EICUG-MCnet MCEG Workshop

Summary of workshop

Feb. 20 – 22

DESY

Elke-Caroline Aschenauer (BNL), Andrea Bressan (Trieste), Markus Diefenthaler (JLAB), Hannes Jung (DESY), and Simon Plätzer (Vienna)

Workshop history
- Started as satellite workshop during POETIC-8

- Collaboration EICUG-MCnet

Goal of workshop series
- Requirements for MCEGs for ep and eA
- R&D for MCEGs for ep and eA

Focus of DESY workshop on Feb. 20 – 22
- Status of ep and eA in general-purpose MCEG
- Status of NLO simulations for ep
- MCEGs and TMDs and GPDs
- Merging QED and QCD effects

Program

Wednesday, February 20, 2019

14:00 - 15:45 General-Purpose MCEG: Precision for ep processes

- **14:00** **Intro** *5'*
  Material: [Slides] 📄

- **14:05** **Simulation of ep and eA processes in general-purpose MCEG** *30'*
  Speaker: Ilkka Helenius
  Material: [Slides]

- **14:35** **Status of (N)NLO simulations for ep and eA processes** *30'*
  Speaker: Stefan Hoeche
  Material: [Slides] 📄

- **15:05** **Status of aMC@NLO for DIS** *10'*
  Speaker: Buarque Franzosi Diogo
  Material: [Slides] 📄

- **15:15** **Discussion** *30'*

15:40 - 16:00 Coffee

16:00 - 18:00 General-Purpose MCEG: Combining QED+QCD effects

- **16:00** **QED corrections** *30'*
  Speaker: Prof. Hubert Spiesberger (Johannes Gutenberg- Universität Mainz)
  Material: [Slides] 📄

- **16:30** **Semi-analytic vs. Monte-Carlo Approaches for QED Corrections to SIDIS** *30'*
  Speaker: Prof. Andrei Afanasev (George Washington University)
  Material: [Slides] 📄
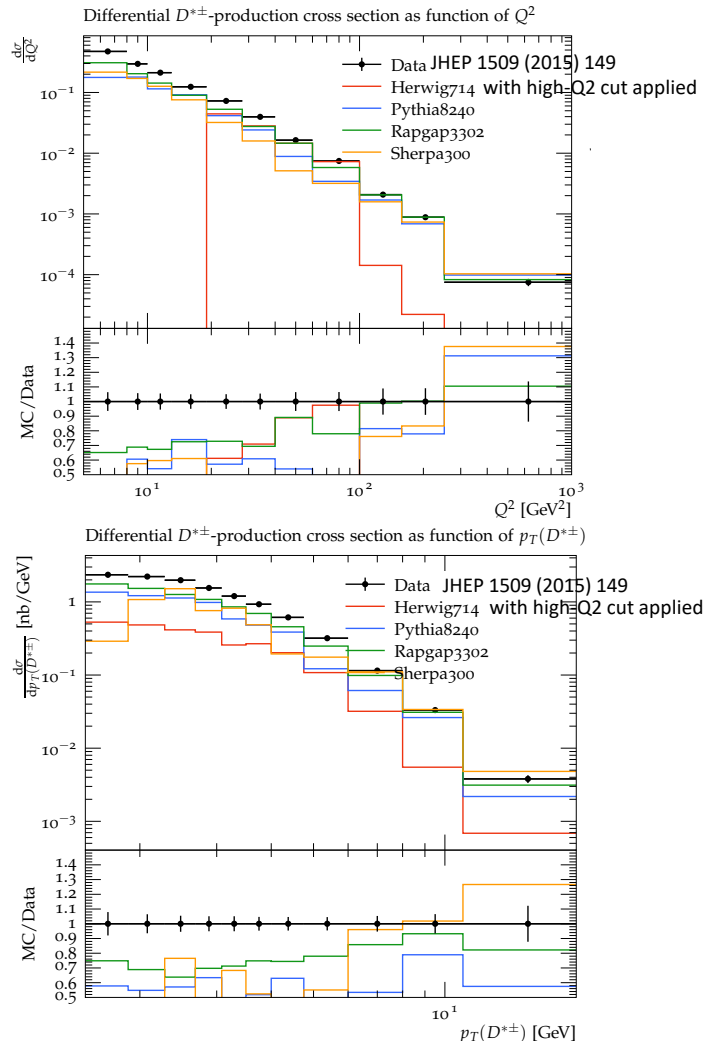
- **17:00** **Discussion and next steps** *1h0'*

Thursday, February 21, 2019

09:00 - 10:30 TMDs and MCEGs: Part I

- **09:00** **PB - TMDs** *30'*
  Speaker: Francesco Hautmann
  Material: [Slides] 📄

- **09:30** **PB TMDs for nucleons** *30'*
  Speakers: Alexander Kusina, Krzysztof Kutak
  Material: [Slides] 📄

- **10:00** **Matrix element calculations with off shell partons: KaTie** *30'*
  Speaker: Andreas van Hameren
  Material: [Slides] 📄

10:30 - 11:00 Coffee

11:00 - 12:00 TMDs and MCEGs: Part II

- **11:00** **Full event generator with TMDs: CASCADE-3** *30'*
  Speaker: Hannes Jung (DESY)
  Material: [Slides] 📄

- **11:30** **Revisited version of a recursive model for the fragmentation of polarized quarks** *30'*
  Speaker: Albi Kerbizi (University of Trieste)
  Material: [Slides] 📄

12:00 - 14:00 Lunch

14:00 - 15:30 TMDs and MCEGs: Part III

- **14:00** **Discussion: TMDs and MCEG** *1h30'*

15:30 - 16:00 Coffee

16:00 - 18:30 GPDs and MCEGs

- **16:00** **Towards event generation for GPD physics with PARTONS** *30'*
  Speaker: Dr. Herve Moutarde (IRFU, CEA)
  Material: [Slides] 📄

- **16:30** **DVCS and exclusive pi0 event generator for JLab fixed-target experiments** *30'*
  Speaker: Dr. Carlos Munoz (IPN-Orsay)
  Material: [Slides] 📄

- **17:00** **Discussion: GPDs and MCEGs** *1h0'*

Friday, February 22, 2019

09:00 - 10:30 Requirements

- **09:00** **Requirements ep** *30'*
  Speaker: Dr. Elke-Caroline Aschenauer (BNL)
  Material: [Slides] 📄

- **09:30** **eA Requirements** *30'*
  Speaker: Dr. Kolja Kauder (BNL)
  Material: [Slides] 📄

- **10:00** **Discussion** *30'*

10:30 - 11:00 Coffee

11:00 - 12:00 Wrapping up

Comparisons to combined H1 and ZEUS analysis (A. Verbytskyi)

Differential $D^{*\pm}$-production cross section as function of Q^2

Data JHEP 1509 (2015) 149
Herwig714 with high-Q2 cut applied
Pythia8240
Rapgap3302
Sherpa300

Differential $D^{*\pm}$-production cross section as function of $p_T(D^{*\pm})$

Data JHEP 1509 (2015) 149
Herwig714 with high-Q2 cut applied
Pythia8240
Rapgap3302
Sherpa300

General-purpose MCEG and ep collisions

- **Sherpa**
  - DIS with ME corrections and PS merging
  - Good description of jet data at low Q^2 with $\gtrsim 3$ partons in the final state
  - Automated NLO matching with Powheg method, applicable for jets at high-Q^2

- **Herwig**
  - Two shower options with spin correlations and NLO matching
  - Good description for single-particle properties in DIS
  - Also QED radiation for angular-ordered shower

- **Pythia**
  - Possible to generate DIS events with the new dipole shower implementation
  - Higher-order corrections via Dire plugin, soon part of Pythia core
  - Photoproduction for hard and soft QCD processes, also hard diffraction

- **Detailed comparisons between modern MCEG and HERA data**
  - Feb. 18 – 20 Workshop on Rivet for ep , mailing list for comparison studies
  - HERA data not (yet) included in MCEG tunes

General-purpose MCEG and eA collisions

- No strong modifications for DIS (nuclear PDFs, what else?)
- For photoproduction need to include interactions between resolved photon and other nucleons
- Complementary to ultra-peripheral collisions at the LHC and RHIC

Stefan Hoeche (SLAC)

arXiv:1803.09973

Transverse energy flow for $\langle x \rangle = 2.10 \cdot 10^{-3}$, $\langle Q^2 \rangle = 31.2 \text{ GeV}^2$
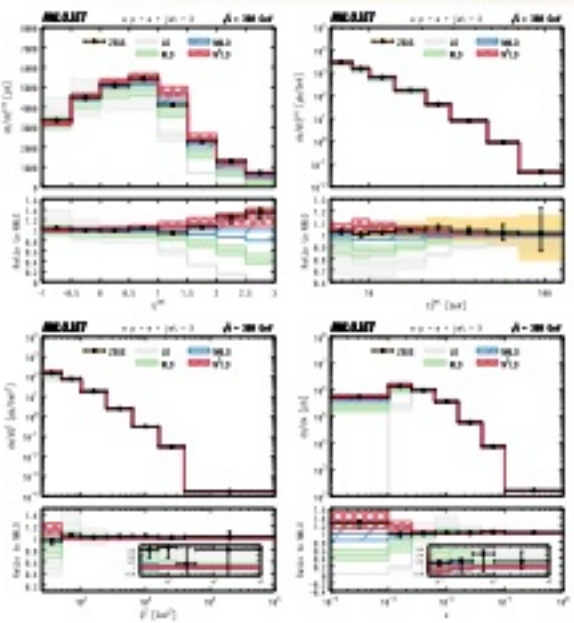
Fixed-order QCD

- QCD calculations available up to N^3LO for inclusive DIS

- Peculiarities of DIS require careful selection of scales

- Excellent description of experimental data from HERA

MC event simulation

- DIS simulations available in all three event generation frameworks

- NLO matching & merging standard, NNLO matching available

- Peculiarities of DIS require careful selection of clustering history

- Very good description of wide range of experimental data

MCEGs for future ep and eA facilities

Workshop Summary
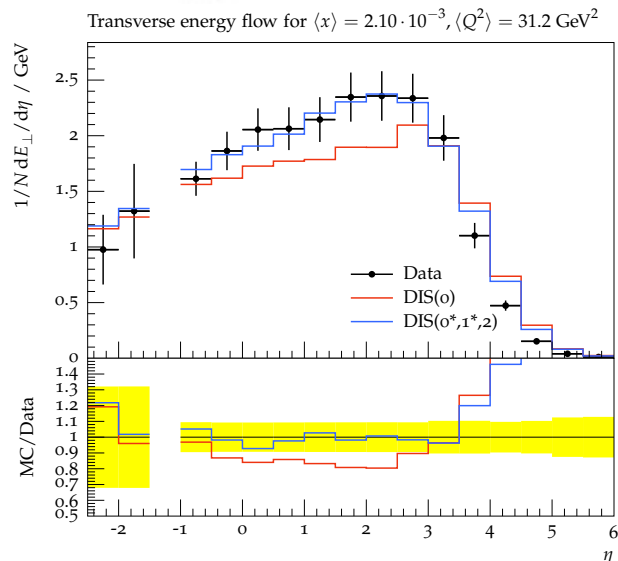
F Hautmann
TMDs from Parton Branching

First all flavor. all Q^2, all x and all k_t TMD at NLO determined.

- Introduction
- The Parton Branching (PB) method
- New results and applications

TMD and parton shower: CASCADE-3

Hannes Jung (DESY)

with contributions from
A. van Hameren, K. Kutak, A. Kusina,
A. Bermudez Martinez, P. Connor F. Hautmann, O. Lelek, R. Zlebcik

- From inclusive to exclusive distributions
- Parton Branching method for TMDs

First TMD parton shower using higher order splitting function.

NCN

nTMD using PB method

First all Q^2, all x, all k_t TMD at NLO for nuclei.

Krzysztof Kutak

Instytut Fizyki Jądrowej
im. Henryka Niewodniczańskiego
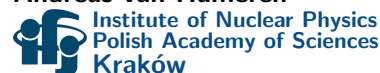Polskiej Akademii Nauk

Based on ongoing project with:
E. Blanco, A. van Hameren, H. Jung, A. Kusina

Comparison with DY data (pp, pPb, CMS)

Updates for KaTie

Andreas van Hameren
Institute of Nuclear Physics
Polish Academy of Sciences
Kraków

presented at the
MCEGs for future ep and eA facilities
21-02-2019, DESY, Hamburg

First ever off-shell hard process calculation for ep including all flavors.

Lively discussion: Factorization Theorem and MCEG approaches
To what extent are TMDs a result of a coherent branching evolution as, e.g., implemented in Herwig

Next: Comparison to TMD theory
Extract TMD from the different MCs and compare to analytic results.

UNIVERSITÀ
DEGLI STUDI DI TRIESTE

INFN
Istituto Nazionale di Fisica Nucleare

21st February 2019,
DESY,
Hamburg

Revisited version of a recursive model for the fragmentation of polarized quarks

Albi Kerbizi

University of Trieste. Trieste INFN Section

Lund string + 3P0; good description of Collins and di-hadron asymmetries; Boer-Mulders, jet handedness can be simulated.

Merging QED and QCD effects

CLASSIFICATION OF $O(\alpha)$ QED CORRECTIONS

- Radiation from the lepton
  model independent (universal),
  dominating by far: enhanced by large logs, $\ln(Q^2/m_e^2)$
- vacuum polarization (boson self energy)
  universal, photon self energy ➔ $\alpha_{em}(Q^2)$
- Radiation from the hadronic initial/final state
  parton model: radiation from quarks
  to be considered as a part of the nucleon structure
- Interference of leptonic and hadronic radiation
  2γ exchange
  new structure
- purely weak corrections

Note: for NC-scattering, straightforward separation
IR divergences: need to combine real and virtual radiation

H. Spiesberger (Mainz)   MCEGs, 20. 2. 2019   5/20

Radiative corrections in SIDIS

The Born cross section

Emission of a radiated photon (semi-inclusive processes)
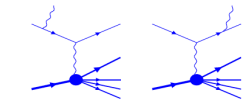
Loop diagrams

Emission of a radiated photon (exclusive processes)

The real polar angle of virtual photon is changing due to radiation of the real photon, introducing azimuthal dependence, coupling to ϕ-dependence of the x-section
Akushevich, Ilyichev, Osipenko, PL B672 (2009) 35

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

Andrei Afanasev, Workshop on MCEGs for Future ep and eA faciities, 20 Feb 2019   4

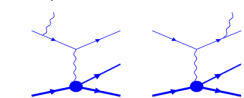**Hubert Spiesberger (Mainz): QED corrections**
- High-precision measurements need careful treatment of radiative corrections.
- Closely related to experimental conditions need full Monte Carlo treatment (Unfolding) including simulation of hadronic final states.
- The basics are known and available ...
- ... 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

Next steps: Discussion based on review by Elke-Caroline Aschenauer (BNL)

- **General-purpose MCEG**s, 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 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 of the radiative corrections (also for TMD and GPD physics and in particular for eA).

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

- **GPD physics**
  - No modern MCEG available.
  - There is a path from PARTONS to a GPD MCEG (Herve Moutarde (IRFU, CEA)), similar there is a project to extend MCEG for exclusive processes from JLAB12 to EIC (Carlos Munoz-Camacho (IPN-Orsay)).

> **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.