

HOW TO PROBE THE
NATURE OF THE UNIVERSE

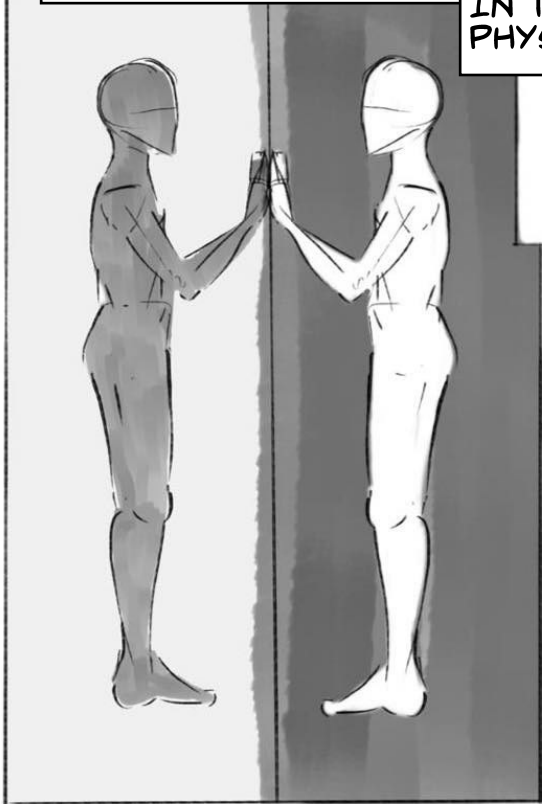


DANIKA WATSON

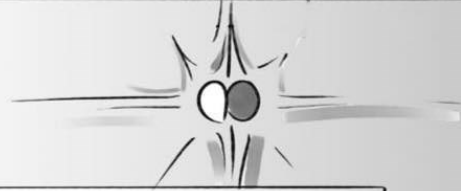
HAVE YOU EVER SEEN A MOVIE WHERE THE PROTAGONIST HAS AN EVIL TWIN?

IN THE WORLD OF PARTICLE PHYSICS, EVIL TWINS ARE REAL.

THEY'RE CALLED ANTIPARTICLES, AND EVERY PARTICLE HAS ONE: A TWIN OF EQUAL MASS BUT OPPOSITE CHARGE.



WHEN THEY COLLIDE,



THEY DESTROY EACH OTHER,



ANNIHILATING INTO NOTHINGNESS,

LEAVING ONLY PURE ENERGY BEHIND.

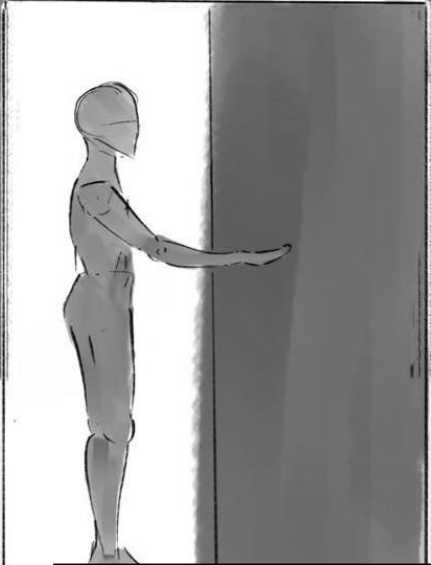
BUT IF ALL MATTER HAS AN ANTIMATTER COUNTERPART,

AND THEY DESTROY EACH OTHER,

HOW IS THERE ANY MATTER LEFT TO MAKE UP YOU, ME, AND THE REST OF THE UNIVERSE?

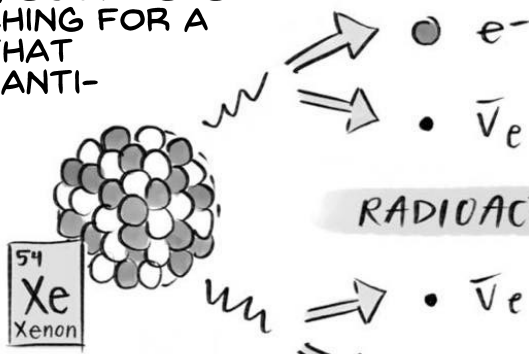
MEANWHILE, WE HARDLY SEE ANY ANTIMATTER AT ALL.

WHY DOES THIS IMBALANCE EXIST?



WHERE DID MOST OF THE ANTIMATTER GO?

TO ANSWER THESE QUESTIONS, SCIENTISTS ARE SEARCHING FOR A PROCESS THAT DESTROYS ANTI-MATTER.



ONE CANDIDATE IS DOUBLE BETA DECAY,

RADIOACTIVE DECAY

A PROCESS WHICH PRODUCES TWO ELECTRONS AND TWO ANTINEUTRINOS.

SCIENTISTS WONDER:

WHAT IF NEUTRINOS AND ANTINEUTRINOS

WERE ONE AND THE SAME?

IN OTHER WORDS, WHAT IF NEUTRINOS WERE THEIR OWN ANTI PARTICLES?

MEANING THE PROCESS WOULD SELECTIVELY DESTROY ANTIMATTER.

IF THIS "NEUTRINOLESS" DOUBLE BETA DECAY PROCESS IS REAL, IT COULD POINT US TO WHERE THE MISSING ANTIMATTER WENT.

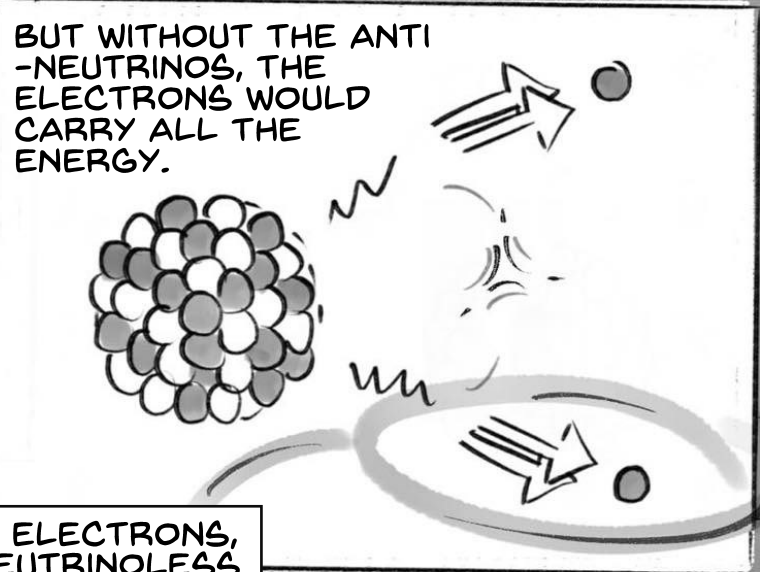
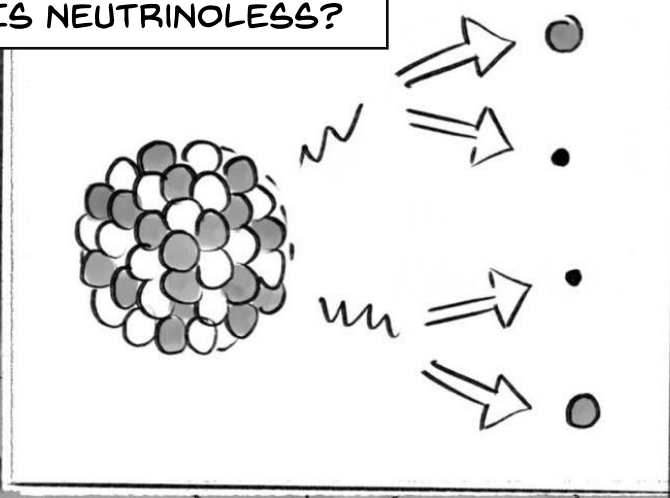
NOT ONLY THAT, IT WOULD ALSO BREAK THE STANDARD MODEL OF PARTICLE PHYSICS,

FUNDAMENTALLY ALTERING OUR UNDERSTANDING OF THE UNIVERSE.

~~TOTAL LEPTON NUMBER CONSERVATION~~

HOW DO WE MEASURE WHETHER A DOUBLE BETA DECAY PROCESS IS NEUTRINOLESS?

IN REGULAR DOUBLE BETA DECAY, BOTH THE ELECTRONS AND ANTINEUTRINOS CARRY AWAY ENERGY.



BUT WITHOUT THE ANTI-NEUTRINOS, THE ELECTRONS WOULD CARRY ALL THE ENERGY.

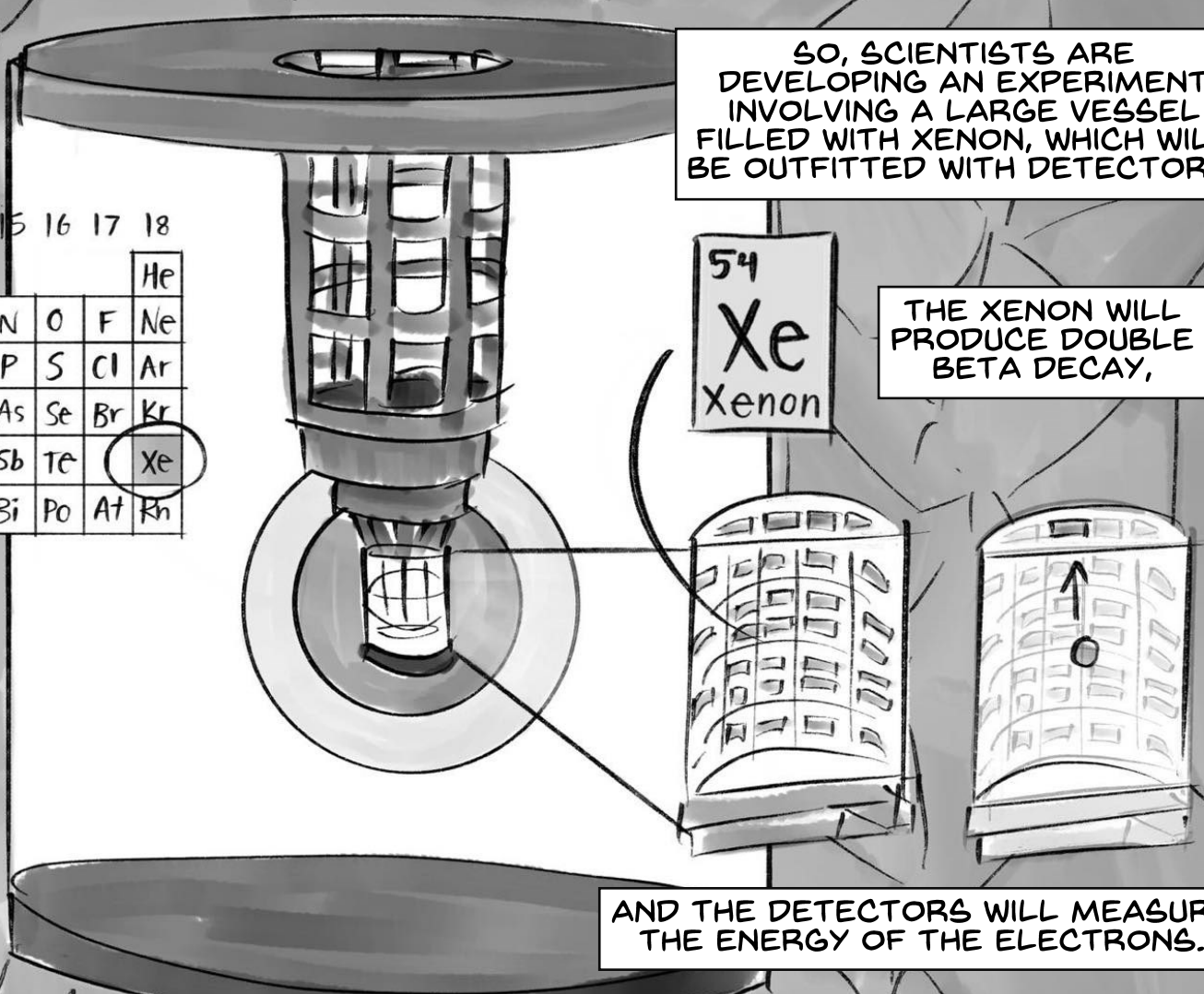
BY MEASURING THE ENERGY OF THE ELECTRONS, WE CAN SEE IF THE PROCESS WAS NEUTRINOLESS.

SO, SCIENTISTS ARE DEVELOPING AN EXPERIMENT INVOLVING A LARGE VESSEL FILLED WITH XENON, WHICH WILL BE OUTFITTED WITH DETECTORS.

| | | | | | |
|----|----|----|----|----|----|
| 13 | 14 | 15 | 16 | 17 | 18 |
| | | | | | He |
| B | C | N | O | F | Ne |
| Al | Si | P | S | Cl | Ar |
| Ga | Ge | As | Se | Br | Kr |
| In | Sn | Sb | Te | Xe | |
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54
Xe
Xenon

THE XENON WILL PRODUCE DOUBLE BETA DECAY,



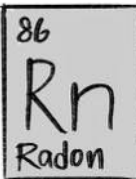
AND THE DETECTORS WILL MEASURE THE ENERGY OF THE ELECTRONS.

HOWEVER, DOUBLE BETA DECAY IS RARE--ONLY A FEW DECAYS WILL HAPPEN IN AN ENTIRE DECADE!

THE EXPERIMENT MUST BE CAREFULLY CRAFTED. THESE RARE EVENTS ARE EASY TO MISS...

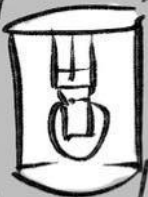
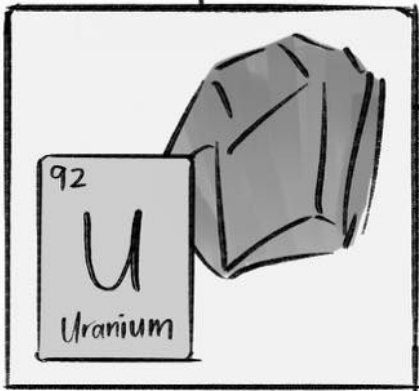
FOR ONE, RADIATION CAN COME FROM BACKGROUND SOURCES,

CREATING FALSE SIGNALS.



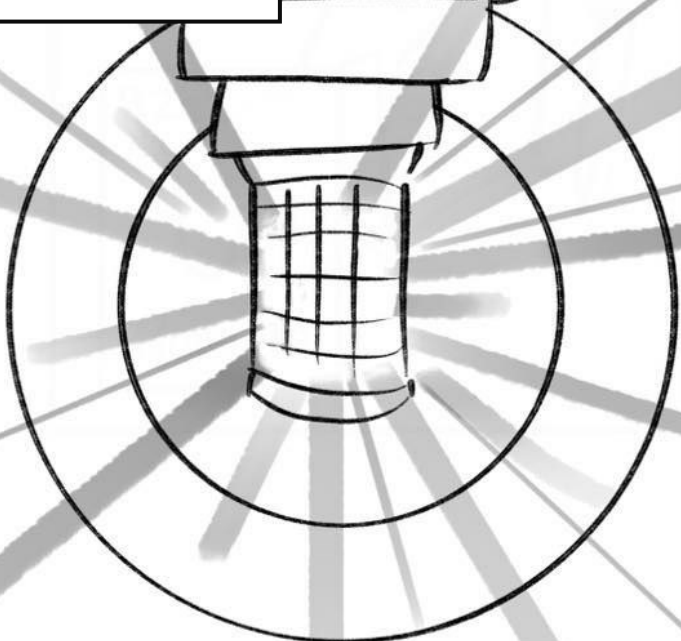
THE XENON VESSEL
WILL BE BURIED
UNDERGROUND

AND SHIELDED UNDER
MANY LAYERS,



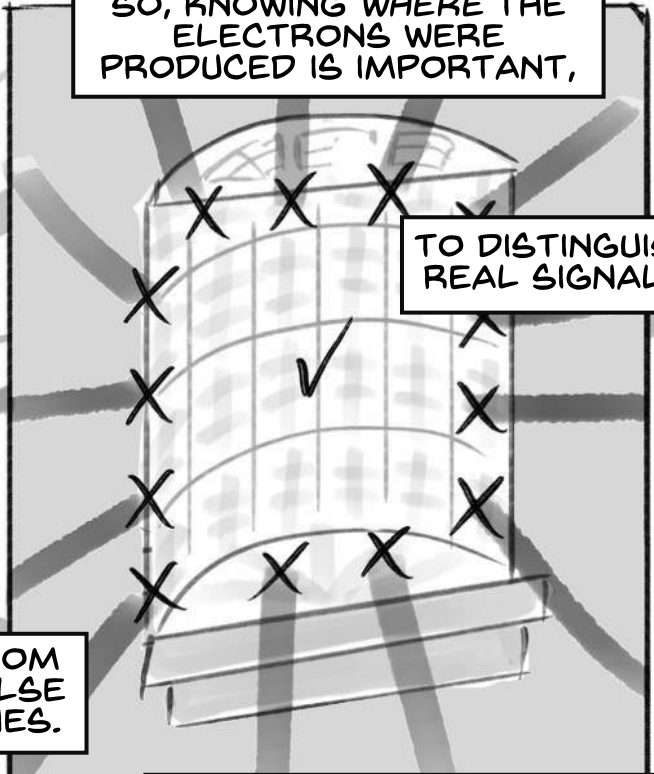
BUT FALSE
SIGNALS MAY
STILL MAKE IT IN,

MOSTLY NEAR
THE EDGES OF
THE VESSEL.



SO, KNOWING WHERE THE
ELECTRONS WERE
PRODUCED IS IMPORTANT,

TO DISTINGUISH
REAL SIGNALS



FROM
FALSE
ONES.

HOW CAN WE PINPOINT THE
ELECTRONS' COORDINATES?

AN ELECTRIC FIELD WILL PULL THE ELECTRONS TOWARDS DETECTORS AT THE TOP OF THE VESSEL.

SO, THE POINT WHERE THE ELECTRONS LAND WILL GIVE TWO OF THEIR ORIGINAL COORDINATES.

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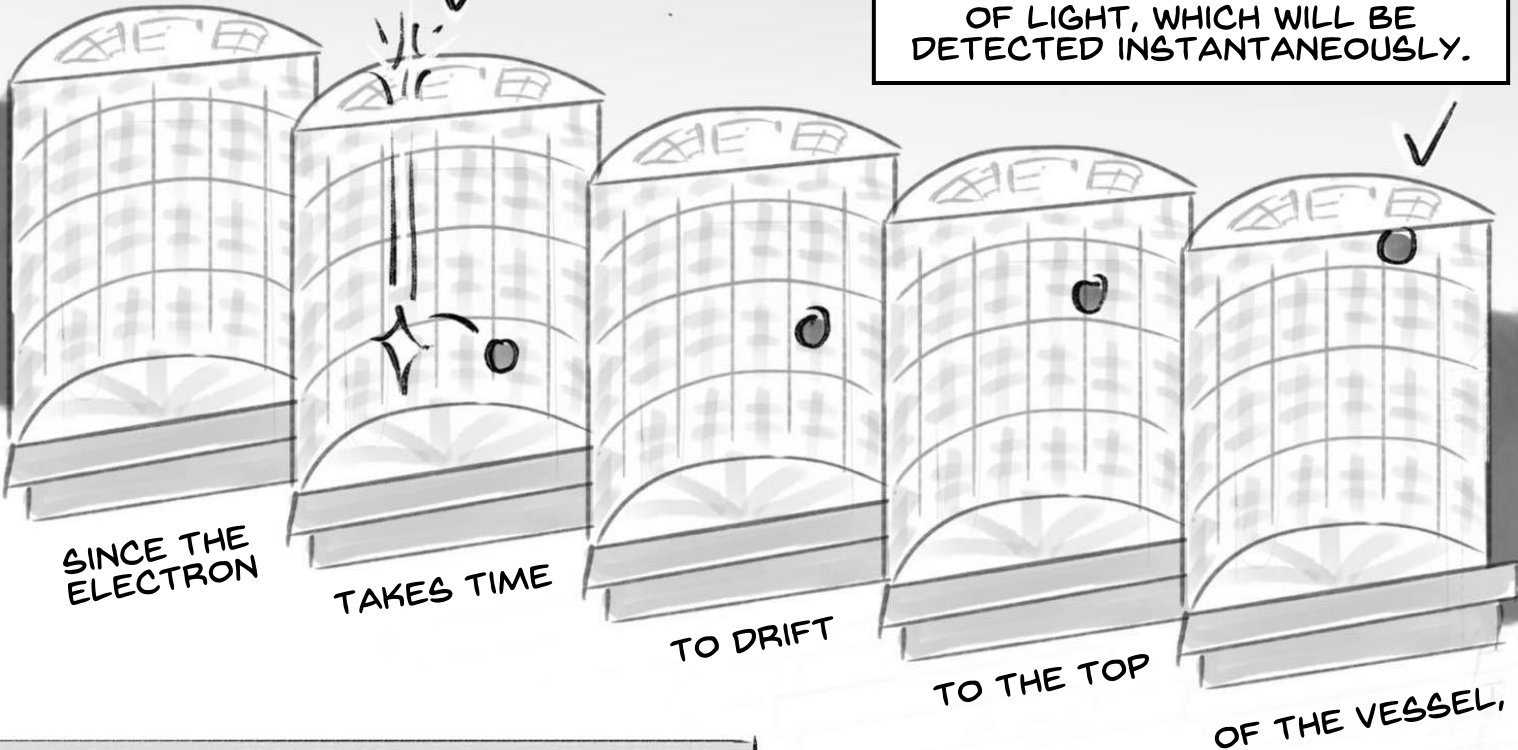
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WHAT ABOUT THE THIRD COORDINATE?

LUCKILY, DOUBLE BETA DECAY IN XENON ALSO PRODUCES A FLASH OF LIGHT, WHICH WILL BE DETECTED INSTANTANEOUSLY.



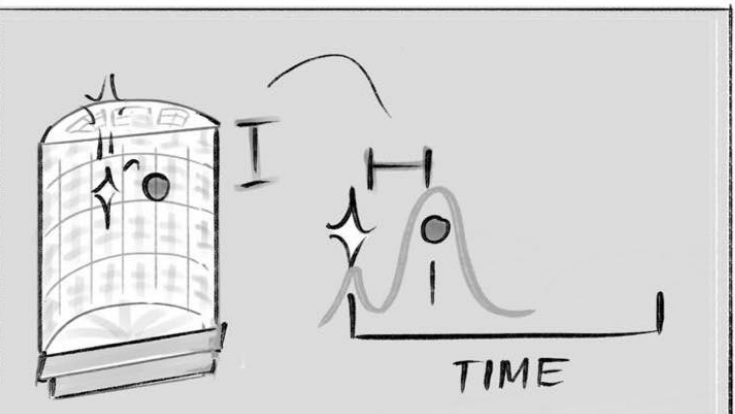
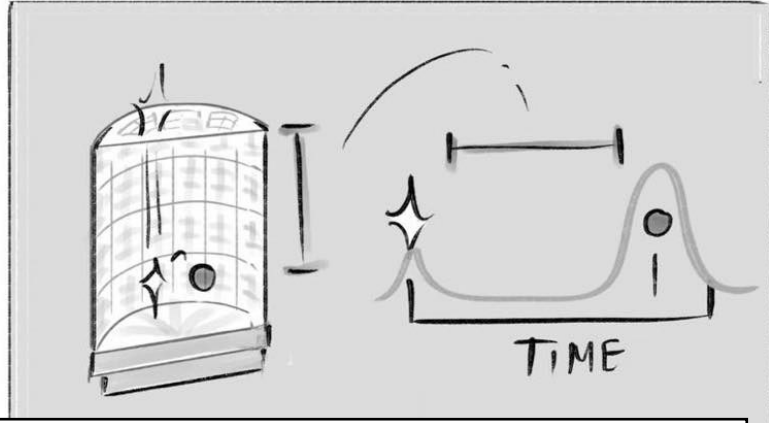
SINCE THE ELECTRON

TAKES TIME

TO DRIFT

TO THE TOP

OF THE VESSEL,



THE DIFFERENCE IN TIMING BETWEEN THE DETECTION OF THE ELECTRONS AND THE FLASH OF LIGHT TRANSLATES INTO THE THIRD COORDINATE.

TIME

TIME

HOWEVER, THAT FLASH OF LIGHT WILL BE EXTREMELY DIM--IT MIGHT JUST BE A SINGLE PHOTON.

SO, THE DIM LIGHT OF THAT SOLITARY PHOTON WILL HAVE TO BE AMPLIFIED INTO AN ELECTRICAL SIGNAL LARGE ENOUGH TO DETECT.

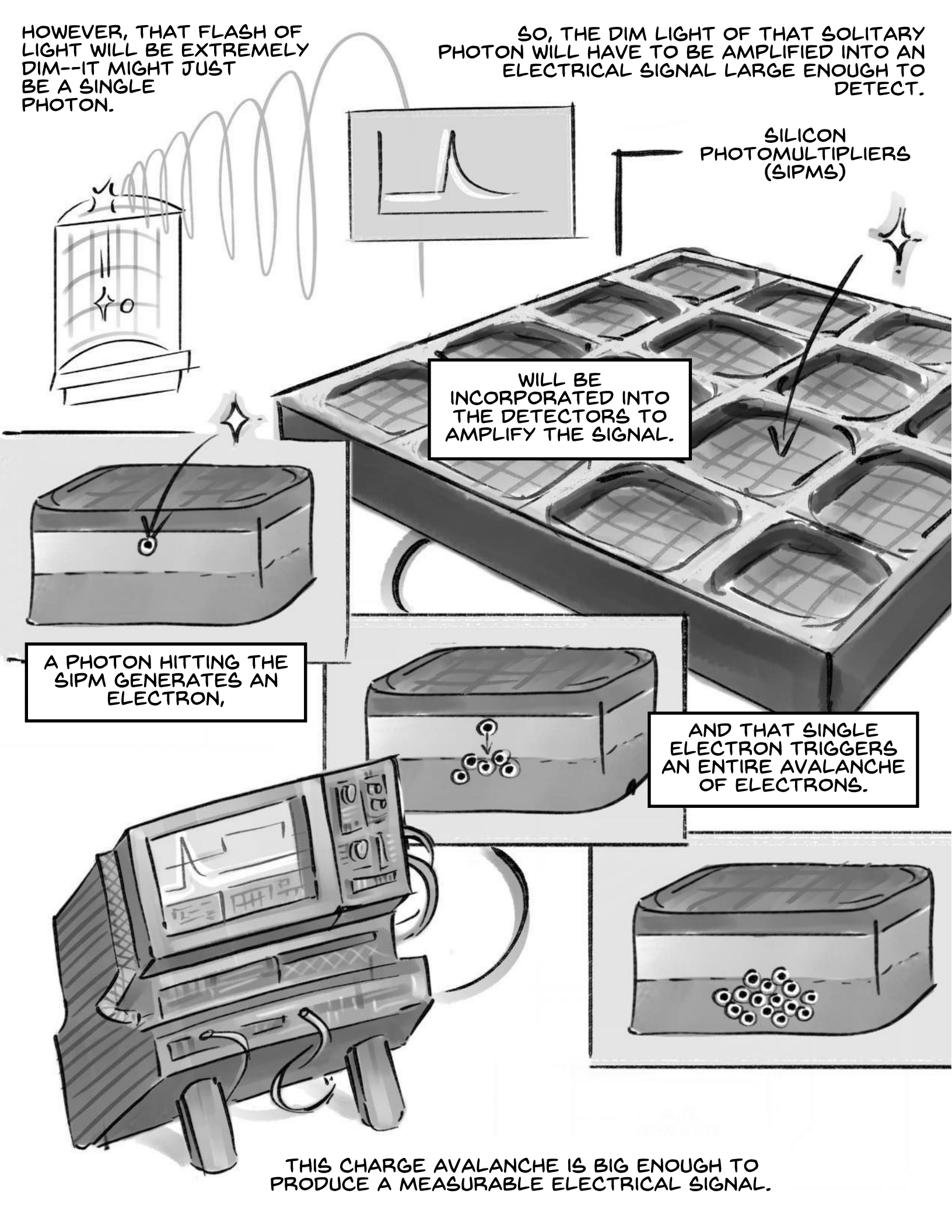
SILICON PHOTOMULTIPLIERS (SIPMS)

WILL BE INCORPORATED INTO THE DETECTORS TO AMPLIFY THE SIGNAL.

A PHOTON HITTING THE SIPM GENERATES AN ELECTRON,

AND THAT SINGLE ELECTRON TRIGGERS AN ENTIRE AVALANCHE OF ELECTRONS.

THIS CHARGE AVALANCHE IS BIG ENOUGH TO PRODUCE A MEASURABLE ELECTRICAL SIGNAL.



LIKE ANY DETECTOR, THE SIPMS ARE SUBJECT TO BACKGROUND NOISE.

THEY CAN EVEN GENERATE FALSE SIGNALS WITHIN THEMSELVES;

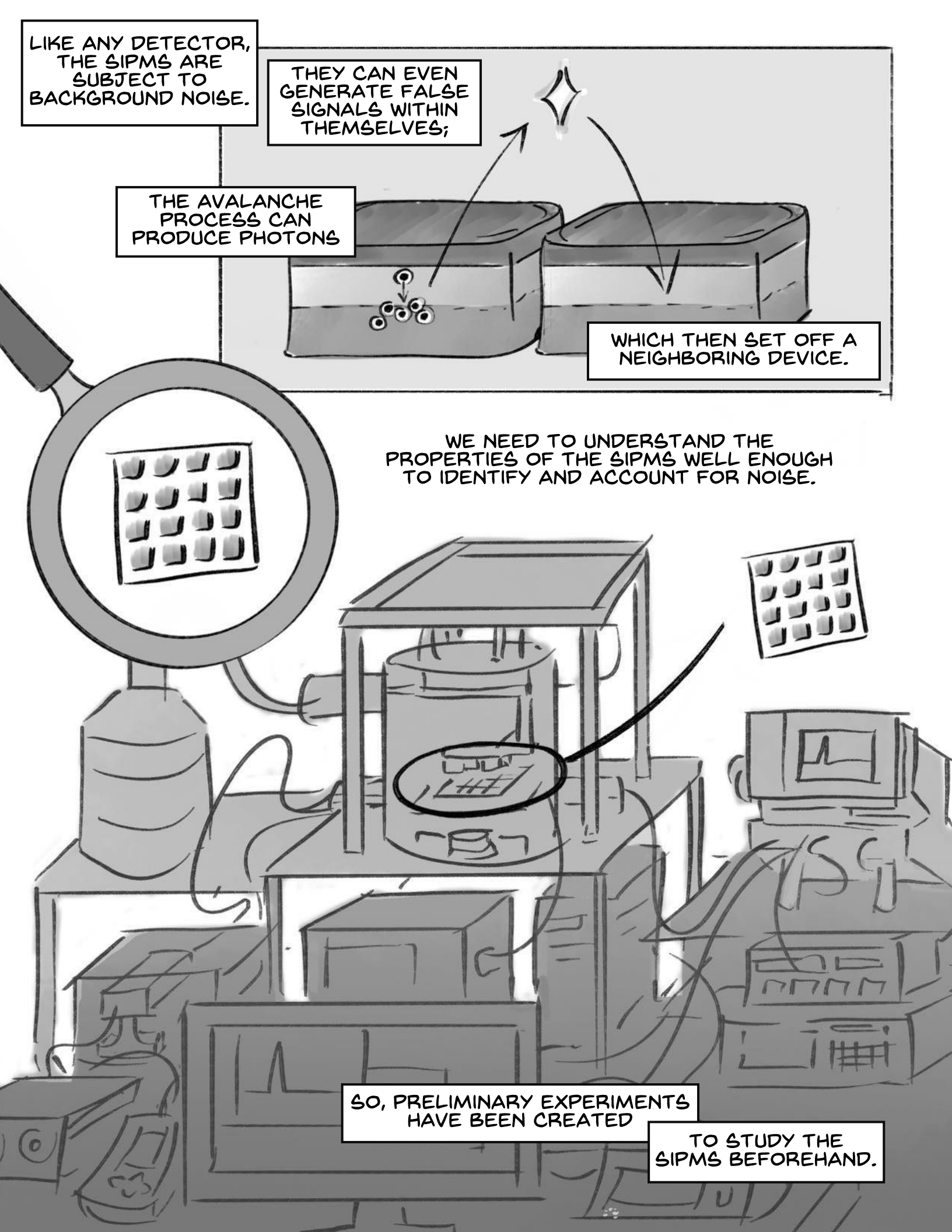
THE AVALANCHE PROCESS CAN PRODUCE PHOTONS

WHICH THEN SET OFF A NEIGHBORING DEVICE.

WE NEED TO UNDERSTAND THE PROPERTIES OF THE SIPMS WELL ENOUGH TO IDENTIFY AND ACCOUNT FOR NOISE.

SO, PRELIMINARY EXPERIMENTS HAVE BEEN CREATED

TO STUDY THE SIPMS BEFOREHAND.



THIS IS WHERE MY OWN RESEARCH COMES IN. IN THIS EXPERIMENT,

A LASER

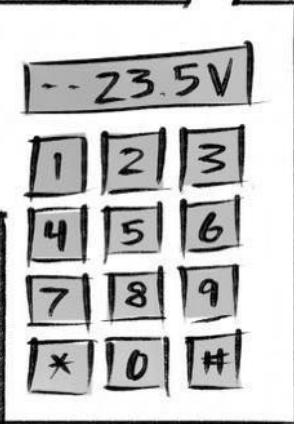
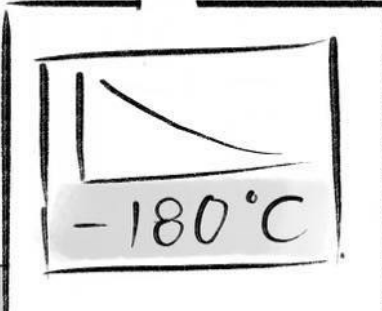
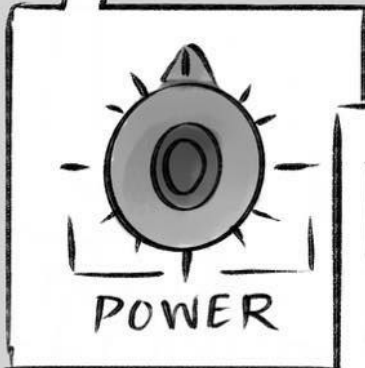
AND PRODUCING A SIGNAL

AT A
SIPM,

TRIGGERING
AVALANCHES

FIRES PHOTONS

THAT IS READ
OUT BY AN
OSCILLOSCOPE.

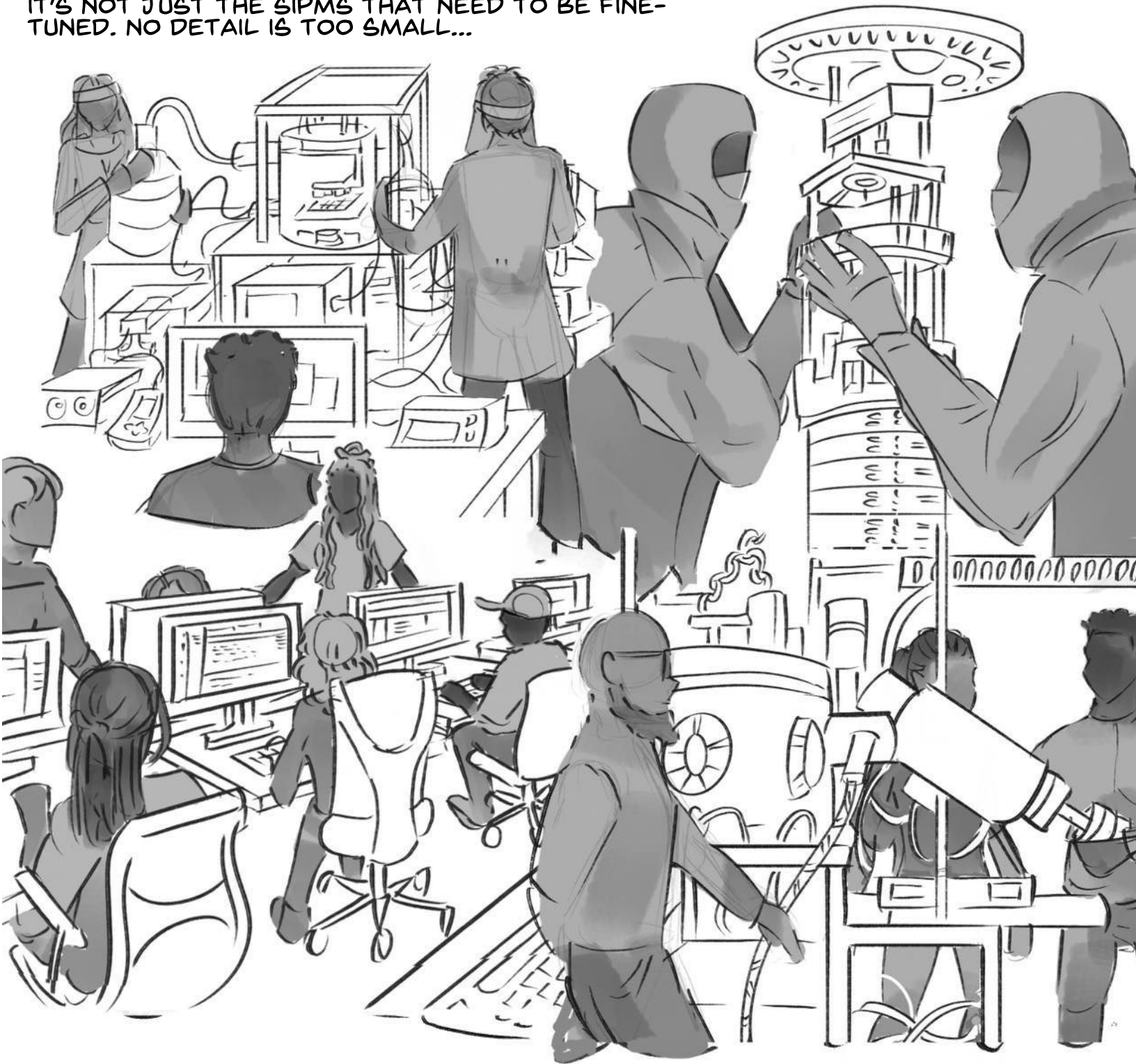


BASED ON MEASUREMENTS LIKE THESE, SCIENTISTS ARE BUILDING COMPUTER MODELS OF THE SIPMS TO SIMULATE DETECTION EVENTS, SO THEY KNOW WHAT TO EXPECT.

BY ALTERING SETTINGS AND MEASURING HOW THE SIGNAL RESPONDS, I CAN IMPROVE MY UNDERSTANDING OF NOISE IN THE SIPM.

ALL THIS RESEARCH WILL BE USED TO FINE-TUNE THE SETTINGS OF THE SIPMS FOR THE FINAL EXPERIMENT.

IT'S NOT JUST THE SIPMS THAT NEED TO BE FINE-TUNED. NO DETAIL IS TOO SMALL...



... WHEN YOU'RE SEARCHING FOR A PROCESS THAT HAS NEVER BEEN OBSERVED BEFORE. IF YOU MISS IT, YOU MAY NOT GET ANOTHER CHANCE.

EVENTUALLY, THROUGH THE COLLECTIVE EFFORTS OF HUNDREDS OF PEOPLE AROUND THE WORLD, THE FINAL EXPERIMENT WILL COME TOGETHER.

WHAT WILL IT TELL US ABOUT THE NATURE OF THE UNIVERSE?

ACKNOWLEDGEMENTS

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ABOUT ME

I AM A MASTER'S STUDENT IN PHYSICAL GEOGRAPHY, WITH A BACHELOR'S IN CHEMISTRY. I LOVE ART AND SCIENCE COMMUNICATION, SO I ENJOY FINDING WAYS TO COMBINE THEM TOGETHER (LIKE THIS COMIC!)

I PUT TOGETHER THIS PROJECT AFTER A SUMMER OF CROSS-DISCIPLINARY PARTICLE PHYSICS RESEARCH AT TRIUMF IN VANCOUVER, BC, CANADA.

BROADLY, THE RESEARCH WAS AIMED TOWARDS THE DEVELOPMENT OF NEXO, THE EXPERIMENT THAT WAS DISCUSSED IN THE COMIC.

CONNECT WITH ME
(ABOUT ART, SCIENCE OR BOTH!)

DANIKAJW ON INSTAGRAM
EMAIL DANIKA.WATSON@QUEENSU.CA
DANIKA WATSON ON LINKEDIN

