Quantum Error Correction in Globally Controlled Arrays

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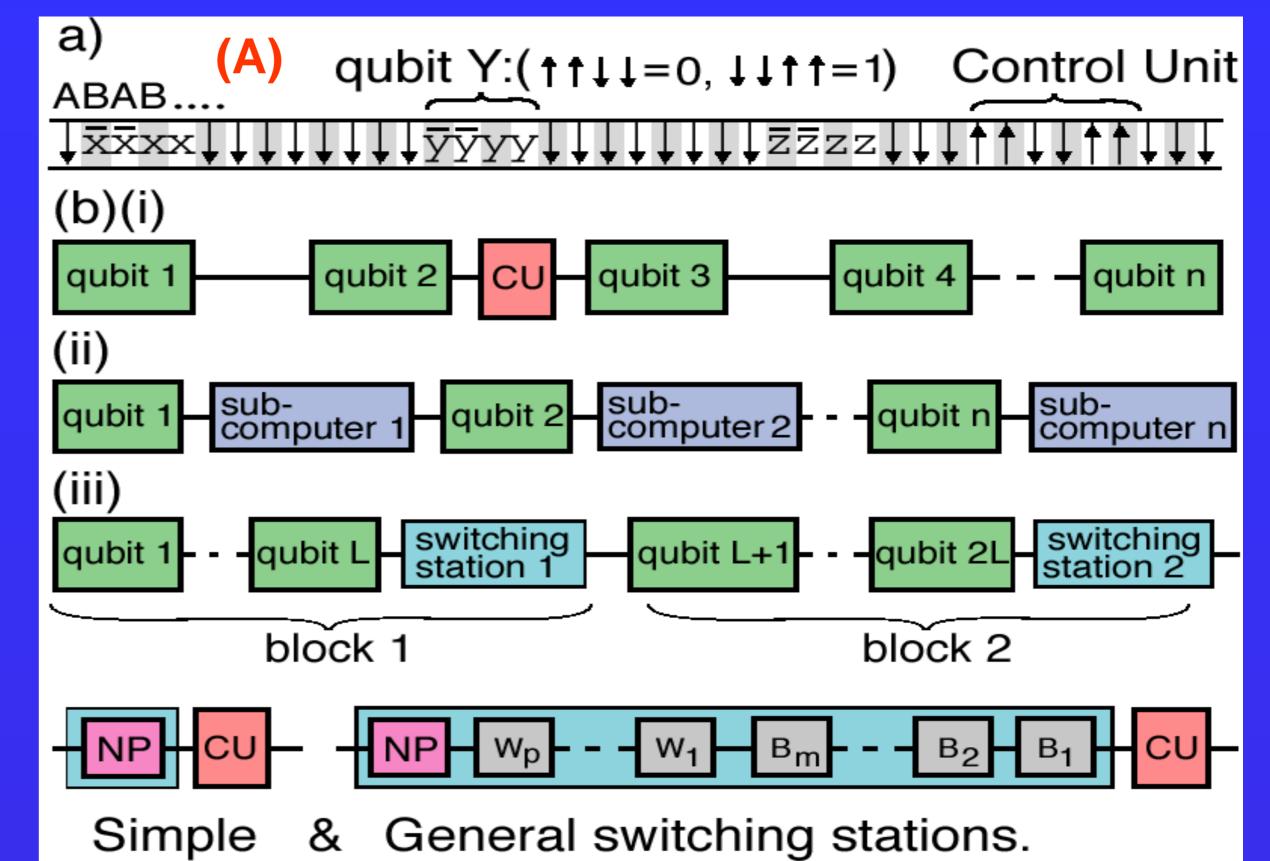
1. Outline

•An interesting concept in quantum computation is that of global control (GC), where there is no need to manipulate qubits individually. One can implement a universal set of quantum gates on a **one-dimensional array** of cells purely via signals that target the entire structure indiscriminately (see Figure A a) for model)

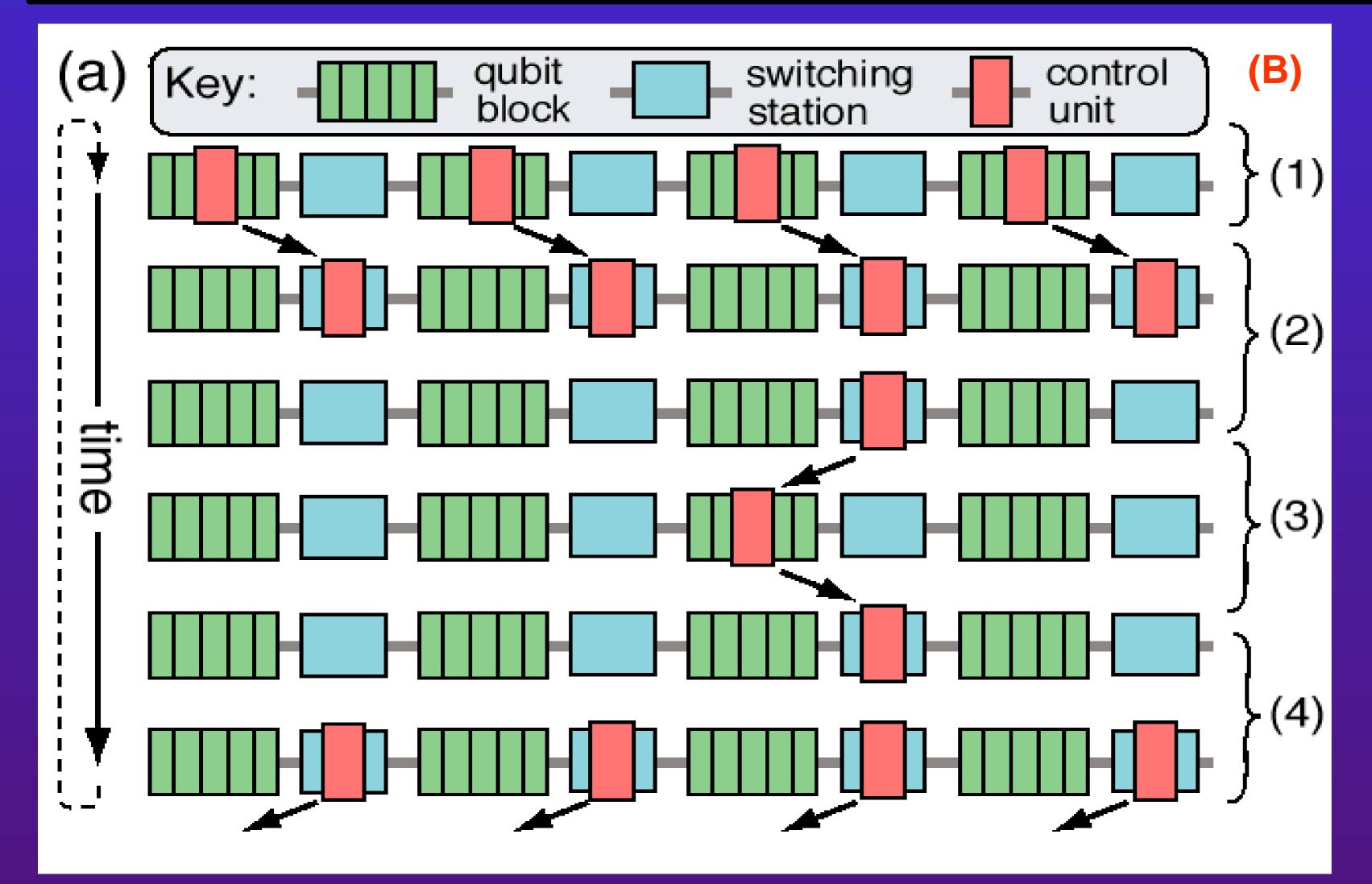
•But large-scale quantum computation imposes several requirements in terms of noise level, time, space (scaling) and in particular parallelism. Keeping in mind these requirements, we show here that GC can support error-correction, by implementing simple codes (here Shor [[9, 1, 3]]). This opens the way to fault-tolerant computation with this type of architecture.

2. Model Characteristics

- One dimensional array of alternating cells of two type (ABABA...) (fig. A a))
- Based on the concept of Control Unit (CU), a simple pattern of cells (fig. A a) and b)(i)) and classical bits which is moved across the array to perform operations on the qubits.



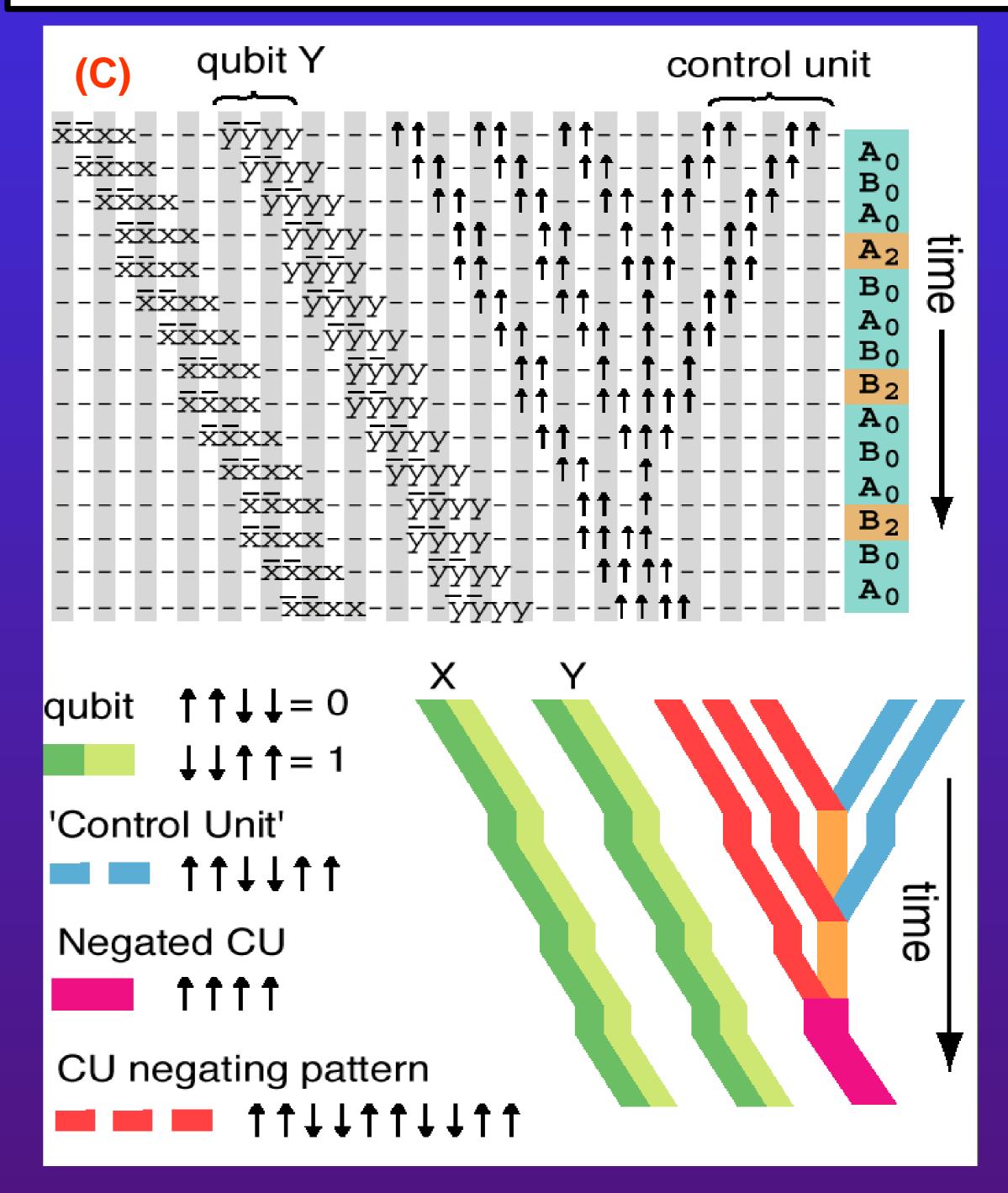
- Parallelism: CUs can be used in a variety of models to perform parallel operations on many qubits simultaneously (for example one for each qubit with subcomputers, fig. A b)(ii)). But we need to find a trade-off between the number of cells involved and the level of parallelism.
- We exploit the fact that typical codes (such as the Steane [[7,1,3]] code, or the Shor [[9,1,3]] code) involve representing each "computational qubit" by encoding it into a **block of adjacent basic qubits**. Our model uses one CU for each block, simultaneously performing the error-correcting code on each computational qubit (fig.B)
- The process of activating and deactivating the CUs takes place in regions which we call **switching station (SS)**, between each block. General SS includes label (classical) bits, a few "working" bits, and "negating pattern" (NP, fig. A(b)(iii)).

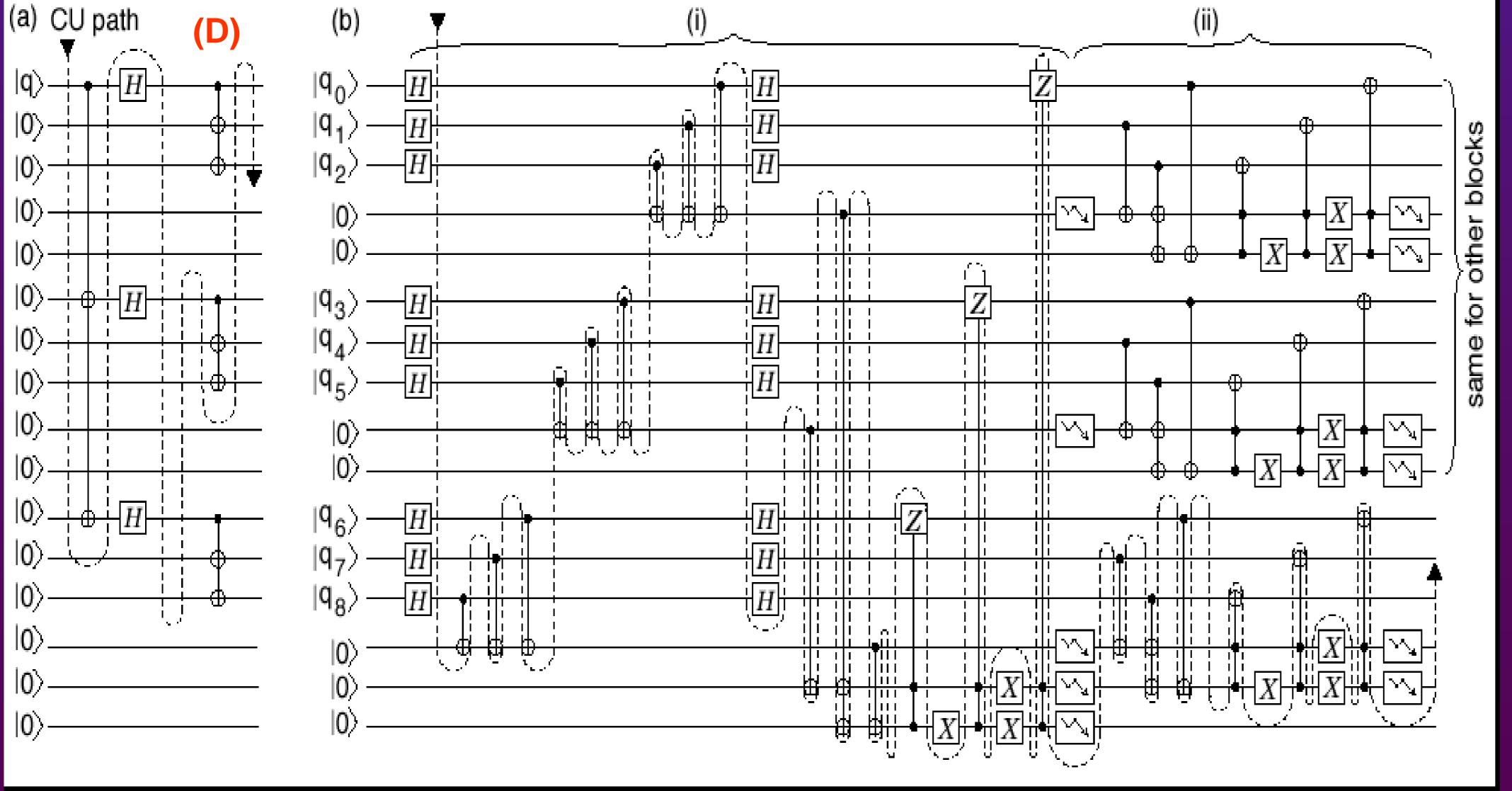


3. Switching between Correction and Operation

•We can switch between M CUs to a single one on the array by applying the appropriate sequence of pulses (Figure C) which will move them to their respective switching station and turn them all off except one (Figure B). This one is then used to perform appropriate quantum operations of the algorithm.

•These operations can be reversed to get back to correction.





4. Block Correction for The Shor[[9, 1, 3]] code (fig D).

• The computational qubits of the circuits are in the same order, from top to bottom, as they are on the cell chain from right to left (c.f. Figs. A).

• EC involves syndrome extraction and subsequent correction for both phaseflip (i) and bit-flip (ii) errors. The movement of the CU back-and-forth through the array is indicated by the dashed line.

 Reset\Readout of qubit is performed by a specific operation (arrow).

•Total number of pulses to perform the circuit: 3352 in the case of Shor & 4086 in the case of Steane code.

