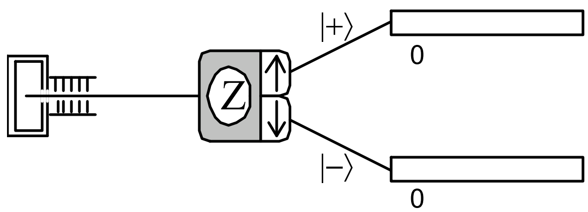
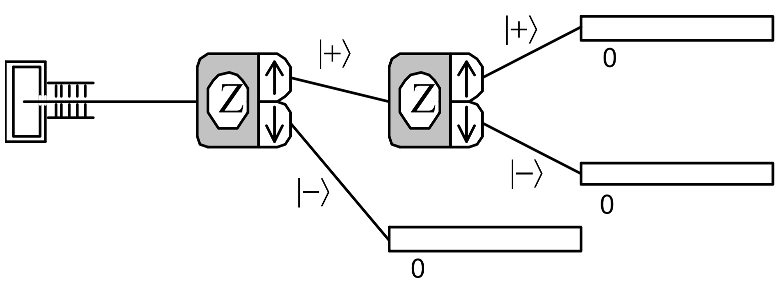
1. Measure the spin projection S_Z along the z-axis. This is the experiment that is ready to go when you start the program, as shown below. Each atom is measured to have spin up or spin down, denoted by the arrows and by the $|+\rangle$ and $|-\rangle$ symbols (we will explain the symbols in more detail later) in the figure below. The measured spin projections for these cases are $S_z = \pm\hbar/2$. Run the experiment by selecting `Do 1(ctrl-1)` the `Control` menu, which sends one atom through the apparatus. Do this repeatedly so you can see the inherent randomness in the measurement process. Try running the experiment continuously `(Go)` and



using the other fixed numbers (10, 100, 1000, 10000).

2. Now set up an experiment to measure the spin projection S_Z along the z-axis twice in succession as shown below. You need an extra analyzer and another counter. Run the experiment and note the results. Focus your attention on the second analyzer. The input state is denoted $|+\rangle$ and there are two possible output states $|+\rangle$ and $|-\rangle$. What is the probability that an atom entering the second analyzer (state $|\text{in}\rangle = |+\rangle$) exits the spin up port (state $|\text{out}\rangle = |+\rangle$) of the second analyzer? This probability is denoted in general as $\text{P}_{out} = |\langle\text{out}|\text{in}\rangle|^2$, and in this specific case as $\text{P}_+ = |\langle\text{out}|\text{in}\rangle|^2 = |\langle+|+\rangle|^2$. What is the probability of exiting the spin down port (state $|-\rangle$)? What conclusions can you draw from the measurements performed in this experiment?



3. Using the same apparatus as above (#2), change the orientation directions of the analyzers. You can choose directions *X*, *Y*, or *Z*, which are oriented along the usual *xyz*-axes of a Cartesian coordinate system (ignore the fourth direction $\hat{\mathbf{n}}$ for now). When a direction other than *Z* is chosen, we use a subscript to distinguish the output states (*e.g.*, $\left|-\right\rangle_y$). Your task is to measure the probabilities $\mathrm{P}_{out} = \left|\left\langle \mathrm{out} \middle| \mathrm{in}\right\rangle\right|^2$ corresponding to these input and output states. Note that this is the probability that an atom leaving the first analyzer also makes it through the second analyzer to the appropriate detector, and not the total probability for getting from the oven to the detector. The experiment performed in #3 above (with both analyzers along the *z*-axis) gave the result $\left|\left\langle + \middle| + \right\rangle\right|^2 = 1$, which is already entered in the table. Now do all other possible combinations and fill in the rest of the table.

$\left\|\left\langle \mathrm{out} \middle\| \mathrm{in}\right\rangle\right\|^2$	$\left\|+\right\rangle$	$\left\|-\right\rangle$	$\left\|+\right\rangle_x$	$\left\|-\right\rangle_x$	$\left\|+\right\rangle_y$	$\left\|-\right\rangle_y$
$\left\langle + \right\|$	1					
$\left\langle - \right\|$						
${}_x\left\langle + \right\|$						
${}_x\left\langle - \right\|$						
${}_y\left\langle + \right\|$						
${}_y\left\langle - \right\|$						