

What Is A Muon?

A muon is an unstable, second generation lepton, which has a mass 207 times that of an electron, and a mean lifetime of 2.2 nanoseconds. A muon is a fundamental particle. In other words, it is a particle incapable of subdivision. The muon has a charge of -1 . According to Newtonian physics, given the half-life of a muon, they would only be able to travel 660 meters. However, muons travel the full 10 to 15 kilometers of the earth's atmosphere due to the relativistic speeds at which they travel, as mandated by Einsteinian physics. Muons form when highly energetic particles from deep space collide with atoms in the earth's upper atmosphere. The initial collision creates pions, which decay into muons. The muons then travel through the atmosphere, and arrive at ground level.

How do the paddles work?

The paddles consist of 9 cm squares of scintillating glass, glass channel and photo tube. As muons pass through the scintillating glass, excited electrons are channeled through to the photo multiplier to the computer counter. The computer counts muons detected as passing through two and only two paddles.

Materials

- ⇒ 2 Scintillating glass paddles and photo tubes
- ⇒ Aluminum rod grid
- ⇒ Three-pronged beaker clamps
- ⇒ Ring stands
- ⇒ A computer with muon data software

Muon Two Paddle Experiment

Hypothesis

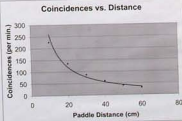
There will be a decrease in the number of coincidences as the distance between the two paddles increases.

Explanation

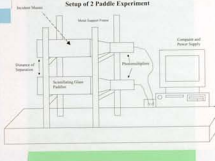
We tested how a change of distance between paddles affects the number of muon collisions detected.

Procedure

1. Using the aluminum tubing support grid set up the first paddle parallel to but not touching the table.
2. Set up the second paddle 10 cm directly over the first paddle making sure they are parallel.
3. Connect the paddles to a computer running on muon detection program under the Linux operating system.
4. Set the computer to gather data every minute for a half hour.
5. Repeat steps 2 - 4 setting the paddles 20 cm, 30 cm, 40 cm, 50 cm and 60 cm apart.
6. Analyze the data and evaluate.



Setup of 2 Paddle Experiment



Data Table for Double Paddle Experiment

Paddle Separation (cm)	Duration (s)	Coincidences	Coincidence/min.
10	1818	6859	226.3696
20	1818	4187	135.5448
30	1818	2626	86.667
40	1818	1824	60.788
50	1818	1230	40.594
60	1818	942	31.083

Conclusion

Our data shows an indirect relationship between distance and coincidences, thus proving our hypothesis. We determined that shorter distances would allow for greater incidence angles of muons, so that when the distance between the two paddles is increased the number of incidences is decreased.

Analysis for 2 Paddle Experiment

After reviewing the data collected, the amount of coincidences for the scintillating glass paddles is collected over time. We recorded the number of coincidences in which both paddles registered hits for a particular time frame. These results showed that the number of registered hits varied from a consistent value as a function of the time between observations. In order to properly analyze the given results, an approach would be to require that enough data will be collected to represent a consistent value of observations. While coincidences registered are approximately 1000 hits per minute, it is not clear how long it would take to collect a consistent number of hits to give enough for an odd counter. To use the data collected, we had a constant duration in order to give enough for an odd counter. To use the data collected, we had a constant duration in order to give enough for an odd counter. To use the data collected, we had a constant duration in order to give enough for an odd counter. To use the data collected, we had a constant duration in order to give enough for an odd counter.

$$N = N_1 \cdot N_2 \cdot \cos(\theta)$$

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If the angle you used is about 10 degrees then $\cos(10) = 0.98$, then these expressions will be approximately the same as $N = N_1 \cdot N_2$. This might not be noticeable together with the small angle given by:

$$\cos(\theta) \approx 1 - \frac{\theta^2}{2}$$



Now that the angle theta has been defined, the results are expressed according to the rest to distance in the surface area, angle and time. The angle theta is given by:

$$\theta = \arcsin\left(\frac{d}{L}\right)$$

Number of Collisions	Angle (theta)	Length (L)	Distance (d)	Coincidences	Total Counts	Flux (cm ⁻² s ⁻¹)
1000	0.1736	100	17.36	1000	1000	1000
1000	0.3472	100	34.72	1000	1000	1000
1000	0.5208	100	52.08	1000	1000	1000
1000	0.6944	100	69.44	1000	1000	1000
1000	0.8680	100	86.80	1000	1000	1000
1000	1.0416	100	104.16	1000	1000	1000
1000	1.2152	100	121.52	1000	1000	1000
1000	1.3888	100	138.88	1000	1000	1000
1000	1.5624	100	156.24	1000	1000	1000
1000	1.7360	100	173.60	1000	1000	1000
1000	1.9096	100	190.96	1000	1000	1000
1000	2.0832	100	208.32	1000	1000	1000
1000	2.2568	100	225.68	1000	1000	1000
1000	2.4304	100	243.04	1000	1000	1000
1000	2.6040	100	260.40	1000	1000	1000
1000	2.7776	100	277.76	1000	1000	1000
1000	2.9512	100	295.12	1000	1000	1000
1000	3.1248	100	312.48	1000	1000	1000
1000	3.2984	100	329.84	1000	1000	1000
1000	3.4720	100	347.20	1000	1000	1000
1000	3.6456	100	364.56	1000	1000	1000
1000	3.8192	100	381.92	1000	1000	1000
1000	3.9928	100	399.28	1000	1000	1000
1000	4.1664	100	416.64	1000	1000	1000
1000	4.3400	100	434.00	1000	1000	1000
1000	4.5136	100	451.36	1000	1000	1000
1000	4.6872	100	468.72	1000	1000	1000
1000	4.8608	100	486.08	1000	1000	1000
1000	5.0344	100	503.44	1000	1000	1000
1000	5.2080	100	520.80	1000	1000	1000
1000	5.3816	100	538.16	1000	1000	1000
1000	5.5552	100	555.52	1000	1000	1000
1000	5.7288	100	572.88	1000	1000	1000
1000	5.9024	100	590.24	1000	1000	1000
1000	6.0760	100	607.60	1000	1000	1000
1000	6.2496	100	624.96	1000	1000	1000
1000	6.4232	100	642.32	1000	1000	1000
1000	6.5968	100	659.68	1000	1000	1000
1000	6.7704	100	677.04	1000	1000	1000
1000	6.9440	100	694.40	1000	1000	1000
1000	7.1176	100	711.76	1000	1000	1000
1000	7.2912	100	729.12	1000	1000	1000
1000	7.4648	100	746.48	1000	1000	1000
1000	7.6384	100	763.84	1000	1000	1000
1000	7.8120	100	781.20	1000	1000	1000
1000	7.9856	100	798.56	1000	1000	1000
1000	8.1592	100	815.92	1000	1000	1000
1000	8.3328	100	833.28	1000	1000	1000
1000	8.5064	100	850.64	1000	1000	1000
1000	8.6800	100	868.00	1000	1000	1000
1000	8.8536	100	885.36	1000	1000	1000
1000	9.0272	100	902.72	1000	1000	1000
1000	9.2008	100	920.08	1000	1000	1000
1000	9.3744	100	937.44	1000	1000	1000
1000	9.5480	100	954.80	1000	1000	1000
1000	9.7216	100	972.16	1000	1000	1000
1000	9.8952	100	989.52	1000	1000	1000
1000	10.0688	100	1006.88	1000	1000	1000
1000	10.2424	100	1024.24	1000	1000	1000
1000	10.4160	100	1041.60	1000	1000	1000
1000	10.5896	100	1058.96	1000	1000	1000
1000	10.7632	100	1076.32	1000	1000	1000
1000	10.9368	100	1093.68	1000	1000	1000
1000	11.1104	100	1111.04	1000	1000	1000
1000	11.2840	100	1128.40	1000	1000	1000
1000	11.4576	100	1145.76	1000	1000	1000
1000	11.6312	100	1163.12	1000	1000	1000
1000	11.8048	100	1180.48	1000	1000	1000
1000	11.9784	100	1197.84	1000	1000	1000
1000	12.1520	100	1215.20	1000	1000	1000
1000	12.3256	100	1232.56	1000	1000	1000
1000	12.4992	100	1249.92	1000	1000	1000
1000	12.6728	100	1267.28	1000	1000	1000
1000	12.8464	100	1284.64	1000	1000	1000
1000	13.0200	100	1302.00	1000	1000	1000
1000	13.1936	100	1319.36	1000	1000	1000
1000	13.3672	100	1336.72	1000	1000	1000
1000	13.5408	100	1354.08	1000	1000	1000
1000	13.7144	100	1371.44	1000	1000	1000
1000	13.8880	100	1388.80	1000	1000	1000
1000	14.0616	100	1406.16	1000	1000	1000
1000	14.2352	100	1423.52	1000	1000	1000
1000	14.4088	100	1440.88	1000	1000	1000
1000	14.5824	100	1458.24	1000	1000	1000
1000	14.7560	100	1475.60	1000	1000	1000
1000	14.9296	100	1492.96	1000	1000	1000
1000	15.1032	100	1510.32	1000	1000	1000
1000	15.2768	100	1527.68	1000	1000	1000
1000	15.4504	100	1545.04	1000	1000	1000
1000	15.6240	100	1562.40	1000	1000	1000
1000	15.7976	100	1579.76	1000	1000	1000
1000	15.9712	100	1597.12	1000	1000	1000
1000	16.1448	100	1614.48	1000	1000	1000
1000	16.3184	100	1631.84	1000	1000	1000
1000	16.4920	100	1649.20	1000	1000	1000
1000	16.6656	100	1666.56	1000	1000	1000
1000	16.8392	100	1683.92	1000	1000	1000
1000	17.0128	100	1701.28	1000	1000	1000
1000	17.1864	100	1718.64	1000	1000	1000
1000	17.3600	100	1736.00	1000	1000	1000
1000	17.5336	100	1753.36	1000	1000	1000
1000	17.7072	100	1770.72	1000	1000	1000
1000	17.8808	100	1788.08	1000	1000	1000
1000	18.0544	100	1805.44	1000	1000	1000
1000	18.2280	100	1822.80	1000	1000	1000
1000	18.4016	100	1840.16	1000	1000	1000
1000	18.5752	100	1857.52	1000	1000	1000
1000	18.7488	100	1874.88	1000	1000	1000
1000	18.9224	100	1892.24	1000	1000	1000
1000	19.0960	100	1909.60	1000	1000	1000
1000	19.2696	100	1926.96	1000	1000	1000
1000	19.4432	100	1944.32	1000	1000	1000
1000	19.6168	100	1961.68	1000	1000	1000
1000	19.7904	100	1979.04	1000	1000	1000
1000	19.9640	100	1996.40	1000	1000	1000
1000	20.1376	100	2013.76	1000	1000	1000
1000	20.3112	100	2031.12	1000	1000	1000
1000	20.4848	100	2048.48	1000	1000	1000
1000	20.6584	100	2065.84	1000	1000	1000
1000	20.8320	100	2083.20	1000	1000	1000
1000	21.0056	100	2100.56	1000	1000	1000
1000	21.1792	100	2117.92	1000	1000	1000
1000	21.3528	100	2135.28	1000	1000	1000
1000	21.5264	100	2152.64	1000	1000	1000
1000	21.7000	100	2170.00	1000	1000	1000
1000	21.8736	100	2187.36	1000	1000	1000
1000	22.0472	100	2204.72	1000	1000	1000
1000	22.2208	100	2222.08	1000	1000	1000
1000	22.3944	100	2239.44	1000	1000	1000
1000	22.5680	100	2256.80	1000	1000	1000