Status of CRPropa: A Monte Carlo Code for Propagating High Energy Cosmic Particles

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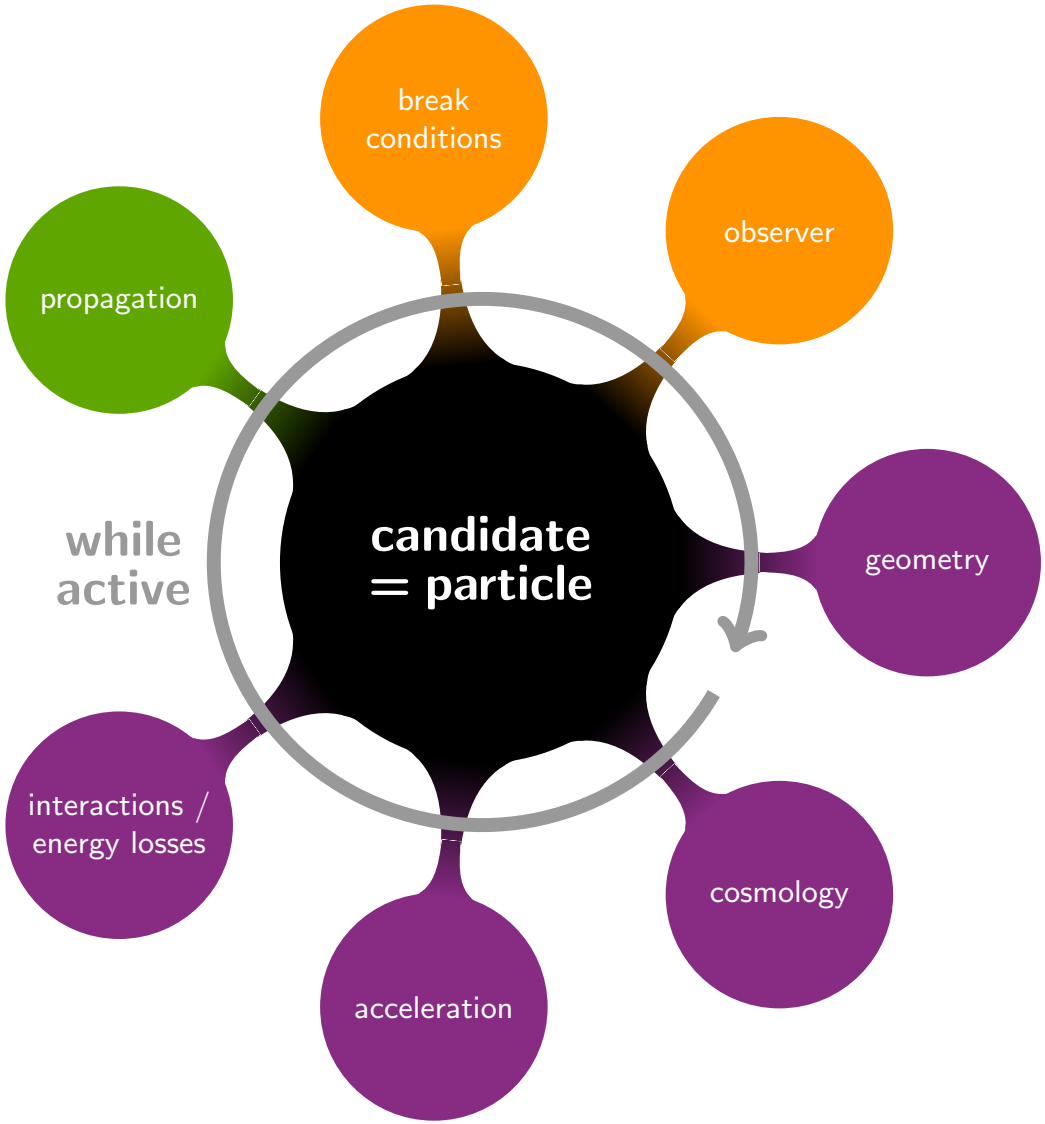
- development on Github: https://github.com/CRPropa/CRPropa3

CRPropa



Sketch by R. Alves Batista

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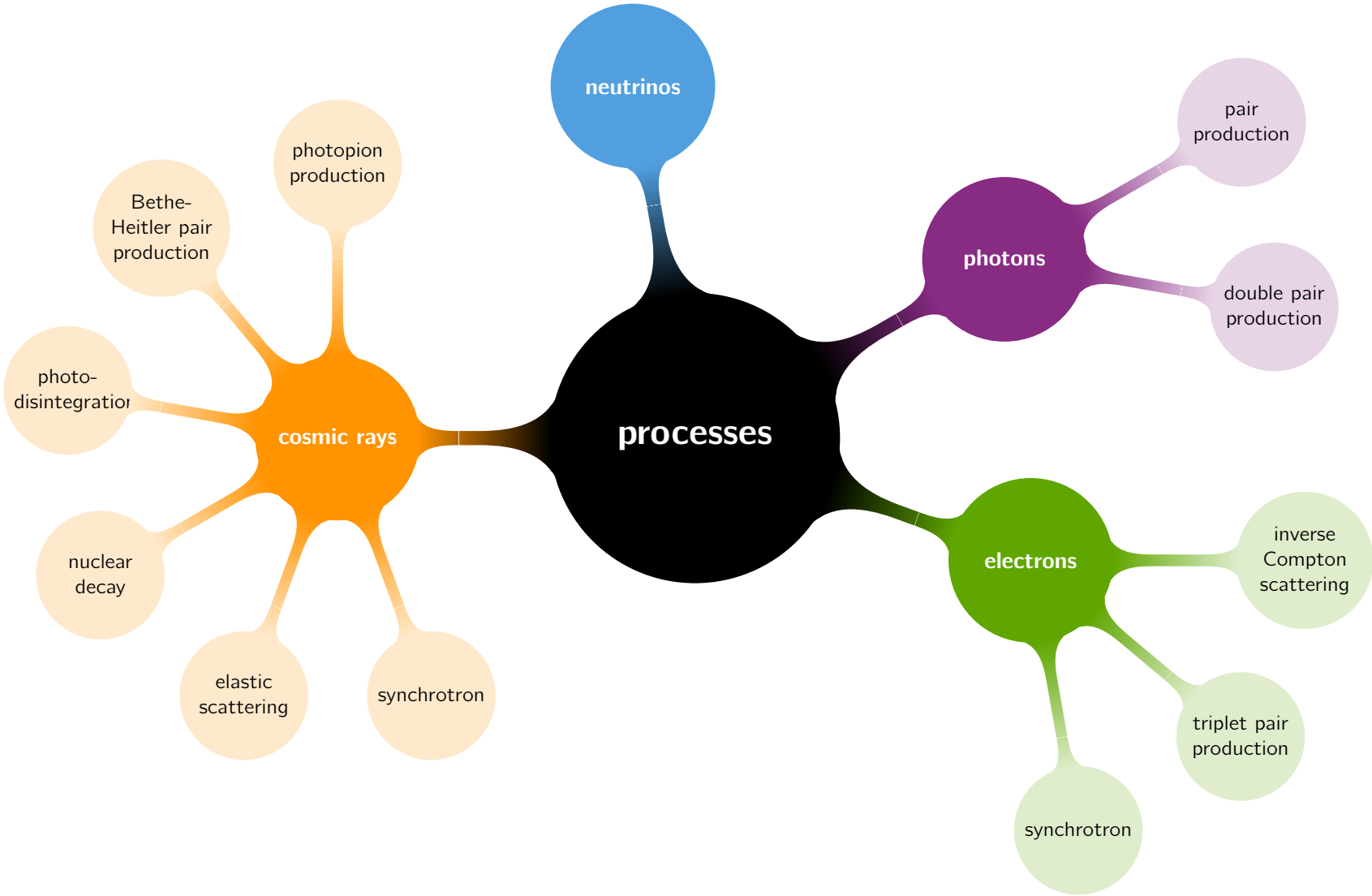

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CRPropa – Some History

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]
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- 2026: Hamburg (GER) May 5th - May 7th
  $\rightarrow$ Join under https://indico.desy.de/event/52740/

CRPropa Workshop 2026

May 5 – 7, 2026
Universität Hamburg
Europe/Berlin timezone

Enter your search term

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Welcome page

The interpretation of modern multi-messenger observations relies heavily on our understanding of how particles travel through the Universe. As current observatories provide increasingly precise measurements of cosmic rays, high-energy gamma rays, and neutrinos, an accurate theoretical modeling of their propagation becomes essential. To bridge the gap between astrophysical source models and the landscape of observational data, robust simulation tools are required to trace particle trajectories and interactions.

CRPropa 3.2 is a comprehensive, open-source simulation framework specifically designed for tracking the propagation of high-energy particles, ranging from GeV to ZeV energies. It enables the modeling of the transport of cosmic rays, electromagnetic particles, and neutrinos across both galactic and extragalactic environments. The simulation framework accounts for several physical processes, such as interactions with cosmic background radiation fields, secondary particle production, and particle deflections in cosmic magnetic fields.

The annual CRPropa meetings, organised since 2017, serve as a platform to connect CRPropa developers and their community of users, alongside researchers working in astroparticle transport. The goal of this workshop is to bring together these communities to present and discuss recent developments of the software, ongoing theoretical and computational challenges, and promote collaborations among groups working on particle transport in astrophysical sources and over cosmological scales.

In 2026, the CRPropa Workshop will be organized by the Universität Hamburg, Germany, from May 5th to 7th. This workshop is organized as an in-person only event. The scientific program will include a series of contributed and invited talks, as well as status reports on the CRPropa development. Additionally, plenty of time will be dedicated to the developers' meeting, informal discussions, and collaborative work.

The deadline for **abstract submission** is **April 13, 2026.**

The deadline for **registration** is **April 20, 2026**.

Universität Hamburg
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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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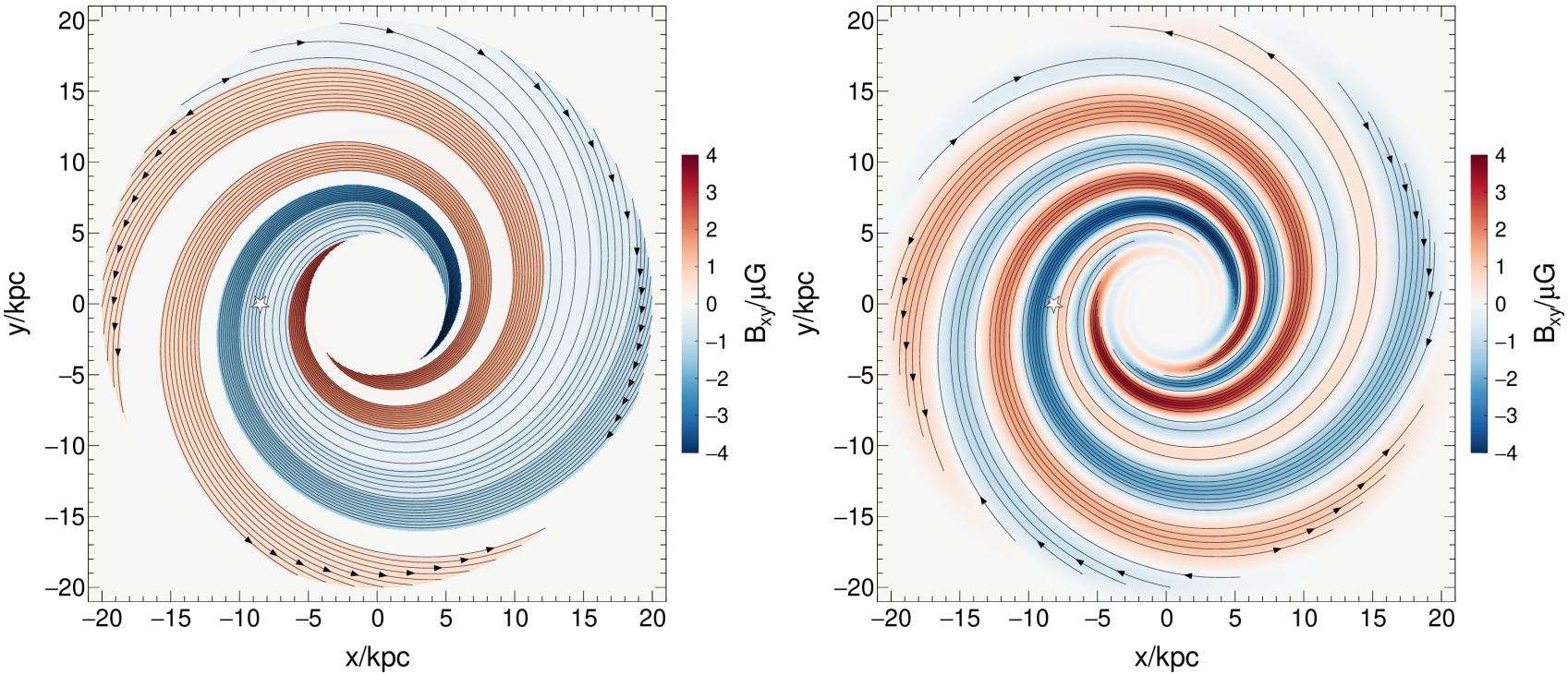
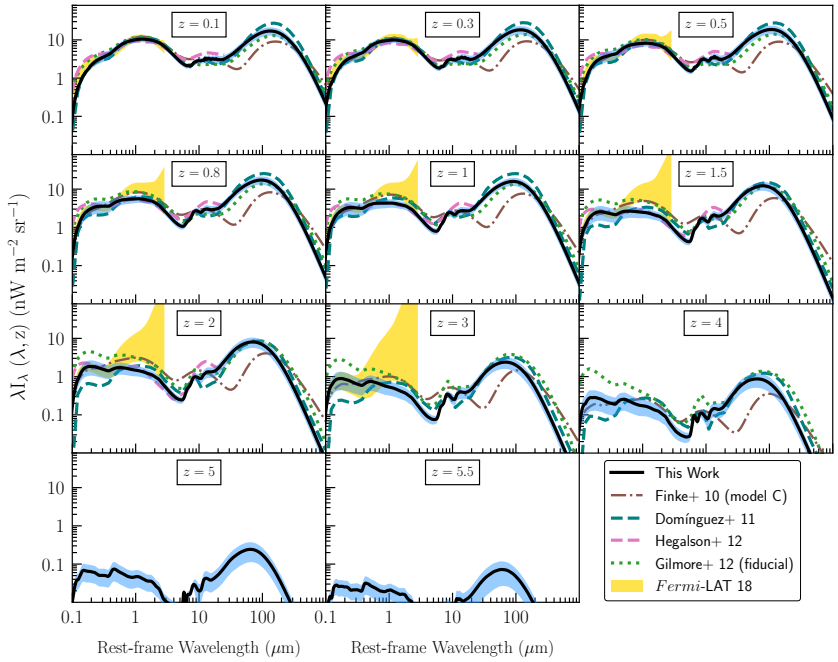
- 2026 – v3.3 [Aerdker et al., 2025], stay tuned!

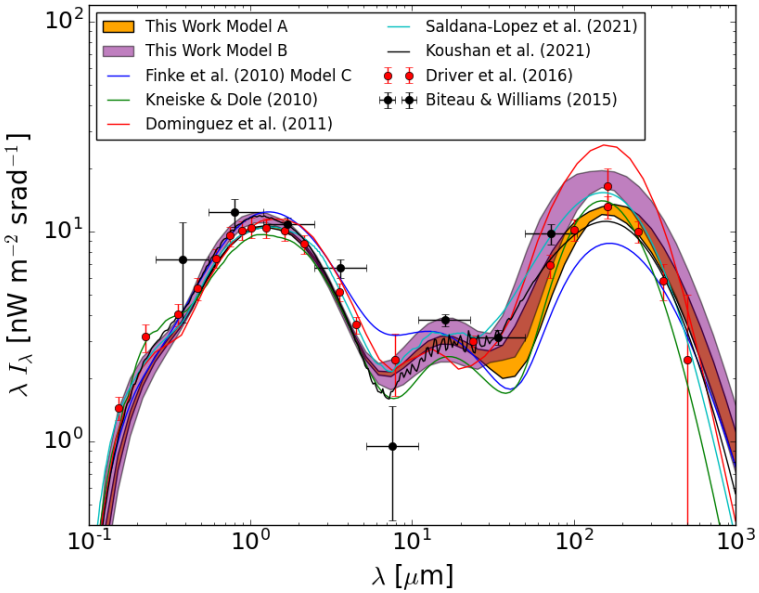
CRPropa 3.3: New Galactic Magnetic Field Model UF24



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)

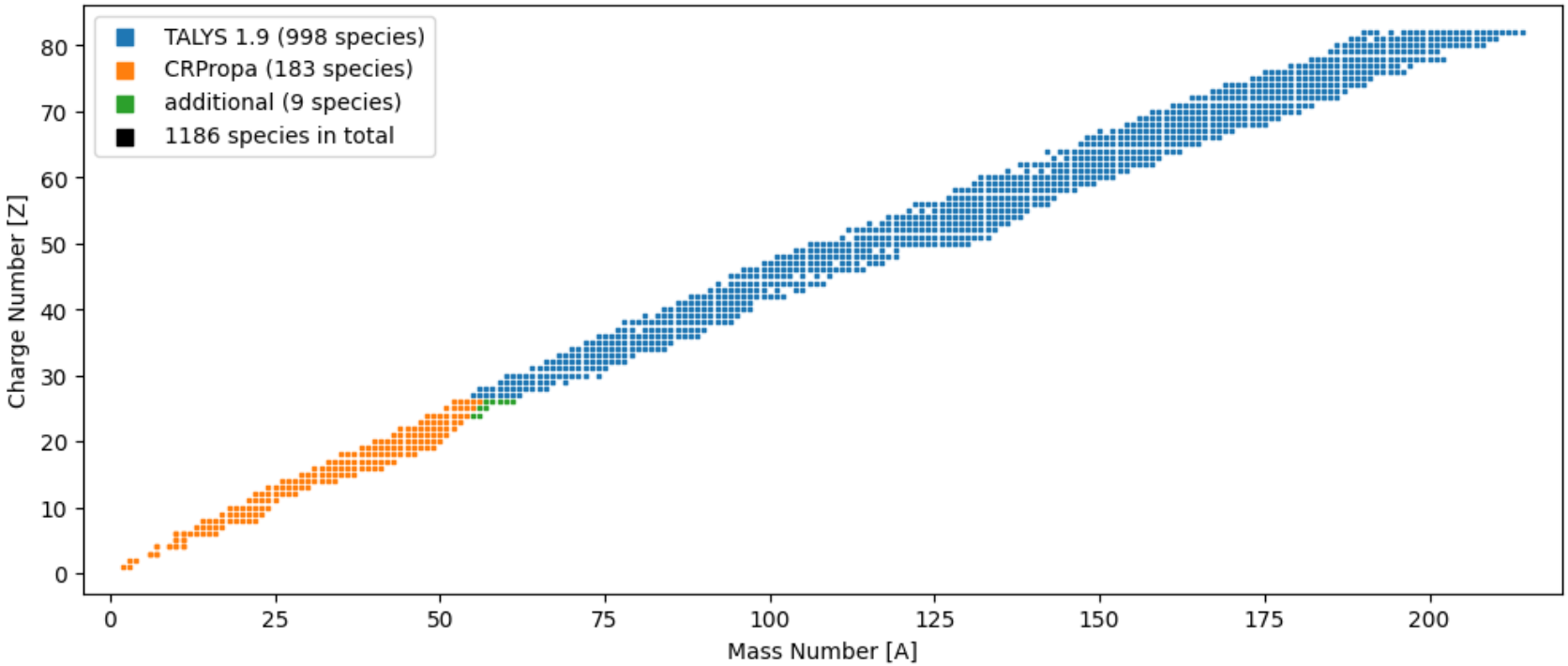
CRPropa 3.3: New EBL Models





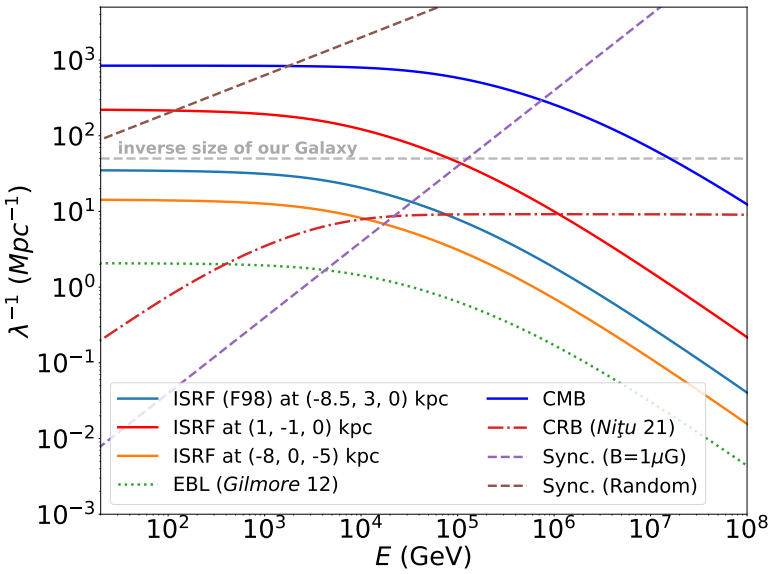
New EBL models included as IRB_Saldana [Saldana-Lopez et al., 2021] and IRB_Finke22 [Finke et al., 2022].

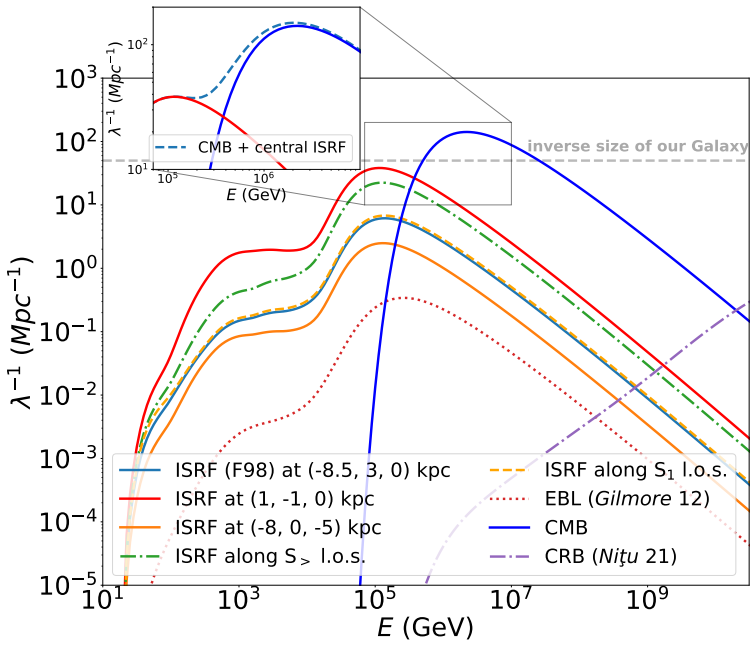
CRPropa 3.3: Inclusion of Nuclei up to Lead



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.

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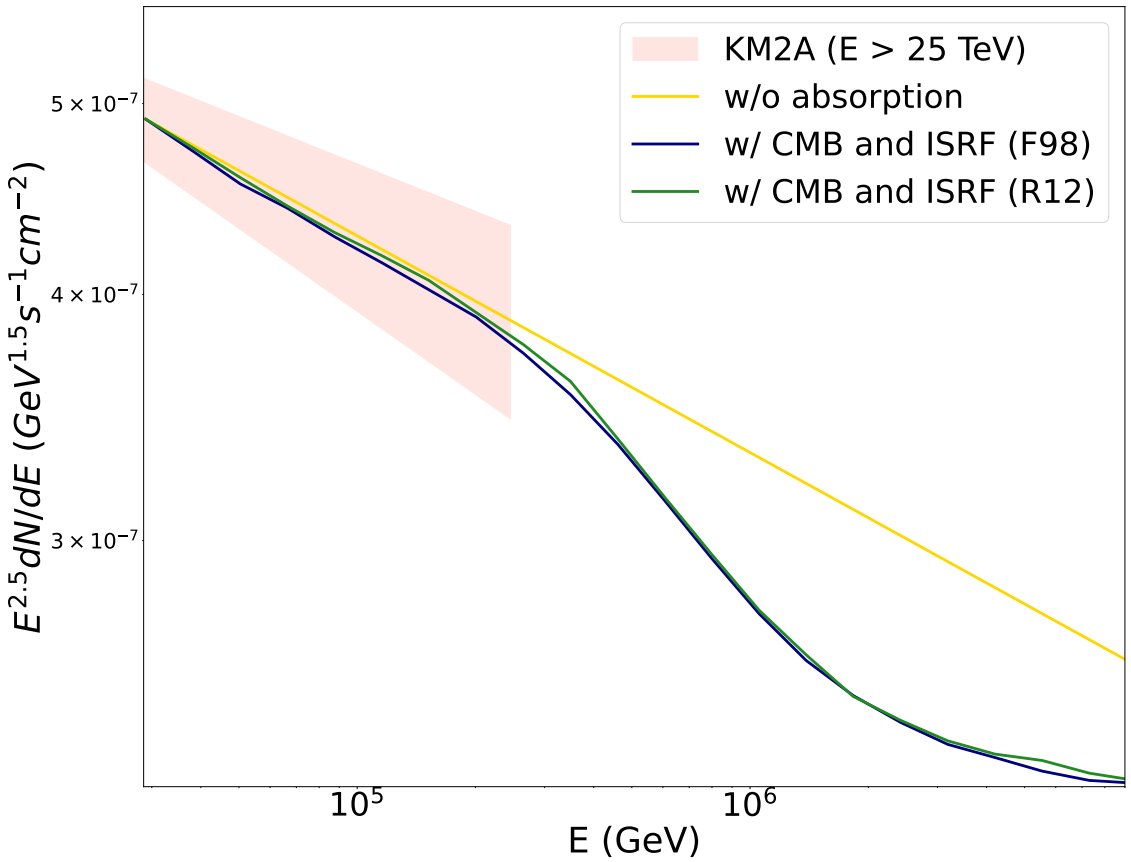

This then may be used to model particle propagation, e.g. for 1LHAASOJ1825-1256u [Aerdker et al., 2025].

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]

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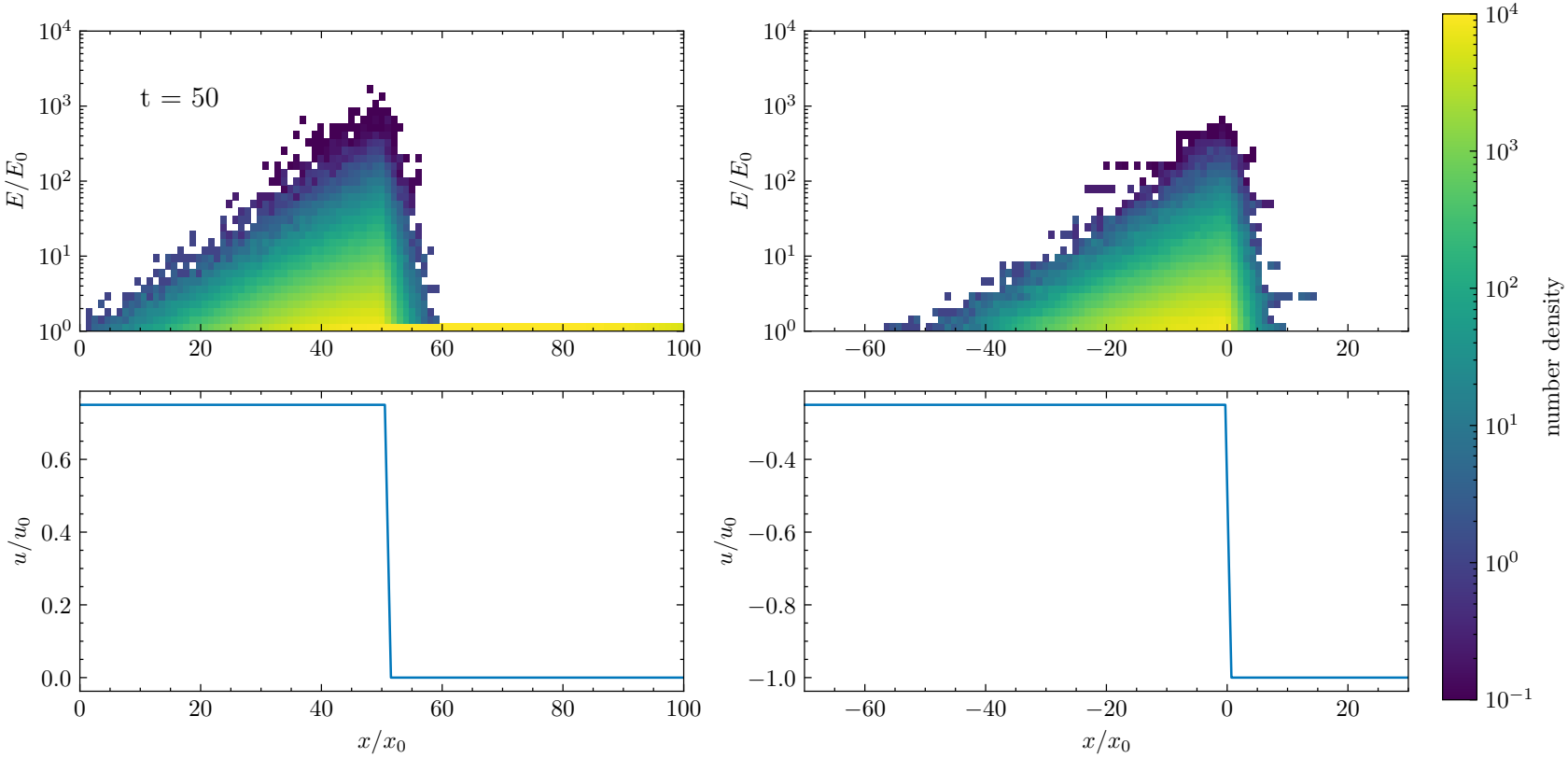

Shock profile and space-energy histogram in the lab frame (left) and the shock rest frame (right).

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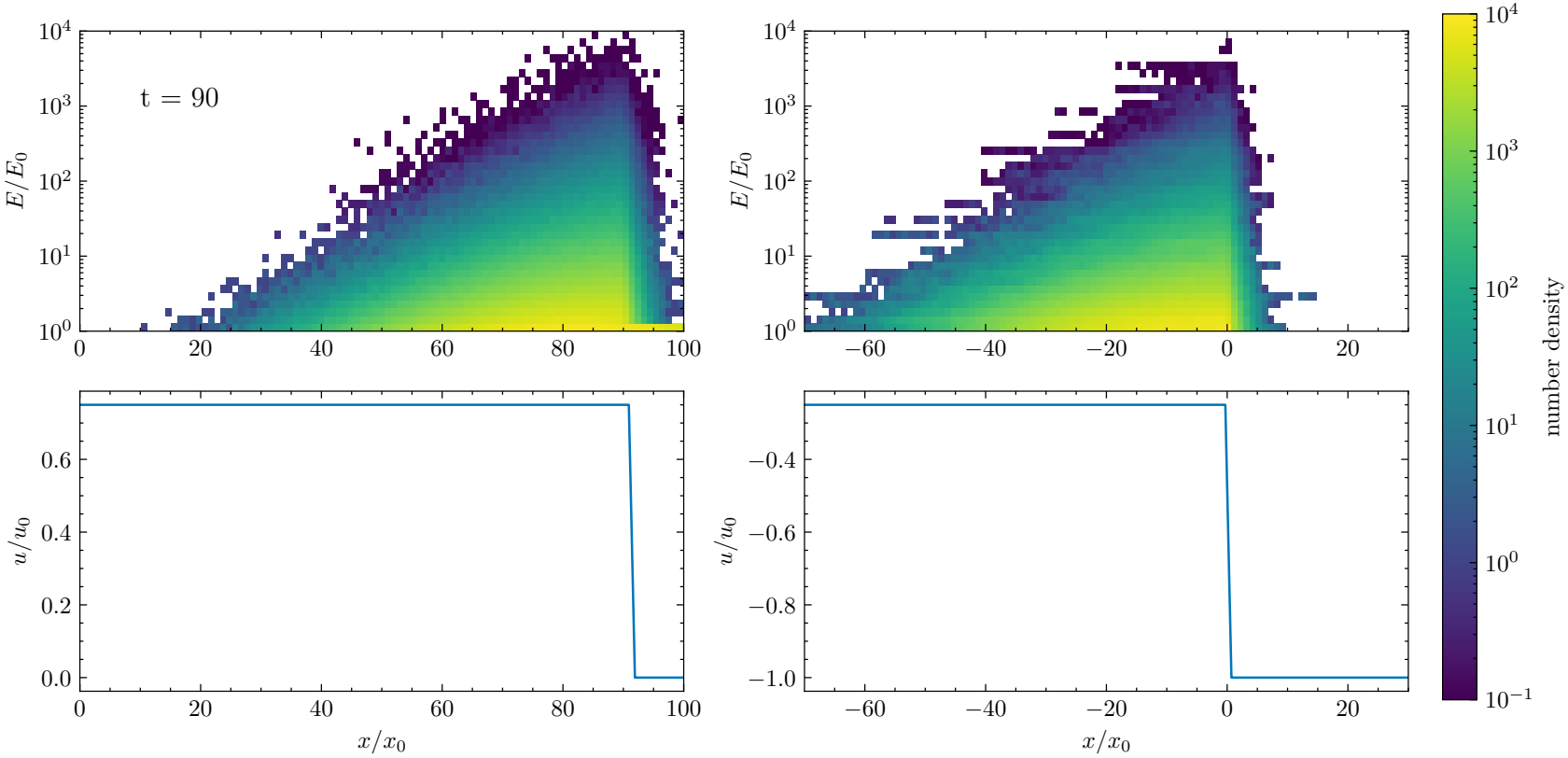

Shock profile and space-energy histogram in the lab frame (left) and the shock rest frame (right).

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].

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

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

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- **Hadronic interactions**[4]: The plugin presented in [Dörner et al., 2025] implements the interaction of CR protons with protons from the ambient gas.
- **Lorentz invariance violation**[5]: Treatment of Lorentz invariance violation effects in quantum electrodynamics, following [Saveliev and Alves Batista, 2024].

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

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

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- 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
- Stay tuned for the upcoming release!

CRPropa

- 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 Hamburg (May 5th to May 7th, 2026): https://indico.desy.de/event/52740/

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