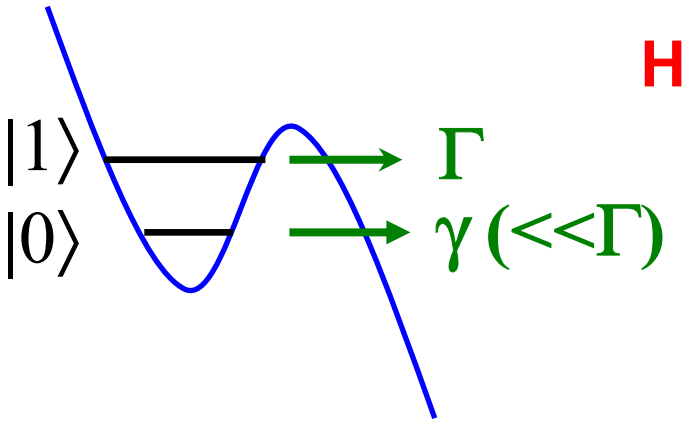
Quantum back-action during "fast" measurement of a phase qubit



How quantum state changes in time?

(what happens if measured for too short time?)

Main idea (for simplicity γ=0):

$$\psi = \alpha|0\rangle + \beta|1\rangle \rightarrow \psi(t) = \begin{cases} |out\rangle, \text{ if switched} \\ \dfrac{\alpha|0\rangle + \beta e^{-\Gamma t/2}|1\rangle}{Norm}, \text{ if not switched} \end{cases}$$

$$Norm = \sqrt{|\alpha|^2 + |\beta|^2 e^{-\Gamma t}}$$

continuous null-result collapse

(similar to optics, Dalibard *et al.*, PRL-92)

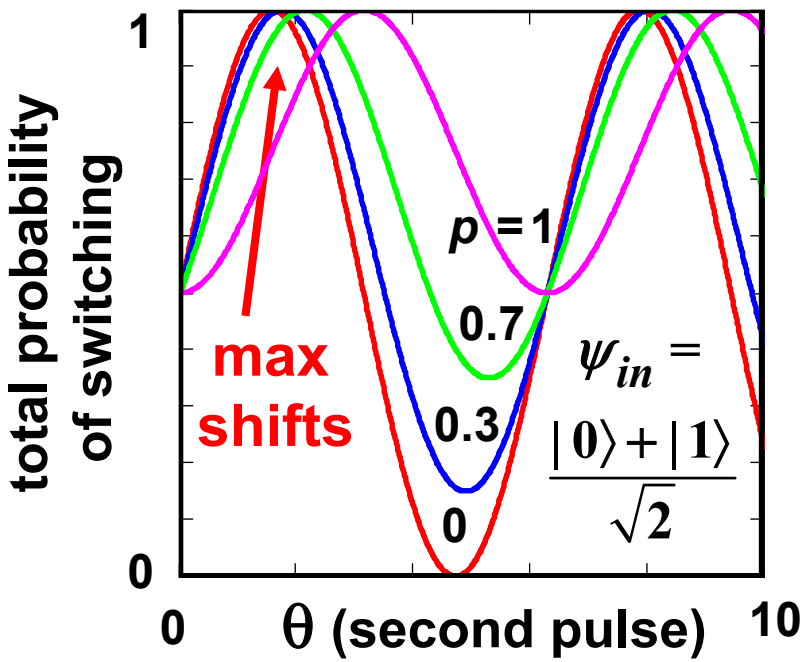
Effect of remaining coherence after incomplete (too short) measurement

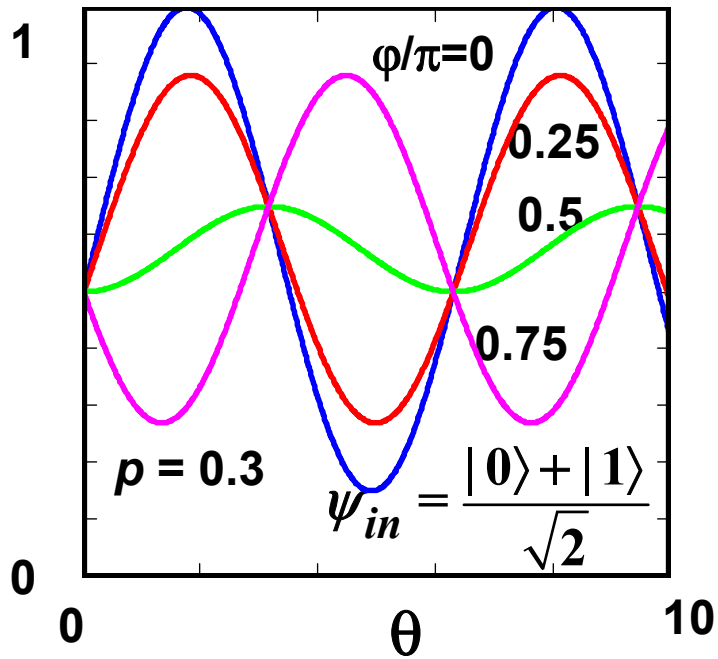
Protocol:

0) state preparation by rf pulse
1) incomplete measurement
2) additional rf pulse (θ-pulse)
3) measurement again (complete)

p = 1-exp(-Γt) – probability of state $|1\rangle$ switching after incomplete measurement

φ – extra phase (z-rotation)





Formulas for ideal case

Step 1. Rabi pulse θ_0 prepares state $\cos(\theta_0/2)|0\rangle + \sin(\theta_0/2)|1\rangle$

Step 2. Incomplete measurement with strength $p = 1 - \exp(-\Gamma\tau)$

switches qubit with probability $P_1 = p\sin^2(\theta_0)$. With probability $1 - P_1$ the state becomes $\cos(\theta_m/2)|0\rangle + \sin(\theta_m/2)e^{-i\varphi_m}|1\rangle$, where

φ_m – accumulated phase shift in rotating frame (levels change) and

$$\theta_m = 2\,\mathrm{atan}(\sqrt{1-p}\tan(\theta_0/2))$$

Step 3. Z-rotation φ and Rabi pulse θ.

Step 4. Complete measurement, switching probability P_2.

Total switching probability $P_t = P_1 + P_2$

$$P_t = 1 - \frac{1}{2}[1 - p\sin^2(\frac{\theta_0}{2})][1 + \cos\theta_m\cos\theta - \sin\theta_m\sin\theta\cos(\varphi - \varphi_m)]$$

If φ_m is compensated ($\varphi = \varphi_m$) then maximum oscillation amplitude:

$$P_t = 1 - \frac{1}{2}[1 - p\sin^2(\frac{\theta_0}{2})][1 + \cos(\theta_m + \theta)]$$

Dependence $P_t(\theta)$ for different p and θ_0 (φ_m is compensated)