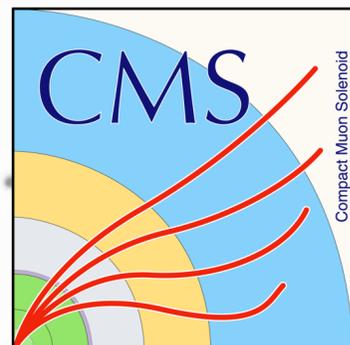


Searching for long lived particles using machine learning with the CMS experiment

First Lithuanian Particle Physics Meeting (LPPM)

V. Čepaitis



09.03.21

Imperial College
London

Introduction

Undergraduate: Manchester University (2013–2017)

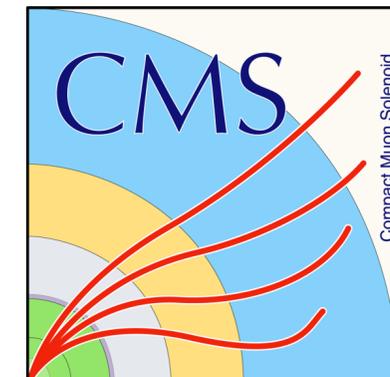


PhD: Imperial College London (2017–)

- ▶ Placement at CERN (2018–)

Imperial College
London

Dissertation title: Search for long-lived heavy neutral leptons using a deep-neural-network based displaced jet tagger



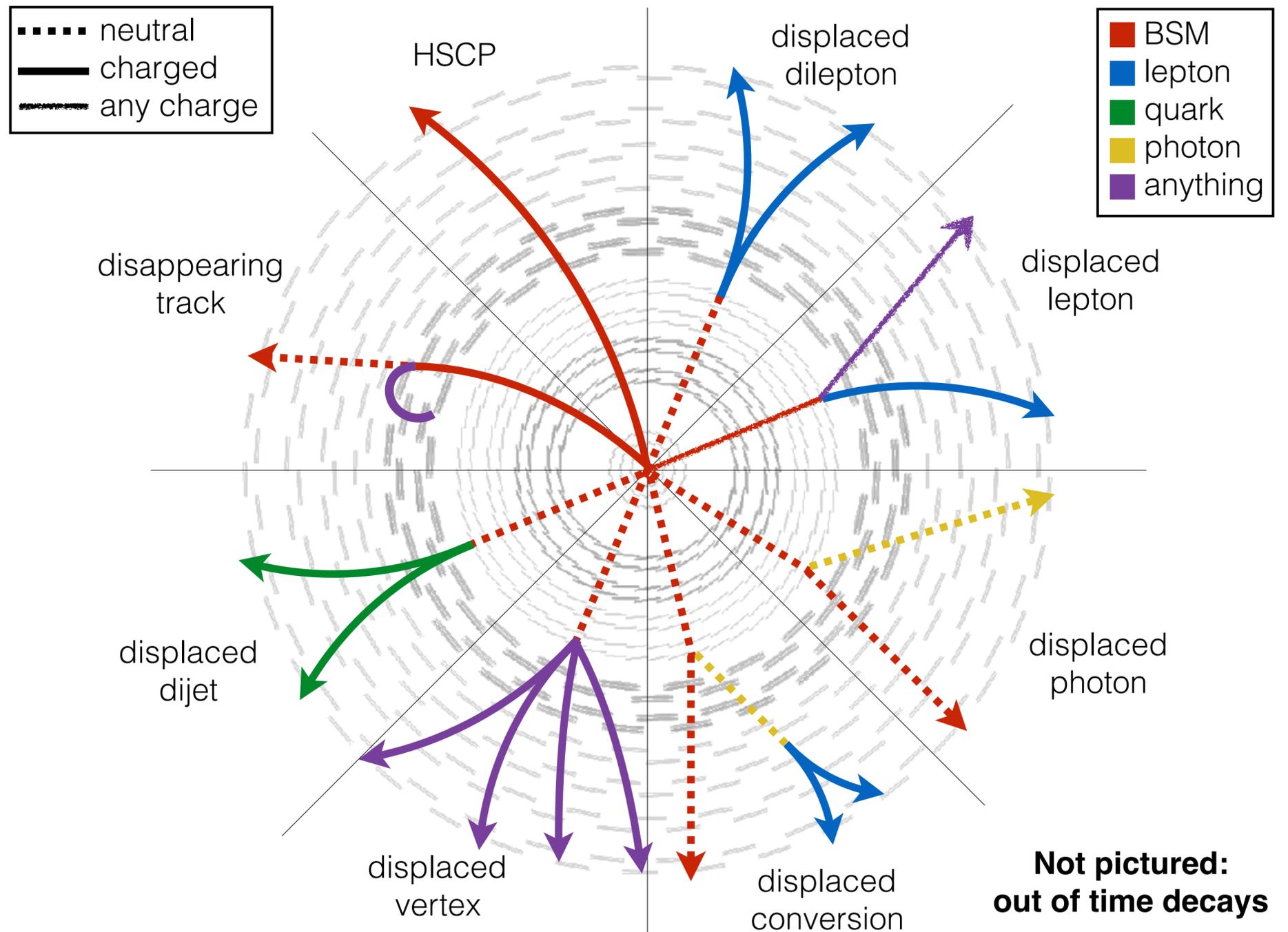
Long lived particles at CMS

A plethora of spectacular signatures

Large amounts of phase space still uncovered

Unconventional signatures, hard to reconstruct/identify physics objects

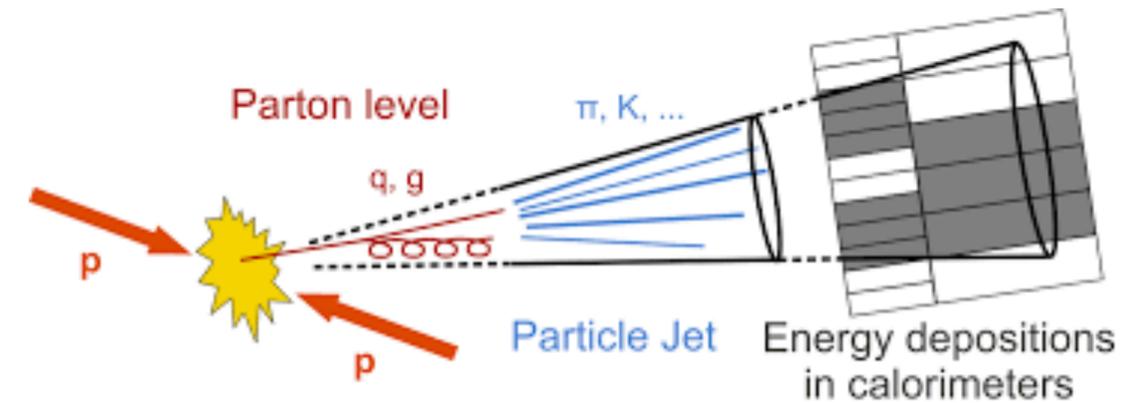
- ▶ Key area to benefit from machine learning methods!



Displaced jets

The experimental signatures of partons are jets
 — collimated sprays of particles

- ▶ Up to 100 particles clustered in a narrow cone



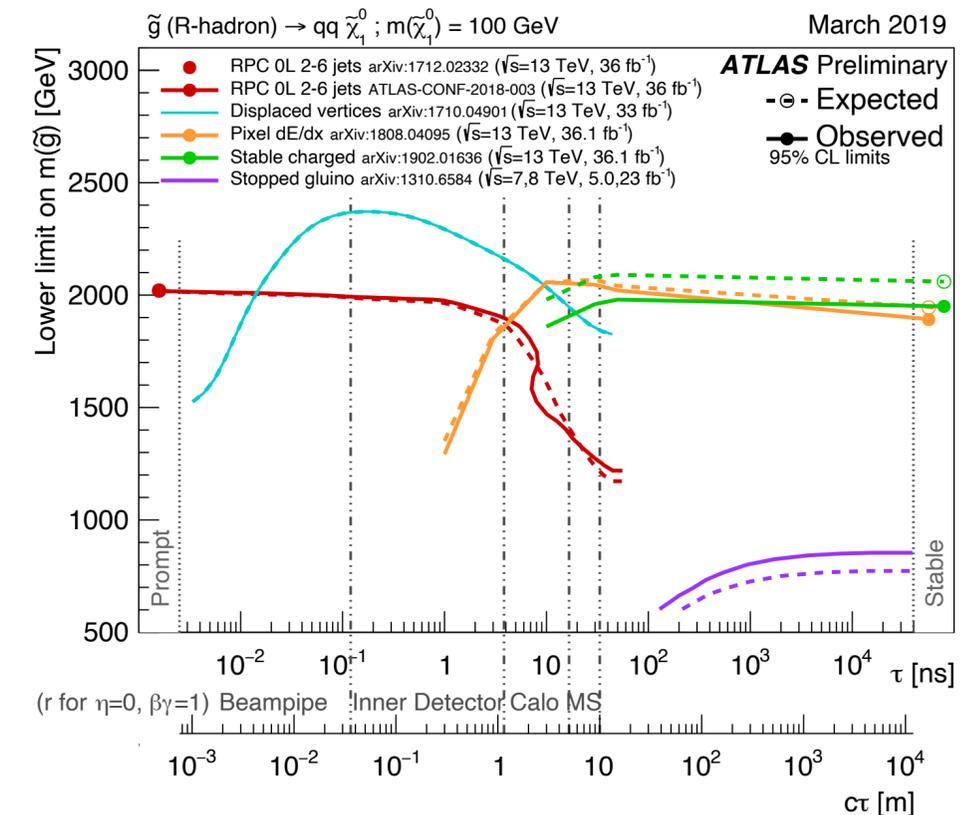
Displaced jets is a dominant signature in many BSM theories

- ▶ Need to be distinguished from regular SM jets

Several complementary approaches: no search has best sensitivity for all lifetimes

- ▶ Displaced vertices
- ▶ Ionisation losses (dE/dx)
- ▶ Decays in the muon systems etc...
- ▶ Machine Learning techniques

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Displaced jet tagger

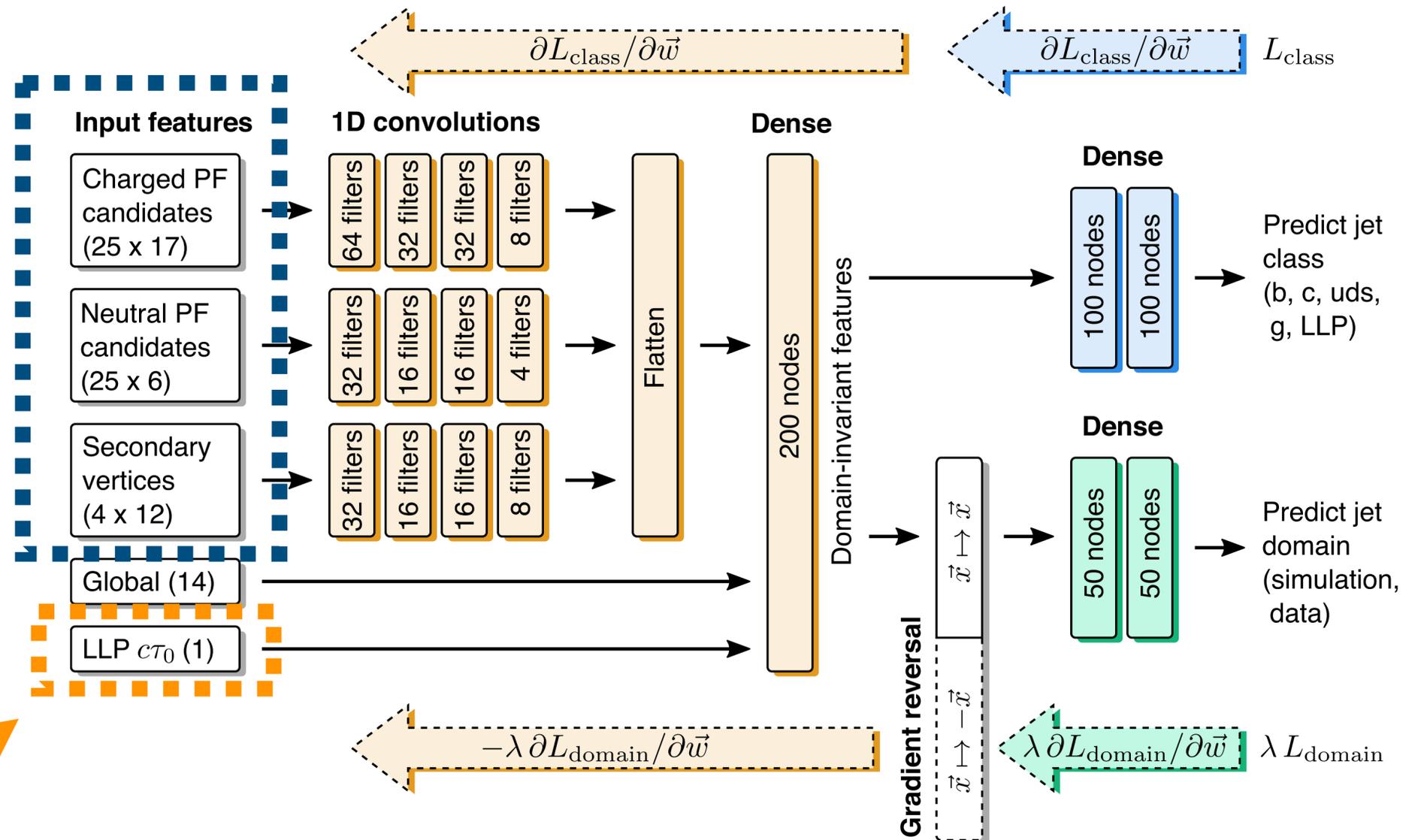
A machine learning algorithm to identify (tag) generic displaced jets

Input features (~700 total!):

- ▶ Charged constituents (tracks)
- ▶ Neutral constituents (calorimeter clusters)
- ▶ Secondary vertices

Displaced jet features strongly depend on LLP $c\tau_0$

- ▶ Parametrise network with LLP $c\tau_0$
- ▶ Allows to identify displaced jets for a wide range of displacements (μm to m)



Domain adaptation

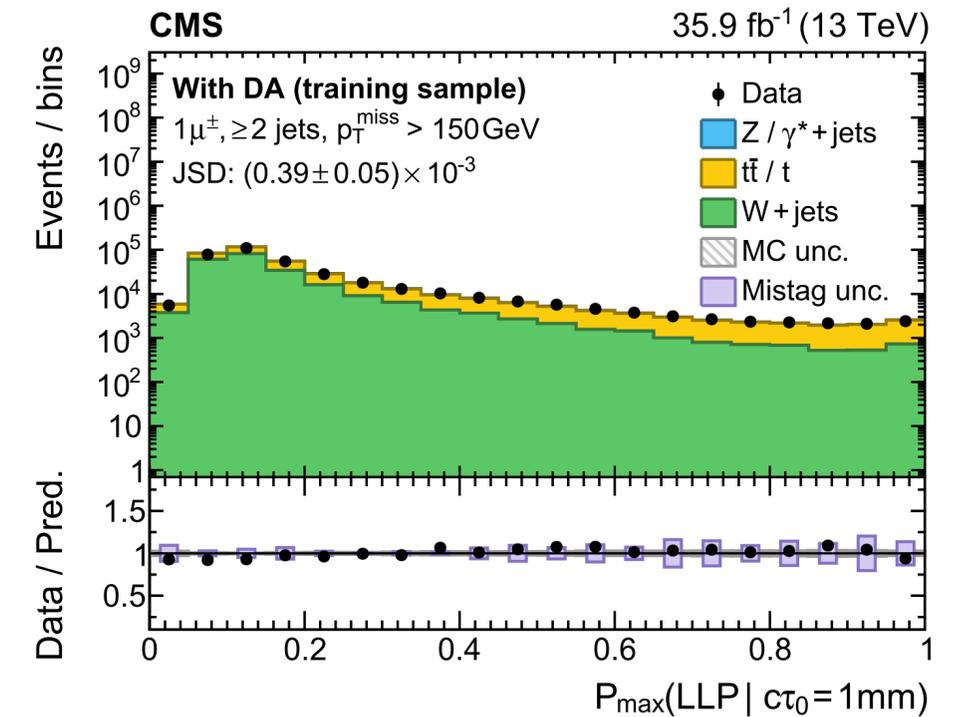
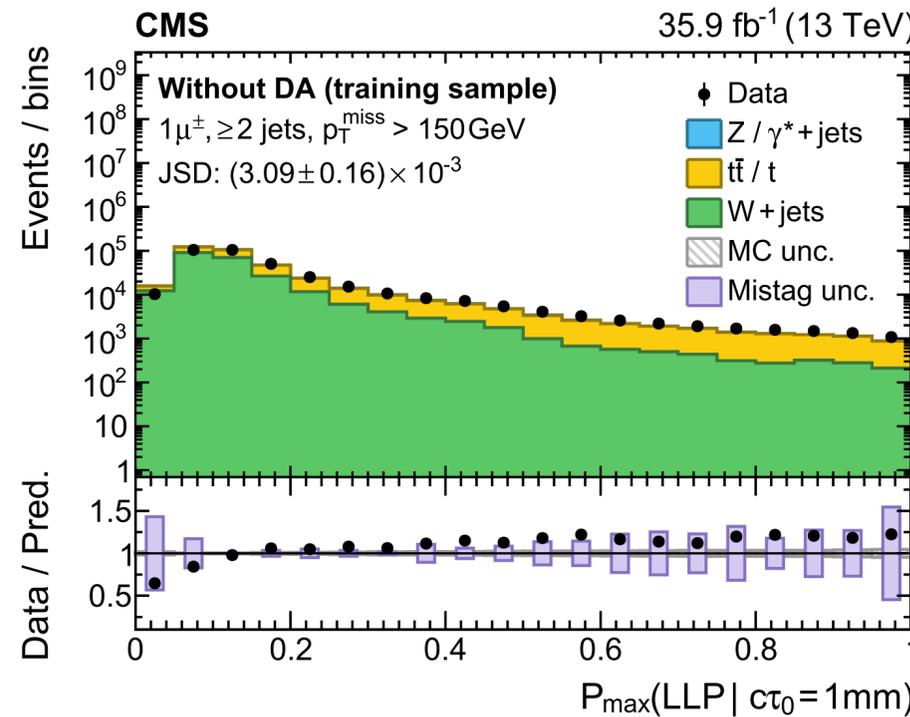
The CMS Collaboration 2020 *Mach. Learn.: Sci. Technol.* **1** 035012

Tagger is trained on simulated signal and background jets

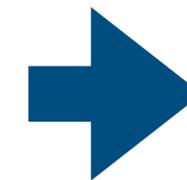
- ▶ Jet input features can be poorly modelled in simulation
- ▶ Tagger can “learn” unphysical features

Use a transfer learning method called domain adaptation (DA)

- ▶ The resulting discriminant is domain invariant
- ▶ The tagger can be applied in a search with much higher confidence!



Without DA



With DA

Much improved agreement between data/simulation in a control region

Searching for Heavy Neutral Leptons

Heavy Neutral Leptons (Right Handed Neutrinos) could:

- ▶ Explain non-zero neutrino masses
- ▶ Provide a dark matter candidate
- ▶ Account for the matter-antimatter asymmetry

HNLs are sufficiently long-lived in the mass range of 1-20 GeV

- ▶ Can decay to displaced jets with leptons
- ▶ Very difficult to discriminate against background low-energy (pileup) QCD jets

Current work: adapt the displaced jet tagger to search for HNL decay products

