Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Bundesministerium für Bildung und Forschung

Emmy Noether-Programm DFG Deutsche Forschungsgemeinschaft

CMS

Search for long-lived Higgs decays in CMS: $H \to \pi_\nu \pi_\nu \to b\bar{b}b\bar{b}$

Lisa Benato, Melanie Eich, Zhiyuan He, Gregor Kasieczka, Karla Peña

karla.pena@cern.ch

University of Hamburg

LHC LLP Workshop, Machine Learning WG
27 May 2019

Theoretical motivation and experimental signatures

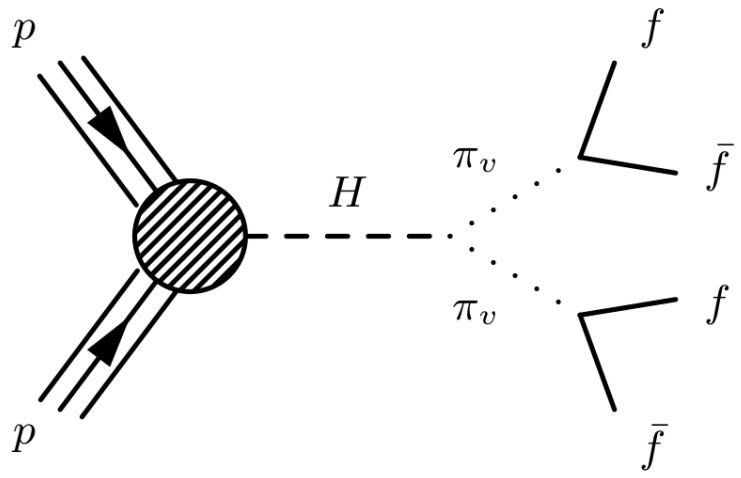
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Motivation:

- Hierarchy problem of the Standard Model
- Strong contraints on new colored particles

Higgs portal models:

- Dark sector, neutral under all SM gauge groups.
- Higgs boson mixing with its dark partner
  $\rightarrow$ predicted to decay to dark particles (π_ν)



Csaki, et al.
arXiv:1508.01522

Benchmark model:

- Dark neutral scalars π_ν are long-lived
  $\rightarrow$ Travel finite distance in CMS, then decay back to SM particles (dominantly $b\bar{b}$)
- Depending on $c\tau$ and m_{π_ν}, decays can manifest in different experimental signatures

$c\tau$	Signature at CMS
< 1mm	very short lifetimes $\rightarrow$ b-quark like
1mm to 1m	decay in tracker $\rightarrow$ displaced vertices
1m to 2m	decay in calorimeters $\rightarrow$ trackless jets
up to $\sim$5m	decay in muon system & no inner detector activity

Vector-Boson Fusion:
$\rightarrow$ Large production cross section

Analysis strategies: Cut-based & ML studies

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Cut-based benchmark analyses:

- b-tagging inputs as a function of $c\tau$ and m_π for short lifetimes
- Displaced-jet tagging variables for decays in tracker*
- High-level jet features (e.g. charged hadron energy fraction) for decays in calorimeters

Machine-Learning approach:

Short lifetimes:

- b-tagging variables with relaxed selection criteria as inputs
- Train modified b-tagging algorithm to find double displaced b-jets

Decays in tracker:

- Using the PFCandidates as inputs
- Potentially adapt Deep-Sets framework to tag displaced-jets†

Studies on ML approaches to vertex reconstruction

Decays in calorimeters:

- First approach: Using high-level jet features as inputs to BDT's
- Now, PFCandidates as inputs to LoLa‡

.

*arXiv:1711.09120

†New ML approach, taking a variable-length unordered set of features as input (arXiv:1703.06114, arXiv:1810.05165)

‡DNN architecture working with Lorentz vectors and the Minkowski metric (arXiv:1707.08966)

Thank you!