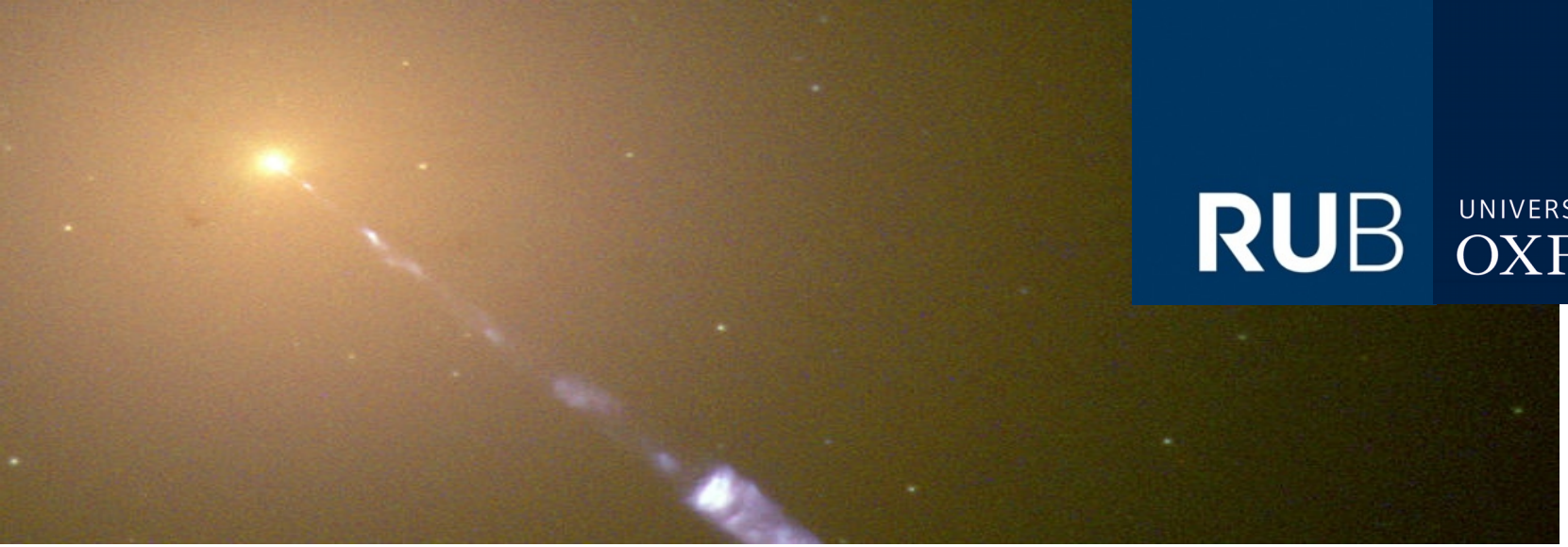

Ruhr-Universität Bochum / University of Oxford

Local Source Simulations in CRPropa - Status & Applications

CRPropa Meeting - Zeuthen, 30th Sept. 2019

Mario Hörbe
Theoretical Physics IV, Bochum (Prof. Julia Tjus)
Dept. of Physics, Oxford (Prof. Garret Cotter)

Studienstiftung des deutschen Volkes

Outline

1 - Science Case

2 - Extensions to CRPropa

3 - Applications & Examples

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1 - Science case

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Science case

CRPropa provides customizable...

- source properties

- propagation parameters

- observer properties

Suitable for:

(extra)galactic CR propagation

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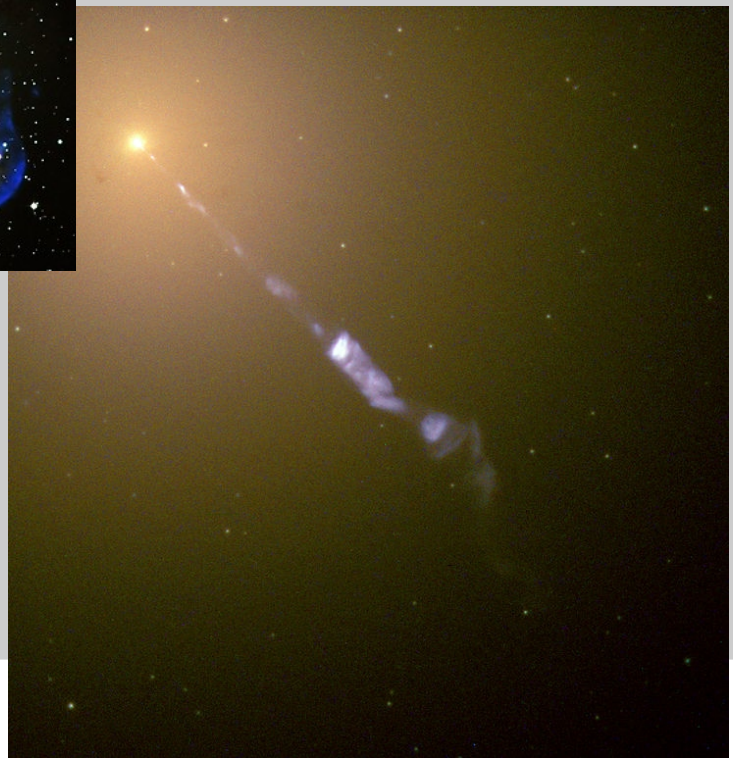
Science case

However, not for:

Accretion discs



Jets

<u>For my research,</u>
<u>I need exactly this:</u>

- **CRPropa-like features**
- **inside sources (i.e. local)**
- **spacial & temporal resolution**

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Science case

Is getting CRPropa to local scale feasible?

→ yes, if one can:

(i) extend it by local features

(ii) guarantee modules' functionalities

(iii) preserve user concept

What's missing?

→ local features:

(i) matter distributions

(ii) space- & time dependence

(iii) new photon fields

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2 – Extensions to CRPropa

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2 – Matter Distributions

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Extensions - Matter Fields

Implemented by Julia Ebeling at

https://github.com/juliaebeling/CRPropa3/tree/Hadronic

→ proton-proton interactions with a background proton field

→ J. Ebeling: Galactic matter fields

→ Me: gridded matter fields

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2 – Space- & Time-Dependence

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Defeating isotropy in CRPropa

→ (1) = Make interactions dependent on space and time

→ (2) Any evolution in (x,y,z,t) or none

→ (3) Easily change in brick-like way

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Extensions - Space - & Time

Realisation:

→ ScalarGrid → in addition: **ScalarGrid4d**

→ relative up- & down-scaling of interactions (on top)

→ pass as argument to interaction modules:

- Module(photonField, …)
- Module(photonField, ScalarGrid, …)
- Module(photonField, ScalarGrid4d, ...)

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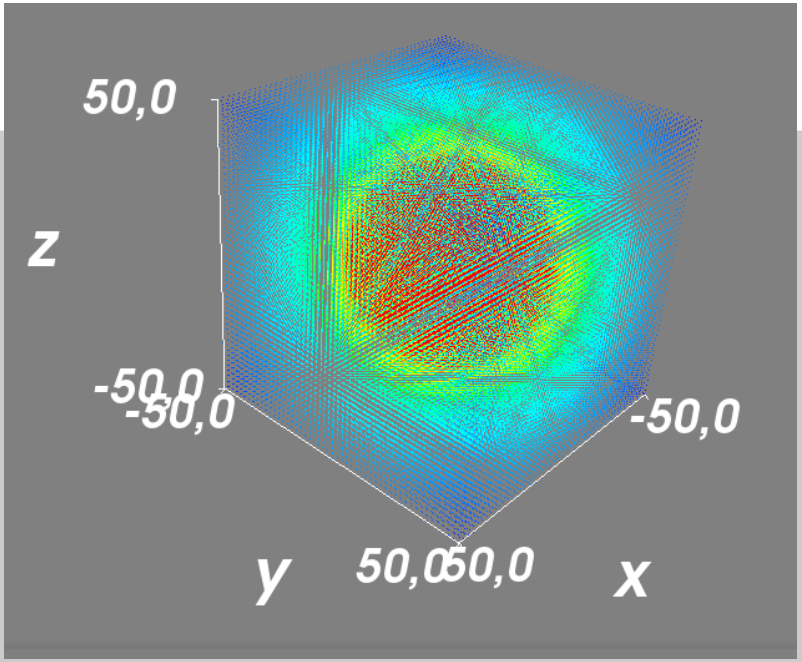
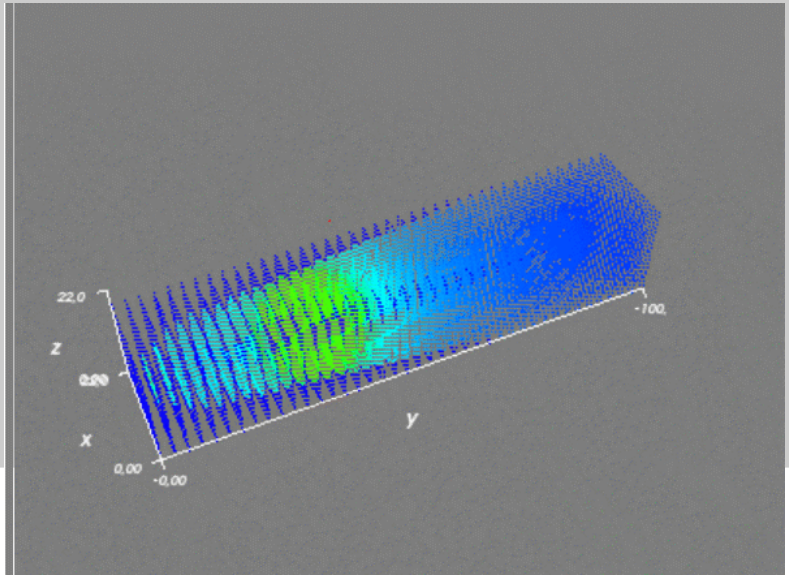
Extensions - Space - & Time

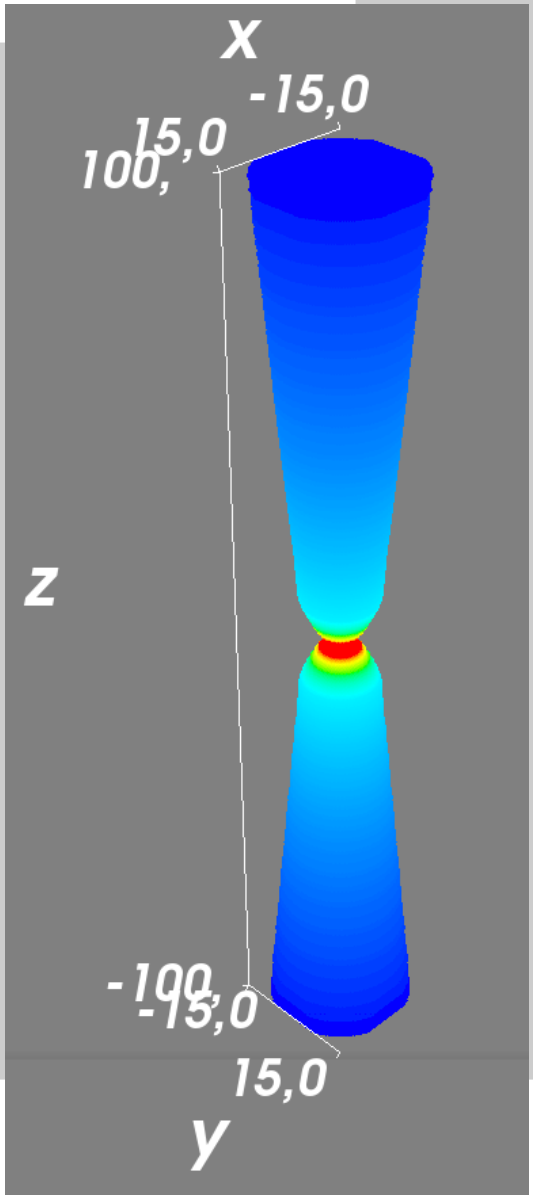
ScalarGrid4d



...uses file containing field scaling “s“ in space & time:

→ s(x, y, z, t)





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2 – Variable Photon Fields

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The photon field

→ must be chosen from a pre-set pool (CMB and 10 x IRB)

→ is hard-coded into most interaction modules

→ is isotropic in the entire simuation

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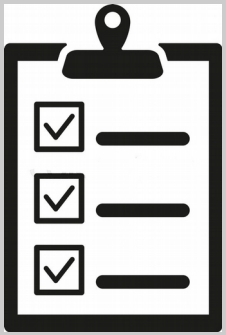
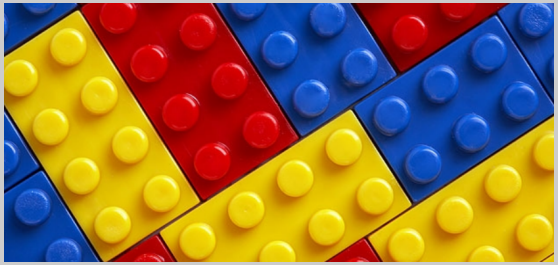
Extensions - Variable Photon Fields

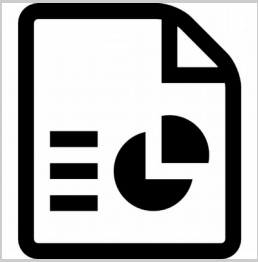
simulation.py



interaction modules



results.txt



~/share/shared_files

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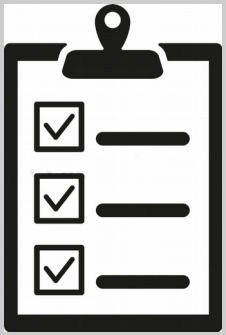
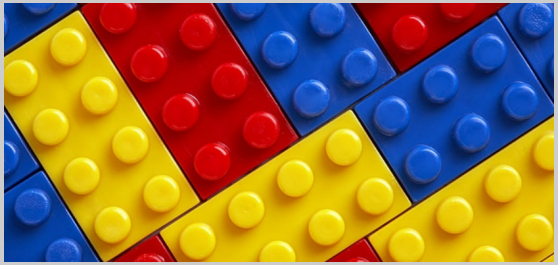
Extensions - Variable Photon Fields

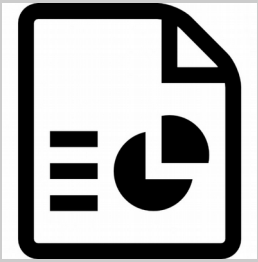
simulation.py

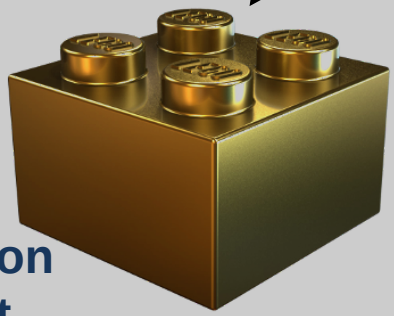


interaction modules



results.txt





dedicated photon field treatment

~/share/shared_files

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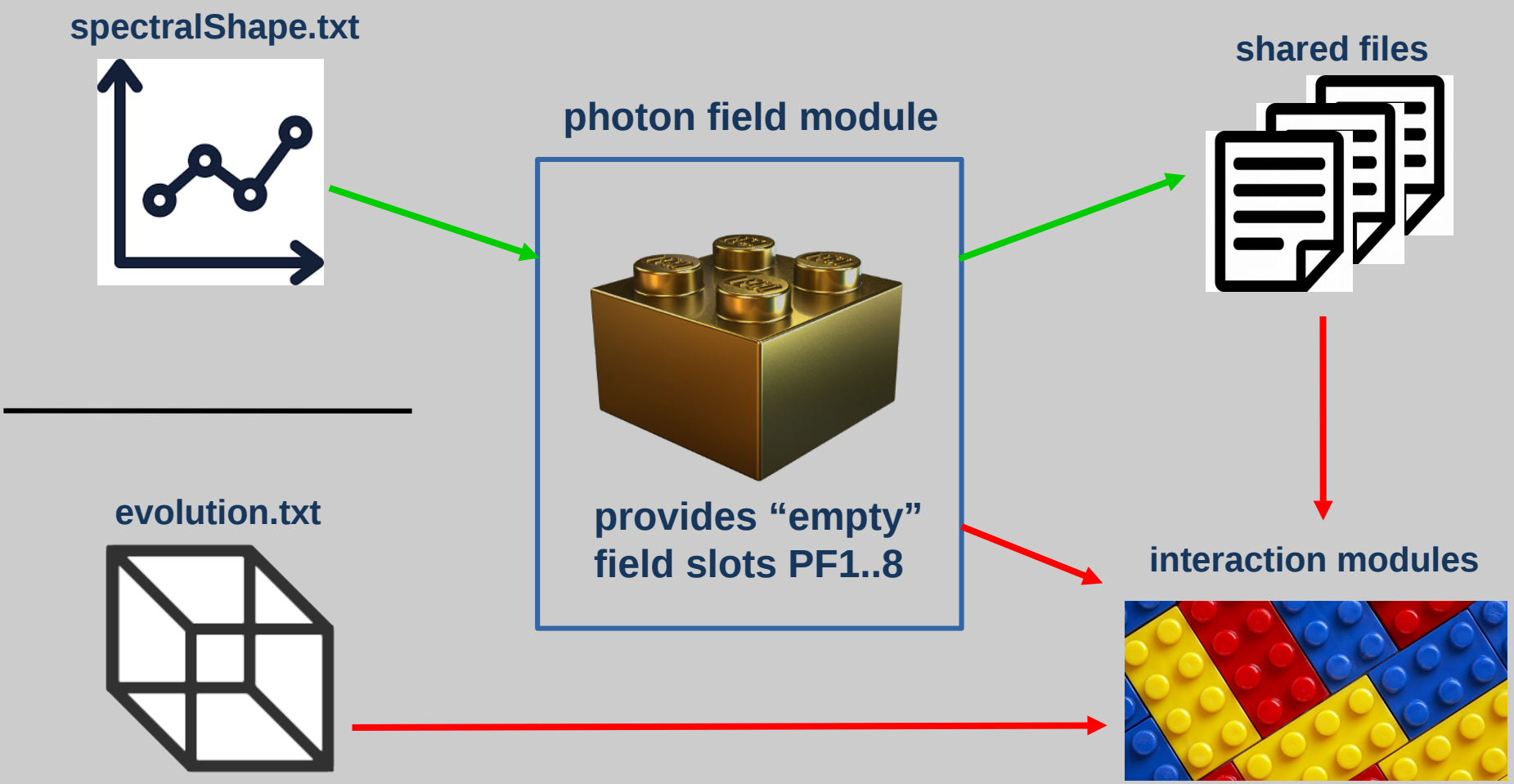
Extensions - Variable Photon Fields



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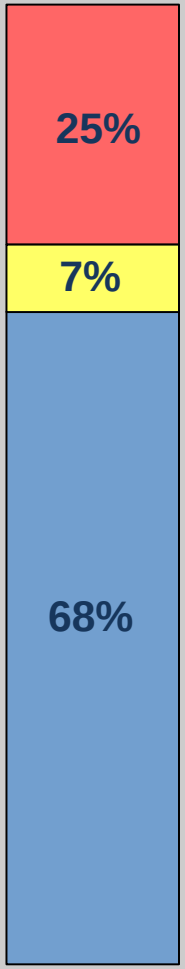
Extensions - Variable Photon Fields

SOPHIA

→ Simulation Of Photo-Hadronic Interactions in Astrophysics

→ hadron-photon interaction event generator

→ written in Fortran77, 17.167 lines of code



event generator

photon sampling

JETSET v7.4 by Torbjorn Sjostrand

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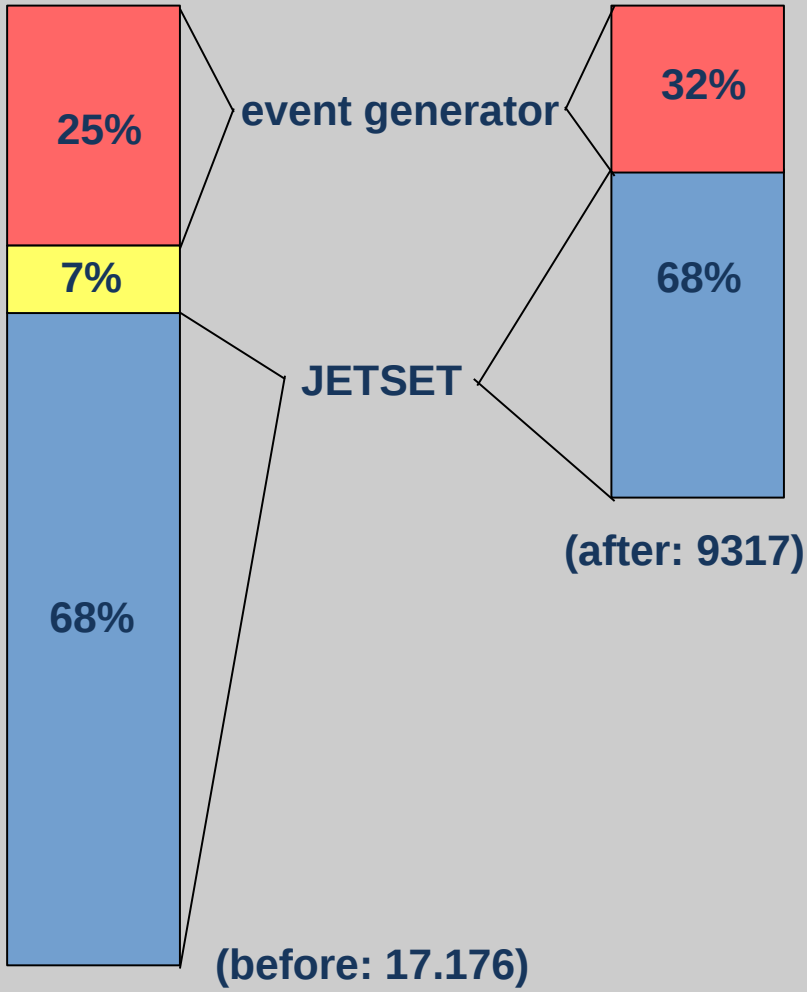
Extensions - Variable Photon Fields

What had to be done?

→ remove photon sampling from SOPHIA

→ implement public photon sampling

→ combine shared-files-generating scripts (CRPropa-data repository)



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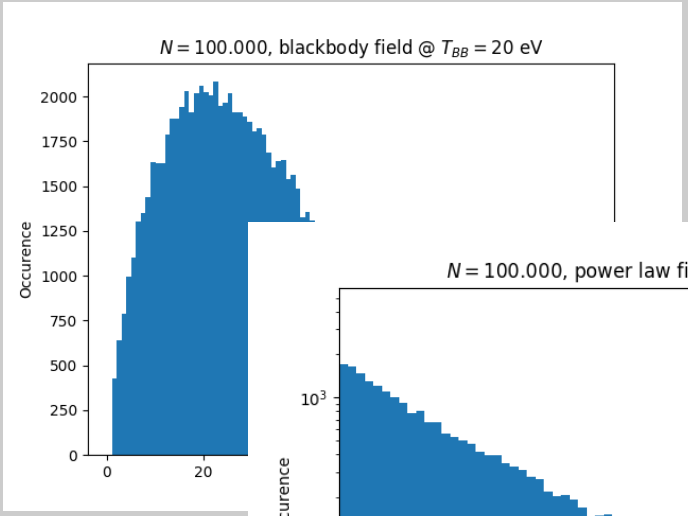
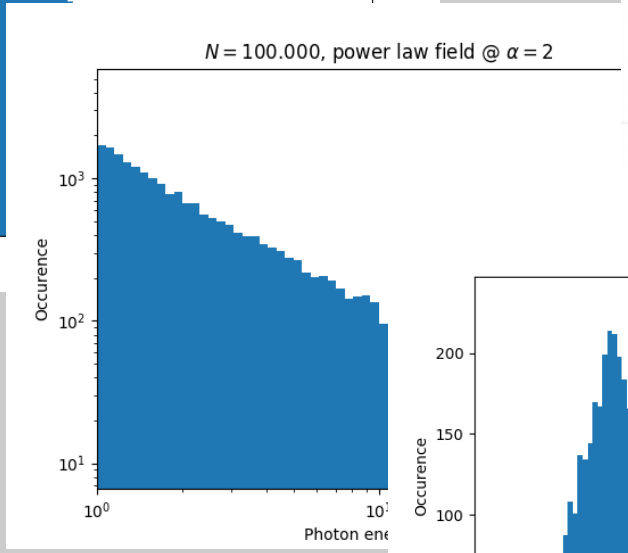
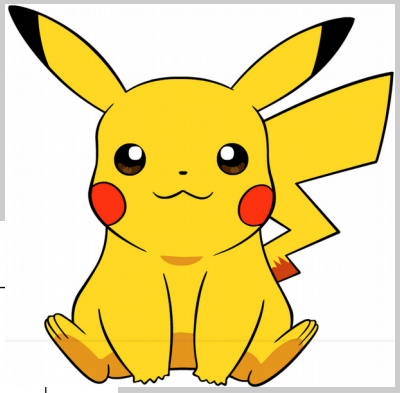
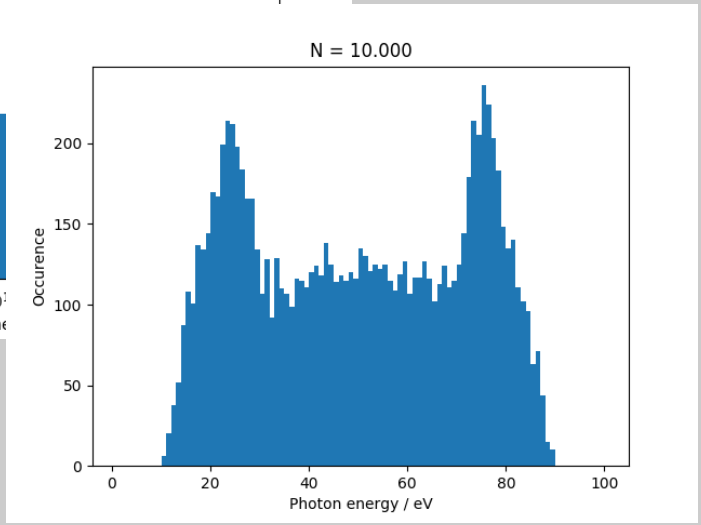
Extensions - Variable Photon Fields

spectral shape









file containing photon density i.d.o.

- energy
- redshift

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2 – Further extensions

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Extensions - Misc.

What else?

→ discretized SOPHIA → avoid runtime saturation beyond 8 CPUs in (Photo-Pion-Production, with variable photon fields)

→ introduced interaction tags (pass to modules)

```
14758   2.90730E-10          12  6.60413E-07 HI_1e15
14759   2.90730E-10          14  3.18360E-07 HI_1e15
14760   4.66442E-10         -14  1.23250E-05 PPP_bb10
14761   2.90730E-10          14  1.57284E-07 HI_1e15
14762   2.90730E-10          12  7.07919E-08 HI_1e15
14763   4.64836E-10         -14  1.81461E-05 PPP_bb10
14764   2.90730E-10          14  9.71875E-07 HI_1e15
14765   4.64836E-10         -12  1.86391E-05 PPP_bb10
14766   2.90730E-10          14  1.71535E-06 HI_1e15
14767   2.90730E-10          12  3.04718E-07 HI_1e15
14768   2.90730E-10          14  2.17046E-06 HI_1e15
```

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4 – Applications & Examples

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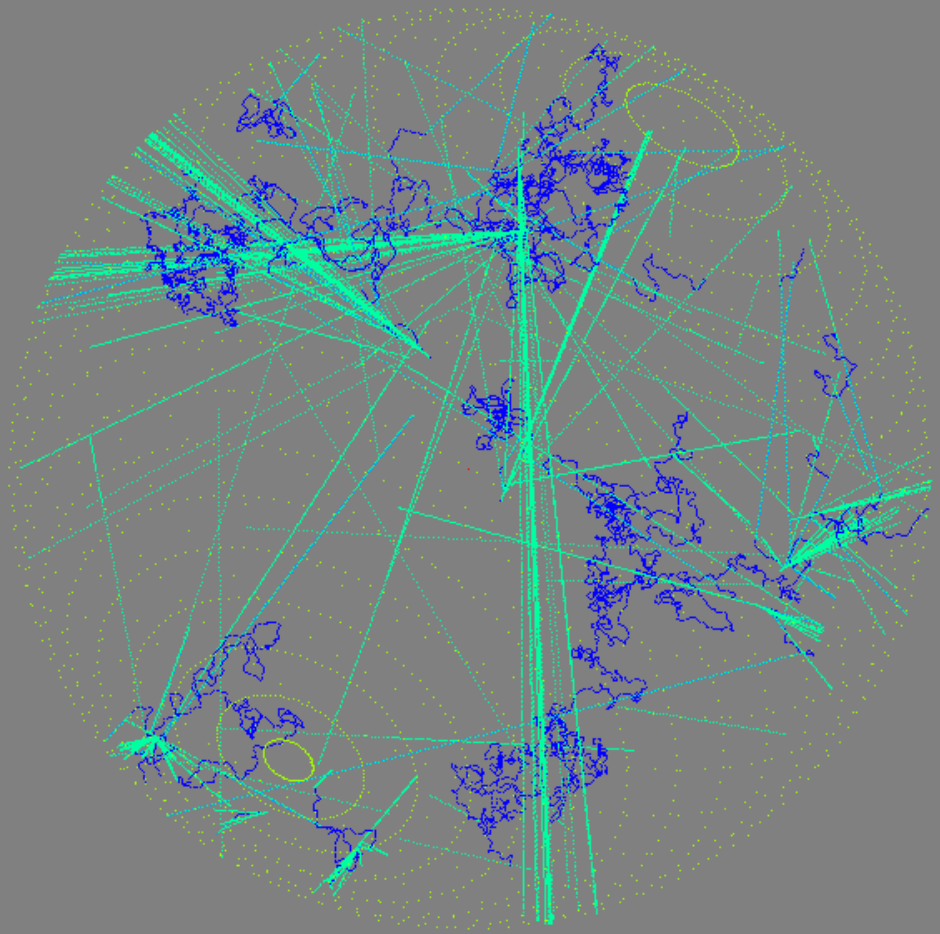
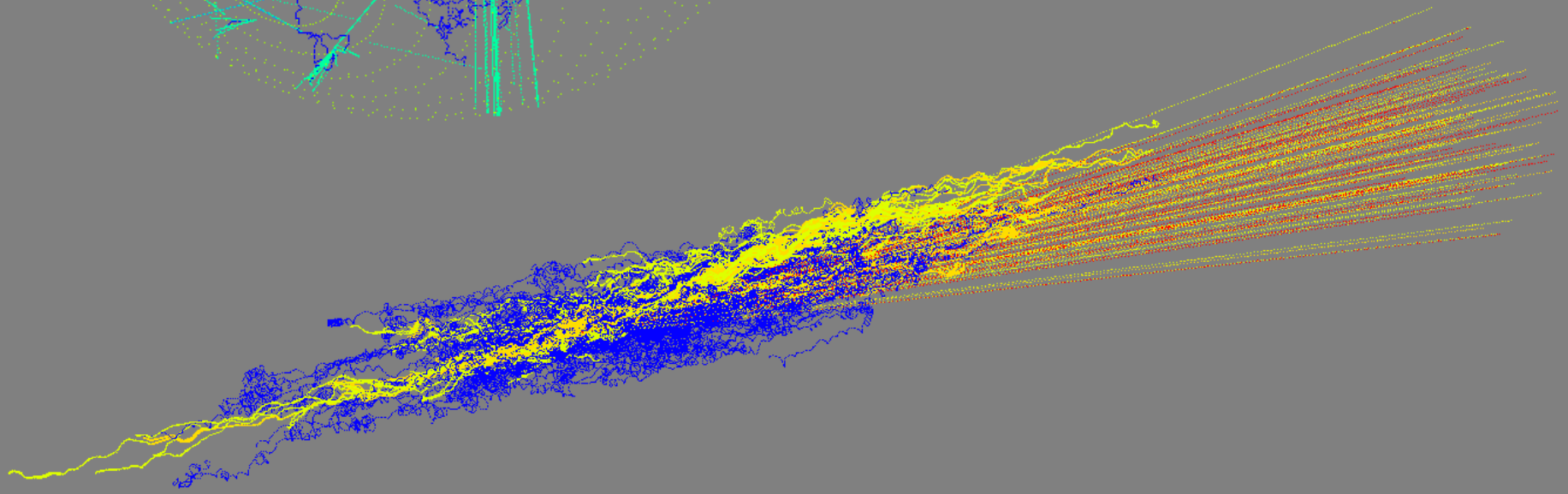


applications:

e.g. jet physics



Outlook

What’s next?

→ submit to main branch on GitHub (happy to talk later!)

→ focus on research

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Summary

Towards local source propagation:

→ we are basically there!
- customizable matter fields
- customizable photon fields
- space- & time dependence
- (discretized SOPHIA)
- interaction tags

→ review ongoing (special meet-up?)

→ increase applications / user base

Thank you!

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