Lifetime of negative muon in the organic material

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Graduate Lab Presentation

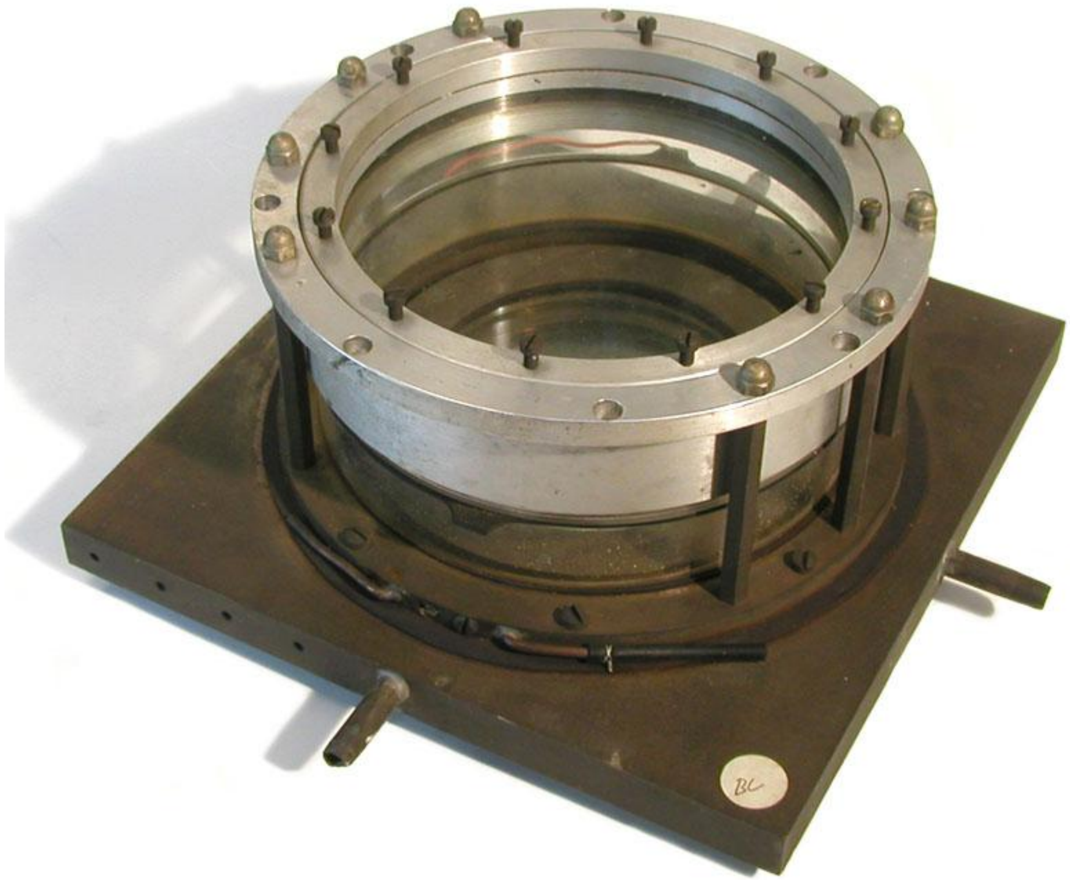
Outline

- History, General information and Origin of muon
- Significance of muon flux on earth surface
- Method of detection of muon
- Experimental description and data analysis
- Discussion of result
- Conclusion

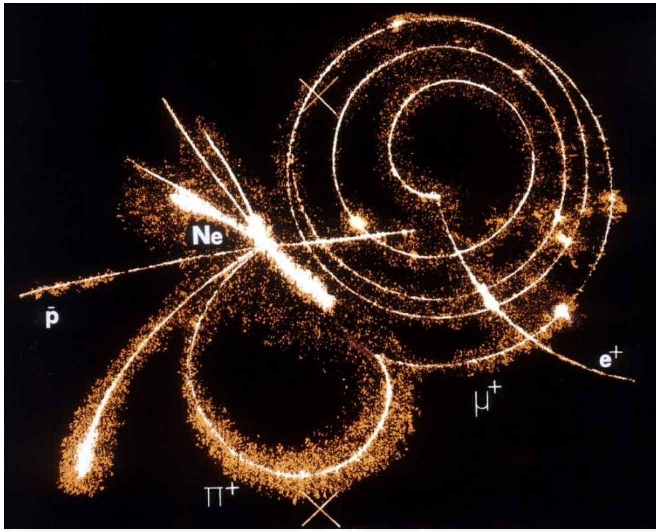
History

- Muon was discovered by Carl D. Anderson and Seth Neddermeyer at Caltech in 1936.
- While studying cosmic radiation, they noticed some particles curve differently from electrons and other known particles.
- They observed the new particle curved less sharply than electrons and more sharply than protons.
- Which gives clue for their mass is greater than electron and less than proton and given a name mesotron.
- With the discovery of other intermediate particles led them to give general name meson.
- In 1947 to differentiate from other meson it is given a name mu-meson.
- Later it was found that they differ significantly from other mesons (in terms of nuclear interaction and decay product) a modern name muon was given.
- Presently the muon is placed in the lepton group together with electron , tau particle and three kinds of neutrinos.

Cloud chamber detector used by Carl D. Andreson and Seth Neddermeyer



Muon detection in the Streamer detector



General information

- Muon(μ^-) is an elementary particle with rest mass= $207m_e$, charge= -e, and spin= ½ (Fermions), also called negative muon.
- Like other elementary particles it has also antiparticle μ^+ called anti muon, also known as positive muon.
- Due to heavier mass than electrons makes them less influenced by electromagnetic field and do not radiate much bremsstrahlung. This makes them penetrate far more deep into the matter than electrons.
- Muon is considered to have relatively long lifetime(2.2 μsec)

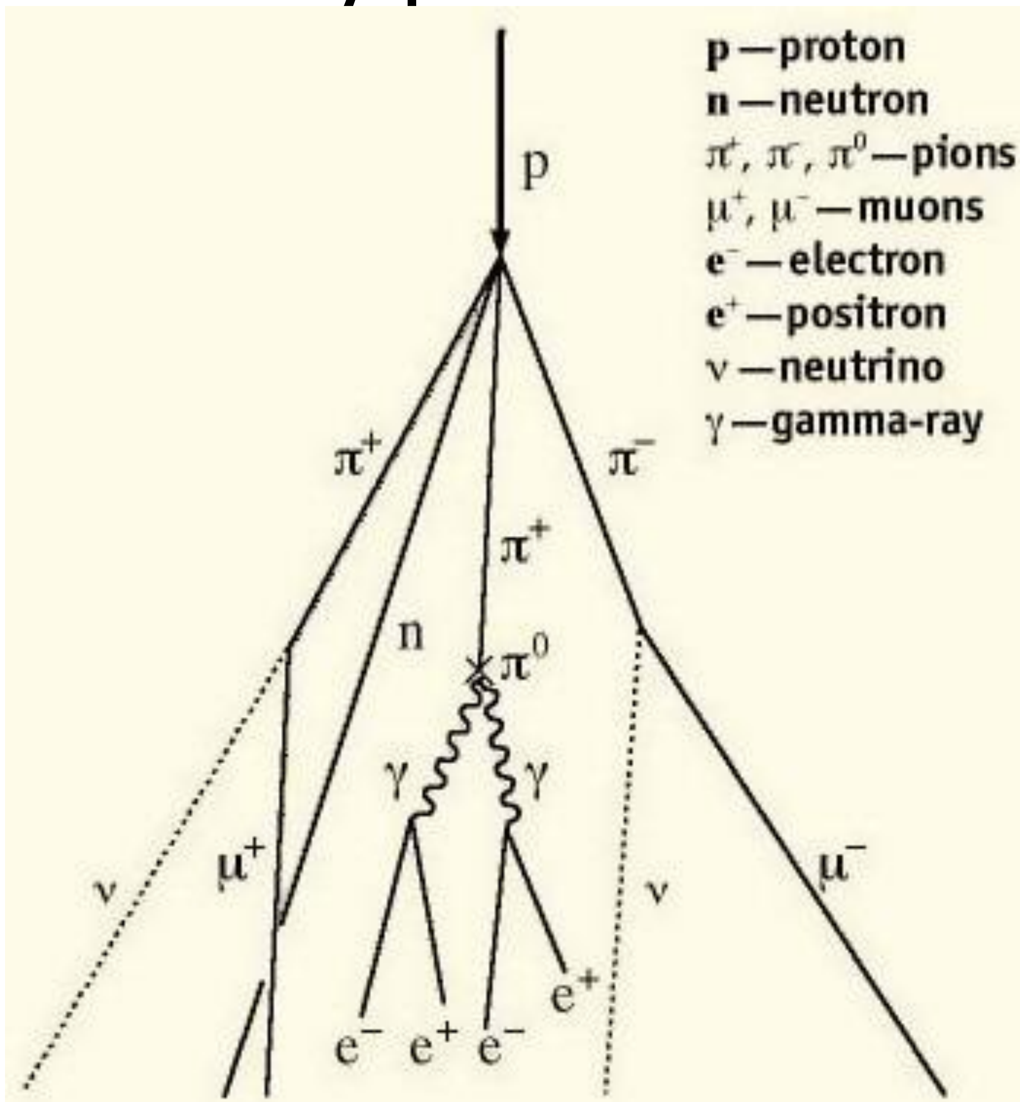
Origin

- Muons are produced at the upper part of atmosphere by the collision of cosmic ray proton with atomic nuclei.
- The cosmic ray shower consists of 89% of protons,10% of alpha-particles,1% heavier nuclei and 1% electrons of unknown source.
- The energy of cosmic ray particle is up to 10^{20} eV which is far greater than 10^{13} eV that can be produced by best particle accelerator on the earth.
- Neither the radioactive decay nor the nuclear fusion are energetic enough to produce muon.
- Initially the interaction of cosmic ray proton with nuclei produce pions, which immediately(~10^{-8} sec) decay into muons as,

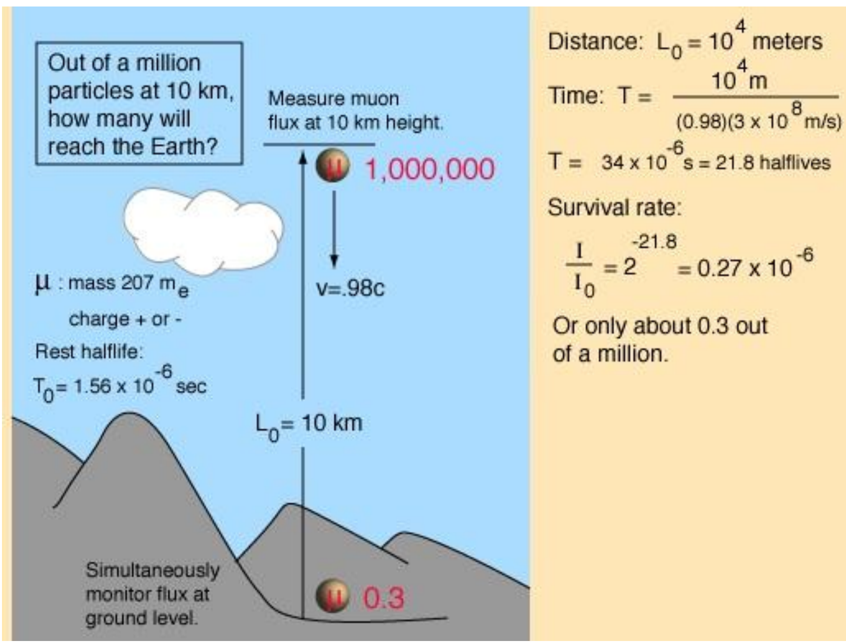
$$\pi^+ = \mu^+ + \nu_\mu \quad \text{and} \quad \pi^- = \mu^- + \bar{\nu}_\mu$$

- The product particles move with in 1^0 of incident proton.

The “Air shower” produced by cosmic ray proton



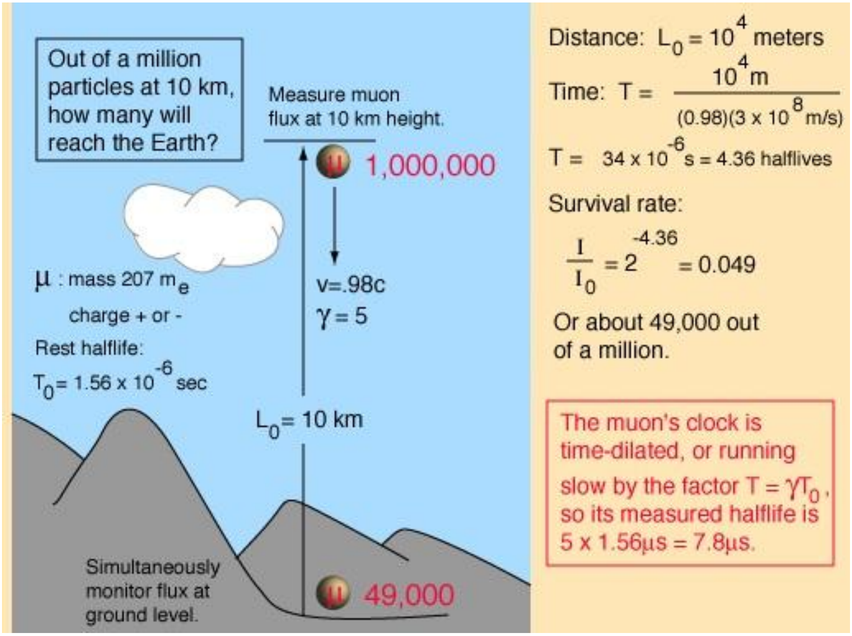
The Significance is the verification of Special Theory of Relativity



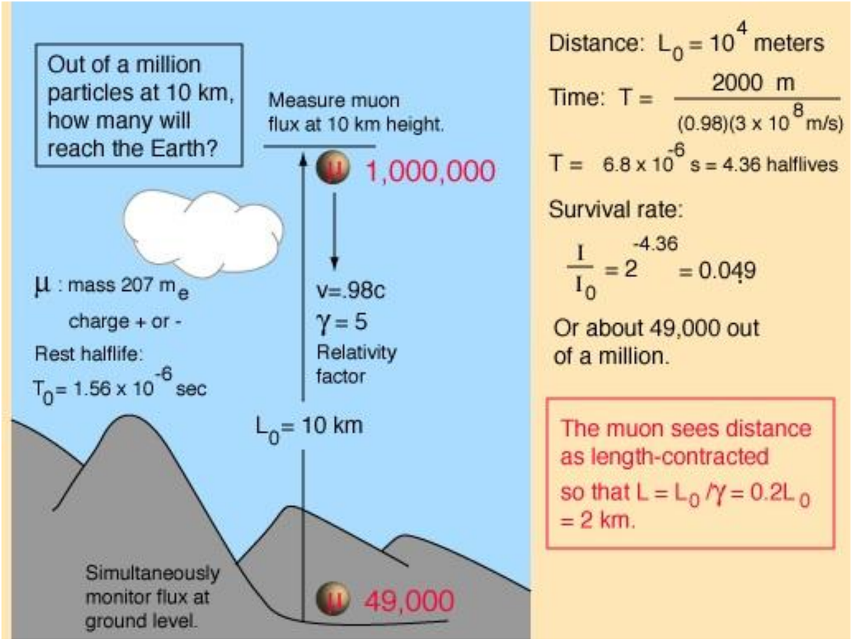
- The half life of muon is 1.56μsec.
- The muon flux at sea level is 10,000/m^2 – minute.
- Without considering relativistic effect we can not observe muon flux in this amount.

Comparison of two inertial frames

For the observer at earth frame



For the observer at muon frame



There are two most common types detectors

Scintillation counters

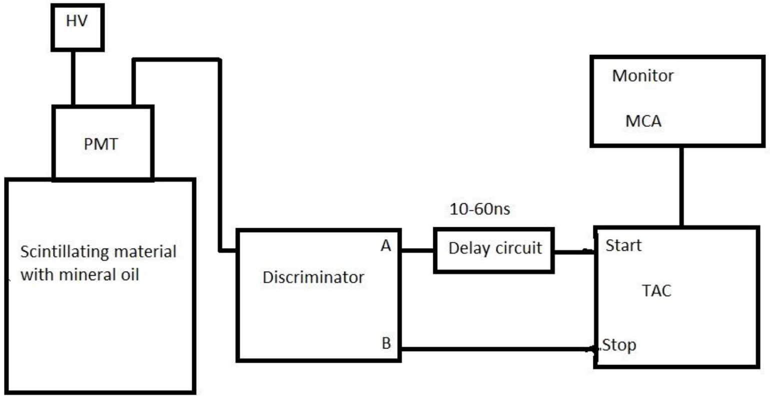
- The basic principle is, the muon deposits energy in the detector and scintillating material produces light pulse.
- The light pulse is detected by Photo Multiplier Tube(PMT) and converts into the electrical signal.
- The scintillation type are important to stop muon.

Gas wire detectors

- The main principle is the muon deposits energy in the gas and produces pairs of electrons and ions.
- The electrons produced then drifts towards the anode wire.
- Amplification occurs near anode wire and provides detectable signal.

Experimental Description

- When muon is stopped inside the scintillator tank, it decays into electron
- Only 1 in 250 muon are stopped inside the scintillator and other are passed through it.
- The TAC time was set to 10μSec.
- We ran the experiment for 399.2 hours.
- The threshold voltage was set to obtain a discriminator rate of 40.08 /sec.

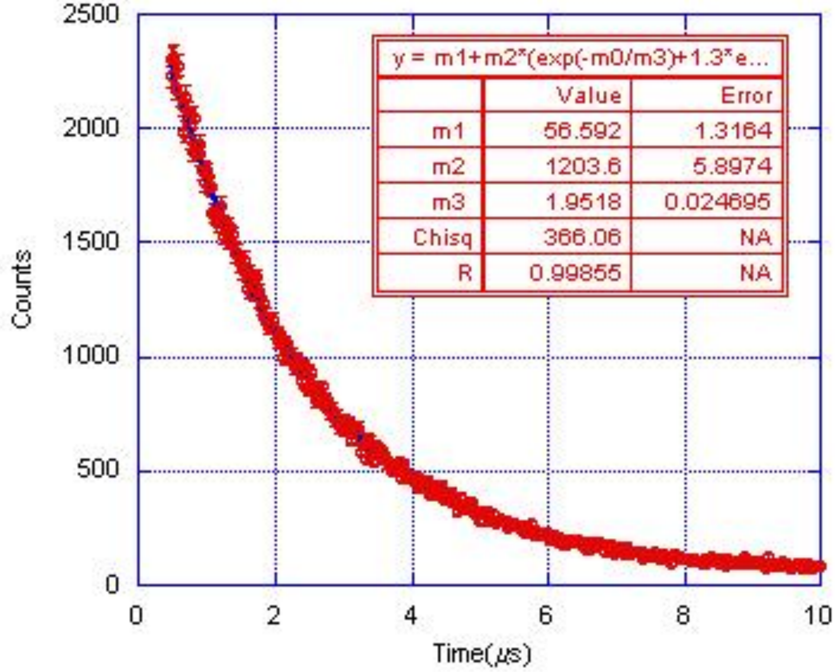


The Block diagram of Experimental setup

Analysis

- The spectrum obtained on the MCA was converted in time spectrum with the help of calibration equation.
- We assumed the decay curve contains the decay for positive and negative muon.
- The lifetime of positive muon does not change in the matter but the life time of negative muon decreases.
- The points fitted in the double decay equation,

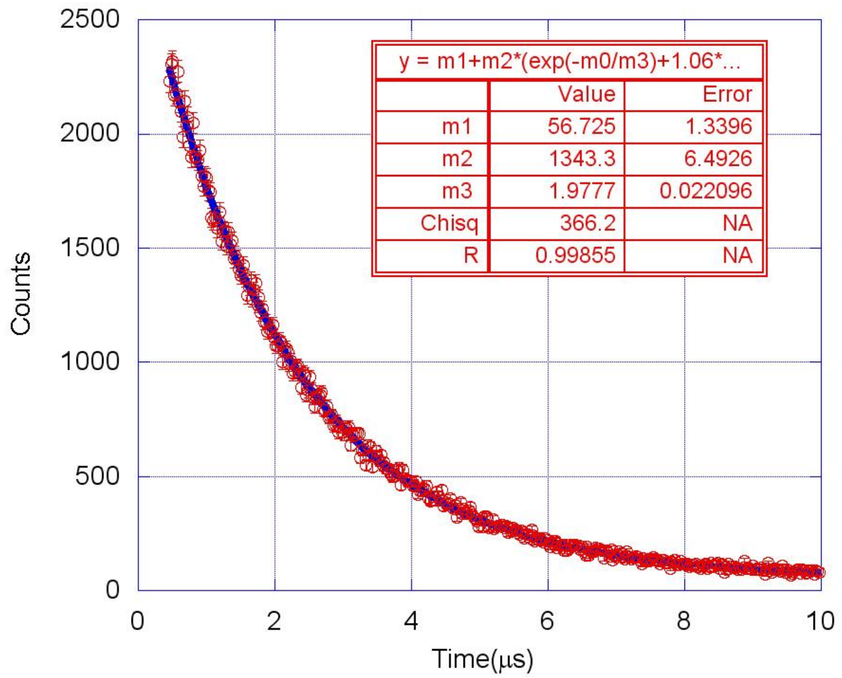
$N=N_0\,(re^{-t/2.197} + e^{-t/T})+ B$, Where r is the ratio of positive to negative muon and B is Background.



The decay curve fitted with r=1.3

Analysis(cont.)

- The value of r fluctuates from 1.06 to 1.3. ~pages.physics.cornell.edu/p510/N-17
- The incident particle being the positively charged particle is the reason for redundancy of positive muons.
- The fluctuation in r gives the uncertainty in the lifetime of negative muon.
- The lifetime in carbon is then obtained as 1.952±0.036μsec.
- The background obtained from the fitting agrees with the theoretical background by using eqn. B=(discriminator rate)^2 × (time width of five channel) × (Experiment run time).= 57.2/per five channel



The decay curve fitted at r=1.06

Discussion

- The lifetime of negative muon in carbon was found to be 1.952±0.036μsec.
- The value agrees closely with the accepted value 2.025±0.004μsec
- M.Eckhause et al.,phys. Rev. Lett. (1963)
- The positive muons are stopped by the matter but are not much captured, except the formation of muonium.
- The decay curve for negative muon is steeper than positive muons.
- The experimental study has shown that the capture rate of negative muon is proportional to Z^4 , called Z^4 law.
- The impurities present in the scintillator also step down the lifetime of negative muon.
- The low energy muons may not be detected due to high threshold at the discriminator and hence unable to count them may deviate the result from the true value.

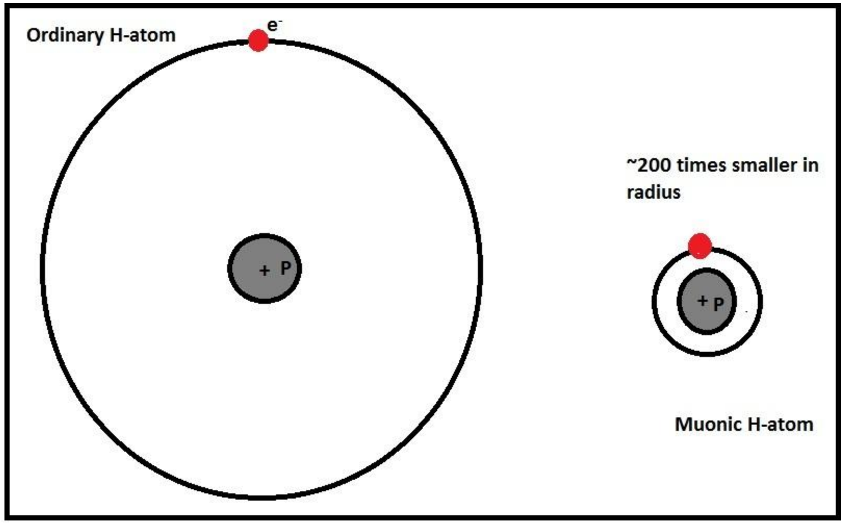
Discussion(cont.)

- The negative muon can be captured in many ways
- Can be captured to form muonic atom by replacing electron (If the μ^- repaces e^- in H-atom the size is 207 times smaller)
- Ordinary muon capture(OMC) involves the capture of negative muon from the atomic orbital with out emission of gamma photon.

  $$\mu^- + P^+ = \nu + n^0$$

- Relative muon capture(RMC) emits a gamma ray photon

  $$\mu^- + P^+ = \nu + \gamma + n^0$$



Conclusion

- The lifetime of negative muon was found 1.952±0.036μsec in the mineral oil.
- The scintillation detecting method is useful to find the lifetime of negative muons in the lab.
- This method is considered to be cheapest than other.
- The experiment provides a good example for the confirmation of theory of relativity.

THANK YOU