Observation Of High-Energy Neutrino Reaction And The Existence Of Two Kinds Of Neutrinos

高エネルギーニュートリノの観測と二種類のニュートリノの存在

G. T. Danby et al.
Phys. Rev. Lett. 9 (1962) 36

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Shibata lab.

Kyosuke Sanpei

Introduction

Today

- Three kinds of neutrinos (ν_e, ν_μ, ν_τ) are known

Around 1960

- Only one type of neutrino (ν_e) was known
- Two kinds of charged leptons (μ , e) were known

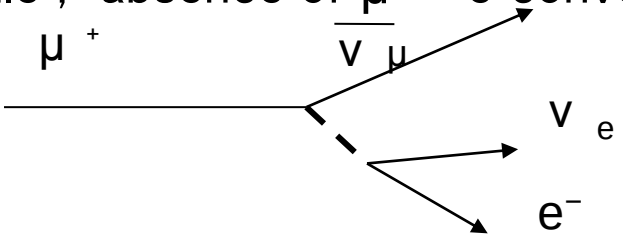
$$ {}_ZA_N \longrightarrow {}_{Z+1}A_{N-1} + e^- + \bar{\nu} $$

This neutrino is associated with electron

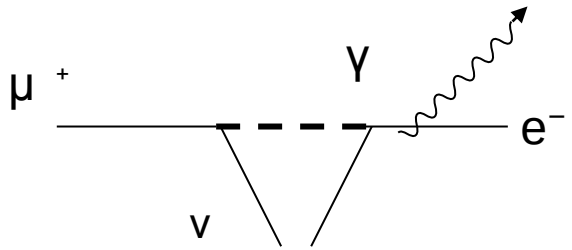
Motivation for this experiment

; confirm the theory "there maybe two kinds of neutrinos"

Puzzle ; absence of μ — e conversion



○ $\mu^+ \longrightarrow e^+ + \nu + \bar{\nu}$ observed



× $\mu^+ \longrightarrow e^+ + \gamma$ not observed (Why?)

If $\nu_\mu = \nu_e$, this reaction should take place

Neutrino associated with muon

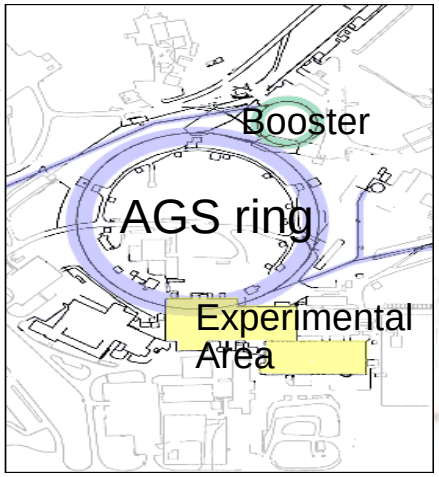
Is it identical with ν_e ?

If $\nu_\mu = \nu_e$, both muon and electron should be produced in the following reactions

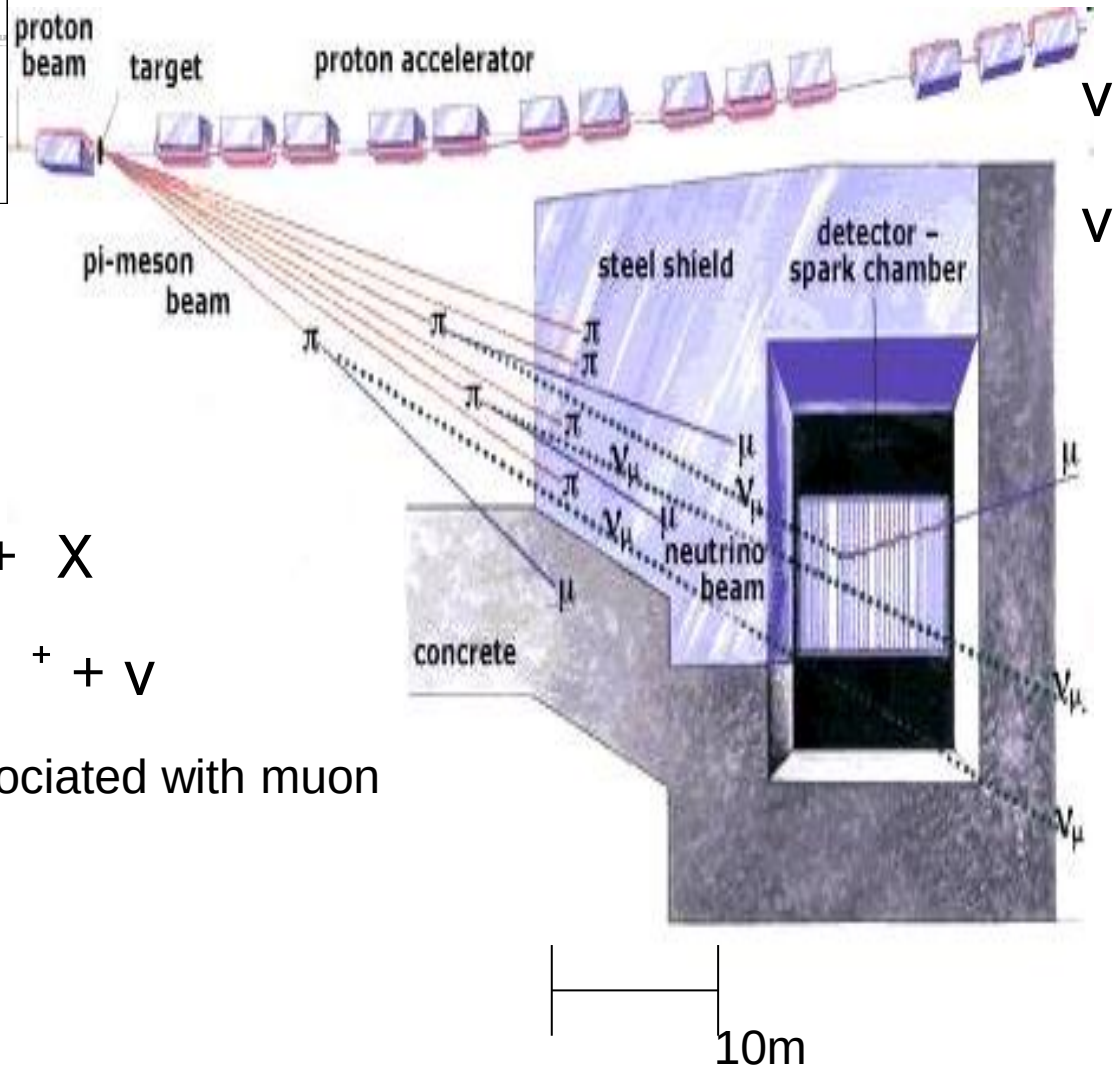
$$ \nu_\mu + n \longrightarrow p + \mu^- $$

$$ \nu_e + n \longrightarrow p + e^- \quad ? $$

Experiment at BNL



Ep = 15 GeV



$$p + Be \longrightarrow \pi^{+} + X$$
$$\pi^{+} \longrightarrow \mu^{+} + \nu$$

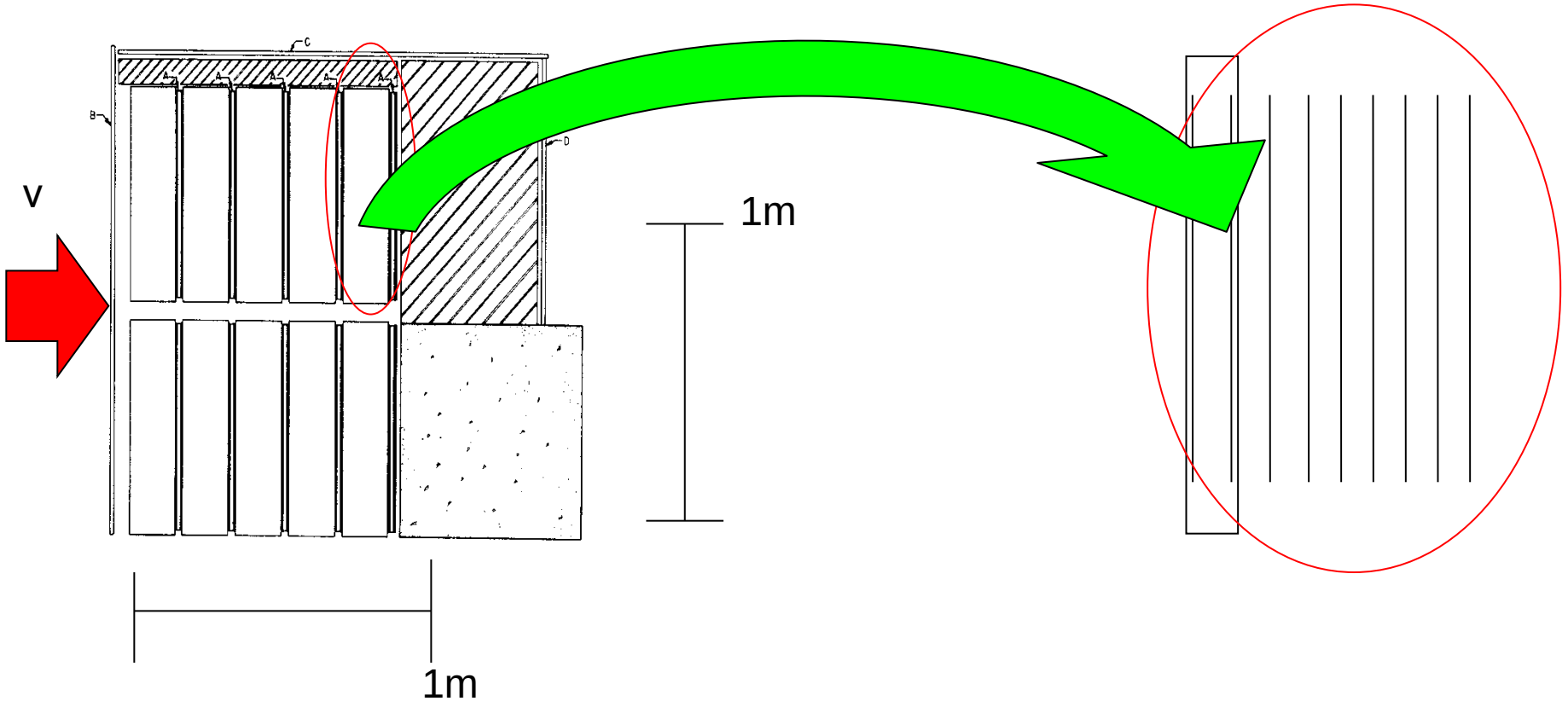
This neutrino is associated with muon

$$\nu + n \longrightarrow p + \mu^{-}$$
$$\nu + n \longrightarrow p + e^{-}$$

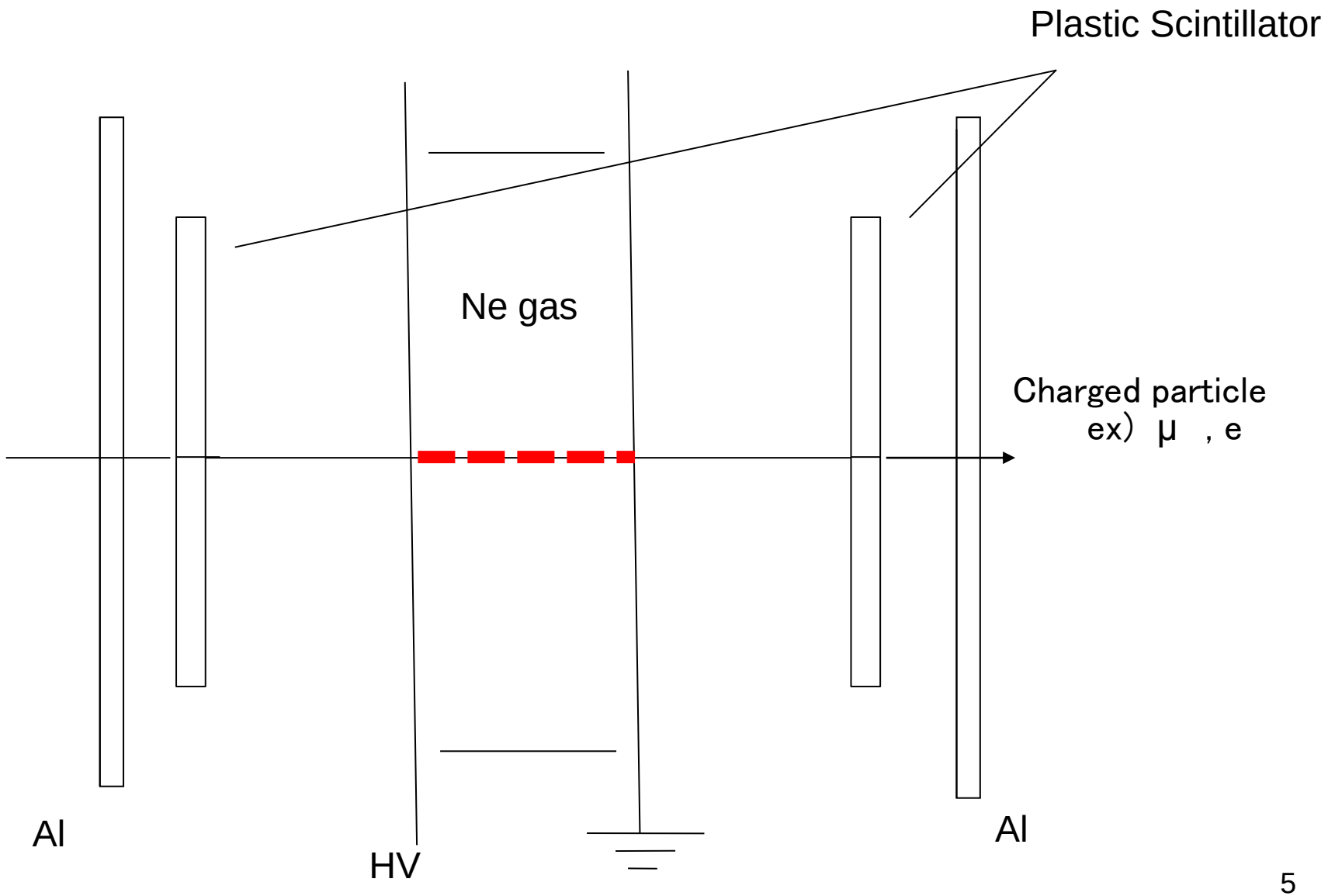
Detector (Spark Chamber)

- There are 10 units
- Each unit has 9 aluminum plates (2.5 cm thick)
- There is spark chamber between the aluminum plates

Side view

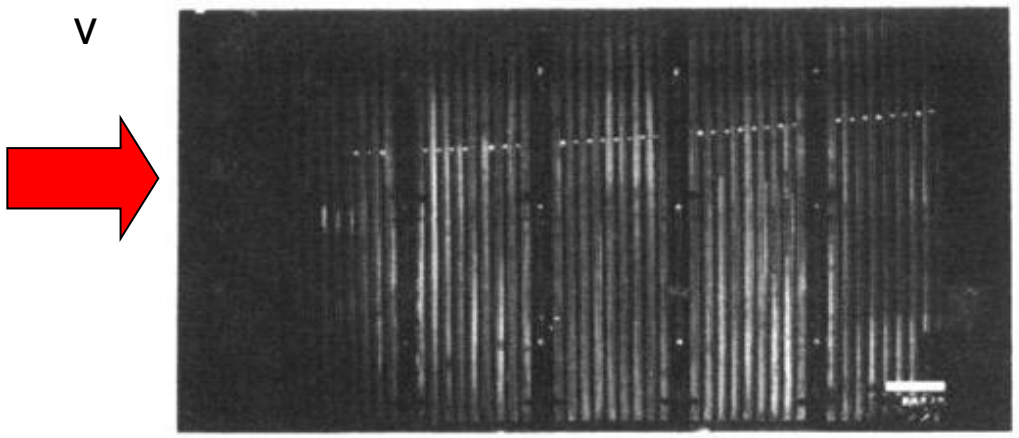


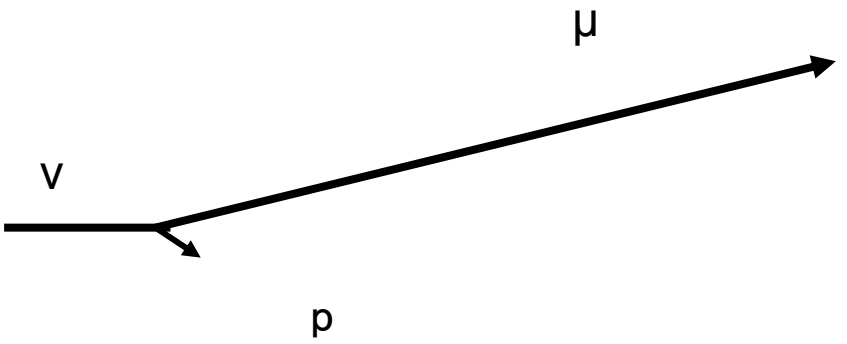
Spark Chamber



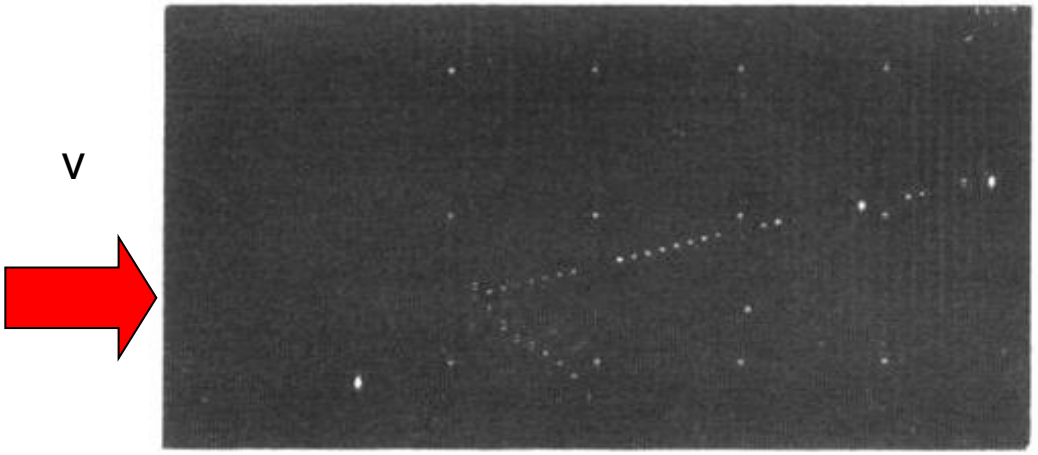
Analysis (1)

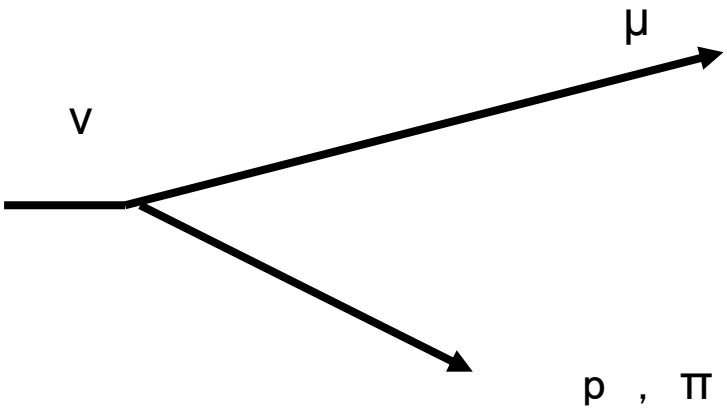
A single track event





A vertex event





Analysis (2)

- In an exposure of 3.48×10^{17} protons, they observed 113 events with the spark chamber

(a) 49 very short single track events

(b) 34 single track events ⎫
(c) 22 vertex events ⎭ → muon candidate

(d) 8 showers → electron candidate

- Muon should be long track

  because of no strong interaction

Mean free path

strongly interacting particle → less than 100 cm in aluminum

observed single track event → 820 cm in aluminum

- Electron should create a shower
- (a) is not muon or electron

  → (a) is discarded

Analysis (3)

In (b) single track events
(c) vertex events

- 5 are judged to be cosmic ray events in (b)
- Therefore, 56 − 5 = 51 events in (b),(c) are muons

In (d) : showers

- Momentum cut $P_e > 300$ MeV/c
- This cut is for the comparison between muon and electron

→ 6 out of 8 events remained

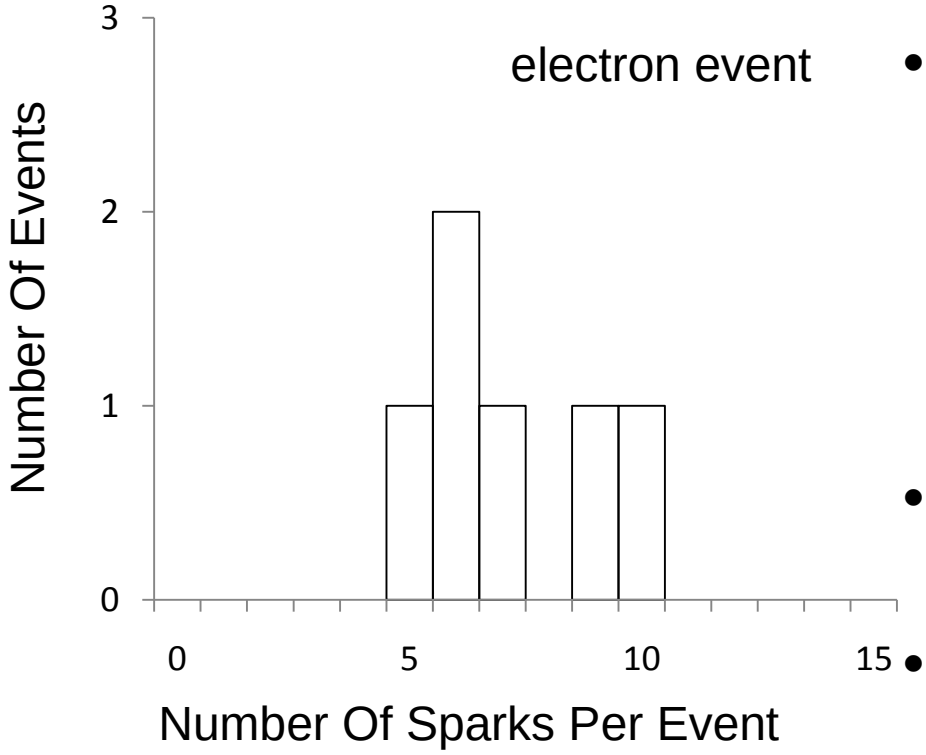
Result

(b) 34 single events

(c) 22 vertex events

} 29 single track events, 22 vertex events } 51 muon events

(d) 8 showers ⟶ 6 electron events



- If ν_μ is identical with ν_e, the following two reactions should take place with the same rate

$$\nu + n \longrightarrow p + \mu^-$$

$$\nu + n \longrightarrow p + e^-$$

- However, only 6 electron events were observed
- Conclusion : $\nu_\mu \neq \nu_e$

Summary

- This experiment was carried out at BNL using neutrino associated with muon
- The aim was to confirm the theory “there maybe two kinds of neutrinos”
- This experiment shows that at least two kinds of neutrinos exist
- This resolves the problem raised by the absence of the reaction $\mu^{+} \longrightarrow e^{+} + \gamma$ （μ －e conversion ）

補足 1

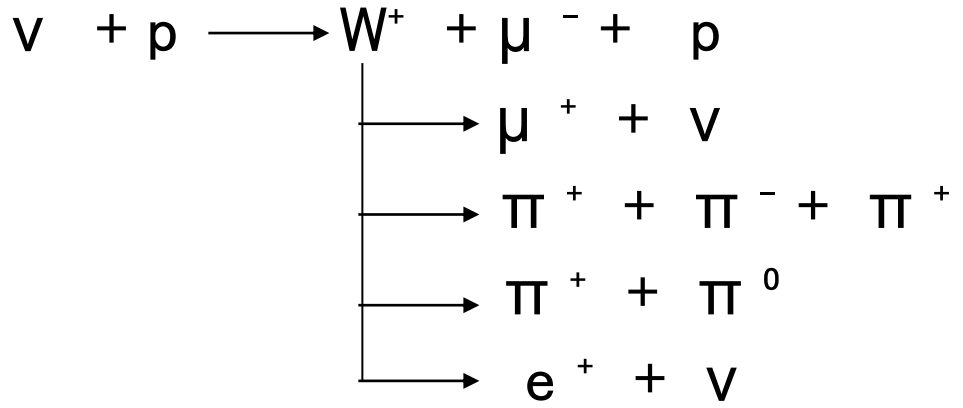
Cosmic rays

- Background is measured experimentally by running with the AGS ring off
- 1 in 90 cosmic ray events is neutrino - like
- Detector is sensitive for 5.5 sec
- Triggering rate is 80 per sec
- Therefore , $5.5 \times 80 / 90 \approx 5$

補足 2

Vertex event

- There are some tracks
- 5 events were considered to be the production of a boson



- In my opinion, others are considered to be muons and protons

- 宇宙空間を飛び交う高エネルギーの放射線のことである
- 約90%が陽子、約8%がアルファ粒子（ヘリウムの原子核）、その他の粒子が約1%含まれます。これらの粒子が地球の大気圏に突入すると、高度数十kmで 空気中の窒素や酸素などの原子核と衝突し、核反応を起こして放射性同位元素を生成させたり中性子や陽子をはじき飛ばしたり、パイ中間子などの粒子を発生さ せたりします。この発生の様子は大気シャワー現象と呼ばれ、一次宇宙線の衝突で発生した粒子を二次宇宙線と呼びます
- 太陽や超新星爆発で生成されるニュートリノ
- **太陽ニュートリノ問題**（たいよう～もんだい、英語：Solar neutrino problem）とは、太陽から到達するニュートリノが、核融合理論から予測される値よりも小さいという現象