

Classifying Fake and Non-Prompt Leptons in the ATLAS Experiment

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The ATLAS Detector

- The ATLAS detector is a general-purpose detector located at the Large Hadron Collider (LHC).
- The LHC produces more than 1 billion proton-proton interactions each second when operating.
- It consists of multiple subdetectors that are designed to track and measure particles.

Signal and Background

- Signal is the process of interest. For this analysis, this is the production of a doubly charged Higgs boson.
- Background consists of all other processes that mimic the final state of the signal.

The background process looks like the signal, but it is not the process we want to look for!

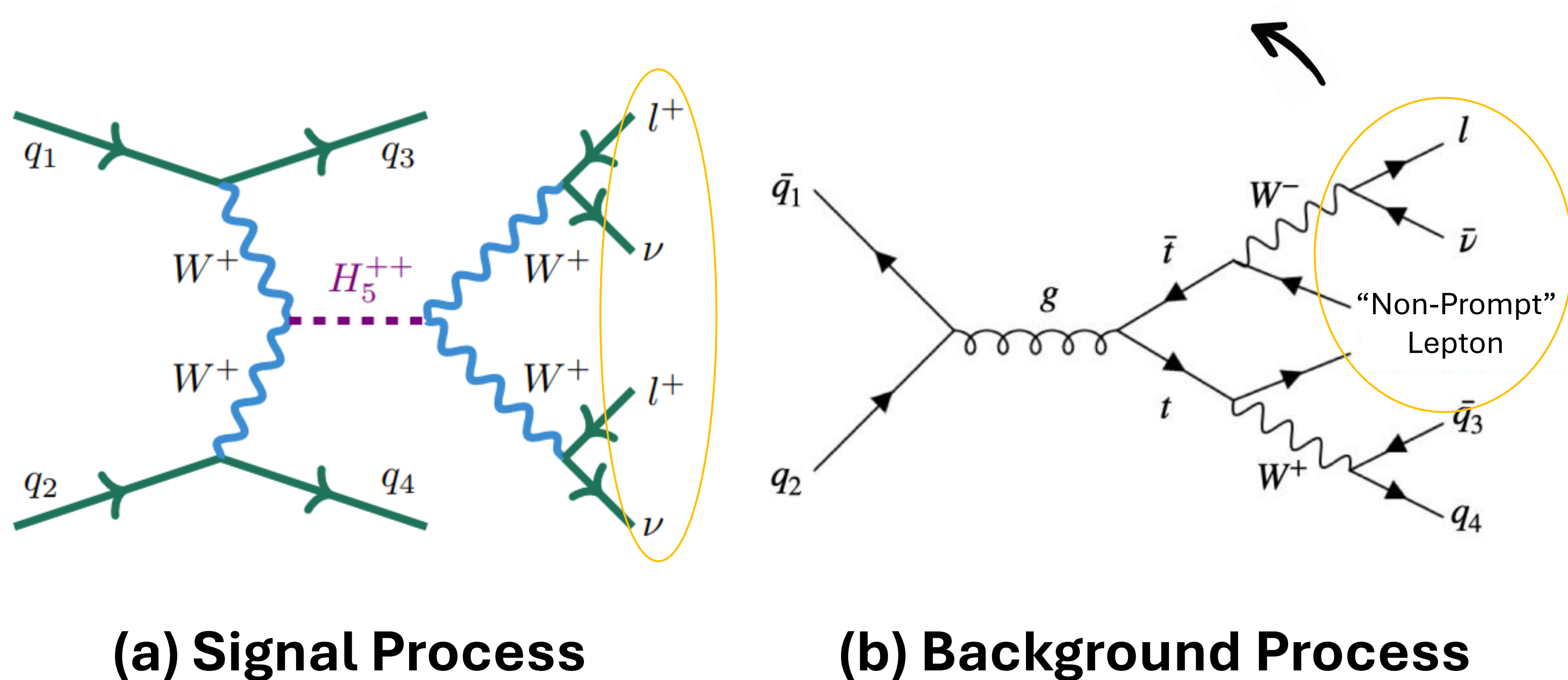


Figure 1. Representative Feynman diagrams for the signal process (a) and a background process showing $t\bar{t}$ production (b). Both processes have similar final state particles. [1] [2]

Classifying Leptons

- Electrons and muons are reconstructed using energy deposits, identification methods, and isolation requirements.
- Leptons from the signal process are **prompt leptons**. Particles that mimic these can be classified as:
 - Fake leptons:** Objects that are misidentified as leptons.
 - Non-prompt leptons:** Leptons originating from secondary decays.

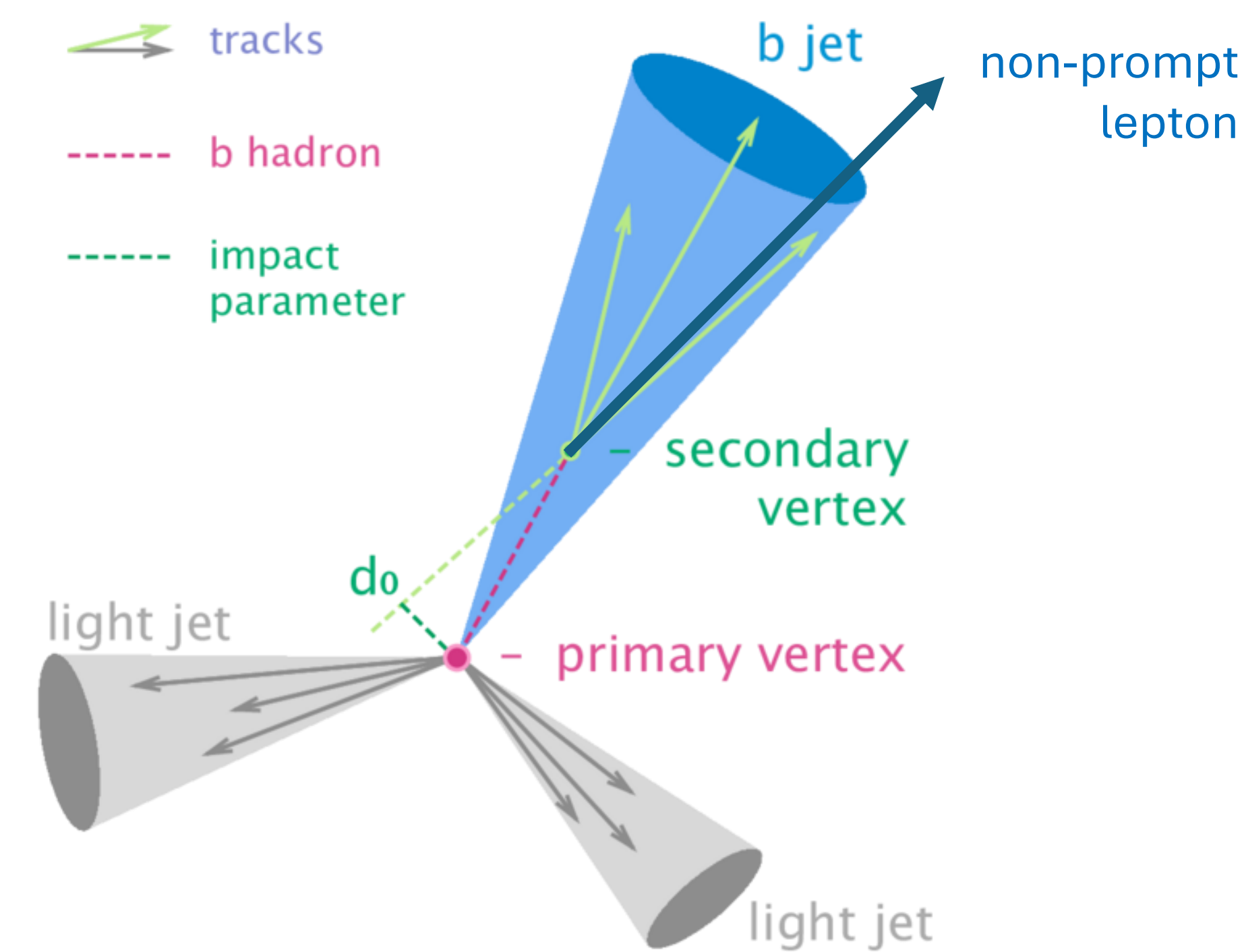


Figure 2. Jets are collimated sprays of particles in the detector and can be incorrectly reconstructed as leptons or produced in secondary decays. [3]

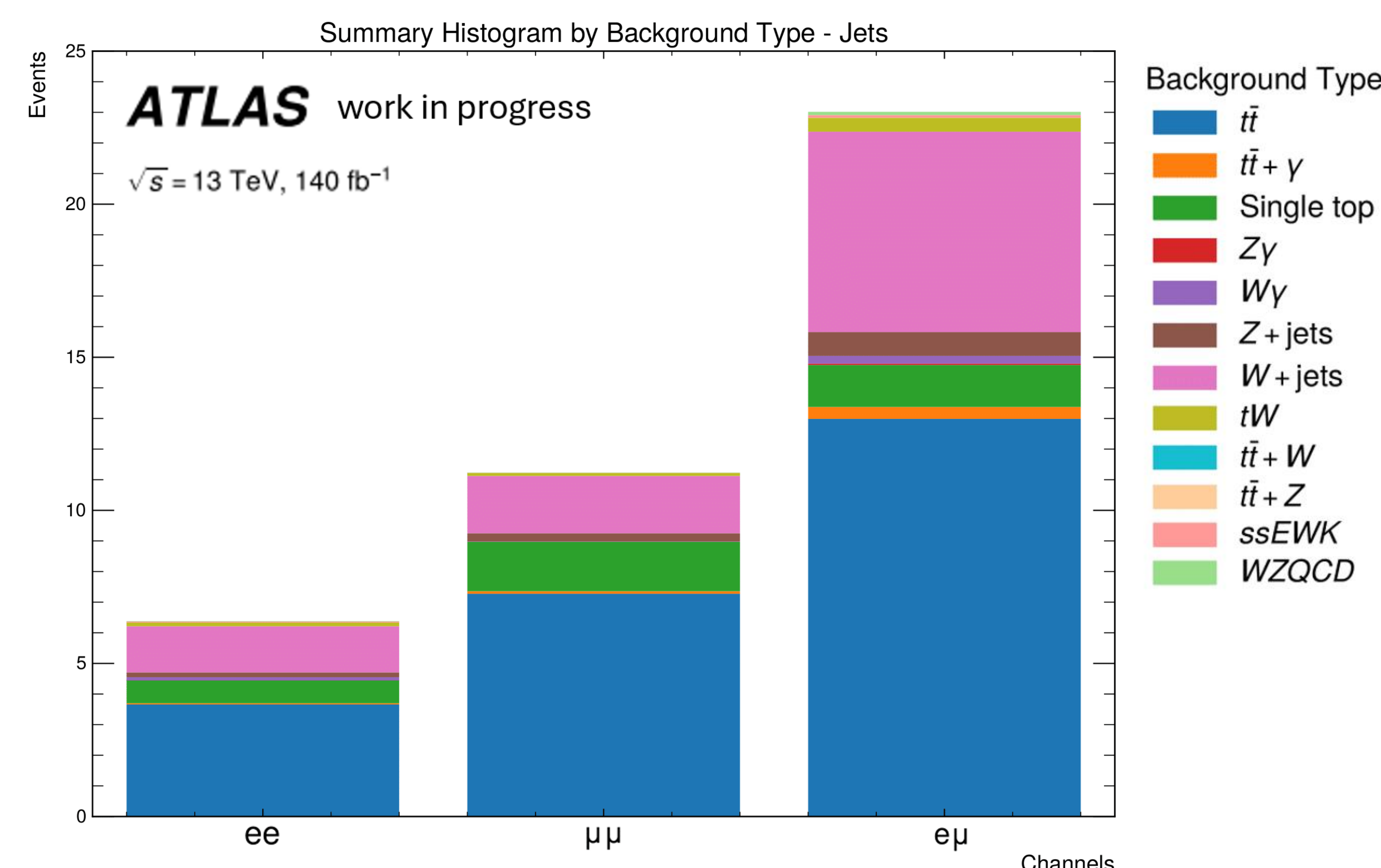


Figure 3. Events containing one fake or non-prompt lepton originating from a jet. This includes b -hadron, c -hadron, and light flavour decays. Analysis is shown for three lepton channels.

Same-Sign $W^\pm W^\pm$ Analysis

- Simulated background events tell us which processes contribute to the analysis.

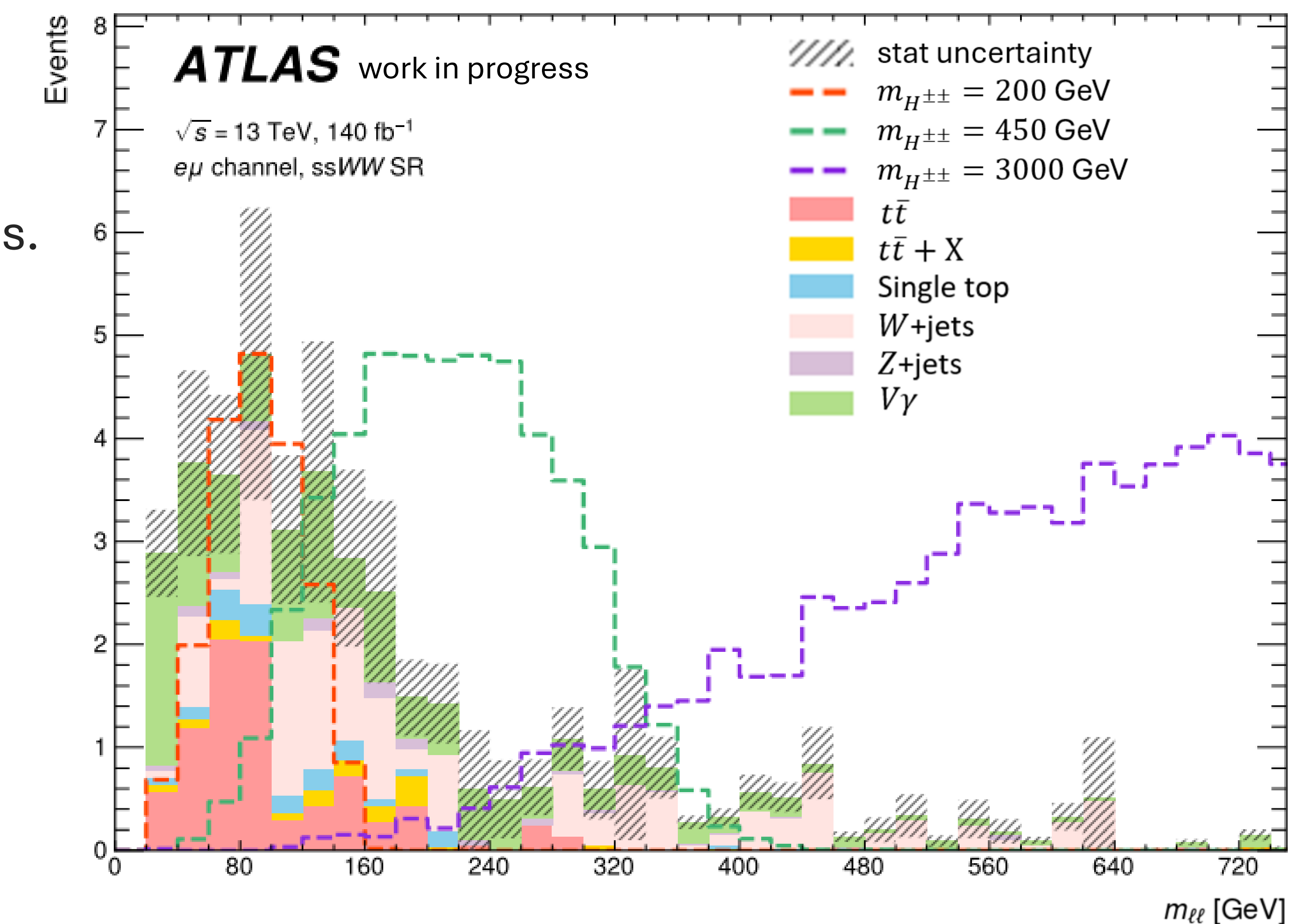


Figure 4. Invariant mass of the two leptons in events containing at least one fake or non-prompt lepton. Signal samples with prompt leptons are plotted for comparison.

Summary

- Background originates from processes with final states that mimic the process of interest.
- Studying the types of non-prompt and fake leptons that pass signal region requirements provides better estimates on the background. This allows for better differentiation between the true signal and background processes.

References

- [1] ATLAS Collaboration (2024). *Combination of searches for singly and doubly charged Higgs bosons produced via vector-boson fusion in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector.*
- [2] S. Solomon (2022). *The First Measurement of the Differential Cross-Section of Electroweak $W^\pm W^\pm jj$ Production at 13 TeV with the ATLAS Detector.*
- [3] P. Charitos (2017). *Deep learning and the quest for new physics at the LHC.*

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