Drell-Yan Differential Cross Section Measurement at √s = 13 TeV with p-p collisions in the CMS Detector

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Abstract

The measurement of the Drell-Yan differential cross section is presented at √s = 13 TeV in the dimuon channel. The differential cross section dσ/dM is measured in the dimuon invariant mass range of 15 to 3000 GeV using an integrated luminosity of 2.8 fb^{-1} of proton-proton collision data collected using the CMS detector at the LHC. The cross section is compared to various theoretical predictions.

Introduction

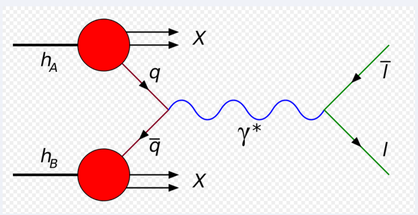
Drell-Yan Process

- This process occurs in hadron-hadron scattering via annihilation of quark of one hadron and an antiquark of another, leading to the creation of a pair of oppositely charged leptons.
- The production of lepton pairs proceeds through the exchange of a virtual photon or Z boson.

$$q\bar{q} \rightarrow \gamma^* / Z \rightarrow l^+ l^-$$

Motivation

- Effective input for PDF constraints
- Important for various LHC physics analysis as a background source for:
  - studies related to Higgs Boson
  - new physics searches beyond the standard model (e.g. Z')



- Drell-Yan differential cross section has been measured in CMS at √s = 7 and 8 TeV [*]
- First measurement using 13 TeV data (CMS-PAS-SMP-16-009)

[*] JHEP10(2011)007, JHEP12(2013)030 and Eur. Phys. J. C (2015) 75:147

Data Analyzed

Data

- Full data collected using single muon triggers in 2015
- Integrated luminosity **2.8 fb^{-1}**

Monte-Carlo

- Signal: Z/γ* → ll simulated using aMC@NLO [*] Monte-Carlo (MC) generator
- Backgrounds: DY -> ττ, tt̄, single top, Standard Model diboson (WW, WZ, ZZ), W+Jets and QCD

[*] Paolo Nason and Bryan Webber, "Next-to-Leading-Order Event Generators" DOI: 10.1146/annurev-nucl-102711-094928

Overview

Measure differential cross section dσ/dm of Drell-Yan process in dimuon channel

Cross section in i-th mass bin.

- N^u_i : Momentum scale corrected, background subtracted, unfolded yield
- A_i : Acceptance correction
- ε_i : Efficiency correction
- L : integrated luminosity

$$\sigma_i = \frac{N_i^u}{A_i \epsilon_i L}$$

Mass Range: 15 GeV to 3000 GeV

- Total 43 bins

{15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 64, 68, 72, 76, 81, 86, 91, 96, 101, 106, 110, 115, 120, 126, 133, 141, 150, 160, 171, 185, 200, 220, 243, 273, 320, 380, 440, 510, 600, 700, 830, 1000, 1500, 3000}

Analysis Steps

Event selection → Background Estimation → Corrections → Systematic uncertainty → Results

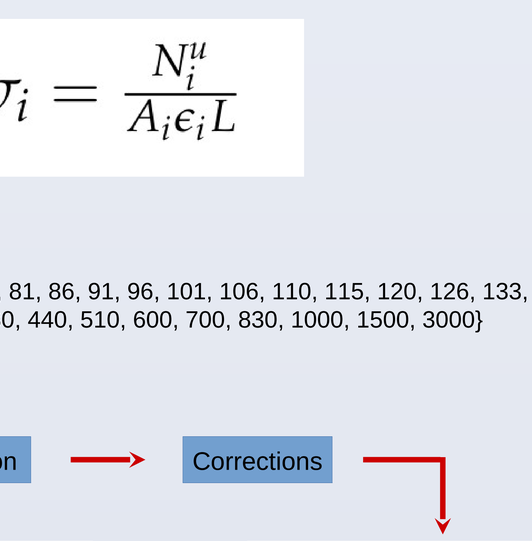
Event Selection & Background Estimation

Selection strategy

- Trigger:
  - Isolated single muon trigger with P_T >20 GeV
- Kinematic cuts:
  - P_T^{lead} > 22 GeV and P_T^{sub} > 10 GeV
  - |η| < 2.4
- CMS standard Muon selection followed

Background estimation

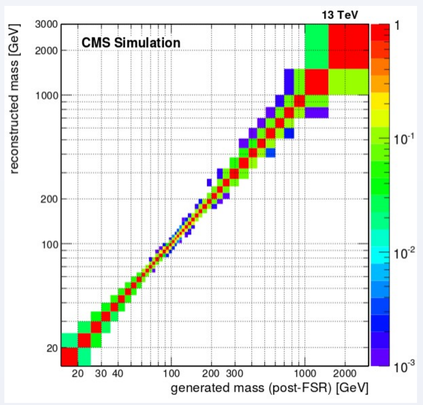
- MC-based estimation: WZ and ZZ
- Data-driven estimation:
  - eμ method: estimate backgrounds with eμ final state, with twice the rate of dimuon pairs
    - DY → ττ, tt̄, single top and WW
  - Fake rate method: estimate backgrounds with atleast one misidentified muon
    - QCD and W+Jets



Corrections

Unfolding for the detector resolution

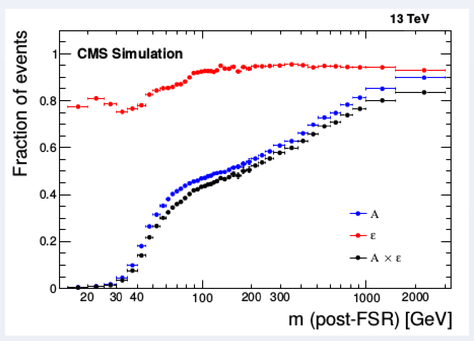
- Correct the detector resolution effects in dimuon mass spectrum
- Response matrix is produced using:
  - aMC@NLO sample
- Unfolding Method used: D'Agostini's iteration method



Acceptance & Efficiency

$$A \times \epsilon = \frac{N_{acc}}{N_{gen}} \times \frac{N_{sel}}{N_{acc}} = \frac{N_{sel}}{N_{gen}}$$

- N_{gen} = # total generated events
- N_{acc} = # events in the aceptance
- N_{sel} = # events passing selection



- Difference of the efficiency between data and MC is corrected using scale factors parameterized in bins of invariant mass.
- These scale factors are computed using Tag & Probe method using DY → μμ events.

$$\epsilon_{event} = \epsilon_{track} \cdot \epsilon_{reco+id} \cdot \epsilon_{iso} \cdot \epsilon_{trig}$$

- The scale factor is defined as:
  - applied to MC

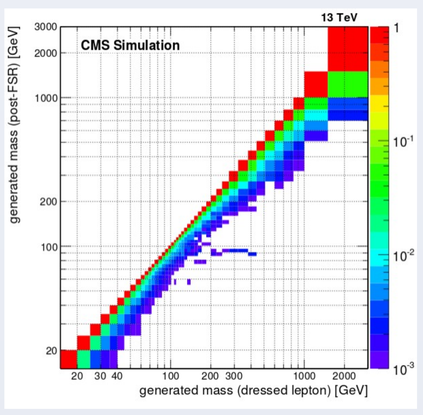
$$\epsilon_{event}^{data} / \epsilon_{event}^{MC}$$

FSR correction

- Obtained using dressed lepton definition:

$$\overrightarrow{P}_{dressed} = \overrightarrow{P}_{post-} \sum_{\Delta R(\mu,\gamma)<0.1} \overrightarrow{P}$$

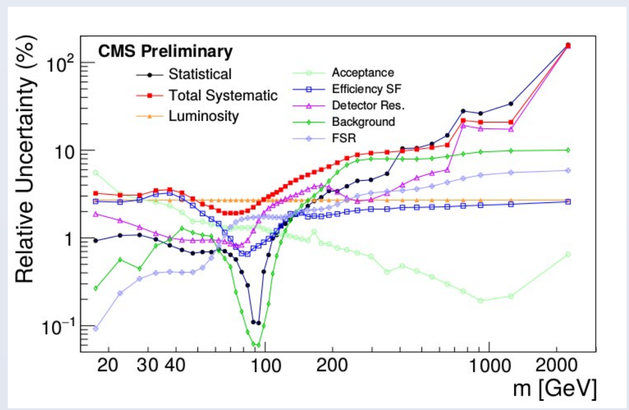
- Response matrix is obtained using aMC@NLO sample
- D'Agostini's iteration method



Systematic uncertainty

Different sources of systematics are considered

- Luminosity measurement (2.7%)
- Experimental:
  - Background Estimation
  - Unfolding correction for detector resolution
  - Efficiency scale factor
  - FSR correction
- Theoretical:
  - Acceptance: PDF and Scale Uncertainty



Dominant uncertainty

- Low mass: Efficiency scale factor (~3%)
- Z-peak region: FSR (< 2%)
- High mass (> 1TeV): Detector resolution (~20-100%)

Results

Drell-Yan differential cross section

- Measured in full phase space: compared with theoretical prediction from aMC@NLO and FEWZ(NNLO, NNPDF3.0)
- Fiducial cross section (within detector acceptance & without FSR correction): compared with aMC@NLO

Conclusion

- Good agreement with theory is observed