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August 24–28, 1987

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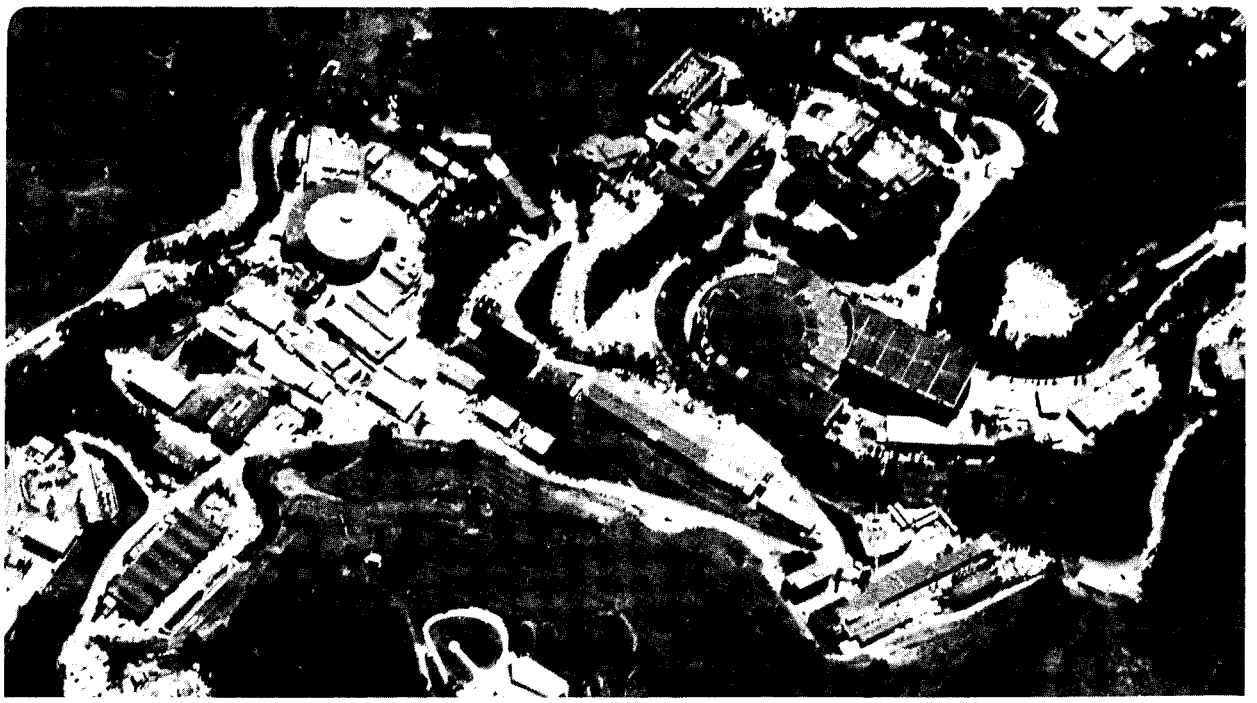
November 1987



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Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

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ABSTRACT

The Berkeley Particle Data Group is considering providing a single standard numbering scheme for use in programs for high energy physics Monte Carlo event generation, detector simulation, and analysis. The purpose is to facilitate standardizing the interfaces between these programs, to reduce the possibility for errors, and to simplify code maintenance. Several schemes have been studied and a tentative proposal is given. The possibility of the Particle Data Group providing decay tables and material properties tables is discussed.

1. INTRODUCTION

In most Monte Carlo event generators, detector simulation programs, and analysis programs used in high energy physics, a numbering scheme is used to indicate the identity of the particles. Since there is no standard scheme, a translation must be made at the interfaces between the programs. When a new particle is added, the translation interface must be modified, creating extra code maintenance. Users of such systems of programs must deal with different numbers for the same particle, sometimes even within the same program.

The Particle Data Group is proposing to help forge a consensus among the high energy physics community on a single scheme. The scheme would be published in the Review of Particle Properties.

The original suggestion for such a numbering scheme came from H. Yamamoto (LBL) in January 1987. Since then, one of the authors (G.L.) has contacted about 35 people, representatives of most major experiments, Monte Carlo event generation experts, and detector simulation experts. A letter was sent to these people describing the general proposal and including a description of the numbering schemes in two of the most commonly used HEP Monte Carlos, ISAJET and LUND (PYTHIA). Input was received from F. Paige and S. Protopopescu (ISAJET), T. Sjostrand and H.-U. Bengtsson (LUND), B. Webber, R. Brun (GEANT), J. Dorfan and A. Petersen (Mark II),

P. Oddone and W. Hofmann (TPC), P. Bagnaia (UA2), T. Kirk and S. Kunori (E665), W. Schmidt-Parzefall (ARGUS), A. Leveque (UA1), R. Felst (Jade), A. Putzer (ALEPH), L. Pape (DELPHI), and R. Odorico. The response to the idea was quite positive, with statements such as "need is evident," "worthwhile," "highly welcome," and "strongly support."

With that encouragement, we went forward and tried to develop a scheme. The scheme presented here is preliminary. It still needs further iteration to resolve disagreements. The scheme also needs further input and that is why it is being presented here in its preliminary form.

2. WHAT KIND OF SCHEME?

The big question is what sort of scheme to use. There was support for our suggestion to start from one of the existing systems rather than trying to reinvent the wheel. The LUND scheme is more compact in the sense that there are less unused small integers. The ISAJET scheme has more physics content. In ISAJET the meson and baryon codes are three and four digit integers, $\pm JKL$ and $\pm IJKL$ respectively, where I, J, and K are quark numbers (1-6) and L is a spin index. The minus sign is used for antiparticles. In ISAJET a more compact set of numbers is needed in the end as the subscript in a particle table, but this is generated from the ISAJET code by a utility routine. The LUND code is compact enough for use directly as a particle table subscript.

Most people preferred the ISAJET style scheme, but questions were raised about it. It is not compact, so a utility routine is needed. It is also not as flexible. New physics could appear that would require revising or abandoning the scheme. There were some strong specific objections to both the ISAJET and LUND schemes. We concluded that neither the ISAJET scheme nor the LUND scheme should be adopted, but that an ISAJET-like scheme should be developed which took into account the objections raised.

In addition to providing the ISAJET-like ID code, the PDG would provide a utility routine to convert it into a compact index.

3. WHAT ARE THE ISSUES?

3.1 Particle vs. Antiparticle

The ISAJET and LUND schemes both use the negative of the particle code for the antiparticle code, but which is the antiparticle? Table I shows the various conventions adopted for which of the K's, D's, B's, and T's should be called the particle.

Table I. Particle vs. antiparticle conventions.

Common sense	K^-	D^+	B^-	T^+
ISAJET	K^+	D^-	B^+	T^-
LUND and PDG	K^+	D^+	B^+	T^+
Some Publications	K^+	D^+	B^+	T^+
Other Publications	K^+	D^+	B^-	T^+

Common sense (and hindsight) would suggest that particles containing heavy quarks should have been called mesons while those containing heavy antiquarks should have been called antimesons. I.e., the K^- should have been called the particle since it contains a strange quark. Its isospin partner would also have been defined to be a particle and would be called K^0 rather than $\overline{K}^0$. Unfortunately, thirty years of publications contain the opposite assignment, so we do not think that the "common sense" convention is a wise choice.

The PDG and the LUND scheme both call all of the positive mesons particles. The B^+ (and B^0) then contain antibottom quarks, in analogy with the K, while the D^+ and T^+ contain charmed and top quarks. This choice is consistent with some publications, roughly half.

The PDG-LUND convention leads to the decays

$$D^+ \rightarrow \overline{K}^0\ e^+\nu$$
$$B^+ \rightarrow \overline{D}^0\ e^+\nu$$
$$T^+ \rightarrow \overline{B}^0\ e^+\nu$$

thus preserving the peculiar characteristic that heavy mesons (with one heavy quark) decay into heavy antimesons, a characteristic first seen in D decays. This characteristic is purely the result of the choice of convention.

If the ISAJET convention were used, then the bar would disappear from the above decays. This happens because in ISAJET, all of the heavy mesons are chosen to contain heavy antiquarks, in analogy to the K. This is a sort of "anti-common-sense" choice which leads to many of the same consistencies as the "common sense" convention and is also consistent with the historical choice for the K. However, the ISAJET choice is not consistent with any published papers on the D or T.

About half of the publications on B's and T's chose the "common sense" assignment for the D, B and T but retained the historical K choice, as shown in the last line of Table I. This removes the bar from the second and third decays above but keeps it on the first decay. The K then must be handled as an exception, e.g., in computer code or in statements such as "the heavy mesons contain heavy quarks, except for the K which contains an antistrange quark."

We suggest that the LUND-PDG convention be used because it is systematic and is used in the literature, especially since its adoption by the PDG in 1986.

3.2 Numbering of Quarks

Both ISAJET and LUND assign the quark codes in the order u, d, s, c, b, and t, as is shown in Table II. Several people objected to this order because it is inconsistent with ordering by weak isospin. Most suggested that we swap u with d, but one person suggested swapping s with c and b with t. We have adopted the former, i.e., d, u, s, c, b and t in the proposed scheme in Table II. The leptons are also ordered in the same way by weak isospin, i.e., e^-, ν_e, μ^-, ν_μ, τ^-, ν_τ.

3.3 Diquark Spin Information

The diquark spin information is missing from ISAJET. We have added it in the proposed scheme in Table II.

3.4 Quark Order in Code

ISAJET codes have the quarks in ascending order reading from left to right, e.g., K^+ is 130 and p is 1120 (the 0 is the spin index). It was suggested that this be reversed so that the heaviest quark would appear as the highest order digit. This would lead to a more sensible grouping of particles in a list which was ordered by code, e.g., all of the B mesons would be in the 500's. While the proposed scheme, shown in Table II, still has the codes in ascending order, we still think reversal is worth consideration.

3.5 Enforcing Negative as Antiparticle

Some specific objections were raised to details of the ISAJET scheme. One was that the K_S and K_L are represented as 20 and -20, violating the rule that negative integers correspond to antiparticles. The proposed scheme in Table II gives the K_S and K_L as 91 and 92 respectively.

3.6 Consolidating the Gauge Bosons

The ISAJET codes for gluon, γ, W^+, and Z^0 are 9, 10, 80, and 90 respectively. It was suggested that we try to consolidate these codes. We suggest 9, 10, 20, and 30. This keeps the gluon as 9 so that glueballs could be represented by combinations of 9's, e.g., 99L or 999L.

3.7 "Official" vs. Less Well-Established Particles

The Particle Data Group could be expected to define codes for established particles, quarks, and gluons. What about less well-established particles, e.g., diquarks, glueballs, and SUSY particles? Perhaps a higher order digit could be used for SUSY particles, e.g.,

SUSY particle code = 100000 + Ordinary particle code

3.8 Spin Index Definition

The rightmost digit of the ISAJET code is a spin index. ISAJET uses J for mesons and $J-1/2$ for baryons. It has been suggested that we use $2J+1$ for both mesons and baryons. This would allow only spins up to 4 to be represented, but it would allow SUSY particles to be represented in the same scheme. There was some objection to having SUSY particles with codes which could easily be confused with ordinary particles, so even if $2J+1$ were used for SUSY particles, a higher order digit might also be included.

4. OTHER POSSIBLE CONTRIBUTIONS OF THE PDG

4.1 Decay Tables

The PDG already produces the Particle Properties Tables for the Review of Particle Properties. A machine readable Particle Properties Table could be produced which would contain the particle number, particle name, mass, mean life, charge, and measured decay modes and branching fractions. This information could be in a standard format, acceptable to different Monte Carlo and analysis programs. The table could be extended by the user to include unmeasured branching fractions. This would make the exchange of decay tables between different Monte Carlo or analysis programs simpler and easier to keep up-to-date.

4.2 Material Properties Tables

The PDG also maintains a table of Atomic and Nuclear Properties of Materials which includes such things as Z, A, interaction length, radiation length, dE/dx, density, and index of refraction. This table could be put into machine readable form and used to provide a standard table for detector simulation programs.

5. CONCLUSION

The Particle Data Group is prepared to contribute where it can to providing standard particle ID codes, decay tables, and material tables to facilitate Monte Carlo event generation, detector simulation, and data analysis. In the latter areas mentioned, decay tables and material properties, no decision has yet been made whether to go forward. Any comments on the potential usefulness of the PDG entering these areas would be valuable to us.

This paper has concentrated on the question of particle ID codes, an area where we have decided to go ahead. Our current proposal is preliminary and is being presented here because it would benefit greatly from any additional input. Our proposed scheme has continued to evolve from the scheme shown in Table II that was presented at the Argonne Workshop on Detector Simulation for the SSC. Table III presents our latest proposal.

6. ACKNOWLEDGMENT

This research was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098, and by the U.S. National Science Foundation under Agreement No. PHY86-15529.

Table II. ISAJET, LUND, and Proposed Numbering Schemes.

	Elementary Particles			
	ISAJET	*Proposed*	*LUND*	
UP	1	2	u	501
DN	2	1	d	502
ST	3	3	s	503
CH	4	4	c	504
BT	5	5	b	505
TP	6	6	t	506
GL	9	9	g	500
GM	10	10	γ	1
NUE	11	12	ν_e	8
E−	12	11	e^-	7
NUM	13	14	ν_μ	10
MU−	14	13	μ^-	9
NUT	15	16	ν_τ	12
TAU	16	15	τ^-	11
W+	80	20	W^+	3
Z0	90	30	Z^0	2

Diquarks

ISAJET	*Proposed*	*LUND*	
1100	2203	uu_1	511
1200	1201	ud_0	512
1300	2301	us_0	513
1200	1203	ud_1	521
2200	1103	dd_1	522
2300	1301	ds_0	523
1300	2303	us_1	531
2300	1303	ds_1	532
3300	3303	ss_1	533

Mesons

	ISAJET	*Proposed*	*LUND*		
PI0	110	111	π^0	23	
PI+	120	121	π^+	17	
ETA	220	221	η	24	
K+	130	231	K^+	18	
K0	230	131	K^0	19	
ETAP	330	331	η'	25	
D0	−140	241	D^0	20	
D+	−240	141	D^+	21	
F+	−340	341	F^+	22	$D_s{}^+$
ETAC	440	441	η_c	26	
RHO0	111	113	ρ^0	33	
RHO+	121	123	ρ^+	27	
OMEG	221	223	ω	34	
K*+	131	233	K^{*+}	28	
K*0	231	133	K^{*0}	29	
PHI	331	333	ϕ	35	
D*0	−141	243	D^{*0}	30	
D*+	−241	143	D^{*+}	31	
F*+	−341	343	F^{*+}	32	$D_s{}^{*+}$
JPSI	441	443	J/ψ	36	
KS	20	91	K_S^0	37	
KL	−20	92	K_L^0	38	

Baryons

	ISAJET	*Proposed*	*LUND*	
P	1120	1222	p	41
N	1220	1122	n	42
S+	1130	2232	Σ^+	43
S0	1230	1232	Σ^0	44
L	2130	2132	Λ	57
S−	2230	1132	Σ^-	45
XI0	1330	2332	Ξ^0	46
XI−	2330	1332	Ξ^-	47
DL++	1111	2224	Δ^{++}	61
DL+	1121	1224	Δ^+	62
DL0	1221	1124	Δ^0	63
DL−	2221	1114	Δ^-	64
S*+	1131	2234	Σ^{*+}	65
S*0	1231	1234	Σ^{*0}	66
S*−	2231	1134	Σ^{*-}	67
XI*0	1331	2334	Ξ^{*0}	68
XI*−	2331	1334	Ξ^{*-}	69
OM−	3331	3334	Ω^-	70

Table III. Proposed Particle Numbering Scheme as of October 21, 1987.

The following proposal takes into account the suggestions that were made at the Argonne Workshop, as well as subsequent input from a number of people, especially Sjostrand and Bengtsson. It has the descending quark order mentioned in section 3.4 (with a few exceptions in the baryons, such as the lambda), but it deviates from what was said in sections 3.5 and 3.6 for the gauge bosons and the K_S and K_L. Table III is also more complete than Table II; it contains all of the particles (with spin less than 9/2) that are in the Summary Particle Property Tables of the Review of Particle Properties. In doing this it uses the fifth digit to distinguish different particles that have the same spin and quark content.

Elementary Particles		*Diquarks*	
DN	1	DD1	1103
UP	2	UD0	2101
ST	3	UD1	2103
CH	4	UU1	2203
BT	5	SD0	3101
TP	6	SD1	3103
		SU0	3201
		SU1	3203

E−	11
NUE	12
MU−	13
NUM	14
TAU−	15
NUT	16
GL	21 and 9
GM	22
Z0	23
W+	24
HIGGS	25

Stable Mesons		*Stable Baryons*	
PI0	111	N	2112
PI+	211	P	2212
ETA	221	S−	3112
K0	311	S0	3212
K+	321	L	3122
D0	421	S+	3222
D+	411	XI−	3312
DS+	431	XI0	3322
B0	511	OM−	3332
B+	521	LC	4122
		XIC+	4322
KS	310	OMC	4332
KL	130	LB	5122

Other Mesons		*Other Baryons*	
ETAP	331	DL−	1114
ETAC	441	DL0	2114
RHO0	113	DL+	2214
RHO+	213	DL++	2224
OMEG	223	S*−	3114
K*0	313	S*0	3214
K*+	323	S*+	3224
PHI	333	XI*−	3314
D*+	413	XI*0	3324
D*0	423		
DS*+	433	N(1440)	12112,12212
JPSI	443	N(1535)	22112,22212
UPSL	553	N(1650)	32112,32212
A(1320)	115,215	N(1710)	42112,42212
F(1270)	225	N(1520)	1214, 2124
K*(1430)	315,325	N(1700)	21214,22124
F′(1525)	335		

RHO(1690)	117, 217
OMEG(1670)	227
K*(1780)	317, 327
F(2030)	229
K*(2060)	319, 329
A(980)	10111,10211
PI(1300)	20111,20211
F(975)	10221
F(1300)	20221
ETA(1440)	30221
F(1590)	40221
K*(1350)	10311,10321
B(1235)	10113,10213
A(1270)	20113,10213
RHO(1600)	30113,30213
H(1190)	10223
F(1285)	20223
F(1420)	30223
K(1280)	10313,10323
K(1400)	20313,20323
PI(1680)	10115,10215
F(1720)	10225
K(1770)	10315,10325
PHI(1680)	10333
CHI(3415)	10441
CHI(3510)	10443
CHI(3555)	445
PSI(3685)	20443
PSI(3770)	30443
PSI(4030)	40443
PSI(4160)	50443
PSI(4415)	60443
CHIB(9860)	551
CHIB(9895)	10553
CHIB(9915)	555
CHIB(10235)	10551
CHIB(10255)	70553
CHIB(10270)	10555
UPSL2S	20553
UPSL3S	30553
UPSL4S	40553
UPSL5S	50553
UPSL6S	60553

N(1720)	31214,32124
N(1675)	2116, 2216
N(1680)	12116,12216
N(2190)	1218, 2128
DL(1620)	1112, 1212, 2122, 2222
DL(1900)	11112, etc.
DL(1910)	21112, etc.
DL(1700)	11114,12114,12214,12224
DL(1920)	21114, etc.
DL(1905)	1116, 1216, 2126, 2226
DL(1930)	11116, etc.
DL(1950)	1118, 2118, 2218, 2228
L(1405)	13122
L(1600)	23122
L(1670)	33122
L(1800)	43122,53122
L(1520)	3124
L(1690)	13124
L(1890)	23124
L(1820)	3126
L(1830)	13126
L(2110)	23126
L(2100)	3128
S(1660)	13112,13212,13222
S(1750)	23112,23212,23222
S(1670)	13114,13214,13224
S(1940)	23114,23214,23224
S(1775)	3116, 3216, 3226
S(1915)	13116,13216,13226
S(2030)	3118, 3218, 3228
XI(1820)	13314,13324

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