

# 23rd MCnet Meeting

Monday, 6 December 2021 - Wednesday, 8 December 2021

University of Manchester



## Book of Abstracts



# Contents

String interactions in PYTHIA8/Angantyr . . . . .	1
Berends-Giele recursion and a $1/N_c$ expansion in MadGraph . . . . .	1
Rivet status report . . . . .	1
Contur status report . . . . .	1
Diboson production including NLO QCD and electroweak corrections . . . . .	2
HEJ2+PYTHIA - Merging High Energy and Soft-Collinear Resummation . . . . .	2
MadGraph5_aMC@NLO: progress realised thanks to MCnet . . . . .	2
PYTHIA status report . . . . .	3
QED real corrections in the Sherpa event generator . . . . .	3
Herwig 7 status report . . . . .	3
Subleading high-energy logarithms and NLO accuracy for $W + \text{jets}$ . . . . .	4
Sherpa status report . . . . .	4
Quarkonia showers in PYTHIA8 . . . . .	4
MadGraph-Rivet/Contur interface development . . . . .	5
Searches for new interactions within the SMEFT framework . . . . .	5
Photoproduction events in Sherpa . . . . .	6
The $K^*/K$ ratio in heavy ion collisions . . . . .	6
Preparing Sherpa for $e+e^-$ . . . . .	6
Recent updates in LHAPDF . . . . .	6
Towards discrimination and improved modelling of dark-sector showers . . . . .	7
Tackling the Uncertainties of Event Generators . . . . .	7
Search for non-resonant di-Higgs searches in $bb\text{-}\gamma\gamma$ channel in CMS experiment and diphoton modelling in Herwig . . . . .	7

Implementing BSM radiations to angular-ordered parton shower process in Herwig and searching for the signal in the CMS detector . . . . .	8
HEJ status report . . . . .	8
Hadronic Interactions at High and Low Energies . . . . .	8

**Student talks / Discussion topic / 74**

## String interactions in PYTHIA8/Angantyr

**Author:** Smita Chakraborty<sup>None</sup>

**Corresponding Author:** smita.chakraborty@thep.lu.se

Summary of the research done in Pythia8/Anagntyr as an MCnetITN3 PhD student.

The first project was to develop a string “shoving” model to describe collective effects in heavy-ion collisions in terms of string interactions within the Lund model. This is done by constructing the Lorentz transformation to a symmetric frame where two string pieces are in parallel planes to calculate the resulting pairwise force due to the space-time overlap. Considering all such pairs of string pieces in a collision, the resulting total momentum change on a string piece is calculated. There is ongoing work to implement this along with the rope hadronization model in PYTHIA8.

The model is now further expanded using rope hadronization in heavy-ion collisions. Analysis involving the effects of string interactions on jets, known as jet quenching and the production yields of different hadron species in leading jets is also to be discussed.

**Student talks / Discussion topic / 75**

## Berends-Giele recursion and a $1/N_c$ expansion in MadGraph

**Author:** Andrew Lifson<sup>None</sup>

**Co-author:** Olivier Mattelaer<sup>1</sup>

<sup>1</sup> *UCLouvain*

**Corresponding Authors:** olivier.mattelaer@uclouvain.be, andrew.lifson@thep.lu.se

In this talk we introduce the still-developing `color_ordering` branch of `MadGraph5_amc@NLO`. This branch uses Berends-Giele recursions to calculate the matrix element, leading to more compact kinematics calculations. Additionally, this branch allows one to calculate matrix elements to a given order in the  $1/N_c$  colour expansion in the trace basis. In this talk, we give an overview of the status of the branch, describe the physics of the colour expansion, show the results of this approximation, and show some speed comparisons with standard MadGraph.

**Student talks / Discussion topic / 76**

## Rivet status report

**Author:** Andy Buckley<sup>1</sup>

<sup>1</sup> *University of Glasgow (GB)*

**Corresponding Author:** a.g.buckley@gmail.com

Status report on Rivet summing up developments in the closing MCnet period.

**Student talks / Discussion topic / 77**

## Contur status report

**Author:** Jonathan Butterworth<sup>1</sup>

<sup>1</sup> UCL

**Corresponding Author:** j.butterworth@cern.ch

Status report on Contur summing up developments in the closing MCnet period

Student talks / Discussion topic / 78

## Diboson production including NLO QCD and electroweak corrections

**Author:** Simon Luca Villani<sup>None</sup>

**Corresponding Author:** simonluca.villani@uni-goettingen.de

Summary of the research done as an MCnetITN3 PhD student.

Di-boson production processes play an important role in many Standard Model studies, including Higgs-boson and electroweak precision measurements. They also form an important background in searches for phenomena beyond the Standard Model. In this talk I will present a recent study on the inclusion of electroweak corrections to  $pp \rightarrow e^+e^-\mu^+\mu^-$  and  $pp \rightarrow e^+e^-\mu^+\mu^-j$ , both at exact NLO and using two approximations: the EW virtual and EW Sudakov approach. We also consider for the first time the all-order NLL Sudakov corrections to the fixed-order prediction. Finally, I am going to present prediction for  $pp \rightarrow e^+e^-\mu^+\mu^- + \text{jets}$  production based on merged NLO QCD matrix-element plus parton-shower simulations in the framework of the Sherpa event generator including electroweak corrections through the aforementioned approximations.

Student talks / Discussion topic / 79

## HEJ2+PYTHIA - Merging High Energy and Soft-Collinear Resummation

**Author:** Hitham Hassan<sup>1</sup>

<sup>1</sup> Durham University

**Corresponding Author:** hitham.t.hassan@durham.ac.uk

Matching of logarithms of high-energy and of the parton shower have previously been reported for the (high energy) leading logarithmic component of the cross section, and only up to the first emission from PYTHIA.

We discuss a method for both extending this matching both to all orders, and to include the non-resummable component of the cross section through standard CKKW-L merging.

First results are presented from a flexible implementation using HEJ2 and PYTHIA, which also allows for matching of the recently calculated leading-logarithmic resummation of the first sub-leading processes.

Student talks / Discussion topic / 80

## MadGraph5\_aMC@NLO: progress realised thanks to MCnet

**Author:** Olivier Mattelaer<sup>1</sup>

<sup>1</sup> *UCLouvain*

**Corresponding Author:** olivier.mattelaer@uclouvain.be

- short presentation of all the papers that intersect between mG5aMC and Mcnet. (likely one slide per paper)
- short Presentation of the work still in progress (likely on slide per project)

**Student talks / Discussion topic / 81**

## **PYTHIA status report**

**Author:** Christian Bierlich<sup>1</sup>

<sup>1</sup> *Lund University (SE)*

**Corresponding Author:** christian.bierlich@thep.lu.se

Status report on developments in Pythia8 in the closing MCnet-funded period.

**Student talks / Discussion topic / 82**

## **QED real corrections in the Sherpa event generator**

**Author:** Lois Flower<sup>1</sup>

<sup>1</sup> *IPPP, Durham University*

**Corresponding Author:** lois.flower@durham.ac.uk

In this talk I will present my work implementing QED real corrections in the Sherpa event generator. Using the Catani-Seymour dipole formalism, a  $k_T$ -ordered QED parton shower was constructed. The correct radiation pattern was obtained by applying negative weights to same-charge dipoles using the existing framework for applying analytic weights in the veto algorithm.

I will also present a supplement to the YFS resummation for Z decay to leptons which allows photons to split into fermion-antifermion pairs. This is motivated by the experimental practice of correcting to Born leptons informed by Monte Carlo simulations. Photon splittings appear at NNLO but are logarithmically enhanced with the fermion mass; this work quantifies their contribution.

**Student talks / Discussion topic / 83**

## **Herwig 7 status report**

**Author:** Patrick Kirchgaesser<sup>1</sup>

<sup>1</sup> *Lund University*

**Corresponding Author:** patrick.kirchgaesser@thep.lu.se

Status report on Herwig 7

**Student talks / Discussion topic / 84**

## **Subleading high-energy logarithms and NLO accuracy for $W +$ jets**

**Author:** Emmet Byrne<sup>None</sup>

**Corresponding Author:** emmet.byrne@ed.ac.uk

Several important processes and analyses at the LHC are sensitive to higher-order perturbative corrections beyond what can currently be calculated at fixed order. One important class of large logarithmic corrections are so-called high-energy logarithms which appear when the centre-of-mass energy of a QCD collision is much larger than the transverse momenta of the observed jets. In this talk I will describe the High Energy Jets (HEJ) framework, which includes the dominant high-energy logarithms to provide all-order predictions for several relevant LHC processes. I will summarise the results of a recent study of  $W$  boson production in association with at least two jets (arXiv:2012.10310), where we introduced a class of next-to-leading logarithmic improvements to the HEJ description of this process, and we performed the first bin-by-bin matching of HEJ to NLO accuracy.

**Student talks / Discussion topic / 85**

## **Sherpa status report**

**Author:** Daniel Reichelt<sup>1</sup>

<sup>1</sup> *IPPP Durham*

**Corresponding Author:** daniel.reichelt@durham.ac.uk

Status report on Sherpa summing up developments in the closing MCnet period

**Student talks / Discussion topic / 86**

## **Quarkonia showers in PYTHIA8**

**Author:** Naomi Cooke<sup>1</sup>

**Co-authors:** Leif Lönnblad<sup>2</sup>; Philip Ilten<sup>3</sup>; Stephen Mrenna<sup>4</sup>

<sup>1</sup> *University of Birmingham (GB)*

<sup>2</sup> *Lund University (SE)*

<sup>3</sup> *University of Cincinnati (US)*

<sup>4</sup> *FERMILAB*

**Corresponding Authors:** naomi.cooke@cern.ch, mrenna@fnal.gov, philten@cern.ch, leif.lonnblad@thep.lu.se



Quarkonia production has been a long-standing puzzle in particle physics. The polarisation measurement of  $J/\psi$  is expected to have significant transverse polarisation at large  $p_T$ , but has been experimentally observed to be consistent with zero. Hard production of onia processes using NRQCD formalism are available in the Pythia8 framework. However, these processes alone cannot fully describe the data; LHCb and CMS have shown with normalised cross section measurements of  $z = p_T(J/\psi)/p_T(jet)$  that  $J/\psi$ 's are produced softer than expected. Hence the need to incorporate onia production within the parton shower. A status report for incorporating quarkonia showers into Pythia8 will be presented.

**Student talks / Discussion topic / 87**

## MadGraph-Rivet/Contur interface development

**Author:** Si Hyun Jeon<sup>1</sup>

**Co-authors:** Jonathan Butterworth<sup>2</sup>; Olivier Mattelaer<sup>3</sup>

<sup>1</sup> *Seoul National University (KR)*

<sup>2</sup> *UCL*

<sup>3</sup> *UCLouvain*

**Corresponding Authors:** j.butterworth@cern.ch, shjeon@cern.ch, olivier.mattelaer@uclouvain.be

For the MCnet shortterm studentship program, my task was to construct the interface that connects MadGraph to Rivet and in the end, Contur to do reinterpretation studies. The interface construction was successfully done, with actual working examples (physics results). The talk will be about latest updates to MadGraph interfaced to Rivet/Contur and reinterpretation results on several heavy neutrino mass models with Contur.

**Student talks / Discussion topic / 88**

## Searches for new interactions within the SMEFT framework

**Author:** Luca Mantani<sup>1</sup>

<sup>1</sup> *DAMTP, University of Cambridge*

**Corresponding Author:** lm962@cam.ac.uk

Summary of my PhD thesis.

In the hypothesis that the scale of new physics is considerably higher than the energies probed at colliders, we can parametrise modified interactions induced by BSM effects among SM particles in a model-independent framework, the Standard Model Effective Field Theory (SMEFT).

In the thesis, several phenomenological aspects of the SMEFT are discussed, both at present and future colliders.

A characteristic feature of modified interactions is that they can induce unitarity violating effects which can be exploited to gain sensitivity. In this direction, a thorough study of the top quark electroweak sector will be presented, focusing on  $2 \rightarrow 2$  scatterings and their embeddings in physical processes at colliders. This analysis allows us to identify several final states that have a good potential to explore the SMEFT parameter space and that could be particularly relevant in a global analysis.

One of the key features of the SMEFT is indeed that deviations from the SM interactions are correlated and global interpretations are therefore of fundamental importance. A combined interpretation of the Higgs, top and diboson data from the LHC is here presented and the interplay between the various datasets discussed.

Finally, the physics potential of a futuristic muon collider will be analysed, focusing in particular on

the prospects to determine the Higgs self-interactions, a task that is arduous even in proposed 100 TeV proton colliders.

**Student talks / Discussion topic / 89**

## Photoproduction events in Sherpa

**Author:** Peter Meinzinger<sup>None</sup>

**Corresponding Author:** peter.meinzinger@durham.ac.uk

I will review recent efforts to extend Sherpa to include photon PDFs in Sherpa and to describe photoproduction events.

**Student talks / Discussion topic / 90**

## The $K^*/K$ ratio in heavy ion collisions

**Author:** Chiara Le Roux<sup>None</sup>

**Corresponding Author:** chiara.le\_roux@thep.lu.se

In this talk I will give a brief introduction about myself as a new PhD student starting to work with Monte Carlo event generators, more specifically, SHERPA. I will also present the main results obtained during my masters' when I studied the  $K/K$  ratio in heavy ion collisions. *The goal of this project was to understand the suppression of this ratio during the hadron gas phase that the collision system undergoes after the hadronization of the quark gluon plasma. Given that the lifetime of the  $K$  meson is shorter than that of the hadron gas itself, it's expected that the daughter particles of the  $K$  decay will rescatter during this phase and, as a result, the observed  $K/K$  ratio will be suppressed when compared with predictions by statistical hadronization models. To take into account these hadronic interactions, we solve a system of differential equations for the abundances of  $K$  and  $K$  mesons and compute the value of the  $K/K$  ratio at the moment of thermal freeze-out, i.e., when the hadronic interactions cease. We explored how this solution was affected by different factors: the temperature evolution of the system, the kinetic freeze-out temperature and the interaction mechanisms for the  $K$  and  $K$  mesons with the constituents of the gas. This analysis showed that the experimental data observed for the  $K/K$  ratio in different collision systems can be described using a Bjorken-like temperature evolution and considering that the thermal freeze-out temperature decreases with the size of the post-collision system. We also showed that the most relevant interaction mechanisms in the hadron gas are  $K^* \rightarrow K\pi$  and  $K\pi \rightarrow K^*$ .*

**Student talks / Discussion topic / 91**

## Preparing Sherpa for $e+e-$

**Author:** Alan Price<sup>1</sup>

<sup>1</sup> Siegen University

**Corresponding Author:** alan.price@uni-siegen.de

I will present Sherpa's ongoing development for future lepton colliders.

**Student talks / Discussion topic / 93**

## Recent updates in LHAPDF

**Author:** Max Knobbe<sup>None</sup>

**Corresponding Author:** max.knobbe@uni-goettingen.de

Review of the most recent changes to the LHAPDF PDF interpolator.

**Student talks / Discussion topic / 94**

## Towards discrimination and improved modelling of dark-sector showers

**Author:** Sukanya Sinha<sup>1</sup>

**Co-author:** Andy Buckley<sup>2</sup>

<sup>1</sup> *University of Witwatersrand*

<sup>2</sup> *University of Glasgow (GB)*

**Corresponding Authors:** sukanya.sinha@cern.ch, a.g.buckley@gmail.com

If dark mesons exist, their evolution and hadronization procedure are currently little constrained. They could decay promptly and result in a very SM QCD like jet structure, even though the original decaying particles are dark sector ones; they could behave as semi-visible jets; or they could behave as completely detector-stable hadrons, in which case the final state is just the missing transverse momentum. Apart from the last case, which is more like a conventional BSM MET signature, the modelling of these scenarios is somewhat an unexplored area, other than the range of phenomenological predictions as implemented in Pythia8's HV module. In this talk I will discuss the prospect of using jet substructure methods for designing observable/s to distinguish between dark jets, semi-visible jets and light q/g jets, by comparing different observables in a IRC-safe linear basis, with some preliminary results, as well as the proposed idea of having a Herwig hidden valley dark shower and hadronisation module. Both these topics are part of my recent MCnet short-term studentship.

**Student talks / Discussion topic / 95**

## Tackling the Uncertainties of Event Generators

**Author:** Leif Gellersen<sup>None</sup>

**Corresponding Author:** leif.gellersen@thep.lu.se

Summary of the work done during my PhD studies in Lund.

**Student talks / Discussion topic / 96**

## Search for non-resonant di-Higgs searches in bb-gamma gamma channel in CMS experiment and diphoton modelling in Herwig

**Author:** Soumya Mukherjee<sup>1</sup>

<sup>1</sup> *Tata Institute of Fundamental Research*

**Corresponding Author:** soumyamukherjee002@gmail.com

After the discovery of Higgs boson by CMS and ATLAS experiment in 2012 the current mandate of the LHC is to search for the Higgs Boson self coupling along, which is yet to be measured. CMS and ATLAS are performing the search in different channels of non-resonant Higgs boson production using full Run-2 data taken by LHC. In this context one of the most clear channels is di-Higgs to  $bb\text{-}\gamma\text{-}\gamma$  final state due to less background and better calorimetric resolution. But it's difficult to estimate the di photon background spectrum along with some jets in Monte Carlo. My talk will cover the basic strategy of di Higgs to  $bb\text{-}\gamma\text{-}\gamma$  searches in CMS and recent work on the di photon background modelling in Herwig interface under MC-Net project.

**Student talks / Discussion topic / 97**

## Implementing BSM radiations to angular-ordered parton shower process in Herwig and searching for the signal in the CMS detector

**Author:** Joon-Bin Lee<sup>1</sup>

<sup>1</sup> *Seoul National University (KR)*

**Corresponding Author:** joon.bin.lee@cern.ch

After the discovery of the Higgs boson at 2012, there is no direct evidence for new physics. It is thus a good time to explore a new phase space. We perform a search for new physics inside a jet using non-isolated leptons related with the muon  $g\text{-}2$  and LHCb's lepton universality violation results. There is no proper shower generator to generate the signal sample for this search, we implement BSM parton showers in Herwig 7. This presentation informs a preliminary result of a non-isolated dimuon production using the CMS dataset and BSM parton radiations.

**Student talks / Discussion topic / 98**

## HEJ status report

**Author:** Jeppe Rosenkrantz Andersen<sup>1</sup>

<sup>1</sup> *IPPP, University of Durham*

**Corresponding Author:** jeppe.andersen@durham.ac.uk

Status report on HEJ summing up developments in the closing MCnet period.

**Student talks / Discussion topic / 99**

## Hadronic Interactions at High and Low Energies

**Author:** Marius Utheim<sup>None</sup>

**Corresponding Author:** marius.utheim@thep.lu.se

In this talk, which will follow a somewhat unconventional format, I will share with you a few things I learned during my PhD that I found particularly interesting. The specific topics I will touch on are hadronic rescattering, exotic hadrons and cosmic rays.