Weak Interactions and Neutrinos 2021
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Searches for new phenomena with the ATLAS detector

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In a nutshell

The SM is our best tool to understand nature…

…but it's not the ultimate one!

- Neutrino masses? LFV? Hierarchy problem? Dark Matter?
- This talk will present some of the most recent ATLAS results from the full Run-II Data

Type—III Seesaw

Vector—like quarks

Long-lived particles

LFV in Z decays

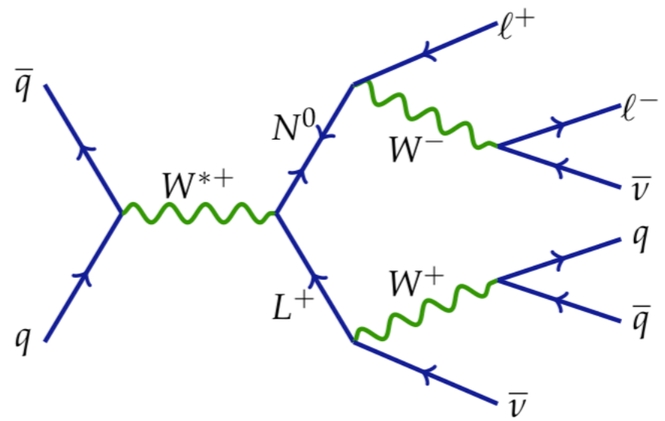
Leptoquarks

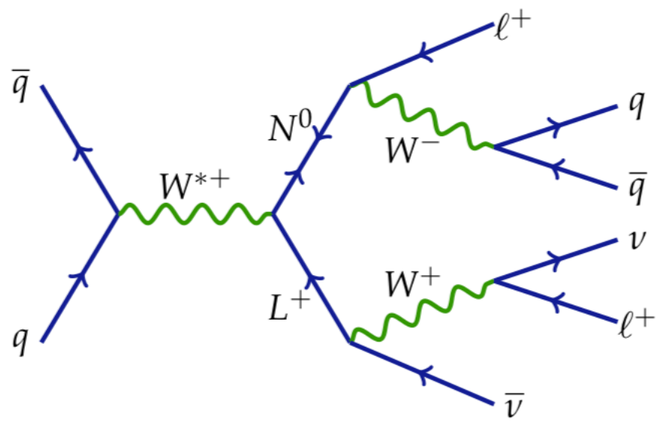
Type III Seesaw (two leptons)

EPJC 81 (2021) 218

- Neutrinos are light partners of new heavy leptons: N^0, $L^{\pm}$
- Pair production via EW gauge bosons
- Final states with 2 SS or OS leptons + missing E_T + jets

$$m_{N^0} = m_{L^{\pm}}$$



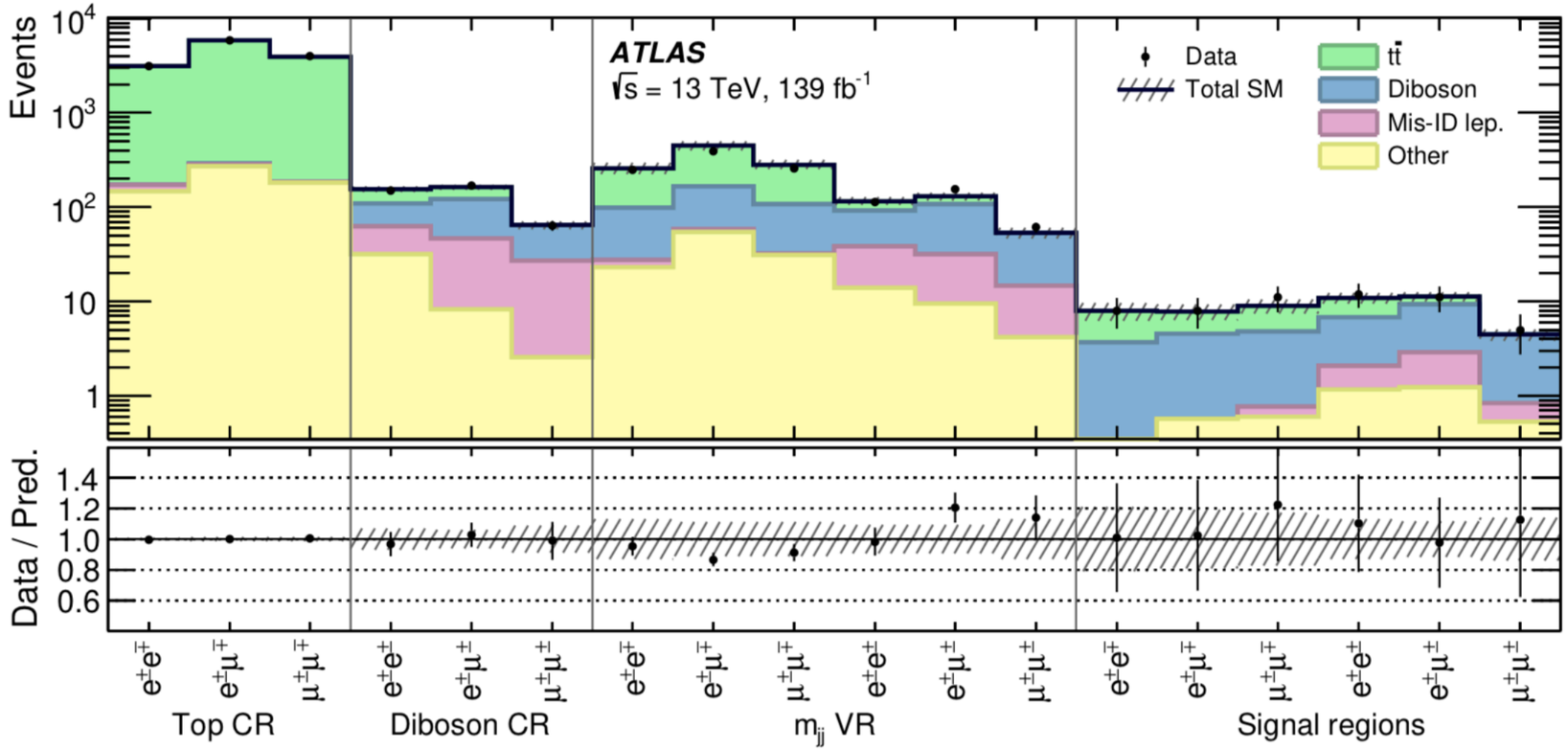


- Separate analysis channel for different lepton flavour & charge combination **(ee, μμ, eμ) x (OS,SS)**

Type III Seesaw (2l) — backgrounds

EPJC 81 (2021) 218

- **Backgrounds**
  - $t\bar{t}$, Di-Boson (irreducible) → **Estimate from MC + normalisation from CRs**
  - Fake non—prompt leptons → **Data driven estimate**
  - Charge mis—id → **MC estimate + Scale factors from Zll events**



Type III Seesaw (2l) - limit setting

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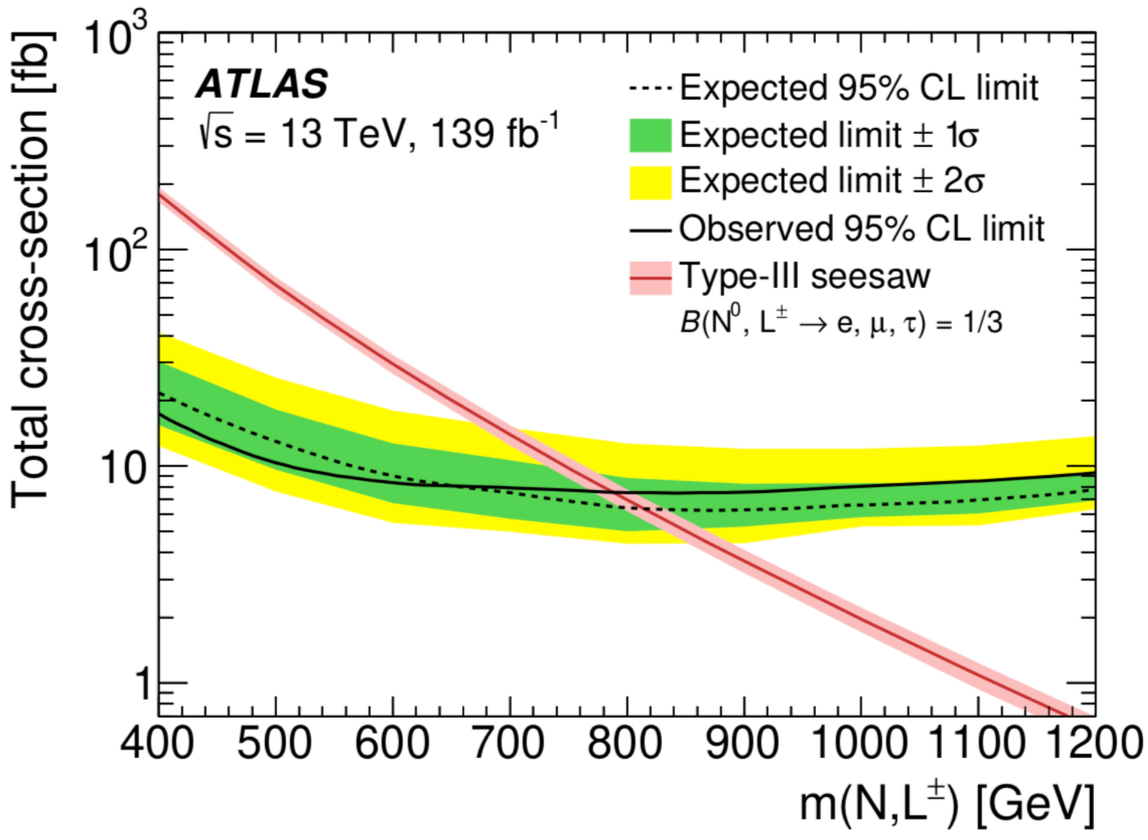
- No significant excess in data w.r.t. SM
- 95% CL upper limit on heavy lepton production cross section

Heavy leptons excluded below 820 GeV

Signal simulation at NLO

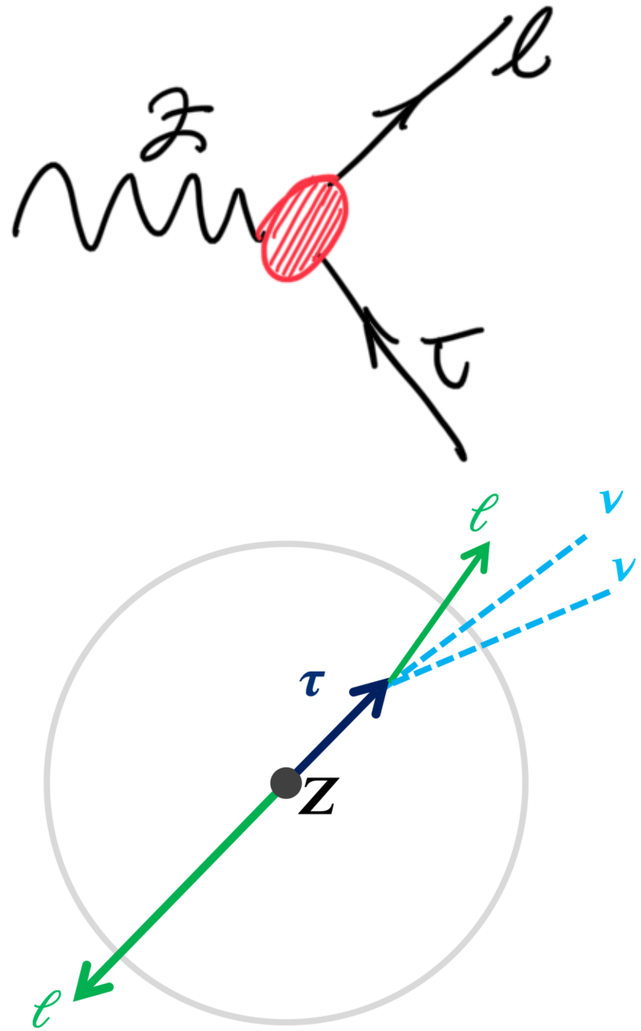


Lepton Flavour Violation in Z→lτ

arxiv: 2105.12491

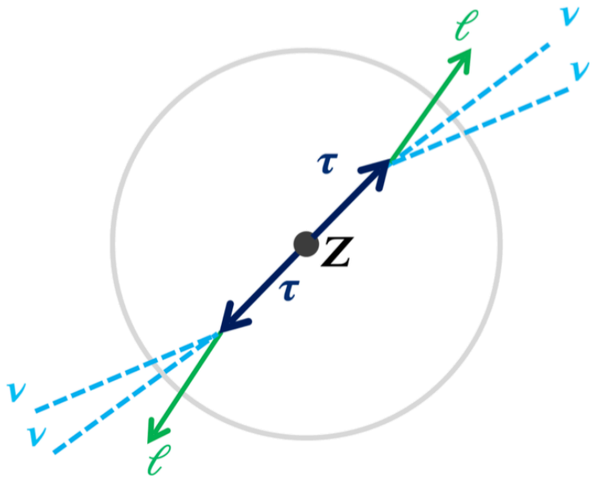
- Neutrino oscillation → LFV observed in nature
- Accidental symmetry violated in many bSM theories
- First LHC search with leptonically decaying τ, extending searches with hadronic τ decays
- Selecting **OS** leptons with **different flavour**
- 2 analysis channels, both divided in high & low p_T:
  - $e\tau_\mu$ channel
  - $\mu\tau_e$ channel

→ Selected by the flavour of the leading lepton



LFV in Z→lτ — Backgrounds

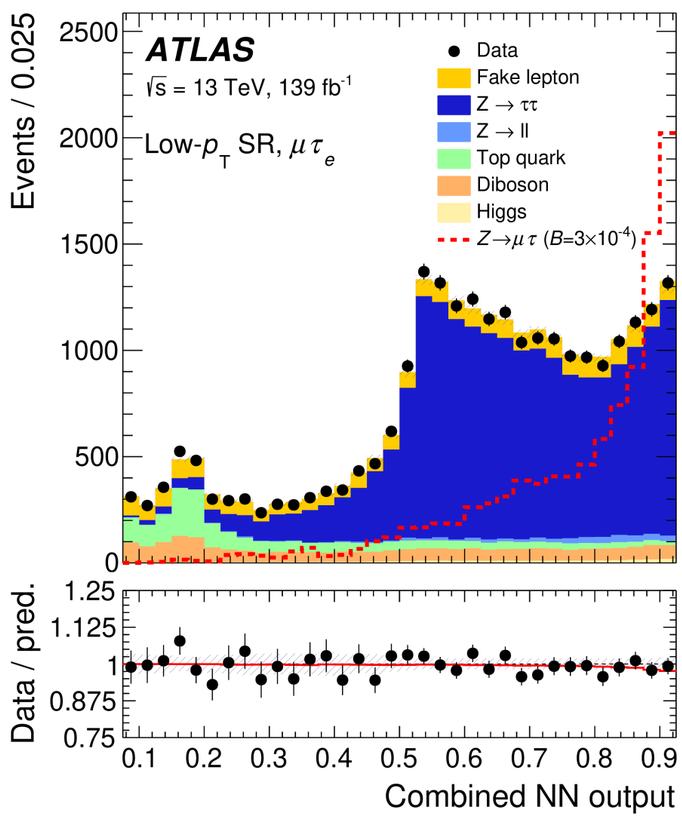
arxiv: 2105.12491

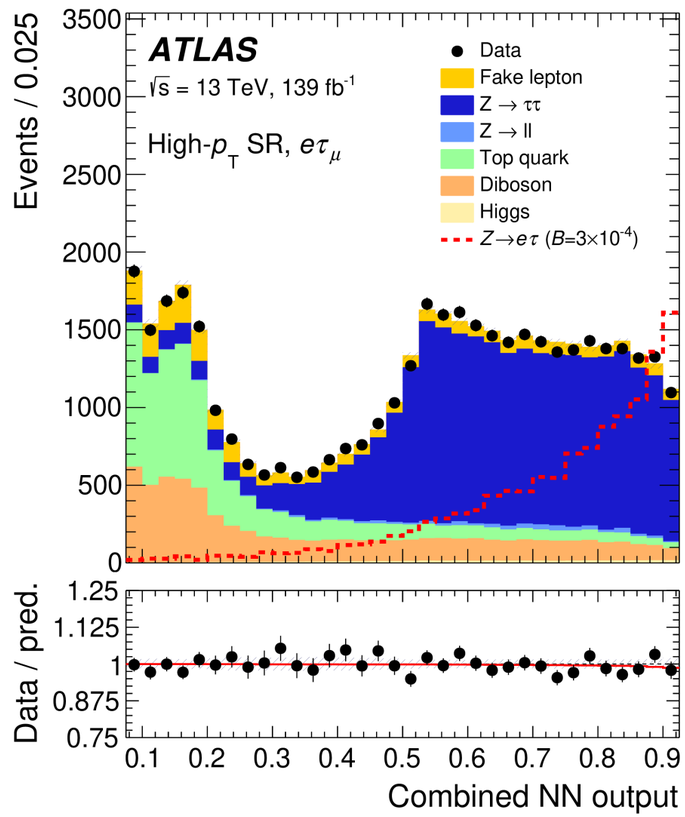


- **Backgrounds**
  - Z→ττ (Z→ll with mis-id leptons) → **MC events with data driven correction**
  - $t\bar{t}$, di-boson, H decay → **MC events with data driven correction**
  - Fake non—prompt leptons → **Data driven estimate**

Three NN taggers trained against Zττ, $t\bar{t}$ and diboson → combined score

Fit SRs + CRs for Zττ and top backgrounds





LFV in Z→lτ — Results

arxiv: 2105.12491

Prediction implied by ν oscillation: **BR (Z→τl) < 10^{-54}**

→ **Far from the reach of ATLAS & CMS**
Still worth searching for disagreement

- This ATLAS search found **agreement with SM** → limit on BR @95% CL
  - $e\tau_\mu$ → BR < 7×10^{-6}
  - $\mu\tau_e$ → BR < 7.2×10^{-6}

After combination with
Z→lτ (hadronic τ decays)
using Run2+Run1 data: arxiv:2010.02566

←

- $e\tau_\mu$ → BR < 5×10^{-6}
- $\mu\tau_e$ → BR < 6.5×10^{-6}

Results are superseding previous LEP limits

Leptoquark to τ + b-jets + E^T_{miss}

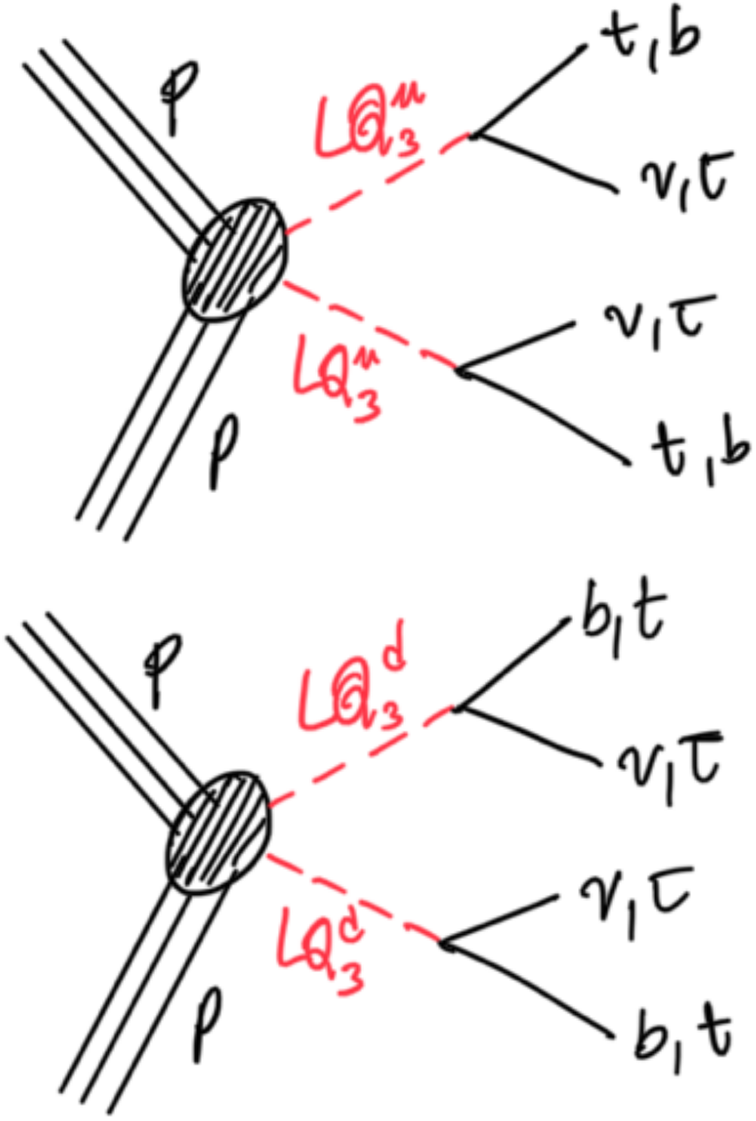
- LQ are predicted by many bSM theories
  → coupling to both quarks and leptons (LFV)
  → pair production at LHC

- Two LQ types (u,d) coupling with 3rd gen. leptons

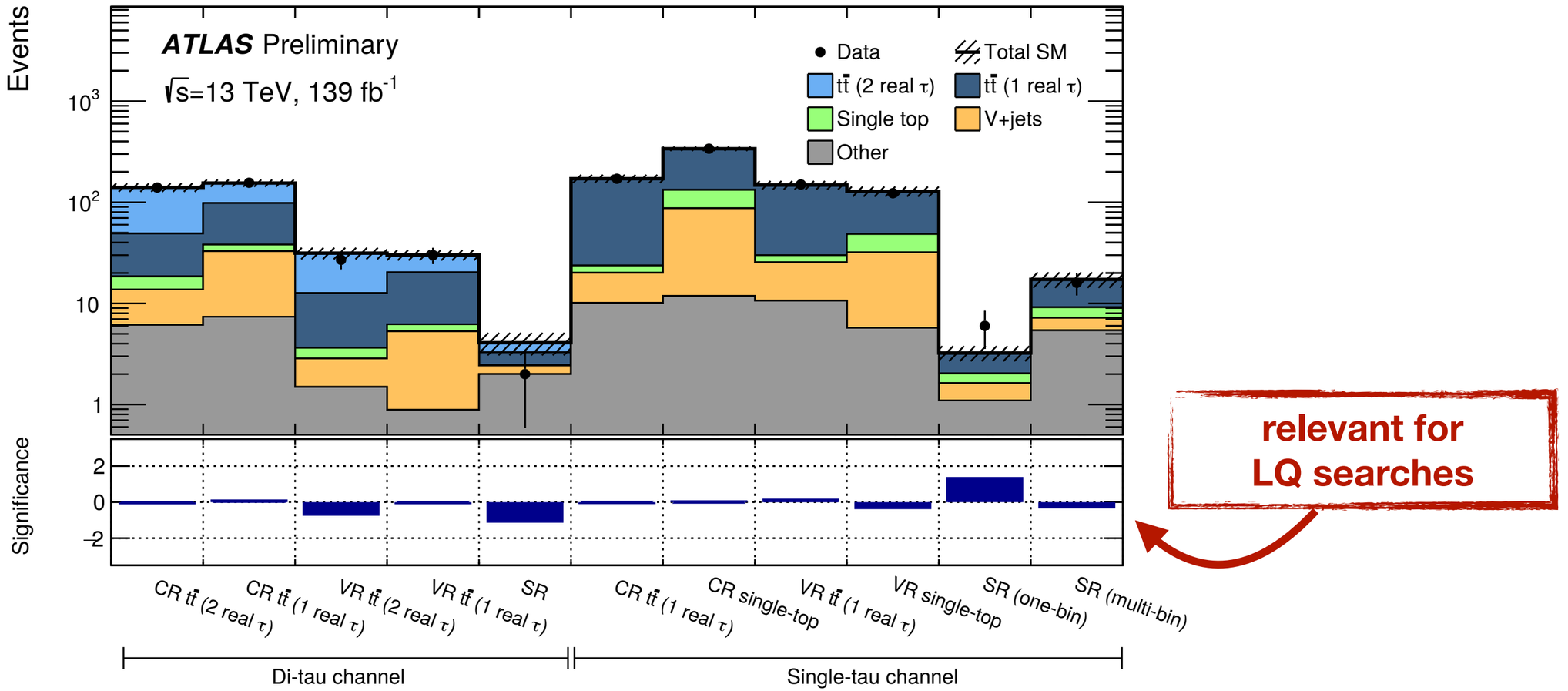
- Model parameters are m_{LQ} and BR (LQ→ql±)

- Two analysis channels:
  - τ→had. + 2 b-jets and missing E_T
  - di-tau channel (SUSY searches)

Other recent ATLAS searches targeting LQ models:
arXiv:2101.11582
EPJC 81 (2021) 313
JHEP 10 (2020) 112



LQ → τ + b-jets + E^{T}_{miss} — Background



relevant for LQ searches

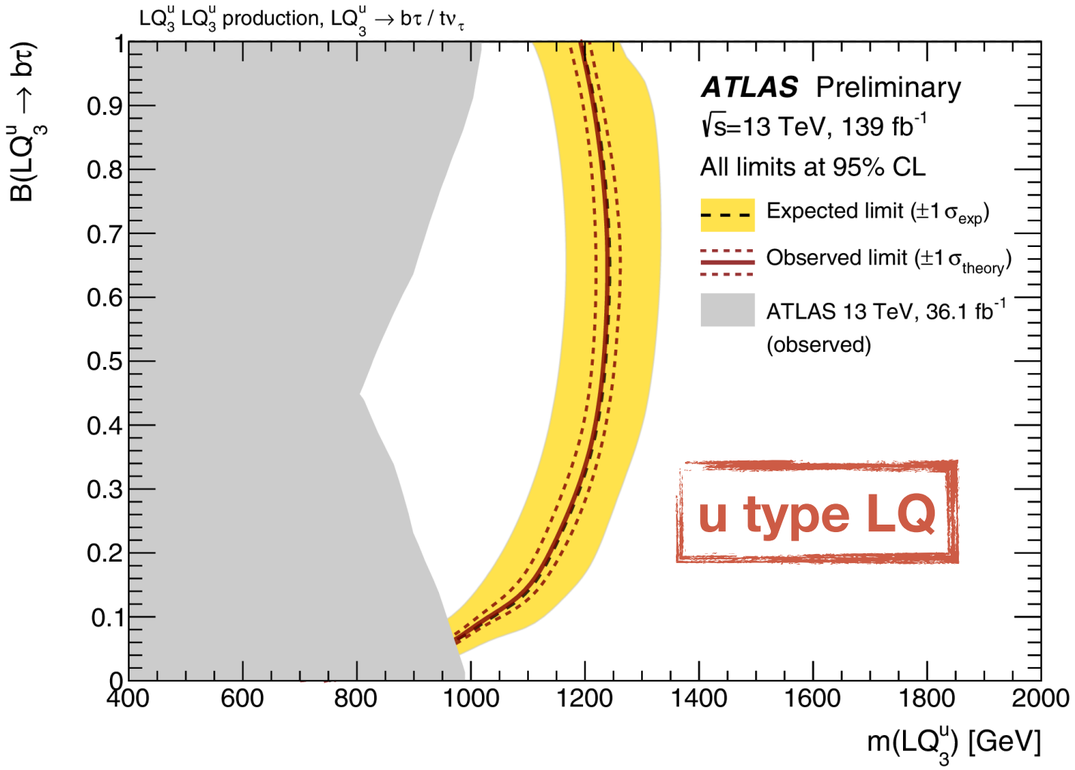
- **Main backgrounds:** $t\bar{t}$, single-t, V+jets → estimated from MC (normalisation in CRs)
- Many different SRs are exploited in the SUSY searches, while a p_T —binned SR is optimised for LQ models

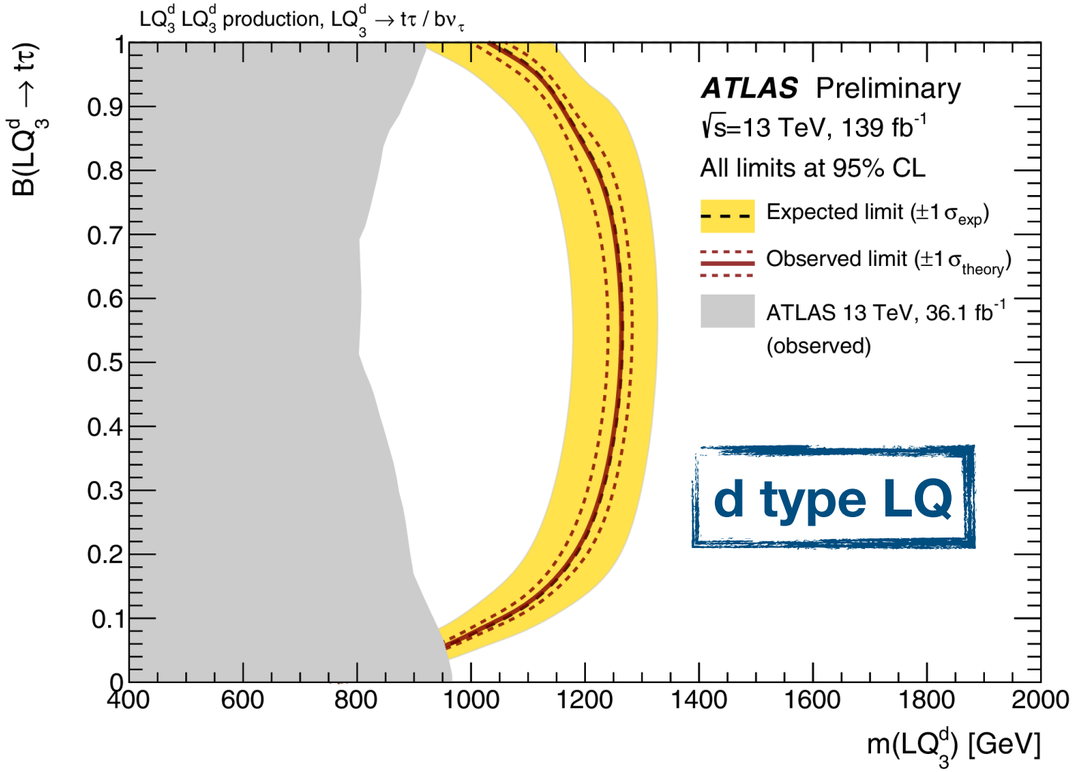
LQ → τ + b-jets + E^{T}_{miss} — Limits

No significant disagreement with SM prediction
→ limits on LQ models

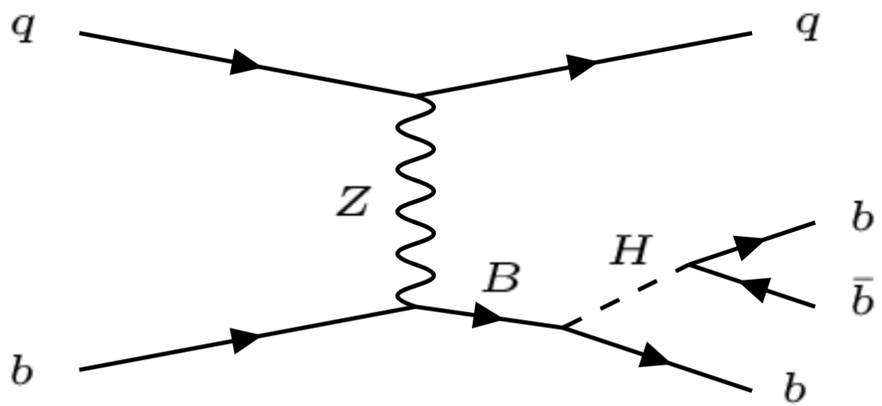
Best exclusion power for intermediate BR values

Results are complementary to other ATLAS SUSY searches
EPJC 80 (2020) 737
JHEP 05 (2021) 093





VLQ → bH(bb)



- **Vector—like quarks** are predicted in bSM theories attempting to solve the **hierarchy problem**
- **This search targets vector like B quarks:**
  - Single VLB production mediated by Z boson
  - Decay to b+H(bb)
- The analysis exploits the **large boost** of H searching for large radius jets and **b-jet identification**

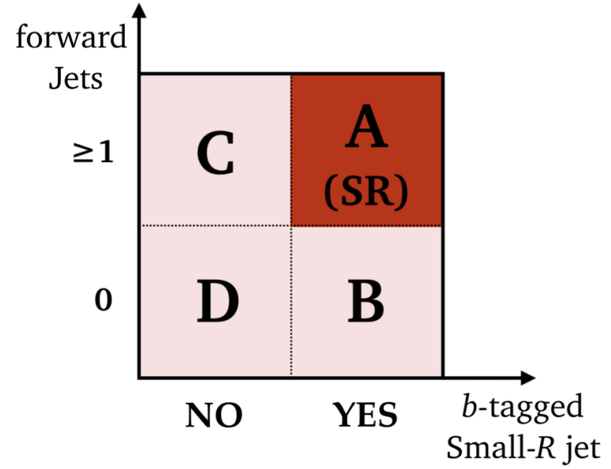
VLQ → bH(bb) — Background strategy

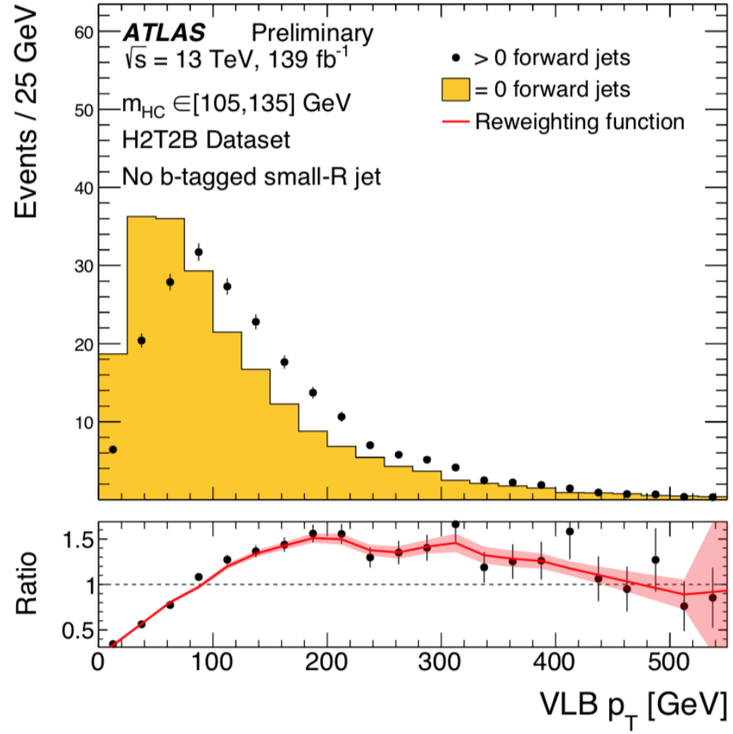
- Target: One large-R jet with at least 2 matching b-tagged track-jet + 1 b-jet + 1 light-jet

- **All hadronic final state**
  → large background from QCD multi-jet events

- Data driven "**ABCD**" background estimation
  → validated with CRs

- Correlation in ABCD plane propagated with k-factors, weighting to adjust kinematic differences in the BCD sub-regions

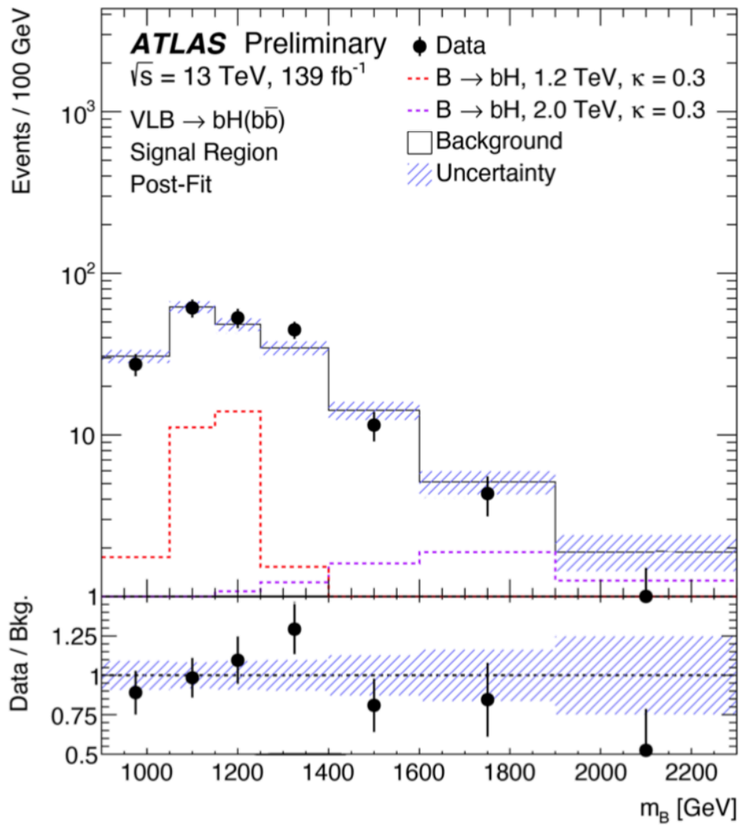




VLQ → bH(bb) — Results

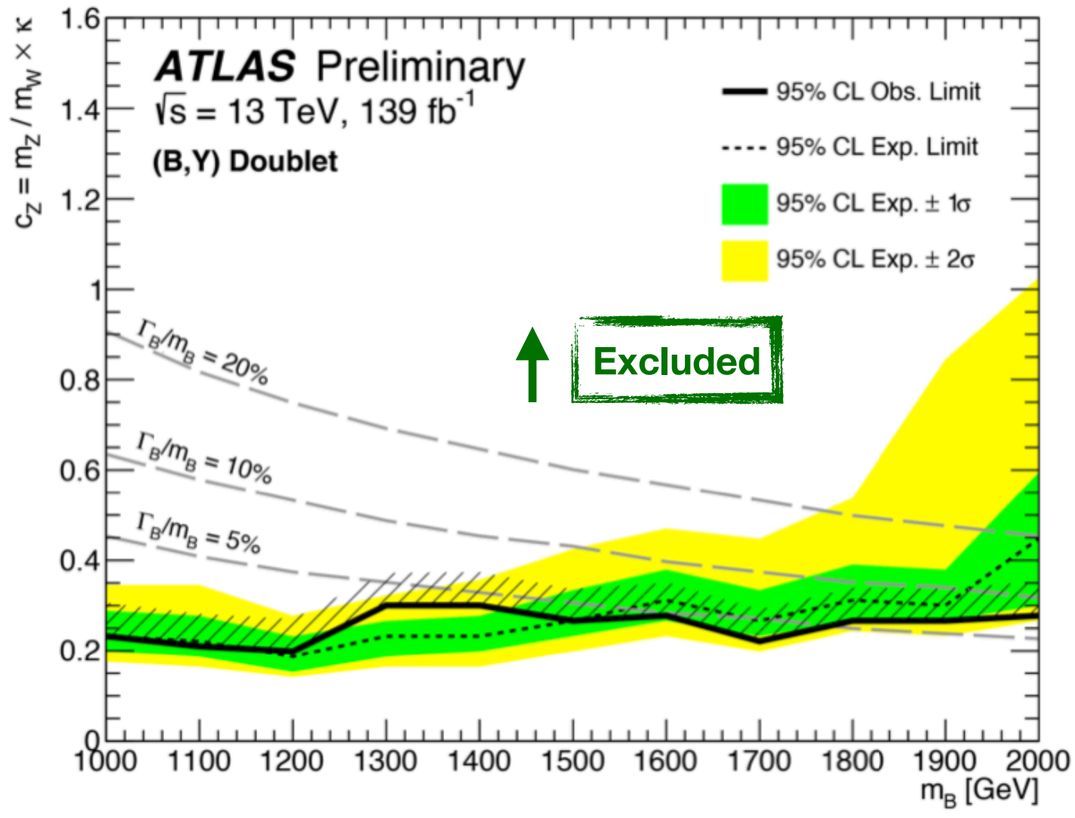
ATLAS-CONF-2021-018

No significant deviation from SM → limits on VLQ production



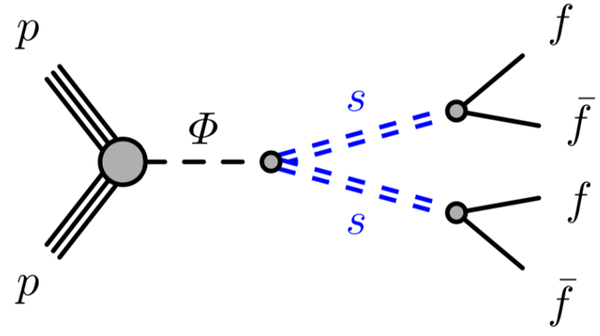
$m_B = m_{H\ candindate} + m_{b\text{-}jet}$

Limits on σ are interpreted in terms of the VLQ coupling with Z boson

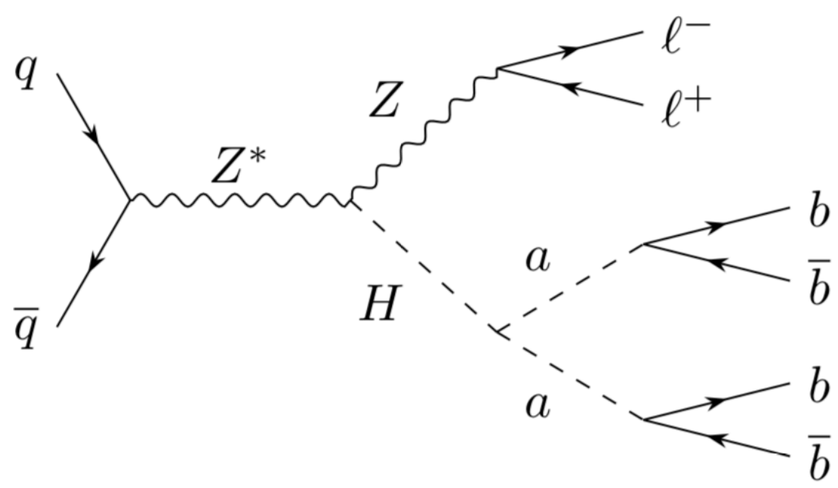


H→aa→4b in the ID

- Long lived particles are predicted by many bSM models
- Higgs decay in pair of neutral long-lived bosons (a), decaying in $b\bar{b}$

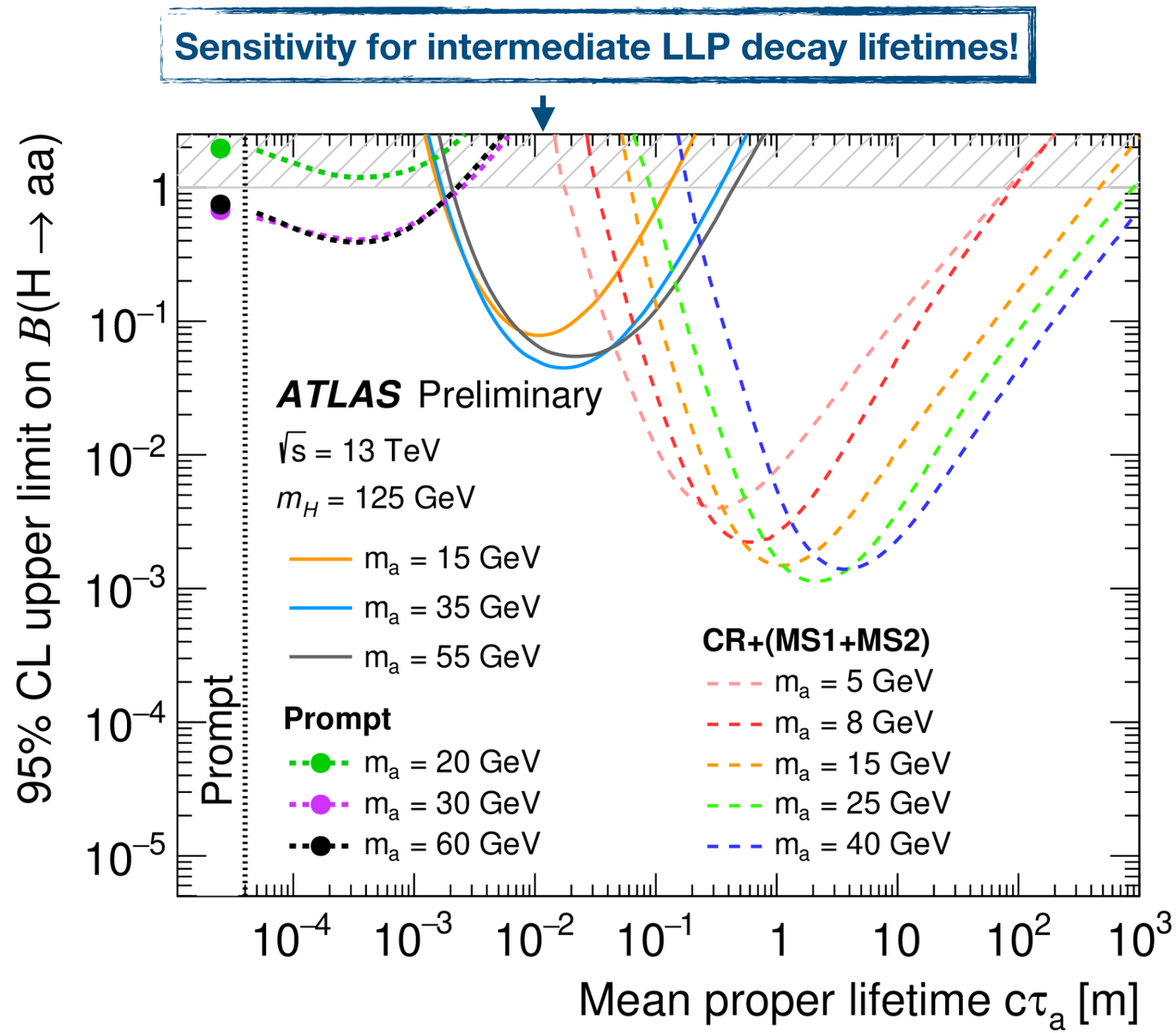


- Z-associated Higgs production considered to alleviate trigger challenges
- Selection targeting 2 ID displaced vertices, with dedicated reconstruction algorithm



H→aa→4b in the ID — strategy & results

- Dedicated SM background estimation, exploiting **DV reconstruction probability**
- **Zero events observed** (compatible with SM prediction)
- **cτ—dependent Limits on Higgs BR to LLPs**
- Complementary results w.r.t analyses exploiting prompt production or displaced jets in ATLAS calorimeter or MS



Conclusions

- Many different scenarios have been explored by these searches
- But no disagreement with SM is found…
  …yet!
- But additional constraint on different theoretical models are given by these analyses

The SM is our best tool to understand nature…

… but we have to keep searching!

There's still a lot to learn from Run 2 data, and even more from the upcoming Run 3!