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The CRPropa framework: an overview

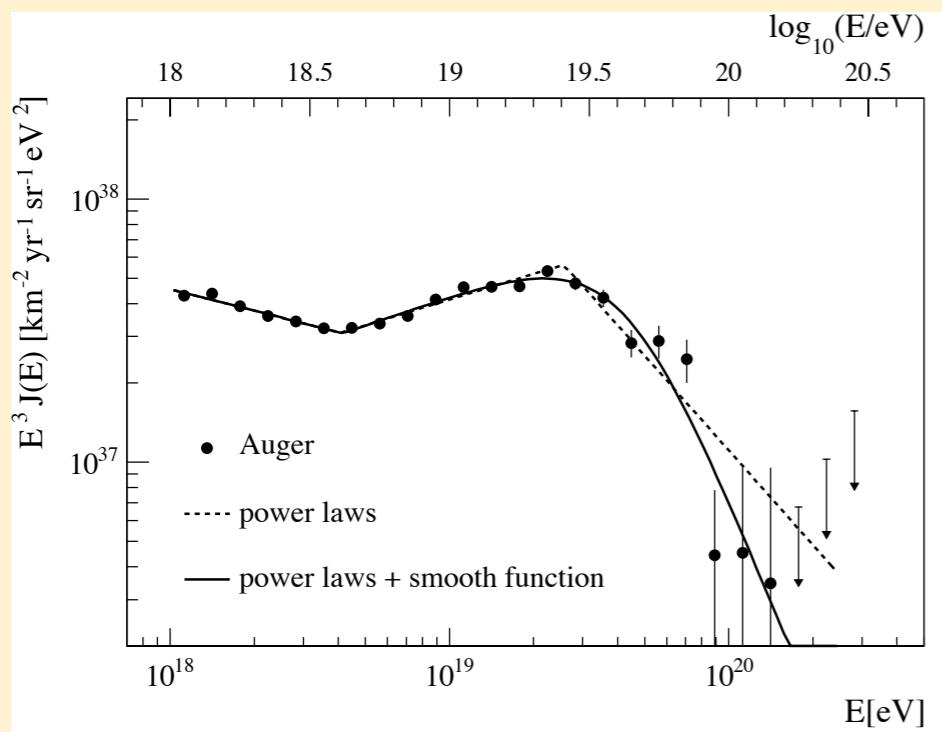
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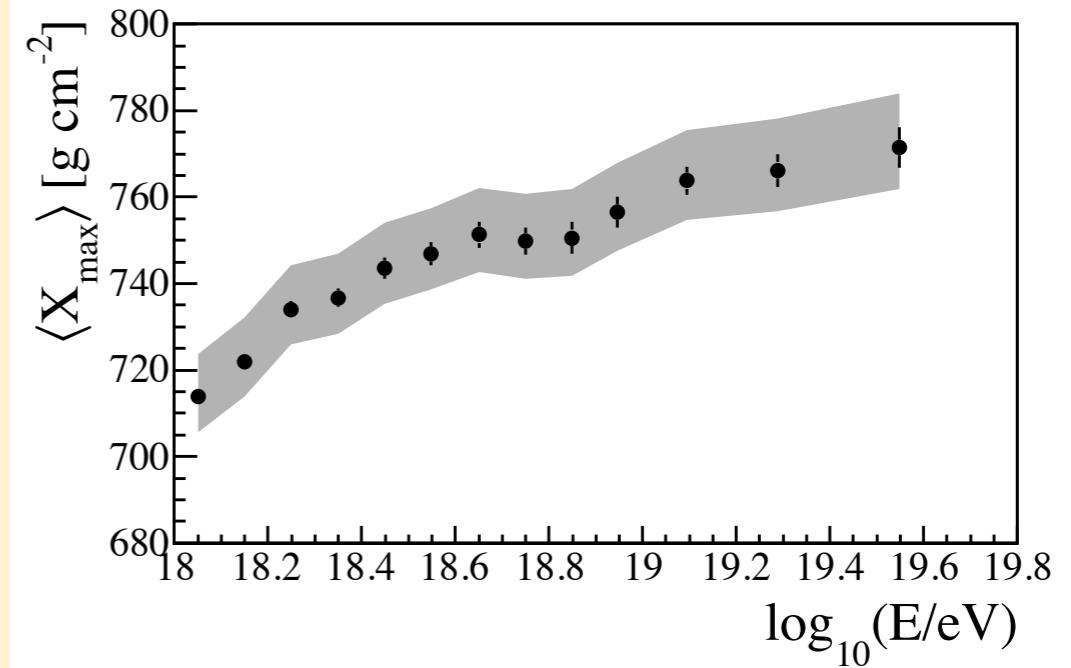
motivation

spectrum



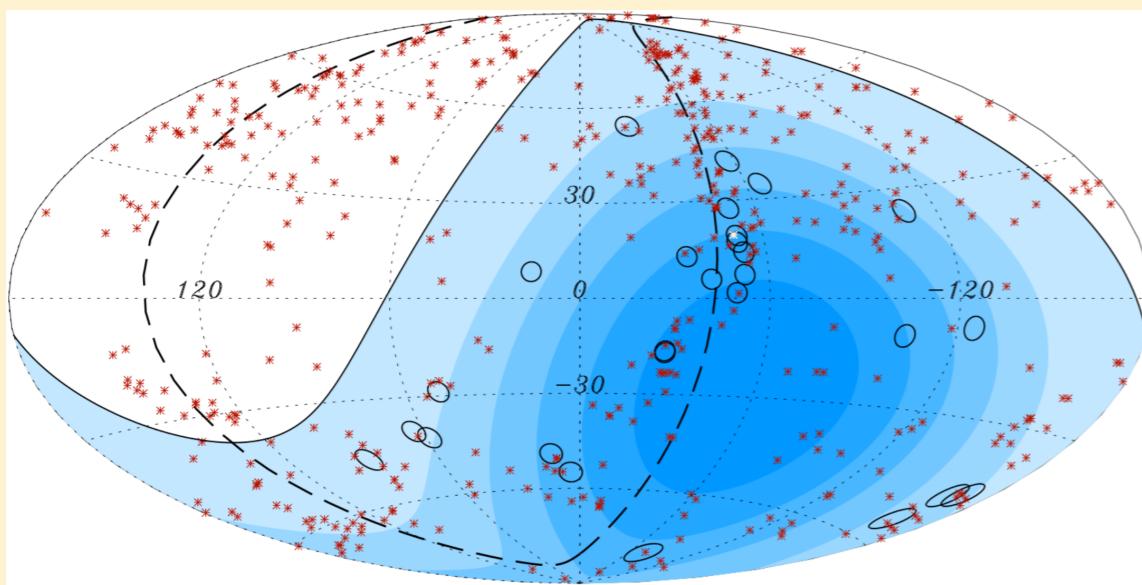
Pierre Auger Collaboration, ICRC 2011.

composition



Pierre Auger Collaboration, JCAP 02 (2013) 026.

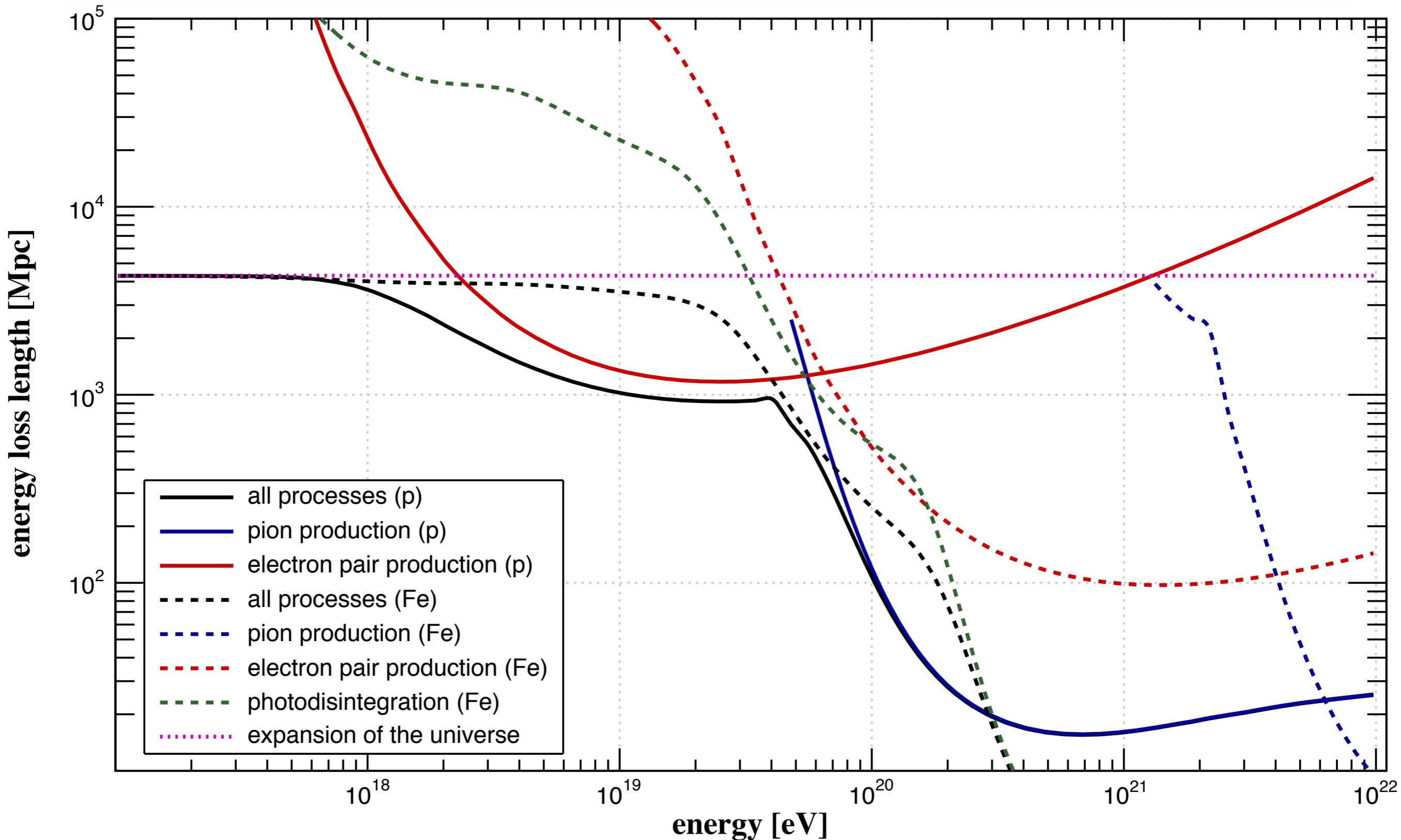
anisotropy



Pierre Auger Collaboration, Science 318 (2007) 938.

- ◆ explain these three observables
- ◆ magnetic fields and source distribution may affect spectrum and composition, and certainly affect anisotropy
- ◆ 3D simulations are needed
- ◆ large parameter space => fast simulations

energy loss processes



CRPropa

CRPropa 2.0

- ◆ available in: crpropa.desy.de
- ◆ “official” release
- ◆ paper: Kampert et al. Astropart. Phys. 42 (2013) 41

CRPropa 3.0

- ◆ available in: crpropa.desy.de/CRPropa3
- ◆ development version
- ◆ new features: modular structure, parallelization, cosmology in 3D, galactic lensing

33RD INTERNATIONAL COSMIC RAY CONFERENCE, RIO DE JANEIRO 2013
THE ASTROPARTICLE PHYSICS CONFERENCE

[arXiv:1307.2643](https://arxiv.org/abs/1307.2643)

ICRC
2013

CRPropa 3.0 – a Public Framework for Propagating UHE Cosmic Rays through Galactic and Extragalactic Space

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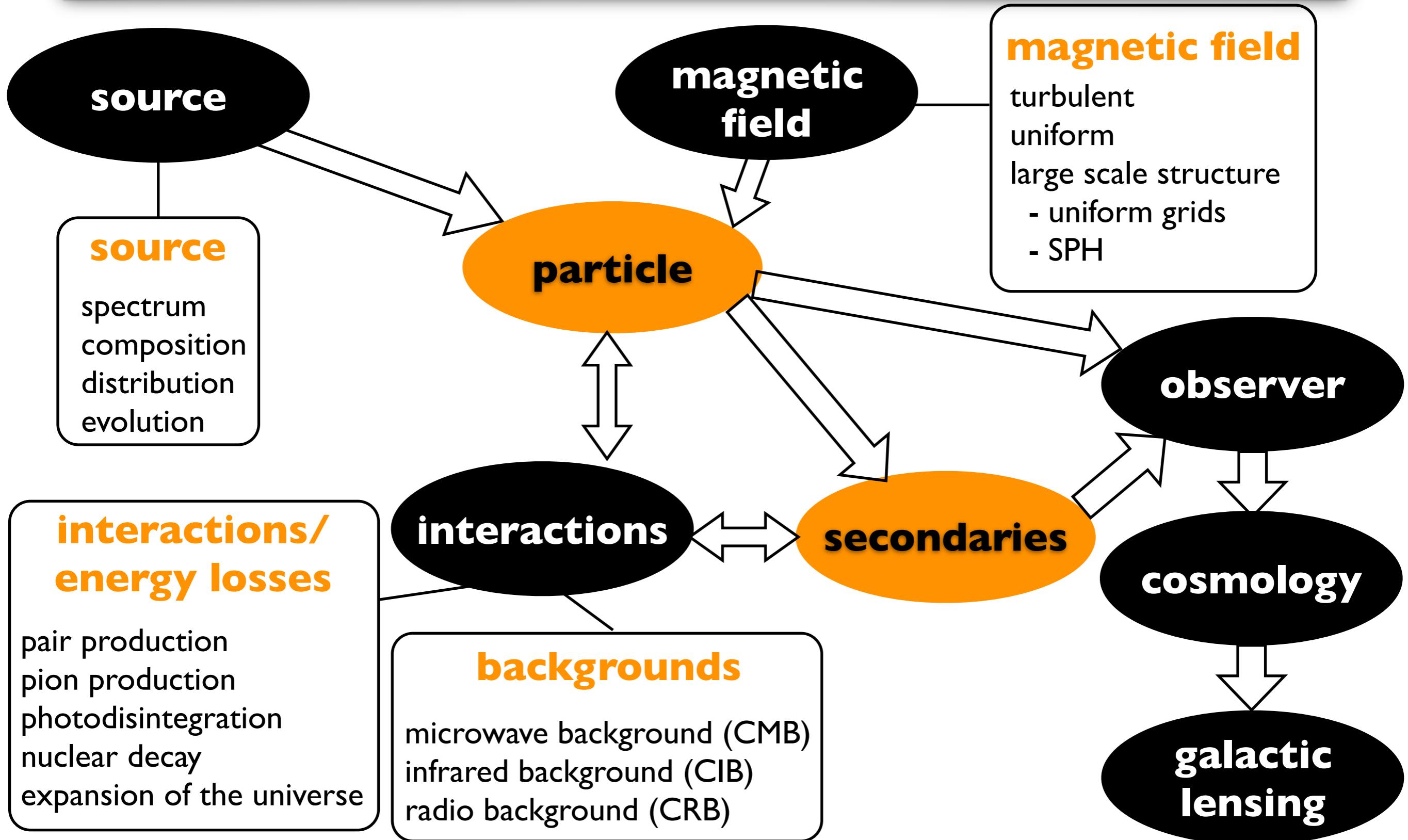
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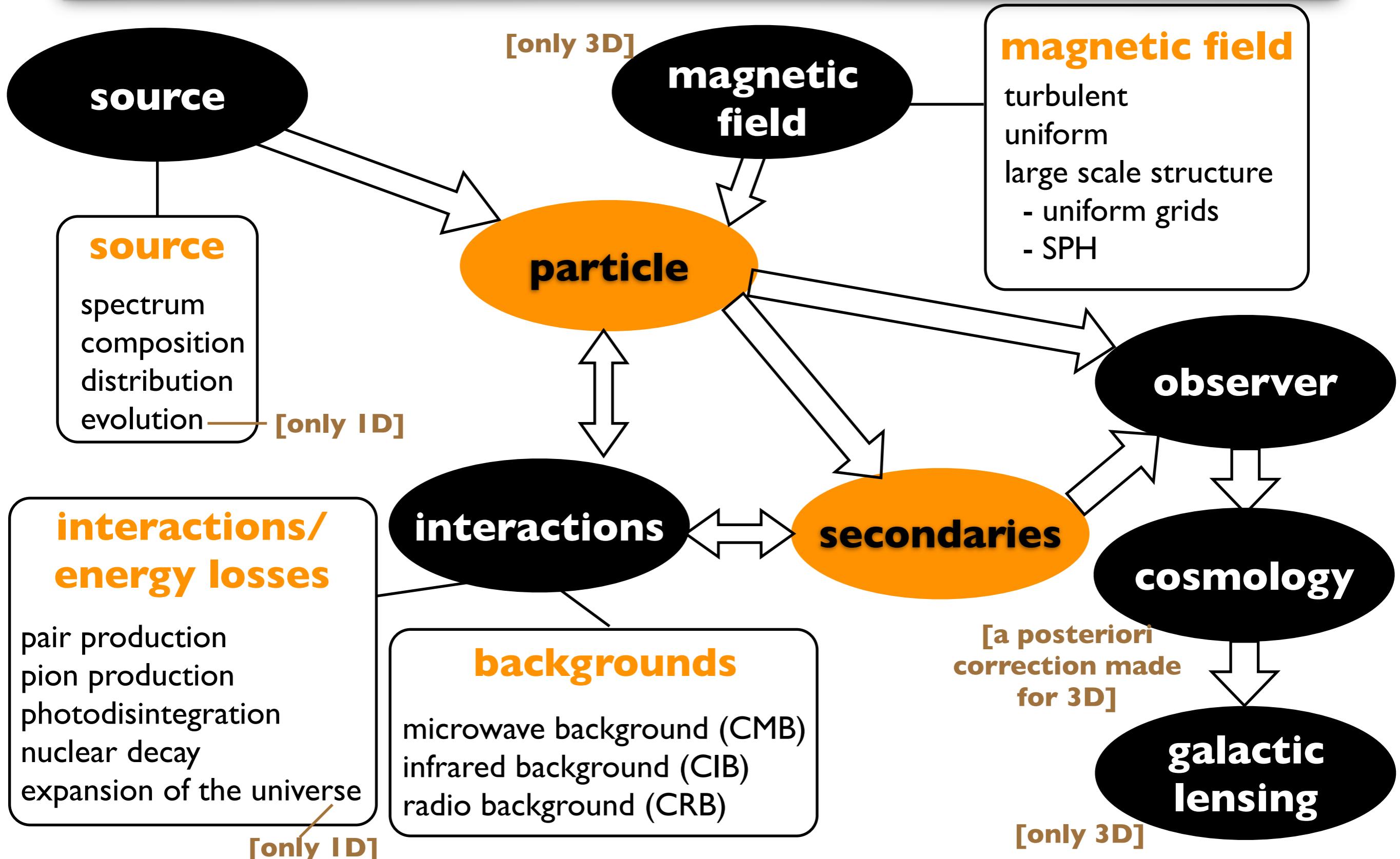
³ University of Wuppertal, Department of Physics, Gaußstr. 20, 42097 Wuppertal, Germany

crpropa@desy.de

how does it work

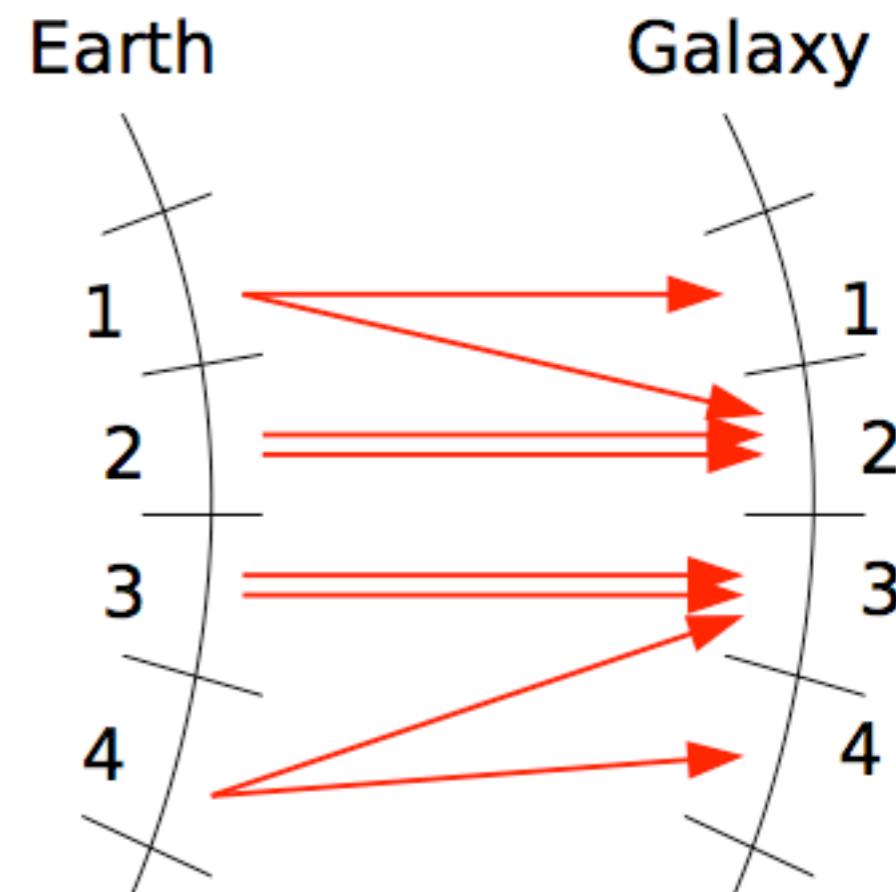
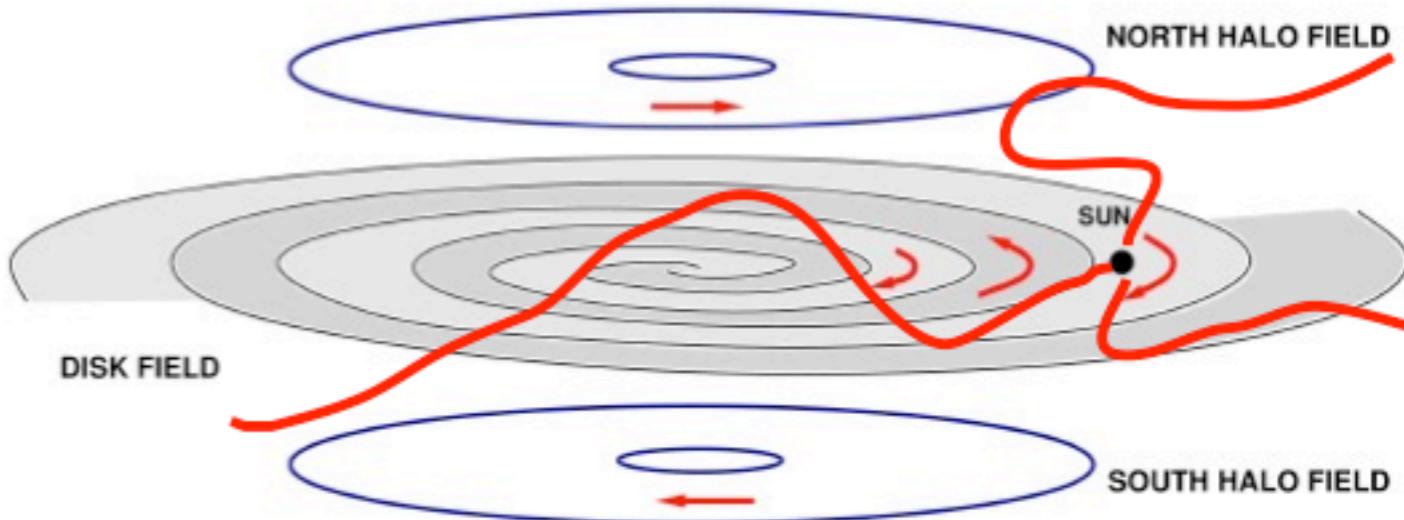


how does it work



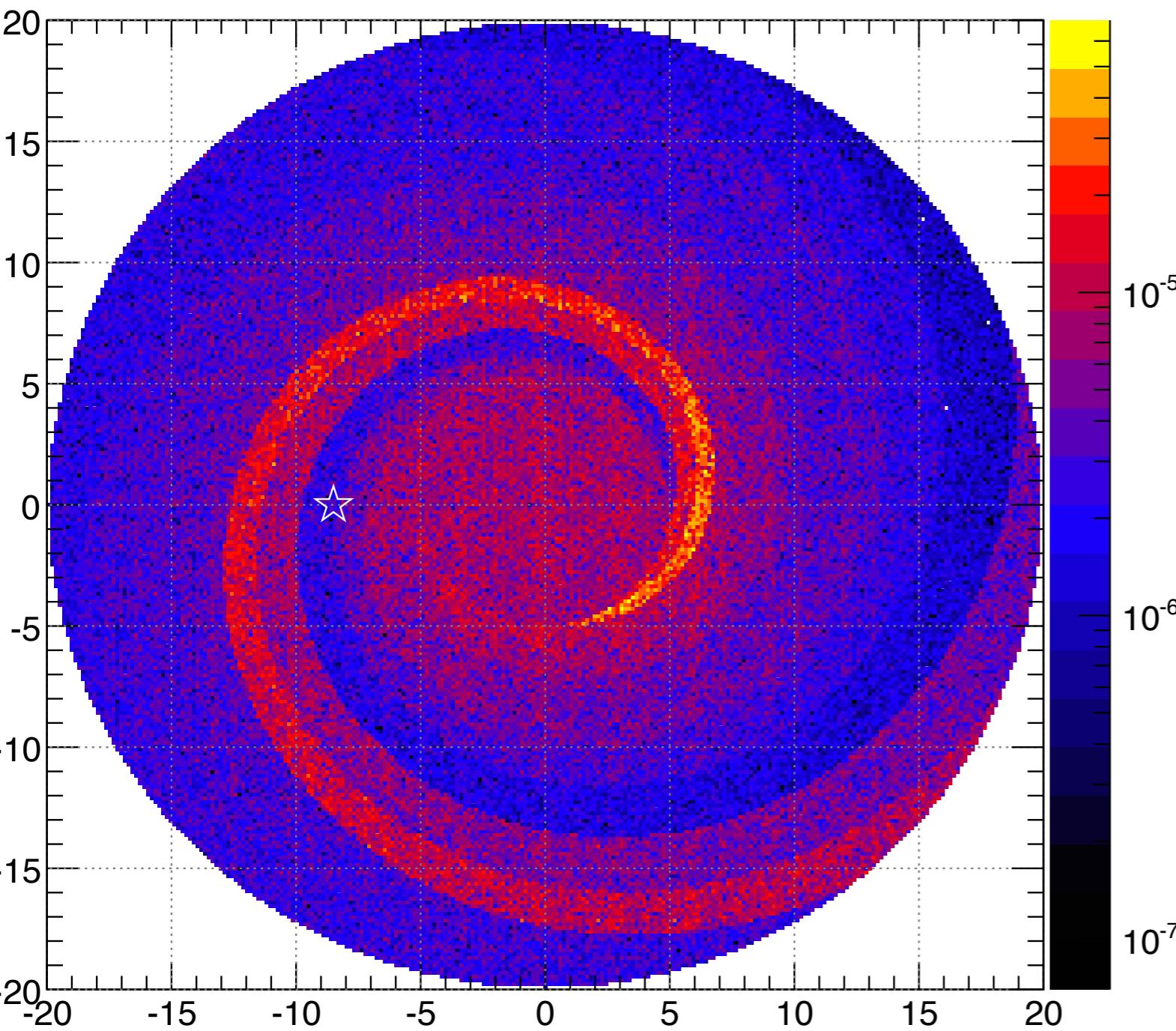
galactic lensing

- ◆ backtrack antiprotons in the galaxy
- ◆ no energy losses (galactic propagation)
- ◆ construct transformation matrix (lens)
- ◆ deflection for nuclei Z times the deflection for protons
- ◆ error estimate is also calculated



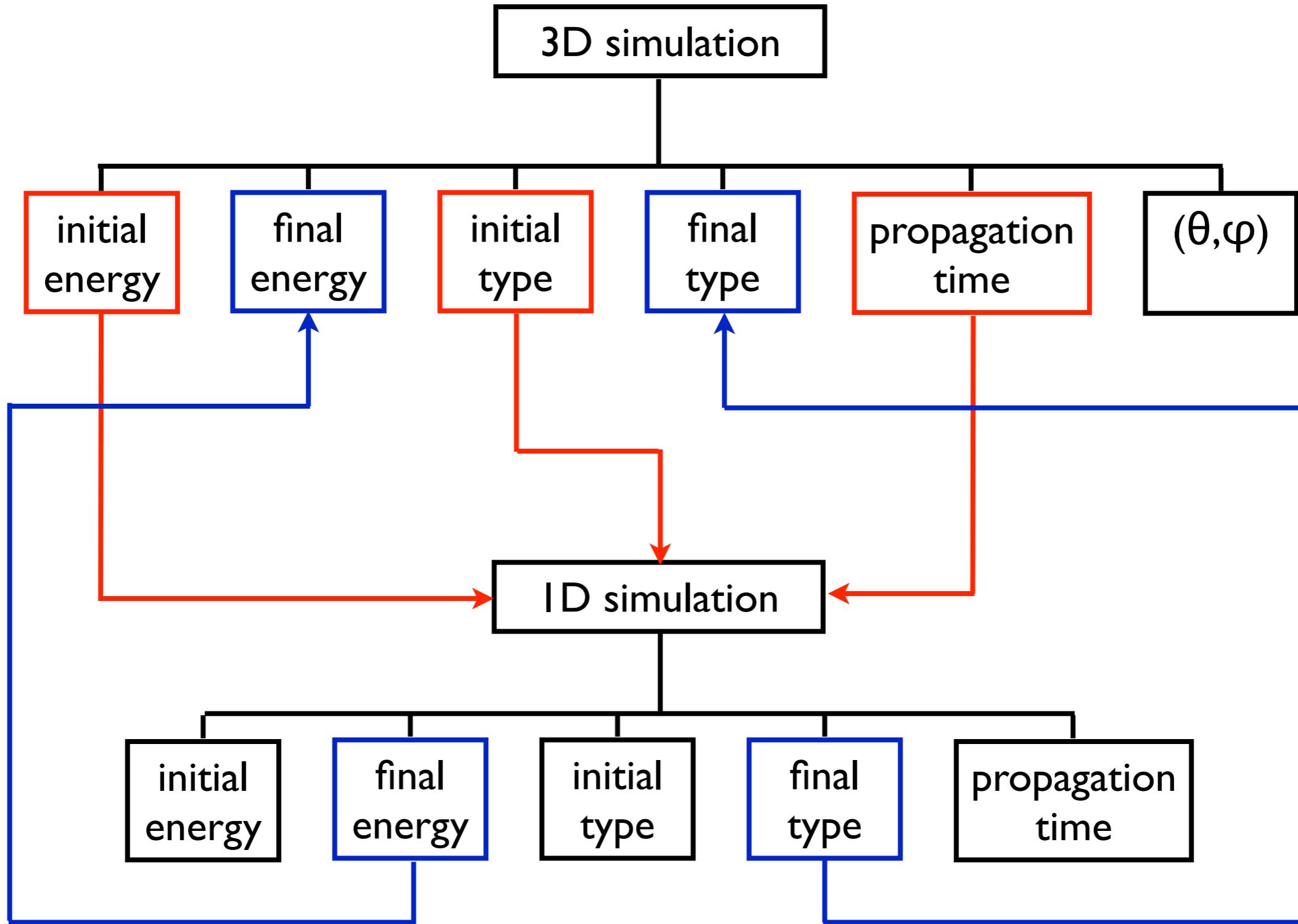
taken from G. Müller's talk in ICRC 2013

lensing technique: galactic magnetic field

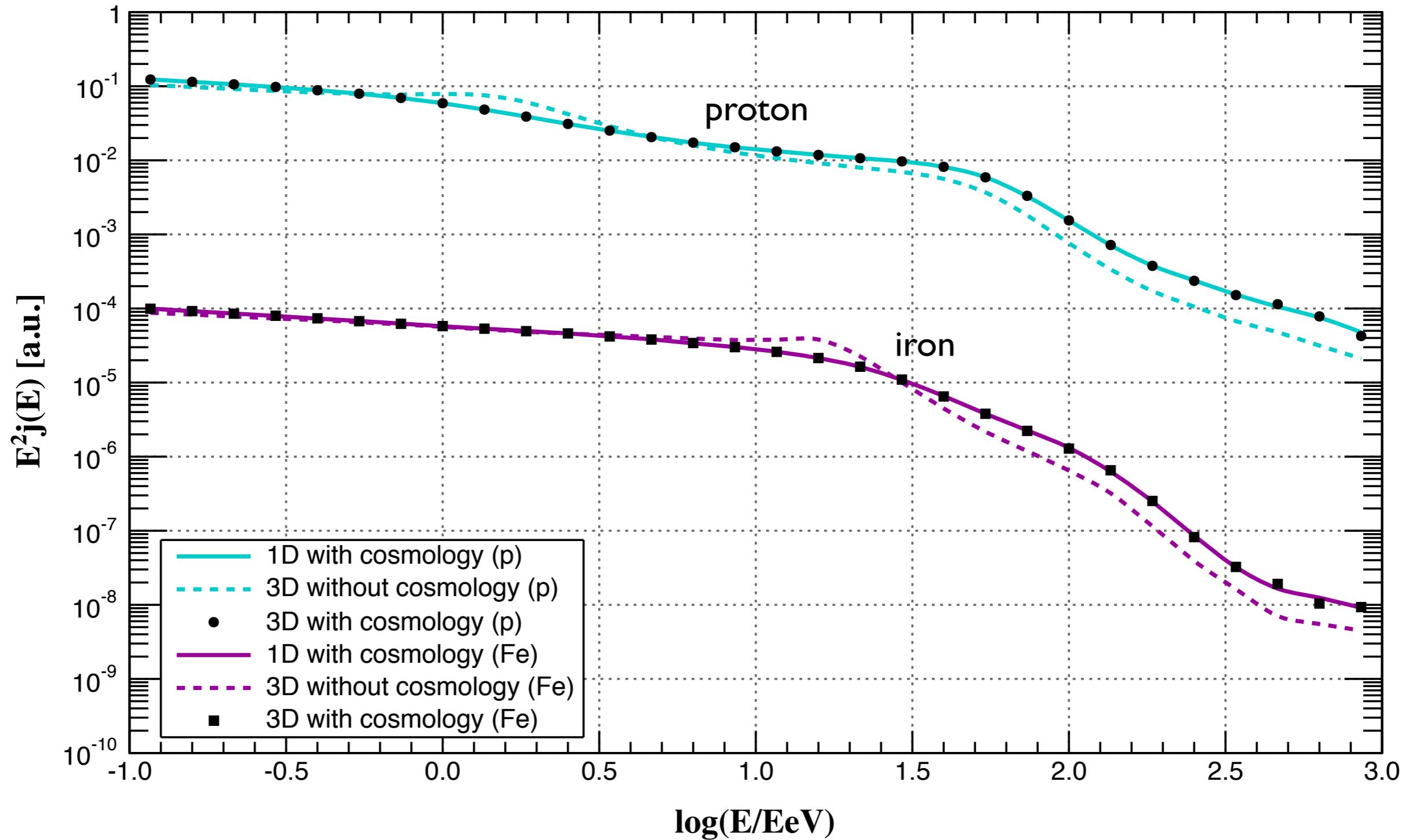


◆ galactic magnetic field lensing: Jansson & Farrar model [ApJ 761 (2012) L11]

correcting for cosmology in 3D simulations



testing the cosmology correction



- uniform source distribution

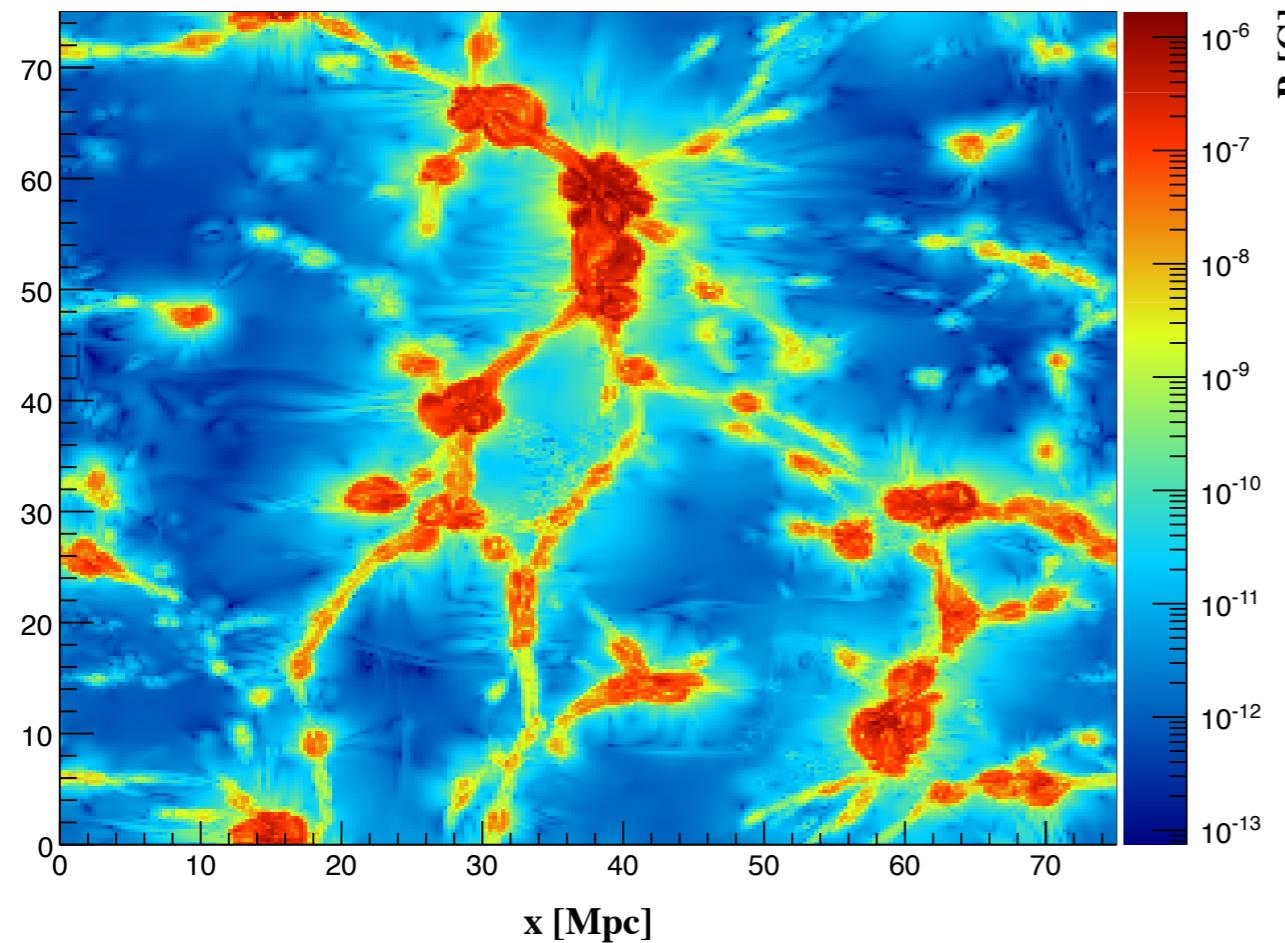
- sources up to 4000 Mpc

- injection spectrum source = -2.2

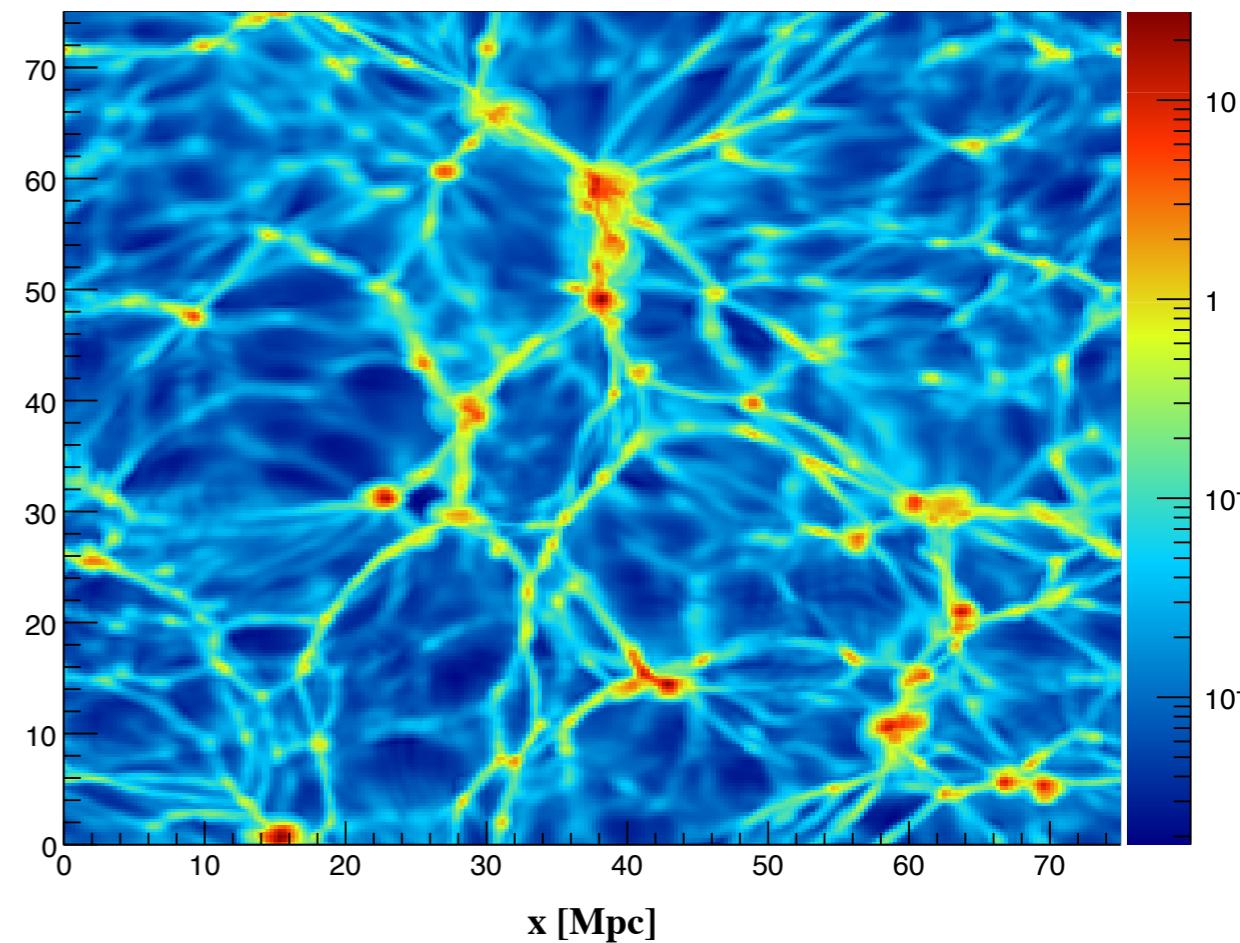
- maximum propagation length = 4000 Mpc

application: simulation setup

magnetic field



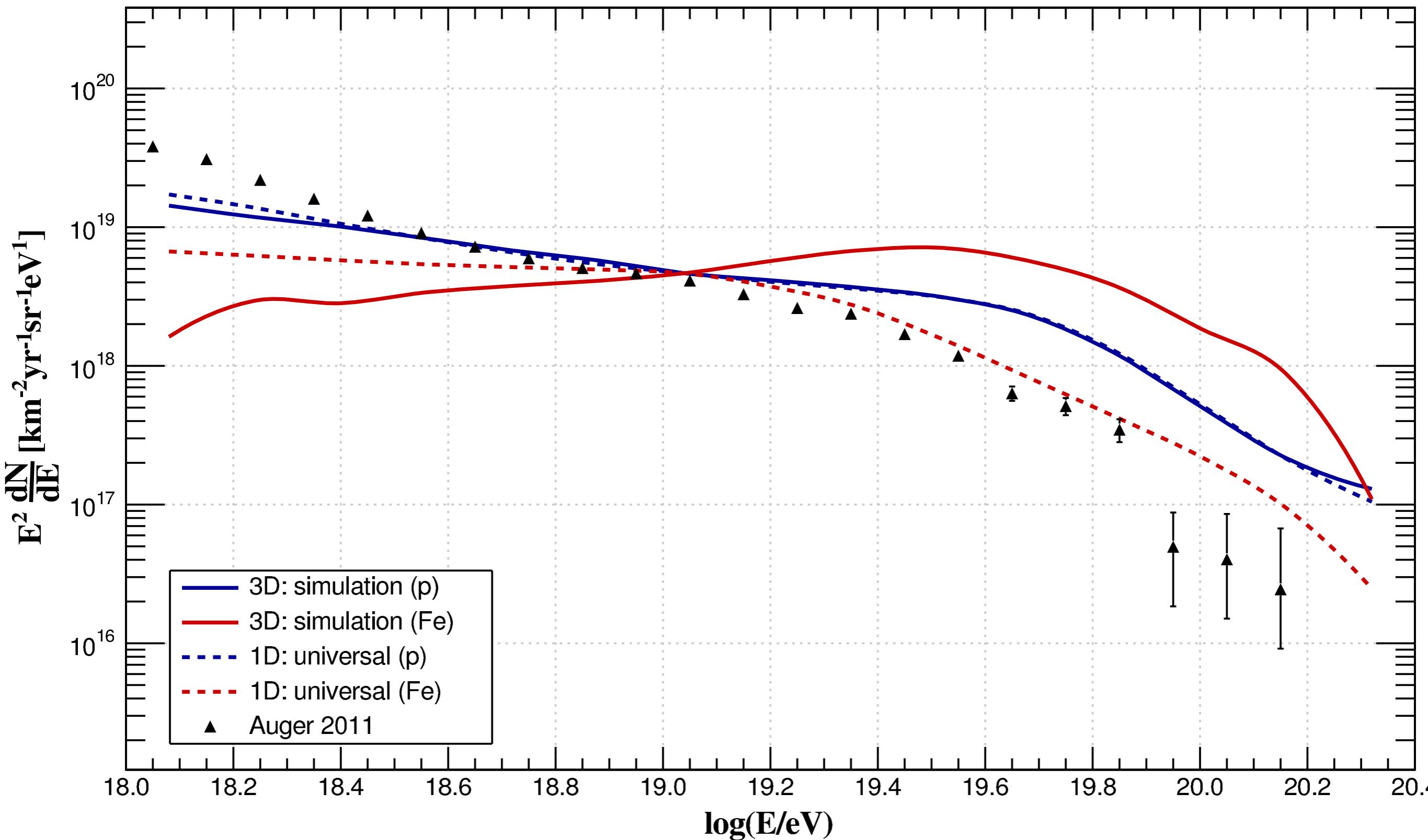
baryon density



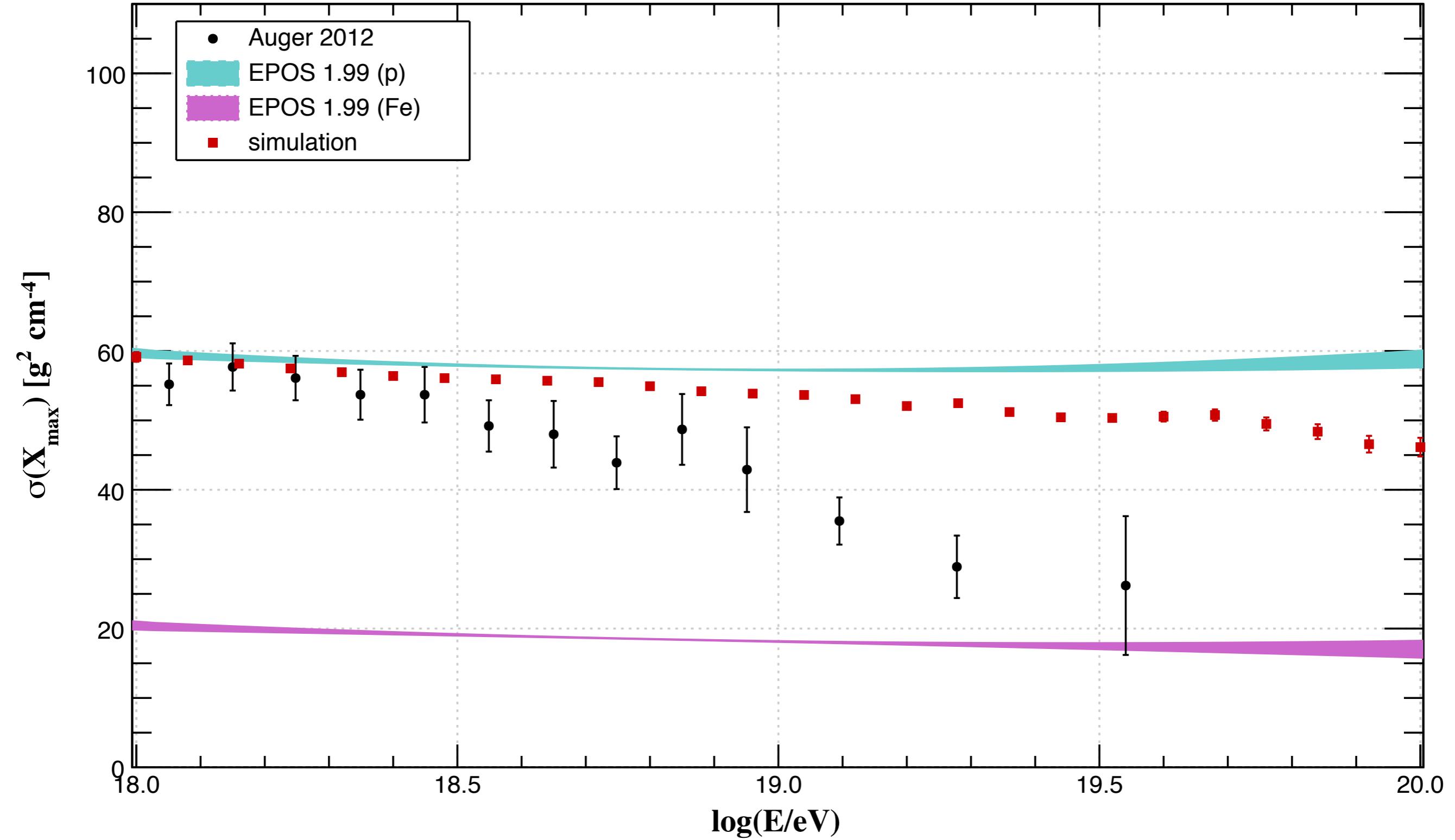
- ◆ MHD simulation from F. Miniatti
- ◆ maximum rigidity = 1000 EeV
- ◆ maximum source distance = 2 Gpc
- ◆ sources following LSS baryon density
- ◆ magnetic field from the grid

- ◆ composition: proton and iron (two cases)
- ◆ minimum energy = 1 EeV
- ◆ uniform grid

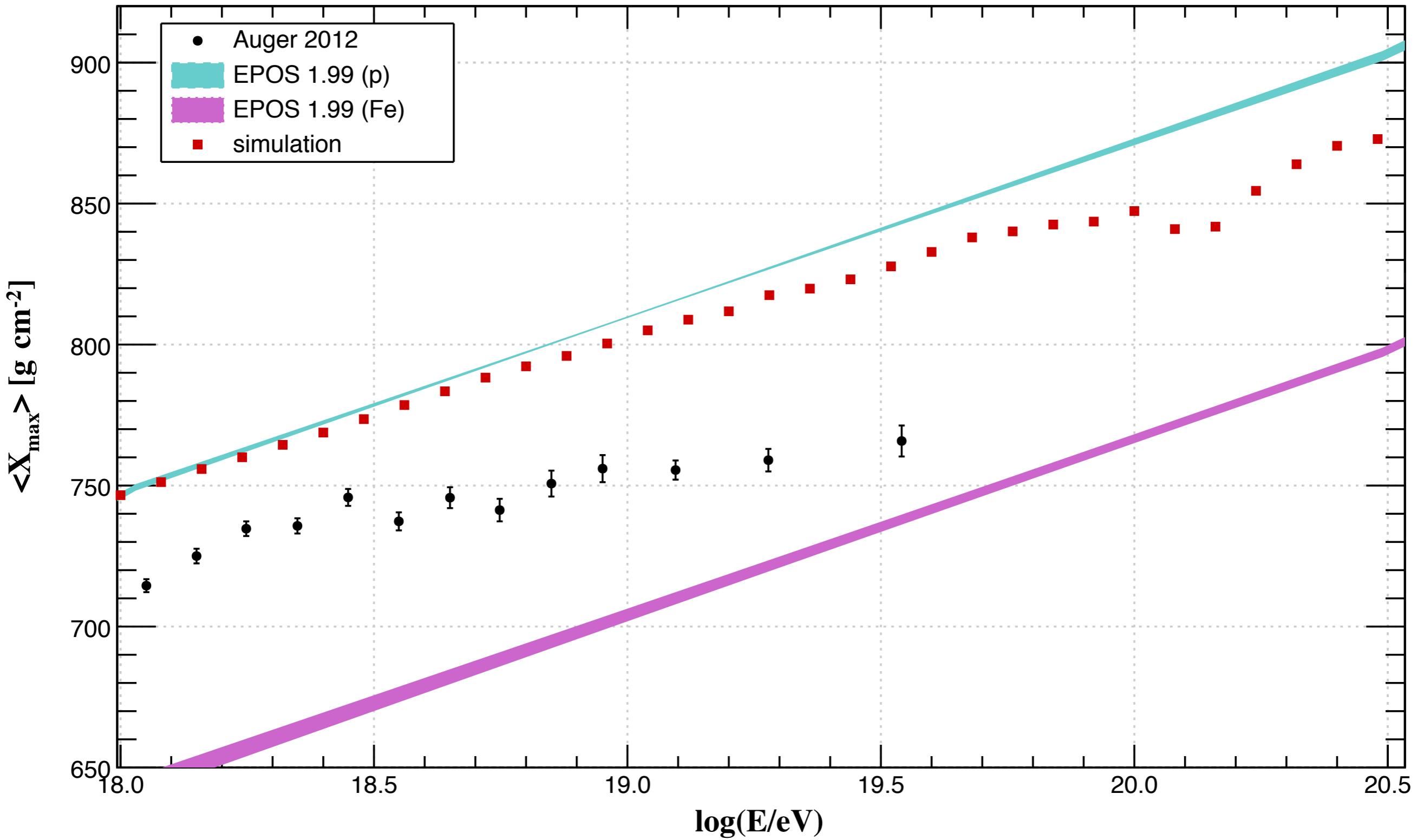
application: spectrum



application: composition

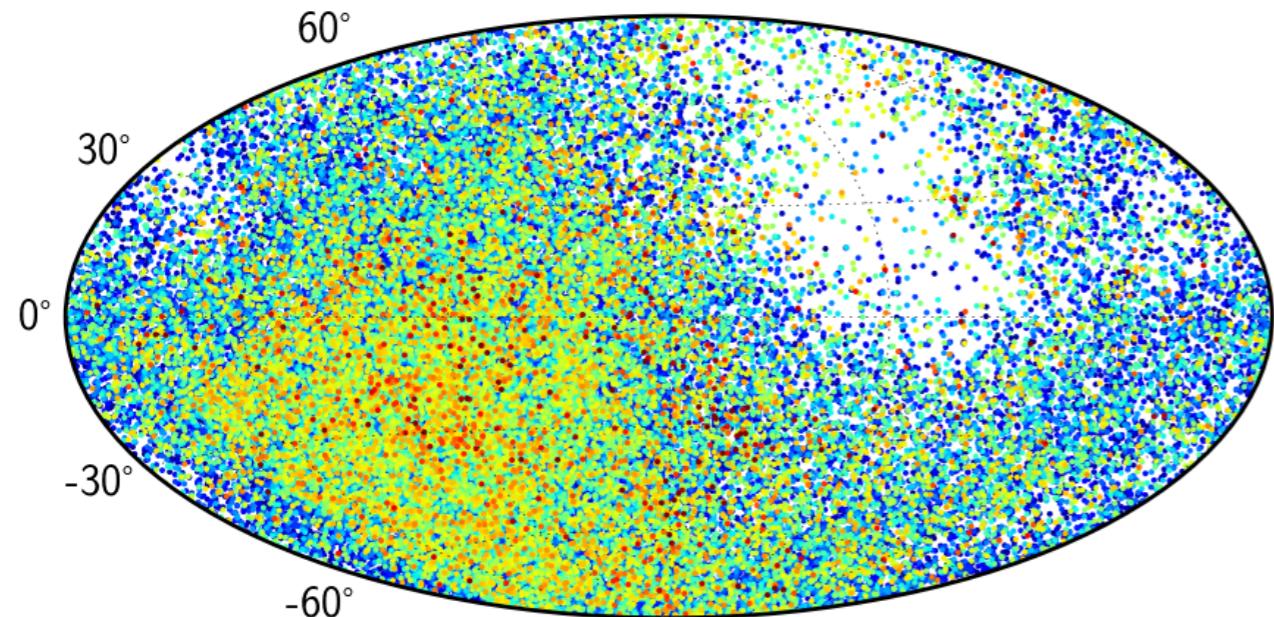


application: composition

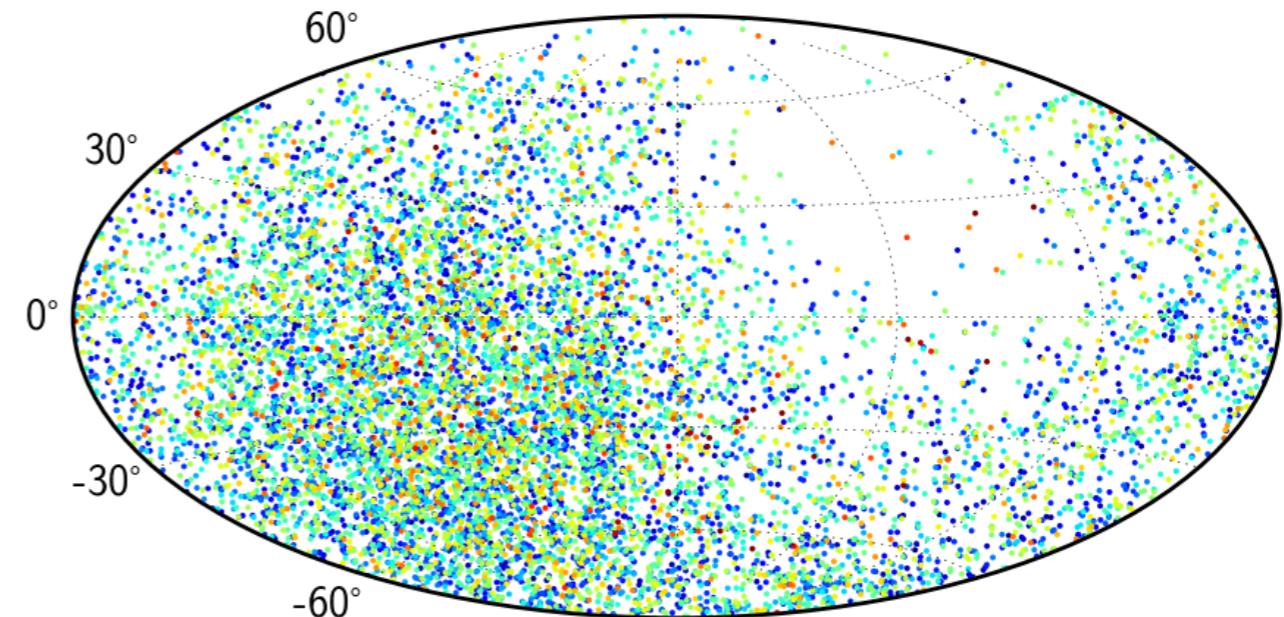


application: anisotropy

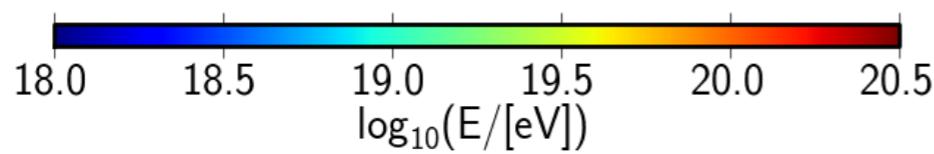
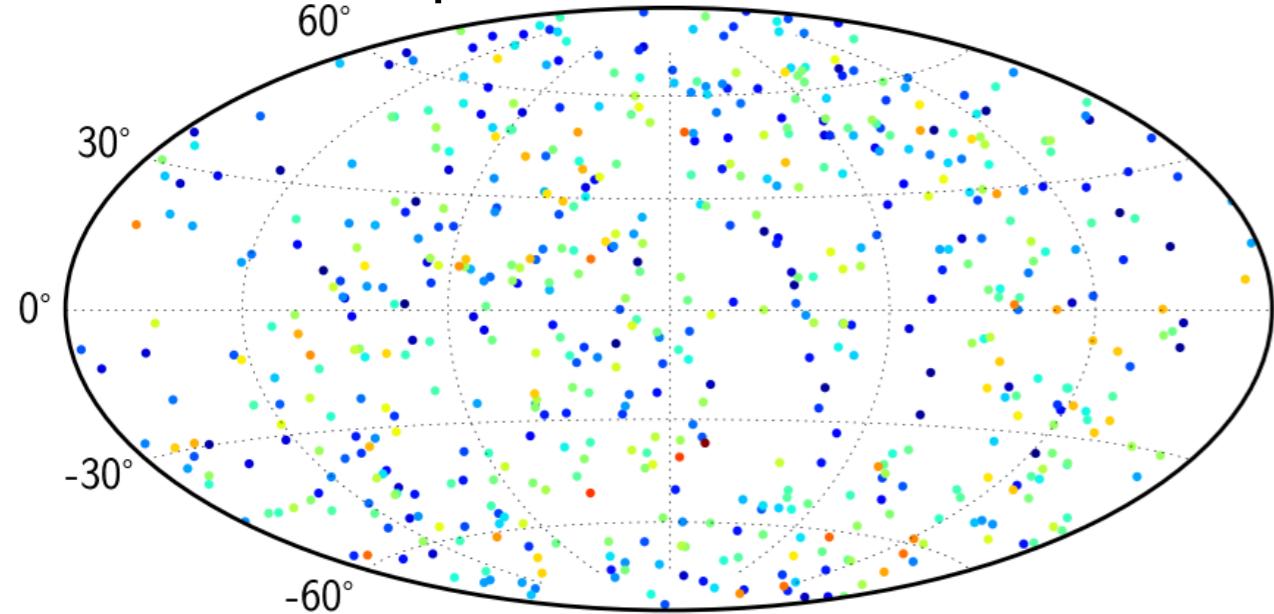
protons at the galactic border



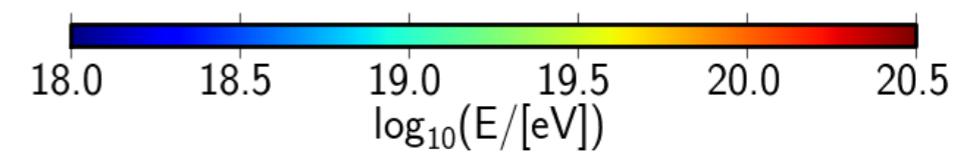
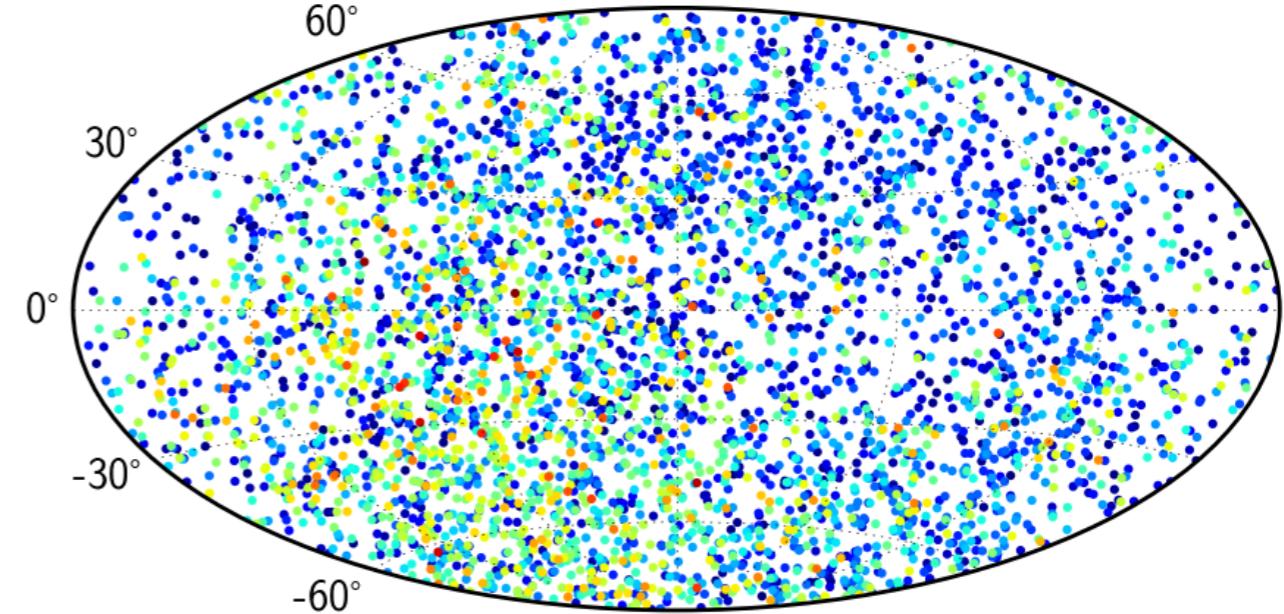
iron at the galactic border



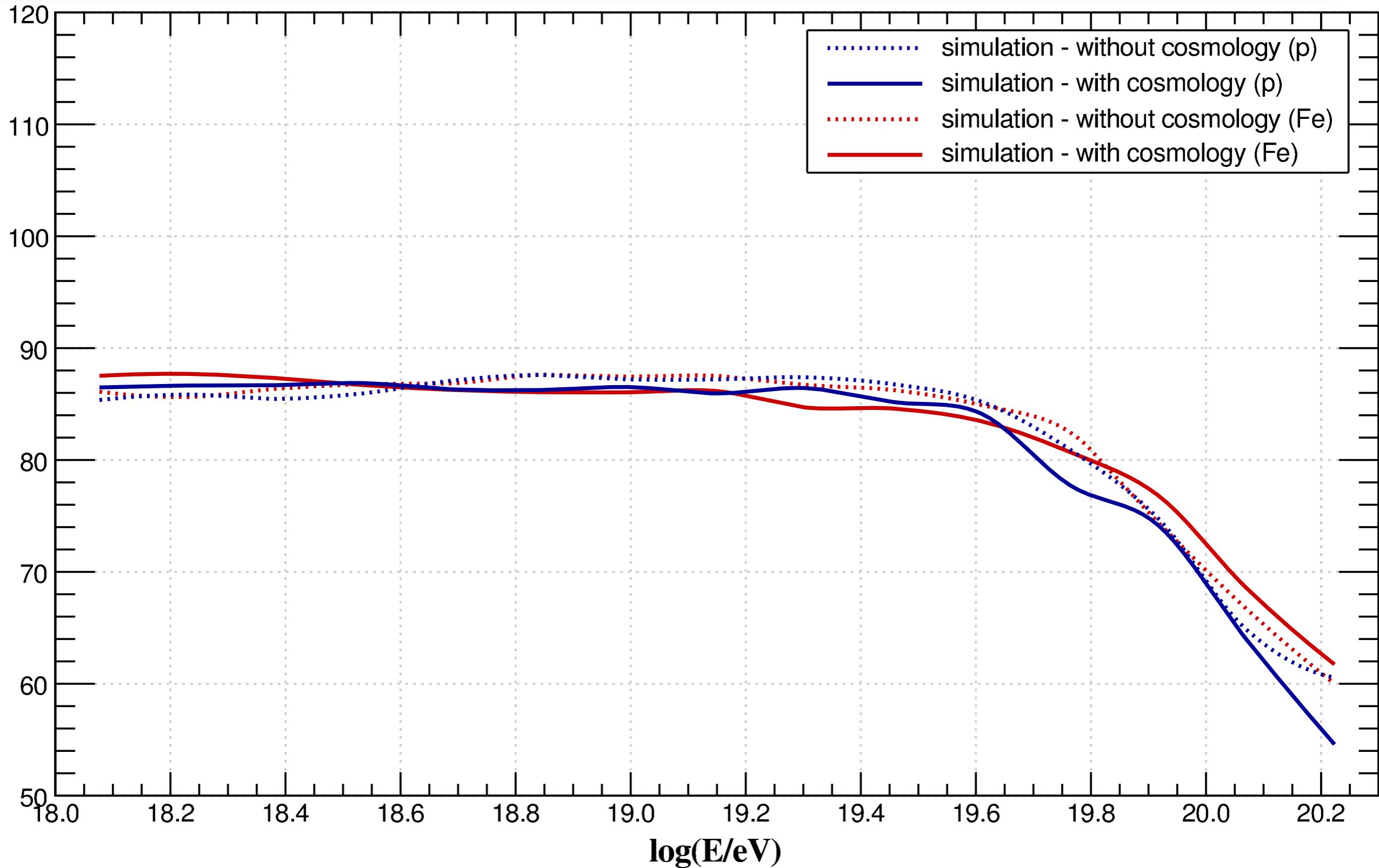
protons at Earth



iron at Earth



application: anisotropy



summary

- ◆ CRPropa framework: allows the simulation of propagation of UHE particle
- ◆ publicly available
- ◆ version 3.0 under development
- ◆ new features of version 3.0: cosmology in 3D, magnetic lensing
- ◆ parallelization allows for fast simulations => span a wide range of parameters
- ◆ comparison of simulations with **multimessenger** observations

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see A. van Vliet's talk

Backup Slides

effects of source distribution

