QUANTUM WEIRDNESS

WEIRDNESS = DOES NOT Agree with my Prejudices.

PREJUDICES ≡ CLASSICAL PHYSICS.

QUANTUM MECHANICS IS NOT CLASSICAL PHYSICS IN DISGUISE.

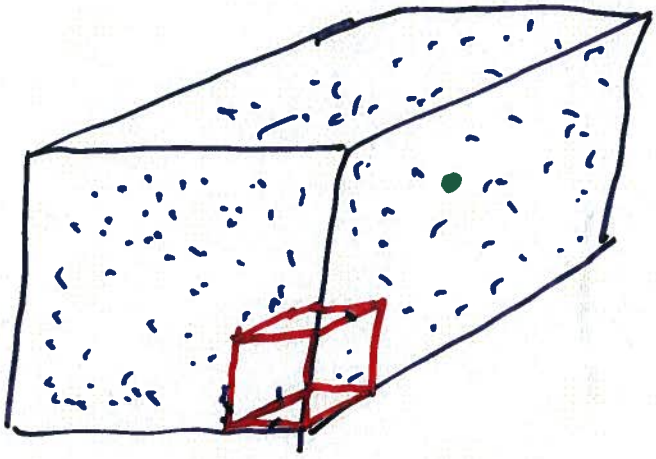
PROBABILITIES

PASCAL - Betting

MAXWELL, BOLTZMAN.

Probabilities in PHYSICS.

LACK OF KNOWLEDGE.

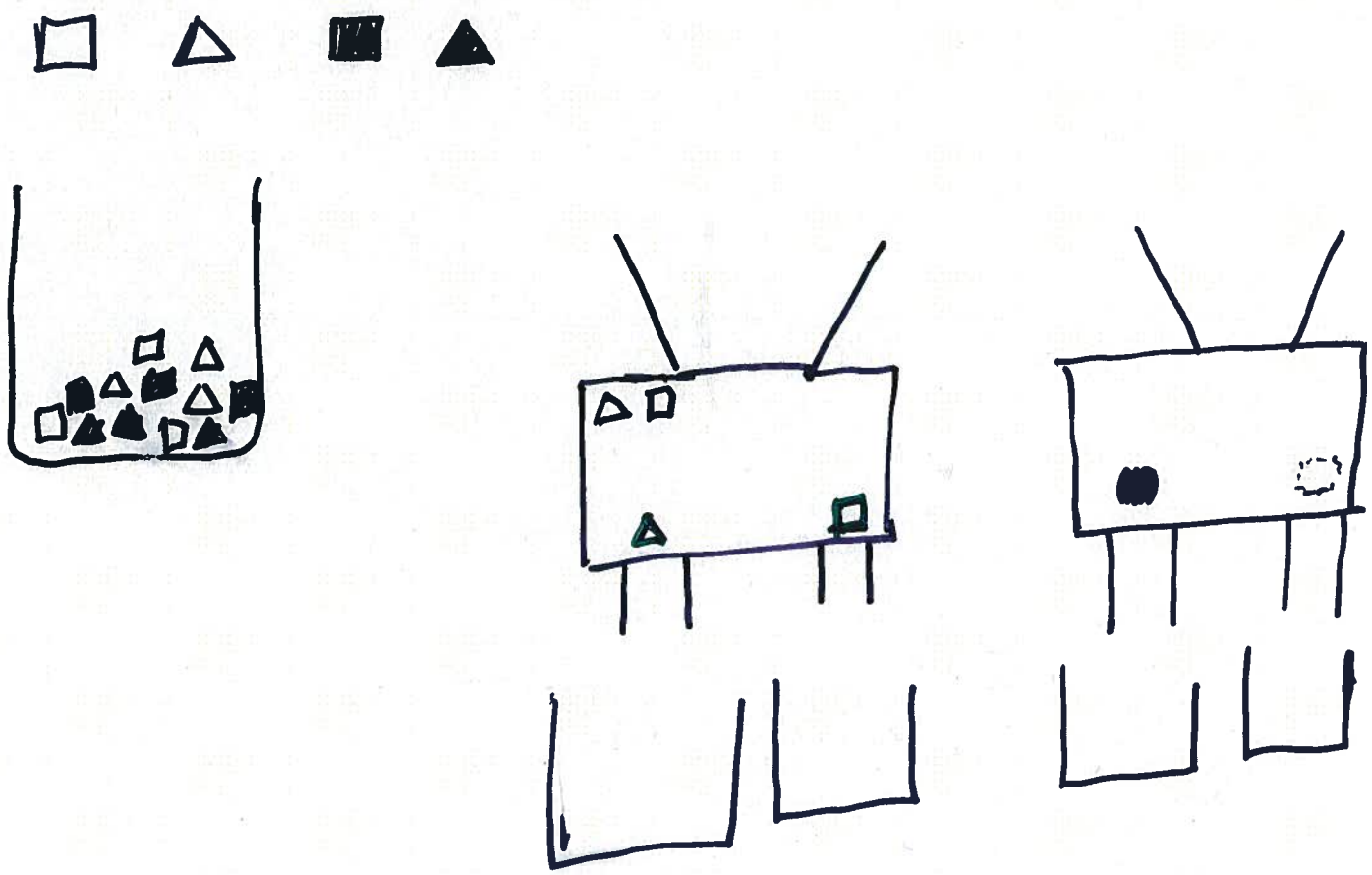


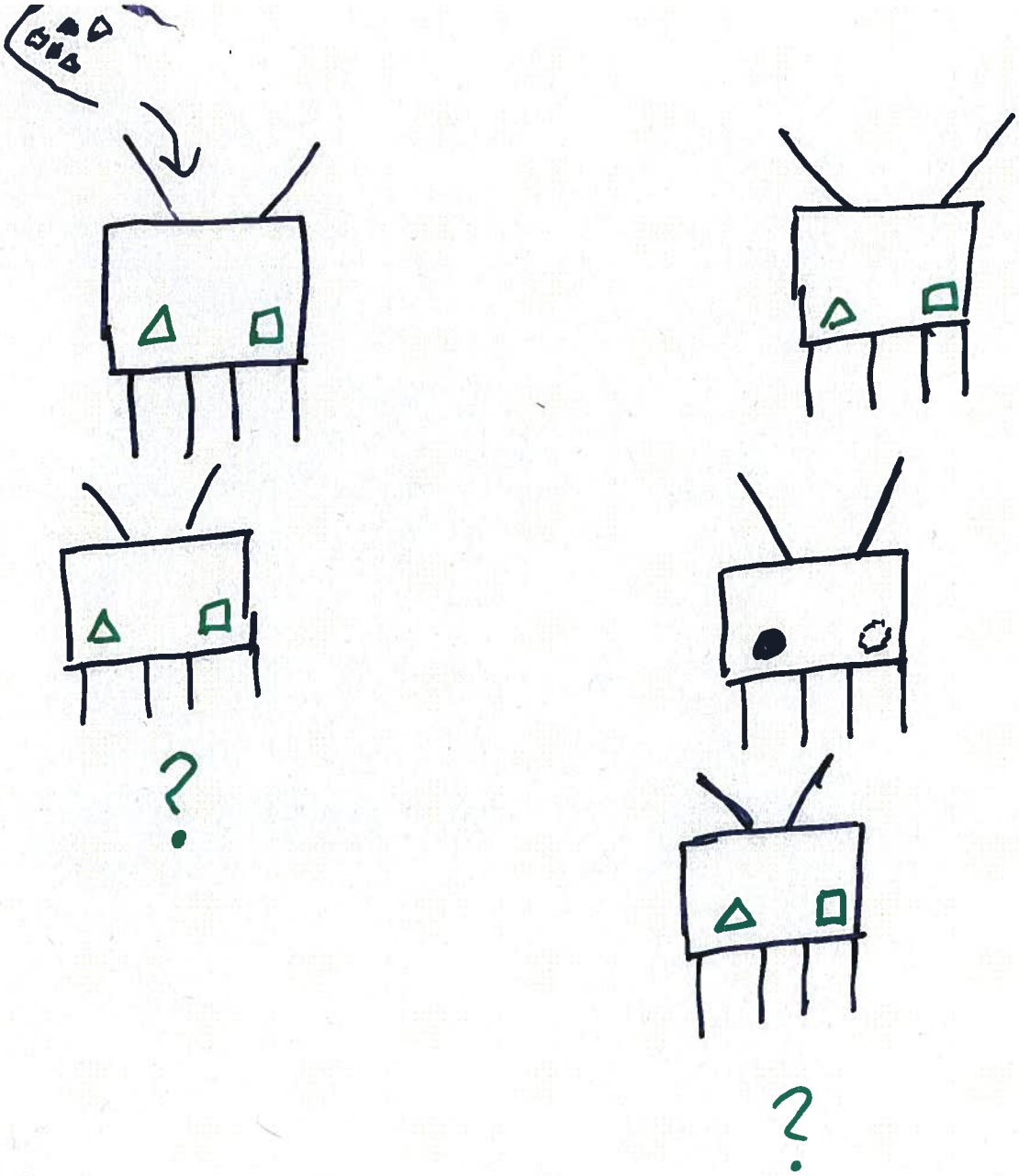
PROBABILITY GREEN PARTICLE BEING IN CERTAIN REGION

WITHOUT SUFFICIENT REASON, Particle has equal Prob anywhere

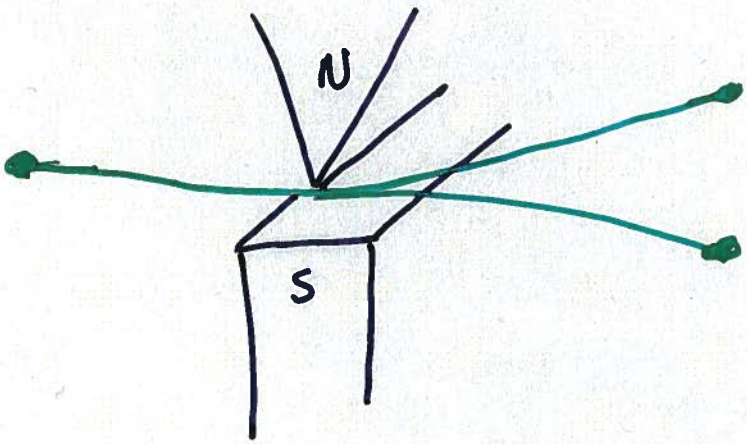
BUT PARTICLE "REALLY" IS AT SOME DEFINITE PLACE.

PROBABILITY IS DUE TO OUR HANDLING LACK OF KNOWLEDGE OF TRUE STATE OF WORLD.

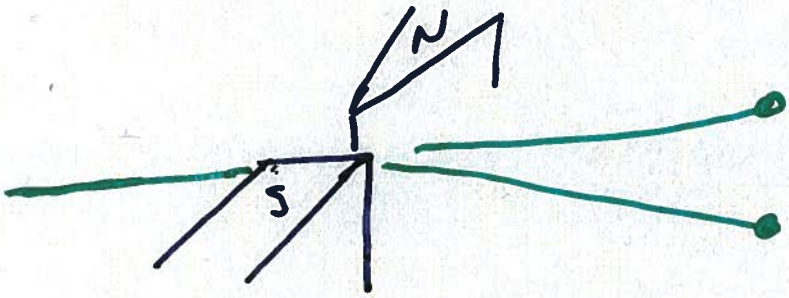




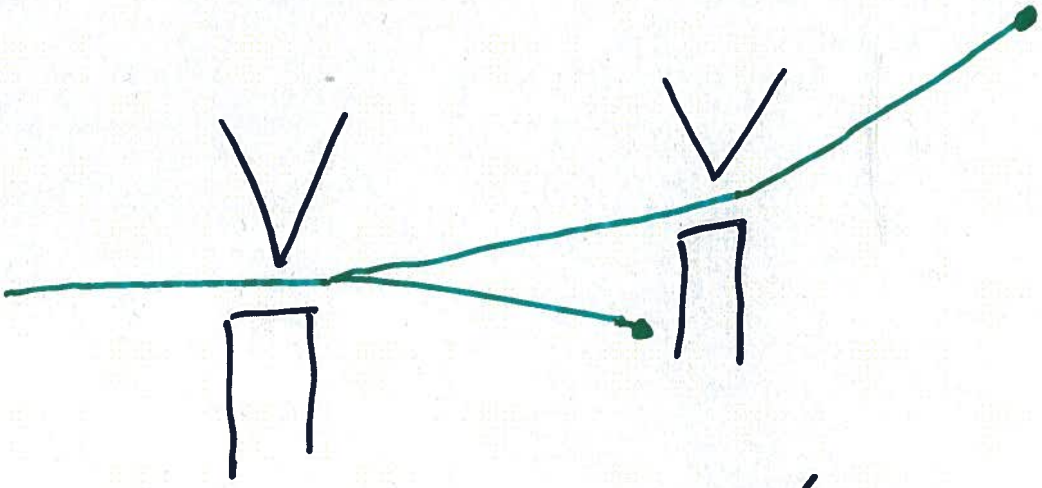
Refinement of Sorting



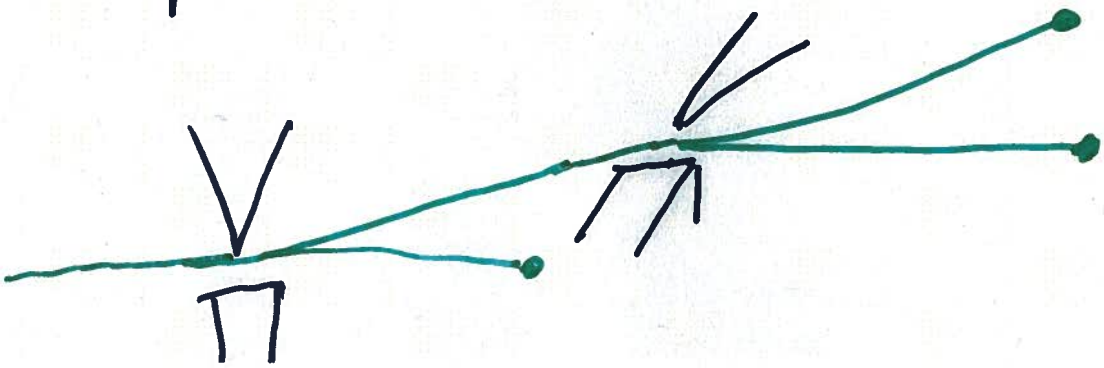
There exists Some property of Silver atom that this is sorte for.



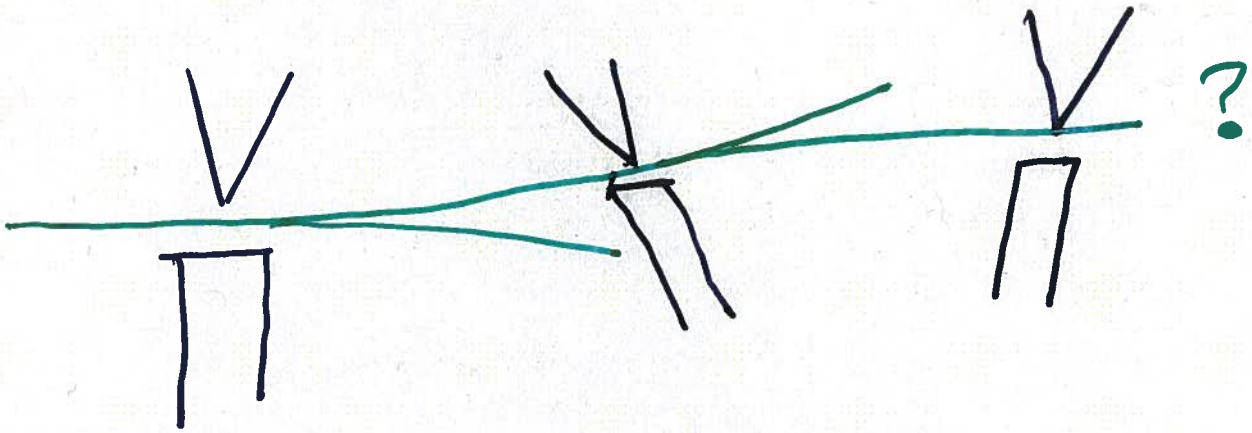
Second Sorter Another attribute?



Sort Same attribute



Sort Diff atribu



Refinement of Sort?

No.

- OUTPUT AT END IS 50-50 Again.

FUNDAMENTAL PROBABILITIE.

EXPLANATION (?)
(Heisenberg. 1925)

- The measurement of the second attribute alters the first.

Rotates around B

THE MEASUREMENT OF ONE ATTRIBUTE ALTERS The "conjugate" attribute.

CAN WE MAKE A CLASSICAL MODEL of Q. MECH. ?

(Use "measurement effect")

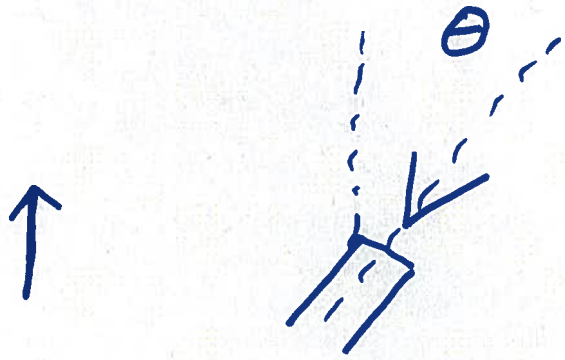
J. S. Bell (believed strongly answer "Yes")

(PROVED ANSWER "No")

Attribute ↑

If particle with attribute ↑ goes through Sorting machine V Π - sorted up always.

↓ sorted down.

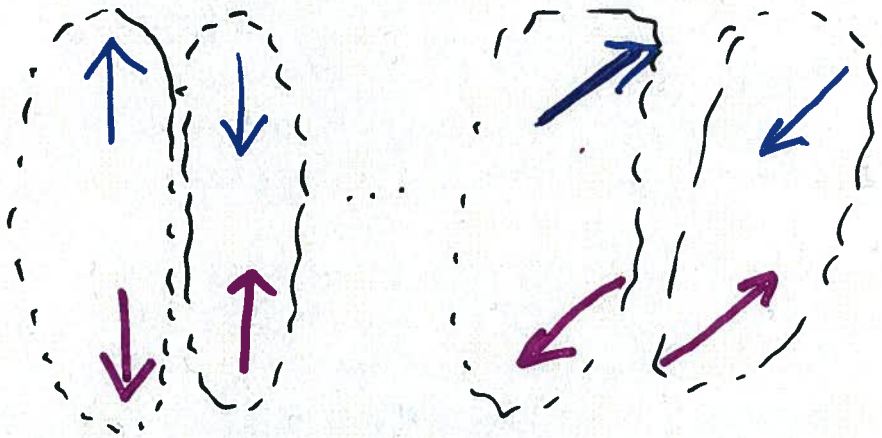


$$\text{Prob. up} = \left(\cos\frac{\theta}{2}\right)^2$$

(Toward N)

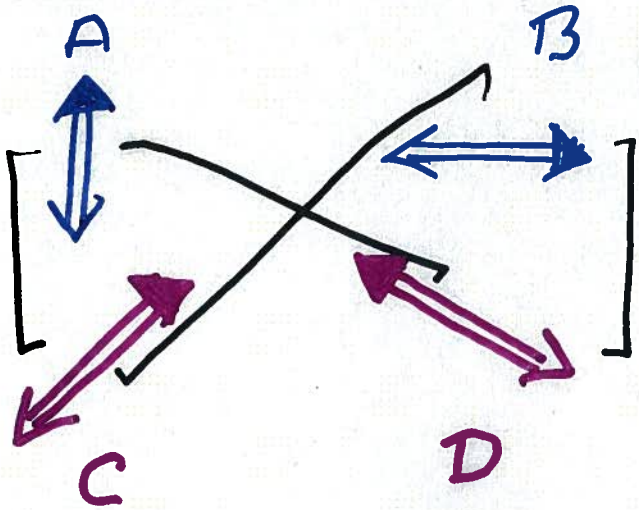
PROBABILITIES INHERENT
(ARE THEY DUE TO
LACK of Knowledge?)

MAKE A 2-PARTICE STATE.



etc (all dir)

Sorting into same direction bins perfectly correlated.



Run 4 experiments sorting into bins combinations

As Long as measurements on BLUE cannot affect outcomes on MAROON.

Up-Down $A = \langle A \rangle$

$$\langle AC \rangle = \frac{\#\,\text{Same} - \#\,\text{Diff.}}{\#\,\text{TOT.}}$$

$$\left| \langle AC \rangle + \langle AD \rangle + \langle BC \rangle - \langle BD \rangle \right| \leq 2$$

(Classical).

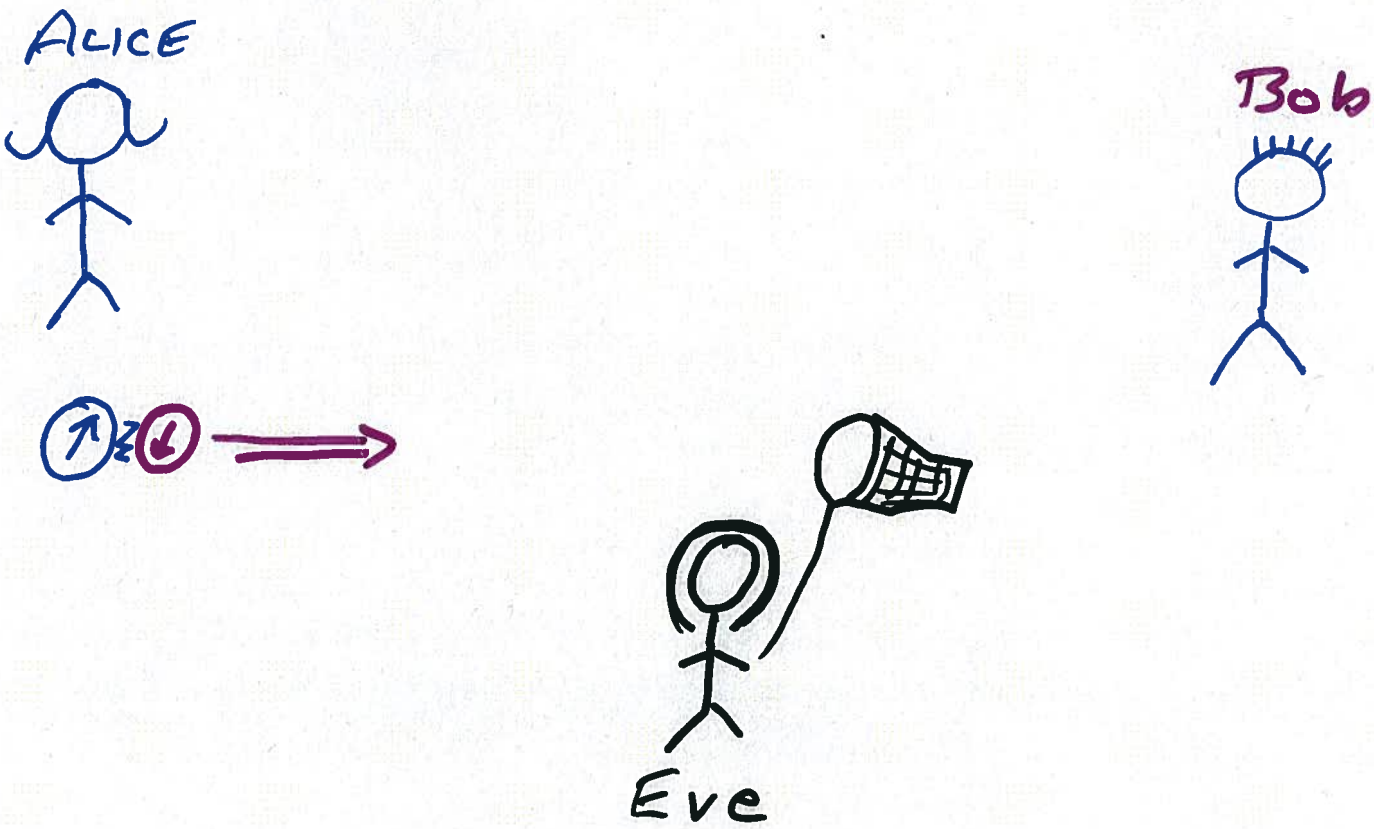
BUT

$$= 2\sqrt{2} \approx 2.8$$

Quantum & experiment.

CANNOT EXPLAIN QUANTUM BY MEASUREMEN EFFECT. (Heisenberg wrong)

CRYTOGRAPHY.



ALICE + Bob randomly choose ↕ or ↔ to measure.

a) (If choose same, know results anticorrelated.)

b) Phone (don't care if Eve hears) + pick out those cases where same direction

(If Eve did not interfere must have opposite results)

(c) Compare <u>results</u> of small subset. If not opposite - Eve listened in. $\Rightarrow$ Discard all.

HARDY STATE.

L_1 R_1

L_2 R_2

$\pm$ $\pm$

(a) If L_1 + R_1 measured and $L_1 = +$ then always $R_1 = +$

(b) If R_1 + L_2 meas. and $R_1 = +$ then $L_2 = +$

(c) If L_2 + R_2 meas and $L_2 = +$ then $R_2 = +$

d If L_1 and R_2 meas. and $L_1 = +$, what is R_2?

$L_1 = + \implies R_1 = +$

$R_1 = + \implies L_2 = +$

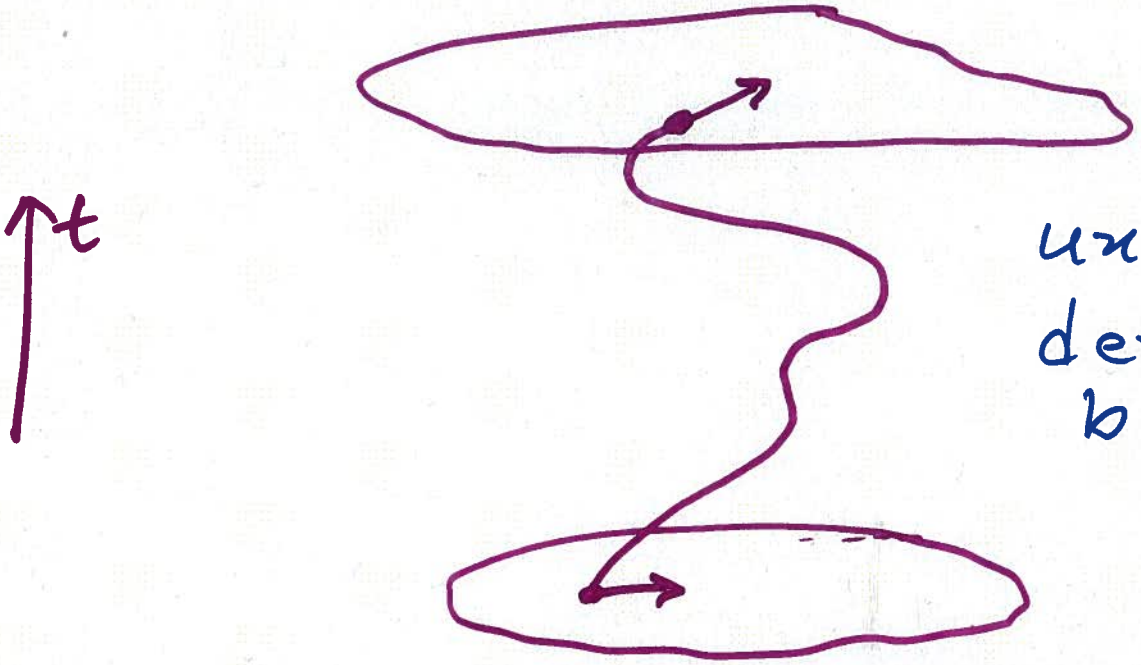
$L_2 = + \implies R_2 = +$

$$\boxed{L_1 = + \implies R_2 \text{ almost always is } -}$$

TRANSITIVITY of classical argument false.

INITIAL, FINAL CONDITIONS

In classical physics all conditions same as initial conditions.



final conditions uniquely determined by initial

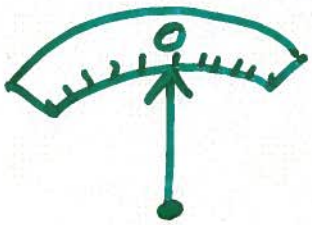
All conditions same as initial conditions

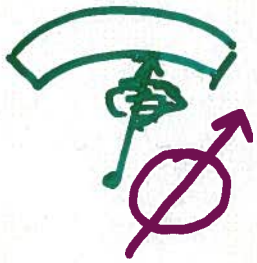
Attribute Spin = 12.5

(ie Values of spin in any direction

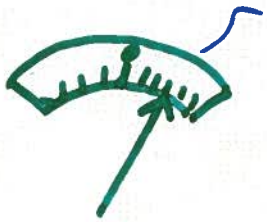
-12.5, -11.5, ..., 10.5, 11.5, 12.5

MEAS. APP.





Interact with spin in certain direction



Needle displaced amount prop. to spin measured

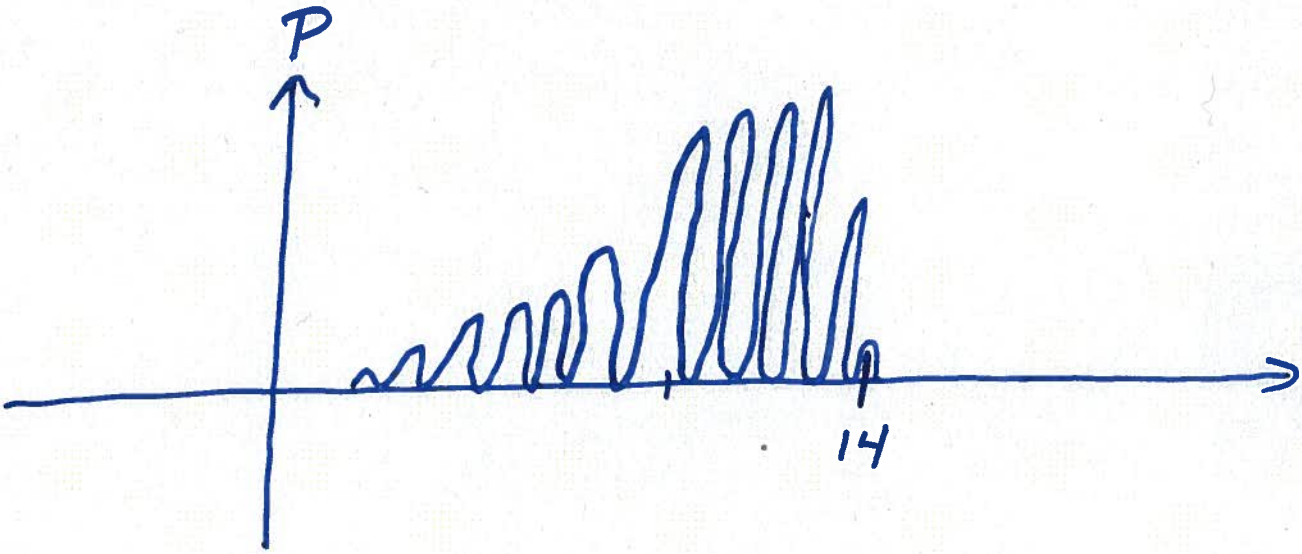
1) MEASURE Accurately Spin in x direction. Keep only those with Spin 14

2) Measure poorly spin in 45° direction

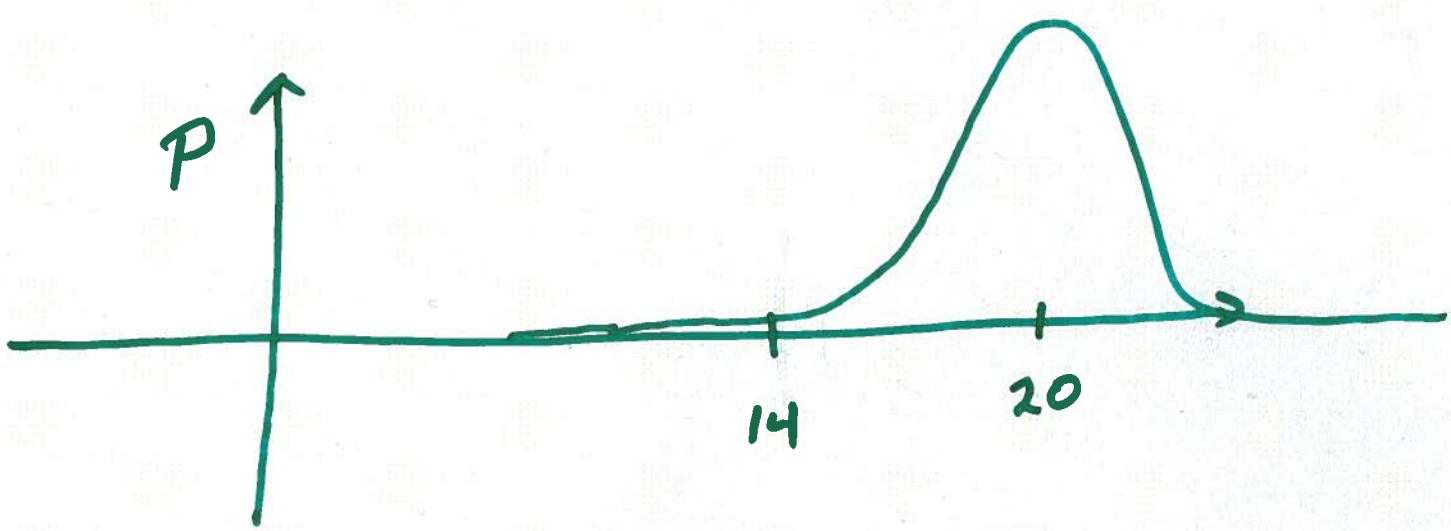
3) Measure spin in y direction + keep only cases where spin 14

What is spin in 45° direction?

(a) Measure accurately

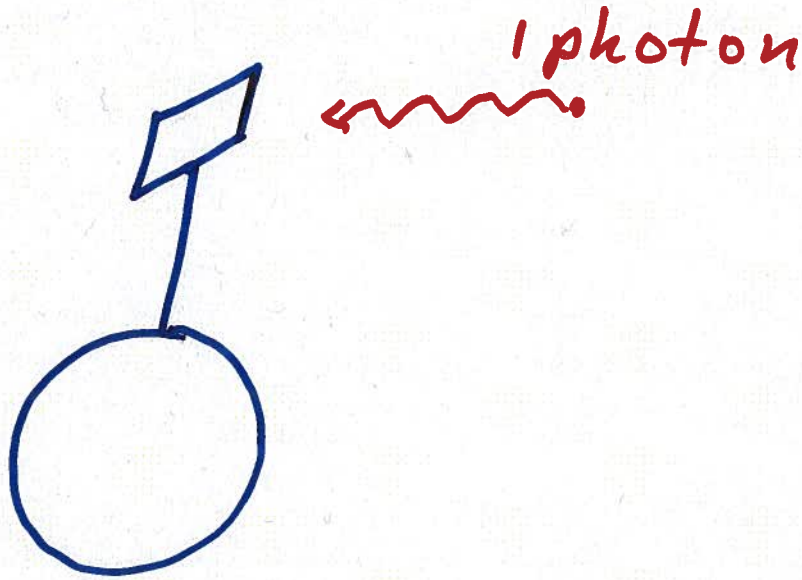


Measure Poorly



Future & Past interfere to give "impossible" value intermediate times.

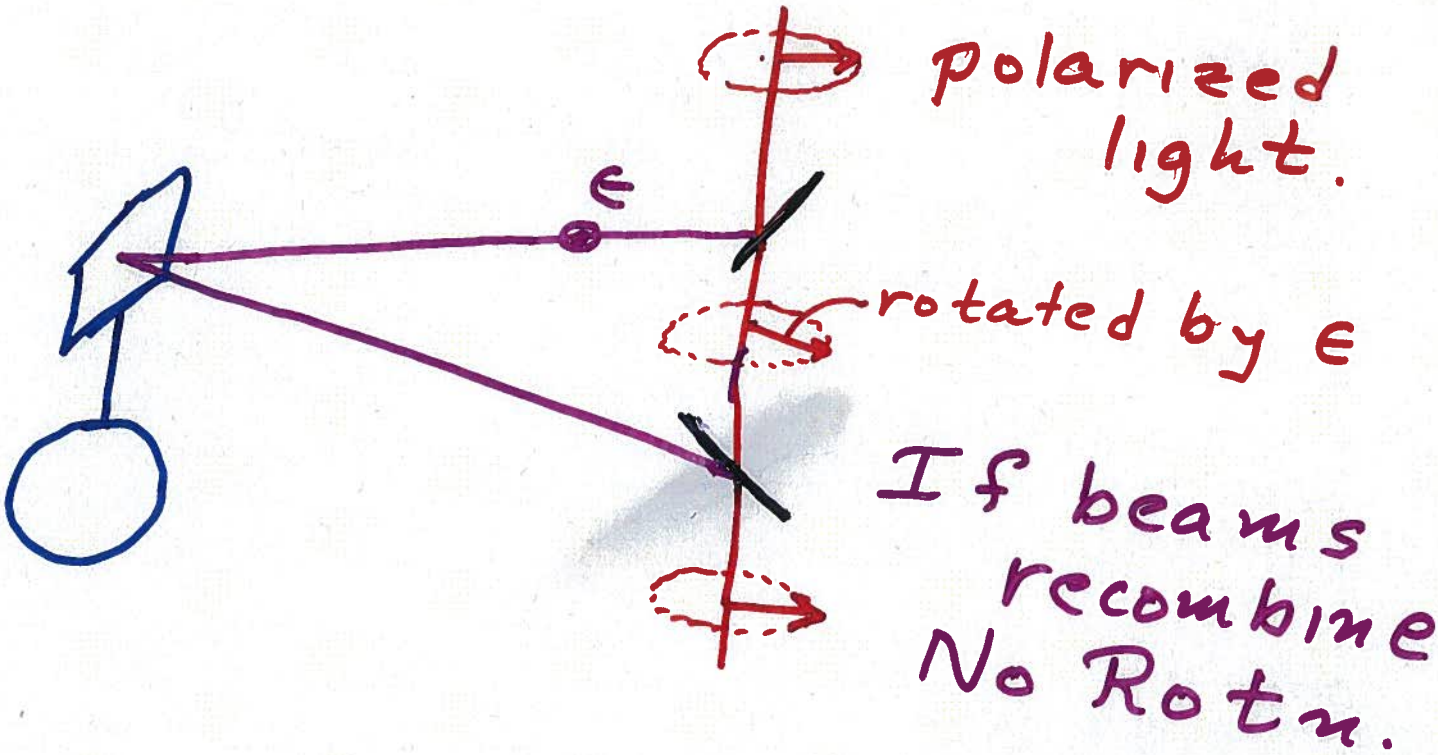
BOMB DETECTOR

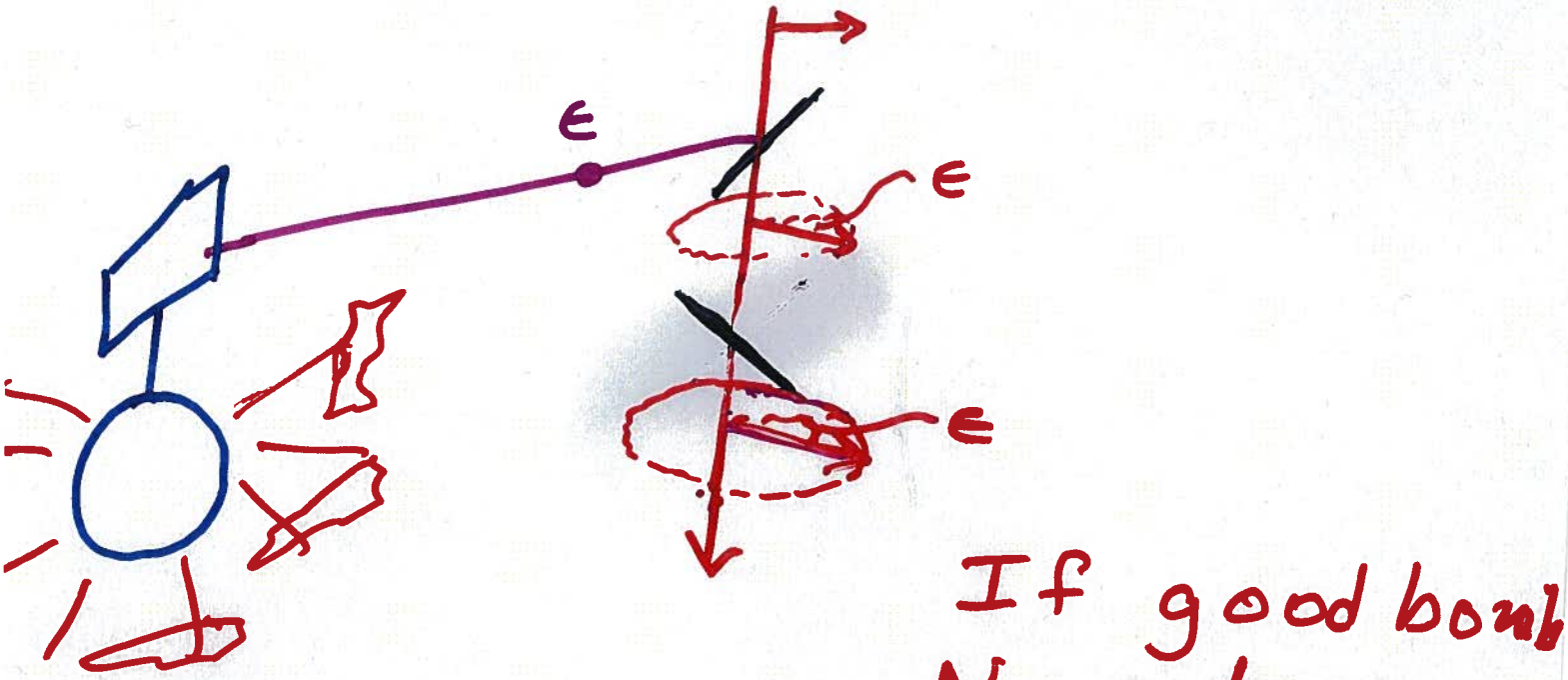


1 photon sets off bomb.

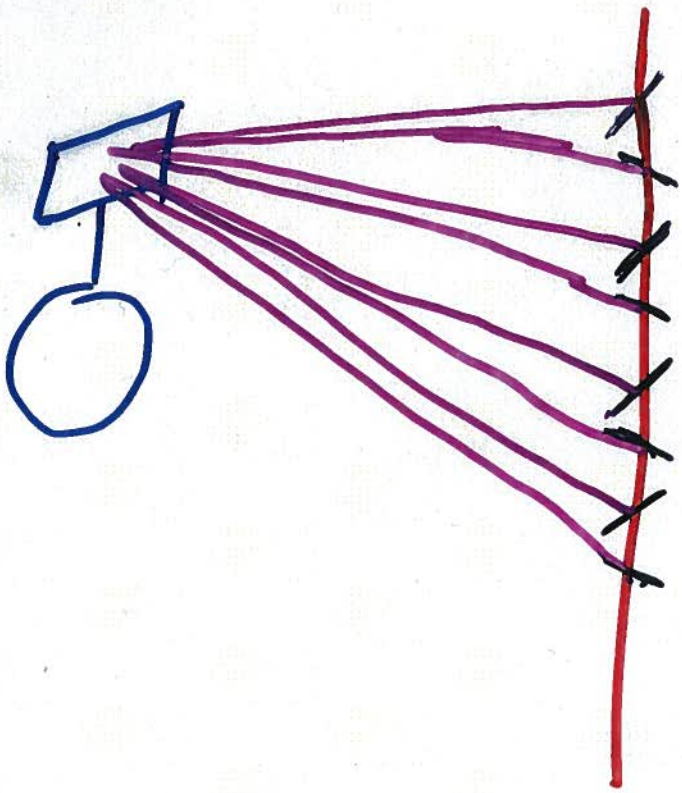
Can you test if bomb is good or not?

without blowing up the good bomb?





Prob. of explosion ϵ^2



Rotation

$$N\epsilon = \frac{\pi}{2}$$

Prob. of explosion

$$= N\epsilon^2 = \frac{\pi^2}{4N}$$

If N large - prob of explosion very small if good bomb.

But rotn of polsn of beam is 90°

If bomb bad, rotn. is 0°. - Can measure exactly.

QUANTUM MECHANICS CAN DETECT GOOD BOMB without exploding it.

Procedure relies completely on fact bomb <u>would</u> explode with single photon!