Electric Field Reconstruction in Radio Detectors with Information Field Theory

Simon Strähnz[1], Tim Huege[1,2], Philipp Frank[3], Torsten Enßlin[3]

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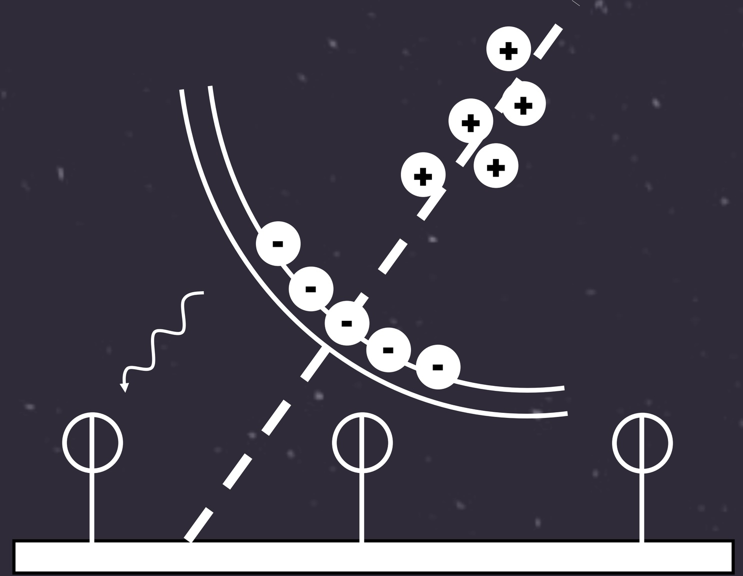
Karlsruhe Institute of Technology

Radio Emission

Geomagnetic emission

Charges separated in the geomagnetic field form a varying transverse current and thus radiate



Charge-Excess emission (Askaryan effect)

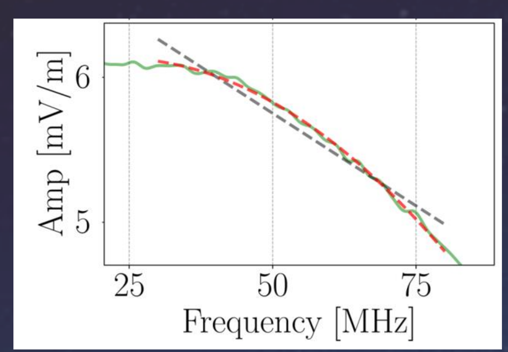
Charges separating along the shower axis produce varying charge density and thus radiate

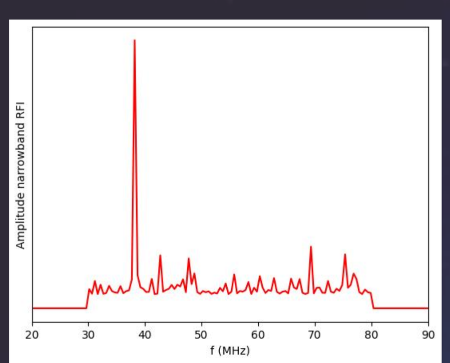
Forward Model

Signal model

- Following the model from Welling et al. [4]
- Parametrised spectra for geomagnetic and charge-excess emission [5]
- Antenna response model
- Instrument response model

→ Voltage from air shower





Noise Model

- Narrowband RFI from inverse Γ distribution
- Gaussian instrument noise
  - Broadband RFI
  - Electronics

→ Voltage from noise

Signal + Noise = Data

Outlook

Expanded Signal Model

- Include lateral distribution function (LDF)
- Include timing information

Data from other Detectors

- Particle detectors
- Fluorescence detectors

Agnostic Model

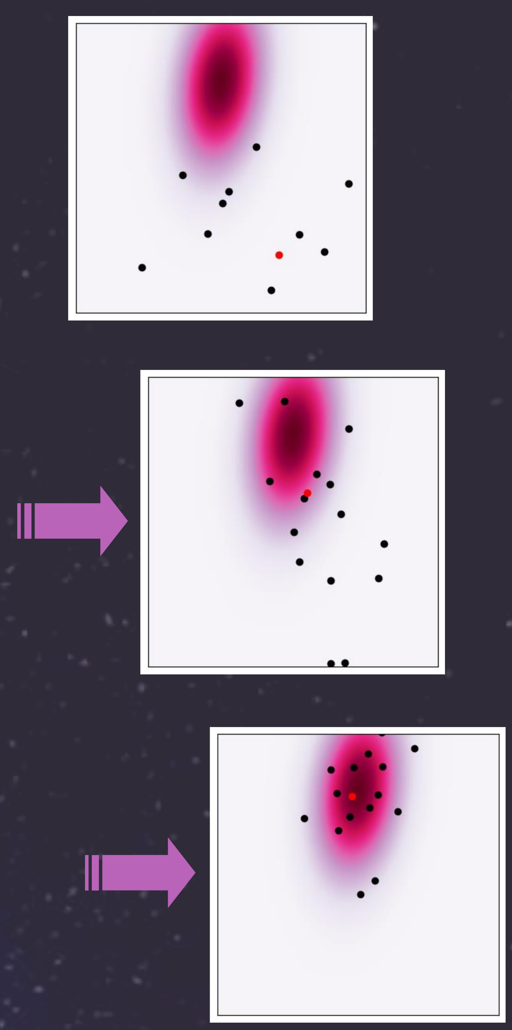
- Remove most simulation-derived constraints
- Cross-Check reconstruction

Information Field Theory

- Framework for Bayesian reasoning on fields [1]
- Bayes theorem

$$P(\theta|d) = \frac{P(d|\theta)P(\theta)}{P(d)}$$

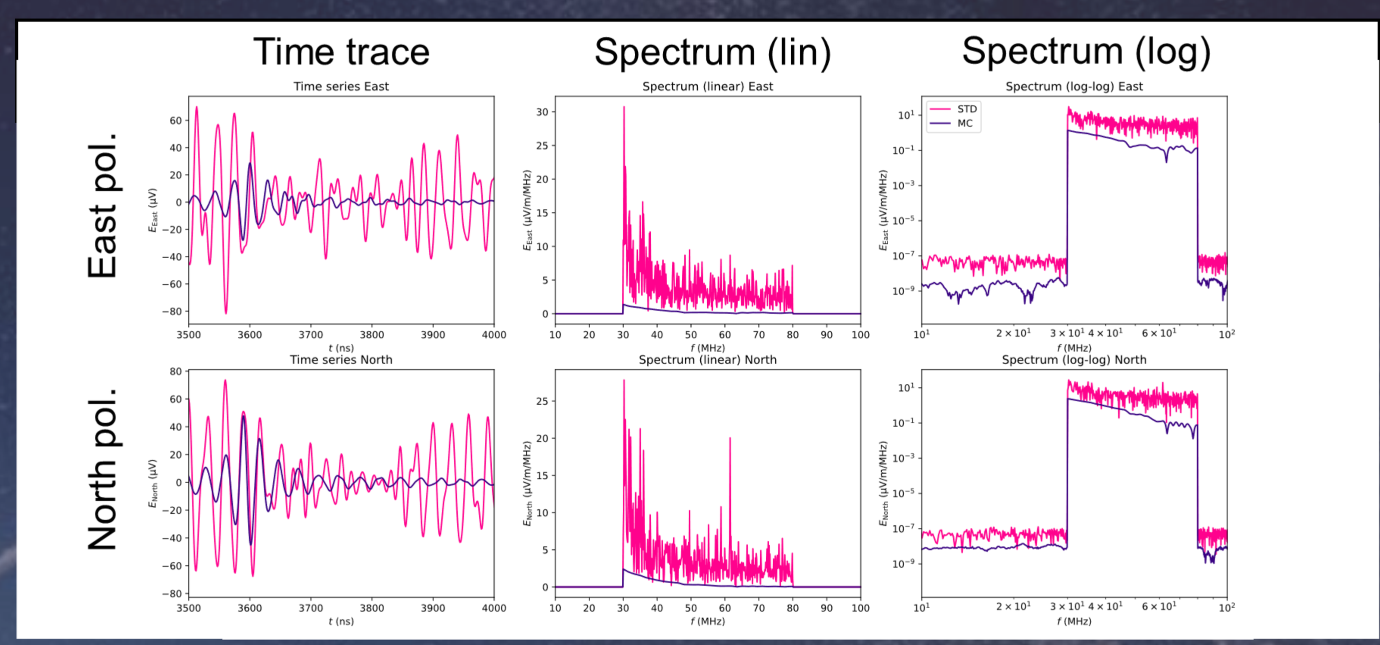
- Define problem in terms of
  - Forward Model
  - Likelihood
- Variational Inference to approximate posterior [2,3]



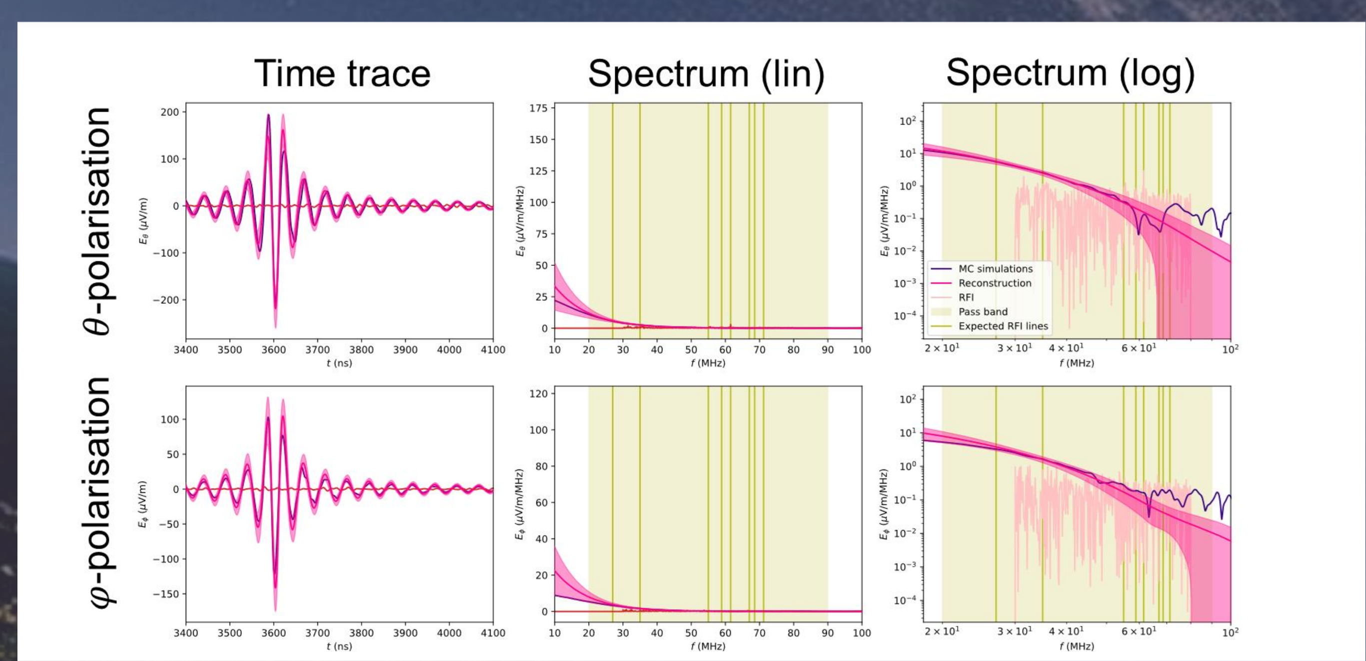
Performance

Performance tested on CORSIKA/CoREAS [6] simulations for the radio detector of the Pierre Auger Observatory [7,8] using measured noise.

"Standard" reconstruction

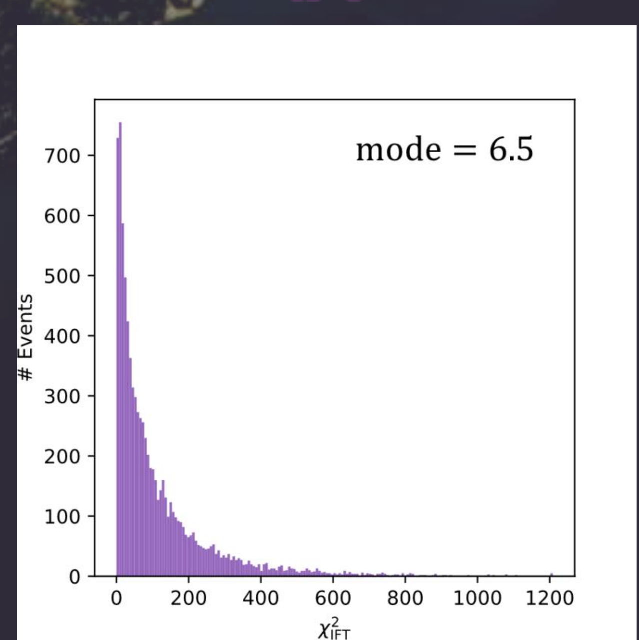


IFT-Based reconstruction

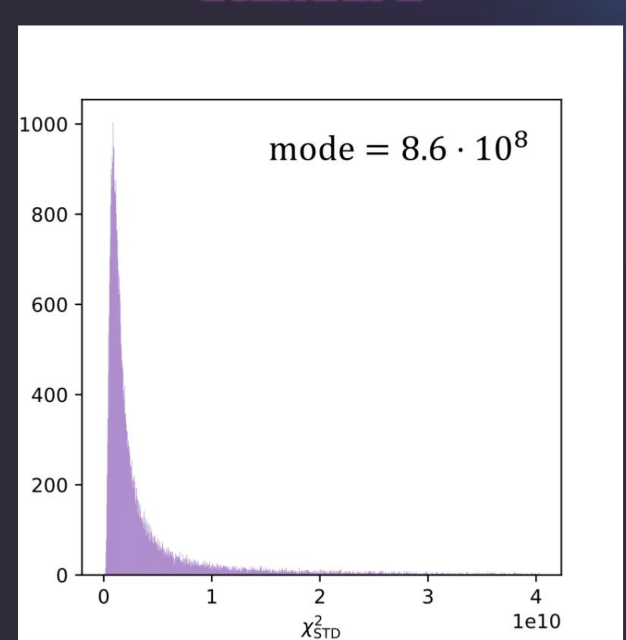


χ² comparison

IFT



"standard"



[1] Karlsruhe Institute of Technology
[2] Astrophysical Institute, Vrije Universiteit Brussel
[3] Max-Planck-Institute for Astrophysics

E-mail: simon.straehnz@kit.edu

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