

The logo for Jefferson Lab features the text "Jefferson Lab" in white, bold, sans-serif font against a black rectangular background. A red, stylized orbital path with a small red sphere at one end curves around the text.

Jefferson Lab

Universal Monte Carlo Event Generator

Supported by Jefferson Lab Laboratory
research and development (LDRD19-13)

Nobuo Sato

A.I. for Nuclear Physics Workshop
Jefferson Lab, 2020

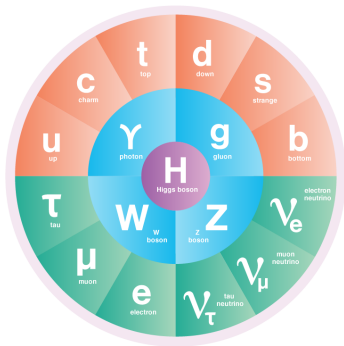
Partnership with computer scientists

- Y. Alanazi (ODU)
- M. P. Kuchera (Davidson College)
- Y. Li (co-PI) (ODU)
- T. Liu (JLab)
- R. E. McClellan (JLab)
- W. Melnitchouk (PI) (JLab)
- E. Pritchard (Davidson College)
- R. Ramanujan (Davidson College)
- M. Robertson (Davidson College)
- NS (co-PI) (JLab)
- R. R. Strauss (Davidson College)
- L. Velasco (Dallas)



The big picture

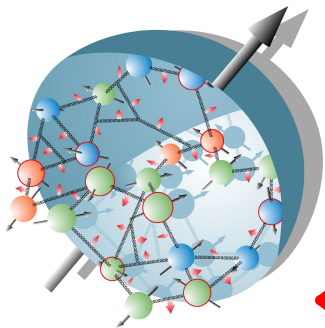
hadrons as **emergent phenomena** of QCD



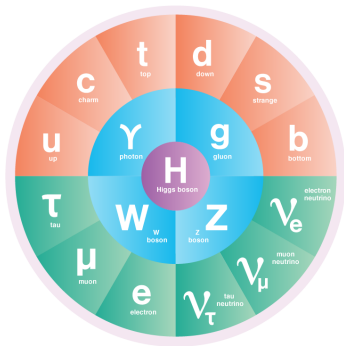
quarks and gluons

The big picture

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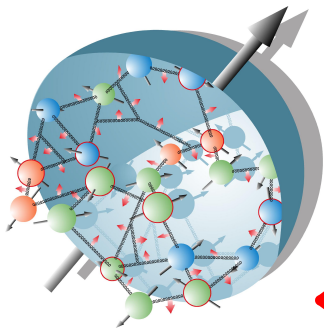
nucleon structure



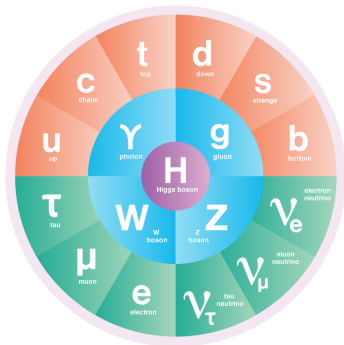
quarks and gluons

The big picture

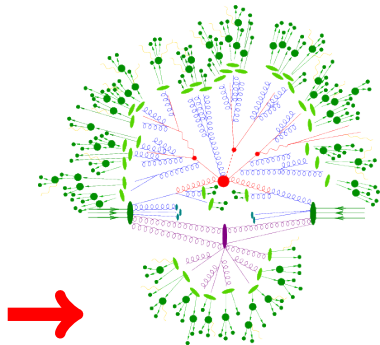
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nucleon structure

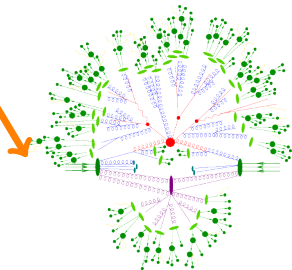
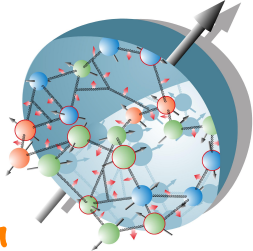
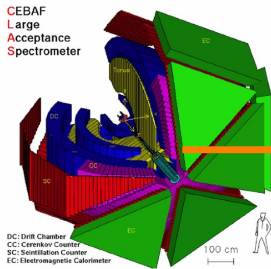


quarks and gluons



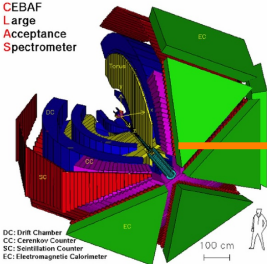
hadronization

From detectors to partons



From detectors to partons

CEBAF
Large
Acceptance
Spectrometer



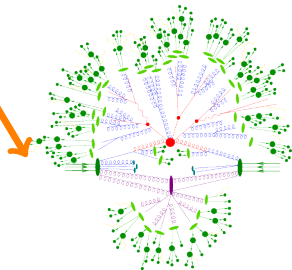
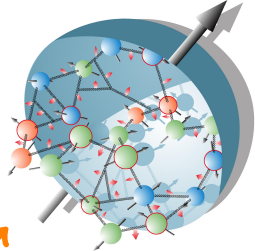
Detector
response



QED
effects

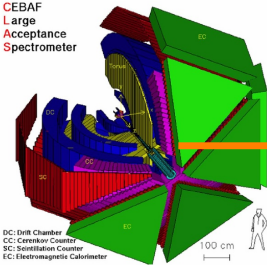


QCD
effects



From detectors to partons

CEBAF
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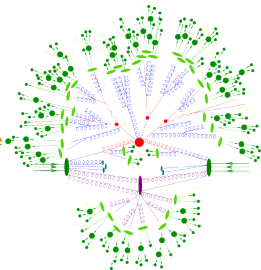
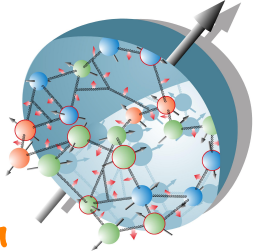
Detector
response



QED
effects



QCD
effects



$$\sigma^{\text{EXP}} = w^{\text{DR}} \otimes w^{\text{QED}} \otimes \sigma^{\text{QCD}}$$

The goals

The goals

- Build a **theory-free** MCEG

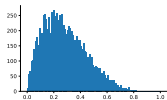
The goals

- Build a **theory-free** MCEG
- Map out particles correlations without biases from **approximated theory**

The goals

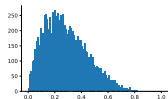
- Build a **theory-free** MCEG
- Map out particles correlations without biases from **approximated theory**
- MCEG as a **data storage utility**

Nature

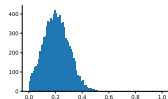


**Events:
vertex level**

Nature



distortion

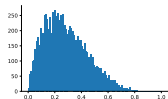


Events:
vertex level

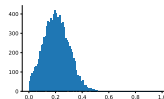
Experimental
detector

Events:
detector level

Nature



distortion



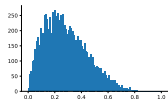
**Events:
vertex level**

**Experimental
detector**

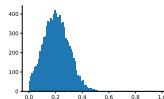
**Events:
detector level**

Inverse problem

Nature



distortion



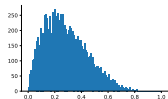
Events:
vertex level

Experimental
detector

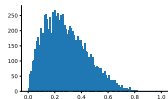
Events:
detector level

Events:
vertex level

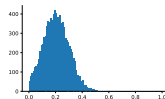
AI



Nature



distortion



Events:
vertex level

Experimental
detector

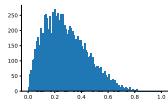
Events:
detector level

Events:
vertex level

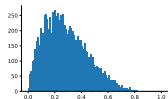
Detector
simulator

neural net
detector

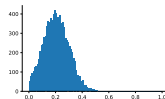
AI



Nature



distortion



Events:
vertex level

Experimental
detector

Events:
detector level

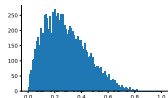
Detector
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Events:
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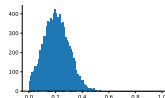
neural net
detector

Events:
detector level

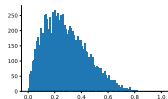
AI



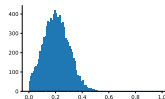
distortion



Nature



distortion



Experimental
detector

Events:
vertex level

Detector
simulator

Events:
detector level

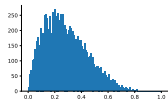
Events:
vertex level

neural net
detector

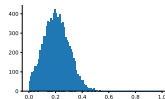
Events:
detector level

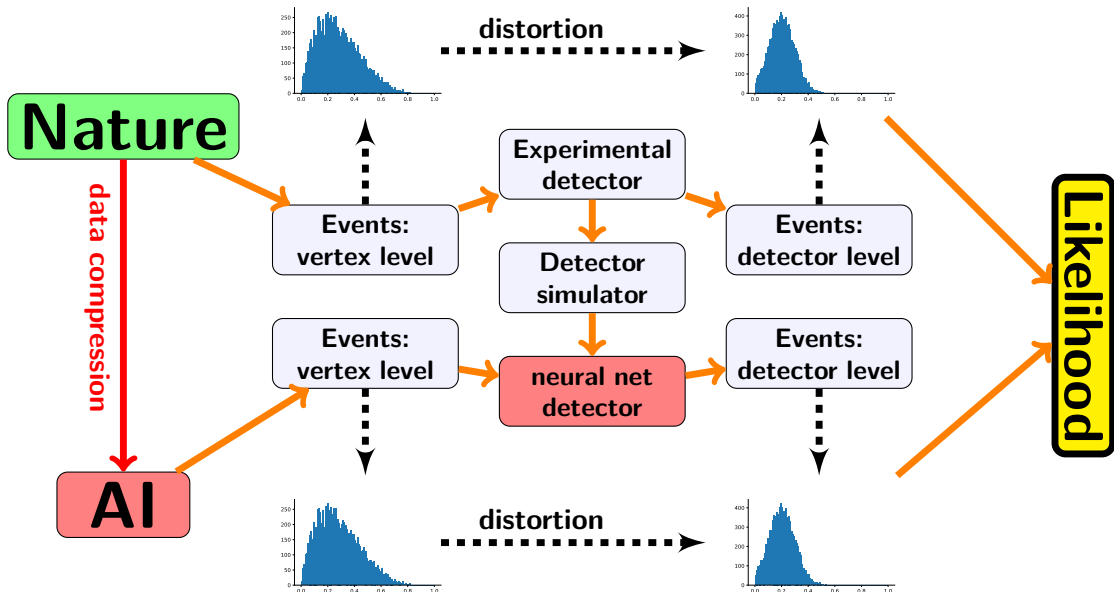
Likelihood

AI



distortion





Our strategy

Our strategy

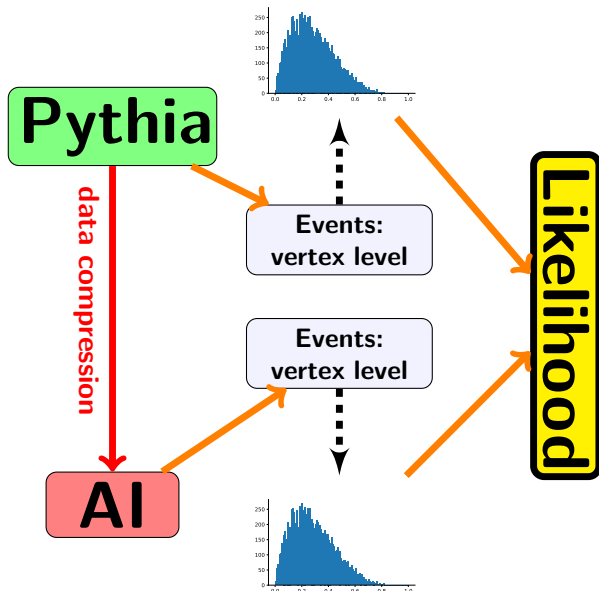
- Replace **Nature** → **Pythia** for validation

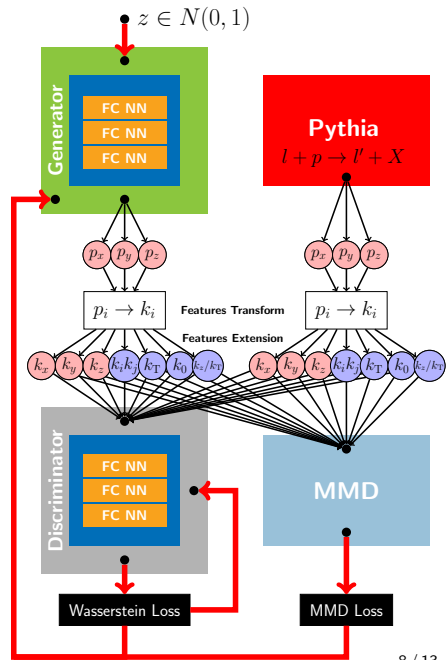
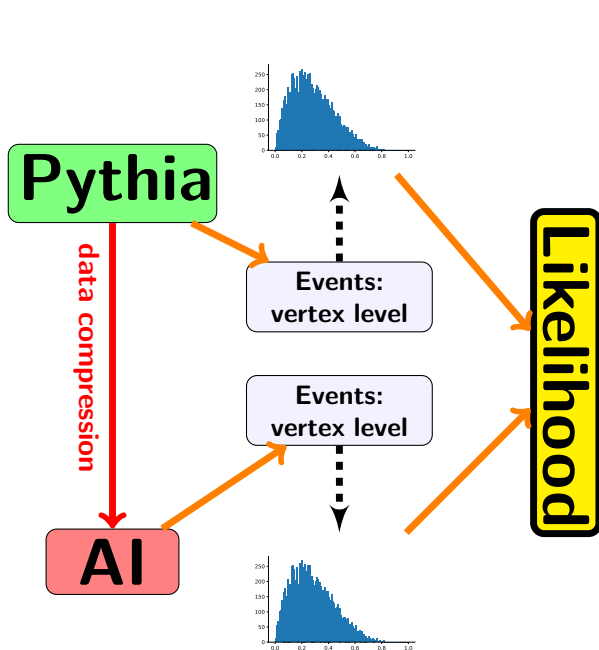
Our strategy

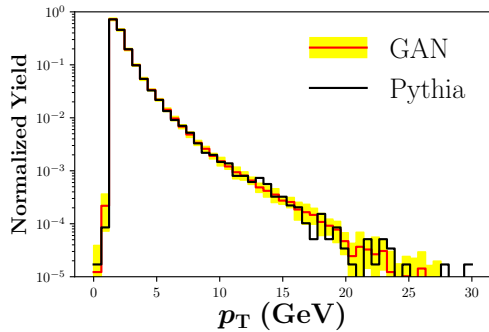
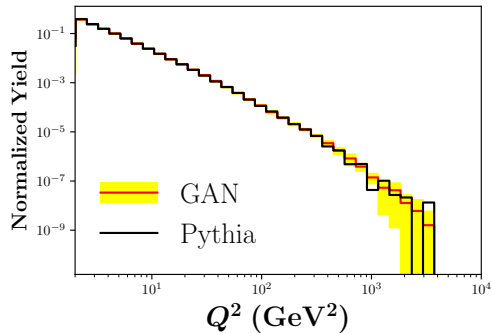
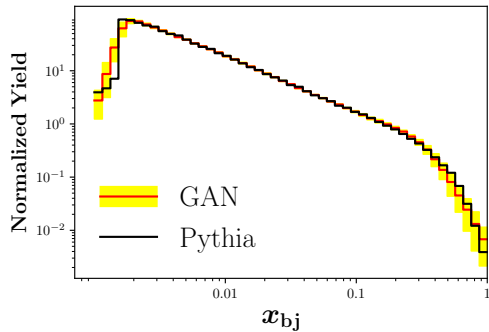
- Replace **Nature** → **Pythia** for validation
- Ignore **detector effects** to start

Our strategy

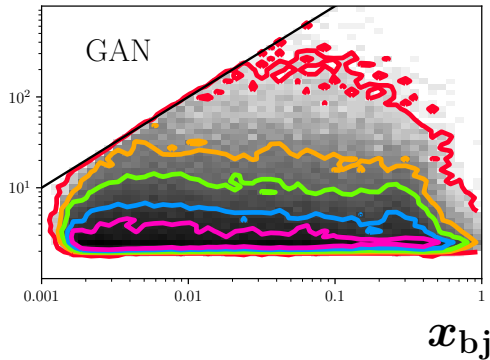
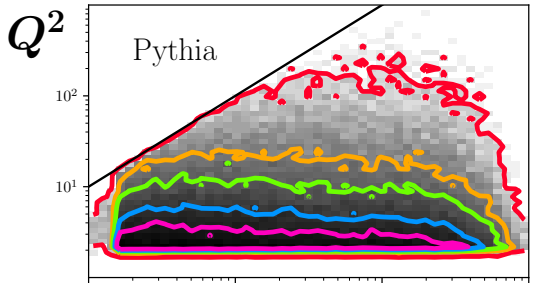
- Replace **Nature** → **Pythia** for validation
- Ignore **detector effects** to start
- Find a suitable **“image”** representation for the events







Error bands generated with bootstrapped samples



- Isocontours are in agreement
- x_{bj}, Q^2 correlation is learned without adding $x_{bj} \cdot Q^2$ feature

Challenges

- Find optimal data representation
→ what is the **image of an event**?

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- How to make the GAN to learn the **features of the event**? → CNN

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- Find optimal data representation
→ what is the **image of an event**?
- How to make the GAN to learn the **features of the event**? → CNN
- How to escalate from low to higher multiplicities?

Summary and outlook

- It is possible to train a GAN at the **event level** to build a MCEG

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- The current design provides **a blueprint** for a generator with higher multiplicity

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- More work is needed, but the **results are encouraging**

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- More work is needed, but the **results are encouraging**
- A fully trained UMCEG will be a **complementary tool** to theory-based MCEGs such as Pythia