

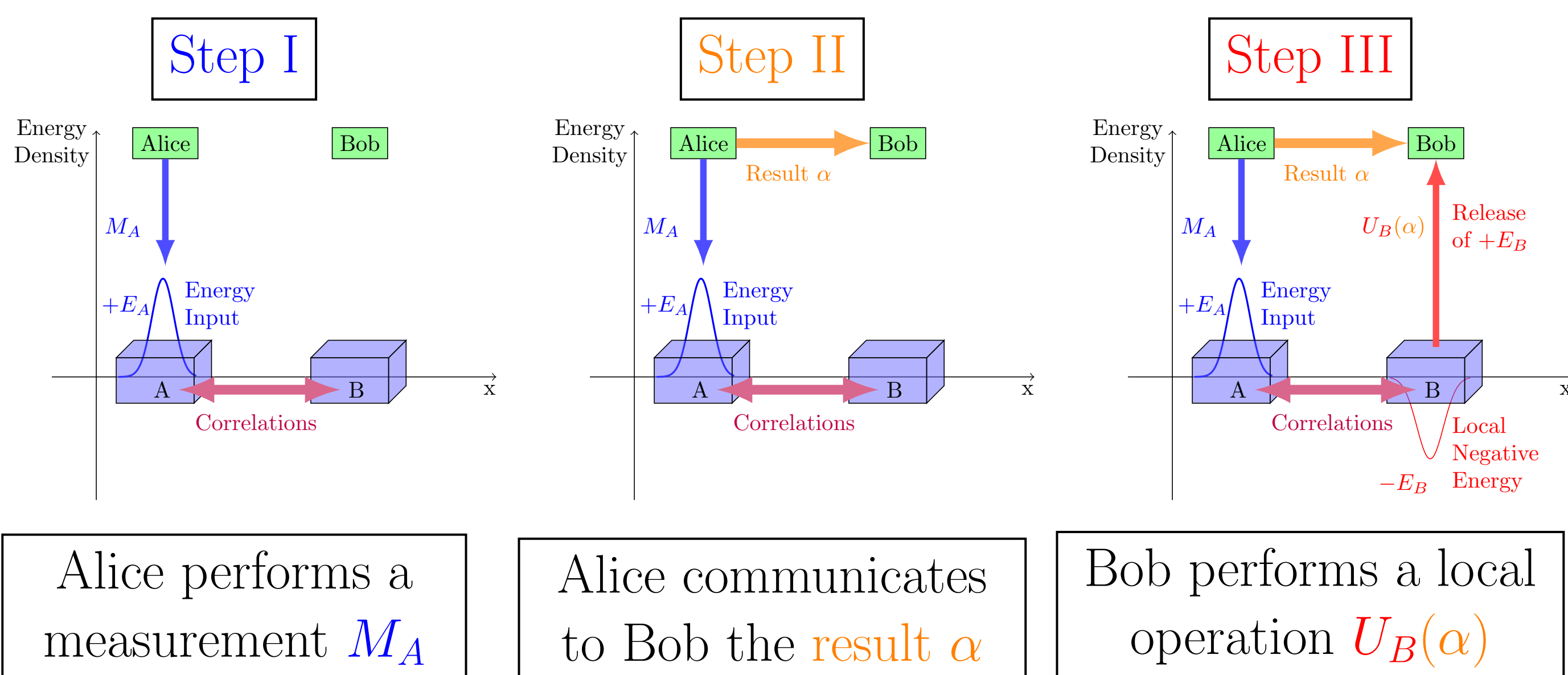
QUANTUM ENERGY TELEPORTATION

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1) What is Quantum Energy Teleportation?

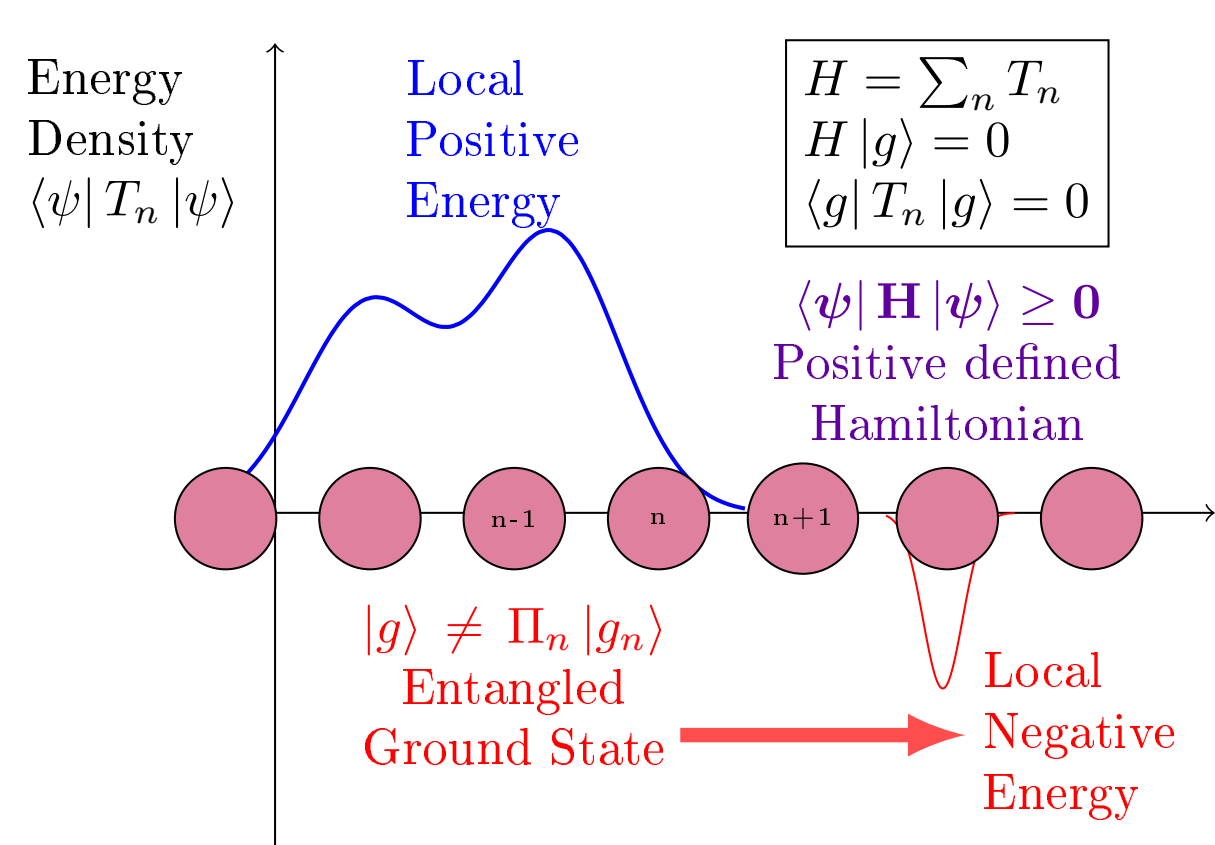
Quantum Energy Teleportation (QET) is a **three step** quantum task in which energy is transported in an operational meaning, without the transfer of energy carriers between physically separated components of a system.

Let it be Alice and Bob two observers then QET is as follows:



Teleported Energy is restricted by two factors

- **Correlation** between Alice and Bob systems
- Amount of **negative energy** that can contain Bob's subsystem.

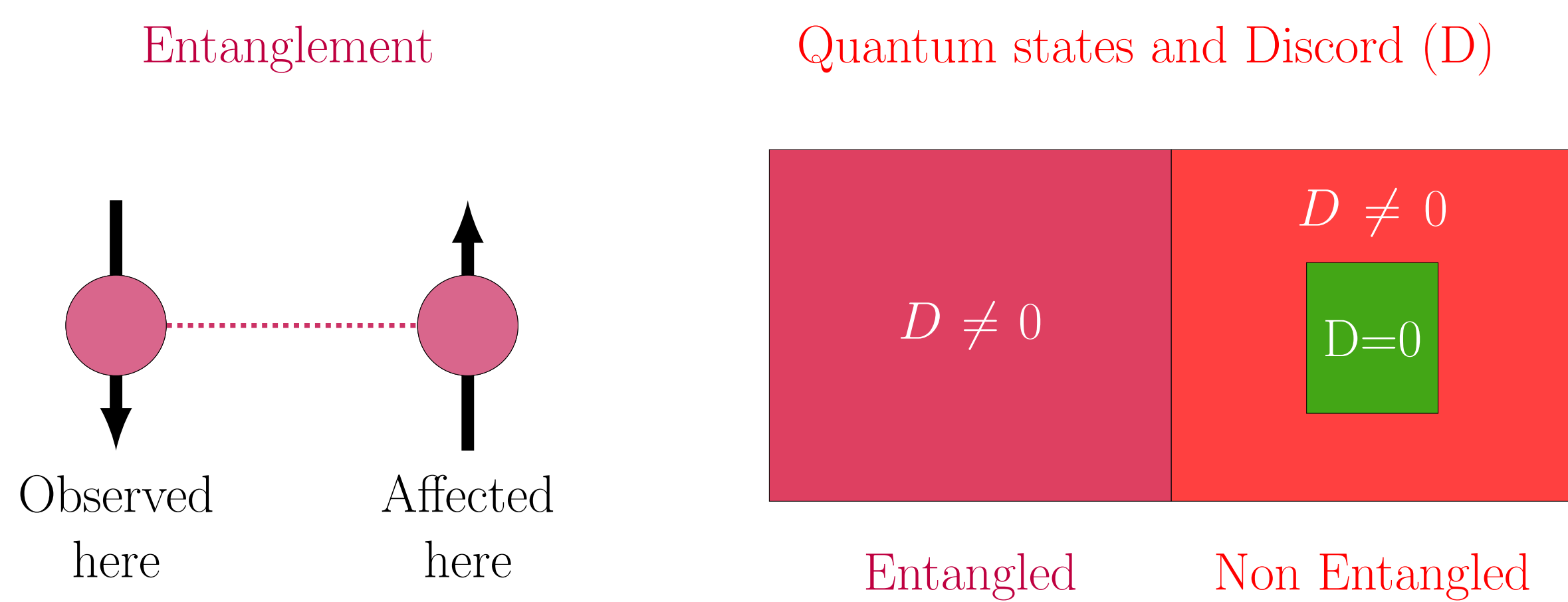


An **entangled** ground state ($T=0$) implies the possibility of local negative energy

Some spin chain systems and Quantum fields have **Entanglement** in the ground state

2) QET and Quantum Correlations

- **Entanglement**: is a kind of quantum correlation that occurs when two or more particles interact in such a way that after the interaction the state of each particle cannot be described independently; meaning that it is required to describe the system as a whole
- **Quantum Discord**: measure of all the quantum correlations, including entanglement, between two components of a quantum system.

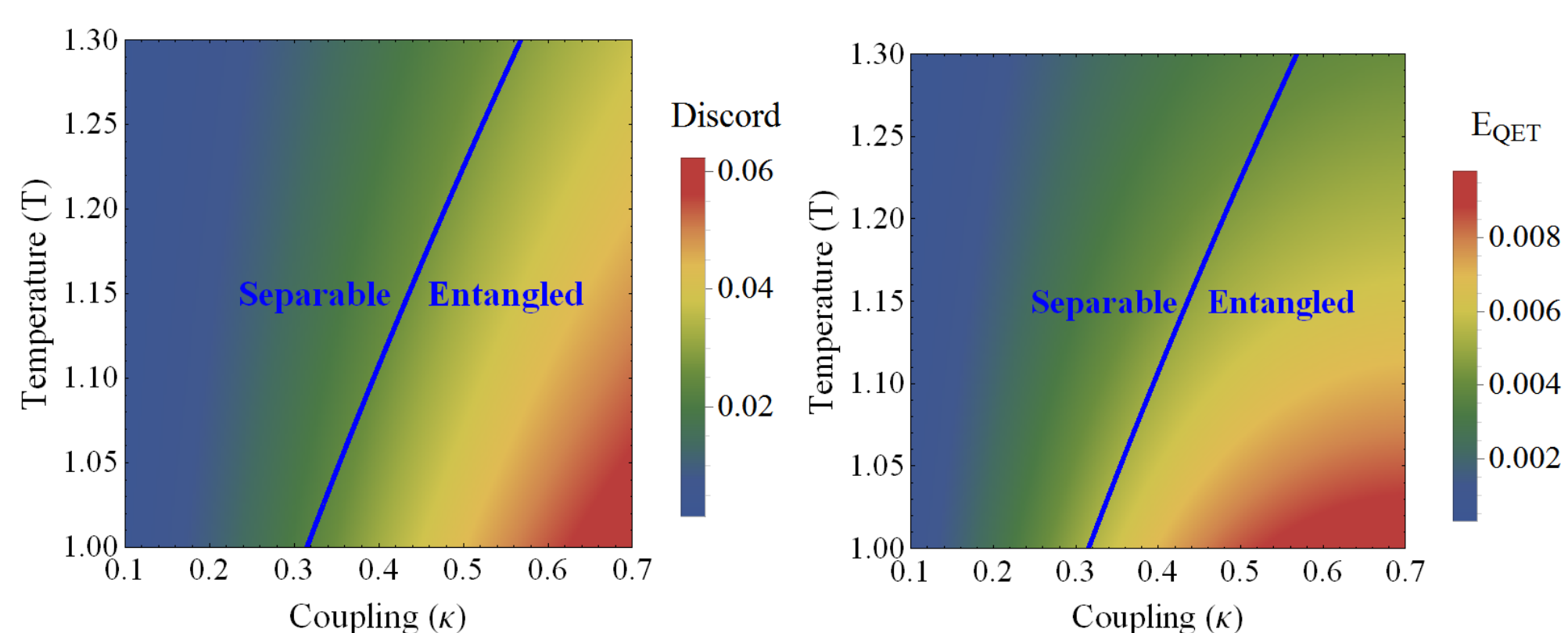


- QET at the ground state ($T=0$) **Entanglement is a necessary condition**

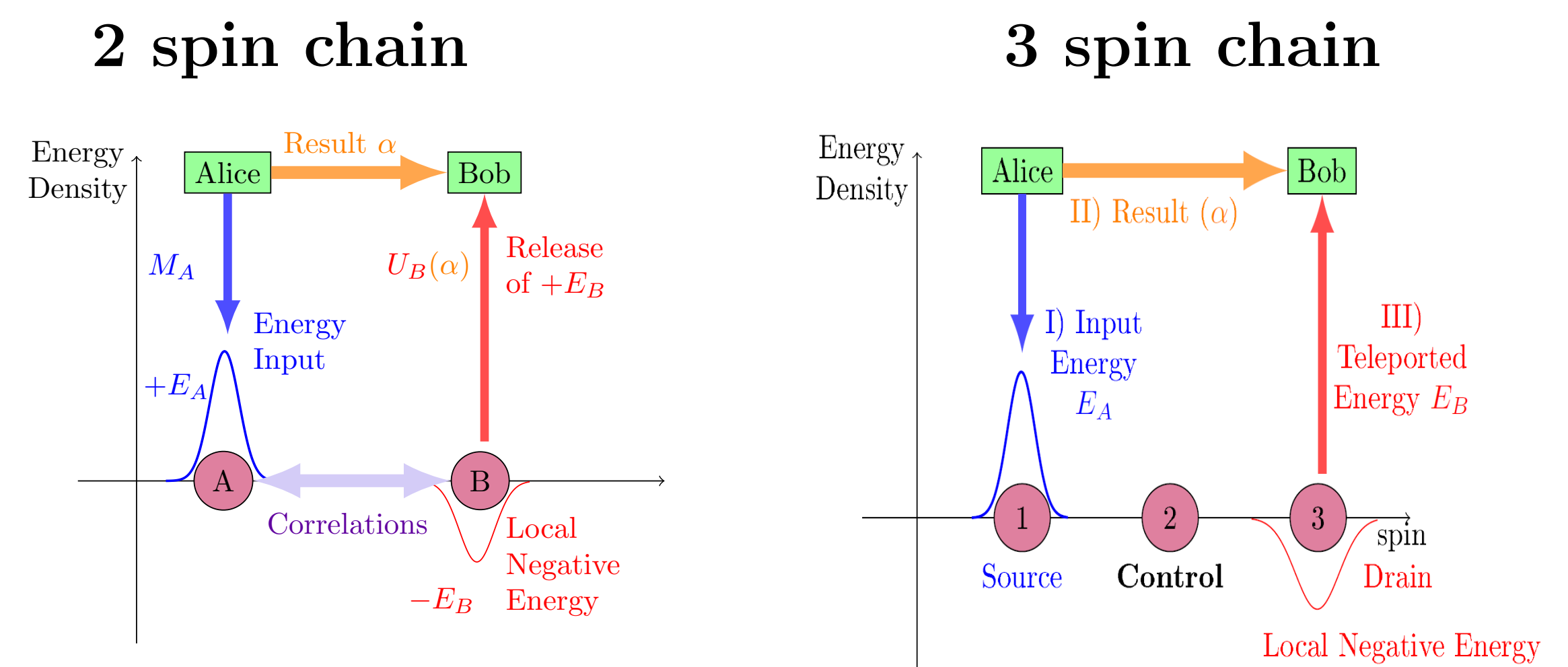
If the ground state of a **general system** is separable, No Entanglement, no energy can be teleported since it is not possible to have local negative energy densities.

- QET at finite temperatures ($T \neq 0$) is **nontrivial**; there is no general proof of the necessary condition

In a simple **toy model with two spins** (qubits) the quantum discord is seen to act as a resource for QET at high temperatures



3) Three spin (qubit) open chain and QET



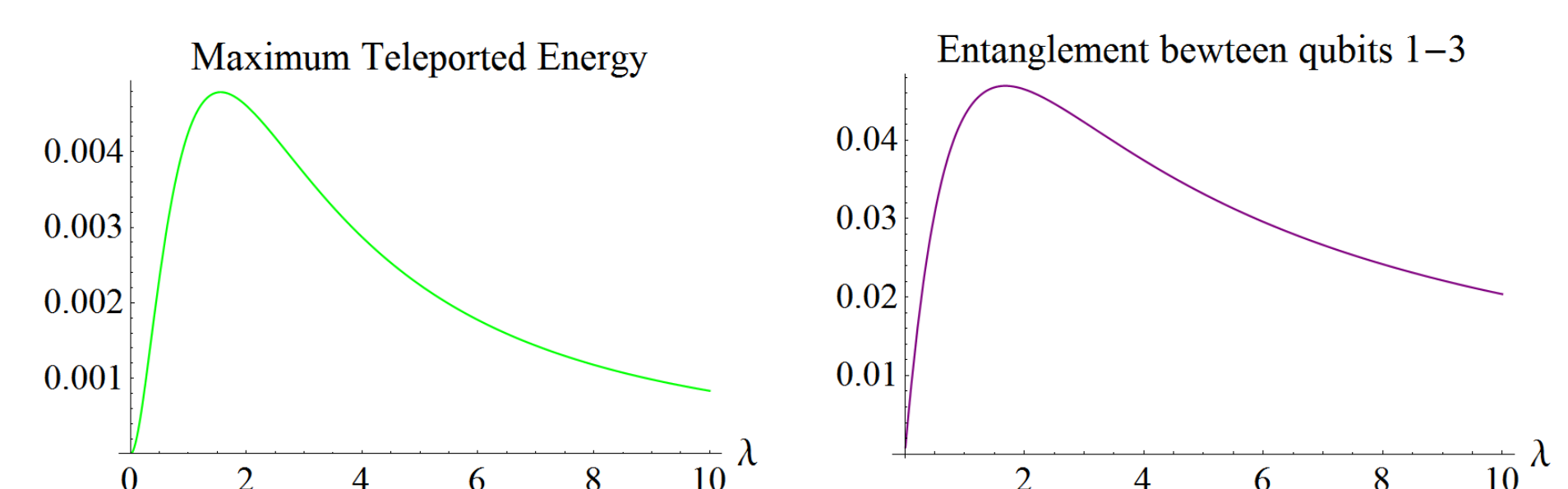
2 spin chain: $H = \sigma_{A,z} + \sigma_{B,z} + 2\kappa \sigma_{A,x} \sigma_{B,x}$

3 spin chain: $H = \sigma_{1,z} + \lambda \sigma_{2,z} + \sigma_{3,z} + \kappa (\sigma_{1,x} \sigma_{2,x} + \sigma_{2,x} \sigma_{3,x})$

Model	2 spin	3 spin
Parameters	κ	κ and λ
Control of Local Negative Energy	κ	Independent of λ
Alice's Measurements	Restricted	Unrestricted
QET at Ground State	Entanglement is a resource	Entanglement is a resource
QET at Finite Temperature	Discord is always a resource	Discord is not always a resource

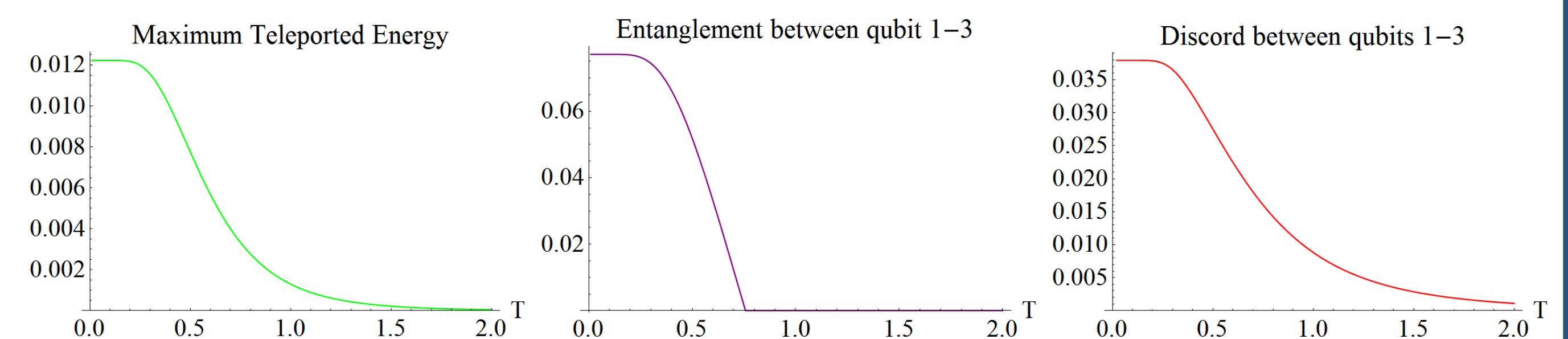
Ground state Results ($T=0$)

- Only Entanglement is a resource of QET; for example if $\kappa = 1$

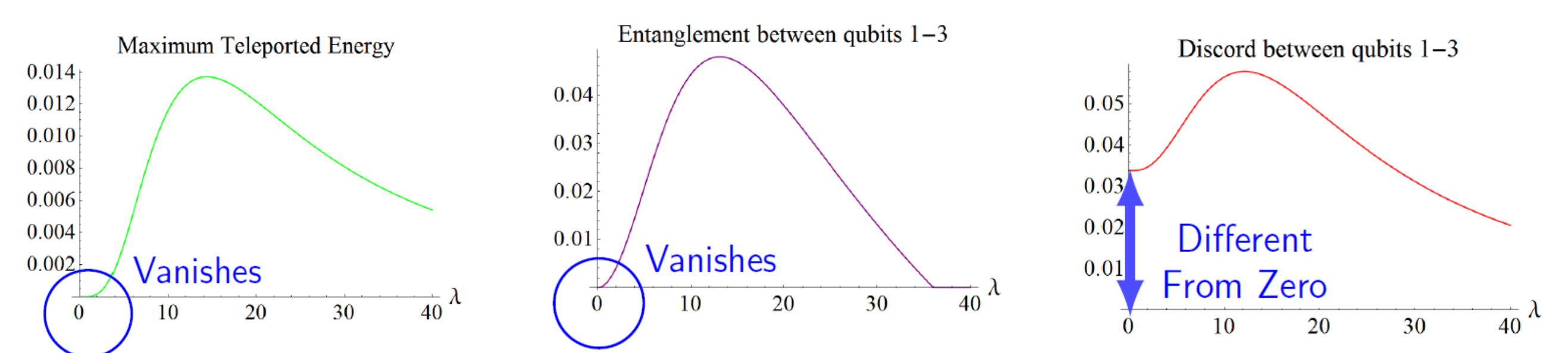


Finite Temperature Results

- Discord without Entanglement can be a resource for QET, like in the two qubit chain, for example if ($\lambda = 10, \kappa = 2$)



- Astonishingly, **Discord without Entanglement is not a resource of QET when $\lambda = 0$** , for example if ($T = 1, \kappa = 5$)



4) Conclusions

1. For $T = 0$ only Entanglement is an informational resource of QET
2. For high temperature: there are regimes for which the discord with and without entanglement acts as a resource of QET.
3. In the case $\lambda = 0$ and finite temperature, although there is quantum discord without entanglement, astonishingly no energy can be teleported.

5) References

1. M. Hotta, "Quantum Energy Teleportation: An Introductory Review", arxiv: 1101.3954
2. J. Trevison and M. Hotta, "Quantum energy teleportation across a three-spin Ising chain in a Gibbs state", J. Phys. A: Math. Theor, 48 (2015) 175302