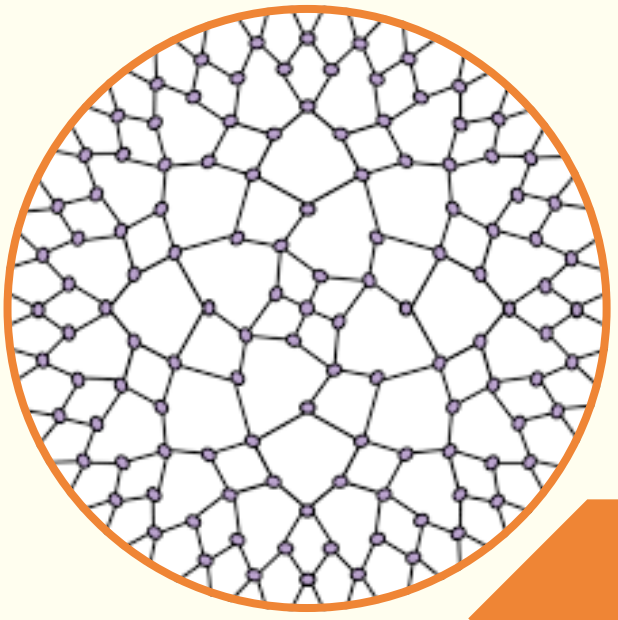
Project Report

2024/2025

Tensor Networks (DMRG ,i-TEBD) and its applications



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Github repository https://github.com/shikharkyadesultory/MB-Localization-TLFIM-

Progress Summary

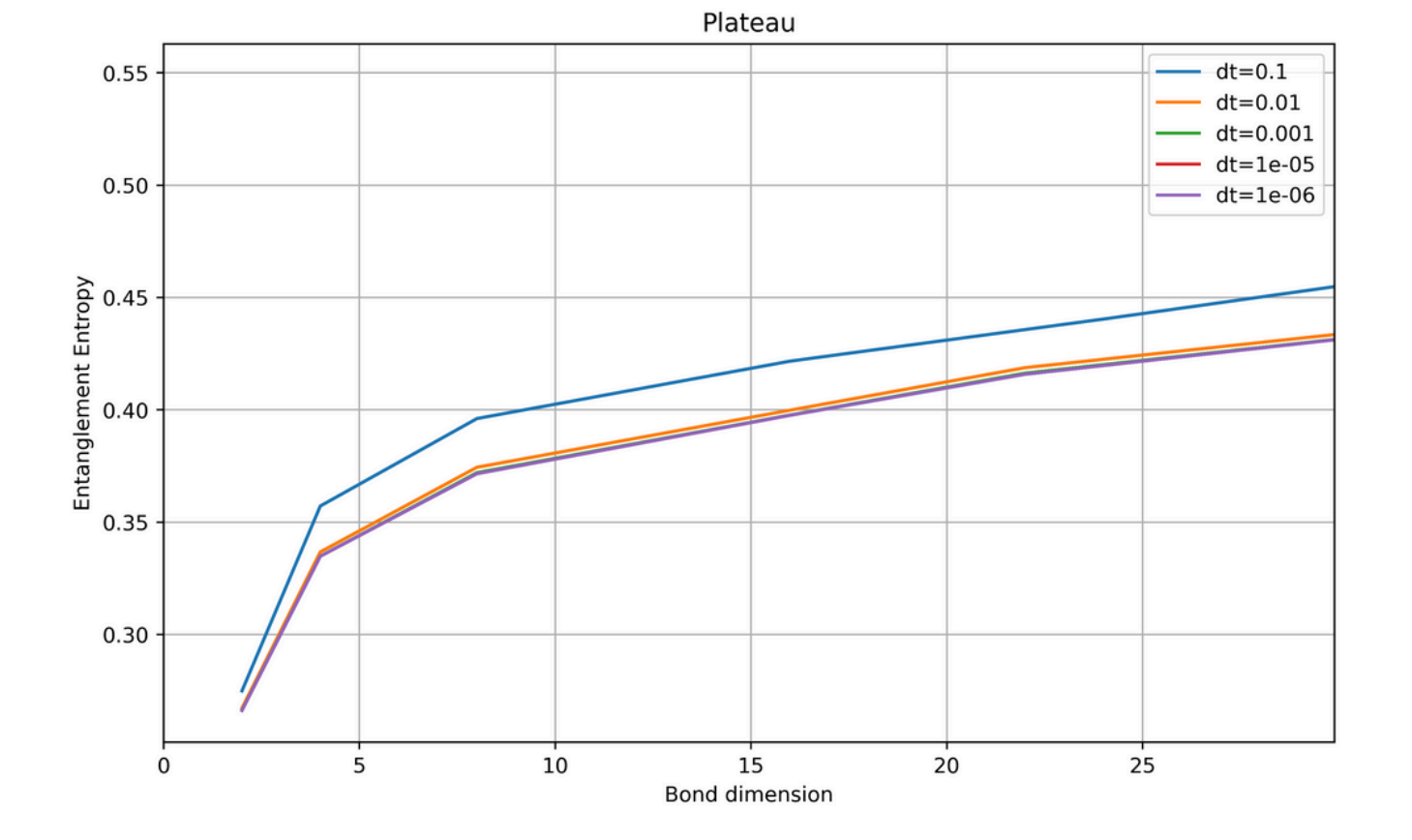
The project aimed at applications of i-TEBD and DMRG in studying the Quantum Dynamics

Objectives: (the details are in github repository)

- Try out different parameters (bond dimension χ, time step $\delta\tau$, time period T, . . .) and check the convergence of the ground state energy
- Detect the quantum phase transition of the transverse field Ising model by plotting the entanglement entropy S for different system sizes L.
- Implement a function to obtain the correlation function Cij = $\langle \sigma$ z i σ z j $\rangle$ and use it to obtain the magnetization m2 .
- Replace the TEBD function with a second order Trotter decomposition.
- Repeat the above for real time evolution and introducing a longitudinal field
- energy plot for exact diagonalization and entropy calculation and plot using finite dmrg.
- 50 site MPS and successful convergence within the tolerance limit under lanczos operation and final implementation for TEBD.
- The density imbalance I and bipartite entanglement entropy characterize oscillations between the two N´eel ordered states for a finite size chain via i-TEBD
- Entanglement Entropy Calculation for Driven case and with an angular variation
- Calculation of Density imbalance for driven case
- Magnetization for both driven and undriven case

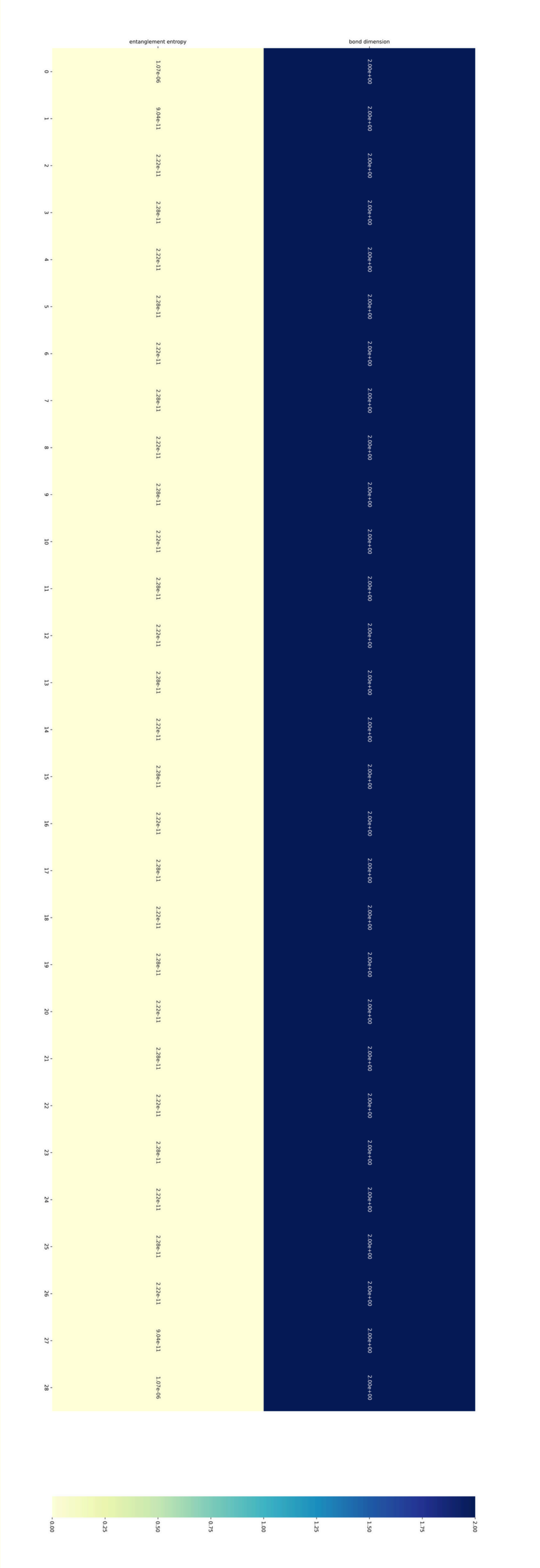
This plot involves the entanglement entropy plot varying with the bond dimension which attains a stationary values after being evolved for 5 different time steps.

The stability attained at later intervals over certain bond dimension denote a robust and persistent response at higher bond dimension when evolved

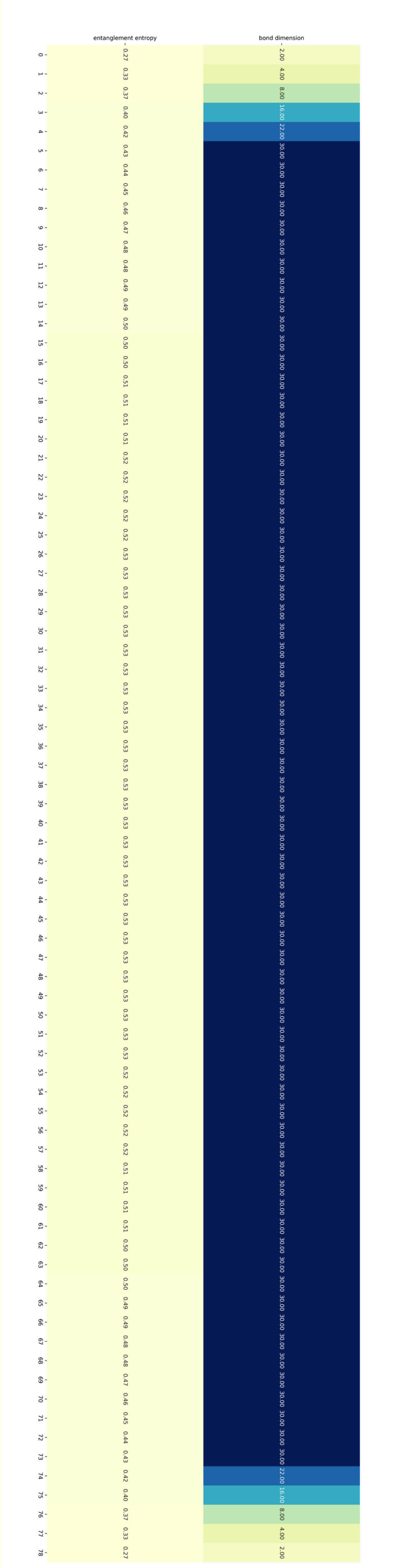


The plot from Fig-1 represents the gradient plot for the entanglement entropy for the Transverse and longitudinal field ising model for the final bond dimension and final entropy

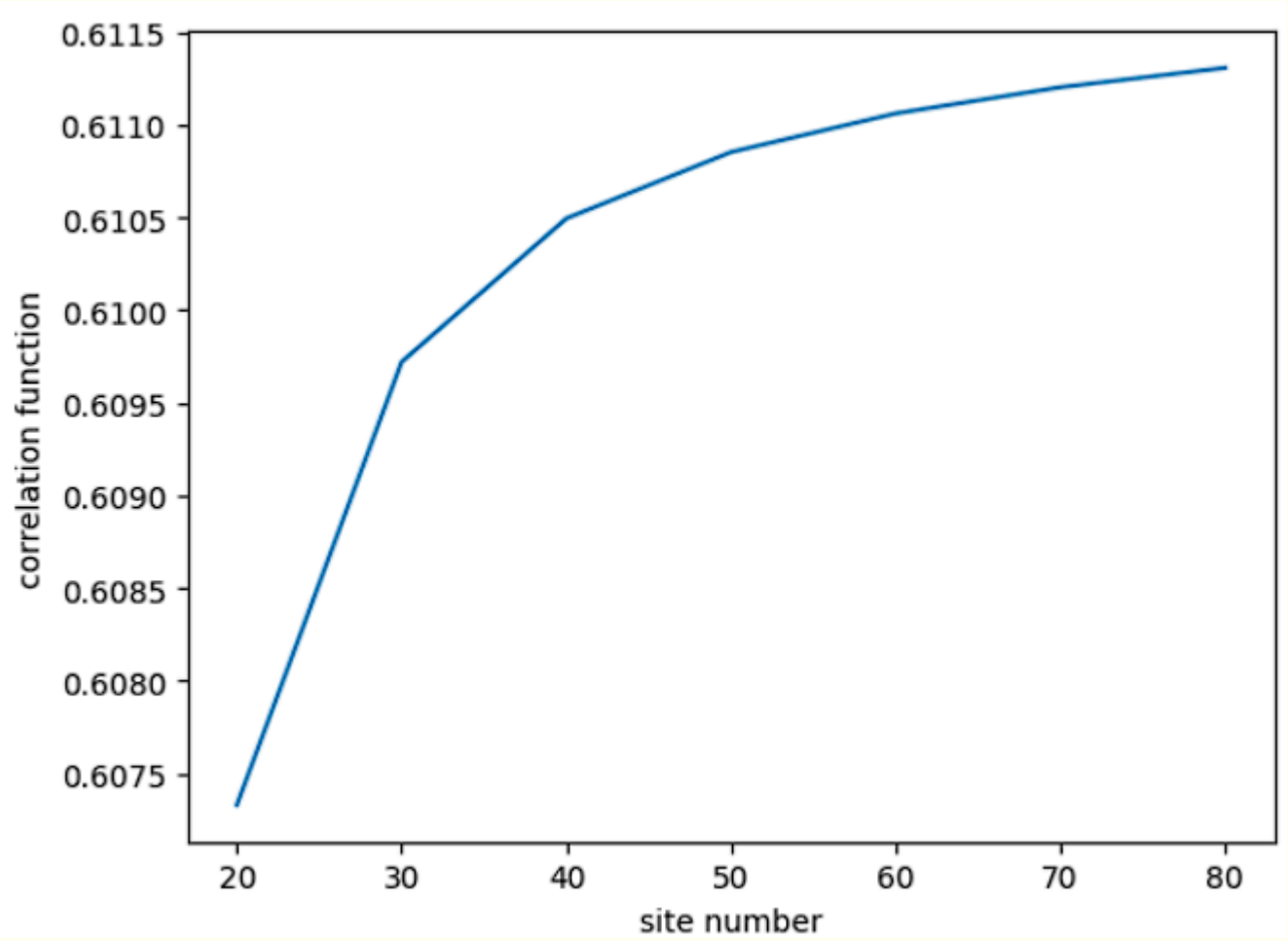
While the Fig - 2 denote the evolution based on suzuki trotter decomposition and denote a separability at the final case as the entropy reduces to zero for lack of entanglement in the system


entanglement entropy
bond dimension

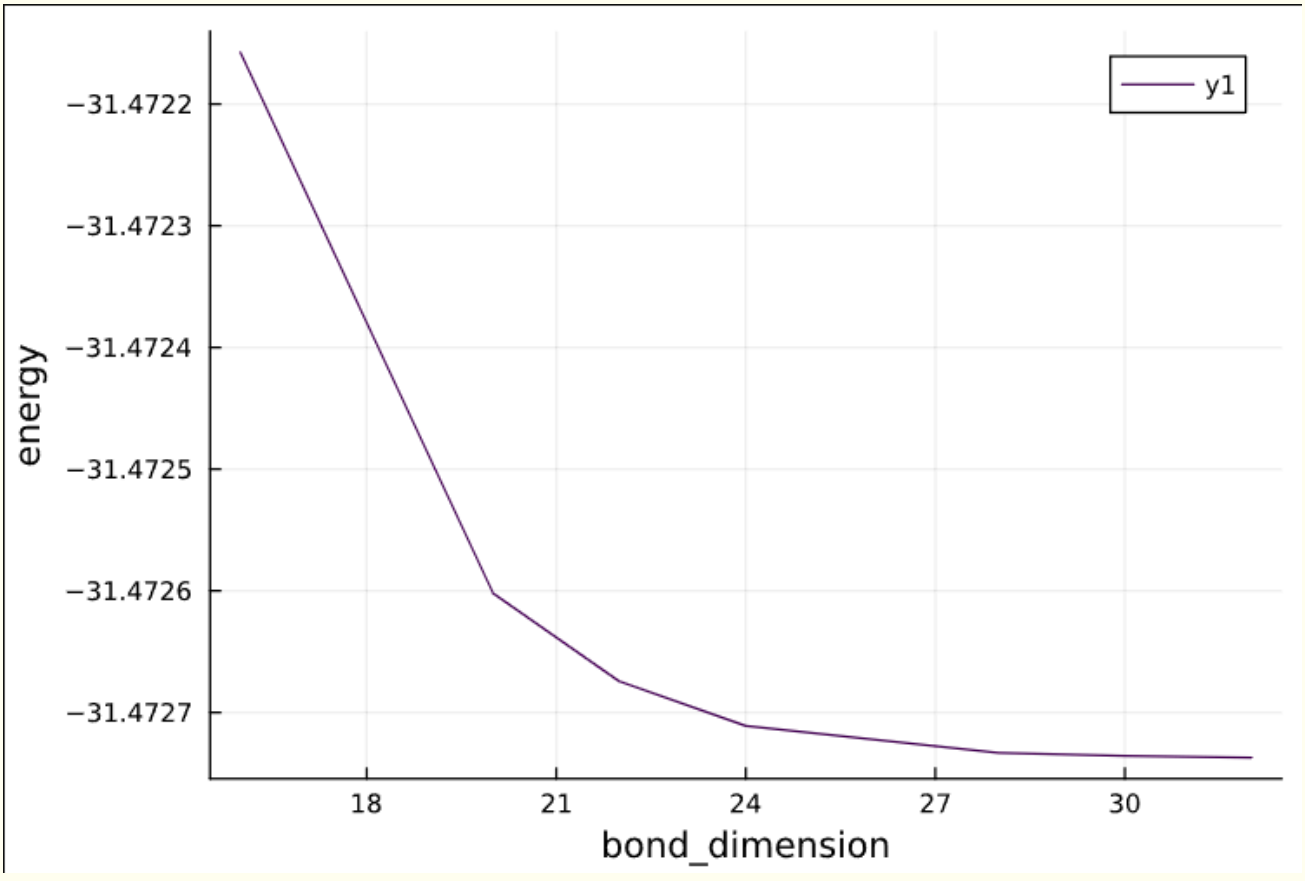
2


entanglement entropy
bond dimension

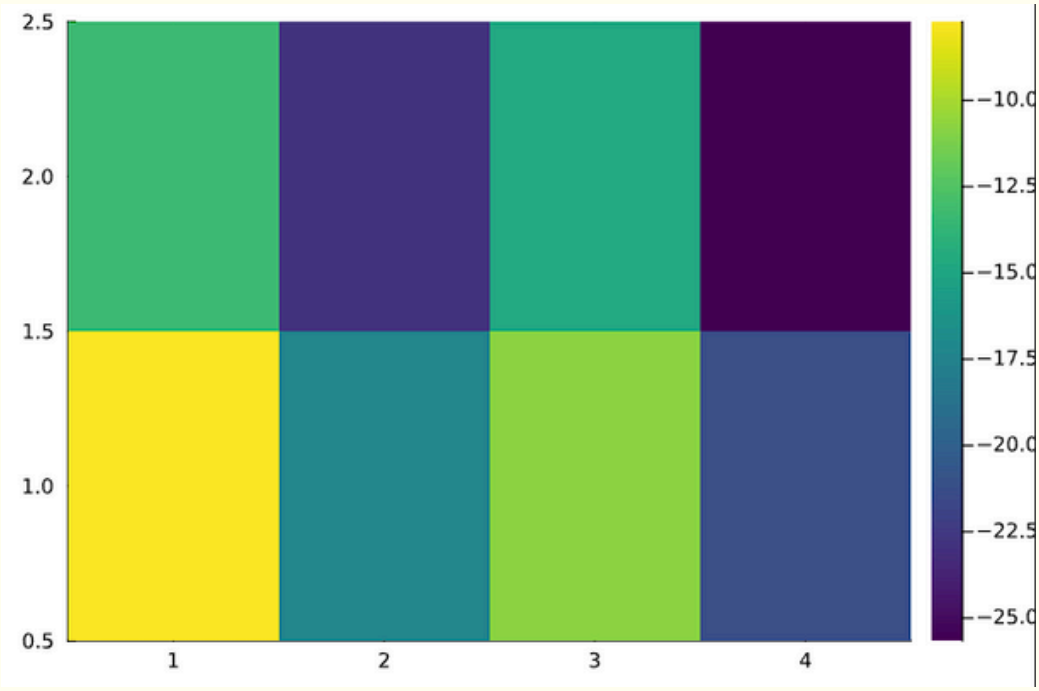
1



The plot involves a 51 site DMRG based analysis for the accuracy of the system based on the Energy variation with the bond dimension

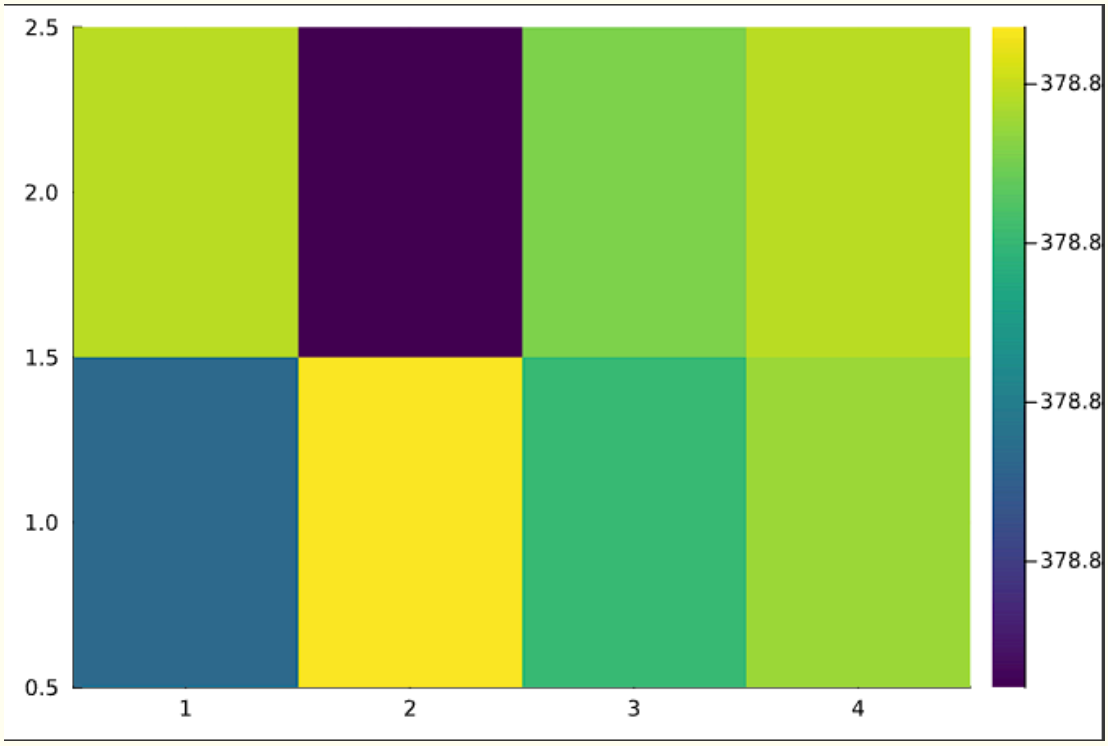


The plot below involves heatmap for Energy random MPS with varying site length analysis using exact diagonalization and DMRG

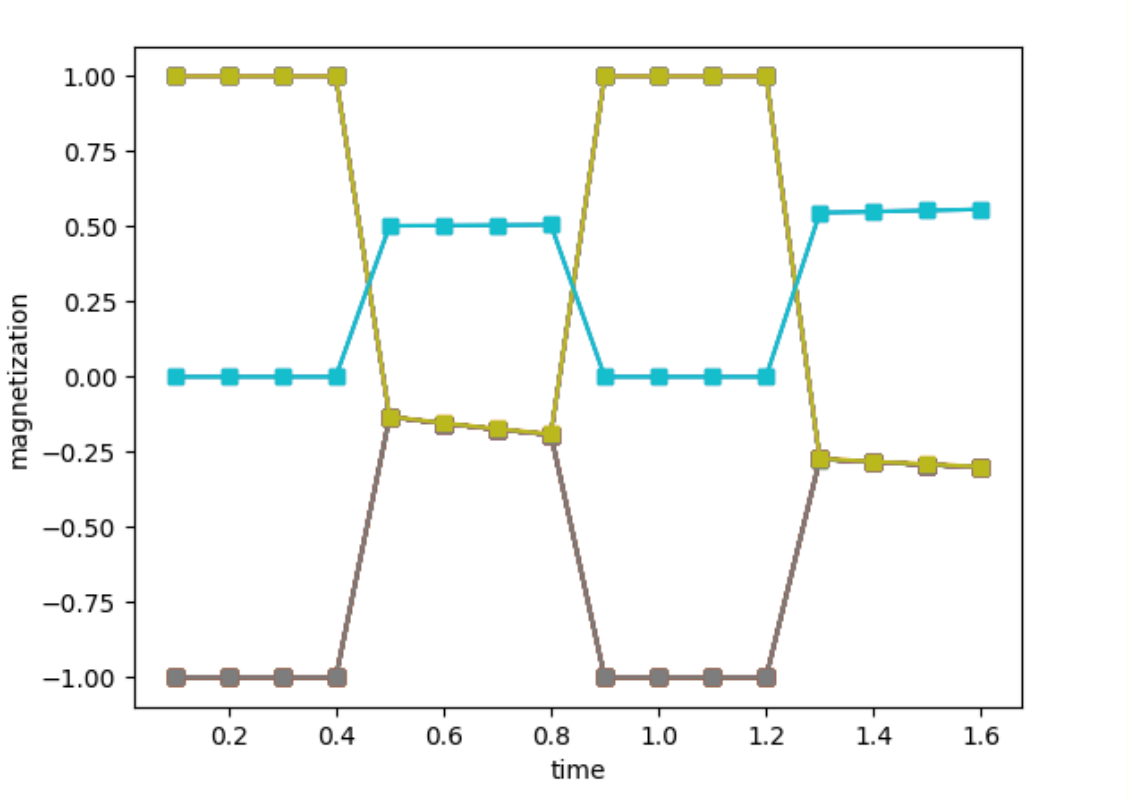


DMRG

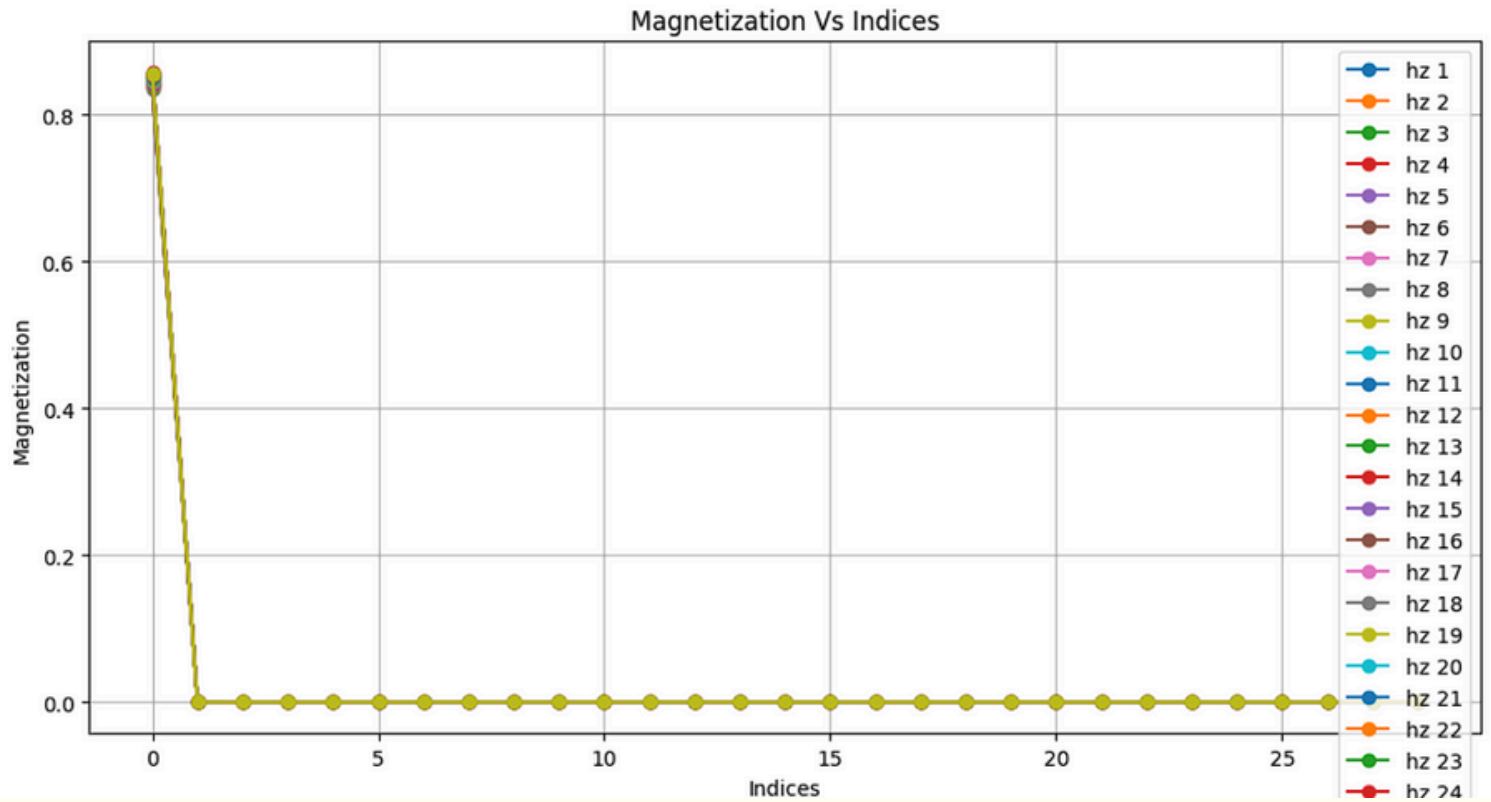
ED



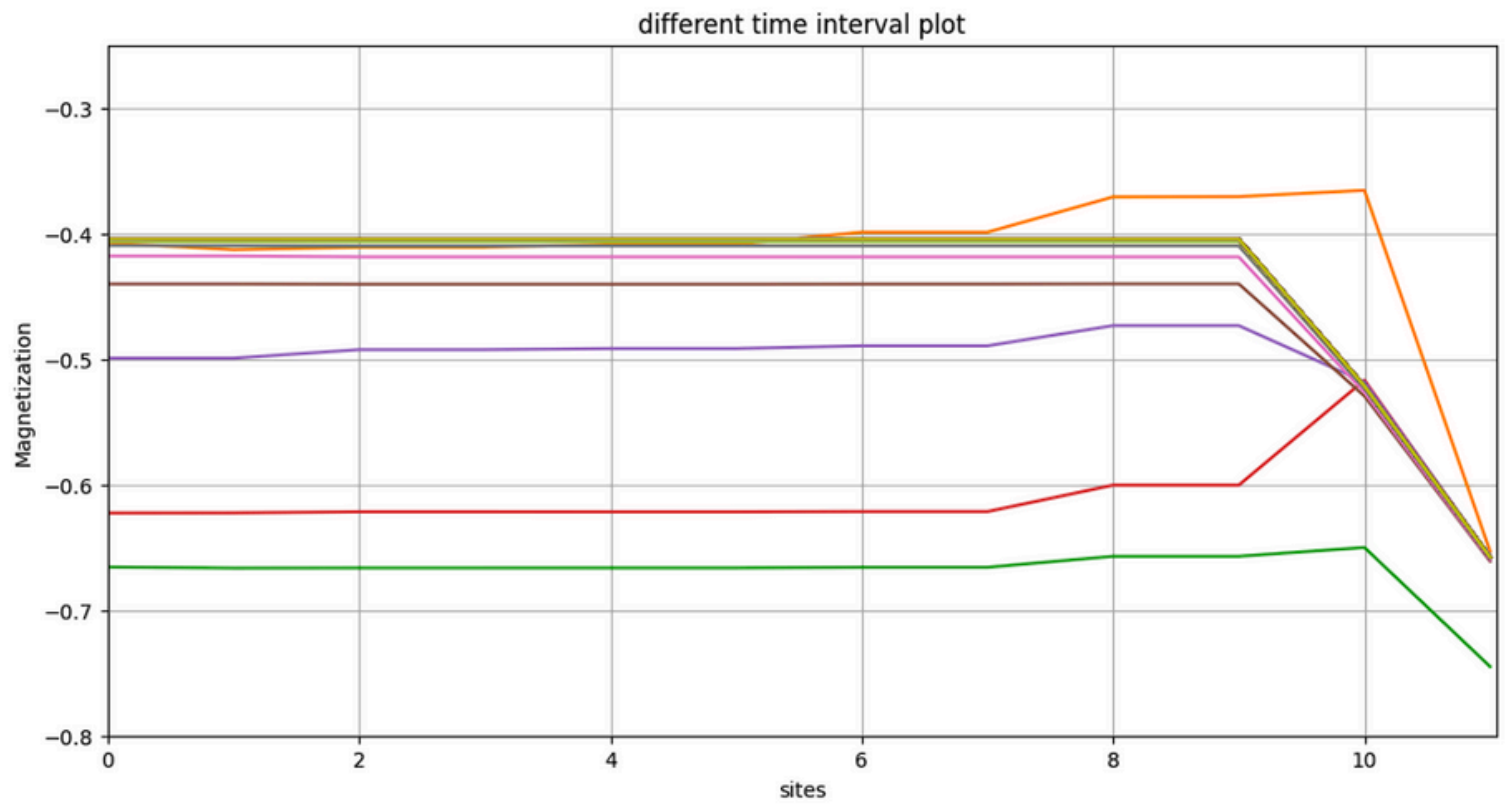
The plot below involves driven magnetization for the case of alteration of the T/4,2T/4,3T/4,T with alternating value of the field for the either cases of transverse and longitudinal field



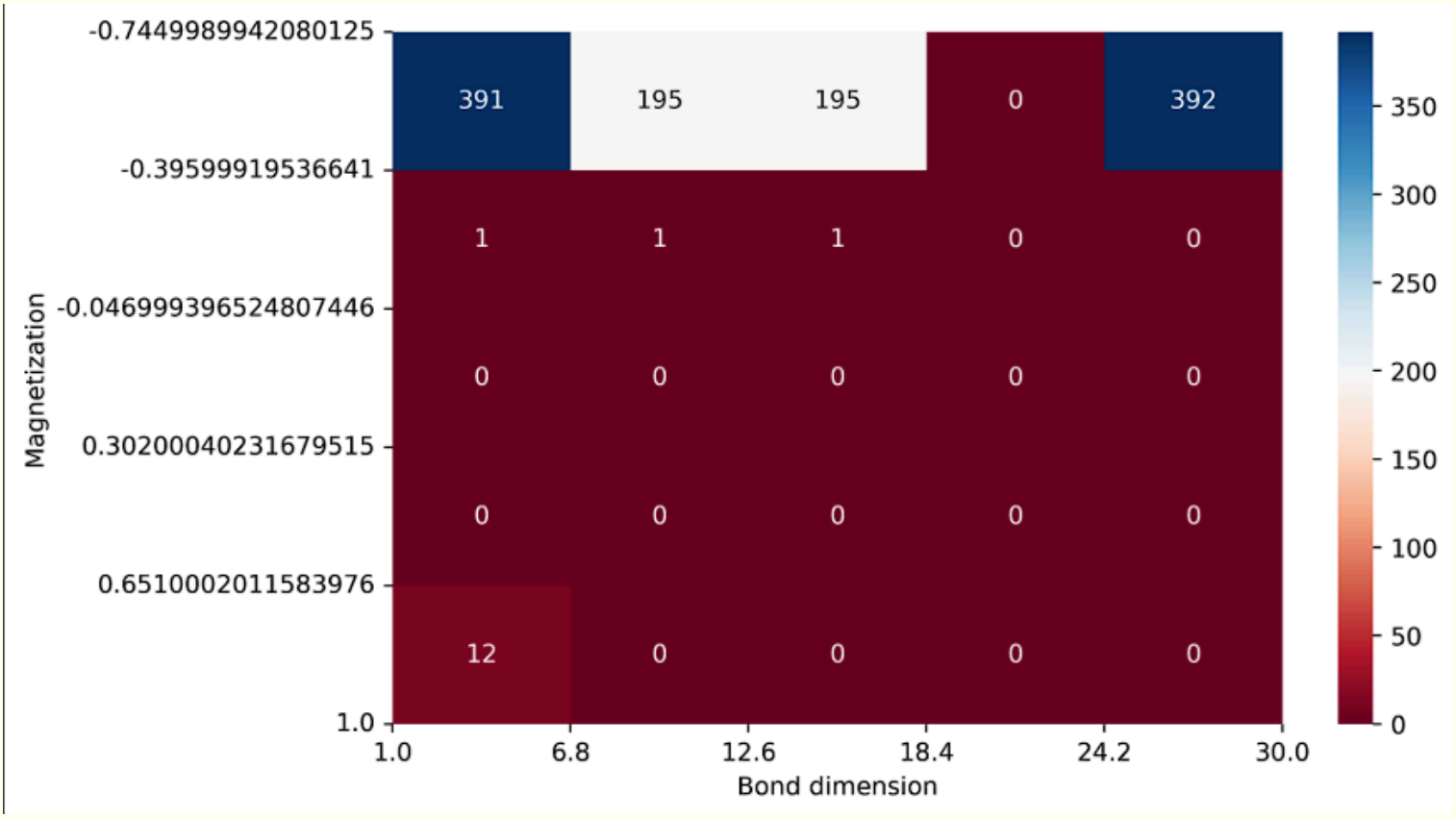
Magnetization plot for manipulation of magnetic field for all the sites at all the evolving intervals



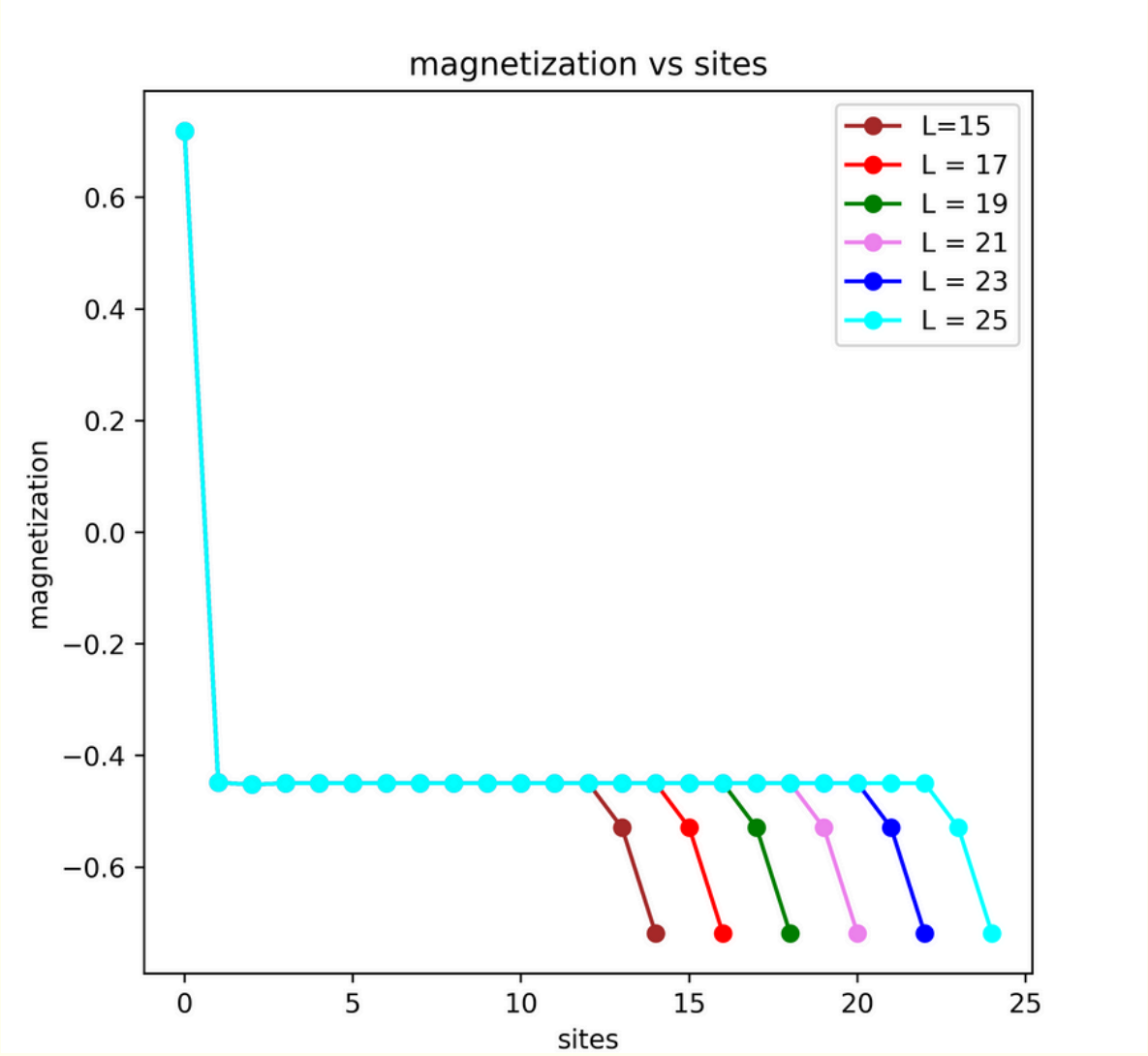
Magnetization for evolution over 99 time steps , undriven in this case it approaches a peak and then reduces to zero



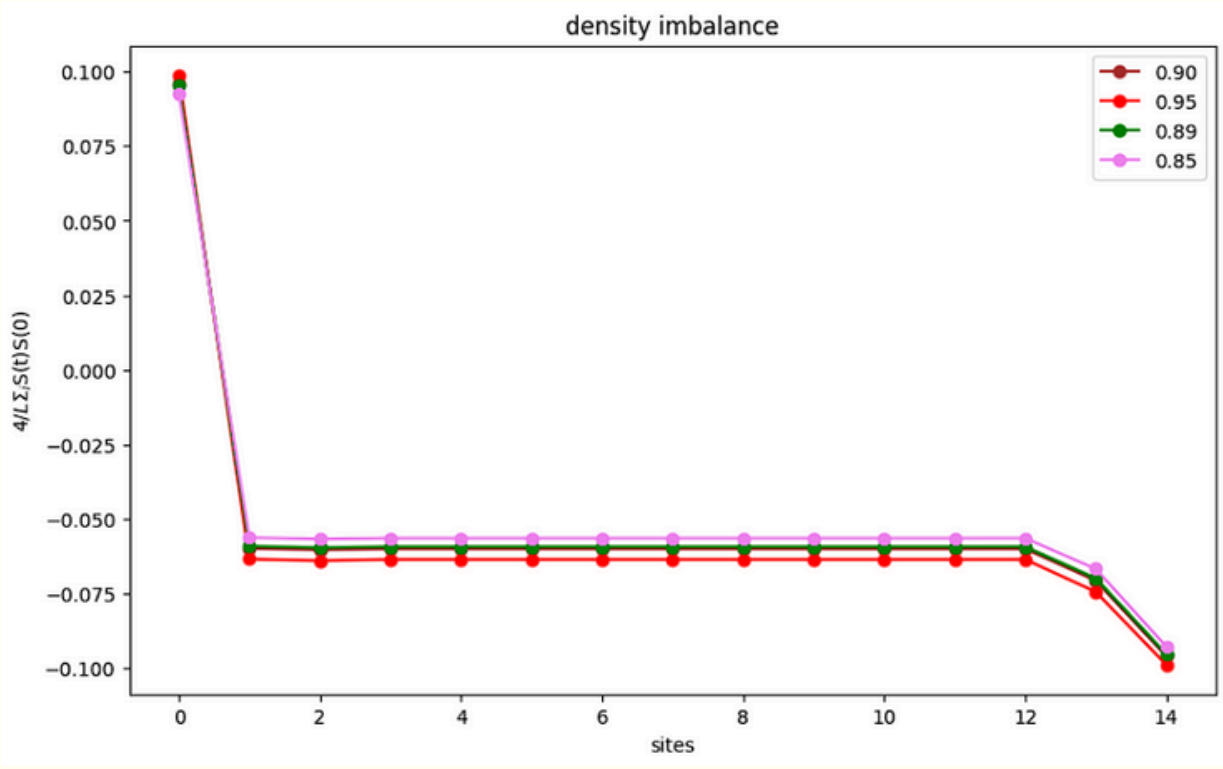
Frequency of sites having magnetization of a certain range under undriven circumstances



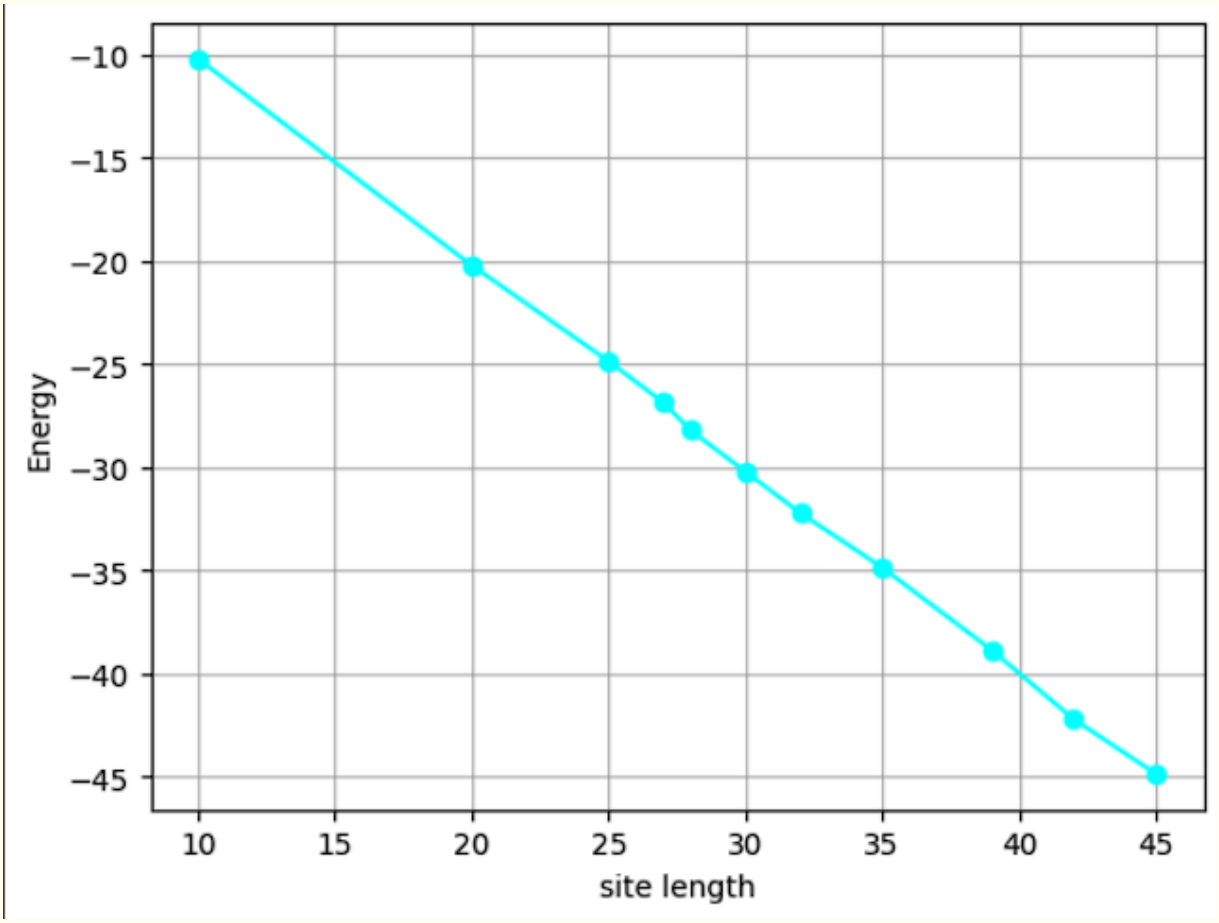
Magnetization for different sites in case of L= 15,17,19,21,23,25



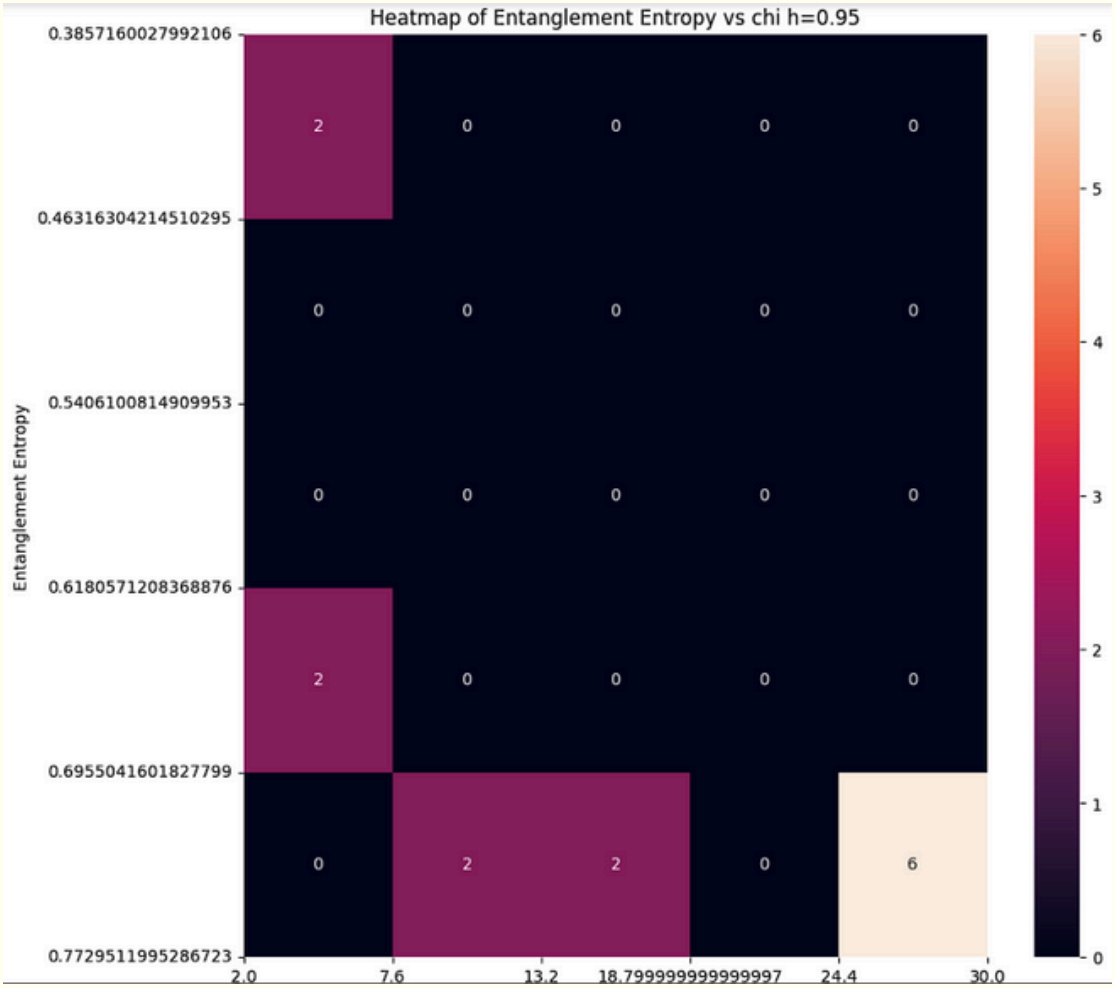
Density Imbalance in alternate driving sequence



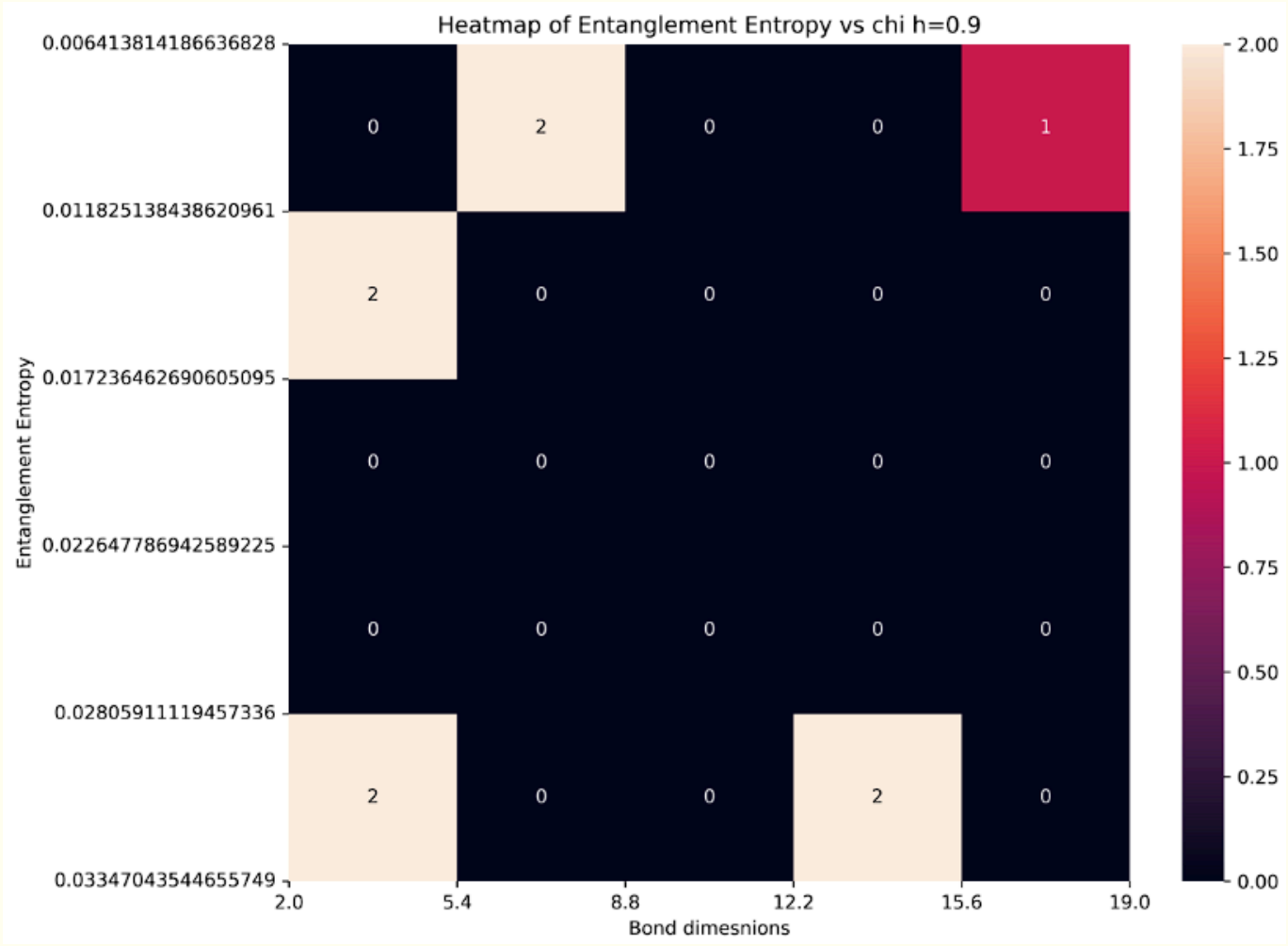
energy vs Bond Dimension variation for Transverse and longitudinal Field Ising model in case of i-TEBD



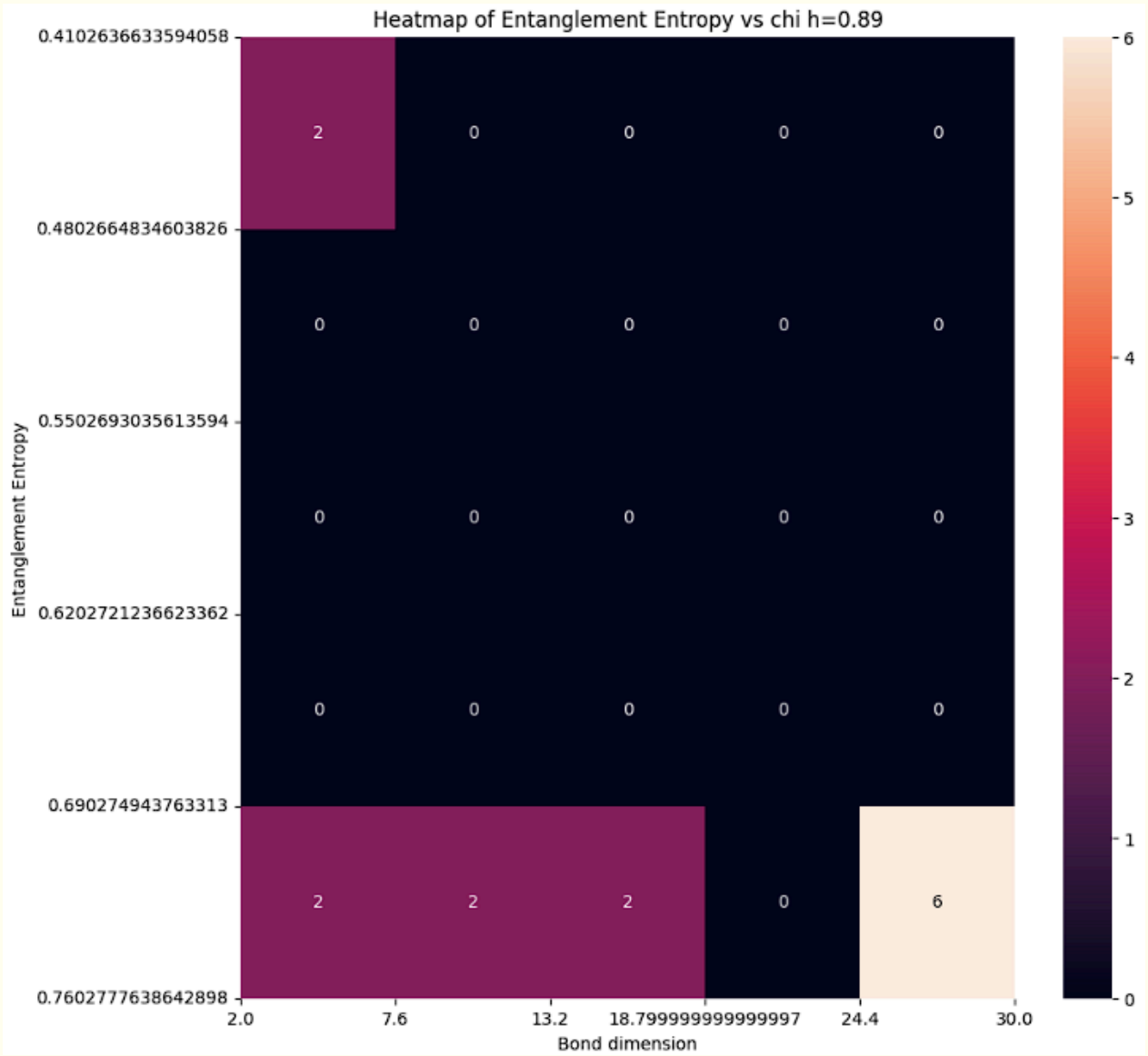
Alternate Driving sequence for different values of hx and hz and Entanglement Entropy vs bond dimension plot



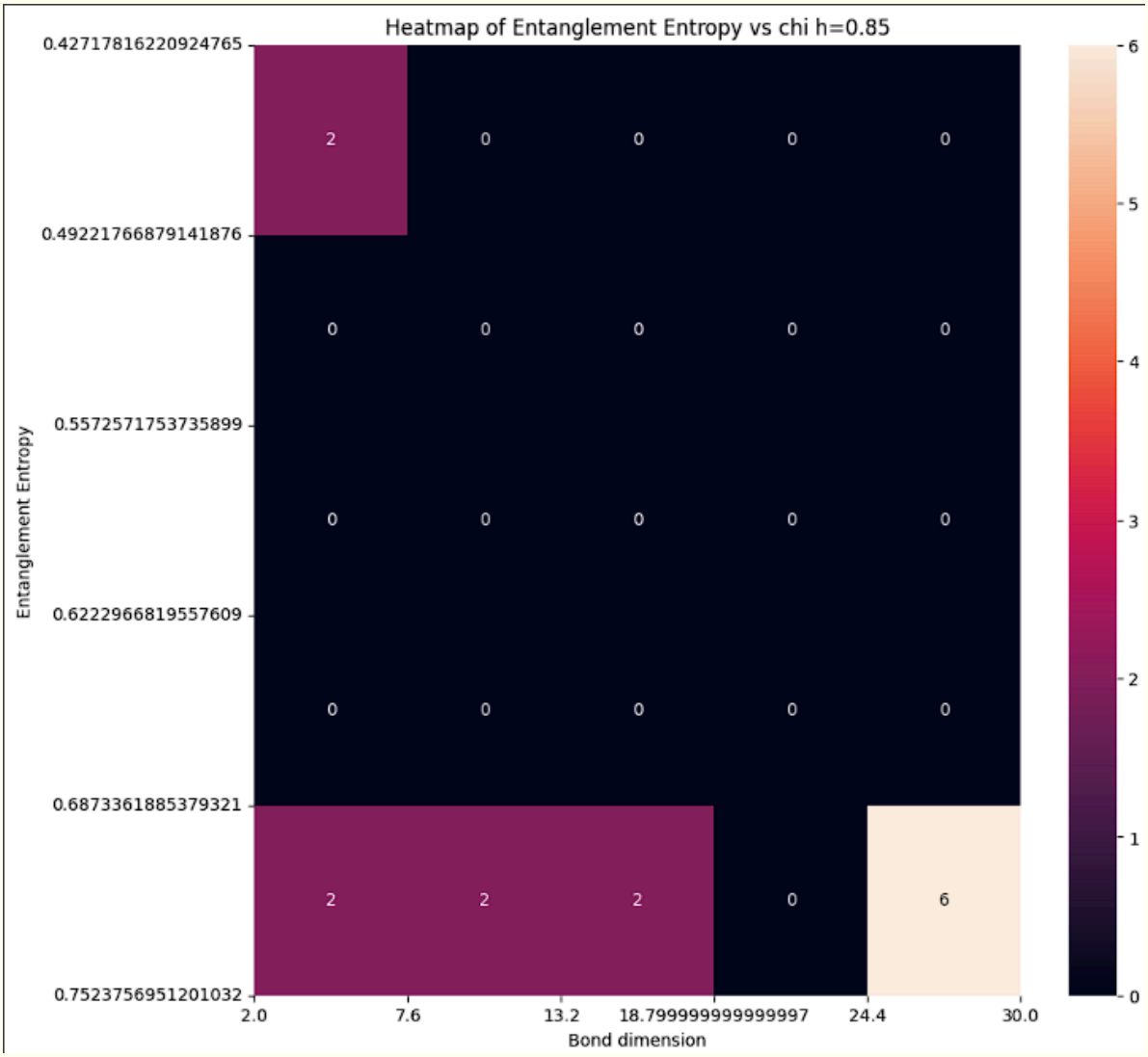
h = 0.95


Heatmap of Entanglement Entropy vs chi h=0.9
Entanglement Entropy
0.006413814186636828
0.011825138438620961
0.017236462690605095
0.022647786942589225
0.02805911119457336
0.03347043544655749
Bond dimesnions
2.0
5.4
8.8
12.2
15.6
19.0
0 2 0 0 1
2 0 0 0 0
0 0 0 0 0
0 0 0 0 0
2 0 0 2 0
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00

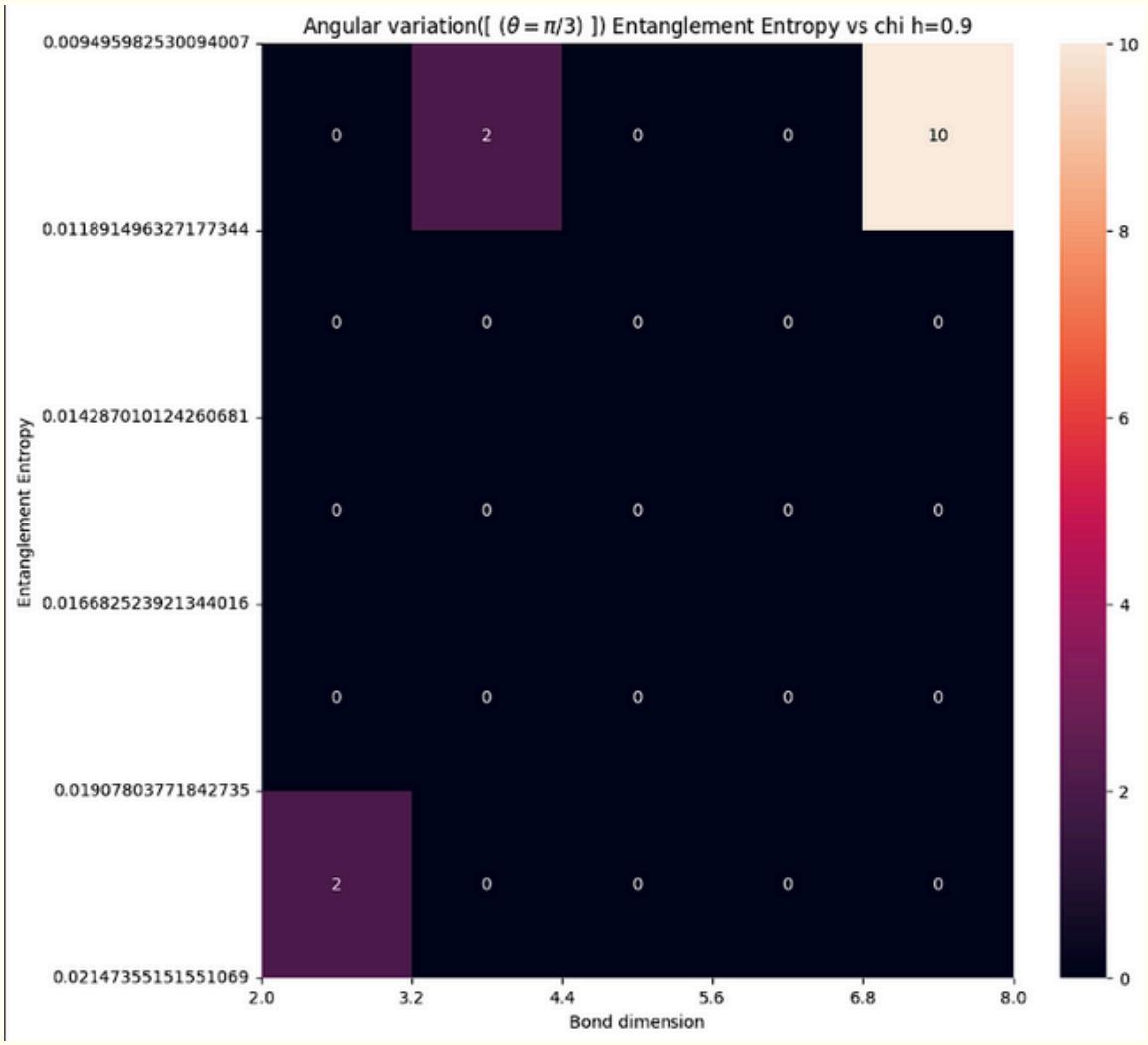
h = 0.9


Heatmap of Entanglement Entropy vs chi h=0.89
Entanglement Entropy
0.4102636633594058
0.4802664834603826
0.5502693035613594
0.6202721236623362
0.690274943763313
0.7602777638642898
Bond dimension
2.0
7.6
13.2
18.799999999999997
24.4
30.0
2 0 0 0 0
0 0 0 0 0
0 0 0 0 0
0 0 0 0 0
2 2 2 0 6
6
5
4
3
2
1
0

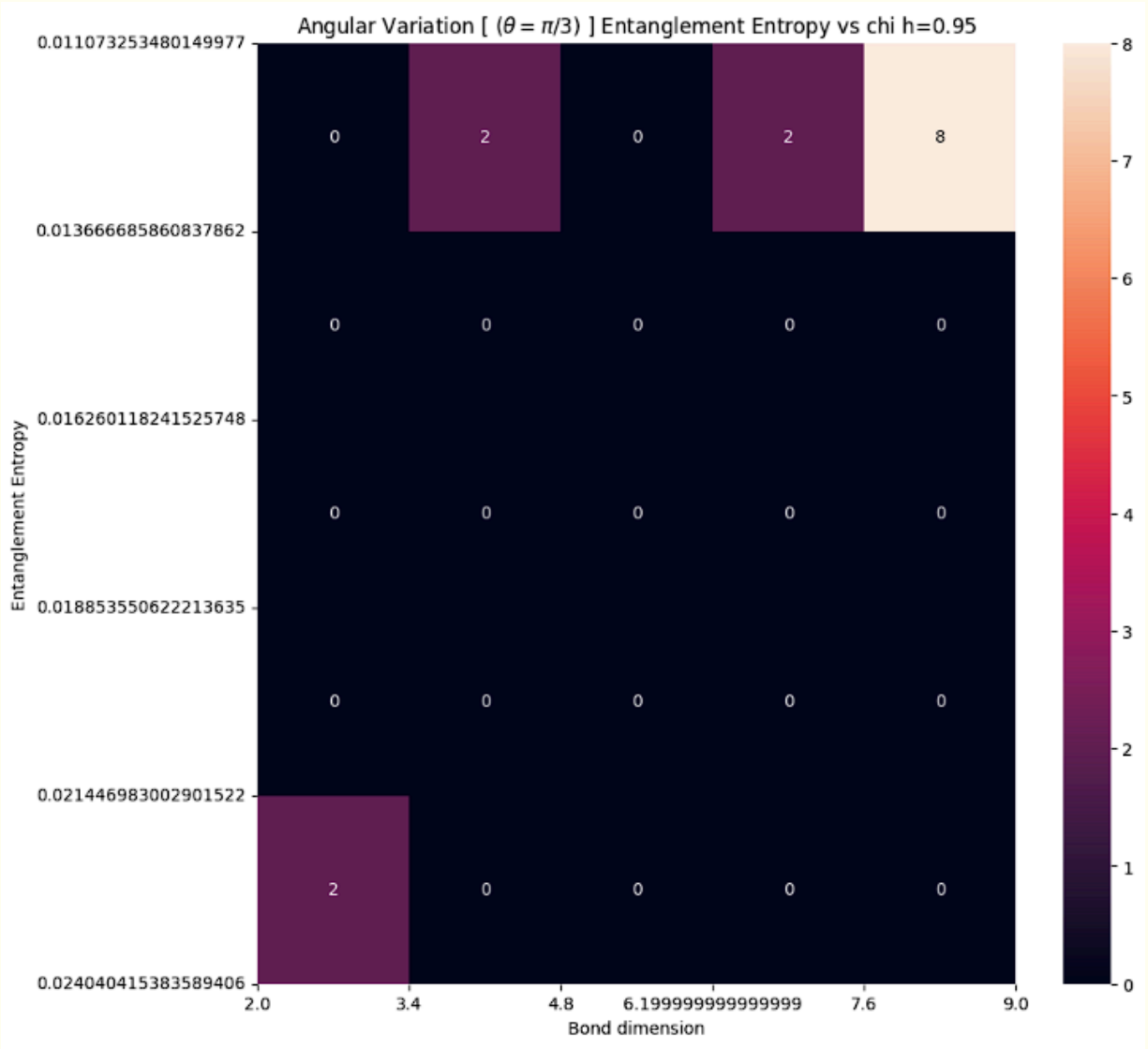
h = 0.89



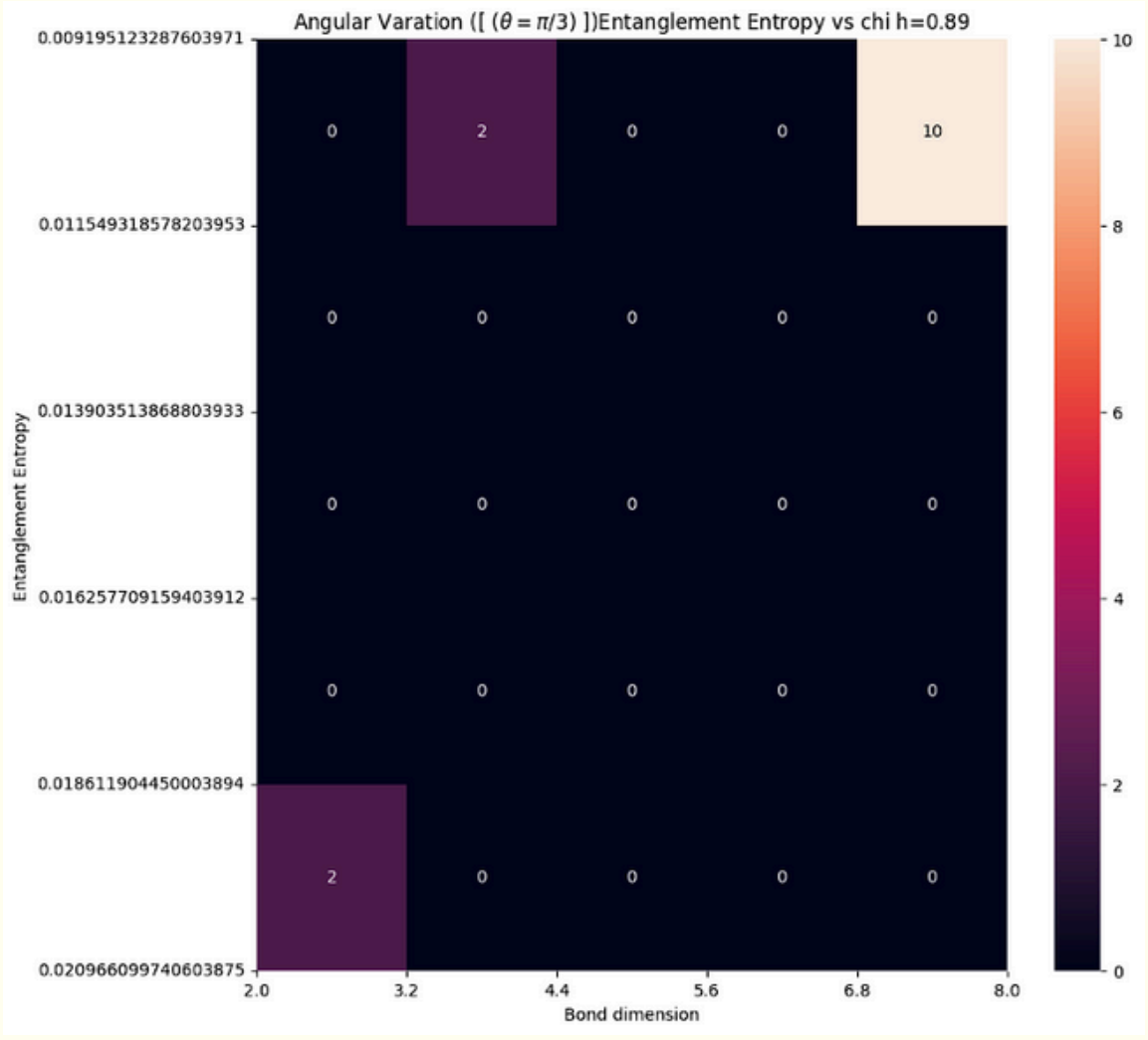
h = 0.85



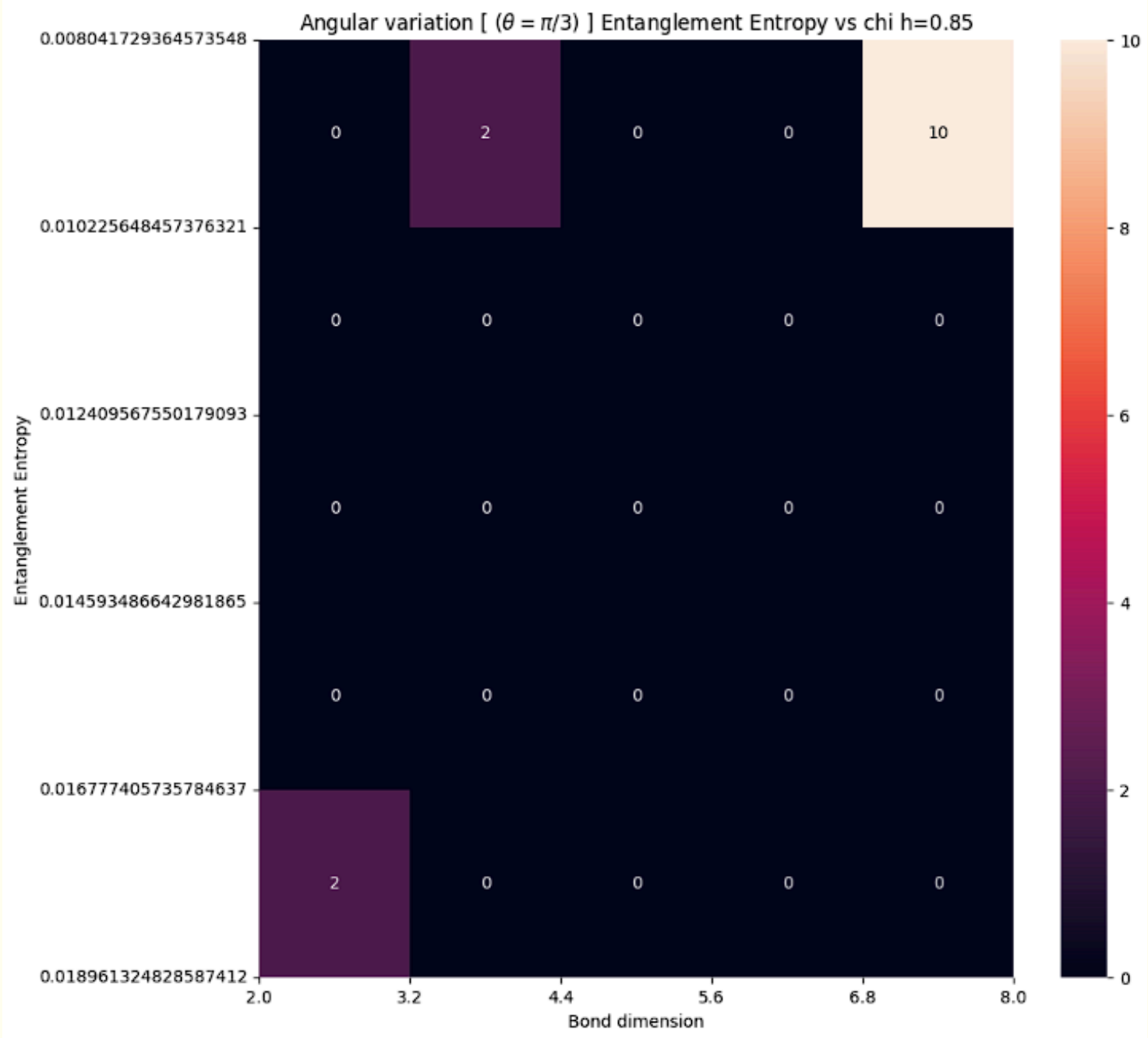
angular variation of theta = pi/3 and h = 0.9



angular variation of theta = pi/3 and h = 0.95



angular variation of theta = pi/3 and h = 0.89



angular variation of theta = pi/3 and h = 0.85