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Muon Pair Production in ep Collisions at HERA

H1 Collaboration

Abstract

Events containing pairs of isolated muons at high invariant masses have been detected at HERA with the H1 detector in a sample corresponding to an integrated luminosity of 70.9 pb^{-1}. The results are compared to Standard Model predictions which are dominated by photon-photon collision.

The data have been collected with the H1 detector at HERA and correspond to an integrated luminosity of 70.9 pb^{-1} of $e^{\pm}p$ scattering at $\sqrt{s} = 318$ GeV.
The muon selection is based on central tracker and muon detector measurements. Muon candidates are selected from charged tracks measured in the central tracker at polar angles between 20° and 160°, which are linked to tracks measured in the muon detector. The finding efficiency for low momentum muons is improved by identifying minimal ionising particles in the Liquid Argon Calorimeter which are linked to an inner track. The momentum and charge measurement is based on central tracker information. One of the muon candidates must have a transverse momentum greater than 2.0 GeV, while for the second muon a minimal transverse momentum of 1.75 GeV is required.
For the final data sample isolated muons are required, i.e. their distance $D_{Track,Jet}$ in the pseudorapidity-azimuthal-plane from other tracks or jets is greater than 1.0. Events with at least two muon candidates with an invariant mass above 5 GeV are selected. Cosmic Background is suppressed by a cut on the opening angle $\alpha < 165$ of the two muons.

The data is compared to a Standard Model prediction. The two photon process $\gamma\gamma \longrightarrow \mu\mu$ forms the major part of the cross section. To Monte Carlo Generators are used to simulated this process: GRAPE [1] and LPAIR [2, 3]. GRAPE uses the automatic calculation program 'GRACE' [4] to determine the feynman amplitudes of the corresponding diagrams. GRAPE allows to simulate the two boson muon production processes $\gamma\gamma$, γZ^0 and Z^0Z^0 as well as the QED Compton type process $\gamma \longrightarrow \mu\mu$ and $Z^0 \longrightarrow \mu\mu$. It allows to include initial and final state radiation. The plots show the total standard model prediction which is determined using GRAPE, the contribution of the $\gamma\gamma$ process determined with LPAIR. Other sources of muon production have been simulated using DIFFVM [5] for the Υ-resonance, LPAIR for muons arising from $\gamma\gamma \longrightarrow \tau\tau$ and AROMA [6] for open heavy flavour quark production ($c\bar{c}$ and $b\bar{b}$).

The total cross section for di-muon production was found to be (46.5 $\pm$1.3 $\pm$ 4.7) pb, for inelastic di-muon production a total cross section of (20.8 $\pm$0.9 $\pm$ 3.3) pb was measured.

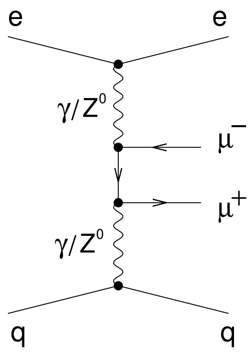

Figure 1: Example of a feynman diagram for $\gamma\gamma \longrightarrow \mu\mu$.

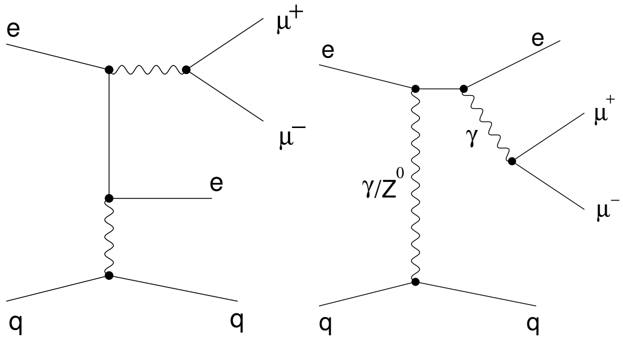

Figure 2: Example of a feynman diagrams for $\gamma \longrightarrow \mu\mu$.

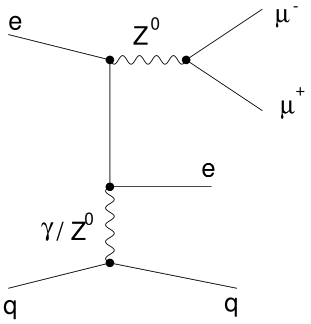

Figure 3: Example of a feynman diagram for Z^0-production.

References

[1] T. Abe, Comput. Phys. Commun. **136** (2001) 126 [hep-ph/0012029].

[2] S. P. Baranov, O. Dünger, H. Shooshtari and J. A. Vermaseren, *In *Hamburg 1991, Proceedings, Physics at HERA, vol. 3* 1478-1482. (see HIGH ENERGY PHYSICS INDEX 30 (1992) No. 12988)*

[3] J. A. Vermaseren, Nucl. Phys. B **229** (1983) 347.

[4] T. Ishikawa, T. Kaneko, K. Kato, S. Kawabata, Y. Shimizu and H. Tanaka [MINAMI-TATEYA group Collaboration], KEK-92-19.

[5] B. List, diploma thesis Technische Univerist"at Berlin, H1-internal note (H1-10/93-319) (1993).

[6] G. Ingelman, J. Rathsman and G. A. Schuler, *AROMA 2.2 - A Monte Carlo Generator for Heavy Flavour Events in ep Collisions*, Comput. Phys. Commun. **101** (1997) 135 [hep-ph/9605285].

σ_{tot}	$(46.5 \pm 1.3 \pm 4.7)$ pb
σ_{tot}^{inel}	$(20.8 \pm 0.9 \pm 3.3)$ pb

Table 1: Total cross sections for di-muon pair production and the total cross section for inelastic di-muon production.

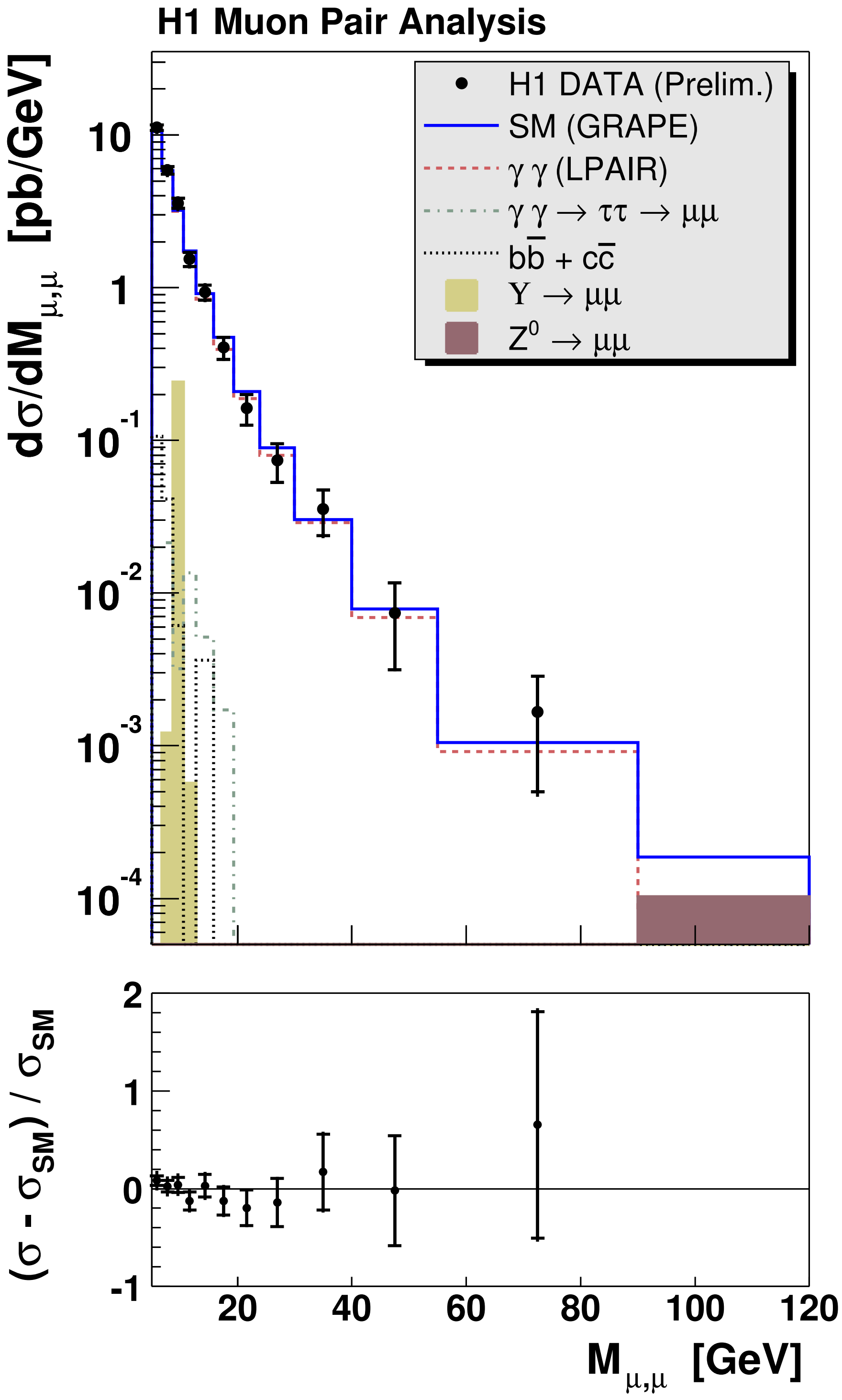

Figure 4: Invariant mass of di-muons in comparison to the SM prediction using GRAPE, the $\gamma\gamma \to \mu\mu$ contribution using LPAIR as well as contributions from $\gamma\gamma \longrightarrow \tau\tau$, $c\bar{c}$ and $b\bar{b}$, Υ and Z^0 decays. Also shown is the relative difference between data and all Standard Model contributions (lower figure).

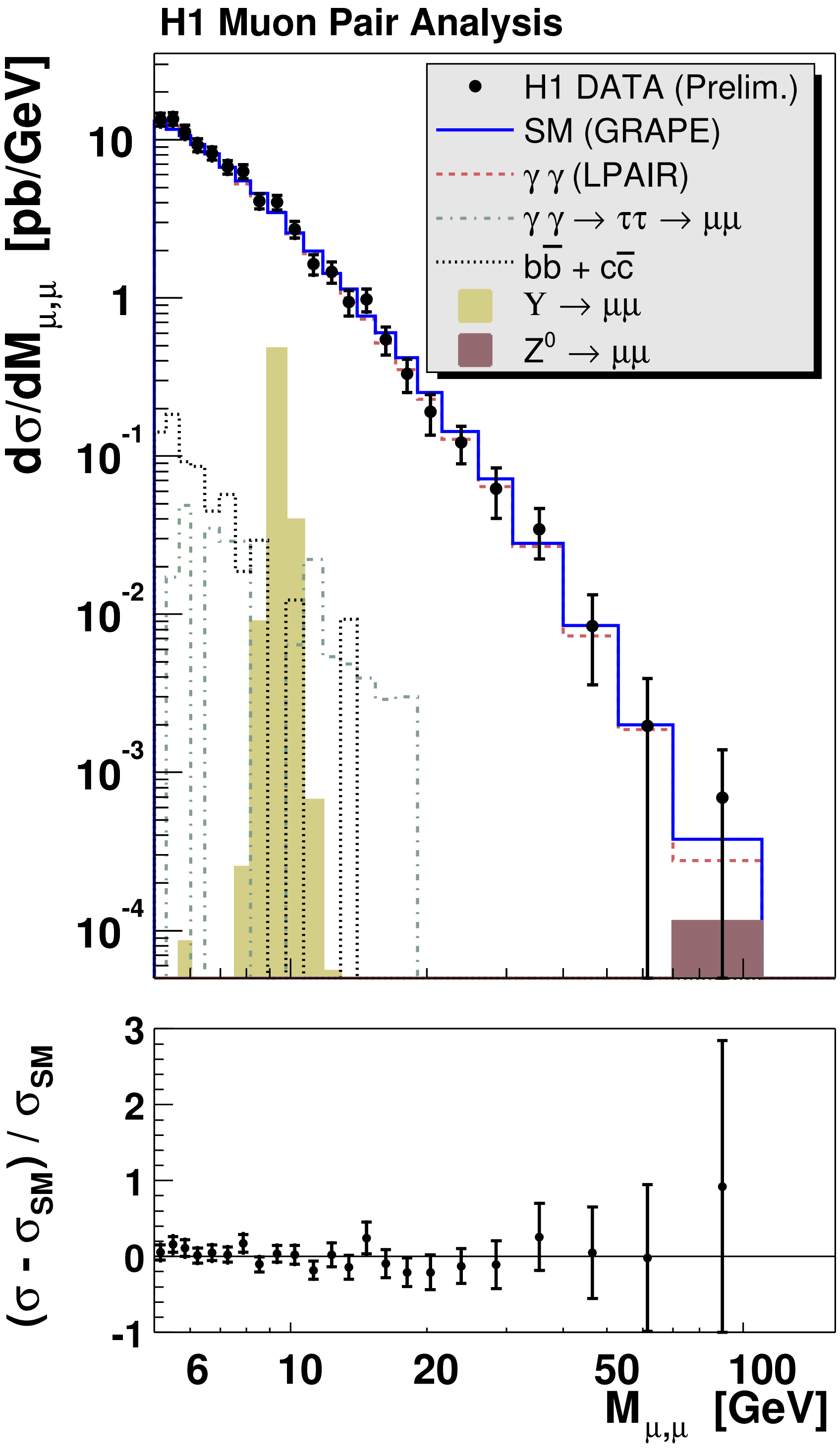

Figure 5: Invariant mass of di-muons (fine binning, logarithmic y axis). For details see figure 4.

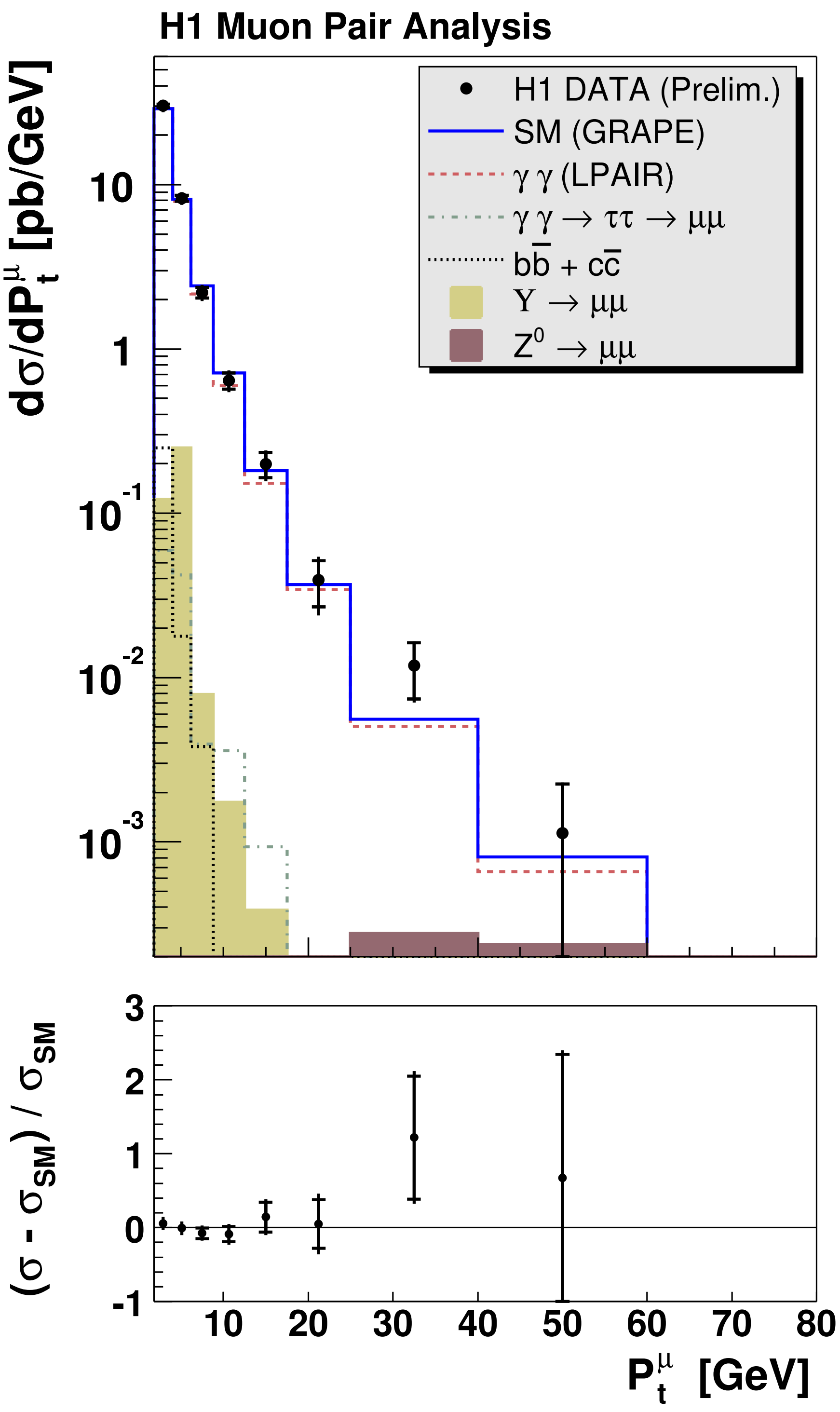

Figure 6: Transverse Momentum of the muons. For details see first figure.

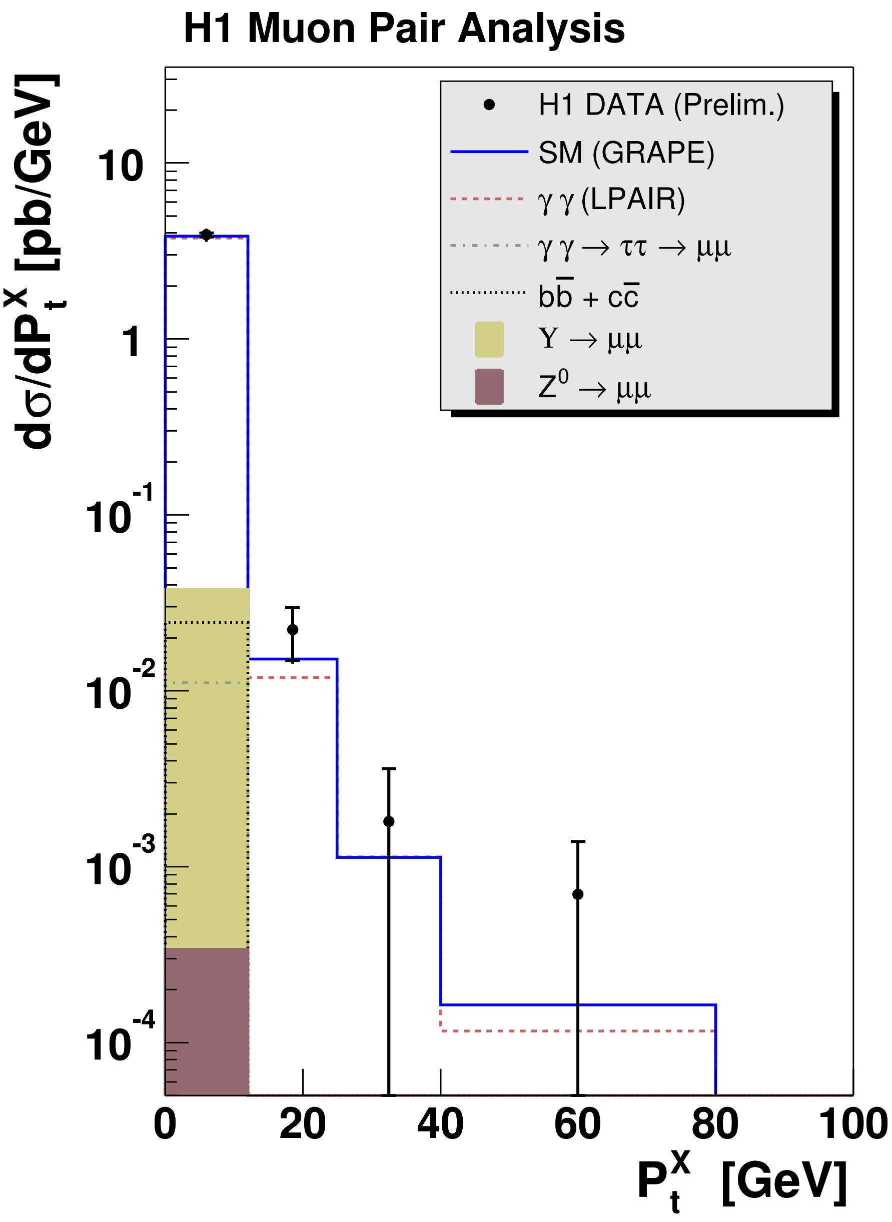

Figure 7: Hadronic transverse momentum distribution in di-muon events. For details see figure 4.

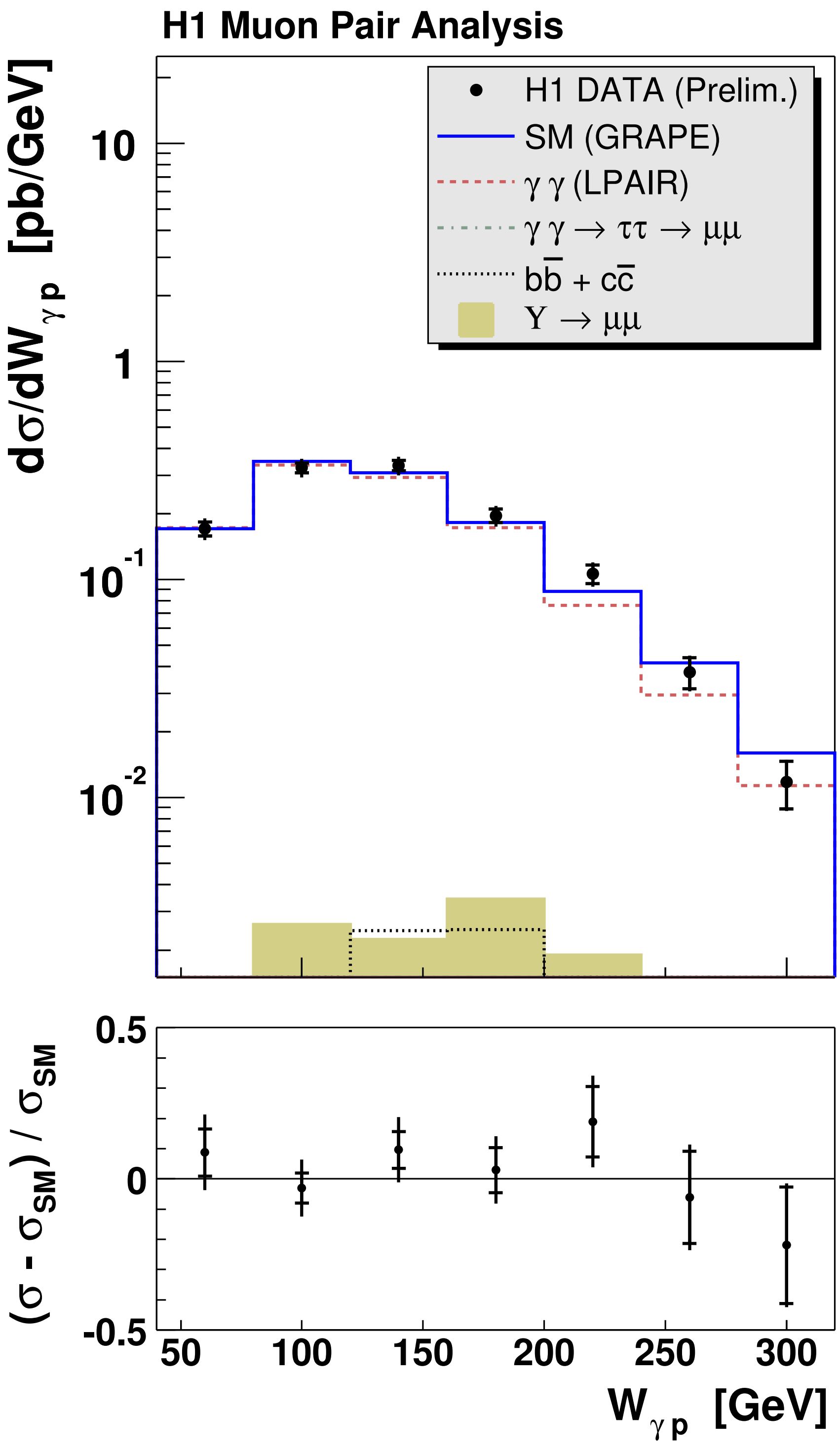

Figure 8: Invariant mass of the γ-proton system for di-muon events. For details see figure 4.

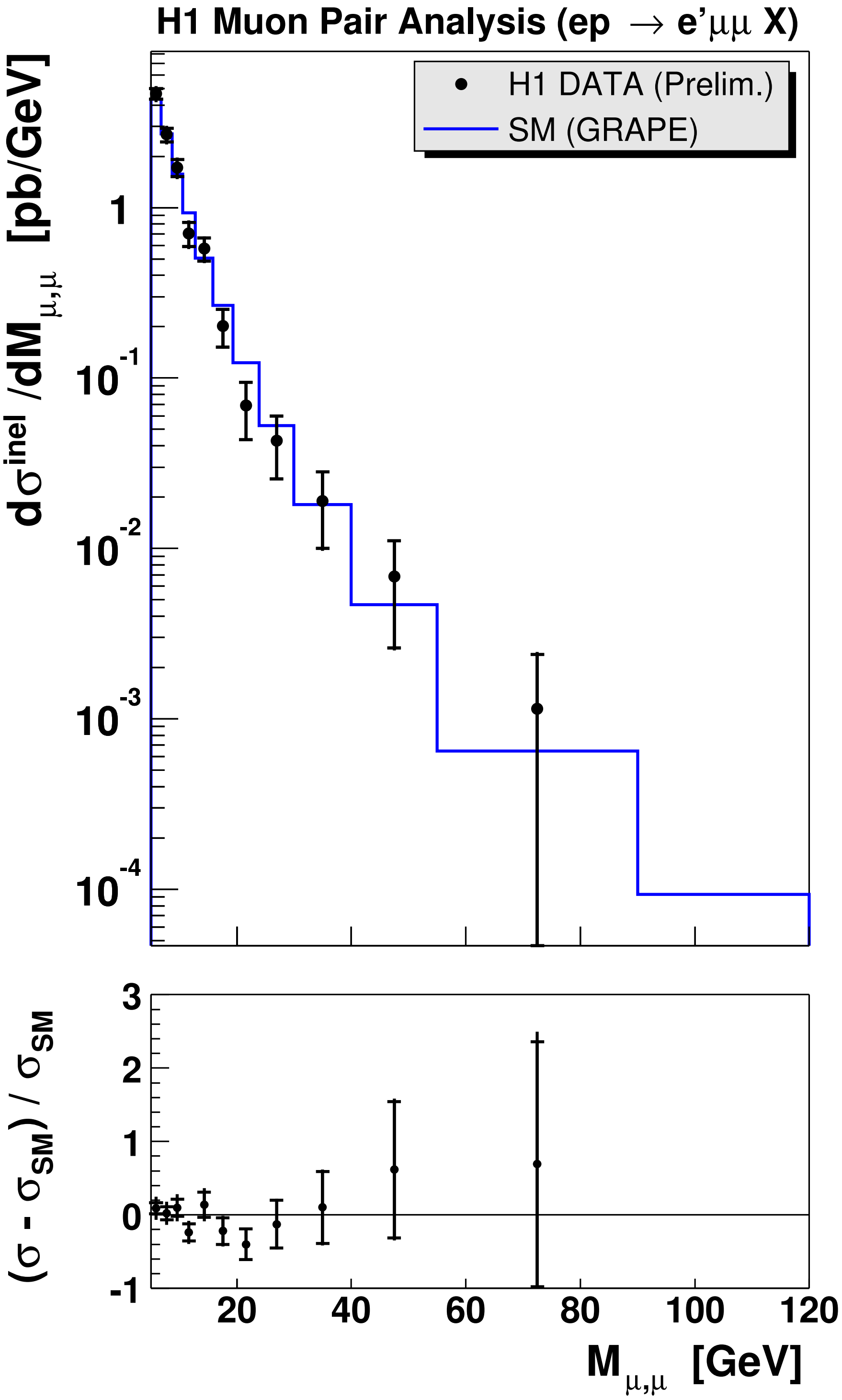

Figure 9: Invariant mass of inelastic produced muon pairs.

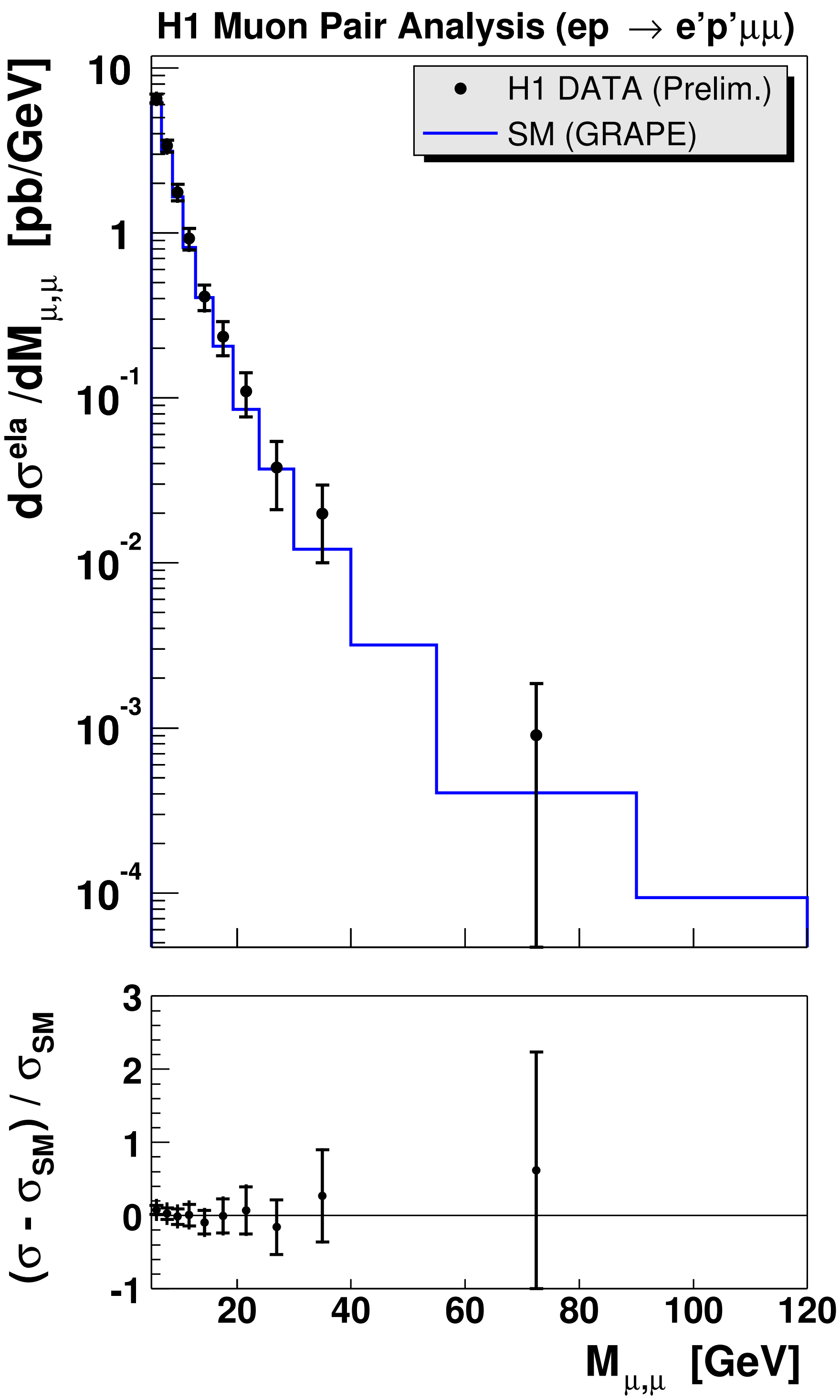

Figure 10: Invariant mass of elastic produced muon pairs.

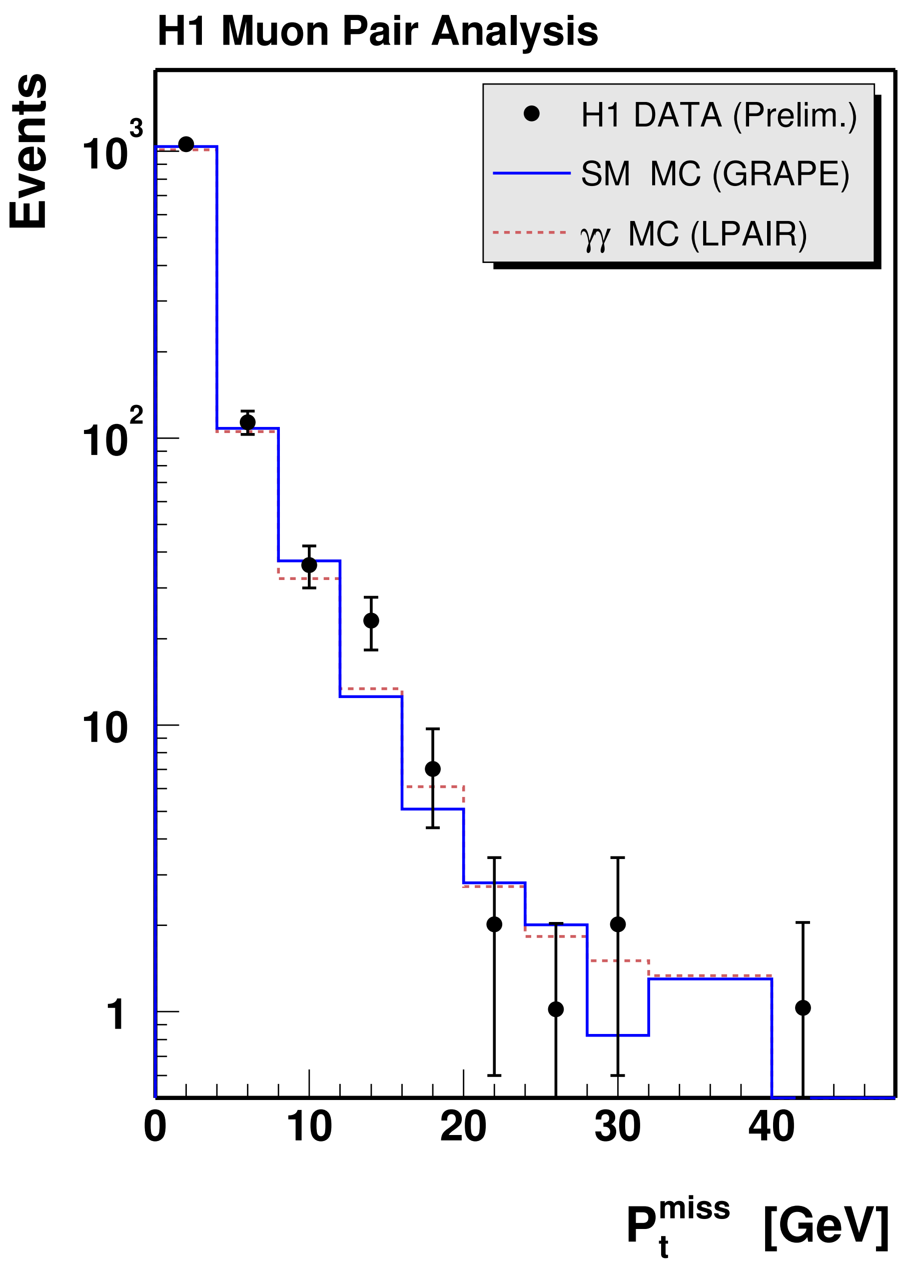

Figure 11: Uncorrected distribution of the missing transverse momentum of di-muon events.

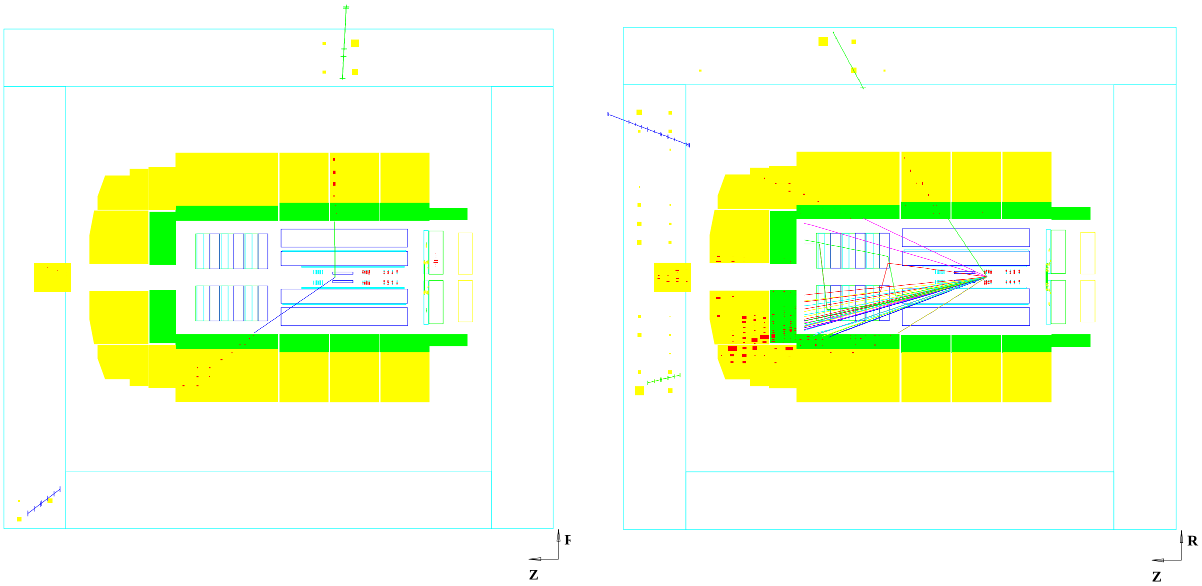

Figure 12: Event display of the event with the highest invariant mass of the muon pair ($M_{|mu,\mu} = 80$ GeV) (left figure) and an event display of the di-muon event with the highest transverse momentum of the hadronic final state ($P_t^X = 47$ GeV) (right figure).