Lepton Flavour Violation in Decays of Tau Leptons at CMS

Matthew French & Liam Malone

H H Wills Physics Laboratory, Bristol University, BS8 1TL, UK

Abstract

CMKIN and FAMOS software programmes were used to simulate the generation and detection of the lepton flavour violating processes $\tau\rightarrow\mu\gamma$ and $\tau\rightarrow e\gamma$ at CMS. The major backgrounds were identified as $\tau\rightarrow\mu\nu_\mu\nu_\tau\gamma$ and $\tau\rightarrow e\nu_e\nu_\tau\gamma$ respectively. In contrast with previous investigations the taus investigated were from $Z\rightarrow\tau\tau$ decays. The tau mass reconstructed from only the muon and photon was found to be the best parameter for background-signal differentiation. If no signal is observed in 100fb^{-1} of data then this project shows the limit CMS can place at 90% CL is BR($\tau\rightarrow\mu\gamma$)<3.63×10^{-7}. This is consistent with other work focusing on taus from $W\rightarrow\tau\nu_\tau$ decays at CMS and also with limits ATLAS may place. No improvement on current limits was achieved for $\tau\rightarrow e\gamma$.

Introduction

The standard model (SM) of particle physics describes the interactions of the known particles via 3 fundamental forces (the SM does not yet include gravity). The three flavours of lepton (electron, muon and tau) until recently were believed to be conserved in all interactions. Recent evidence from the Sudbury neutrino oscillation experiment and other studies have suggested that neutrinos can oscillate between flavours due to them having a very small mass - this is lepton flavour violation (LFV) in neutrinos. This suggests that LFV may also occur in the charged leptons – i.e. decays such as $\tau\rightarrow\mu\gamma$ may occur. LFV is not currently included in the SM, however a number of extensions to the SM such as supersymmetry (SUSY) allow its existence.

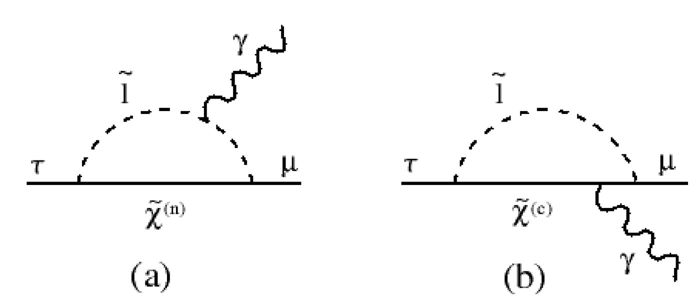

Figure 1: Generic SUSY Feynman diagrams for $\tau\rightarrow\mu\gamma$.

The next large particle accelerator to come online will be a 14TeV proton-proton collider named the Large Hadron Collider (LHC). Its high energy and luminosity presents a unique opportunity to study rare processes with high accuracy. The two processes of interest here are $\tau\rightarrow\mu\gamma$ (branching ratio < 1.1×10^{-6}) and $\tau\rightarrow e\gamma$ (branching ratio < 2.7×10^{-6}). These were studied using Monte Carlo simulations of the production and the detection of events.

CMS

The Compact Muon Solenoid (CMS) is one of four detectors which are going to be placed in the Large Hadron Collider (LHC) at CERN. It is a general purpose detector whose aims are to find the Higgs boson and study Physics at the TeV scale. The detector is designed to measure the energy and momentum of photons and charged particles (such as electrons and muons) with very high precision over a pseudorapidity range $|\eta|<2.5$. It primarily consists of a silicon tracker, an electromagnetic calorimeter (ECAL), a hadron calorimeter (HCAL), a magnet system and muon chambers – see Figure 2.

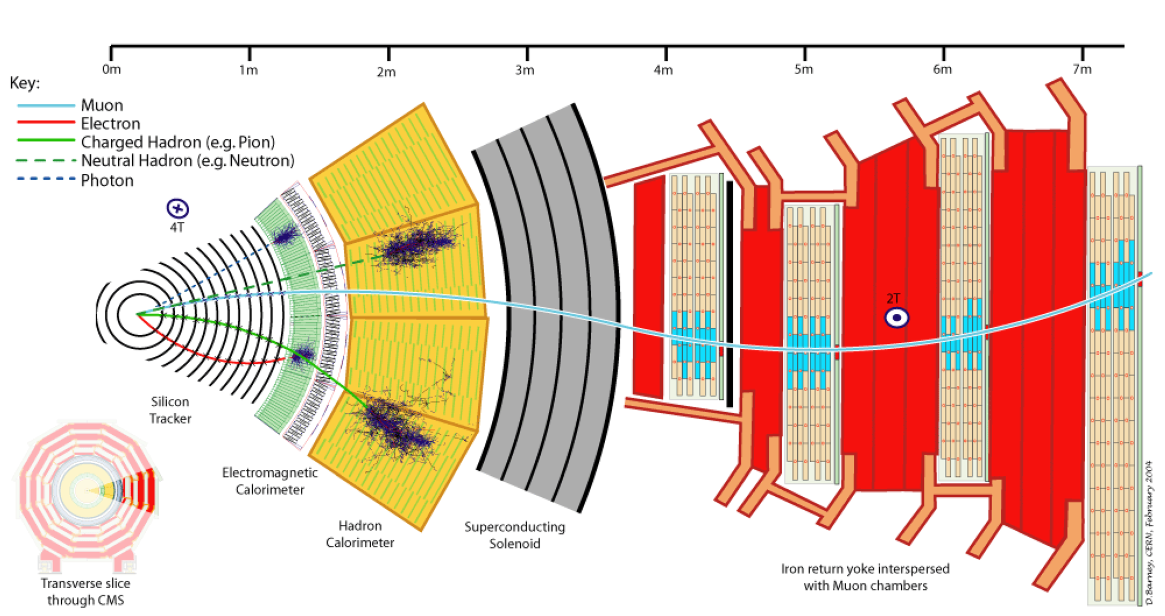

Figure 2: Transverse slice of the CMS detector.

Figure 3: Photos of CMS under construction.

Generator Simulation: $\tau\rightarrow\mu\gamma$

Initially the event $pp\rightarrow Z\rightarrow\tau\rightarrow\mu\gamma$ was simulated using the CMKIN software programme. Examining properties of the final state particles such as transverse momentum, energy, angular distribution and invariant mass it was determined that the best parameter for background-signal differentiation was the tau reconstructed mass.

In 1 year of LHC operation 100fb^{-1} of data will be generated. Using the expected LHC luminosity and relevant branching ratios [1] it was calculated that 1.08 million background events would be required to simulate 100fb^{-1}. The associated number of signal events at a branching ratio of 1.1×10^{-6} was 330.

All results applied the standard CMS trigger cuts of:

- a muon with transverse momentum greater than 25 GeV or
- a photon with transverse momentum greater than 35 GeV or
- a muon with transverse momentum greater than 5 and a photon with transverse momentum greater than 15.

A further cut of pseudorapidity less than 2.5 was also applied.

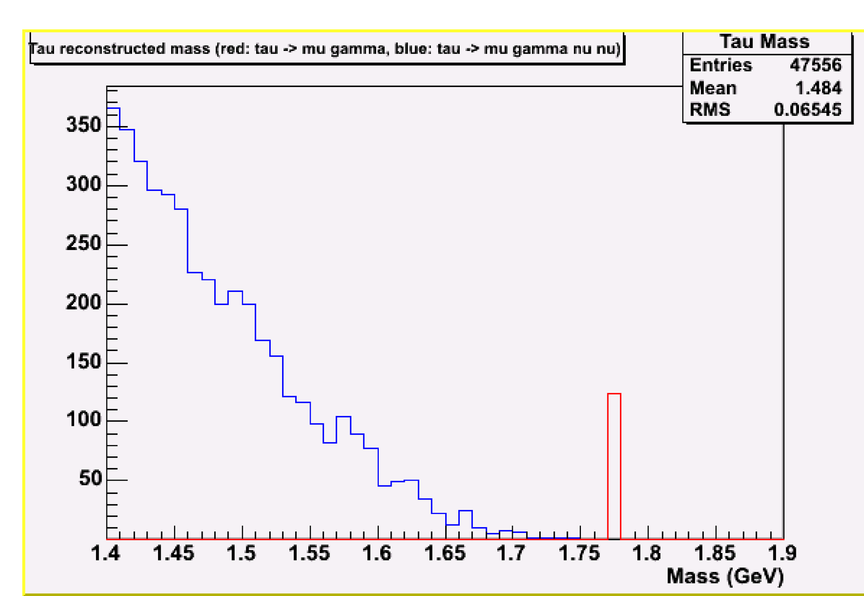

Figure 4: Generator level tau reconstructed mass with CMS trigger cuts showing background in blue and signal (scaled to 1.1×10^{-6}) in red.

Detector Simulation: $\tau\rightarrow\mu\gamma$

Using FAMOS, which provides a software simulation of CMS based on Monte-Carlo parameterisations of the detector response, the events from the generator simulation were analysed. A range of parameters of the final state particles were examined. Again only with the tau invariant mass could the signal be distinguished from the background.

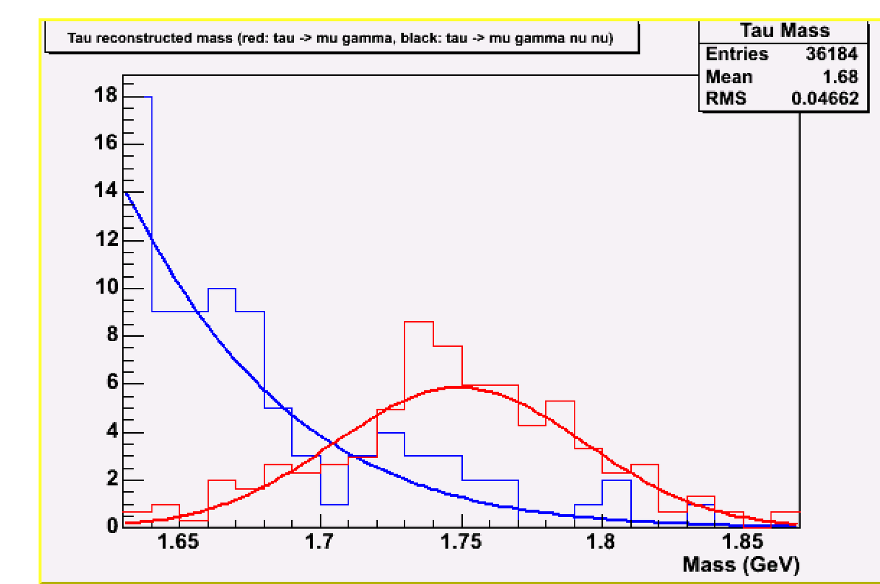

Figure 5: Detector level tau reconstructed mass with CMS trigger cuts showing background in blue and signal (scaled to 1.1×10-6) in red.

Analysis & Conclusion

An answer to the question "what limit can be placed on the branching ratio should no signal be seen?" was found by analysing the distribution of the signal and background events in Figure 5. The fluctuation of the signal from its gaussian fit was compared with that of the signal to give a certain number of events that would be required in order for the signal and the background to be differentiated at 90%CL. This was found to be 35. When the efficiency of the detector and the trigger cuts were calculated and taken into account this figure became 109. So the branching ratio of 109 events in 100fb^{-1} of tau decays is 3.63×10^{-7}. This is consistent (i.e. within an order of magnitude) with the limit of 3×10^{-7} at 90% CL calculated for $\tau\rightarrow\mu\gamma$ but with taus decayed from Ws [2] and a study of the same process at the ATLAS detector giving a limit of 6×10^{-7} at 90% CL [3].

The same process applied to the $\tau\rightarrow e\gamma$ decay did not yield a branching ratio that was better than the currently accepted value.

References

[1] T. Matsuura, Nucl Phys B **345** 331-368 (1990)

[2] Mazumdar K., 2004, CMS Conference Report: Lepton Flavour Violation at the LHC, CMS CR 2004/013

[3] Serin L. and Stroynowski R., 1997, Report No. ATL-PHYS-97-114