Determination of $\sigma(pp \to Z/\gamma* \to \mu^+\mu^-)$ and Muon Performance

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For precise measurements of $Z/\gamma* \to \mu^+\mu^-$ events a good understanding of the muon performance of the ATLAS detector is needed. Especially the momentum resolution and efficiency have to be determined from real data.

The measured transverse momentum of the muon tracks depends (relative to the true muon p_T) on an overall momentum scale s and a resolution width σ

$$p_T \to s \cdot f(p_T, \sigma), \quad (1)$$

where f is a function which smears $1/p_T$ randomly (e.g. by a Gaussian) with a certain width σ. The impact of the precision of the p_T measurement for single muons on the reconstructed Z boson mass is used for the determination of s and σ. Larger values of σ will lead to a broader reconstructed width of the Z boson, while s affects the value of the reconstructed maximum. The basic idea is to vary the parameters s and σ to reproduce the measured Z boson mass distribution.

By comparing the reconstructed p_T with the true p_T in Monte Carlo events the real resolution can be determined. In Fig. 1 this true resolution is compared to the results of the method described earlier for the standalone Muon Spectrometer for three different η bins. The difference is treated as systematic uncertainty. The overall p_T-resolution is expected to be determined from $50\,pb^{-1}$ to a *relative* precision [1]

$$\frac{\Delta s}{s} \approx \pm 0.001(stat) \pm 0.003(sys),$$

$$\frac{\Delta\sigma}{\sigma} \approx \pm 0.02(stat) \pm 0.04(sys).$$

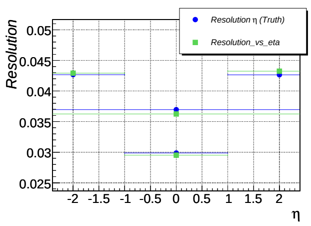

Fig. 1: Comparison of p_T-resolution determined via Monte-Carlo-Truth and the Monte-Carlo based in-situ approach for combined track reconstruction vs. η.

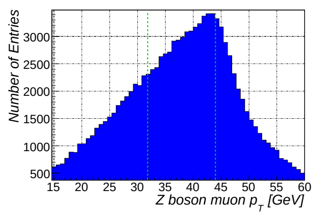

Fig. 2: Monte Carlo truth p_T distribution of muons originating from a Z boson.

The "Tag and Probe" method is one possible way to determine muon spectrometer efficiencies, with data. We require two tracks in the ATLAS Inner Tracker, of which at least one has an associated track in the Muon Spectrometer and an invariant mass of the two muons which is close to the mass of the Z boson. The inner track which could be associated to the track in the Muon Spectrometer is called the "tag" muon. Since $Z \to \mu\mu$ events always have two muons, the second track then should also be a muon and is therefore called "probe muon". Now one can search in the Muon Spectrometer for a reconstructed muon close to the "probe muon" to determine the efficiency of muon reconstruction.

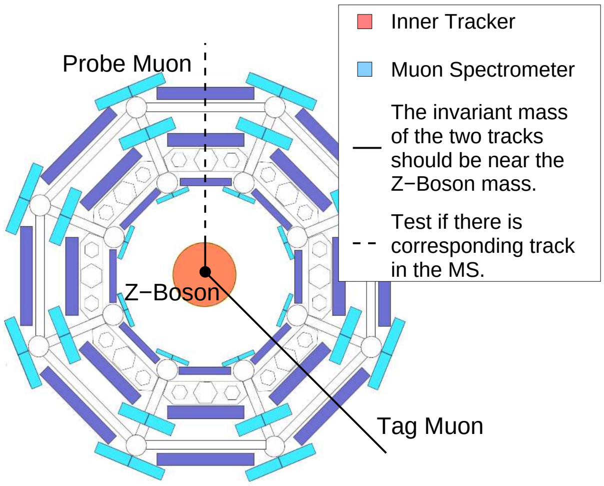

Fig. 3: Schematic Illustration of the "tag and probe" method

Overall, we expect to determine the Muon Spectrometer reconstruction efficiency ϵ_{MS} with $50pb^{-1}$ to a precision [1]

$$\Delta\epsilon_{MS} \approx \pm 0.001(stat) \pm 0.003(sys).$$

With a good understanding of the performance of the muon spectrometer the cross-section of $pp \to Z/\gamma* \to \mu^+\mu^-$ can be determined with $50\,pb^{-1}$ to a relative precision [1]

$$\frac{\Delta\sigma}{\sigma} \approx 0.006(\text{stat}) \pm 0.008(\text{sys}) \,{}^{+0.016}_{-0.008}(\text{pdf}) + \text{Lum. Uncertainty.}$$

The background uncertainty is included in the systematic errors, and effects like trigger efficiencies, misalignment and PDF contributions have been studied and included in the systematic errors.

As shown in Fig. 2 the statistics for muons from Z Bosons drops fast above 50 GeV but many new physics processes rely on muons of much higher transverse momenta, some up to a TeV. For such high energetic muons, new methods have to be developed, or the existing ones have to be adapted. The Tag & Probe method uses the high signal cross-section at the Z-Peak to suppress background contributions by requiring a dimuon mass close to the mass of the Z Boson. For high energetic muons this cut is no longer feasible, so much harder cuts on isolation and kinematics have to be implemented to reduce the $W \to \mu\nu$, $t\bar{t}$ and $b\bar{b}$ background.

References

[1] Study of the Z Boson Production at the ATLAS Experiment with First Data, L, Ph.D. thesis, M. Schott2007