

# New particle Searches in the dijet final state at 13TeV with the ATLAS detector

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## 1 INTRODUCTION

In Standard Model (SM) of particle physics there are six type of quarks up(u), down(d), charm(c), strange(s), bottom(b), top(t). Gluons are the mediator of strong force among quarks. Quarks and gluons are also known as partons. The proton is made-up of partons (2 up quarks, 1 down quark and gluons). When protons collide head-on, like at the LHC, quarks and gluons interact with each other and produce sprays of energetic particles (called hadrons). This spray of energetic particles is known as "JET". New particles can be produced in proton-proton collisions at LHC and decay into quarks and gluons. So we can study the production of new particles that decay into two partons through a "bump" in the dijet mass distribution.

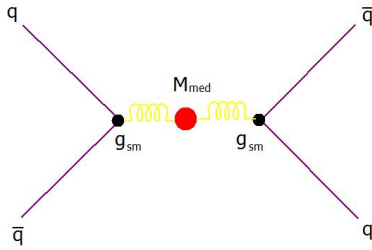


Figure 1: Process

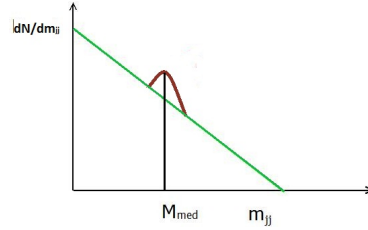


Figure 2: Cartoon of the "bump" in the dijet mass distribution

## 2 OBJECTIVES OF THIS PROJECT

In this project we study the SM background to new particles beyond the SM, in the dijet mass distribution. We are producing the same SM background by two different event generators (Madgraph+Herwig and Pythia stand-alone) at 13TeV and comparing their properties.

### 3 Used Simulation Software

I have used Madgraph and Pythia as event generator to generate the events. MadAnalysis is used for the analysis of output files of both generator.

#### 3.1 Madgraph (Madevent+herwig)

MadGraph is an event generator software for high energy physics processes. The basic structure of the event generation in MadGraph follows:

Theoretical Model  $\rightarrow$  Feynman Rules  $\rightarrow$  Generation of Events (at parton level)  $\rightarrow$  Particles, products of showering and hadronisation (Pythia or Herwig)  $\rightarrow$  Detector simulation(Delphes)  $\rightarrow$  Event display

In MadGraph5 to produce the background sample I have used these commands

- `cd MADGRAPH5`
- `./bin/mg5_aMC`
- `p p > j j [QCD]`
- `output SAMPLE`
- `launch`

After launch I have used only leading order (LO) contribution and put a parton-level generation cut  $PT > 40$ , `nevent = 40000` by editing `run_card.dat`. For LO, jet matching is automatically done by MadGraph.

First events were produced at parton level and then I hadronized the parton level events using Herwig as a Monte-Carlo (MC) generator by editing `run_card.dat`. Both output files produced at parton level and after hadronization are analysed in MadAnalysis.

#### 3.2 Pythia

Pythia is other event generator in high energy physics that I used to generate the events. I have used PYTHIA stand alone to produce the same background process by using the following command: `" - -collision-energy 13000 -c "HardQCD:all = on" -c "PhaseSpace:pTHatMin = 40.0" -c "PhaseSpace:bias2Selection = on" -c "PhaseSpace:bias2SelectionPow = 5.0" -n 40000 -o "`.

#### 3.3 Madanalysis

MadAnalysis is a software package for analysing events from event generations in standard formats. Madanalysis is used to analyse the output files produce by Madgraph (MadEvent+Herwig) and Pythia (standalone). I have used the reconstruction mode of MadAnalysis to do the plots. I have used these command to reconstruct the jets:

- `cd MadAnalysis`
- `./bin/ma5 -R`

- `set main.fastsim.package = fastjet`
- `set main.fastsim.algorithm = antikt`
- `set main.fastsim.ptmin = 10`
- `set main.fastsim.radius = 0.5`
- `set main.lumi = 20`
- `set main.normalize = lumi`
- `import sample/Pythia.hepmc as pythia`
- `import sample/HERWIG6.hep.gz as madevent`
- `set main.stacking_method = superimpose`
- `plot PT(j[1])`
- `plot PT(j[2])`
- `plot M(j[1] j[2])`
- `submit PLOTS`

## 4 Analysis

### 4.1 Comparing Madgraph event at parton level and after hadronization

In this part of the project we have compared the transverse momentum of leading jet (PT j[1]), the transverse momentum of the sub-leading jet (PT j[2]) and the Invariant mass of the dijet (M j[1] j[2]) system, using the output file produced at parton level (MadGraph) and hadronized (MadGraph+Herwig).

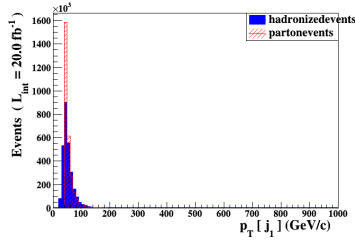


Figure 3: transverse momentum of leading jet.

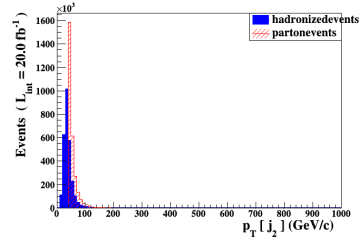


Figure 4: transverse momentum of sub-leading jet.

We can see in the plots that events produce at parton level their PT j[1] and PT j[2] has a smaller spread than the hadronized events shows spreading in distribution. The two outputs have a different behaviour, also because the MC-subtraction terms to avoid double-counting when the hadronic shower is activated on top of the hard scattering are included in the parton level result. We have to remember that the parton-level result are not physical; they need to be showered before they can be used in a physical analysis.

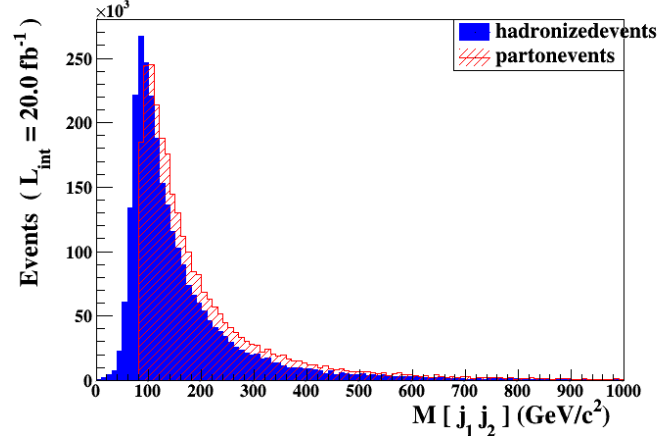


Figure 5: Invariant mass distridution of leading and sub-leading jets.

## 4.2 Comparing Madevent = (Madgraph+herwig) and Pythia stand alone

For the analysis of SM backgrounds from two different generators, the anti-kT jet finding algorithm is used with a cone radius of 0.5 to reconstruct the jet in Madanalysis. In the analysis I have set the minimum jet pT cut to 10. I have compared these three variables: the transverse momentum of leading jet, the transverse momentum of sub-leading jet and the invariant mass of dijet of output file produce by two different simulation programs.

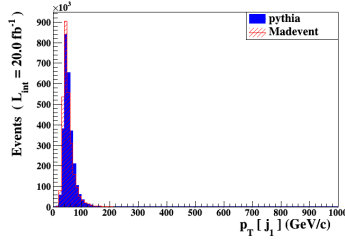


Figure 6: transverse momentum of leading jet.

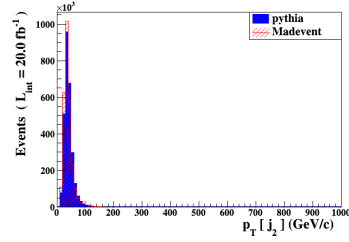


Figure 7: transverse momentum of sub-leading jet.

In the above plots; we have compared transverse momentum distribution of leading jet( $PT\ j[1]$ ) and transverse momentum distribution of sub-leading jet( $PT\ j[2]$ ) of background produced by (MADGRAPH+HERWIG) and PYTHIA. In both cases these distributions look quite similar which confirm that we have produced the same background by two different tools (or codes).

Now we have compared the third property which is the observable for the study of new physics beyond the Standard Model: the dijet mass distribution.

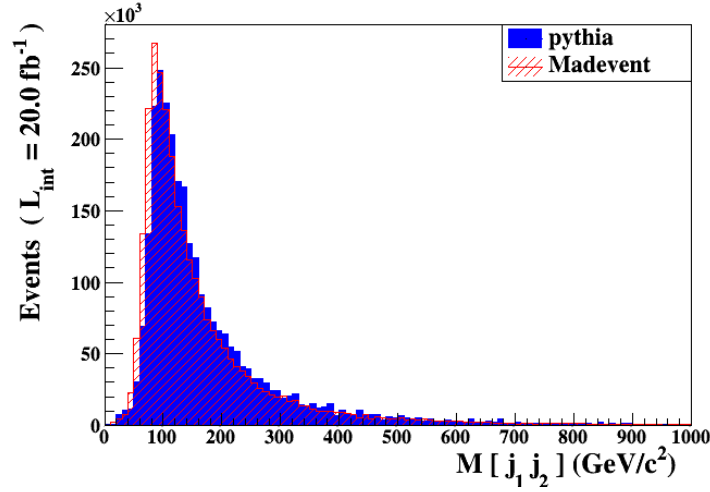


Figure 8: Invariant mass distridution of leading and sub-leading jets.

In the plot it is very clear that distribution of Madevent (MADGRAPH + HERWIG) and PYTHIA have same kind of distribution which matches quite well, but there are still differences. This means that whenever we perform a search and use a background estimation derived from simulation, we should account for these differences using a systematic uncertainty.

## 5 CONCLUSION

What I have learned from this project is that:

- if the events are generated using MadGraph, we should not use the output file generated at parton level for physics analysis. The output file produced after showering is physical, and it should be used for the next step of the analysis.
- When comparing the (Madgraph+herwig) events and Pythia stand alone events we found that the kinematic distributions match quite well. So from these two output files one from (Madgraph+herwig) second from Pythia alone , any output file can be used as SM background for the "bump" hunting in dijet mass distribution, but we should account for the differences using a systematic uncertainty related to the shower modelling.

## 6 References

- MadGraph 5 : Going Beyond, arXiv:1106.0522v1 [hep-ph]
- The anti-k t jet clustering algorithm, arXiv:0802.1189v2 [hep-ph]
- Search for new phenomena in the dijet mass distribution using pp collision data at s = 8 TeV with the ATLAS detector [ <http://arxiv.org/pdf/1407.1376.pdf>]

- <https://launchpad.net/mg5amcnlo>
- <https://madanalysis.irmp.ucl.ac.be/>
- <http://home.thep.lu.se/~torbjorn/pythiaaux/present.html>
- <https://twiki.cern.ch/twiki/bin/view/Sandbox/VanderbiltSUSY>
- <http://amcatnlo.web.cern.ch/amcatnlo/list`detailed2.html>