Validation note for the MadAnalysis5 implementation of the monophoton analysis of CMS (CMS-EXO-12-047)

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I. INTRODUCTION

In this note, we describe the validation of a reimplementation of the CMS-EXO-12-047 analysis [1] within the MadAnalysis5 (MA5) framework [2–4]. We have used the verison 1.2 of MadAnalysis5 jointly with the standard Delphes3 program [5] that we have run from the MadAnalysis5 platform. The validation has been achieved on the basis of a single benchmark scenario that has been provided by CMS, for which we have generated events with the Pythia8 Monte Carlo program [6]. The necessary configuration file has been provided by CMS and can be found on the public analysis database webpage of madanalysis,
http://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase
together with the MA5tune detector card that we have used for the simulation of the detector. This card is the standard one provided with MA5.

The CMS monophoton search relies on an integrated luminosity of 19.6 fb^{-1} of proton-proton LHC collisions at a center-of-mass energy of $\sqrt{s} = 8$ TeV, and focuses on a signal containing one isolated hard photon (with a transverse energy $E_T^\gamma > 145$ GeV) a significant amount of missing transverse energy $E_T^{\rm miss} > 140$ GeV. In addition, a lepton veto and a jet veto are applied.

II. SIMULATION DETAILS

The CMS collaboration has kindly provided us generation and validation information for one ADD [7, 8] benchmark scenario yielding monophoton events. From this information, we have been able to generate a monophoton event sample with the help of the Pythia8 program and that we have encoded under the HEPMC format [9]. We have made use of the user-friendly mode of MadAnalysis5 version 1.2 to perform the simulation of the detector response via its interface with the Delphes3 package, and using the standard CMS detector description shipped with MadAnalysis5. Event reconstruction is internally performed by Delphes that makes use of the FastJet package [10] with an anti-k_T reconstruction algorithm [11].

The validation sample describes the process,

$$pp \to G\gamma \ , \tag{1}$$

where G stands for an invisible graviton that will be responsible for the missing energy $E_T^{\rm miss}$ of the process. More precisely, signal events at the hadron level (*i.e.*, before the simulation of the detector) have been generated by means of the following snippet of code,

```
ExtraDimensionsLED:ffbar2Ggamma = on
ExtraDimensionsLED:CutOffmode = 1
ExtraDimensionsLED:t = 0.5
ExtraDimensionsLED:LambdaT = 2000.
ExtraDimensionsLED:n = 6
ExtraDimensionsLED:MD = 2000
5000039:m0 = 1200.
5000039:mWidth = 1000.
```

where ffbar2Ggamma switches the process $pp \to G\gamma$ on in Pythia, CutOffmode is a flag allowing to prevent the hard process scale to be above the scale of validity of the underlying low-energy effective theory. Furthermore, the t parameter setting is related to the unknown details of the running of the gravity coupling and the LambdaT parameter is the ultraviolet cutoff of the virtual graviton exchange subprocesses. The benchmark scenario description is completed by fixing the number of extra dimensions n to 6, the fundamental theory scale MD in $4 + n$ dimensions to 2000 GeV and the graviton properties (whose PDG identifier is 5000039). Its mass is fixed to 1000 GeV (m0) and its decay width (mWidth) to 1 GeV. Selection cuts are also imposed at the generation level,

	Selection step	CMS	$\epsilon_i^{\rm CMS} = (n_i/n_{i-1})^{\rm CMS}$	MA5	$\epsilon_i^{\rm MA5} = (n_i/n_{i-1})^{\rm MA5}$	$\delta_i^{\rm rel}$
0	Nominal	10000		10000		
1	$E_T^\gamma > 145$ GeV, $\lvert\eta\rvert < 1.44$	6400	0.64	6205	0.62	3.125%
2	PhotonID+iso	4600	0.72	5751	0.92	-28.1%
3	$E_T^{\rm miss} > 140$ GeV	4100	0.89	5283	0.92	-3.146%
4	$\triangle\phi(\gamma^{leading}, m_T^{miss}) > 2$ rad	4100	1.00	5278	1.00	0.1%
5	lepton veto	4100	1.00	5262	1.00	0.4%
6	$E_T^{\rm miss}$ mini	4100	1.00	5262	1.00	0
7	jet veto	3700	0.90	4642	0.88	2.217%

TABLE I: Comparison of results obtained with the MA5 reimplementation (MA5) and those provided by the CMS collaboration (CMS). The relative difference between the CMS and the MA5 results has been defined as $\delta_i^{\rm rel} = 1 - \epsilon_i^{\rm MA5}/\epsilon_i^{\rm CMS}$.

```
5000039:mMin = 1.
5000039:mMax = 13990.
PhaseSpace:pTHatMin = 125.
```

where the graviton invariant mass is allowed to vary between 1 GeV (`mMin`) and 13990 GeV (`mMax`) and its transverse momentum must be larger than 125 GeV (`pTHatMin`).

The configuration of the parton densities, the parton showering and the hadronization is performed as

```
PartonLevel:MPI = on
PartonLevel:ISR = on
PartonLevel:FSR = on
Tune:pp 5
Tune:ee 3
PDF:pSet = LHAPDF5:MRST2001lo.LHgrid
PDF:extrapolate = on
```

The `Tune:ee 3` setup switches on a tune to a wide selection of LEP1 data, while the `Tune:pp 5` command switches one a tune allowing for getting a better agreement with some early key LHC data [12]. Finally, the MRST2001 set of parton ditributions [13] is used *via* the `LHAPDF` [14] interface of `Pythia`.

III. RESULTS

A. Cutflow

The CMS analysis relies on a single signal region defined by 7 selection cuts. For the benchmark scenario under consideration, we compare our results, that have been derived with an MA5 reimplementation, to those provided by the CMS collaboration (see Table I). For each cut, we have calculated the related efficiency defined as

$$\epsilon_i = \frac{n_i}{n_{i-1}} \ ,$$

where n_i and n_{i-1} mean the event number after and before the considered cut, respectively. The initial event number have been normalized to 10000 in both the CMS and MA5 cases. The *relative difference* given in the table corresponds to the difference between the `MA5` and the CMS efficiencies, normalized to the CMS result,

$$\delta_i^{\rm rel} = 1 - \frac{\epsilon_i^{\rm MA5}}{\epsilon_i^{\rm CMS}} \ .$$

We have found that all selection steps are properly described by the MA5 implementation, with the exception of the second cut that exhbitits a discrepancy of about 25%. This has been tracked down to a poor description by `Delphes` of the CMS detector machinery concerning photon isolation. We have also ignored the $6^{\rm th}$ selection step in our implementation. This cut, called '$E_T^{\rm miss}$ mini', represents effects that could be due to mismeasurements in the missing energy due to the finite detector resolution, something that we cannot simulate. This has however almost no effect for the benchmark scenario under consideration.

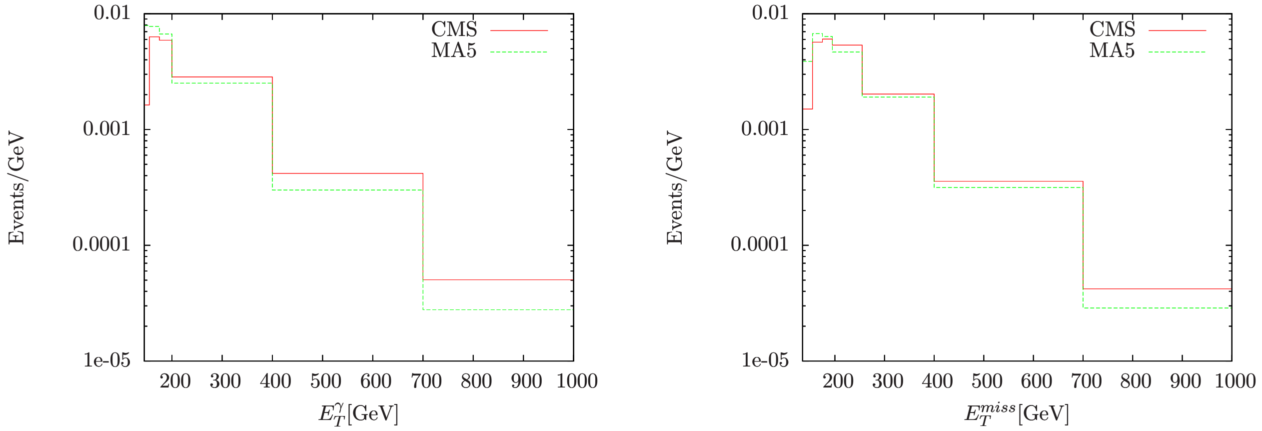

FIG. 1: Official results: solid lines, MA5 results: dashed lines.

B. Histograms

We have also generated two figures depicting the photon transverse energy E_T^γ and the missing transverse energy E_T^{miss} distributions for the chosen benchmark, respectively. The CMS results can be found in the Figure 1 of Ref. [1]. Although the CMS results are shown for a slightly different scenario with a number of i$n = 3$ extra dimensions instead of $n = 6$, the resulting distributions are expected to only very mildly depend on this parameter. According to the CMS paper [1], the product of the acceptance and the efficiency only vary in the 33.4-37.4% range when n is varied between 3 and 6. In Figure 1, we have normalized the curves to 1 and good agreement has been found, with the exception of the small E_T^γ region where a large discrepancy has been found.

IV. CONCLUSION

We have validated our reimplementation of the CMS-EXO-12-047 monophoton analysis by making use of `Pythia8` to simulate ADD events that can be compared to results provided by CMS. We have employed the standard `Delphes3` program for the modeling of the detector simulation, with the `MA5tune` CMS detector card shipped with `MadAnalysis5`. Our results agree with the CMS numbers at the 20% level, the dominant source of discrepancy being traced down to issues in correctly modeling photon isolation in our machinery.

The validation of this analysis cannot be performed at a higher level due to the lack of information from CMS.

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