Probing the Higgs boson-gluon coupling at e^+e^- colliders

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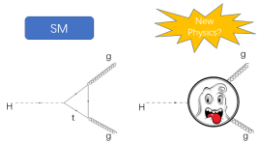
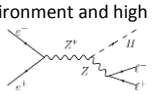
Motivation

Higgs boson was discovered in 2012 at the LHC. The precision measurement of Higgs boson-gluon effective coupling is very necessary to search the new physics.

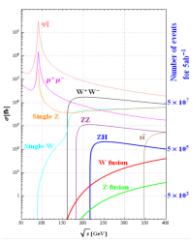


$$\kappa_g = \frac{g(hgg)}{g(hgg)^{SM}}$$

Lepton colliders (CEPC, FCC-ee and ILC) have clean environment and high luminosity.

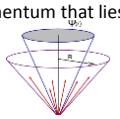


The lepton pair can be easily identified and the Higgs boson can be reconstructed with the recoil mass method.

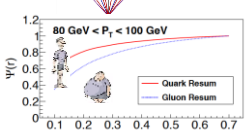


New jet substructure observables

Jet Energy Profile (JEP) is defined as the fraction of jet transverse momentum that lies inside a sub-cone of size r (< R).



$$\psi(r) = \frac{1}{N_j}\sum_j \psi_j(r) = \frac{1}{N_j}\sum_j \frac{\sum_{r_i<r} p_{T,i}(r_i)}{\sum_{r_i<R} p_{T,i}(r_i)}$$



Quark initiated jets radiate less and are narrower with a quickly raising JEP. Gluon initiated jets radiate more and are broader with a slowly raising JEP.

Construct a generic observable with accumulated JEP

$$Z^N(r) = \frac{\sum_j(\psi_j + a)}{\sum_j^{SM}(\psi_j + a)} \quad \begin{cases} \Lambda^N(a=0) \\ Y^N(a=-1) \end{cases}$$

The uncertainty of κ_g around the SM prediction κ_g = 1 is

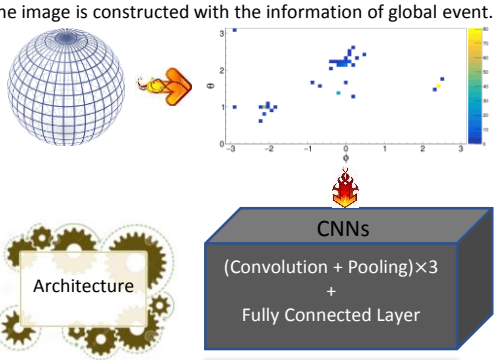
$$\delta\kappa_g^Z = \delta\kappa_g^N\left[\left(\frac{\sigma(r)}{\psi_g + a}\right)^2 + f_g + f_q\left(\frac{\psi_q + a}{\psi_g + a}\right)^2 + f_{BG}\left(\frac{\psi_{BG} + a}{\psi_g + a}\right)^2\right]^{1/2}$$

The minimal uncertainty is obtained at $\partial\delta\kappa_g^Z/\partial a = 0$,

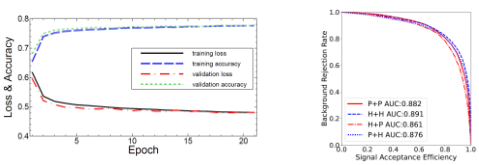
$$\delta\kappa_g^Z = \delta\kappa_g^N\left\{1 - f_B\left[1 + \frac{\sigma^2(r)}{(\psi_g - \psi_q)^2 f_B}\right]^{-1}\right\}^{1/2}.$$

Convolutional Neural Networks (CNNs) Method

The image is constructed with the information of global event.



The stability and performance of CNNs



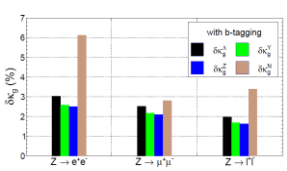
The features of images are actually extracted without overfitting. P(H)+P(H) is training with PYTHIA (HERWIG) data and testing with PYTHIA (HERWIG) data.

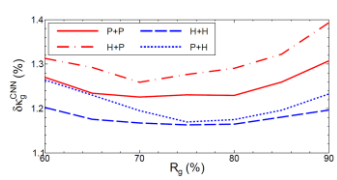
The uncertainty of κ_g after using CNNs at each point on the ROC curve is

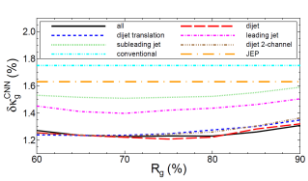
$$\delta\kappa_g^{CNN} = \frac{\sqrt{N_g R_g + N_B R_B}}{2N_g R_g}.$$

Results

MC simulation for $\sqrt{s} \sim 250GeV, \int Ldt \sim 5ab^{-1}$ in the channel of a Z boson decaying to lepton pair.







- Using the optimal observable constructed with the JEP, $\delta\kappa_g$~1.63%.
- Using CNNs method, $\delta\kappa_g$~1.23% (Pythia) and $\delta\kappa_g$~1.16% (Herwig).
- The difference between the expected $\delta\kappa_g$ using PYTHIA and HERWIG data is about 0.1%.
- The jet substructure information is very important for distinguishing signal and background processes.