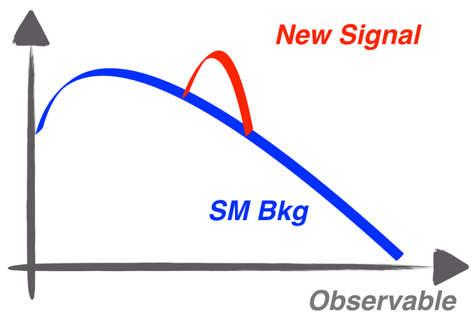
12th International Workshop on Boosted Object Phenomenology, Reconstruction and Searches in HEP (BOOST 2020 webinars)
20-24 July 2020

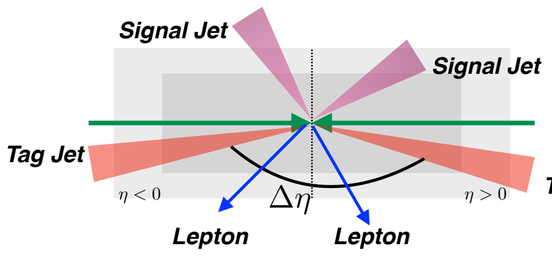
ML approach to VBF event topology classification: Recurrent Neural Network based on jets information

New physics searches

- Searches in order to exploit theories beyond the Standard Model of particles physics.
- Diboson resonances —> semi-leptonic channel as experimental signature.
- Look for a bump in data.

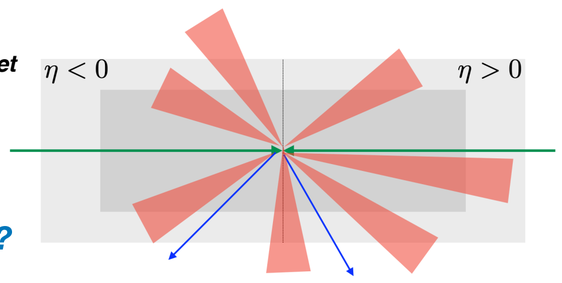


VBF topology



How do we expect to be a VBF event?

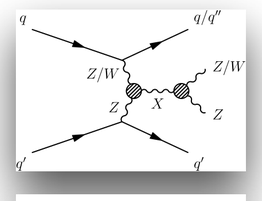
How do we see an event in the detector?

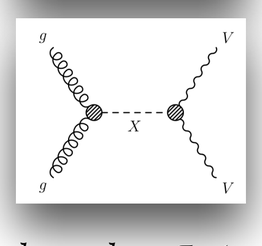


Recurrent Neural Network (RNN)

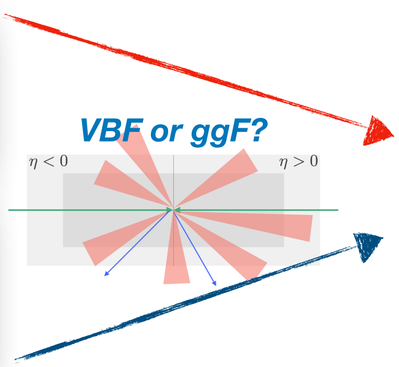
- RNN in order to use variable-length inputs (4-momentum of the jets) in order to learn the VBF or the ggF topology.

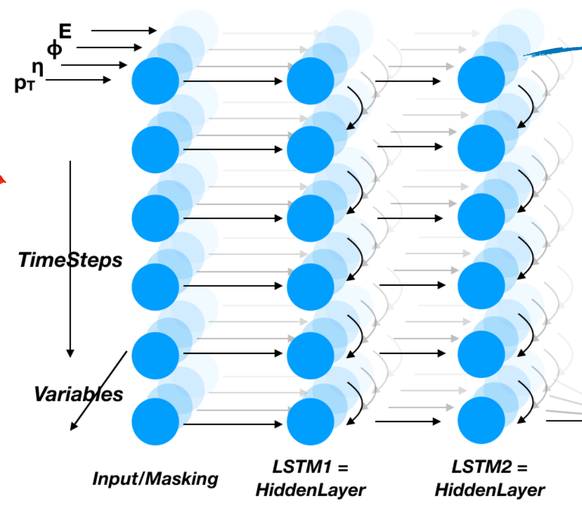
Vector Boson Fusion (VBF)



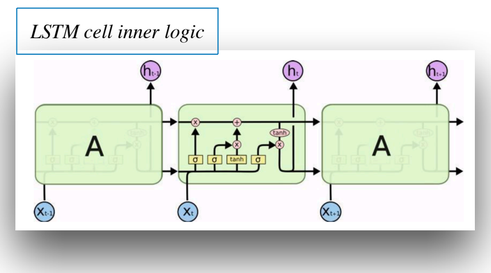


gluon-gluon Fusion (ggF)





LSTM cell inner logic

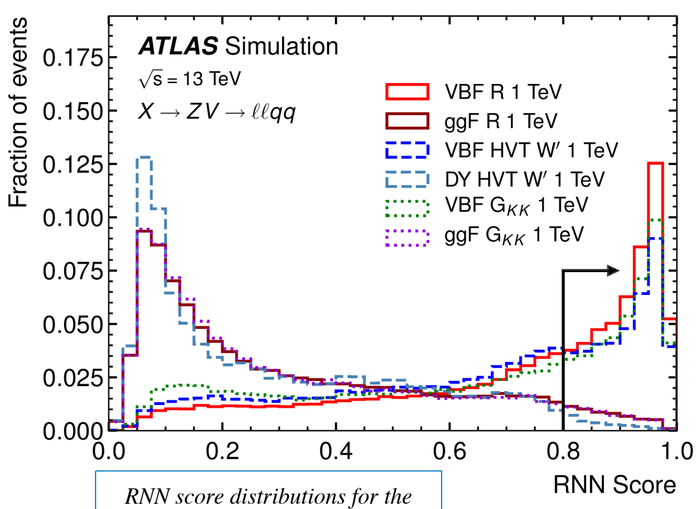


- RNN is an architecture able to solve problem in which the inputs are a recurrent sequence of information.
- The LongShortTimeMemory (LSTM) is a special kind of RNN, capable of learning long-term dependencies.
- Each LSTM cell has an inner structure able to learn properly the input time sequences during the learning phase.

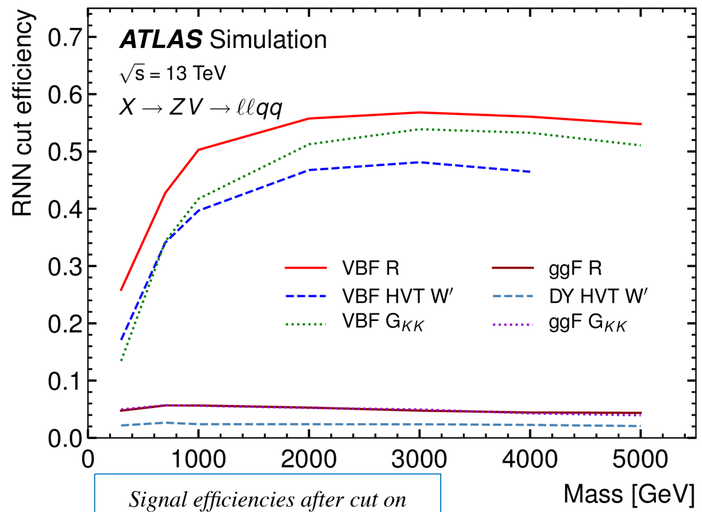
- RNN model used has been published on HEP Data
  - https://doi.org/10.17182/hepdata.93922.v1/t7
- Architecture and weights are available to reproduce results outside ATLAS collaboration.

VBF/ggF classification performances

- Machine Learning approach shows better performances with respect to any traditional cut-based analysis:
  - the VBF signal efficiency improves of 10% (@0.5 TeV) and of 60% (@3 TeV)
- The VBF topology is rather independent of the signal hypothesis:
  - one single model trained on spin-0 1 TeV mass hypothesis
  - only jets information allows complete independence by the lepton channel
  - the net learned only the VBF/ggF topologies and it works for different masses, leptons, spins hypotheses



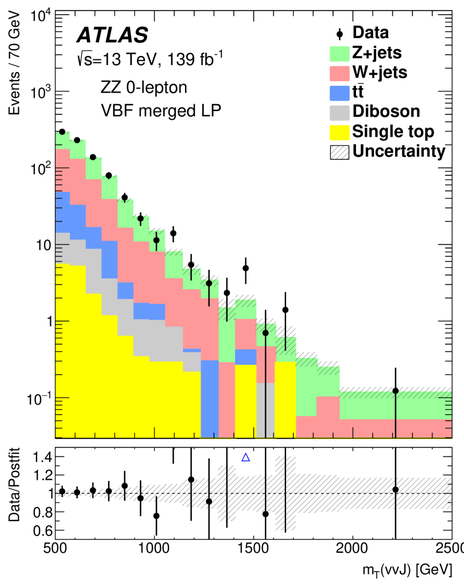
RNN score distributions for the truth ggF events and for the truth VBF events.

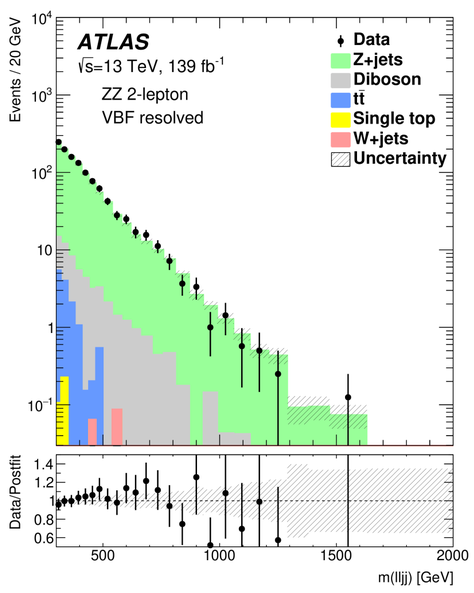


Signal efficiencies after cut on RNN score as function of the mass and spin hypothesis.

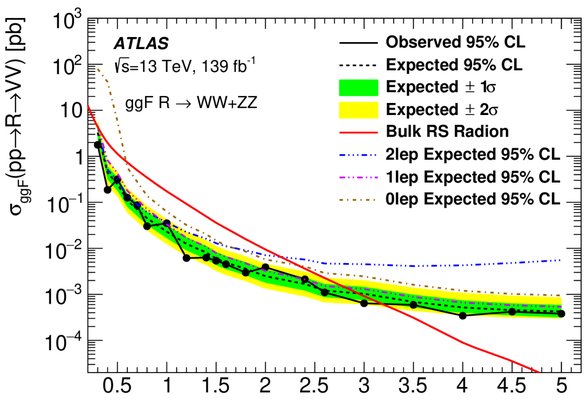
New resonances interpretation

- The RNN approach has been tested in X —> VV —> vv/lv/ll + qq searches.
- Several models (Radions, HVT, RS Gravitons) have been tested both in VBF or ggF/DY categories.

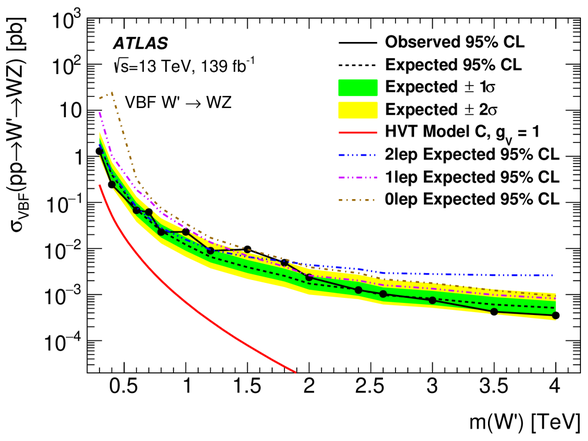




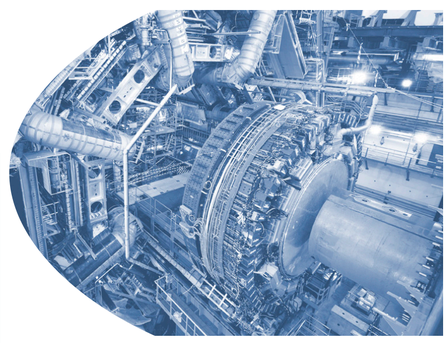
Comparisons of the observed data and expected background distributions of the final discriminants of the VBF category for vvJ (left) and lljj (right) final states. The middle panes show the ratios of the observed data to the background predictions.



Observed (black solid curve) and expected (black dashed curve) 95% CL upper limits on σ×B(R→ WW+ZZ) at √s=13 TeV for the ggF production of a spin-0 boson in the RS Radion model as a function of its mass, combining ℓℓqq, ℓνqq and νvqq final states.



Observed (black solid curve) and expected (black dashed curve) 95% CL upper limits on σ×B(W'→ ZW) at √s=13 TeV for the VBF production of a W' boson in the HVT model as a function of its mass, combining ℓℓqq, ℓνqq and νvqq final states.



Look at more info at links:

- https://arxiv.org/abs/2004.14636
- https://arxiv.org/abs/1808.03314
- https://github.com/YaleATLAS/CERNDeepLearningTutorial/blob/master/deeplearning_intro.ipynb
- https://keras.io/

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