Study of a L1 topological trigger to select radiative Z decay in the ATLAS detector

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LHC RUN 2

- Larger luminosity and higher energy (up to $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$, $\sqrt{s} = 14 \text{ TeV}$)
- Increased pile-up (up to 50-60 interactions/bunch crossing)
- Immense QCD background
- Necessity to reduce the rate, especially at the hardware-based Level-1 trigger.

Idea

Include a selection in the L1 topological trigger to select radiative Z decays in the electron channel

Radiative Z decay are used to study photon trigger and identification efficiencies.
ATLAS detector and trigger system

ATLAS is a multi-purpose detector

Electrons and photons are reconstructed by combining information from the **electromagnetic calorimeter** and the inner tracking detectors.

The trigger system is composed of a hardware-based L1 and a software-based high-level trigger

In Run 2 it will be possible to require additional constraints at L1 (e.g. Invariant mass).

↓

**L1 Topological Trigger**
Run 1: 20 Mhz L1 input/65 kHz L1 output, 8 TeV, lumi $0.7 \times 10^{34}$ cm$^{-2}$s$^{-1}$
Run 2: 40 Mhz L1 input/100 kHz L1 output, 14 TeV, lumi $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
Z invariant mass: Offline and L1

- The samples used for the signal were MC $Z \rightarrow ee\gamma$.

- For the signal we selected offline $e^-$, $e^+$ and $\gamma$, that satisfied the standard quality criteria of the ATLAS collaboration.

  Only $Z \rightarrow ee\gamma$ events detected by the offline within a minimal mass window (70,100) GeV, where considered.

- The match between L1 clusters and the Offline objects was done finding the closest cluster (to each object) and considering $\Delta R < 0.15$, with:

\[
\Delta R = \sqrt{\Delta \eta^2 + \Delta \phi^2}
\]
Z invariant mass: L1 cuts

- We perform different cuts on the invariant mass of the Z, calculated using the L1 Calo clusters.

- We open the window around the peak and save the number of entries as a function of the window size from ±1 to ±80 GeV.

- We calculate the efficiency as

$$Eff = \frac{\# \text{ of entries}^{after\ cut}}{\# \text{ of entries}^{total}}$$
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\[
\text{L1 Invariant Mass (e^+ e^- \gamma)}
\]

\[
\begin{array}{c}
\text{Entries} \\
\text{Mean} \\
\text{RMS}
\end{array}
\]

\[
\begin{array}{c}
1713 \\
81.03 \\
10.69
\end{array}
\]

\[
\begin{array}{c}
\text{Mass (GeV)} \\
\text{Entries per GeV}
\end{array}
\]

\[
\begin{array}{c}
40 \\
50 \\
60 \\
70 \\
80 \\
90 \\
100 \\
110 \\
120
\end{array}
\]

\[
\begin{array}{c}
0 \\
20 \\
40 \\
60 \\
80 \\
100
\end{array}
\]

\[
\begin{array}{c}
\gamma - e^+ e^- +\text{L1 Invariant Mass (e}}
\end{array}
\]

<table>
<thead>
<tr>
<th>Opening (GeV)</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>10</td>
<td>0.4</td>
</tr>
<tr>
<td>20</td>
<td>0.6</td>
</tr>
<tr>
<td>30</td>
<td>0.8</td>
</tr>
<tr>
<td>40</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[
94\%
\]
Already the 3 object requirement with $p_T > 7$ GeV leads to a background reduction of 97%.

We then perform the same $Z$ mass window selection at L1 as described for the signal, to the background.

The background efficiency as a function of the window size shows a significant further reduction.
Comparison of the signal efficiency and the background efficiency.

Aim to get a high signal and a low background efficiency.

A possible choice leads to $\sim 94\%$ signal efficiency with a background efficiency of 0.75%.

**Signal Efficiency vs Background Efficiency**

94% S.E.

0.75% B.E.

$\pm$ 20 GeV window
Summary

We studied a possible L1 topological trigger selection for radiative Z decay in the electron channel

- Requiring 3 L1 calo objects with $p_T > 7$ GeV leads to a background reduction of 97%.
- Applying an additional Z invariant mass selection of $\pm 20$ GeV around the peak, we found a signal efficiency of $\sim 94\%$ with a background efficiency of 0.75%.

Next step:
- Estimate additional signal efficiency and trigger rate due to this new selection w.r.t. existing triggers.