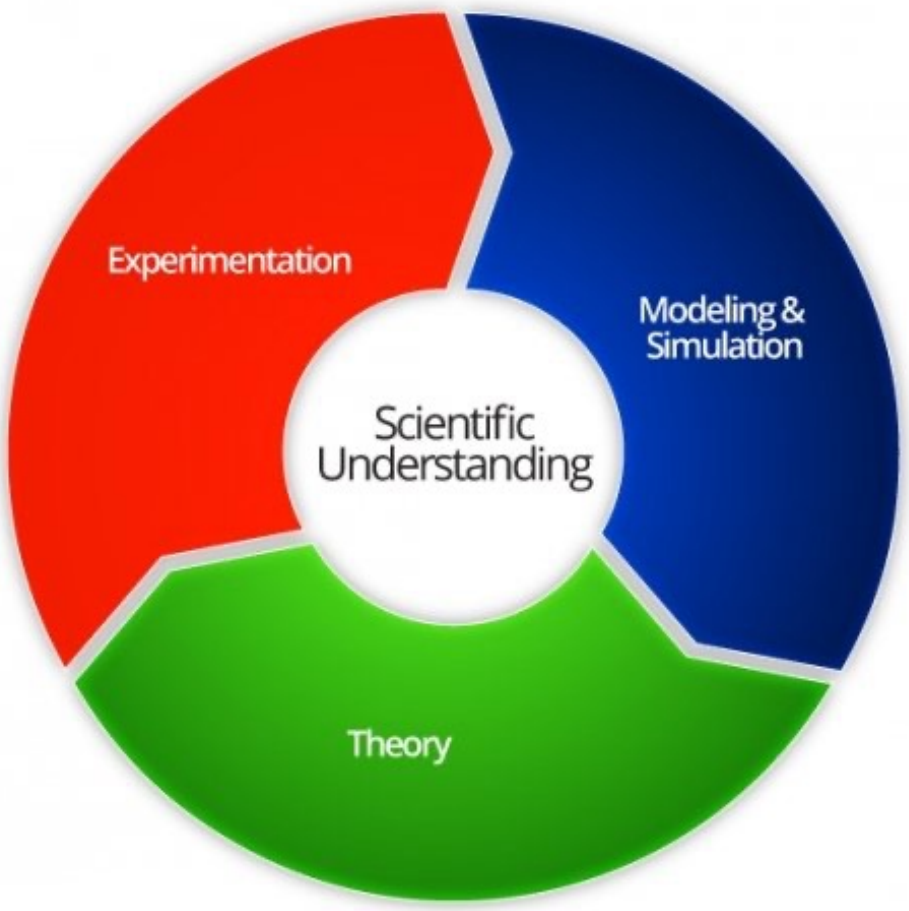
Monte Carlo Event Generation for the EIC



Discussion on MC4EIC

What are our objectives for this discussion?

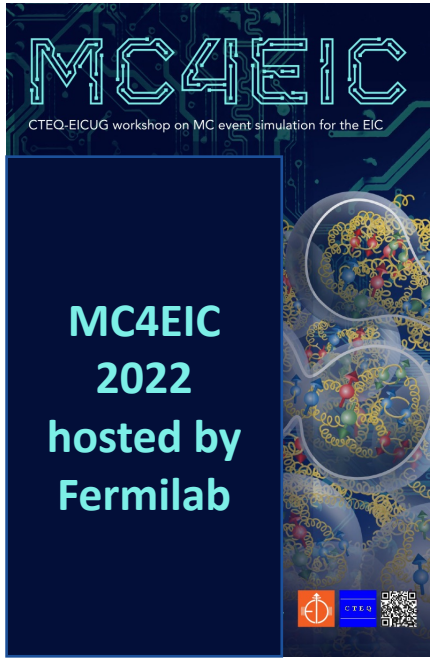
- Define priorities for the next year(s).
- Identify strategies to strengthen our efforts.

How will we work?

- Collect feedback by passing the microphone around and by contributing to Google doc.

Start Building a MC Event Generator (MCEG) Community for the EIC

Satellite workshop during POETIC 8



Organizers over the years Elke-Caroline Aschenauer (BNL), Andrea Bressan (Trieste), Markus Diefenthaler (JLab), Ilkka Helenius (Jyväskylä), Stefan Höche (FNAL), Hannes Jung (DESY), Josh McFayden (Sussex), Pavel Nadolsky (SMU), Simon Plätzer (Vienna), Stefan Prestel (LUND, now in industry), Felix Ringer (ODU), Andrii Verbytskyi (MPP), Efe Yazgan (CERN)

Strong interest from HEP, highlighted in red.

MCEGs for EIC and HEP Experiments

MCEG Requirements for EIC

- 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.

Snowmass Contribution

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.

arXiv:2203.11110

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

Summary from MCEG Workshop Series

MCEG for ep On a good path, but still a lot of work ahead.

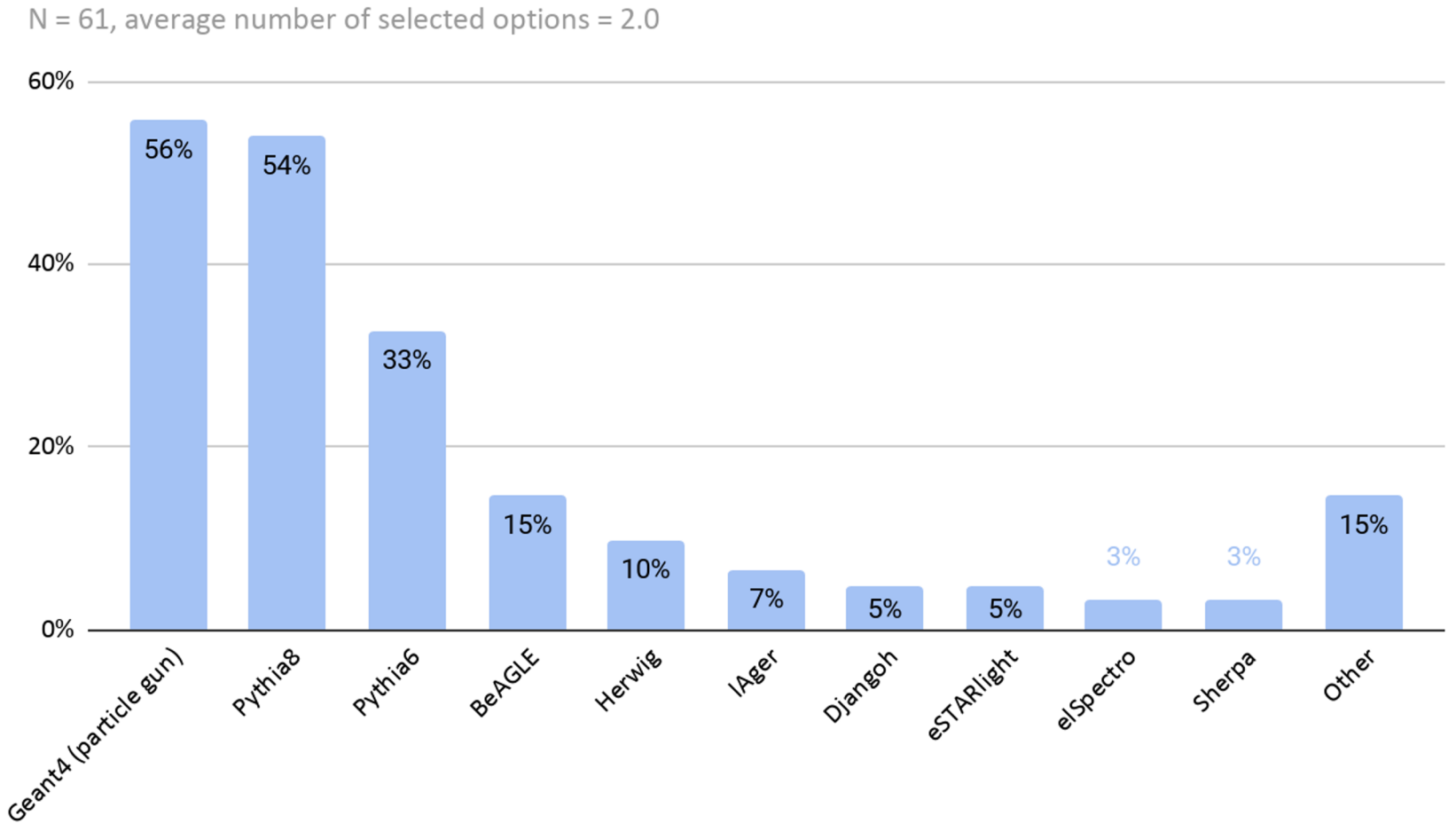
- **General-purpose MCEG**s, HERWIG, PYTHIA, and SHERPA, will be significantly improved w.r.t. MCEGs at HERA time:
- Comparisons with HERA data and QCD predictions critical:
  - To learn where physics models need to be improved,
  - To complement MC standard tunes with first DIS/HERA tune.
- The existing general-purpose MCEG should be able to simulate NC and CC unpolarized observables also for eA. A precise treatment of the nucleus and, e.g., its breakup is needed.
- First parton showers and hadronization models for ep with spin effects, but far more work needed for polarized ep / eA simulations.
- Need to clarify the details about merging higher QED+QCD effects (in particular for eA).

MCEG for eA Less clear situation about theory and MCEG.

- **Pioneering projects**, e.g., BeAGLE, spectator tagging in ed, Sartre.
- **Active development,** e.g., eA adaptation of JETSCAPE, Mueller dipole formalism in Pythia8 (ala DIPSY).

MCEGs used for Yellow Report

Source State of Software Survey



Other (N = 9): personal computer codes (N = 2), ACT, CLASDIS, ComptonRad, GRAPE-DILEPTON, MADX, MILOU, OPERA, RAYTRACE, Sartre, Topeg, ZGOUBI

- **Goals of MC4EIC (Organized by CTEQ, EICUG, HSF, MCnet)**
  - In-depth look at MC event generators (MCEGs) 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:
    - Understand mismatches between QCD theory and MCEGs.
    - Get nuclear theory involved in MCEG development.
  - Establish benchmarks for MCEG development.

- **Workshop report of MC4EIC 2021** has been input to Snowmass white paper on "*Event Generators for High-Energy Physics Experiments*".

- **Workshop reports of MC4EIC 2021 and MC4EIC 2022** encompass highly interesting and relevant discussions, deserving proper documentation.
  - Paper is currently in preparation (will need help from EICUG).
  - Computing and Software for Big Science interested in publishing it.

Next Steps

- **MC4EIC 2023** (or 2024?) as part of HSF workshop on MCEGs:
  - Cross-cutting aspects with EIC and other experiments in NHEP (DUNE, LHC, HL-LHC).
  - Event Generator Tuning Workshop (June 27 and 28)
    - Lessons learned from MCEG community and LHC experiments being summarized in technical note.
  - Future technologies, in particular quantum simulations.
- **Standards for shared elements** (think about LHAPDF but for components of MCEGs):
  - Developers of general-purpose MCEGs highly interested.
  - HSF supportive.
- **Funding?**

Discussion:
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- Define priorities for the next year(s).
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Let's get started: Collect feedback by passing the microphone around and by contributing to Google doc.