

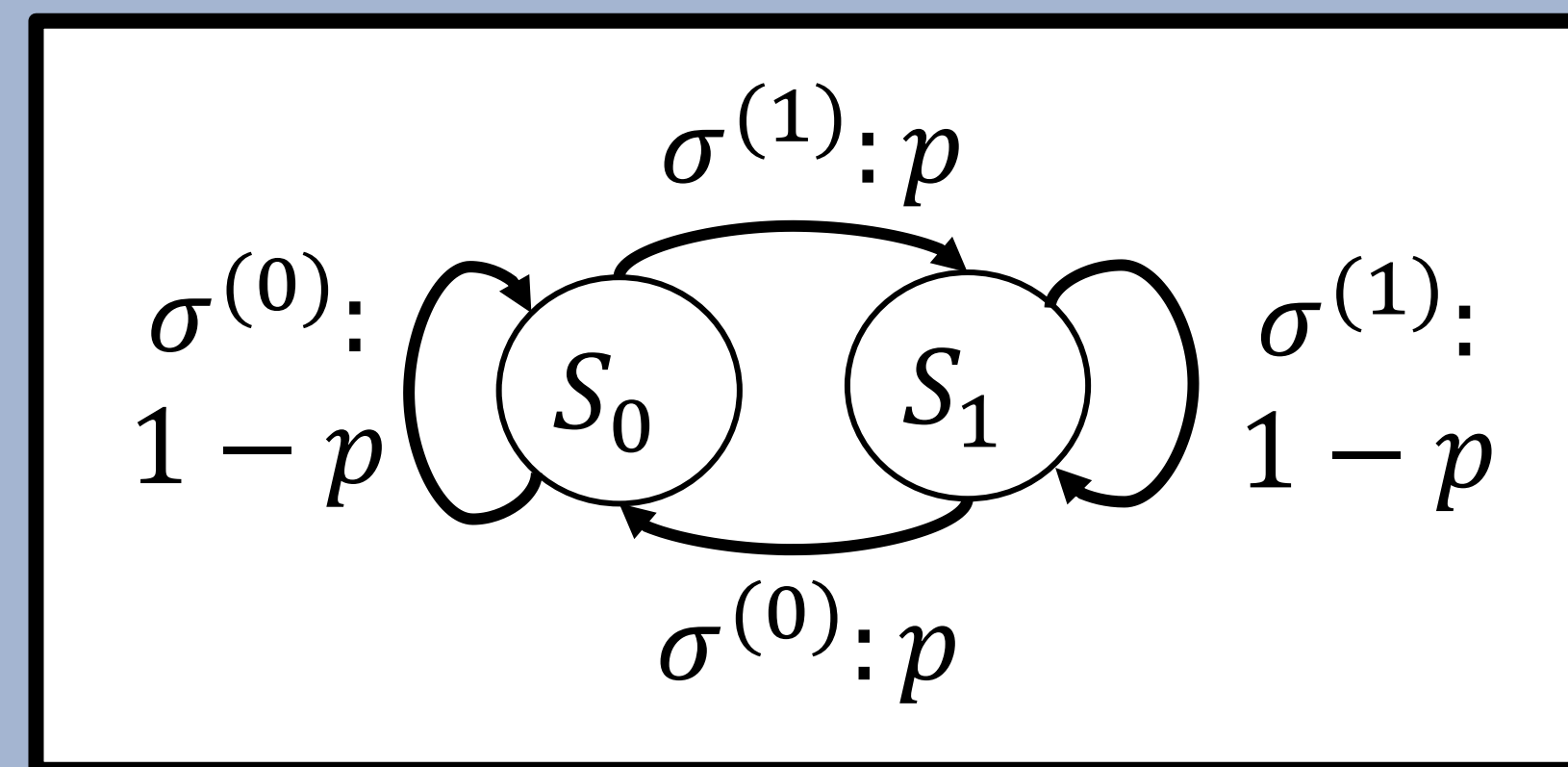
# Work extraction from quantum systems with complex temporal correlations

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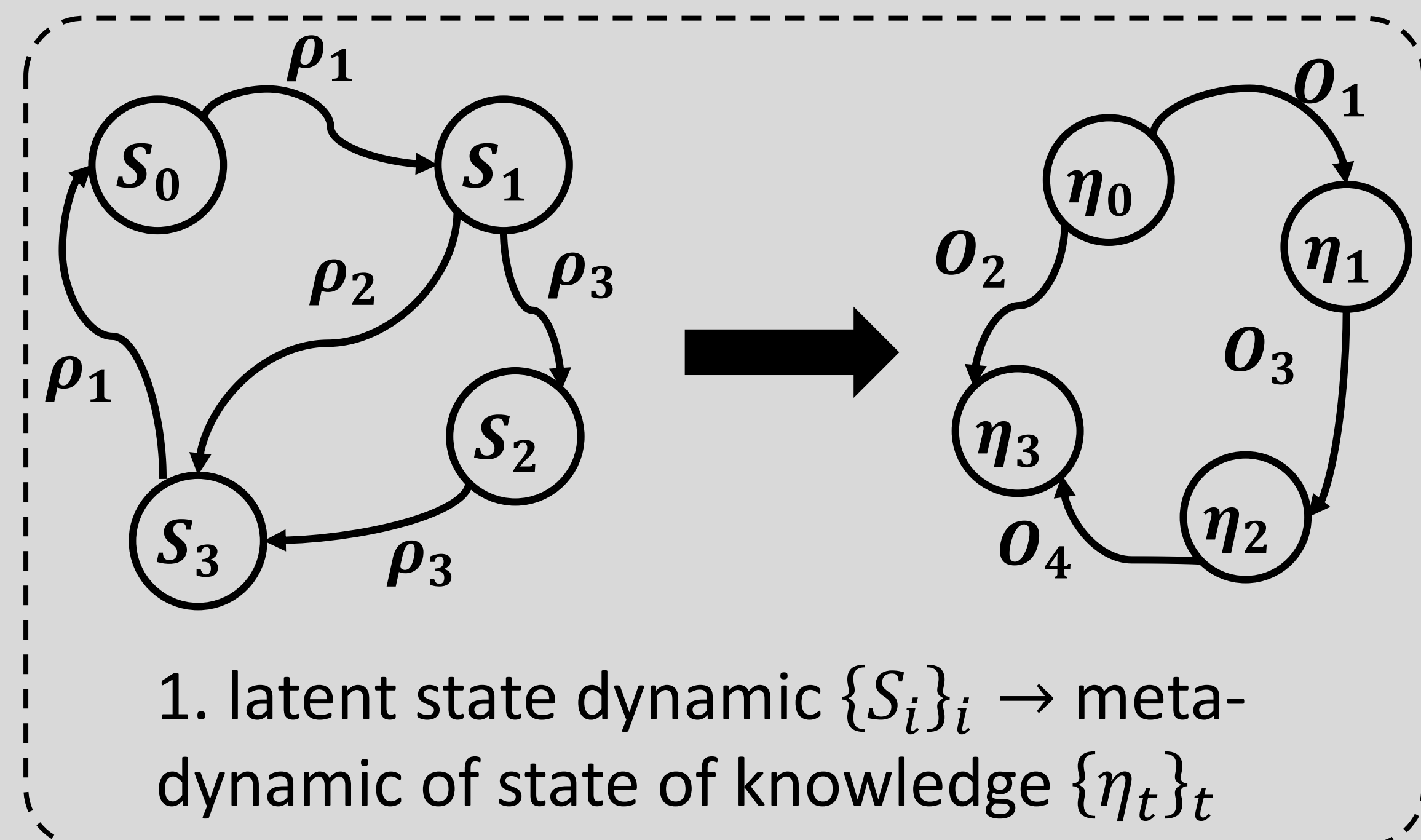
## Aim

- Must be able to **adapt** protocol based on **past performance**

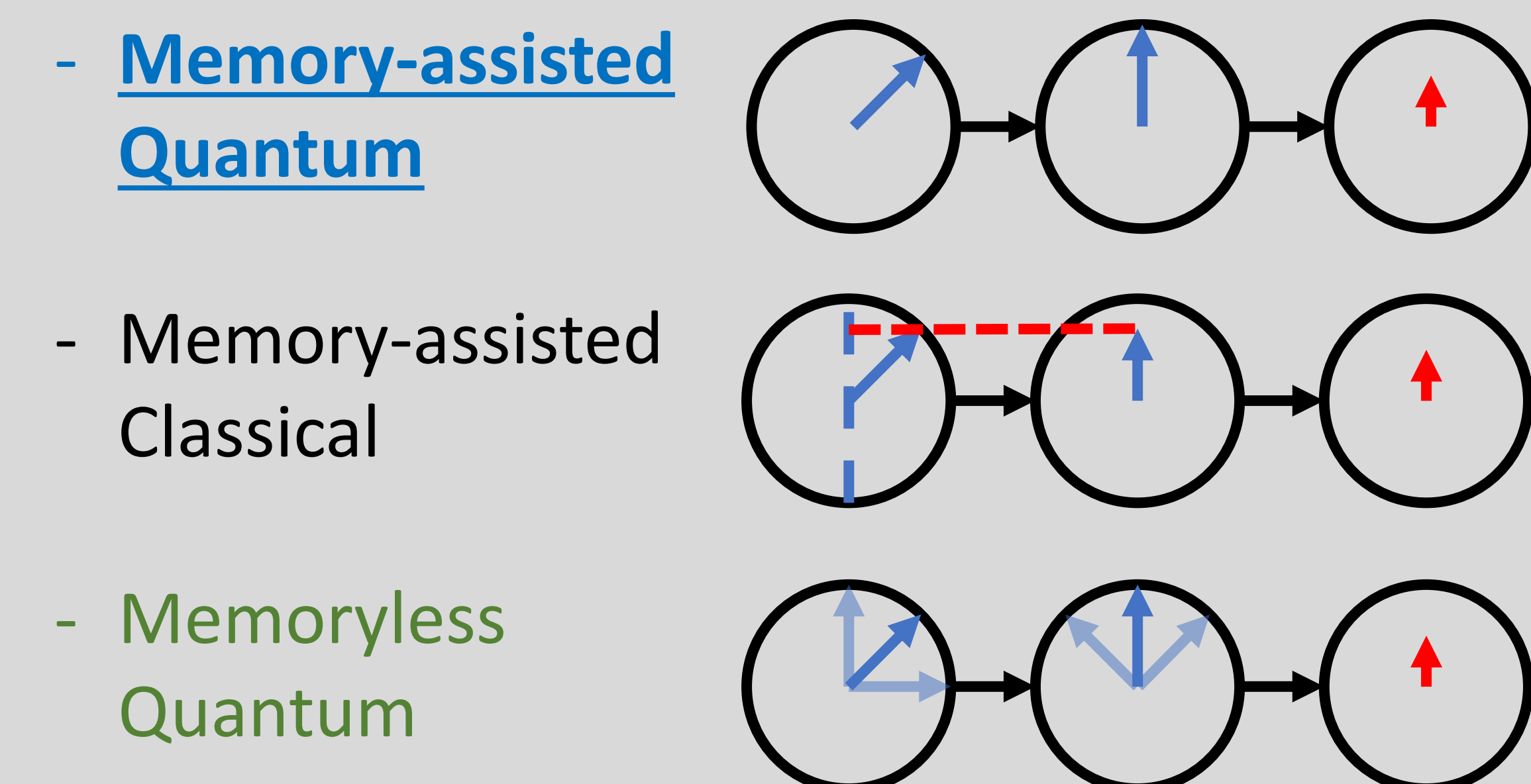


- Classical stochastic process
- $\{S_i\}_i$  are latent states
- $\sigma^{(x)}: p$  represent a transition occurring with probability,  $p$ , and emitting  $\sigma^{(x)}$
- quantum state,  $\sigma^{(x)}$  is emitted at each time step

## Results

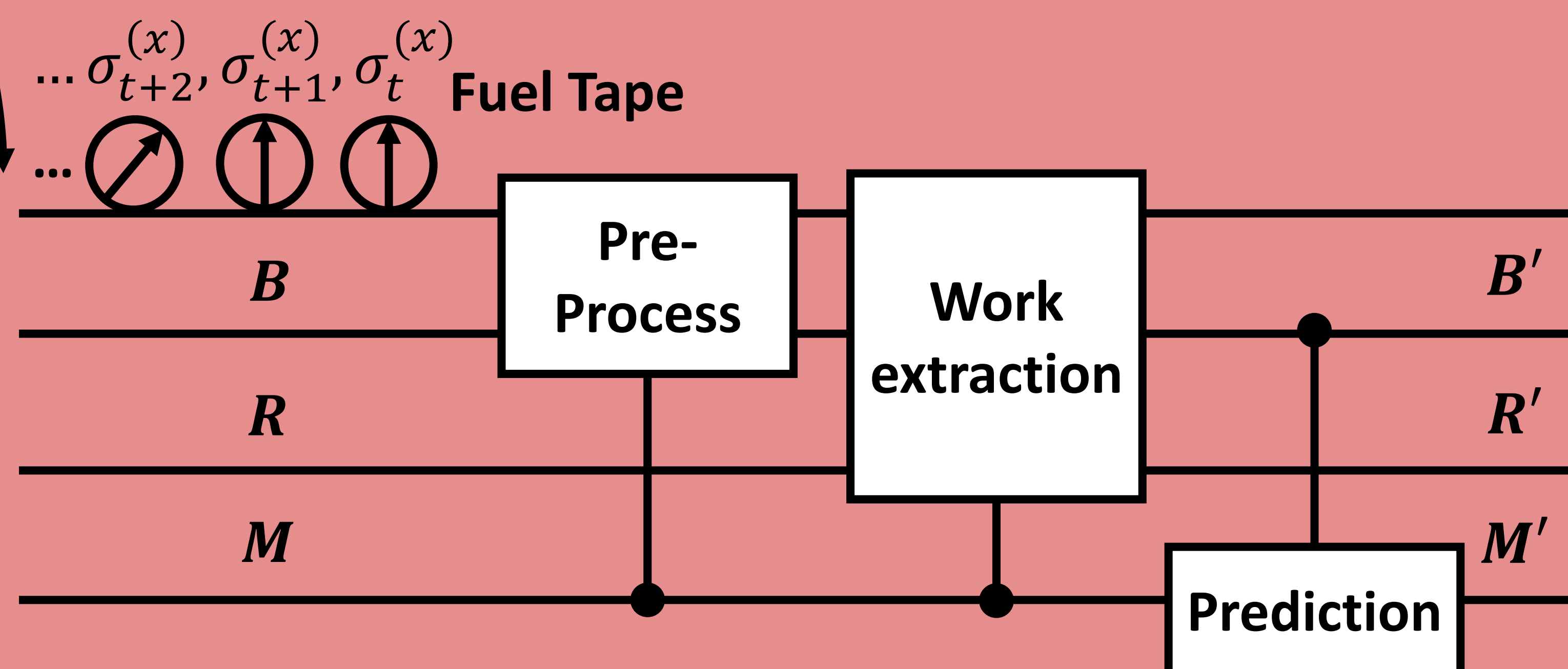


## Benchmarking



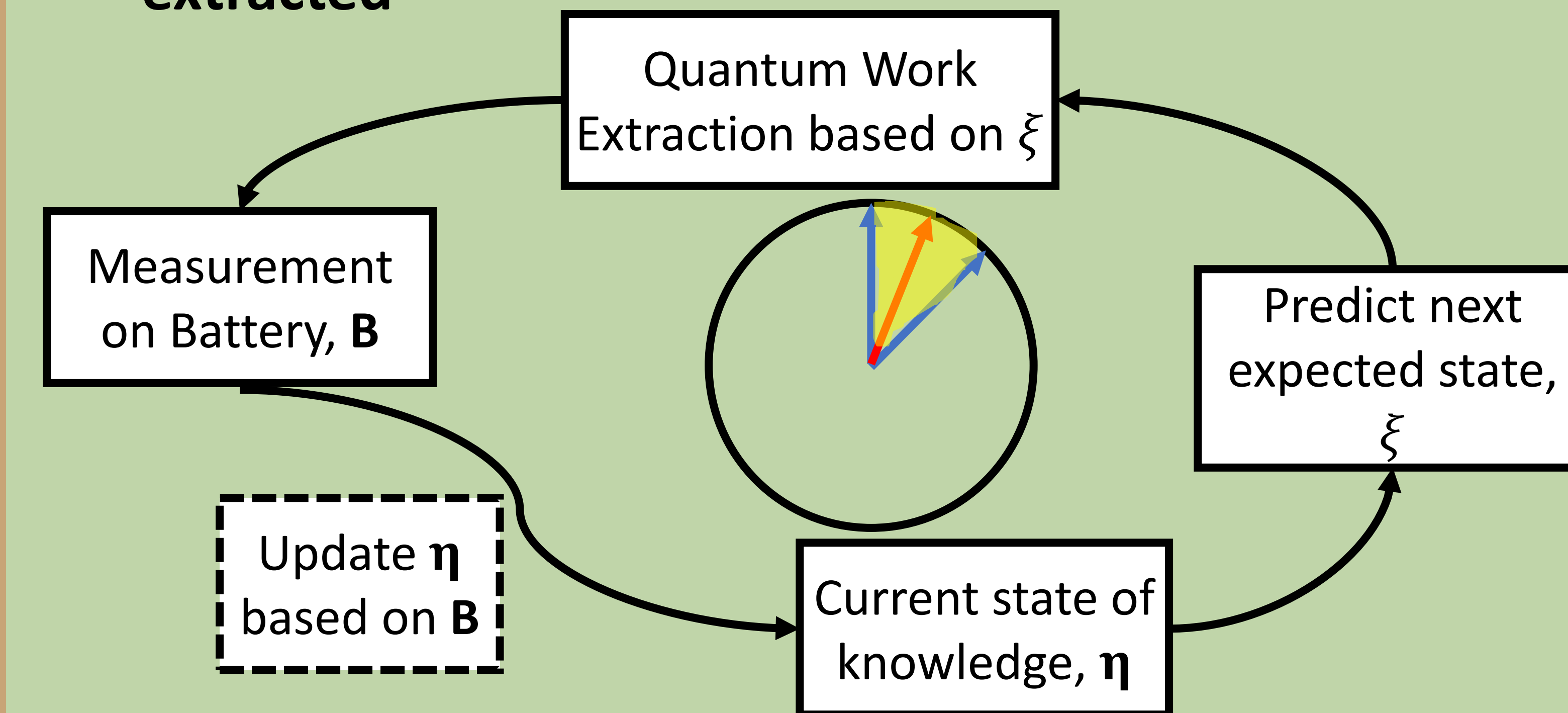
## Construction of Engine

- **Fuel tape**, internal memory  $M$ , heat reservoir  $R$ , Battery,  $B$ , to be charged.
- $M$  keeps track of *state of knowledge*,  $\eta_t$  [1]
- $\eta_t = \{\Pr(s_t = s_i)\}_{i \in |S|}$
- **Work extraction** (knowledge dependent) [2]
- **Pre-process**, rotation of state to eigenstate
- **Thermalization**, bring state to thermal state

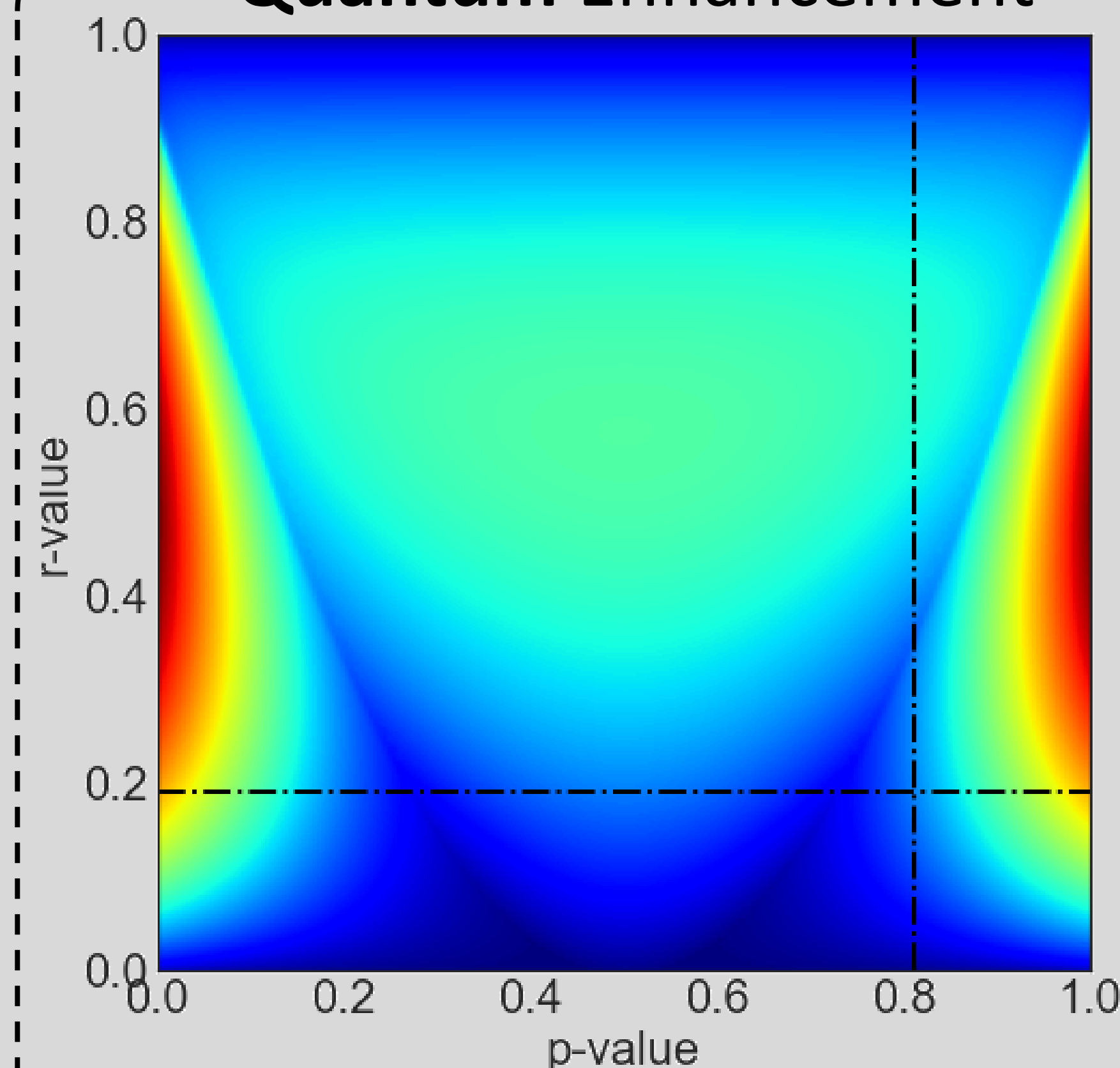


## Operation of Engine

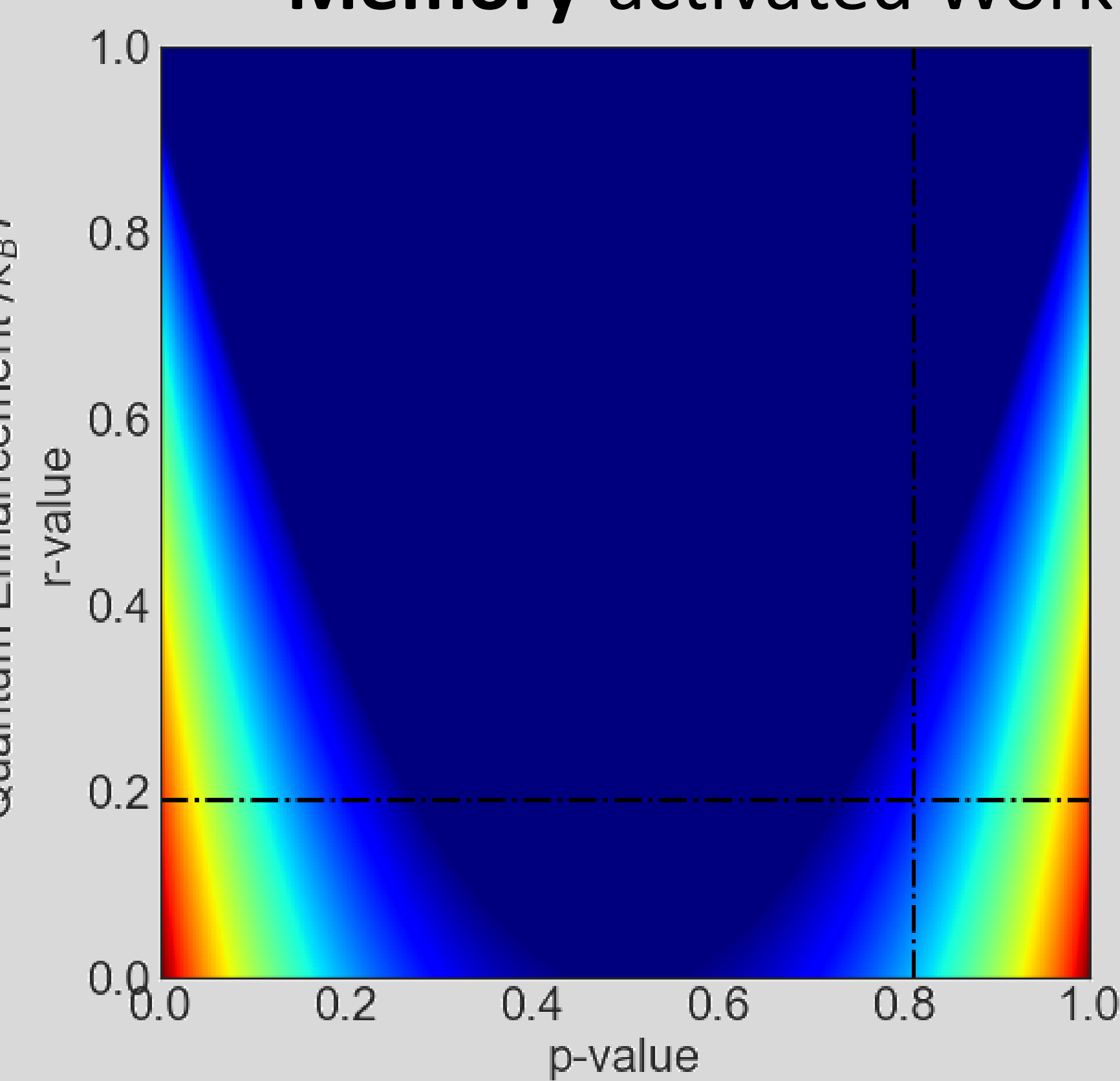
- Engine tailors extraction to expected state,  $\xi_t$
- Measure  $B$  to obtain work value
- $\eta_t$  is iteratively updated conditioned on **work extracted**



## Quantum Enhancement



## Memory-activated Work

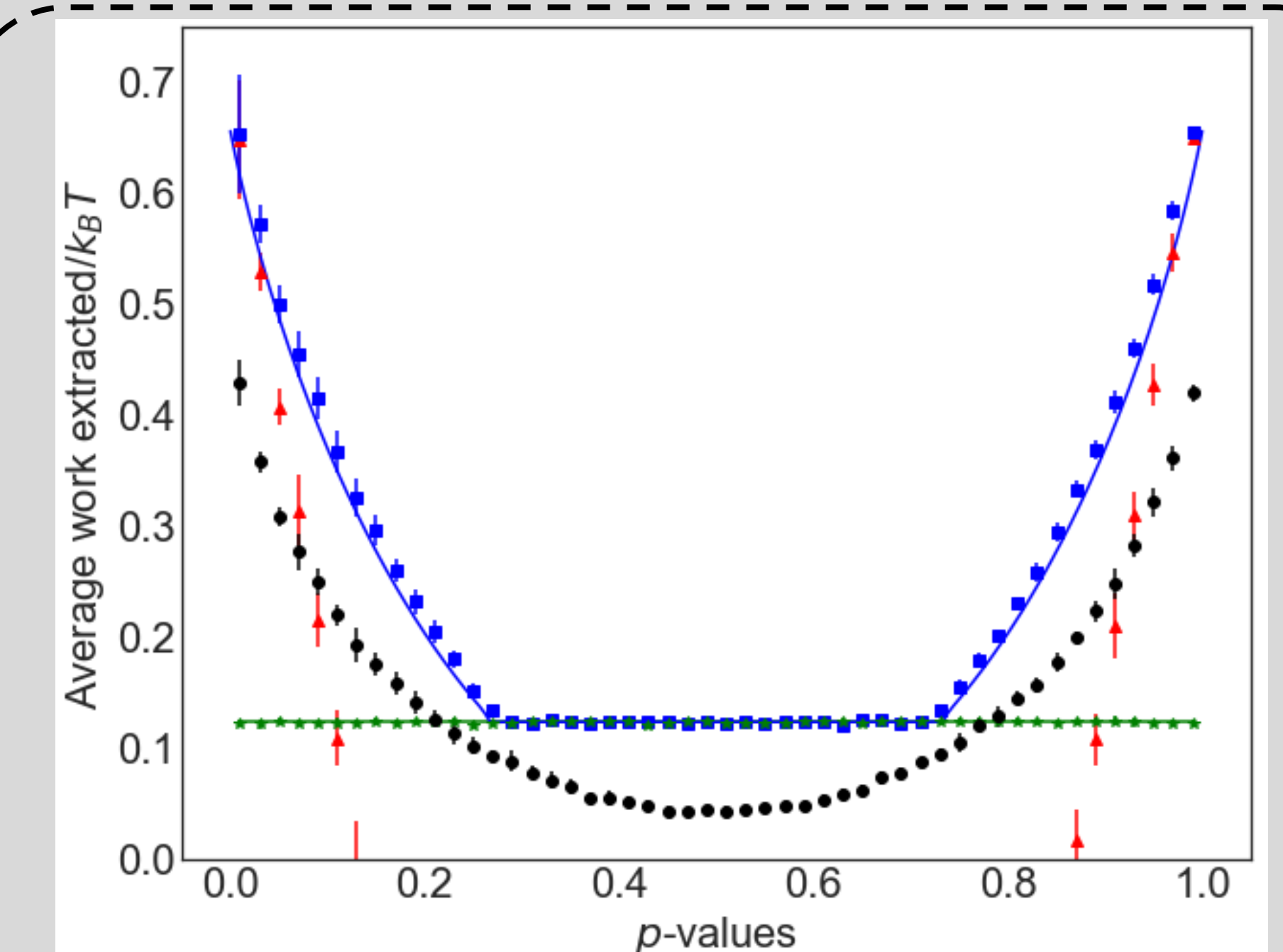


2. Quantum **always** outperform classical in the presence of coherence

3. Memory of past output is **not always** useful

$$r = \text{Fidelity}(\sigma^{(0)}, \sigma^{(1)})$$

1. Skrzypczyk, P., A.J. Short, and S. Popescu, *Work extraction and thermodynamics for individual quantum systems*. Nature communications, 2014. 5(1): p. 1-8.  
 2. Crutchfield, J.P., *The calculi of emergence: computation, dynamics and induction*. Physica D: Nonlinear Phenomena, 1994. 75(1-3): p. 11-54.



4. Sharp **phase boundary** between area with and without memory-advantage

