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IN KRAKÓW

SHERPA Event Generator

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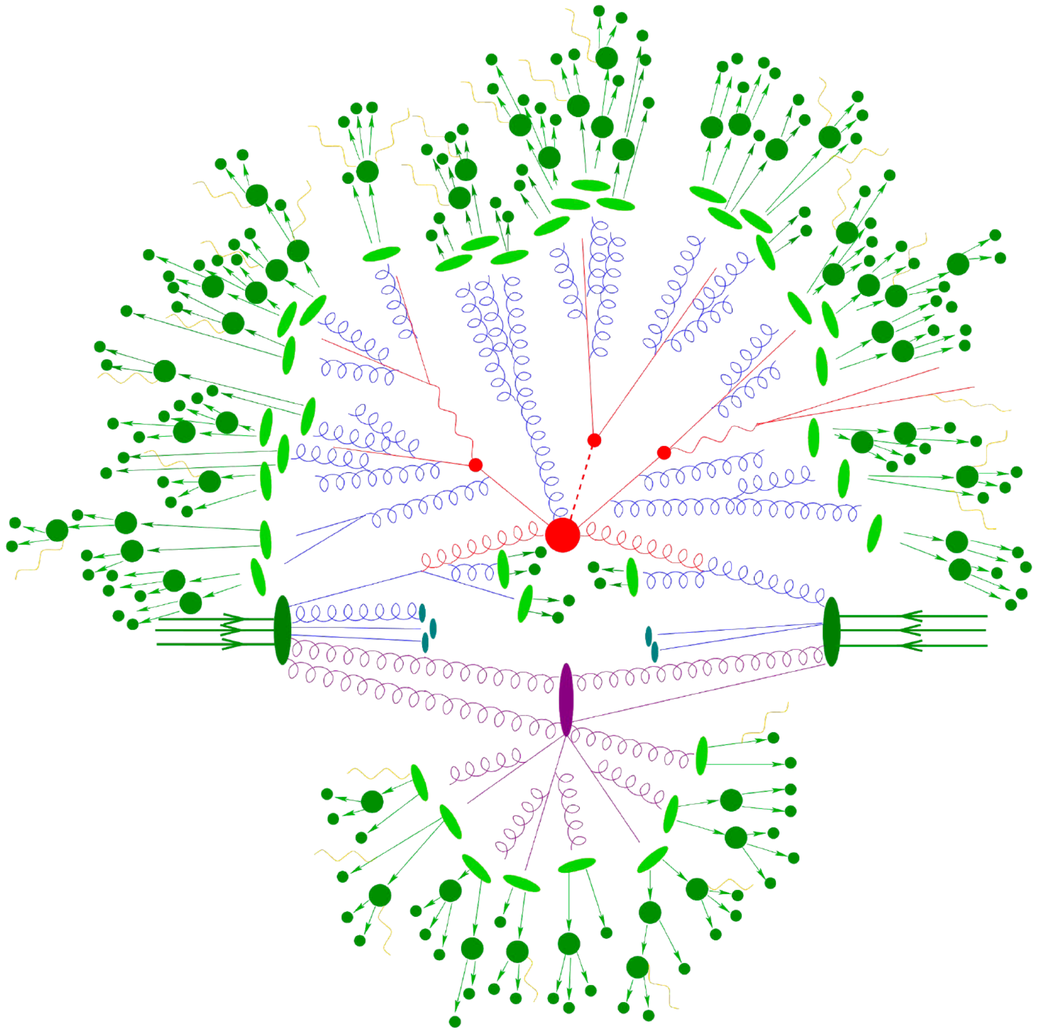
SHERPA Framework

- **Automated Hard Interaction**
  - LO, NLO QCD/EW, NNLO QCD
  - Internal ME generators AMEGIC/COMIX
- **Radiative Corrections**
  - Catani-Seymour based PS
  - DIRE, YFS QED resummation
  - EW Sudakovs
- **Multiple interactions**
  - Sjöstrand-Zijl model
- **Hadronization**
  - Cluster hadronization model
- **Hadron Decays**
  - Phase space or EFTs,
  - YFS QED corrections



SciPost Phys. 7 (2019) 3, 034

SHERPA Framework

Sherpa has traditionally focused on LHC physics, but is becoming more broad in its application

Lepton-Lepton Colliders

YFS Resummation for Future Lepton-Lepton Colliders in SHERPA
SciPost Phys. 13 (2022) 2, 026, F.Krauss, A.P, M. Schönherr

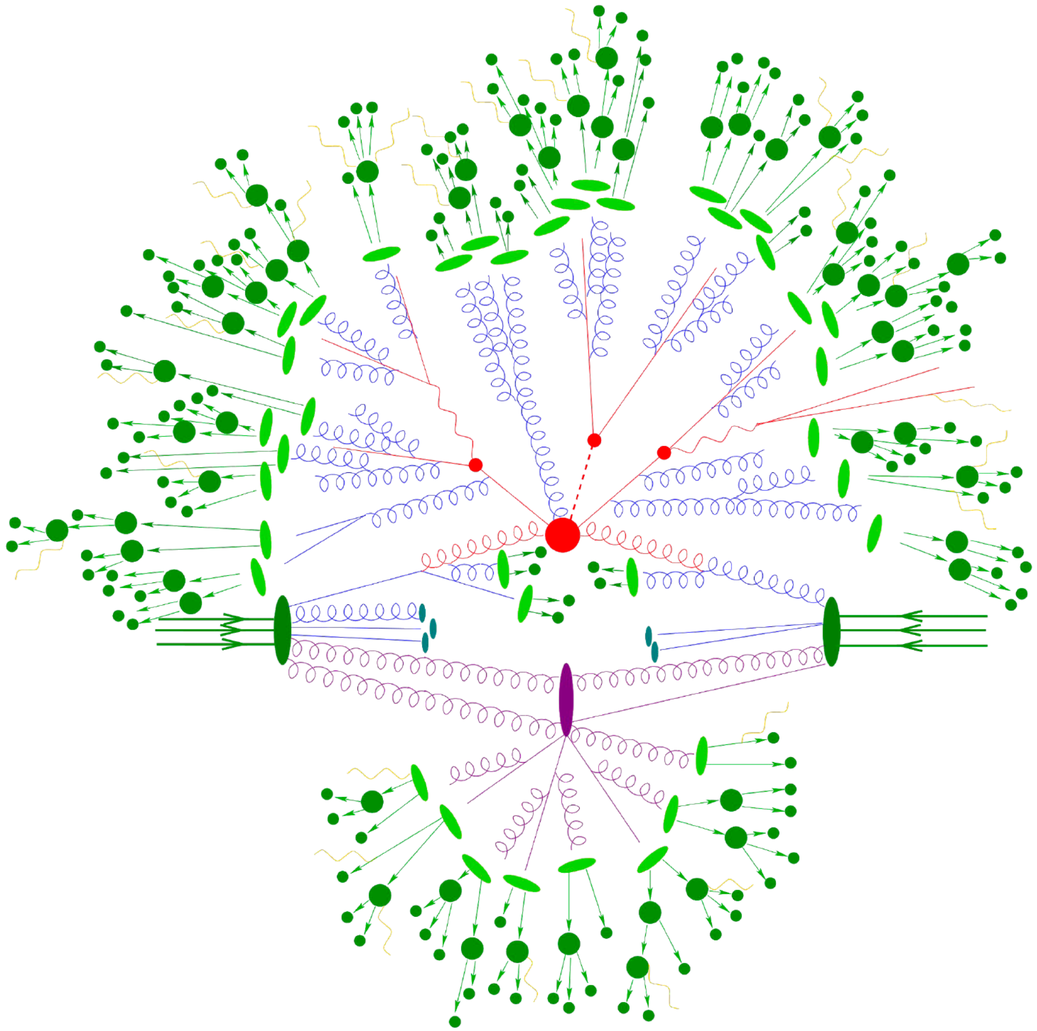
Measuring Hadronic Higgs Boson Branching Ratios at Future Lepton Colliders 2306.03682 M.Knobbe, F.Krauss, D.Reichlet, S. Schumann

Lepton-Hardron Colliders

(N)NLO+NLL' accurate predictions for plain and groomed 1-jettiness in neutral current DIS
JHEP 09 (2023) 194 M.Knobbe, D.Reichelt, S.Schumann

Neutrino Experiments

Novel event generator for the automated simulation of neutrino scattering
Phys.Rev.D 105 (2022) 9, 096006 J.Isaacson, S.Höche, D.Gutierrez, N.Rocco



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YFS Resummation

- Yennie-Frautschi-Suura allows us to resum **soft logs to infinite order**
- Provides a systematic method to include **perturbative corrections**
- The multi-photon phasespace is treated exactly => Explicit Photons
- The MC implementation developed and championed by the Krakow group

Comput.Phys.Commun. 130 (2000) 260-325

$$d\sigma = \sum_{n_\gamma=0}^{\infty} \frac{e^{Y(\Omega)}}{n_\gamma!} d\Phi_Q \left[\prod_{i=1}^{n_\gamma} d\Phi_i^\gamma \, S(k_i)\, \Theta(k_i, \Omega) \right] \left(\tilde{\beta}_0 + \sum_{j=1}^{n_\gamma} \frac{\tilde{\beta}_1(k_j)}{S(k_j)} + \sum_{\substack{j,k=1 \\ j<k}}^{n_\gamma} \frac{\tilde{\beta}_2(k_j,k_k)}{S(k_j)S(k_k)} + \cdots \right),$$

~Process Independent

Process Dependent

Sherpa for Strong2020

Process	LO	YFS	YFS@NLO
$e^+e^- \to \mu^+\mu^-$	Complete	Complete	Complete
$e^+e^- \to e^+e^-$	Complete	Complete	Complete
$e^+e^- \to \mu^+\mu^-\gamma$	Complete	Complete	Complete Virtual, approximate Real
$e^+e^- \to e^+e^-\gamma$	Complete	Complete	Complete Virtual, approximate Real
$e^+e^- \to \pi^+\pi^-$	Complete	Complete in Scalar QED	??
$e^+e^- \to \pi^+\pi^-\gamma$	Approximate from YFS	??	??

Complete = No approximations, all mass effects etc

YFS = Not quite LO, contains LL approximations to (N)NLO

YFS@NLO = “Modern” NLO i.e Full real and virtual corrections

Sherpa for Strong2020

Process	LO	YFS	YFS@NLO
$e^+e^- \to \mu^+\mu^-$	Complete	Complete	Complete
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$e^+e^- \to \pi^+\pi^-$	Complete	Complete in Scalar QED	??
$e^+e^- \to \pi^+\pi^-\gamma$	Approximate from YFS	??	??

HVP = alphaQED F. Jegerlehner. Can provide separate contributions e.g Leptonic only

Pion Form-Factor = Same as git repo

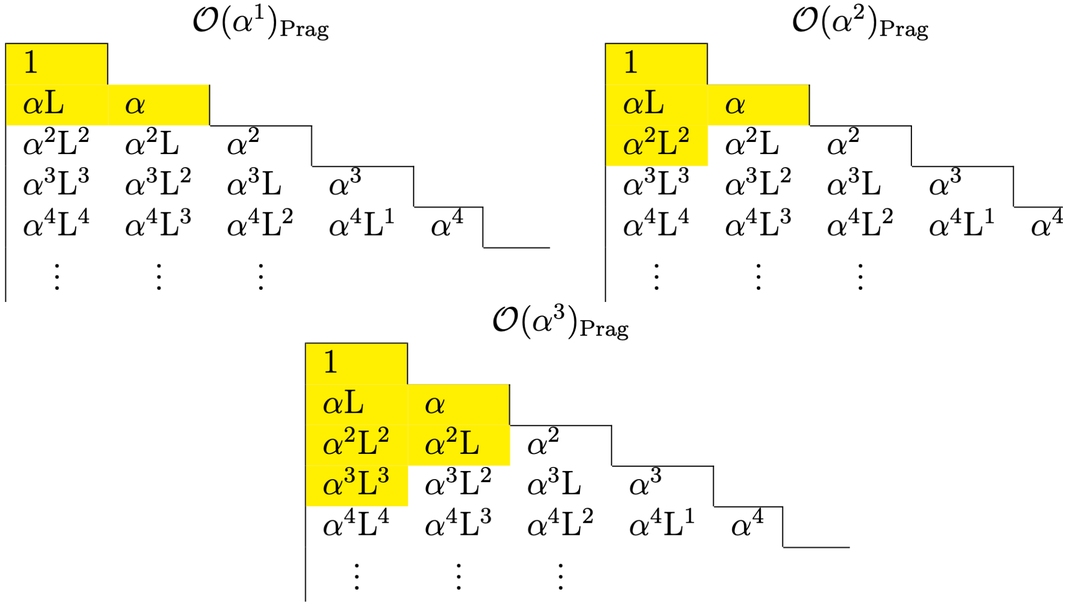
Higher Order Corrections

$$\tilde{\beta}_0 + \sum_{j=1}^{n_\gamma} \frac{\tilde{\beta}_1(k_j)}{S(k_j)} + \sum_{\substack{j,k=1 \\ j<k}}^{n_\gamma} \frac{\tilde{\beta}_2(k_j,k_k)}{S(k_j)S(k_k)} + \cdots$$

Originally implemented in EEX framework of KKMC

While easy to implement suffers from a lack of accuracy e.g No Initial-final interference

Solved in KKMC with CEEX corrections



Automatic One-Loop Corrections

$$\tilde{\beta}_0^1\left(\Phi_n\right) = \mathscr{V}\left(\Phi_n\right) - \sum_{ij} \mathscr{D}_{ij}\left(\Phi_{ij}\right)$$

- Full One Loop EW contribution
  - Contains IR divergent terms
- Need a loop generator that can include all lepton masses!
  - Currently only Recola can provide this
- All or nothing. Cannot separate ISR/FSR

- Fully automated within YFS module
- Constructed from all dipoles
- Really should be limited to leptonic final states only
- Works for massive quarks but should not be combined with QCD resummation

Real Corrections

$$\tilde{\beta}_1^1\left(\Phi_{n+1}\right) = \mathscr{R}\left(\Phi_{n+1}\right) - \tilde{\beta}_0^0\left(\Phi_n\right)\sum_{ij}\tilde{S}_{ij}(k)$$

- Real photon correction to born process
- In Principle, can be taken from AMEGIC or COMIX

- Subtraction term calculate from the eikonals of all dipoles
- Automated within YFS

The SHERPA 2.2 event generator framework

User Inputs

Initial Beams

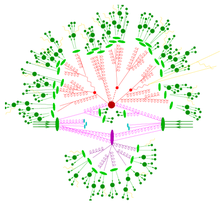
- collider setup
- PDFs (built-in, LHAPDF)
- beam spectra

Parameters/Models

- FeynRules/UFO
- couplings
- masses
- variations
- shower settings
- non-perturbative parameters

Physics Process

- parton level
- perturbative order (QCD/EW)
- selectors
- matching/merging
- partonic decays



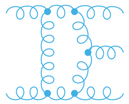
Matrix Elements

Matrix Element Generators

- AMEGIC
- COMIX
- CS subtraction

1-loop Amplitudes

- OpenLoops
- Recola
- GoSam
- BLHA



Parton Showers

CS-Shower (default)

- dipole shower
- fully massive
- QED splittings

DIRE

- hybrid dipole-parton shower algorithm
- fully massive

Matching and Merging

Automated MC@NLO style matching

Multijet-merging algorithms

- based on truncated showers
- tree-level and one-loop matrix elements: MEPS@LO and MEPS@NLO
- approximate electroweak corrections

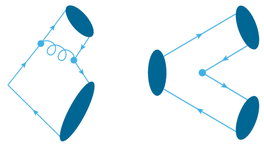
NNLO QCD with parton showers

- selected processes only

Soft Physics

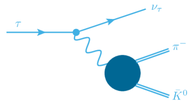
Hadronisation

- AHADIC: a cluster fragmentation model
- interface to Pythia string fragmentation



Hadron Decays

- decay tables for hadronic resonances
- dedicated form-factor models, e.g. τ, B, Λ
- spin correlations
- YFS QED corrections
- partonic channels



Underlying Event

- multiple parton interactions
- beam-remnant colours
- intrinsic transverse momentum

Interfaces/Outputs

Output Formats

- HepMC
- LHEF
- Root Ntuple

Interfaces

- RIVET analyses
- C++/Python ME access
- MCgrid
- integration into ATLAS/CMS

Code/Docu

- HepForge
- GitLab
- online documentation

sherpa.hepforge.org

gitlab.com/sherpa-team/sherpa