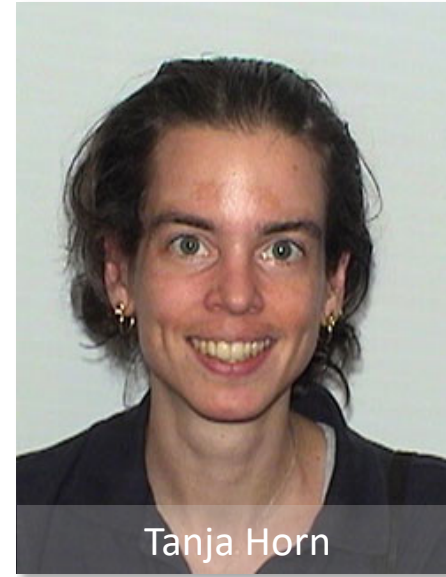
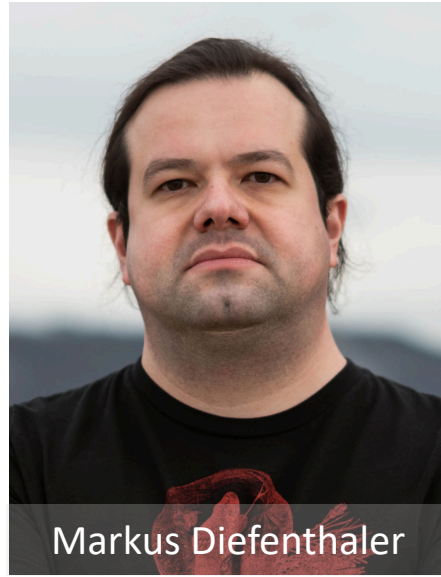




Update from EICUG Software Working Group

# EICUG Software Working Group: Conveners



**Liaison to EICUG SC**

**Many thanks to EICUG SC for support.**

**Mailing list (135 members):** [eicug-software@eicug.org](mailto:eicug-software@eicug.org)

**Meetings (16 meetings in 2022):** <https://indico.bnl.gov/category/301/>

# EIC Software Efforts

---

**2016 – 2020**    **EIC Software Consortium (ESC)**

**2018 – now**    **EICUG Software Working Group (SWG)**

**2019 – 2021**    **Yellow Report Initiative**

**2021 – 2022**    **Detector Collaboration Proposals**

**2022 – now**    **EPIC Computing and Software (CompSW) Working Group**  
**EPIC Simulation, Production, and QA (SimQA) Working Group**

# EPIC CompSW and EICUG SWG

## EPIC CompSW



## Sylvester's Picture of Salt & Pepper



## EICUG SWG

- EPIC Collaboration and EIC project have strict timeline with well-defined deliverables from short to long term.
- This defines the scope and deliverables of EPIC CompSW.
  
- EICUG fosters the community.
- EICUG SWG is a forum for discussion and forward-looking projects.
- Ideal platform for cross-collaboration:
  - Experiment and theory
  - EPIC and 2<sup>nd</sup> Detector
  - Interdisciplinary collaborations (data scientists, HEP, ...)

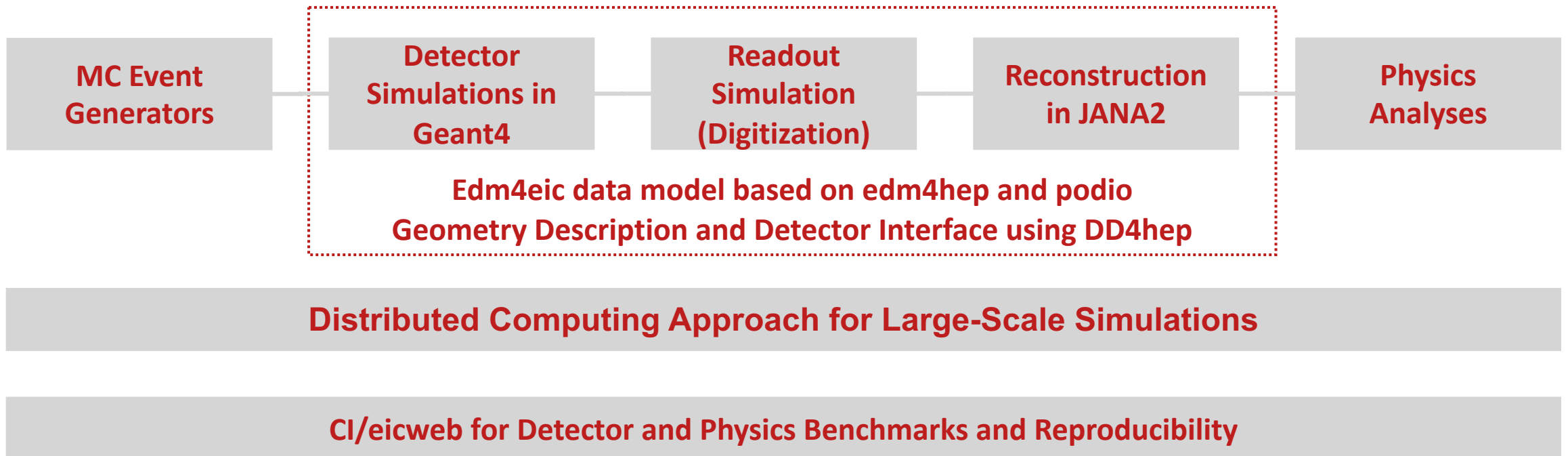


# EPIC Software

Results from the “State of Software” surveys: Commonality; one software stack.

The design of the **modular simulation and reconstruction toolkit** for the development of the EPIC detector and the EPIC science program is based on the **EIC Software: Statement of Principles** and a **decision-making process involving the wider EIC community.**

## Simulation



# EIC Software Vision and Guiding Principles for EIC Software R&D

## EIC SOFTWARE: Statement of Principles

- 1 We aim to develop a diverse workforce, while also cultivating an environment of equity and inclusivity as well as a culture of belonging.**
- 2 We will have an unprecedented compute-detector integration:**
  - We will have a common software stack for online and offline software, including the processing of streamed data and its time-ordered structure.
  - We aim for autonomous alignment and calibration.
  - We aim for a rapid, near-real-time turnaround of the raw data to online and offline productions.
- 3 We will leverage heterogeneous computing:**
  - We will enable distributed workflows on the computing resources of the worldwide EIC community, leveraging not only HTC but also HPC systems.
  - EIC software should be able to run on as many systems as possible, while supporting specific system characteristics, e.g., accelerators such as GPUs, where beneficial.
  - We will have a modular software design with structures robust against changes in the computing environment so that changes in underlying code can be handled without an entire overhaul of the structure.
- 4 We will aim for user-centered design:**
  - We will enable scientists of all levels worldwide to actively participate in the science program of the EIC, keeping the barriers low for smaller teams.
  - EIC software will run on the systems used by the community, easily.
  - We aim for a modular development paradigm for algorithms and tools without the need for users to interface with the entire software environment.

- 5 Our data formats are open, simple and self-descriptive:**
  - We will favor simple flat data structures and formats to encourage collaboration with computer, data, and other scientists outside of NP and HEP.
  - We aim for access to the EIC data to be simple and straightforward.
- 6 We will have reproducible software:**
  - Data and analysis preservation will be an integral part of EIC software and the workflows of the community.
  - We aim for fully reproducible analyses that are based on reusable software and are amenable to adjustments and new interpretations.
- 7 We will embrace our community:**
  - EIC software will be open source with attribution to its contributors.
  - We will use publicly available productivity tools.
  - EIC software will be accessible by the whole community.
  - We will ensure that mission critical software components are not dependent on the expertise of a single developer, but managed and maintained by a core group.
  - We will not reinvent the wheel but rather aim to build on and extend existing efforts in the wider scientific community.
  - We will support the community with active training and support sessions where experienced software developers and users interact with new users.
  - We will support the careers of scientists who dedicate their time and effort towards software development.
- 8 We will provide a production-ready software stack throughout the development:**
  - We will not separate software development from software use and support.
  - We are committed to providing a software stack for EIC science that continuously evolves and can be used to achieve all EIC milestones.
  - We will deploy metrics to evaluate and improve the quality of our software.
  - We aim to continuously evaluate, adapt/develop, validate, and integrate new software, workflow, and computing practices.

The "Statement of Principles" represent guiding principles for EIC Software. They have been endorsed by the international EIC community. For a list of endorses, see <https://eic.github.io/activities/principles.html>



Webpage: <https://eic.github.io/activities/principles.html>

# Focus on Common Tools

- Software in very early life stage:

- **8 We will provide a production-ready software stack throughout the development:**

- We will not separate software development from software use and support.
    - We are committed to providing a software stack for EIC science that continuously evolves and can be used to achieve all EIC milestones.
    - We will deploy metrics to evaluate and improve the quality of our software.
    - We aim to continuously evaluate, adapt/develop, validate, and integrate new software, workflow, and computing practices.

- **Focus on common software tools**

- Avoid duplication of efforts.
  - Team up on challenges, e.g., heterogeneous computing.

- **Engage with the wider NHEP community**

- **AIWG:** 5 meetings and AI4EIC workshop
  - **Detector collaborations**
    - EPIC and 2<sup>nd</sup> detector efforts
  - Geant4 collaboration
- HEP Software Foundation
  - **Key4Hep:** Meeting with CERN and DESY in Sept.
  - **Theory community**
    - MC event generators (MCEGs), next slides

# Start building a MCEG Community for the EIC

**P O E T I C 8**  
8th International Conference on Physics Opportunities at an Electron-Ion Collider  
**19-23 March 2018, University of Regensburg**

**Local Organizing Committee:**  
Gunnar Bali  
Vladimir Braun  
Falk Bruckmann  
Sara Collins  
Andreas Schäfer (chair)  
Stefan Solbrig

**International Advisory Committee:**  
Nestor Armesto (Univ. de Santiago de Compostela, Spain)  
Elke Aschenauer (BNL, USA)  
Daniel Boer (University of Groningen, Netherlands)  
Marco Contalbrigo (INFN Ferrara, Italy)  
Markus Diehl (DESY, Germany)  
Rolf Ent (Lab, USA)  
Max Klein (University of Liverpool, UK)  
Andrzej Sandacz (National Centre for Nuclear Research, Poland)  
Marco Stratmann (University of Tübingen, Germany)  
Lech Szymanowski (National Centre for Nuclear Research, Poland)  
Tony Thomas (University of Adelaide, Australia)  
Thomas Ullrich (BNL, USA)  
Raju Venugopalan (BNL, USA)

**Topics:**

- Structure of hadrons: (nuclear) parton distribution functions (PDFs, nPDFs), transverse momentum dependent (TMDs) and generalized parton distributions (GPDs), Distribution Amplitudes (DAs), Double Distributions (DDs).
- QCD at high parton densities and small-x: saturation, evolution, Color Glass Condensate
- Fragmentation functions and Jet properties
- Complementarity and connections of EIC physics with p+p, p+A and A+A collisions: high p<sub>T</sub> processes, diffraction, multi-parton interactions, quark-gluon plasma and colored probes in hot nuclear matter.
- Physics beyond the Standard Model and connections to other areas in physics.
- Future DIS facilities: accelerator and detector developments.

Satellite workshop during POETIC 8

**February 20-22, 2019**  
DESY Hamburg, Germany

EIC User Group and MCnet present

# MCEGs

for future ep and eA facilities

**PROGRAM**

Updates to general-purpose MCEG for ep/eA  
Status of NLO simulations for ep/eA  
GPDs and TMDs in MCEGs  
QED+QCD effects in ep/eA simulations

**ORGANIZERS**

Elke-Caroline Aschenauer (BNL)    Simon Plätzer (University of Vienna)  
Andrea Bressan (INFN Trieste)    Stefan Prestel (Lund University)  
Markus Diefenthaler (JLAB)  
Hannes Jung (DESY)

[www.desy.de/mceg2019](http://www.desy.de/mceg2019)

**November 20-22, 2019**  
Erwin-Schrödinger Institute  
Vienna, Austria

EIC User Group and MCnet present

# MCEGs

for future ep and eA facilities

**PROGRAM**

MCEGs for eA, including light and heavy ions  
Validation of HERA data  
MCEGs for TMDs

**ORGANIZERS**

Elke-Caroline Aschenauer (BNL)    Simon Plätzer (Vienna)  
Andrea Bressan (Trieste)    Stefan Prestel (Lund)  
Markus Diefenthaler (JLAB)  
Hannes Jung (DESY)

<https://indico.cern.ch/event/845653/>

Zoran Matic / shutterstock.com



# MC4EIC in 2021



18-19 November 2021  
Online  
US/Eastern timezone

Overview
Timetable
Live Notes
Participant List
Registration
Code of conduct
Contact
✉ <a href="mailto:cfns_contact@stonybro...">cfns_contact@stonybro...</a>

Due to the COVID-19 virus, the MC4EIC workshop is being held online using Zoom.

We have taken live notes during the meeting, which will form the basis for a workshop report. This document will inform future discussions and become part of the Snowmass community planning process. The live notes are available as a [Google document](#), anyone can edit the live notes directly.

The MC4EIC workshop has been organized by the CTEQ collaboration and the EIC User Group and has been hosted by CFNS as a remote meeting from November 18-19.

Success of the EIC science program critically depends on precise theoretical predictions for electron-ion collisions. Parton showering programs serve as a backbone for such calculations in most particle physics experiments, and the EIC is no exception. Developing precision simulations will therefore be mandatory. It will require advancements in QCD theory and computational methods, as well as a close dialog between experimentalists and theorists.

To facilitate this dialog, we have brought together experts in various domains of QCD theory and experiment to discuss recent advances in the development of event generators, as well as needs and requirements for future progress.

This MC4EIC kick-off workshop will establish a foundation for an in-depth look at the MC event generators that are currently used or developed for the EIC. Questions that will be defined at the kick-off workshop will be addressed at the next workshop, tentatively to be held in Spring 2022.

MC4EIC is part of the [CFNS workshop/ad-hoc meeting series](#).

## Goals of MC4EIC

- Establish a foundation for in-depth look at event generators currently used or developed for the EIC.
- Understand precision level to be satisfied by event generators in order to match experimental analysis requirements.
- Highlight areas in need of cross-talk between theory and experiment.
- Establish benchmarks for MCEG development.

**210 participants.**

**Workshop report** has been input to Snowmass white paper on [“Event Generators for High-Energy Physics Experiments”](#)

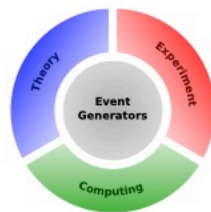
# Event Generators for the EIC

[arXiv:2203.11110](https://arxiv.org/abs/2203.11110)

Submitted to the US Community Study  
on the Future of Particle Physics (Snowmass 2021)

## Event Generators for High-Energy Physics Experiments

We provide an overview of the status of Monte-Carlo event generators for high-energy particle physics. Guided by the experimental needs and requirements, we highlight areas of active development, and opportunities for future improvements. Particular emphasis is given to physics models and algorithms that are employed across a variety of experiments. These common themes in event generator development lead to a more comprehensive understanding of physics at the highest energies and intensities, and allow models to be tested against a wealth of data that have been accumulated over the past decades. A cohesive approach to event generator development will allow these models to be further improved and systematic uncertainties to be reduced, directly contributing to future experimental success. Event generators are part of a much larger ecosystem of computational tools. They typically involve a number of unknown model parameters that must be tuned to experimental data, while maintaining the integrity of the underlying physics models. Making both these data, and the analyses with which they have been obtained accessible to future users is an essential aspect of open science and data preservation. It ensures the consistency of physics models across a variety of experiments.



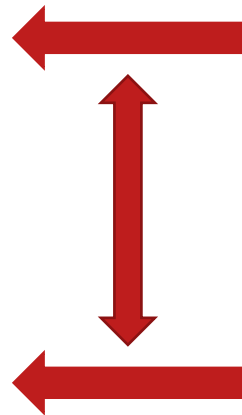
CP3-22-12    DESY-22-042    FERMILAB-PUB-22-116-SCD-T    IPPP/21/51  
JLAB-PHY-22-3576    KA-TP-04-2022    LA-UR-22-22126    LU-TP-22-12  
MCNET-22-04    OUTP-22-03P    P3H-22-024    PITT-PACC 2207    UCI-TR-2022-02

## Monte Carlo Simulation of

- electron-proton (ep) collisions,
- electron-ion (eA) collisions, both light and heavy ions,
- including higher order QED and QCD effects,
- including a plethora of spin-dependent effects.

**Common challenges**, e.g. with HL-LHC: **High-precision QCD measurements require high-precision simulations.**

**Unique challenges** MCEGs for electron-**ion** collisions and **spin-dependent** measurements, including novel QCD phenomena (e.g., GPDs or TMDs).  
Will result in deeper understanding of QCD factorization and evolution, QED radiative corrections, hadronization models etc.



arXiv:2203.11110v1 [hep-ph] 21 Mar 2022

# MC4EIC

CTEQ-EICUG-HSF-MCnet Workshop on MCEGs for the EIC

November 16-18, 2022 <https://indico.bnl.gov/event/17608/>

- 1) Following up directly on previous workshops, we have had **in-depth reports on the precision of foreseen measurements and the related MCEG** needs.
- 2) This will frame a discussion of **MCEGs that are currently being developed for the EIC**. Developers are presenting today the status of their MCEG project and the thrust of future R&D. We will discuss where we can work together.
- 3) Developing precision simulation will require advancements in QCD theory and computational methods, as well as a close dialogue between experimentalists and theorists. We would like to conclude the workshop with a discussion on how to facilitate this dialogue and **work together on cross-cutting aspects between theory and experiment in NHEP**.



AI/ML already has an **important presence in EIC** with many prototypes, e.g., for detector optimization or reconstruction methods using ML.

To explore and develop the full potential of **AI/ML for the EIC**, we as a community need to **move from prototyping to production** and add promising AI/ML solutions into our workflows.

Promising candidate: Detector optimization using ML.







- EICUG fosters the community.
- EICUG SWG is a forum for discussion and forward-looking projects.
- Ideal platform for cross-collaboration:
  - Experiment and theory
  - EPIC and 2<sup>nd</sup> Detector
  - Interdisciplinary collaborations (data scientists, HEP, ...)