



HAL
open science

The Qubit in de Broglie-Bohm Interpretation

Michel Gondran, Alexandre Gondran

► **To cite this version:**

Michel Gondran, Alexandre Gondran. The Qubit in de Broglie-Bohm Interpretation. Advances in Quantum Information & Simulations, Nov 2014, Lyon, France. , Book of Abstracts, 2014. hal-01348981

HAL Id: hal-01348981

<https://hal.science/hal-01348981>

Submitted on 1 Aug 2016

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

How to explain spin's quantification ?

- ▶ Either by the measurement postulates of quantum theory
- ▶ Either by Pauli equation with spatial extension of the spinor

Representation of the particle with spin

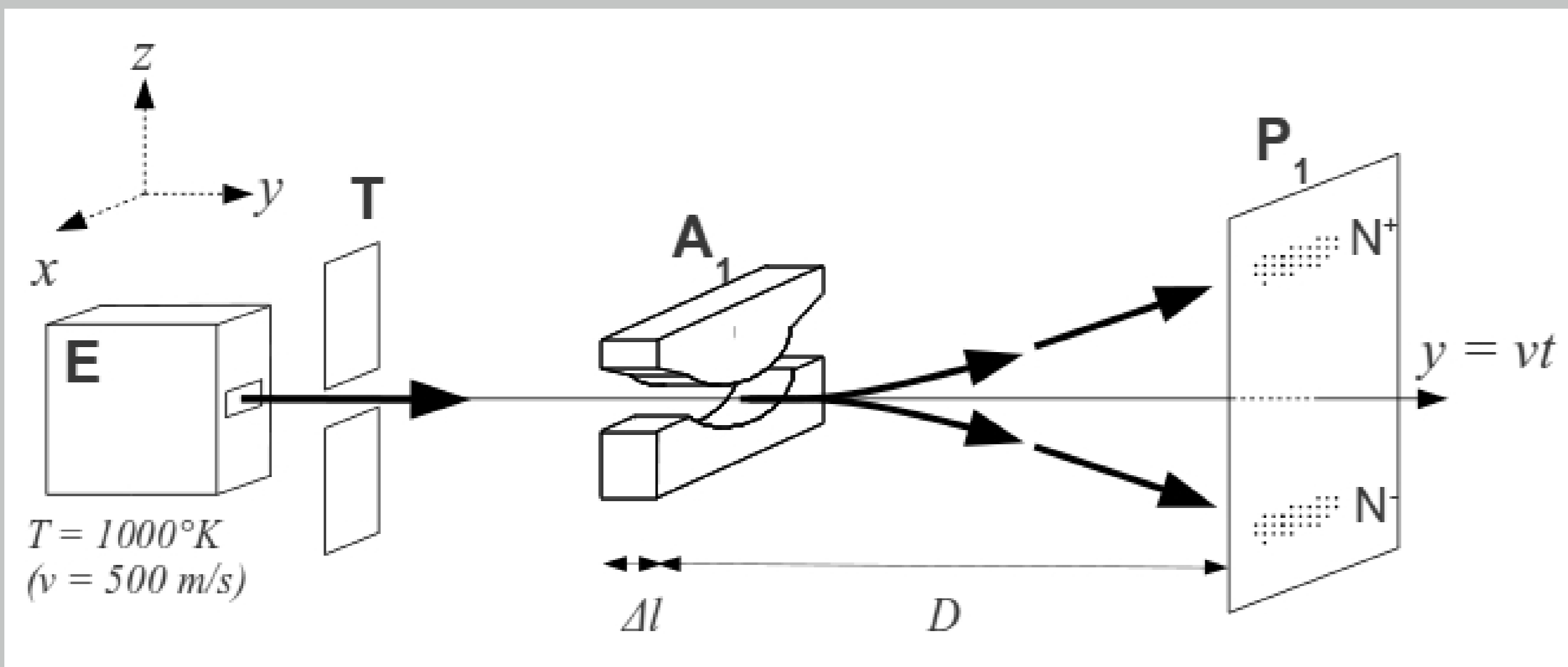
- ▶ Complete spinor with spatial extension

$$\Psi^0(z) = (2\pi\sigma_0^2)^{-\frac{1}{4}} e^{-\frac{z^2}{4\sigma_0^2}} \begin{pmatrix} \cos \frac{\theta_0}{2} e^{-i\frac{\varphi_0}{2}} \\ \sin \frac{\theta_0}{2} e^{i\frac{\varphi_0}{2}} \end{pmatrix}$$

- ▶ Simplified spinor used in quantum information (qubit)

$$\Psi^0 = \begin{pmatrix} \cos \frac{\theta_0}{2} e^{-i\frac{\varphi_0}{2}} \\ \sin \frac{\theta_0}{2} e^{i\frac{\varphi_0}{2}} \end{pmatrix}$$

Stern-Gerlach experiment



$$\Psi^0(z) = (2\pi\sigma_0^2)^{-\frac{1}{4}} e^{-\frac{z^2}{4\sigma_0^2}} \begin{pmatrix} \cos \frac{\theta_0}{2} e^{-i\frac{\varphi_0}{2}} \\ \sin \frac{\theta_0}{2} e^{i\frac{\varphi_0}{2}} \end{pmatrix}$$

- ▶ Pure state : θ_0 and φ_0 fixed
- ▶ Mixed states : θ_0 and φ_0 randomly drawn

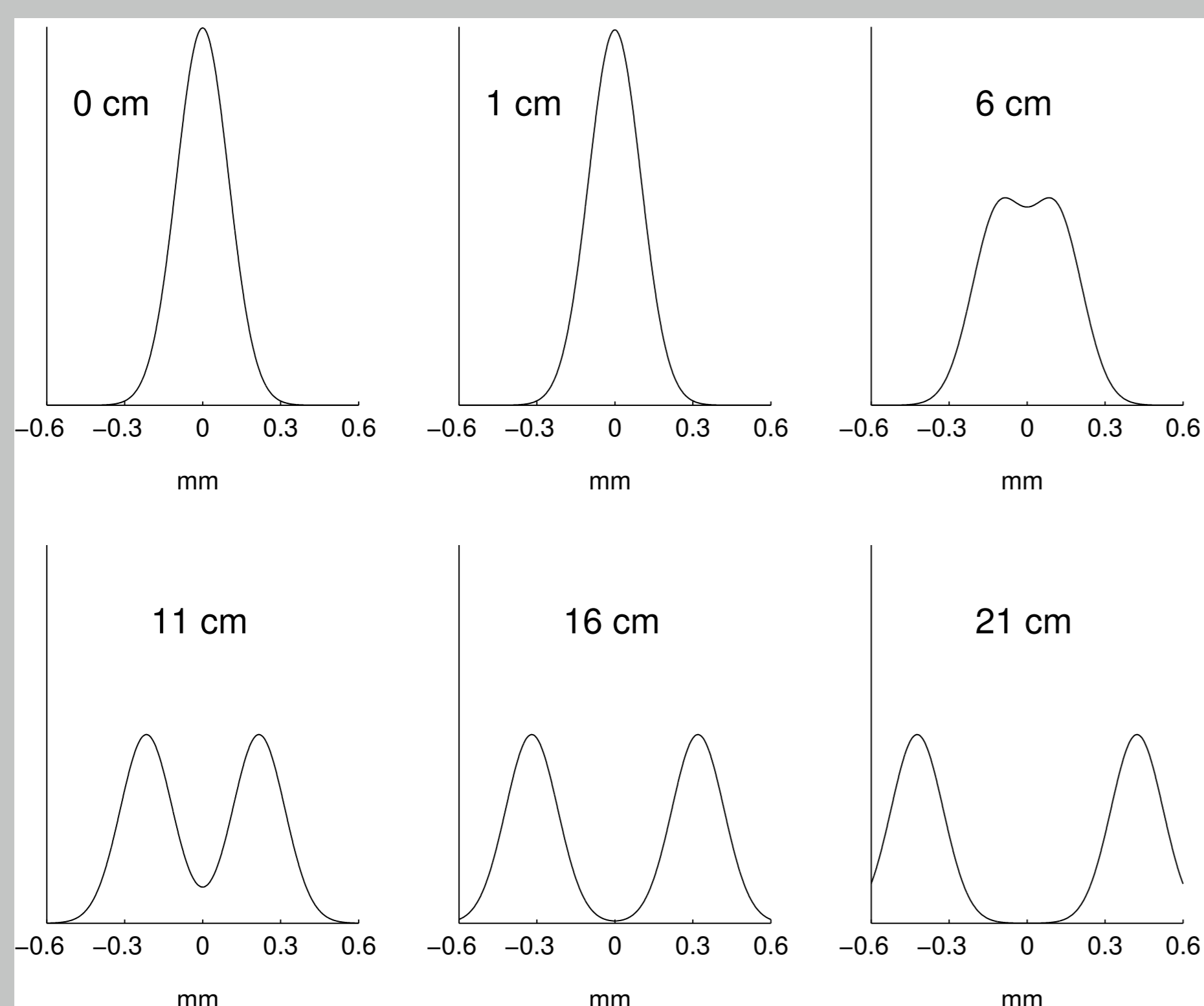
Pauli equation

- ▶ After the magnetic field: at $t + \Delta t$

$$\Psi(z, t + \Delta t) \simeq (2\pi\sigma_0^2)^{-\frac{1}{4}} \begin{pmatrix} \cos \frac{\theta_0}{2} e^{-\frac{(z-z\Delta-ut)^2}{4\sigma_0^2}} e^{i\frac{muz+h\varphi_+}{\hbar}} \\ \sin \frac{\theta_0}{2} e^{-\frac{(z+z\Delta+ut)^2}{4\sigma_0^2}} e^{i\frac{-muz+h\varphi_-}{\hbar}} \end{pmatrix}$$

- ▶ Decoherence in Stern-Gerlach experiment

$$\rho(z, t + \Delta t) \simeq (2\pi\sigma_0^2)^{-\frac{1}{2}} \frac{1}{2} \left(e^{-\frac{(z-z\Delta-ut)^2}{2\sigma_0^2}} + e^{-\frac{(z+z\Delta+ut)^2}{2\sigma_0^2}} \right)$$



- ▶ The decoherence time Spots N^+ and N^- appear :

$$y = vt > 16 \text{ cm}$$

⇒ the decoherence time :

$$t_D \simeq \frac{3\sigma_0 - z_\Delta}{u} = \frac{(3\sigma_0 - z_\Delta)mv}{\mu_B B'_0 \Delta l} = 3 \times 10^{-4} \text{ s.}$$

How is the transformation done ?

Mixed states θ_0 and φ_0 randomly drawn \implies Quantized mixture $\theta_0 = \pi$ and $\theta_0 = 0$

Measure quantization's postulates

or

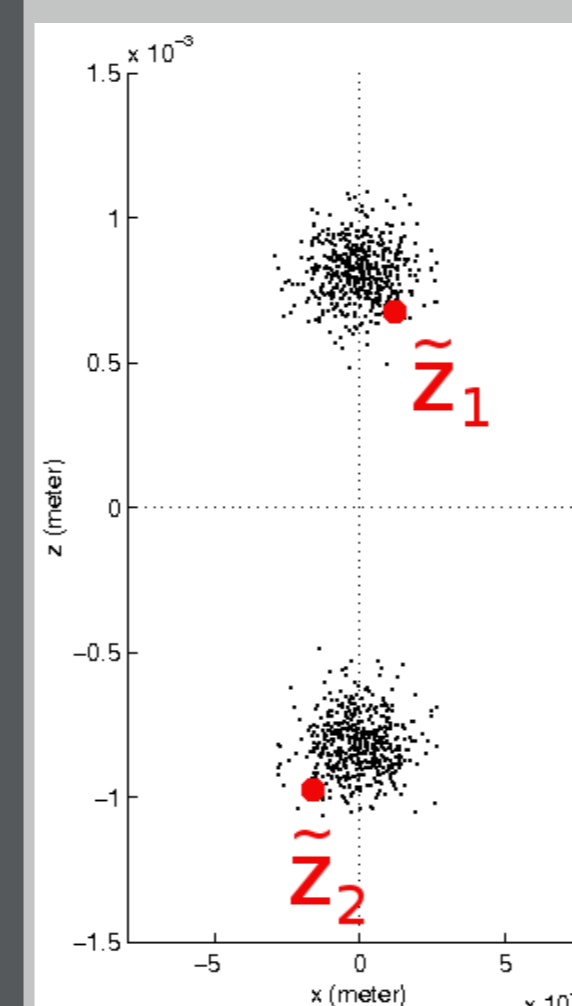
Pauli equation with spinor spatial extension

Decoherence in Stern-Gerlach experiment

Quantization postulates' proof for $S_z = \frac{\hbar}{2}\sigma_z$

$$\Psi(z, t + \Delta t) \simeq (2\pi\sigma_0^2)^{-\frac{1}{4}} \begin{pmatrix} \cos \frac{\theta_0}{2} e^{-\frac{(z-z\Delta-ut)^2}{4\sigma_0^2}} e^{i\frac{muz+h\varphi_+}{\hbar}} \\ \sin \frac{\theta_0}{2} e^{-\frac{(z+z\Delta+ut)^2}{4\sigma_0^2}} e^{i\frac{-muz+h\varphi_-}{\hbar}} \end{pmatrix}$$

Experimentally, one measures the particle position \tilde{z}



- ▶ $\tilde{z}_1 \in N^+$

$$\Psi(\tilde{z}_1, t + \Delta t) \simeq (2\pi\sigma_0^2)^{-\frac{1}{4}} \cos \frac{\theta_0}{2} e^{-\frac{(\tilde{z}_1 - z\Delta - ut)^2}{4\sigma_0^2}} e^{i\frac{m\tilde{z}_1 + h\varphi_+}{\hbar}} \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

- ▶ $\tilde{z}_2 \in N^-$

$$\Psi(\tilde{z}_2, t + \Delta t) \simeq (2\pi\sigma_0^2)^{-\frac{1}{4}} \sin \frac{\theta_0}{2} e^{-\frac{(\tilde{z}_2 + z\Delta + ut)^2}{4\sigma_0^2}} e^{i\frac{-m\tilde{z}_2 + h\varphi_-}{\hbar}} \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

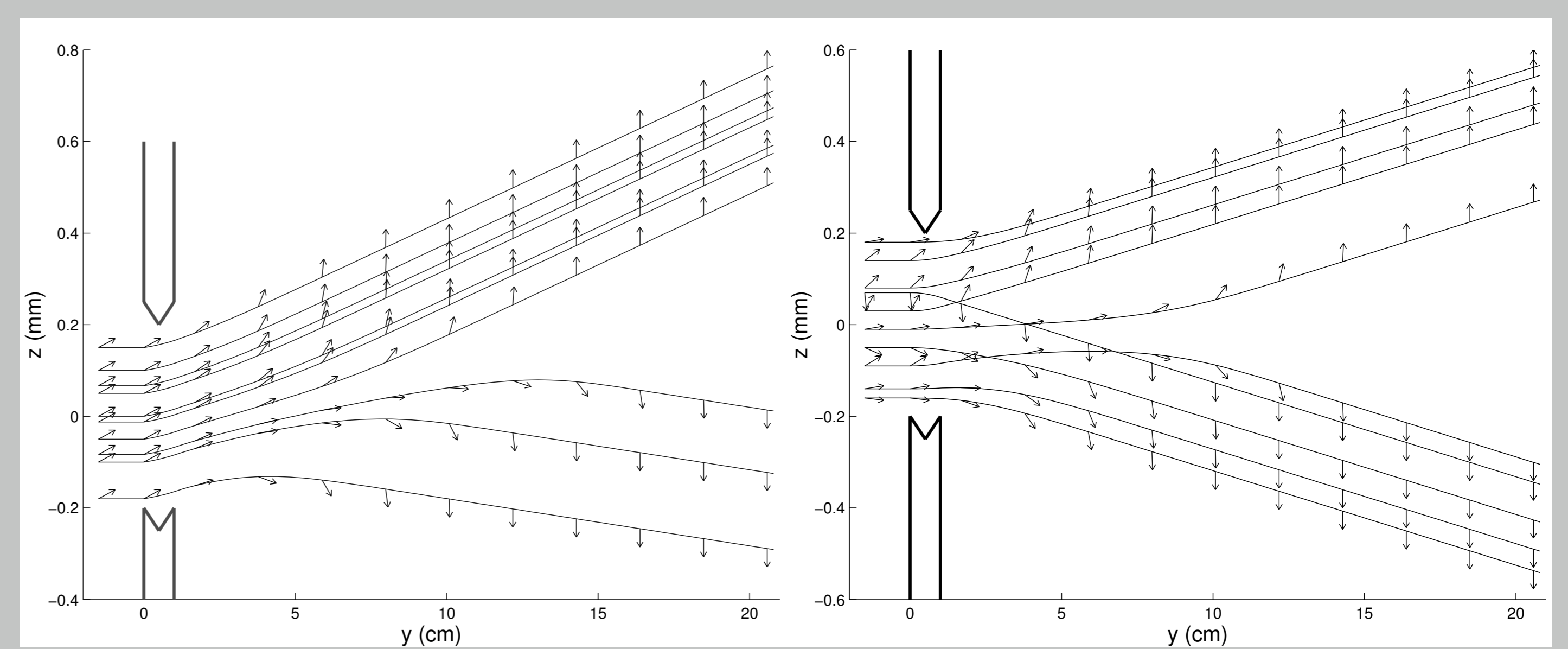
Marginal density matrix of spin variables of a pure state

$$\rho^S(z, t) = \begin{pmatrix} |\psi_+(z, t)|^2 & \psi_+(z, t)\psi_-^*(z, t) \\ \psi_-(z, t)\psi_+^*(z, t) & |\psi_-(z, t)|^2 \end{pmatrix}$$

When $t > t_D$:

$$\rho^S(z, t) \simeq \begin{pmatrix} |\psi_+(z, t)|^2 & 0 \\ 0 & |\psi_-(z, t)|^2 \end{pmatrix}$$

Experimental results : z_0 randomly drawn



Pure state (left) : $\theta_0 = \pi/3$ and $\varphi_0 = \pi/4$

Mixed states (right) : $\theta_0 \in [0; \pi]$ and $\varphi_0 \in [0; 2\pi]$

randomly drawn

Conclusion on quantum computer

- ▶ Spin-based qubit's existence?
 - Space and spin variables are not factorizable during treatment
- ▶ Chuang NMR results' explanation
 - Each wave function must be physically splitted because it takes at least two particles to represent the quantum system
 - \implies Signal decay with a factor 2 for each additional qubit
- ▶ Statistical qubit (10^8 spins) exists but not individual qubit
 - \implies Quantum mechanics is not complete