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MUON PAIR PRODUCTION*

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Events containing pairs of isolated muons at high invariant masses have been detected at HERA with the H1 detector in a data sample corresponding to an integrated luminosity of 70.9 pb^{-1} of $e^{\pm}p$ scattering at $\sqrt{s}$ = 318 GeV. The results are well described by the Standard Model prediction which is dominated by photon–photon collisions.

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1. Introduction

Isolated muon pair production, $ep \longrightarrow (e)\mu\mu X$, at high invariant masses has been studied by H1 using the data from 1999–2000. Isolated muon pairs are dominantly produced via the multiperipheral two-photon process, $\gamma\gamma \longrightarrow \mu^+\mu^-$, depicted in Fig. 1.

As well as testing QED and the photon spectrum of the proton this analysis provides constraints on backgrounds to searches for new physics. In particular, it complements the analysis of multi lepton pair production [1,2].

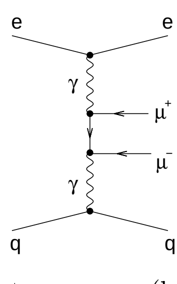

Fig. 1. Multiperipheral two-photon process (here for the deep inelastic case).

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2. Selection

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. For low momentum muons the finding efficiency is increased by accepting also 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. The analysis is carried out in the phase space given by a cut on the invariant mass of the muon pair ($M_{\mu,\mu} > 5$ GeV), requirements of minimal transverse momenta ($P_{\mathrm{t}}^{\mu_1} > 2.0$ GeV and $P_{\mathrm{t}}^{\mu_2} > 1.75$ GeV) and the given polar angle region. Background is suppressed by dedicated cuts against cosmic ray muons and an isolation requirement: the distance of the muons to the nearest track or jet in the pseudorapidity-azimuthal-plane $D_{\mathrm{Track,Jet}}$ has to be greater than 1.0. For muons with high transverse momentum ($P_{\mathrm{T}} > 10$ GeV) $D_{\mathrm{Track,Jet}} > 0.5$ is required.

3. Inclusive isolated muon pair production

Pair production of isolated muons is measured inclusively and compared to the Standard Model prediction, which is strongly dominated by electroweak production, especially by the Multiperipheral process. Electroweak muon pair production is simulated with the GRAPE generator [3], which uses the calculation program 'GRACE' [4] to determine the Feynman amplitudes of the corresponding diagrams in leading order. In addition to the Multiperipheral process contributions from Bremsstrahlung with subsequent photon conversion and electroweak contributions like real Z^0-production with decay to $\mu^+\mu^-$ are considered. Not simulated is the negligible contribution from the resolved Drell–Yan process [5]. To compare the contribution of the Multiperipheral process to the full electroweak calculation (GRAPE), the Multiperipheral process alone is simulated also with the LPAIR generator [6, 7]. Other sources of muon production have been simulated using DIFFVM [8] for the Υ-resonance, LPAIR for muons arising from $\gamma\gamma \longrightarrow \tau\tau$ and AROMA [9] for muons stemming from semi-leptonic decays in open heavy quark production ($c\bar{c}$ and $b\bar{b}$). Having corrected the data for detector effects, cross sections in the observed phase space are derived.

Fig. 3 presents the visible cross section as a function of the invariant mass of the muon pair (upper left plot) and the transverse momenta of the muons (upper right plot). The mass spectrum falls steeply over more

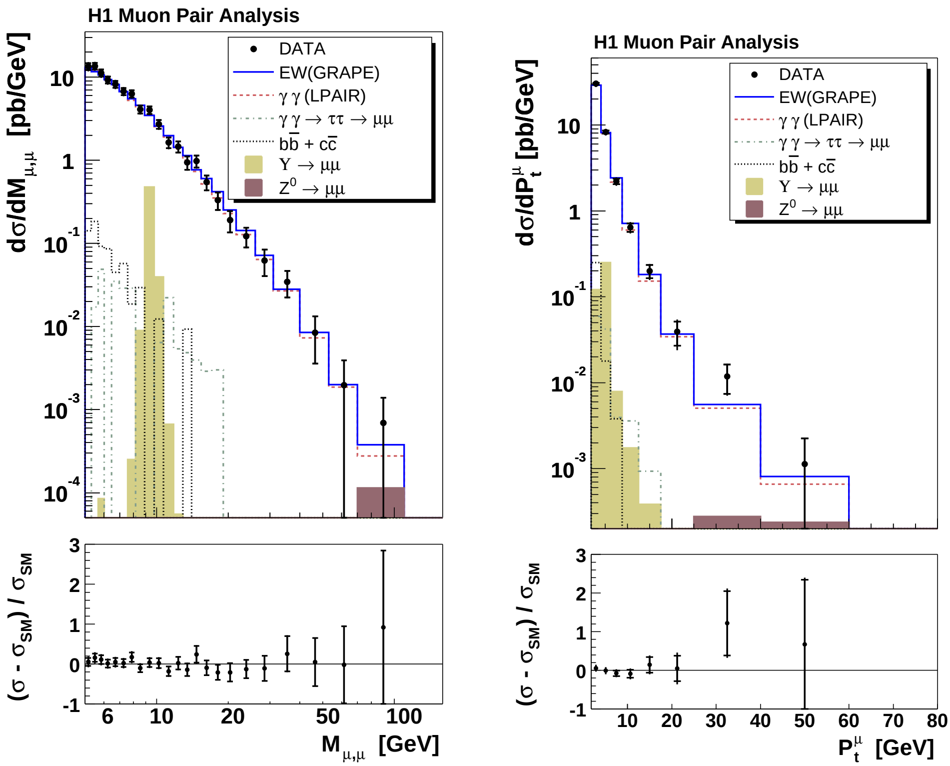

Fig. 2. Invariant di-muon mass (left) and transverse muon momenta (right) of di-muons in comparison to the electroweak (EW) prediction using GRAPE, the $\gamma\gamma \to \mu\mu$ contribution using LPAIR as well as contributions from $\gamma\gamma \longrightarrow \tau\tau$, $c\bar{c}$ and $b\bar{b}$, Υ and Z^0 decays. Also shown is the relative difference between data and all Standard Model contributions (lower figures).

than four decades and extends up to 80 GeV. The Multiperipheral process almost saturates the data. As shaded histograms the expectation from the Υ and Z^0 resonances are given. At small masses minor contributions from muons arising from open heavy flavour quark production, which are strongly suppressed due to the isolation requirement, and τ-decays are expected. The lower figures show the relative difference between data and the sum of all Standard Model contributions. The agreement between data and the standard model in both distributions is very good.

The distribution of the transverse hadronic momentum $P_{\rm t}^X$ is depicted in Fig. 3. The event with the highest measured transverse hadronic momentum has a $P_{\rm t}^X$ of approximately 50 GeV. The data is described within errors.

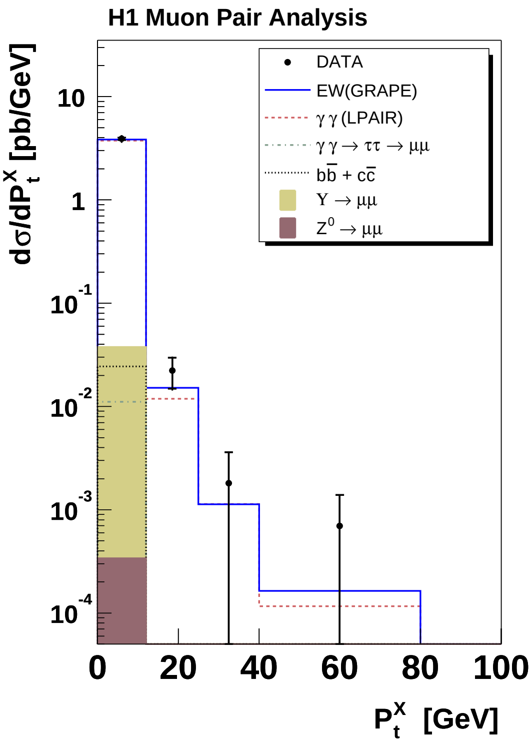

Fig. 3. Hadronic transverse momentum distribution in di-muon events. For details see Fig. 2.

4. Elastic and inelastic muon pair production

Elastic $ep \longrightarrow e\mu\mu p$ and inelastic $ep \longrightarrow e\mu\mu X$ muon pair production are separated from each other by detecting the proton remnant X using forward detectors like the Proton Remnant Tagger [10]. Fig. 4 shows the resulting mass spectra for the elastic (left) and the inelastic (right) data samples. Elastic muon production dominates the small mass region, but both spectra extend to similar high masses and match very well with the Standard Model prediction. The additional error arising from the separation of the two production mechanisms is conservatively estimated to be 10 %.

The total cross section of muon pair production was found to be (46.5 $\pm$1.3 $\pm$ 4.7) pb, which agrees nicely with the GRAPE prediction of 46.2 pb. For inelastic di-muon production a total cross section of (20.8 $\pm$0.9 $\pm$ 3.3) pb was measured,which agrees within errors with the expected cross section of 21.5 pb.

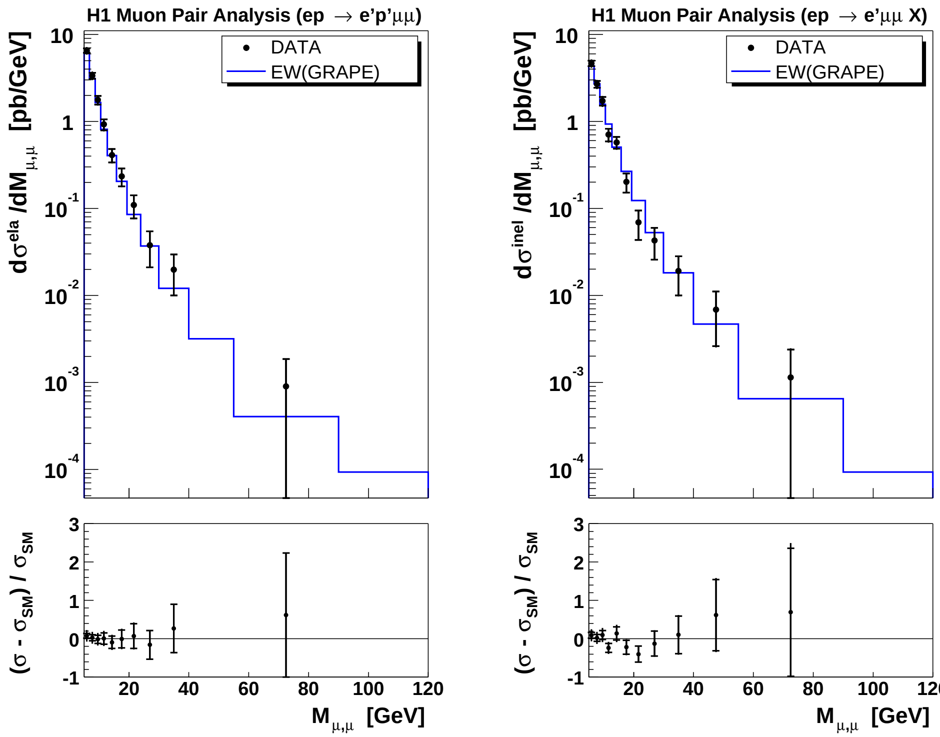

Fig. 4. Invariant di-muon mass of elastic (left) and inelastic (right) produced muon pairs.

5. Summary

Isolated muon pair production at high invariant masses has been analysed and both the inclusive cross section and the elastic and inelastic cross section have been found to agree very well with the Standard Model prediction. No excesses in the mass and the other spectra have been observed. An increase in the integrated luminosity and extension to the μe channel will shed further light on the high mass excess reported in [2].

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