

Measurement of the Muon Lifetime

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Outline

Theory

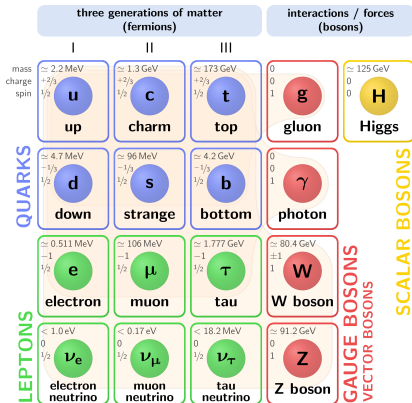
Schematics

Data Analysis and Results

Discussion and Conclusion

What are Muons?

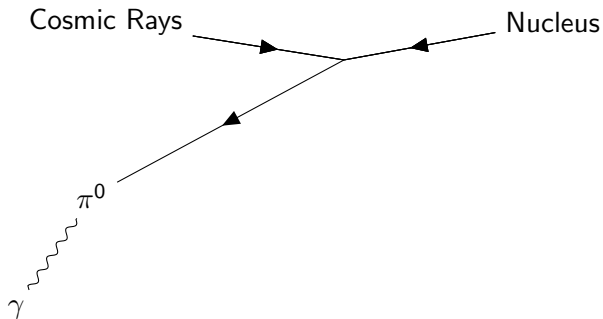
- Elementary particle in lepton family
- Over 200 times heavier than electron [2]
- Forms in upper atmosphere [1]



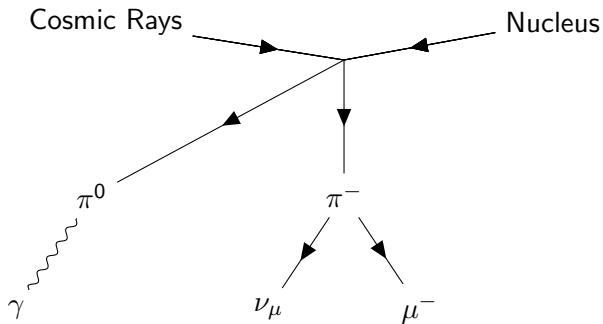
Cosmic Ray Muon Production



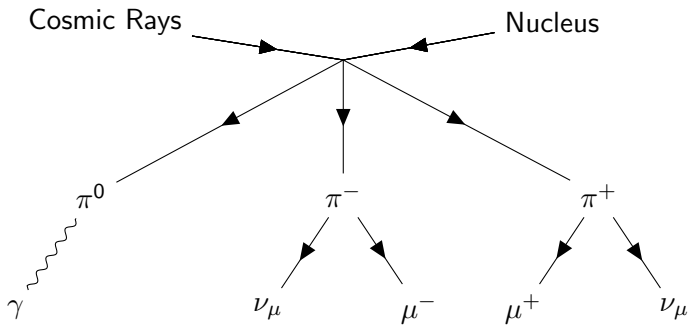
Cosmic Ray Muon Production



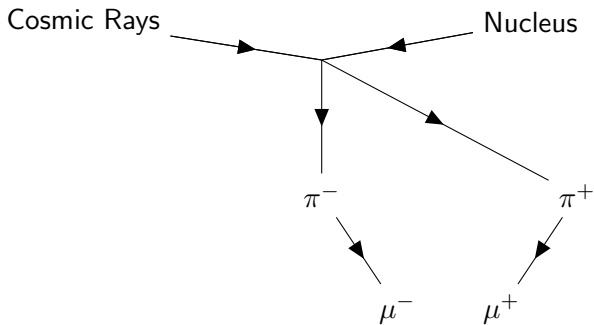
Cosmic Ray Muon Production



Cosmic Ray Muon Production

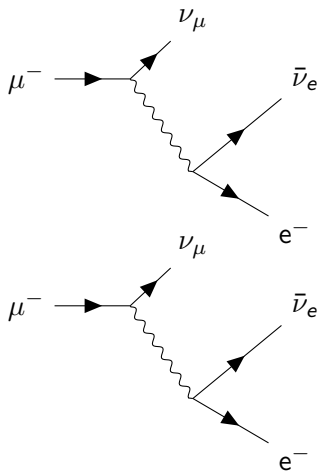


Cosmic Ray Muon Production

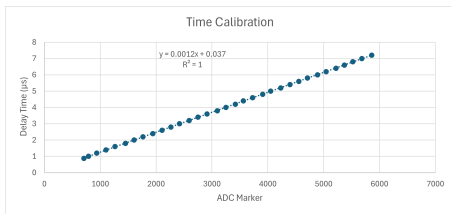
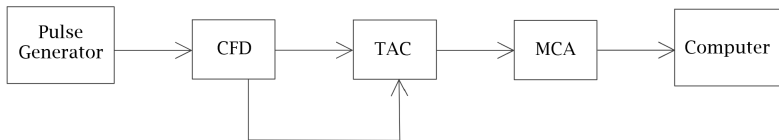


How Muons Decay

- Two main decay modes
- Lifetime in rest frame: 2.197 μ [1]



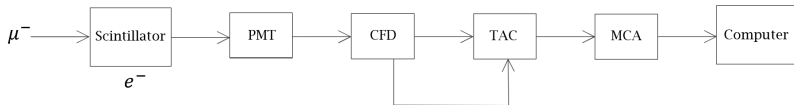
Calibration



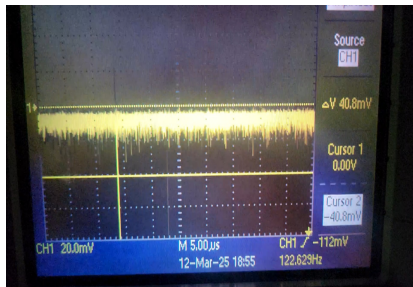
- Send two known pulses
- Recorded channel numbers from the MCA
- Repeat
- Created a calibration curve

$$t = (1.22 \pm 0.001) \times 10^{-3} \cdot \gamma + (0.0361 \pm 0.0042)$$

Experiment



Procedure



- PMT bias voltage: -2.2 kV
- Cover computer screen to reduce noise
- CFD threshold: 40 mV
- Approx. 7 days runtime

Data Analysis

- Convert chn. to txt.
- Mapped MCA channel numbers using calibration curve
- Histogram and exponential decay curve

$$N(t) = N_0 e^{-t/\tau}$$

- Extract mean lifetime τ

The image shows a web browser window at the top with the title "Converting a .chn file to a text file". Below the title is a text box with instructions: "Convert an Ortec '1000 channel file' (.chn) to a text file as follows: First click on the 'Browse' button to select the '.chn file from your computer. Next, click on the 'Upload .chn File' button to upload the file to memory. Then, click on the 'Write Data to text window' button to produce a text file of the data. Finally, copy and paste the data in the text window to a text file on your computer." There are two buttons: "Choose File" and "Upload .chn File". Below these is a link: "Write Data to text window".

Below the browser window is a terminal window showing MATLAB code. The code is as follows:

```

1  % Load 'chny' file
2  chny = load('chny');
3  % Extract channel numbers
4  channel_numbers = chny(:,1);
5  % Extract counts
6  counts = chny(:,2);
7  % Create histogram
8  [h,edges] = histogram(channel_numbers,counts);
9  % Plot histogram
10 plot(channel_numbers,counts);
11 % Fit exponential decay curve
12 % Create fit function
13 fit_fun = @(t) a * exp(-t/tau);
14 % Fit data
15 [fit_params,fit_err] = fit(channel_numbers,counts,fit_fun);
16 % Extract fit parameters
17 tau = fit_params(1)/-1;
18 % Print results
19 fprintf('Mean lifetime: %f\n',tau);
20 % Plot fit
21 plot(channel_numbers,counts,'o');
22 hold on;
23 plot(channel_numbers,fit_fun(channel_numbers),'r');
24 % Save fit parameters to file
25 save('fit_params.mat','tau','fit_err');
26 % End of script

```


Implications

Relativity

- Muon should only travel about 660 meters before decaying
- Muons detected at sea-level, about 10,000 meters
- In lab frame, appears to have longer lifetime
- *Supports time dilation*

Weak Force

- Weak nuclear force
- Rate of decay determined by strength of force
- Strength characterized by Fermi constant G_F
- *Supports Fermi's Theory*

Conclusion



Sources of Error

- Electronic noise
- Systematic timing uncertainties
- Improper light seal

Potential Improvements

- Better sealing
- Environment change
- Higher threshold

Acknowledgments and Citations

Acknowledgments:

- Lab partner Preeti Sharma
- Prof. Ngabonziza
- LSU Physics Department

Sources:



Particle Data Group,
Review of Particle Physics,
2022.



David J. Griffiths and Darrell
F. Schroeter,
*Introduction to Quantum
Mechanics*, 3rd Edition,
Cambridge University Press,
2018.