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Information Field Theory based Event Reconstruction for Cosmic Ray Radio Detectors

Detection of extensive air showers with radio antennas is an appealing technique in cosmic ray physics. However, because of the high level of measurement noise, current reconstruction methods still leave room for improvement. Furthermore, reconstruction efforts typically focus only on a single aspect of the signal, such as the energy fluence or arrival time. Bayesian inference is then a natural choice for a holistic approach to reconstruction, yet, this problem would be ill-posed, since the electric field is a continuous quantity. Information Field Theory provides the solution for this by providing a statistical framework to deal with discretised fields in the continuum limit.

We are currently developing two models for this novel approach to reconstructing extensive air showers. The first model is based on the best current understanding of the emission mechanisms: It uses parametrisations of the lateral distribution, charge-excess contribution and spectral shape. Shower-to-shower fluctuations and narrowband RFI are modelled using Gaussian processes. Combined with a good detector description, this model can infer not only the electric field, but also the shower geometry, electromagnetic energy and position of shower maximum. Since the first model is largely based on simulations, a second model is being designed, based only on Gaussian processes and conservative assumptions about the electric field. While it has no predictive power of the shower parameters, it can serve as a data driven cross-check for the reconstruction of the electric field by the first model.

Another big achievement of this approach is its ability to naturally provide uncertainties for the reconstruction, which has been shown to be difficult in more traditional methods. With such an open framework and robust computational methods based in Information Field Theory, it will also be easy to incorporate new insights and additional data, such as timing distributions or particle detector data, in the future. This approach has a high potential to exploit the full information content of a complex detector with rigorous statistical methods, in a way that directly includes domain knowledge.

Collaboration(s)

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