Nikhef

Amsterdam, The Netherlands, April 30 - May 3, 2024

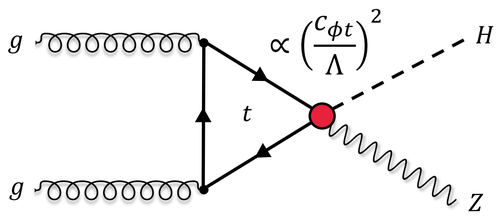
EUROPEAN AI FOR FUNDAMENTAL PHYSICS CONFERENCE
EuCAIFCon 2024

Towards the First Time Measurement of $gg \to ZH$ at the LHC Using Transformer Networks

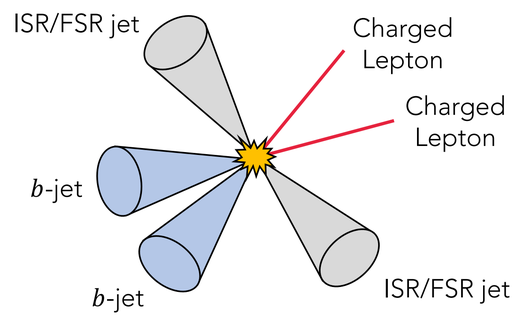
Geoffrey Gilles, Wouter Verkerke, Marcel Vreeswijk

Motivations

- Associated production of a Higgs boson with a vector boson is a primary process for studying Higgs-boson properties at the LHC.
- The gluon-initiated $gg \to ZH$ process is of particular interest due to its sensitivity to new physics operators, especially $O_{\phi t}$ in the context of Standard Model Effective Fields Theory (SMEFT).



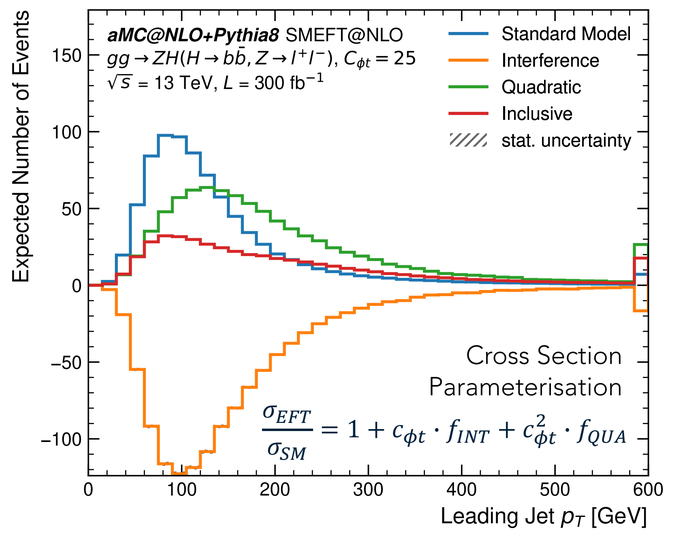
Learning from Event Final State

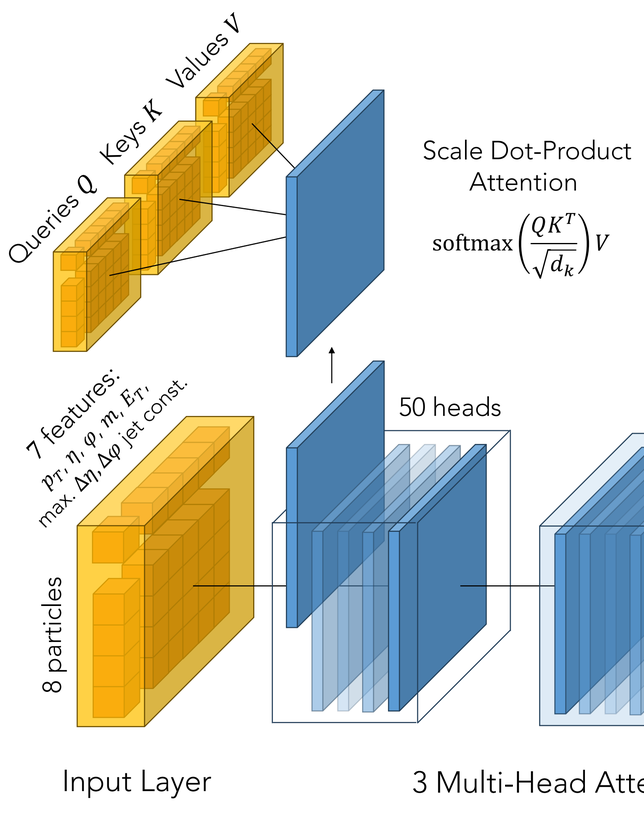


- Exploit kinematic features of particle-collision final-state objects to discriminate signal from background and assess SMEFT contributions.
- Main background characterised by $qq \to ZH$ process, closely mirroring $gg \to ZH$ signal.

The $gg \to ZH$ signal in SMEFT

- Structured into the sum of Standard Model, Interference & Quadratic terms.



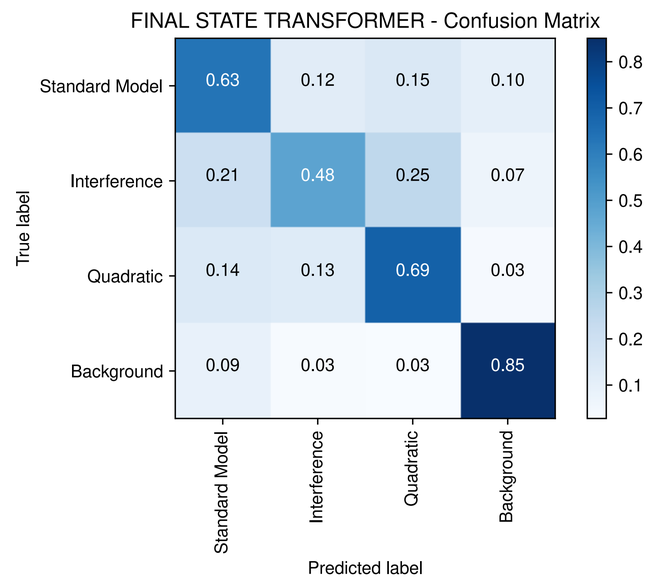


Final State Transformer

- Machine Learning development toolkit built upon Transformer encoders.
- Leverage the power of multi-head attention mechanism to capture long-range dependencies & contextual information in sequences of particle-collision event final-state objects.

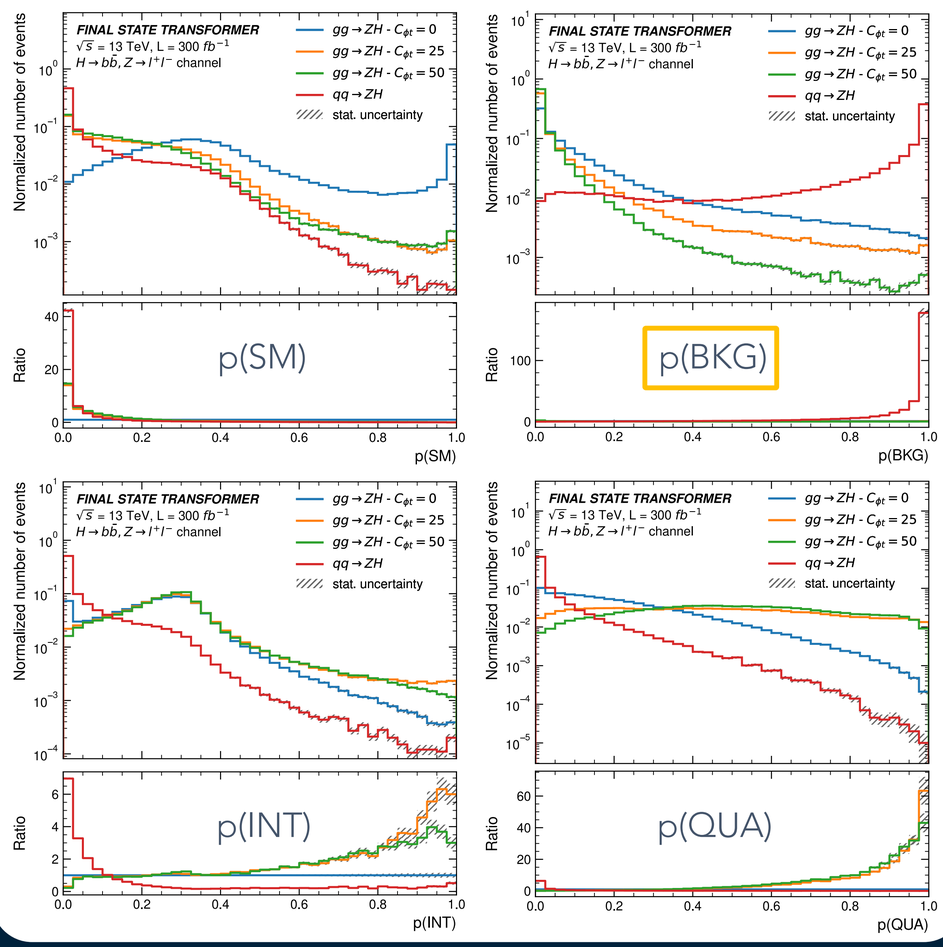
Multi-Class Classification Training

- Discriminate Standard Model, Interference and Quadratic components of $gg \to ZH$ as well as $qq \to ZH$ background.



Output Probabilities

- Powerful 4D phase space to discriminate signal from background and infer SMEFT coefficients.



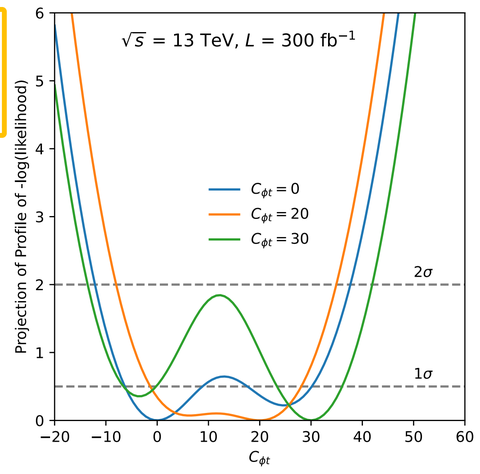
Exploring Simulation-Based Inference (SBI)

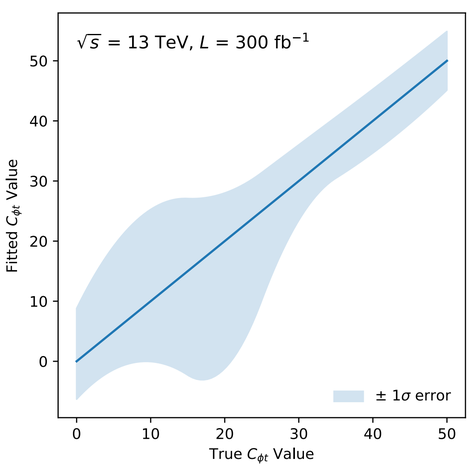
- Allow to construct likelihood functions that capture intricacies of SMEFT interactions and detector responses in unprecedented details.
- Proof of concept using most discriminating Transformer output probability (i.e. p_{BKG})

Likelihood function based on $obs = p_{BKD}$ pdfs for SM, INT, QUA and BKG events

$$\mathcal{L} = P_{obs}^{SM} + c_{\phi t} \cdot P_{obs}^{INT} + c_{\phi t}^2 \cdot P_{obs}^{QUA} + \mu_{BKG} \cdot P_{obs}^{BKG}$$

NB: Incorporates ATLAS detector acc. effects and luminosity scaling as well in probability templates





Conclusions

- SBI, empowered by Transformer networks, has the potential to greatly enhance sensitivity across large range of LHC measurements.
- Prospective study exploiting $gg \to ZH$ events shows that $c_{\phi t}$ coefficient could be constrained to [-5, 10].

Nikhef