

Tunka-Rex: Status and Plans

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Content

- Cosmic-ray instruments of TAIGA
(Tunka Advanced Instrument for cosmic rays and Gamma Astronomy)
- Measurement basics of Tunka-Rex
 - Event reconstruction
- Energy reconstruction
 - Comparison to air-Cherenkov measurements
 - Systematic uncertainties
 - **Scale comparison with LOPES**

Tunka-Rex Collaboration



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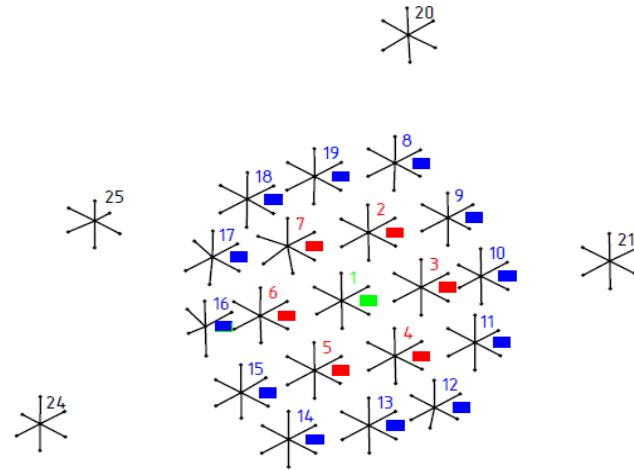
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Tunka-133 and Tunka-Grande at TAIGA

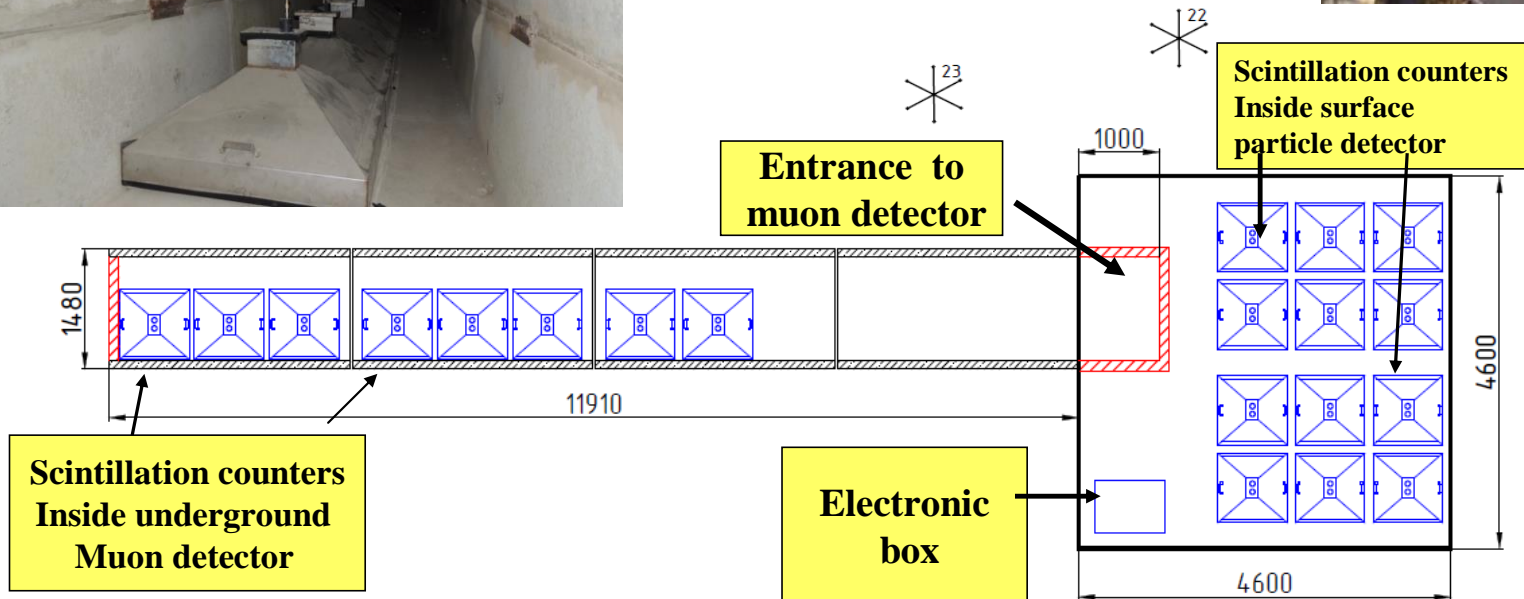


■ Cosmic Rays

- Tunka-133
- Tunka-Grande
- Tunka-Rex

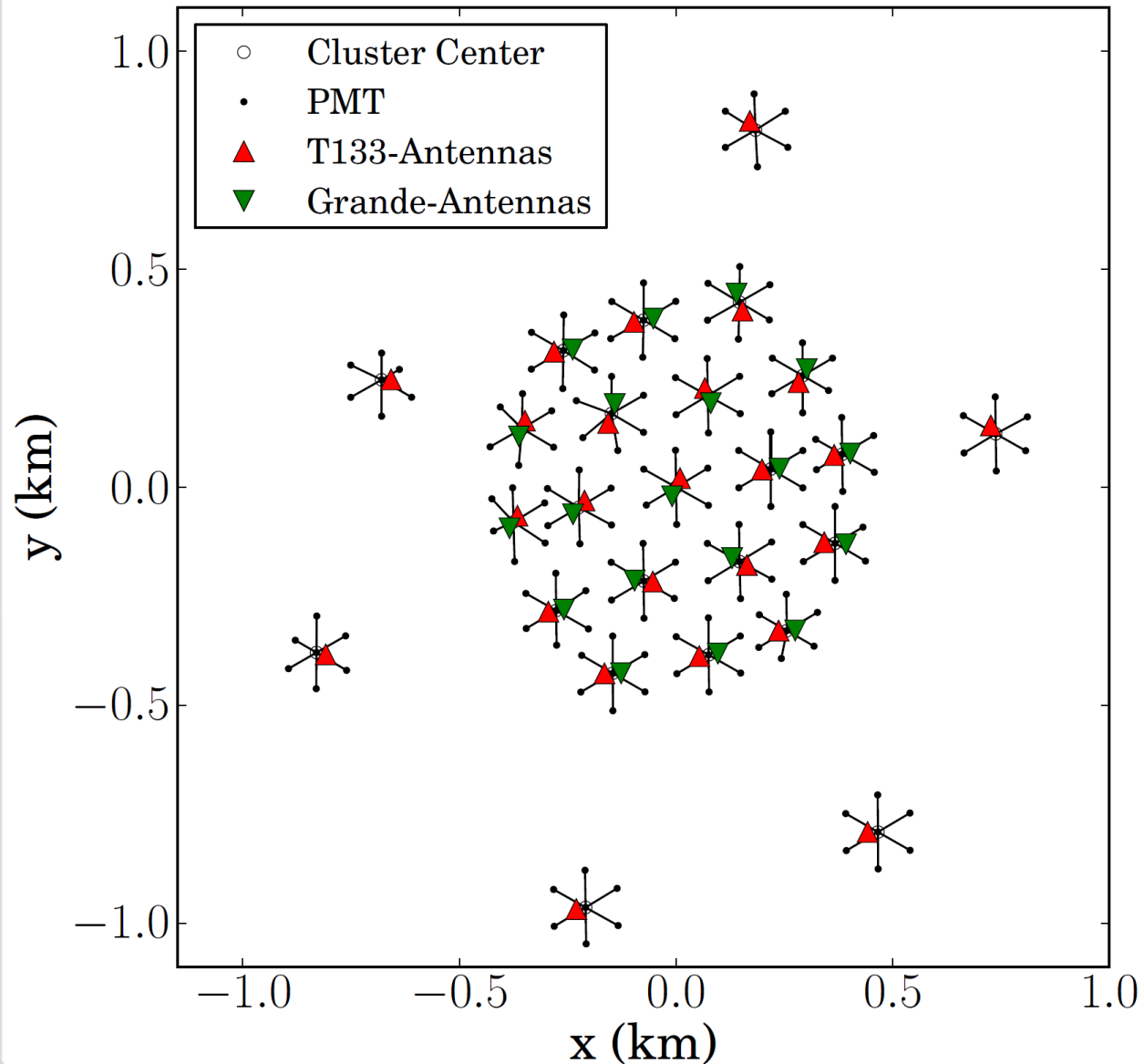
■ Gamma Rays

- HiSCORE
- IACT
- Muon detectors as veto



ECRS 2014
Tunka Coll.

Layout of Tunka-Rex



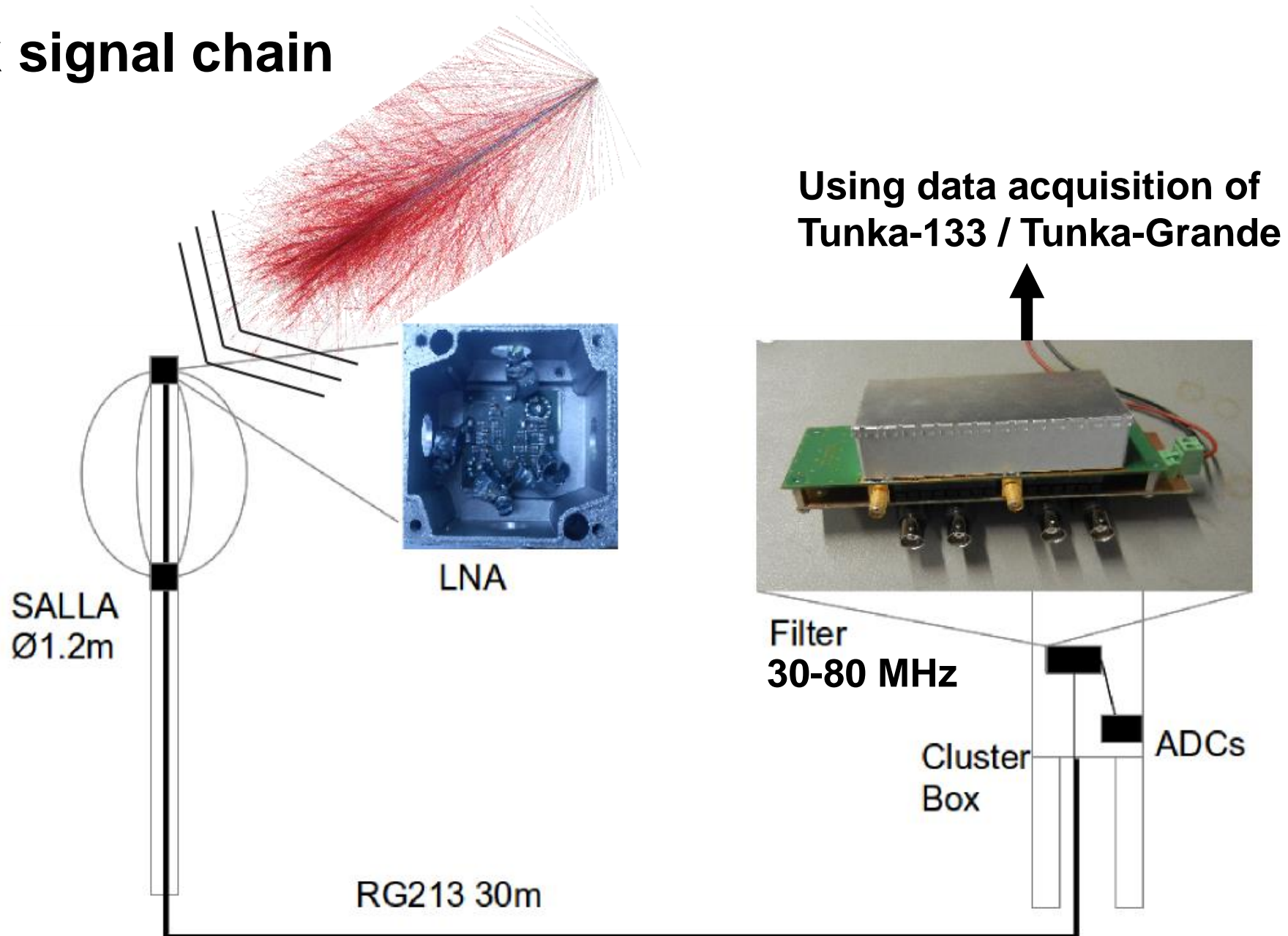
■ Array layout

■ 200 m spacing in 1 km² inner area

■ Fully analyzed: Oct 2012 – Apr 2014

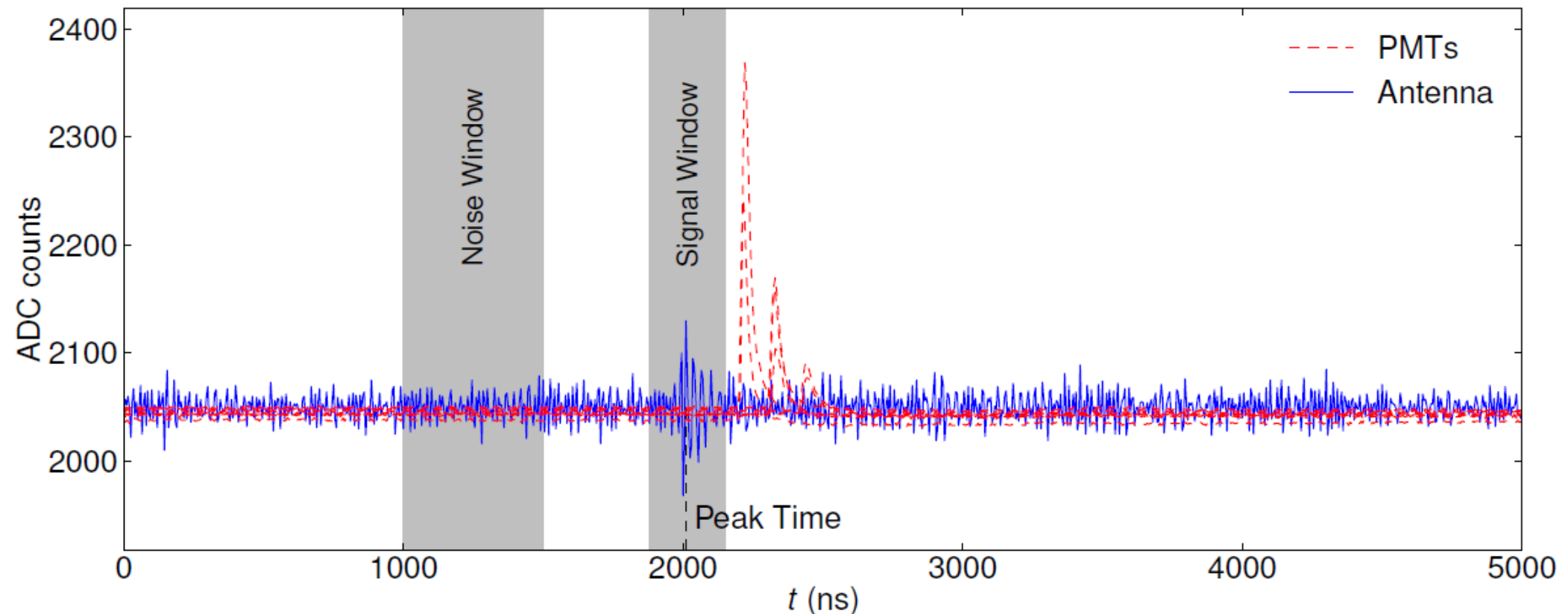
Year	Stations	Trigger
2012	19	Tunka-133
2013	25	Tunka-133
2014	timing problem	
2015	44	Tunka-133 + Grande
2016	44 + 19 in summer	Tunka-133 + Grande

Tunka-Rex signal chain

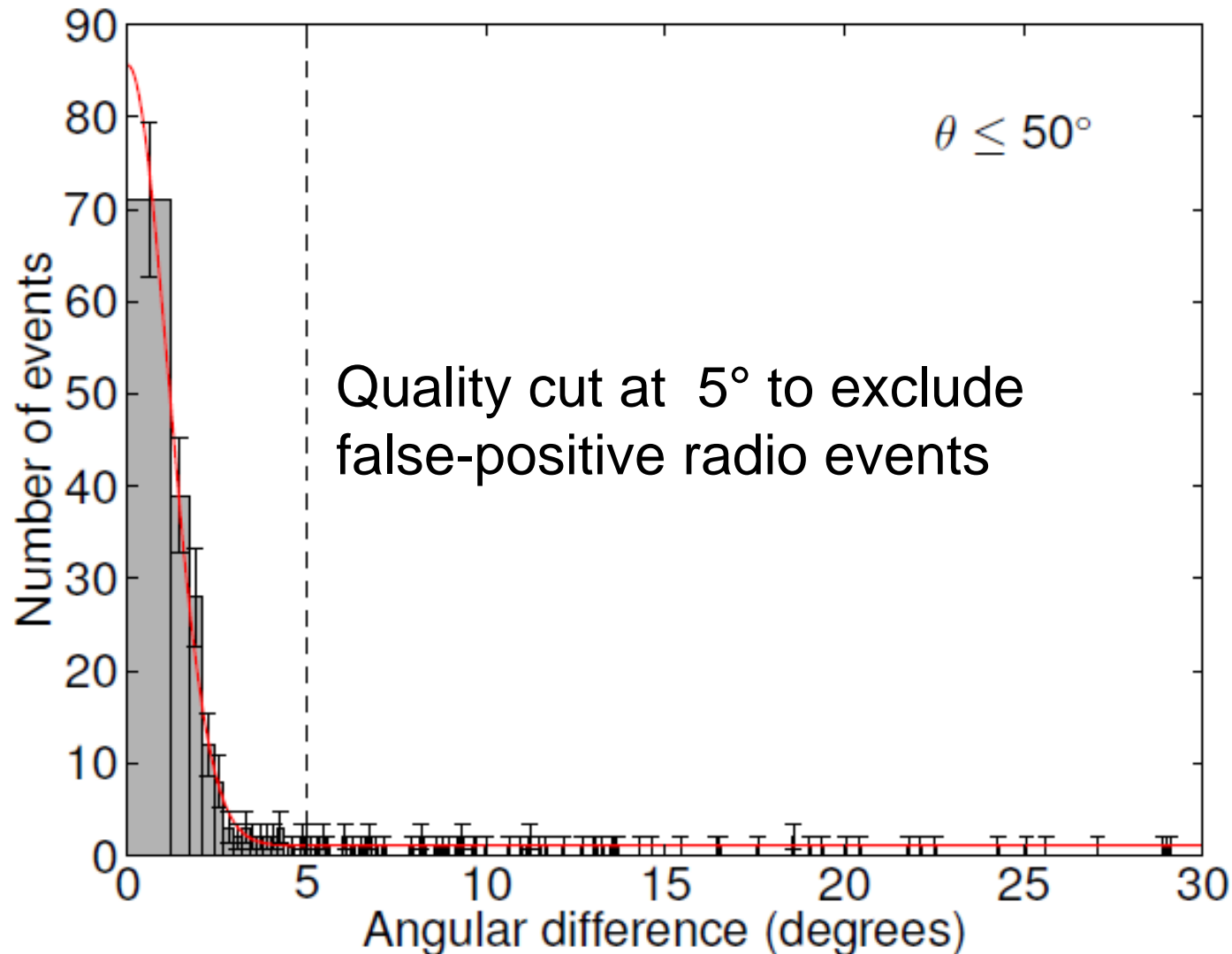


Reconstruction of Tunka-Rex event

- Signal-to-noise ratio (in power) > 10
 - 5% chance probability of false-positive detection in a single antenna
- 3 antennas + direction agreement with Tunka-133 required



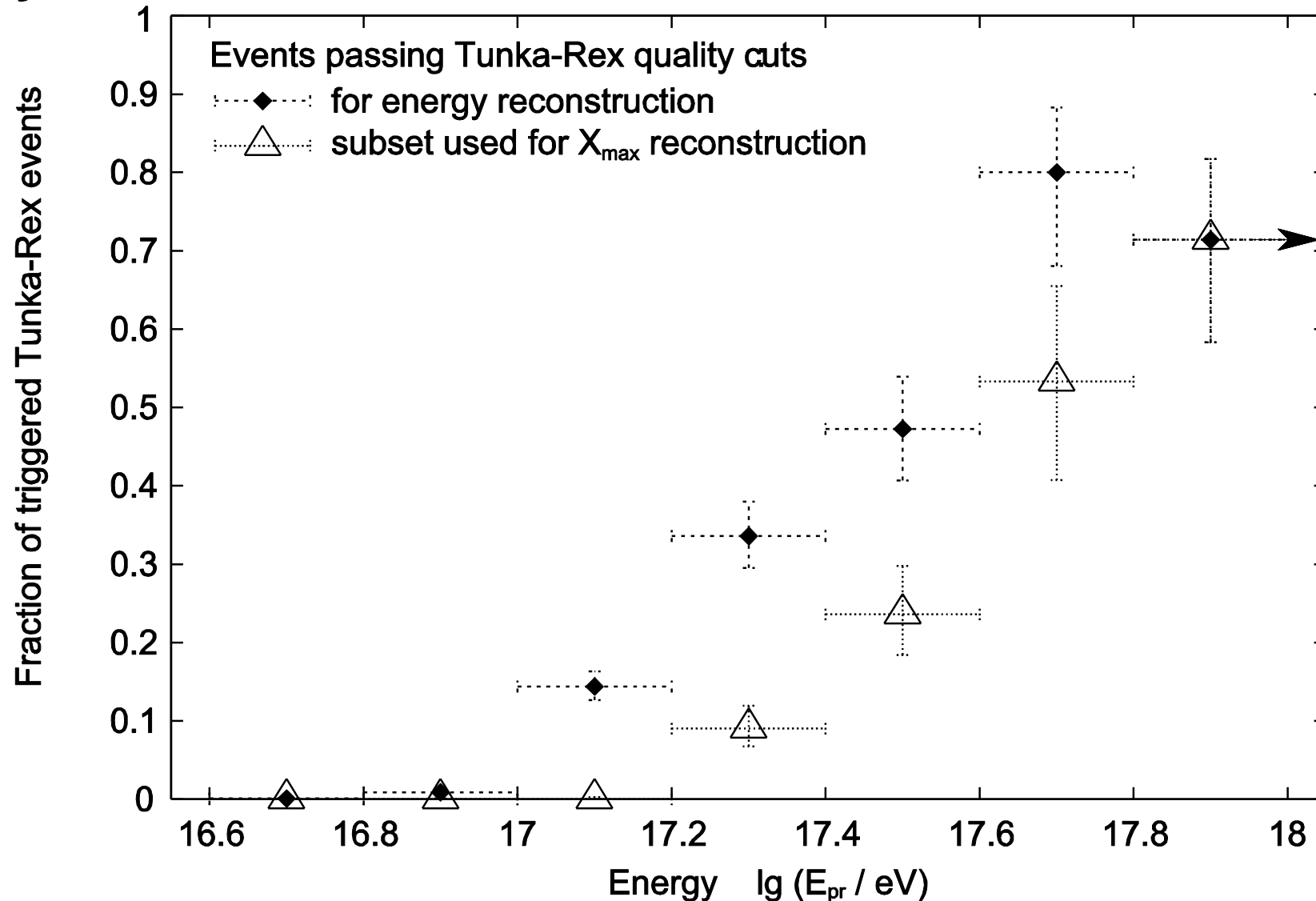
Arrival direction: Tunka-Rex vs. Tunka-133



Timing uncertainties

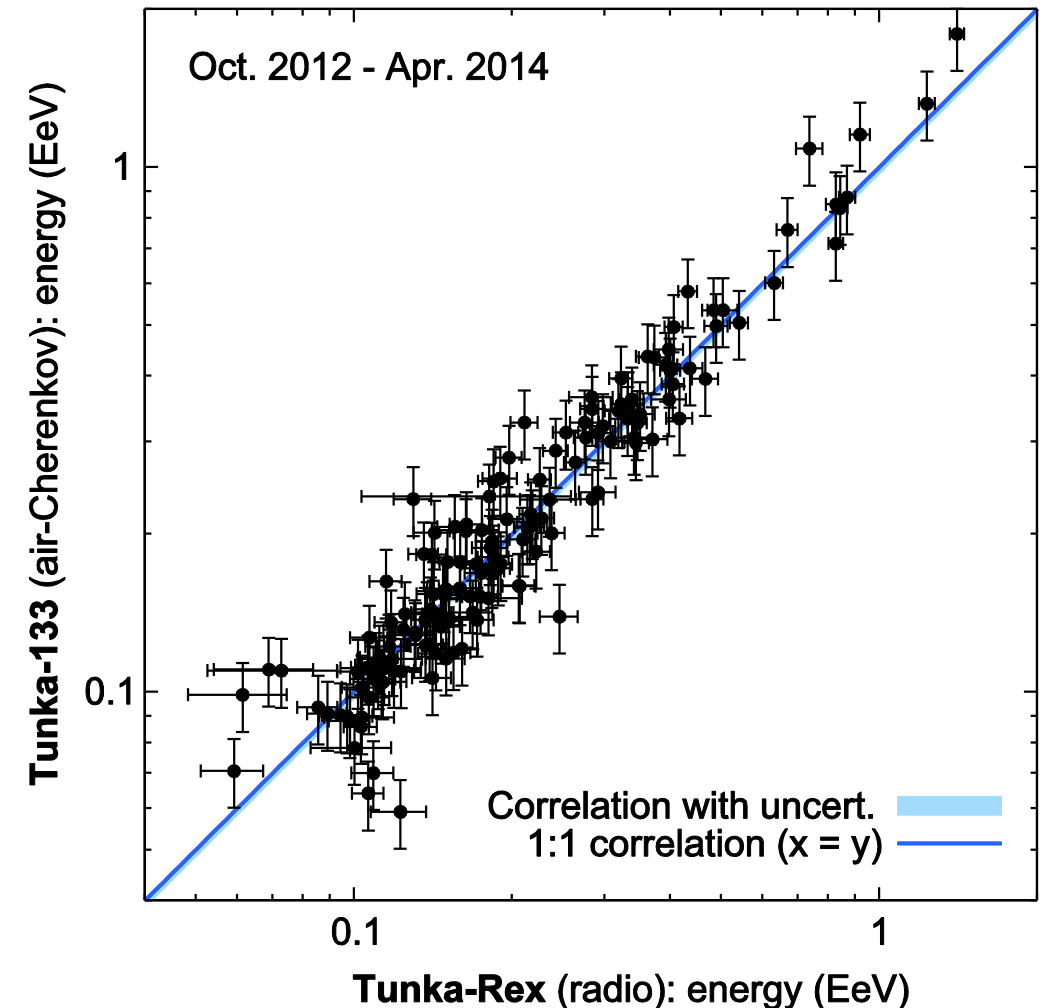
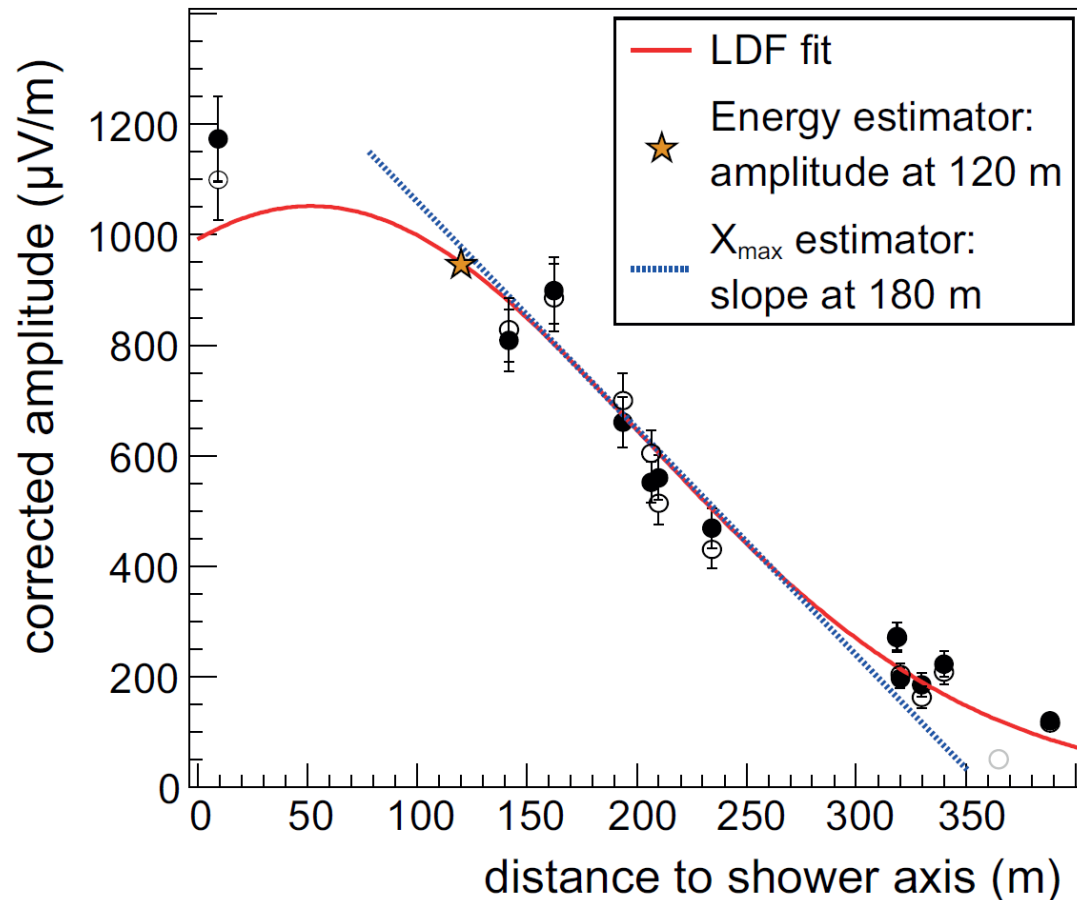
- Total uncertainty: 5 - 10 ns
- Relative contributions studied with simulations + data
 - plane wavefront model 54 %
 - calibration of array 65 %
 - background (noise) 53 %
- squared sum 100 %
- All important, but nothing critical for direction reconstruction

Efficiency of Tunka-Rex standard reconstruction



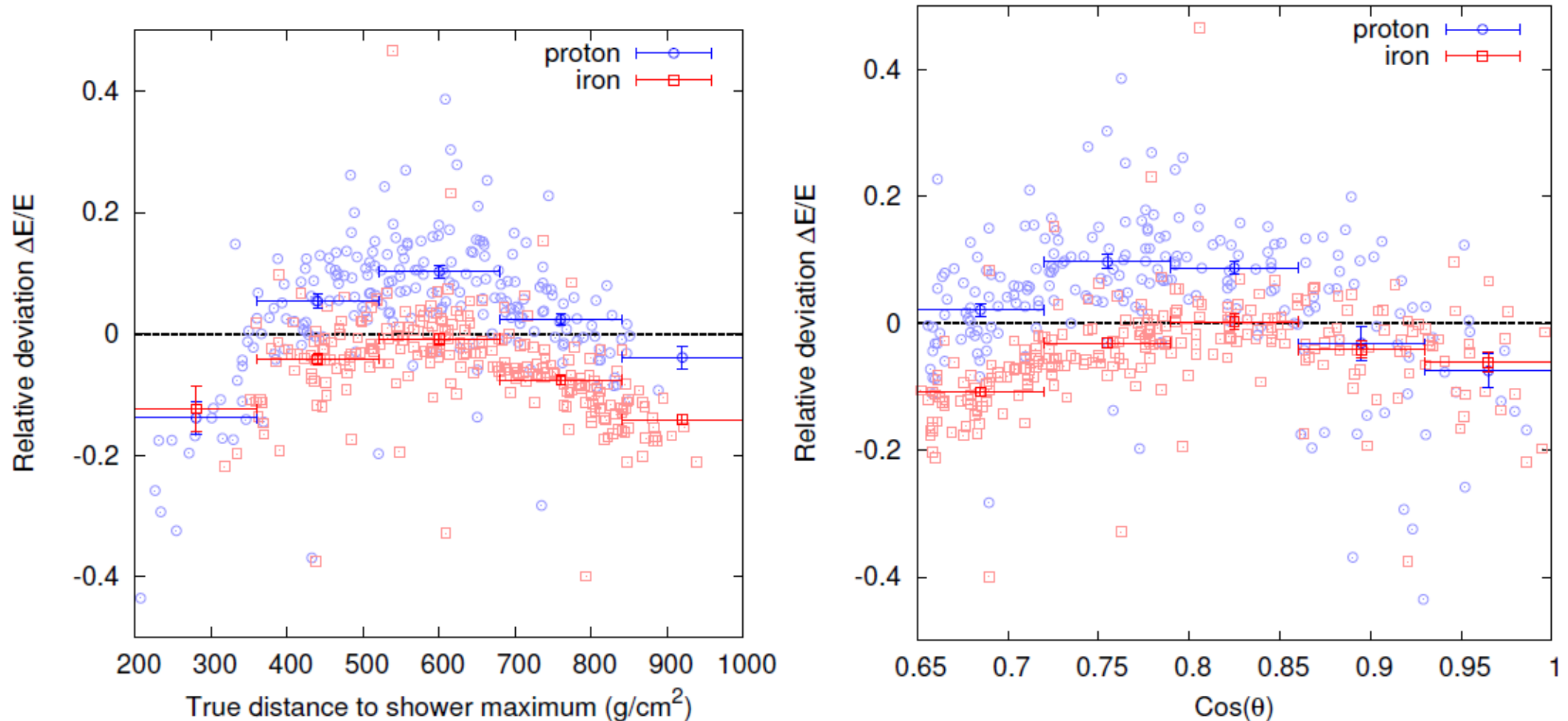
Energy reconstruction

- Energy \sim amplitude at 120 m after geomagnetic and asymmetry correction
- 15 % precision, 20 % scale accuracy



Systematic uncertainties in CoREAS simulations

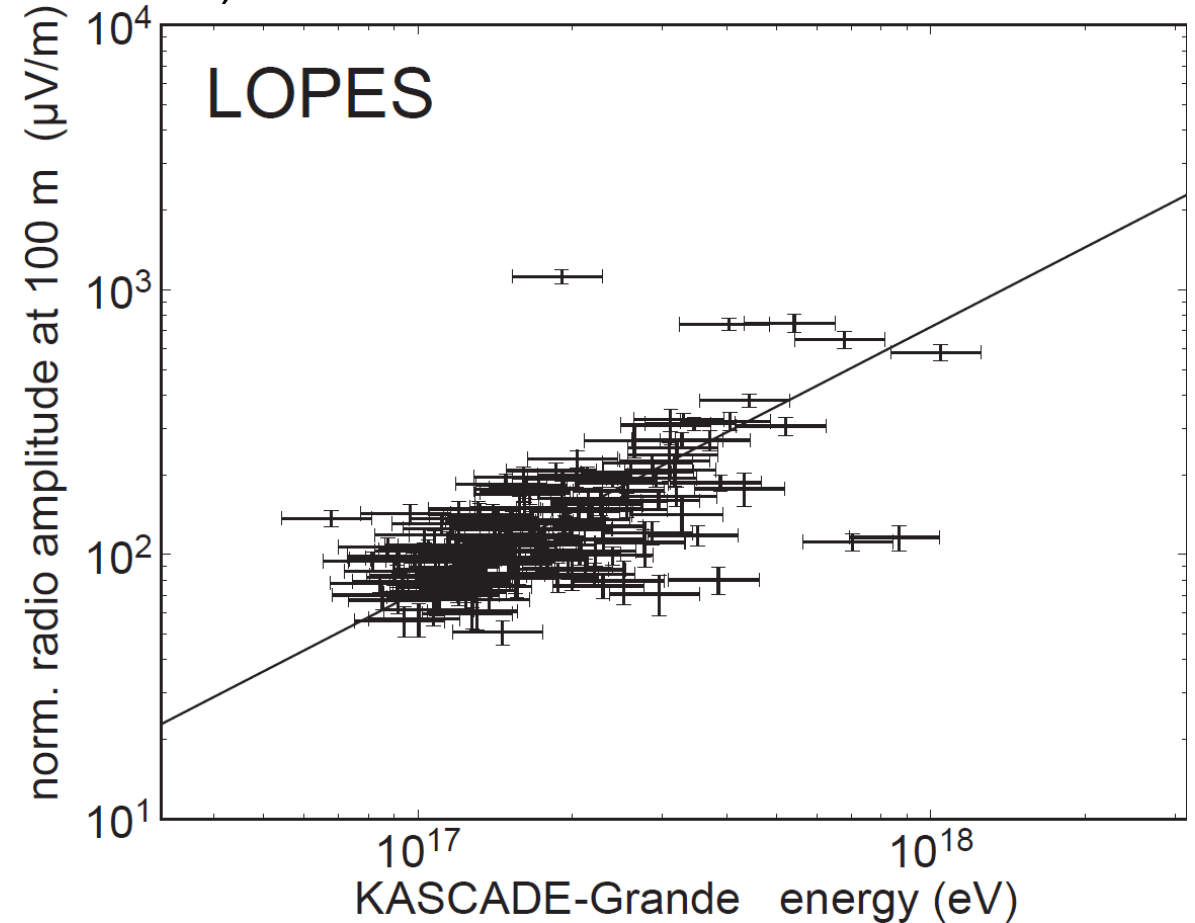
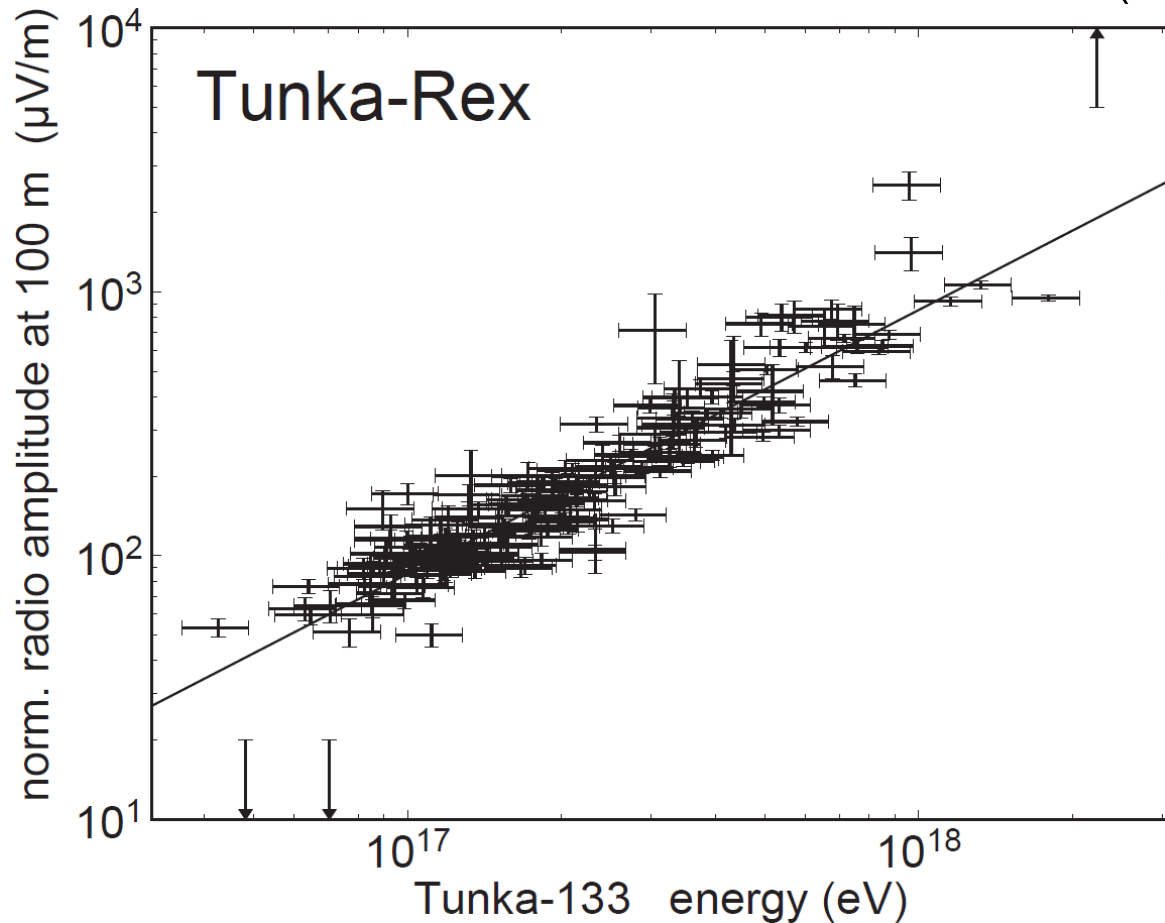
- About 10 % each due to zenith angle and X_{\max} + difference between p and Fe



Comparing energy scales of Tunka and KASCADE-Grande

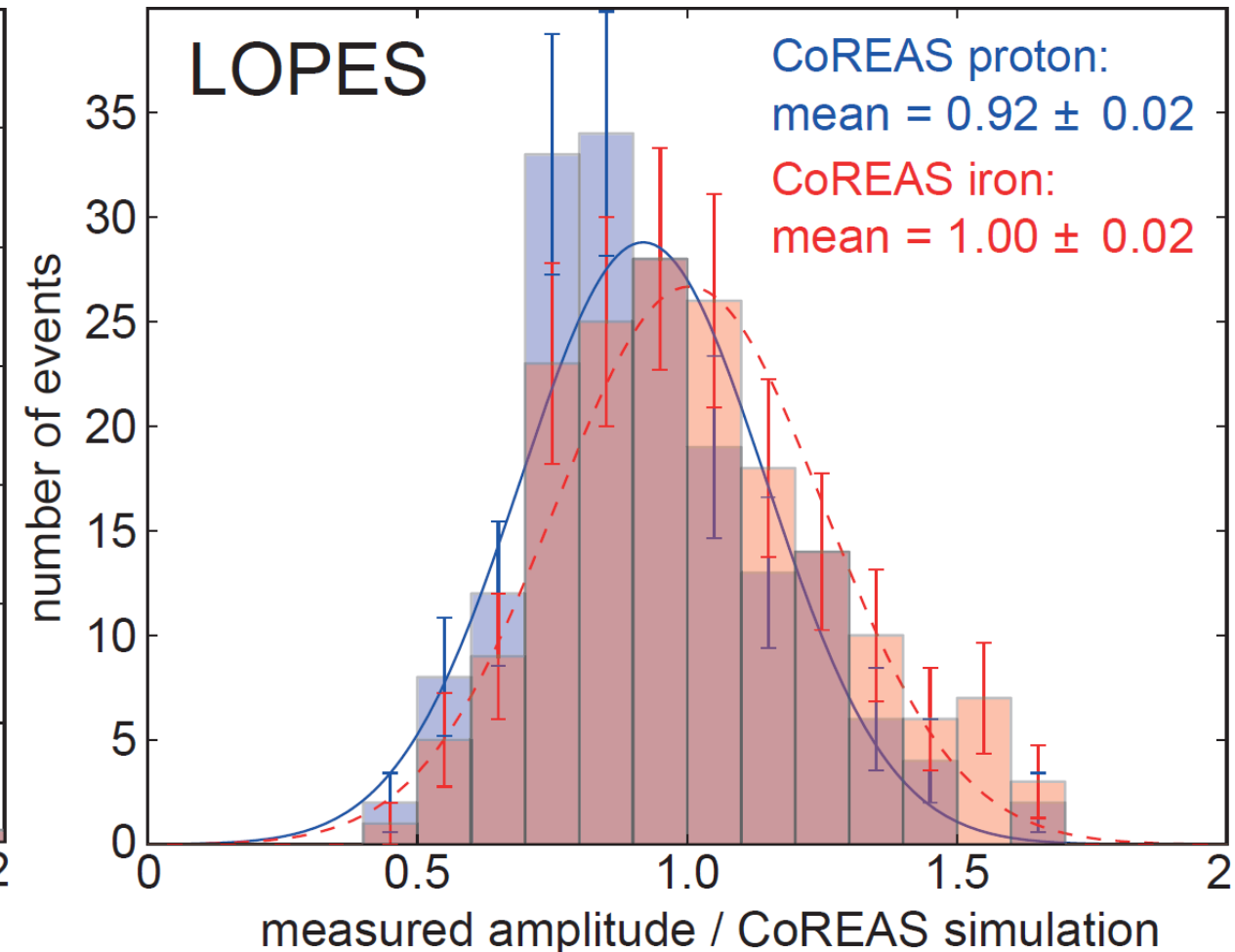
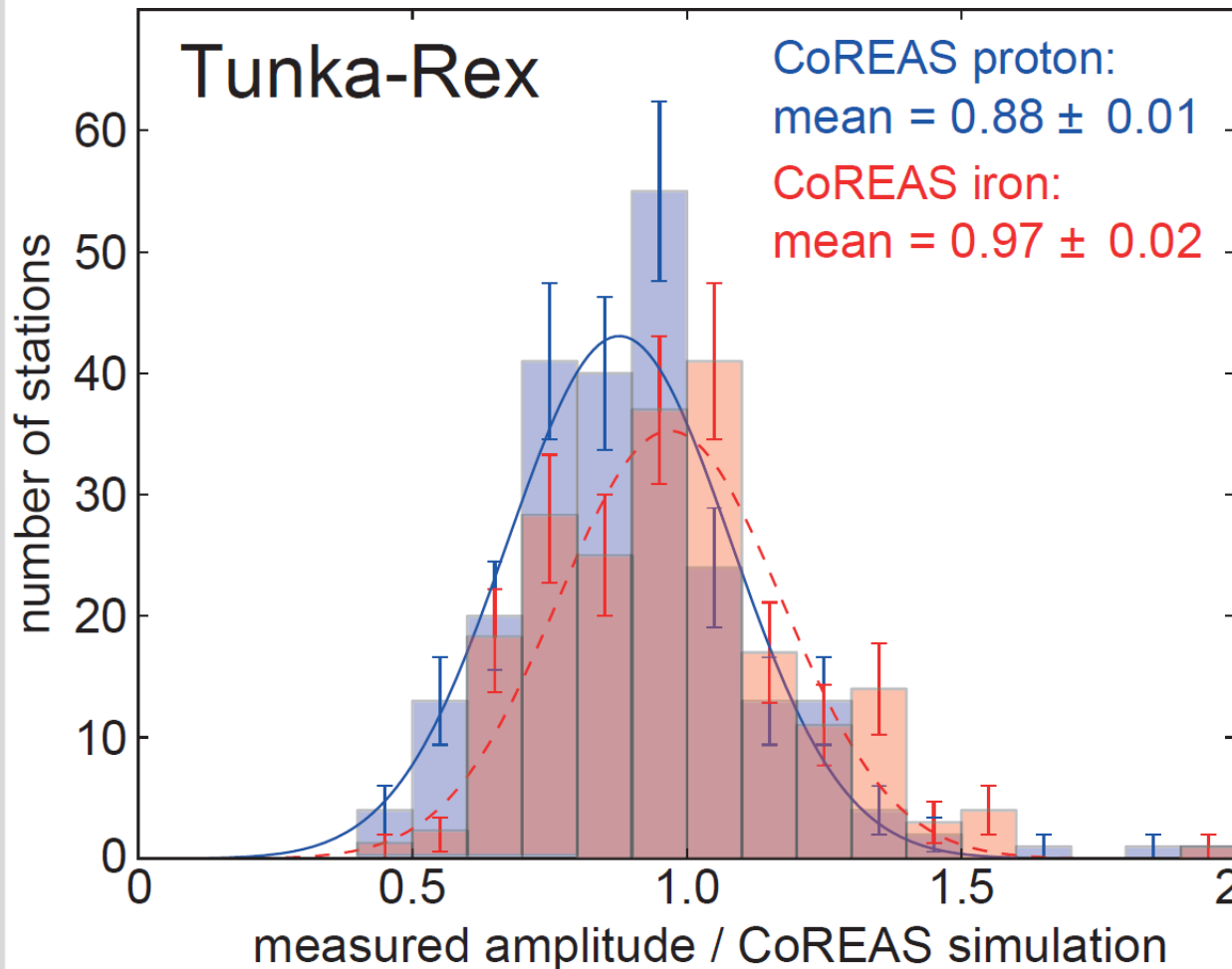
■ Energy scales comparable via radio amplitude at 100 m per energy

■ Uncertainties: 7 % relative calibration (same source) + 9 % different observation levels

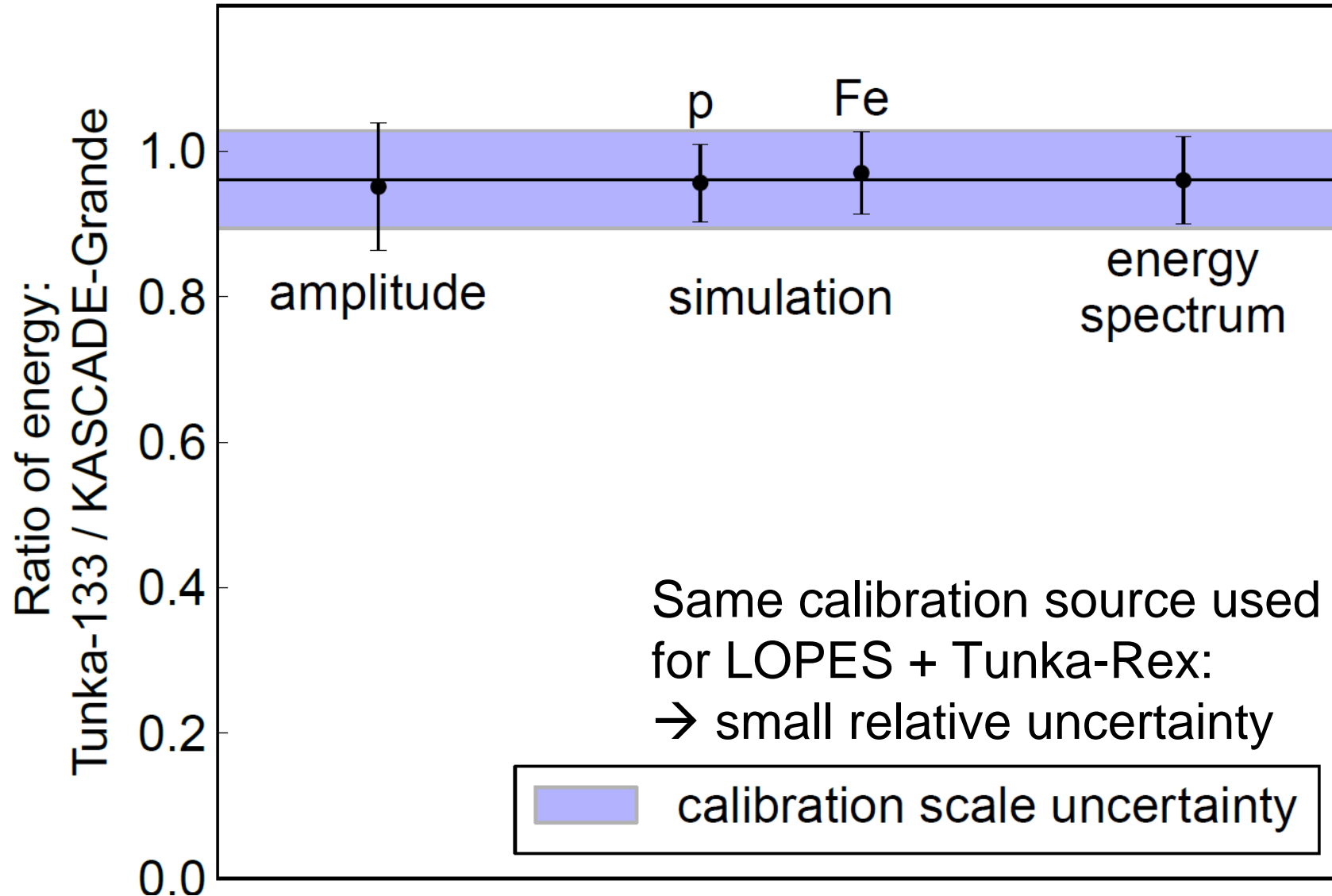


Alternative way: Ratio of measured to simulated amplitude

- CoREAS takes situation of each experiment into account



Result: KASCADE-Grande + Tunka-133 consistent to 10 %



Conclusion

■ Tunka-Rex

- Economic radio extension for Tunka-133 and Tunka-Grande

■ Achieved results

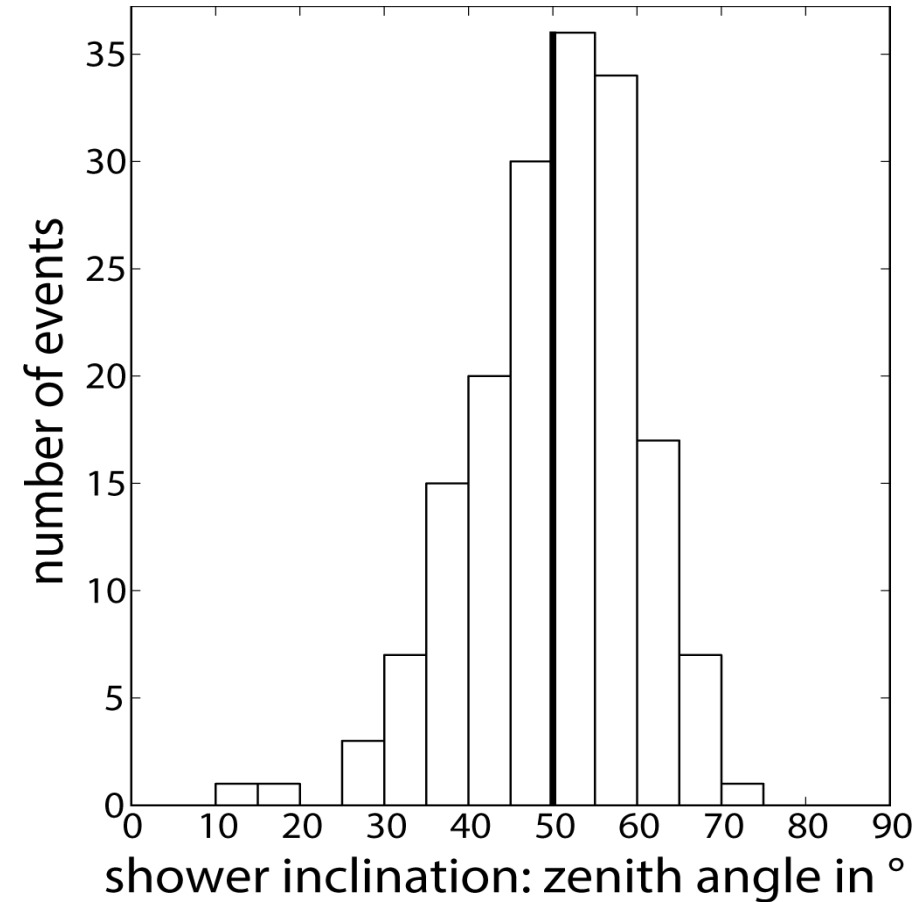
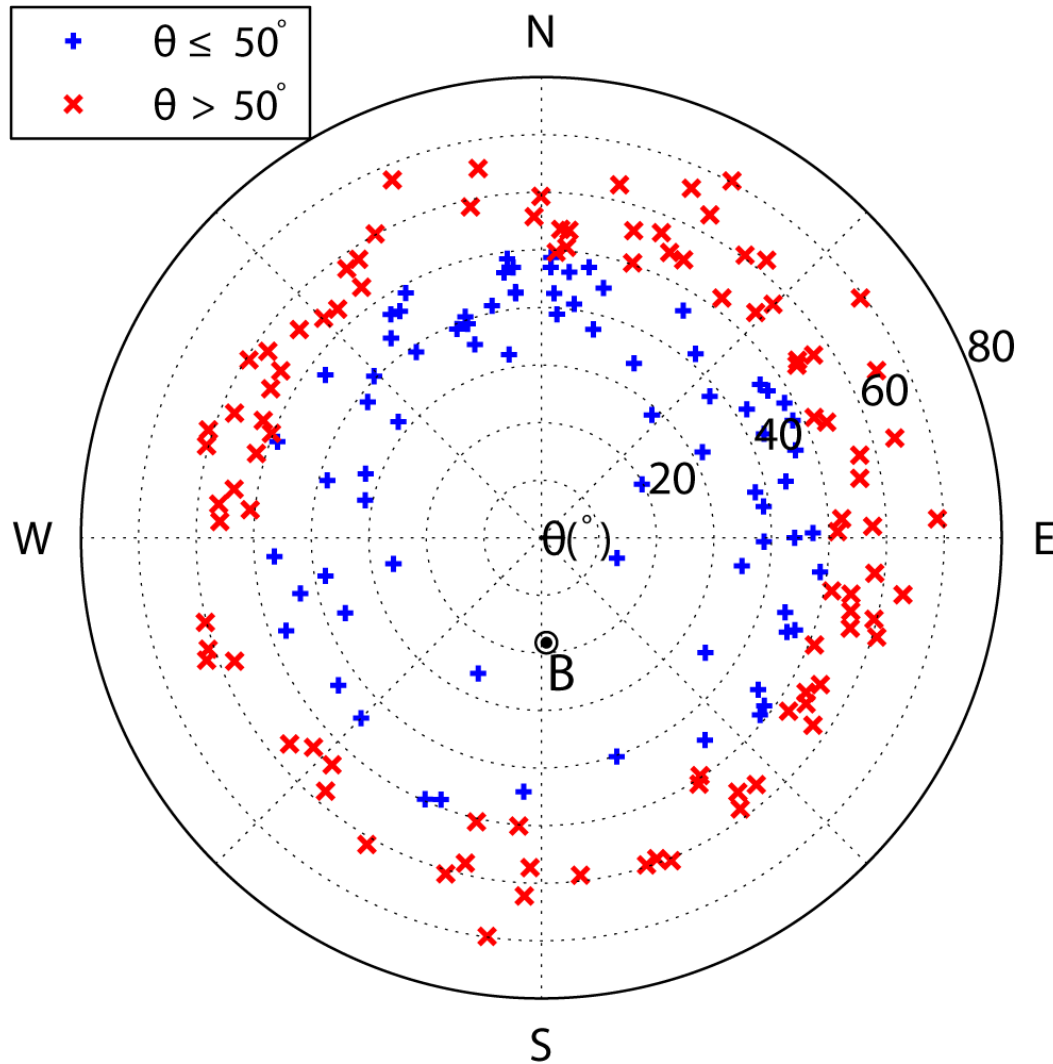
- Energy precision of 15 % with 20 % absolute scale accuracy
- X_{\max} precision of 40 g/cm²
- Energy scale of Tunka-133 and KASCADE-Grande compared via radio

■ Outlook

- Extension to 3 antennas per cluster in summer
- Trigger by Tunka-Grande scintillators will boost the event statistics

Backup

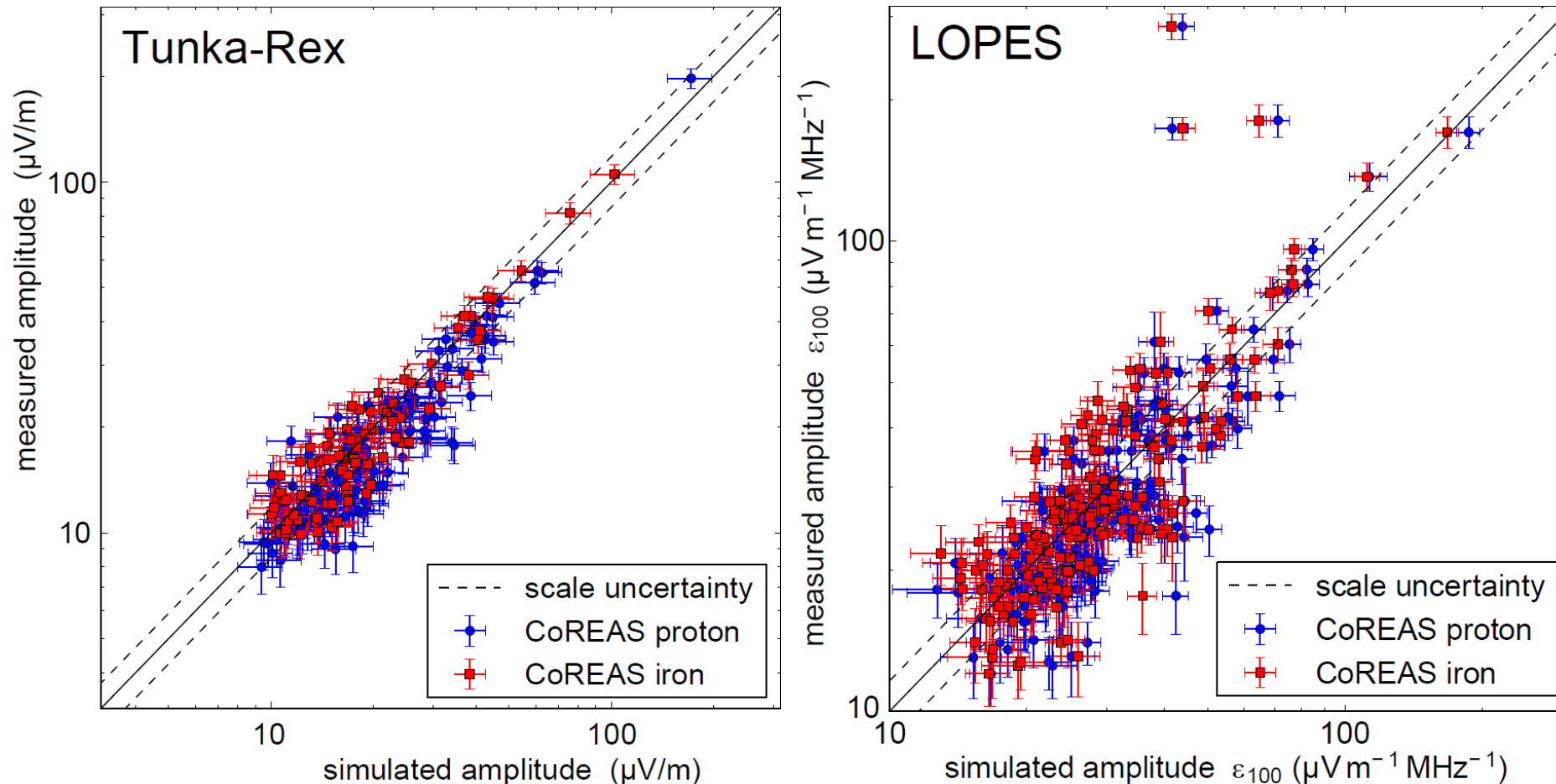
Events of first season (Oct 2012 – Apr 2013)



+: 77 events **x**: 97 events in 450 hours; $E > 10^{17}$ eV

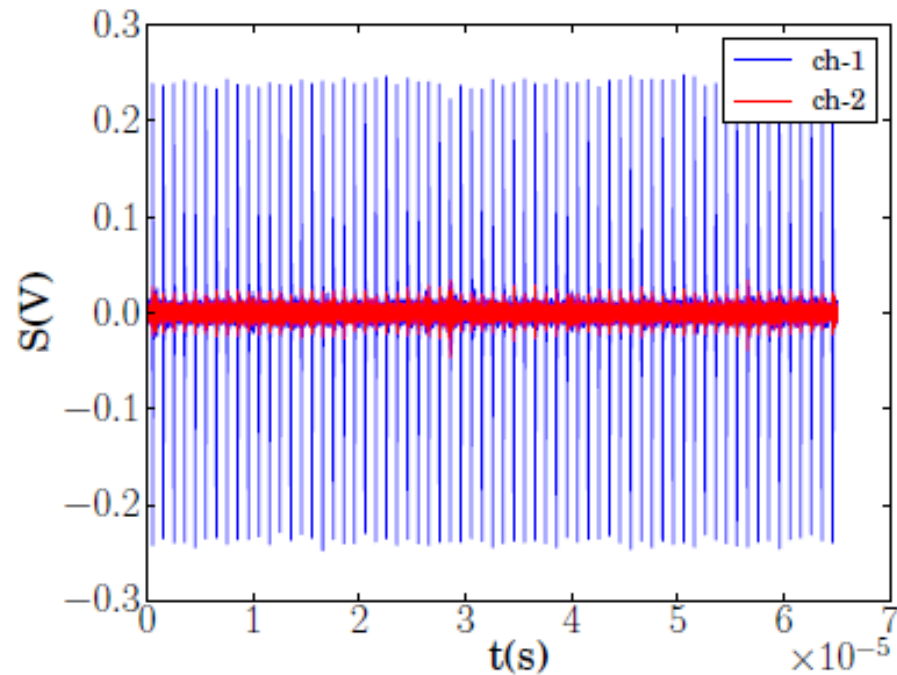
Comparison of energy scales

- Simulations with energy reconstructed by host experiments



Amplitude Calibration

- Commercial reference source used already by LOPES experiment



Uncertainties on radio amplitude

- Absolute scale for primary energy accurate to about 20 %

Level	Origin	Uncertainty (%)
Antenna-to-antenna	positioning and alignment	2
	antenna production	1
	Total	2
Event-to-event	antenna model	12
	environmental temperature	4
	ground conditions	3
	crosstalk	2
	Total	13
Absolute scale	source calibration	16
	temperature during calibration	6
	source positioning + alignment	3
	Total	17
Total		22