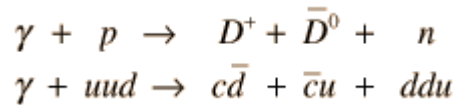


# D Meson

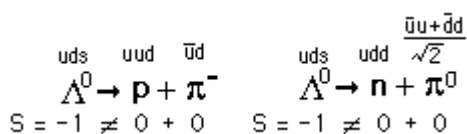
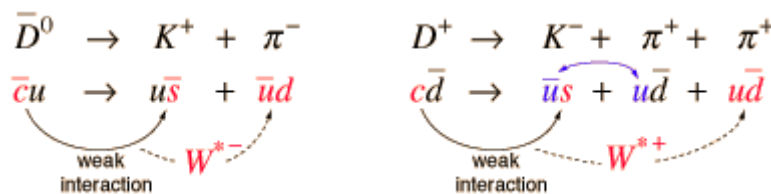
The D Meson is the lightest particle which contains a [charm quark](#), and therefore is a good example for the study of decay by [quark transformation](#) by the [weak interaction](#).

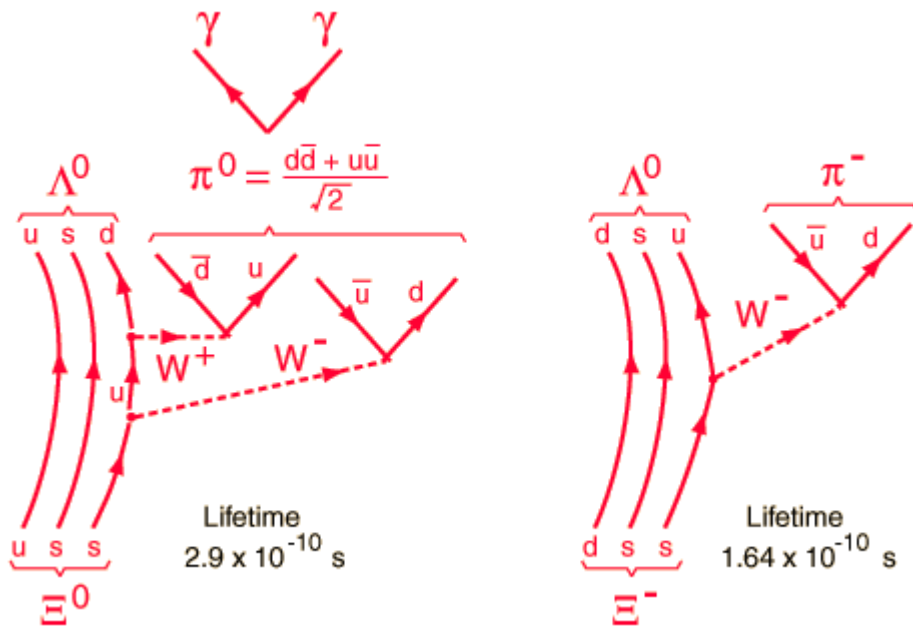
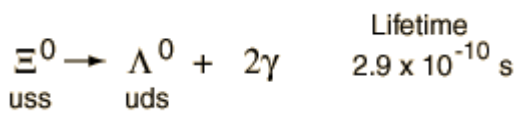
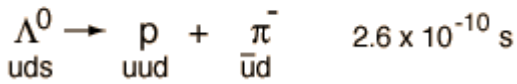
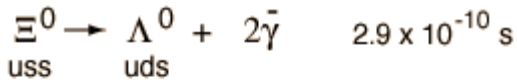
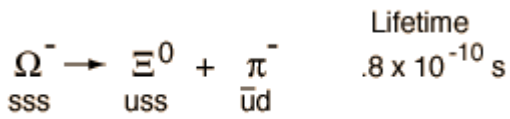
Particle	Symbol	Anti-particle	Makeup	Rest mass MeV/c <sup>2</sup>	S	C	B	Lifetime	Decay Modes
D	D <sup>+</sup>	D <sup>-</sup>	c <u>d</u>	1869.4	0	+1	0	10.6x10 <sup>-13</sup>	K+ <sub>-</sub> , e+ <sub>-</sub>
D	D <sup>0</sup>	D <sup>0</sup> <sub>-</sub>	c <u>u</u>	1864.6	0	+1	0	4.2x10 <sup>-13</sup>	[K,μ,e]+ <sub>-</sub>
D	D <sup>+</sup> <sub>s</sub>	D <sup>-</sup> <sub>s</sub>	c <u>s</u>	1969	+1	+1	0	4.7x10 <sup>-13</sup>	K+ <sub>-</sub>

An interesting example of a particle interaction which involves the D meson was observed in a bubble chamber at [SLAC](#) in 1982 (K. Abe et al., Phys. Rev. Lett. 48,1526 (1982)). Photons at about 20 GeV were produced by [Compton scattering](#) of radiation from a [YAG laser](#) from energetic electrons from the linear accelerator. The interaction is sketched from the bubble chamber photograph. The presumption is that the photon interacted with a proton, producing the D mesons indicated. The reaction which produced these products would appear to be the following.



The reaction can be analyzed by examining the quark content of the products, and is seen to involve the production of a [charm](#)-anticharm quark pair. From the bubble chamber tracks, it can be seen that the neutral D meson decays into two products and the positive D meson decays into three. While the specific products can not be identified with just this photograph, it is interesting to propose possibilities for this process. The decays shown below are one possibility.





Quark	Process	Example	Mean Lifetime (s)
<a href="#">Up</a>	$u \rightarrow d + W^{*+}$	$p+p \rightarrow pn + e^+ + \nu_e$	...
<a href="#">Down</a>	$d \rightarrow u + W^{*-}$	$n \rightarrow p + e^- + \bar{\nu}_e$	900
<a href="#">Strange</a>	$s \rightarrow u + W^{*-}$	$K^- \rightarrow \pi^0 + e^- + \bar{\nu}_e$	$1.24 \times 10^{-8}$
<a href="#">Charm</a>	$c \rightarrow s + W^{*+}$	$D^+ \rightarrow K^- + \pi^0 + \pi^+ + e^+ + \nu_e$	$1.1 \times 10^{-12}$
<a href="#">Bottom</a>	$b \rightarrow c + W^{*-}$	$B^0 \rightarrow D^{*-} + e^+ + \nu_e$	$1.3 \times 10^{-12}$

<a href="#">Top</a>	$t \rightarrow b + W^{*+}$	...
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$$\begin{array}{ccc} \text{uds} & \text{uud} & \bar{u}d \\ \Lambda^0 \rightarrow p + \pi^- & & \\ S = -1 & \neq & 0 + 0 \end{array} \quad \begin{array}{ccc} \text{uds} & \text{udd} & \frac{\bar{u}u + \bar{d}d}{\sqrt{2}} \\ \Lambda^0 \rightarrow n + \pi^0 & & \\ S = -1 & \neq & 0 + 0 \end{array}$$

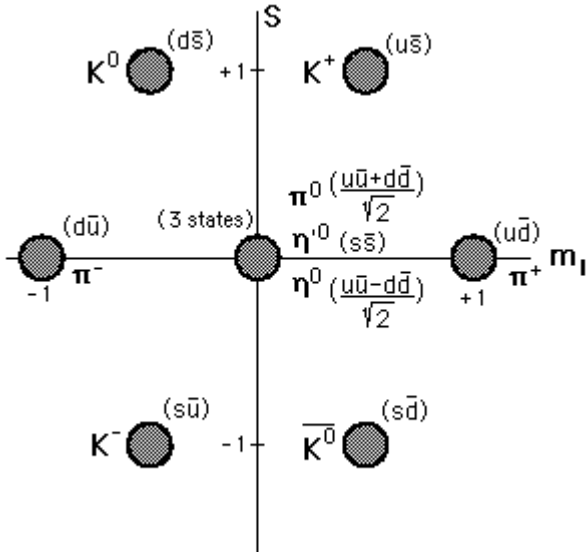
$$\Sigma^+ \rightarrow p + \pi^0 \quad \text{and} \quad \Sigma^+ \rightarrow n + \pi^+$$

## Table of Baryons

Particle	Symbol	Makeup	Rest mass MeV/c <sup>2</sup>	Spin	B	S	Lifetime (seconds>)	Decay Modes
<a href="#">Proton</a>	p	uud	938.3	1/2	+1	0	Stable	...
<a href="#">Neutron</a>	n	ddu	939.6	1/2	+1	0	920	$p e^- \bar{\nu}_e$
<a href="#">Lambda</a>	$\Lambda^0$	uds	1115.6	1/2	+1	-1	$2.6 \times 10^{-10}$	$p \pi^-, n \pi^0$
<a href="#">Sigma</a>	$\Sigma^+$	uus	1189.4	1/2	+1	-1	$0.8 \times 10^{-10}$	$p \pi^0, n \pi^+$
<a href="#">Sigma</a>	$\Sigma^0$	uds	1192.5	1/2	+1	-1	$6 \times 10^{-20}$	$\Lambda^0 \gamma$
<a href="#">Sigma</a>	$\Sigma^-$	dds	1197.3	1/2	+1	-1	$1.5 \times 10^{-10}$	$n \pi^-$
<a href="#">Delta</a>	$\Delta^{++}$	uuu	1232	3/2	+1	0	$0.6 \times 10^{-23}$	$p, \pi^+$
<a href="#">Delta</a>	$\Delta^+$	uud	1232	3/2	+1	0	$0.6 \times 10^{-23}$	$p, \pi^0$
<a href="#">Delta</a>	$\Delta^0$	udd	1232	3/2	+1	0	$0.6 \times 10^{-23}$	$n, \pi^0$
<a href="#">Delta</a>	$\Delta^-$	ddd	1232	3/2	+1	0	$0.6 \times 10^{-23}$	$n, \pi^-$
<a href="#">Xi Cascade</a>	$\Xi^0$	uss	1315	1/2	+1	-2	$2.9 \times 10^{-10}$	$\Lambda^0 \pi^0$
<a href="#">Xi Cascade</a>	$\Xi^-$	dss	1321	1/2	+1	-2	$1.64 \times 10^{-10}$	$\Lambda^0 \pi^-$
<a href="#">Omega</a>	$\Omega^-$	sss	1672	3/2	+1	-3	$0.82 \times 10^{-10}$	$\Xi^0 \pi^-, \Lambda^0 K^-$
<a href="#">Lambda</a>	$\Lambda_c^+$	udc	2281	1/2	+1	0	$2 \times 10^{-13}$	

Particle	Symbol	Anti- particle	Makeup	Rest mass MeV/c <sup>2</sup>	S	C	B	Lifetime	Decay Modes
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J/Psi	J/ $\psi$	Self	$c\bar{c}$	3096.9	0	0	0	$0.8 \times 10^{-20}$	$e^+ e^-, \mu^+ \mu^-, \dots$
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Particle	Symbol	Anti-particle	Makeup	Rest mass MeV/c <sup>2</sup>	S	C	B	Lifetime	Decay Modes
J/Psi	J/ $\psi$	Self	$c\bar{c}$	3096.9	0	0	0	$0.8 \times 10^{-20}$	$e^+ e^-, \mu^+ \mu^-, \dots$

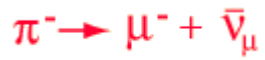
## pion

Particle	Symbol	Anti-particle	Makeup	Rest mass MeV/c <sup>2</sup>	S	C	B	Lifetime	Decay Modes
Pion	$\pi^+$	$\pi^-$	$u\bar{d}$	139.6	0	0	0	$2.60 \times 10^{-8}$	$\mu^+ \nu_\mu$
Pion	$\pi^0$	Self	$\frac{\bar{u}u + \bar{d}d}{\sqrt{2}}$	135.0	0	0	0	$0.83 \times 10^{-16}$	$2\gamma$

## The Xi Baryon

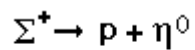
Particle	Symbol	Makeup	Rest mass MeV/c <sup>2</sup>	B	S	Lifetime	Decay Modes
Xi	$\Xi^0$	uss	1315	+1	-2	$2.9 \times 10^{-10}$	$\Lambda^0 \pi^0$

Cascade							
Xi Cascade	$\Xi^-$	dss	1321	+1	-2	$1.64 \times 10^{-10}$	$\Lambda^0 \pi^-$



$$\frac{\pi^-}{x^1 \cdot t^1} \rightarrow \frac{\mu^-}{x^1 \cdot t^2} + \frac{\nu_\mu}{x^1 \cdot t^0} \quad (3 \ 3)$$

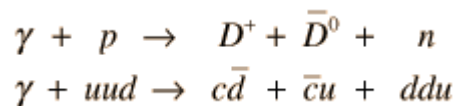
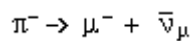
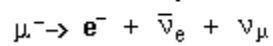
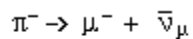
$$\frac{\pi^-}{x^1 \cdot t^1} = \frac{\mu^-}{x^1 \cdot t^1} \cdot \frac{\nu_\mu}{x^1 \cdot t^1} \quad (3 \ 3)$$



$I = 1 \neq 1/2 + 0$  Isospin

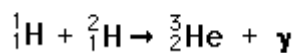
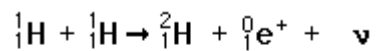
$$\frac{\Sigma^+}{x^4 \cdot t^0} \rightarrow \frac{p}{x^3 \cdot t^0} + \frac{\eta^0}{x^1 \cdot t^0} \quad (5 \ 2)$$

$$\frac{\Sigma^+}{x^1 \cdot t^2} = \frac{p}{x^0 \cdot t^2} \cdot \frac{\eta^0}{x^1 \cdot t^0} \quad (5 \ 2) \quad \text{?????}$$



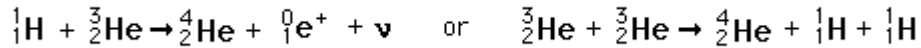
# Proton-Proton Cycle

The fusion of hydrogen in lower temperature stars like our Sun involve the following reactions yielding [positrons](#), [neutrinos](#), and [gamma rays](#).



[The solar neutrino problem](#)

which can be followed by either



The latter of these reactions is part of what is usually called the [proton-proton cycle](#), which yields about 25 MeV and can be combined to the form

