Symmetry reduction induced by anyon condensation: a tensor network approach

José Garre Rubio
Joint work with Sofyan Iblisdir and David Pérez García
UCM & ICMAT

(Soon on the ArXiv…)

Funded by

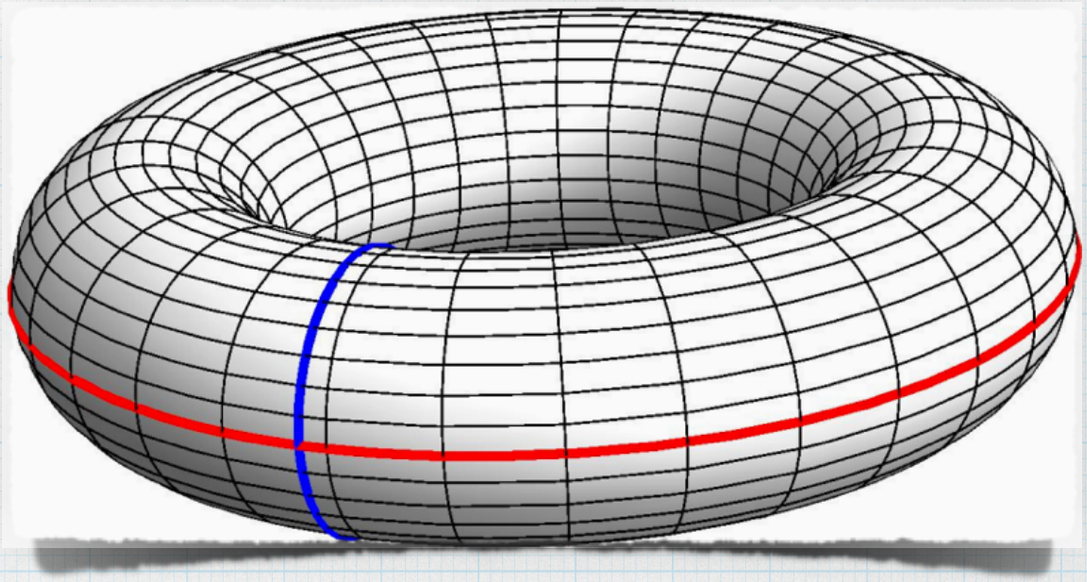
Topological order

* No local order parameter classification

* GS Degeneracy- Exotic statistics of quasiparticle excitations

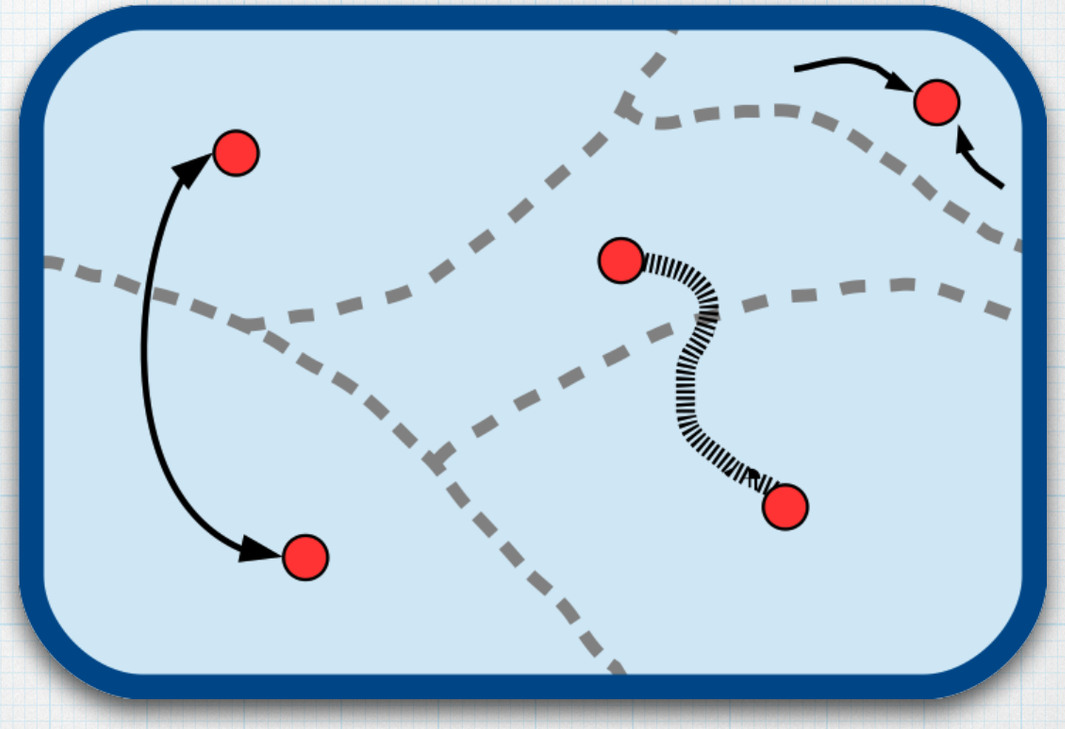
* RFP. Properties of anyons: Braiding-Fusion

* How do we go from one phase to another?



Topological phase transitions and TN

* Relate two topological model restricting the topological content [1]



* Anyon Condensation: Spontaneous Symmetry Breaking (Sharp)

* Modelled with PEPS (path) [2]

[1] JHEP05(2003)068 Alexander F. Bais, Bernd J. Schroers, Joost K. Slingerland

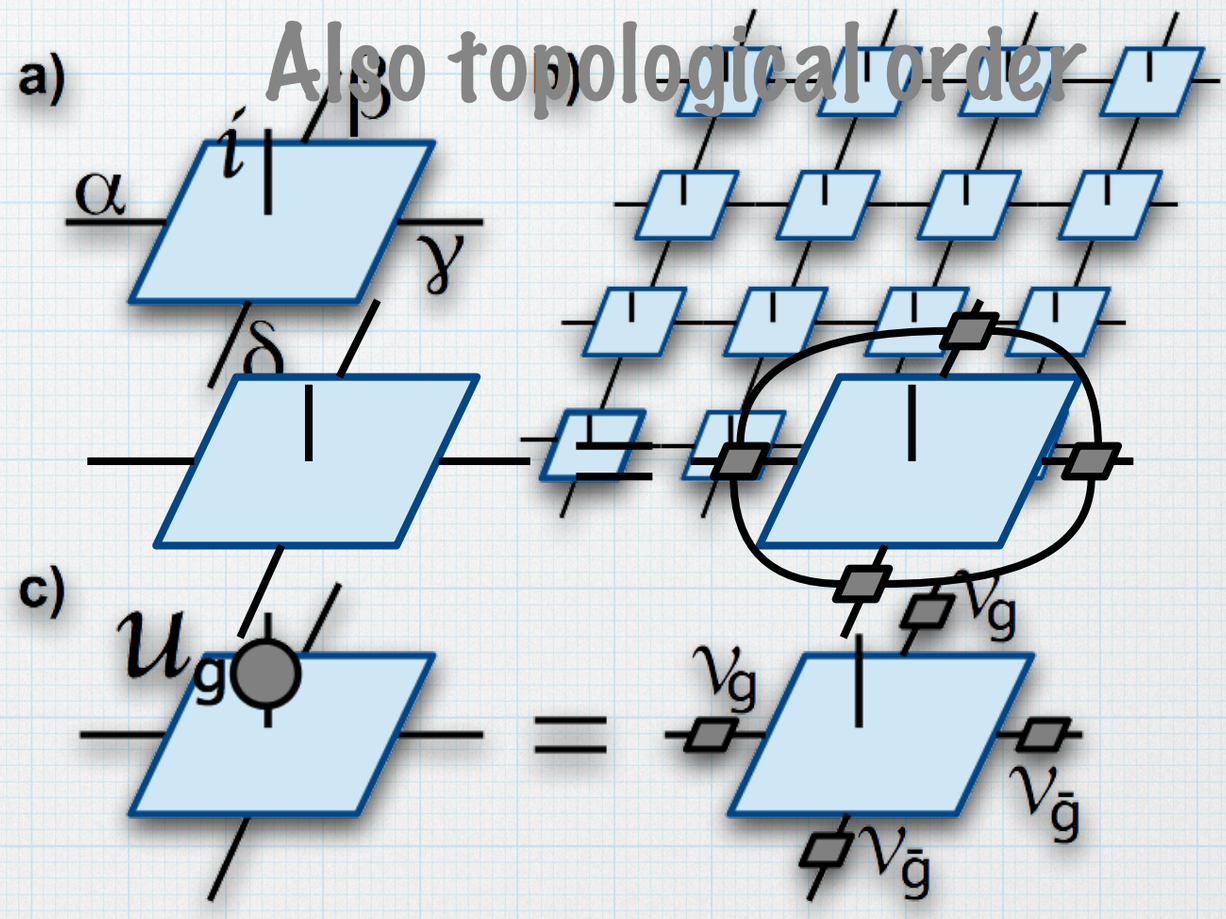
[2] *Nature Communications* **6**, 8284 (2015) J. Haegeman, V. Zauner, N. Schuch, F. Verstraete

Projected Entanglement Pair States (PEPS)

* GS of local Hamiltonian-Area Law and topological order

* Tensor Construction: Auxiliary d.o.f

* Action under Global Symmetries



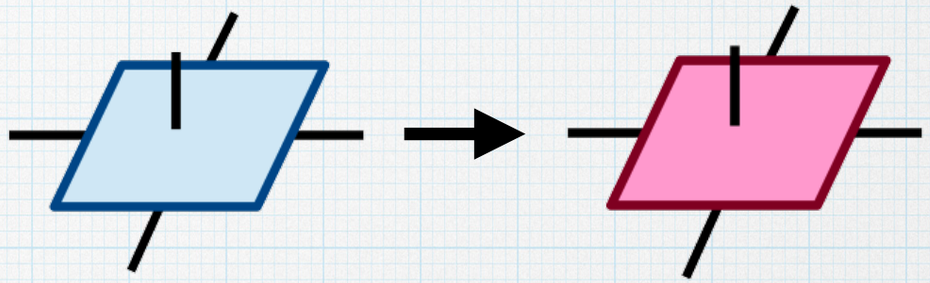
Also topological order

Overview

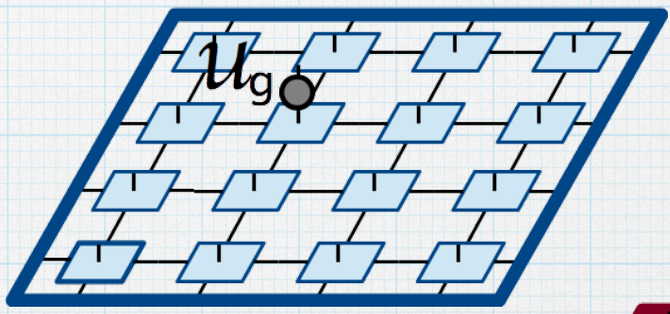
* Motivation and introduction
* Our Work
* Global and gauge symmetries
* Symmetries over anyons
* Approach in 1D

Our Work

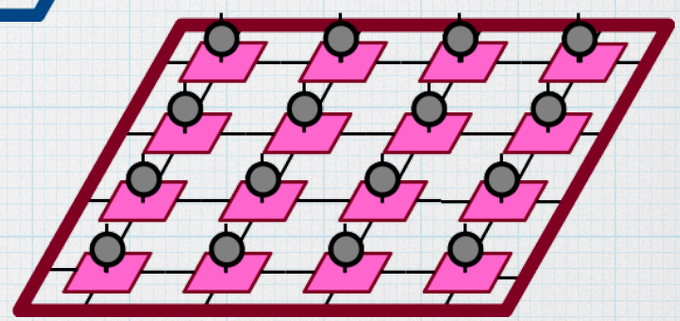
* Pairs of PEPS connected by Anyon condensation (QD)



* We study symmetries: From Gauge to Global



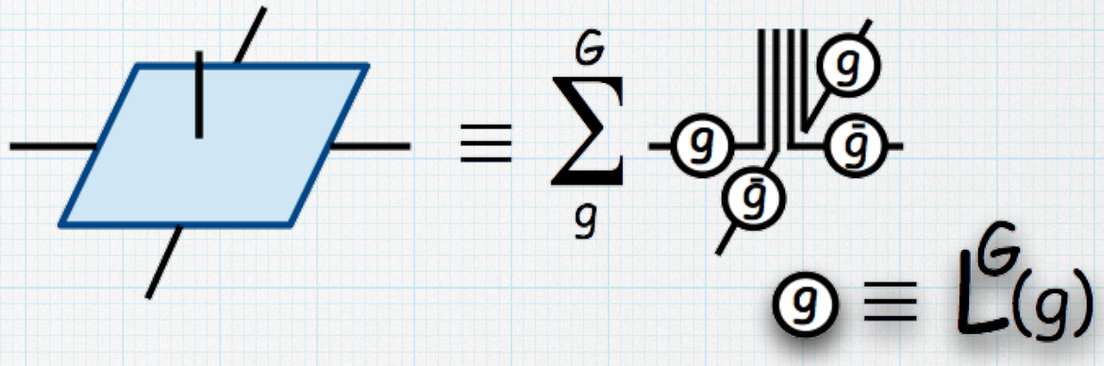
* Charge condensation and Flux Confinement



* Global Symmetry over Anyons

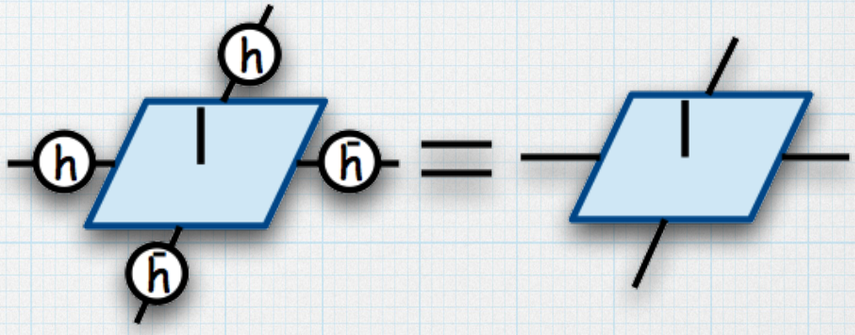
Parent Tensor: G-isometric PEPS [2]

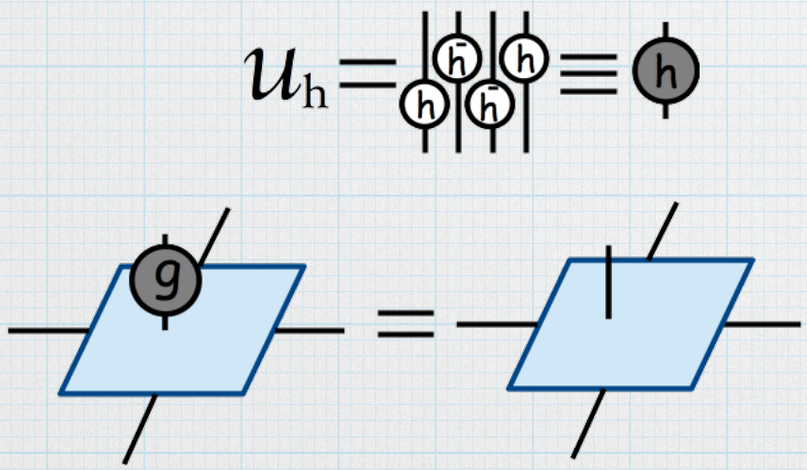
* Quantum Double of G.

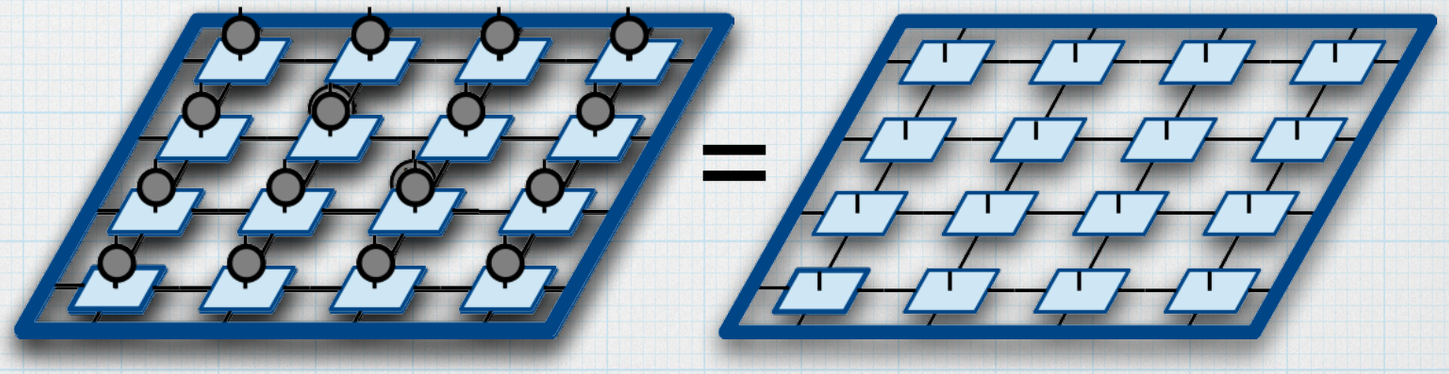


* Local Gauge Symmetry of G

* Gauge invariance on the virtual d.o.f



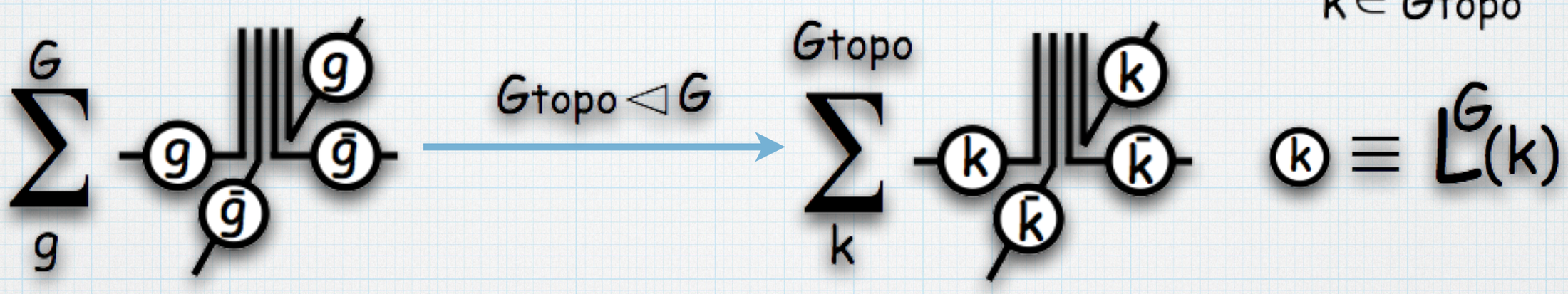




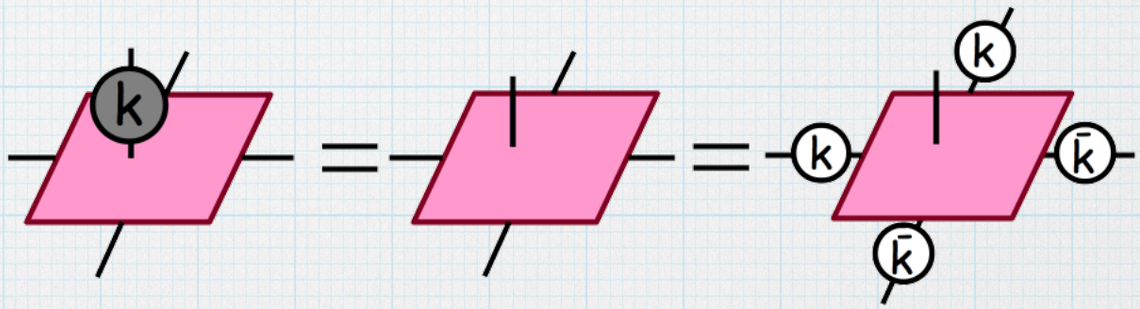
[3] Annals of Physics, 325 (10). (2010) N. Schuch, D. Pérez-García, I.Cirac

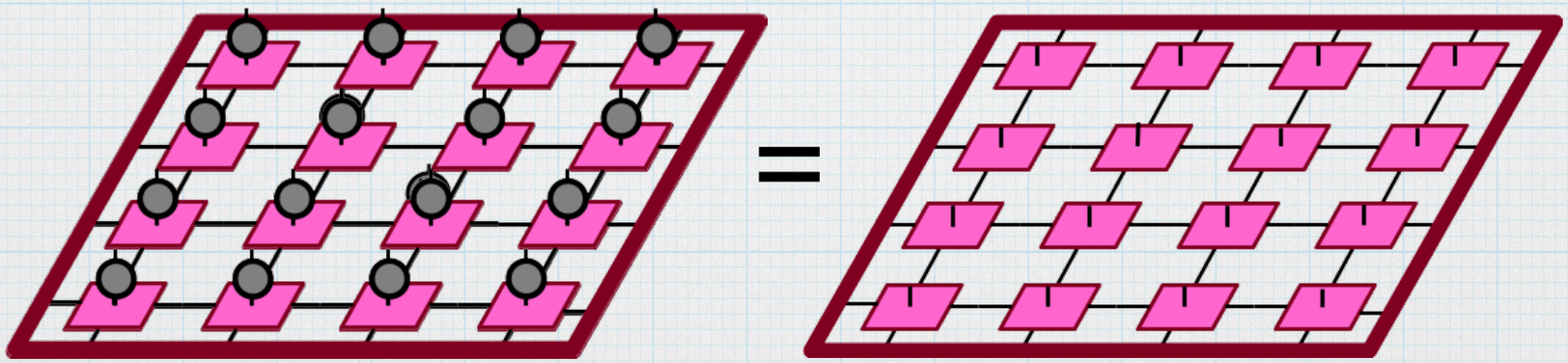
Restricted Tensor

Anyon Condensation ⟷ Restrict Gauge invariance

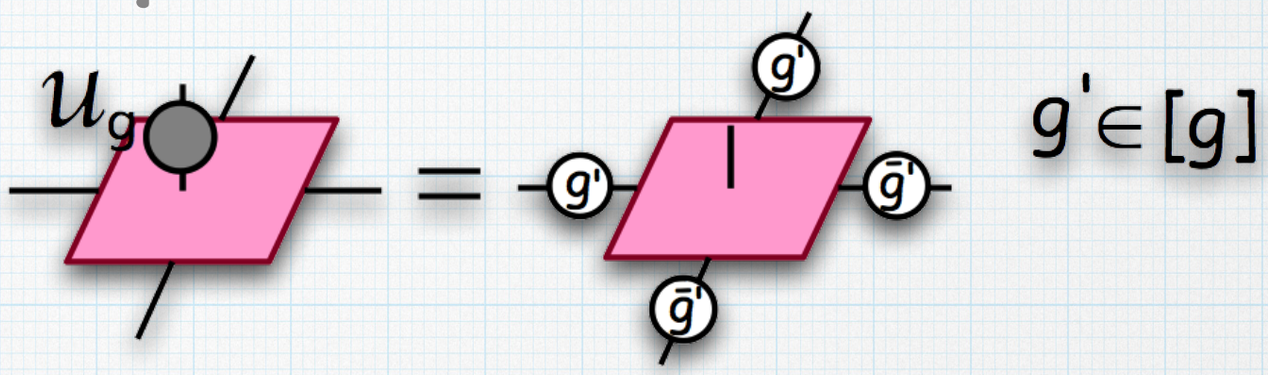


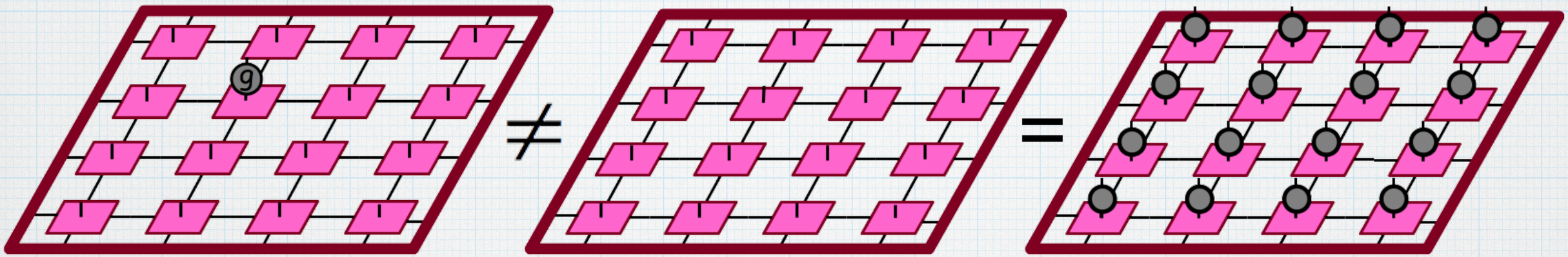
Gtopo Gauge invariance



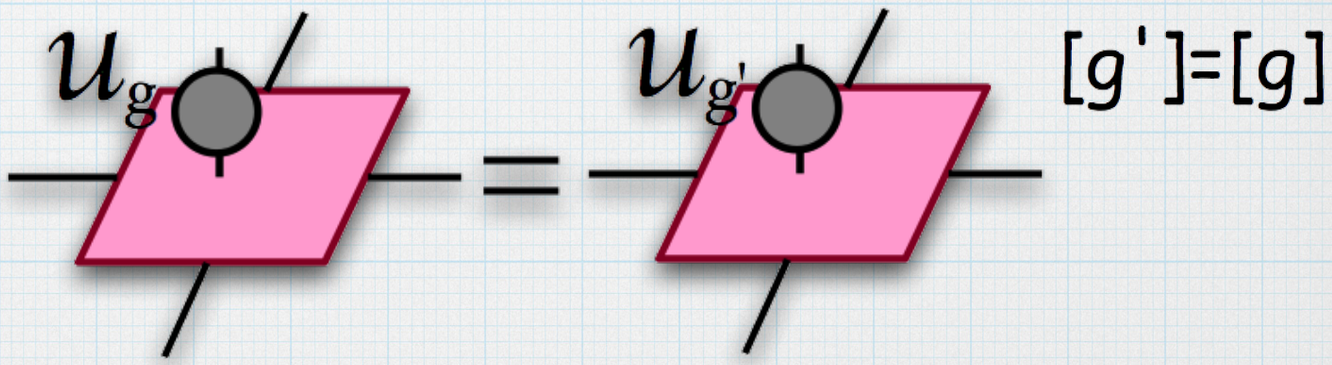


G is no longer a gauge symmetry





$G/G_{topo} \simeq G_{sym}$



Pure G Gauge symmetry

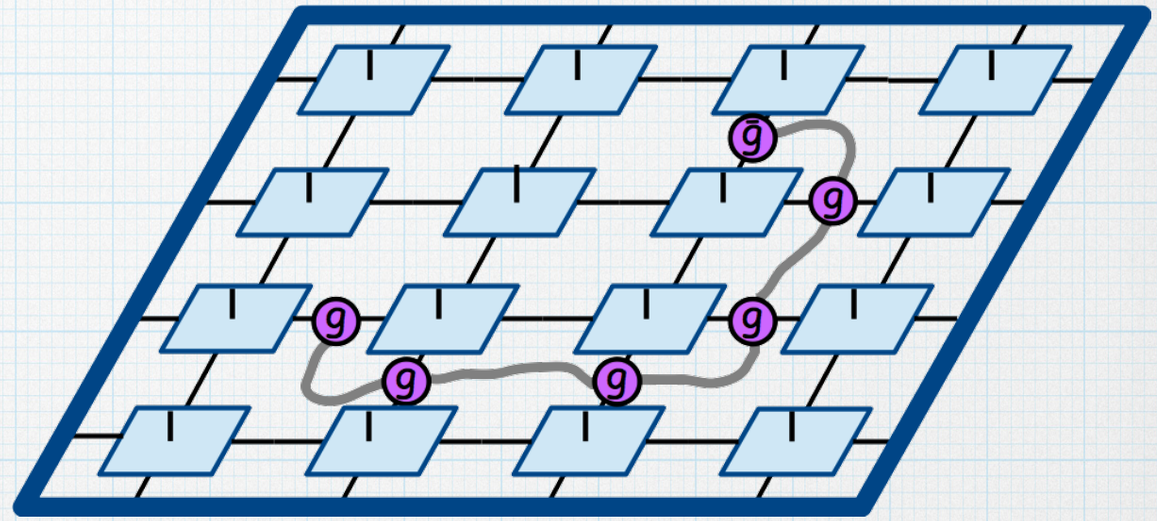
G_{topo} Gauge symmetry + G_{sym} Global symmetry

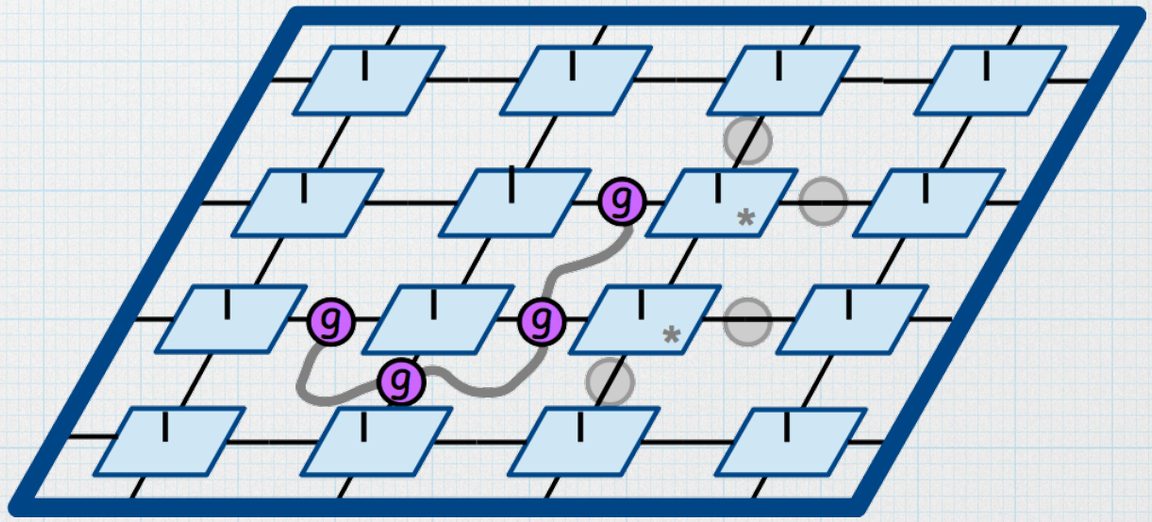
Pure Flux excitations

* Flux Excitations on Parent Model

* Possibility of deforming freely

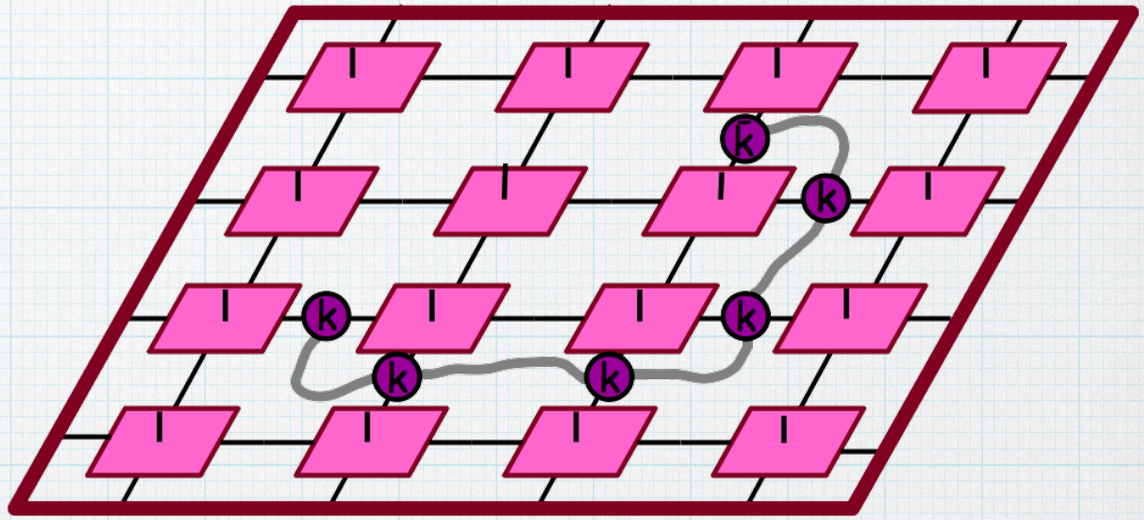
* Energy independence on length





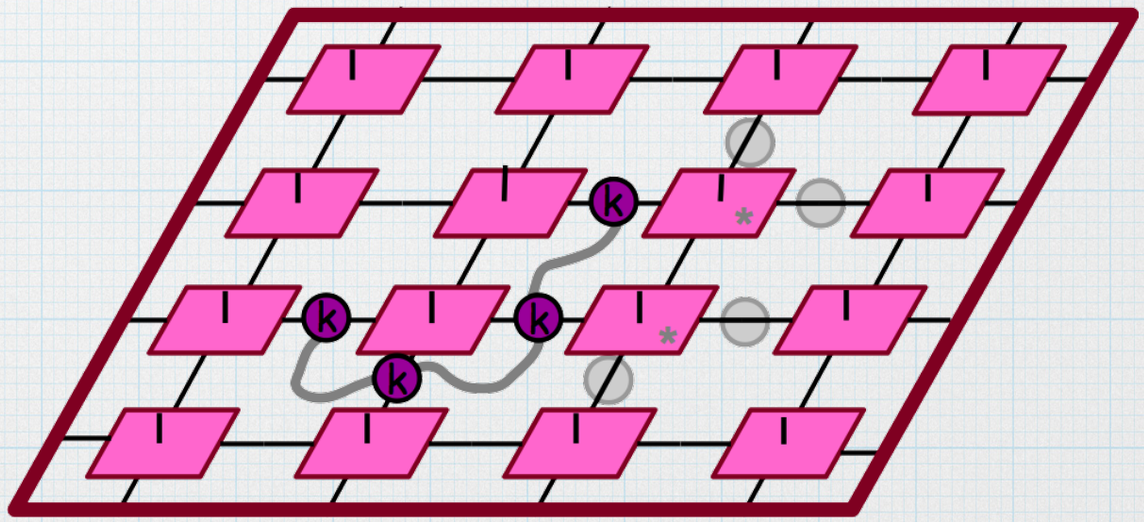
Pure Flux excitations

* Flux Excitations on Rstricted Model



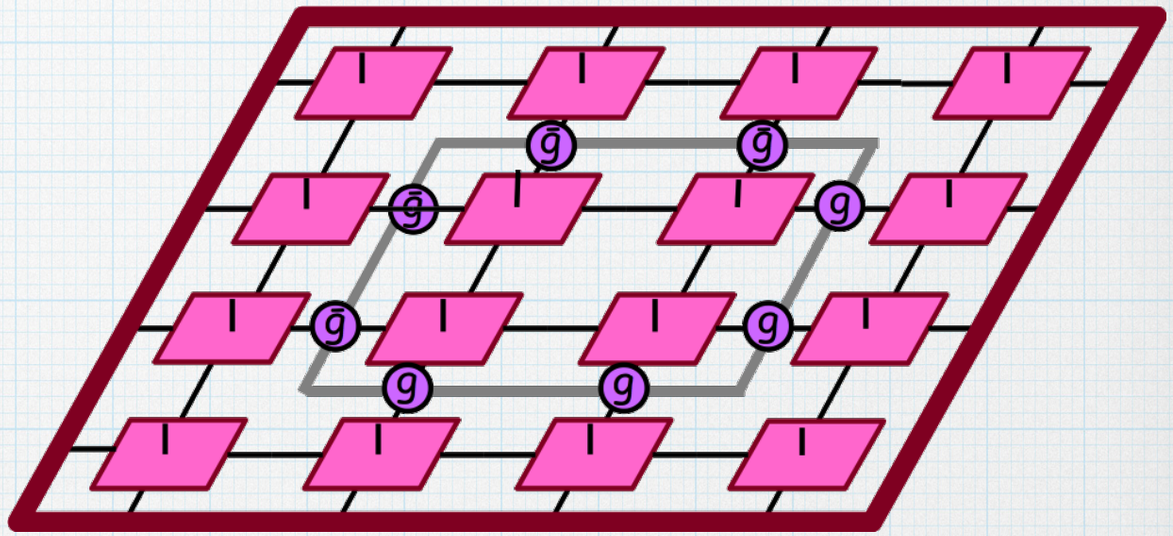
* Possibility of deforming freely

* Energy independence on length



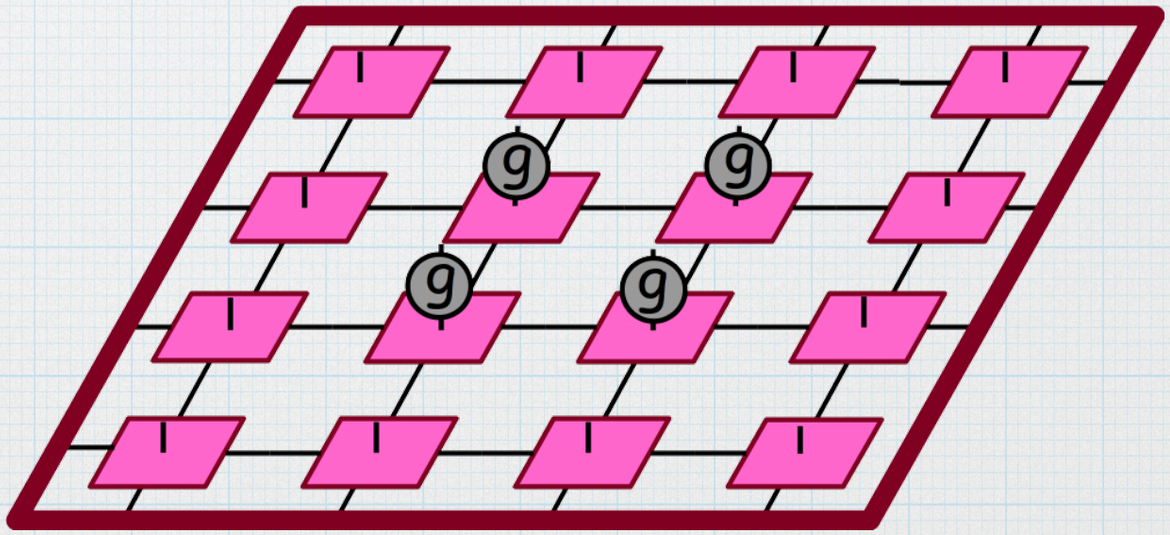
Flux Confinement

* Insert Flux Excitation on Restricted Model



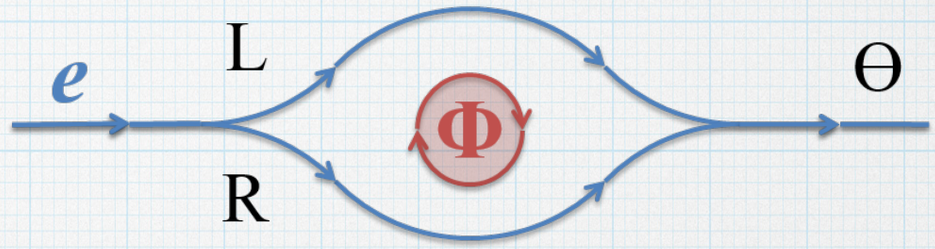
* Impossibility of moving freely

* Energy dependence on length



Charge Condensation

* Braiding with unconfined fluxes



* Indistinguishable from vacuum using braiding

* Not topological excitation- Trivial Sector

$$\left| \frac{\chi_R^G(k)}{|R|} \right|^2 = 1$$

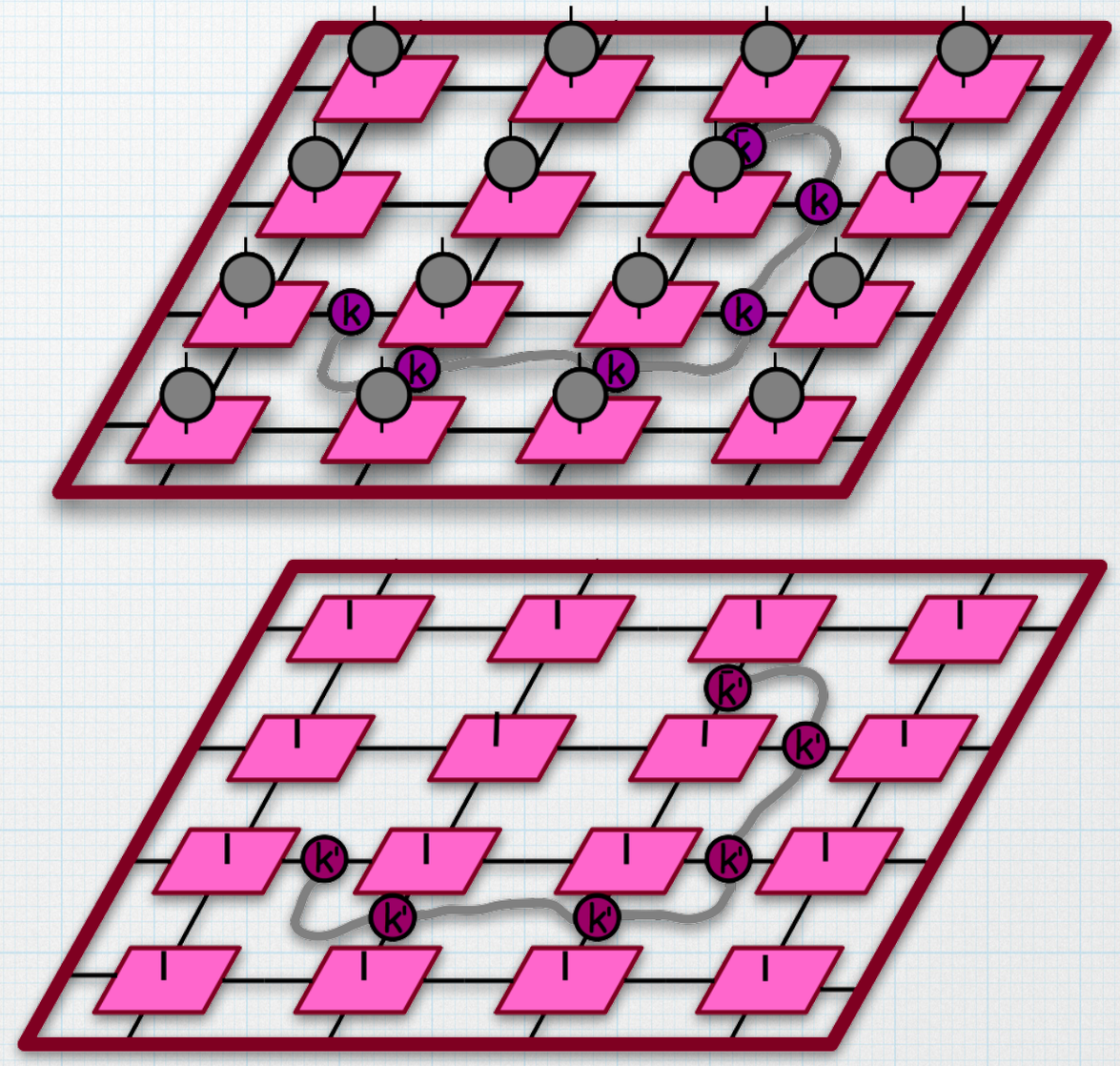
[1] JHEP05(2003)068 Alexander F. Bais, Bernd J. Schroers, Joost K. Slingerland

Global Symmetries over Anyons: Pure Flux case

* Pair of fluxes C[k] + global symmetry action Ug

* The action of Ug conjugates:
  $k'=gkg^{-1}$; C[k]-> C[k']

* Homomorphism:
  p: Gsym-> Aut(Gtopo)

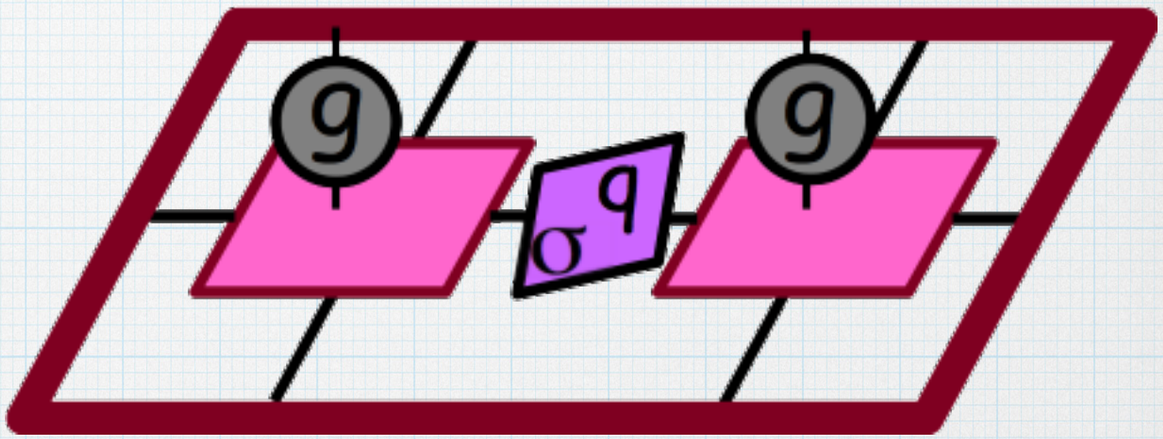


Global Symmetries over Anyons: Pure Charge case

* Action of the symmetry permutes irreps [4]

* Cocycle function:
  w: Gsym x Gsym-> Gtopo
  $g'h'(gh')^{-1} = w(g,h)$

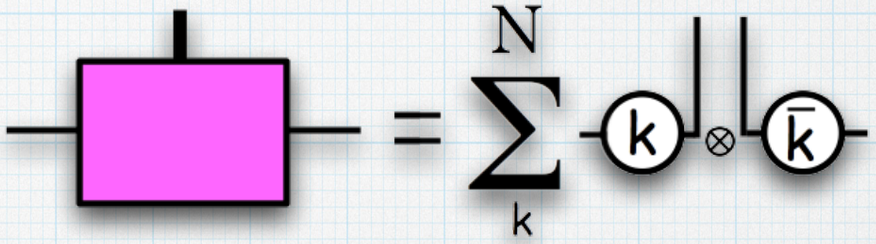
* Extension groups: (p, w)



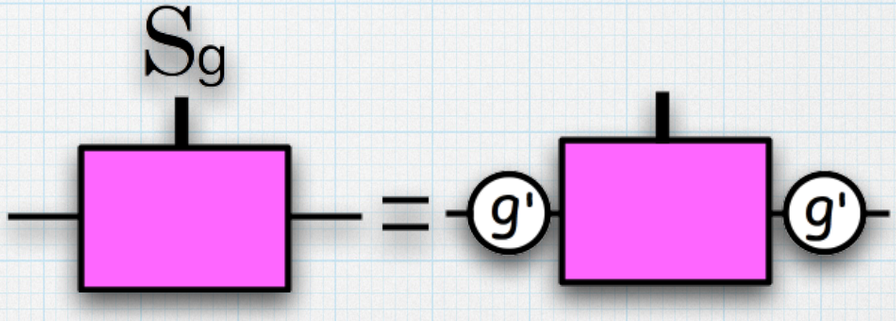
[4] H. Clifford, *Representations Induced in an Invariant Subgroup*, Annals of Mathematics 38 (3): 533-550, (1937)

1-D Approach: MPS

* Topological order-> Symmetry Breaking Pattern



* Action of Operator: Virtual representation of all phases



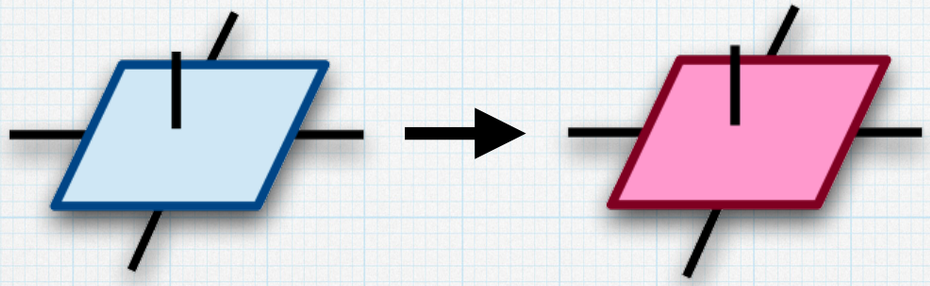
* Induced Representation: Permutation + Projective representation [5]

$$P_{g'}\left[\bigoplus_{\alpha=1}^{\mathcal{A}} V_{g'}^{\alpha}\otimes \bar{V}_{g'}^{\alpha}\right]$$

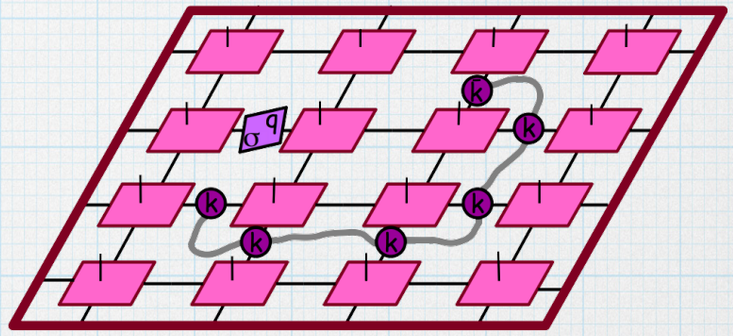
[5] Phys. Rev. B 84, 165139 (2011) Norbert Schuch, David Perez-Garcia, Ignacio Cirac

Conclusion and Outlook

* Modifying the tensor: Symmetries by Condensation

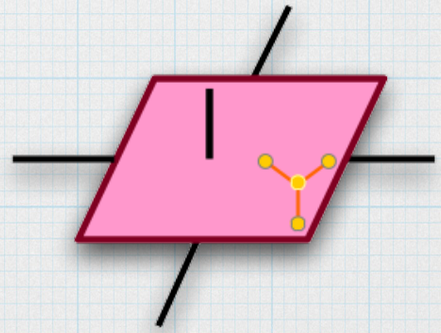


* TO, Local-Global, Anyon symmetries



* Generalizing the restricted tensor to flux condensator

* Combined Symmetry in all sectors
(+ S.F. with twisted QD?)



Thank You!