# Muon Identification and Combined Reconstruction Study in Higgs to Four Muons Physics Events with the ATLAS Detector at the LHC at CERN.

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**Abstract**

The decay physics channel $H \rightarrow ZZ^* \rightarrow \mu\mu\mu\mu$ ($mH^0$ = 130-180 GeV) provides a rather clean signature for the search of the Higgs boson at the LHC. A large amount of work has been done for the Physics TDR in order to understand the ATLAS capability to look for the Higgs in this mass window. However, this physics analysis was necessary to be done to understand the signal reconstruction using the new object-oriented muon identification and combined reconstruction procedure (MUID) in the ATLAS ATHENA framework: using the combined information from the inner detector, the muon spectrometer and the calorimeter. Also the purpose of this study was to investigate with the full detector simulation the reducible background rejections with the aim to reduce the ttbar and Zbbar backgrounds below the irreducible one ($ZZ^*/\gamma^*$). To achieve such a goal, it was necessary to use the isolation and the impact parameter criteria. This work for ATLAS reports the recent muon combined SM Higgs signal reconstruction progress and the achievable reducible background rejections.

## Reconstructed Signal and Background Samples

The signal samples, $H \rightarrow ZZ^* \rightarrow 4\mu$, for $m_H$ = 130, 150, 180 GeV have been reconstructed (10 K) into ATHENA with RecExCommon - MUID with ATLAS Software Physics Release 7.0.2. These events (50 K) were generated for the ATLAS Data Challenge 1 with Release 5.3.0 and afterwards fully simulated with Atlsim 6.0.2.

The background samples (10 K) Zbbbar$\rightarrow 4\mu$, (20 K) ttbar$\rightarrow$WbWbbar$\rightarrow 4\mu$ were also reconstructed with same procedure used for signal samples.

The full reconstruction chain has been executed, namely: the reconstruction in the Muon Spectrometer alone (MOORE), the extrapolation to the vertex of the track found in the Muon Spectrometer (MUID StandAlone), the reconstruction in the Inner Detector (iPatRec) and the combination of the track found in the Muon Spectrometer and in the Inner Detector (MUID Combined).

## First stage of event selection

***Table I.*** *For $H \rightarrow ZZ^* \rightarrow 4\mu$ final* states, mass window, $m_{12}$, used *around the Z mass and threshold $m_{34}$ applied to the mass of the other lepton pair, together with the acceptance of the kinematic cuts as a function of $m_H$. The staistical error on the acceptance is ±0.003.*

| Higgs mass (GeV) | 130 | 150 | 180 |
|---|---|---|---|
| $m_{12}$ window (GeV) | ±15 | ±10 | ±6 |
| $m_{34}$ threshold (GeV) | 20 | 30 | 60 |
| Acceptance of kinematic cuts | 0.335 | 0.415 | 0.535 |

## Signal reconstruction

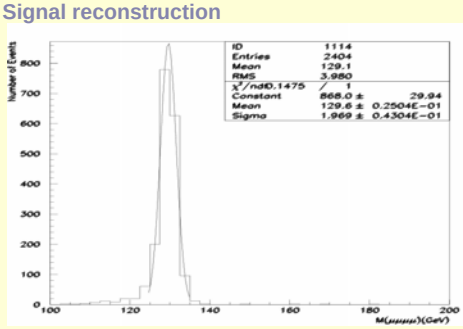


***Figure 1*** *The corresponding MUID Combined reconstructed four muon mass for the 130 GeV Higgs decays and Z-mass constraint.*

***Table 2*** *Mass resolutions of the four muons from $H \rightarrow ZZ^* \rightarrow 4\mu$ decays as a function of $m_H$ without and with a Z mass constraint application. The mass resolutions are obtained from full simulation and MUID Combined reconstruction for the events passing the standard kinematic cuts.*

| Higgs mass (GeV) | 130 | 150 | 180 |
|---|---|---|---|
| σ (4μ) (GeV) without Z | 2.61±0.04 | 2.75±0.05 | 3.28±0.17 |
| σ (4μ) (GeV) with Z | 1.97±0.04 | 2.18±0.05 | 2.67±0.16 |

## Background rejections

### Tracker isolation

***Table 3*** *Background rejection using the tracker isolation cuts*

| Signal efficiency, $m_H$=130 GeV | Rejection Zbbbar | Rejection ttbar |
|---|---|---|
| 90% | 20±0.2 | 29±0.1 |
| *Physics TDR* | *32±8* | *110±20* |

### Impact parameter

***Table 4*** *Background rejections using the impact parameter cuts*

| Signal efficiency, $m_H$=130 GeV | Rejection Zbbbar | Rejection ttbar |
|---|---|---|
| 90% | 3±0.2 | 3±0.2 |
| *Physics TDR* | *5.5±0.6* | *12.5±1.1* |

### Combined rejection of reducible backgrounds with MUID

***Table 5*** *Combined overall rejection (using both tracker isolation and impact parameter cuts) against the ttbar and Zbbbar reducible backgrounds and efficiency for the signal $H \rightarrow ZZ^* \rightarrow 4\mu$ with $m_H$=130 GeV.*

| Signal efficiency, $m_H$=130 GeV | Overall Rejection Zbbbar | Overall Rejection ttbar |
|---|---|---|
| 81% | 119±38 | 124±43 |
| *Physics TDR* | *105±50* | *1200±350* |

## Conclusions

A large amount of work has been done to understand the reconstruction methods for the $H \rightarrow ZZ^* \rightarrow 4\mu$ using the MUID/MOORE Muon Combined Reconstruction package.

For $H \rightarrow ZZ^* \rightarrow 4\mu$ ($m_H$= 130 GeV) the obtainable resolution using the MUID Combined is σ = 1.97 GeV.

The capability to reject the reducible ttbar and Zbbbar backgrounds has been investigated with this reconstruction software after full simulation.

The tracking isolation appears to be more powerful than the impact parameter. A rejection of 20 is found for the Zbbbar and 29 for the ttbar for a signal efficiency of 90% at low luminosity.

The impact parameter is still necessary to complete these rejections. It reduces the ttbar and Zbbar backgrounds by a factor of 3.

The combined rejections after the complete simulation, are sufficient to reduce the ttbar and Zbbbar backgrounds well bellow the $ZZ^*/\gamma^*$ continuum irreducible background, giving large safety margins on the Higgs to four muons discovery.