Application of a novel Machine Learning approach for the search of heavy resonances with topological features at the LHC

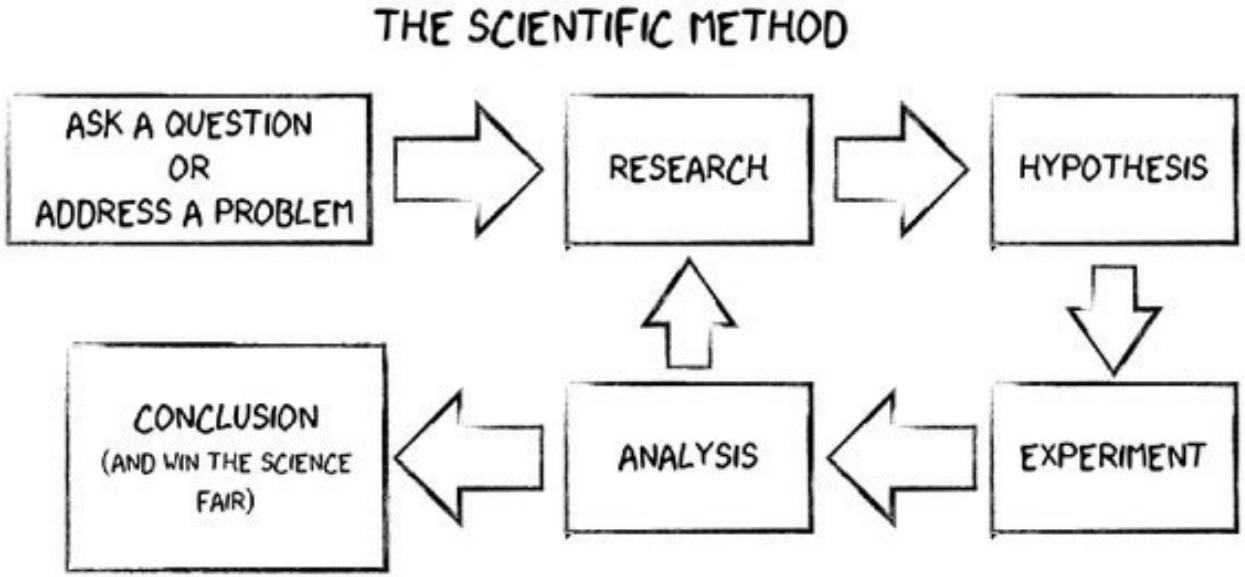
SALAH-EDDINE DAHBI[1]

[1] School of Physics, University of the Witwatersrand, Johannesburg, South Africa.

High Energy Particle Physics workshop (HEPP2020)
University of Venda

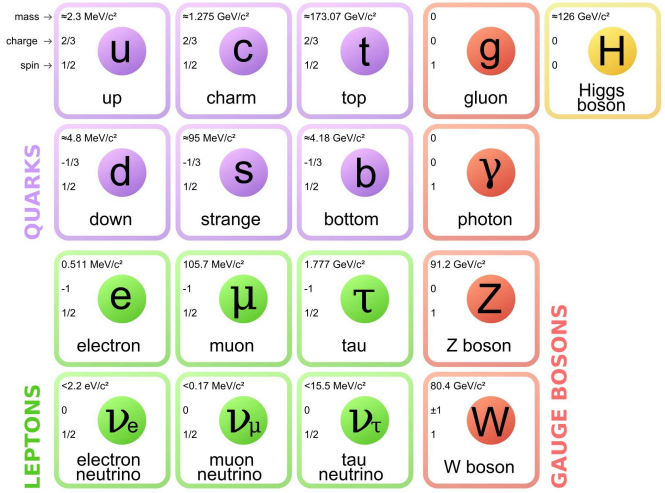
January 29-31, 2020

Outline



The Standard model of particle physics

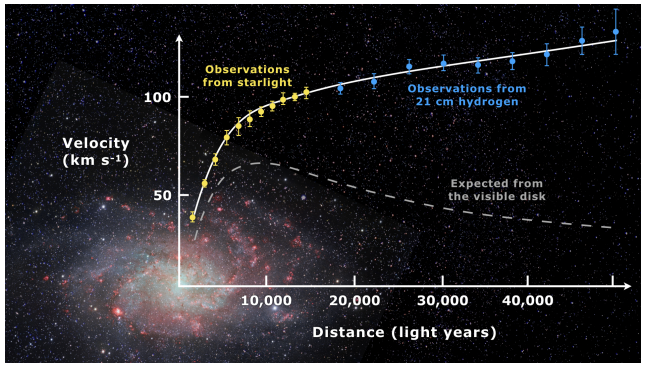
- The Standard model of particle physics (SM) has been developed in 1967, to describe the elementary particles and their interactions.



- The SM explains about 5% of the energy
- The SM can not explain the full elementary particle phenomenology of the universe :

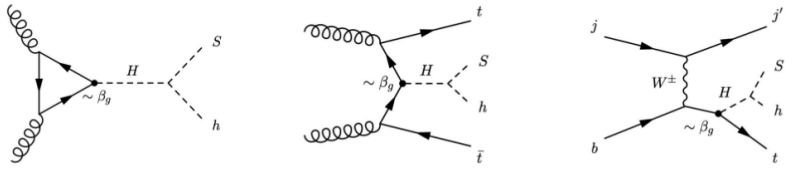
The rotation of the galaxies indicates the exciting of D.M .

- Quadratic divergence of the Higgs mass.
- The nature of the neutrino mass.
- The Gravity is not included in the SM.
- Dark matter ! Dark energy !
- ...



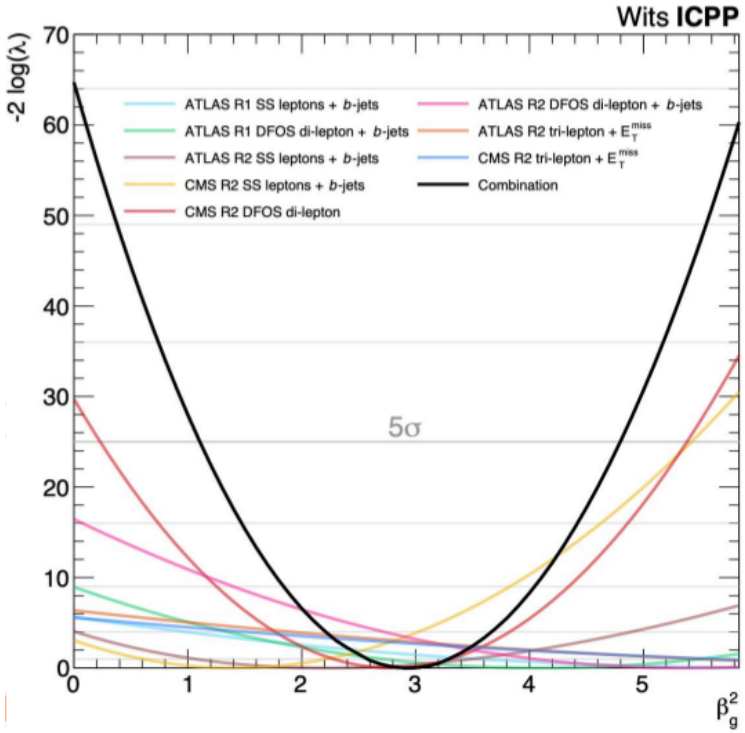
Beyond the Standard Model

- Many theories beyond the Standard Model (BSM) are introduced to explain the SM deficiencies.
- Among these theories, a simplified model predicting a heavy scalar of mass in the range of 250-280 GeV (H), which interacts strongly with the SM Higgs boson and an additional Higgs-like scalar singlet (S) has been introduced.
- This model might aid in the understanding of Dark Matter which makes about 27% of the Universe.



JHEP 1910 (2019) 157

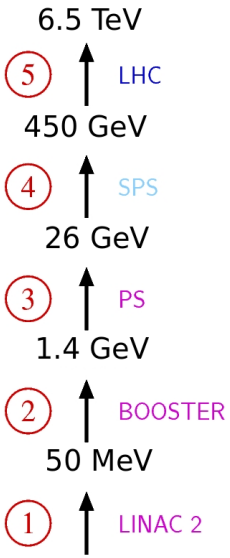
Selection	Best-fit β_g^2	Significance
ATLAS Run 1 SS $\ell\ell$ and $\ell\ell\ell$ + b-jets	6.51 ± 2.99	2.37σ
ATLAS Run 1 OS $e\mu$ + b-jets	4.09 ± 1.37	2.99σ
CMS Run 2 SS $e\mu$, $\mu\mu$ and $\ell\ell\ell$ + b-jets	1.41 ± 0.80	1.75σ
CMS Run 2 OS $e\mu$	2.79 ± 0.52	5.45σ
CMS Run 2 $\ell\ell\ell + E_T^{miss}$ (WZ)	9.70 ± 3.88	2.36σ
ATLAS Run 2 SS $\ell\ell$ and $\ell\ell\ell$ + b-jets	2.22 ± 1.19	2.01σ
ATLAS Run 2 OS $e\mu$ + b-jets	5.42 ± 1.28	4.06σ
ATLAS Run 2 $\ell\ell\ell + E_T^{miss}$ (WZ)	9.05 ± 3.35	2.52σ
Combination	2.92 ± 0.35	8.04σ

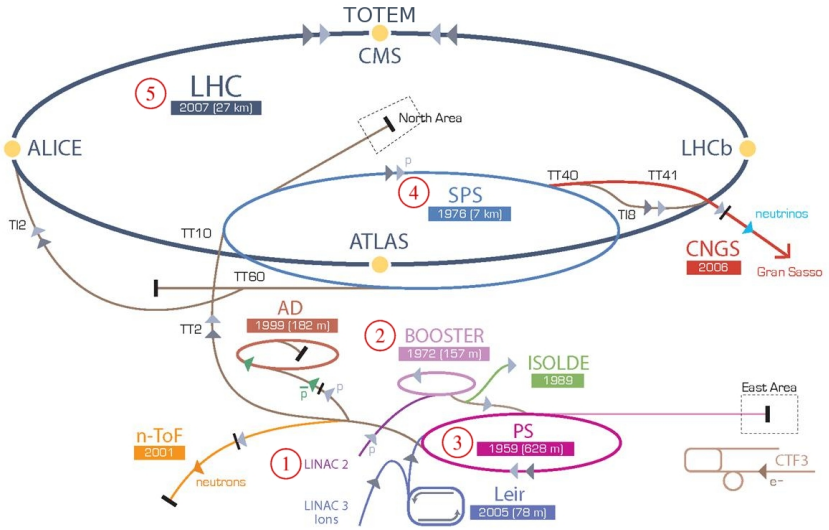


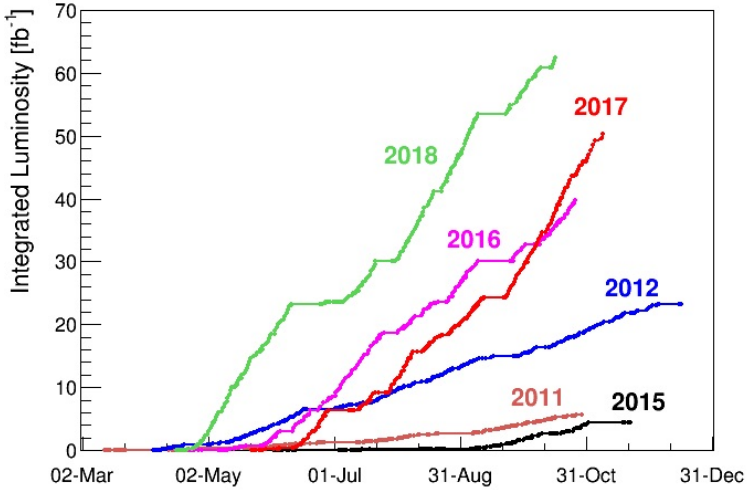
- The simplified model seems to describe the discrepancies in different corners of the phase-space with large differences in cross-sections (See Bruce's and Stefan's talks).

The Large Hadron Collider

- The Large Hadron Collider (LHC) is a 26.7 Km circular accelerator located at CERN.
- Beams of protons travel in opposite direction and collide at four points along the ring : ATLAS, ALICE, CMS and LHCb.



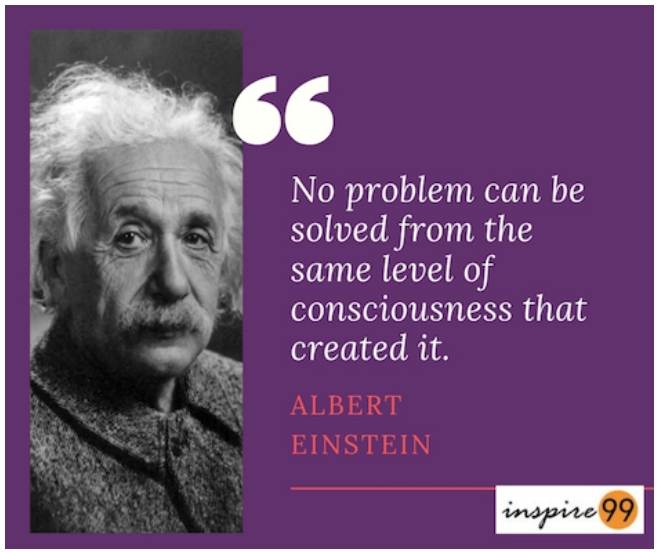




LHC Beam parameter	2010	2011	2012	2015	2016	2017	2018
Beam energy	3.5	3.5	4.0	6.5	6.5	6.5	6.5
Number of protons per bunch $N_b \times 10^{11}$	1.0	1.3	1.5	1.0	1.1	-	-
Number of bunch per beam n_b	368	1380	1380	2244	2200	-	-
$\int_0^T \mathcal{L}\mathbf{dt}$	48.1 pb^{-1}	5.46 fb^{-1}	22.8 fb^{-1}	4.2 fb^{-1}	38.5 fb^{-1}	50.2 fb^{-1}	65 fb^{-1}

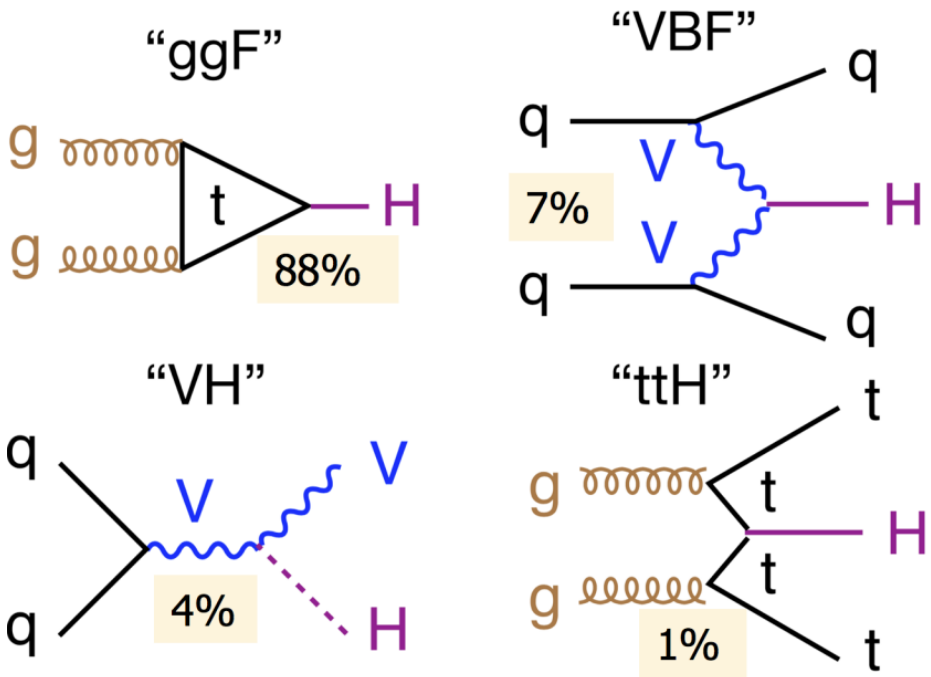
Why Machine learning ?

- The power of artificial intelligence is so incredible and it will change virtually every aspect of our world in some very deep ways.
- Machine learning is a method of data analysis that automates analytical model.
- Using Deep Neural Networks (DNN) and computing power to find complex patterns in data.
- These neural networks learn how to do complex analyses.
- Their algorithms can be employed in the problem of classifying signal and background events with high precision.

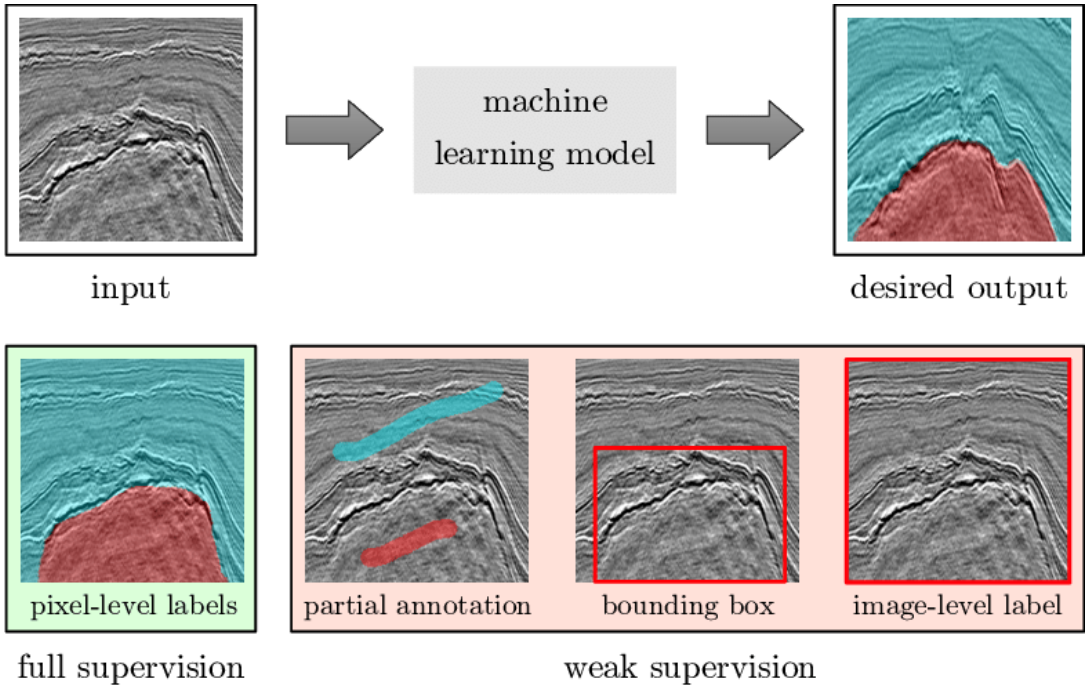


Methodology

- Strategy : Combining weak-supervision and full-supervision learning in conjunction with Deep Neural Network algorithms.
- Evaluation of the strategy on the production of SM Higgs boson decaying to a pair of photons inclusively and in exclusive regions of phase space.
- After verifying the ability of the methodology to extract different Higgs signal mechanisms, a search for new phenomena in high-mass diphoton final states is setup for the LHC.
- Classifying events as Signal or Background :
  - Signal (Monte Carlo Period 15-17) : ggH, WH, ZH, $VBFH$, $t\bar{t}H$.
  - Background (Monte Carlo 15-17) : $\gamma\gamma$, γjet, $V\gamma$, $V\gamma\gamma$.



The difference between full supervision and weak supervision.



Full supervision

- Sampld 1 : Background in Side Band :
  115 $GeV < m_{\gamma\gamma} < 120\ GeV$ ||
  130 $GeV < m_{\gamma\gamma} < 135\ GeV$.
- Sampld 2 : Signal Mass window :
  120 $GeV < m_{\gamma\gamma} < 130\ GeV$.

Weak supervision

- Sampld 1 : Background Side Band :
  115 $GeV < m_{\gamma\gamma} < 120\ GeV$ ||
  130 $GeV < m_{\gamma\gamma} < 135\ GeV$.
- Sampld 2 : Signal and backg. in the Mass window :
  120 $GeV < m_{\gamma\gamma} < 130\ GeV$.

Results

" Unless you are a student, you cant show any result which makes use of ATLAS samples. This restriction does apply to Post-Docs ".

Results

14:50

Testing the search for new resonances in the di-photon channel with topological requirements on the production of the Standard Model Higgs boson at the LHC 15m

Unlike supervised learning which is known to assume a full knowledge of the underlying model, weak supervision allows with partial knowledge to extract new information from the data.
The objective of this study is to set up the search for heavy resonances at the electroweak scale with topological requirements. These resonances are expected to be produced with different production mechanisms. In this case we will be focusing on the searches for new resonances in the di-photon final state. The performance of weak supervision methodology will be tested in the production of the Higgs boson in the Standard Model using deep neural networks. This will then be compared to the performance of the full supervision approach.

Speaker: Mr Nalamotse Joshua Choma (University of the Witwatersrand (ZA))

"Results can be discussed in the next talk".