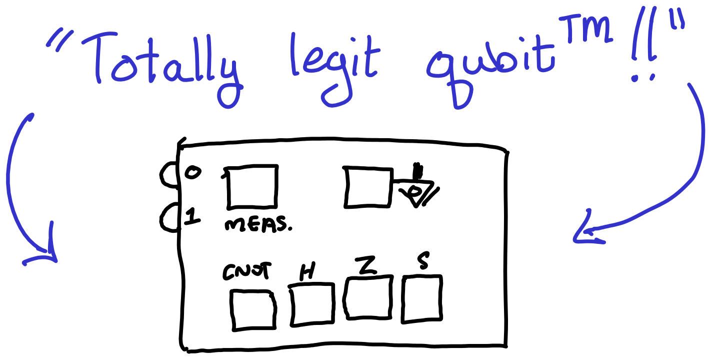
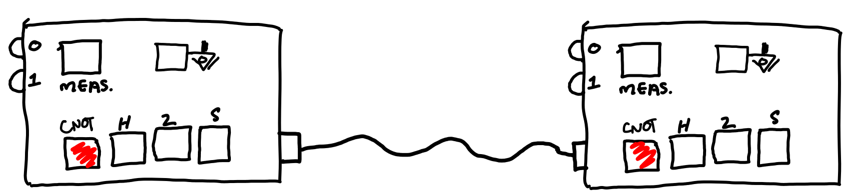
Chapter 11: Quantum Foundations

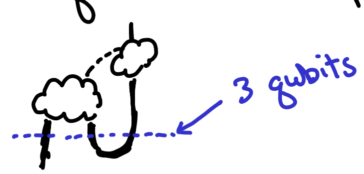
* Suppose I have a box that looks like this, which I bought for $10,000:



* .... actually I bought 3 of them (for $30,000!)

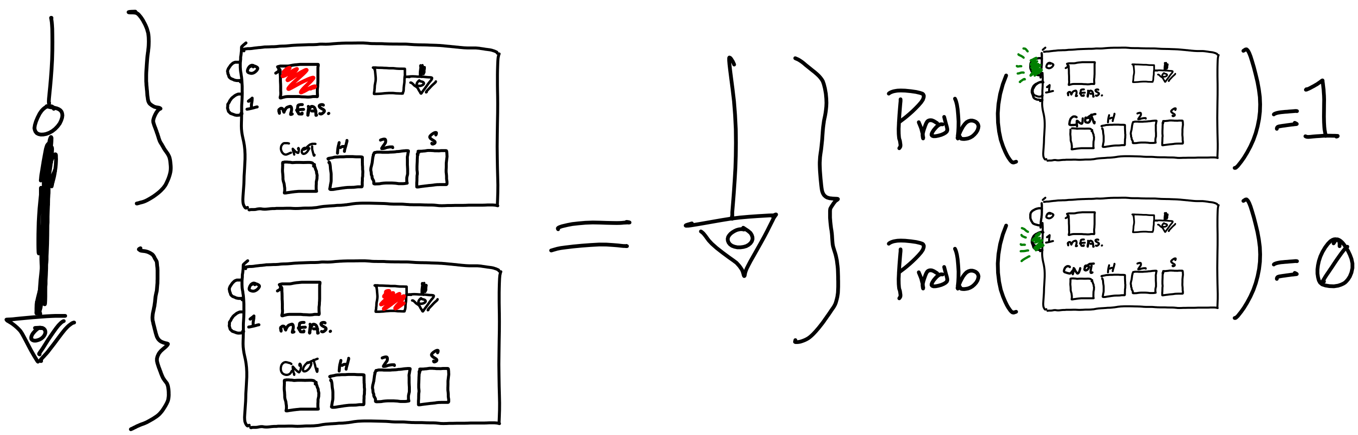


so I can do quantum teleportation:

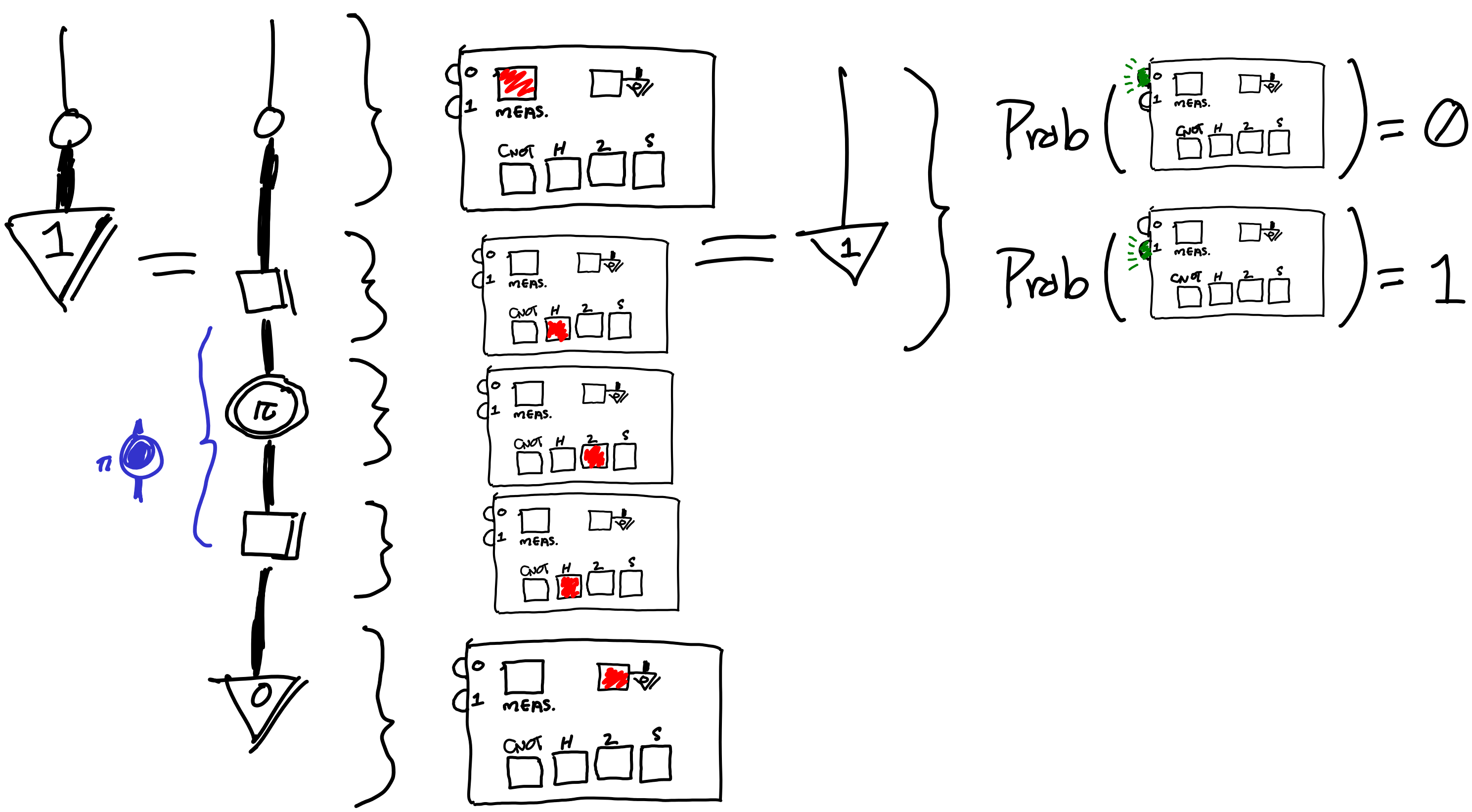


Q: Did I get ripped off?

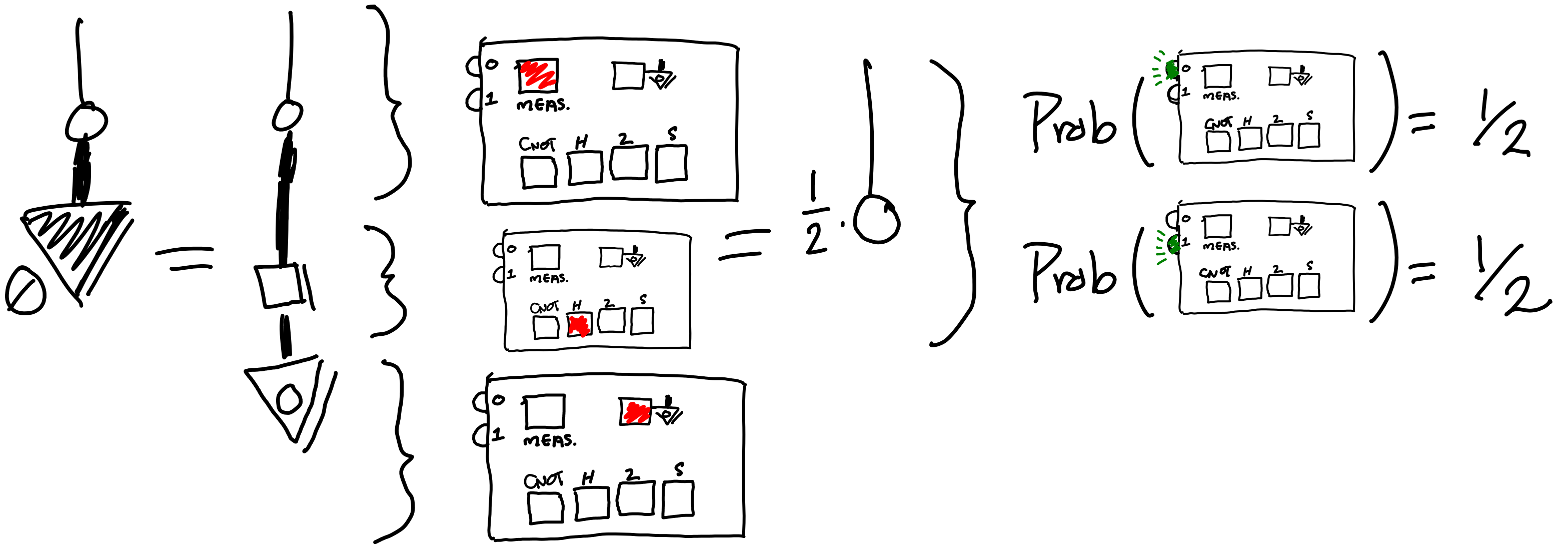
Test #1 ✓



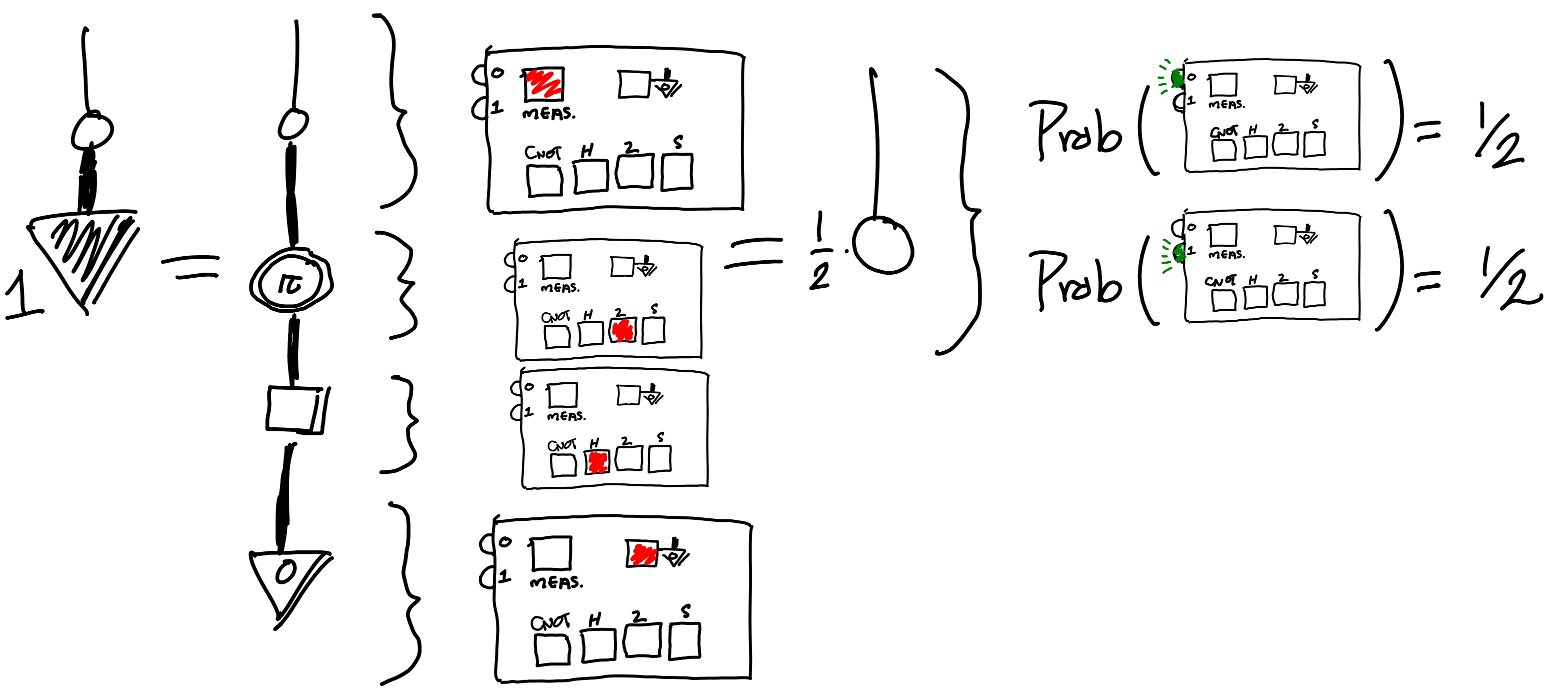
Test #2 ✓



Test #3 ✓



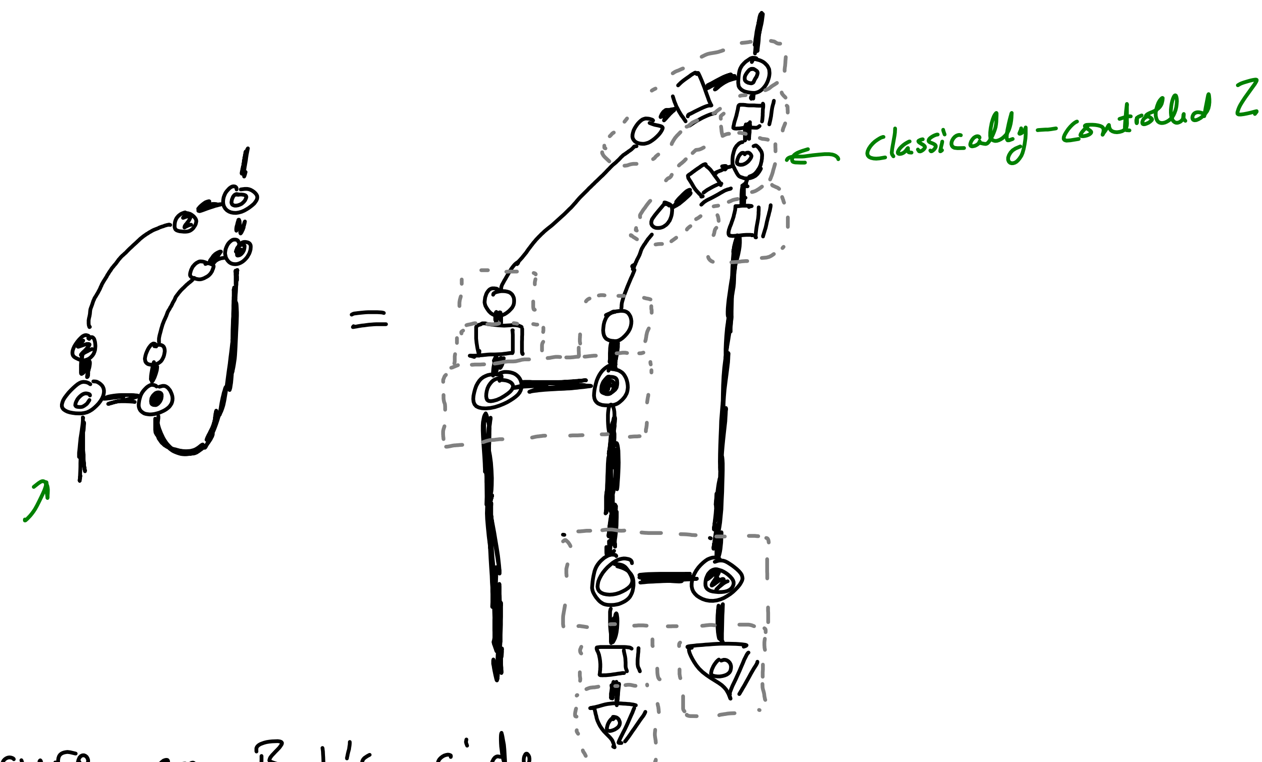
Test #4 ✓



Test #5

1. Prepare {  }

2. Teleport to Bob:

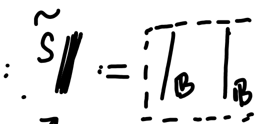


3. Measure on Bob's side.

$\Rightarrow$ still looks quantum!

Q: Did I get ripped off?

The trick: use 2 classical bits:



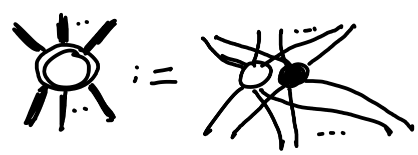
"Spekbit"

– R. Spekkens. "In defense of an epistemic view on quantum states: a toy theory."

...or classical maps

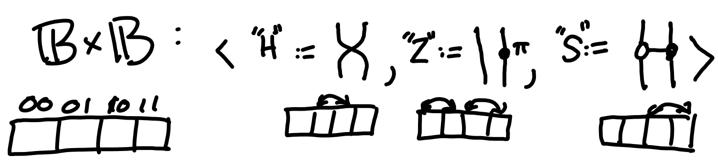
DEF The process theory <u>spek</u> ⊆ <u>relations</u> is generated by:

* "spek spiders"

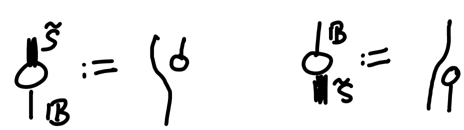


(⇐ n.b. this is <u>not</u> a quantum map)

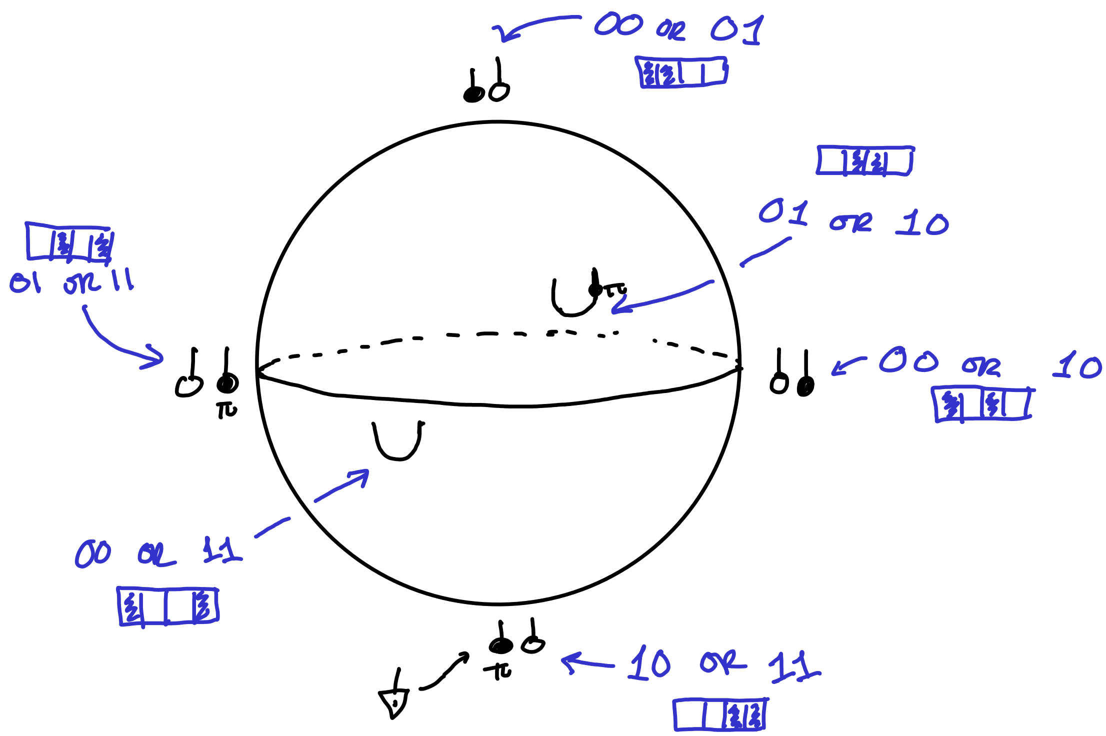
* all permutations on $\mathbb{B}\times\mathbb{B}$:



* "encoding" & "measurement"



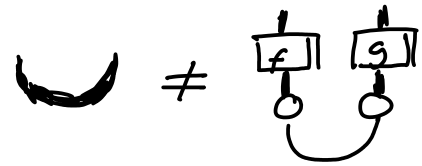
States for a single system ⇝ The Spekspere:



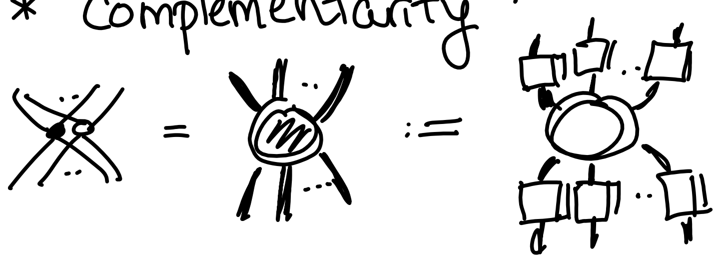
Classical Local Hidden Variable Model.

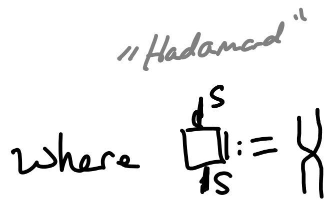
Spek is classical by design, but it has:

* entanglement:

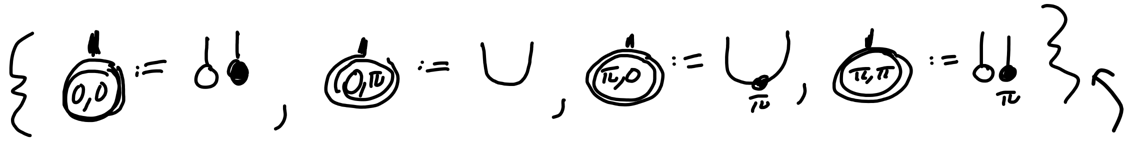


* (strong) complementarity:





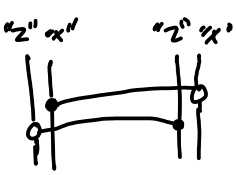
* phase groups

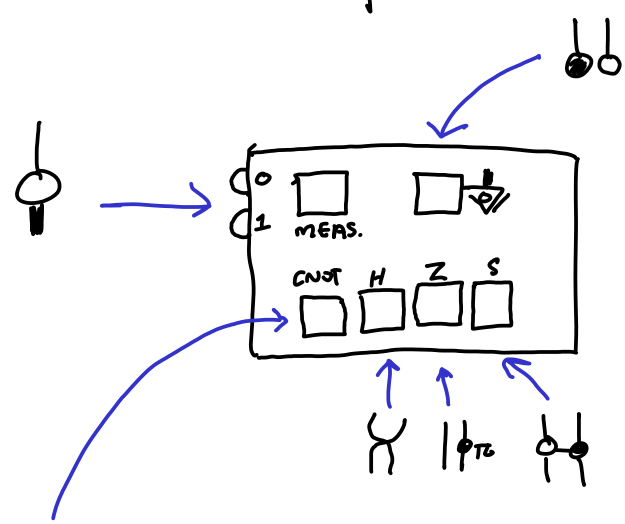


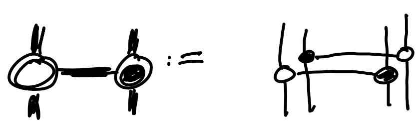
$\cong \mathbb{Z}_2 \times \mathbb{Z}_2$

not $\mathbb{Z}_4$

* "quantum-like" processes

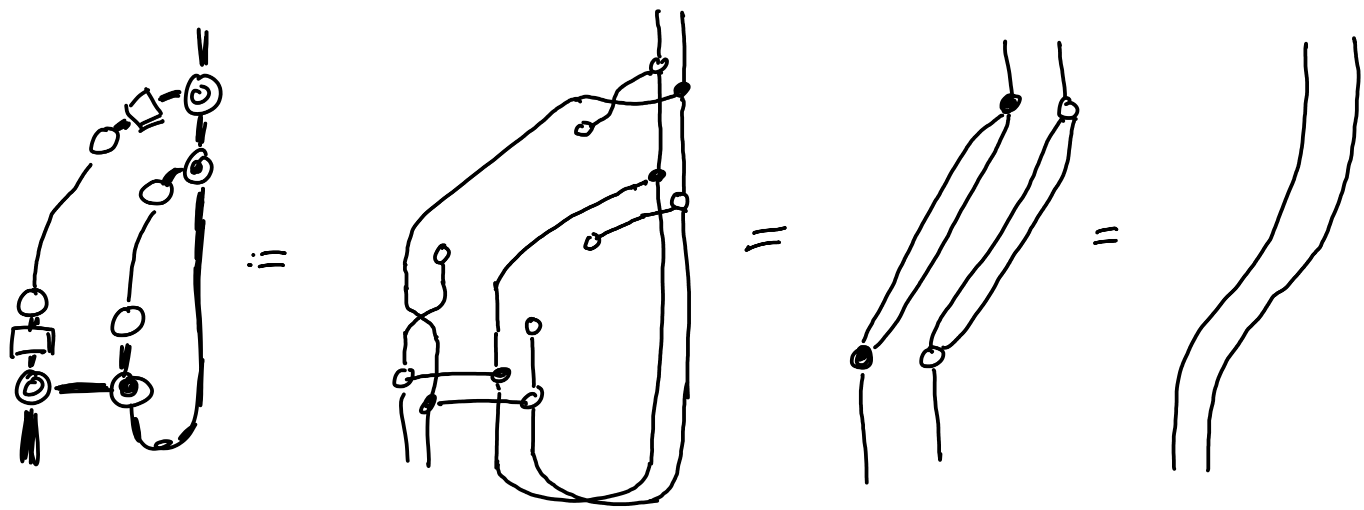




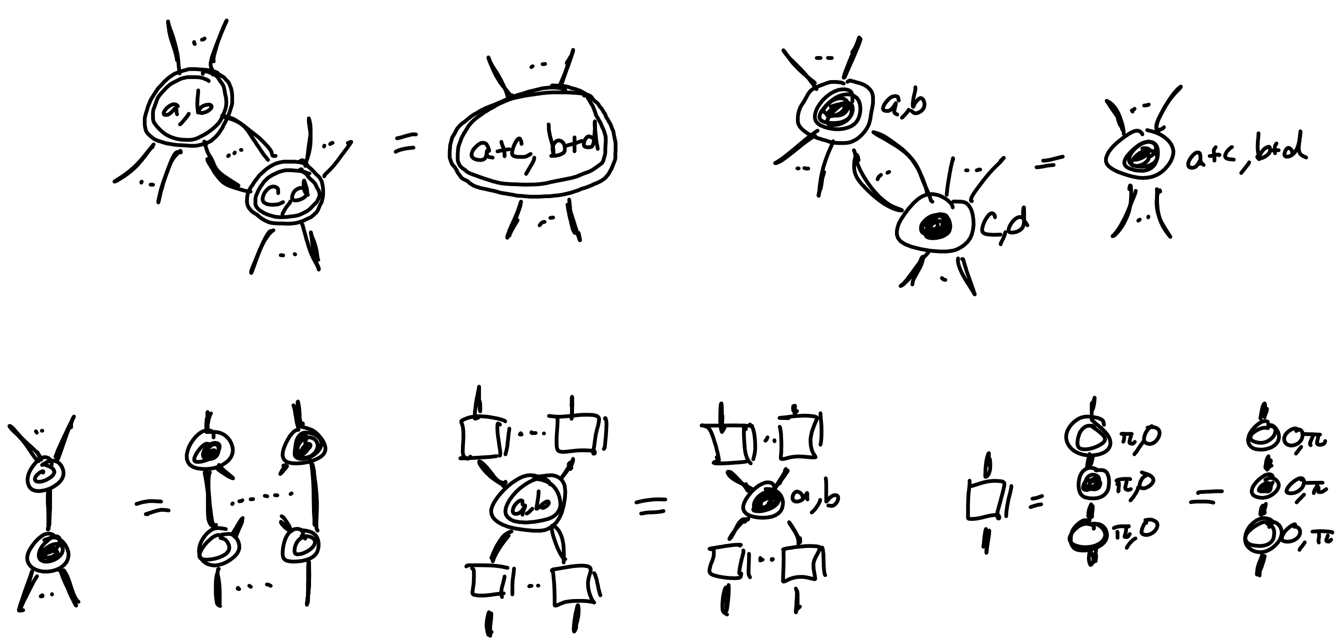


$((a,b),(x,y)) \mapsto ((a, y\oplus b), (a\oplus x, y))$

* teleportation:



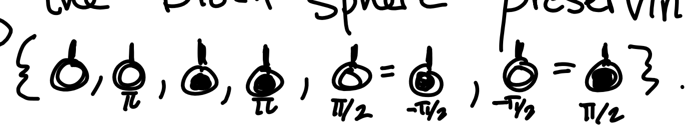
* ... and a complete "spek-ZX" calculus:



clifford maps ⊆ quantum maps

generated by:

* a family of spiders 

* all rotations of the Bloch sphere preserving the 6 states .

spek ⊆ relations

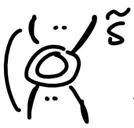
generated by:

* a family of spiders 

* all transformations of the 6 spek sphere states  coming from a permutation

Q: What's the difference?

A: The phase group:

$\Phi\Big($  $\Big) \cong \mathbb{Z}_4$ $\qquad$ $\Phi\Big($  $\Big) \cong \mathbb{Z}_2 \times \mathbb{Z}_2$

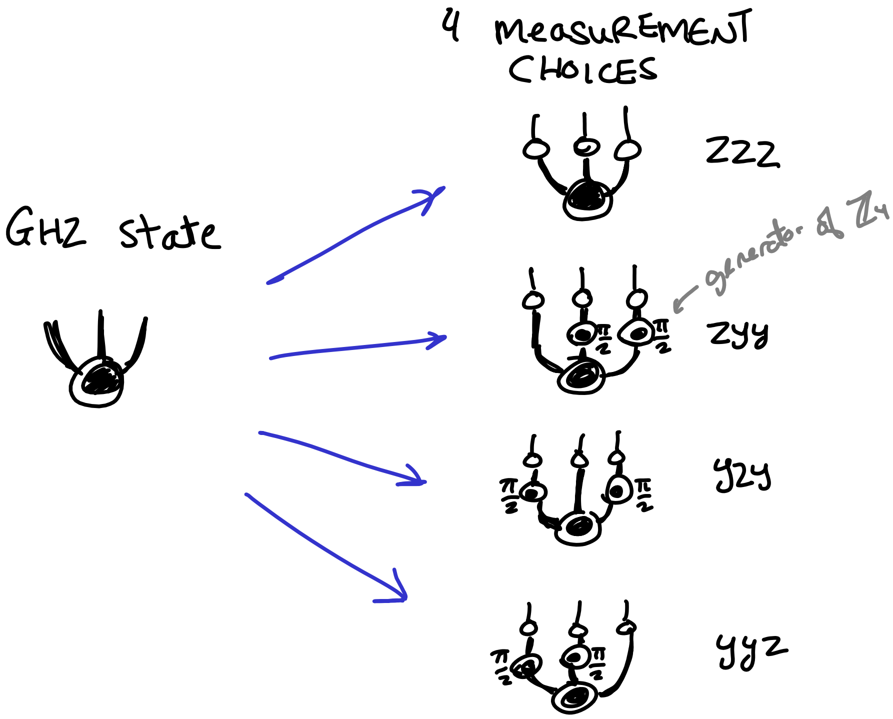
Clifford maps 

spek 

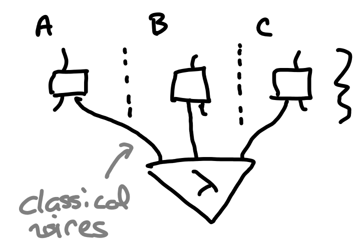
Q: Is it a big deal?

A: Yes! $\mathbb{Z}_4$ can be used to prove quantum nonlocality!

The GHZ/Mermin Argument 11.1.2



Statistics cannot be reproduced by:



Local hidden variable model.