The QM of spin-1/2 particles; the Stern-Gerlach experiment

Preview: the statistical algorithm
vs the orthodox interpretation
(vs the other interpretations)

Spin in classical mechanics: chalk and talk

Experiment A: the "basic" Stern-Gerlach experiment

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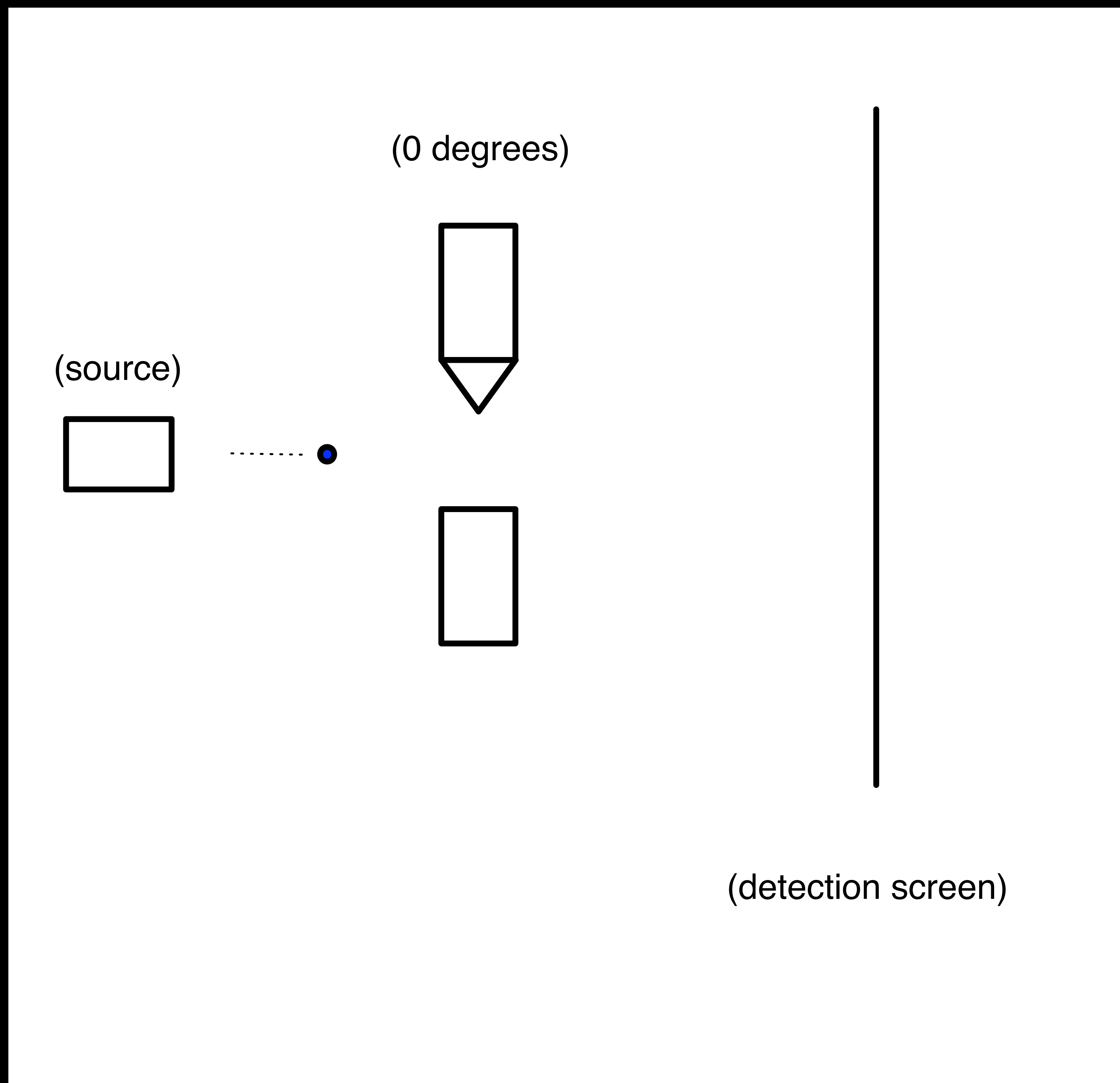
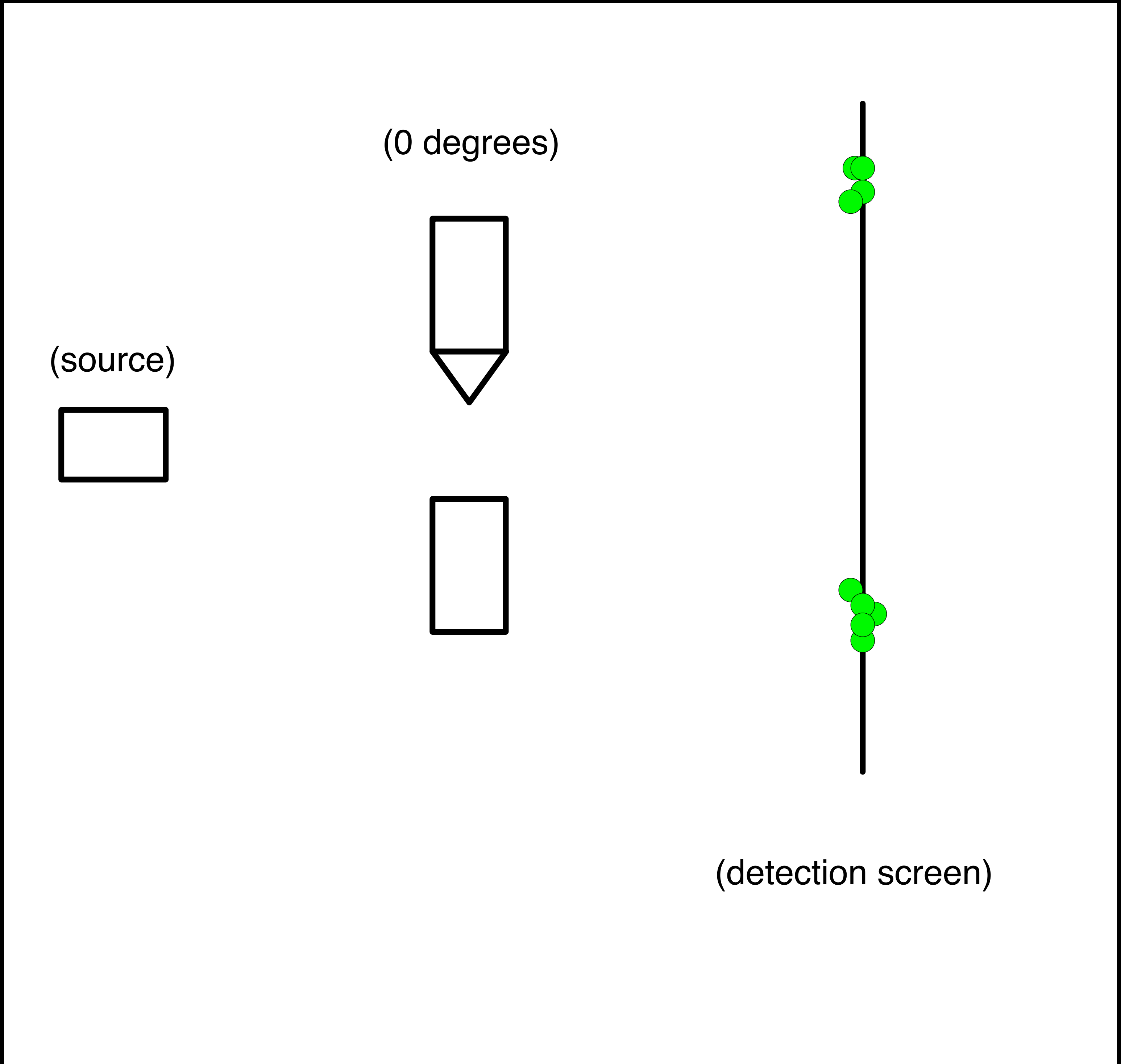
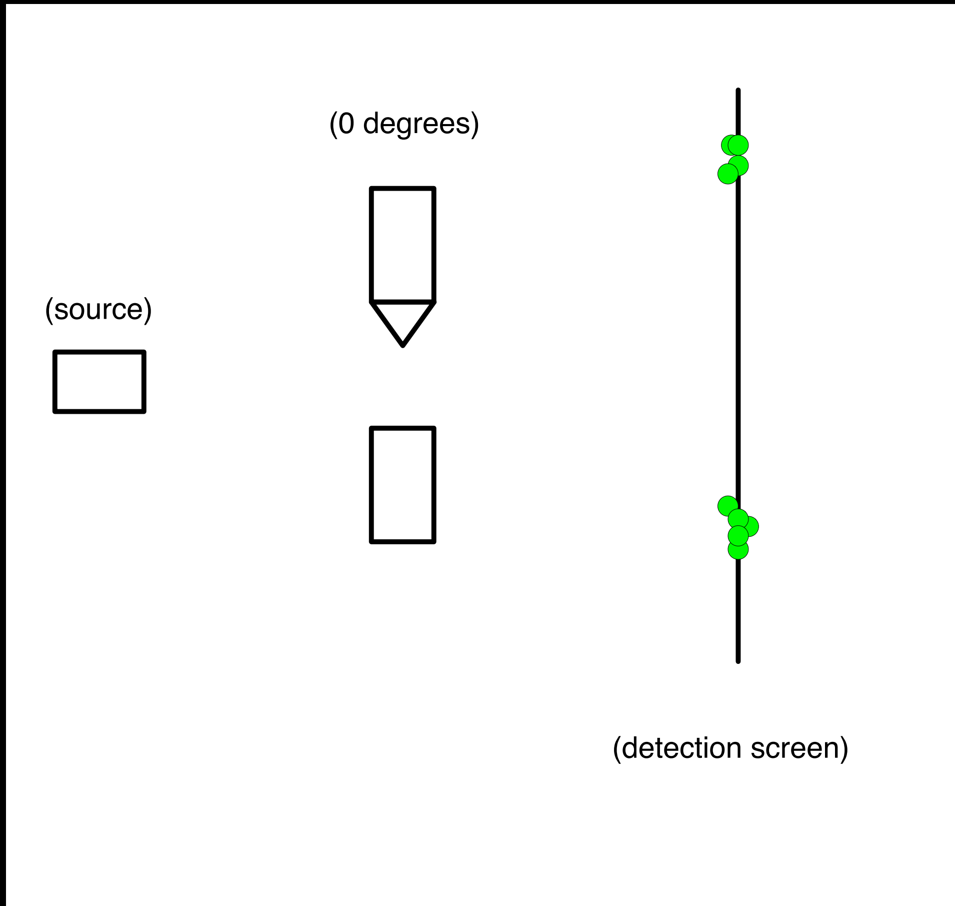


Experiment A: the "basic" Stern-Gerlach experiment

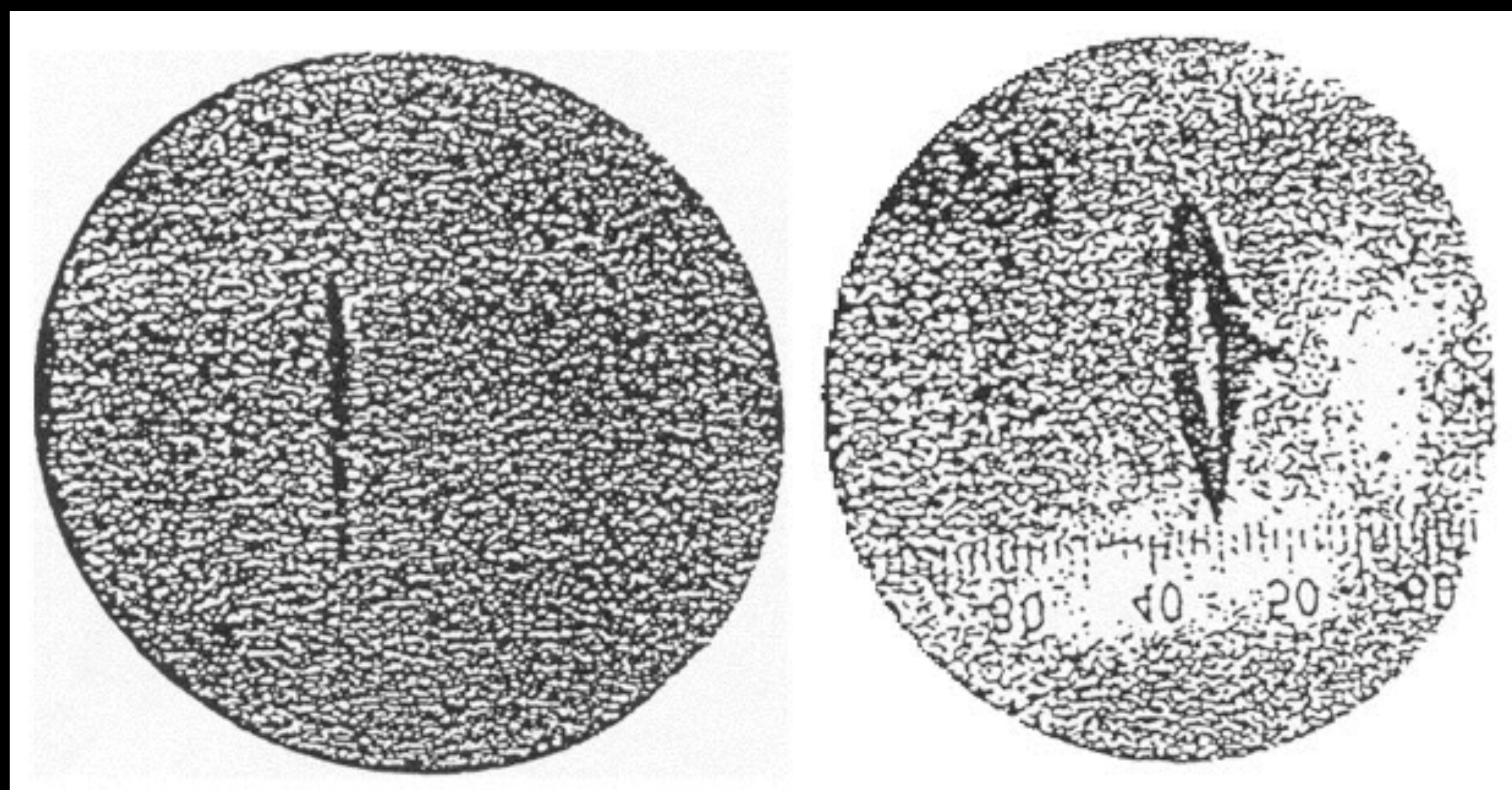


Experiment A: the "basic" Stern-Gerlach experiment

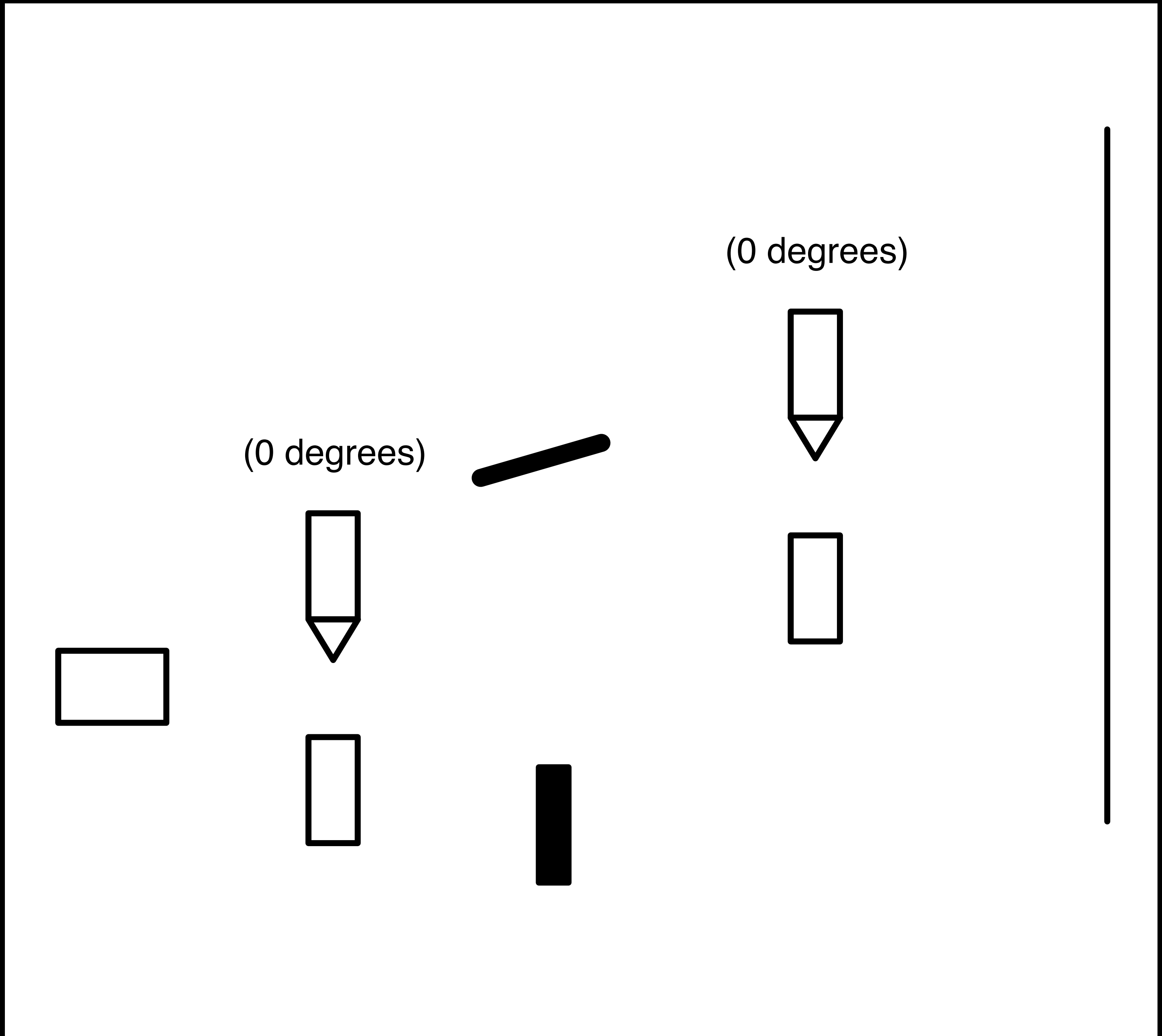
- Observational fact #1: In experiment A, some of the particles are detected in the upper region, and some in the lower region; none are detected in between.



Experiment A: the “basic” Stern-Gerlach experiment



Experiment B: two consecutive S-Gs



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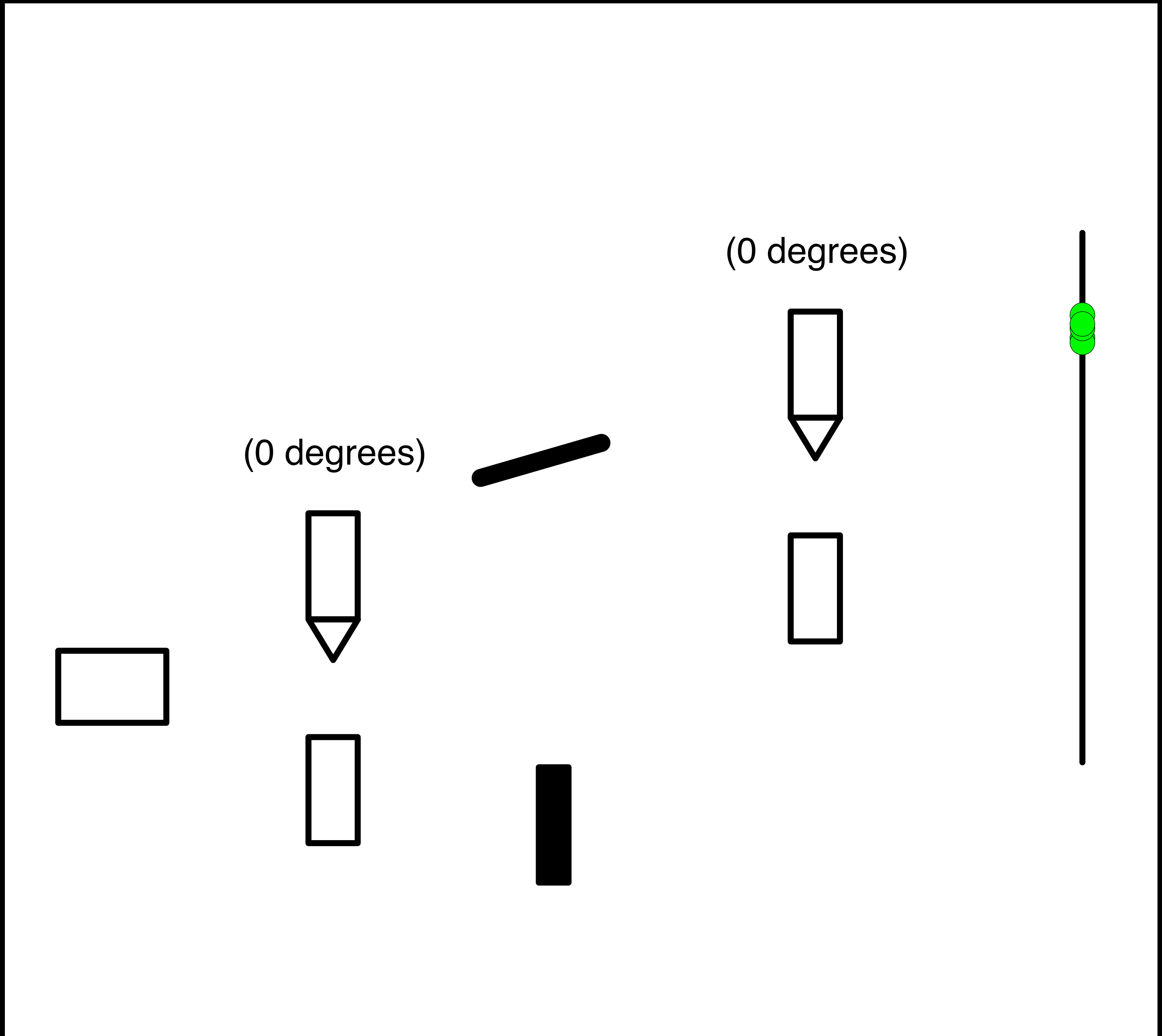
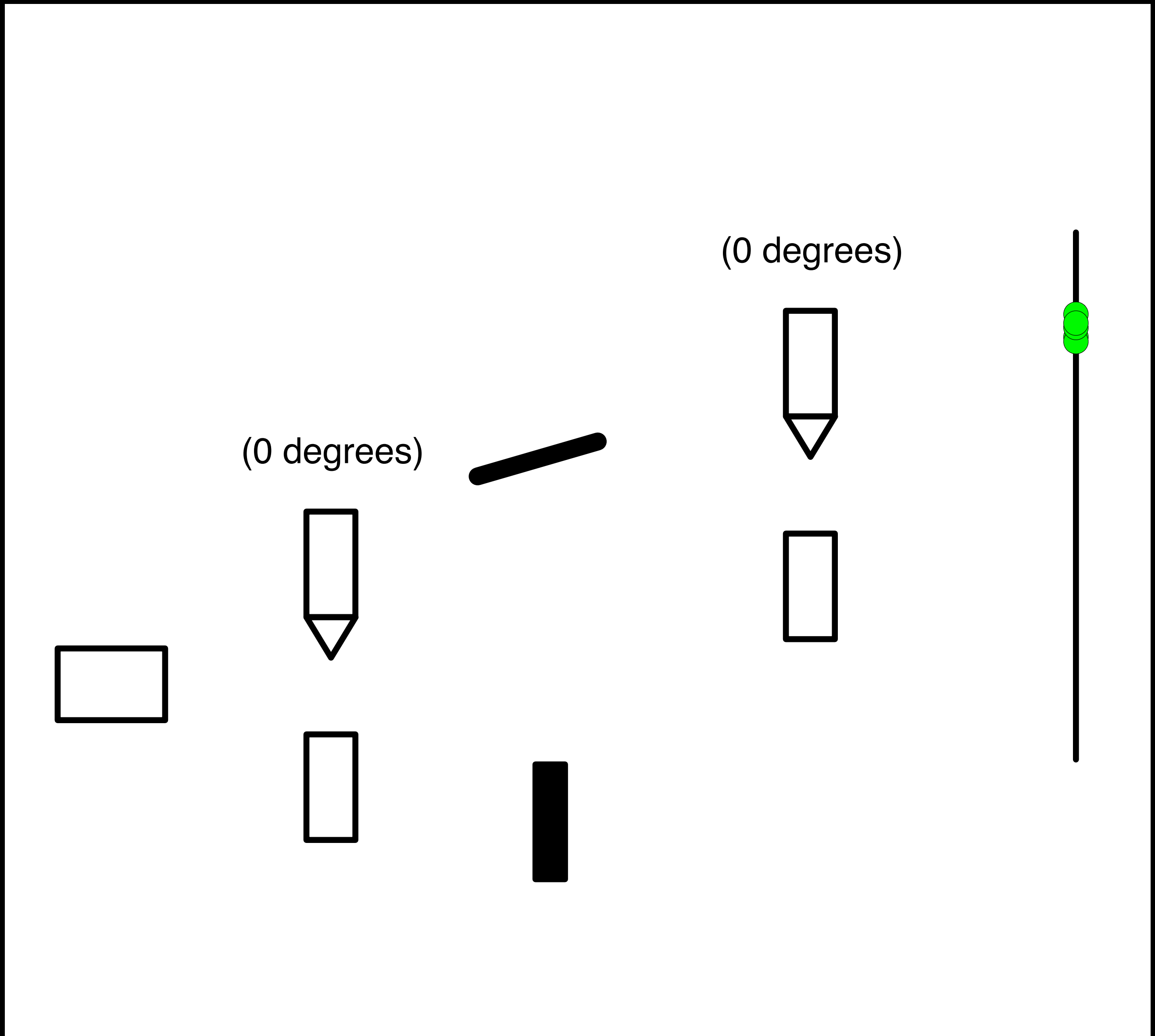


Experiment B: two consecutive S-Gs

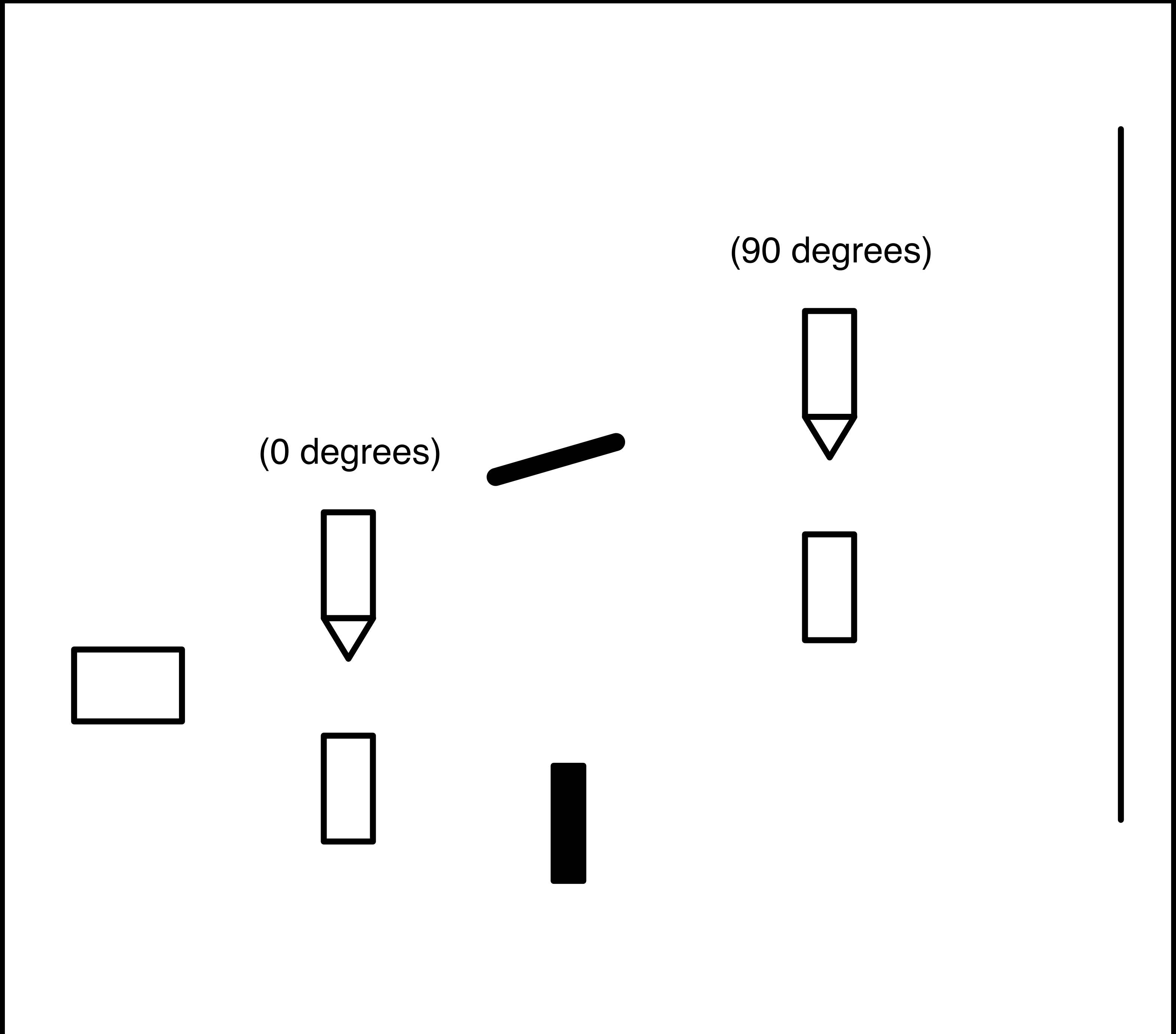
Observational fact #2: In experiment B, all of the particles are detected in the upper region.



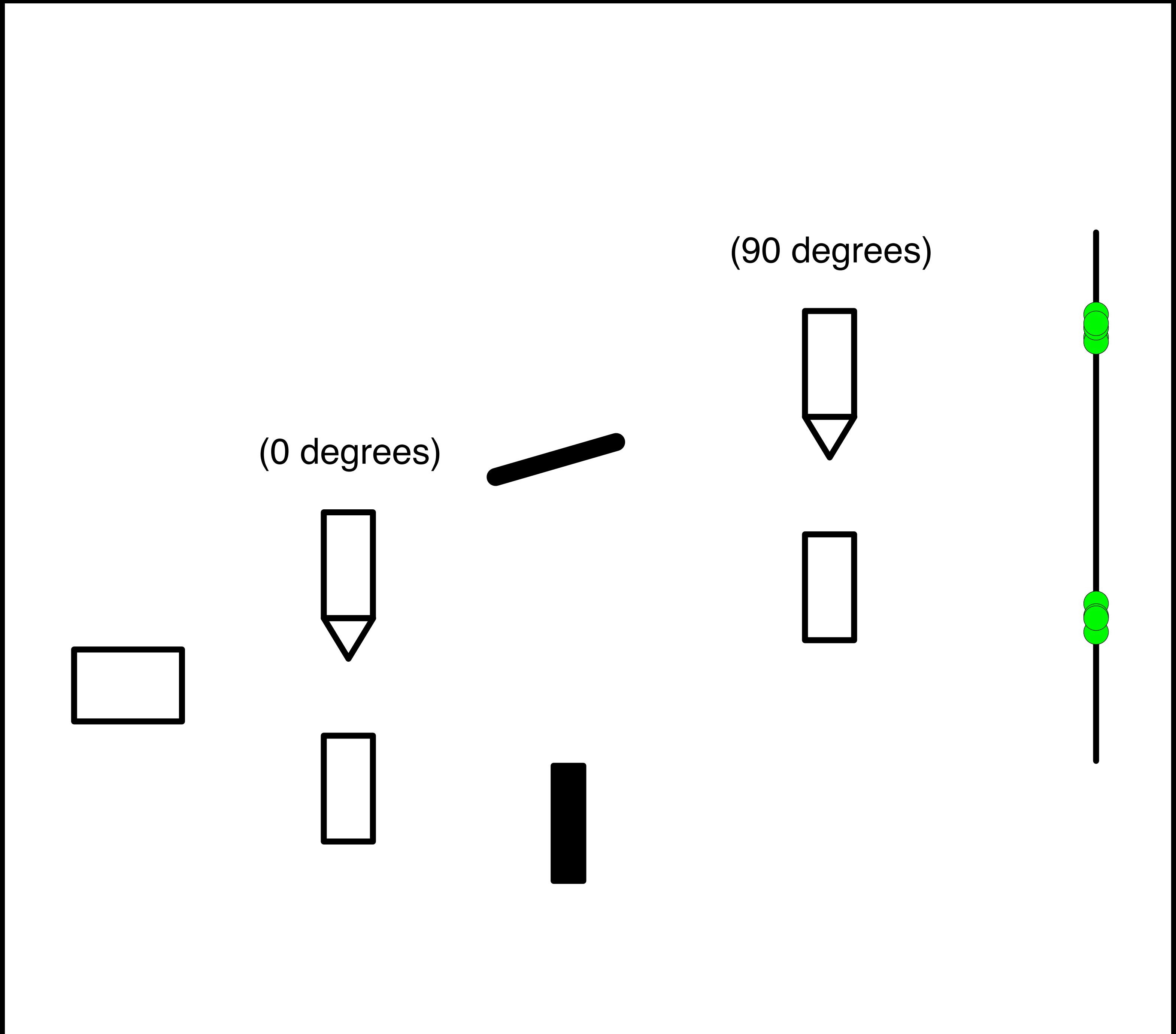
A conservative Hypothesis:

Spin is “quantized”: spin 1/2 particles can be thought of as little compass needles, but only two orientations out of the infinitely many are possible: North up, or North down.

Experiment C: two S-Gs, different angles

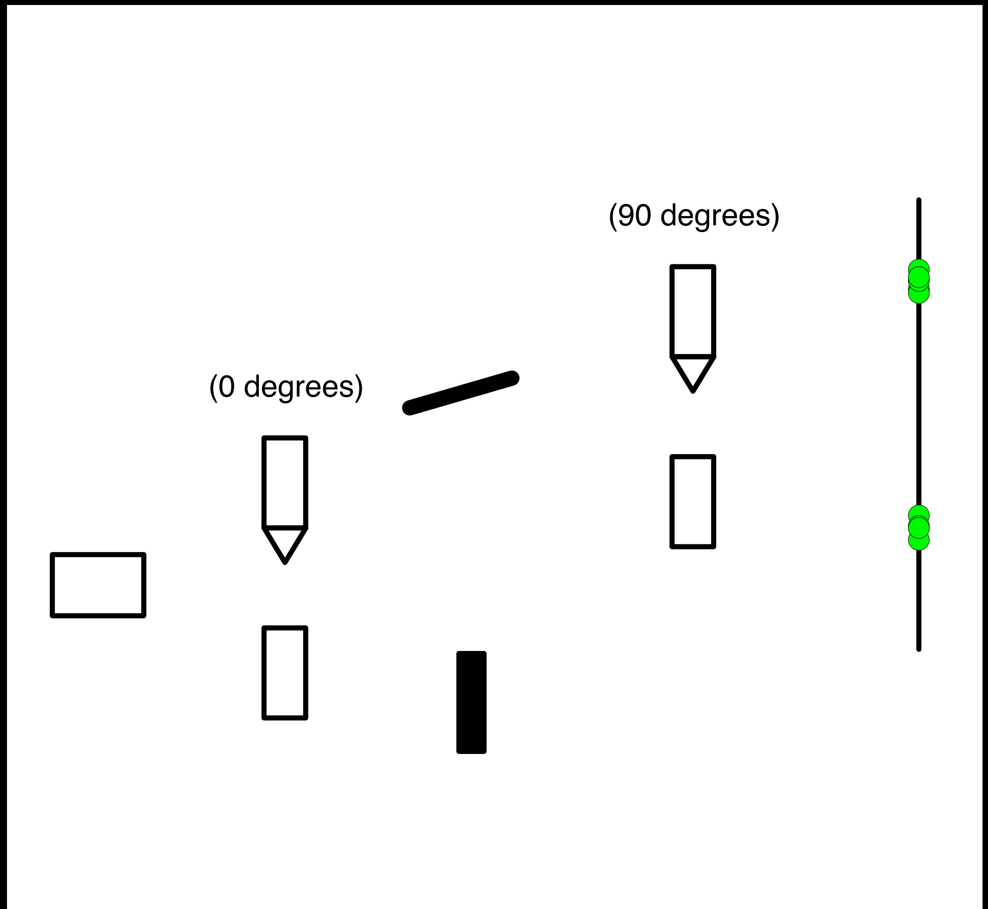


Experiment C: two S-Gs, different angles



Experiment C: two S-Gs, different angles

- Observational fact #3: In Experiment C, 1/2 of the particles (that make it through) are detected in the upper region, and 1/2 in the lower region. (And, only half make it through.)



~~Conservative hypothesis~~

If we think of spin 1/2 particles as compass needles, Experiment C shows that they are not forced to point either North up or North down.

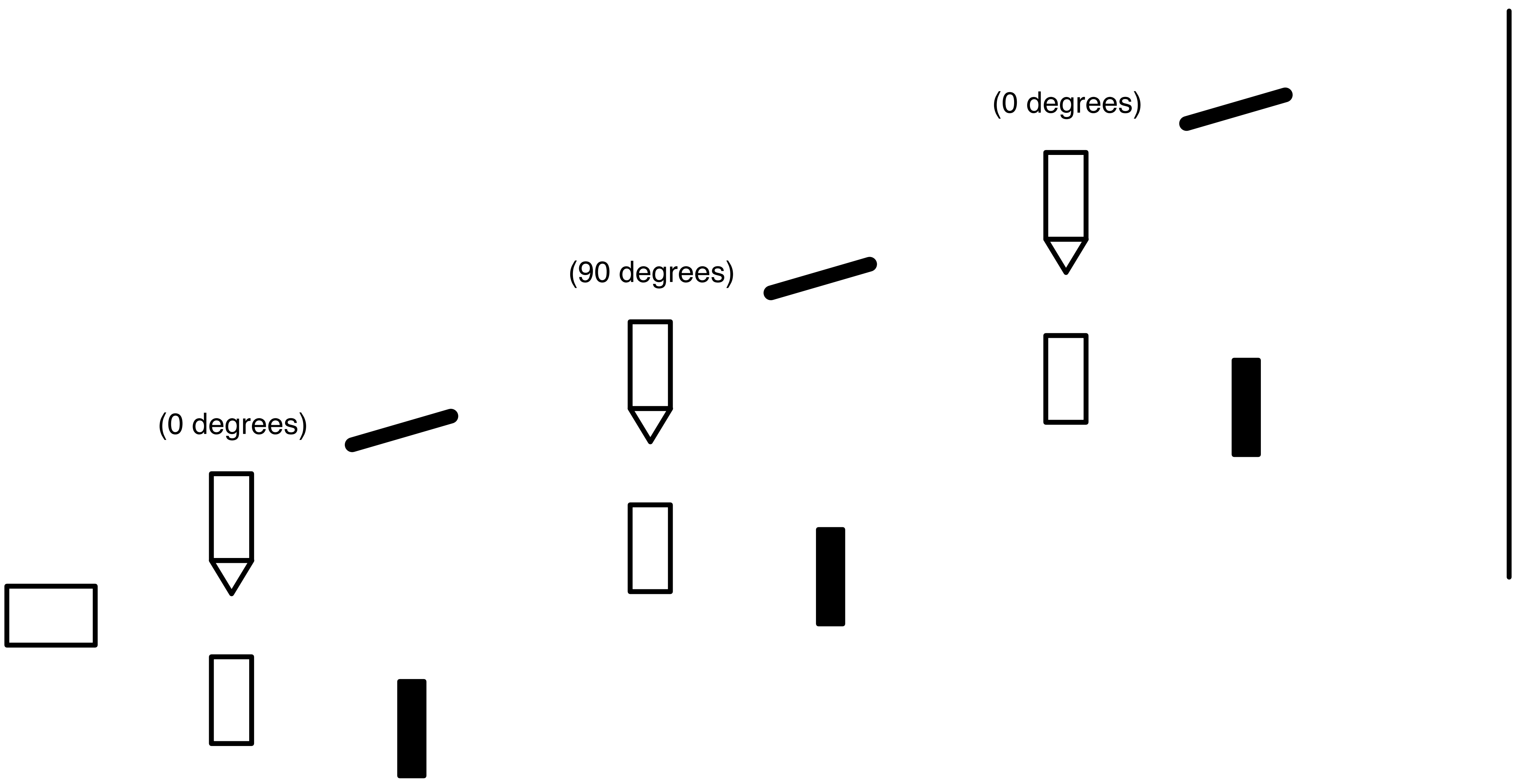
The cos^2 law for spin measurements:

- If a large number of spin-1/2 particles that have been deflected up after passing through magnets oriented at angle T (measured clockwise from the vertical) are passed through magnets oriented at angle U, then the proportion of the particles that are deflected up is

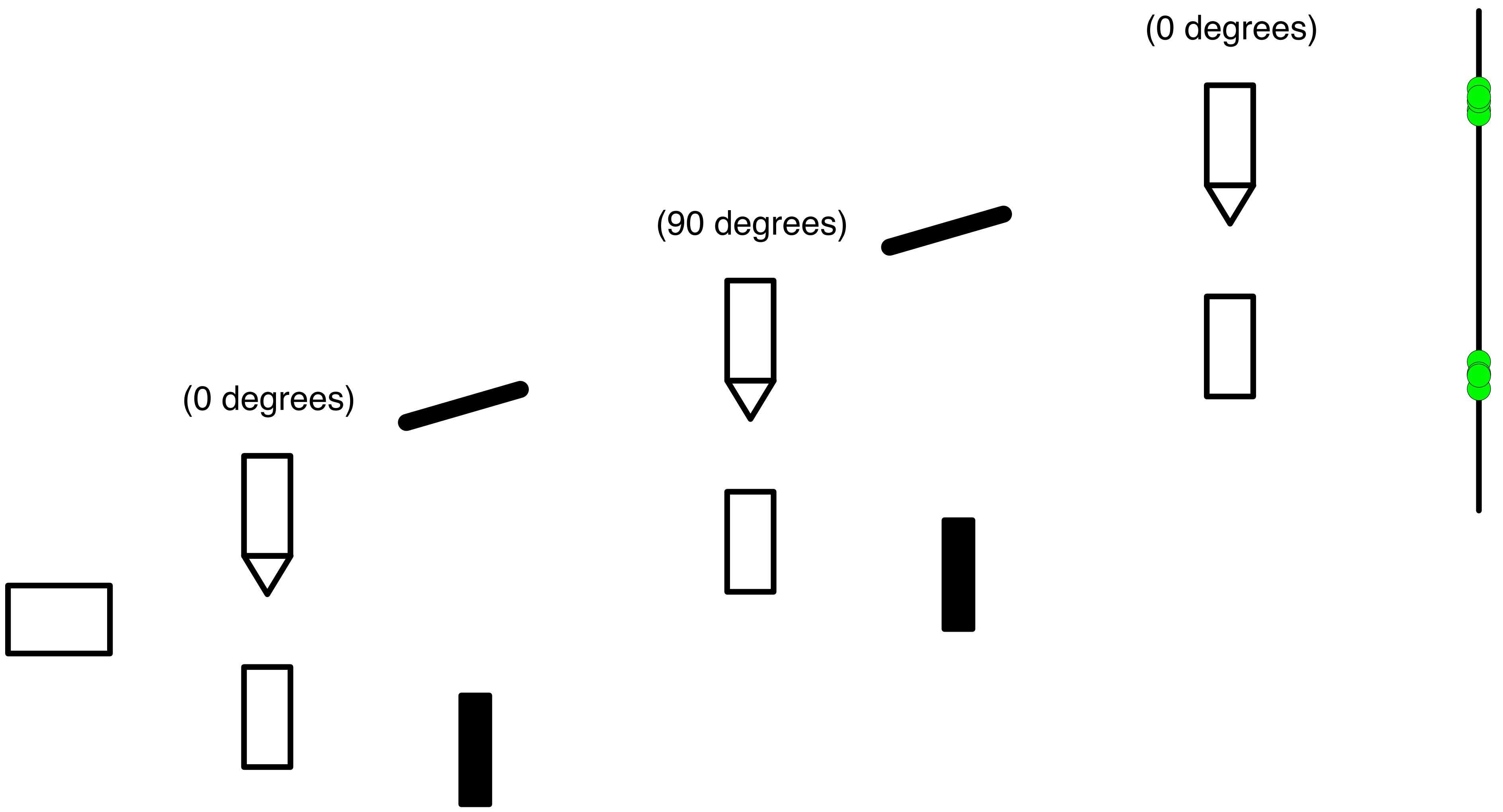
$$\cos^2 [(T-U)/2]$$

Interlude: the wild and crazy world of quantum mechanics

Experiment D: 3 S-Gs

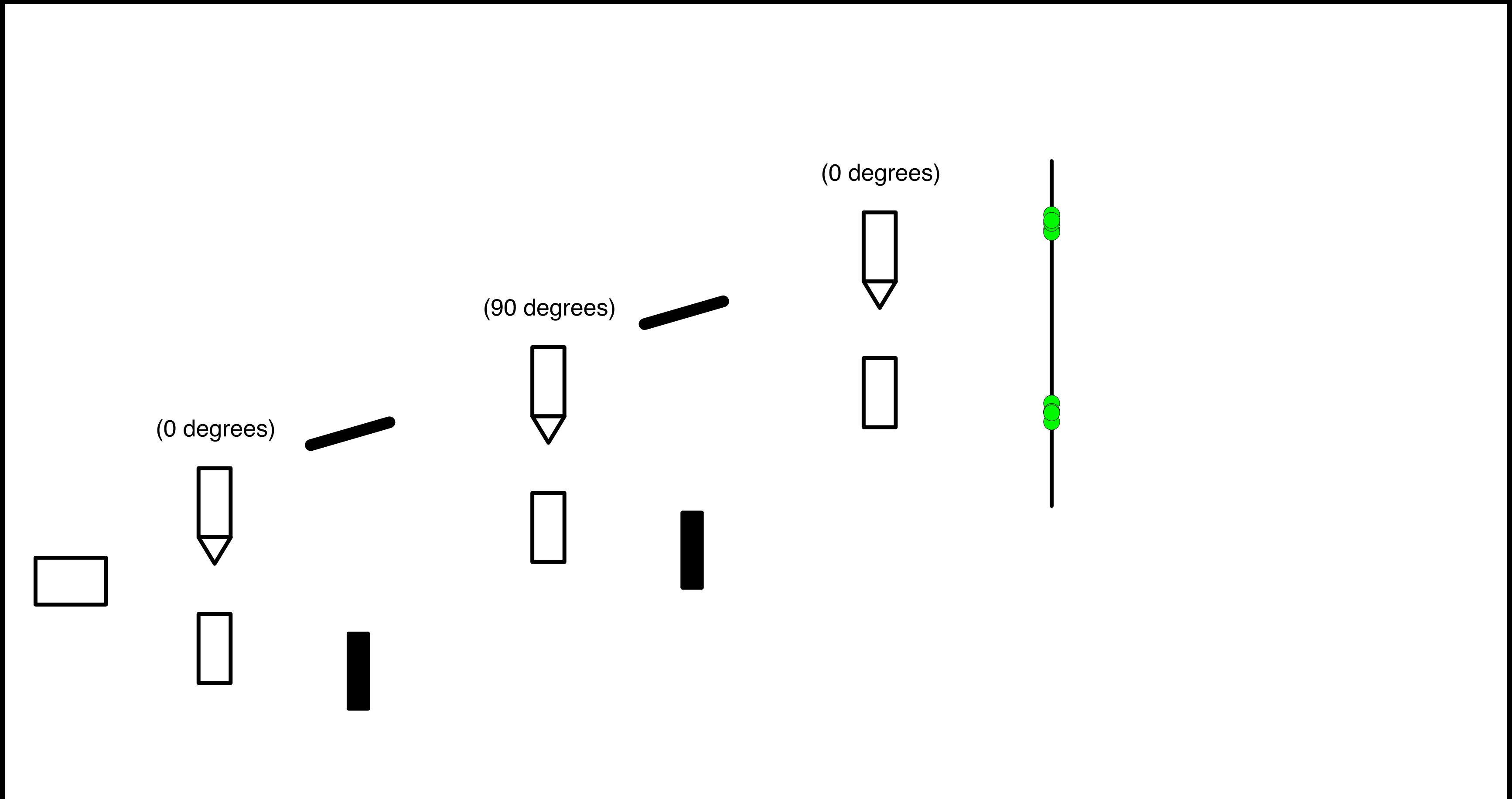


Experiment D: 3 S-Gs



Experiment D: 3 S-Gs

- Observational fact #4: In Experiment D, 1/2 of the particles (that make it through) are detected in the upper region, and 1/2 in the lower region. And, only 1/4 make it through.



A less conservative hypotheses?

When a spin 1/2 particle encounters a magnetic field, it almost instantly turns to align, or anti-align, itself with the field.

A start on the QM statistical algorithm

- (chalkboard!)

A start on the QM statistical algorithm

- Born’s rule: If the “state vector” of a spin-1/2 particle is v, and it is about to pass through SG magnets oriented at angle A, then the probability that it will be deflected up is equal to

  <v|A up>^2.

  - The probability that it will be deflected down is <v|A down>^2.

A start on the QM statistical algorithm

- Vectors play TWO DIFFERENT ROLES in this algorithm:
  - Role 1: encode information about what the "system" (particle) will do, when we measure its spin in various directions.
  - Role 2: represent possible outcomes of spin measurements.