چشم‌اندازهای نو در فیزیک بنیادی

به کمک هوش مصنوعی

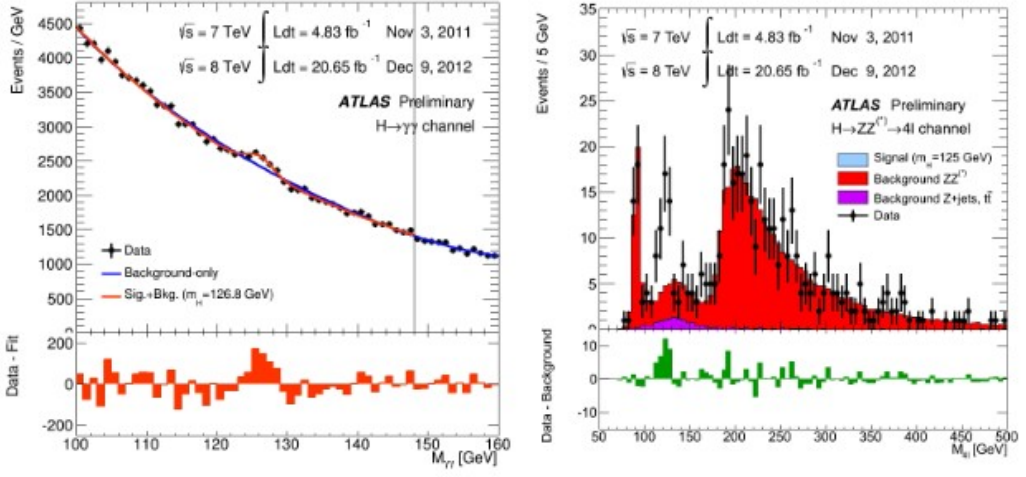
حامد بخشیان

۱۰ خرداد ۱۴۰۳

همایش مسیری به آینده:

دانش و فناوری‌های نوین در فیزیک انرژی‌های بالا

July 2012



ImageNet Classification with Deep Convolutional Neural Networks

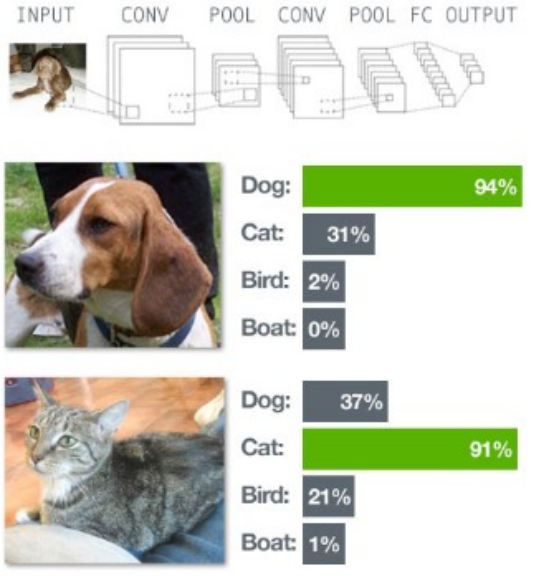
Alex Krizhevsky University of Toronto kriz@cs.utoronto.ca

Ilya Sutskever University of Toronto ilya@cs.utoronto.ca

Geoffrey E. Hinton University of Toronto hinton@cs.utoronto.ca

Abstract

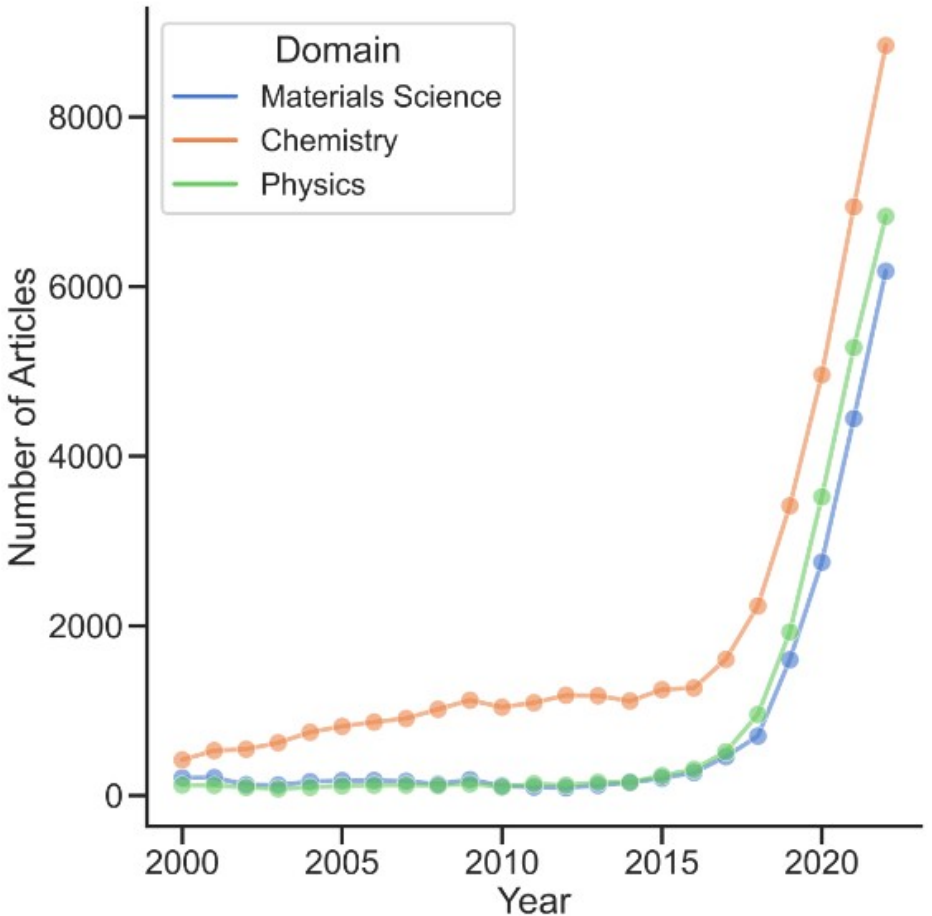
We trained a large, deep convolutional neural network to classify the 1.2 million high-resolution images in the ImageNet LSVRC-2010 contest into the 1000 different classes. On the test data, we achieved top-1 and top-5 error rates of 37.5% and 17.0% which is considerably better than the previous state-of-the-art. The neural network, which has 60 million parameters and 650,000 neurons, consists of five convolutional layers, some of which are followed by max-pooling layers, and three fully-connected layers with a final 1000-way softmax. To make training faster, we used non-saturating neurons and a very efficient GPU implementation of the convolution operation. To reduce overfitting in the fully-connected layers we employed a recently-developed regularization method called "dropout" that proved to be very effective. We also entered a variant of this model in the ILSVRC-2012 competition and achieved a winning top-5 test error rate of 15.3%, compared to 26.2% achieved by the second-best entry.

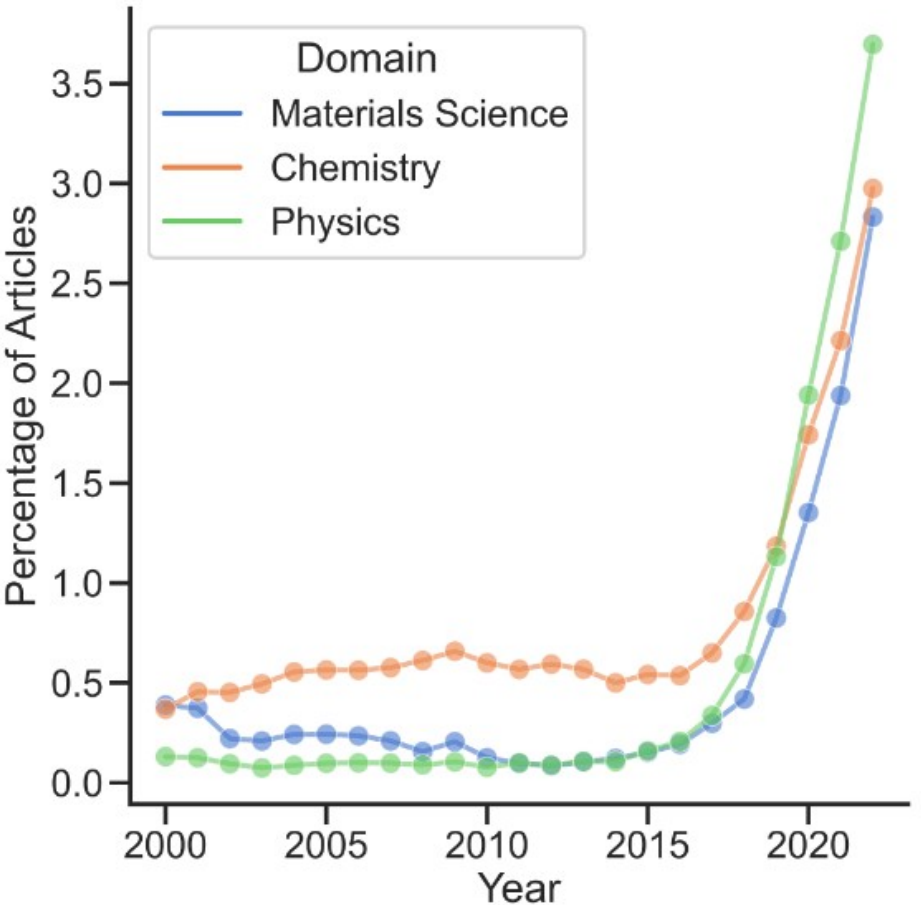


"New directions in science are launched by new tools much more often than by new concepts. The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained."

– FREEMAN DYSON

ML Publications in Science





Ben Blaiszik, "2021 AI/ML Publication Statistics and Charts". Zenodo, Sep. 07, 2022. doi: 10.5281/zenodo.7057437.

- چه انتظاراتی می‌توان از «هوش مصنوعی» در علوم بنیادی داشت
  - سرعت و دقت بیشتر در محاسبات
    - تحلیل/آنالیز داده‌های بیشتر
    - شبیه‌سازی سریع‌تر برهم‌کنش‌ها/رویدادها
  - یافتن راه‌های جدید برای تعبیر نتایج
  - یادگیری مجدد قوانین و تشخیص ناهنجاری‌ها
  - .....

سابقه‌ی یادگیری ماشین در فیزیک ذرات تجربی

The use of neural networks in $\gamma-\pi^0$ discrimination

Wayne S. Babbage and Lee F. Thompson
Department of Physics, University of Sheffield, Sheffield, S3 7RH, England, UK

Received 21 October 1992

Pattern recognition in high energy physics with artificial neural networks – JETNET 2.0

Leif Lönnblad, Carsten Peterson and Thorsteinn Rögnvaldsson
Department of Theoretical Physics, University of Lund, Sölvegatan 14 A, S-223 62 Lund, Sweden

Received 27 August 1991

Higgs search by neural networks at LHC

P. Chiappetta [a], P. Colangelo [b], P. De Felice [b,c], G. Nardulli [b,c] and G. Pasquariello [d]

[a] *Centre de Physique Théorique, CNRS Luminy, Marseille, France*
[b] *INFN, Sezione di Bari, Bari, Italy*
[c] *Dipartimento di Fisica, Università di Bari, Bari, Italy*
[d] *Istituto Elaborazione Segnale Immagini, CNR, Bari, Italy*

Received 10 December 1993
Editor: R. Gatto

JETNET 3.0 – A versatile artificial neural network package

Carsten Peterson [a], Thorsteinn Rögnvaldsson [a], Leif Lönnblad [b]

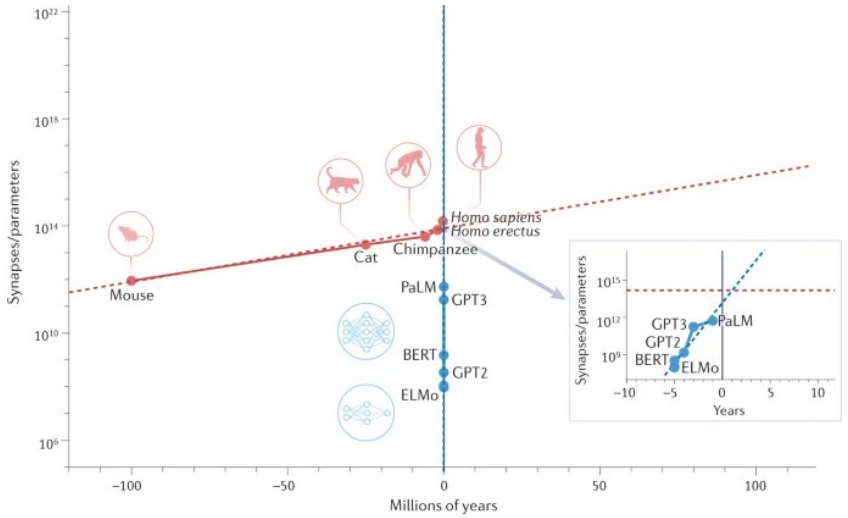
[a] *Department of Theoretical Physics, University of Lund, Sölvegatan 14 A, S-223 62 Lund, Sweden*
[b] *Theory Division, CERN, CH-1211 Geneva 23, Switzerland*

Received 17 January 1994

«یادگیری ماشین» یا «یادگیری عمیق»؟

- یادگیری ماشین: پالایش اولیه داده‌ها با پیش‌فرض های فیزیکی
- یادگیری عمیق: پیش‌فرضهای فیزیکی حداقلی
  - استفاده از داده‌های (خیلی) بیشتر برای آموزش ماشین
  - نیازمند منابع محاسباتی (خیلی) بیشتر
  - یادگیری فیزیک توسط ماشین ؟؟؟؟

یادگیری فیزیک از ماشین



Should artificial intelligence be interpretable to humans?

Nature Reviews Physics volume 4, pages 741–742 (2022)

- رشد بسیار سریع ماشین در ۱۰ سال
- پروژه‌ی Google's Minerva:
  - یادگیری زبان برنامه‌نویسی جدید (latex) توسط ماشین

یادگیری فیزیک از ماشین

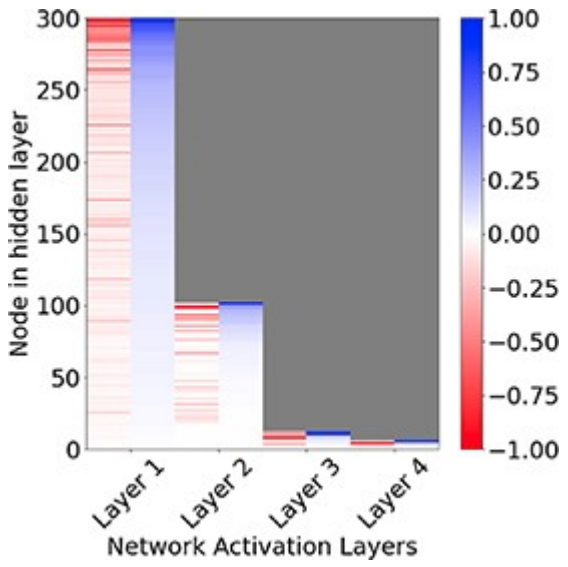
- مثال:
-

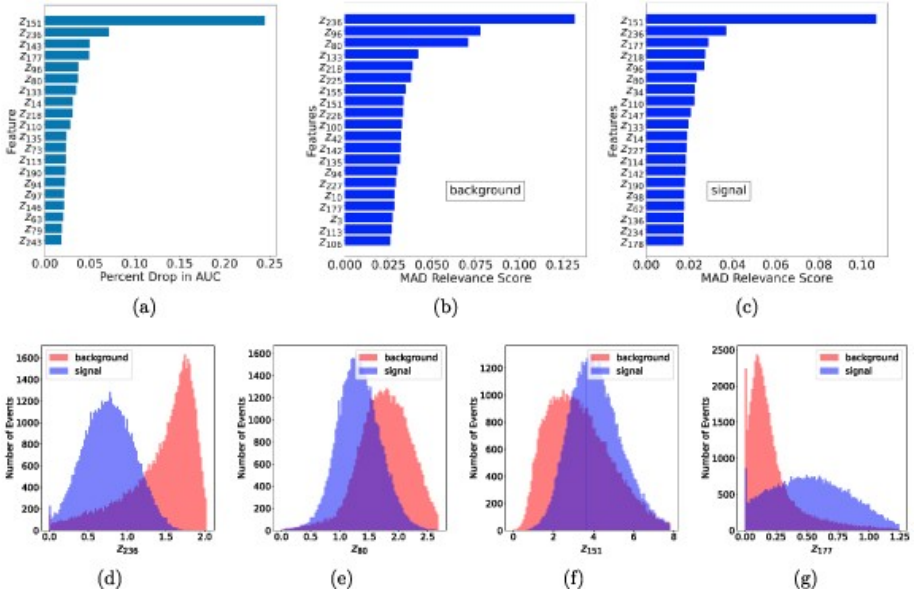
A detailed study of interpretability of deep neural network based top taggers

Ayush Khot[1], Mark S Neubauer[1] and Avik Roy[2,1]

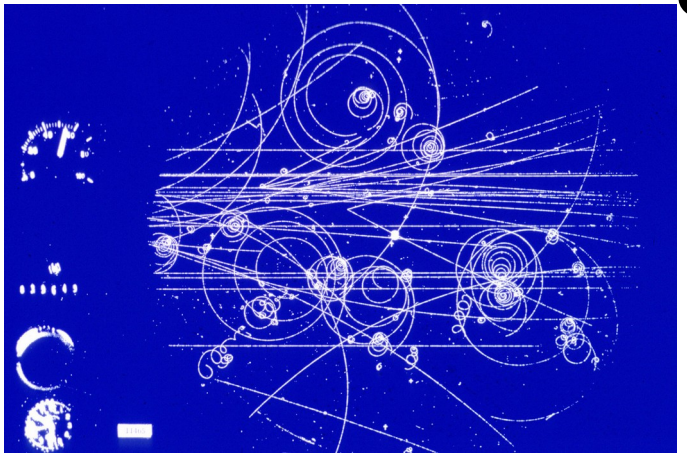
Published 11 July 2023 • © 2023 The Author(s). Published by IOP Publishing Ltd

Machine Learning: Science and Technology, Volume 4, Number 3

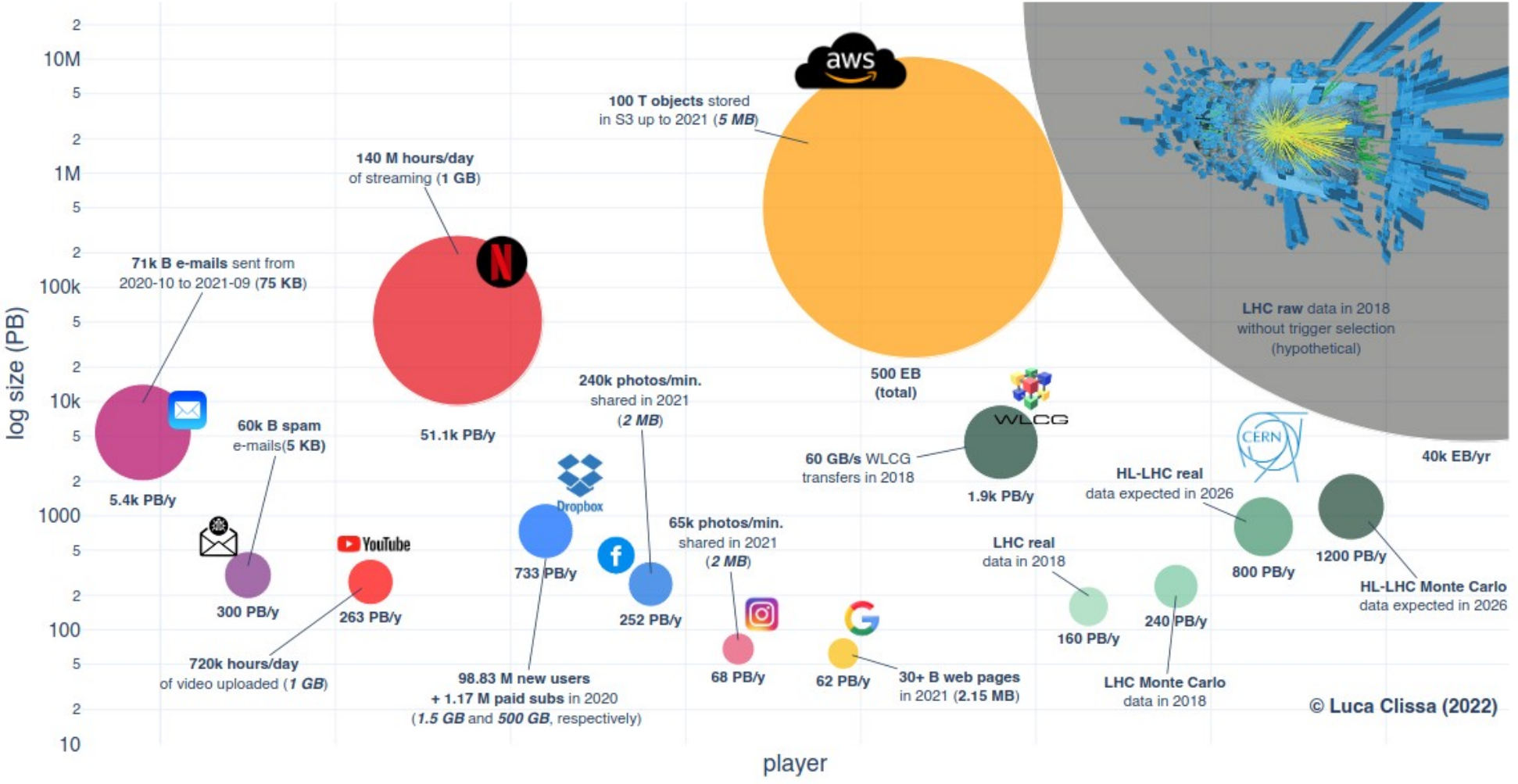




«یادگیری ماشین» در تحلیل داده‌ها



- آشکارسازهای اولیه: برمبنای مشاهده
- حجم داده‌ها:
  - کل داده‌های Big European Bubble Chamber در 11 سال (1973-1983) =
    ٦ ثانیه داده‌ی LHCb
  - داده‌های CMS و ATLAS ~ داده‌های facebook


log size (PB)
2
10M
5
2
1M
5
2
100k
5
2
10k
5
2
1000
5
2
100
5
2
10
player
71k B e-mails sent from 2020-10 to 2021-09 (75 KB)
5.4k PB/y
60k B spam e-mails(5 KB)
300 PB/y
720k hours/day of video uploaded (1 GB)
140 M hours/day of streaming (1 GB)
51.1k PB/y
263 PB/y
YouTube
100 T objects stored in S3 up to 2021 (5 MB)
500 EB (total)
240k photos/min. shared in 2021 (2 MB)
Dropbox
733 PB/y
98.83 M new users + 1.17 M paid subs in 2020 (1.5 GB and 500 GB, respectively)
65k photos/min. shared in 2021 (2 MB)
252 PB/y
68 PB/y
62 PB/y
30+ B web pages in 2021 (2.15 MB)
60 GB/s WLCG transfers in 2018
WLCG
1.9k PB/y
LHC raw data in 2018 without trigger selection (hypothetical)
40k EB/yr
HL-LHC real data expected in 2026
CERN
800 PB/y
1200 PB/y
HL-LHC Monte Carlo data expected in 2026
LHC real data in 2018
160 PB/y
240 PB/y
LHC Monte Carlo data in 2018
© Luca Clissa (2022)

Anomaly detection

Lots of interest recently in anomaly detection — fueled by machine learning

- Driven by a desire to be model-independent

The LHC Olympics 2020

A Community Challenge for Anomaly Detection in High Energy Physics

Gregor Kasieczka (ed),[1] Benjamin Nachman (ed),[2,3] David Shih (ed),[4] Oz Amram,[5] Anders Andreassen,[6] Kees Benkendorfer,[2,7] Blaz Bortolato,[8] Gustaaf Brooijmans,[9] Florencia Canelli,[10] Jack H. Collins,[11] Biwei Dai,[12] Felipe F. De Freitas,[13] Barry M. Dillon,[8,14] Ioan-Mihail Dinu,[5] Zhongtian Dong,[15] Julien Donini,[16] Javier Duarte,[17] D. A. Faroughy[10] Julia Gonski,[9] Philip Harris,[18] Alan Kahn,[9] Jernej F. Kamenik,[8,19] Charanjit K. Khosa,[20,30] Patrick Komiske,[21] Luc Le Pottier,[2,22] Pablo Martín-Ramiro,[2,23] Andrej Matevc,[8,19] Eric Metodiev,[21] Vinicius Mikuni,[10] Inês Ochoa,[24] Sang Eon Park,[18] Maurizio Pierini,[25] Dylan Rankin,[18] Veronica Sanz,[20,26] Nilai Sarda,[27] Uroš Seljak,[2,3,12] Aleks Smolkovic,[8] George Stein,[2,12] Cristina Mantilla Suarez,[5] Manuel Szewc,[28] Jesse Thaler,[21] Steven Tsan,[17] Silviu-Marian Udrescu,[18] Louis Vaslin,[16] Jean-Roch Vlimant,[29] Daniel Williams,[9] Mikaeel Yunus[18]

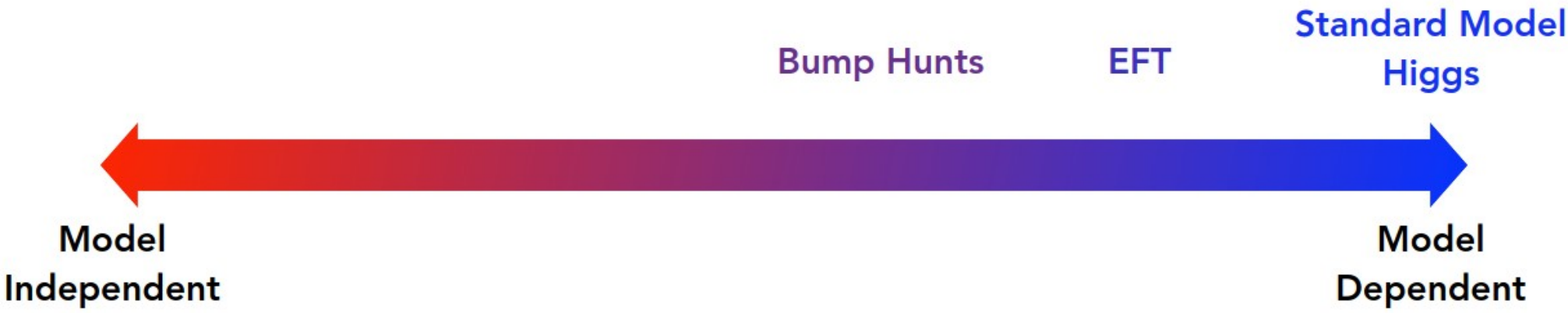
A spectrum

A spectrum

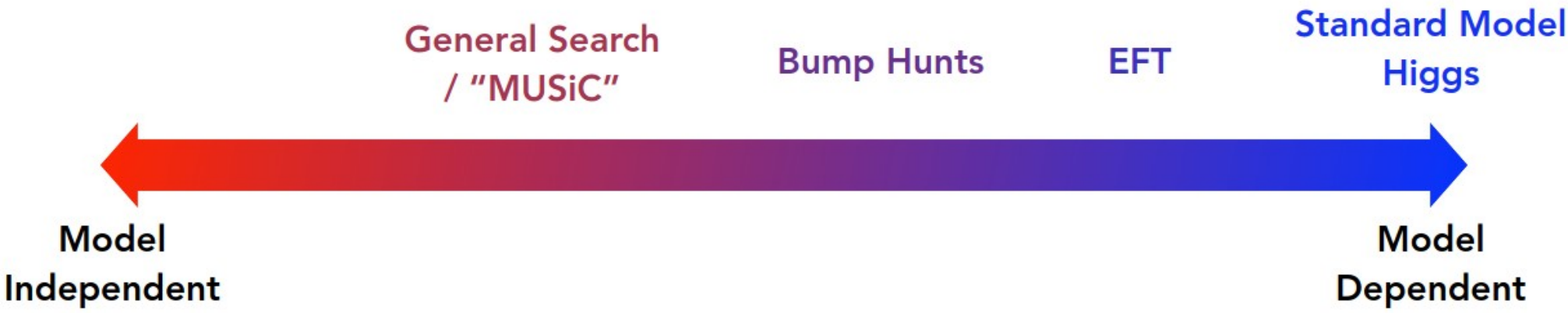
A spectrum


Standard Model
Higgs
EFT
Model
Independent
Model
Dependent

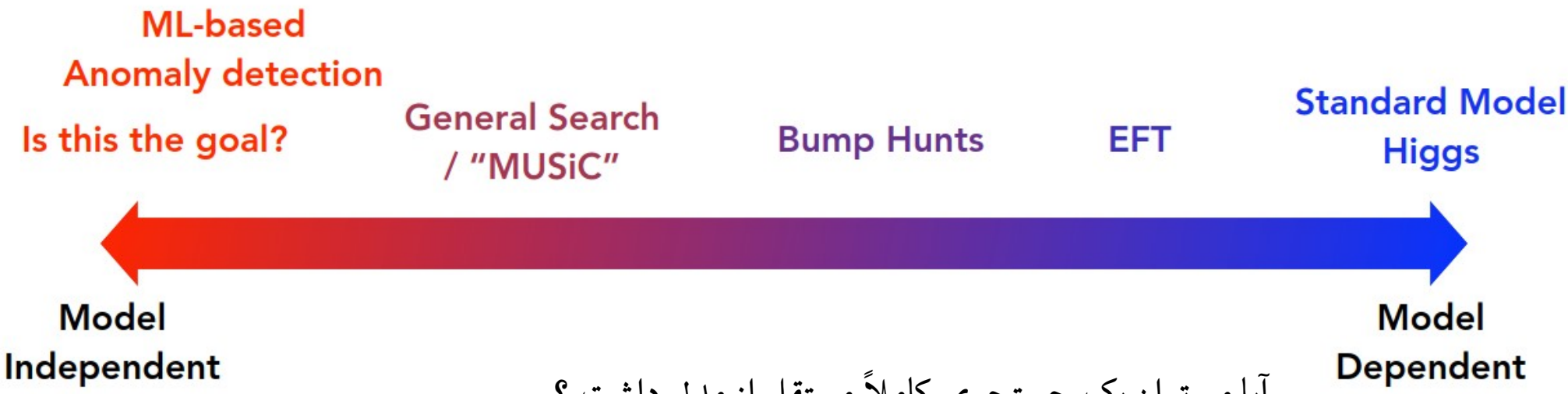
A spectrum


Bump Hunts
EFT
Standard Model Higgs
Model Independent
Model Dependent

A spectrum


General Search
/ "MUSiC"
Bump Hunts
EFT
Standard Model
Higgs
Model
Independent
Model
Dependent

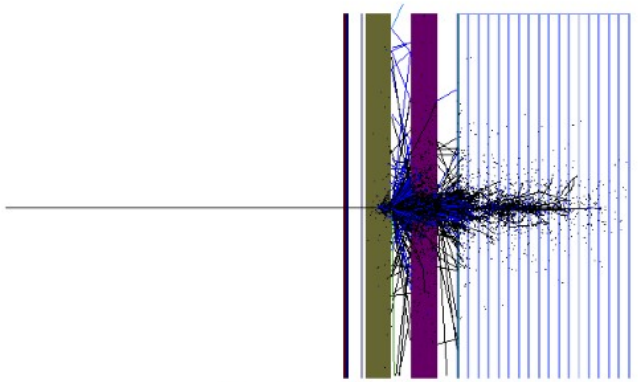
A spectrum



آیا می‌توان یک جستجوی کاملاً مستقل از مدل داشت ؟
چگونه آن را می‌توان به نظریه متصل نمود؟

قطعاً در بهینه‌سازی تریگر می‌تواند مفید باشد

بازسازی رویدادها

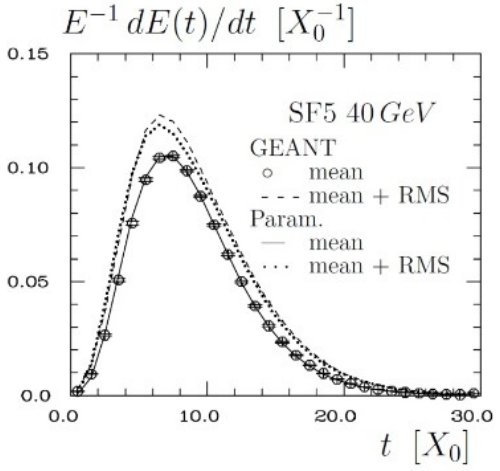


“FullSim”

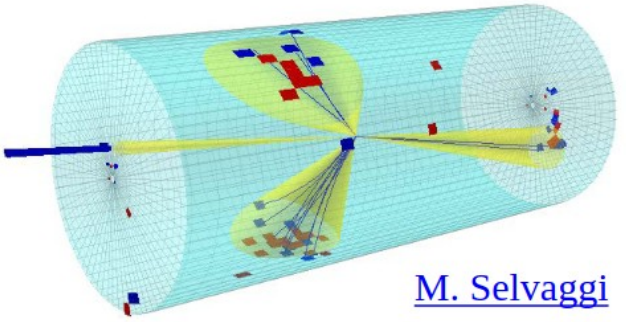
- Common software framework (i.e. Geant4)
  - Experiments can provide additional code via user actions
- Explicit modeling of detector geometry, materials, interactions w/ particles

“FastSim”

- Usually experiment-specific framework
- Implement approximations: analytical shower shapes (e.g. GFLASH), truth-assisted track reconstruction, etc.



arXiv:hep-ex/0001020

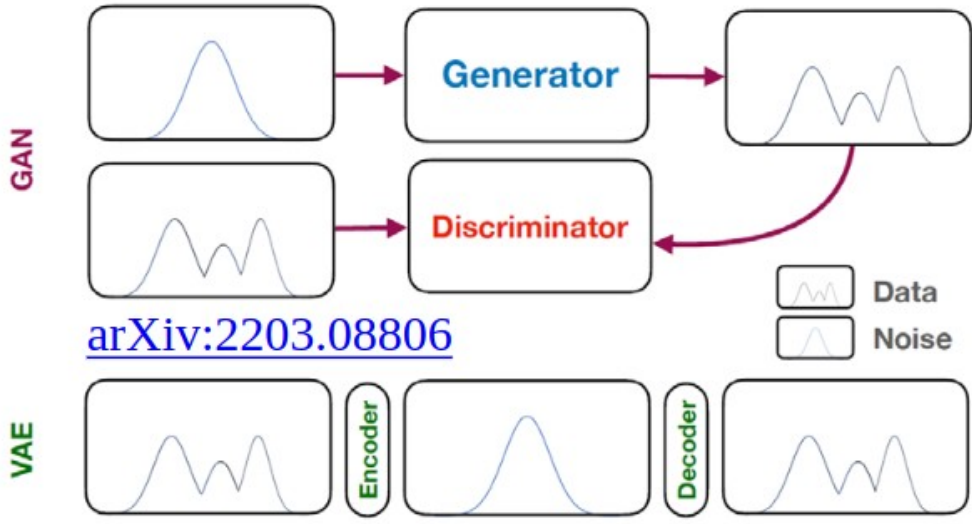


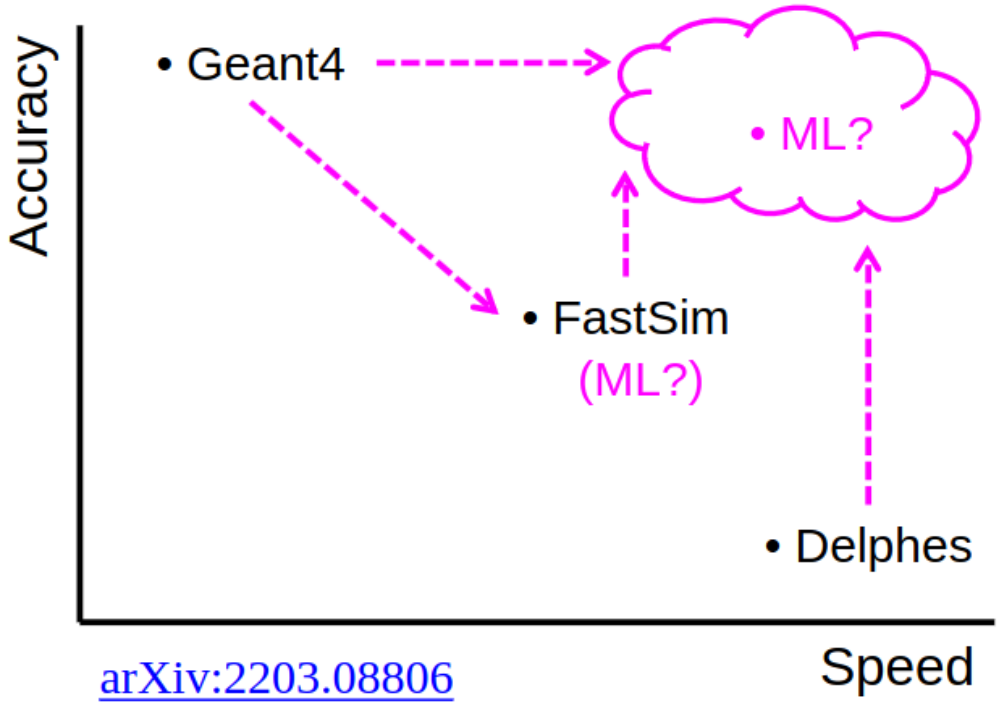
M. Selvaggi

Delphes

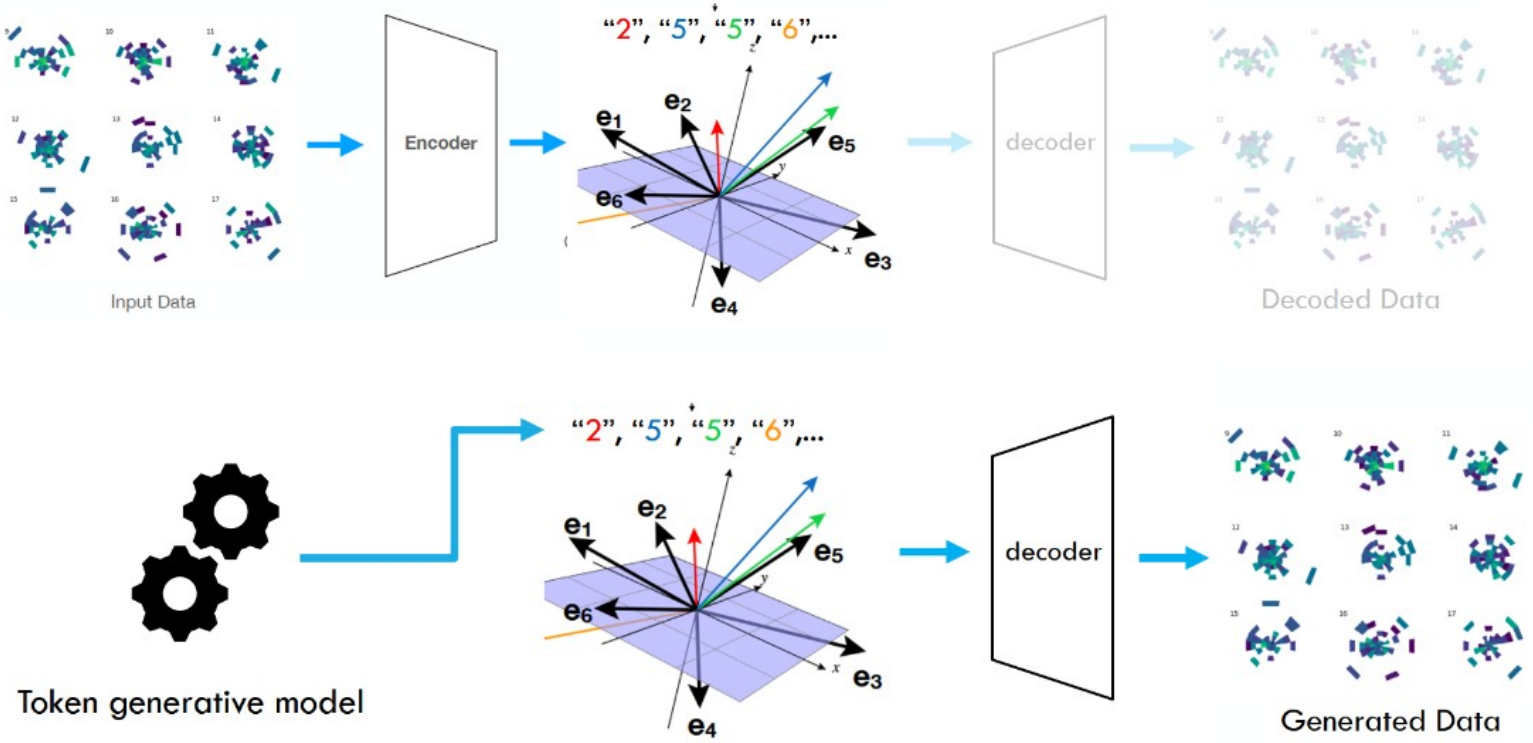
- Ultra-fast parametric simulation
- Used for phenomenological studies, future projections, etc.

Simulation is crucial in HEP!


GAN
Generator
Discriminator
Data
Noise
arXiv:2203.08806
VAE
Encoder
Decoder

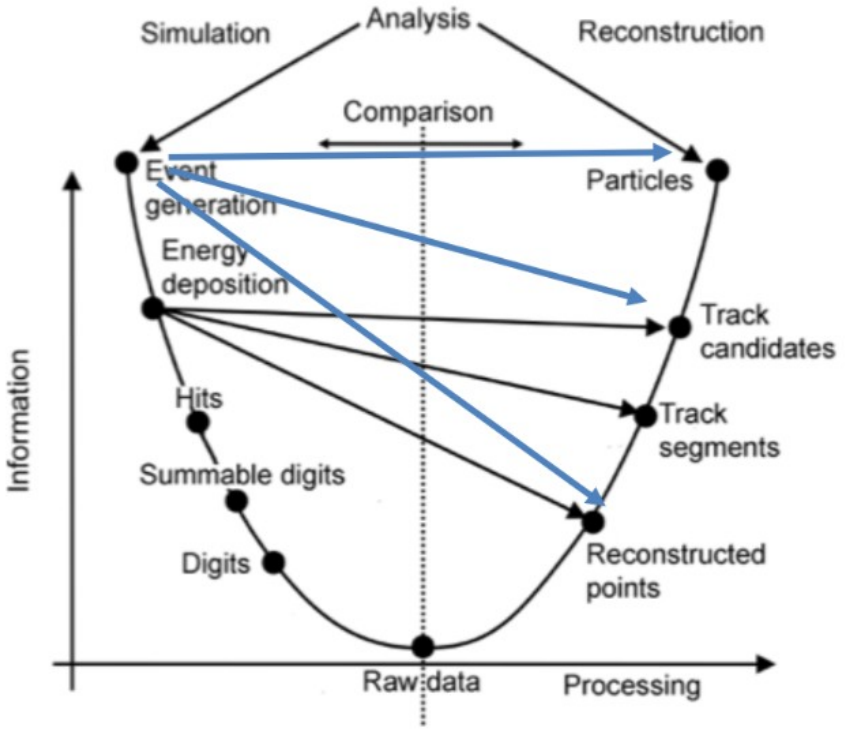

Accuracy
• Geant4
• ML?
• FastSim
(ML?)
• Delphes
Speed
arXiv:2203.08806

Calo-VQ: Vector-Quantized Two-Stage Generative Model in Calorimeter Simulation



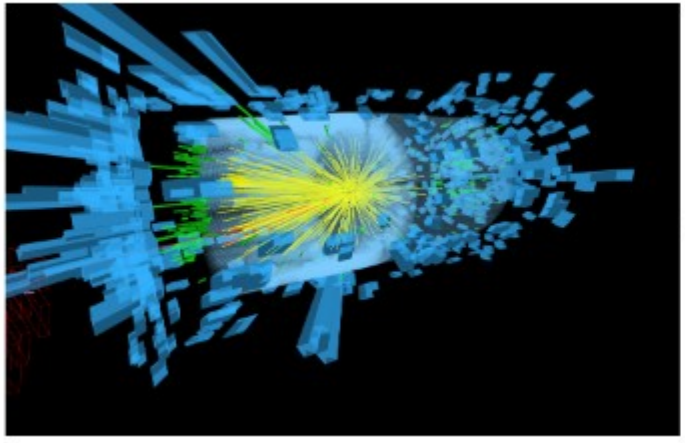
arxiv:2405.06605

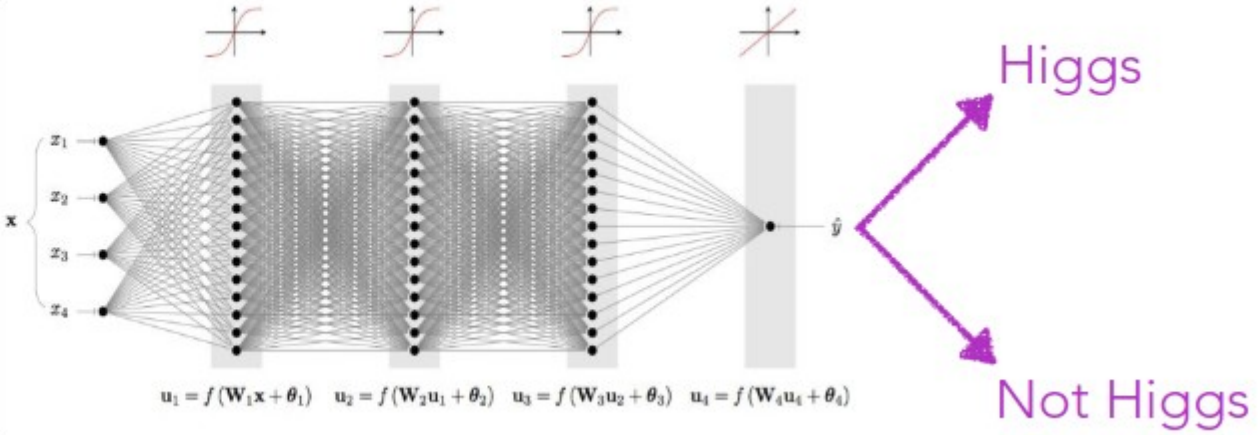
میان‌برهای بازسازی رویداد



"la mia parabola" Figure by Federico Carminati, independent parallel inventions by Vincenzo Innocente & K.C.

کشف هیگز بدون بازسازی ذرات نهایی





End-to-End Physics Event Classification with CMS Open Data

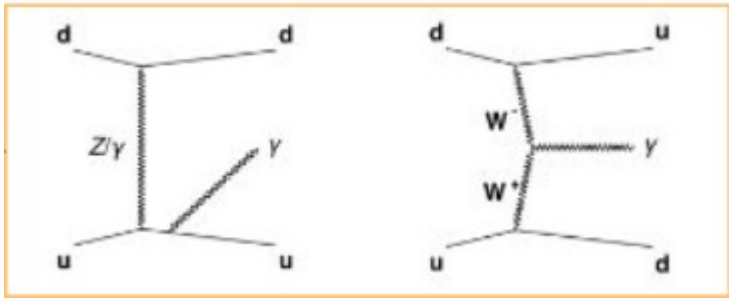
Applying Image-Based Deep Learning to Detector Data for the Direct Classification of Collision Events at the LHC

M. Andrews, M. Paulini, S. Gleyzer, B. Poczos

پروژه‌های مرتبط با یادگیری ماشین در گروه سرن دانشگاه صنعتی اصفهان

آقای مهدی حاج مقصود

جستجوی EFT در تولید ewkγjj

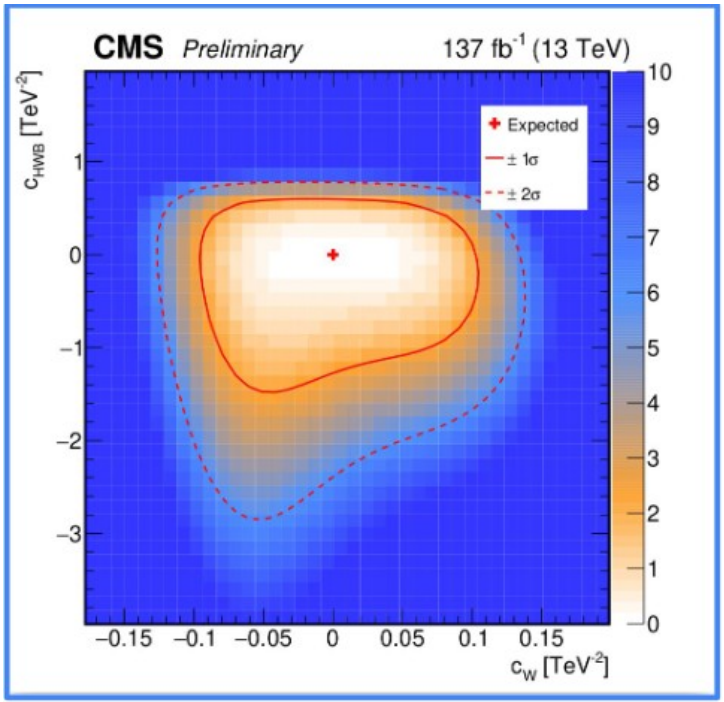


هدف: تشخیص اثر میدان‌های‌موثر در تولید فوتون

روش: آموزش ماشین برای جداسازی رویدادمدل استاندارد از EFT

List of variables

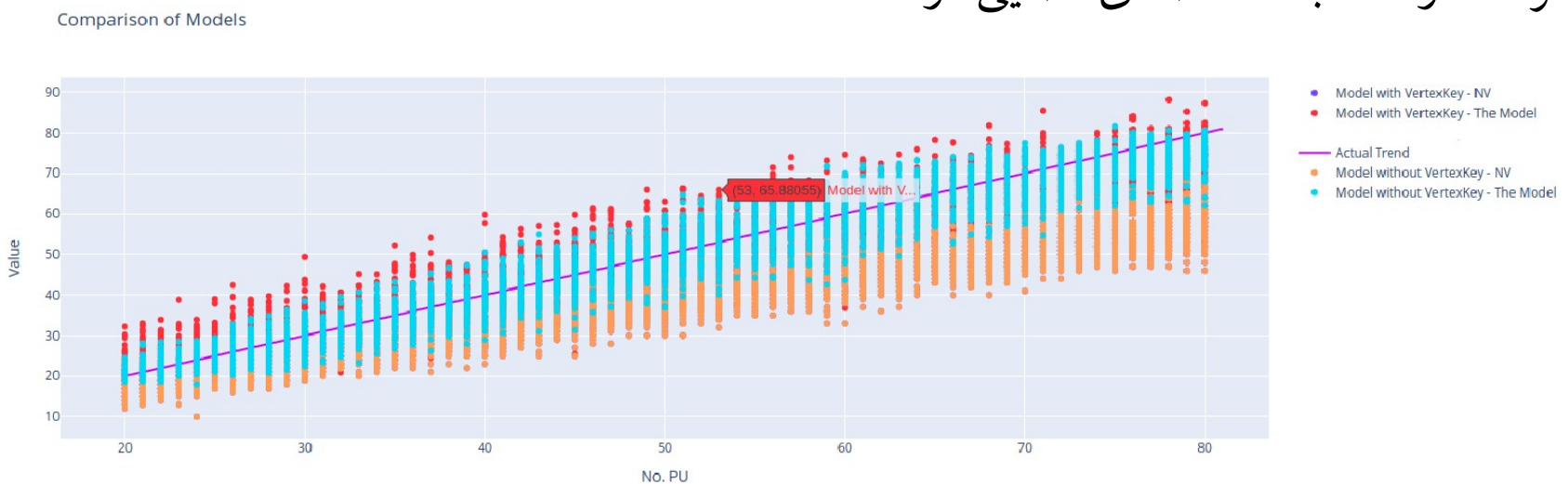
V eta	j1 eta	vjj eta
vjj M	vjj delta eta	jj eta
jj M	ystar	jj dr v
j1 dr v	j1 deta V	isotropy
circularity	sphericity	C



آقای ذریه
خانم جلالوندی

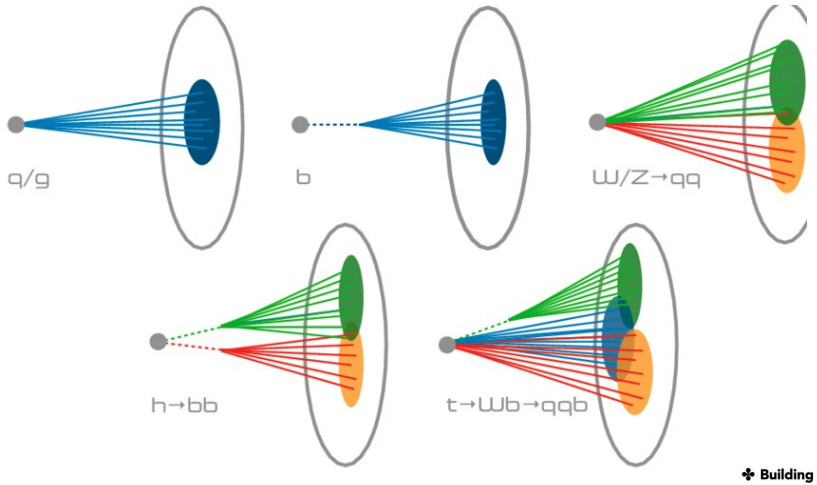
شبکه عصبی گراف برای تخمین پایل‌آپ

- پایل‌آپ: تعداد برخوردهای پروتون-پروتون در هر BX
  - کمیتی مهم برای شبیه‌سازی و اندازه‌گیری درخشندگی
- نمایش اطلاعات رویداد به صورت گراف
  - رئوس گراف: ذرات ـ لبه ها: فاصله‌ی فضایی ذرات

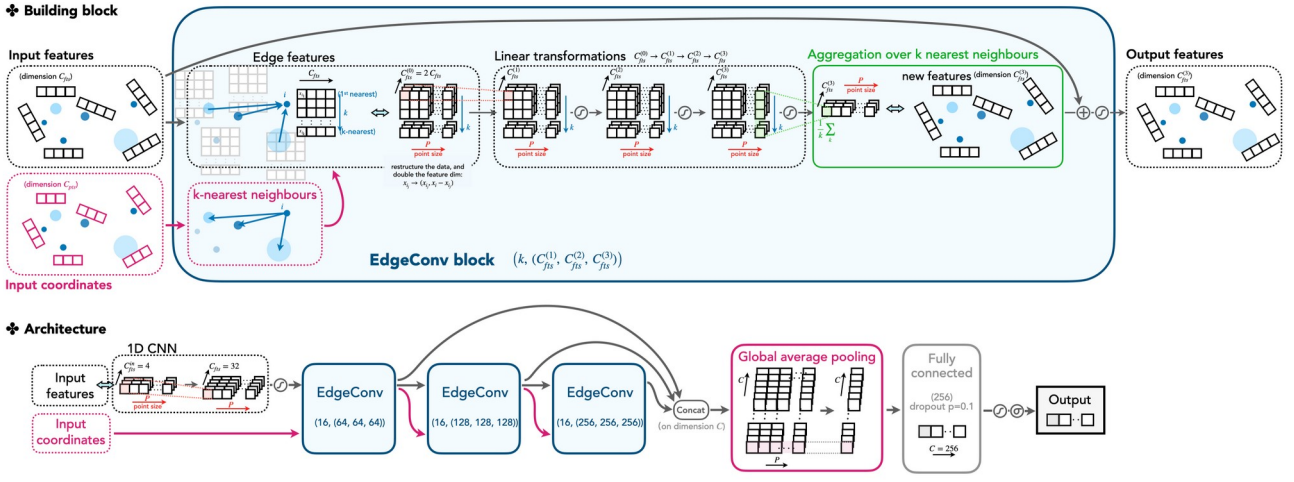


صدیق‌زاده
ارشدی - شریفیان

مطالعه‌ی ساختار جت



- هدف: تشخیص جت سبک حاصل از دو b کوارک
- ابزار: particle-net (فعلاً مخصوص جت‌های سنگین آموزش داده شده)



یادگیری ماشین کوانتومی

Quantum Computing for High-Energy Physics
State of the Art and Challenges
Summary of the QC4HEP Working Group

Alberto Di Meglio,[1,*] Karl Jansen,[2,3,†] Ivano Tavernelli,[4,‡] Constantia Alexandrou,[5,3] Srinivasan Arunachalam,[6] Christian W. Bauer,[7] Kerstin Borras,[8,9] Stefano Carrazza,[10,1] Arianna Crippa,[2,11] Vincent Croft,[12] Roland de Putter,[6] Andrea Delgado,[13] Vedran Dunjko,[12] Daniel J. Egger,[4] Elias Fernández-Combarro,[14] Elina Fuchs,[1,15,16] Lena Funcke,[17] Daniel González-Cuadra,[18,19] Michele Grossi,[1] Jad C. Halimeh,[20,21] Zoë Holmes,[22] Stefan Kühn,[2] Denis Lacroix,[23] Randy Lewis,[24] Donatella Lucchesi,[25,26,1] Miriam Lucio Martinez,[27,28] Federico Meloni,[8] Antonio Mezzacapo,[6] Simone Montangero,[25,26] Lento Nagano,[29] Voica Radescu,[30] Enrique Rico Ortega,[31,32,33,34] Alessandro Roggero,[35,36] Julian Schuhmacher,[4] Joao Seixas,[37,38,39] Pietro Silvi,[25,26] Panagiotis Spentzouris,[40] Francesco Tacchino,[4] Kristan Temme,[6] Koji Terashi,[29] Jordi Tura,[12,41] Cenk Tüysüz,[2,11] Sofia Vallecorsa,[1] Uwe-Jens Wiese,[42] Shinjae Yoo,[43] and Jinglei Zhang[44,45]

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[3] *Computation-based Science and Technology Research Center, The Cyprus Institute, 20, Constantinou Kavafi str., 2121 Nicosia, Cyprus*
[4] *IBM Quantum, IBM Research – Zurich, 8803 Rüschlikon, Switzerland*
[5] *Department of Physics, University of Cyprus, PO Box 20537, 1678 Nicosia, Cyprus*
[6] *IBM Quantum, IBM Research - 1101 Kitchawan Rd, Yorktown Heights, NY, USA*
[7] *Physics Division LBNL - M/S 50A5104 1 Cyclotron Rd Berkeley, CA, USA*
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[9] *RWTH Aachen University, Templergraben 55, 52062 Aachen, Germany*
[10] *TIF Lab, Dipartimento di Fisica, Università degli Studi di Milano and INFN Sezione di Milano, Milan, Italy*
[11] *Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany*
[12] $\langle aQa^L \rangle$ *Applied Quantum Algorithms Leiden, The Netherlands*
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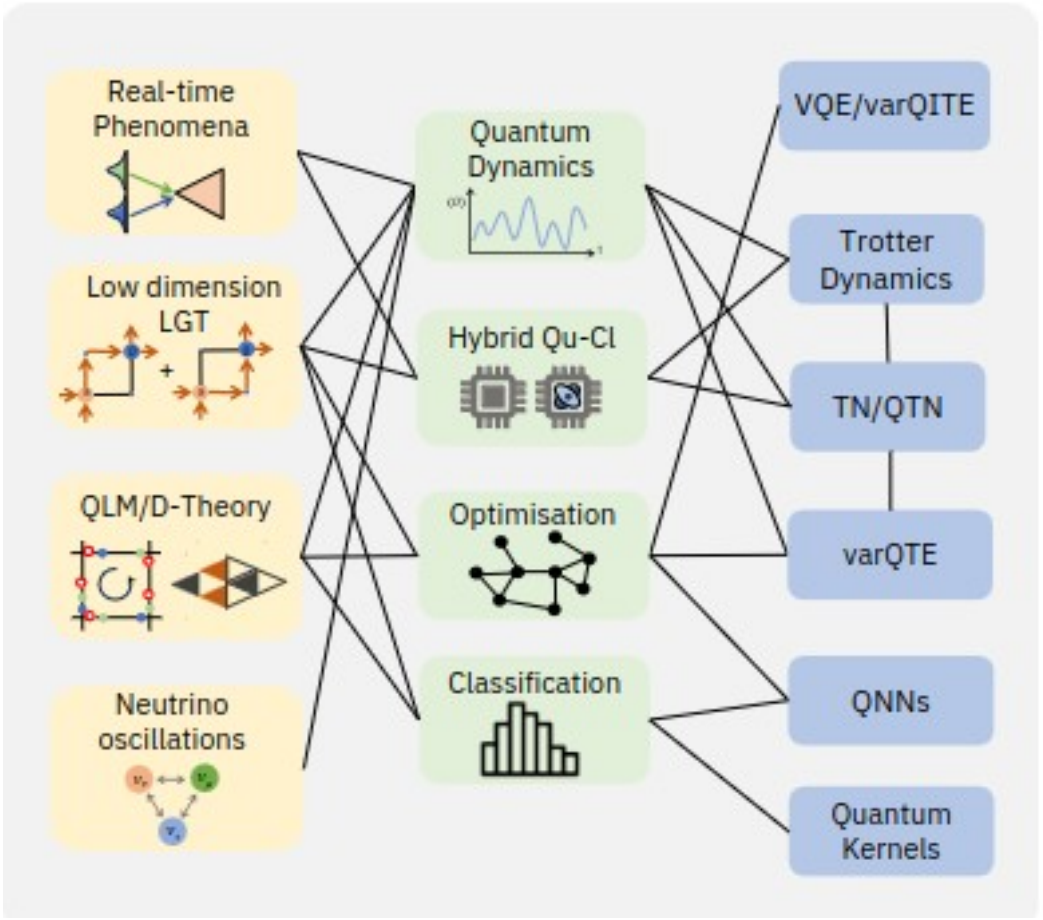
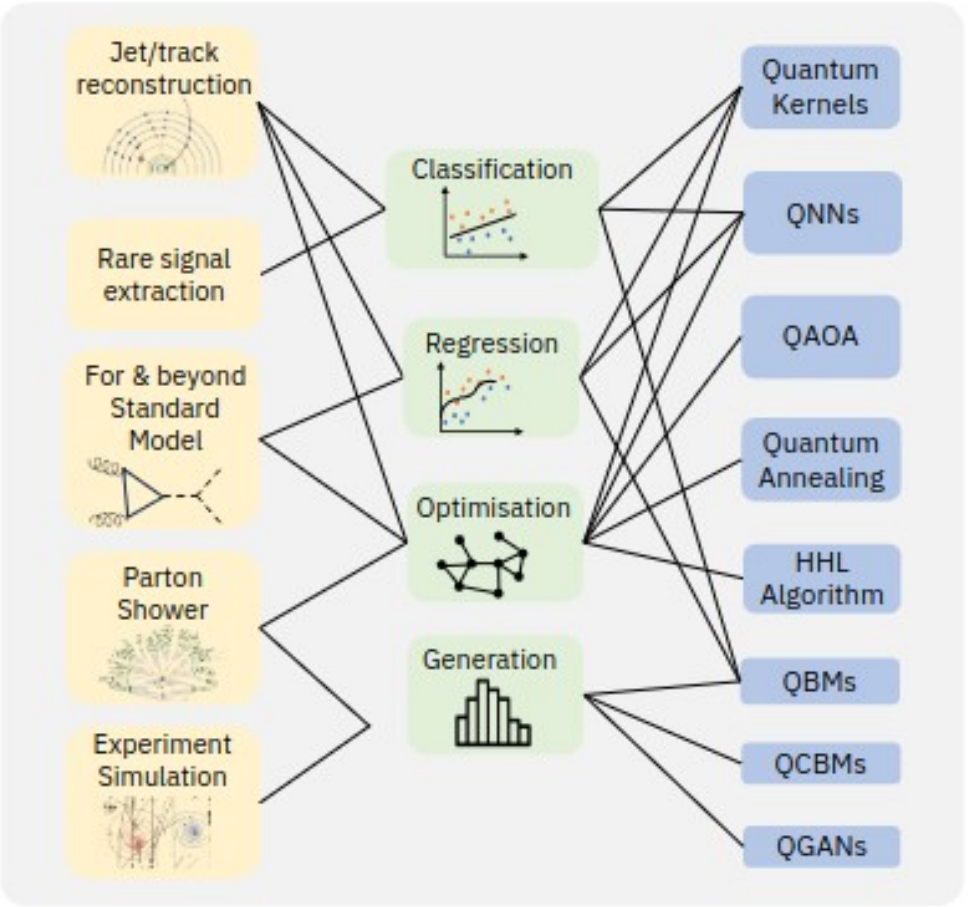
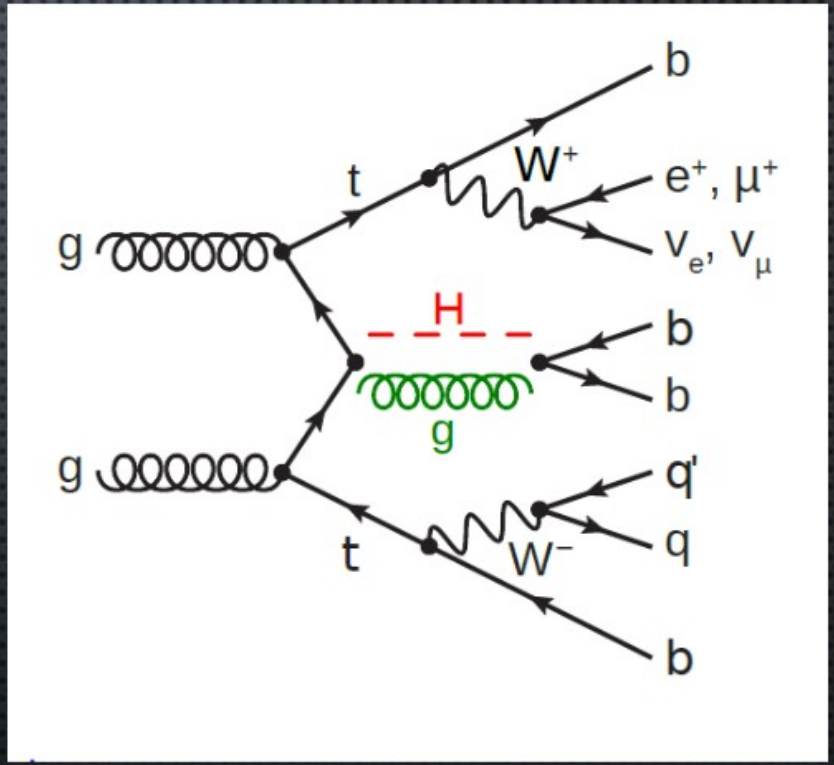

Real-time Phenomena
Low dimension LGT
QLM/D-Theory
Neutrino oscillations
Quantum Dynamics
Hybrid Qu-Cl
Optimisation
Classification
VQE/varQITE
Trotter Dynamics
TN/QTN
varQTE
QNNs
Quantum Kernels

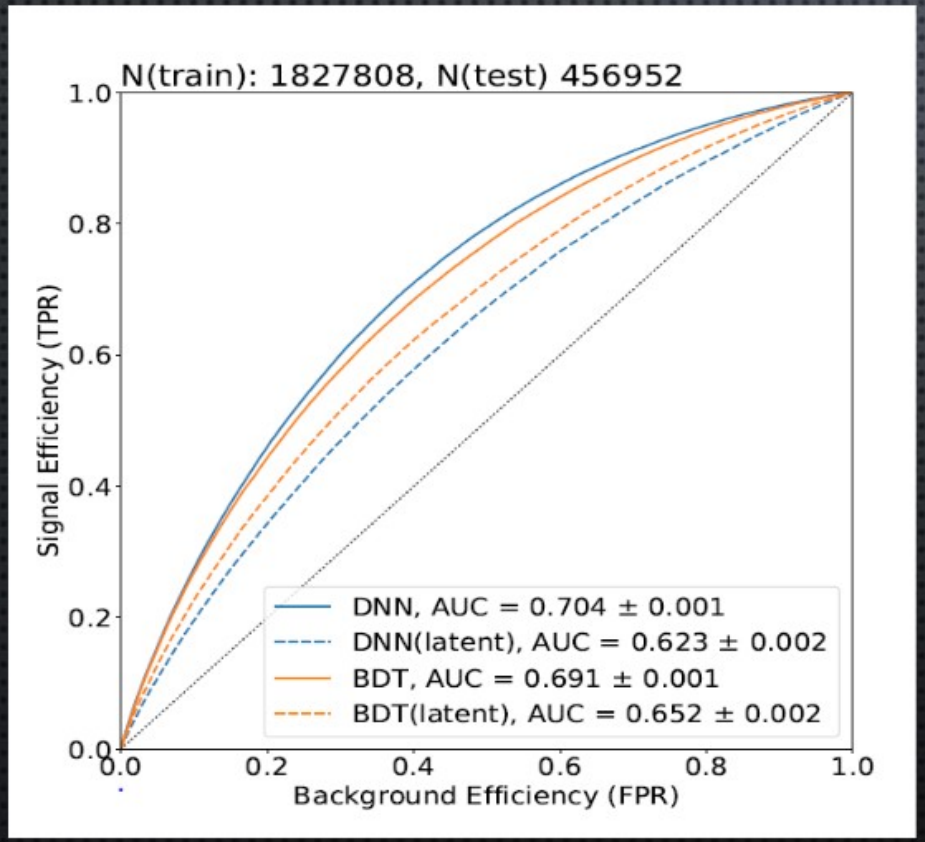

Jet/track reconstruction
Rare signal extraction
For & beyond Standard Model
Parton Shower
Experiment Simulation
Classification
Regression
Optimisation
Generation
Quantum Kernels
QNNs
QAOA
Quantum Annealing
HHL Algorithm
QBMs
QCBMs
QGANs

Classification of $\bar{H}(\bar{b}b)$ versus the dominant $\bar{}(\bar{b}b)$ background

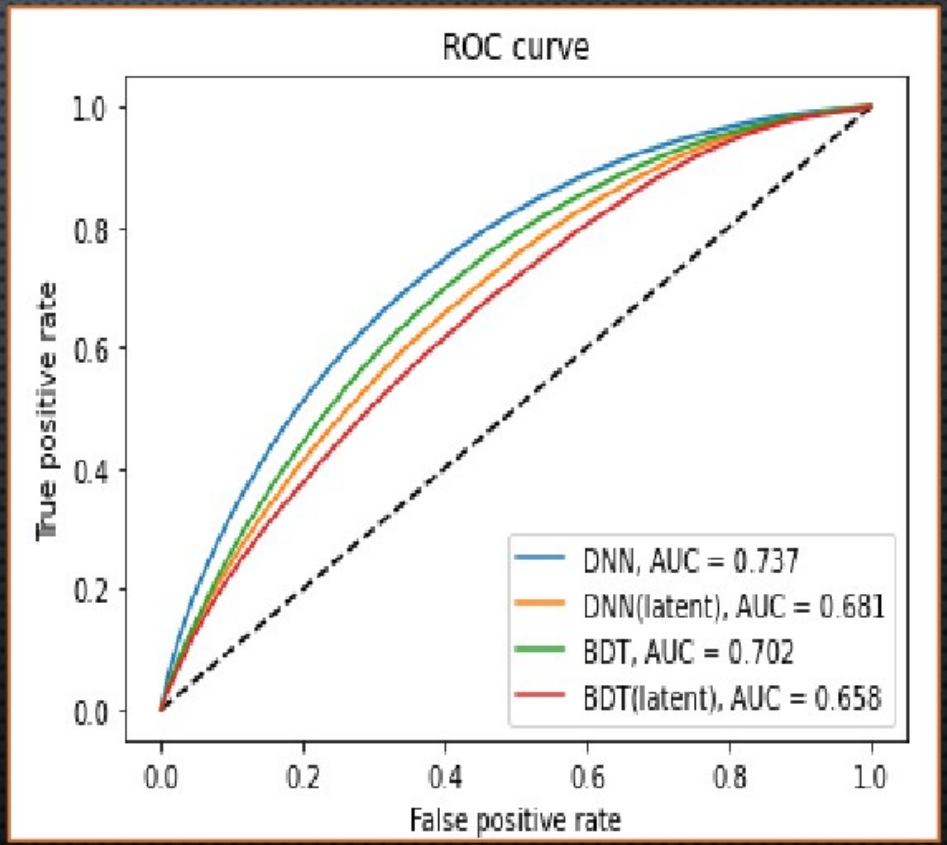
- pre-processing
- using hybrid quantum-classical algorithms
  - QSVM
  - VQC



✓Article results



✓Our results



با سپاس از توجه شما