The simulation chain and first results

Presented by
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White Paper Workshop @Nijmegen
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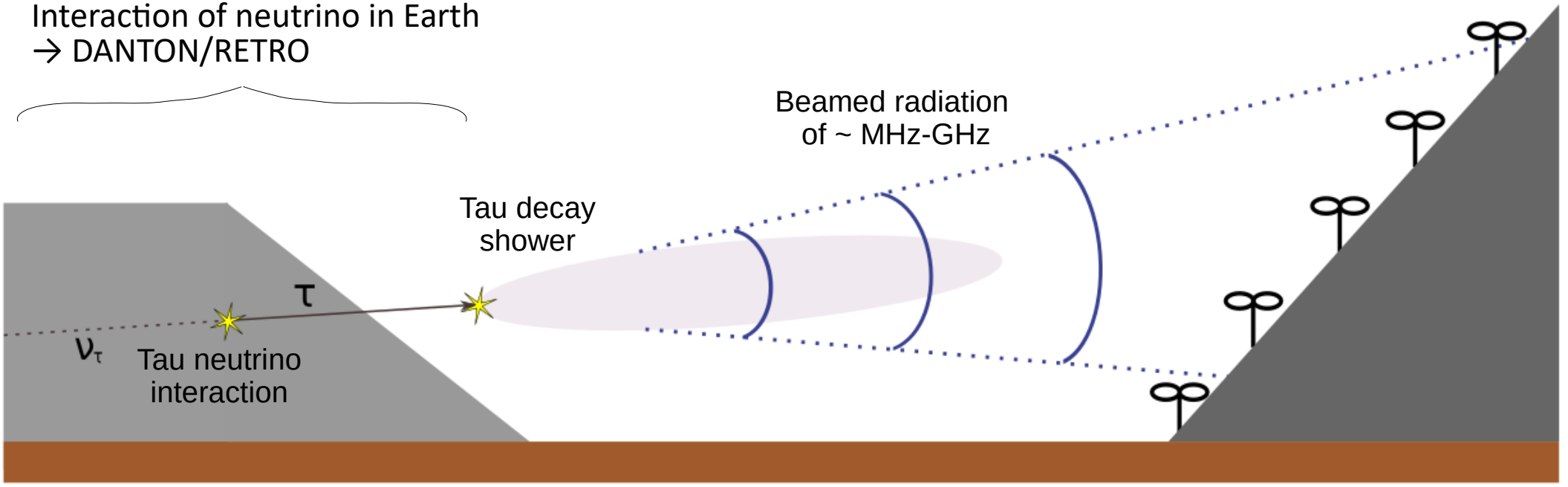
1) Description of simulation chain
2) Results for HS1

Simulation of noise
(galactic & ground sources)
to define a threshold

Calculation of emitted radio signal
→ Radio Morphing

Application of
antenna response

Interaction of neutrino in Earth
→ DANTON/RETRO



The simulation chain

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Valentin Niess

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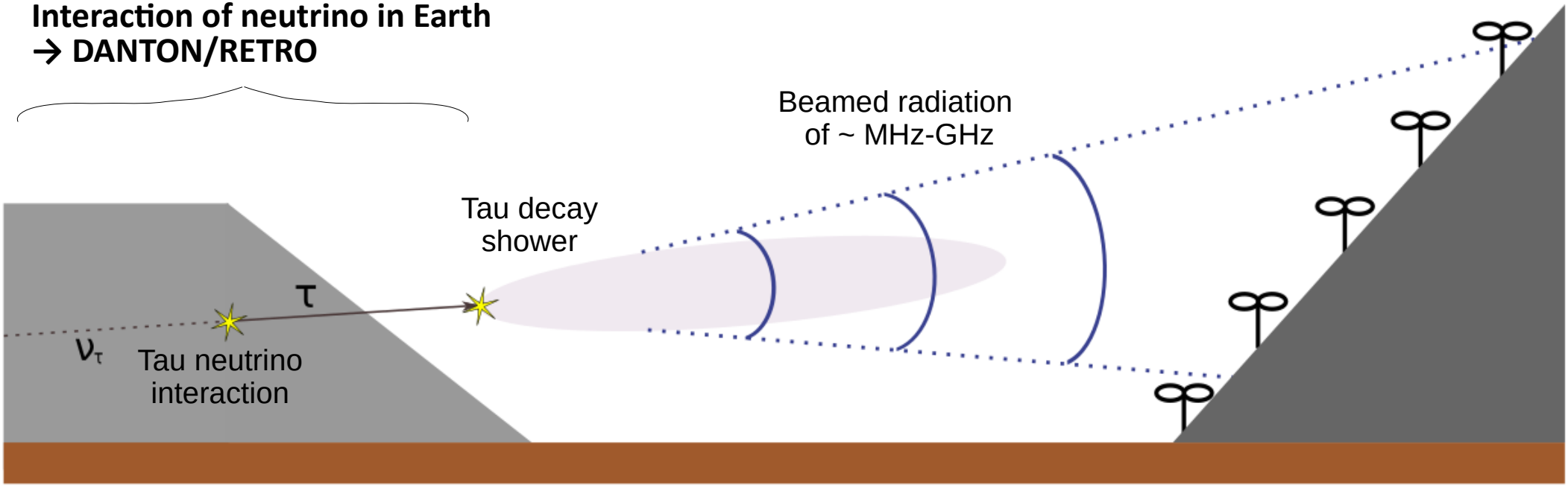


DANTON/RETRO

DecAyiNg Taus frOm Neutrinos Radio nEuTRino simulatiOn (RETRO)

DANTON:
https://github.com/niess/danton → wiki

neutrino transport by *ENT*

default DIS model: CT14 NLO PDF (any PDF can be plugged in as long as given in LHA format)

τ transport by *PUMAS* (detaild MC, https://github.com/niess/pumas, https://arxiv.org/abs/1705.05636)
reads in energy loss tables, other models can be plugged in (photonuclear losses: Dutta 2000, https://arxiv.org/abs/hep-ph/0012350)

τ decays by *ALOUETTE* (https://github.com/niess/alouette),
encapsulation of TAUOLA (e.g. https://arxiv.org/abs/1609.04617), a reference package for tau decays

→ decouple neutrino and radio simulation (parallel, independent!)
by using backward Monte-Carlo in *DANTON*:

retro: framework for the end-to-end simulation
https://github.com/grand-mother/retro
- including event-model, grand-tour, danton, etc

RETRO tries to sample τ decay vertices *uniformly* above the topography, provided that they are consistent with a τ converted in rocks

→ populate the area above the detector *uniformly* with relevant events

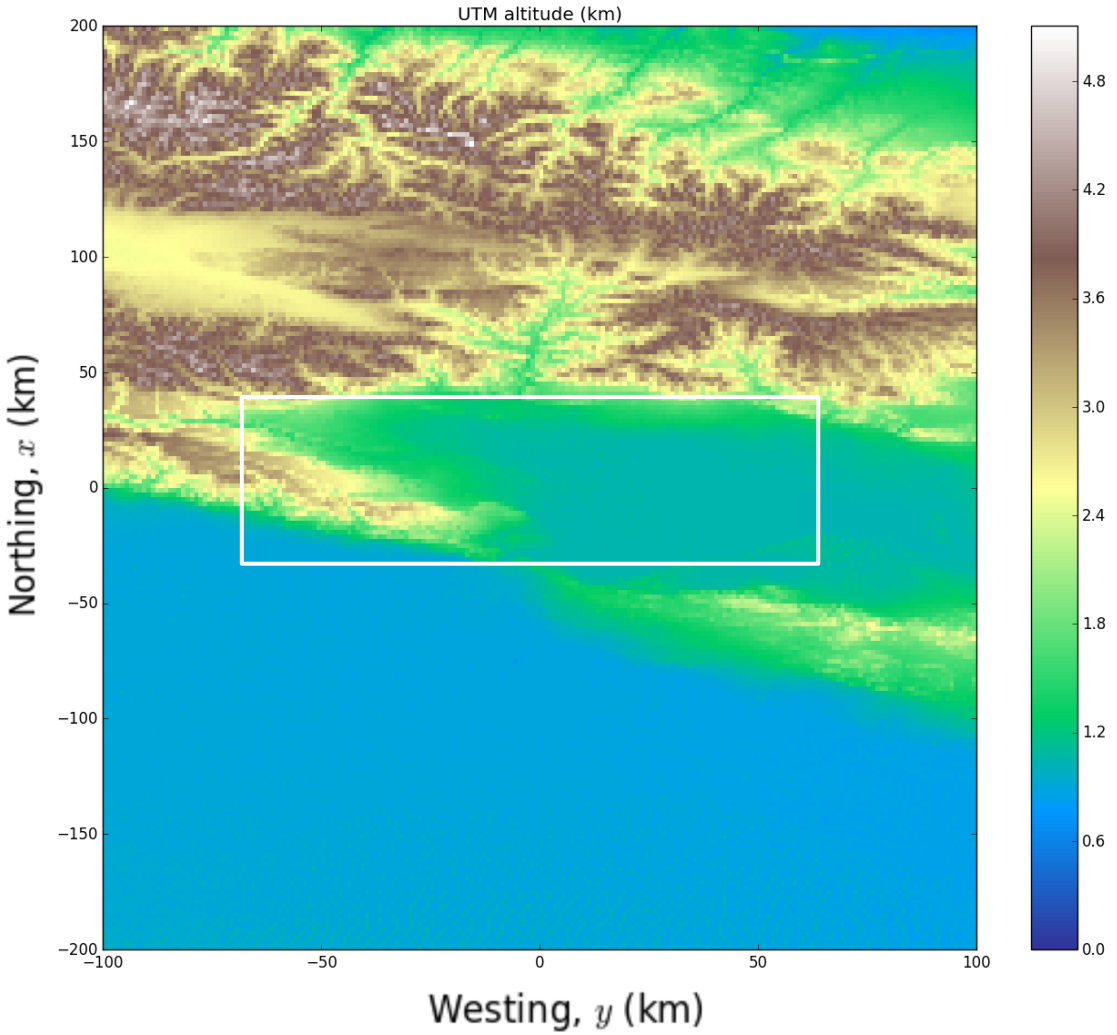
== seed of simulation

→ *downstream*: simulated radio signal and antenna response

→ *upstream*: sample the primary neutrino flux with DANTON,

i.e. estimate the flux of decaying τs at each seed given a primary model

Including Topography



Topogrophy included by TURTLE C99 library (https://github.com/niess/turtle)

ASTER:
Advanced Spaceborne Thermal Emission and Reflection Radiometer on Terra Satellite
- spatial resolution: 30m,
  altitude resolution: 10m

As local framework:
Cartesian coordinates, origin centred on middle of simulated array

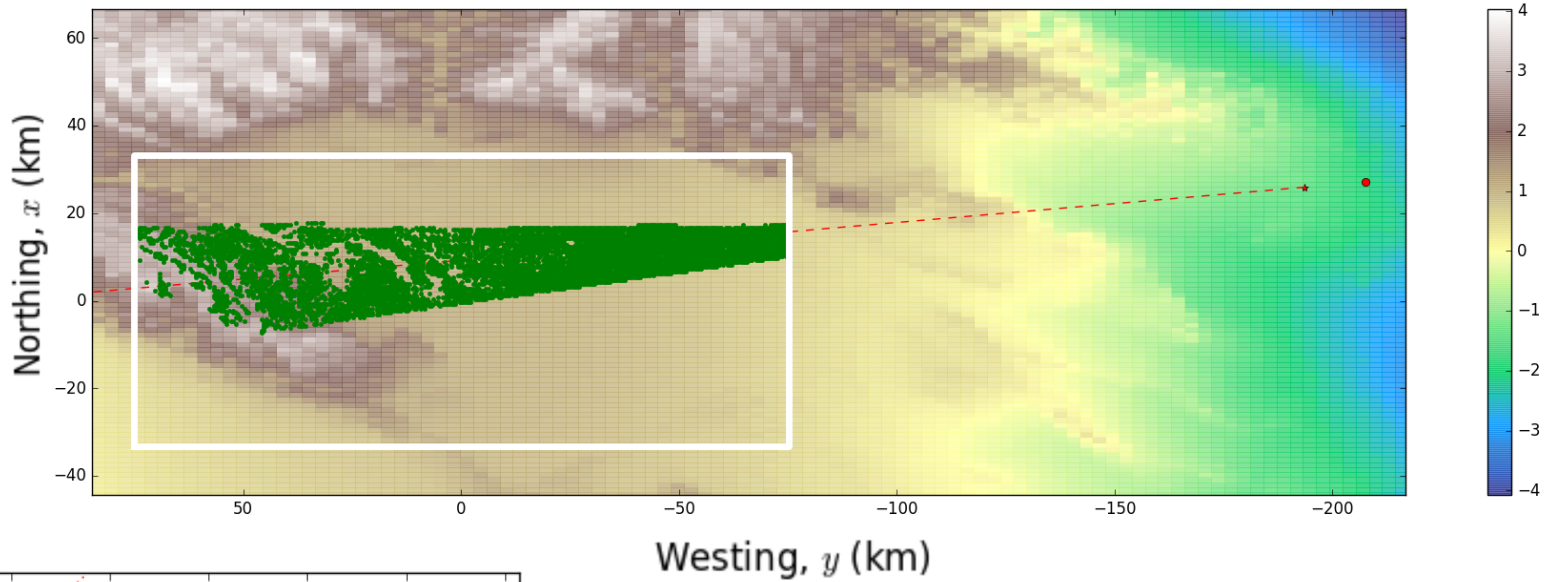
→ extend the simulated area (add additional tiles)
Main issue: tile properly the simulation area in geodetic coordinates.

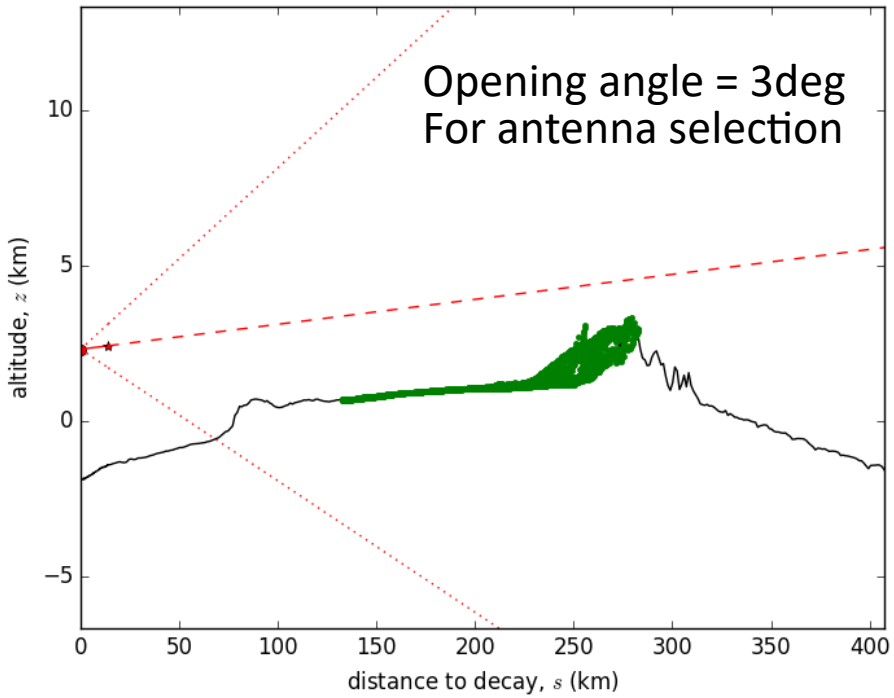
Cannot use local x,y,z for large areas because of Earth's curvature →
Use latitude-longitude, then generation procedure has to be adapted

https://earthexplorer.usgs.gov/ → download data set
https://lpdaac.usgs.gov/dataset_discovery/aster
Find downloaded files here:
/sps/hep/trend/neu/maps/ASTER-GDEM2 + README.pdf

Mountain shadowing

Included in the selection of antenna positions for the simulation





- 500m steps between antenna positions
- 4 antennas in footprint to select shower for simulation
- Longitudinal range: 14km to 100km @10^{17}eV

The simulation chain

K. De Vries, O.Martineau,
M. Tueros, V. Niess, A. Zilles

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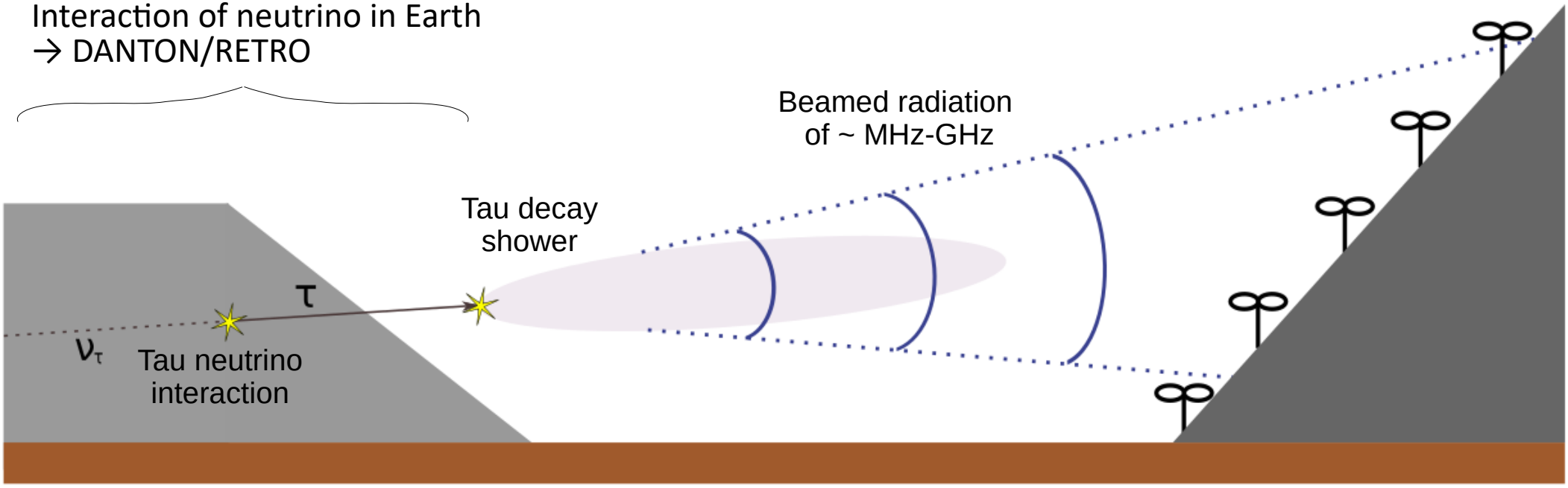
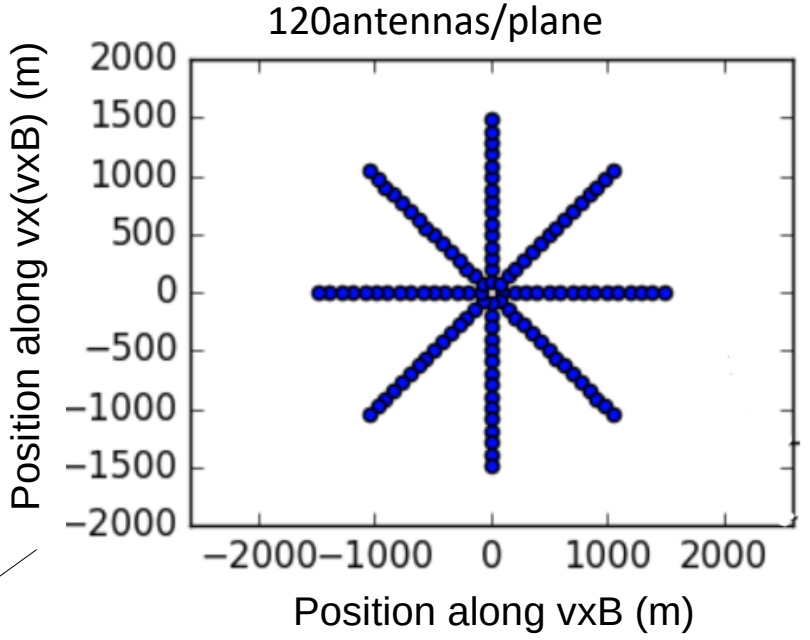


Radio morphing

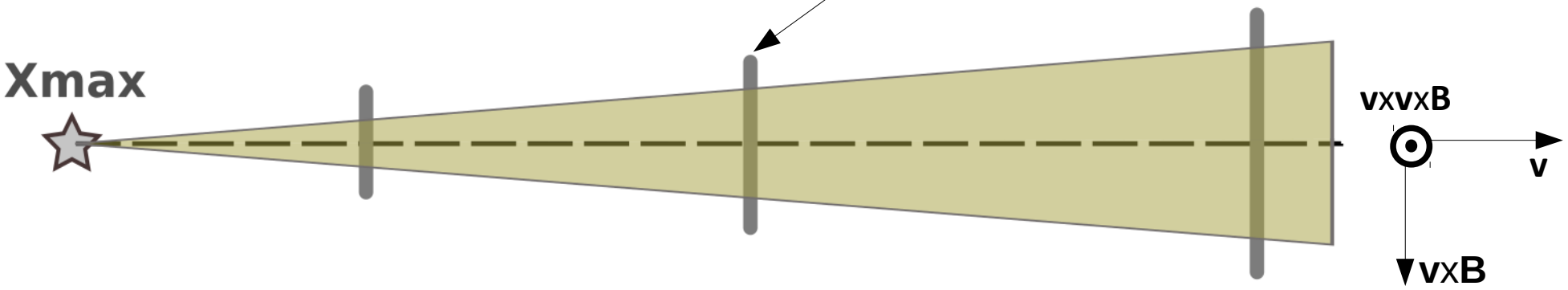
→ **Morph $E_B(t)@x_i$ to $E_A(t)@x$**

- **Scaling of amplitude $E_A(x_i, t) = k_{AB} \cdot E_B(x_i, t)$ + "scaling of ref. position" $x_i \rightarrow x_j$**
- **Interpolation of pulse shape $E_B(x_j, t) \rightarrow E_B(x, t)$**

RM ~O(mins)/shower
ZHAireS ~O(h)/shower

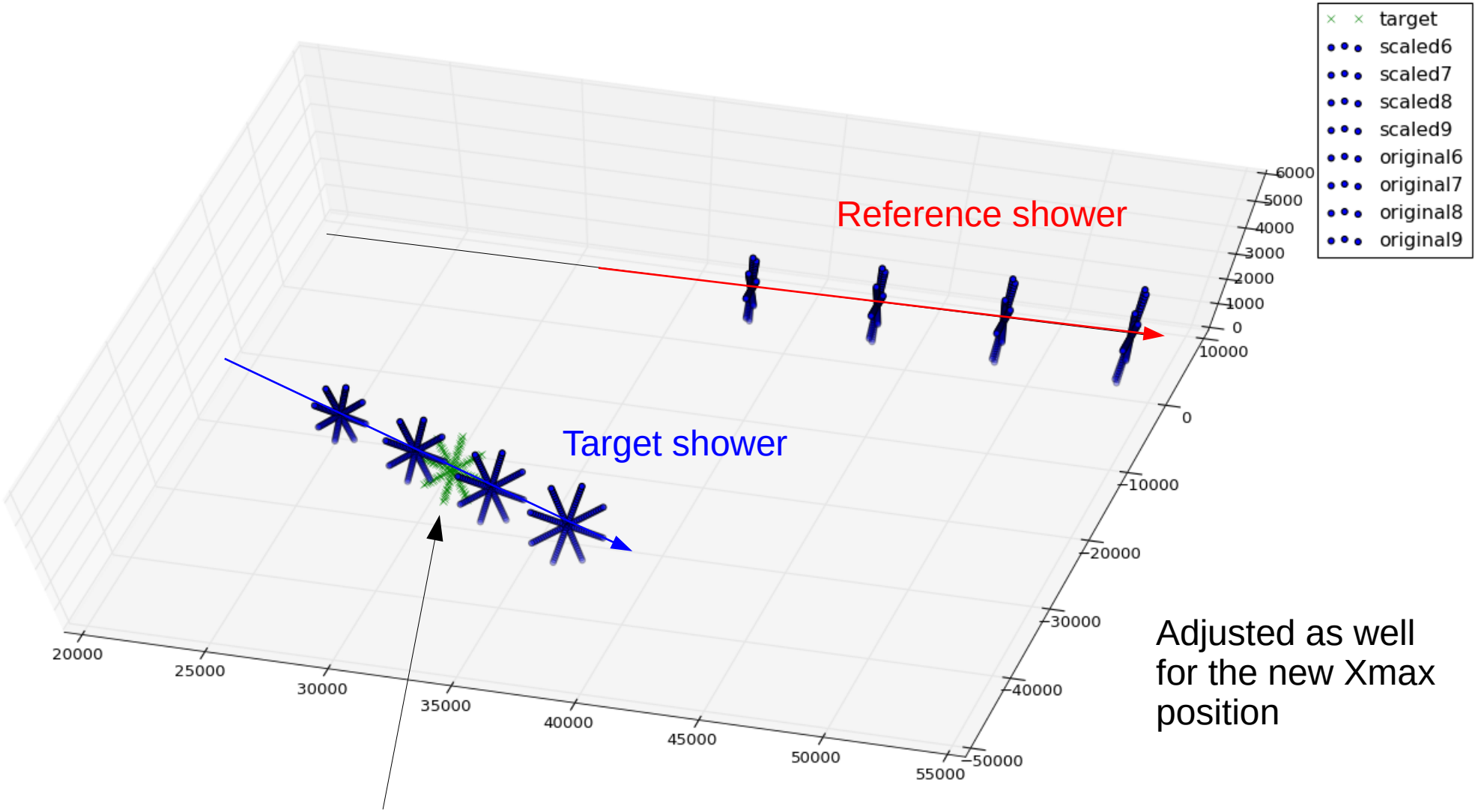


Reference shower
with 16 star planes in diff. distances



https://github.com/grand-mother/radiomorphing

Principle – scaling positions



Adjusted as well for the new Xmax position

Target positions, here a “test” shower

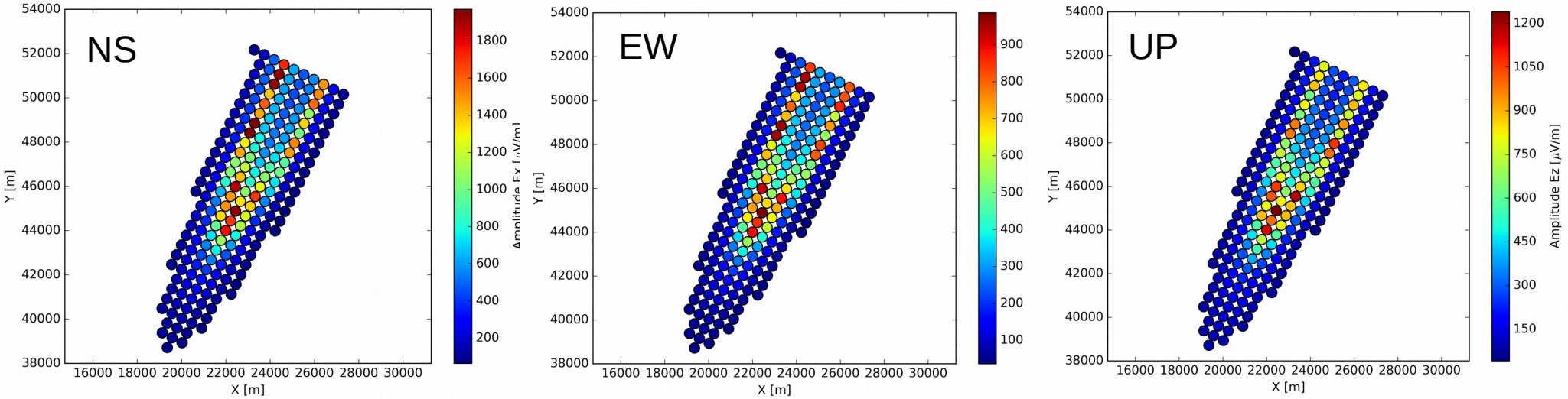
Reliability – ZHAireS vs RM

max(abs(E(t))) plotted
f=0-500MHz

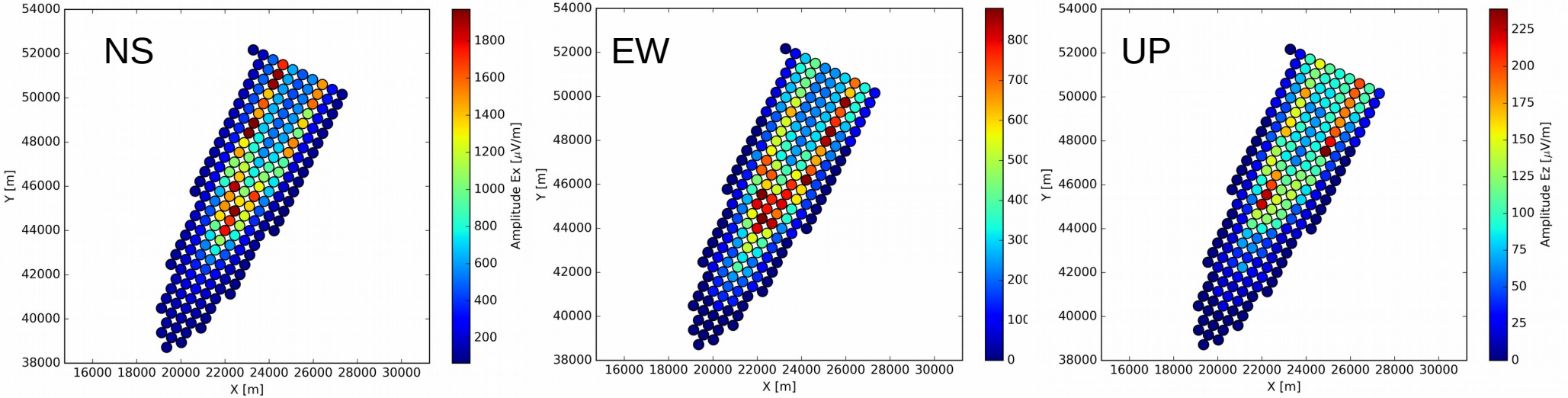
Nicolas as a beta user of RM applied his ZHAireS scripts to RM output

pi-, E= 1.44EeV, θ=88.15°, φ=63.45° height= 2540.18m

ZHAireS



Radiomorphing

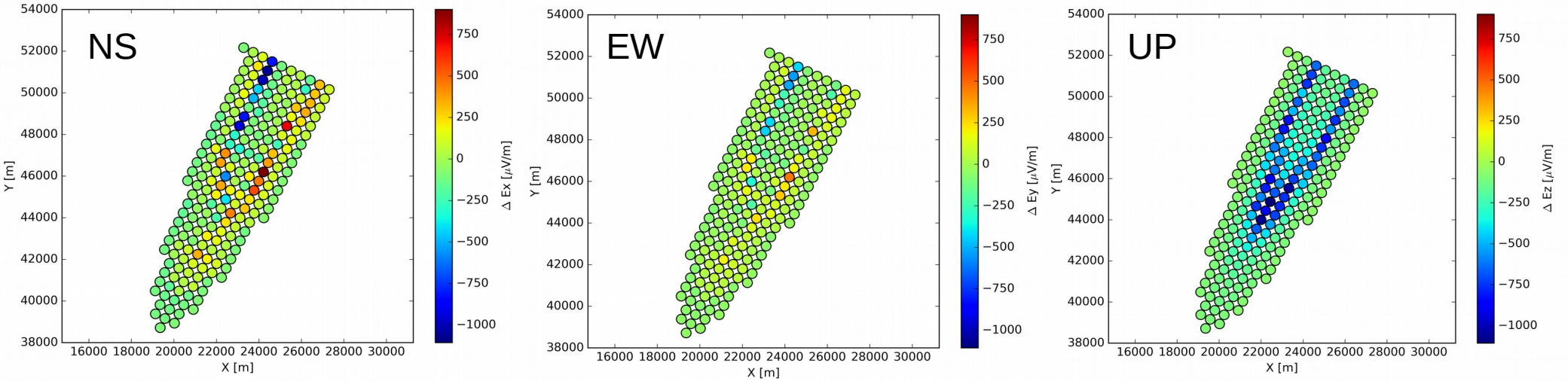


Reliability – ZHAireS vs RM

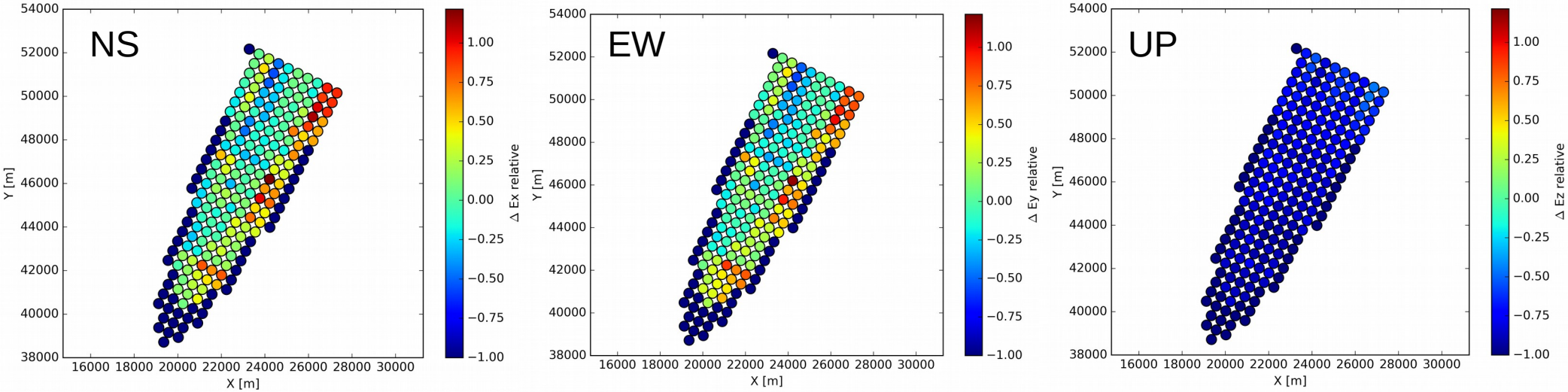
f=0-500MHz

pi-, E= 1.44EeV, θ=88.15°, φ=63.45° height= 2540.18m

Absolute difference : RM-ZHAireS



Relative difference : (RM-ZHAireS)/ZHAires



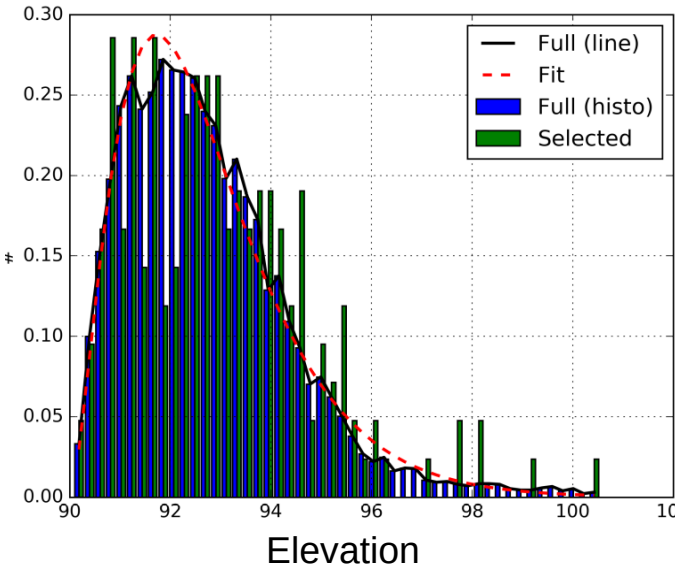
→ Radiomorphing underestimates the signal

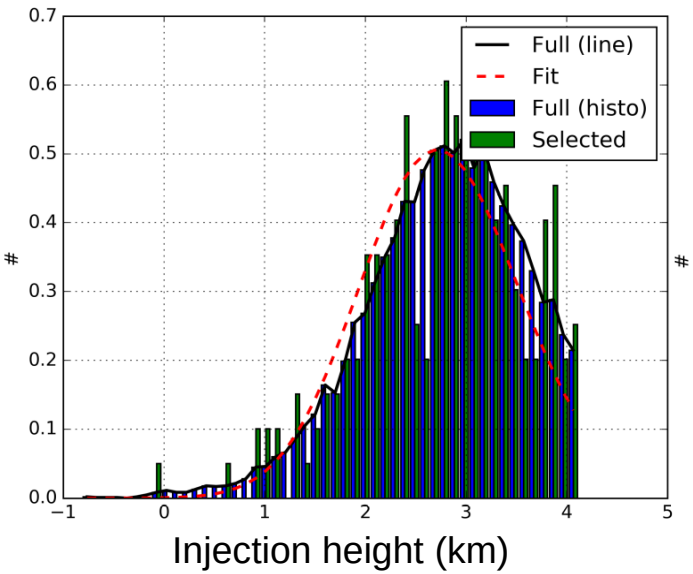
[Nicolas]

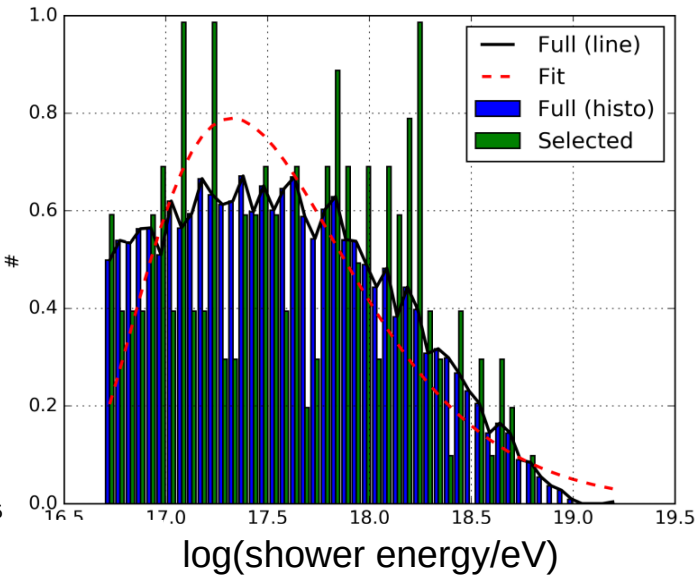
[Nicolas]

Reliability – ZHAireS vs RM

- selected 200 showers from a DANTON library which fit the global distribution of events in the library, but with randomly drawing an azimuth for each shower
- Array = 40 km from decay point, slope = 10 deg, spacing = 500 m, maximum height above ground = 3000 m, Ground Altitude = 1500 m
- for RM, only the leading particle is considered and the energy provided is always the total primary energy
- After applying antenna response:
  → check detection i.e. check whether V_{EW}, V_{NS},V_{UP},V_{tot} > 50/150 muV (aggressive/conservative)
- a shower is detected if $N_{ant\_triggered}$ >8



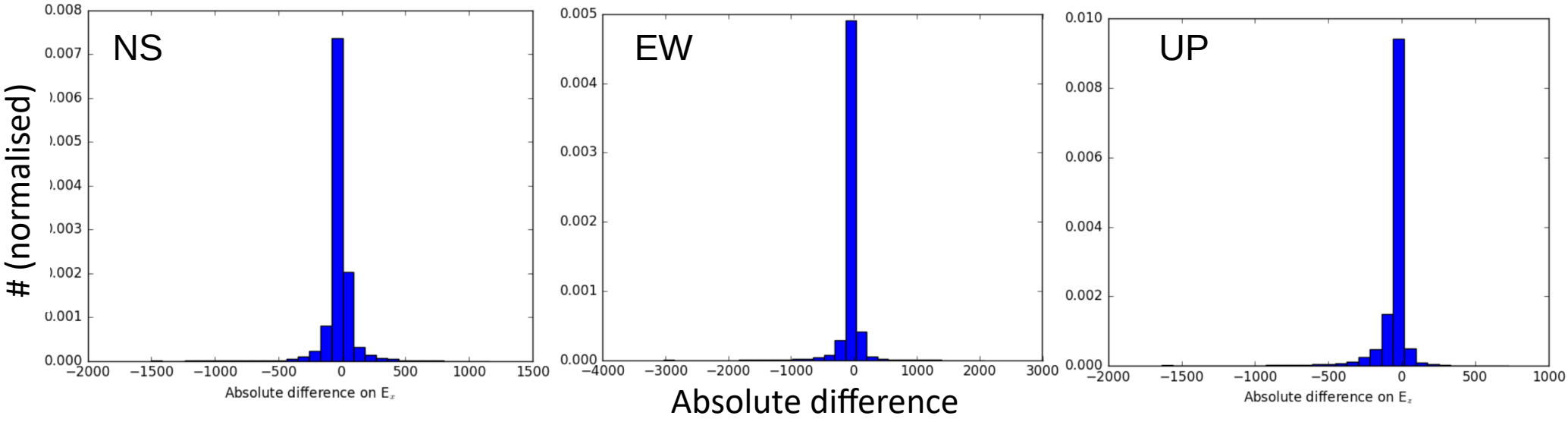


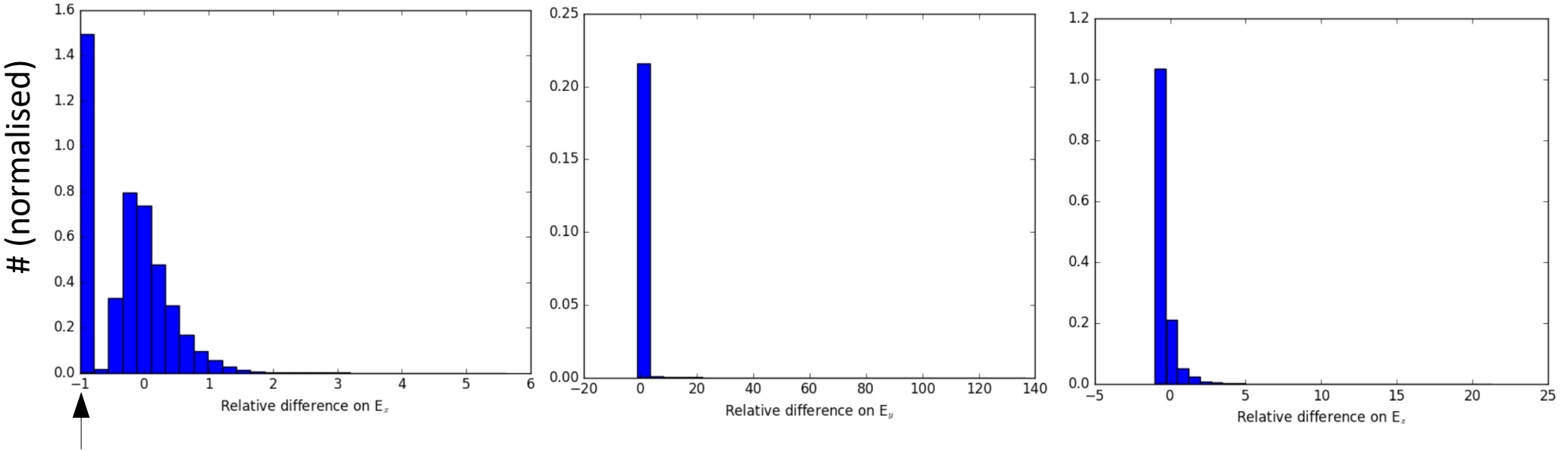


[Nicolas]

Reliability – ZHAireS vs RM

128 simulated showers





RM returns no signal for these antennas

[Nicolas]

Reliability – ZHAireS vs RM

Trigger conditions:
- V_{EW}, V_{NS},V_{UP},V_{tot} > 50/150 muV (aggressive/conservative)
- a shower is detected if $N_{ant\_triggered}$ >8

Comparison of the shower triggers:

Total number of showers: 128

Shower trigger for ZHAireS and RM: 84 (aggr.),
for RM but not for ZHAireS: 3,
for ZHAireS but not for RM: 11,
for none of them: 30

N triggered showers (Aggressive case) with RM: 87
with ZHAireS: 95
Absolute Delta Ntriggered showers ZHAireS-RM (Aggressive case): 8.0
Relative Delta Ntriggered showers (ZHAireS-RM)/ZHAireS (Aggressive case): 8.4 %

N triggered showers (Conservative case) with RM: 53
with ZHAireS: 66
Absolute Delta Ntriggered showers ZHAireS-RM (Conservative case): 13.0
Relative Delta Ntriggered showers (ZHAireS-RM)/ZHAireS (Conservative case): 19.7 %

→ RM tends to underestimate signal strength, few percent difference in trigger rate
→ Shower-to-shower fluctuations not studied yet!

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