

Summary and plans on Generators

Alan Price
Siegen University

1st ECFA Workshop on e^+e^- Higgs/EW/Top Factories



General Purpose Monte-Carlos are the true workhorse of phenomenology



SHERPA



PYTHIA



HERWIG

It is difficult to imagine particle physics without them

~85% of LHC papers cite at least one of them

Monte Carlo Talks

Event Shapes and Jet substructure at lepton colliders

Daniel Reichelt

Institute for Particle Physics Phenomenology, Durham University

UNIVERSITÄT GRAZ
UNIVERSITY OF GRAZ



Parton showers from old to new paradigms

Simon Plätzer
Institute of Physics — NAWI, University of Graz
Particle Physics — University of Vienna

At the
ECFA workshop on e+e- colliders
Hamburg | 6 October 2022

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At the

Institute of Physics — University of Vienna
Particle Physics — University of Graz

QED Status and Benchmarking Event Generators for Lepton Colliders

Alan Price
Siegen University



Measurements to Improve Hadronization Models

Frank Krauss

Institute for Particle Physics Phenomenology
Durham University

First ECFA Workshop - 6.10.2022 - DESY



F. Krauss IPPP

Measurements for Hadronization Models

F. Krauss



Generators

BACK TO THE FUTURE



Andrzej Siódmok



NCN, Poland Grant No. 2019/34/E/ST2/00457



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Photoproduction: towards NLO accuracy

First ECFA workshop at DESY, Hamburg

Peter Meinzinger
6th October 2022

IPPP, Durham University

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Parton showers from
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**50% of talks by Early Stage
Researchers**

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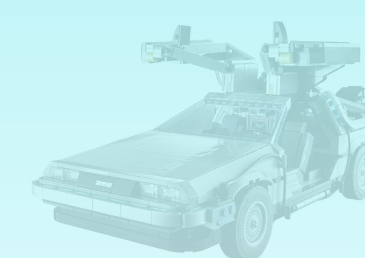
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Measurements to Improve Hadronization Models

Frank Krauss

Soft physics effects may dominate theory uncertainties:
no first-principles theory → **must measure!**

• typical observables:

- event shapes → dynamics
(trust, major, minor, ...)
- (differential) jet multiplicities → dynamics
(differential jet multis, ...)
- single-particle distributions → dynamics, popping
(x_p for charged/hadron species, dependent on primary quarks...)
- fragmentation functions → dynamics
(especially B fragmentation (from SLD))
- (PDG) hadron multiplicities → popping & multiplets
(especially K, p, \dots ; possibly also ratios w.r.t. π^\pm)

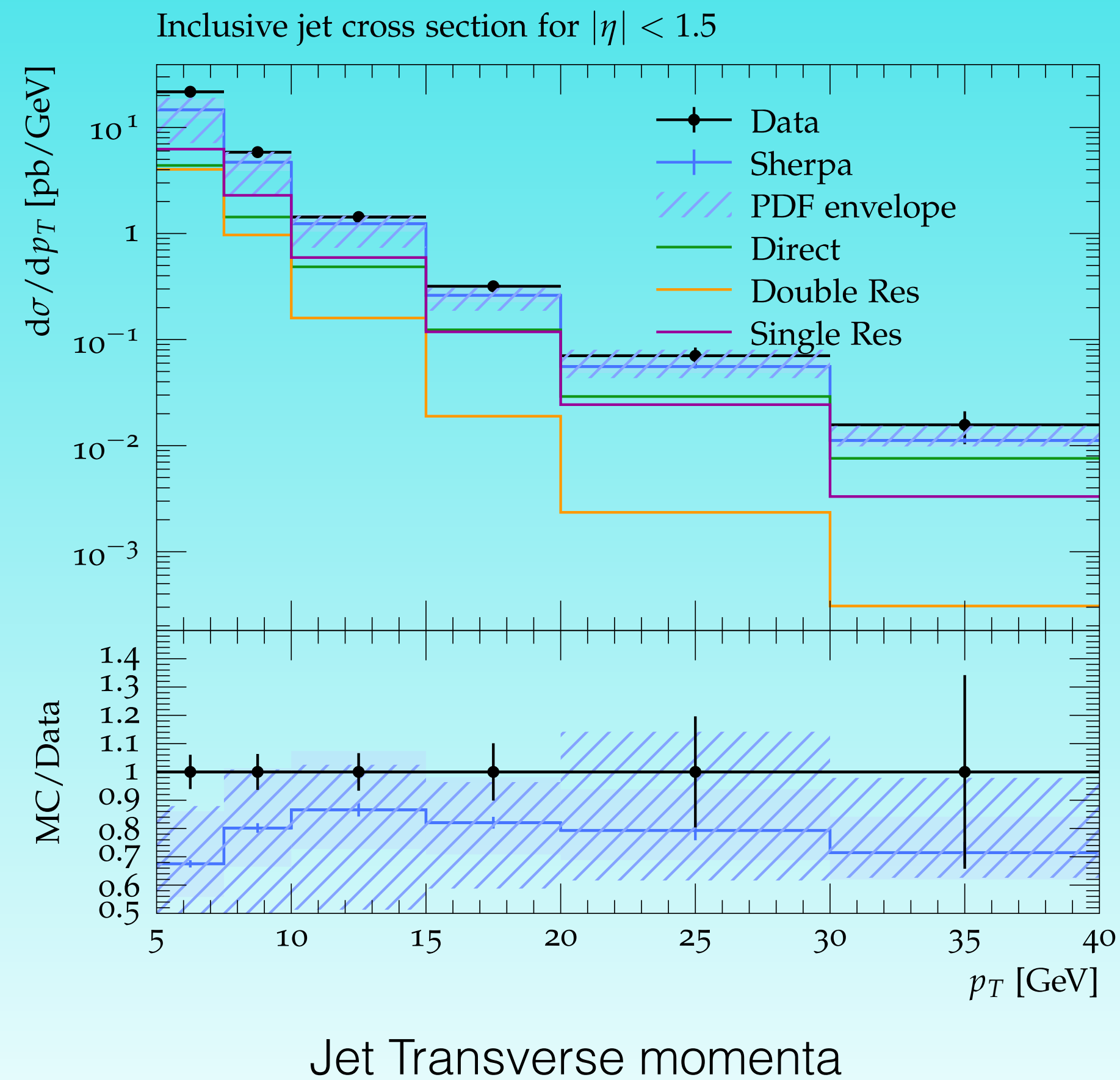
Missing Pieces

1. Gluon fragmentation
 - $g \rightarrow Q\bar{Q}$ splitting tricky in parton showers
2. The riddle of the soft photons
 - Photons number scales with neutral hadrons
3. BE Effects
 - Improved algorithms needed
4. Color Reconnections
 - How to systematically test it in $Z/\gamma^* \rightarrow q\bar{q}$

there is a good chance that it will become a **limiting factor** for the analysis and interpretation of precise data and their uncertainties

Photoproduction: towards NLO accuracy

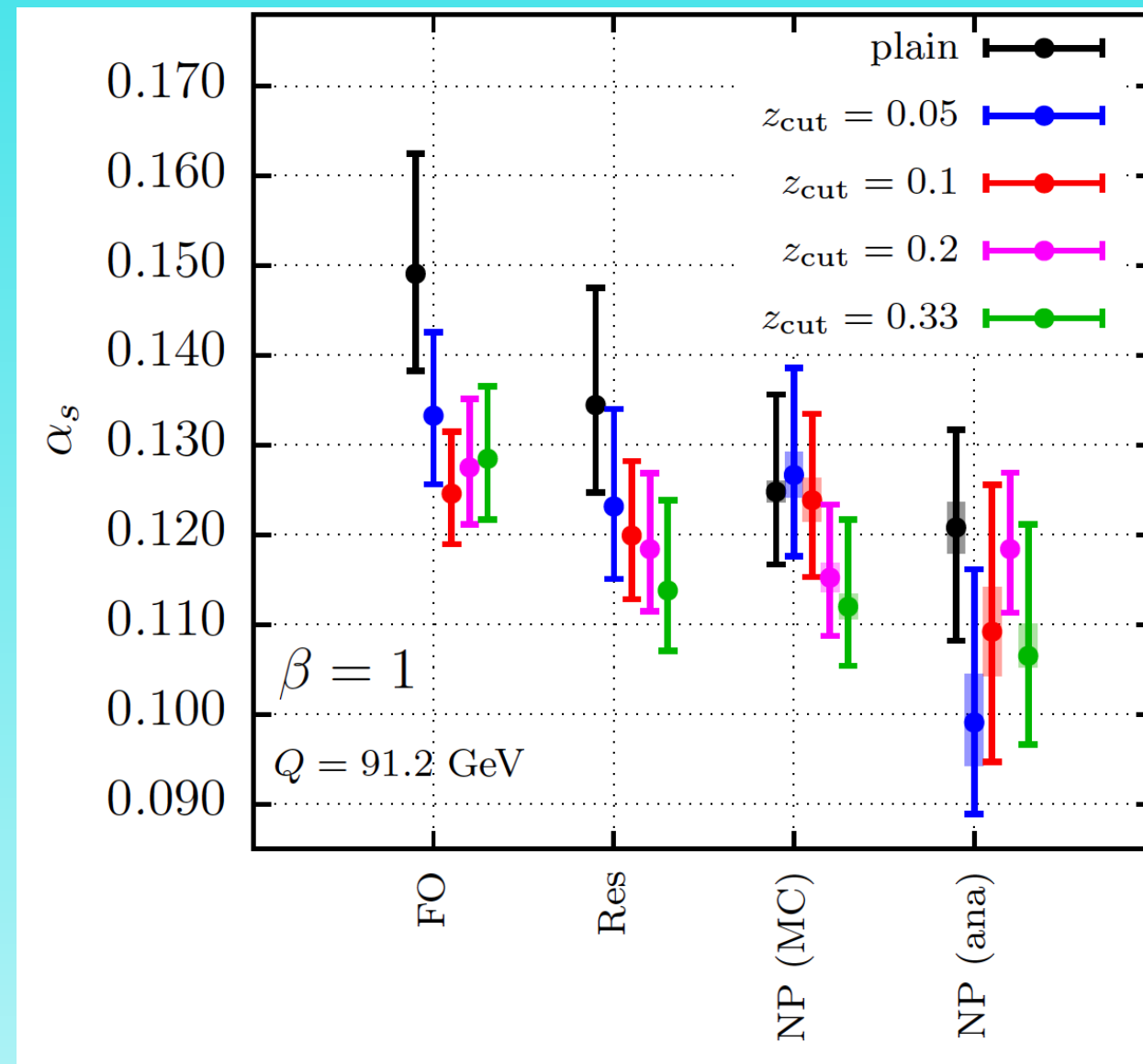
Peter Meinzinger



- Photoproduction, i.e, $\gamma\gamma \rightarrow X$, is an important ingredient for QCD at lepton-lepton collider phenomenology, dominant process for jet production
- Simulation in Sherpa validated against LEP and HERA data, running at MEPS@LO
- Uncertainties dominated by photon PDFs
- Extension to NLO QCD using
- MC@NLO needs some attention, but is feasible

Event Shapes and Jet substructure at lepton colliders

Daniel Reichelt



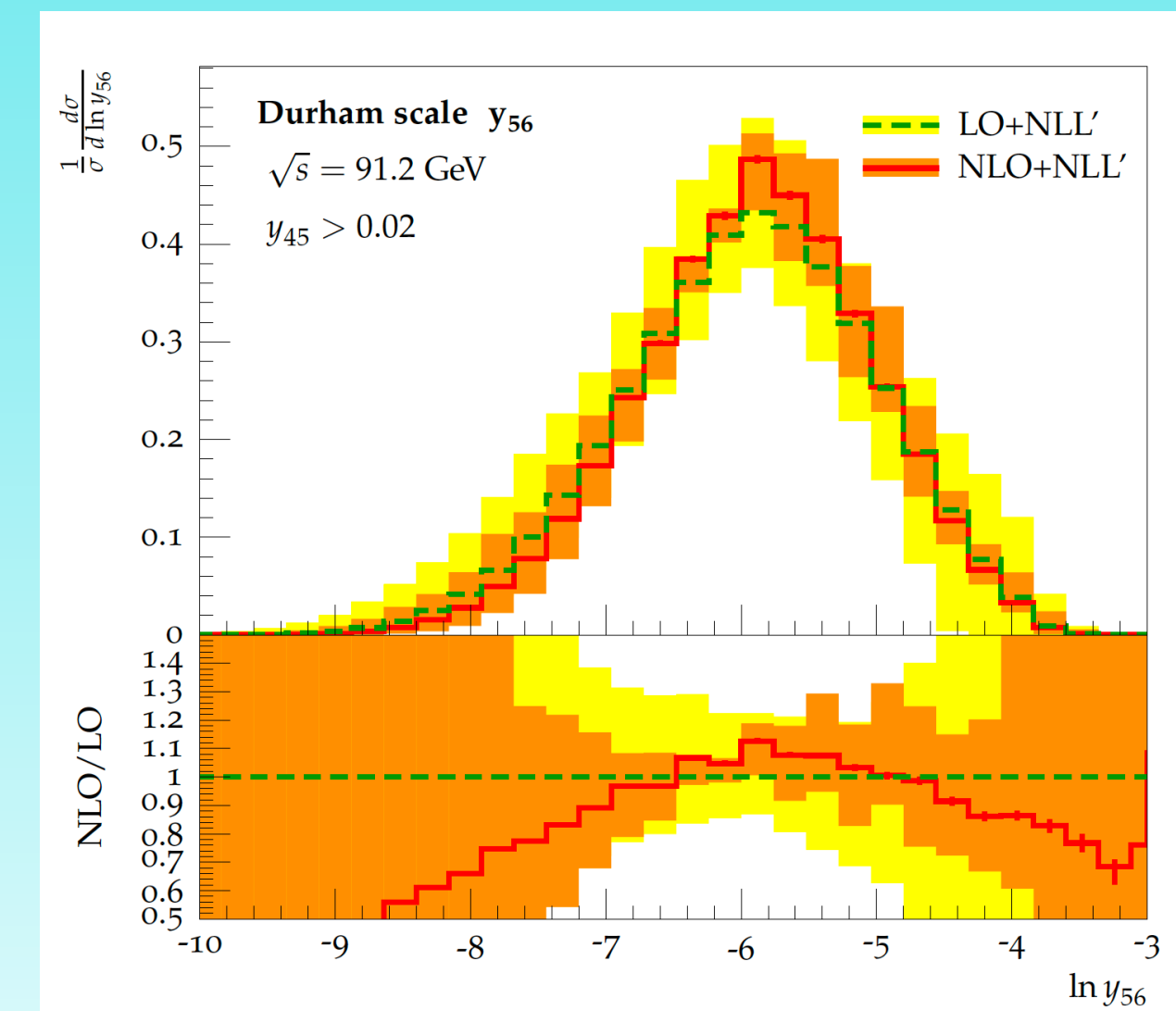
α_s from soft drop groomed event shapes [Larkoski, Marzani, Soyez, Thaler '14]

Fits to MC data (SHERPA MEPS@NLO w/ up to 5 jets)

Higher-Order understanding of grooming => smaller error bars

Multi-Jet Rates

NLO+NLL' accuracy for y_{34}, y_{45}, y_{56}
Resummation plugin to SHERPA



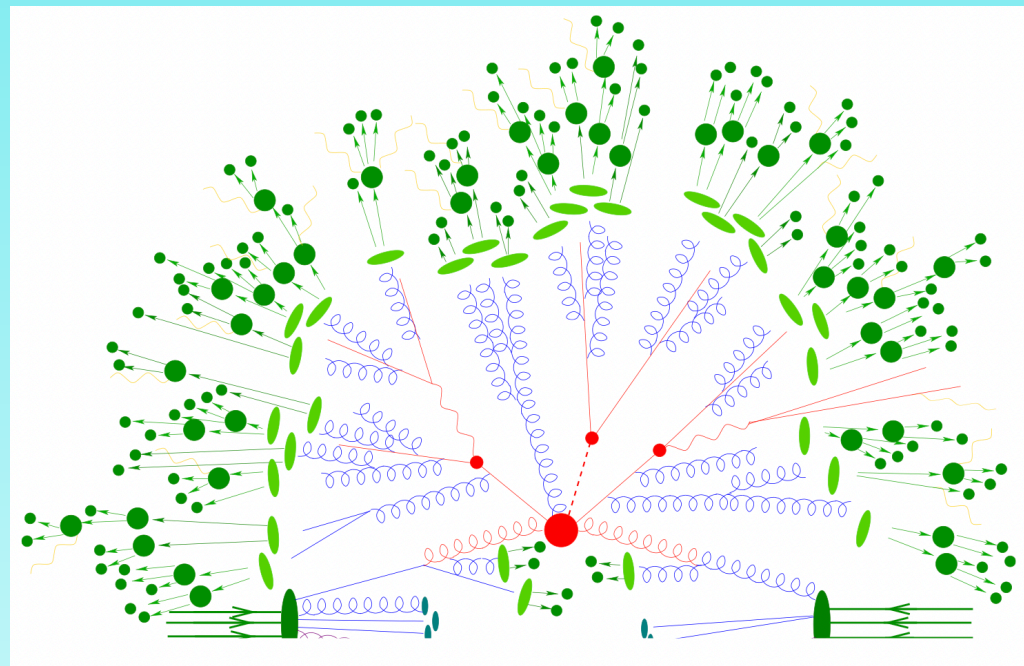
[Baberuxki, Preuss, DR, Schumann '19]

Overview Talks

QCD for Lepton Colliders

Daniel Reichelt

- Review of Analytical Resummation
- Recent developments in Parton Showers
- For more detail on PS, see **Simon Plätzer** talk



QED Status and Benchmarking Event Generators for Lepton Colliders

Alan Price

- Different approaches to QED radiation
- Collinear vs Soft resummation
- Update on technical Benchmarking

Generators: Back to the Future

Andrzej Siódmok

- General overview of Monte Carlos, past and present
- Recording available on the indico page



Tools For e^+e^-

KKMCee

[Jadach, Ward, Was, Yost, Siodmok]

- Dedicated $e^+e^- \rightarrow f\bar{f}$ $f = \mu, \tau, q$ event generator
- Resummed (exponentiated) multi photon effects at the AMPLITUDE level (CEEX scheme) keeping (exponentiated) initial-final state interferences
- Non-soft QED complete up to 3rd order LO, NLO 2nd order, in the initial and final states
- Very precise, theory error is $<0.1\%$
- Recently, heroic effort to rewrite to C++
- Next steps, adding CEEX $\mathcal{O}(\alpha^3 L^3)$ corrections, while maintaining the soft limit. Also port the resummation to other processes e.g HZ
- Improved treatment of NLO-EW corrections
- **BHLUMI**: did not change from LEP but it was used to reanalyse LEP data [Jadach and Janot, Phys. Letters B803 (2020) 135319]

KORALW, YFSWW

[S. Jadach, W. Placzek, M. Skrzypek, B.F.L. Ward, Z. Was]

- Dedicated $e^+e^- \rightarrow W^+W^- \rightarrow f_1f_2f_3f_4$ event generators, now merged into KandY
- Resumed (exponentiated) multi photon effects at the AMPLITUDE squared level (EEX)
- Includes Coulomb corrections, “Naive” QCD corr, CKM, FSR Photos, Tauola, JETSET
- Next steps, adding CEEX style resummation, theoretical work done

[Eur.Phys.J.C 80 (2020) 6, 499]

RaccoonWW

[Denner, A., Dittmaier, S., Roth, M., & Wackerth, D.]

- Dedicated $e^+e^- \rightarrow W^+W^- \rightarrow 4f$ and $e^+e^- \rightarrow W^+W^- \rightarrow 4f\gamma$ event generator
- ISR resummed via Collinear resummation
- Includes Coulomb corrections
- Important check for WW physics => Two independent MC

BabaYaga

[Balossini, Bignamini, Carloni Calame, Lunardini, Montagna, Nicrosini, Piccinini]

- Dedicated $e^+e^- \rightarrow e^+e^-, \mu^+\mu^-, \gamma\gamma$
- ISR by collinear resummation at LL and matched to NLO QED
- Final state photons are fully exclusive
- Future work to include NNLO QED and NLO EW effects

WHIZARD

[Kilian, Ohl, Reuter, Brass, Bredt, Kreher, Rothe, Stenemeier, Striegli]

- NLO for both QCD and EW.
- ISR via collinear resummation. LL pdfs but NLL on the way
- Photon kinematics: Inclusive in ISR, exact in hard process and optional single photon emission from ISR.
- Beam dynamics via CIRCE interface
- NLO EW calculations at lepton collisions with beam polarisations
- Planned improvement to multi-photon emissions: PS + YFS



Madgraph5 aMC@NLO

[Alwall, Frederix, Frixione, Hirschi, Maltoni, Mattelaer, Pagani, Shao, Stelzer, Torrielli, Zaro, Zhao]

- NLO for both QCD and EW.
- ISR via collinear resummation. State of the art NLL
- Photon kinematics: Inclusive in ISR, exact in hard process
- Beam dynamics simulation based on GuineaPig results
- NLO+NLL predictions completed.



Sherpa

[Bothmann, Chahal, Höche, Krauss, Napoletano, Price, Schönherr, Schumann, Siegert]

- Two options for QED radiation
 - Dipole shower combined with LL electron PDF
 - Automised YFS (EEX) resummation for e^+e^-
 - NNLO QED and NLO EW corrections to decays
- Next steps: Automise NLO-EW + YFS corrections, include photon splittings $\gamma \rightarrow f\bar{f}$
- Photoproduction see Peter Meinzinger
- Importantly, independent YFS MC from the Krakow MC
- One Author dedicated to e^+e^- (funding dependent)



Outlook

- MC are far from being ready for future lepton colliders
 - ➔ But, we still have a lot of time. Personally, I believe we will reach the required perturbative accuracy
 - ➔ Hadronization will be a bottle neck
- Recent developments for e^+e^- physics gives us a lot to be hopeful for