Quantum Computation

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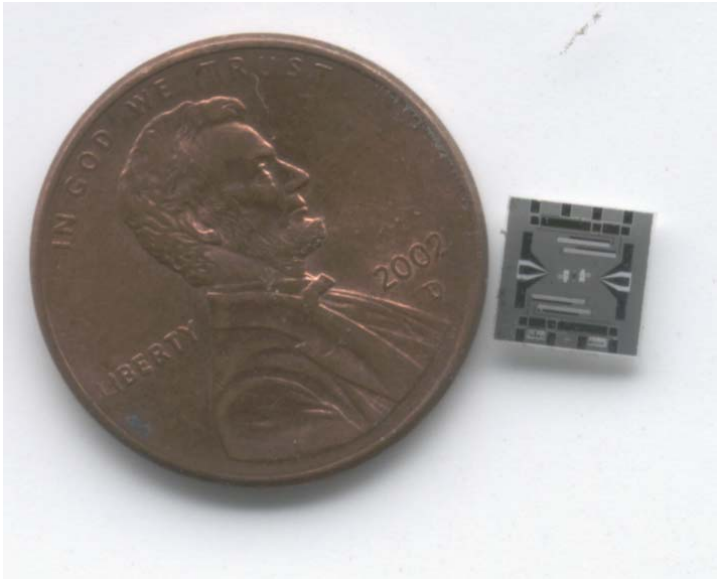
- Professor: Dr. John Martinis
- Big spenders: Disruptive Technologies Office (DTO)

Classical Computation

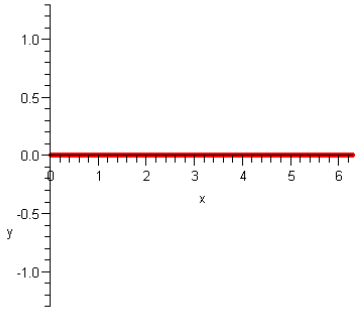
- Operates on classical principles
- Bit can be in state 0 or 1
- Operations performed by logic gates (like flipping light switches)

Quantum Computation

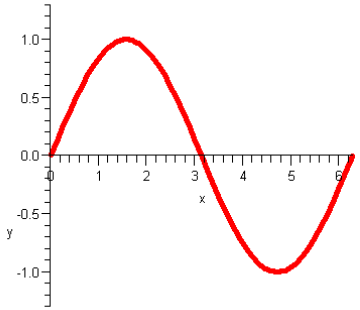
- Operates on Quantum principles
- Qubit can be in any state A|0>+B|1>
- Operations performed by unitary transformations



$$\sin\left(\frac{1}{2}x\right)$$



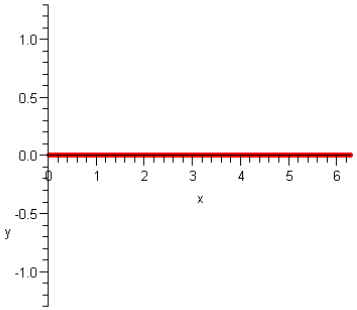
- Quantum Systems
- Plucked Strings



- Quantum Systems

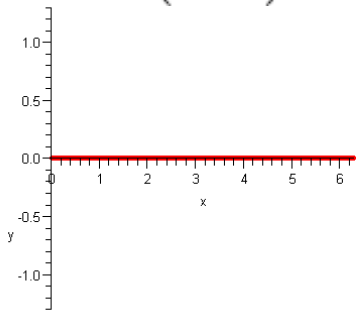
- Plucked Strings

$$\sin\left(\frac{3}{2}x\right)$$

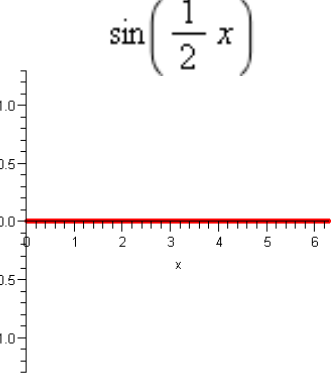


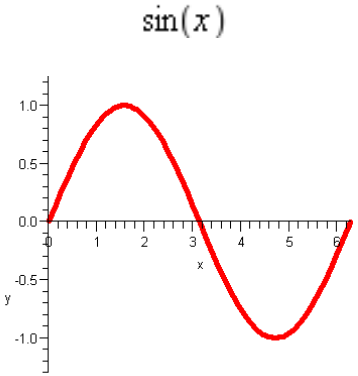
- Quantum Systems
- Plucked Strings

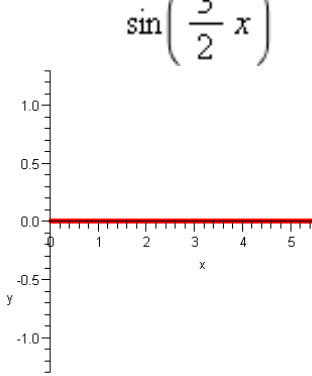
$$\sin\left(\frac{9}{10}x\right)$$



- Quantum Systems
- Plucked Strings



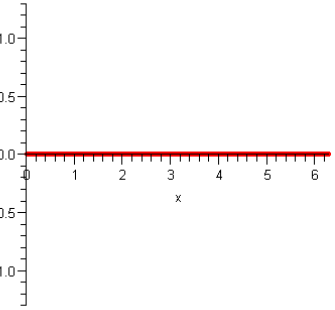




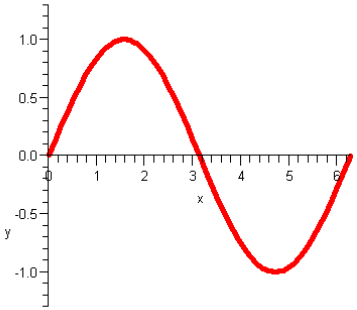
- Quantum Systems

- Plucked Strings
- Can only have specific vibrational modes

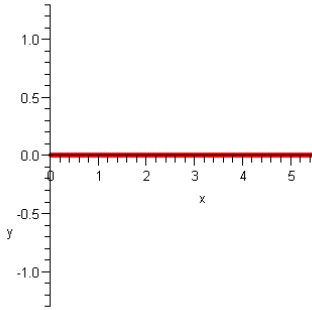
|0 >



|1 >

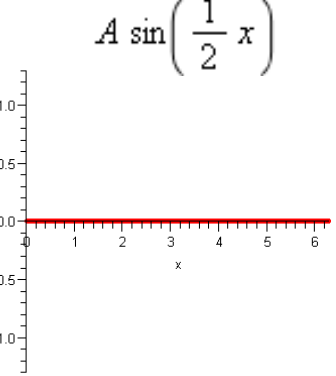


|2 >



- Quantum Systems
- Exist only in specific energy states

- Plucked Strings
- Vibrate only at specific frequencies – called harmonics



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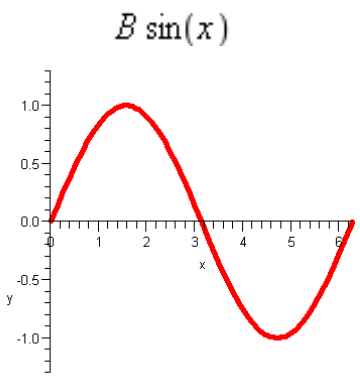

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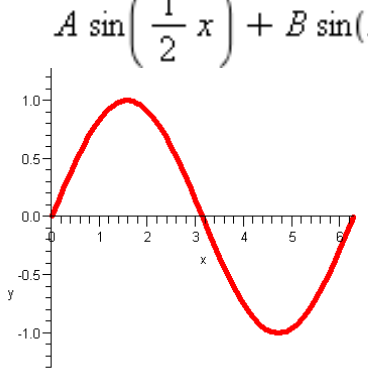
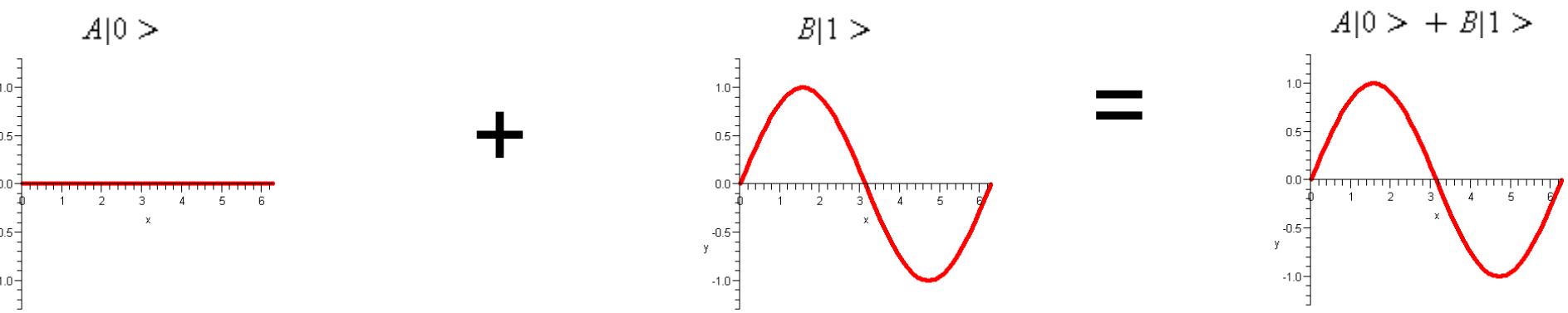


- Quantum Systems
- Exist only in specific energy values

- Plucked Strings
- Vibrate only at specific frequencies – called harmonics
- Linear combinations of harmonics are okay



- Quantum Systems
- Exist only in specific energy values
- Can be in a superposition of energy states: A|0>+B|1>

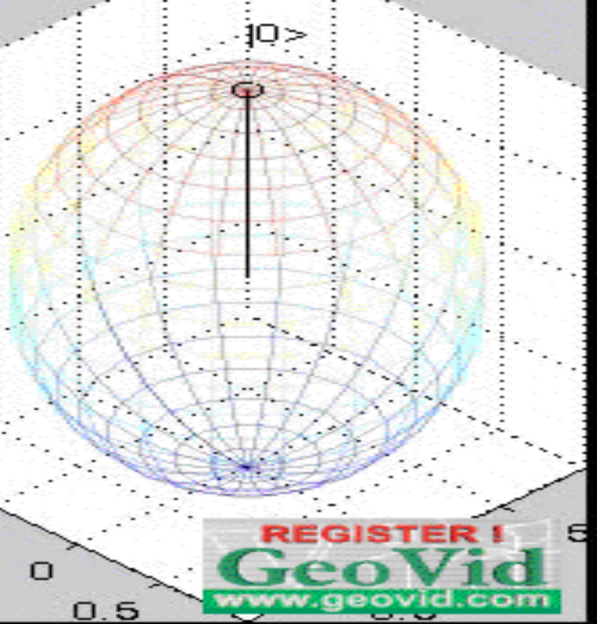
- Plucked Strings
- Vibrate only at specific frequencies – called harmonics
- Linear combinations of harmonics are okay

- Quantum Systems
- Exist only in specific energy values
- Can be in a superposition of energy states: A|0>+B|1>
- We can only measure a |0> or a |1>

$$P(|0>) = |A|^2$$

$$P(|1>) = |B|^2$$

- Plucked Strings
- Vibrate only at specific frequencies – called harmonics
- Linear combinations of harmonics are okay



$$A_0 |0> + A_1 |1>$$

- State represented by vector on Bloch Sphere
- Operations represented by rotations about an axis

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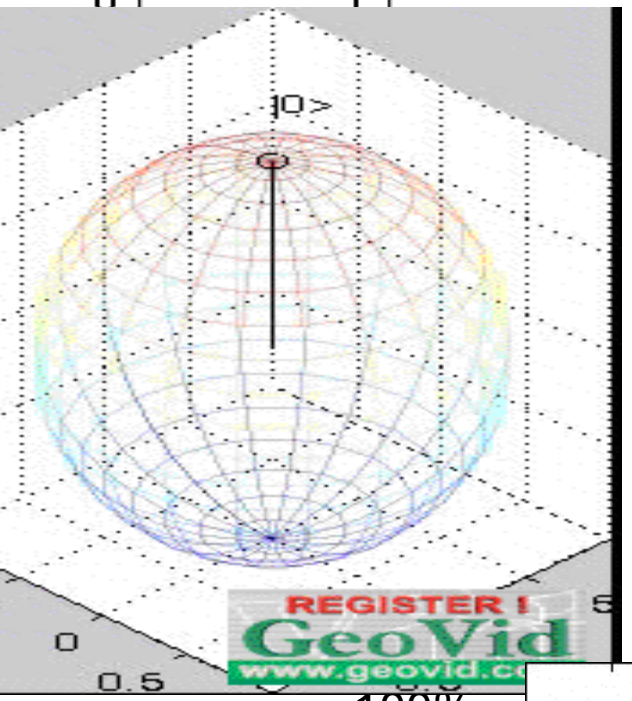
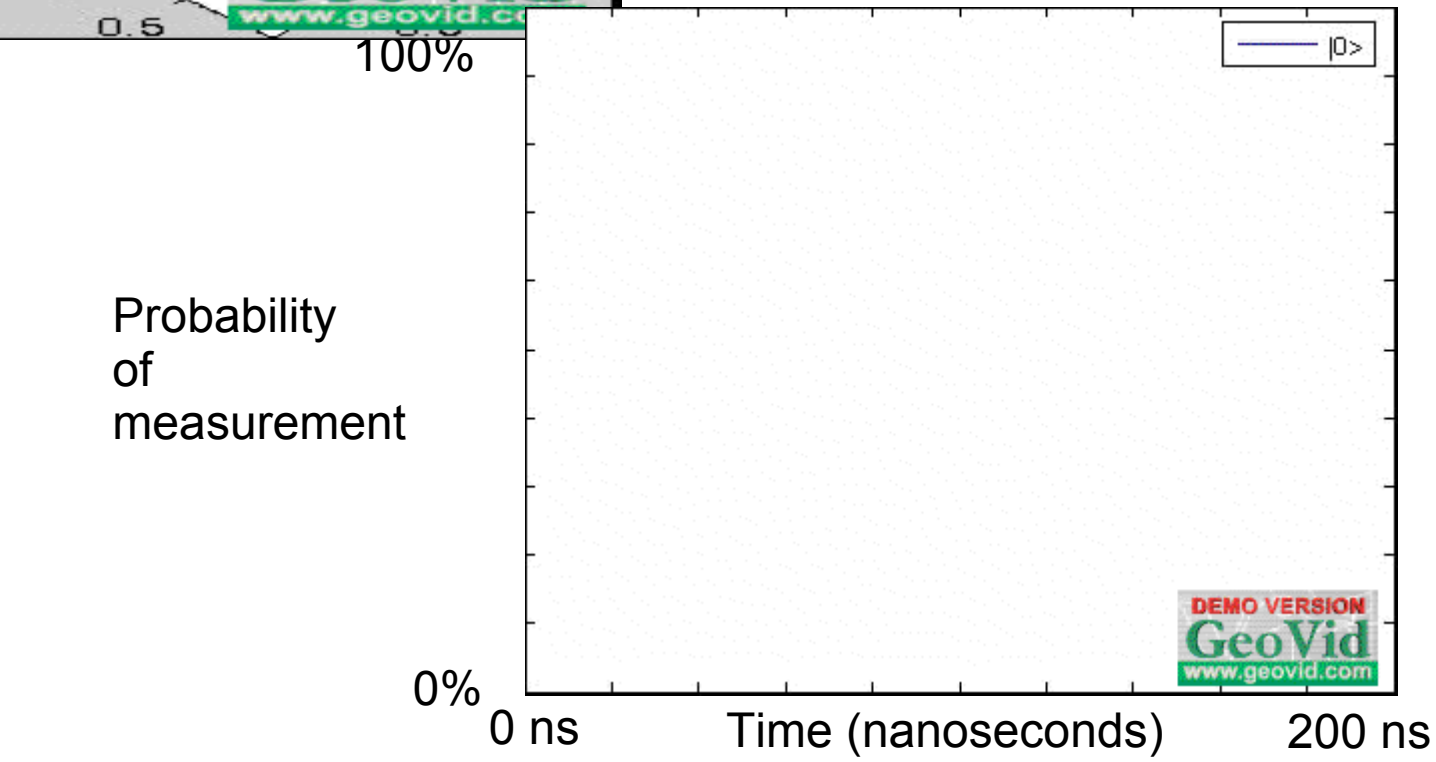
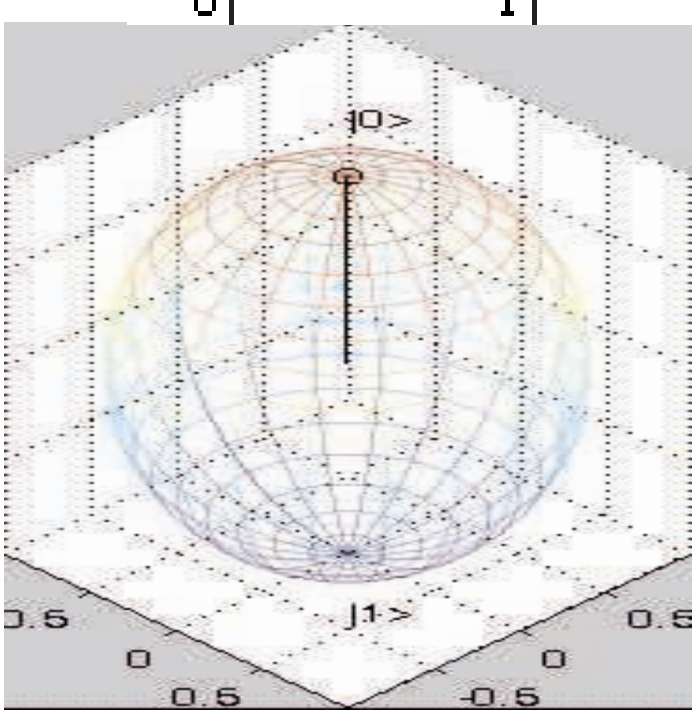
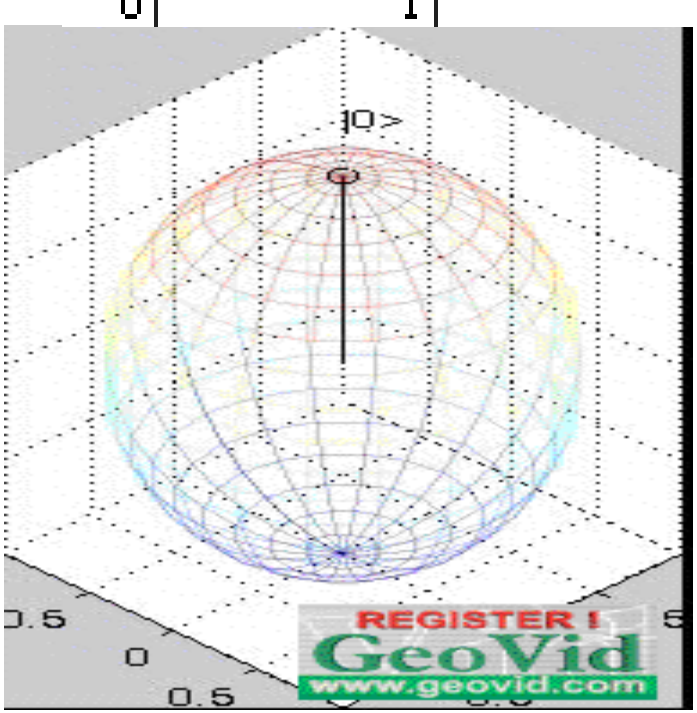
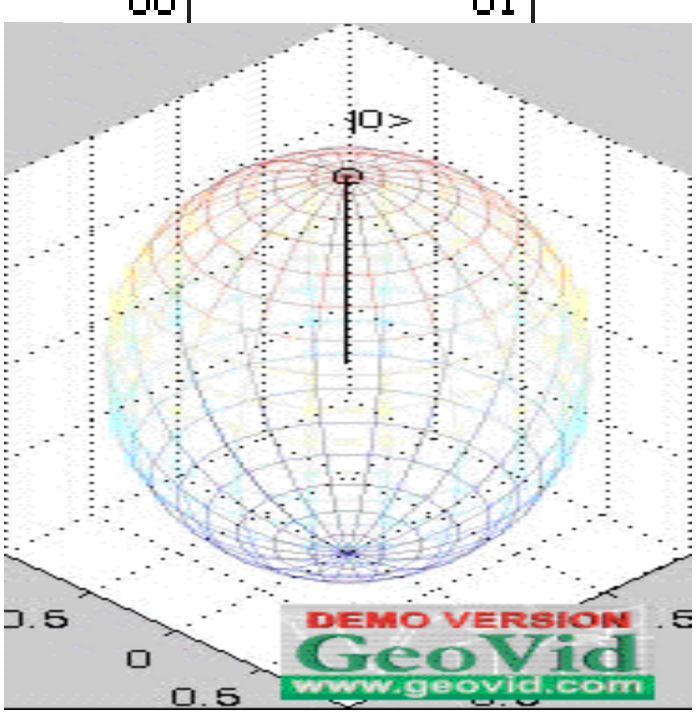
- Operations represented by rotations about an axis

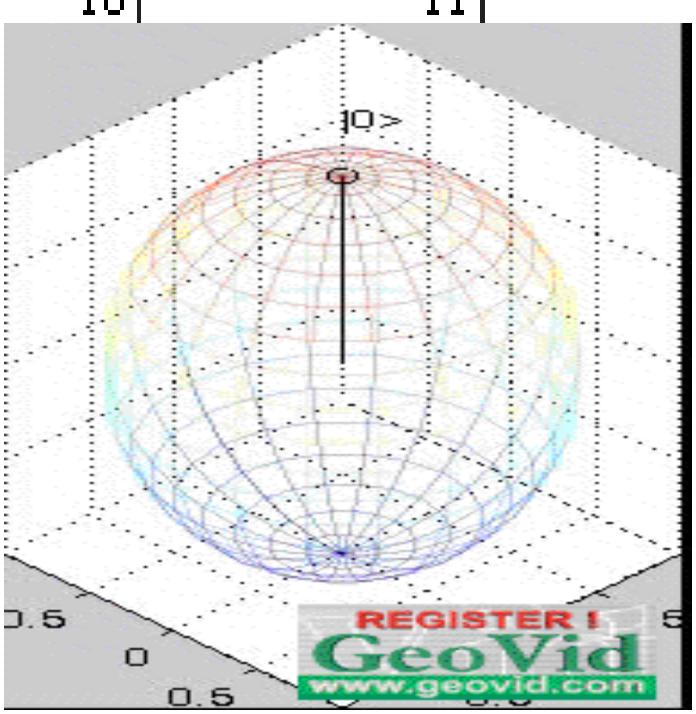




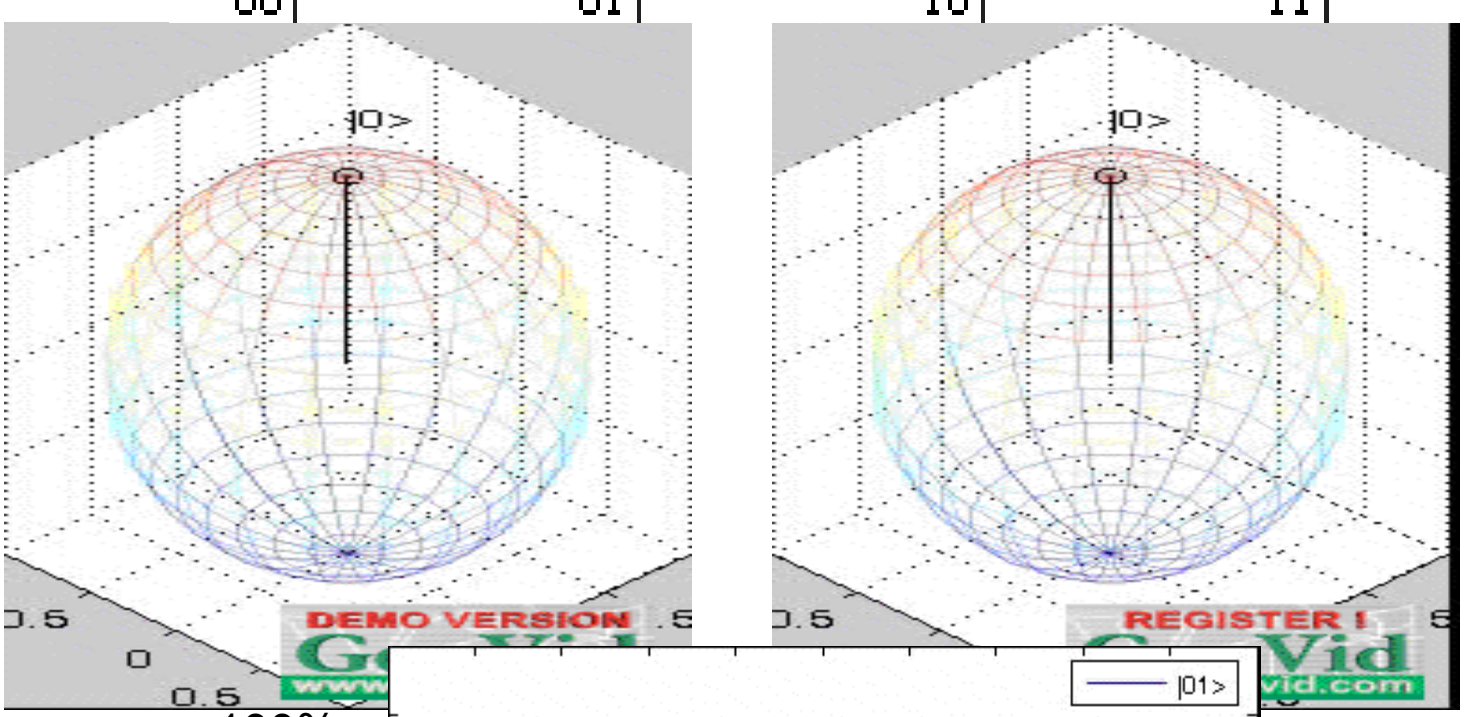

|0>
|1>
0.5
0
0.5
0
0.5
-0.5


|0>
0.5
0
0.5
REGISTER !
GeoVid
www.geovid.com



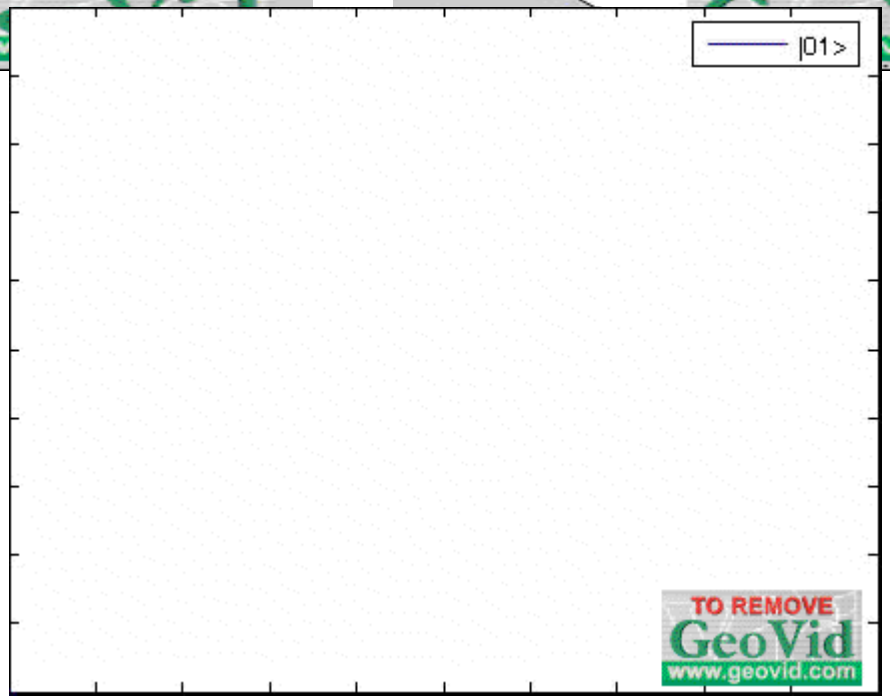


- Coupled Qubits behave as a single system
- A change in one qubit has an immediate effect on the other



100%

Probability of measurement

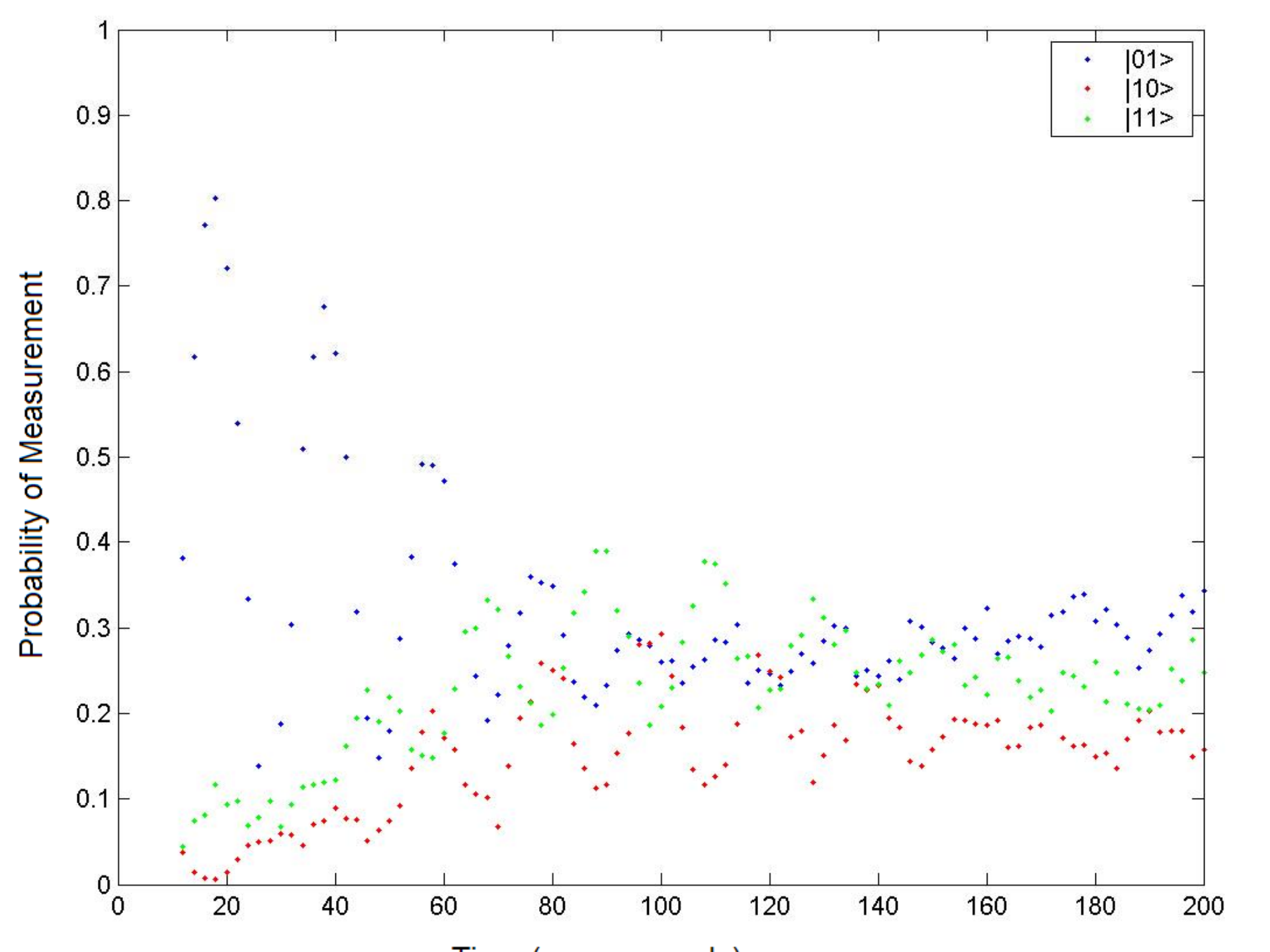


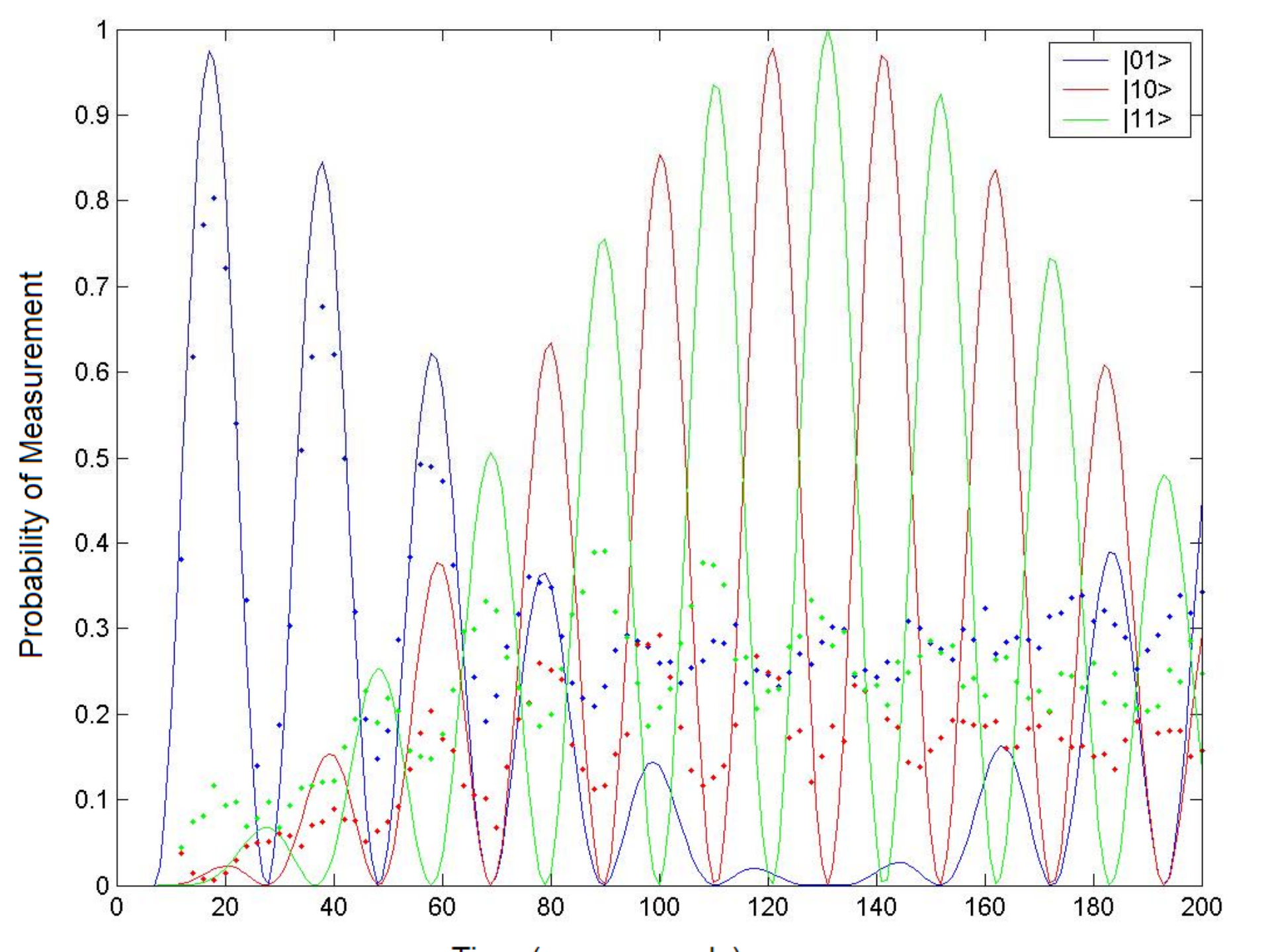
0%

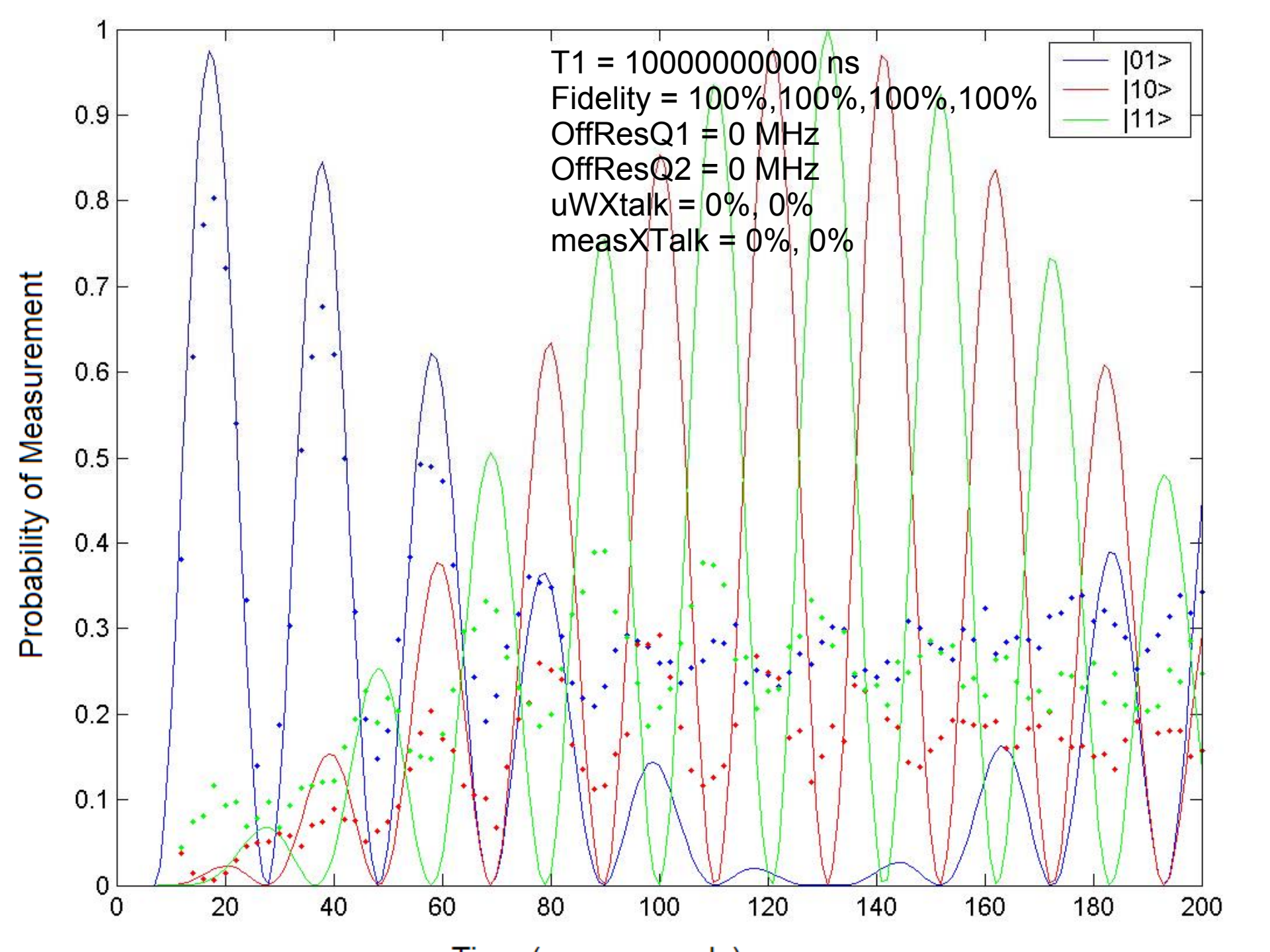
0 ns

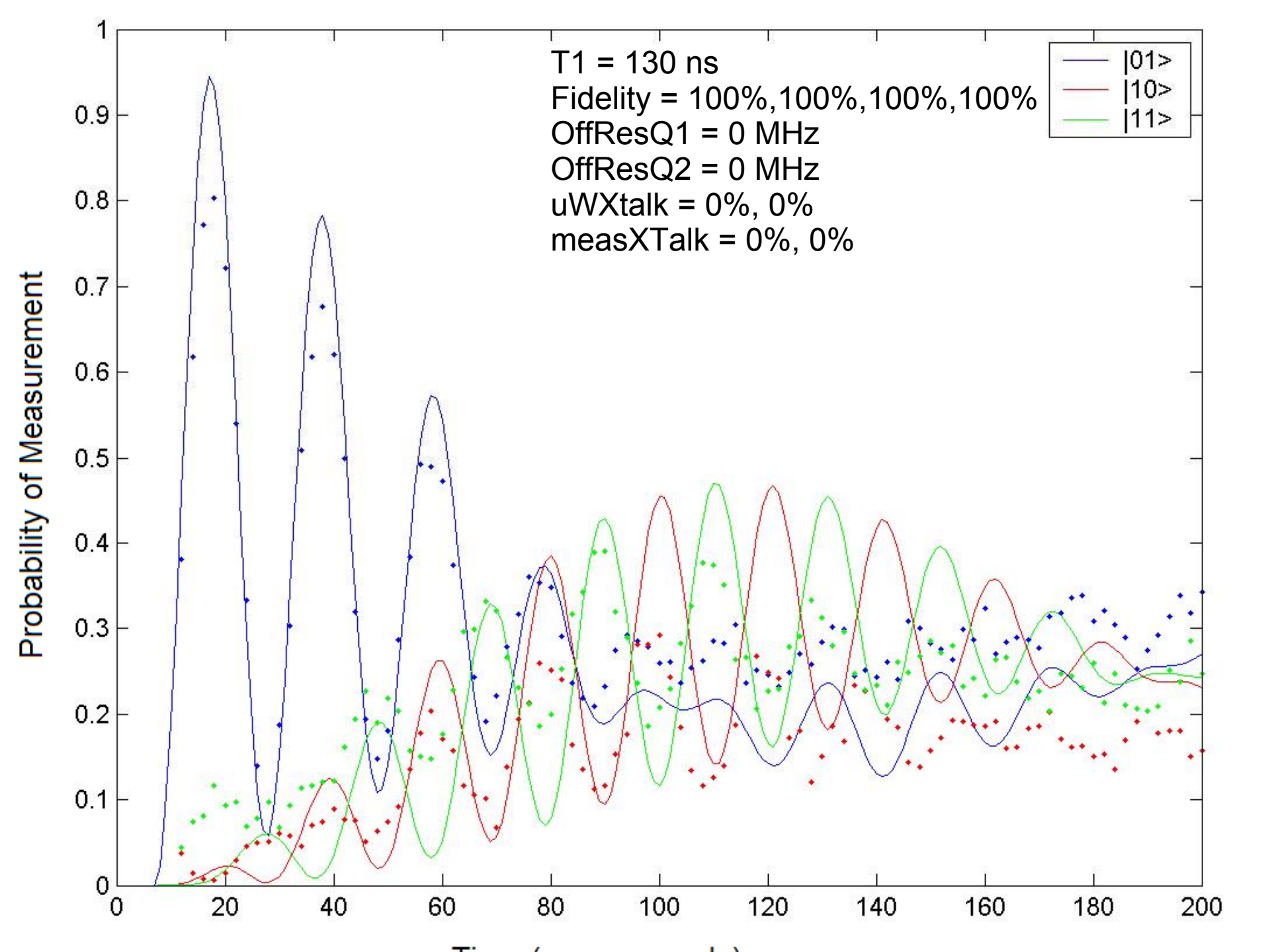
Time (nanoseconds)

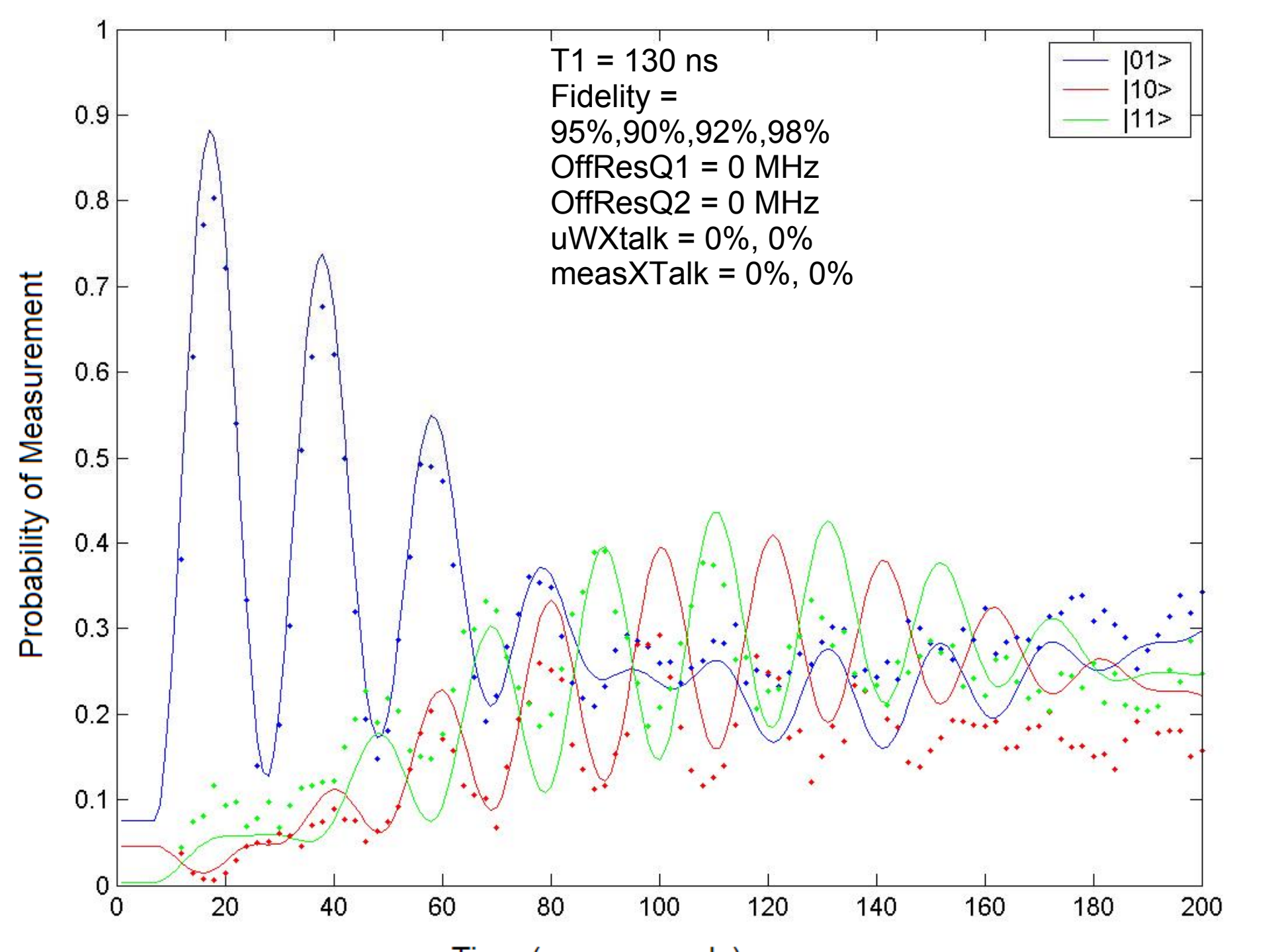
200 ns

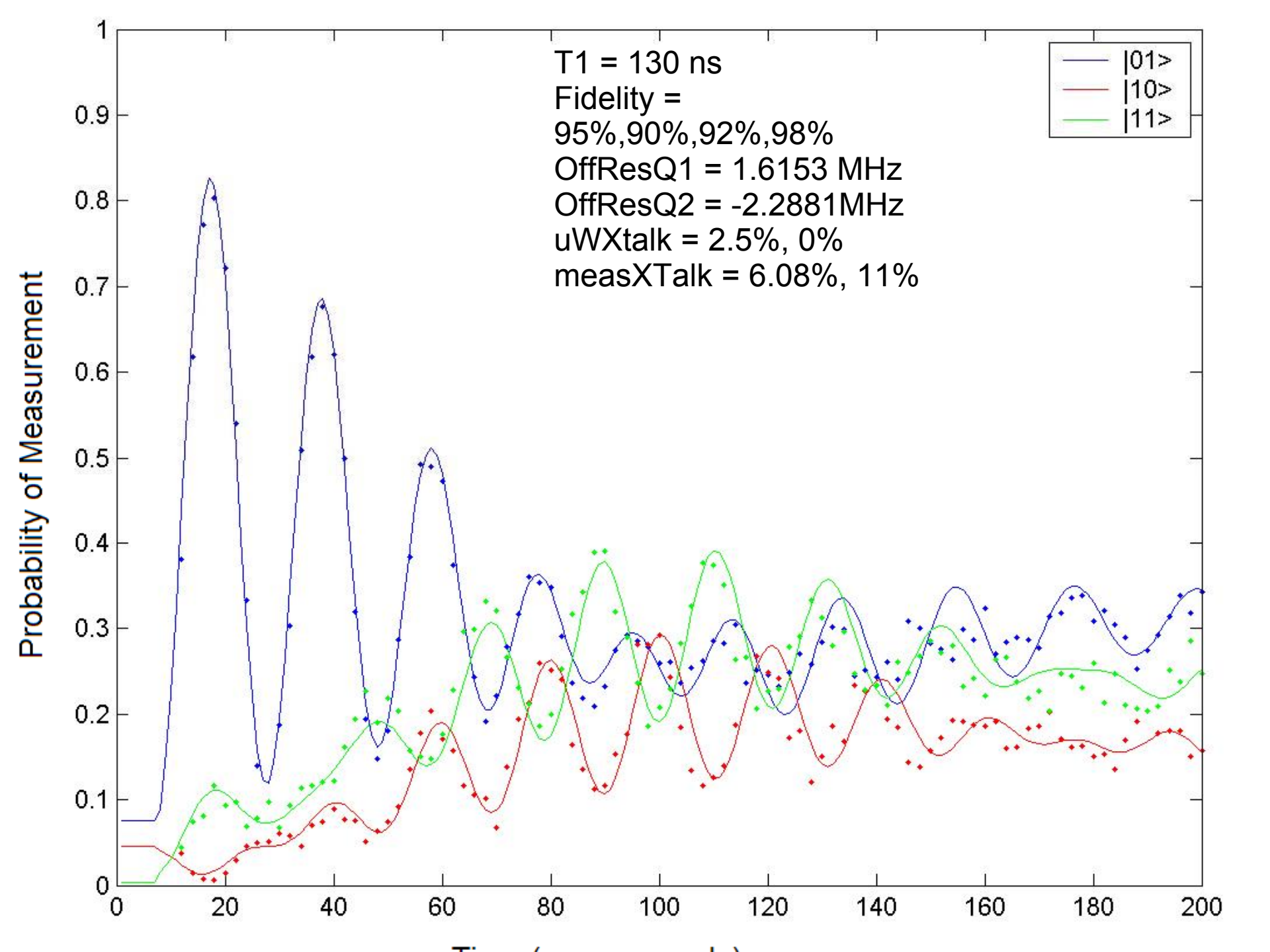

Probability of Measurement
|01>
|10>
|11>
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120
140
160
180
200


|01>
|10>
|11>
Probability of Measurement
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120
140
160
180
200


T1 = 10000000000 ns
Fidelity = 100%,100%,100%,100%
OffResQ1 = 0 MHz
OffResQ2 = 0 MHz
uWXtalk = 0%, 0%
measXTalk = 0%, 0%
|01>
|10>
|11>
Probability of Measurement
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120
140
160
180
200

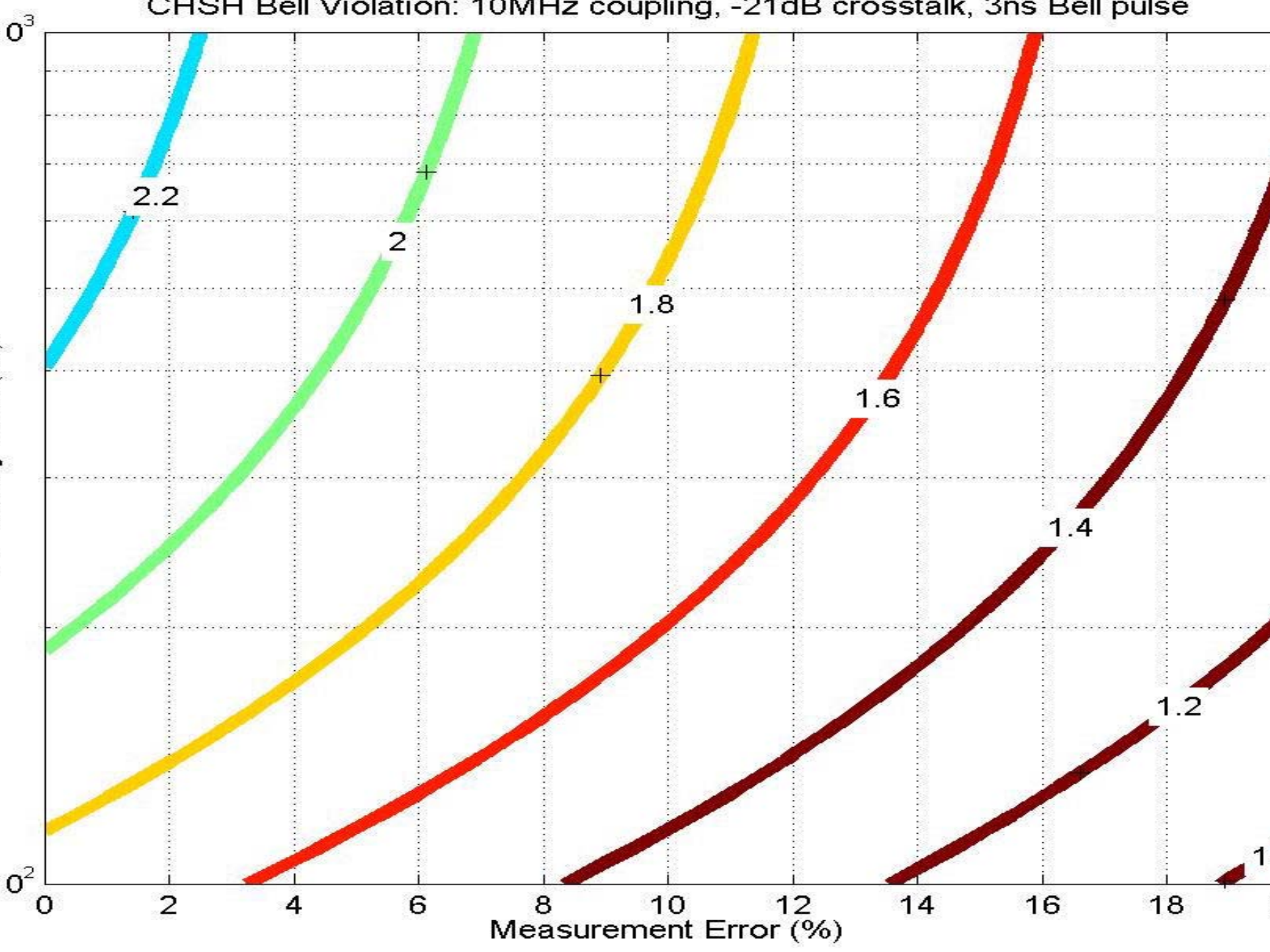

T1 = 130 ns
Fidelity = 100%,100%,100%,100%
OffResQ1 = 0 MHz
OffResQ2 = 0 MHz
uWXtalk = 0%, 0%
measXTalk = 0%, 0%
|01>
|10>
|11>
Probability of Measurement
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120
140
160
180
200


T1 = 130 ns
Fidelity =
95%,90%,92%,98%
OffResQ1 = 0 MHz
OffResQ2 = 0 MHz
uWXtalk = 0%, 0%
measXTalk = 0%, 0%
|01>
|10>
|11>
Probability of Measurement
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120
140
160
180
200


T1 = 130 ns
Fidelity =
95%,90%,92%,98%
OffResQ1 = 1.6153 MHz
OffResQ2 = -2.2881MHz
uWXtalk = 2.5%, 0%
measXTalk = 6.08%, 11%
|01>
|10>
|11>
Probability of Measurement
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120
140
160
180
200

Why Simulate?

- Interpretation of the results of experiments
- Characterization of qubits
- Determination of whether experiments are feasible
- Determination of necessary improvements


CHSH Bell Violation: 10MHz coupling, -21dB crosstalk, 3ns Bell pulse
10^3
10^2
2.2
2
1.8
1.6
1.4
1.2
1
0
2
4
6
8
10
12
14
16
18
Measurement Error (%)

Acknowledgements

Martinis Group

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