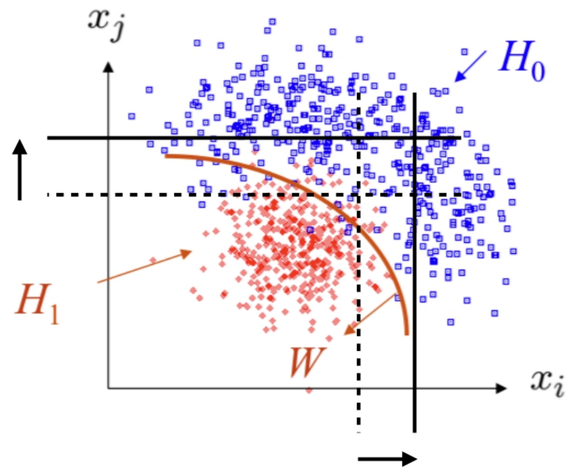
Machine Learning for analysis
- Personal related

Bo Liu

ATLAS EXPERIMENT

Usage of Machine Learning for physics

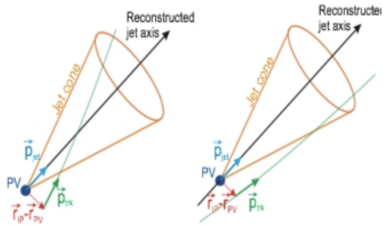
- Classification
  - Objection tagging
    - ✓ Btagging
    - ✓ Electron/photon identification
    - ✓ q/g tagging
    - ✓ Fatjet tagging
  - Event selection and tagging



- Regression
  - Correction to truth objection
    - ✓ B-jet energy correction
  - Background estimation
    - ✓ Reweight from CR to SR

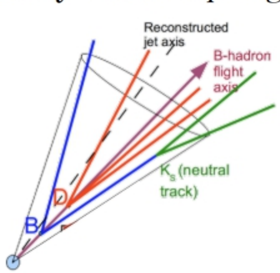
ML for btagging

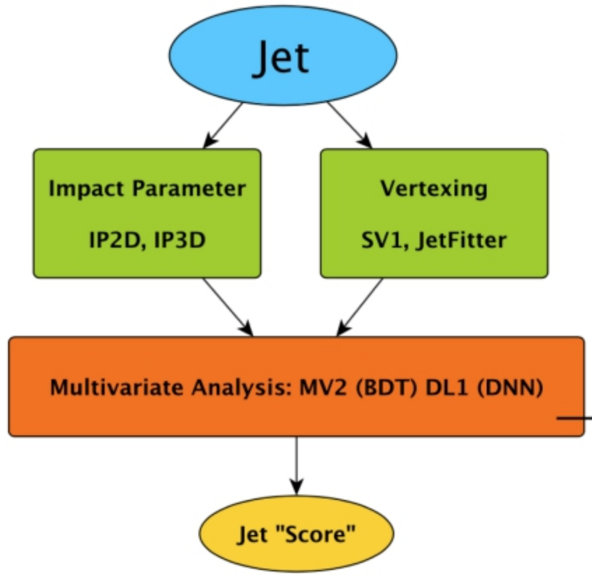
- **IP3D / IP2D:**
  - **Impact parameter algorithm**
  - Exploit (in)compatibility of track with PV

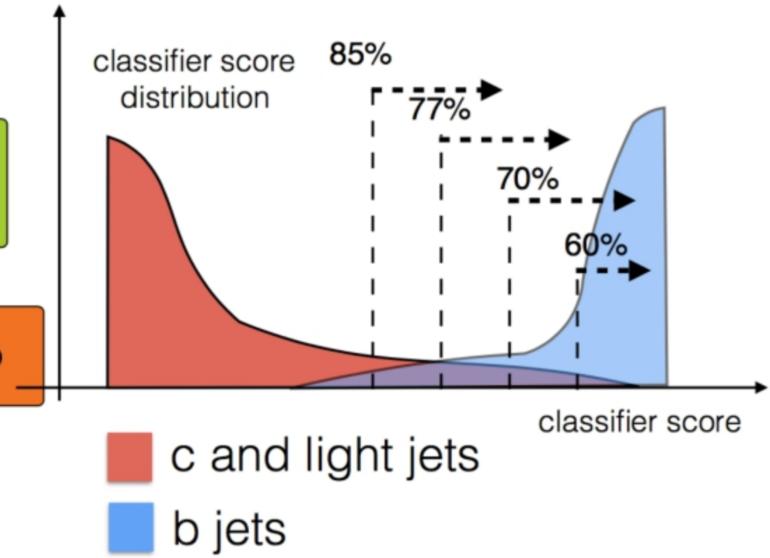


- **SV:**
  - **Inclusive Secondary vertexing**
  - Determination of single inclusive weak b-hadron decay vertex

- **JetFitter:**
  - **PV→B→D decay chain finding**
  - More detailed determination of decay vertex topology



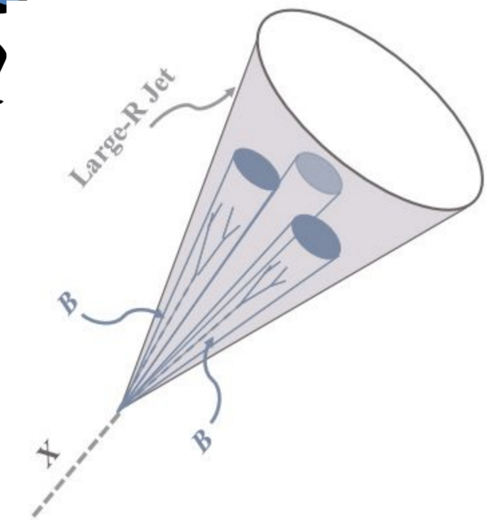


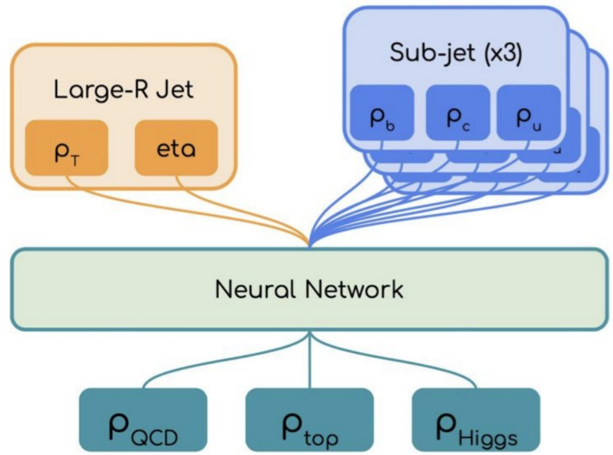


- Train models utilizing the outputs of impact parameter taggers and properties of vertices from vertexing algorithms
- MV2 - Boosted Decision tree based model
- DL1 – 8-hidden layer Deep Neural Network, multi-class classification

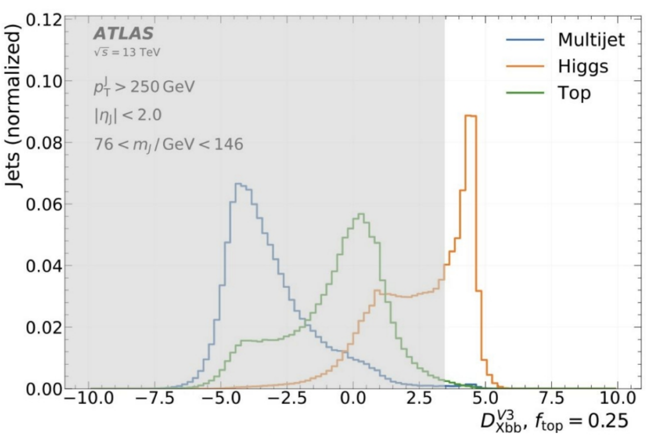
- Now ATLAS default btagging is based DNN (DL1)
  - ✓ Potential new ML algoritm? GNN?
- Potential multi-b-jet tagging?
  - ✓ Including color flow?
  - ✓ Better for H->bb event tagging

Boosted X→bb





- Double bjet tagging in boosted regime
- Reject top and QCD events



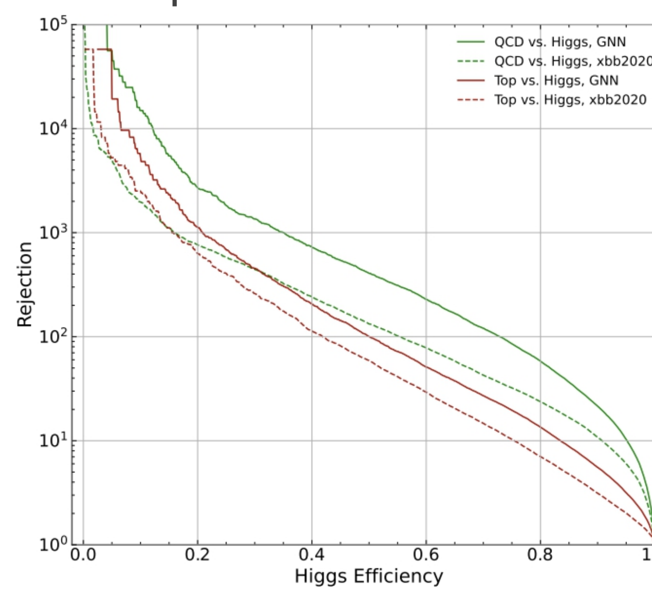
Grey shaded area 60% WP

$$D_{\mathrm{Xbb}} = \ln \frac{p_{\mathrm{Higgs}}}{f_{\mathrm{top}} \cdot p_{\mathrm{top}} + (1 - f_{\mathrm{top}}) \cdot p_{\mathrm{multijet}}}$$

https://indico.cern.ch/event/1132691/timetable/#b-457079-tagging-techniques

For future: GNN

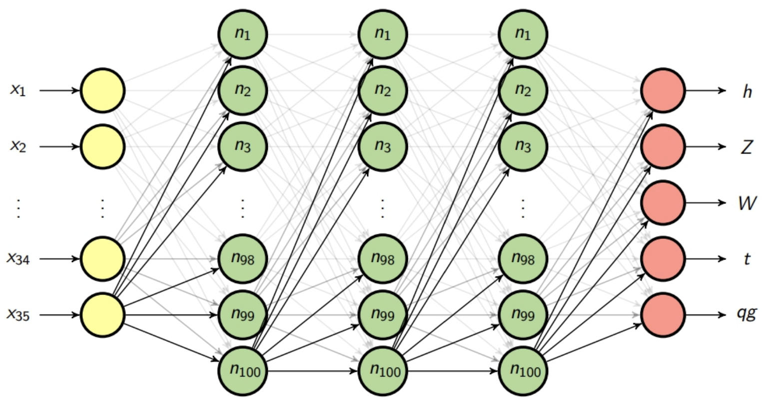
✓ An overall better performance

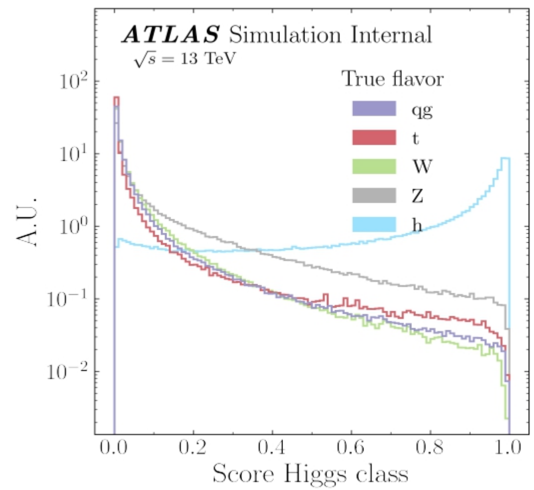


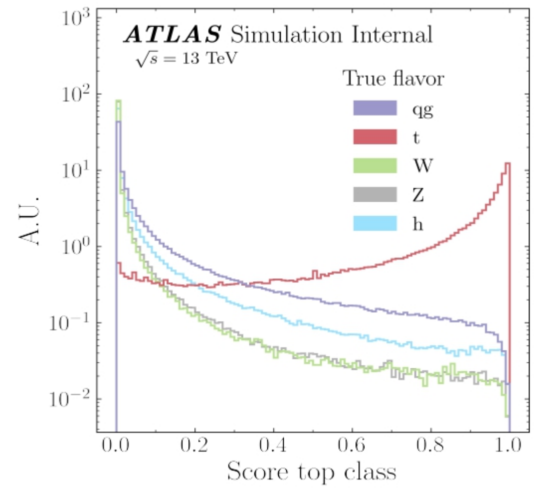
Boson/top tagger

https://indico.cern.ch/event/1132691/contributions/4989392/attachments/2503249/4300531/HDBSUppsala22_MCT_mmazza.pdf

- Classification for multiple classes







❖ For future: polarization-wised tagger?

✓ More classes

Regression for background

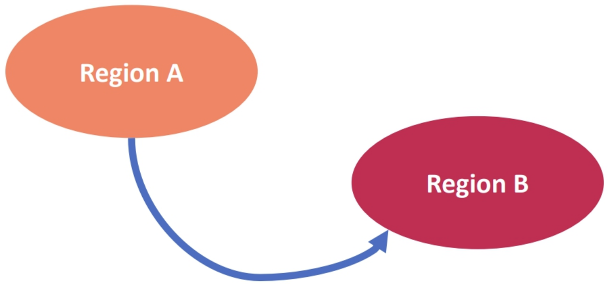
Reweighting with Neural Networks

A Brief Introduction

- Histogram-based reweightings suffer from "curse of dimensionality"
  - Prone to over- or under-fitting depending on choice of bin width
- Goal: determine an event-by-event reweighting to transform data from Region A into Region B
  - $p_A(x)\, w(x) = p_B(x) \rightarrow w(x) = \frac{p_B(x)}{p_A(x)}$
- Utilize dedicated loss function:

$$\mathcal{L}(Q(x)) = \mathbb{E}_{x\sim p_A}[\sqrt{e^{Q(x)}}] + \mathbb{E}_{x\sim p_B}[\frac{1}{\sqrt{e^{Q(x)}}}]$$

$$\arg\min_{Q} \mathcal{L}\,(Q(x)) = \log\frac{p_{B(x)}}{p_{A(x)}}$$



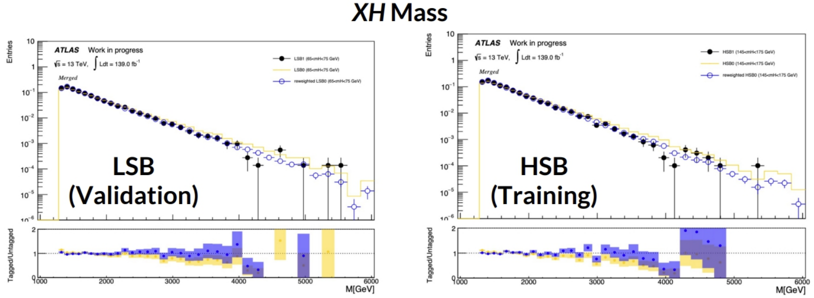
$$\boldsymbol{w(x) = \exp[\arg\min_{Q} \mathcal{L}\,(Q(x))]}$$

Methodology adapted from [arxiv:1911.00405](https://arxiv.org/abs/1911.00405)

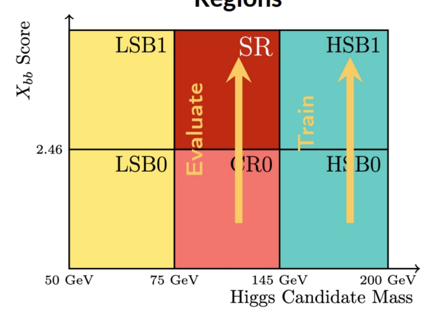
DBL $Y \rightarrow XH \rightarrow qqbb$

- Use DNN to derive reweighting from "fail"-$D_{H_{bb}}$ region to "pass"-$D_{H_{bb}}$ region
  - Expect consistent m_H dependence on X_{bb} (60% WP) cut $\rightarrow$ create CR by inverting X_{bb} cut

***XH* Mass**



Training (HSB), Validation (LSB), and Evaluation (CR0/SR) Regions



- Data driven BKG estimation based on ML
- Better for densing events

Other interesting thought

https://indico.cern.ch/event/1132691/timetable/#b-457081-new-machine-learning

New machine learning approaches

Conveners: Nicole Michelle Hartman (SLAC National Accelerator Laboratory (US)), Rafael Coelho Lopes De Sa (University of Massachusetts (US))

Zoom recording

19:30 — **Recent developments for autodiff and analysis optimization in pyHF (15'+3')** — 15m

Speaker: Matthew Feickert (University of Wisconsin Madison (US))

Feickert_2022-09-0... | Source GitHub repo... | talk: pyhf and analy...

19:48 — **Analysis optimization with pyHF and NEOS (15'+3')** — 15m

Speaker: Mr Nathan Daniel Simpson (Lund University (SE))

Link to Google Slides

20:06 — **ML methods for parton-object assignment (15'+3')** — 15m

Speaker: Yuan-Tang Chou (University of Massachusetts (US))

JetPartonAssignme...

Regression

20:24 — **Study on Different Machine Learning Algorithms Used in the Search for di-Higgs in the Multi-lepton Final State (7'+3')** — 7m

Speaker: Santosh Parajuli (Southern Methodist University (US))

HDBS_Uppsala_202...

20:34 — **Searches using a per-event likelihood approach (15'+3')** — 15m

Speaker: Jay Ajitbhai Sandesara (University of Massachusetts (US))

HDBS_Uppsala_Jay...

Classification