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COMPILATION OF DATA ON ELEMENTARY PARTICLES

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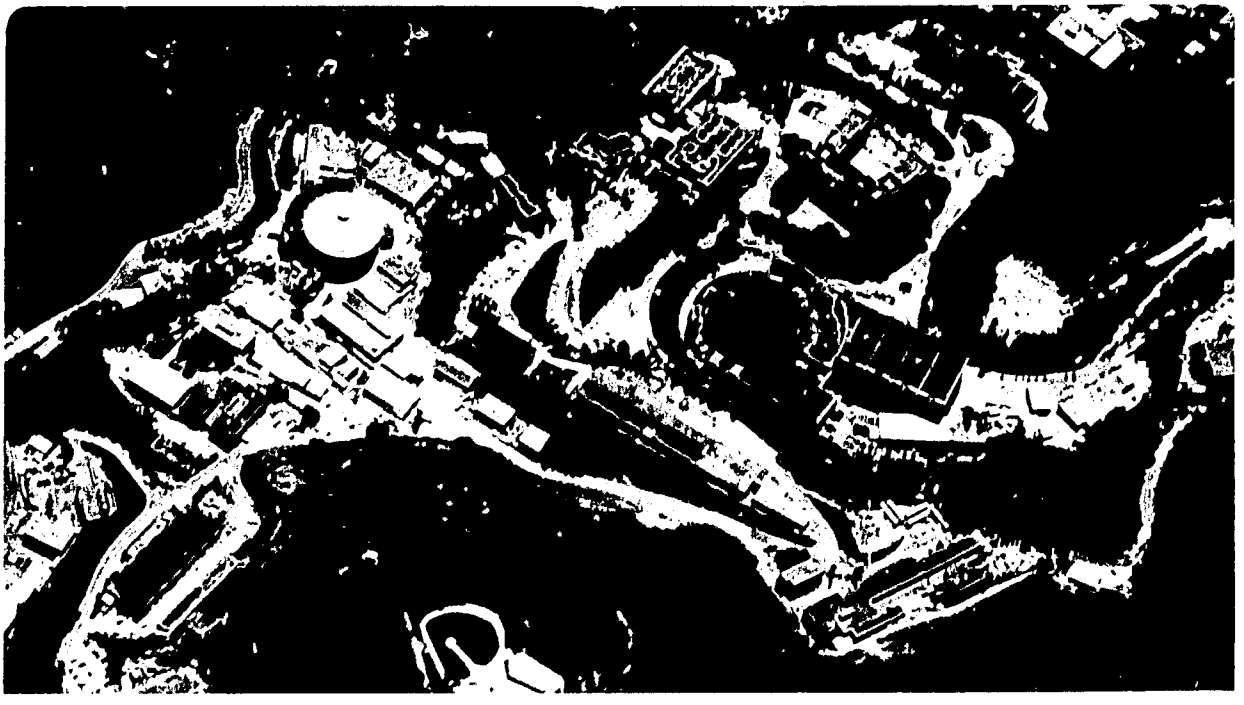

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The most widely used data compilation in the field of elementary particle physics is the Review of Particle Properties. The origin, development and current state of this compilation are described, with emphasis on the features which have contributed to its success: active involvement of particle physicists; critical evaluation and review of the data; completeness of coverage; regular distribution of reliable summaries including a pocket edition; heavy involvement of expert consultants; and international collaboration. The current state of the Review and new developments such as providing interactive access to the Review's database are described. Problems and solutions related to maintaining a strong and supportive relationship between compilation groups and the researchers who produce and use the data are discussed.

INTRODUCTION

In thinking about what to talk about which would be useful to an audience of data compilation specialists from a wide range of fields, I thought that the most useful would be to present our primary and most successful product, the Review of Particle Properties (1), and to pursue the features of this Review which seem to account for its success. This success is based on a philosophy of providing the most useful information for a practicing elementary particle physicist to have close at hand. The implementation of this philosophy relies on the heavy involvement of practicing physicists in the project. Another important factor in the Review's success is having a strong and dedicated core group to handle the organization, database updating, computer systems, production and distribution.

In order to identify the specific factors which account for the success of this Review, I will give you an overview of the whole project: its origin, development, current state and new developments, pointing out the factors which I think have led to its success. I will also discuss some of the problems which we have had and which are common to data compilation groups working in a research environment.

What I mean by the Review's success is that there is a large demand for it, both within and outside of the high energy physics community. About 18,000 copies of the April 1984 full edition and 18,000 copies of the pocket edition were printed for distribution, based mostly on requests. About half of these copies go to elementary particle physicists and the rest are requested by researchers in other fields, teachers, and students.

As an example of the interest in this review by the general science community, I refer you to an unsolicited full page editorial on the Review of Particle Properties in the May 24 issue of Nature (2). The editorial refers to the Review as a "monument" to experimental particle physicists, and goes on to say that it "is likely to be many people's bible for years to come" and that "It is also a model of how data should be compiled in a fast-moving field."

HISTORY

Arthur H. Rosenfeld, the founding father and longtime guiding light of the Berkeley Particle Data Group has described the early history of the Review of Particle Properties in a 1975 article (3). He identifies Table I, a summary table of masses and lifetimes of elementary particles, from a 1957 article which he coauthored with Murray Gell-Mann as the direct ancestor of the current Particle Properties Tables (4). At that time Rosenfeld was doing bubble chamber experiments and preparing to automate the processing of photographs of particle interactions; Walter H. Barkas was using nuclear emulsions to measure precise particle masses; and both needed the best available values of particle properties for use in computer programs to process measurements of particle interactions.

Data on particles was coming in at an increasing rate so that Rosenfeld and Barkas decided to update these tables and to distribute them as a Lawrence Radiation Laboratory Report UCRL-8030 (1958, unpublished): "Data for Elementary Particle Physics." This report was the first edition of what is now known as the "Review of Particle Properties."

The important point here is that it was created by particle physicists to satisfy their own needs for data.

Another new idea was introduced in 1958: wallet cards. The most frequently referenced tables and information were put onto a folding card for physicists to carry in their wallets, ready to be pulled out at conferences or lunchtime discussions. The card was made of stiff paper and consisted of three panels which folded to wallet size. The Table of Particle Properties from the original wallet card listed only 10 particle states (not counting antiparticles or particles which differ only by their charge as separate states) compared with 122 particle states today.

As the number of particle discoveries grew, so did the number of claims of discoveries which were later shown to be false. This is because elementary particles are observed rather indirectly, often as peaks above a background in a mass spectrum. Sometimes low statistics, the pressure to publish, and the bandwagon effect conspire to produce several consistent claims which later prove to be wrong. These situations require critical evaluation by someone who is active in the field and who can communicate effectively with the experimenters themselves.

The growth continued until in 1963 it was no longer possible to cope with the amount of literature, about 300 new papers

per year, without computerization.

By 1964, Europe had become quite active in particle physics so to improve communication the Particle Data Group went international. Matts Roos at the University of Helsinki joined five Berkeley authors in the first version to be published in a journal, Reviews of Modern Physics (5). By this time the wallet card had grown into three cards and was printed in two sizes, small ones to fit American wallets and larger, more readable ones for European wallets.

In 1967 we switched from wallet cards to wallet sheets on thinner bond paper in order to include all of the new particles. There were three sheets printed on both sides. Still the print was too small and they were unwieldy.

To make the pocket summary more manageable we switched in 1968 to a data booklet format. This format is still used today. It is 3 by 5 inches, comes with a companion diary, a list of high energy physics institutions and a complimentary pocket atlas. These fit in a blue plastic cover which can often be seen poking out of a particle physicist's pocket. The data booklet is our most well-known product.

I emphasize the form of our products because I believe this is a key to the Review's success. The most important information is readily available in a pocket edition.

The pocket edition also forced us to constantly think about what the most important information was for physicists to have close at hand. Until the data booklet was introduced, almost all of the summary information we published was related to our database of particle properties information. With the possibilities for expansion afforded by the new data booklet format, the ideas for additional useful information began to flow and the subject coverage of the review was expanded. An unfortunate result of this trend is that the data booklet has now grown to 168 pages so that some physicists have suggested that we reintroduce wallet sheets to summarize the data booklet.

In 1968 we added a K decay appendix. In 1970 we added information on atomic and nuclear properties, multiple scattering, statistics, special relativity, SU(3) symmetry, particle ranges, center-of-mass energy versus beam momentum, and Clebsch-Gordan coefficients. In 1971 we added an appendix on SU(3) classification of baryons.

In that same year two new steps were taken which have turned out to be very important to us. First, we established a verification procedure in which the authors whose data we cite in the Review verify our encoding and interpretation of their data. Before publication we send each author a listing of the subsections of the Review in which their data appear, with their own data printed in boldface. About 70% respond to our letters. Most errors found in this way are small although occasional major errors like the omission of someone's new data are found in this way. About a third of those responding give us some some kind of useful comment, even when they find no errors in our treatment of their data. These responses are one of our most valuable sources of external feedback.

The second step was to begin using consultants to overcome unavoidable gaps in our intellectual and geographical coverage. The consultants advise us on specific areas of the Review. In some cases they act as representatives of the Particle Data Group (PDG) in their interactions with other physicists. In some cases, their contributions have grown until they became authors. Consultants have become an increasingly important part of our operation. There are 50 consultants on the 1984 edition.

The consultants further fed the list of ideas for new subject coverage. In 1972, Overseth, a consultant, wrote an appendix on the $\Delta I = 1/2$ rule in hyperon decay. Then we added cross section plots, data on particle detectors, absorbers and ranges by consultants Parker and Sadoulet, electromagnetic relations, a periodic table of the elements, and several new sections on particle searches: quarks, magnetic monopoles, heavy leptons, and intermediate bosons. Of these new additions, only the last, the search sections, were compiled in the particle properties database.

Publication of new information in particle properties seemed to be slowing down so after the 1974 edition we decided to skip the 1975 edition and to begin publishing only every two years. Then in late 1974 the field exploded with activity when the J/ψ was discovered. This was a particle which theorists predicted to contain quarks with a new property which they named charm. To cover the new data we published a J/ψ supplement in 1975.

Then right on schedule, immediately after our 1976 edition, charmed particles were discovered, forcing us to publish a charm supplement in 1977. Particle physics has been booming ever since but at a steady enough rate that we now publish biennially.

The next addition was "Lorentz Invariant Phase Space" in 1978. Then in 1980 we added a more theoretically oriented section, "Weak Interactions of Quarks and Leptons." This signaled an increasing effort on our part to incorporate some of the major advances which theorists had made.

This brings us nearly to the present. Before discussing the current state of the Review however, I want to describe a crisis which threatened the Berkeley Particle Data Group (BPDG) and the Review a few years ago but which has led to a strengthening of both.

CRISIS

The crisis was a financial one. When the 1982 budget cuts in particle physics struck the LBL Physics Division, the BPDG was among the most severely affected groups in the Division. The reason that it was so severely affected is that the BPDG had evolved into a group which was rather isolated from the rest of the Division, was not very involved in the Division's research program and had no members who were on the Division's Senior Staff. As a result, the BPDG was not in a good position to defend its program when the Division leadership was coping with the budget cuts.

This evolution toward a state of isolation is not uncommon among compilation groups with which I am familiar, those operating in a research environment. I suspect that it is also common to other compilation groups as well. Therefore I think it is worthwhile to trace the development of our crisis and the steps we have taken to resolve it.

Through the early seventies the BPDG had strong ties to Group A (earlier called the Alvarez Group), the largest particle physics research group at LBL. These ties were through A. Rosenfeld, founder of the BPDG, and L. Galtieri, a longtime member of the BPDG and a major contributor to the

Review. Both were LBL Senior Scientists who had established their positions based on their research.

During the energy shortage of 1972–73, Rosenfeld became involved in energy conservation and created a new group in the Energy and Environment Division of LBL. In 1974 Galtieri began and headed a major experiment at Stanford Linear Accelerator Center (SLAC). As a result of these major commitments their participation in the BPDG diminished until around 1977 when they left the BPDG.

After they left, the remaining group was composed entirely of people who had been hired at LBL to work with the BPDG and whose primary commitment was to data compilation. The group was strong in terms of manpower and capabilities for handling the Review and other group efforts. However, none of the members were Senior Scientists and as a result the group had very little influence on decisions made at the Physics Division level.

The group also had little involvement in the Division's research program. As a result the group became somewhat isolated from the rest of the Physics Division. This isolation together with the negative views which some researchers held of data compilers severely limited the possibilities for advancement of any from BPDG physicist to a Senior Scientist position. As a result several people left the group, among them the group leader.

When news of federal funding cuts in particle physics reached LBL in 1981, the BPDG had no Senior Staff to defend it. Our compilation work was seen as competing directly with the research effort at LBL for funds. Senior researchers with the important task of sustaining a viable research program but with little conception of the difficult task of data compilation were making decisions about how to cope with the reduced budget. The result was predictable: our budget was slashed and our staff was further reduced. Some of our compilation projects were stopped and the 1982 edition of the Review came out three months late.

Because our work was known and respected throughout the particle physics community, when the word of our difficulties got out there was widespread support for finding a solution to our problems. As a part of this support, the BPDG crisis was thoroughly reviewed by the Baltay Panel (a U.S. Department of Energy Technical Assessment Panel), the Galtieri Committee (an LBL Physics Division committee), and the PDG Advisory Committee (5 U.S. physicists advising PDG and LBL). All concurred on the importance of the Review and the necessity for adequate funding which was as immune as possible from the vagaries of the overall funding support for the LBL Physics Division. They also recommended that the BPDG be given strong LBL support including the involvement of Senior Staff in the project. Various recommendations were made on achieving this involvement, including the possible addition of Senior Staff leadership to the group or the development of such leadership from within the group.

The way in which J.D. Jackson, the Division Head achieved immediate strong support and Senior Staff involvement is interesting and perhaps useful to other groups. He formed a PDG Steering Committee consisting of R. Cahn, a senior theorist, G. Gidal, a senior experimentalist, and me. They participate in all of the groups meetings and major decisions. They also work directly on some group projects. They work with the BPDG about 5 to 10 percent of their time for a 2 or 3 year term. Gidal developed a new compilation on particle detectors and Cahn was responsible for extensive revisions of the contents of the Review of Particle Properties. This has proven to be a very effective way to create a substantial involvement of Senior Staff researchers in our program.

The Division also recognized the necessity for developing and maintaining the strongest possible staff. To promote such a development better salaries and more assurance of permanent positions are being offered to attract more talented and experienced physicists. M. Barnett, a well known theorist with a phenomenological orientation, will soon join the BPDG and will bring new strengths to our group as well as to theoretical physics research at LBL.

The next step which we must take to insure the long-term health of the BPDG is to develop Senior Staff from within the group. Here we are facing two problems. The first problem is that many physicists have the prejudice that data compilation is not real physics and that participation in data compilation is a negative factor on a physicist's record. Those of us doing compilation, especially highly evaluative compilation, realize that this work is demanding of a broad knowledge of current physics. However if we expect to alter this prejudice we need to present our work in discussions and at physics meetings. It is necessary to give researchers a clearer picture of our work if we expect them to recognize achievements in this area as they would recognize achievements in research.

This brings us to the second problem facing us: the lack of major BPDG participation in the Division's research program. This lack certainly limits the acceptability of BPDG members as candidates for Senior Staff appointments because of the Division's research orientation. In addition, this lack of research has also had a negative effect on the group's work by reducing the amount of the BPDG's in-depth expertise in fields of current interest, thus making us even more dependent on consultants. It has also affected the Review of Particle Properties which, although carefully prepared and up-to-date in most areas, was becoming somewhat dated in its overall selection of topics covered.

Greater participation in the Division's research program is clearly a key to strengthening the BPDG. To achieve this we have included sufficient funds in our budget to support half time research for the group's physicists. With the restoration of our staff nearly to full strength when M. Barnett joins us we will be able to begin making a significant contribution to the Division's research program.

To resolve the issue of competing with LBL research groups for funds the BPDG applied to the DOE for supplementary funds beyond LBL's existing budget. This was in order to spread the burden of funding data compilation over the whole U.S. high energy physics budget rather than having LBL's existing budget support all of our work. The DOE approved this request and granted supplemental funds in FY83 amounting to about 1/3 of the BPDG's budget. These supplemental funds have helped to change LBL researcher's perceptions of PDG from that of being a competitor for the Division's research money to being a self-supporting national program hosted and strongly supported by the LBL Physics Division.

CURRENT STATE

The current Review of Particle Properties (1) is based on a 5 Mbyte database of particle properties. This is small enough that the database can be printed out, interleaved with explanatory notes and statistical plots. Most of the Review is phototypeset using the UNIX TROFF system (4). The database listings take 217 pages of the 304 total pages in the 1984 edition.

These listings are used to determine best values of particle properties, either by statistical methods or by subjective estimates. The results are summarized in 21 pages of phototypeset tables.

This year, in addition to updating the database and tables, we made a big effort to improve the usefulness of the other sections by modernizing their contents. We added sections on "SU(n) multiplets and Young Diagrams," "Tests of Conservation Laws," the "Standard Model of Electroweak Interactions," "Cabibbo and Kobayashi-Maskawa Mixing," the "Quark-Parton Model for Deep Inelastic Scattering," the "Nonrelativistic Quark Model," the "Perturbative QCD Coupling Constant," and "Muon Structure Function Plots." We also added a list of recent particle physics compilations, instructions on accessing and using particle physics databases, and an index.

Two of the new theory sections, "Standard Model of Electroweak Interactions" and "Cabibbo and Kobayashi-Maskawa Mixing," are presented in very condensed versions as well as in longer more complete presentations given in the appendices of the Review. Only the condensed versions appear in the data booklet. This is analogous to the presentation of particle properties information in two sections, complete listings and summary tables, with the booklet containing only the summary tables.

Several of the new sections were contributed by consultants, e.g. "Cabibbo and Kobayashi-Maskawa Mixing" by F. Gilman, the "Perturbative QCD Coupling Constant" by I. Hinchliffe, and "Muon Structure Function Plots" by J. Carr. The latter plots are examples of compiled data provided to us by an author of one of the experiments, Carr, who suggested to us that the compiled data should be added to the Review. We agreed that it was appropriate material for the Review so he joined us as a consultant and prepared the plots.

NEW DEVELOPMENTS

The complete database for the Review of Particle Properties is now available on-line as database RPP on the SPIRES system based at Stanford Linear Accelerator Center (SLAC). This is part of a group of high energy physics databases with which we are involved. Other databases include REAC-DATA which contains numerical data on particle interactions, the EXPERIMENTS database which contains summaries of experiment proposals, and the DOC database which contains indexing of documents which contain data. The DOC database is linked to the HEP bibliographic database which is maintained by the SLAC library. DOC provides extra indexing for HEP. The REAC-DATA database is produced by the UK-PDG and has been discussed by M.R. Whalley at this conference (6). The COMPAS group at Serpukhov collaborates on the REAC-DATA and DOC databases. They and many other institutions collaborate on the EXPERIMENTS database.

Our next major task is to modernize the data handling system for the Review. We still use old special-purpose file-oriented systems to handle the data and to run analysis programs. We want to redo this part of the system to take advantage of modern developments in database management.

CONCLUSION

I have tried to give you a picture of the Review of Particle Properties, its development, its successes, and some of the problems we have had along the way. I have emphasized the importance of the involvement of researchers, that is, the data producers and users. It is this involvement which has allowed us to develop a Review which provides the information which physicists need to have close at hand. It is this fact, that the Review of Particle Properties satisfies a real need, which is the basis for its success.

ACKNOWLEDGEMENT

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