30. MONTE CARLO PARTICLE NUMBERING SCHEME

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- NOTE: We have received a proposal for a significant revision to our numbering scheme. The revision would include numbering for particles expected in the quark model but not yet discovered and for hypothetical states such as supersymmetric particles. The proposal was developed by the QCD Monte Carlo Event Generators working group of a LEP2 Workshop in 1995 and conveyed to us by Ian Knowles and Torbjorn Sjöstrand [1]. Lynn Garren, who is responsible for the STDHEP standard [2] at Fermilab, is also involved. We will put this proposal on the Particle Data Group WWW page (`http://pdg.lbl.gov/`) in the near future to invite comment and to provide information on the status of its acceptance.

Most particle physics Monte Carlo and analysis systems use a numbering scheme to represent particles. The lack of standardization of such schemes inhibits interfacing different programs. The following table proposes a standard numbering scheme. Some of the properties of this scheme are:

1. Quarks and leptons are ordered by family, and within the family, by isospin. This puts the u and d in the opposite order than is often used in other numbering schemes. In our scheme we call the highest numbered quark the heaviest quark.
2. For multiple quark systems (mesons, baryons, and diquarks), the rightmost digit is generally $L = 2J + 1$. (The K^0_S and K^0_L are exceptions.) Particles with $J > 4$ have not been assigned numbers.
3. Mesons are represented by the form NML and baryons by $NMKL$, where N, M, and K are quark numbers.
4. For these systems the highest quark number (see quark list below) is usually on the left and the quarks are in decreasing order of quark number from left to right. One exception to this convention is the K^0_L-K^0_S pair. A second exception is for the Λ's for which we invert the up and down quarks to distinguish the Λ from the Σ^0.
5. The other exception to this quark-number order rule is for some N's and Δ's. For N's, the u and d quark are reversed for spins 3/2 and 7/2. For Δ's, they are reversed for spins 1/2 and 5/2. The quarks are in the normal decreasing order when $I + J$ is odd.
6. Mesons, and only mesons, have the third digit nonzero and the fourth digit zero. (We designate the rightmost digit as the first digit.)
7. Only baryons and diquarks have the fourth digit nonzero.
8. Only quarks and diquarks have the second digit equal to zero.
9. Particles have positive numbers; each antiparticle has the negative of its counterpart.
10. The particle-antiparticle convention is the one used by the Particle Data Group, so that the K^+ and B^+ are particles.
11. The above rules imply that for mesons (as opposed to anti-mesons), when the number of the leftmost (heaviest) quark is even, it is a quark, and when the number of the leftmost quark is odd, it is an antiquark.
12. The gluon has two numbers. Its official number is 21 to place it with the other gauge bosons. Its number is also 9 so that a glueball is specified as 99.
13. The fifth digit is used to differentiate different particles with the same quark content and spin.
14. Although isospin is not manifest in this scheme, the isospin of any hadron can be determined from the number. Mesons with $11L$ are isospin 1 and those with $22L$ are isospin 0. For nonstrange baryons, if the quarks are in the normal decreasing order, then $I + J$ is odd, otherwise $I + J$ is even. If a strange baryon does not have the normal decreasing quark order, it has $I = 0$.

More details about the motivation behind, and properties of, this scheme can be found in Ref. 3. Although this scheme has the advantage that a particle's number has considerable physics content, it has the disadvantage that it is not compact. An algorithm that translates this scheme into a more compact scheme is needed for its implementation. Contact the Berkeley Particle Data Group for further information on such an algorithm.

A list of particle numbers follows.

References:

1. I. Knowles *et al.*, QCD Event Generators Report, LEP2 Workshop, 1995, CERN Yellow Report 96-01, vol. 2, p. 103.
2. L. Garren, StdHep 3.01, Monte Carlo Standardization at FNAL, Fermilab PM0091 (Nov. 17, 1995) and StdHep WWW site: `http://fnpspa.fnal.gov/stdhep.html`.
3. T.G. Trippe and G.R. Lynch, "Particle I.D. Numbers, Decay Tables, and Other Possible Contributions of the Particle Data Group to Monte Carlo Standards," LBL-24287, in *Proceedings of the Workshop on Detector Simulation for the SSC* (August 1987).

QUARKS

d	1
u	2
s	3
c	4
b	5
t	6

GAUGE AND HIGGS BOSONS

γ	22
W	24
Z	23
g	21 and 9
H^0_1	25
H^0_2	35
H^0_3	36
H^+	37

LEPTONS

ν_e	12
ν_μ	14
ν_τ	16
e	11
μ	13
τ	15

DIQUARKS

$(dd)_1$	1103
$(ud)_0$	2101
$(ud)_1$	2103
$(uu)_1$	2203
$(sd)_0$	3101
$(sd)_1$	3103
$(su)_0$	3201
$(su)_1$	3203

MESONS

π^+	211
π^0	111
η	221
$f_0(400–1200)$	60221
$\rho(770)$	113, 213
$\omega(782)$	223
$\eta'(958)$	331
$f_0(980)$	10221
$a_0(980)$	10111, 10211
$\phi(1020)$	333
$h_1(1170)$	10223
$b_1(1235)$	10113, 10213
$a_1(1260)$	20113, 20213
$f_2(1270)$	225
$f_1(1285)$	20223

MESONS (Cont'd)

$\eta(1295)$	20221
$\pi(1300)$	20111, 20211
$a_2(1320)$	115, 215
$f_0(1370)$	30221
$f_1(1420)$	30223
$\omega(1420)$	50223
$\eta(1440)$	40221
$\rho(1450)$	40113, 40213
$f_0(1500)$	50221
$f_1(1510)$	40223
$f_2'(1525)$	335
$\omega(1600)$	60223
$\omega_3(1670)$	227
$\pi_2(1670)$	10115, 10215
$\phi(1680)$	10333
$\rho_3(1690)$	117, 217
$\rho(1700)$	30113, 30213
$f_J(1710)$	30113, 30213
$\phi_3(1850)$	337
$f_2(2010)$	20225
$f_4(2050)$	229
$f_2(2300)$	30225
$f_2(2340)$	40225
K^+	321
K^0	311
K_S^0	310
K_L^0	130
$K^*(892)$	313, 323
$K_1(1270)$	10313, 10323
$K_1(1400)$	20313, 20323
$K^*(1410)$	30313, 30323
$K_0^*(1430)$	10311, 10321
$K_2^*(1430)$	315, 325
$K^*(1680)$	40313, 40323
$K_2(1770)$	10315, 10325
$K_3^*(1780)$	317, 327
$K_2(1820)$	20315, 20325
$K_4^*(2045)$	319, 329
D^+	411
D^0	421
$D^*(2007)^0$	423
$D^*(2010)^+$	413
$D_1(2420)^0$	10423
$D_2^*(2460)^0$	425
$D_2^*(2460)^+$	415
D_s^+	431
D_s^{*+}	433
$D_{s1}(2536)^+$	10433
B^+	521
B^0	511
B^*	513, 523
B_s^0	531

MESONS (Cont'd)

$\eta_c(1S)$	441
$J/\psi(1S)$	443
$\chi_{c0}(1P)$	10441
$\chi_{c1}(1P)$	10443
$\chi_{c2}(1P)$	445
$\psi(2S)$	20443
$\psi(3770)$	30443
$\psi(4040)$	40443
$\psi(4160)$	50443
$\psi(4415)$	60443
$\Upsilon(1S)$	553
$\chi_{b0}(1P)$	551
$\chi_{b1}(1P)$	10553
$\chi_{b2}(1P)$	555
$\Upsilon(2S)$	20553
$\chi_{b0}(2P)$	10551
$\chi_{b1}(2P)$	70553
$\chi_{b2}(2P)$	10555
$\Upsilon(3S)$	30553
$\Upsilon(4S)$	40553
$\Upsilon(10860)$	50553
$\Upsilon(11020)$	60553

BARYONS

p	P_{11}	2212
n	P_{11}	2112
$N(1440)$	P_{11}	12112, 12212
$N(1520)$	D_{13}	1214, 2124
$N(1535)$	S_{11}	22112, 22212
$N(1650)$	S_{11}	32112, 32212
$N(1675)$	D_{15}	2116, 2216
$N(1680)$	F_{15}	12116, 12216
$N(1700)$	D_{13}	21214, 22124
$N(1710)$	P_{11}	42112, 42212
$N(1720)$	P_{13}	31214, 32124
$N(2190)$	G_{17}	1218, 2128
$\Delta(1232)$	P_{33}	1114, 2114, 2214, 2224
$\Delta(1600)$	P_{33}	31114, 32114, 32214, 32224
$\Delta(1620)$	S_{31}	1112, 1212, 2122, 2222
$\Delta(1700)$	D_{33}	11114, 12114, 12214, 12224
$\Delta(1900)$	S_{31}	11112, 11212, 12122, 12222
$\Delta(1905)$	F_{35}	1116, 1216, 2126, 2226
$\Delta(1910)$	P_{31}	21112, 21212, 22122, 22222
$\Delta(1920)$	P_{33}	21114, 22114, 22214, 22224
$\Delta(1930)$	D_{35}	11116, 11216, 12126, 12226
$\Delta(1950)$	F_{37}	1118, 2118, 2218, 2228

BARYONS (Cont'd)

Λ	P_{01}	3122
$\Lambda(1405)$	S_{01}	13122
$\Lambda(1520)$	D_{03}	3124
$\Lambda(1600)$	P_{01}	23122
$\Lambda(1670)$	S_{01}	33122
$\Lambda(1690)$	D_{03}	13124
$\Lambda(1800)$	S_{01}	43122
$\Lambda(1810)$	P_{01}	53122
$\Lambda(1820)$	F_{05}	3126
$\Lambda(1830)$	D_{05}	13126
$\Lambda(1890)$	P_{03}	23124
$\Lambda(2100)$	G_{07}	3128
$\Lambda(2110)$	F_{05}	23126
Σ^+	P_{11}	3222
Σ^0	P_{11}	3212
Σ^-	P_{11}	3112
$\Sigma(1385)$	P_{13}	3114, 3214, 3224
$\Sigma(1660)$	P_{11}	13112, 13212, 13222
$\Sigma(1670)$	D_{13}	13114, 13214, 13224
$\Sigma(1750)$	S_{11}	23112, 23212, 23222
$\Sigma(1775)$	D_{15}	3116, 3216, 3226
$\Sigma(1915)$	F_{15}	13116, 13216, 13226
$\Sigma(1940)$	D_{13}	23114, 23214, 23224
$\Sigma(2030)$	F_{17}	3118, 3218, 3228
Ξ^0	P_{11}	3322
Ξ^-	P_{11}	3312
$\Xi(1530)$	P_{13}	3314, 3324
$\Xi(1820)$	D_{13}	13314, 13324
Ω^-		3334
Λ_c^+		4122
$\Lambda_c(2593)^+$		14122
$\Sigma_c(2455)$		4112, 4212, 4222
Ξ_c^+		4322
Ξ_c^0		4312
Ω_c^0		4332
Λ_b^0		5122