University of Sussex

open data ATLAS

# SEEKING THE INVISIBLE

## DARK MATTER SEARCH WITH JUPYTER NOTEBOOK

The Abdus Salam International Centre for Theoretical Physics
Physics Without Frontiers

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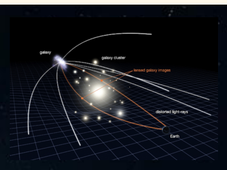
## Introduction



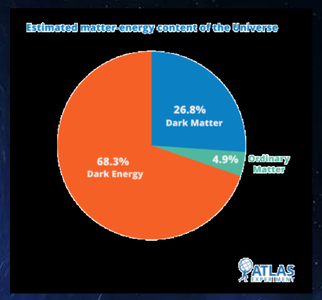
**Dark Matter is a hypothesized type of matter that does not interact with the electromagnetic force.**

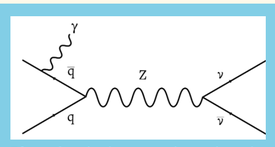
**It is invisible because it does not emit, absorb, or reflect light.**

**All visible matter comprises only %5 of the universe.**

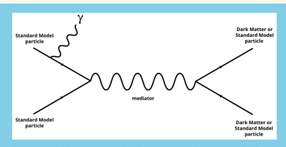
**The observations or simulations involving dark matter don't give a clear indication of what dark matter is made of.**

**Thus, it has become one of the important issues to know more about dark matter to understand about our universe.**




Z boson decaying into a neutrino-antineutrino pair where the Z boson is produced in association with a photon




New mediator particle decaying into a pair of dark matter particles, produced in association with a photon.

**Data table for DM_300**

| | totalWeight | sum_lep_charge | lead_lep_pt | sublead_lep_pt | mll | ETmiss | dRll | dphi_pTll_ETmiss | fractional_pT_difference | ETmiss_over_HT | N_bjets |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.041298 | 0 | 113.229602 | 37.342027 | 91.874195 | 124.311867 | 1.568130 | 3.036052 | 0.047148 | 0.599380 | 0 |
| 1 | 0.042212 | 0 | 89.615922 | 31.122283 | 87.832052 | 105.491891 | 1.697633 | 3.083360 | 0.032974 | 0.873724 | 0 |
| 2 | 0.061651 | 0 | 112.169008 | 65.336797 | 87.876299 | 170.239734 | 1.030940 | 3.133160 | 0.028335 | 0.959066 | 0 |
| 3 | 0.067919 | 0 | 108.710273 | 93.620266 | 89.113704 | 221.266453 | 0.872517 | 3.052979 | 0.005579 | 0.940918 | 0 |
| 4 | 0.085524 | 0 | 85.937289 | 40.265805 | 88.230021 | 132.649672 | 1.573029 | 2.554065 | 0.040406 | 0.613755 | 0 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 486 | 0.078610 | 0 | 78.753086 | 29.951379 | 89.358800 | 83.341703 | 1.647736 | 3.060483 | 0.232954 | 0.766681 | 0 |
| 487 | 0.073187 | 0 | 94.828984 | 45.348254 | 90.757753 | 127.364039 | 1.360179 | 3.128948 | 0.014387 | 0.908593 | 0 |
| 488 | 0.077624 | 0 | 121.088344 | 37.106082 | 90.977416 | 162.607063 | 1.432372 | 3.068947 | 0.195871 | 1.027894 | 0 |
| 489 | 0.075400 | 0 | 166.182469 | 79.551945 | 86.336938 | 252.362641 | 0.740335 | 3.119813 | 0.038813 | 1.026973 | 0 |
| 490 | 0.073081 | 0 | 63.209102 | 50.553152 | 74.461895 | 81.179734 | 1.437425 | 3.139421 | 0.056863 | 0.713591 | 0 |

491 rows × 11 columns

**To study whether there is dark mater or not precisely we use one column from the DM_300 table that is lead_lep_pt**

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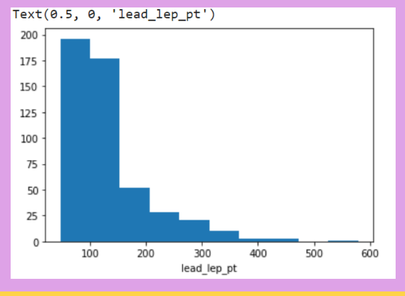
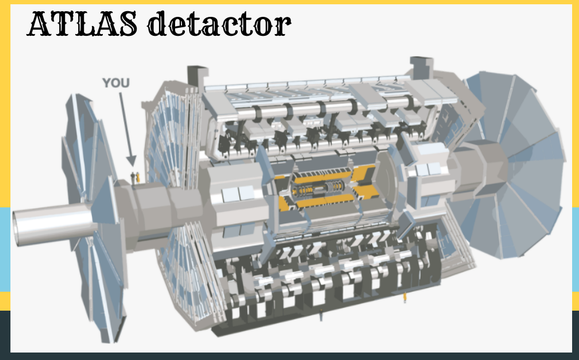



**In LHC, we know the initial conditions of the collisions such as the type and energy of the particles being collided. We can also create a large number of collisions and observe them in a controlled environment. These are essential features for detecting dark matter particles at experiments like ATLAS.**



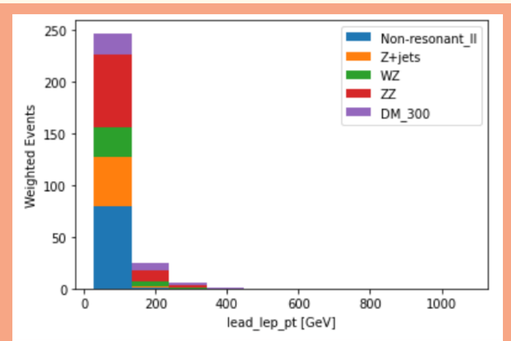

**LHC recreates bigbang like condition in small scale but the detector is not able to detect the dark matter.**

**Momentum is conserved in the collision and we apply this concept while experimenting in LHC.**

**It is challanging to calculate the momentum of all the particle in near perfect resolution. Failure to do so leads to fake missing momentum. Can say missing momentum are dark matter.**

**The most popular example of a more complete theory that includes a dark matter candidate is supersymmetry (SUSY). SUSY was one of the first dark matter models to be studied extensively at the LHC**

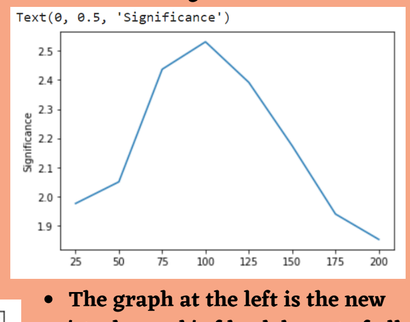
The Dark Matter process we'll be looking for is 'DM_300', which we call "signal". The others are processes that may look like our signal, so we have to consider them as well, which we call "backgrounds", they are 'Non-resonant_ll', 'Z+jets', 'WZ' and 'ZZ'

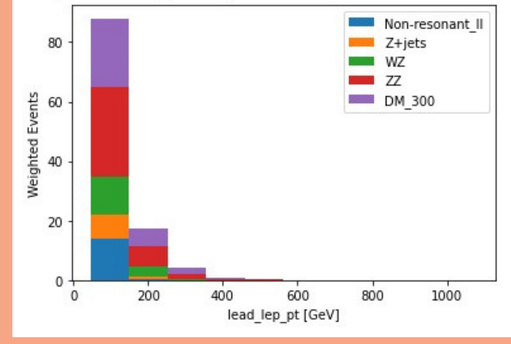



- **The graph at left represents the 'stack graph' of lead_lep_pt of all the signals of Non-resonant_ll, Z+jets, WZ, ZZ and DM_300.**
- **We can see that there is more number of backgrounds below 100 GeV. Thus the significance we will get is less than 3.**
- **In particle physics, we declare that we have evidence for a process such as Dark Matter if we find a "significance" over 3.**

$$\text{significance} = \frac{\text{total signal weights}}{\sqrt{\text{total background weights}}}$$

- **The graph at right represents the significance of the DM_300 with the backgrounds.**
- **Since there are backgrounds with high values compared to the value of the signal, we can see the significance is less than 3.[no dark matter]**
- **To get the significance we remove the background implementing cuts as shown below**




- **The graph at the left is the new 'stack graph' of lead_lep_pt of all the signals of Non-resonant_ll, Z+jets, WZ, ZZ and DM_300 after applying the cuts.**
- **The value of signal weight is 31.11 and total background is 29.23**
- **We get significance above three**

```
29.2292242230559
31.106055426064305
```

## Result

**The significance number after applying the cut is 5.76.**

**Thus, we declare that we have evidence for a process such as Dark Matter in DM_300 signal.**

**The nature of dark matter is currently still unknown, many experimentalists and theorists are on the quest to better understand it.**