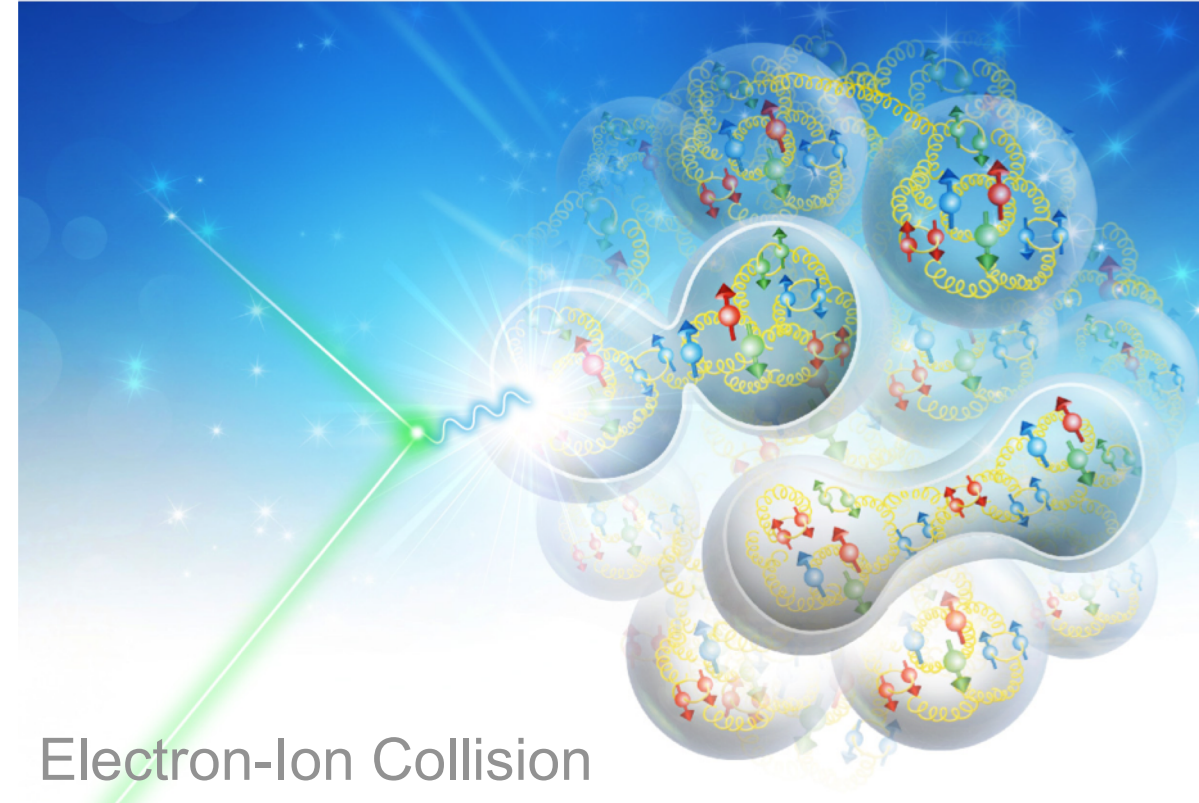
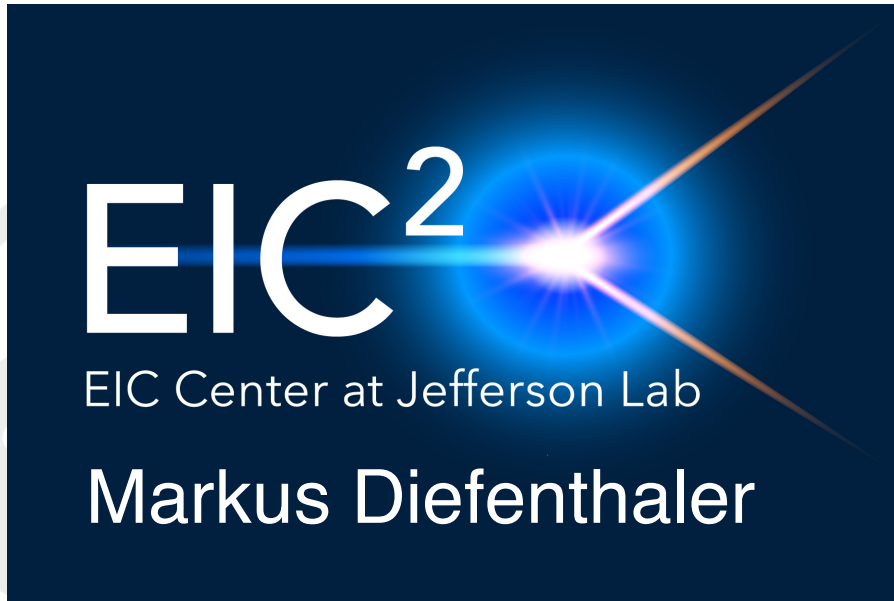


# Reaching out to the Semi-Inclusive Reactions Subgroup

Update from EICUG Software Working Group

Update from Center for Nuclear Femtography



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# **Update from** **EICUG Software Working Group**

# Role of Software Working Group

**Develop**

**Support**

## Workflow environment for EIC simulations

- **to use** (tools, documentation, support) **and**
- **to grow with user input** (direction, documentation, tools)



**Involvement from EICUG**

e.g. benchmark processes,  
detector design, tracking algorithms,  
MC reweighting, SSA analysis

# Point of entry

HOME	<b>JOIN EICUG</b>	SCIENCE	ORGANIZATION	PHONEBOOK	CALENDAR	<b>SOFTWARE</b>	DOCUMENTS	MEDIA	LOGIN
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[Home](#) » [EIC Software](#)

## EIC Software

### Software Working Group

The EICUG has formed a [Software Working Group](#) that collaborates with EIC Software initiatives and other experts in NP and HEP on detector and physics simulations for the EIC. The short-term goal of the working group is to meet in FY20 the requirements for common tools and documentation in the EICUG. The current work focusses on a common Geant4 infrastructure for the EIC that allows geometry exchange between the eRHIC and JLEIC concepts.

### JupyterLab

The Software Working Group has adapted JupyterLab as a collaborative workspace to further develop EIC Science, to examine detector requirements, and to work on detector designs and concepts. JupyterLab is a web-based interactive analysis environment to create and share documents that contain the analysis code, the narrative of the analysis including graphics and equations, and visualizations of the analysis results. This will allow the EICUG not only to pursue simulations in a manner that is accessible, consistent, and reproducible to the EICUG as a whole, but also to build a collection of analyses and analysis tools in the fully extensible and modular JupyterLab environment. A [quick start tutorial for fast simulations](#) is available on the [website for EIC Software](#).

### Important links

Mailing list	<a href="mailto:eicug-software@eicug.org">eicug-software@eicug.org</a> (subscribe via <a href="#">Google Group</a> )
Repository	<a href="http://gitlab.com/eic">http://gitlab.com/eic</a>
Website	<a href="https://software.eicug.org">https://software.eicug.org</a>

# Collaborative workspace for EIC simulations

## JupyterLab

- web-based interactive analysis environment

The screenshot shows a JupyterLab environment with a file browser on the left, a code editor in the center, and a plot at the bottom. The code in the editor defines a tree structure, calculates vertical and horizontal angles, and uses Matplotlib to create a 2D histogram titled "Neutrons angle distribution". The plot shows a distribution of vertical angle (y) versus horizontal angle (x) in radians, with a color scale from  $10^1$  to  $10^3$ .

```
[3]: tree = uproot.open('./data/eventless_output.root')['eventless']['tree']
tracks_df = tree.pandas.df(["pdg_b", "p_b", "px_b", "py_b", "pz_b"])

[10]: tracks_df['vertical_angle'] = np.arcsin(tracks_df['py_b']/tracks_df['p_b'])
tracks_df['horizontal_angle'] = np.arctan(tracks_df['px_b']/tracks_df['pz_b'])
v_angle = tracks_df[tracks_df.pdg_b == 2212].vertical_angle.values
h_angle = tracks_df[tracks_df.pdg_b == 2212].horizontal_angle.values

Horizontal angle (x):  $\alpha_h = \arctan\left(\frac{p_x}{p_z}\right)$ 

Vertical angle (y):  $\alpha_v = \arcsin\left(\frac{p_y}{p}\right)$ 

[11]: fig, ax = plt.subplots()
h, xedges, yedges, im = ax.hist2d(h_angle, v_angle,
bins=[np.arange(-200,101,5)/1000,np.arange(-150,151,5)/1000],
norm=matplotlib.colors.LogNorm())
plt.colorbar(im, ax=ax)
plt.xlabel('Horizontal angle (x) [rad]')
plt.ylabel('Vertical angle (y) [rad]')
plt.title('Neutrons angle distribution')
ax.set_axisbelow(True)
plt.grid(True)
plt.show()
```

## Jupyter Notebooks

- writing analysis code

```
[4]: jana.plugin('hepmc_reader') \
.plugin('jana', nevents=10000, output='hepmc_sm.root') \
.plugin('eic_smear', detector='jleic') \
.plugin('open_charm')

[4]: eJana configured
plugins: hepmc_reader,eic_smear,open_charm

[5]: jana.source('../data/herwig6_20k.hepmc')

[5]: eJana configured
plugins: hepmc_reader,eic_smear,open_charm
sources:
../data/herwig6_20k.hepmc

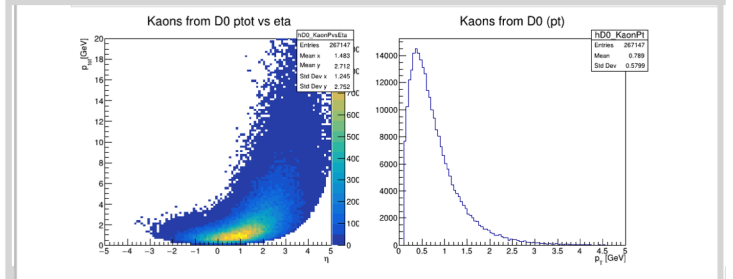
[6]: jana.run()

Total events processed: 10001 (~ 10.0 kevt)
```

Python

Root/C++

- visualization of results



- narrative of the analysis

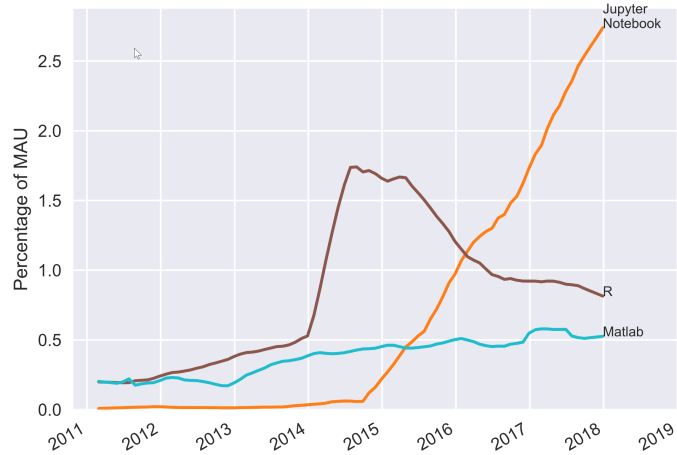
Open charm

The high luminosity at the EIC would allow measurements of open charm production with much higher rates than at HERA and COMPASS, extending the kinematic coverage to large  $x_B \gg 0.1$  and rare processes such as high- $p_T$  jets. Heavy quark production with electromagnetic probes could for the first time be measured on nuclear targets and used to study the gluonic structure of nuclei and the propagation of heavy quarks through cold nuclear matter with full control of the initial state.

The figure shows four Feynman diagrams illustrating open charm production. The diagrams are labeled  $D^0$ ,  $D^+$ ,  $D^+$ , and  $D_s^+$ . Each diagram shows a quark line (red) and a gluon line (blue) interacting to produce a charm quark (red) and a gluon (blue), which then decay into a charm meson and a gluon.

# JupyterLab environment

- **bridge to modern data science**, e.g.,



- *Nature* **563**, 145-146 (2018): “Why Jupyter is data scientists’ computational notebook of choice”
- more than three million Jupyter Notebooks publicly available on GitHub

- **collaborative workspace** to create and share Jupyter Notebooks
- **web-based interactive analysis environment** accessible, consistent, reproducible analyses
- **fully extensible and modular** build a collection of analyses and analysis tools

## Jupyter Notebooks

- **writing analysis code**

```
[4]: jana.plugin('hepmc_reader') \
     .plugin('jana', nevents=10000, output='hepmc_sm.root') \
     .plugin('eic_smear', detector='jleic') \
     .plugin('open_charm')

[4]: eJana configured
     plugins: hepmc_reader,eic_smear,open_charm

[5]: jana.source('../data/herwig6_20k.hepmc')

[5]: eJana configured
     plugins: hepmc_reader,eic_smear,open_charm
     sources:
     ../data/herwig6_20k.hepmc

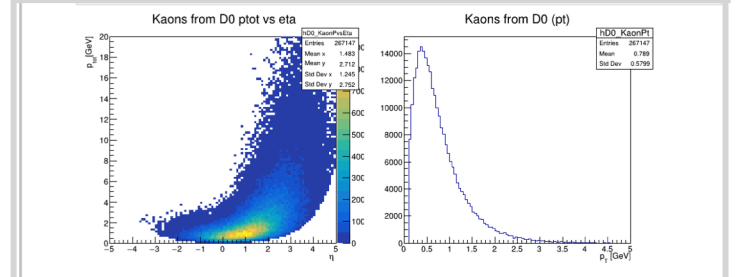
[6]: jana.run()

Total events processed: 10001 (~ 10.0 kevt)
```

Python

Root/C++

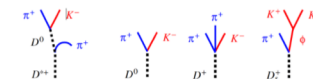
- **visualization of results**



- **narrative of the analysis**

### Open charm

The high luminosity at the EIC would allow measurements of open charm production with much higher rates than at HERA and COMPASS, extending the kinematic coverage to large  $x_B \gg 0.1$  and rare processes such as high- $p_T$  jets. Heavy quark production with electromagnetic probes could for the first time be measured on nuclear targets and used to study the gluonic structure of nuclei and the propagation of heavy quarks through cold nuclear matter with full control of the initial state.



# Modular design

## Escaping complexity scaling trap

- provide interfaces to internal layers
- interaction between layers must be clear

**Modularity** each layer must be replaceable

**simple**

JupyterLab web interface

**moderate**

analysis scripts, python

**complex**

eJANA, plugins, C++

**expert**

JANA, eic-smear, *fun4all*, ROOT, Geant4

../data/beagle\_eD.txt

```
[3]: jana.run()
```

Total events processed: 10001 (~ 10.0 kevt)

► Full log

▼ Run command

```
ejana
-Pplugins=beagle_reader,vmeson,event_writer
-Pnthreads=1
-Pnevents=10000
-Poutput=beagle.root
../data/beagle_eD.txt
-Pjana:debug_plugin_loading=1
```

# EIC Software

---

**Simulation of physics processes**

**Monte Carlo Event Generators**  
Tutorials in preparation

**Simulation of detector responses**

**Fast simulations**  
Tutorials ✓

**Full simulations**  
Tutorials ✓

**Physics analysis**

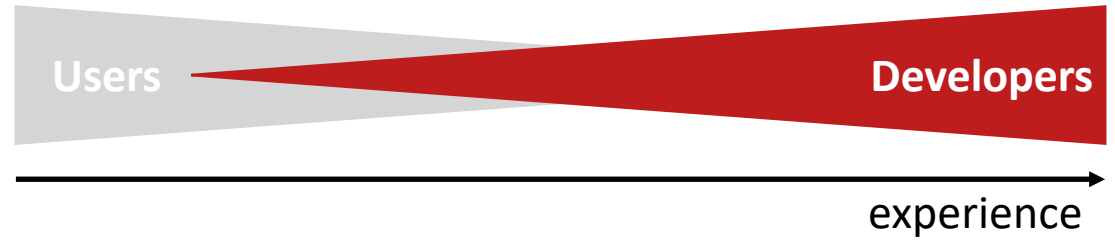
**Reconstruction of physics processes**  
Tutorials in preparation



# Support

**support team**

**being built up  
weekly shifts**



**[software-support@eicug.org](mailto:software-support@eicug.org)**

**Mailing list** (anyone can contact)  
**Google forum** (for archive of support requests and start of knowledge base)

**<http://eicug.slack.com/>**

**EICUG Slack workspace with software-support channel**

# Requests from EICUG Software Working Group

**Develop**

## Workflow environment for EIC simulations

- **to use** (tools, documentation, support) **and**
- **to grow with user input** (direction, documentation, tools)

**Support**



**Semi-Inclusive Reactions  
Subgroup**

## Engage with us

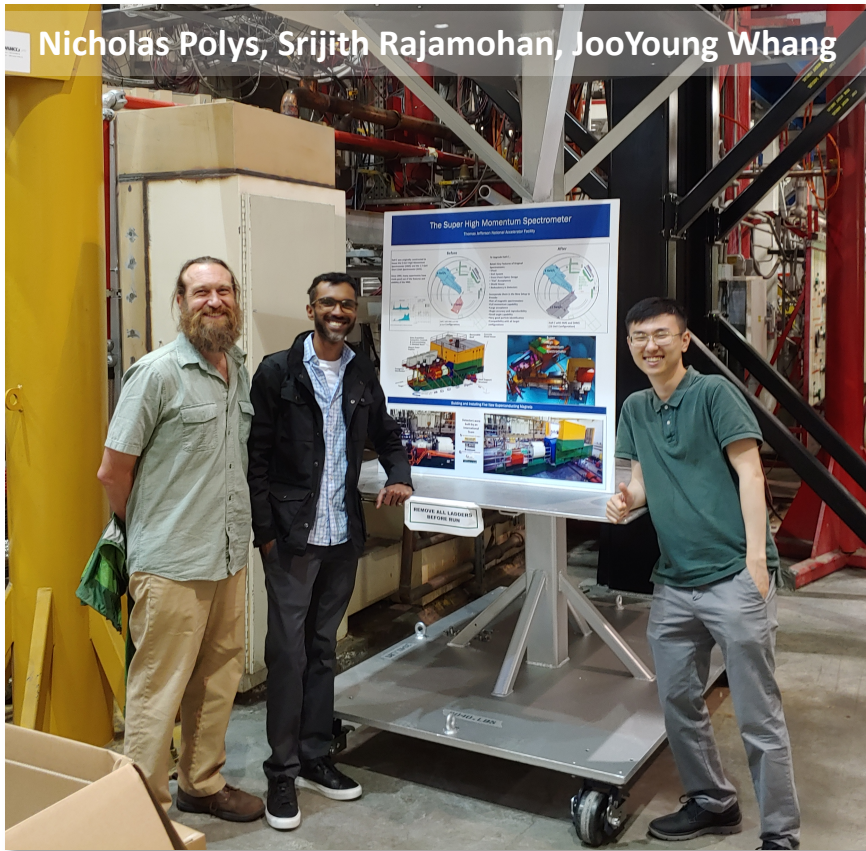
- Make your MC samples available
- Integrate your software into our workflow environment
- Send us requests



## **Update from Center for Nuclear Femtography**

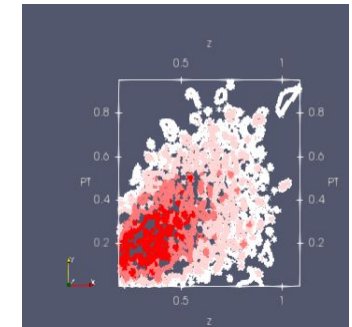
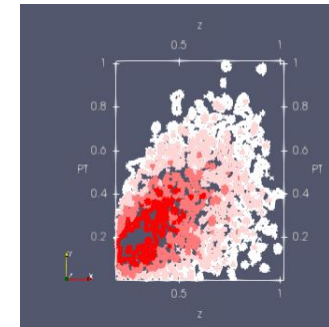
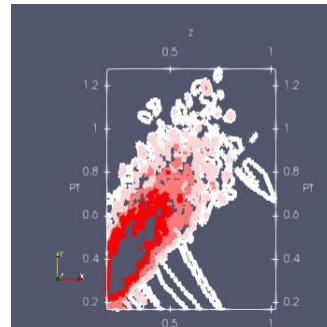
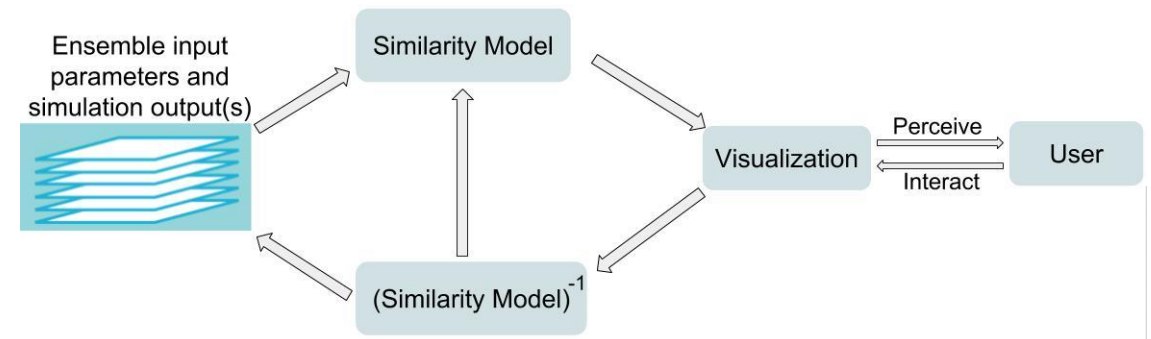
# **Next-generation Visual Analysis Workspace for Multi-Dimensional Nuclear Femtography Data**

# Next-Generation Visual Analysis Workspace for SIDIS



**Project by Virginia Tech and Jefferson Lab** Explore new visualization methods for Nuclear Physics

**First approach** Can we use **Semantic Interactions** to explore SIDIS regions?



# Exploring SIDIS regions

**JHEP** PUBLISHED FOR SISSA BY SPRINGER

RECEIVED: May 10, 2019  
REVISED: September 3, 2019  
ACCEPTED: September 14, 2019  
PUBLISHED: October 9, 2019

## Mapping the kinematical regimes of semi-inclusive deep inelastic scattering

M. Boglione,<sup>a</sup> A. Dotson,<sup>b</sup> L. Gamberg,<sup>c</sup> S. Gordon,<sup>d</sup> J.O. Gonzalez-Hernandez,<sup>a</sup>  
A. Prokudin,<sup>e,c</sup> T.C. Rogers<sup>e,d</sup> and N. Sato<sup>e</sup>

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Via P. Giuria 1, 10125 Torino, Italy  
<sup>b</sup>Department of Physics, New Mexico State University,  
Las Cruces, NM, 88003, U.S.A.  
<sup>c</sup>Science Division, Penn State University Berks,  
Reading, Pennsylvania 19610, U.S.A.  
<sup>d</sup>Department of Physics, Old Dominion University,  
Norfolk, VA 23529, U.S.A.  
<sup>e</sup>Jefferson Lab,  
12000 Jefferson Avenue, Newport News, VA 23606, U.S.A.  
E-mail: [elena.boglione@to.infn.it](mailto:elena.boglione@to.infn.it), [adots004@msu.edu](mailto:adots004@msu.edu), [lpg10@psu.edu](mailto:lpg10@psu.edu),  
[ssgordon@odu.edu](mailto:ssgordon@odu.edu), [joseosvaldo.gonzalez@to.infn.it](mailto:joseosvaldo.gonzalez@to.infn.it), [prokudin@jlab.org](mailto:prokudin@jlab.org),  
[troggers@jlab.org](mailto:troggers@jlab.org), [nsato@jlab.org](mailto:nsato@jlab.org)

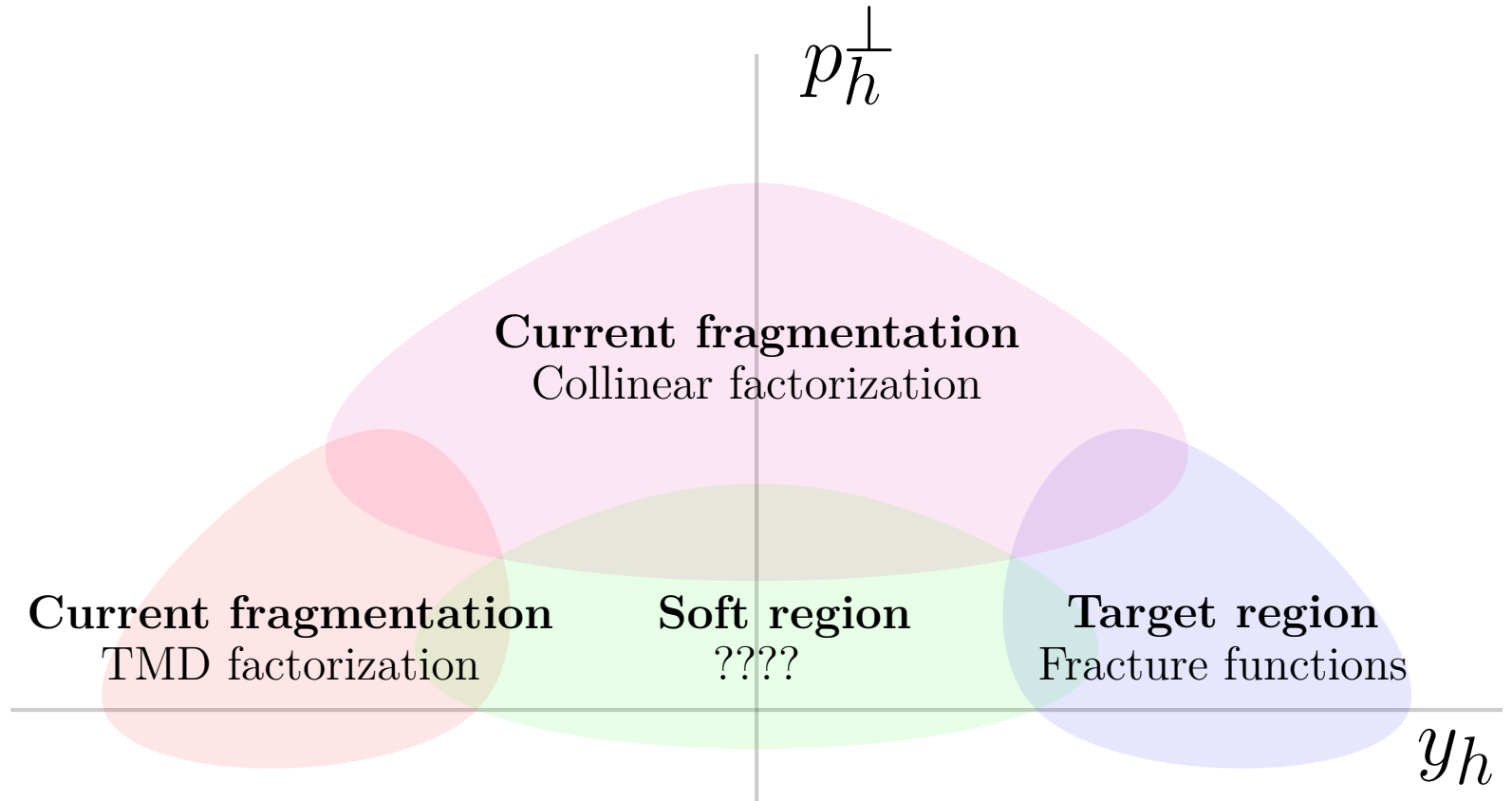
ABSTRACT: We construct a language for identifying kinematical regions of transversely differential semi-inclusive deep inelastic scattering (SIDIS) cross sections with particular underlying partonic pictures, especially in the regions of moderate to low  $Q$  where sensitivity to kinematical effects becomes non-trivial. These partonic pictures map to power law expansions whose leading contributions ultimately lead to well-known QCD factorization theorems. In order to establish the consistency of a particular observable in SIDIS process with an estimate of the appropriate underlying partonic picture, we introduce new quantitative criteria expressed in terms of various ratios of partonic and hadronic momentum degrees of freedom. We propose how to use these criteria in phenomenology and provide a web tool which allows visualization of these ratios for any chosen kinematic configuration.

KEYWORDS: Deep Inelastic Scattering (Phenomenology), QCD Phenomenology

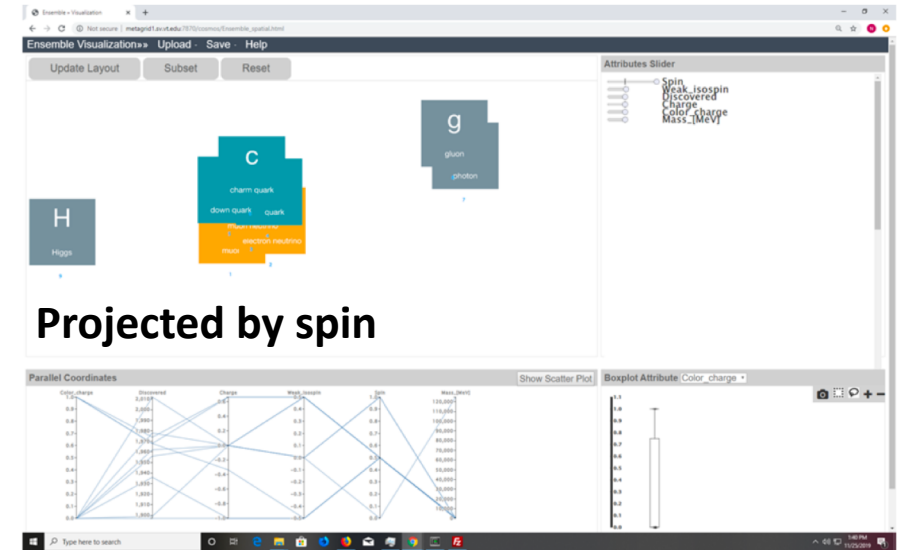
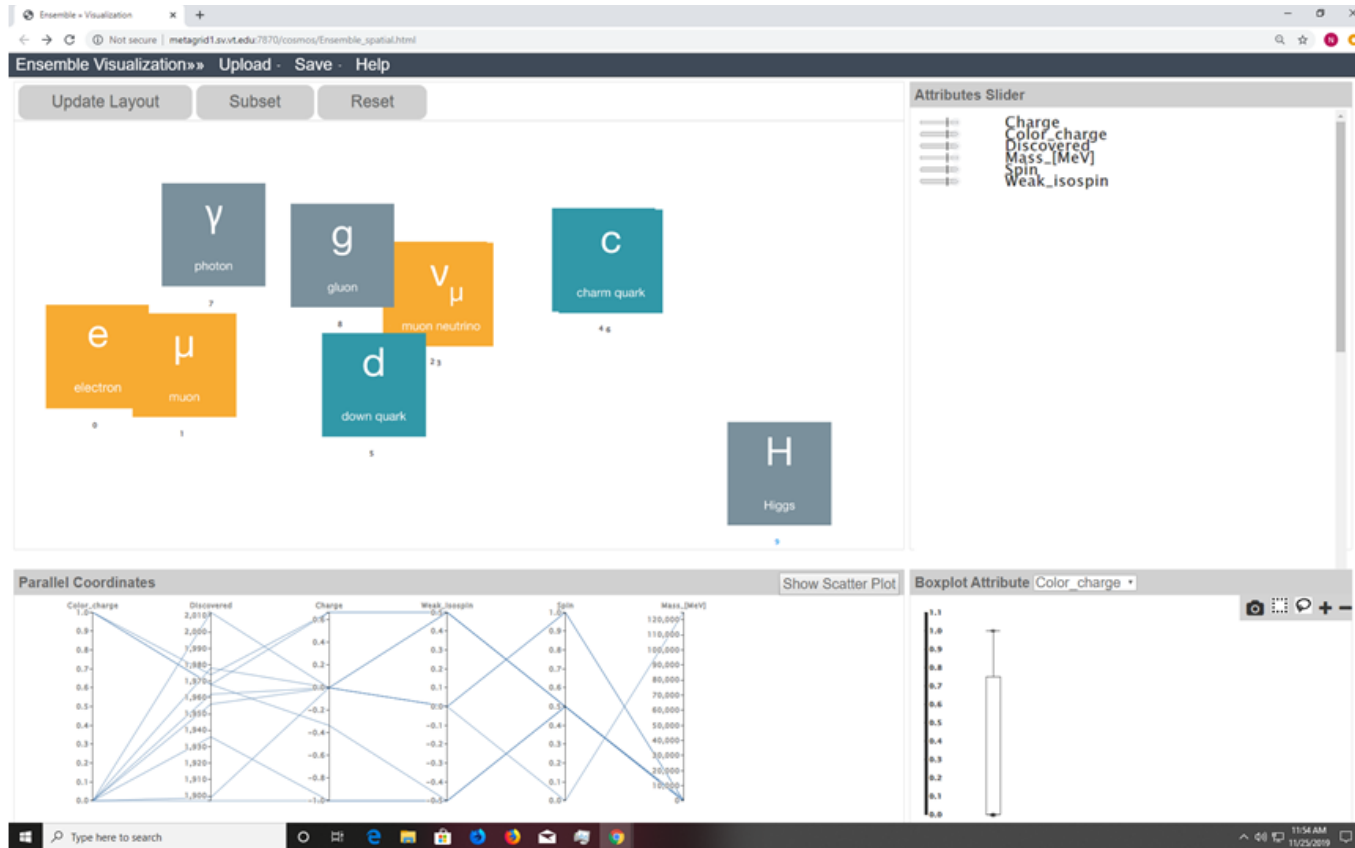
ARXIV EPRINT: [1904.12882](https://arxiv.org/abs/1904.12882)

OPEN ACCESS, © The Authors.  
Article funded by SCOAP<sup>3</sup>. [https://doi.org/10.1007/JHEP10\(2019\)122](https://doi.org/10.1007/JHEP10(2019)122)

JHEP10(2019)122



# Toy example: Particle zoo



Projected by spin

Projected by year of discovery

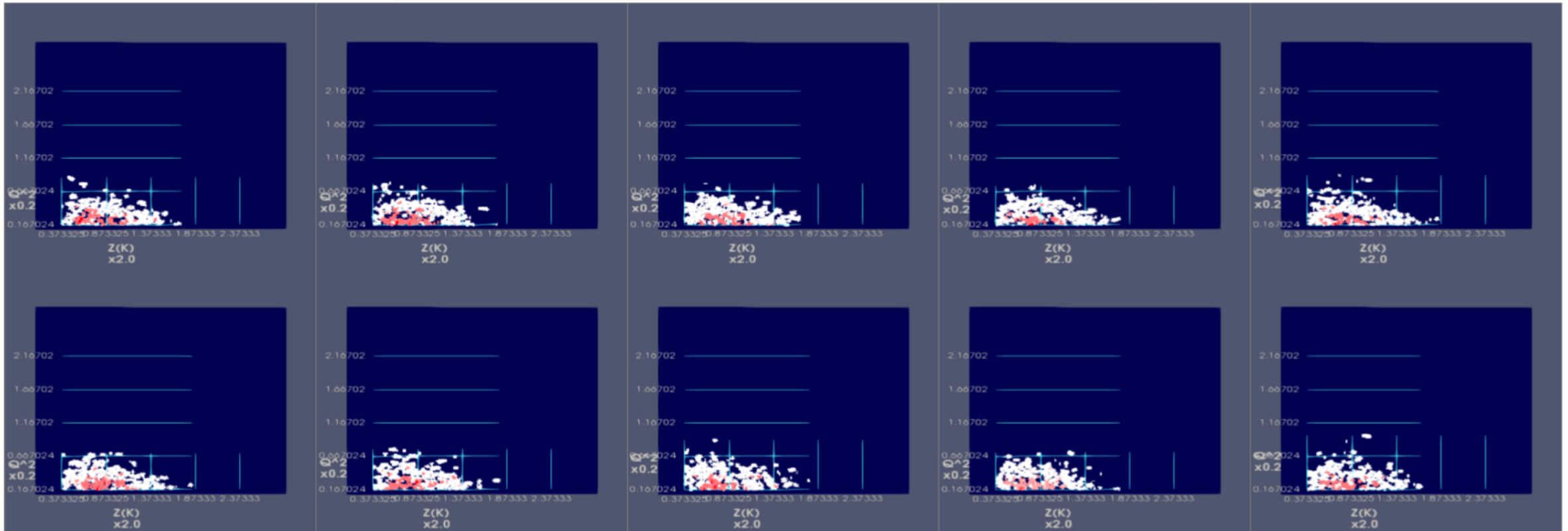
# Create thumbnails from SIDIS events

Particle Type:  
 ▾  
 QZP Threshold:  
 ▾

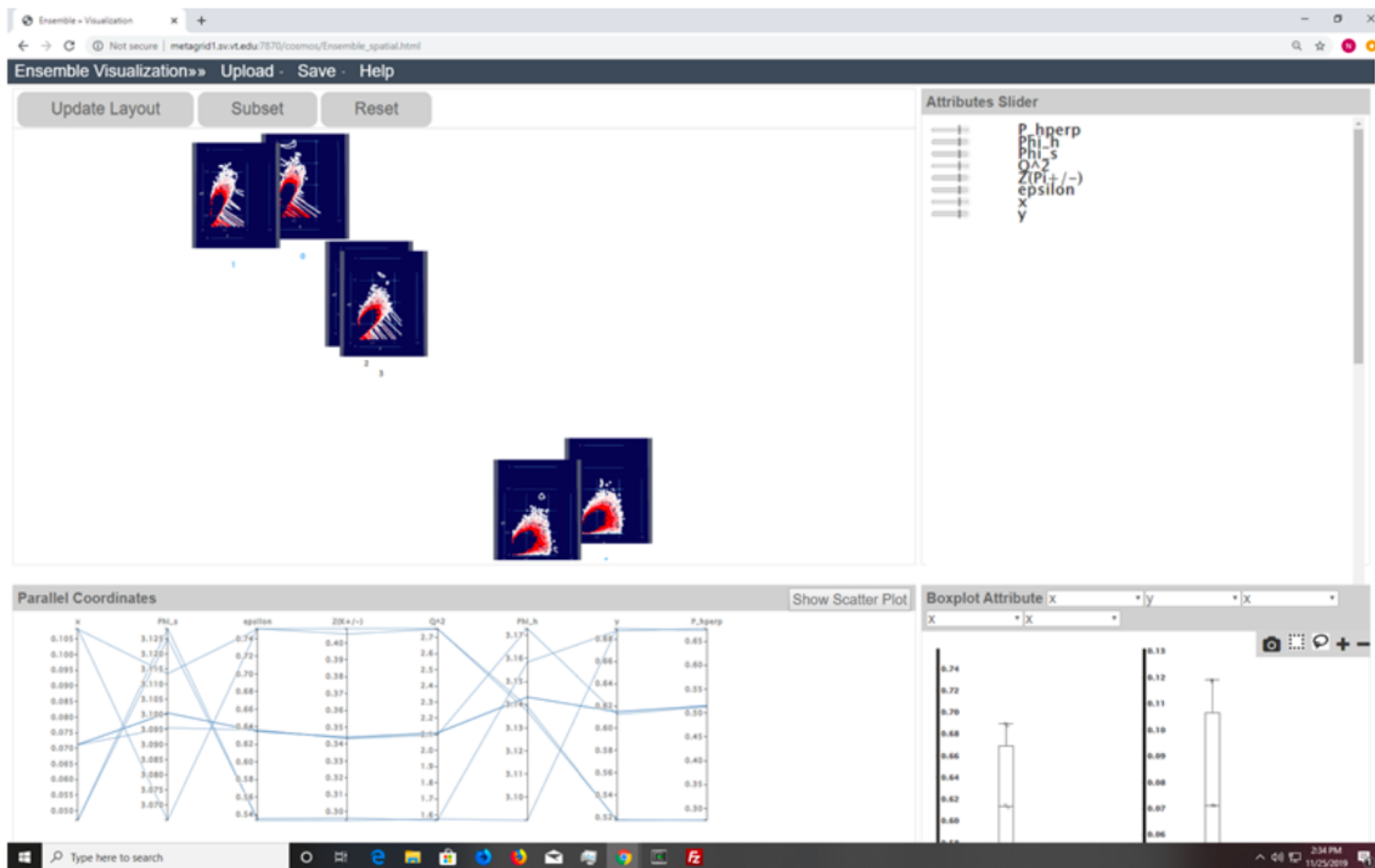
Use the above drop down to choose which particle type to display and which QZP threshold to use, then click on the matrix cells to display thumbnails for that particular combination of variables.  
 The axis label values are scaled;  
 divide by the scaled label value to get the true value.  
 $QZP = Q^2 / (P_{\text{hperp}} / Z)^2$

Thumbnail Matrix

VARIABLES	X	Y	Z(Pi)	Z(K)	P_hperp	Q^2	Epsilon
X							
Y							
Z(Pi)							
Z(K)							
P_hperp							
Q^2							
Epsilon							



# Kinematic studies based on semantic interactions



Of interest  
for YR  
studies?