ULTRA-PERIPHERAL J/ψ PRODUCTION IN PbPb COLLISIONS IN CMS*

Marek Walczak

on behalf of the CMS Collaboration

Faculty of Physics, University of Warsaw
Pasteura 5, 02-093 Warszawa, Poland

(Received April 5, 2017)

I briefly introduce the Ultra-Peripheral Collisions (UPCs) and explain what is the benefit of studying these events. I also show the current status of an ongoing analysis, which concerns the UPC J/ψ production in PbPb 2015 data from the CMS experiment at CERN. This analysis forms the basis of my Ph.D. Thesis and its results have not been yet approved by the CMS Collaboration.

DOI:10.5506/APhysPolB.48.1231

1. Introduction

In heavy-ion physics analyses, it is always necessary to distinguish between final-state particles produced directly by the nuclei themselves from those originating from the quark–gluon plasma (QGP). Therefore, there is a great need to study the nature of the initial state formed during collisions. Lack of understanding of these states leads to uncertainties of the measured properties of QGP, *e.g.* viscosity. Most recent nuclear parton distribution functions (PDFs) obtained by [1] show that gluon distributions are still poorly known. This is especially true at low-energy scales Q^2 and small Bjorken x, $x < 10^{-2}$ (see Fig. 1). The Large Hadron Collider (LHC) apart from QCD driven interactions is a very powerful source of γ–γ and γ–hadron interactions. Accelerated protons and ions carry an electromagnetic field, which is the source of interacting photons. A photon generated by one of the passing hadrons can interact with another photon or with a parton inside a second hadron (photoproduction) producing a wide variety

* Presented at the Cracow Epiphany Conference "Particle Theory Meets the First Data from LHC Run 2", Kraków, Poland, January 9–12, 2017.

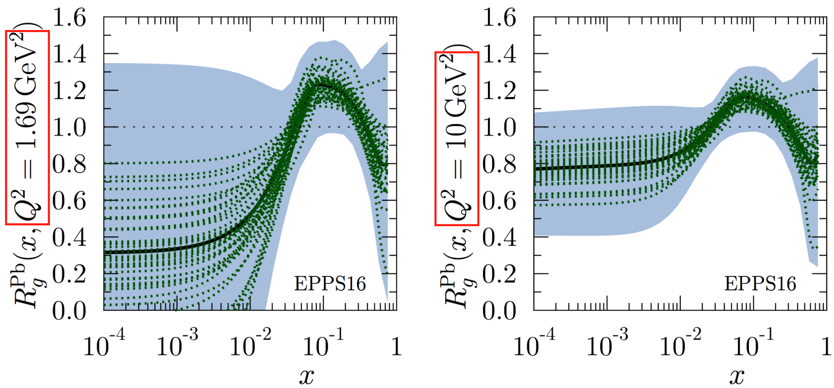

Fig. 1. The EPPS16 nuclear modifications for lead. Largest uncertainty for gluon distributions is for $x < 10^{-2}$ and low Q^2. This is because of a lack of data in this region. Dotted lines show different contributions to the uncertainties [1].

of particles (see Fig. 2). In particular the Ultra-Peripheral Collisions (UPCs) are events, where two hadrons do not collide head on, they pass close to each other (see Fig. 3). Due to their electric field, they exchange a very energetic photon. The studies of UPCs allow to set constrains on the theoretical models in the previously mentioned kinematic region (see Fig. 4). These photon-induced processes provide a great opportunity to study fundamental aspects of quantum electrodynamics (QED) and quantum chromodynamics (QCD) [2]. A photo-nuclear interaction that has attracted a lot of interest is exclusive vector meson production. In this reaction, only a vector meson is produced in the final state (Fig. 2 (a)).

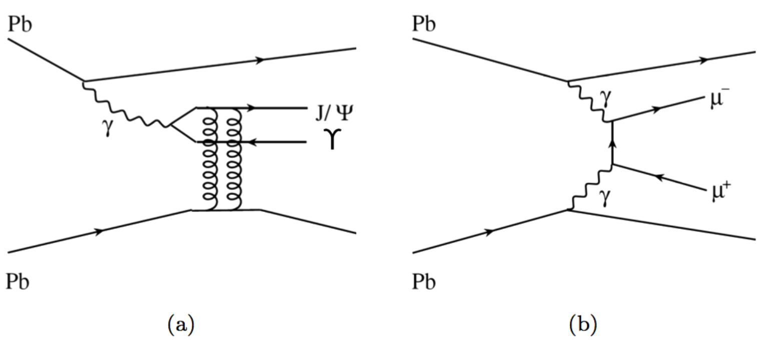

Fig. 2. The Feynman diagrams of an UPC for PbPb. Diagram (a) shows photoproduction process of vector mesons, (b) is a $\gamma\gamma$ interaction producing two muons, the main background to the analysed process.

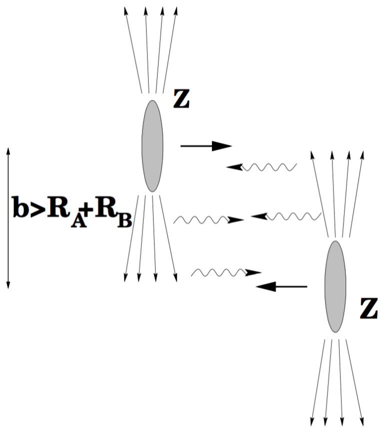

Fig. 3. A representation of an UPC. The pancake-like shape of the nuclei is due to the relativistic Lorentz contraction.

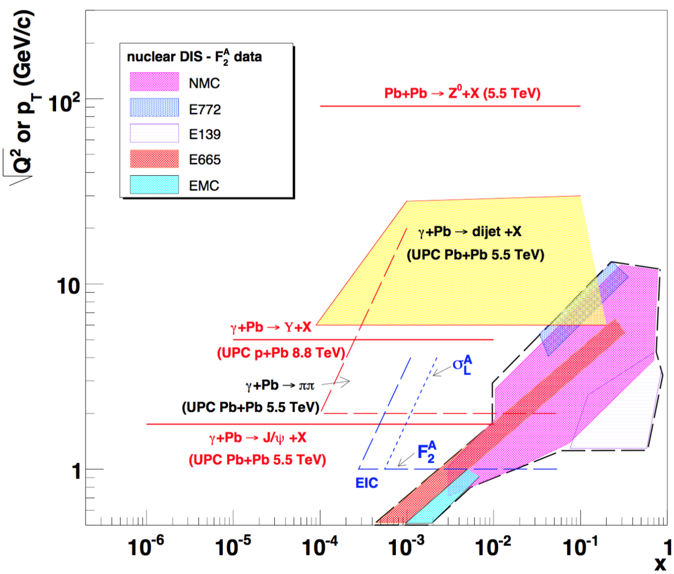

Fig. 4. The kinematic range in which UPCs at the LHC can probe gluons in protons and nuclei in quarkonium production, dijet and dihadron production. The Q^2 value for the typical gluon virtuality in exclusive quarkonium photoproduction is shown for J/ψ and Υ. For comparison, the kinematic ranges for J/ψ at RHIC, structure function F_2^{A} and cross section $\sigma_{\mathrm{L}}^{\mathrm{A}}$ at eRHIC and Z^0 hadron production at the LHC are also shown [2].

2. UPC J/ψ photoproduction in CMS

2.1. Compact Muon Solenoid

In my analysis, the 2015 PbPb data from the Compact Muon Solenoid (CMS) experiment at CERN is used. The CMS is a general purpose detector designed mainly to study *pp* collisions, but due to its high coverage in the forward region and advanced muon system (see Fig. 5), it is also well-suited for heavy-ions analyses, especially the one described in this section. More details on the CMS experiment can be found in [3].

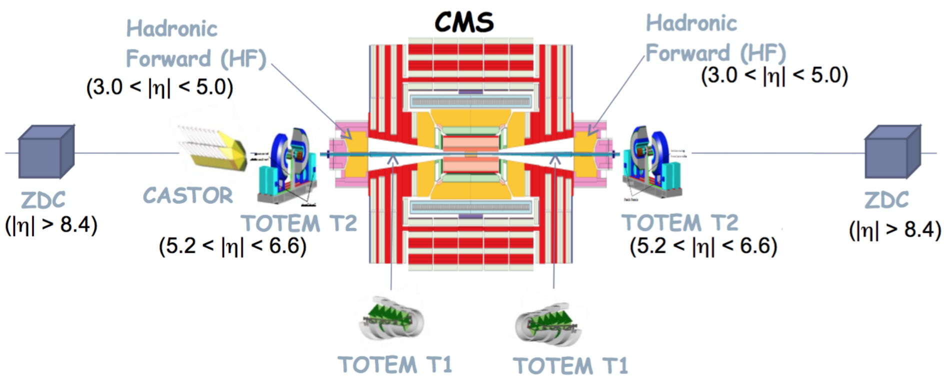

Fig. 5. Forward sub-detectors in the CMS. On both sides, there are HF calorimeters, TOTEM and ZDC detectors. CASTOR calorimeter is installed on one side only.

2.2. Selection criteria

For the analysed PbPb data, the center-of-mass energy was $\sqrt{s_{NN}} = 5.02$ TeV. In this analysis, an UPC J/ψ photoproduction with the produced vector meson decaying into $\mu^+\mu^-$ pair is selected. The luminosity corresponding to the analysed data was 446 μb^{-1}. For the initial on-line selection of events, a dedicated L1 (hardware) and HLT (software) triggers are used. The selection is as follows:

- L1: at least one reconstructed muon without p_{T} threshold requirement,
- L1: veto on energy deposits in at least one HF calorimeter,
- HLT: at least one track in pixel detector.

Then additional cuts are applied:

- exactly two muons of opposite sign,
- for dimuon systems $p_{\mathrm{T}} < 0.3$ GeV.

The last cut is based on Monte Carlo (MC) studies and removes the non-exclusive background (the STARLIGHT MC is used [4]). The MC models two-photon and photon–hadron interactions at ultra-relativistic energies.

The presented selection reflects a general signature of the UPC $J/\psi \to \mu\mu$ events. It provides a qualitative information and it is a first step to the final analysis leading to the cross-section measurement. This analysis will be described in my Ph.D. Thesis.

3. Results

Although there are no approved results that could be published yet, the described selection gives good insight into the interesting events in the data. The number of J/ψ candidates passing above criteria is of the order of thousands. This provides good prospects for the future cross-section estimation. The transverse momenta p_{T} of the dimuon pairs are small, below 1 GeV, and most of them have $p_{\mathrm{T}} < 0.1$ GeV. The rapidity of the selected events is mostly forward and symmetric as expected for the PbPb collisions. In Fig. 6, an event display of one of the events passing selection criteria is presented — the reconstructed trajectories come from the two muons. As can be seen, the detector is empty but the two muons going into forward direction.

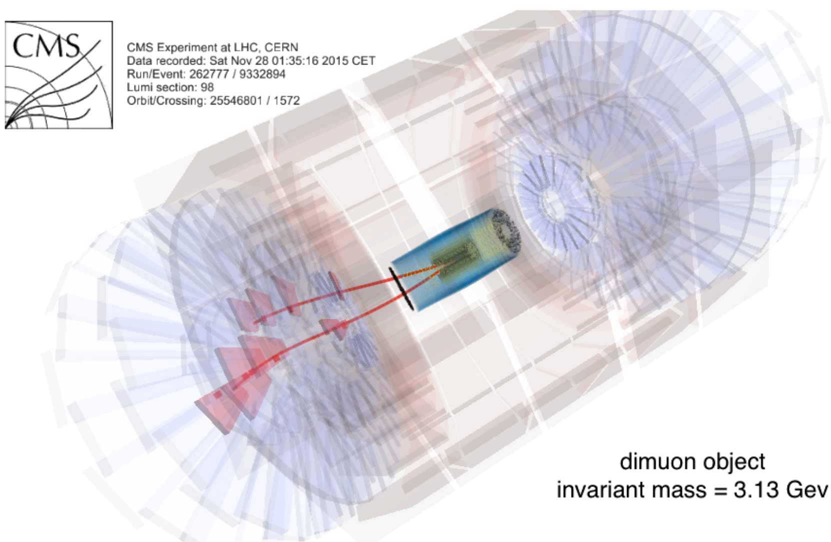

Fig. 6. The event display shows one of the selected events, the visualisation of the CMS detector can be seen, together with two trajectories of muons going into forward direction. The reconstructed invariant mass of the two leptons is about the J/ψ mass.

4. Conclusions

Because of our poor understanding of the nuclear PDFs at low Q^2 and low-x kinematic range, there is a great need for results probing this area. It occurs that this problem can be addressed with the UPC photoproduction of vector mesons. Similar measurement has been done at $\sqrt{s_{NN}} = 2.76$ TeV at CMS [5] and now will be done for higher energies. In the mentioned paper, the obtained cross section has been compared to the theoretical predictions, and occurred to be in a good agreement with the leading twists approximation. This corresponds to the effective nuclear gluon shadowing. The measurement of my analysis, obtained at higher energies, will be used to further constrain theoretical predictions, leading to better understanding of the nature of QCD.

This work was supported by the National Science Centre, Poland (NCN) grant 2015/19/N/ST2/02697.

REFERENCES

[1] K.J. Eskola, P. Paakkinen, H. Paukkunen, C.A. Salgado, *Eur. Phys. J. C* **77**, 163 (2017) [arXiv:1612.05741 [hep-ph]].

[2] A.J. Baltz *et al.*, *Phys. Rep.* **458**, 1 (2008).

[3] CMS Collaboration, *JINST* **3**, S08004 (2008).

[4] S.R. Klein *et al.*, *Comput. Phys. Commun.* **212**, 258 (2017).

[5] CMS Collaboration, arXiv:1605.06966 [nucl-ex].