ML4Jets2021: summary talk

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August 2, 2021

Institute for Theoretical Physics
University of Heidelberg
https://indico.cern.ch/event/980214/

BOOST Online 2021

ML4Jets hybrid

July 6-8 2021

INSTITUTE FOR THEORETICAL PHYSICS

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

Local Organizers
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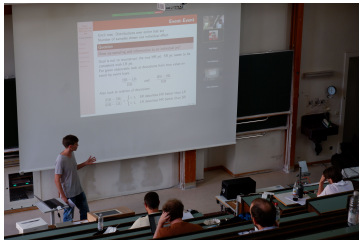
Overview

- the series follows on from 2017, 2018, and 2020
- 384 registered participants
- hybrid!

  → ∼ 30 people in-person, the rest online

  → daily testing & socially distanced lecture hall
- 11 sessions & 99 talks over 3 days! ($\gtrsim$ 12 hours per day)

  → worked well since we had talks from all over the globe
- talks from theory, experiment, and ML communities
- .. and.. the Euros



Overview

- Big gains from new architectures

  Attention mechanisms, transformers, INNs/flows, deep sets, graphs

- Many impressive ML advances in ATLAS & CMS

  calibration, jet tagging, ...

- Simulation & generation

- New challenges!

  Anomalies @40 MHz & calorimeter simulation

- Understanding uncertainties in ML tools

- Symmetries $\leftrightarrow$ deep-learning

- Deep-learning & anomaly detection

  ATLAS implementation of CWoLa search

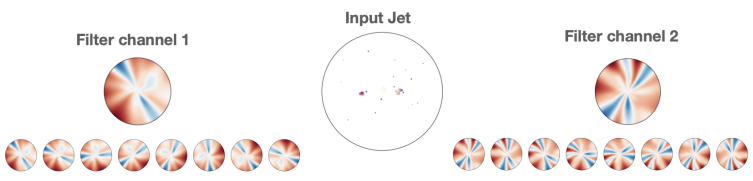
  Several new advances in techniques and interpretability

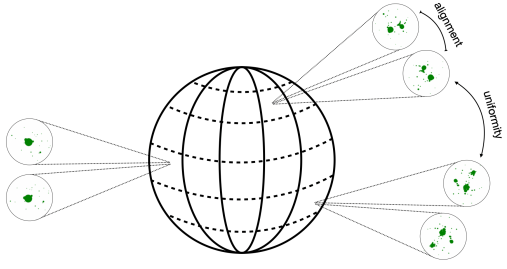
New architectures

Part 1: equivariance / invariance

Incorporating symmetries explicitly in the neural network architectures

- SO(3)-equivariant Neural Network for b-tagging (Ema Catalina Smith)
- Equivariant energy flow networks for jet tagging (Ayodele Ore)
- SPANet: Generalized Permutationless Set Assignment for Particle Physics using Symmetry Preserving Attention (Michael James Fenton)
- Particle Convolution for Jets (Chase Owen Shimmin)
- Lorentz Group Equivariant Autoencoder (Zichun Hao)





Part 2: new strategies or representations

Designing optimisation strategies to construct better representations of the data, or to incorporate symmetries

- Linearized Optimal Transport for Jet Physics (Ms Tianji Cai)
- Supervised Attention for Jet Classification (Jonathan Shlomi)
- The information content of quenched jets (James Mulligan)
- Identifying Heavy-Flavor Jets Using Vectors of Locally Aggregated Descriptors (Jitka Mrazkova)
- A new approach to unsupervised learning in jet physics (Peter Rangi Sorrenson)

Beyond the Standard Model

Part 1: over-density methods

In-distribution anomaly detection

- High-dimensional Anomaly Detection with Radiative Return in e+e- Collisions (Julia Lynne Gonski)
- CATHODE part 1: introducing a new model-agnostic search strategy for resonant new physics at the LHC (Anna Hallin)
- CATHODE part 2: robustness and comparison to other methods (Manuel Sommerhalder)
- Anomaly Detection in the Copula Space (Tommaso Dorigo)

Part 2: latent space anomaly detection

Out-of-distribution anomaly detection in latent space

- Jet Metrics and Autoencoders (Rashmish Mishra)
- Detecting Anomalous jets with Graph Neural Networks (Mr Vishal Singh Ngairangbam)
- Review of the Dark Machine Anomaly Score Challenge I (Joe Davies)
- Review of the Dark Machine Anomaly Score Challenge II (Bryan Ostdiek)

Part 3: data-space searches with autoencoders

Out-of-distribution anomaly detection with reconstruction errors

- Boosting new physics sensitivity with Variational Autoencoders (Kinga Anna Wozniak)
- Autoencoders for unsupervised anomaly detection in high energy physics (Thorben Finke)
- Recognizing hadronic SUEP at the LHC with Unsupervised Machine Learning (Jared Barron)
- Classifier-based Anomalous Jet Tagging (Taoli Cheng)

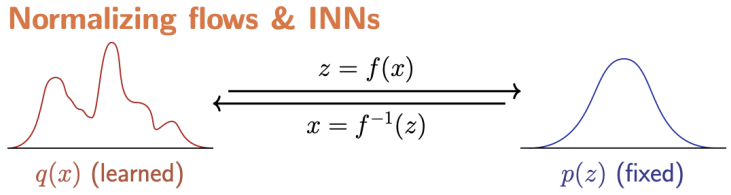
ML-assisted measurements & searches

Invertible neural networks

- Invertible Neural Networks beyond Particle Physics (Lynton Ardizzone)
- Invertible Networks or Partons to Detector and Back Again (Anja Butter)
- Measuring QCD Splittings with Invertible Networks (Theo Heimel)

$$P_{qq}(z,y) = C_F \left[D_{qq} \frac{2z(1-y)}{1-z(1-y)} + F_{qq}(1-z) + C_{qq} yz(1-z) \right]$$

leading term finite term rest term



Searches

- Combining NN predictions with Hypothesis Testing for discovery in the LHC (Michael Soughton)
- Parametrized classifiers for optimal EFT sensitivity (Alfredo Glioti)

NNPDF

- Compressing PDF sets using Generative Adversarial Networks (Tanjona Radonirina Rabemananjara)
- Towards a new generation of PDFs using ML (Roy Stegeman)

Inference tecniques

- Emerging techniques for sampling, searching, and summing over the combinatorially large space of shower histories (Sebastian Macaluso)
- Computing the exact optimal classifier for Ginkgo jets (Lauren Greenspan)
- Tuning the parton shower parameters with the marginal likelihood (Matthew Drnevich)
- Jet-based TMD measurements with H1 data, unfolded using ML techniques (Miguel Ignacio Arratia Munoz)
- Parameter Inference from Event Ensembles and the Top-Quark Mass (Katherine Fraser)

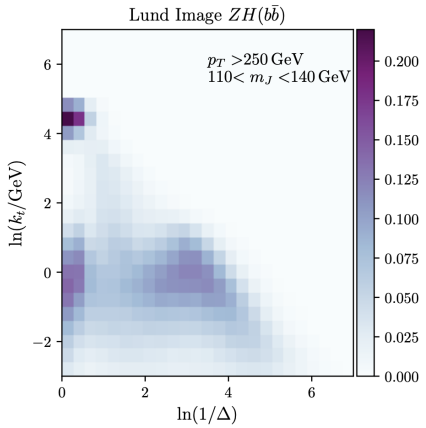
Classification

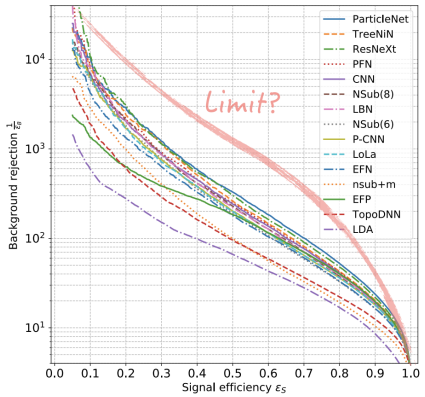
ML-taggers already in use in ATLAS & CMS

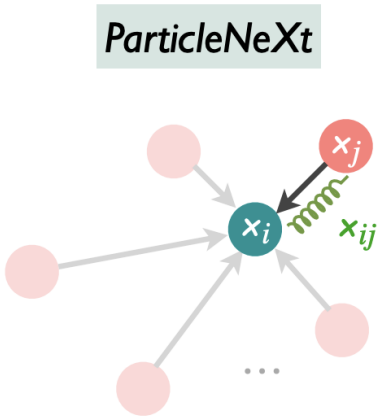
Advances in the state-of-the-art ParticleNet

Gains from new ML architectures and physics-motivated representations

- Combine and Conquer: Event Reconstruction with Bayesian Ensemble Neural Networks (Jack Araz)
- Pushing the limit of jet tagging with graph neural networks (ParticleNeXt) (Huilin Qu)
- Jet tagging in the Lund plane with graph networks (Frederic Alexandre Dreyer)
- Higgs tagging with the Lund jet plane (Charanjit Kaur Khosa)
- Identifying the Quantum Properties of Hadronic Resonances using Machine Learning (Jakub Filipek)
- Morphology for Jet Classification (Sung Hak Lim)
- Boosted jet tagging in CMS (Congqiao Li)
- A $W^{\pm}$ polarization analyzer from Deep Neural Networks (Taegyun Kim)
- Testing Universality in various Monte Carlo Generators in Deep Learning with Application in Higgs-boson pair searches in 2HDM (Yi-Lun Chung)



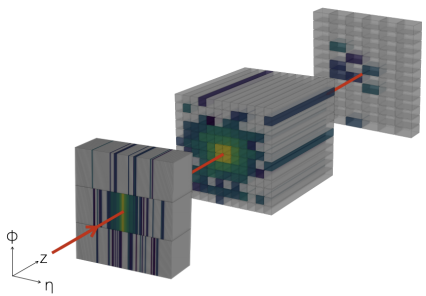


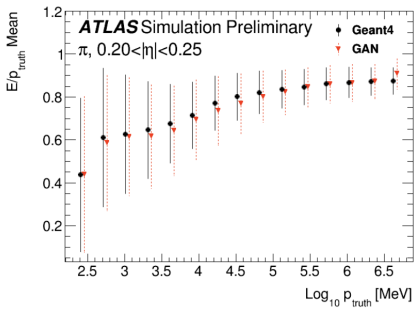


Simulation & generative models

Part 1: Detector simulation

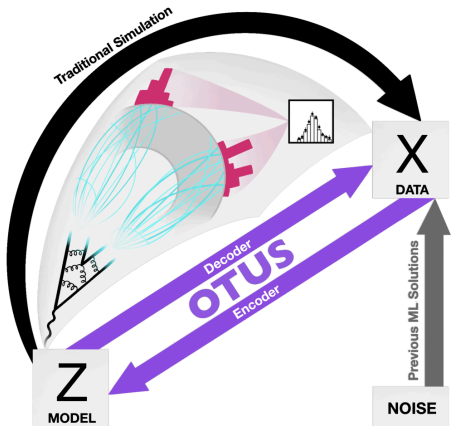
- CaloFlow: Fast and Accurate Generation of Calorimeter Showers with Normalizing Flows (Claudius Krause)
- Multi-detector geomotery modeling and Geant4 Integration (Dalila Salamani)
- Angular Conditioning of Deep Generative Models for Fast Simulation of High Granularity Calorimeters (Peter McKeown)
- Fast and Accurate Electromagnetic and Hadronic Showers from Generative Models (Engin Eren)
- AtlFast3: The next generation of fast simulation in ATLAS (Joshua Falco Beirer)





Part 2: Event and jet generation

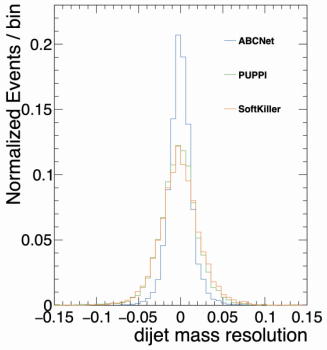
- Fast Simulation of Jets with VAEs (Mary Touranakou)
- Foundations of a Fast, Data-Driven, Machine-Learned Simulator (Jessica N. Howard)
- Particle Cloud Generation with Message Passing GANs (Raghav Kansal)
- White Box AI for parton shower development (Felix Ringer)
- How to GAN Event Unweighting (Mr Mathias Backes)
- Sparse Data Generation with Convolutional VAE (Breno Orzari)
- Super-Resolution for QCD and Top Jets (Lukas Blecher)
- Exploring phase space with Neural Importance Sampling (Timo Janßen)
- Latent Space Refinement for Deep Generative Models (Ramon Winterhalder)



Regression, calibration, & fast inference

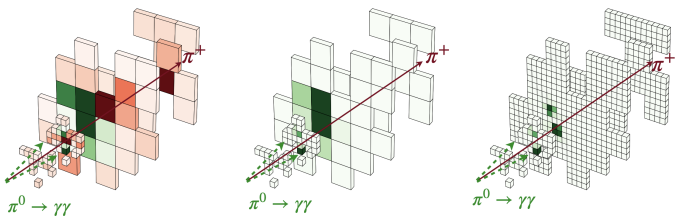
Part 1: Regression

- Pileup mitigation in CMS (Benedikt Maier)
- Lightweight Jet Reconstruction as an Object Detection Task (Adrian Alan Pol)
- Measurement of Muon Energy From Radiative Losses in a Granular Calorimeter (Giles Chatham Strong)
- Deep learning jet modifications in heavy-ion collisions (Yilun Du)



Part 2: Calibration

- Machine learning based Particle Flow algorithm and application of super-resolution techniques (Sanmay Ganguly)
- Using Machine Learning for Heavy-Ion Jet p_{T} Reconstruction in ALICE (Hannah Bossi)
- Learning Uncertainties the Frequentist Way: Calibration and Correlation in High Energy Physics (Rikab Gambhir)
- ML in jet physics beyond classification (Loukas Gouskos)



Part 3: Fast inference

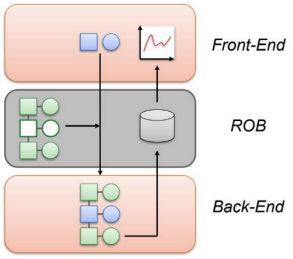
- Matrix Element Calculations on the GPU (Joshua Isaacson)
- Jet Identification in L1 Trigger at HL-LHC based on DNN implementation on FPGA (Andre Sznajder)
- OnlineFlow: Trigger Free Analysis Using Online Learned Generative Models (Sascha Daniel Diefenbacher)

Datasets & challenges

Part 1: Datasets

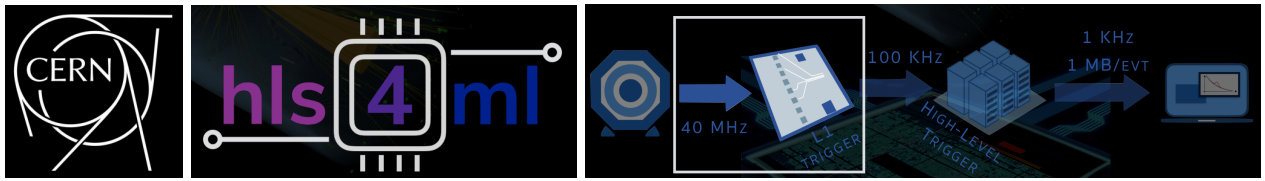
- Implementation of Jupyter Notebooks into The Reproducible Open Benchmarks for Data Analysis Platform (ROB) (Aaron Wang)
- Shared Data and Algorithms for Deep Learning in Fundamental Physics (William Korcari, ErUM-Data)

ErUM-Data IDT



Part 2: Challenges

- Introduction to Anomaly Detection Challenge - Anomaly detection @40 MHz (Katya Govorkova)



- Calorimeter Simulation Challenge Proposal (David Shih)

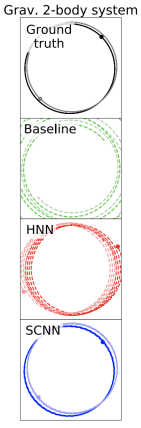
A community challenge, based on a common dataset, for developing and benchmarking different approaches to fast calorimeter simulation

Community input welcome!!

Exploring the latent structure of data

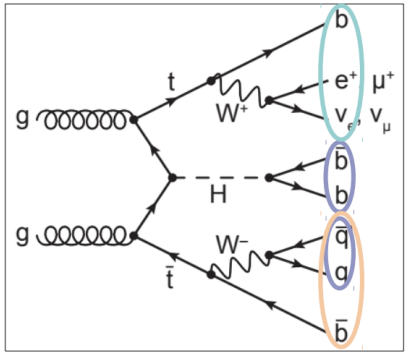
Part 1: Data structure

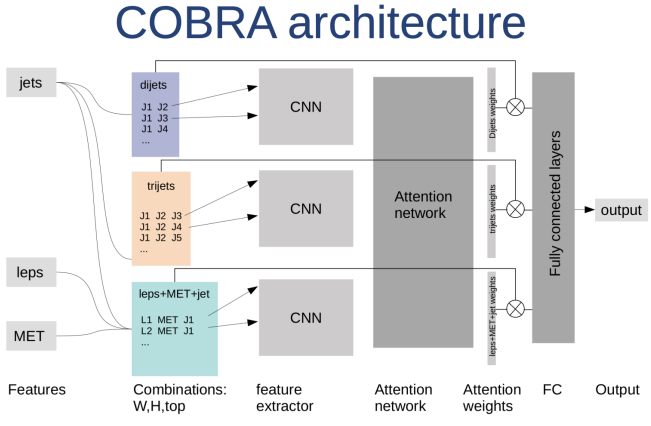
- Learning Symmetries and Conserved Quantities of Physical Systems (Sven Krippendorf)
- Bump Hunting in Latent Space (Aleks Smolkovic)
- Symmetry Discovery with Deep Learning (Krish Desai)
- The Blessing of Dimensionality: Dimensionality Estimation for Event Clustering (Malte Jacobsen)



Part 2: Latent space exploration

- Detecting hidden patterns in jet substructure with probabilistic models (Darius Faroughy)
- Attention and Dynamic Graph Convolution Neural Network in the context of classifying ttH(bb) vs. tt(bb) in the semi-leptonic top quark pair decay channel (Christina Reissel)
- Better latent spaces for better autoencoders (Barry M. Dillon)
- Decoding Photons: Physics in the Latent Space of a BIB-AE Generative Network (Erik Buhmann)
- Jet Topology (Sijun Xu)





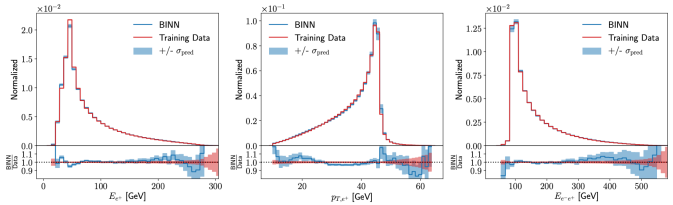
Interpretability, robustness, & uncertainties

Part 1: Introduction

- Learning Partially Known Stochastic Dynamics with Empirical PAC Bayes (Manuel Haußmann)
- Uncertainties Associated with GAN Generated Datasets (Prasanth Shyamsundar)

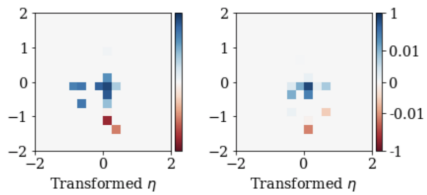
Part 2: Uncertainties

- Generative Networks with Uncertainties (Michel Luchmann)
- Uncertainty Aware Learning for High Energy Physics (Aishik Ghosh)
- Amplifying Statistics with Generative Models (Sebastian Bieringer)



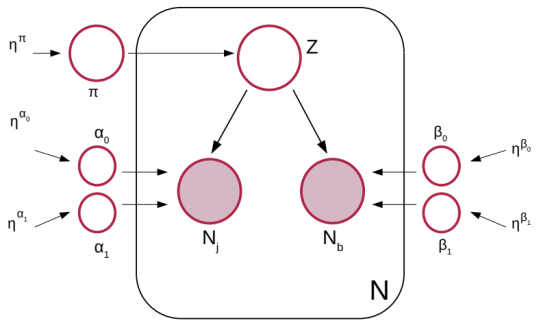
Part 3: Information content

- Safety of Quark/Gluon Jet Classification (Alexis Romero)
- Thoughts on the expressive power and inductive bias of DeepSets and Tree-Based models (Kyle Stuart Cranmer)
- Explainable AI for ML Jet Taggers (Christine Angela McLean)



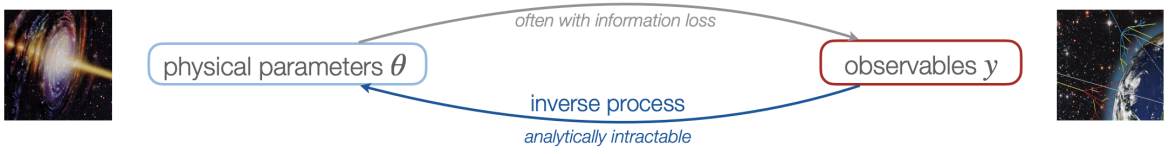
Part 4: Constructing observables

- Bayesian Inference in for Four Tops at the LHC (Ezequiel Alvarez)
- Spectral Clustering for Jet Formation (Henry Day-Hall)
- Deep-Learned Event Variables (Doojin Kim)



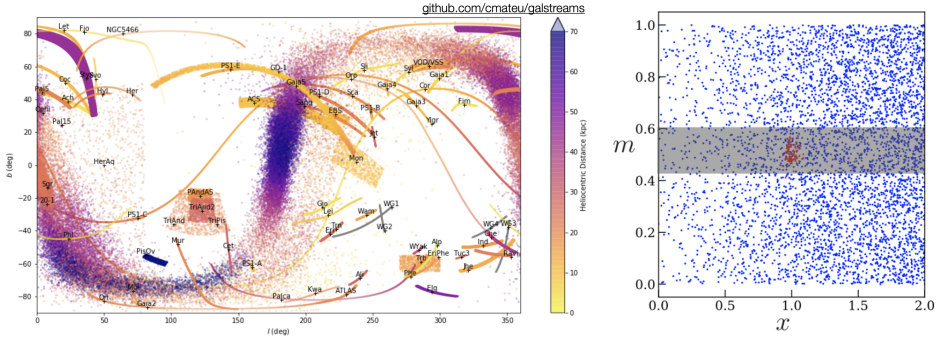
New horizons

- ML in Cosmological Simulations (Annalisa Pillepich)
- Conditional invertible neural networks to probe cosmic-ray sources (Josina Schulte)



- Via Machinae (Matthew Buckley)

  Discovering Stellar Streams using Machine Learning



- Synergies between Quantum Computing and Machine Learning (Michael Spannowsky)

ML4Jets 2022/3

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  calibration, jet tagging, ...
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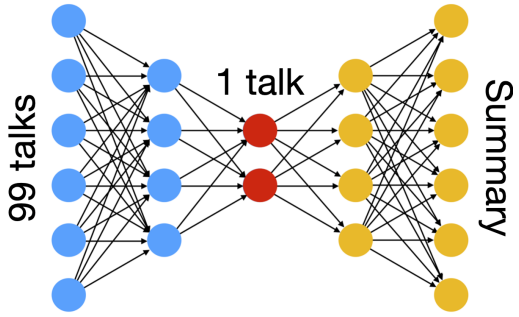

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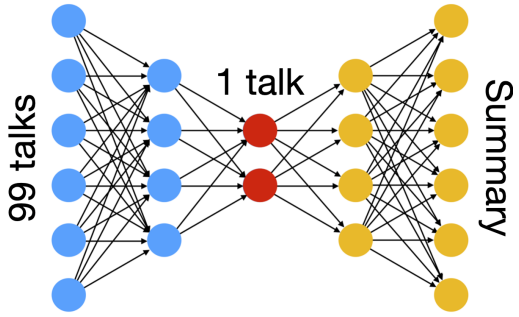

Thank you

& boostamos!