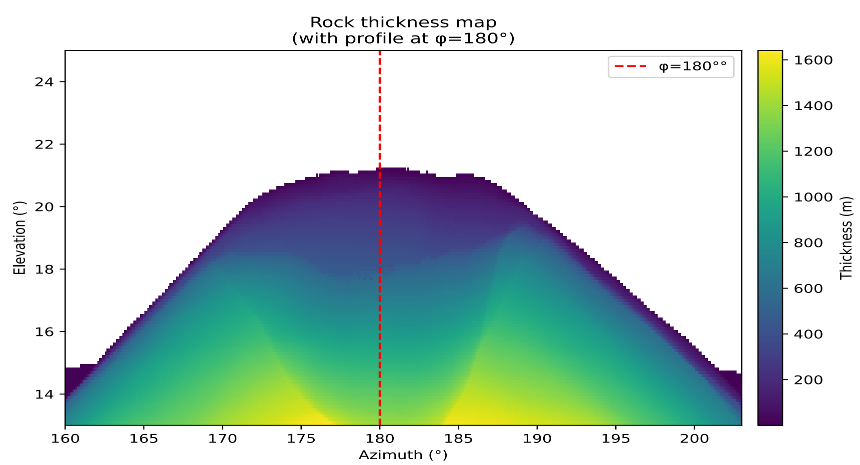
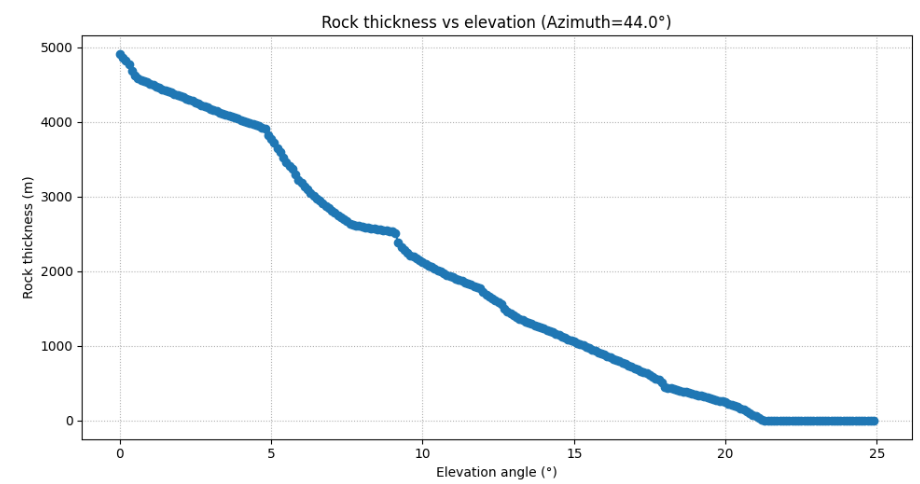
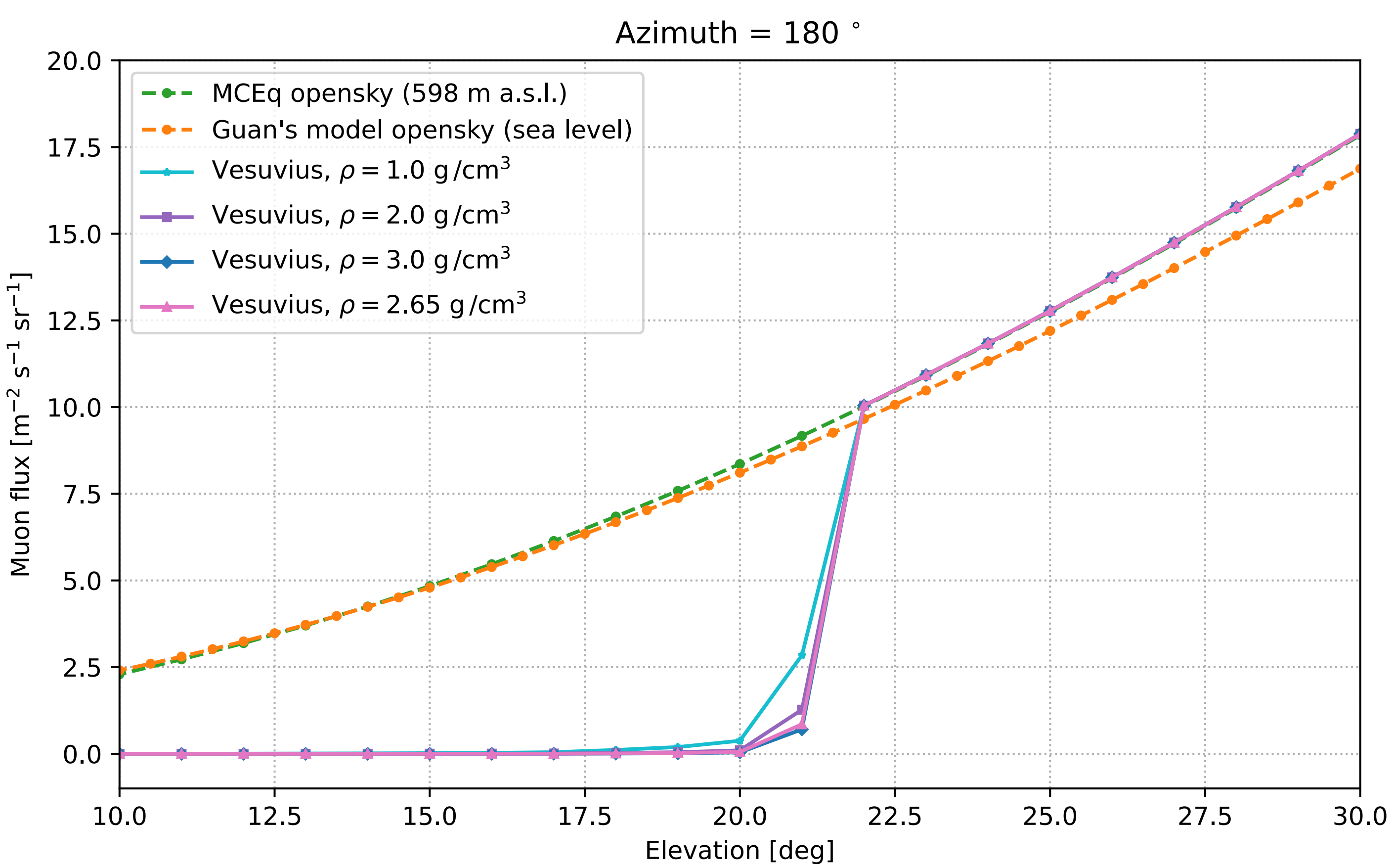
Flux at Freesky area ✅

- 5-meter precision DEM file is used, originally used by Mariaelena.
- The height/altitude of the observation point need to be updated precisely.

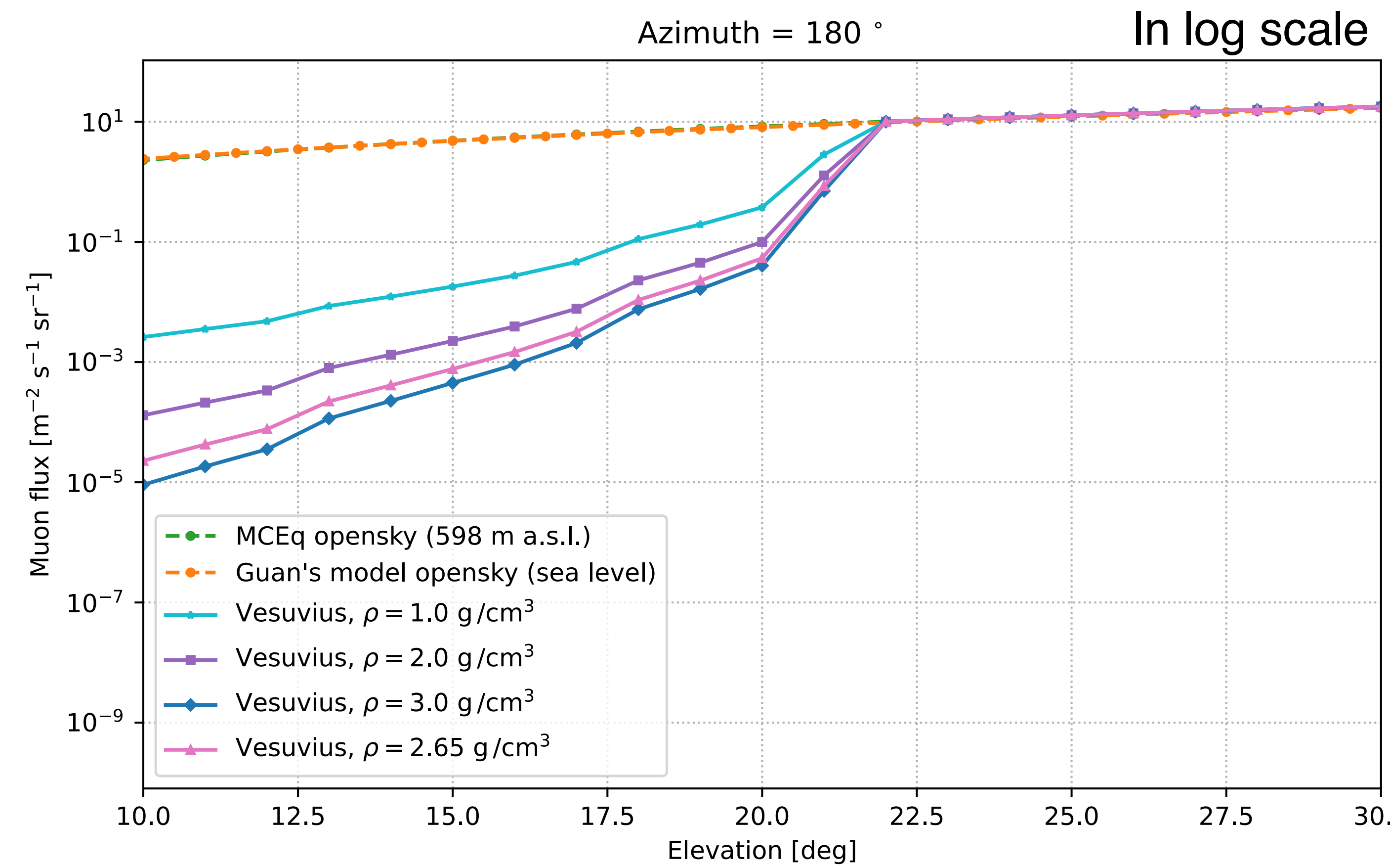
```
proj = rock.project(latitude=xMURAVES, longitude=yMURAVES)
topo = rock.height(x=proj.x, y=proj.y)
for i, az in enumerate(az_vals):
    for j, el in enumerate(el_vals):
        # Differential flux vs energy at the observation po
        # Units from Guan model: GeV^-1 m^-2 s^-1 sr^-1
        flux_E = fluxmeter.flux(
            latitude  = xMURAVES,
            longitude = yMURAVES,
            height    = topo,
            azimuth   = az,
            elevation = el,
            energy    = energy
        )
```





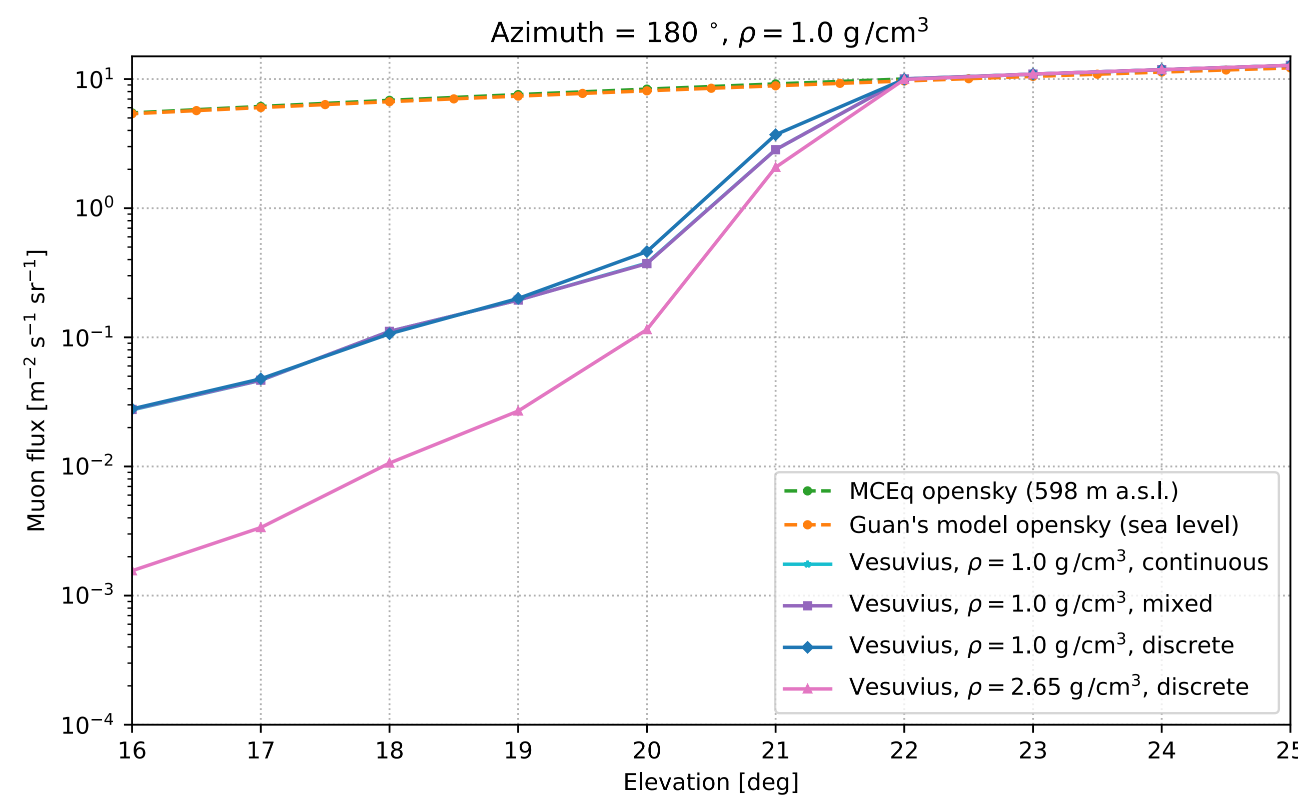


In log scale

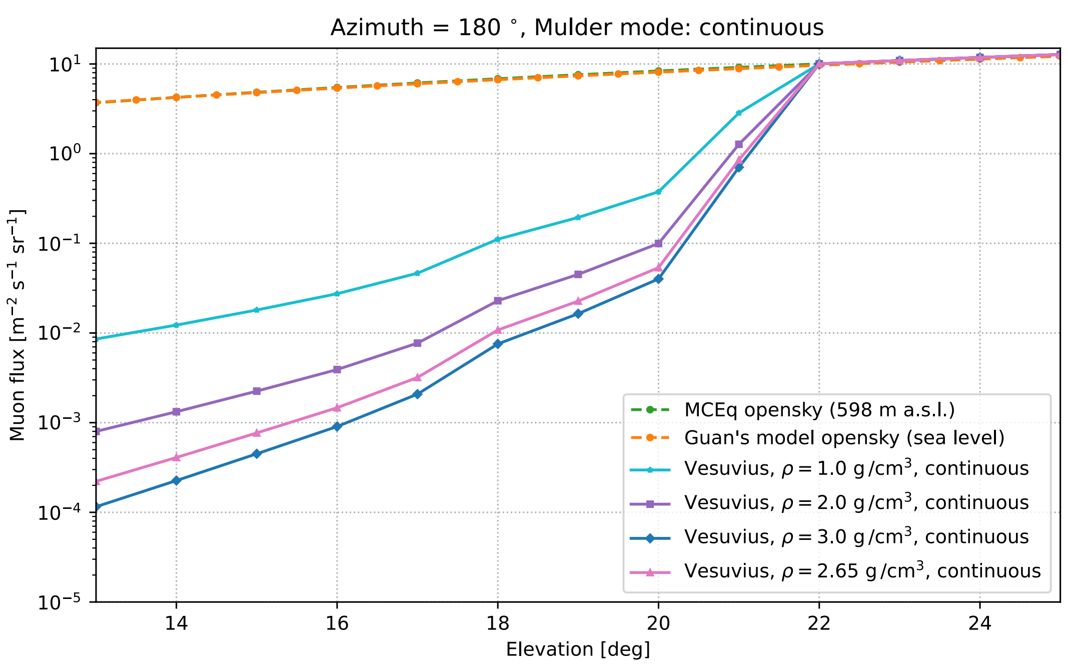


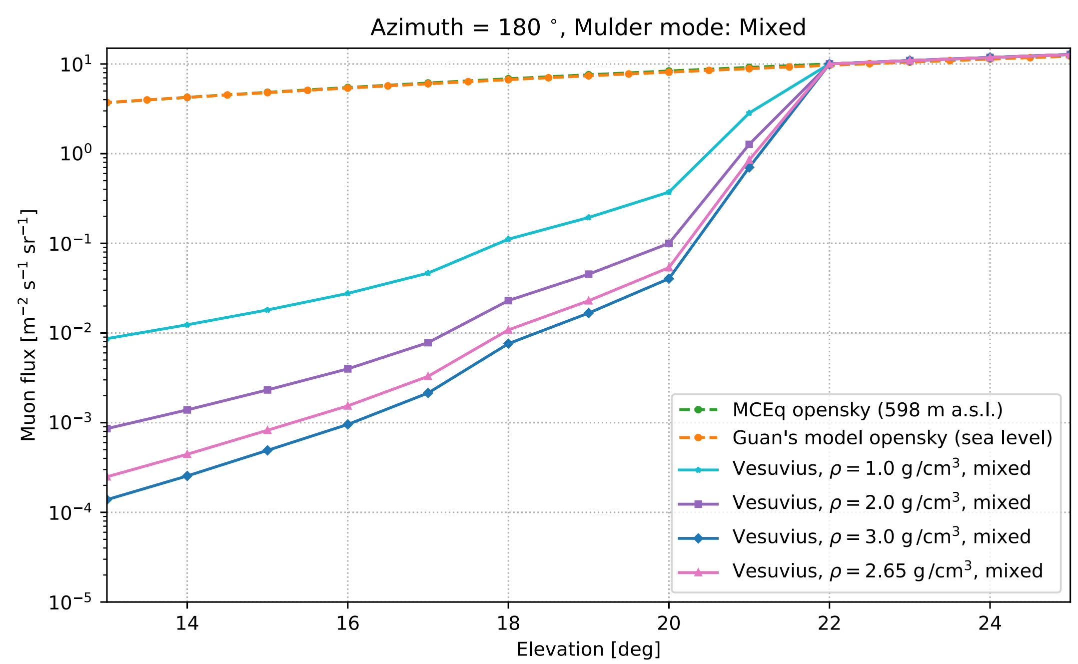
Modes in Mulder

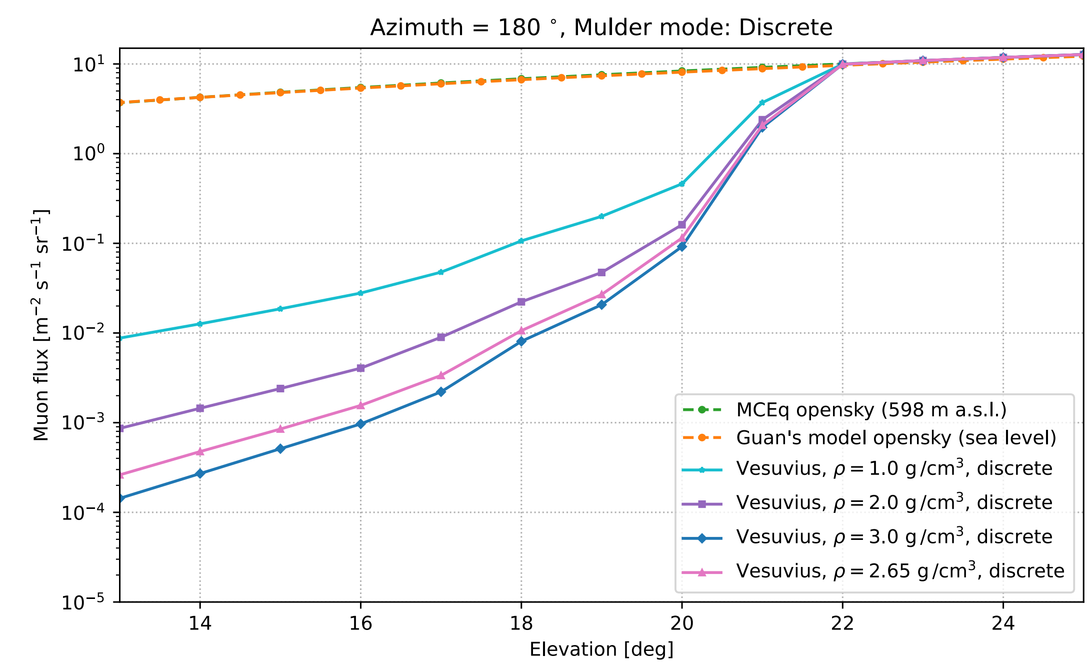
- **Continuous mode**
  Muons follow straight (deterministic) trajectories and lose energy as a smooth average (CSDA), approximating the cumulative effect of many soft collisions; fluctuations from hard losses are ignored.
- **Mixed mode**
  Trajectories remain deterministic, but soft losses are treated continuously while hard (catastrophic) collisions are simulated individually; each observation state yields many conjugated states whose flux must be averaged.
- **Discrete mode**
  Both energy loss and trajectories are fully individually (including multiple scattering and hard losses), so muon paths and final states are sampled event-by-event with maximal realism but highest computational cost.



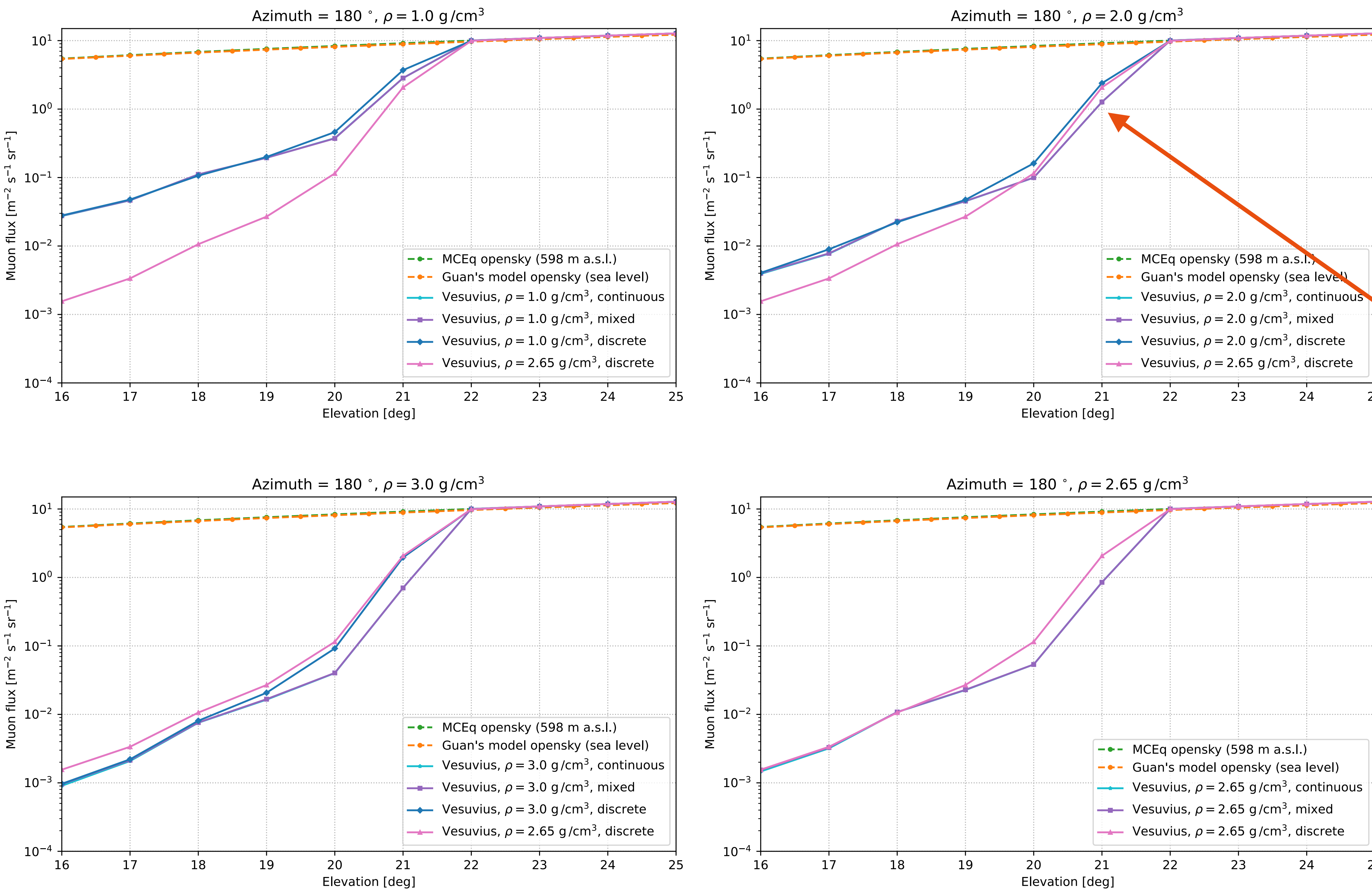
Modes in Mulder - I







Mulder transport modes comparison in **fixed density** - II



- **Pink**: ρ = 2.65 g/cm3 discrete is shown across all plotting for a comparison.
- Continuous and Mixed modes behavior similar.
- ρ = 2.65 g/cm3 discrete (**pink**) has higher flux value than ρ = 2.0 g/cm3 mixed (**purple**).

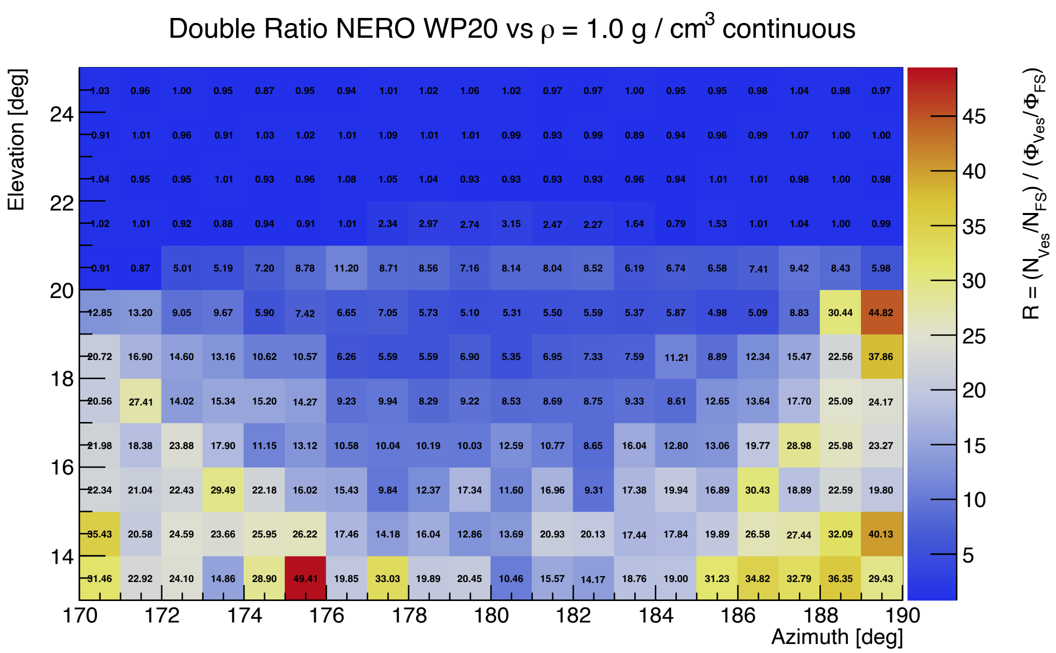
  It is at the edge of crater (~ elevation 20° - 22°, rock length ~ 150m)
- Will compare with calculations by Gabor.

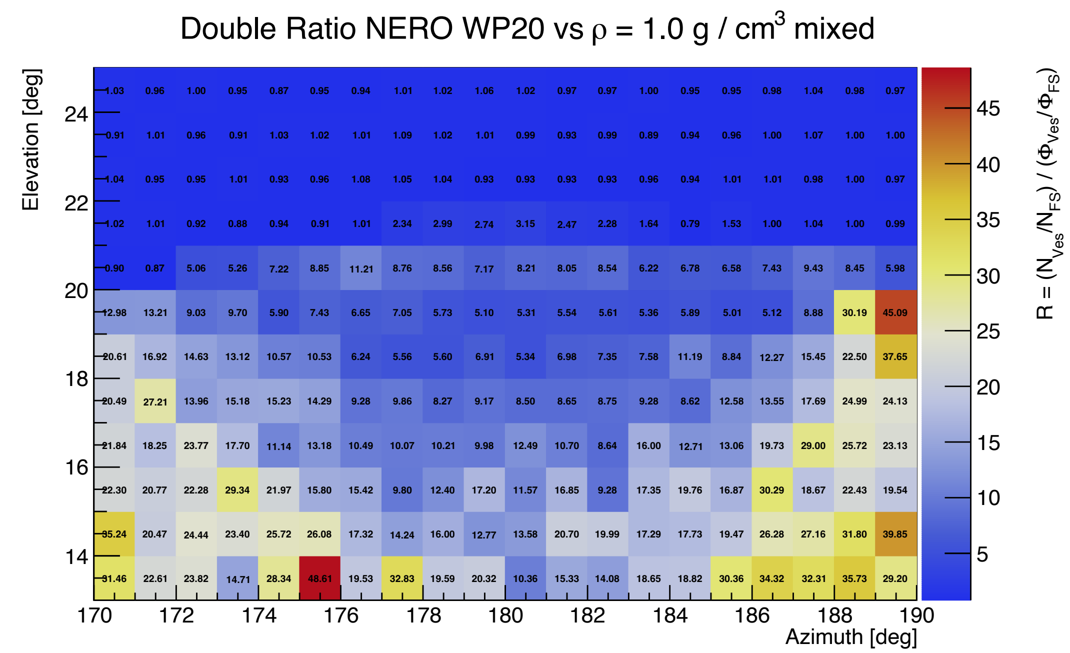
Double ratio

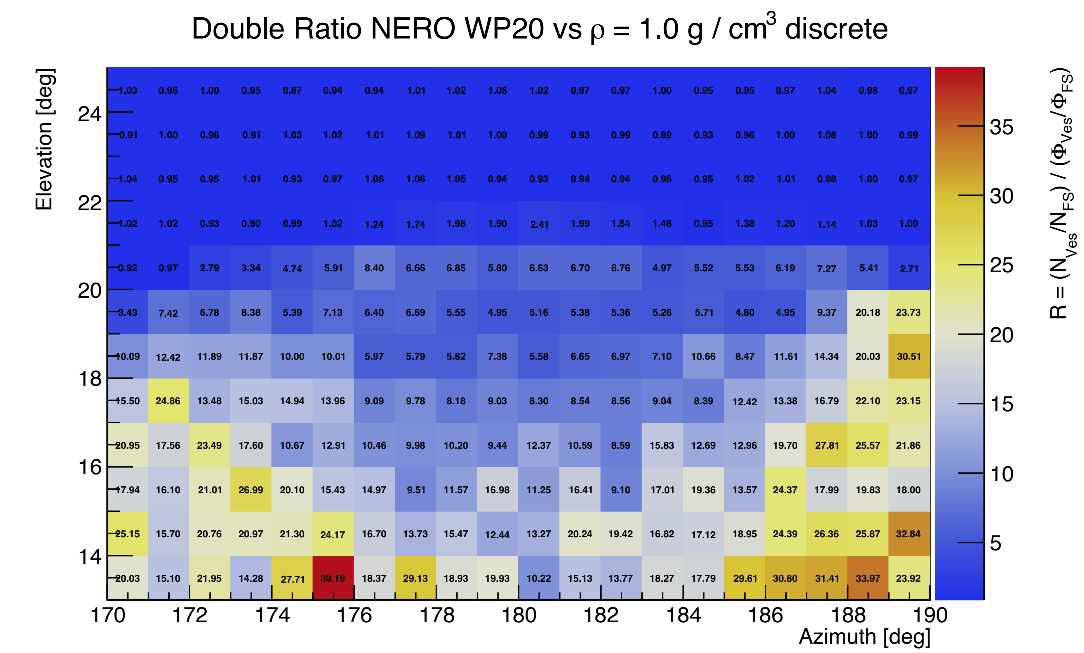
$$\text{ratio}_N = \frac{\frac{N_{meas}^{Ves}/\Delta T_{Ves}}{N_{meas}^{fs}/\Delta T_{fs}}}{\frac{I_{sim}^{Ves}}{I_{sim}^{fs}}}$$

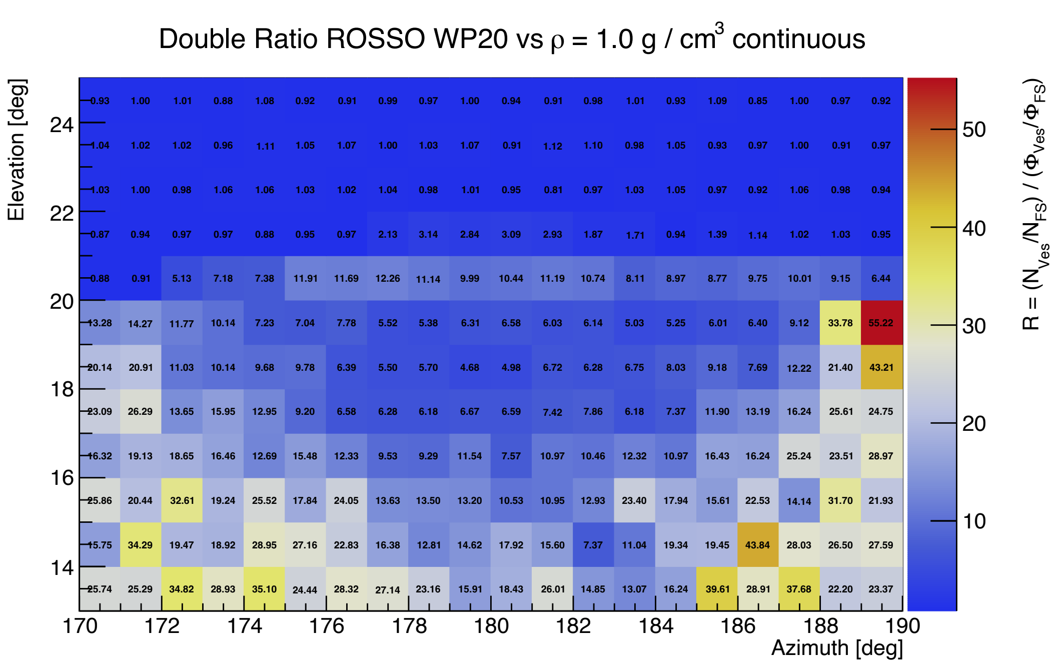
, similar concept with relative Transmission ratio.

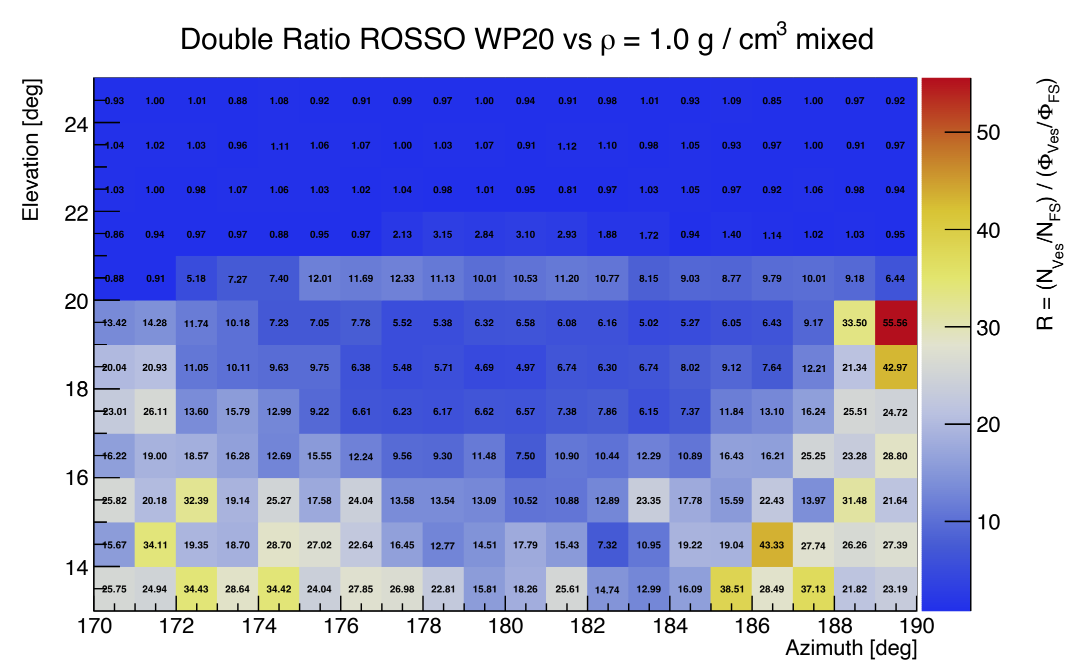
Double Ratio with different Modes in Mulder

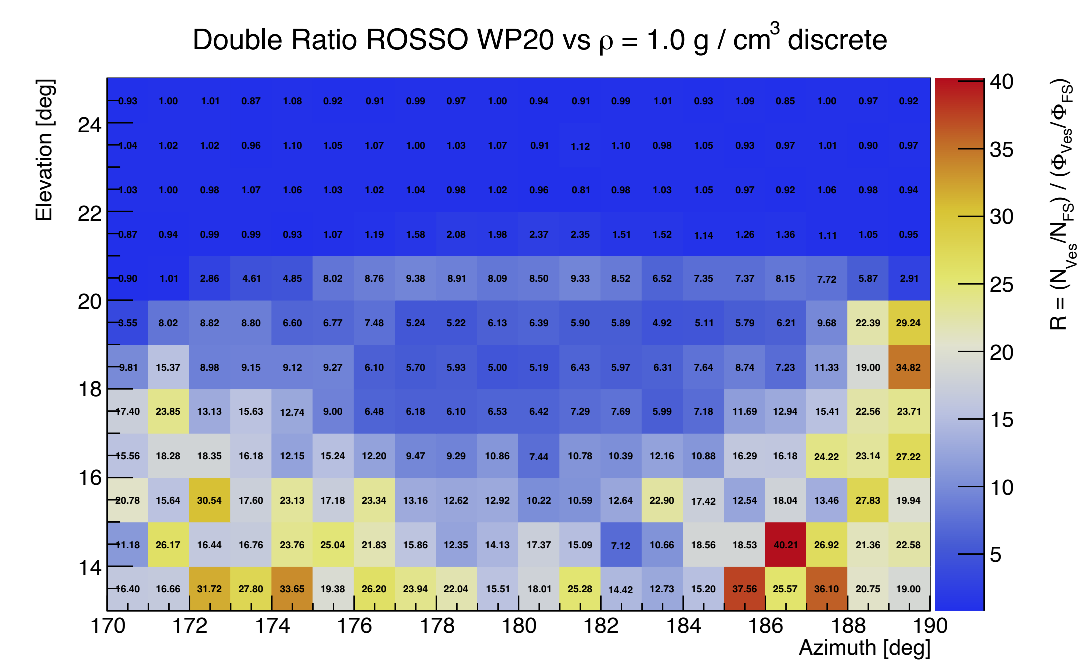




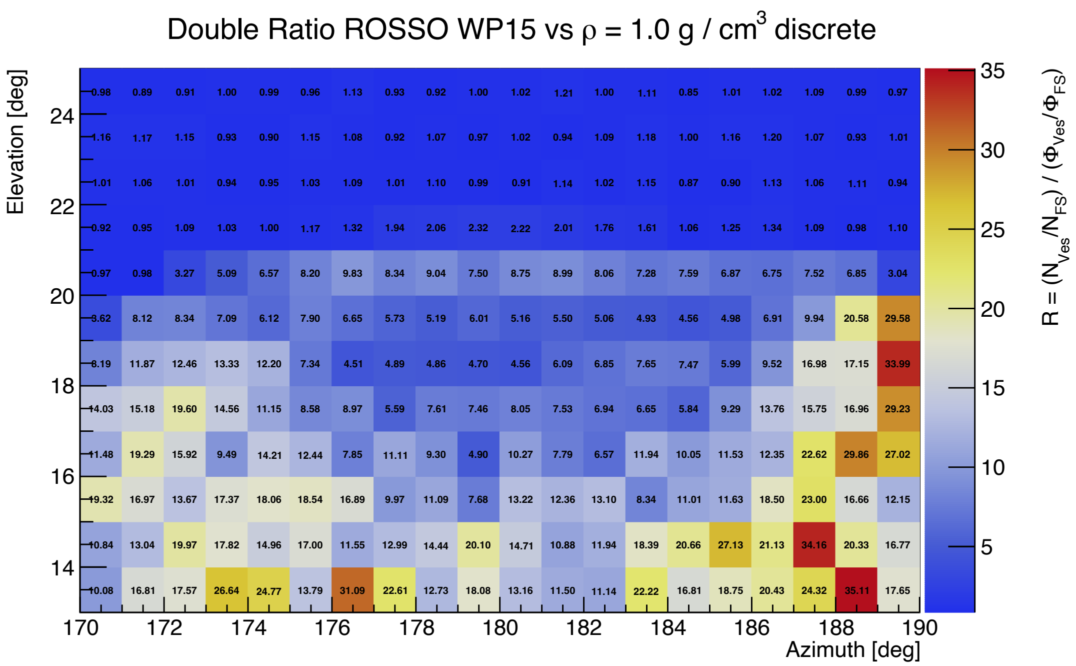


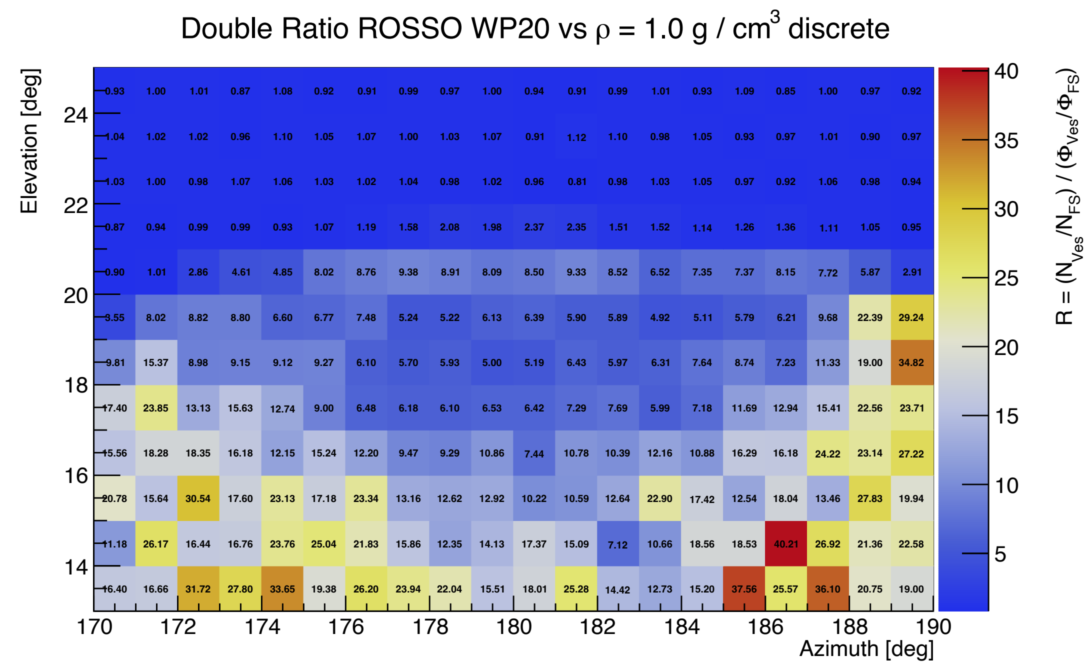


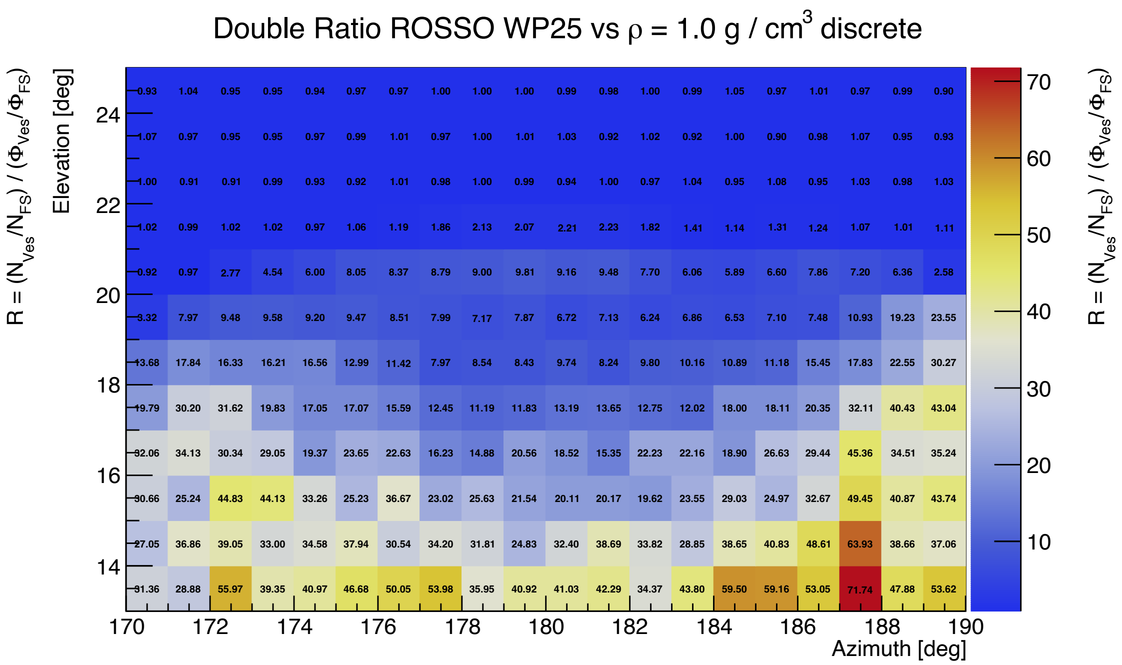


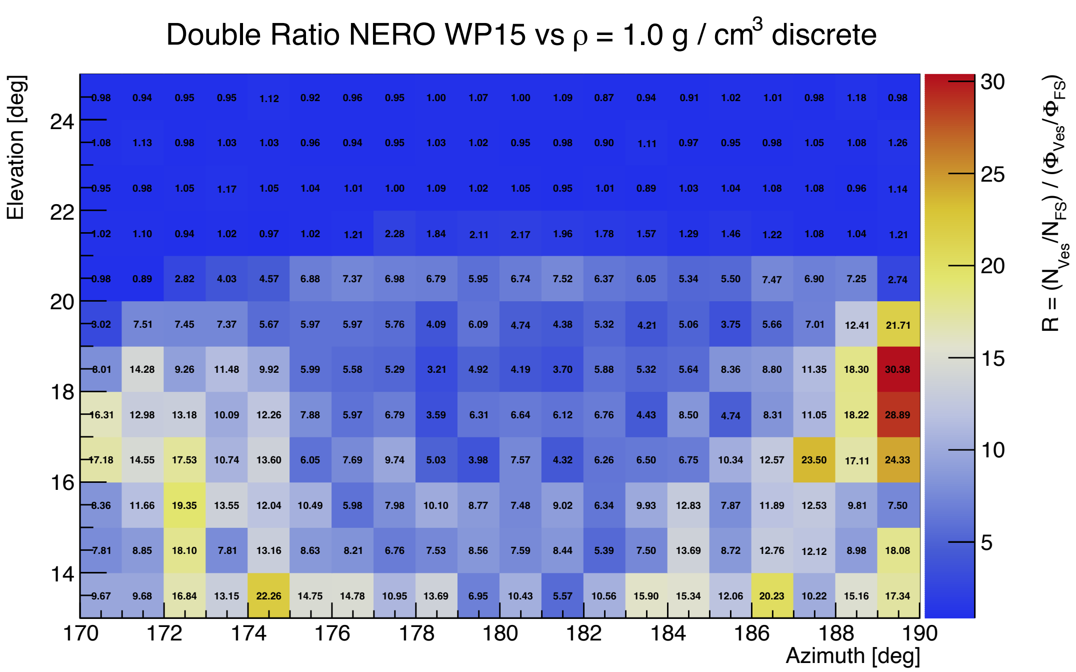


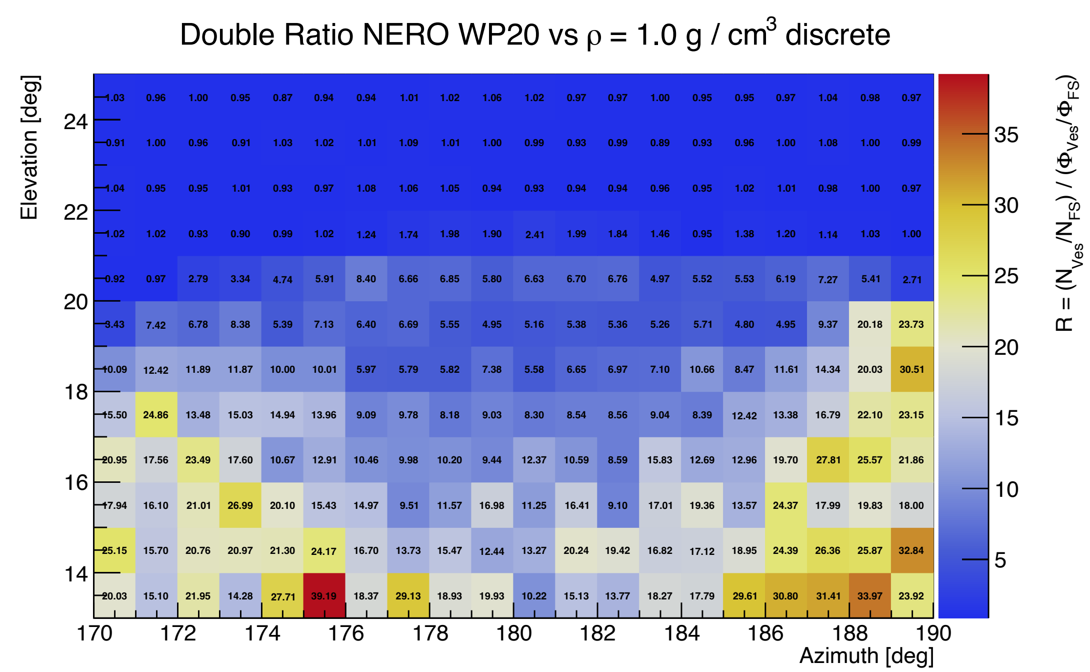
Double Ratio Discrete Mode among different hodoscopes

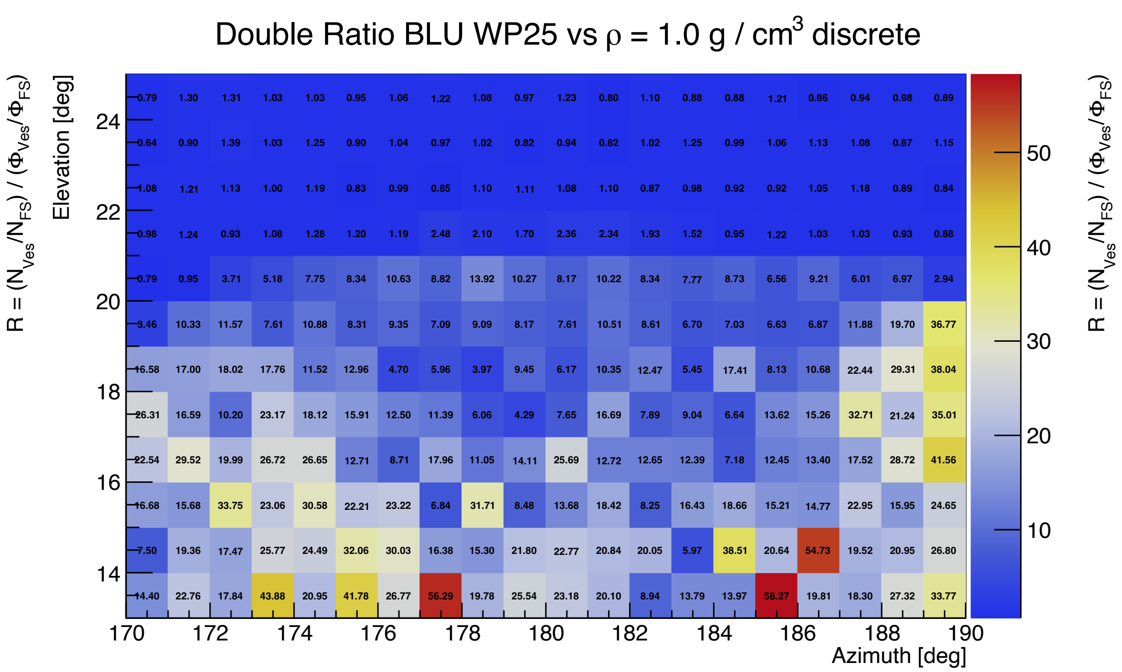


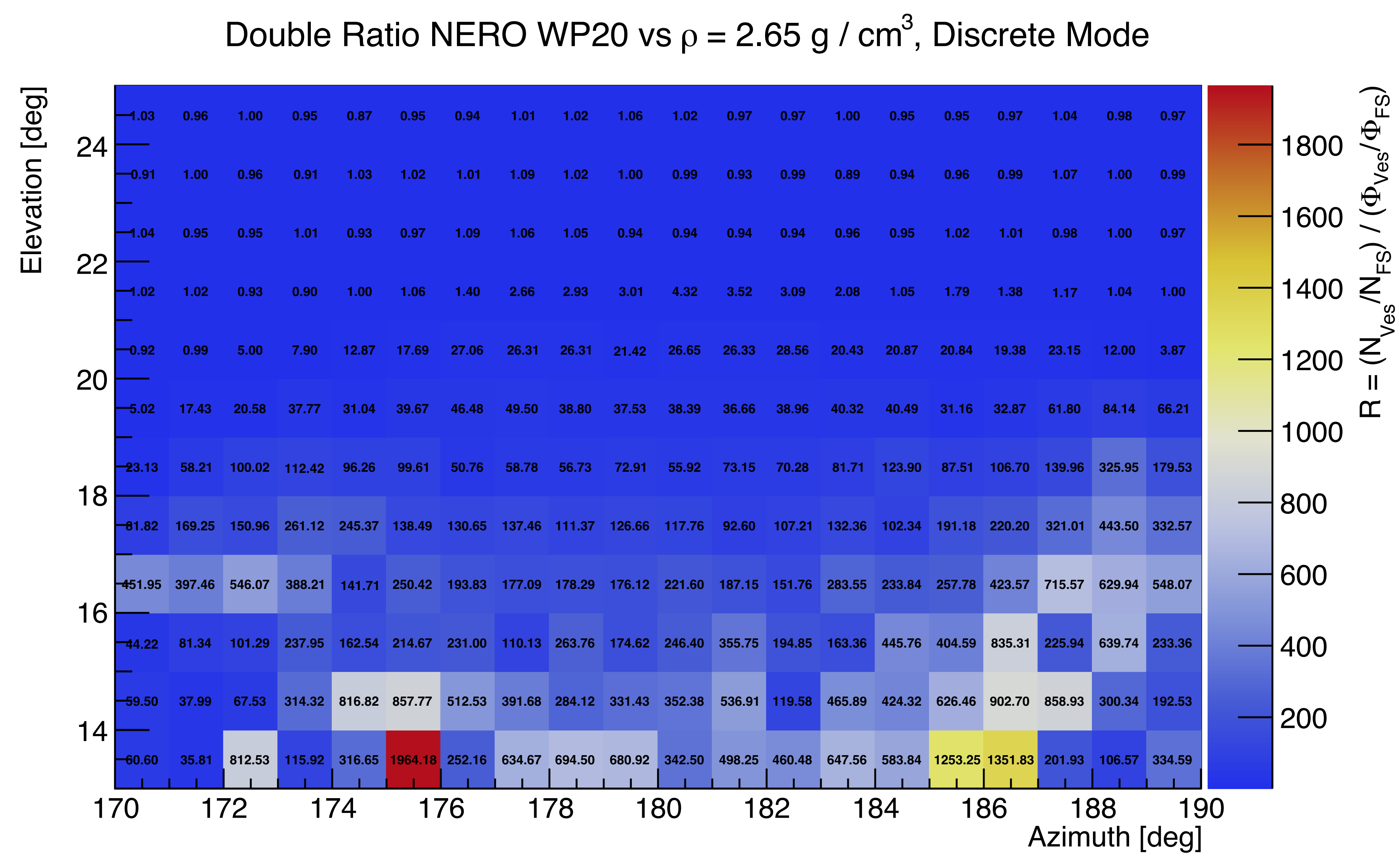











Double Ratio NERO WP20 vs ρ = 2.65 g / cm³, Discrete Mode
Elevation [deg]
Azimuth [deg]
R = (N_Ves /N_FS) / (Φ_Ves/Φ_FS)
24
22
20
18
16
14
170
172
174
176
178
180
182
184
186
188
190
1800
1600
1400
1200
1000
800
600
400
200
1.03 0.96 1.00 0.95 0.87 0.95 0.94 1.01 1.02 1.06 1.02 0.97 0.97 1.00 0.95 0.95 0.97 1.04 0.98 0.97
0.91 1.00 0.96 0.91 1.03 1.02 1.01 1.09 1.02 1.00 0.99 0.93 0.99 0.89 0.94 0.96 0.99 1.07 1.00 0.99
1.04 0.95 0.95 1.01 0.93 0.97 1.09 1.06 1.05 0.94 0.94 0.94 0.94 0.96 0.95 1.02 1.01 0.98 1.00 0.97
1.02 1.02 0.93 0.90 1.00 1.06 1.40 2.66 2.93 3.01 4.32 3.52 3.09 2.08 1.05 1.79 1.38 1.17 1.04 1.00
0.92 0.99 5.00 7.90 12.87 17.69 27.06 26.31 26.31 21.42 26.65 26.33 28.56 20.43 20.87 20.84 19.38 23.15 12.00 3.87
5.02 17.43 20.58 37.77 31.04 39.67 46.48 49.50 38.80 37.53 38.39 36.66 38.96 40.32 40.49 31.16 32.87 61.80 84.14 66.21
23.13 58.21 100.02 112.42 96.26 99.61 50.76 58.78 56.73 72.91 55.92 73.15 70.28 81.71 123.90 87.51 106.70 139.96 325.95 179.53
81.82 169.25 150.96 261.12 245.37 138.49 130.65 137.46 111.37 126.66 117.76 92.60 107.21 132.36 102.34 191.18 220.20 321.01 443.50 332.57
451.95 397.46 546.07 388.21 141.71 250.42 193.83 177.09 178.29 176.12 221.60 187.15 151.76 283.55 233.84 257.78 423.57 715.57 629.94 548.07
44.22 81.34 101.29 237.95 162.54 214.67 231.00 110.13 263.76 174.62 246.40 355.75 194.85 163.36 445.76 404.59 835.31 225.94 639.74 233.36
59.50 37.99 67.53 314.32 816.82 857.77 512.53 391.68 284.12 331.43 352.38 536.91 119.58 465.89 424.32 626.46 902.70 858.93 300.34 192.53
60.60 35.81 812.53 115.92 316.65 1964.18 252.16 634.67 694.50 680.92 342.50 498.25 460.48 647.56 583.84 1253.25 1351.83 201.93 106.57 334.59