

DISCRETE-2022
7th-11th November 2022



Recent searches for new phenomena with the ATLAS detector

Matteo Franchini

on behalf of the ATLAS collaboration



Intro

- * **Focus** on phase-space regions having **the most interesting “tensions”** with respect to **SM**.

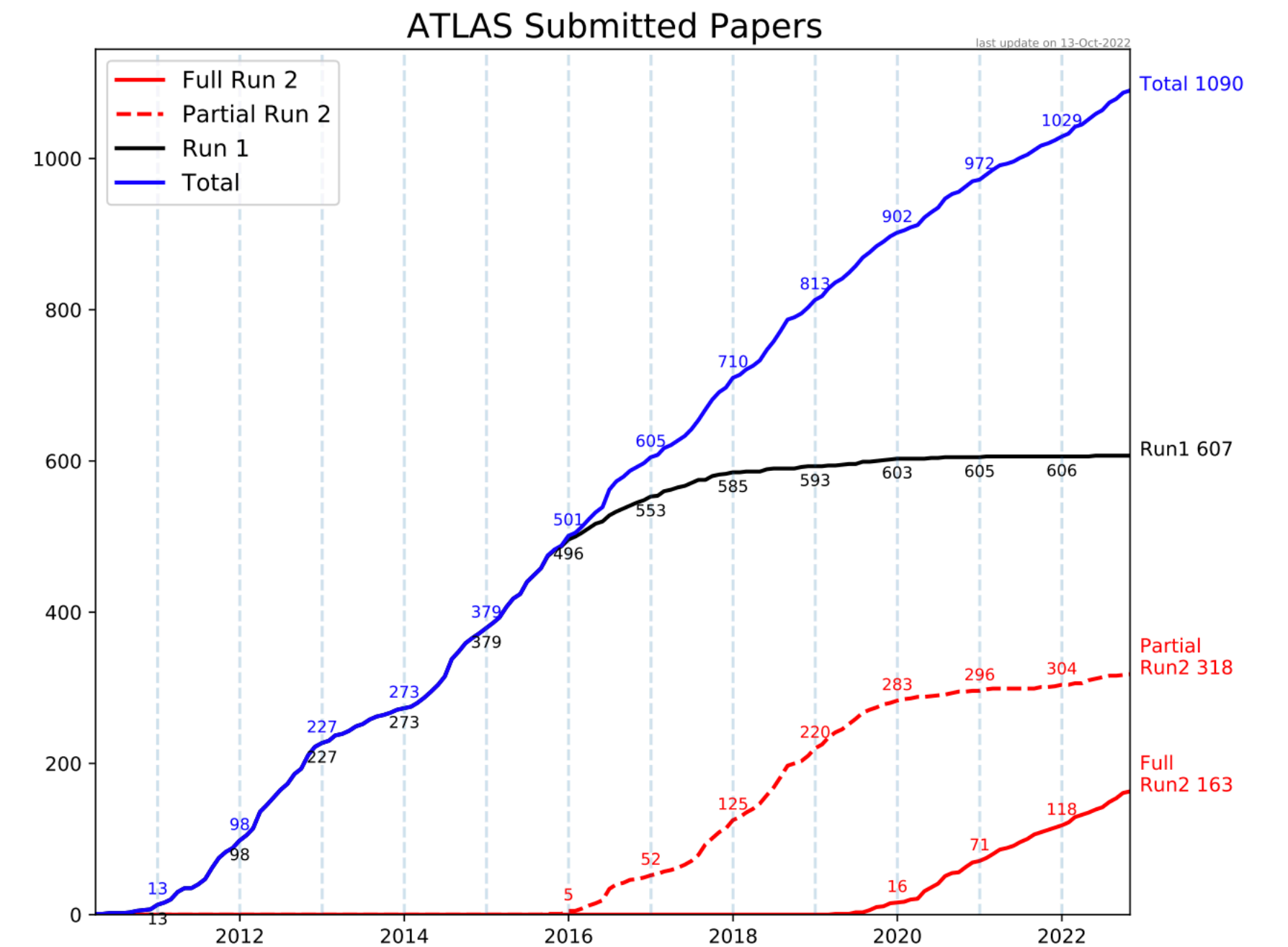
- * Extensive **run-2 analysis program** in both **ATLAS** & **CMS** advancing well:

- more than 400 run-2 papers submitted each and more than 300 in progress only in ATLAS

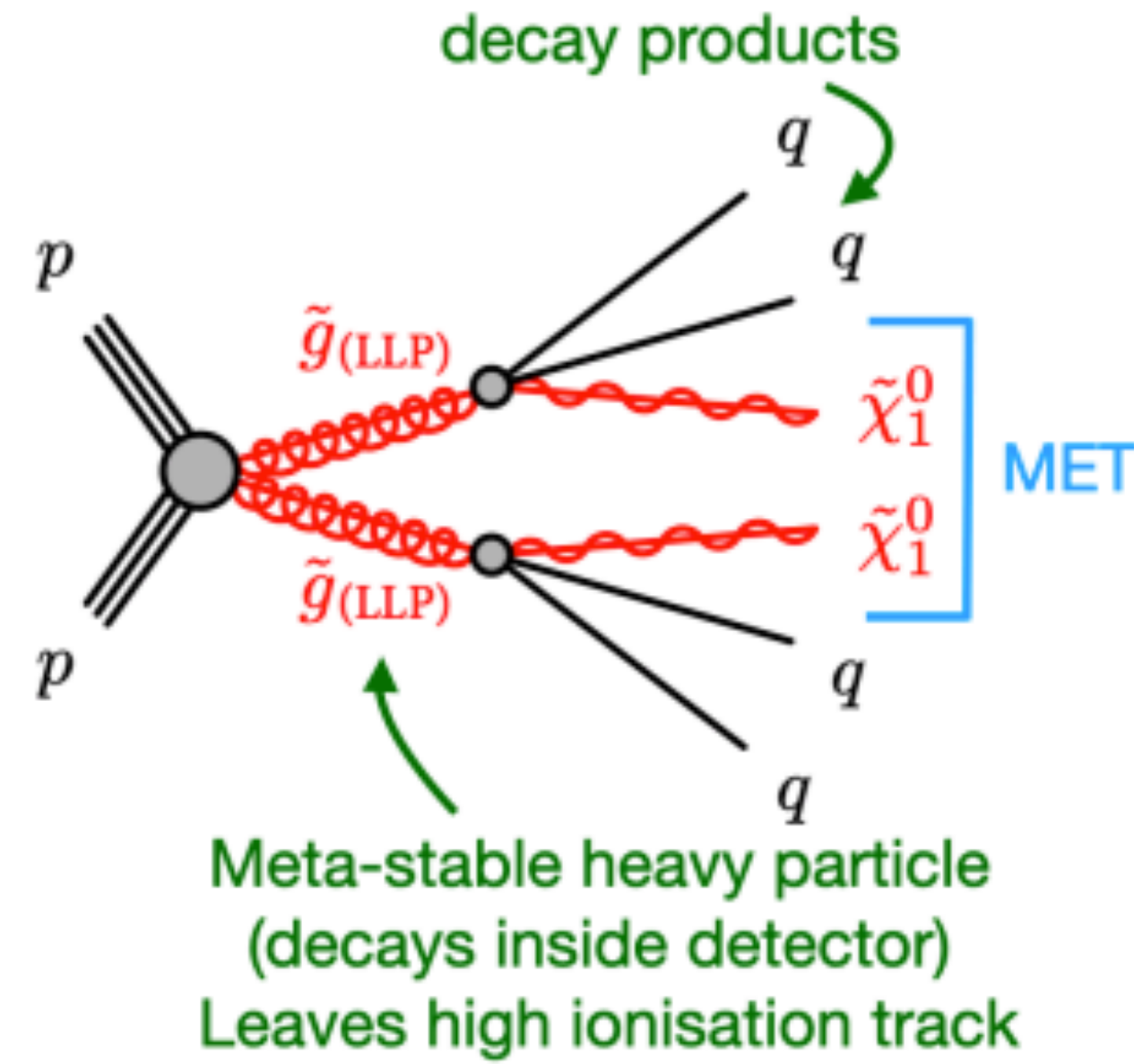
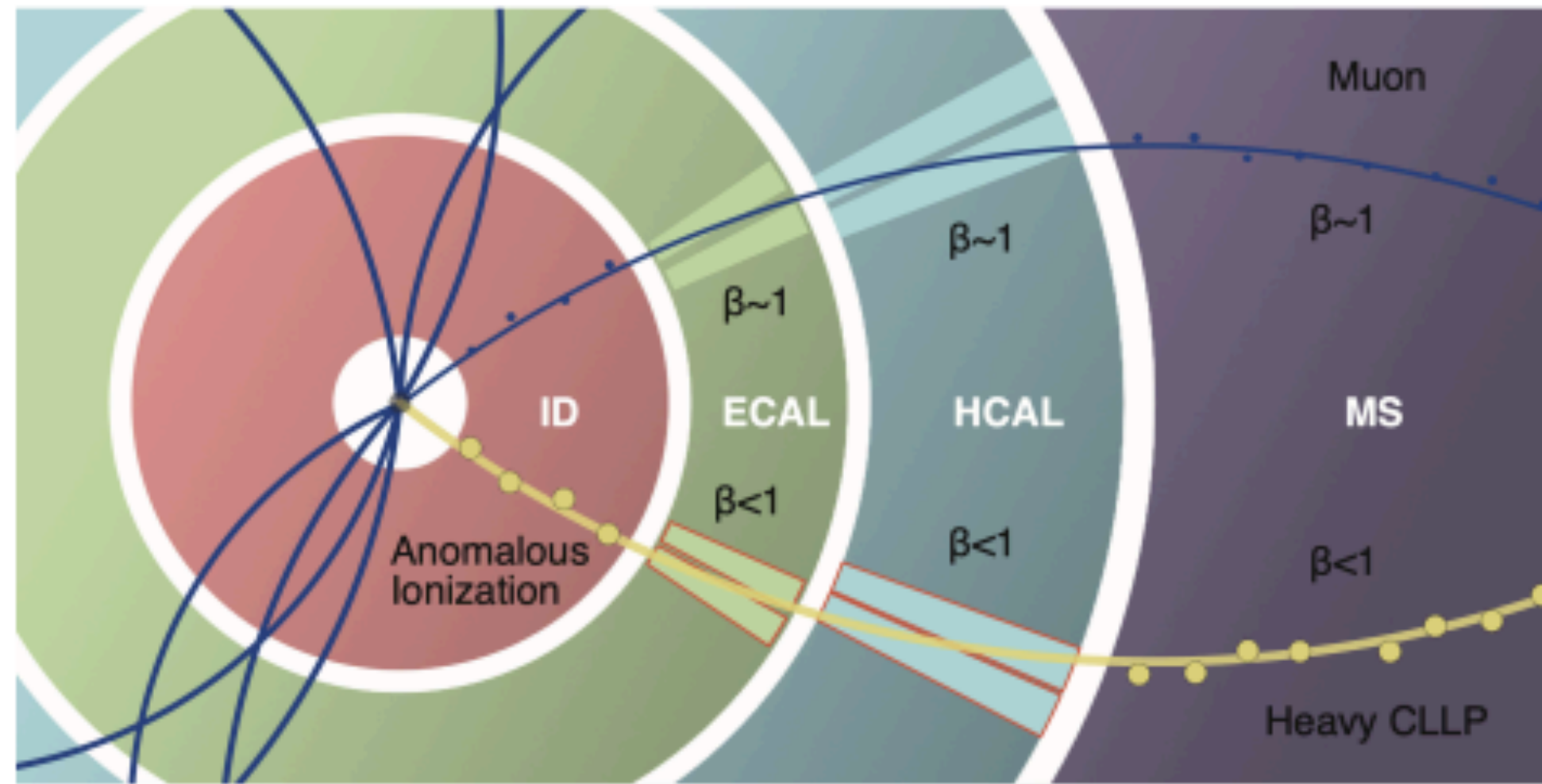
- * **More run-2 results to come**, carefully scrutinising more specific/exclusive final states. Also preparing for **run-3** in most interesting phase-space region first.

- * Necessarily to consider **every hint** of new physics from both experiments: both cross check and search wide-spreading.

- **ATLAS** looks at results from **CMS**... they see more 2-3 σ excesses!



Pixel dE/dx analysis

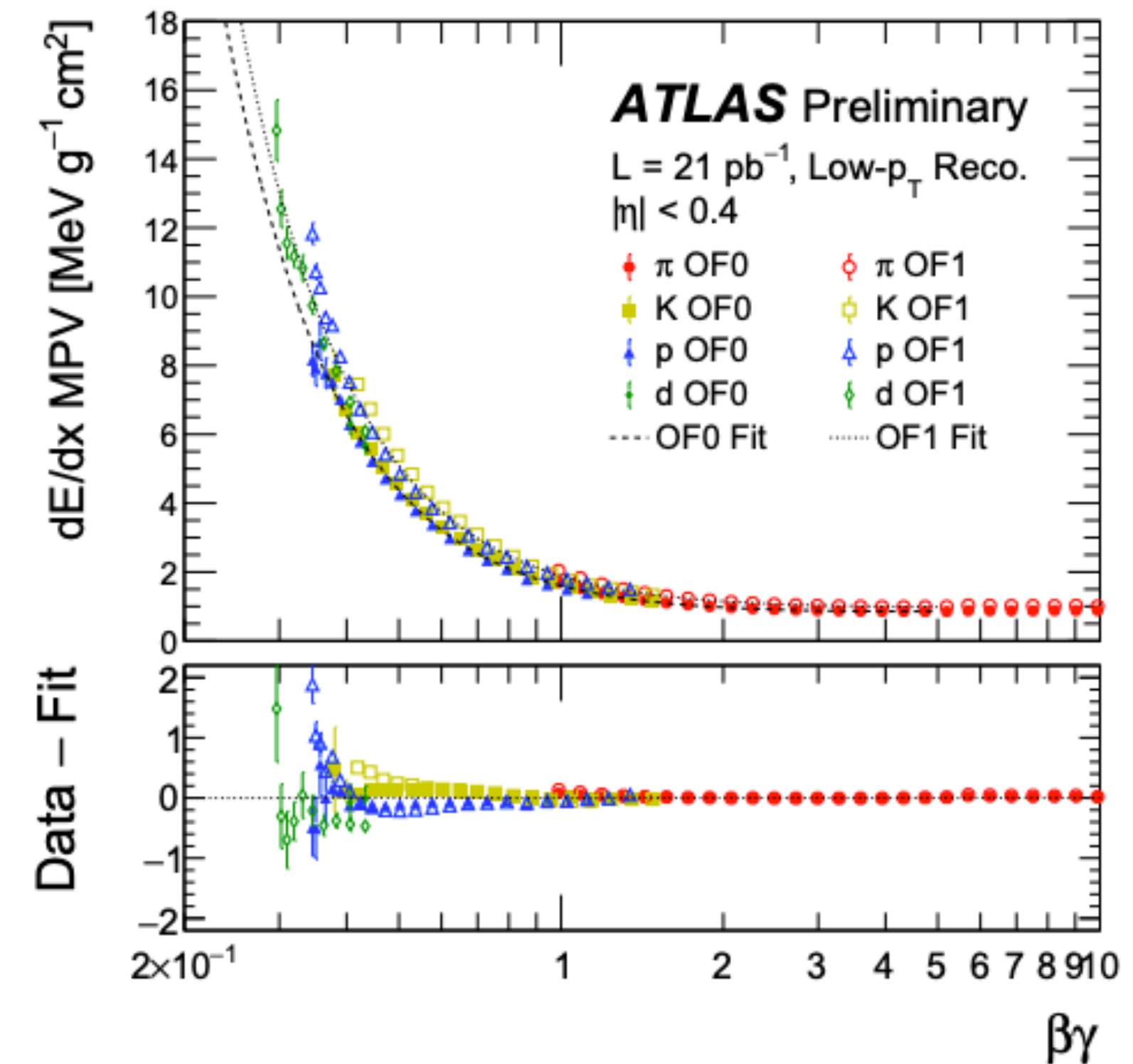


Data-Driven Bkg

Generate bkg tracks from measured events ($1/p_T$ and dE/dx) in control region inverting cuts

Validate in dedicated regions: low track p_T ([50, 100] GeV) and high η ([1.8, 2.5])

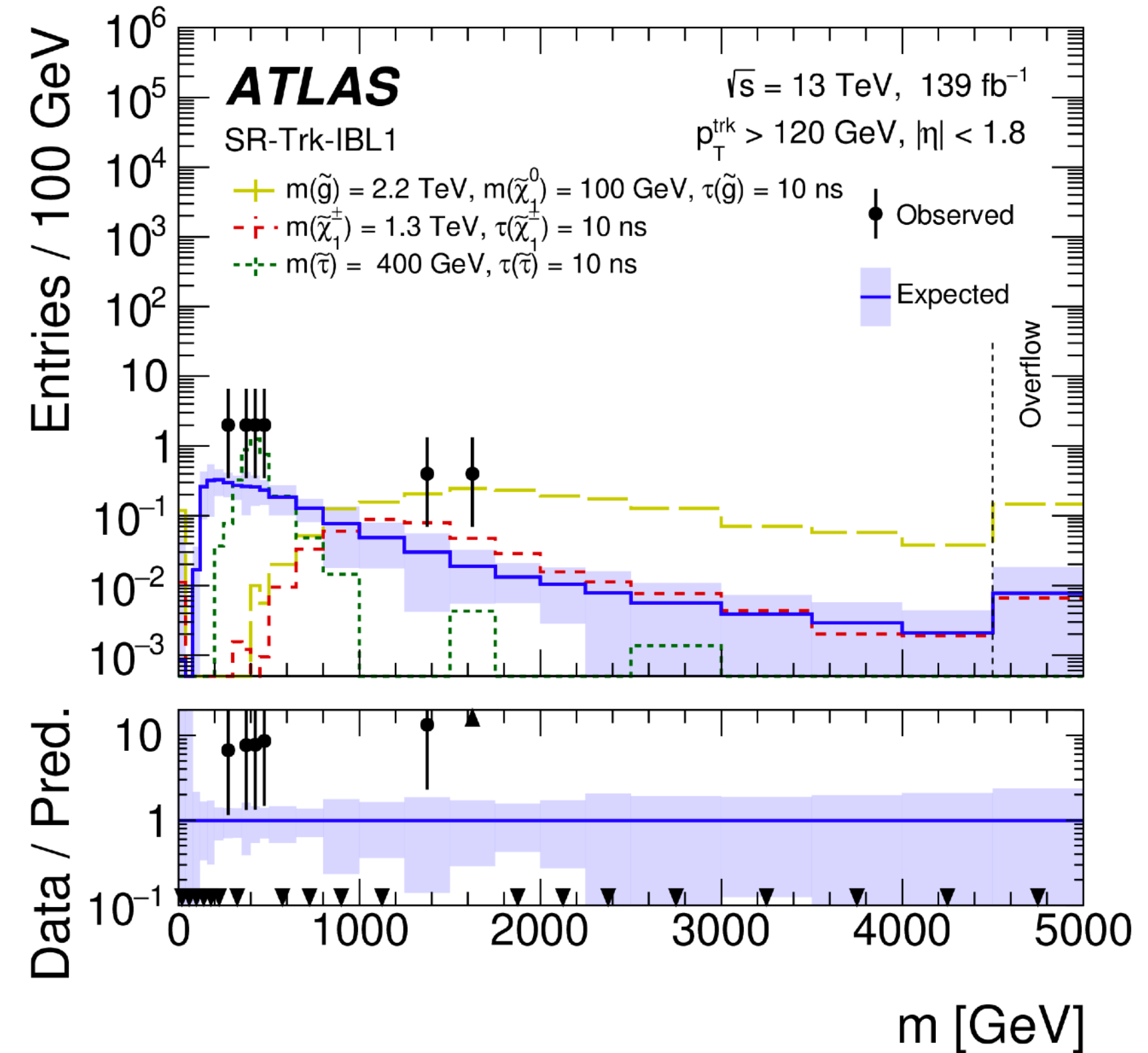
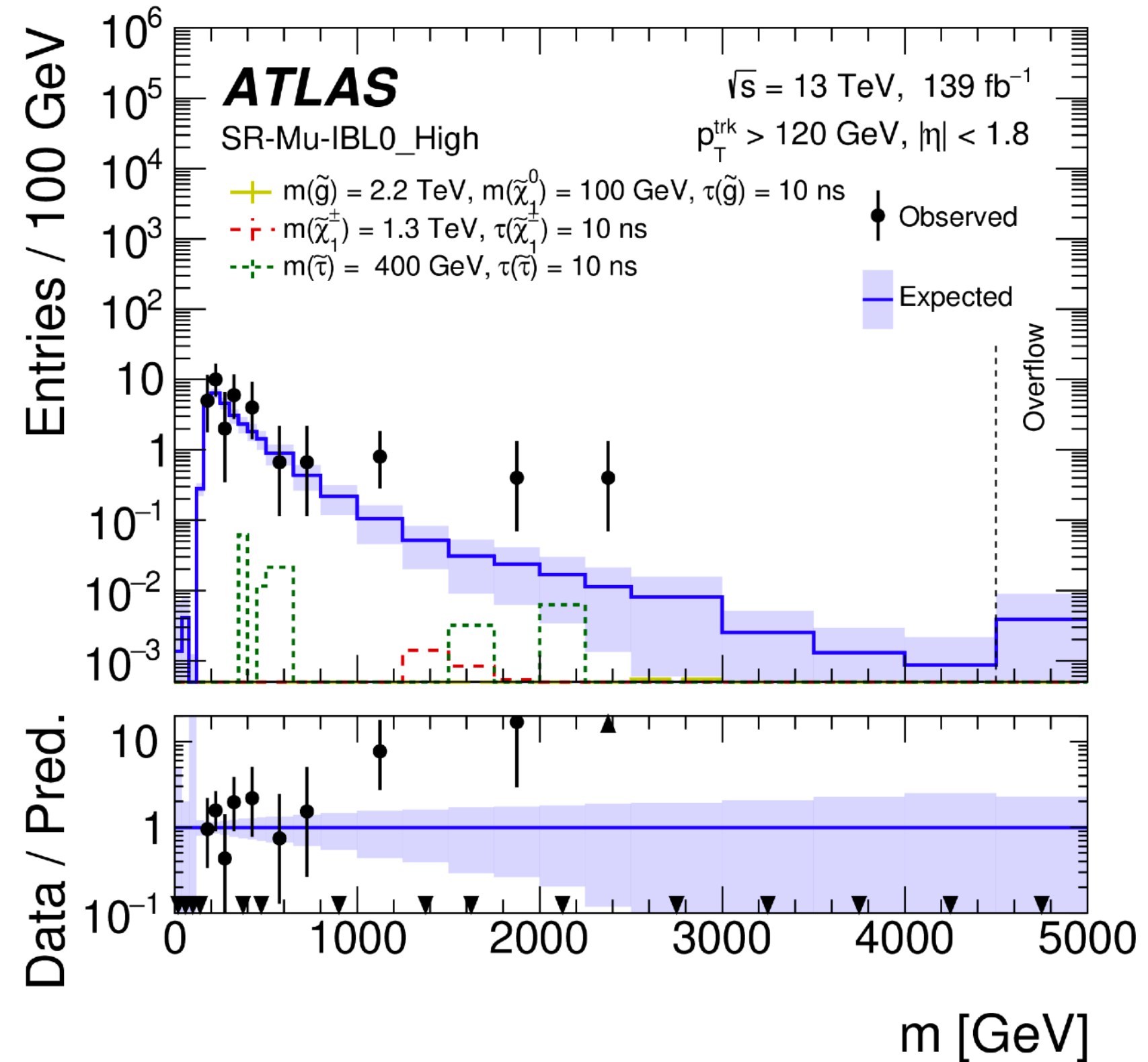
- * **Signature:** anomalously high ionisation (dE/dx) tracks due to heavy non-relativistic particles
- * **Strategy:** parameterise Bethe-Bloch to turn dE/dx into a mass measurement (from $\beta\gamma$ and p_T)
- * Search for **excess of heavy ionising tracks** over data-driven background



Pixel dE/dx analysis

* **Excess** (3.6σ local, 3.3σ global) in high dE/dx SR (> 2.4) with mass hypothesis of 1.4 TeV

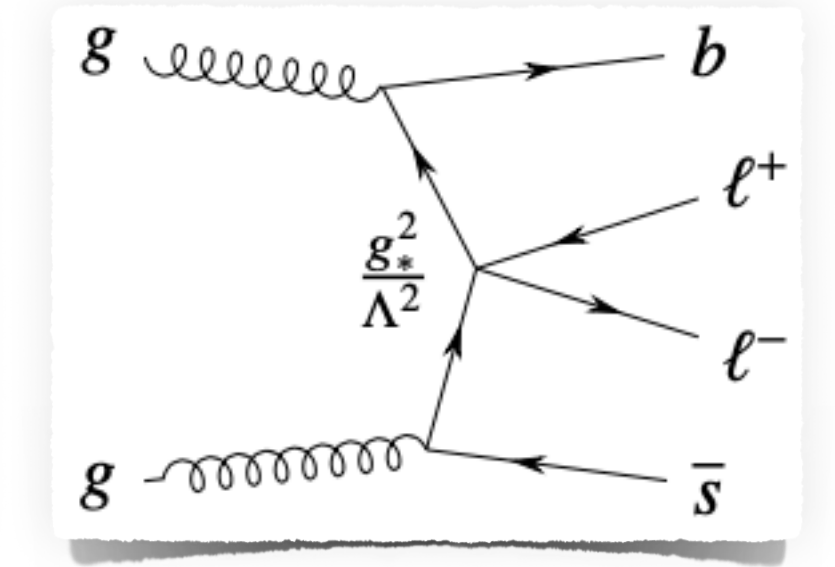
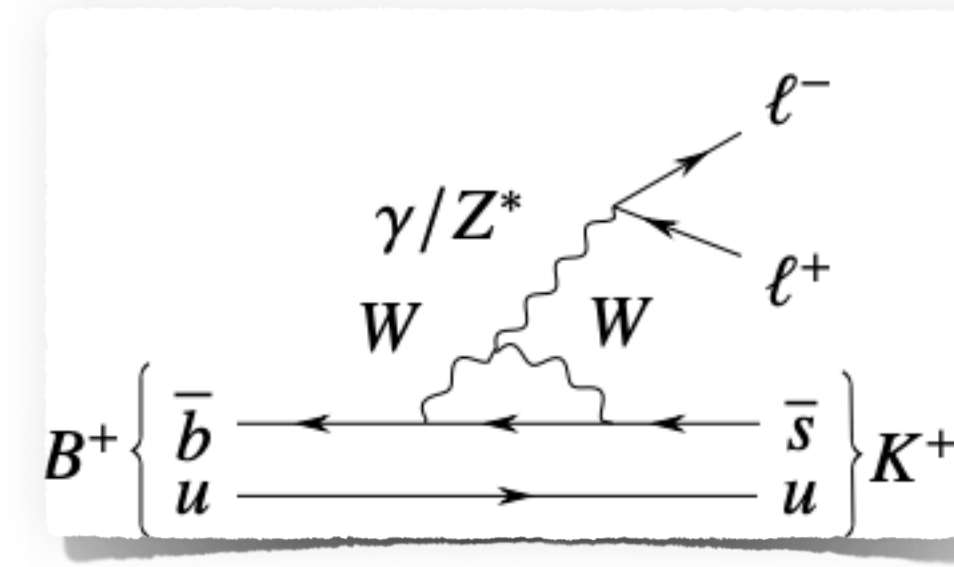
* A **cross-check** with timing variables show that candidate tracks have $\beta \approx 1$, which does **not support** a heavy **LLP(long lived particle)** signal-like interpretation of the excess



[arXiv:2205.06013](https://arxiv.org/abs/2205.06013)

LFUV

Lepton Flavour Universality Violation

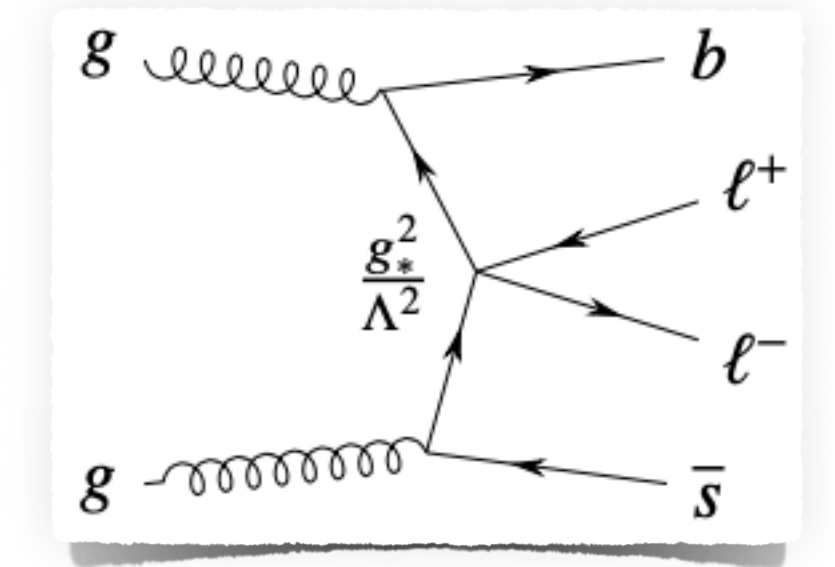
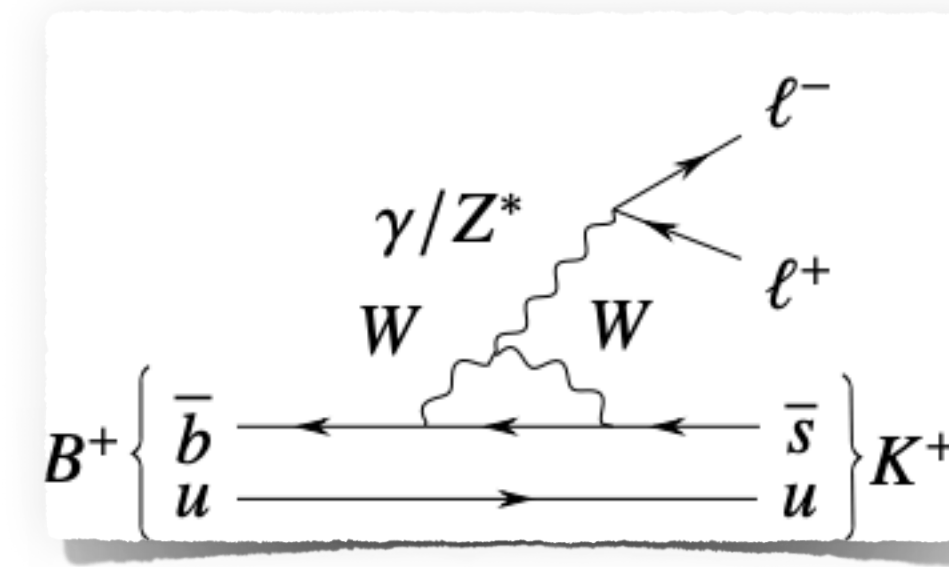
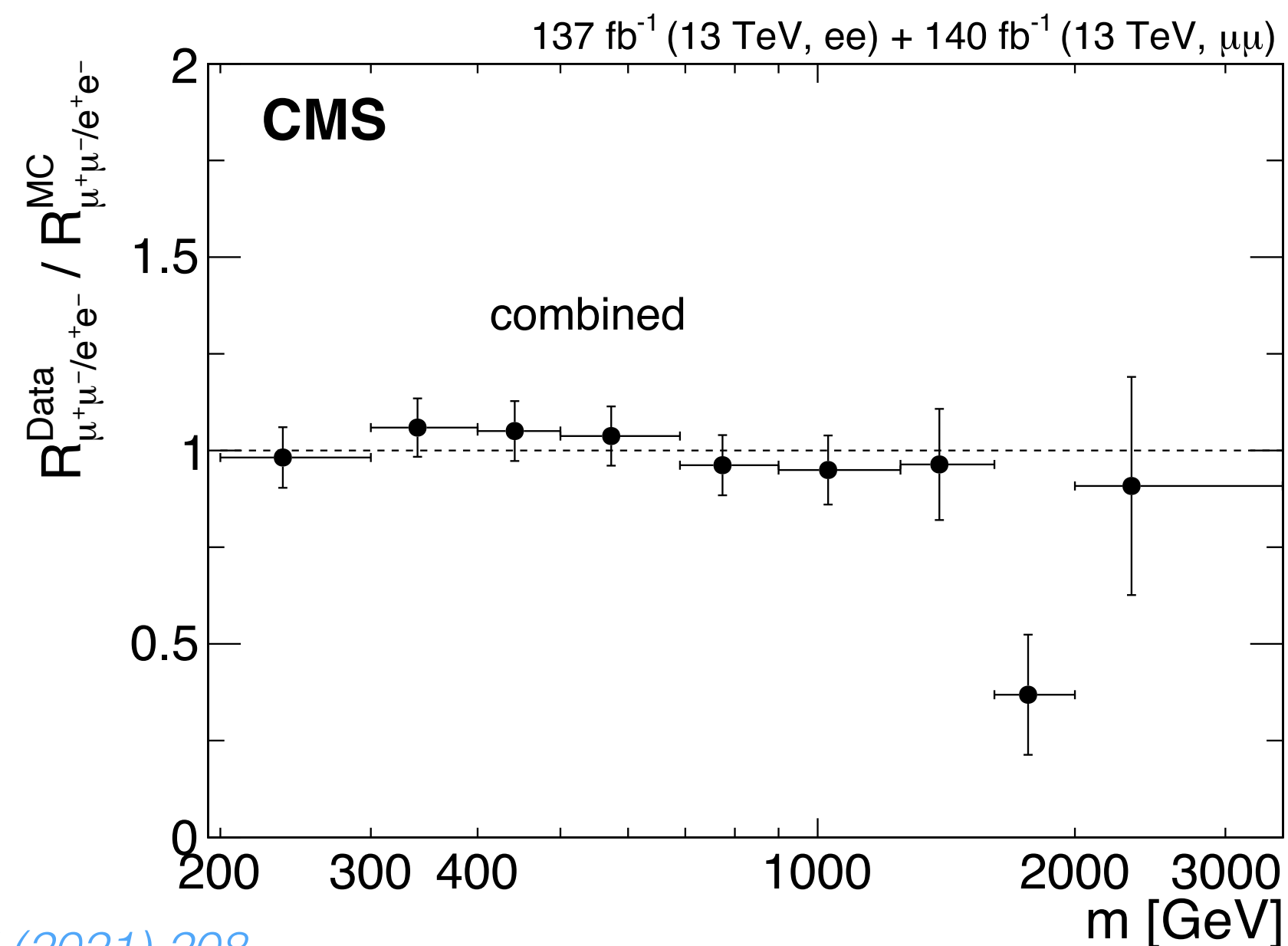


LFOV

Lepton Flavour Universality Violation

* **CMS** found **possible deviations**
in ratio $ee/\mu\mu$ @ high masses

$$R_{\mu^+\mu^-/e^+e^-} = \frac{d\sigma(q\bar{q} \rightarrow \mu^+\mu^-)/dm_{\ell\ell}}{d\sigma(q\bar{q} \rightarrow e^+e^-)/dm_{\ell\ell}}$$



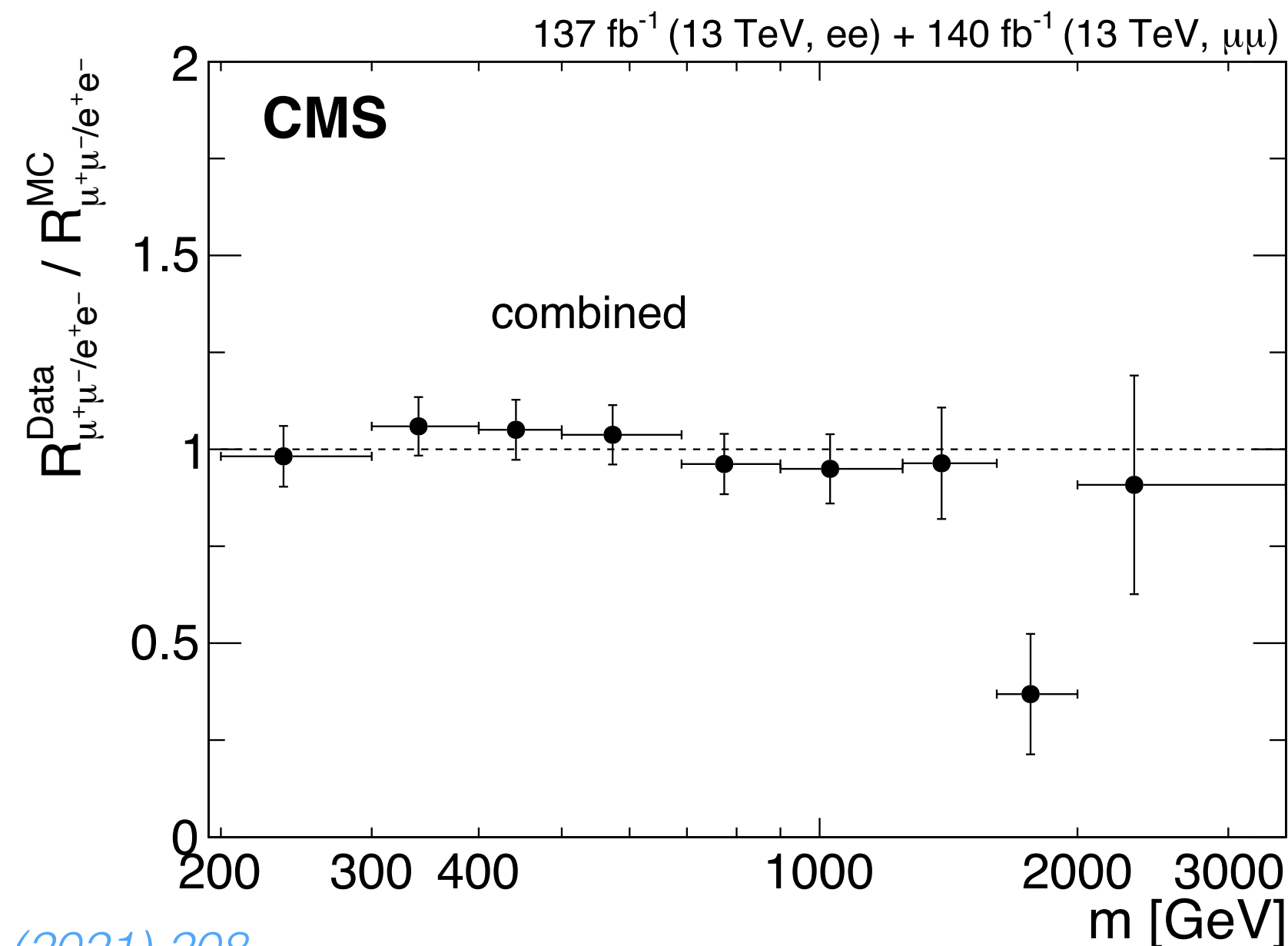
[JHEP 07 \(2021\) 208](#)

LFUV

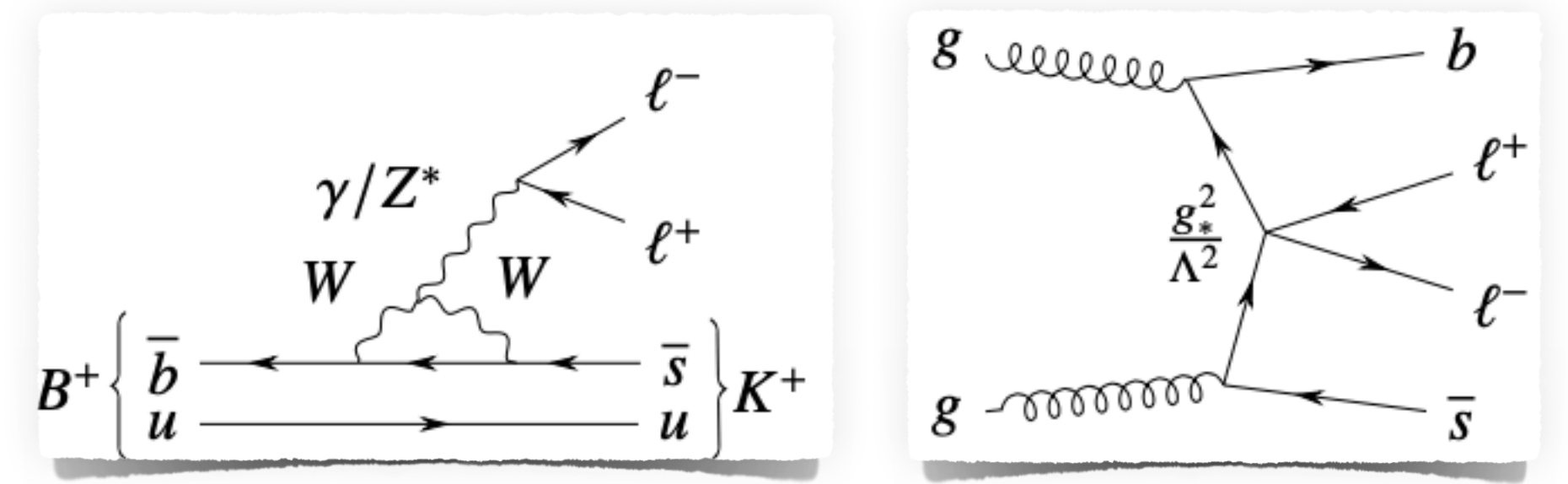
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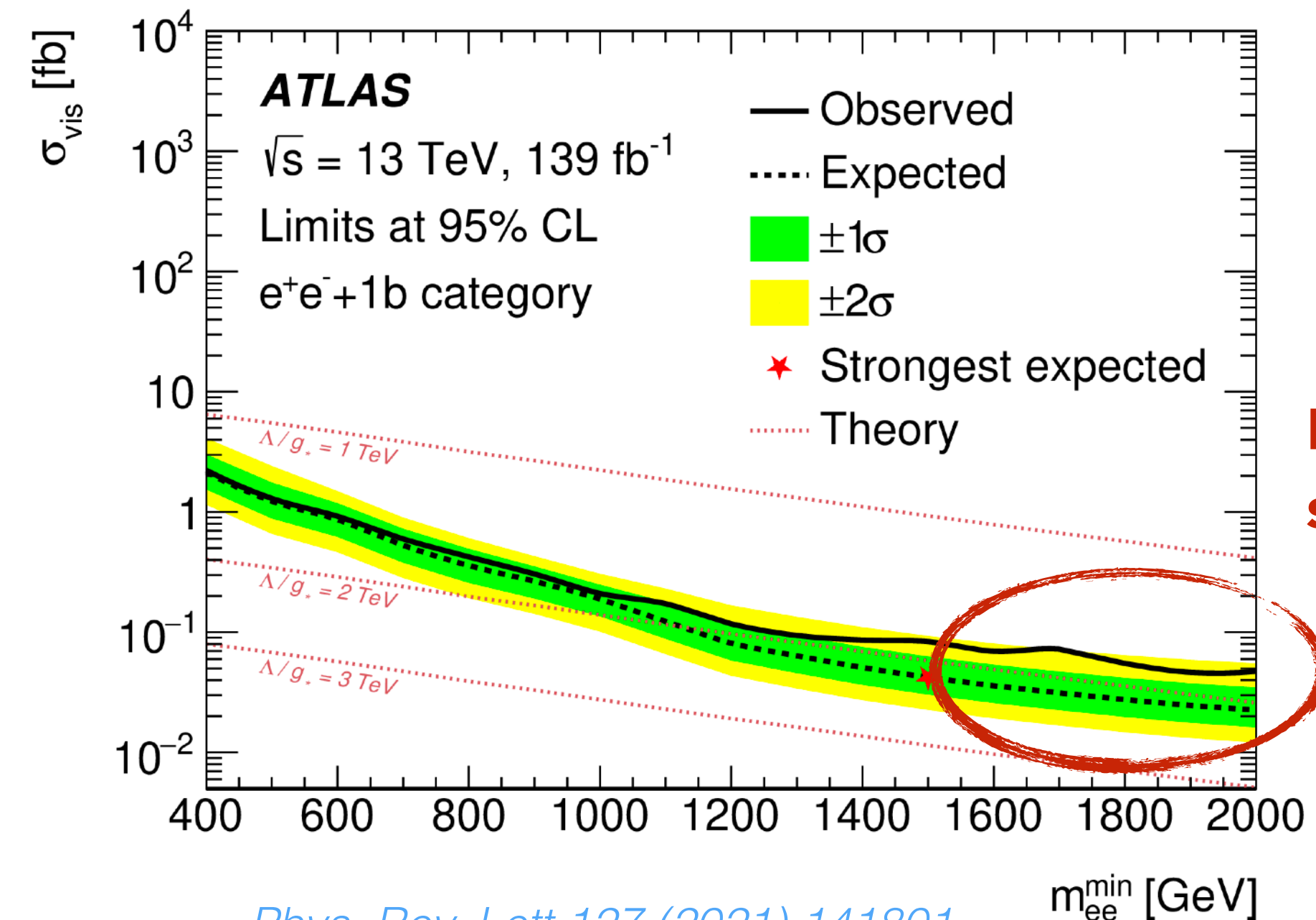
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[JHEP 07 \(2021\) 208](#)



- * **ATLAS** non-resonant high mass dilepton+1b search



[Phys. Rev. Lett 127 \(2021\) 141801](#)

Possible hint of similar effect?

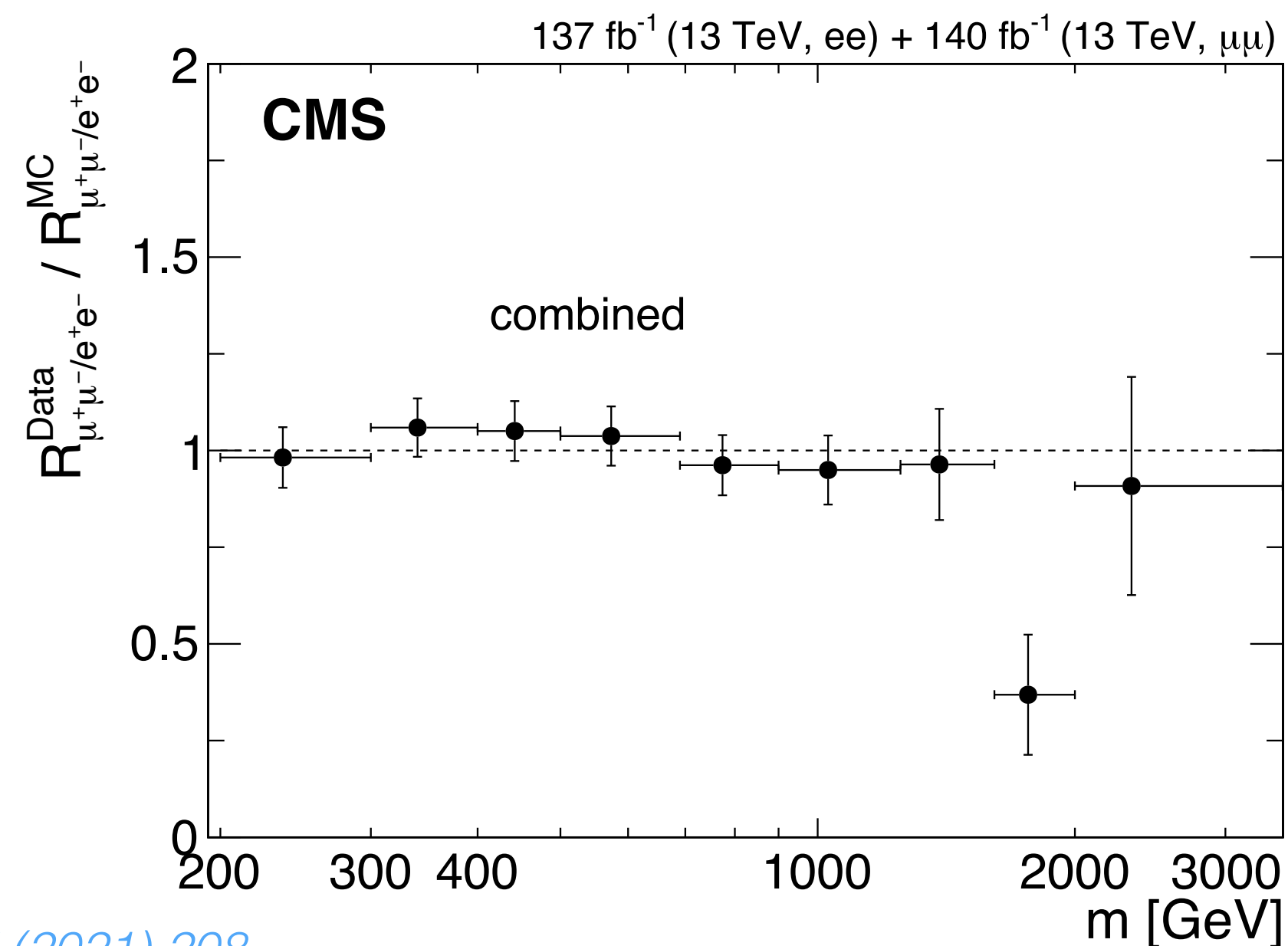
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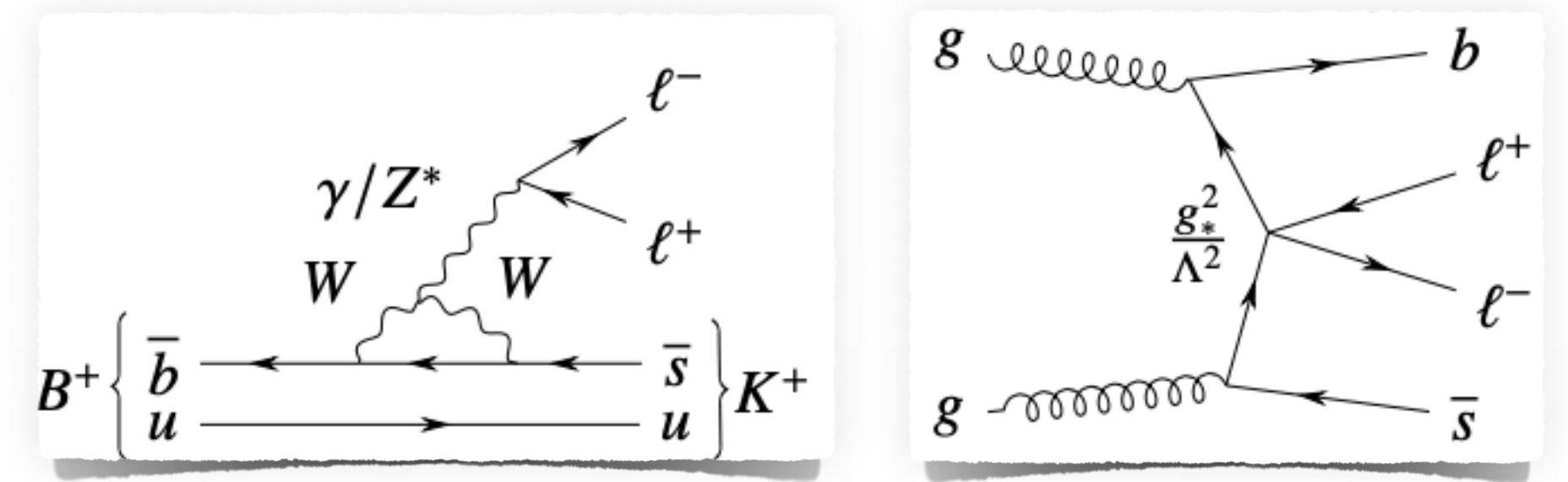
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[JHEP 07 \(2021\) 208](#)



* **ATLAS** ongoing **follow-up studies** on LFUV in high-mass Drell-Yan is twofold :

* **double differential** measurement of high-mass **Drell-Young** inclusive ratios

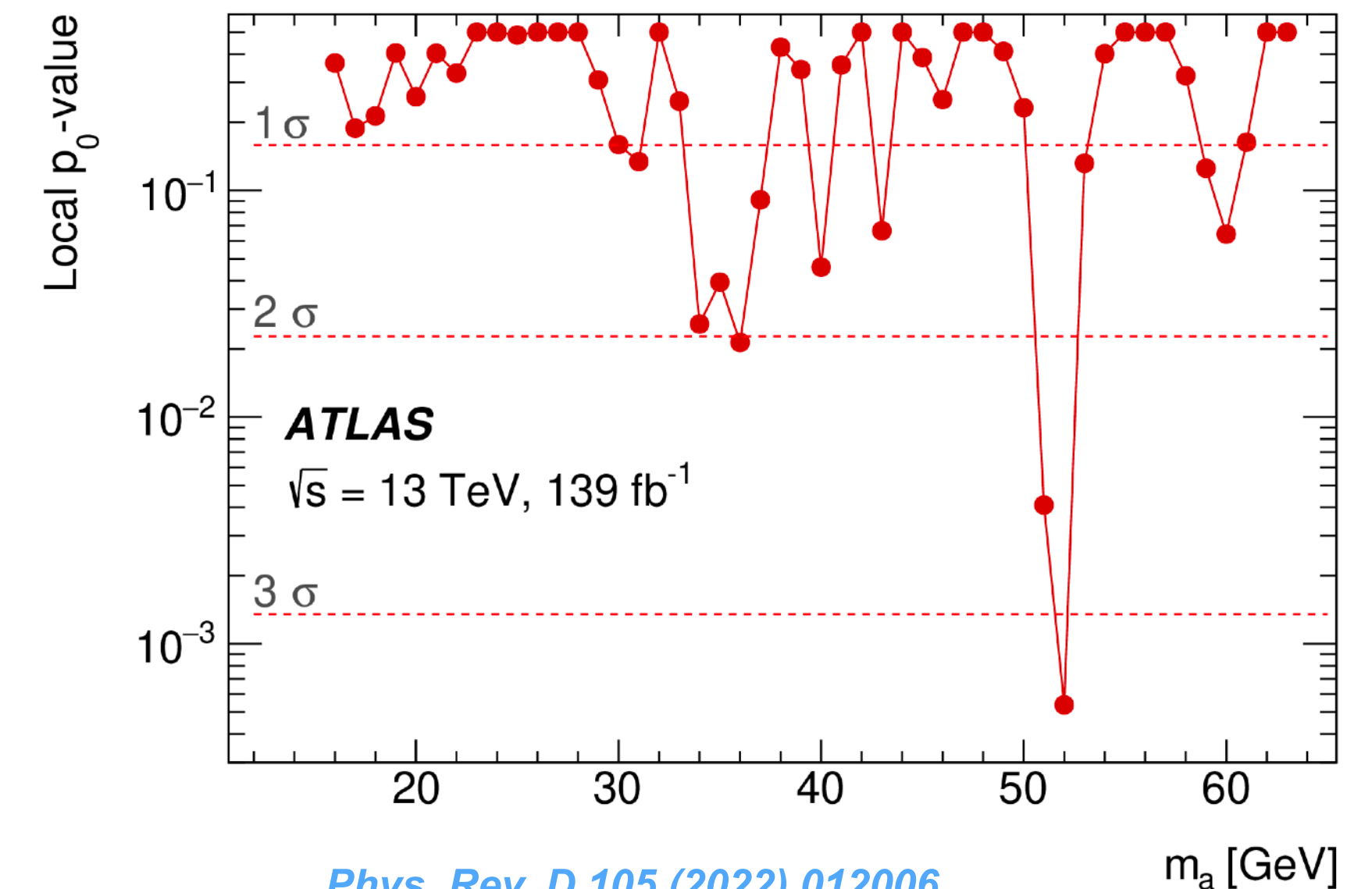
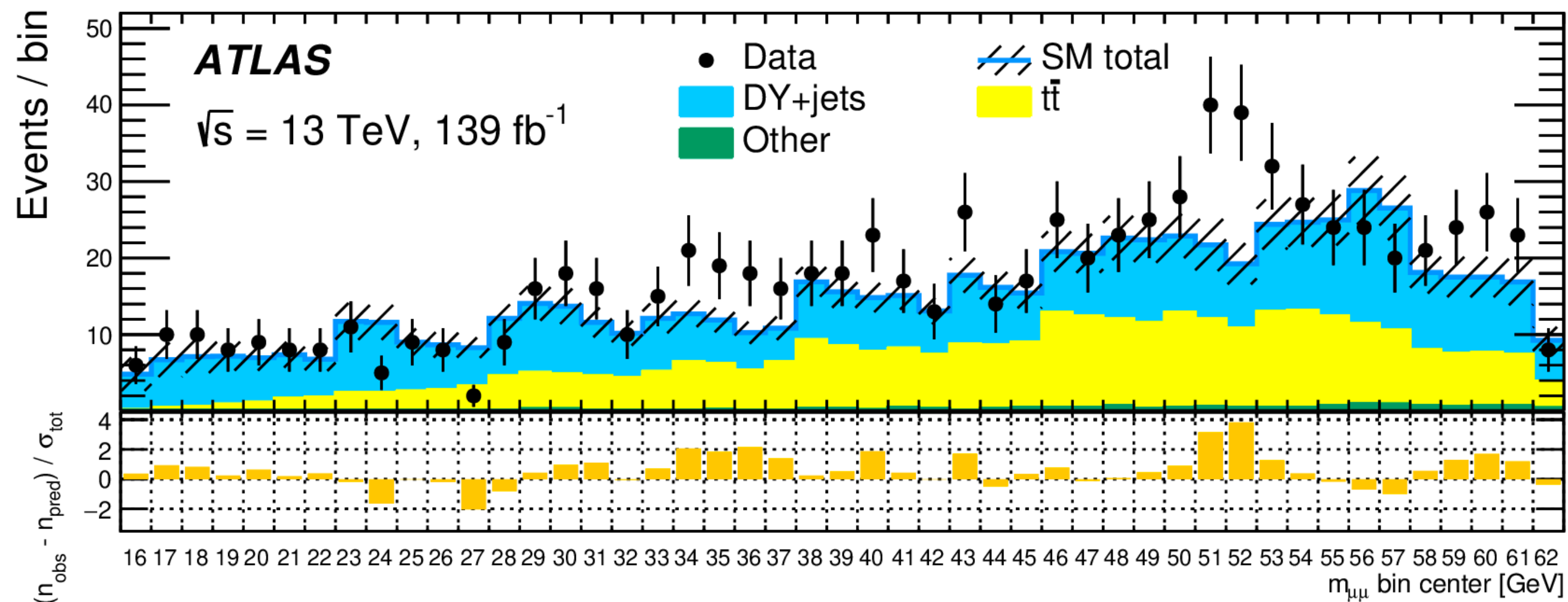
* follow-up search in **dilepton + 0/1/2b** final states:

- Including more operators ($bbll$, $tull$, $tcll$, and $ttll$) + $\mu\mu/ee$ ratios
- Including also unfolded results in b -jet bins

Narrow di-muon resonance

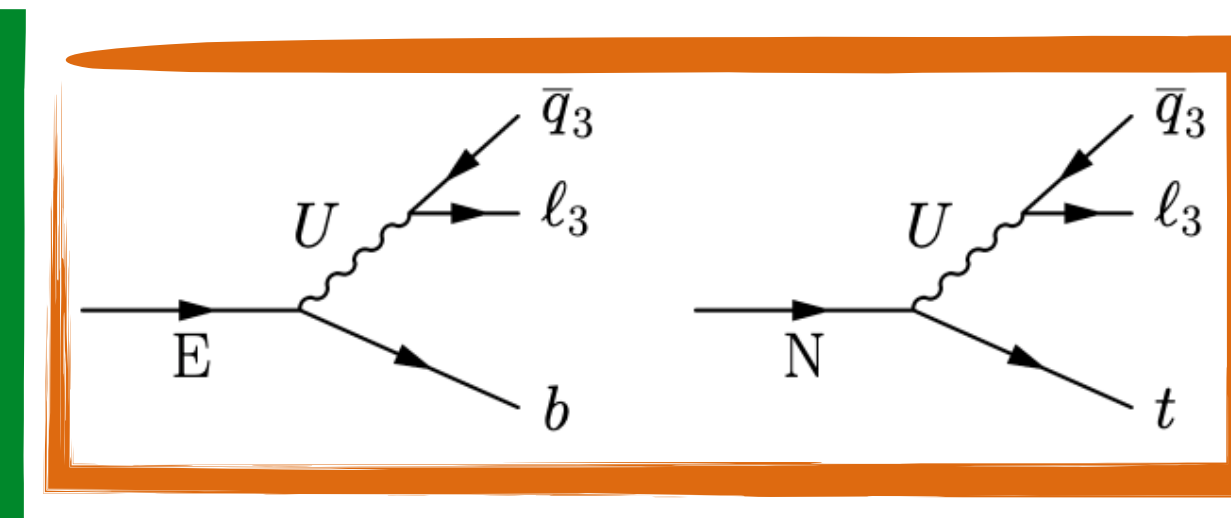
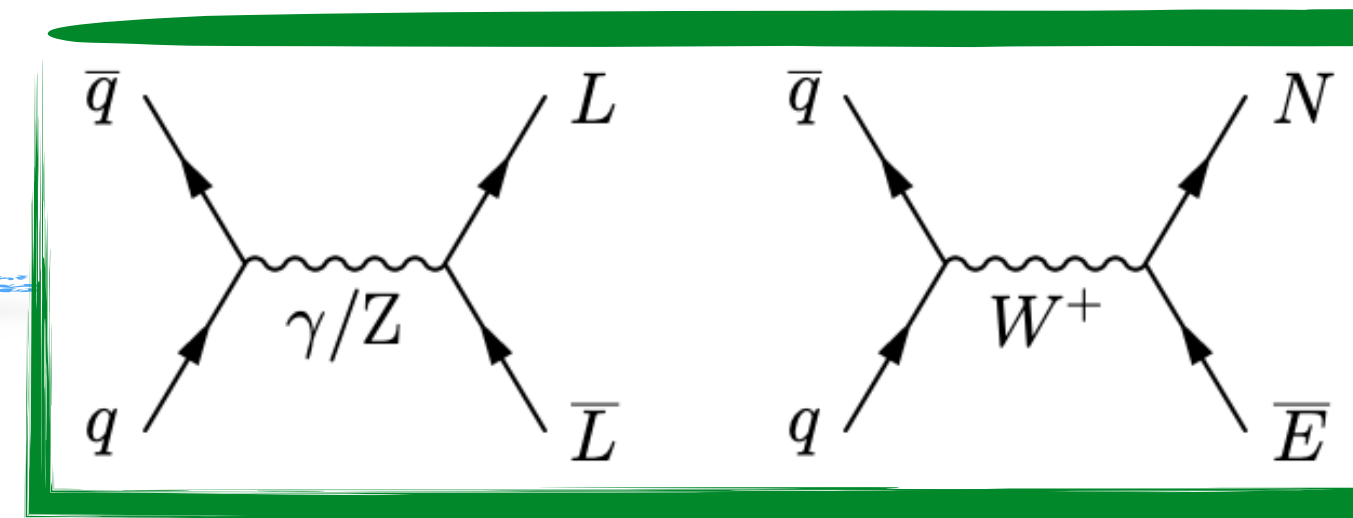
$$h \rightarrow aa \rightarrow b\bar{b}\mu^+\mu^-$$

- * A **narrow di-muon resonance** in **ATLAS** is searched for in $m_{\mu\mu} \in [16, 62]$ GeV.
- * Good balance between a high BR ($b\bar{b}$) and clean, high mass-resolution ($\mu\mu$). **Main backgrounds:** $Z + jets$ and $t\bar{t}$. **BDT** is used to discriminate the signal from SM.
- * The **largest excess** is observed at a $m_{\mu\mu} = 52$ GeV and is 3.3σ local (1.7σ global).



[Phys. Rev. D 105 \(2022\) 012006](#)

VLL in 4321model



- * Search for **vector-like leptons VLL** (N,L) decaying via off-shell **leptoquarks** (U) [[arXiv:2208.09700](https://arxiv.org/abs/2208.09700)] [[4321 model](#)] motivated by *b*-anomalies

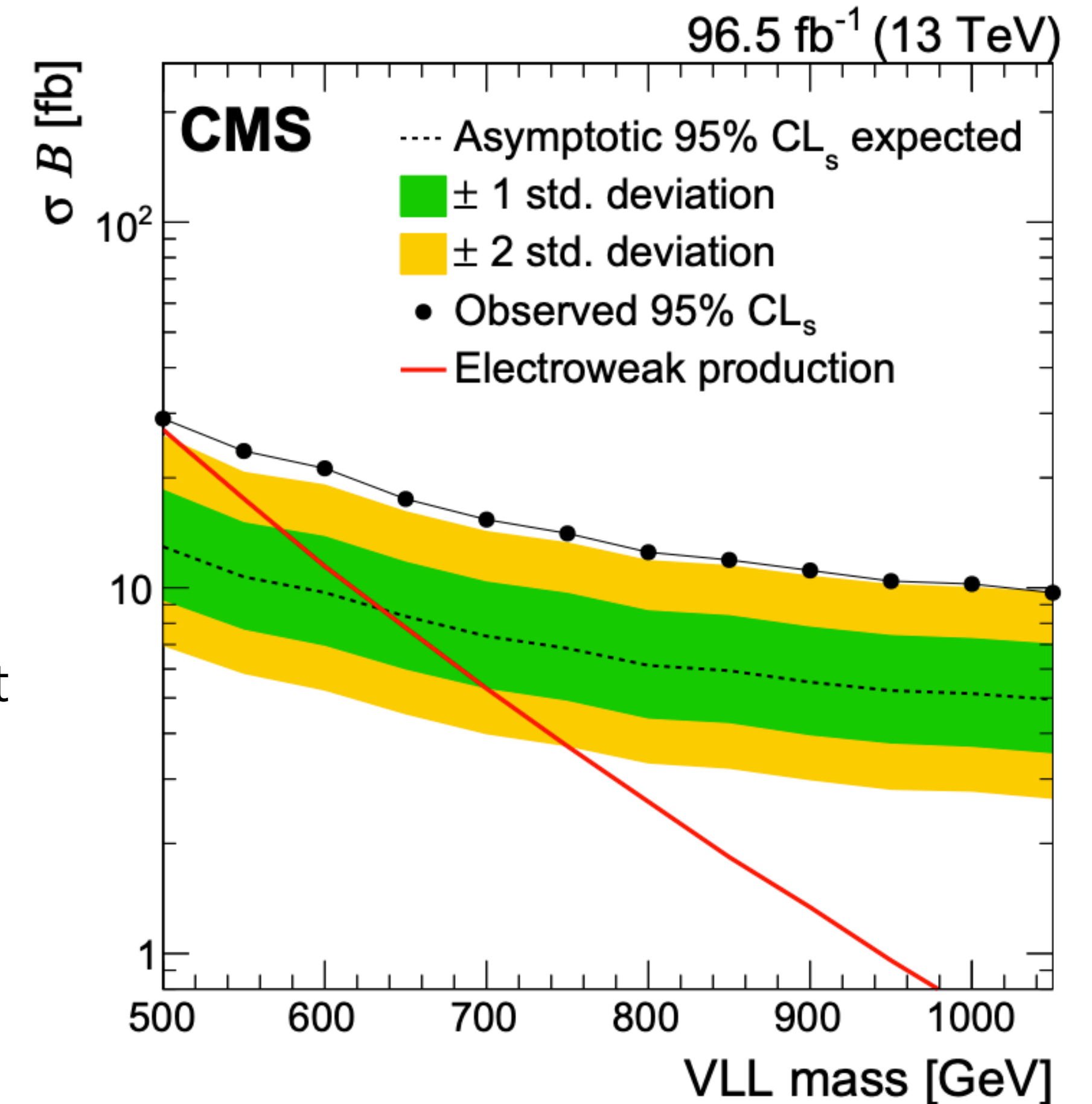
- * **CMS: ML-based** analysis covering **3*b* + 0/1/2*τ*** *final states*

- **Excess:** $\sim 2.8\sigma$, located in 1 and 2 τ regions. No VLL-mass dependence

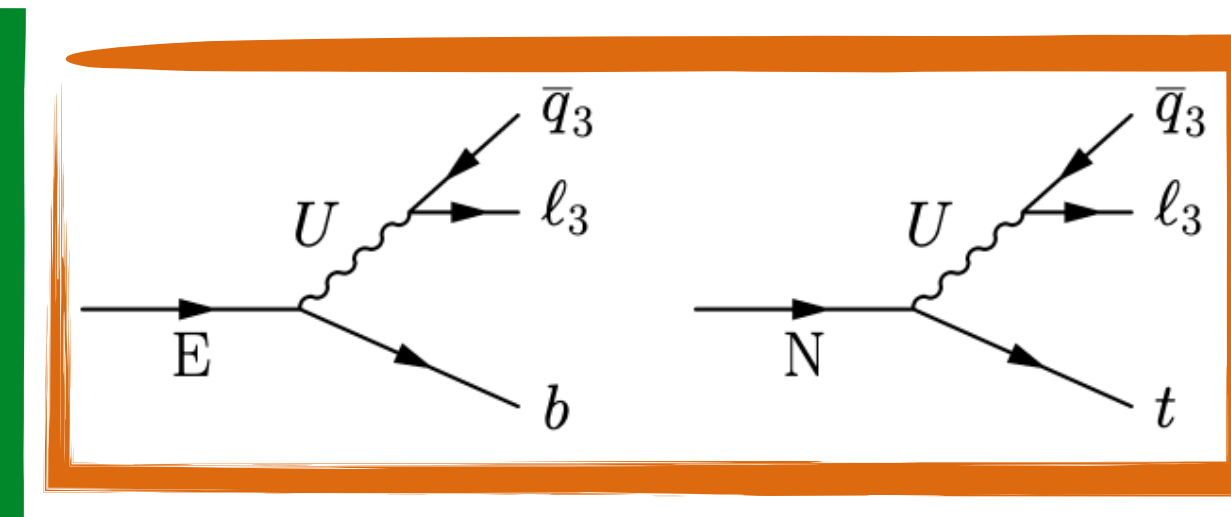
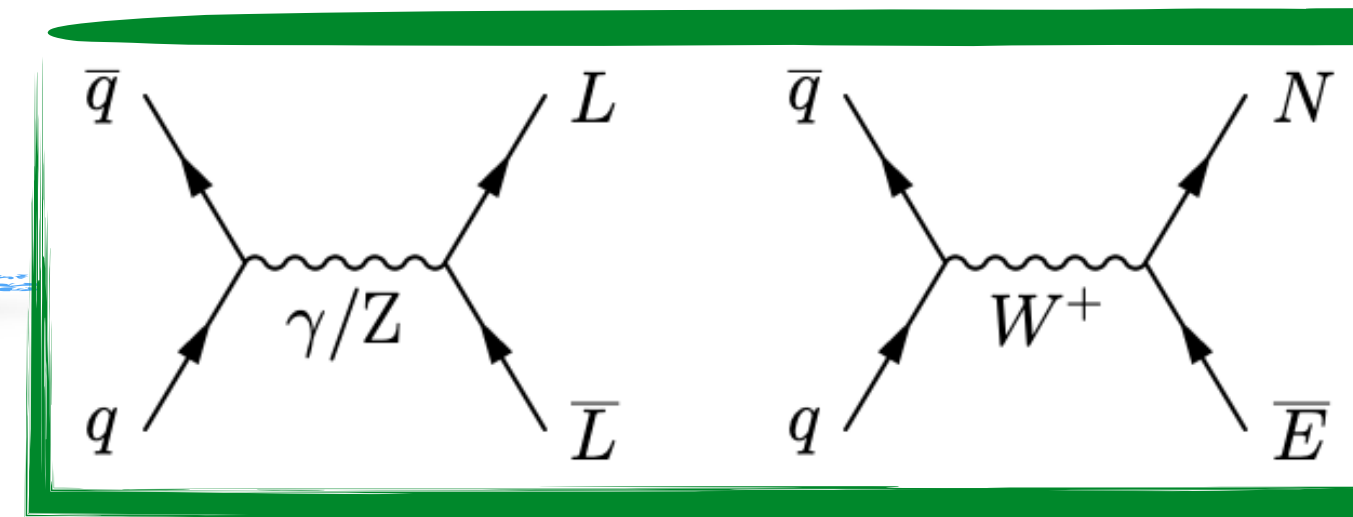
- * Already published **ATLAS** result of VLL in τ final states (doublet model) doesn't see any excess [[ATLAS-CONF-2022-044](#)].

- * **ATLAS:** New, ambitious analysis looking 4321model VLL targeting Moriond'23

- Strategy based on ML discrimination.



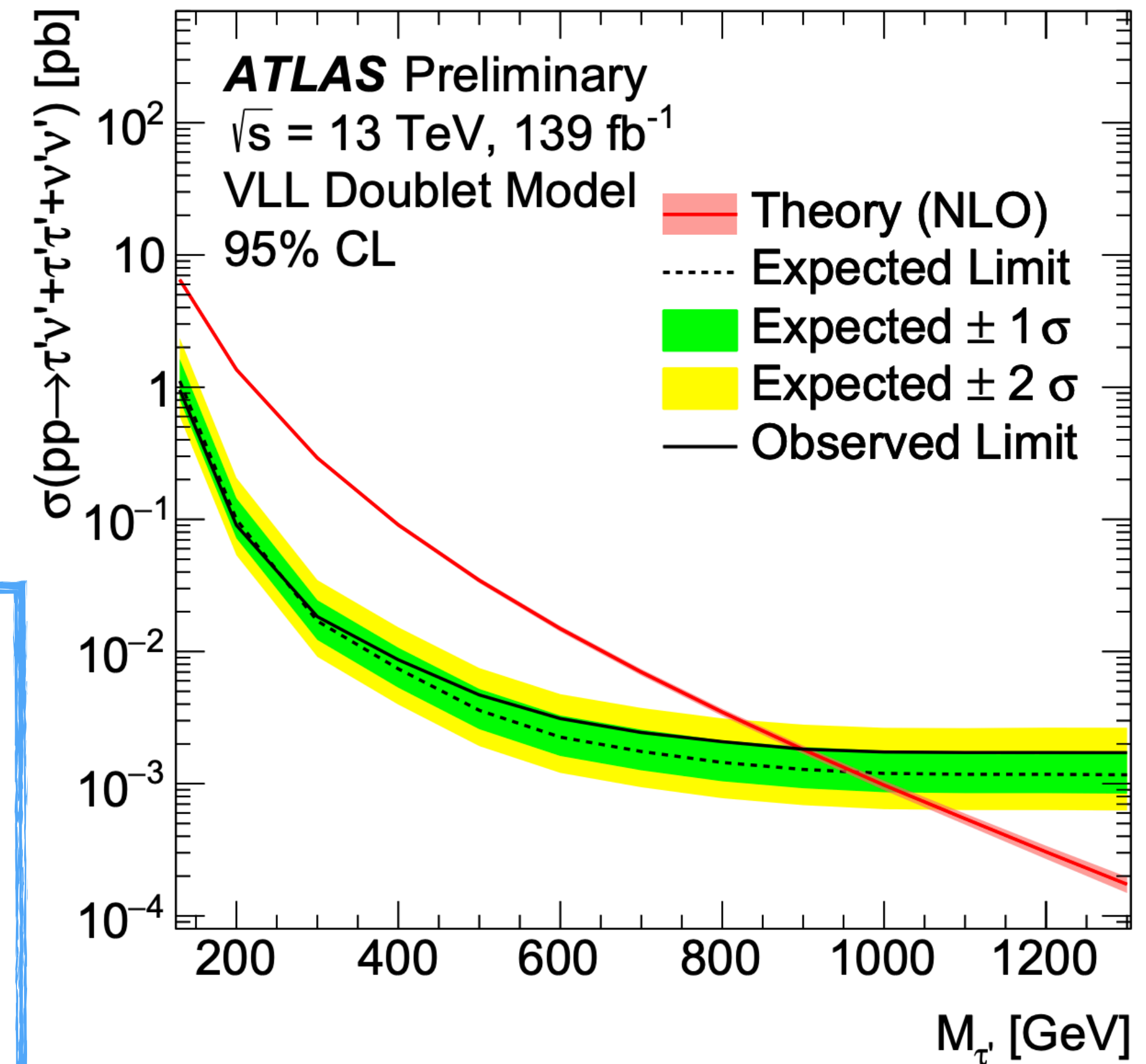
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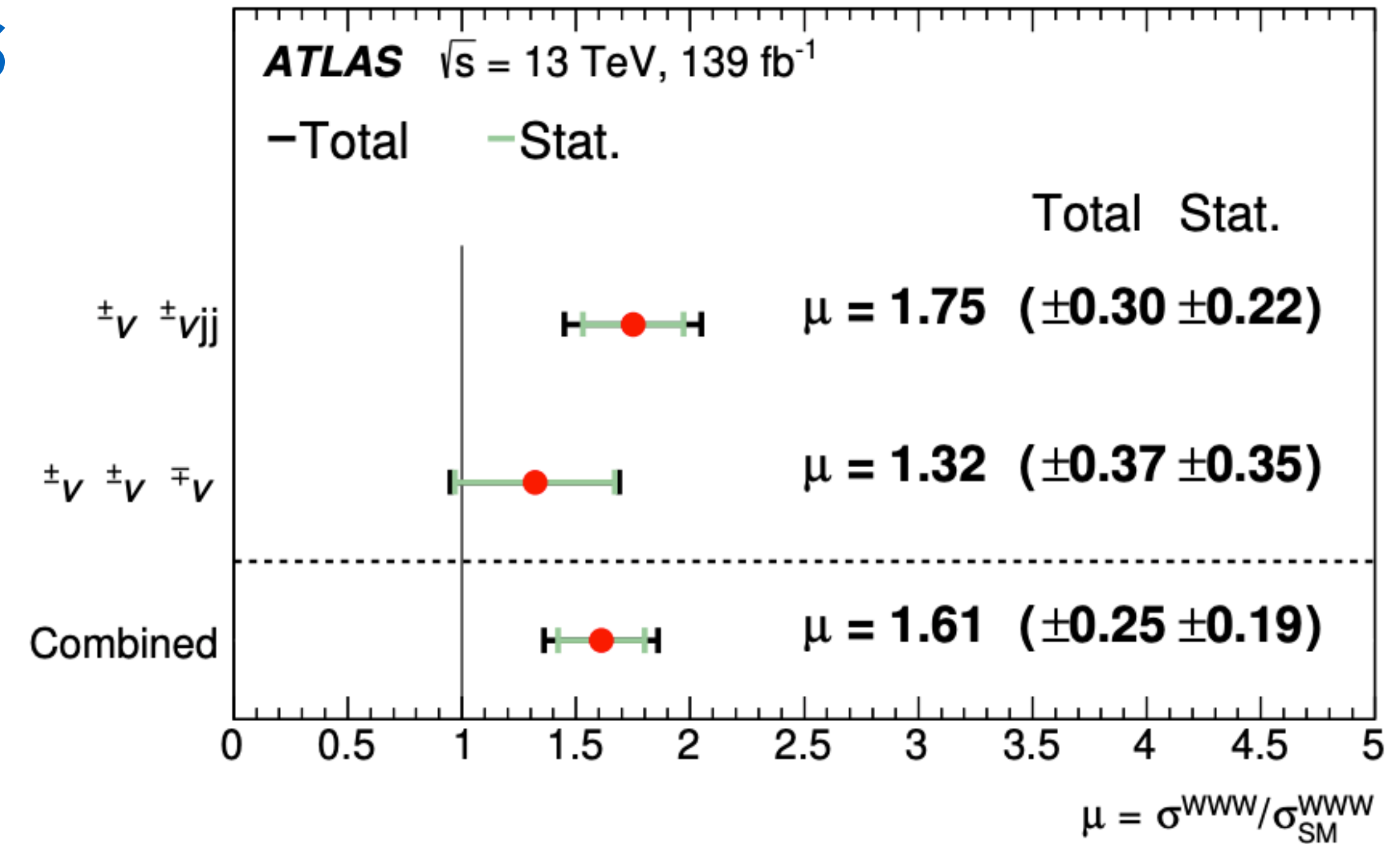
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Multiboson WWW

ATLAS

- * **Goal:** Measure of the WWW production cross-section in **final states:** 2leptonSameSign(2ℓSS) and 3leptons(3ℓ)
- * Use a **BDT** to discriminate signal VS background.
- * 4 **SRs**($e^\pm e^\pm, \mu^\pm \mu^\pm, e^\pm \mu^\pm, 3\ell$) simultaneously fitted using the BDT distributions to obtain the total signal-strength μ_{WWW} .
- * **Results:** Bkg-only hypothesis rejected at 8.0σ (5.4σ)
 - Limits: $\sigma_{obs} = 820 \pm 100 \pm 80$ fb. $\sigma_{exp} = 511 \pm 18$ fb (@NLO QCD and LO EW accuracy)



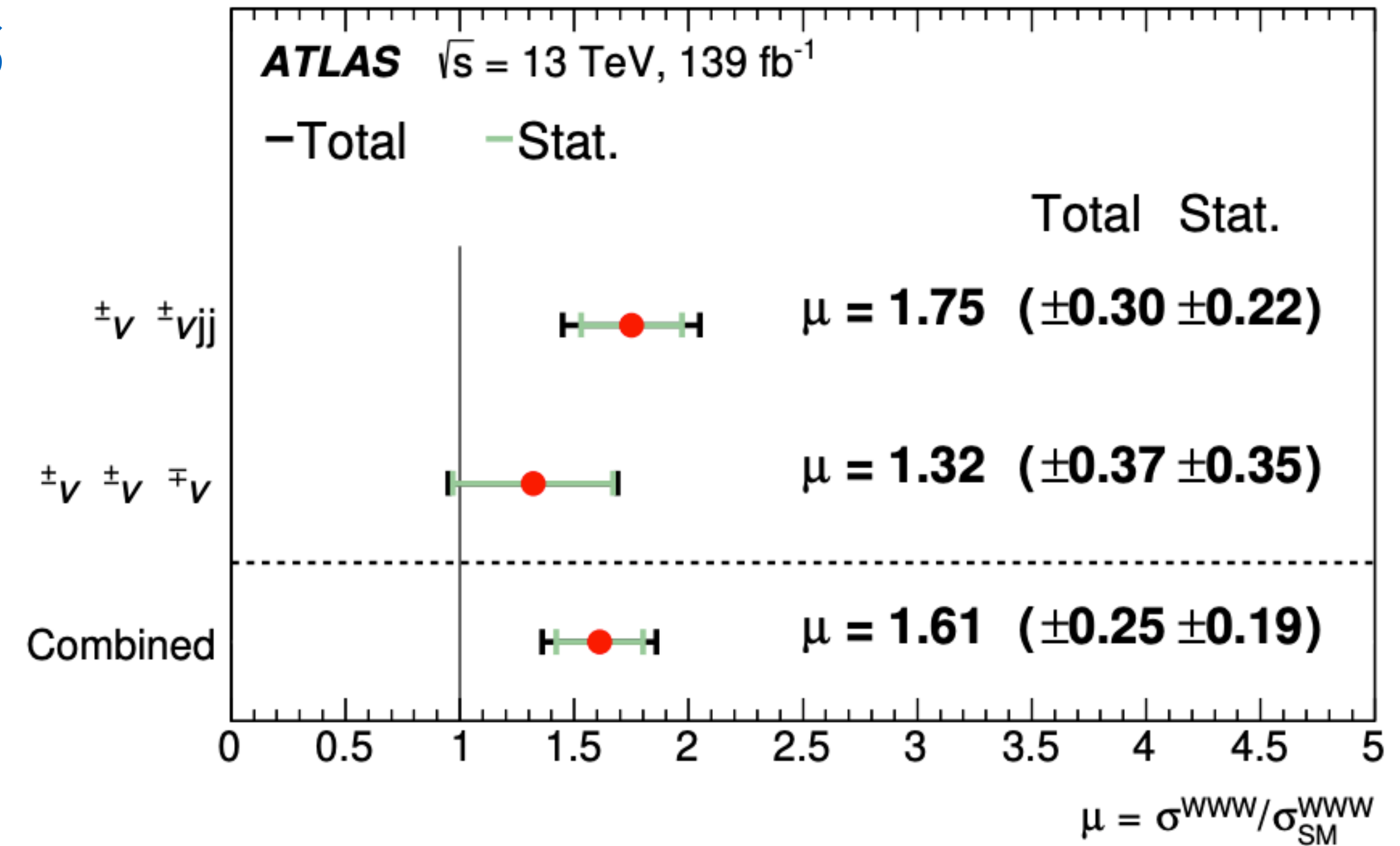
Fit	$\mu(WWW)$	Significance observed (expected)
$e^\pm e^\pm$	1.54 ± 0.76	2.2 (1.4) σ
$e^\pm \mu^\pm$	1.44 ± 0.39	4.1 (3.0) σ
$\mu^\pm \mu^\pm$	2.23 ± 0.46	5.6 (2.7) σ
2ℓ	1.75 ± 0.30	6.6 (4.0) σ
3ℓ	1.32 ± 0.37	4.8 (3.8) σ
Combined	1.61 ± 0.25	8.0 (5.4) σ

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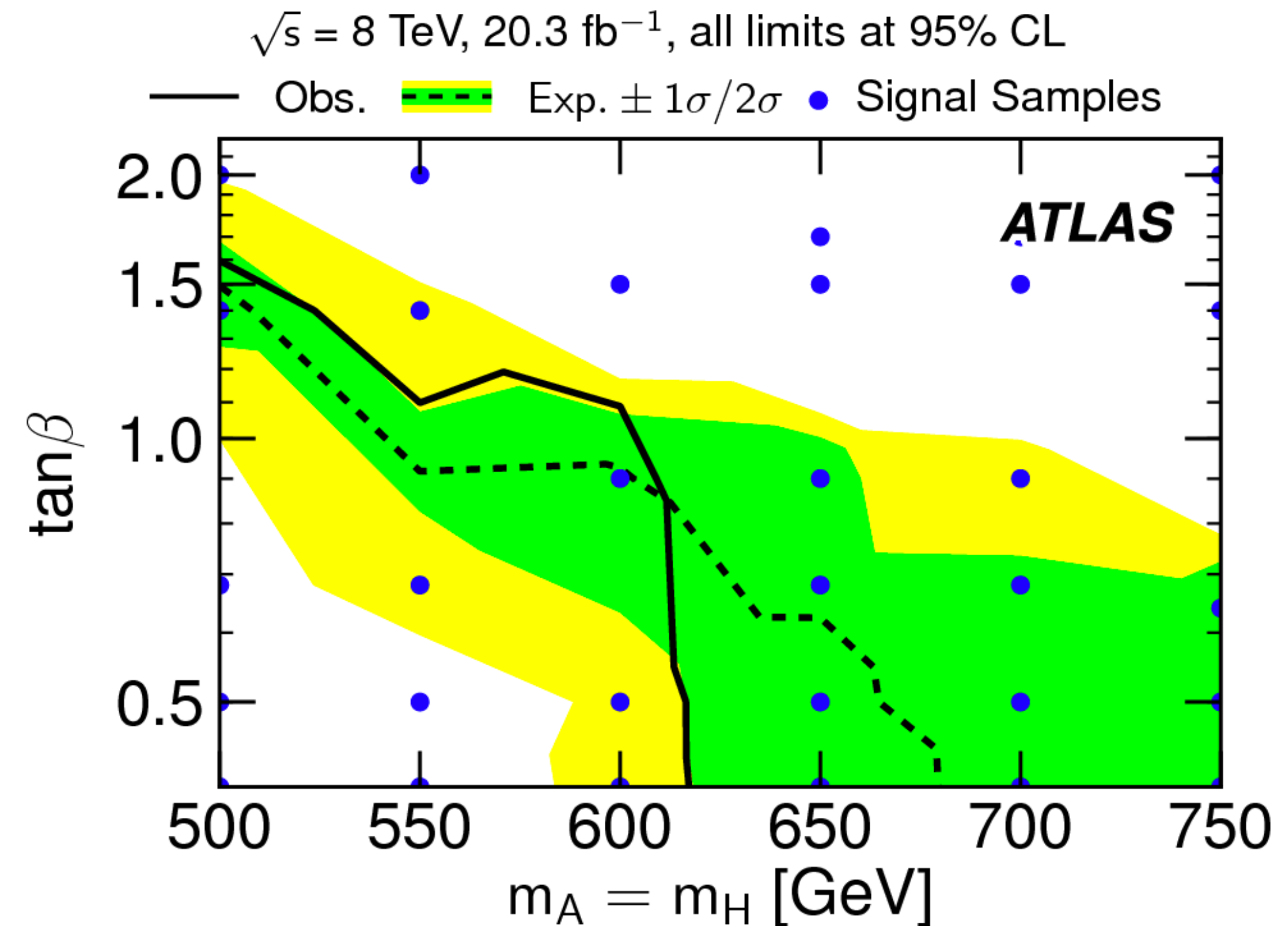
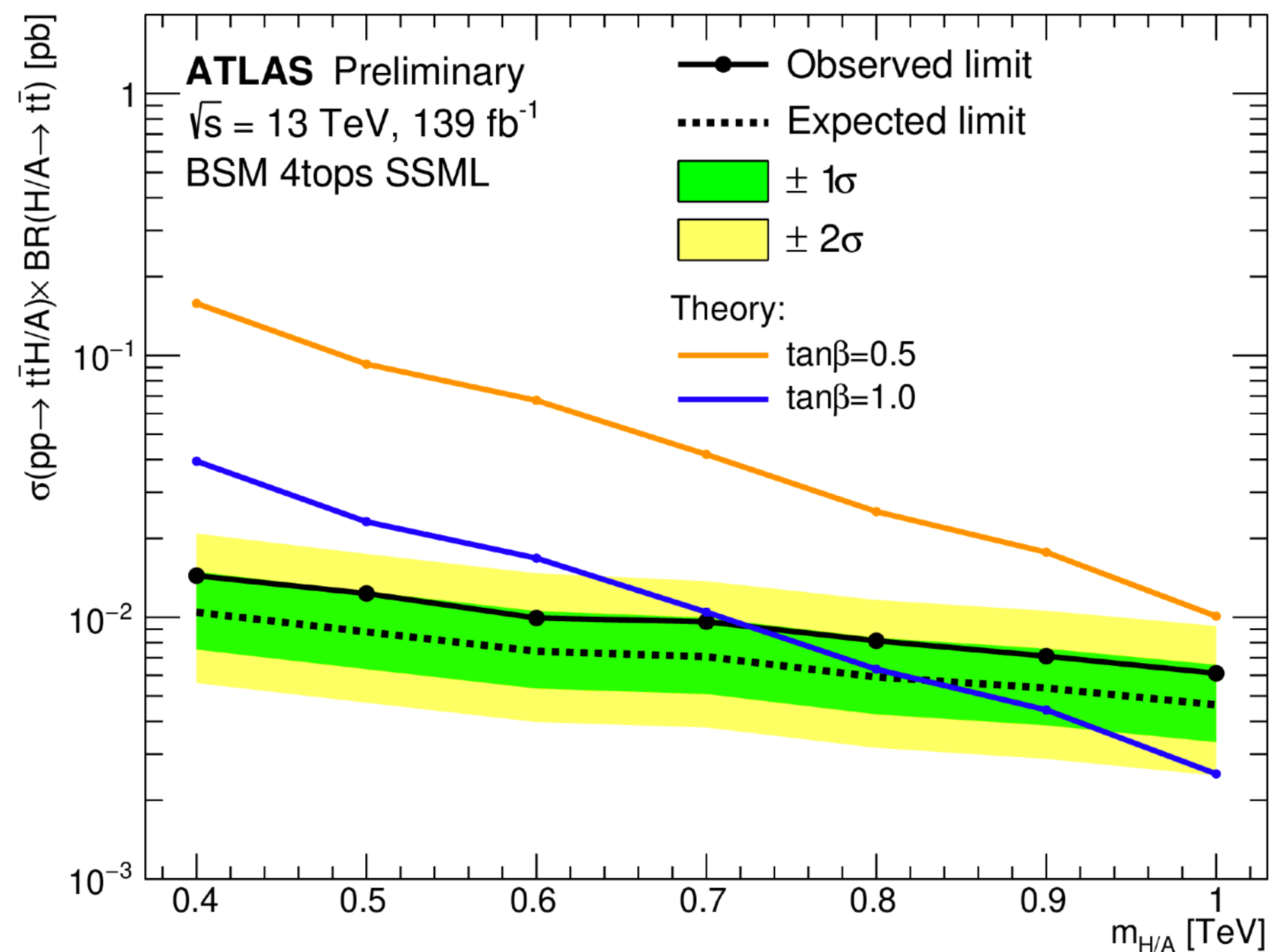
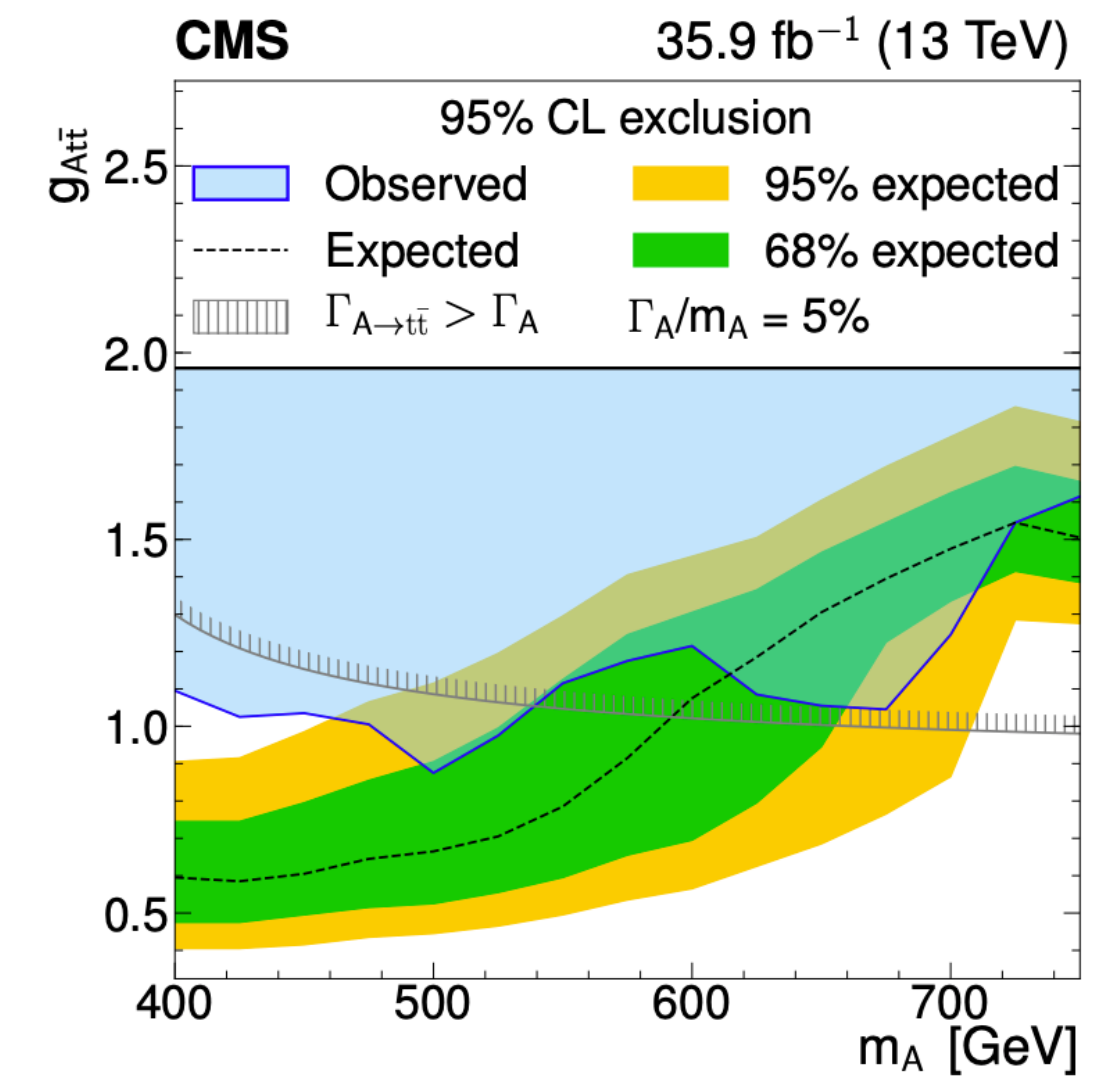
* Unfortunately this time no significance excess seen by **CMS**



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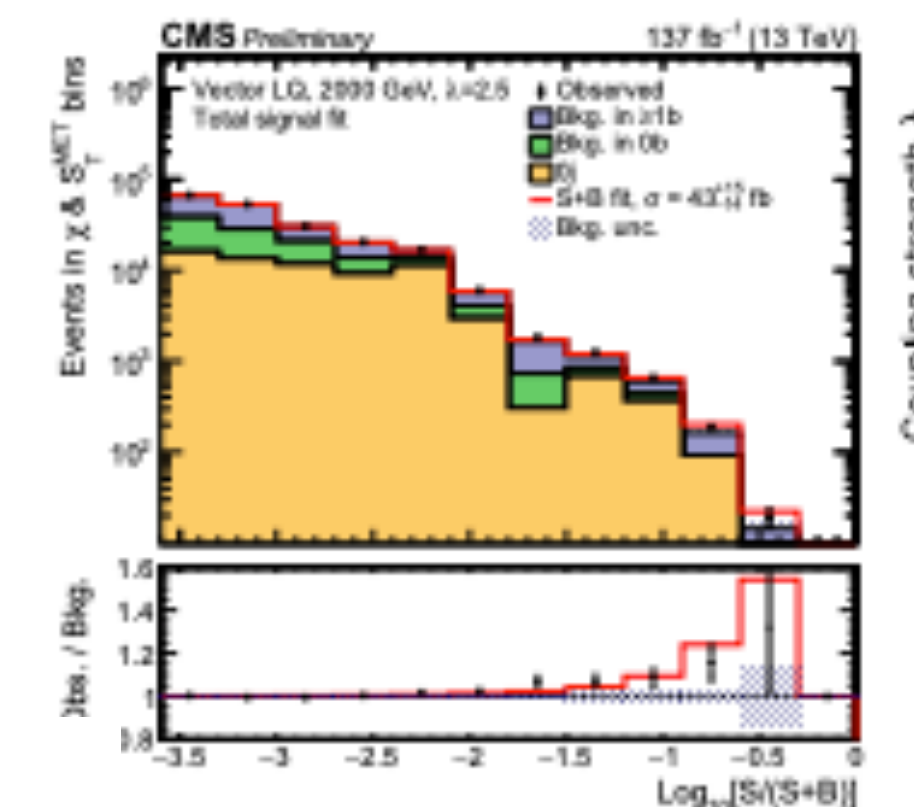
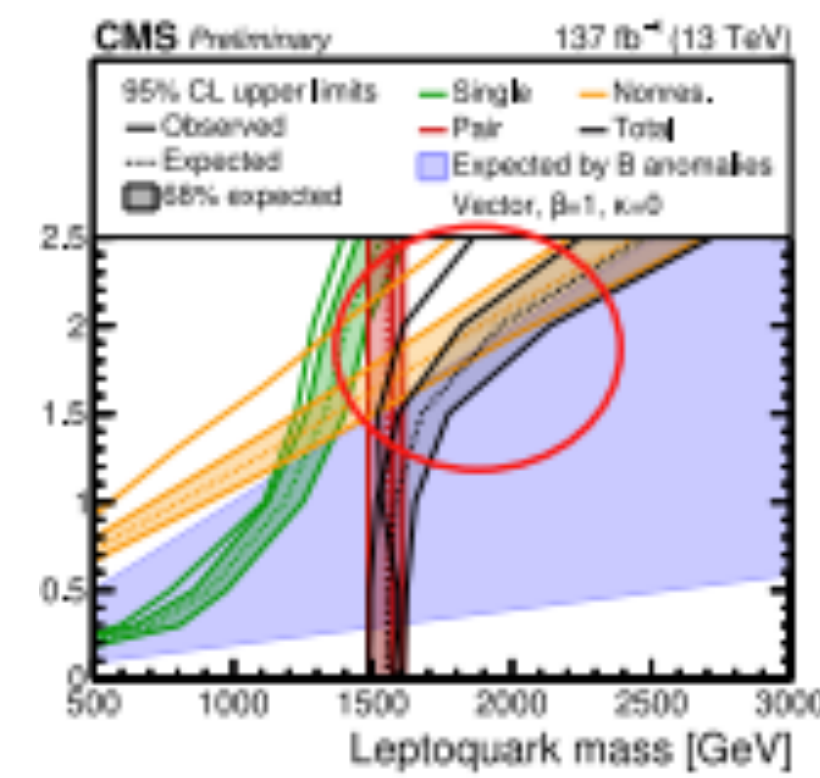
$t\bar{t}$ resonances

- * **CMS** search for $A/H \rightarrow t\bar{t}$: **Observe excess** local 3.5σ (1.9σ global) @400 GeV for pseudo-scalar in dilepton channel
- * **ATLAS**: similar previous search @ 8 TeV but *did not interpret results below 500 GeV*.
- * **ATLAS**: current full run-2 effort underway can cross-check the result: search in associated production $t\bar{t}A/H \rightarrow t\bar{t}t\bar{t}$ *but saw no excesses* so far.

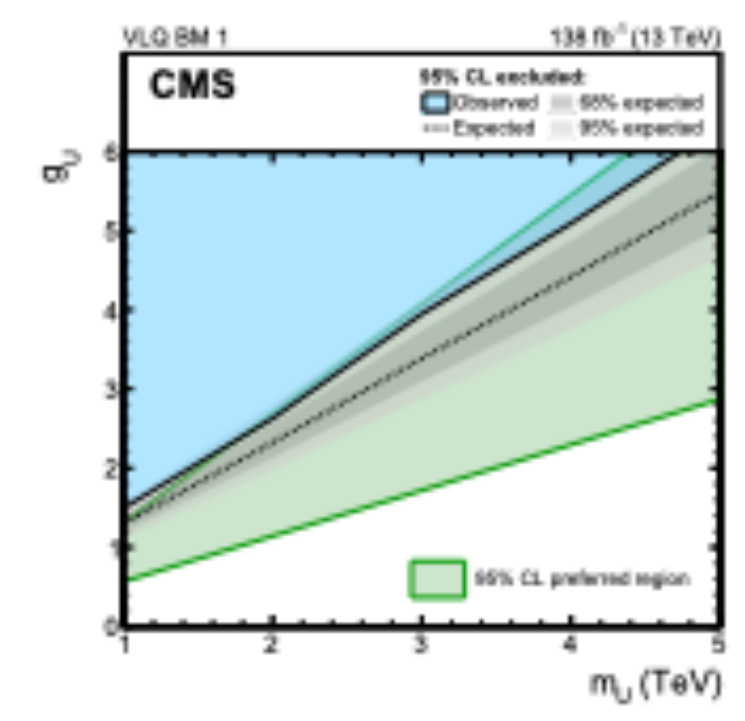
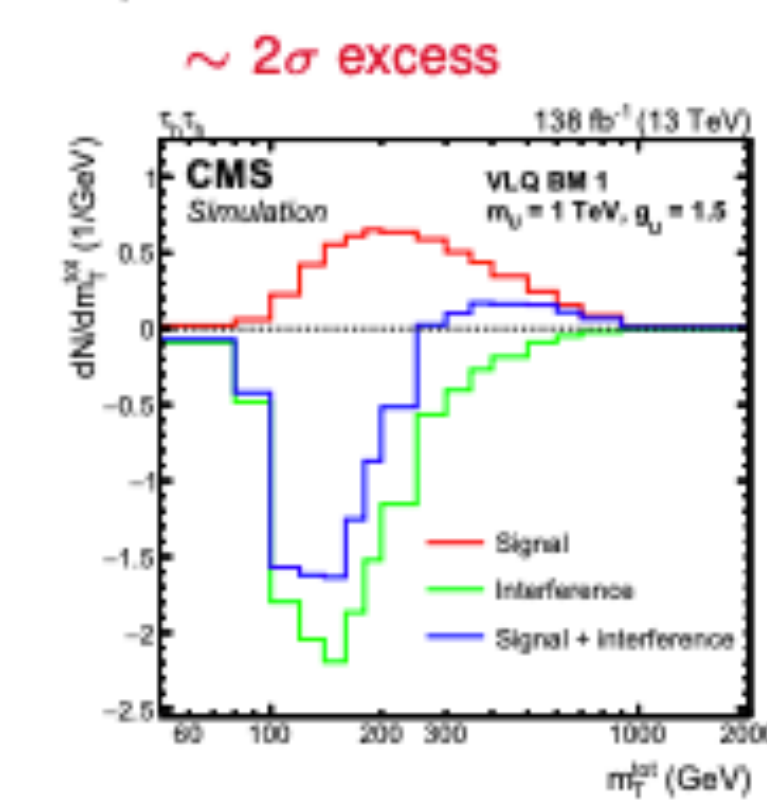


Conclusion

- * Big effort in searching **signs of new physics**. Many excess hints observed by **ATLAS** and (especially) **CMS**
- **Most promising** ones presented here, but not exhaustive of them all...



LQ $\rightarrow b\tau$ search (0/1/2b, all production modes)
 CMS-PAS-EXO-19-016 (2022) **3.4 σ excess**



$Y \rightarrow \tau\tau$ (0b, non-resonant)
 arXiv:2208.02717 (2022)

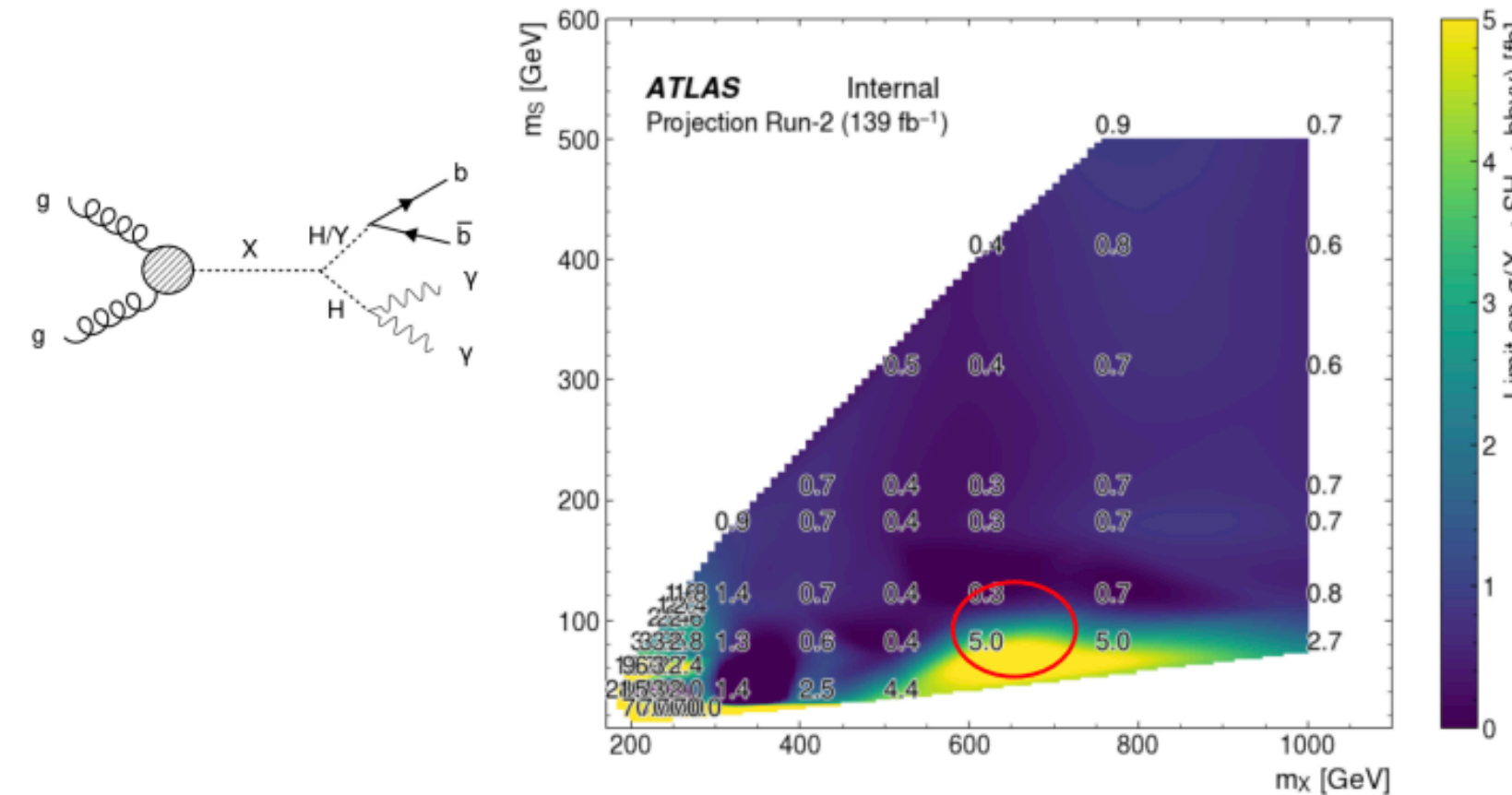
- * Are these **excesses** coming from New Physics? Or maybe from background mis-modelling? Or event fluctuation?

- * **Important** because we know where to **look in the future**, ready for further investigations, many already *ongoing* or *planned*.

Backup

Double Resonance $Y \rightarrow XX'$

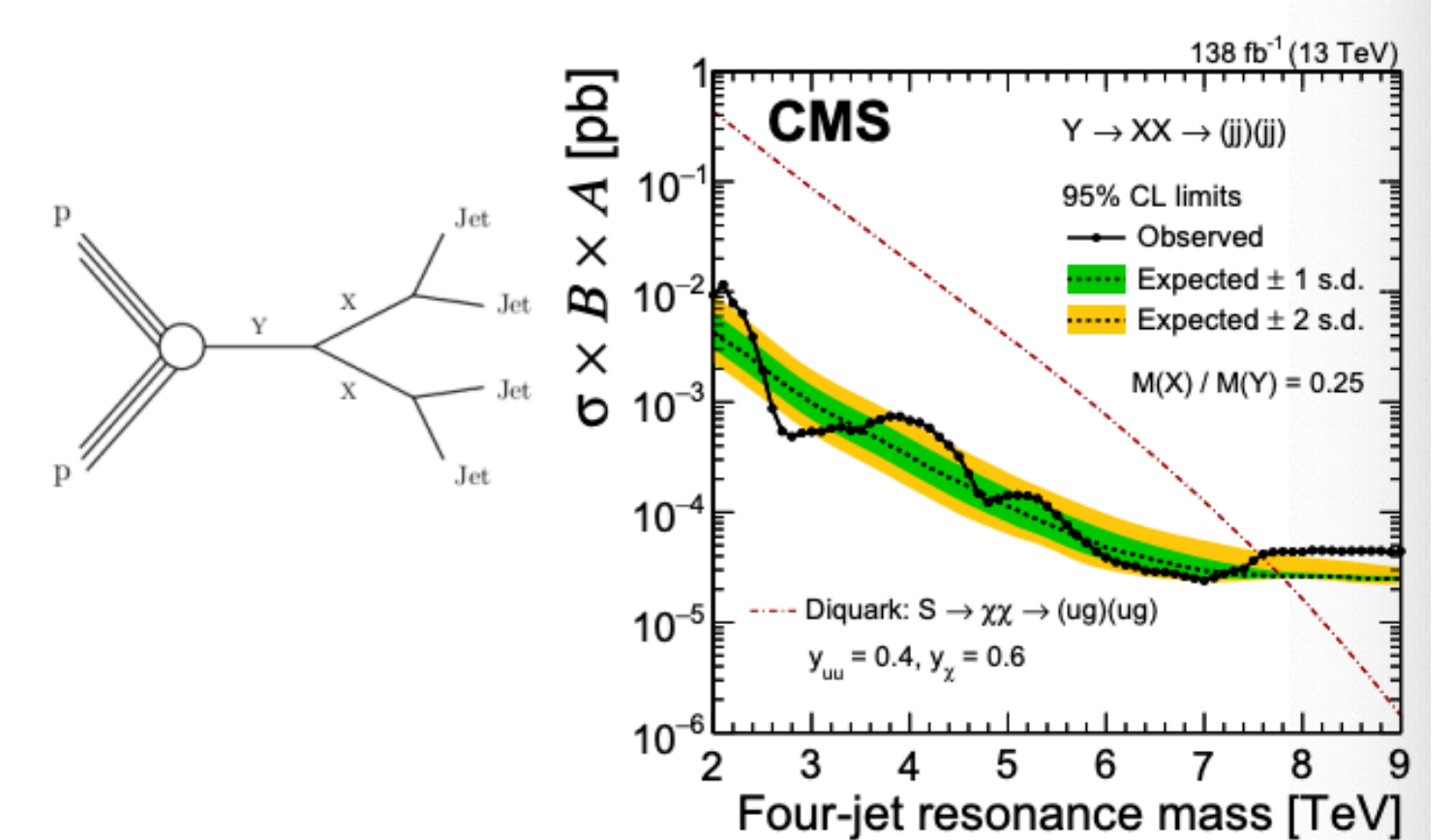
$X \rightarrow YH \rightarrow bb\gamma\gamma$ CMS-PAS-HIG-21-011 (2022)



(125,90) GeV with $m_X = 650$ GeV, **3.8 σ local, 2.8 σ global**
also some excess for $m_X = 850$ GeV

- same mass region (within resolution) than 2-body single resonance Y excess
- **HDBS-2021-17** on-going \rightarrow Moriond'23
 - **comparable sensitivity than CMS expected**
 $\rightarrow \sigma$ down to few fb in region of interest
 - **ATLAS-CONF-2022-045** looked at $X \rightarrow YH \rightarrow qqbb$, no excess

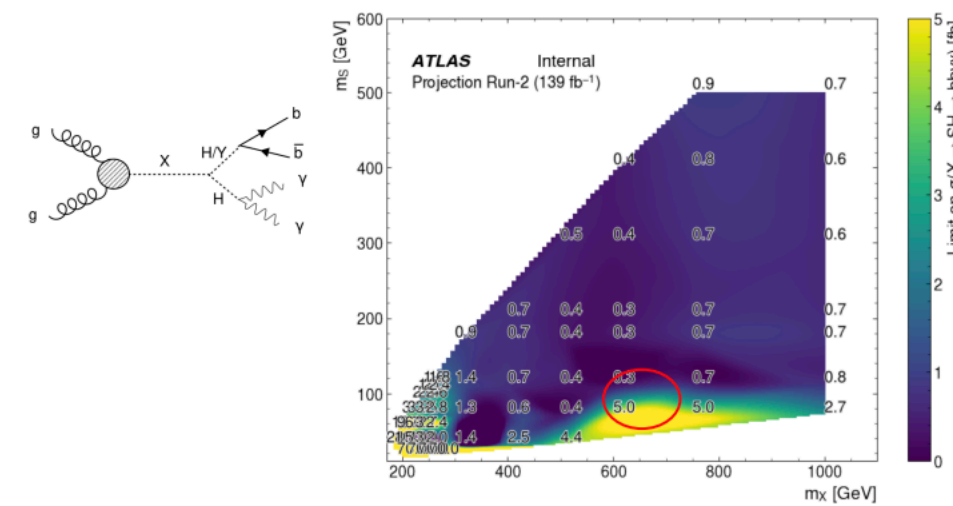
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2 events with four-jet mass ~ 8 TeV and $\langle m_{jj} \rangle \sim 2$ TeV
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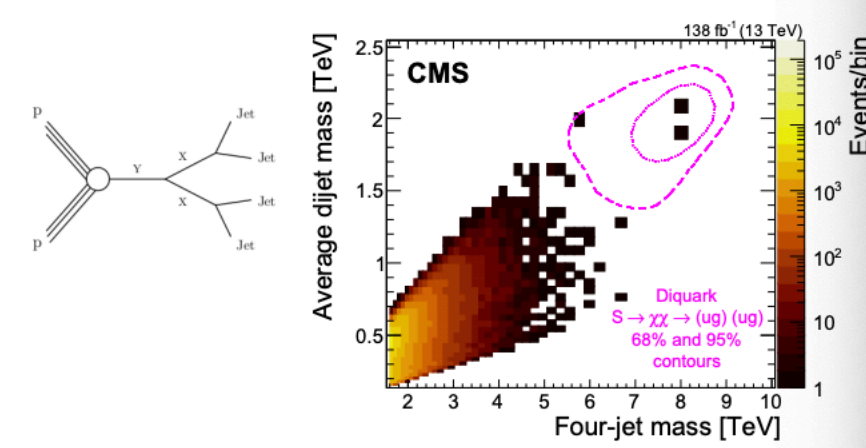
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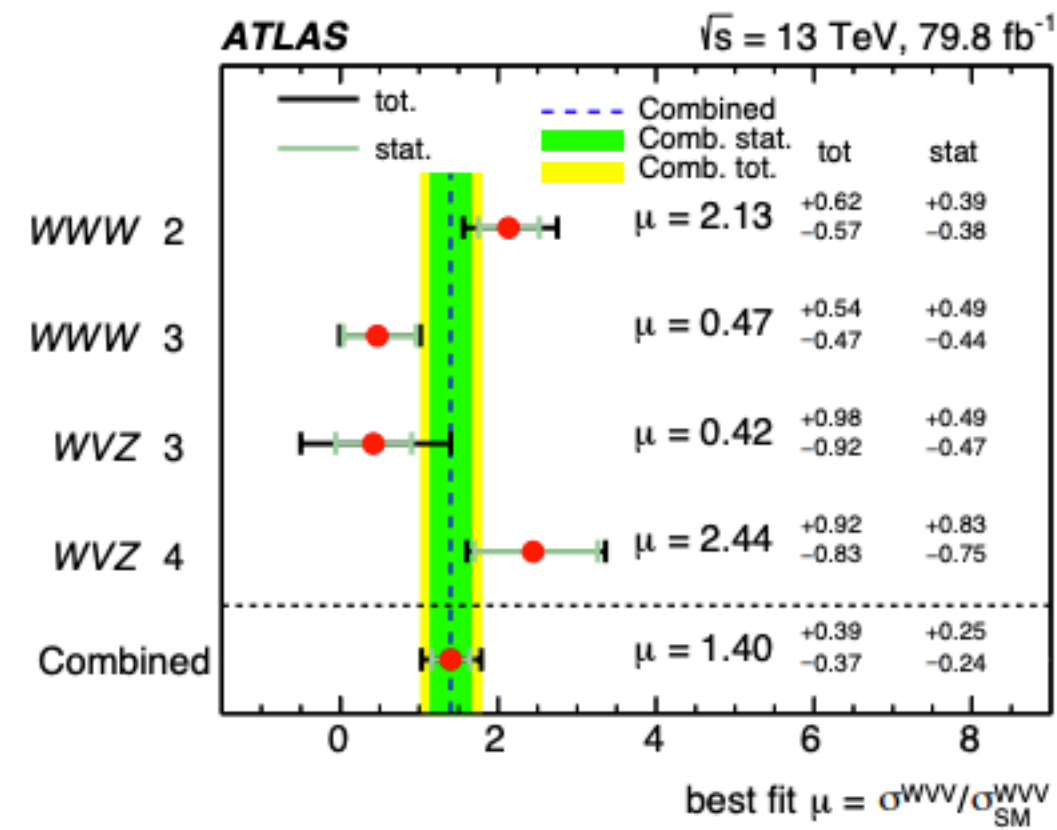
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- signal model : diquark $\rightarrow 2$ VLQs $\rightarrow 4j$
also excess for $XX \rightarrow 4j$ @ 0.95 TeV (RPV stop)
- EXOT-2022-18 on-going → Moriond'23
 - first focus bump search in m_{jj} and m_{4j}

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Decay channel	Significance	
	Observed	Expected
WWW combined	3.2σ	2.4σ
WWW $\rightarrow l\nu l\nu q\bar{q}$	4.0σ	1.7σ
WWW $\rightarrow l\nu l\nu l\nu$	1.0σ	2.0σ
WVZ combined	3.2σ	2.0σ
WVZ $\rightarrow l\nu q\bar{q} l l$	0.5σ	1.0σ
WVZ $\rightarrow l\nu l\nu l l/q\bar{q} l l l l$	3.5σ	1.8σ
WVV combined	4.1σ	3.1σ

Results with 80 fb^{-1}