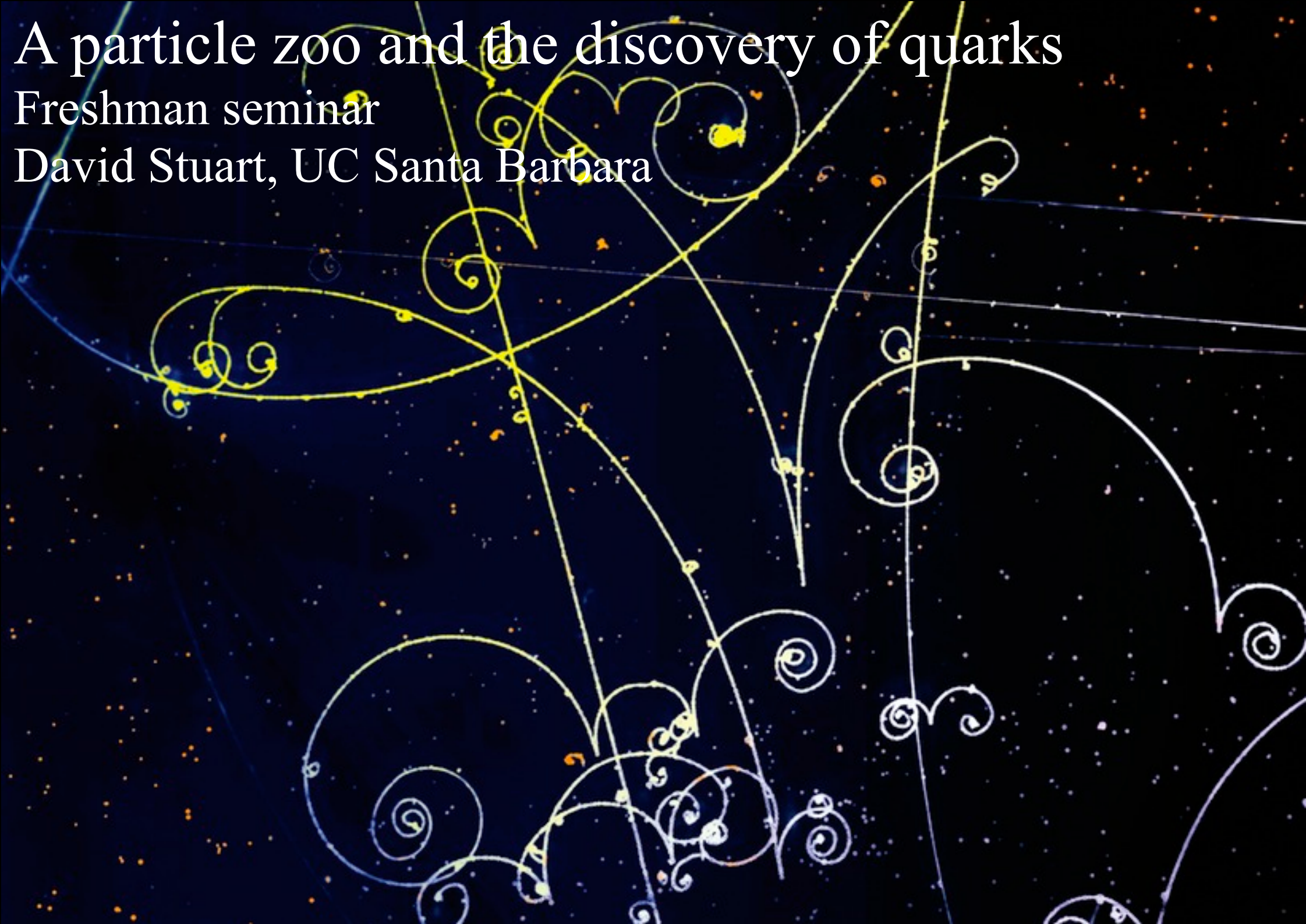
A particle zoo and the discovery of quarks

Freshman seminar

David Stuart, UC Santa Barbara



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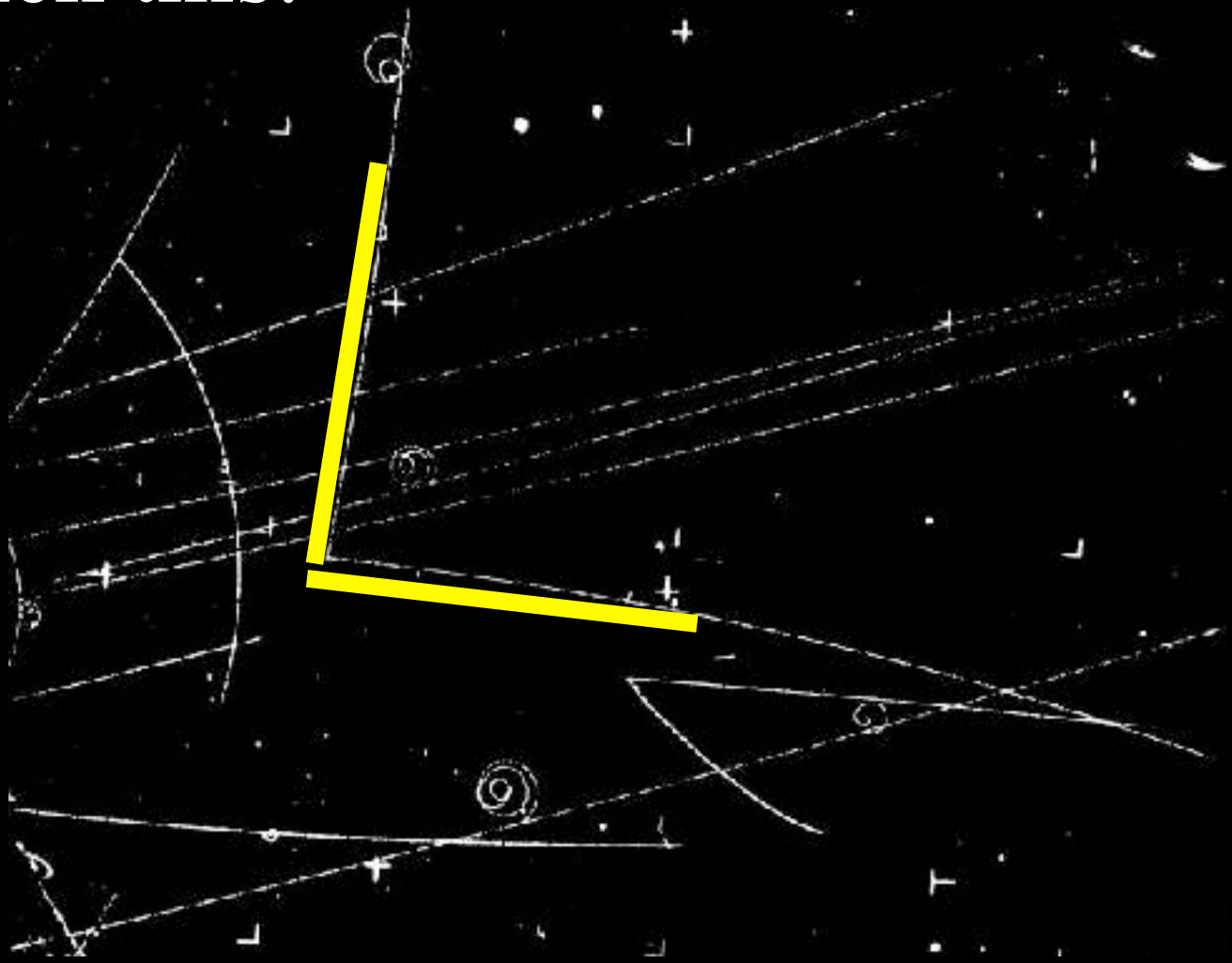

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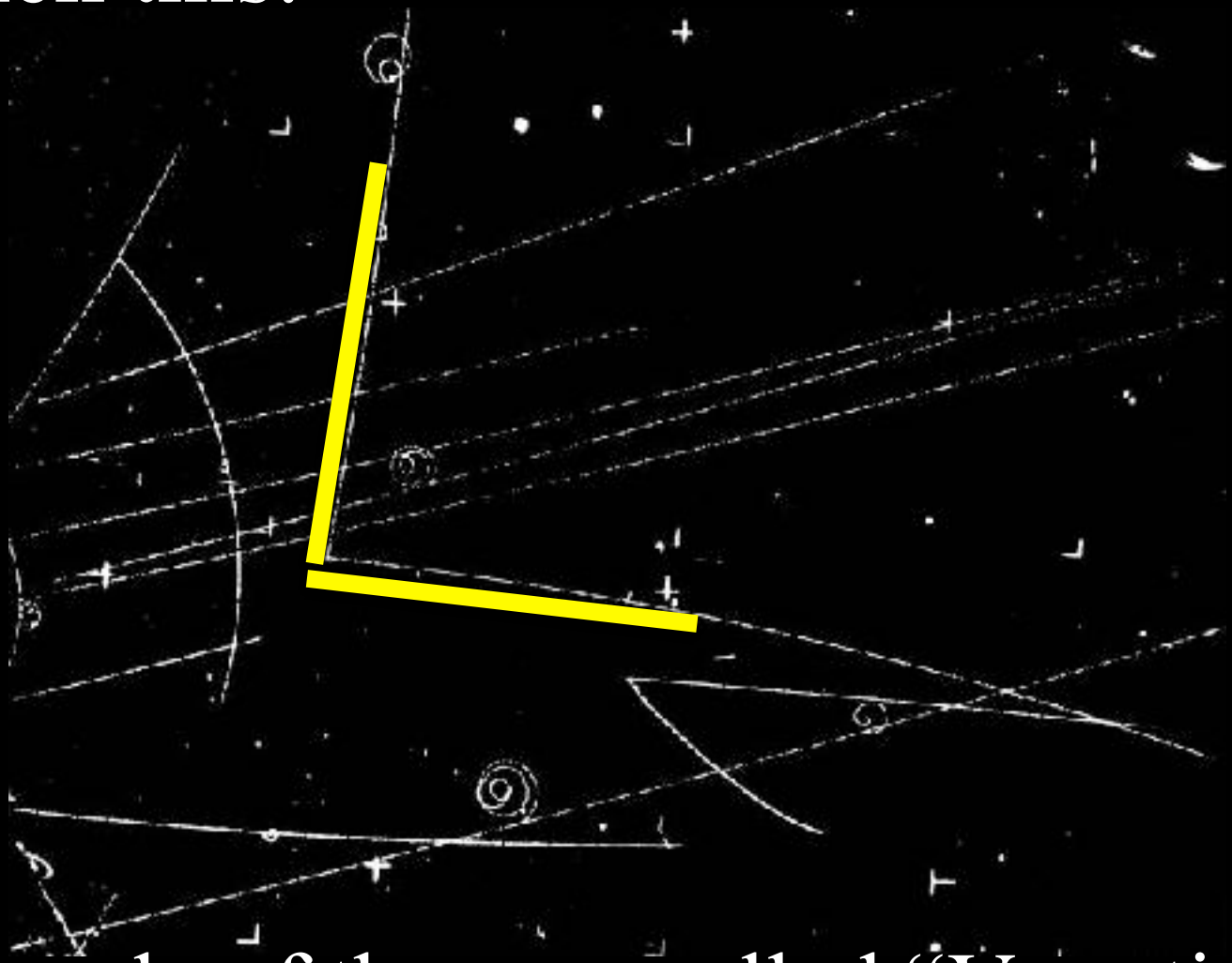

Several example of these so called “V particles” where seen in cloud chambers exposed to cosmic rays

What could this be?
How to test possibilities?

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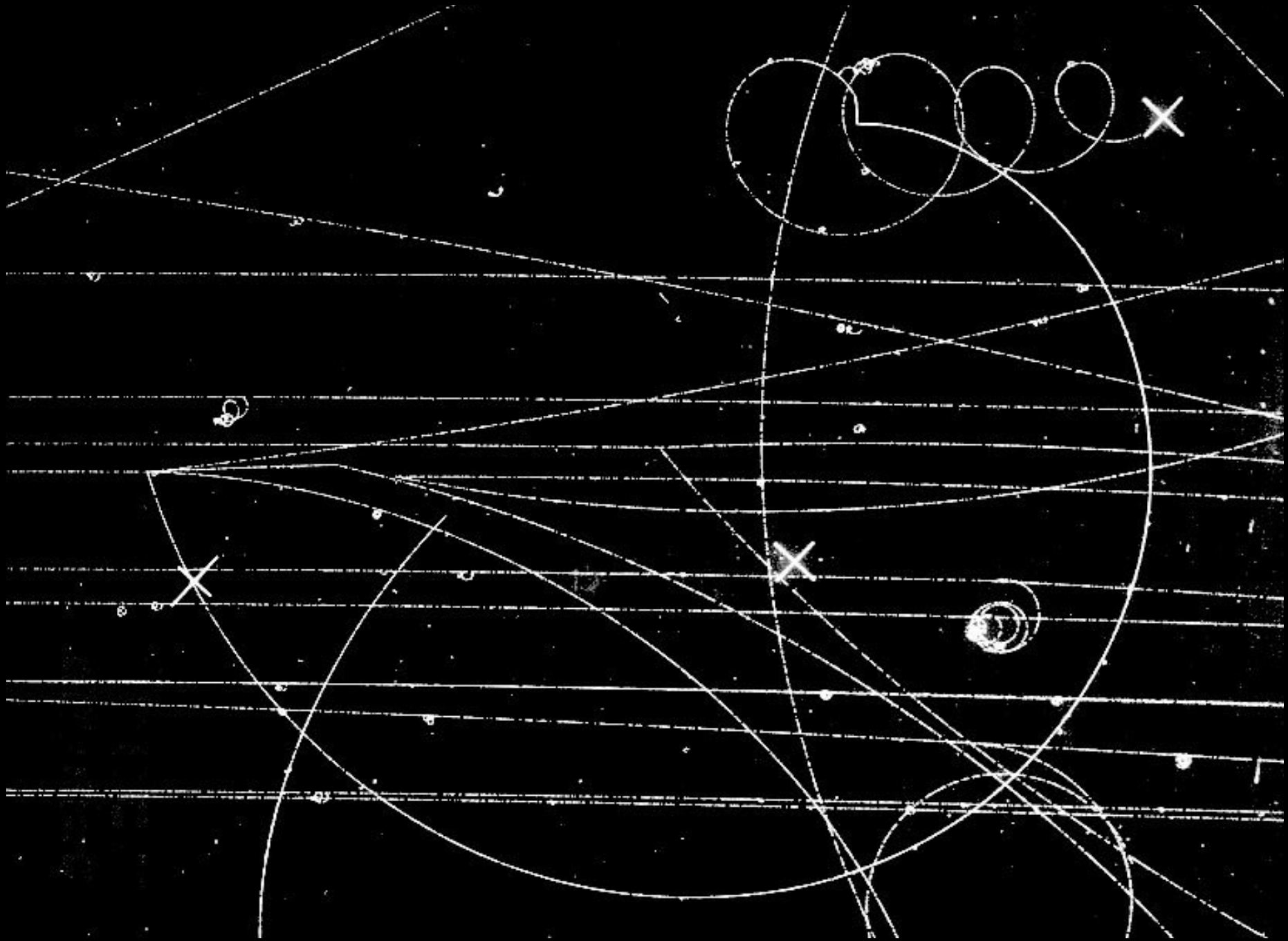
Two particles in the V are opposite charge.

What could this be?
How to test possibilities?

Two particles in the V are opposite charge.
Ionization consistent with pions.

Eventually understood to be a new particle called the "kaon" or K^0 decaying to $\pi^+ \pi^-$

Lots of other stuff



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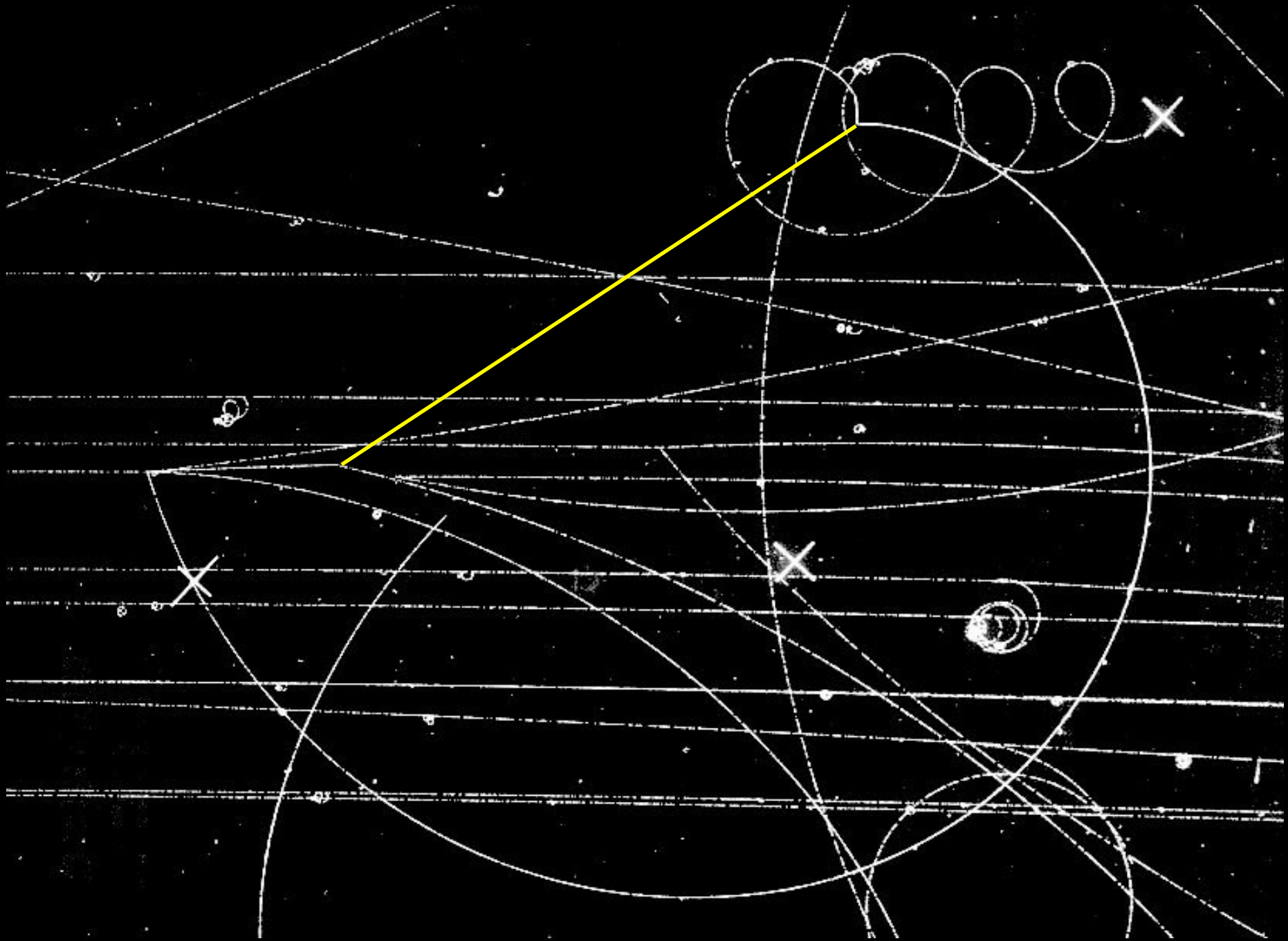

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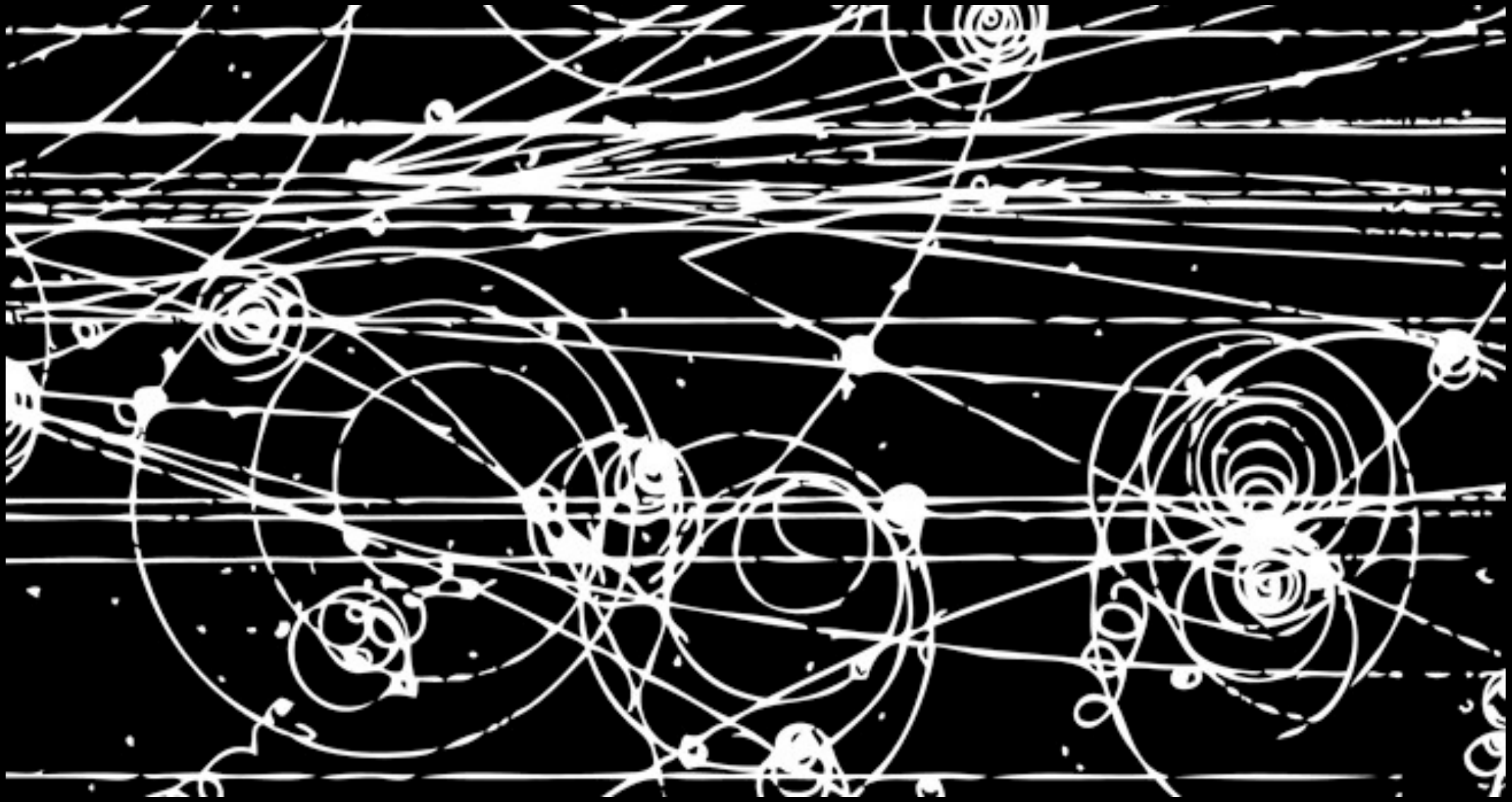

Lots of other stuff

So, how to study all this stuff?

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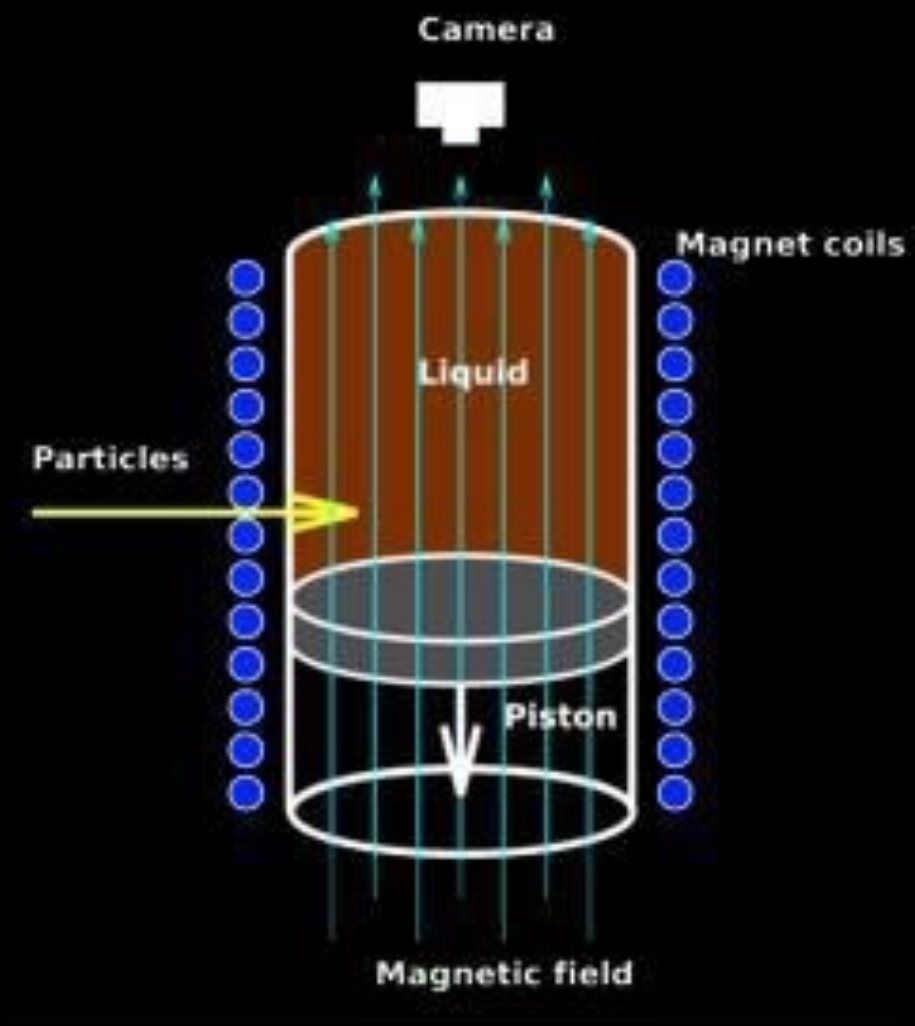
1. Better detectors
2. Controlled experiments
   cosmic rays exposures → beams of particles

Better detectors:
Cloud chamber → Emulsion → Bubble chamber



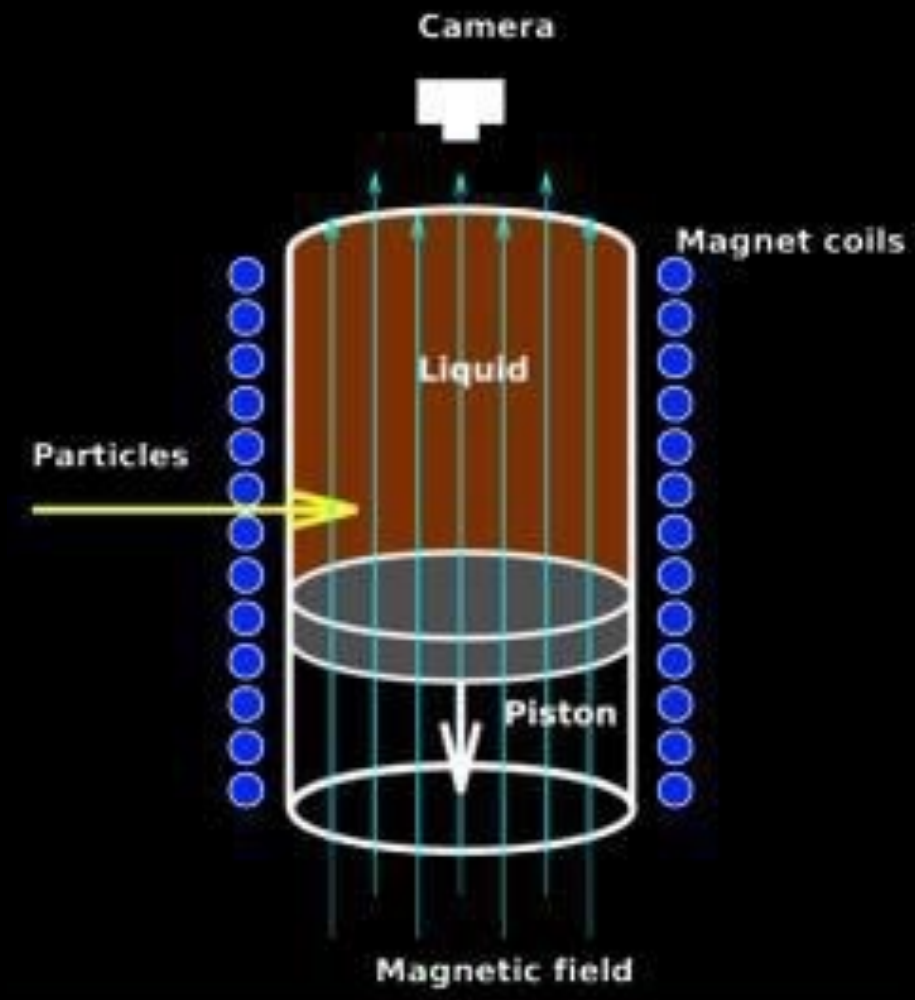
Rather than clouds forming on ions, bubbles form when pressure drops due to piston motion.

Trigger the piston with an electronic trigger,
e.g., Geiger counter.

Liquid being denser than gas gives denser, clearer trails.

Faster than emulsions.

Better detectors:
Cloud chamber → Emulsion → Bubble chamber



Example bubble chamber photo
What are these?

Controlled experiments with beams of particles
How do you make beams of particles?

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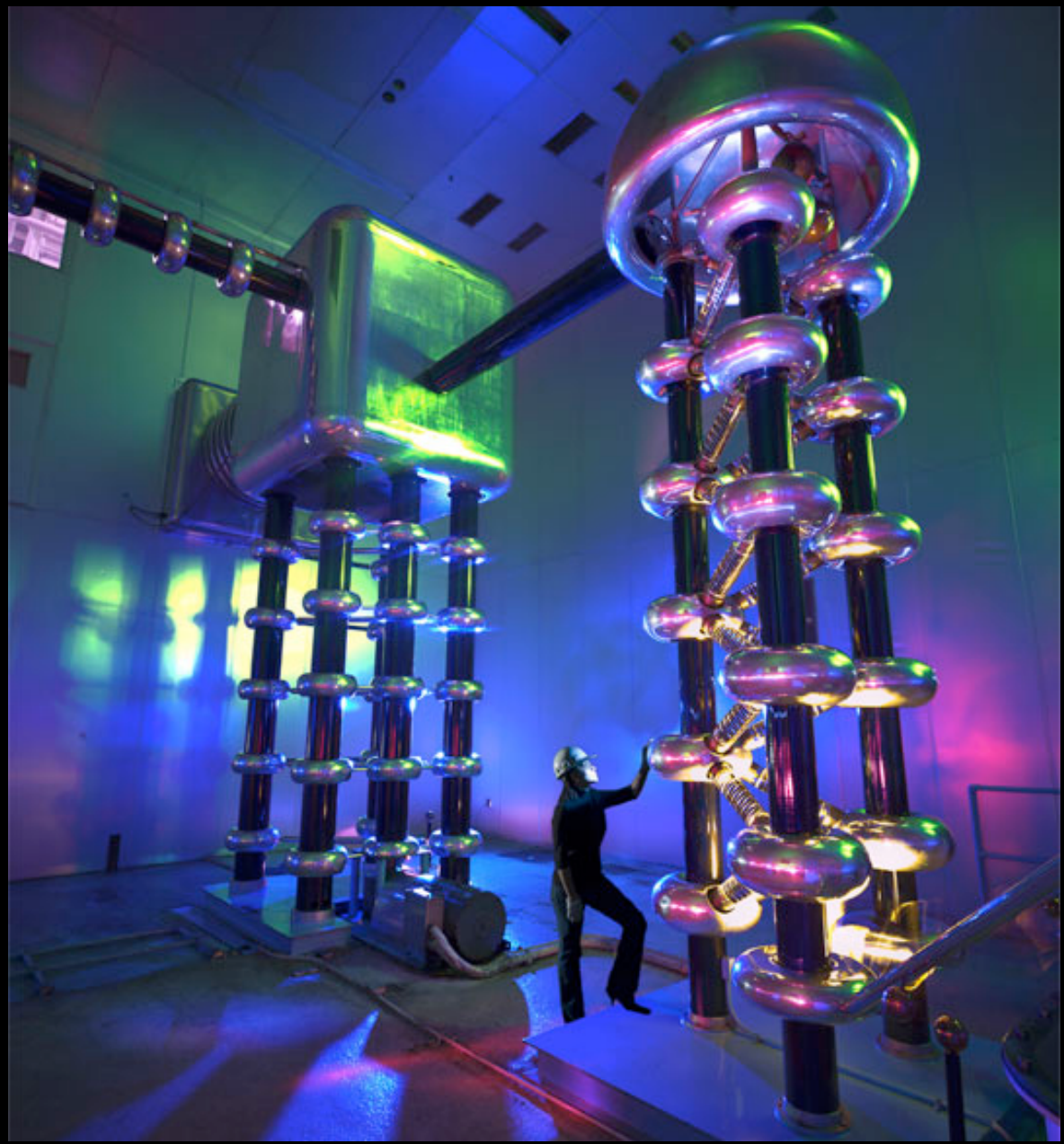
Cockroft-Walton produced nearly 1M volts to accelerate protons.

But need higher energy, so higher voltage.



Controlled experiments with beams of particles
How do you make beams of particles?

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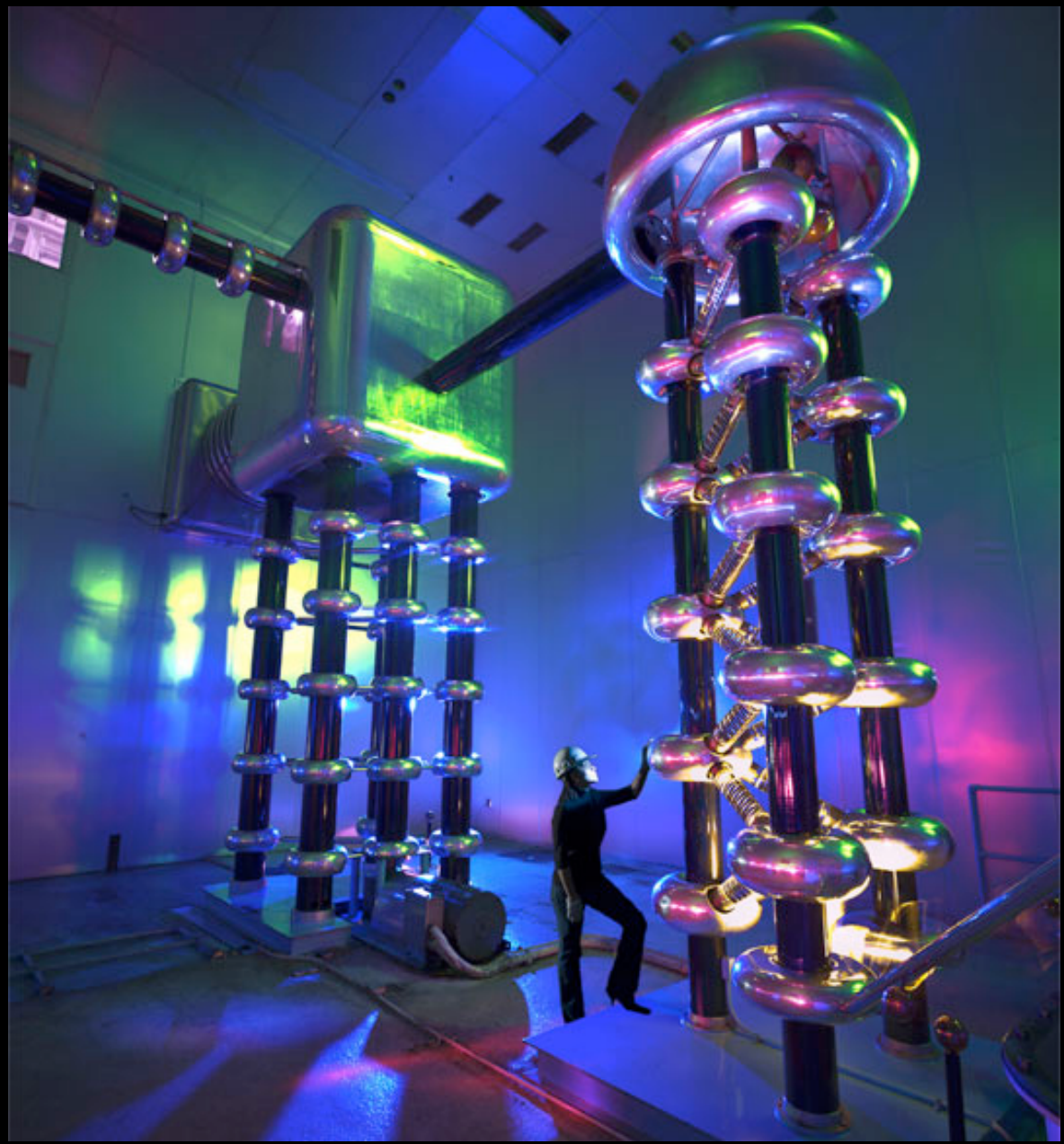
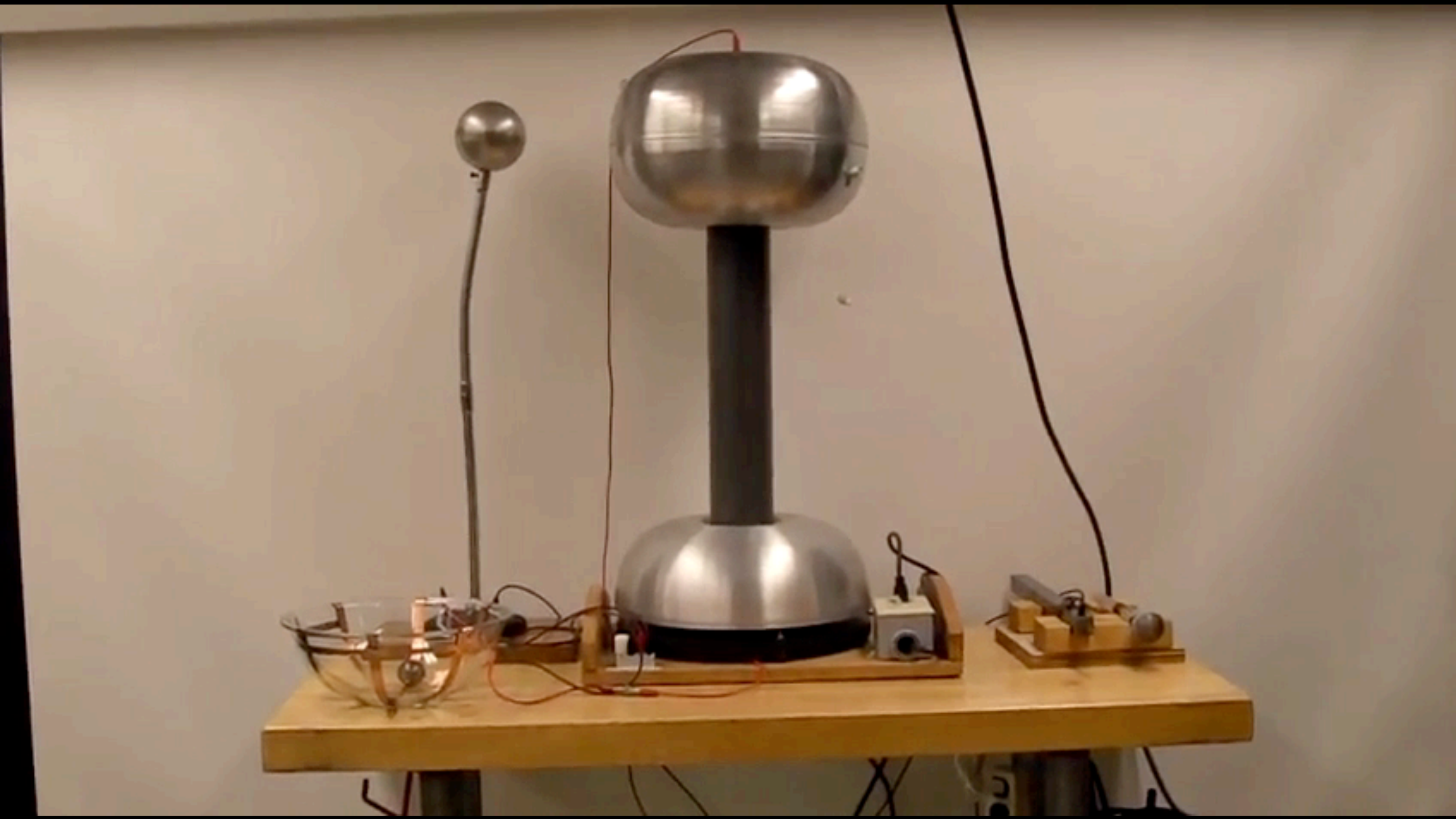
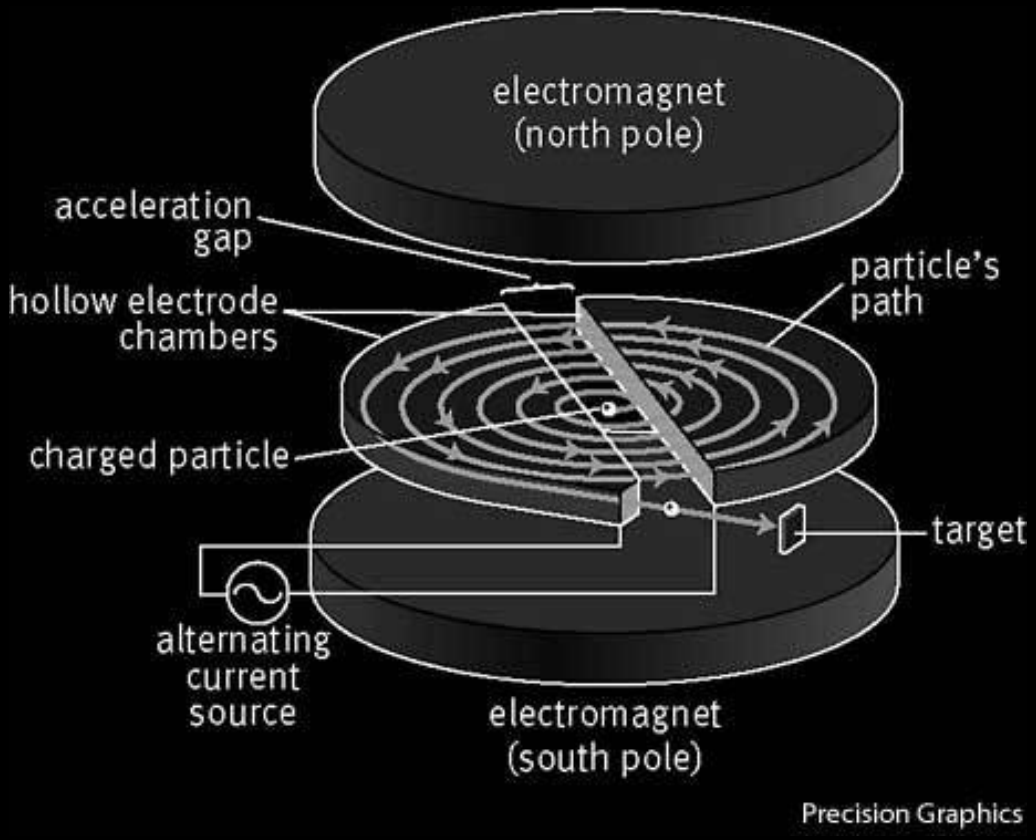
Give repeated kicks.

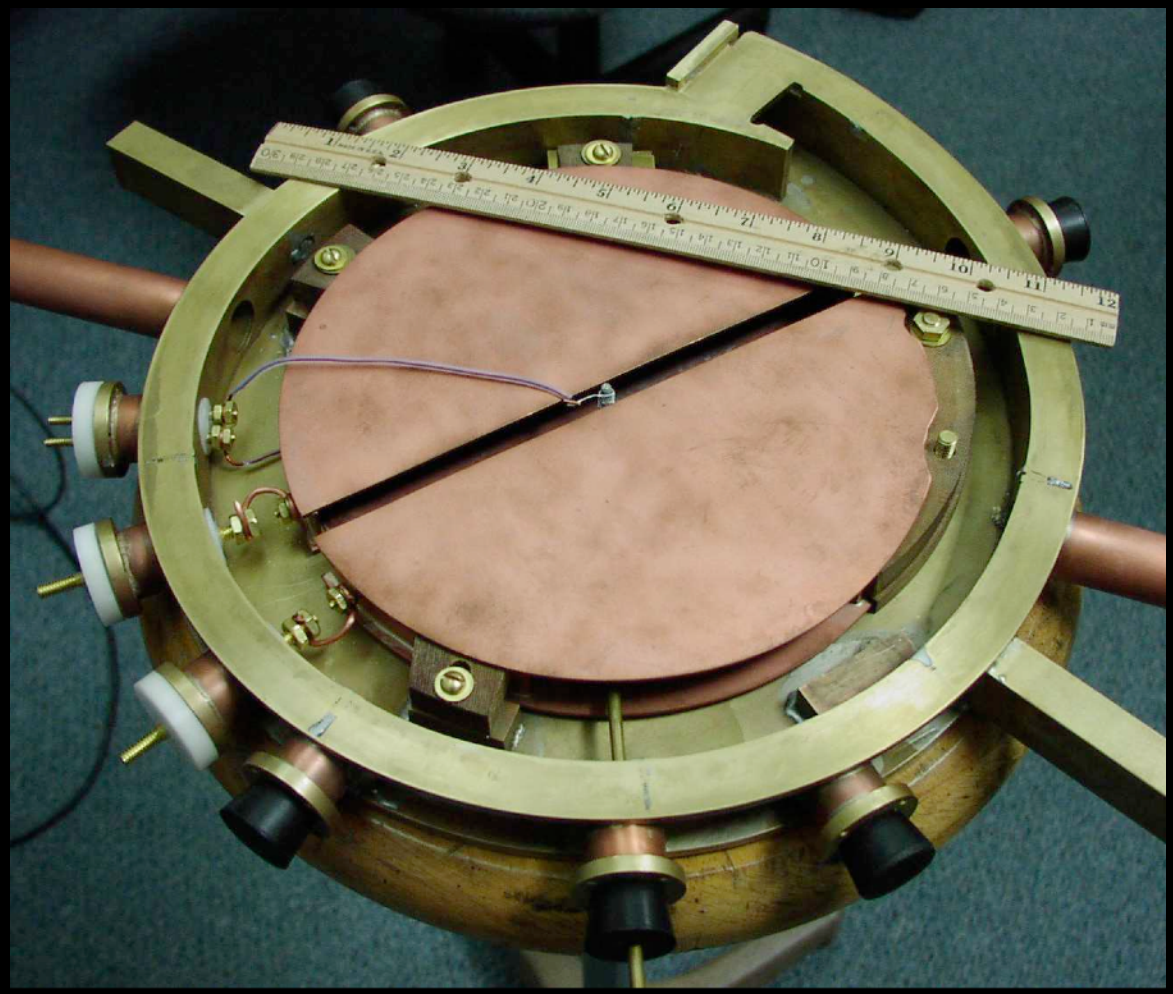


A simple example using a salad bowl



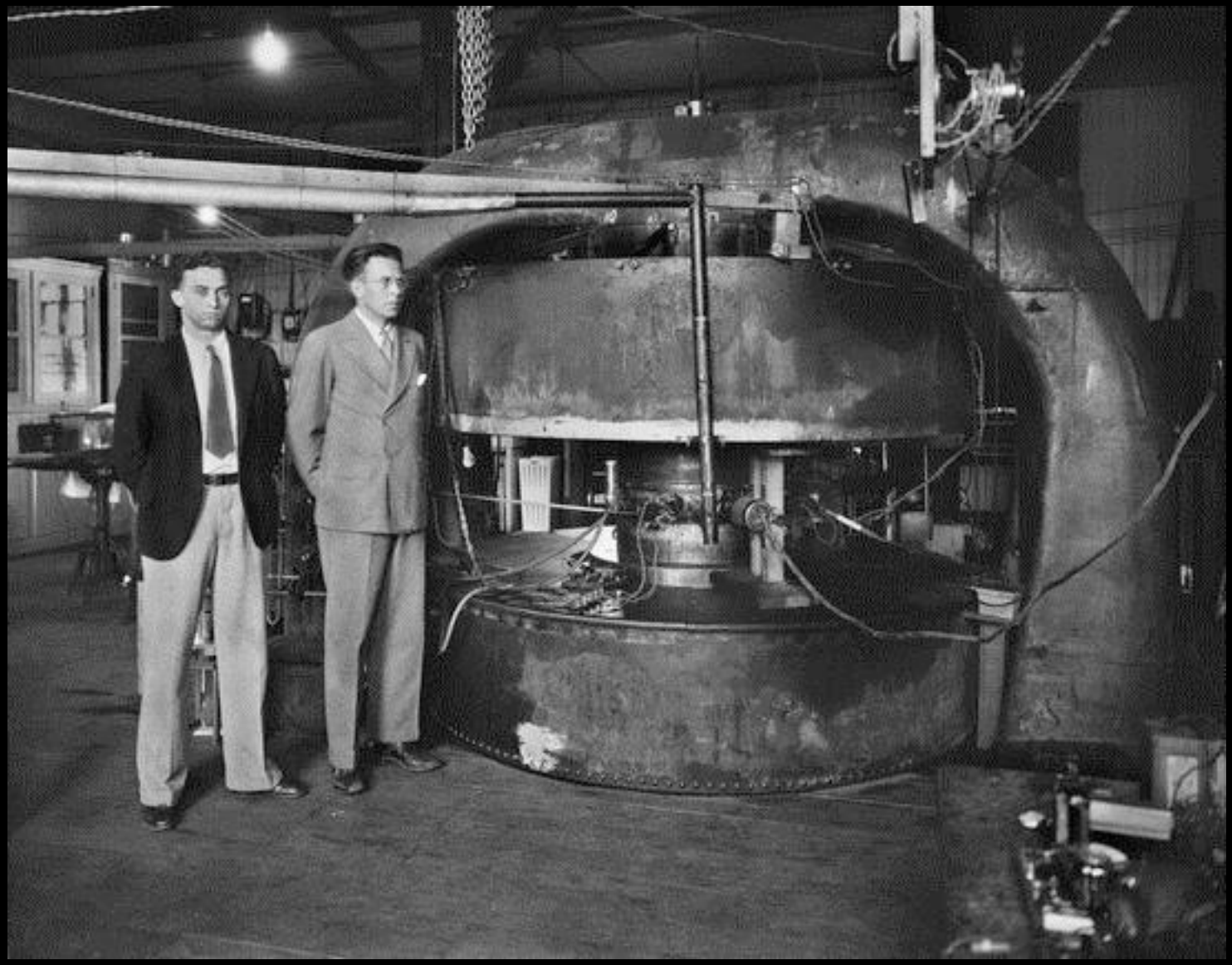
The cyclotron uses the same principle.
A magnetic field provides the confinement.
An alternating electric field provides the kicks.





The cyclotron was developed by Lawrence in 1931

Lawrence Berkeley National Laboratory at UC Berkeley



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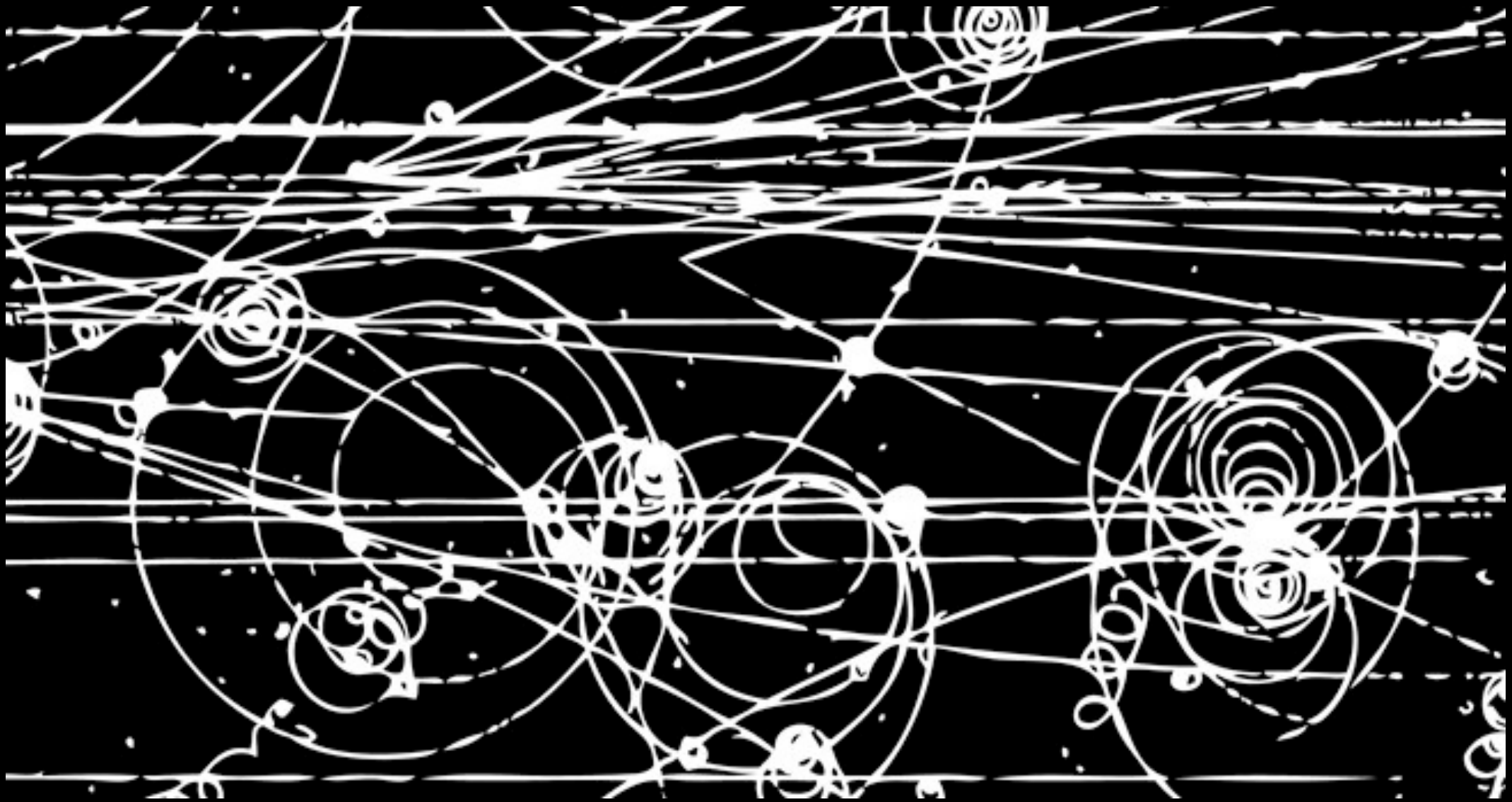
Lawrence Berkeley National Laboratory at UC Berkeley
Lawrence Hall of Science above it.

This is a bubble chamber image from a proton beam



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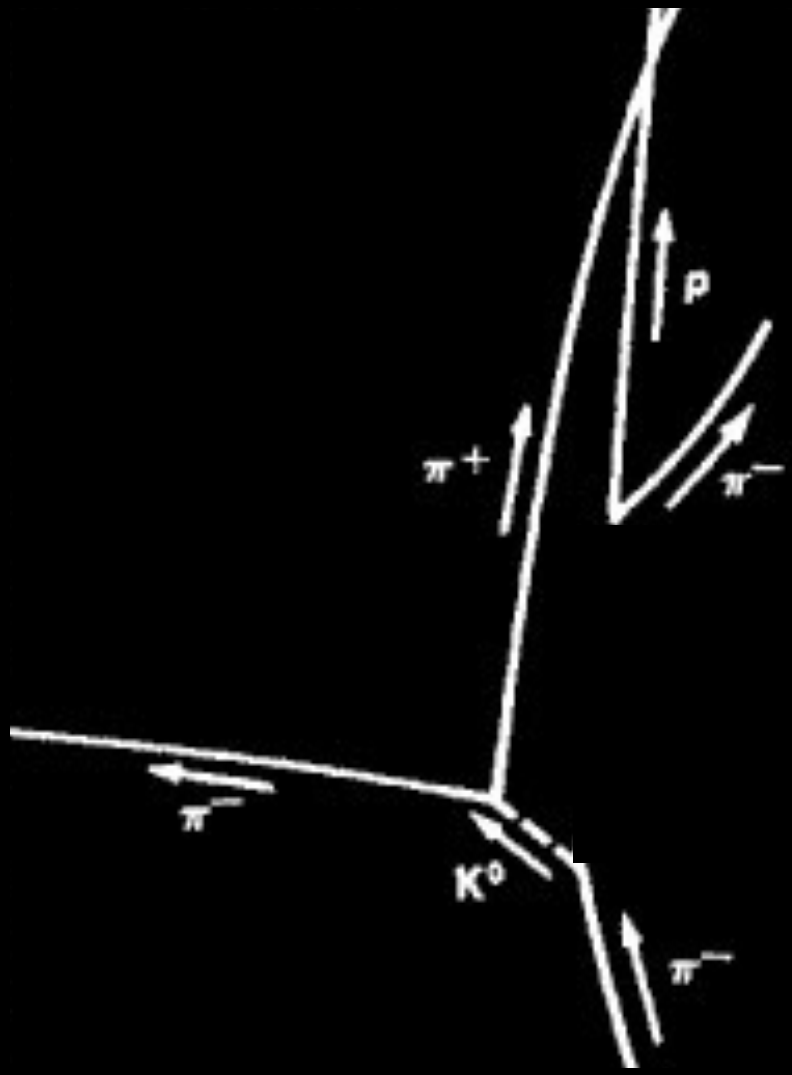

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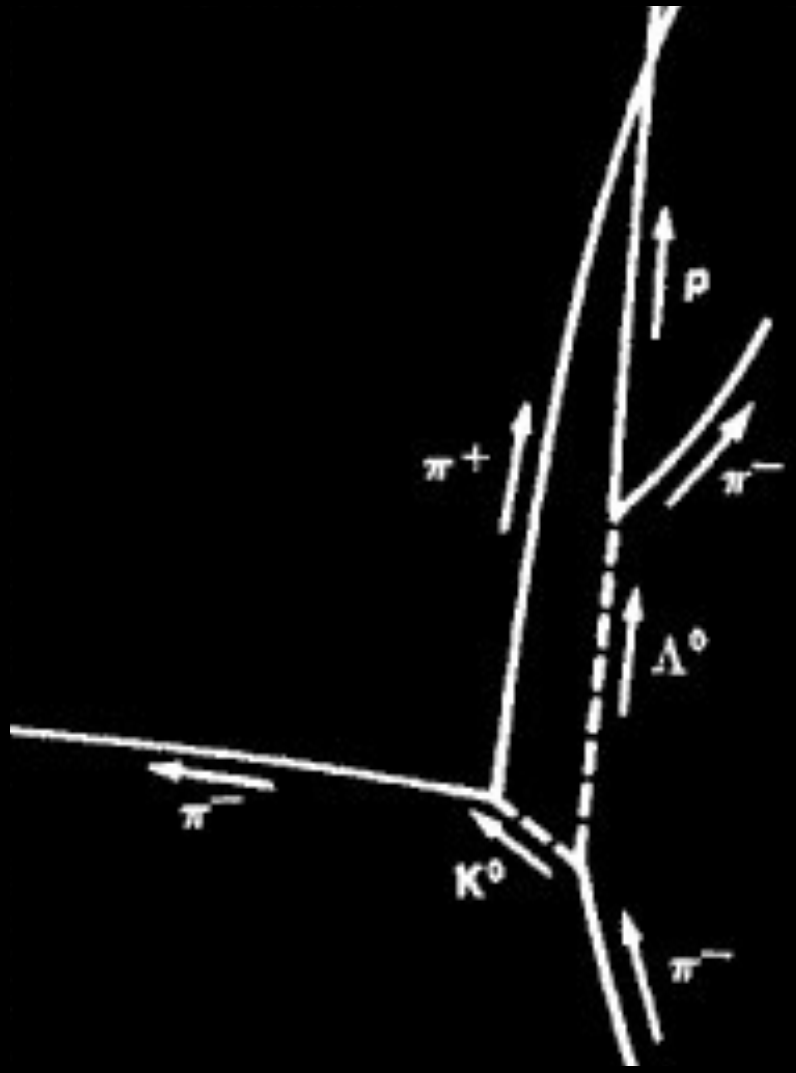
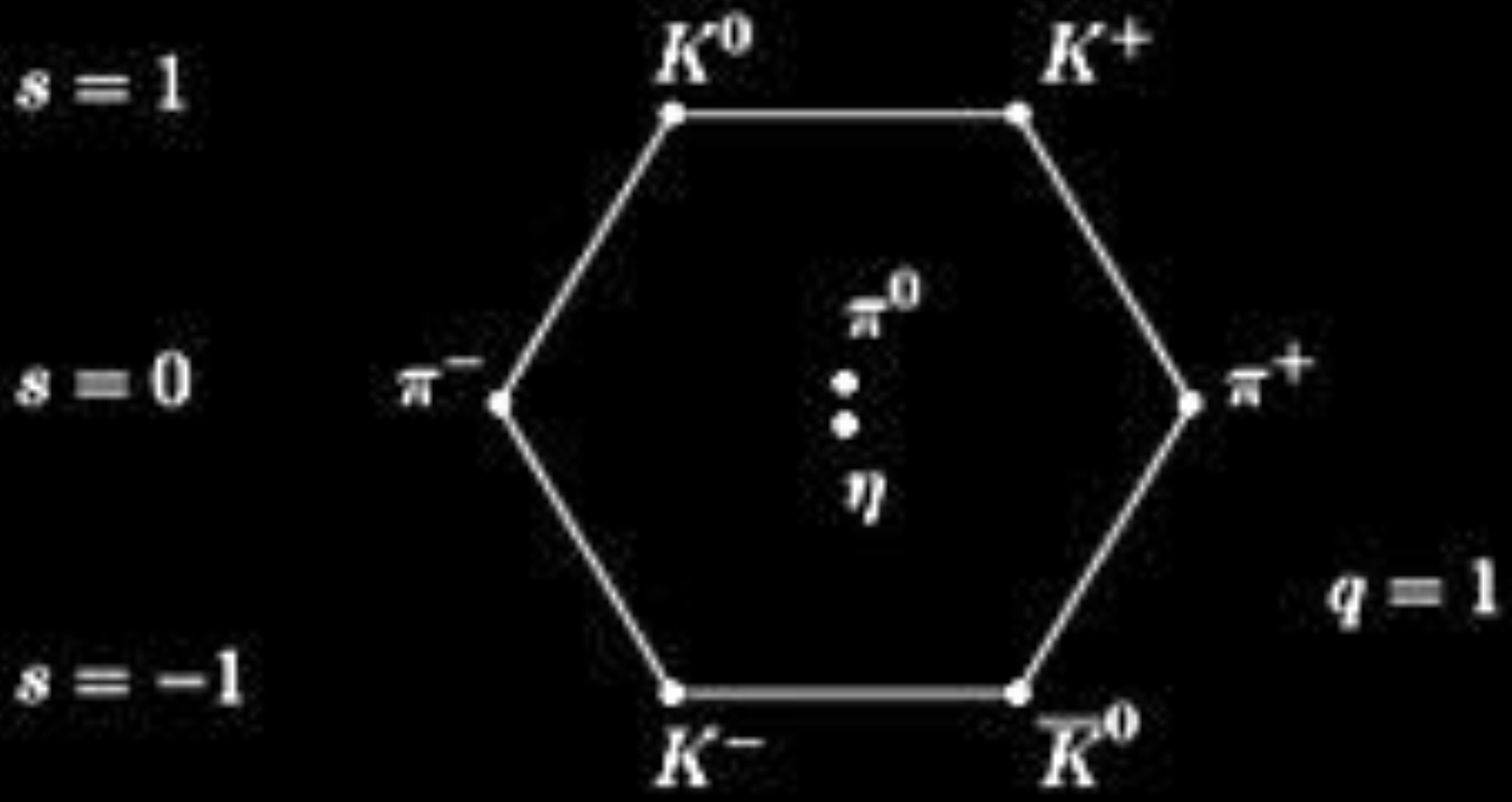


Many experiments with increasing energy proton beams and larger bubble chambers

15 foot liquid hydrogen bubble chamber
at Fermilab near Chicago

Began to see patterns and symmetry in the particle types wrt new "quantum numbers" like isospin & strangeness



Meson Octet

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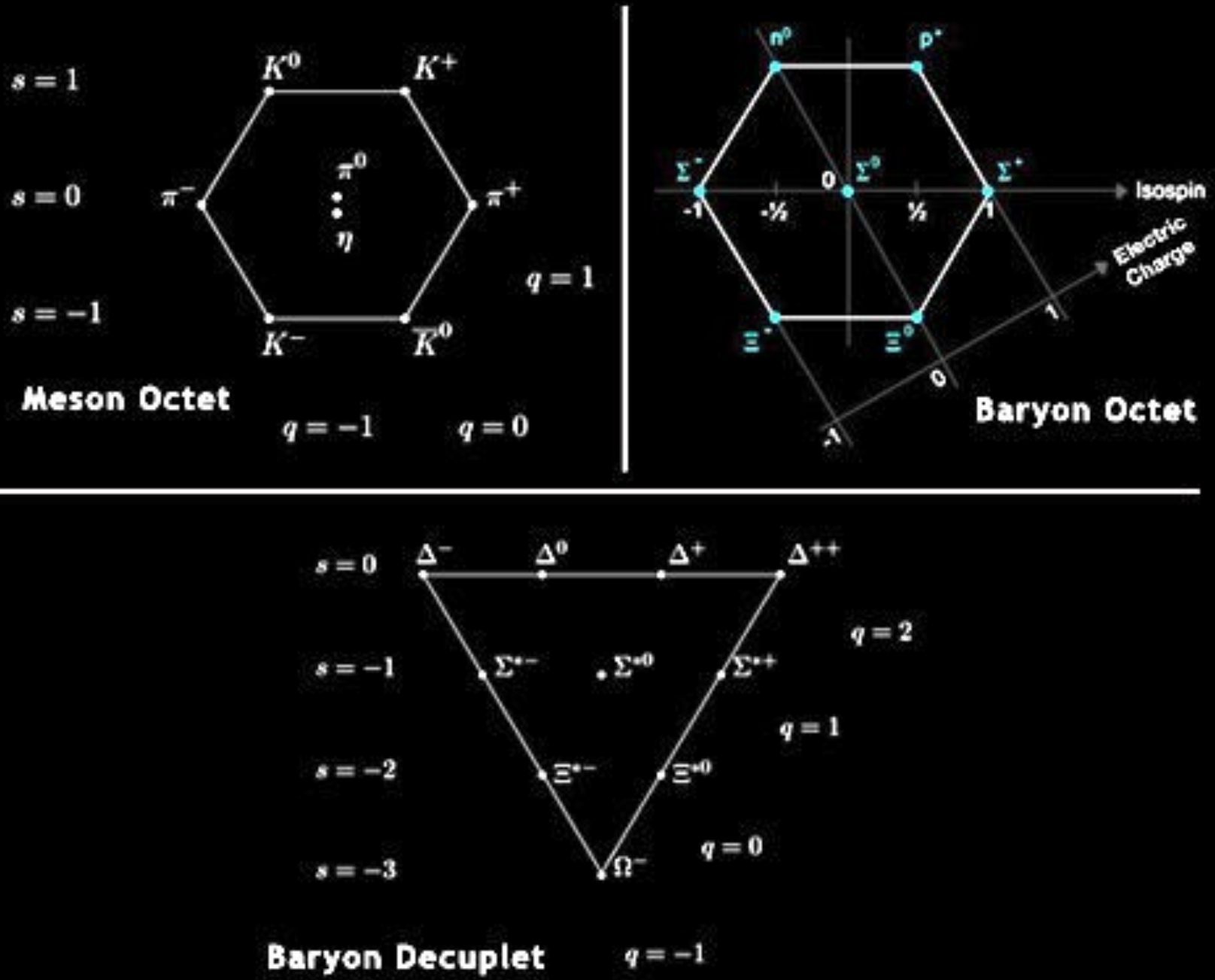

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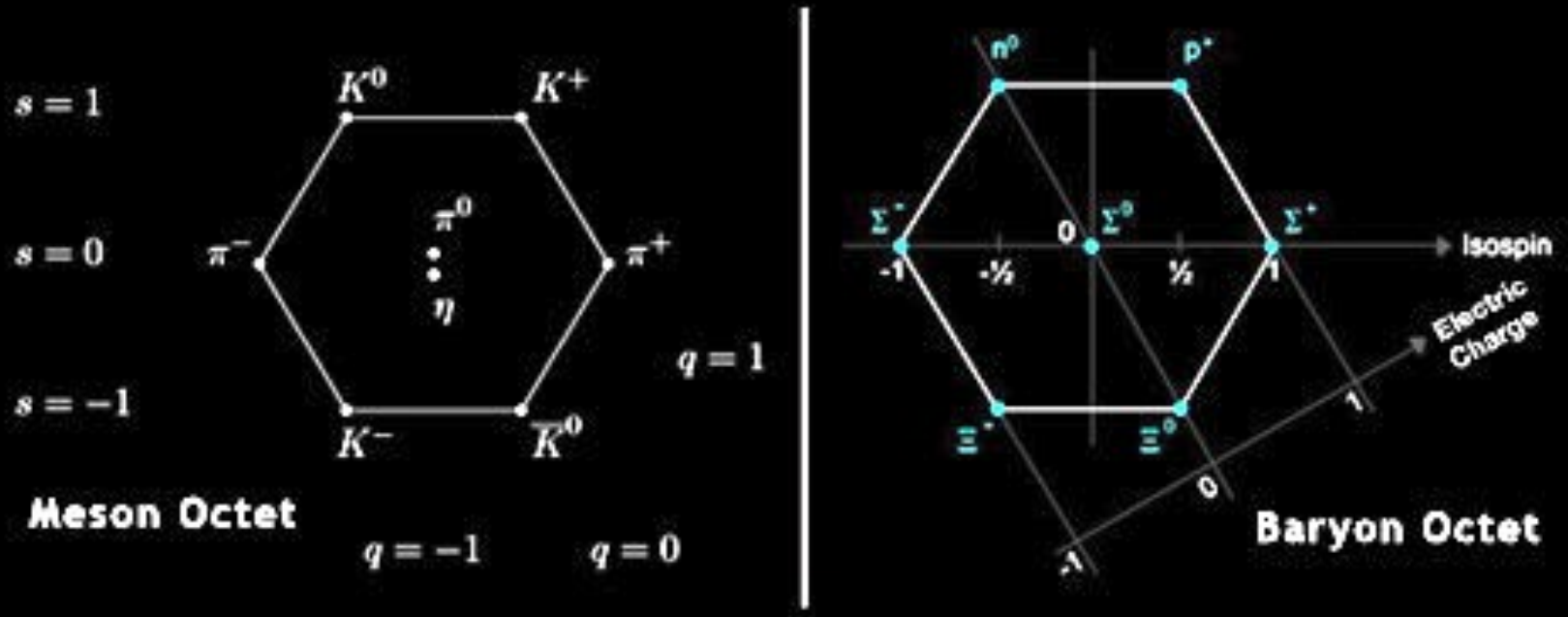

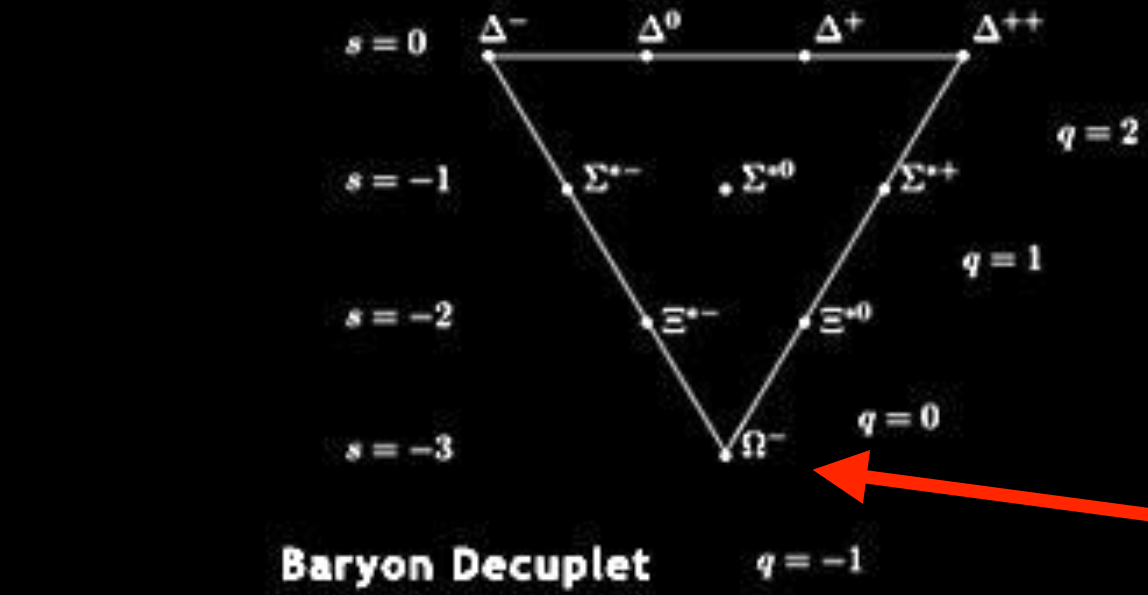

But this one was missing

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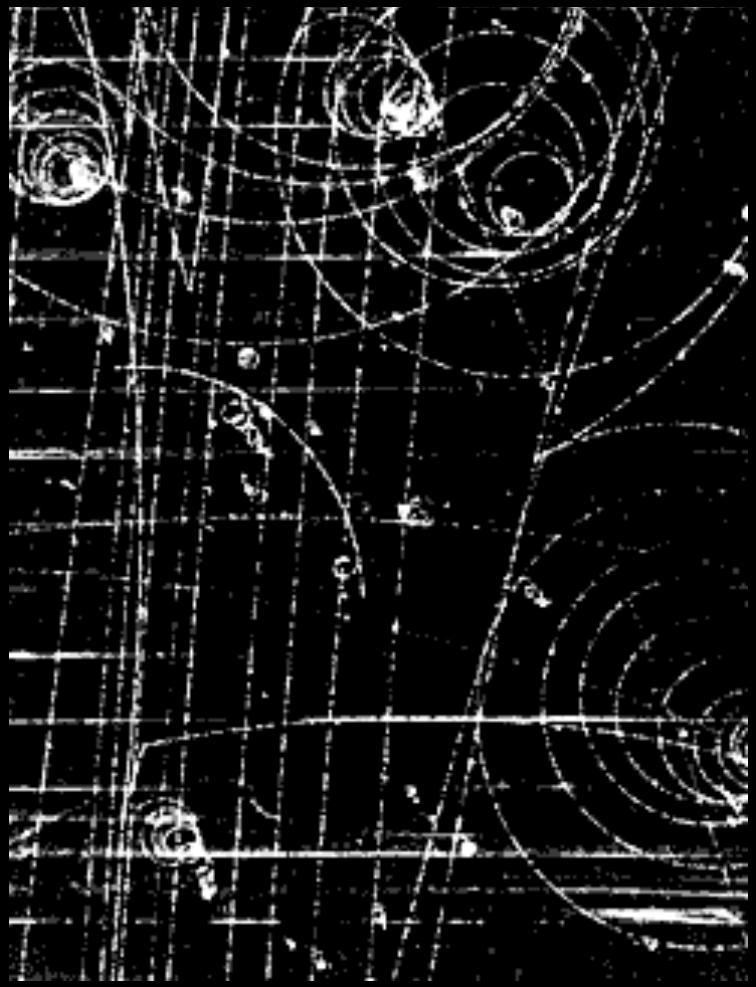
Discovery of the Omega minus



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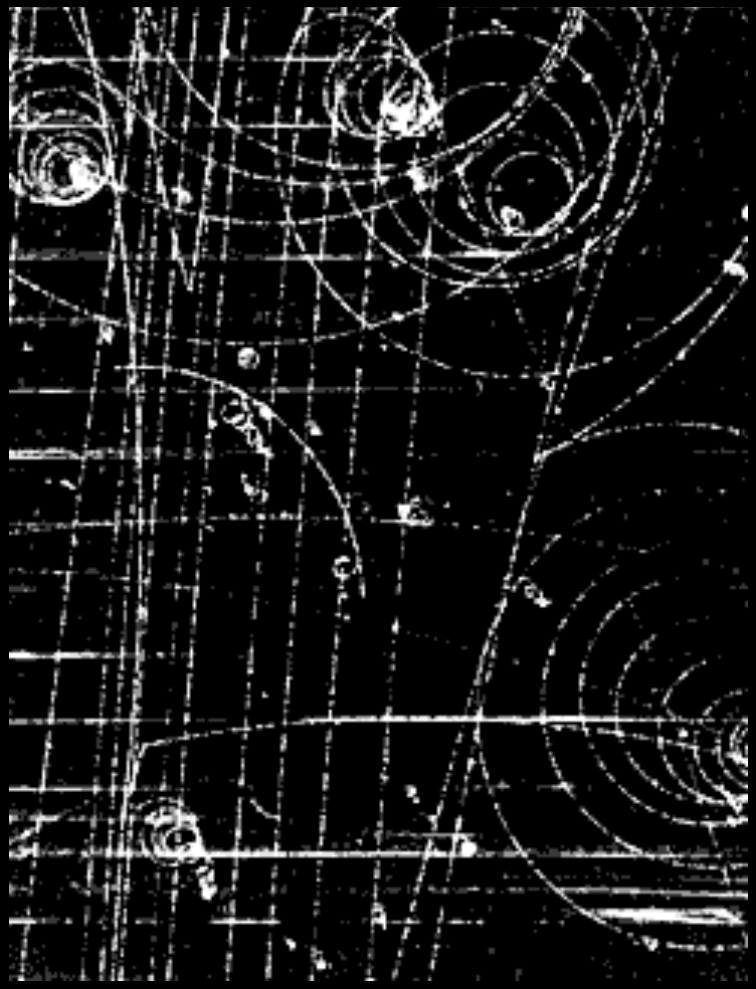

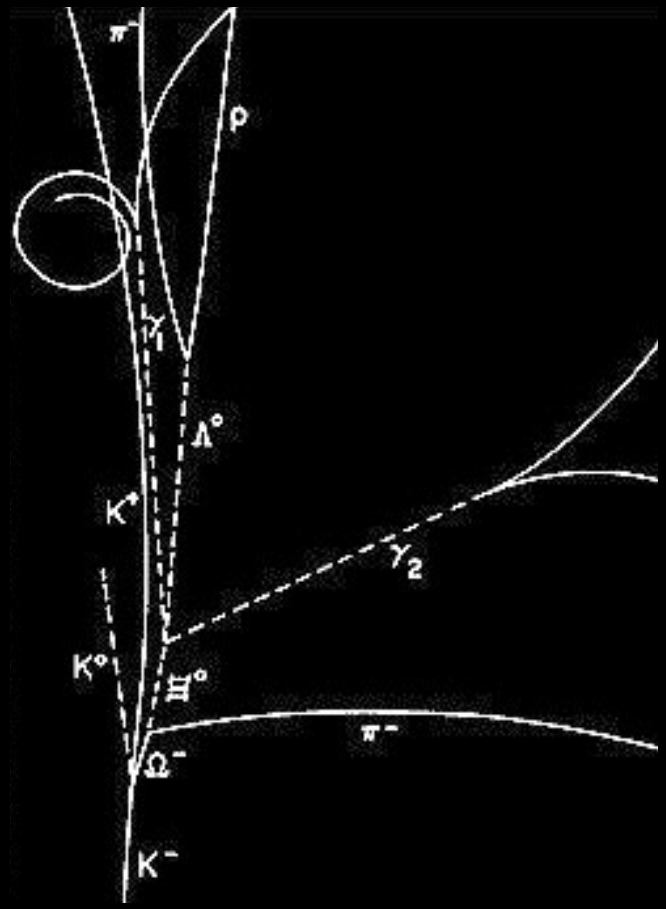

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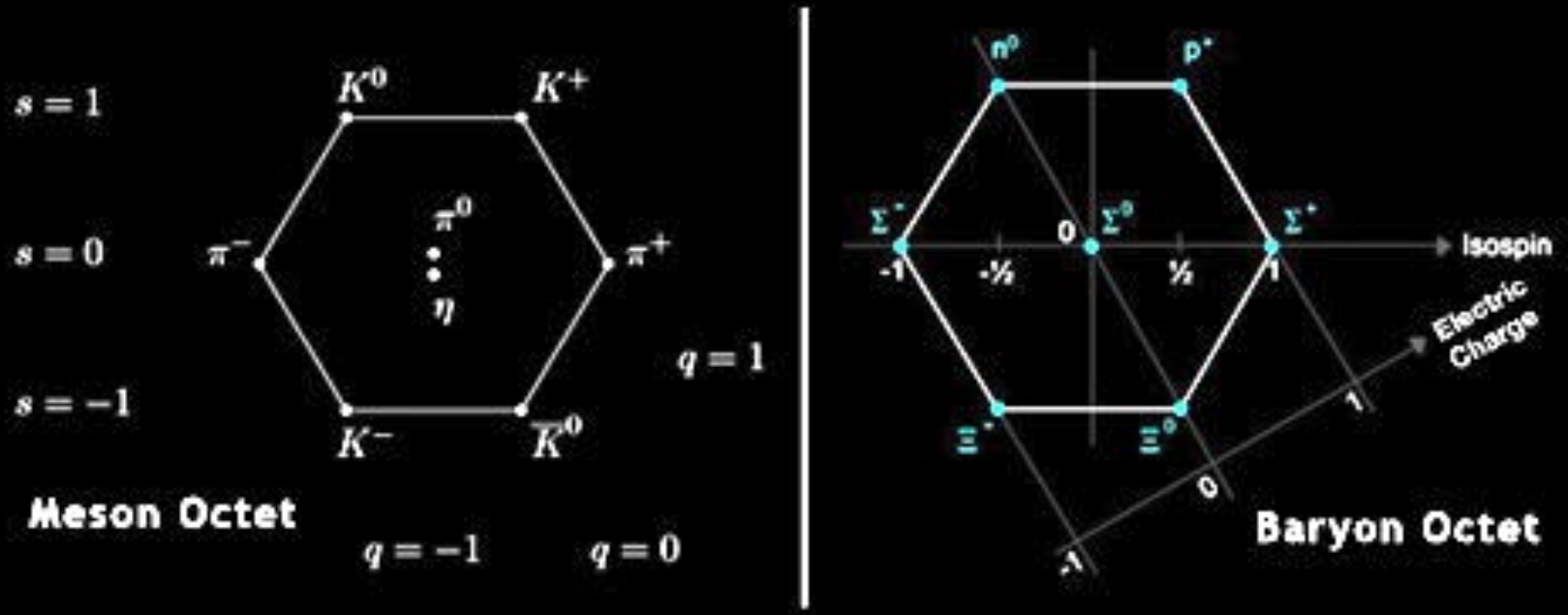
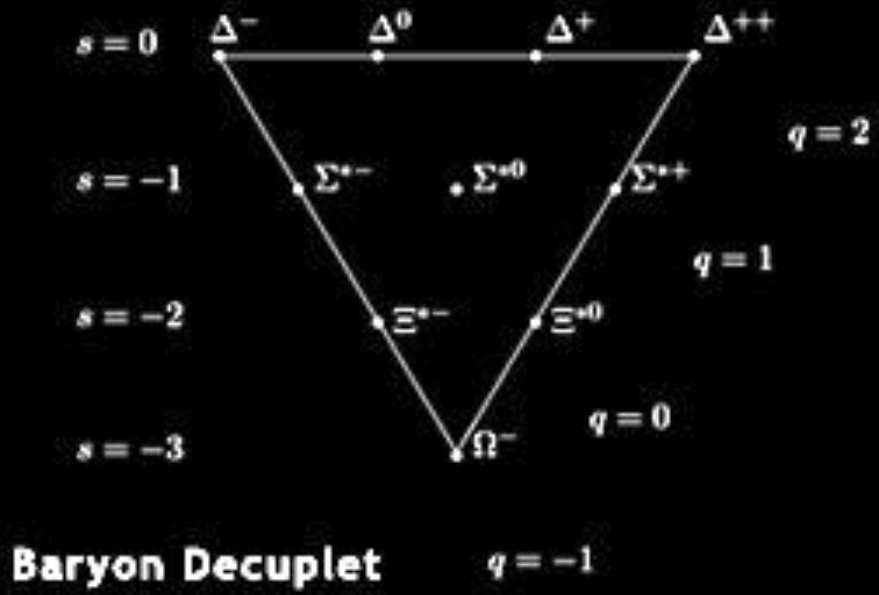
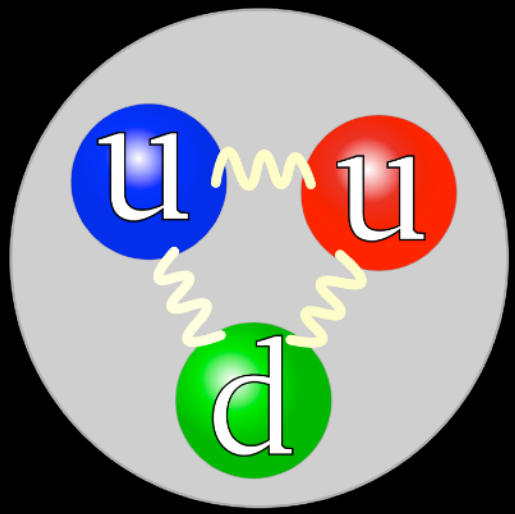
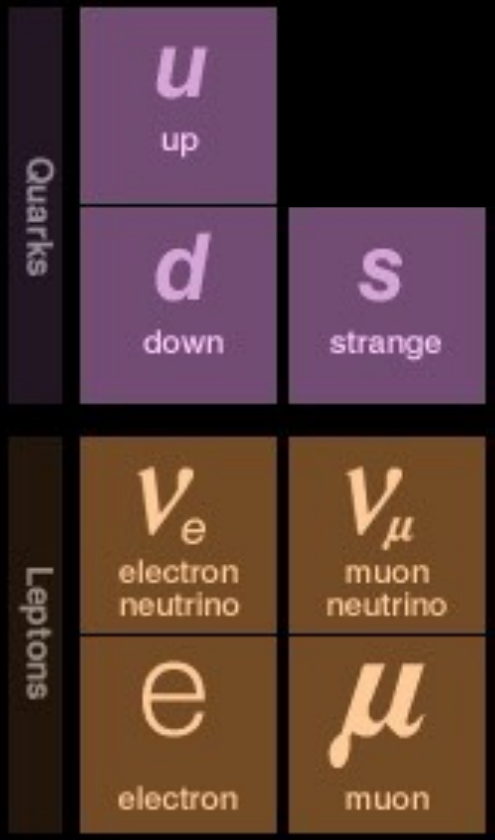


What could cause this pattern of periodic particle properties?



Gell-Man and Zweig proposed the “quark model” in 1964 that explained these periodic patterns as arising from substructure; the proton and neutron are composed of fractionally charged constituents. Called them quarks. Up has charge +2/3; down has charge -1/3.





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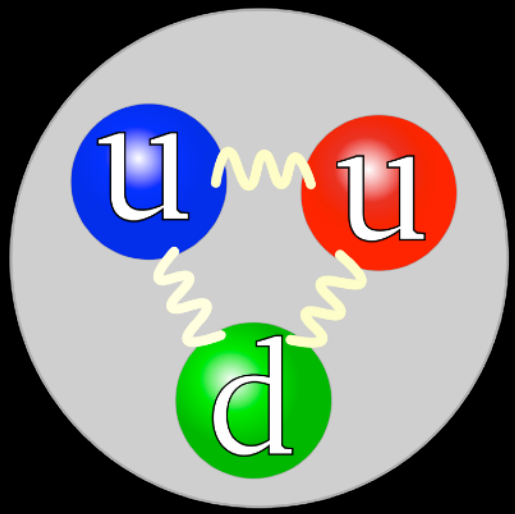

Quarks	u up	c charm
	d down	s strange
Leptons	ν_e electron neutrino	ν_μ muon neutrino
	e electron	μ muon

New particles containing another "up type" quark where discovered in 1974. Called the "charm" quark; charmed that the model seems to work.

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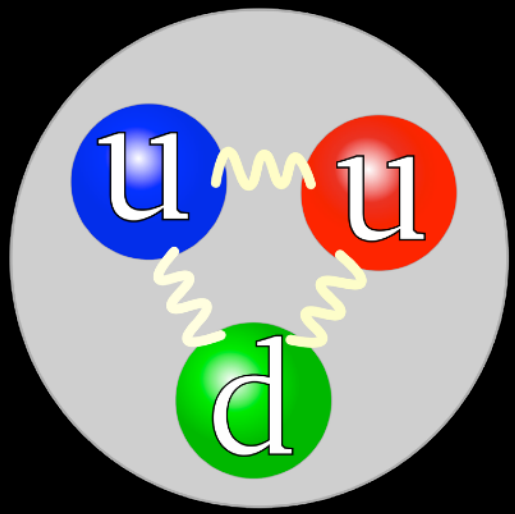
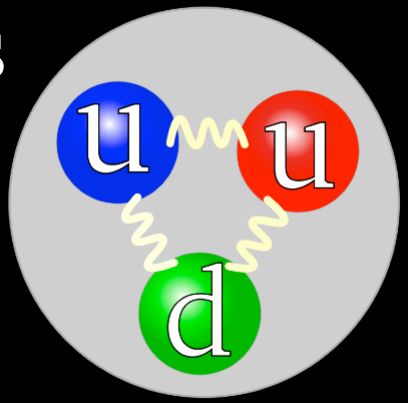


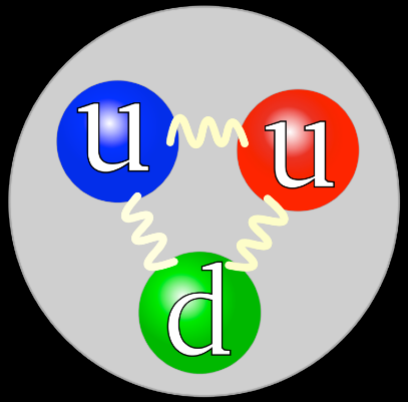
Quarks	u up	c charm	t top
	d down	s strange	b bottom
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino
	e electron	μ muon	τ tau

A 3rd generation discovered in 80's and 90's.

How would you test this hypothesis that protons and neutrons are composed of sub-structure?



Quarks observed with “Rutherford like scattering” experiments in 70’s. High energy electrons scattered off protons showed point like substructure.



Done at Stanford Linear Accelerator Center (SLAC)

Next time we'll talk about the LHC

How to get into undergraduate research

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Summer Intern, 199, 99, 25L/13H, personal project

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Get some hands on skills that will make you useful

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Start a project on your own to answer the question "What have you done?"

Not grandiose but well done & well documented. Illustrate curiosity, independence, perseverance, ability to learn.

Some examples of things you could do over summer:

Learn skills, e.g., code academy or just googling.
Measure something well:

- Temperature as a function of time in your house *every minute*.
- The ping of your ISP as a function of time.
- WiFi map of your house.
- Muzzle velocity of air soft gun.
- Measure g with a pendulum — video analysis for precision
- Measure g as a function of time (can you see the tides?)
- Count meteors vs time with automated long exposures

Some examples of things you could do over summer:

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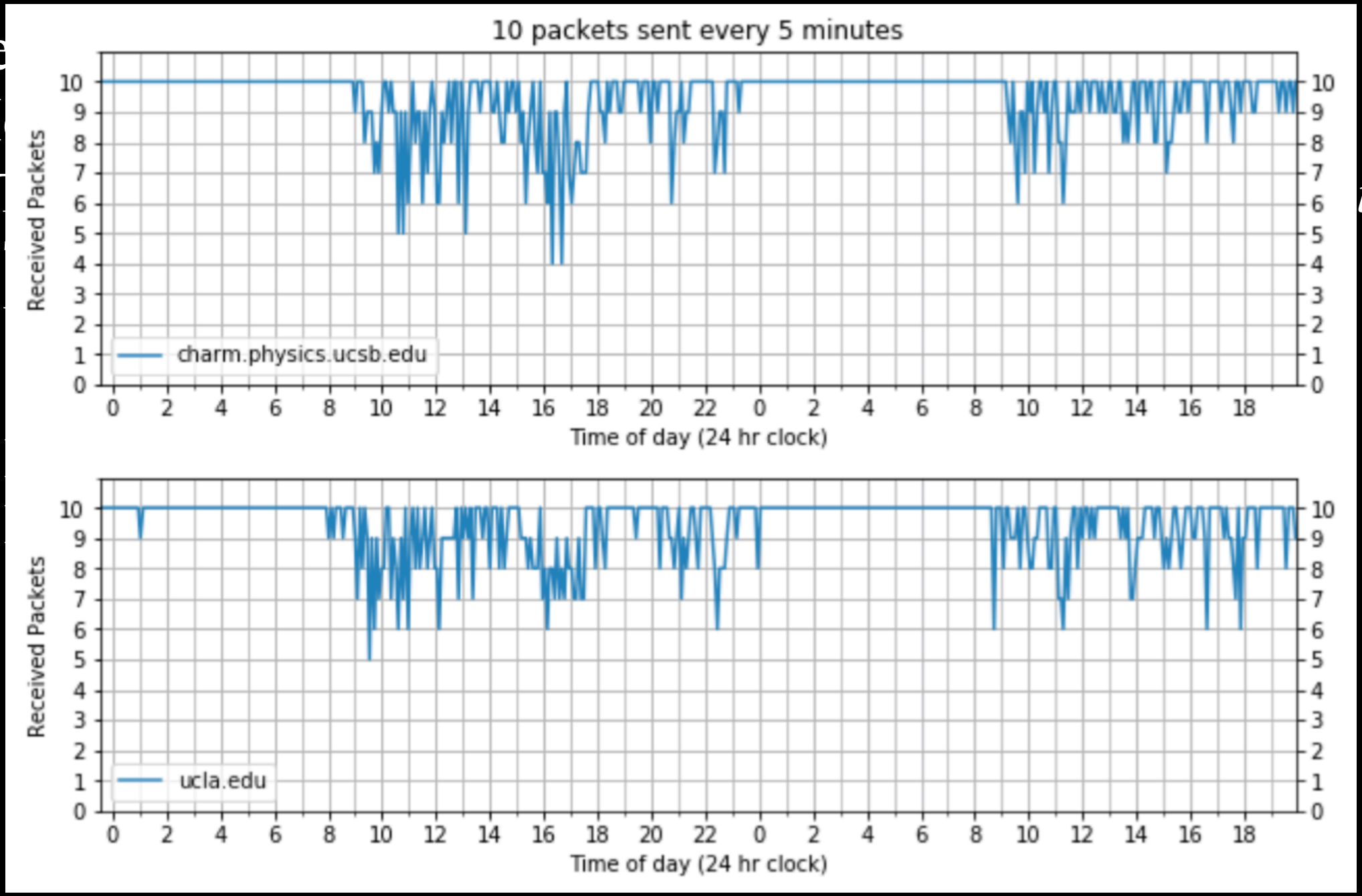

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Learn techniques and make it fun, cool, and solid.

Then to get into a 99 or 199 research position:

- Get the best grade in your classes.
- Once you've gotten your name recognition that way…
- Email/meet with professor and say you are thrilled with the idea of research and would like to get involved somehow. Be prepared to describe what you have done in individual projects, concisely but enthusiastically.
- Keep trying.
- Consider honors contract to get known by instructor

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Excel in the research class to get a recommendation for a summer intern and/or graduate school.