Completeness study of the “train” sample

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2022.07.18

Rationale

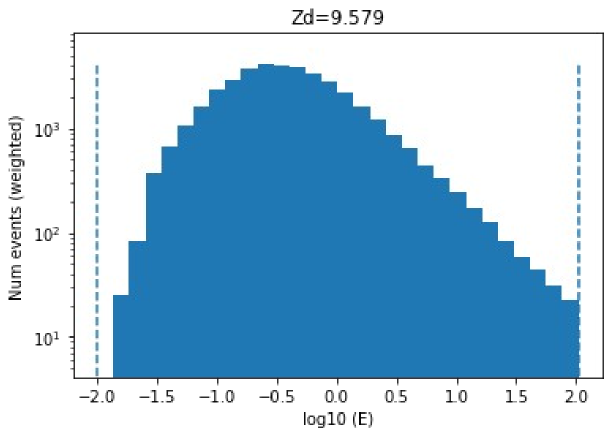
- The “train” samples were generated with a purpose of RF training – completeness (having nearly all the events that are possible to trigger the telescopes) was not a high priority
- We need protons (and Helium, electrons, …) also for other purposes: MC sensitivity, matching trigger – there it is much more important to have the sample complete

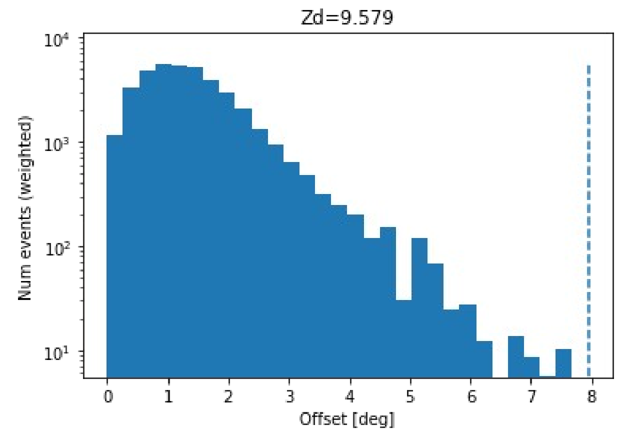
Scalings of protons in the “train” sample

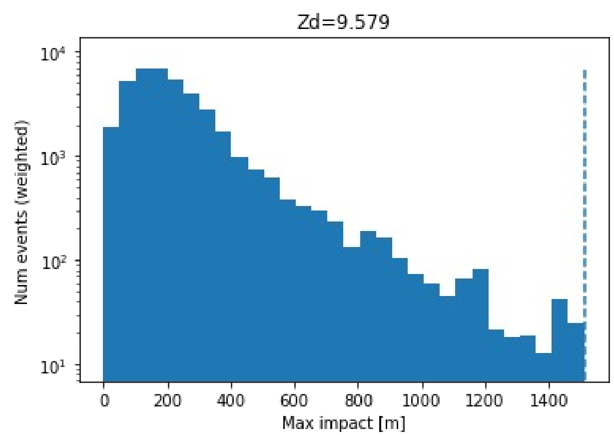
- https://github.com/cta-observatory/lst-sim-config/issues/3
- Viewcone: 8 deg scaled as $\cos^{0.5}$ ZD
- Energy range: 10GeV – 100 TeV scaled as $\cos^{-2.5}$ ZD
- Max impact: 1500 m, scaled as $\cos^{-0.5}$ ZD

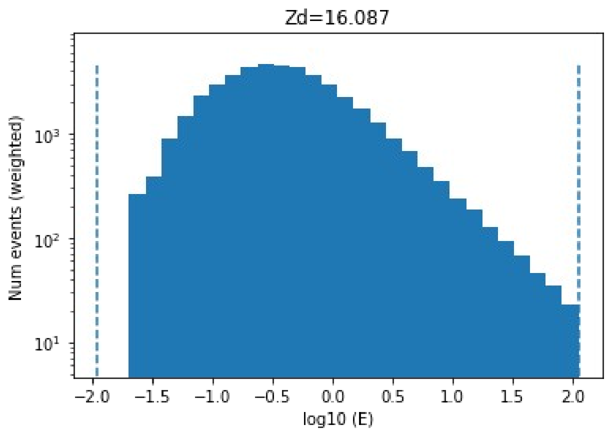
Tests

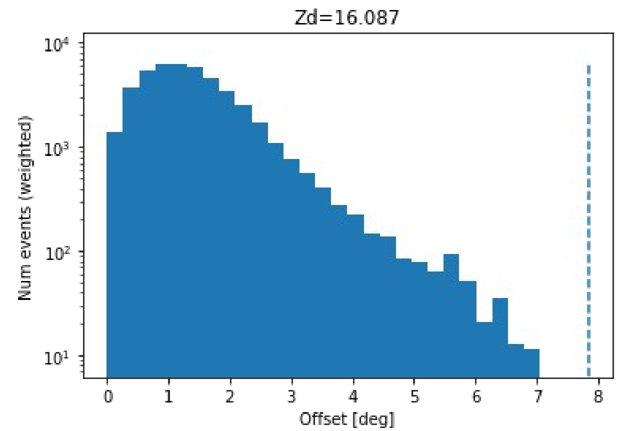
- Using the train samples DL1 files I checked the basic completeness parameters (true energy range, impact, offset angle from the camera center).
- For impact there is actually a bit of asymmetry because LST1 is not at the center of the array.
- Plots are for LST1 telescope (the one with highest light yield – hence likely the most problematic one in terms of completeness), but with applied “magic_stereo” condition (i.e. surviving the trigger condition of both LST1 and both MAGICs)
- Simulation slope is -2, but I weighted it to -2.8 to simulate the true proton spectrum
- Dashed lines show the simulated limits
- Each page is one zenith angle (stacking up a few azimuth angles)
- The range in all the panels is (ymax /1000, ymax*2), where ymax is the maximum bin content (30 bins per simulated range)

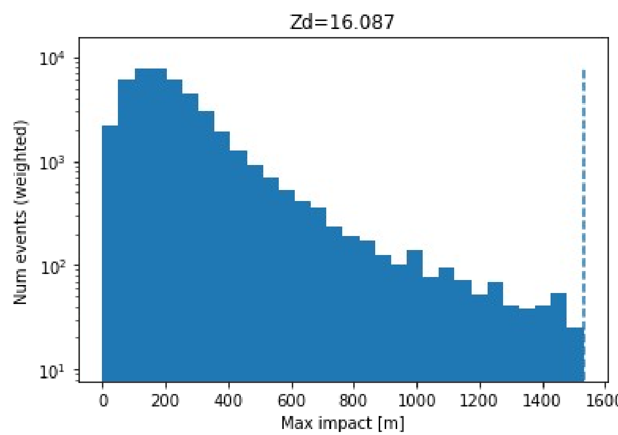

Zd=9.579
Num events (weighted)
log10 (E)

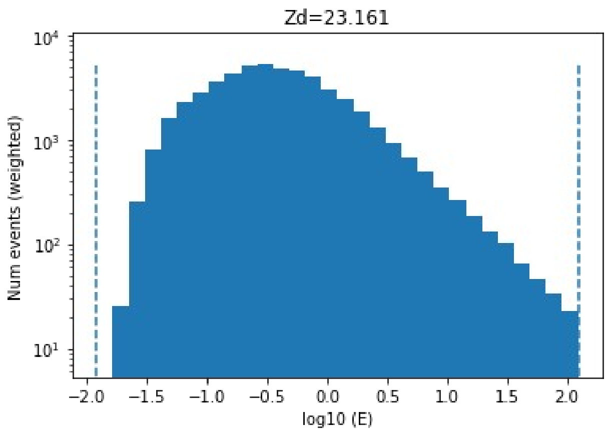

Zd=9.579
Num events (weighted)
Offset [deg]

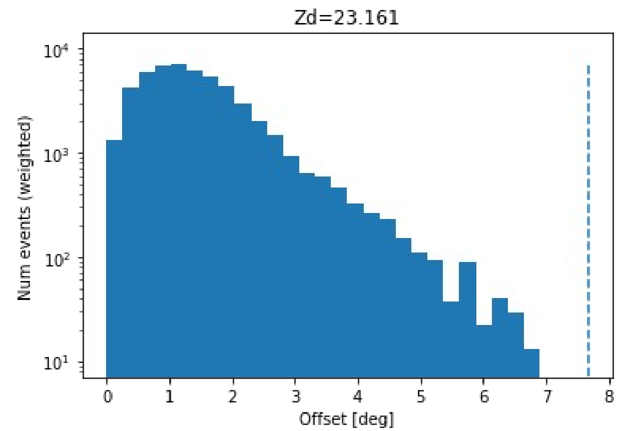

Zd=9.579
Num events (weighted)
Max impact [m]

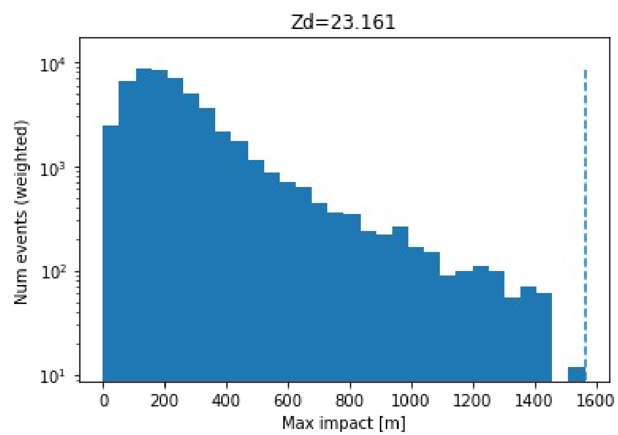

Zd=16.087
Num events (weighted)
log10 (E)
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
10¹
10²
10³

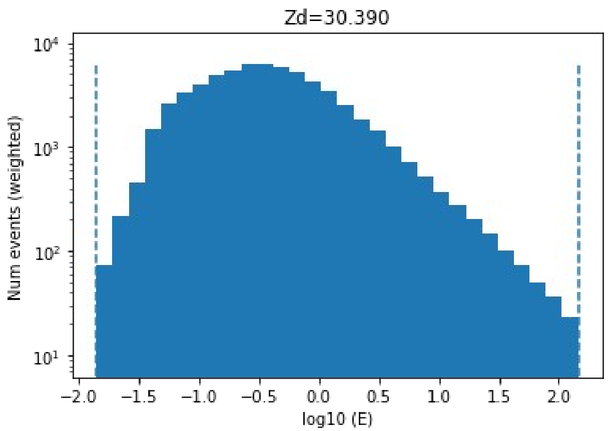

Zd=16.087
Num events (weighted)
Offset [deg]
0
1
2
3
4
5
6
7
8
10¹
10²
10³
10⁴

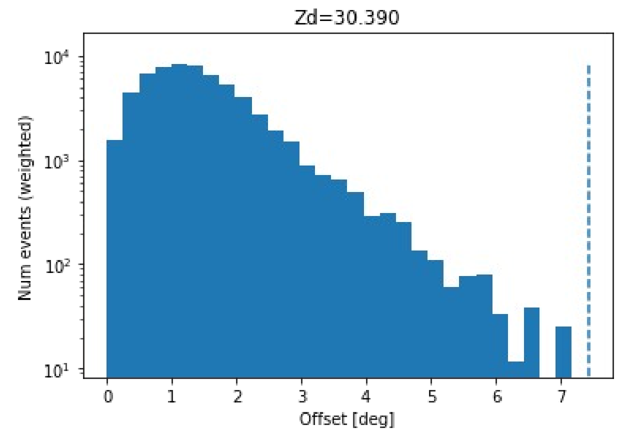

Zd=16.087
Num events (weighted)
Max impact [m]
0
200
400
600
800
1000
1200
1400
1600
10¹
10²
10³
10⁴

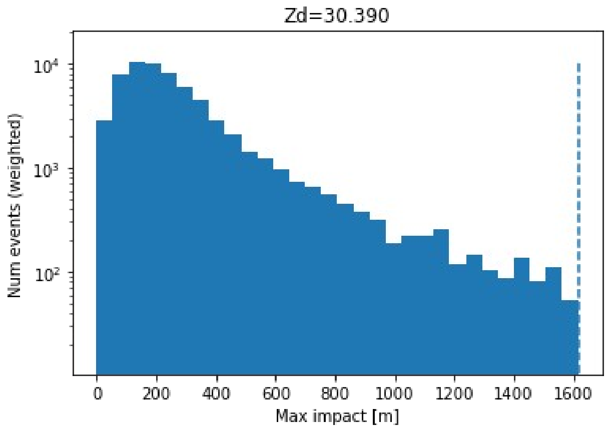

Zd=23.161
Num events (weighted)
log10 (E)

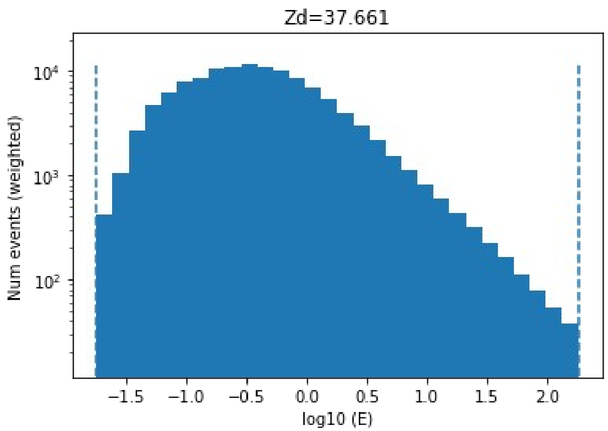

Zd=23.161
Num events (weighted)
Offset [deg]

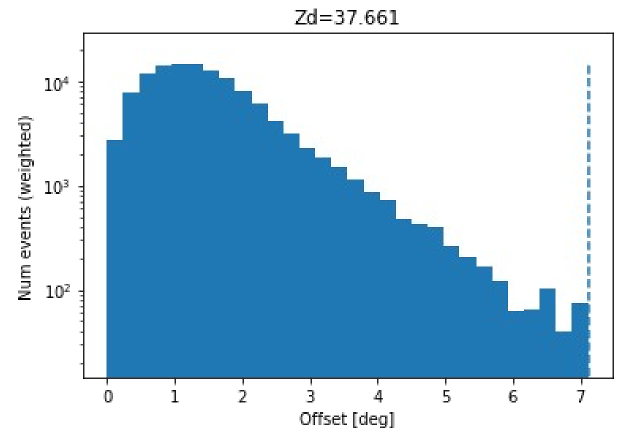

Zd=23.161
Num events (weighted)
Max impact [m]

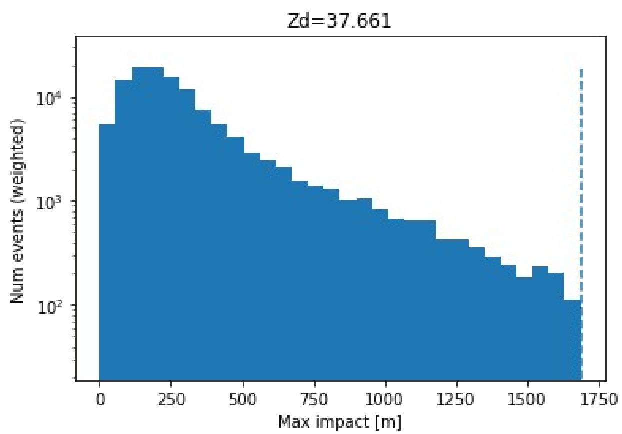

Zd=30.390
Num events (weighted)
log10 (E)

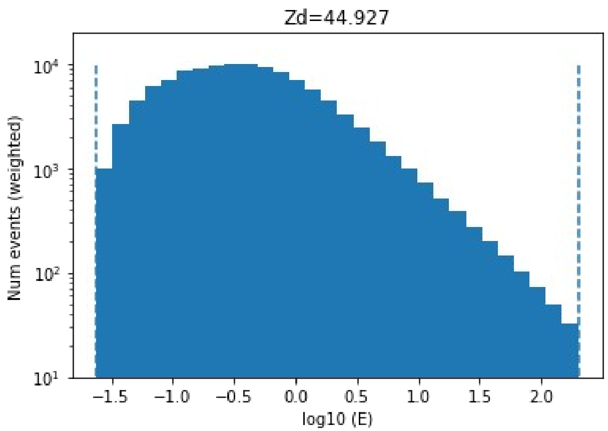

Zd=30.390
Num events (weighted)
Offset [deg]


Zd=30.390
Num events (weighted)
Max impact [m]

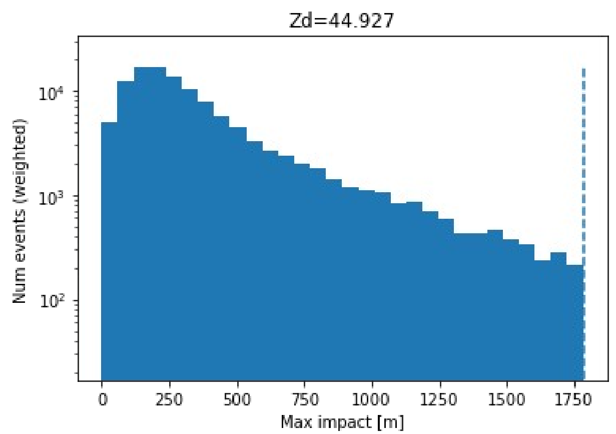

Zd=37.661
Num events (weighted)
10^4
10^3
10^2
−1.5 −1.0 −0.5 0.0 0.5 1.0 1.5 2.0
log10 (E)

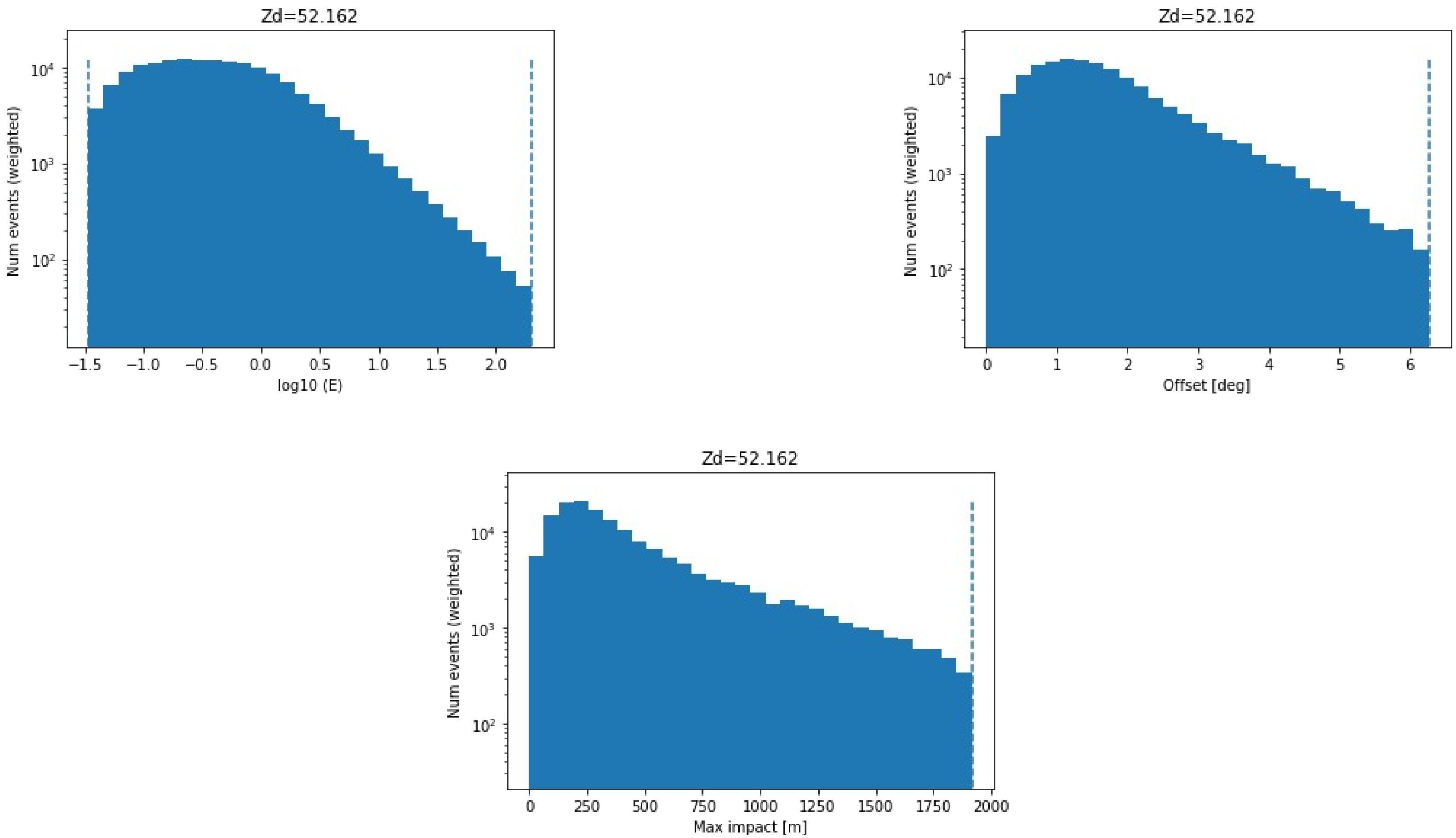

Zd=37.661
Num events (weighted)
10^4
10^3
10^2
0 1 2 3 4 5 6 7
Offset [deg]

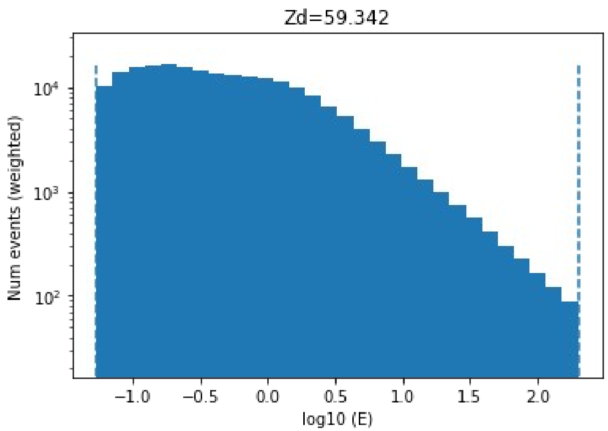

Zd=37.661
Num events (weighted)
10^4
10^3
10^2
0 250 500 750 1000 1250 1500 1750
Max impact [m]

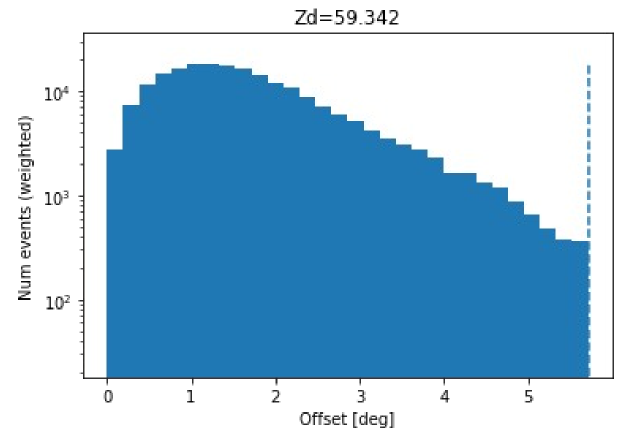

Zd=44.927
Num events (weighted)
log10 (E)

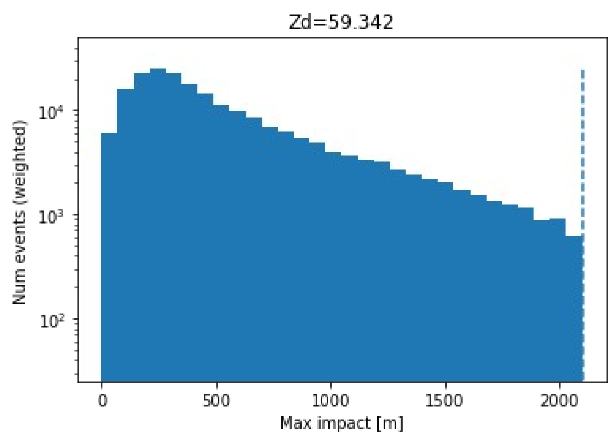

Zd=44.927
Num events (weighted)
Offset [deg]

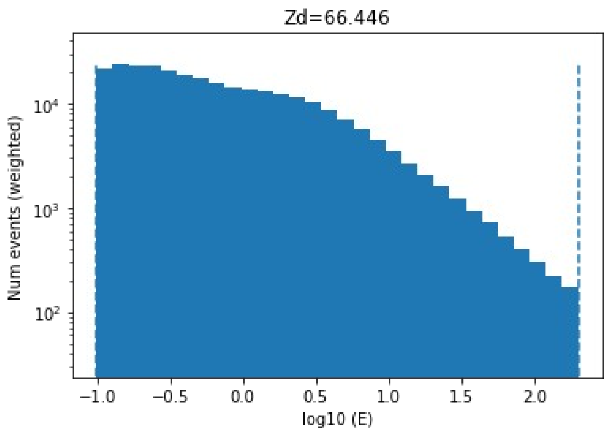

Zd=44.927
Num events (weighted)
Max impact [m]

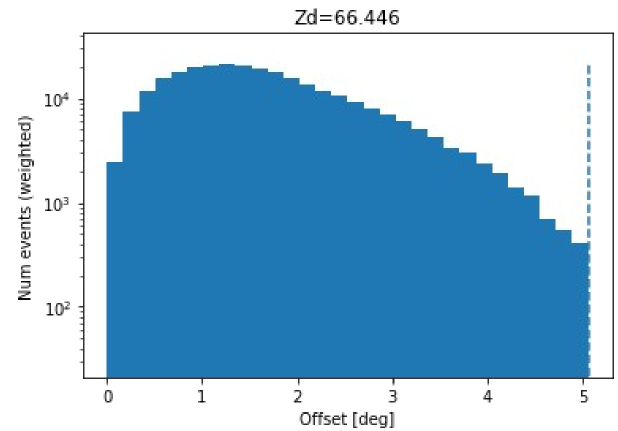

Zd=52.162
Num events (weighted)
log10 (E)
Zd=52.162
Num events (weighted)
Offset [deg]
Zd=52.162
Num events (weighted)
Max impact [m]

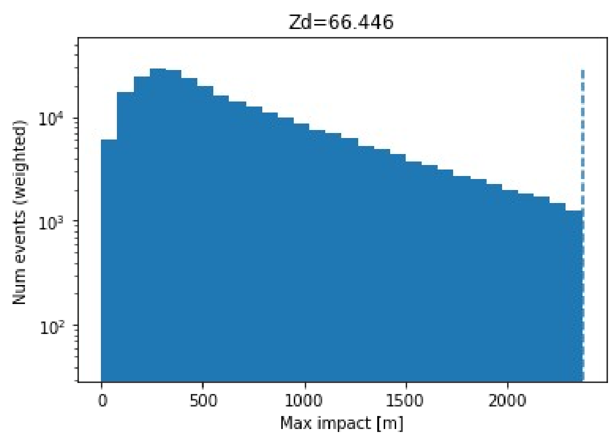

Zd=59.342
Num events (weighted)
log10 (E)
−1.0 −0.5 0.0 0.5 1.0 1.5 2.0
10^2 10^3 10^4


Zd=59.342
Num events (weighted)
Offset [deg]
0 1 2 3 4 5
10^2 10^3 10^4


Zd=59.342
Num events (weighted)
Max impact [m]
0 500 1000 1500 2000
10^2 10^3 10^4


Zd=66.446
Num events (weighted)
10^4
10^3
10^2
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
log10 (E)


Zd=66.446
Num events (weighted)
10^4
10^3
10^2
0
1
2
3
4
5
Offset [deg]


Zd=66.446
Num events (weighted)
10^4
10^3
10^2
0
500
1000
1500
2000
Max impact [m]

Energy range

- While the $\cos^{-2.5}$ZD scaling might work for gamma rays, for protons it is much more complicated. The peak of the true energy distribution gets much broader with increasing zenith – effect of deep interacting events ? Single muons?
- Maybe apply a weaker scaling: e.g. $\cos^{-1.5}$ZD, this would result in 27GeV threshold instead of 52 GeV at the 59 deg zenith – highest energies are either way clipped at 200 TeV so will not be affected much

Impact

- Scaling with $\cos^{0.5}$ZD definitely does not work, we are losing many high-impact events
- At 59deg we are simulating until 2 km and this makes a drop of an order of magnitude from the peak value at ~250m. Similar drop for 10deg zenith happens to distance of 800m
- I propose to use the “naive” scaling of cos ZD instead (i.e. going to 3 km at 60 deg)

Viewcone

- Shrinking the viewcone with raising zenith seems to be a bad idea, at low zenith 8 deg is perfectly fine (could be even slightly less), but the distribution is not getting narrower with incresing zenith but even slightly broader
- At low zenith the drop by an order of magnitude happens at 3.5 deg, at ZD=60deg it happens at 4.5 deg
- Propose to keep fixed 8 deg

Summary

- At low zenith the samples look rather complete, but with increasing zenith it gets worse and worse.
- Proposed scalings of protons:
  - Energy range: (10GeV-100TeV) * $\cos^{-1.5}$ZD
  - Impact: 1500m * cos ZD
  - Viewcone: fixed 8 deg
- For helium:
  - Like protons, but multiply energy range by a factor of 2 (classical scaling is a factor of 4, but keeping a factor 2 of margin due to fluctuations at the lowest energies, the highest energies will be incomplete, but they are not that important for helium