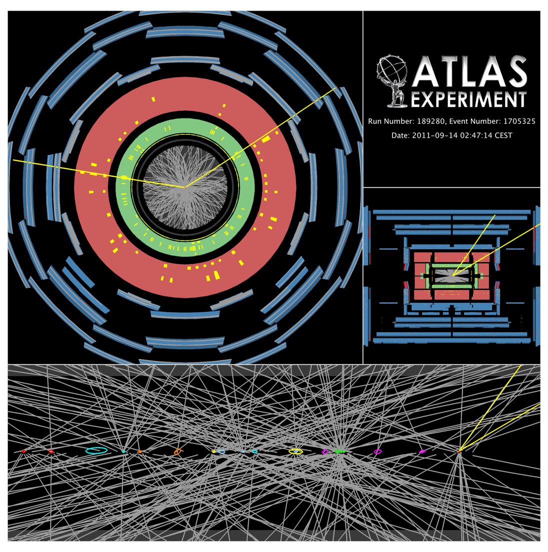
HCP Poster Session – Paris, 17 November 2011

Pile-up effects on muon isolation variables in 2011 data @ ATLAS

Event display: Z dimuon decay in a 20 vertices event



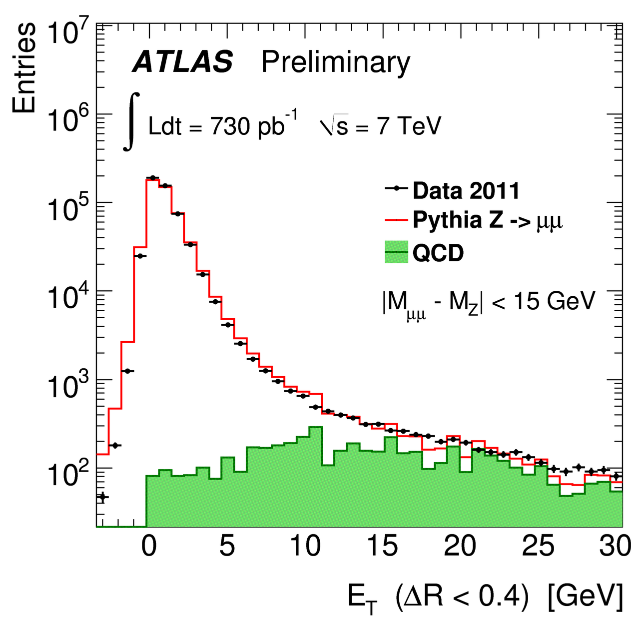
Introduction: pile-up and muon isolation @ ATLAS

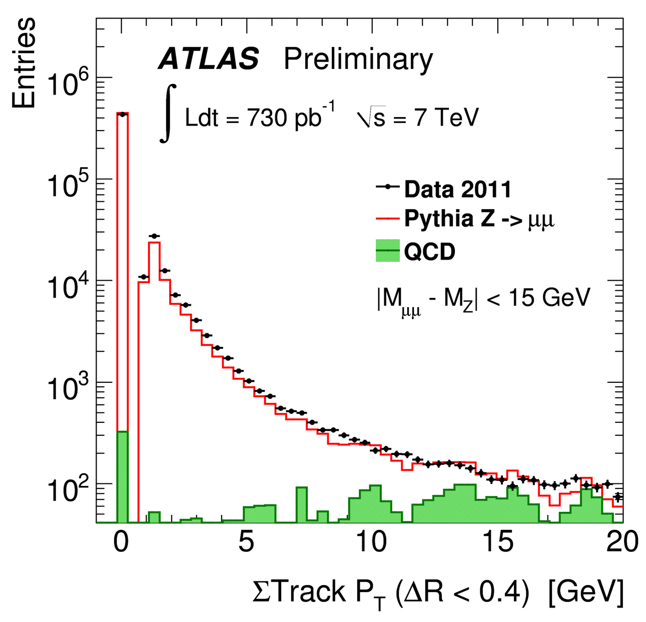
The LHC has recently switched to 50 ns bunch spacing collisions, with of the order of 1300 bunches circulating in the collider, giving a total of ~10^{14} protons. In the current configuration a mean value of 14 interaction per bunch crossing is expected (in data analyzed in this study was 7), furthermore the bunches are so near in time that pile-up of signal originated from different bunches is possible, especially for calorimeter signals.

A common signature of interesting physics are well isolated muons, the ATLAS Muon Combined performance group has developed two independent variable to tag this kind of muons, a calorimeter based isolation variable and a tracking based isolation variable. Those isolation quantity are influenced by pile-up because of energy deposit of particle from secondary interactions (in time pile-up), or of pile-up signals from different bunches (out of time pile-up). The influence of pile-up on muon isolation variable has been studied and compared to Monte Carlo prediction in case of highly isolated muon.

Z dimuon selected sample:
Selections according to the Z dimuon decay signature has been applied to data and simulation. Two high quality muon object, provided from the ATLAS reconstruction software, are required, those muons should have: transverse momentum greater than 20 GeV, opposite charge and $|M_{\mu\mu} – M_Z| < 15$ GeV.
This study is based on a 2011 data sample corresponding to 730 pb^{-1} of integrated luminosity. Simulation of Z dimuon decay event generated by Pythia are used as a signal and as a background $b\bar{b}$, $c\bar{c}$, and $t\bar{t}$ samples are used.

Muon Isolation variables





Muon isolation variables are used to calculate the energy surrounding the muon along its trajectory released from other particles. Those variables are useful for distinguishing muons from hadron decays and muons from decays of resonances. In ATLAS there are two independent approaches, a calorimeter based and a tracking based method, both define a cone around the muon trajectory in which the energy deposit is calculated. Different cone size are available, respectively $\Delta R < 0.4$, 0.3 and 0.2

Calorimeter based muon isolation variable
This represent the sum of the calorimeter cluster energy in a cone around the muon trajectory of the sizes defined above ($E_{T\,\Delta R<0.X}$). A narrow core cone is subtracted to take into account the muon energy deposit. Only calorimeter signals 3.6 σ above noise are considered.

Track based muon isolation variable
This is the sum of the transverse momenta (P_T) of all the tracks in a cone around the muon trajectory ($P_{T\,\Delta R<0.X}$). Tracks are required to have a small impact parameter with respect to the primary vertex and $P_T > 1$ GeV. The first cuts reduces enormously contributions from pile-up vertices tracks.

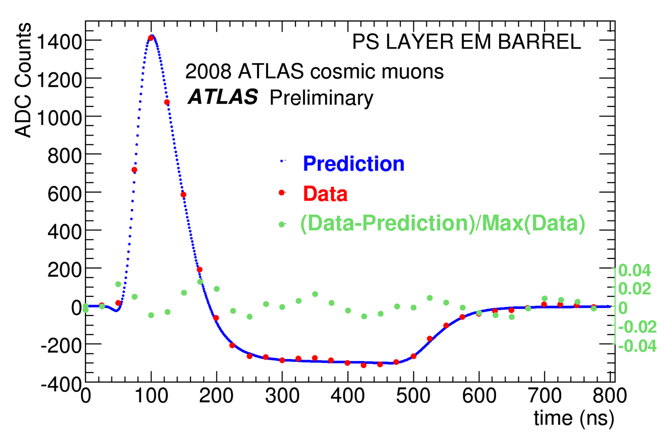
Definitions:
$\Delta R = \sqrt{\Delta\varphi^2 + \Delta\eta^2}$

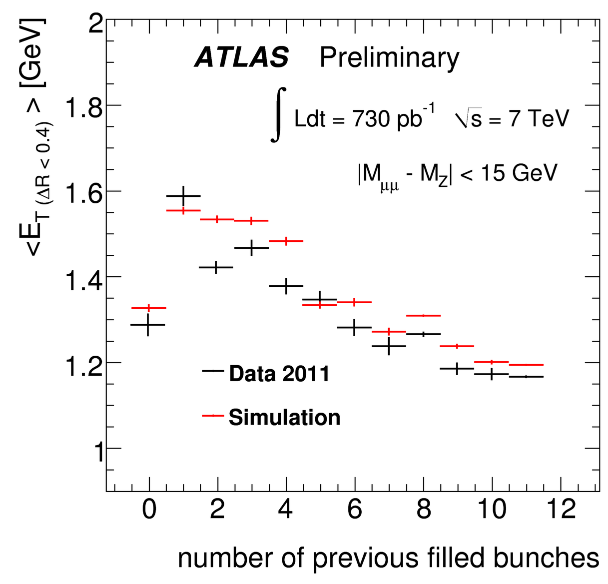
Plots: muon isolation variables distributions
Represent the muon calorimeter isolation energy (top) and the track isolation energy (bottom) distribution in a cone of $\Delta R < 0.4$, for Z dimuon decay selected sample. Data - Monte Carlo agreement is good, but a small offset is visible in the distributions.

Out of time pile-up influence

Out of time pile-up:
This is due to the superimposition of signals in the detector that come from different bunch crossings (collisions). The most important example is pile-up of calorimeter signals. The left plot represent a typical calorimeter signal (for muons), this is 600 ns wide and has a long negative tail. At the moment in 600 ns LHC provides 12 collision, so signals can add up starting from negative baseline.

Typical calorimeter signal for a muon.

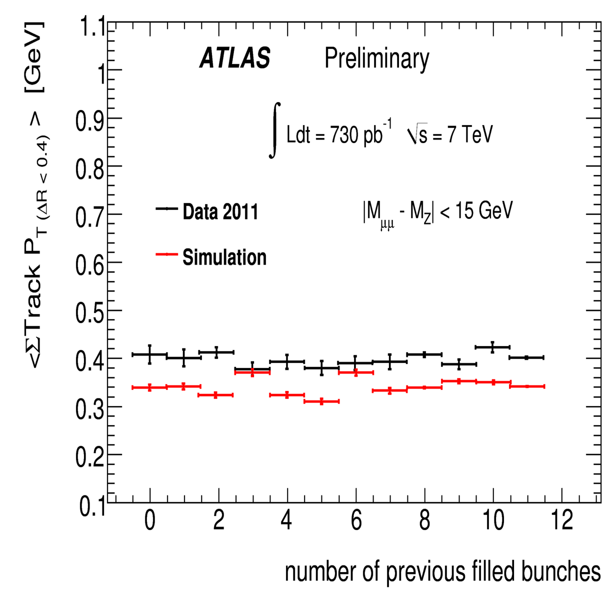




Right plots:
Those plots represent the mean value of the $E_{T\,\Delta R<0.4}$ (top plot) and $P_{T\,\Delta R<0.4}$ (bottom plot) distributions versus the number of previous filled bunches, the latter taken with respect to the bunch analysed.

Plots compare data in black and simulation in red. Simulation contains $Z\rightarrow\mu\mu$ decays plus QCD backgrounds.

As expected calorimeter isolation variable present an evident dependence with respect to the number of previous filled bunches, so on out of time pile-up. Previous bunches contribute to lower the mean energy in a cone around the muon. The track isolation variable is independent of out-of-time pile-up. Monte Carlo description of out of time pile-up influence seems reasonably modelled.

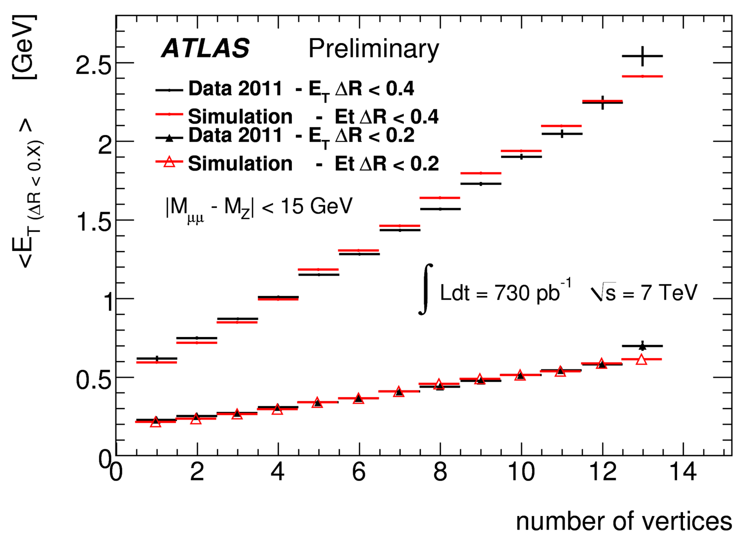


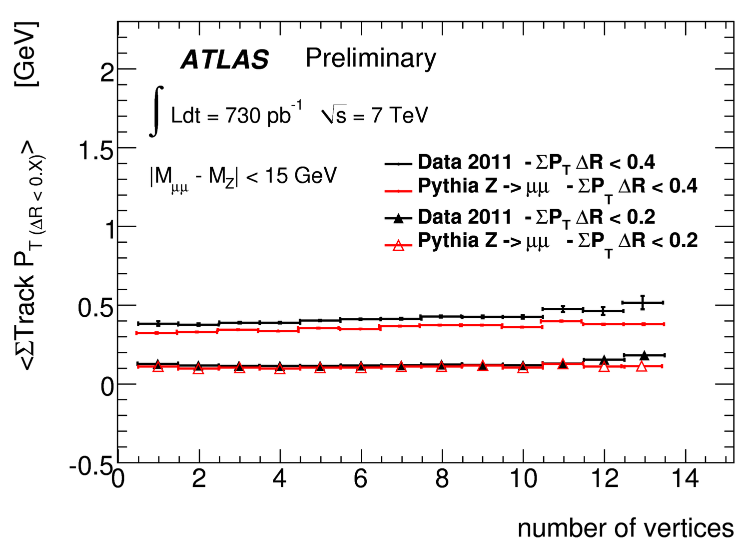
In time pile-up influence

In time pile-up:
Particles emerging from "secondary" vertices constitutes pile-up signals to the interesting event within the same bunch crossing. All the tracks, the energy deposit in the calorimeter of those particle is a source of in time pile-up. A direct measure of the in time pile-up contribution to the event is the number of reconstructed vertices in the event (all the vertices with at least two tracks).

Plots:
Plots on the right represent the mean value of calorimeter isolation variable (top) and tracking isolation variable (bottom) as a function of the number of vertices in the event. Data and simulation are compared, for simulation is intended Z dimuon decay plus QCD background. Different cone size are compared. A cut on isolation variables at 20 GeV is applied to avoid data-MC disagreement in the tail of the distributions.

Calorimeter Isolation variable is clearly dependent on pile-up, while tracking isolation variable present a little dependency, this is mainly due to the impact parameter cut.

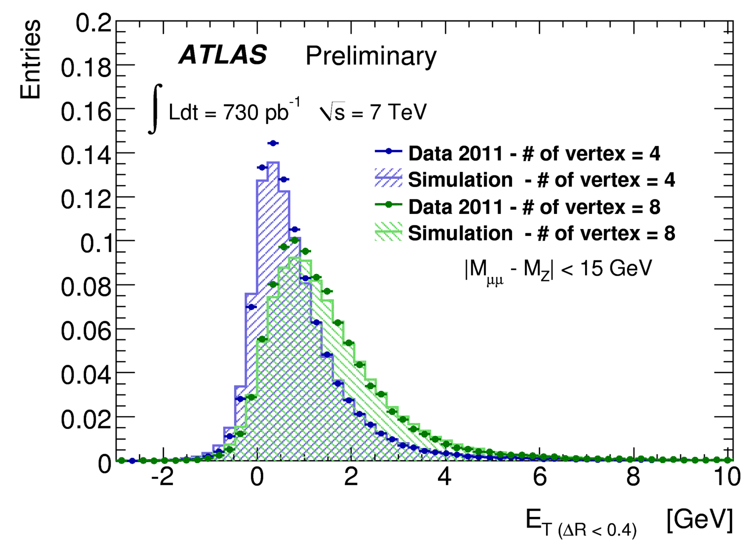


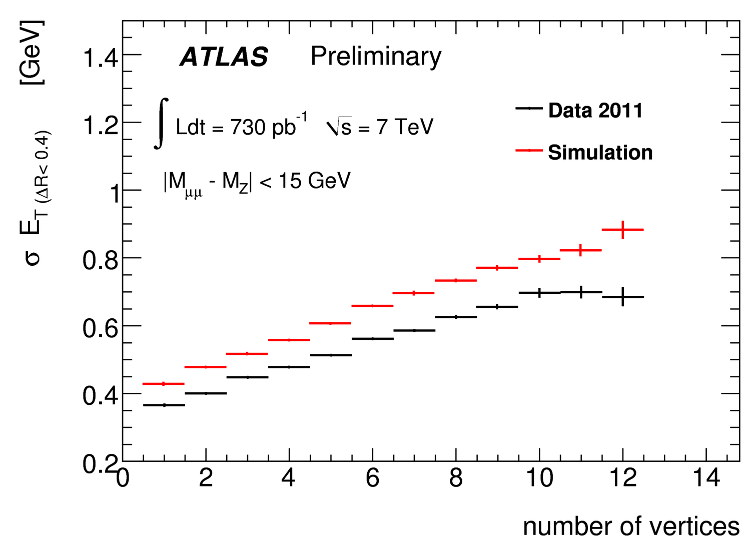


Fit procedure:
Let's concentrate here on calorimeter isolation variable. To describe better data and MC dependence on pile-up of calorimeter isolation variable avoiding problem of tail behaviors, the $E_{T\,\Delta R<0.4}$ distribution has been fitted with a CrystalBall function.

Plots:
The right top plot is an example of $E_{T\,\Delta R<0.4}$ distributions for different number of vertices in the event, data and simulation are compared. Distribution are normalized to the same area.
The bottom plot represent instead the σ of the CrystalBall as a function of the number of vertices.

Data-Monte Carlo agreement:
As you can see from those for plots here, there is an overall good data-MC agreement in describing pile-up dependency of those isolation variable and this is particularly true for smaller cone size. However for track isolation variable there is an offset in the description of the distribution; for calorimeter isolation variable there is a small difference in the width of the distribution, MC distributions tend to be broader.





Conclusion

Out of time small pile-up has a smaller effect on isolation variable than in time pile-up, in fact the difference here is made by few bunches that occupy the front of the train. Track Isolation is present a weak pile-up dependency, calorimeter isolation variable are much more influenced instead. Simulation describes quite well the in time and the out of time dependency influence on isolation variable, however small deviation in reproducing the distribution are observed.

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ATLAS EXPERIMENT