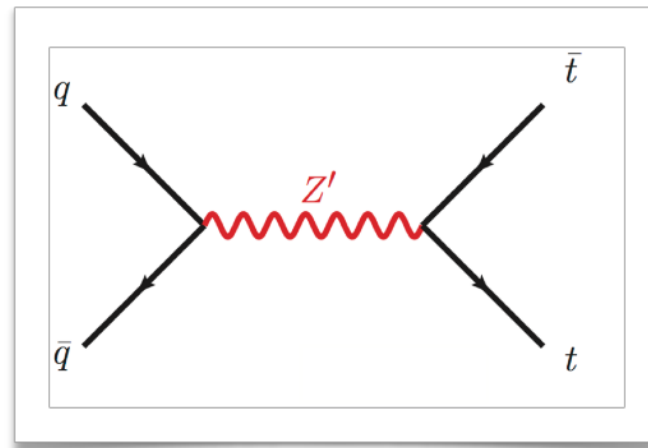
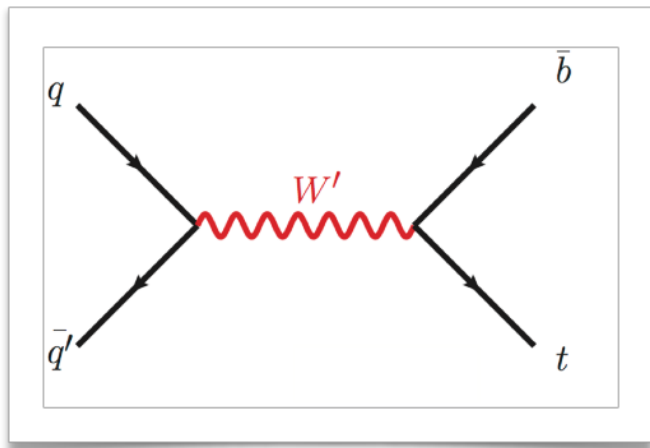


Beyond the Standard Model

Where we go ...

- Changing/adding symmetries

- SM low-energy effective theory ?
- SM based on $SU(3) \times SU(2) \times U(1) \rightarrow$ Belong to a **larger symmetry group** ?
 - E_6 , $SO(10)$, ... (e.g. SSM, GUT theories)
- Breaking $\Rightarrow$ new symmetries remain $\Rightarrow$ **additional gauge bosons predicted**
 - e.g. Z' , W'

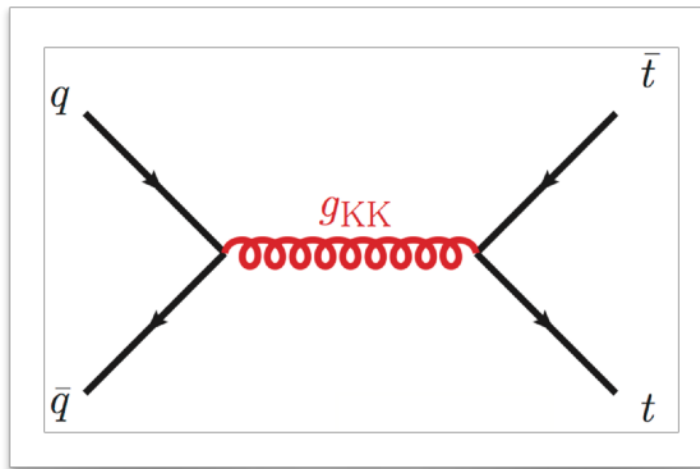


Beyond the Standard Model

Where we go ...

- **New dimensions**

- Could explain e.g. **mass hierarchy**, scale hierarchy
- Constraints $\Rightarrow$ extra-dimensions **compactified**
 - e.g. warped extra-dimensions (Randall-Sundrum)
- **Excitations of SM particles** $\Rightarrow$ new particles
 - e.g. Kaluza-Klein gluons, gravitons, ...

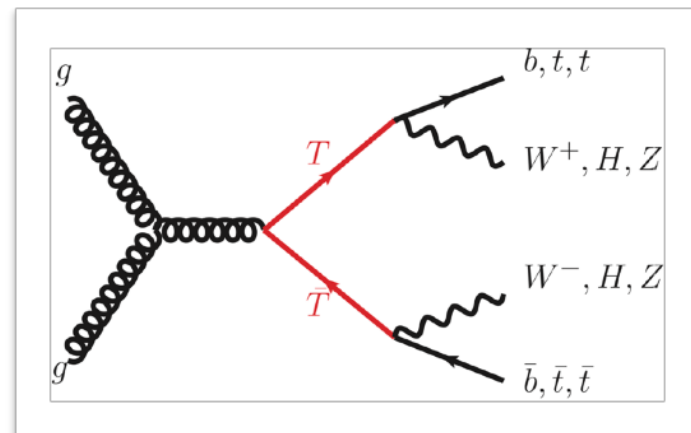
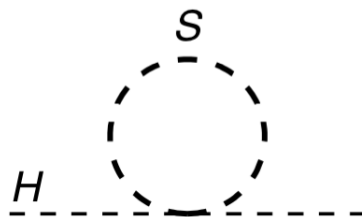
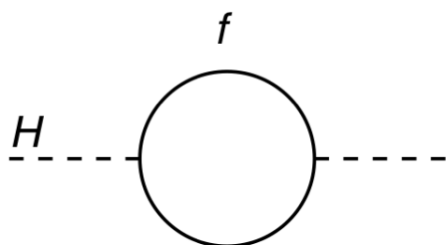


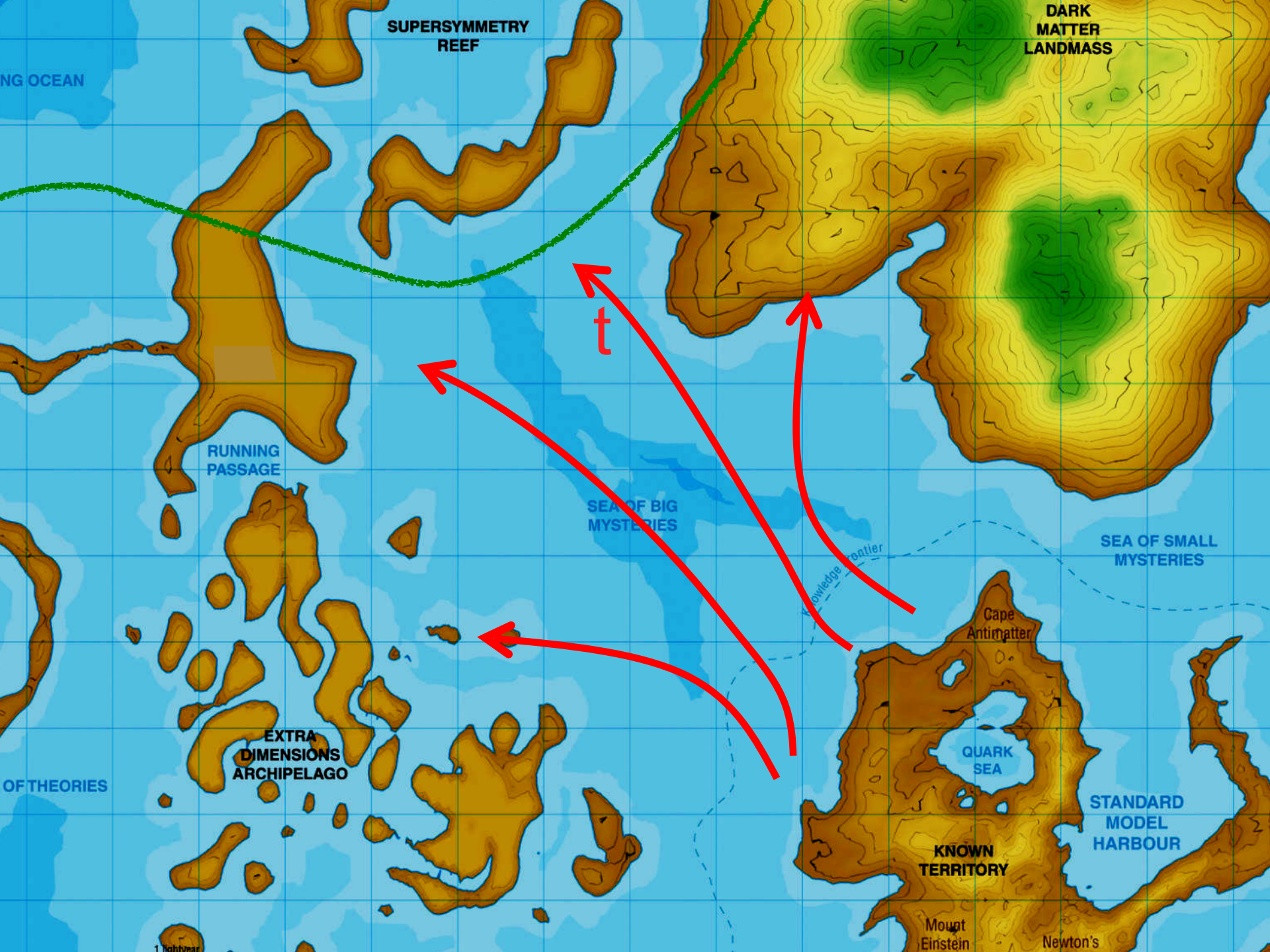
Beyond the Standard Model

Where we go ...

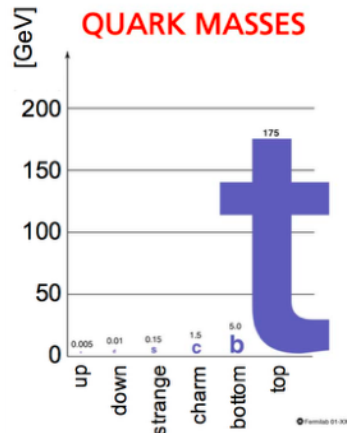
- **Top quark partners**

- New Physics at higher scale (Planck) $\Rightarrow$ **could lead to large radiative corrections**
- Reduction of these corrections: **top quark's partners**
 - superpartners (stops), **vector-like partners** (e.g. Higgs compositeness)

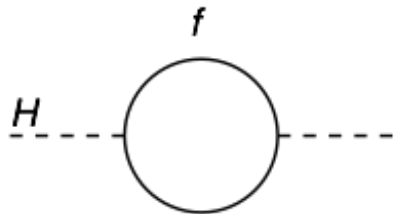




Top quark: probe for New Physics?

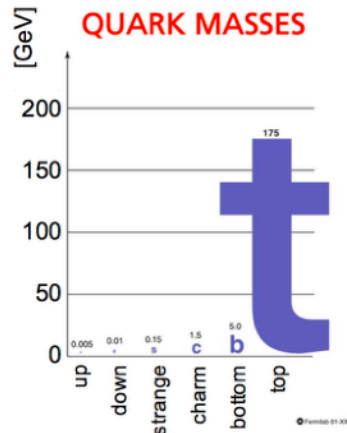


Distinctive **properties**
(mass, y_t , ...)

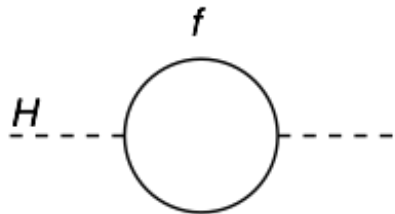


Leading radiative corrections
to Higgs mass

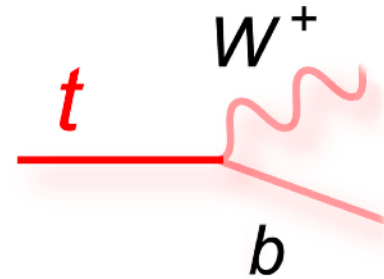
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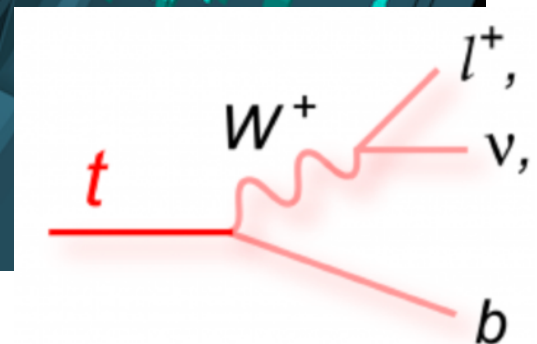
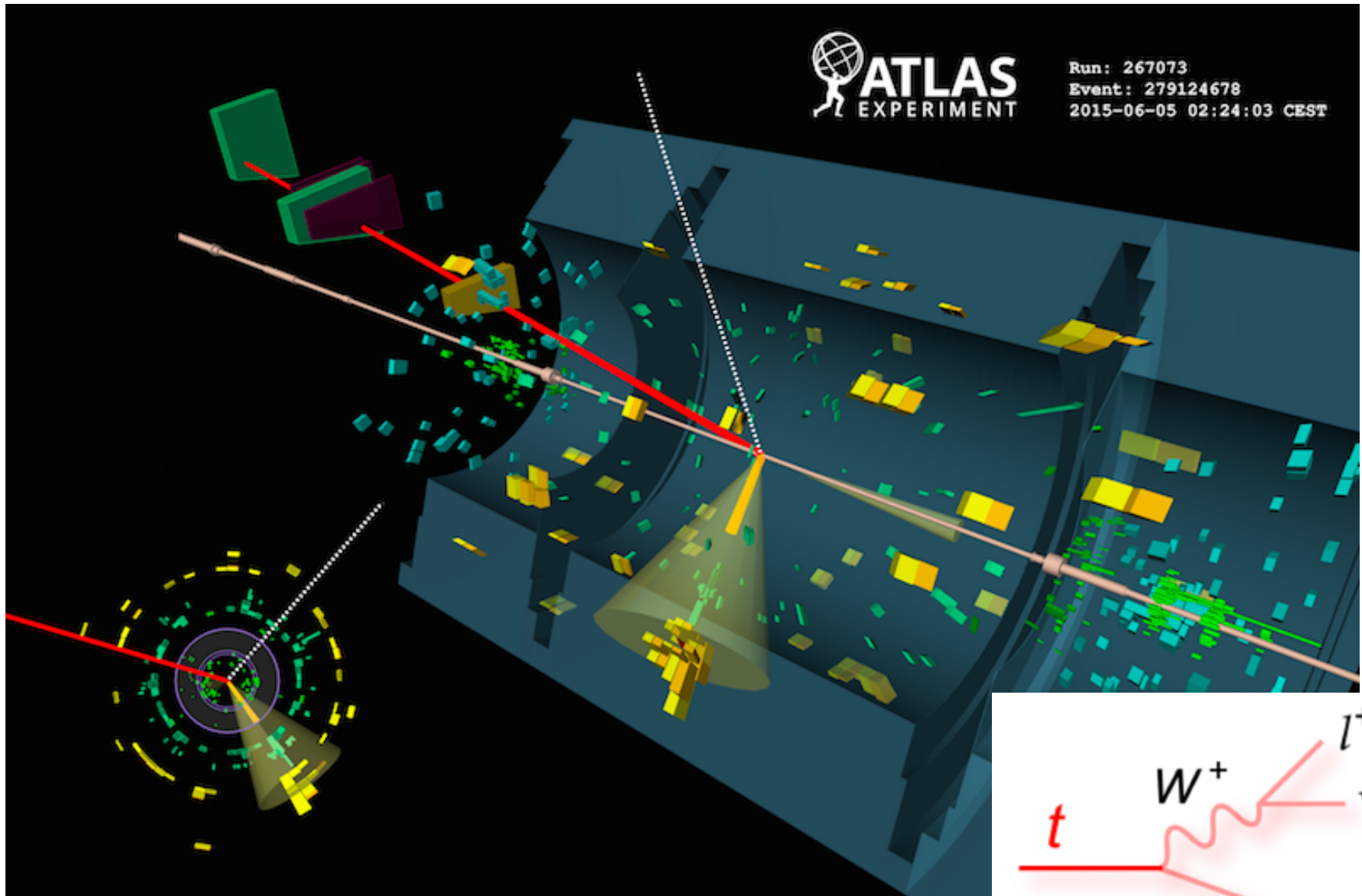


Leading radiative corrections
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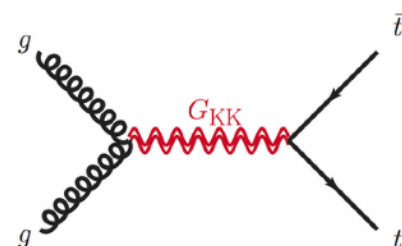
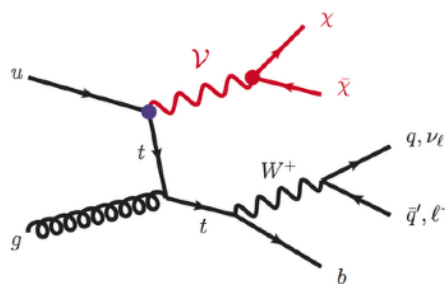
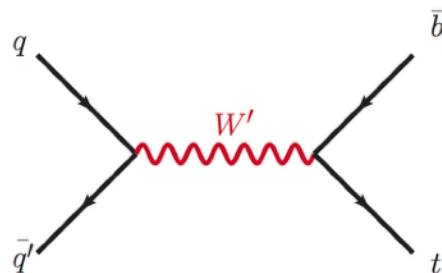
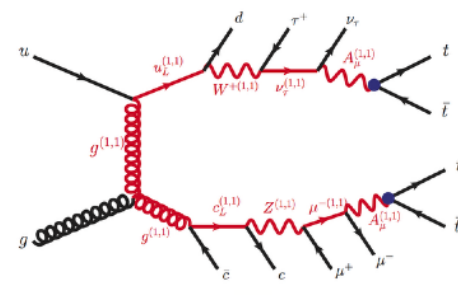
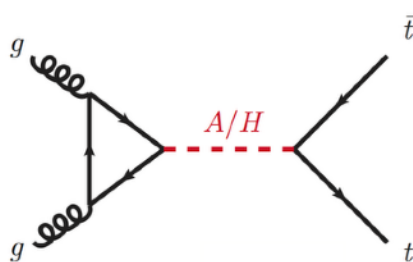
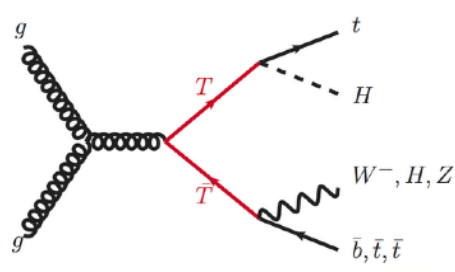
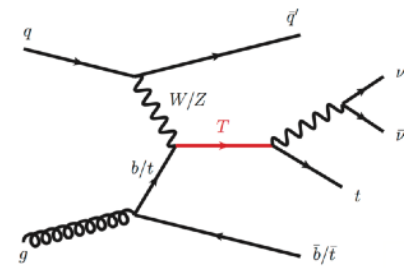
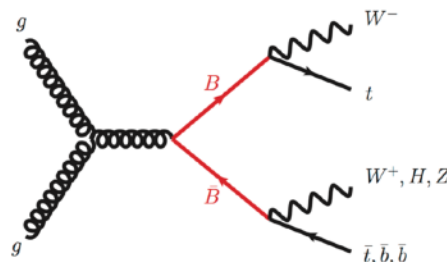
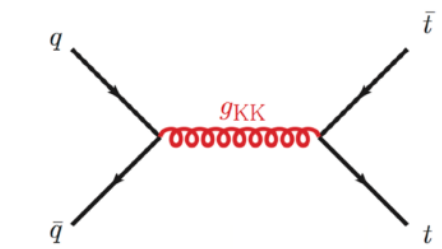
Unique **experimental**
signature

Top quark: probe for New Physics?



Top quark: probe for New Physics?

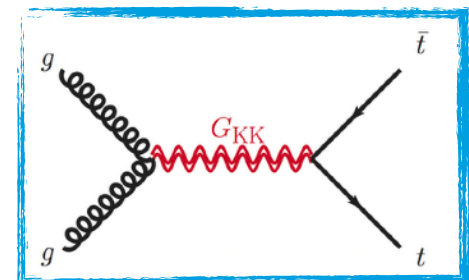
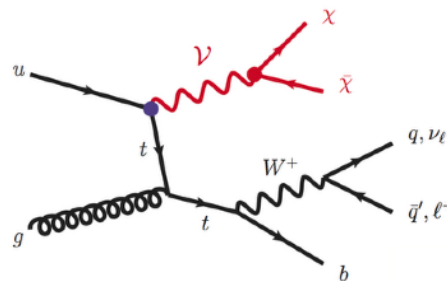
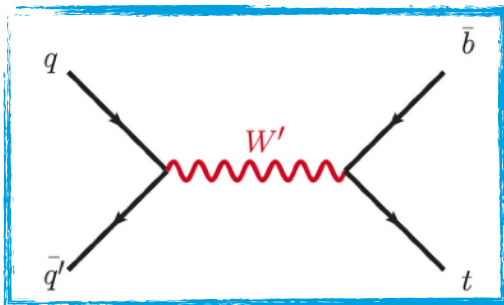
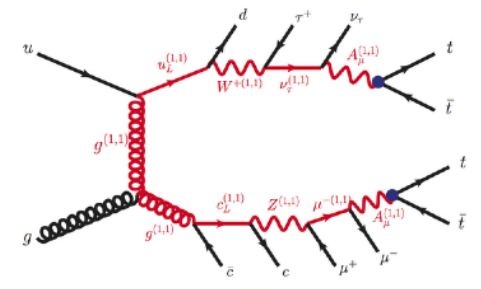
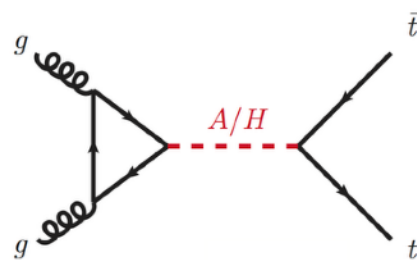
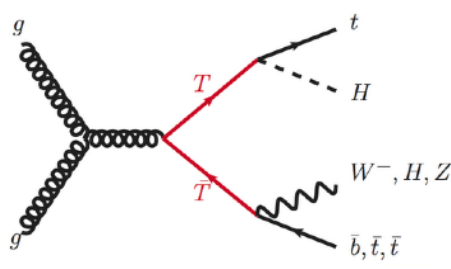
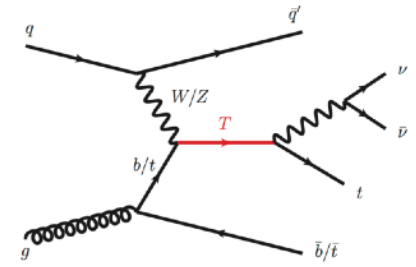
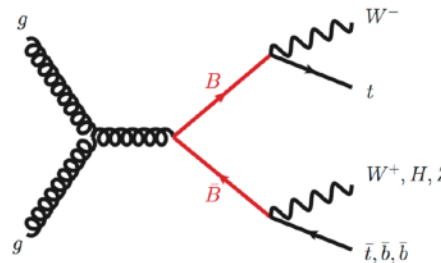
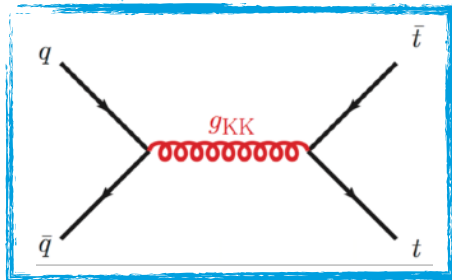
- **Large coupling** expected to BSM sector in several models



Top quark: probe for New Physics?

- Large coupling expected to BSM sector in several models

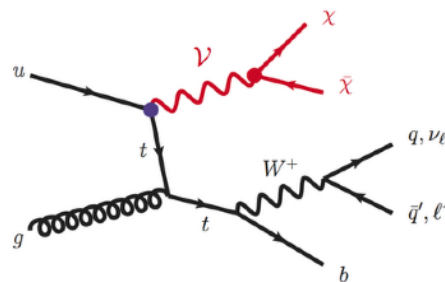
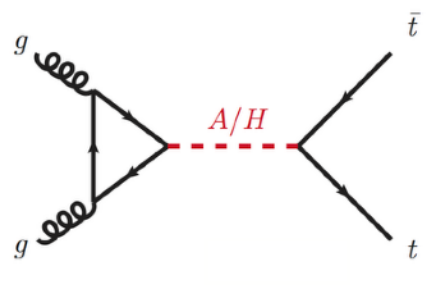
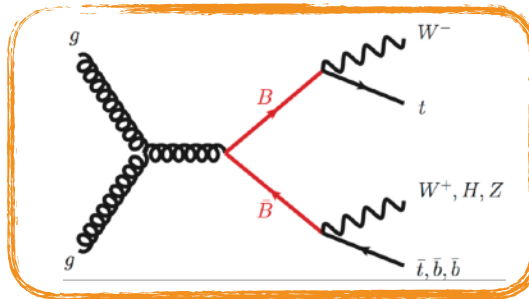
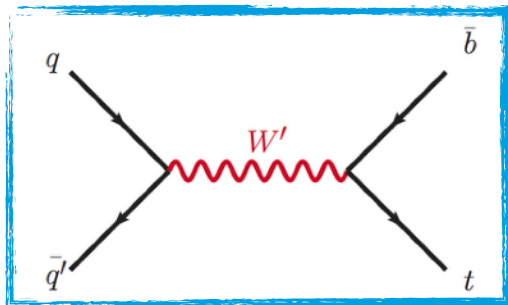
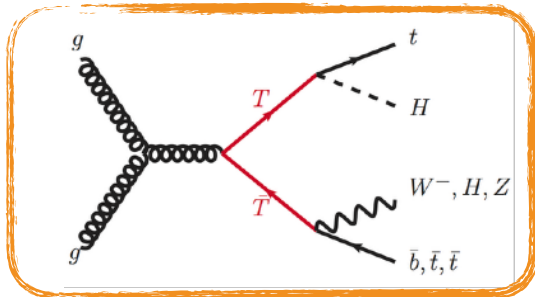
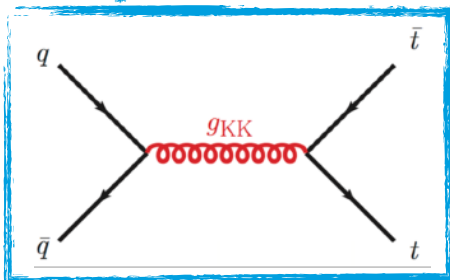
Heavy resonances



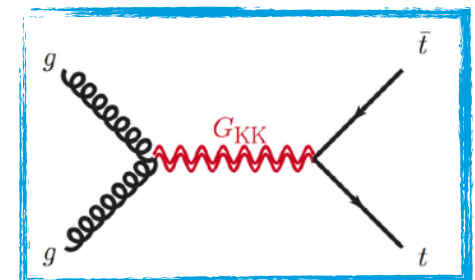
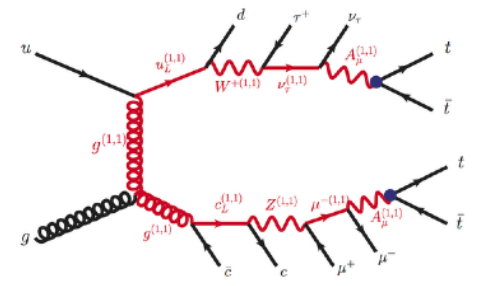
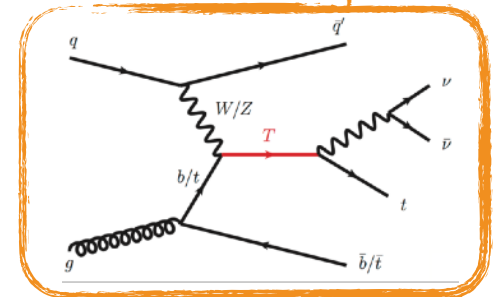
Top quark: probe for New Physics?

- Large coupling expected to BSM sector in several models

Heavy resonances



Vector-like quarks

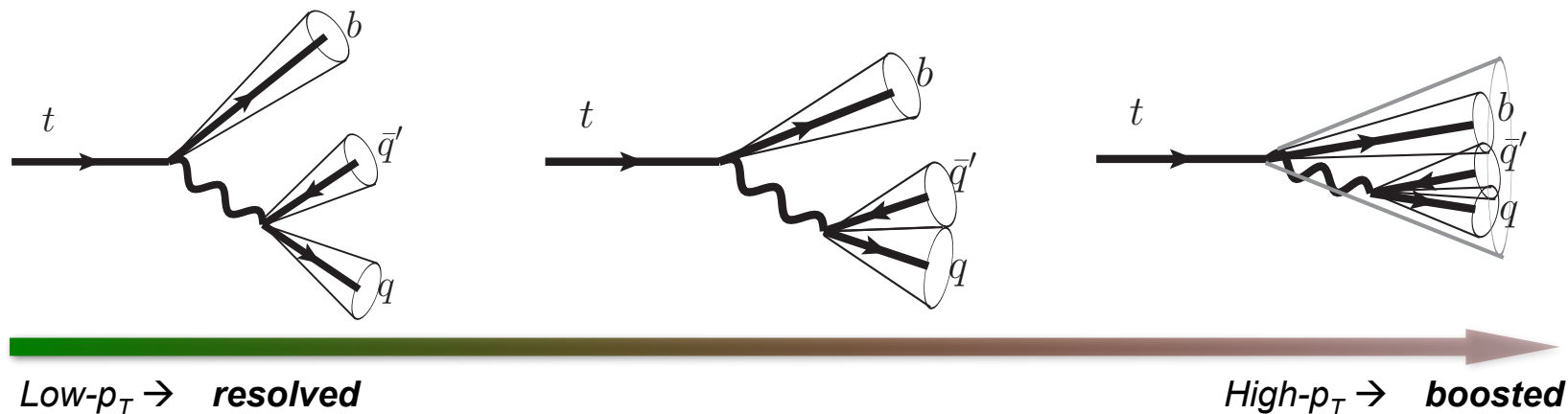


Looking for new physics with top quarks

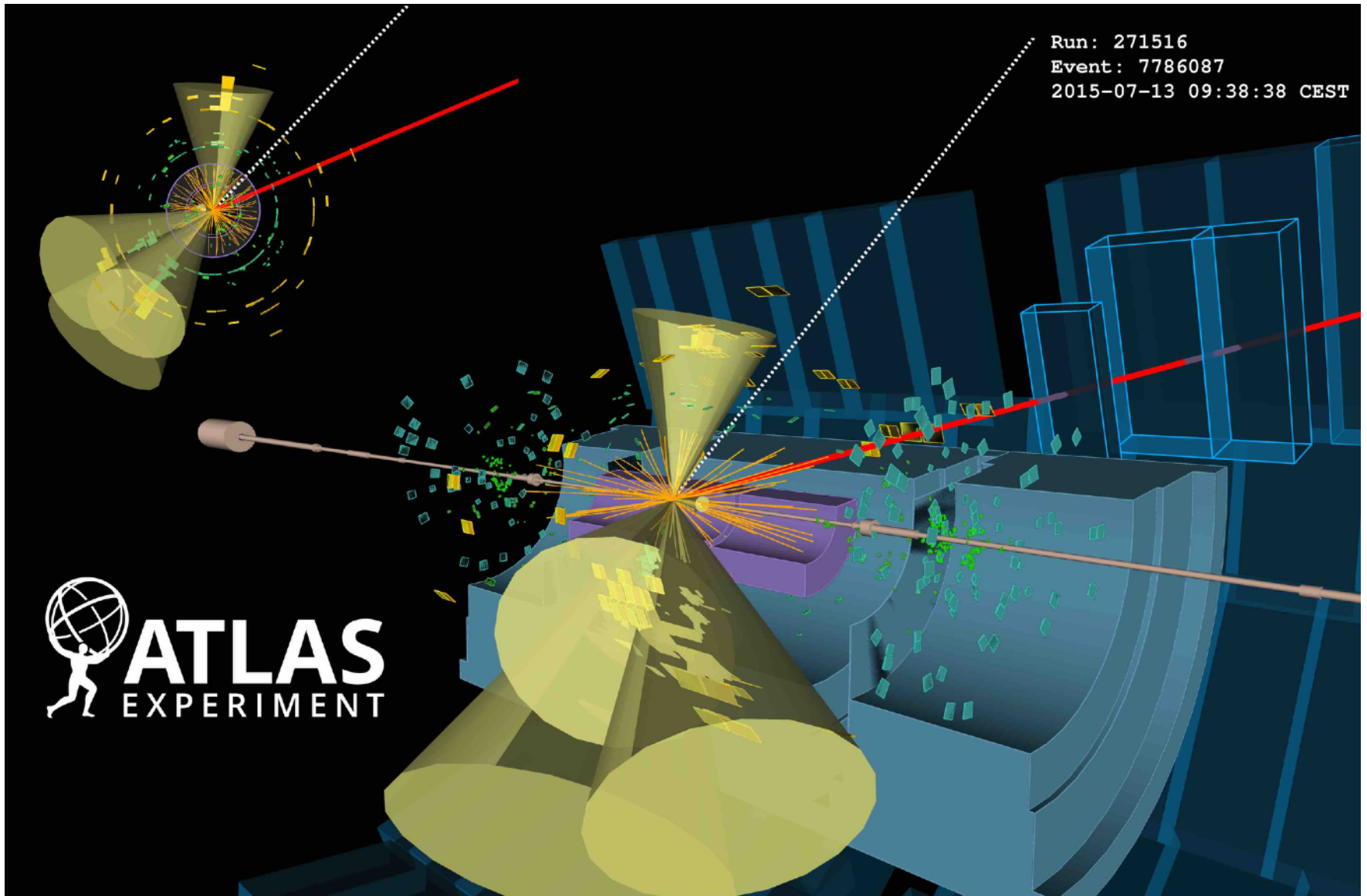
Key features

Event reconstruction

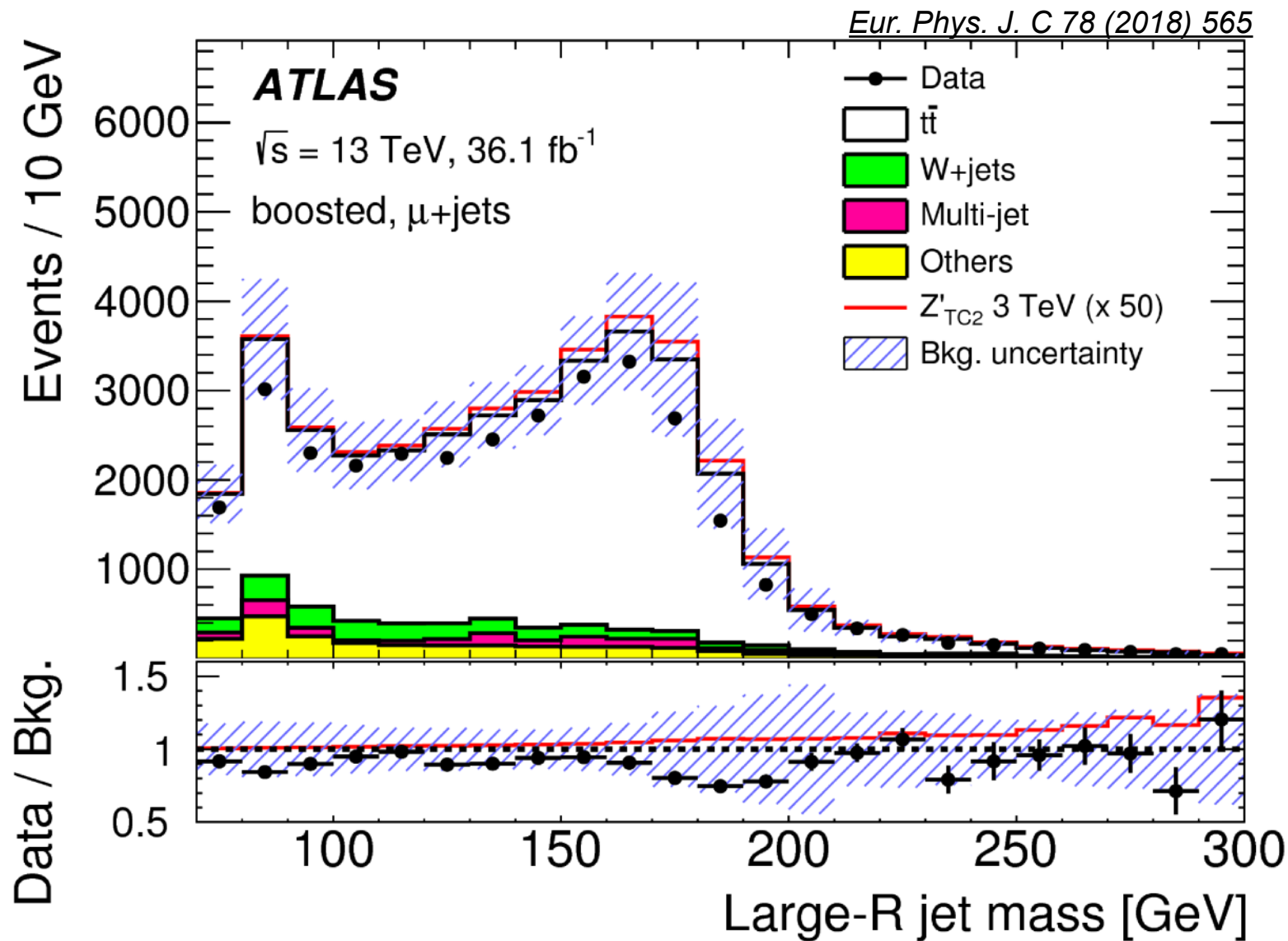
- New heavy particles: **high- p_T hadronically-decaying objects**



Event reconstruction

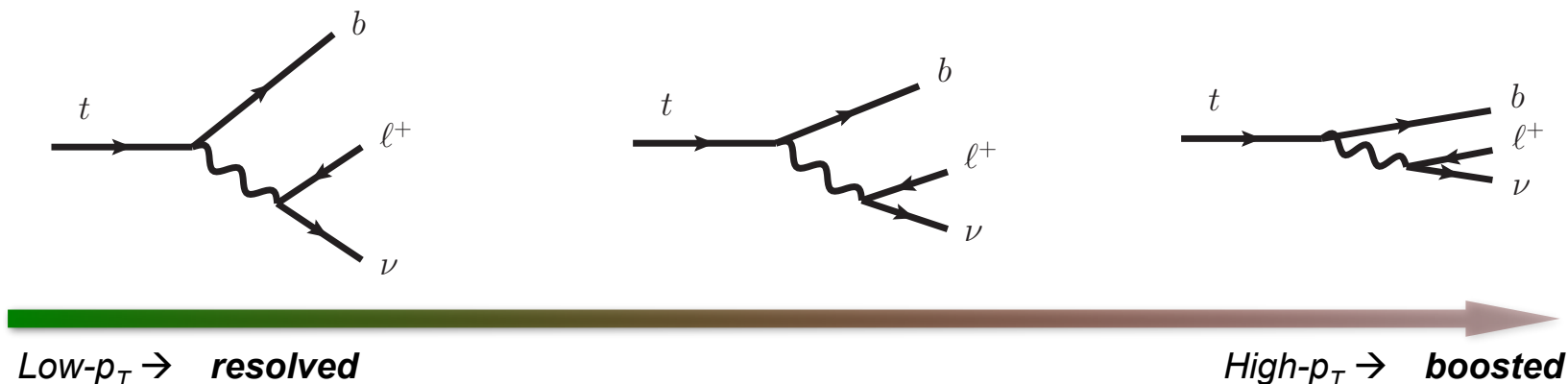


Event reconstruction



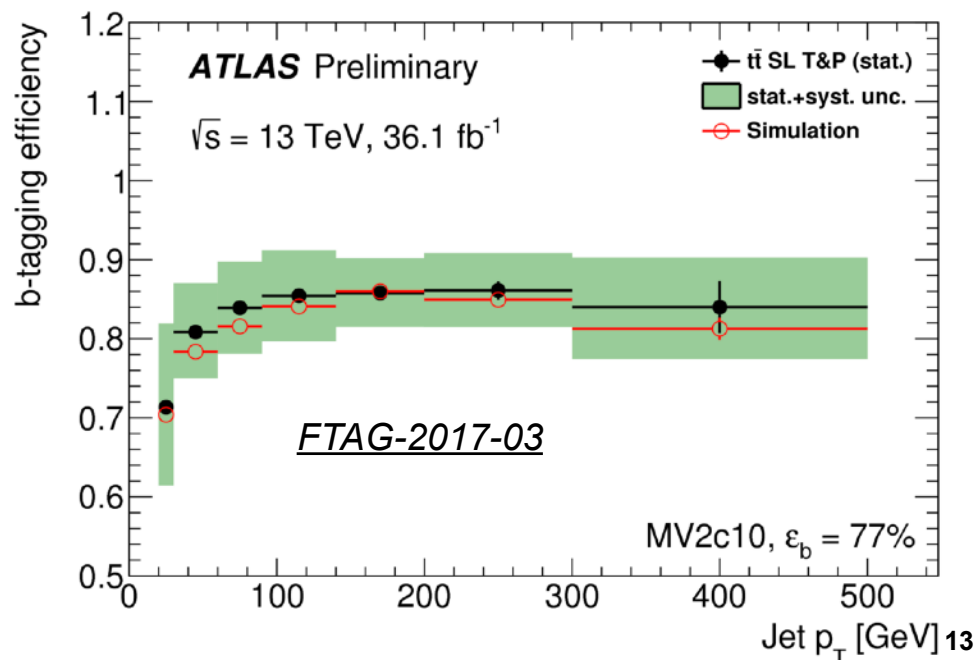
Event reconstruction

- New heavy particles: **high- p_T semi-leptonically-decaying objects**



- Key aspects**

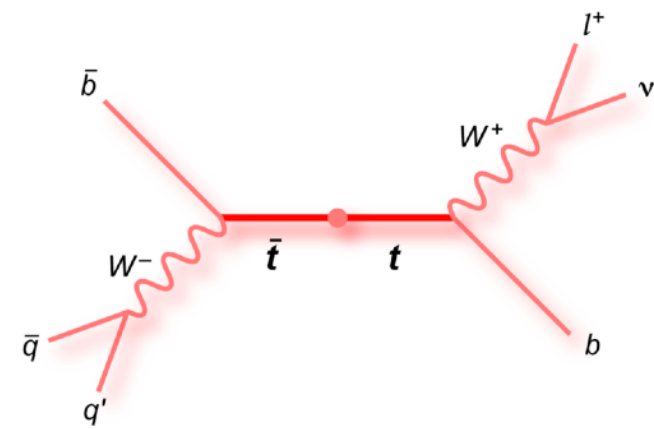
- Lepton **isolation**
- Impact of **overlapping b-jet**
- **b-jets** tagging at high- p_T



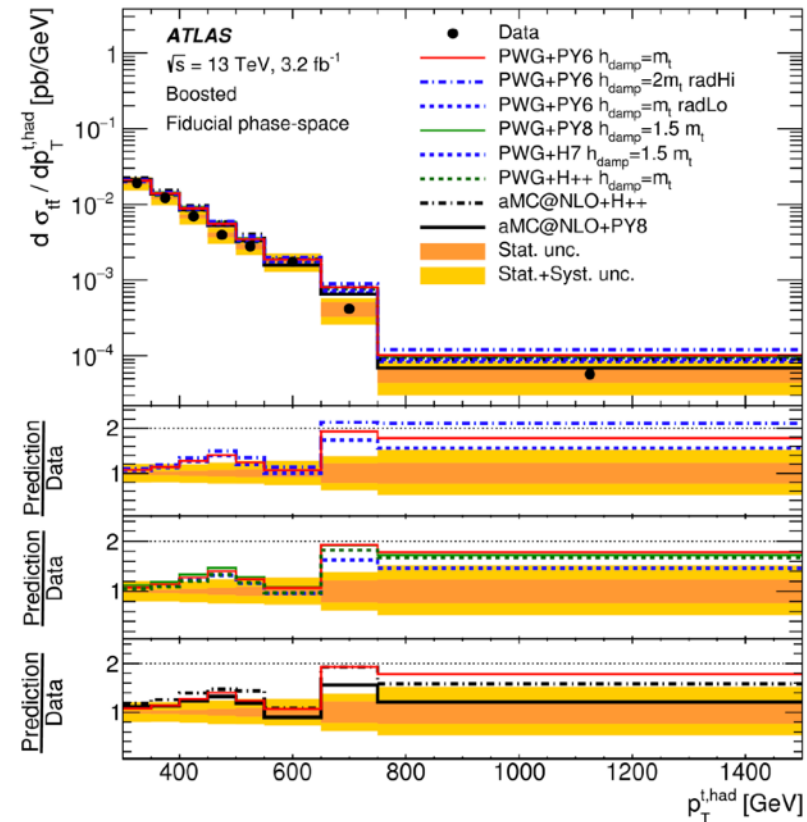
$t\bar{t}$ +jets background

- $t\bar{t}$ + jets process: often largest background source in top-enriched BSM searches
- Different types probed in searches:
 - many additional jets, b-jets
 - high- p_T top quarks
 - high- p_T top-antitop system

**Background estimation strategy
adapted to each phase space and
observable**



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Resonance searches

Resonances

- **New heavy leptophobic gauge bosons** (Z' , W' , g_{KK} , ...)
 - Several models probed (e.g. extra-dimension, SSM, Dark Matter)
 - Charge conservation: decays to $t\bar{t}$ or $t\bar{b}$

Resonances

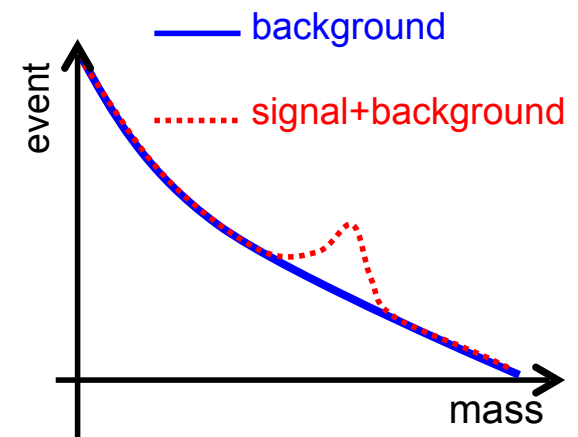
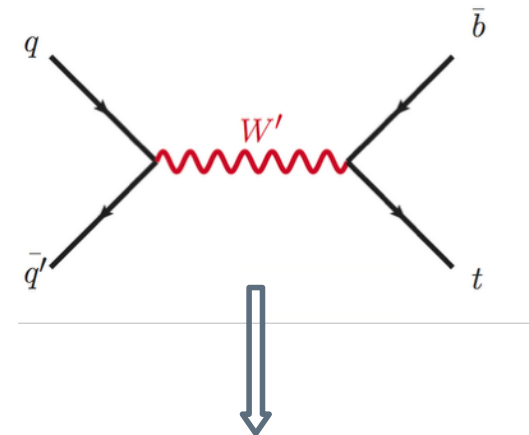
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- **Strategy**

- Continuously falling background
- New Physics → **bump on invariant mass spectrum**

- **Key aspects**

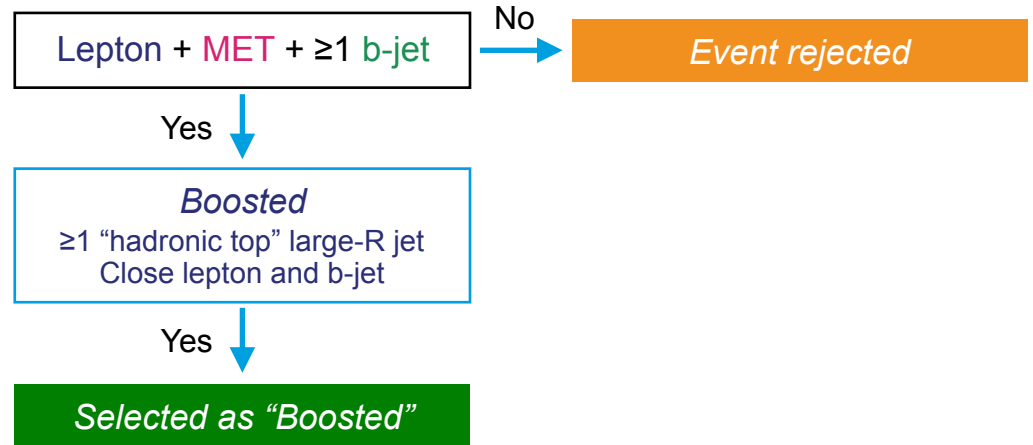
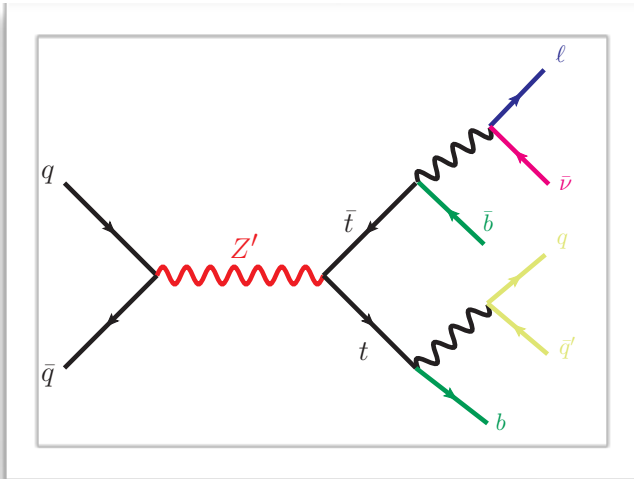
- Identification of boosted objects (e.g. boosted top quarks)
- **Reconstruction** of invariant mass
- **Background shape** modelling



$t\bar{t}$ resonances

1-lepton channel

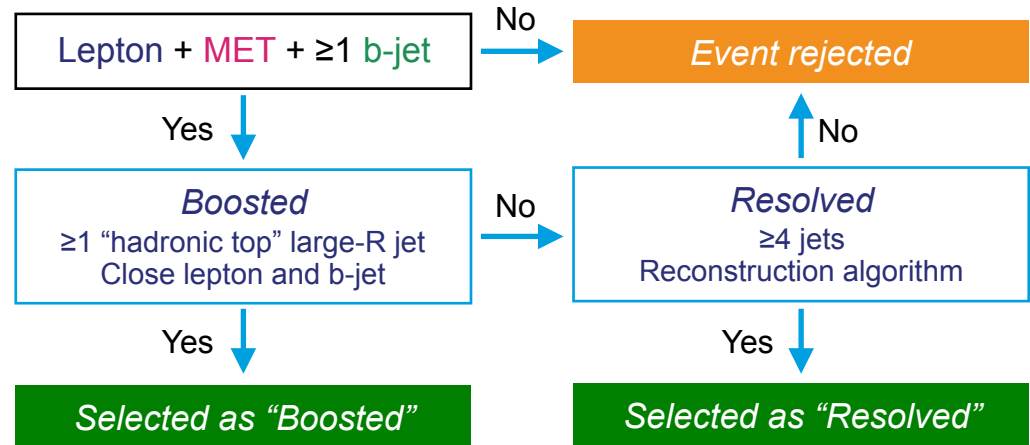
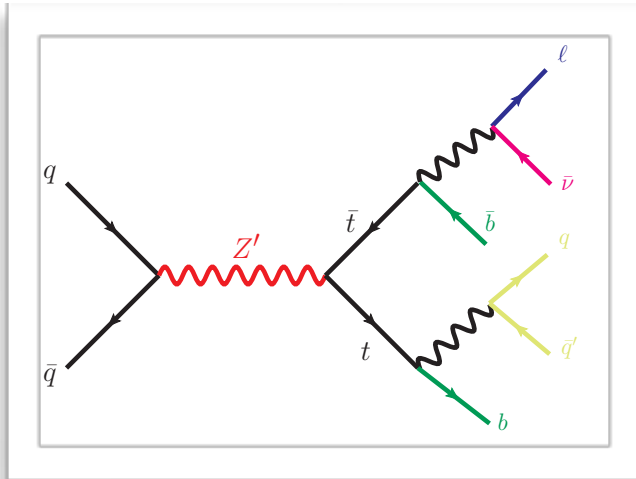
Eur. Phys. J. C 78 (2018) 565



$t\bar{t}$ resonances

1-lepton channel

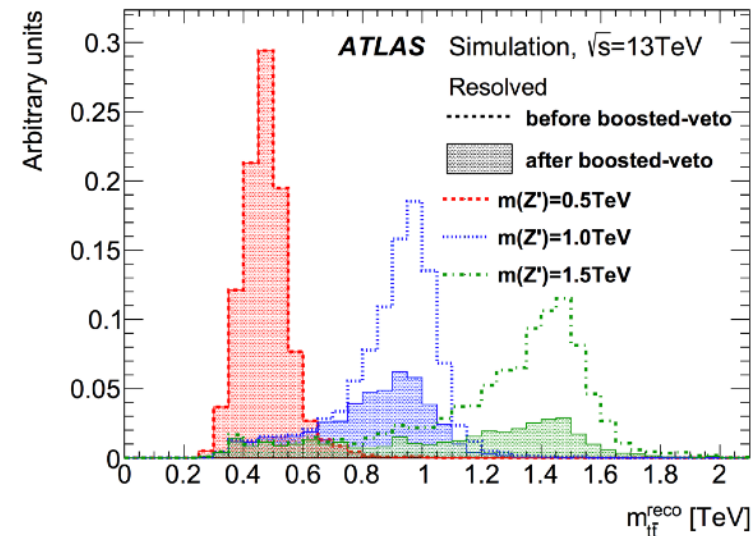
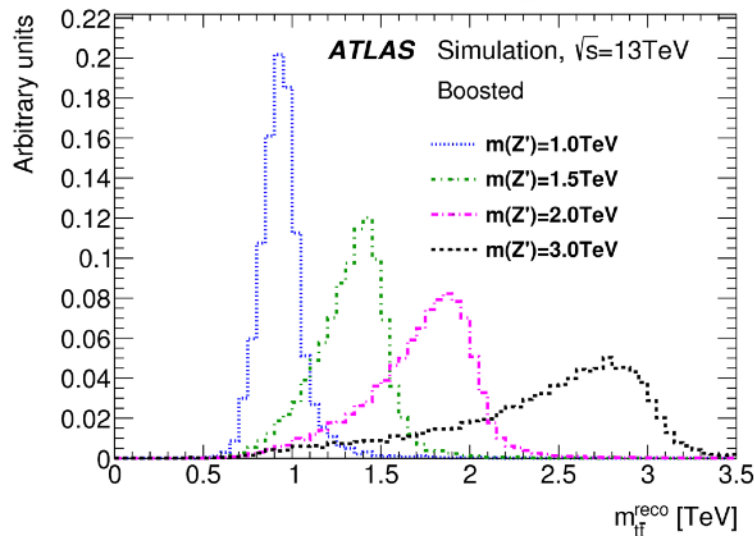
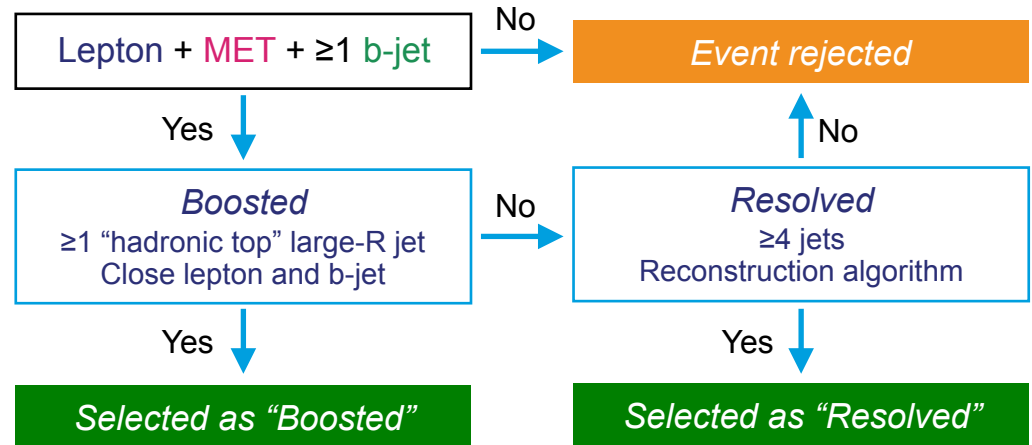
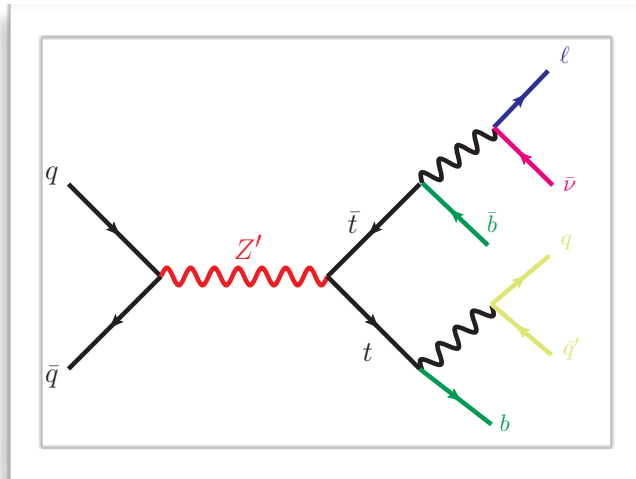
Eur. Phys. J. C 78 (2018) 565



$t\bar{t}$ resonances

1-lepton channel

Eur. Phys. J. C 78 (2018) 565

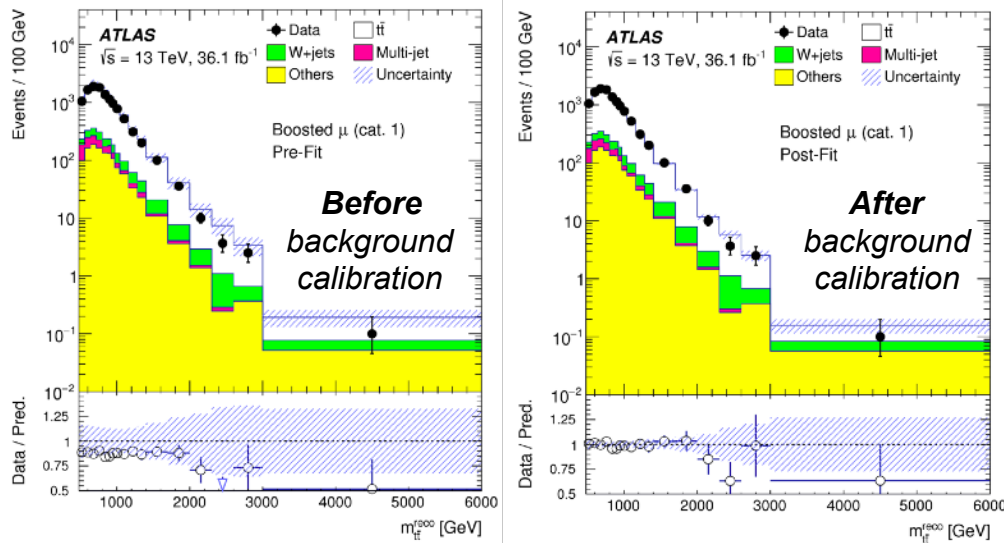


$t\bar{t}$ resonances

Eur. Phys. J. C 78 (2018) 565

1-lepton channel

- $m_{t\bar{t}}$ spectrum compared between data and background prediction
 - Data/prediction agreement can be improved → **background calibration**
 - simultaneous profile likelihood fit in all channels with all nuisance parameters

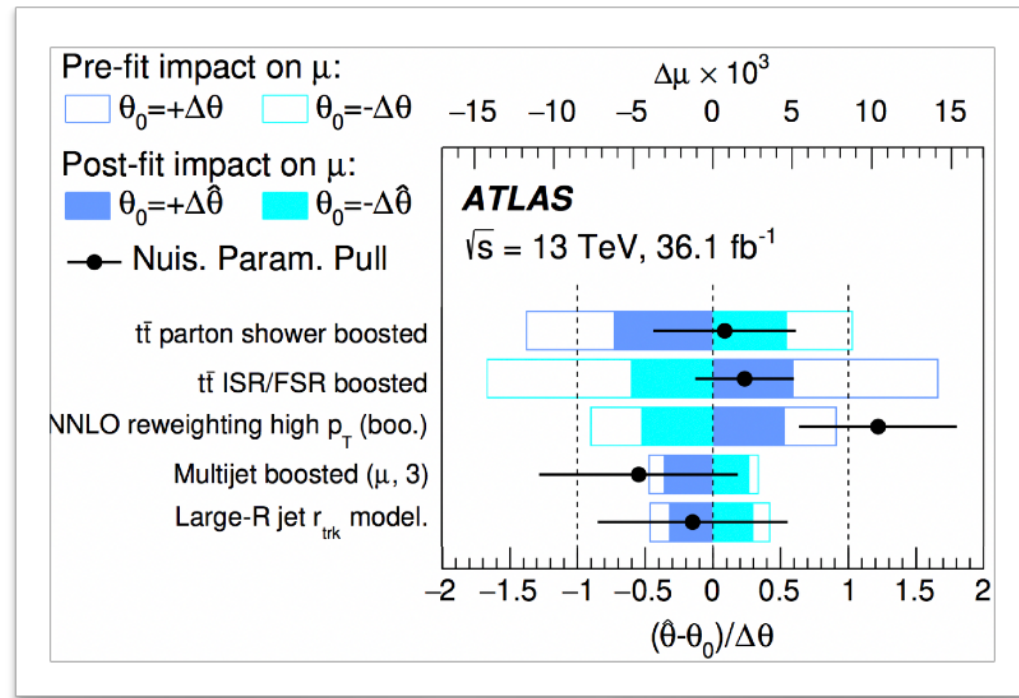


$t\bar{t}$ resonances

1-lepton channel

- Background estimate **parameters**
 - Background **normalisation**
 - MC generator **settings**
 - **Alternative** generators
- Background calibration
 - **Background model fit to data**

Eur. Phys. J. C 78 (2018) 565



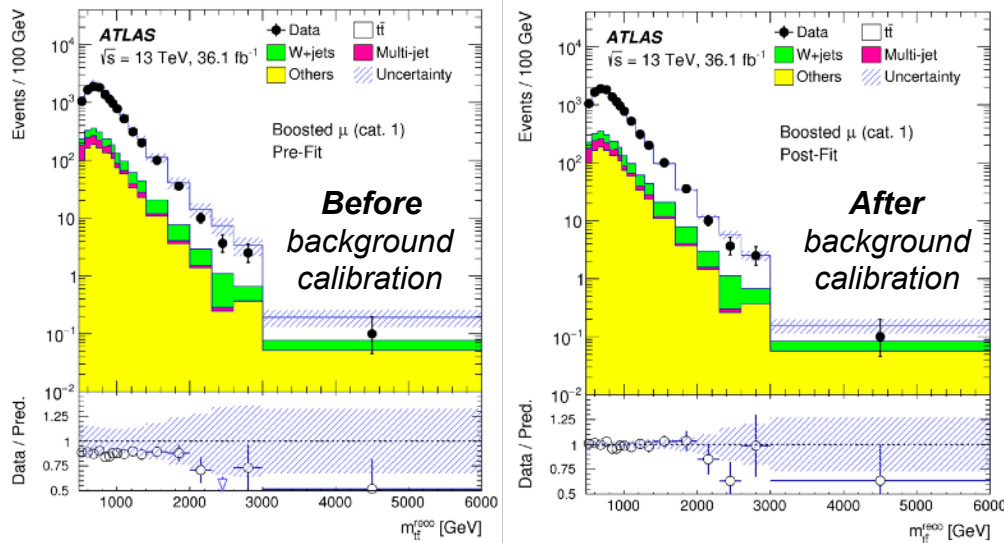
Extracted from Eur. Phys. J. C 78 (2018) 565

$t\bar{t}$ resonances

Eur. Phys. J. C 78 (2018) 565

1-lepton channel

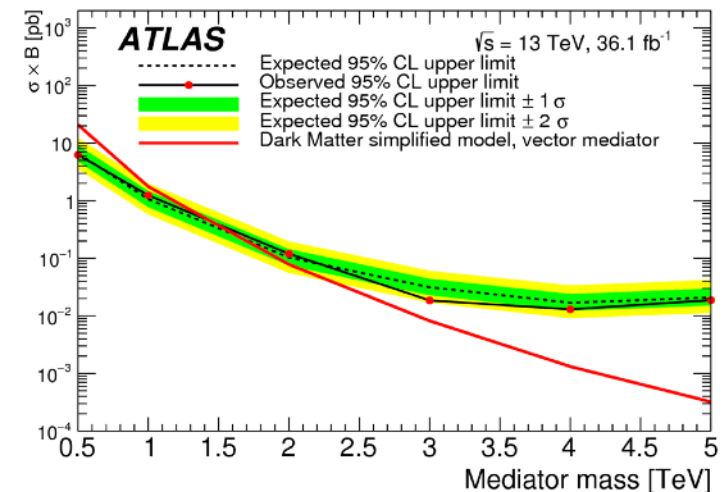
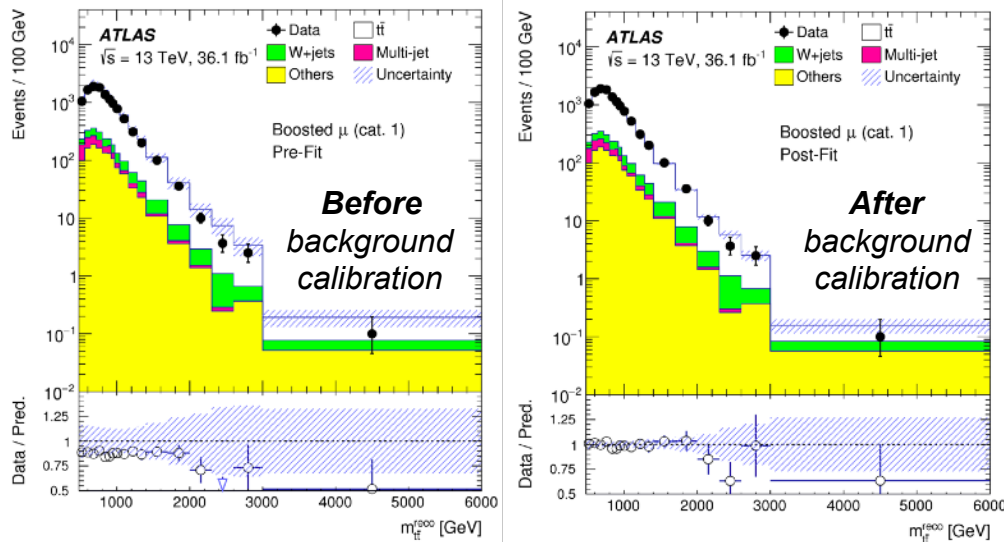
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 - After fit, **very good agreement with prediction**



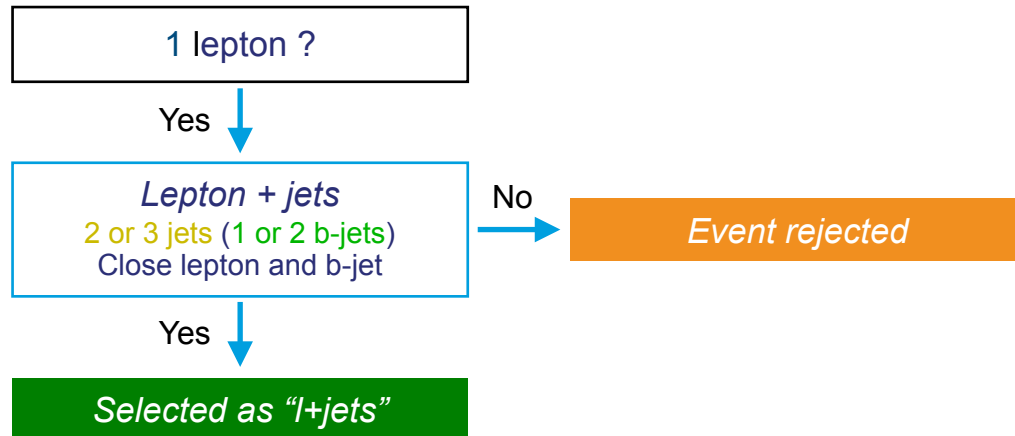
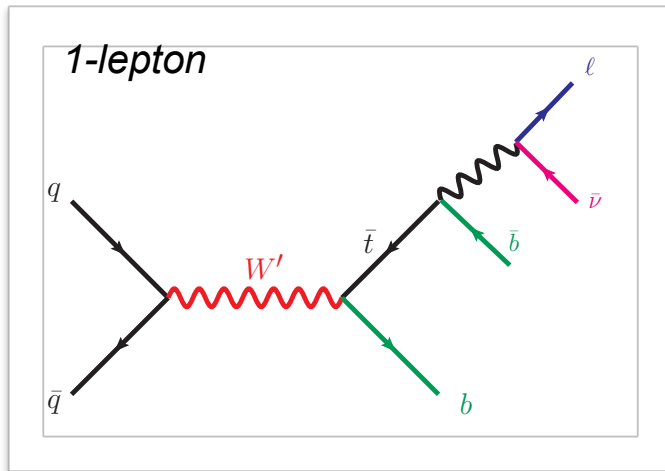
$t\bar{t}$ resonances

1-lepton channel

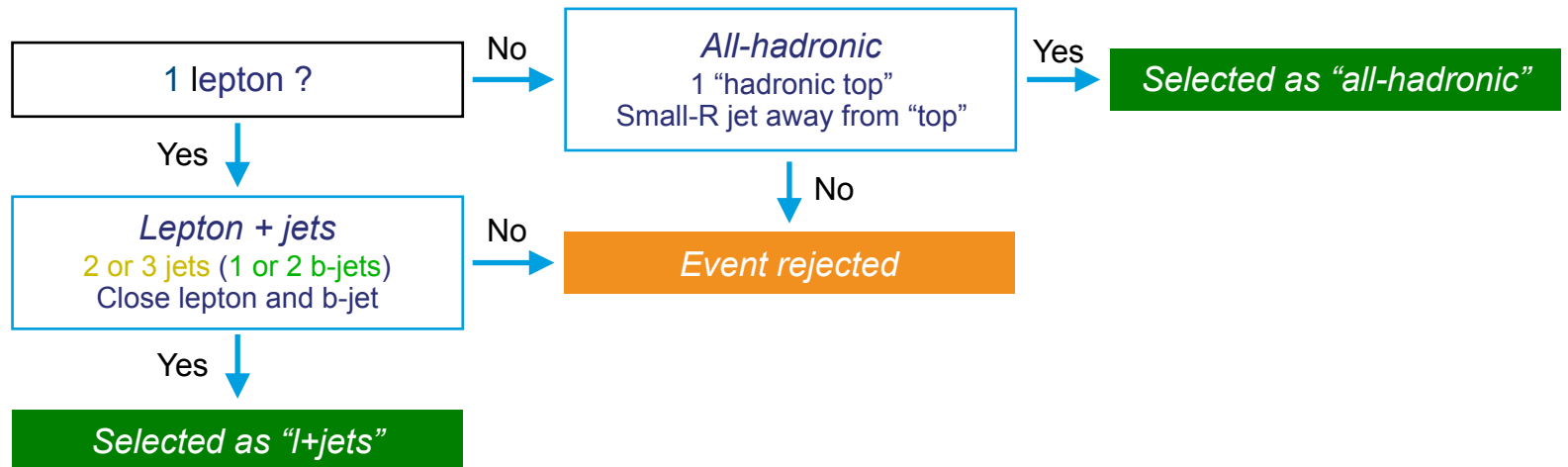
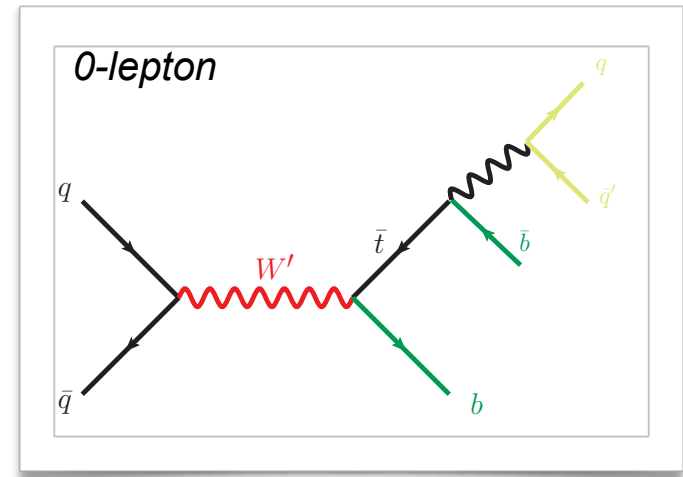
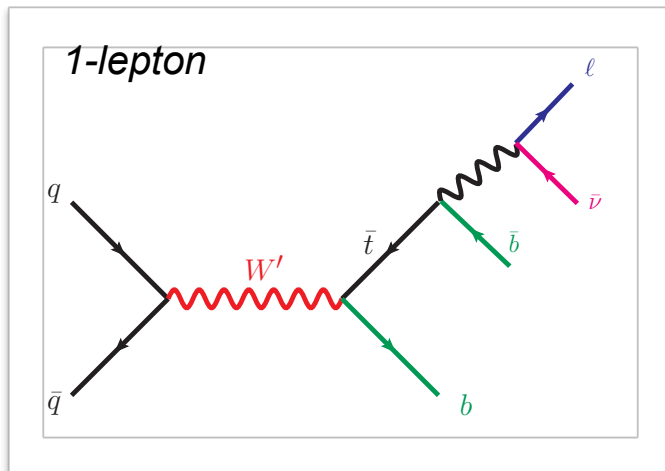
- $m_{t\bar{t}}$ spectrum compared between data and background prediction
 - Data/prediction agreement can be improved → **background calibration**
 - simultaneous profile likelihood fit in all channels with all nuisance parameters
 - After fit, **very good agreement with prediction**
- Bumps searched for in all channels → **no significant bump observed**
- CL_s limits set at 95% CL for various **models**, **masses** and **widths**



$t\bar{b}$ resonances



$t\bar{t}$ resonances

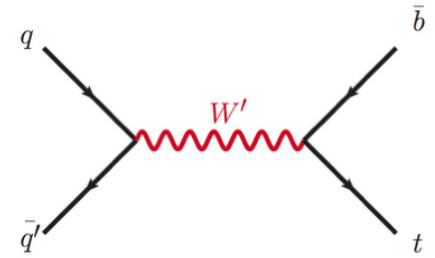


$t\bar{b}$ resonances

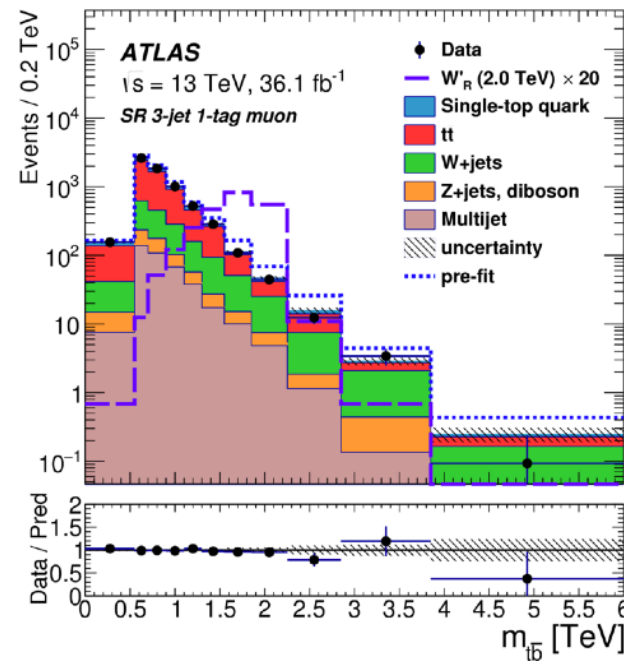
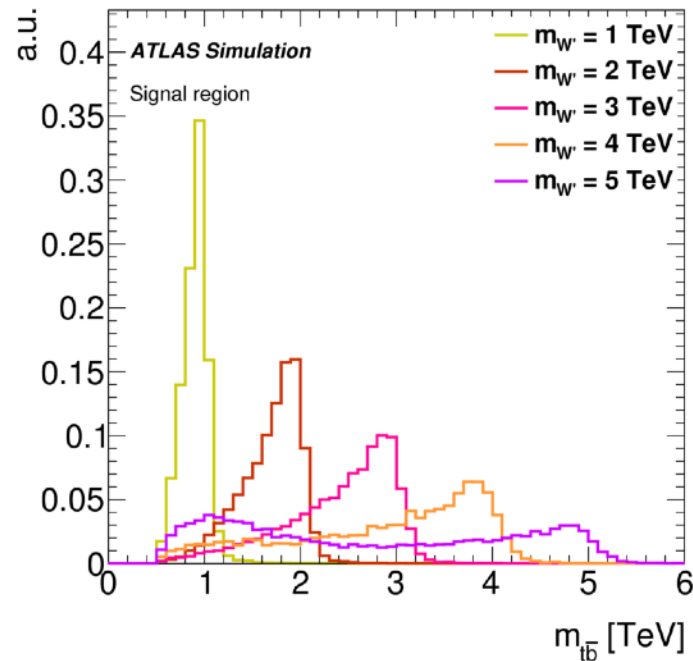
1-lepton search

arXiv:1807.10473

Accepted by PRD



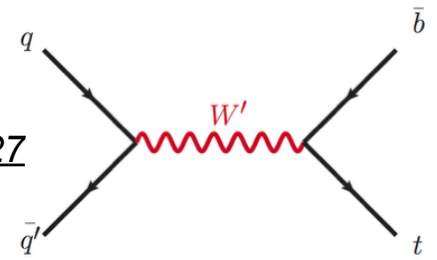
- Event **reconstruction**
 - W' candidate: combination of lepton, MET and b-jet candidate
 - Resolution effects: combinatorics and PDF
- After fit, **background prediction in good agreement with data**



$t\bar{t}$ resonances

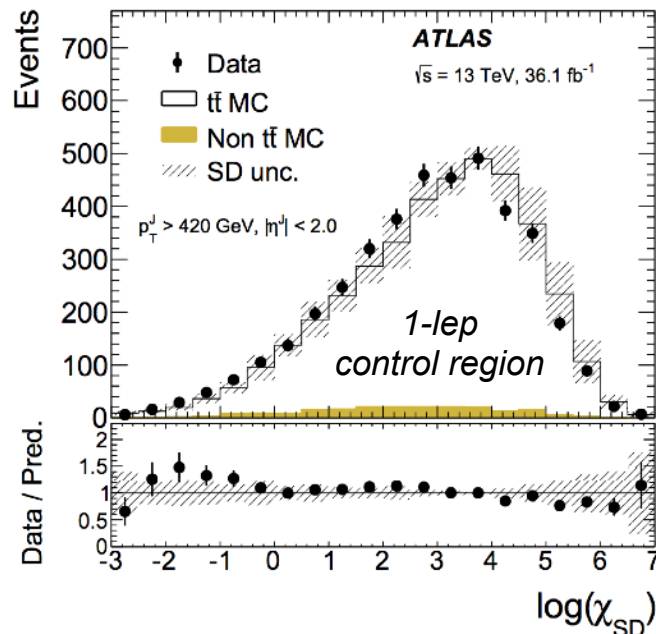
0-lepton search

Phys. Lett. B 781 (2018) 327



- **Top-tagging** algorithm

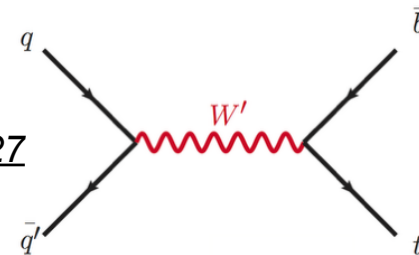
- Using **shower deconstruction** (SD) algorithm on large-R jets [*Phys. Rev. D 84, 074002*]
 - consider all possible shower histories leading to subjet configuration
 - **variable of interest** (likelihood ratio): χ_{SD}



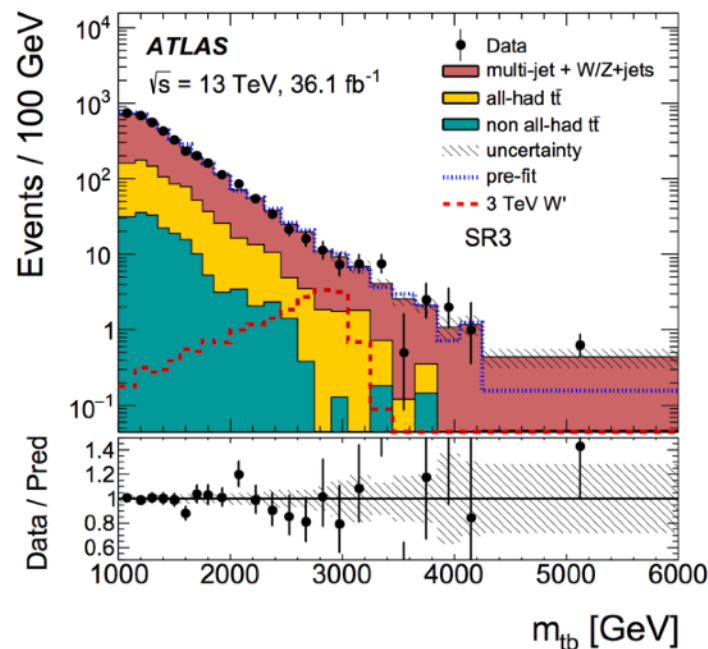
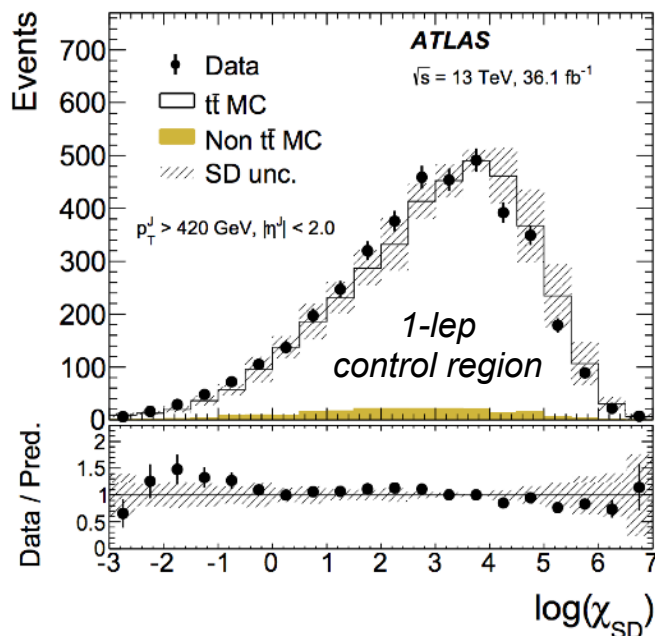
$t\bar{b}$ resonances

0-lepton search

Phys. Lett. B 781 (2018) 327



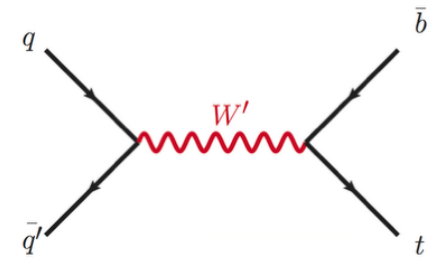
- **Top-tagging** algorithm
 - Using **shower deconstruction** (SD) algorithm on large-R jets [*Phys. Rev. D 84, 074002*]
 - consider all possible shower histories leading to subjet configuration
 - **variable of interest** (likelihood ratio): χ_{SD}
- Data-driven **multijet background** estimation
- **Very good data/prediction agreement** across all bins and regions



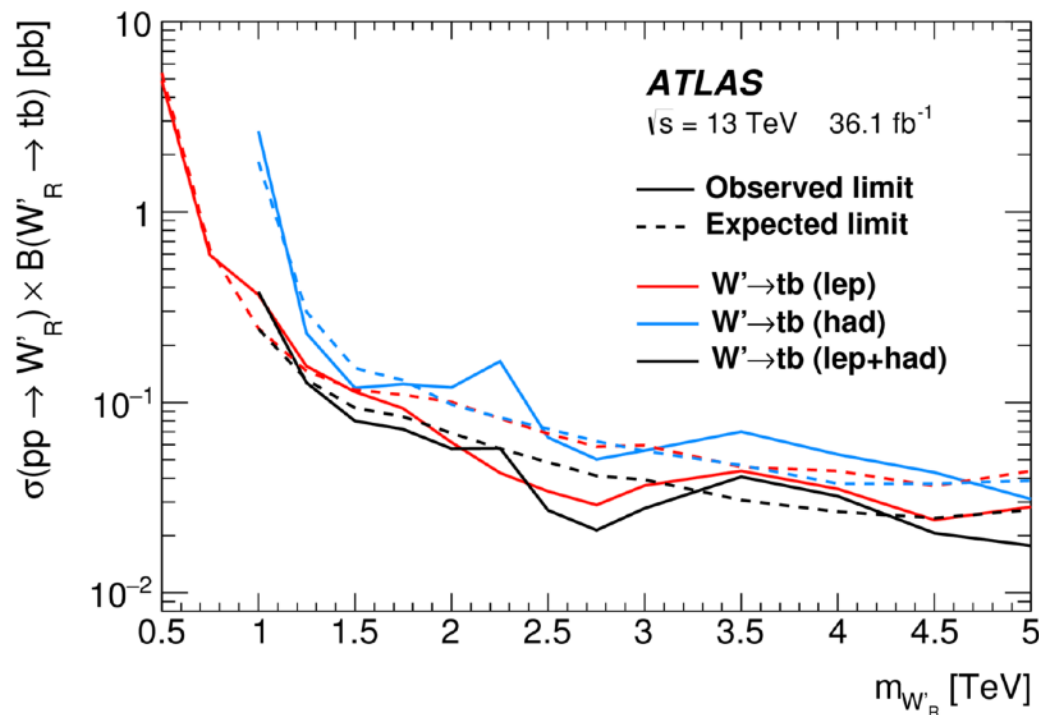
$t\bar{b}$ resonances

Combination

[arXiv:1807.10473](https://arxiv.org/abs/1807.10473)
Accepted by PRD

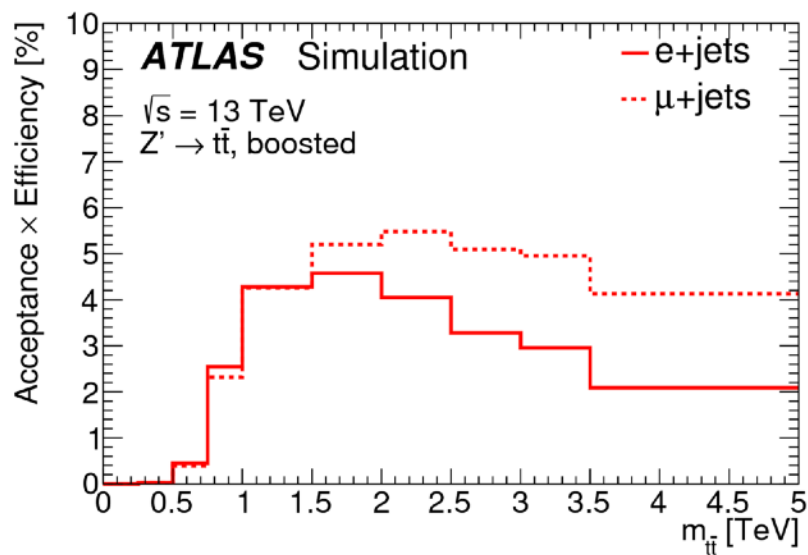
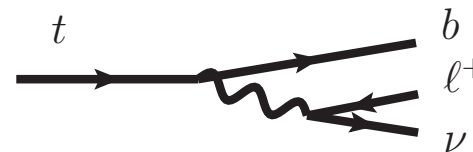


- 1- and 0-lepton searches: **similar sensitivity**
- **Different** dominating **background sources**
- Combination: **expected sensitivity improved by factor ~ 2**



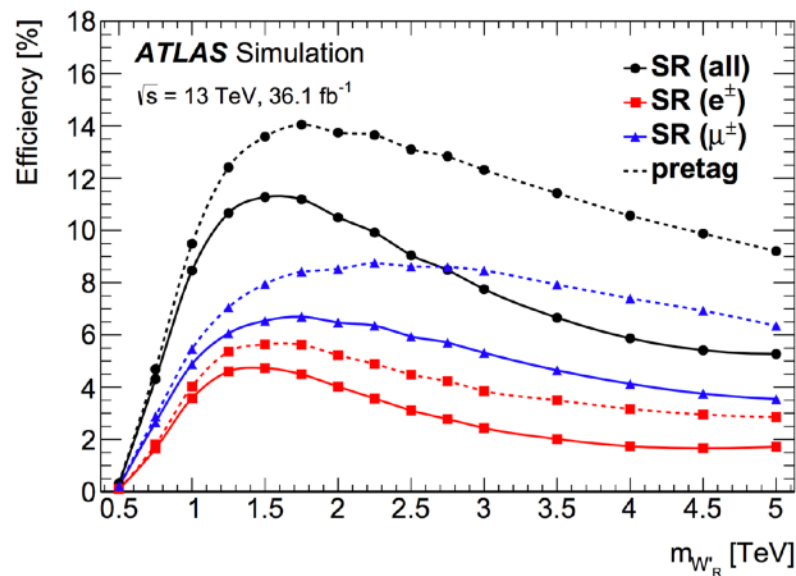
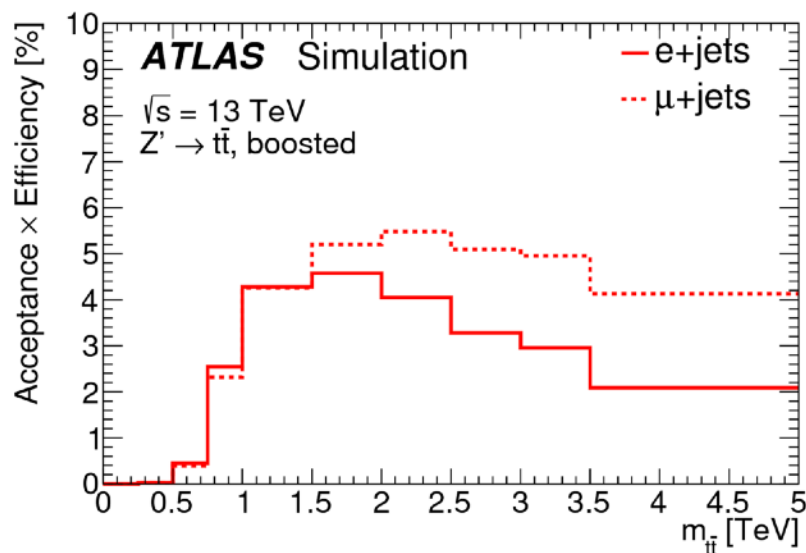
Resonances: a few lessons learnt ?

- High mass regime: statistics is limiting
- **Event selection**
 - *Electrons close to jets*: electron channel less powerful
 - *High- p_T jets b -tagging*: efficiency loss at high p_T (more likely to miss high- p_T b -jets)



Resonances: a few lessons learnt ?

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- **Improvements** ongoing for next generation (e.g. [ATL-PHYS-PUB-2017-013](#))

Vector-like quark searches

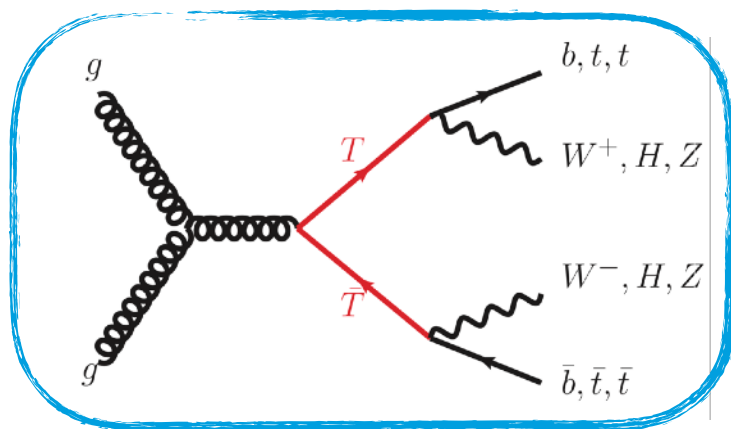
Vector-like quarks

- **Heavy quarks** for which **left-** and **right-handed** chirality components transform the same under $SU(2)$
 - Predicted in **many theories** (extra-dimensions, Higgs compositeness, ...)
 - Gauge invariant mass term

Vector-like quarks

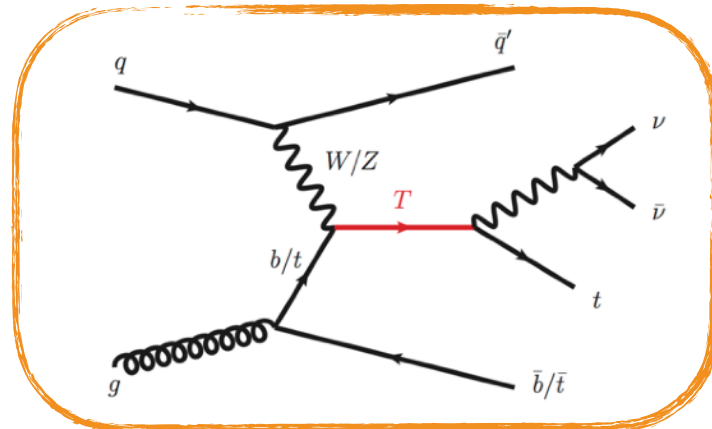
- **Heavy quarks** for which **left-** and **right-handed** chirality components transform the same under $SU(2)$
 - Predicted in **many theories** (extra-dimensions, Higgs compositeness, ...)
 - Gauge invariant mass term

Pair-production



- Production $\sim$ independent on VLQ coupling to SM partners
- Dominant for **low masses**

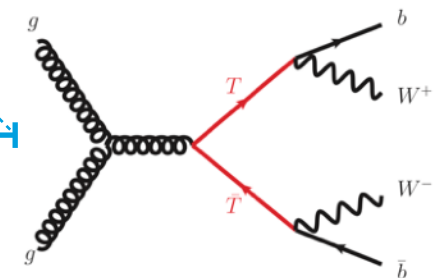
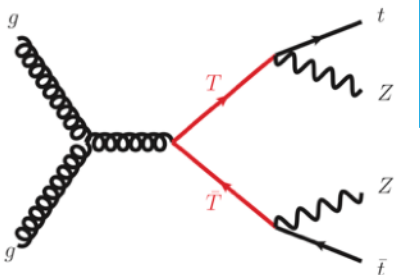
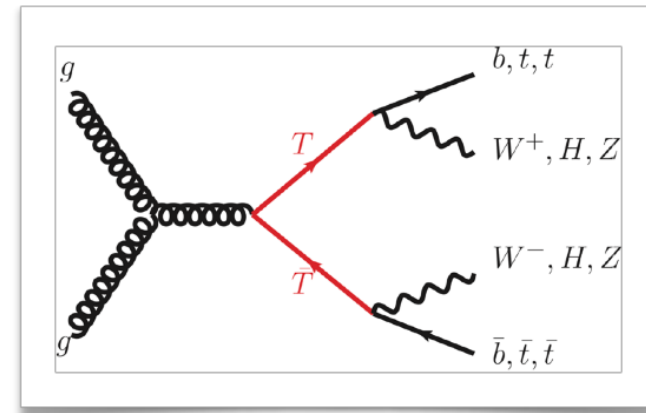
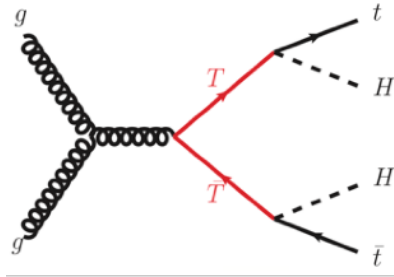
Single-production



- Cross-section depends on VLQ coupling assumptions
- Can be dominant for **high masses**

Pair-production searches

Decay configurations

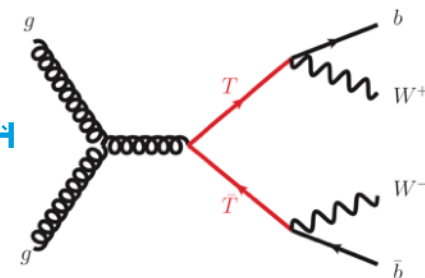
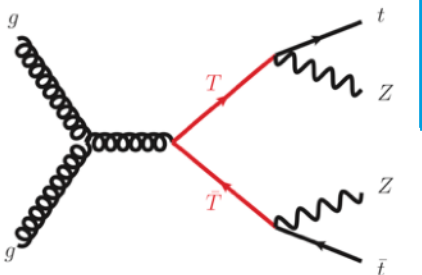
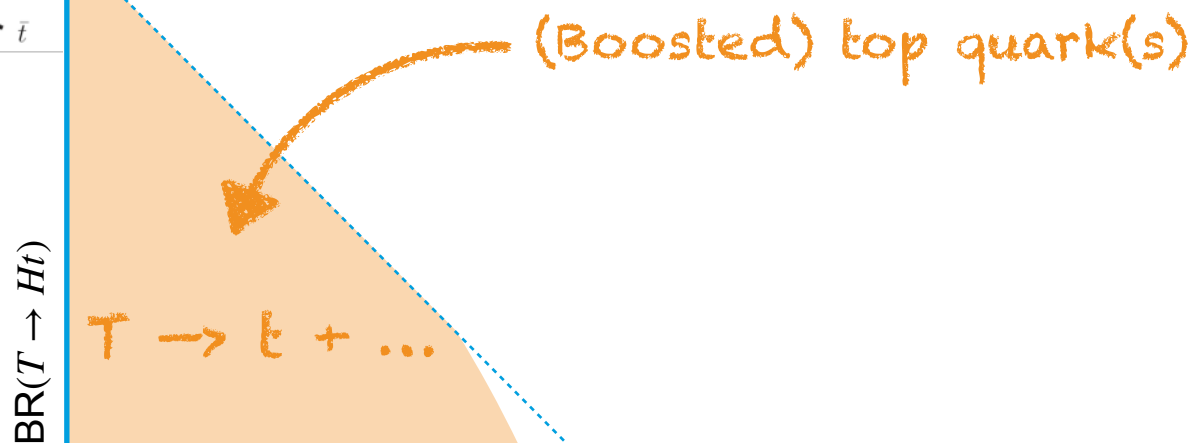
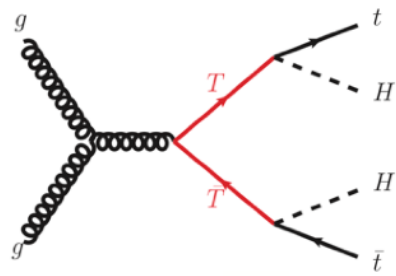
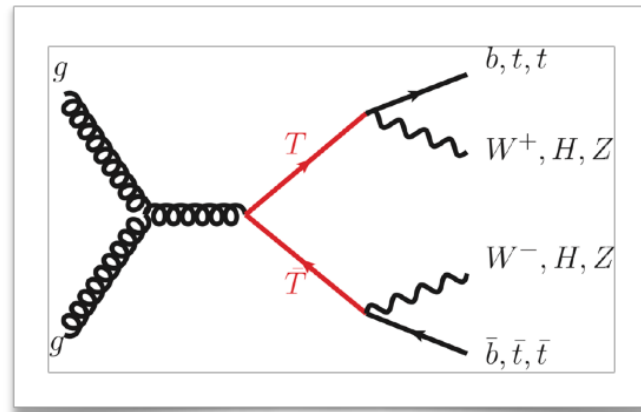


$BR(T \rightarrow Ht)$

$BR(T \rightarrow Wb)$

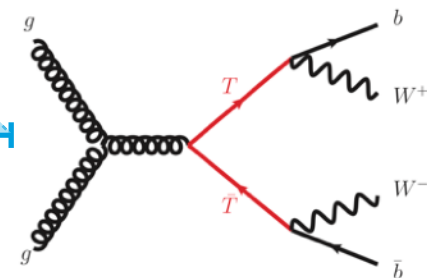
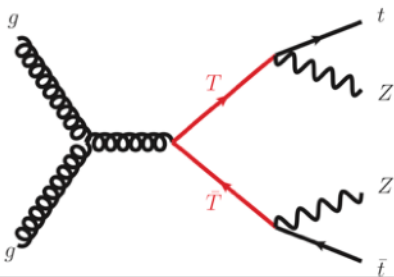
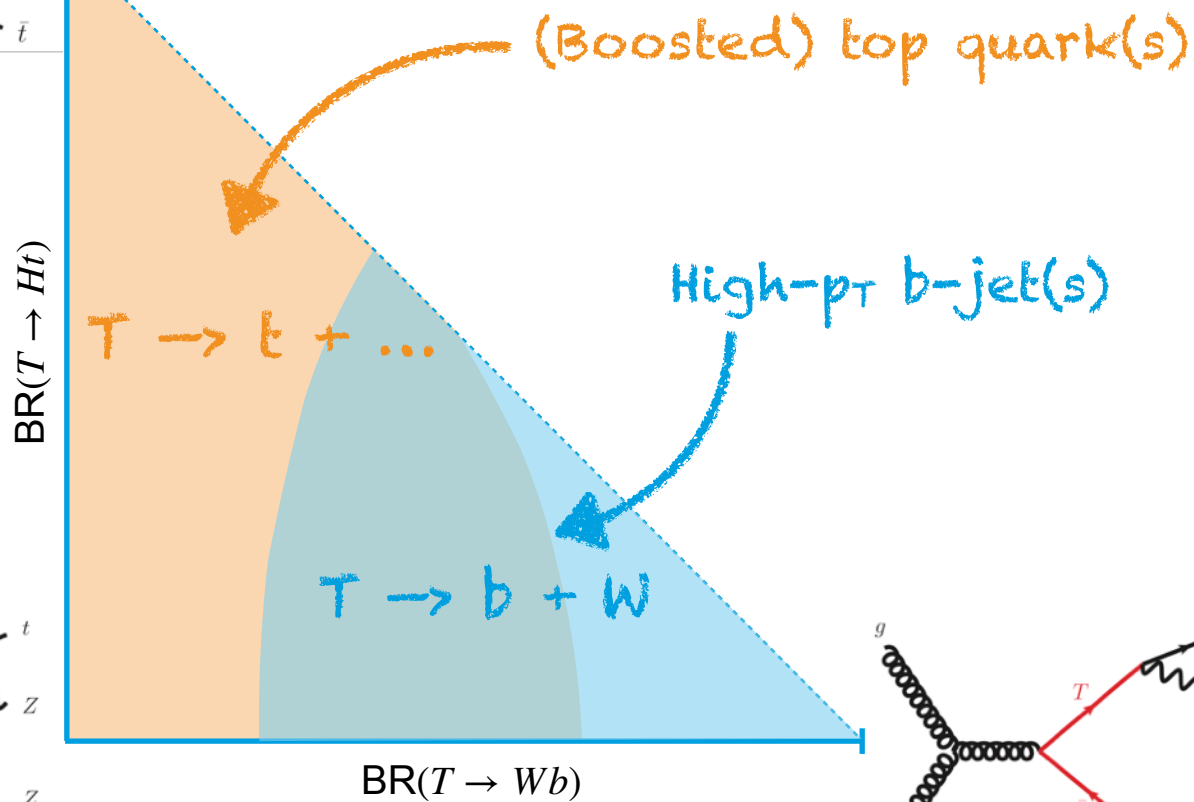
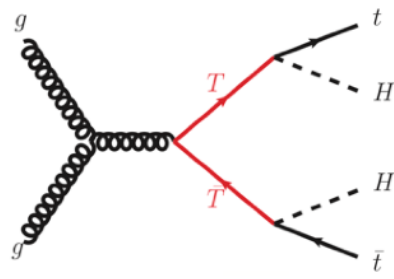
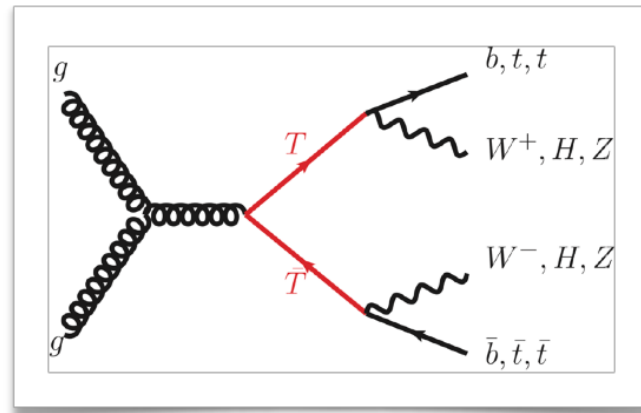
Pair-production searches

Decay configurations



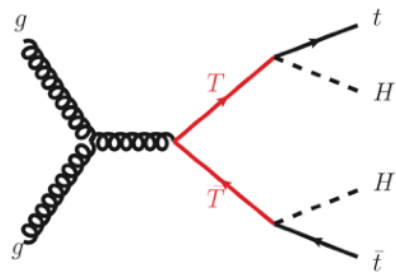
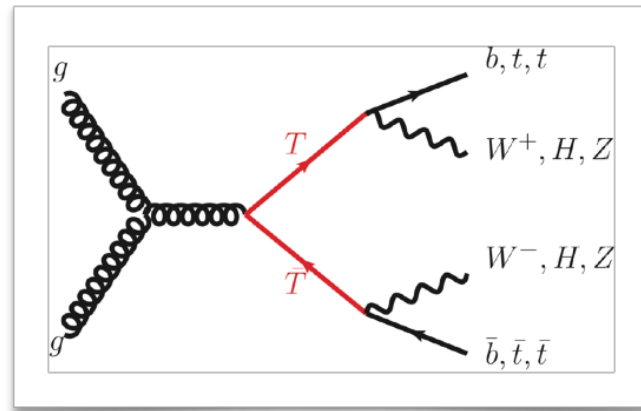
Pair-production searches

Decay configurations



Pair-production searches

Decay configurations



$H \rightarrow b\bar{b}$
 $H \rightarrow WW^*$

(Boosted) top quark(s)

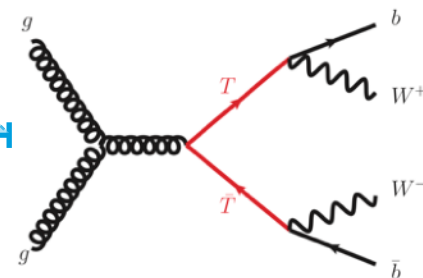
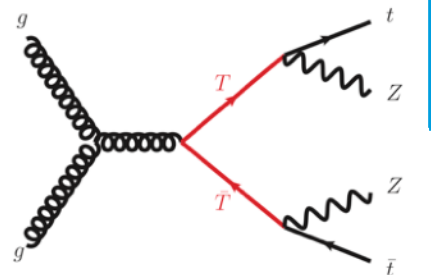
$BR(T \rightarrow Ht)$

$T \rightarrow t + \dots$

High- p_T b-jet(s)

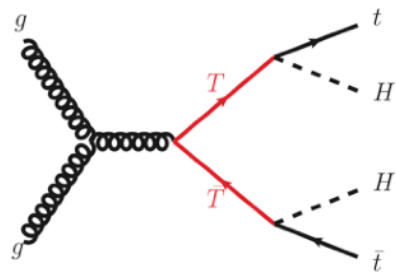
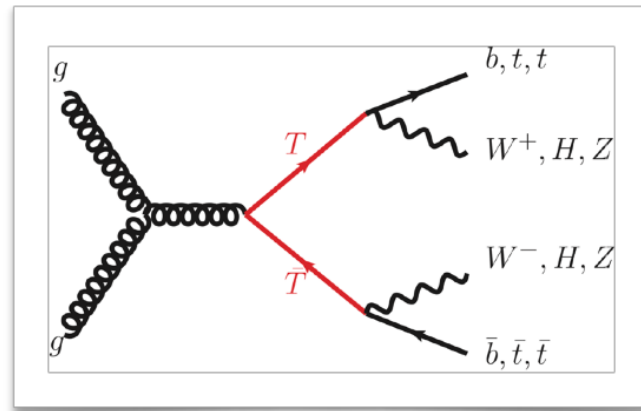
$T \rightarrow b + W$

$BR(T \rightarrow Wb)$



Pair-production searches

Decay configurations



$H \rightarrow b\bar{b}$
 $H \rightarrow WW^*$

(Boosted) top quark(s)

$BR(T \rightarrow Ht)$

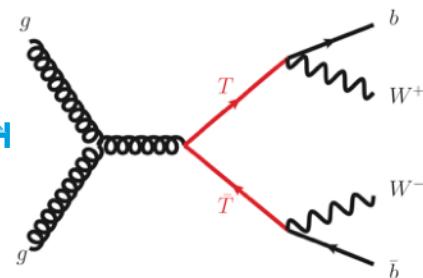
$T \rightarrow t + \dots$

High- p_T b-jet(s)

$T \rightarrow b + W$

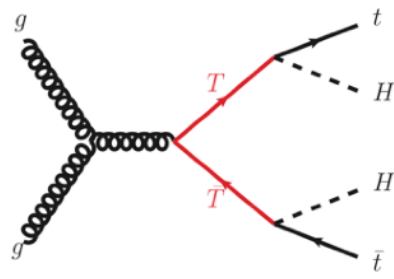
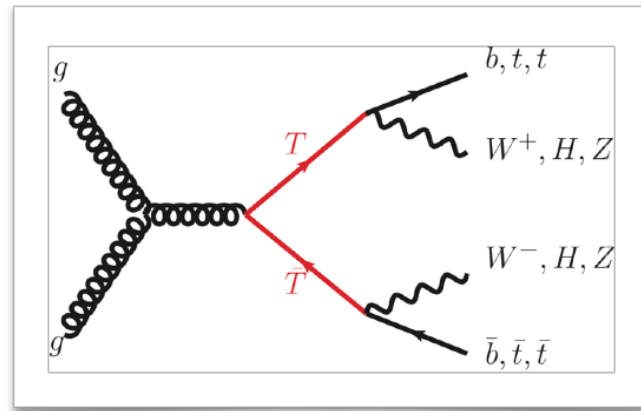
$Z \rightarrow \ell\ell$
 $Z \rightarrow \nu\nu$
 $Z \rightarrow q\bar{q}$

$BR(T \rightarrow Wb)$



Pair-production searches

Decay configurations



$H \rightarrow b\bar{b}$
 $H \rightarrow WW^*$

(Boosted) top quark(s)

$BR(T \rightarrow Ht)$

$T \rightarrow t + \dots$

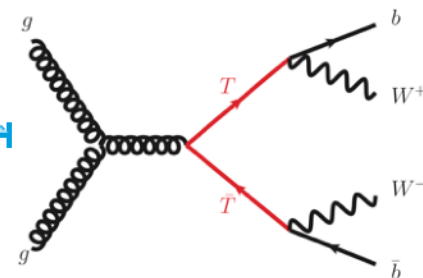
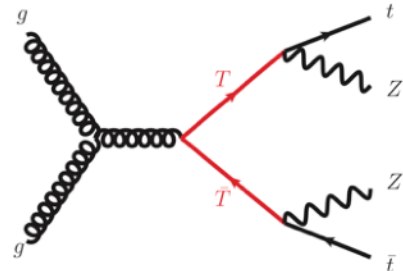
High- p_T b-jet(s)

$T \rightarrow b + W$

$Z \rightarrow \ell\ell$
 $Z \rightarrow \nu\nu$
 $Z \rightarrow q\bar{q}$

$W \rightarrow q\bar{q}'$
 $W \rightarrow l\nu$

$BR(T \rightarrow Wb)$

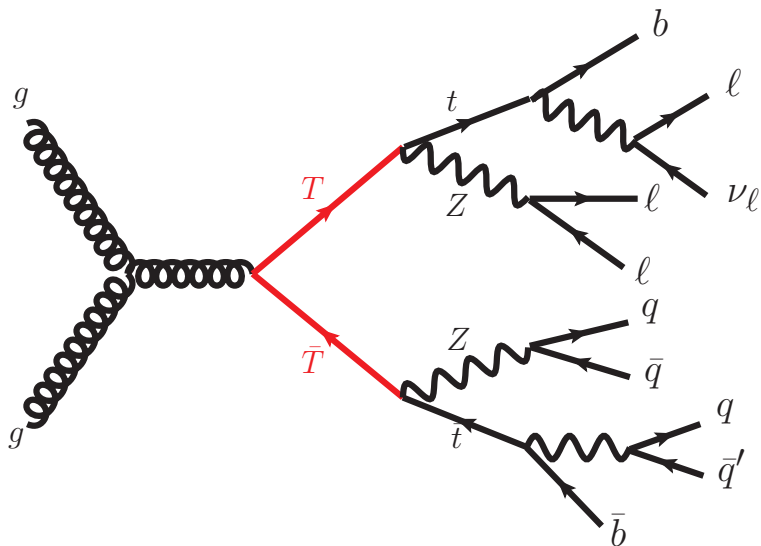


Pair-production searches

Signatures

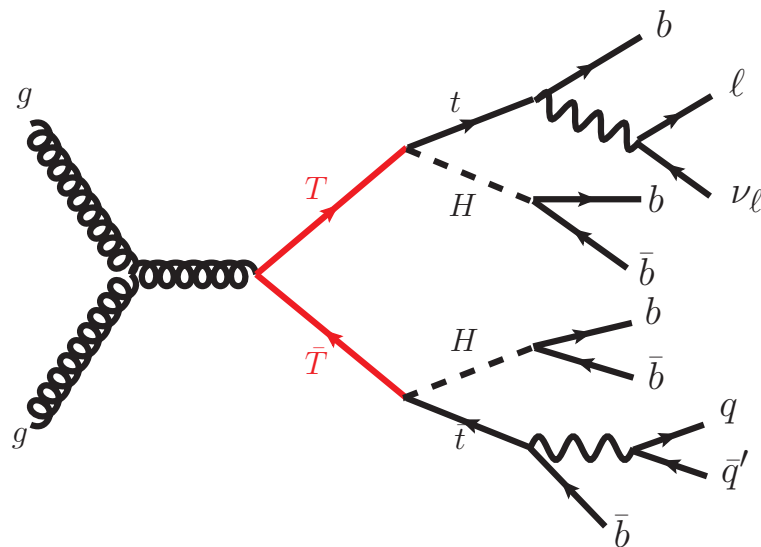
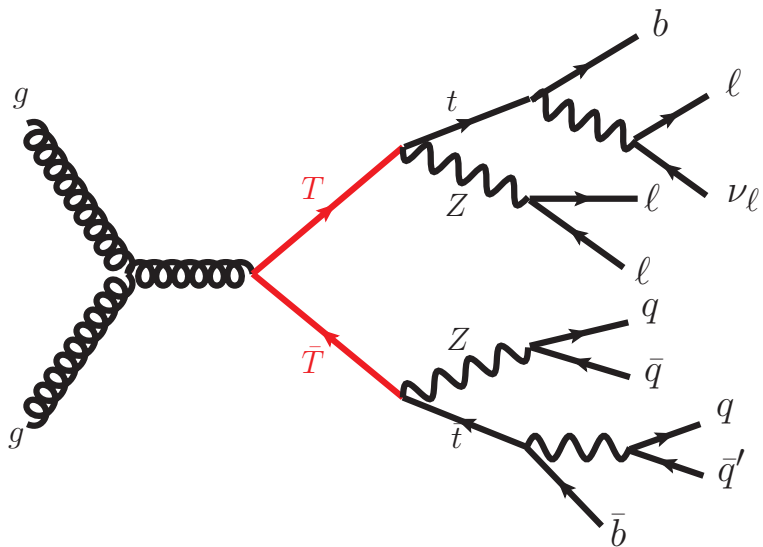
Pair-production searches

Signatures



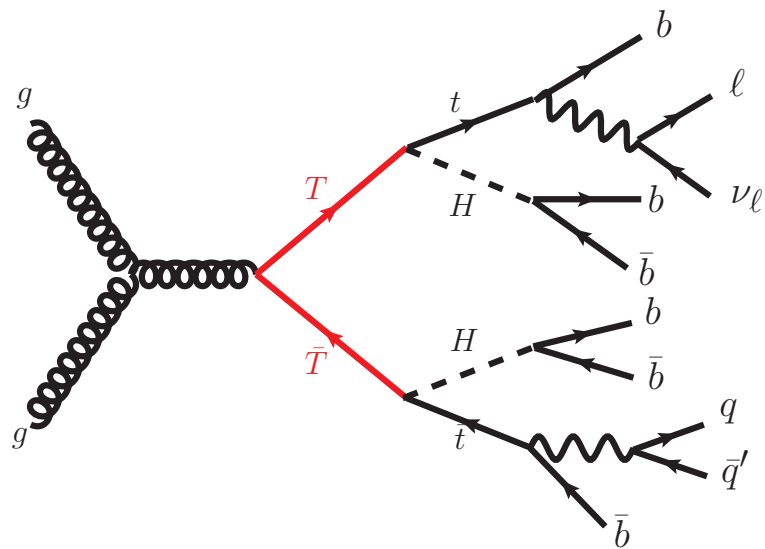
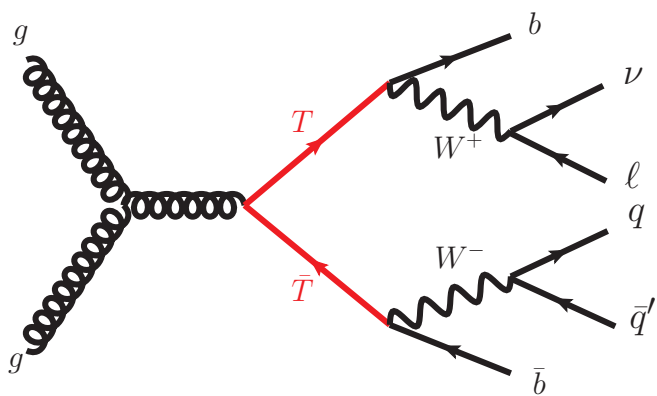
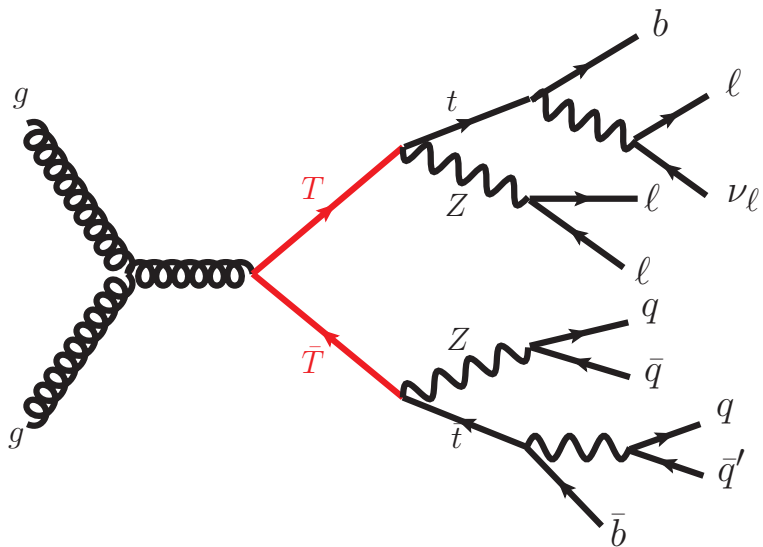
Pair-production searches

Signatures



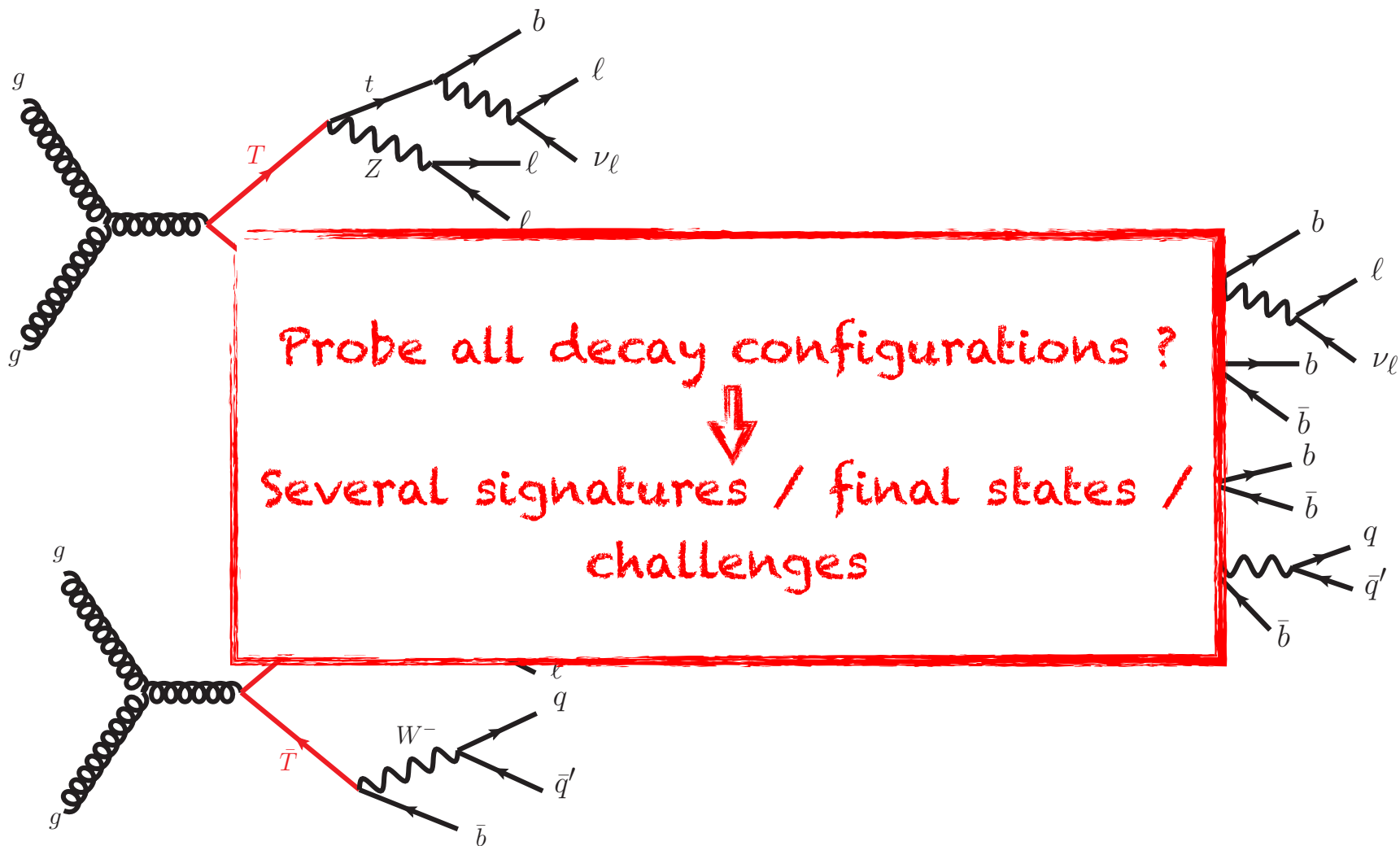
Pair-production searches

Signatures

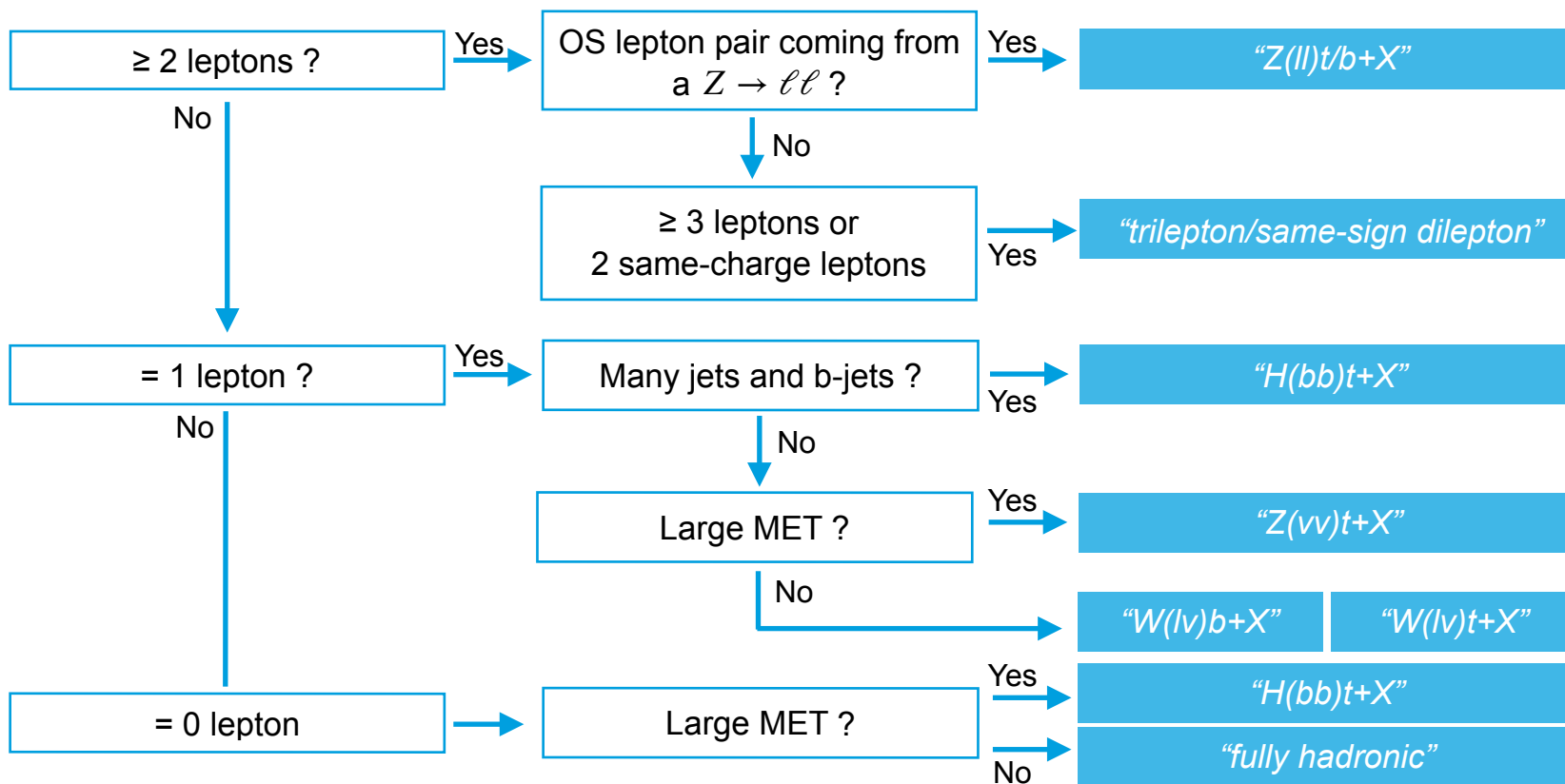
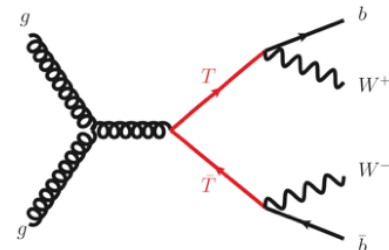
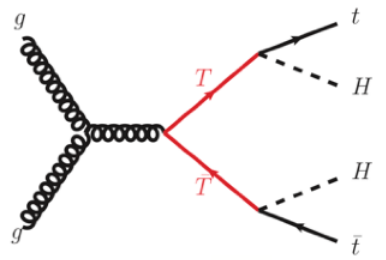
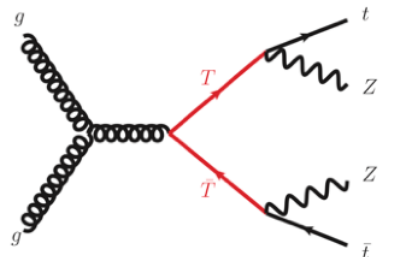


Pair-production searches

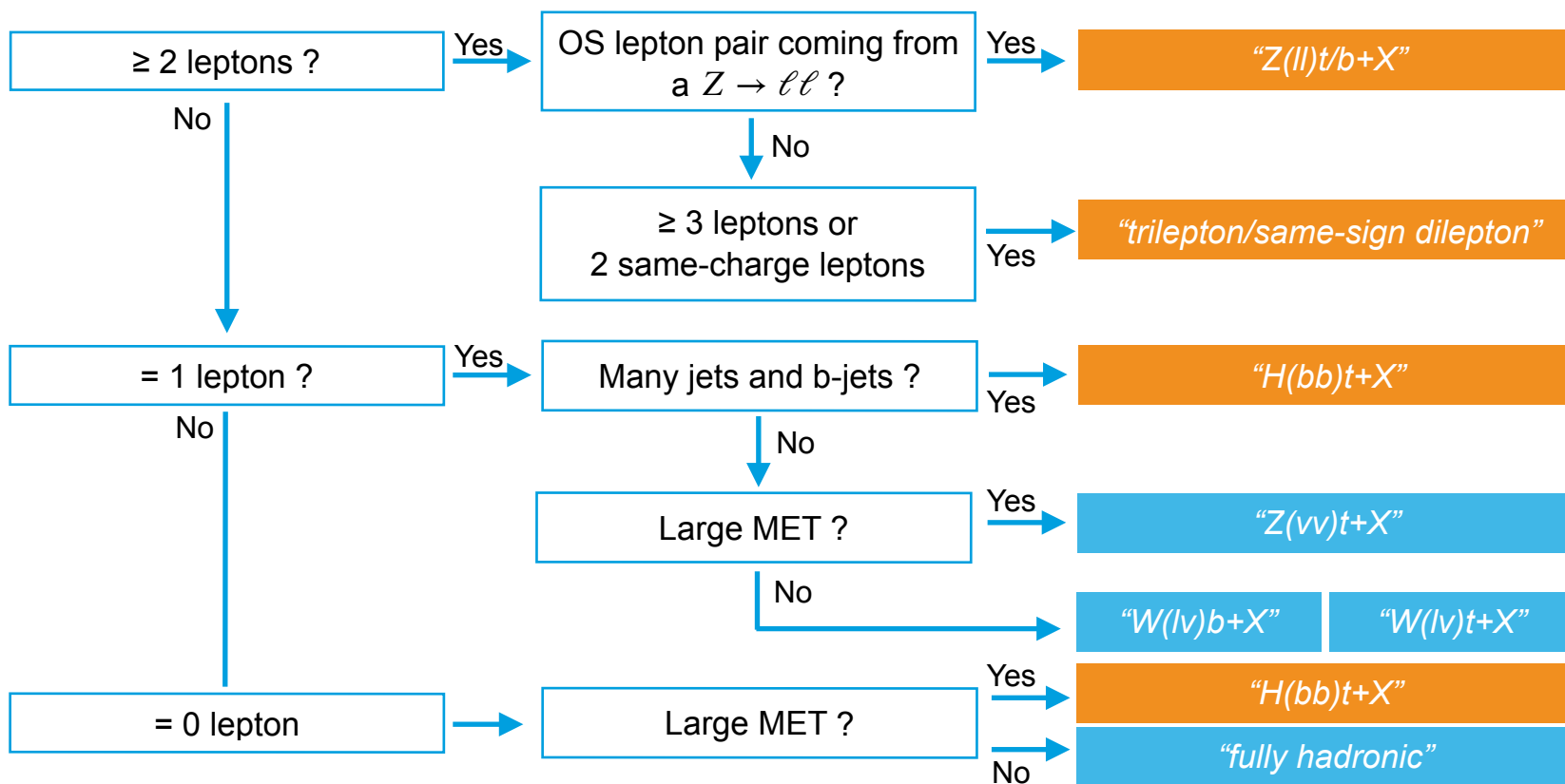
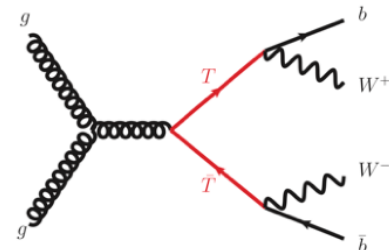
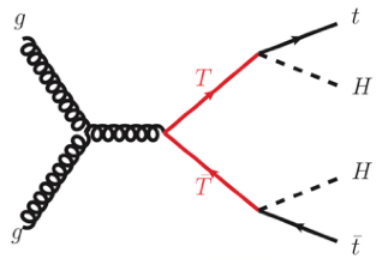
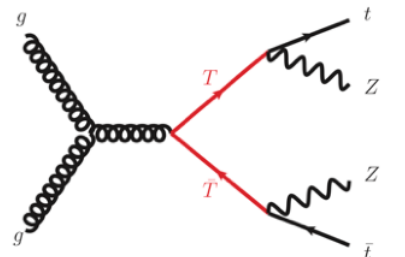
Signatures



Pair-production searches



Pair-production searches

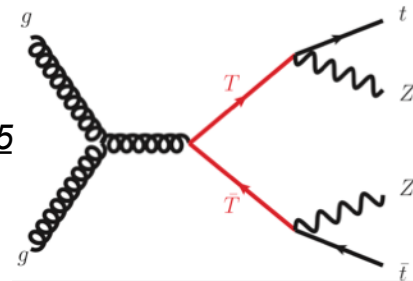


Pair-production searches

Zt/b+X

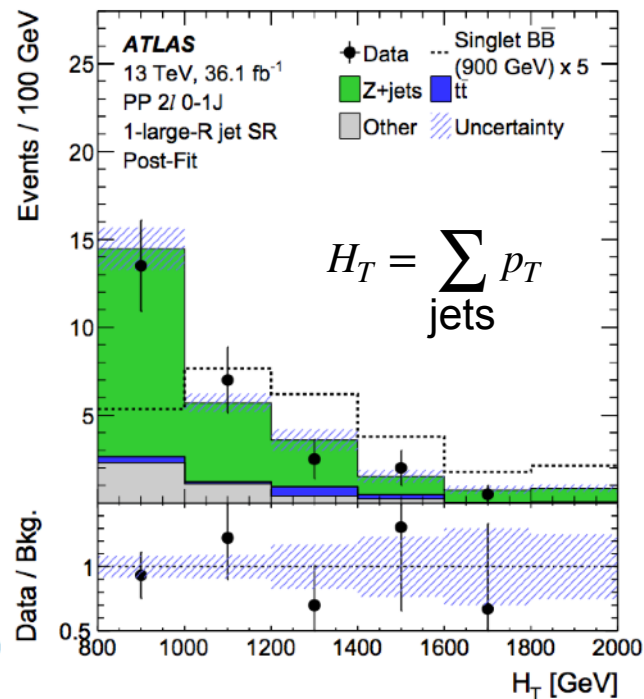
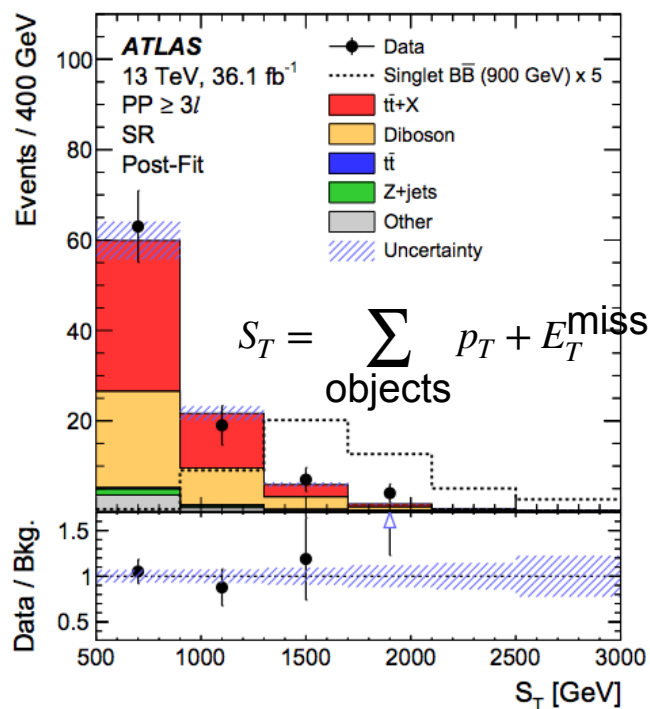
[arXiv:1806.10555](https://arxiv.org/abs/1806.10555)

Accepted by JHEP



- Selects **high- p_T** $Z \rightarrow \ell\ell$ events in dilepton / trilepton events
 - sub-channels depending on N_{leptons} and $N_{\text{boosted tops}}$ (4 signal regions)
 - 3-lepton channel: **most sensitive**
- **Main backgrounds:** $t\bar{t}+V$, diboson, depending on SR (calibrated in data)

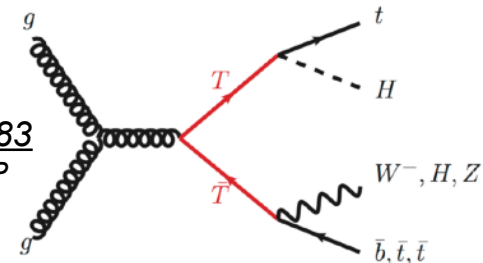
Highest purity channel



Pair-production searches

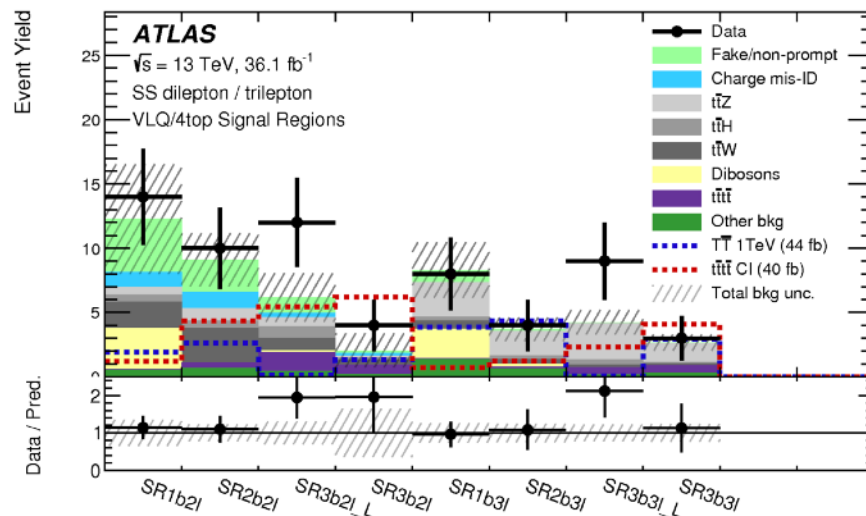
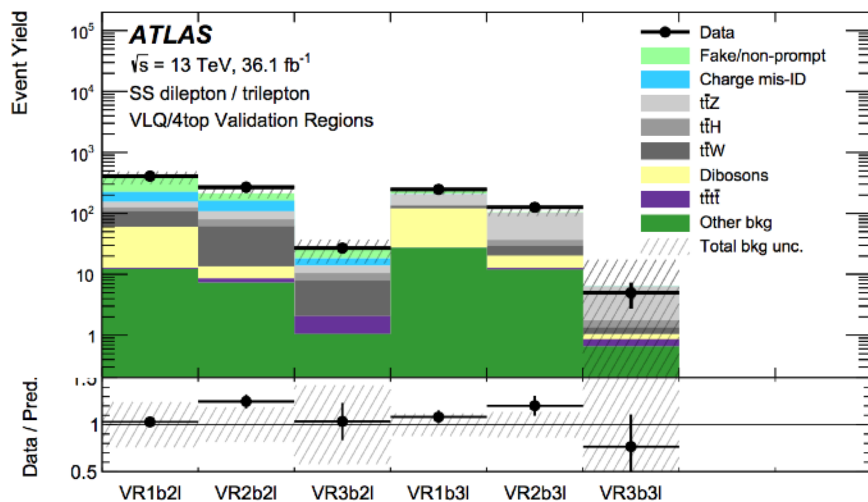
Same-sign leptons

arXiv:1807.11883
Accepted by JHEP



Background estimation

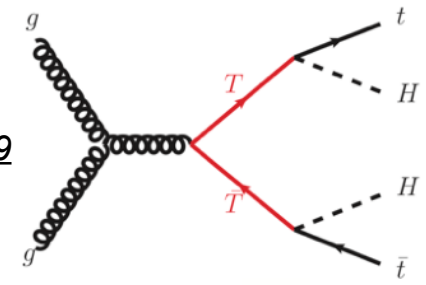
- Selects **same-sign dilepton** and non-Z **trilepton** events
 - typically from $T \rightarrow Ht \rightarrow WW^* t$ or $BB \rightarrow WtWt$ decays
 - signal regions: depending on N_{leptons} , $N_{\text{b-jets}}$, kinematic cuts
- **Main backgrounds:** fake/non-prompt leptons, charge mis-measurement, $t\bar{t}+V$
 - validated in dedicated regions



Pair-production searches

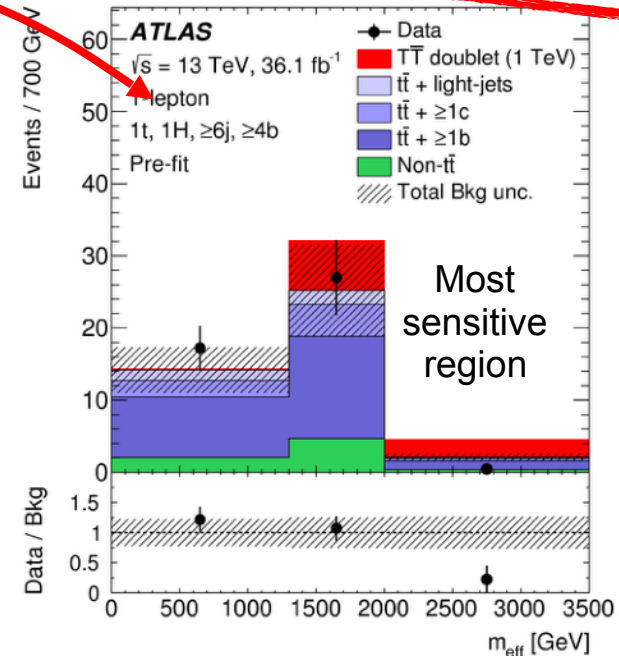
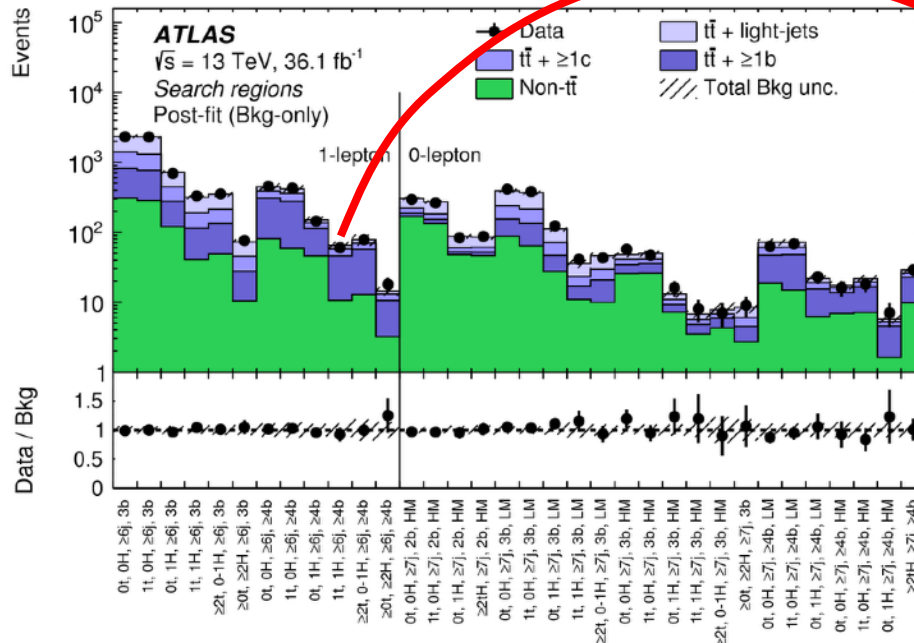
Ht+X

JHEP 07 (2018) 089



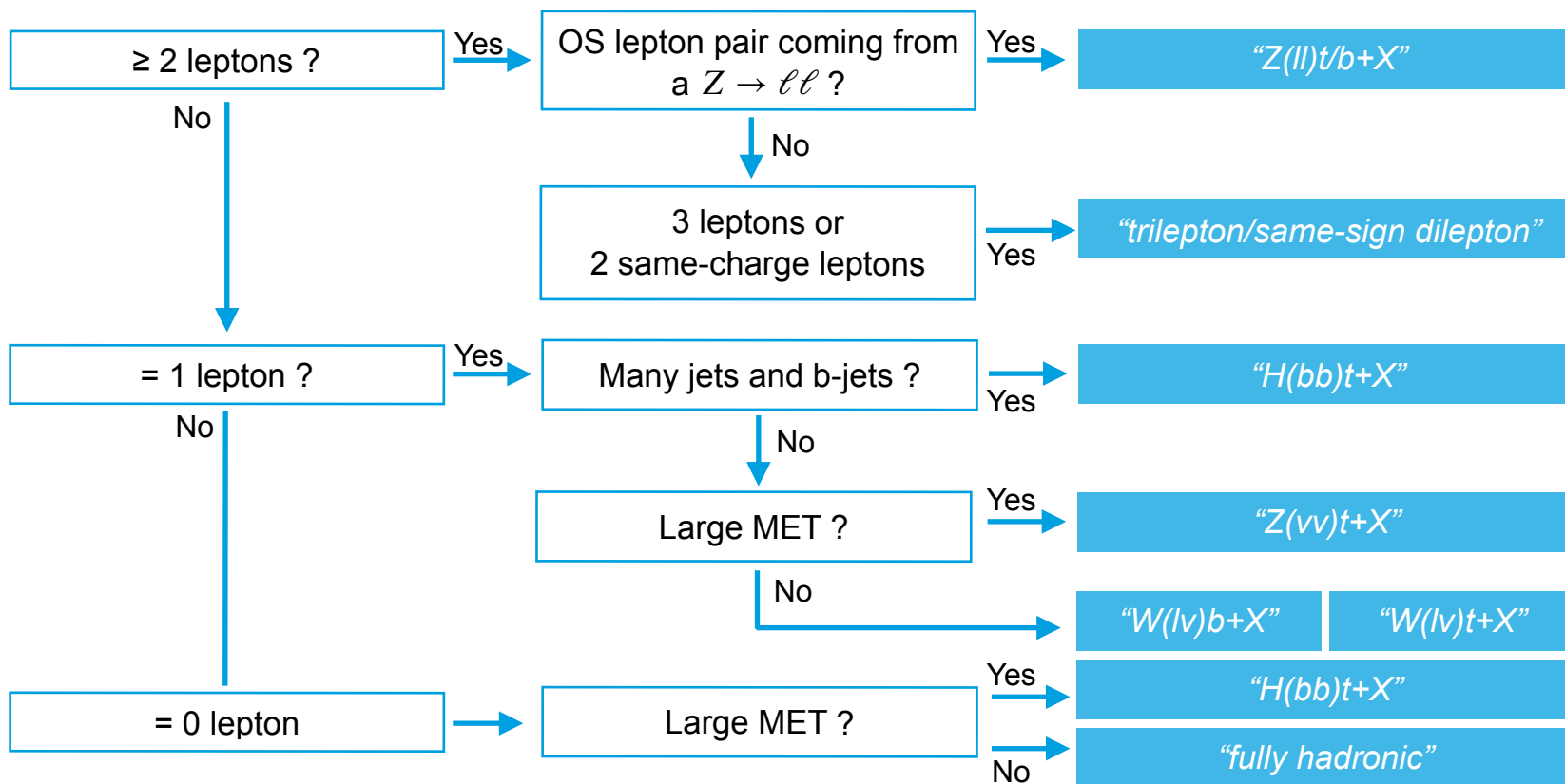
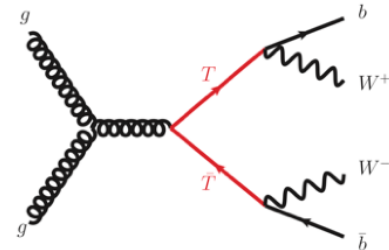
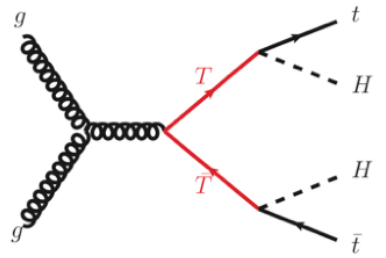
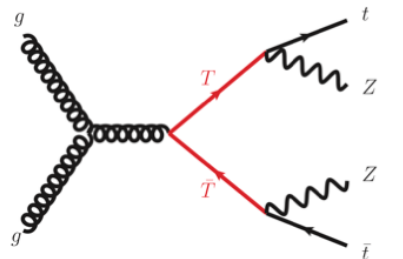
- Selects **high- p_T top quarks / Higgs bosons** in 1-lepton/0-lepton (high-MET) events
 - sub-channels depending on N_{leptons} , N_{tops} , N_{Higgs} , $N_{\text{b-jets}}$ (34 signal regions)
- **Main background:** $t\bar{t} + \geq 1b$ (calibrated in data)

Background estimation



$$m_{\text{eff}} = \sum_{\text{objects}} p_T + E_T^{\text{miss}}$$

Pair-production searches



Pair-production searches

Sensitivity

arXiv:1808.02343

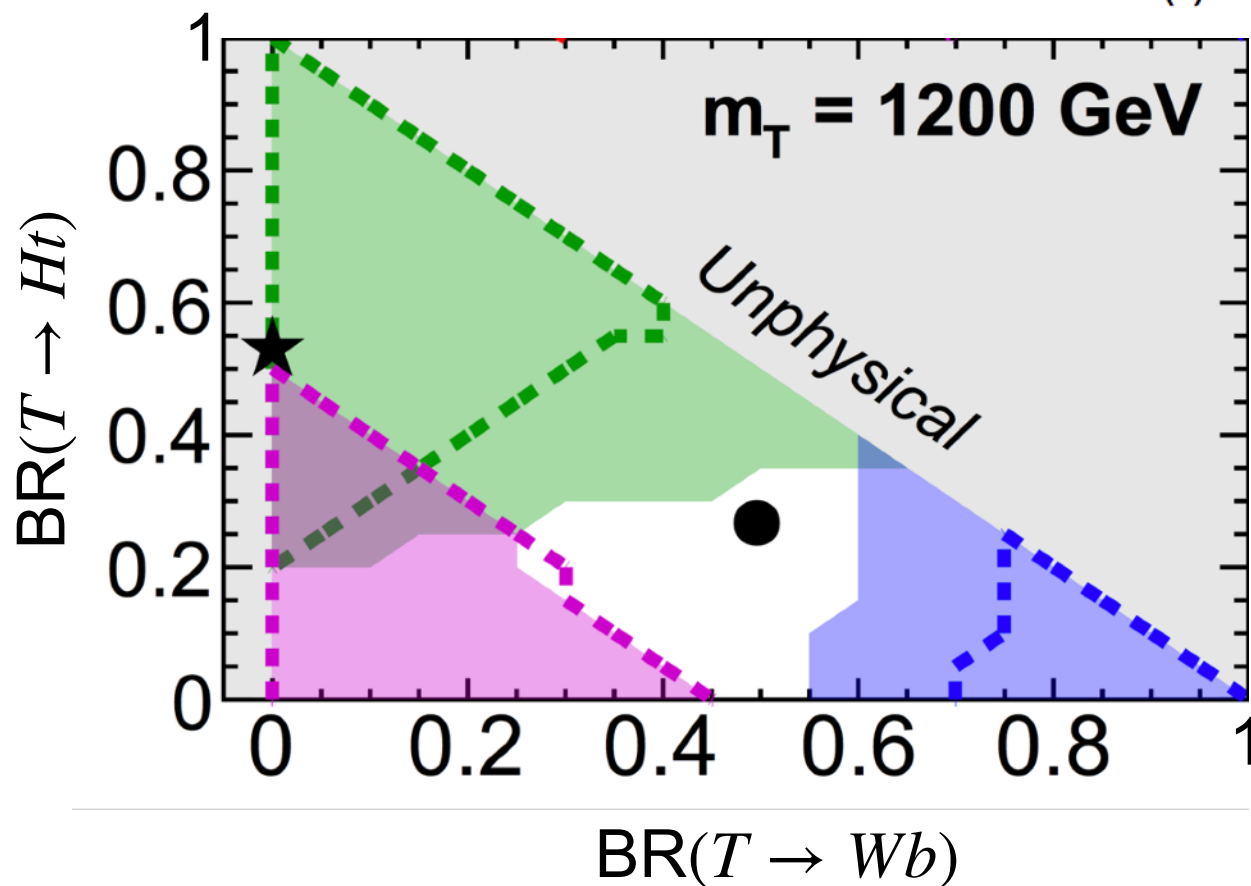
Accepted by PRL

■ ■ ■ Exp. exclusion ■ ■ ■ Obs. exclusion

— $W(l\nu)b+X$ [arXiv:1707.03347]

— $H(bb)t+X$ [arXiv:1803.09678]

— $Z(l\bar{l})t/b+X$ [arXiv:1806.10555]

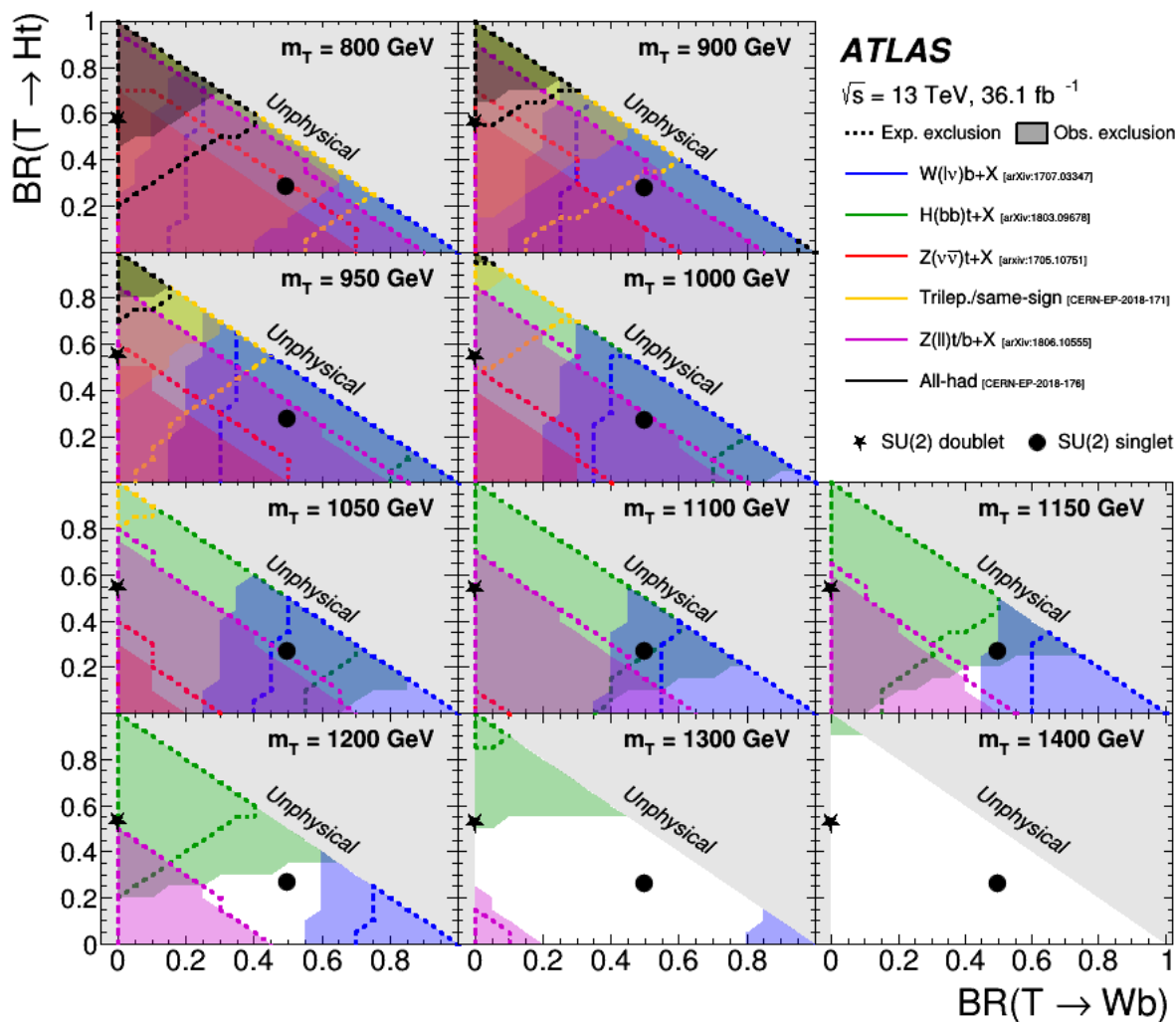


Pair-production searches

Summary plots

arXiv:1808.02343

Accepted by PRL



- **Excellent complementarity** between analyses: most parameter space “covered”
- **Non-overlapping** analyses

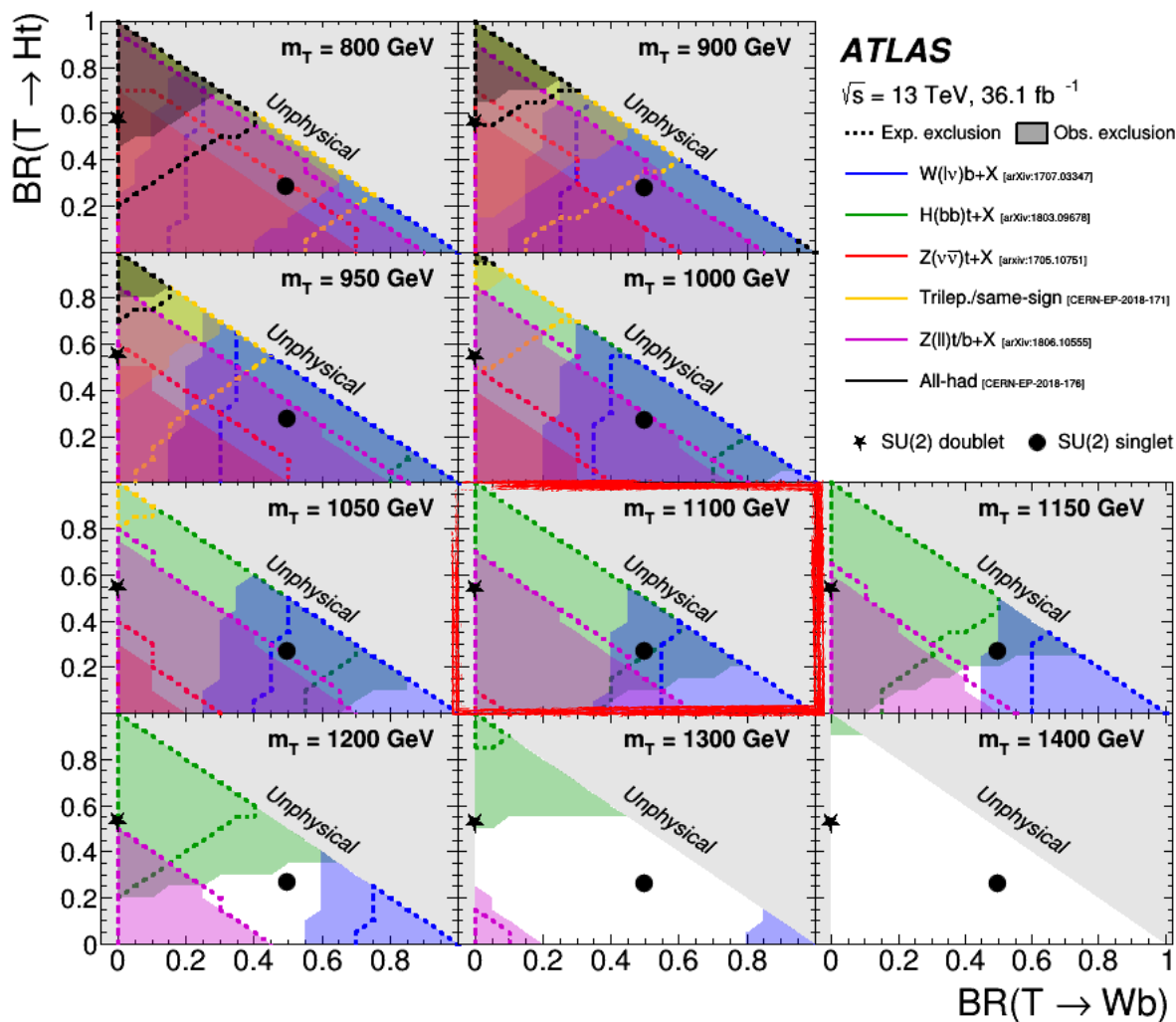
→ **combined interpretation !**

Pair-production searches

Summary plots

arXiv:1808.02343

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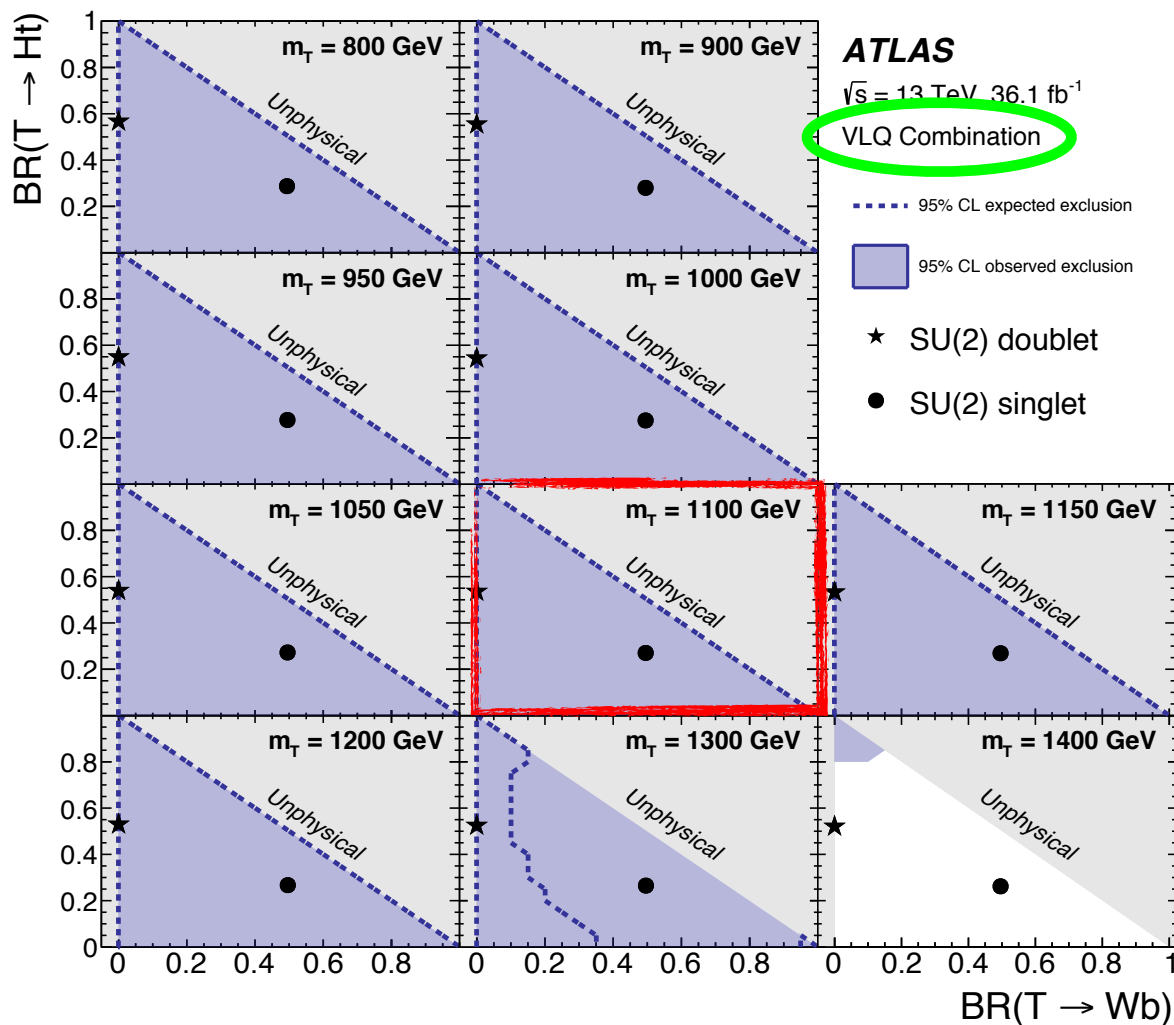
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Pair-production searches

Combination

arXiv:1808.02343

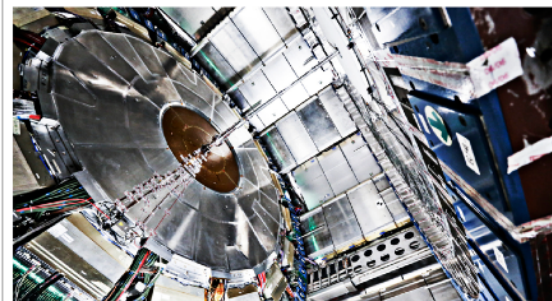
Accepted by PRL



The incredible lightness of the Higgs

ATLAS searches for vector-like top quarks that could explain the Higgs boson's small mass

11 SEPTEMBER, 2018 | By Ana Lopes

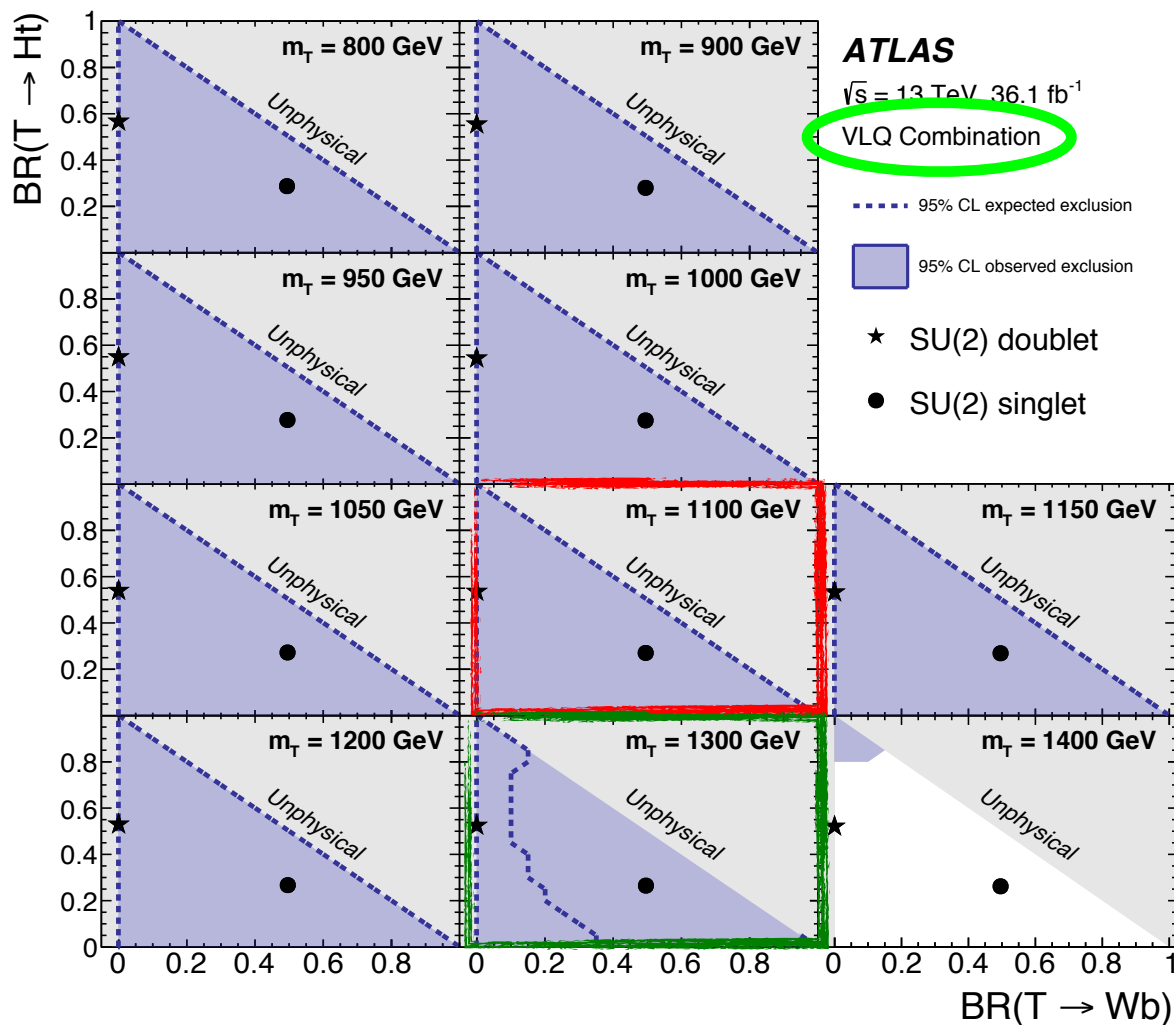


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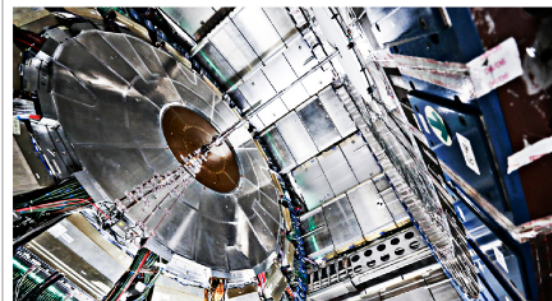
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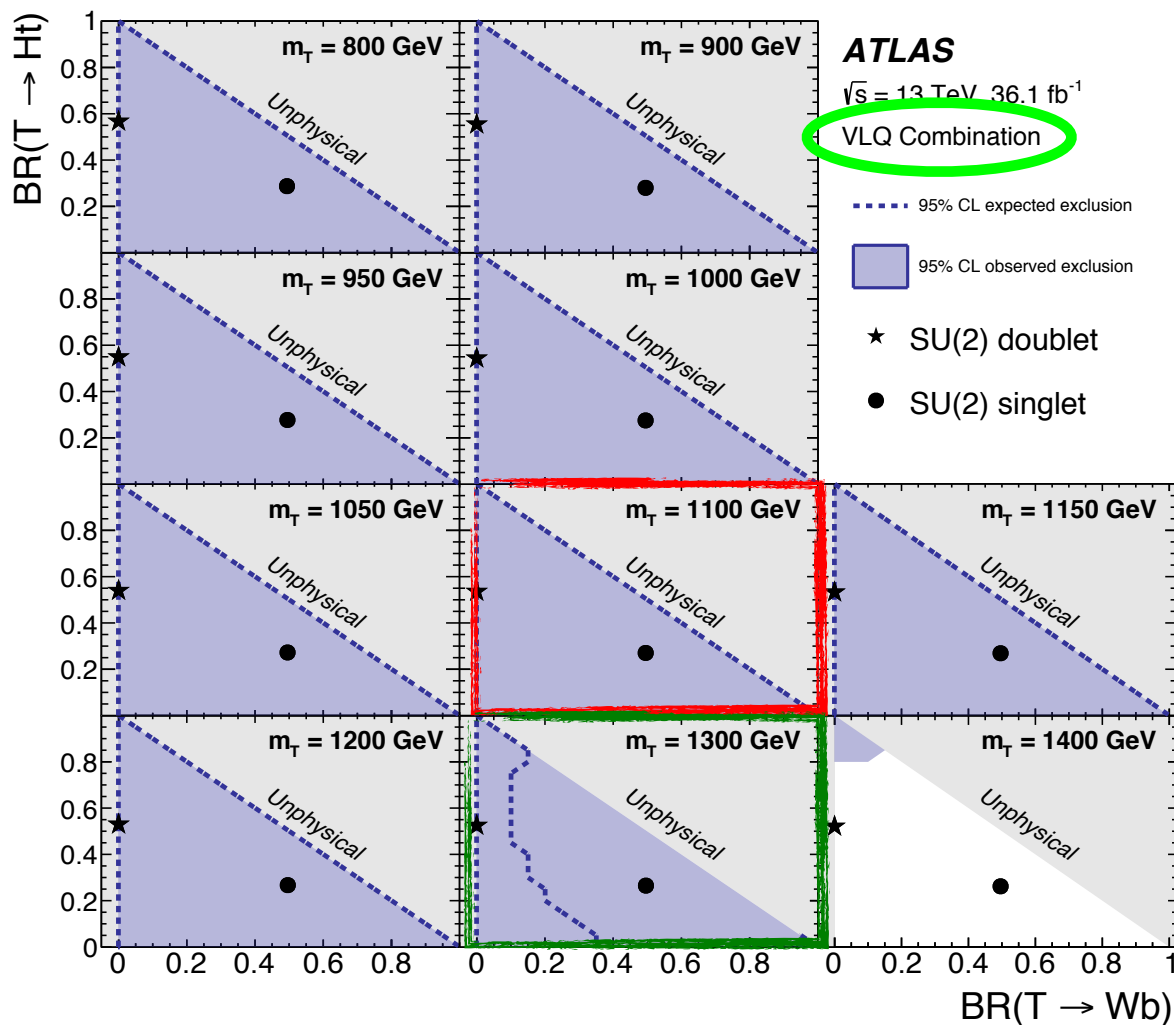


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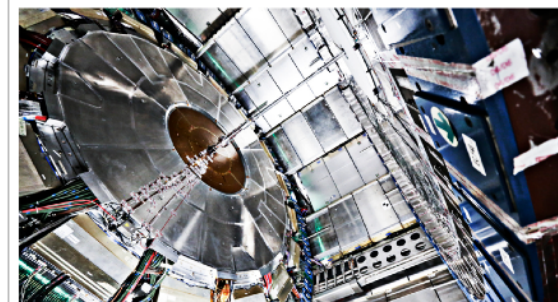
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Strong sensitivity gain !

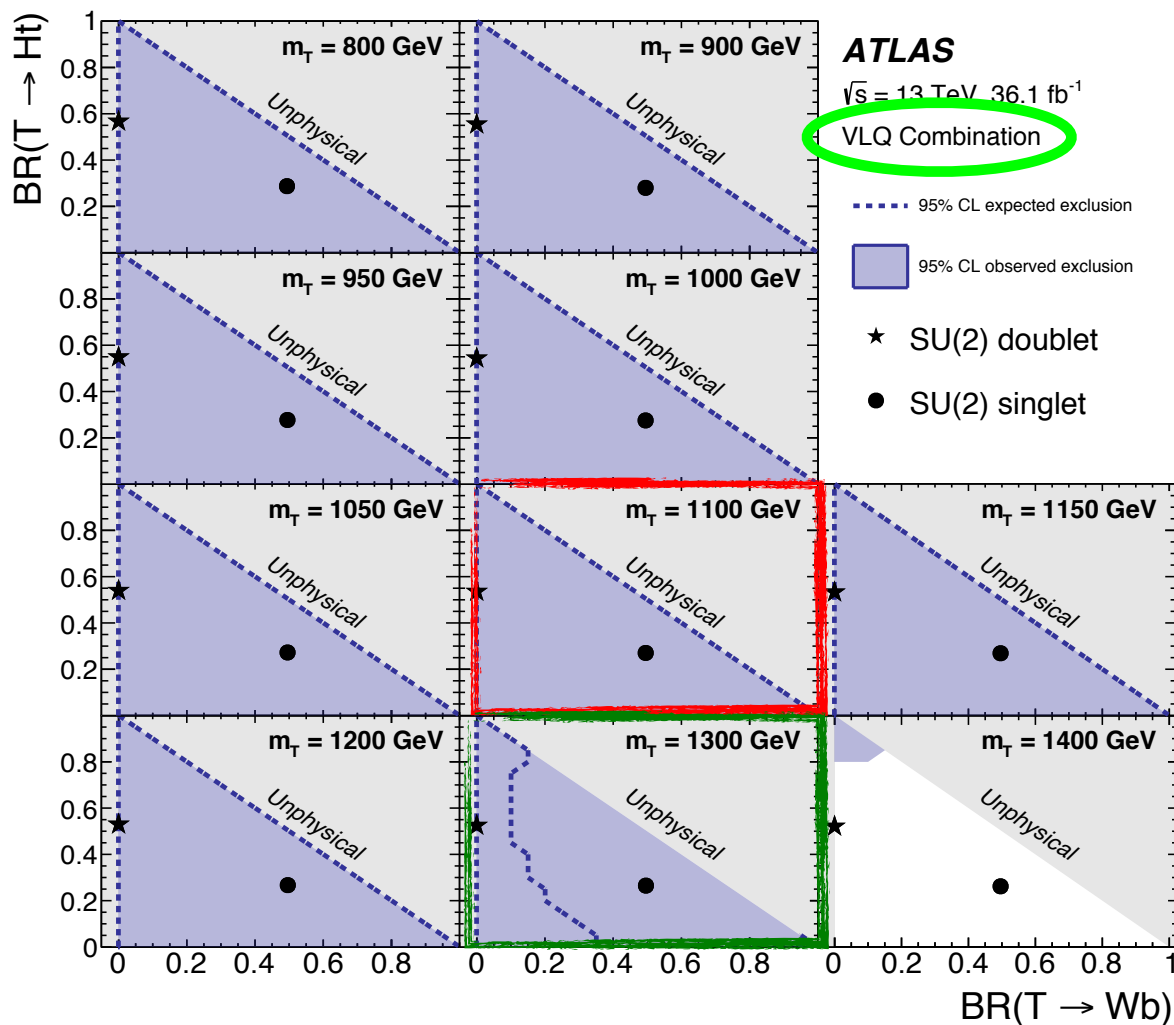
=> No evidence for low-mass VLQs

Pair-production searches

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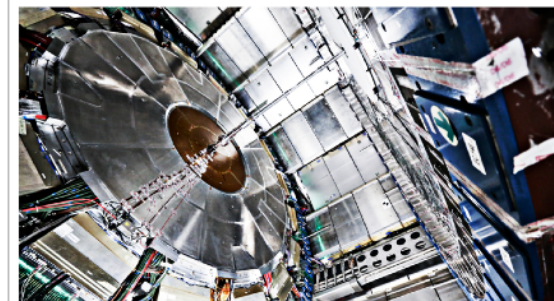
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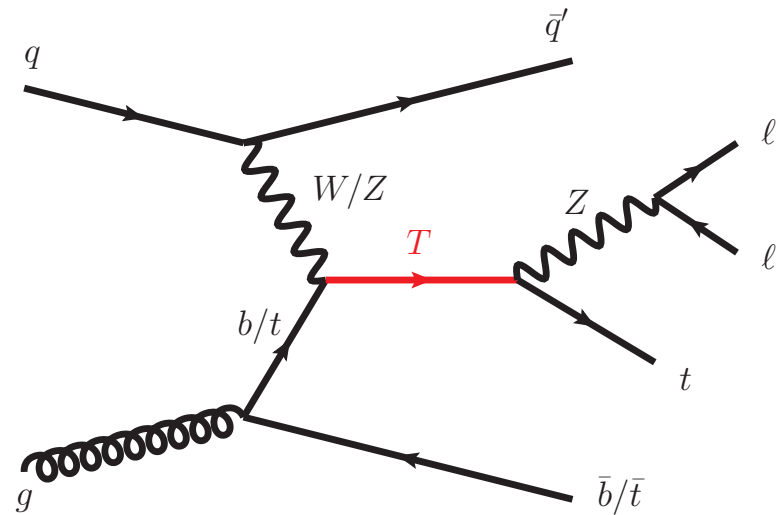
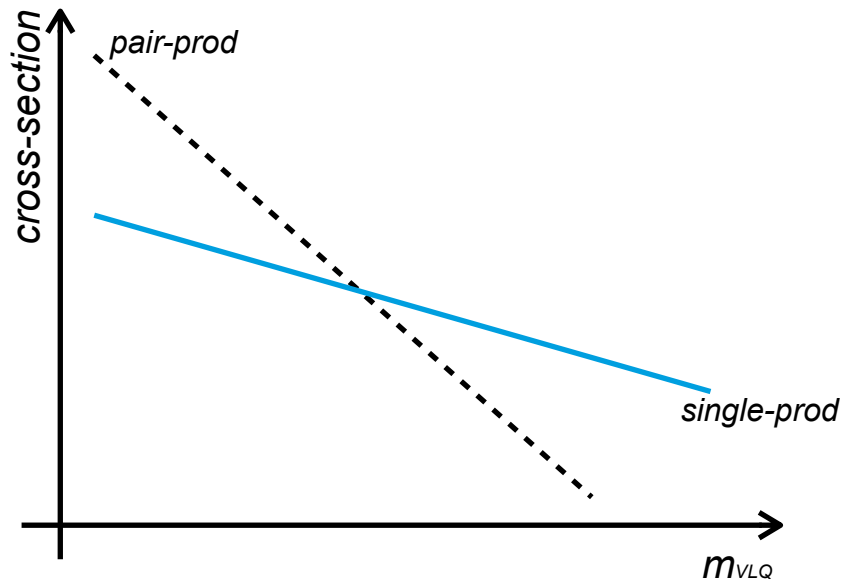
=> No evidence for low-mass VLQs

Look for high mass VLQ: single-production !

Single-production searches

Topologies

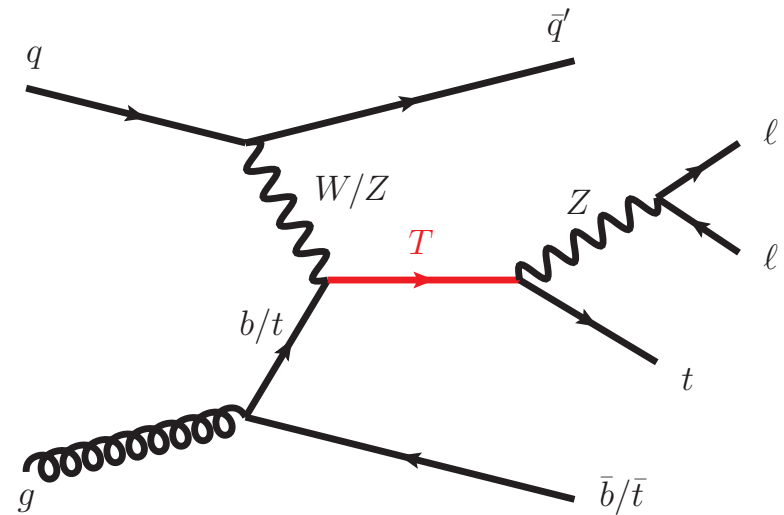
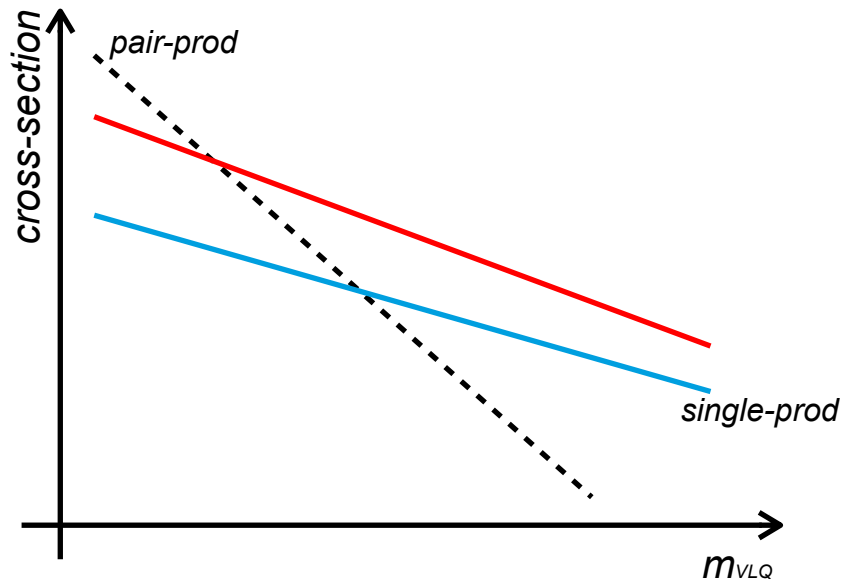
- Single production possibly **more important for high VLQ masses**
- Cross-section depends on **VLQ coupling to SM particles**



Single-production searches

Topologies

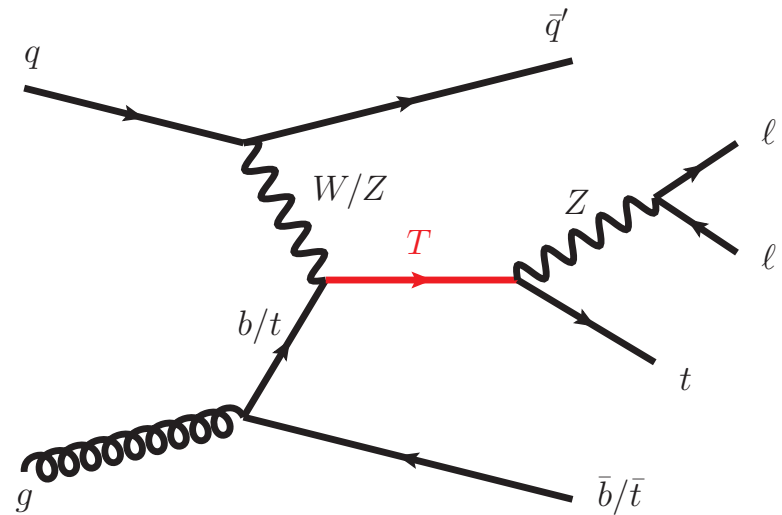
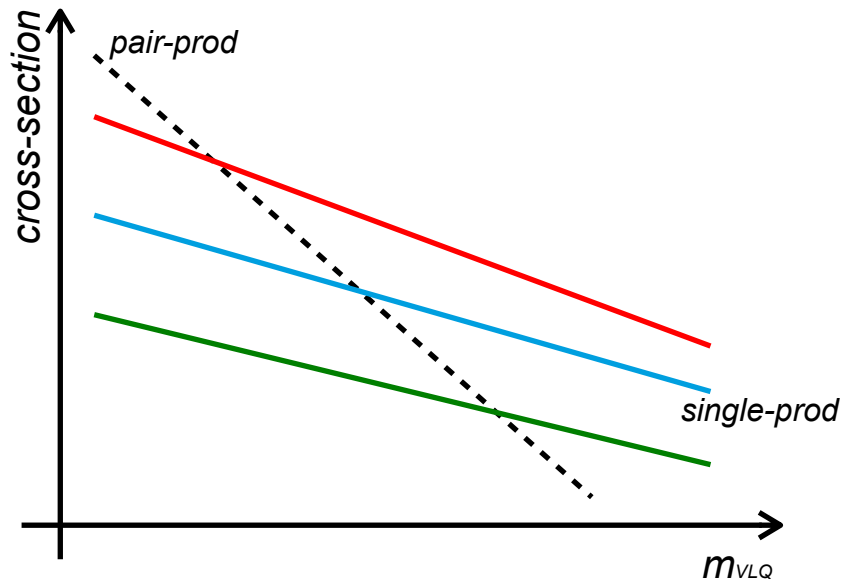
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Single-production searches

Topologies

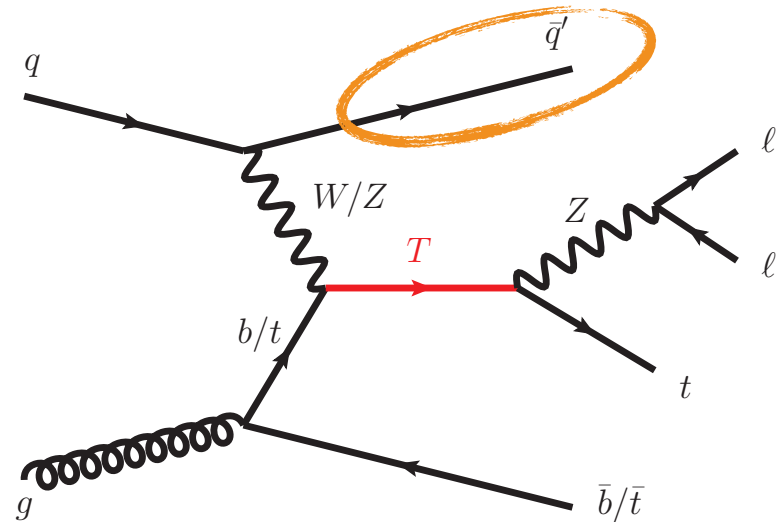
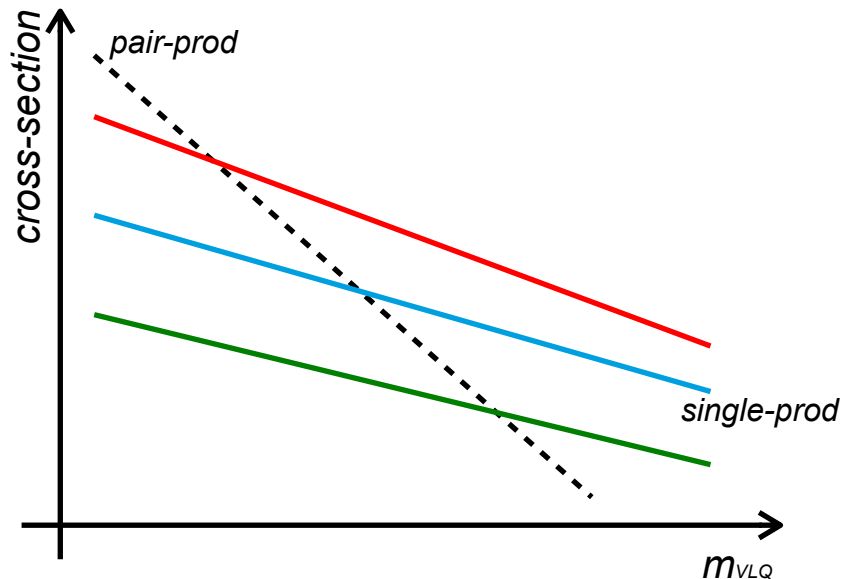
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Single-production searches

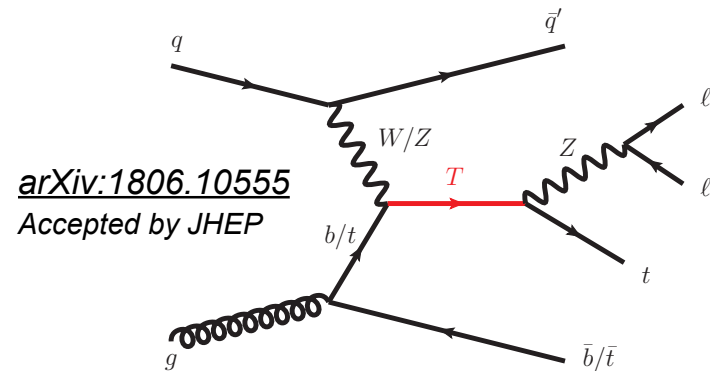
Topologies

- Single production possibly **more important for high VLQ masses**
- Cross-section depends on **VLQ coupling to SM particles**
- **Event properties** different wrt pair-production
 - Less busy final state **but forward jet**

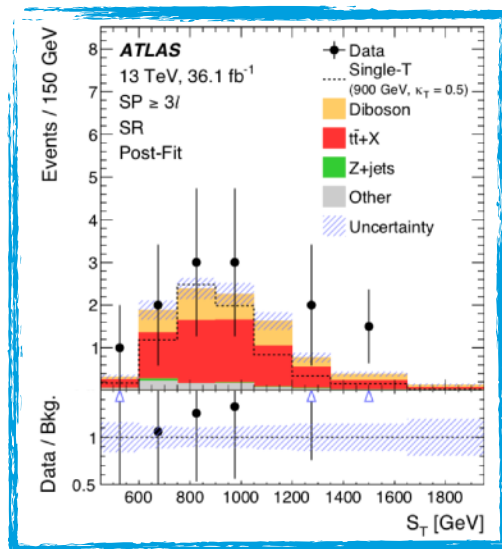
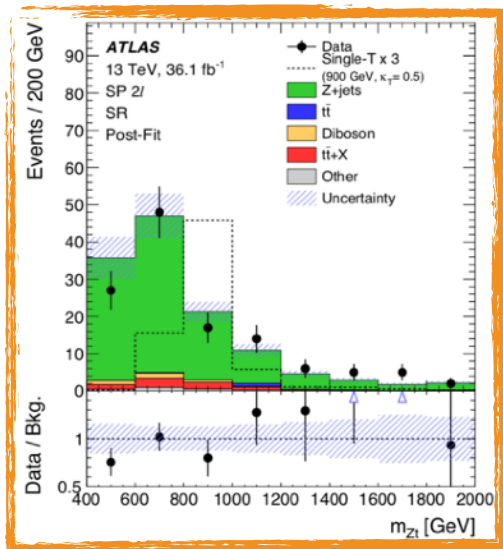


Single-production searches

Single $T/B \rightarrow Z(\ell\ell)t/b$



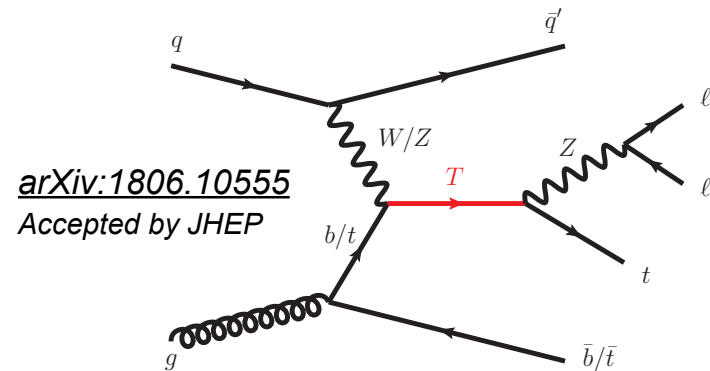
- Selects **high- p_T** $Z \rightarrow \ell\ell$ events
 - *dilepton*: presence of a **top-tagged jet** $\rightarrow$ **full VLQ reconstruction**
 - *trilepton*: ambiguity in reconstruction $\rightarrow$ **use kinematic variable**
- Main background: Z+jets or $t\bar{t}+V$



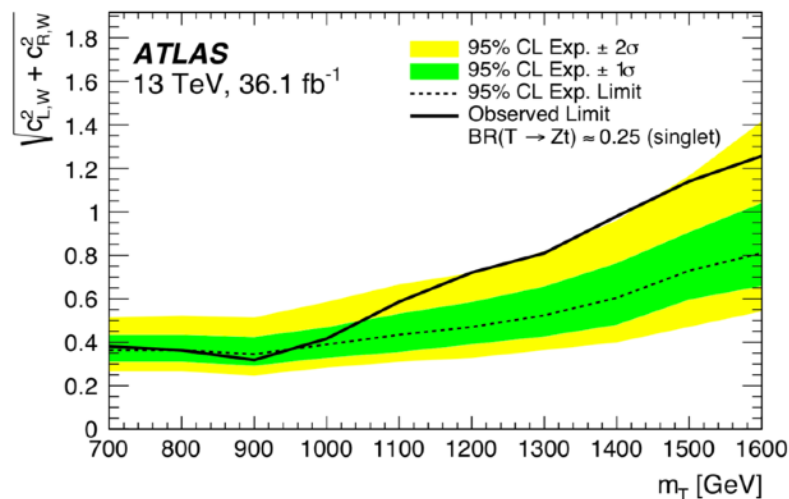
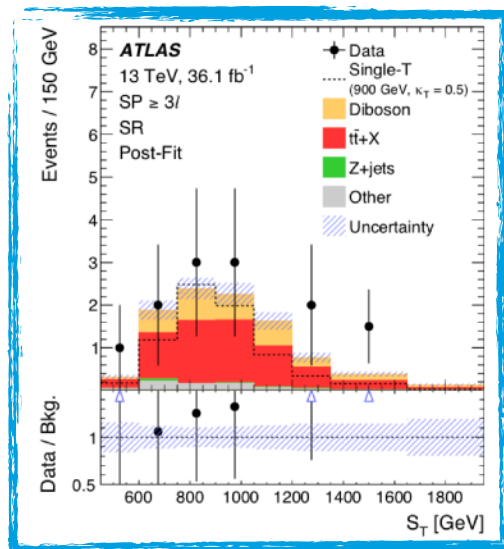
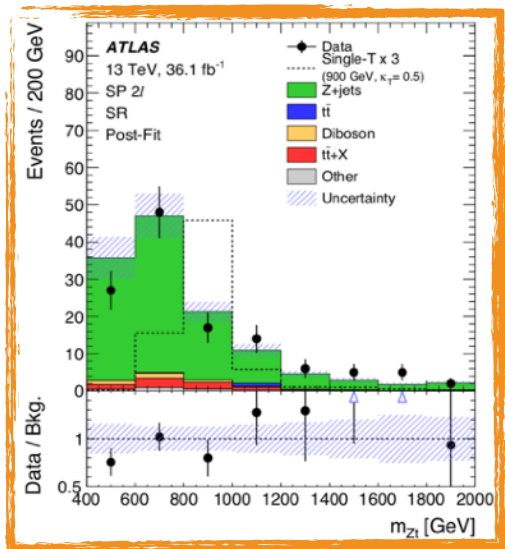
$$S_T = \sum_{\text{objects}} p_T + E_T^{\text{miss}}$$

Single-production searches

Single $T/B \rightarrow Z(\ell\ell)t/b$



- Selects **high- p_T** $Z \rightarrow \ell\ell$ events
 - *dilepton*: presence of a **top-tagged jet** $\rightarrow$ **full VLQ reconstruction**
 - *trilepton*: ambiguity in reconstruction $\rightarrow$ **use kinematic variable**
- Main background: Z+jets or $t\bar{t}+V$
- Limits set for variable coupling assumptions $\rightarrow$ **model-independent interpretation**



$$S_T = \sum_{\text{objects}} p_T + E_T^{\text{miss}}$$

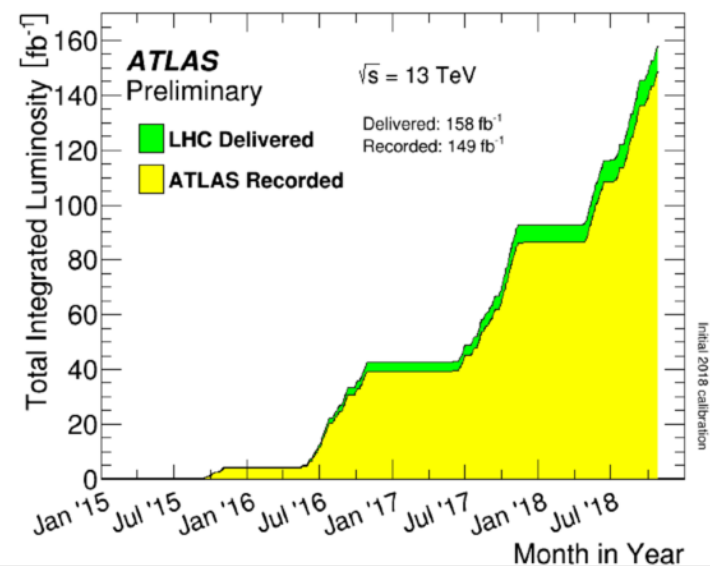
VLQ searches: next steps ?

- For all VLQ searches: sensitivity **limited by statistics**
- Excellent coverage in **pair-production** → low-mass VLQs strongly constrained
 - Combination significantly extends sensitivity !
- Single-production **more and more relevant**: several studies underway !
 - Quite challenging to interpret in a “model-independent” manner
- More complete models ? Exotics decays ?



Summary

- Top quark: ideal to **probe several new theories extending Standard Model**
- **Heavy resonances** decaying to top quarks and **vector-like quarks**
 - Thoroughly searched for by ATLAS in several (new) channels
 - Challenging experimental final states
 - No signs of new particles (yet) → strong **constraints** on many BSM theories
- Sensitivity mostly **limited by statistics**
 - Will benefit from new data coming from LHC ...
 - ... and increase of signal acceptance !
- **Stay tuned for full Run 2 results !**



Thank you

Contact

DESY. Deutsches
Elektronen-Synchrotron

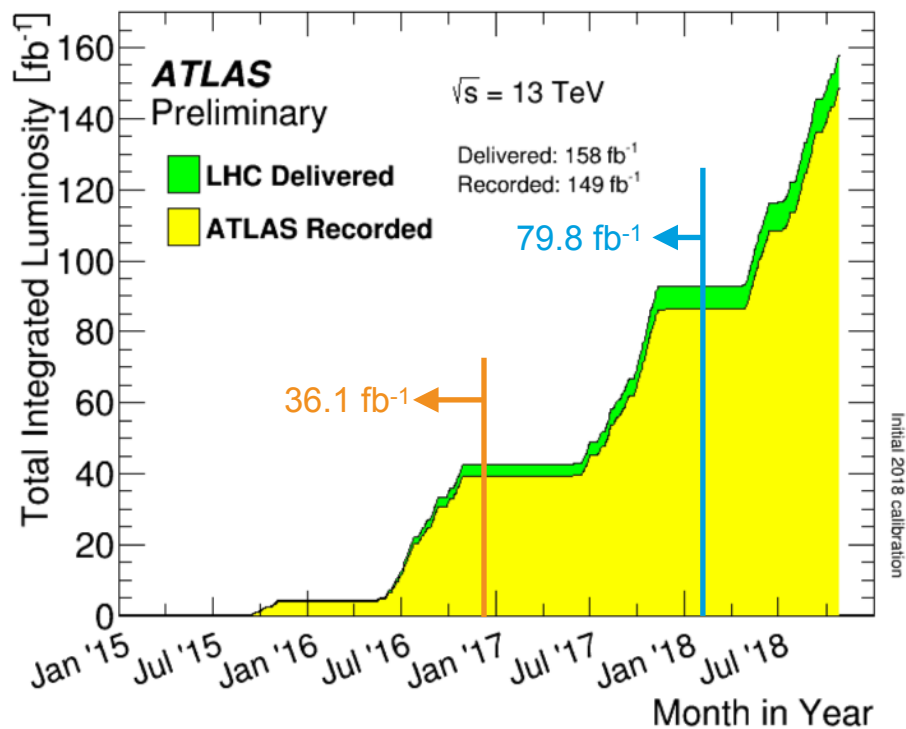
www.desy.de

Loïc Valéry
ATLAS
loic.valery@desy.de

Backup

LHC and luminosity

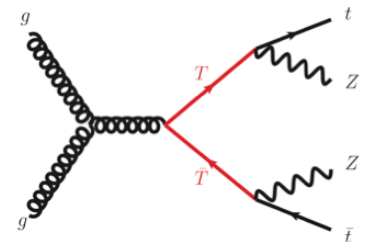
- New Physics events: **rare** and at **high energy**
- Searches using **Run 2 LHC data**
 - Centre-of-mass energy: $\sqrt{s} = 13$ TeV
 - Luminosity: **36.1** fb⁻¹ or **79.8** fb⁻¹



Pair-production searches

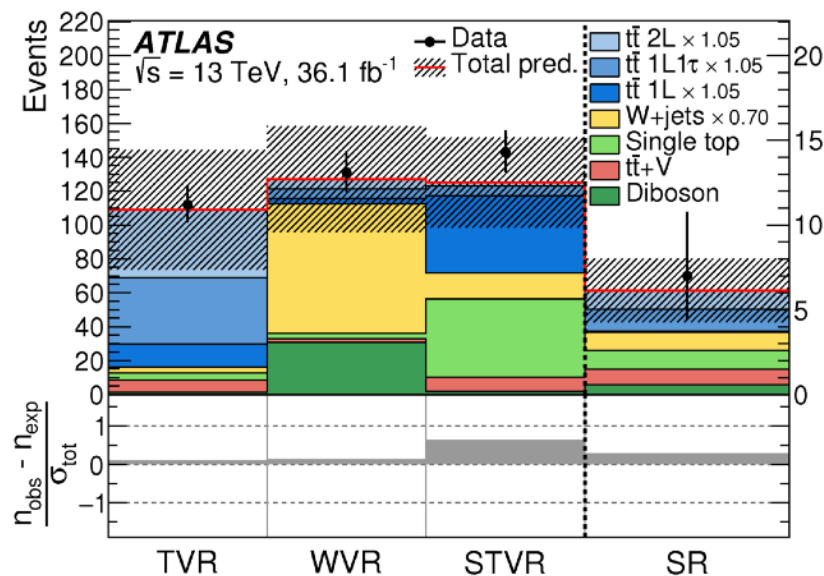
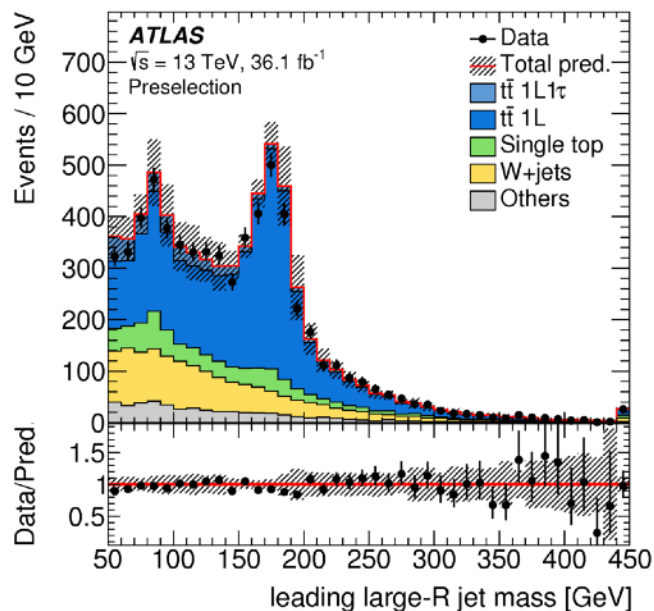
$Z(\nu\nu)t+X$

JHEP 08 (2017) 052



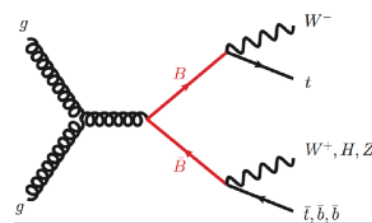
- Selects 1-lepton events with **large MET**
 - Selecting $T \rightarrow Z(\nu\nu)t$ events
 - **Jet-reclustering** to identify boosted top quarks
- **Main backgrounds:** top background and W+jets (calibrated in data)

Hadronic top identification

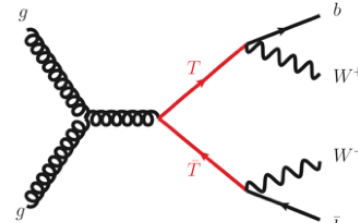


Pair-production searches

Wb/t+X



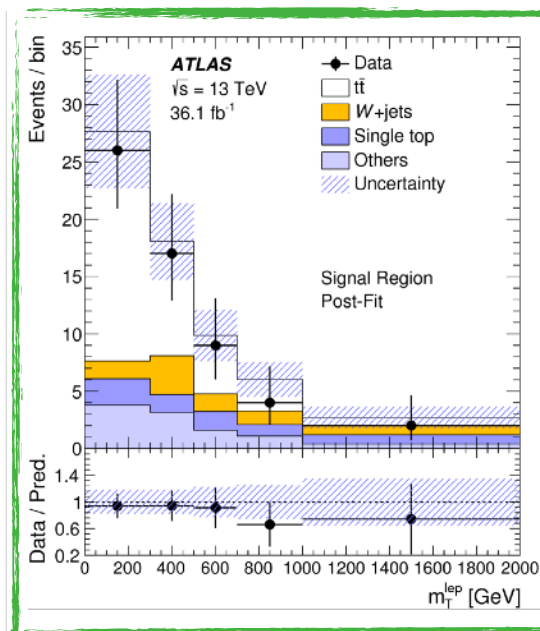
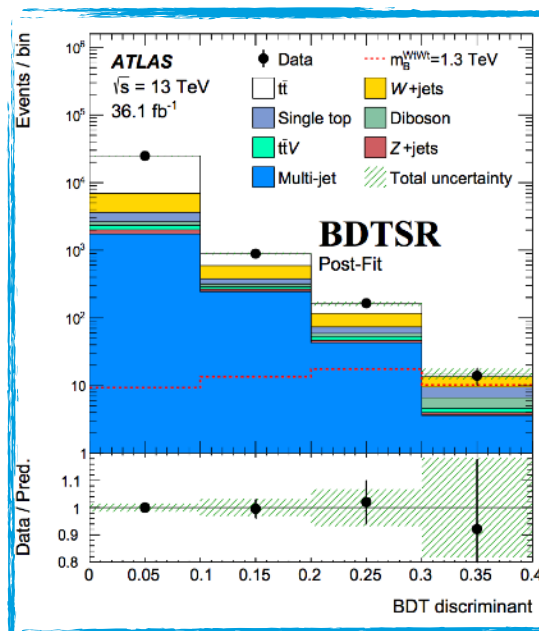
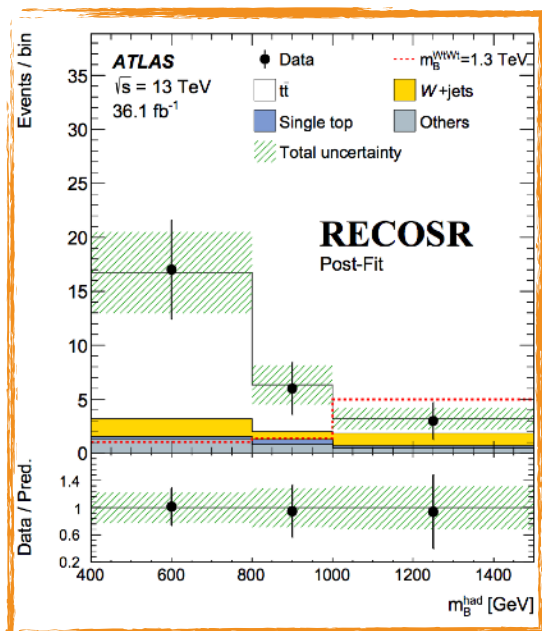
JHEP 08 (2018) 048



JHEP 10 (2017) 141

- Select 1-lepton events with **high- p_T hadronic W bosons**
 - BB $\rightarrow$ Wt+X: complex final state $\rightarrow$ **full reconstruction** otherwise **MVA strategy**
 - TT $\rightarrow$ Wb+X: **reconstruct $T \rightarrow Wb \rightarrow l\nu b$ mass**
- **Main background:** $t\bar{t}$ (calibrated in data)

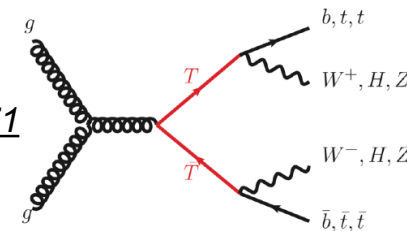
Event reconstruction



Pair-production searches

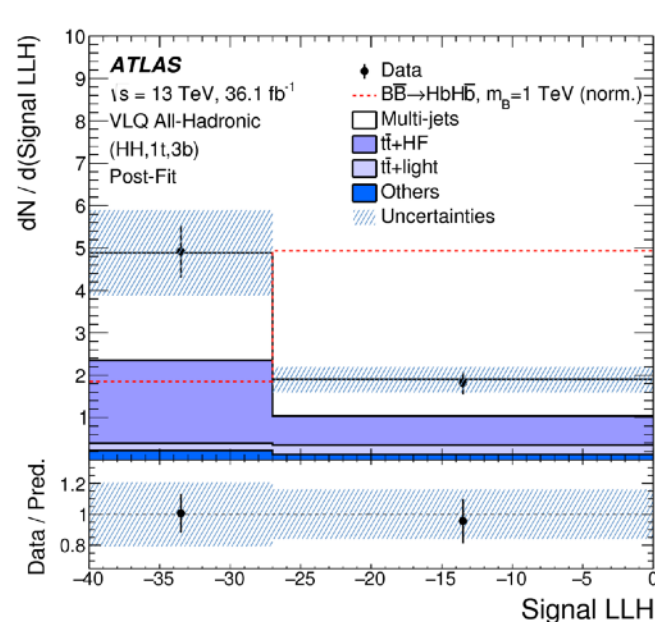
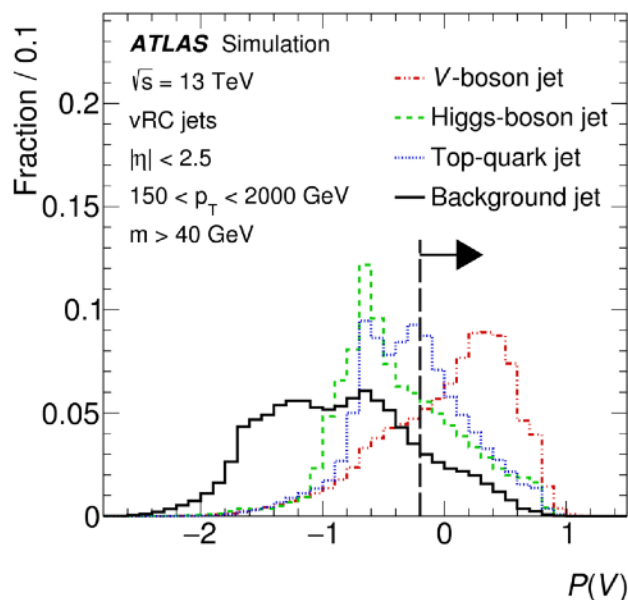
Fully-hadronic

[arXiv:1808.01771](https://arxiv.org/abs/1808.01771)



- Selects **0-lepton events** with **high- p_T** top quarks or V/H bosons
 - sub-channels depending on boosted object content (12 channels)
- **Main background:** multi-jet (data-driven)
- Boosted object tagging: **multi-class DNN classifier** on vRC jets
 - using of jet and subjet kinematic properties
- Final discriminant: **Matrix Element Method**

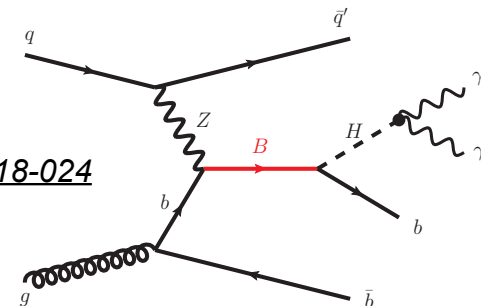
Background suppression



Single-production searches

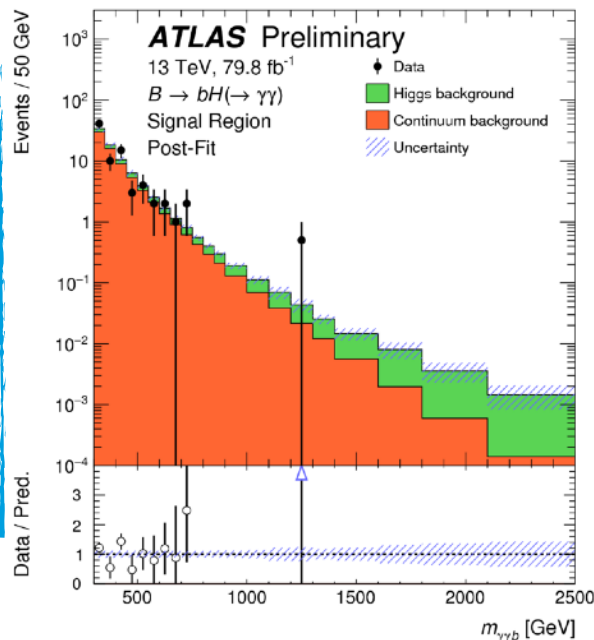
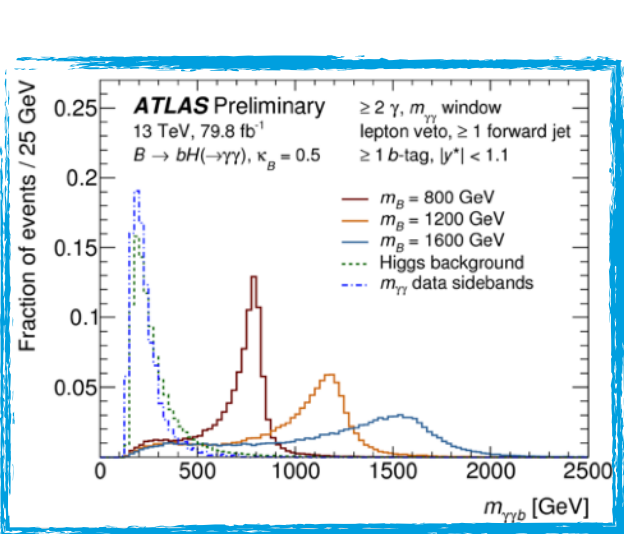
Single $B \rightarrow Hb \rightarrow \gamma\gamma b$

ATLAS-CONF-2018-024



- Selects **events with two photons** originating from Higgs + **b-jet**
 - Use $m_{\gamma\gamma b}$ to **reconstruct vector-like B mass**
- Main background: continuum $\gamma\gamma$ + jets (estimated from data in sidebands)

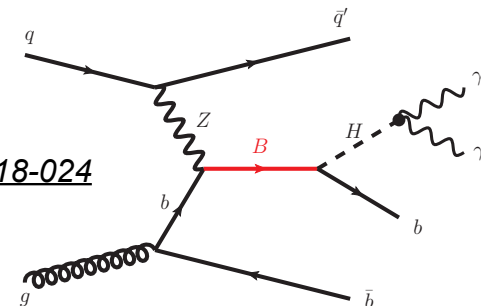
With 2017 data!



Single-production searches

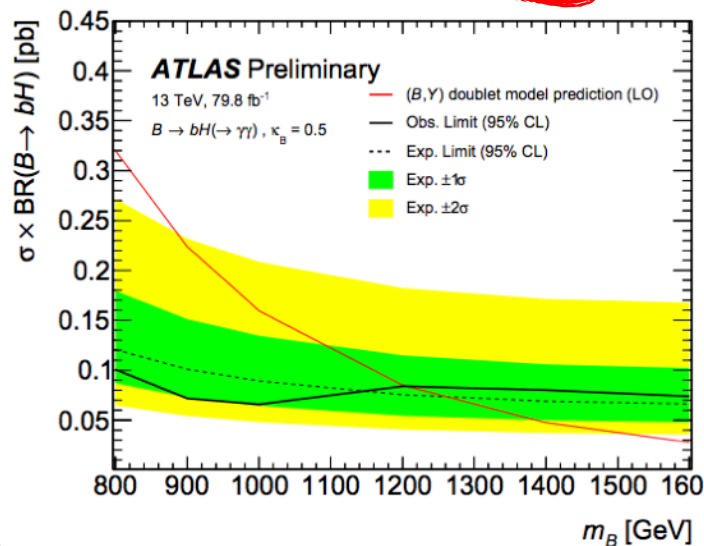
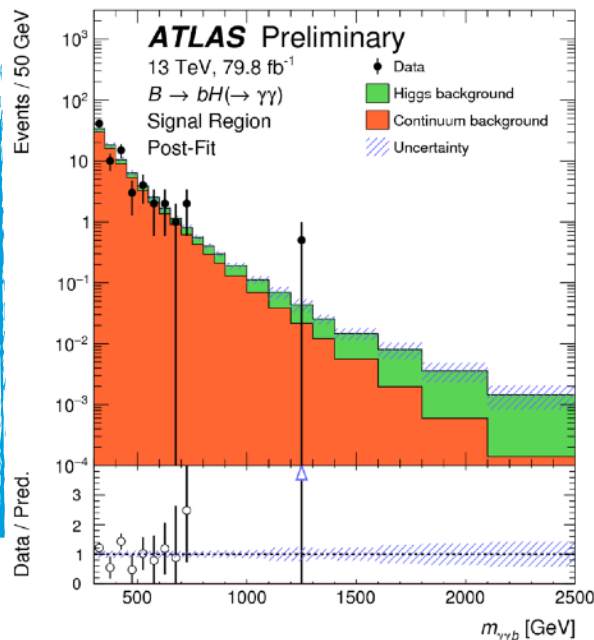
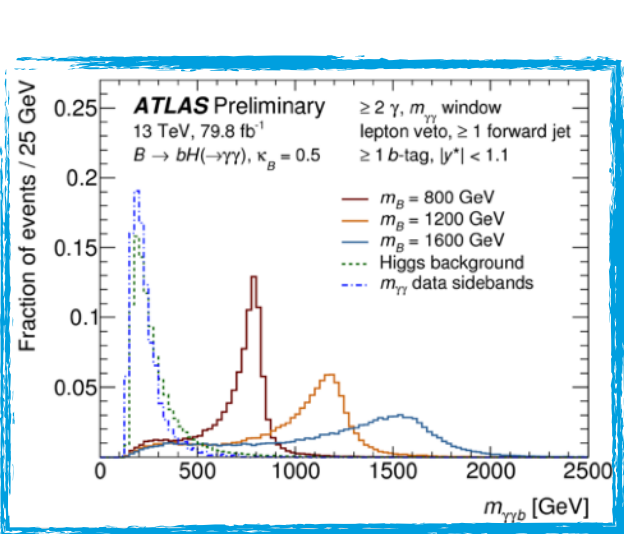
Single $B \rightarrow Hb \rightarrow \gamma\gamma b$

ATLAS-CONF-2018-024



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- Main background: continuum $\gamma\gamma$ + jets (estimated from data in sidebands)
- Limits set with **fixed coupling**

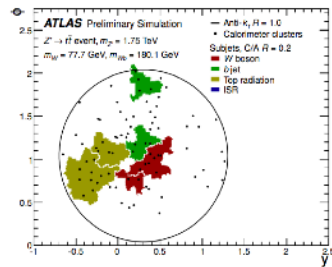
With 2017 data!



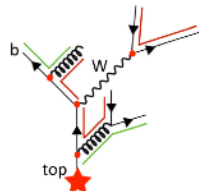
Shower deconstruction algorithm

A bit more information

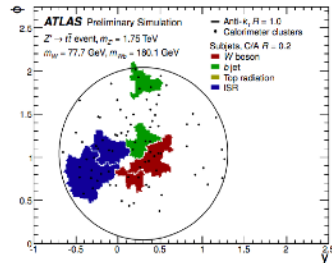
- Taken from <https://cds.cern.ch/record/1648661>



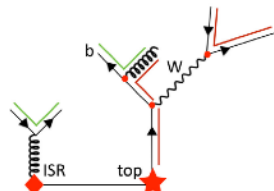
(a)



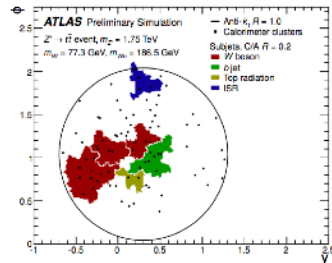
(b)



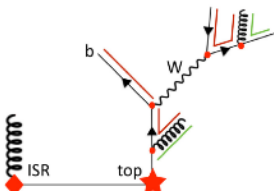
(c)



(d)



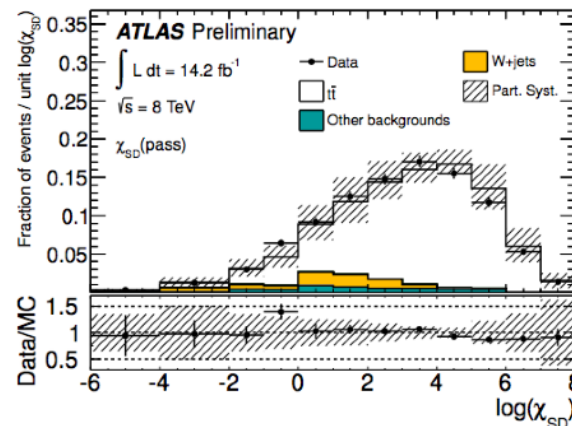
(e)



(f)

- Subjets used as proxies to parton
- All parton shower history leading to this parton configuration are used: **each has a probability** $\sum_{\text{signal-hypotheses PS histories}}$

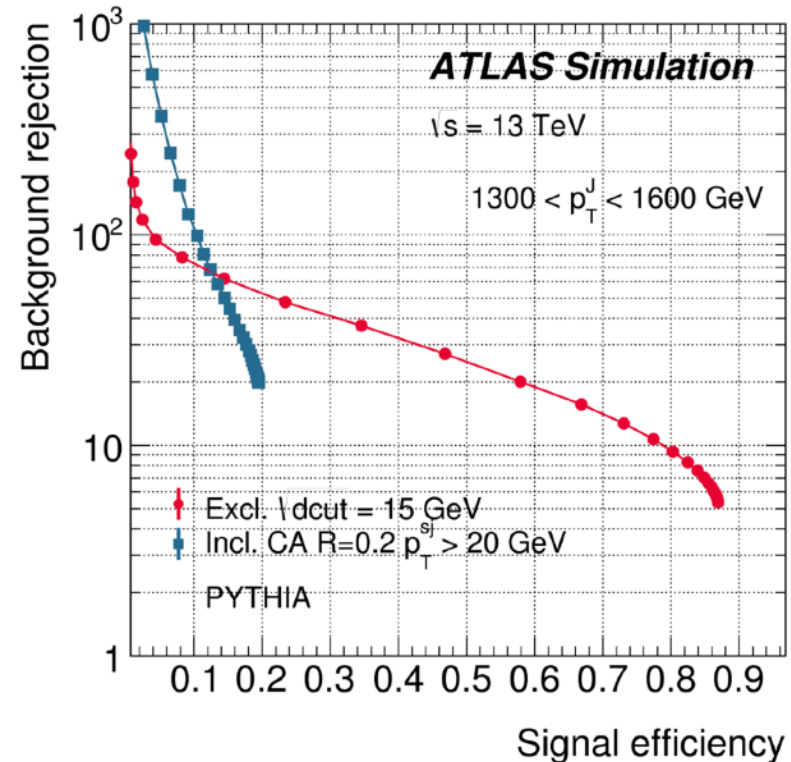
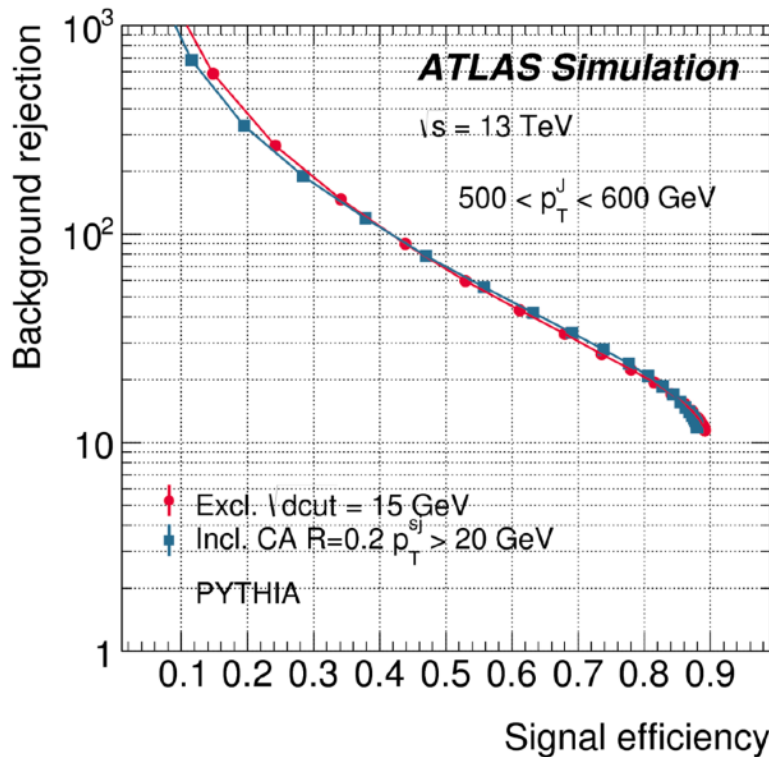
$$\chi_{SD}(\{p\}_N) = \frac{P(\{p\}_N|S)}{P(\{p\}_N|B)} = \frac{\sum_{\text{histories}} P(\{p, c^j\}_N|S)}{\sum_{\text{histories}} P(\{p, c^j\}_N|B)}$$



$\sum_{\text{background-hypotheses PS histories}}$

Shower deconstruction performance

A bit more information

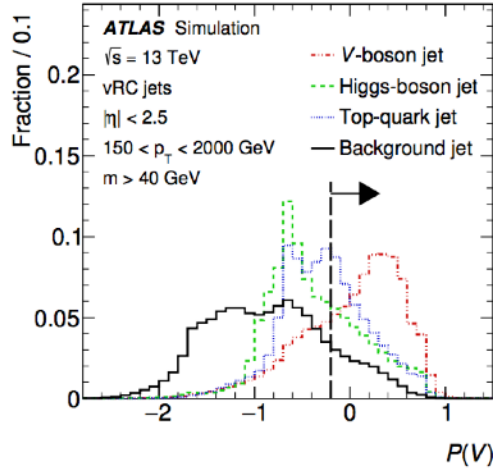


- Use of **exclusive subjects** => better performance for very-highly-boosted top quarks.

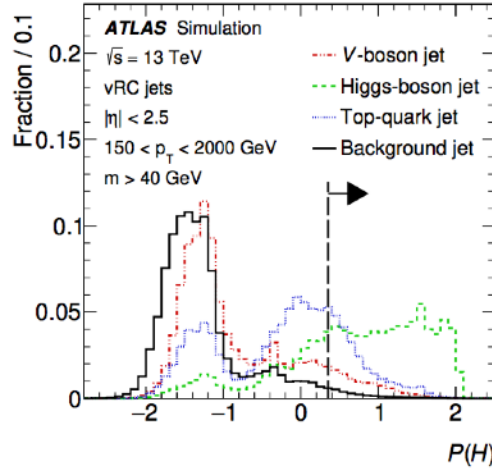
DNN tagger

A bit more information

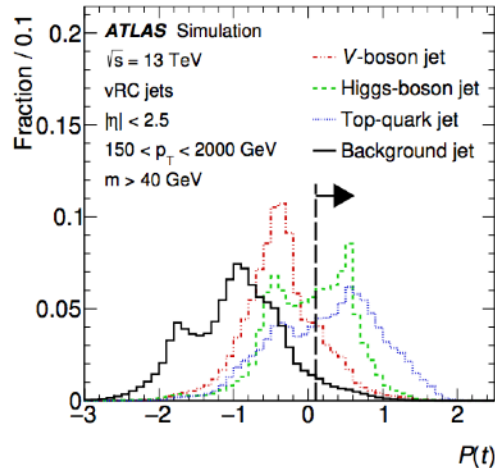
<https://arxiv.org/pdf/1808.01771.pdf>



(a)



(b)



(c)

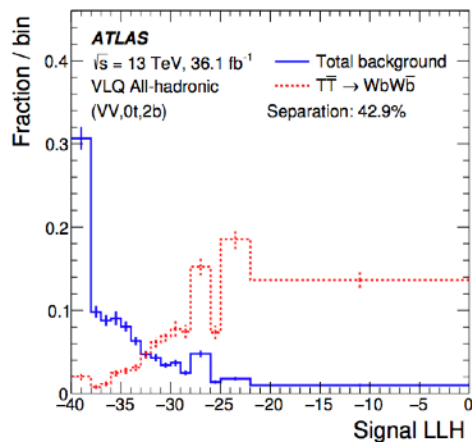
$$P(V) = \log_{10} \left(\frac{D_{\text{DNN}}^V}{0.9 \cdot D_{\text{DNN}}^{\text{background}} + 0.05 \cdot D_{\text{DNN}}^t + 0.05 \cdot D_{\text{DNN}}^H} \right),$$

$$P(H) = \log_{10} \left(\frac{D_{\text{DNN}}^H}{0.9 \cdot D_{\text{DNN}}^{\text{background}} + 0.05 \cdot D_{\text{DNN}}^V + 0.05 \cdot D_{\text{DNN}}^t} \right) \text{ and}$$

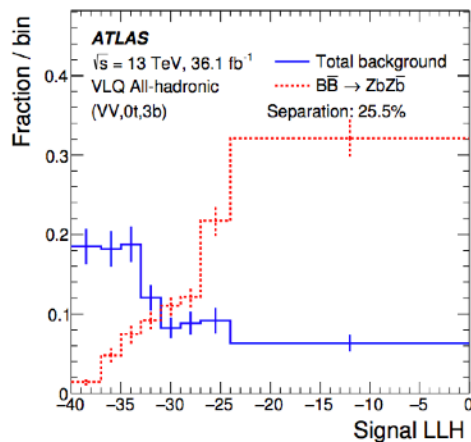
$$P(t) = \log_{10} \left(\frac{D_{\text{DNN}}^t}{0.9 \cdot D_{\text{DNN}}^{\text{background}} + 0.05 \cdot D_{\text{DNN}}^H + 0.05 \cdot D_{\text{DNN}}^V} \right),$$

Matrix element method

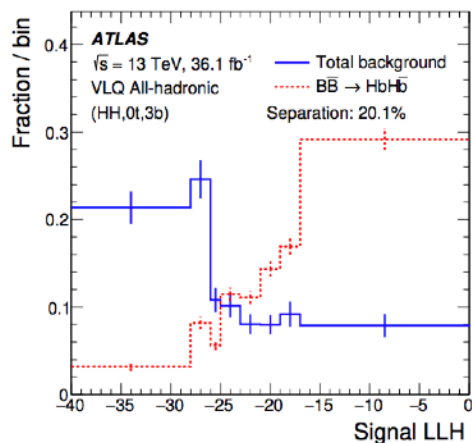
A bit more information



(a)



(b)



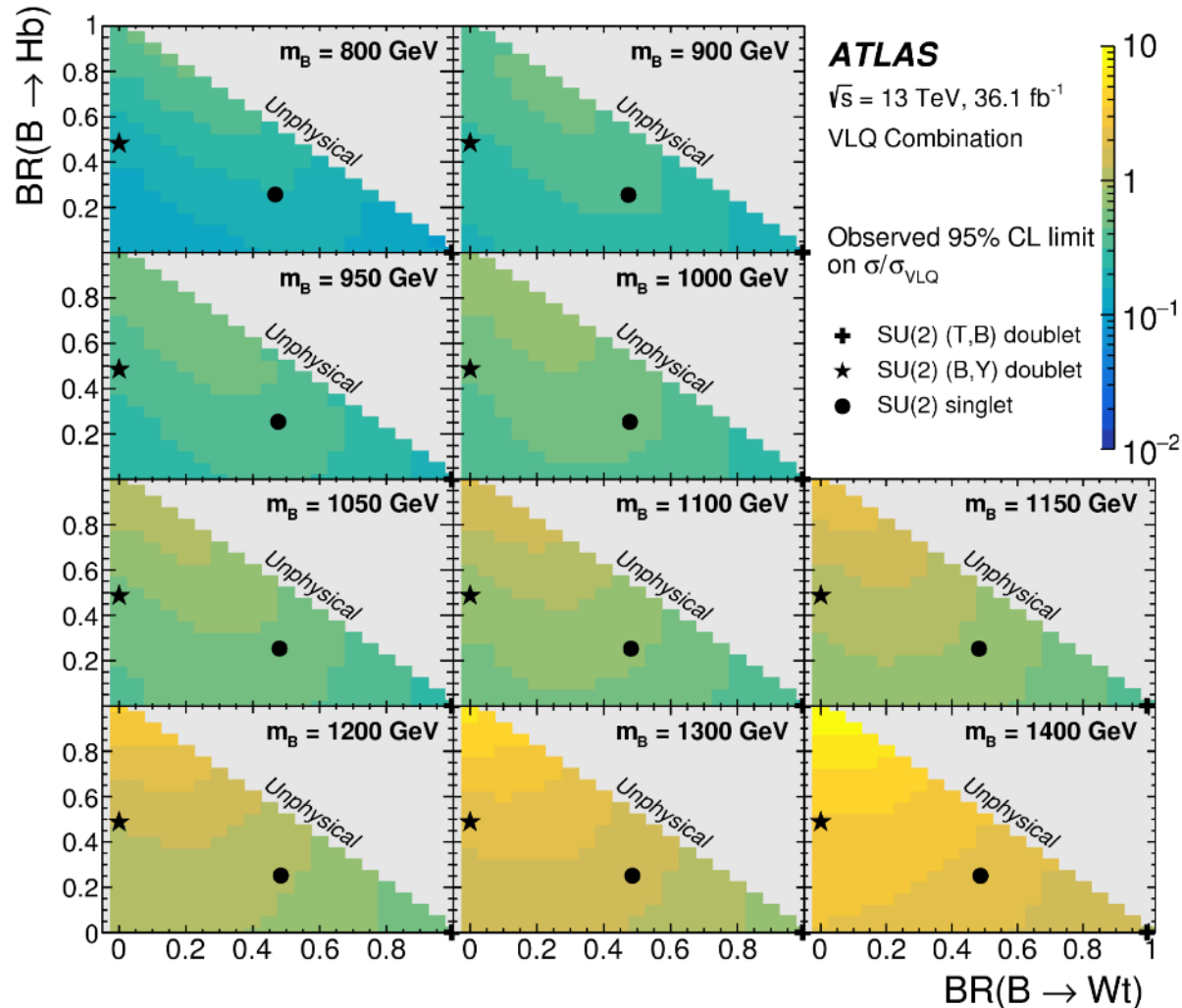
Phase space element

Truth-reco transfer function

$$P_i(x|\alpha) = \frac{(2\pi)^4}{\sigma_i^{\text{eff}}(\alpha)} \int d\Phi_N(y) \underbrace{f(p_A)}_{\text{PDF}} \underbrace{f(p_B)}_{\text{PDF}} \underbrace{\frac{M_i(y|\alpha)}{\mathcal{F}}}_{\text{Transition matrix element of the process}} \underbrace{\mathcal{V}(y|x)}_{\text{Truth-reco transfer function}}$$

VLQ searches: next steps ?

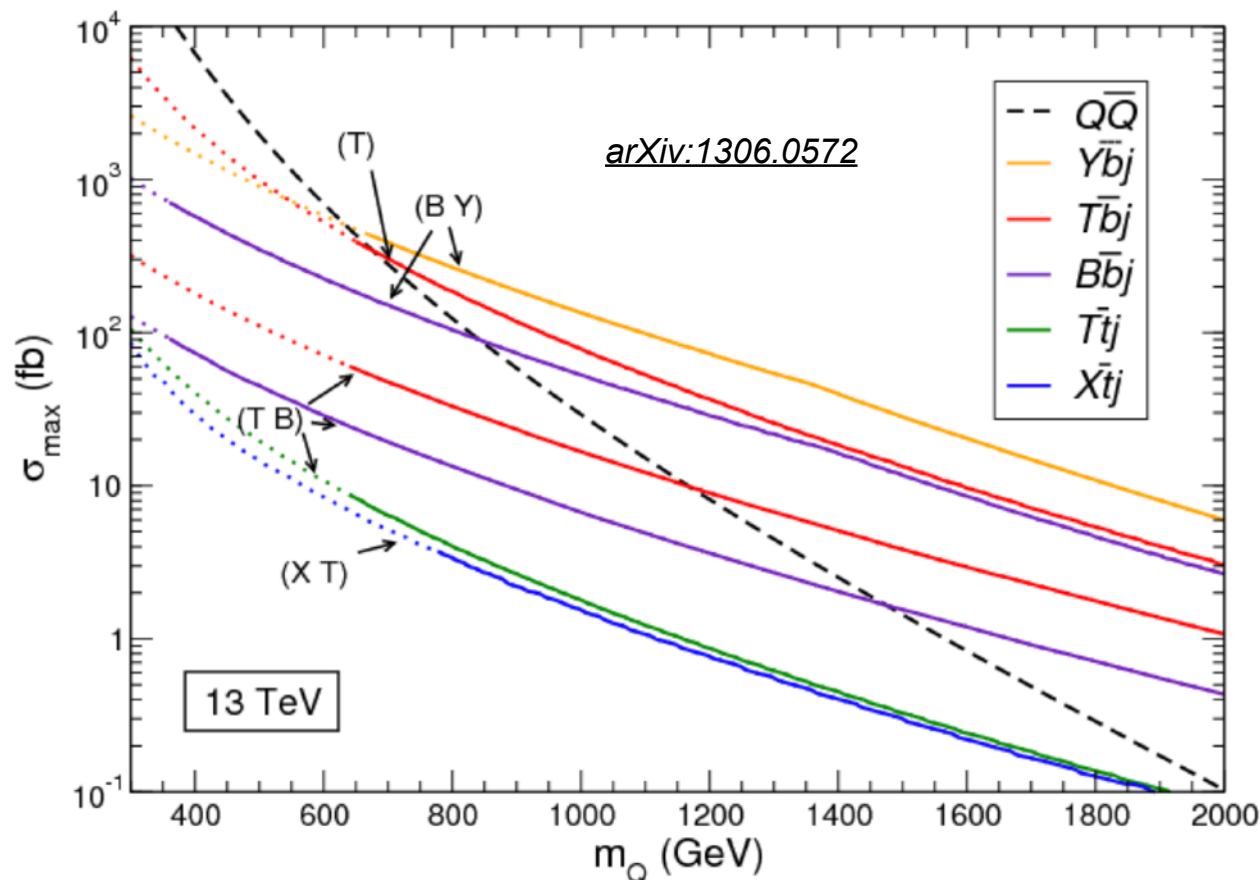
[arXiv:1808.02343](https://arxiv.org/abs/1808.02343)



Single VLQ production

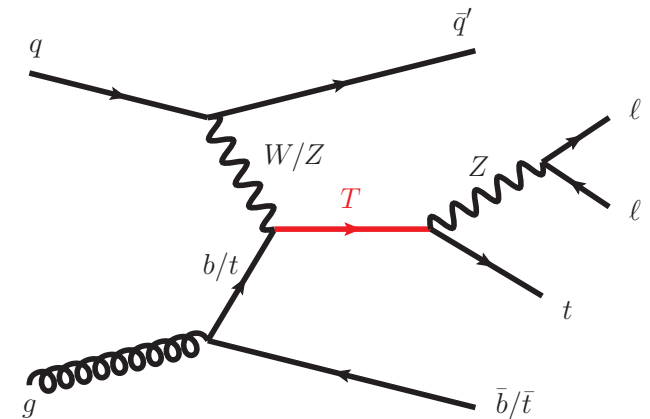
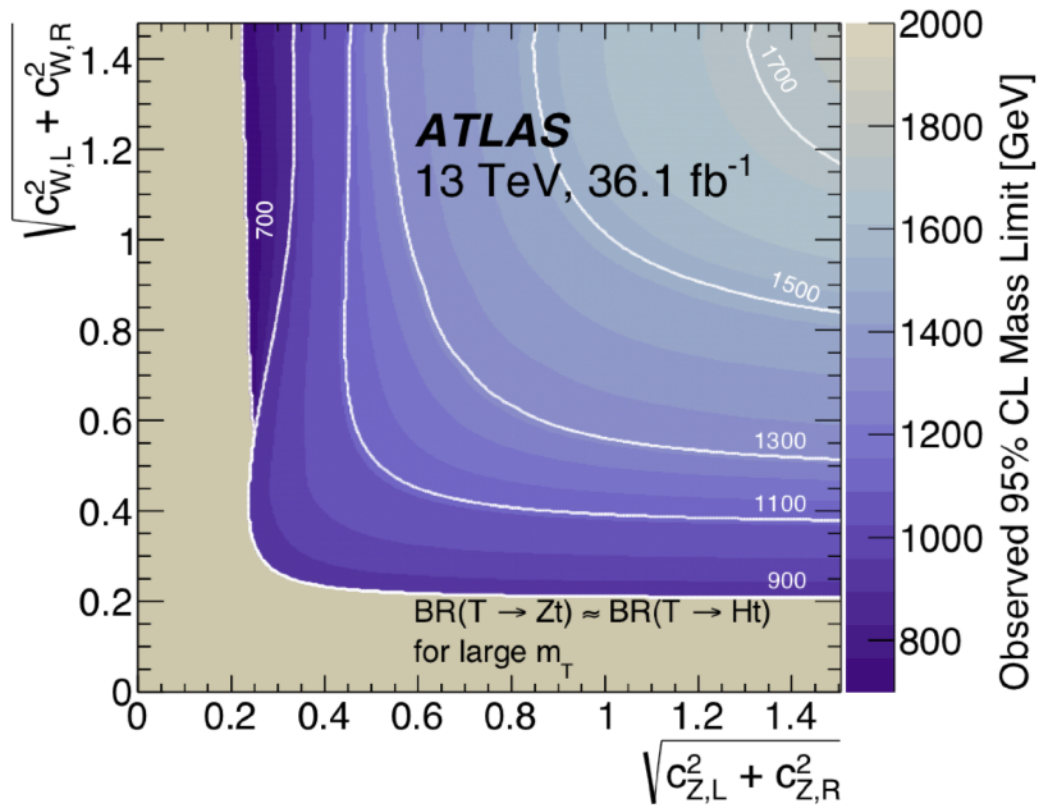
A bit more information

- Single production cross-section **depends on coupling** between quarks and vector-like partners.



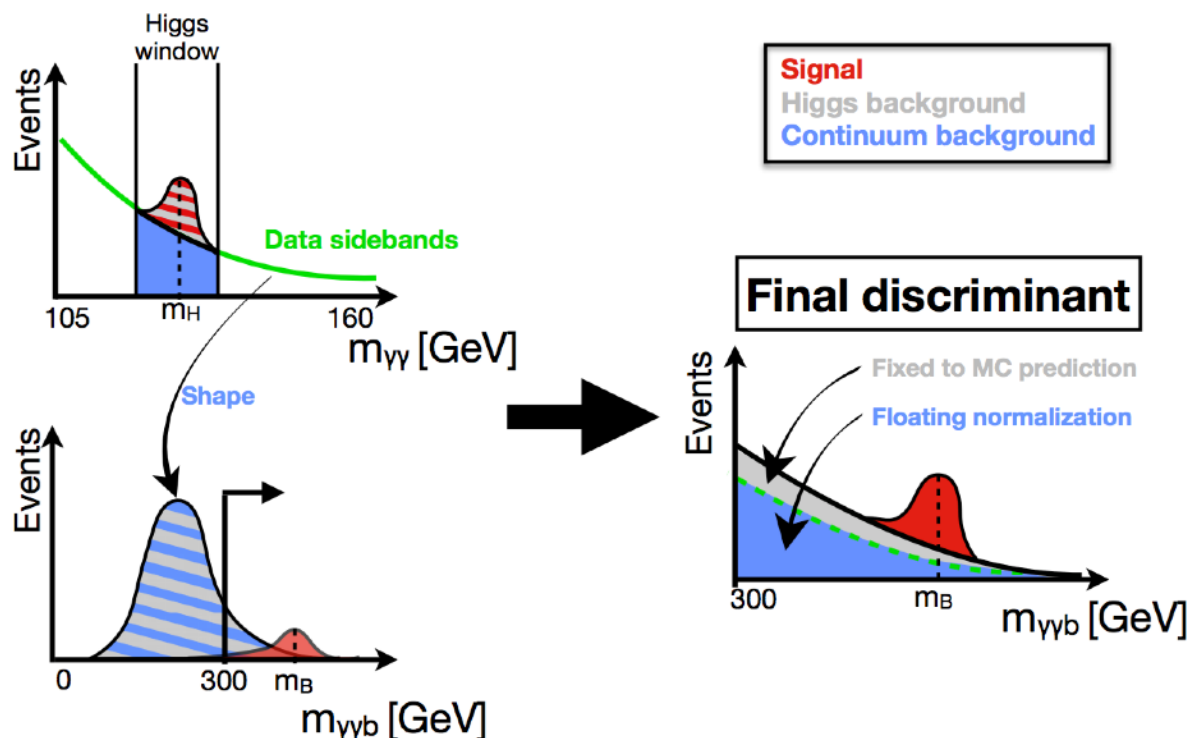
Single VLQ interpretation

A bit more information



$B \rightarrow H \rightarrow \gamma\gamma b$

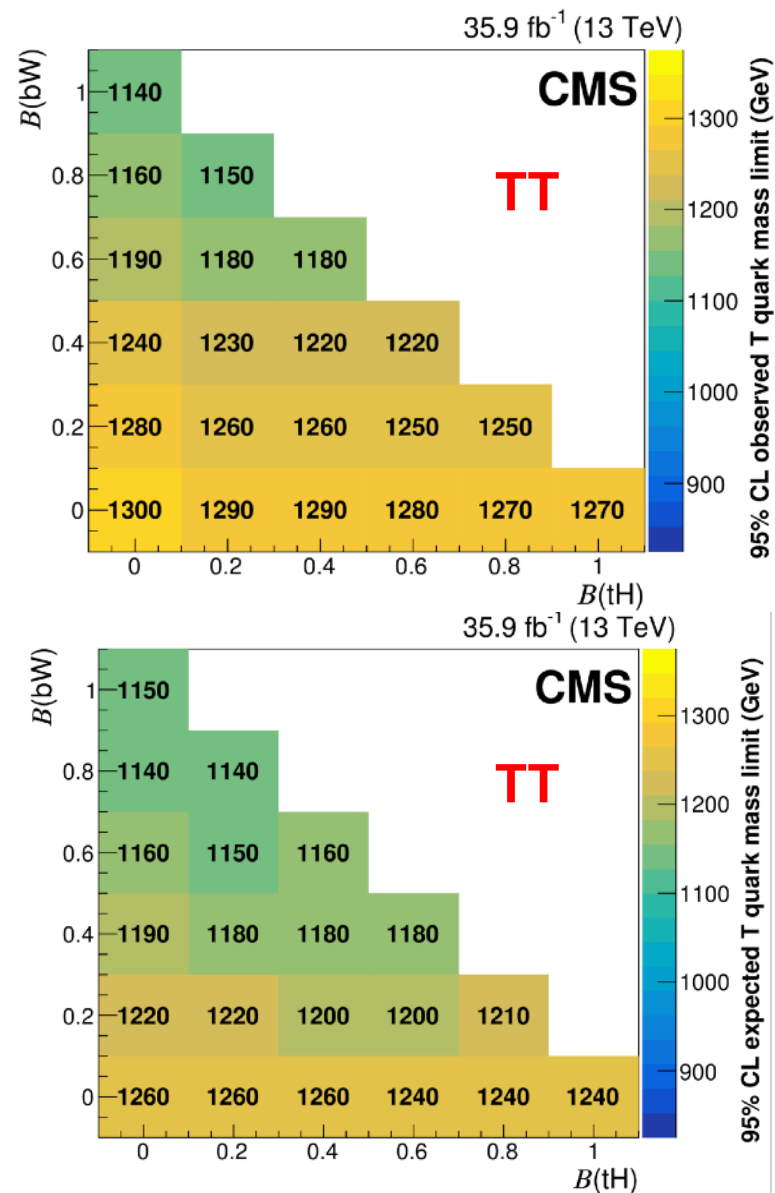
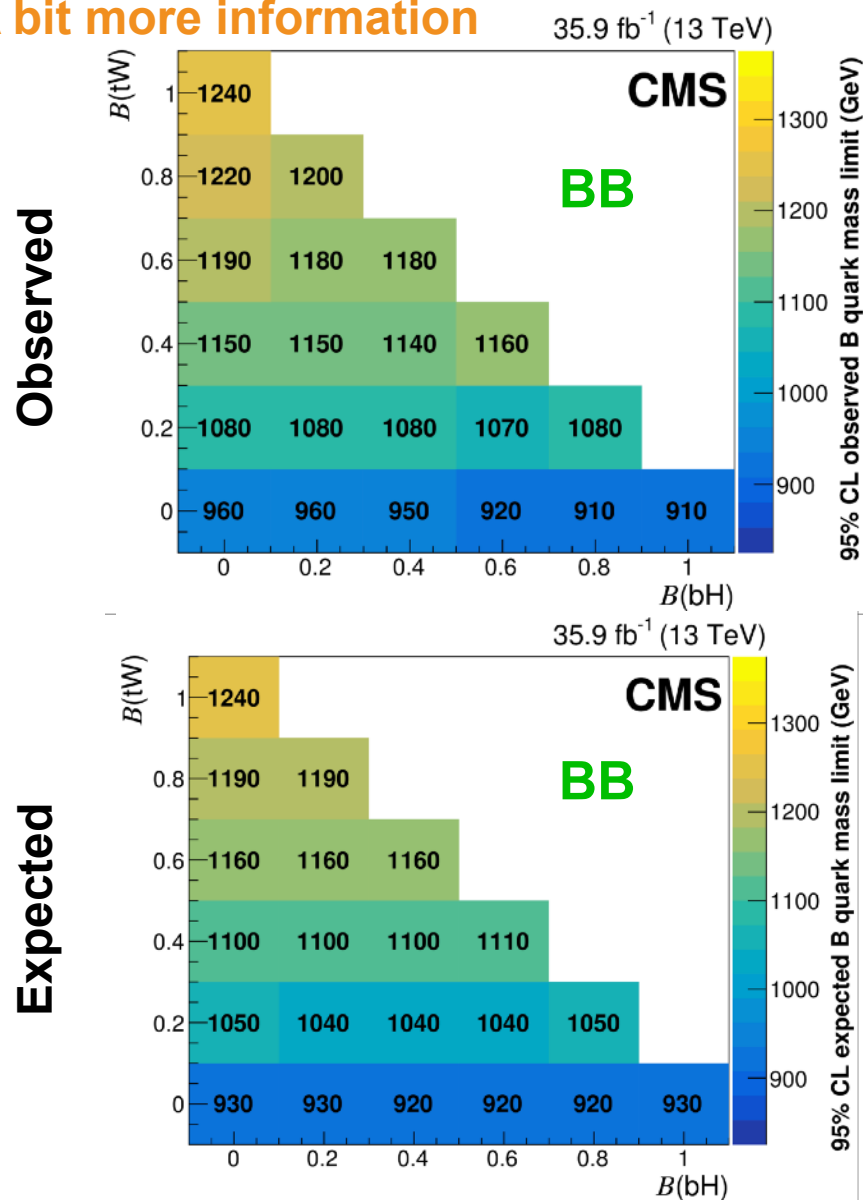
Some more information



CMS results

A bit more information

arXiv:1805.04758 (Accepted by JHEP)



ATLAS results

A bit more information

arXiv:1808.02343 (Accepted by PRL)

