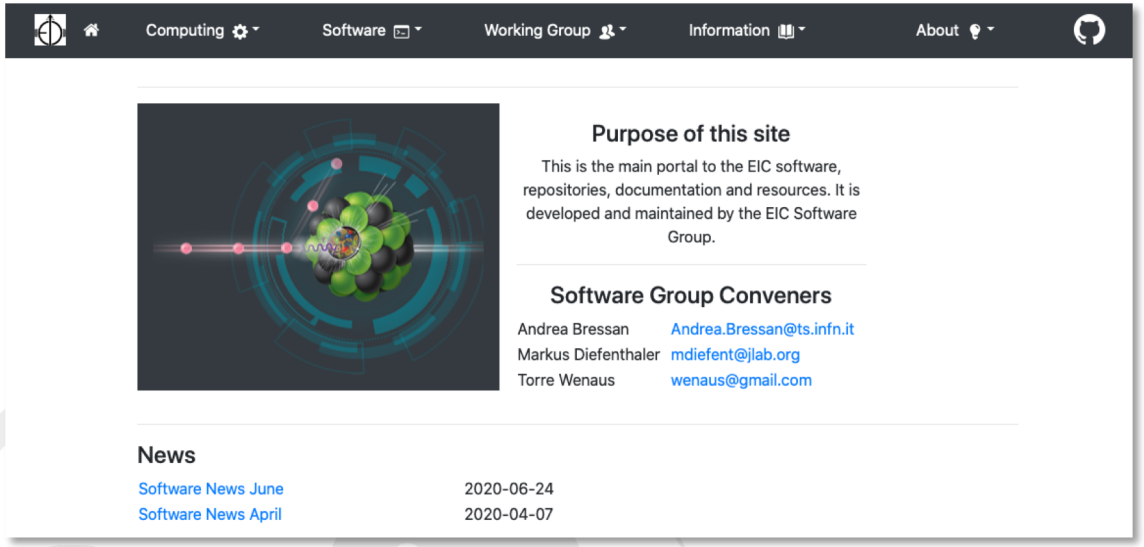
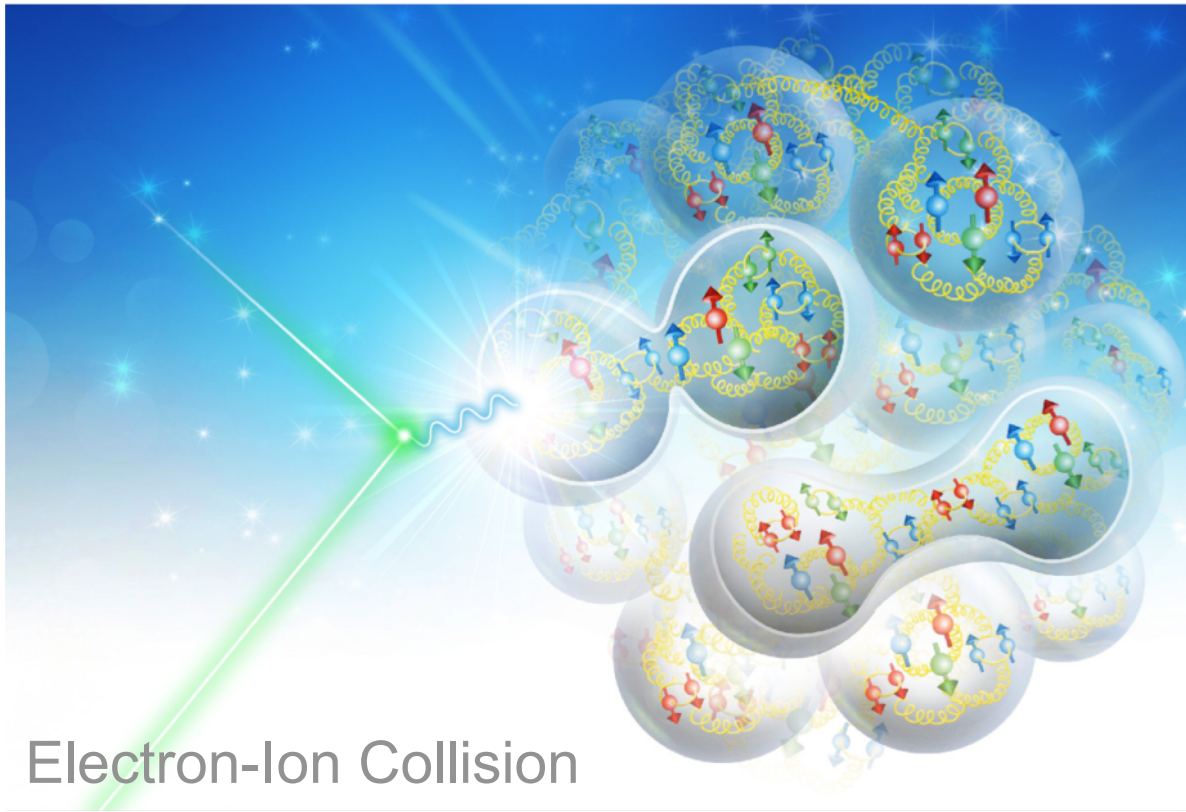
EICUG Software Working Group: EIC MC activities





Markus Diefenthaler (EIC^2, Jefferson Lab)

Electron-Ion Collision

Jefferson Lab

EICUG Software Working Group

83 members

Convener
A. Bressan (Trieste)
M. Diefenthaler (JLAB)
T. Wenaus (BNL)

Mailing list eicug-software@eicug.org
subscribe via Google Group
Repository https://github.com/eic
Website https://eic.github.io/

Core Group

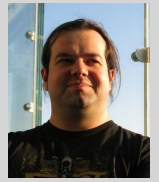

J. Adam (BNL)


M. Asai (SLAC)


N. Brei (JLAB)


A. Bressan (Trieste)


W. Deconinck (Manitoba)


M. Diefenthaler (JLAB)


J. Furletova (JLAB)

Picture
S. Furletov (JLAB)


S. Joosten (ANL)


K. Kauder (BNL)


A. Kiselev (BNL)

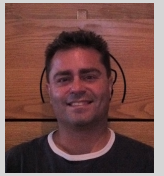

J. Lauret (BNL)


D. Lawrence (JLAB)


C. Pinkenburg (BNL)


M. Potekhin (BNL)


D. Romanov (JLAB)


M. Ungaro (JLAB)


T. Wenaus (BNL)

Working together with the EICUG

Develop

Support

Workflow environment for EIC simulations

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

software-support@eicug.org
mailing list anyone can contact

http://eicug.slack.com/
with software-support channel

in-person support

Involvement from EICUG

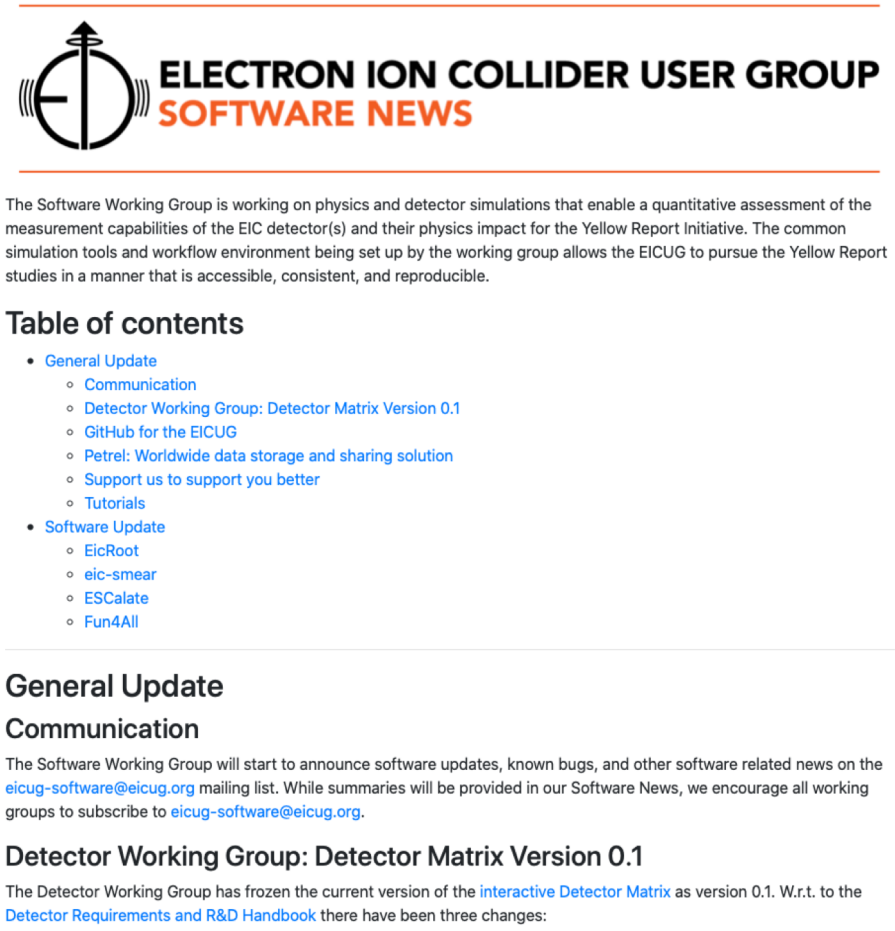
- **Coordinate simulations** with EICUG Detector and Physics Working Groups.
- **Analysis preservation** Work with EICUG to make software available and integrate it.
- Rely on expertise of EICUG:
  - **Design detectors**
  - **Developing reconstruction algorithms**
  - **Develop physics analysis**
  - **Simulations of QED+QCD effects**

Communication

eicug-software@eicug.org

Software News

Mailing list please subscribe via Google Group
Have to start using it consistently and reliably for Software News



ELECTRON ION COLLIDER USER GROUP
SOFTWARE NEWS

The Software Working Group is working on physics and detector simulations that enable a quantitative assessment of the measurement capabilities of the EIC detector(s) and their physics impact for the Yellow Report Initiative. The common simulation tools and workflow environment being set up by the working group allows the EICUG to pursue the Yellow Report studies in a manner that is accessible, consistent, and reproducible.

Table of contents

- General Update
  - Communication
  - Detector Working Group: Detector Matrix Version 0.1
  - GitHub for the EICUG
  - Petrel: Worldwide data storage and sharing solution
  - Support us to support you better
  - Tutorials
- Software Update
  - EicRoot
  - eic-smear
  - ESCalate
  - Fun4All

General Update

Communication

The Software Working Group will start to announce software updates, known bugs, and other software related news on the eicug-software@eicug.org mailing list. While summaries will be provided in our Software News, we encourage all working groups to subscribe to eicug-software@eicug.org.

Detector Working Group: Detector Matrix Version 0.1

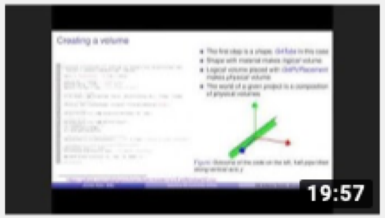
The Detector Working Group has frozen the current version of the interactive Detector Matrix as version 0.1. W.r.t. to the Detector Requirements and R&D Handbook there have been three changes:

Simulation tools

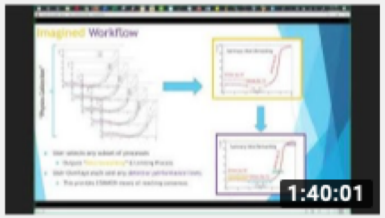
Full simulations	EicRoot	ESCalate	Fun4All
Fast simulations	eic-smear	Delphes	

Online tutorials https://www.youtube.com/channel/UCXc9WfDKdlLXoZMGrotkf7w

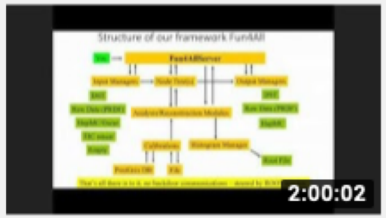
EIC Software Group: An Introduction (01/09/2020)



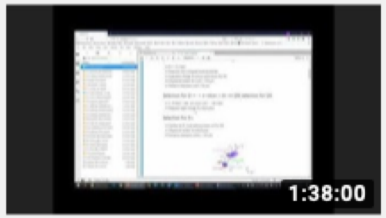
EIC Software Tutorial: Example Detector...



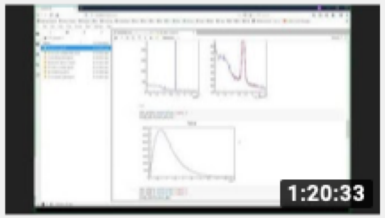
EICUG Software Working Group: Greenfield



EIC Software Tutorial: Detector Full Simulations in...



EIC Software Tutorial: Detector Full Simulations in...



EIC Software Tutorial: Fast Simulations (01/09/2020)

Making software easier to use

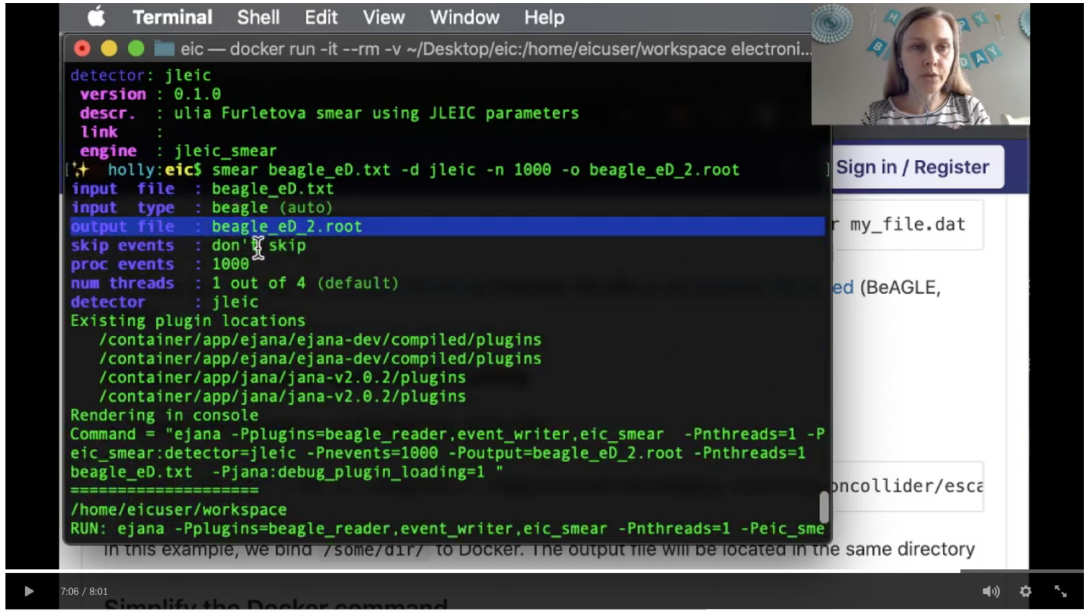
Fast simulations on the command line

smear beagle-eD.txt # smears MC input file (BeAGLE format) with handbook detector
smear pythia-ep.hepmc2 -o myfile.root # smears MC input file (now HepMC format)and sets output file name
smear -d beast -n 10000 beagle-eD.txt # uses beast detector and smears only 10k events

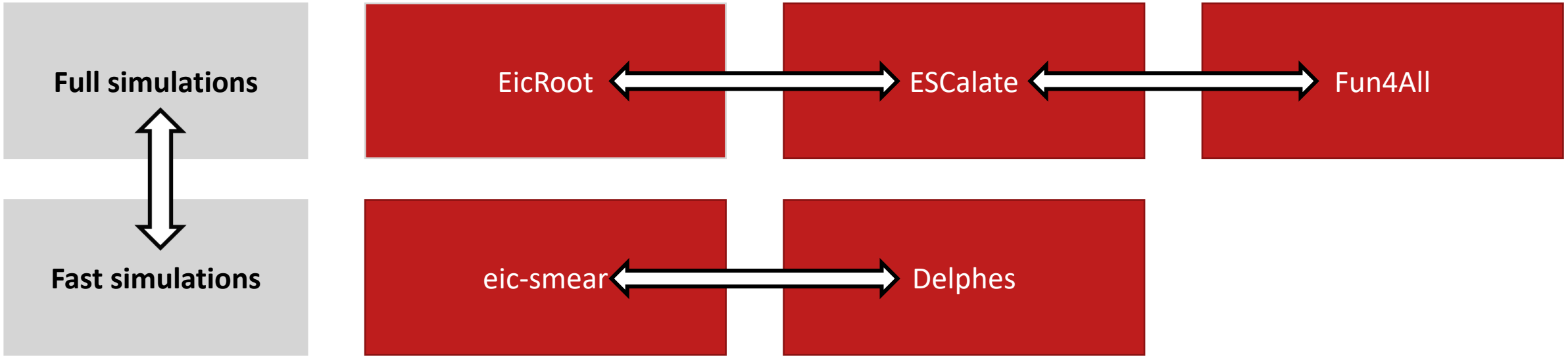
Instructions (and linked files), based on modular ESCalate framework
Works on local system (using Docker), BNL and JLAB systems (using singularity), and cloud (using JupyterHub)

Video tutorial by Holly Szumila-Vance (8:01 minutes)

Temporary link (to appear on YouTube)



Cross-tool validation (⟺)



Benchmarks and validation

Cross-tool validation

- **Unified format for the output ROOT tree of all tools (work in progress)**
- **Collect simulation configuration and physics analyses (work in progress)**
  - Any study that is shared with the SWG can be used to **benchmark & validate** the EIC Software tools.
  - Based on analysis scripts and macros for the given study, the SWG can reproduce studies and build up a **validation scheme and tools** on top of it.
- **Call for additional (wo)manpower** (via institutional board)

MCEG validation

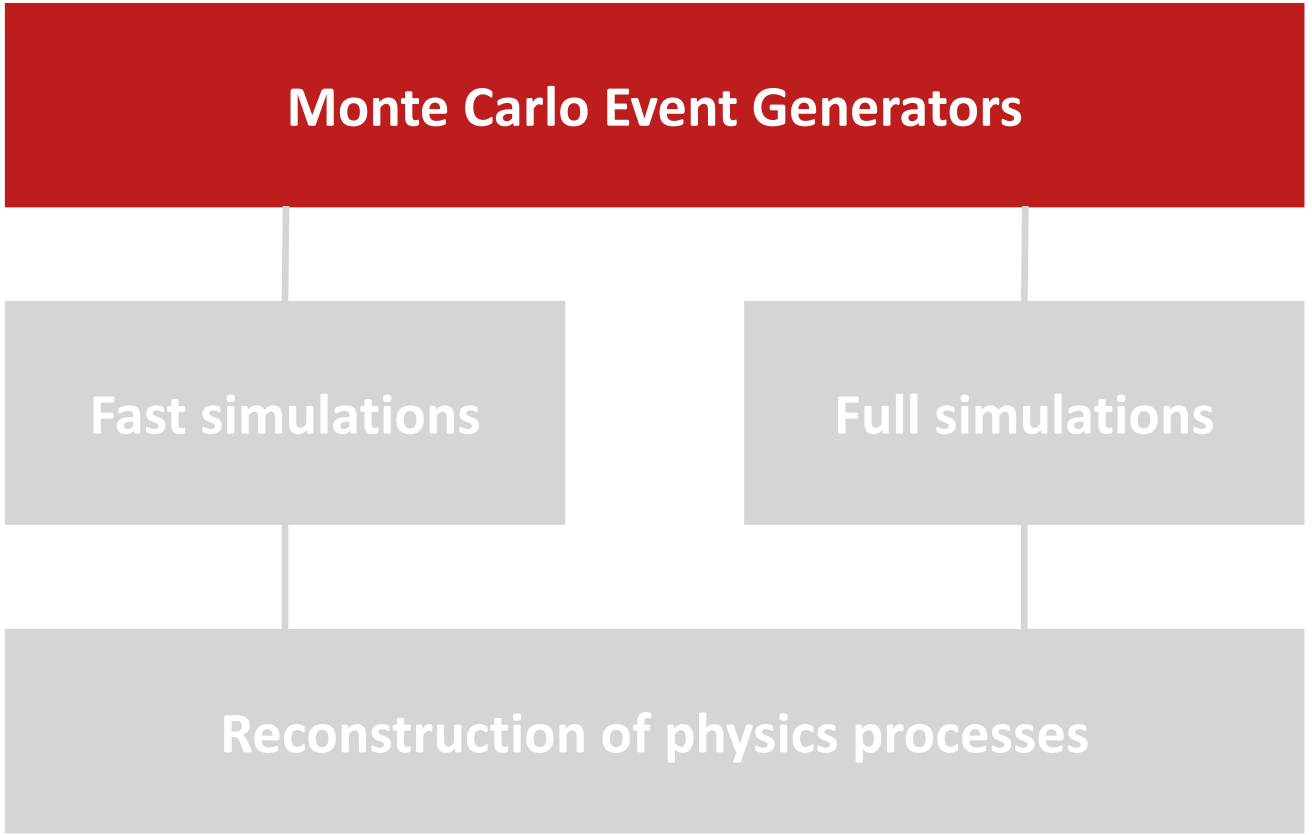
- MC-data comparisons and eventually tuning will help to support Yellow Report studies and beyond with the *right* simulations
- more on next slides

Simulations of physics processes and detector responses

Simulation of physics processes

Simulation of detector responses

Physics analysis



Broad collection of event generators used for EIC

Monte Carlo Event Generators (MCEG)

The following event generators are available:

- ep
  - DJANGOH: (un)polarised DIS generator with QED and QCD radiative effects for NC and CC events.
  - gmc_trans: A generator for semi-inclusive DIS with transverse-spin- and transverse-momentum-dependent distributions.
  - LEPTO: A leptoproduction generator - used as a basis for PEPSI and DJANGOH
  - LEPTO-PHI: A version of LEPTO with "Cahn effect" (azimuthal asymmetry) implemented
  - MILOU: A generator for deeply virtual Compton scattering (DVCS), the Bethe-Heitler process and their interference.
  - PYTHIA: A general-purpose high energy physics event generator.
  - PEPSI: A generator for polarised leptoproduction.
  - RAPGAP: A generator for deeply inelastic scattering (DIS) and diffractive $e + p$ events.
- eA
  - BeAGLE: Benchmark eA Generator for LEptoproduction - UNDER CONSTRUCTION - a generator to simulate ep/eA DIS events including nuclear shadowing effects (based on DPMJetHybrid)
  - DPMJet: a generator for very low Q2/real photon physics in eA
  - DPMJetHybrid: a generator to simulate ep/eA DIS events by employing PYTHIA in DPMJet
  - Sartre is an event generator for exclusive diffractive vector meson production and DVCS in ep and eA collisions based on the dipole model.

From https://wiki.bnl.gov/eic/index.php/Simulations and available in https://gitlab.com/eic/mceg

MCEG2019 – Building a MCEG community for the EIC

Unique MCEG requirements for EIC Science

- MCEG for polarized ep, ed, and eHe^3
  - including novel QCD phenomena: GPDs, TMDs
- MCEG for eA
- **Merging of QED+QCD effects**

MCEG community

- focus of last two decades: **LHC**
  - **lesson learned** high-precision QCD measurements require high-precision MCEGs
  - MCEG not about tuning but about physics
- ready to work on ep/eA

MCEG2019 – Status of MCEG for the EIC

General-purpose MCEGs, HERWIG, PYTHIA, and SHERPA, will be significantly improved w.r.t. MCEGs at HERA time:

- MCEG-data comparisons in Rivet will be critical to tune the MCEGs to DIS data and theory predictions.
- The existing general-purpose MCEG should soon 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 QED+QCD effects (in particular for eA).

MCEG for eA

- **pioneering projects** BeAGLE, spectator tagging in ed, Sartre
- **active development** eA adaptation of JETSCAPE, Mueller dipole formalism in Pythia8 (ala DIPSY)

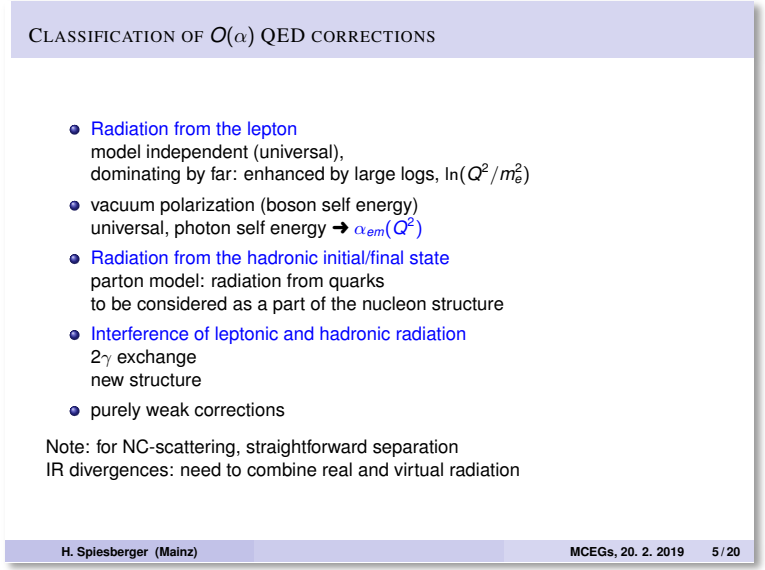
TMD physics

- Vibrant community working on various computational tools for TMDs.
- CASCADE: MCEG for unpolarized TMDs (unintegrated TMDs) at high energy.
- Need more verification of MCEG models with TMD theory / phenomenology (ongoing).

MCEG for ep We are on a very good path, but still quite some work ahead.
MCEG for eA Less clear situation about theory and MCEG.

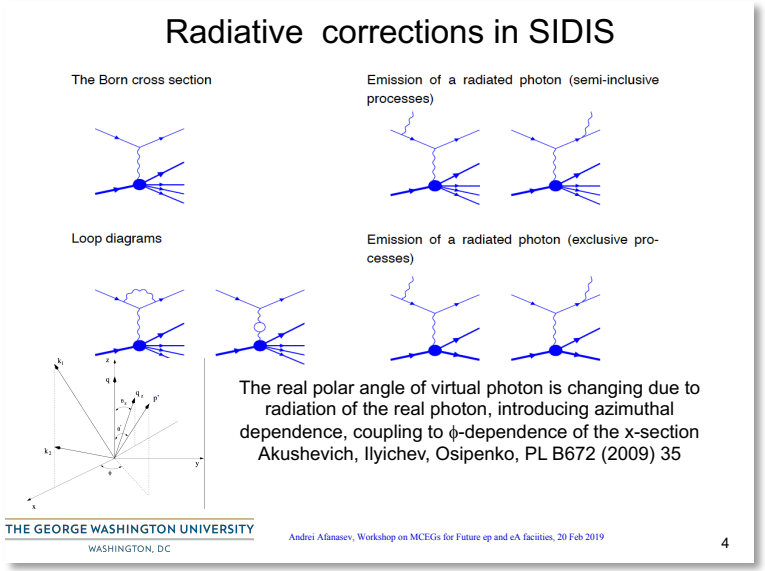
MCEG2019 – Merging QED and QCD effects

Far more detailed discussion at your workshop



Hubert Spiesberger (Mainz): QED corrections for electron scattering

- High-precision measurements need careful treatment of radiative corrections.
- Closely related to experimental conditions need full Monte Carlo treatment (Unfolding) including simulation of hadronic final states.
- The basics are known and available …
- … but improvements are needed.



Andrei Afanasev (GWU): Semi-analytic vs. Monte-Carlo Approaches for QED Corrections to SIDIS

- Consistent approach to address RC for SSA in polarized SIDIS

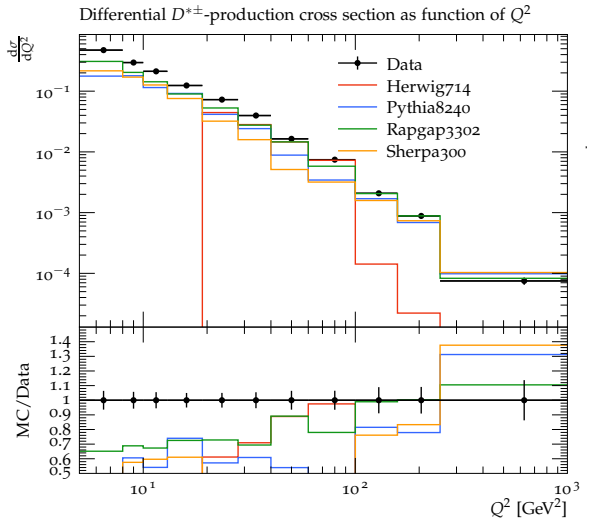
- SSA due to two-photon exchange need to be included in analysis of SSA from strong interaction, of same size at JLAB experiments
- More detailed calculation of the two-photon exchange at quark level required: elastic scattering, inclusive, semi-inclusive, and exclusive DIS

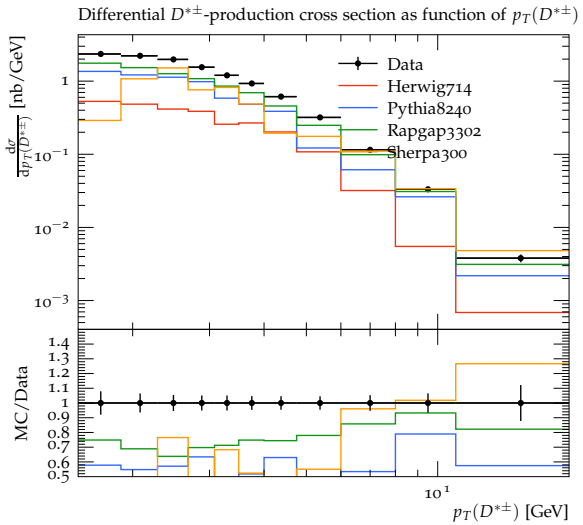
MCEG–HERA comparisons and MCEG validation for ep

MCEG R&D requires *easy* access to *data*

- data := analysis description + data points

HEP existing workflow for MCEG R&D using tools such as HZTool, Rivet and Professor





Detailed comparisons between modern MCEG and HERA data

- ongoing validation effort, **growing working group**
- preparing document for Yellow Reports and Snowmass 2021
- HERA data not (yet) included in MCEG tunes

Rivet example

SIDIS analysis at HERMES

```
// Extract the particles other than the lepton
const FinalState& fs = apply<FinalState>(event, "FS");
Particles particles;
particles.reserve(fs.particles().size());
const GenParticle* dislepGP = dl.out().genParticle();
foreach (const Particle& p, fs.particles()) {
  const GenParticle* loopGP = p.genParticle();
  if (loopGP == dislepGP)
    continue;
  particles.push_back(p);
}

// Apply HERMES cuts.
bool validx = (x > 0.023 && x < 0.6);
if (q2 < 1. || w2 < 10. || y < 0.1 || y > 0.85 || !validx)
  vetoEvent;

// good inclusive event, let's do bookkeeping before we look at the hadrons
dis_tot += weight;
dis_x->fill(x, weight);
dis_Q2->fill(q2, weight);

for (size_t ip1 = 0; ip1 < particles.size(); ++ip1) {
  const Particle& p = particles[ip1];

  // get the particle index, check if it is a particle of interest
  const int part_idx = get_index(p.genParticle()->pdg_id());
  if (part_idx < 0) {
    continue;
  }

  // we have a particle of interest, let's calculate the kinematics
  // z
  const double z = (p.momentum() * pProton) / (pProton * q);
  // pt
  const double pth = sqrt(p.momentum().pT2());

  // get our z index, if negative, we have a particle outside of [.2, .8]
  const int z_idx = calc_zslice(z);
  if (z_idx < 0) {
    continue;
  }

  // store the events and make cuts where necessary
  //
  // pt cut for variables not binned in pt
  if (pth > 0 && pth < 1.2) {
    mult_z[part_idx]->fill(z, weight);
    mult_zx[part_idx][z_idx]->fill(x, weight);
    mult_zQ2[part_idx][z_idx]->fill(q2, weight);
  }
  mult_zpt[part_idx][z_idx]->fill(pth, weight);
}
```

How to build the EIC Software collection?

EICUG Question on Pythia 6 vs. Pythia 8

- There seem to be different MC codes for SIDIS events propagated by the SW group. In particular Pythia 6 and Pythia 8 with DIRE. Our studies showed substantial difference in the simulated events. Are you planning to select on default MC, tune, so simulations become comparable? We realize that we could do this within our WG, but it seems a more general question.
- Why is Pythia 8 promoted as a generator even so it does *not* reproduce the HERA data and gives factors of different c.s. to Pythia 6 which reproduces *all* the data?

Example for discussion when to adapt modern MCEG for the EIC

Next slides A discussion by C. Bierlich (Copenhagen, LUND), M. Diefenthaler (JLAB), I. Helenius (Jyväskylä), S. Joosten (ANL), S. Prestel (LUND)

Pythia (1978 – now)

General-purpose MCEG

- extensively used for e^+e^-, ep and pp physics, e.g. at LEP, HERA, Tevatron, and LHC
- as a building block used in heavy-ion and cosmic-ray physics
- recent pA effort in Pythia 8 with Angantyr model

Pythia 6 product of over thirty years of progress

Pythia 8 successor to Pythia 6, standalone generator, but several optional hooks for links to other programs are provided

December 2012

Dear Pythia Users and Supporters,

We would like to communicate to you some important information regarding the development of the Pythia event generator.

Over the years, we have enjoyed a fruitful relationship with the major collider experiments. You have provided important feedback on the comparison of data and predictions, noted errors in the code, and made suggestions for improvements. We have responded to requests, helped debug code when necessary, and been a partner in the data analysis process. We look forward to continuing this relationship in the future.

A key request of the LHC community has been for us to transition from Fortran to C++. We have been manpower-limited, so that project has taken much longer than it ought to have. However, since some time now, the new Pythia 8 code should be able to do just about everything the old Pythia 6 code could, and then some more.

We have retained a commitment to Pythia 6 because of its continued use in Run 2 and the early stages of the LHC. However, we find it is no longer tenable to split our resources between the development of Pythia 8 and the support of Pythia 6.

Therefore we here present our timeline for transitioning to a frozen version of Pythia 6, that will then remain a legacy code.

Development of Pythia 6 now stops. We will still provide support and urgent fixes to the code, if necessary, until 1 March 2013. At this point, the Pythia 6 code will be frozen, and a final legacy version will be released later in 2013. We will then continue to answer questions regarding the behavior of Pythia 6 until 1 July 2013, after which only Pythia 8 will be actively developed and supported.

We believe this decision will allow us to have the most positive impact on the field. We look forward to continuing our current relationship based on Pythia 8.

Sincerely,
The Pythia6 Collaboration
(Torbjörn Sjöstrand, Stephen Mrenna, Peter Skands)

Why has DIS been first missing in Pythia 8

MCEG community focus of last two decades: **LHC**

Problems with default parton shower for DIS (used in Pythia6)

- The parton shower has been developed for positron-election annihilation and Drell-Yan.
- The parton shower is using a s-hat approach where *s-hat* = $x_1 * x_2 * s$ at all scales. This works well for hadron-hadron collisions, e.g., for preserving the W/Z mass in the parton shower.
- When expanding the parton shower for electron-hadron scattering, one has to replace one incoming parton with an electron at *x=1*. The Bjorken-*x* value of the event will be not preserved during the reconstruction of the initial state shower, as the introduction of the a transverse momentum will change the value of *P * q*. This also implies that the cross-section is changed.
- This was solved (for a single splitting) by a very specific handling of the initial and final state cascades and limiting the maximum allowed virtuality to W^2 with additional rejection techniques.

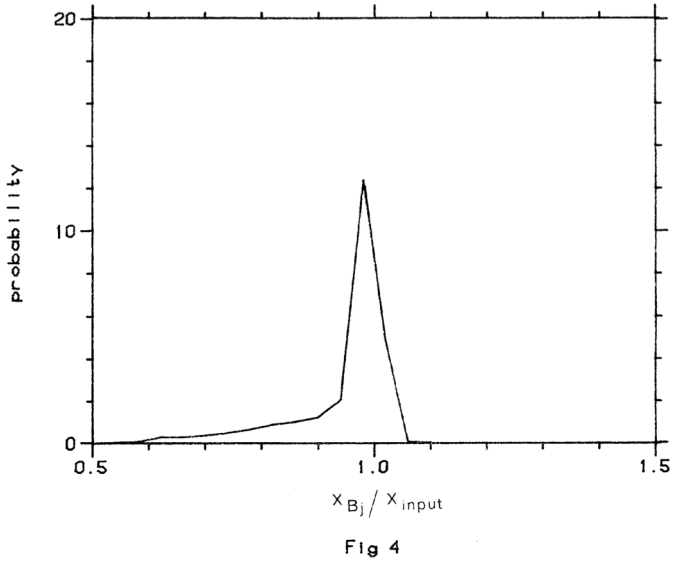


Fig 4

Status of ep simulations in Pythia 8

DIS

New option for dipole-recoil shower introduced by Torbjörn and B. Cabouat (EPJC 78 2018 no.3, 226) which addresses the limitations of the default shower for DIS. Reasonable agreement for some HERA DIS data as shown in the paper but not extensively tested nor tuned. DIRE should provide a more complete setup but more studies would be welcome. The phase-space generation still needs some refining.

Photoproduction

Photoproduction (for quasi-real photons so $Q^2 = 0$) have been implemented into Pythia 8 and compared to Pythia 6 and HERA data for dijets and charged hadron production. Using the same PDFs etc. the partonic cross sections are the same in Pythia 6 and 8 but there are of course some minor differences due to the updated shower implementation and small changes in the hadronization.

Transition region ($1\ \text{GeV}^2 < Q^2 < 10\ \text{GeV}^2$)

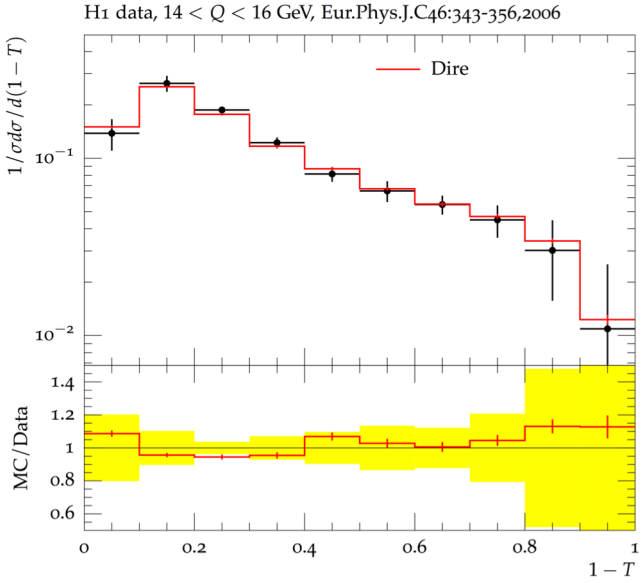
So far no implementation is present for this region. This is something we have made plans to consider in detail later on but so far left as an open question. Note that in Pythia 6, a description of the transition region is available, heavily relying on tweaking parameters. Thus, Pythia 6 cannot provide a predictive model, and is thus dangerous to use.

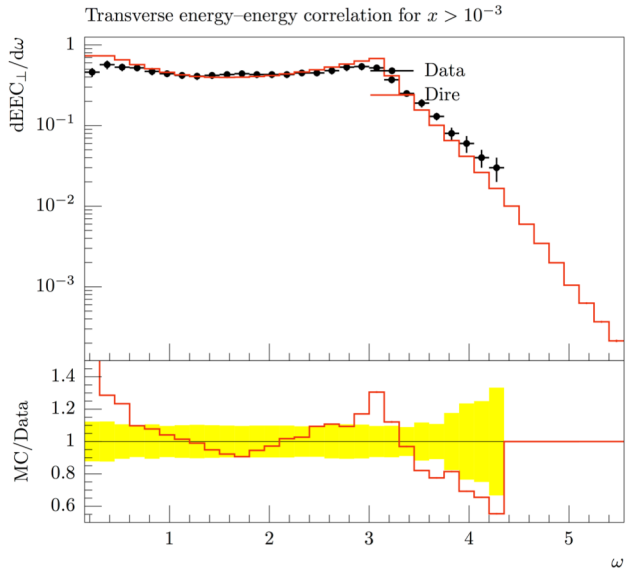
Diffraction

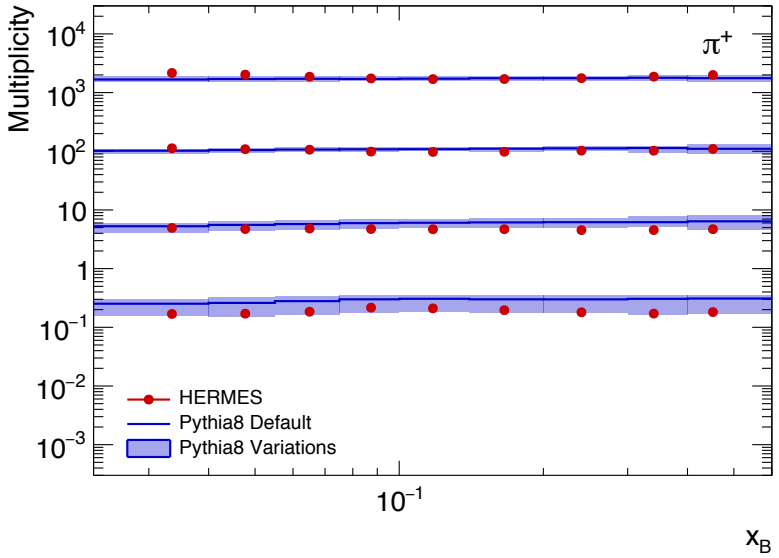
Soft diffraction in photoproduction includes the same parametrizations as Pythia 6. Exclusive vector-meson production cross sections is in a fair agreement with HERA data for low-mass states (rho, omega) but not for high-mass states (phi, J/Psi).

Hard diffraction (like dijets) is not implemented in Pythia 6 but the new Pythia 8 implementation provide a fair description of the ZEUS and H1 data for photoproduction. Diffractive DIS have not been studied since the main feature of the model, MPI rejection, would not do anything there.

DIS in Pythia 8 + DIRE (early studies by MD, SJ, SP)





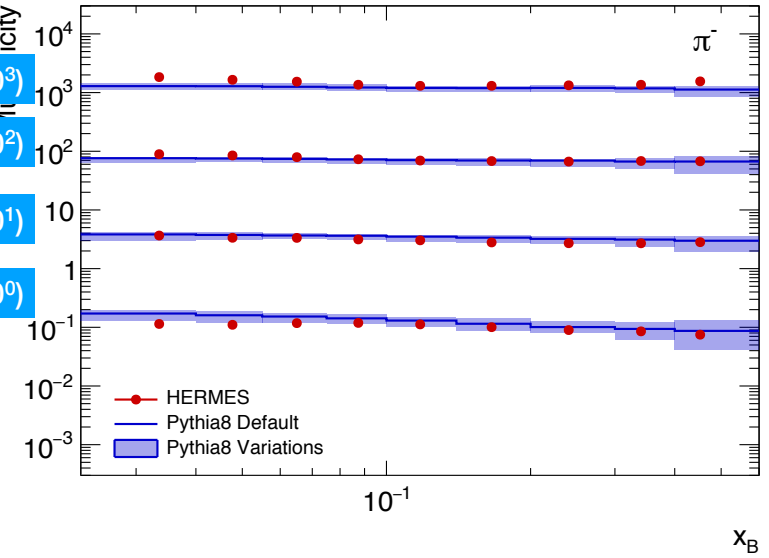


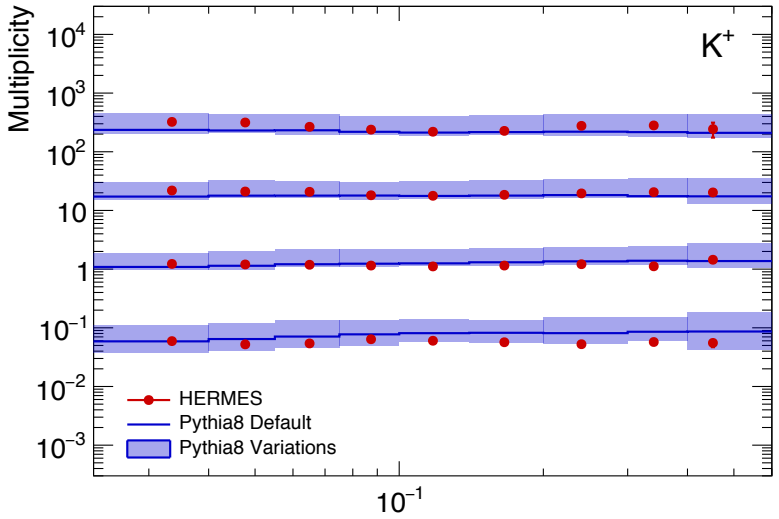
0.2 < z < 0.3 (x10³)

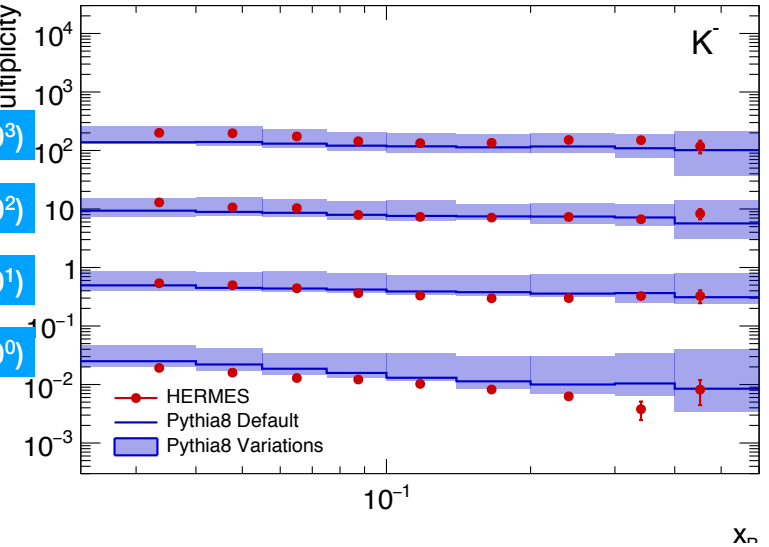
0.3 < z < 0.4 (x10²)

0.4 < z < 0.6 (x10¹)

0.6 < z < 0.8 (x10⁰)







MCEG status report at 2019 EICUG meeting (I. Helenius)

DIS with Pythia

New shower option: `dipoleRecoil`

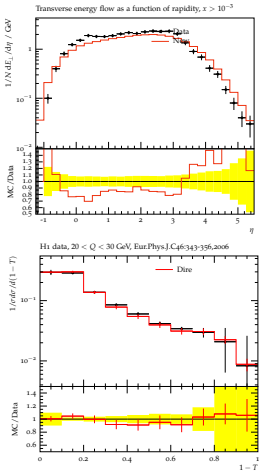
[B. Cabouat and T. Sjöstrand, EPJC 78 (2018 no.3, 226)]

- No PS recoil for the scattered lepton
- Reasonable description of single-particle properties, such as transverse energy flow
- Results based on tune with the default global-recoil shower

DIRE plugin (to be included in PYTHIA 8.3)

[S. Höche, S. Prestel, EPJC 75 (2015) no.9, 461]

- Correct soft-gluon interference at lowest order
- Inclusive NLO corrections to collinear splittings
- Good agreement with HERA data for thurst T



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Hard diffraction in photoproduction with PYTHIA

Implemented from PYTHIA 8.235

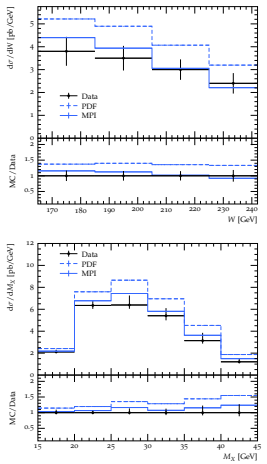
[I.H., C. O. Rasmussen, Eur.Phys.J. C79 (2019) no.5, 413]

- Based on dynamical rapidity gap survival
  [C. O. Rasmussen, T. Sjöstrand, JHEP 1602 (2016) 142]
- Begin with factorized approach with diffractive PDFs (Ingelman-Schlein picture)
- Reject events where MPIs between resolved γ and p would destroy the rapidity gap

Comparison to HERA diffractive dijet data

[H1: EPJC 51 (2007) 549, ZEUS: EPJC 55 (2008) 177]

- More MPI suppression towards higher W, M_X
- Natural explanation for observed factorization breaking in pp and γp



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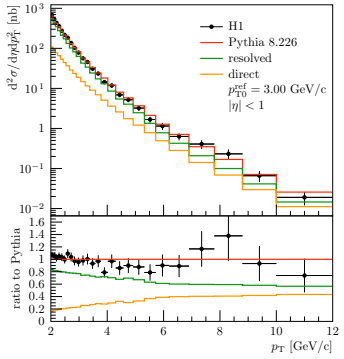
Photoproduction with PYTHIA

Photoproduction in PYTHIA 8

- Hard and soft QCD processes
- Mix of resolved and direct processes
- Photon PDFs from CJKL fit
- MPIs for the resolved processes
  ⇒ Regulated with p_{T0} as in pp
- Applicable also for UPCs

Inclusive hadron spectra from H1

- Resolved contribution dominates
- Good agreement with the data using $p_{T0}^{\text{ref}} = 3.00$ GeV (pp: $p_{T0}^{\text{ref}} = 2.28$ GeV)
  ⇒ MPI probability reduced from pp



[H1: Eur.Phys.J. C10 (1999) 363-372]

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Exclusive vector meson production with PYTHIA

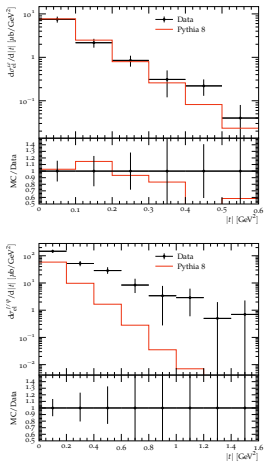
Implemented from PYTHIA 8.240

[I.H., C. O. Rasmussen, in progress]

- Based on (pre-HERA) SAS parametrizations
  [G.A. Schuler, T. Sjöstrand, Phys.Rev. D49 (1994) 2257-2267]
- Includes ρ, ω, ϕ and J/Ψ production via elastic scattering

Comparison to HERA data

- Good agreement with low-mass mesons (ω)
- Underestimate heavy-meson (J/Ψ) production
  ⇒ Require improved parametrizations using HERA data



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Pythia 6 vs. 8

Pythia 6 is nice on the user end, because with the click of a button, you can produce something that looks like data, without thinking too much about the limitations of the models. This is, however, also the drawback. The modelling of the intermediate region in Pythia 6 is not really on solid ground and limits its predictive power.

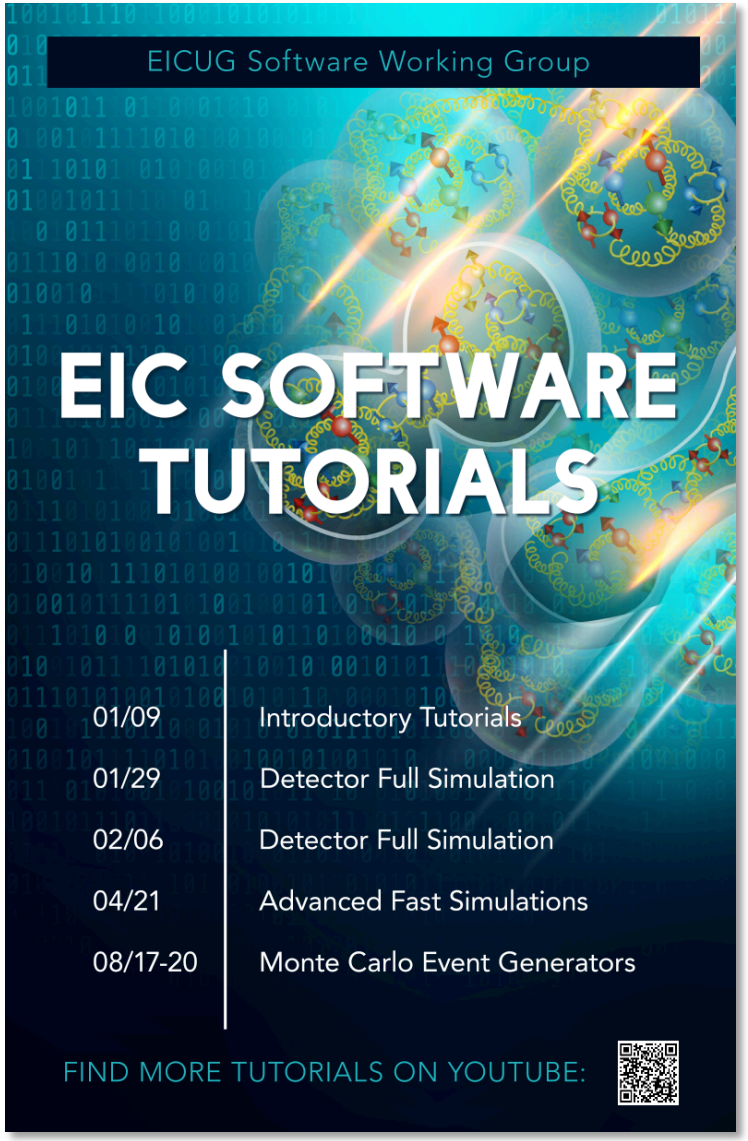
The same thing goes for the elaborate tuning efforts carried out by experiments. Once an MC has been tuned to give a full description of a particular data set and little else, all predictive power is lost, and the MC at that point basically functions just as a parametrization of that data set. While parametrizations can be good, there is no guarantee that a specific tune will have anything reasonable to say about EIC. Basing R&D decisions on such a specific parametrization of data, can be outright dangerous.

Ideal path forward

- comparison of Pythia 8 + DIRE to HERA data **(ongoing)**
- comparison of Pythia 6 with current tune to HERA data **(started)**
- discussion of Pythia 6 intermediate region model and why it is not continued **(started)**
- discussion on difference between global and local tunes

Path forward for Yellow Report initiative? Related to that: **Guidance on QED effects?**

Next steps



Introduce modern MCEGs to EIC community

- Integration in EIC simulation software ongoing
- Tutorials:

08/17	**Pythia 8** Stefan Prestel (LUND)
08/18	**Rivet** Christian Bierlich (LUND)
08/19	**Herwig 7** Simon Plätzer (Vienna)
08/20	**Sherpa** Stefan Hoeche (FNAL)

Validation of modern MCEGs with DIS data

- **HERA** H1, ZEUS, HERMES
- COMAPSS

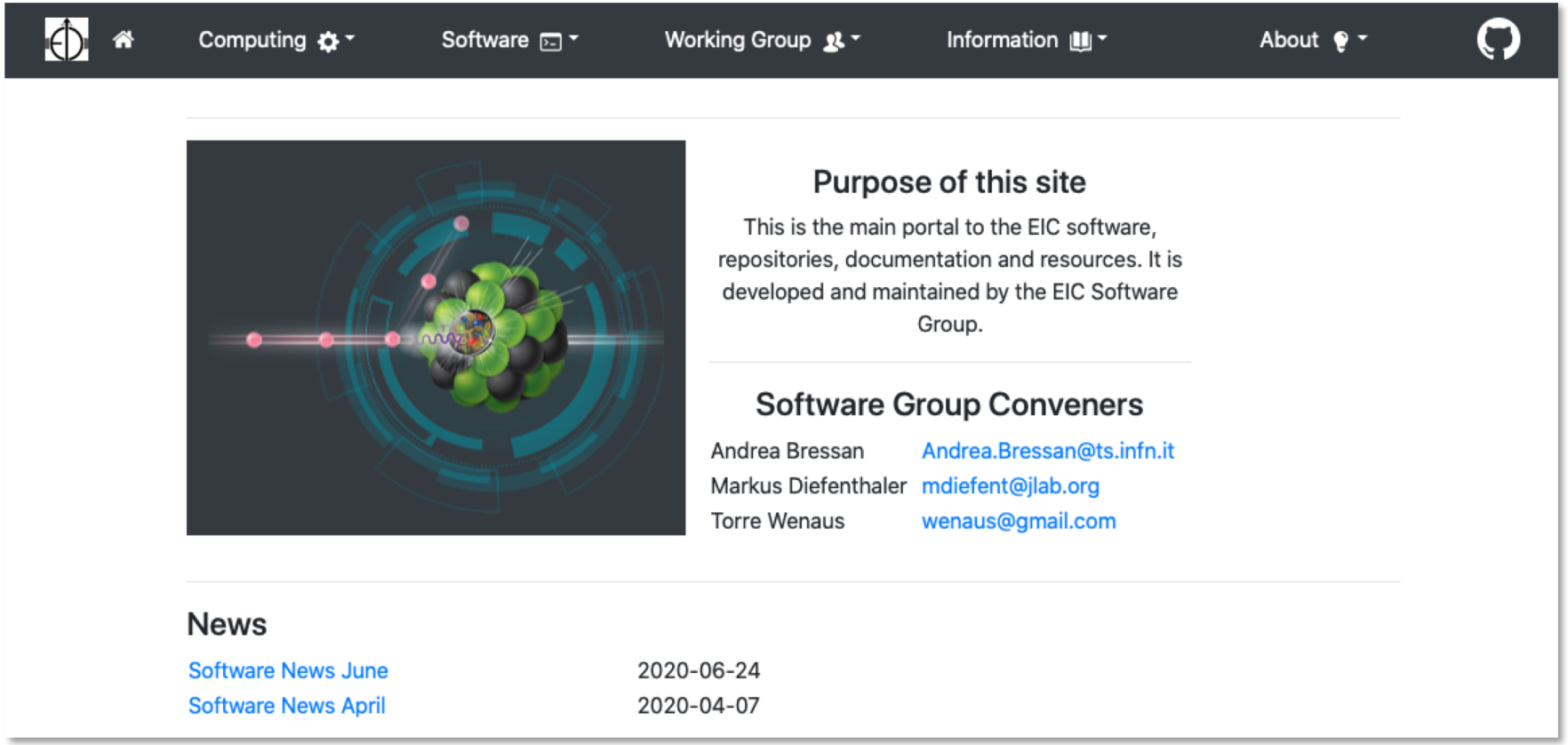
Collecting, organizing, and documenting EIC Software

new GitHub organization for the EIC community **https://github.com/eic**

- Please help us to make your software available on the GitHub organization and build an EIC Software Collection.

https://eic.github.io

- **new** SWG website
- based on HEP Software Foundation website that Torre et al. created
- set up by Maxim
- regular updates on content and structure by SWG
- available for your group and your documentation



Requests

Please consider storing (or mirroring) your **source code and examples** on:
https://github.com/eic

Unfolding algorithms will be fundamental for EIC analyses.
Please consider sharing an example or giving an unfolding tutorial.

MCEG validation Please consider joining our validation effort and help us with your expertise.

Markus Diefenthaler (EIC², Jefferson Lab)

mdiefent@jlab.org

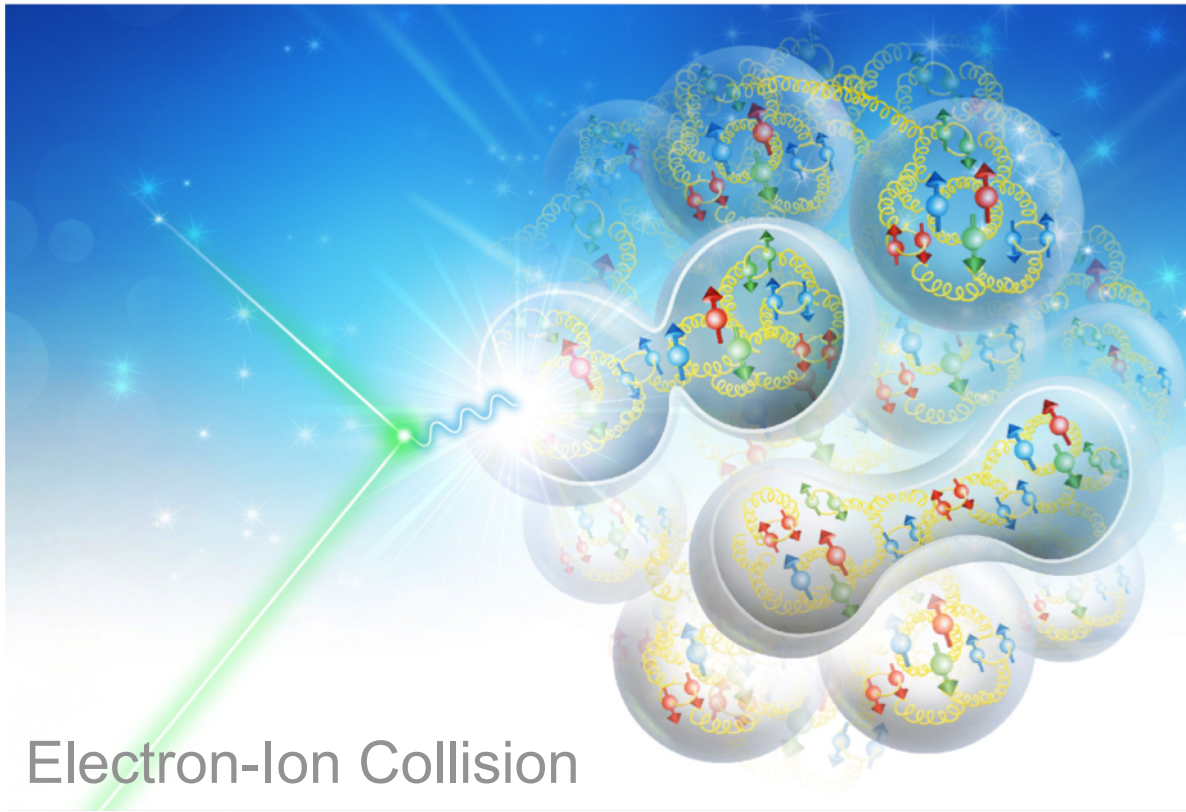
EICUG Software Working Group

Workflow environment for EICUG

- **fast and full simulation tools** available and being extended with community input
- **documentation** started and being improved with community input
- **support** available

Grow with user input

- excited to be core part EIC Physics and Detector Conceptual Development / Yellow Report
- Please consider to share your expertise with us and help us improving EIC simulations.



Electron-Ion Collision

Jefferson Lab