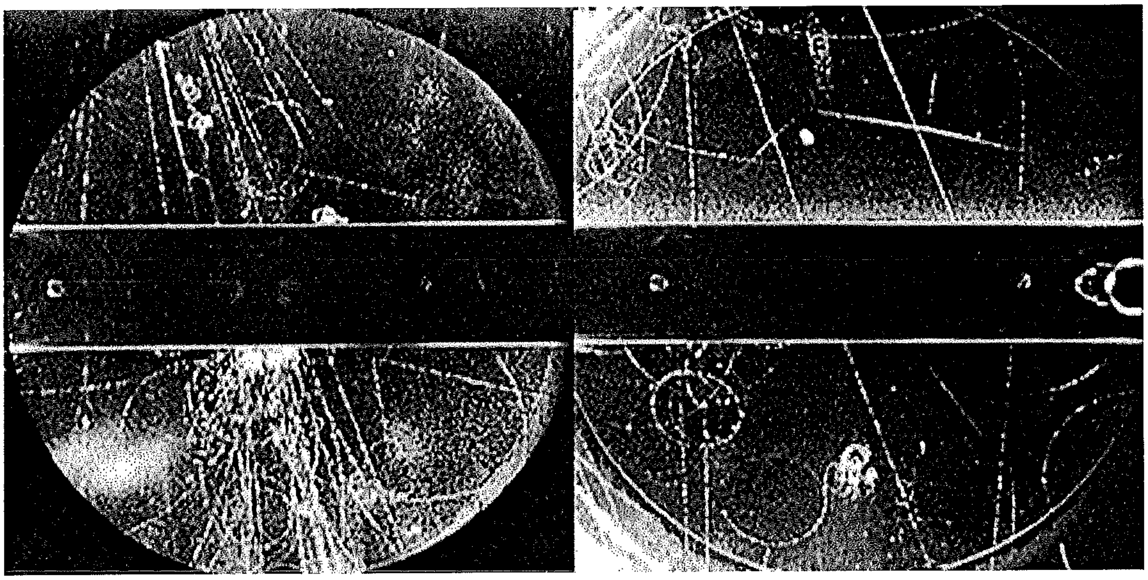
Just talk about this

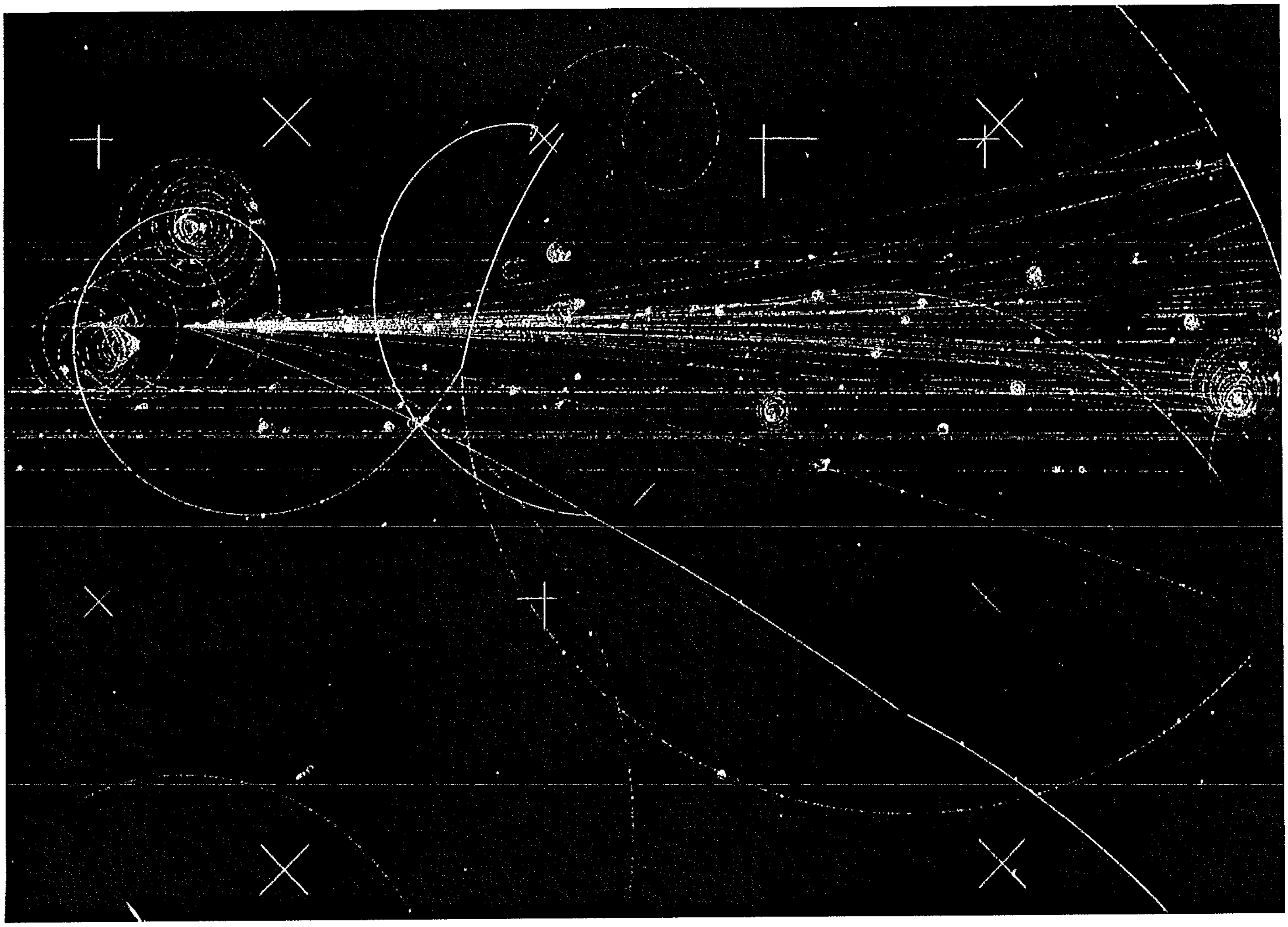
Detection of slowly-decaying charged particles

- cloud chambers [photo →]
- photographic emulsions
- bubble chambers (1952: Glaser) [photo →]
- spark chambers
- multiwire proportional chambers / drift chambers

[ionize atoms which serve as centers of nucleation for water droplets or gas bubbles in supersaturated environments]

[see photos →]





The New York Times

.arch 4, 2013

Donald Glaser, Nobel Winner in Physics, Dies at 86

By KENNETH CHANG

Donald A. Glaser, who won the Nobel Prize in Physics in 1960 for inventing, at 25, an ingenious device called the bubble chamber to trace the paths of subatomic particles, died on Thursday at his home in Berkeley, Calif. He was 86.

His death was confirmed by his wife, Lynn.

In creating the chamber, Dr. Glaser — a restless scientist who later turned to microbiology and developing cancer therapies — proved his most renowned skeptic, Enrico Fermi, a giant of 20th-century physics, wrong.

In the 1950s, physicists were becoming more adept at building powerful atom smashers to help decipher the building blocks of matter. But in breaking atoms apart they were often stymied in their efforts to identify the particles that flew out from the collisions.

Dr. Glaser's bubble chamber generated data that enabled physicists to figure out that most particles of matter, like protons and neutrons, are composed of even smaller particles known as quarks.

"It was a very powerful technique," said Nicholas Samios, a physicist at Brookhaven National Laboratory on Long Island. "It was very instrumental in that period of physics."

Dr. Glaser, who was teaching at the University of Michigan at the time, was fortunate that he did not know that Fermi had calculated that a bubble chamber would never work. Only afterward, after Fermi had invited Dr. Glaser to the University of Chicago to give a talk about the bubble chamber, did Dr. Glaser look up Fermi's calculation in a thermodynamics textbook. There he found an erroneous equation.

"It's just a small error, but that error made it possible for him to prove that it couldn't work," Dr. Glaser said of the bubble chamber in an oral history conducted by the Bancroft Library at Berkeley. "And luckily I didn't know about his book because it would have turned me off. Instead, I did my the 1960s into the 1970s before other technologies superseded them.

In 1964, for example, Dr. Samios led a team that used an 80-inch bubble chamber at Brookhaven to discover a particle called the omega-minus, which helped confirm the quark theory.

Dr. Glaser moved from Michigan to the University of California, Berkeley, in 1959. He was 34 when he won the Nobel, in 1960.

Dr. Glaser's first marriage, to Ruth Bonnie Thompson, ended in divorce. In addition to his wife, the former Lynn Bercovitz, he is survived by a daughter, Louise, and a son, William, both from his first marriage, and four grandchildren.

Dr. Glaser always denied popular accounts suggesting that he had been inspired to create the bubble chamber by staring at a glass of beer. "It's totally wrong," Dr. Glaser said in the oral history interview. "The story is perverted by journalists."

But he did attempt to use beer in a bubble chamber as he looked for an alternative to the first liquid he used, an organic compound known as diethyl ether.

"Why fool around with all of these exotics?" Dr. Glaser recalled. "Water is probably out of the question, but I decided, 'What the hell?' "

It didn't work, but in heating the beer, it sprayed the ceiling, and the physics building stank of beer. That, he said, was a problem for two reasons. First, alcohol was not allowed within 500 yards of the campus.

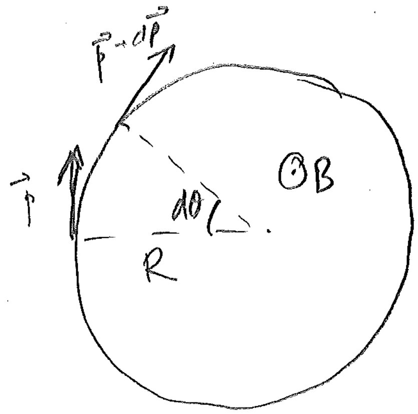
"The other problem was that the chairman was a very devout teetotaler, and he was furious," Dr. Glaser said. "He almost fired me on the spot."

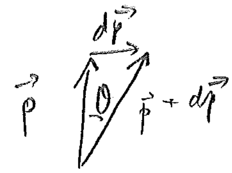
This article has been revised to reflect the following correction:

Correction: March 6, 2013

An obituary on Tuesday about the physicist Donald A. Glaser misidentified an organic compound that was the first liquid he used in the bubble chamber, the invention for which he won the Nobel Prize. It was diethyl ether, not diethyl ester. And because of an editing error, the obituary referred incorrectly to the college from which Dr. Glaser received his bachelor's degree. It was the Case School of Applied Science, which later became part of Case Western Reserve University; he did not receive his degree from "what became the Case Western University."

The momentum of a charged particle is given by $p = qRB$.





Proof:

$$d\theta = \frac{dp}{p}$$

$$\omega = \frac{d\theta}{dt} = \frac{1}{p}\frac{dp}{dt}$$

$$\frac{d\vec{p}}{dt} = \vec{F} = q\vec{v}\times\vec{B}$$

$$\frac{dp}{dt} = qvB$$

$$\omega = \frac{qvB}{p} = \frac{q\omega RB}{p}$$

$$\Rightarrow p = qRB \quad \text{(relativistically valid)}$$

measure R, to determine p

Leptons : not affected by strong interaction

[originally "light" but now it means non-quark matter]

1895 J. J. Thompson : "cathode rays" → electrons

1932 Anderson discovers e^+ in cosmic rays

[original figure of Anderson]

[Fig 6.7]

[like e^-; but curves the wrong way
spirals in because losing momentum, R ↓]

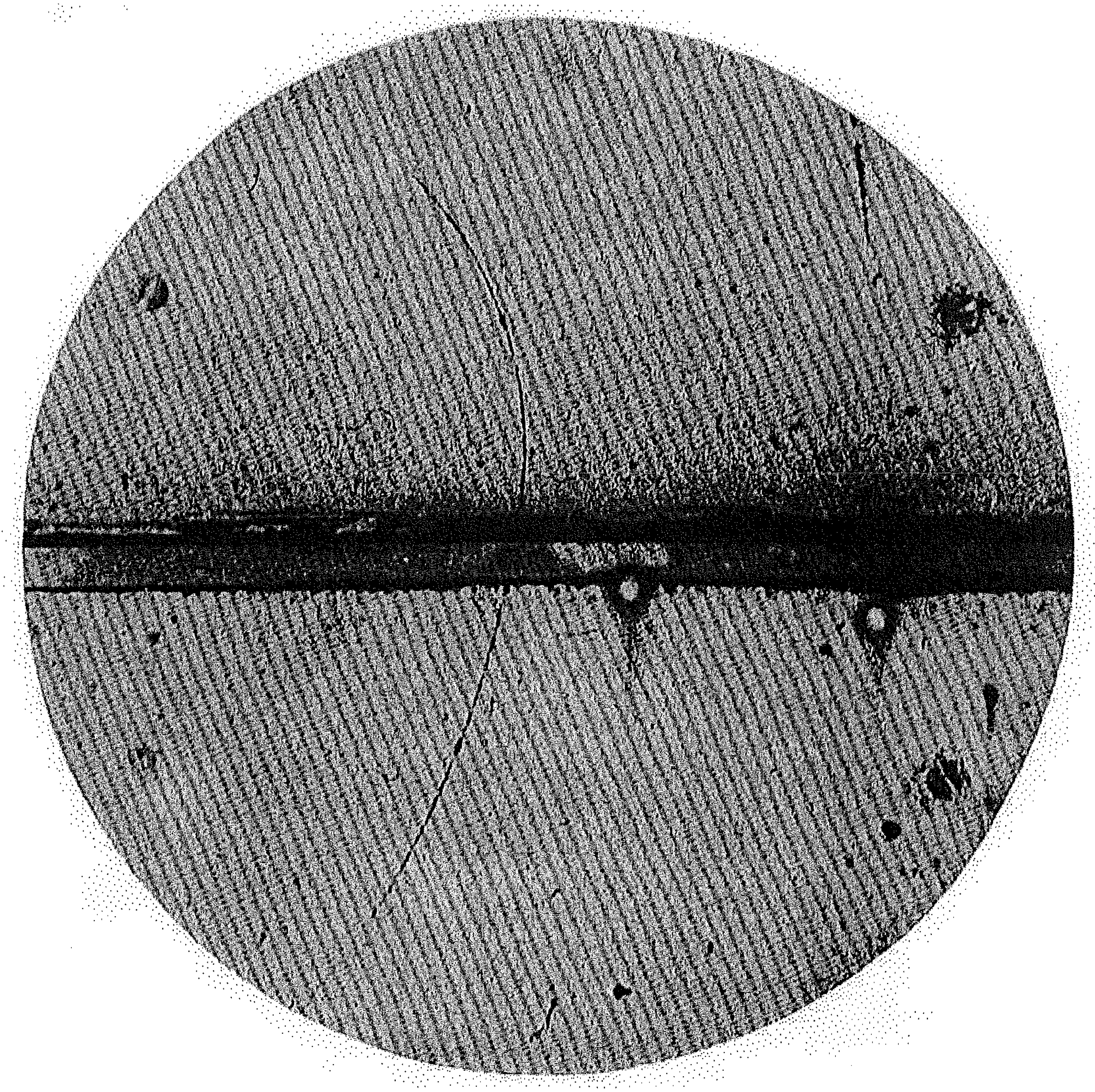
1937 μ^- discovered [photo] [Anderson & Neddermeyer
Street & Stevenson]

$m_\mu = 105.66$ MeV

[like e^- but heavier. Who ordered that?]

1975 τ^- discovered [Perl. Nobel 1995]

$m_\tau = 1776$ MeV



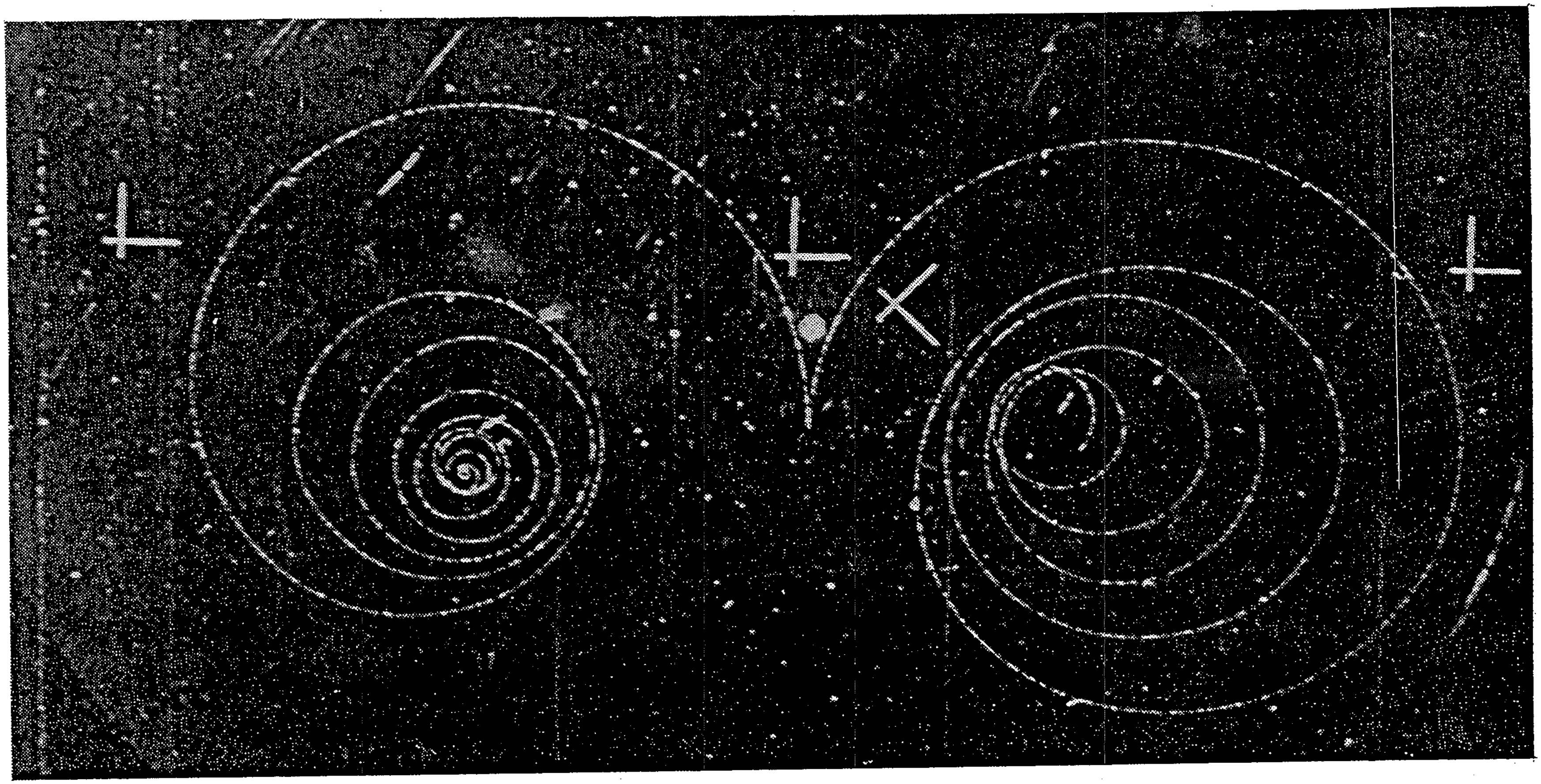


Fig. 6–7 Production of an electron-positron pair in a liquid hydrogen bubble chamber in a magnetic field.

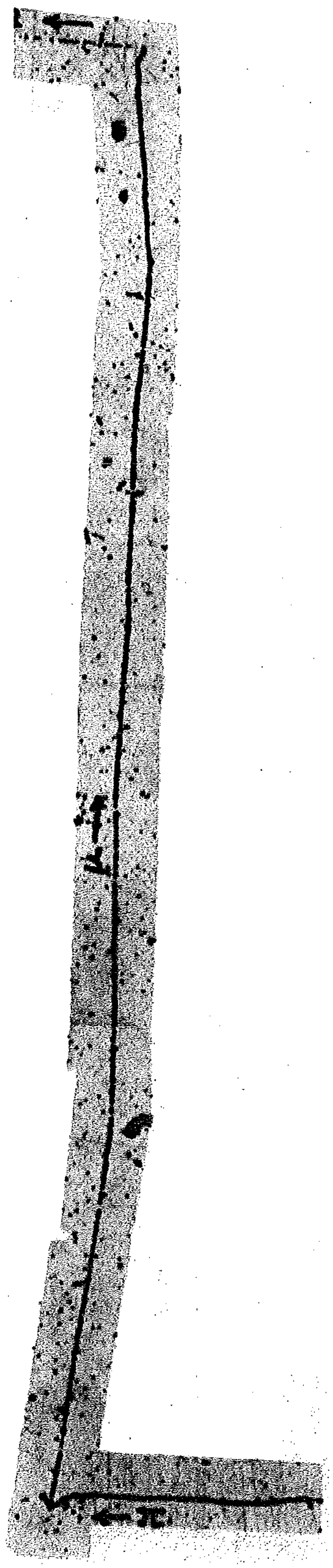


Figure 1.7 Here, a pion decays into a muon (plus a neutrino); the muon subsequently decays into an electron (and two neutrinos). Reprinted by permission from C. F. Powell, P. H. Fowler, and D. H. Perkins, *The Study of Elementary Particles by the Photographic Method* (New York: Pergamon, 1959). First published in *Nature* **163,** 82 (1949).

<u>μ decay:</u> $\tau = 2.2 \times 10^{-6}$ s [2.197E-6 s]

$\mu^- \to e^- \; +$ neutral particle (or particles)
↑ not γ because no e^+e^- pairs produced

[e^- = only lighter charged particles
neutral because no tracks

$\mu^- \to e^- \; \nu$?

[theoretical objection: violates lepton #
experimental objection:
e^- not monochromatic

$\mu^- \to e^- \; \nu \; \bar{\nu}$
[analogous to β decay of nucleus
i.e. 3 light pcls in final state
rather than 2 light pcls & a heavy nucleus]

Since $m_e \ll m_\mu$ can treat e^- as approx. massless (in the massless electron approximation)
Standard model predicts

$$\Gamma_{\mu \to e \nu \bar{\nu}} = \frac{G_F^2 (m_\mu c^2)^5}{192 \pi^3 (\hbar c)^6}$$

[similar to Sargent rule: Q^5.
factor of $\frac{1}{60\pi^3} \to \frac{1}{192\pi^3}$]

[HW: compute τ_μ & compare to expt]
$\Gamma = 3.0094\text{E-}19$ GeV $\Rightarrow \tau_\mu = 2.187\text{E-}6$ s
expt 2.197E-6 s

Why not $\mu^- \to e^- \gamma$? [Since γ same as $\nu\bar{\nu}$ in terms of qu. #s]

BR $< 2.4\times10^{-12}$ [PPB]

[Maybe ν + $\bar{\nu}$ aren't antiparticles of each other. Different kinds of ν]

Two-neutrino hypothesis

$$\mu^- \to e^- \bar{\nu}_e \nu_\mu$$

Two types of lepton #

	L_e	L_μ
e^-	1	0
ν_e	1	0
μ^-	0	1
ν_μ	0	1

[Schwartz Steinberger Lederman at BNL 1962, Nobel 1988]

$\bar{\nu}_\mu p \not\to n e^+$ not observed

$\bar{\nu}_\mu p \to n \mu^+$ observed!

[Actually 3 types of neutrinos]

	L_e	L_μ	L_τ
e^-			0
ν_e			0
μ^-			0
ν_μ			6
τ^-	0	0	1
ν_τ	0	0	0

τ decay: $\tau = 2.9 \times 10^{-13}$ s [2.91E-13 s]

$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$

$\to e^- \bar{\nu}_e \nu_\tau$

$\to$ other stuff

} decay modes or "channels"

$\frac{\hbar}{\tau} = \Gamma = \sum_{i = \text{decay channel}} \Gamma_i = (\Gamma_{\tau \to \mu\nu\bar{\nu}}) + (\Gamma_{\tau \to e\nu\bar{\nu}}) + \ldots$

Γ ↑ width; Γ_i ↑ "partial widths"

[more channels ⇒ shorter τ]

BR = branching ratio = $\frac{\Gamma_i}{\Gamma}$

[PDB] $\frac{\Gamma_{\tau \to e\nu\bar{\nu}}}{\Gamma} = 0.1786$

[Why is τ of τ so much shorter than μ? More channels, yes, but mostly more phase space!]

$\frac{\Gamma_{\tau \to e\nu\bar{\nu}}}{\Gamma_{\mu \to e\nu\bar{\nu}}} \sim \frac{m_\tau^2}{m_\mu^2} \sim 17^5 \sim 10^6$

[HW: compute τ_τ. Compare w/ expt.]

#neutrinos

php qualitatively here & more quantitatively in GWS

Maybe not do here

weak: $Z^0 \longrightarrow e^+e^-, \mu^+\mu^-$, etc. [look up in PPB]

$\tau \sim 10^{-25}$ s

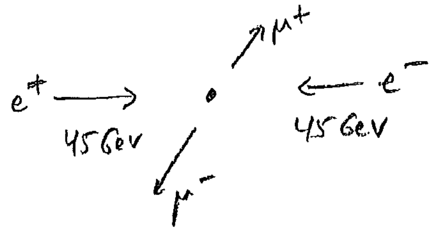
interaction is weak but there's lots of phase space

$Q \sim 91$ GeV $\sim 91{,}000$ MeV [goes as 5th power]

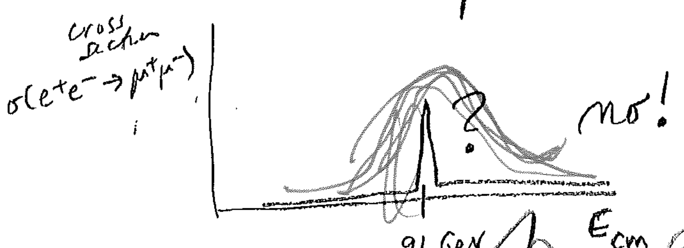
(calculate)

How to produce Z^0? $e^+e^- \longrightarrow Z^0 \longrightarrow \mu^+\mu^-$ etc.

e.g. at LEP (Large Electron Positron Collider) at CERN in 1989



$e^+e^- \longrightarrow \sum s$

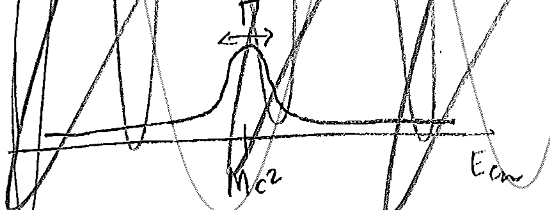


$\Gamma = \sum_{\text{final}} d\Gamma$ final state = visible + invisible

already did this

Heisenberg uncertainty $\Delta E \, \Delta t \geq \frac{\hbar}{2}$

$\Rightarrow$ the energy (mass) of a particle having mean life τ is uncertain by $\Delta E \sim \frac{\hbar}{\tau}$. Define the width Γ of an unstable particle as



$$\Gamma = \frac{\hbar}{\tau} = \frac{(6.6 \times 10^{-22}\ \text{MeV} \cdot \text{s})}{\tau}$$

expt $\Rightarrow \Gamma_Z = 2.5$ GeV

$\Rightarrow \tau = 3 \times 10^{-25}$ s