Estimation of jet-faked muon background in W-boson scattering at $\sqrt{s} = 13$ TeV with the ATLAS detector

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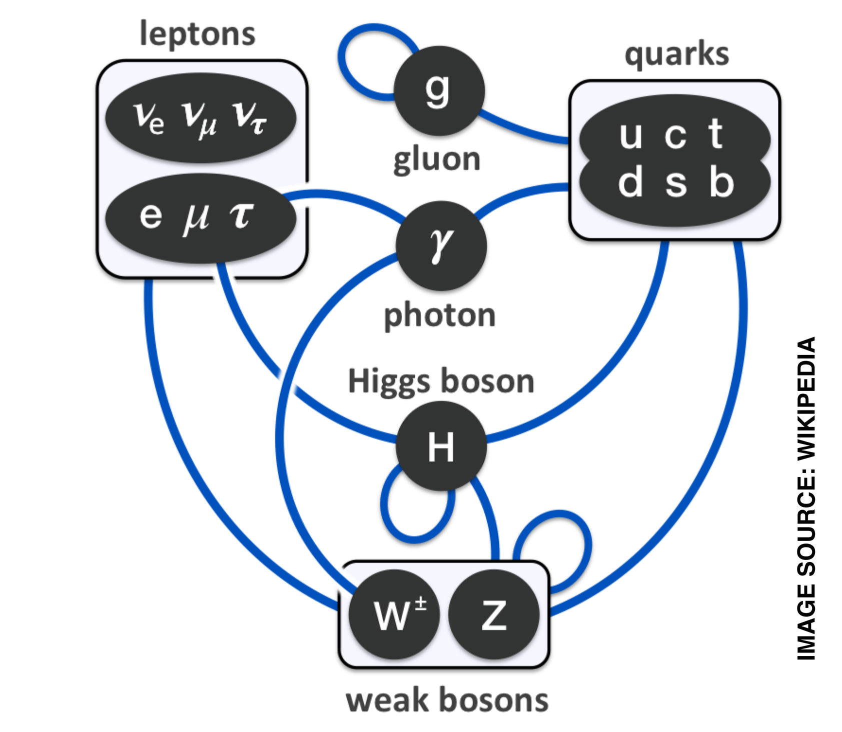
SAIP Conference 2016

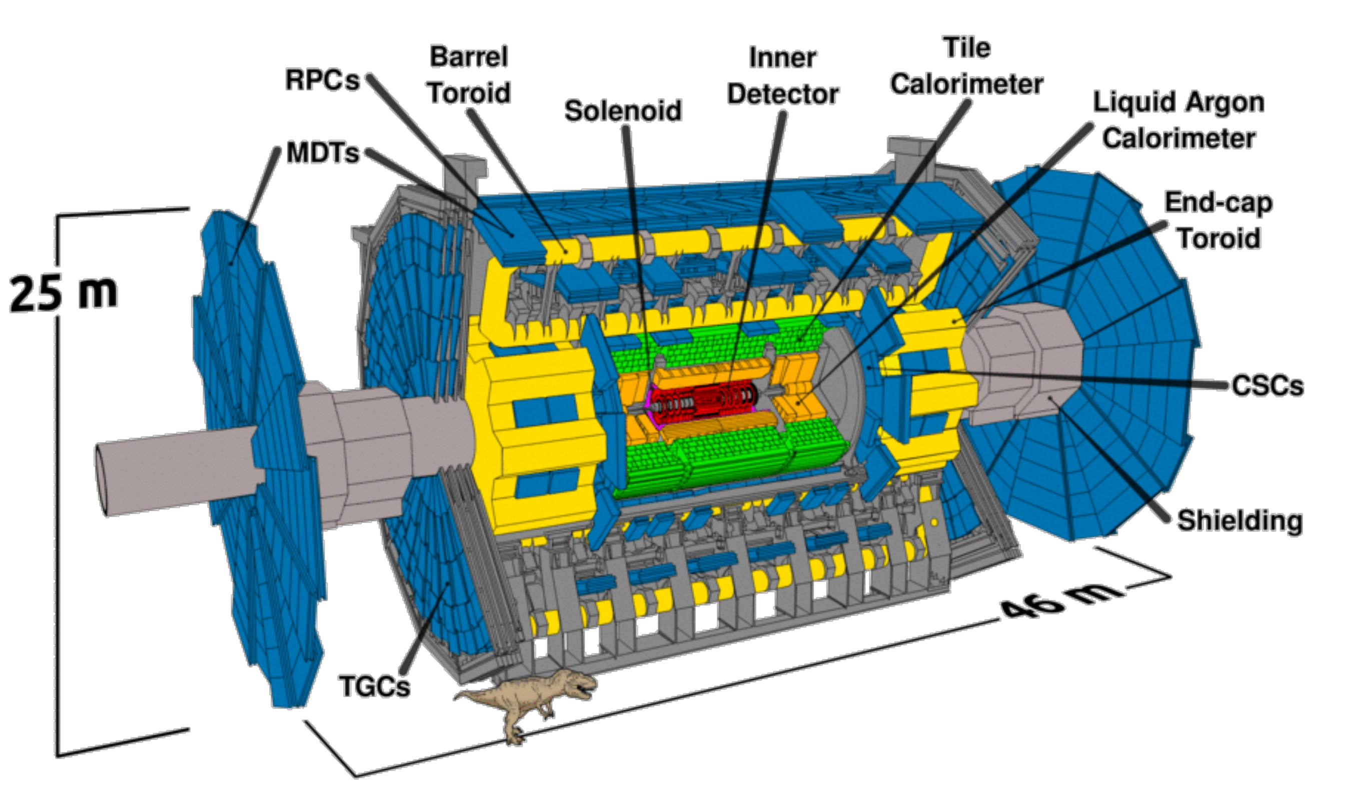
Why W-boson Scattering?

The scattering of **W-bosons** is a key process in probing electroweak symmetry breaking. The longitudinally polarised scattering amplitude of *W-bosons* scattering **violates unitarity** when the WW centre-of-mass energy exceeds approximately 1 TeV. A mechanism required to unitarise this process.

Enter the 125 GeV Higgs Boson.

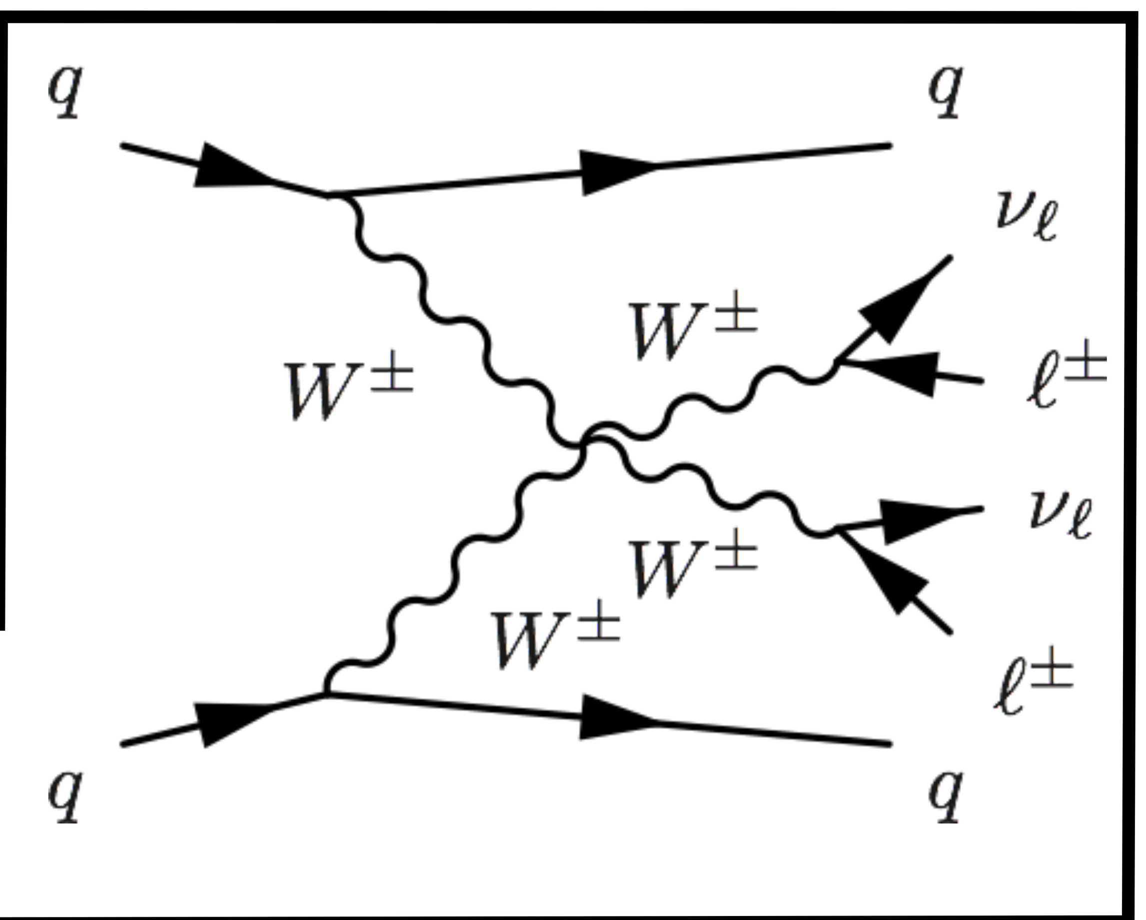
By adding the Standard Model[1] Higgs boson, the cross section regains reasonable behaviour at high energies and the mathematical consistency of the Standard Model is preserved.

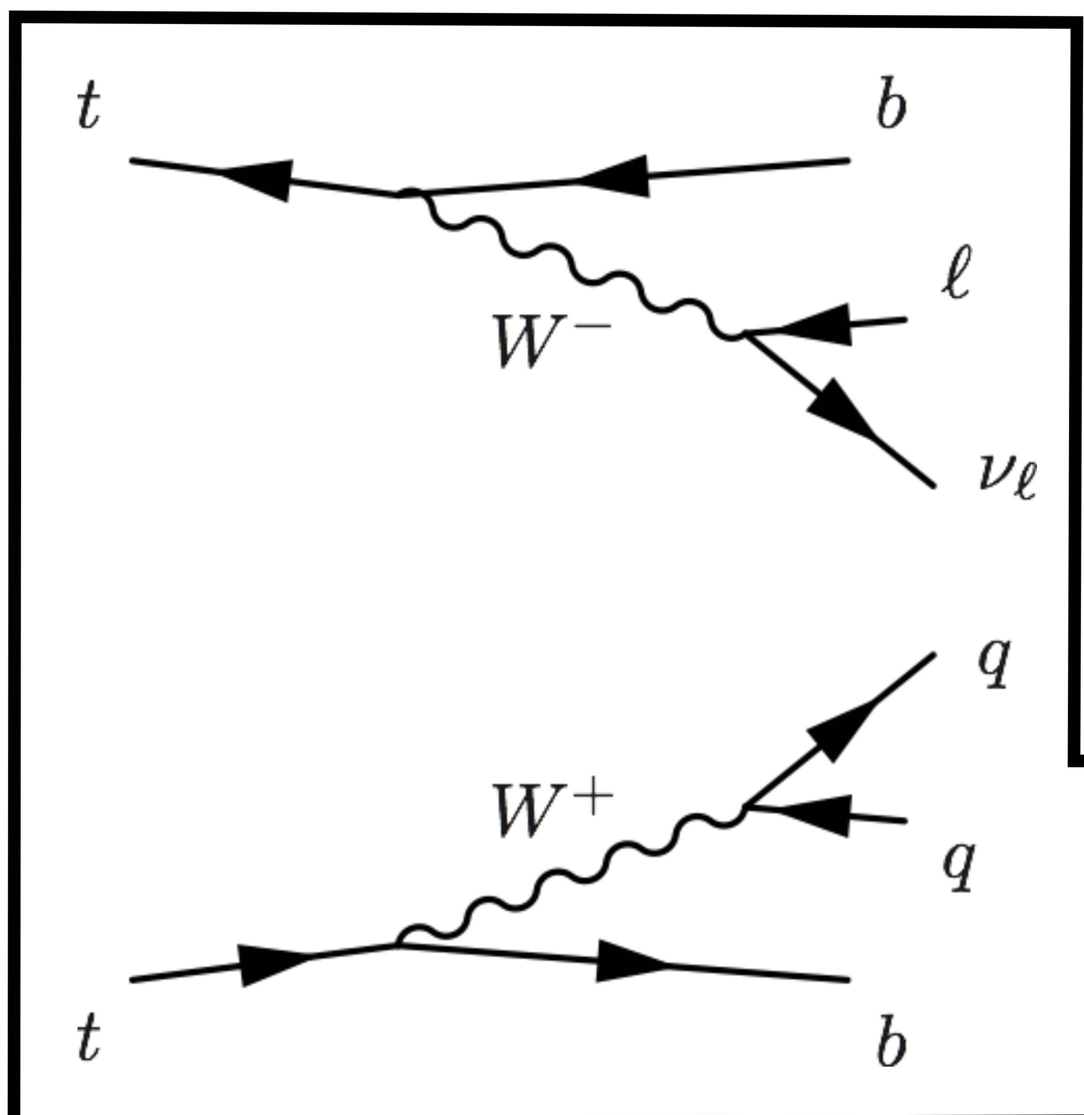




The ATLAS Detector

One of two general purpose detectors at the Large Hadron Collider [2], the ATLAS detector [3] is designed to analyse data from proton-proton collisions. A number of layered subsystems around the collision point record the properties of particles produced in the proton-proton collision. The trajectory and transverse momentum of charged particles is measured with the Inner Detector; particle energy is measured with the Calorimeters, and muons are measured with the muon spectrometer. **Muons** are able to travel straight through the calorimeter with little perturbation (in contrast to other particles) and reach the outermost part of the detector called the muon spectrometer (comprised of the MDTs, RPCs, CSCs, TGCs). Due to this muons are often extremely useful in identifying new physics phenomena.



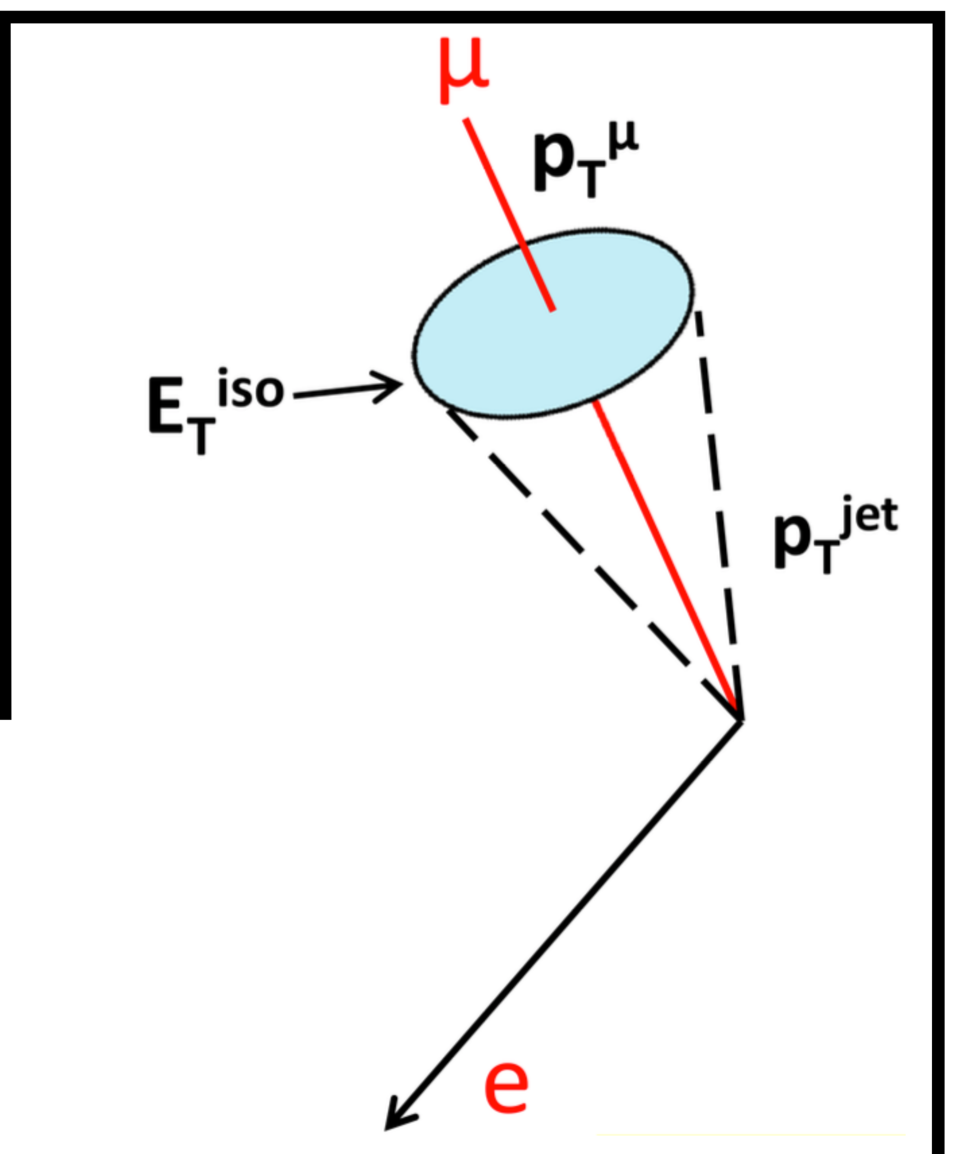


The Search for W-boson Scattering

The W-boson scattering can be either opposite sign or same sign. Same sign scattering has less background and is thus expected to be more sensitive to the quartic coupling. Using the leptonic decays of the W-bosons, the experimental signature chosen for this study is thus two same sign leptons ($e^\pm e^\pm$, $e^\pm\mu^\pm$, and $\mu^\pm\mu^\pm$) with two jets and missing transverse energy. First evidence for same sign *WW* (*ssWW*) scattering was found to a significance of 4.5 σ by ATLAS [4], while a similar analysis by the CMS Experiment found a 2.0 σ effect [5]. This poster reports on some of the work to increase the significance for the measurements using $\sqrt{s} = 13$ TeV proton-proton collision data recorded by the ATLAS detector.

Fake Lepton Background

A prompt lepton is one which comes from a *W-boson,* while a non-prompt lepton is one which comes from the decay of a hadron. Processes that contain non-prompt leptons contribute to background in events selected for the same sign *WW* measurement. These, non-prompt leptons are called the 'fake lepton background'. The dominant contribution to the fake lepton background is from the process: $t\bar{t} \longrightarrow WbWb \longrightarrow l\nu bbqq$



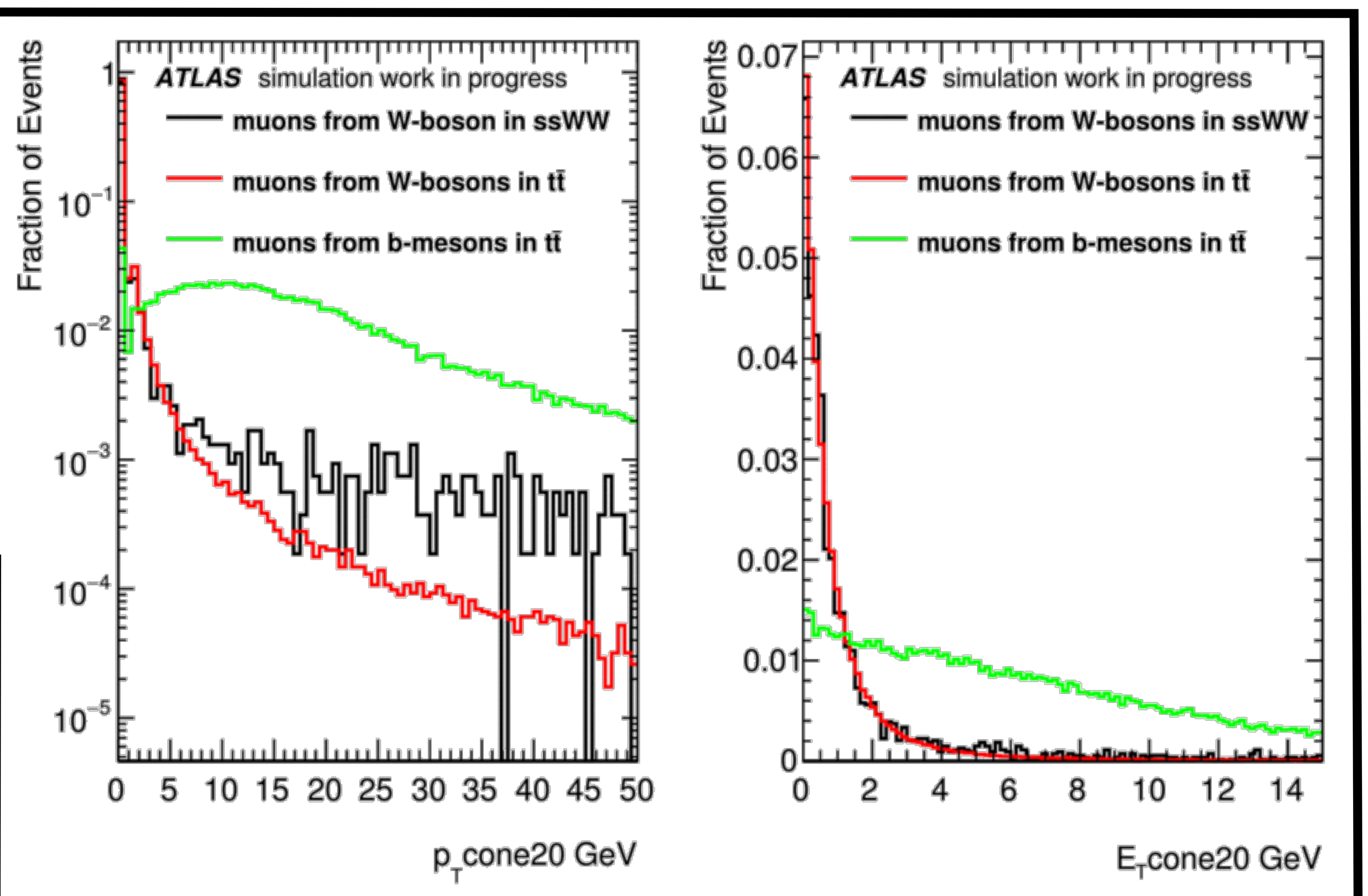
Isolation Studies

Isolation is a measure of the number of particles produced in a cone in $\eta - \phi$ space, defined by $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$ (pseudo-rapidity η and azimuthal angle ϕ), around the detector signature corresponding to the reconstructed lepton. 'pTcone20' is the sum of the transverse momenta of all tracks within a cone of $\Delta R = 0.20$, while 'eTcone20' is the sum of the transverse energy within a cone of $\Delta R = 0.20$ centred on the lepton's deposit in the calorimeter. Fake leptons are likely to be less isolated than prompt leptons, because hadrons are often produced in collimated flows, called jets. The primary goal of this work is to optimise the event selection criteria related to the lepton isolation to reduce the background from fake leptons.

Comparing Isolation

The plots to the right display the isolation variables for muons with three different origins. The $t\bar{t}$ sample is produced using the PowHeg event generator, while the *ssWW* sample is produced by Sherpa the event generator. Using a sample as background, reconstructed muons were matched to truth muons using the standard ATLAS Monte Carlo (MC) truth classifier tool. It was found that the majority of the background muons come from either *W-bosons* or *b-mesons*, representing a prompt and non-prompt background respectively.

These backgrounds were plotted with the *ssWW* sample. Note that the muons from the *ssWW* and the prompt background muons are similarly isolated since both originate from *W-bosons*. The muons coming from *b-mesons* are less isolated, indicative of the muon having being decayed from a jet. A large fraction, 34%, of the reconstructed muons are unable to be truth-matched using the MC classifier tool. *See SAIP 2016 poster by Xolisile Thusini for the efforts to classify these leptons coming from an unknown origin.*



References

[1] Particle Data Group, *Chin. Phys.* C, **38** (2014), 090001
[2] L. Evans and P. Bryant (editors), *JINST* **3** (2008) S08001
[3] ATLAS Collaboration, *JINST* **3** (2008) S08003
[4] ATLAS Collaboration, *Phys. Rev. Lett.* **113** (2014), 141803
[5] CMS Collaboration, *Phys. Rev. Lett.* **114**, 051801

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