The LHC as Lepton-Proton Collider:
Search for the Resonant Production of Leptoquarks

Daniel Buchin on behalf of the ATLAS Collaboration

MAX-PLANCK-INSTITUT FÜR PHYSIK

EPS-HEP 2025 – POSTER SESSION

ATLAS EXPERIMENT

MOTIVATION

Leptoquarks have been a **long-standing target of LHC** new physics searches:

- Essential part of grand unification of interactions
- Anomalies in flavour universality measurements

Probing a **novel production** mode of Leptoquarks involving elusive **lepton content of the proton [1]:**

➢ **Resonant Leptoquark production** with clean **1-lepton+jet** signature

➢ **Competitive** to previous LHC searches for Leptoquarks [2]

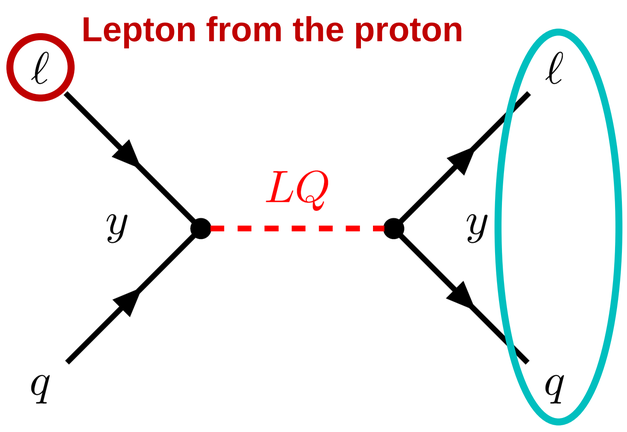


Fig. 1: Resonant Leptoquark Production with initial state lepton

ANALYSIS STRATEGY

- Considering **full ATLAS Run2 AND early Run3** (2022 – 23) dataset
- Targeting scalar $\mathrm{LQ}^{q=4/3}$ model ($\tilde{S}_1$), in final states:

➢ e + light-jet, μ + light-jet, e + b-jet, μ + b-jet (plus associated 2-lepton+jet final states)

- For each final state channel, define a 1-lepton and a 2-lepton region enriched in signal events (**SR-1L and SR-2L**)

➢ Binned in the **invariant mass $m_{\ell j}$ of the lepton-jet system**

➢ This observable serves as a handle on the Leptoquark resonance mass peak

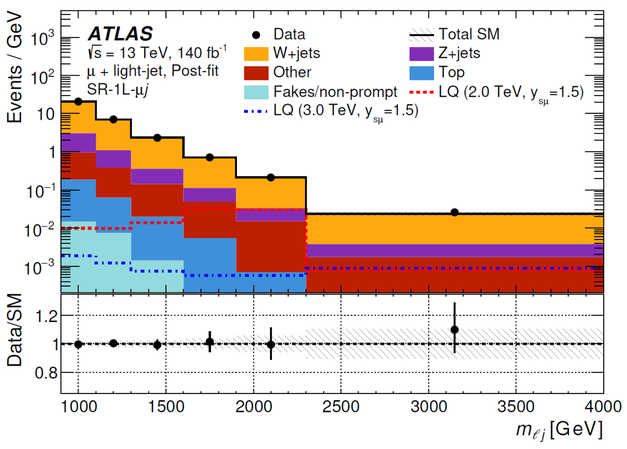


Fig. 3: SR-1L binning in the μ + light-jet channel (Run2)

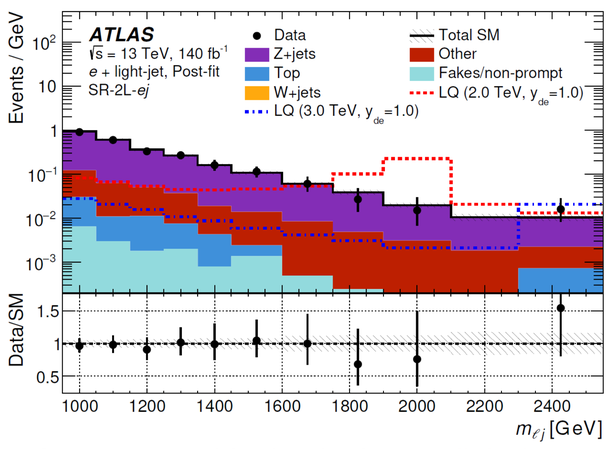


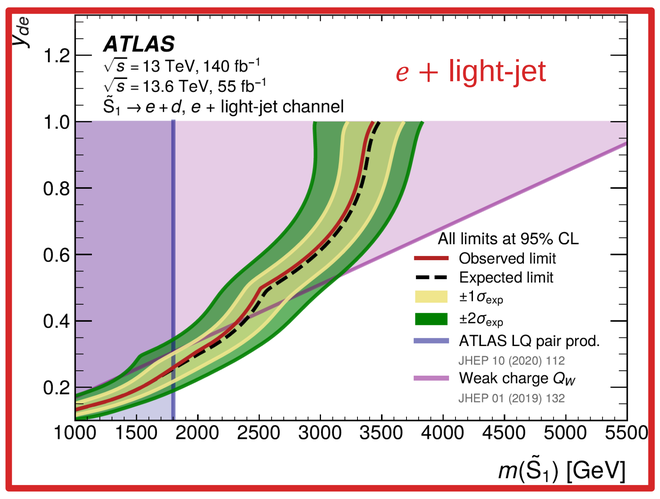
Fig. 4: SR-2L binning in the e + light-jet channel (Run2)

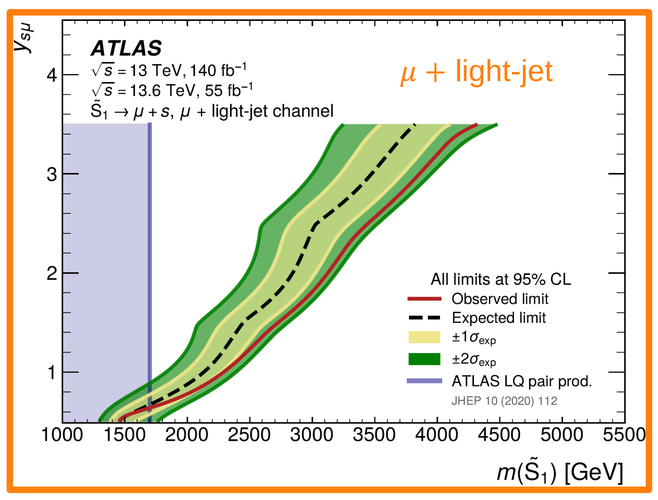
RESULTS

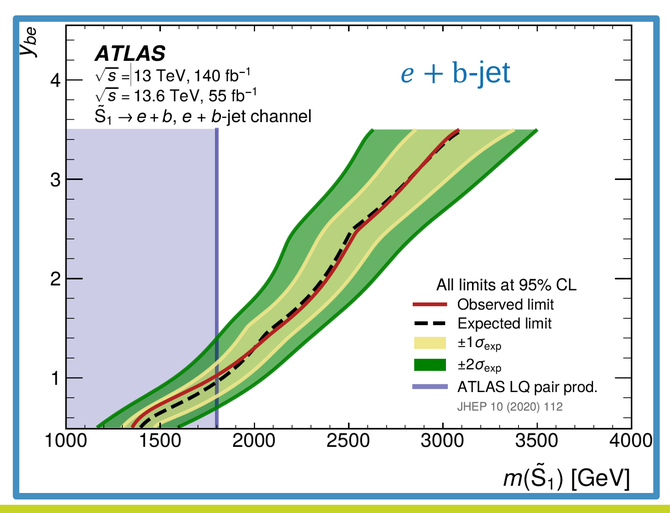
- **First ATLAS result** making use of the **lepton content of the proton;** one of the first new physics searches **combining Run2 and Run3 data**

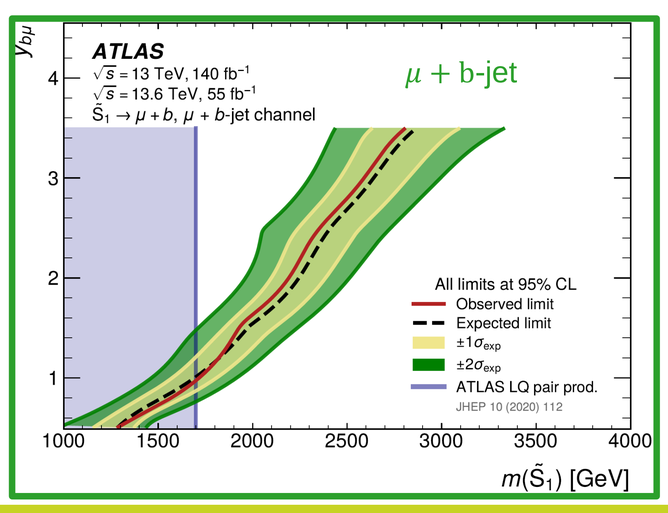
• Observed data agrees with SM predictions

- **Improve existing constraints** from LQ pair production searches at large coupling values ($y \gtrsim 1$) [4]









LEPTOQUARKS AT NEXT-TO-LEADING ORDER

- State-of-the-art NLO modelling of the process used [3]. Additional signature due to real lepton emission:

➢ **2-lepton+jet**

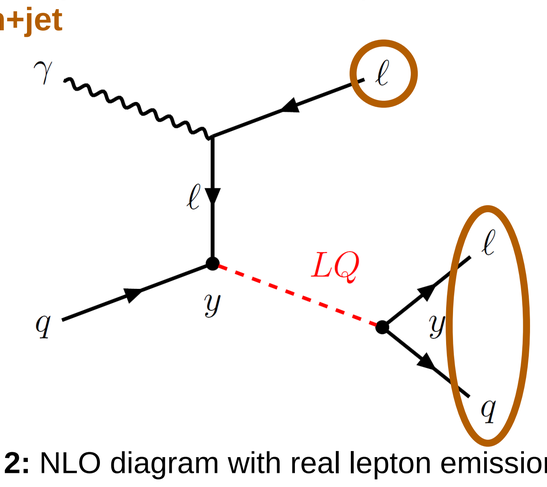


Fig. 2: NLO diagram with real lepton emission

BACKGROUND ESTIMATION

- Main Standard Model background in SR-1L is W-boson production with associated jets (**W+jets**)
- Main background in SR-2L is Z-boson production with associated jets (**Z+jets**)
- In channels with b-tagged jets, also top background relevant
- **Normalise** these backgrounds in **dedicated control regions** (CRs) to observed data and extrapolate this normalisation to SRs
- Validation of extrapolation in dedicated validation regions (VRs)
- Data-driven estimation of processes with jets misidentified as leptons in the detector (“fakes”) using the **fake factor method** (only relevant in electron channels)

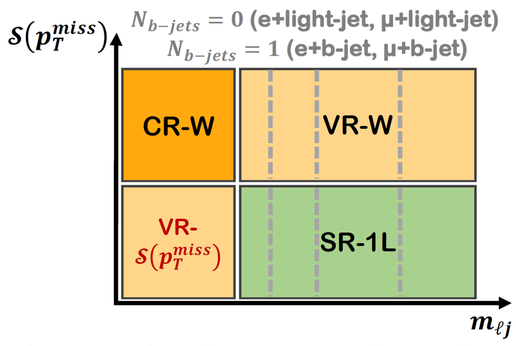


Fig. 5: Estimation strategy for W+jets

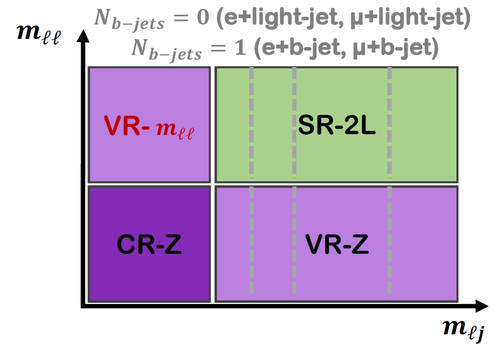


Fig. 6: Estimation strategy for Z+jets

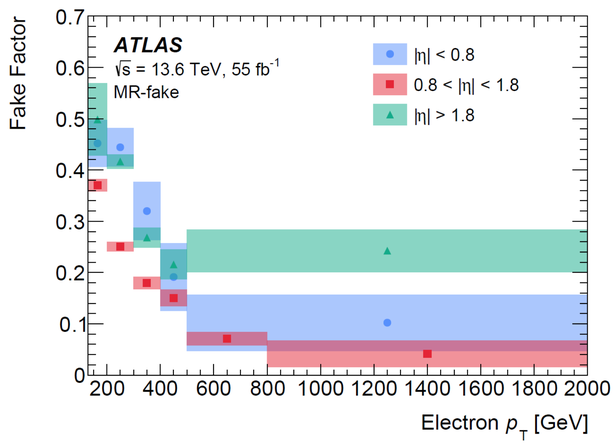


Fig. 7: Fake factor estimation in Run3

REFERENCES

[1] Buonocore, Nason, Tramontano, Zanderighi, JHEP 08 (2020) 019

[2] Buonocore, Haisch, Nason, Tramontano, Zanderighi, PRL 125 (2020) 23

[3] Buonocore, Greljo, Krack, Nason, Selimovic, Tramontano, Zanderighi, JHEP 11 (2022) 129

[4] The ATLAS collaboration, JHEP 10 (2020) 112