Search for exclusive processes in the CMS experiment at the LHC

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Exclusive processes at the LHC

In **exclusive processes**, each event is treated as a whole where the initial state as the final state is fully known, in comparison to the inclusive processes where only one class of observable final state is selected and treated.

For a proton colliding experiment such as the ***Large Hadron Collider*** (LHC) these processes can take form as the emission of colour-singlet particles (photons, pomerons, ...) by the protons, giving rise to a central production of particles observed in the detector in the final state.

The **CMS experiment** at the LHC has access to a very high center of mass energy to **probe the exclusive processes** in a very precise way. This enables the search for **anomalies in the Standard Model** (SM) of particle physics by observing such theoretically well-understood decays at a sufficiently high rate.

Such exclusive events are characterized by the reconstruction of the **outgoing protons** as well as the **produced central system**. An apparatus, the ***High Precision Spectrometer*** (HPS) currently under development, will soon enable to *tag* precisely these "elastic" events in which both the protons survived after they gave birth to the central system.

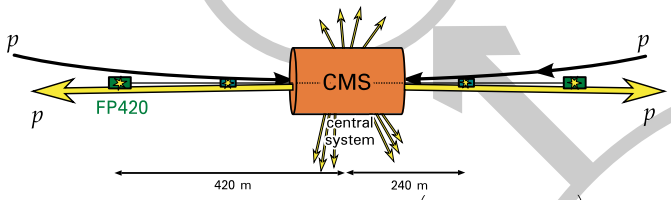
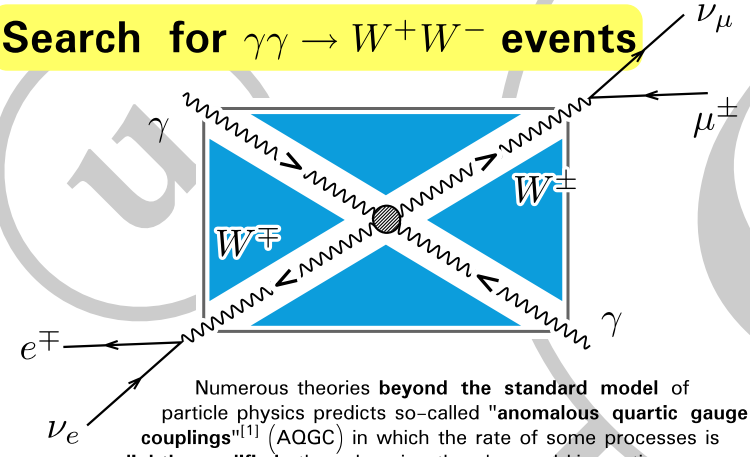


Fig. 1 The **HPS**, or High Precision Spectrometer (in green and blue) located at 240 and 420 m of the interaction point (at the center of CMS).

Search for $\gamma\gamma \to W^+W^-$ events



Numerous theories **beyond the standard model** of particle physics predicts so-called "**anomalous quartic gauge couplings**"[1] (AQGC) in which the rate of some processes is **slightly modified**, thus changing the observed kinematic distributions of such processes (as seen in **fig. 2**). For this analysis the different samples involving various couplings have been simulated by the **CalcHEP** events simulator.

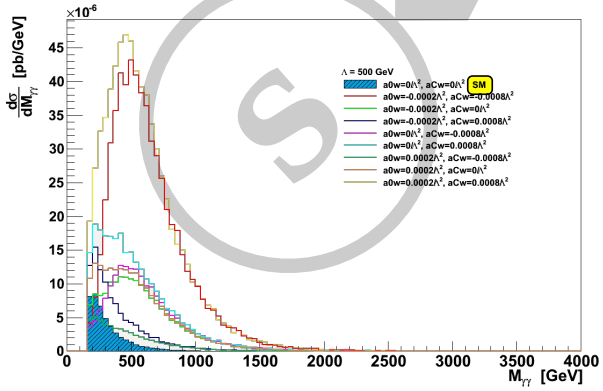


Fig. 2 Invariant mass distribution for the two photons for different models hypothesis (the standard model prediction is in filled blue). Every model is parameterized by its own a_{0w} and a_{Cw} coupling value. Figure from [1].

The standard signal for this analysis is a **pair of virtual photons** coming from the initial protons, which are quadratically coupled to a pair of W bosons. These bosons, thanks to their short lifetime, decay finally in numerous channels.

In this analysis the **fully-leptonic channel** was probed, in which each W decays as a **lepton** and a **same-flavour neutrino.**

An analysis without the HPS

For this analysis the full 2011 collected dataset covering an integrated luminosity of ~**5 fb^{-1}** was used. The center of mass energy during the whole data-taking period was **7 TeV**. Since the tagging of the outgoing protons is currently not available one had to take into account in the final state the **two extra cases** in which one of (or both) the protons was dissociated and to select events with an **absolute cleanliness** of the observed central system.

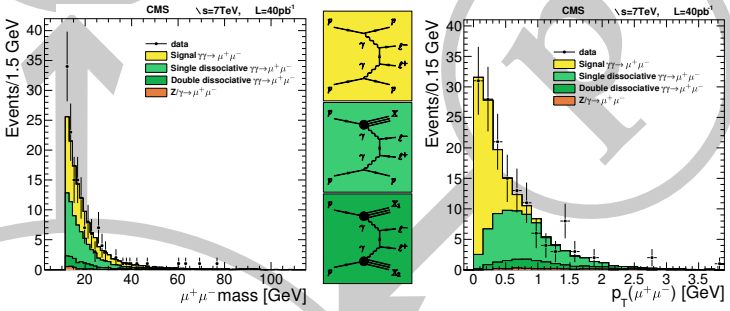


Fig. 3 Elastic production of exclusive lepton pairs by the exchange of two photons arising from the incoming protons. Figure from [3] (using 40 pb^{-1} of 7 TeV CMS data collected in 2010)

For a complete **understanding of the processes** involved in the signal region of the data, one previously probed other kinematic regions such as the "**elastic region**" in which processes as detailed in the three central boxes of the **fig. 3** are producing same flavour lepton pairs, like muons. Such events are simulated using the **LPAIR**[4] Monte-Carlo generator interfaced to the full CMS reconstruction framework.
As shown in the l.h.s. and r.h.s. of this figure, the agreement is achieved, thus enabling to evaluate the **fraction of inelastic** (green distributions) events added to the **pure elastic** events (yellow distribution) for the WW analysis.

How many events are expected?

The phase space for such a process is strictly tightened by the surrounding backgrounds, such as the inclusive Drell-Yan production of lepton pairs (taus and muons) or the inclusive production of W pairs.

The **events selections** was tuned to enhance significantly the signal/background ratio :
* two different flavours leptons (**muon** and **electron** pair)
* high transverse momentum of both leptons
* high invariant mass and transverse momentum of the lepton pair
* exclusivity condition : **no extra tracks** on the primary vertex

a_{0w}	a_{Cw}	n_{evt}
-2×10^{-4}	-8×10^{-4}	9
	0	3
	8×10^{-4}	2
0	-8×10^{-4}	3
SM	0	1
	8×10^{-4}	4
2×10^{-4}	-8×10^{-4}	1
	0	3

Tab. 1 Number of expected events within the CMS acceptance according to the different values of the a0w aCw couplings probed in this analysis.

As shown in the **tab. 1** the number of expected events at the integrated luminosity of 5 fb^{-1} for the previously quoted signal selection is **clearly dependant** on the anomalous coupling parameters. This prediction will enable for the first time to **put a limit** on this crucial part of the electroweak sector in the standard model, thanks to the high integrated luminosity delivered by the LHC machine so far as well as the outstanding performances of the CMS detector.

Latest results are still under the approval process from the CMS collaboration. Stay tuned...

References

[1] Sensitivity to anomalous quartic gauge couplings in photon-photon interactions at the LHC, Nucl. Phys. Proc. Suppl. **179-180** (2008), T. Pierzchala, K. Piotrzkowski [arXiv:0807.1121]
[2] CalcHEP 3.4 for collider physics within and beyond the Standard Model, A. Belyaev, N. D. Christensen, A. Pukhov [arXiv:1207.6082]
[3] Exclusive photon-photon production of muon pairs in proton-proton collisions at $\sqrt{s} = 7$ TeV, JHEP **01** (2012) 052, The CMS collaboration [arXiv:1111.5536]
[4] LPAIR: A generator for lepton pair production, S. Baranov, O. Duenger, H. Shooshtari et al.