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Tau, D, and other kaonium mesons in the onium particle theory

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The onium theory evolved from the relativistic positronium solution discovered by Milne, Feynman, and Sternglass and takes into consideration the known mass quantization of particles in units of m_e/α and $m_e/2\alpha$ where m_e is the electron mass and α is the fine structure constant. The relativistic positronium mass is approximately a factor of m_e/α multiplied by its two particles and is equivalent to the neutral pion. In onium theory only electrons and protons are elementary particles and they are the components of all unstable resonances. The theory accounts for their composition by considering the total number of pions in their most complex decay modes. The tau particle has eight decay modes to two kaons and at least 30 decay modes to the equivalent of four pions, indicating it is much more complex than a simple excited muon. In the onium theory, tau particles are composed of two kaons in relativistic orbit making them kaonium. They are effectively a lower energy D meson. This paper also examines the composition and masses of other kaonium resonances. In onium theory mu and tau particles are mesons rather than leptons, and they are not elementary.

1. Background

In 1948 Milne worked out the relativistic positronium solution where an electron and positron orbit at relativistic velocities with the Coulomb attraction counteracted by the centrifugal force to make it briefly stable.[1] Unfortunately, it was deep in a book and did not receive serious attention. Some years later Sternglass was inspired by the Fermi-Yang model of pions as nucleon pairs and was researching the idea of a relativistic electron-proton resonance. Feynman suggested to Sternglass that he attempt the electron-positron solution first and so Sternglass worked it out in Feynman's office under his watchful eye. When finished Sternglass had shown that relativistic positronium has a mass of approximately 140 MeV/c^2 and Feynman recognized immediately that it was a classical model of a neutral pion.[2]

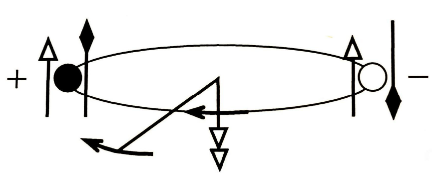

Fig. 1. A Sternglass style drawing of a neutral pion. Open arrows indicate spin direction and closed arrows indicate the direction of the magnetic moment.[3]

Sternglass published the solution alone after refining the mass estimate to 263m_e (134.4 MeV/c^2) which was an excellent estimate for the time.[3] See Figure 1. Sternglass went on to consider that the muon and charged pion can be accounted for by having a non-relativistic electron or positron orbited by a neutral pion. The lower mass muon solution was due to the pion's internal orbit being in the same direction as its orbit around the electron, while in a charged pion the neutral pion orbits in the opposite direction.[4] See figure 2 for a simple positive pion illustration.

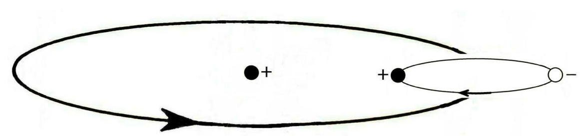

Fig. 2. A positive pion with a positron orbited by a neutral pion with the orbits in opposite directions. (not to scale)

The muon and pion are discussed in greater detail in a prior paper and book by the author.[5][6] I also attempted an earlier model of the tau particle as an excited muon based on the Sternglass model, but based on the research conducted recently, the earlier model is incorrect.[7]

Sternglass unfortunately abandoned the onium model for his model of the kaon and other more complicated resonances and he failed to develop a convincing particle theory. His muon and pion models are, however, consistent with the onium theory and form the basis of that theory. In onium theory, muons are mesons and are not elementary.

2. Onium Theory

It has been well-documented by MacGregor that the masses of particles are quantized in units of $m_e/2\alpha$ = 35 MeV/c^2 or m_e/α = 70 MeV/c^2.[8] The relativistic positronium solution is also quantized in units of m_e/α per particle, so it is obvious that all unstable particles should be investigated as possible onium resonances. In a basic two-pion kaonium resonance where each charged pion contains three electrons, which is consistent with its decay products, the added relativistic mass is 6 x 35 MeV/c^2 = 210 MeV/c^2. The sum of the masses of two pions at 139.57 MeV/c^2 each and this relativistic mass energy is 489.22 MeV/c^2. This is close to the known masses of charged and neutral kaons of 493.677 MeV/c^2 and 497.614 MeV/c^2 respectively. Charged kaons have a central electron or positron in addition to the pions.

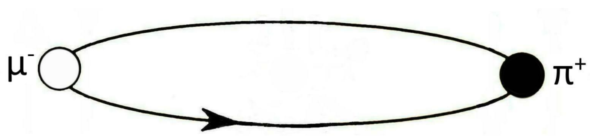

Fig. 3. A K-long neutral kaon

Note that a K-short neutral kaon often decays to two pions and the K-long usually decays to a muon and pion which tells us the difference in their composition. See figure 3 for the onium model of a K-long. Depending on if a K-long has a negative or positive muon it decays preferentially to matter or antimatter thus leading to matter and antimatter versions. Note that because kaons contain two neutral pions with opposing orbits, the non-relativistic electron and position have no preferred orbital direction. This causes the K-long and K-short to have the same mass.[5][6]

Neutral rho mesons can decay to two neutral pions and two charged pions. The sum of the masses of a neutral kaon and two neutral pions is 767.56 MeV/c^2. That compares well with the known mass of 775.26 MeV/c^2. A charged rho has a mass of 775.11 MeV/c^2. The sum of the masses of a kaon, charged pion, and neutral pion is 772.16 MeV/c^2. Rho mesons have two pions and a kaon in nested or collocated orbits as shown in figure 4.

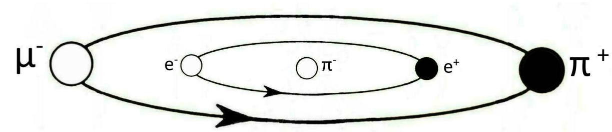

Fig. 4. An illustration of a charged rho meson (orbits not to scale)

In the onium theory, the decay products can be used to determine the composition of most mesons and baryons. Mesons are composed entirely of electrons and positrons while baryons contain a single non-relativistic nucleon in addition to electrons and positrons. Quarks are unnecessary to describe the composition of any known particle.

In some cases, electron-positron or proton-antiproton quantum fluctuations are excited during decay adding two or more particles to the decay products. But the maximum number of pions in a particle's decay modes is usually an excellent indicator of its composition. Mesons and baryons can be grouped based on the number of pions they contain with base kaons in Group 2, the eta in Group 3, and the tau and base D mesons in Group 4.

In onium theory, kaons are pionium, D mesons are kaonium, and B mesons are Donium. Similarly, charmed baryons have two kaons in relativistic orbit while bottom baryons have two D mesons in orbit. Resonances containing relativistic protons have masses quantized in units of $m_p/2\alpha$ = 64.3 GeV/c^2 and m_p/α = 128.6 GeV/c^2 where m_p is the proton mass.

3. Tau Decay Modes

To investigate the composition of tau particles it is necessary to study their decay modes. The most common are listed below.[9]

a. $\tau^- \rightarrow \pi^0 + \pi^-$ or $\tau^+ \rightarrow \pi^0 + \pi^+$ (25.49%)
b. $\tau^- \rightarrow e^-$ or $\tau^+ \rightarrow e^+$ (17.82%)
c. $\tau^- \rightarrow \mu^-$ or $\tau^+ \rightarrow \mu^+$ (17.39%)
d. $\tau^- \rightarrow \pi^-$ or $\tau^+ \rightarrow \pi^+$ (10.82%)
e. $\tau^- \rightarrow 2\pi^0 + \pi^-$ or $\tau^+ \rightarrow 2\pi^0 + \pi^+$ (9.26%)
f. $\tau^- \rightarrow \pi^+ + 2\pi^-$ or $\tau^+ \rightarrow \pi^- + 2\pi^+$ (8.99%)
g. $\tau^- \rightarrow \pi^+ + 2\pi^- + \pi^0$ or $\tau^+ \rightarrow \pi^- + 2\pi^+ + \pi^0$ (2.74%)
h. $\tau^- \rightarrow \omega + \pi^-$ or $\tau^+ \rightarrow \omega + \pi^+$ (1.95%)
i. $\tau^- \rightarrow 3\pi^0 + \pi^-$ or $\tau^+ \rightarrow 3\pi^0 + \pi^+$ (1.04%)

While decay modes (b) and (c) could be thought of as the decay of an excited muon, the other decay modes tell us a different story. In total, the tau has eight known decay modes to two kaons and at least 30 to a total of four pions. These decay modes are consistent with a resonance composed of two kaons forming a kaonium compound. Note for comparison that D mesons also decay preferentially to four pions or two kaons and are close to the tau in mass.

4. Relativistic Kaonium Resonances

In onium theory we can readily determine the mass of relativistic kaonium resonances as they often have the mass of two charged kaons plus the relativistic orbital mass. Each charged kaon contains two pions plus a central electron or positron, for 7 particles total. Therefore, a m_e/α per particle orbit has 14 x m_e/α = 980.35 MeV/c^2 in relativistic orbital mass. Summing the masses of an electron, two charged kaons with a mass of 493.677 MeV/c^2 each, plus that orbital energy, totals 1968.22 MeV/c^2. This is a strange D meson which has a known mass of 1968.30 MeV/c^2. See figure 5 for a model of the strange D meson. They readily decay to two kaons.

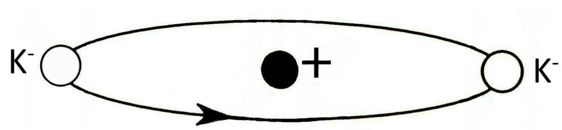

Fig. 5. A strange D meson with a positron orbited by two relativistic kaons

If we take the mass of the tau of 1776.86 MeV/c^2 and subtract 980.35 MeV/c^2 in relativistic orbital energy and the mass of an electron, 796.00 MeV/c^2 is left, or 398.00 MeV/c^2 per kaon. This is a deexcited form of a kaon. If we subtract the mass of an electron, charged kaon, and the orbital energy from a charged D meson with a mass of 1869.61 MeV/c^2, 395.07 MeV/c^2 is left for its deexcited kaon. Similarly, if we subtract the relativistic orbital mass and the mass of a charged kaon from the mass of a neutral D meson of 1864.84 MeV/c^2, then 390.81 MeV/c^2 is left. D mesons contain a single deexcited kaon similar to the two in the tau. A charged D meson is illustrated in Figure 6.

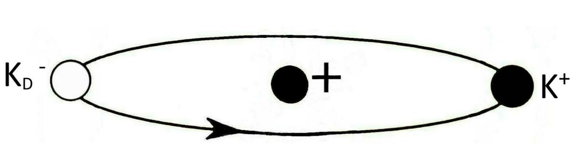

Fig. 6. A charged D meson with a positron orbited by a K_D-K kaon pair

Even more interesting, if we take the mass of the charged $K^*(892)^\pm$ kaon of 891.66 MeV/c^2 and subtract the mass of a charged kaon and an electron, 397.47 MeV/c^2 is left. So the $K^*(892)$ kaons contain the same deexcited kaon found in the tau and D mesons. It is notable that the $K^*(892)$ kaons are also known to decay to four pions, so they appear to be a non-relativistic combination of a regular kaon and a deexcited kaon rather than being a single excited kaon. They would need to have non-relativistic orbits which may be nested or collocated.

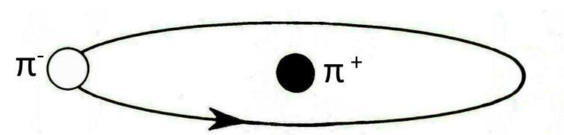

Fig. 7. A K_D kaon as a stationary pion orbited by a relativistic pion.

In onium theory the deexcited kaon can be illustrated as shown in figure 7 as there should be a form of pionium where one pion is stationary and nonrelativistic while orbited relativistically by a pion. We can call a deexcited kaon with a single relativistic pion a K_D kaon. If a charged pion is orbited by a charged pion with 105 MeV/c^2 in relativistic orbital mass, the K_D resonance has a total mass of ~384.18 MeV/c^2. A charged version has either an electron added to that or a neutral pion instead of a charged pion. In the tau, D meson, and $K^*(892)$ the K_D acquires slightly more mass for reasons that need to be determined.

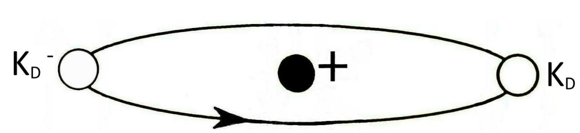

Fig. 7. A negative tau as a positron orbited by two K_D kaons.

A tau resonance is clearly a K_DK_D kaonium resonance as shown in Figure 7. In this case it is shown as a positron orbited by two negative K_D resonances. It could alternatively have oppositely charged K_D resonances. Note that having two types of orbital solutions appears to be the source of many of the rule violating decay modes in the standard model.

In the onium theory there could also be a neutral K_DK_D resonance. The closest known resonance that fills that vacancy in the model is the $K_2(1770)$ which has a mass of 1773 MeV/c^2 and has dominant decay modes that begin with a kaon and two pions.

5. Nested Kaonium Resonances

There are also kaonium resonances where the two kaons are nested or collocated, and not in relativistic orbit with each other. The K_DK_D resonance can decay to four charged pions and have a mass of approximately 782.16 MeV/c^2 if one has the calculated mass and one the estimated mass. The meson which matches that is the omega (ω) which has a mass of 782.65 MeV/c^2. The omega is electrically neutral.

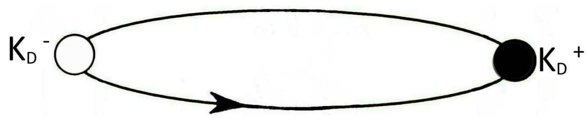

Fig. 9. An omega meson illustrated as two oppositely charge K_D resonances in a non-relativistic orbit.

There is also the $K^*(800)$ or **κ** meson which is thought to have a mass of around 800 MeV/c^2, and may be charged. In the standard model, the $K^*(800)$ is said to be a pseudoscalar meson while the omega is said to be a vector meson. In the onium theory those designations are not meaningful, but the two resonances usually turn out to have different orbital configurations and energy or a different number of pions. The $K^*(800)^{\pm}$ does not fit the quark model, and it is often ignored given the evidence is inconclusive. Based on the onium theory there may be a charged K_DK_D resonance with a mass of approximately 800 MeV/c^2 having the same composition as a tau.

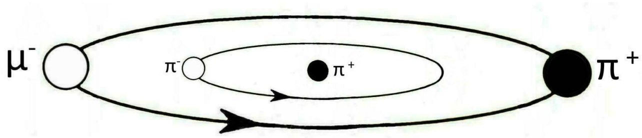

Fig. 10. A $K^*(892)^0$ with a charged pion orbited by a relativistic oppositely charged pion orbiting with a relativistic muon-pion pair forming a neutral kaon. (orbits not to scale)

The next resonances are the nested or collocated K_DK resonances. As mentioned, these are the $K^*(892)^{\pm}$ and $K^*(892)^0$ kaons. The $K^*(892)$ mesons decay most importantly to a kaon and two oppositely charged pions. In $K^*(892)^{\pm}$ decay the kaon is charged while the $K^*(892)^0$ decays most often to a neutral kaon. That indicates the $K^*(892)^0$ is likely composed of a neutral K_DK pair. The $K^*(892)^{\pm}$ is likely composed of neutral kaon and a charged K_D. The mass difference of 4.15 MeV/c^2 is similar to the 4.59 MeV/c^2 mass difference between neutral and charged pions.

Next are the nested KK resonances which should have a mass of around 990 MeV/c^2. There are three resonances that are known to decay to two kaons in that energy range. They are the $f_0(980)$, $a_0(980)$, and phi meson. The $f_0(980)$ and phi meson are neutral and the $a_0(980)$ can be neutral or charged. The $f_0(980)$ and $a_0(980)$ can decay to two neutral kaons with one being an antikaon. The $f_0(980)$, as illustrated in figure 11, is only found in a neutral form so seems most likely that it is made of an oppositely charged pair of kaons.

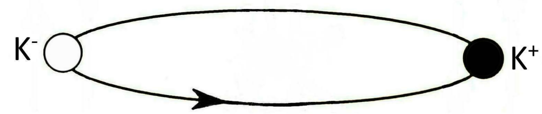

Fig. 11. An illustration of a $f_0(980)$

The $a_0(980)$ has a principal decay mode to an eta and can decay to a rho and π, meaning it is likely a Group 5 meson based on an eta. The phi has many decays to five total pions and is also likely to be a Group 5 meson instead. The sum of the masses of a $\pi^{\pm}$, a 384.69 MeV/c^2 $K_D^{\pm}$, and a K^0, as illustrated in figure 12, is 1021.87 MeV/c^2 which is close to the phi's measured mass of 1019.461 MeV/c^2. The $a_0(980)$ may be similar but with a muon in the center.

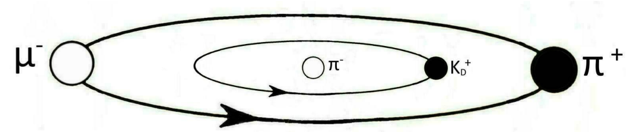

Fig. 12. An illustration of a phi meson.

6. D_D Resonances

The tau and D mesons are m_e/α per particle kaonium resonances and in the onium theory there are also $m_e/2\alpha$ per particle kaonium resonances. These can be thought of as deexcited D mesons or D_D mesons. Instead of having 980.35 MeV/c^2 in relativistic orbital mass they have 490.18 MeV/c^2.

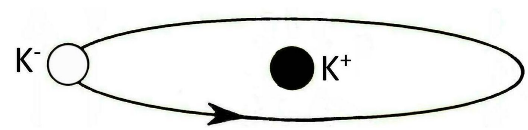

Fig. 13. An illustration of one type of D_D meson

D_D mesons appear in B mesons and can possibly come in two forms. In the basic form, one kaon is stationary as shown in Figure 13. In the other form, both kaons are in relativistic orbit, but at the lower $m_e/2\alpha$ per particle relativistic orbital energy.

The base KK D_D meson resonance with two oppositely charged kaons has a mass of approximately 1477.53 MeV/c^2. The $a_0(1450)$ with a mass of 1474 MeV/c^2 is the best fit with that mass while the $f_0(1500)$ with a mass of 1504 MeV/c^2 is close. Both are neutral and decay to two kaons. There is no known charged resonance at this energy and some other candidates in that mass range decay to more than four pions. It is possible that both are KK resonances, however the $a_0(1450)$ is likely to be an eta based resonance like the $a_0(980)$. The $f_0(1500)$ has one decay mode to an eta and eta prime and the sum of their masses is 1505.64 MeV/c^2 which may indicate where it gets the extra mass.

Next is the $m_e/2\alpha$ K_DK kaonium resonances which have a mass of approximately 1381.32 MeV/c^2. The $f_0(1500)$ commonly decays to a $f_0(1370)$ which is closest to that mass and is known to decay to two kaons. The $f_1(1420)$ with a mass of 1426.4 MeV/c^2 and $K_1(1400)$ with a mass of 1403 MeV/c^2, are close to this mass energy but appear to have five pions in their decay modes meaning they are more likely to be Group 5 mesons.

The $m_e/2\alpha$ K_DK_D kaonium resonance similarly has a mass of ~1285.12 MeV/c^2. The $f_2(1270)$ with a mass of 1275.1 MeV/c^2 and the $f_1(1285)$ with a mass of 1281.9 MeV/c^2 are possibly resonances of this type. The $K_1(1270)$ is also in this mass range at 1272 MeV/c^2, but it appears to contain more than four pions based on its decay modes. The $a_2(1320)$ has a mass of 1318.3 MeV/c^2, however, it is probably based on an eta rather than being part of the kaonium group.

7. Other D mesons

The so-called vector D mesons, the $D^*(2007)^0$, $D^*(2010)^\pm$, and $D_s^{*\pm}$, typically decay to a base D meson plus a pion and are therefore composed of five pions making them Group 5 mesons.

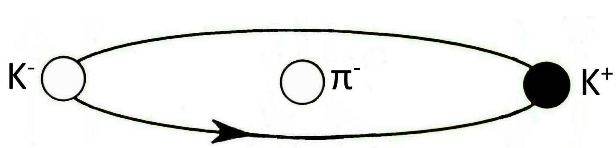

Fig. 14. An illustration of a $D_s^{*\pm}$

They have a pion orbited by two kaons. The $D^*(2007)^0$ and $D^*(2010)^\pm$, are K_DK resonances while the $D_s^{*\pm}$, is a KK resonance. A $D_s^{*\pm}$ is shown in figure 14. There are many other Group 5 or greater mesons based on their known decay products, but an analysis of those resonances is left for a future paper.

8. Group 4 Kaonium Summary

Table 1 summarizes the data of the best-known Group 4 kaonium mesons along with the other kaon, rho, and D mesons discussed in the paper. This table shows the symbol of each resonance, its composition, known mass, and calculated mass based on the onium theory. The mass of the K_D from the $K^*(892)^\pm$ kaons of 397.47 MeV/c^2 was used as its base mass for the purposes of these onium theory mass calculations with the exception of one K_D in the omega meson which has the calculated mass of 384.69 MeV/c^2.

Table 1 Composition and mass comparison of kaon, rho, tau, D, and other kaonium mesons.

Symbol	Composition	Mass (MeV/c^2)	Calculated (MeV/c^2)
$K_D^\pm$	$e^\pm, \pi^\pm, \pi^\pm$	397.47	384.69
K_D^0	$\pi^\pm, \pi^\pm$	396.96	384.18
$K^\pm$	$e^\pm, \mu^\pm, \pi^\pm$	493.677	489.73
K-long	$\mu^\pm, \pi^\pm$	497.614	489.22
K-short	π^+, π^-	497.614	489.22
$\rho^\pm$	$\pi^\pm, \pi^0, \mu^\pm, \pi^\pm$	775.11	772.16
ρ^0	$\pi^0, \pi^0, \mu^\pm, \pi^\pm$	775.26	767.56
ω	K_D^+, K_D^-	782.65	782.16
$K^*(800)^\pm$	$e^\pm, K_D^+, K_D^-$	800	794.94
$K^*(892)^\pm$	$e^\pm, K_D^\pm, K^\pm$	891.66	891.66
$K^*(892)^0$	$K_D^\pm, K^\pm$	895.81	891.15
$f_0(980)$	K^0, K^0	990	995.22
$a_0(980)^\pm$	$e^\pm, K^\pm, K^\pm$	980	979.56
$a_0(980)^0$	$K^\pm, K^\pm$	980	979.05
φ	$K^\pm, K^\pm$	1019.461	1021.87
$f_1(1285)$	K_D^+, K_D^-	1281.9	1285.12
$f_0(1370)$	$K_D^\pm, K^\pm$	~1370	1381.32
$a_0(1450)^0$	$K^\pm, K^\pm$	1474	1477.53
$f_0(1500)^0$	$K^\pm, K^\pm$	1504	1505.64
$K_2(1770)$	K_D^+, K_D^-	1773	1775.29
$\tau^\pm$	$e^\pm, K_D^+, K_D^-$	1776.86	1775.81
$D^\pm$	$e^\pm, K_D^\pm, K^\pm$	1869.61	1872.01
D^0	$K_D^\pm, K^\pm$	1864.84	1871.50
$D_S^\pm$	$e^\pm, K^\pm, K^\pm$	1968.30	1968.22
$D^*(2010)^\pm$	$\pi^\pm, K_D^\pm, K^\pm$	2010.26	2011.07
$D^*(2007)^0$	$\pi^0, K_D^\pm, K^\pm$	2006.96	2006.48
$D_S^{*\pm}$	$\pi^\pm, K^\pm, K^\pm$	2112.1	2107.28

The excellent correlation with the known masses shows how well the onium theory works and in particular that it accounts for resonances that do not fit the quark model. There is, however, often more than one possible solution for a given mass in the onium theory so a complete case-by-case analysis is needed to be confident that we understand the precise composition of each resonance. For example, kaonium group and eta group resonances can have similar masses, so a careful review of their decay modes is needed to properly identify their composition.

9. Conclusion

It is clear from the tau's decay products that it is much more complex than a simple excited muon. Its decay modes indicate that it must have four pions with two pairs of two pions each making it a Group 4 meson. The pion pairs are related to kaons but at lower mass than the base kaons. In order to account for this lower mass relativistic orbit, only one pion in each pair can be in relativistic orbit. We can call this a K_D kaon. The tau mass is equivalent to two K_D kaons in relativistic orbit around an electron.

The masses of the base D mesons are equivalent to a K_DK kaon pair in relativistic orbit. Depending on whether the base (K) kaon is negatively or positively charged, the D meson can appear to decay preferentially to matter or antimatter. The strange D meson mass is a kaonium resonance with both kaons in their base energy state. The relationship between the tau and D mesons makes it clear that the tau is actually the lowest energy form of D meson. Perhaps it should be called a D_t meson.

The lowest energy forms of kaonium are the omega and $K^*(892)$ mesons which are nested or collocated kaonium compounds. There are also lower energy Group 4 mesons that are not adequately described in the quark model that fit the onium model very well, such as the $K^*(800)$ and $f_0(980)$. In the onium theory, the so-called vector D mesons are Group 5 mesons composed of a pion orbited by a pair of kaons.

The tau is not a lepton and not an elementary particle. In the onium theory the muon is a meson as well, not a lepton and not elementary. That also means mu and tau neutrinos are not elementary and neutrino theory must be simplified, but that is a topic for another paper.

Note

This is a revision of the original paper that was published on June 28, 2020.

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All particle data not otherwise cited is from Olive, K.A., et al. (Particle Data Group), (2014) Chin. Phys. C38, 090001.

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