ELEMENTARY PARTICLES INVOLVING ORBITS WITH ANGULAR MOMENTUM GREATER THAN ZERO

by

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Abstract

In order to comply with Pauli's exclusion principle baryons with spin greater than ½ can not be interpreted by using linear oscillation orbits alone. The masses of such baryons can, nevertheless, be calculated in many cases by interpolation between the result obtained by using our oscillation orbits machine program and that obtained by our circular orbits program. The results are consistently better than those obtained by the oscillation program alone. The method has also made possible a calculation of the masses of several baryons of spin greater thatn 3/2 including a spin 5/2 Octet (see table 2).

The method has also improved the interpretation of the masses of several mesons of spin greater than zero, although in this case the necessity of using orbits with angular momentum greater than zero is not as obvious as it is for baryons of spin greater than ½.

1. Introduction

In a preceding paper (Barricelli 1981, section 9) it was noticed that several decaplet baryons of spin 3/2 could not be interpreted by linear oscillation orbits without violating Pauli's exclusion principle. For example the spin 3/2 baryon $\Delta^-(1232)$ is ascribed the (L-5) configuration ((BD)1 DD)5. If all orbits were linear oscillation orbits which have angular momentum equal to 0, the spin 3/2 would have to be interpreted by assigning parallel spins to the three D quarks. The positionally associated D quarks in the external (L-5) orbit would therefore have parallel spins in violation of Pauli's exclusion principle.

The simplest solution to this dilemma was found by ascribing to the positionally associated D quarks an (L-5) orbit of angular momentum equal to 1 instead of a linear oscillation orbit. This way the two external D quarks could be assigned anti-parallel spins and the angular momentum of the baryon could nevertheless be 3/2 if the internal D quark is assigned a spin parallel to the angular momentum of the external orbit.

We have no data-machine program which can directly calculate the mass of a system with an (L-5) orbit of angular momentum 1. We have, however, a program which can handle linear oscillation orbits, of angular momentum 0, and one which can handle circular orbits. The circular (L-5) orbit has angular momentum 5. An interpolation between the mass (1152.828 MEV) obtained with the circular orbit program applied to the (L-5) orbit and the mass (1244.530 MEV) obtained with the linear oscillation program for the configuration ((BD)1DD)5 ascribed to the Δ^-(1232) baryon may be possible for example on the following assumption: that the (L-5) orbit's energies corresponding to angular momentum values 0,1,2,...5 are about equally spaced. On this assumption, which is consistent with observations in various examples of multiple energy levels, the mass of Δ^-(1232) can be calculated by interpolation, and the value one finds is 1226 MEV in fairly good agreement with the observed value of roughly 1232 MEV.

In the preceding paper (Barricelli 1981, table 7) the same method has been applied for the calculation of interpolated masses of the other decaplet baryons, obtaining in each case a better fit than that obtained by linear oscillation orbits alone.

The same interpolation method is also found useful in the interpretation of several spin 1 mesons, also included in the same table, whose angular momentum could be ascribed to an orbit of angular momentum 1 rather than two quarks with parallel spins.

The data contained in the mentioned table are also included in the table 1 below, which is calculated by a new data-machine program, to be described below, which is capable of calculating directly the interpolated masses. The new program has also made it possible to carry out an investigation leading to the interpretation of several other masses of elementary particles whcih had not been interpreted by earlier programs.

2. The interpolation program

The interpolation program is intended to be used for the theoretic calculation of masses of certain groups of elementary particles with spin greater than ½. The groups of particles in which the program has been fairly succesful (predicted masses with errors lower than 1%) are:

1. Several common mesons of spin 1.
2. Common decaplet baryons of spin 3/2.
3. Recently also a group (octet) of baryons of spin 5/2 has been interpreted by the interpolation program.

The program operates in the following way. For each particle whose mass is to be calculated, the input data will contain the name of the particle, its configuration and spin (see Barricelli 1981, tables 5 and 6). Besides the mass calculated by using oscillation orbits, the program will also calculate a mass obtained by assuming that the orbit (or the external orbit if there are several) is circular. An interpolated mass will than be calculated by the rules presented below. The three masses, namely the oscillation orbit mass, the circular orbit mass and the interpolated mass will be printed in the machine output together with the usual information including the name and the observed mass of the particle, its configuration, its spin etc. (See table 1).

The interpolated mass for an elementary particle with spin larger than ½ is calculated as follows. For an (L-n) meson (XY)n of orbital energy level n and spin s the interpolated mass M is calculated by the formula

$$(1) \qquad M = \frac{sM_C + (n-s)M_0}{n}$$

where M_0 = oscillation orbit mass, and M_C = circular orbit mass.

For example in the PHI(1020)-meson with the ascribed configuration (TT)3 and spin s = 1, the orbital energy level is n = 3, the M_0 and M_C masses calculated by the machine and listed in table 1 are respectively 1026.3 MEV and 997.0 MEV and the interpolated mass is according to formula (1):

$$M = \frac{M_C + 2M_0}{3} = 1016 \text{ MEV}$$

in good agreement with the observed mass of 1020 MEV.

TABLE 1.

INTERPRETATION OF SOME BARYONS OF SPIN 3/2 AND MESONS OF SPIN 1.

DEFINITION OF QUARKS AND MAGNETICALLY CHARGED OBJECTS.

PARTICLE DEFINED: B	MASS: 9.00021301	EL CHARGE: -1	MAGN.CHARGE: -3	SPIN: 0
PARTICLE DEFINED: L	MASS: 1.00000000	EL CHARGE: 0	MAGN.CHARGE: -1	SPIN: 0
PARTICLE DEFINED: U	MASS: 1.00021301	EL CHARGE: 1	MAGN.CHARGE: 1	SPIN: 1/2
PARTICLE DEFINED: T	MASS: 1.06300000	EL CHARGE: 0	MAGN.CHARGE: 1	SPIN: 1/2

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
-1	1	-1	3	1.00021301	9.00021301	0.00000000	0.00000000	0.00000000	4.00000001	0	9596.064	F	(BU)0	1/2
0	0	-1	2	1.00000000	4.00000001	0.00000000	0.00000000	0.00000000	1.00000001	0	2399.016	D	(FL)0	1/2
0	0	-1	2	1.00000000	4.00000001	.29535403	.33936446	.08982903	1.07932591	1	2589.320	S	(FL)1	1/2
0	1	-1	2	1.00000000	4.27224383	.44833314	.53961972	.16843280	1.57227803	3	3771.920	C	((HS)2L)3	1/2
0	1	-1	2	1.00000000	4.26194400	.44838048	.58958027	.16881144	1.56206891	3	3747.428	I	((PT)2L)3	1/2

BARYONS

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0	-1	2	-2	4.00000002	4.05484245	.28652372	.24680216	.24197921	.48043614	5	1152.574	CIRCULAR ORBIT.		
0	-1	2	-2	4.00000002	4.03484245	.40181465	.31808333	.31212650	.51878061	5	1244.563	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.51111172		1226.165	DLTA(1232)	((BD)1DD)5	3/2
0	-1	2	-2	4.06800001	4.08484245	.23608645	.24327618	.24233214	.54636313	5	1310.734	CIRCULAR ORBIT.		
0	-1	2	-2	4.06800001	4.03484245	.40115096	.31372704	.31256010	.58459650	5	1402.456	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.57694982		1384.112	SGMA(1385)	((HD)1DT)5	3/2
0	-1	2	-2	4.06800001	4.14984165	.28567603	.24360496	.23907788	.60945133	5	1462.083	CIRCULAR ORBIT.		
0	-1	2	-2	4.06800001	4.14984165	.40053713	.31413078	.30853069	.64758053	5	1553.556	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.63995469		1535.262	XI(1530)	((BT)1DT)5	3/2
0	-1	2	-2	4.13600000	4.14984165	.28524139	.24017642	.23942131	.67543206	5	1620.372	CIRCULAR ORBIT.		
0	-1	2	-2	4.13600000	4.14984165	.39988676	.30988811	.30895330	.71345121	5	1711.581	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.70584738		1693.339	OMGA(1672)	((BT)1TT)5	3/2

MESONS

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0	0	-1	1	1.06800000	1.06800000	.40136721	.37821745	.37821745	.41551745	3	996.833	CIRCULAR ORBIT.		
0	0	-1	1	1.06800000	1.06800000	.57825823	.47534060	.47534060	.42781938	3	1026.346	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.42371874		1016.508	PHI(1020)	(TT)3	1
0	0	-1	1	1.06800000	1.07932591	.33768253	.30635975	.30344240	.31830203	2	763.612	CIRCULAR ORBIT.		
0	0	-1	1	1.06800000	1.07932591	.43187968	.3 071144	.38722905	.33087871	2	793.733	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.32459037		778.697	OM(783)	(ST)2	1
0	-1	2	-2	4.08462164	4.16069666	.20439075	.13850520	.13602002	.36607636	2	878.224	CIRCULAR ORBIT.		
0	-1	2	-2	4.08462164	4.16069666	.28263385	.18110508	.17789946	.38144281	2	915.087	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.37375984		896.656	K++(892)	((HS)1(BU)1)2	1
1	-1	2	-2	4.08484245	4.16069666	.20438782	.13847980	.13602194	.36587177	2	877.732	CIRCULAR ORBIT.		
1	-1	2	-2	4.08484245	4.16069666	.28262968	.18109813	.17790193	.38123783	2	914.596	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.37355480		896.164	K0+(892)	((HS)1(HD)1)2	1
0	0	2	-2	4.08462164	4.62823527	.20254709	.13974006	.12359386	.82966967	2	1990.391	CIRCULAR ORBIT.		
0	0	2	-2	4.08462164	4.62823597	.28001136	.18269602	.16183558	.84460652	2	2026.225	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.83713309		2008.308	D0+(2006)	((BI)1(BU)1)2	1
1	0	2	-2	4.08484245	4.62823527	.20254707	.13973335	.12359447	.82988331	2	1990.915	CIRCULAR ORBIT.		
1	0	2	-2	4.08484245	4.62823527	.28000 0	.18268736	.16183637	.84482492	2	2026.749	OSCILLATION ORBIT.		
							INTERPOLATED MASS		.83735662		2008.832	D++(2009)	((BI)1(BD)1)2	1

For an (L-n) baryon ((BX)rYZ)n with an external orbits energy level n and spin s_0, we calculate a reduced spin s by the formula

(2) $$s = s_0 - \frac{1}{2}$$

which eliminates the spin ½ of the internal quark. With this definition of s and n, formula (1) can still be used also for baryons.

For example in the SGMA(1385)-baryon with the ascribed configuration ((BD)1DT)5 and spin $s_0 = \frac{3}{2}$, the reduced spin is $s = 1$, its external orbits energy level is $n = 5$, the M_0 and M_c masses are respectively 1402.4 and 1311.0 and the interpolated mass is according to formula (1):

$$M = \frac{M_c + 4M_0}{5} = 1384 \text{ MEV}$$

in good agreement with the observed mass of 1385 MEV.

3. Results

Besides the masses of mesons and baryons calculated in the machine output presented in table 1, a new group of baryons, an octet of spin 5/2, has been tentatively interpreted by using the interpolation program. The result is presented in table 2. The model follows quite closely the one used in the interpretation of the first spin ½ octet (see Barricelli 1981, tables 5,6 and 8). The main difference is an increase of the energy levels. The first spin ½ octet includes two groups of baryons. One group consisting of the Proton P(938) = ((BUD)4U)1, the Neutron N(939) = ((BUD)4D)1 and Λ(1115) = ((BUD)4S)1 is replaced in the spin 5/2 octet by the group of baryons N^+(1670) = ((BUD)4U)4, N^0(1679) = ((BUD)4D)4 and Λ(1830) = ((BUD)4S)4. (see table 2). An other group consisting of 5 baryons Σ^-(1197) = ((BD)1DS)4, Σ^0(1192) = ((BU)1DS)4, Σ^+(1189) = ((BU)1US)4, Ξ^-(1321) = ((BS)1DT)4, Ξ^0(1321) = ((BS)1UT)4 is replaced in the spin 5/2 octet by the group Σ^-(1915) = ((BD)2DS)6, Σ^0(1915) = ((BU)2DS)6, Σ^+(1915) = ((BU)2US)6, Ξ^-(2030) = ((BD)2TT)6, Ξ^0(2030) = ((BU)2TT)6 (see table 2). Besides the increased energy levels in the two Ξ baryons of spin 5/2 there is also a substitution of a split strange quark (T) for a compact one (S) com-

TABLE 2.
INTERPRETATION OF SOME BARYONS OF SPIN 5/2 (OCTET+LAMBDA(1315)).

BARYONS

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0	0	1	-1	1.00000001	1.31436132	.44210027	.46132651	.36786155	.69132976	4	1658.509		CIRCULAP ORBIT.	
0	0	1	-1	1.00000001	1.31436132	.65530397	.56737320	.46476362	.69932027	4	1677.681		OSCILLATION ORBIT.	
							INTERPOLATED MASS		.69532462		1668.095	N(1670)	((BUD)4D)4	5/2
0	0	1	-1	1.07932591	1.31436132	.44541[illegible]04	.43691458	.37048597	.76220289	4	1828.554		CIRCULAR ORBIT.	
0	0	1	-1	1.07932591	1.31436132	.64996541	.54159918	.46764692	.77091481	4	1849.437		OSCILLATION ORBIT.	
							INTERPOLATED MASS		.76656235		1838.995	LMDA(1830)	((BUD)4S)4	5/2
0	0	2	-2	4.07932592	4.20021769	.30576274	.27036513	.26312961	.76947394	6	1845.992		CIRCULAR ORBIT.	
0	0	2	-2	4.07932592	4.20021769	.43049040	.34705988	.33822840	.81295411	6	1950.290		OSCILLATION ORBIT.	
							INTERPOLATED MASS		.79846238		1915.524	SGMA(1915)	((BU)2DS)6	5/2
1	-1	2	-2	4.06821301	4.26194400	.30543203	.27132136	.25983930	.81794367	6	1962.260		CIRCULAR ORBIT.	
1	-1	2	-2	4.06821301	4.26194400	.42998970	.34822166	.33419797	.86135012	6	2066.393		OSCILLATION ORBIT.	
							INTERPOLATED MASS		.84688131		2031.682	XI(2030)*	((BT)2UT)6	5/2
1	-1	2	-2	4.06821301	4.27224383	.30536523	.27137635	.25930791	.82789046	6	1986.122		CIRCULAR ORBIT.	
1	-1	2	-2	4.06821301	4.27224383	.42983854	.34828805	.33354627	.87128260	6	2090.221		OSCILLATION ORBIT.	
							INTERPOLATED MASS		.85681856		2055.521	XI UNIDF	((DS)2UT)6	5/2
0	0	1	-1	1.07932591	1.41543774	.39046879	.38374739	.30207947	.75295731	3	1806.357		CIRCULAP ORBIT	
0	0	1	-1	1.07932591	1.41543774	.56070444	.49135551	.38625953	.76590048	3	1837.408		OSCILLATION ORBIT.	
							INTERPOLATED MASS		.75727170		1816.707	LMDA(1815)	((BUD)5S)3	5/2

pared with the Ξ baryons of spin ½. If we had used one compact and one split quark as is done in the spin ½ case we would have obtained a too large mass value (see table 2). Whatever its cause, this is in line with the general tendency of split s-quarks to substitute for compact ones the more frequently the higher the energy level (see Barricelli 1981, table 8).

A tentative identification of the spin 5/2 baryon Λ(1815) is also indicated at the end of table 2.

The possibility of interpreting the masses of other elementary particles by interpolation methods like the one presented here is being explored.

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