Quantum Behaviour in Macroscopic Systems

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Group Meeting

28 Mar 09

Outline

- Introduction
- The most recent “Claim”
  Di Martini et. al. 09
  - Macro-Macro Entanglement/Superposition
- Macro-Micro Entanglement/ Superposition
  Di Martini et. al. 08
  (Theory & Experiment)
  - State Preparation
  - Entanglement Measurement

Schroedinger Cat: Entanglement test in a Micro-Macroscopic system

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A Macro-state consisting of $\mathbf{N} \approx 3.5 \times 10^4$ photons in a quantum superposition and entangled with a far apart single-photon state (Micro-state) is generated. Precisely, an entangled photon pair is created by a nonlinear optical process, then one photon of the pair is injected into an optical parametric amplifier (OPA) operating for any input polarization state, i.e. into a phase-covariant cloning machine. Such transformation establishes a connection between the single photon and the multi particle fields. We then demonstrate the non-separability of the bipartite system by adopting a local filtering technique within a positive operator valued measurement.

PACS numbers:

In recent years two fundamental aspects of quantum mechanics have attracted a great deal of interest, namely the investigation on the irreducible nonlocal properties of Nature implied by quantum entanglement and the physical realization of the "Schrœdinger Cat" [1, 2]. The last concept, by applying the nonlocality property to a combination of a microscopic and of a Macroscopic systems, enlightens the concept of the quantum state, the dynamics of large systems and ventures into the most intriguing philosophical problem, i.e. the em... ence of quantum mechanics in the re... ife. In recent ... uantum entanglement has b... onstrated ... wo photon systems [3], wi... photo... nsemble [4, 5] ... hil...

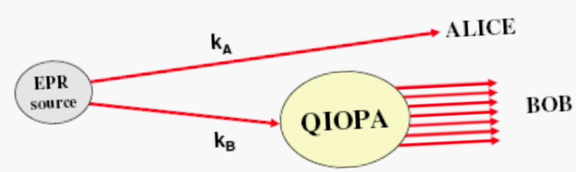
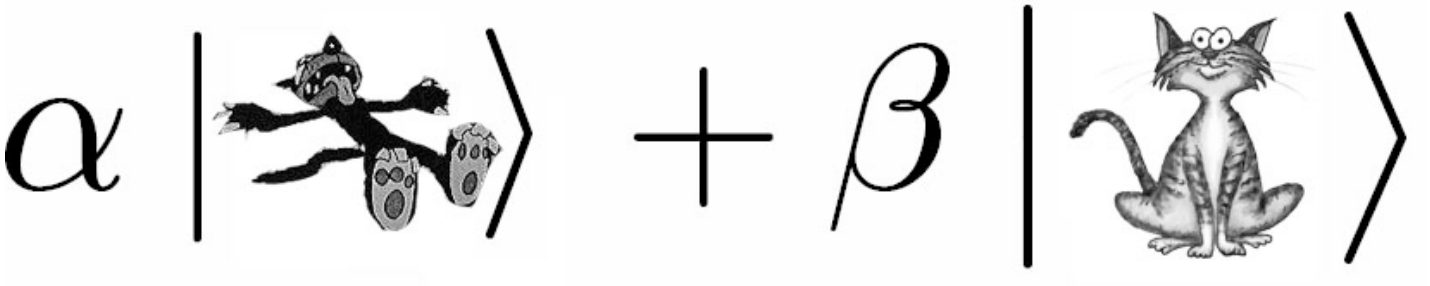


FIG. 1: Schematic diagram showing the single photon Quantum-Injected Optical Parametric Amplification (QIOPA).

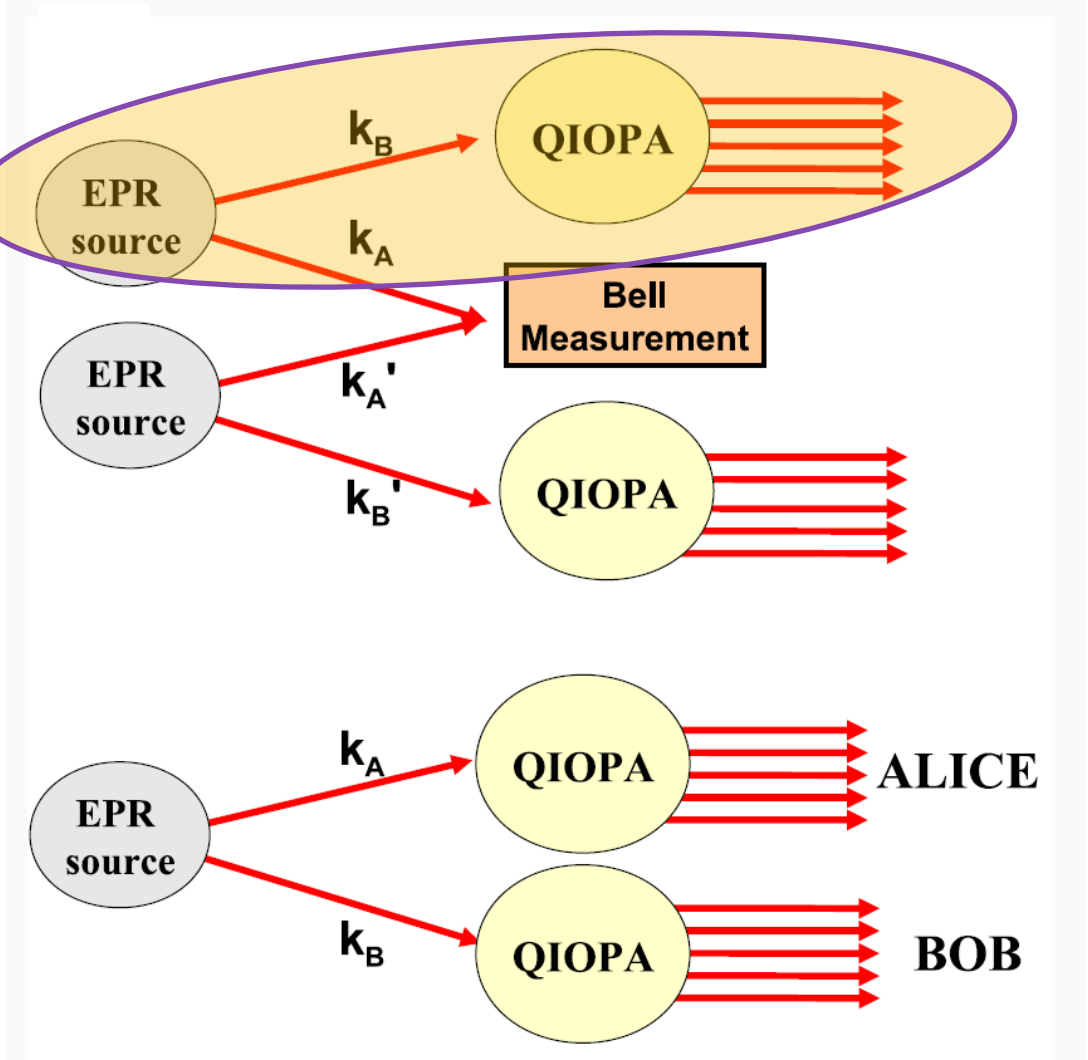
Introduction and

- QM = debate!
  - QM limit
  - QM behaviour in macro systems
    - eg. Schrodinger Cat

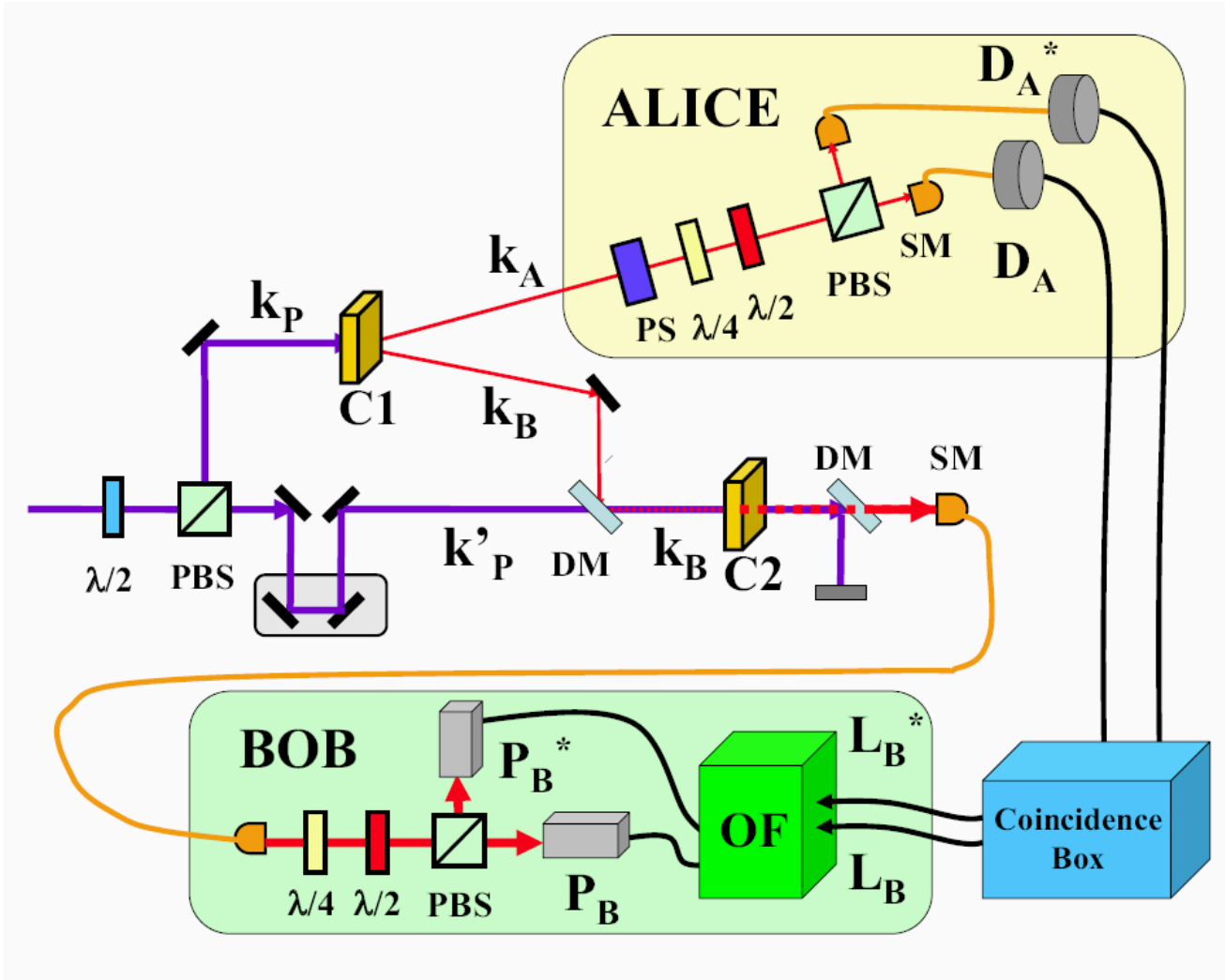
Cat States



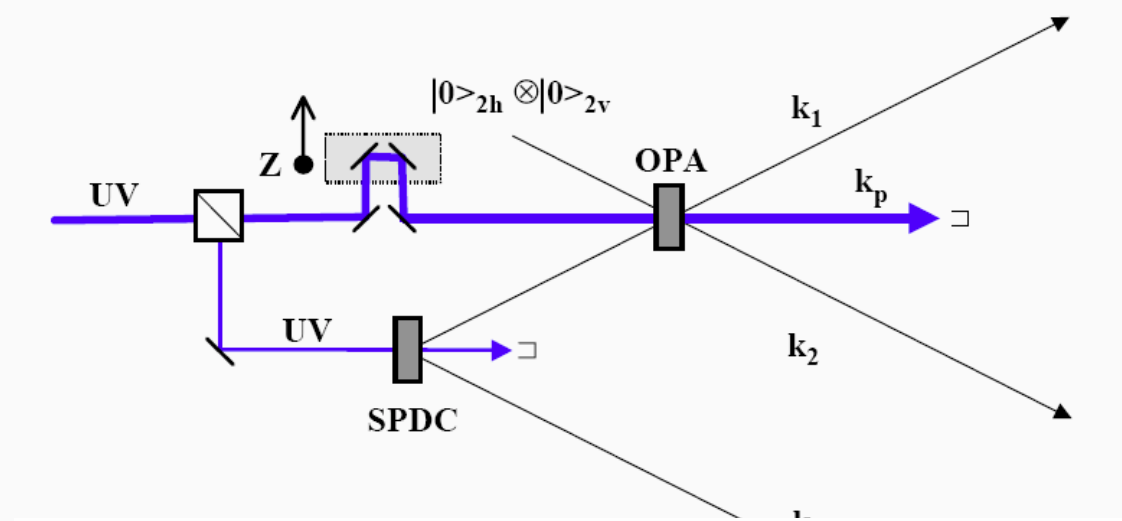
Di Martini 09



Di Martini 98/ 05/ 08



State Preperation

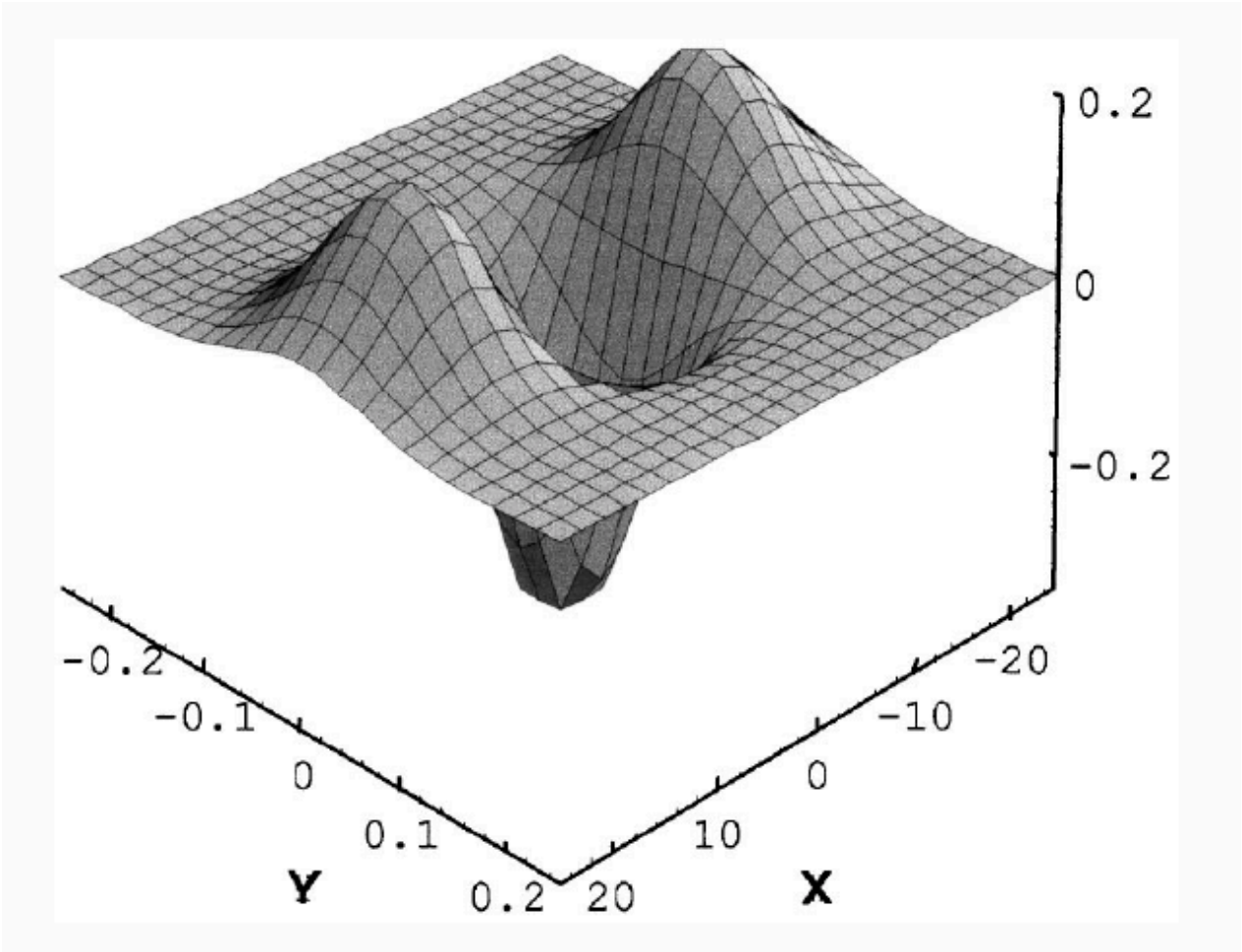


$$|\Sigma\rangle_{A,B} = 2^{-1/2}\left(\left|\Phi^{\phi}\right\rangle_B \otimes \left|1\phi^{\perp}\right\rangle_A - \left|\Phi^{\phi\perp}\right\rangle_B \otimes |1\phi\rangle_A\right)$$

$$\left|\Phi^{\phi}\right\rangle_B = \sum_{i,j=0}^{\infty} \gamma_{ij} \left|(2i+1)\phi;(2j)\phi^{\perp}\right\rangle_B$$

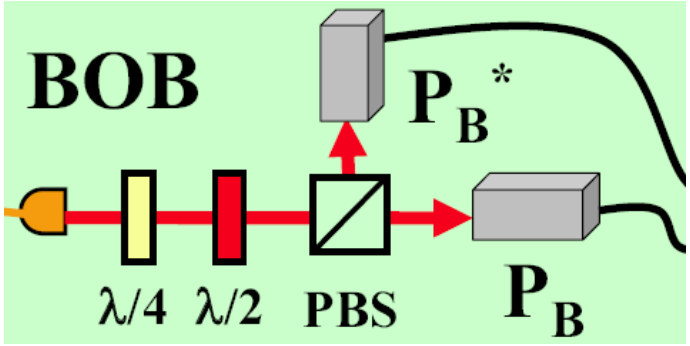
$$\left|\Phi^{\phi\perp}\right\rangle_B = \sum_{i,j=0}^{\infty} \gamma_{ij} \left|(2j)\phi;(2i+1)\phi^{\perp}\right\rangle_B$$

Wigner Function



Measurement

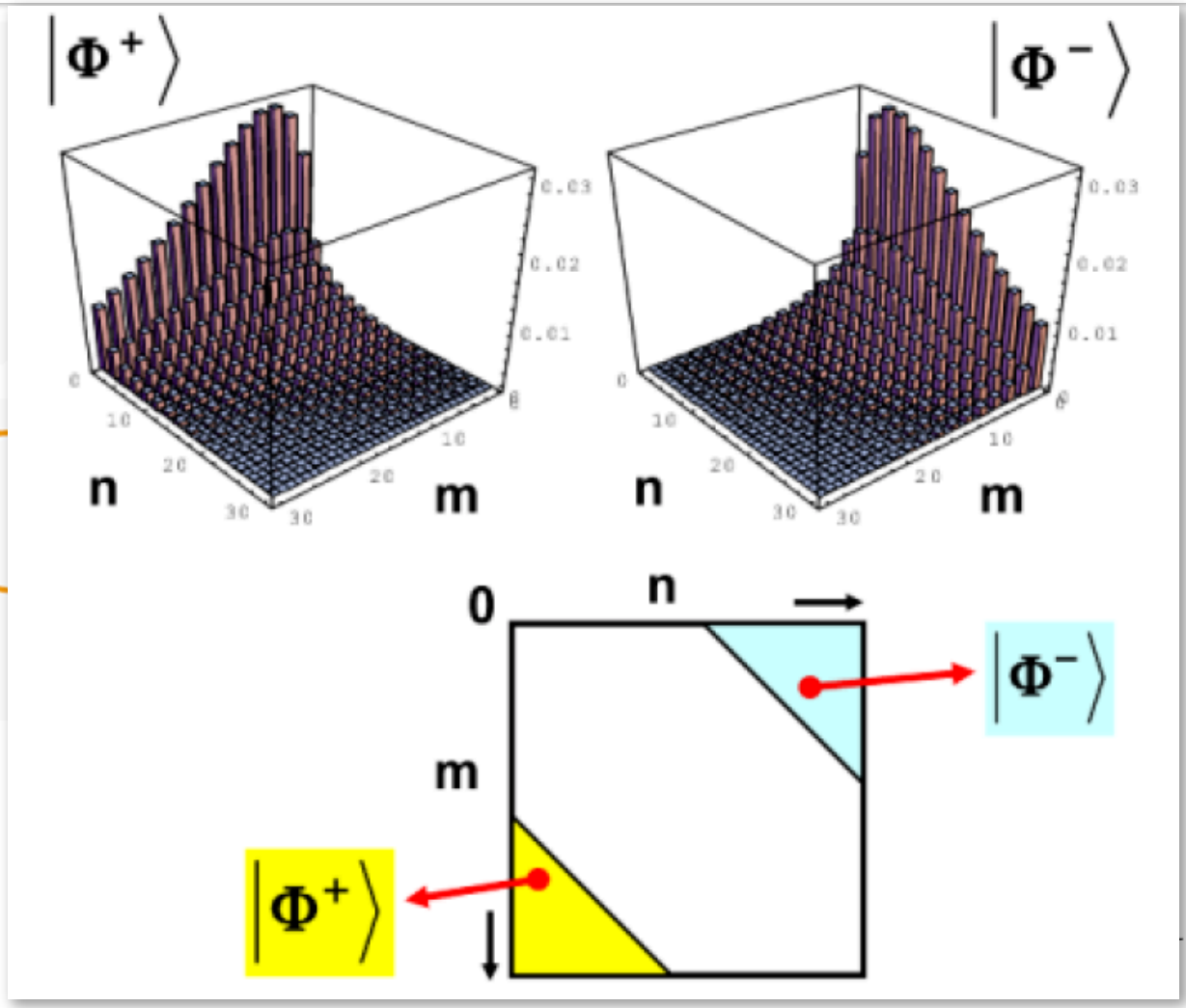
- In {H,V}, {H+V,H−V} and {H+iV,H−iV}



$$\hat{\sigma}_i = |\psi_i\rangle\langle\psi_i| - |\psi_i^\perp\rangle\langle\psi_i^\perp|$$

$$\hat{\Sigma}_i = \hat{U}\hat{\sigma}_i\hat{U}^\dagger = |\Phi^{\psi i}\rangle\langle\Phi^{\psi i}| - |\Phi^{\psi i\perp}\rangle\langle\Phi^{\psi i\perp}|$$

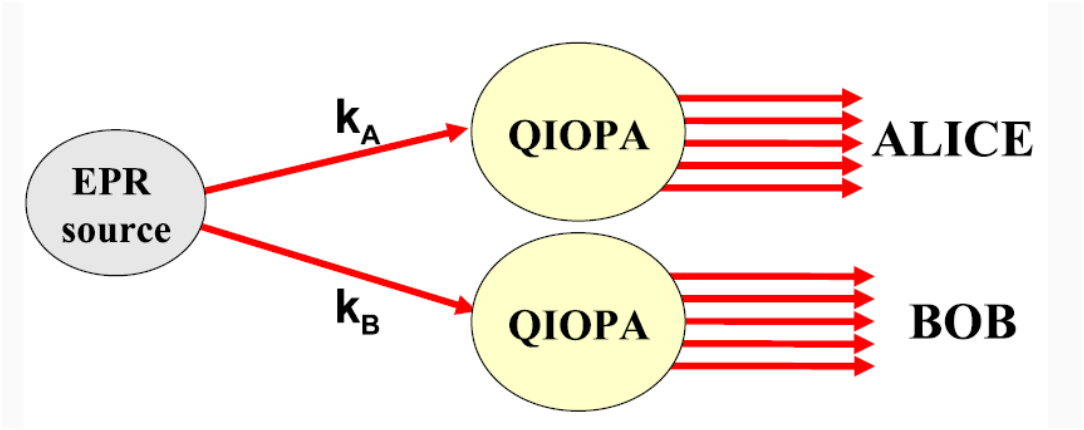
Nonlocal Behaviour



$$V_i = |P(\psi_i, \quad , \Phi^{\psi i})|$$

Go baaaaaack...!

- Putting two of these together to form Macro-Macro entanglement



Summary and Conclusion

- Macroscopic entanglement and superposition
- Extension of binary logic algorithms and techniques to multiparticle regime
- Enhancement of Kerr-type nonlinearities

"In conclusion, we have reported a feasible proposal that may lead of a relevant conceptual breakthrough in the context of some most intriguing foundational aspects of

Schrödinger was arrested for cruelty to animals.
His fate is uncertain ...

QUESTIONS?