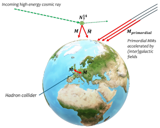

CRPropa 3.3: A Unified Multimessenger Framework for SM Physics and Beyond

Andrey Saveliev[1]

September 13th, 2026

[1]for the CRPropa Collaboration (crpropa@desy.de, https://crpropa.desy.de/)

CRPropa

- publicly available Monte Carlo code

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- propagation of high-energy cosmic rays, gamma rays, neutrinos, and electrons

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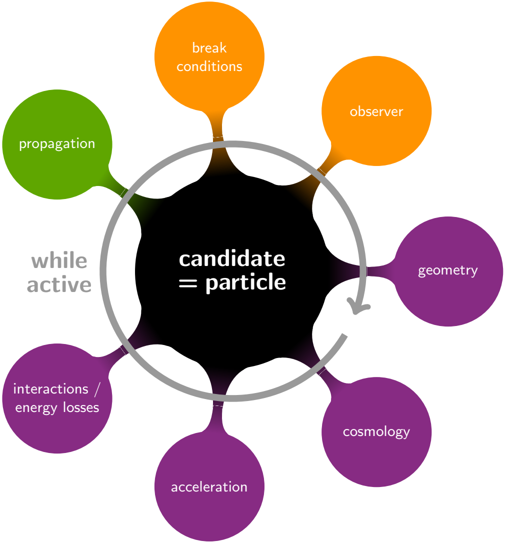
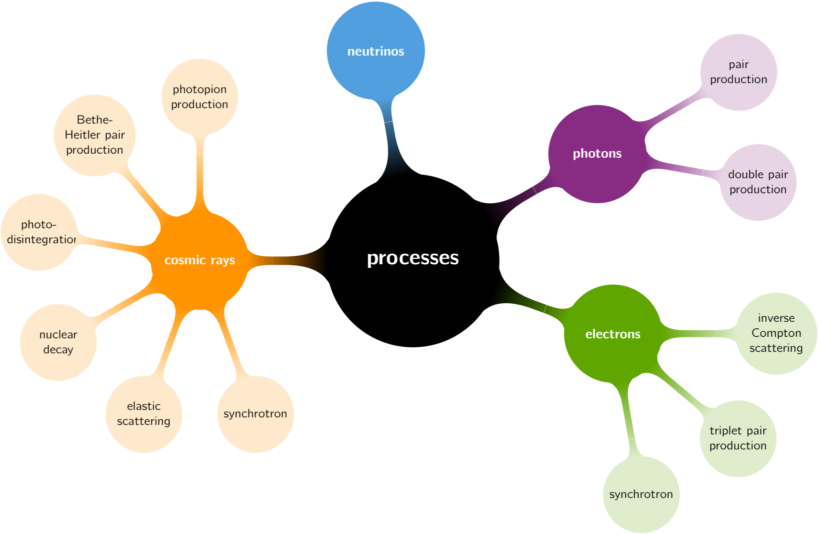
- publicly available Monte Carlo code
- propagation of high-energy cosmic rays, gamma rays, neutrinos, and electrons
- propagation in any environment (Galactic, extragalactic, around sources)
- modular structure
- can be installed simply over its conda package
- development on Github: https://github.com/CRPropa/CRPropa3

CRPropa



Sketch by R. Alves Batista



Sketch by R. Alves Batista

CRPropa – Some History

Online meetings (approximately) once every one to two months
Annual in-person meetings for users and developers:

- 2013: Hamburg (GER) [as part of CASPAR 2013]
- 2014: Hamburg (GER) [as part of CASPAR 2014]
- 2017: Brussels (BE)
- 2018: Bochum (GER)
- 2019: Zeuthen (GER)
- 2021: Nijmegen (NL) [online]
- 2022: Madrid (ESP)
- 2023: Bochum (GER)
- 2025: Abu Dhabi (UAE)
- 2026: Hamburg (GER)

CRPropa – Some History

- 2007 – v1.0 [Armengaud et al., 2007]: Pair/pion production and deflections in EGMF of nucleons; propagation of secondaries in 1D via DINT (for EM cascades)
- 2013 – v2.0 [Kampert et al., 2013]: Nuclei with $Z \leq 26$ are included, featuring photodisintegration and nuclear decay
- 2016 – v3.0 [Alves Batista et al., 2016]: Implementation of modularity; propagation in Galactic Magnetic Fields including Galactic Lensing; enhanced cosmological features ("4D simulations")
- 2017 – v3.1 [Merten et al., 2017]: low-energy extension using stochastic differential equations
- 2022 – v3.2 [Alves Batista et al., 2022]: Cosmic-ray acceleration, interactions within astrophysical source environments, full Monte Carlo treatment of electromagnetic cascades, improved ensemble-averaged Galactic propagation

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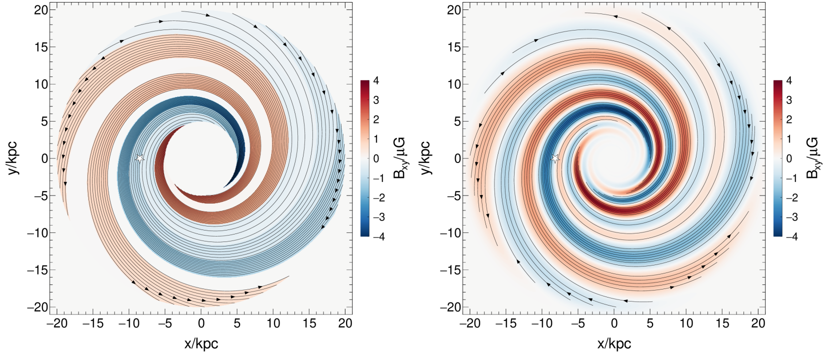
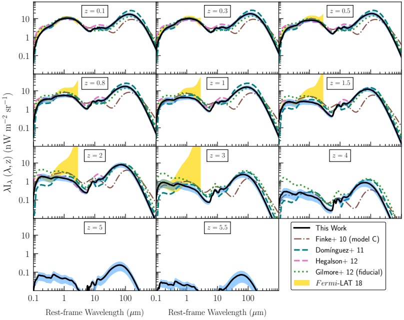
- 2026 – v3.3 [Aerdker et al., 2025]

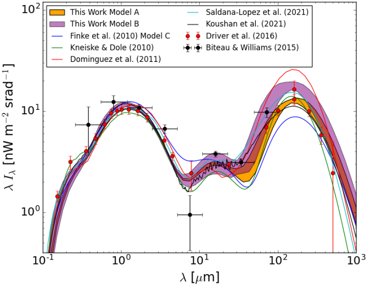
CRPropa 3.3: New Galactic Magnetic Field Model UF24



Example for the new galactic magnetic field model: UF24 from [Unger and Farrar, 2024] (on the left), compared to the JF12 [Jansson and Farrar, 2012] model (on the right)

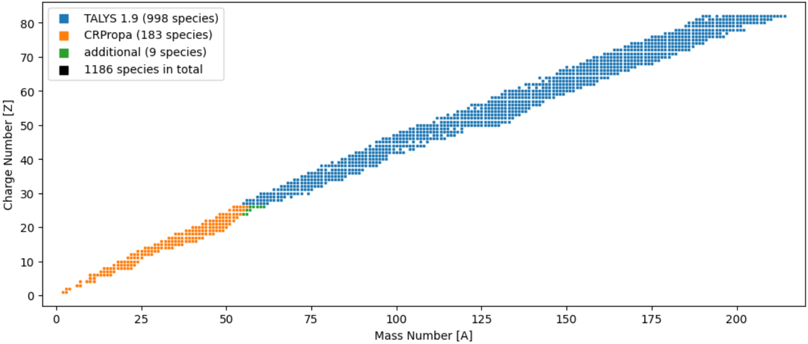
CRPropa 3.3: New EBL Models





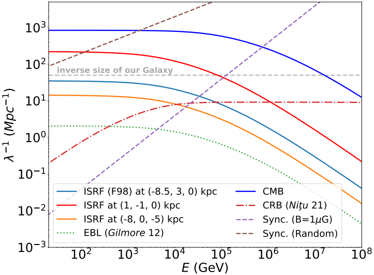
New EBL models included as IRB_Saldana [Saldana-Lopez et al., 2021] and IRB_Finke22 [Finke et al., 2022].

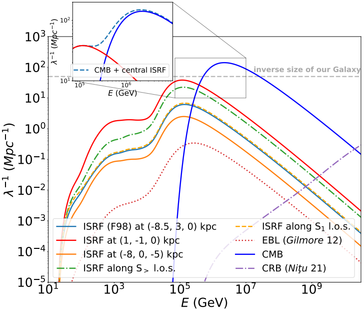
CRPropa 3.3: Inclusion of Nuclei up to Lead



To improve the coverage and accuracy of nuclear data for astrophysical and high-energy physics applications, additional cross sections, compiled in [Morejon, 2021], have been included for nuclei up to lead ($Z = 82$) based on TALYS 1.9 [Koning et al., 2023]

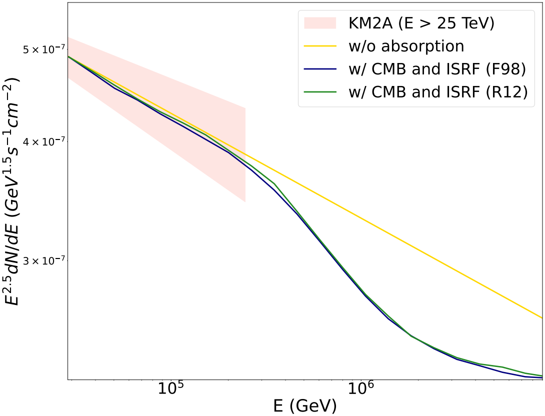
CRPropa 3.3: Position-Dependent Radiation Fields





Position-dependent radiation fields may be used to account for interactions with, e.g., the interstellar radiation field (ISRF) [Di Marco et al., 2025]. Two actual Milky Way ISRF models, F98 [Freudenreich, 1998] and R12 [Robitaille et al., 2012], have been implemented.

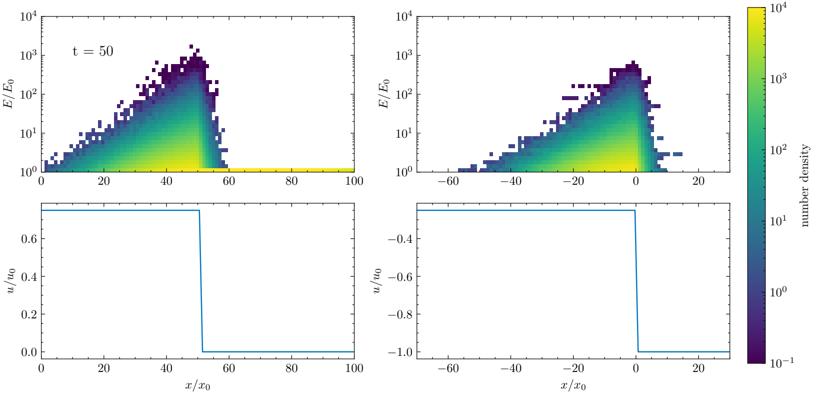
CRPropa 3.3: Position-Dependent Radiation Fields



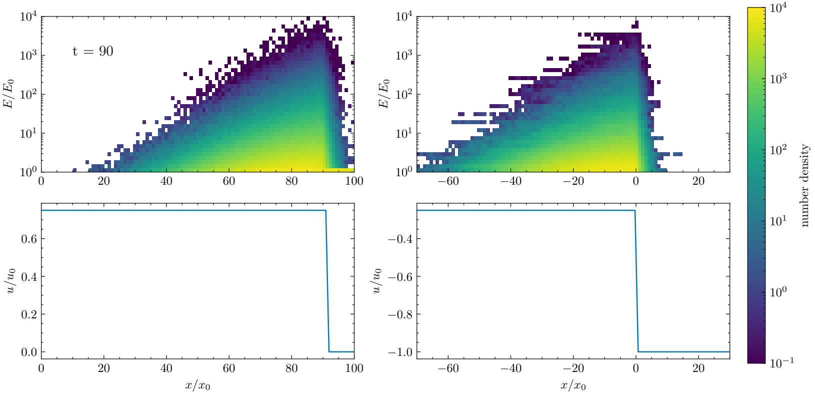
This then may be used to model particle propagation, e.g. for 1LHAASOJ1825-1256u [Aerdker et al., 2025].

CRPropa 3.3: Study of Time-Dependent Phenomena

- An explicit time dependence may now be used in CRPropa
- As a first example, time-dependent advection fields have been implemented (in addition to the existing spatial dependence)
- A first physics use case is diffusive shock acceleration [Aerdker et al., 2024]



Shock profile and space-energy histogram in the lab frame (left) and the shock rest frame (right).



Shock profile and space-energy histogram in the lab frame (left) and the shock rest frame (right).

CRPropa 3.3: External Plugins

Several external plugins have been developed to extend CRPropa's capabilities, among them

- **Extreme electromagnetic cascades**[2]: Treats the production of heavy leptons or hadrons from leptonic processes [Di Marco et al., 2026].
- **Interface with PYTHIA**[3]: This additional plugin interfaces with the PYTHIA event generator [Bierlich et al., 2022] for the treatment of decays [Di Marco et al., 2026].
- **Hadronic interactions**[4]: The plugin presented in [Dörner et al., 2025] implements the interaction of CR protons with protons from the ambient gas.

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[2] Muon, electron-muon, tauon and charged pion pair productions.

[3] `https://github.com/GDMarco/CRPYTHIAxDecays`

[4] `https://gitlab.ruhr-uni-bochum.de/doernjkj/hadronic-interaction-in-crpropa`

CRPropa 3.3: External Plugins

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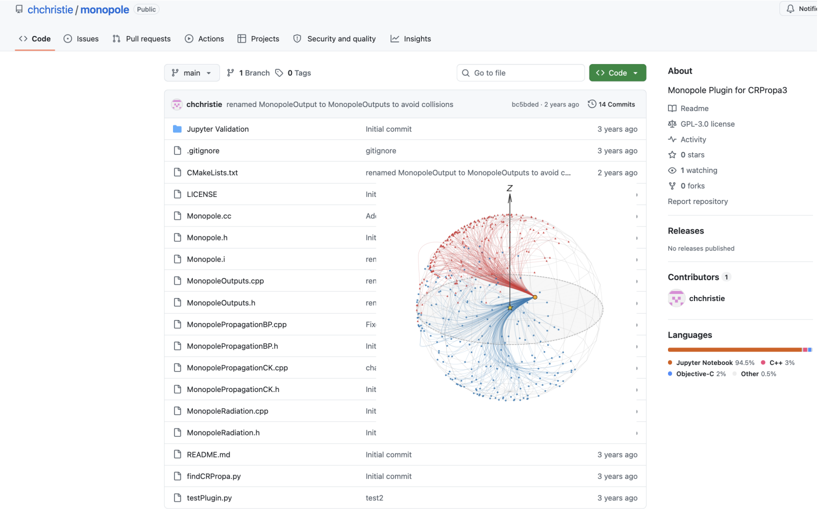
- **Magnetic monopoles**[5]: A plugin developed specifically for particles with magnetic charge, see [AL-Zetoun et al., 2026] for a recent application
- **Lorentz invariance violation**[6]: Treatment of Lorentz invariance violation effects in quantum electrodynamics, following [Saveliev and Alves Batista, 2024]

[5] `https://github.com/chchristie/monopole`

[6] `https://github.com/rafaelab/LIVpropa`

CRPropa 3.3: External Plugins



CRPropa 3.3: External Plugins

rafaelab / **LIVpropa** Public

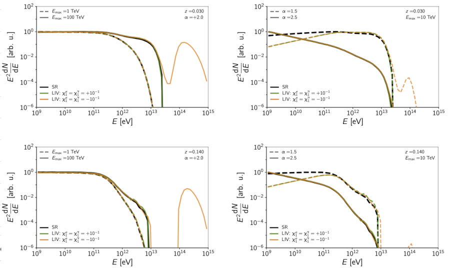
Notifications · Fork 1

Code · Issues · Pull requests · Actions · Projects · Security and quality · Insights

main · 1 Branch · 2 Tags · Go to file · Code

rafaelab new helper function to create kinematics-type object · 4907e28 · 10 months ago · 240 Commits

cmake	add CRPropa finder for CMake	2 years ago
data	keep data folder, even if empty	3 years ago
examples		
external		
helper		
include		
python		
src		
.editorconfig		
.gitignore		
CMakeLists.txt		
LICENSE		
README.md		



About

CRPropa plugin for treating Lorentz invariance violation

Readme

GPL-3.0 license

Activity

32.8%

Python 8.1%

Make 3.7%

README · GPL-3.0 lic

LIVpropa

This is a plugin for the CRPropa code. It enables simulations including Lorentz invariance violation (LIV).

For now, only the following (QED) processes are considered:

- Breit-Wheeler pair production
- inverse Compton scattering
- photon decay
- vacuum Cherenkov Other processes will be added later.

Summary and Outlook

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Summary and Outlook

- We presented CRPropa 3.3, the upcoming major update to the CRPropa framework for high-energy astroparticle simulations
- This release marks a significant step toward a unified, flexible, and extensible platform for multi-messenger astrophysics across a vast energy range – from GeV to ZeV
- The new features, which range from time-dependent advection and position-dependent photon fields to the inclusion of heavy nuclei up to lead, allow for more realistic simulations in various astrophysical environments

- Want to try it out?

https://github.com/CRPropa/CRPropa3/releases/latest

- Want to ask a question/report an issue?

Open an ticket at https://github.com/CRPropa/CRPropa3/issues

- Want to stay up to date?

Subscribe to our mailing list by sending a mail with subject SUBSCRIBE CRPROPA-USER to sympa@desy.de from the e-mail-address you wish to subscribe

- Want to meet the people behind CRPropa?

Join the CRPropa Workhop in 2027 (location to br confirmed...)

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