# Giant Radio Array for Neutrino Detection

# Xmax Study

Claire Guépin, Anne Zilles

**Setup and previous work**

- *Inclined UHECR air showers*, **proton** or **iron** progenitor.
- Impact of progenitor energy, spacing between antennas, frequency band, mountain slope, inclination (zenith).

**Updates**

- Antenna response included, using ComputeVoltage
  - ‣ power of voltage traces used for reconstruction
  - ‣ power integrated over 41 bins (time window)
  - ‣ sampling of 2ns
- Noise included: amplitude 15muV
- Threshold included: 2x15muV or 5x15muV
- Core position uncertainty: random gaussian with standard deviation = step
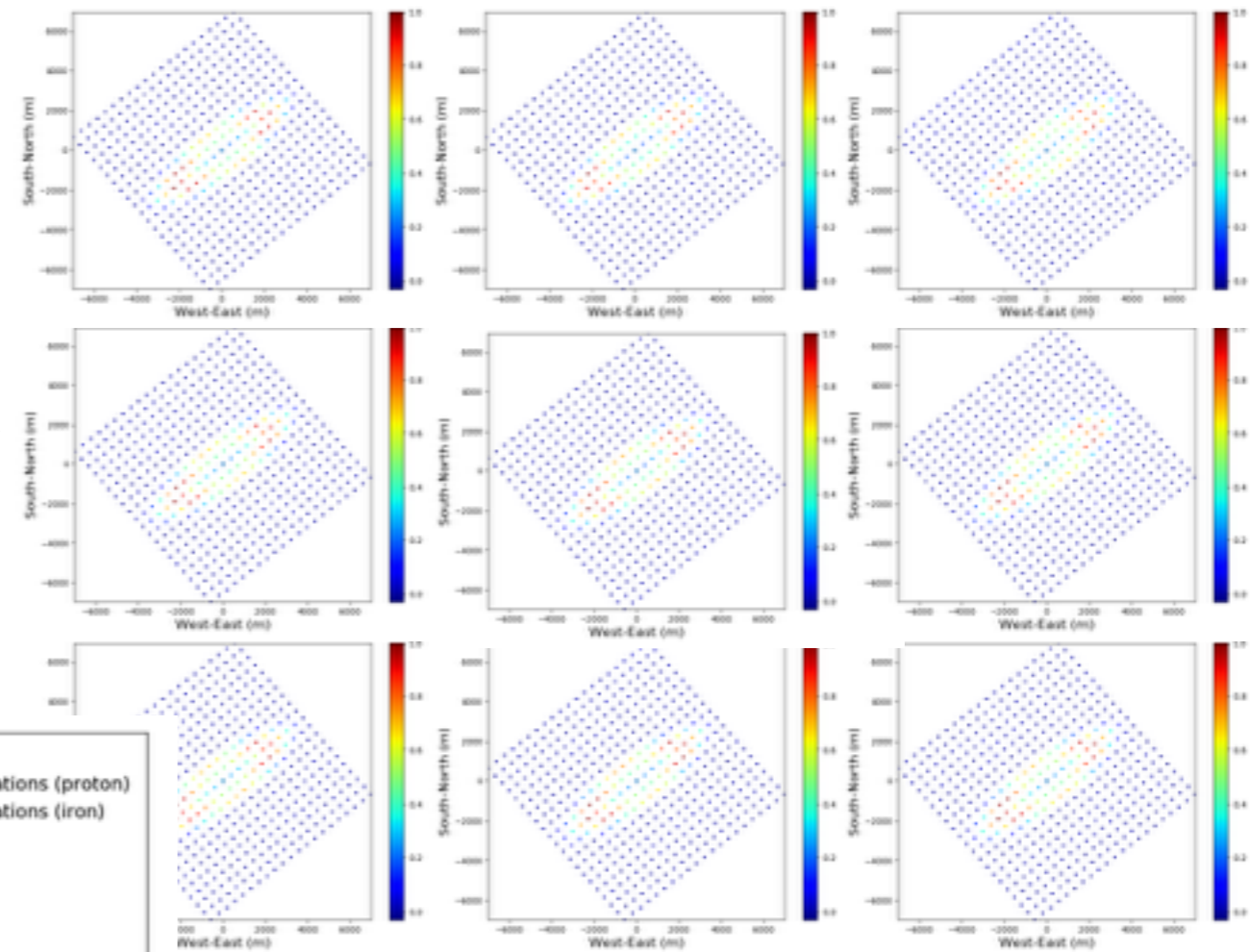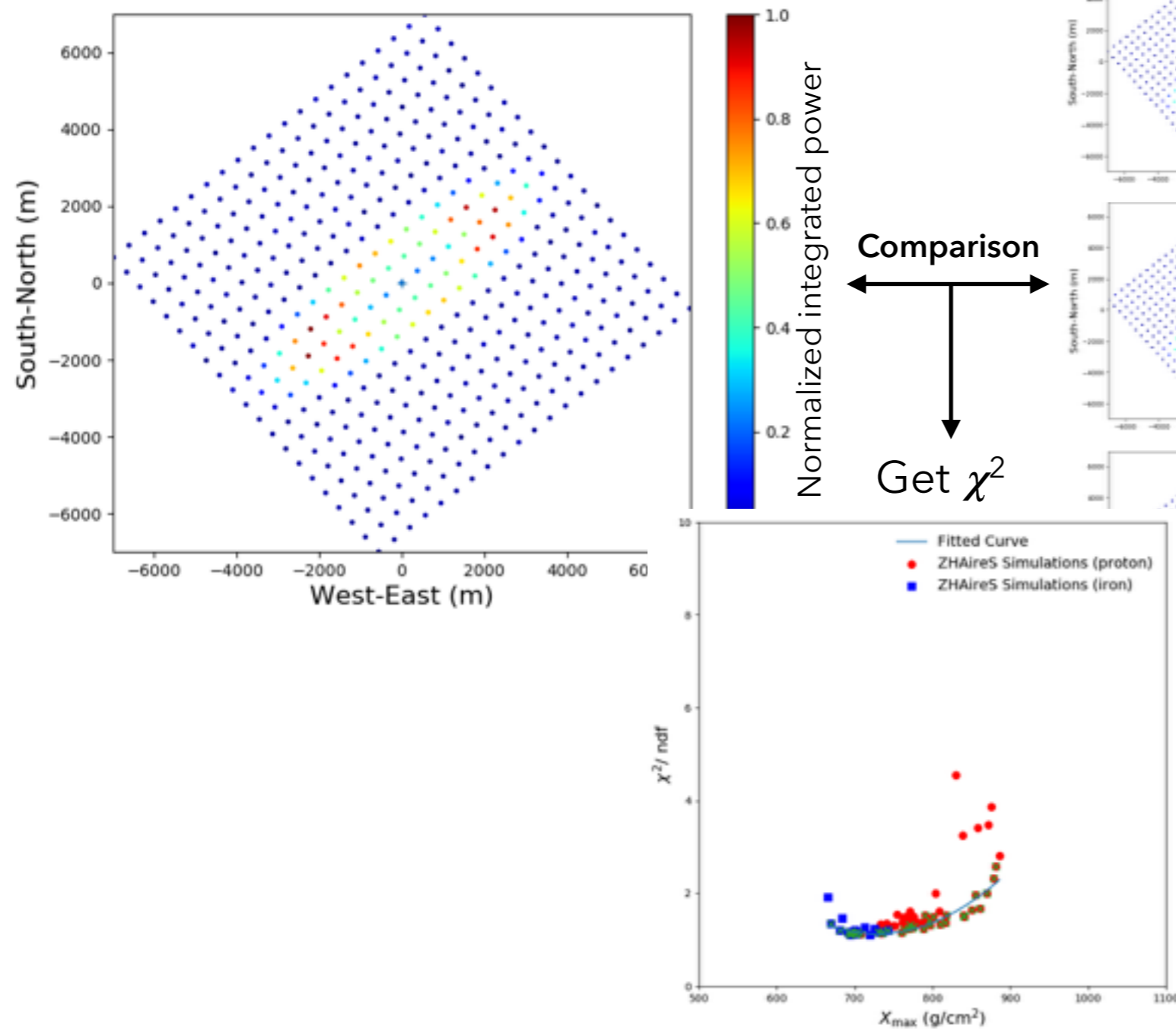
**Limitations**

- No uncertainty on zenith, azimuth and energy
- No realistic topography, flat array

# Reconstruction method - Reminder

For each parameter set, 70 simulations (50 proton, 20 iron).

**One simulation = "fake data" (known Xmax)**

**Simulation set (same properties, known Xmax)**



Normalized integrated power

**Comparison**

Get $\chi^2$

Minimum of parabola fit
= reconstructed shower depth

# Impact of zenith angle

**Fixed parameters**
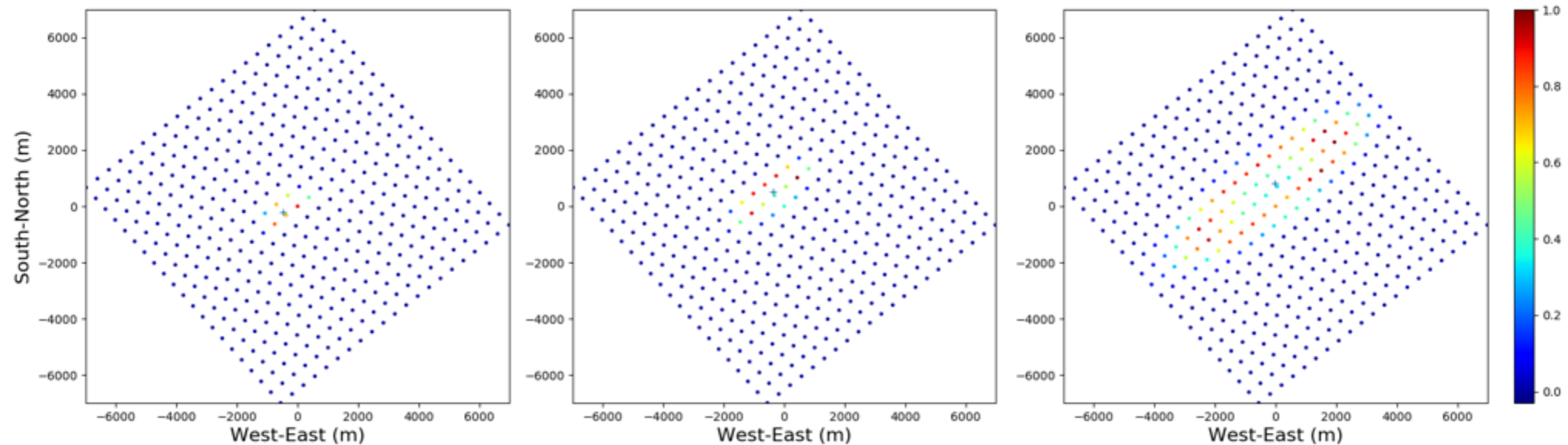- energy $10^{19}$ eV
- azimuth 40°
- mountain slope 10°

frequency band : 50 - 200 MHz
step 500 m

**Footprints**

# Impact of zenith angle

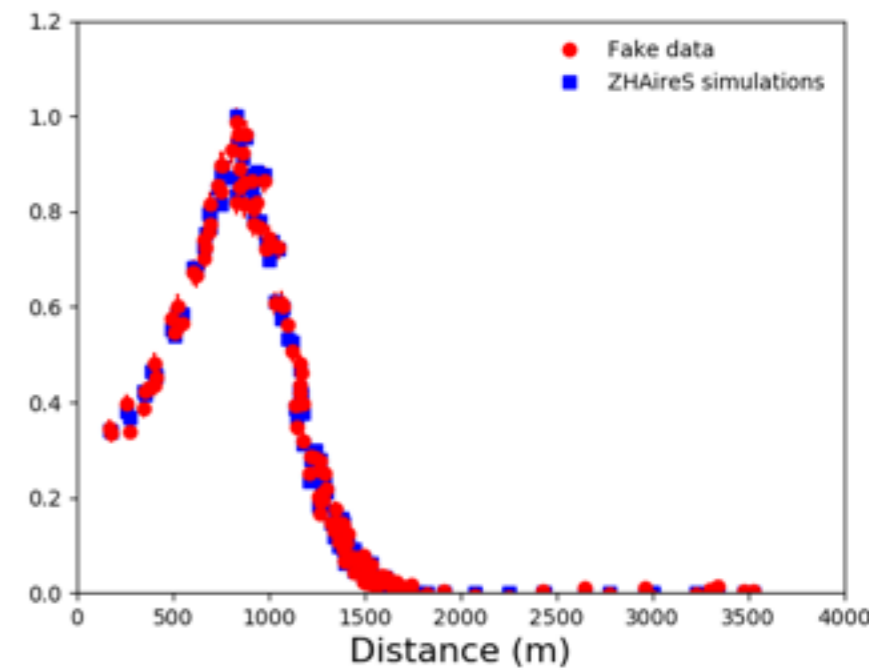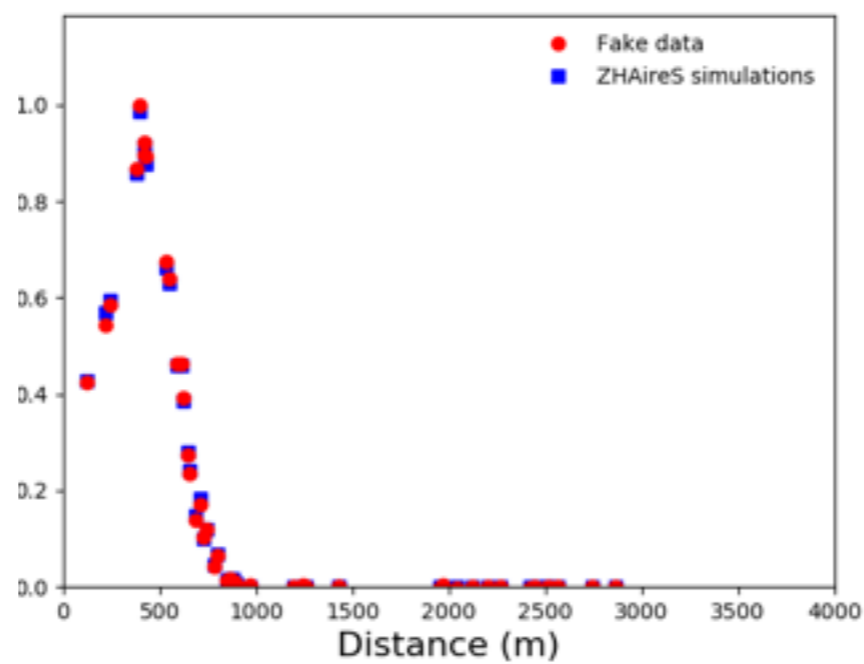**Fixed parameters**
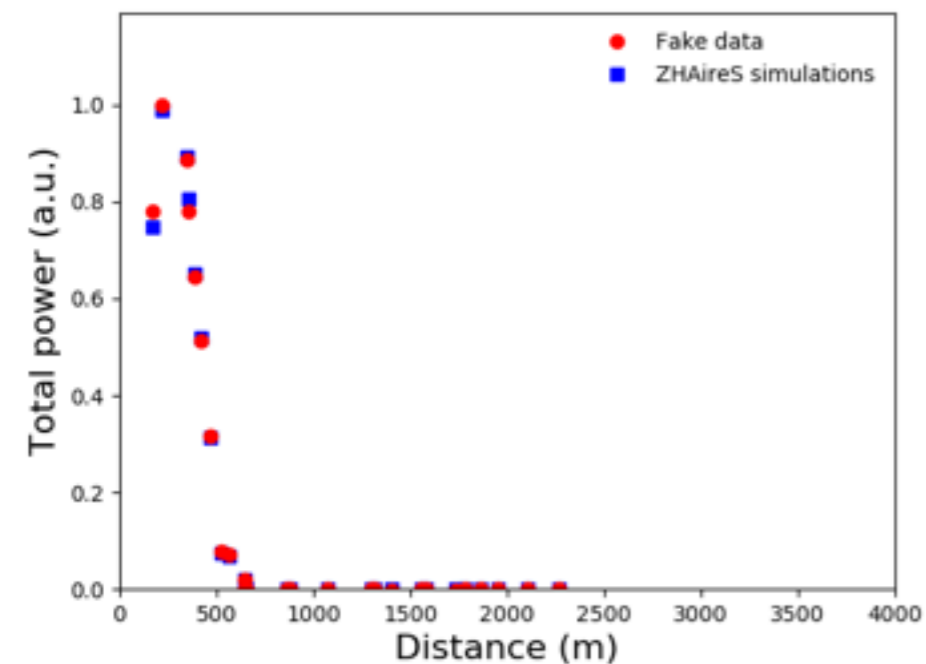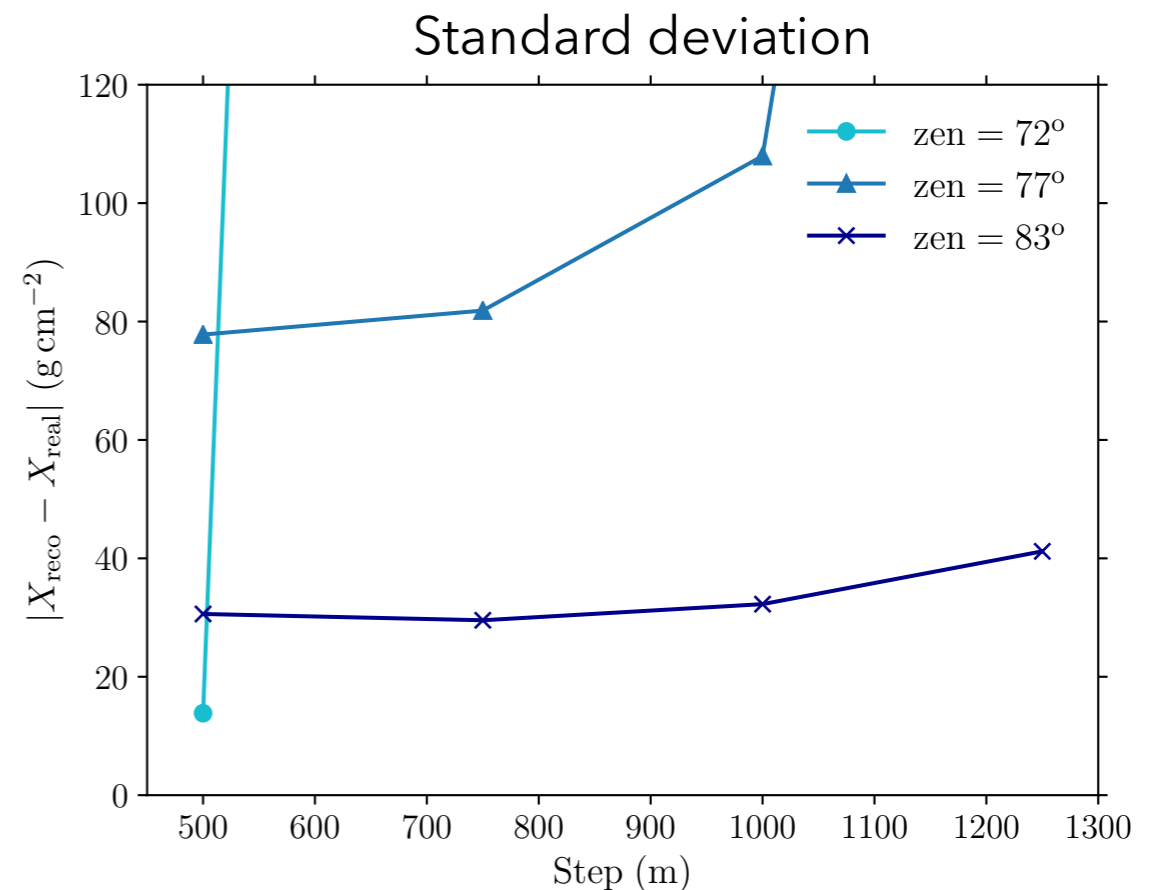
- energy $10^{19}$ eV
- azimuth 40°
- mountain slope 10°

frequency band : 50 - 200 MHz
step 500 m

**Power - lateral distribution function**



zenith 72°



zenith 77°



zenith 83°
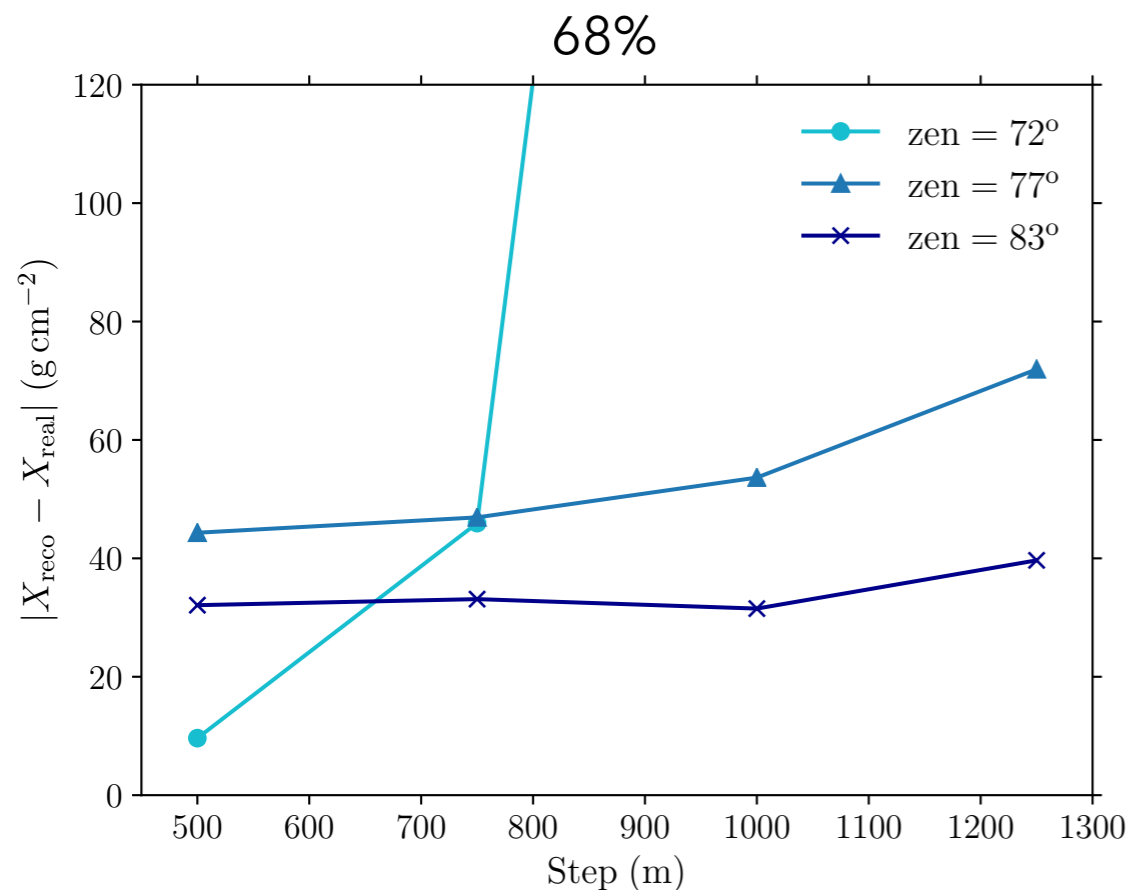
# Impact of zenith angle

**Fixed parameters**

- energy $10^{19}$ eV
- azimuth 40°
- mountain slope 10°

frequency band : 50 - 200 MHz



- zenith = 77° and 83°: larger footprint for 83°, better reconstruction.
- zenith = 72°: very small footprint, no reconstruction for sparse array, **but good reconstruction for dense array (?)**

# Impact of energy and spacing

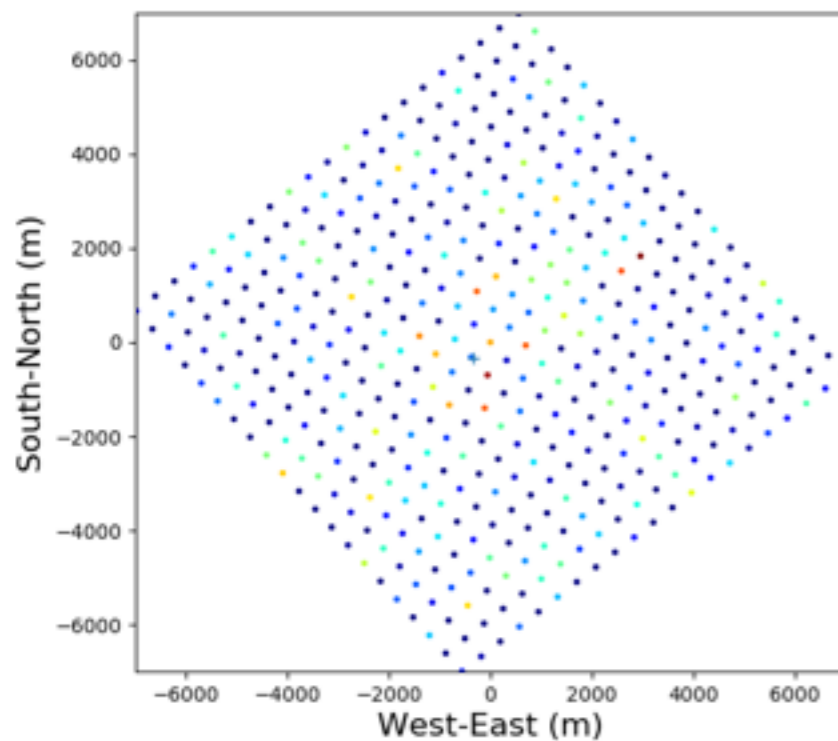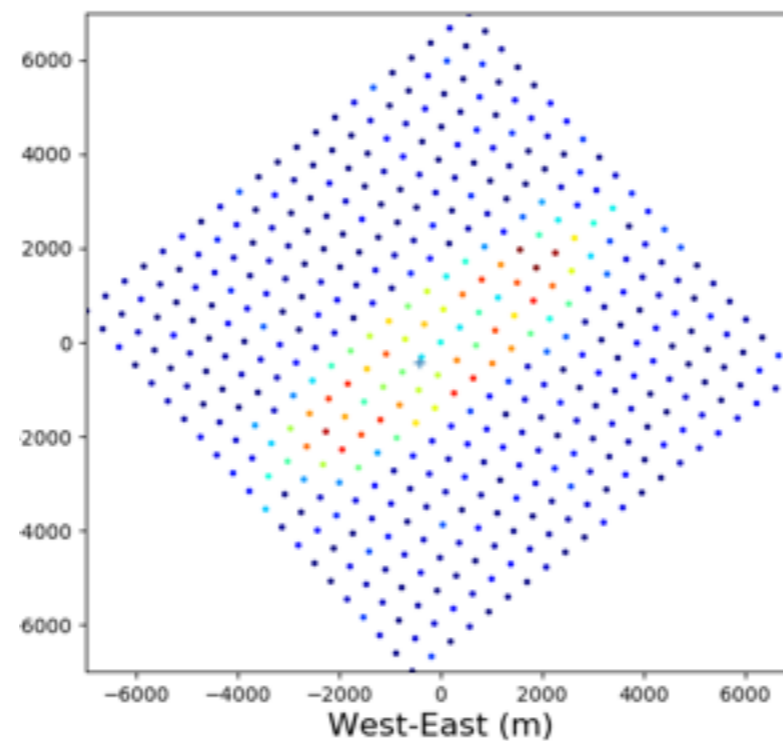**Fixed parameters**

- zenith 83°
- azimuth 40°
- mountain slope 10°

frequency band : 50 - 200 MHz
step 500 m

**Footprints**

# Impact of energy and spacing

**Fixed parameters**

- zenith 83°
- azimuth 40°
- mountain slope 10°

frequency band : 50 - 200 MHz
step 500 m

**Power - lateral distribution function**
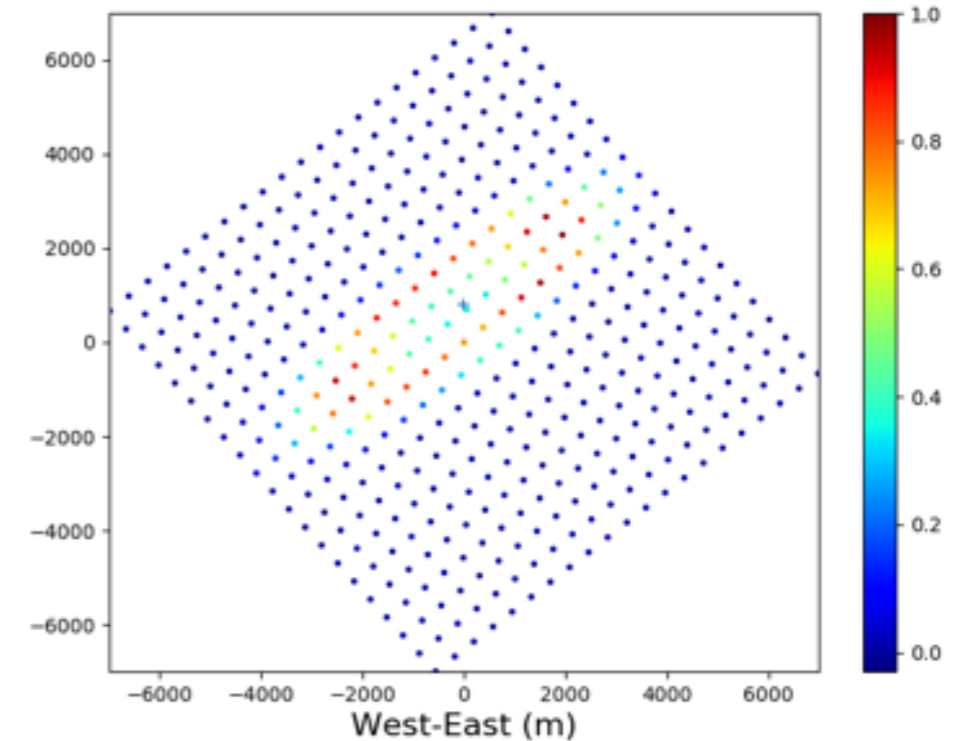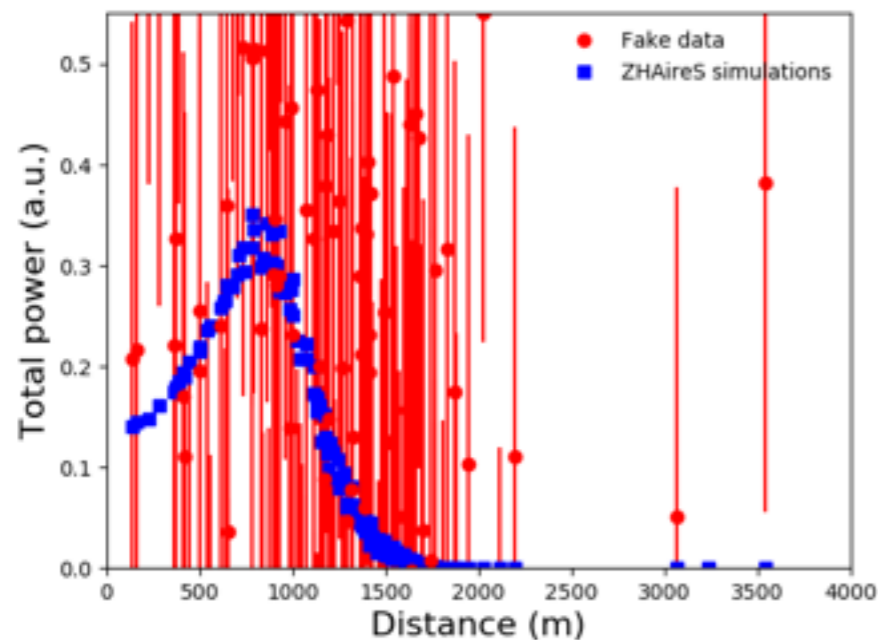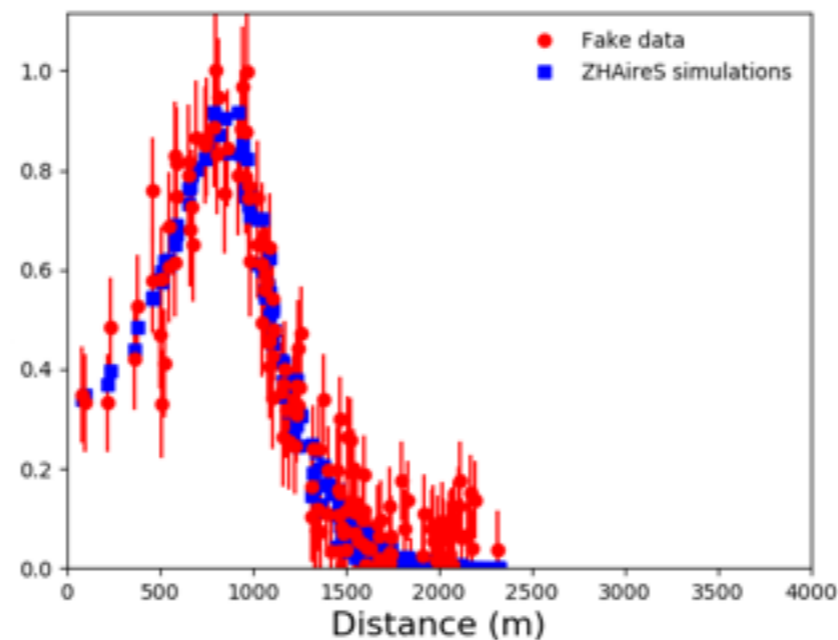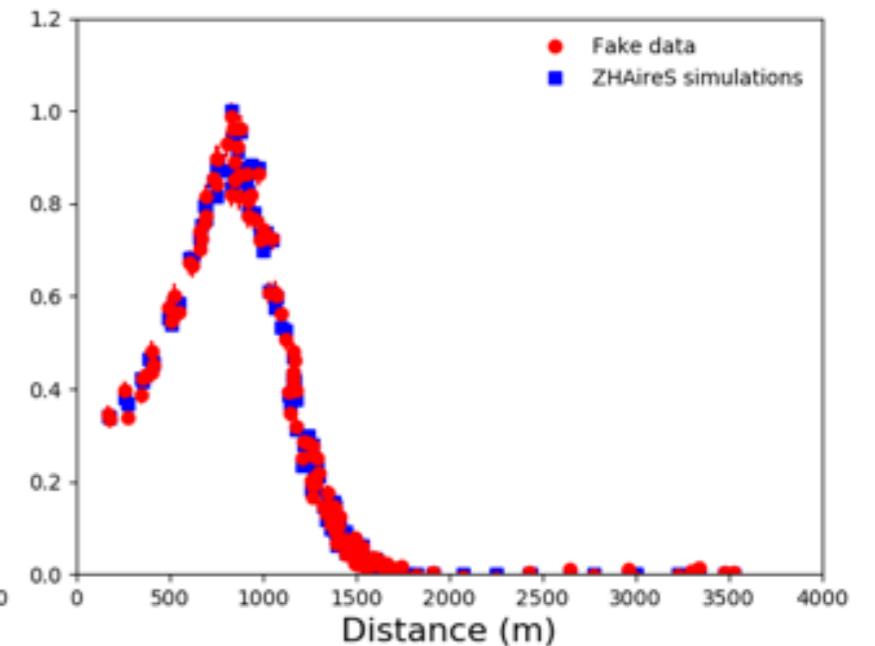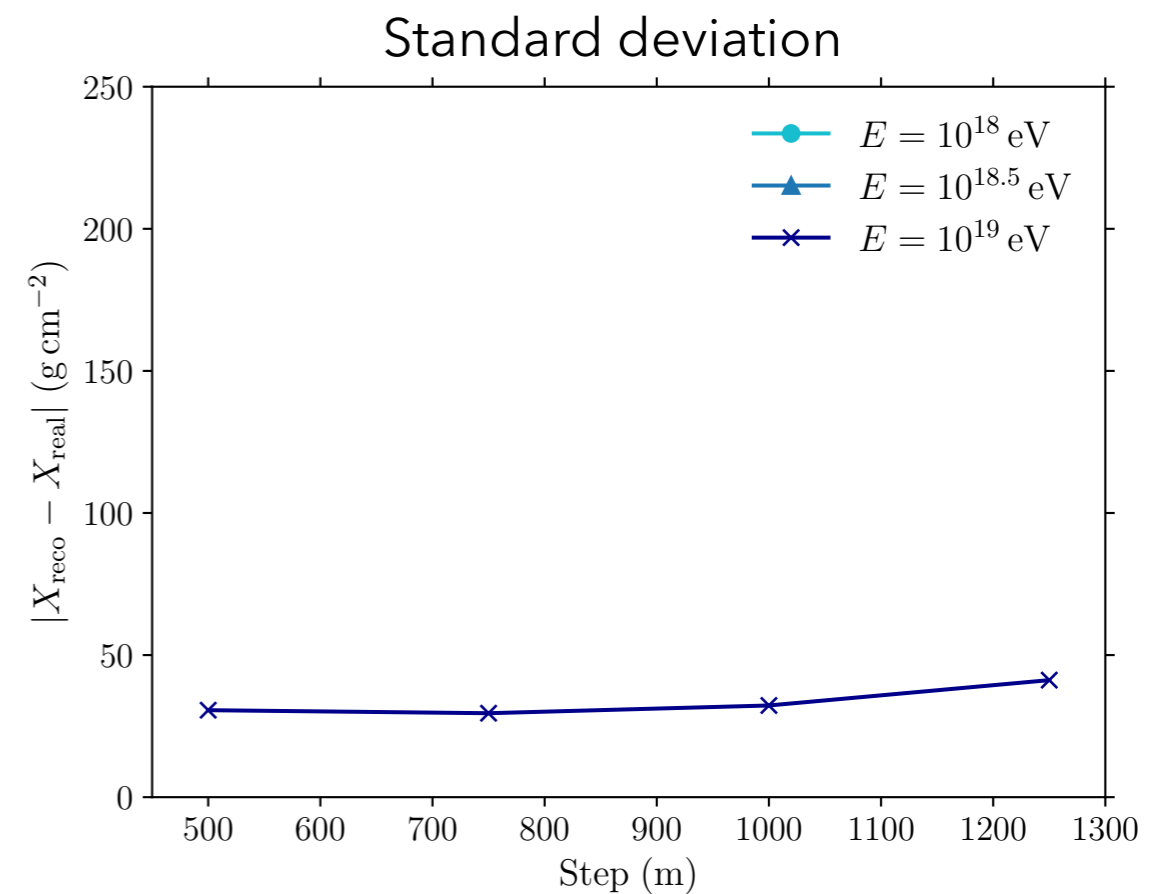
$10^{18}$ eV

$10^{18.5}$ eV

$10^{19}$ eV

# Impact of energy and spacing

**Fixed parameters**

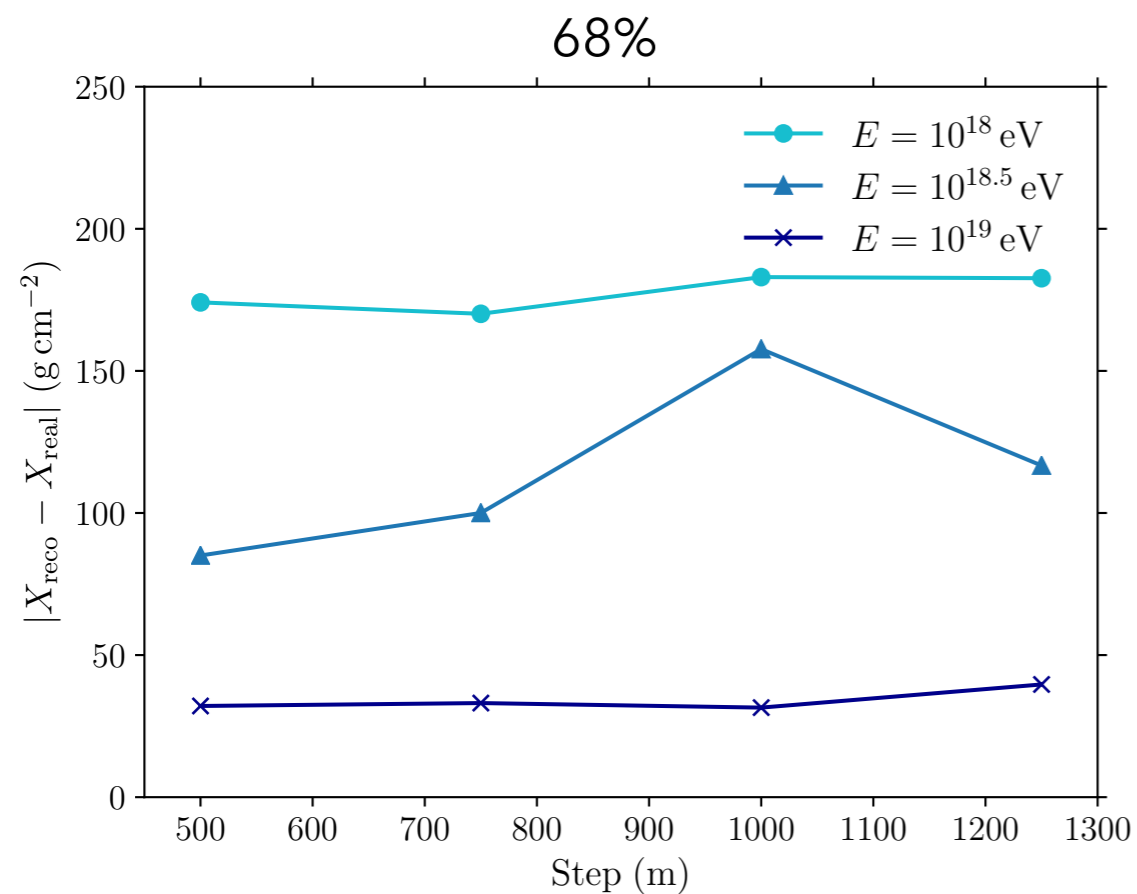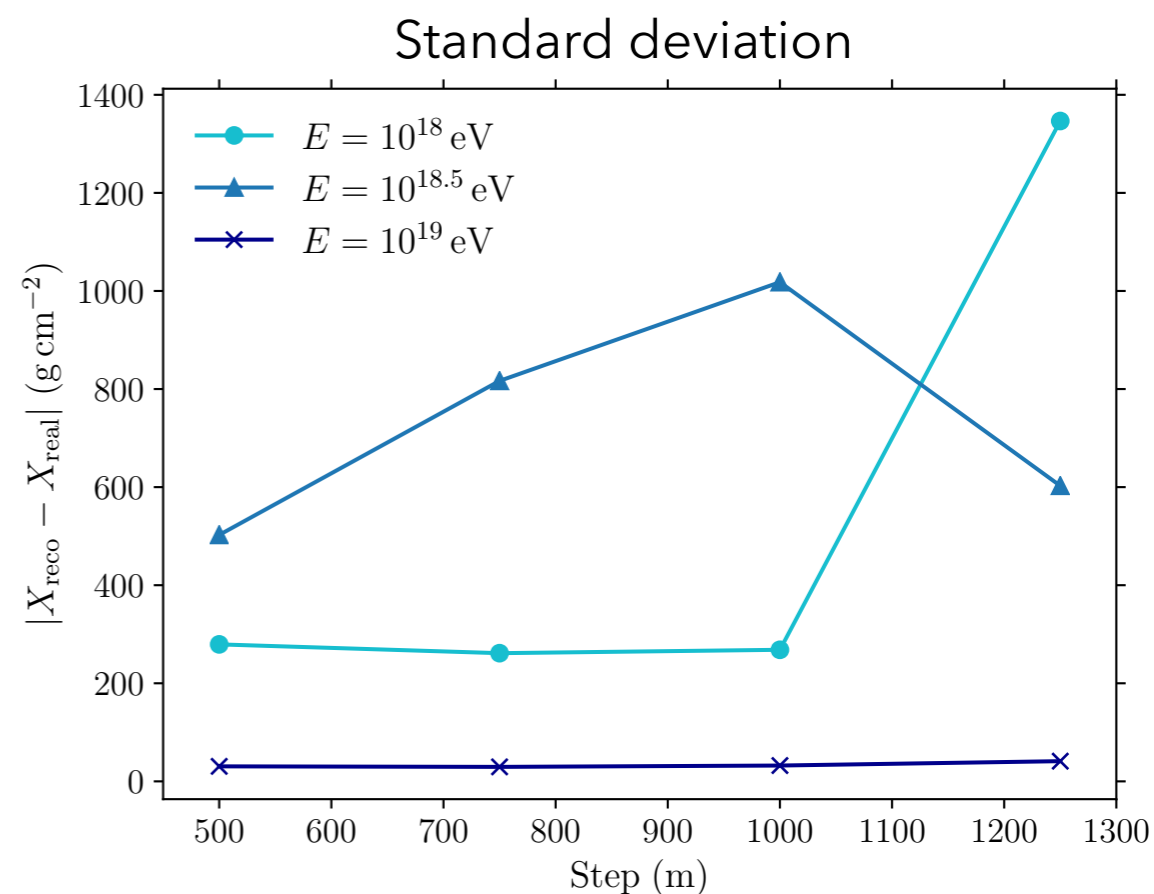- zenith 83°
- azimuth 40°
- mountain slope 10°

frequency band : 50 - 200 MHz
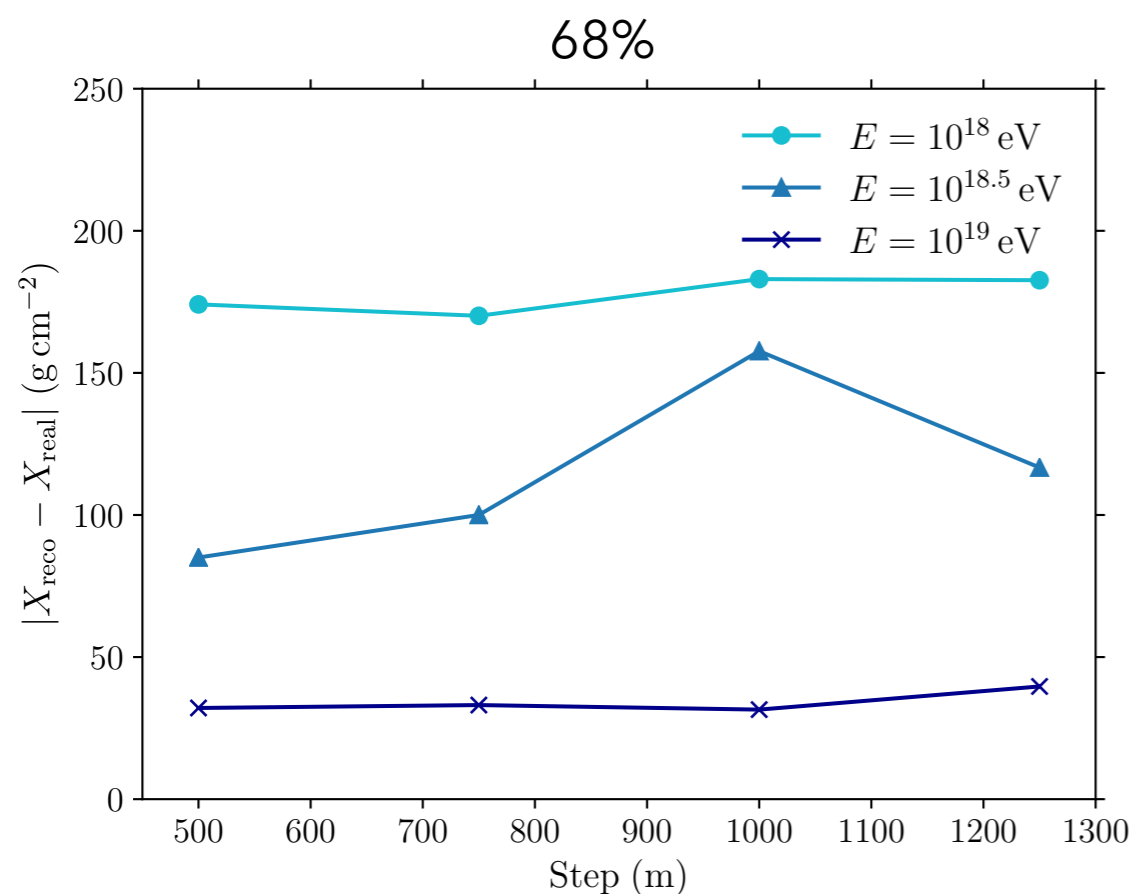
# Impact of energy and spacing

**Fixed parameters**

- zenith 83°
- azimuth 40°
- mountain slope 10°
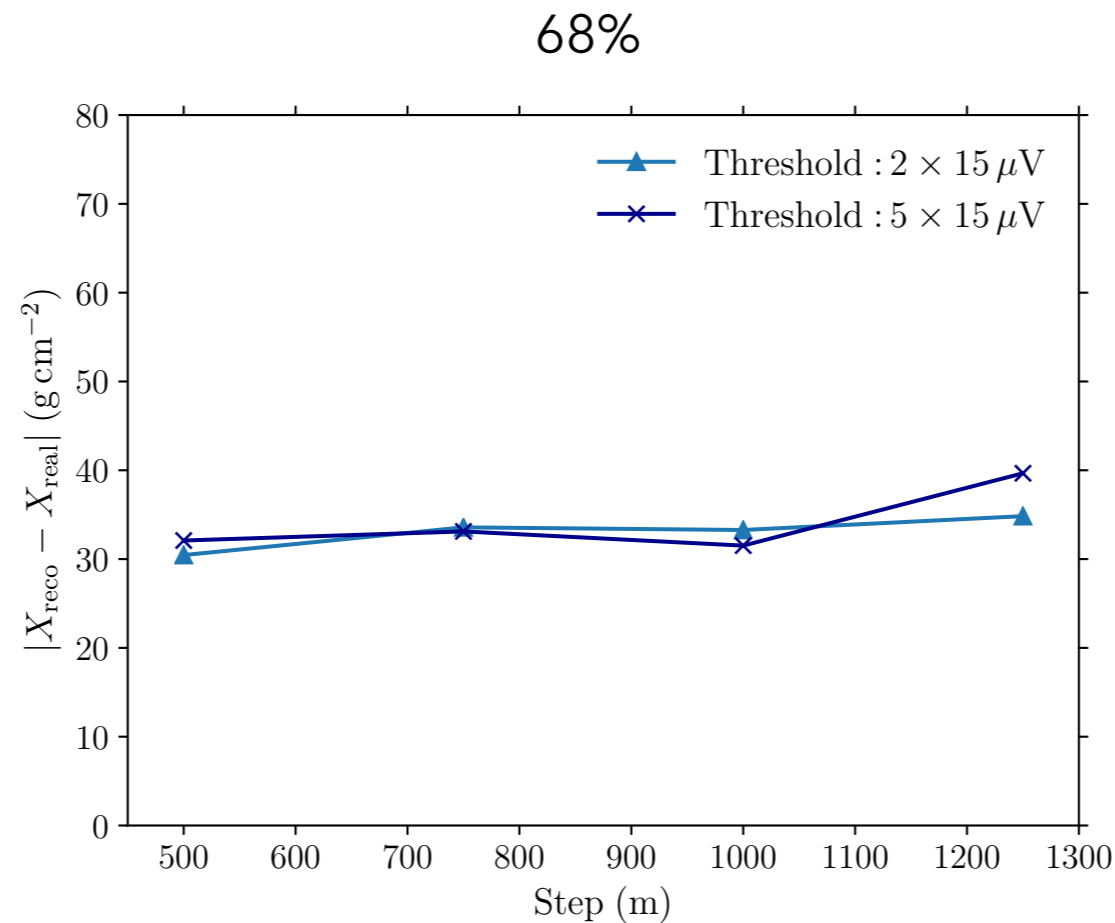
frequency band : 50 - 200 MHz



68%



Standard deviation

- difficulties to deal with the noise with this method: power is too low at energies below $10^{19}$ eV to obtain an acceptable reconstruction.

# Impact of antenna threshold

**Fixed parameters**

- energy $10^{19}$ eV
- zenith 83°
- azimuth 40°
- slope 10°

frequency band : 50 - 200 MHz
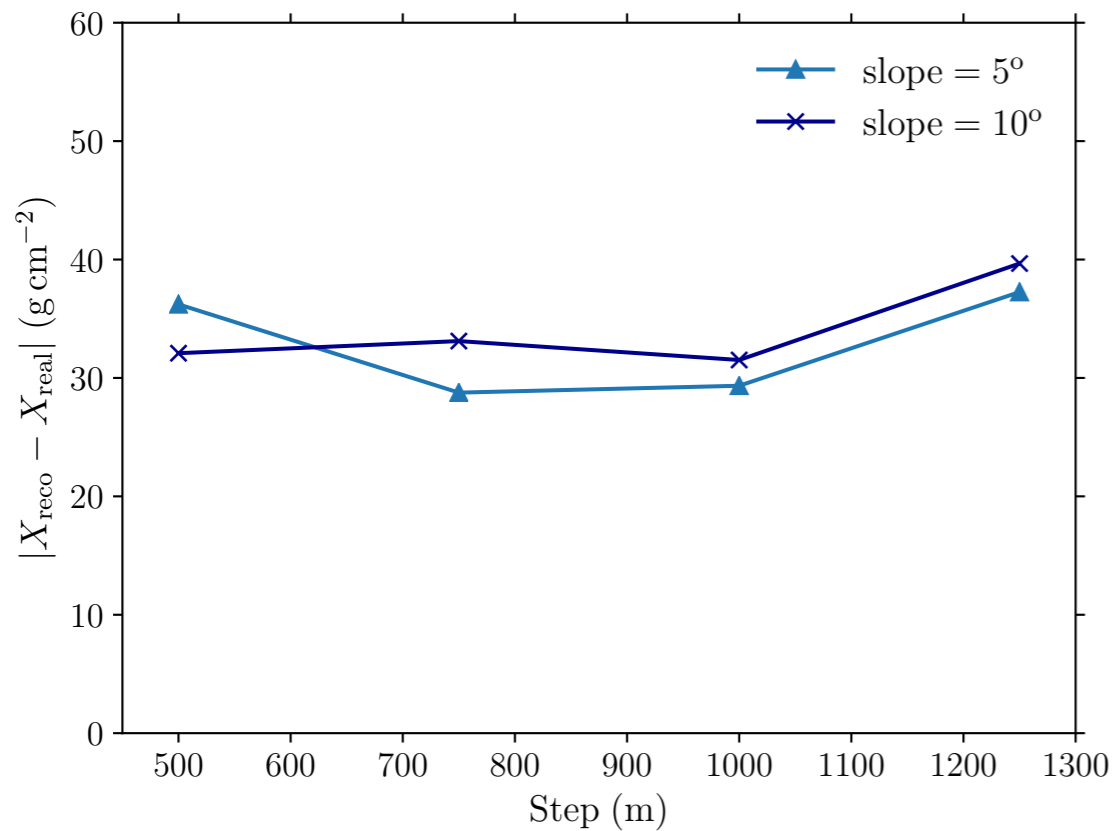


68%

- no strong difference in the reconstruction
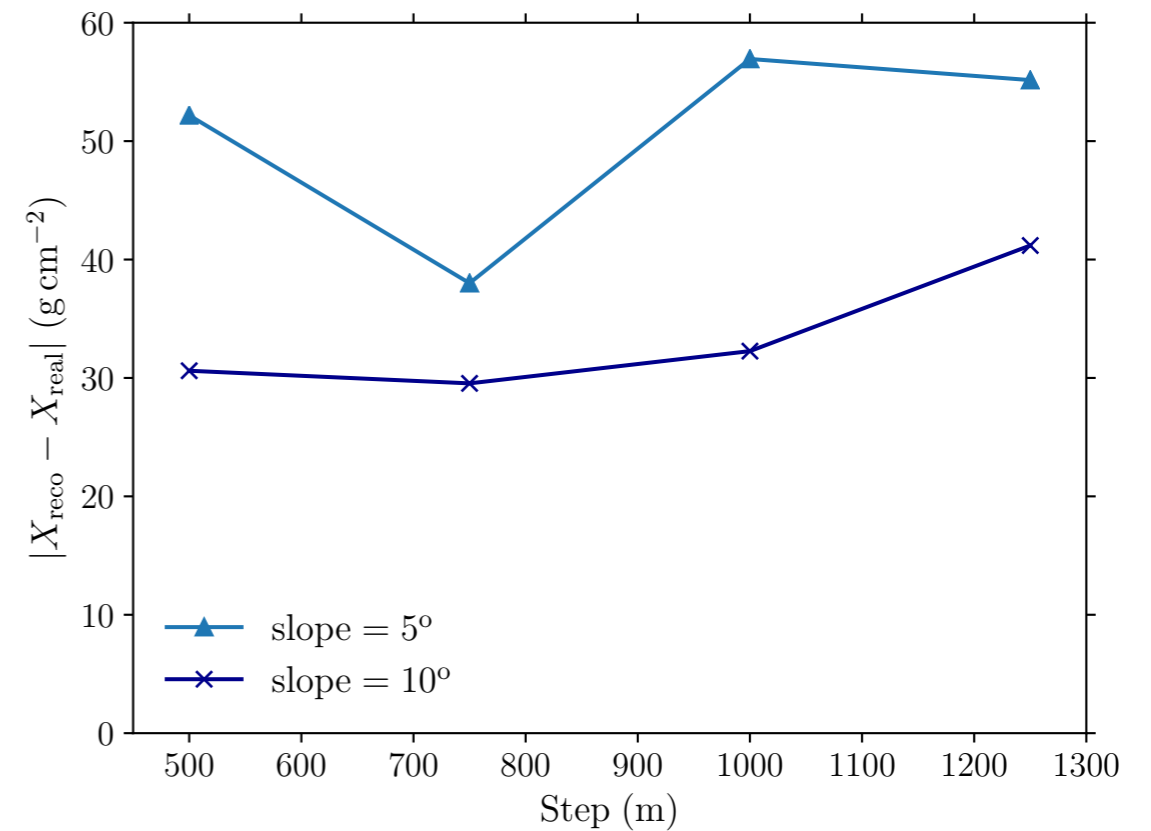
# Impact of mountain slope

**Fixed parameters**
- energy $10^{19}$ eV
- zenith 83°
- azimuth 40°

frequency band : 50 - 200 MHz

68%

Standard deviation



- slope facing the shower, size of the footprint increased by smaller slope and nevertheless results difficult to interpret.

# UHECR air showers - Xmax reconstruction

**Impact of zenith angle for $10^{19}$ eV**

- larger zenith angle -> larger footprint -> better reconstruction.
- good reconstruction for zen = 72° and step = 500m.

**Impact of energy for zen = 83°**

- noise makes reconstruction very difficult below $10^{19}$ eV
- possible improvement with smaller time window (at least for $10^{18.5}$ eV)

**Next steps**

- investigate other reconstruction methods?
- include realistic topography + uncertainties on energy, zenith and azimuth.

**Thank you for your attention!**
**Questions?**