Studying muon pair production based on open data from CMS

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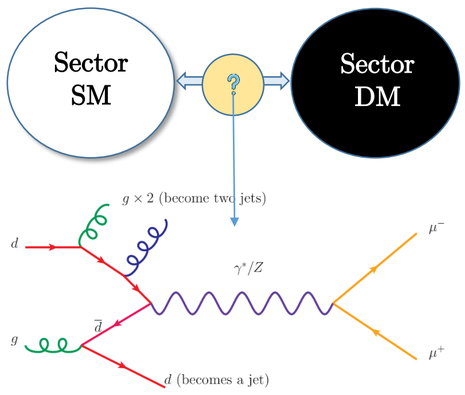
1. Motivation

Search for dark matter candidate particles (TM) and verification of predictions "portal" models of TM are one of the priorities of the physical program of experiments at the Large Hadron Collider. The efforts of the collaborations will make it possible to verify the predictions of only a small number of simplified theoretical scenarios. In this regard, the task rise of reinterpreting previously obtained experimental results within the framework of extended theoretical models. To do this, it is proposed to use open data from LHC, which are posted in public access. The initial stage of such an analysis is to compare measurements of the characteristics of the processes of the Standard Model on open data with official experimental results and to simulate the processes of formation of particles of the extended calibration sector (as a reference model) and TM particles



The Drell-Yan process is the main background in the search for signals of new physics beyond the Standard Model (SM), particularly in the search for candidate particles for the role of the Dark Matter

2. Muon selections

1.Kinematic cuts

$p_{T1} > 22\ GeV/c, \quad |\eta| < 2.4$
$p_{T2} > 10\ GeV/c, \quad |\eta| < 2.4$

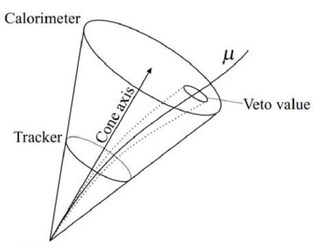
2.Muon identification

$\chi^2 / ndof < 20\%$
$N_{trk.layers} > 5$
$N_{muon} > 0$
$N_{pixel} > 0$
$N_{segmentmachted} > 1$
$\partial P_T / P_T < 0.3$

3. Impact parameter

$|d_{xy}| < 2\ mm$

4. Muon isolation



$\sum_i (I_{trk} + I_{HACL}) / p_T^{\mu} < 0.15$

5. Vertex Probability

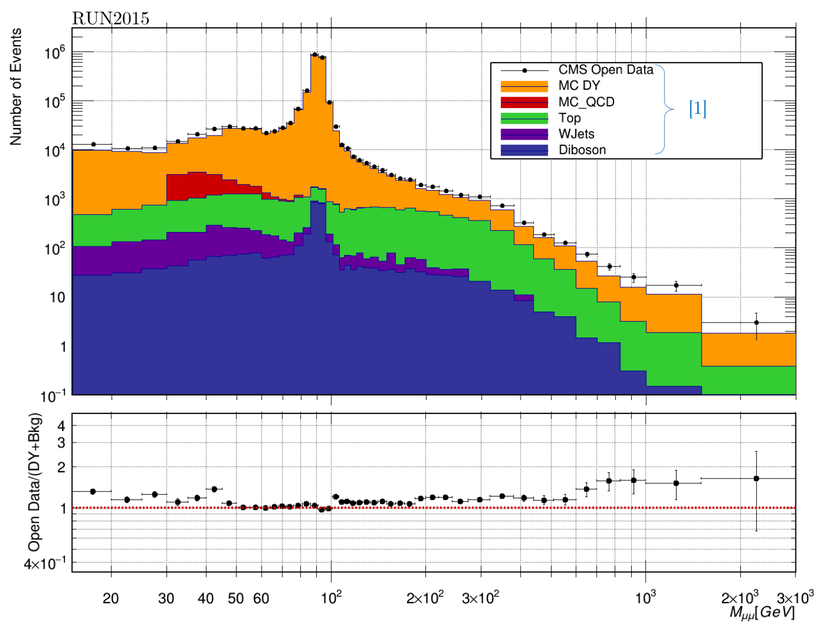
$VP > 0.02$

4. Angel between muon tracks

$\alpha_{3D} = ((\vec{p}_1^{\,track}, \vec{p}_2^{\,track}) / p_1^{track} / p_2^{track}) < 5\ mrad$

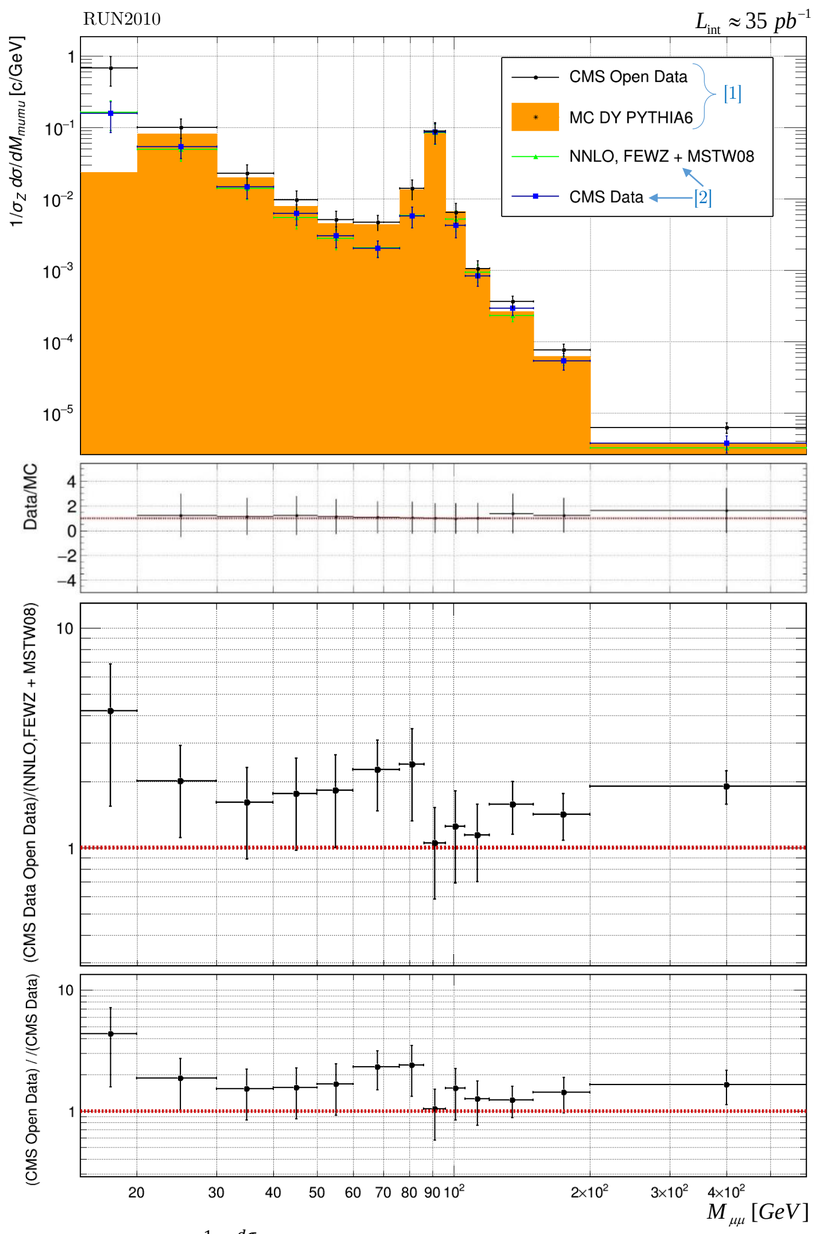
Selection path:
RUN2010
RUN2015

3. Invariant mass

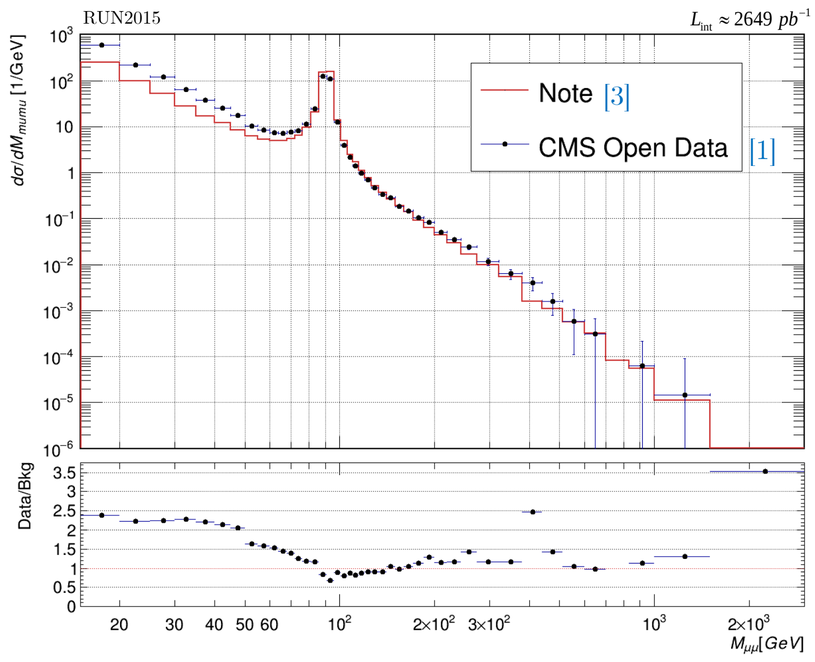


Distributions of the number of dimuons based on the invariant mass. The orange color represents the contribution of the Drell-Yan process from Monte Carlo simulations. Other colors depict contributions from background events. The lower histogram illustrates the ratio of reconstructed data to background.

4. Cross Sections



The differential cross-section $\frac{1}{\sigma_{Z^0}}\frac{d\sigma}{dM_{\mu\mu}}$ for the Drell-Yan process as a function of the invariant mass of the muon pair is presented. Open data (CMS Open Data) and official data (CMS Data) from the CMS collaboration for LHC RUN1 at $\sqrt{s}$=7 TeV are utilized. Below, the ratios of the cross-sections obtained from CMS Open Data to those of the simulated processes using PYTHIA6 and FEWZ are provided. Additionally, the ratios of CMS Open Data cross-sections to the official data from the CMS Data collaboration are presented.



The differential cross-section for the Drell-Yan process as a function of the invariant mass of the muon pair is presented. Open data (CMS Open Data) and official data (CMS Data) from the CMS collaboration for LHC RUN1 at $\sqrt{s}$=13 TeV are utilized. The lower histogram illustrates the ratio of reconstructed data to background.

5. What has been done

- All statistics from RUN2010 and RUN2015 have been analyzed
  - ✓ Kinematic characteristics of events with muon pairs have been obtained
  - ✓ The Differential cross-section of the Drell-Yan process has been calculated based on the invariant mass of muon pair $1035 \pm 16\ pb, 60 < m_{\mu\mu} < 120\ GeV/c^2$ for RUN2010.
  - ✓ A comparison is made between the results of the analysis of the CMS open data and predictions of the Standard Model, as well as previously published results from the collaboration.
  - ✓ The agreement between the measurement results and calculations at the leading-order of the electroweak theory and the next-to-leading order of QCD is demonstrated

6. What is planned to be done

- There are plans to end an analysis of the second stage of data from LHC RUN2 (open data) collected by the CMS experiment to obtain the differential cross-sections of the Drell-Yan process.
- Additionally, there are plans to model the processes of new calibration boson production and measure the upper limit of the Z' boson decay cross-section into a lepton pair.
- Within this study, a comparison will be made between the theoretical predictions of the model to establish the lower limit on the mass of the new Z' boson carrier. The obtained results will be compared with previously published data by the CMS collaboration.

7. References

[1] CMS Open Data, https://opendata.cern.ch/
[2] CMS Collaboration, "Measurement of the Drell-Yan Cross Section in pp Collisions at √s = 7 TeV," Journal of High Energy Physics, October 2011
[3] CMS Collaboration, "Measurement of the differential Drell-Yan cross section in proton-proton collisions at √s = 13 TeV", Journal of High Energy Physics, December 2019