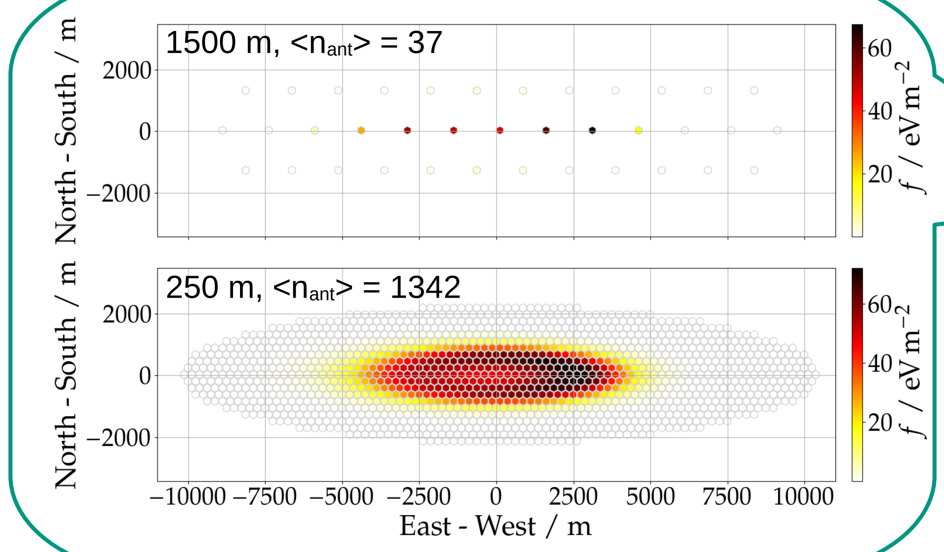
Expected performance of interferometric air-shower measurements with radio antennas

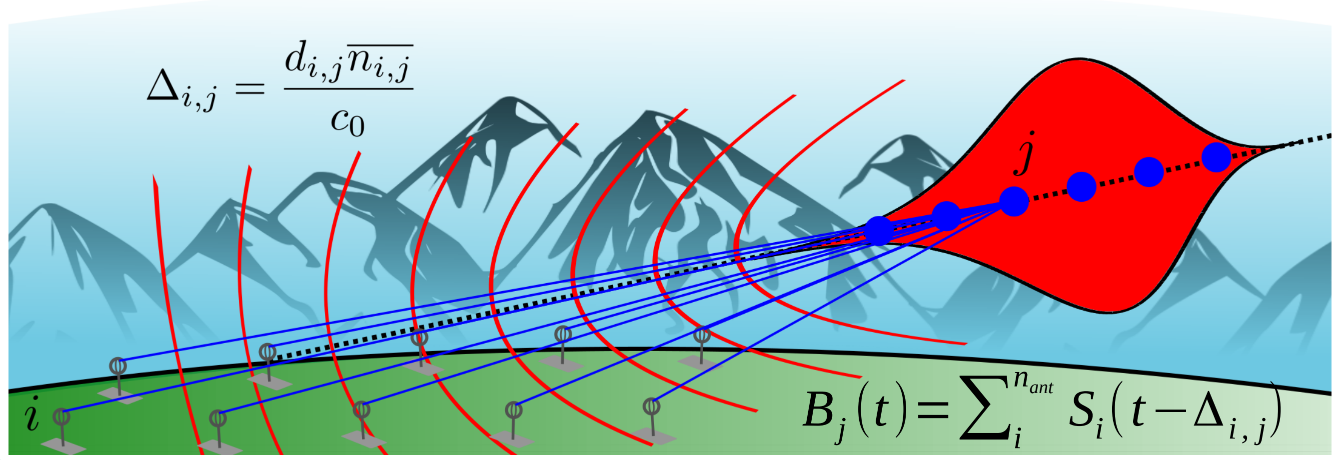
Felix Schlüter* and Tim Huege

PoS (ICRC2021) 228

Study performance of radio-interferometric-technique (RIT) reconstruction of the shower maximum X_{max} for inclined air showers [1] with realistic detectors [2]. Inclined air showers allow to detect cosmic rays up to the highest energies with radio antennas. An accurate X_{max} measurement would boost mass sensitivity.



Determine beam-formed signal B_j



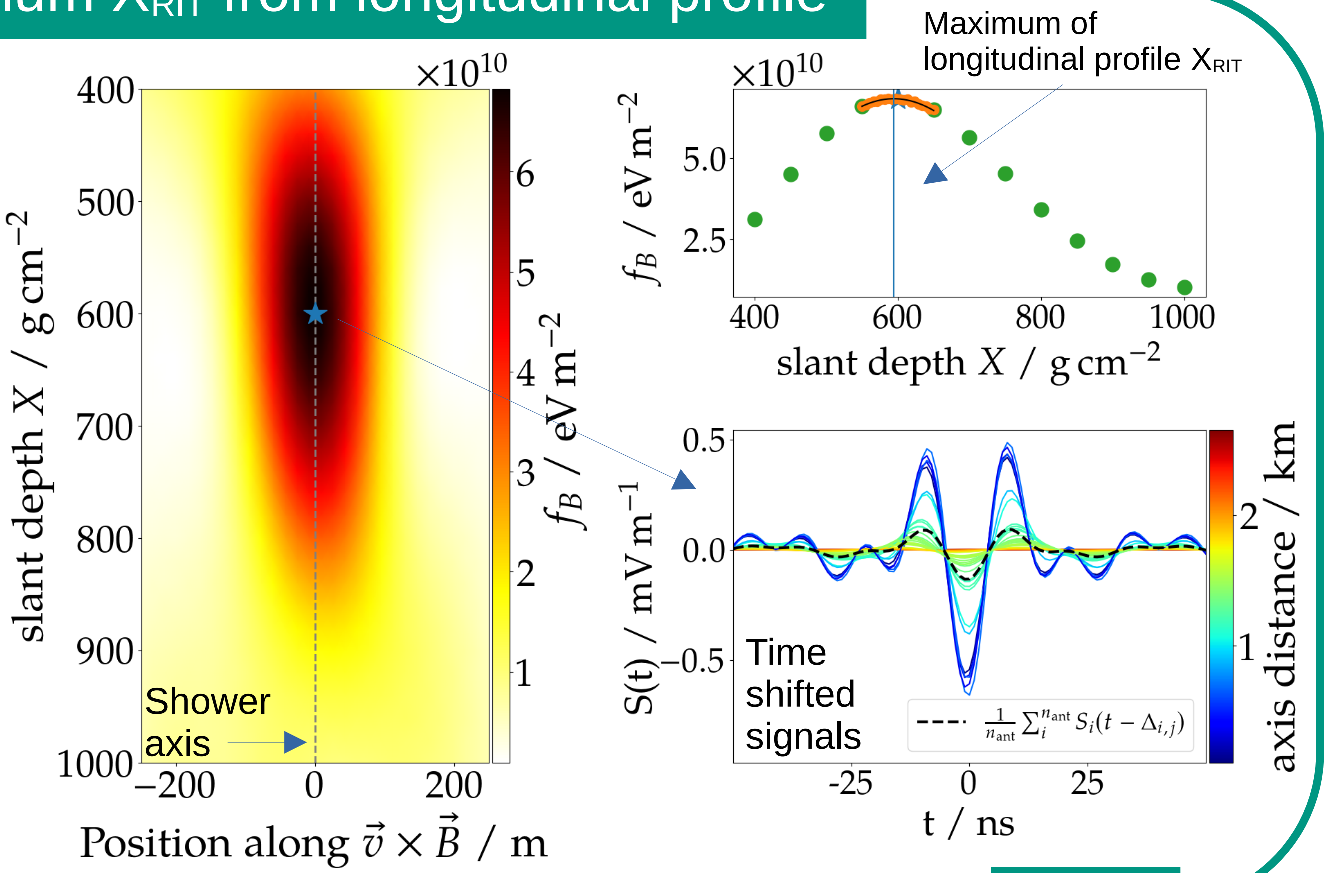
- Calculate B_j at arbitrary position **j** in atmosphere from signals at ground S_i
- Calculate light-propagation time $\Delta_{i,j}$ between **j** and antenna locations **i**

Click on me!

Determine maximum X_{RIT} from longitudinal profile

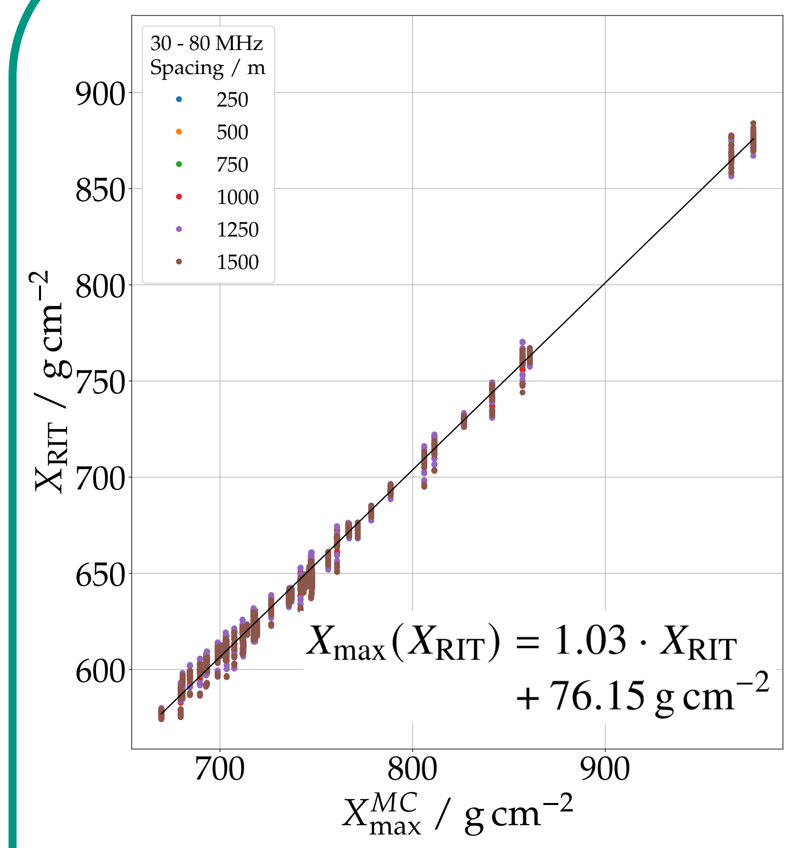
$$f_{B_j} = \epsilon_0 \, c \, \Delta t \sum_{t_{peak}-50ns}^{t_{peak}+50ns} B_j^2(t)$$

- Calculate coherent energy fluence f_{B_j} for 30 – 80 MHz in **v**x**B** polarisation
- Sample 3d f_{B_j} profiles → Interferometric maps
- Maps correlate with shower development
- Infer shower axis and X_{RIT} from maps



Click on me!

Reconstruct X_{max} from X_{RIT}



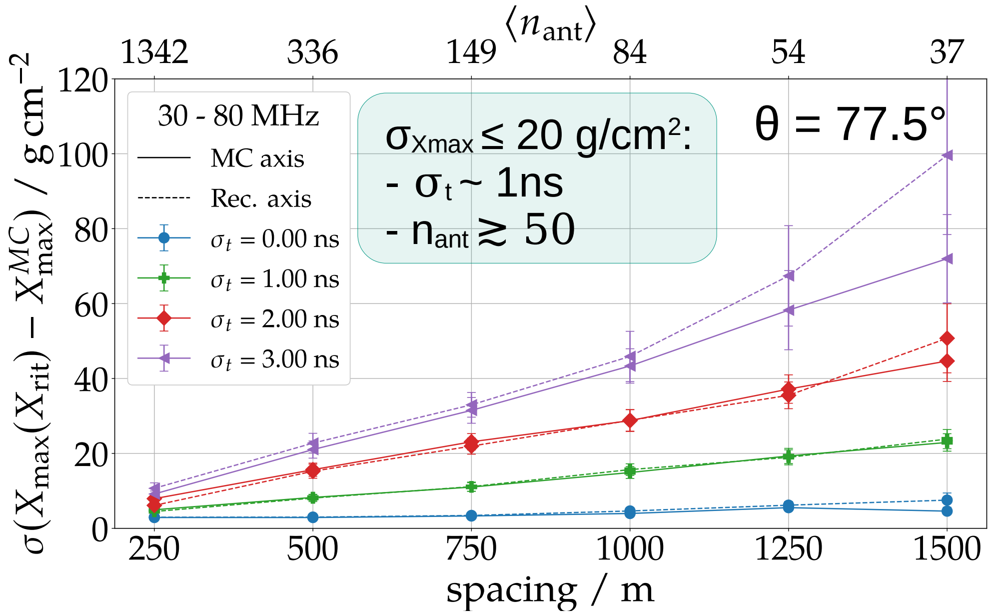
- With perfect time synchronization and MC shower axis
- Excellent resolution (< 5 g/cm²) regardless of the antenna spacing
- Confirming results from [1] with ideal detector

[1] H. Schoorlemmer and W. R. Carvalho Jr., arXiv:2006.10348

[2] F. Schlüter and T. Huege, arXiv:2102.13577v1 (press. in JINST)

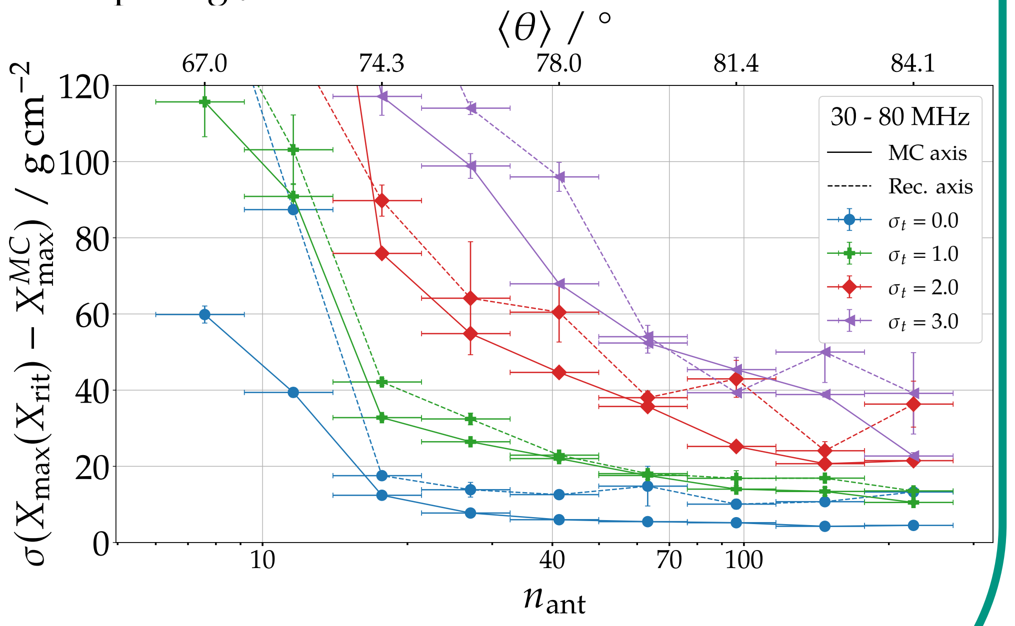
Evaluate RIT with realistic detector

- Mimic imperfect time synchronisation by adding Gaussian time jitter σ_t to signals' arrival time
- Reconstruct with different detector layouts, i.e., different antenna spacings → antenna multiplicity n_{ant}



- Found strong inter-dependency between n_{ant} and σ_t
- Larger σ_t more problematic with low n_{ant}

- Finite 1.5 km grid
- θ ∈ [65°, 85°]
- Sufficient n_{ant} only for largest θ



$$X_{max}(X_{RIT}, \theta) = 1.04 \cdot X_{RIT} + \left(68.31 - \frac{\theta - 77.5°}{0.35°}\right) \text{g cm}^{-2}$$

To apply RIT, experiments have to achieve a very good time resolution $\sigma_t \lesssim$ 1ns while also providing a high antenna multiplicity $n_{ant} \geq 50$. For more information (including RIT application at higher frequencies) see [2].

*felix.schlueter@kit.edu